Preliminary Draft

Energy Levels of Light Nuclei A=13*

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Abstract: Experimental nuclear spectroscopic data are evaluated for the 7 known nuclides of mass 13 (Li, Be, B, C, N, O, F). Detailed information is compiled and presented for each reaction and decay experiment. The results are combined and used to provide a set of recommended values that include level energies, spins and parities, half-lives of levels, decay branching ratios, and other nuclear properties. This work supersedes the earlier work by Fay Ajzenberg-Selove (1990Aj01) published in Nuclear Physics A **523** (1991) 1. Earlier reviews were published in (1986Aj01, 1981Aj01, 1976Aj04, 1970Aj04, 1959Aj76).

Cutoff Date: Literature available up to December 1, 2023 has been considered; the primary bibliographic source, the NSR database (2011Pr03) available at Brookhaven National Laboratory web page: www.nndc.bnl.gov/nsr/.

General Policies and Organization of Material: See the January issue of the *Nuclear Data Sheets* or https://www.nndc.bnl.gov/nds/docs/NDSPolicies.pdf.

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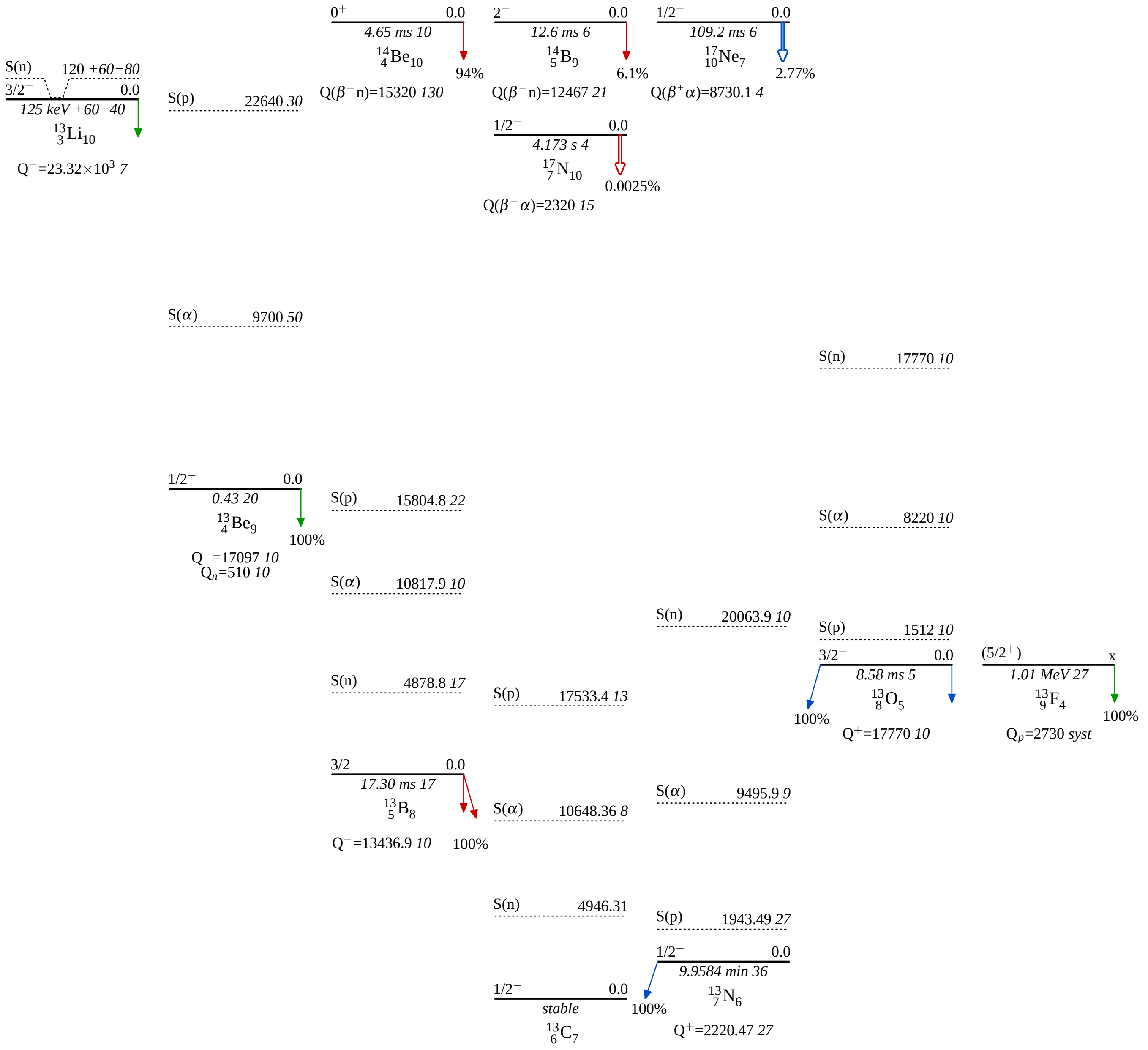
Index for A=13

Skeleton Scheme for A=13



Ground-State and Isomeric-Level Properties

Nuclide	Level	Jπ	$T_{1/2}$	Decay Mode
^{13}Li	0.0	$3/2^-$	125 keV *+60−40*	%2n=100
^{13}Be	0.0	$1/2^-$	0.43 *20*	%n=100
^{13}B	0.0	$3/2^-$	17.30 ms *17*	%β^-=100; %β^-n=0.276 *37*
^{13}C	0.0	$1/2^-$	stable	
^{13}N	0.0	$1/2^-$	9.9584 min *36*	%ε+%β^+=100
^{13}O	0.0	$3/2^-$	8.58 ms *5*	%ε+%β^+=100; %β^+p=11.3 *23*
^{13}F	x	$(5/2^+)$	1.01 MeV *27*	%p=100
^{14}Be	0.0	0^+	4.65 ms *10*	%β^-n=94 *5*
^{14}B	0.0	2^-	12.6 ms *6*	%β^-n=6.1 *3*
^{17}N	0.0	$1/2^-$	4.173 s *4*	%$\beta^-\alpha$=0.0025 *4*
^{17}Ne	0.0	$1/2^-$	109.2 ms *6*	%$\beta^+\alpha$=2.77 *19*

Adopted Levels

Q(β^-)=23.32×10^3 *7*; S(n)=120 *+60−80* 2021Wa16

S(n): The value commonly used in literature is S_n=120 keV *+60−80*; this compares with S_n=100 keV *80* from (2021Wa16), which is based on the same result, but with the uncertainty symmetrized.

1973Bo30,1974Bo05: Spallation products from 4.8 Gev proton bombardment of natural uranium targets at the LBNL Bevatron were identified via ΔE-E and time-of-flight techniques. The particle stability of ^{14}Be and ^{17}B isotopes was confirmed, but there was some uncertainty about ^{13}Be because of a relatively high background. It was later found to be particle unbound. The first observation of ^{13}Li resonance structure was at GSI using the ALADIN-LAND setup (2008Ak03).

In early theoretical work, a J$^\pi$=3/2$^-$ ground state (1985Po10 and 1996Ch38) was predicted to be unbound to ^{11}Li+2n decay by 3.34 MeV (1985Po10). The lowest excited states with J$^\pi$=7/2$^-$ and 1/2$^-$ were also predicted by (1985Po10) to lie at E_x=1.42 and 2.09 MeV, respectively. See also (2018Fo07).

^{13}Li Levels

Cross Reference (XREF) Flags

A	^{1}H(^{14}Be,2p)
B	^{9}Be(^{14}Be,^{13}Li)

E(level)	J$^\pi$	Γ	$E_{c.m.}$(^{11}Li+2n)(MeV)	XREF	Comments
0	3/2$^-$	125 keV *+60−40*	0.120 *+60−80*	B	%2n=100 E(level),J$^\pi$,Γ: From (2013Ko03). J$^\pi$: Analysis of the T and Y Jacobi systems find emission of a strongly correlated $^1s_0$ n-n pair with dineutron character and indicate J^π=3/2$^-$, which is the J^π of ^{11}Li.
1.35×10^3 *32*		2 MeV *1*	1.47 *31*	A	%2n=100 E(level),Γ: from (2008Ak03).

^{1}H(^{14}Be,2p) 2008Ak03,2010Jo07

2008Ak03:XUNDL dataset compiled by ANL, 2008.

First observation of ^{13}Li nuclide as neutron-unbound resonance was achieved using the ALADIN-LAND setup.

A beam of E(^{14}Be)=304 MeV/nucleon ions, from the GSI/FRS facility, impinged on a 50 mm long cylindrical liquid-hydrogen target with an effective thickness of 350 mg/cm^2 that was placed at the ALADIN large-gap dipole magnet target position. Residual lithium ions resulting from 1-proton knockout reactions from the ^{14}Be were momentum analyzed using position-sensitive multi-wire proportional counters and the ALADIN dipole while the coincident neutrons were momentum analyzed using the large area neutron detector LAND array.

A peak at E_{res}(^{11}Li+2n)=1.47 MeV *31* was observed in the ^{11}Li+2n relative energy spectrum.

2010Jo07: A re-analysis of the (2008Ak03) ^{11}Li+n+n data was carried out by the authors using a sophisticated model to evaluate the three-body correlations. In this re-analysis, the data indicated a similar structure to that observed for ^{10}He: where a $J^\pi=0^+$ ground state and $J^\pi=2^+$ excited state are favored. In the case of ^{13}Li, the authors interpreted the data as a broad $J^\pi=3/2^-$ ground state at E_{res}=1.47 MeV comprising s-wave neutrons coupled with the $J^\pi=3/2^-$ ^{11}Li core. In addition, they suggested an unresolved group of broad and overlapping excited states whose structure yields $J^\pi=1/2^-$, $3/2^-$, $5/2^-$ and $7/2^-$; these unobserved excited states are understood as a 2^+ coupling with the $J^\pi=3/2^-$ ^{11}Li core.

^{13}Li Levels

E(level)	J^π	Γ	$E_{c.m.}$(^{11}Li+2n)(MeV)	Comments
1.35×10^3 *32*	($3/2^-$)	2.1 MeV *11*	1.47 *31*	E(level): Resonance energy of 1.47 MeV *31* above the ^{11}Li+2n threshold in the c.m. system (2008Ak03) and using S_{2n}(g.s.)=−120 keV *+60−80*. Γ: From (2010Jo07); see also Γ=2 MeV *1* from (2008Ak03). J^π: The $J^\pi=3/2^-$ spin deduced by (2010Jo07) for the E_{res}=1.47 MeV state is complicated by the subsequent observations of (2013Ko03) where a lower-lying E_{res}=120 keV state is identified with $J^\pi=3/2^-$ character.

^{9}Be(^{14}Be,^{13}Li) 2013Ko03

2013Ko03: XUNDL dataset compiled by TUNL, 2013.

A beam of 53.6 MeV/nucleon ^{14}Be ions was produced using the NSCL/A1900 fragment separator. The beam impinged on a 477 mg/cm^{2} Be target where 1-proton removal reactions produced ^{13}Li nuclei that decayed to ^{11}Li+2n. The MONA+sweeper magnet system detected the 2 neutrons and ^{11}Li ions, respectively.

Data were analyzed to obtain the ^{11}Li+2n relative energy spectrum; a causality cut was included that minimized contributions from the double scatter of a single neutron. The results were compared with a Monte Carlo simulation that was used to evaluate the device acceptances and energy dependent efficiencies, etc.

A peak at E_{res}=120 keV $+60-80$ with Γ=125 keV $+60-40$ was observed. ^{13}Li is bound to one neutron emission, but unbound to 2n emission. Analysis of the Y and T Jacobi systems indicates that the emitted pair of neutrons have a strong dineutron character; this implies $J^{\pi}=3/2^{-}$.

^{13}Li Levels

E(level)	J^{π}	Γ	$E_{c.m.}$(^{11}Li+2n)(MeV)	Comments
0	$3/2^{-}$	125 keV $+60-40$	0.120 $+60-80$	

Adopted Levels

Q(β^-)=17097 *10*; S(n)=−510 *10*; S(p)=22640 *30*; Q(α)=−9700 *50* 2021Wa16
See Shell Model analyses in: 1983Va31,1984Va06,1985Po10, 1987Sa15, 1992Go17, 1996Wa35, 2007Gu03.
See Mean Field model analyses in: 1996Su24, 1997Ba23, 1997Ba54, 1997Re07, 2005Ar12, 2006Sh20, 2020Al27.
See Cluster Model and AMD analyses in: 1981Se06, 1994De32, 1995De31, 2005Ne03, 2005Th06, 2012Ka10, 2013Ma53, 2021Co07.
See other analyses in: 1995Ta32, 1999Ka67, 2000Bh07, 2004De60, 2004La24, 2004Ne16, 2004Sa50, 2006Ko02, 2007Bl02.
See discussion on low-lying ^{13}Be levels and possible level inversion in: 1985Po10, 1995De31, 1997Re07, 1999La20, 2004Ta03, 2008Ha16, 2009BlZZ, 2010Bl12, 2012Bo15, 2012Fo22, 2013Fo03, 2014Fo21, 2014Ho08, 2015Fo06, 2018Fo07, 2019Fo02.

In the present analysis the data are somewhat discrepant. The experimental approaches often provide incomplete measurements of the reaction observables and result in what appear as incompatible observations. The ^{14}C(^{11}B,^{12}N) and ^{14}C(π^-,p) results have been used to guide an initial level scheme since these results are insensitive to ambiguities present in level energy determination based on n+^{12}Be momentum reconstruction. The modern results where n+^{12}Be kinematics are measured provide meritous information on levels energies and decay modes and have been heavily consulted.

In surveying the results a trend appears where two groups around E_{rel}(n+^{12}Be)≈0.5-0.7 MeV and 2.3-2.5 MeV can reasonably fit the energy spectrum. However in studies utilizing γ+n+^{12}Be coincidence events, where ^{12}Be excited states are considered, evidence is found for a larger number of neutron groups corresponding to levels at E_{res}(n+$^{12}Be_{g.s.}$)≈0.4, 0.8, 2.0 and 3.0 MeV. The importance of including γ emission in analyzing the n+^{12}Be spectra is highlighted below with comments on two mesurements. First, in (2001Th01) the ^{9}Be(^{18}O,^{13}Be→^{12}Be+n) reaction was measured; evidence for two components, at E_{res}≈0 and 2.0 MeV, was found in the relative energy spectrum; however subsequent understanding supports the interpretation that these groups are connected to a E_{res}(n+^{12}Be)≈2 MeV level that decays to $^{12}Be_{g.s.}$ with E_n≈2 MeV and also decays to the high energy tail of ^{12}Be*(2.1 MeV) . Second, in the initial analysis of the ^{1}H(^{14}Be,^{13}Be→^{12}Be+n) resonance spectrum of (2010Ko17), resonances at E_{res}=0.51 MeV *1* with Γ=0.45 MeV *3* and E_{res}=2.39 MeV *5* with Γ=2.4 MeV *2* were found, but the discussion indicated the E_{res}=2.39 MeV region could also be reproduced with groups at E_{res}=2.0 MeV and E_{res}=2.9 MeV as suggested by (1992Os04,1998Be28). A reanalysis of (2010Ko17) in (2013Ak02) found evidence for 5 levels that decay to ^{12}Be ground and excited states.

Lastly, the virtual play-by-play analysis of experimental results given in the discussion of Fortune′s (2012-2019) articles provides insight into the evolution of our understanding of this nucleus. In these articles, extensive discussion on experimental work is given along-side a simple potential model analysis. Early on, the statement is made that, “The (lowest) *s* state in ^{13}Be is unbound, and unbound neutron *s* states are notoriously hard to handle.” Throughout the series of articles, listed above, the discussion focuses on likely structure configurations, the order of low-lying level spins and reasonable widths, and decay modes that can reasonably explain the data. See related discussion in (2021Co07).

Adopted Levels (continued)

^{13}Be Levels

Cross Reference (XREF) Flags

A	^{1}H(^{14}Be,^{13}Be):1	G	^{9}Be(^{18}O,^{13}Be)	M	^{14}C(π^-,p)
B	^{1}H(^{14}Be,^{13}Be):2	H	^{9}Be(^{48}Ca,X)	N	^{14}C(π^-,pd)
C	^{1}H(^{14}B,^{13}Be)	I	C(^{14}Be,^{13}Be)	O	^{14}C(^{7}Li,^{8}B)
D	^{2}H(^{12}Be,p)	J	C(^{14}B,^{13}Be)	P	^{14}C(^{11}B,^{12}N)
E	^{2}H(^{12}Be,^{13}Be)	K	^{13}C(π^-,π^+)	Q	U(p,X),^{232}Th(^{15}N,X)
F	^{9}Be(^{13}B,^{13}Be)	L	^{13}C(^{14}C,^{14}O)		

E(level)[‡#]	J^π	Γ	$E_{c.m.}$(^{12}Be$_{g.s.}$+n) (MeV)[†]	XREF	Comments
0	1/2$^-$	0.43 *20*	0.45 *1*	AB e J Q	%n=100 From E_{res}=0.46 MeV *1* (see fit to (2010Ko17) ^{1}H(^{14}Be,^{13}Be) given in (2013Ak02)), 0.44 MeV *1* (2013Ak02) ^{1}H(^{14}Be,^{13}Be) and 0.40 MeV *3* (2014Ra07) C(^{14}B,^{13}Be). Also see E_{res}=0.51 MeV *1* initially reported in (2010Ko17). Γ: From unweighted average of Γ=0.11 MeV *2* (see fit to (2010Ko17) given in (2013Ak02)), 0.39 MeV *5* (2013Ak02) and 0.80 MeV *20* (2014Ra07). J^π: From (2010Ko17) whose analysis of the n+^{12}Be momentum distribution and the resonance width indicate an inversion of the $1s_{1/2}$ and $0p_{1/2}$ shells. The inversion is further supported from analysis of the low-lying ^{14}Be level structures (1999La20). (2007Bl02, 2018Ri05,2019Fo02) discuss the expectation for a J^π=1/2$^-$ state to be populated in neutron stripping from ^{14}Be and to be absent in proton stripping from ^{14}B; hence J^π=1/2$^-$ is recommended for this resonance.
0.39×10^{3} *3*	1/2$^+$	1.78 MeV *16*	0.84 *3*	A C eF J M P	%n=100 XREF: A(0.36E3). From E_{res}=0.81 MeV *6* (analysis of (2004Le29) C(^{14}B,^{13}Be) given in (2013Ak02)), 0.86 MeV *4* (2018Ri05) ^{1}H(^{14}B,^{13}Be), 0.85 MeV *15* (2014Ra07) C(^{14}B,^{13}Be) and 0.80 MeV *9* (1998Be28) ^{14}C(^{11}B,^{12}N). Γ: From Γ=2.1 MeV *3* (see fit to (2010Ko17) given in (2013Ak02)) and Γ=1.70 MeV *15* (2018Ri05). See other value Γ=0.30 MeV *30* in (2014Ra07). J^π: From (2015Ma62) ^{9}Be(^{13}B,^{13}Be) where the ^{12}Be+n resonance is *s*-wave in character, see additional discussion in (2013Ak02, 2019Fo02). E(level): Decays via ^{12}Be$_{g.s.}$+n.
1.61×10^{3} *3*	5/2$^+$	0.40 MeV *+4−5*	2.06 *3*	ABCDEFGHIJKLM OP	%n=100

^{13}Be Levels (continued)

E(level)[‡#]	J$^{\pi}$	Γ	E$_{c.m.}$(^{12}Be$_{g.s.}$+n) (MeV)[†]	XREF	Comments
					XREF: A(1.50E3)F(2.11E3)J(1.90E3)K(2.0E3)M(1.42E3). From E$_{res}$=2.07 MeV *3* (2010Ko17 in 2013Ak02) ^{1}H(^{14}Be,^{13}Be), 1.95 MeV *5* (2013Ak02) ^{1}H(^{14}Be,^{13}Be), 2.11 MeV *5* (2018Ri05) ^{1}H(^{14}B,^{13}Be), 2.01 MeV *5* (1992Os04) ^{13}C(^{14}C,^{14}O), 1.87 MeV *10* (1998Go30) ^{14}C(π^{-},p), 1.9 MeV *5* (1983Al20) ^{14}C(^{7}Li,^{8}B), 2.02 MeV *6* (1998Be28) ^{14}C(^{11}B,^{12}N) and 2.22 MeV *+4−5* (2023Ko21). Γ: From (2023Ko21). See also 0.3 MeV *1* in (1998Go30), 0.3 MeV *2* in (1992Os04), ≈0.5 MeV in (2013Ak02), ≈0.4 MeV in (2018Ri05) and ≈0.3 MeV in (2007Si24). J$^{\pi}$: From (2013Ak02) ^{1}H(^{14}Be,^{13}Be) where *d*-wave decay is reported in ^{12}Be$_{g.s.}$+n and *s*-wave character is reported in ^{12}Be(2^{+})+n decay. In (1998Be28) the ^{12}C(^{11}B,^{12}N) and ^{14}C(^{11}B,^{12}N) spectra are shown to be similar, which supports 5/2^{+} for this state. E(level): Decays via ^{12}Be$_{g.s.}$+n [E$_{res}$=2.11] and ^{12}Be*(2.109)+n [E$_{res}$<0.1 MeV] (2013Ak02,2018Ri05,2019Co12).
2.53×10^{3} *4*	(5/2^{+})	≈0.4 MeV	2.98 *4*	A C F IJ M P	%n=100 XREF: F(2.11E3)J(1.90E3). E(level): From E$_{res}$=2.98 MeV 4 (2010Ko17 in 2013Ak02) ^{1}H(^{14}Be,^{13}Be), 3.02 MeV *9* (2013Ak02) ^{1}H(^{14}Be,^{13}Be), 2.90 MeV *13* (1998Be28) ^{14}C(^{11}B,^{12}N). Γ: From ≈0.5 MeV (2010Ko17, 2013Ak02), ≈0.4 MeV (2007Si24, 2018Ri05) and ≤0.15 MeV (1998Go30). J$^{\pi}$: From (2018Ri05) ^{1}H(^{14}B,^{13}Be). The state′s population in proton knockout, where negative parity states are suppressed, supports a positive parity assignment. The state is thought to decay most strongly to ^{12}Be(0^{+}_{2}), but this branch is difficult to observe; see discussion in (2019Fo02). E(level): Decays via ^{12}Be$_{g.s.}$+n (2013Ak02,2018Ri05); an unobserved branch via ^{12}Be(0^{+}_{2})+n is expected.
≈3.55×10^{3}	(3/2^{+})	≈0.4 MeV	4.0	C	%n=100 E(level),J$^{\pi}$,Γ: From (2018Ri05) ^{1}H(^{14}B,^{13}Be). J$^{\pi}$: Populated in proton knockout from ^{14}B indicating π=+; see further discussion in (2019Fo02) indicating a J$^{\pi}$=3/2^{+} state is expected in this vicinity with similar decay properties. E(level): Decays via ^{12}Be$_{g.s.}$+n [E$_{res}$=4.0] and ^{12}Be*(2109)+n [E$_{res}$≈2.1 MeV].

Adopted Levels (continued)

^{13}Be Levels (continued)

E(level)[‡#]	J$^{\pi}$	Γ	E$_{c.m.}$(^{12}Be$_{g.s.}$+n) (MeV)[†]	XREF	Comments
4.63×10^{3} *5*	(3/2^{-},5/2^{+})	1.4 MeV *2*	5.08 *5*	AB D LM P	%n=100 XREF: P(4.49E3). E(level): From E$_{res}$=5.2 MeV *1* (2010Ko17 in 2013Ak02) ^{1}H(^{14}Be,^{13}Be), 5.1 MeV *13* (2019Co12) ^{1}H(^{14}Be,^{13}Be), 5.13 MeV *7* (1992Os04) ^{13}C(^{14}C,^{14}O), 4.96 MeV *20* (1998Go30) ^{14}C(π^{-},p) and 4.94 MeV *8* (1998Be28) ^{14}C(^{11}B,^{12}N). Γ: From (2010Ko17 in 2013Ak02). Others are 0.4 MeV *2* (1992Os04) and ≈1.7 MeV (1998Go30). J$^{\pi}$: From (2013Ak02) ^{1}H(^{14}Be,^{13}Be) where *s*-wave neutron emission from a 3/2^{-} state (or *p*-wave emission from a 5/2^{+} state) to ^{12}Be(1^{-}) are prefered. E(level): (2013Ak02) report the state decays to ^{12}Be*(2.71 MeV) while (2019Co12) report the state decays to ^{12}Be*(2.1 MeV).
5.43×10^{3} *10*			5.88 *10*	B P	%n=100 E(level): From (1998Be28) ^{14}C(^{11}B,^{12}N); see also E$_{res}$=5.7 MeV *14* in (2019Co12) ^{1}H(^{14}Be,^{13}Be). E(level): Decays to ^{12}Be*(2.71 MeV)+n (2019Co12).
6.55×10^{3}[@]			7.0	D	E(level): From (1995Ko10, 1995Ko27) ^{2}H(^{12}Be,p).
8.1×10^{3}[@] *2*		0.9 MeV *3*	8.5 *2*	L P	XREF: P(7.5E3). E(level),Γ: From E$_{res}$=8.5 MeV *2* (1992Os04) ^{13}C(^{14}C,^{14}O); see also 7.9 MeV *2* (1998Be28) ^{14}C(^{11}B,^{12}N).
9.6×10^{3}[@]			10.0	D	E(level): From (1995Ko10, 1995Ko27) ^{2}H(^{12}Be,p).
16.7×10^{3}[@]		9.0 MeV *15*		K	E(level),Γ: From (1992Wa11) ^{13}C(π^{-},π^{+}).
≈30×10^{3}[@]				N	E(level): From (2016Ko22) ^{14}C(π^{-},pd).

[†] E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{g.s.}$ center of mass energy.

[‡] The ground state is taken as E$_{c.m.}$(n+^{12}Be$_{g.s.}$)=0.45 MeV *1*.

[#] Broad states are reported at E$_{c.m.}$(^{12}Be$_{g.s.}$+n)=2.56 MeV and 2.35 MeV in ^{9}Be(^{13}B,^{13}Be) and C(^{14}B,^{13}Be), respectively. The present evaluation assumes these correspond to unresolved groups at E$_{c.m.}$(^{12}Be$_{g.s.}$+n)=2.0 MeV and 2.98 MeV.

[@] Decay mode not reported; likely mode is %n=100.

^{1}H(^{14}Be,^{13}Be):1 2013Ak02

2010Ko17: The authors studied resonances in the ^{13}Be nucleus by measuring products from the one-neutron removal reaction on ^{14}Be via the ^{1}H(^{14}Be,^{12}Be+n) reaction using a E(^{14}Be)=69 MeV/nucleon beam (at target center) at RIKEN (ΔP/P=$\pm$2%).

The ^{12}Be ions were detected in a spectrometer, while 54 plastic scintillator rods detected the neutrons; γ-rays identifying populated ^{12}Be states were also measured. The ^{13}Be resonance energies were deduced from reconstruction of the invariant mass. A low-energy s-wave strength is observed, which is characterized with a scattering length $a_s=-3.4$ fm *6*. Resonances are suggested at E_{res}=0.51 MeV *1* with Γ=0.45 MeV *3* and σ=48 mb *4*, along with E_{res}=2.39 MeV *5* with Γ=2.4 MeV *2* and σ=34 mb *3*. The peak corresponding to E_{res}=2.39 MeV can also be reproduced with groups at E_{res}=2.0 MeV and E_{res}=2.9 MeV as suggested by (1992Os04,1998Be28). This three-state interpretation is preferred in the ENSDF evaluation. Analysis of the transverse momentum distribution along with the 0.45 MeV width of the lower state was interpreted as evidence for a *p*-wave ($J^{\pi}=1/2^{-}$) nature for this state. The authors suggest this intruder configuration implies a disappearance of N=8 magicity.

In this measurement, the low energy strength is attributed to a background resulting from ^{1}H(^{14}Be,^{14}Be*$\rightarrow$^{12}Be+2n) channel vs the single-neutron removal ^{1}H(^{14}Be,^{13}Be+n$\rightarrow$(^{12}Be+n)+n) channel. However, the measurement provided n+^{12}Be+γ coincidence data that gave hints for a low-energy neutron component feeding ^{12}Be*(2.1 MeV).

The (2010Ko17) data is reanalyzed in (2013Ak02) guided by details on other resonances discovered in other measurements. In this reanlysis information on states isolated in the the n+^{12}Be+γ coincidence data provided new information. Relevant fit parameters from that analysis are E_{res}=0.46 MeV *1* with Γ=0.11 MeV *2*, E_{res}=2.07 MeV *3*, E_{res}=2.98 MeV *3*, E_{res}=5.2 MeV *1* with Γ=1.4 MeV *2*; resonances at E_{res}=0.81 MeV *1* with Γ=2.1 MeV *3* and E_{res}=2.0 MeV *1* decaying to ^{12}Be*(2.1 MeV), and the Γ=0.5 MeV widths of E_{res}=2.0, 2.07, 2.98 were fixed in the analysis. Results from the reanalysis are preferred in this evaluation.

2013Ak02: XUNDL dataset compiled by TUNL, 2013.

The authors reconstructed the ^{12}Be+n relative energy of ^{13}Be states populated in the one-neutron knockout reaction ^{1}H(^{14}Be,^{13}Be$\rightarrow$^{12}Be+n) at E(^{14}Be)=304 MeV/u. Analysis was carried out by simultaneously fitting new data as well as data collected earlier at RIKEN at E(^{14}Be)=69 MeV/nucleon (2010Ko17).

An E(^{14}Be)=304 MeV/nucleon beam, produced by fragmenting a ^{18}O beam on a Be target at the GSI/FRS, impinged on a 5.0 cm long liquid hydrogen target. The ^{12}Be ions were identified by ΔE-E techniques while their momentum was determined using a set of Multi-Wire Proportional Chamber (MWPC) combined with the magnetic rigidity analysis of the ALADIN spectrometer. Neutron momenta were measured using the large area neutron detector (LAND). Resolution for the relative energies varies from 250 keV at E_{rel}=500 keV to 700 keV at E_{rel}=2 MeV.

The new E(^{14}Be)=304 MeV/nucleon GSI data are simultaneously analyzed with the relative energy spectrum data from RIKEN, which was collected at E(^{14}Be)=69 MeV/nucleon (2010Ko17). While subtle differences are visible among the two spectra, the analysis resulted in a coherent description of both data sets by fitting the resonances with Breit-Wigner shapes whose locations and angular momenta were partly guided by information from previously observed ^{13}Be and ^{12}Be states.

Strength from six neutron resonances were considered in fitting the measured neutron spectra: the unbound resonances at $S_n=-0.44$, -0.81, -1.95, -2.0, -3.02 and -5.2 MeV. In the analysis, two components were fixed by prior neutron + γ coincidence data of (2010Ko17): first, neutron decay from the high energy tail of a $J^{\pi}=5/2^{+}$ level at $S_n=-2.0$ MeV with Γ=0.5 MeV decays to ^{12}Be*(2.1: $J^{\pi}=2^{+}$) producing a structure peaked near E_{rel}(n+^{12}Be*)$\approx$0 MeV; second, neutron decay from a $J^{\pi}=(5/2^{+},3/2^{-})$ level at $S_n=-5.2$ MeV with Γ=1.4 MeV decays to ^{12}Be*(2.7) producing a peak near E_{rel}(n+^{12}Be*)$\approx$2.5 MeV. Results from that fit are in table 3 of (2013Ak02) and are given below.

In contrast to the above analysis of the neutron group energies, the low-energy part of the spectrum was analyzed with an assumption that two expected *l*=0 ($J^{\pi}=1/2^{+}$) resonances are present at E_{res}=0.46 and 2.9 MeV. Such an assumption results in a good fit to the data for destructive interferences, and is able to account for the enhancement at $E_{rel.}$=0.81 MeV without requiring a level at $S_n=-0.81$ MeV. This interpretation is not preferred in the present ENSDF evaluation.

See detailed discussion on spin values, taken from other experimental results.

Theory.

2010Fo11: A simple model is developed suggesting that an appreciable part of the strength associated with decay of the $\approx$ 0.5 MeV resonance to $^{12}Be_{g.s.}$ is actually decay from the $5/2^{+}_{2}$ to the long lived ^{12}Be($J^{\pi}=0^{+}_{2}$) isomer.

${}^{1}H({}^{14}Be,{}^{13}Be)$:1 **2013Ak02 (continued)**

${}^{13}Be$ Levels

E(level)[#][@]	J^{π}[#]	Γ[#]	E′ (MeV)[†]	Comments
0	1/2$^-$	0.39 *5*	0.44 *1*	See also S_n=−0.46 MeV *1* and Γ=0.11 MeV *2* in (2013Ak02) analysis of (2010Ko17) data. J^{π}: From *l*=1 resonance in (2010Ko17).
0.36×10^3 *6*	1/2$^+$	2.1 MeV *3*	0.81 *6*	E(level),J^{π},Γ: Parameters are taken from a fit to data given in (2004Le29). Precise values appear to be from a private communication. The authors debate the origin of this group; since a two interfering state interpretation suggests the strength may arise from destructive interference between 1/2$^+$ states. This evaluation does not accept the two interfering state interpretation.
1.50×10^3 *5*	5/2$^+$	0.5[‡] MeV	1.95 *5*	See also S_n=−2.07 MeV *3* in (2013Ak02) analysis of (2010Ko17) data. E(level): decays to ${}^{12}Be_{g.s.}$ and its high energy tail decays to ${}^{12}Be$*(2.1 MeV) with $E_{res}(n+{}^{12}Be^{*})\approx0$ MeV.
2.57×10^3 *9*	1/2$^-$	0.5[‡] MeV	3.02 *9*	See also S_n=−2.98 MeV *4* in (2013Ak02) analysis of (2010Ko17) data. E(level): decays to ${}^{12}Be_{g.s.}$ with $E_{res}(n+{}^{12}Be)$=3.02 MeV.
4.75×10^3	(3/2$^-$,5/2$^+$)	1.4 MeV *2*	5.2 *1*	E(level),Γ: From (2013Ak02) analysis of (2010Ko17) data. E(level): decays to ${}^{12}Be$*(2.71 MeV) with $E_{res}(n+{}^{12}Be^{*})$=2.5 MeV.

[†] E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+${}^{12}Be_{g.s.}$ center of mass energy.

[‡] For the fit, the width of these states was held fixed, based on details discussed in the text.

[#] From (2013Ak02), except where noted.

[@] The ground state is taken as $E_{c.m.}(n+{}^{12}Be_{g.s.})$=0.45 MeV *1*; see Adopted Levels.

^{1}H(^{14}Be,^{13}Be):2 2019Co12

2019Co12: XUNDL dataset compiled by TUNL 2020.

The authors populated resonances in the unbound ^{13}Be nucleus using (p,pn) quasi-free scattering reactions to knock-out a neutron from ^{14}Be nuclei.

A cocktail beam, including 265 MeV/nucleon ^{14}Be ions, was produced by fragmenting a ^{48}Ca beam at the RIKEN/BigRIPS fragment separator. The ^{14}Be ions were identified in the beam using time-of-flight techniques before impinging on the 15 cm thick liquid hydrogen target of the MINOS device that is surrounded by a charged-particle time projection chamber (TPC). Protons scattered out of the target were momentum analyzed using the TPC, a multi-wire drift chamber (MWDC) and an array of plastic energy detectors covering $\theta \approx 30° - 65°$; the quasi-free scattered neutron was momentum analyzed on the opposite side of the beam using the WINDS array of plastic scintillators that covered $\theta \approx 20° - 60°$.

The ^{13}Be products decayed in flight into a ^{12}Be+n pair; the heavy ^{12}Be fragment was momentum analyzed using the SAMURAI dipole magnet and a set of MWDCs for tracking while the associated neutron was momentum analyzed using the position-sensitive NEBULA array of plastic scintillators. Finally, 68 crystals from the DALI2 γ ray detection array partially covered $\theta = 34° - 115°$ to measure γ rays from ^{13}Be*→n+^{12}Be* decays.

Separate spectra for the n+^{12}Be*(0,2.1,2.7 MeV) components are obtained using the coincidence γ rays. Analysis of the spectra presented in figure 4 indicates ^{13}Be resonances at $S_n = -0.48$, -2.3, -5.1 and -5.7 MeV decaying to ^{12}Be*(0,2.1,2.7 MeV). A detailed analysis of the knocked−out neutrons associated with the low energy part of the n+^{12}Be relative energy spectrum is best fit assuming dominant p-wave strength rather than s-wave strength; this supports a $J^{\pi} = 1/2^{-}$ assignment for the $S_n = -0.48$ MeV resonance. A significant discussion on the nature of the low-energy strength is included that compares the findings of (2010Ko17, 2013Ak01, 2013Ak02, 2018Ri05). The authors developed a three-body ^{12}Be+n+n model for the ^{14}Be projectile and analyzed the quasi-free neutron scattering reaction dynamics; the results are consistent with dominant p-wave strength at low energies with no need for significant contributions from a $J^{\pi} = 1/2^{+}$ virtual state of ^{13}Be.

^{13}Be Levels

E(level)#	J^{π}	E′ (MeV)†‡	Comments
0	($1/2^{-}$)	0.48 *40*	Decays via $^{12}\mathrm{Be}_{\mathrm{g.s.}}$+n with $E_{\mathrm{rel.}}$(n+^{12}Be)=0.48 MeV.
1.9×10^{3}	($5/2^{+}$)	2.3 *9*	Decays via $^{12}\mathrm{Be}_{\mathrm{g.s.}}$+n and ^{12}Be*(2.1 MeV)+n.
4.7×10^{3}		5.1 *13*	Decays via ^{12}Be*(2.1 MeV)+n with $E_{\mathrm{rel.}}$(n+$^{12}\mathrm{Be}^{*}$)=3.0 MeV.
5.3×10^{3}		5.7 *14*	Decays via ^{12}Be*(2.7 MeV)+n with $E_{\mathrm{rel.}}$(n+^{12}Be)=3.0 MeV.

† E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+$^{12}\mathrm{Be}_{\mathrm{g.s.}}$ center of mass energy.

‡ Invariant mass resolution is $0.587\times(E_{\mathrm{res}})^{-1/2}$.

The ground state is taken as $E_{\mathrm{c.m.}}$(n+$^{12}\mathrm{Be}_{\mathrm{g.s.}}$)=0.45 MeV *1*; see Adopted Levels.

^{1}H(^{14}B,^{13}Be) 2018Ri05

2015Ri03: ^{1}H(^{14}B,^{13}Be). A beam of ^{14}B ions, produced by fragmenting a 490 MeV/nucleon ^{40}Ar beam at the GSI/FRS, impinged on a 9.7 mm thick CH$_2$ foil that was located at the ALADIN spectrometer target position. Quasi-free (p,2p) scattering reactions removed protons from ^{14}B and populated states in neutron-unbound ^{13}Be nuclei, which quickly break apart into ^{12}Be+n. At the exit of the spectrometer, the momenta of breakup ^{12}Be ions and associated neutrons were measured using a ΔE-ΔE-ToF array (for heavy particles) and the LAND neutron array (for neutrons). Additionally, an array of 162 NaI scintillator detectors surrounded the target with the aim of detecting any emitted γ rays, which is necessary to determine the contributions from ^{12}Be$_{g.s.}$ and excited states. Data from this experiment is included in the analysis of (2018Ri05).

2018Ri05: XUNDL data set compiled by TUNL, 2018.

The present study aims to measure the full set of ^{12}Be+n system and γ-ray experimental observables for decay of ^{13}Be resonances.

A beam of 400 MeV/nucleon ^{14}B ions, from the GSI/FRS facility impinged on a 922 mg/cm^2 polyethylene target that was surrounded by the 159 NaI element Crystal Ball γ-ray detector array. The ^{13}Be nuclides, formed in single-proton removal reactions, immediately decayed into ^{12}Be+n; the decay neutrons were momentum analyzed using the 2 ×2 meter^2 LAND neutron wall, while the ^{12}Be core ejecta were identified and momentum analyzed using the ALADIN dipole along with a double sided ΔE strip detector and the “time-of-flight wall”. Associated γ-rays were detected using the Crystal Ball.

The E$_{c.m.}$(^{12}Be+n) relative energy spectrum is analyzed for ^{12}Be+n and ^{12}Be+n+γ data. Evidence for five groups is found. Notably, two groups are found in coincidence with the ^{12}Be*(2.109 MeV)→^{12}Be(0) γ-ray transition: first from a neutron group at E$_{res}$<500 keV and second from a neutron group at E$_{res}$≈2 MeV. Overall, five neutron groups are identified in the present experimental work, with the three additional groups at E$_{res}$≈2.11, 2.92 and 4.0 associated with decay directly to ^{12}Be$_{g.s.}$.

The authors highlighted the shortcomings of past experiments, due to incomplete collection of necessary information, and they aimed to give an explanation of the complete evidence on ^{13}Be level data. Results from proton knockout from ^{14}B at 35 MeV/nucleon (2014Ra07) and 400 MeV/nucleon (present), neutron neutron knockout data from ^{14}Be at 69 MeV/nucleon (2010Ko17), 287 MeV/nucleon (2007Si24) and 304 MeV/nucleon (2013Ak02), and single charge exchange reactions with ^{13}B at 71 MeV/nucleon were considered in developing an overall interpretation. The analysis aimed to explain differences in peak positions and group widths by accounting for branching to ^{12}Be*(2.109) and the differences in strengths for levels populated by the different reaction mechanisms and at different reaction energies.

In general, the present work identifies levels at S$_n$=−0.86, −2.11, −2.92 and −4.0 MeV that decay to ^{12}Be$_{g.s.}$. In addition, the levels at S$_n$=−2.11 and −4.0 MeV also decay to ^{12}Be*(2.109) with resonance energies around E$_{c.m.}$(^{12}Be*+n)≈0.1 and 2.0 MeV; since there is overlap of the neutron groups, it is necessary to deconvolute ground state branches from the ^{12}Be*(2.109) branches in order to obtain accurate state widths. Furthermore, the authors suggest that the different reactions/mechanisms result in different amplitudes for populating the levels, which further complicates an overall analysis.

A note in proof of (2016Fo07) details unpublished ^{1}H(^{14}B,2p) data where a E$_{res}$(n+^{12}Be)= 0.95 MeV group is connected to population of ^{12}Be*(2.1 MeV).

^{13}Be Levels

E(level)[#]	J$^\pi$	Γ	E′ (MeV)[‡]	Comments
0.41×10^3 *4*	1/2$^+$	1.70 MeV *15*	0.86 *4*	E(level): Decays via ^{12}Be$_{g.s.}$+n.
1.66×10^3 *5*	5/2$^+$	0.4[†] MeV	2.11 *5*	E(level): Decays via ^{12}Be$_{g.s.}$+n with E$_{res}$=2.11 MeV and ^{12}Be*(2109)+n with E$_{res}$(n+^{12}Be*)<0.1 MeV.
≈2.47×10^3[†]	5/2$^+$	0.4[†] MeV	2.92[†]	E(level): Decays via ^{12}Be$_{g.s.}$+n.
≈3.6×10^3[†]	(3/2$^+$)	0.4[†] MeV	4.0[†]	E(level): Decays via ^{12}Be$_{g.s.}$+n with E$_{res}$=4.0 MeV and ^{12}Be*(2109)+n with E$_{res}$(n+^{12}Be*)≈2.1 MeV].

[†] From (1992Os04, 1998Go30, 1998Be28).

[‡] E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{g.s.}$ center of mass energy.

[#] The ground state is taken as E$_{c.m.}$(n+^{12}Be$_{g.s.}$)=0.45 MeV *1*; see Adopted Levels.

^{2}H(^{12}Be,p) 1995Ko10,1995Ko27

1995Ko10,1995Ko27,1995KoZK: ^{2}H(^{12}Be,p) E=55 MeV/nucleon. A beam of ^{12}Be ions was produced at the RIKEN/RIPS facility and impinged on a CD$_2$ target. The recoil proton spectrum was measured and analyzed to determine the excitation spectrum, as a function of energy above the ^{12}Be+n threshold. Four peaks were observed at E$_{rel}$(^{12}Be+n)≈2, 5, 7, 10 MeV. Resolution is rather poor.

See theoretical analysis in (2018Ma05).

^{13}Be Levels

E(level)‡	E′ (MeV)†
1.6×10^3	≈2.0
4.6×10^3	≈5.0
6.6×10^3	≈7.0
9.6×10^3	≈10.0

† E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{g.s.}$ center of mass energy.

‡ The ground state is taken as E$_{c.m.}$(n+^{12}Be$_{g.s.}$)=0.45 MeV *1*; see Adopted Levels.

^{2}H(^{12}Be,^{13}Be) 2023Ko21

2023Ko21: XUNDL dataset compiled by TUNL (2023).

A beam of 9.5 MeV/nucleon ^{12}Be ions from the TRIUMF ISAC-II facility impinged on a 52 μm thick solid deuterium target that was frozen on a 4.64 μm silver foil that was positioned at the center of the IRIS experimental facility. The reaction protons scattered in the backward direction were detected by an annular array of MICRON YY1 position sensitive Si detectors that covered $\theta_{\text{lab.}}$=122° to 148°. Associated ^{12}Be remnants from ^{12}Be(d,p+[^{13}Be$\rightarrow$^{12}Be+n]) were detected at small angles using a position sensitive MICRON S3 annular detector that was paired with a CsI scintillator detector to provide ΔE-E particle identification. Events were analyzed only in a triple coincidence when a ^{12}Be was identified in the upstream (IC) and when both the backward recoiling proton and ^{12}Be remnant were detected.

A Q-value spectrum covering Q=−5.5 to −2.0 MeV was obtained from the data. A Bayesian optimization in combination with a GEANT4 Monte Carlo simulation of the experiment guided the interpretation of the spectrum. Two broad structures dominate the lineshape; a low-energy component with E$_{\text{c.m.}}$(n+^{12}Be)=0.55^{+8}_{-7} MeV and Γ=0.11^{+4}_{-5} MeV and a high-energy component with E$_{\text{c.m.}}$=2.22^{+4}_{-5} MeV and Γ=0.40^{+3}_{-4} MeV. The addition of a third state had little impact on the quality of the fit.

The autors evaluated the character of the peaks using several approaches. The higher-energy component was identified as the *d*-wave resonance reported in previous works. For the low-energy strength, a DWBA analysis using the FRESCO code was used to evaluate the *s*-, *p*-, *d*-, *sp*-, *sd*-, or *pd*-wave character. Involvement of two states having ≈67% *s*-wave and ≈33% *p*-wave character provided the best fit to the data.

A *p*-wave resonance is suggested between 0.44-0.55 MeV with an additional less-understood low-energy *s*-wave strength; additionally a *d*-wave resonance is present between 2.11 and 2.3 MeV. Weighing this, the evaluator attributes the lower group as an unresolved combination of J^{π}=1/2^{+} and 1/2^{-} *s*- and *p*-wave strength and attributes the higher group to a J^{π}=5/2^{+} *d*-wave resonance.

^{13}Be Levels

E(level)†	J$^{\pi}$†	Γ†	E$_{\text{c.m.}}$(n+^{12}Be) (keV)	Comments
0.10×10^{3} *8*	1/2^{-}&1/2^{+}	0.11 MeV *+4−5*	0.55 *+8−7*	E(level): E=0.10 MeV +8−7. E(level): This peak comprises unresolved *s*-wave and *p*-wave resonances.
1.75×10^{3} *5*	5/2^{+}	0.40 MeV *+3−4*	2.22 *+4−5*	E(level): E=1.75 MeV +4−5.

† From R-matrix analysis in (2023Ko21). The ground state is taken as E$_{\text{c.m.}}$(n+^{12}Be$_{\text{g.s.}}$)=0.45 MeV *1*; see Adopted Levels.

^{9}Be(^{13}B,^{13}Be) 2015Ma62

2015Ma62: XUNDL dataset compiled by TUNL, 2015.

The authors populated neutron-unbound states in ^{13}Be using a ^{13}B beam and charge exchange reactions on a ^{9}Be target.

A beam of 71 MeV/nucleon ^{13}B ions was produced by fragmenting a 120 MeV/nucleon ^{18}O beam on a ^{9}Be target at the NSCL/A1900 beam facility. The ^{13}Be beam impinged on a 51 mg/cm^2 ^{9}Be target placed at the large-gap sweeper magnet target position. Charge-exchange reactions populating ^{13}Be states resulted in events where neutrons from the decay of ^{13}Be states were detected in the MONA-LISA array, while ^{12}Be ions from the decay were momentum analyzed and characterized using the dipole sweeper magnet. Finally the decay energy was reconstructed by the invariant-mass method.

The present results are fitted with both two- and three-resonance assumptions. The best fit includes an s-wave resonance at E_{res}=0.73 MeV *9* [J^π=1/2$^+$ Γ=1.98 MeV *34*] and a d-wave resonance at E_{res}=2.56 MeV *13* [J^π=5/2$^+$, Γ=2.29 MeV *73*].

A three-resonance fit is provided, though the approach is complex. The parameters of the lowest state are fixed by (2014Ra07) at E_{res}=0.40 MeV, Γ=0.80 MeV and J^π=1/2$^+$; the parameters of the highest resonance are taken from the 2-resonance fit E_{res}=2.56 MeV, Γ=2.29 MeV and J^π=5/2$^+$; in this case a third resonance can be fitted at E_{res}=1.05 MeV *10* with J^π=5/2$^+$ and Γ=0.50 MeV *20*.

^{13}Be Levels

E(level)[‡]	J^π	Γ	E′ (MeV)[†]
0.28×10^3 *9*	1/2$^+$	1.98 MeV *34*	0.73 *9*
2.11×10^3 *13*	5/2$^+$	2.29 MeV *73*	2.56 *13*

[†] E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{g.s.}$ center of mass energy.

[‡] The ground state is taken as $E_{c.m.}$(n+^{12}Be$_{g.s.}$)=0.45 MeV *1*; see Adopted Levels. Resonance energies from the best fit, which is a two-parameter fit shown in Fig. 1. An alternate 3-resonance fit is provided in Fig. 2 and presented in Table 1.

^{9}Be(^{18}O,^{13}Be) **2001Th01**

2001Th01: ^{9}Be(^{18}O,^{13}Be→^{12}Be+n) E(^{18}O)=80 MeV/nucleon. The authors impinged ^{18}O ions onto a 94 mg/cm^{2} berylium foil and momentum analyzed the residual ^{12}Be and neutron reaction products that were emitted along $\theta\approx0°$. The decay products were analyzed using typical sequential decay neutron spectroscopy technques. Monte Carlo analysis of the n+^{12}Be relative energy spectrum is most consistent with a low-lying s-wave state with a scattering length $a_s<-10$ fm, which corresponds to $E_{res}\leq200$ keV. The analysis explores the possibility for participation of ^{12}Be excited states. In the best fit, there is also a contribution from a $d_{5/2}$ state at $E_{res}\approx2.0$ MeV.

See also (1995ThZZ).

^{13}Be Levels

E(level)[†]	J^{π}	$E_{c.m.}$(^{12}Be+n) (MeV)	Comments
x	$1/2^{+}$	<0.2	E(level): This group was later associated with decay from the high-energy tail of the $J^{\pi}=5/2^{+}$ state to ^{12}Be*(2.1 MeV; $J^{\pi}=2^{+}$).
$\approx1.55\times10^{3}$	$5/2^{+}$	≈2.0	

[†] The ground state is taken as $E_{c.m.}(n+^{12}Be_{g.s.})=0.45$ MeV *1*; see Adopted Levels.

^{9}**Be(**^{48}**Ca,X)** **2008Ch07**

2008Ch07: ^{9}Be(^{48}Ca,^{12}Be+n) E=60 MeV/nucleon. The authors measured the neutron+charged particle ejecta produced in fragmentation reactions of ^{48}Ca on a berylium target. The charged fragments were momentum analyzed using a large gap dipole sweeper magnet, while neutrons were analyzed using the MSU/MoNA neutron wall, which was positioned along θ=0° with respect to the incident beam. The correlated (fragment)(neutron)-coincidences were analyzed using sequential neutron decay spectroscopy techniques.

The ^{12}Be+n decay energy spectrum compared favorably with a fit that assumed a Breit−Wigner shaped resonance at $E_{decay}\approx 60$ keV with Γ=10 keV and perhaps slightly less well with a shape related to an *s*-wave resonance having a scattering length of $a_s=-20$ fm.

^{13}Be Levels

E(level)	$E_{c.m.}$(^{12}Be+n) (MeV)	Comments
x	≈0.06	E(level): the observed shape can be related to either a Breit-Wigner shaped resonance at $E_{decay}\approx 60$ keV with Γ=10 keV or an *s*-wave resonance having a scattering length of $a_s=-20$ fm. E(level): This group was later associated with decay from the high-energy tail of the $J^{\pi}=5/2^{+}$ state to $^{12}Be^{*}$(2.1 MeV; $J^{\pi}=2^{+}$).

C(^{14}Be,^{13}Be) 2007Si24

2001La02, 2003LeZX, 2003JoZZ: ^{12}C(^{14}Be,^{13}Be*) at E=35 MeV/nucleon. The ^{12}Be+n relative energy spectrum was reconstructed at GANIL using the DeMoN array to measure neutrons and a 5×5 cm^2 position sensitive ΔE-E telescope. The relative energy spectrum is is consistent with a low-lying s-wave state having a scattering length a_s=−20 fm and a higher-lying state at E_{rel}=2 MeV with Γ≈ 0.5 MeV. The longitudinal momentum distribution of neutrons following ^{14}Be breakup were also reported.

2007Si24: ^{12}C(^{14}Be,^{13}Be*) at E=287 MeV/nucleon. Measured ^{12}C(^{14}Be,^{12}Be+n) at GSI using the ALADIN−LAND facility. A beam of ^{14}Be ions impinged on a 1.29 g/cm^2 carbon target and residual ^{12}Be ions were momentum analyzed using the ALADIN spectrometer while neutrons were characterized using the LAND/Large Area Neutron Detector. A low-energy state is observed with the scattering length a_s=−3.2 fm; this state is considered a virtual *s*-wave state. At higher energies, the relative energy spectrum agrees with two previously reported ^{12}Be+n resonances at E=2.00 MeV *5* and 3.04 MeV *7* with Γ=0.3 MeV and 0.4 MeV, respectively (1998Be28,1998Go30,1992Os04). The discussion highlights the need for n+^{12}Be+γ coincidence data. See preliminary reports of the results in (2001AlZZ, 2004Si12).

^{13}Be Levels

E(level)‡	J$^\pi$	Γ†	$E_{c.m.}$(^{12}Be+n) (MeV)†	Comments
x	1/2$^+$			E(level): Low-energy strength is observed corresponding to a scattering of a=−3.2 $+0.9$-1.1 fm (2007Si24). E(level): This group was later associated with decay from the high-energy tail of the J$^\pi$=5/2$^+$ state to ^{12}Be*(2.1 MeV; J$^\pi$=2$^+$).
1.55×10^3	5/2$^+$	0.3 MeV	2.00 *5*	
2.59×10^3	1/2$^-$	0.4 MeV	3.04 *7*	

† From (2007Si24).

‡ The ground state is taken as $E_{c.m.}$(n+${}^{12}Be_{g.s.}$)=0.45 MeV *1*; see Adopted Levels.

C(^{14}B,^{13}Be) 2014Ra07

2004Le29: ^{12}C(^{14}B,^{13}Be) E=41 MeV/nucleon, Measured ^{12}Be+n relative energy spectrum. Preliminary data from GANIL. The relative energy spectrum is fit with an s-wave resonance at low energies (≈800 keV), along with a d-wave resonance around 2 MeV and perhaps some influence from a higher state.

2014Ra07: XUNDL dataset compiled by TUNL, 2014. Includes ^{12}C(^{15}B,^{13}Be) reaction.

Beams of 35 MeV/nucleon ^{14,15}B ions were separately tuned by fragmenting a 55 MeV/nucleon ^{18}O beam on a thick ^{9}Be target at GANIL. The beams were optimized at the LISE target position, where nuclides were clearly identified event-by-event via time-of-flight. The incident beam particle trajectories were measured using two position sensitive drift chambers, and the position on a ^{nat}C target was determined with a resolution of ≈1.5 mm (FWHM).

Reaction products were detected by either a 5×5 cm^2 position sensitive ΔE-ΔE-E Si-strip array or by the 90 element DEMON neutron array. The ^{12}Be+n events were analyzed for the one proton removal reactions on ^{14}B, while ^{12}Be+n+n events were analyzed for ^{15}B breakup events. In the case of the ^{14}B→^{13}Be+p→(^{12}Be+n)+p breakup events, the decay energy is straight forward to determine. On the other hand, the breakup of ^{15}B→^{13}Be+n+p→(^{12}Be+n)+n+p can involve more complex processes and requires further analysis to consider the two neutrons in the final state and potential involvement of ^{14}Be states; essentially a non-resonant continuum shape that is generated by random fragment-neutron event mixing is subtracted from the net kinematic energy reconstructed spectrum.

The potential systematic involvement of ^{12}Be excited states was evaluated by analyzing the γ-ray energy deposited in the DEMON array for ^{12}Be+γ events. Limits of ≈<5% were estimated for participation of excited states.

The analysis of ^{15}B→(^{12}Be+n+n)+p data indicated that ^{14}Be*(1.5 MeV) breakup events, with E(^{12}Be+n+n)<800 keV, contribute significantly to the structure of the ^{12}Be+n relative energy spectrum, by creating/enhancing a peak in the spectrum at E(^{12}Be+n)≈200 keV.

Initial analysis suggested that the ^{14}B breakup data could be fit with either a single E(^{12}Be+n)=2.40 MeV *20* resonance with Γ=0.90 MeV *22*, or a better fit with s-wave and d-wave resonances located at E(^{12}Be+n)=0.70 MeV *11* and 2.40 MeV *14* with Γ=1.70 MeV *22* and 0.70 MeV *32* respectively.

A significant discussion on the shell structures of both, the N=9 isotones and the ^{12}Be structure, led to a third interpretation, which is preferred by the authors. The data are well fit by J$^{\pi}$=1/2$^+$ and 5/2$^+$ resonances at E(^{12}Be+n)=0.40 MeV *3* and 0.85^{+15}_{-11} MeV with Γ=0.80^{+18}_{-12} MeV and 0.30^{+34}_{-15} MeV, and a higher energy J$^{\pi}$=5/2$^+$ state at E(^{12}Be+n)=2.35 MeV *14* with Γ=1.50 MeV *40*.

^{13}Be Levels

E(level)#	J$^{\pi}$	Γ	E′ (MeV)†‡	Comments
0	1/2$^+$	0.80 MeV *+18−12*	0.40 *3*	E(level): The state has an intensity defined as I=1.0.
0.40×10^3 *15*	5/2$^+$	0.30 MeV *+34−15*	0.85 *15*	E(level): from E(^{12}Be+n)=0.85 MeV *+15−11*. E(level): The state has an intensity of I=0.40 *7* relative to the E$_{res}$=0.40 MeV state.
1.90×10^3 *14*	5/2$^+$	1.50 MeV *40*	2.35 *14*	E(level): The state has an intensity of I=0.80 *9* relative to the E$_{res}$=0.40 MeV state.

† E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{g.s.}$ center of mass energy.

‡ From (2014Ra07).

The ground state is taken as E$_{c.m.}$(n+^{12}Be$_{g.s.}$)=0.45 MeV *1*; see Adopted Levels.

^{13}C(π^-,π^+) 1992Wa11

1992Wa11: ^{13}C(π^-,π^+) E=295 MeV, measured $\sigma(\theta)$, $\sigma(\theta$,E(π)). Deduced double GDR in ^{13}Be. The (π^-,π^+) double charge-exchange reaction was studied on a 329 mg/cm^2 ^{13}C target at 295 MeV and at θ=5° using the EPICS spectrometer at LAMPF. Peaks corresponding to the ground state and the double dipole resonance are observed at Q=−32.84 MeV and −49.5 MeV *5*, respectively.

^{13}Be Levels

E(level)	Γ	Comments
≈2.0×10^3		From Q=−32.84 MeV.
18.7×10^3 *5*	9.0 MeV *15*	From Q[(GDR)^2]=−49.5 MeV *5* and Γ=9.0 MeV *14*.

^{13}C(^{14}C,^{14}O) 1992Os04

1992Os04: ^{13}C(^{14}C,^{14}O) E=337 MeV, measured spectra; deduced Q, ΔM, possible levels, J, π. Used a 300 μg/cm^2 highly enriched ^{13}C target at the VICKSI-facility at HMI. Momentum analyzed reaction products using Q3D spectrometer at θ=5°. Essentially three states are seen, initially presumed to be E$_x$=0 (Q$_0$=−37.02 MeV and ΔM=35.16 MeV), 3.12 MeV *7* and 6.5 MeV *2*. The measured widths are analyzed and used to constrain possible J$^\pi$ values. A J$^\pi$=1/2$^+$ ground state is expected from theory, but the lowest state reported here is inconsistent with this interpretation.

See also (1992BoZV,1993BoZP,1993BoZT,1993BoZW,1994PeZZ,1995Pe12, 1995OsZX).

^{13}Be Levels

E(level)‡	J$^\pi$	Γ	E′ (MeV)†	Comments
1.56×10^3 *5*	(5/2$^+$,1/2$^-$)	0.3 MeV *2*	2.01 *5*	State is reported with Q$_0$=−37.02 MeV *5*, which implies ΔM=35.16 MeV *5*.
4.68×10^3 *7*		0.4 MeV *2*	5.13 *7*	
8.1×10^3 *2*		0.9 MeV *3*	8.5 *2*	

† E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{g.s.}$ center of mass energy.

‡ The ground state is taken as E$_{c.m.}$(n+^{12}Be$_{g.s.}$)=0.45 MeV *1*; see Adopted Levels.

^{14}C(π^-,p) **1998Go30**

1998Go30: ^{14}C(π^-,p) E at rest. Measured missing mass spectra.

A 30 MeV π^- beam, from the LAMPF, was slowed in a beryllium moderator and stopped in a 25 mg/cm^2 ≈77% enriched ^{14}C target. Protons from the ^{14}C(π^-,p) capture reactions were measured using the MEPI two-armed ΔE-E semiconductor spectrometer; the ^{13}Be excited state energies were deduced by analysis of the missing mass spectra.

Three resolved peaks are observed above the ^{12}Be+n threshold at E$_{res}$=1.87, 2.95 and 4.96 MeV. However, poor statistics in the lower energy region yield two ambiguous interpretations; the region below E$_{res}$=1.5 MeV can be fit using either one peak at E$_{res}$=0.65 MeV *10* with Γ≈250 keV or with two peaks at 0.09 MeV *10* and 0.68 MeV *10* each having Γ<200 keV. We take the single peak interpretation.

^{13}Be Levels

E(level)‡	Γ	E′ (MeV)†
0.20×10^3 *10*	≈250 keV	0.65 *10*
1.42×10^3 *10*	0.3 MeV *1*	1.87 *10*
2.50×10^3 *10*	<150 keV	2.95 *10*
4.51×10^3 *10*	≈1.7 MeV	4.96 *20*

† E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{g.s.}$ center of mass energy.

‡ The ground state is taken as E$_{c.m.}$(n+^{12}Be$_{g.s.}$)=0.45 MeV *1*; see Adopted Levels.

^{14}C(π^-,pd) 2016Ko22

2016Ko22: ^{14}C(π^-,pd) E=stopped. A beam of 30 MeV π^- mesons, from the LAMPF facility, was moderated in a berylium foil before stopping in a ≈24 mg/cm^2 77% enriched ^{14}C target. Deuterons ejected from the target were analyzed to obtain details on the *inclusive* $\pi^-+{}^{14}C\rightarrow p+{}^{13}Be^*\rightarrow p+{}^{11}Li+d$ reaction; the deuteron emission threshold is 20.8 MeV. The authors suggest a broad state or group of unresolved states around $E_x\approx30$ MeV.

^{13}Be Levels

E(level)[†]
$\approx30\times10^3$

[†] The ground state is taken as $E_{c.m.}(n+{}^{12}Be_{g.s.})$=0.45 MeV *1*; see Adopted Levels.

^{14}C(^{7}Li,^{8}B) 1983Al20

1983Al20: ^{14}C(^{7}Li,^{8}B) E=82 MeV, measured σ(E(^{8}B)).

First evidence for observation of ^{13}Be is reported in the ^{14}C(^{7}Li,^{8}B) reaction at E=82 MeV. A peak is observed in the yield corresponding to ^{13}Be ΔM=35.0 MeV *5*; this ^{13}Be level is then unbound to ^{12}Be+n decay by 1.9 MeV *5*.

^{13}Be Levels

E(level)[‡]	E′ (MeV)[†]
1.45×10^{3} *50*	1.9 *5*

[†] E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{\text{g.s.}}$ center of mass energy.

[‡] The ground state is taken as E$_{\text{c.m.}}$(n+^{12}Be$_{\text{g.s.}}$)=0.45 MeV *1*; see Adopted Levels.

^{14}C(^{11}B,^{12}N) 1998Be28

1998Be28: The ^{14}C(^{11}B,^{12}N) spectrum was measured at E(^{11}B)=190 MeV using the JINR U-400 cyclotron and the MSP-144 spectrograph. The beam impinged on a 360 μg/cm^2 70% enriched ^{14}C target, and reaction products were measured using the spectrograph, which was positioned at θ_{lab}=4.6°. Two position sensitive proportional counters in the focal plane array were used along with a series of ΔE, ΔE, E and VETO detectors; the ^{13}Be ground state Q-value and several excited states were observed.

See also (2001Pe27).

^{13}Be Levels

E(level)‡	E′ (MeV)†	Comments
0.35×10^3 *9*	0.80 *9*	From Q=−39.60 MeV *9*, ΔM=33.95 MeV *9* and S$_n$=−0.80 MeV *9*.
1.57×10^3 *6*	2.02 *6*	From ΔM=35.17 MeV *6*.
2.45×10^3 *13*	2.90 *13*	From ΔM=36.05 MeV *13*.
4.49×10^3 *8*	4.94 *8*	From ΔM=38.09 MeV *8*.
5.43×10^3 *10*	5.88 *10*	From ΔM=39.03 MeV *10*.
7.5×10^3? *2*	7.9 *2*	From ΔM=41.0 MeV *2*.

† E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{g.s.}$ center of mass energy.

‡ The ground state is taken as E$_{c.m.}$(n+^{12}Be$_{g.s.}$)=0.45 MeV *1*; see Adopted Levels.

U(p,X),^{232}Th(^{15}N,X) 1970Ar27

1966Po09,1974Bo05: U(p,X). In (1966Po09) a 5.3 GeV proton beam from the Bevatron impinged on a 26 mg/cm^2 uranium target, and in (1974Bo05) a 4.8 GeV proton beam impinged on 28 mg/cm^2 uranium target. The products were identified by a ΔE-E telescope. ^{13}Be was not observed; in the later work an upper limit of ≈10 ns was set for the life-time.

1970Ar27: ^{232}Th(^{15}N,X) E=145 MeV. The particle instability of ^{13}Be was deduced. The fragmentation products emitted at θ=40° resulting from bombardment of a metalic 20 mg/cm^2 ^{232}Th target were analyzed using a magnetic spectrograph and set of silicon detectors (assumed ΔE-E). No events could be attributed to either ^{13}Be or ^{14}Be, while 500 and 30 events were expected based on the ^{12}Be yield that was observed. It is known from later work that ^{14}Be is particle bound.

1986Gi10: A study of fragmentation products produced in reactions of 44 MeV/nucleon ^{40}Ar ions on a 160 mg/cm^2 tantalum target confirmed the particle instability of ^{13}Be.

^{13}Be Levels

E(level)	Comments
0?	E(level): Level not observed. Particle instability confirmed.

Adopted Levels, Gammas

Q(β^-)=13436.9 *10*; S(n)=4878.8 *17*; S(p)=15804.8 *22*; Q(α)=−10817.9 *10* 2021Wa16

General theory:

1973Sa25, 1973Sa30, 1974Ch46, 1981Av02, 1981Se06, 1983Va08, 1984Va06, 1990Wo10, 1991Po11, 1994Ho21, 1995Ka23, 1997Ba54, 1997Re07, 1999Gu14, 1999Kn04, 1999Ta09, 2001Ka66, 2001Ta04, 2003Is17, 2003Jh01, 2003Sm02, 2003Su04, 2004Um01, 2005Ar12, 2007Gu03, 2008Ka24, 2008Ka36, 2008Sh16, 2011Al11, 2011SuZU, 2012Yu07, 2013Ma60, 2014Me02, 2015Fo06, 2015Ka02, 2015Sh21, 2020Ch40, 2021Ca23, 2021Ma32, 2022Mo36, 2023Me02.

Calculations related to dipole and quadrupole moments:

1972Gu05, 1984Ku07, 1984Va06, 1988Va03, 1991Bo02, 1998Hu08, 1999Ki27, 1999Ki28, 2001Sa24, 2002Sa12, 2003Is17, 2003Jh01, 2003Sm02, 2003Su04, 2003Su28, 2003Um02, 2014Ra17, 2021Ca23).

Mirror nuclear decay and fundamental symmetry effect studies:

1970Wi02, 1971Bl12, 1973Sa25, 1973Wi11, 1977Az02, 1977Ri08, 1993Ch06, 1999Ba21, 2023Se01.

Other relevant results:

1973Sa25: General review of the A=13 isobars and discussion on the isobaric multiplet mass equation. See also (1983An15).

2010Ma44: Measured G-parity conservation via correlations of nuclear spins and β-ray angular distribution. Found $\alpha_-(^{13}B)$=+0.05% *2* MeV^{-1} and g_{II}/g_a=−0.8 *5*.

^{13}B Levels

Cross Reference (XREF) Flags

A	^{14}Be β^-n decay	P	^{12}C(^{9}Be,^{8}B)	AD	^{14}C(γ,p)
B	^{1}H(^{12}Be,^{13}Be)	Q	^{12}C(^{12}Be,^{13}B)	AE	^{14}C(d,^{3}He)
C	^{1}H(^{13}B,X)	R	^{12}C(^{13}C,^{12}N)	AF	^{14}C(t,^{4}He)
D	^{2}H(^{12}B,p)	S	^{12}C(^{14}C,^{13}N)	AG	^{14}C(^{11}B,^{12}C)
E	^{2}H(^{13}B,^{13}B)	T	^{12}C(^{15}N,^{14}O)	AH	^{15}N(p,3p)
F	^{2}H(^{15}C,α)	U	^{12}C(^{16}O,^{13}B),(^{18}O,^{13}B)	AI	^{16}O(^{14}C,^{17}F)
G	^{4}He(^{9}Li,α)	V	^{13}C(γ,π^+)	AJ	^{48}Ca(^{11}B,^{13}B)
H	^{4}He(^{12}Be,^{13}Bγ)	W	^{13}C(μ^-,ν)	AK	^{136}Xe(p,^{13}B)
I	^{7}Li(^{7}Li,p),^{7}Li(^{7}Li,pγ)	X	^{13}C(π^-,γ)	AL	^{181}Ta(^{22}Ne,^{13}B),(^{20}Ne,^{13}B)
J	^{9}Be(^{13}B,X)	Y	^{13}C(π^-,π^0)	AM	^{197}Au(^{15}N,^{13}B)
K	^{9}Be(^{14}B,^{13}Bγ),^{197}Au(^{14}B,^{13}Bγ)	Z	^{13}C(n,p)	AN	^{208}Pb(^{13}B,^{13}B)
L	^{9}Be(^{15}N,^{13}B)	Others:		AO	^{232}Th(^{18}O,^{13}B),^{232}Th(^{22}Ne,^{13}B)
M	^{9}Be(^{40}Ar,^{13}B)	AA	^{13}C(d,^{2}He)	AP	^{238}U(^{18}O,^{13}B)
N	^{11}B(t,p)	AB	^{13}C(t,^{3}He)	AQ	U(p,^{13}B),^{232}Th(p,^{13}B)
O	^{11}B(^{18}O,^{16}O)	AC	^{13}C(^{7}Li,^{7}Be)		

E(level)	J$^\pi$	T$_{1/2}$ or Γ	XREF	Comments
0.0	3/2$^-$	17.30 ms *17*	A CDEF HIJKLMNOP RSTUVWX Z	XREF: Others: AA, AB, AC, AD, AE, AF, AG, AH, AI, AJ, AK, AL, AM, AN, AO, AP, AQ %β^-=100 %β^-n=0.276 *37* (1974Al12) T=3/2 μ=+3.1778 *5* (2004Na38,2019StZV) Q=(+)0.0365 *8* (2021StZZ) μ: See previous value +3.17712 *51* (1971Wi09,1989Ra17). Q: From β-NMR in (2004Na38,2004Na46). See previous values Q=0.0374 *14* (1973HaVZ,1989Ra17) and Q=0.0369 10 in (2003Og03). %β^-n: See also (1962Ma19,1969Jo21). The preliminary work of found %β-n=0.254 *36* in an experiment that didn't

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
				resolve discrete neutron decay groups; the work of (1974Al12) was carried out by the same group, but with significantly improved experimental sensitivity and neutron group resolution. See theoretical discussion in (2003Fo11). $T_{1/2}$: from the weighted average of 17.39 ms *41* (1962Ma19), 17.33 ms *17* (1971Wi07), 17.6 ms *12* (1988Sa04), 16.7 ms *6* (1994ReZZ). $T_{1/2}$: Excluded values are 16.59 ms *2* (2006Ge21), ≈17.36 (2002GeZT, 2005GeZY), 17.0 ms *4* (1997So34) and 16 ms 1 (1968Ch28), 11 ms 9 (1991Re02) and 16.7 ms *3* (1995ReZZ, 2008ReZZ). See also the evaluated value $T_{1/2}$=17.16 ms *18* in (2015Bi05). J^{π}: (2000Gu23) ^{9}Be(^{14}B,^{13}Bγ): L=0 proton removal from ^{14}B, and allowed β^- decay to ^{13}C $J^{\pi}=1/2^-$, $3/2^-$ and $5/2^-$ states.
3483 *5*	$1/2^+$		D H K N p v x z	%IT=100 XREF: p(3600)v(3.5E3)x(3.5E3)z(3.5E3). E(level): From average of 3483 keV *5* (1964Mi04) and 3482 keV *10* (1978Aj02). J^{π}: From (2010Ba06) where L=0 is dominant in ^{12}B(d,p), arguments from spectroscopic factor analysis and shell model expectation of pure L=0 strength from a $1/2^+$ state support this assignment. In (2000Gu23) ^{9}Be(^{14}B,^{13}Bγ): L=1 proton removal from ^{14}B is reported; arguments based on cross section values led to an assignment of $3/2^+$. See also π=+ (1978Aj02) ^{11}B(t,p).
3536.4 *17*	$3/2^-$	0.90 ps *21*	A HI N p v x z	XREF: Others: AB, AC %IT=100 XREF: p(3600)v(3.5E3)x(3.5E3)z(3.5E3)AB(3.6E3)AC (3.5E3). E(level): From average of 3537 keV *2* (2002Ao03:Eγ=3536 keV *2*) ^{14}Be β-n, 3536.8 keV *42* (1969Th01) ^{7}Li(^{7}Li,pγ), 3533 keV *5* (1964Mi04) ^{11}B(t,p) and 3531 keV *10* (1978Aj02) ^{11}B(t,p). $T_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J^{π}: From (2009Iw03) ^{7}Li(^{7}Li,pγ) based on lifetime and M1+E2 decay to ^{13}B$_{g.s.}$. See also $3/2^-$ from (2009Gu23) ^{13}C(t,^{3}He) and see π=− (1978Aj02) ^{11}B(t,p).
3681 *5*	$(5/2^+,3/2^+)$	38 ps *14*	D F HI K NOP rst	XREF: Others: AA XREF: P(3600)r(3690)s(3680)t(3720)aa(3.8E3). E(level): From average of 3681 keV *5* (1964Mi04) ^{11}B(t,p) and 3681 keV *10* (1978Aj02) ^{11}B(t,p). $T_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J^{π}: From (2010Ba06) where L=2 is dominant in ^{12}B(d,p); arguments from spectroscopic factor analysis and shell model expectation of dominant L=2 strength from a $5/2^+$ state support this assignment. A $3/2^+$ state, with equal admixtures of L=0 and 2, is expected within 60 keV of the $5/2^+$

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
				state. (2000Gu23) ^{9}Be(^{14}B,^{13}Bγ) had suggested J^{π}=3/2^{+} and 5/2^{+} for ^{13}B*(3.48,3.61 MeV), respectively, based in L=1 proton removal from ^{14}B and cross section arguments. See also π=+ (1978Aj02) ^{11}B(t,p).
3713 *5*	1/2^{-}	≤0.21 fs	HI N P rst	XREF: Others: AA, AE %IT=100 XREF: P(3600)r(3690)s(3680)t(3720)aa(3.8E3). E(level): From average of 3712 keV *5* (1964Mi04) ^{11}B(t,p) and 3715 keV *10* (1978Aj02) ^{11}B(t,p). $T_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J^{π}: From (1975Ma41, 2016Be08) ^{14}C(d,^{3}He) based on L=1 and the spectroscopic factor magnitude. See also π=− (1978Aj02) ^{11}B(t,p), and see (5/2^{-}) from analysis of various 1p plus 2n transfer reactions on ^{12}C in (2000Ka21) where the E_x=3.6 and 3.7 MeV states are unresolved.
4131 *5*	$^{-}$	≤0.21 fs	HI K NO RST	XREF: Others: AC %IT=100 XREF: AC(4.0E3). E(level): From average of 4134.1 keV *78* (1969Th01) ^{7}Li(^{7}Li,pγ), 4130 keV *10* (1964Mi04) ^{11}B(t,p) and 4128 keV *10* (1978Aj02) ^{11}B(t,p). $T_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J^{π}: See π=− (1978Aj02) ^{11}B(t,p).
4829 *6*	1/2^{+}	≤0.21 fs	HI N S	XREF: Others: AB, AE, AI %IT=100 XREF: S(4910). E(level): From average of 4833 keV *10* (1972Wy01) 4820 keV *10* (1964Mi04) ^{11}B(t,p) and 4834 keV *10* (1978Aj02) ^{11}B(t,p). $T_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J^{π}: From L(p)=0: (2008Ot05) ^{4}He(^{12}Be,^{13}B). See also (1/2^{+}) (2016Be08) ^{14}C(d,^{3}He) where L=0 is deduced. In (2000Ka21) ^{16}O(^{14}C,^{17}F), ^{13}B*(4.8,6.9 MeV) are reported; the authors suggest a mechanism with one 1$p_{1/2}$ and two 1$p_{3/2}$ proton transfers from ^{16}O; leaving remaining protons to couple to 0^{+} for the lower state and 2^{+} for the higher state, resulting in J^{π}=1/2^{-} and (3/2,5/2)$^{-}$, respectively.
5024† *6*			I N R T	E(level): From average of 5033 keV *8* (1972Wy01) 5010 keV *10* (1964Mi04) ^{11}B(t,p) and 5023 keV *10* (1978Aj02) ^{11}B(t,p).
5106† *10*		60 keV *10*	D N P	XREF: Others: AA, AB XREF: P(5200). E(level),Γ: From (1978Aj02).
5388† *6*	(1/2,3/2)$^{-}$	14 keV *5*	D I NOP RST	XREF: Others: AE XREF: P(5200). E(level): From average of 5391 keV *8* (1972Wy01) ^{7}Li(^{7}Li,p), 5380 keV *10* (1964Mi04) ^{11}B(t,p) and 5393 keV *10* (1978Aj02) ^{11}B(t,p).

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	T$_{1/2}$ or Γ	XREF	Comments
			Γ: From average of 15 keV *5* (1964Mi04) and 10 keV *10* (1978Aj02). J^{π}: From L(p)=1 in ^{14}C(d,^{3}He) (2016Be08).
5557?[†] *7*		I	E(level): From (1972Wy01) ^{7}Li(^{7}Li,p).
6167[†] *6*	<20 keV	I NOP T	XREF: Others: AE XREF: AE(6.3E3). E(level): From average of 6169 keV *8* (1972Wy01) ^{7}Li(^{7}Li,p), 6170 keV *20* (1964Mi04) ^{11}B(t,p) and 6164 keV *10* (1978Aj02) ^{11}B(t,p). Γ: In Fig. 10 of (1978Aj02) this state is narrower than the E$_{x}$=5.39 MeV state. It's width is assigned Γ<20 keV. See also Γ≈60 keV (2000Ka21) ^{12}C(^{15}N,^{14}O).
6425[†] *7*	36 keV *5*	I NOP RST V X ZA	XREF: Others: AE XREF: S(6370)AE(6.3E3). E(level): From average of 6419 keV *8* (1972Wy01) ^{7}Li(^{7}Li,p) and 6434 keV *10* (1978Aj02) ^{11}B(t,p). Γ: From (1978Aj02). J^{π}: In (2000Ka21) analysis of ^{12}C(^{13}C,^{12}N),(^{14}C,^{13}N) and (^{15}N,^{14}O) multi-nucleon transfer reactions suggest J^{π}=(9/2^{+}).
6934[†] *9*	55 keV *15*	I N ST	XREF: Others: AB, AI XREF: AI(6900). E(level): From average of 6939 keV *15* from (1972Wy01) ^{7}Li(^{7}Li,p) and 6932 keV *10* (1978Aj02) ^{11}B(t,p) See also (2000Ka21) where E$_{x}$≈6930 keV and Γ≈150 keV are reported. J^{π}: In (2000Ka21) ^{16}O(^{14}C,^{17}F), ^{13}B*(4.8,6.9 MeV) are reported; the authors suggest a mechanism with one 1$p_{1/2}$ and two 1$p_{3/2}$ proton transfers from ^{16}O; leaving remaining protons to couple to 0^{+} for the lower state and 2^{+} for the higher state, resulting in J^{π}=1/2^{-} and (3/2,5/2)$^{-}$, respectively. Γ: From (1978Aj02).
7516?[†] *8*		I ST X Z	XREF: S(7580)T(7760). E(level): From (1972Wy01). E(level): A low-energy shoulder is reported on the 8133 keV peaks reported in (2000Ka21) ^{12}C(^{14}C,^{13}N) and ^{12}C(^{15}N,^{13}O); the authors suggest this group may correspond to unresolved groups that include^{13}B*(7516,7859).
7859?[†] *20*		I ST	XREF: S(7580)T(7760). E(level): From (1972Wy01). E(level): A low-energy shoulder is reported on the 8133 keV peaks reported in (2000Ka21) ^{12}C(^{14}C,^{13}N) and ^{12}C(^{15}N,^{13}O); the authors suggest this group may correspond to unresolved groups that include^{13}B*(7516,7859).
8134[†] *7*	100 keV *15*	I NO RST	XREF: O(8.32E3). E(level): From average of 8129 keV *10* (1972Wy01) and 8138 keV *10* (1978Aj02). Γ: From (1978Aj02).
8683[‡] *7*	89 keV *20*	I N RST	E(level): From average of 8682 keV *9* (1972Wy01) and 8684 keV *10* (1978Aj02). Γ: From (1978Aj02).

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	S	XREF	Comments
9.0×10^{3}		≈8.1 MeV		Y	T=3/2 (1994Ha41) E(level),Γ: From (1994Ha41). Represents the T=3/2 giant resonance built on ^{13}C$_{g.s.}$
9440[‡] *30*		81 keV *25*		N RST	XREF: R(9310). E(level),Γ: From (1978Aj02).
9.5×10^{3}?[‡] *3*					XREF: Others: AC Γ: Γ=broad. E(level),Γ: From (1990Na03) ^{13}C(^{7}Li,^{7}Be).
10220[‡] *20*		210 keV *20*		F N RST X Z	XREF: Others: AB E(level),Γ: From (1978Aj02). J$^{\pi}$: In (2000Ka21) analysis of ^{12}C(^{13}C,^{12}N),(^{14}C,^{13}N) and (^{15}N,^{14}O) multi-nucleon transfer reactions suggest J^{π}=(11/2^{-}).
10890[#] *20*				N	E(level): From (1978Aj02).
11050[#]		1.8 MeV		RST	XREF: R(11180)S(10980). Γ: Broad, possibly many states. E(level),Γ: From (2000Ka21) ^{12}C(^{15}N,^{14}O).
11.7×10^{3}[#]	(5/2^{+},7/2^{+})			F N	E(level),J$^{\pi}$: From (2014Wu10) ^{2}H(^{15}C,α). See also (11.8 MeV) (1978Aj02) ^{11}B(t,p). J$^{\pi}$: For 11.7- and 12.2-MeV doublet. Comparison of the angular distribution of the E$_{x}$≈12 MeV group with the ^{2}H(^{14}C,α)^{12}B*(5.61, J^{π}=3^{+}) suggests this doublet results from the coupling of a 1s$_{1/2}$ neutron to an aligned [(0p$_{3/2}$)$^{-2}$]$_{3+}$ configuration in ^{12}B (2014Wu10).
12.2×10^{3}[#]	(5/2^{+},7/2^{+})			F	E(level): From (2014Wu10) ^{2}H(^{15}C,α). J$^{\pi}$: See comment on E$_{x}$=11.7 MeV.
13.6×10^{3} *1*		≤320 keV		I Q T	%α≤100 E(level),Γ: From (2008Ch28) ^{12}C(^{12}Be,^{13}Be), see also E$_{x}$=13.65 MeV *23* and Γ≈300 keV (2000Ka21) ^{12}C(^{15}N,^{14}O).
14390[#]		≈400 keV		T	E(level),Γ: From (2000Ka21) ^{12}C(^{15}N,^{14}O).
16.3×10^{3}				G	E(level): From (2022Di05) ^{4}He(^{9}Li,α). %α: Observed in ^{4}He(^{9}Li,α).
18.25×10^{3} *10*	1/2^{+}	0.7 MeV *+4−3*		B G	T=(5/2) (2023Hu20) Γ: T=0.66 MeV $^{+40}_{-25}$. E(level),J$^{\pi}$,Γ: From R-matrix analysis in (2023Hu20). See also 18.4E3 MeV from (2022Di05)

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	J$^\pi$	T$_{1/2}$ or Γ	S	XREF	Comments
					^{4}He(^{9}Li,α). %p,%α: Observed in ^{1}H(^{12}Be,^{13}Be) and ^{4}He(^{9}Li,α).
19.95×10^3 *6*	5/2$^+$	0.60 MeV *10*	0.49 *8*	B G	T=(5/2) (2023Hu20) E(level),J$^\pi$,Γ: From R-matrix analysis in (2023Hu20). See also 19.5E3 MeV from (2022Di05) ^{4}He(^{9}Li,α). %p,%α: Observed in ^{1}H(^{12}Be,^{13}Be) and ^{4}He(^{9}Li,α).

[†] Decay mode not reported; only IT and neutron emission are possible.
[‡] Decay mode not reported; IT, 1n and 2n emission are possible.
[#] Decay mode not reported; IT, 1n, 2n and α emission are possible.

γ(^{13}B)

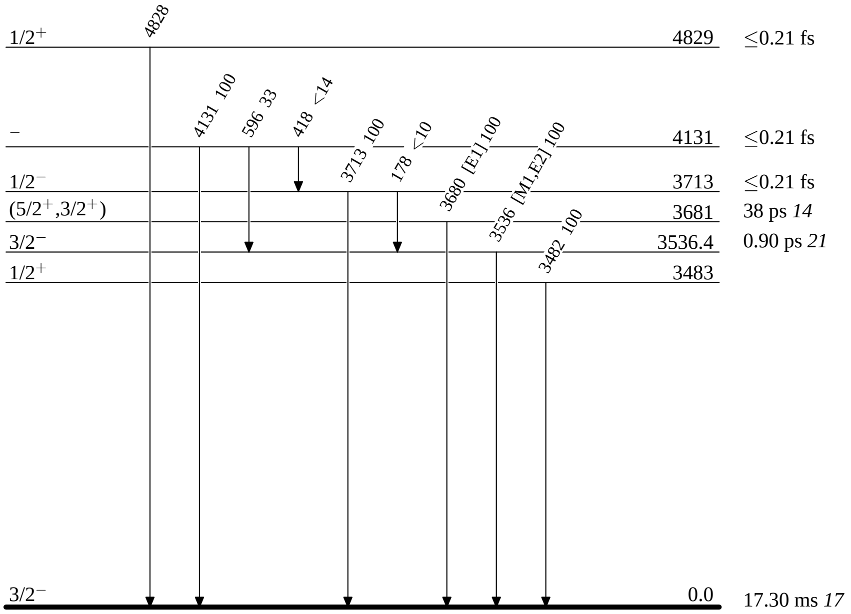
E$_i$(level)	J$^\pi_i$	E$_\gamma$	I$_\gamma$	E$_f$	J$^\pi_f$	Mult.	Comments
3483	1/2$^+$	3482[†] *6*	100	0.0	3/2$^-$		
3536.4	3/2$^-$	3536 *2*	100	0.0	3/2$^-$	[M1,E2]	B(M1)(W.u.)$<7.2\times10^{-4}$ (2009Iw03); B(E2)(W.u.)<0.81 (2009Iw03) E$_\gamma$,I$_\gamma$: From (2002Ao03) ^{14}Be β-n.
3681	(5/2$^+$,3/2$^+$)	3680	100	0.0	3/2$^-$	[E1]	B(E1)(W.u.)$=6.4\times10^{-4}$ *23* (2009Iw03) E$_\gamma$,I$_\gamma$: See (2000Gu23,2009Iw03)).
3713	1/2$^-$	178[†] *6*	<10[‡]	3536.4	3/2$^-$		
		3713[†] *5*	100[‡]	0.0	3/2$^-$		
4131	$^-$	418[†] *8*	<14[‡]	3713	1/2$^-$		
		596[†] *8*	33[‡] *14*	3536.4	3/2$^-$		
		4131[†] *6*	100[‡] *14*	0.0	3/2$^-$		
4829	1/2$^+$	4828[†]		0.0	3/2$^-$		

[†] From level-energy difference.
[‡] From (1963Ca09).

Adopted Levels, Gammas

Level Scheme

Intensities: Relative photon branching from each level



$^{13}_{5}$B$_{8}$

^{14}Be β^-n decay **1988Du09,1999Be53,2002Ao03**

Parent: ^{14}Be: E=0; $J^{\pi}=0^+$; $T_{1/2}$=4.65 ms *10*; $Q(\beta^-n)=1.532\times10^4$ *13*; %β^-n decay=94 *5*

^{14}Be-$Q(\beta^-n)$: From 2021Wa16.

^{14}Be-%β-1n from (2002Ao03): %β-0n<0.6% (2002Ao03): %β-2n<1.6 and %β-3n<0.5 from (1999Be53) where $P_{2n}+3P_{3n}<1.6\%$ was deduced.

^{14}Be-The reported ^{14}Be lifetime values are discrepant: $T_{1/2}$=4.2 ms *7* (1986Cu01), 4.35 ms *17* (1988Du09), 4.78 ms *19* (2005ReZZ,2008ReZZ), 4.8 ms *2*(sta) *4*(sys) and 4.0 ms *12* (1995Be25), 4.29 ms *12* (1997Be66), and 4.84 ms *10* (2002Ao03). The value $T_{1/2}$=4.65 ms *10* is accepted; this value is the weighted average of measurements.

^{14}Be-%β^-n decay: With the exception of (1988Du09), all experiments find only upper limits on the population of the π=− bound levels in ^{14}B*(0,740); stringent limits of P(0n)<4% (1999Be53) and <0.6% (2002Ao03) are determined. P(0n)<0.6%, which is based on the search for ^{14}B decay radiations is accepted. P(0n)<0.6% is compatible with expectations for the forbidden decay to $\Delta\pi$=yes states and incompatible with the unexpected P_{0n}=14% *3* findings of (1988Du09).

^{14}Be-%β^-n decay: Evidence for β-delayed one neutron decay is significant. Analysis of the ^{13}B radiations implies P(1n)=94% *5* (2002Ao03) while data from a moderated ^{3}He counter gives P(1n)>96% (1999Be53). In (1988Du09) P(1n)=81% *4* is reported, but these results appear unreliable. P(1n)=94% *5* is accepted. The decay path is not fully understood for all the β^-n intensity. (2002Ao03) assign 91% *9* of the intensity to decay from ^{14}B*(1.28 MeV *1*) to $^{13}B_{g.s.}$; no γ-rays are observed in coincidence, so the β-decay is here assumed to populate ^{14}B*(1.28 MeV) directly. Two additional decay radiations appear relevant to β^-1n decay; first is the 3536 keV transition to ^{13}B ground state observed by (1995Be25) and (2002Ao03), and second is the E_n=3.02 MeV group observed by (1995Be25). The intensity I(γ:3536)=0.9% *3* was measured by (2002Ao03), though no neutron group was observed in a coincidence spectrum. Very weak population of an E_n=3.02 MeV group was observed by (1995Be25); while no γ-rays are observed in a coincidence, the neutron group cannot be definitively associated with decay to $^{13}B_{g.s.}$.

^{14}Be-%β^-n decay: The 2n and 3n decay modes are not clearly identifiable, most reported values are given as upper limits. Two relevant results are given in (2002Ao03), where P(2n)=6% *5* is deduced from their P(0n)<0.6% and P(1n)=94% *6* values, and in (1999Be53) where analysis of the n-n and n-n-n correlations in their moderated ^{3}He counter set the limit (P(2n)+3P(3n))<1.6% (1σ value) (based on the 95% confidence limit $P_{2n}+3P_{3n}<2.4\%$ *8*).

^{14}Be-%β^-n decay: Further studies on the open charged particle decay channels have found the $\beta^-\alpha$ intensity of P(α)<0.004% (2002Je14) and the β^-t intensity of P(t)=0.02% *1* (2002Je14); the parent levels are not identified. See also P(α)<0.002% (2002Je11) and the β^-t intensity of P(t)=0.021% *8* (2002Je11).

1986Cu01: A beam of ^{14}Be ions was produced by fragmenting a 540 MeV ^{18}O beam on Be and Ta targets. The secondary fragments were filtered using the RPMS Wein Filter at NSCL and were focused on a ΔE-E stopping detector telescope. When a particle was measured in the telescope the rf was scrambled until a decay was measured in the telescope. Analysis of the implantation to decay period, gated on nuclear species, provided the lifetime measurement. $T_{1/2}$=4.2 ms *7* was measured.

1988Du09: ^{14}Be was produced by fragmenting a 60 MeV/nucleon ^{22}Ne beam on either a tantalum or a carbon target; ^{14}Be was selected using the LISE spectrometer. The β-particles were detected using a plastic scintillator while the delayed neutrons were detected through the Gd(n,γ) reaction. $T_{1/2}$=4.35 ms *17*, P_{0n}=0.14 *3*, P_{1n}=0.81 *4* and P_{2n}=0.05 *2* were measured. See also (1988DuZT,1988DuZZ). *Evaluator's comment:* ^{14}B has two bound states with π=− (2013Be25); any combination of intensities adding to 14% *3* feeding these forbidden transitions is unreasonable. An upper limit of %Iβ≤0.6 is expected. The later work of (2002Ao03), which searched for radiations from the ^{14}B daughter, convincingly verified this upper limit. A systematic error appears to be present in the work of (1988Du09).

1995Be25: ^{14}Be ions were produced by fragmenting an 80 MeV/nucleon ^{18}O beam on a Be target and filtering in the A1200 separator. The beam was implanted in a thick BC412 scintillator during a 10.3 ms accumulation period, followed by either a 10.3 ms or 40 ms beam-off counting period. Beta particles from the decay were detected by the implantation detector, while delayed neutrons were detected using an array of 15 curved scintillator bars that were placed 1 meter from the implantation scintillator. Neutron energies were deduced from the time-of-flight (tof) between the β-detector and the neutron array. In addition a HPGe detector was placed 83 mm from the implantation target.

Analysis of the data indicated 3-4% contamination from ^{11}Li, a correction was possible since the ^{11}Li decay had been studied in the same configuration. A neutron detector threshold of 0.77 MeV was unfortunately used in the measurements, which led to a significantly low number of β-n events. The data showed evidence for delayed neutron groups at E_n= 3.02 MeV *3* and 3.52 MeV *7* with intensities of 0.11% *2*(stat) *4*(sys) and 0.30% *3*(stat) *5*(sys); the peaks from these weak branches lay on top of a broad peak that is likely associated with 2n and 3n decay. The multi-neutron branching ratio associated with the broad peak is 5% *1*(stat) *2*(sys). Furthermore, it is plausible that, for example, the E_n=3.52 MeV neutron group may correspond to sequential 2n decay.

Data from the HPGe detector indicated small participation from two transitions related to ^{13}B with E_{γ}=3528 keV *1* and 3680 keV *1*, however low statistics prevented analysis of the neutron groups that feed these transitions. No 740 keV γ-ray was observed for the transition between the ^{14}B first excited state and ground state. Note: the 3680 keV *1* energy for the $^{13}C^*$(3684.507)→g.s.

^{14}Be β^{-}n decay 1988Du09,1999Be53,2002Ao03 (continued)

transition is lower than expected.

A critical issue in the data collection is the relatively low rate of delayed neutron emission. While more than 85% of the decays were expected to be accompanied with neutrons, only about 7% of that intensity is presently observed. It is then suggested that a state in ^{14}B, neutron unbound by <800 keV, is strongly populated. Lifetimes were deduced by two techniques, though high backgrounds significantly complicated the determinations; 4.8 ms *2*(stat) *4*(sys) was deduced from the raw decay curve while 4.0 ms *12* was deduced from the β-n coincidence data.

1997Be66: The authors of 1995Be25 carried out a new measurement at RIKEN, aimed at identifying the low-energy neutron group that participates in the decay. A ^{14}Be beam was produced by fragmenting a 100 MeV/nucleon ^{18}O beam on a Be target; the beam was implanted in the center of a Si detector telescope comprised of 5 detectors. The telescope was sandwiched between two sets of plastic scintillators that detected beta particles. Neutrons were detected in an array of BC408 scintillator walls that were positioned ≈ 200 cm from the implantation detector. In addition a HPGe detector was positioned 131 mm from the implantation detector.

Analysis of the decay curve indicates $T_{1/2}$=4.29 ms *18*. Attention was focused on the neutron energy region below E_n=800 keV, where a sharp peak with E_n=287 keV *3* and width=60 keV *5* is observed. The peak falls at the edge of the neutron detectors′ thresholds and hence yields significant uncertainty in the branching ratio; I(n:287)=39 to 100%. No γ-rays are observed in coincidence with the neutron group, strongly (but inconclusively) suggesting decay to ^{13}B ground state. Decay to $^{13}B_{g.s.}$ would imply decay from a ^{14}B*(1.28 MeV *2*). The 740 keV γ-ray is not found in the spectrum, and no comment is given on the 3528 and 3680 keV gamma rays.

1998KoZP, 1999Be53, 2002Be53: An uranium carbide target was bombarded by a 1-GeV proton beam to produce a ^{14}Be beam that was implanted in a kapton foil located at the center of a moderated ^{3}He cylindrical neutron counter array. The β-particles from ^{14}Be decay were detected by a plastic scintillator located directly behind the implantation foil. The P_n value was determined from the rate of neutrons detected in the ^{3}He counter. The total neutron-emission probability P_n=101% *4* was measured along with an upper limit of $P_{2n}+3P_{3n} < 2.4\%$ (95% confidence limit). Combining P_n with the $P_{2n}+3P_{3n}$ limit $P_{1n}\approx100\%(>96\%)$, $P_{0n}<4\%$, and $P_{2n}+3P_{3n}$=0.8% *8* were deduced. See additional discussion suggesting an error in %β-2n value of (1988Du09).

1997Ao01, 1997Ao04, 2002Ao03: A thick Be target was bombarded by a 100 MeV/nucleon ^{18}O beam to produce a ^{14}Be beam that was selected by the RIPS separator. The beam was implanted in a Si detector.

The β-rays were detected using a set of ΔE-ΔE-E plastic scintillator detectors that were positioned above and below the implantation detector, and a ΔE-ΔE coincidence requirement was implemented to reduce background. Neutrons were detected either in a low-energy array located 50 cm away from the stopper or in a high-energy array located 1.5 m from the stopper. In addition a HPGe clover detector was placed 149 mm from the target.

$T_{1/2}$=4.84 ms *10* was deduced by analyzing the the decay curve associated with the E_n=288−keV group; there is no understanding of the discrepancy between this and prior values. The neutron tof spectrum was dominated by E_n=288 keV *1* peak, I(n:288)=91% *9*, that was not found in coincidence with any γ-ray. The intensity of an additional neutron group at E_n=3.51 MeV *6* is found to be in agreement with the expectation from β-delayed neutron decay of the ^{13}B daughter nucleus. The present analysis was insensitive to the 3.02 MeV group reported by 1995Be25. The γ-ray spectrum indicated peaks at E_γ=3536 keV *2* and 3685 keV *1*; the 3536 keV transition with I(γ)=0.9% *3* is ascribed to a transition fed following delayed neutron decay to states in ^{13}B, while the 3685 keV transition is fed in ^{13}B decay to ^{13}C states.

Analysis of the data provides a measure on the 0n, 1n and 2n decay branches. While the 740 keV transition between ^{14}B first excited state and $^{14}B_{g.s.}$ is not observed, a limit on decay to either of these states is found as I(0n)<0.6% by searching for the 6.09 MeV γ-ray that is fed in 81% of ^{14}B decays to ^{14}C. Similarly, the intensity of the 3685 keV transition, which is fed by 7.6% of ^{13}B decays to ^{13}C, implies I(1n)=94% *5*. No γ rays from ^{12}B decay were observed so I(2n)=6% *5* is deduced from $1=P_{0n}+P_{1n}+P_{2n}$.

See theoretical analyses in (1996Ti05).

^{13}B Levels

E(level)[†]	J^{π}[†]	$T_{1/2}$[†]
0.0	3/2⁻	17.30 ms *17*
3536.4 *17*	3/2⁻	0.90 ps *21*

[†] From Adopted Levels.

^{14}Be β^{-}n decay 1988Du09,1999Be53,2002Ao03 (continued)

$\gamma({}^{13}B)$

E_γ	I_γ[†]	E_i(level)	J^π_i	E_f	J^π_f	Comments
3536 *2*	0.9 *3*	3536.4	3/2$^-$	0.0	3/2$^-$	E_γ: From (2002Ao03); see also 3528 keV 1 (1995Be25). I_γ: From (1995Be25).

[†] Absolute intensity per 100 decays.

Delayed Neutrons (^{13}B)

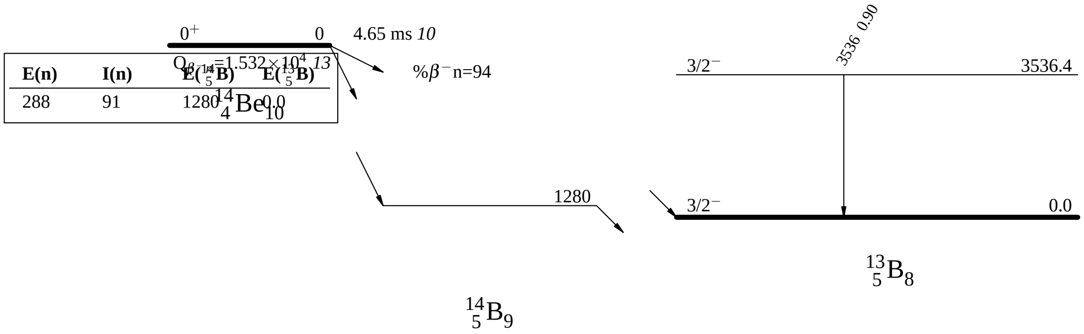
E(n)	E(^{13}B)	I(n)[†]	E(^{14}B)	Comments
3.02×10^3 *3*		0.11 *5*		E(n),I(n): From (1995Be25).
288 *1*	0.0	91 *9*	1280	The decay is from ^{14}B*(1280 keV *10*). E(n),I(n): From (2002Ao03).

[†] Absolute intensity per 100 decays.

^{14}Be β^{-}n decay 1988Du09,1999Be53,2002Ao03

Decay Scheme

γ Intensities: $I_{(\gamma+ce)}$ per 100 parent decays
I(n) Intensities: I(n) per 100 parent decays



^{1}H(^{12}Be,^{13}Be) **2023Hu20**

XUNDL dataset compiled by TUNL (2023).

T=5/2 states in ^{13}B were populated using thick-target inverse kinematics scattering techniques. An R-matrix analysis of the excitation function determined the J^{π} values for the near-threshold resonances. Using these results, the J^{π} values for near threshold n+^{12}Be analog resonances in ^{13}Be were deduced using isospin symmetry arguments.

A beam of 6.0 MeV/nucleon ^{12}Be ions from the TRIUMF ISAC-II facility entered the TexAT active target time-projection chamber, and backscattered protons were detected using a set of six ΔE-E detector telescopes at the downstream wall of the TexAT chamber. The reaction kinematics were determined from analysis of the incident ^{12}Be and recoiling ^{12}Be and proton tracks. Excitation functions for elastic scattering were obtained by analyzing events in the different ΔE-E telescopes separately.

Evidence for a J^{π}=1/2^{+} resonance at $E_{c.m.}$=2.45 MeV and a J^{π}=5/2^{+} resonance at $E_{c.m.}$=4.15 MeV was found using the MINRMATRIX code. The authors explored any improvement of the fit by adding J^{π}=1/2^{-} and or 3/2^{-} states, but found their experimental data was not sensitive to negative parity states. Expanding on this point, the *conclusion* discussion indicates participation of negative parity states cannot be excluded. The p+^{12}Be reaction can populate T=3/2 and 5/2 states, but an argument is made for preferential population of T=5/2 resonances; in this case, the observed resonances may be related to expected ^{13}Be resonances by isospin symmetry arguments. As a result, J^{π}=1/2^{+} and 5/2^{+} neutron unbound states in ^{13}Be are expected at $E_{c.m.}$=0.6 MeV *1* and 2.34 MeV *6*, respectively. These agree well with known states in ^{13}Be, and the authors claim this is the first definitive determination of J^{π} values in ^{13}B.

^{13}B Levels

E(level)	J^{π}	Γ	S	Comments
18.25×10^{3} *10*	1/2^{+}	0.7 MeV *+4−3*	0.16 *+9−6*	T=(5/2) Γ: T=0.66 MeV *+40−25*. E(level): From $E_{c.m.}$(p+^{12}Be)=2.45 MeV *10*.
19.95×10^{3} *6*	5/2^{+}	0.60 MeV *10*	0.49 *8*	T=(5/2) E(level): From $E_{c.m.}$(p+^{12}Be)=4.15 MeV *6*.

^{1}H(^{13}B,X) 2021Li64

2021Li64: XUNDL dataset compiled by TUNL (2022).

The authors determined the spectroscopic factors for ^{1}H(^{13}B,d) *s*-, *p*- and *d*-wave neutron transfer to low-lying ^{12}B states. Using these spectroscopic factors, they analyzed the intruder *s*- and *d*-wave strengths that comprise the ^{13}B ground state.

A beam of 23 MeV/nucleon ^{13}B ions from the RCNP/Osaka electromagnetic isotope separator impinged on a 6.76 mg/cm^{2} polyethylene target that was rotated slightly by 20° with respect to the incident beam. The ^{12}B +*d* reaction products were momentum analyzed using a set of three 5 cm × 5 cm position sensitive ΔE-ΔE-E telescopes. The ^{12}B ejectiles were detected using the T0 telescope, which was centered along θ=0°; deuterons were detected by the T1 and T2 telescopes, which were centered on the horizontal plane at θ=−31° and θ=−70°, respectively. Lastly, a position sensitive Si annular detector was positioned at backward angles to detect protons from any ^{2}H(^{13}B,p) reactions.

Differential cross sections for ^{1}H(^{13}B,p) elastic scattering were obtained and evaluated via optical model analysis, while ^{1}H(^{13}B,d) reactions to ^{12}B states up to E$_{x}$=6.0 MeV were evaluated via DWBA using FRESCO to obtain the relative spectroscopic factors. For some higher-lying states, the ^{12}B ejectile neutron decayed to ^{11}B, which was detected and identified via ΔE-E in the T0 telescope. The dominant neutron transfer orbital from each state was analyzed to obtain the ^{13}B$_{\text{g.s.}}$ *s*-, *p*- and *d*-wave neutron strengths. The relevant contributions are given below. Values of 83% *6* *p*-wave, 5% *2* *s*-wave and 12% *2* *d*-wave were determined for ^{13}B$_{\text{g.s.}}$. Using these observations, the authors find consistency with shell model predictions and N=8 magicity in the ^{13}B nucleus.

See also (2013Ti05).

Levels in ^{12}B

Level Energy (keV)	L	neutron orbital	J$^{\pi}$	S$_{\text{rel}}$
0	1	1$p_{1/2}$	1^{+}	0.54 *5*
953	1	1$p_{1/2}$	2^{+}	1.11 *7*
1674	0	2$s_{1/2}$	2^{-}	0.06 *2*
2621	0	2$s_{1/2}$	1^{-}	0.04 *1*
3389	2	1$d_{5/2}$	3^{-}	0.13 *2*
4460&4523	2	1$d_{5/2}$	2^{-}&4^{-}	(Sum)=0.11 *2*
6000	2	1$d_{5/2}$	1^{-}	≤0.01

^{13}B Levels

E(level)	J$^{\pi}$	Comments
0	3/2^{-}	J$^{\pi}$: 83% *6* *p*-wave, 5% *2* *s*-wave and 12% *2* *d*-wave neutron strengths were deduced for ^{13}B$_{\text{g.s.}}$, which are consistent with shell model predictions and N=8 magicity in ^{13}B.

^{2}H(^{12}B,p) 2010Ba06

J^{π}(^{12}B g.s.)=1^{+}.

2010Ba06: XUNDL dataset compiled by TUNL, 2010.

A 75 MeV/nucleon beam of ^{12}B ions, produced by bombarding a cryogenic deuterium gas cell with ^{11}B ions at the ANL/ATLAS facility, impinged on a 73 μg/cm^{2} CD_2 target located at the HELIOS (HELIcal Orbit Spectrometer) target position. Reaction protons were emitted in the backwards direction and followed a single helical orbit in the 1.05 T axial magnetic field before reaching a barrel shaped array of position sensitive Si detectors that surrounded the incident beam axis. The forward moving ^{13}C ions were stopped in a ΔE-E telescope that covered θ_{lab}=0.5°−2.8°.

The momentum of the emitted proton was determined and excited states were resolved with ΔE≈100 keV FWHM. The angular distribution for population of ^{13}B(3.48, 3.68 MeV) was determined over $\theta_{\text{c.m.}}$=8°−30° by analyzing the p+^{13}B coincidences. The angular distributions were analyzed via DWBA analysis.

2010Le02: XUNDL dataset compiled by TUNL, 2010.

A 75 MeV/nucleon beam of ^{12}B ions, from the ANL/ATLAS facility, impinged on a 150 μg/cm^{2} CD_2 target. A set of three position-sensitive annular Si detectors measured protons at $\theta_{\text{lab.}}$=110°−161° while forward moving boron isotopes were identified in a ΔE-E telescope that covered θ_{lab}=1.3°−7.2°. Neutron bound and unbound states of ^{13}B were identified at E_x=0, 3.48, 3.68, 5.105, 5.388 MeV; only the ground state was resolved.

The angular distribution was determined for the ground state over $\theta_{\text{c.m.}}$=7.5°−30°, and it was analyzed via DWBA analysis to obtain spectroscopic data useful for determining the astrophysical ^{12}B(n,γ) reaction rates. Also see 2008WuZY, 2011BaZX for other ANL reports.

See (2021Du10) for a calculation of the cross section at astrophysically relevant energies.

^{13}B Levels

E(level)†	J^{π}#	L#	S#	Comments
0	3/2^{-}	1	1.1 *3*	
3.48×10^{3}‡	(1/2^{+})	0,2		$S_{L=2} \leq 0.05\ S_{L=0}$ component (2010Ba06).
3.68×10^{3}‡	(5/2^{+},3/2^{+})	2,0		The L=0 component is less than ≈2% of the L=0 component for the 3.48 MeV state. The authors suggest that J^{π}=5/2^{+} is favored based on absence of L=0 component in the angular distribution and a better fit to the ratios of spectroscopic factor (2010Ba06).
5105‡				
5388‡				

† Nominal values given in (2010Ba06, 2010Le02).

‡ Unresolved in (2010Le02).

From DWBA analysis in (2010Le02).

^{2}H(^{13}B,^{13}B) 2022Li15

2022Li15: Elastic scattering of ^{13}B ions from a 3.98 mg/cm^{2} CD_2 target (rotated by 20° with respect to the beam direction) was measured at the RCNP/Osaka. The 23 MeV/nucleon ^{13}B beam was produced by fragmentation of a ^{18}O beam and purified using an electromagnetic separator. The $\sigma(\theta)$ for $\theta_{c.m.}$=20° to 60° was determined from the measured deuteron scattering distribution and used an exclusive d+^{13}B coincidence requirement. Scattered ^{13}B ions were identified using a position sensitive ΔE-ΔE-E (Si-Si-CsI) telescope placed along the beam axis, while associated deuterons were measued using two additional position sensitive ΔE-ΔE-E telescopes that covered θ_{lab}=31° to 70°. Elastic scattering dominated the observations; though broad unresolved groups were evident at $E_x \approx 4$ and 6.5 MeV. The data were compared with optical model calculations obtained using FRESCO.

^{13}B Levels

E(level)
0

^{2}H(^{15}C,α) 2014Wu10

2014Wu10: XUNDL dataset compiled by TUNL, 2015.

The authors used the highly spin selective (d,α) deuteron transfer reaction to study states with “stretched” nuclear configurations.

A beam of 15.7 MeV/nucleon ^{15}C ions was produced using the ^{2}H(^{14}C,^{15}C) reaction at the ANL/ATLAS In-Flight production facility. The beam impinged on 145 μg/cm^{2} $(Cd_2)_n$ polyethylene foils located at the HELIcal Orbit Spectrometer (HELIOS) target position. The kinematics of α particles from (d,α) reactions were determined from analysis of the HELIOS array data, while recoiling boron isotopes were detected in an array of position sensitive Si detectors that covered θ_{lab}=1.0°−5.6° for 92% of the azimuthal angle range. The resolution for excitation energy was found as ≈ 240 keV FWHM.

The reaction data were analyzed for α-particles in coincidence with any boron isotope; this gave access to population of bound states, as well as, 1-n and 2-n unbound states.

^{13}B Levels

E(level)	J$^{\pi}$	L	Comments
0	$3/2^-$		J$^{\pi}$: From Adopted Levels.
3.6×10^3			E(level): three states have previously been observed at E_x=3.53, 3.68 and 3.71 MeV.
10.0×10^3			
11.7×10^3	$(5/2,7/2)^{+}$ †	(2)†	
12.2×10^3	$(5/2,7/2)^{+}$ †	(2)†	

† For 11.7- and 12.2-MeV doublet. Comparison of the angular distribution of the E_x≈12 MeV group with the ^{2}H(^{14}C,α)^{12}B*(5.61, $J^{\pi}=3^{+}$) suggests this doublet results from the coupling of a $1s_{1/2}$ neutron to an aligned $[(0p_{3/2})^{-2}]_{3+}$ configuration in ^{12}B.

^{4}He(^{9}Li,α) **2017Di05,2022Di05**

2017Di05: E < 32 MeV. The reaction was measured at TRIUMF for $\sigma(E_{\alpha},\theta=180°)$ using the TUDA chamber filled with 650-680 Torr of ^{4}He gas. Scattered α particles were detected along the beam axis. The excitation function was analyzed using thick target inverse kinematics to study the excitation region of E_x=14-20 MeV. Peaks at $E_x\approx$16.3 and 19.5 MeV are observed; the peak at 19.5 MeV is asymmetric and suggests participation of multiple states.

2022Di05: Additional data collected by two other telescope arrays used by (2017Di05) are presented. Details on the angular coverage indicate three 50×50 mm^{2} ΔE-E Si detector telescopes were used. The ΔE detectors were segmented into quadrants; and the measured α energy was used to deduce the c.m. elastic scattering angle. Telescope 1 (T1) was along the beam axis and provided data for $\theta_{\text{c.m.}}\approx175°-178°$. The T2 telescope covered $\theta_{\text{c.m.}}\approx156°-174°$; lastly T3 provided data for $\theta_{\text{c.m.}}\approx128°-165°$. Using Thick-Target Inverse Kinematics relations for the elastic scattering events, angular resolutions of 0.1° to 3° were obtained from the scattered α-particle energy.

The peaks at $E_x\approx$16.3 and 19.5 MeV remain prominent, while visible suggestions of a third peak appears at 18.4 MeV in the T3 data. Analysis via the AZURE2 R-matrix code revealed evidence for a fourth resonance at E_x=18.9 MeV; the peaks appear to correspond to single broad resonances rather than groups of states as suggested in (2017Di05). Various models were explored in order to explain the resonances. Some success was found using a α+^{9}Li molecular-like rotational model, but findings were inconclusive.

^{13}B Levels

E(level)†	L†
16.3×10^{3}	4,5
18.4×10^{3}	5,6
18.9×10^{3}?	5,6
19.5×10^{3}	5,6

† From figure 5 in (2022Di05).

^{4}He(^{12}Be,^{13}Bγ) 2008Ot05

2008Ot05: XUNDL file prepared by ANL (2008). A beam of 50 MeV/nucleon ^{12}B ions produced by fragmentation of a 100 MeV/nucleon ^{18}O beam at the RIKEN/RIPS facility bombarded a liquid He located at the final focus of the RIPS. The beam was identified via ΔE vs. time-of-flight techniques before reaching the $\approx$143 mg/cm^{2}target that was surrounded by an array of six 6-cm by 2-cm HPGe γ-ray detectors from the GRAPE array positioned at θ=140°. The ^{13}B products were detected downstream of the target using a 1 meter^2 position-sensitive ΔE-E plastic scintillator.

The angular distributions of ^{13}B states are determined by gating on relevant de-excitation γ rays in the HPGE detectors. However, only three strong groups are naively visible in the γ spectrum to states at E_x=3681+3713, 4130, 4830 keV and no cascade transitions are observed. A more sophisticated deconvolution of the spectrum using GEANT4 premitted the authors to determine the relative populations of ^{13}B*(3483, 3535, 3681, 3713, 4130, 4830). In the present work, only the ^{13}B*(4830) angular distribution is analyzed using a DWBA, which found L=0. The author suggest the state is a deformed J^π=1/2$^+$ intruder state.

Also See (2004OtZY, 2004OtZZ, 2004Sh24, 2008OtZZ).

^{13}B Levels

E(level)	J$^\pi$	L	Relative population[†]	Comments
0	3/2$^-$			J$^\pi$: From Adopted Levels, Gammas.
3483			19 *5*	
3535			20 *5*	
3681			74 *7*	
3713			68 *7*	
4131			49 *4*	
4829	1/2$^+$	0	100	L: from DWBA analysis of dσ/dΩ. J$^\pi$: From L(p)=0. C^{2}S=0.20 *2*. Systematic uncertaintity=60%. Configuration=π 1/2[220]$^1\otimes$(^{12}B deformed core); interpreted by 2008Ot05 as an intruder (deformed) state from the sd-shell. No cascading transitions to other states in ^{13}B were seen.

[†] Relative population is normalized to 100 for 4829 keV state, the quoted uncertainties are statistical only.

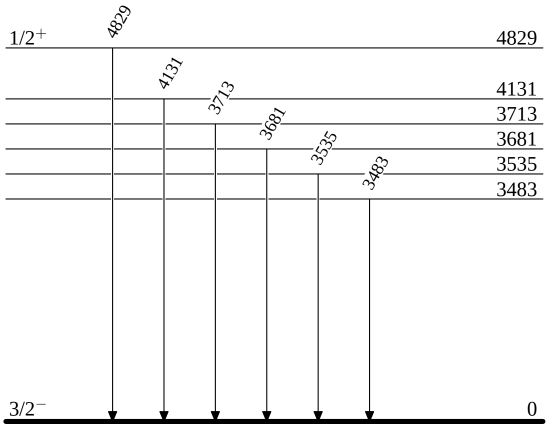
γ(^{13}B)

E$_\gamma$[†]	E$_i$(level)	J$^\pi_i$	E$_f$	J$^\pi_f$
3483[#]	3483		0	3/2$^-$
3535[#]	3535		0	3/2$^-$
3681[‡]	3681		0	3/2$^-$
3713[‡]	3713		0	3/2$^-$
4131	4131		0	3/2$^-$
4829	4829	1/2$^+$	0	3/2$^-$

[†] From commonly accepted γ-ray energy values listed in (2008Ot05).
[‡] 3681 and 3713 γ rays form an unresolved doublet.
[#] 3483 and 3535 γ rays form an unresolved doublet.

^{4}He(^{12}Be,^{13}Bγ) 2008Ot05

Level Scheme



${}^{13}_{5}B_{8}$

^{7}Li(^{7}Li,p),^{7}Li(^{7}Li,pγ) 1972Wy01,2009Iw03

1956Al60, 1957No14: ^{7}Li(^{7}Li, p)^{13}B E=1.61 MeV, Measured σ(E$_p$,θ=90°), deduced reaction Q=5.97 MeV *3* and ΔM=20.39 MeV *3*. First observation of ^{13}B (2012Th01).

1959Mo12: ^{7}Li(^{7}Li,p), E=2 MeV; identified reaction protons using ΔE-E. Deduced Q=5.97 MeV *5* and observed states at 0, 3.70 *5*, 4.16 *5*, 5.05 *8* and 5.5 *1* MeV. The 3.70 MeV state is later identified by (1963Ca09) as a doublet, but with similar precision.

1963Ca09: ^{7}Li(^{7}Li,pγ)) E=3 MeV. Evaporated ^{7}LiF target. Measured γ rays in coincidence with associated charge particles using a solid state particle detector and NaI(Tl) detectors. Resolved previously reported first excited state as two groups; deduced E$_x$=3.50 *5*, 3.70 *5* and 4.16 MeV. Estimated cascade from 4.16 MeV →3.50 is 25% *10*.

1969Th01: ^{7}Li(^{7}Li,pγ) E=5.1-6.3 MeV; measured σ(E$_\gamma$,θ(γ)) for γ rays emitted from a 156 μg/cm^2 enriched ^{7}LiF target. Measurements were taken at θ=0°, 90° and 150°. Deduced T$_{mean}$ of >0.3 ps and <0.38 ps for ^{13}B*(3.53,3.71), respectively. For ^{13}B(4.13) T$_m$=62 fs *50* was deduced and J=7/2 was suggested. E$_\gamma$ for ^{13}B(3.53,4.13) were reported.

1972Wy01: ^{7}Li(^{7}Li,p) E=14 MeV; measured σ(E$_p$). Deduced seven new levels at 5558-8683 keV from analysis of protons measured at θ=10° using Si detectors. Used beam from Van de Graaff at Univ. of Iowa. Published energies are based on ^{13}B(4132) peak, which has subsequently been reduced by 1 keV.

2003Fl02: ^{7}Li(^{7}Li,p), E=50.9 MeV from Florida State Univ. Tandem/LINAC accelerator facility; measured ^{9}Li+α coincidences; reconstructed relative energies and deduced resonance at E$_x$≈13.6 MeV along with higher-energy unresolved structures.

2009Iw03: ^{7}Li(^{7}Li,p) E=5.4 MeV beam provided by the FN Tandem facility at the Univ. of Cologne. Targets consisted of ^{7}LiF deposited on Au foil. Measured γ rays using EUROBBALL cluster Ge detector at 0° and five coaxial detectors at 140°. They detected particles in coincidence with γ using eight Si photodiodes at θ=62°−81° and used the Doppler-shift method to measure the lifetime of excited states in ^{13}B. A lifetime limit of T$_m$<30 fs is deduced for ^{13}B(3.71, 4.13, 4.83). For the 3.68 MeV state, T$_m$=55 fs *20* was deduced. For 3.53 MeV the lifetime T$_m$=1.3 ps *3* is four times longer than earlier results. The long lifetime of ^{13}B(3.53) suggests it is a 3/2$^-$ intruder state. The double escape peak from 4.54 MeV ^{11}B contaminant γ ray was found to be less than 10% of the 3.53 MeV peak.

Also see (2009IwZZ).

^{13}B Levels

E(level)	J$^\pi$	T$_{1/2}$†	Comments
0	3/2$^-$		
3536.8 *42*	(3/2$^-$)	0.90 ps *21*	E(level): From Eγ (1969Th01). J$^\pi$: From (2009Iw03). T$_{1/2}$: From T$_{mean}$=1.3 ps *2* (2009Iw03). See also T$_{mean}$>0.3 ps (1969Th01).
3681	+	38 fs *14*	E(level),T$_{1/2}$: From T$_{mean}$=55 fs *20* (2009Iw03). J$^\pi$: From L(t,p)=1 from 3/2$^-$ ^{11}B$_{g.s.}$ (quoted by (2009Iw03) from (1964Mi04)).
3700 *50*		≤21 fs	E(level): From (1959Mo04). T$_{1/2}$: From T$_{mean}$<30 fs (2009Iw03); see also T$_{mean}$<0.38 ps (1969Th01).
4134.1 *78*		≤21 fs	E(level): From Eγ (1969Th01); see also 4160 *50* (1959Mo04). T$_{1/2}$: From T$_{mean}$<30 fs (2009Iw03); see also T$_{mean}$=62 fs *50* (1969Th01). 1963Ca09 reports a 25% *10* branch to unresolved 3.48+3.53 MeV states, and 75% *10* to ground and an upper limit of <10% to the 3.70 MeV state.
4833‡ *10*		≤21 fs	T$_{1/2}$: From T$_{mean}$<30 fs (2009Iw03).
5033‡ *8*			E(level): other: 5050 keV *80* (1959Mo12).
5391‡ *8*			
5557‡ *8*			E(level): other: 5500 keV *100* (1959Mo12).
6169‡ *8*			
6419‡ *8*			
6939‡ *15*			
7516‡ *8*			
7859‡ *20*			
8129‡ *10*			
8682‡ *9*			
13600			E(level): From ^{9}Li+α kinematic reconstruction (2003Fl02).

Continued on next page (footnotes at end of table)

^{7}Li(^{7}Li,p),^{7}Li(^{7}Li,pγ) 1972Wy01,2009Iw03 (continued)

^{13}B Levels (continued)

† Deduced from lifetime measured in the Doppler-shift attenuation method (2009Iw03).

‡ From values given in (1972Wy01) that used E_x=4132 as the energy standard. When the energy of the standard was decreased by 1 keV, previous evaluations decreased these energies by 1 keV as is done for values given here.

γ(^{13}B)

E_i(level)	J^π_i	E_γ†	I_γ‡	E_f	J^π_f	Mult.	Comments
3536.8	(3/2⁻)	3536.3 *42*		0	3/2⁻	[M1,E2]	B(M1)(W.u.)<7.2×10⁻⁴ (2009Iw03); B(E2)(W.u.)<0.81 (2009Iw03) E_γ: From (1969Th01).
3681	+	3680		0	3/2⁻	[E1]	B(E1)(W.u.)=6.4×10⁻⁴ *23* (2009Iw03)
3700		163	<10	3536.8	(3/2⁻)		E_γ: No evidence for this transition is reported; (1963Ca09) assign an upper limit of <10%.
		3700	100	0	3/2⁻		
4134.1		434	<10	3700			
		597.3	25 *10*	3536.8	(3/2⁻)		
		4133.4 *78*	75 *10*	0	3/2⁻		E_γ: From (1969Th01).
4833		4832		0	3/2⁻		E_γ: Observed by (2009Iw03).

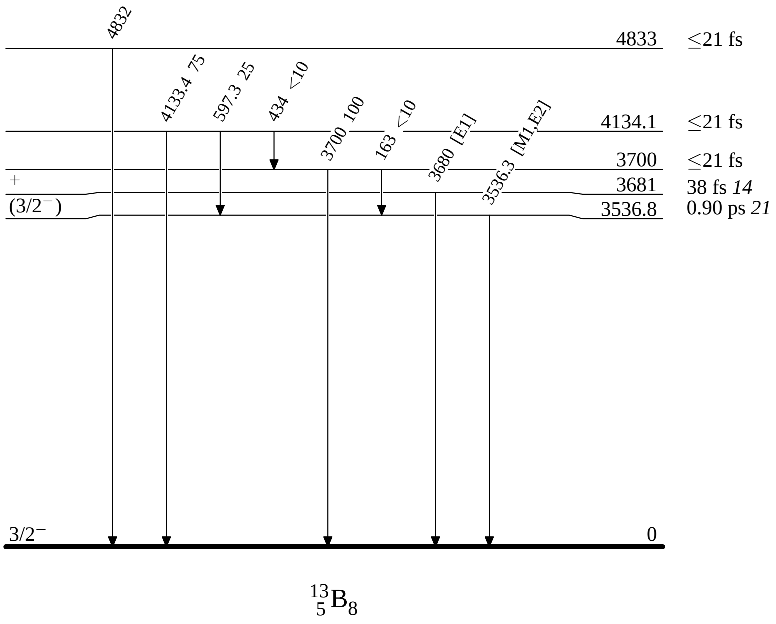
† From level-energy difference unless otherwise indicated.

‡ From (1963Ca09).

^{7}Li(^{7}Li,p),^{7}Li(^{7}Li,pγ) 1972Wy01,2009Iw03

Level Scheme

Intensities: % photon branching from each level



^{9}Be(^{13}B,X) 2014Es07

1988Ta10: Measured the interaction cross section of ≈790 MeV/nucleon ^{13}B on ^{9}Be, ^{nat}C, ^{27}Al targets at the LBNL/Bevalac. Analyzed cross sections in a Glauber model and deduced the interaction radius, R_I=2.76 fm *10*. They also deduced the rms radii for the proton (2.42 fm *11*), neutron (2.50 fm *12*) and matter (2.46 fm *12*) distributions.

2014Es07: XUNDL dataset compiled by TUNL, 2014.

The authors measured the charge changing reaction cross sections of boron isotopes and deduced their root mean square proton radii.

Beams of ≈850 – 900 MeV/nucleon boron isotopes were produced by fragmenting ^{22}Ne($^{10,14-17}$B) and ^{40}Ar($^{11-13}$B) ions on a thick ^{9}Be foil at the GSI/FRS fragment separator. The beam species were identified by ΔE (ionization chamber) vs time-of-flight before they impinged on a 4.010 g/cm^2 thick carbon target. An ionization chamber located after the target was used to identify charge changing reaction events.

In the discussion, the rms proton radii for ^{10,11}B are obtained from e^- and π^- scattering and muonic X-ray studies, while for heavier boron isotopes the proton radii are obtained by analyzing the charge changing cross sections, σ_α, in a Glauber model. The proton (2.44 fm *8*) and matter (2.41 fm *5*) rms radii values are given for ^{13}B. Finally, the rms proton radii are compared with rms matter radii derived from interaction cross section measurements in the literature.

2017Ta06: Measured reaction cross sections on ^{1}H, ^{9}Be, $^{nat.}$C, and ^{27}Al at the NIRS/Japan. Analyzed data using Glauber model. Deduced matter density distribution.

See other analysis in (1990Li39, 1990Lo10, 1992La13, 1995Pe19, 1996Sh13, 1997Ho04, 1997Ka32, 2000Bh09, 2001Oz04, 2003Um02, 2004Ne16, 2012Ji01, 2017Ah08, 2019Fo08).

^{13}B Levels

E(level)	J^{π}†	Comments
0	3/2$^-$	R_{rms}(proton)=2.48 fm *3* obtained from Glauber model analysis of the charge changing cross section σ_α=723 mb *6* at E(^{13}B)=897 MeV/nucleon.

† From Adopted Levels.

^{9}Be(^{14}B,^{13}Bγ),^{197}Au(^{14}B,^{13}Bγ) 2000Gu23

2000Gu23, 2004Gu21: ^{9}Be(^{14}B,^{13}Bγ), ^{197}Au(^{14}B,^{13}Bγ). One neutron knock-out reactions were used to study the ^{13,14}B systems. A beam of 830 MeV ^{14}B ions, from the NSCL/A1200, impinged on either a ^{9}Be or ^{197}Au target. The ^{13}B products were momentum analyzed using the S800 spectrometer, while coincident were measured using an array of 38 NaI(Tl) scintillator detectors that surrounded the target. The Doppler corrected γ-ray spectrum is obtained cross sections to ^{13}B(0, 3.48, 3.68, 4.13) are deduced. Shell model calculations are compared with the data and used to suggest J^{π} values.

^{13}B Levels

E(level)	J$^{\pi}$†	L	S	Comments
0	[3/2$^-$]	0+2		σ(L=0)=113 mb *15*; σ(L=2)=14 mb *3*; S(L=0)=0.622; S(L=2)=0.306.
3480	[3/2$^+$]	1	0.407	σ=18 mb *3*.
3680	[5/2$^+$]	1	0.886	σ=30 mb *5*.
4130				σ=1.2 mb *12*.

† From comparison with shell model calculations.

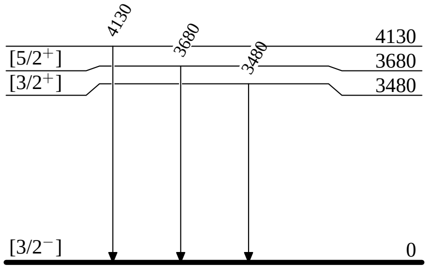
γ(^{13}B)

E$_{\gamma}$†	E$_i$(level)	J$^{\pi}_{i}$	E$_f$	J$^{\pi}_{f}$
3480	3480	[3/2$^+$]	0	[3/2$^-$]
3680	3680	[5/2$^+$]	0	[3/2$^-$]
4130	4130		0	[3/2$^-$]

† From Figure 1 in (2000Gu23).

^{9}Be(^{14}B,^{13}Bγ),^{197}Au(^{14}B,^{13}Bγ) 2000Gu23

Level Scheme



$^{13}_{5}B_{8}$

^{9}Be(^{15}N,^{13}B) 2004Na38

2004Na37, 2004Na38: ^{9}Be(^{15}N,^{13}B): ^{13}B ions were produced by fragmentation at the HIMAC accelerator in Chiba Japan. The ions were collected at θ=1.5° and implanted into a TiO_2 crystal placed in an external magnetic field to maintain polarization. Analyzed β asymmetry and deduced magnetic moment μ=3.1778 μ_N *5* with Knight shift correction. The quadrupole moment was determined as Q=+36.6 mb *8* (with respect to ^{12}B (2004Na46)). The allignment correlation term was also studied.

2004Na47: ^{9}Be(^{15}N,^{13}B), measured momentum dependences of the nuclear spin polarization and spin alignment.

^{13}B Levels

E(level)	$T_{1/2}$	Comments
0	17.36 ms	μ=3.1778 *5*; Q=+0.0366 *8* μ,Q: From (2004Na38).

^{9}Be(^{40}Ar,^{13}B) 2007No13

2007No13: ^{9}Be(^{40}Ar,X), ^{181}Ta(^{40}Ar,X) at E=90 MeV/nucleon and 94 MeV/nucleon, respectively. Measured fragmentation cross sections for A=6-39 nuclei at RIKEN/RIPS.

2012Kw02: ^{9}Be(^{40}Ar,X), Ni(^{40}Ar,X), ^{181}Ta(^{40}Ar,X) at E=140 MeV/nucleon. Measured fragmentation cross sections for A=10-39 nuclei at NSCL.

2015Mo17: ^{9}Be(^{40}Ar,X) at E=95 MeV/nucleon. Analyzed fragment transverse momentum distributions measured at RIKEN.

See also (2000Fa06), who calculated isospin effects in fragmentation production of light nuclei from ^{18}O.

^{13}B Levels

E(level)
0

^{11}B(t,p) 1964Mi04,1978Aj02

1960Mu07: ^{nat}B(t,p) E=5 MeV; θ=10°−61°; ΔE_{res}=15 keV; Q=−0.233 MeV *4* and ΔM=20.397 MeV *4*. University of Manchester.

1962Ma19: ^{11}B(t,p) E=3.3 MeV; ^{13}B ions were produced in a 2 mg/cm^2 ^{11}B target at the University of Manchester. The ^{10}B content was measured to be less than 0.2%. Beam on/beam off periods were 100 ms, with counting starting 5 ms after the beam was removed and lasting an additional 65 ms. The β and γ particles were measured in singles and coincidence mode using a plastic phosphor detector for βs and a NaI scintillator for γ rays. The decay is mainly to ^{13}C. Deduced ratio of ^{13}B/^{12}B lifetimes =0.86 *2* initially resulting in $T_{1/2}$=18.6 ms *5*; using the present $T_{1/2}$(^{12}B)=20.22 ms *4* gives 17.39 ms *41*. Deduced β branch to ^{13}C(3.67 MeV *2*) as 7.0% *15* and set an upper limit for delayed neutrons as <1.5%. Other limits are set.

1964Mi04: ^{11}B(t,p) E=11 MeV. Tritons from the Aldermaston Tandem generator impinged on a ≈50 μg/cm^2 98.6% enriched ^{11}B target. Reaction protons were measured using a multi-channel magnetic spectrometer. The ground state and nine excited states were observed and measurements were taken over for θ≈2°−170°. The *l* and J^π values were determined via plane-wave analysis.

1968Ch28: ^{11}B(t,p) E=3.0 MeV. ^{13}B nuclei were produced via triton bombardment of a natural boron target at the Nippon Atomic Industry Group Laboratory in Kawasaki Japan. The beam was chopped and the beam-off period permitted counting for at least 80 ms. The target was surrounded by a pile of paraffin blocks and the yield of β-delayed was counted with a BF$_3$ scintillator counter. Analysis of the neutron counting rate indicated $T_{1/2}$=16 ms *1*. Additionally, a plastic scintillator counter was placed near the target to count decay β rays. By comparing the β and neutron yields %β-n≈(0.52 *26*) was determined.

1969Jo21: ^{11}B(t,p) E=3.0 MeV. The β decay of ^{13}B was studied at the BNL Van de Graaff. β, $\beta\gamma$ and βn measurements permitted a determination of the branching ratios to ^{13}C states. The β-n branches through ^{13}C(7.55, 8.86) are measured with 0.094% *20* and 0.16% *3*.

1971Wi07: ^{11}B(t,p) at 3.0 MeV at BNL. Measured βs from ^{13}B decay using a plastic scintillator. Deduced $T_{1/2}$=17.33 ms *17*.

1971Wi09: ^{11}B(t,p). ^{13}B ions, produced using a 2 MeV triton beam on a ^{11}B target at the BNL Van de Graaff, were collected in Au, Pt and Pd metallic stopper foils that were held in a strong magnetic field. Measured g=2.11808 *34*. μ=+3.17712 μ_N *51* was deduced from analysis of the β-decay asymmetries. See also (1973HaZV).

1974Al12: ^{11}B(t,p) E_t=3 MeV. Measured %β-n=(0.022 *7*) at BNL Van de Graaff facility.

1978Aj02: ^{11}B(t,p), A series of (t,p) reactions were studied at E_t=23 MeV at the LANL three-stage Van de Graaff facility. The reaction products were momentum analyzed in a broad range magnetic spectrometer for θ=5°−55°. Eighteen states up to E_x=11.8 MeV were reported. Widths are deduced for the higher-lying states, and L values are deduced for ^{13}B(0, 6.93 MeV).

1983An15: ^{11}B(t,p), The authors determined Q=−233.54 keV *100* by measuring the ^{11}B(t,p) reaction protons at θ=28°−40° using a 30 μg/cm^2 target at the Strasbourg Van de Graff. Using this, ΔM(^{13}B)=16562.17 keV *104* was deduced. The authors evaluated the IMME mass equation for the A=13 quartet.

2006Ge21: The ^{11}B(t,p) excitation function was measured for E_t=2.53-6.95 MeV using the RFNC EGP-10 Tandem accelerator; The measurement utilized activation and off-line counting techniques and deduced information on ^{14}C. $T_{1/2}$=16.59 ms *2* was also deduced. Also see (2002GeZT, 2005GeZY).

^{13}B Levels

E(level)†	J^π‡	$T_{1/2}$ or Γ†	L‡	Comments
0	3/2$^-$	17.33 ms *17*	0	μ=+3.17712 *51* (1971Wi09) E(level): (1983An15) deduced Q=−233.36 keV *100* and ΔM=16562.17 keV *104*. Analyzed IMME equation. $T_{1/2}$: From 17.39 ms *41* (1962Ma19) and 17.33 ms *17* (1971Wi07); see also 16 ms *1* (1968Ch28) and 16.59 ms *2* (2006Ge21). J^π: (1960Mu07).
3483 *5*	(1/2,3/2,5/2)$^+$		1	E(level): weighted average of 3483 keV *5* (1964Mi04) and 3482 keV *10* (1978Aj02).
3533 *5*	(1/2,5/2,7/2)$^-$		2	E(level): weighted average of 3533 keV *5* (1964Mi04) and 3531 keV *10* (1978Aj02).
3681 *5*	(1/2,3/2,5/2)$^+$		1	E(level): weighted average of 3681 keV *5* (1964Mi04) and 3681 keV *10* (1978Aj02).
3713 *5*	(1/2,5/2,7/2)$^-$		2	E(level): weighted average of 3712 keV *5* (1964Mi04) and 3715 keV *10* (1978Aj02).
4129 *10*	(1/2,5/2,7/2)$^-$		2	E(level): average of 4130 keV *10* (1964Mi04) and 4128 keV *10* (1978Aj02).
4827 *10*				E(level): weighted average of 4820 keV *10* (1964Mi04) and 4834 keV *10* (1978Aj02).
5017 *10*	(1/2,3/2,5/2)		1	E(level): average of 5010 keV *10* (1964Mi04) and 5023 keV *10* (1978Aj02).

Continued on next page (footnotes at end of table)

^{11}B(t,p) **1964Mi04,1978Aj02 (continued)**

^{13}B Levels (continued)

E(level)†	$T_{1/2}$ or Γ†	L‡	Comments
5106 *10*	60 keV *10*		
5387 *10*	14 keV *4*		E(level): average of 5380 keV *10* (1964Mi04) and 5393 keV *10* (1978Aj02). Γ: weighted average of 15 keV *5* (1964Mi04) and 10 keV *10* (1978Aj02).
6165 *10*	<20 keV		E(level): weighted average of 6170 keV *20* (1964Mi04) and 6164 keV *10* (1978Aj02). Γ: In Fig. 10 of (1978Aj02) this state is narrower than the E_x=5.39 MeV state. Γ<20 keV is assigned.
6434 *10*	36 keV *5*		
6932 *10*	55 keV *15*	>4	L: From (1978Aj02).
8138 *10*	100 keV *15*		
8684 *10*	89 keV *20*		
9.44×10^3 *3*	81 keV *25*		
10.22×10^3 *2*	210 keV *20*		
10.89×10^3 *2*			
11800?			

† From (1978Aj02), except as noted.

‡ From plane-wave analysis in (1964Mi04), except as noted.

^{11}B(^{18}O,^{16}O) 2013Ni06

2013Ni06: A beam of 85 MeV/nucleon ^{18}O ions impinged on a 78 μg/cm^2 ^{11}B target at the INFN/Catania. The angular distributions of reaction products were measured for θ=7° to 24° using the the MAGNEX spectrometer. Collective 2n transfer peaks are identified and compared with 2n reactions in nearby nuclei. See also (2011CaZX, 2011Ca36, 2018Ag04).

^{13}B Levels

E(level)
0
3.68×10^3
4.13×10^3
5.39×10^3
6.16×10^3 †
6.43×10^3 †
8.32×10^3

† Unresolved.

^{12}C(^{9}Be,^{8}B) 1999Ca48

1975Wi26: A ^{12}C target was bombarded by a 121 MeV beam of ^{9}Be ions from Lawrence Berkeley Laboratory 88-inch cyclotron. The ^{8}B reaction products were measured at θ=14° using a ΔE-ΔE-E Si detector telescope. Poorly resolved groups of ^{13}B states were observed. The objective was to provide an energy calibration point for a measurement on ^{10}Li.

1999Ca48: ^{12}C(^{9}Be,^{8}B). E=40.1 MeV/nucleon. A ^{9}Be beam, produced by fragmentation at the MSU/NSCL, impinged on a ^{12}C target at the S800 spectrometer target position. The σ(E,θ) was measured for $\theta\approx3.5°-8.3°$. The reaction to ^{13}B$_{g.s.}$ was used to calibrate the focal plane.

^{13}B Levels

E(level)†	Comments
0	
3600	E(level): unresolved multiplet (1975Wi26).
5200	E(level): possible group of states.
6170	E(level): unresolved with 6430.
6430	E(level): unresolved with 6170.

† From (1999Ca48).

^{12}C(^{12}Be,^{13}B) 2008Ch28

2008Ch28: ^{12}C(^{12}Be,^{9}Li+α) E=50 MeV/nucleon. A beam of ^{12}Be ions from the NSCL/A1900 impinged on a ^{12}C target placed at the S800 spectrometer target position that was surrounded by 16 position sensitive ΔE-E telescopes from the HiRA array. The array covered θ=2.7°−24.8° A kinematic reconstruction of the ^{9}Li+α relative energy spectrum indicated a state at E(^{9}Li+α)≈2.8 MeV. After correcting for the experimental resolution, $\Gamma\leq$320 keV is deduced.

^{13}B Levels

E(level)	Γ (keV)	Comments
13.6×10^{3} *1*	≤320 keV	E(level): determined from α+^{9}Li correlations using S_{α}=10.82 MeV.

^{12}C(^{13}C,^{12}N) **2000Ka21**

1986Vo02: ^{12}C(^{13}C,^{13}B), E=30 MeV/nucleon at Grenoble; measured σ(E(^{13}B$_{g.s.}$)) using a QD spectrometer at θ=1.8° with ΔE≈800 keV.
1993Bo03: ^{12}C(^{13}C,^{12}N) E=336 MeV at the HMI/VICKSI facility. Measured $\sigma(\theta)$ at θ=3.8° using a Q3D spectrometer. Deduced states at ^{13}B(0, 3.65, 5.21, 6.33, 8.24, 10.25 MeV) with no associated uncertainties; the differential cross sections are reported in Table 1.
1994Ic02: ^{13}C(^{12}C,^{12}N) E=135 MeV/nucleon from the RIKEN/K=540 MeV ring cyclotron. Measured σ(^{13}B$_{g.s.}$) for θ<10° using the SMART spectrograph. Deduced model parameters, reaction mechanism, strong selectivity of ΔS=1, ΔT=1 transitions.
2000Ka21: +12C(^{13}C,^{12}N) E=336.4 MeV. Measured excitation energy spectra for θ=1.8°−5.2° using the Q3D spectrometer at HMI. Ambiguity exists in the reported angular coverage. Deduced excited states, discussed the reaction mechanism and likely J^{π} values.

^{13}B Levels

E(level)†	J^{π}‡	Γ‡	Comments
0	3/2⁻		dσ/dΩ(6.2°)=1.0 μb/sr *3* (2000Ka21).
3690	(5/2⁻)		E(level): doublet consisting of unresolved states at 3680 and 3710 keV. dσ/dΩ(6.2°)=1.8 μb/sr *4*.
4120			dσ/dΩ(6.2°)=1.4 μb/sr *3*.
5000			dσ/dΩ(6.2°)=1.4 μb/sr *3*.
5370			dσ/dΩ(6.2°)=3.2 μb/sr *5*.
6400		30 keV	dσ/dΩ(6.2°)=19.0 μb/sr *12*.
7200?		170 keV	E(level): This group appears as a shoulder on the 6.40 MeV peak and may correspond to unresolved states at 7.51 and 7.86 MeV. dσ/dΩ(6.2°)=1.9 μb/sr *4*.
8160		70 keV	dσ/dΩ(6.2°)=3.9 μb/sr *6*.
8680		≤80 keV	dσ/dΩ(6.2°)=3.4 μb/sr *5*.
9310		≤80 keV	dσ/dΩ(6.2°)=2.6 μb/sr *4*.
10220		170 keV	E(level): other: 10250 (1993Bo03). dσ/dΩ(6.2°)=15.1 μb/sr *11*.
11180			E(level): broad structure which may be due to several unresolved states. dσ/dΩ(6.2°)=7.1 μb/sr *7*.

† From (2000Ka21); ΔE≈300 keV.
‡ From analysis of ^{12}C(^{13}C,^{12}N),(^{14}C,^{13}N) and (^{15}N,^{14}O) multi-nucleon transfer reactions in (2000Ka21).

^{12}C(^{14}C,^{13}N) **2000Ka21**

2000Ka21: ^{12}C(^{14}C,^{13}N) E=336.8 MeV. Measured excitation energy spectra for θ=1.4°−5.0° using the Q3D spectrometer at HMI. Ambiguity exists in the reported angular coverage. Deduced excited states, discussed reaction mechanism and likely J^{π} values. Typo on the last line of p.454: 4^{-} should be 4^{+}.

^{13}B Levels

E(level)†	Jπ‡	Γ‡	Comments
0	$3/2^{-}$		dσ/dΩ(5.4°)=2.2 μb/sr *2* (2000Ka21).
3680	$(5/2^{-})$		E(level): doublet consisting of unresolved states at 3680 and 3710 keV. dσ/dΩ(5.4°)= 5.3 μb/sr *3*.
4130			dσ/dΩ(5.4°)=1.2 μb/sr *2*.
4910			dσ/dΩ(5.4°)=1.8 μb/sr *2*.
5390			dσ/dΩ(5.4°)=5.8 μb/sr *4*.
6370	(5/2,7/2,9/2,11/2)	30 keV	Jπ: Authors suggest this formed via a two-step process with a p-wave proton pickup to ^{15}N followed by a 2n transfer to ^{13}N. dσ/dΩ(5.4°)=15.1 μb/sr *6*.
6960		150 keV	dσ/dΩ(5.4°)=2.0 μb/sr *2*.
7580		170 keV	E(level): This group appears as a small shoulder on the 8.14 MeV peak and may correspond to unresolved states at 7.51 and 7.86 MeV. dσ/dΩ(5.4°)=1.1 μb/sr *2*.
8140		70 keV	dσ/dΩ(5.4°)=5.3 μb/sr *3*.
8690		≤80 keV	dσ/dΩ(5.4°)=1.9 μb/sr *2*.
9440		≤80 keV	dσ/dΩ(5.4°)=1.6 μb/sr *2*.
10220		170 keV	dσ/dΩ(5.4°)=4.0 μb/sr *3*.
10980			E(level): this may be several unresolved states. dσ/dΩ(5.4°)=6.4 μb/sr *4*.

† From (2000Ka21); ΔE≈300 keV.

‡ From analysis of ^{12}C(^{13}C,^{12}N),(^{14}C,^{13}N) and (^{15}N,^{14}O) multi-nucleon transfer reactions in (2000Ka21).

^{12}C(^{15}N,^{14}O) **2000Ka21**

2000Ka21: ^{12}C(^{15}N,^{14}O) E=240.1 MeV. Measured excitation energy spectra for θ=2.0°−5.4° using the Q3D spectrometer at HMI. Ambiguity exists in the reported angular coverage. Deduced excited states, discussed reaction mechanism and likely J^{π} values.

^{13}B Levels

E(level)†	J$^{\pi}$‡	Γ‡	Comments
0	3/2$^-$		dσ/dΩ(9.1°)=0.3 μb/sr *1* (2000Ka21).
3720	(5/2$^-$)		E(level): doublet consisting of unresolved states at 3680 and 3710 keV. dσ/dΩ(9.1°)=1.8 μb/sr *2*.
4140			dσ/dΩ(9.1°)=0.7 μb/sr *1*.
5030	(3/2$^-$)		dσ/dΩ(9.1°)=0.4 μb/sr *1*.
5380	(7/2$^-$)		dσ/dΩ(9.1°)=3.0 μb/sr *2*.
6170		60 keV	dσ/dΩ(9.1°)=1.8 μb/sr *2*.
6430	(9/2$^+$)	30 keV	dσ/dΩ(9.1°)=13.4 μb/sr *5*.
6920		150 keV	dσ/dΩ(9.1°)=1.2 μb/sr *2*.
7760		170 keV	E(level): This group appears as a small shoulder on the 8.12 MeV peak and may correspond to unresolved states at 7.51 and 7.86 MeV. dσ/dΩ(9.1°)=0.5 μb/sr *1*.
8120		70 keV	dσ/dΩ(9.1°)=3.4 μb/sr *2*.
8690		≤80 keV	dσ/dΩ(9.1°)=2.8 μb/sr *2*.
9440		≤80 keV	dσ/dΩ(9.1°)=1.6 μb/sr *2*.
10220	(11/2$^-$)	170 keV	E(level): other: 10250 (1993Bo03). dσ/dΩ(9.1°)=9.2 μb/sr *4*.
11050		1.8 MeV	E(level): broad structure which may be due to several unresolved states. dσ/dΩ(9.1°)=8.0 μb/sr *4*.
13650		300 keV	dσ/dΩ(9.1°)=1.7 μb/sr *2*.
14390		400 keV	dσ/dΩ(9.1°)=1.4 μb/sr *2*.

† From (2000Ka21); ΔE≈300 keV.

‡ From analysis of ^{12}C(^{13}C,^{12}N),(^{14}C,^{13}N) and (^{15}N,^{14}O) multi-nucleon transfer reactions in (2000Ka21).

^{12}C(^{16}O,^{13}B),(^{18}O,^{13}B) 2022Bo01

2022Bo01: ^{12}C(^{16}O,^{13}B): Using the R^{3}B/LAND facility, measured ^{13}B production yields in the fragmentation of ^{16,20,22}O at E=450, 415, and 414 MeV/nucleon, respectively.

2022Ji03,2022Xu12: A cocktail beam of $^{12-16}$C isotopes was produced at the HIRFL by fragmenting a 240 MeV/nucleon ^{18}O ion beam on a ^{9}Be target. The different isotopes of the cocktail beam were identified by time-of-flight techniques and subsequently used to measure fragment production yields of boron isotopes (elemental analysis).

^{13}B Levels

E(level)
0

$^{13}C(\gamma,\pi^+)$ **1994Ch39**

1982Le26: $^{13}C(\gamma,\pi+)^{13}B$(0,3.6) using Bremsstrahlung photons from E_e=190-204 MeV on a 99% enriched ^{13}C target at MIT/Bates. Measured $\sigma(\theta=90°)$ for emitted π^+ energies of 18, 29, 42 MeV. Analyzed $^{13}B_{g.s.}$ population via DWIA. Higher-lying states were unresolved.

1983Mi06: $^{13}C(\gamma,\pi^+)$. Photopion production was deduced from $^{13}C(e,e'\pi+)$ data obtained using a 195 MeV electron beam from the Tohoku/Japan LINAC. Determined $\sigma(E(\pi),\theta)$ for θ=30°−150°. Deduced photopion $\sigma(\theta)$ vs. E_γ. Deduced the M2, M4 transition strength distribution and giant analog resonance excitation. 99% enriched ^{13}C target. $^{13}B^*$(0,3.5, 6.4, 9 MeV) are reported.

1983Sh01: $^{13}C(\gamma,\pi^+)$, deduced from measurement of the $^{13}C(e,\pi^+)^{13}B_{g.s.}$ reaction using a 195 MeV electron beam from the Tohoku/Japan LINAC. Measured $\sigma(\theta)$ for θ=30-150°. Compared with DWIA calculations. 99% enriched ^{13}C target.

1988Ka41: $^{13}C(\gamma,\pi+)$: compiled $\sigma(E\gamma,\theta)$.

1994Ch39, 1994Ch43: $^{13}C(\gamma,\pi^+)$, E_γ=191 MeV produced from 290 MeV electrons from the Saskatchewan 300 MeV electron accelerator. Measured $\sigma(E(\pi),\theta(\pi))$. Groups are reported at ^{13}B(0, 3.5, 6.4, 9.5 MeV). Discussed ΔS=1, ΔT=1 transitions features.

Theoretical analyses.

1973Na14: compared $(\gamma,\pi+)$ vs $(\gamma,\pi-)$ calculated cross sections.

1983To17: $^{13}C(\gamma,\pi+)^{13}$, DWBA, calculated $\sigma(\theta)$.

1982Ch16: $^{13}C(\gamma,\pi+)^{13}B_{g.s.}$, calculated $\sigma(\theta)$.

1983Ch54: $^{13}C(\gamma,\pi+)$, calculated $\sigma(\theta)$.

1983Mi06: $^{13}C(\gamma,\pi+)$ Theory, E=162, 173, 186 MeV, calculated $\sigma(\theta)$.

1986Si07: $^{13}C(\gamma,\pi+)$, calculated $\sigma(\theta)$, deduced Δ-isobar term.

1989Je02: $^{13}C(\gamma,\pi+)$, calculated $\sigma(\theta)$, theory, E=193 MeV. Chiral Bag Model.

1991Er06: Comparison of calculated (e,e′), $(\gamma,\pi+)$ and $(\pi-,\gamma)$ cross sections at E≈180, 200 MeV.

^{13}B Levels

E(level)	Comments
0	
$3.5\times10^{3\dagger}$	
$6.4\times10^{3\dagger}$	
$9.5\times10^{3\dagger}$	E(level): other: 9000 (1983Mi06).
$13000^{\dagger}$	

† E_x from (1994Ch39); levels may contain a complex of states. Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

^{13}C(μ^{-},ν)

1987Su06, 1981SuZS: ^{13}C(μ-,ν), E at rest, measured muonic capture lifetime.

2016Ab02: Deduced cross section limit for the ^{13}C(μ-,ν)^{13}B reaction obtained in the Double Chooz detector and discussed cosmogenic production of radionuclides. See similar discussion in (2010Ab05, 2019Zh29).

Theoretical analyses.

1973Mu11: ^{13}C(μ-,ν), calculated capture cross sections.

1972Bu29: ^{13}C(μ-,ν), estimated capture rates to ^{13}B(0,3.7 MeV).

1979De01: ^{13}C(μ-,ν), theory – shell model, calculated partial transition rates for muon capture on 1p-shell nuclei.

1985Ko39: ^{13}C(μ-,ν), E at rest, calculated partial muon capture rates, deduced *g*p/*g*A.

1998Mu17: ^{13}C(μ-,ν), calculated total capture rate. (assumed at rest).

^{13}B Levels

E(level)
0

^{13}C(π^-,γ) **1983Ma16**

1983Ma16: ^{13}C(π-,γ), Measured stopped π- capture at the Low Energy Pion Channel of the LANL Clinton P. Anderson Meson Physics Facility. Measured E_γ, I_γ. Deduced feeding to ^{13}B states. See also (1981MaZS).

Theoretical analyses.

1977Do06: Calculated transition probabilities to ^{13}B(0, 3.6, 5.5 MeV).

1978Ki13: Shell model calculations for spin-dipole transitions. Analysis of the gross structure of resonances. Predicted population of several states at E_x=0 to 22 MeV.

1982Gm02: ^{13}C(π-,γ): compiled available data. Deduced reaction mechanism.

1991Er06: Compared of calculated (e,e′), (γ,π+) and (π-,γ) cross sections at E≈180, 200 MeV.

^{13}B Levels

E(level)†	Comments
0	
3.5×10^3	E(level): possible doublet.
6.5×10^3	
7.6×10^3	
$\approx10.2\times10^3$	Γ: Broad state or group of levels: order of MeV(s).

† From (1983Ma16).

^{13}C(π^{-},π^{0}) **1994Ha41**

1994Ha41: ^{13}C(π+,π_0), E=165; measured $\sigma(\theta$, E$_\pi$) at LAMPF using π^0 spectrometer to measure the decay γ-γ photons.
Reported π_0 to E$_x$≈9 MeV T=3/2 state. See also (1999Ha24).

Theoretical analyses.

1980Jo06: ^{13}C(π-,π_0), E=180 MeV, calculated $\sigma(\theta)$.

1981Os04: ^{13}C(π+,π_0), E=130-250 calculated σ(E,θ) estimated importance of Δ resonance.

^{13}B Levels

E(level)	Γ	Comments
9.0×10^3	≈8.1 MeV	T=3/2 E(level): Represents the T=3/2 giant resonance built on ^{13}C$_{g.s.}$ (1994Ha41).

^{13}C(n,p) 1996Wa06

1987Br32: ^{13}C(n,p), E= 65 MeV with neutrons produced via ^{7}Li(p,n) at the UC Davis laboratory. Measured σ(E(p),θ) for θ=0° to 40° utilizing a dipole magnet and ΔE-E telescopes. Data presented only for ^{12}C target.

1988Ja01: ^{13}C(n,p), E=198 MeV. Measured σ(E(p),θ) at θ=0° at the TRIUMF charge exchange facility. Related σ(0°) to B_{GT} for $^{13}B_{g.s.}$

1992So02: ^{13}C(n,p) E=60 to 260 MeV. Measured σ(E(p),θ) at θ=0° to 10° for the ground state G-T transition at the LANL/WNR facility. Obtained information on the volume integral of the spin-isospin term of the effective N-N interaction and on the relation between σ($\theta\approx$0°) and B_{GT}.

1996Wa06: ^{13}C(n,p), E= 65 MeV. Measured σ(E(p),θ) for θ=0° to 40° at the UC Davis laboratory. Observed peaks at E_x=0, 3.5, 6.5, 7.6, 10.2 MeV. Suggest the 6.5 and 7.6 MeV states are spin dipole in character while the broad 10.2 MeV state is likely the giant E1 resonance.

1996Ma58: ^{13}C(n,p)$^{13}B_{g.s.}$ E= 118 MeV. Measured σ(E(p),θ) for θ=0° to 19° at IUCF. Analyzed σ(0°) vs. G-T strength.

1998Ha24: E_n=118 MeV. Measured σ(E_p,θ=0° and 7.5°) at IUCF. General discussion.

^{13}B Levels

E(level)[†]	Comments
0	
3.5×10^{3}	
6.5×10^{3}	
7.6×10^{3}	
10.2×10^{3}	Γ: Broad.

[†] From 1996Wa06. Peaks include unresolved states.

^{13}C(d,^{2}He) **1986Mo27**

1986Mo27: ^{13}C(pol. d,^{2}He), E=70 MeV. Measured $\sigma(\theta)$, $A_y(\theta)$ for $\theta \approx 10°$ to 65° at the RCNP/Osaka. Observed groups at E_x=0, 3.8, 5.2, 6.6 MeV, but only analyzed the reaction to the ground state via DWBA analysis.
1993Oh01: ^{13}C(d,^{2}He), E=260 MeV. Measured $\sigma(\theta)$ for θ=0° to 10° at RIKEN. Analyzed σ relation with B(GT).
1995Xu02, 1998GaZS: ^{13}C(d,^{2}He) E=125.2 MeV. Measured $\sigma(\theta=0°)$ at Texas A&M. Analyzed σ relation with B(GT).

^{13}B Levels

E(level)[†]
0
3.8×10^{3}
5.2×10^{3}
6.6×10^{3}

[†] From (1986Mo27). Peaks include unresolved states.

^{13}C(t,^{3}He) 2009Gu23

1998Da05: ^{13}C(t,^{3}He) E=127 MeV/nucleon. Measured dσ/dΩ(0°) at MSU/NSCL using the A1200 as a dispersion-matched energy-loss spectrometer. Measured ^{3}He energy spectrum at θ=0°. Analyzed σ relation with B(GT).

See also (2011Pe12) who analyzed the cross section to $^{13}B_{g.s.}$ and the relationship to B(GT).

2009Gu23: XUNDL dataset compiled by TUNL (2009).

Measured ^{13}C(t,^{3}He) at E_t=115 MeV/nucleon using a 99.3% enriched $^{13}CH_2$ target at the object position of the S800 spectrometer. Measured ^{3}He particles with plastic scintillators and time-of-flight to identify particles. FWHM=480 keV. Measured $\sigma(\theta)$ for dipole transitions up to E_x=20 MeV. Deduced Gamow-Teller strengths. 10% systematic uncertainty. DWBA calculations. Used COSY to reconstruct (non)dispersive angles, position and momentum.

^{13}B Levels

E(level)†	J^{π}†	ΔL†‡	dσ/dΩ (mb/sr)†#	Comments
0	3/2$^-$	0,2	13.1 *13*	B(GT)=0.711 *2*; calculated from relevant β-decay log *ft* value. Unit σ(q=0)=22.8 mb/sr *23*.
3.6×10^3	3/2$^-$	0,1	1.07 *9*	E(level): Unresolved multiplet. B(GT)=0.065 *5*; error calculated from the square root of the sum squared of 0.07 mb/sr statistical error and 0.05 mb/sr systematic error.
5.2×10^3	(3/2$^+$,5/2$^+$)	1		
7×10^3	(3/2$^+$,5/2$^+$)	1		
10×10^3	(3/2$^+$,5/2$^+$)	1		

† From DWBA analysis in (2009Gu23). In (1998Da05), broad unresolved groups at E_x=3.9, 4.7 and 6.2 MeV are shown in Fig. 1.

‡ Transferred from the J^{π}=1/2$^-$ $^{13}C_{g.s.}$

θ=0°, L=0.

^{13}C(^{7}Li,^{7}Be) **1990Na03**

1984Gl06: ^{13}C(^{7}Li,^{7}Be), E=78 MeV. Measured σ(E(^{7}Be),θ). Deduced single-step spin-flip charge-exchange process dominance.

1990Na03: ^{13}C(^{7}Li,^{7}Be), E=21 MeV/nucleon beam from the AVF cyclotron of the RCNP, Osaka. Measured σ(E(^{7}Be),θ) for $\theta \leq 10°$ using the DUMAS spectrometer. Data taken with the RAIDEN spectrometer are also discussed. An energy resolution of ≈300 keV was obtained. Analyzed levels up to E_x=9.5 MeV using DWBA.

^{13}B Levels

E(level)	J$^{\pi}$	Γ	ΔJ$^{\pi}$ [‡]
0	3/2^{-}		1-
3.5×10^{3} [†]			2-
4.0×10^{3} [†]			2-
5.1×10^{3} [†#]			2-+4-
6.3×10^{3} [†#]			2-+4-
7.0×10^{3} [†#]			2-+4-
7.6×10^{3} [†#]			1-
9.5×10^{3} [†]		≈2.3 MeV	1-

[†] Unresolved states. ΔE≈300 keV.

[‡] (^{7}Li,^{7}Be) angular distributions were measured on ^{12}C(J^{π}=0^{+}) and ^{13}C(J^{π}=1/2^{-}) targets, and ΔJ^{π} values were deduced for population of ^{13}B states by comparison of angular distribution shapes with those to known ^{12}B states.

[#] Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

^{14}C(γ,p) **1991Mc05**

1991Mc05: ^{14}C(γ,p) E=threshold(20.8)−29.1 MeV using bremsstrahlung photons produced using the Melbourne betatron. Measured $\sigma(E_\gamma)$ to ^{13}B using activation methods. See also (1993Mc02).

^{13}B Levels

E(level)	J^π
0	$3/2^-$

^{14}C(d,^{3}He) **2016Be08**

1975Ma41: ^{14}C(d,^{3}He), E=52 MeV from Karlshuhe Cyclotron; measured $\sigma(E(^{3}He),\theta)$ for θ=10° to 40° using four ΔE-E telescopes. Deduced levels at ^{13}B(0, 3.71 MeV) with C^{2}S=3.75 and 0.29, respectively. DWBA analysis. Self supporting 40% enriched ^{14}C 30 μg/cm^{2} target. See eranalysis of this data and discussion on the ANC for ^{14}C→^{13}B+p in (2022Ke03).

2016Be08: XUNDL dataset compiled by TUNL (2016).

The authors analyzed the angular distributions of ^{3}He particles from the ^{14}C(d,^{3}He)^{13}B proton-removal reaction, in inverse kinematics, to study the J^{π} values of ^{13}B states involved in the reaction.

A beam of 17.1 MeV/nucleon ^{14}C ions with the intensity of ≈0.1 pnA, produced in the sputter source at the ANL/ATLAS facility, impinged on 140 μg/cm^{2}(Cd$_{2}$)$_{n}$ polyethylene foils located at the HELIcal Orbit Spectrometer (HELIOS) target position. The kinematics of ^{3}He particles from (d,^{3}He) reactions were determined from analysis of the HELIOS array data, while recoiling boron isotopes were detected in set of silicon detector ΔE-E telescopes that covered θ_{lab}=1°−5°. The resolution for excitation energies was found as FWHM≈180 keV. Angular distributions were analyzed via DWBA to obtain L, J^{π} and C^{2}S values.

The ^{3}He particle reaction data were analyzed in coincidence with any boron isotope to give access to population of unbound states.

^{13}B Levels

E(level)†	J^{π}†	L†	C^{2}S†	Comments
0	3/2^{-}	1	2.80 *30*	C^{2}S: See also C^{2}S=3.75 (1975Ma41).
3.8×10^{3}	(1/2^{-})	1	0.70 *8*	C^{2}S: See also C^{2}S=0.29 (1975Ma41).
4.8×10^{3} *2*	(1/2^{+})	0	0.13 *2*	
5.3×10^{3} *3*	(1/2,3/2)$^{-}$	1	0.35 *6*	
6.3×10^{3} *4*	+	(0)		E(level): This peak likely contains more than one unresolved state (2016Be08).

† From DWBA analysis in (2016Be08).

^{14}C(t,^{4}He) 1979Se07

1979Se07: ^{14}C(t,^{4}He) E=23.0 MeV. Measured $\sigma(\theta)$ for θ=20° to 60° at Los Alamos Scientific Laboratory, using a Q3D spectrometer. DWBA analysis does not fit the data well. ^{14}C target on Au foil. See also (1978SeZX).

^{13}B Levels

E(level)	J^{π}	S
0	$3/2^{-}$	5.7

^{14}C(^{11}B,^{12}C) 2022Me03

2022Me03: ^{14}C(^{11}B,^{12}C) E=45 MeV; measured angular distribution for $\theta_{c.m.}$=35° to 70° at the Warsaw cyclotron facility.
Analyzed data to obtain ^{13}B+p asymptotic normalization constant. See further analysis in (2022Ke03, 2022Me09, 2022Me11).

^{13}B Levels

E(level)
0

^{15}N(p,3p) 1965Po03

1965Po03: ^{15}N(p,^{13}B) E=2.2 GeV; a proton beam from the BNL Cosmotron bombarded a ^{15}N in a search for evidence of ^{13}B β-n decay. Ambiguous results were obtained. The authors suggested %B^{-}n<0.3.

^{13}B Levels

E(level)
0?

^{16}O(^{14}C,^{17}F) 2000Ka21

2000Ka21: ^{16}O(^{14}C,^{17}F) E=334.4 MeV. Measured excitation energy spectra for θ=1.0°−4.3° using the Q3D spectrometer at HMI. Ambiguity exists in the reported angular coverage. Deduced excited states, discussed reaction mechanism and likely J^{π} values.

^{13}B Levels

E(level)[†]	J^{π}[†#]	Γ[‡]	Comments
0	$3/2^-$		$\pi 1p_{3/2}$. dσ/dΩ(5.4°)=0.28 μb/sr *3* (2000Ka21).
4830	$(1/2^-)$		dσ/dΩ(5.4°)=0.09 μb/sr *2*.
6900	$(3/2^-,5/2^-)$	150 keV	dσ/dΩ(5.4°)=0.10 μb/sr *2*.

[†] From (2000Ka21), ΔE≈600 keV.

[‡] From analysis of ^{16}O(^{14}C,^{17}F) and other reactions in (2000Ka21).

[#] For ^{13}N*(4.3,6.9 MeV) the authors suggest a mechanism with one $1p_{1/2}$ and two $1p_{3/2}$ proton transfers; they suggest the remaining protons couple to 0^+ for the lower state and 2^+ for the higher state. These values are not adopted.

^{48}Ca(^{11}B,^{13}B) 1978KeZP

1978KeZP: ^{48}Ca(^{11}B,^{13}B$_{g.s.}$) E=115 MeV. Measured isotope yields from reactions of ^{11}B ions on a 200 μg/cm^{2} ^{48}Ca carbonate target using a QSD spectrometer positioned at θ=8°. LBNL lab report.

^{13}B Levels

E(level)
0

^{136}Xe(p,^{13}B) 2007Na31

2007Na31: ^{1}H(^{136}Xe,X) E=1 GeV/nucleon. Measured spallation yields (in inverse kinematics) using the GSI fragment separator. Deduced spallation cross sections and isotope production yields.

^{13}B Levels

E(level)
0

^{181}Ta(^{22}Ne,^{13}B),(^{20}Ne,^{13}B) **1988Sa04**

1988Sa04: ^{13}B ions produced by fragmenting a 770 MeV ^{22}Ne beam on a thick ^{nat}Ta target were separated using the NSCL/RPMS. The beam was stopped in a ΔE-E-VETO telescope; detection of an ion in the telescope resulted in an *rf*-inhibit that prevented implantation of further activity. Implanted specied were determined via ΔE-E particle identification and the half-life, $T_{1/2}$=17.6 ms *12*, was deduced from an event-by-event analysis of the implantation time vs the decay time.

1997So34: A beam of ^{13}B ions was produced by fragmentation of a 20 MeV/nucleon ^{20}Ne beam on a Ta target at the FLNR U-400 cyclotron facility. The ^{13}B beam was stopped at the center of a 182 element array of ^{3}He counters that incorporated a paraffin neutron moderator. $T_{1/2}$=17.0 ms *4* and P_n<0.03% were deduced for ^{13}B decay.

^{13}B Levels

E(level)	$T_{1/2}$	Comments
0	17.0 ms *4*	$T_{1/2}$: From (1997Sa04). See also T=17.6 ms *12* (1988Sa04). P_n<0.03% (1997Sa04).

^{208}**Pb(^{13}B,^{13}B)** **2022Wa16**

2022Wa16: XUNDL dataset compiled by TUNL (2022).

The authors measured elastic scattering of the ^{13}O and ^{13}B mirror nuclei on ^{208}Pb and analyzed the nuclear densities obtained from optical model analyses.

A beam of 254 MeV ^{13}B ions from the HIRFL in Lanzhou impinged on a 12.24 mg/cm^2 thick ^{208}Pb target. Scattered ^{13}B ions were momentum analyzed using an array of four position sensitive ΔE-E Si-detector telescopes that covered $\theta \approx 3°$ to 27°. Differential cross sections were analyzed for $\theta_{lab}=4°$ to 15°. Authors indicate $^{13}B_{g.s.}$ was resolved from the E_x=3.28 MeV first excited state, but participation of any ^{208}Pb excited states was unresolved.

The data were analysed using two optical model approaches: first, using the double-folding Sao Paulo potential-2 (L. Chamon, et al., Computer Physics Communications **267**, 108061 (2021)), and second using the single-folding Xu and Pang potential model (2013Xu06). The data are reasonably fit using standard global parameterization inputs. The discussion details an approach for obtaining the proton, neutron and matter rms radii. A comparison of the ^{13}B results with those of ^{13}O suggests a thin proton skin for ^{13}O.

^{13}B Levels

E(level)	Comments
0	$<r_p^2>^{1/2}$=2.354 fm. $<r_n^2>^{1/2}$=2.641 fm. $<r_m^2>^{1/2}$=2.534 rm.

^{197}Au(^{15}N,^{13}B) 1991OkZZ

1991OkZZ: ^{197}Au(^{15}N,^{13}B) E=112 MeV/nucleon. ^{13}B ions were collected in a Pt stopper at θ=2°,4°,6° using RIKEN/RIPS beam swinger facility. The β asymmetry was measured and used to deduce the spin polarization. RIKEN progress report.

2007Gr23: ^{27}Al, ^{93}Nb, ^{197}Au(^{15}N,^{13}B) E≈60, 110 MeV/nucleon; calculated spin polarization after breakup.

^{13}B Levels

E(level)
0

^{232}Th(^{18}O,^{13}B),^{232}Th(^{22}Ne,^{13}B) 1969Ar13

1969Ar13: The authors analyzed the transfer reaction products resulting from E(^{18}O)=122 MeV bombardment of a 5 mg/cm^2 metallic ^{232}Th foil at Dubna. The reaction products were momentum analyzed in a magnetic spectrometer and then focused on a Si ΔE-E detector telescope, which provided particle identification. ^{13}B was identified.

1977Ar06: The transfer reaction products resulting from E(^{22}Ne)=172 MeV bombardment of a 2.5 mg/cm^2 metalic ^{232}Th foil were measured at Dubna. The reaction products were momentum analyzed in a magnetic spectrometer positioned at θ=12° and 40° and then focused on a ΔE-E Si detector telescope, which provided particle identification. ^{13}B was identified.

^{13}B Levels

E(level)
0

U(p,^{13}B),^{232}Th(p,^{13}B) 1973Bo30

1973Bo30: Proton spallation cross sections on a uranium target, were measured at the Bevatron using 4.8 GeV protons. Reaction products including ^{13}B were identified using ΔE vs E and ΔE vs time-of-flight techniques.

1991Re02: Spallation products from 800 MeV proton bombardment of a ^{232}TH target were captured by a transport line with a mass-to-charge filter and transferred to the TOFI spectrometer at LAMPF. For ^{13}B, the β-delayed neutron probability %β-n=0.3% *1* was deduced and $T_{1/2}$ = 11 ms *9* was measured. A reanalysis of the (1991Re02) data, with additional data was published in the (1994ReZZ). The reanalysis indicates Pn=0.25% *15* and $T_{1/2}$=16.7 ms *6*. See also (1994KiZU, 1995ReZZ, 2008ReZZ) for different lifetime values deduced from this dataset.

^{13}B Levels

E(level)	$T_{1/2}$	Comments
0	16.7 ms *6*	$T_{1/2}$: From (1994ReZZ).

^{238}U(^{18}O,^{13}B) 2018St06

2018St06: ^{238}U(^{18}O,X) E=8.5 MeV/nucleon. Isotope production cross sections were measured using the GANIL/LISE spectrometer. The momentum distributions of produced isotopes were also analyzed.

^{13}B Levels

E(level)
0

Adopted Levels, Gammas

Q(β^-)=−2220.47 *27*; S(n)=4946.31; S(p)=17533.4 *13*; Q(α)=−10648.36 *8* 2021Wa16
S(n)=4946.3087 *5* 2021Wa16
add F xrefs.
1929Ki01, 1929Ki02: Discovered ^{13}C in the carbon spectrum from an electric furnace. See (2012Th01).
1984De53: Natural abundance: 1.10% *3*.
1985De42: Deduced rms charge radius 2.4628 fm *39* from 2p-1s muonic transition. See also (1984Aa02).
Mass measurements: 1935Be02, 1969Wo03, 1993VaZY, 1995Di08, 1995Va38, 1997Br44, 2004Ra33, 2006Re19.

Nuclear moments:
Measurements: $^{13}C_{g.s.}$ 1954Ro34 μ=+0.7024118 *14*, 2005An15 μ=0.7023694 *35*. ^{13}C(3.85 MeV) 1981Ru04 μ=1.40 *4*.
Tabulations: 1964Li14, 1967Sh14, 1969Fu11, 1972Gl06, 1975Go12, 1989Ra17, 2011StZZ: μ(3.85 MeV)=1.40 *4*, 2019StZV: μ=0.702369 *4*.
Calculations: 1937Ro01, 1963Be36, 1968Pe16, 1974Ha27, 1984Ka25, 1988Va03, 1990Iw02, 1991Bo02, 1996Ka14, 1999Ga57, 1999Ki27, 2003Su04, 2003Su09, 2003Su28, 2004Sa58, 2005Ko18, 2012Fu06, 2013Ma60, 2017Ya19, 2021Fr07.

Theory:
Ground state and level properties: 1961Ku17, 1963Se19, 1966El08, 1967Ba12, 1970Pe18, 1971Gr02, 1971Ja13, 1973Ma48, 1975Er09, 1975Me24, 1975Yu03, 1978Sm02, 1981Av02, 1981Li19, 1983Sh38, 1984Fr13, 1987Sa15, 1990Mo17, 1992Zh01, 1993Ki01, 1993Pa19, 1993Sa20, 1995Vi06, 1996Ki24, 1996Ot01, 1996Re19, 1996Su24 1997Ba54, 1997Mo06, 1997Po12, 1998Ch38, 1998Sh16, 2000Ko23, 2001Ot04, 2003Sa50, 2003Su28, 2005Ni24, 2006Ko02, 2007Na16, 2007Sa50, 2014Ho08, 2015Sh21, 2019Bi03, 2020Su20, 2020So01, 2021Ga21, 2021Ma32, 2022Sa37.
Shell model 1965Co25, 1970Hs02, 1971Ja14, 1971No02, 1973Ha49, 1973Sa30, 1978Bo31, 1983Va08, 1983Va08, 1983Va31, 1984Va06, 1987Nu02, 1988Wo04, 1990Bl16 1990Sk05, 1990Va01, 1992Kw01, 1993Go03, 1993Ki23, 1993Po11, 1993Zh17, 1996Ki27, 2003Na21, 2005Na41, 2006Le33, 2007Gu03, 2008Sh16, 2009Um05,2010Ti04, 2012Yu07, 2013Ma60, 2015Fo06, 2016Ho14, 2018Fu14, 2018Ti08.
Cluster model and multi-body forces 1974Si04, 1989Va06, 1995Ho13, 1996Du12, 1997De27, 1997Ho04, 1997Ka25, 1997Vo17, 2001Ka66, 2002Mi32, 2002Vo19, 2003Fr39, 2003Mi33, 2003Mi34, 2003Th06, 2003Vo24, 2004Bu25, 2004Mc02, 2004Na35, 2004Th11, 2004To14, 2004Vo09, 2005Du03, 2005NeZZ, 2006It06, 2006Ka55, 2006Ta28, 2007Fr22, 2008Ya24, 2009Yo03, 2010VoZY, 2011Fu01, 2011Ya08, 2012Ya16, 2015Ya16, 2017De19, 2020Ca21, 2020Ro08, 2022Ur01.

Various topics.
Mirror and analog states: 1938Be05, 1963Fa03, 1971Ar03, 1971DiZT, 1971Ng01, 1972Ch16, 1974Ch46, 1975Gr03, 1975Ku21, 1973Sa25, 1975Me24, 1980Ba54, 1985An28 (IMME), 1986RoZQ, 1986Si22, 1995Fo18, 1998Ao02, 2005Ti14, 2006Sh10, 2011Ti09, 2012Am06 (IMME), 2015Fr04, 2018Fo04, 2019Mu05, 2022Va06.
Nuclear size: 1976Du04, 1982Sc11, 1992He21, 1992La13, 1996Sh13, 2001Oz03, 2001Oz04, 2002Me12, 2003Li31, 2004Ne16, 2005Ch02, 2006Pe01,2008Ch34, 2011Gu03, 2016Og03 (radius of 3.09 MeV state), 2017Ah08,
Electromagnetic transitions: 1970Fo14, 1971DiZT, 1972Gu05, 1978Ki08, 1982MoZR, 1983Mi08, 1984Ku07, 1984Sc09, 1985Uc01, 2001Ra41, 2004Sa58, 2004Su23, 2005Sa63, 2021Sh20, 2011SuZU, 2015IzZZ.
Giant resonance: 1962Ea01, 1963Pe04, 1972Le06, 1974Mu13, 1989GoZQ, 1992Ba02, 2004El05, 2004Is09.
Others: 1981Pl03, 1986Co21, 1990Mu10, 1994Fe06, 2009Ti11, 2013Ti05, 1978Le04, 1982We02, 2012Su15, 2013Su17, 2015Mo24.

Other reactions populating ^{13}C:
1966De09: ^{17}O(d,^{6}Li),
1969Ba17: ^{14}N(α,αp),
1973Va07, 1974Bu06, 1978Da17 : ^{13}C(pol. d,d),
1974Li15: ^{16}O(π^-,^{13}C),
1975Sc35, 1975Sc42: ^{14}C(^{16}O,^{17}O),
1977Ar06: ^{232}Th(^{22}Ne,^{13}C),
1979Pr07: ^{12}C(^{16}O,^{15}O),
1980Mi01: ^{27}Al(^{16}O,^{13}C),
1981Wh01: ^{14}C(π^+,p),
1984Ho23: ^{197}Au(^{20}Ne,^{13}C),
1991Eu01: ^{7}Li(^{6}Li,γ),

Adopted Levels, Gammas (continued)

1999Az04, 2001Az01: ^{14}N(^{7}Be,^{8}B),
2021Ci02: ^{181}Ta(^{18}O,^{13}C),
2021Su15: C(^{14}C,^{13}C).
2022Bo01: ^{12}C(X,^{13}C): X=^{15,16}O, ^{14}N.

^{13}C Levels

Cross Reference (XREF) Flags

A	^{13}B β^- decay	X	^{12}C(n,γ):res	AT	^{13}C(α,α),(α,α'),(α,$\alpha'\gamma$)
B	^{13}N ε decay	Y	^{12}C(n,n):res	AU	^{13}C(^{6}Li,^{6}Li),(^{7}Li,^{7}Li)
C	^{14}B β^-n decay	Z	^{12}C(n,p):res	AV	^{13}C(^{9}Be,^{9}Be),(^{9}Be,^{9}Be′)
D	^{17}N $\beta^-\alpha$ decay	Others:		AW	^{13}C(^{11}B,^{11}B)
E	^{1}H(^{12}B,p):res	AA	^{12}C(n,n′),(n,n′γ):res	AX	^{13}C(^{18}O,^{18}O)
F	^{7}Li(^{9}Be,α^{9}Be),^{14}C(^{13}C,α^{9}Be)	AB	^{12}C(p,π^+)	AY	^{14}C(p,d)
G	^{9}Be(α,α):res	AC	^{12}C(d,p),(d,pγ)	AZ	^{14}C(d,t)
H	^{9}Be(α,nγ):res	AD	^{12}C(t,d),^{13}C(t,t),(t,t′)	BA	^{14}C(^{3}He,α)
I	^{9}Be(^{6}Li,d),(^{7}Li,t)	AE	^{12}C(^{3}He,2p)	BB	^{14}N(γ,p)
J	^{9}Be(^{9}Be,^{13}Cγ)	AF	^{12}C(α,^{3}He)	BC	^{14}N(μ^-,νn)
K	^{9}Be(^{16}O,^{12}C)	AG	^{12}C(^{7}Li,^{6}Li),(^{8}Li,^{7}Li)	BD	^{14}N(n,d),(n,dγ)
L	^{10}B(t,p)	AH	^{12}C(^{9}Be,^{8}Be)	BE	^{14}N(p,2p)
M	^{10}B(α,p),(α,pγ)	AI	^{12}C(^{11}B,^{10}B),(^{12}C,^{11}C)	BF	^{14}N(d,^{3}He)
N	^{10}B(^{6}Li,^{3}He)	AJ	^{12}C(^{13}C,^{13}C),(^{13}C,X)	BG	^{14}N(t,α)
O	^{10}B(^{7}Li,α)	AK	^{12}C(^{14}N,^{13}N)	BH	^{15}N(p,^{3}He)
P	^{10}B(^{10}B,^{13}C)	AL	^{13}C(γ,γ')	BI	^{15}N(d,α)
Q	^{10}B(^{14}N,^{11}C)	AM	^{13}C(γ,n),(γ,nγ),(γ,p)	BJ	^{16}O(n,α),(n,$\alpha\gamma$)
R	^{11}B(d,γ):res	AN	^{13}C(γ,p)	BK	^{16}O(p,p^{3}He)
S	^{11}B(d,p):res	AO	^{13}C(e,e),(e,e′),(e,e′p)	BL	^{16}O(α,α^{3}He)
T	^{11}B(d,nγ):res	AP	^{13}C(π,π),(π,π')	BM	^{20}Ne(n,2α)
U	^{11}B(^{3}He,p),(^{3}He,pγ),(α,d)	AQ	^{13}C(n,n),(n,n′),(n,n′γ)	BN	^{93}Nb(^{12}C,^{13}C)
V	^{11}B(^{6}Li,α)	AR	^{13}C(p,p),(p,p′),(p,pn)	BO	^{159}Tb(^{19}F,^{13}C)
W	^{12}C(n,γ):E=thermal	AS	^{13}C(^{3}He,^{3}He),(^{3}He,^{3}He′)	BP	^{165}Ho(^{14}N,n^{12}C)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
0	1/2$^-$	stable	ABCD IJK MNOPQ UVWX	XREF: Others: AB, AC, AD, AE, AF, AG, AH, AI, AJ, AK, AL, AO, AP, AQ, AR, AS, AT, AU, AV, AW, AX, AY, AZ, BA, BB, BC, BD, BE, BF, BG, BH, BI, BJ, BK, BL, BM, BN, BO μ=0.702369 *4* (2019StZV,2005An15) J$^{\pi}$: From mixed L=0+2 in ^{15}N(pol. p,^{3}He) (1974Ma12) and trivial shell model consideration.
3089.451 *19*	1/2$^+$	0.98 fs *9*	A IJK MNOPQ UVW	XREF: Others: AB, AC, AD, AF, AG, AH, AI, AK, AL, AO, AP, AQ, AR, AS, AT, AU, AW, AX, AY, AZ, BA, BB, BC, BD, BE, BF, BG, BH, BI, BJ, BK, BO %IT=100 XREF: BE(3100). E(level): From least squares fit to E$_{\gamma}$=169.300 keV *4*, 764.316 keV *10* and 3089.049 keV *20* (1980Wa24), and E$_{\gamma}$=595.22 keV *8* from (1982Mu14, 2008FiZZ) and E$_{\gamma}$=3684.01 keV *6* from (1967Pr10, 1982Mu14, 2008FiZZ). J$^{\pi}$: From E1 from 1/2$^-$ in ^{13}C(e,e′) (1989Mi01). T$_{1/2}$: from τ=1.42 fs *13* corresponding to Γ=0.464 eV *42* which is the weighted average of 0.463 eV *56* and 0.413

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
				eV *50* (1968Ro02), 0.537 eV *42* (1993Mo23), and 0.39 eV *6* (1975Ra22).
3684.496 *22*	3/2^{-}	1.13 fs *6*	A IJ MNOpQ UVW	XREF: Others: AB, AC, AD, AF, AG, AH, AI, AJ, AK, AL, AO, AP, AQ, AR, AS, AT, AU, AV, AW, AX, AY, AZ, BA, BB, BC, BD, BE, BF, BG, BH, BI, BJ, BK, BL, BN, BO %IT=100 E(level): From least squares fit to E_{γ}=169.300 keV *4*, 764.316 keV *10* and 3089.049 keV *20* (1980Wa24), and E_{γ}=595.22 keV *8* from (1982Mu14, 2008FiZZ) and E_{γ}=3684.01 keV *6* from (1967Pr10, 1982Mu14, 2008FiZZ). J^{π}: from M1+E2 from 1/2^{-} in ^{13}C(e,e′) (1989Mi01). $T_{1/2}$: from τ=1.63 fs *9* obtained from the average of τ=1.59 fs *13* (1991Li12: Γ_{0}^{2}/Γ=0.408 eV *26*) and τ=1.63 fs *12* (1993Mo23: Γ=0.403 eV *30*) from ^{13}C(γ,γ') and τ=1.82 fs *25* (1970Wi04: Γ=0.36 eV *5*) from ^{13}C(e,e′).
3853.796 *21*	5/2^{+}	8.6 ps *2*	A IJK MNOp UV	XREF: Others: AB, AC, AD, AE, AF, AG, AH, AI, AK, AO, AP, AQ, AR, AS, AT, AW, AX, AY, AZ, BA, BB, BC, BD, BG, BI, BJ, BK %IT=100 μ=1.40 *4* (1981Ru04,2011StZZ,2020StZV) E(level): From least squares fit to E_{γ}=169.300 keV *4*, 764.316 keV *10* and 3089.049 keV *20* (1980Wa24), and E_{γ}=595.22 keV *8* from (1982Mu14, 2008FiZZ) and E_{γ}=3684.01 keV *6* from (1967Pr10, 1982Mu14, 2008FiZZ). J^{π}: from M2+E3 from 1/2^{-} in ^{13}C(e,e′) (1989Mi01). $T_{1/2}$: from τ_{m}=12.4 ps *3* which is the weighted average of ^{12}C(d,p) values: τ_{m}=12.4 ps *8* (1974Be48), 13.0 ps *4* (1975Ra29), 12.6 ps *3* (1977He12) and 12.2 ps *4* (1981Ru04) and ^{10}B(α,p) values: τ_{m}=10.7 ps *10* (1969He22) and 9.9 ps *9* (1970Ga01). See also τ_{m}=9.0 ps *+25−15* (1968Ri16).
(4946.33 *5*)	1/2^{+}		W	E(level),J^{π}: From L=0 ^{12}C(n,γ):E=thermal capture state.
6860.04 *46*	5/2^{+}	6 keV	I MNOP UV Y	XREF: Others: AB, AC, AD, AG, AH, AI, AK, AO, AP, AQ, AR, AS, AT, AW, AY, BF, BG, BH, BI, BP %n<100; %IT>0 (1973Ad02) Γ_{n0}/Γ=0.99 *9* (1973Ad02) E(level): From (1990Pi05) ^{12}C(d,p). J^{π}: From L=2 and phase-shift analysis in ^{12}C(n,n) (1973Ab07). Γ: From (1977Ta08) ^{12}C(d,p). See other values around Γ=7-9 keV listed in ^{12}C(n,n):res.
7492 *10*	(7/2^{+})	<5 keV	I NOp UV	XREF: Others: AB, AC, AD, AI, AO, AP, AS, AT, AW, BG, BI %IT=0.3 (1971HiZF) Γ_{γ}/Γ=0.003 *1* (1971HiZF) XREF: V(7500). E(level): From the average of 7470 keV *20* (1955Mc75) and 7500 keV *12* (1959Yo25) ^{11}B(^{3}He,p). J^{π}: from E3+M4 from 1/2^{-} in ^{13}C(e,e′) (1989Mi01). Γ: From (1959Yo25) ^{11}B(^{3}He,p).

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J$^{\pi}$	$T_{1/2}$ or Γ	XREF	Comments
7547 *3*	$5/2^-$	1.2 keV *3*	A I MNOpQ UV Y	XREF: Others: AB, AC, AD, AG, AI, AM, AO, AP, AQ, AR, AS, AT, AU, AV, AW, AY, BB, BE, BF, BG, BH, BI %n≈100; %IT=9.2×10^{-3} (1980Ho11,1975He02) $\Gamma_{\gamma0}$=0.110 eV *15* (1980Ho11) XREF: V(7550)AG(7600)AY(7560)BE(7500)BI(7530). E(level): From the average of 7546 keV *5* (1975He02) ^{12}C(n,n), 7554 keV *12* (1959Yo25) ^{11}B(^{3}He,p) and 7547 keV *3* ^{13}C(e,e′). J$^{\pi}$: from E2+M3 from $1/2^-$ in ^{13}C(e,e′) (1989Mi01). The conference proceedings (1970CiZY) reports J=(5/2) and L=2 from ^{12}C(n,n): res. Γ: From (1975He02) ^{12}C(n,n). See also 6.5 keV (1970CiZY) ^{12}C(n,n) and 5 keV (1977Ta08) ^{12}C(d,p).
7688 *5*	$3/2^+$	69 keV *4*	I NO UV Y	XREF: Others: AB, AC, AD, AG, AI, AM, AO, AR, AS, AT, AW, AY, BE, BG, BI %n≈100; %IT=8.7×10^{-4} (1980Ho11) $\Gamma_{\gamma0}$=0.6 eV *1* (1980Ho11) XREF: Y(7658)AC(7641)AG(7.6E3)BE(7800)BI(7640). E(level): From average of E_x=7694 keV *14* (1959Yo25) ^{11}B(^{3}He,p), 7690 keV *10* (2013Ca25) ^{12}C(^{11}B,^{10}B) and 7686 keV *6* (1980Fu04) ^{13}C(α,α′). See also 7641 keV *20* (1955Mc75) ^{12}C(d,p), and 7658 keV *9* (1973Fa06) ^{12}C(n,n). J$^{\pi}$: From L=2 and phase-shift analysis in ^{12}C(n,n) (1973Ab07). Γ: From the average of Γ=60 keV *13* (1955Mc75) ^{12}C(d,p), 75 keV *15* (1959Yo25) and 70 keV *10* (1970Me24) from ^{11}B(^{3}He,p) and 70 keV *5* (1980Fu04) ^{13}C(α,α′). $\Gamma_{\gamma0}$: From (1980Ho11) ^{13}C(γ,n_0).
8220 *40*	$3/2^+$	1026 keV *15*	Y	XREF: Others: AB, AC, AD, AE, AH, AI, AM, AO, AR, AW, AY %n≈100; %IT=6.8×10^{-4} (1972Ga13,1980Ho11) $\Gamma_{\gamma0}$=7.0 eV *9* (1980Ho11) Γ_{n0}/Γ≈1.0 (1972Ga13) XREF: AB(8400)AC(8.4E3)AI(8250)AO(8200)AR(8200). E(level): from the unweighted average of values in ^{12}C(n,n): E_x=8149 keV *15* (1973Fa06), 8193 keV *50* (1960Ts02) and 8267 keV *50* (1966Li03). See also 8400 keV *300* (1955Mc75) ^{12}C(d,p). J$^{\pi}$: From L=2 and phase-shift analysis in ^{12}C(n,n) (1973Ab07). Γ: From average of Γ=1050 keV *100* (1966Li03) and 1025 keV *15* (1975Fa06) ^{12}C(n,n). See also 375 keV (1977Wo04) ^{13}C(γ,n). $\Gamma_{\gamma0}$: From (1980Ho11) ^{13}C(γ,n_0).
8866 *9*	$1/2^-$	179 keV *17*	A I N UV Y	XREF: Others: AC, AM, AO, AP, AR, AS, AT, AY, BB, BF, BG, BH, BI, BJ %n≈100; %IT=3.0×10^{-3} (1972Ga13,1980Ho11) $\Gamma_{\gamma0}$=5.4 eV *5* (1980Ho11) Γ_{n0}/Γ≈1.0 (1972Ga13)

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				E(level): From the average of E$_x$=8869 keV *36* (1959Yo25) ^{11}B(^{3}He,p), 8860 keV *30* (1970Me24) ^{11}B(^{3}He,p), 8874 keV *14* (1973Fa06) ^{12}C(n,n), 8860 keV *20* (1970Wi04) ^{13}C(e,e′), 8860 keV *30* (1969Ba06) ^{13}C(^{3}He,^{3}He′) and 8860 keV *20* (1962Si04) ^{14}N(t,α). See other values in ^{11}B(^{3}He,p), ^{15}N(p,^{3}He) and ^{15}N(d,α). J$^{\pi}$: From L=1 and phase-shift analysis in ^{12}C(n,n) (1973Ab07). Γ: From the weighted average (external errors) of Γ=142 keV *30* from ^{11}B(^{3}He,p), 205 keV *15* from ^{12}C(n,n), 190 keV *35* (1970Wi04) ^{13}C(e,e′) and 145 keV *20*(1962Si04) ^{14}N(t,α).
9499.71 *6*	9/2$^+$	1.72 keV *8*	I MNOP UV Y	XREF: Others: AA, AB, AC, AD, AE, AG, AI, AM, AO, AP, AR, AS, AT, AY, BF, BG, BH, BI, BP %n≈100; %IT>0 (1972Ga13) Γ$_{n0}$/Γ≈1.0 (1972Ga13) XREF: AA(9522). E(level),Γ: From (1980Ci03) ^{12}C(n,n). See also E$_x$=9500 keV *7* (1989Mi01) ^{13}C(e,e′) and 9510 keV *12* from ^{11}B(^{3}He,p). J$^{\pi}$: From M4(+E5) from 1/2$^-$ in ^{13}C(e,e′) (1989Mi01); analysis of the σ(π$^+$)/σ(π$^-$) in (1979De34) ^{13}C(π$^{\pm}$,π$^{\pm}$) is consistent with a pure neutron transition and 9/2$^+$; further support for an L=4 transfer is found in ^{13}C(p,p′) see references in (1981Aj01). See also J$^{\pi}$=(1/2$^-$,3/2$^-$) from phase-shift analysis of ^{12}C(n,n) in (1972Ga13). Later, based on the (1972Ga13) result, J$^{\pi}$=3/2$^-$ was deduced in comparisons of mirror pairs in (1968Hi01) ^{14}N(d,^{3}He) and (d,t) and (1968Fl03) ^{15}N(p,^{3}He) and (p,t), but note: in these studies J$^{\pi}$ for ^{13}C(9.5 MeV) was still speculative because the 3/2$^-$ partner in ^{13}N was absent or unresolved.
9894.50 *17*	3/2$^-$	23.7 keV *4*	A I NOP UV Y	XREF: Others: AA, AC, AM, AO, AR, AS, AT, AY, BG, BI %n>87; %IT>0 (1980Ci03) Γ$_{n0}$=20.6 keV *5* (1980Ci03) Γ$_{n0}$/Γ=0.869 (1980Ci03) XREF: AA(9946). Γ$_{n1}$/Γ$_{n0}$<0.15 (1973Ad02). E(level),Γ: From (1980Ci03) ^{12}C(n,n). See also E$_x$=9946 keV and Γ<80 keV (1959Ha13) ^{12}C(n,n′) and 9898 keV *12* in ^{11}B(^{3}He,p). J$^{\pi}$: From phase-shift analysis of ^{12}C(n,n) in (1972Ga13).
10463		200 keV	O U	XREF: Others: AA, AO, AT %n≈100 E(level),Γ: From (1959Ha13) ^{12}C(n,n′). See also E$_x$=(10460) keV and J$^{\pi}$=5/2$^+$ (1989Mi01) ^{13}C(e,e′).
10753.73 *30*	7/2$^-$	50.9 keV *6*	HI N p U Y	XREF: Others: AA, AC, AD, AR, AS, AT, BG, BH %n>85; %IT>0 (1980Ci03) Γ$_{n0}$=43.4 keV *9* (1980Ci03)

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
				Γ_{n0}/Γ=0.853 (1980Ci03) XREF: BG(10736). E(level): From (1980Ci03) ^{12}C(n,n). See also 10752 keV 5 (1969Da13) ^{12}C(n,n) and 10775 keV 5 (1973Go04) ^{12}C(d,p). J^{π}: From phase-shift analysis of ^{12}C(n,n) in (1972Ga13). Γ: From (1980Ci03) ^{12}C(n,n). See also 56 keV 2 (1973Go04).
10812.8 *6*	(5/2)$^{-}$	18.7 keV *4*	HI MN p U Y	XREF: Others: AA, AC, AR, AS, AT, BG %n>25; %α>0; %IT>0 (1980Ci03,1994Wr01) Γ_{n0}=4.7 eV *3* (1980Ci03) Γ_{n0}/Γ=0.25 E(level): From (1980Ci03) ^{12}C(n,n). See also 10815 keV 2 (1994Wr01) ^{9}Be(α,α) and 10818 keV 5 (1973Go04) ^{12}C(d,p). J^{π}: In (1974Ho06) the state is suggested as the analog of the ^{13}N(10.36 MeV) J^{π}=5/2^{-} member of the J^{π}=5/2−&7/2^{-} doublet from comparison of the ^{10}B(^{6}Li,^{3}He) and ^{10}B(^{6}Li,t) reactions. See also L=4 from J^{π}=1/2^{-} in ^{9}Be(^{6}Li,d). Γ: From (1994Wr01). See also 18.1 keV *10* (1980Ci03) and 24 keV *3* (1973Go04).
11001 *2*	1/2^{+}	56.4 keV *1*	HI NO U Y	XREF: Others: AA, AC, AM, AR, AT, AY, BG %n≥40; %α>0; %IT>0 (1972Ga13,1994Wr01) Γ_{n0}/Γ=0.4 *1* (1972Ga13) XREF: I(10969)AA(10970). E(level): From the average of E_{x}=10994 keV *7* (1972Ga13) ^{12}C(n,n), 11002 keV *2* (1994Wr01) ^{9}Be(α,n) and 10997 keV *8* (1973Go04) ^{12}C(d,p). J^{π}: From L=0 transfer in (1990Ya01) ^{14}C(p,d). See also the resonance phase analysis in (1956Ja28: E_{x}=11010 keV) ^{9}Be(α,n) and phase-shift analysis in (1972Ga13) ^{12}C(n,n). Γ: From (1994Wr01) ^{9}Be(α,n). See also Γ=33 keV *5* (1998Le17) ^{9}Be(^{6}Li,d) and 82 keV *15* (1973Go04) ^{12}C(d,p).
11076.01 *18*	1/2^{-}	4.681 keV *19*	HI NO U Y	XREF: Others: AA, AC, AO, AR, AS, AT, AY, BG, BH %n≥63; %α>0; %IT>0 (1980Ci03,1994Wr01) Γ_{n0}/Γ=0.63 (1980Ci03) E(level): From (1980Ci03) ^{12}C(n,n). See also E_{x}=11076 keV *2* (1994Wr01) ^{9}Be(α,n), 11080 keV *5* (1973Go04) ^{12}C(d,p) and 11080 keV *5* (1989Mi01) ^{13}C(e,e′). J^{π}: from E0+M1 from 1/2^{-} in ^{13}C(e,e′) (1989Mi01). Γ: From (1994Wr01). See also Γ=4.0 keV *4* (1980Ci03).
11727 *2*	3/2^{-}	122.5 keV *8*	HI U Y	XREF: Others: AC, AO, AP, AR, AT, AY, BB, BE, BF, BG, BH %n≥80; %α>0 (1983To19,1994Wr01) Γ_{n0}/Γ=0.80 *8* (1983To19) XREF: AO(11750)AR(11748)AT(11748)AY(11750)B

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
				E(level): From (1994Wr01) ^{9}Be(α,n). See also E_x=11733 keV *15* (1996Ku07) ^{9}Be(α,n) and 11748 keV *10* (1973Go03) ^{12}C(d,p). J^{π}: From phase-shift analysis of ^{12}C(n,n) in (1983To19). Γ: From (1994Wr01). See also Γ=125 keV *20* (1962Si04) ^{14}N(t,a), 107 keV *14* (1973Go03) and 38 keV *10* (1998Le17) ^{9}Be(^{7}Li,t). Γ_n: See also Γ_{n0}/Γ=0.67 16 and Γ_{n0}/Γ=0.33 8 (1973Ad02).
11848[‡] *4*	7/2^{+}	68 keV *4*	HI M PQ	XREF: Others: AA, AC, AO, AP, AR, AS, AT %n>0 (1959Ha13) XREF: H(11825)AP(11820). E(level): From the average of E_x=11851 keV *5* (1973Go03) ^{12}C(d,p) and 11845 keV *5* (1989Mi01) ^{13}C(e,e′). J^{π}: From E3+M4 from 1/2^{-} in ^{13}C(e,e′) (1989Mi01). Γ: From (1973Go03) where the peak is well resolved. See also Γ=144 keV *5* (1989Mi01) and 46 keV *9* (1998Le17) ^{9}Be(^{6}Li,d).
11947 *3*	5/2^{+}	148.7 keV *4*	FGHI MNO Y	XREF: Others: AA, AB, AC, AO, AR %n≈60; %α=40 (1983To19,1974Sa16) Γ_{n0}/Γ=0.51 *6* (1983To19) $\Gamma\alpha/\Gamma$=0.4 (1974Sa16) XREF: G(11990)M(11900)AR(11920). E(level): From the average of ^{9}Be(α,n) E_{res} values given in (1955Ta28, 1996Ku07, 1994Wr01). J^{π}: From phase-shift analysis of ^{12}C(n,n) in (1983To19) and M2+E3 from 1/2^{-} in ^{13}C(e,e′) (1989Mi01). See discrepant J^{π} values of (1/2^{-},7,2^{-}) reported in ^{9}Be(α,n) (1956Ja28, 1970Va23, 1969Kl09). Γ: From (1994Wr01) ^{9}Be(α,n). See also Γ=150 keV *13* (1996Ku07) ^{9}Be(α,n) and see (1983To19) ^{12}C(n,n) where E_x=11.97 MeV *8* and Γ=500 keV *80* are reported. Note: the broad E_x=11.84 and 11.95 MeV states are typically poorly resolved.
12055[†] *3*	1/2^{-}	≈38 keV		XREF: Others: AT E(level),J^{π},Γ: From (2021In04) ^{13}C(α,α'). DWBA analysis indicated a doublet at E_x=12055 keV *1* with Γ=38 keV *4*. They find ΔL=0 and 2, which they assign L=0 and L=2 to the two states: one with J^{π}=1/2^{-} and the other to (3/2,5/2)$^{-}$. The ΔE=1 keV is statistical; the evaluator assumes 3 keV uncertainty from the Grand Raiden focal plane energy calibration.
12055 *3*	(3/2,5/2)$^{-}$	≈38 keV	Y	XREF: Others: AT %n≥84 Γ_{n0}/Γ=0.84 (1980Ci03) XREF: Y(12071.9).

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J^π	$T_{1/2}$ or Γ	XREF	Comments
				E(level),J^π,Γ: From (2021In04) ^{13}C(α,α′). DWBA analysis indicated a doublet at E_x=12055 keV *1* with Γ=38 keV *4*. They find ΔL=0 and 2, which they assign L=0 and L=2 to the two states: one with J^π=1/2$^-$ and the other to (3/2,5/2)$^-$. The ΔE=1 keV is statistical; the evaluator assumes 3 keV uncertainty from the Grand Raiden focal plane energy calibration. See also a ^{12}C(n,n) resonance reported with E_x=12072 keV *2* with Γ=82 keV *4* and J^π=(3/2$^-$).
12120 *70*	3/2$^+$	540 keV *70*	Y	XREF: Others: AM, AR %n≥28 (1983To19) Γ_{n0}/Γ=0.28 *5* (1983To19) XREF: AM(12106)AR(12106). E(level),Γ: From (1983To19) ^{12}C(n,n):res. See also E_x=12106 keV and Γ=150 keV (1977Wo04) ^{13}C(γ,n). In (1986Aj01) and later, the evaluations accepted E_x=12106 keV from (1977Wo04) and Γ=540 keV from the phase-shift analysis of (1983To19). The past and present evaluations accept much of the (1983To19) analysis; for this J^π=3/2$^+$ level, E_x and Γ from (1983To19) are accepted. J^π: From phase-shift analysis of ^{12}C(n,n) in (1983To19).
12130 *46*	5/2$^-$	77 keV *30*	I N Y	XREF: Others: AC, BG %n≥43 Γ_{n0}/Γ=0.43 *6* (1983To19) XREF: N(12110). E(level),Γ: From (1983To19) ^{12}C(n,n):res. See also E_x=12131 keV *30* and Γ=125 keV *30* (1962Si04) ^{14}N(t,α) and 12108 keV *5* with Γ=81 keV *8* (1973Go03) ^{12}C(d,p). J^π: From phase-shift analysis of ^{12}C(n,n) in (1983To19).
12141 *2*	1/2$^+$	370.2 keV *17*	H Y	%n≥50; %α>0 (1983To19,1984Wr01) Γ_{n0}/Γ=0.50 *7* (1983To19) E(level): From (1994Wr01) ^{9}Be(α,n). See also E_x=12139 keV *65* (1983To19) ^{12}C(n,n):res. J^π: From phase-shift analysis of ^{12}C(n,n) in (1983To19). See previously reported J^π=5/2$^-$ from ^{9}Be(α,pol. n) (1969Kl09). Γ: From (1994Wr01). See also Γ=426 keV *70* (1983To19).
12189 *7*	3/2$^-$	130 keV *40*	H Op Y	XREF: Others: AA, AO, AR %n≥73; %α>0 (1983To19,1969Kl09) Γ_{n0}/Γ=0.73 *8* (1983To19) XREF: Y(12268). E(level): From the average of E_x=12187 keV *10* (1989Mi01) ^{13}C(e,e′) and 12190 keV *10* (1988Co05: priv. comm.) See also E_x=12268 keV *65*, Γ=186 keV *50* and J^π=3/2$^-$ from (1983To19) ^{12}C(n,n), which had been adopted in (1985Aj01). J^π: From phase-shift analysis of ^{12}C(n,n):res in (1983To19).

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
				Γ: From Γ=180 keV (1959Ha13) ^{12}C(n,n), 120 keV (1969Kl09) ^{9}Be(α,n), 109 keV *48* (1989Mi01) ^{13}C(e,e′) and 110 keV *50* (1988Co05) ^{13}C(p,p′).
12282 *6*	1/2⁻	122 keV *22*	HI p	XREF: Others: AT, BE %n>0; %α>0 (1968Le24) XREF: H(12229)BE(12300). E(level),Γ: From (2021In04) ^{13}C(α,α′). E(level): A statistical ΔE=5 keV is given in the text; the evaluator assumes 3 keV uncertainty from the Grand Raiden focal plane energy calibration and added that in quadrature. J^{π}: From L=0 in ^{13}C(α,α′) (2021In04).
12420 *2*	7/2⁻	226 keV *3*	H NOp Y	XREF: Others: AO, AR, BH %n≥42; %α>0 (1983To19,1984Wr01) Γ_{n0}/Γ=0.42 *6* (1983To19) XREF: AO(12438)AR(12438). E(level),Γ: From (1994Wr01) ^{9}Be(α,n). See also E_x=12434 keV *46* (1983To19) ^{12}C(n,n) and 12438 keV *12* (1989Mi01) ^{13}C(e,e′). J^{π}: From phase-shift analysis of ^{12}C(n,n) in (1983To19).
12450?[†] *4*	1/2⁻	<70 keV		XREF: Others: AT E(level),J^{π},Γ: From (2021In04) ^{13}C(α,α′). J^{π}: From L=0 in ^{13}C(α,α′) (2021In04). E(level): A statistical ΔE=3 keV is given in the text; the evaluator assumes 3 keV uncertainty from the Grand Raiden focal plane energy calibration and added that in quadrature.
12601?[†] *4*	1/2⁻	<70 keV		XREF: Others: AT E(level),J^{π},Γ: From (2021In04) ^{13}C(α,α′). J^{π}: From L=0 in ^{13}C(α,α′) (2021In04). E(level): A statistical ΔE=3 keV is given in the text; the evaluator assumes 3 keV uncertainty from the Grand Raiden focal plane energy calibration and added that in quadrature.
12775?[†] *6*	1/2⁻	<70 keV		XREF: Others: AT E(level),J^{π},Γ: From (2021In04) ^{13}C(α,α′). J^{π}: From L=0 in ^{13}C(α,α′) (2021In04). E(level): A statistical ΔE=5 keV is given in the text; the evaluator assumes 3 keV uncertainty from the Grand Raiden focal plane energy calibration and added that in quadrature.
≈13000			HI M	XREF: Others: AM %n>0; %α>0; %IT>0 (1996Ku07) XREF: I(12830)M(13010). E(level): From (1996Ku07,1968Le24) ^{9}Be(α,n). Γ: broad.
13.20×10^{3} *10*	3/2⁻	340 keV	G I	XREF: Others: AY %α=86; %n=14 (2011Fr12) Γα=294 keV; Γ_n=46 keV (2011Fr12) XREF: AY(13280). E(level): From (2006Pr01) ^{7}Li(^{9}Be,α). J^{π},Γ: From R-matrix analysis of ^{9}Be(α,α) in (2011Fr12).

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
13420	(9/2^{-})	41 keV *6*	FGHI M	XREF: Others: AR %n>0; %α>0 (2017Lo04) XREF: F(13.2E3). E(level): From (1973Go15) ^{9}Be(α,α). J$^{\pi}$: From (1973Go15) ^{9}Be(α,α), where 9/2^{-} was deduced by comparison of the resonance shapes for other J$^{\pi}$=9/2^{-} resonances, and from (2017Lo04) R-matrix analysis of ^{9}Be(α,n) and ^{9}Be(α,α). Γ: From the average of values given in ^{9}Be(α,n) and ^{9}Be(α,α).
13.6×10^{3} *2*	7/2^{-}	619 keV *50*	FGH O Y	XREF: Others: AA, AM %n=14; %α=86; %IT>0 (2011Fr12) Γα/Γ=0.86; Γ$_{n}$/Γ=0.14 (2011Fr12) E(level): From (2006Pr01) ^{7}Li(^{9}Be,α). Γ: From (1985To02) ^{12}C(n,n′). J$^{\pi}$: From polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1985To02).
13760	5/2^{+}	77 keV *30*	GHI	XREF: Others: AM, AO, AR %n=69; %α=31 (2011Fr12) Γα/Γ=0.306; Γ$_{n}$/Γ=0.694 (2011Fr12) E(level): From (2011Fr12) ^{9}Be(α,α). J$^{\pi}$: From R-matrix analysis of ^{9}Be(α,α) in (2011Fr12). Γ: From (1998Le17) ^{9}Be(^{7}Li,t). See also Γ=117 keV (2012Wh01) ^{9}Be(^{7}Li,t) and Γ=335 keV (2011Fr12).
13920?† *30*		100 keV *30*	I	E(level),Γ: From (1998Le17) ^{9}Be(^{7}Li,t).
14.13×10^{3}	(3/2^{-},5/2^{-})	160 keV *20*	FGHI M p Y	XREF: Others: AB, AR %n>0; %α≈100 (2011Fr12) Γα/Γ≈1; Γ$_{n}$/Γ>0 (2011Fr12) XREF: F(14.2E3)M(14080)Y(14167)AB(14E3) . E(level): From (1988Co05) ^{13}C(p,p′). Γ: From (1998Le17) ^{9}Be(^{7}Li,t). J$^{\pi}$: Polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1985To02) indicate J$^{\pi}$=3/2^{-} while an R-matrix analysis of ^{9}Be(α,α) in (2011Fr12) indicates J$^{\pi}$=5/2^{-} in R-matrix. See extensive discussion and comparative fits in (2011Fr12). In (2002Mi32,2003Mi34) known levels were surveyed and, based on level spacings, they suggest this state is the J$^{\pi}$=9/2^{-} member of a rotational band.
14390 *15*	7/2^{-}	282 keV *65*	GHI	XREF: Others: AO, AR %n=89; %α=11 (2011Fr12) Γα/Γ=0.108; Γ$_{n}$/Γ=0.892 (2011Fr12) XREF: I(14360). E(level),Γ: From (1989Mi01) ^{13}C(e,e′).

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J^π	$T_{1/2}$ or Γ	XREF	Comments
				J^π: From R-matrix analysis of ^{9}Be(α,α) in (2011Fr12,2018Lo07). See also J^π=7/2$^{(+)}$ from (1973Go15) ^{9}Be(α,α_0), and see J^π=(1/2,5/2)$^-$ from (1973De14) ^{9}Be(α,α_0).
14.5×10^{3}[†] *1*	(1/2,3/2)$^+$			XREF: Others: AT %n=? (1985To02) E(level),J^π,Γ: From L=1 in (2021In04) ^{13}C(α,α'). E(level): (1985To02) suggests two broad and overlapping J^π=3/2$^-$ states in this region. Γ: broad.
14582 *10*	9/2$^+$	227 keV *41*	FGHI	XREF: Others: AO, AR %n=14; %α=86 (2011Fr12) $\Gamma\alpha/\Gamma$=0.856; Γ_n/Γ=0.144 (2011Fr12) E(level),Γ: From (1989Mi01) ^{13}C(e,e′). J^π: From R-matrix analyses of ^{9}Be(α,α) in (2011Fr12,2018Lo07).
14819[†]			M	XREF: Others: AP E(level): From (1991Br26) ^{10}B(α,p) and ^{10}B(^{9}Be,^{6}Li).
14983 *10*	7/2$^-$	380 keV *53*	FGH Y	XREF: Others: AM, AO, AR %n=41; %α=59; %IT>0 (2011Fr12) $\Gamma\alpha/\Gamma$=0.586; Γ_n/Γ=0.414 (2011Fr12) XREF: H(14941)Y(14997). E(level),Γ: From (1989Mi01) ^{13}C(e,e′). J^π: From polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1985To02).
15108.7 *9*	3/2$^-$	5.49 keV *25*	GHI U Y	XREF: Others: AM, AO, AR, AS, AT, AY, BA, BH %n≥53.8; %α=1.89; %IT≥0.82 (1977Ma16,1978Hi06) T=3/2 (1966Ba13,1967Pe07,1969Ad01) $\Gamma_{\gamma0}$=23.2 eV *15* $\Gamma_{\gamma1}$=4.12 eV *74* (1977Ma16) $\Gamma_{\alpha0}$=0.104 keV *28* (1978Hi06) Γ_{n0}=0.38 eV *10* Γ_n: Γ_{n1}=1.43 eV *18* and Γ_{n2}=0.14 eV *10*. E(level): From average of E_x=15109.3 keV *1.4* (1978Hi06) ^{9}Be(α,α) and 15108.2 keV *12* (1987Hi03) ^{12}C(n,n). J^π: From M1+E2 from 1/2$^-$ in ^{13}C(e,e′) (1989Mi01). Γ: From (1978Hi06) ^{9}Be(α,α). $\Gamma_{\gamma0}$: Obtained using the average of $\Gamma_{\gamma0}/\Gamma$=0.0053 *6* (1968Co27) and $\Gamma_{\gamma0}/\Gamma$=0.00396 *30* (1977Ma16), which yields $\Gamma_{\gamma0}/\Gamma$=0.00423 *27*; this value with Γ=5.49 keV *25* (1978Hi06) gives $\Gamma_{\gamma0}$=23.2 eV *18*; this value is then averaged with $\Gamma_{\gamma0}$(M1)=22.7 eV *27* and $\Gamma_{\gamma0}$(E2)=0.59 eV *11* from (1969Wi22,1970Wi04) to obtain $\Gamma_{\gamma0}$=23.2 eV *15*. The transition widths to

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				other levels are determined in (1977Ma16). Γ_{γ}: $\Gamma_{\gamma(2+3)}$=18.2 eV *24* and $\Gamma_{\gamma\to7.55\ \mathrm{MeV}}$<0.9 eV (1977Ma16). Γ_{n}: See Γ_{n0}/Γ=0.070 *18*, Γ_{n1}/Γ=0.261 *30* and Γ_{n2}/Γ=0.026 *18* (1973Ad02).
15270	(5/2^{-},9/2^{+})	493 keV	FGH Y	%n=69; %α=31 (2011Fr12) Γα=154 keV; Γ_{n}=339 keV (2011Fr12) E(level),Γ: From (2011Fr12) ^{9}Be(α,α). J$^{\pi}$: From (2011Fr12,1985To02). In (1991Aj01) the resonance is listed with J$^{\pi}$=9/2^{+}, based on polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1985To02), but the R-matrix analysis of (2011Fr12) ^{9}Be(α,α) find that interference from a J$^{\pi}$=9/2^{+} resonance is incompatible with their finding of a J$^{\pi}$=9/2^{+} resonance at E$_{x}$=14582; they assign J$^{\pi}$=5/2^{-}. The issue is unresolved.
15526 *11*	3/2^{-}	147 keV *23*	H M Y	XREF: Others: AO, AR %n>0; %α>0 (1966Mi12) XREF: Y(15458). E(level),Γ: From (1989Mi01) ^{13}C(e,e′). J$^{\pi}$: From polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1985To02).
16080 *7*	7/2^{+}	148 keV *13*	FGH M O R Y	XREF: Others: AO, AP, AR, AS, AT %n≈85; %α=15; %IT>0 (2011Fr12) Γα/Γ=0.15; Γ_{n}/Γ=0.85 (2011Fr12) XREF: H(16023)Y(16103)AP(16050). E(level),Γ: From (1986Hi06) ^{13}C(e,e′). J$^{\pi}$: From R-matrix analysis in (2011Fr12) ^{9}Be(α,α), a comparison (1981Pe08) of the ^{13}C(^{3}He,t) with the ^{13}C(^{3}He,^{3}He)^{13}N(16.0 MeV: 7/2^{+}) angular distributions, and from E3+M4 from 1/2^{-} in ^{13}C(e,e′) (1986Hi06).
16.1×10^{3}† *1*	(1/2,3/2)$^{+}$			XREF: Others: AO, AT XREF: AO(16183). E(level),J$^{\pi}$: From L=1 in (2021In04) ^{13}C(α,α′). See also E$_{x}$=16183 keV and Γ=40 keV *20* (1989Mi01) ^{13}C(e,e′).
16152 *35*	(5/2^{-})	240 keV	GH Y	XREF: Others: AR %n=91; %α=9 (2011Fr12) Γα/Γ=0.091; Γ_{n}/Γ=0.909 (2011Fr12) XREF: Y(16103). E(level),Γ: From (1966Mi12) ^{9}Be(α,n). J$^{\pi}$: From R-matrix analysis in (2011Fr12) ^{9}Be(α,α). See other discussion on polarization data and phase-shift analysis in (1985To02) ^{12}C(n,n).
16948 *35*		330 keV	F H	XREF: Others: AM, AO, AR %n>0; %α>0; %IT>0 (1966Mi12) XREF: F(16.8E3). E(level),Γ: From (1966Mi12) ^{9}Be(α,n).
17363 *69*		190 keV	H	XREF: Others: AR %n>0; %α>0 (1966Mi12)

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J$^{\pi}$	$T_{1/2}$ or Γ	XREF	Comments
				E(level),Γ: From (1966Mi12) ^{9}Be(α,n).
17533 *3*		17 keV *6*	Y	XREF: Others: AP %n≤100 (1987Hi03) T=(3/2) (1987Hi03) XREF: AP(17500). E(level),Γ: From (1987Hi03) ^{12}C(n,n).
17709 *35*	($3/2^{-}$,5/2)	225 keV	H	XREF: Others: AO, AR %n>0; %α>0 (1966Mi12) E(level): From (1966Mi12) ^{9}Be(α,n). J$^{\pi}$: From (1988Co05) ^{13}C(p,p′), L=2 or 3 were consistent, but $7/2^{+}$ was considered unlikely because of the shape at small angles. Γ: From average of Γ=170 (1965Gr22) and 280 (1966Mi12) from ^{9}Be(α,n). See also Γ=300 keV (1971Be51). E(level): In (1981Aj01) E_x=17699 keV *5* is listed; the origin of this value is untraceable.
17920? *50*	($9/2^{+}$,$7/2^{+}$)		M	XREF: Others: AM, AP %n≈100; %IT>0 (1977Wo04) E(level),J$^{\pi}$: From (1982Se04) ^{13}C(π,π); angular distributions are consistent with ΔJ=4, ΔL=3 and ΔS=1 amplitudes indicating ($9/2^{+}$,$7/2^{+}$).
18081 *3*		12 keV *7*	Y	%n≤100 T=(3/2) (1987Hi03) E(level),Γ: From (1987Hi03) ^{12}C(n,n).
18332 *35*		305 keV	H	XREF: Others: AO, AR %n>0; %α>0 (1965Gr22) E(level): From (1965Gr22) ^{9}Be(α,n). Γ: From Γ=210 keV (1965Gr22) and Γ=400 keV (1966Mi12) in ^{9}Be(α,n).
18497?[†] *10*		91 keV *23*		XREF: Others: AO E(level),Γ: From (1989Mi01) ^{13}C(e,e′).
18699 *5*	($3/2^{+}$,$5/2^{+}$)	98 keV *11*	H	XREF: Others: AN, AO, AR %n>0; %p>0; %α>0; %IT>0 (1965Gr22,1983Zu02) XREF: H(18750)AN(18600). E(level),Γ: from (1989Mi01) ^{13}C(e,e′). J$^{\pi}$: From (1988Co05) ^{13}C(p,p) where the angular distribution suggests the state corresponds to ^{12}C(18.3 MeV: 2^{-};T=0)⊗$1p_{1/2}$ and where the ^{12}C state is that reported in (1983Ba57).
19.0×10^{3} *1*		≈600 keV	F P	%α>0 (2023Je05) XREF: F(18.7E3). E(level),Γ: From ^{10}B(^{10}B,^{7}Be) and ^{10}B(^{10}B,α+^{9}Be) (2023Je05).
19512	$5/2^{-}$	≥500 keV	T Y	XREF: Others: AO, AR %n>0 (1987To03) XREF: T(19692)AO(19300). %d>0 (1972Se09). E(level),Γ: From (1987To03) ^{12}C(n,n). J$^{\pi}$: From polarization data and phase-shift

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
				analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1987To03). See also (1980Th07).
19.74×10^{3}?	(3/2,5/2,7/2)$^{+}$	200 keV	E	%p≤100 (2008Sk06) T=3/2 E(level),J^{π},Γ: From (2008Sk06) ^{1}H(^{12}B,p). J^{π}: From L=0,2 in ^{1}H(^{12}B,p). J=3/2^{+} is prefered.
19.9×10^{3}		≈600 keV	E ST	XREF: Others: AA, AR %n>0; %p>0 (1967Di01,2008Sk06) XREF: E(19740)AA(19798). %d>0 (1967Di01). E(level),Γ: From (1967Di01) ^{11}B(d,n).
20021 *12*		232 keV *27*	T	XREF: Others: AO, AR %n>0 (1965Al17) %d>0 (1965Al17). E(level),Γ: From (1989Mi01) ^{13}C(e,e′).
20057 *4*		11 keV *8*	Y	%n≤100 (1987Hi03) T=(3/2) (1987Hi03) E(level),Γ: From (1987Hi03) ^{12}C(n,n).
20111	1/2^{-}	1090 keV	Y	XREF: Others: AO %n≤100 (1987To03) Γ_{n0}/Γ=0.16 (1987To03) XREF: AO(20100). E(level),Γ: From (1987To03) ^{12}C(n,n). See also E_{x}=20.1 MeV and Γ=0.7 MeV from (1971Be51) ^{13}C(e,e′). J^{π}: From polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1987To03).
20111	5/2^{+}	440 keV	Y	%n≤100 (1987To03) Γ_{n0}/Γ=0.05 (1987To03) E(level),Γ: From (1987To03) ^{12}C(n,n). J^{π}: From polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1987To03).
20.13×10^{3}?	(5/2,1/2,3/2)$^{-}$	120 keV	E	%p≤100 (2008Sk06) T=3/2 E(level),J^{π},Γ: From (2008Sk06) ^{1}H(^{12}B,p). J^{π}: From L=1 in ^{1}H(^{12}B,p). J=5/2^{-} is prefered.
20200 *70*	7/2^{+}	560 keV *90*	R T Y	%n>11; %IT>0 (1987To03,1985Au10) Γ_{n0}/Γ=0.11 (1987To03) XREF: Y(20185). %d>0 (1965Al17). E(level),Γ: From (1985Au10) ^{11}B(d,γ). J^{π}: From polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				(1987To03).
20296	7/2^{-}	1.56 MeV	Y	%n≤100 (1987To03) Γ_{n0}/Γ=0.08 (1987To03) E(level),Γ: From (1987To03) ^{12}C(n,n). J$^{\pi}$: From polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1987To03).
20.30×10^{3}?	(5/2,3/2,7/2)$^{+}$	170 keV	E	%p≤100 (2008Sk06) T=3/2 E(level),J$^{\pi}$,Γ: From (2008Sk06) ^{1}H(^{12}B,p). J$^{\pi}$: From L=0,2 in ^{1}H(^{12}B,p). J=5/2^{+} is prefered.
20342	9/2^{+}	320 keV	R Y	%n≥6; %IT>0 (1987To03,1973We12) Γ_{n0}/Γ=0.06 (1987To03) %d>0 (1973We12). E(level),Γ: From (1987To03) ^{12}C(n,n). See also E$_{x}$=20.37 MeV *9* and Γ=508 keV from (1973We12) ^{11}B(d,γ). J$^{\pi}$: From polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1987To03).
20429† *8*		112 keV *23*		XREF: Others: AO, AR E(level),Γ: From (1989Mi01) ^{13}C(e,e′).
20.52×10^{3} *7*	5/2^{-}	510 keV *70*	ST XYZ	XREF: Others: AO %n>0; %p>0; %IT>0 (1984Wo05,1958Ka31) XREF: Z(20500). %d>0 (1958Ka31). E(level),Γ: From (1984Wo05) ^{12}C(n,γ). See (1984Wo05) for discussion on penetrability effects that impact the ^{11}B(d,nγ) results of (1958Ka31): E$_{x}$=20521 keV *8* and Γ=115 keV *10*, and (1964Ku09): E$_{x}$=20521 keV *16* and Γ=120 keV. In (1984Wo05) primary and secondary doorway states at E$_{x}$=20.52 and 21.05 MeV with Γ=0.51 MeV *7* and 4.2 MeV *4*, respectively, are discussed. J$^{\pi}$: From polarization data and phase-shift analysis of ^{12}C(n,n),(pol. n,n$_{0,1}$) in (1987To03).
20.6×10^{3} *8*		5.6 MeV *4*	R X	XREF: Others: AM, AN %n>0; %p>0; %IT>0 (1985Au10,1983Zu02) XREF: X(21050)AM(20.8E3)AN(20700). %d>0 (1985Au10). E(level),Γ: From (1985Au10) ^{11}B(d,γ).

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
20.93×10^{3}[†] *10*		0.24 MeV *10*		XREF: Others: AR E(level),Γ: From (1988Co05) ^{13}C(p,p′).
21281 *15*		160 keV *15*	ST	XREF: Others: AO, AR %n>0; %p>0 (1958Ka31) %d>0 (1958Ka31). E(level),Γ: From (1958Ka31) ^{11}B(d,p). See also Γ=530 keV in (2003So24) ^{7}Li(^{9}Be,α) and Γ=400 keV (1971Be51) ^{13}C(e,e′).
21.3×10^{3}		530 keV	F	%α>0 (2023Je05) E(level),Γ: From (2003So24) ^{7}Li(^{9}Be,α+^{9}Be).
21466 *8*	(9/2^{+},7/2^{+})	268 keV *14*	M	XREF: Others: AB, AO, AP, AR %n=24; %p=76 (2022Ci07) T=(3/2) (1986Hi06) Γ_{n}/Γ=0.24 *5* Γ_{p0}/Γ<0.23; Γ_{p1}/Γ=0.69 *6* XREF: AP(21370). Γ: partial widths from (2022Ci07). Γ_{p}: $\Gamma_{p(2+3)}/\Gamma$=0.07 2. Γ_{n}: Decay is to ^{12}C*(15.11 MeV: J^{π}=1^{+}, T=1). T: T=3/2 is suggested by (2022Ci07) because of the strong neutron branch to ^{12}C*(15.1 MeV: T=1) state. E(level),Γ: From (1986Hi06,1989Mi01) ^{13}C(e,e′). J$^{\pi}$: From M4 from 1/2^{-} in ^{13}C(e,e′) in (1986Hi06); 9/2^{+} is strongly preferred. See also (1982Se04) ^{13}C(π,π) where angular distributions are consistent with ΔJ=4, ΔL=3 and ΔS=1 amplitudes indicating (9/2^{+},7/2^{+}), and see discussion in (1988Co05).
21703 *4*		18 keV *9*	Y	XREF: Others: AP %n≤100 (1987Hi03) T=(3/2) (1987Hi03) XREF: AP(21600). E(level),Γ: From (1987Hi03) ^{12}C(n,n). J$^{\pi}$: See J^{π}=(9/2,7/2)$^{+}$ in (1982Se04) ^{13}C($\pi^{\pm}$,$\pi^{\pm}$).
21814 *17*	≥5/2	144 keV *21*	P T	XREF: Others: AO, AR %n>0 (1964Ku09) XREF: P(22.0E3). %d>0 (1964Ku09). E(level),Γ: From (1964Ku09) ^{11}B(d,n). J$^{\pi}$: From (1988Co05) ^{13}C(p,p) where a uniform magnitude in the angular distribution distribution suggests a high spin.
22.2×10^{3} *1*	≤5/2	1.1 MeV *5*	R T Z	XREF: Others: AO, AR

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Adopted Levels, Gammas (continued)

^{13}C Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
				%n>0; %p>0; %IT>0 (1981Ka16,1968Ri02) XREF: Z(22000). %d>0 (1981Ka16). E(level),Γ: From (1988Co05) ^{13}C(p,p′). J^{π}: From (1988Co05) ^{13}C(p,p′) where forward peaking in the angular distribution suggests low spin.
23.0×10^{3} *2*	(5/2^{+},3/2^{+})	≈1.5 MeV	Y	XREF: Others: AA, AN, AO, AR %n≤100 (1970De14) XREF: AN(23500)AO(24700). E(level),J^{π}: From (1970De14) ^{12}C(n,n) where the resonance is best fit with a $d_{5/2}$ component, but where $d_{3/2}$ and $f_{7/2}$ could not be ruled out. See also (1988Co05) ^{13}C(p,p′) where forward peaking in the angular distribution suggests low spin (≤5/2). Γ: See references in ^{12}C(n,n).
23.6×10^{3} *1*		≈1.1 MeV	F P	%α>0 (2023Je05) XREF: F(23.9E3). E(level): From ^{10}B(^{10}B,α+^{9}Be) (2023MaAA). Γ: From ^{7}Li(^{9}Be,α+^{9}Be) (2003So24,2004So19,2004So35).
24×10^{3} *2*		10 MeV *2*		XREF: Others: AM, AN, AO %n>0; %p>0; %IT>0 (1957Co57) XREF: AN(24500)AO(24700). E(level),Γ: From (1957Co57) ^{13}C(γ,n),(γ,p).
26000?				XREF: Others: AN, AO %p<100; %IT>0 (1983Zu02) XREF: AO(25500). E(level): From (1983Zu02) ^{13}C(γ,p).
26791			T	%n>0 (1965Al17) %d>0 (1965Al17). E(level): From (1965Al17) ^{11}B(d,nγ).
27466			L T	XREF: Others: AO %n>0; %p>0 (1965Al17,1964GuZY) XREF: L(28025)AO(27300). %d>0 %t>0 (1965Al17,1964GuZY). E(level): From (1965Al17) ^{11}B(d,nγ).
$\approx30\times10^{3}$				XREF: Others: AM, AO %n<100; %IT>0 (1979Ju01) XREF: AO(28100). E(level): From (1979Ju01) ^{13}C(γ,n).

† Decay mode not specified.

‡ The decay mode listed in (1991Aj01) indicates %IT>0 based on the level′s population in ^{13}C(e,e′). This interpretation is not followed here.

$\gamma(^{13}C)$

E_i(level)	J^π_i	E_γ	I_γ	E_f	J^π_f	Mult.	δ	Comments
3089.451	1/2$^+$	3089.049 *20*	100	0	1/2$^-$	[E1]		B(E1)(W.u.)=4.16×10^{-2} *38* E_γ: From (1980Wa24) ^{10}B(α,pγ). See also E_γ=3088.95 keV *19* from ^{12}C(n,γ):E=th (1982Mu14,2008FiZZ).
3684.496	3/2$^-$	595.22 *8*	0.75 *3*	3089.451	1/2$^+$	[E1]		B(E1)(W.u.)=3.97×10^{-2} *30* E_γ: From E_γ=595.5 *2* (1982Mu14) and 595.16 keV *9* (2008FiZZ). from ^{12}C(n,γ):E=th. I_γ: From (1982Mu14).
		3684.01 *6*	100.00 *3*	0	1/2$^-$	[M1+E2]	−0.093 *9*	B(M1)(W.u.)=0.380 *20*; B(E2)(W.u.)=3.4 *7* Mult.,δ: From (1980Wa24). See also δ=−0.096 *+30−21* (1966Po11), δ=−0.154 54 (1973Go02) and δ=−0.100 8 (1969Wi22, 1970Wi04). E_γ: From E_γ=3684.0 *2* (1982Mu14), 3683.94 keV *17* (1967Pr10), and 3684.02 keV *7* (2008FiZZ) from ^{12}C(n,γ):E=th. See also E_γ=3685.041 keV *20* (1991Li12) ^{13}C(γ,γ). I_γ: From (1982Mu14). Mult.: From (1980Wa24).
3853.796	5/2$^+$	169.300 *4*	58.1[#] *10*	3684.496	3/2$^-$	[E1]		B(E1)(W.u.)=1.06×10^{-2} *30* E_γ: From (1980Wa24) ^{10}B(α,pγ) & ^{12}C(d,pγ). See also E_γ=169.356 keV *20* (1984Sc09).
		764.316 *10*	1.92[#] *6*	3089.451	1/2$^+$	[E2]		B(E2)(W.u.)=1.63 *54* E_γ: From (1980Wa24) ^{10}B(α,pγ) & ^{12}C(d,pγ).
		3853.183 *21*	100.0[#] *10*	0	1/2$^-$	[E3+M2]	+0.12 *3*	B(M2)(W.u.)=0.473 *12*; B(E3)(W.u.)=10 *5* Mult.,δ: From (1966Po11). E_γ: Deduced from E_x.
(4946.33)	1/2$^+$	1261.74[‡] *4*	47.96[‡] *65*	3684.496	3/2$^-$			
		1856.89[‡] *19*	0.24[‡] *2*	3089.451	1/2$^+$			
		4945.32[‡] *6*	100.0[‡] *14*	0	1/2$^-$			
7492	(7/2$^+$)	7490[†]		0	1/2$^-$	[E3]		Γ_γ: $\Gamma\gamma/\Gamma$ from (1971HiZF) ^{11}B(^{3}He,pγ).
7547	5/2$^-$	7545[†]		0	1/2$^-$	[E2+M3]		Γ_γ=0.110 eV *15* (1980Ho11) B(E2)(W.u.)=3.0 *4*; B(M3)(W.u.)=34 Γ_γ: From (1980Ho11) ^{13}C(γ,n$_0$). The decay γ ray is reported in (1971HiZF) ^{11}B(^{3}He,pγ). See also Γ_γ(E2)=0.115 EV *7* and Γ_γ(M3)=1.01E−5 EV *61*.
8866	1/2$^-$	8863[†]		0	1/2$^-$	[M1]		Γ_γ=5.4 eV *5* (1980Ho11) B(M1)(W.u.)=0.369 *34* $\Gamma_{\gamma0}$: From (1980Ho11) ^{13}C(γ,n$_0$). The decay γ ray is observed in (2001Ne09) ^{16}O(n,$\alpha\gamma$).
15108.7	3/2$^-$	7559[†]	<3.9	7547	5/2$^-$	[M1]		Γ_γ<0.9 eV

$\gamma(^{13}C)$ (continued)

E_i(level)	J_i^{π}	E_γ	I_γ	E_f	J_f^{π}	Mult.	δ	Comments
								B(M1)(W.u.)<9.92×10^{-2} I_γ: From (1977Ma16).
15108.7	$3/2^-$	11419[†]	78 *10*	3684.496	$3/2^-$	[M1]		B(M1)(W.u.)≤0.58 I_γ: From (1977Ma16). Γ: $\Gamma\gamma_{2+3}$=18.2 eV *24* unresolved.
		12013[†]	17.8 *32*	3089.451	$1/2^+$	[E1]		Γ_γ=4.12 eV *74* B(E1)(W.u.)=6.3×10^{-3} *11* I_γ: From (1977Ma16).
		15099[†]	100.0 *65*	0	$1/2^-$	[M1+E2]	0.161 *17*	Γ_γ=23.2 eV *15* B(M1)(W.u.)=0.314 *37*; B(E2)(W.u.)=0.50 *9* I_γ: From $\Gamma\gamma0$ deduced from analysis of (1968Co27, 1977Ma16, 1978Hi06, 1969Wi22, 1970Wi04). Mult.,δ: From $\Gamma_{\gamma0}$(M1)=22.7 eV *27* and $\Gamma_{\gamma0}$(E2)=0.59 eV *11* (1969Wi22, 1970Wi04). See also δ^2=0.009 $+18-8$ and δ=0.095 *7* (1968Di04) from ^{12}C(p,γ), which is used in earlier studies of the analog transition since the ^{13}C and ^{13} δs are expected to be similar.
16080	$7/2^+$	16069[†]		0	$1/2^-$	[E3]		Decay transition reported in (1984Wo05) ^{12}C(n,γ).
18497?		18483[†]		0	$1/2^-$			Decay transition reported in (1984Wo05) ^{12}C(n,γ).
20200	$7/2^+$	20183[†]		0	$1/2^-$			Decay transition reported in (1985Au10) ^{11}B(d,γ).
20342	$9/2^+$	20325[†]		0	$1/2^-$			Decay transition reported in (1973We12) ^{11}B(d,γ).
20.52×10^3	$5/2^-$	20503[†]		0	$1/2^-$			Decay transition reported in (1984Wo05) ^{12}C(n,γ).
20.6×10^3		20582[†]		0	$1/2^-$			Decay transition reported in (1984Wo05) ^{12}C(n,γ) and (1985Au10) ^{11}B(d,γ).
22.2×10^3	≤5/2	22180[†]		0	$1/2^-$			Decay transition reported in (1981Ka16) ^{11}B(d,γ).

[†] From level-energy difference.

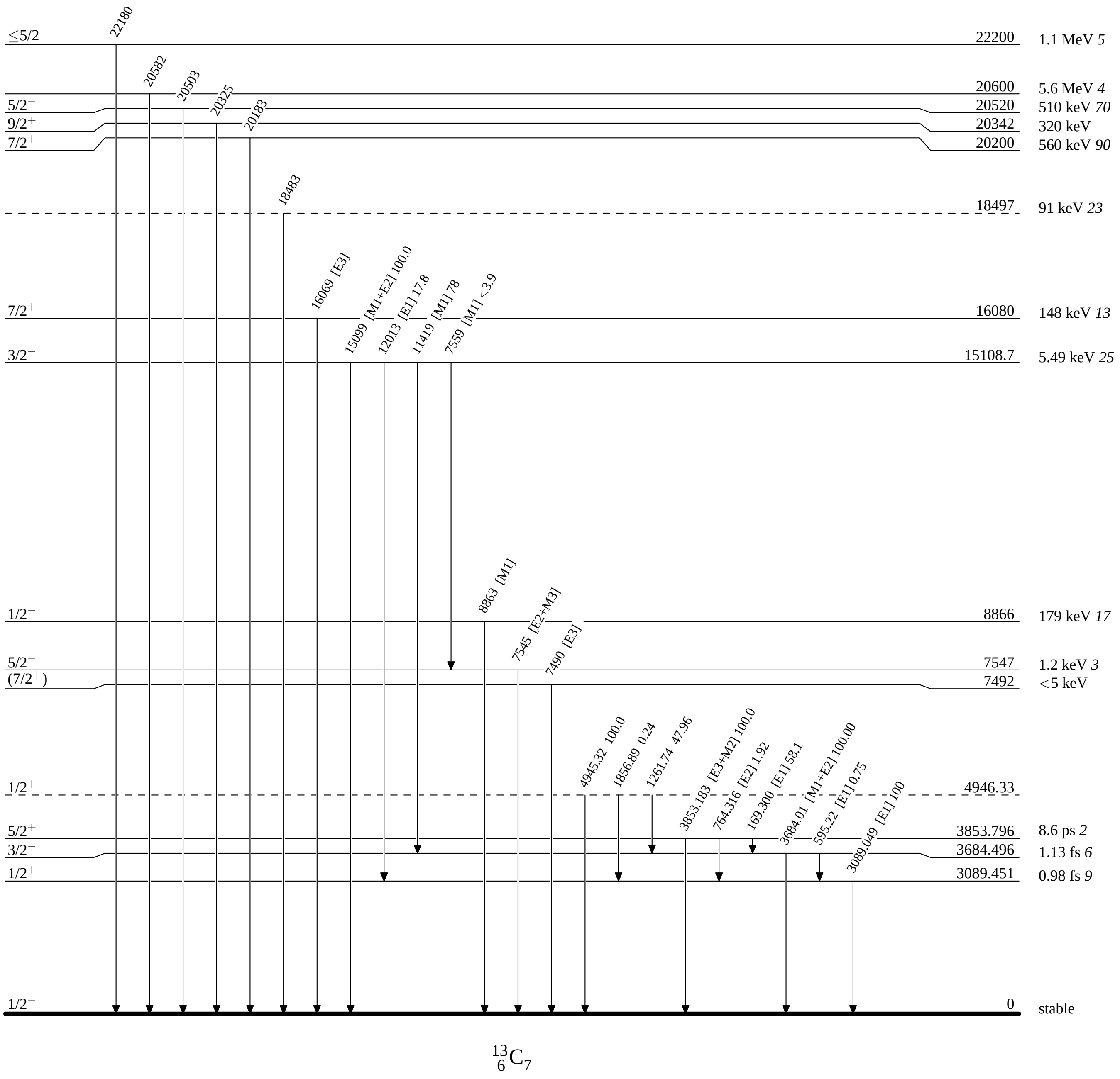
[‡] From ^{12}C(n,γ):E=thermal.

[#] From (1980Wa24).

Adopted Levels, Gammas

Level Scheme

Intensities: Relative photon branching from each level



^{13}B β^- decay

Parent: ^{13}B: E=0; J^π=3/2$^-$; $T_{1/2}$=17.30 ms *17*; $Q(\beta^-)$=13436.9 *10*; %β^- decay=100

1962Ma19: ^{13}B(β^-) from ^{11}B(t,p); measured β particles, and γ rays. Deduced ratio of $T_{1/2}$(^{13}B/^{12}B)=0.86 *2*. This presently implies $T_{1/2}$=17.39 ms *41*. Deduced dominant decay branches to ^{13}C(0,3.68 MeV) with I$\beta\approx$93% and 7%, respectively; limits are set on other branches, including <1.5% from β-n events..

1968Ch28: Activated a natural boron target with tritons and measured β particles and delayed neutrons. Deduced $T_{1/2}$=16 ms *1* and %β-n=0.52 *26*. Compared with ^{13}O β-p.

1969Jo21: ^{13}B(β^-) from ^{11}B(t,p). Measured $\beta\gamma$-coin, E_β, β-n. Deduced branches to ^{13}C(0,3.68,7.58 *6*,8.79 *10*) with Iβ(%)=92.1 *8*, 7.6 *8*, 0.094 *20* and 0.16 *3*, respectively.

1971Wi07: ^{13}B(β^-) from ^{11}B(t,p); measured $T_{1/2}$=17.33 ms *17*.

1974Al12: ^{13}B(β^-) from ^{11}B(t,p); measured βn-coin; deduced %Iβ(9.90)=0.022 *7* by normalizing to %Iβ(8.86)=0.16 *3* from (1969Jo21). Set upper limit on %Iβ(9.50)<0.01. Discussed J^π values.

1988Sa04: ^{13}B(β^-) from ^{181}Ta(^{22}Ne,^{13}B);^{13}B; measured $T_{1/2}$=17.6 ms *12*.

1991Re02,1994ReZZ, 1995ReZZ, 2008ReZZ: ^{13}C(β^-) using spallation products from p+^{232}Th. Ions were implanted in a Si detector and identification via standard techniques. %β-n from polyethylene moderated ^{3}He counter (zero-threshold). The β-delayed neutron probability (P_n= P_{1n}+2P_{2n}+3P_{3n}+...) and half−life were deduced. The evaluator favors the values from (1994ReZZ,2008ReZZ) $T_{1/2}$=16.7 ms *6* and P_n=0.24 *15*, but other values based on this work are (1991Re02) $T_{1/2}$=11 ms *9* and P_n=0.3 *1*.

1997So34: ^{13}B(β^-n); measured β-delayed neutrons, En, In; deduced limit on %Iβ and $T_{1/2}$=17.0 ms *4*. Results are generally excluded due to the limited description of the method.

2002GeZT,2005GeZY: ^{13}B(β^-) from ^{11}B(t,p); measured reaction excitation function from analysis of Eγ=3681 keV yield. Deduced $T_{1/2}\approx$17.36 ms.

2004Na38: ^{13}B(β^-); measured $I_\beta(\theta$,H,t), β-NMR and β-NQR spectra from polarized source. Deduced ^{13}B quadrupole moment and μ.

2006Ge21: ^{13}B(β^-) from ^{11}B(t,p); measured reaction excitation function from analysis of Eγ=3681 keV yield. Deduced $T_{1/2}\approx$16.59 ms *2*; discussed observed lifetime and suggested (t,d) contamination gives higher lifetime.

2010Ma44: ^{13}B(β^-); measured E_β, $I_\beta(\theta)$ from aligned ^{13}B deduced alignment correlation coefficient, G-parity tensor coupling constant.

Theory:

1977Ri08: Analysis of log *ft* values for A=10-15.

2003Fo11: ^{13}B; analyzed β-delayed neutron decay data; deduced ground-state configuration features.

2003Sm02: ^{13}B(β^-); calculated Gamow-Teller decay rates. Comparison with data. ^{13}C calculated μ, quadrupole moments.

^{13}C Levels

E(level)†	J^π†	$T_{1/2}$	Comments
0	1/2$^-$	stable	
3089.451 *19*	1/2$^+$		
3684.496 *22*	3/2$^-$		
3853.796 *21*	5/2$^+$		
7547 *3*	5/2$^-$		%n≈100
8866 *9*	1/2$^-$		%n≈100
9894.50 *17*	3/2$^-$		%n≈100

† From Adopted Levels.

^{13}B β^- decay (continued)

β^- radiations

E(decay)	E(level)	$I\beta^-$[†#]	Log *ft*
(3542.4 *10*)	9894.50	0.022[‡] *7*	4.95 *14*
(4571 *9*)	8866	0.16 *3*	4.59 *9*
(5889.9 *32*)	7547	0.094 *20*	5.33 *10*
(9583.1 *10*)	3853.796	≤0.7	≥5.4
(9752.4 *10*)	3684.496	7.6 *8*	4.45 *5*
(10347.5 *10*)	3089.451	≤0.7	≥5.6
(13436.9 *10*)	0	92.1 *8*	4.033 *6*

[†] From (1969Jo21), except where noted.

[‡] From (1974Al12) intensities are determined relative to %Iβ=0.16 to ^{13}C(8.86) from (1969Jo21).

[#] Absolute intensity per 100 decays.

γ(^{13}C)

E_γ[†]	I_γ[‡@]	E_i(level)	J^π_i	E_f	J^π_f	Mult.[#]	δ[#]
169.300 *4*	≤0.009	3853.796	5/2$^+$	3684.496	3/2$^-$	[E1]	
595.22 *8*	0.057 *7*	3684.496	3/2$^-$	3089.451	1/2$^+$	[E1]	
764.316 *10*	≤0.3	3853.796	5/2$^+$	3089.451	1/2$^+$	[E2]	
3089.049 *20*	≤0.7	3089.451	1/2$^+$	0	1/2$^-$	[E1]	
3684.01 *6*	7.6 *8*	3684.496	3/2$^-$	0	1/2$^-$	M1+E2	+0.094 *9*
3853.183 *21*	≤0.5	3853.796	5/2$^+$	0	1/2$^-$	[M2+E3]	−0.12 *3*

[†] From Adopted Gammas.

[‡] Deduced from Iβ and adopted γ branching ratios.

[#] From Adopted Gammas.

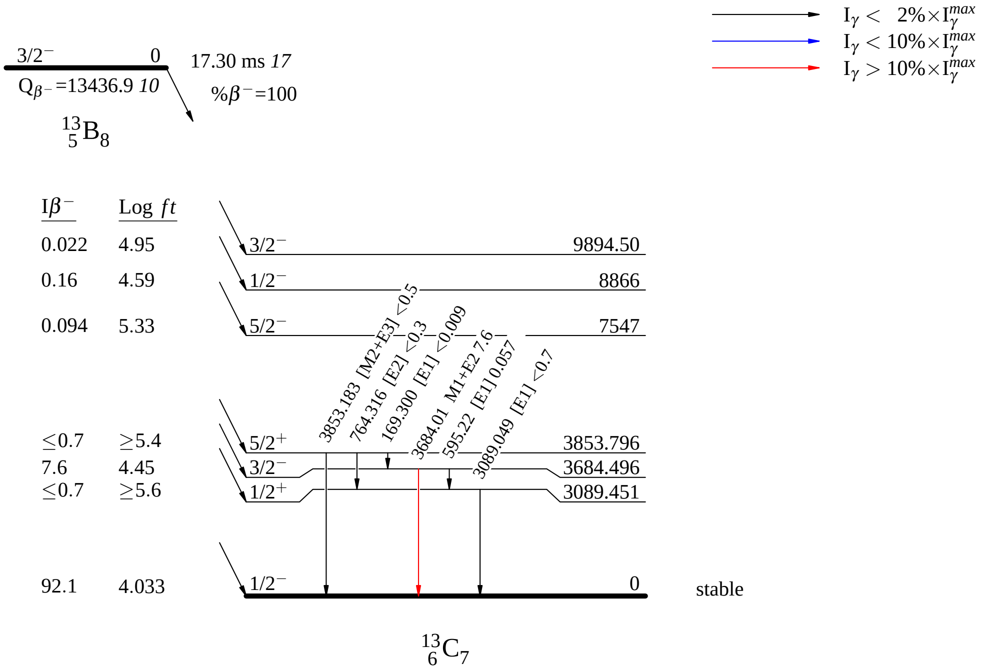
[@] Absolute intensity per 100 decays.

^{13}B β^- decay

Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays

Legend



^{13}N $\varepsilon+\beta^{+}$ decay

Parent: ^{13}N: E=0; $J^{\pi}=1/2^{-}$; $T_{1/2}$=9.9584 min *36*; Q(ε)=2220.47 *27*; %ε+%β^{+} decay=100
^{13}N-$T_{1/2}$: From Adopted Levels of ^{13}N.
^{13}N-Q(ε): from (2021Wa16).

1935Ru01: ^{13}N(β^{+}): ^{10}B(α,n) was used to produce ^{13}N, which was found to decay with $T_{1/2}\approx$14 minutes.
Ward, Proc. Cambridge Phil. Soc. **35** (1939) 523: measured $T_{1/2}$=9.93 min *3*.
Cook et al., Phys. Rev. **74** (1948) 502: ^{13}N(β^{+}); measured $T_{1/2}$=10.2 min *1*.
1950Ho01: ^{13}N(β^{+}); measured end-point energy E_{β}(max)=1.202 MeV *5* and $T_{1/2}$=10.05 min *10*.
1953Ch34: ^{13}N(β^{+}); measured $T_{1/2}$=602.9 sec *19*=10.05 min *3*.
1954Gr66: ^{13}N(β^{+}); measured E_{β}(max)=1.185 MeV *25*.
1955Wi43: ^{13}N; measured $T_{1/2}$=10.08 min *4*.
1957Da08: ^{13}N(β^{+}); measured $T_{1/2}$=9.96 min *3*.
1957De22: ^{13}N(β^{+}); measured $T_{1/2}$=10.02 min *10*.
1957No17: ^{13}N(β^{+}); measured $T_{1/2}$=10.07 min *6*.
1958Ar15: ^{13}N(β^{+}); measured $T_{1/2}$=9.96 min *3*.
1958Da09: ^{13}N(β^{+}); measured E_{β}(max)=1.190 MeV *3* and $T_{1/2}$ as in (1957Da08).
1960Ja12: ^{13}N(β^{+}); measured $T_{1/2}$=9.9965 min *5*.
1960Ki02: ^{13}N(β^{+}); measured $T_{1/2}$=9.93 min *5*.
1961Ra06: ^{13}N(β^{+}); measured $T_{1/2}$=12.3 min *7* (excluded).
1965Bo42: ^{13}N(β^{+}); measured $T_{1/2}$=10.05 min *5*.
1965Eb01: ^{13}N(β^{+}); measured $T_{1/2}$=9.96 min *2*.
1968Ri15: ^{13}N(β^{+}); measured $T_{1/2}$=9.963 min *9*.
1971Go40: ^{13}N(β^{+}); for decay to ${}^{13}C_{g.s.}$, log*ft*=3.667 *1*.
1973SiYS: ^{13}N(β^{+}); measured $T_{1/2}$=10.0 min *5*.
1977Az01: ^{13}N(β^{+}); measured $T_{1/2}$=9.965 min *10*.
1980An40: ^{13}N(β^{+}); measured $T_{1/2}$=9.967 min *10*.
Katoh, Kawade and Yamamoto, JAERI-M89-083 (1989): ^{13}N(β^{+}); measured $T_{1/2}$=9.962 min *20*.
2022Lo14: 13N(β^{+}); measured $T_{1/2}$=9.9508 min *32*; provided an analysis using only their value and (1968Ri15,1977Az01) and recommended $T_{1/2}$=9.9532 min *37*.
1995Va27: ^{13}N(β^{+}); measured β asymmetry following beam implantation in Pt; deduced beam polarization.

Theory:
1970Ko41: general model for β decay in even-odd nuclei.
1970Da21: generalized pairing-force model analysis of log *ft* values.
1972Ma72: calculated β shape spectra.
1973Wi04: analysis of the Axial-Vector coupling constant.
1973Su04: analysis of K-electron capture branching ratios.
1975Kr14: developed O(5) symmetry model to analyzed log *ft* values.
1977Ri08: Shell model analysis of log *ft* values.
1980An31: analysis of K-electron capture rates.
1984Ko40: analyzed isotensor component in isovectorial transition.
1991Na05: analyzed mirror nuclei decays in a search for evidence of right-handed currents.
1995Go34: analyzed β-decay polarization asymmetry data in a search for evidence of right-handed chirality.
2008Se10: analyzed half-lives, branching ratios, electron-capture probabilities; deduced *ft* values in mirror decays.
2008Pe13: analyzed correlations between β decays in mirror nuclei and their magnetic moments.
2012Sa50: analysis of isospin related corrections for superallowed β transitions.
2015Mo10, 2010MoZU: calculated improved beta spectra, shape factors, mean energies, experimental mean energies.
2015To02: developed parametrization of the statistical rate functions, *f*, for superallowed T=1/2 transitions.
2021Ir01: single-particle model analysis of the ^{13}N(β^{+}) reaction. Emphasized asymptotic normalization coefficients (ANCs) and spectroscopic factor data.
2021Da11: analyzed the role of tensor forces in β decay.

^{13}N $\varepsilon+\beta^{+}$ decay (continued)

^{13}C Levels

E(level)	J^{π}	$T_{1/2}$
0	$1/2^{-}$	stable

ε,β^{+} radiations

E(decay)	E(level)	$I\beta^{+}$ †	$I\varepsilon$†	Log *ft*	$I(\varepsilon+\beta^{+})$†
(2220.47 *27*)	0	99.8036 *20*	0.1964 *20*	3.6645 *4*	100

† Absolute intensity per 100 decays.

^{14}B β^-n decay **1994ReZZ**

Parent: ^{14}B: E=0; J^{π}=2$^-$; $T_{1/2}$=12.6 ms *6*; Q(β^-n)=12467 *21*; %β^-n decay=6.1 *3*

^{14}B-$T_{1/2}$: weighted average (external errors) of $T_{1/2}$=16.1 ms *12*: (1974Al11), 12.8 ms *8*: (1986Cu01) and 12.4 ms *3*: (1994ReZZ, see other results in 1991Re02, 1993ReZX, 1994KiZU, 1995ReZZ, 2008ReZZ). See also 13.7 ms *6* in (1987IsZZ).

^{14}B-Q(β^-n): from (2021Wa16).

1991Re02: ^{14}B(β^-n); measured $T_{1/2}$, neutron emission probability, upper limits. TOF isochronous spectrometer, ion-neutron delayed coincidence.

1993ReZX: Spallation products from 800 MeV proton bombardment of a ^{232}Th target were captured by a transport line with a mass-to-charge filter and transferred to the TOFI spectrometer at LAMPF. The beamline was separately tuned to transport a number of different nuclides. The neutrons were detected in a polyethylene moderated ^{3}He counter, and standard techniques were implemented. The β-delayed neutron probabilities were deduced from analysis of the number of implanted ions (per beam pulse) and the rate of β-delayed neutrons detected in the zero-threshold counter.

An associated conference report (1994ReZZ) indicates the β-delayed neutron probability P_n=6.1% *3* and $T_{1/2}$ = 12.4 ms *3*.

Results presented in (1993ReZX) analyzed the data measured in the polyethylene moderated ^{3}He counter and deduced a general value for the energy of neutrons emitted from the decay; E_n=1.38 MeV *+86−65*. The value E_n=1.3 MeV *3* is published in (1994ReZZ).

1993Ok02: ^{14}B(β^-n); measured NMR spectra; deduced g factor.

1994KiZU: ^{14}B(β^-n); measured decay products, TOF, En, In, E_α, I_α; deduced $T_{1/2}$, neutron emission probability. Comparison with available data.

1995ReZZ: ^{14}B(β^-n); measured neutron emission probabilities. TOF isochronous spectrometer.

1996OgZY: ^{14}B(β^-); measured E_β, β-delayed E_γ.

^{13}C Levels

E(level)	J^{π}†
0.0	1/2$^-$

† From Adopted Levels for ^{13}C.

Delayed Neutrons (^{13}C)

E(^{13}C)	I(n)†
0.0	6.1 *3*

† Absolute intensity per 100 decays.

^{17}N $\beta^-\alpha$ decay **1994Do08**

Parent: ^{17}N: E=0; J^π=1/2$^-$; $T_{1/2}$=4.173 s *4*; Q($\beta^-\alpha$)=2320 *15*; %$\beta^-\alpha$ decay=0.0025 *4*

^{17}N-$T_{1/2}$: from weighted average of (1976Oh05,1972Al42).

^{17}N-Q($\beta^-\alpha$): from (2021Wa16).

1993Bu21: ^{17}N($\beta^-\alpha$); measured β-delayed E_α, I_α. The alphas (E_α=1.24 and 1.40 MeV) result from decay of the 7.99 MeV and 8.20 MeV states in ^{17}O. More details in (1994Do08).

1994Do08: A thick target was bombarded by 600 MeV protons to produce ^{17}N ions that were selected by the TISOL separator. The ^{17}N beam was implanted into a thin carbon-foil collector. Thin surface barrier detector pairs counted the decay α particles in coincidence with ^{13}C recoils.

$T_{1/2}$=3.92 s *44* was reported which is in good agreement of 4.173 s *4* (weighted average of 1976Oh05: 4174 ms *4* and 1972Al42: 4169 ms *8*). The α spectrum was reasonably fitted with a K-matrix parametrization using the known resonances at ^{17}O*(7.985 and 8.204 MeV). Although two states are sufficient to fit the α-spectrum, the possibility of decay from the broad ^{17}O*(7.56) state cannot be entirely discounted.

A small contamination of ^{18}N in the beam was used to make a relative normalization of the ^{17}N and ^{18}N activities; then using the lifetimes and ^{18}N decay results from (1989Zh04), the absolute $\beta\alpha$ branching of ^{17}N was determined to be (2.5 *4*)$\times10^{-5}$. The $\beta\alpha$ branching intensities to ^{17}O*(7.985, 8.204) were found to be (1.5 *3*)$\times10^{-5}$ and (9.8 *20*)$\times10^{-6}$, respectively. An upper limit of delayed α decay intensity from ^{17}O*(7.56), <6.9$\times10^{-7}$, is deduced; though the small Γ_α/Γ=0.0002 for this state corresponds to a rather large I <3.5% beta-decay intensity to this state that could be observed in other decay channels. Another possible level at ^{17}O*(8.18) could influence the $\beta\alpha$ decay, but the best fit in this experiment showed a minimal and excludable effect.

^{13}C Levels

E(level)	J^π
0.0	1/2$^-$

Delayed Alphas (^{13}C)

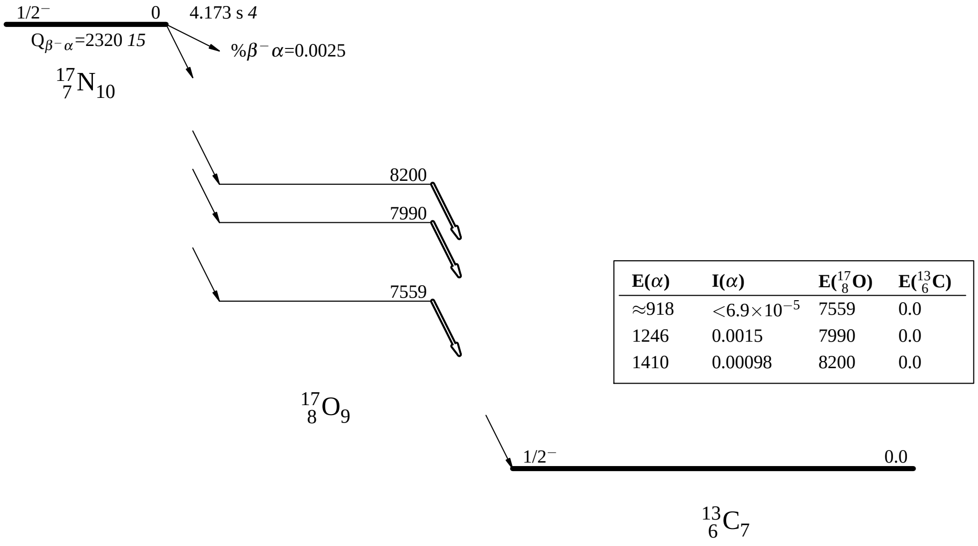
E(α)	E(^{13}C)	I(α)[†]	E(^{17}O)
≈918	0.0	<6.9$\times10^{-5}$	7559
1246 *12*	0.0	1.5$\times10^{-3}$ *3*	7990
1410 *5*	0.0	9.8$\times10^{-4}$ *20*	8200

[†] Absolute intensity per 100 decays.

^{17}N $\beta^-\alpha$ decay 1994Do08

Decay Scheme

I(α) Intensities: I(α) per 100 parent decays



E(α)	**I(α)**	**E(${}^{17}_{8}$O)**	**E(${}^{13}_{6}$C)**
≈918	$<6.9\times10^{-5}$	7559	0.0
1246	0.0015	7990	0.0
1410	0.00098	8200	0.0

$^{1}H(^{12}B,p)$:res **2008Sk06**

2008Sk06: XUNDL dataset compiled by McMaster, 2008.

A E(^{12}B)=44.6 MeV beam from the Notre Dame TwinSol RIB facility impinged on a 16.97 mg/cm^{2} CH_2 target that stopped the beam. Scattered protons were detected at θ=7.5° and 15° using two Si ΔE-E telescopes. The excitation function for elastic proton scattering at $E_{c.m.}$=1.25-3.2 MeV was obtained using a thick-target inverse kinematics technique. Resonances were deduced and analyzed using an R-matrix analysis. Based on comparison with ^{13}O and ^{13}B, resonances at $E_{c.m.}$=0.87 (l=0, (1/2^{+}),Γ=190 keV) and 1.07 MeV (l=0+2, (3/2^{+}), Γ=90 keV) are assumed in the unmeasured low-energy region to account for the excess strength in this area.

Potential analog states in ^{13}N and ^{13}C are discussed.

^{13}C Levels

E(level)[†]	J^{π}[‡]	Γ[‡]	L[‡]	E(c.m.) (MeV)[‡]	Comments
19110?	$(3/2,1/2,5/2)^{-}$	<30 keV	1	1.58	T=3/2 J^{π}: $3/2^{-}$ is preferred.
19740	$(3/2,5/2,7/2)^{+}$	200 keV	0,2	2.20	T=3/2 J^{π}: $3/2^{+}$ is preferred. E(level): If J=$5/2^{+}$ or $7/2^{+}$ then $E_{c.m.}$=2350 keV (E_x=19900 keV).
20130	$(5/2,1/2,3/2)^{-}$	120 keV	1	2.60	T=3/2 J^{π}: $5/2^{-}$ is preferred.
20300	$(5/2,3/2,7/2)^{+}$	170 keV	0,2	2.77	T=3/2 J^{π}: $5/2^{+}$ is preferred.

[†] S(p)+E(c.m.), where S(p) of ^{13}C=17533.4 *13* (2021Wa16).

[‡] From R-matrix analysis.

^{7}Li(^{9}Be,α^{9}Be),^{14}C(^{13}C,α^{9}Be)

2003So24, 2004So19, 2004So35: ^{7}Li(^{9}Be,α^{9}Be), E=70 MeV at the ANU accelerator facility in Canberra. Measured $E_{rel}(\alpha+^{9}Be)$ spectrum using four strip detector telescopes. Deduced resonance energies, cluster structure.

2006Pr01: ^{14}C(^{13}C,^{13}C$'\rightarrow\alpha^{9}$Be), E=77.8,112.25,119.25 MeV at the Vivitron facility in Strasbourg. Measured $E_{rel}(\alpha+^{9}Be)$ spectrum using two strip detector telescopes at θ=(+)21.2° and θ=(−)17.4°. Deduced excited state energies, $\sigma(E_x,\theta)$ for $\theta\approx5°-25°$, J, π, α-decay features, α-cluster structure. Compared with earlier results.

Theory:

2003Fr38: ^{7}Li(^{9}Be,α^{9}Be), E=70 MeV; analyzed excitation energy spectra. Deduced level energies, cluster structure.

2007Pe26: ^{13}C; calculated α-decay and cluster decay widths; deduced Γ. Self-consistent mean-field model, folding form cluster potential.

2008Yo10: ^{13}C; calculated low-lying negative parity state energies, J, π, B(E0); deduced α-breaking effect. Microscopic cluster model.

^{13}C Levels

E(level)†	J$^{\pi}$@	Γ#	Comments
12.0×10^{3}	5/2^{+}		
13.2×10^{3}‡ *1*	(9/2)$^{-}$		E(level): see also (2003So24,2004So19,2004So35: E_x=13400 keV).
13.6×10^{3}?‡ *2*	7/2^{-}		
14.2×10^{3}‡ *1*	3/2^{-}		E(level): see also (2003So24,2004So19,2004So35: E_x=14100 keV). J$^{\pi}$: measurements of (2006Pr01) suggest 5/2^{+}.
14.6×10^{3}	(7/2^{+},9/2^{+})		
15.0×10^{3}‡ *1*	(7/2^{-})		
15.2×10^{3}?	9/2^{+}		
16.0×10^{3}‡ *1*	(7/2^{+},5/2^{-})		E(level): see also (2003So24,2004So19,2004So35: E_x=(16000) keV). J$^{\pi}$: measurements of (2006Pr01) suggest positive parity.
16.8×10^{3}		310 keV	
17.9×10^{3}?			
18.7×10^{3}	(3/2^{+},5/2^{+})	570 keV	
21.3×10^{3}		530 keV	
23.9×10^{3}		1100 keV	
27.3×10^{3}?			

† From ^{7}Li(^{9}Be,^{9}Be+α) (2003So24,2004So19,2004So35) except where noted; ^{13}C states are α-decaying to $^{9}Be_{g.s.}$ ($E_{thres.}$=10.648 MeV).

‡ From ^{14}C(^{13}C,^{9}Be+α) (2006Pr01).

\# From (2003So24).

@ From α-cluster configuration analysis in (2006Pr01); mainly from Adopted Levels (1991Aj01), except where noted.

^{9}Be(α,α):res

1964Gr39: ^{9}Be(α,α),(α,α'), E=23.8 MeV; measured $\sigma(\theta)$ for θ=20° to 175°.

1965Ta04: ^{9}Be(α,α), E=4-20 MeV; measured σ(E;θ) for θ=15° to 165°. Multiple peaks are reported.

1969Ha14: ^{9}Be(α,α), E=104 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=5° to 80°; deduced phase shifts, optical potentials.

1973Go15: ^{9}Be(α,α), E=1.7-6.2 MeV; measured σ(E;E$_\alpha$,θ) for $\theta\approx$50° to 175°. ^{13}C deduced levels, level-width, J, π. See also (1970GoZX).

1974Sa16: ^{9}Be(α,α), E=1.4-2.5 MeV; measured σ(E,θ) for θ=90°−160°. ^{13}C deduced resonance, J, π, α-width, level-width.

1978Hi06: ^{9}Be(α,α_0), E=6.4-6.5 MeV; measured σ(E,θ). for $\theta_{c.m.}$=54.7°, 90°, 125.3° and 175°. Deduced resonance parameters.

2011Fr12: XUNDL dataset compiled by TUNL, 2011.

The authors measured cross sections for ^{9}Be+α resonant scattering with the aims of characterizing the ^{13}C excitation spectrum and evaluating the 3α+n cluster structure of ^{13}C.

Beams of E(^{9}Be)=12, 17, 20 and 21.4 MeV ions impinged on a helium gas cell having 460 to 1020 mb pressure (adequate to stop the ^{9}Be beam). Scattered α particles escaped the gas cell and were detected in a 16-by-16 double-sided Si-strip detector that was positioned downstream at 0°. Resonant states in ^{13}C are visible in the scattered α-particle energy spectra. Analysis of the spectra indicates that contributions by ^{9}Be excited states to the reaction exit channel are minor.

An R-matrix analysis is used to evaluate the resonance parameters and partial widths. Results are compared with ENSDF and a prior ^{9}Be(α,α_0) measurement (1973Go15). Finally there is some commentary given on J^π assignments in ^{13}C and associated molecular bands.

2013Lo16: ^{9}Be(α,α),(α,α'), E=3.5-10 MeV; Measured $\sigma(\theta$,E) for θ=110°−160°.

2017Lo04: ^{9}Be(α,α),(α,α'). Combined data from (2013Lo16, 1973Go15) and performed R-matrix analysis; deduced J^π=9/2$^-$ for E$_x$=13.42 MeV in agreement with earlier result. See also (2020De05).

2018Lo07: ^{9}Be(α,α)(α,α'), E(cm)=2.5-7 MeV; AZURE R-matrix analysis of experimental energy spectra, and differential $\sigma(\theta$,E). ^{9}Be(α,n) reactions are also considered in the fit. Deduced ^{13}C levels above the α threshold of E$_x$=10.648 MeV, J, π, Γ, Γ_{α_0}, Γ_{α_1}, Γ_n, and compared with literature data. The work merits consideration as as an independent analysis; the narrow resonances deduced in the analysis are consistent with known literature values, but several new $\Gamma\geq$1 MeV broad resonances have been added to give an improved fit to the rather structureless spectral shapes.

1975Va19: See for ^{9}Be(α,d), E=15-25 MeV.

1973Ku03: See for α structure amplitudes in transfer reactions.

^{13}C Levels

E(level)[†][#]	J^π[†][‡]	Γ[†]	L[†]	E$_\alpha$(res) (MeV)[†]	Comments
11990	5/2$^+$	180 keV	1	1.93	E(level),J^π,Γ,E$_\alpha$(res) (MeV): from (1974Sa16). Γ: Γ_α/Γ=0.4; Γ_α=72 keV. γ^2=0.36.
13280	3/2$^-$	340 keV	(0,2)	3.80	E(level): see also (2011Fr12: from E$_{res}$(c.m.)=2730 keV). J^π: from (2011Fr12). See also (1973Go15: favored by the analysis but the assignment is not certain and more than one state may be involved). Γ: from (2011Fr12: Γ_α=294 keV; Γ_n=46 keV); see also Γ=343 keV (1973Go15).
13420	(7/2$^+$,9/2$^-$)	58 keV	(4,6)	4.00	E(level): see also (2011Fr12: from E$_{res}$(c.m.)=2780 keV). J^π: J^π=(9/2$^-$) is reported in (1973Go15); this is confirmed in (2017Lo04). This finding is in disagreement with (2002Mi32). In (2011Fr12), 7/2$^+$ appears favored though 9/2$^-$ is not excluded. Γ: From (1973Go15); (1991Aj01) indicates a resonance with (9/2$^-$) and Γ=35 keV *3*.
13560	7/2$^-$	596 keV	(1,3)	4.20	E(level): see also (2011Fr12: from E$_{res}$(c.m.)=2880 keV). J^π: from (2011Fr12); see also J^π=5/2$^+$ (1973Go15), (1973De14: ^{9}Be(α,n)) suggest the opposite ordering

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^{9}Be(α,α):res (continued)

^{13}C Levels (continued)

E(level)$^{\dagger\#}$	J$^{\pi\dagger\ddagger}$	$\Gamma^{\dagger}$	L†	E$_{\alpha}$(res) (MeV)†	Comments
					(3/2^{+},5/2^{+}) for 13560 and 13760 states. Γ: from (2011Fr12: Γ_{α}=512 keV; Γ_{n}=84 keV); see also Γ=685 keV (1973Go15).
13760	5/2^{+}	337 keV	(1,3)	4.50	E(level): see also (2011Fr12: from E$_{res}$(c.m.)=3280 keV). J$^{\pi}$: from (2011Fr12); see also J$^{\pi}$=3/2^{+} (1973Go15), (1973De14: ^{9}Be(α,n)) suggest the opposite ordering (3/2^{+},5/2^{+}) for 13560 and 13760 states. Γ: from (2011Fr12: Γ_{α}=103 keV; Γ_{n}=334 keV); see also Γ=247 keV (1973Go15).
14110	5/2^{-}	124 keV	(2,4)	5.00	E(level): see also (2011Fr12: from E$_{res}$(c.m.)=3480 keV). J$^{\pi}$: an equally good fit to the data is obtained with a 7/2^{-} state at E$_{\alpha}$=5.0 MeV and a (3/2,5/2,7/2)$^{+}$ state at E$_{\alpha}$=5.075 MeV (1973Go15). J$^{\pi}$: (5/2^{-}) is reported in (1973Go15); this is confirmed in (2017Lo04). See also J$^{\pi}$=5/2^{-} (2011Fr12). This finding is in disagreement with an analysis of level spacings in (2002Mi32,2003Mi34); the analysis suggests this level is a J$^{\pi}$=9/2^{-} member of a rotational band. (1991Aj01) indicates a resonance with J$^{\pi}$=3/2^{-} and $\Gamma\approx$150 keV. Γ: from (2011Fr12: Γ_{α}=124 keV; Γ_{n}=0 keV); see also Γ=75 keV (1973Go15).
14162?	7/2^{+}	73 keV	(3,5)	5.075	J$^{\pi}$: In (1973Go15) an equally good fit to the data is obtained with a 7/2^{-} state at E$_{\alpha}$=5.0 MeV and a (3/2,5/2,7/2)$^{+}$ state at E$_{\alpha}$=5.075 MeV. In (2011Fr12), the state appears not to be required.
14390	7/2^{-}	111 keV			$\Gamma\alpha$=12 keV; Γ_{n}=999 keV (2011Fr12) E(level): from (2011Fr12: E$_{res}$(c.m.)=3760 keV). J$^{\pi}$,Γ: from (2011Fr12). J$^{\pi}$: See also J^{π}=7/2$^{(+)}$ (1973Go15) ^{9}Be(α,α_{0}).
14460?	(5/2^{+})	400 keV	(1,3)	(5.50)	E(level): This level was introduced by (1973Go15) mainly to improve the fit near E$_{\alpha}$=5 MeV.
14580	9/2^{+}	285 keV			$\Gamma\alpha$=244 keV; Γ_{n}=41 keV (2011Fr12) E(level): from (2011Fr12: E$_{res}$(c.m.)=4070 keV). J$^{\pi}$,Γ: from (2011Fr12).
14983	7/2^{-}	406 keV			$\Gamma\alpha$=238 keV; Γ_{n}=168 keV (2011Fr12) E(level): from (2011Fr12: E$_{res}$(c.m.)=4310 keV). J$^{\pi}$,Γ: from (2011Fr12).
15109.3 *14*	3/2^{-}	5.49 keV *25*		6.4435 *20*	T=3/2 E(level),J$^{\pi}$,Γ,E$_{\alpha}$(res) (MeV),T: from (1978Hi06). Γ: weak anomaly. $\Gamma_{\alpha_0}/\Gamma\geq$0.017 with $\Gamma_{\alpha_0}\geq$0.093 keV (1978Hi06). See also Γ_{α_0}=0.104 keV *28* (1978Hi06 and Ref. 19 (Nettles & Hensley, BAPS 1969)).
15270	(5/2^{-})	493 keV			$\Gamma\alpha$=154 keV; Γ_{n}=339 keV (2011Fr12) E(level): from (2011Fr12: E$_{res}$(c.m.)=4500 keV). J$^{\pi}$,Γ: from (2011Fr12). (1991Aj01) and (2003Mi34) indicate a resonance with J$^{\pi}$=9/2^{+}, but (2011Fr12) find interference from J^{π}=9/2^{+} states at E$_{x}$=14580 and 15270 is incompatible with their data. In (2018Lo07) J^{π}=3/2^{+} is suggested.
16080	7/2^{+}	140 keV			$\Gamma\alpha$=21 keV; Γ_{n}=119 keV (2011Fr12) E(level): from (2011Fr12: E$_{res}$(c.m.)=5510 keV). J$^{\pi}$,Γ: from (2011Fr12).
16150	5/2^{-}	253 keV			$\Gamma\alpha$=23 keV; Γ_{n}=230 keV (2011Fr12) E(level): from (2011Fr12: E$_{res}$(c.m.)=5490 keV). J$^{\pi}$,Γ: from (2011Fr12).

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^{9}**Be(α,α):res (continued)**

^{13}C Levels (continued)

† From single-level approximation analysis in (1973Go15) except where noted. Level energies are deduced using E_{α}(res) and ^{9}Be, ^{4}He and ^{13}C masses from (2021Wa16: AME-2020). E_x=S(α)+$E_{c.m.}$(relativistic).

‡ Values from (2011Fr12) are deduced from R-matrix analysis.

Several broad resonances from an R-matrix analysis are reported in (2018Lo07). These resonances are listed here, but are not adopted. E_x= 15.04 MeV *5* with Γ=965 keV *37*, 16.27 MeV *5* with Γ=1596 keV *142*, 16.64 MeV *5* with Γ=1502 keV *156*, 16.67 MeV *5* with Γ=904 keV *100*, 16.91 MeV *5* with Γ=1079 keV *200*, 17.23 MeV *5* with Γ=393 keV *200*, 17.52 MeV *5* with Γ=2153 keV *290*.

^{9}Be(α,nγ):res

1932Ch02: ^{9}Be(α,n), deduced existence of the neutron.
1953Ta06: ^{9}Be(α,nγ), E$\leq$3.0 MeV; measured γ-radiation yield, two resonances corresponding to ^{13}C*(11.95,12.46 MeV) states were reported.
1954Be08: ^{9}Be(α,n), E<1.5 MeV; measured reaction products, En, In; deduced yields, resonances.
1955Ta28: ^{9}Be(α,n), E=1.2-2.5 MeV; measured dσ/dΩ(90°) for 4.4 MeV γ-rays. In the region of 12 MeV excitation in ^{13}C, the states are not well defined and any attempt to assign such properties as spins and parities must be speculative.
1956Be98: ^{9}Be(α,n), E=4.3-8.7 MeV; measured products; deduced σ, σ(E).
1956Bo61: ^{9}Be(α,n), E=1.8-5.3 MeV. Excitation curves at 0° and 90° were studied for neutrons and γ rays produced in this reaction. Resonances were reported at bombarding energies of 1.9, 2.3, 2.6, 3.98, 4.4, and 5.0 Mev.
1956Ja28: ^{9}Be(α,n), E=0.4-1.3 MeV; measured the angular distributions of the neutron groups. Tentative spin and parity to certain levels in ^{13}C were assigned.
1957Ri38: ^{9}Be(α,n), E=1.7-5.0 MeV; measured angular distribution and 0° excitation curves.
1958Ta05: ^{9}Be(α,n), E=1.15,2.8 MeV; stripping plays only a minor role.
1959Gi47: ^{9}Be(α,n), E=2.5-8.2 MeV; measured absolute neutron yields, several resonances were reported.
1963De27: ^{9}Be(α,n$_{0,1}$), E=14-23 MeV; measured angular distributions for $\theta\approx10°$ to 170°. Discussed reaction mechanism.
1963Se04: ^{9}Be(α,n), E=3.6-7.6 MeV; measured angular distributions, the excitation function of the 4.43-MeV γ-ray from the ^{9}Be(α,n$_{1}\gamma_{4.43}$)^{12}C reaction has been studied. Many broad resonances are found.
1965Gi02: ^{9}Be(α,n), E=1.7-10.5 MeV; measured the absolute total (4π) neutron yield. Resonances peaks were reported.
1965Gr22: ^{9}Be(α,n), E=5-12 MeV; measured the neutron cross sections for the ground state and first excited state of ^{12}C. Resonances were reported.
1965Li09: ^{9}Be(α,n), E=1.9-4.5 MeV; measured polarization (E,θ). Natural target.
1966Mi12: ^{9}Be(α,n$_{0}$), E=5.0-12.0 MeV; ^{9}Be(α,n$_{1}$), E=4.3-12.0; ^{9}Be(α,n$_{2}$), E=6.0-10.1; measured σ(E,θ=0°). ^{13}C deduced levels.
1968Da05: ^{9}Be(α,n), E=0.34-0.68 MeV; measured σ(E;En,θ).
1968Le24: ^{9}Be(α,n), E=1-6 MeV; measured σ(E;En). ^{13}C deduced resonance parameters.
1968Ve06: ^{9}Be(α,n), E=6-10 MeV; measured absolute differential cross sections.
1969Kl09: ^{9}Be(α,n), E=1.75,1.96 MeV; measured σ(θ), Q, P(θ). ^{13}C deduced resonances, J, π, level-width.
1970St16: ^{9}Be(α,n), E=2.4-2.9 MeV; measured P(n)(E;θ), deduced J of E$_{x}$=11.95 MeV.
1970Va23: ^{9}Be(α,n), E=1.5-7.8 MeV; measured σ(E;En,θ).
1971Kl04: ^{9}Be(α,n), E=2.6 MeV; measured P$_{n}$(θ).
1972Ob01: ^{9}Be(α,n), E=1.69-6.44 MeV; measured σ(E;θ).
1973De14: ^{9}Be(α,n$_{0}$), (α,n$_{1}$), E=4.5-5.85 MeV; measured P(E;En,θ). ^{13}C deduced levels, J, π.
1973Ok06: ^{9}Be(α,n), E=22.9 MeV; measured σ(En,θ), P(En,θ).
1973We03: ^{9}Be(α,n), E=5.01,5.44,6.37,7.44 MeV; measured σ(E;En,θ).
1975Ka26: ^{9}Be(α,n), E=2.65 MeV; measured polarization.
1977ScZG,1978Hi06: ^{9}Be(α,n$_{0}$),(α,n$_{1}$), E=6.4-6.5 MeV; measured σ(E,θ). ^{13}C deduced resonance parameters.
1978Le10: ^{9}Be(α,n), E=100 MeV; measured En, neutron polarization.
1982RaZP: ^{9}Be(α,n), E=0.51-0.65 MeV; measured σ(E). Resonance observed corresponding to level of ^{13}C*(11.076 MeV).
1990We10: ^{9}Be(α,n), E=2.4-3.3 MeV; measured σ(θ), polarization.
1994Ha32: ^{9}Be(α,n), E=480-740 keV; measured σ(E); deduced resonance σ, width, tokamak materials study relevance. 4π neutron detector.
1994Wr01: ^{9}Be(α,n), E(cm)=0.16-1.87 MeV; measured σ(E), thick target yield. deduced (α,n) reaction rate vs temperature, astrophysical S-factor.
1996Ku07: ^{9}Be(α,n), E=0.5-3.5 MeV; measured yield, σ(E); deduced astrophysical S-factor vs E, reaction rate. ^{13}C deduced resonances, Γ. Astrophysical implications.

Theory:
1975Fo19: ^{9}Be(α,n); compiled, calculated thermonuclear reaction rates.
1989He04: Be(α,n), E=1-9.8 MeV; analyzed thick target neutron yields data.
2003Sh22: ^{9}Be(α,n); E=0.1-10 MeV; calculated σ, neutron spectra. Comparison with data.
2017Lo04: ^{9}Be(α,n); E=1.6-10 MeV; calculated σ(θ) using R-matrix and comprehensive fit to published data. ^{13}C deduced 13.42 MeV resonance new J, π assignment.
2018Lo07: ^{9}Be(α,n); E(cm)=1-5 MeV; analyzed experimental energy spectra, and differential σ(θ,E) data by R-matrix approach,

^{9}Be(α,nγ):res (continued)

^{13}C deduced levels above the α threshold of 10.648 MeV, J, π, Γ, $\Gamma_{\alpha 0}$, $\Gamma_{\alpha 1}$, Γ_{n}, and compared with literature data. Discussed possible existence of molecular bands associated to cluster structures.

^{13}C Levels

E(level)†	J^{π}	Γ	E_{α}(res) (keV)	Comments
10754		50.9 keV	153	E(level),Γ: from (1994Wr01).
10815 *2*		18.7 keV *4*	240 *2*	E(level),Γ: from (1994Wr01).
11002 *2*	$1/2^{+}$	56.43 keV *7*	511 *2*	J^{π}: From the resonance phase analysis in (1956Ja28: E_{x}=11010 keV). E_{α}(res) (keV): from (1994Wr01), see also 511 keV *7* (1996Ku07) and 530 keV (1954Be08,1956Ja28), 520 keV (1968Da05), 540 keV (1968Le24). Γ: from (1994Wr01); see also 56 keV *5* (1996Ku07), 70 keV (1969Kl09), ≈55 keV (1968Da05). $\omega\gamma$(cm)=2.86 eV *100* determined from S(cm)=2.0×10^{5} MeV·b *3* (1996Ku07); see also $\omega\gamma$(cm)=3.97 eV (1968Da05).
11076 *2*		4.681 keV *19*	618 *2*	Γ: from (1994Wr01); see also ≈5.3 keV (1994Ha32), <4 keV (1968Da05) and <4.8 keV (1996Ku07). E_{α}(res) (keV): from average of 618 keV *2* (1994Wr01) and 620 keV *4* (1996Ku07). See also 610 keV (1954Be08,1956Ja28), 600 keV (1968Da05), 618 keV (1982RaZP), 620 keV (1994Ha32). $\omega\gamma$(cm)=1.31 eV *34* determined from S(cm)=1.4×10^{5} MeV·b *3* (1996Ku07); see also $\omega\gamma$(cm)=0.88 eV (1968Da05).
11188?			(780)	E_{α}(res) (keV): from (1968Le24).
11410?			(1100)	E_{α}(res) (keV): from (1968Le24).
11618?			(1400)	E_{α}(res) (keV): from (1968Le24).
11726 *2*		122.5 keV *8*	1557 *2*	E_{α}(res) (keV): from average of 1567 keV *22* (1996Ku07) and 1557 keV *2* (1994Wr01). Γ: from (1994Wr01); see also 122 keV *20* (1996Ku07). $\omega\gamma$(cm)=2.7 keV *9* determined from S(cm)=6.5×10^{3} MeV·b *15* (1996Ku07).
≈11825			≈1700	E_{α}(res) (keV): from (1996Ku07).
11947 *3*	$(1/2^{-},7/2^{-})$	148.7 keV *4*	1876 *4*	J^{π}: see (1956Ja28,1970Va23: $7/2^{-}$, 1969Kl09 (neutron polarization): $1/2^{-}$). Γ: from (1994Wr01); see also 150 keV *13* (1996Ku07), 200 keV (1956Bo61,1965Gi02) and 70 keV (1969Kl09). $\Gamma_{n}/\Gamma_{\alpha}\geq12$ where Γ_{n} is width for neutron emission to both ^{12}C*(0,4.44 MeV) states and Γ_{α} is width for α-particle emission=0.09 MeV *1* (1955Ta28). E_{α}(res) (keV): weighted value of 1905 keV *10* (1955Ta28), 1879 keV *7* (1966Ku07) and 1874 keV *2* (1994Wr01). See also 1900 keV (1953Ta06,1954Be08,1956Bo61,1956Ja28), 1920 keV (1965Gi02), 1910 keV (1970Va23). $\omega\gamma$(cm)=50.3 keV *80* determined from S(cm)=3.3×10^{4} MeV·b *4* (1996Ku07).
12141 *2*	$5/2^{-}$	370.2 keV *17*	2156 *2*	J^{π}: from (1969Kl09) (neutron polarization). Γ: from (1994Wr01); see also 243 keV *40* (1996Ku07) and 280 keV (1969Kl09: E_{x}=12070 keV). E_{α}(res) (keV): from (1994Wr01); see also 2157 keV *29* (1996Ku07). $\omega\gamma$(cm)=36.8 keV *97* determined from S(cm)=6.9×10^{3} MeV·b *10* (1996Ku07).
12180	$7/2^{+}$	120 keV		E(level),J^{π},Γ: from (1969Kl09) (neutron polarization).
12229		≈300 keV	2283	Γ: average of 400 keV (1965Gi02) and ≈200 keV (1956Bo61). E_{α}(res) (keV): average of 2300 keV (1956Bo61,1968Le24) and 2250 keV (1965Gi02).

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^{9}Be(α,nγ):res (continued)

^{13}C Levels (continued)

E(level)†	J$^{\pi}$	Γ	E$_{\alpha}$(res) (keV)	Comments
12420 *2*	(7/2^{-},1/2^{-})	226 keV *3*	2559 *2*	J$^{\pi}$: see (1956Ja28: (1/2^{-}),1969Kl09 (neutron polarization): 7/2^{-} for E$_{x}$=12440 keV). Γ: from (1994Wr01); see also 336 keV *50* (1996Ku07), ≈200 keV (1956Bo61), 300 keV (1959Gi47, 1965Gi02), 90 keV (1965Gr22: n$_{0}$), 400 keV (1969Kl09). E$_{\alpha}$(res) (keV): from (1994Wr01); see also 2526 keV 29 (1996Ku07), 2650 keV (1953Ta06), 2600 keV (1955Ta28,1956Bo61,1956Ja28) and 2580 keV (1959Gi47, 1965Gi02, 1965Gr22). $\omega\gamma$(cm)=58.5 keV *15* determined from S(cm)=3.5×10^{3} MeV·b *6* (1996Ku07).
≈13002			≈3400	E$_{\alpha}$(res) (keV): from (1996Ku07); see also 3200 keV (1968Le24: E$_{x}$=12864 keV).
13418	9/2^{-}	45 keV *7*	4000	J$^{\pi}$: from R-matrix analysis in (2017Lo04). Γ: (1972Ob01). See also 60 keV (1956Bo61,1965Gr22: n$_{1}$), 80 keV (1959Gi47,1965Gi02). E(level),E$_{\alpha}$(res) (keV): from (1959Gi47, 1965Gi02, 1965Gr22, 1968Le24). E$_{\alpha}$(res) (keV): see also 3980 keV (1956Bo61, 1957Ri38, 1963Se04: n$_{1}\gamma_{4.43}$, 1972Ob01).
13542	(3/2^{+},5/2^{+})	570 keV	4180	E(level),E$_{\alpha}$(res) (keV): from (1965Gr22: n$_{0}$, 1957Ri38, 1973De14). J$^{\pi}$: from (1957Ri38); see also (1973De14: 3/2^{+} (neutron polarization)). Γ: from (1965Gr22: n$_{0}$).
13764	5/2^{+}	≈500 keV	4500	J$^{\pi}$: from (1973De14) (neutron polarization). E(level),E$_{\alpha}$(res) (keV): from (1959Gi47, 1965Gi02, 1973De14); see also E$_{\alpha}$(res)=4400 keV (1956Bo61), 4450 keV (1963Se04), 4480 keV (1965Gr22: n$_{1}$). Γ: from (1959Gi47,1965Gi02); see also ≈400 keV (1956Bo61), 90 keV (1965Gr22).
14110		≈300 keV	5000	E(level),E$_{\alpha}$(res) (keV): from (1956Bo61, 1959Gi47, 1963Se04, 1965Gi02); see also E$_{\alpha}$(res)=4800 keV (1968Le24), 5020 keV (1965Gr22: n$_{1}$). Γ: from (1956Bo61,1959Gi47,1965Gi02); see also 90 keV (1965Gr22).
14387 *69*	(1/2^{-},5/2^{-})	260 keV	5.4×10^{3} *1*	J$^{\pi}$: from (1973De14) (neutron polarization). Γ: average of 280 keV (1965Gr22: n$_{0}$) and 240 keV (1966Mi12). E$_{\alpha}$(res) (keV): from (1966Mi12); see also 5300 keV (1963Se04,1973De14), 5400 keV (1965Gr22).
14595		210 keV	5700	Γ: from (1965Gr22: n$_{1}$). E$_{\alpha}$(res) (keV): average of 5750 keV (1959Gi47, 1965Gi02, 1965Gr22: n$_{1}$), 5700 keV (1963Se04), 5600 keV (1968Le24).
14941 *35*	3/2^{+}	375 keV	6200 *50*	J$^{\pi}$: from (1973De14) (neutron polarization). Γ: average of 350 keV (1965Gr22: n$_{0}$) and 400 keV (1966Mi12). E$_{\alpha}$(res) (keV): from (1966Mi12); see also 6250 keV (1965Gr22,1973De14).
15109.4 *14*	3/2^{-}	5.49 keV *25*	6443.5 *20*	T=3/2 (1978Hi06) J$^{\pi}$,E$_{\alpha}$(res) (keV): from (1978Hi06). Γ: from (1978Hi06); also used (1973Ad02: ^{11}B(^{3}He,np) Γ$_{n}$/Γ values to obtain Γ$_{n0}$=0.38 keV *10*, Γ$_{n1}$=1.43 keV *18*, Γ$_{n2}$=0.14 keV *10*. Other analysis in the text using Γ$_{\gamma 0}$/Γ can be used to obtain Γ$_{\gamma 0}$≈22.8 keV.

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^{9}Be(α,nγ):res (continued)

^{13}C Levels (continued)

E(level)[†]	Γ	E_α(res) (keV)	Comments
			Other discussion in (1978Hi06) finds reduced transition strength, δ(M1)(W.u.)=−0.15 *7* and δ(E2)(W.u.)=1.0 *6* where $\delta \equiv B(^{13}C)/B(^{13}N)-1$.
15280		6690	E_α(res) (keV): from (1968Le24); see also (6700) keV; (broad) state (1965Gi02).
15564 *35*	215 keV	7100 *50*	Γ: average of 220 keV (1965Gr22: $n_{0,1}$) and 210 keV (1966Mi12). E_α(res) (keV): from (1966Mi12); see also 7100 keV (1963Se04,1965Gr22: n_0), 7000 keV (1965Gr22: n_1).
16023	210 keV	7763	Γ: from (1965Gr22: n_1). E_α(res) (keV): average of 7800 keV (1959Gi47, 1965Gi02, 1968Le24), 7700 keV (1963Se04) and 7750 keV (1965Gr22).
16152 *35*	225 keV	7950 *50*	Γ: average of 210 keV (1965Gr22: n_0) and 240 keV (1966Mi12). E_α(res) (keV): from (1966Mi12); see also 7940 keV (1965Gr22).
16948 *35*	330 keV	9100 *50*	Γ: average of 280 keV (1965Gr22: n_0) and 380 keV (1966Mi12). E_α(res) (keV): from (1966Mi12); see also 9100 keV (1965Gi02), 9050 keV (1965Gr22).
17363 *69*	190 keV	9.7×10^{3} *1*	Γ: average of 240 keV (1965Gr22: $n_{0,1}$) and 140 keV (1966Mi12). E_α(res) (keV): from (1966Mi12); see also (9600) keV (1965Gr22: n_0), 9700 keV (1965Gr22: n_1), 9800 keV (1968Le24).
17709 *35*	225 keV	10200 *50*	Γ: average of 170 keV (1965Gr22: n_0) and 280 keV (1966Mi12). E_α(res) (keV): from (1966Mi12); see also 10110 keV (1965Gr22).
17986?	40 keV	10600	Γ,E_α(res) (keV): from (1965Gr22: n_0).
18332 *35*	305 keV	11100 *50*	Γ: average of 210 keV (1965Gr22: n_0) and 400 keV (1966Mi12). E_α(res) (keV): from (1966Mi12); see also 10950 keV (1965Gr22).
18750 *21*	70 keV	11700 *30*	Γ: average of 60 keV (1965Gr22: $n_{0,1}$) and 80 keV (1966Mi12). E_α(res) (keV): from (1966Mi12); see also 11600 keV (1965Gr22).

[†] Level energies are deduced using E_α(res) and ^{9}Be, ^{4}He and ^{13}C masses from (2021Wa16: AME-2020) where E_α(res) is listed. $E_x=S(\alpha)+E_{c.m.}$(relativistic).

^{9}Be(^{6}Li,d),(^{7}Li,t)

1964Ca05: ^{9}Be(^{7}Li,t), E=3.2 MeV; the first eight states of ^{13}C (not all resolved). No triton groups are observed to the previously reported ^{13}C states at 5.51 and 6.10 MeV.

1969Sn02: ^{9}Be(^{7}Li,t), E=5.6,5.8,6.0,6.2 MeV; measured σ(E;E$_t$,θ). Absolute differential cross sections at θ=10°−170° have been measured; ^{13}C levels observed.

1971Go24: ^{9}Be(^{6}Li,d),(^{7}Li,t), E=24,30 MeV; measured σ(E$_d$,θ), σ(E$_t$,θ). ^{13}C deduced levels, α-particle structure.

1989As01: ^{9}Be(^{6}Li,d), E=30 MeV; measured σ(E$_d$), $\sigma(\theta)$; deduced optical model parameters. ^{13}C deduced levels, L, J, π, spectroscopic strengths.

1998Le17: ^{7}Li(^{9}Be,t), E≈6.5-9.0 MeV/nucleon; measured E$_\alpha$ vs angle following compound nucleus decay. ^{13}C deduced levels, widths, α-decay branching ratios.

2010RoZR, 2010RoZZ: ^{9}Be(^{6}Li,d), E=25.5 MeV; measured E$_d$, I$_d$(θ); deduced $\sigma(\theta)$; calculated $\sigma(\theta)$ using DWBA.

2011Bo17: ^{9}Be(^{6}Li,d), E=25.5 MeV; measured reaction products, deuteron spectra; deduced $\sigma(\theta)$, J, π. Comparison with DWBA calculations.

2012Wh01: XUNDL dataset compiled by TUNL, 2012.

The authors studied the decay modes of ^{13}C states by measuring deuterons from the ^{9}Be(^{6}Li,d)^{13}C reaction in coincidence with ^{12}C or α particles from breakup of ^{13}C into ^{12}C+n or α+^{9}Be, respectively.

A beam of 42 MeV ^{6}Li ions impinged on a 240 μg/cm^2 ^{9}Be target at the Munich MLL tandem laboratory. Recoiling deuterons were detected in the Q3D spectrometer, which was optimized for sensitivity to E$_x$=11550 keV (10.6 to 13.0 MeV) or 13280 keV (12.4 to 15.1 MeV). Charged particle ejectiles from breakup of correlated ^{13}C* were detected in an array of four 50 mm×50 mm position sensitive Si strip detectors that covered 12° to 91° and −36° to 39° in the vertical and horizontal planes, respectively. The ^{12}C+n$_0$/n$_1$ and ^{9}Be+α_0 breakup paths were analyzed.

The absolute particle widths were determined for n$_0$, n$_1$ and α_0 decay reactions by correlating deuterons in the Q3D focal plane with events in the strip detector array.

^{13}C Levels

E(level)†	J$^\pi$†	Γ‡#	L†	Spectroscopic Strength†	Comments
0	1/2$^-$		2	1.9	E(level): from (1964Ca05,1969Sn02,1971Go24,1989As01).
3089	1/2$^+$		1	2.3	E(level): from (1964Ca05,1969Sn02,1971Go24,1989As01, 2010RoZZ).
3685	3/2$^-$		0+2	1.7	E(level): from (1964Ca05,1971Go24,2010RoZZ); see also (1969Sn02,1989As01: unresolved doublet). L: from (2010RoZZ, 2011Bo17), L=0 in (1989As01).
3854	5/2$^+$		1	1.4	E(level): from (1964Ca05,2010RoZZ); see also (1969Sn02,1989As01: unresolved doublet).
6864	5/2$^+$		1+3	0.19	E(level): see (1964Ca05,1969Sn02,1971Go24,1989As01, 2010RoZZ). Spectroscopic Strength: for L=1 transfer; S=0.38 for L=3 transfer.
7492	(7/2$^+$)				E(level): from (2010RoZZ); see also (1964Ca05,1969Sn02: unresolved doublet) and (1971Go24,1989As01: unresolved levels).
7547	5/2$^-$				E(level): from (2010RoZZ); see also (1964Ca05,1969Sn02: unresolved doublet).
7686	3/2$^+$				E(level): from (1964Ca05,1969Sn02).
8860	1/2$^-$				E(level): from (^{7}Li,t) (1971Go24).
9500	9/2$^+$		3	0.55	E(level): from (1969Sn02,1989As01,2010RoZZ); see also (1971Go24: unresolved levels).
9897	3/2$^-$		0+2	7.2	E(level): from (1969Sn02,1989As01,2010RoZZ); see also (1971Go24: unresolved levels). Spectroscopic Strength: for L=0 transfer; S=1.45 for L=2 transfer.
10772	7/2$^-$	61 keV	4	24.6	E(level): from (2010RoZR,2010RoZZ,2011Bo17,2012Wh01(the experimental resolution is 82 keV)); see also (1971Go24: unresolved levels), (1989As01: the centroid of the peak is

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^{9}Be(^{6}Li,d),(^{7}Li,t) (continued)

^{13}C Levels (continued)

E(level)[†]	J^{π}[†]	Γ[‡#]	L[†]	Comments
				10750 keV *18* with Γ=130 keV after removal of the 70 keV experimental resolution, more likely, the doublet E_x=10.753 and 10.818 MeV are populated) and (1998Le17: E_x=10768 keV with energy separation for fitting fixed at 70 keV). Γ: $\Gamma\alpha_0/\Gamma<(0.05)$, Γ_{n0}/Γ=0.91 *11*, $\Gamma_{n1}/\Gamma\leq0.13$ (2012Wh01). See also Γ=55 keV (1998Le17: Γ_{exp} was fixed at $\Gamma_{exp}=(\Gamma^2+50^2)^{1/2}$, using Γ values from (1991Aj01)). L: from (2011Bo17); L=2 in (1989As01).
10816	(5/2$^-$)	35 keV	4	E(level): from (2010RoZR,2010RoZZ,2011Bo17,2012Wh01(the experimental resolution is 82 keV)); see also (1989As01: unresolved doublet) and (1998Le17: E_x=10838 keV with energy separation for fitting fixed at 70 keV). Γ: $\Gamma\alpha_0/\Gamma<(0.02)$, Γ_{n0}/Γ=0.51 *4*, Γ_{n1}/Γ=0.51 *4* (2012Wh01). See also Γ=25 keV (1998Le17: Γ_{exp} was fixed at $\Gamma_{exp}=(\Gamma^2+50^2)^{1/2}$, using Γ values from (1991Aj01)). L: from (2011Bo17).
10969	1/2$^+$	33 keV *5*		E(level): from (1998Le17); see also E_x=11010 keV (2012Wh01). Γ: from (1998Le17); see also Γ=85 keV, $\Gamma\alpha_0/\Gamma<(0.08)$, Γ_{n0}/Γ=0.68 *3*, Γ_{n1}/Γ=0.42 *2* (2012Wh01).
11080	1/2$^-$	<15 keV		E(level): from (2010RoZZ,2011Bo17); see also E_x=11112 keV (1998Le17). Γ: from (1998Le17).
11711		38 keV *10*		E(level): from (1998Le17: see also E_x=11700 keV); the authors compared with (1991Aj01) Adopted Levels and suggested E_x=11.74 MeV *1* and Γ=40 keV *10*. Γ: average of 33 keV *10* and 43 keV *10* (1998Le17).
11841	7/2$^+$	46 keV *9*		E(level): from (1998Le17,2012Wh01(the experimental resolution is 82 keV)); see also (1989As01: unresolved doublet whose peaks have widths that are consistent with proposed 3/2$^-$ strength at 11.85 MeV and a 5/2$^-$ state at 12.13 MeV (1986Aj01)) and (1998Le17). Γ: from (1998Le17); see also 238 keV ((2012Wh01)). $\Gamma\alpha_0/\Gamma<(0.10)$, Γ_{n0}/Γ=0.49 *8*, Γ_{n1}/Γ=0.71 *11* (2012Wh01).
11959		240 keV *30*		E(level): from (1998Le17: see also E_x=11969 keV); the authors compared with (1991Aj01) Adopted Levels and suggested E_x=11.96 MeV *3*. See also (1971Go24). Γ: from (1998Le17: see also Γ=235 keV *40*).
12123	5/2$^-$	219 keV		E(level): from (2012Wh01: the experimental resolution is 82 keV); see also (1989As01: unresolved doublet). Γ: $\Gamma\alpha_0/\Gamma<(0.17)$, Γ_{n0}/Γ=0.49 *8*, Γ_{n1}/Γ=0.53 *8* (2012Wh01).
12300	1/2$^-$		2	E(level): from (2011Bo17,2010RoZR). J^{π}: from (2010KaZZ: ^{13}C(α,α'); E_x=12.5 MeV); see discussions in (2010RoZR,2011Bo17). L: from (2011Bo17).
12830		1 MeV		E(level),Γ: from (1998Le17); the authors compared with (1991Aj01) Adopted Levels and suggested E_x=12.8 MeV *2* and Γ=1.0 MeV *2*.
13270		315 keV *30*		E(level): from (1998Le17: see also E_x=13360 keV); the authors compared with (1991Aj01) Adopted Levels and suggested E_x=13.28 MeV *3* and Γ=310 keV *30*. See also E_x=13300 keV (1971Go24). Γ: from (1998Le17: see also Γ=380 keV *40*).
13410	(9/2$^-$)	33 keV *10*		E(level): from (1989As01); see also E_x=13300 and 13370 keV (1998Le17). Γ: from (1998Le17).
13570?		(75) keV		E(level): from (1998Le17: see also E_x=13530 keV); see also E_x=13500 keV (2011Bo17). Γ: average of (65) keV and (85) keV (1998Le17).
13779?	(5/2,3/2)$^+$	77 keV *30*		E(level): from (1971Go24, 2012Wh01(the experimental resolution is 82 keV)); see also E_x=13730 keV (1998Le17). Γ: from (1998Le17); see also 117 keV (2012Wh01). $\Gamma\alpha_0/\Gamma$=0.54 *2*, $\Gamma_{n0}/\Gamma<(0.10)$, Γ_{n1}/Γ=0.45 *2* (2012Wh01).

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^{9}Be(^{6}Li,d),(^{7}Li,t) (continued)

^{13}C Levels (continued)

E(level)[†]	J$^{\pi}$[†]	Γ[‡#]	Comments
13920		100 keV *25*	E(level): from (1998Le17); the authors compared with (1991Aj01) Adopted Levels and suggested E_x=13.92 MeV *3* and Γ=100 keV *30*. Γ: from (1998Le17).
14120		160 keV *20*	E(level): (1989As01: unresolved doublet; E_x=14.11 MeV ($5/2^-$) and 14.16 MeV($7/2^+$)), (2011Bo17: broad resonance) and E_x=14080 keV (1998Le17). Γ: from (1998Le17).
14360		115 keV *35*	E(level),Γ: from (1998Le17).
14582?	($7/2^+$,$9/2^+$)	130 keV	E(level): from (1971Go24,2011Bo17,2012Wh01(the experimental resolution is 82 keV)). Γ: $\Gamma\alpha_0/\Gamma$=0.94 *3*, Γ_{n0}/Γ<(0.12), Γ_{n1}/Γ=0.13 *2* (2012Wh01).
15100			E(level): from (2011Bo17).
15200[@]			E(level): from (1971Go24).
16700[@]			E(level): from (1971Go24).
18500[@]			E(level): from (1971Go24).

[†] Values mainly from DWBA analysis in (1989As01) ^{9}Be(^{6}Li,d), except where noted.

[‡] From (2012Wh01) except where noted; the experimental resolution of 82 keV has been removed from the quoted Γ_{total} value.

[#] Widths shown in Fig. 6 in (1998Le17) are Γ_{exp}, while the width listed here are $\Gamma=(\Gamma^2_{exp}-50^2)^{1/2}$, taking the experimental resolution as 50 keV from state 4 (1998Le17).

[@] Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

^{9}Be(^{9}Be,^{13}Cγ)

1986Cu02: ^{9}Be(^{9}Be,^{13}Cγ), E(cm)≈1.25-3 MeV; measured E$_{\gamma}$, I$_{\gamma}$, γ, residual production σ(E). α-transfer, statistical model analysis of ^{18}O excitation and decay, DWBA analyses. Enriched targets, Ge detectors.

1988La25: ^{9}Be(^{9}Be,^{13}Cγ), E(cm)=1.4-3.4 MeV; measured elastic $\sigma(\theta)$, total reaction σ(E), σ(E,E(γ)) for transitions in ^{13}C. Optical model, statistical model and DWBA analysis. NaI and Ge detectors.

1993Da17: ^{9}Be(^{9}Be,^{13}Cγ), E=4.5-12.4 MeV; measured σ(E) for γ transitions in ^{13}C. Statistical model analysis of ^{18}O excitation and decay. Similar analyses for ^{14}C+α and ^{7}Li+^{11}B.

1997Mu04: ^{9}Be(^{9}Be,^{13}Cγ), E(cm)=1.3-7.6 MeV; measured γ production σ vs E; deduced partial, total fusion σ. Statistical model analysis, optical model calculations.

2011Gi03: ^{9}Be(^{9}Be,^{13}Cγ), E=30,35,40 MeV; measured reaction products, E$_{\gamma}$, I$_{\gamma}$; deduced production yields. Comparison with PACE, LisFus and GEMINI calculations.

^{13}C Levels

E(level)[†]	J$^{\pi}$[†]	T$_{1/2}$	L$_{\alpha}$[‡]	Comments
0	1/2^{-}			J$^{\pi}$: see (1997Mu04).
3090	1/2^{+}	0.69 fs	1	E(level): see (1986Cu02,1988La25,1993Da17,1997Mu04). J$^{\pi}$: see (1986Cu02,1988La25,1997Mu04). T$_{1/2}$: from τ=0.001 ps (1988La25).
3680	3/2^{-}	0.69 fs	0	E(level): see (1986Cu02,1988La25,1993Da17,1997Mu04). J$^{\pi}$: see (1986Cu02,1988La25). T$_{1/2}$: from τ=0.001 ps (1988La25).
3850	5/2^{+}	8.32 ps	1,3	E(level): see (1986Cu02,1988La25,1993Da17,1997Mu04). J$^{\pi}$: see (1986Cu02,1988La25,1997Mu04). T$_{1/2}$: from τ=12 ps (1988La25).

[†] Values based on Adopted Levels.
[‡] From (1986Cu02).

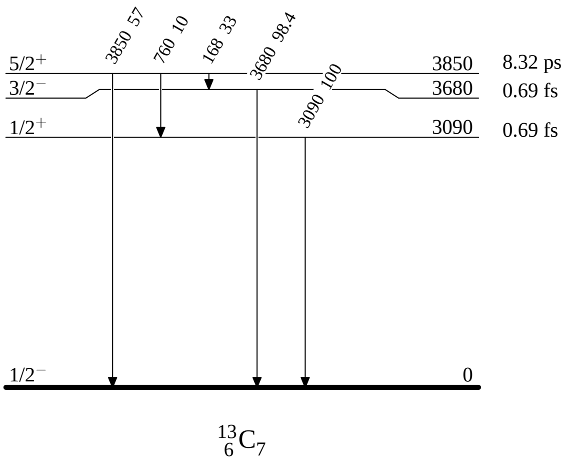
γ(^{13}C)

E$_{i}$(level)	J$^{\pi}_{i}$	E$_{\gamma}$	I$_{\gamma}$	E$_{f}$	J$^{\pi}_{f}$	Comments
3090	1/2^{+}	3090	100	0	1/2^{-}	E$_{\gamma}$: see (1986Cu02,1988La25,1993Da17,1997Mu04). I$_{\gamma}$: from (1988La25,1997Mu04).
3680	3/2^{-}	3680	98.4	0	1/2^{-}	E$_{\gamma}$: see (1986Cu02,1988La25,1993Da17,1997Mu04). I$_{\gamma}$: from (1988La25), see also 99% (1997Mu04).
3850	5/2^{+}	168	33	3680	3/2^{-}	E$_{\gamma}$: (2011Gi03). I$_{\gamma}$: (1997Mu04), see also 37% (1986Cu02).
		760	10	3090	1/2^{+}	E$_{\gamma}$,I$_{\gamma}$: (1997Mu04).
		3850	57	0	1/2^{-}	E$_{\gamma}$: see (1986Cu02,1988La25,1993Da17,1997Mu04). I$_{\gamma}$: (1997Mu04), see also 63% (1986Cu02: 3850→3090 not observed), 63.4% (1988La25).

^{9}Be(^{9}Be,^{13}Cγ)

Level Scheme

Intensities: % photon branching from each level



^{9}Be(^{16}O,^{12}C) **1988We17**

1987We08: ^{9}Be(^{16}O,^{12}C), E≈barrier; measured $\sigma(\theta)$; deduced ^{9}Be+α molecular effects role.
1988We17: ^{9}Be(^{16}O,^{12}C), E(cm)=7.2,8.4,9,9.6,10.2 MeV; measured $\sigma(\theta)$, low-lying states; deduced ^{9}Be+α molecular effects existence. Second-order exact finite-range DWBA calculations.

Theory:
1994Os08: ^{9}Be(^{16}O,^{12}C), E=7.2-10.2 MeV; analyzed $\sigma(\theta)$. ^{13}C levels deduced spectroscopic factors. Exact finite-range DWBA.

^{13}C Levels

E(level)[†]	J^{π}[†]
0	1/2^{-}
3090	1/2^{+}
3850	5/2^{+}

[†] From α-cluster configuration analysis in (1988We17).

^{10}B(t,p)

1981Ci06: ^{10}B(t,p), E=0.9,1.1 MeV; measured $\sigma(\theta)$; deduced evidence for different reaction mechanisms. DWBA.
1984GuZY: ^{10}B(t,p), E=3-12 MeV; measured σ(E). ^{13}C deduced resonances, Γ.
1985Ab10: ^{10}B(t,p), E=3-12 MeV; measured σ(E).
Theory:
1970Ma38: ^{10}B(t,p), E=5-20 MeV; calculated $\sigma(\theta)$.

^{13}C Levels

E(level)†	Γ	E_t(res) (MeV)	Comments
28025	≈1 MeV	5.4	E(level),Γ,E_t(res) (MeV): from (1984GuZY). A broad structure is reported in the activation cross section at E_t(res)≈5.5 MeV, Γ=2.7 MeV and σ_{res}(max)=17 mb (1985Ab10).

† Deduced using E_t(res) and ^{10}B, ^{3}H and ^{13}C masses from (2021Wa16: AME-2020). E_x=S(^{3}H)+$E_{c.m.}$(relativistic).

^{10}B(α,p),(α,pγ)

1953Sh64: ^{10}B(α,p), E=1-2 MeV; resonances for production of γ-rays and protons from the reaction were observed. Spins and parities of $3/2^{-}$ and $5/2^{+}$ were confirmed for the second and third excited levels of ^{13}C.

1954St20: ^{10}B(α,pγ), The angular distributions of the high energy γ-rays (a mixture of 3.7 and 3.9 Mev γ-rays) and of the low energy γ-rays (0.2 Mev) from the reaction, and the angular correlations of the high energy γ-rays with the emitted protons have been measured at five α-particle resonances E_{α}= 1.13, 1.51, 1.64, 1.68 and 1.83 MeV.

1956Ma52: A scintillation spectrometer and a magnetic lens spectrometer have been used to study gamma rays from excited states of ^{13}C at 3.84 and 3.68 Mev, produced in the reactions ^{12}C(d,p) and ^{10}B(α,p). Lines have been measured at 169.5 keV *4*, 3.844 Mev *15*, and 3.69 Mev *2*.

1960Ka13: ^{10}B(α,p); Estimate the strength of the corresponding but non-mirror Ml transition from the ^{13}C*(3.68 MeV:$3/2^{-}$) state to the $1/2^{-}$ ground state and to compare it with the same IPM calculation as accounts for the transition in ^{13}N.

1960Pi09: ^{10}B(α,p), E=1.64 MeV; measured branching ratios of the ^{13}C*(3854) level.

1961Ya02: ^{10}B(α,p), E=27.5,33.1 MeV; measured angular distributions of ground state protons.

1962Ed01: ^{10}B(α,p), proton groups have been observed to the first four states of ^{13}C.

1967Od01: The ground-state Q values of the reaction ^{10}B(α,p) was measured.

1968Ri16: ^{10}B(α,p), E=2.9 MeV; measured Doppler-shift attenuation. ^{13}C, ^{13}N levels, deduced $T_{1/2}$.

1969Ga01: ^{10}B(α,pγ), E=1.0-3.5 MeV; measured $\sigma(E;E_{\gamma})$.

1969He22: ^{10}B(α,p), E=4.5 MeV; measured $\sigma(E_{\gamma}, E(^{13}C))$. ^{13}C*(3.85) level deduced τ=10.7 ps *10*. Recoil distance method.

1969Li07: ^{10}B(α,pγ), E=5.15 MeV; measured E_{γ}, I_{γ}. ^{13}C levels deduced γ-branching. Ge(Li) detector.

1970Ga01: ^{10}B(α,pγ), E=1.96 MeV; measured $E_{\gamma}(\theta(\gamma)=0°)$, Doppler shift, recoil distance. ^{13}C*(3.85) deduced levels, τ=9.9 ps *9*.

1971HiZF: Studies of this reaction lead to $J^{\pi}=3/2^{-}$ and $5/2^{+}$ for ^{13}C*(3.68,3.85) states respectively.

1974WiZL: ^{10}B(α,p), E=2.1-10.75 MeV; measured σ(Ep).

1975Wi04: ^{10}B(α,p), E=2-10 MeV; measured σ(E,Ep,θ). Proton groups have been observed to the first four states of ^{13}C.

1980Wa24: ^{10}B(α,p), E=1.66 MeV; measured E_{γ}, I_{γ}, γγ-coin, γ(θ). ^{13}C level deduced $T_{1/2}$, levels, γ-branching, B(λ). Shell model.

1981Ki08: ^{10}B(α,p_{1}γ), E=2.563-3.064 MeV; measured $\sigma(\theta_{p})$. Legendre Polynomial analysis.

1983Cs03: ^{10}B(α,p_{1}γ), E=2.56-3.06 MeV; measured σ(E). See also (1983CsZY).

1983La17: ^{10}B(α,pγ), E=2.4 MeV; measured E_{γ}, I_{γ}, thick target γ yields.

1986Ba58: ^{10}B(α,p), E=2.3 MeV; measured $\sigma(E_{p})$, $\sigma(E_{\alpha})$. ^{13}C level deduced no neutral particle decay evidence, $\Gamma(\phi)/\Gamma_{\gamma}\leq 7\times 10^{-5}$; upper limit of 10^{-6}. Fundamental symmetries.

1987MiZY: ^{10}B(α,p), E=48 MeV; measured $\sigma(E_{p})$. ^{13}C deduced levels.

1988BrZY: ^{10}B(α,p), E=48 MeV; ^{13}C deduced levels, J, π.

1990JaZZ: ^{10}B(α,p), E=48 MeV; ^{13}C deduced level, possible T.

1991Br26: ^{10}B(α,p), E=48 MeV at 25° and 35°; measured particle spectra. ^{13}C deduced levels, possible isospin. Also reported the analog reaction ^{10}B(^{9}Be,^{6}Li) at E=40 MeV and θ=22.5° with low statistics. Compared with shell model predictions.

1995He40: ^{10}B(α,p), E=5.6-10 MeV; measured thick target γ yields; deduced γ production intensity distributions from materials related features.

1996Gi13: ^{10}B(α,p), E=4-5 MeV; measured $\sigma(E_{p},\theta)$ for p_{0-3} at θ_{lab}=135°.

1997He11: ^{10}B(α,p), E=5.6-10 MeV; measured thick target residuals yields; deduced reaction mechanism related features.

1999Ki29: ^{10}B(α,p), E=1.2-4.0 MeV; measured Doppler broadened E_{γ}, $I_{\gamma}(\theta)$; deduced proton distributions; analyzed energy dependence of angular distribution parameters.

2003Ch44: ^{10}B(α,p), E=1.4-5.3 MeV; measured Ep, σ(E,θ). Application to boron depth profiling discussed.

2019Li42: ^{10}B(α,p), E=2.2-4.9 MeV; measured secondary E_{γ}, γ-ray yields, used for troubleshooting during the experiment.

2020Li08: ^{10}B(α,pγ), E=835-1665 keV; measured E_{γ} and I_{γ}.

Theory:

2018Zh51: ^{10}B(α,p), E<10 MeV; analyzed available data; deduced σ, reaction rates. Comparison with TALYS calculations.

^{10}B(α,p),(α,pγ) (continued)

^{13}C Levels

E(level)[†]	J$^{\pi}$[&]	T$_{1/2}$ or Γ	Comments
0	$1/2^-$		Q$_0$=4130 keV *20* (1953Sh64), 4063.4 keV *24* (1967Od01).
3089.443[‡] *20*	$1/2^+$	<6.93 fs	T$_{1/2}$: from τ<10 fs (1968Ri16: Doppler shift method, ^{13}C(p,p′) and ^{12}C(d,p)). Total radiation width Γ_γ>0.066 eV (1968Ri16).
3684.482[#] *23*	$3/2^-$	<18.02 fs	T$_{1/2}$: from τ<26 fs (1968Ri16: Doppler shift, ^{13}C(p,p′) and ^{12}C(d,p)); see also τ<300 fs (1956Ma52: Doppler shift). Total radiation width Γ_γ>0.025 eV (1968Ri16). See also Γ_γ=0.40-0.75 eV (1960Ka13: 3.68→g.s. M1 transition).
3853.783[@] *22*	$5/2^+$	7.02 ps *+51−36*	T$_{1/2}$: from τ=10.13 ps *+73−52* which is the weighted value of τ=9.0 ps *+25−15* (1968Ri16: Doppler shift), τ_m=10.7 ps *10* (1969He22: recoil-distance method), τ_m=9.9 ps *9* (1970Ga01: recoil-distance method). See also 10.8 ps *10* (Fossan et al., Bull. Am. Phys. Soc. 13 (1968) 1387; ref. within 1970Ga01). Total radiation width Γ_γ=7.3×10^{-5} eV *16* (1968Ri16).
6860[b]			
7570[b]			
9500[a,b]			
10800[a,b]			E(level): unresolved in (α,p).
11850[a]			
11900[b]			
13010[a]			
13400[a,b]			E(level): unresolved in (α,p).
14080[a,b]		132[a] keV	J$^{\pi}$: shell model predicts J$^{\pi}$=7/2$^+$; However, the authors identified this strong state as the ^{13}C*(14.13; J$^{\pi}$=3/2$^-$) state seen in the ^{12}C(n,n) reaction (1985To02).
14819[a,b]			
15490[a]			E(level): unresolved in (α,p).
16080[a]			E(level): unresolved in (α,p).
17950[a]			
19560[a,c]			
20100[a,c]			
21400?[b]			T=(3/2,1/2) T: 3/2 is favorable over T=1/2 (1991Br26). Not strongly populated.
22520[a,c]			

[†] For each level in ^{13}C*(0,3.09,3.68,3.85 MeV) reported by references: 1953Sh64, 1954St20, 1956Ma52, 1960Ka13, 1960Pi09, 1967Od01, 1968Ri16, 1969He22, 1969Li07, 1970Ga01, 1975Wi04, 1980Wa24, 1983La17, 1995He40, 1996Gi13, 1997He11, 2007Ma58, 2020Li08.

[‡] From measured E$_\gamma$=3089.049 keV *20* with recoil energy E$_R$=394 eV where E$_i$-E$_f$=E$_\gamma$+E$_R$ (1980Wa24).

[#] From derived E$_\gamma$=3683.921 keV *23* with E$_R$=561 eV (1980Wa24).

[@] From derived E$_\gamma$=3853.170 keV *22* with E$_R$=613 eV (1980Wa24).

[&] From angular distributions and angular correlations in (1953Sh64,1954St20,1971HiZF).

[a] Reported in ^{10}B(α,p) (1991Br26).

[b] Reported in ^{10}B(^{9}Be,^{6}Li) (1991Br26).

[c] Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

^{10}B(α,p),(α,pγ) (continued)

γ(^{13}C)

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	δ	Comments
3089.443	1/2$^+$	3089.049 *20*		0	1/2$^-$	E1		E_γ: Measured in (1980Wa24). E_γ also reported in (1960Pi09, 1968Ri16, 1983La17, 1997He11, 2020Li08). Mult.: (1960Pi09).
3684.482	3/2$^-$	595.013 *11*	0.75 *4*	3089.443	1/2$^+$	E1		E_γ: Deduced in (1980Wa24). See also E_γ= 590 keV *15* (1960Ka13,1960Pi09). Mult.: (1960Ka13). I_γ: From (1980Wa24). See also Iγ=6.5×10^{-3} *10* (1960Ka13) and 9.3×10^{-3} 20 (1960Pi09).
		3683.921 *23*	99.25 *4*	0	1/2$^-$	E2+M1	−0.093 *9*	E_γ: Deduced in (1980Wa24). See also E_γ=3730 keV *60* (1953Sh64: transitions from 3.68 or/and 3.85→g.s.), 3690 keV *20* (1956Ma52). E_γ also reported in (1954St20: very weak except at the E_α(res)=1.51 MeV, where 16% of the total proton counts contributed to this decay, 1968Ri16, 1969Li07, 1983La17, 1997He11, 2007Ma58, 2020Li08). I_γ: From (1980Wa24). Mult.: (1980Wa24). See also (1960Ka13: M1). δ: from (1980Wa24: using B(E2)=3.63 *40* from (1970Wi04: ^{13}C(e,e′)) and τ_m=1.59 fs *13* from (1991Aj01)). Γ_γ=0.40-0.75 eV (1960Ka13: M1).
3853.783	5/2$^+$	169.300 *4*	36.3 *6*	3684.482	3/2$^-$	E1		E_γ: Measured in (1980Wa24). See also E_γ=210 keV *30* (1953Sh64: about 30% decays to g.s. via 3.68 state), 169.5 keV *4* (1956Ma52), 180 keV (1960Pi09), 170 keV (1983La17). I_γ: From (1980Wa24). See other values: I(3.85→3.68)/I(3.85→g.s.)=0.32 *7* (1960Pi09), 0.55 *3* (1969Li07). See also (1956Ma52: 3.85-MeV level decays through the 3.68-Mev level with a probability 0.24 *5*). Mult.: (1960Pi09;1956Ma52: though M1 is not excluded).
		764.316 *10*	1.20 *4*	3089.443	1/2$^+$	E2		E_γ: Measured in (1980Wa24). See also E_γ=765 keV *8* (1960Ka13,1960Pi09). I_γ: From (1980Wa24). See other reported values: I(3.85→3.09)/I(3.85→g.s.)= 9.3×10^{-3} *20* (1960Pi09), 2.5×10^{-2} *5* (1969Li07). Transitions to the 3.09 MeV not observed in (1956Ma52) with the intensity <3% concluded. Mult.: (1960Pi09).
		3853.170 *22*	62.5 *6*	0	1/2$^-$	M2		E_γ: Deduced in (1980Wa24). See also E_γ=3844 keV *15* (1956Ma52), 3854 keV *1* (1969Li07). E_γ also reported in (1960Pi09, 1968Ri16, 1983La17, 1995He40, 1997He11, 2007Ma58, 2020Li08).

Continued on next page (footnotes at end of table)

^{10}B(α,p),(α,pγ) (continued)

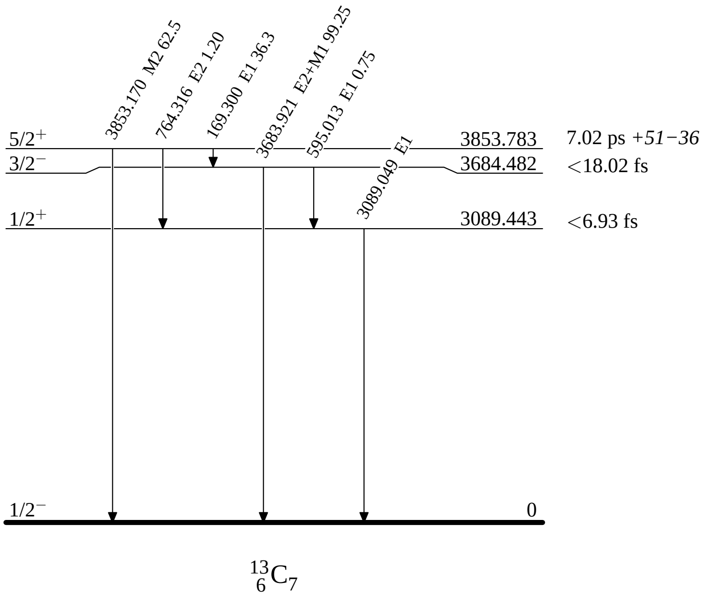
γ(^{13}C) (continued)

E$_i$(level)	E$_\gamma$	Comments
		I$_\gamma$: From (1980Wa24). See other reported values in (1960Pi09, 1969Li07) above and I(3.85→g.s.)/I(3.85→3.68→g.s.)=7:3 (1954St20). Mult.: (1960Pi09). Γ_γ(FWHM)=4.5 keV (1969Li07).

^{10}B(α,p),(α,pγ)

Level Scheme

Intensities: % photon branching from each level



^{10}B(^{6}Li,^{3}He)

1965Ca05: ^{10}B(^{6}Li,^{3}He), E≈5 MeV; differential cross sections were measured at 15 angles, θ_{lab}=0°-≈150°. ^{13}C states were observed. Analyzed σ vs. (2J+1) dependence.

1966Mc05: ^{10}B(^{6}Li,^{3}He), E=4.89 MeV; measured cross section at five angles from 0-60 degrees. The first four states of ^{13}C have been observed. Analyzed σ vs. (2J+1) dependence.

1974Ho06: ^{10}B(^{6}Li,^{3}He), E=18 MeV; measured σ(E(^{3}He),θ). Identified J, π and analog pairs of states in ^{13}C and ^{13}N. An angular distribution is also reported for ^{13}C*(9.50). See also (1972HoZN,1974HoZW).

^{13}C Levels

E(level)	J^{π}[#]	Γ[‡]	^{13}C total cross sections (mb)[@]	Comments
0[†]	$1/2^-$		0.48	
3090[†]	$1/2^+$		0.42	
3680[†]	$3/2^-$			E(level): unresolved with 3850 (1965Ca05,1966Mc05). ^{13}C total cross sections (mb): σ=22.2 mb for ^{13}C*(3680+3850).
3850[†]	$5/2^+$			E(level): unresolved with 3680 (1965Ca05,1966Mc05). ^{13}C total cross sections (mb): σ=22.2 mb for ^{13}C*(3680+3850).
6860[‡]	$5/2^+$			E(level): reported in (1965Ca05).
7490[‡]	$7/2^+$			J^{π}: identified as a mirror analog of ^{13}N*(7.17;J^{π}=$7/2^+$) from (1970Aj04).
7550[‡]	$5/2^-$	<30 keV		
7690[‡]	$3/2^+$	60 keV *30*		
8860[‡]	$1/2^-$			
9500[‡]	$(3/2^-)$	<30 keV		
9900[‡]	$3/2^-$			
10750[‡]	$7/2^-$			
10820[‡]	$5/2^-$			J^{π}: identified as a mirror analog of ^{13}N*(10.35;J^{π}=$5/2^-$) from (1970Aj04).
11000[‡]	$(1/2^+)$			
11080[‡]	$(1/2^-)$			
11950[‡]	$(7/2^-)$			
12110[‡]				
12440[‡]				

[†] Reported in (1965Ca05 and 1966Mc05: ΔE≈50 keV).

[‡] Reported in (1974Ho06).

[#] From (1970Aj04) and comparison of mirror state pairs populated in ^{10}B(^{6}Li,^{3}He) and (^{6}Li,t) in (1974Ho06).

[@] From (1966Mc05) based on data at five angles from 0°−60°.

^{10}B(^{7}Li,α)

1963Mi02: ^{10}B(^{7}Li,α), deduced ^{13}C level properties.
1965Ca05: ^{10}B(^{7}Li,α), E≈5 MeV; differential cross sections were measured at 15 angles, θ_{lab}=0°-≈150°. ^{13}C states were observed. Analyzed σ vs. (2J+1) dependence.
1966Mc05: ^{10}B(^{7}Li,α), E=5.20 MeV; measured cross section. ^{13}C states have been observed. Analyzed σ vs. (2J+1) dependence.
1977Ko27: ^{10}B(^{7}Li,α), E=24 MeV; measured $\sigma(\theta)$; deduced total absolute σ, reaction mechanism. Unresolved high-energy ^{13}C states up to 30 MeV; a detailed analysis of the angular distributions is not performed.

^{13}C Levels

E(level)†	^{13}C total cross sections (mb)†	Comments
0‡	0.37	
3090‡	0.20	
3680‡		E(level): unresolved with 3850. ^{13}C total cross sections (mb): σ=1.42 mb for ^{13}C*(3680+3850).
3850‡		E(level): unresolved with 3680. ^{13}C total cross sections (mb): σ=1.42 mb for ^{13}C*(3680+3850).
6860‡	1.19	
7500		E(level): unresolved with 7550, 7690. ^{13}C total cross sections (mb): σ=2.86 mb for ^{13}C*(7500+7550+7690).
7550		E(level): unresolved with 7500, 7690. ^{13}C total cross sections (mb): σ=2.86 mb for ^{13}C*(7500+7550+7690).
7690		E(level): reported (1966Mc05: ΔE≈50 keV). E(level): unresolved with 7500, 7550. ^{13}C total cross sections (mb): σ=2.86 mb for ^{13}C*(7500+7550+7690).
9500		
9900		
10460		
11000		E(level): unresolved with 11080.
11080		E(level): unresolved with 11000.
11950		E(level): unresolved with 12190, 12440.
12190		E(level): unresolved with 11950, 12440.
12440		E(level): unresolved with 11950, 12190.
13570		
16080		

† Values listed in (1966Mc05: ΔE≈50 keV), except where noted.
‡ From (1965Ca05).

^{10}B(^{10}B,^{13}C) 2023Je05

2023Je05: XUNDL dataset compiled by TUNL (2023).

Beams of 72.2 MeV ^{10}B ions from the Catania SMP Tandem accelerator impinged on 99.8% enriched ^{10}B targets. A set of four position-sensitive Si ΔE-E telescopes were positioned around the target to detect the reaction products. Three different configurations were utilized so that events with azimuthal angles in the range of 20° to 53° were measured.

Analysis of the ^{10}B(^{10}B,^{7}Be) singles events revealed well-resolved states up to $E_x\approx12$ MeV. Above this energy a smooth and increasing background was subtracted, revealing many states up to $E_x\approx22$ MeV. An energy resolution of FWHM≈300 keV for the peak widths suggests some observed peaks could represent unresolved doublets. A $\Gamma\approx600$ keV state at $E_x\approx19.15$ MeV appears to be a new state. The suggested members of a $K^{\pi}=3/2^{-}$ rotational band (2002Mi32,2003Mi34) are all observed.

The relative energy spectrum of ^{10}B(^{10}B,^{13}C$\rightarrow\alpha+^{9}$Be) events was analyzed by requiring detection of the $\alpha+^{9}$Be products. The ^{7}Be(0,0.429 MeV) levels populated with ^{13}C could not be separated, but the excited state component appears negligible. Participation of ^{7}Be(4.57 MeV) is observed and analyzed separately from the lower-energy ground-state component. A prominent peak at $E_x\approx19$ MeV is likely the new state mentioned above in the singles. result. Near threshold ($S_{\alpha}=10.65$ MeV) states at $E_x=10.8$ and 12.1 MeV were observed along with other weaker groups at $E_x=22$ and 24 MeV.

^{13}C Levels

E(level)	J^{π}[†]	$T_{1/2}$[‡]	Comments
0.0[‡] *3*			
3.0×10^{3}[‡] *1*			
3.78×10^{3}[‡&] *1*			E(level): Likely unresolved ^{13}C*(3.68+3.85 MeV).
6.75×10^{3}[‡] *4*			
7.50×10^{3}[‡&] *1*			E(level): Likely unresolved ^{13}C*(7.49+7.55 MeV).
9.48×10^{3}[‡] *2*			
9.89×10^{3}[‡] *4*	$3/2^{-}$		
10.78×10^{3}[‡#@&] *2*	$(5/2^{-})$		E(level): Reported at $E_x=10.8$ MeV *1* in ^{10}Be(^{10}Be,$\alpha+^{9}$Be). E(level): Likely unresolved ^{13}C*(10.75+10.81 MeV).
11.84×10^{3}[‡] *8*			
12.3×10^{3}[‡#@&] *1*	$7/2^{-}$		E(level): Reported at $E_x=12.1$ MeV *1* in ^{10}Be(^{10}Be,$\alpha+^{9}$Be). E(level): Likely unresolved ^{13}C*(12.19+12.44 MeV).
14.20×10^{3}[‡] *7*	$(9/2^{-})$		J^{π}: Spin suggested by level spacings.
19.15×10^{3}[‡#@] *4*		≈600 keV	Suggested new level. E(level): Reported at $E_x=19.0$ MeV *1* with $\Gamma\approx660$ keV in ^{10}Be(^{10}Be,$\alpha+^{9}$Be).
22.0×10^{3}[‡@] *3*			E(level): Reported at $E_x=21.9$ MeV *1* in ^{10}Be(^{10}Be,$\alpha+^{9}$Be).
23.6×10^{3}[#] *1*			E(level): From ^{10}Be(^{10}Be,$\alpha+^{9}$Be).

[†] Based on $K^{\pi}=3/2^{-}$ rotational band suggested in (2002Mi32,2003Mi34) deduced from level spacings.

[‡] From the inclusive ^{10}Be(^{10}Be,^{7}Be) reaction, except where noted.

[#] Observed in the exclusive ^{10}Be(^{10}Be,$\alpha+^{9}$Be)^{7}Be$_{g.s.}$ reaction.

[@] Observed in the exclusive ^{10}Be(^{10}Be,$\alpha+^{9}$Be)^{7}Be*(4.57) reaction.

[&] Possible doublet.

^{10}B(^{14}N,^{11}C)

1966Co27: $^{10}B(^{14}N,^{11}C)$, E=16.3,19.8 MeV. The proton transfers to both the ground state and the first excited state of ^{13}C were observed. Total cross sections were measured.

1975Na15: $^{14}N(^{10}B,^{11}C)$, E=100 MeV; measured $\sigma(\theta)$. ^{13}C levels deduced S-factors. See also (1976Na09: theory).

1979Mo14: $^{10}B(^{14}N,^{13}C)^{11}C$, S_1S_2=1.1 for $^{11}C_{g.s.}$

^{13}C Levels

E(level)†	J$^{\pi}$†	L transfer†	$C_2^2S_2$†	Comments
0	1/2$^-$	1,2	0.62	E(level): also reported in (1966Co27). $C_2^2S_2$: deduced from $C_1^2S_1C_s^2S_2$=0.68 (1975Na15) and assuming $C_1^2S_1$ given by (1967Co32).
3090	1/2$^+$			E(level): reported in (1966Co27).
3680	3/2$^-$	0,1,2	0.22	$C_2^2S_2$: deduced from $C_1^2S_1C_s^2S_2$=0.24 (1975Na15) and assuming $C_1^2S_1$ given by (1967Co32).
7550	5/2$^-$			
11850	7/2$^+$			

† From DWBA analysis in (1975Na15).

^{11}B(d,γ):res

1966Su05: ^{11}B(d,γ_0), 0.5<E<5.5 MeV; measured σ(E).
1972BlZU: ^{11}B(d,γ), E=1.5-4.2 MeV; measured σ(E;E$_\gamma$). ^{13}C deduced giant dipole resonance, level-width, J, π.
1973We12: ^{11}B(d,γ_0), E=1-4 MeV; measured σ(E,θ). ^{13}C deduced resonances. Enriched targets.
1981Ka16: ^{11}B(d,γ), E=1.95-12 MeV; measured σ(θ,E$_\gamma$), σ(θ,E). ^{13}C deduced resonances, Γ, possible GDR excitation. NaI(Tl) crystal spectrometer, plastic scintillator anticoincidence shield.
1982AuZX: ^{11}B(d,γ), E=4-17 MeV; measured γ(θ), E$_\gamma$, I$_\gamma$; deduced reaction mechanism.
1985Au10: ^{11}B(pol. d,γ), E=1.6-4 MeV; measured σ(E,θ), A(E,θ), T$_{20}$(E,θ). ^{13}C deduced doorway state parameters. Enriched targets. Secondary doorway state formalism. See also (1985AuZZ).
1991Co07: ^{11}B(d,$\gamma_{0,2+3}$), E=12 MeV; measured capture σ(θ); deduced reaction mechanism. Large anticoincidence NaI detectors.

See also (1969Fr03) ^{11}B(d,α) E=0.7-2.2 MeV.

^{13}C Levels

E(level)[†]	Γ	E$_d$(res) (keV)	Comments
20200 *70*	560 keV *90*		E(level),Γ: from (1985Au10).
20369 *85*	508 keV	2.0×10^3 *1*	E(level),Γ,E$_d$(res) (keV): from (1973We12). E(level): See also E$_x$=20400 keV *100* reported at E$_d$≈2000 keV (1981Ka16). Γ: from Γ$_{lab}$=600 keV (1973We12). See also (1981Ka16: Γ=600 keV).
20.57×10^3 *84*	5.64 MeV *43*		E(level),Γ: from (1985Au10).
22.0×10^3 *2*	≈1 MeV		E(level),Γ: from (1981Ka16). E(level): reported at E$_d$≈4000 keV.

[†] Where E$_d$(res) listed: E(level) are deduced using ^{13}C, ^{11}B and d masses from (2021Wa16: AME-2020) and E$_d$(res). E$_x$=S(^{2}H)+E$_{c.m.}$(relativistic).

^{11}B(d,p):res

1949Hu41: ^{11}B(d,p), E=0.3-1.85 MeV; no evidence of resonances.
1957Ja37: ^{11}B(d,p), E=0.2-1.8 MeV; cross sections were measured with no evidence of resonances.
1958Ka31: ^{11}B(d,pγ(15.1 MeV)), the thin-target yield indicates $E_{thresh.}$=1633 keV with resonances at E_d=2180 and 3080 keV. At E_d=1.5 MeV, $\sigma\approx$0.38 b.
1967Pf02: ^{11}B(d,p), the polarization of ^{12}B recoils has been studied for E_d=0.9 to 3.2 MeV: resonances in the recoil polarization are observed at E_d=1.5, 2.1 and 3.0 MeV.
1970Fi07: ^{11}B(pol. d,p), E=10, 12 MeV; measured analyzing power A(θ).
1971HiZG: ^{11}B(d,p), E=5.5 MeV; measured $\sigma(\theta)$, DSA. ^{13}C deduced levels, Γ, $T_{1/2}$, J, π.
1976Ta07: ^{11}B(d,p), E=1.3-3.0 MeV; measured polarization; deduced magnetic substate populations, J-mixing of transferred neutron, reaction mechanism.
1977AnZO: ^{11}B(d,p), E<1.4 MeV; measured absolute $\sigma(E,\theta)$.
1985Ab10: ^{11}B(d,p), E=3-10 MeV; measured σ(E).
1997Ya02: ^{11}B(d,p_0), E(cm)=76-144 MeV; measured energy spectra, $\sigma(\theta)$; deduced σ, astrophysical S-factor vs E.
1997Ya08: ^{11}B(d,p_0), E(cm)=57-141 keV; measured astrophysical S-factors.
2009Ko09: ^{11}B(d,p_0), E=900-1200 keV; measured $\sigma(\theta,E)$.

Theory:
1970Vo09: ^{11}B(d,p), E=0.7-3.5 MeV; analyzed $\sigma(\theta)$. DWBA.
1977Sa25: ^{11}B(d,p), E=1.3-3.0 MeV; calculated magnetic substate populations, optical model parameters. DWBA calculations.
1982Go05: ^{11}B(d,p), E=12 MeV; analyzed data. ^{13}C level deduced S-factors. DWBA, nuclear vertex constants.
2012Co01: ^{11}B(d,p), E<10 MeV; calculated astrophysical reaction rates. TALYS code, comparison with NACRE compilations.

^{13}C Levels

E(level)#	Γ	E_d(res) (keV)
19946†		1500†
20521‡ *10*	115‡ keV *10*	2180‡ 10
21282‡ *15*	160‡ keV *15*	3080‡ 15

† From (1967Pf02); authors identified with E_x=19.90 and also reported E_x=20.5 and 21.28 MeV.
‡ From (1958Ka31);
# Level energies are deduced using E_d(res) and ^{11}B, d and ^{13}C masses from (2021Wa16: AME-2020). E_x=S(^{2}H)+$E_{c.m.}$(relativistic).

^{11}B(d,nγ):res

1954Bu06: ^{11}B(d,n), E<2 MeV, angular distributions were measured. The authors suggest that the stripping process plays an important part in the reaction. No narrow resonances were observed in the excitation functions.
1955Ma76: ^{11}B(d,n), E=1.0-5.5 MeV; measured the absolute cross sections for the reaction.
1955Wa30: ^{11}B(d,n), E=600 keV, angular distributions of the neutron groups leading to the ground state and first excited state of ^{12}C, have been determined. For the excited-state group ^{12}C*(4.4), the interpretation is less clear; the observed distribution can be accounted for by p-wave formation of a $J^{\pi}=7/2^{+}$ level in ^{13}C.
1957Am48: ^{11}B(d,n), E=0.5-1.15 MeV; measured angular distributions of the ground-state neutrons from the reaction.
1958Ka31: ^{11}B(d,nγ), E$\leq$3.25 keV; measured σ. ^{13}C deduced resonance parameters at 20.52 MeV (Γ=115 keV *10*) and 21.28 Mev (Γ=160 keV *15*) at 2.180 MeV *10* and 3.080 MeV *15*, respectively.
1961Su17: ^{11}B(d,nγ), E_{γ}=15.1 MeV; E_{d}=1.3-5.6 MeV, deduced σ(E).
1964Ku09: ^{11}B(d,nγ), E_{d}=1.5-5.5 MeV; measured σ. ^{13}C deduced resonance parameters.
1965Al17: ^{11}B(d,nγ), E=1-11 MeV; measured $\sigma(E;E_{n},\theta)$. Natural, enriched targets.
1965Cl02: ^{11}B(d,n_{0}),(d,n), E=1.5-3 MeV; measured $\sigma(E,\theta)$. Natural target.
1967Di01: ^{11}B(d,n), E=1.1-2.9 MeV; measured $\sigma(E;E_{n})$. Enriched targets.
1971Ri19: ^{11}B(pol. d,n), E=900 keV; measured analyzing power(θ). ^{13}C deduced resonance, J, π. See also (1971RiZL).
1972Th14: ^{11}B(d,nγ), E=4-4.8 MeV, θ(n)=0°; measured $\sigma(E,E_{n},E_{\gamma},\theta(n\gamma))$; deduced stripping reduced width amplitudes. Natural, isotopic targets.
1981An16: ^{11}B(d,2n), E=7-16 MeV; measured σ(E), thick target yields. Activation technique. Statistical model, pre-equilibrium decay modes.
2001Ho23: ^{11}B(d,n), E=24-111 keV; measured σ, S-factor. Comparison with earlier data.
2006Pa27: ^{11}B(d,n), E=120-160 keV; measured E_{n}, yields, angular distributions; deduced astrophysical S-factors.
2013Co12: ^{11}B(d,n), E<5 MeV; measured reaction products, E_{γ}, I_{γ}; deduced thin and thick target yields, $\sigma(\theta)$. Comparison with available data.
See discussion on polarized neutron production in (1966Ma21, 1969Mi20, 1970Bu15, 1971Hi09, 1972Me06, 1974Th02, 1975Si22).

Theory:
1972Se09: ^{11}B(d,n), E=0.2-1.02 MeV; analyzed polarization effects, resonant matrix elements. Polarized beams.
1975Se07: ^{11}B(pol. d,n); analyzed data; deduced criteria for simplified polarization measurement analysis.
1977Se09: ^{11}B(pol. d,n); calculated A(θ).
2012Co01: ^{11}B(d,n), E<10 MeV; calculated astrophysical reaction rates. TALYS code, comparison with NACRE compilations.

^{13}C Levels

E(level)†	J^{π}	Γ	E_{d}(res) (keV)	Comments
19692	$5/2^{-}$		1200	E(level): from E_{d}=1200 keV (1967Di01: n_{1}); see also $E_{d}\approx$1 MeV (1972Se09). J^{π}: from polarization data in (1971Ri19); see also (1971Ri19, 1972Se09, 1975Se07, 1977Se09).
19904	$(3/2^{+},5/2^{+})$	$\approx$600 keV	1450	E(level): from E_{d}=1450 keV (1967Di01: n_{0}). J^{π}: from polarization data in (1971Ri19); see also (1977Se09). Γ: from Γ_{lab}=700 keV (1967Di01).
20030		200 keV	1600	E(level): from E_{d}=1600 keV (1965Al17: n_{0}); see also (1977Se09). Γ: from (1977Se09: proposed).
20200			1800	E(level): from E_{d}=1800 keV (1965Al17: n_{1}).
20521 *8*		116 keV *10*	2180 *10*	E(level): from E_{d}=2180 keV *10* (1958Ka31: $\gamma_{15.1\ MeV}$); see also E_{d}=2180 keV *20* (1964Ku09: $\gamma_{15.1\ MeV}$), and 2200 keV (1967Di01: n_{1}). Γ: weighted value from (1958Ka31: Γ_{cm}=115 keV *10*) and (1964Ku09: Γ_{lab}=140 keV *20*).
21281 *13*		159 keV *15*	3080 *15*	E(level): from E_{d}=3080 keV *15* (1958Ka31: $\gamma_{15.1\ MeV}$); see also 3080 keV *20* (1964Ku09: $\gamma_{15.1\ MeV}$). Γ: weighted value from (1958Ka31: Γ_{cm}=160 keV *15*) and (1964Ku09: Γ_{lab}=185 keV *20*).
21721?			3600	E(level): from E_{d}=3600 keV (1965Al17: n_{0}).

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^{11}B(d,nγ):res (continued)

^{13}C Levels (continued)

E(level)[†]	Γ	E_d(res) (keV)	Comments
21814 *17*	144 keV *21*	3710 *20*	E(level): from E_d=3710 keV *20* (1964Ku09). Γ: from Γ_{lab}=170 keV *25* (1964Ku09).
22198		4165	E(level): from average of E_d=4100 keV (1965Al17: n_1,n_2) and 4230 keV (1965Al17: n_0); see also 4400 keV (1964Ku09: $\gamma_{15.1\ MeV}$). Γ: broad (1964Ku09).
23073?		5200	E(level): from E_d=(5200) keV (1965Al17: n_1).
26791		9600	E(level): from E_d=9600 keV (1965Al17: n_0,n_1,n_2,n_3).
27466		10400	E(level): from E_d=10400 keV (1965Al17: n_0,n_2,n_3).

[†] Deduced from E_d(res), using ^{13}C, ^{11}B and d masses from (2021Wa16: AME-2020). E_x=S(^{2}H)+$E_{c.m.}$(relativistic).

^{11}B(^{3}He,p),(^{3}He,pγ),(α,d)

1955Bi26: ^{11}B(^{3}He,p), E=900 keV; measured particle spectra. ^{13}C deduced level energies.
1957Ga01: ^{11}B(^{3}He,p), E=1.25 MeV; spectra of charged particles were observed at θ=45°, 90° and 135° in a NaI-crystal spectrmeter. With the well known states ^{13}C*(0,3.097,3.684,3.844,6.864) calibrations, ten ^{13}C states were determined.
1957Ho61: ^{11}B(^{3}He,p), E=4.5 MeV; angular distributions have been measured for the p_0, p_1 and p_{2+3} groups at 14 angles θ=5°−130°. The p_0 group appears to be peaked in both the forward and the backward direction. The other groups do not exhibit a strong angular variation.
1958Mo99: ^{11}B(^{3}He,p), E≤1.25 MeV. With the well-known ^{13}C levels up to 6.87 Mev being used as calibrations, other levels of ^{13}C*(5.51,6.10,7.55,8.87,9.52,9.91 Mev) were reported. The levels at 5.51 and 6.10 Mev have not previously been detected.
1958Sw63: ^{11}B(^{3}He,p), E=6.05 MeV; the angular distributions of proton groups were investigated using 6 MeV Van de Graaff generator at AWRE, Aldermaston. The p_0 group is strongly peaked forward.
1959Yo25: ^{11}B(^{3}He,p), E=5.5 MeV. Q values corresponding to excitations of ^{13}C from 3.7 to 9.90 Mev were observed. Level widths were determined.
1963Ga03: ^{11}B(^{3}He,p), E=3.50 MeV; the proton spectrum was observed at θ=132.5°. Peaks corresponding to the ground state and to the well-established levels in ^{13}C at 3.09, 3.68, 3.85, 6.86, 7.47, 7.53, and 7.64 MeV are present.
1963Ma24: ^{11}B(^{3}He,p), E=8.6,9.6,10.3 MeV; angular distributions have been measured for p_0.
1964Ma57: ^{11}B(^{3}He,p), E=1.51 MeV; measured nuclear reaction Q_0 value at the National University of Mexico (UNAM).
1966Ch18: ^{11}B(^{3}He,p), E=1.23,1.50,2.00 MeV. Previously reported levels of ^{13}C*(5.51,6.10) have been found to come from the proton decay of the states of ^{13}N*(9.48,10.37) rather than from states in ^{13}C. ^{13}C states at E_x=3.09, 3.68, 3.85, 6.86 MeV were reported.
1967Od01: The ground state Q_0 value of the reaction ^{11}B(^{3}He,p) was measured as 13185.4 keV *40*.
1968Co27: ^{11}B(^{3}He,p), E=7.3 MeV; measured E_γ, pγ-coin. ^{13}C deduced levels, level-width, isobaric analog, γ-decay.
1969Ad01: ^{11}B(^{3}He,p)^{13}C*(15.11)→n+^{12}C, E=7 MeV; measured $\sigma(E_n)$. ^{13}C levels deduced n-decay branching, form of isospin impurity.
1970Me24: ^{11}B(^{3}He,p), E=3 MeV; measured σ, σ(E), $\sigma(\theta)$, E_γ, I_γ, Q, $\sigma(E_p,\theta)$. ^{13}C deduced levels and widths.
1971HiZF: Experimental studies of some excited levels of nuclei ^{12}B, ^{13}C, and ^{19}O: considerations on the mixtures of configurations and on the residual interaction. Values of Γ_γ/Γ=(0.3±0.1)%, <0.1% were given for ^{13}C*(7.49,7.55) states, respectively.
1971Me01: ^{11}B(^{3}He,p), E=2.8,3 MeV; measured $\sigma(E_p,\theta)$; deduced reaction mechanism. ^{13}C deduced levels, J, π. Natural, enriched target.
1971WuZY: ^{11}B(^{3}He,p), E=4-12 MeV; measured $\sigma(E;\theta)$.
1971WuZZ: ^{11}B(^{3}He,p), E=4,6,8,10,12 MeV; measured $\sigma(Ep,\theta)$. Zero-range DWBA analysis.
1973Ad02: ^{11}B(^{3}He,np), E=7.5,6.6 MeV; measured $\sigma(E_n,E_p,\theta(n),\theta(p))$, np-coin. ^{13}C deduced level-width(γ), level-width(n).
1973Wu01: ^{11}B(^{3}He,p), E=4,6,8,10,12 MeV; measured $\sigma(\theta)$. Enriched target.
1975Ma21: ^{11}B(^{3}He,pγ); measured pγ-coin.
1975Va19: ^{11}B(α,d), E=15-25 MeV.
1977Ma16: ^{11}B(^{3}He,pγ), E=5.3 MeV; measured particle γ-coin. ^{13}C levels deduced partial, total Γ, B(λ).
1975MaXS: ^{11}B(^{3}He,pγ), measured γ-spectra, proton decays. ^{13}C deduced levels.
1983Va28: ^{11}B(α,d), E=25-30 MeV; measured $\sigma(\theta)$; deduced reaction mechanism, optical model parameters, residual level production σ. ^{13}C levels deduced L. DWBA analysis.
1996Mc09: ^{11}B(^{3}He,p), E=2-4 MeV; measured $\sigma(E_p,\theta)$.

Theory:
1970Ma38: ^{11}B(^{3}He,p), calculated $\sigma(\theta)$.
1984Be23: ^{11}B(α,d), E=30.1 MeV; analyzed $\sigma(\theta)$; deduced optical model parameters, exchange process role.

^{13}C Levels

E(level)[†‡&]	Γ[#]	L[@]	Comments
0		0+2	
3090		1	
3685	<5 keV	0+2	E(level): unresolved (1958Mo99: E_x=3.74 MeV, 1977Ma16).
3854	<5 keV	1+3	E(level): unresolved (1958Mo99: E_x=3.74 MeV, 1977Ma16).

Continued on next page (footnotes at end of table)

^{11}B(^{3}He,p),(^{3}He,pγ),(α,d) (continued)

^{13}C Levels (continued)

E(level)[†][‡][&]	Γ[#]	L[@]	Comments
6871 *12*	<10 keV	1+3	E(level): from (1959Yo25). Branching ratio of the decay ^{13}C*(6.87 MeV)→^{12}C$_{g.s.}$+n=0.99 *9* (1973Ad02). See also Γ_n/Γ=1.05 *11* (1969Ad01).
7500 *12*	<5 keV		E(level): from (1959Yo25). E(level): unresolved (1958Mo99: E$_x$=7.55 MeV; 1973Wu01). Γ: Γ_γ/Γ=0.3% *1* (1971HiZF).
7554 *12*	<5 keV		E(level): from (1959Yo25). E(level): See also E$_x$=7580 *60* (1957Ga01) and 7550 *40* (1958Mo99). E(level): Unresolved (1973Wu01). Γ: Γ_γ/Γ<0.1% (1971HiZF).
7694 *14*	72 keV *10*	1+3	E(level): from (1959Yo25). Γ: weighted value of 75 keV *15* (1959Yo25) and 70 keV *10* (1970Me24).
8863 *30*	142 keV *30*		E(level): weighted value of 8850 keV *60* (1957Ga01), 8870 keV *50* (1958Mo99), 8869 keV *36* (1959Yo25) and 8860 keV *30* (1970Me24). Γ: weighted value of 175 keV *50* (1959Yo25) and 130 keV *30* (1970Me24).
9510 *12*	<10 keV		E(level): weighted value of 9540 keV *80* (1957Ga01), 9520 keV *60* (1958Mo99) and 9509 keV *12* (1959Yo25).
9898 *12*	<10 keV	0+2	E(level): weighted value of 9920 keV *60* (1957Ga01), 9910 keV *50* (1958Mo99), 9896 keV *12* (1959Yo25). Branching ratio of the decay ^{13}C*(9.899)→^{12}C$_{g.s.}$+n=1.0 *2* vs →^{12}C*(4.4)+n<0.15 (1973Ad02).
10460			E(level): from (1970Me24).
10760 *10*			E(level): from (1970Me24).
10820 *10*			E(level): from (1970Me24).
11006 *30*			E(level): weighted value of 10900 keV *150* (1957Ga01) and 11010 keV *30* (1970Me24).
11.10×10^3 *15*			E(level): from (1957Ga01).
11720			E(level): from (1973Ad02); see also E$_x$=11670 keV (1955Bi26). Branching ratio of the decay ^{13}C*(11.72)→^{12}C$_{g.s.}$+n=0.67 *16*; →^{12}*C(4.4)+n=0.33 *8* (1973Ad02).
12.08×10^3[a] *10*			E(level): from (1957Ga01).
12.81×10^3[a] *10*			E(level): from (1957Ga01).
15110	≈5.31 keV		T=3/2 (1969Ad01) Γ: (1968Co27) measured $\Gamma_{\gamma0}/\Gamma$=0.53% *6*. Using this and $\Gamma_{\gamma0}$(M1)=25 eV *7* from (1967Pe07:13C(e,e′)) and δ^2=E2/M1=0.009 *+18−8* (1968Di04: ^{12}C(p,γ)) they deduced Γ=4.7 keV. Γ: (1969Ad01) measured Γ_{n0}/Γ=0.065 *14* and Γ_{n1}/Γ=0.250 *36*. Γ: (1973Ad02) measured Γ_{n0}/Γ=0.070 *18*, Γ_{n1}/Γ=0.261 *30* and Γ_{n2}/Γ=0.026 *18*. Γ: (1975Ma21,1977Ma16) measured $\Gamma_{\gamma0}/\Gamma$=0.396% *30* and the relative γ_0, γ_1 and γ_{2+3} intensities. They combined with $\Gamma_{\gamma0}$(M1)=22.7 eV *27* from (1969Wi22,1970Wi04:13C(e,e′)) and δ^2=E2/M1=0.009 *+18−8* (1968Di04: ^{12}C(p,γ)) to obtain $\Gamma_{\gamma0}$(M1)=22.7 eV *26*, $\Gamma_{\gamma0}$(E2)=0.59 eV *11*, $\Gamma_{\gamma1}$=4.12 eV *74*, $\Gamma_{\gamma_{2+3}}$=18.2 eV *24* and $\Gamma_{\gamma(7.55\ \mathrm{MeV})}$<0.9 eV. They deduced Γ=5.88 keV.

[†] Values listed in, for example, (1977Ma16) except where noted.

[‡] For levels reported, see (1955Bi26, 1957Ga01, 1958Mo99, 1959Yo25, 1963Ga03, 1964Ma57, 1966Ch18, 1967Od01, 1968Co27, 1969Ad01, 1970Me24, 1971HiZF, 1971Me01, 1973Ad02, 1973Wu01, 1975Ma21, 1977Ma16).

[#] From (1959Yo25) except where noted.

[@] From (1973Wu01).

[&] Levels at E$_x$=5.50 MeV and 6.10 MeV were reported by (1957Ga01, 1958Mo99) based on the observed proton energy; however, these levels were misidentified. They result from the decay of proton unbound levels populated in ^{11}B(^{3}He,n)^{13}N*; see (1966Ch18).

[a] Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

^{11}B(^{3}He,p),(^{3}He,pγ),(α,d) (continued)

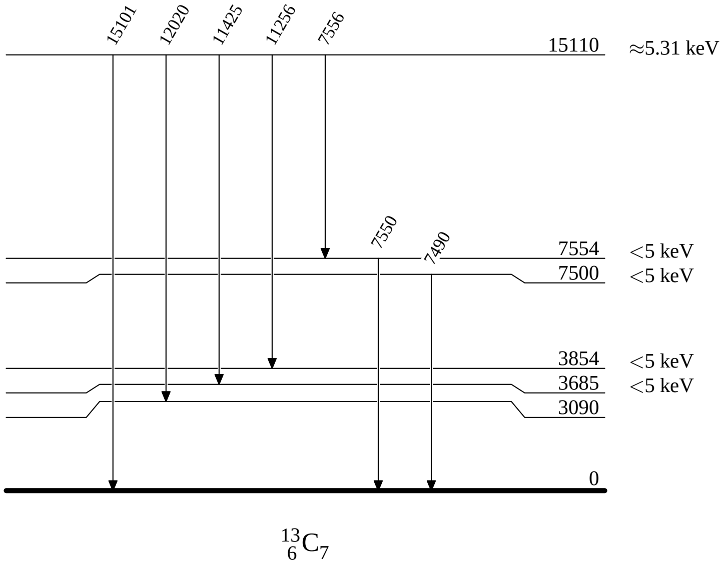
γ(^{13}C)

E_γ†	E_i(level)	E_f	Comments
7490	7500	0	E_γ: Γ_γ/Γ=0.3% *1* (1971HiZF).
7550	7554	0	E_γ: Γ_γ/Γ<0.1% (1971HiZF).
7556	15110	7554	
11256	15110	3854	Unresolved.
11425	15110	3685	Unresolved.
12020	15110	3090	
15101	15110	0	$\Gamma_{\gamma0}/\Gamma$=0.53% *6* (1968Co27); $\Gamma_{\gamma0}/\Gamma$=0.396% *30* (1975Ma21,1977Ma16).

† See (1968Co27,1969Ad01,1973Ad02,1975Ma21,1977Ma16) except where noted.

^{11}B(^{3}He,p),(^{3}He,pγ),(α,d)

Level Scheme



^{11}B(^{6}Li,α)

1965Ca05: ^{11}B(^{6}Li,α), E≈5 MeV; measured differential cross sections were measured at 15 angles in the laboratory. ^{13}C states were observed. Analyzed σ dependence on J.

1966Mc05: ^{11}B(^{6}Li,α), E=4.72 MeV; measured cross section. ^{13}C states have been observed.

^{13}C Levels

E(level)†	σ(mb)†	Comments
0‡	0.36	
3090‡	0.23	
3680‡		E(level): unresolved with 3850. σ(mb): σ=1.91 mb for ^{13}C*(3680+3850).
3850‡		E(level): unresolved with 3680. σ(mb): σ=1.91 mb for ^{13}C*(3680+3850).
6860‡	1.16	
7500		E(level): unresolved with 7550, 7690. σ(mb): σ=2.27 mb for ^{13}C*(7500+7550+7690).
7550		E(level): unresolved with 7500, 7690. σ(mb): σ=2.27 mb for ^{13}C*(7500+7550+7690).
7690		E(level): unresolved with 7500, 7550. σ(mb): σ=2.27 mb for ^{13}C*(7500+7550+7690).
8860		
9500		
9900		

† From (1966Mc05).

‡ Reported in (1965Ca05).

^{12}C(n,γ):E=thermal

1953Ba18: ^{12}C(n,γ), measured thermal neutron capture radiation from carbon, in addition to the 4948 keV *8* ground state γ ray previously reported, E_{γ}=3.68 Mev *5* was also found.

1958Gr01: ^{12}C(n,γ), measured thermal neutron capture radiation E_{γ}=4950 keV 15, 3680 keV *20* and 1260 keV *15*; deduced I_{γ}.

1958Hu18: ^{12}C(n,γ), measured thermal capture cross sections as 3.3 mb *2*.

1961Ja19: ^{12}C(n,γ), measured thermal neutron capture radiation E_{γ}; deduced I_{γ}.

1964St25: ^{12}C(n,γ), measured thermal capture cross sections as 3.4 mb *3*.

1965Ja09: ^{12}C(n,γ), the neutron separation energy for the reaction was determined by measuring the γ-ray transitions: E_{γ}=4946 keV *1* implies S_n=4947.0 keV *10*.

1967Pr10: ^{12}C(n,γ), Deduced S_n=4946.28 keV *17* from analysis of $E_{\gamma0}$=4945.46 keV *17*, $E_{\gamma1}$=1261.92 keV *6* and E_{γ}(3864→0)=3683.94 keV *17*. Ge(Li) detector.

1967Ra24: ^{12}C(n,γ), E=thermal; measured E_{γ}; deduced Q. Natural targets.

1967Th05: ^{12}C(n,γ), measured thermal neutron capture radiation E_{γ}; deduced I_{γ}(4945)=66 *3* per 100 decays; I_{γ}(3685)=34 *2* and I_{γ}(1262)=34 *2*.

1968Sp01: ^{12}C(n,γ), E=thermal; measured E_{γ}=1261.76 keV *7*, I_{γ}=32 *1* per 100 decays; E_{γ}=3684.28 keV *I14*, I_{γ}=32 *1*; E_{γ}=4945.8 keV *6*, I_{γ}=68 *1*; Q=4946.03. keV *15*.

1972Op01: ^{12}C(n,γ), E=thermal; measured E_{γ}, I_{γ}, used as calibration line. Ge(Li), NaI detectors.

1973Mu14: ^{12}C(n,γ), measured thermal capture cross section as 3.4 mb *3*.

1974Sp04: ^{12}C(n,γ); measured E_{γ}; deduced Q=4946.2 keV *4*.

1975Sm02: ^{12}C(n,γ), deduced Q from rf spectrometer mass measurement.

1978Ha14: ^{12}C(n,γ), deduced Q from double focusing mass spectrometer measurement; result implies S_n=4946.320 keV *50*.

1981MuZQ: ^{12}C(n,γ), E=thermal; measured σ(capture), ratio.

1981Pr04: ^{12}C(n,γ), E=thermal; measured thermal capture cross section on ^{nat}C as σ=3.50 mb *16*.

1982Ju01: ^{12}C(n,γ), E=thermal; measured E_{γ}, I_{γ}, at LANL Omega West reactor. Reported the thermal capture cross section as σ=3.53 mb *7*. Deduced I_{γ}(4946)=68.6 *9* per 100 decays and I_{γ}(3684)=31.0 *4*; implies I_{γ}(1261)≈31.4 *9*. Additionally, they observed a ground state decay from ^{13}C(3089) with I_{γ}(3089)/I_{γ}(4946)≈0.006.

1982Mu14: ^{12}C(n,γ), E=thermal; measured E_{γ}, I_{γ} using a 55 cm^3 Ge-Li detector at Chalk River. For six transitions they deduced I_{γ}(4945.32)=67.47 *92* per 100 decays; I_{γ}(1856.6 keV *4*)=0.16 *1*; I_{γ}(1261.6 keV *1*)=32.36 *44*; I_{γ}(3684.0 keV *2*)=32.14 *64*; I_{γ}(595.5 keV *2*)=0.24 *1* and I_{γ}(3089.5 keV *4*)=0.43 *2*. Notably, I_{γ}(3089)/I_{γ}(4946)≈0.00597 in agreement with (1982Ju01). Analyzed capture mechanism.

1982Va13: ^{12}C(n,γ). Measured γ rays from ^{1}H(n,γ):E=thermal. Using this value, the Q-values for various reactions, such as ^{12}C(n,γ) were evaluated and associated γ-ray energies were calculated.

1983Co09: ^{12}C(n,γ), deduced Q from analysis of atomic mass data.

In (1986Aj01) the E_{γ} values 4946.397 keV *31*, 1261.854 keV *6* and 3684.516 keV *30* are credited to van der Leun, et al., Neutron-Capture Gamma-Ray Spectroscopy and Related Topics 1981, London, No. 62 (1981) 548.

2008FiZZ and unpublished EGAF (Evaluated Gamma-ray Activation File) data: ^{12}C($n_{th.}$,γ), E=thermal; measured $\sigma(E_{\gamma})$, deduced I_{γ}.

The authors measured thermal neutron capture reactions on several natural and enriched isotopic targets at the 10-MW Budapest Reactor. Yields were normalized to a limited set of standard targets, with the aim of improving absolute capture cross sections and transition probabilities. The capture γ rays from a graphite powder target were measured using a single Compton suppressed 27% HPGe detector. The relative γ intensities were normalized primarily to the ^{1}H(n,γ) (σ_{γ}=332.5±0.7 mb) cross section. The transition probabilities and cross sections were deduced by balancing the intensity feeding and deexciting each state. the neutron separation energy. S_n=4946.32 keV *6* is deduced along with σ=3.87 mb *3*.

For six transitions the unpublished Budapest data used for EGAF gives: I_{γ}(4945.30 keV *7*)=68.6 *20* per 100 decays; I_{γ}(1856.98 keV *22*)=0.193 *40*; I_{γ}(1261.71 keV *6*)=31.2 *8*; I_{γ}(3684.02 keV *7*)=29.7 *10*; I_{γ}(595.16 keV *9*)=0.274 *25* and I_{γ}(3088.80 keV *21*)=0.373 *56*.

2016Fi06: XUNDL dataset compilded by TUNL, 2016.

The authors combined their EGAF data with other literature results to obtain a set of recommended values. Because the (2016Fi06) data are folded with other results, they are a resource for comparison. The present evaluation develops a different set of recommended reaction parameters based solely on reported ^{12}C($n_{th.}$,γ) data.

For six transitions they deduced I_{γ}(4945.30 keV *7*)=67.8 *4* per 100 decays; I_{γ}(1856.98 keV *22*)=0.0162 *9*; I_{γ}(1261.71 keV *6*)=32.1 *4*; I_{γ}(3684.02 keV *7*)=32.0 *4*; I_{γ}(595.16 keV *9*)=0.0248 *9* and I_{γ}(3088.80 keV *21*)=0.041 *12*. Noteably, I_{γ}(3089)/I_{γ}(4946)≈0.00060 is in disagreement with (1982Ju01) and (1982Mu14); the three weak transitions are reported with intensities that are 10 times lower than (1982Mu14). Comparison with (2008FiZZ) suggests the discrepancy is a typo, but the

^{12}C(n,γ):E=thermal (continued)

collection of associated works contains many inconsistencies.

Theory:
1980Gr02: Analyzed S_n.
1981MuZQ: ^{12}C(n,γ), E=thermal; Z=1-60; compiled, evaluated thermal neutron induced σ, resonance parameter data.
1983Ho17: ^{12}C(n,γ), E=thermal; calculated radiative capture σ; deduced potential, resonance scattering interference effects.
1987Ly01: ^{12}C(n,γ), E=thermal; calculated capture σ. Optical model, Lane-Lynn-Raman method.
1999ZhZM: ^{12}C(n,γ), E=thermal; compiled, evaluated prompt γ-ray data.
2000ZhZP: ^{12}C(n,γ), E=thermal; compiled, analyzed prompt E_γ, I_γ.
2002Re13: ^{12}C(n,γ), E=thermal; compiled, analyzed prompt E_γ, I_γ.
2003MoZU: ^{12}C(n,γ), E=thermal; compiled, analyzed k_0 factors and capture σ, neutron binding energies.
2003MuZZ: compiled, analyzed thermal neutron capture σ.
2004Ma76: ^{12}C(n,γ), E=thermal; analyzed data; deduced k_0 factors, γ-emission probabilities.
2011Sl01: ^{12}C(n,γ), E=thermal; compiled, evaluated σ, $\sigma(E_\gamma)$, γ decay schemes, levels, J, π using ENDF, DICEBOX.
2021Si17: ^{12}C(n,γ), E=thermal−0.86 MeV; calculated σ, reaction rates using TALYS nuclear model code.

^{13}C Levels

E(level)†	J^π	Comments
0	1/2$^-$	J^π: see (1953Ba18,1967Pr10,1967Th05,1968Sp01,1982Mu14,2016Fi06). Q_0=4946.32 keV *6* (2016Fi06), 4946.336 keV *14* (1983Co09), 4946.337 keV *20* (1982Va13); for earlier values see (1965Ja09, 1967Th05, 1968Sp01, 1974Sp04, 1975Sm02, 1978Ha14, 1980Wa24).
3089.30 *8*	1/2$^+$	J^π: see (1982Mu14,2016Fi06).
3684.52 *5*	3/2$^-$	J^π: see (1967Pr10, 1967Th05, 1968Sp01, 1982Mu14, 2016Fi06); see also (1953Ba18: (1/2$^-$,3/2$^-$)).
4946.33 *5*	1/2$^+$	E(level): see (1953Ba18, 1958Gr01, 1961Ja19, 1965Ja09, 1967Pr10, 1967Th05, 1968Sp01, 1972Op01, 1980Wa24, 1982Ju01, 1982Mu14, 1982Va13, 1986Ke14). J^π: see (1967Th05,1968Sp01,1982Mu14,2016Fi06).

† From least squares fit to Eγ.

$\gamma(^{13}$C)

E_γ‡	I_γ†#	E_i(level)	J^π_i	E_f	J^π_f	Comments
595.22 *8*	0.24 *1*	3684.52	3/2$^-$	3089.30	1/2$^+$	E_γ,I_γ: See I_γ(*595.5 keV *2*)=0.24 *1* (1982Mu14) and I_γ(*595.16 keV *9*)=0.274 *25* (2008FiZZ); I_γ<0.6 (1967Th05).
1261.74 *4*	32.36 *44*	4946.33	1/2$^+$	3684.52	3/2$^-$	E_γ,I_γ: See I_γ(*1261.6 keV *1*)=32.36 *44* (1982Mu14), E_γ=*1261.92 *6* (1967Pr10), E_γ=*1261.7 *4* (1972Op01: from 1261.9 *4*, the Eγ recoil corrected value given in the text), E_γ=1261.847 *33* (1980Wa24: deduced), E_γ=1261.765 *28* (1983Ra04: listed as a calibration line) I_γ(*1261.71 *6*)=31.2 *8* (2008FiZZ), I_γ(1260 *15*)=25 (1958Gr01), I_γ(1270)=30 (1961Ja19), I_γ(1262)=34 *2* (1967Th05), I_γ(*1261.61 *7*)=32 *1* (1968Sp01: from 1261.76 *7*, the Eγ recoil corrected value given in the test), $\sigma(\gamma)$=1.14 mb *2*, S-factor(dp)=0.1 with R=2.91 fm (1982Mu14).
1856.89 *19*	0.16 *1*	4946.33	1/2$^+$	3089.30	1/2$^+$	E_γ,I_γ: See I_γ(*1856.6 keV *4*)=0.16 *1* (1982Mu14) and I_γ(*1856.98 keV *22*)=0.193 *40* (2008FiZZ).
3088.95 *19*	0.43 *2*	3089.30	1/2$^+$	0	1/2$^-$	E_γ,I_γ: see I_γ(*3089.5 keV *4*)=0.43 *2* (1982Mu14) and I_γ(*3088.80 keV *21*)=0.373 *56* (2008FiZZ). If 3.1 MeV γ-ray occurs, its intensity is ≤0.10 γ/capture (1953Ba18).
3683.96 *6*	32.14 *64*	3684.52	3/2$^-$	0	1/2$^-$	E_γ,I_γ: See I_γ(*3684.0 *2*)=32.14 *64* (1982Mu14), E_γ(*3683.94 *17*) (1967Pr10), E_γ=3683.915 *15* (1990Wa22: deduced value). I_γ(*3684.02 *7*)=29.7 *10* (2008FiZZ), I_γ(3680 *50*)=30 (1953Ba18), I_γ(3680 *20*)=25 (1958Gr01), I_γ(3680)=31

Continued on next page (footnotes at end of table)

^{12}C(n,γ):E=thermal (continued)

γ(^{13}C) (continued)

E_γ[‡]	I_γ[†#]	E_i(level)	J^π_i	E_f	J^π_f	Comments
						(1961Ja19), I_γ(3684)=34 *2* (1967Th05), I_γ(3684)=31.0 *4* (1982Ju01), I_γ(*3683.72 *14*)=32 *1* (1968Sp01: from 3684.28 *14*, the Eγ recoil corrected value given in the text). If 3.9 MeV γ-ray occurs (transition 3850→0), its intensity is <0.06 γ/capture (1953Ba18).
4945.32 *6*	67.47 *92*	4946.33	1/2$^+$	0	1/2$^-$	E_γ,I_γ: See I_γ(4945.32)=67.47 *92* (1982Mu14), E_γ=4946 *1* (1965Ja09), E_γ=*4945.46 *17* (1967Pr10), E_γ=4945.328 *20* (1982Va13: deduced from Q_0), I_γ(*4945.30 *7*)=68.6 *20* (2008FiZZ), I_γ(4948 *8*)=70 (1953Ba18), I_γ(4950 *15*)=75 (1958Gr01), I_γ(4946)=69 (1961Ja19), I_γ(4945)=66 *3* (1967Th05: I_γ<0.2 for capture state→3848 transition), I_γ(*4944.8 *6*)=68 *1* (1968Sp01: from 4945.8 *6*, the Eγ recoil corrected value given in the text), I_γ(4946)=68.6 *9* (1982Ju01), I_γ(4945)=68.4 *5* (1986Ke14). $\sigma(\gamma)$=2.38 mb *5*, S-factor(dp)=1.1 with R=2.91 fm (1982Mu14).

† From (1982Mu14).

‡ From average of values listed with *.

\# Intensity per 100 neutron captures.

^{12}C(n,γ):E=thermal

Legend

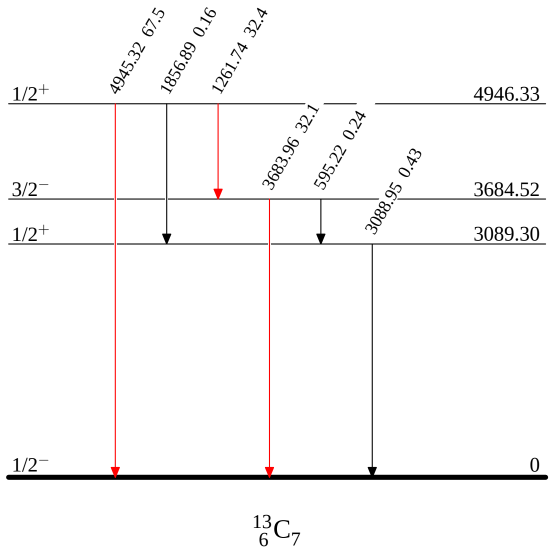
Level Scheme

Intensities: I_γ per 100 neutron captures

I_γ < 2%×I_γ^{max}

I_γ < 10%×I_γ^{max}

I_γ > 10%×I_γ^{max}



^{12}C(n,γ):res

1950Ki68: ^{12}C(n,γ), E=slow; measured E_γ, I_γ.

1963Ma60: ^{12}C(n,γ), E≈30,65 keV; measured neutron radiative capture cross sections for Z≤92.

1975Ar19: ^{12}C(n,γ_0), E=14 MeV; measured γ-yields, $I_\gamma(\theta)$. There is an indication γ_0 peaks at backward angles.

1984Wo05: ^{12}C(n,γ_0),(pol. n,γ_0), E=12-18.8 MeV; measured $\sigma(\theta)$, analyzing power for $\theta\approx50°-140°$. Deduced states at E_x=16-21.75 MeV. Combined analysis with other data indicates a secondary doorway state. Deduce a_1, a_2, b_1, b_2 from Legendre fit.

1985AuZZ: ^{12}C(n,γ), E=6.5-18.5 MeV; measured $\sigma(\theta)$. ^{12}C(pol. n,γ), E=12-18.8 MeV; measured analyzing, vector analyzing power vs θ. ^{13}C deduced resonances, doorway characteristics.

1986Be17: ^{12}C(n,γ), E=7-19.5 MeV; measured $\sigma(E,\theta=90°)$. Deduced $T_<$=1/2 giant resonance at E_x=20.8 MeV with $\Gamma\approx2.5$ MeV along with lower unresolved strength near $E_n\approx$ 10 MeV identified as the *pygmy* resonance. DSD model.

1987Au02: ^{12}C(n,γ), E=6.5-18.5 MeV; measured $\sigma(E,\theta)$, $\theta=90°$. Pygmy and giant resonance region. Direct-semidirect calculations.

1988McZT: ^{12}C(n,γ), Analysis of $\sigma(E_n)$.

1989Hu15: ^{12}C(n,γ), E=14.2 MeV; measured $\gamma(\theta)$; deduced γ-multipolarity. Direct-semidirect model.

1990Ha19: ^{12}C(n,γ), E=8-11 MeV; measured $\sigma(\theta=90°)$ in the Pygmy and giant resonance region.

1990Ma52: ^{12}C(n,γ), E<46 keV; measured effective capture σ(E); deduced Maxwellian averaged σ.

1991Hu05: ^{12}C(n,γ), E=7-14 MeV; measured $\sigma(\theta)$ vs E, E_γ, I_γ, $\gamma(\theta)$. Analyzed pygmy resonance.

1991Na06,1991Na19: ^{12}C(n,γ), E=30 keV, stellar energy; measured capture σ, Eγ, Iγ; deduced nucleosynthesis implications.

1992Wi08: ^{12}C(pol. n,γ), E=20-35 MeV; measured $\gamma(\theta)$, A_y vs E, γ(recoil)-coin; deduced E2, E1 capture interference. Direct semidirect model. Deduce a_1, a_2, b_1, b_2 from Legendre fit.

1994Oh02, 1996Na27: ^{12}C(n,γ), E=10-250 keV; measured E_γ, I_γ, σ(E); deduced Maxwellian averaged σ and astrophysical implications.

1998Ki09: ^{12}C(n,γ), E=550 keV; measured E_γ, I_γ; deduced partial capture σ. Deduced spectroscopic factor of ^{13}C(3.09 MeV).

1999Oh04: ^{12}C(n,γ), E≈42 keV; measured capture σ(E), E_γ, I_γ.

2008Oh05: XUNDL dataset compilded by Compiled by McMaster, 2008.

E(n)=10-80 keV neutrons produced in the reaction ^{7}Li(p,n) reaction using the 3.2 MV Pelletron accelerator at the Tokyo Institute of Technology. Measured Eγ, Iγ, $\gamma\gamma$ coin using anti-Compton NaI(Tl) spectrometer, time-of-flight method. Non-resonant study.

Theory:

1971Al33,1971AlYV: ^{12}C(n,γ), E≈30 keV; compiled experimental Maxwellian averaged σ; deduced empirical correlation between σ and nucleosynthesis abundances.

1974Ma10: ^{12}C(n_0,γ), analyzed isospin splitting in the giant dipole resonance.

1986Li16: ^{12}C(pol. n,γ), E≤9 MeV; calculated polarization effects.

1987LyZY: ^{12}C(n,γ), E=slow; analyzed data; deduced model parameters, capture mechanism.

1990Wa22: ^{12}C(n,γ), ^{13}C analyzed data; deduced calibration γ-energies. Proposed E_γ=3683.915 keV *15* for transition 3.684→0.

1991Ho18: ^{12}C(n,γ), E=threshold−30 keV; calculated σ; deduced reaction mechanism.

1993Ho06: ^{12}C(n,γ), E≈8-20 MeV; analyzed $\sigma(\theta)$ vs E; deduced GDR, resonance parameters. Unified formalism.

1994Ot04: ^{12}C(n,γ), E<0.5 MeV; calculated σ(E); deduced S-factor. Kinematically complete approach.

1995Li31: ^{12}C(n,γ), E≈6-20 MeV; calculated capture $\sigma(\theta)$ vs E. Direct-semidirect model.

1995Me14: ^{12}C(n,γ), E≤500 keV; calculated capture σ(E). Direct capture model.

1996Re16: ^{12}C(n,γ), analyzed inverse Coulomb dissociation reaction and relevance for astrophysical input.

1997Du09: ^{12}C(n,γ), E(cm)≤0.5 MeV; calculated capture σ(E). Calculated levels, B(λ), rms radius vs R(c). Multicluster approach.

1997Li10: ^{12}C(n,γ), E<600 keV; calculated σ(En); deduced influence of scattering potential depth. Consistent direct-semidirect model.

1997Ti03: analyzed vertex constants for capture reactions.

1998Ki01: ^{12}C(n,γ), E<1 MeV; calculated σ; deduced optical potential features.

1999MeZW: ^{12}C(n,γ), E<0.8 MeV; analyzed capture σ; deduced parameters.

2003Wu01: ^{12}C(n,γ), E=0-1 MeV; calculated σ. Asymptotic normalization coefficient method, comparison with data.

2004Ba62: ^{12}C(n,γ), E=0-0.6 MeV; calculated S-factors, σ(E) for radiative capture. Taylor expansion.

2004Hu10: ^{12}C(n,γ), E=low; calculated astrophysical reaction rate, resonance effects.

2009Wa17: ^{12}C(n,γ), E(cm)<1 MeV; analyzed σ, spectroscopic factors and other parameters for nonresonant neutron capture using simple polynomials obtained from Taylor expansions. Comparison with experimental data.

2010Hu11: ^{12}C(n,γ), E(cm)<2 MeV; calculated binding energies, σ, S-factors, spectroscopic factors. Single-particle potential model.

2012Pr13, 2020Pr08: ^{12}C(n,γ), E<20 MeV; calculated Maxwellian-averaged σ,astrophysical reaction rates, neutron thermal σ,

^{12}C(n,γ):res (continued)

Westcott factors, resonance integrals.
2013Di12: ^{12}C(n,γ), E<20 MeV; analyzed available data; deduced recommended σ, k_{eff}.
2013Du08: ^{12}C(n,γ), E<1 MeV; calculated σ, low-energy phase shifts. Potential cluster model, comparison with available data.
2013Du16: ^{12}C(n,γ), E<1 MeV; calculated σ, phase shifts. Young diagrams, potential cluster model.
2017HaZY: ^{12}C(n,γ), E=0-0.2 MeV; calculated σ.
2018Br05: ^{12}C(n,γ), E=30 keV; calculated Maxwellian-averaged σ.

^{13}C Levels

E(level)†	J^{π}	Γ	Comments
0	1/2⁻		
20520 *70*		510 keV *70*	E(level),Γ: from the analyzing power data in (1984Wo05): secondary doorway state.
21050 *60*		4.2 MeV *4*	E(level),Γ: from the analyzing power data in(1984Wo05): primary doorway state. See also E_x≈20.81 MeV and Γ≈2.5 MeV in (1986Be17).

† (1986Be17) also observed an unresolved broad peak at E_n(res)≈10 MeV (E_x≈14180 keV).

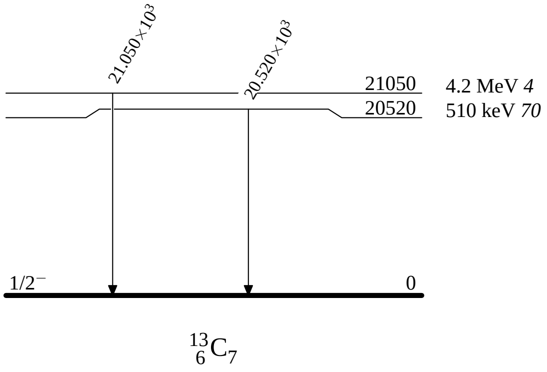
γ(^{13}C)

E_γ†	E_i(level)	E_f	J^{π}_{f}
20.520×10^{3}	20520	0	1/2⁻
21.050×10^{3}	21050	0	1/2⁻

† From level energy difference.

^{12}C(n,γ):res

Level Scheme



^{12}C(n,n):res

1950Fr61: C(n,x), E=530 keV-4.8 MeV; measured total σ via transmission study.
1951Bo45: ^{12}C(n,n), E=1-3.3 MeV; measured the total σ; resonances were observed around E_n=2.08 and 2.95 MeV.
1953Ne01: C(n,x), E=2.6-13.9 MeV; measured σ(E); several broad resonances are observed.
1956Be98: C(n,x), E=4.3-8.7 MeV; measured σ(E). Peaks are observed around E_n=4.95, 5.4, 7.8 MeV.
1957Bo13: C(n,n), E=3.8-8.1 MeV; measured the total σ of C. Several peaks are observed. Table of σ(E) is given.
1958Wi36: ^{12}C(n,n), E=1.45-4.10 MeV; measured angular distributions, deduced resonances, J, Γ.
1960Br13: ^{12}C(n,n), E=5.6 MeV; the differential elastic scattering cross sections for carbon have been obtained for θ=30° to 150°.
1960Hu02: ^{12}C(n,n), E_n=500 to 1350 keV. Measured the total σ in search of resonances. No resonances were observed within the 5% accuracy.
1960Ts02: ^{12}C(n,n), E=3.3-5.0 MeV; several resonances in the cross sections were analyzed to give spin assignments.
1961Bo06: ^{12}C(n,n), E=15-120 MeV; measure rather structureless neutron total cross section at high energies.
1961Fo07: ^{12}C(n,n), E=3.4-16 MeV; observed several sharp peaks in the total σ; deduced E_x, Γ, J.
1963Pi03: ^{12}C(n,n), the elastic scattering of neutrons by ^{12}C has been investigated at low energies.
1963Se13: ^{12}C(n,n), E=3-660 keV; measured total σ via transmission method. No structures were observed.
1964Ma46: C(n,X), E=7.0-14.3 MeV; measured total σ; Presented table of σ(E).
1965Ha21: ^{12}C(n,n), E=17-21 MeV; measured total σ(E) and $\sigma(E,\theta)$ for θ=36°, 51°, 60°, 86°, 123.5° and 139°. Report peak at 19.5 MeV (Γ≈1.1 MeV) in $\sigma(E,\theta)$ data and at 19.6 MeV (Γ≈1.2 MeV) in σ(E).
1966Li03: ^{12}C(n,n), E=3.0-4.7 MeV; measured differential cross sections, level parameters were determined for ^{13}C(8.2,8.9).
1968Bo34: ^{12}C(n,nγ), E=14-25 MeV; measured $\sigma(E,\theta)$ for θ=30°, 39.2°, 54.7° and 90°. Deduced high-lying resonances.
1969Da13: ^{12}C(n,X), E=3-8 MeV; measured σ(E). ^{13}C deduced resonances at ^{13}C(9.5, 9.9, 10.75, 12.1 MeV).
1970CiZY: C(n,X), E=0.5-30 MeV; measured total σ(E). Deduced resonance parameters.
1970De14: ^{12}C(n,n), E=17-20.5 MeV; measured $\sigma(E;En',\theta)$ for θ≈10° to 150°. Deduced optical model parameters, E_x=23 MeV resonance energy, J, π.
1970UtZZ: C(n,X), E=70 eV-1.5 MeV; measured σ(E); analyzed levels.
1972Ga13: C(n,n), E=3-7 MeV; measured $\sigma(E;\theta)$ for θ=16.3° to 157°; σ(E) tables provided; deduced phase shifts. Deduced J, π, Γ for levels between E_x=8.3 to 11 MeV.
1973Ab07: ^{12}C(n,n), E=1.98-4.64 MeV; measured $\sigma(E;\theta)$ for θ=30° to 150°. Deduced resonances, L, J, π, Γ.
1973Fa06: ^{12}C(n,n), E=2.1-4.7 MeV; measured σ(E), $\sigma(E,\theta)$; calculated phase shifts, polarization P(E,θ). Deduced E_x, Γ.
1973Ho39: ^{12}C(n,n), E=2-5 MeV; θ(lab)=20°−150°; measured P(E,θ); R-function, phase-shift analyses.
1973Kn06: ^{12}C(n,n), E=2.63 MeV; measured total σ, $\sigma(\theta)$ for $\theta_{c.m.}$≈20° to 130°, n-polarization. Deduced phase shifts. The influence of narrow states at E_x=7.50 and 7.55 MeV is discussed.
1975He02: ^{12}C(n,X), E=1 keV-15 MeV; measured total σ. Deduced resonance energies.
1979Sm08: ^{12}C(n,n), E=1.5-4.0 MeV; measured total s(E), $\sigma(\theta)$ for θ≈15° to 175°. Deduced R-function parameters. Multilevel R-matrix analysis.
1980Th07: ^{12}C(n,n),(pol n, n′) E=15-18.25 MeV; measured $\sigma(E,\theta)$, $A_y(\theta)$. Mainly focused on ^{13}C, but includes OM analysis finding a dominant $f_{5/2}$ resonance at E_n=15.7 MeV *2* with Γ=0.6 MeV (E_x≈19.4 MeV); the fit was improved by including a $d_{3/2}$ resonance at E_n=15.4 MeV *2* with Γ≈2.2 MeV (E_x≈ 19 MeV).
1980Ci03: C(n,X), E=3-30 MeV; measured total σ. Deduced resonances, Γ, T. Tof. Breit-Wigner analysis.
1983Wo02: ^{12}C(pol. n,n),(pol. n,n′) E=8.9-14.9 MeV; measured $A_y(\theta)$ for θ=30° to 150°.
1985To02: ^{12}C(pol. n,n), E=8.91-12 MeV; measured $\sigma(\theta)$ for θ≈30° to 170°, analyzed $A_y(\theta)$ from (1983Wo02) and other literature data to carry out a phase-shift analysis. Deduced σ(E), J, π.
1987Hi03: ^{12}C(n,X),(n,n), E≤22 MeV; measured total σ(E), transmission. Deduced resonance energies, Γ, Γ_{n0}. Discussed isospin and likely ^{13}C T=3/2 states at $^{13}C^{*}$(15.1, 17.5, 18.1, 20.1 and 21.7 MeV) along with suggested analog states in ^{13}B.
1987To03: ^{12}C(pol. n,n), E=15.55-17.35 MeV; measured analyzing power vs θ. ^{13}C deduced levels, J, π. Phase-shift analysis. Authors indicate more data are needed to further support their results.

Theory:
1968Da31: ^{12}C(n,n), E<5 MeV; analyzed available data; deduced σ, single effective ranges.
1971ClZV: ^{12}C(n,n), E below inelastic threshold; calculated σ(E). ^{13}C levels calculated 2p-1h contributions.
1971Gr48: ^{12}C(n,n), E=4.4 MeV; analyzed P(n). ^{13}C resonance deduced parity.
1971LeZG: ^{12}C(n,n), E not given; calculated $\sigma(\theta)$, P(θ), phase shifts. ^{13}C calculated resonances, level-width, J, π.
1971We08: ^{12}C(n,n), E=0.5-4 MeV; calculated σ(E). ^{13}C resonances deduced S.
1971WeZQ: ^{12}C(n,n), E not given; analyzed σ(E). ^{13}C deduced resonance parameters. R-matrix, potential-resonance method.

^{12}C(n,n):res (continued)

1972Mo45: ^{12}C(n,n), E<4.4 MeV; calculated σ(E). ^{13}C calculated binding energy. Coupled-channel method.
1972Ro07,1972Ro08: ^{12}C(n,n), E<5 MeV; calculated σ(E). ^{13}C calculated levels. Feshbach, R-matrix theories; shell model, particle-rotator model.
1973Co27: ^{12}C(n,n); calculated σ(E). ^{13}C calculated levels.
1973Le02: ^{12}C(n,n), E<5 MeV; calculated $\sigma(E;\theta)$. ^{13}C calculated levels, level-width.
1981Az01: ^{12}C(n,n), E=1.9-5.2 MeV; calculated P(θ). ^{13}C resonances deduced Γ_n. Reaction matrix method.
1981KnZY: ^{12}C(n,n), E not given; analyzed data. ^{13}C levels deduced J, π. R-matrix.
1981KnZZ: ^{12}C(n,n), E not given; analyzed data. ^{13}C level deduced tentative J, π, configuration. R-matrix.
1982Kn02: ^{12}C(n,n), E=0.0-9 MeV; analyzed data. ^{13}C deduced levels, J, π, reduced widths. R-matrix analysis, comparison to model predictions.
1983To19: ^{12}C(n,n), E=7.03-8.56 MeV; analyzed phase-shift data. ^{13}C levels deduced J, π, Γ.
1986ToZY: ^{12}C(pol. n,n), E=12-17 MeV; analyzed data. ^{13}C deduced resonances. Phase-shift analysis.
1991Io01: ^{12}C(n,n), E=0.9-10 GeV/c; calculated σ vs beam momentum; deduced collective dual diffractive resonances role.
2003Am08: ^{12}C(n,n), E=0-5 MeV; calculated elastic σ, polarization, resonance effects. Sturmian expansions of multichannel interactions. Comparison with data.
2004Ke08: ^{12}C(n,n), E=7.5 MeV; calculated $\sigma(\theta)$. Comparisons with data.
2005Ch58: ^{12}C(n,n), E=7-26 MeV; compiled, analyzed $\sigma(\theta)$, analyzing power, total σ. ^{13}C deduced level and resonance parameters. Phase-shift analysis, comparison with previous results.
2005Pi16: ^{12}C(n,n), E$\approx$0-5 MeV; analyzed elastic σ. ^{13}C deduced sub-threshold bound state and resonance features. Multichannel algebraic scattering theory.
2005WaZV: ^{12}C(n,n), E<3 GeV; analyzed σ.
2006Oh02: analyzed E_x/S_n systematics.
2009We04: ^{12}C(n,n), analyzed σ, $\sigma(\theta)$.
2010Na18: ^{12}C(n,n), calculated σ, $\sigma(\theta)$, analyzing powers, phase shifts. No-core shell model, resonating-group method (NCSM/RGM). Comparison with experimental data.
2012Pr13: ^{12}C(n,n), E<20 MeV; calculated Westcott factors, resonance integrals and their uncertainties.
2016Fr09: ^{12}C(n,n), E<6.5 MeV; calculated elastic and reaction σ(E), deduced effect of particle-emitting resonances on the scattering cross section.
2017HaZY: ^{12}C(n,n), E=0-6.45 MeV; calculated σ, $\sigma(\theta)$, analyzing power.
2017Lo02: ^{12}C(n,n), E=17.29 MeV; analyzed differential $\sigma(\theta)$ data.
2018We08: ^{12}C(n,n), E=75 MeV; calculated $\sigma(\theta)$, σ; deduced optical model parameters.
2019Bl07: ^{12}C(n,n), E=0.050-1.040 MeV; calculated asymptotic normalization coefficients (ANC) for excited s-states in ^{13}C.

^{13}C Levels

E(level)†	J^{π}‡	Γ	L	E_n(res) (keV)	Comments
3090					E(level): see (1963Se13) who determined the relative reduced width for this bound $2s_{1/2}$ state; θ^2=0.20 *2*. They also set upper limits on widths for a proposed state at E_x=(5510) keV with $\Gamma_n\leq$0.01 keV.
6864 *3*	5/2$^+$	6.9 keV	2	2079 *3*	E(level): from E_{res}=2079 keV *3* (1975He02); see also E_{res}(keV)=2076 *8* (1958Wi36), 2077 *3* (revised value from 1968Da31) and (1951Bo45,1963Pi03,1970CiZY,1973Ab07,1973Ho39). J^{π}: from (1958Wi36,1963Pi03,1973Ab07); see also $J^{\pi}\geq$3/2 (1951Bo45), 5/2 (1970CiZY). Γ: average of Γ_{lab}(keV)=7 (1958Wi36), 7.9 (1963Pi03), $\Gamma_{c.m.}$=7 keV (1973Ab07); see also $\Gamma_{c.m.}\leq$11 keV (1951Bo45), Γ_{lab}=9 keV (1970CiZY). L: from (1963Pi03,1970CiZY,1973Ab07); see also L>0 (1951Bo45). The dimensionless single particle reduced width, θ^2=0.006 (1958Wi36).
7546 *5*	(5/2)	1.2 keV *3*	2	2819 *5*	E(level): from E_{res}=2819 keV *5* (1975He02); see also (1950Fr61,1970CiZY). J^{π},L: from (1970CiZY). Γ: from (1975He02). See also Γ_{lab}=7 keV (1970CiZY).
7658 *9*	3/2$^+$	124 keV *7*	2	2940 *10*	E(level): from E_{res}=2940 keV *10* (1973Fa06); see also (1951Bo45,

Continued on next page (footnotes at end of table)

^{12}C(n,n):res (continued)

^{13}C Levels (continued)

E(level)†	J^{π}‡	Γ	L	E_n(res) (keV)	Comments
					1958Wi36, 1970CiZY, 1973Ab07, 1973Ho39). J^{π}: from (1958Wi36,1973Ab07); see also J^{π}=3/2 (1951Bo45,1970CiZY). Γ: from (1973Fa06); see also Γ(keV)=120 (1951Bo45), 100 (1973Ab07), Γ_{lab}=90 keV (1958Wi36). L: from (1973Ab07,1970CiZY); see also L=1,2 (1951Bo45). θ^2=0.038 (1958Wi36).
8220 *40*	$3/2^+$	1026 keV *15*	2	3530 *40*	E(level): from the unweighted average of E_{res}=3472 keV *15* (1973Fa06) 3520 keV *50* (1960Ts02), 3600 keV *50* (1966Li03). See other results in (1950Fr61, 1958Wi36, 1961Fo07, 1970CiZY, 1972Ga13, 1973Ab07, 1973Ho39). J^{π}: from (1958Wi36, 1966Li03, 1972Ga13, 1973Ab07); see also J^{π}=3/2 (1961Fo07,1970CiZY). Γ: weighted average of 1050 keV *100* (1966Li03) and 1025 keV *15* (1973Fa06); see also Γ_{lab}=1690 keV (1958Wi36), $\Gamma_{c.m.}$(keV)=700 (1961Fo07), 900 (1973Ab07). Γ_n/Γ>0.99 (1966Li03), Γ_{n0}/Γ=1.00 (1972Ga13). L: from (1970CiZY,1973Ab07). θ^2=0.51 (1958Wi36), 0.35 (1966Li03).
8874 *14*	$1/2^-$	205 keV *15*	1	4259 *15*	E(level): from E_{res}=4259 keV *15* (1973Fa06); see also E_{res}(keV)=4320 *50* (1960Ts02), 4250 *20* (1966Li03), 4260 *20* (1972Ga13) and (1950Fr61, 1961Fo07, 1970CiZY, 1973Ab07, 1973Ho39). J^{π}: from (1966Li03,1972Ga13,1973Ab07); see also J^{π}=$1/2^+$ (1960Ts02), 1/2 (1961Fo07,1970CiZY). Γ: weighted average of 180 keV *50* (1966Li03), 200 keV*40* (1972Ga13: lab value), 210 keV *15* (1973Fa06); see also Γ(keV)≈300 (1960Ts02), 220 (1961Fo07), 180 (1973Ab07). Γ_n/Γ>0.99 (1966Li03), Γ_{n0}/Γ=1.00 (1972Ga13). L: from (1970CiZY,1973Ab07). θ^2=0.03 (1966Li03).
9499.71 *6*	$(9/2^+)$	1.72 keV *8*	1	4937.07 *7*	E(level): from E_{res}=4937.07 keV *7* (1980Ci03: Table 2); see also E_{res}(keV)=4940 *10* (1960Ts02), 4935 *4* (1969Da13), 4940 *11* (1975He02) and (1956Be98, 1961Fo07, 1970CiZY, 1972Ga13). J^{π}: from (1982Kn02); see also J^{π}≥1/2 (1961Fo07,1970CiZY), $(1/2^-,3/2^-)$ (1972Ga13), $(5/2^-)$ (1980Ci03). Γ: from (1980Ci03); see also Γ(keV)≈20 (1960Ts02), ≤10 (1961Fo07), Γ_{lab}=14 keV (1970CiZY). Γ_{n0}=1.60 keV *4* (1980Ci03), Γ_{n0}/Γ=1.00 (1972Ga13). L: from (1972Ga13).
9894.50 *17*	$3/2^-$	23.7 keV *4*	1	5365.21 *18*	E(level): from E_{res}=5365.21 keV *18* (1980Ci03: Table 5b); see also E_{res}(keV)=5368 *5* (1969Da13), 5378 *13* (1975He02) and (1956Be98, 1961Fo07, 1970CiZY, 1972Ga13). J^{π}: from (1972Ga13); see also J^{π}>1/2 (1956Be98), ≥3/2 (1961Fo07), 3/2 (1970CiZY). Γ: derived from (1980Ci03); see also Γ=30 keV (1961Fo07), Γ_{lab}=30 keV (1970CiZY). Γ_{n0}=20.6 keV *5* (1980Ci03), Γ_{n0}/Γ=0.70 *10* (1972Ga13). L: from (1970CiZY,1972Ga13).
10753.73 *30*	$7/2^-$	50.9 keV *6*	3	6297.07 *32*	E(level): from E_{res}=6297.07 keV *32* (1980Ci03: Table 5b); see also E_{res}(keV)=6294 *5* (1969Da13), 6295 keV *16* (1975He02) and (1953Ne01, 1957Bo13, 1961Fo07, 1970CiZY, 1972Ga13). J^{π}: from (1972Ga13); see also J^{π}>1/2 (1953Ne01), ≥7/2 (1961Fo07, 1970CiZY).

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^{12}C(n,n):res (continued)

^{13}C Levels (continued)

E(level)†	J^{π}‡	Γ	L	E_n(res) (keV)	Comments
					Γ: from (1980Ci03); see also Γ=65 keV (1961Fo07), Γ_{lab}=55 keV (1970CiZY). Γ_{n0}=43.4 keV *9* (1980Ci03), Γ_{n0}/Γ=0.70 *10* (1972Ga13). L: from (1972Ga13).
10812.8 *6*		18.1 keV *10*		6361.1 *6*	E(level): from E_{res}=6361.1 keV *6* (1980Ci03: Table 5b). Γ: from (1980Ci03). Γ_{n0}=4.7 keV *3* (1980Ci03).
10941?				6500	E(level): from E_{res}=6500 keV (1961Fo07).
10994 *7*	(1/2^{+})		0	6558 *8*	E(level): from E_{res}=6558 keV *8* (1972Ga13); see also E_{res}=6570 keV (1961Fo07). J^{π},L: from (1972Ga13). Γ_{n0}/Γ=0.40 *10* (1972Ga13).
11076.01 *18*		4.0 keV *4*		6646.71 *20*	E(level): from E_{res}=6646.71 keV *20* (1980Ci03: Table 5b); see also E_{res}=6700 keV (1961Fo07). J^{π}: (1980Ci03) identified with the E_x=11080 keV; J^{π}=(1/2^{-}) state in (1976Aj04). Γ: from (1980Ci03). Γ_{n0}=2.52 keV *16* (1980Ci03).
11725 *46*	3/2^{-}	129 keV *40*		7350 *50*	E(level): from E_{res}=7350 keV *50* (1983To19). J^{π},Γ: from (1983To19). Γ_{n0}/Γ=0.80 *8* and γ^2=29 keV *7* (1983To19).
11973 *90*	5/2^{+}	494 keV *80*		7620 *90*	E(level): from E_{res}=7620 keV *90* (1983To19). J^{π},Γ: from (1983To19). E_n(res) (keV): see also E_{res}=(7400) keV (1961Fo07: identified with the E_x=11870 keV; J^{π}=(7/2^{-}) state). J^{π}: see also J^{π}=(≥5/2) (1961Fo07). Γ: see also Γ=(250) keV (1961Fo07). Γ_{n0}/Γ=0.51 *6* and γ^2=100 keV *12* (1983To19).
12071.9 *19*	(3/2^{-})	81.5 keV *33*		7726.8 *21*	E(level): from E_{res}=7726.8 keV *21* (1980Ci03: Table 5b). J^{π},Γ: from (1980Ci03). Γ_{n0}=69.0 keV *30* (1980Ci03).
12120 *70*	3/2^{+}	538 keV *65*		7759 *8*	E(level): From E_{res}=7780 keV *80* (1983To19); see also E_{res}=7759 keV *8* (1969Da13); 7730 (1961Fo07). J^{π}: from (1983To19); see also J^{π}=(≥7/2) (1961Fo07). Γ: from (1983To19); see also Γ=(200) keV (1961Fo07). Γ_{n0}/Γ=0.28 *5* and γ^2=58 keV *12* (1983To19).
12130 *46*	5/2^{-}	77 keV *30*		7790 *50*	E(level): from E_{res}=7790 keV *50* (1983To19). J^{π},Γ: from (1983To19). Γ_{n0}/Γ=0.43 *6* and γ^2=29 keV *7* (1983To19).
12139 *65*	1/2^{+}	426 keV *70*		7800 *70*	E(level): from E_{res}=7800 keV *70* (1983To19). J^{π},Γ: from (1983To19). Γ_{n0}/Γ=0.50 *7* and γ^2=49 keV *10* (1983To19).
12268 *65*	3/2^{-}	186 keV *50*		7940 *70*	E(level): from E_{res}=7940 keV *70* (1983To19). J^{π},Γ: from (1983To19). Γ_{n0}/Γ=0.73 *8* and γ^2=36 keV *9* (1983To19).
12434 *46*	7/2^{-}	114 keV *40*		8120 *50*	E(level): from E_{res}=8120 keV *50* (1983To19). J^{π},Γ: from (1983To19). Γ_{n0}/Γ=0.42 *6* and γ^2=39 keV *9* (1983To19). See also E_{res}=(8100) keV; J^{π}=(≥1/2); Γ=(150) keV (1961Fo07).
13568	7/2^{-}	619 keV *50*		9350	E(level): from E_{res}=9350 keV (1985To02); see also E_{res}=9300 keV (1961Fo07). J^{π}: from (1985To02); see also J^{π}=(≥1/2) (1961Fo07). Γ: from (1985To02); see also Γ=370 keV (1961Fo07). Γ_{n0}/Γ=0.18 *3* (1985To02).
14167	3/2^{-}			10000	E(level): from E_{res}=10000 keV (1985To02). J^{π}: from (1985To02).
14997	7/2^{-}			10900	E(level): from E_{res}=10900 keV (1985To02). J^{π}: from (1985To02).

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^{12}C(n,n):res (continued)

^{13}C Levels (continued)

E(level)[†]	J^{π}[‡]	Γ	L	E_n(res) (keV)	Comments
15108.2 *12*	3/2$^-$				T=3/2 (1987Hi03) E(level): from E_{res}(c.m.)=10161.9 keV *12*(1987Hi03). J^{π}: from (1987Hi03). Γ_{n0}=0.34 keV *9* (1987Hi03: weak resonance anomaly).
15273	9/2$^+$			11200	E(level): from E_{res}=11200 (1985To02). J^{π}: from (1985To02). See also E_x=15181 keV from E_{res}=11100 keV, Γ=450 keV and J≥3/2 in (1961Fo07).
15458	3/2$^-$			11400	E(level): from E_{res}=11400 (1985To02). J^{π}: from (1985To02).
16103	(≥1/2)	230 keV		12100	E(level): from E_{res}=12100 keV (1961Fo07). J^{π},Γ: from (1961Fo07). See discussion in (1985To02) where an unresolved pair of states with J^{π}=7/2$^+$ and 5/2$^-$ are suggested near E_x=16 MeV.
17533 *3*		17 keV *6*			T=(3/2) (1987Hi03) E(level): from E_{res}(c.m.)=12587 keV *3* (1987Hi03). Γ: from (1987Hi03); (J+1/2)Γ_{n0}/Γ=14% *3* (1987Hi03).
18081 *3*		12 keV *7*			T=(3/2) (1987Hi03) E(level): from E_{res}(c.m.)=13135 keV *3* (1987Hi03). Γ: from (1987Hi03); (J+1/2)Γ_{n0}/Γ=11% *4* (1987Hi03).
19512	5/2$^-$	≥500 keV	0,1	15800	E(level): from E_{res}=15800 keV (1968Bo34,1987To03). J^{π}: from (1987To03); see also J^{π}=1/2 (1968Bo34). Γ: from (1987To03); see also Γ=500 keV (1968Bo34). L: from (1968Bo34).
20057 *4*		11 keV *8*			T=(3/2) (1987Hi03) E(level): from E_{res}(c.m.)=15111 keV *4* (1987Hi03). Γ: from (1987Hi03); (J+1/2)Γ_{n0}/Γ=15% *8* (1987Hi03).
20111	1/2$^-$	1090 keV		16450	E(level): from E_{res}=16450 keV (1987To03). J^{π},Γ: from (1987To03). Γ_{n0}/Γ=0.16 (1987To03).
20111	5/2$^+$	440 keV		16450	E(level): from E_{res}=16450 keV (1987To03). J^{π},Γ: from (1987To03). Γ_{n0}/Γ=0.05 (1987To03).
20185	7/2$^+$	630 keV		16530	E(level): from E_{res}=16530 keV (1987To03). J^{π},Γ: from (1987To03). Γ_{n0}/Γ=0.11 (1987To03).
20296	7/2$^-$	1560 keV		16650	E(level): from E_{res}=16650 keV (1987To03). J^{π},Γ: from (1987To03). Γ_{n0}/Γ=0.08 (1987To03).
20342	9/2$^+$	320 keV		16700	E(level): from E_{res}=16700 keV (1987To03). J^{π},Γ: from (1987To03). Γ_{n0}/Γ=0.06 (1987To03).
20526	5/2$^-$	≈500 keV		16900	E(level): from E_{res}=16900 keV (1987To03). J^{π},Γ: from (1987To03).
21703 *4*		18 keV *9*			T=(3/2) (1987Hi03) E(level): from E_{res}(c.m.)=16757 keV *4* (1987Hi03). Γ: from (1987Hi03); (J+1/2)Γ_{n0}/Γ=21% *6* (1987Hi03).
23.00×10^3 *19*	5/2$^+$,1/2$^-$,3/2$^-$,7/2$^-$	≈1.5 MeV	0,1		E(level): weighted average of 23.0 MeV *2* (1970De14) and 22.99 MeV *19* (1964Ha36,1965Ha21: using E_{res}=19.55 MeV *20*

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^{12}C(n,n):res (continued)

^{13}C Levels (continued)

E(level)[†]	J^{π}[‡]	Γ	L	E_n(res) (keV)	Comments
					which is the average of 19.5 MeV *2* and 19.6 MeV *2*); see also E_{res}=19500 keV (1968Bo34). J^{π}: $5/2^-$ is concluded in (1970De14); yet they are unable to eliminate ($1/2^-$, $3/2^+$, $7/2^-$); see also J^{π}=1/2 (1968Bo34). Γ: average of Γ(MeV)=2.0 (1968Bo34), 1.1 (1965Ha21), 1.2 (1965Ha21), 1.6 (1970De14). L: from (1968Bo34).

[†] Level energies are deduced using ^{12}C, ^{13}C and n masses from (2021Wa16: AME-2020) and the resonance energy E_n(res) except where noted. $E_x=S_n+E_{c.m.}$(relativistic).

[‡] Values determined in (1973Ab07,1972Ga13,1983To19,1985To02,1987To03) are via a phase-shift analysis of available data.

^{12}C(n,p):res

1953Ke50: ^{12}C(n,p), E=90 MeV; measured different reaction channels using cloud-chamber and β-activity counting. Deduced σ, σ(E).
1958Kr65: ^{12}C(n,p), E=17.5 MeV, measured σ= 29.1 mb *40*.
1959Kr69: ^{12}C(n,p), E=14.9-17.5 MeV; measured products; deduced σ, σ(E) using activation technique. No resonances reported. Deduced ^{12}B lifetime.
1968Ri02: ^{12}C(n,p), E=14.5-22 MeV, measured σ(E). ^{13}C deduced resonances. Natural target.
1972Bo73: ^{12}C(n,p), E=16-18 MeV; measured σ(E).
1975Mc19: ^{12}C(n,p), E=56 MeV; measured $\sigma(\theta)$.
1979RoZV: C(n,p), E=27.4,39.7,60.7 MeV; measured σ(E,Ep,θp).
1979SuZR: ^{12}C(n,p), E=27.4, 39.7, 60.7 MeV; measured σ(E,θ); deduced reaction mechanism.
1981NeZY: ^{12}C(n,p), E=60 MeV; measured σ(Ep), $\sigma(\theta)$; deduced reaction mechanism.
1982De16: ^{12}C(pol. n,p), E=18 MeV; measured ^{12}B β-decay asymmetry.
1983Su07: ^{12}C(n,pX), E=27.4,39.7,60.7 MeV; measured $\sigma(\theta$,Ep).
1985Fr07: ^{12}C(n,p), E=545 MeV; measured $\sigma(\theta$,Ep).
1987Fr16: C(n,p), E=300-580 MeV; measured light particle production σ(E,θ) vs particle energy.
1988RaZX: ^{12}C(n,p), E=30-150 MeV; measured σ(E).
2017PiZW: ^{12}C(n,p_0, E=18.9-20.7 MeV. Measured σ(E).
2021Ku19: ^{12}C(n,p_0, E=16.25-21.75 MeV. Measured σ(E).

Theory:
1974Ol03: ^{12}C(n,p), calculated σ. ^{13}C deduced resonances.
1972Ed01: ^{12}C(n,p), E=14-15 MeV; compile, study cross sections.
1986Ko26: ^{12}C(n,p), E=545 MeV; calculated decay probability distributions, σ(Ep,θ).
1988Pe01: ^{12}C(n,pX), E=27,40,61 MeV; calculated $\sigma(\theta$,Ep); deduced direct reaction component.
1989Br05: ^{12}C(n,p), E=15-60 MeV; calculated $\sigma(\theta$,E).
2016Zu01: ^{12}C(n,p), E<10 GeV. Compiled and analyzed σ.
2020Pr08: ^{12}C(n,p), E<20 MeV; calculated astrophysical reaction rates.

^{13}C Levels

E(level)	Comments
≈20500	E(level): (1968Ri02,1972Bo73: weak resonance).
≈22000	E(level): strong resonance with a peak cross section σ=19 mb (1968Ri02).

^{12}C(n,n′),(n,n′γ):res

1958Hu18: ^{12}C(n,n′), En=4.4-8 MeV, four resonances are reported in the yield of 4.4 MeV γ-rays, at En=6.30,6.49,7.6,7.87 and 8.15 MeV, corresponding to ^{13}C*(10.76,10.94,12.0,12.21,12.47 MeV). The differential cross section at 90° reaches a maximum of 60 mb/sr at 7.87 MeV.

1959Ha13: ^{12}C(n,n′γ), E=4.6-9.8 MeV; measured the cross section for the production of 4.43 MeV γ rays. Ten resonances were observed in this energy range and the maximum cross section of 45 mb/sr was obtained at a neutron-energy of 8.1 MeV.

1960He10: ^{12}C(n,n′), E=14 MeV; measured the angular distribution of inelastically scattered neutrons from ^{12}C*(9.6 MeV) for for θ=30° to 150°. Time-of-flight measurement.

1962Ba25: ^{12}C(n,n′), E=15 MeV; measured σ(E,θ=40°).

1968Bo34: ^{12}C(n,n′), E=14-21 MeV; measured σ(E).

1970De14: ^{12}C(n,n), E=17-20.5 MeV; measured σ(E;En′,θ) for $\theta\approx$10° to 150°. Deduced optical model parameters, E$_x$=23 MeV resonance energy, J, π.

1970Dr11: ^{12}C(n,n′γ), E=5.8-7.5 MeV; measured differential cross sections for inelastic scattering via ^{12}C(4.4 MeV); θ=25° to 90°.

1972Ga13: C(n,n′), E=3-7 MeV; measured σ(E;θ).

1974Po03: ^{12}C(n,nγ), E=14.9 MeV; measured nγ-coin. ^{13}C deduced threshold level transitions.

1987BeYP: ^{12}C(pol. n,n′), E=16.1 MeV; measured analyzing power. ^{13}C deduced resonances, Γ, L.

Theory:

1970Ca13: ^{12}C(n,n′γ), E<9 MeV; analyzed available data; deduced J, π.

1971LeZG: ^{12}C(n,n′), calculated $\sigma(\theta)$, P(θ), phase shifts. Calculated resonance energies, Γ, J, π.

1982Kn02: ^{12}C(n,n′), E=0.0-9 MeV; analyzed data. Deduced levels, J, π, reduced widths. R-matrix analysis, comparison to model predictions.

2017HaZY: ^{12}C(n,n′), E=5.3-6.45 MeV; calculated σ, $\sigma(\theta)$, analyzing power.

2017Lo02: ^{12}C(n,n′), E=17.29 MeV; analyzed differential $\sigma(\theta)$ data.

^{13}C Levels

E(level)†	J$^{\pi}$	Γ	L	E$_n$(res.) (keV)	Comments
9522		<80 keV		4960	E$_n$(res.) (keV),Γ: from (1959Ha13).
9946		<80 keV		5420	E$_n$(res.) (keV),Γ: from (1959Ha13).
10463		200 keV		5980	E$_n$(res.) (keV),Γ: from (1959Ha13).
10758				6300	E$_n$(res.) (keV): from (1959Ha13).
10804		120 keV		6350	E$_n$(res.) (keV),Γ: from (1959Ha13).
10970		<80 keV		6530	E$_n$(res.) (keV): from E$_{res}$=6530 keV which is the average of 6490 keV (1958Hu18) and 6570 keV (1959Ha13). Γ: from (1959Ha13).
11080		<80 keV		6650	E$_n$(res.) (keV),Γ: from (1959Ha13).
11865		260 keV		7500	E$_n$(res.) (keV),Γ: from (1959Ha13).
11957				7600	E$_n$(res.) (keV): from (1958Hu18).
12178		180 keV		7840	E$_n$(res.) (keV): from E$_{res}$=7840 keV which is the average of 7870 keV (1958Hu18) and 7810 keV (1959Ha13). Γ: from (1959Ha13).
12460		220 keV		8145	E$_n$(res.) (keV): from E$_{res}$=8145 keV which is the average of 8150 keV (1958Hu18) and 8140 keV (1959Ha13). Γ: from (1959Ha13).
13534		500 keV		9310	E$_n$(res.) (keV),Γ: from (1959Ha13).
19798 *92*		≈100 keV	1	16.1×10^{3} *1*	E$_n$(res.) (keV): from E$_{res}$=16.1 MeV *1* (1987BeYP: however authors deduced E$_x$=19.9 MeV *1*). Γ,L: from (1987BeYP). The observed Γ corresponds to $\tau\approx7\times10^{-21}$ sec.
23.0×10^{3} *2*	5/2$^-$,1/2$^-$,3/2$^+$,7/2$^-$	1.6 MeV		19600	E(level),J$^{\pi}$,Γ,E$_n$(res.) (keV): from (1970De14).

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^{12}C(n,n′),(n,n′γ):res (continued)

^{13}C Levels (continued)

E(level)[†]	J^π	Γ	L	E_n(res.) (keV)	Comments
					J^π: 5/2$^-$ is concluded in (1970De14); yet they are unable to eliminate (1/2$^-$, 3/2$^+$, 7/2$^-$).

[†] Level energies are deduced using ^{12}C, ^{13}C and n masses from (2021Wa16: AME-2020) and the resonance energy E_n(res) except where noted. $E_x=S_n+E_{c.m.}$(relativistic).

^{12}C(p,π^+)

Most relevant:

1973Da24: ^{12}C(p,π^+), E=185 MeV; measured σ(E(π^+),θ); deduced levels.

1980So05: ^{12}C(p,π^+), E=200 MeV; measured σ(E(π^+)); deduced reaction mechanism.

1984Lo13: ^{12}C(pol. p,π^+), E=200-250 MeV; measured σ(θ), analyzing power vs θ; deduced isobar excitation role. Microscopic two-nucleon models.

1985Bi04: ^{12}C(p,π^+), E=201,180 MeV; measured σ(θ,E(π)); deduced σ(E).

1987Ko01: ^{12}C(pol. p,π^+), E=200 MeV; measured σ(E(π)), analyzing power vs θ; deduced quasifree two nucleon collisions role. Magnetic spectrometer.

Others:

1970Do04: ^{12}C(p,π^+), E=600 MeV; measured σ(E$_\pi$).

1971Da10: ^{12}C(p,π^+), E=185 MeV; measured σ(E(π^+),θ).

1977BeZY: ^{12}C(p,π^+), E=148-160 MeV; measured σ.

1978Au07: ^{12}C(pol. p,π^+), E=200 MeV; measured σ(θ).

1979Ma38: ^{12}C(p,π^+), E=0.5-10 MeV above threshold; measured σ.

1979Ma39: ^{12}C(p,π^+), E=8-16 MeV above threshold; measured inclusive σ; deduced A-dependence.

1980Ho20: ^{12}C(p,π^+), E=300 MeV; measured σ(θ); deduced structure, reaction process interplay.

1980So05: ^{12}C(p,π^+), E=200 MeV; measured σ(E(π^+)); deduced reaction mechanism.

1981MaZT: ^{12}C(pol. p,π^+), E=200 MeV; measured σ(θ), analyzing power vs θ. ^{12}C(pol. p,π^+), E=330-425 MeV; measured σ(inclusive). Semiclassical model analysis.

1981Sj02: ^{12}C(pol. p,π^+); E=147-159 MeV; measured σ(θ), analyzing power vs θ.

1981So04: ^{12}C(p,π^+), E=156-200 MeV; measured σ(θ); deduced single-particle, two particle-one hole final state effects.

1982Lo03: ^{12}C(pol. p,π^+), E=200-250 MeV; measured σ(θ), analyzing power vs θ; deduced analyzing power energy, structure dependences.

1984GrZW: ^{12}C(pol. p,π^+), E=170,183,190 MeV; measured σ(θ), analyzing power vs θ; deduced P-, S-wave amplitude energy dependence, barrier penetration factor consistency effects.

1986Fa03: ^{12}C(pol. p,π^+), E=400,450 MeV; measured σ(θ,E(π^+)), analyzing power vs θ, E(π^+). Quasi-free model.

1987Ho21: ^{12}C(p,π^+), E=166,186 MeV; measured σ(θ). Recoil detection method.

1987Hu08: ^{12}C(p,π^+), E=250,354,489 MeV; measured σ(θ,E); deduced reaction mechanism.

1988Ab05: ^{12}C(p,π^+), E=1 GeV; measured σ(θ) vs pion momentum; deduced reaction mechanism.

1989Ko21: ^{12}C(pol. p,π^+), E=200 MeV; measured σ(θ) analyzing power vs θ deduced reaction mechanism. ^{13}C deduced levels, J, π. Shell model calculations.

1996Ja25: ^{12}C(p,π^+), E=166,294 MeV; measured σ(θ). High momentum transfer, recoil detection at a cooler ring.

Theory:

1971Re12: ^{12}C(p,π^+), E=600 MeV; calculated σ.

1972Am05: ^{12}C(p,π^+), E=600 MeV; analyzed σ. Single-particle model.

1973Di08: ^{12}C(p,π^+), E=185 MeV; calculated σ(E$_{\pi^+}$,θ).

1973Ei01,1973Ei05: ^{12}C(p,π^+), E=600 MeV; calculated σ.

1973Ke02: ^{12}C(p,π^+), E=185 MeV; calculated σ.

1973Ro10: ^{12}C(p,π^+), E=68,185 MeV; calculated σ(θ). DWBA.

1974Ho13: ^{12}C(p,π^+), E=185 MeV; calculated σ(E(π^+),θ).

1974Mi06,1974Mi11: ^{12}C(p,π^+), E=185 MeV; calculated σ(θ,E(π^+)).

1975No05: ^{12}C(pol. p,π^+), calculated polarization.

1976Le02: ^{12}C(p,π^+), E=185 MeV; calculated σ. DWBA calculations.

1976Mi14: ^{12}C(p,π^+); calculated σ(θ).

1977Gi06: ^{12}C(p,π^+), E=185 MeV; calculated σ(θ).

1977Ku21: ^{12}C(p,π^+), E=185 MeV; calculated σ.

1978Mi02: ^{12}C(p,π^+), E=185 MeV; calculated σ(θ).

1978Yo02: ^{12}C(pol. p,π^+), E=200 MeV; calculated asymmetry.

1981Bu18: ^{12}C(p,π^+), E=730 MeV; calculated σ(θ), inclusive spectra. Isobar model, intranuclear cascade.

1982Co07: ^{12}C(pol. p,π^+), E=159,200 MeV; caculated σ(θ), A(θ). DWBA, Dirac equation, different pion-nucleon verticies.

1984Gu27: ^{12}C(p,π^+), E=threshold$-$325 MeV; calculated pion production σ(E). Knockout model.

^{12}C(p,π^+) (continued)

1984Ke02: ^{12}C(pol. p,π^+), E=200 MeV; calculated $\sigma(\theta)$, analyzing power vs θ. Isobar-doorway model.
1985Iq01: ^{12}C(p,π^+), E=250,265,200 MeV; calculated $\sigma(\theta)$. Two-nucleon model, intermediate isobar effects.
1987Ku06, 1987KuZW: ^{12}C(p,π^+), E≈200 MeV; calculated $\sigma(\theta)$ vs momentum transfer; deduced structure effects. Shell model.
1994Fa10: ^{12}C(pol. p,π^+), E=200 MeV; analyzed $\sigma(\theta)$, analyzing power data.

^{13}C Levels

E(level)	J^{π}‡	Comments
0†	1/2$^-$	
3089†	1/2$^+$	
3685†	3/2$^-$	E(level): unresolved from nearby states.
3854†	5/2$^+$	E(level): unresolved from nearby states.
6860†	5/2$^+$	
7490†	(7/2$^+$)	E(level): unresolved from nearby states.
7550†	5/2$^-$	E(level): unresolved from nearby states.
7686?†	3/2$^+$	E(level): unresolved from nearby states.
8400†	3/2$^+$	
9.50×10^3†	9/2$^+$	
11.9×10^3		E(level): reported in (1987Ko01,1987Hu08,1989Ko21).
14×10^3		E(level): reported in (1985Bi04,1987Ko01,1987Hu08,1989Ko21).
21470		E(level): reported in (1985Bi04,1987Ko01,1987Hu08,1989Ko21). J^{π},T: (1987Ko01,1989Ko21) suggested J^{π}=(7/2$^+$,9/2$^+$) with a preference for 7/2$^+$; and they discussed a potential 1/2, 3/2 isospin mixing for this level. On the other hand, (1994Fa10) suggests this is a 13/2$^-$ level with a $(1d_{5/2})^2(1p_{3/2})^{-1}$ configuration.

† Values listed in (1980So05). See also (1971Da10, 1980So05, 1981Sj02, 1987Ko01, 1989Ko21) for discussion on unresolved states.

‡ From, for example, A_y measurements in (1989Ko21). See (1970Do04, 1971Da10, 1973Da24, 1978Au07, 1980Ho20, 1980So05, 1981Sj02, 1981So04, 1982Lo03, 1984Lo13, 1987Hu08, 1987Ko01, 1989Ko21, 1996Ja25) for angular distributions, differential cross sections, A_y measurements and for discussion on single and multi-step reaction processes.

^{12}C(d,p),(d,pγ)

1951St19: ^{12}C(d,p), The Q-value (2716 keV *5*) is determined.

Van Patter et al., Phys. Rev. 82, 248 (1951): ^{12}C(d,p), E=1.51, 1.80 MeV; deduced E_x=3686 keV *11*.

1952Th24: ^{12}C(d,p),(d,pγ) E=1-2 MeV; Deduced E_γ=3082 keV *7* after correcting for doppler broadening, from the positron spectrum of internal conversion pairs.

1954Fr24: ^{12}C(d,p), E=19 MeV; measured d$\sigma(\theta)$ to ^{13}C(0, 3.08, 3.89 MeV): $\theta_{c.m.}$=20° to 160°, Deduced L, J.

1954Ho48: ^{12}C(d,p), E=3.29 MeV; measured differential cross sections ar θ=5°−140°.

1955Be62: ^{12}C(d,p), E=4.0 MeV; E_γ=3.74 MeV *3* and 3.84 MeV *3* were observed.

1954Sp01: ^{12}C(d,p), four Q-values are determined corresponding to ^{13}C*(0,3.090,3.684,3.855) with error range from 10 keV for the g.s. to 7 keV for the 3.855 state. The spacing between 3.684 and 3.855 level is 170 keV *3*.

1955Kh35: ^{12}C(d,p), E=3.76 MeV; ^{13}C*(0,3.10,3.69.3.86) investegated; errors ±10-15 keV.

1955Mc75: ^{12}C(d,p), E=14.8 MeV; measured yields for θ=9.8°−86.6°. Observed 11 excited states at $^{13}C^{*}$(0, 3.09, 3.68, 3.86, 6.87, 7.47, 7.53, 7.64, 8.4, 9.5, 9.90, 10.76 MeV), deduced L, J.

1956Do41: ^{12}C(d,p), measured the reaction energies; Q=−0.960 MeV *2* and −1.130 MeV *2* for ^{13}C*(3.68,3.86), respectively.

1956Gr37: ^{12}C(d,p), measured angular distributions of protons to ^{13}C(0, 3.09, 3.68, 3.85): $\theta_{c.m.}\approx$5°−45°. Deduced L, J.

1956Ma52: A scintillation spectrometer and a magnetic lens spectrometer have been used to study γ rays from excited states of ^{13}C at 3.84 and 3.68 Mev, produced in the reactions ^{12}C(d,p) and ^{10}B(α,p). Transitions energies have been measured as 169.5 keV *4*, 3.844 Mev *15*, and 3.69 Mev *2*. The internal conversion coefficient for the 170 keV γ ray is $Y_e/Y_\gamma=1.4\times10^{-4}$ *3*. Lastly, γ decay branching ratios were deduced for $^{13}C^{*}$(3.84).

1958Bo67,1958He47,1958Hi74,1958Ju39,1958Ju42: ^{12}C(vec(d),vec(p)), measured analyzing powers to ^{13}C(0, 3.09, 3.86).

1958He47: ^{12}C(vec(d),vec(p)), E=7.8 MeV; measured analyzing powers to ^{13}C(0, 3.09).

1958Mc63: ^{12}C(d,p), E_d(res)=2.502 and 2.735 MeV; angular distributions are analyzed to obtain the reduced neutron widths of ^{13}C*(0,3.09) states. Deduced reduced widths θ_n^2.

1959Ha29,1961Ha19: ^{12}C(d,p), E=10.2,12.4,14.8 MeV; angular distributions to the ^{13}C*(0, 3.09) states were obtained for $\theta_{c.m.}\approx$10°−90°. Deduced L, g.s. reduced width θ_n^2.

1960Al35: ^{12}C(d,p), measured angular distributions.

1960Ch01,1960Ch12: ^{12}C(d,$p_3\gamma$), E=1.7-3.1 MeV; the cross section was obtained from the yield of the 170 keV γ-ray, transition of ^{13}C*(3.85 MeV:5/2+^{13}C*(3.68 MeV:3/2$^-$).

1960Mo05: ^{12}C(d,p_{0-3}), E=14.9-19.6 MeV; angular distributions for θ=15°−165°. Deduced g.s. radius.

1960Za04,1960Za06: ^{12}C(d,p_{0-3}), E=4.7-13.3 MeV; angular distributions.

1961Go29: ^{12}C(d,p), measured the γ-ray energies for ^{13}C*(3.09,3.68,3.86) with ≈15 keV resolution.

1961Ja23: ^{12}C(d,p), Reported Q_0=2725 keV *5* and E_x= 3093 keV *6* for the first excited state.

1962Fl06: ^{12}C(d,pγ), E=2.80,3.23,3.70 MeV; measured p-$\gamma_{2,3}$ angular correlations at reaction angles near the stripping maximum. Tentative multipole mixtures assigned are $\Gamma(E2)/\Gamma_\gamma\leq$ 5% for the E_γ=3.68 MeV and $\Gamma(E3)/\Gamma_\gamma\leq$ 2% for the E_γ=3.85 MeV.

1962Si08: ^{2}H(^{12}C,pγ), E=14 MeV; measured $\tau_m=7.5\ ^{+3}_{-2}$ ps for ^{13}C*(3.85) using DSAM. Deduced the transition strengths of the competing decay modes.

1962Sl04: ^{12}C(d,$p_{0,2}$), E=27.7 MeV; measured angular distributions for $\theta\approx$20°−100°, deduced L.

1962Zh01: ^{12}C(d,$p_{0,1}$), E=6.6 MeV; measured angular distributions for $\theta\approx$20°−80°.

1963Ev04: ^{12}C(d,$p_{0,1}$), 5.5<E<12 MeV; measured angular distributions for ^{13}C(0, 3.09) at $\theta\approx$10°−120°, proton polarization for ^{13}C(3.09) and p-γ correlations for ^{13}C(3.09, 3.68, 3.85).

1963Li09: ^{12}C(d,$p_{0,1}\gamma$), E=6.03 MeV; measured angular correlation function for $\theta\approx$20°−160°.

1963Pi04: ^{12}C(d,pn), E=4.66,4.90,5.46 MeV; search for sequential 3-body breakup states; no evidence was observed for involvement of ^{13}C. See also (1968Bo02, 1973Sa03).

1963Va23: ^{12}C(d,$p_{0,1}$), E=25.9 MeV; measured absolute differential cross sections $\theta_{c.m.}\approx$5°−70° and 30°−140°, respectively.

1964Sc12: ^{12}C(d,$p_{0,1}$), E=11.8 MeV; measured the angular distributions of protons at θ=10°−165°. Deduced the reduced widths θ^2.

1964Wa05: ^{12}C(d,p), measured not abstracted; deduced nuclear properties.

1965Fi05: ^{12}C(d,p_{0-3}), E=1.7,2.7,3.1,4.0 MeV.

1965Wa16: ^{12}C(d,p), ^{13}C*(3.09,3.68,3.85)→0 transitions observed.

1965Wi11: ^{12}C(d,p_0), E=0.717-1.740 MeV; measured $\sigma(E;\theta)$ for $\theta_{c.m.}\approx$5°−165°.

1966Be31: ^{12}C(d,pγ), ^{13}C; measured p-γ angular correlation functions.

1966Ga09: ^{12}C(d,p_0), E=1.2-4.5 MeV; measured σ(Ep,θ). ^{13}C deduced S-factors.

1966Ge03: ^{12}C(d,$p_{2,3}\gamma$), E=2.80,3.23,3.70 MeV; measured σ(Ep,θ), $\sigma(\theta)$, $\theta_{c.m.}\approx$20°−160°; deduced θ^2, S-factors.

1966Gl01: ^{12}C(d,p0-3), E=8,12 MeV; measured σ(Ep,θ). ^{13}C deduced levels, L, J^π, S-factors, reduced width.

^{12}C(d,p),(d,pγ) (continued)

1966Go15: ^{12}C(d,pγ), inconclusive results on mixing ratios are found from p-γ angular-correlation measurements, measured ^{13}C(3.85) γ branching ratio.

1966Ka05: ^{12}C(d,pγ), E=2.0-3.2 MeV; measured σ(E;Ep,θp,θpγ) for $\theta_{\text{c.m.}}\approx30°$ to 125°; analyzed p-γ angular correlations, deduced reduced widths, J, π.

1966Kl05: ^{12}C(d,p$_{0,1}$), E=0.9-1.75 MeV; measured angular distributions.

1966Ma25: ^{12}C(pol. d,p), analyzed the asymmetry in the proton angular distributions.

1966Po11: ^{12}C(d,pγ), E=2.51 MeV; measured γ-γ coinc. from ^{13}C(3.85 MeV); deduced mixing ratios for 3.68$\rightarrow$0 and 3.85$\rightarrow$0.

1966Sc09: ^{12}C(d,p$_{0-3}$), E=11,13 MeV; measured angular distributions for $\theta_{\text{c.m.}}\approx10°-160°$, analyzed J.

1967Au05: ^{12}C(d,p), E=63 MeV; measured σ=65 mb *5*.

1967Me02: ^{12}C(d,p), E=2.72, 2.8 MeV; measured τ=55 fs *6* for ^{13}C*(3.09).

1967Od01: ^{12}C(d,p), measured Q$_0$=2.7223 MeV *61*.

1967Po01: ^{12}C(d,p$_{0,1}$), E=0.9-2.1 MeV; measured σ(Ep,θ) for $\theta_{\text{c.m.}}\approx20°-160°$. Deduced reduced widths, S-factors, L(n), π.

1967Sc29: ^{12}C(d,p$_{0,2}$), E=12 MeV; angular distributions (d$\sigma(\theta)$) for $\theta_{\text{c.m.}}\approx15°-175°$, deduced S-factors.

1968Al03: ^{12}C(d,p), E(^{12}C)=15.0 MeV; measured τ_m<15 fs for ^{13}C*(3.09).

1968Co04: ^{12}C(d,p), E=4.66 MeV; measured $\sigma(\theta=70°)$.

1968Go14: ^{12}C(d,pγ), measured polarization of 170 keV γ rays.

1968Ho23: ^{12}C(d,p$_{0-11}$), E=12.3-14.7 MeV; measured σ(Ep,θ) for θ=20° to 60°; deduced reaction mechanism.

1968Ri16: ^{12}C(d,p), E=1.79, 2.715, 3.60 MeV; measured T$_{1/2}$<10 fs and <26 fs for ^{13}C(3.08,3.68) via DSAM.

1968Yu01: ^{12}C(pol. d,p$_{0,1}$), E=8 MeV; measured vector analyzing powers for $\theta\approx10°-120°$.

1969Al17: ^{12}C(d,p), E=3.25 MeV; measured E$_\gamma$=169.25 keV *4* for ^{13}C(3.85$\rightarrow$3.68).

1969Bo32: ^{12}C(d,p$_0$), E=0.9-2.0 MeV; measured σ(E), σ(E;Ep,θ) for $\theta=20°-140°$.

1969Co02: ^{12}C(d,p$_{0-3}$), E=5-10 MeV; measured σ(E,θ), σ(E;Ep,θ) for $\theta=30°-160°$.

1969Cu10: ^{12}C(pol. d,p), E=7.7-10 MeV; measured vector analyzing power for $\theta=20°-170°$.

1969Gu02: ^{12}C(d,p$_0$), E=4.5 MeV; measured σ(Ep,θ), P(θ) for $\theta\approx10°-165°$; deduced optical parameters.

1969So07: ^{12}C(d,p), E=2.9,3.07,3.25 MeV; measured proton polarization(E,θ) for $\theta=30°-120°$.

1970Al26: ^{12}C(d,p$_0$), E=1.4-2.3 MeV; measured σ(E;θ) for $\theta=25°-160°$.

1970Bo20: ^{12}C(pol. d,p) E=1.4-2.4 MeV, measured proton polarization, determined sign, compared with (pol. d,n).

1970Ho37: ^{12}C(d,p), E=14.6 MeV; measured σ(Ep); deduced phase shifts, levels up to E$_x$=9.90 MeV.

1970Le20: ^{12}C(d,p$_0$), E=3.31-3.69 MeV; measured σ(E;θ) for $\theta_{\text{c.m.}}=10°-170°$.

1970Za10: ^{12}C(d,p), E=12.8 MeV; measured σ(Ep).

1971Bo44: ^{12}C(d,p), E=2.7-3.1 MeV; measured vector analyzing power(E;θ).

1971Br44: ^{12}C(d,p$_0$), E=12.3 MeV; measured tensor analyzing power(θ) for $\theta=0°-50°$.

1971Bu03: ^{12}C(pol. d,p$_{0,1}$) E=12.35 MeV, measured $\sigma(\theta)$, proton analyzing powers, $\theta=20°-136°$. DWBA analysis.

1971Du09: ^{12}C(d,p$_{0,1,3}$), E=80 MeV; measured $\sigma(\theta)$ for $\theta=15°-50°$; deduced optical potentials, S-factors.

1971Pu01: ^{12}C(d,p$_0$), E=0.4-0.85 MeV; measured σ(E;θ) for $\theta\approx30°-150°$; deduced optical-model parameters, deduced S-factors.

1972Bl04: ^{12}C(pol. d,p) E=4-6 MeV, measured proton analyzing powers for $\theta=10°-135°$, deduced minimal influence from compound-nucleus resonance.

1972Bo56: ^{12}C(pol. d,p$_{0,1}$), E=1.6-3.0 MeV; measured σ(Ep,θ), vector analyzing power(90°); analyzed reaction mechanism.

1972Hu13: ^{12}C(d,p$_0$), E=0.4-1.35 MeV; measured σ(E;θ) for $\theta=80°-160°$.

1972Ma77: ^{12}C(pol. d,p), E=1.9-3.0 MeV; measured vector analyzing power A(E,θ), analyzed reaction mechanism.

1972Pe11: ^{12}C(pol. d,p), E=4-21 MeV; analyzed $\sigma(\theta)$ for $\theta=20°-160°$, deduced S-factors.

1972SaYS: ^{12}C(d,p), E=4.04 MeV; measured $\sigma(\theta)$.

1973Be25: ^{12}C(d,p$_{0-3}$), E=2.5, 2.72 MeV; measured $\sigma(\theta)$, deduced S-factors.

1973Da17: ^{12}C(pol. d,p$_{0-4,8-11}$), E=9.3,13.3,15.0 MeV; measured polarization parameters iT$_{11}$(Ed,Ep,θ), cross sections σ(Ed,Ep,θ) for $\theta=20°-150°$, deduced S-factors, resonance widths.

1973Go02: ^{12}C(d,pγ), E=4.15 MeV; measured p$\gamma(\theta)$ angular correlations, deduced mixing ratio for ^{13}C(3.68$\rightarrow$0).

1973Go03: ^{12}C(d,p), E=14.0-15.5 MeV; measured σ(E;Ep;θ) for $\theta=60°-120°$, deduced levels, level-width for E$_x$=10.8-12.1 MeV.

1973HaVB: ^{12}C(d,p), measured $\sigma(\theta)$.

1973Jo10: ^{12}C(pol. d,p$_0$), E=12.3 MeV; measured analyzing powers iT$_{11}(\theta)$, T$_{20}(\theta)$, T$_{22}(\theta)$ for $\theta=0°-50°$, analyzed reaction mechanism and deduced importance of deuteron d-state effects.

1973Le26: ^{12}C(d,p$_0$), E=1.13,1.17 MeV; measured σ(E,θ), P(E,θ).

1973Me22: ^{12}C(pol. d,p), E=5-12 MeV; measured T$_{20}$(E;θ) for $\theta=0°-15°$; analyzed importance of deuteron d-state effects.

^{12}C(d,p),(d,pγ) (continued)

1973Tr02, 1973TrZP: ^{12}C(d,p$_1\gamma$), E=0.8-2.1 MeV; measured σ(E); analyzed γ-ray lines shape; deduced $\sigma(\theta)$, resonance interference.

1974Be48: ^{2}H(^{12}C,pγ), E=15 MeV; measured p$\gamma(\theta)$, DSA, p$\gamma(\theta$,t). Deduced ^{13}C(3.85 MeV) g=0.59 *5* via time-differential recoil-in-vacuumg, τ_{m}=12.4 ps *8* δ(E3/M2)=+0.12 *4*. See also (1973RaZH).

1974Da06: ^{12}C(d,p$_{0-3}$), E=2.61-2.82 MeV; measured σ(E,Ep,θ(p)) for $\theta=10°-160°$; deduced levels, L(n).

1974Gm01: ^{12}C(d,p$_{0,1,2}$), E=1.82-2.50 MeV; measured σ(E,Ep,θ). ^{13}C levels deduced S-factors.

1974Jo14: ^{12}C(d,p), measured Q=2721.9 keV *8*.

1975Ra29: ^{12}C(d,pγ), E=2.51 MeV; measured E$_\gamma$($\theta(\gamma)=0°$) Doppler shift, recoil distance. Deduced τ_{m}(3.85)=13.0 ps *4*.

1975Tr07: ^{12}C(d,pγ), E=1.4-3.2 MeV; measured σ(E,E$_\gamma$); deduced σ(E,Ep,θ), levels energies up to E$_{\mathrm{x}}$=3854, γ-branching.

1975ZaZS: ^{12}C(d,p), E=13.6 MeV; measured $\sigma(\theta)$.

1976Dy05: ^{2}H(^{12}C,pγ), E=15.5 MeV; measured spin precession of ^{13}(3.85), deduced transient magnetic field in Fe.

1977AnZO: ^{12}C(d,p), E<1.4 MeV; measured absolute σ(E,θ).

1977Ba39: ^{12}C(pol. d,p), E=12.3 MeV; measured T$_{20}$, T$_{22}$; analyzed importance of deuteron D-state, deduced J-mixing ratio.

1977He12: ^{2}H(^{12}C,pγ), E=15 MeV; measured γ-ray Doppler patterns. Deduced τ_{m} of ^{13}C*(3.85)=12.6 ps *3*.

1977Ta08: ^{12}C(d,p$_{0-7}$), E=9.0 MeV; measured $\sigma(\theta)$ for $\theta\approx30°-170°$ with an emphasis on ^{13}C*(6.864(5/2$^+$),7.677(3/2$^+$)). Deduced J^π, Γ, S-factors; DWBA analysis.

1979Dy05: ^{2}H(^{12}C,pγ), E=15.5,33 MeV; measured $\gamma(\theta$,H), E$_\gamma$, I$_\gamma$.

1979Os11: ^{12}C(d,p$_1$), E=1.5-3 MeV; measured σ(E,θ) $\theta\approx60°-160°$. Analyzed reaction mechanism.

1979Si07: ^{12}C(vec. d,p), E=2.34-2.74 MeV; measured P(θ); deduced spin-orbit potential parameters.

1979Wa24: ^{12}C(d,p), E=9 MeV; measured $\sigma(\theta)$. Optical model, zero-range DWBA, Hauser-Feshbach analyses.

1980Wa24: ^{12}C(d,p), E=2.51 MeV; measured E$_\gamma$, I$_\gamma$, $\gamma\gamma$-coin, $\gamma(\theta)$. Deduced Eγ, level energies, γ-branching. Analyzed T$_{1/2}$, compared trensition strengths via shell model.

1981Ru04: ^{2}H(^{12}C,p), E=15 MeV; measured p$\gamma(\theta)$, recoil. For ^{13}C(3.85) deduced g=0.558 *15* and τ_{m}=12.2 ps *4*. Enriched target, recoil into vacuum, plunger technique. This gives μ=1.40 *4* (2011StZZ).

1982Sa29: ^{12}C(d,p), E=9 MeV; measured $\sigma(\theta$,Ep). Deduced possible excitation of ^{13}C(8.2 MeV:3/2$^+$) state..

1984Ha26: ^{12}C(pol. d,p$_{0-3}$), E=56 MeV; measured $\sigma(\theta)$, A(θ) for $\theta=10°-70°$. Deduced S-factors. DWBA, adiabatic model analyses.

1986Oh01: ^{12}C(d,p), E=30 MeV; measured $\sigma(\theta)$ for $\theta=10°-85°$. Deduced Γ, S-factors, shell model configurations for positive parity states below 10 MeV. CCBA, DWBA analysis.

1988La03: ^{12}C(pol. d,p$_{0-7}$), E=12 MeV; measured $\sigma(\theta)$, iT$_{11}(\theta)$, T$_{20}(\theta)$, T$_{21}(\theta)$, T$_{22}(\theta)$ for $\theta=15°-85°$. Deduced S-factors. DWBA analysis.

1989Ie01: ^{12}C(pol. d,pX), E=65 MeV; measured $\sigma(\theta$p,Ep), analyzed polarization transfer coefficient vs θ and reaction mechanism.

1990Pi05: ^{12}C(d,p), E=12.3 MeV; measured $\sigma(\theta)$ for $\theta=0°-90°$, deduced Q=2721.803 keV *38* and E$_{\mathrm{x}}$ for (d,p$_{1-4}$) reactions with ΔE$\approx$0.06-0.5 keV.

1991Le36: ^{12}C(d,p), E=735 keV-1.1 MeV; measured products, deduced $\sigma(\theta)$ at $\theta=150°$.

1991We09: ^{2}H(^{12}C,p), E=6-9 MeV; measured $\sigma(\theta=120°)$ vs E. High sensitivity analysis method.

1992Na17: ^{12}C(d,p$_0$), E=160-300 keV; measured $\sigma(\theta)$ for $\theta=25°-140°$.

1993Qu04: ^{12}C(d,p), E=968 keV; measured $\sigma(\theta)$ for $\theta=10°$, $20°$ and $30°$.

1997Pa43: ^{12}C(d,pγ), E=0.5-4 MeV; measured σ(E$_\gamma$) for $\theta=170°$; deduced excitation function.

1999Al49: ^{12}C(d,p), E=223,250,308,332 keV; measured $\sigma(\theta)$ for $\theta=40°-160°$.

2000El08: ^{12}C(d,pγ), E=0.7-3.4 MeV; measured Eγ, I$_\gamma$ at $\theta=135°$; deduced thick target γ-ray yields.

2001Im02: ^{12}C(d,p), E=11.8 MeV; measured $\sigma(\theta)$, deduced S-factors, asymptotic normalization coefficient for ^{13}C(3.089 MeV).

2001Li45,2001Li55,2002ZhZZ: ^{12}C(d,p), E=11.8 MeV; measured σ(E,θ) for $\theta\approx5°-140°$. deduced ground and excited state asymptotic normalization coefficients, radii, halo features. Finite-range DWBA calculations.

2004Ch69: ^{2}H(^{12}C,p), E=20, 24 MeV; measured reaction products, Ep, Ip, thick target.

2004Ji10: ^{12}C(d,p), E<3 MeV; measured Ep, Ip; deduced σ, $\sigma(\theta=150°)$. Compared with available data.

2006Ko23: ^{12}C(d,p), E=900-2000 keV; measured $\sigma(\theta)$. Comparison with previous results.

2007Ko02: ^{12}C(d,p$_{0-3}$), E=900-2000 keV; measured Ep, σ(E,θ) for $\theta=135°-170°$.

2008Ja07, 2008Ki17: ^{12}C(pol. d,p$_{0,1,2+3}$), E=140,200,270 MeV; measured analyzing powers. Investigated deuterium spin structure. Compared results to model predictions.

2008Pa09: ^{12}C(d,p$_0$), E=0.81-2.07 MeV; measured $\sigma(\theta)$ for $\theta=135°$, $160°$.

2014Cs03,2016Cs02: ^{12}C(d,pγ),(d,p), E<2 MeV; measured reaction products, E$_\gamma$, I$_\gamma$; deduced σ, $\sigma(\theta=55°)$.

2023HoAA: ^{2}H(^{12}C,p$_{0-3}$), E=111.4 MeV; measured reaction in inverse kinematics at TRIUMF/ISAC-II to validate experimental

^{12}C(d,p),(d,pγ) (continued)

proceedures.

Theory:

1969Pe09: ^{12}C(d,p), E=7.26 MeV; calculated $\sigma(\theta)$, P(θ), vector analyzing power (θ).
1970Do10: ^{12}C(d,p_0), E=12,15,26 MeV; analyzed $\sigma(\theta)$. Deduced S-factors. Absorption model.
1970Oh06: ^{12}C(d,p), E=12 MeV; calculated $\sigma(\theta)$. Coupled channel theory.
1971BrYP: ^{12}C(d,p), E=15 MeV; calculated $\sigma(\theta)$. Analyzed quasi-bound states, intermediate structure.
1972Go08: ^{12}C(d,p_0), E=51 MeV; calculated $\sigma(\theta)$, P(θ). Sudden approximation.
1973Co23: ^{12}C(d,p), calculated σ(E).
1973Co27: ^{12}C(d,p), calculated, level energies.
1973CoYL: ^{12}C(d,p), calculated σ(E). ^{13}C deduced transitions.
1974St05: ^{12}C(d,p), calculated σ(E,Ep,θ). Deduced second-order process contributions.
1975Gr12: ^{12}C(d,p), E=12 MeV; calculated σ(Ep,θ), sudden approximation.
1975Hu01: ^{12}C(d,p), E=8-10 MeV; calculated σ.
1975Is03: ^{12}C(d,p), E=2.8 MeV; calculated σ(Ep,θ).
1975Se07: ^{12}C(pol. d,p), analyzed data; deduced criteria for simplified polarization measurement analysis.
1975Za06: ^{12}C(d,p), analyzed data; deduced σ dependence on J.
1976He17: ^{12}C(d,p), E$\leq$20 MeV; calculated σ(Ep,θ).
1976Os07: ^{12}C(d,p), sub-Coulomb energy stripping; calculated σ for ^{13}C(3.09), deduced S-factors .
1976Sa04: ^{12}C(pol. d,p), E=6-13.3 MeV; calculated A(θ). Surface reaction model.
1976Sh13: ^{12}C(d,p), E=6-15 MeV; calculated $\sigma(\theta)$.
1977Se09: ^{12}C(pol. d,p), calculated A(θ).
1982Go05: ^{12}C(d,p), E=12 MeV; analyzed data. Deduced S-factors. DWBA, nuclear vertex constants.
1982Ta19: ^{12}C(pol. d,p), E=9, 15 MeV; analyzed $\sigma(\theta)$, $A_y(\theta)$. Deduced Γ. Core excitation, CCBA analysis.
1982Th06: ^{12}C(d,p), E=2.2,2.71 MeV; calculated channel nonorthogonality effects.
1984Bl21: ^{12}C(d,p), E=12 MeV; calculated $\sigma(\theta)$.
1984PeZW: ^{12}C(d,p), E=17.7 MeV; analyzed S-factor data.
1996Ma36: ^{12}C(d,p), E=12 MeV; calculated $\sigma(\theta)$; analyzed 2- and 3-body interaction features.
1998Ko11: ^{12}C(pol. d,p), E at 9.1 GeV/c; analyzed $\sigma(\theta)$, $T_{20}(\theta)$, polarization transfer; deduced multiple scattering role.
2003Li50: ^{12}C(d,p), E=11.8 MeV; analyzed data; deduced asymptotic normalization coefficients. See also (2001Kr12, 2001Nu03).
2004Ke08: ^{12}C(d,p), E=15,30 MeV; calculated $\sigma(\theta)$. Comparisons with data.
2004Li41: ^{12}C(d,p), E=4-56 MeV; analyzed $\sigma(\theta)$, S- factors. Johnson-Soper adiabatic and distorted-wave theories.
2005De33: ^{12}C(d,p), E=7-60 MeV; calculated $\sigma(\theta)$, σ; deduced reaction mechanism features. Coupled-channels approach.
2005Mu24: ^{12}C(d,p), E=51 MeV; analyzed data; deduced S-factors.
2005Ts03: ^{12}C(d,p). Survey of ground state neutron spectroscopic factors from (d,p) and (p,d) reactions.
2007Al28: ^{12}C(d,p), E=4.66,15,56 MeV; calculated σ and A_y within few-body framework.
2009De02: ^{12}C(d,p), E=30 MeV; calculated $\sigma(\theta)$, binding energies. Momentum-space three-body Fadeev-like equations. Comparison with experimental data.
2009De07: ^{12}C(d,p), E=30 MeV; calculated differential cross sections, analyzing powers for polarized beam using local and nonlocal optical potentials parameters in the framework of Faddeev type scattering equations.
2010Ng02: ^{12}C(d,p), E=2-80 MeV; calculated $\sigma(\theta)$ using adiabatic distorted-wave approximation (ADWA) and local energy approximation (LEA). Deuteron breakup and finite range effects.
2011Nu03: ^{12}C(d,p), E=7,12,56 MeV; calculated σ(E,θ) using Faddeev AGS, and finite-range adiabatic wave approximation.
2012Up01: ^{12}C(d,p), E=12,56 MeV; calculated σ(E,θ) for elastic, transfer and breakup channels. Continuum-discretized coupled channels (CDCC) calculations. Comparison with exact three-body Faddeev formulation.
2013Ab06: ^{12}C(d,p), E<2 MeV; analyzed available data; deduced $\sigma(\theta)$, yields. DWBA and R-matrix calculations.
2014Be47: ^{12}C(d,p), E=11.8,25.9,30 MeV; analyzed differential σ(E) data using coupled-reaction-channels method. Deduced S-factors, asymptotic normalization coefficients (ANCs), and rms radii of the last neutron, existence of neutron halos.
2014BeZU: ^{12}C(d,p), E=12,25,30 MeV; calculated, analyzed $\sigma(\theta)$ to the first excited state. Deduced first excited state S-factor, asymptotic normalization coefficients, radii of last neutron, first excited state neutron halo.
2014Up02: Analyzed screening effects at astrophysical energies.
2015De38: ^{12}C(d,p), E=12 MeV; calculated differential $\sigma(\theta)$. Faddeev-Alt-Grassberger-Sandhas (AGS) formalism with three-body model (proton+neutron+nuclear core) for proton−transfer reactions, and realistic CD Bonn potential.

^{12}C(d,p),(d,pγ) (continued)

2015Ke07: ^{12}C(d,p), E=30 MeV; calculated $\sigma(\theta)$ for 9.50-MeV, 9/2^{+} resonance; deduced best fit spectroscopic amplitudes and corresponding empirical mixing ratios for various state configurations. Coupled reaction channel calculation including the one- and two-step transfer via the ^{12}C 4.44-MeV, 2^{+} state.
2016Ca20: ^{12}C(d,p), E=56 MeV; calculated $\sigma(\theta$,E), Ep, Ip using the post-form DWBA approximation.
2017Lo02: ^{12}C(d,p), E=11.8 MeV; analyzed differential $\sigma(\theta)$ data using optical potential method,
2018Xu11: ^{12}C(d,p), E=51.93 MeV; analyzed experimental $\sigma(\theta)$ distributions, spectroscopic amplitudes for neutrons in normal and high-lying single-particle components in the ground and excited states. Coupled reaction channel calculations.
2020SaZX: ^{12}C(d,p), E=12 MeV; calculated σ(E,θ). DWBA model. Comparison with experimental data.
2020Vi06: ^{12}C(d,p), E=3.4-25.9 MeV; calculated S-factors. Comparison with available data.
2022Bl04: discuss method to deduce ANCs from ^{12}C(d,p) measurements.

^{13}C Levels

E(level)	J$^{\pi}$†	T$_{1/2}$ or Γ	L	S†	Comments
0	1/2^{-}		1	0.58 *4*	μ=1.40 *4* (1981Ru04) Q$_0$(keV)=2716 *5* (1951St19), 2721 *2* (1957Va11), 2725 *5* (1961Ja23), 2722.3 *61* (1967Od01), 2721.9 *8* (1974Jo14), 2721.803 *38* (1990Pi05), 2717 *10*(1954Sp01), 2722 (1997Pa43). J$^{\pi}$: see (1956Gr37, 1962Si08, 1964Sc12, 1966Gl01, 1966Ka05, 1966Po11, 1968Ho23, 1971Du09, 1973Go02, 1974Gm01, 1974St05, 1975Ra29, 1980Wa24, 1986Oh01, 1988La03, 2001Li45, 2002ZhZZ); see also J$^{\pi}$=1/2 (1968Yu01, 1972Pe11, 1973Jo10, 1973Me22), (1/2^{-},3/2^{-}) (1955Mc75). L: see (1954Fr24, 1955Mc75, 1956Gr37, 1961Ha19, 1964Sc12, 1966Ka05, 1968Ho23, 1968Yu01, 1972Pe11, 1973Jo10, 1973Me22, 1974Da06, 1974Gm01, 1974St05, 2001Li45, 2002ZhZZ). S: from (1972Pe11); see also S=0.8 (1966Gl01: average), 0.65 (1971Du09), 0.82 (1971Pu01), 1.1 (HD parameters) and 1.4 (MB parameters) (1973Da17), 0.9 (1974Gm01), 0.77 (1986Oh01). ANC=1.93 fm$^{-1/2}$ *17*; R$_{rms}$=3.39 fm *31* (2001Li45, 2001Li55, 2002ZhZZ). θ^2(average)=0.037 *3* (1961Ha19), 0.035 (1964Sc12).
3089.443 *20*	1/2^{+}	<6.93 fs	0	0.36 *2*	Q(keV)=−367.65 *7* (1990Pi05), −366 (Van Patter et al., Phys. Rev. 82, 248 (1951)), −373 *10* (1954Sp01), −368 (1967Po01). E(level): from E$_{\gamma}$=3089.049 keV *20* measured in (1980Wa24); see also E$_x$=3090 keV *10* (1954Sp01), 3093 KeV *6* (1961Ja23), 3088.45 keV *15* (1975Tr07: from E$_{\gamma}$ measurement, relative to the adopted energy of 3684.15 keV *11* from (1970Aj04)), 3089.39 keV *7* (using Q=−367.65 keV *7* (1990Pi05) and Q$_0$=2721.74 keV from (2017Wa10)), 3100±(10-50) keV (1955Kh35). J$^{\pi}$: see (1955Mc75, 1956Gr37, 1962Si08, 1964Sc12, 1966Gl01, 1966Ka05, 1968Ho23, 1971Du09, 1973Da17, 1973Tr02, 1974Da06, 1974Gm01, 1974St05, 1975Ra29, 1980Wa24, 1986Oh01, 1988La03, 2001Im02, 2001Li45, 2002ZhZZ); see also J$^{\pi}$=1/2 (1954Fr24, 1968Yu01, 1972Pe11, 1973Jo10). J$^{\pi}$: 94.02% 0⊗s$_{1/2}$ (1986Oh01). T$_{1/2}$: from τ<10 fs (1968Ri16); see also τ=55 fs *6* (1967Me02) and <15 fs (1968Al03: corresponds to a ratio of reduced E1 transition strengths in ^{13}C and ^{13}N of greater than 0.06) which is in disagreement with (1967Me02) but is consistent with expectations based on the mean life of the mirror state ^{13}N*(2.37 MeV; 1/2^{+}; radiative width=0.7 eV for E1 transitions to the 3/2^{-} g.s.). L: see (1954Fr24, 1955Mc75, 1956Gr37, 1961Ha19, 1964Sc12, 1966Ka05, 1967Po01, 1968Ho23, 1968Yu01, 1971Du09, 1972Pe11, 1973Jo10, 1974Da06, 1974Gm01, 1974St05, 2001Li45, 2002ZhZZ). S: from (1972Pe11); see also S=0.9 (1966Gl01: average), 1.1 (HD parameters) and 1.2 (MB parameters) (1973Da17), 0.29 (1974Gm01), 0.65 (1986Oh01), ANC=1.84 fm$^{-1/2}$ *16* (2001Li45, 2001Li55, 2002ZhZZ); see also ANC^2=3.65 fm^{-1} *34*(stat) *35*(syst) (2001Im02) which agrees with (1994Oh02: ^{12}C(n,γ)); R$_{rms}$=5.04 fm *75* (2001Li45, 2001Li55, 2002ZhZZ). θ^2=0.0157 (1964Sc12).

Continued on next page (footnotes at end of table)

^{12}C(d,p),(d,pγ) (continued)

^{13}C Levels (continued)

E(level)	J^{π}†	$T_{1/2}$ or Γ	L	S†	Comments
3684.482 *23*	3/2$^-$	<18 fs	1	0.10	Q=−0.969 MeV *10* (Van Patter et al., Phys. Rev. 82, 248 (1951)), −0.967 MeV *10* (1954Sp01: the spacing between 3.684 and 3.855 is 170 keV *3*), −0.960 MeV *2* (1956Do41: the spacing between 3.684 and 3.855 is 170 keV *15*) and −962.73 keV *6* (1990Pi05). E(level): derived from γ rays measured in (1980Wa24); see also E_x=3686 keV *11* (Van Patter), 3684 keV *10* (1954Sp01), 3690 keV *15* (1955Kh35: uncertainty is ±10-15 keV), and 3684.47 keV *6* (using Q=−962.73 keV *6* (1990Pi05) and Q_0=2721.74 keV (2017Wa10)). J^{π}: see (1956Gr37, 1962Si08, 1966Gl01, 1966Ka05, 1966Po11, 1968Ho23, 1973Da17, 1973Go02, 1974Da06, 1974Gm01, 1974St05, 1975Ra29, 1976Dy05, 1980Wa24, 1986Oh01, 1988La03); see also J^{π}=(1/2$^-$,3/2$^-$) (1955Mc75). $T_{1/2}$: from τ<26 fs (1968Ri16); see also τ<300 fs (1956Ma52). L: see (1955Mc75, 1956Gr37, 1966Ka05, 1974Da06, 1974Gm01, 1974St05). S: HD parameters (1973Da17); see also S=0.09 (1974Gm01), 0.14 (1986Oh01), 0.26 (1966Gl01: average) and 0.20 (1973Da17: MB parameters).
3853.773 *22*	5/2$^+$	8.7 ps *2*	2		Q=−1131.90 keV *20* (1990Pi05), −1130 keV *2* (1956Do41), −1138 keV *10* (1954Sp01). E(level): from γ rays measured in (1980Wa24); see also E_x=3855 keV *7* (1954Sp01), 3860 keV *15* (1955Kh35: E_x uncertainty is ±10-15 keV), 3853.62 keV *15* (1969Al17: deduced by the separation energy between 3.85 and 3.68 states (E_γ=169.25 keV *4*; neglect the small recoil energy E_R=1 eV) and the adopted level E_x=3684.37 keV *14* (weighted average of 3684.50 keV *17* (1967Pr10: ^{12}C(n,γ)) and 3684.28 keV *14* (1968Sp01: ^{12}C(n,γ))), 3853.55 keV *15* (1975Tr07: from E_γ measurement, relative to the adopted energy of 3684.15 keV *11* from (1970Aj04)), 3853.64 keV *20* (using Q=1131.90 keV *20* (1990Pi05) and Q_0=2721.74 keV from (2017Wa10)). J^{π}: see (1956Gr37, 1962Si08, 1966Gl01, 1966Ka05, 1966Po11, 1968Ho23, 1971Du09, 1973Da17, 1974Be48, 1974Da06, 1974Gm01, 1974St05, 1975Ra29, 1976Dy05, 1980Wa24, 1981Ru04, 1986Oh01, 1988La03, 2001Li45, 2002ZhZZ); see also J^{π}=(3/2,5/2) (1954Fr24), (3/2$^+$,5/2$^+$) (1955Mc75). J^{π}: 78.13% 0⊗$d_{5/2}$ (1986Oh01). $T_{1/2}$: from τ_m=12.55 ps *30* which is the weighted average of ^{12}C(d,p) values: 9.0 ps *+25−15* (1968Ri16), 12.4 ps *8* (1974Be48), 13.0 ps *4* (1975Ra29), 12.6 ps *3* (1977He12) and 12.2 ps *4* (1981Ru04); see also τ=7.5 ps *+3−2* (1962Si08) and 12.5 ps *5*: adopted by (1980Wa24: weigted average of 12.6 ps *7* (1977He12: but using higer uncertainty) and 12.4 ps *6* (weighted average of 10.7 ps *10* (1969He22: ^{10}B(α,p)), 15.4 ps *20* (ref. 5 in 1968Al03, 1968LaZZ), 9.9 ps *9* (1970Ga01: ^{10}B(α,pγ)), 12.4 ps *8* (1974Be48), 13.0 ps *4* (1975Ra29)), >0.3 ps (1956Ma52), ≥1 ps (2000El08), . L: see (1954Fr24, 1955Mc75, 1956Gr37, 1966Ka05, 1968Ho23, 1974Da06, 1974Gm01, 1974St05, 2001Li45, 2002ZhZZ). S: S=0.8 (1966Gl01: average), 0.7 (1971Du09), 1.1 (HD parameters) and 1.4 (MB parameters) (1973Da17), 0.85 (1974Gm01), 0.58 (1986Oh01). ANC=0.15 fm$^{-1/2}$ *1* ((2001Li45,2002ZhZZ), 0.149 fm$^{-1/2}$ *12* (2001Li55); R_{rms}=3.68 fm *40* (2001Li45,2001Li55,2002ZhZZ).
6864.04 *46*	5/2$^+$	6 keV	0,2	0.017	E(level): using Q=−4142.30 keV *46* (1990Pi05) and Q_0=2721.74 keV (2017Wa10). E_x(MeV) also reported at 6.86 (1968Ho23, 1970Ho37), 6.864 (1973Da17, 1986Oh01, 1988La03), 6.868 (1955Mc75), 6.87 (1969Co02, 1971Du09). J^{π}: see (1968Ho23, 1973Da17, 1986Oh01, 1988La03); see also J^{π}≤5/2$^+$

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^{12}C(d,p),(d,pγ) (continued)

^{13}C Levels (continued)

E(level)	$J^{\pi\dagger}$	$T_{1/2}$ or Γ	L	$S^{\dagger}$	Comments
					(1955Mc75). J^{π}: 67.5% $2\otimes s_{1/2}$, 31.4% $2\otimes d_{5/2}$ (1986Oh01). Γ: from (1977Ta08). L: from (1955Mc75). S: from (1986Oh01); see also S=0.02 (1988La03), 0.04 (1973Da17: HD parameters).
7470 *20*	$7/2^+$				E(level): from (1955Mc75). E_x(MeV) also reported at 7.47 (1968Ho23, 1970Ho37), 7.50 (1969Co02, 1971Du09, 1973Da17), 7.492 (1986Oh01), 7.498 (1988La03). J^{π}: from (1986Oh01). J^{π}: 95.11% $2\otimes d_{3/2}$ (1986Oh01).
7533 *20*	$5/2^-$			0.009	E(level): from (1955Mc75). E_x(MeV) also reported at 7.53 (1968Ho23, 1970Ho37), 7.55 (1969Co02, 1971Du09, 1973Da17), 7.547 (1986Oh01, 1988La03). $T_{1/2}$ or Γ: See also Γ≈5 keV (1977Ta08). J^{π}: see (1968Ho23, 1986Oh01, 1988La03). S: from (1986Oh01); see also S=0.32 (1988La03).
7641 *20*	$3/2^+$	60 keV *13*		0.11	E(level),Γ: from (1955Mc75). E_x(MeV) also reported at 7.64 (1968Ho23, 1970Ho37), 7.68 (1969Co02, 1971Du09, 1973Da17), 7.686 (1986Oh01, 1988La03). Γ: Γ from $\Gamma_{lab.}$=70 keV *15* (1955Mc75). See also Γ=80 keV (1977Ta08). J^{π}: see (1968Ho23, 1986Oh01, 1988La03). J^{π}: 29.7% $0\otimes d_{3/2}$, 68.3% $2\otimes s_{1/2}$ (1986Oh01). S: from (1986Oh01); see also S=0.10 (1988La03).
8.4×10^{3} *3*	$3/2^+$	0.94 MeV *3*	2	1.0	E(level),Γ: from (1955Mc75). E_x(MeV) also reported at 8.33 (1968Ho23, 1970Ho37, 1971Du09), 8.25 (1973Da17), 8.2 MeV (1986Oh01). Γ: Γ from $\Gamma_{lab.}$=1.1 MeV *3* (1955Mc75). J^{π}: see (1968Ho23, 1973Da17, 1986Oh01). J^{π}: 40.0% $0\otimes d_{3/2}$, 37.8% $2\otimes d_{5/2}$ (1986Oh01). L: from (1968Ho23). S: HD parameters (1973Da17).
8858	$1/2^-$			0.5	E(level),J^{π}: from (1973Da17). E_x(MeV)=8.82 also reported (1968Ho23, 1970Ho37). S: HD parameters (1973Da17).
9500 *20*	$9/2^+$				E(level): from (1955Mc75). E_x(MeV) also reported at 9.50 (1968Ho23, 1970Ho37, 1984Pe24, 1984Pe24, 1986Oh01), 9.51 (1971Du09), 9.499 (1973Da17). J^{π}: see (1984Pe24,1986Oh01); see also J^{π}=($3/2^-$) (1973Da17). J^{π}: 88.7% $2\otimes d_{5/2}$ (1986Oh01).
9897 *20*	$3/2^-$			0.1	E(level): from (1955Mc75). E_x(MeV) also reported at 9.90 (1968Ho23, 1970Ho37), 9.899 (1973Da17). J^{π}: from (1973Da17). S: HD parameters (1973Da17).
10755 *5*	$7/2^-$	56 keV *2*		0.026	E(level),Γ: from (1973Go03); E_x was measured with respect to the state E_x=9.499 MeV *4* (1970Aj04). See also E_x=10759 keV *20* (1955Mc75) and 10753 keV (1986Oh01). J^{π}: from (1986Oh01). S: from (1986Oh01).
10818 *5*		24 keV *3*			E(level),Γ: from (1973Go03). Unresolved E_x=10.81-11.02 MeV also reported in (1971Du09).
10997 *8*		82 keV *15*			E(level),Γ: from (1973Go03).
11080 *5*	$1/2^-$	<8 keV			E(level),Γ: from (1973Go03). E_x=11080 keV also reported in (1986Oh01). J^{π}: from (1986Oh01).
11748 *10*		107 keV *14*			E(level),Γ: from (1973Go03).
11851 *5*		68 keV *4*			E(level),Γ: from (1973Go03).
11970? *40*		≈260 keV			E(level),Γ: from (1973Go03: possibly more than one level). E_x=11970 keV

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^{12}C(d,p),(d,pγ) (continued)

^{13}C Levels (continued)

E(level)	$T_{1/2}$ or Γ	Comments
		also reported in (1971Du09).
12108 *5*	81 keV *8*	E(level),Γ: from (1973Go03).

† From, for example, DWBA analysis in (1986Oh01).

γ(^{13}C)

E_i(level)	J^π_i	E_γ	I_γ	E_f	J^π_f	Mult.	δ	Comments
3089.443	1/2$^+$	3089.049 *20*	100	0	1/2$^-$	E1		E_γ: measured (1980Wa24); see also E_γ=3082 keV *7* (corrected for Doppler shift) and 3097 keV *5* (uncorrected) (1952Th24), 3110 keV *12* (1961Go29). E_γ also reported in (1960Go19, 1961Go29, 1968Al03, 1995Ro28, 1997Pa43: E_{thres}=428 keV, 2000El08, 2014Cs03, 2014Cs08). I_γ: see (1962Si08,1966Ka05); the absolute E_γ yield is 1.55 *7* (2000El08). Mult.: see (1952Th24,1962Si08, 1966Ka05,1968Al03). Γ_γ>0.066 eV (1968Ri16: Doppler shift).
3684.482	3/2$^-$	595.013	0.75 *4*	3089.443	1/2$^+$	E1		E_γ: 595.013 keV *11* derived from γ rays measured in (1980Wa24). I_γ: from (1980Wa24); see also I_γ=1.6% *3* (1975Tr07), 1% (1966Ka05) and 0.6% (1962Si08). Mult.: see (1962Si08, 1966Ka05).
		3683.921	99.25 *4*	0	1/2$^-$	E2+M1	−0.096 +*30*−*21*	E_γ: 3683.921 keV *23* derived from γ rays measured in (1980Wa24); see also E_γ=3740 keV *30* (1955Be62: corrected for Doppler shift (required)), 3675 keV *15* (1956Ma52: corrected for Doppler shift), 3687 keV *15* (1961Go29), 3760 keV *20* (1955Be62: uncorrected), 3690 keV *20* (1956Ma52: uncorrected). E_γ also observed in (1960Go19, 1961Go29, 1962Si08, 1966Ka05, 1966Po11, 1973Go02, 1975Tr07, 1997Pa43: E(thres)=1122 keV, 2000El08, 2014Cs03). I_γ: from (1980Wa24); see also I_γ=98.4% *3* (1975Tr07), 99% (1966Ka05) and 100% (1962Si08). The absolute E_γ yield is 1.14 *6* (2000El08). Γ_γ>0.025 eV (1968Ri16: Doppler shift). Γ(E2)/Γ_γ</≈5% (1962Fl06). Mult.: see (1962Si08, 1966Ka05,

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^{12}C(d,p),(d,pγ) (continued)

γ(^{13}C) (continued)

E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.	δ	Comments
								1966Po11, 1973Go02). δ: From -0.096 $+$*30*$-$*21* (1966Po11). See also δ= -0.154 *54* (1973Go02).
3853.773	$5/2^+$	169.300 *4*	36.3 *6*	3684.482	$3/2^-$	E1		E_γ: measured (1980Wa24); see also E_γ=169.5 keV *4* (1956Ma52), 169.25 keV *4* (1969Al17: recoil energy E_R=1 eV), 169.3 keV (2000El08), 170 keV (1962Si08, 1966Po11, 1968Go14, 1976Dy05, 1997Pa43). E_γ also reported in (1960Ch01, 1960Ch12, 1966Go15, 1966Ka05, 1975Ra29, 1975Tr07). I_γ: from (1980Wa24); see also I_γ=37% *4* (1966Go15: the γ-ray intensity ratio, (total 3.68)/3.85=0.59 *7*), 36.0% *7* (1975Tr07), 24% *5* (1956Ma52: the γ-ray intensity ratio, (total 3.68)/3.85=0.46), 24% (1962Si08, 1966Ka05, 1966Po11), 30% (1975Ra29). Mult.: see (1962Si08, 1966Ka05). M1 cannot be excluded although the internal conversion coefficient, 1.4×10^{-4} *3*, is consisitent with E1 (1956Ma52). M^2(E1)=0.01 W.u. (1962Si08).
		764.316 *10*	1.20 *4*	3089.443	$1/2^+$	E2		E_γ: measured (1980Wa24). E_γ also reported in (1962Si08, 1966Go15, 1966Ka05, 1975Ra29, 1975Tr07). I_γ: from (1980Wa24); see also I_γ=0.93% *20* (1962Si08), 0.6% *2* (1975Tr07), 1% (1966Go15, 1966Ka05, 1975Ra29), not detected (1956Ma52: <3%, 1966Po11). Mult.: see (1962Si08, 1966Ka05). M^2(E2)=2.00 W.u. (1962Si08).
		3853.170	62.5 *6*	0	$1/2^-$	E3+M2	+0.12 *3*	E_γ: 3853.170 keV *22* derived from γ rays measured in (1980Wa24); see also E_γ=3860 keV *20* (1955Be62: uncorrected for Doppler shift (not required)), 3844 keV *15* (1956Ma52), 3863 keV *15* (1961Go29), 3840 keV *30* (1955Be62: corrected for Doppler shift). E_γ also reported in (1960Go19, 1961Go29, 1962Si08, 1966Go15, 1966Ka05, 1966Po11, 1968Al03, 1974Be48, 1975Ra29, 1975Tr07, 1977He12, 1997Pa43: E(threshold)=1321 keV, 2000El08, 2014Cs03). No γ-rays are observed with E_γ=3.9-5.8 MeV with intensity >10% of the 3.85 MeV γ-ray (1955Be62). I_γ: from (1980Wa24); see also I_γ=62% *4* (1966Go15), 63.4% *8* (1975Tr07), 75% (1962Si08,1966Ka05), 76% (1966Po11) and 69% (1975Ra29). The absolute E_γ yield is 6.92 *4* (2000El08). ω=0.61 rad/ps *5* which leads to the nuclear g-factor=0.59 *5* (1974Be48); see also g-factor=0.558 *15* (1981Ru04) and

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^{12}C(d,p),(d,pγ) (continued)

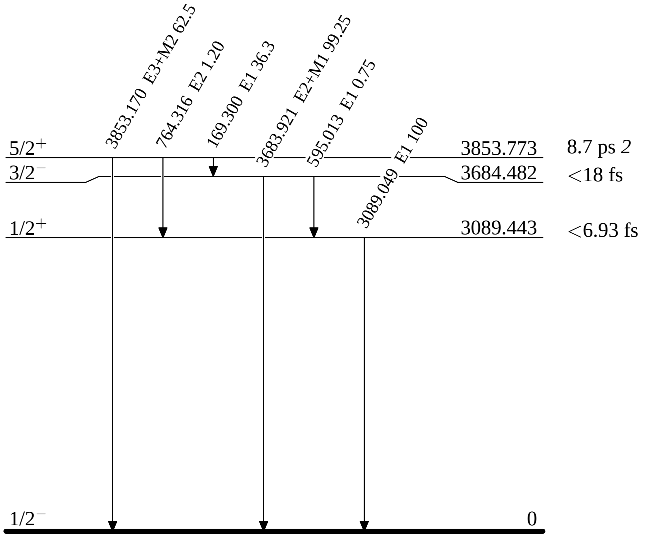
γ(^{13}C) (continued)

E_i(level)	E_γ	Comments
		g-factor=0.60 *5* (1973RaZH). The sign was found to be negative (1976Dy05). M^2(E3)=3.3 *+42−20* single-particle unit or 17.5 W.u. *+225−104*) (one standard deviation) (1966Po11), M^2(M2)=0.90 W.u. (1962Si08). M^2(E3)=2.0 *10* single-particle unit (1975Ra29) using Γ(E3,single particle)=2.6×10^{-7} eV (1966Po11). Γ(E3,single particle)=2.6×10^{-7} eV (1966Po11), Γ(E3)=5.2×10^{-7} eV *26* (1975Ra29), Γ(M2)=3.61×10^{-5} eV *23* (1975Ra29) using BR=69% *4* (average value of (1956Ma52,1966Go15) and the mixing ratio E3/M2=+0.12 *3* (1966Po11)). Γ(E3)/Γ_γ</≈2% (1962Fl06). δ: from (1966Po11). β_0=4.40% *5* (1977He12: average). Γ_γ(Doppler shift)=8.8×10^{-5} eV *30* (1962Si08), 4.4×10^{-5} eV *6* (1968Al03): see Table VI in (1968Ri16), 7.3×10^{-5} eV *16* (1968Ri16).

^{12}C(d,p),(d,pγ)

Level Scheme

Intensities: % photon branching from each level



$^{13}_{6}C_7$

^{12}C(t,d),^{13}C(t,t),(t,t′) 1966Gl01,1988Si08

1961Ba10: ^{12}C(t,d_0), E=5.5 MeV; measured angular distribution.
1966Gl01: ^{12}C(t,d), E =8,12 MeV; measured $\sigma(E_d,\theta)$; ^{13}C deduced levels, reduced width. Enriched ^{13}C targets.
1988Si08: ^{12}C(t,d), ^{13}C(t,t),(t,t′), E=38 MeV; measured $\sigma(\theta)$; deduced potential parameters. ^{13}C levels deduced β_2, β_4, single particle Γ of the resonances, spectroscopic factors. Optical DWBA analyses.
1961Ba10: ^{12}C(t,d_0); ^{13}C analysis.
2008Za05: ^{12}C(t,d), calculated energy and angular distributions.
2007Li55: ^{13}C(t,t′), E<40 MeV; analyzed elastic scattering σ and angular distribution data to obtain a set of global optical model potential parameters. Compared results to other calculations.
2009Pa07: ^{13}C(t,t), E=38 MeV; analyzed $\sigma(\theta)$ using global optical model potential GDP08; deduced set of global optical potential parameters.
2015Pa10: ^{13}C(t,t), E=4-118.5 MeV; analyzed $\sigma(\theta)$ for 142 sets of experimental data; deduced optical model parameters.

^{13}C Levels

E(level)[†]	J^{π}[†]	C^2S (Finite Range=0)[†]	Comments
0[‡]	1/2$^-$[‡]	0.74	β_2=−0.428 *40*, β_4=−0.20 *10* (1988Si08). C^2S (Finite Range=0): See also S=0.81 (1966Gl01).
3088[‡]	1/2$^+$[‡]	0.28	C^2S (Finite Range=0): See also S=0.90 (1966Gl01).
3684[‡]	3/2$^-$[‡]	0.14	C^2S (Finite Range=0): See also 0.28 (1966Gl01).
3854[‡]	5/2$^+$[‡]	0.61	C^2S (Finite Range=0): See also S=0.77 (1966Gl01).
6860[#]	5/2$^+$[#]	0.03	
7490	7/2$^+$	0.03	
7550[#]	5/2$^-$[#]	0.02	
7690?	3/2$^+$	0.015	
8200	3/2$^+$	0.014	
9500	9/2$^+$	0.006	
10750	7/2$^-$	0.09	

[†] From DWBA analysis in (1988Si08: ^{12}C(t,d)).
[‡] Also reported in (1966Gl01 and 1988Si08: ^{13}C(t,t′)).
[#] Also reported in (1988Si08: ^{13}C(t,t′)).

^{12}C(^{3}He,2p)

1971St21,1971StZL: ^{12}C(^{3}He,2p), E=40 MeV; measured σ(E(p1), θ(p1), θ(p2)), $\sigma(\theta)$; deduced p-p final-state interaction contribution. The angular distributions for the transitions to ^{13}C*(0,3.85) have been studied.

1974No01: ^{12}C(^{3}He,2p), E=12,13.5,14 MeV; measured σ(Ep,θ), pp(θ). The sequential proton decay of via various ^{14}N states to $^{13}C_{g.s.}$ was measured.

1976StYX: ^{12}C(^{3}He,2p), E=60 MeV; measured σ.

1980StZO: ^{12}C(^{3}He,2p), E=60 MeV; measured σ(E(^{2}He),θ(^{2}He)) via pp-coin; deduced final state interaction effects. Zero-range, exact finite-range, microscopic DWBA calculations. Kinematically complete coincidence measurement,charge exchange reaction.

1980Aa01, 1984Aa01: ^{12}C(^{3}He,2p), E=52 MeV; measured inclusive $\sigma(\theta$p), σ(Ep), $\sigma(\theta1,\theta2$,Ep1), $\sigma(\theta1,\theta2)$; deduced reaction mechanism, σ vs target mass. Quasifree breakup calculations.

1986Ka44: ^{12}C(pol. ^{3}He,2p), E=33 MeV; measured $\sigma(\theta)$, analyzing power vs E1, E2, θ_1, θ_2; deduced j-dependence. ^{13} levels deduced normalization. Sequential breakup model analysis. ^{13}C*(3.85) is strongly populated. ^{13}C*(0,8.0(broad),9.5) have also been populated.

^{13}C Levels

E(level)	Comments
0	Q=−2.77 MeV (1971St21). E(level): reported in (1971St21,1974No01,1986Ka44).
3850	E(level): reported in (1971St21,1986Ka44: strongly populated).
≈8000	E(level): broad (1986Ka44).
9500	E(level): reported in (1986Ka44).

${}^{12}C(\alpha,{}^{3}He)$

1969Ga11: ${}^{12}C(\alpha,{}^{3}He_0)$, E=56 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=15° to 60°; deduced relative S for $(\alpha,{}^{3}He)$.
1972Ha08: ${}^{12}C(\alpha,{}^{3}He_0)$, E=104 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}\approx$11° to 70°; deduced normalization factors, absolute S.
1973Sm03: ${}^{12}C(\alpha,{}^{3}He)$, E=139 MeV; measured $\sigma(E\alpha,\theta)$, $\sigma(E({}^{3}He),\theta)$ for $\theta_{c.m.}\approx$5° to 60°. Deduced spectroscopic strengths of S(g.s.)=0.69 ± 15% and S(3.85)=0.40 ± 15%.
1994Da32: ${}^{12}C(\alpha,{}^{3}He)$, E=90 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=10° to 90°; deduced far-side component role, rainbow effect evidence.
1995Da08: ${}^{12}C(\alpha,{}^{3}He){}^{13}C_{g.s.}$, E=90 MeV; measured $\sigma(\theta)$; deduced nuclear rainbow effect evidence, model parameters. Fuller′s model, near/far-side formalism.
2021Ki07: $C(\alpha,{}^{13}C\gamma)$ E=50-90 MeV; measured $\sigma(E_\alpha,E_\gamma)$ for E_γ=3685, 3854 keV.

Theory:
1974Ha32: ${}^{12}C(\alpha,{}^{3}He)$, E=139 MeV; calculated $\sigma(\theta)$, recoil effects.

${}^{13}C$ Levels

E(level)	J^π	L	S	Comments
0	$1/2^-$	1	1.38	E(level): see (1969Ga11,1972Ha08,1973Sm03,1994Da32,1995Da08). J^π,L,S: from DWBA analysis in (1972Ha08). See also S=1.15-1.4 in (1969Ga11).
3090				E(level): reported in (1994Da32).
3685				E(level): reported in (1994Da32).
3850				E(level): see (1983Sm03,1994Da32).

^{12}C(^{7}Li,^{6}Li),(^{8}Li,^{7}Li)

1973Sc26: ^{12}C(^{7}Li,^{6}Li), E=34,36 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=15° to 70°. FRDWBA, deduced optical model parameters.
1979Ze01: ^{12}C(^{7}Li,^{6}Li), E=48 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=5° to 90°; deduced optical-model parameters. ^{13}N, ^{13}C deduced S-factors. Enriched targets, finite range DWBA analysis.
1982Ta23: ^{12}C(^{7}Li,^{6}Li), E=36,32,28 MeV; measured yield vs particle energy, $\sigma(\theta)$ for θ=7.5° to 50°, fusion σ, breakup σ vs E; deduced reaction mechanism.
1984Mo06: ^{12}C(pol. ^{7}Li,^{6}Li), E=21.1 MeV; measured $\sigma(\theta)$, $T_{20}(\theta)$, $T_{21}(\theta)$, $T_{22}(\theta)$ for $\theta\approx30°$ to 110°. Optical model analysis.
1986Co02: ^{12}C(^{7}Li,^{6}Li), E=34 MeV; measured particle spectra, $\sigma(\theta)$ for θ=20° to 120°; deduced potential parameters. ^{13}C levels deduced S-factors.
1989Be28: ^{12}C(^{8}Li,^{7}Li), E=13 MeV; measured $\sigma(\theta)$, $\sigma(E(^{7}Li))$; deduced astrophysical abundance implications.
1989BeZY: ^{12}C(^{8}Li,^{7}Li), E=14.3 MeV; measured $\sigma(\theta)$. Radioactive beams.
1993Be22: ^{12}C(^{8}Li,^{7}Li), E≈13-20 MeV; measured $\sigma(\theta)$.

Theory:
1973DuZP: ^{12}C(^{7}Li,^{6}Li), E=36 MeV; calculated $\sigma(E,\theta)$, $\sigma(E(^{6}Li),\theta)$.
1973Ku12: ^{12}C(^{7}Li,^{6}Li), E=36 MeV; calculated $\sigma(\theta)$, cluster model DWBA analysis.
1976Ku06: ^{12}C(^{7}Li,^{6}Li), E=36 MeV; analyzed anomalous $\sigma(\theta)$.
1988Ke07: ^{12}C(^{7}Li,^{6}Li), E=34 MeV; analyzed $\sigma(\theta)$; deduced reaction mechanism.
2002Ke04: ^{12}C(pol. ^{7}Li,^{6}Li), E=34 MeV; measured $\sigma(E,\theta)$, analyzing powers. Coupled channels analysis.
2002Ke11: ^{12}C(^{7}Li,^{6}Li), E=34 MeV; analyzed $\sigma(\theta)$. ^{13}C deduced neutron binding potential radius, possible core deformation.

^{13}C Levels

E(level)	J$^{\pi}$[‡]	L[#]	S[‡]	Comments
0[†]	1/2^{-}	0,1,2	0.65 *6*	S: see also 0.80 (1979Ze01,1993Be22).
3090[†]	1/2^{+}	1	0.75 *8*	S: see also 0.9 (1973Sc26: estimated), and 0.44 (1979Ze01).
3680	3/2^{-}		0.17	E(level),J$^{\pi}$,S: from (1979Ze01).
3850[†]	5/2^{+}	1,2,3	0.68 *10*	S: see also 1.0 (1973Sc26: estimated), 0.74 (1979Ze01), 1.1 (1993Be22).
6.86×10^{3}				
7.6×10^{3}				E(level): unresolved multiplet.
9.5×10^{3}				

[†] Angular distributions to these states were studied; some higher-energy states were also observed (1973Sc26,1979Ze01,1986Co02).
[‡] From DWBA analysis in (1986Co02), except where noted. In (1993Be22) S are deduced from normalization to FRDWBA calculations assuming (^{8}Li,^{7}Li$_{g.s.}$) is the dominant transfer mode. We assume $^{8}Li_{g.s.}\rightarrow{}^{7}Li_{g.s.}$+n has S=1.0.
[#] From (1973Sc26).

^{12}C(^{9}Be,^{8}Be)

1970Ba49: ^{9}Be(^{12}C,^{13}C), E=12,15 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}\approx70°$ to 150°. Deduced neutron S.
1977St20: ^{12}C(^{9}Be,^{8}Be), E=50 MeV; measured $\sigma(\theta)$. ^{13}C levels.
1978MaZR,1978Ma44: ^{9}Be(^{12}C,^{8}Be), E(cm)=10-15 MeV; measured $\sigma(\theta)$ for θ=13° to 75°.
1979Bo06: ^{9}Be(^{12}C,^{8}Be), E(cm)=11.4-14.8 MeV; measured excitation curves, $\sigma(\theta(^{8}Be))$ for $\theta\approx11°$ to 165°. DWBA analysis, n-, α-transfer, compound nucleus formation.
1979Ja05: ^{12}C(^{9}Be,^{8}Be), E=20 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}\approx10°$ to 140°. Deduced S for n-, α-transfer. Finite range DWBA.
1981Hu12: ^{9}Be(^{12}C,^{8}Be), E(cm)=6-15 MeV; measured $\sigma(\theta$,E); deduced deviation function confidence limits.
1982Hu06: ^{12}C(^{9}Be,^{8}Be), E(cm)=5.9-15.4 MeV; measured σ(E) for θ=7.5° and 27.5°.
1982Ta21: ^{9}Be(^{12}C,^{8}Be), E(cm)≈4-7 MeV; measured $\sigma(\theta)$ vs E; deduced sub-Coulomb molecular resonances.

Theory:
1981La15: ^{9}Be(^{12}C,^{8}Be), E(cm)=6-15 MeV; calculated σ(E); deduced resonance structure. Statistical model, energy-dependent deviation function.
1983DeZW: ^{9}Be(^{12}C,^{8}Be), E not given; calculated production σ; deduced reaction mechanism. Statistical model.
1983Ka17: ^{12}C(^{9}Be,^{8}Be), E=20-45 MeV; analyzed $\sigma(\theta)$; deduced higher order processes role. Optical model, DWBA, potential scattering, direct interaction interference, incoherent compound nucleus contribution.

^{13}C Levels

E(level)	J^{π}†	S†	Comments
0	1/2^{-}	1.15	E(level),J^{π}: listed in (1977St20, 1982Hu06). See also (1970Ba49, 1978Ma44, 1979Bo06, 1979Ja05, 1982Ta21). S: See also S=0.80 (1970Ba49).
3086	1/2^{+}	0.95	E(level),J^{π}: listed in (1977St20, 1982Hu06). See also (1970Ba49, 1979Bo06, 1979Ja05). S: See also S=1.02 (1970Ba49).
3680	3/2^{-}	0.20	E(level),J^{π}: listed in (unresolved: 1982Hu06, 1978Ma44). See also (1979Bo06, 1979Ja05).
3850	5/2^{+}	1.02	E(level),J^{π}: listed in (1977St20, 1982Hu06:unresolved). See also (1970Ba49, 1978Ma44:unresolved, 1979Bo06, 1979Ja05). S: See also S=0.89 (1970Ba49).
6860	5/2^{+}		E(level),J^{π}: from (1977St20,1978Ma44: 6.87 MeV).
7500			E(level): from (1977St20). See also (1978Ma44: cluster of states near 7.55 MeV).
8200	3/2^{+}		E(level),J^{π}: from (1977St20).
9500‡			E(level): from (1977St20).
10800‡			E(level): from (1977St20).

† From DWBA analysis in (1979Ja05), except where noted.
‡ Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

^{12}C(^{11}B,^{10}B),(^{12}C,^{11}C)

Also includes ^{12}C(^{14}N,^{13}N), ^{12}C(^{17}O,^{16}O), ^{12}C(^{18}O,^{17}O) reactions.

1967Bi06: ^{12}C(^{14}N,^{13}N), E=148 MeV; Measured ^{13}N energy spectrum at θ=18° to 28° at the Yale linear accelerator. Observed states at ^{13}C(0,3.89,7.6,9.5 MeV); discussed configurations.

1967Po13: ^{12}C(^{11}B,^{10}B), E=115.9 MeV; Measured ^{10}B energy spectrum at θ_{lab}=8.5° at the Yale linear accelerator. Populated states at ^{13}C(0,3.85,5.8 MeV).

1974An36: ^{12}C(^{11}B,^{10}B),(^{12}C,^{11}C), E=114 MeV from the AERE Harwell cyclotron; measured particle spectra, σ(E,θ) for $\theta\approx$10° to 60°. Deduced levels, J, π, spectroscopic amplitudes.

1978Ch16: ^{12}C(^{17}O,^{16}O),(^{18}O,^{17}O), E(cm)=12.6-14.0 MeV from the Weizmann Institute Tandem; measured $\sigma(\theta)$ for $\theta\approx$40° to 140°; deduced reaction mechanisms, S. ^{12}C natural targets.

1979Fu04: ^{12}C(^{12}C,^{11}C), E=93.9 MeV; measured $\sigma(\theta)$. DWBA analysis.

1989HeZU: ^{12}C(^{12}C,^{11}C), E=344.5 MeV; measured $\sigma(\theta)$; deduced model parameters, spectroscopic factor. DWBA analysis.

1992Ja10: ^{12}C(^{12}C,^{11}C), E=344.5 MeV from the JULIC cyclotron; measured particle spectra, $\sigma(\theta)$ for $\theta\approx$10° to 35°. Deduced single particle transfer spectroscopic factors, products of spectroscopic factor, $C^2S_1\cdot C^2S_2$. DWBA analyses.

2013Ca25: XUNDL dataset compiled by TUNL, 2014.

The authors measured angular distributions for the one-neutron transfer reaction ^{12}C(^{18}O,^{17}O)^{13}C. Data were analyzed via exact finite range Coupled Reaction Channel Calculations (CRCC) based on a parameter free double folding potential. This reaction study is part of a greater work, which included measurements on ^{13}C(^{18}O,^{17}O)^{14}C and ^{12}C(^{18}O,^{16}O)^{14}C. As a result, a detailed analysis of the two-neutron transfer reaction was carried out.

Beams of E(^{18}O)=84 MeV ions, from the INFN Catania impinged on 50 μg/cm^2 targets of either ^{12}C(pure) or ^{13}C(99% enrichment). Reaction products were analyzed using the MAGNEX spectrometer with θ_{lab}=8°, 12° and 18°. Angular distributions were analyzed. In the one-neutron transfer reaction a complex relation of levels in the carbon and oxygen residuals is excited which makes interpretation non-trivial.

^{13}C Levels

E(level)	J^{π}[†]	L[‡]	S[†]	Comments
0	1/2$^-$	1	0.78 *10*	E(level),J^{π}: (1974An36,1992Ja10,2013Ca25); see also (1967Bi06,1967Po13). S: from (1978Ch16: $^{13}C_{g.s.}$=$^{12}C_{g.s.}\times1p_{1/2}$); see also 0.66 (1974An36), 0.52 (1992Ja10).
3090 *10*	1/2$^+$	0	0.90 *17*	E(level),J^{π}: (2013Ca25); see also (1974An36). S: from (1978Ch16: $^{13}C^*(3.09)$=$^{12}C_{g.s.}\times2s_{1/2}$); see also 1.17 (1974An36).
3680	3/2$^-$	1	0.21	E(level),J^{π},S: (1974An36).
3850 *10*	5/2$^+$	2	0.48	E(level),J^{π}: (2013Ca25); see also (1967Bi06,1967Po13,1974An36,1992Ja10). S: from (1992Ja10); see also 1.07 (1974An36).
6860 *10*	5/2$^+$			E(level),J^{π}: (2013Ca25).
7490	7/2$^+$		0.052	E(level),J^{π},S: (1992Ja10).
7550	5/2$^-$		0.108	E(level),J^{π},S: (1992Ja10).
7690 *10*	3/2$^+$	2	0.09	E(level),J^{π}: (2013Ca25); see also (1967Bi06: weak peak,1974An36: E_x=7680 keV). S: from (1974An36).
8250	3/2$^+$	2	0.67	E(level),J^{π},S: (1974An36).
9500 *10*	9/2$^+$		0.047	E(level),J^{π}: (2013Ca25); see also (1992Ja10) and (1967Bi06: J^{π}=7/2$^-$). S: from (1992Ja10).

[†] From DWBA analyses in (1974An36,1992Ja10,2013Ca25).

[‡] From (1974An36).

^{12}C(^{13}C,^{13}C),(^{13}C,X) 2016Ka37

1977Gu07: ^{12}C(^{13}C,^{13}C), E=12 MeV; measured $\sigma(\theta)$ for θ=39° to 136° at Heidelberg Tandem accelerator. DWBA analysis. Deduced a model-independent value of C^2=2.55 *10* for the asymptotic normalization of the 1$p_{1/2}$ neutron wave function. Using this, and a bound-state wave function obtained from analysis of electron elastic scattering, the absolute spectroscopic fasctor S=0.81 *4* was deduced.

1985Bo39: ^{12}C(^{13}C,^{13}C),(^{13}C,^{13}C′), E=240 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}\leq 60°$ using the VICKSI spectrometer in Berlin; analyzed refractive scattering and nuclear rainbow effects for ^{13}C(0, 3.85 MeV).

1986Ba80: ^{12}C(^{13}C,^{13}C),(^{13}C,^{13}C′), E≈50 MeV; measured $\sigma(\theta)$ for θ=20° to 160°. Deduced reaction mechanism.

1991Fu10: C(^{13}C,X) E≈33 MeV/nucleon. Measured total reaction cross section.

2000Fa12, 2000Fa17: C(^{13}C,X) E≈33.4 MeV/nucleon. Measured total reaction cross section.

2001Oz03: C(^{13}C,^{13}C) E≈960 MeV. Measured interaction cross section. Deduced matter radius of 2.28 fm *4*. See also (2001Oz04).

2010Al10: ^{13}C(^{12}C,^{13}C), E=10.6 MeV/nucleon; σ and $\sigma(\theta)$ for $\theta_{c.m.}\leq 60°$ using the Texas A&M MDM spectrometer; deduced optical model parameters and asymptotic normalization coefficients (ANC) $C^2_{p1/2}$=2.24 fm^{-1} *11*. They average their value with those from other reactions to obtain $C^2_{p1/2}$=2.31 fm^{-1} *8*; with this value they analyze stellar reaction rates.

2016Ka37: XUNDL dataset compiled by TUNL, 2017.

The authors carried out a systematic study of the charge changing cross sections of ≈900 MeV/nucleon carbon isotopes on a carbon target and analyzed the data to obtain the proton and matter radii of $^{12-19}$C.

A beam of 828 MeV/nucleon ^{13}C ions was produced by fragmenting either a 1 GeV/nucleon ^{20}Ne beam or 1 GeV/nucleon ^{40}Ar beam on a thick beryllium target at the GSI/FRS facility. After magnetic separation, the ^{13}C beam particles were identified event-by-event using a multi-sampling ionization chamber and the time-of-flight between two scintillators. The beam then passed through a thick carbon target before being reanalyzed in a second multi-sampling ionization chamber that measured the Z of ions after the target. In the analysis, the ratio of the charge changing events to the non-charge changing events was determined and used to obtain σ_{α}, the charge changing cross section. For ^{13}C, σ_{α}=726 mb *7* was determined.

The data were then compared with a finite-range Glauber model to obtain root-mean-square radii for the proton distribution and for the matter distribution. The results from the systematic study across $^{12-19}$C is then compared with various models and comments are given on the development of neutron skins and neutron halos.

Theory:

1973Vo04: ^{12}C(^{13}C,^{13}C); calculated $\sigma(\theta)$, particle, hole transfer.

1975De09: ^{13}C(^{12}C,^{12}C), ^{13}C(^{12}C,^{12}C), ^{13}C(^{14}C,^{14}C): E=7.8-12.6 MeV; analyzed data and deduced optical model parameters.

1984Vo11: ^{12}C(^{13}C,^{13}C), E(cm)=5-20 MeV; calculated $\sigma(\theta)$ vs E. ^{12}C(^{13}C,^{13}C′), E(cm)=7.8,9.88 MeV; calculated $\sigma(\theta)$, P(θ), σ. Coupled reaction channels model, valence nucleon molecular orbiting.

2019Ay05: ^{12}C(^{13}C,^{13}C); E<300 MeV; analyzed available σ data; deduced the real part of the optical potential using the double folding model.

2021Do04: ^{12}C(^{13}C,^{13}C) E=7.8, 14.2 MeV; used CDCC model to calclate exchange effects in scattering reactions.

^{13}C Levels

E(level)	J$^{\pi}$	S	Comments
0	1/2$^-$	0.81 *4*	S: From (1977Gu07). $R^{protons}_{r.m.s.}$=2.30 fm *4*, $R^{matter}_{r.m.s.}$=2.28 fm *4* (2016Ka37). ANC is $C^2_{p1/2}$=2.24 fm^{-1} *11* (2010Al10).
3.85×10^3	5/2$^-$		E(level): See discussion in (1985Bo39).

^{12}C(^{14}N,^{13}N)

1969Vo01,1970Vo02: ^{12}C(^{14}N,^{13}N), E=78 MeV; measured σ(E(^{13}N), E(^{13}C),θ), $\sigma(\theta)$ for θ=5°−37°. DWBA analysis.
1974De03: ^{12}C(^{14}N,^{13}N), E=100 MeV; measured σ(E(^{13}N),θ) for $\theta_{c.m.}$=10° to 35°. ^{13}C deduced levels, L.
1975Na15: ^{12}C(^{14}N,^{13}N), E=155 MeV; measured $\sigma(\theta)$ for θ=20° to 50°. ^{13}C levels deduced S-factors.
1975Vo05: ^{12}C(^{14}N,^{13}N), E=155 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=20° to 50°.
1976Ba16: ^{12}C(^{14}N,^{13}N), E=28,32,34,36 MeV; measured σ(E(^{13}N),θ) at $\theta_{c.m.}\approx$40° to 90°; deduced angular symmetry violation, existence of complex (2-step) reaction mechanism.
1981LiZV: ^{12}C(^{14}N,^{13}N), E=53.5 MeV; measured $\sigma(\theta)$. DWBA analysis.
1983Qu02: ^{12}C(^{14}N,^{13}N), E=48 MeV; measured σ(E1,E2,θ1,θ2); deduced reactions σ, proton rapidity plot. Dalitz plot analysis, analyzed projectile fragmentation, light particle emission.
1997Zi05: ^{12}C(^{14}N,^{13}N), measured $\sigma(\theta)$ for $\theta_{c.m.}$=10° to 70°; deduced reaction mechanism. Coupled reaction channels analysis.

Theory:
1969Do07: ^{12}C(^{14}N,^{13}N), calculated $\sigma(\theta)$ with recoil damping.
1973De02: ^{12}C(^{14}N,^{13}N), calculated $\sigma(\theta)$; analyzed recoil effects. DWBA.
1973De35: ^{12}C(^{14}N,^{13}C)^{13}N, calculated $\sigma(\theta)$, S-factors, recoil effects.
1974Br18: ^{12}C(^{14}N,^{13}N), E=78 MeV; calculated recoil, finite range effects.
1974Br37: ^{12}C(^{14}N,^{13}N)^{13}C$_{g.s.}$, E=78,100,150 MeV; calculated σ(E(^{13}N),θ).
1975Re04: ^{12}C(^{14}N,^{13}N), E=78 MeV; calculated σ.
1976Ku06: ^{12}C(^{14}N,^{13}N), E=100 MeV; analyzed anomalous $\sigma(\theta)$.
1976Na09: ^{12}C(^{14}N,^{13}N), E=155 MeV; calculated $\sigma(\theta)$.
1978Na15: ^{12}C(^{14}N,^{13}N), E=100 MeV; calculated $\sigma(\theta)$. DWBA, CCBA, finite range.
1979Do13: ^{12}C(^{14}N,^{13}N), E=78 MeV; calculated $\sigma(\theta)$. DWBA with recoil, strong absorption, eikonial-like representation of elastic scattering.
1983Os08: ^{12}C(^{14}N,^{13}N), E=100 MeV; analyzed $\sigma(\theta)$; deduced model parameters. ^{13}C levels deduced S-factors.
1984Bl21: ^{12}C(^{14}N,^{13}N), E=70 MeV; calculated $\sigma(\theta)$.
1988Ka27: ^{12}C(^{14}N,^{13}N), E=68 MeV; analyzed $\sigma(\theta)$.
2002Ke11: ^{12}C(^{14}N,^{13}N), E=100 MeV; analyzed $\sigma(\theta)$. ^{13}C deduced neutron binding potential radius, possible core deformation. Coupled channels approach.

^{13}C Levels

E(level)†	J$^{\pi}$†	L†	$C_2^2S_2$†	Comments
0	1/2$^-$	0,1	0.72	E(level),J$^{\pi}$: see (1974De03,1975Na15). L: (1974De03,1975Na15). $C_2^2S_2$: deduced from $C_1^2S_1C_2^2S_2$=0.50 (1975Na15) and assuming $C_1^2S_1$ given by (1967Co32). See also the product S-factor=0.51 (1974De03) and 0.53 (1973De35).
3090	1/2$^+$	1		E(level),J$^{\pi}$: see (1974De03,1975Na15). L: (1974De03).
3680	3/2$^-$			E(level): see (1974De03,1975Na15,1997Zi05). J$^{\pi}$: see (1974De03,1975Na15).
3850	5/2$^+$	2,3		E(level): see (1974De03,1975Na15,1997Zi05). J$^{\pi}$: see (1974De03,1975Na15). L: (1975Na15).
6870	5/2$^+$		0.57	E(level),J$^{\pi}$: see (1975Na15). $C_2^2S_2$: deduced from $C_1^2S_1C_2^2S_2$=0.39 (1975Na15) and assuming $C_1^2S_1$ given by (1967Co32). See also the product S-factor=0.37 (1974De03).
7.3×10^3 *3*				E(level): Unresolved group including ^{13}C*(6.86+7.50+7.55+7.68) from (1974De03).

† From DWBA analysis in, for example, (1974De03,1975Na15) as noted.

^{13}C(γ,γ')

1968Ro02: ^{13}C(γ,γ'), measured the mean lifetime of ^{13}C*(3089), τ_m=1.5 fs *2*.
1969Ra20: ^{13}C(γ,γ'), E<3.8 MeV; measured σ(Eγ',θ). Deduced level-width. Resonance fluorescence.
1975Ra22: ^{13}C(γ,γ'), E$_{brem.}$=3.19 MeV; measured Γ(^{13}C*(3.086))=0.39 eV *6* using nuclear resonant scattering.
1991Li12: ^{13}C(γ,γ'), E=4.1 MeV bremsstrahlung; measured Eγ, Iγ. Nuclear resonance fluorescence technique, Monte Carlo simulations.
1993Mo23: ^{13}C(γ,γ'), E=4.7 MeV bremsstrahlung; measured precise Eγ, Iγ. Deduced Γ_0. Self-absorption technique, enriched target, amorphous ^{13}C absorbers. They give some commentary on the thermal corrections that were overlooked by other reports.
2000Ka08: ^{13}C(γ,γ'), E=6.7 MeV bremsstrahlung; measured Eγ, Iγ, γ polarization.

^{13}C Levels

E(level)	J$^{\pi}$	T$_{1/2}$	Comments
0			
3080 *30*	1/2	0.98 fs *9*	E(level): From (1975Ra22); see also E$_x$=3089 keV (1968Ro02,1991Li12,1993Mo23). J$^{\pi}$: see (1993Mo23). T$_{1/2}$: from τ=1.42 fs *13* corresponding to Γ=0.464 eV *42* which is the weighted average of 0.463 eV *56* and 0.413 eV *50* from (1968Ro02), 0.537 eV *42* (1993Mo23: using Γ_0/Γ=1 and T$_e$=930 K) and 0.39 eV *6* (1975Ra22).
3685.041 *20*	3/2	1.12 fs *6*	E(level): deduced from the measured E$_\gamma$ (1991Li12); see also (1969Ra20,1993Mo23). J$^{\pi}$: see (1993Mo23). T$_{1/2}$: from τ=1.61 fs *9* obtained from the average of τ=1.59 fs *13* (1991Li12: Γ_0^2/Γ=0.408 eV *26*) and τ=1.63 fs *12* (1993Mo23: Γ=0.403 eV *30* using Γ_0/Γ=1, T$_e$=930 K). See also τ=1.50 fs *14* (1969Ra20: Γ=0.44 eV *4*), but this value is omitted because the authors neglected thermal effects; see (1993Mo23) and footnote 20 in (1969Ra20).

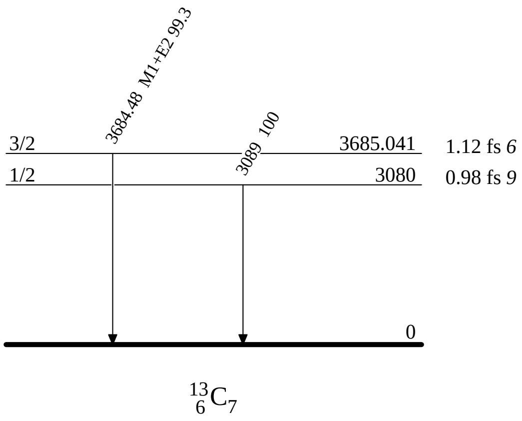
γ(^{13}C)

E$_i$(level)	J$^{\pi}_i$	E$_\gamma$	I$_\gamma$	E$_f$	Mult.	Comments
3080	1/2	3089	100	0		
3685.041	3/2	3684.48 *2*	99.3 *7*	0	M1+E2	E$_\gamma$,I$_\gamma$: (1991Li12). Mult.: (1969Ra20).

^{13}C(γ,γ′)

Level Scheme

Intensities: % photon branching from each level



^{13}C(γ,n),(γ,nγ),(γ,p)

1956Co72, 1957Co57: ^{13}C(γ,n),(γ,p); The neutron yield up to E_{γ}=41 MeV was measured using bremsstrahlung photons, and the photoproton yield was also measured using activation techniques. Measured σ(E). Deduced broad peaks at E_x=13.5 MeV *10* and 25.5 MeV *2* with Γ=5 MeV *1* and 10 MeV *2*, respectively.

1960Ed01: Using the mixture of E_{γ}=6.13, 6.9 and 7.1 MeV γ rays from the ^{19}F(p,αγ) reaction at E_p=874 keV, the $E_{\gamma}\approx$6.4 MeV cross section for ^{13}C(γ,n) was found to be 94.1 mb *10*.

1961Ko01: ^{13}C(γ,n), measured not abstracted; deduced nuclear properties.

1964De12: ^{13}C(γ,p), E=17-32 MeV. measured σ(E) for photonproton emission using activation techniques. Deduced peaks at E_x=18.5, 20.0, 23.5, 26.0, 29 MeV.

1964Gr40: ^{13}C(γ,n), E=5.4-10.8 MeV; measured photoneutron production; deduced σ(E). Resonances near ≈7.7 MeV are evident.

Bertozzi et al., NIM **33** 199 (1965): ^{13}C(γ,n), $E_{brem.}$=13.6 MeV; measured σ(E,θ) for θ=77° and 157°. Observed peaks corresponding to E_x=7.8, 8.9, 10.9, 12.9 MeV.

1970Fu09: ^{13}C(γ,n), $E_{brem.}$=14.5 MeV; measured σ(E;θ), observed peaks corresponding to E_x=6.2, 7.5, 8.2, 9.1, 11 and 13 MeV; deduced integrated σ. Analyzed pygmy resonance region.

1971Mu11: ^{13}C(γ,nγ), $E_{brem.}$=21,28 MeV; measured σ(E;E_{γ}). Analyzed ^{12}C*(15.11) [$J^{\pi}=1^{+}$; T=1] population following neutron emission from the T=3/2 component of the ^{13}C giant resonance.

1975Pa09: ^{13}C(γ,nγ′),(γ,pγ′), E<44 MeV; measured σ(E,$E_{\gamma'}$), analyzed population of ^{12}C and ^{12}B states. Deduced giant resonance structure. ^{12}C*(4.4) is populated most strongly at ^{13}C*(13 MeV). A low-energy giant resonance component around 22 MeV decays to ^{12}B states, while a higher-energy component around 28 MeV decays to ^{12}C states.

1976Ko22: ^{13}C(γ,n), E=4.8-25 MeV; measured yield curve; deduced σ(E_{γ},n), integrated σ. ^{13}C deduced resonances, Γ. Observed peaks at E_x=7.7, (8.2), (9.1), (10.0), 11, 13, 15, (16.5) 20.5, 24.0 MeV.

1977Wo04: ^{13}C(γ,n), E=6-35.5 MeV; measured σ(E). ^{13}C deduced resonances, Γ. Observed peaks at E_x=7.71, 7.88, 8.87, 9.49, 9.69, 11.0, 12.08, (13.62), (15.09), 15.13, 16.94, 17.95 MeV.

1979Ju01: ^{13}C(γ,n), E=7.6-41.8 MeV; measured 4π-neutron yield, integrated σ(γ,n), σ(γ,2n); deduced isospin splitting of giant resonance. Observed peaks at E_x=7.8, 9, 10, 11, 10.5, 13.8, 16.5, 17.8,20.8, 24 (GR), 30, 37 MeV. Discussion on pygmy and giant resonance regions.

1979Wo06: ^{13}C(γ,n), E=7.6-24 MeV; measured photoneutron angular distributions, deduced σ(E_{γ},n), angular distribution coefficients. $E_{brem}\leq$12 MeV: θ=56° to 144°; $E_{brem}\leq$16 MeV: θ=75° to 145° and $E_{brem}\leq$18.4 to 24.6 MeV: θ=48° to 160°. Reported levels at E_x=7.70 MeV: $J^{\pi}=3/2^{+}$, 7.95: $3/2^{+}$, 8.95: ($1/2^{-}$), 10.0: ($3/2^{-}$), 11.0: ($1/2^{+}$) and 12.05: ($3/2^{+}$).

1980Ho11: ^{13}C(γ,n_0), E=6.5-9.3 MeV; measured σ(θ), θ=90°, 135°; deduced Γ_{γ}. High-resolution R-matrix analysis. Reported on E_x=7.56, 7.69, 8.19, 8.89 MeV.

1982Ki09: ^{13}C(γ,n), E=5-25 MeV; analyzed σ(E). ^{13}C deduced GDR isospin splitting.

1983Zu02: ^{13}C(γ,p), E=17.5-28 MeV. measured σ(E) for photonproton emission using activation techniques. Deduced peaks at E_x=18.6, (19.7), 20.7, (22), 23.5, 24.5, (26) MeV. Compared with (1979Ju01).

See (1999Su12) for related discussion and analysis of the ^{13}C pygmy and giant resonances.

Theory:

1969Au06: ^{13}C(γ,n), E<17 MeV; analyzed σ(E) data, deduced resonant contributions.

1972Go27: ^{13}C(γ,n),(γ,p), E<30 MeV; calculated σ(E); analyzed giant resonance.

1972Ha16: ^{13}C(γ,n), derived isospin sum rules for photonuclear reactions.

1973KiZI, 1974Ki03: ^{13}C(γ,n); calculated σ(En) in GDR region.

1974Ma10: ^{13}C(γ,n); calculated giant dipole resonance, isospin splitting.

1977Al18: ^{13}C(γ,X); calculated σ. ^{13}C calculated resonances, T. Two-particle, one-hole shell model.

1977Ho32: ^{13}C(γ,np), E=10-35 MeV; calculated σ(E).

1977Ma06: ^{13}C(γ,n); calculated σ. ^{13}C calculated GDR decay properties.

1979Ho17: ^{13}C(γ,n); E=10-35 MeV; calculated σ(E). Continuum shell model, 3 particle-2 hole configurations.

1993Mc02: ^{13}C(γ,n); E<36 MeV; analyzed σ(E); deduced isospin component splitting.

2017Dz03: ^{13}C(γ,p), E=18-30 MeV; analyzed σ(E). Compared with experimental results.

^{13}C(γ,n),(γ,nγ),(γ,p) (continued)

^{13}C Levels

E(level)[†]	J$^{\pi}$[†]	Γ[‡]	Comments
7560	5/2$^-$		$\Gamma_{\gamma 0}$=0.110 eV *15* (1980Ho11) E(level): from (1980Ho11). E2 transition (1980Ho11).
7690	3/2$^+$	60 keV	$\Gamma_{\gamma 0}$=0.6 eV *1* (1980Ho11); Γ_n=0.17 MeV (1980Ho11) E1 transition (1980Ho11). Γ: see also 0.6 MeV (1976Ko22).
8200	3/2$^+$	375 keV	$\Gamma_{\gamma 0}$=7.0 eV *9* (1980Ho11); Γ_n=1.11 MeV (1980Ho11) E1 transition (1980Ho11).
8860	1/2$^-$	175 keV	$\Gamma_{\gamma 0}$=5.4 eV *5* (1980Ho11); Γ_n=0.17 MeV (1980Ho11) M1 transition (1980Ho11).
9500	(3/2$^-$)	<90[#] keV	E(level): from (1977Wo04). J$^{\pi}$: from (1970Aj04).
9897	3/2$^-$	<100[#] keV	
10996	1/2$^+$	<150[#] keV	Γ: see also 0.4 MeV (1976Ko22).
12106	3/2$^+$	150 keV	
13000?		3.3 MeV	Γ: from (1976Ko22).
13570		500 keV	E(level): see also 13.5 MeV *10* with Γ=5 MeV *1* (1956Co72, 1957Co57).
13760			E(level): from (1979Ju01).
14983		400 keV	Γ: see also 0.54 MeV (1976Ko22).
≈15120	3/2$^-$	<135[#] keV	T=3/2 (1977Wo04,1979Ju03) $\Gamma_{\gamma 0}$=19.7 eV *20* (1979Ju01) E(level): see (1977Wo04,1979Ju03).
16950		<400[#] keV	
17920		<450[#] keV	
20.8×10^3		3.9 MeV	E(level): (1979Ju01). See also E$_x$=20.5 MeV (1976Ko22). Γ: from (1976Ko22). Γ value is uncertain.
24×10^3 *2*		10 MeV *2*	E(level),Γ: from (1957Co57). See also (1956Co72).
≈30×10^3			E(level): (1979Ju01).
≈37×10^3			E(level): weak resonance (1979Ju01).

[†] From the R-matrix analysis of (1980Ho11) and the Legendre polynomial analysis of (1979Wo06). See (1976Ko22, 1977Wo04, 1979Ju01, 1979Wo06, 1980Ho11).

[‡] From (1977Wo04) except where noted.

[#] From (1977Wo04: system resolution).

^{13}C(γ,p) **1983Zu02**

1956Co72,1957Co57: ^{13}C(γ,p) $E_\gamma\approx5$ to 42 MeV, a broad $\Gamma\approx6$ MeV giant resonance structure near $E_\gamma=25.5$ MeV has been reported.

1964De12: ^{13}C(γ,p) $E_\gamma\approx15$ to 32 MeV, structures are reported at $E_\gamma=18.5$, 20.0, 23.5, 26.0 and 29.0 MeV. The dominant peak is near 23.5 MeV with $\Gamma\approx3$ MeV.

1964Ko09: ^{13}C(γ,p), $E_{brem.}=31.5$ MeV; the energy spectra of photoprotons was investigated.

1975Pa09: ^{13}C(γ,pγ'), E<44 MeV; measured $\sigma(E,E_{\gamma'})$. Deduced giant resonance structure.

1983Zu02: ^{13}C(γ,p), E=17.5-28 MeV bremsstrahlung; measured σ(E). Deduced GDR isospin splitting, $T_<$ and $T_>$ appear to be split by 6.8 MeV. Activation technique.

Theory:

1972Go27: ^{13}C(γ,p), E<30 MeV; calculated σ(E); analyzed giant resonance structure.

1973KiZI, 1973KiZJ: ^{13}C(γ,p), calculated σ(Ep).

1977Ma06: ^{13}C(γ,p), calculated σ. ^{13}C calculated GDR decay properties.

1993Mc02: ^{13}Cγ,p); E<36 MeV; analyzed σ(E); deduced isospin component splitting.

2017Dz03: ^{13}Cγ,p)); E<50 MeV; analyzed photoproton σ for applications.

^{13}C Levels

E(level)[†]
18600[‡]
19700?
20700[‡]
22000?
23500
24500
26000?

[†] From (1983Zu02). In (1964De12) structures are reported at $E_\gamma=18.5$, 20.0, 23.5 ($\Gamma\approx3$ MeV), 26.0, 29.0 MeV. See also a broad maximum at $E_\gamma\approx25.5$ MeV with $\sigma=8.8$ mb (1956Co72,1957Co57) and $\Gamma\approx6$ MeV (1957Co57). The integrated cross section from $E_\gamma=17.5$ (threshold) to 28 MeV is 36 MeV·mb *5* (1983Zu02).

[‡] state has a significant $T_>$ component (1983Zu02).

^{13}C(e,e),(e,e′),(e,e′p)

1967Pe07: ^{13}C(e,e′), E=40-65 MeV; the Ml radiation widths from ^{12}C(15.11) and ^{13}C(15.11) to the ground states were determined to be 36 eV *3* and 25 eV *7*, respectively.
1969To05: ^{13}C(e,e′), Measured σ(E,θ) for ^{13}C(3.08). Discussed transition probabilities.
1969Wi22: ^{13}C(e,e′), E=36-65 MeV; measured σ(E;Ee′). Deduced levels, level-width, γ-mixing, deduced B(E/M,$\Lambda\downarrow$).
1970He24: ^{13}C(e,e), E=120,170,200,250,350,500,750 MeV; measured σ(E;θ). Deduced nuclear charge distribution.
1970Wi04: ^{13}C(e,e′), E=36-75 MeV; measured σ(E;Ee′,θ). Deduced levels, level-width, transition radii.
1970WoZX: ^{13}C(e,e′p), E=45,43 MeV; measured σ(Ep,θ(p)). Deduced giant resonance structure.
1971Be25: ^{13}C(e,e), E=30,60 MeV; measured σ(θ). Deduced rms nuclear charge radii.
1971Be51: ^{13}C(e,e′), E=55,77,81,106 MeV; measured σ(Ee′). ^{13}C deduced resonances, level-width, giant resonance structure.
1971Sh09: ^{13}C(e,e′p), E=43 MeV; measured σ(Ep,θ(p)). Deduced giant resonance structure. Enriched targets.
1971Ya02: ^{13}C(e,e),(e,e′), E=40-125 MeV; measured σ(E;θ), σ(E;Ee′,θ); Discussed form factors, level-width, γ-mixing, rms charge radius.
1974LaYT,1975La23: ^{13}C(e,e′), E=35-90 MeV; measured σ(E;θ=180°). ^{13}C deduced parameters of nuclear ground-state magnetization distribution. Deduced magnetic rms radius.
1974LaZH: ^{13}C(e,e′), E=40-90 MeV; measured σ(Ee,Ee′,θ,H). Discussed μ.
1982Hi07: ^{13}C(e,e), E=80-338 MeV; measured σ(E,θ). Deduced M1 form factor. Shell model.
1986Hi06: ^{13}C(e,e′), E=78-338 MeV; measured σ(E,θ). Deduced from factors, isoscalar, isovector transition amplitudes for M4 transitions. Shell model.
1986HuZX: ^{13}C(e,e),(e,e′), measured form factors.
1987Hi09: ^{13}C(e,e′), E=80-485 MeV; measured σ(E(e′),θ). Deduced transverse excitation form factors. Shell model.
1989Mi01: ^{13}C(e,e′), E=45-340 MeV; measured σ(E,θ). Data from (1969Wi22,1970Wi04: Darmstadt) were included in the analysis. Deduced longitudinal, transverse form factors, multipole matrix elements. Shell model.
1991Mi13: ^{13}C(e,e′), measured elastic σ upper limit. Deduced M1 form factor high-q enhancement. Shell model.
1992Co07: ^{13}C(e,e′), E=28.5-56.5 MeV; measured σ(E(e′)), σ(θ), transverse form factors. Deduced B(λ).
1994Zu01: ^{13}C(e,e′p), E=21-23 MeV; measured proton yields vs E, θ=90°; deduced σ(θ) for (γ,p) reaction. Deduced GDR, decay features, isospin splitting effects.

Theory:
1972ThZF: ^{13}C(e,e′), compiled spectroscopic data.
1973Fe13: ^{12}C(e,e); analyzed data. ^{13}C rms radii was deduced from ^{12}C deduced rms radii.
1973Ga19: ^{13}C(e,e′), ^{13}C calculated form factors, radii.
1974Be10: ^{13}C(e,e); calculated form factors.
1979Se06: ^{13}C(pol. e,e′), E=30,200 MeV/c,1 GeV/c; calculated σ(θ); deduced one-body transition densities.
1980Er01: ^{13}C(e,e′), E=70 MeV; calculated σ(Ee′); deduced giant M2 resonance, configuration, isospin splitting. Shell model.
1981De07: ^{13}C(e,e), calculated M1 form factors; deduced possible critical opalescence effects. Static limit, coupled integral equations, effective spin operators. (1983Si11) also discussed (1981De07).
1981Is11: ^{13}C(e,e′), analyzed reaction data; deduced Majorana force role in GDR configuration splitting.
1981Li13: ^{13}C(e,e′), calculated M1 form factors. Nilsson model.
1981Su03: ^{13}C(e,e), calculated M1 form factors; deduced core polarization effects. Cohen-Kurath wave functions, one pion exchange currents.
1981Su08: ^{13}C(e,e), calculated M1 form factors. Core polarization.
1982Ch16: ^{13}C(e,e′), calculated transverse form factor. Cohen-Kurath wave function, DWIA model.
1983Ch15: ^{13}C(e,e),(e,e′), calculated transverse form factors.
1983Ma40: ^{13}C(e,e′), calculated transverse form factors; deduced pion wave distortion dependence, reaction dependent sensitivity to nuclear wave function.
1983Su10: ^{13}C(e,e), calculated M1 form factors; deduced Landau-Migdal parameter momentum transfer dependence. Short-range correlations, particle-hole, isobar-hole excitation exchange effects.
1984Do20: ^{13}C(e,e), study the elastic magnetic electron scattering and how it has come to be a useful tool for studying the spatial distributions of convection and magnetization currents in the nuclear ground state.
1984Li25: ^{13}C(e,e′), E=196.5-225 MeV; analyzed σ(Ee′,θe′). The M4 strength in ^{13}C*(21.4 MeV) was reported. Since $^{13}C_{g.s.}$ neither has zero angular momentum nor zero isospin, $J^{\pi}=7/2^{+}$ or $9/2^{+}$ and T=3/2 or 1/2 (1980Le17: ^{13}C(π,π); shell model calculation) this M4 transition poses a strong theoretical challenge.

^{13}C(e,e),(e,e′),(e,e′p) (continued)

1984LiZX: ^{13}C(e,e), calculated M1 form factor; deduced core deformation effects.
1985Hi04: ^{13}C(e,e),(e,e′), calculated form factors.
1985Sa06: ^{13}C(e,e′), calculated M1, E2 form factors.
1985Si05: ^{13}C(e,e),(e,e′), calculated form factors; deduced configuration mixing effects.
1986AmZX: ^{13}C(e,e′), analyzed form factors, $\sigma(\theta)$; deduced structure effects.
1986Do11: ^{13}C(pol. e,e),(pol. e,e′), E=400 MeV; calculated asymmetry, polarization ratio vs momentum transfer.
1987De43: ^{13}C(e,e), compilation of nuclear charge-density-distribution parameters.
1989Am02: ^{13}C(e,e′), calculated form factors.
1990Wo10: ^{13}C(e,e′), calculated form factors. Effective interactions, (0+2)$\hbar\omega$ space.
1991Be40: ^{13}C(e,e), analyzed longitudinal, transverse form factors. ^{13}C deduced single particle radial functions, virtual p-, n-decay vertex constants.
1991Er06: ^{13}C(e,e′), calculated longitudinal, transverse form factors.
1994Am01: ^{13}C(pol. e,e), calculated magnetic and Coulomb form factors, response functions. Meson exchange effects, polarized target.
1994Ch03: ^{13}C(e,e), analyzed charge form factor. Phenomenological, microscopic models, beam linear polarization.
1994Mo19: ^{13}C(e,e′), calculated response functions. Shell model wave functions, meson exchange effects, different target polarizations.
1997Ga31: ^{13}C(e,e), analyzed form factors; deduced meson exchange currents role. Calculated wavefunctions, potentials, binding energies, resonance E, Γ. Astrophysical processes discussed.

^{13}C Levels

Authors have been inconsistent in how they have presented the transition strengths. The early work found in (1969Wi22,1970Wi04) presented partial widths and transition strengths in the downward formalism, while the later works, such as (1989Mi01, 1992Co07) presented transition strengths in the expected upward formalism from inelastic scattering reactions.

E(level)	J$^{\pi}$†	Γ	Multipolarity†	Comments
0	1/2$^-$			T=1/2 (1967Pe07,1989Mi01) J$^{\pi}$: from (1967Pe07,1989Mi01). The ^{13}C rms nuclear charge radius $<r^2>^{1/2}_{Ch.}$=2.384 fm *47* and the charge radius ratio $R_{Ch.}(^{13}C/^{12}C)$=0.995 *8* (1971Be25); $R_{Ch.}(^{13}C/^{12}C)$=0.975 *2* (1971Ya02); $<r^2>^{1/2}_{Ch.}(^{13}C)$=2.452 fm *47* (1973Fe13: relative to $<r^2>^{1/2}_{Ch.}(^{12}C)$=2.462 fm *22*). The magnetic rms radius is $<r^2>^{1/2}_{M}$=3.3 fm *3* (1975La23). The form factor for M1 elastic scattering is discussed in (1982Hi07, 1987Hi09, 1991Mi13).
3080 *30*	1/2$^+$	0.39 eV *6*	E1	E(level): from (1970Wi04). J$^{\pi}$: from (1970Wi04,1989Mi01). Multipolarity: from (1970Wi04,1987Hi09,1989Mi01). Γ: from (1975Ra22). $\Gamma_{\gamma 0}$=0.68 eV *23*; $\Gamma_{\gamma 0}/\Gamma_W$(E1)=0.62 W.u. (1970Wi04). B(C1,↑) W.u.=0.047 *5* (1989Mi01). A priv. comm. with D.J. Millener (DJM), see Table 13.12 in (1991Aj01), indicates $\Gamma_{\gamma 0}$=0.52 eV and B(E1,↓) W.u.=0.047 *10*: noting the uncertainty is double the statistical errors given in (1989Mi01); (DJM) does not understand why the uncertainties were doubled.
3690 *20*	3/2$^-$		M1+E2‡	T=1/2 (1971Ya02,1989Mi01) E(level): from (1969Wi22,1970Wi04). J$^{\pi}$: from (1969Wi22,1970Wi04,1971Ya02,1989Mi01,1992Co07). Multipolarity: from (1969Wi22,1970Wi04,1989Mi01); see also (1992Co07: M1). Multipolarity: MR (δ)=0.100 *8* from (1969Wi22,1970Wi04).

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^{13}C(e,e),(e,e′),(e,e′p) (continued)

^{13}C Levels (continued)

E(level)	J$^{\pi}$†	Γ	Multipolarity†	Comments
				$\Gamma_{\gamma0}$(M1)=0.36 eV *5*; $\Gamma_{\gamma0}$(E2)=3.6×10^{-3} eV *4*; $\Gamma_{\gamma0}$(M1)/Γ_{W}=0.339 W.u.; $\Gamma_{\gamma0}$(E2)/Γ_{W}=3.52 W.u. (1969Wi22,1970Wi04). B(M1,↑) W.u.=0.57 *6*=1.02 μ_{N}^{2} *11* (1992Co07: transition radius=2.48 fm *19*). B(C2,↑) W.u.=7.1 *3* (1989Mi01).
3850	5/2^{+}		M2+E3	E(level),J$^{\pi}$: from (1970Wi04,1989Mi01,1992Co07). Multipolarity: from (1989Mi01). B(M2,↑) W.u.=0.64 *25*=5.8 μ_{N}^{2}fm^{2} *22* (1992Co07: transition radius=1.7 fm *11*; alternate B(M2,↑) W.u.=1.16 *20*=10.5 μ_{N}^{2}fm^{2} *10* with fixed transition radius 3.2 fm). B(C3,↑) W.u.=3.9 *3* (1989Mi01). A priv. comm. with D.J. Millener (DJM), see Table 13.12 in (1991Aj01), indicates $\Gamma_{\gamma0}$=6×10^{-8} eV and B(C3,↓) W.u.=1.3 *2*: see comment on ^{13}C(3.09).
6850 *60*	5/2^{+}		M2+E3	E(level): from (1969Wi22,1970Wi04); see also E$_{x}$=6860 keV (1989Mi01). J$^{\pi}$: from (1969Wi22,1970Wi04,1989Mi01). Multipolarity: from (1989Mi01); see also (1969Wi22,1970Wi04: M2). $\Gamma_{\gamma0}$(M2)=6.9×10^{-5} eV *36*; $\Gamma_{\gamma0}$(M2)/Γ_{W}=0.055 W.u. (1969Wi22,1970Wi04). B(C3,↑) W.u.=0.32 *9* (1989Mi01). A priv. comm. with D.J. Millener (DJM), see Table 13.12 in (1991Aj01), indicates $\Gamma_{\gamma0}$=3×10^{-7} eV and B(C3,↓) W.u.=0.10 *6*: see comment on ^{13}C(3.09).
7490	7/2^{+}		E3+M4	E(level),J$^{\pi}$,Multipolarity: from (1989Mi01).
7547 *3*	5/2^{-}		E2+M3	T=1/2 (1971Ya02,1989Mi01) E(level): from (1989Mi01); see also E$_{x}$=7540 keV *20* (1969Wi22,1970Wi04), 7550 keV (1971Ya02). J$^{\pi}$: from (1969Wi22,1970Wi04,1971Ya02,1989Mi01). Multipolarity: from (1970Wi04,1989Mi01). $\Gamma_{\gamma0}$(E2)=0.115 eV *7*; $\Gamma_{\gamma0}$(M3)=1.01×10^{-5} eV *61*; $\Gamma_{\gamma0}$(E2)/Γ_{W}=3.15 W.u.; $\Gamma_{\gamma0}$(M3)/Γ_{W}=35 W.u. (1969Wi22,1970Wi04). B(C2,↑) W.u.=10.8 *3* (1989Mi01: the dominant 7.55 level is not resolved from the much weaker 7.49 and 7.69 levels).
7690	3/2^{+}		E1+M2	E(level),J$^{\pi}$,Multipolarity: from (1989Mi01); see also E$_{x}$=7680 keV (1970Wi04).
7830				E(level): from (1970Wi04). A tail on the 7.54 MeV level is interpreted as a new level; this is not reported in other studies and is not adopted.
8200	3/2^{+}		E1+M2	E(level),J$^{\pi}$,Multipolarity: from (1989Mi01).
8860 *20*	1/2^{-}	190 keV *35*	E0+M1	T=1/2 (1989Mi01) E(level): from (1969Wi22,1970Wi04); see also E$_{x}$=8860 keV (1971Ya02,1989Mi01). J$^{\pi}$: from (1969Wi22,1970Wi04,1989Mi01). Γ: from (1970Wi04). Multipolarity: from (1969Wi22,1970Wi04,1989Mi01). $\Gamma_{\gamma0}$(E0)=2.09 fm^{2} *38* (monopole matrix element in fm^{2}); $\Gamma_{\gamma0}$(M1)=3.4 eV *5*;$\Gamma_{\gamma0}$(M1)/Γ_{W}=0.23 W.u. (1969Wi22,1970Wi04). B(C0,↑) W.u.=0.66 *2* (1989Mi01).
9500 *7*	9/2^{+}		M4(+E5)	T=1/2 (1986Hi06,1987Hi09) E(level): from (1989Mi01); see also E$_{x}$=9500 keV (1971Ya02,1986Hi06,1987Hi09). J$^{\pi}$,Multipolarity: from (1986Hi06,1987Hi09,1989Mi01). Multipolarity: In (1986Hi06) the electromagnetic components were deduced from the transverse form factors. Only an upper limit on electromagnetic strength was obtained, consistent with expectations for E5. B(M4,↑) W.u.=77 *3* (1989Mi01).
9900 *30*	3/2^{-}		M1+E2‡	E(level): from (1969Wi22,1970Wi04); see also E$_{x}$=9900 keV (1989Mi01). J$^{\pi}$,Multipolarity: from (1969Wi22,1970Wi04,1989Mi01). Multipolarity: MR (δ)=0.44 *8* from (1969Wi22).

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^{13}C(e,e),(e,e′),(e,e′p) (continued)

^{13}C Levels (continued)

E(level)	$J^{\pi\dagger}$	Γ	Multipolarity†	Comments
				$\Gamma_{\gamma0}$(M1)=0.32 eV *5*; $\Gamma_{\gamma0}$(E2)=6.3×10^{-3} eV *21*; $\Gamma_{\gamma0}$(M1)/Γ_W=0.0159 W.u.; $\Gamma_{\gamma0}$(E2)/Γ_W=0.045 W.u. (1969Wi22,1970Wi04). B(C2,↑) W.u.=0.11 *2* (1989Mi01).
10460?	5/2$^+$		M2+E3	E(level),J^π,Multipolarity: from (1989Mi01).
10860				E(level): from (1970Wi04) where a slight enhancement is observed in the cross section. This group is not reported in other measurements and is not considered in the Adopted Levels.
11080 *5*	1/2$^-$		E0+M1	E(level): from (1989Mi01); see also E$_x$=11070 keV *20* (1969Wi22,1970Wi04), 11100 keV (1971Be51). J^π: from (1989Mi01); see also J^π=(1/2$^-$,3/2$^-$) (1969Wi22,1970Wi04,1971Be51). Multipolarity: From (1969Wi22,1970Wi04,1989Mi01). Results for J^π=3/2$^-$ are presented, but they are not relevant now. $\Gamma_{\gamma0}$(E0)=2.6 fm^2 *3* (monopole matrix element in fm^2); $\Gamma_{\gamma0}$(M1)=1.0 eV *2*; $\Gamma_{\gamma0}$(M1)/Γ_W=0.0359 (1969Wi22,1970Wi04).
11750	3/2$^-$		M1	T=1/2 (1989Mi01) E(level): from (1989Mi01); see also E$_x$=11720 keV (1971Ya02), 11800 keV (1969Wi22,1970Wi04,1971Be51). J^π: from (1969Wi22,1970Wi04,1971Be51,1989Mi01). Multipolarity: from (1970Wi04); see also (1989Mi01: M1+E2). $\Gamma_{\gamma0}$(M1)=3.45 eV *86*; $\Gamma_{\gamma0}$(M1)/Γ_W=0.100 (1970Wi04).
11845 *5*	7/2$^+$	144 keV *5*	E3+M4	E(level),J^π,Γ,Multipolarity: from (1989Mi01). B(C3,↑) W.u.=27.5 for the unresolved doublet (11.85+11.95).
11950	5/2$^+$		M2+E3	E(level),J^π,Multipolarity: from (1989Mi01). See also E$_x$=11970 keV (1971Ya02). B(C3,↑) W.u.=27.5 for the unresolved doublet (11.85+11.95).
12187 *10*		109 keV *48*		E(level),Γ: from (1989Mi01).
12438 *12*		160 keV *37*		E(level),Γ: from (1989Mi01). See also E$_x$=12320 keV (1971Ya02), (12300) keV (1971Be51: possibly 12400 keV state).
13760				E(level): from (1971Ya02).
14390 *15*		281 keV *65*		E(level),Γ: from (1989Mi01).
14582 *10*		227 keV *41*		E(level),Γ: from (1989Mi01).
14983 *10*		380 keV *53*		E(level),Γ: from (1989Mi01).
15106 *2*	3/2$^-$		M1+E2‡	T=3/2 (1967Pe07,1971Ya02,1989Mi01) E(level): from (1989Mi01); see also E$_x$=15110 keV *20* (1969Wi22,1970Wi04), 15110 keV (1967Pe07,1971Be51,1971Ya02). J^π: from (1967Pe07,1969Wi22,1970Wi04,1971Be51,1971Ya02,1989Mi01). $\Gamma_{\gamma0}$(M1)= 25 eV *7* (1967Pe07), $\Gamma_{\gamma0}$(M1)=22.7 eV *27*; $\Gamma_{\gamma0}$(E2)=0.59 eV *11*; $\Gamma_{\gamma0}$(M1)/Γ_W=0.313 W.u.; $\Gamma_{\gamma0}$(E2)/Γ_W=0.50 W.u. (1969Wi22,1970Wi04). Multipolarity: from (1969Wi22,1970Wi04,1989Mi01); see also (1967Pe07: M1). Multipolarity: MR (δ)= 0.161 *17* from (1969Wi22,1970Wi04).
15526 *11*		147 keV *23*		E(level),Γ: from (1989Mi01).
16080 *7*	7/2$^+$	148 keV *13*	E3+M4	T=1/2 (1986Hi06) E(level),Γ: from (1989Mi01). See also E$_x$=16080 keV (1986Hi06: probably unresolved). J^π,Multipolarity: from (1986Hi06).
16183? *28*		40 keV *20*		E(level),Γ: from (1989Mi01); see also E$_x$=16200 keV, Γ=300 keV (1971Be51).
16900?				E(level): from (1971Be51).
17700		300 keV		E(level),Γ: from (1971Be51).
18300		400 keV		E(level),Γ: from (1971Be51).
18497? *10*		91 keV *23*		E(level),Γ: from (1989Mi01).
18699 *5*		98 keV *11*		E(level),Γ: from (1989Mi01); see also E$_x$=18700 keV, Γ=1200

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^{13}C(e,e),(e,e′),(e,e′p) (continued)

^{13}C Levels (continued)

E(level)	J$^{\pi}$†	Γ	Multipolarity†	Comments
				keV(1971Be51).
19300		500 keV		E(level),Γ: from (1971Be51). See also E_x=19150 keV (1971Ya02).
20021 *13*		232 keV *27*		E(level),Γ: from (1989Mi01).
20100		700 keV		E(level),Γ: from (1971Be51).
20429 *8*		112 keV *23*		E(level),Γ: from (1989Mi01).
20500		400 keV		T=1/2 E(level),Γ: from (1971Be51). In (1971Be51) the giant resonance region is characterized by two dominant components, a lower structure centered around 20.5 MeV with Γ≈3 MeV and a higher structure centered around 24.5 MeV with Γ≈ 4 MeV. T: probably 1/2 although the 4 MeV splitting of the two giant resonance components is somewhat smaller than expected (1971Be51).
21300		400 keV		E(level),Γ: from (1971Be51).
21466 *8*	(7/2^{+},9/2^{+})	268 keV *14*	M4	T=3/2 (1986Hi06) E(level),Γ: from (1989Mi01). See also E_x=21470 keV (1986Hi06). J$^{\pi}$: from (1986Hi06). Multipolarity: from (1986Hi06).
21800?				E(level): from (1971Sh09).
22200		1100 keV		E(level),Γ: from (1971Be51).
23000				E(level): giant resonance at 23 MeV via the p_4 channel (1994Zu01).
24700		600 keV		T=(3/2) E(level),Γ: from (1971Be51). See also E_x=24200 keV (1971Sh09), and (1994Zu01). T: probably 3/2 although the 4 MeV splitting of the two giant resonance components is somewhat smaller than expected (1971Be51).
25500		500 keV		E(level): from (1971Be51,1971Sh09). Γ: from (1971Be51).
27300		600 keV		E(level),Γ: from (1971Be51). See also E_x=27500 keV (1971Sh09).
28100		500 keV		E(level),Γ: from (1971Be51).
29400?		1200 keV		E(level),Γ: from (1971Be51).
31500				E(level): from (1971Sh09).

† Deduced from fits to the experimental longitudinal and transverse form factors. The Eλ and Mλ components are obtained from the transverse form factors, whilst the Cλ components are obtained from the longitudinal form factors and have a non-trivial relation to the Eλ components. J is deduced from the Eλ and Mλ components.

‡ In some cases, mixing ratios have been obtained from the B(Eλ) and B(Mλ) strengths. These are listed amongst the level properties since no γ rays are reported in these experiments.

^{13}C(n,n),(n,n′),(n,n′γ)

1979Gl12: ^{13}C(n,n), E=slow; measured spin-dependent scattering length using pseudomagnetism method.
1979Ko26: ^{13}C(n,n), E=0.51,0.68 MeV; measured small angle scattering; deduced coherent scattering length (*b*=6.19 fm *9*). Free scattering cross section of ^{13}C σ_0=4.16 b *13*.
1982Da05: ^{13}C(n,n),(n,n′), E=10-18 MeV; measured $\sigma(\theta)$ for θ=30° to 150°, σ(En). Legendre polynomial, optical model analyses.
1983Da22: ^{13}C(n,n), E=7-15 MeV; measured $\sigma(\theta)$ for θ=30° to 150°; deduced spherical optical model parameters.
1983Gl07: ^{13}C(n,n), E=thermal; measured neutron phase shift, precession angle vs target polarization, σ(absorption). Deduced spin-dependent part of scattering length.
1985Pe10: ^{13}C(n,n), E=24 MeV; measured $\sigma(\theta)$ vs E for for θ=20° to 160°. Microscopic optical model.
1987Re01: ^{13}C(n,n),(n,n′), E=4.55-10.99 MeV; measured $\sigma(\theta$n,En); deduced levels, decay characteristics. Tof.
1988Re09: ^{13}C(n,n),(n,n′), E=8.25 MeV; measured neutron spectra. Multiple scattering analysis.
1989Re01: ^{13}C(n,n),(n,n′), E=4.5-11 MeV; measured $\sigma(\theta)$; deduced ^{13}C(n,α)^{10}Be σ. R-matrix analysis.
2008Ha27: ^{13}C(n,n); comparison of levels. Measured branching ratios for the neutron decay of ^{14}C states to ^{13}C*0[1/2$^-$],3.089[1/2$^+$]+3.684[3/2$^-$]+3.854[5/2$^+$].
2012Pr13: ^{13}C(n,n), E<20 MeV; calculated neutron thermal σ, Westcott factors, resonance integrals and their uncertainties using evaluated neutron libraries; deduced neutron-induced reaction σ deficiencies. Comparison with experimental data Atlas of Neutron Resonances.

Theory:
1977No07: ^{13}C(n,n), E=low; calculated scattering parameters.
1985We02: ^{13}C(n,n),(n,n′), E(cm)≈0.5-10 MeV; calculated σ(E); deduced potential parameters. Continuum shell model.
1994Sa73: ^{13}C(n,n), E=11 MeV; calculated neutron spectra. Experimental MACHO code simulation.
1998Kr25: ^{13}C(n,n), E=10,30,50 MeV; calculated optical potentials; deduced spin-orbit, spin-spin, tensor contributions. Hartree-Fock method, Skyrme forces.
1999Kr12: ^{13}C(n,n), calculated optical potential for nucleus-nucleon scattering. Hartree-Fock theory.
2005MaZR: ^{13}C(n,n′), E≈1-11 MeV; analyzed data; deduced parameters. R-matrix analysis.
2005WaZV: ^{13}C(n,n), E<3 GeV; analyzed σ.
2019Aq01: ^{13}C(n,n), E=9-16 MeV; calculated elastic scattering $\sigma(\theta)$ MeV using nonlocal OMP; deduced potential parameters (dependent on target and energy), constant set of nonlocal parameters using fitting to the data.

^{13}C Levels

E(level)	J^{π}[†]	Comments
0	1/2$^-$	E(level): see (1982Da05,1982ReZX,1985Pe10,1989Re01,2008Ha27,2021Mc05).
3090	1/2$^+$	E(level): see (1982Da05,1982ReZX,1989Re01,2008Ha27,2021Mc05). E(level): branching ratios and the total decay widths of ^{14}C excited states decaying to ^{13}C*(0,3.09+3.68+3.85)+n are deduced (2008Ha27).
3685	3/2$^-$	E(level): see (1982Da05,1982ReZY,1989Re01,2021Mc05).
3854	5/2$^+$	E(level): see (1982ReZY,1989Re01,2021Mc05).
6864		E(level): the decay from ^{14}C*(16.72 MeV) to ^{13}C*(6.864)+n was studied but the branching ratio could not be determined (2008Ha27).
7547		E(level): This level is involved in the 2n sequential decay of E_x≈15.8-18.4 MeV ^{14}C states; it mainly neutron decays to $^{12}C_{g.s.}$; Γ_n≈1.2 keV (1987Re01).

[†] From R-matrix analysis in (1989Re01).

γ(^{13}C)

E_γ[†]	E_i(level)	J^{π}_i	E_f	J^{π}_f
169	3854	5/2$^+$	3685	3/2$^-$
595	3685	3/2$^-$	3090	1/2$^+$
764	3854	5/2$^+$	3090	1/2$^+$
3089	3090	1/2$^+$	0	1/2$^-$

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^{13}C(n,n),(n,n′),(n,n′γ) (continued)

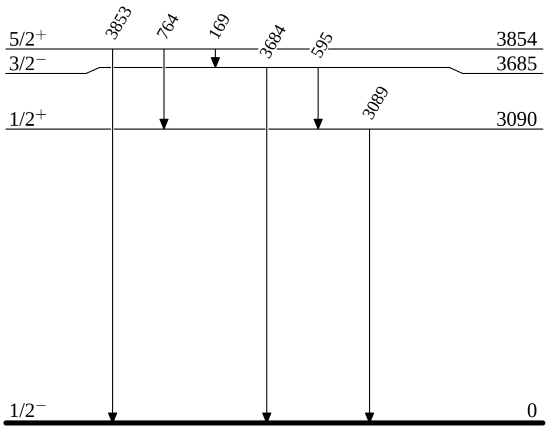
γ(^{13}C) (continued)

E_γ †	E_i(level)	J_i^π	E_f	J_f^π
3684	3685	$3/2^-$	0	$1/2^-$
3853	3854	$5/2^+$	0	$1/2^-$

† From (2021Mc05).

^{13}C(n,n),(n,n′),(n,n′γ)

Level Scheme



$^{13}_{6}C_{7}$

^{13}C(p,p),(p,p′),(p,pn)

1957Ba29: ^{13}C(p,p′), angular distributions of the 3.09 MeV γ-rays are isotropic for Ep=3.7 to 4.2 MeV, consistent with the assignment J=1/2 to ^{13}C*(3.09). Angular distributions of the 3.68 MeV radiation have also been studied near the Ep=4.5 MeV resonance.
1957Zi09: ^{13}C(p,p), E=1.5-3.4 MeV; measured reaction products, Ep, Ip, $\sigma(\theta)$ for θ=45° to 148.9°.
1960Ba35: ^{13}C(p,p′γ), E=3.6-5 MeV; angular distributions of the 3.09 MeV γ-rays are isotropic for up to E_p=5 MeV consistent with the assignment J=1/2 for the ground state.
1966Ge03: ^{13}C(p,p_0), E=1.55-2.38 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=20° to 170°.
1968Ri16: ^{13}C(p,p′), E=4.1,4.125,4.55 MeV; measured Doppler-shift attenuation. Deduced $T_{1/2}$ of ^{13}C(3.09, 3.68 MeV).
1969Gu02: ^{13}C(p,p), E=7 MeV; measured σ(Ep,θ), P(θ) for $\theta_{c.m.}\approx$25° to 160°; deduced optical parameters. Natural, enriched targets.
1971Ot02: ^{13}C(p,pn), E=7.9-12.5 MeV; measured σ(E;Ep,θ(p),θ(n)); deduced singlet deuteron contribution. One or more ^{13}C states at E_x=7.5 MeV seem to be involved in the sequential decay.
1971Ri13: ^{13}C(p,p′γ(3.09,3.68,3.85 MeV)), E=3-17 MeV; measured σ(E).
1971Va29: ^{13}C(p,p_1), E=6.36,6.48 MeV; measured σ(Ep′,θ).
1972Gr02: ^{13}C(pol. p,$p_{0,1}$) E=30.4 MeV; measured $\sigma(\theta)$, P(θ), analyzing power(θ) for $\theta_{c.m.}$=25° to 170°; formulated effective interaction. Enriched targets.
1973DeYW, 1975De26: ^{13}C(p,p),(p,p′γ),(p,d), E=6 MeV; measured σ(Ep,θ). Deduced level configurations.
1974Mi05: ^{13}C(p,pn), E=46 MeV; measured σ(Ep,θ).
1978Bl02: ^{13}C(p,p′), E=0.8 GeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=2° to 40°. Reported states up to 11.9 MeV. Discussed deformation length. Optical potential, DWBA analysis.
1978We13: ^{13}C(pol. p,p_0), measured σ(E,θ) for E=9.1-18.4 MeV and for θ=30° to 155°, measured A(E,θ) for E=10-17.5 MeV. See further discussion in (1985Pe10).
1979Al26: ^{13}C(p,p_0), E=1 GeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=5° to 25°. Deduced nuclear density parameters, quadrupole effects. Glauber theory.
1980Fa07: ^{13}C(p,p),(p,p′), E=35.2 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}\approx$30° to 180°; deduced optical-model parameters.
1981Me02: ^{13}C(pol. p,p), E=200 MeV; measured $\sigma(\theta)$, analyzing power vs θ for θ=10° to 120°.
1982Co08: ^{13}C(p,p),(p,p′), E=135 MeV; measured $\sigma(\theta)$ for θ=8° to 80° and for states below E_x=11 MeV. Deduced possible configurations of ^{13}C(8.86, 11.08 MeV). Optical model, DWBA analyses.
1982Ri05: ^{13}C(p,p′), E=135 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=10° to 85°. Analyzed angular momentum transfer, configuration of ^{13}C(9.50). Microscopic DWBA analysis. Deduced J=9/2$^+$.
1984Se12: ^{13}C(pol. p,p′), E=547 MeV; measured σ(Ep′), $\sigma(\theta)$, analyzing power vs θ for $\theta_{c.m.}$=5° to 35° and for ^{13}C(0,3.09, 3.68,3.86,6.86,7.55,8.86,9.50). DWIA analysis, shell model transition densities.
1985Al16: ^{13}C(p,p_0), E=1 GeV; measured $\sigma(\theta)$; deduced model parameters, rms matter radii =2.394 fm.
1985Bl22: ^{13}C(p,p_0),(pol. p,p_0), E=0.8 GeV; measured $\sigma(\theta)$, analyzing power vs θ for $\theta_{c.m.}\approx$5° to 50°; deduced optical potential parameters.
1985Ki07: ^{13}C(p,p′γ), E=2.4-4.2 MeV; measured thick target relative γ yields, E_γ, I_γ. Particle induced prompt gamma emission analysis.
1986Oh03: ^{13}C(pol. p,p′), E=35 MeV; measured $\sigma(\theta)$, A(θ) for $\theta_{c.m.}\approx$20° to 120° and for ^{13}C(0,3.09, 3.68,3.86). Compared with analogous (p,n) reactions, analyzed isoscalar component. Enriched target. DWBA analysis.
1988Ba30: ^{13}C(p,p_0), E=30.95 MeV; measured $\sigma(\theta)$ for θ=10° to 160°.
1988Co05: ^{13}C(p,p),(p,p′), E=135 MeV; ^{13}C(pol. p, p),(pol. p,p′), E=119 MeV; measured $\sigma(\theta)$, A(θ) for $\theta_{c.m.}\approx$5° to 90°. Analyzed states up to 23 MeV. Optical model, DWA analyses, density-dependent t-matrices.
1989Vo05: ^{13}C(pol. p,p_0), E=72 MeV; measured $\sigma(\theta)$, A(y)(θ) for $\theta\approx$20° to 160°; deduced optical model potential.
1990Ho06: ^{13}C(pol. p,p), E=494 MeV; measured $\sigma(\theta)$, analyzing powers, spin rotation depolarization observables for $\theta\approx$5° to 37°; deduced phenomenological Dirac optical potentials. Calculated retativistic impulse approximation optical potentials.
1990Ho22: ^{13}C(pol. p,p), E=497.5 MeV; measured spin correlation parameter, target analyzing power vs θ for $\theta\approx$12° to 30°. Dynamic nuclear polarization technique, polarized, cooled target, enriched ethylene glycol target.
1990Vo02,1991Vo03: ^{13}C(pol. p,p_0), E=72 MeV; measured depolarization parameter vs θ for $\theta_{c.m.}\approx$34° to 69°; deduced nucleon-nucleus, spin-spin interaction evidence and effects. Optical model.
1993YuZX: ^{13}C(p,p), E=200 MeV; measured $\sigma(\theta)$ at backward angles; deduced optical potential parameters. DWIA analysis.
1996Ho08: ^{13}C(pol. p,p), E=500 MeV; measured polarization transfer parameter D(NN). Non-relativistic DWBA analysis, coupled-channels Dirac, relativistic DWBA analyses.
1996Yu02: ^{13}C(p,p), E=200 MeV; measured spectra, $\sigma(\theta)$ for $\theta_{c.m.}$=160° to 180°; deduced model parameters. DWIA analysis.

^{13}C(p,p),(p,p′),(p,pn) (continued)

1998Hu29: ^{1}H(^{13}C,^{13}C),^{13}C(p,p), E=2.8-11.2 MeV; measured products, Deduced $\sigma(\theta)$. E_{res}=0.511 MeV. Thick Target Inverse Kinematics.

2003An11: ^{13}C(p,p), E=22 MeV; ^{13}C(p,p′), E=22 MeV; measured $\sigma(\theta)$ for θ=9° to 130°. Deduced ^{13}C(3.09 MeV) neutron halo structure, related features. Microscopic DWBA analysis, compared with related data.

2013Ba56: ^{13}C(p,p), E=0.8-2.4 MeV; measured reaction products, Ep, Ip; deduced σ, yields; compared with available data.

Cieplicka-Orynczak et al., Phys. Lett. B **834** (2022) 137398: ^{13}C(p,p′) Ep=135 MeV at the CCB at IFJ PAN in Krakow. Populated the E_x=21.47 MeV stretched resonance in ^{13}C and analyzed its decay branches and structure. Scattered protons were measured at θ=36° using the KRATTA array, while branches for particle emission were deduced either by direct measurement with a position sensitive Si detector or by measurement of γ rays from the deexcitation of the ^{12}B or ^{12}C remnants. Evidence for neutron and proton decay branches was observed, but no evidence was found for d or α emission. Neutron emission to proceeds to ^{12}C(15.11 MeV: J=1^{+},T=1), suggesting T=3/2 for the ^{13}C state. Results were compared with a gamow Shell Model calculation; observed decay branches are consistent with $J^{\pi}=7/2^{+}$, but a $7/2^{+}$ + $9/2^{+}$ doublet cannot be excluded.

Theory:

1973Ka04: ^{13}C(p,p′), calculated integral cross sections for low-lying levels.

1974Av02: ^{13}C(p,d),(p,pn), E=12,17 MeV; calculated σ(Ed,θ), σ(Ep,θ); deduced singlet deuteron effects.

1978Al36: ^{13}C(p,p), E=1 GeV; calculated $\sigma(\theta)$. Glauber theory, n, p-density parameters from electron scattering data.

1982Ba14: ^{13}C(p,p′), E=6 MeV; calculated $\sigma(\theta)$. Triangle diagram method, Coulomb effects.

1983Pe14: ^{13}C(p,p′), E=26.1 MeV; analyzed $\sigma(\theta)$. ^{13}C levels deduced differences in excitation probabilities from other charge exchange reaction data.

1986AmZX: ^{13}C(p,p), analyzed form factors, $\sigma(\theta)$; deduced structure effects.

1986Ra05: ^{13}C(pol. p,p), E=500 MeV; calculated $\sigma(\theta)$, polarization, other parameters vs θ; deduced relativistic effects role.

1988GoZH: ^{13}C(p,p), E=10-20 MeV; analyzed $\sigma(\theta)$; deduced optical model parameters.

1988KuZL: ^{13}C(p,p),(pol. p,p), E=0.8 GeV; calculated $\sigma(\theta)$, A(θ). Multi-scattering diffraction theory.

1988Ra08: ^{13}C(pol. p,p), E=500 MeV; calculated $\sigma(\theta)$, P(θ), spin observables; deduced target nucleus relativistic effects role. Relativistic dynamics, pseudovector coupling.

1989Am02: ^{13}C(p,p′), E=135 MeV; analyzed data; deduced degree of M1 quenching. Shell model, medium corrected DWA.

1989Am05: ^{13}C(pol. p,p), E=547 MeV; calculated $\sigma(\theta)$, analyzing power vs θ. Nonrelativistic optical model potential.

1989BeXT: ^{13}C(pol. p,p),(pol. p,p′), E=135,547,800 MeV; calculated $\sigma(\theta$,E), analyzing power vs θ. Diffraction model.

1989Go14: ^{13}C(p,p), E=13.5-17.5 MeV; calculated $\sigma(\theta)$, P(θ); deduced model parameters. Phenomenological, folding model potentials.

1989Ku07: ^{13}C(pol. p,p), E=547-1000 MeV; calculated $\sigma(\theta)$, polarization observables vs θ. Multiple diffraction scattering theory.

1989Ku14: ^{13}C(p,p), E=550,800 MeV; calculated $\sigma(\theta)$, polarization observables vs θ. Polarized target.

1989Ku32: ^{13}C(pol. p,p), E=0.8,1 GeV; calculated $\sigma(\theta)$, analyzing power vs θ. Diffraction model.

1990Du01: ^{13}C(pol. p,p), E=1.13-1.17 MeV; calculated σ(E), analyzing power vs E.

1990He32: ^{13}C(pol. p,p), E=65 MeV; analyzed depolarization parameter; deduced nucleon-nucleus spin-spin interaction features.

1990St32: ^{13}C(pol. p,p), E=65,72 MeV; compiled data analysis; deduced Gamow-Teller type transition extraction possibility.

1991Br28: ^{13}C(p,p),(pol. p,p), E≤1.17 MeV; calculated $\sigma(\theta)$, analyzing power vs E. Double-folding interaction potential, multi-step direct compound nuclear reactions.

1991Mc03: ^{13}C(pol. p,p), E=497 MeV; compiled, reviewed data analyses; deduced nucleon-nucleus interaction features, spin-effects, spin-isospin modes role.

1992Ra02: ^{13}C(pol. p,p), E=497.5 MeV; calculated polarization observables. Shell model configurations. Pauli blocking.

1993By02: ^{13}C(p,p), E=72 MeV; calculated $\sigma(\theta)$; deduced nucleon-nucleon bound state role.

1993Ra05: ^{13}C(pol. p,p), E=500 MeV; calculated $\sigma(\theta)$, analyzing power, polarization transfer observables vs θ. Relativistic impulse approximation, density dependent nucleon-nucleon effective interaction.

1994Me14: ^{13}C(pol. p,p), E=500,574 MeV; calculated $\sigma(\theta)$, depolarization parameter, other spin observables vs θ. Relativistic Schrodinger equation, microscopic, momentum space optical potentials.

1997Do01: ^{13}C(pol. p,p), E=200 MeV; analyzed $\sigma(\theta)$, polarization observables data. Microscopic model.

1998Ki17: ^{13}C(p,p), E=1 GeV; analyzed $\sigma(\theta)$; deduced neutron halo role. Glauber theory.

1998Kr25: ^{13}C(p,p), E=10,30,50 MeV; calculated optical potentials; deduced spin-orbit, spin-spin, tensor contributions. Hartree-Fock method, Skyrme forces.

1999Kr12: ^{13}C(p,p), calculated optical potential for nucleus-nucleon scattering. Hartree-Fock theory.

2000De61: ^{13}C(p,p), E=30 MeV; E=40 MeV; calculated $\sigma(\theta)$, Ay(θ). Optical potential, comparison with data.

^{13}C(p,p),(p,p′),(p,pn) (continued)

2001Mi20: ^{13}C(pol. p,p), E*≈9 MeV; calculated longitudinal and transverse analyzing powers.
2002Mo28: ^{13}C(p,p), E=10 MeV; calculated $\sigma(\theta)$; deduced continuum effects. Continuum discretized coupled channels formalism.
2004Be16: ^{13}C(p,p), E=500,547,800 MeV; calculated $\sigma(\theta)$, polarization observables. Multiple diffractive scattering theory, comparison with data.
2004Be35: ^{13}C(p,p), E=500 MeV; calculated $\sigma(\theta)$, analyzing powers, other polarization observables.
2005Ko28: ^{13}C(p,p), E≈800-1100 MeV; analyzed $\sigma(\theta)$; deduced black-sphere radius parameters.
2009De02: ^{13}C(p,p), E=35 MeV; calculated $\sigma(\theta)$, binding energies. Momentum-space three-body Fadeev-like equations. Comparison with experimental data.
2009De07: ^{13}C(p,p), E=35 MeV; calculated differential cross sections, analyzing powers for polarized beam using local and nonlocal optical potentials parameters in the framework of Faddeev type scattering equations. Comparison with experimental data.
2009De13: ^{13}C(pol. p,p), E=17.5, 35 MeV; calculated $\sigma(\theta)$, analyzing powers using Faddeev-type model. Compared various optical potentials with experimental data.
2009We04: ^{13}C(p,p), E=25-155 MeV; analyzed σ, $\sigma(\theta)$ using isospin dependent global nucleon-nucleus optical model. ^{13}C(pol. p,p), E=30-152 MeV; analyzed vector analyzing powers using isospin dependent global nucleon-nucleus optical model.
2012Du11: ^{13}C(p,p), E=250-770 keV; analyzed $\sigma(\theta)$ measurements; deduced S-wave phase shift, triplet states in the resonance region.
2015Be12: ^{13}C(p,p),(p,p′), E<200 MeV; calculated charge radii and densities, form factors, $\sigma(\theta)$, scattering parameters, polarization. Multiple diffraction scattering theory (MDST) and the α-cluster model with dispersion, comparison with experimental data.
2017Ka45: ^{13}C(p,p), E=71,100,200,300,425,550,650 MeV; calculated σ, $\sigma(\theta)$. Comparison with available data.
2018We08: ^{13}C(p,p), E=70,72 MeV; calculated $\sigma(\theta)$, σ; deduced optical model parameters. Comparison with experimental data.
2018Zh31: ^{13}C(p,p′), E=0.6,0.8,1.0 GeV; calculated $\sigma(\theta)$, analyzing power to $(1/2)^+$ and $(5/2)^+$ levels using Glauber Multiple Scattering Theory and DWBA. Compared with available data.
2021An01, 2021An13: ^{13}C(p,p), E<5 MeV; calculated σ; deduced optical model potential, S-factors in the folding model, using a realistic density dependent nucleon-nucleon interaction.
2022Vo02: ^{13}C(p,p), E=200 MeV; calculated $\sigma(\theta)$ and $A_y(\theta)$.

^{13}C Levels

E(level)†	J^π‡	T or Γ#	L	Comments
0	$1/2^-$			E(level): see (1978Bl02,1982Co08,1984Se12,1985Ki07,1986Oh03,1988Co05,2003An11). Analyzing power A_y was also measured (1984Se12).
3089	$1/2^+$	<6.93 fs		B(E1)↑=0.00014 (1988Co05) E(level): see (1957Ba29, 1960Ba35, 1968Ri16, 1978Bl02, 1982Co08, 1984Se12, 1985Ki07, 1986Oh03, 1988Co05, 2003An11). The analysis in (2003An11) indicates the existence of neutron halo in this state. $T_{1/2}$: from τ<10 fs (1968Ri16).
3685	$3/2^-$	<18 fs	2	B(M1)↑=1.42 (1988Co05); B(E2)↑=0.131 (1988Co05) B(E2)↑: See also 0.066 (1982Co08). E(level): see (1957Ba29, 1960Ba35, 1968Ri16, 1978Bl02, 1982Co08, 1984Se12, 1986Oh03, 1988Co05, 2003An11). Analyzing power A_y was also measured (1984Se12). $T_{1/2}$: from τ<26 fs (1968Ri16). L: transfer L (1984Se12). Spin transfer ΔS=0 (1984Se12).
3854	$5/2^+$		3	B(E1)↑=0.0303 (1988Co05); B(M2)↑=0.131 E(level): see (1982Co08,1984Se12,1986Oh03,1988Co05,2003An11). Analyzing power A_y was also measured (1984Se12). L: transfer L (1984Se12). Spin transfer ΔS=0 (1984Se12).
6864	$5/2^+$			B(M2)↑=0.0153 (1988Co05) E(level): see (1978Bl02,1982Co08: weak,1984Se12,1988Co05). Analyzing power A_y was also measured (1984Se12).
7547	$5/2^-$		2	B(E2)↑=0.175 (1988Co05); B(M3)↑=0.518 B(E2)↑: See also 0.058 (1982Co08). E(level): see (1978Bl02,1982Co08,1988Co05). L: transfer L (1984Se12). Spin transfer ΔS=0 (1984Se12).
7686				

Continued on next page (footnotes at end of table)

^{13}C(p,p),(p,p′),(p,pn) (continued)

^{13}C Levels (continued)

E(level)[†]	J^{π}[‡]	T or Γ[#]	L	Comments
8200				
8860	$1/2^-$		0	B(M1)↑=0.418 (1988Co05) E(level): see (1982Co08,1984Se12,1988Co05). Analyzing power A_y was also measured (1984Se12). L: transfer L (1984Se12). Spin transfer ΔS=0 (1984Se12).
9500	$9/2^+$		4	E(level): see (1982Co08,1982Ri05,1984Se12,1988Co05). Analyzing power A_y was also measured (1984Se12). J^{π}: see also (1982Ri05). L: from (1982Ri05: a pure $1p_{3/2}$ to $1d_{5/2}$ neutron transition).
9897	$3/2^-$			B(M1)↑=0.058 (1988Co05); B(E2)↑=0.0016 (1988Co05)
10753	$7/2^-$			
10818				
10996				
11080	$1/2^-$			B(M1)↑=0.065 (1988Co05)
11748				
11851	$7/2^+$			J^{π}: assigned by (1988Co05).
11920 *60*	$(5/2^+)$	200 keV		E(level): from (1978Bl02); see also (1988Co05). J^{π}: assigned by (1988Co05); see also $J^{\pi}=(5/2,7/2)^+$ (1978Bl02).
12106	≤5/2	80 keV		J^{π}: assigned by (1988Co05).
12190 *10*	≤5/2	110 keV *50*		E(level),Γ: from (1988Co05, S. Collins, Ph.D. thesis, and B. Spicer, private communication). J^{π}: assigned by (1988Co05).
12438		160 keV		
13280?				E(level): possibly seen at Ep=135 MeV (1988Co05).
13410				
13570?				E(level): possibly seen at Ep=135 MeV (1988Co05).
13760?				E(level): possibly seen at Ep=135 MeV (1988Co05).
14130		210 keV		
14390		300 keV		
14582	$(7/2,9/2)^+$	250 keV		J^{π}: assigned by (1988Co05).
14983	$(5/2^+)$	410 keV		J^{π}: assigned by (1988Co05).
15108	$3/2^-$			B(M1)↑=1.12 (1988Co05); B(E2)↑=0.0189 (1988Co05) T=3/2 T: value listed in (1982Co08).
15526		220 keV		E(level): see (1982Co08,1988Co05). Γ: from (1988Co05).
16080	$(7/2^+)$	220 keV		E(level),Γ: from (1988Co05). J^{π}: assigned by (1988Co05).
16150				E(level): Reported in (1982Co08) and possibly seen at Ep=135 MeV (1988Co05).
16950?				E(level): possibly seen at Ep=135 MeV (1988Co05).
17360?				E(level): possibly seen at Ep=135 MeV (1988Co05).
17699	$(3/2^-,5/2)$			J^{π}: assigned by (1988Co05); L=2 or 3 was consistent, but $7/2^+$ was considered unlikely because of the shape at small angles.
18300?				E(level): possibly seen at Ep=135 MeV (1988Co05).
18699	$(3/2,5/2)^+$			E(level): see (1988Co05). J^{π}: assigned by (1988Co05).
19500				
19900?				E(level): possibly seen at Ep=135 MeV (1988Co05).
20021				
20429				
20.93×10^3 *10*		0.24 MeV *10*		E(level),Γ: from (1988Co05, S. Collins, Ph.D. thesis, and B. Spicer, private communication).
21280				
21466	$(7/2,9/2)^+$	270 keV *20*		T=3/2 Γ_n/Γ=0.24 *5*

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^{13}C(p,p),(p,p′),(p,pn) (continued)

^{13}C Levels (continued)

E(level)[†]	J^{π}[‡]	T or Γ[#]	Comments
			$\Gamma_{p0}/\Gamma\leq0.23$; $\Gamma_{p1}/\Gamma=0.69$ *6* Γ: Γ and partial widths from (2022Ci07). Γ_p: $\Gamma_{p2+3}/\Gamma=0.07$ 2. Γ_n: Decay is to ^{12}C(15.11 MeV: $J^{\pi}=1^+$, T=1). T: From (2022Ci07). J^{π}: assigned by (1988Co05).
21810	≥5/2		J^{π}: assigned by (1988Co05).
22.20×10^3 *10*	≤5/2	1.1 MeV *5*	E(level),Γ: from (1988Co05, S. Collins, Ph.D. thesis, and B. Spicer, private communication). J^{π}: assigned by (1988Co05).
23000	≤5/2		J^{π}: assigned by (1988Co05).

[†] Level-energy values listed in, for example, (1982Co08,1988Co05). Angular distributions were studied.

[‡] Values from, for example, DWBA analysis of (p,p′) and (pol. p,p′) angular distributions from (1982Co08,1988Co05) except where noted.

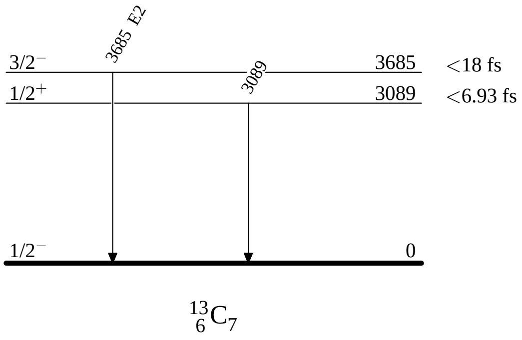
[#] Γ values from (1988Co05) except where noted.

$\gamma(^{13}C)$

E_{γ}	E_i(level)	J^{π}_i	E_f	J^{π}_f	Mult.	Comments
3089	3089	$1/2^+$	0	$1/2^-$		$\Gamma_{\gamma}>0.066$ eV (1968Ri16: Doppler shift method). E_{γ}: see also (1985Ki07). Angular distributions of E_{γ}=3.09 MeV are isotropic, consistent with the J=1/2 assignment for 3.09 MeV state (1957Ba29,1960Ba35).
3685	3685	$3/2^-$	0	$1/2^-$	E2	$\Gamma_{\gamma}>0.025$ eV (1968Ri16: Doppler shift method). Angular distributions of E_{γ} were studied (1957Ba29, 1960Ba35).

^{13}C(p,p),(p,p′),(p,pn)

Level Scheme



^{13}C(^{3}He,^{3}He),(^{3}He,^{3}He′) 1969Ba06,1981Pe08,2000Bu25

1966Ke08: ^{13}C(^{3}He,^{3}He), E(^{3}He)=12, 15 and 18 MeV; angular distributions have been studied.
1967Ar17: ^{13}C; deduced nuclear properties.
1968We15: ^{13}C(^{3}He,^{3}He) E(^{3}He)=6-8 MeV; measured $\sigma(\theta)$, deduced optical model parameters.
1969Ar08: ^{13}C(^{3}He,^{3}He), E=36 MeV; measured $\sigma(\theta)$; deduced optical model parameters.
1969Ar10: ^{13}C(^{3}He,^{3}He′), E≈36 MeV; measured σ(E(^{3}He′),θ). ^{13}C deduced deformation parameters.
1969Ba06: ^{13}C(^{3}He,^{3}He′), E=40-50 MeV; measured σ(E(^{3}He′),θ); deduced optical model parameters. ^{13}C deduced levels.
1969Zu02: ^{13}C(^{3}He,^{3}He), E=15 MeV, measured $\sigma(\theta)$. Enriched, natural targets.
1970Nu02: ^{13}C(^{3}He,^{3}He), E=14 MeV; measured $\sigma(\theta)$; deduced optical model parameters.
1973LuZL: ^{13}C(^{3}He,^{3}He); E=20 MeV polarized ^{3}He, measured $\sigma(\theta)$.
1975Ha33: ^{13}C(^{3}He,^{3}He), E=15 MeV; measured $\sigma(\theta)$; deduced optical parameters.
1976Ma26: ^{13}C(^{3}He,^{3}He), E=18,20,24.5 MeV; measured $\sigma(\theta)$ at backwards angles.
1977Pe23: ^{13}C(^{3}He,^{3}He), E=20 MeV; measured σ(E(^{3}He),θ).
1980PeZV: ^{13}C(^{3}He,^{3}He′), E=43.6 MeV; measured $\sigma(\theta)$. ^{13}C levels deduced analog character. DWBA analysis.
1980Tr02: ^{13}C(^{3}He,^{3}He), E=41 MeV; measured $\sigma(\theta)$. Optical model analysis.
1981Pe08: ^{13}C(^{3}He,^{3}He′), E=43.6 MeV; measured σ(E(^{3}He),θ). ^{13}C levels deduced isoscalar, isovector transition amplitude ratio. DWBA, CCBA analyses.
1986Dr03: ^{13}C(^{3}He,^{3}He), E=33 MeV; measured $\alpha(\theta)$, A(θ); deduced optical model parameters. ^{13}C*(0,3.68,7.55).
1987BuZR: ^{13}C(^{3}He,^{3}He), E=39.6 MeV; measured $\sigma(\theta)$. Optical model.
1992Ad06: ^{13}C(^{3}He,^{3}He), E=50,60 MeV; measured $\sigma(\theta)$; deduced model parameters.
1994Bu01: ^{13}C(^{3}He,^{3}He), E=37.9 MeV; measured $\sigma(\theta)$; deduced optical model parameters, rainbow mechanism.
2000Bu13: ^{13}C(^{3}He,^{3}He), E=50,60 MeV; measured $\sigma(\theta)$. Comparison with optical model calculations with energy-dependent terms.
2000Bu25, 2002Th01: ^{13}C(^{3}He,^{3}He), ^{13}C(^{3}He,^{3}He′), E=37.9 MeV; measured $\sigma(\theta)$, σ(E,θ); deduced optical model parameters. ^{13}C deduced levels, J, π, configurations. Comparisons with model predictions.

Theory:
1986Ze04: ^{13}C(^{3}He,^{3}He), E=16-22 MeV; calculated $\sigma(\theta)$; deduced model parameters. Optical model.
1987Ra36: ^{13}C(^{3}He,^{3}He), E=41 MeV; analyzed $\sigma(\theta)$; deduced model parameters.
1990De31: ^{13}C(^{3}He,^{3}He), E=39.6, 12 MeV; analyzed $\sigma(\theta)$; deduced model parameters, rainbow characteristics.
2009Pa07: ^{13}C(^{3}He,^{3}He), E=450 MeV; analyzed $\sigma(\theta)$ using global optical model potential GDP08; deduced set of global optical potential parameters.
2011Og09: ^{13}C(^{3}He,^{3}He), E(cm)<300 MeV; analyzed $\sigma(\theta)$ and diffraction radii data; deduced abnormally large radii for the ^{13}C*(3.09;1/2^{+}) state located 1.86 MeV below the neutron emission threshold.
2011Og10: ^{13}C(^{3}He,^{3}He), E=39.6 MeV; analyzed $\sigma(\theta)$; deduced rms radii, diffraction radii, neutron halos in the excited states. Modified diffraction model.
2014El01: ^{13}C(^{3}He,^{3}He), ^{13}C(^{3}He,^{3}He′), E=37.9 MeV; calculated σ, $\sigma(\theta)$; deduced deformation parameters from the best fit. M3Y-Reid effective interaction, comparison with available data.
2015Pa10: ^{13}C(^{3}He,^{3}He), E=4-118.5 MeV; analyzed $\sigma(\theta)$ for 142 sets of experimental data; deduced optical model parameters.
2016De39: ^{13}C(^{3}He,^{3}He′), E=43.6 MeV; ^{13}C(^{3}He,^{3}He), E=39.6 MeV; analyzed available data, discussed ^{13}C*(3.09) radius.

^{13}C Levels

T: From (1969Ba06).

E(level)[†]	J$^{\pi}$[‡]	L[d]	deformations β[#]	Comments
0[&]				
3.09×10^{3}[&ab]	1/2^{+}	1	0.113	T=1/2
3.68×10^{3}[&ab]	3/2^{-}	2	0.166	T=1/2 E(level): unresolved with 3.85 MeV level in (1969Ba06).
3.85×10^{3}[&ab]	5/2^{+}	3	0.172	T=1/2 E(level): unresolved with 3.68 MeV level in (1969Ba06).

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^{13}C(^{3}He,^{3}He),(^{3}He,^{3}He′) **1969Ba06,1981Pe08,2000Bu25 (continued)**

^{13}C Levels (continued)

E(level)[†]	J$^\pi$[‡]	L[d]	deformations β[#]	Comments
6.86×10^3[&a]	5/2$^+$	3	0.055	
7.49×10^3[a]				E(level): unresolved with 7.55 MeV level.
7550[&ab]	5/2$^-$	2		T=1/2 E(level): unresolved with 7.49 MeV level; the higher state is 5/2$^-$;T=1/2 (1969Ba06). ΔL=2&3 for the unresolved pair.
7.68×10^3[@&]	3/2$^+$	1	0.065	
8860[ab] 30	1/2$^-$	0	0.050	T=1/2
9500[&a] 30	9/2$^+$	5	0.072	
9.897×10^3[@]		2		
10.75×10^3[@]		2	[c]	E(level): unresolved with 10.82 MeV level (1981Pe08).
10.82×10^3[@]		2	[c]	E(level): unresolved with 10.75 MeV level (1981Pe08).
11.08×10^3[a]	(3/2$^-$,5/2$^-$)	2	0.046	J$^\pi$: from the ΔL=2 angular distributions seen in (1981Pe08). E(level): weakly populated (1969Ba06).
11840[ab] 30	(7/2$^+$)		0.12	T=1/2 J$^\pi$: In (1981Pe08) this level is identified with L=2 and J$^\pi$=(3/2$^-$), while in, for example (2000Bu25) it is identified with L=3 and 7/2$^+$.
15.11×10^3[a]		2	0.065	
16.0×10^3[@]		3	0.062	

[†] E$_x$ from (1969Ba06) except where noted.
[‡] From DWBA and shell model analysis in (2000Bu25,2002Th01), except where noted.
[#] From (1981Pe08).
[@] Reported in (1981Pe08).
[&] Also reported in (1986Dr03).
[a] Also reported in (1981Pe08).
[b] Also reported in (2000Bu25,2002Th01).
[c] The deformations β value for the unresolved states at E$_x$=10.8 MeV is 0.035 (1981Pe08).
[d] From (1981Pe08,2000Bu25).

^{13}C(α,α),(α,α'),(α,$\alpha'\gamma$)

1959Fu62: ^{13}C(α,α'), E=20 MeV; scattering angle θ=45°, ^{13}C*(3.7 MeV) observed.
1960St02: ^{13}C(α,α'), measured not abstracted; ^{13}C deduced nuclear properties.
1963Ba05: ^{13}C(α,α'), measured not abstracted; deduced nuclear properties.
1966Ha19: ^{13}C(α,α'),(α,α'), E=40.5 MeV; angular distributions were measured for a large number of excited states of ^{13}C.
1967Ar17: ^{13}C(α,α'),(α,α'), E=33.4 MeV; angular distributions of ealstic and inelastic scatterings were measured.
1971Co14: ^{13}C(α,α'), E=15,18,20,28.4 MeV; measured $\sigma(\theta)$; deduced optical model parameters. Enriched targets.
1972Ku19,1974Ch58,1974Ku15: ^{13}C(α,α'), E=26.6 MeV; measured $\sigma(\theta)$.
1973Ku18: ^{13}C(α,α'), E=18,19,22,24,25,26.6 MeV; measured σ(E;θ); deduced reaction mechanism.
1974Fe08: ^{13}C(α,α'),(α,α'), E=24 MeV; measured $\sigma(E_{\alpha'},\theta)$.
1976Ja17: ^{13}C(α,α'), E=65 MeV; measured $\sigma(\theta)$.
1976Pa05: ^{13}C(α,α'), E=30.9, 50.5 MeV; analyzed deformation.
1980Fu04: ^{13}C(α,α'), E=22,36 MeV; measured $\sigma(E_\alpha,\theta)$. The line shape of the ^{13}C*(7.686 MeV;3/2$^+$) resonance is measured. Enriched target.
1981Pe08: ^{13}C(α,α'), E=35.5 MeV; measured $\sigma(E_\alpha,\theta)$. ^{13}C levels deduced isoscalar, isovector transition amplitude ratio. DWBA, CCBA analyses.
1983Pi07: ^{13}C(α,$\alpha'\gamma$), E=32 MeV; measured E_γ, I_γ. Low energy prompt γ measurement technique.
1984De44: ^{13}C(α,α'), E=24-35 MeV; measured α(^{12}C)(θ,ϕ). ^{13}C level deduced substate population probabilities.
1984DeZR: ^{13}C(α,α'), E not given; measured (recoil nucleus)(α)-coin. ^{13}C levels deduced Γ_γ/Γ.
1985De11: 13C(α,$\alpha'\gamma$), E=24 MeV; measured E_γ, I_γ, recoil. ^{13}C levels deduced Γ_γ/Γ.
1987Ab03: ^{13}C(α,α_0), E=48.7, 54.1 MeV; measured $\sigma(\theta)$. ΔE-E telescopes. Optical model analyses.
1987Bu27: ^{13}C(α,α'), E=50.5 MeV; measured σ.
1993AtZZ: ^{13}C(α,α'), E=54.1,104,155 MeV; ^{13}C(α,α'), E=54.1,104,155 MeV; measured $\Sigma(E,\theta)$; deduced model parameters. ^{13}C levels deduced B(λ). Coupled-channels analysis.
2001He22: ^{13}C(α,α'), E=2.6-6.2 MeV; measured $\sigma(\theta)$.
2002Ar16: ^{13}C(α,α'),(α,α'), E=25.5-35.15 MeV; measured elastic and inelastic $\sigma(\theta)$, excitation functions. Comparison with model predictions.
2006SaZP,2007SaZS: ^{13}C(α,α'), E=400 MeV; measured E_α, I_α; deduced $\sigma(\theta)$, B(E0), B(E2), level properties: J, π.
2008He11: ^{13}C(α,α'), E=2.6-6.2 MeV; measured radii, σ, $\sigma(\theta)$, S-factor.
2008Ka44: ^{13}C(α,α'), E=388 MeV; measured E_α, I_α; deduced $\sigma(\theta)$, B(E0). Comparison with DWBA calculations.
2010KaZO,2010KaZZ: ^{13}C(α,α'), E=388 MeV; measured E_α, $I_\alpha(\theta)$; deduced d$\sigma(\theta)$ to individual states, B(E0).
2014DeZW: ^{13}C(α,α'), E=65 MeV; measured E_α, $I_\alpha(\theta)$; deduced resonances, $\sigma(\theta)$ to discrete states, neutron halo radius to excited states using MDM (modified diffraction model).
2015Og04: ^{13}C(α,α'), E=65,90 MeV; measured reaction products; deduced $\sigma(\theta)$, rms radii. Comparison with available data.
2016Bu24: ^{13}C(α,α'), E=26.6-65 MeV; measured reaction products, E_α, I_α; deduced $\sigma(\theta)$, optical model and semi-microscopic parameters.
2016DeZX: ^{13}C(α,α),(α,α'), E=65,90 MeV [inelastic scattering to 3.09 MeV state in ^{13}C]; measured E_α, $I_\alpha(\theta)$; deduced $\sigma(\theta)$; calculated $\sigma(\theta)$ using optical model; calculated 1/2$^+$ 3.09 MeV state neutron halo radius using MDM (Modified Diffraction Model), NRM (Nuclear Rainbow Method) and ANC (Asymptotic Normalization Coefficients). Compared with published radii of 1/2$^-$ 8.86 MeV state (diluted cluster) and of 3/2$^-$ 9.90 state (compact cluster).
2018Bu05: ^{13}C(α,α),(α,α'), E=29 MeV; measured reaction products, E_α, I_α; deduced $\sigma(\theta)$, diffraction and rms radii, J, π. The radii of the excited states ^{13}C*(3.09, 8.86) are determined using Modified Diffraction Model (MDM) and are larger than that of the ^{13}C$_{g.s.}$, confirming the suggestion that the 8.86 (1/2$^-$) MeV state could be an analog of the Hoyle state in ^{12}C and the 3.09 (1/2$^+$) MeV state has a neutron halo. ^{13}C*(9.9) state is a possible “exotic” excited state. Comparison with theoretical calculations. See discussion on a ^{13}C analog of the Hoyle state in (2010Og03, 2010OgZZ, 2020Ch06, 2021Sh42).
2020InZZ: ^{13}C(α,α') E=388 MeV; measured E_α, $\sigma(\theta)$, deduced L, J, π.
2021De32: ^{13}C(α,α') E=65 and 90 MeV; measured angular distributions for θ=5° to 72° and 6°−40°, respectively. Searched for evidence of a Hoyle state analog in ^{13}C. Analyzed data for ^{13}C*(9.9, 11.080) and deduced radii.
2021In04: ^{13}C(α,α') E=388 MeV; measured E_α $\sigma(\theta)$ for $\theta\approx$0° to 20.2° at the RCNP/Osaka using the Grand Raiden spectrometer. Populated states up to E_x=16 MeV, DWBA analysis focused mainly on E_x=10.5 – 13 MeV in a search for α condensate states. Deduced isoscalar transition strengths. I addition to known states, a state at E_x=12.06 has isoscalar monopole and dipole character, while other states at E_x=12.3, 12.5, 12.6 and 12.8 have isoscalar monopole character. Notably, no evidence of the 12.14 MeV state was observed. ΔL=1 states are reported at E_x=14.5 and 16.1 MeV; authors suggest the 16.1 MeV state is a candidate for the α

$^{13}C(\alpha,\alpha),(\alpha,\alpha'),(\alpha,\alpha'\gamma)$ (continued)

condensate state. Find related discussion in (2008To18).

Theory:

1971Te10: $^{13}C(\alpha,\alpha')$, E=20,25 MeV; analyzed interference between states of transferred nucleus.

1974Ch58: $^{13}C(\alpha,\alpha')$, E=26.6 MeV; analyzed $\sigma(\theta)$. The calculated and experimental angular distributions for (α,α') transitions to the $^{13}C_{g.s.}$ state are studied.

1977Sa19: $^{13}C(\alpha,\alpha')$, E=40.5 MeV; calculated $\sigma(\theta)$ at forward angles.

1978Ze03: $^{13}C(\alpha,\alpha')$, E=26.6 MeV; calculated $\sigma(\theta)$.

1983Go27: $^{13}C(\alpha,\alpha')$, E=26.6 calculated $\sigma(\theta)$; deduced spin-orbit potential effects.

1988Le05: $^{13}C(\alpha,\alpha')$, calculated resonances, Γ, α-particle strength distribution. Optical model.

1990Mu19: $^{13}C(\alpha,\alpha')$, E=65 MeV; ; analyzed $\sigma(\theta)$; deduced model parameters. Microscopic overlap integrals, vertex form factors.

1992AtZU: $^{13}C(\alpha,\alpha')$, E≈50-105 MeV; analyzed data. ^{13}C levels deduced B(λ) ratios. Harmonic-vibrational, other models.

2010DaZY: $^{13}C(\alpha,\alpha)$, (α,α'), E=388 MeV; calculated $\sigma(\theta)$; deduced radii for specified excited states.

2011De17: $^{13}C(\alpha,\alpha')$, E=35.5 MeV; calculated $\sigma(\theta)$. ^{13}C deduced rms radii.

2011Og09: $^{13}C(\alpha,\alpha')$, E(cm)<300 MeV; analyzed $\sigma(\theta)$ and difraction radii data; deduced abnormally large radii for excited states.

2011Og10: $^{13}C(\alpha,\alpha),(\alpha,\alpha')$, E(cm)=388 MeV; analyzed $\sigma(\theta)$; deduced rms radii, diffraction radii, neutron halos in the excited states. Modified diffraction model.

2017HaZY: $^{13}C(\alpha,\alpha')$, E=2-5.7 MeV; calculated $\sigma(\theta)$. Calculations using R-matrix; results compared with available data.

^{13}C Levels

R_{rms} radius determined by MDM (Modified Diffraction Method) except where noted.

E(level)[†‡]	J^{π}[#]	L[#]	deformation β[#]	Comments
0	1/2⁻	0		R_{rms}=2.33 fm *3* (2018Bu05: E_{α}=29 MeV); see also 2.31 fm (2011DeZY,2014DeZW) and 2.33 fm (2015Og04: E_{α}=65,90 MeV).
3090	1/2⁺	1	0.19	B(E1)↑=0.096 *5* (2021In04) R_{rms}(fm)=3.04 *22* (2011DeZY), 2.92 *7* (2014DeZW), 2.98 *9* (2016DeZX: E_{α}=65 MeV), 2.88 *19* and ≥2.6 (NRM: Nuclear Rainbow Method) (2016DeZX: E_{α}=90 MeV), 2.7 *4* (2018Bu05).
3680	3/2⁻	2	0.17	B(E2)↑=0.00560 *20* (2021In04) B(E2)↓≈6 e^2fm^4 (1966Ha19); DWBA fit not good. deformation β: see also β=0.54 (WS: Woods-Saxon form), 0.51 (DF: double folding calculation) at E_{α}=29 MeV and β=0.44 (WS), 0.4 (DF) at E_{α}=50 MeV (2016Bu24).
3850	5/2⁺	3	0.31	B(E3)↑=0.000472 *26* (2021In04)
6860	5/2⁺	3	0.042	$\Gamma_{\gamma}/\Gamma\leq3\times10^{-4}$ (1984DeZR,1985De11). $\Gamma_{\gamma}\leq$1.5 eV using Γ=5.2 keV from (1982Kn02: $^{12}C(n,x)$). (1985De11) indicates that the most probable channel for the decay of this state is the E1 transition to the 3.69 MeV, 3/2⁻ level. deformation β: see also β=0.54 (WS), 0.51 (DF) at E_{α}=29 MeV (2016Bu24).
7490[@]				E(level): unresolved in (1966Ha19,1974Fe08,1981Pe08,1984DeZR,1985De11). L: (1981Pe08) fits the unresolved $^{13}C^{*}$(7490+7550) angular distributions with ΔL=2 (J^{π}=3/2⁻,5/2⁻). The fit is rather poor. The Adopted Levels gives J^{π}=(7/2⁺) and 5/2⁻, respectively, which implies ΔL=3 and 2, respectively.
7550[@]		(2)		B(E2)↑=0.00663 *24* (2021In04) E(level): unresolved in (1966Ha19,1974Fe08,1981Pe08,1984DeZR,1985De11). B(E2; IS(isoscalar transition))=77 fm^4 *8* (2007SaZS); B(E2)↓≈6 e^2fm^4 (1966Ha19); DWBA fit not good. deformation β: See also β=0.54 (WS), 0.51 (DF) at E_{α}=29 MeV and β=0.44 (WS), 0.4 (DF) at E_{α}=50 (2016Bu24).

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^{13}C(α,α),(α,α′),(α,α′γ) (continued)

^{13}C Levels (continued)

E(level)[†‡]	J^{π}[#]	Γ	L[#]	deformation β[#]	Comments
7686[@] *6*	$3/2^+$	70 keV *5*	1	0.097	T=1/2 (1980Fu04). E(level),Γ: from (1980Fu04).
8860	$1/2^-$		0	0.10	B(E0)↑=29.6 23 (2021In04). B(E0,IS)=55 fm^4 *6* (2007SaZS); see also preliminary results B(E0,IS)=37 fm^4 *6* (2008Ka04) and 42 fm^4 *6* (2010KaZO,2010KaZZ). R_{rms}(fm)=2.63 *12* (2011DeZY), 2.68 *10* (2014DeZW), ≥2,5 (NRM, R_{α}=65, 90 MeV) and 2.63 *16* (E_{α}=90 MeV) (2016DeZX), 2.50 *32* (exotic state) (2018Bu05).
9500	$9/2^+$		5	0.16	intense neutron decay to the 1st excited state of ^{12}C with probability 20% *10* assuming the angular distribution of the neutrons is isotropic.
9900	$3/2^-$				J^{π}: From (2015Og04), suggested rotational band member. R_{rms}(fm)=2.00 *14* (2014DeZW), 2.02 *14* (E_{α}=65 MeV) and 1.76 *23* (E_{α}=1.76 *23* (E_{α}=90 MeV) (2015Og04). E(level): exotic state (2018Bu05).
10460					
10753	$(7/2^-)$				B(E4)↑=0.0000037 *14* (2021In04) E(level),J^{π}: unresolved doublet (1981Pe08,2021In04).
10820	$(5/2^-)$		2	0.18	B(E2)↑=0.00017 *1* (2021In04) E(level),J^{π}: unresolved doublet (1981Pe08,2021In04).
11010					B(E1)↑<0.023 (2021In04) E(level): from (2014DeZW).
11080	$(1/2^-)$		0	0.15	B(E0)↑=19.2 3 (2021In04). J^{π}: (1981Pe08) report a ΔL=2 J^{π}=($3/2^-$,$5/2^-$) angular distribution, but we take ΔL=0 J^{π}=($1/2^-$), which is reported in (2007SaZS, 2008Ka44, 2010KaZO, 2010KaZZ, 2020InZZ). B(E0,IS)=35 fm^4 *4* (2007SaZS); see also preliminary results 18 fm^4 *3* (2008Ka44) and 23 fm^4 *3* (2010KaZO,2010KaZZ).
11748					B(E2)↑=0.00056 *16* (2021In04)
11850	$(7/2^+)$		3	0.35	B(E3)↑=0.00074 *8* (2021In04) J^{π}: (1981Pe08) report a ΔL=2 J^{π}=($3/2^-$) angular distribution, but we take ΔL=3 J^{π}=($7/2^+$), which is reported in (2020InZZ, 2021In04).
12055[&] *1*	$1/2^-$&$(3/2,5/2)^-$	38 keV *4*	0+2		B(E2)↑=0.00022 *1* (2021In04) E(level): Unresolved doublet. B(E0)↑=1.7 3 (2021In04).
12282[&] *5*	$1/2^-$	122 keV *22*	0		B(E0)↑=4.1 4 (2021In04). E(level),Γ,L: From (2021In04).
12450[&] *3*	$1/2^-$	<70 keV	0		B(E0)↑=4.9 4 (2021In04). E(level),Γ,L: From (2021In04). E(level): See also the broad ≈12.5 MeV state reported in (2008Ka44,2010KaZO,2010KaZZ), which is presently associated with E_x=12.3, 12.5, 12.6 and 12.8.
12601[&] *3*	$1/2^-$	<70 keV	0		B(E0)↑=3.1 2 (2021In04). E(level),Γ,L: From (2021In04).
12775[&] *4*	$1/2^-$	<70 keV	0		B(E0)↑=0.92 5 (2021In04). E(level),Γ,L: From (2021In04).

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^{13}C(α,α),(α,α′),(α,α′γ) (continued)

^{13}C Levels (continued)

E(level)[†‡]	J$^{\pi}$[#]	L[#]	deformation β[#]	Comments
14.5×10^{3}[&] *1*	1/2$^+$,3/2$^+$	1		B(E1)↑=6.9 *7* (2021In04) E(level),J$^{\pi}$,L: From (2021In04).
15110	3/2$^-$	2		T=3/2 (1981Pe08)
16080	7/2$^+$	3	<0.1	
16.1×10^{3}[&] *1*	(1/2$^+$,3/2$^+$)	1		B(E1)↑=2.1 *8* (2021In04) E(level),J$^{\pi}$,L: From (2021In04). E(level): Suggested as a possible candidate for α condensed state.

[†] Values listed in, for example, (1981Pe08) except where noted.

[‡] For levels reported, see (1959Fu62, 1966Ha19, 1967Ar17, 1974Fe08, 1980Fu04, 1981Pe08, 1983Pi07, 1984De44, 1984DeZR, 1985De11, 2002Ar16, 2006SaZP, 2007SaZS, 2008Ka44, 2010KaZO, 2010KaZZ, 2011DeZY, 2014DeZW, 2015Og04, 2016Bu24, 2016DeZX, 2018Bu05).

[#] From DWBA analysis in (1981Pe08) except where noted.

[@] Unresolved in (1985De11) who determined $\Gamma_{\gamma}/\Gamma\leq3\times10^{-4}$ (1984DeZR,1985De11) for the unresolved group. In their discussion, they considered various scenerios depending upon which of the levels ^{13}C*(7.49,7.55,7.69) is populated.

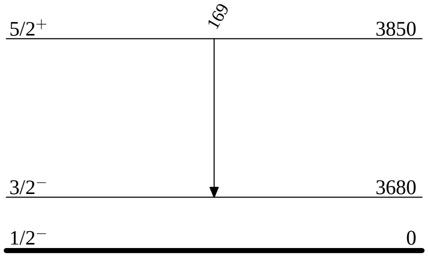
[&] Uncertainties in the level energies are statistical only. These results, obtained using the Grand Raiden (Fujiwara, NIM A 422 (1999) 484), were collected with a peak FWHM of 170 keV; peak energy resolution should be dominated by the focal plane energy calibration and is estimated by a reasonable ΔE≈3 keV.

γ(^{13}C)

E_{γ}	E_i(level)	J^{π}_{i}	E_f	J^{π}_{f}
169	3850	5/2$^+$	3680	3/2$^-$

^{13}C(α,α),(α,α′),(α,α′γ)

Level Scheme



$^{13}_{6}C_{7}$

^{13}C(^{6}Li,^{6}Li),(^{7}Li,^{7}Li)

1969Be90: ^{13}C(^{6}Li,^{6}Li),(^{7}Li,^{7}Li) E=20 MeV; measured $\sigma(\theta_{c.m.})$ for $\theta\approx40^\circ-110^\circ$. Deduced Optical Model parameters.
1972Ba52: ^{13}C(^{6}Li,^{6}Li) E=28 MeV; measured $\sigma(\theta)$ for $\theta\approx15^\circ-90^\circ$. Deduced Optical Model parameters.
1973Sc26: ^{13}C(^{6}Li,^{6}Li),(^{7}Li,^{7}Li) E=34, 36 MeV; measured elastic and inelastic scattering for $\sigma(\theta)$ and $\theta\approx$ 15° to 80°. Finite-range DWBA analysis.
1976Po02: ^{13}C(^{6}Li,^{6}Li),(^{7}Li,^{7}Li) E=4-13 MeV; measured $\sigma(\theta)$ for $\theta\approx15^\circ-90^\circ$, optical model analysis.
1978Dr07: ^{13}C(pol. ^{6}Li,^{6}Li),(pol. ^{7}Li,^{7}Li) E=9 MeV; E=28 MeV; measured $\sigma(\theta)$ for $\theta\approx20^\circ-100^\circ$.
1979Ze01: ^{13}C(^{6}Li,^{6}Li) E=40 MeV; measured $\sigma(\theta)$ for $\theta\approx10^\circ-70^\circ$.
1987Co02, 1987Co16: ^{13}C(^{7}Li,^{7}Li),(^{7}Li,^{7}Li′) E=34 MeV; measured $\sigma(\theta)$ for $\theta\approx10^\circ-170^\circ$. Folding model analysis.
1988DeZT, 1992DeZQ, 1994De43: ^{13}C(^{6}Li,^{6}Li) E=93 MeV; measured $\sigma(\theta)$ for θ=14° to 163°, analyzed rainbow effects.
1989De34: ^{13}C(^{6}Li,^{6}Li) E=93 MeV; measured $\sigma(\theta)$ for $\theta\approx10^\circ-120^\circ$ also studied (^{6}Li,^{6}He). DWBA analysis.
2000Tr01: ^{13}C(^{7}Li,^{7}Li) E=63, 130 measured elastic $\sigma(\theta)$ for $\theta_{c.m.}\approx5^\circ$ to 70°. Also measured ^{13}C(^{14}N,^{14}N) for E=162 MeV, and several other reactions. Optical model analysis. Deduced global optical model parameters and applied results to (^{7}Be,^{8}B) transfer reactions and the ^{7}Be(p,γ) problem.
2004Ca46, 2004CaZZ: ^{13}C(^{6}Li,^{6}Li) E=54 MeV, ^{13}C(^{7}Li,^{7}Li) E=63, 130 MeV; measured elastic scattering $\sigma(\theta)$ for θ=10° to 80°. Also measured ^{13}C(^{7}Li,^{8}Li) transfer reaction. Analyzed refractive scattering via optical model analysis.
2012Li14: ^{13}C(^{7}Li,^{7}Li) E=34 MeV; measured elastic scattering $\sigma(\theta)$ for $\theta_{c.m.}$=10° to 45°. DWBA analysis.

1976St22: ^{13}C(^{6}Li,dα): calculated d+α angular correlations.
1991Bo48: ^{13}C(^{6}Li,^{6}Li),(^{7}Li,^{7}Li): analyzed utility of lithium beam studies for Rutherford backscattering analysis of materials.
2018Xu01: ^{13}C(^{7}Li,^{7}Li): developed a global optical potential model for ^{7}Li scattering up to 200 MeV.
2020Ch17: ^{13}C(^{7}Li,^{7}Li): developed a microscopic optical potential model for ^{7}Li scattering up to 450 MeV.
2022Mi16: ^{13}C(^{6}Li,^{6}Li) E=38 MeV; analyzed refractive scattering for lithium beams in a laser polarizing field.
2022Xu14: ^{13}C(^{6}Li,^{6}Li) E=4-210 MeV; developed a global optical potential model for ^{6}Li scattering on 1*p*-shell nuclei.
2023Ma02: ^{13}C(^{6}Li,^{6}Li),^{7}Li,^{7}Li); analyzed mass asymmetry and charge asymmetry effects in elastic scattering of light nuclei.

^{13}C Levels

E(level)	J^{π} †	Comments
0	1/2$^-$	E(level): Angular distributions analyzed in (^{6}Li,^{6}Li) and (^{7}Li,^{7}Li).
3.09×10^{3} ‡		L: L=1 (^{6}Li,^{6}Li) (1973Sc26).
3.68×10^{3} ‡	3/2$^-$	δ_2=−1.30 (1987Co02).
7.55×10^{3} ‡	5/2$^-$	δ_2=−1.00 (1987Co02).

† From folding model analysis of (1987Co02, 1987Co16).
‡ Angular distributions analyzed in coupled-channels (^{7}Li,^{7}Li) analysis of (1987Co02).

^{13}C(^{9}Be,^{9}Be),(^{9}Be,^{9}Be′)

1990Ba16: ^{13}C(^{9}Be,^{9}Be),(^{9}Be,^{9}Be′), E=50.46 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}\approx 10°$ to 170°. Deduced α-cluster spectroscopic strengths. DWBA analysis, α-cluster form factors.

Theory:
1998Gr21: ^{13}C(^{9}Be,^{9}Be), E=27 MeV; calculated $\sigma(\theta)$; deduced optical model parameters, nuclear compressibility constant.

^{13}C Levels

T: From DWBA analysis in (1990Ba16).

E(level)†	J^{π}†	L_{α}=2 α-cluster spectroscopic strengths	Comments
0	1/2^{-}	0.407	T=1/2 L_{α}=2 α-cluster spectroscopic strengths: from (1990Ba16). σ(7°−90°)=1777 mb *250* and σ(90°−170°)= 0.39 mb *12*.
3680	3/2^{-}	0.0214	T=1/2 L_{α}=2 α-cluster spectroscopic strengths: from (1990Ba16); see also 0.235 for L_{α}=0 (1990Ba16). σ(10°−90°)=6.5 mb *98* and σ(90°−170°)= 0.38 mb *11*.
7550	5/2^{-}	0.0014	T=1/2 L_{α}=2 α-cluster spectroscopic strengths: from (1990Ba16); see also 0.212 for L_{α}=4 (1990Ba16). σ(10°−92°)=4.93 mb *74* and σ(92°−170°)= 0.31 mb *12*.

† From DWBA analysis in (1990Ba16).

^{13}C(^{11}B,^{11}B)

2003Me13: ^{13}C(^{11}B,^{11}B),(^{11}B,^{11}B′), E=45 MeV; measured $\sigma(\theta)$ for $\theta \approx 20°$ to 170°. Optical model and coupled-reaction-channels analysis; deduced optical model and deformation parameters.

^{13}C Levels

E(level)[†]	J$^{\pi}$[†]	L[†]	Comments
0	1/2$^-$		
3088	1/2$^+$	1	
3684	3/2$^-$	2	
3854	5/2$^+$	3	
6864	5/2$^+$	3	
7490	7/2$^+$	3	
7547	5/2$^-$	2	δ_λ=0.90 fm, β_λ=0.31 (2003Me13).
7680	3/2$^+$	1	
8200	3/2$^+$	1	

[†] From coupled-reaction-channels model analysis in (2003Me13).

^{13}C(^{18}O,^{18}O)

2010Ru13: ^{13}C(^{18}O,^{18}O),(^{18}O,^{18}O′), E=105 MeV; measured reaction products; deduced partial σ, optical model parameters, spectroscopic amplitudes.
2011Ru04: XUNDL dataset compiled by TUNL, 2011.
The authors measured the angular distribution of ^{18}O and ^{13}C recoils from ^{13}C + ^{18}O –>^{13}C + ^{18}O reactions. A beam of E(^{18}O)=105 MeV ions from the Warsaw University Cyclotron impinged on a 500 μg/cm^2 ^{13}C target that was enriched to 90%. The recoils were detected in a ΔE-E telescope. The ^{13}C and ^{18}O elastic and inelastic data were analyzed with other data at E_{cm}=6.29-13.94 MeV, and optical potential parameters were deduced.

^{13}C Levels

E(level)	J^{π}[†]
0	$1/2^-$
3.09×10^3	$1/2^+$
3.68×10^3[‡]	$3/2^-$
3.85×10^3[‡]	$5/2^+$

[†] From coupled-reaction-channels model analysis in (2011Ru04).
[‡] Unresolved.

^{13}C(π,π),(π,π')

1976DyZY: ^{13}C(π^+,π^+), E=50 MeV; measured $\sigma(\theta)$.
1977AmZZ: ^{13}C(π^+,π^+),(π^+,$\pi^{+\prime}$), E=50 MeV; measured σ.
1978Dy01: ^{13}C(π^+,π^+), E=50 MeV; measured $\sigma(\theta)$; deduced isotopic effects. Optical model analysis.
1978EiZZ: ^{13}C(π^+,π^+), E=50 MeV; measured σ.
1979De34: ^{13}C($\pi^\pm$,$\pi^\pm$),($\pi^\pm$,$\pi^{\pm\prime}$), E=162 MeV; measured $\sigma(\theta)$. ^{13}C deduced pure n, p transitions. Shell-model, weak coupling-model configurations.
1979GyZZ: ^{13}C(π^-,π^-), E=29 MeV; measured ratios of $\sigma(\theta)$ for ^{12}C and ^{13}C targets. Optical model analysis.
1979Jo08: ^{13}C(π^-,π^-), E=29.2-49.5 MeV; measured $\sigma(\theta)$. ^{13}C deduced neutron radius relative to ^{12}C. Neutron rms radius is 2.35 fm *3*. Optical model analysis.
1979MaYZ: ^{13}C(π^-,π^-), E=30,50 MeV; analyzed $\sigma(\theta)$. ^{13}C deduced model dependence of neutron radius. Optical model, absorption parameter constraints, different pion-nucleon phase shifts, modified harmonic osillator density distribution. Found the neutron rms radius is 2.372 fm *+15−22*.
1979MaZB: ^{13}C(π^-,π^-), E=30,50 MeV; measured $\sigma(\theta)$. ^{13}C deduced neutron radii. Optical model, global fit parameters.
1979Sc25: ^{13}C($\pi^\pm$,$\pi^\pm$),($\pi^\pm$,$\pi^{\pm\prime}$), E=180 MeV; measured $\sigma(\theta)$. ^{13}C levels deduced $\sigma(\pi^-)/\sigma(\pi^+)$.
1979TrZR: ^{13}C(π^+,$\pi^{+\prime}$), E=116,162,180,200,240 MeV; measured $\sigma(E,\theta)$. ^{13}C deduced levels, J, π.
1980Sc30: ^{13}C($\pi^\pm$,$\pi^{\pm\prime}$), E=148,180,230 MeV; measured $\sigma(\theta)$. High resolution pion spectrometer.
1980Th01: ^{13}C($\pi^\pm$,$\pi^{\pm\prime}$), E=162 MeV; measured π^+/π^- asymmetry.
1981Se08: ^{13}C($\pi^\pm$,$\pi^{\pm\prime}$), E=100-300 MeV; measured $\sigma(\theta,E)$. ^{13}C deduced dominant ΔS=1 transitions. One-step mechanism, fixed scatterer impulse approximation.
1981SeZX: ^{13}C($\pi^\pm$,$\pi^\pm$),($\pi^\pm$,$\pi^{\pm\prime}$), E=162 MeV; measured $\sigma(\theta)$; deduced $\sigma(\pi^-)/\sigma(\pi^+)$. ^{13}C levels deduced B(E2). Optical, collective model analyses.
1982An18: ^{13}C($\pi^\pm$,$\pi^\pm$),($\pi^\pm$,$\pi^{\pm\prime}$), E=100 MeV; measured $\sigma(\theta)$.
1982Se04: ^{13}C($\pi^\pm$,$\pi^{\pm\prime}$), E=162 MeV; measured $\sigma(\theta)$. ^{13}C levels deduced L. Microscopic DWIA analysis, shell model wave functions.
1983Bl11: ^{13}C($\pi^\pm$,$\pi^\pm$), E=65,80 MeV; measured $\sigma(\theta)$; deduced isospin effects, pion-nucleus optical potential parameters.
1983Se15: ^{13}C($\pi^\pm$,$\pi^\pm$),($\pi^\pm$,$\pi^{\pm\prime}$), E=162 MeV; measured $\sigma(\theta)$. ^{13}C levels deduced neutron, proton B(λ) components. Optical, collective model analyses.
1984An11: ^{13}C($\pi^\pm$,π^π),($\pi^\pm$,$\pi^{\pm\prime}$), E=100 MeV; measured $\sigma(\theta)$, $\sigma(E(\pi))$. Isobar-hole model analysis.
1987MiZX: ^{13}C($\pi^\pm$,$\pi^{\pm\prime}$), E=65,50 MeV; measured $\sigma(\theta)$; deduced medium corrections energy dependence.
1988Mi02: ^{13}C($\pi^\pm$,$\pi^\pm$),($\pi^\pm$,$\pi^{\pm\prime}$), E=65 MeV; measured $\sigma(\theta)$. ^{13}C levels deduced deformation lengths, $\sigma(\pi^-)/\sigma(\pi^+)$ enhancement features; deduced deformation length. Comparison with DWIA calculations with ρ-squared medium corrections.
1990Se04: ^{13}C(π^-,π^-), E=30,50 MeV; measured $\sigma(\theta)$for elastic scattering; deduced optical model fits. ^{13}C enriched targets, range spectrometer. DWBA analysis.
1990Ye06,1991Ye01: ^{13}C($\pi^\pm$,$\pi^\pm$), E=114-226 MeV; measured analyzing power vs θ. Polarized target. DWIA analyses.
1992Br02: ^{13}C($\pi^\pm$,$\pi^\pm$),($\pi^\pm$,$\pi^{\pm\prime}$), E=100 MeV; measured analyzing power. Polarized target. Model analysis.
1994Ye06: ^{13}C($\pi^\pm$,$\pi^\pm$), E=130-180 MeV; ^{13}C(π^+,π^+), E=223 MeV; ^{13}C(π^-,π^-), E=226 MeV; measured analyzing power A(y)(θ), $\sigma(\theta)$ for elastic scattering; deduced spin-flip transition quadrupole component role. Polarized, unpolarized targets. DWIA, optical, and Δ-hole models.

Theory:
1977Fu10: ^{13}C(π^+,π^+), calculated scattering.
1980Ch08: ^{13}C(π^+,$\pi^{+\prime}$), E=120-226 MeV; calculated $\sigma(\theta)$. Coupled-channels, momentum space.
1980Ei01: ^{13}C(π^+,$\pi^{+\prime}$), E=75-200 MeV; calculated $\sigma(\theta)$; deduced connection between charge exchange, inelastic scattering processes near (3,3) resonance. Optical potential, eikonal approximation.
1980Le02: ^{13}C($\pi^\pm$,$\pi^{\pm\prime}$), E=162 MeV; calculated $\sigma(\theta)$.
1980Le17: ^{13}C($\pi^\pm$,$\pi^{\pm\prime}$), E=162 MeV; calculated $\sigma(\theta)$; deduced structure effects. DWIA, momentum space.
1980Sa04: ^{13}C($\pi^\pm$,$\pi^\pm$), E=150 MeV; calculated $\sigma(\theta)$. Isobar-doorway optical potential.
1981HaZU: ^{13}C($\pi^\pm$,$\pi^\pm$), analyzed data; deduced excess neutron density distributions.
1981Li02: ^{13}C($\pi^\pm$,$\pi^\pm$), E=180 MeV; calculated $\sigma(\theta)$. Coupled-channels method, single charge exchange mechanism, pion absorption.
1981Mo11: ^{13}C($\pi^\pm$,$\pi^{\pm\prime}$), E=resonance; calculated $(\sigma(\pi^-)-\sigma(\pi^+))/(\sigma(\pi^-)+\sigma(\pi^+))$; deduced isospin effects in pion-nucleon scattering amplitude.
1983Li15: ^{13}C(π^-,$\pi^{-\prime}$), E=180 MeV; calculated $\sigma(\theta)$. DWIA, core excitation, eikonal distorted waves.

^{13}C(π,π),(π,π') (continued)

1984HiZX: ^{13}C(π,π'), analyzed data. ^{13}C deduced M4 excitation isoscalar, isovector transition densities.
1986AmZX: ^{13}C(π,π'), analyzed form factors, $\sigma(\theta)$; deduced structure effects.
1988ChZU: ^{13}C($\pi^{\pm}$,$\pi^{\pm\prime}$), E=50-100 MeV; calculated σ asymmetry. Polarized target. DWIA.
1990Gl09: ^{13}C(π^{+},π^{+}), E=132 MeV; compiled data analyses.
1993Si15: ^{13}C($\pi^{\pm}$,$\pi^{\pm}$), E=114-226 MeV; analyzed $\sigma(\theta)$, analyzing power data.
1995Av07: ^{13}C(π^{-},π^{-}), E=132,226 MeV; calculated $\sigma(\theta)$, asymmetry vs θ in some cases. Polarized targets, spin effects.
1995Ku04: ^{13}C($\pi^{\pm}$,$\pi^{\pm}$),($\pi^{\pm}$,$\pi^{\pm\prime}$), E=114-226 MeV; analyzed $\sigma(\theta)$, asymmetry data; deduced first-order core polarization effects related features. DWIA.
1999Ta33: ^{13}C(π^{+},π^{+}), E=162-223 MeV; calculated $\sigma(\theta)$, Ay(θ). ^{13}C(π^{-},π^{-}), E=114-226 MeV; calculated Ay(θ). Isobar-doorway state model, comparisons with data.
2004Sa28: ^{13}C($\pi^{\pm}$,$\pi^{\pm}$), E≈80-800 MeV; analyzed $\sigma(\theta)$; deduced strong absorption model parameters.

^{13}C Levels

E(level)†	J$^{\pi}$†	L	Comments
0	1/2^{-}		E(level): see (1978Dy01, 1979De34, 1979Sc25, 1982AnZW, 1982Se04, 1983Bl11, 1983Se15, 1988Mi02, 1984An11, 1990Se04, 1994Ye06).
3090	1/2^{+}		E(level): see (1979De34,1982Se04,1994Ye06).
3680	3/2^{-}	2	E(level): see (1979De34, 1979Sc25, 1981Se08, 1982AnZW, 1982Se04, 1983Se15, 1988Mi02, 1984An11, 1994Ye06). L: L transfer (1981Se08,1982Se04,1988Mi02). Spin transfer ΔS=0 (1981Se08,1988Mi02). The extracted deformation lengths (βR) in fm: $(\beta R)_{+}$=1.34 *11*, $(\beta R)_{-}$=1.40 *25*; $(\beta R)_{avg}$=1.37 *14*, $(\beta R)_{+}/(\beta R)_{-}$=0.95 *20* (1988Mi02). See also (1983Se15).
3850	5/2^{+}		E(level): see (1979De34,1982Se04,1994Ye06).
6860			E(level): see (1994Ye06).
7490	7/2^{+}		E(level): see (1979De34,1983Se15).
7550	5/2^{-}	2	E(level): see (1979De34, 1979Sc25, 1981Se08, 1982AnZW, 1982Se04, 1983Se15, 1988Mi02, 1984An11, 1994Ye06). L: L transfer (1981Se08,1982Se04,1988Mi02). ΔS=0 (1981Se08,1988Mi02). The extracted deformation lengths (βR) in fm: $(\beta R)_{+}$=1.30 *10*, $(\beta R)_{-}$=1.10 *10*; $(\beta R)_{avg}$=1.19 *7*, $(\beta R)_{+}/(\beta R)_{-}$=1.18 *12* (1988Mi02).
8860	1/2^{-}	0	E(level): see (1982Se04,1988Mi02,1994Ye06). L: L transfer (1988Mi02). ΔS=0 (1988Mi02), ΔS=1 (1982Se04). The extracted deformation lengths (βR) in fm: $(\beta R)_{+}$=0.10 *1*, $(\beta R)_{-}$=0.09 *1*; $(\beta R)_{avg}$=0.095 *10*, $(\beta R)_{+}/(\beta R)_{-}$=1.11 *15* (1988Mi02).
9500	9/2^{+}		E(level): see (1979De34, 1979Sc25, 1981Se08, 1982AnZW, 1982Se04, 1988Mi02, 1984An11, 1994Ye06). J$^{\pi}$: assigned by (1982Se04). The enhancement factor $\sigma(\pi^{-})/\sigma(\pi^{+})$≈9 is consistent with a pure neutron transition and a 9/2^{+} assignment (1979De34); see also (1982Se04). The transitions to ^{13}C*(9.5) is enhanced by a factor of 4.0 *+20−7* in π^{-} scattering indicating an almost pure neutron transition (1979Sc25). ΔS=1 (1981Se08).
11700			E(level): see (1979Sc25,1984An11).
11820	(5/2^{+},7/2^{+})	3	E(level): see (doublet: 1982Se04,1983Se15,1988Mi02 and 1994Ye06). J$^{\pi}$: assigned by (1982Se04,1983Se15,1988Mi02). L: L transfer (1982Se04,1983Se15,1988Mi02). ΔS=0 (1988Mi02). The extracted deformation lengths (βR) in fm: $(\beta R)_{+}$=1.48 *13*, $(\beta R)_{-}$=1.02 *7*; $(\beta R)_{avg}$=1.23 *8*, $(\beta R)_{+}/(\beta R)_{-}$=1.45 *16* (1988Mi02).
14800			E(level): see (1984An11). Probably the same state reported at E$_{x}$=15 MeV in (1979Sc25).
16050 *50*	9/2^{+}		E(level): from (1982Se04); see also E$_{x}$=16050 keV (1981Se08), ≈16000 (1979De34: a group of states). J$^{\pi}$: assgined by (1982Se04); see also J$^{\pi}$=(9/2^{+},7/2^{+}) (1981Se08). ΔS=1 (1981Se08,1982Se04).
17500			E(level): see (1979Sc25).
17920 *50*	(9/2^{+},7/2^{+})		E(level): from (1982Se04); see also E$_{x}$=17920 keV (1981Se08). J$^{\pi}$: assgined by (1981Se08,1982Se04).

Continued on next page (footnotes at end of table)

^{13}C(π,π),(π,π') (continued)

^{13}C Levels (continued)

E(level)[†]	J$^{\pi}$[†]	Comments
		ΔS=1 (1981Se08,1982Se04).
21370 *50*	(9/2$^+$,7/2$^+$)	E(level): from (1982Se04); see also E$_x$=21370 keV (1981Se08). J$^{\pi}$: assgined by (1981Se08,1982Se04). ΔS=1 (1981Se08,1982Se04). The π^-/π^+ asymmetry near 21.5 MeV suggests that there is isospin mixing between T=1/2 and 3/2 states of J$^{\pi}$=7/2$^+$ and/or 9/2$^+$ (1982Se04).
21600 *50*	(9/2$^+$,7/2$^+$)	E(level): from (1982Se04); see also E$_x$=21600 keV (1981Se08). J$^{\pi}$: assgined by (1981Se08,1982Se04). ΔS=1 (1981Se08,1982Se04).
≈22000		E(level): see (1979De34,1979Sc25); probably a group of states. The centroid of a group of states near 22 MeV is found in (π^-,$\pi^{-\prime}$) at a higher excitation energy than in (π^+,$\pi^{+\prime}$) (1979De34).

[†] From shell model and DWIA analyses in (1982Se04) and (1979De34), except where noted.

^{14}C(p,d) **1990Ya01**

1963Le03: ^{14}C(p,d), E=17.6-20 MeV; measured $\sigma(\theta)$ for $\theta\approx10°$ to 50°. Deduced reduced width θ^2.
1966Gl01: ^{14}C(p,d), E=8,12 MeV; measured σ(Ed,θ). ^{13}C deduced levels, L, reduced width. Enriched ^{14}C target.
1971Cu01: ^{14}C(p,d), E=14.5 MeV; measured σ(Ed,θ) for $\theta_{c.m.}\approx20°$ to 120 °. Deduced S.
1975Ce04: ^{14}C(p,d), E=27 MeV; measured $\sigma(\theta)$ for $\theta\approx5°$ to 50°. Deduced S. DWBA analysis.
1990Ya01: ^{14}C(p,d), E=35,40.1 MeV; measured $\sigma(E_d,\theta)$ for θ=10° to 80°. Deduced S.

^{13}C Levels

E(level)[†]	J^π[†]	L	C^2S[†]	Comments
0	$1/2^-$[‡]	1	1.85	E(level),J^π: see (1963Le03,1966Gl01,1971Cu01,1975Ce04,1990Ya01). L: from (1963Le03). C^2S: from (1990Ya01); see also spectroscopic factors S=1.4 (1975Ce04). Different analyses are presented in (1971Cu01) who find S=1.27 (LZR (local zero range); cut-off radius R=0 fm), 1.58 (LZR; R=2 fm), 1.41 (NLFR (non-local finite range); R=0 fm). Reduced width θ^2=0.063 (1963Le03), 0.038 (1966Gl01).
3090	$1/2^+$[&]	0	0.03	E(level),J^π: see (1963Le03,1975Ce04,1990Ya01). L: from (1963Le03). C^2S: from (1990Ya01); see also spectroscopic factors S=0.02 (1975Ce04). Reduced width θ^2=0.017 *9* (1963Le03).
3680	$3/2^-$[#]	1	1.70	E(level),J^π: see (1963Le03,1971Cu01,1975Ce04,1990Ya01). L: from (1963Le03). C^2S: from (1990Ya01); see also spectroscopic factors S=1.8 (1975Ce04). Different analyses are presented in (1971Cu01) who find S=1.52 (LZR; R=0 fm), 1.81 (LZR; R=2 fm), 1.97 (NLFR; R=0 fm). Reduced width θ^2=0.051 *5* (1963Le03).
3850	$5/2^+$[@]	2	0.15	E(level),J^π: see (1963Le03,1975Ce04,1990Ya01). L: from (1963Le03). C^2S: from (1990Ya01); see also spectroscopic factors S=0.13 (1975Ce04). Reduced width θ^2=0.026 *+7−13* (1963Le03).
6860	$5/2^+$[@]		0.04	
7560	$5/2^-$[b]		0.08	
7690	$3/2^+$[a]		0.02	
8200	$3/2^+$[a]		0.05	
8860	$1/2^-$[‡]		0.02	
9500	$9/2^+$[c]		0.1	
9900	$3/2^-$[#]		0.04	
11000	$1/2^+$[&]		0.01	
11080	$1/2^-$[‡]		0.10	
11750	$3/2^-$[#]		0.13	
13280	$3/2^-$[#]		0.15	
15110	$3/2^-$[#]		1.18	T=3/2 T: (1990Ya01).

[†] From DWBA analysis in (1990Ya01).
[‡] $0p_{1/2}$ neutron pickup (1990Ya01).
[#] $0p_{3/2}$ neutron pickup (1990Ya01).
[@] $0d_{5/2}$ neutron pickup (1990Ya01).
[&] $1s_{1/2}$ neutron pickup (1990Ya01).
[a] $0d_{3/2}$ neutron pickup (1990Ya01).
[b] ($0f_{5/2}$) neutron pickup (1990Ya01).
[c] ($0g_{9/2}$) neutron pickup (1990Ya01).

^{14}C(d,t)

1966Gl01: ^{14}C(d,t), E=12 MeV; measured $\sigma(\theta)$. Deduced levels, J, Spectroscopic factors, reduced widths θ^2.
1976We01: ^{14}C(pol. d,t), E=14 MeV; measured $\sigma(E,\theta)$, polarization parameters A(Et,θ) for $\theta\approx20°$ to 105°. Deduced S. Enriched targets.

^{13}C Levels

Preferred S values from (1976We01) are listed; authors suggest ±50% uncertainties are a realistic estimation.

E(level)†	J$^{\pi}$†	S†	Comments
0	1/2$^-$	1.00	$\sigma(\theta=10°)=42.4$ (1966Gl01: no units).
3086	1/2$^+$	0.06	$\sigma(\theta=10°)=2.5$ (1966Gl01: no units).
3684	3/2$^-$	1.0	$\sigma(\theta=10°)=8.3$ (1966Gl01: no units).
3854	5/2$^+$	0.08	$\sigma(\theta=10°)=1.3$ (1966Gl01: no units).

† From DWBA analysis in (1976We01).

^{14}C(^{3}He,α)

1966Ba13: ^{14}C(^{3}He,α), E=39.8-44.8 MeV; measured $\sigma(\theta)$ for θ=15° to 80°.
1971Co14: ^{14}C(^{3}He,α), E=6, 8 and 10 MeV. Measured $\sigma(\theta)$ for $\theta\approx$30° to 160°. Deduced optical model parameters.
1971Ke08, 1972Ke08: ^{14}C(^{3}He,α), E=2-5.5 MeV. Measured $\sigma(\theta)$ for θ=20° to 160°. Analyzed resonances in $\alpha_{0,1,2,3}$.
1984RoZQ: ^{14}C(^{3}He,α), E=25.05 MeV Measured $\sigma(\theta)$ for θ=13° to 46° at the BIG KARL spectrometer in Julich. populated ^{13}C(15.102 MeV, T=3/2).
1994Bu01: ^{14}C(^{3}He,α), E=37.9 MeV. Measured $\sigma(\theta)$ for $\theta_{c.m.}\approx 8°-160°$. Analyzed rainbow scattering.

^{13}C Levels

E(level)[†]	J^{π}[†]	Comments
0	1/2^{-}	T=1/2 (1966Ba13) $p_{1/2}$ neutron picked up.
3080		E(level): reported in (1971Ke08).
3680	3/2^{-}	T=1/2 (1966Ba13) $p_{3/2}$ neutron picked up.
3854		E(level): From (1972Ke08).
15108 *14*	3/2^{-}	T=3/2 (1966Ba13) E(level),J^{π}: see also (1984RoZQ). $p_{3/2}$ neutron picked up.

[†] From (1966Ba13), except where noted. A J dependence is found in the (1966Ba13) analysis of (^{3}He,α) angular distributions.

^{14}N(γ,p)

1962Ko23: ^{14}N(γ,p), E=17-90 MeV; measured products, ^{13}C deduced σ(E), $\sigma(\theta)$.
1970Sh06: ^{14}N(γ,pn), E<15-30 MeV; measured σ(E;En). ^{13}C levels deduced neutron de-excitation.
1970Th01: N(γ,X), E<29 MeV; measured σ(E;Eγ); deduced integrated σ.
1971BeWW: ^{14}N(γ,p), E<26 MeV; measured σ(E;Ep,θ).
1972Ca34: ^{14}N(γ,p_0), E≤17-25 MeV MeV; measured σ(E;En); deduced integrated σ.
1972Ge11: ^{14}N(γ,p), E<15.5-29.5 MeV; measured σ(E;En); deduced integrated σ.
1974Ba37: ^{14}N(γ,p), E=18-26 MeV; measured σ(Eγ,Ep,θ).
1984PyZZ, 1985Ku01: See for discussion on ^{14}C(γ,n), E<36 MeV.
1993Ir01: ^{14}N(γ,p), E≤ 60 MeV; measured σ(Eγ,Ep,θ) for θ=60° to 120°. Compared results with direct-knockout calculations. Assumed p-shell proton knockout.

Theory:
1973Ki05: ^{14}N(γ,X); calculated σ(E).
1972Go23: ^{14}N(γ,p), E<30 MeV; calculated σ(E;Ep).
1975Ch44: ^{14}N(γ,p), analyzed σ.
1978Di12: ^{14}N(γ,p),(γ,np); calculated σ.

^{13}C Levels

E(level)†	J$^{\pi}$†	Comments
0	1/2$^-$	E(level),J$^{\pi}$: see (1974Ba37,1972Ca34,1993Ir01).
3090	1/2$^+$	E(level),J$^{\pi}$: see (1970Th01).
3680	3/2$^-$	E(level),J$^{\pi}$: see (1970Th01,1974Ba37,1993Ir01).
3850	5/2$^+$	E(level),J$^{\pi}$: see (1970Th01).
7550	5/2$^-$	E(level),J$^{\pi}$: see (1970Sh06,1972Ge11,1993Ir01). A large fraction of the ^{14}N(γ,p)^{13}C*→^{12}C+n neutron yield appears to be associated with sequential decay via ^{13}C*(7.75,8.86,11.80) (1970Sh06,1972Ge11).
8860	1/2$^-$	E(level),J$^{\pi}$: see (1972Ge11,1993Ir01).
11800	3/2$^-$	E(level),J$^{\pi}$: see (1970Sh06,1972Ge11,1993Ir01).

† From shell model analysis of proton knock-out reactions in (1970Th01,1993Ir01).

^{14}N(μ^-,νn)

1973Ki12: ^{14}N(μ^-,νn), E=slow; calculated population of nuclides and levels. See also (1990Ch13).
2002St01: ^{14}N(μ^-,νn), E=slow; measured E_γ, I_γ; deduced yields, level population.

^{13}C Levels

E(level)[†]	J^π[†]
0	$1/2^-$
3089	$1/2^+$
3685	$3/2^-$
3854	$5/2^+$

[†] From (2002St01) and Adopted Levels.

γ(^{13}C)

E_γ	I_γ[†]	E_i(level)	J^π_i	E_f	J^π_f
169		3854	$5/2^+$	3685	$3/2^-$
595		3685	$3/2^-$	3089	$1/2^+$
764	<0.20	3854	$5/2^+$	3089	$1/2^+$
3089	1.5 *3*	3089	$1/2^+$	0	$1/2^-$
3685	5.5 *2*	3685	$3/2^-$	0	$1/2^-$
3854	1.9 *2*	3854	$5/2^+$	0	$1/2^-$

[†] %I_γ per captured μ^-.

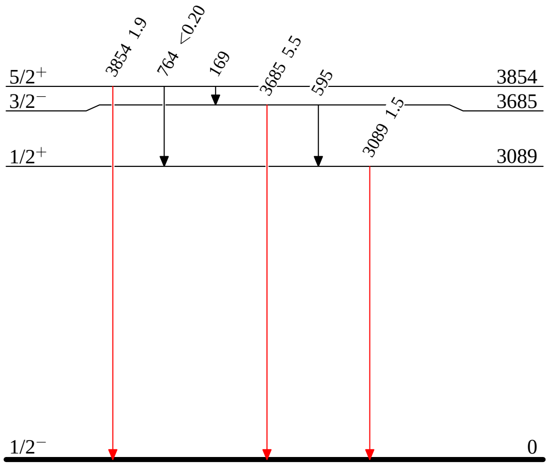
^{14}N(μ^-,νn)

Legend

→ $I_\gamma < 2\% \times I_\gamma^{max}$
→ $I_\gamma < 10\% \times I_\gamma^{max}$
→ $I_\gamma > 10\% \times I_\gamma^{max}$

Level Scheme

Intensities: Relative I_γ



$^{13}_{6}C_{7}$

^{14}N(n,d),(n,dγ)

1952Li24: ^{14}N(n,x), E=14.1 MeV; analyzed gas cloud chamber data.
1957Ca07: ^{14}N(n,$d_{0,2}$), E=14 MeV; measure the absolute differential cross sections at seven laboratory angles θ_{lab}=0°−65°.
1963Za01: ^{14}N(n,d), E=14.1 MeV; measured angular distributions of deuterons corresponding to ^{13}C*(0,3.09,3.68 MeV) states; θ=0° to 150°.
1967An08: ^{14}N(n,d_0), E=14.4 MeV; measured angular distributions for θ=20° to 100°.
1967Fe06: ^{14}N(n,$d_{0,2}$), E=14.1,14.8 MeV; measured angular distributions for θ=0° to 100°.
1968Mi02: ^{14}N(n,d_0), E= 4.4 MeV; measured σ(Ed,θ); deduced S. Natural targets.
1971Ny03: ^{14}N(n,xγ), E=15 MeV; measured E_γ, $\sigma(E_\gamma)$; deduced levels. Ge(Li) detector.
1979SuZR: ^{14}N(n,d), E=27.4,39.7,60.7 MeV; measured σ(E,θ); deduced reaction mechanism. Hauser-Feshbach calculation.
1981NeZY: ^{14}N(n,d), E=60 MeV; measured $\sigma(\theta)$; deduced reaction mechanism. DWBA analysis, Goldhaber-Teller form factor.

Theory:
1971Mi12: ^{14}N(n,d), analyzed $\sigma(\theta)$; deduced S.
1971Mi18: ^{14}N(n,d), calculated $\sigma(\theta)$.

^{13}C Levels

E(level)	$J^{\pi\dagger}$	$L^{\dagger}$	$S^{\dagger}$	Comments
0	1/2$^-$	1	0.92 *9*	Q_0=−5320 keV (1967Fe06,1968Mi02). E(level): reported in (1957Ca07,1963Za01,1967An08,1967Fe06,1968Mi02). J^π: (1967Fe06); see also (1963Za01: (1/2$^-$)). L: see (1963Za01,1967Fe06,1968Mi02). S: (1967Fe06). See also S=1.41 (1963Za01), 2 (1968Mi02). θ^2=0.065 (1963Za01), 0.042 *4* (1967Fe06). C^2S=0.46 *4* (1967Fe06).
3090				E(level): not observed.
3686	3/2$^-$	1	3.0	Q=−9000 keV (1967Fe06). E(level): see (1957Ca07,1963Za01,1967Fe06,1971Ny03). J^π: (1967Fe06); see also (1963Za01: (3/2$^-$)). L: see (1963Za01,1967Fe06). S: (1963Za01). θ^2=0.12 (1963Za01).
3853				E(level): (1971Ny03).

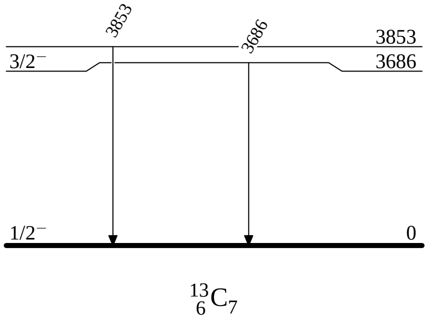
† From Butler theory and DWBA analyses in (1963Za01,1967Fe06).

γ(^{13}C)

E_γ	E_i(level)	J^π_i	E_f	J^π_f	Comments
3686 *3*	3686	3/2$^-$	0	1/2$^-$	E_γ: (1971Ny03).
3853 *3*	3853		0	1/2$^-$	E_γ: (1971Ny03).

^{14}N(n,d),(n,dγ)

Level Scheme



^{14}N(p,2p)

1958Ty49: ^{14}N(p,2p), E=185 MeV; measured absolute σ for the reaction versus binding energy of the removed proton.
1961Cl09: ^{14}N(p,2p), E=150 MeV; measured σ_{total}.
1965De21: ^{14}N(p,2p), E=19 MeV; measured σ(Ep,θ(1),θ(2)), pp-coin.
1966Ty01: ^{14}N(p,2p), E=460 MeV; measured σ(Ep;θ), Q.
1970We09: ^{14}N(p,2p), E=46 MeV; measured σ(Ep,θ).
1970WeZW: ^{14}N(p,2p), E=46 MeV; measured σ(Ep,θ(p)).
1986VdZY: ^{14}N(p,2p), E=50 MeV; measured σ. ^{13}C deduced resonances. Nuclear emulsion technique.

Theory:
1965Ba21: ^{14}N(p,2p), calculated the neutron width of the ^{13}C*(J$^{\pi}$=5/2$^-$) level.
1972Ch21: ^{14}N(p,2p), E=46 MeV; calculated $\sigma(\theta)$. Distorted-wave t-matrix approximation.
1974OlZR: ^{14}N(p,2p), E=46 MeV; calculated $\sigma(\theta)$.
1979Ki10: ^{14}N(p,2p), calculated σ. Particle-hole excitation model, analyzed high-lying hole states.
1979Ma20: ^{14}N(pol. p,2p), calculated $\sigma(\theta)$ for quasifree scattering; deduced structure of initial, final nuclear states.
1981Fe04: ^{14}N(pol. p, 2p), E=320 MeV; calculated effective polarization. Quasifree scattering, shell, cluster models.
1984Vd02: ^{14}N(p,2p), E=50 MeV; calculated σ(Ep1,Ep2), deduced residual level production σ. Quasielastic, two-step process model.
1986Os08: ^{14}N(p,2p), E=46,47,50 MeV; calculated σ(E1,θ1,θ2). T-matrix approximation.
1990Go34: ^{14}N(p,2p), E=46 MeV; analyzed σ(θ1,θ2); deduced noncoplanarity role. T-matrix approach.
1990Lo18: ^{14}N(p,2p), E=46 MeV; calculated σ(θ1,θ2,E1).

^{13}C Levels

E(level)	J$^{\pi}$†	Comments
0	1/2$^-$	E(level): corresponding to ejection of $p_{1/2}$ proton (1958Ty49,1966Ty01) with binding energy E_b≈7 MeV (1958Ty49), 7.5 MeV *5* (1966Ty01); also reported in (1965De21,1970We09,1986VdZY).
3100		E(level): see (1961Cl09,1986VdZY).
3680	3/2$^-$	E(level): see (1961Cl09,1966Ty01,1970We09,1986VdZY). E_b=11.5 MeV (1966Ty01).
7500	5/2$^-$	E(level): see (1970We09).
7800		E(level): corresponding to ejection of $p_{3/2}$ proton (1958Ty49,1966Ty01) with E_b≈15 MeV (1958Ty49: E_x≈8 MeV), 15.3 MeV *5* (1966Ty01).
11900	3/2$^-$	E(level): see (1970We09).
12300		E(level): corresponding to ejection of $p_{3/2}$ proton with E_b=19.8 MeV *6* (1966Ty01).

† From Distorted Wave T-matrix Approximation analysis of the quasi-elastic scattering reaction mechanism in (1970We09).

^{14}N(d,^{3}He)

1968Ga13: ^{14}N(d,^{3}He), E=28 MeV; measured $\sigma(\theta)$ to g.s; DWBA analysis for comparison of (d,^{3}He),(d,t) cross sections.
1968Hi01: ^{14}N(d,^{3}He), E=52 MeV; measured $\sigma(E(^{3}He),\theta)$, ^{13}C deduced levels, J, π, S. Natural targets.
1970PiZV: ^{14}N(d,^{3}He), E=20.13 MeV; measured $\sigma(\theta)$; deduced optical model parameters.
1974Lu06: ^{14}N(pol. d,^{3}He), E=15 MeV; measured $\sigma(E(^{3}He),\theta)$, A(θ). ^{13}C g.s. deduced S, J-dependence, J-admixtures. DWBA analysis. Natural, enriched targets.
1981Ma14: ^{14}N(pol. d,^{3}He), E=52 MeV; measured $iT_{11}(E(^{3}He),\theta)$ for ^{13}C*(0,7.55 MeV). Enriched targets. DWBA, Nilsson model analyses.

^{13}C Levels

E(level)	J$^{\pi}$[†]	C^{2}S	Comments
0[‡]	1/2^{-}	0.63	L=1 (1974Lu06).
3.09×10^{3}[#]			
3.68×10^{3}	3/2^{-}	0.16	E(level): The 3.85 MeV; J$^{\pi}$=5/2^{+} state is not resolved from the 3.68 MeV state, but it is reasonable to assume only a small contribution to the 3.7 MeV group with regard to the weak excitation of the other positive-parity states (1968Hi01).
6.87×10^{3}[#]		1.55	
7.55×10^{3}	5/2^{-}	0.63	
8.85×10^{3}	1/2^{-}		The sum of the cross section of the ^{13}C*(8.85+9.51) states is identical with the angular distribution of the unresolved states that appear at ^{13}N*(9.2).
9.51×10^{3}	(3/2^{-})	0.13	J$^{\pi}$: 9/2^{+} is accepted in the Adopted Levels. J$^{\pi}$: In (1968Hi01), the known ^{13}N*(8.9+9.4 MeV) states are unresolved, but their angular distributions and cross section sum are compared with the resolved ^{13}C*(8.9+9.5 MeV) states. The authors first indicate the ^{13}C*(9.5 MeV) state does not have a “pick-up pattern” as would be expected, and later they suggest a complex configuration that can explain the spectroscopic factor. The discussion shows reservations, and their conclusions are based on comparison with an unresolved group of states in ^{13}N.
11.90×10^{3} *15*	3/2^{-}	0.95	

[†] From comparison of (d,^{3}He) and (d,t) mirror states in (1968Hi01) ΔE≈100 keV. C^{2}S is from Figure 7 of (1968Hi01).
[‡] See also (1974Lu06). The spectroscopic factors, C^{2}S, extracted for the reaction ^{14}N(d,^{3}He)^{13}C$_{g.s.}$ agree within 5% to those for the reaction ^{14}N(d,t)^{13}N$_{g.s.}$.
[#] Weakly populated.

^{14}N(t,α) **1962Si04**

1962Si04: ^{14}N(t,α), E=2.6 MeV; α spectra were measured at θ_{lab}=30° and 90° with a double-focusing magnetic spectrometer. ^{13}C levels up to 12 MeV were analyzed.

1964Sc09: ^{14}N(t,α), E=1-2 MeV; measured differential cross sections for ^{13}C*(0,3.085,3.680+3.850,6.868).

^{13}C Levels

E(level)	Γ[&]	Comments
0		
3085[#]		E(level): reported (1962Si04,1964Sc09).
3680[#@]		
3850[#@]		
6868[#]	<30 keV	
7498[#@]		
7553[#@]		
7680[#@]		
8860[†] *20*	145 keV *20*	
9509[‡]	<30 keV	
9897[‡]	<30 keV	
10736[†] *20*	<30 keV	
10809[†] *20*	<30 keV	
11000[†] *20*	<30 keV	
11078[†] *20*	<30 keV	
11721[†] *30*	125 keV *20*	
12131[†] *30*	125 keV *30*	

[†] From (1962Si04).

[‡] Used as energy references for other E_x in (1962Si04).

[#] Reported in (1962Si04,1964Sc09).

[@] Unresolved.

[&] From (1962Si04). Level widths have had an instrumental width of 65 keV unfolded from them and are estimated to be <30 keV where the instrumental width was dominant (1962Si04).

^{15}N(p,^{3}He) **1968Fl03**

1964Ce03,1966Ce02: ^{15}N(p,^{3}He), E=43.7 MeV; experiments were performed at the Berkeley 88-inch cyclotron. Emitted ^{3}He particles from a pure ^{15}N gas target were simultaneously detected by a (dE/dx)-E counter telescope which fed a particle identifier. The typical resolution (FWHM) is 150 keV.

1968Fl03: A 43.7-Mev proton beam has been used to induce (p,t) and (p,^{3}He) reactions on a ^{15}N target. Transitions to mirror final states of ^{13}N and ^{13}C have been investigated over 15 MeV of excitation and several new spin and parity assignments have been made. The DWBA predictions of angular distributions for these ^{15}N(p,t)^{13}N and ^{15}N(p,^{3}He)^{13}C reactions were generally found to reproduce experiment well. See also (1968Fl02).

1970Ha23: ^{15}N(pol. p,^{3}He), E=44 MeV; measured $\sigma(\theta)$, analyzing power(θ). ^{13}C transitions deduced L.

1974Ma12,1973MaZH: ^{15}N(p,^{3}He), E=43.8 MeV; measured σ(E(^{3}He),θ), A(θ). Analyzed ^{13}C*(0,3.68,7.55,15.1), L.

1974Pi05: ^{15}N(p,^{3}He), E=20-45 MeV; measured σ(E(^{3}He),θ), deduced optical model parameters. ^{13}C levels deduced L, J, π.

1975Mi01: ^{15}N(p,^{3}He), E=26.8-43.1 MeV; measured σ(E(^{3}He),θ).

1982RaZU: ^{15}N(p,^{3}He), E=45 MeV; measured $\sigma(\theta)$.

^{13}C Levels

E(level)[†]	J$^{\pi}$[†]	L[†#]	Comments
0	1/2^{-}	0,2	E(level): Also reported in (A)=(1964Ce03, 1966Ce02, 1974Ma12, 1974Pi05, 1975Mi01, 1982RaZU).
3080 *20*	1/2^{+}		
3680[‡] *10*	3/2^{-}	0,2	E(level): Also reported in (A, 1970Ha23). A doublet (1974Pi05); 3.68 MeV gives a dominant contribution, see (1968Fl03).
6870[‡] *15*	5/2^{+}		
7550 *20*	5/2^{-}	2	E(level): Also reported in (A, 1970Ha23).
8860[@] *60*	1/2^{-}	0,2	
9520[@] *30*	(3/2^{-})	2	J$^{\pi}$: 9/2^{+} in Adopted Levels. Note: the authors are somewhat “puzzled” by the absence of the ^{13}N mirror in the (p,t) reaction and by this state’s appreciable cross section.
10750	7/2^{-}		E(level),J$^{\pi}$: from (1982RaZU).
11090 *50*	(1/2^{-})	0,2	
11800[@] *30*	(3/2^{-})	0,2	
12400[@] *50*	7/2^{-}	2	
15110[‡] *20*	3/2^{-}	2	T=3/2 (1968Fl03) E(level): see also E$_{x}$=15103 keV *45* (1964Ce05,1966Ce02). E(level): Also reported in (1974Ma12,1982RaZU).

[†] From DWBA analysis of (p,^{3}He) and (p,t) mirror partners and comparison of related differential cross sections (1968Fl03).

[‡] Considered known E$_{x}$ in the energy analysis (1968Fl03).

[#] From (1968Fl03,1974Ma12).

[@] Also reported in (1982RaZU).

^{15}N(d,α)

1951Ma08: ^{15}N(d,α), E=1.4 Mev; measured Q values; deduced ^{13}C excited states.
1957Wa01: ^{15}N(d,α), E=14.8 MeV; α-particle groups corresponding to level energies in ^{13}C up to 9.9 MeV excitation were observed at θ=12.6°, 18°, 30°. Reported dσ/dΩ(18°) for all states.
1958Fi27,1959Fi30: ^{15}N(d,α_0), E=21 MeV; measured $\sigma(\theta)$ for $\theta_{c.m.}$=−20° to 140°. The angular distribution of the ground-state α particles shows a relative maximum at $\theta_{c.m.}$=70°.
1961Ja23: ^{15}N(d,α), Deduced Q_0= 7675 keV *9* and E_x=3100 keV *20* and 3695 keV *10* for the 1st and the 2nd excited states, respectively.
1961Lo10: ^{15}N(d,α), reaction observed at θ_{lab}=90°, measured Q_0 value of 7675 keV *9*. See also (1961Lo02).
1965Ma59: ^{15}N(d,$\alpha_{0,1}$), E=1.2-2.5 MeV; measured σ(q) for $\theta_{lab.}$=30° to 150°.
1966St16: ^{15}N(d,α_0), E=1.0-1.2 MeV; measured the angular distributions of the α particles.
1968Pr04: ^{15}N(d,$\alpha_{0,1}$), E=20.9 MeV; measured the angular distributions of the α particles for $\theta_{c.m.}$=20° to 110°.
1974WeZT: ^{15}N(d,α), measured σ(Eα). ^{13}C deduced levels.
1976Ca28: ^{15}N(d,$\alpha_{0,1}$), E<3 MeV; measured σ(E,Eα,θ) for θ=71° to 146°.
1986Sa41: ^{15}N(d,α_0), E=804 keV-1.2 MeV; measured products, ^{13}C deduced $\sigma(\theta$=150°).
1996Vi12: ^{15}N(d,α_0), E=0.4-2 MeV; measured σ(E,θ) for $\theta_{c.m.}$=85° to 160°. Comparison with earlier results.

^{13}C Levels

E(level)[†]	L	Comments
0	2	E(level): see (1951Ma08, 1957Wa01, 1958Fi27, 1959Fi30, 1961Ja23, 1961Lo10, 1966St16, 1968Pr04, 1976Ca28, 1986Sa41, 1996Vi12). Q_0=7681 keV *6* (1951Ma08), 7675 keV *9* (1961Ja23,1961Lo10). L: see (1968Pr04).
3084 *5*		E(level): weighted average of 3083 keV *5* (1951Ma08) and 3100 keV *20* (1961Ja23); see also (1957Wa01,1968Pr04,1976Ca28). Q_1=4598 keV *4* (1951Ma08).
3681 *7*		E(level): weighted average of 3677 keV *5* (1951Ma08) and 3695 keV *10* (1961Ja23); see also (1957Wa01,1976Ca28). Q_2=4004 keV *3* (1951Ma08).
3860		E(level): see (1957Wa01,1976Ca28).
6870		
7470[‡]		
7530[‡]		
7640[‡]		
8800 *40*		
9500		
9900		

[†] Values listed in (1957Wa01) except where noted.
[‡] Unresolved triplet.

^{16}O(n,α),(n,$\alpha\gamma$)

1952Li24: ^{16}O(n,α), E=14.1 MeV; measured products, ^{4}He; deduced σ, σ(E). ^{13}C*(3.0,3.7 MeV) states are found.
1961Ci01: ^{16}O(n,α_0), E=14.4 MeV; measured angular distributions.
1963Da12: ^{16}O(n,α_0), E=5.0-8.8 MeV; ^{16}O(n,α_1), E=7.6-8.7 MeV; ^{16}O(n,$\alpha_{2,3}$), E=8.1-8.7 MeV; measured σ(E).
1963Se08: ^{16}O(n,α), E=14 MeV; Measured α-particle angular distributions σ(E,θ).
1965Ch13: ^{16}O(n,α), E=14.5 MeV; measured σ(E$_\alpha$,θ). This reaction leading to about 4 MeV excitation of ^{13}C has been studied.
1966Mc14: ^{16}O(n,α_0), E=14.1 MeV; measured σ(E$_\alpha$,θ), the absolute differential cross sections for the transitions to the ^{13}C$_{\mathrm{g.s.}}$. Natural targets.
1967Hs04: ^{16}O(n,α), E=14.1 MeV; measured σ(E$_\alpha$,θ). The angular distributions of the α-particle groups leading to ^{13}C*(0,3.08 and 3.68+3.85 MeV) are observed. Natural target.
1968Le11: ^{16}O(n,α), E=14.9 MeV; measured σ(E$_\alpha$,θ). The angular distributions have been obtained from 20° to 160° for the transitions ^{16}O(n,α_0)^{13}C and are compared to the predictions of direct interaction mechanisms.Natural targets.
1968Ma10: ^{16}O(n,α), E=14.1 MeV; measured σ(E$_\alpha$,θ). Absolute differential cross sections were measured for the (n,α) transitions to the ground state of ^{13}C and to an unresolved triplet of known levels at E$_x$=3.09, 3.68 and 3.86 MeV. Natural target.
1968Si06: The differential cross section of ^{16}O(n,α_0) and ^{16}O(n,α_{1+2+3}) has been measured at 28 E$_n$ energies between 14.8 and 18.8 MeV with 60 keV energy spread at θ=0°−156°.
1969AjZZ,1970Aj03: ^{16}O(n,α), E=14 MeV; measured σ(E$_\alpha$,θ). Angular distributions of the unresolved group of α-particles corresponding to three levels of ^{13}C at E$_x$=3.09, 3.68 and 3.86 MeV were measured.
1970Br17,1971Br33,1972Br50: ^{16}O(n,α), E=13.9 MeV; measured σ(E$_n$;θ=0°).
1971Ny03: ^{16}O(n,$\alpha\gamma$), E=15 MeV; measured E$_\gamma$, σ(E$_\gamma$). ^{13}C, deduced levels from E$_\gamma$=3.685 MeV *3* and 3.855 MeV *3*.
1972Ki12: ^{16}O(n,α), E=4.9 MeV; measured σ(θ).
1973Bo26: ^{16}O(n,α), E=14.1 MeV; measured σ(E$_\alpha$,θ). The angular distributions of the α_0 and α_{1+2+3} groups for this reactions have been measured.
1978No04: ^{16}O(n,$\alpha\gamma$), E=7-10.5 MeV; measured σ(E,E$_\gamma$). The production of 3.09 and 3.68+3.85−MeV gamma rays has been studied.
2008GiZY: ^{16}O(n,α_0), E=3.95-9 MeV; measured E$_\alpha$, I$_\alpha$; deduced σ(E*).
2001Ne09: ^{16}O(n,$\alpha\gamma$), E=4-200 MeV; measured E$_\gamma$, I$_\gamma$, photon production σ(E), σ(θ). Comparison with model calculations, previous measurements.
2011KhZW: ^{16}O(n,α_0), E=5.2-6.2 MeV; deduced σ.

Theory:
1989Br05: ^{16}O(n,α), E=15-60 MeV; calculated σ(θ1,E1).
1995Ch84: ^{16}O(n,α), E=6.2-10.5 MeV; analyzed σ, σ(θ).
2008VaZT: ^{16}O(n,α), E≈3-10 MeV; calculated σ; evaluated σ.
2020FlZY: ^{16}O(n,α), E<20 MeV; analyzed available data; deduced recommended σ.
2021Pr01, 2022Pr01: Deduced ^{16}O(n,α_0) by analyzing ^{13}C(α,n) for E$_\alpha$=2.0-6.2 MeV.

^{13}C Levels

E(level)	J^{π}[†]	$T_{1/2}$ or Γ[‡]	Comments
0	1/2$^-$		E(level): reported in (1961Ci01, 1966Mc14, 1967Hs04, 1968Le11, 1968Ma10, 1968Si06, 1971Br33, 1973Bo26, 2008GiZY, 2011KhZW, 2012Kh05).
3090[#]	1/2$^+$	1.07 fs	E(level): reported in (1952Li24, 1967Hs04, 1971Br33).
3686[#@] *3*	3/2$^-$	1.10 fs	E(level): derived from γ-ray measurements (1971Ny03); also reported in (1952Li24).
3856[#@] *3*	5/2$^+$	8.60 ps	E(level): derived from γ-ray measurements (1971Ny03).
8860	1/2$^-$	150 keV	E(level): reported in (2001Ne09).

[†] From Adopted Levels.
[‡] Listed in (2001Ne09).
[#] Also reported in (1968Ma10, 1968Si06, 1970Aj03, 1973Bo26: unresolved triplet).
[@] Also reported in (1967Hs04, 1971Br33: unresolved doublet).

^{16}O(n,α),(n,$\alpha\gamma$) (continued)

$\gamma(^{13}C)$

E_γ	I_γ[†]	E_i(level)	J_i^π	E_f	J_f^π	Comments
169	58.4 *12*	3856	$5/2^+$	3686	$3/2^-$	E_γ: measured in (2001Ne09). I_γ: from (2001Ne09).
764	1.4 *4*	3856	$5/2^+$	3090	$1/2^+$	E_γ: measured in (2001Ne09). I_γ: from (2001Ne09).
3090		3090	$1/2^+$	0	$1/2^-$	E_γ: measured in (2001Ne09); observed in (1978No04).
3685 *3*		3686	$3/2^-$	0	$1/2^-$	E_γ: measured in (1971Ny03); see also (2001Ne09).
3855 *3*	100.0 *15*	3856	$5/2^+$	0	$1/2^-$	E_γ: measured in (1971Ny03); see also (2001Ne09). I_γ: from (2001Ne09).
8857		8860	$1/2^-$	0	$1/2^-$	E_γ: measured in (2001Ne09).

[†] Relative intensities.

^{16}O(n,α),(n,$\alpha\gamma$)

Level Scheme

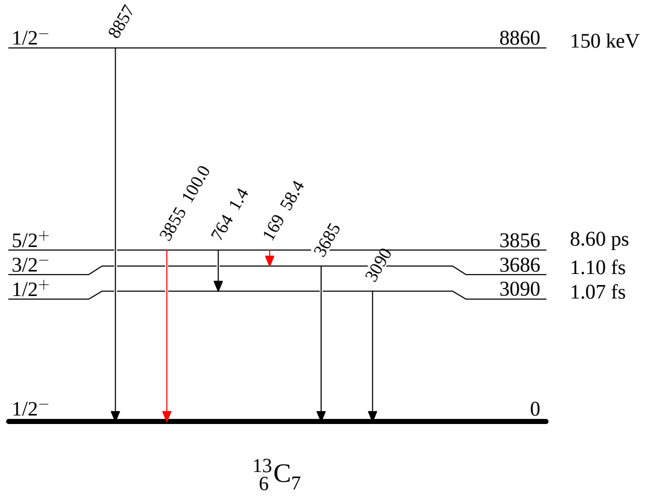
Intensities: Relative I_γ

Legend

→ $I_\gamma < 2\% \times I_\gamma^{max}$

→ $I_\gamma < 10\% \times I_\gamma^{max}$

→ $I_\gamma > 10\% \times I_\gamma^{max}$



^{16}O(p,p^{3}He)

1973Be36: ^{16}O(p,p^{3}He), E=29, 39 and 62 MeV. Analyzed particle knockout systematics.

1975Gr40, 1977Gr04: ^{16}O(p,p^{3}He), E=75 MeV; also ^{12}C(p,p^{3}He) measured p^{3}He-coin; compaired reaction on ^{12} and ^{16}O, deduced S. Indicate the rection mechanism is more complex than quasifree knockout.

^{13}C Levels

E(level)	J^{π}†	L†	S†
0	$1/2^-$	1	1.57
3090	$1/2^+$		
3680	$3/2^-$	1	2.29
3850	$5/2^+$		
7600‡			

† From DWIA analysis in (1975Gr40,1977Gr04). S is normalized to the predicted spectroscopic factor of the $^{12}C\rightarrow^{9}B_{g.s.}$ transition.

‡ Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

^{16}**O(**α**,**α^{3}**He)**

1982Sa24: $^{16}O(\alpha,\alpha^{3}He)$, E=139.2 MeV; measured $\sigma(E_{\alpha},E_{3He},\theta_{\alpha},\theta_{3He})$. Deduced L, S. DWIA analysis. see also (1982SaZU).

^{13}C Levels

E(level)	J^{π}†	L†	S†
0	$1/2^{-}$	1	55
3680	$3/2^{-}$		

† from DWIA analysis in (1982Sa24).

^{20}Ne(n,2α) **1971Ka18**

1966Pe08: ^{20}Ne(n,2α), E=14.2 MeV; gas-chamber study; analyzed Q.
1971Ka18: ^{20}Ne(n,2α), E=14.3 MeV; ionization chamber active target; measured Q.

^{13}C Levels

E(level)	Cross Section (mb)	Comments
0	41.8 *81*	Q_0=−7.00 MeV *2* (1971Ka18); see also Q=−6.94 MeV (1966Pe08). Cross Section (mb): (1971Ka18: relative to ^{12}C(n,α_0)=76 mb *11*).

^{93}Nb(^{12}C,^{13}C) 2020Na24

2020Na24: ^{93}Nb(^{12}C,^{13}C), E=65 MeV; measured kinetic-energy spectra of projectile-like fragments (PLFs) and target-like fragments (TLFs), $\sigma(\theta)$ of PLF and TLF fragments for $\theta\approx20°$ to 80°; deduced spectroscopic factors and other structure data.

^{13}C Levels

E(level)†	J$^{\pi}$†	S†
0	1/2^{-}	0.274
3680	3/2^{-}	1.750

† From the FRESCO coupled reaction-channels analysis of (2020Na24).

^{159}Tb(^{19}F,^{13}C) 1986So10

1986So10: ^{159}Tb(^{19}F,^{13}C), E=181 MeV at the ORNL/HHIRF. Measured ^{13}C+γ-coin for γ rays detected in the ORNL spin spectrometer and for ^{13}C detected in Si ΔE-E charged particle telescopes at θ=20° and 30°. Deduced particle-bound ejectile yields; excited state population. Discussed reaction temperature.

^{13}C Levels

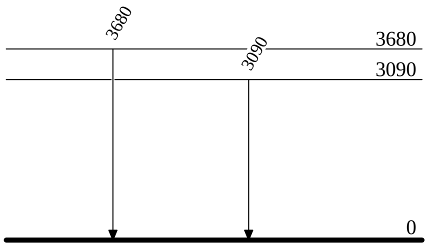
E(level)
0
3090
3680

γ(^{13}C)

E_γ	E_i(level)	E_f
3090	3090	0
3680	3680	0

^{159}Tb(^{19}F,^{13}C) 1986So10

Level Scheme



$^{13}_{6}C_{7}$

^{165}Ho(^{14}N,n^{12}C)

1987Ki05: ^{165}Ho(^{14}N,n^{12}C), E=490 MeV at the MSU/NSCL. Measured ^{12}C+n relative velocity spectra for colinear events along θ=10° and 30°. Neutrons were measured using NE 213 scintillators while Si ΔE-E telescopes measured the ^{12}C ions. Deduced levels, Γ.

^{13}C Levels

E(level)	Γ	Comments
6864	6 keV	E(level),Γ: from (1987Ki05). ^{13}C*(6864)→n+$^{12}C_{g.s.}$ with E_{decay}=1.918 MeV.
9500	5 keV	E(level),Γ: from (1987Ki05). ^{13}C*(9500)→n+^{12}C*(4439) with E_{decay}=0.114 MeV.

Adopted Levels, Gammas

Q(β^-)=−17770 *10*; S(n)=20063.9 *10*; S(p)=1943.49 *27*; Q(α)=−9495.9 *9* 2021Wa16

The ^{13}N nucleus was first identified by its characteristic β-decay lifetime property observed in the α bombardment of a boron sample (I.Curie,M.F.Joliot,Compt.Rend.Acad.Sci.198(1934)254, 2012Th01).

Nuclear moments:
Measurements:
1961Po09: μ=0.321 *3*.
1964Be24: μ=(−) 0.32212 nm *35*, sign is assumed.
Tabulations: 1989Ra17, 2019StZV: μ=0.3219 *4*.
Calculations: 1966El08, 1968Pe16, 1969Sc33, 1969Sc34, 1974Ha27, 1976Br26, 1978Le03, 1988Va03, 1990Iw02, 1991Bo02, 1999Ki27, 1999Ga57, 2003Su04, 2016Me17.

Theory:
Shell model: 1965Co25, 1971Ja13, 1973Sa30, 1976Br26, 1996Du21, 2000Ko23, 2013Ho14.
Other model analyses: 1963Ba43, 1963Fa03, 1973Le06,1974Va24, 1975Me24, 1983Sh38, 1993Po11, 1996Ki24, 1997Po12, 2000Zh42, 2002Zh37, 2003Ch33, 2005Du03, 2008Ch34, 2008Sh16, 2013Ci04, 2013Ma60, 2017De19, 2022Sa37.

Mirrors and analog states: 1963Se19, 1966Ce02, 1972Gu05, 1973Sa25, 1974Ch46, 1993Zh17, 1996Ki27, 2005Ch02, 2005Ti07, 2005Ti14, 2006Sh10, 2013Fo22, 2015Fr05, 2018Fo04, 2019Mu05, 2022Va06, 2022Zo01, 2023Se01.

Other related studies: 2003Ar33, 2008Pe13, 2008Se10, 2010Ti04, 2011Ti09, 2015Mo10, 2015To02, 2018Ge07.

Unplaced experimental results:
1962Wa31: ^{12}C(p,d) E=18 to 19.8 MeV. No resonant structures are observed.
1975Na15, 1976Na09: ^{16}O(^{14}N,^{17}O) E=155 MeV.
1976Mo03: ^{16}O(^{14}N,^{17}O) E=79 MeV.
1998Di14: The ${}^{13}N_{g.s.}$ structure was studied via the ^{11}B(^{13}N,^{12}C)^{12}C transfer reaction at E(^{13}N)=29.5 and 45 MeV.
2001Na02: Si(p,^{13}N) calculated spallation yields.
2004Be16: calculated ^{13}N(pol. p,p) observables at E_p=500, 547, 800 MeV.
2005Ba40: measured ^{13}N production in p+^{16}O spallation at 3.2 GeV.
2007Na31: measured ^{13}N production in p+^{136}Xe spallation at 1 GeV.
2007No13: ^{9}Be(^{40}Ar, ^{13}N) E=100 MeV/nucleon. Measured fragmentation production σ.
2010Mi08: ^{181}Ta(^{18}O,^{13}N) E=35 MeV/nucleon. Calculated fragment production yields at forward angles. Compared with measurements of (2002Ar07).
2002Ar07, 2002Ar09:^{9}Be,^{181}Ta(^{18}O,^{13}N) E=35 MeV/nucleon. Measured fragment production yields at forward angles.
2012Fl02: Studied 1 proton removal from ^{14}O at ≈53 MeV/nucleon.
2019Ch50: Excited states in ^{14}O are observed to 1p decay to ^{13}N+p and to decay sequentially via ^{13}N(2.36, 3.50, 3.55).
2020Na24: Measured fragment yields in ^{93}Nb(^{12}C,X),(^{13}C,X) at E=65 MeV.
2022Bo01: Measured ^{13}N production yields from ^{12}C(X,^{13}N): X=^{14,15,20}O, ^{14}N at $E_{beam}\approx$450 MeV/nucleon.

Adopted Levels, Gammas (continued)

^{13}N Levels

Cross Reference (XREF) Flags

A	^{13}O ε decay	U	^{12}C(d,n)	AN	^{13}C(^{14}N,^{14}C)
B	^{1}H(^{13}N,p)	V	^{12}C(^{3}He,d)	AO	^{14}N(γ,n)
C	^{1}H(^{14}O,^{13}N)	W	^{12}C(α,t)	AP	^{14}N(π^{+},π^{+}n),(π^{+},p)
D	^{2}H(^{14}O,^{3}He)	X	^{12}C(^{7}Li,^{6}He)	AQ	^{14}N(n,2n)
E	^{9}Be(^{10}C,^{13}N)	Y	^{12}C(^{10}B,^{9}Be)	AR	^{14}N(p,d)
F	^{9}Be(^{13}N,X)	Z	^{12}C(^{11}B,^{10}Be)	AS	^{14}N(d,t)
G	^{10}B(^{3}He,n),(^{3}He,X):res	Others:		AT	^{14}N(^{3}He,α)
H	^{10}B(^{3}He,p)	AA	^{12}C(^{12}C,^{11}B)	AU	^{14}N(^{6}Li,^{7}Li)
I	^{10}B(^{3}He,d)	AB	^{12}C(^{13}C,^{12}B)	AV	^{14}N(^{10}B,^{11}B)
J	^{10}B(^{3}He,^{3}He)	AC	^{12}C(^{13}N,^{13}N),^{13}C(^{13}N,^{13}N)	AW	^{14}N(^{14}N,^{13}N)
K	^{10}B(^{3}He,α)	AD	^{12}C(^{14}N,^{13}C)	AX	^{15}N(p,t)
L	^{10}B(α,n)	AE	^{12}C(^{16}O,^{15}N)	AY	^{16}O(n,^{13}N)
M	^{10}B(^{6}Li,t)	AF	^{13}C(γ,π^{-})	AZ	^{16}O(p,pt)
N	^{10}B(^{9}Be,^{6}He)	AG	^{13}C(ν,μ^{-}),(ν,e)	BA	^{16}O(p,α)
O	^{11}B(^{3}He,n),^{11}B(^{3}He,nγ)	AH	^{13}C(π^{+},π^{0})	BB	^{16}O(^{3}He,^{6}Li)
P	^{12}C(p,γ)	AI	^{13}C(π^{+},γ)	BC	^{17}Ne $\beta^{+}\alpha$ decay
Q	^{12}C(p,π^{0})	AJ	^{13}C(p,n)	BD	^{208}Pb(^{13}N,^{13}N): coulex
R	^{12}C(p,n)	AK	^{13}C(^{3}He,t)	BE	^{232}Th(^{22}Ne,^{13}N),^{154}Sm(^{16}O,^{13}N)
S	^{12}C(p,p)	AL	^{13}C(^{6}Li,^{6}He)		
T	^{12}C(p,α)	AM	^{13}C(^{13}N,^{13}C)		

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
0.0	1/2^{-}	9.9584 min *36*	ABCD F LMNOPQ UVWXYZ	XREF: Others: AA, AB, AC, AD, AE, AF, AG, AH, AI, AJ, AK, AL, AM, AN, AO, AP, AQ, AR, AS, AT, AU, AV, AW, AX, AY, AZ, BA, BB, BC, BD, BE %ε+%β^{+}=100 T=1/2; μ=0.3219 *4* (2019StZV,1964Be24) J$^{\pi}$: From L=0 ^{15}N(p,t) (1968Fl03). T$_{1/2}$: From the average of T$_{1/2}$=9.9502 min *32* (2022Lo14), 9.962 min *20* (Katoh, et al., JAERI-M89-083 (1989)), 9.967 min *10* (1980An40), 9.965 min *10* (1977Az01), 10.0 min *5* (1973SiYS), 9.963 min *9* (1968Ri15), 10.05 min *5* (1965Bo42), 9.96 min *2* (1965Eb01), 9.965 min *5* (1960Ja12), 9.93 min *5* (1960Ki02), 9.96 min *3* (1958Ar15), 9.96 min *3* (1957Da08, 1958Da09), 10.02 min *10* (1957De22), 10.07 min *6* (1957No17), 10.08 min *4* (1955Wi43), 10.05 min *3* (1953Ch34), 10.05 min *10* (1950Ho01), 10.2 min *1* (Cook et al., Phys. Rev. 74 (1948) 502) 10.13 min *10* (Siegbahn, Arkiv. f. Ast. Math-Fys. 32A No. 9 (1945)) 9.93 min *3* (Ward, Proc. Cambridge Phil. Soc. 35 (1939) 523). T$_{1/2}$: See also 12.3 min ±5.4% (1961Ra06), 9.9670 min *37* (DDEP) and 9.9647 min *39* (2008Se10). T$_{1/2}$: In (1935Ru01), Rutherford discusses β decay.
2367.8 *8*	1/2^{+}	34.5 keV *3*	LM OP S UV XY	XREF: Others: AB, AD, AE, AF, AJ, AK, AL, AR, AS, AT, AU, AX, AZ, BA, BC, BD %p≈100; %IT=1.4×10^{-3} Γ$_{\gamma}$=0.49 eV *2* E(level): From the average of E$_{x}$=2367.6 keV *9* from references in ^{12}C(p,γ), 2369 keV *3* from (1953

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				Jackson) in ^{12}C(p,p):res and 2368.2 keV *28* from (1974Bl06) ^{12}C(^{3}He,d). J$^{\pi}$: From L=0 ^{12}C(p,p):res (1951Ja21). Γ: From the average (external errors) of Γ=36.15 keV *54* (1973Cl04) ^{12}C(d,n), 36.1 keV *28* (1974Bl06) ^{12}C(^{3}He,d), 34.5 keV *9* (1953Hu18,1973Cl04) ^{12}C(p,γ), 33.7 keV *20* (1968Bl17) ^{12}C(p,γ) 31.4 keV *9* (1968Ri16) ^{12}C(p,γ), 33.3 keV *18* (1974Bl06) ^{12}C(p,γ), 36 keV *2* (1974Ro29) ^{12}C(p,γ), 34.9 keV *2* (2023Sk02) ^{12}C(p,γ) 35.2 keV *5* (2023Cs01) ^{12}C(p,γ) and 34.0 keV *2* (2023Ke11: includes 2008Bu19) ^{12}C(p,γ). Note: uncertainty surrounds some Γ values related to assigning the values as lab or c.m. frame values. Table 1 of (1992HiAA) is helpful for resolving some issues. Γ: In (1991Aj01) Γ=31.7 keV *8* was determined by averaging only (1974Bl06) and (1968Ri16) values from ^{12}C(p,γ).
3500.4 *8*	3/2^{-}	55.0 keV *6*	A CD LMNOP S UV XYZ	XREF: Others: AF, AH, AJ, AK, AL, AM, AR, AS, AT, AV, AX, AZ, BA, BB, BC %p≈100; %IT=9.6×10^{-4} $\Gamma_{\gamma0}$=0.49 eV *3*; $\Gamma_{\gamma1}$=0.043 eV Γ_{γ}≈0.533 eV XREF: AJ(3464)AK(3.53E3)AS(3.51E3)AV(3.51E3). E(level): From E$_{x}$=3499 keV *6* (1966Ar03) ^{12}C(p,p):res and 3500.4 keV *8* from references in ^{12}C(p,γ). J$^{\pi}$: From L=0,2 ^{11}B(^{3}He,n) (1971Hs03). Γ: From the average of Γ=60 keV *3* (1974Ro29) ^{12}C(p,γ), 61.9 keV *40* (1968Bl17) ^{12}C(p,γ), 55.2 keV *3* (2023Ke11) ^{12}C(p,γ), 53.2 keV *7* (2023Cs01) ^{12}C(p,γ), and 63 keV *4* (2005Kn02) ^{13}O β-p. $\Gamma_{\gamma0}$: From the R-matrix analysis in (2023Ke11) as detailed above. In (1991Aj01) the analysis of (1952Se01, 1963Yo06) cross sections given in (1980Ba54) was accepted. $\Gamma_{\gamma1}$: From $\Gamma_{\gamma0}$, I(γ0)=92% *1* and I(γ1)=8% *1* from (1974Ro29).
3544.5 *5*	5/2^{+}	49.0 keV *5*	LM O S UV XYZA	XREF: Others: AB, AD, AE, AF, AH, AJ, AK, AR, AT, BA, BC %p=100 XREF: AE(3.5E3)AF(3.51E3)AH(3.5E3)AJ(3.5E3). E(level): From the average of E$_{x}$=3544.4 keV *5* from the (2023Ke11) analysis of (1976Me22) ^{12}C(p,p):res and 3549.1 keV *50* (1974Bl06) ^{12}C(^{3}He,d). J$^{\pi}$: From phase-shift analysis of ^{12}C(p,p) (1951Ja21). Γ: From the (2023Ke11) R-matrix analysis of (1976Me22) ^{12}C(p,p):res. See also 47 keV *7* from (1974Bl06).
6368 *9*	5/2^{+}	11 keV	MNO S V	XREF: Others: AF, AJ, AK, AR, AT, AX, BA, BB %p=100 XREF: AJ(6.3E3). E(level): From the weighted average (external errors) of E$_{x}$=6378 keV *8* (1956Re39) ^{12}C(p,p):res, 6353 keV *9* (1971Hs03) ^{11}B(^{3}He,n) and 6380 keV *30* (1968Fl03)

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				^{15}N(p,t). J$^{\pi}$,Γ: From phase-shift analysis (1956Re39) ^{12}C(p,p):res.
6886 *5*	3/2^{+}	115 keV *5*	M O S V YZ	XREF: Others: AD, AK, AT %p=100 Γ$_{p0}$=51 keV; Γ$_{p1}$=63 keV (1963Ba36) E(level): From the average of E$_{x}$=6890 keV *6* from values in ^{12}C(p,p):res and 6875 keV *10* (1971Hs03) in ^{11}B(^{3}He,n). J$^{\pi}$: From phase-shift analysis of angular distributions and σ(E) in (1956Re39) ^{12}C(p,p),(p,p$_{1}\gamma(\theta)$). Γ: From the average of Γ=115 keV *5* (1963Ni05) ^{12}C(p,p):res, 110 keV *15* (1962Cl12) ^{14}N(^{3}He,α) and 120 keV *30* (1974Ho06) ^{10}B(^{6}Li,t).
7156 *5*	7/2^{+}	9.0 keV *5*	MNO S V YZA	XREF: Others: AB, AJ, AK, AT %p=100 XREF: O(7145)AJ(7.2E3). E(level): From the average of E$_{x}$=7145 keV *9* (1971Hs03) ^{11}B(^{3}He,n), 7155 keV *9* (1963Ba36) ^{12}C(p,p):res and 7166 keV *8* (1962Cl12) ^{14}N(^{3}He,α). J$^{\pi}$: From phase-shift analysis in (1963Ba36, 1963Ni05) ^{12}C(p,p):res. Γ: From (1963Ni05) ^{12}C(p,p):res.
7376 *9*	5/2^{-}	66 keV *9*	A M O S V Y A	XREF: Others: AH, AK, AL, AR, AS, AT, AV, AX, BA, BB %p=100 Γ$_{p0}$/Γ=0.10 (1963Ni05) XREF: O(7363)AL(7.4E3). E(level): From the average (external errors) of E$_{x}$=7363 keV *8* (1971Hs03) ^{11}B(^{3}He,n), 7380 keV *20* (1968Fl03) ^{15}N(p,t) and 7388 keV *8* (1962Cl12) ^{14}N(^{3}He,α). J$^{\pi}$: From phase-shift analysis of ^{12}C(pol. p,p) (1968Be31). L=2 ^{15}N(p,t) (1968Fl03). Γ: From the average (external errors) of Γ=69 keV *5* (1963Ni05) ^{12}C(p,p):res, 104 keV *20* (2005Kn02) ^{13}O β-p and 45 keV *10* (1962Cl12) ^{14}N(^{3}He,α). Γ: In (1970Aj04) the value Γ=75 keV *5* from (1963Ni05) is listed, but this value given in the abstract was Γ$_{lab}$.
8×10^{3}	3/2^{+}	≈1.5 MeV	O S V Z	XREF: Others: AB %p=100 XREF: AB(7.9E3). E(level),Γ: From (1962Sh22, 1966Ba35) ^{12}C(p,p):res. See also E$_{x}$=8200 keV *22* from (1971Hs03) ^{11}B(^{3}He,n), but note that data supporting this value is not shown in the article. J$^{\pi}$: From phase-shift analysis of ^{12}C(p,p) (1962Sh22).
8918 *11*	1/2^{-}	278 keV *16*	A M O S V Y	XREF: Others: AB, AJ, AK, AR, AS, AT, AX, BA %p=100 Γ$_{p0}$/Γ≈0.541; Γ$_{p1}$/Γ≈0.459 (2005Kn02) XREF: AB(8.5E3)AJ(8.8E3)AS(8.93E3). E(level): From (1971Hs03) ^{11}B(^{3}He,n).

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				J$^{\pi}$: From L=0 ^{15}N(p,t) (1968Fl03) and phase-shift analysis of ^{12}C(p,p) (1962Sh22). Γ: From (2005Kn02) ^{13}O β-p. See also 230 keV from ^{12}C(p,p):res.
9×10^{3}[†]	9/2^{+}	280 keV *30*	MN V Z	XREF: Others: AA, AK E(level),Γ: From (1974Ho06) ^{10}B(^{6}Li,t). J$^{\pi}$: In (1974Ho06) comparison of angular distributions in ^{10}B(^{6}Li,^{3}He) and ^{10}B(^{6}Li,t) indicates the state is the analog of ^{13}C(9.5 MeV), which is presently identified as 9/2^{+}. See also L=4 in ^{12}C(^{3}He,d) (1980Pe13). Γ: See also 0.40 MeV *5* in ^{12}C(^{3}He,d) (1969Fo02).
9476 *8*	3/2^{-}	30 keV	A M O S V	XREF: Others: AJ, AK, AS, BA %p=100 Γ_{p0}/Γ=0.72 (1972Be15) XREF: M(9.52E3)BA(9.52E3). E(level): From (1971Hs03) ^{11}B(^{3}He,n). See also E$_{x}$=9520 keV *20* from (1966Ch18) ^{11}B(^{3}He,n). J$^{\pi}$: From L=0,2 ^{11}B(^{3}He,n) (1971Hs03) and phase-shift analysis of ^{12}C(p,p) (1962Sh22). Γ: From (1962Sh22) ^{12}C(p,p):res. See also Γ=143 keV *18* (2005Kn02) ^{13}O β-p, but note the fit in this region is rather poor.
10.26×10^{3} *14*	(1/2^{+},3/2^{+})	260 keV *90*	P	%p≈100; %IT≥2.3×10^{-4} $\Gamma_{\gamma0}$>0.6 eV (1973Me12) E(level),Γ: From (1973Me12) ^{12}C(p,γ). For J$^{\pi}$=3/2^{+}, Γ_{lab}=280 keV *100* and for J$^{\pi}$=1/2^{+}, Γ_{lab}=300 keV *100*. J$^{\pi}$: From ^{12}C(p,γ_{0}) (1973Me12) where detector(θ)=90° and γ_{0} to ^{13}N$_{g.s.}$(J^{π}=1/2^{-}) is observed.
10.36×10^{3}	5/2^{-}	30 keV	E MNO S V	XREF: Others: AK, BA %p=100 Γ_{p0}/Γ=0.26 (1968Be31) XREF: M(10.35E3)O(10381). E(level),Γ: From (1968Be31) ^{12}C(p,p):res where the 5/2^{-} and 7/2^{-} doublet partners are both analyzed. In (1968Be31) the authors find the level energies do not differ by more than 2 keV. See also E$_{x}$=10381 keV *8* (1971Hs03) ^{11}B(^{3}He,n) and 10350 keV *20* (1966Ch18) ^{11}B(^{3}He,n). J$^{\pi}$: From phase-shift analysis of ^{12}C(pol. p,p) (1968Be31).
10.36×10^{3}	7/2^{-}	76 keV	E MN S V	XREF: Others: AK, BA

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				%p=100 Γ_{p0}/Γ=0.81 (1968Be31) XREF: M(10.35E3). E(level),Γ: From (1968Be31) ^{12}C(p,p):res. See above comment. J$^{\pi}$: From phase-shift analysis of ^{12}C(pol. p,p) (1968Be31).
10833[†] *9*	1/2^{-}	75 keV *15*	E M O V	XREF: Others: AJ, AK, AX XREF: M(10.78E3)V(10.78E3)AX(10780). E(level): From (1971Hs03) ^{11}B(^{3}He,n). J$^{\pi}$: From L=0 ^{15}N(p,t) (1968Fl03). Γ: From (1980Pe13) ^{12}C(^{3}He,d).
11530 *12*	5/2^{+}	430 keV *35*	E O S	XREF: Others: BA %p=100 Γ_{p0}/Γ=0.70 *5* (1973Me03) XREF: BA(11.5E3). E(level): From (1971Hs03) ^{11}B(^{3}He,n). See also E$_{x}$=11490 keV *50* (1973Me03) ^{12}C(p,p):res. J$^{\pi}$: From phase-shift analysis of ^{12}C(pol.p, p),(pol. p,p′) (1973Me03). Γ: From (1973Me03) ^{12}C(p,p):res.
11700 *30*	5/2^{-}	115 keV *30*	A M S V	XREF: Others: AB %p=100 Γ_{p0}/Γ=0.60 *4* (1973Me03) XREF: M(11.65E3)V(11.1E3)AB(11.3E3). E(level),J$^{\pi}$,Γ: From (1973Me03) ^{12}C(p,p):res. J$^{\pi}$: From phase-shift analysis of ^{12}C(pol.p, p),(pol. p,p′) (1973Me03).
11740 *40*	3/2^{+}	250 keV *30*	P S	%p≈100; %IT≥1.7×10^{-3} $\Gamma_{\gamma 0}$≈4.2 eV (1973Me12) Γ_{p0}/Γ=0.30 *5* (1973Me03) E(level),Γ: From (1973Me03) ^{12}C(p,p):res where the 3/2^{+} and 3/2^{-} doublet partners are both analyzed. J$^{\pi}$: From phase-shift analysis of ^{12}C(pol.p, p),(pol. p,p′) (1973Me03).
11740 *50*	3/2^{-}	530 keV *80*	O S	XREF: Others: AJ, AK, AR, AS, AX %p=100 Γ_{p0}/Γ=0.55 *5* (1973Me03) XREF: O(11878)AK(11850)AR(11.86E3)AS(11.9E3)AX(11880). E(level),Γ: From (1973Me03) ^{12}C(p,p):res. Other results associated with J$^{\pi}$=3/2^{-} but reported with energies near the next highest level are E$_{x}$=11878 keV *12* (1971Hs03) ^{11}B(^{3}He,n), 11850 keV *40* (1969Ba06) ^{13}C(^{3}He,t) and 11880 keV *40* (1968Fl03) ^{15}N(p,t); these likely correspond to unresolved 3/2^{-}&1/2^{+} states. Γ: See also 98 keV (2004Fu12) ^{13}C(^{3}He,t). ^{13}C(^{3}He,t). J$^{\pi}$: From phase-shift analysis of ^{12}C(pol.p, p),(pol. p,p′) (1973Me03).
11860 *40*	1/2^{+}	380 keV *50*	S	XREF: Others: AR, AT, AV %p=100 Γ_{p0}/Γ=0.35 *5* (1973Me03)

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^\pi$	T$_{1/2}$ or Γ	XREF	Comments
				XREF: AR(11.86E3). E(level),Γ: From (1973Me03) ^{12}C(p,p):res. J$^\pi$: From phase-shift analysis of ^{12}C(pol. p,p) (1973Me03); see also J$^\pi$=3/2$^-$ from L=0,2 ^{11}B(^{3}He,n) (1971Hs03).
12130 *50*	7/2$^-$	250 keV *30*	S V	XREF: Others: AB, BA %p=100 Γ_{p0}/Γ=0.30 *5* (1973Me03) XREF: V(12.08E3)AB(12.6E3). E(level),Γ: From (1973Me03) ^{12}C(p,p):res. See also E$_x$=12130 keV *60* (1972Ma72) ^{16}O(p,α). J$^\pi$: From phase-shift analysis of ^{12}C(pol.p, p),(pol. p,p′) (1973Me03).
12558† *23*		>400 keV	O Z	XREF: Others: AL, BA XREF: ba(12.75E3). E(level),Γ: From (1971Hs03) ^{11}B(^{3}He,n).
12937 *24*		>400 keV	A O	XREF: Others: BA %p=100 XREF: A(13.26E3)ba(12.75E3). E(level),Γ: from (1971Hs03) ^{11}B(^{3}He,n). E(level): See nearby E$_x$=13260 keV *100* with Γ≈520 keV reported in (2005Kn02) ^{13}O β-p.
13.50×10^3 *20*	3/2$^+$	≈6.5 MeV	P	XREF: Others: AH %p≈100; %IT≥1.7×10^{-2} $\Gamma_{\gamma0}$>1.1 keV (1973Me12) XREF: AH(12.8E3). E(level),Γ: From (1973Me12) ^{12}C(p,γ). J$^\pi$: From ^{12}C(p,γ_0) (1973Me12) where detector(θ)=90° and γ_0 to ^{13}N$_{g.s.}$(J$^\pi$=1/2$^-$) is observed; also strong interference with J$^\pi$=3/2$^+$ states at ^{13}N*(11.74, 14.05); assumed component of GDR. Γ: See also Γ≈7.9 MeV (1994Ha41) ^{13}C(π$^+$,π^0).
13650?† *10*		<300 keV	E S	XREF: Others: BA %p=100 XREF: BA(?13.48E3). E(level),Γ: From (2009Ch38) ^{9}Be(^{10}C,^{13}N). Γ: See also Γ≈500 keV (1961Na02) ^{12}C(p,p):res. and Γ≈ few hundred keV (1972Ma21) ^{16}O(p,α).
14050 *20*	3/2$^+$	162 keV *16*	P ST	XREF: Others: AR %p<100; %α>0; %IT≥2.3×10^{-3} T=1/2 (1976Me18) $\Gamma_{\gamma0}$=3.7 eV *10* (1973Me12) Γ_{p0}/Γ=0.29 *7* (1976Me18) XREF: T(13962)AR(14.0E3). E(level): From (1976Me18) ^{12}C(p,p):res. See also E$_x$=14050 keV *80*. J$^\pi$: From phase-shift analysis of ^{12}C(pol. p,p) (1976Me18). Γ: From the average of Γ=157 keV *18* (1973Me12) ^{12}C(p,γ) and 180 keV *35*

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				(1976Me18) ^{12}C(p,p):res.
15064.56 *40*	3/2^{-}	0.932 keV *28*	A C OP ST	XREF: Others: AJ, AK, AX %IT=4.7 *4*; %p=69.9 *42*; %α=16 *7* T=3/2 (1969Ad02) $\Gamma_{\gamma0}$=24.5 eV *15* (1975Ma21,1973Ad02) $\Gamma_{\gamma1}$≤2.82 eV (1975Ma21) Γ_{p0}/Γ=0.236 *12*; Γ_{p0}=220 eV *13* Γ_{p1}/Γ=0.150 *10*; Γ_{p1}=140 eV *10* Γ_{p2}/Γ=0.053 *15*; Γ_{p2}=49 eV *14* $\Gamma_{\alpha0}$/Γ=0.049 *27*; $\Gamma_{\alpha0}$=46 eV *25* $\Gamma_{\alpha1}$/Γ=0.039 *39*; $\Gamma_{\alpha1}$=36 eV *36* $\Gamma_{\alpha2}$/Γ=0.072 *45*; $\Gamma_{\alpha2}$=67 eV *42* Γ_{γ}=44.1 eV *35* Γ_{p}=651 eV *40* Γα=149 eV *61* XREF: AJ(15.1E3). E(level),Γ: From (1973Hu07) ^{12}C(p,p):res. E(level): See also E$_{x}$=15064 keV *4* (1969Le18) and 15068 keV *8* (1969Ad02). Γ: See also Γ=1.10 keV *9* (1975Hi07) ^{12}C(p,α). Beginning in (1981Aj01) the value Γ=0.86 keV *12* was given in the evaluations. This value is derived in (1977Ma16) using their measured $\Gamma_{p0}\Gamma_{\gamma0}$/Γ=5.79 eV *20* value. J$^{\pi}$: From L=0 ^{11}B(^{3}He,n) (1971Hs03) and phase-shift analysis of (1969Le18). Γ_{p},Γα: Branching ratios for p- and α-decay branches are from (1973Ad02); partial widths are deduced using these and Γ=0.932 keV *28*. Γ_{p}: See also Γ_{p}(→^{12}C(9.6 MeV))/Γ=0.096 *14* and Γ_{p}(→^{12}C(10.8 MeV))/Γ=0.164 *36* (Adelberger, Marrs, Snover and Cooper, Bull. Amer. Phys. Soc. 19 (1974) 452); these imply Γ_{p}(→^{12}C(9.6 MeV))=89.5 eV *5* and Γ_{p}(→10.8 MeV))=153 eV *34* Hence Γ_{p}=651 eV *40* for all proton branches. $\Gamma_{\gamma0}$: $\Gamma\gamma_{0}$=24.5 eV *15* is obtained by combining Γ_{p0}/Γ=0.236 *12* (1973Ad02) with $\Gamma_{p0}\Gamma\gamma0$/Γ=5.79 eV *20* (1975Ma21). Γ_{γ}: Γγ=44.1 eV *35* from $\Gamma\gamma_{0}$=24.5 eV *15* $\Gamma\gamma_{1}$≤2.82 eV *30* and $\Gamma\gamma_{(2+3)}$=19.6 eV *14* (1975Ma21,1973Ad02).
15.30×10^{3} *20*	(3/2^{+})	0.35 MeV *14*	A P	%p≈100; %IT≥1.4×10^{-4} $\Gamma_{\gamma0}$≥0.5 eV (1973Me12) Γ_{p0}/Γ≈1.0 (2005Kn02) E(level),Γ: From (1973Me12) ^{12}C(p,γ). J$^{\pi}$: From ^{12}C(p,γ_{0}) (1973Me12) where detector(θ)=90° and γ_{0} to ^{13}N$_{g.s.}$(J$^{\pi}$=1/2^{-}) is observed. See also (3/2^{-}) in (2005Kn02) ^{13}O β-p; but note the reported %Iβ=0.03 *3* intensity corresponds to perhaps three counts in a region where no background is considered.
16000 *30*	7/2^{+}	135 keV *90*	ST	XREF: Others: AK

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^\pi$	T$_{1/2}$ or Γ	XREF	Comments
				%p<100; %α>0 T=1/2 (1967Ku02,1976Me18) Γ_{p0}/Γ=0.05 *4* (1976Me18) XREF: AK(15980). E(level): From the average of E$_x$=16010 keV *40* (1973Me12) ^{12}C(p,p):res and E$_x$=15980 keV *50* (1969Ba06) ^{13}C(^{3}He,t). See also E$_x$=16 MeV and Γ=500 keV (1964Da03) ^{12}C(p,p):res. J$^\pi$: From phase-shift analysis of ^{12}C(pol. p,p) (1976Me18). Γ: From (1973Me12). See also Γ≈100 keV (1969Le18) ^{12}C(p,α) and ≈163 keV (2004Fu12) ^{13}C(^{3}He,t).
16.6×10^3 *1*		<350 keV	E	%α≈100 E(level),Γ: From (2009Ch38). Decays to α+^{9}B(2.345).
17.4×10^3			S	%p=100 E(level): From (1976Be28) ^{12}C(p,pγ(12.71 MeV)).
17680 *30*		1212 keV *74*	P	XREF: Others: AB, AK, AL %p>0; %IT>0 (1976Be28) XREF: P(18.1E3)AB(16.2E3)AL(17.5E3). E(level),Γ: From (2004Fu12) ^{13}C(^{3}He,t). E(level),J$^\pi$: (1988Vo08) ^{12}C(^{13}C,^{12}B) suggests a broad (5/2$^+$) GDR component near E$_x$=16.2 MeV.
18130 *17*	3/2$^+$	287 keV *36*	S	XREF: Others: AK %p=100 T=1/2 (1967Ku02,1976Me18) Γ_{p0}/Γ=0.08 *2* (1976Me18) E(level): From the average of E$_x$=18150 keV *30* (1976Me18) ^{12}C(p,p):res and 18120 keV *20* (2004Fu12) ^{13}C(^{3}He,t). J$^\pi$: From phase-shift analysis of ^{12}C(pol. p,p) (1976Me18). Γ: From the average of Γ=322 keV *75* (1976Me18) and 276 keV *41* (2004Fu12).
18170 *20*	1/2$^-$	225 keV *50*	ST	%p<100; %α>0 T=1/2 (1976Me18) Γ_{p0}/Γ=0.24 *6* (1976Me18) XREF: T(18232). E(level),Γ: From (1976Me18) ^{12}C(p,p):res. See also E$_x$=18232 keV and Γ=300 keV in (1969Le18) ^{12}C(p,α). J$^\pi$: From phase-shift analysis of ^{12}C(pol. p,p) (1976Me18).
18405 *5*	3/2$^+$	66 keV *8*	O ST	XREF: Others: AK %p<100; %α>0 T=3/2 (1967Ku02,1969Ad02) Γ_{p0}/Γ=0.25 (1969Le18) XREF: O(18.44E3)T(18352). E(level),Γ: See comments in ^{12}C(p,p):res. Values are apparently from Snover BAPS **13** (1968) p. 1662 and a private communication reported in (1970Aj04). See also E$_x$=18370 keV

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				10 (2004Fu12) ^{13}C(^{3}He,t) and 184400 keV *40* (1969Ad02) ^{11}B(^{3}He,n). J$^{\pi}$: From phase-shift analysis of ^{12}C(p,p) (1969Le18).
18963 *8*	(3/2^{-},7/2^{+})	23 keV *5*	O ST	%p<100; %α>0 T=3/2 (1967Ku02,1969Ad02) Γ$_{p0}$/Γ=0.017 (1969Le18) XREF: O(18.98E3). E(level): From the average of E$_{x}$=18960 *9* see comments in ^{12}C(p,p):res and 18980 keV *20* (1969Ad02) ^{11}B(^{3}He,n). J$^{\pi}$: From phase-shift analysis in (1969Le18) ^{12}C(p,p). Γ: See discussion in ^{12}C(p,p):res related to Snover BAPS. See also Γ=40 keV *20* (1969Ad02).
19110† *10*		183 keV *41*		XREF: Others: AK E(level),Γ: From (2004Fu12) ^{13}C(^{3}He,t).
19830 *20*	5/2^{-}	1542 keV *84*	T	XREF: Others: AK %p<100; %α>0 T=1/2 (1969Le18) Γ$_{p0}$/Γ=0.18 (1969Le18) E(level),Γ: From (2004Fu12) ^{13}C(^{3}He,t). J$^{\pi}$: From phase-shift analysis of ^{12}C(p,p) (1969Le18).
19880	7/2^{+}	750 keV	ST	%p<100; %α>0 T=1/2 (1969Le18) Γ$_{p0}$/Γ=0.40 (1969Le18) E(level): From (1969Le18) ^{12}C(p,p),(p,α). J$^{\pi}$: From (1979Ga13) analysis of σ(θ) and A$_{y}$(θ) from ^{12}C(pol. p,p),(pol. p′) See also 3/2^{+} in phase-shift analysis (1969Le18). Γ: From (1979Ga13) ^{12}C(p,p):res. See also Γ=520 keV (1969Le18).
20.2×10^{3}	5/2^{-}	1 MeV	S	%p=100 E(level),Γ: From (1979Ga13) ^{12}C(p,p):res. E(level): In ^{12}C(p,γ) broad Γ≈1.2-4.0 MeV groups are reported with E$_{x}$ ranging from 20.0 MeV to 20.8 MeV. J$^{\pi}$: From (1979Ga13) analysis of σ(θ) and A$_{y}$(θ) from ^{12}C(pol. p,p),(pol. p′).
20.90×10^{3} *30*	1/2^{+}	1.2 MeV	P RS	%p<100; %IT>0; %n=? Γ$_{γ0}$>0 eV (1976Be28) Γ$_{p0}$/Γ≈0.1 (1973Me12) XREF: P(20.5E3). E(level): From (1973Me12) ^{12}C(p,p):res. J$^{\pi}$: From (1979Ga13) analysis of σ(θ) and A$_{y}$(θ) from ^{12}C(pol. p,p),(pol. p′). Γ: From (1979Ga13) ^{12}C(p,p):res.
21200 *10*	5/2^{-}	581 keV *44*	S	XREF: Others: AK

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				%p=100 XREF: S(21.4E3). E(level),Γ: From (2004Fu12) ^{13}C(^{3}He,t). The previous evaluation accepted a state at E$_{x}$=21.4 MeV with Γ=750 keV (1979Ga13) ^{12}C(p,p):res; the evaluator assumes (2004Fu12) observed the same level. J$^{\pi}$: From (1979Ga13) analysis of $\sigma(\theta)$ and A$_{y}(\theta)$ from ^{12}C(pol. p,p),(pol. p′).
21.7×10^{3}	(3/2^{+})		S	%p=100 E(level): From ^{12}C(p,p):res. See for discussion on 1964 Tamura et al. analysis of (1963Di16) data and see (1979Ga13). J$^{\pi}$: From (1979Ga13) analysis of $\sigma(\theta)$ and A$_{y}(\theta)$ from ^{12}C(pol. p,p),(pol. p′) and 1964 Tamura et al..
22140 *10*	1/2^{+}	1706 keV *82*	P S	XREF: Others: AB, AK %p≈100; %IT>0 (1976Be28) Γ$_{p0}$/Γ≈0.1 (1973Me12) XREF: S(22.4E3)AB(22.5E3). E(level),Γ: From (2004Fu12) ^{13}C(^{3}He,t). The previous evaluation accepted a state at E$_{x}$=22.4 MeV *5* with Γ≈1 MeV (1973Me12, 1979Ga13) ^{12}C(p,p):res; the evaluator assumes (2004Fu12) observed the same level. J$^{\pi}$: From (1979Ga13) analysis of $\sigma(\theta)$ and A$_{y}(\theta)$ from ^{12}C(pol. p,p),(pol. p′). E(level),J$^{\pi}$: (1988Vo08) ^{12}C(^{13}C,^{12}B) suggests a broad (3/2^{+}) GDR component near E$_{x}$=22.5 MeV. E(level): See (1994Ha41) ^{13}C(π^{+},π^{0}) where a T=3/2 state with Γ=10.4 MeV is suggested at E$_{x}$=23.3 MeV.
23.3×10^{3}[†]		10.4 MeV	A H	T=3/2 (1994Ha41) E(level),Γ: From (1994Ha41). Represents the T=3/2 giant resonance built on ^{13}C$_{g.s.}$
23.3×10^{3}	3/2^{-}	500 keV	H J P	%p<100; %IT>0 Γ$_{\gamma0}$>0 eV (1976Be28) XREF: P(23.2E3). Γ(^{3}He)/Γ > 0. E(level): From E$_{x}$=23.2 MeV (1976Be28) ^{12}C(p,γ), 23.25 MeV (1987Ba34) ^{10}B(^{3}He,^{3}He) and 23.3 MeV (1966Pa10) ^{10}B(^{3}He,p$_{0}$). In the prior evaluation the (p,γ) resonance was listed separately with E$_{x}$=23 MeV. J$^{\pi}$: From L=1 and R-matrix analysis in (1987Ba34) ^{10}B(^{3}He,^{3}He). Γ: From Γ=500 keV (1987Ba34) ^{10}B(^{3}He,^{3}He) and Γ=500 keV (1966Pa10) ^{10}B(^{3}He,p$_{0}$). See also Γ≈1 MeV (1976Be28) ^{12}C(p,γ).
23830 *40*	3/2^{-}	346 keV *38*	H J	%p<100 XREF: J(23.87E3). Γ(^{3}He)/Γ > 0.

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
				E(level): From (1964Ku09) ^{10}B(^{3}He,p). J$^{\pi}$: From L=1 and R-matrix analysis in (1987Ba34) ^{10}B(^{3}He,^{3}He). Γ: From (1956Sc01) ^{10}B(^{3}He,p).
23.93×10^{3}	13/2^{-}	20 keV	J	Γ(^{3}He)/Γ > 0. E(level),Γ: From (1987Ba34) ^{10}B(^{3}He,^{3}He). J$^{\pi}$: From L=3 and R-matrix analysis in (1987Ba34) ^{10}B(^{3}He,^{3}He).
24.1×10^{3}	7/2^{-}	≈500 keV	H JK RS	%α<100; %n>0 XREF: H(24.5E3)J(24.40E3)R(24E3). Γ(^{3}He)/Γ > 0. E(level),Γ: From (1966Lo16) ^{12}C(p,p):res. In the previous evaluation, Γ=700 keV from (1987Ba34) was listed, but this resonance was not covered in the energy range of that study; inclusion of the resonance did improve the fit in that study, but the value is not accepted here. Other reported widths are Γ=750 keV (1970Gi04) ^{10}B(^{3}He,α), ≤500 keV (1966Lo16) ^{12}C(p,p):res. J$^{\pi}$: From Legendre polynomial analysis of ^{10}B(^{3}He,α) in (1987Ba34) and scattered proton polarization results from ^{12}C(p,p) (1966Lo16).
24500 *40*		2.46 MeV *22*	P	XREF: Others: AK %p<100; %IT>0 $\Gamma_{\gamma0}$>0 eV (1976Be28) Γ(^{3}He)/Γ > 0. E(level): From (2004Fu12) ^{13}C(^{3}He,t). See also E$_{x}$=24.5 MeV (1963Fi07,1991Co07) ^{12}C(p,γ). Γ: From (2004Fu12) ^{13}C(^{3}He,t). See also Γ=3.5 MeV (1991Co07).
24.8×10^{3}		120 keV	H	%p<100 Γ(^{3}He)/Γ > 0. E(level),Γ: From (1956Sc01) ^{10}B(^{3}He,p).
25.64×10^{3} *10*	(3/2)$^{-}$	184 keV *60*	H S	%p<100 Γ(^{3}He)/Γ > 0. E(level),Γ: From (1964Ku09). J$^{\pi}$: From (1967Sc11) where L=1 waves in the entrance and exit channels are found in ^{12}C(p,p′)^{12}C(15.11 MeV: 1^{+}),
25900	7/2^{-}	1.0 MeV	GHI K	%n>0; %p<100; %d>0; %α>0 XREF: H(26.1E3)K(26.1E3). Γ(^{3}He)/Γ > 0. E(level),Γ: From discussion in (1972Be56) finding ^{10}B(^{3}He,X) where X=α_{0}, d$_{0}$, p$_{0,2,3}$ γ_{0} and (n). J$^{\pi}$: From (1970Gi04) Legendre polynomial analysis of ^{10}B(^{3}He,α) and analyzing power data in ^{12}C(pol. p,p). See also J≤3/2 (1966Pa10) ^{10}B(^{3}He,p) and see discussion in (1972Be56).

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Adopted Levels, Gammas (continued)

^{13}N Levels (continued)

E(level)	J^π	$T_{1/2}$ or Γ	XREF	Comments
26.90×10^3 *90*		4.38 MeV *47*	RS	XREF: Others: AK %p≈100; %n=? E(level),Γ: From (2004Fu12) ^{13}C(^{3}He,t). See also E_x=26.87 MeV (64 Tamura analysis of 1963Di16) and 26.84 (1966Cr04) in ^{12}C(p,p):res.
28000	$9/2^+$		GH K	%IT=?; %p<100; %α=? Γ(^{3}He)/Γ > 0. IT and α branches are tentative. E(level): From discussion in (1972Be56) finding ^{10}B(^{3}He,X) where X=α_0, p_0 and γ_0, and (1966Pa10) ^{10}B(^{3}He,p). J^π: From (1970Gi04) where both Legendre polynomial analysis of ^{10}B(^{3}He,α) and analyzing power data in ^{12}C(pol. p,p) are discussed. See also J≤7/2 (1966Pa10) ^{10}B(^{3}He,p) and see discussion in (1972Be56).
31.7×10^3?			P S	%p≈100; %IT>0 XREF: P(31.9E3). E(level): From the average of E_x=31.4 MeV (1976Fe11) ^{12}C(p,p′γ(4.44)) and 31.9 MeV from the average of (1963Fi07, 1976Fe11, 1991Co07) values in ^{12}C(p,γ). In earlier evaluations this level is listed with E_x=31 MeV. The level appears distinct from the E_x=32 MeV level, since it is not populated in ^{10}B(^{3}He,p) reactions.
32000		≈2000 keV	G I K	%IT>0; %d>0; %α<100 $\Gamma_{\gamma 0}$>0 eV (1976Be28) Γ(^{3}He)/Γ > 0. E(level),Γ: From discussion in (1972Be56) finding ^{10}B(^{3}He,X) where X=α_0, $d_{4,5}$ and γ_0.

† Decay mode not specified.

γ(^{13}N)

E_i(level)	J^π_i	E_γ†	I_γ	E_f	J^π_f	Mult.	δ‡	Comments
2367.8	$1/2^+$	≈2367.7	100	0.0	$1/2^-$	[E1]		Γ_γ=0.49 eV *2* B(E1)(W.u.)=0.100 *8* Γ_γ: From Γ_γ=0.52 eV 4 (2002SeZY) ^{208}Pb(^{13}N,^{12}C+p), and the ^{12}C(p,γ) values 0.45 eV *5* (1968Ri16), 0.53 eV *5* (1992HiAA), 0.49 eV *3* (2023Sk02), 0.48 eV *3* (2023Ke11: includes 2008Bu19).
3500.4	$3/2^-$	1135.6	8.4	2367.8	$1/2^+$	[E1]		Γ_γ≈0.043 eV (2023Ke11,1974Ro29) B(E1)(W.u.)≈0.1
		3500.3	100	0.0	$1/2^-$	[M1+E2]	−0.09 *2*	Γ_γ≈0.49 eV (2023Ke11) B(M1)(W.u.)≈0.7; B(E2)(W.u.)≈7 Mult.,δ: From (1974Ro29). See also δ=−0.092 (1963Yo06).

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Adopted Levels, Gammas (continued)

$\gamma(^{13}N)$ (continued)

E_i(level)	J_i^π	E_γ†	I_γ	E_f	J_f^π	Mult.	δ‡	Comments
10.26×10^3	$(1/2^+,3/2^+)$	≈10256		0.0	$1/2^-$			$\Gamma_\gamma>0.6$ eV
11740	$3/2^+$	11734		0.0	$1/2^-$	[E1]		$\Gamma_\gamma\approx4.2$ eV B(E1)(W.u.)≈0.007
13.50×10^3	$3/2^+$	≈13492		0.0	$1/2^-$			$\Gamma_\gamma\geq1.1$ keV
14050	$3/2^+$	14042		0.0	$1/2^-$	[E1]		$\Gamma_\gamma=3.7$ eV *10* B(E1)(W.u.)=3.6×10^{-3} *10*
15064.56	$3/2^-$	11558		3500.4	$3/2^-$	[M1]		B(M1)(W.u.)≤0.6 $\Gamma p_{(2+3)}=19.6$ eV *14*.
		12693	<2.82	2367.8	$1/2^+$	[E1]		$\Gamma_\gamma\leq2.82$ eV B(E1)(W.u.)<3.7×10^{-3}
		15055	100	0.0	$1/2^-$	[E2+M1]	−0.115 *21*	$\Gamma_\gamma=24.5$ eV *15* B(M1)(W.u.)=0.338 *20*; B(E2)(W.u.)=0.28 *10* Mult.,δ: From $\Gamma\gamma0$(M1)=24.2 eV *15* and $\Gamma\gamma0$(E2)=0.32 eV *12*; δ^2=0.013 *5* (1975Ma21, 1977Ma16). See also δ^2=0.095 7 (1968Di04).
15.30×10^3	$(3/2^+)$	≈15290		0.0	$1/2^-$			$\Gamma_\gamma\geq0.5$ eV
17680		17667		0.0	$1/2^-$			
20.90×10^3	$1/2^+$	20.90×10^3		0.0	$1/2^-$			
23.3×10^3	$3/2^-$	23.3×10^3		0.0	$1/2^-$			
24500		21.0×10^3		3500.4	$3/2^-$			
$31.7\times10^{3?}$		28.2×10^3		3500.4	$3/2^-$			
		31.7×10^3		0.0	$1/2^-$			

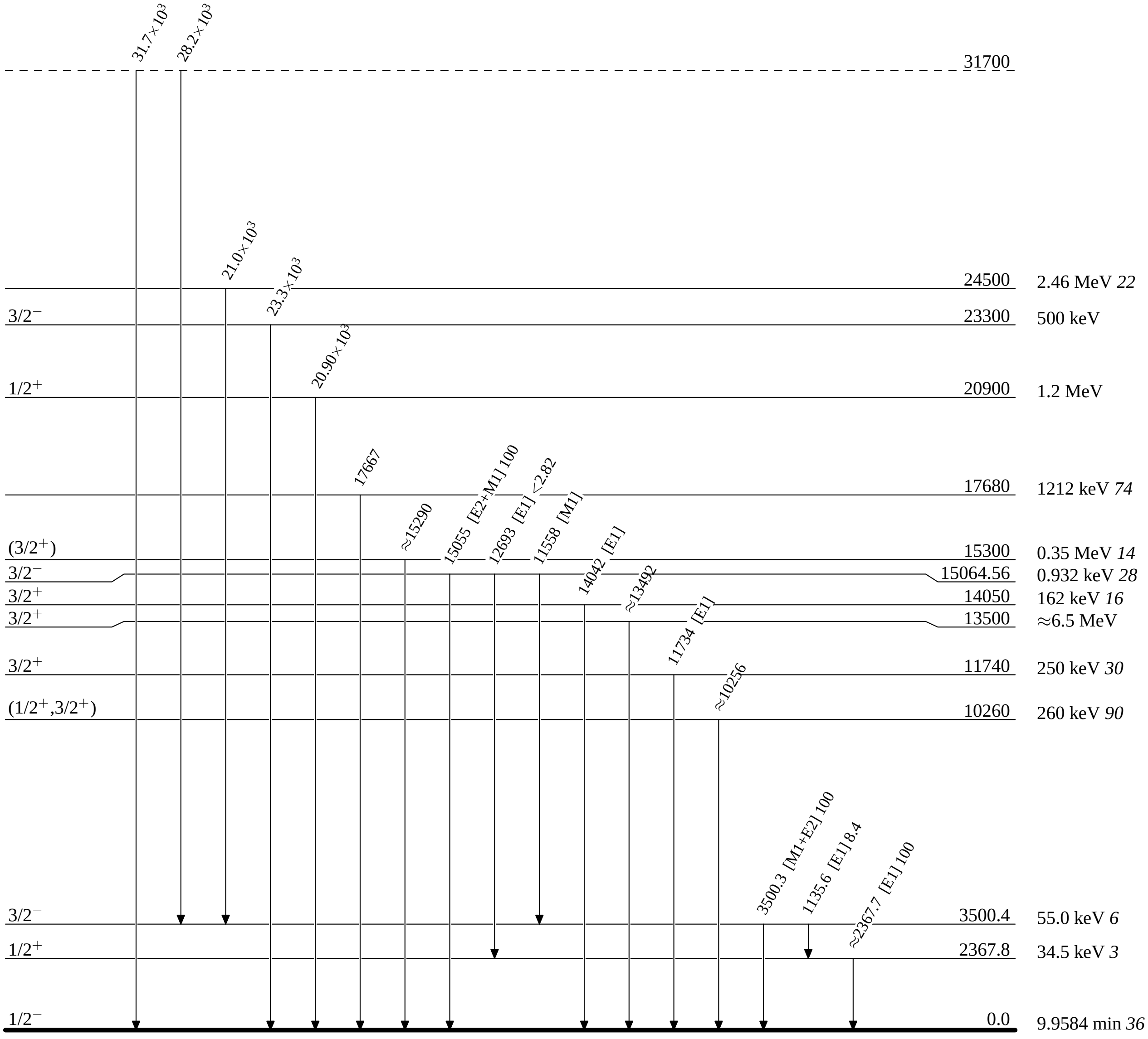
† From level-energy difference.

‡ The sign has been changed, where necessary, from that given in 1991Aj01 in order to conform to the convention used in the nuclear data sheets.

Adopted Levels, Gammas

Level Scheme

Intensities: Relative photon branching from each level



$^{13}_{7}N_{6}$

^{13}O $\varepsilon+\beta^{+}$ decay 2005Kn02

Parent: ^{13}O: E=0; J$^{\pi}$=3/2^{-}; T$_{1/2}$=8.58 ms *5*; Q(ε)=17770 *10*; %ε+%β^{+} decay=100

All daughter levels deexcite mainly by proton decay, except the ground state. The 3501 keV level has a small %Iγ=0.0011 branch compared to it′s main %p≈100 decay. Consequently, there is no observable γ emission following ^{13}O β^{+} decay.

1965Mc09: ^{13}O(β+p), [from ^{14}N(p,2n)], measured delayed p spectrum; analyzed proton groups at E$_{p}$=6.06 and 6.65 MeV; deduced E$_{x}$=8.77 *4* and 9.49 *4* MeV.

1970Es03: ^{13}O(β+p), [from ^{14}N(p,2n)], measured delayed p spectrum, analyzed E$_{p}$ groups; deduced I$_{p}$, E$_{p}$, I$_{p}$, I$_{\beta}$ and Log ft. (*Expected but not observed).

E$_{c.m.}$=1.565 MeV from ^{13}N(3.509) with I$_{rel}$=100;
E$_{c.m.}$=1.01(*) MeV and 5.48 MeV *5* from ^{13}N(7.387) with I$_{rel}$=0.33 *10*;
E$_{c.m.}$=2.56 MeV *5* and 6.98 MeV from ^{13}N(8.92) with I$_{rel}$=1.5 *3* and 3.5 *3*, resp.;
E$_{c.m.}$=3.12 MeV *5* and 7.58 MeV from ^{13}N(9.52) with I$_{rel}$=0.43 *15* and 0.8 *1*, resp.;
and E$_{c.m.}$=3.97 *5* and 8.41(*) MeV from ^{13}N(10.35) with I$_{rel}$=0.13 *7*.

1990As01: ^{13}O(β+p) [from ^{14}N(p,2n)], measured β delayed I$_{p}$, E$_{p}$, I$_{p}$, I$_{\beta}$.

E$_{c.m.}$=1.568 MeV from ^{13}N(3.511) with I$_{p\_rel}$=100;
E$_{c.m.}$=0.994 MeV and 5.433 MeV ^{13}N(7.387) with I$_{p\_rel}$=1.7 *8* and 0.17 *7*, resp.;
E$_{c.m.}$=2.536 MeV and 6.975 MeV from ^{13}N(8.918) with I$_{p\_rel}$=1.44 *25* and 4.83 *51*, resp.;
E$_{c.m.}$=3.094 MeV and 7.533 MeV from ^{13}N(9.476) with I$_{p\_rel}$=0.61 *15* and 0.98 *14*, resp.;
E$_{c.m.}$=3.97 MeV *5* and 8.42 MeV from ^{13}N(10.36) with I$_{p\_rel}$=0.12 *8* and 0.05 *3*. resp. Analyzed total Iβ along with I$_{p}$ from ^{13}N(3.51) to obtain an absolute I$_{p}$(3.51)=Iβ(3.51)=9.8% *20*; this implies Iβ(g.s.)=89.2% *22*.

2005Kn02: ^{13}O ions were produced at the IGISOL facility via the ^{14}N(p,2n)reaction by impinging an E$_{p}$=45 MeV beam on a 1 mg/cm^{2} target. The ^{13}O ions recoiled out of the target and were collected in a helium carrier gas which delivered them to the mass separator. The ions were then implanted into a 30 μg/cm^{2} carbon foil. The implantation target was surrounded by three position sensitive ΔE-E Si detector telescopes, which triggered the DAQ; the ISOLDE Si ball was not included in the trigger due to a high sensitivity to β particles.

The delayed-proton energy spectrum was analyzed using Breit-Wigner shapes, the analysis deduced relative Ip and I$_{\beta}$ values, which were normalized to I$_{p}$(3.51)=Iβ(3.51)=9.8% *20* from (1990As01).

The (2005Kn02) data set has the highest statistical relevance and covers a broader energy range than other measurements (1965Mc09, 1970Es03, 1990As01). Furthermore, the discussion on the line-shape analysis suggests the results of (2005Kn02) should be adopted. Noteworthy differences between other measurements are for decay from ^{13}N(8.918), (2005Kn02) observe a stronger p$_{1}$ branch than earlier measurements. Second, no evidence is seen for decay of ^{13}N(10.360); the difference is attributed to the more sophisticated line-shape analysis.

A subtle note to understanding the (2005Kn02) manuscript: in Table 2 for %Iβ for ^{13}N(15.065), the value includes unobserved contributions from γ decay, proton decay and α decay.

2003Bi03: A 15.1 MeV ^{13}O beam from the Texas A&M MARS facility was implanted into the TexAT TPC. The β-delayed charged-particle emission events producing 3αp events were analyzed. A total of 147 events (%β3αp≈0.078 *6*) mainly included decay via ^{13}N$^{*}\rightarrow$p+[^{12}C*(7.65 MeV)$\rightarrow\alpha$+^{8}Be$_{g.s.}$] and ^{13}N$^{*}\rightarrow$a+[^{9}B$^{*}\rightarrow$p+^{8}Be$_{g.s.}$]; three low-lying ^{9}B states appear to be involved. The excitation energy spectrum of ^{13}N states was deduced from an invariant mass analysis. Four new states are suggested at ^{13}N*(11.3, 12.4, 13.1 and 13.7 MeV). The letter does not discuss branching ratios; furthermore as many of 15 different ^{13}N levels appear populated based on Fig. 5. It is puzzling that branches from ^{13}N*(15064 keV) were not reported; it is known to p$_{2}$ decay to ^{12}C*(7.65 MeV) and to α decay to ^{9}B. In the present evaluation, these results are considered preliminary.

Theory:
1993Ch06: Shell model analysis of β-decay.
2003Sm02: Analysis of B(GT) rates.
2012Sa50: Global analysis of isospin-breaking corrections in superallowed decays.

Studies relevant to ^{13}O properties include: (1996Ma37, 1996Ma38, 1999Ma46).

^{13}O ε+β^{+} decay **2005Kn02 (continued)**

^{13}N Levels

E(level)†#	J^{π}†	Γ‡	Comments
0	$1/2^{-}$		
3500.4 *8*	$3/2^{-}$	63 keV *4*	%Iβ-p0=9.8 *20*; this implies $\%p_0$=100.
7376 *9*	$5/2^{-}$	104 keV *20*	%Iβ-p0=0.009 *4* and %Iβ-p1=0.235 *29*; this implies $\%p_0$=3.6 and $\%p_1$=96.4.
8918 *11*	$1/2^{-}$	278 keV *16*	%Iβ-p0=0.519 *40* and %Iβ-p1=0.441 *29*; this implies $\%p_0$=54.1 and $\%p_1$=45.9.
9476 *8*	$3/2^{-}$	143 keV *18*	%Iβ-p0=0.137 *12* and %Iβ-p1=0.104 *11*; this implies $\%p_0$=56.9 and $\%p_1$=43.1.
11700 *30*	$5/2^{-}$	0.32 MeV *11*	Γ: from 315 keV *112* (2005Kn02). Iβ-p0=0.015 *4* and $\%p_1\leq0.002$; this implies $\%p_0$=100.
13.26×10^{3} *10*	$(^{-})$	0.52 MeV *21*	E(level): deduced from E_p. Γ: From 521 keV *210* (2005Kn02). J^{π}: From (2005Kn02). %Iβ-p0=0.011 *3*; this implies $\%p_0$=100.
15064.56 *40*	$3/2^{-}$		%Iβ-p0=0.0048 *7*, %Iβ-p1=0.0029 *5* and %Iβ-p2=0.0011 *2*; when γ and α decay are considered, this implies %γ=4.9%, %α=53.4, $\%p_0$=22.8, $\%p_1$=14.0 and $\%p_2$=4.9.
15.3×10^{3} *2*	$(3/2^{+})$		E(level): deduced from E_p. J^{π}: If populated in this (2005KnO2), the transition is allowed and π=−; however the evaluator expresses reservations upon consideration of the background near where perhaps three or four counts attributed to this broad state are identified. The evaluator discounts the merit of any J^{π} constraints based on the suggestion this is an allowed transition. %Iβ-p0=0.004 *3* and $\%p_1\leq0.0004$; this implies $\%p_0$=100.

† From Adopted Levels, except where noted.

‡ From fit to β-p spectrum from ^{13}O β^{+} decay (2005Kn02).

Four new states are suggested at $^{13}N^{*}$(11.3, 12.4, 13.1 and 13.7 MeV) (2023Bi03), but these are considered preliminary in the present evaluation.

ε,β^{+} radiations

E(decay)	E(level)	$I\beta^{+}$ †‡	Iε‡	Log *ft*	$I(\varepsilon+\beta^{+})$‡	Comments
(2.47×10^{3} *20*)	15300	0.004 *3*	$7.\times10^{-6}$ *7*	3.5 *5*	0.004 *3*	The deduced Iβ differs slightly from (2005Kn02) Iβ=0.004 *2*. $I\beta^{+}$: From 100%-Σ(decay to excited states).
(2705 *10*)	15064.56	0.019 *4*	2.1×10^{-5} *4*	3.15 *10*	0.019 *4*	
(4.51×10^{3} *10*)	13260	0.011 *3*		4.78 *14*	0.011 *3*	The $I_{p\_rel}(p_0)$=0.11 *9* and $I_{p\_rel}(p_1)\leq0.09$ given in (2005Kn02) are incompatible with %Iβ=0.011 *3* given in their table II; after considering Fig. 2, the evaluator takes $I_{p\_rel}(p_0)$=0.11 *3* rather than $I_{p\_rel}(p_0)$=0.11 *9*, and uncertainty from p_1 is neglected.
(6070 *32*)	11700	0.015 *4*		5.38 *12*	0.015 *4*	The deduced Iβ differs slightly from (2005Kn02) Iβ=0.015 *8*.
(8294 *13*)	9476	0.24 *2*		4.91 *4*	0.24 *2*	
(8852 *15*)	8918	0.96 *5*		4.463 *24*	0.96 *5*	The deduced Iβ differs slightly from (2005Kn02) Iβ=0.96 *4*.
(10394 *14*)	7376	0.24 *3*		5.44 *6*	0.24 *3*	The deduced Iβ differs slightly from (2005Kn02) Iβ=0.24 *2*.
(14270 *10*)	3500.4	9.8 *20*		4.55 *9*	9.8 *20*	
(17770 *10*)	0	88.7 *20*		4.084 *11*	88.7 *20*	

† Normalized to absolute $I_p(3.51)=I\beta(3.51)$=9.8% *20* from (1990As01).

‡ Absolute intensity per 100 decays.

^{1}H(^{13}N,p)

1992De19: ^{1}H(^{13}N,p) E≈8.2 MeV; analyzed ^{14}O resonance.

2007Te09: ^{1}H(^{13}N,p) E=0.4-3.3 MeV; measured $\sigma(E_p,\theta_p)$ for $\theta=-5°$ to 5° and 10° to 22°. Analyzed ^{14}O resonances via thick-target inverse kinematics study (TTIK).

2008Wa09, 2009Wa25, 2010Wa18: ^{1}H(^{13}N,p) $E_{c.m.}$=0.5-3.0 MeV. TTIK study of ^{14}O.

2015Be12: ^{13}N(p,p′) E<200 MeV. Cluster model analysis of proton scattering.

^{13}N Levels

E(level)
0

$^{1}H(^{14}O,^{13}N)$ 2015KaZU

2015KaZU: $^{1}H(^{14}O,^{13}N)$ E≈250 MeV/nucleon at the RIKEN/SHARAQ facility. Measured the $^{14}O(p,2p)$ reaction in inverse kinematics; $^{13}N(0, 3.5, 15)$ were populated.

See also (2015KaZY, 2018Go21, 2018At01, 2019Ph04).

2023Po05: $^{1}H(^{14}O,^{13}N)$ E=94 MeV/nucleon at RIKEN/RIBF; also studied $^{1}H(^{14}O,^{13}O)$. Measured the parallel momentum distributions and reaction cross sections. Analyzed quasifree knockout and other mechanisms. Deduced S=1.58 in DWIA analysis.

^{13}N Levels

E(level)	J^{π}†	C^2S†	Comments
0	$1/2^-$	1.51 *8*	σ=251 μb *14.*
3.5×10^3	$3/2^-$	2.02 *14*	σ=326 μb *22.*
15×10^3	$3/2^-$	0.65 *19*	T=3/2 σ=63 μb *18.*

† from DWIA analysis using the THREEDEE code (2015KaZU).

$^{2}H(^{14}O,^{3}He)$ **2013Fl01**

2013Fl01: XUNDL dataset compiled by TUNL (2013).

The $^{2}H(^{14}O,^{14}O)$ elastic scattering and $^{14}O(d,^{3}He)$ and $^{14}O(d,t)$ single nucleon transfer reactions were measured in inverse kinematics and spectroscopic factors, $C^{2}2S$, were deduced.

A 18.1 MeV/nucleon ^{14}O beam was produced at the GANIL/SPIRAL facility. The beam impinged on a 1.5 mg/cm^{2} CD_2 target (elastic scattering) or a 0.5 mg/cm^{2} target $(d,^{3}He)$ and the light recoil nuclei were detected in one of six MUST2 array telescopes: four covered $\theta_{cm}\approx15°-70°$ for the nucleon transfer reactions while the other two were near $\theta_{lab}\approx90°$ and were used to extend the elastic measurements.

The angular distributions were analyzed using the FRESCO code. Spectroscopic factors are deduced using both phenomenological and microscopic overlap functions and compared with literature results for $^{16}O(d,^{3}He)$, (d,t) and $^{18}O(d,^{3}He)$.

See further analysis in (2018Fl03).

^{13}N Levels

J,$C^{2}S$: From FRESCO coupled-reactions channel analysis in (2013Fl01).

E(level)	J^{π}	Comments
0.0	$1/2^{-}$	$C^{2}S$(phenomenological)=1.14 *16*(exp.) *15*(analysis), also see $C^{2}S$(microscopic)=1.58 *22*(exp.) *2*(analysis).
3.5×10^{3}	$3/2^{-}$	$C^{2}S$(phenomenological)=0.94 *19*(exp.) *7*(analysis), also see $C^{2}S$(microscopic)=1.00 *20*(exp.) *1*(analysis).

^{9}Be(^{10}C,^{13}N) **2009Ch38**

2009Ch38: XUNDL dataset compiled by TUNL (2009).

^{9}Be(^{10}C,^{13}N→p+3α) and ^{12}C(^{10}C,^{13}N→p+3α) at E(^{10}C)=10.7 MeV/nucleon at the Texas A&M MARS facility.

A set of four HiRA detectors covering θ=1.3° to 7.7° were used to measure resonance decay of particle-unbound ^{13}N states. The analysis identified states that p- and α-decay to ^{12}C and ^{9}B excited states.

^{13}N Levels

E(level)	J^{π}	$T_{1/2}$	Comments
10.36×10^{3}†			E(level): a doublet is identified at this energy in the Adopted Levels.
10.83×10^{3}†	($1/2^{-}$,$1/2^{+}$,$3/2^{-}$)		J^{π}: Suggested from systematics.
11.53×10^{3}†		<300 keV	
13.65×10^{3}‡# *1*		<300 keV	Approximate branching ratios (p+^{12}C(9.65))=48% and (α+^{9}B$_{g.s.}$)=52%.
16.6×10^{3}@ *1*		<350 keV	

† Decays to p+^{12}C(7.65).

‡ Decays to p+^{12}C(9.64).

Decays to α+^{9}B$_{g.s.}$

@ Decays to α+^{9}B(2.345).

^{9}Be(^{13}N,X) 1996Oz01

1996Oz01, 2001Oz04: ^{9}Be, C, ^{27}Al(^{13}N,^{13}N) E≈730 MeV. Measured interaction cross sections. Deduced proton, charge, neutron and matter radii of 2.32 fm *4*, 2.45 fm *4*, 2.30 fm *4* and 2.31 fm *4*, respectively.
2001Oz04: Glauber analysis of available breakup data.
2002Me12: Calculated charge changing σ on carbon, radius.
2017Ah08: Glauber model analysis of nuclear radii.

^{13}N Levels

E(level)
0

^{10}B(^{3}He,n),(^{3}He,X):res

1955Bi26: ^{10}B(^{3}He,X) E=900 keV; measured particle spectra.
1957Aj71: ^{10}B(^{3}He,n) E=2.54 and 3.60 MeV analyzed ^{12}N yields.
1963Pe10: ^{10}B(^{3}He,n) E=2-6.3 MeV; measured excitation function.
1972Be05: ^{10}B(^{3}He,p), ^{10}B(^{3}He,γ) E=4-14 MeV; measured $\sigma(E_{3He},E_{\gamma})$; reported no resonances.
1972Be56: ^{10}B(^{3}He,n), (^{3}He,p), (^{3}He,d), (^{3}He,α) E=11-19 MeV; measured $\sigma(E,E_n)$, $\sigma(E,E_p,\theta)$, $\sigma(E,E_d,\theta)$, for θ=90° and 150° and $\sigma(E,E_\alpha,\theta)$ for θ=30° to 150°. Analyzed existing data and deduced resonances at E_{res}= 5.6 MeV (α_0, d_0, $p_{0,2,3}$, pγ(12.71,15.11), n, γ_0), 8.5 MeV (α_0, p_0, pγ(12.71,15.11), γ_0), and 13.5 MeV ($\alpha_{1,2}$, $d_{4,5}$, γ_0).

See also:
1966Za01: ^{10}B(^{3}He,n) E=2.6, 3.0, 4.0, 5.8 MeV; measured $\sigma(E_n,\theta)$. Deduced reaction Q-value.
1968Ad03: ^{10}B(^{3}He,n) E=3 MeV; measured $\sigma(E_n)$. Deduced Q-value.
1970Bo39: ^{10}B(^{3}He,n) E=6.2 MeV, ^{10}B(^{3}He,n/p) E=10, 11 MeV, measured $\sigma(E_n,\theta)$, $\sigma(E_p,\theta)$.
1970Si16: ^{10}B(^{3}He,n) E=6.9-30.6 MeV; measured σ(E).
1974Fu11: ^{10}B(^{3}He,n) E=10.5-13 MeV; measured $\sigma(E_n,\theta)$.

^{13}N Levels

E(level)	Γ	$E_{^3He}$(res) (MeV)	Comments
25.9×10^{3}	1000 keV	5.6	(1972Be56) indicate a state near 26 MeV that decays via α_0, d_0,$p_{0,2,3}$,γ_0, (n).
$28.\times10^{3}$		8.5	(1972Be56) indicate a state near 28 MeV that decays via α_0,p_0,γ_0.
$32.\times10^{3}$	≈2 MeV	13.5	(1972Be56) indicate a state near 32 MeV that decays via α_1,$d_{4\&5}$,γ_0.

^{10}B(^{3}He,p)

1956Sc01: ^{10}B(^{3}He,p) E=1-5 MeV; measured $\sigma(\theta)$ for θ=0° and 90°. Deduced resonances at $E_{^3He}$(res)= 2.0, 3.7, 4.1, 4.6 MeV (E_x=23.2, 24.5, 24.8, 25.2 MeV) with Γ=0.5 MeV, 0.7 MeV, 120 keV and 150 keV, respectively.
1961Al27: ^{10}B(^{3}He,p$_2$)^{12}C*(7.65 MeV) E=2.2 MeV; measured p$\gamma\gamma$-coincidence.
1964Ku09: ^{10}B(^{3}He,p)^{12}C*(15.11 MeV) E(^{3}He)=1.8-5.5 MeV; measured σ(E) excitation function for E_γ=15.1 MeV. Deduced resonances at $E_{^3He}$(res)=2.85 and 5.2 MeV.
1966Ba01: ^{10}B(^{3}He,p)^{12}C*(15.11 MeV) E(^{3}He)=4.5-9 MeV; measured σ(E) excition function for E_γ=15.1 MeV across $E_x\approx$ 26 MeV region. No evidence of resonances.
1966Pa10: ^{10}B(^{3}He,p) E(^{3}He)=1.2-12 MeV; deduced resonances to ^{12}C(0,4.44,7.65,9.64 MeV) at $E_{^3He}$(res)=2.2, 3.7, 5.8 and 8.2 MeV, $E_x\approx$23.3, 24.5, 26.1, 28.0 MeV.
1972Be56: ^{10}B(^{3}He,n), (^{3}He,p), (^{3}He,d), (^{3}He,α) E=11-19 MeV; measured σ(E,E$_n$), σ(E,E$_p$,θ), σ(E,E$_d\theta$), for θ=90° and 150° and σ(E,E$_\alpha$,θ) for θ=30° to 150°. Analyzed existing data and deduced resonances at $E_{^3He}$(res)=5.6, 8.5, 13.5 MeV.

See also:
1972Al03: ^{10}B(^{3}He,p)^{12}C*(15.11 MeV) E=2.2 MeV; measured σ(E$_p$,E$_\gamma$).
1983Ch08: ^{10}B(^{3}He,p) E=15.75 MeV; measured σ(E$_p$), deduced Q-value.
1996Mc09: ^{10}B(^{3}He,p) E=2-4 MeV; measured σ(E$_p$,θ) for θ=90° and 135°.

^{13}N Levels

E(level)	J$^\pi$†	Γ	$E_{^3He}$(res) (MeV)	Comments
23.3×10^3		500 keV	2.2	$E_{^3He}$(res) (MeV): From (1966Pa10): (^{3}He,p$_0$). Γ: From (1956Sc01): $E_{^3He}$(res)=2.0 MeV.
23.83×10^3 *4*		346 keV *38*	2.85 5	$E_{^3He}$(res) (MeV),Γ: From (1964Ku09): (^{3}He,p) resonance to ^{12}C(15.1 MeV).
24.5×10^3		0.7 MeV	3.7	$E_{^3He}$(res) (MeV): From (1966Pa10): (^{3}He,p$_{0,1}$). Γ: From (1956Sc01): $E_{^3He}$(res)=3.7 MeV.
24.8×10^3		120 keV	4.1	$E_{^3He}$(res) (MeV),Γ: From (1956Sc01).
25.2×10^3?		150 keV	4.6	$E_{^3He}$(res) (MeV),Γ: From (1956Sc01).
25.64×10^3 *8*		184 keV *60*	5.2	$E_{^3He}$(res) (MeV),Γ: From (1964Ku09): (^{3}He,p) resonance to ^{12}C(15.1 MeV). (1966Ba01) suggest no evidence of a GDR at $E_x\approx$ 26 MeV.
26.1×10^3	≥3/2		5.8	$E_{^3He}$(res) (MeV): From (1966Pa10): (^{3}He,p) resonance to ^{12}C(0,4.44,9.6 MeV) See also (1972Be56) where $E_{^3He}$(res)=5.6 is reported for p$_{0,2,3}$.
28.0×10^3	≥7/2		8.2	$E_{^3He}$(res) (MeV): From (1966Pa10): (^{3}He,p$_0$) resonance See also (1972Be56) where $E_{^3He}$(res)=5.5 is reported for p$_0$.

† From analysis of angular distributions in (1966Pa10).

$^{10}B(^{3}He,d)$

1965Pa10: $^{10}B(^{3}He,d)$ E=3.5-10 MeV; measured $\sigma(\theta)$ for at E(^{3}He)=3.7, 5.8, 7.5, 9.8 MeV. Mainly focused on the prominent E_{res}=5.8 MeV resonance.

1972Be56: $^{10}B(^{3}He,n)$, (^{3}He,p), (^{3}He,d), (^{3}He,α) E=11-19 MeV; measured $\sigma(E,E_n)$, $\sigma(E,E_p,\theta)$, $\sigma(E,E_d,\theta)$, for θ=90° and 150° and $\sigma(E,E_\alpha,\theta)$ for θ=30° to 150°. Analyzed existing data and deduced resonances at E_{res}=5.6, 8.5, 13.5 MeV.

See also:

1967Ha20: $^{10}B(^{3}He,d)$ and $^{11}B(^{3}He,t)$ E=6-18 MeV, measured thick target yields; deduced σ(E). Discussed reaction mechanism.

1970Bo07: $^{10}B(^{3}He,d)$, $^{10}B(^{3}He,np)$ E=8, 10, 11 MeV; measured $\sigma(\theta(n+p))$, $\sigma(E_n,E_p)$. Deduced singlet deuteron emission.

1976Ga27: $^{10}B(^{3}He,d)$ E=1.5-4.6 MeV; measured σ(E).

^{13}N Levels

E(level)	$T_{1/2}$	$E_{^3He}$(res) (MeV)[†]	Comments
25.9×10^{3}		5.6	Γ: Broad. $E_{^3He}$(res) (MeV): From (1972Be56) for d_0. See also (1965Pa10) where $E_{^3He}$(res)=5.8 is reported.
32×10^{3}	≈2 MeV	13.5	$E_{^3He}$(res) (MeV): From (1972Be56) for $d_{4\&5}$.

[†] From (1972Be56).

^{10}B(^{3}He,^{3}He)

1987Ba34: ^{10}B(^{3}He,^{3}He) E=1.5-3.3 MeV; measured $\sigma(\theta)$ for θ=75.1°, 107.5° and 143.3°. R-matrix analysis. Deduced levels, level parameters.

See also:
Osgood: Phys. Lett. **10** (1964) 75: ^{10}Be(^{3}He,t) E=5-10.5 MeV; measured excitation function.
1970Du07: ^{10}B(^{3}He,^{3}He) E=4-18 MeV; measured σ(E,θ) for θ=15° to 160°; deduced optical model parameters.
1970Nu02: ^{10}B(^{3}He,^{3}He), (^{3}He,t) E=14 MeV; measured $\sigma(\theta)$ for θ=5° to 140°; deduced optical model parameters.
1972Bu30: ^{10}B(^{3}He,^{3}He) E=13-27 MeV; measured $\sigma(\theta)$ for θ=8° to 150°; deduced optical model parameters.
1979Go07: ^{10}B(^{3}He,^{3}He) E=46.1 MeV, measured $\sigma(\theta)$ for θ=10° to 160°; deduced optical model parameters.
1980Tr02: ^{10}B(^{3}He,^{3}He) E=41 MeV, measured $\sigma(\theta)$ for θ=20° to 85°; deduced optical model parameters.

^{13}N Levels

E(level)‡	J^{π}†	Γ†	L	$E_{^3He}$(res) (MeV)†	Comments
23.25×10^{3}	3/2^{-}	500 keV	1	2.10	Γ: Γ_{3He}=0.25 MeV (1987Ba34).
23.87×10^{3}	3/2^{-}	400 keV	1	2.90	Γ: Γ_{3He}=0.12 MeV (1987Ba34).
23.93×10^{3}	(11/2,13/2)$^{-}$	20 keV	3	2.975	Γ: Γ_{3He}=0.020 MeV (1987Ba34).
24.40×10^{3}	(5/2,7/2)$^{+}$	700 keV	0	3.60	Γ: Γ_{3He}=0.35 MeV (1987Ba34). E(level): The upper energy covered in (1987Ba34) was E(^{3}He)=3.3. The authors found an improved fit by including this resonance. Fit values should be considered tentative.

† From R-matrix analysis in (1987Ba34).
‡ Level energies are deduced using E_{res}(^{3}He) and ^{10}B, ^{3}He and ^{13}C masses from (2021Wa16: AME-2020). E_x=S(^{3}He)+$E_{c.m.}$(relativistic).

^{10}B(^{3}He,α)

1963Ea03: ^{10}B(^{3}He,α) E(^{3}He)=3-10.5 MeV; measured excitation function.
1965Pa05: ^{10}B(^{3}He,$\alpha_{0,1}$) E(^{3}He)=2-10 MeV; measured $\sigma(\theta=30°, 90°, 150°)$, focused on broad E_{res}=5.8 MeV group in α_0.
1970Gi04: ^{10}B(^{3}He,α) E(^{3}He)=1-10 MeV. Analysis included measurements on ^{12}C(pol. p,p). Measured $\sigma(E,\theta)$; Legendre polynomial analysis; deduced resonances at E_{res}=3, 5.8, and 8 MeV with Γ= 0.75 *25*, 1.35 *15* and 2.25 *25* MeV and $J^{\pi}=7/2^{-}$, $7/2^{-}$ and $9/2^{+}$, respectively.
1972Be56: ^{10}B(^{3}He,n), (^{3}He,p), (^{3}He,d), (^{3}He,α) E=11-19 MeV; measured $\sigma(E,E_n)$, $\sigma(E,E_p,\theta)$, $\sigma(E,E_d,\theta)$, for θ=90° and 150° and $\sigma(E,E_{\alpha},\theta)$ for θ=30° to 150°. Analyzed existing data and deduced resonances at E_{res}=5.6, 8.5, 13.5 MeV.

See also:
1955Al57: ^{10}B(^{3}He,α) E=900 keV. Measured E_{α}. First author is Bigham; details are given in (1959Al96).
1968Kr02: ^{10}B(^{3}He,α) E=2.49, 3.24, 3.74 MeV, Measured $\sigma(E_{\alpha},\theta)$ for θ=30° to 140°.
1971Sq03: ^{10}B(^{3}He,α) E=33.7 MeV; measured $\sigma(E_{\alpha},\theta)$ for θ=10° to 120°.
1986Ar14, 1988Ar05: ^{10}B(^{3}He,α) E=2.3, 5 MeV; measured $\alpha\alpha$-coin, $\sigma(\theta_{\alpha 1},\theta_{\alpha 2})$.

^{13}N Levels

E(level)	J^{π}	Γ	$E_{^3He}$(res) (MeV)	Comments
24×10^{3}	$7/2^{-}$	0.75 MeV *25*	3	$E_{^3He}$(res) (MeV),J^{π},Γ: From R-matrix analysis in (1970Gi04). Γ from Γ=0.5-1.0 MeV.
26.1×10^{3}	$7/2^{-}$	1.35 MeV *15*	5.8	$E_{^3He}$(res) (MeV): From (1965Pa05, 1970Gi04). J^{π},Γ: From R-matrix analysis in (1970Gi04). Γ from 1.2-1.5 MeV. Γ: Broad (1965Pa05) See also (1972Be56) where $E_{^3He}$(res)=5.6 is reported for α_0.
28×10^{3}	$9/2^{+}$	2.25 MeV *25*	8	$E_{^3He}$(res) (MeV),J^{π},Γ: From R-matrix analysis in (1970Gi04). Γ from 2.0-2.5 MeV See also (1972Be56) where $E_{^3He}$(res)=8.5 is reported for α_0.
32×10^{3}		≈2 MeV	13.5	$E_{^3He}$(res) (MeV): From (1972Be56) for α_1.

^{10}B(α,n) 1973Va25

1935Ru01: ^{10}B(α,n). Measured ^{13}N $T_{1/2}\approx$14 minutes.
A.R. Quinton, et al., Phys. Rev. 101 (1956) 669: ^{10}B(α,n) E=8.0 MeV; measured states at ^{13}N(2.4 MeV *3*, 3.6 *3*, (4.3 *3*), 5.0 3).
1973Va25: ^{10}B(α,n) E=1.0-5.0 MeV. Studied excitation functions and deduced ^{14}N levels and level parameters.
1975Wi04: ^{10}B(α,n) E=2-10 MeV. Studied excitation functions and deduced ^{14}N levels and level parameters.
1976Du08: ^{10}B(α,$n_{0,1}$) E=18-20 MeV; measured σ(E,θ).
1977Li19: ^{10}B(α,n); analyzed σ(E<7 MeV).
1979Ba48: ^{10}B(α,n) E=3-7.5 MeV; measured neutron yield, deduced σ(E).
1979Gi09: ^{10}B(α,n) E=4-14 MeV; measured σ(E) via activation technique.
1983Ro26: ^{10}B(α,n) E=3.2-14 MeV; measured yield.
2019Li42: ^{10}B(α,n_0) E=2.2-4.9 MeV; measured σ(E,θ), analyzed available data.
2020Li08: ^{10}B(α,n_0) E=575-2522 keV. Measured σ(θ), analyzed available data. Discussed astrophysical relevance.
2021Wi02: ^{10}B(α,n): Analyzed available σ(E_α,θ) data for astrophysically relevant reactions.
2023Gu04: ^{10}B(α,n),(α,X) E=0.21-1.4 MeV; R-matrix analysis of available data.

^{13}N Levels

E(level)[†]	$T_{1/2}$	Comments
0	≈14 min	$T_{1/2}$: From (1935Ru01).
2366		
3.51×10^3		
3.55×10^3		

[†] From (1973Va25).

^{10}B(^{6}Li,t)

1966Mc05: ^{10}B(^{6}Li,t): $E_{c.m.}$=3.05 MeV, measured angular distributions and σ to ^{13}N(0,2.36, 3.51+3.56,6.38) $\theta\approx10°$ to 150°.
1974Ho06: ^{10}B(^{6}Li,t) E=18 MeV; measured $\sigma(E_t,\theta)$), Deduced E, Γ, J, p. Analyzed ^{13}C analog pairs from comparison with (^{6}Li,^{3}He). They associate ^{13}N(7.17,9.00,9.52,10.35+10.36) with ^{13}C(7.49,9.50,9.90,10.81+10.75), respectively.

^{13}N Levels

E(level)[†]	$T_{1/2}$[†]	Comments
0[‡]		$\sigma_{tot.}$=0.47 (1966Mc05).
2.36×10^{3}[‡]		$\sigma_{tot.}$=0.30 (1966Mc05).
3.51×10^{3}[‡]		$\sigma_{tot.}$(3.51+3.56)=2.02 (1966Mc05).
3.56×10^{3}[‡]		
6.38×10^{3}[‡]		$\sigma_{tot.}$=1.21 (1966Mc05).
6.90×10^{3}	120 keV *30*	
7.17×10^{3}		
7.38×10^{3}	70 keV *30*	
8.92×10^{3}?		E(level): The authors suggest this level may not be strongly populated in this reaction since its ^{13}C(8.86) analog is weakly populated in (^{6}Li,^{3}He). This level cannot be resolved from ^{13}N(9.00).
9.00×10^{3}	280 keV *30*	
9.52×10^{3}		
10.35×10^{3}		
10.35×10^{3}		
10.78×10^{3}		
11.65×10^{3}		

[†] From (1974Ho06).
[‡] Reported in (1966Mc05).

^{10}B(^{9}Be,^{6}He)

1992Co05: ^{10}B(^{9}Be,^{6}He) E=40 MeV; measured $\sigma(\theta)$ for θ=10° to 30°.

^{13}N Levels

E(level)[†]
0
3.5×10^{3}
6.38×10^{3}
7.16×10^{3}
9.00×10^{3}
10.36×10^{3}

[†] From (1992Co05).

^{11}B(^{3}He,n),^{11}B(^{3}He,nγ)

1966Di04: ^{11}B(^{3}He,n$_0$) E=1.5-5.5 MeV; measured σ(E,θ) for $\theta\approx0°$ to 170°.
1966Ch18: ^{11}B(^{3}He,nγ) E=1.23-2.00 MeV; measured n-p, n-γ coincidences. Explained erronious identification of ^{13}C(6.27,5.56) states.
1968Co27: ^{11}B(^{3}He,nγ) E=7.3 MeV; measured decay modes of ^{13}N(15.07 MeV). Analyzed E$_\gamma$, I$_\gamma$, pγ-, nγ-coincidences. Deduced level energy, γ, IAS γ decay. Deduced $\Gamma_{\gamma0}/\Gamma_{p0}$=0.12 *2* from; when combined with $\Gamma_p\Gamma_{\gamma0}/\Gamma$ from (1968Di04) and Γ_{p0}/Γ from (Adelberger, BAPS 12, 1194 (1967)) this gives $\Gamma_{\gamma0}/\Gamma$=0.024 *5* and Γ=1.13 keV *3*. Reviewed other IAS decay branches.
1969Ad01,1969Ad02: ^{11}B(^{3}He,n) E=7-13.5 MeV, measured σ(E$_n$,θ). Deduced level energies, T, Γ, J, π, L, discussed T=3/2 states (1969Ad02). Found Γ_{p0}/Γ=0.202 *20* and Γ_{p1}/Γ=0.121 *15* (1969Ad01). When combined with results from (1968Di04, 1969Le18,1968Co27) this implies Γ=1.17 keV *12*, $\Gamma_{\gamma0}$=27 keV *5*, Γ_{p0}=0.24 keV *5* and Γ_{p1}=0.14 keV *3*.
1971Hs03: ^{11}B(^{3}He,n) E=4.7, 6.1, 6.49 MeV; measured σ(E,E$_n$,θ) for θ=0° to 150°. Deduced Q-value to levels, level energies, L, J, Γ.
1973Ad02: ^{11}B(^{3}He,n) E=7.0 MeV. Detected neutrons and decay protons from ^{13}N(15.07) to ^{12}C(0,4.4,7.65). Deduced Γ_p/Γ and Γ_α/Γ branching ratios and partial widths. Referenced E$_x$=15.066 MeV 4 from the (1968Ce01) review.
1975Ma21: ^{11}B(^{3}He,nγ) Measured pγ-, nγ-coincidences with θ_γ=125° and θ_n=0°. For ^{13}N(15.07) deduced $\Gamma_p\Gamma_{\gamma0}/\Gamma$=5.79 eV *20* from ^{12}C(p,γ) measurements. They combine results with (1973Ad02) to obtain $\Gamma_{\gamma0}$=24.5 eV *15*. Using the E2/M1 intensity ratio they measured (=0.013 *5*) they found Γγ0(M1)=24.2 eV *15* and Γγ0(E2)=0.32 eV *12*. They determined relative transition strengths for γ_0, γ_1 and γ_2. Lastly, they discussed ^{13}C/^{13}N isotensor asymmetries.
1977Da18: ^{11}B(^{3}He,n$_0$) E=5-12 MeV; measured σ(E,E$_n$,θ).
1977Ma16: ^{11}B(^{3}He,nγ) E=7.0 MeV; measured nγ-coincidence. θ_γ=125°. Deduced $\Gamma_{\gamma0}/\Gamma_{p0}$=0.121 *11*. Combined their results with others to find Γ=0.86 keV *12*.
1977Os08: ^{11}B(^{3}He,n) E=1.7, 1.9 MeV; analyzed 2-p stripping reactions and spectroscopic factors.
1979Os10: ^{11}B(^{3}He,n$_0$) E=0.9-1.9 MeV; measured σ(θ). deduced S using different models.

^{13}N Levels

E(level)†	J$^{\pi\dagger}$	Γ	L†	Comments
0	1/2$^-$		2	
2358 *10*	1/2$^+$		1	
3502 *10*	3/2$^-$		0+2	
3550 *18*				
6353 *9*	5/2$^+$		1+3	
6875 *10*	3/2$^+$		1+3	
7145 *9*	7/2$^+$		3+5	
7363 *8*	5/2$^-$		2+4	
8200 *22*				
8918 *11*				
9476 *8*	3/2$^-$		0+2	E(level): See also E$_x$=9.52 MeV 2 (1966Ch18).
10381 *8*	5/2$^-$		2+4	E(level): See also E$_x$=10.35 MeV 2 (1966Ch18).
10833 *9*				
11530 *12*				
11878 *12*	3/2$^-$		0+2	
12558 *23*		>400 keV		Γ: From (1971Hs03).
12937 *24*		>400 keV		Γ: From (1971Hs03).
15068 *8*	3/2$^-$	<15 keV	0	T=3/2 E(level),Γ,J$^\pi$,L: and T from (1969Ad02). (1968Co27): $\Gamma_{\gamma0}/\Gamma_{p0}$=0.12 *2*. (1969Ad02): Γ<15 keV; Γ_{p0}/Γ=0.202 *20* and Γ_{p1}/Γ=0.121 *15* from (1969Ad01). (1973Ad02) Measured Branching ratios to ^{12}C and ^{9}B states. Assuming Γ=0.82 keV *20* from (1973Ad02,1968Co27,1968Di04), ^{12}C(0)=23.6% *12* and Γ_{p0}=0.19 keV *5*, ^{12}C(4.44)=15.0% *10* and Γ_{p1}=0.12 keV *3*, ^{12}C(7.65)=5.3% *15* and Γ_{p2}=0.043 keV *16*, ^{9}B(0)=4.9% *27* and $\Gamma_{\alpha0}$=0.040 keV *24*, ^{9}B(1.6)=3.9% *39* and $\Gamma_{\alpha1}$=0.032 keV *32*, ^{9}B(2.36)=7.2% *45* and $\Gamma_{\alpha2}$=0.059 keV *40*, $\Gamma_{\gamma0}$=23.3 eV *36*.

Continued on next page (footnotes at end of table)

^{11}B(^{3}He,n),^{11}B(^{3}He,nγ) (continued)

^{13}N Levels (continued)

E(level)†	Γ	Comments
		(1975Ma21):$\Gamma_p\Gamma_{\gamma 0}/\Gamma$=5.79 eV *20* and 0.013 *5* for the E2/M1 intensity ratio from ^{12}C(p,γ). In (1975Ma21) $\Gamma_{\gamma 0}$=24.5 eV *15* and reduced M1 and E2 transition strengths are deduced after making several assumptions. Using relative intensities measured via ^{11}B(^{3}He,nγ) and with θ_γ=125° and θ_n=0°, they obtained $\Gamma\gamma$0(M1)=24.2 eV *15*, $\Gamma\gamma$0(E2)=0.32 eV *12*, $\Gamma\gamma$1(E1)$\leq$2.18 eV *30* and $\Gamma\gamma$2(M1)=19.6 eV *14*. (1977Ma16): $\Gamma_{\gamma 0}/\Gamma_{p0}$=0.121 *11*.
18.44×10^{3} *4*		T=3/2 E(level),T: and T from (1969Ad02).
18.98×10^{3} *2*	40 keV *20*	T=3/2 E(level),Γ,T: and T from (1969Ad02).

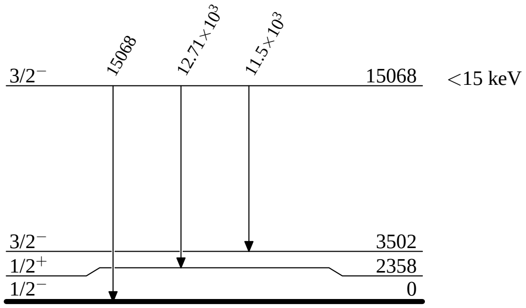
† From DWBA analysis in (1971Hs03), except where noted.

γ(^{13}N)

E$_\gamma$	E$_i$(level)	J$_i^\pi$	E$_f$	J$_f^\pi$	Comments
11.5×10^{3}	15068	3/2$^-$	3502	3/2$^-$	(1975Ma21: with ^{12}C(pγ) data): Γ_γ(M1)=19.6 eV *14* and B(M1)W=0.613 *44*.
12.71×10^{3}	15068	3/2$^-$	2358	1/2$^+$	(1975Ma21: with ^{12}C(p,γ) data): Γ_γ(E1) $\leq$ 2.82 eV *30* and B(E1)W $\leq$ 03.69E-3 *39*.
15068	15068	3/2$^-$	0	1/2$^-$	(1973Ad02): Combined their Γ_{p0}/Γ=0.236 *12* value with $\Gamma_{p0}\Gamma_{\gamma 0}/\Gamma$=5.5 eV *8* from (1968Di04) and obtained $\Gamma_{\gamma 0}^{M1}$=23.0 eV *36* and $\Gamma_{\gamma 0}$=23.3 eV *36*. (1975Ma21: with ^{12}C(p,γ) data $\Gamma_{p0}\Gamma_{\gamma 0}/\Gamma$=5.79 eV *20* and the Γ_{p0}/Γ value from (1973Ad02)): Γ_γ(M1)=24.2 eV *15*, Γ_γ(E2)=0.32 eV *12* and B(M1)W=0.342 *21* and B(E2)W=0.28 *11*; I(E2/M1)=0.013 *5* See discussion in (1975Ku21).

^{11}B(^{3}He,n),^{11}B(^{3}He,nγ)

Level Scheme



$^{13}_{7}N_{6}$

^{12}C(p,γ)

1949Fo18: ^{12}C(p,γ) E≈456 keV; measured resonance γ-ray production. Deduced E$_{p}$=456.0 keV *20*, $\omega\gamma$=0.63 and Γ=35 keV.

1950Ba89: E=128-202 keV; measured activation σ.

1950Ha78: E=88-128 keV; measured activation σ.

1951Se67: E<2.5 MeV; measured thick target activation yield. Deduced resonances at 0.45 MeV and 1698 keV *5*; the later resonance has Γ_{lab}=70 keV *10*.

1952Se01: ^{12}C(p,γ) E=0.4-2.7 MeV; measured Eγ, Iγ. Deduced E$_{res}$=0.45 and 1.70 MeV with Γ_{lab}=35 and 70 keV, and $\omega\gamma$=0.67 and 1.39 eV, resp.

1953Ch34: ^{12}C(p,γ) measured T$_{1/2}$=602.9 s *19*.

1953Hu18: ^{12}C(p,γ) E≈450 keV; measured γ rays with a Geiger-Muller counter. Deduced E$_{res}$=456.8 keV *5* with $\Gamma_{lab.}$=39.5 keV *10*.

1954Wo09: ^{12}C(p,γ) E=1-3 MeV; measured E$_{\gamma}$, I$_{\gamma}$ with a NaI(Tl) counter at θ=0° and 90°. Deduced resonance at E$_{res.}$=1.7 MeV; also found $\Gamma_{\gamma1}$=0.04 eV and compared with $\Gamma_{\gamma0}$=0.7 eV from (1952Se01).

1955Co57: E=5, 11 MeV; measured activation σ.

1957La15: E=85-130 keV; measured σ(E) for capture γ ray.

1957De22: ^{12}C(p,γ) and (d,n); measured activation cross sections in the few hundred keV range. Deduced T$_{1/2}$=10.02 min *10*.

1958Ar15: ^{12}C(p,γ); measured ^{13}N decay. Deduced T$_{1/2}$=597.6 s *18*.

1963Fi07: ^{12}C(p,$\gamma_{0,2}$) E=10-48.5 MeV; measured $\sigma(\theta)$ for θ=90°. Identified peaks in γ_{0} associated with T=1/2 states at E$_{x}$=13, 20, (24), and 32.5 MeV; in addition γ_{2} capture to the ^{13}N*(3.5 MeV) indicated a resonance at E$_{x}$=24.5 MeV.

1960He14, 1963VoZZ: ^{12}C(p,γ) E<700 keV, measured σ(E). Deduced first excited state at E$_{p}$=462 keV with θ^{2}_{p}=0.567 and $\omega\Gamma_{\gamma}$=0.63 eV (see 1992Hinds) and Γ_{lab}=35 keV.

1963Yo06: ^{12}C(p,γ) E=1.5-2.0 MeV; measured E$_{\gamma}$, I$_{\gamma}$ at θ=0° to 135°. Deduced no participation of ^{13}N(3.56: 5/2^{+}). Upper limit is σ=0.16 μb ($\omega\gamma$<0.006 eV) vs. σ=37 μb ($\omega\gamma$=1.06 eV) for ^{13}N(3.51: 3/2^{-}). Analyzed angular distributions.

1968Bl17: ^{12}C(p,γ) E<5 MeV; measured σ(E,E$_{\gamma}$) using Ge(Li) detectors. Reported resonance energies of E$_{res}$=459 keV and 1.697 MeV and $\Gamma_{c.m.}$=33.7 keV *20* and 61.9 keV *40* for ^{13}N(2365,3502). (Uncertainty given in (1970Aj04) from Blatt, BAPS 13 (1968) 173),

1968Di04: ^{12}C(p,γ) E$_{x}$ ≈ 15.07 MeV; measured decay γ rays with Li(Ge). For ^{13}N(15.07) deduced $\Gamma_{p}\Gamma_{\gamma}/\Gamma$=5.5 eV *8*, J^{π}=3/2^{-}, T=3/2 and amplitude ratio E2/M1=−0.095 *7*. Branching ratios $\Gamma_{\gamma1}/\Gamma_{\gamma0}$<0.14 and ($\Gamma_{\gamma2}$+$\Gamma_{\gamma3}$)/$\Gamma_{\gamma0}$=0.84 *8*.

1968Ri16: ^{12}C(p,γ) E≈0.459 MeV; measured Γ_{γ}(2.37 MeV)=0.45 eV *5* and Γ_{lab}=34 keV *1* via DSAM, which implies τ=1.47 fsec *15*. A private communication in (1973Cl04) establishes this Γ is a lab value. Analysis given in (1992Hinds) indicates Γ_{γ} is a c.m. value.

1970Di09: ^{12}C(p,γ) E=14.2 MeV, characterized detector array with decay from 15.07 MeV level.

1972Ha32: ^{12}C(p,γ_{0}) E=8.6-16.3 MeV; measured σ(E). Deduced destructive interference, Deduced resonances, widths. States are reported at E$_{res}$=9.01, 10.62, 13.12 and 14.50 MeV (E$_{x}$=10.25, 11.74, 14.04 and 15.31 MeV) with Γ=280 keV *100*, 220 keV *50*, 170 keV *20* and 380 keV *150* (assumed lab in 1981Aj01), and with $\Gamma_{p0}\Gamma_{\gamma0}$=0.17 keV^{2} *9*, 0.28 keV^{2} *10*, 0.47 keV^{2} *12* and 0.21 keV^{2} *8*, respectively.

1973Cl14: ^{12}C(p,γ) E=480, 600, 1750 keV; measured σ(E$_{p}$,E$_{\gamma}$).

1973Me12: ^{12}C(p,γ) E=9-24 MeV; measured σ(Eγ). Deduced low-energy states as in (1972Ha32). Reported at E$_{res}$=9.01 MeV *15*, 10.62 MeV *12*, 12.5 MeV *2*, 13.12 MeV *9* and 14.5 MeV *2* (E$_{x}$=10.25, 11.74, 13.5, 14.04 and 15.31). The Γ and $\Gamma_{p0}\Gamma_{\gamma0}$ are also given along with $\Gamma_{\gamma0}$≥0.6 eV, ≈4.2 eV, 3.7 eV *10* and ≥0.5 eV, respectively. Various assumptions are described in finding $\Gamma_{\gamma0}$. Also analyzed ^{12}C(p,p$'\gamma_{12.71,15.11}$) yield curves where resonances at E$_{p}$=15.27, 19.35, 20.55 and 22.2 MeV were found (see ^{12}C(p,p$'$)).

1974Al16: ^{12}C(p,γ) E=1.65 GeV, Measured σ(E$_{\gamma}$).

1974Bl06: ^{12}C(p,γ) E=600 keV; measured I$_{\gamma}$, E$_{\gamma}$. Deduced ^{13}N(2364) resonance width $\Gamma_{c.m.}$=33.3 keV *18*.

1974Ro29: ^{12}C(p,γ) E=150-3000 keV, Measured σ(E), E$_{\gamma}$, I$_{\gamma}$, for θ=0° and 90°. Deduced levels at E$_{p}$=457 keV *1* and 1699 keV *2* with Γ=39 keV *2* and 65 keV *3*, respectively. Also C^{2}S(0,2366,3512,3547)=0.49 *15*(l=1), 1.02 *15*(l=0), <0.5(l=1) and ≤1.0(l=2), respectively, and δ_{R}(E2/M1)(3.5 MeV)=−0.09 *2*. Lastly, the branching ratio I$_{\gamma}$(3512→2366)=8% *1* was obtained. An associated lab report (Fox, Polchinski, Rolfs and Tombrello, LAP-144 (1975)) indicates $\Gamma_{\gamma0}$=0.64 eV *7* but insufficient details can be understood.

1975Ma21: ^{12}C(p,γ) E=14.2-14.3 MeV; measured resonance γ0 yield from ^{13}N(15.07). Deduced $\Gamma_{p0}\Gamma_{\gamma0}/\Gamma$=5.79 eV; deduced E2/M1 intensity ratio of 0.013 *5*. In (1975Ma21) Γ_{γ} and reduced transition strengths are deduced from ^{11}B(^{3}He,nγ) data after making several assumptions.

1976Be28: ^{12}C(p,γ) E=9-24 MeV; measured σ((E$_{p}$,θ) for θ≈45° to 135°. Deduced resonances structures in γ_{0} capture at E$_{p}$=9.01 MeV *15* with Γ≈300 keV, E$_{p}$=17.5 MeV with Γ≈1 MeV, E$_{x}$=20.8 MeV with Γ≈4 MeV and E$_{p}$=23 MeV with Γ≈1

^{12}C(p,γ) (continued)

MeV. The discussion was sometimes ambiguous when listing E_p vs. E_x. See additional reference to E_x=11.74. Their results for capture to excited states are complicated by high backgrounds. For γ_1 capture they find a resonance at $E_p\approx$21.8 MeV, which gives $E_x\approx$22 MeV; (1981Aj01) gave $E_x\approx$20 MeV for this peak, but it is clear in Fig. 10 and related discussion. Further, in (1981Aj01) an E_p=23 MeV group is connected to E_x=23 MeV (accepted in the Adopted Levels), but this corresponds better to the E_x=23.3 MeV state. The authors report no strong resonances in γ_{2+3} They discuss other relevant measurements.

1976Fe11: ^{12}C(p,p′γ(4.44,12.7,15.1)), ^{12}C(p,$\gamma_{0,2,3}$) E=16-40 MeV; measured σ(E). Observed resonances at E_p=20, 27, 32 MeV ($E_x\approx$20.4, 26.8, 31.5 MeV). The 20 MeV resonance is seen in all channels, while the 27 MeV state is not seen in capture reactions. The 32 MeV resonance is seen in ^{12}C(p,p′γ(4.44)) and in the capture reactions.

1977Fr20: ^{12}C(p,γ) E=150-350 keV; measured yield, deduced Q=1943.31 keV *32*, calibrated accelerator.

1977He26: ^{12}C(p,γ) E$\approx$774 keV; measured γ-ray spectrum, deduced Q=1944.01 keV *22*.

1977Ma16: ^{12}C(p,γ) E$\approx$14.25 MeV; measured thick target yield at θ=125°. Combined results with ^{11}B(^{3}He,n). Deduced $\Gamma_{p0}\Gamma_{\gamma0}/\Gamma$=5.79 eV *20*. Also determined E2/M1 intensity ratio of 0.013 *5*. Matches (1975Ma21) analysis. Significant discussion of ^{13}N parameters when additional observables are considered.

1979Ko05: ^{12}C(p,γ) E=40 MeV; measured E_γ, I_γ. Deduced unconfirmed evidence excited states around E_x=8.1, 12, 16.1 MeV.

1980An40: ^{12}C(p,γ) E=0.8-2 MeV; measured thick target yield via activation technique. Deduced T_{mean}=862.76 sec *88*.

1980He04: ^{12}C(vec p,γ_0)) E=10-17 MeV; measured σ(E_p,θ(γ)) for θ=43° to 137°, deduced asymmetry. Deduced (E1/E2) ratios in σ(E) in energy region below the GDR.

1980Sn01: ^{12}C(vec p,γ) E=5-30 MeV; measured σ(E) Deduced GDR, T=3/2 M1(E2) interference.

1984Bl10: ^{12}C(p.$\gamma_{0,2,3}$), (vec p,γ) E=24-80 MeV; measured σ(θ), analyzing power vs θ for θ=30° to 150°. Deduced reaction mechanism.

1984Po13: ^{12}C(p,γ) E=1.5-2 MeV; measured σ(E_γ,E). Deduced coherent energy width effect.

1985Br06: ^{12}C(vec p,γ) E=1.6-1.8 MeV; measured A(E,θ), γ-ray yield vs E. R-Matrix analysis in region of ^{13}N(3.5 MeV).

1985Ki07: ^{12}C(p,γ) E=2.4-4.2 MeV; measured thick target yields.

1985Wa12: ^{12}C(p,γ) E=14.26 MeV; measured E_γ, I_γ, analyzed NaI response function to high-energy γ rays.

1986Ai04: ^{12}C(p,γ) E<14.7 MeV; measured σ via activation technique.

1987La11: ^{12}C(p,γ) E=40, 65, 85 MeV measured E_γ, I_γ; deduced σ(E).

1987Po09: ^{12}C(p,γ) E=400-2500 keV; measured E_γ, I_γ σ(E_γ,θ=90°). Observed decay radiations from ^{13}N(2316, 3512) from thick target study. Found a deviation from expected γ-ray energies from E_x=3512 level. E_γ=1123 and 3500 keV *2* were observed while E_γ=1146 and 3512 keV were expected. Continued with a 15 μg/cm^2 target and measured E_γ at θ=0° and 90°. Found Doppler shifted E_γ(0°)=3517 keV *2* and E_γ(90°)=3500 keV *2*; A more detailed study is given in (1991Po18).

1987Re11: ^{12}C(p,γ) E=140 MeV; measured σ(E_γ,θ).

1987Se13: ^{12}C(p,γ) E=220-340 keV; measured γ-ray yields.

1988Ha04: ^{12}C(vec p,γ) E=20-100 MeV; measured $E_{\gamma0}$, I_γ, σ(E,θ), A_y(θ) for θ=30° to 150°. Deduced GDR at E_x=20.40 MeV with Γ=3.5 MeV.

1989Ki21: ^{12}C(p,γ) E=1.5-1.9 MeV; measured E_γ, I_γ, γ yield vs E. Deduced E_{res}=1688.7 keV *7* with E_γ=3501.5 keV, and Γ=65.6 keV *18* for a thick target measurement. E_{res}=1689 keV *2* was deduced for a thin target measurement.

1990Co34: ^{12}C(p,$\gamma_{0,2+3}$) E=27 MeV; measured E_γ.

1991Ca25: ^{12}C(p,γ) E=14.24 MeV; measured γ-ray spectrum.

1991Co07: ^{12}C(p,γ) E_x=19.6-47 MeV; measured σ(E,θ), deduced dipole resonances for γ_0 at E_x=14.0, 20.6, 32.0 MeV with Γ=12.0, 1.2, 10.0 MeV, respectively; for γ_{2+3} at E_x=24.5 and 35.0 with Γ=3.5, 14.0 MeV, respectively.

1991Po18: ^{12}C(p,γ) E=1.69-1.75 MeV; study of the $E_x\approx$3500 keV region where E_p, E_γ and I_γ were measured for θ=0° to 90°. The aim is to resolve discrepancies between identification of the $E_x\approx$3500 keV state at E_{res}=1688 keV (1987Po09,1989Ki21) vs other studies that found E_{res}=1699 keV (see 1986Aj01). Target thicknesses varying from 20-50 μg/cm^2 along with a thick 2mm thick plate of carbon were used to measure the excitation function and produced γ rays. Similarly, on the thick target, the Doppler shifted spectrum was measured over θ=0° to 140°. Considering all measurement, E_{res}=1686 keV 1 was found. Widths of Γ=63.6 keV *15* and Γ=62.2 keV *15* were deduced for the different measurements (referenced as half-width in E_p spectrum so assumed as lab frame). Additionally, an anomolous slope was observed in the Doppler function.

1991Zh31: ^{12}C(p.γ) E=0.6-0.9 MeV; measured E_γ, I_γ analyzed suitability for PIGE analysis.

1992Hinds: (Aust. J. Phys., 1992 45 749): ^{12}C(p.γ) E=400-480 keV; measured σ(E) at Canberra. Deduced resonance at $E_p\approx$424 with $\Gamma_{c.m.}\approx$36.4 and Γ_γ=0.53 eV *5*. Compared with prior works and discussed astrophysical reaction rates.

1994Zu05: ^{12}C(p,γ) E=40-54 MeV; measured σ(E,θ) for θ=30° to 148°. Observed capture to states up to 11 MeV, i.e. E_x=0, 2.37. 3.50+3.55, 6.36, 7.38, 7.90, 9.0, 10.36 MeV. Analyzed reaction mechanism.

1997Br19: ^{12}C(p,γ_{0-3}) E=98, 176 MeV; measured σ(θ) for $\theta\approx$40°−100°: γ_{3+4} unresolved. Analyzed reaction mechanism.

^{12}C(p,γ) (continued)

1997Ko24: ^{12}C(p,γ) E=72,140 MeV; measured $\sigma(E_\gamma,\theta)$. Analyzed γ emission.

2023Sk02, 2023SkZZ: ^{12}C(p,γ) E=320-620 keV; measured σ(E) at Dresden. Deduced $E_{c.m.}$=426.1 keV *4*, Γ_p=35.6 keV *2* and Γ_γ=0.48 eV *3* from an R-matrix analysis.

2023Cs01: ^{12}C(p,γ) E$\approx$460 keV and 1.69 MeV; measured $\sigma(E,\theta(\gamma))$ for θ=0°, 90° and 112° at Atomki in Hungary. Analyzed excitation with a Breit-Wigner shape and deduced resonances at E_p=459.8 keV *8* and 1685.1 keV *7* with Γ_{lab}=38.2 keV *5* and 57.6 keV *8*, respectively.

2023Ke11: ^{12}C(p,γ). Measured $\sigma(E,\theta(\gamma))$ for E=1-2.5 and θ=0° to $\approx$130° at Notre Dame using a thin-target approach and measured σ(E) using thick-target activation methods. At Bochum they measure $\sigma(E,\theta(\gamma))$ around the $E_p\approx$460 keV resonance. The analysis is a continuation of (2010Az01), where (p,γ) data (1974Ro29,1963VoZZ) and (pol. p,p) data of (1976Me22) were reanalyzed using the AZURE R-matrix code; in (2023Ke11) additional (p,γ) data from (Hinds,1963Yo31,2008Bu19) have been added along with the new (2023Ke11) data. The data of (1974Ro29) were not considered. A global R-matrix analysis using AZURE found resonance parameters of E_p=460.3 keV *5* with $J^\pi=1/2^+$, Γ=34.0 keV *2* and Γ_γ=0.48 eV *3*, E_p=1688.8 keV *8* with $J^\pi=3/2^-$, Γ=55.2 keV *3*, Γ_γ(M1)=0.49 eV *3* and Γ_γ(E2)=7.2×10-4 *11*, and E_p=1735.5 keV *5* with $J^\pi=5/2^+$, and Γ=49.0 keV *5*.

2023Gy02: ^{12}C(p,γ) E=0.3-1.9 MeV; measured σ(E) using activation techniques at ATOMKI. Discussed astrophysical rate.

Theoretical analysis:

1977Ba29: ^{12}C(p,γ) E=low, theoretical analysis of direct capture to ^{13}N(2366).

1980Ba54: ^{12}C(p,γ) Shell model analysis of E=100-800 keV capture.

1982Ph01: ^{12}C(p,γ) single-particle model of capture to continuum states.

1984Se16: ^{12}C(vec p,$\gamma_{0,3}$) analyzed $\sigma(\theta)$, A_y and b_2 coefficients to determine *j* sensitivity.

1990Lo20: ^{12}C(p,γ) E=40 MeV, calculated $A_y(\theta)$).

1992Lo01: Theory: E=40 MeV; analyzed angular distributions.

1993Ho06: Theory: analyzed giant resonance region.

1997Du09: Theory: GCM analysis of cluster effects in the ^{12}C+p system.

2000Li06: ^{12}C(p,γ) E=98, 176 MeV. Calculated $\sigma(\theta)$, analyzed reaction mechanism.

2010Hu11: ^{12}C(p,γ). Theoretical analysis of reaction mechanism.

2015Ti03: ^{12}C(p,γ). Shell model analysis of ^{13}N(3.5: $3/2^-$) proton resonance.

2018Ti06: Potential model analysis of direct capture reaction.

2020Br14: R-matrix analysis of ^{12}C(p,γ).

Astrophysically relevant:

1937Be10, 1939Be01: Early review of energy production in stars.

1979Ro12: Analyzed astrophysical reaction rates.

1980Ba27: ^{12}C(p,γ) 100-800 keV; calculated σ(E).

1984Ma36: ^{12}C(p,γ) E$\leq$1 MeV; analyzed data from (1974Ro29) with input from (Barker&Ferdious, Aust. J. Phys **33**, 691 (1980)) and obtained spectroscopic factor $S_{g.s.}$=0.88 *11*. Analysed astrophysical reaction rates.

1985La06: ^{12}C(p,γ) E=90-600 keV, calculated σ(E).

1994Ka02: Theory: analyzed vacuum polarization corrections in solar fusion rates.

1996Gi11: ^{1}H(^{12}C,γ), E(^{12}C)=11 MeV; measured $\sigma(\theta)$, nonresonant capture.

1998Ad12: Review of solar-fusion cross sections; includes analysis of the ^{12}C(p,γ) reaction at astrophysical energies.

1999An35: ^{12}C(p,γ) E$\approx$100 keV-2.5 MeV; analyzed astrophysical S-factor.

2000Ic01: ^{12}C(p,γ) Calculated electron screening effects.

2001Ge10: ^{12}C(p,γ). Analysis of CNO rates in dense stellar plasma.

2000Li13: Calculated screening effects for astrophysical energies.

2001Ne15: ^{12}C(p,γ) E$\leq$160 keV; analyzed S-factor shape.

2004Ue05: Calcluated astrophysical reaction rate.

2008Bu19: ^{12}C(p,γ) E=354, 390, 460, 463, 565, 750, 1061 KeV; measured E_γ, I_γ, σ, $\sigma(\theta)$. Deduced astrophysical S-factors, Analyzed Γ_p and Γ_γ for various resonances. Deduced Γ_p=35.0 keV *10* and Γ_γ=0.65 eV *7* for $E_{c.m.}$=421 keV; Γ_p=62 keV for $E_{c.m.}$=1.7 MeV. To fit their data, the tail of the $E_{c.m.}$=8.2 MeV state was included in their R-matrix analysis; using Γ_p=280 keV from (1973Me12); they suggest Γ_γ=6 keV, but it is important that the $E_p\approx$9 MeV region is not included in their measurement.

2010Az01: ^{12}C(p,γ). AZURE R-matrix analysis of astrophysically relevant data.

2011Ad03: ^{12}C(p,γ). Broad analysis of CNO reactions.

2012Du10: ^{12}C(p,γ). Broad analysis of astrophysically relevant reactions.

2012Mi24: ^{12}C(p,γ). Broad analysis of astrophysically relevant reactions.

^{12}C(p,γ) (continued)

2017Mu06: potential model analysis of ^{13}N(2.37 MeV) radiative width and related ANC.
2018Ti06: potential model analysis of capture reactions for E_p<1.2 MeV.
2021An01: Folding model analysis of ^{12}C(p,γ) at low energies.
2021An05: Mean-field analysis of ^{12}C(p,γ) and other astrophysical CNO cycle reactions.
2021An13: potential model analysis of capture reactions for E_p<800 keV.
2022An15: analyzed capture cross section for E≤600 keV.
2023Sk04: compared proton capture on ^{12,13}C and discussed stellar abundances.

^{13}N Levels

E(level)[†‡]	J^{π}	Γ	E_p(res.) (MeV)[@]	Comments
0	$1/2^{-}$[#]	598.02 s *61*		J^{π}: From Adopted Levels. $T_{1/2}$: $T_{1/2}$ from (1980An40). (1953Ch34): $T_{1/2}$=602.9 s *19*. (1957De22): $T_{1/2}$=10.02 min *10*. (1958Ar15): $T_{1/2}$= 597.6 s *18*. (1980An40): $T_{1/2}$=598.02 s *61* from T_{mean}=862.76 s *88*. (1974Ro29): C^2S=0.49 *15* L=1.
2367.6 *9*	$1/2^{+}$	34.7 keV *3*	459.7 *9*	$\Gamma_{\gamma0}$=0.51 eV *3* E(level): E_p=459.7 keV *9* from the average (external errors) of E_{res}=456.0 keV *20* (1949Fo18), E_p=456.8 keV *5* (1953Hu18) E_{res}=457 keV *1* (1974Ro29), $E_{c.m.}$=426.1 keV *4* (E_p=461.9 *4*) (2023Sk02) E_p=460.3 keV *5* (2023Cs01) and E_p=459.8 keV *8* (2023Ke11: includes global analysis of data). Γ: From weighted average (external errors) of Γ_{lab}=37.4 keV *10* (1953Hu18, 1973Cl04), $\Gamma_{c.m.}$=33.7 keV *20* (1968Bl17), Γ_{lab}=34 keV *1* (1968Ri16), $\Gamma_{c.m.}$=33.3 keV *18* (1974Bl06), $\Gamma_{(lab)}$=39 keV 2 (1974Ro29), $\Gamma_{c.m.}$=34.9 keV *2* (2023Sk02), Γ_{lab}=38.2 keV *5* (2023Cs01) and $\Gamma_{c.m.}$=34.0 keV *2* (2023Ke11: includes 2008Bu19). See also Γ_p=33.5 keV *10* obtained from a global analysis in (2022Ar03). Note: some inconsistencies exist in the literature related to assigning the values as lab or c.m. frame values. Table 1 of (1992HiAA:Hinds) is helpful for resolving some issues. $\Gamma_{\gamma0}$: Weighted average (external errors) of Γ_{γ}=0.45 eV *5* (1968Ri16-c.m. value), Γ_{γ}=0.53 eV *5* (1992HiAA-c.m. value), Γ_{γ}=0.49 eV *3* (2023Sk02-c.m. value); Γ_{γ}=0.48 ev *2* (2023Ke11-c.m. value: includes 2008Bu19); see also $\Gamma_{\gamma0}$=0.63 eV (1949Fo18-lab value). As with Γ, there are some inconsistencies with determining the reference frame of the widths. J^{π}: From R-matrix analysis in (2023Ke11). C^2S=1.02 *15* (1974Ro29). (1949Fo18): Eres=456.0 keV *20*, Γ=35 keV and $\omega\gamma$=0.63 eV. (1951Se67,1952Se01): E_p=0.45 MeV, Γ_{lab}=35 keV and $\omega\gamma$=0.67 eV (implies $\Gamma_{\gamma0}$=0.67 eV). (1953Hu18): E_p=456.8 keV *5* and Γ_{lab}=39.5 keV *10* (analysis in (1973Cl04) deduced Γ_{lab}=37.4 keV *13* after correcting for target thickness effects). (1968Bl17): E_p=459 keV and $\Gamma_{c.m.}$=33.7 keV *20* (Uncertainty given in (1970Aj04) from Blatt, BAPS 13 (1968) 173), see also (1973Cl04) where γ uncertainty of 2 keV is given. (1968Ri16): Γ_{lab}=34 keV *1*, τ=1.47 fs *15* and Γ_{γ}=0.45 eV *5*. A private communication in (1973Cl04) establishes this Γ is a lab value. (1974Bl06): $\Gamma_{c.m.}$=33.3 keV *18* (assumed lab in (1976Aj04). (see for discussion on Γ variation in prior measurements).

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^{12}**C(p,γ) (continued)**

^{13}N Levels (continued)

E(level)[†‡]	J$^{\pi}$	Γ	E$_p$(res.) (MeV)[@]	Comments
				(1974Ro29): E$_{res}$=457 keV *1*, $\Gamma_{(lab)}$=39 keV 2, L=0, C^{2}S=1.02 *15*, θ^2(l=0)≈0.81 A lab report (Fox, Polchinski, Rolfs and Tombrello, LAP-144 (1975)) indicates $\Gamma_{\gamma0}$=0.64 eV *7*. (1992Hinds): E$_p$≈424, $\Gamma_{c.m.}$≈36.4 and Γ_{γ}=0.53 eV *5*. (2008Bu19): Γ_p=35.0 keV *10* and Γ_{γ}=0.65 eV *7* (assumed c.m.). (2023Sk02): E$_{c.m.}$=426.1 keV *4*, $\Gamma_{c.m.}$=34.9 keV *2* and Γ_{γ}=0.49 eV *3*. (2023Cs01): E$_p$=459.8 keV *8* and Γ_{lab}=38.2 keV *5*. (2023Ke11): E$_p$=460.3 keV *5*, Γ_p=34.0 keV *2* and Γ_{γ}=0.48 eV *3*. See additional discussion in (2017Mu06).
3500.4 *8*	3/2$^-$	55.0 keV *3*	1.6878 *8*	$\Gamma_{\gamma0}$=0.49 eV *3*; $\Gamma_{\gamma1}$=0.043 eV E(level): From E$_p$=1687.8 keV *8* the weighted average of E$_p$=1687 keV *1* (1991Po18), E$_p$=1688.7 keV *7* (1989Ki21: thick target), E$_p$=1689 keV *2* (1989Ki21: thin target), E$_p$=1685.1 keV *7* (2023Cs01) and E$_p$=1688.8 keV *5* (2023Ke11). Γ: From $\Gamma_{c.m.}$=61.9 keV *40* (1968Bl17), Γ_{lab}=65 keV *3* (1974Ro29), Γ_{lab}=57.6 keV *8* (2023Cs01) and $\Gamma_{c.m.}$=55.2 keV *3* (2023Ke11). See also Γ=65.6 keV *18* (1989Ki21: thick target − taken as lab), see also Γ=74 keV *9* (1949 Van Patter), Γ_{lab}=70 keV *10* (1951Se67,1952Se01) and Γ=62.2 keV *15* (1991Po18-reference frame is unclear). J$^{\pi}$: From phase-shift analysis in (1974Ro29). $\Gamma_{\gamma0}$: From the R-matrix analysis in (2023Ke11) as detailed above. In (1991Aj01) the analysis of (1952Se01, 1963Yo06) cross sections given in (1980Ba54) was accepted; see discussion in (1991Aj01). See also $\Gamma_{\gamma0}$=0.70 eV from $\omega\gamma$=1.39 eV (1951Se67,1952Se01) as quoted in (1954Wo09), and see $\omega\gamma$=1.06 and Γ_{γ}=0.53 eV in (1963Yo06). $\Gamma_{\gamma1}$: From $\Gamma_{\gamma0}$ and Iγ1=8% *1* from (1974Ro29). 1949 Van Patter: E$_{res}$=1697 keV *12*, Γ=74 keV *9*, ratio of yield from E$_{res}$=1697 keV *12* and E$_{res}$=456 keV is R=1.3 *2*, which is used to deduce Γγ=1.3 eV *2* (this may be a typo). (1951Se67,1952Se01): E$_p$=1.698 MeV *5* and Γ_{lab}=70 keV *10* and $\omega\gamma$=1.39 eV (implies $\Gamma_{\gamma0}$=0.70 eV). (1954Wo09): $\Gamma_{\gamma1}$=0.04 eV. (1963Yo06): σ=37 μb, $\omega\gamma$=1.06 eV (Γ_{γ}=0.53 eV (no participation of ^{13}N(3.56: 5/2$^+$); $\sigma\leq$0.16 μb ;$\omega\gamma$<0.006 eV); δ(M2/E1)=−0.092 from A$_2$/A$_0$=−0.65. (1968Bl17): E$_p$=1697 keV and $\Gamma_{c.m.}$=61.9 keV *40* (Uncertainty given in (1970Aj04) from Blatt, BAPS 13 (1968) 173). (1974Ro29): E$_{res}$=1699 keV *2*, Γ_{lab}=65 keV *3*, L=1, C^{2}S<0.5 and δ_R(M2/E1)=−0.09 *2* from *a*2=−0.64 *4*. (1989Ki21: thick target): E$_p$=1688.7 keV *7* and Γ=65.6 keV *18*. (1989Ki21: thin target):E$_p$=1689 keV *2*; in this work the energy shift is attributed to the thick target measurement methodology. (1991Po18: see important discussion): E$_p$=1687 keV *1*. Γ_{lab}=63.6 keV *16* and Γ_{lab}=62.2 keV *15* were deduced from separate configurations. (2008Bu19): Γ_p=62 keV (2008Bu19) (assumed c.m.). (2023Cs01): E$_p$=1685.1 keV *7* and Γ_{lab}=57.6 keV *8*. (2023Ke11): E$_p$=1688.8 keV *5*, $\Gamma_{c.m.}$=55.2 keV *3*, Γ_{γ}(M1)=0.49 eV *3* and Γ_{γ}(E2)=7.2E−4 eV 11.

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^{12}C(p,γ) (continued)

^{13}N Levels (continued)

E(level)†‡	J$^{\pi}$	Γ	Comments
10.26×10^3 *14*	(1/2$^+$,3/2$^+$)	0.26 MeV *9*	$\Gamma_{\gamma0}>0.6$ eV E(level): E$_{res}$=9.01 MeV *15* from E$_{res}$=9.01 MeV *15* (1972Ha32,1973Me12) and E$_p$=9.01 MeV 15 (1976Be28). Γ: From Γ_{lab}=0.28 MeV *10* (1972Ha32,1973Me12). $\Gamma_{\gamma0}$: From (1973Me12); see other discussion in (2008Bu19). (1972Ha32,1973Me12): E$_{res}$=9.01 MeV *15*, Γ_{lab}=0.28 MeV *10*, detector θ=90° gives π=+, J^{π}=(1/2$^+$,3/2$^+$) and $\Gamma_{p0}\Gamma_{\gamma0}$=0.17 keV^2 *9*. (1973Me12): $\Gamma_{\gamma0}\geq0.6$ eV. (1976Be28): E$_p$=9.01 MeV *15* and Γ≈300 keV. (2008Bu19): E$_{c.m.}$=8.371 MeV accounting for the tail of this resonance in the E$_p\leq$2 MeV region suggests Γ_{γ}=6 keV (assumed lab).
11.74×10^3 *11*	3/2$^+$	202 keV *46*	$\Gamma_{\gamma0}\approx4.2$ eV E(level),Γ: From (1972Ha32,1973Me12). $\Gamma_{\gamma0}$: From (1973Me12). (1972Ha32,1973Me12): E$_{res}$=10.62 MeV 12, Γ_{lab}=220 keV 50, J^{π}=3/2$^+$ and $\Gamma_{p0}\Gamma_{\gamma0}$=0.28 keV^2 *10*. (1973Me12): $\Gamma_{\gamma0}\approx4.2$ eV. (1976Be28): See discussion on J^{π} assignments of ^{13}N*(11.74, 14.05) and other nearby levels..
13.5×10^3 *2*	(3/2$^+$)	6500 keV	$\Gamma_{\gamma0}>1.1$ keV E(level),Γ: From (1973Me12). J^{π}: From (1973Me12) ^{12}C(p,γ_0); L=0,2, strong interference with J^{π}=3/2$^+$ states at ^{13}N*(11.74, 14.04), assumed component of GDR. $\Gamma_{\gamma0}$: From (1973Me12). (1973Me12): E$_p$=12.5 MeV *2*, Γ=7 MeV, $\Gamma_{\gamma0}\geq$ 1.1 keV. (1963Fi07): E$_x$=13 MeV. (1991Co07): E$_x$=14.0 MeV, Γ=12 MeV ^{12}C(p,γ_0).
14.05×10^3 *8*	3/2$^+$	157 keV *18*	$\Gamma_{\gamma0}$=3.7 eV *10* E(level),Γ: From (1972Ha32,1973Me12). $\Gamma_{\gamma0}$: From (1973Me12). (1972Ha32,1973Me12): E$_{res}$=13.12 MeV *9*, Γ_{lab}=170 keV *20* J^{π}=3/2$^+$ and $\Gamma_{p0}\Gamma_{\gamma0}$=0.47 keV^2 *12*. (1973Me12): $\Gamma_{\gamma0}$=3.7 eV *10*; associated with the J^{π}=3/2$^+$ state from (1969Le18) (p,p) phase-shift analysis. (1976Be28): See discussion on J^{π} assignments of ^{13}N*(11.74, 14.05) and other nearby levels.
15.07×10^3	3/2$^-$		T=3/2 (1968Di04): $\Gamma_p\Gamma\gamma/\Gamma$=5.5 eV *8*, J^{π}=3/2$^-$ from $\gamma(\theta)$, T=3/2 I(E2/M1)=−0.095 *7*, $\Gamma_{\gamma1}/\Gamma_{\gamma0}<0.14$, $(\Gamma_{\gamma2}+\Gamma_{\gamma3})/\Gamma_{\gamma0}$=0.84 *8*. (1975Ma21,1977Ma16) $\Gamma_p\Gamma\gamma/\Gamma$=5.79 eV *20*, I(E2/M1)=0.013 5. Using Γ_{p0}/Γ=0.236 *12* from (1973Ad02) they deduced $\Gamma_{\gamma0}$(M1)=24.2 eV *15*, $\Gamma_{\gamma0}$(E2)=0.32 eV *12*, B(M1)W=0.342 21 and B(E2)W=0.28 11 for the ground state transition. They also measured ^{11}B(^{3}He,nγ) and determined relative transition strengths for γ_0, γ_1 and γ_2.
15.3×10^3 *2*	(3/2$^+$)	0.35 MeV *14*	$\Gamma_{\gamma0}>0.5$ eV E(level),J^{π},Γ: From (1972Ha32,1973Me12). $\Gamma_{\gamma0}$: From (1973Me12). (1972Ha32,1973Me12): E$_{res}$=14.5 MeV *2*, Γ_{lab}=0.38 MeV *15*, $\Gamma_{p0}\Gamma_{\gamma0}$=0.21 keV^2 *8*. Possible doublet. (1973Me12): $\Gamma_{\gamma0}\geq0.5$ eV.
18.1×10^3		≈1 MeV	E(level),Γ: From (1976Be28). (1976Be28): E$_p\approx$17.5 MeV and Γ≈1 MeV.
20.5×10^3		≈3.7 MeV	E(level): From average of measured values listed below.

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^{12}C(p,γ) (continued)

^{13}N Levels (continued)

E(level)[†‡]	Γ	Comments
		E(level): In (1981Aj01) an additional level at $E_p \approx 20$ MeV was deduced based a peak seen in Figure 11 of (1976Be28). However, those authors indicated, "at lower energies the γ_{2+3} pulses are completely submerged in the sea of inelastic γ rays"; therefore there seems to be evidence for only one level in this region. (1963Fi07): $E_x=20$ MeV ^{12}C(p,γ_0). (1976Fe11): $E_p=20$ MeV ^{12}C(p,$\gamma_{0,2+3}$). (1976Be28): $E_x \approx 20.8$ MeV and $\Gamma \approx 4$ MeV. (1988Ha04): $E_x \approx 20.40$ MeV and $\Gamma \approx 3.5$ MeV (GDR). (1991Co07): $E_x=20.6$ MeV with $\Gamma=1.2$ MeV.
22.0×10^3		E(level): From (1976Be28). (1976Be28): $E_p=21.8$ MeV ^{12}C(p,γ_1).
23.2×10^3	≈1 MeV	E(level),Γ: From (1976Be28). (1976Be28): $E_p \approx 23$ MeV and $\Gamma \approx 1$ MeV (1976Be28).
24.5×10^3	3.5 MeV	E(level): From (1963Fi07, 1991Co07). Γ: From (1991Co07). (1963Fi07): $E_x=24.5$ MeV (γ_2) and E_x=(?24 MeV) (γ_0). (1991Co07): $E_x=24.5$ MeV with $\Gamma=3.5$ MeV ^{12}C(p,γ_{2+3}).
31.9×10^3		Γ: Γ=broad. E(level): From average (1963Fi07, 1976Fe11). (1963Fi07): $E_x=32.5$ MeV ^{12}C(p,γ_0). (1976Fe11): $E_p=32$ MeV ^{12}C(p,$\gamma_{0,2+3}$). (1991Co07): $E_x=32.0$ MeV, $\Gamma=10$ MeV ^{12}C(p,γ_0) and $E_x=35.0$ MeV, $\Gamma=14$ MeV ^{12}C(p,γ_{2+3}).

[†] Level energies are deduced using E_p(res) and ^{12}C, p and ^{13}C masses from (2021Wa16: AME-2020). $E_x=S_p+E_{c.m.}$(relativistic).

[‡] In (1994Zu05), the continuum region was populated and capture γ rays to ^{13}N states at E_x=0, 2.37. 3.50+3.55, 6.36, 7.38, 7.90, 9.0, 10.36 MeV were observed. See also (1979Ko05).

[#] From Adopted Levels.

[@] Authors symbols are used in the discussion; for reference $E_p=E_{res}$=proton laboratory energy; $E_{c.m.}$=center of mass energy energy and $E_x=E_{c.m.}+S_p$.

γ(^{13}N)

E_i(level)	J^π_i	E_γ	I_γ	E_f	J^π_f	Mult.	δ	Comments
2367.6	1/2$^+$	2367.4	100	0	1/2$^-$			E_γ: from level-energy difference.
3500.4	3/2$^-$	1135	8	2367.6	1/2$^+$	E1		E_γ: From (1987Po09). I_γ: From (1974Ro29).
		3498 *2*	92	0	1/2$^-$	M1+E2	−0.09 *2*	I_γ: In (1954Wo09), the partial widths $\Gamma_{\gamma1}=0.04$ eV and $\Gamma_{\gamma0}=0.7$ eV are given (5%:95%); $\Gamma_{\gamma0}=0.7$ eV is from $\omega\gamma=1.39$ eV in (1952Se01). Later, (1963Yo06) claim agreement and show Iγ=5% and 95%, respectively. In (1974Ro29) uncertainties of 1% are added to the branching ratios of (1954Wo09); however (1974Ro29) reported Iγ=8% *1* for γ_1. In (1991Aj01) $\Gamma_{\gamma1}=0.06$ eV and $\Gamma_{\gamma0}=0.64$ eV (8.5%:91.5%) were adopted based on an analysis of (1952Se01,1963Yo06) given in (1980Ba54) and using the $I_{\gamma1}$=8% *1*, which is the only related value that is reported with an uncertainty. We accept the branching ratio given in (1974Ro29) however we accept the partial $\Gamma_{\gamma0}$ width from the R-matrix analysis in (2023Ke11) as detailed above where $\Gamma_{\gamma0}=0.49$ eV *3* (δ=0.038 *6*: $\Gamma_{\gamma0}$(M1)=0.49 eV *3* and

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^{12}C(p,γ) (continued)

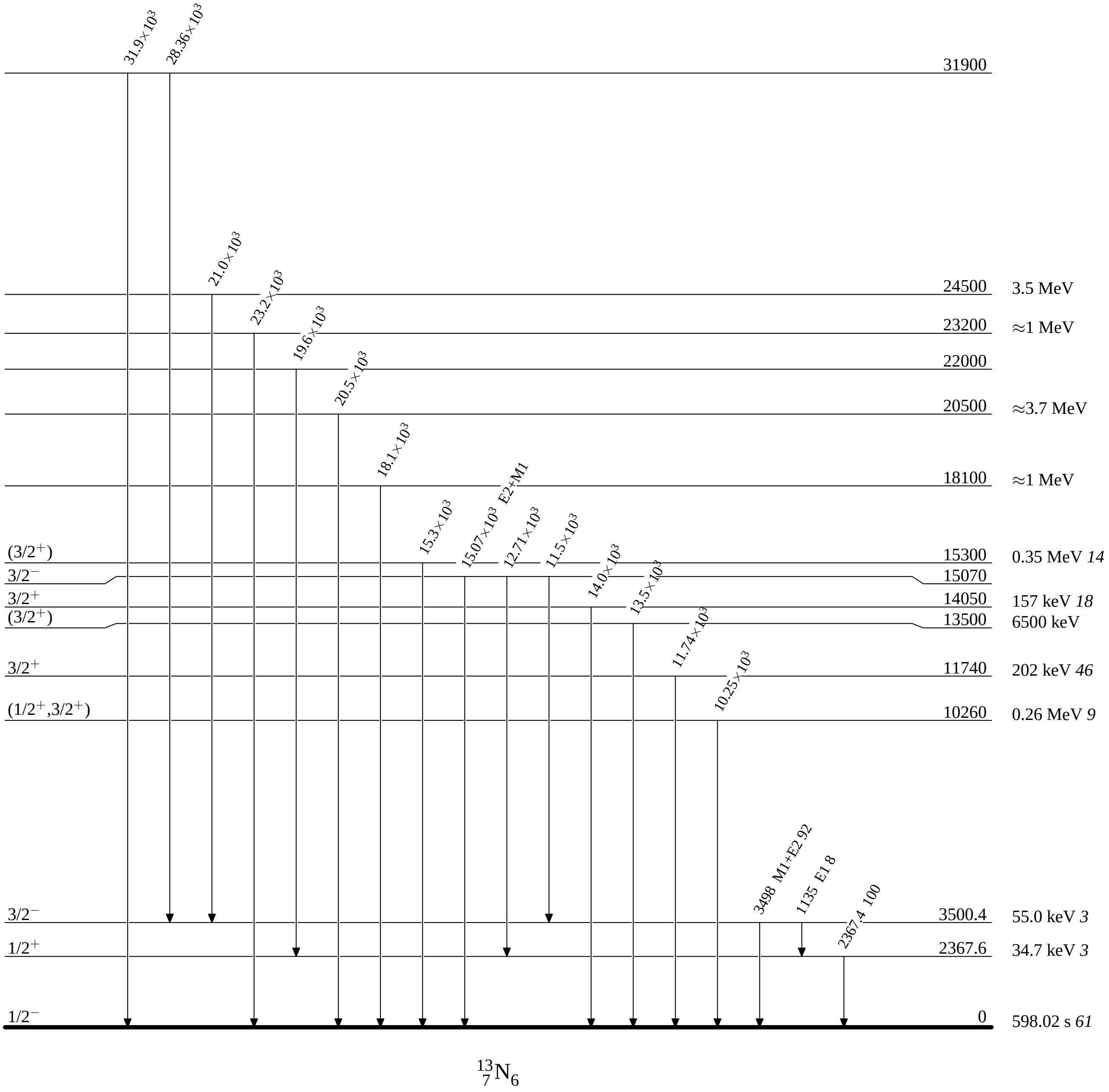
γ(^{13}N) (continued)

E_i(level)	J^π_i	E_γ	E_f	J^π_f	Mult.	δ	Comments
							$\Gamma_{\gamma0}$(E2)=0.49 eV *3*). See also δ(E2/M1)=−0.09 *2* (1974Ro29) from *a2*=−0.64 4 compared with δ(E2/M1)=−0.092 from *a2*=−0.65 reported in (1963Yo06). E_γ: From (1987Po09); see also 3501.5 keV (1989Ki21).
10.26×10^3	(1/2$^+$,3/2$^+$)	10.25×10^3	0	1/2$^-$			$\Gamma_{\gamma0}\approx$6 eV
11.74×10^3	3/2$^+$	11.74×10^3	0	1/2$^-$			$\Gamma_{\gamma0}\approx$4.2 eV (1973Me12)
13.5×10^3	(3/2$^+$)	13.5×10^3	0	1/2$^-$			
14.05×10^3	3/2$^+$	14.0×10^3	0	1/2$^-$			$\Gamma_{\gamma0}$=3.7 eV *10* (1973Me12)
15.07×10^3	3/2$^-$	11.5×10^3	3500.4	3/2$^-$			(1968Di04):$\Gamma_{\gamma(3.5+3.56)}$=23 eV *5*.
		12.71×10^3	2367.6	1/2$^+$			Γ_γ<4.5 eV (1968Di04)
		15.07×10^3	0	1/2$^-$	E2+M1	−0.115 *21*	(1968Di04): $\Gamma_{p0}\Gamma_{\gamma0}/\Gamma$=5.5 eV *8*, I(E2/M1)=−0.095 *7*. Then, $\Gamma_{\gamma0}$=27 eV *5* assuming Γ_{p0}/Γ=0.200 eV *25* (1967 Adleberger BAPS 12 1194). (1975Ma21, 1977Ma16): $\Gamma_p\Gamma_\gamma/\Gamma$=5.79 eV *20*, I(E2/M1)=−0.013 *5* and $\Gamma_{\gamma0}/\Gamma_{p0}$=0.121 *11*. assuming Γ_{p0}/Γ=0.236 *12* from (1973Ad02) gives Γ_γ(M1)=24.2 eV *15*, Γ_γ(E2)=0.32 eV *12* and B(M1)W=0.342 *21* and B(E2)W=0.28 *11*; I(E2/M1)=0.013 5 See discussion in (1975Ku21). Also see (1975Ma21, 1977Ma16) where ^{11}B(^{3}He,nγ) data are used to deduce γ-ray partial widths $\Gamma_{\gamma(2+3)}$=19.6 eV *14*, $\Gamma_{\gamma1}\leq$2.82 eV *30*, $\Gamma_{\gamma0(M1)}$=24.2 eV *15*, $\Gamma_{\gamma0(E2)}$=0.32 eV *12*, and Γ=0.86 keV *12*.
15.3×10^3	(3/2$^+$)	15.3×10^3	0	1/2$^-$			$\Gamma_{\gamma0}\geq$0.5 eV (1973Me12)
18.1×10^3		18.1×10^3	0	1/2$^-$			
20.5×10^3		20.5×10^3	0	1/2$^-$			
22.0×10^3		19.6×10^3	2367.6	1/2$^+$			
23.2×10^3		23.2×10^3	0	1/2$^-$			
24.5×10^3		21.0×10^3	3500.4	3/2$^-$			
31.9×10^3		28.36×10^3	3500.4	3/2$^-$			
		31.9×10^3	0	1/2$^-$			

^{12}C(p,γ)

Level Scheme

Intensities: % photon branching from each level



^{12}C(p,π^0)

1987Ho21: ^{12}C(p,π0) E=186 MeV; measured $\sigma(\theta)$ for θ=30° to 180°.
1992Ho03: ^{12}C(p,π0) E=153-204 MeV; measured $\sigma(\theta)$ for θ=0° to 180°. Compared with ^{12}C(p,π+) and analyzed isospin invariance.
1993Pi14: ^{12}C(pol. p,π0) E=146.9 MeV; measured A_y, $\sigma(\theta)$.
1993Na17: ^{12}C(pol. p,π0) E=330 MeV; measured $\sigma(\theta)$.

^{13}N Levels

E(level)
0

^{12}C(p,n)

1968Ri01: ^{12}C(p,n) E=18.9-50 MeV; measured $\sigma(E_p)$.
1984Na06: ^{12}C(p,n) E=30 MeV; measured E_n, thick target yields.
1984Sa12: ^{12}C(p,n) E=65 MeV; measured spin-transfer coefficient.

^{13}N Levels

E(level)†	Comments
21×10^3	
24×10^3	
27×10^3	Γ: Broad.

† From (1968Ri01).

^{12}C(p,p)

1951Ja21: ^{12}C(p,p) E_p=0.32-4.0 MeV; analyzed Goldhaber and Williamson Phys. Rev. 82 (1951) data via partial wave analysis and deduced a $S_{1/2}$ level at E_x=2379, $P_{3/2}$ at 3501 and $D_{5/2}$ at 3549 keV with Γ=33, 42 and 40 keV, respectively.

1952Ja21, 1953Ja03,(Jackson et al., Phys. Rev. **89** 370 (1953)): ^{12}C(p,p) E=0.32-4 MeV; deduced E_p 0.461, 1.698, 1.748, with Γ_{cm}=31, 55, 61 keV, and J^π= $1/2^+$, $3/2^-$ and $5/2^+$, respectively. See further discussion on reduced widths.

1954Mi05: ^{12}C(p,p) E=300-550 keV; measured $\sigma(\theta)$ for θ=30° to 160°. Deduced E_{res}=462 keV *4* with $\Gamma_{c.m.}$=32 keV.

1954Wo09: ^{12}C(p,pγ) E=1-3 MeV; observed influences of ^{13}N(2.37,3.51,3.58 MeV) states. Observed (p,γ) capture to ^{13}N(2.37) followed by proton emission. They note the higher $5/2^+$ state is suppressed in the capture reaction.

1956Br27: ^{12}C(p,p′) E_p=1.5-5.5 MeV; measured scattered proton yield. Deduced state at E_{res}=5.891 MeV with Γ_{lab}=55 keV.

1956Re39: ^{12}C(p,p′)1.5-5.5 MeV; deduced resonances at E_p=4.808 MeV *8* and 5.37 MeV with J^π=$5/2^+$ and $3/2^+$, and with Γ_{lab}=12 keV and 125 keV, respectively. J^π(5.37) from angular distribution of ^{12}C(p,p′$\gamma_{4.4}$). The great Charlie Reich. See further discussion on reduced widths.

1956Sc29: ^{12}C(p,p),(p,p′) E=4.7-7 MeV; measured σ(E) for θ=40° to 160°. Deduced levels at E_{res}=5.05, 5.30, 5.85, 6.65 MeV ^{13}N((6.61), 6.84, 7.35, (8.1)) with L:J^π=0:$1/2^+$, 2:$3/2^+$, 1:$3/2^-$, 2:$3/2^+$ and with Γ=75, 50, 50 and 350 keV, respectively. These states are not all accepted.

1960Ev02: ^{12}C(p,p$_0$) E=2.3-4.3 MeV; measured induced polarization at θ=60°.

1960St09: ^{12}C(p,p$_0$) E=9.4 MeV; measured induced polarization for θ=34° to 140°.

1960To09: ^{12}C(p,p$_0$) E=3-5 MeV; measured induced polarization for θ=50° to 160°.

1960Ya07: ^{12}C(p,p) E=14,16 MeV; measured induced polarization for θ=45°.

1960Yo05: ^{12}C(p,p′γ) E=5.3-6.1 MeV; measured excitation function for γ(^{12}C=4.4 MeV). Deduced resonances at E_{res}=5.37, 5.69 and 5.93 MeV. (E_x=6.91, 7.17 and 7.42 MeV; analyzed angular correlation ($\theta\approx$35° to 140°) of γ-p for E_x=7.42 MeV.

1961Ad04: ^{12}C(p,p′γ(4.44)) E=5-12 MeV; measured yield at θ=90°. Deduced resonances E_{res}=5.36, 5.89, 7.55, 8.17, 9.12, 10.51, 10.74 and 10.99 MeV and widths for ^{13}N(6.89, 7.38, 8.91, 9.48, 10.36, 11.64, 11.85, 12.09) with Γ_{lab}=140, 70, 255, 38, 70, 85, 140, 150 keV, respectively.

1961Ba25, 1961Mc11: ^{12}C(p,p) E=5-11.5 MeV; measured angular distributions (θ=10° to 170°) and excitation functions with resonances at $E_p\approx$5.4, 5.9, 6.65, 7.6, 8.2, 9.2 and 10.5 MeV including new states at $E_x\approx$8.9, 9.5, 10.4 and 11.6 MeV.

1961Mc16: ^{12}C(p,p′) E=5-11.5 MeV measured angular distributions (θ=25° to 170°) and excitation functions with resonances at $E_p\approx$7.6, 8.2, 9.2, 10.3, 10.5 and 11.0 MeV.

1961Na02: ^{12}C(p,p$_{0,1}$) E=6.5-16 MeV; measured angular distributions for θ=21.8° to 166.2°. Deduced resonances at E_p=(6.65), 9.1, 10.5, 12.5, 13.2, 13.7 and 15.1 MeV for ^{13}N(8.08, 10.4, 11.6. 13.5, 14.2, 14.6, 15.9 MeV). Widths of Γ=150, 700, 500, 500, 500 keV are deduced for ^{13}N(10.4, 11.6. 13.5, 14.2, 14.6), respectively.

1962Sh22: ^{12}C(p,p) E=5-11.5 MeV; measured σ(E) for θ=30° to 170°. Deduced levels at E_{res}=5.38, 5.90, 6.6, 7.53, 8.17, 9.14 MeV with J^π=$3/2^+$, $5/2^+$, $3/2^+$, $1/2^-$, $3/2^-$, $7/2^-$, with Γ=115, 80, 1400, 225, 30 and 73 keV. Reduced widths of θ^2=0.01, 0.01, 0.14, 0.02, 0.001 and 0.01 are also given. Phase-shift analysis.

1962Wa31: ^{12}C(p,γ),(p,p′γ(4.44,12.7, 15.1),(p,d) E=14-20 MeV and $\theta(\gamma)$=90°. Yields for (p,γ) and (p,d) reactions were reported as relatively structureless. For (p,p′γ(15.1)) resonances corresponding at E_p=17.5, 18.05 and 19.3 MeV ^{13}N(18.1, 18.65, 19.8 MeV) are reported. The width of the 18.1 MeV level is $\Gamma_{c.m.}$=330 keV *100*, while the other two levels have $\Gamma_{c.m.}\leq$200 keV.

1963Ba36: ^{12}C(p,p$_{0,1}$) E=5.2-6.6 MeV; measured $\sigma(\theta)$ for $\theta\approx$30° to 150° (table provided). Also measured angular distribution of Eγ=4.44 MeV. Deduce E_{res}=5.35 MeV *1*, 5.65 MeV *1* and 5.89 MeV *1* for ^{13}N(6.88, 7.16, 7.38 MeV) with $\Gamma_{c.m.}$=114, 7.7 and 61 keV, J^π=$3/2^+$, $7/2^+$ and ($5/2^-$,$7,2^-$), respectively. J^π(7.38)=$7/2^-$ is preferred, but $5/2^-$ is accepted in the Adopted Levels giving Γ_{p0}=51, 0.03 and 5.0 keV and Γ_{p1}=63, 7.4 and 56 keV, respectively for the states.

1963Ba43: Theoretical analysis of $E_x\approx$7 MeV state spins. Find ^{13}N(7.42) should be J^π=$5/2^-$.

1963Di16: ^{12}C(p,p′γ) E=18-30 MeV; measured $\sigma(E_p,\theta)$ for θ=14° to 153° (tables provided).

1963Me04: ^{12}C(p,p′γ) E≤50 MeV; measured excitation function for proton scattering to ^{12}C*(12.7,15.11). Deduced some evidence for a resonance at E_p=20 MeV and give discussion on a possible width 0.27 MeV<Γ_p<3.7 MeV. They give additional discussion suggesting as many as 4 resonances in the region.

1963Ni05: ^{12}C(p,p$\gamma_{4.4}$) E=5-6 MeV; measured $\sigma(E\gamma,\theta)$ for $\theta\approx$5° to 150°. Deduced resonances at E_p=5.38, 5.68 and 5.90 MeV indicating ^{13}N*(6.91, 7.19, 7.40 MeV) with $\Gamma_{c.m.}$=115 keV *5*, 9.0 keV *5* and 69 keV *5*, respectively. The J^π values of $3/2^+$, $7/2^+$ and $5/2^-$ and c.m. elastic proton widths Γ_p=46 keV, 0.36 keV and 6.9 keV, respectively, are also deduced.

1964Bo18: ^{12}C(p,p$_0$) E_p=4.5 MeV; measured induced polarization for θ=50° to 128°.

1964Da03: ^{12}C(p,p$_{0,1}$) E_p=13.6-19.6 MeV; measured $\sigma(\theta)$ for θ=15° to 160°. Suggest fluctuations at Ep= 13.9, 14.4, 14.9, 15.3, 15.6, 16.5, 17.9, 18.2, 18.8 MeV with ΔE≈50-100 keV. They indicate higher resolution is necessary for meaningful results.

1964Dr04: ^{12}C(p,p$_0$) E_p=4.5-5.2 MeV; measured induced polarization at 48°.

^{12}C(p,p) (continued)

Tamura and Teresawa, Phys. Lett. **8** (1964) 41: optical model analysis of the (1963Di16) data. Deduced resonances at $E_{c.m.}$=19.75 ($3/2^+$), 20.05 ($5/2^+$), 24.93 MeV with $\Gamma_{c.m.}$=2.49, 1.46 and 2.17 MeV, respectively.

1965Be12: ^{12}C(p,p′γ) E=5.37 MeV (E_x=6.91 MeV); measured triple correlation for θ_p=40° to 150° and θ_γ=0° and 150°. Compared with phase-shift analysis of (1956Re39). Data is well represented with a $3/2^-$ state interfering with a small mixture of a $1/2^-$ state. This is in disagreement with accepted interpretation.

1965Ma26: ^{12}C(p,p) E=16-28 MeV; measured total reaction cross sections; estimated elastic and inelastic cross sections. Deduced resonances at $E_{c.m.}$=19.8, 20.01 and 24.9 MeV ^{13}N(21.7, 21.94, 26.8 MeV).

1965Mo15: ^{12}C(p,p) E=4.7-11.3 MeV; measured induced proton polarization for θ=20° to 140°.

1966Ar03: ^{12}C(p,p) E=1.48-2.02 MeV; measured $\sigma(\theta)$ for θ=25° to 125.5°. Deduced resonances at E_p=1686 keV *6* and 1734 keV *6* with J^π=$3/2^-$ and $5/3^+$, with reduced widths θ^2=0.036 *2* and 0.25 *2* and with Γ=63 keV and 74 keV, respectively. The level energy difference is 48 keV *2*. Cross-sections table given.

1966Ba35: ^{12}C(p,p) E=2.4-11.6 MeV, ^{12}C(p,p′) E=6.6-11.6 MeV, ^{12}C(p,α) E=11.6 MeV; measured $\sigma(E,\theta)$. Deduced resonances at E_p=4.80, 5.30, 5.88, 6.35, 7.53, 8.16, 9.13 MeV for ^{13}N(6.37, 6.83, 7.37, 7.79, 8.89, 9.47, 10.37) with J^π=$5/2^+$, $3/2^+$, $5/2^-$, $3/2^+$, $1/2^-$, $3/2^-$, $7/2^-$ and with Γ_{lab}=12, 74, 70, 1720, 250, 30 and 84 keV, respectively.

1966Cr04,1966Cr14: ^{12}C(pol. p,p),(pol. p,p′) E=20-28 MeV; measured polarization observables for θ=20° to 160°. Compared with earlier predictions of Tamura and Teresawa (1964).

1966Lo16: ^{12}C(p,p) E=20-28 MeV; measured $\sigma(\theta)$ for θ=15° to 160°. Deduced three states at $E_{c.m.}$=19.0, 20.8, ≈22.2 MeV with J^π=(5/2,9/2), (5/2,9/2) and 7/2 with Γ=1.5, 1.0, 0.5 MeV, respectively.

1966Sh10: ^{12}C(p,p′γ) E=5.9 MeV; measured $\sigma(E_p,\theta_p,\theta_{\gamma 4.44})$ for θ_p=30° to 145°. Analyzed in-plane p-γ correlations with the aim of resolving the ^{13}N(7.4 MeV) J^π spin assignment. $5/2^-$ is favored, but not fully adopted.

1966Sw04: ^{12}C(p,p) E=4.7-12.8 MeV, ^{12}C(p,p′) E=6.0-12.8 MeV, measured $\sigma(E,\theta)$ for θ=25.4°−159.5°. Deduced new level at E_x=10.38 MeV.

Barnard, Phys. Rev. 155 (1967) 1135: Theory, phase-shift analysis of E_x≈6.5 MeV region. Deduce the E_p=4.808 and ≈5.3 MeV features are due to the 0.461 keV *s*-wave resonance.

Duval, Barnard and Swint, Nucl. Phys. A93 (1967) 164 : ^{12}C(p,p) E=5.179-5.480 MeV and θ=30° to 150°. Phase-shift analysis. Deduce resonance energy E_0=5374 keV *20*; discuss earlier results including some discussion on the complex process for determining the total width.

1967Cl04: ^{12}C(pol. p,p),(pol. p,p′) E=4-12 MeV; measured polarization observables for θ=17° to 60°.

1967Fa06: ^{12}C(pol. p,p),(pol. p,p′) E=49.5 MeV Measured $\sigma(\theta)$ for θ=11° to 147°.

1967Ku02: ^{12}C(p,p) E=13-19 MeV; measured $\sigma(E,\theta)$ for $\theta_{c.m.}$= 90° and 166.5°. Deduced T=3/2 resonances at E_x=18.43 MeV *2* and 18.98 MeV *2*. For 18.43, Γ≈30 keV is aparent, but if these are analogs of ^{13}N(3.68,3.71) the width is unclear. For 19.89, Γ<10 keV and *l*=1 is likely from comparison with E_x=15.07; J=$1/2^-$ is suggested . They suggest population of T=1/2 states at E_p=14.4, 15.2 (broad), and 17.6 MeV.

1967Pa25: ^{12}C(p,p) E=1 BeV; measured $\sigma(\theta)$ for θ=6° to 18°.

1967Sc11: ^{12}C(p,p′γ(15.11)) E=20.5-30.3 MeV; measured excitation function. Deduced levels at ^{13}N(20.9, 22.5, 25.5) with J^π=$5/2^+$, $5/2^-$ and $3/2^-$, respectively. See further discussion on L-values.

J.B. Swint, et al., Nucl. Phys. A93 (1967) 177: ^{12}C(p,p) E=8.20 and 9.10-9.26 MeV: measured $\sigma(\theta)$ for θ=20° to 160°. phase-shift analysis. Deduced resonances at E_p= 9145 and 9152 keV with J^π=$5/2^-$ and $7/2^-$ and with Γ_{lab}=12 and 90 keV, respectively.

1967Tr08: ^{12}C(pol. p,p) E=1.5-3 MeV; measured polarization observables for θ=30° to 140°. Phase-shift analysis in the region around E_x=3.5 MeV.

1968An25: ^{12}C(p,p),(p,p′) E=6 MeV; measured $\sigma(E_p,\theta)$.

1968Be31: ^{12}C(pol. p,p) analyzed the data of (1968Te05). For the E_{res}=5.38 and 5.88 MeV levels, they deduce J^π=$3/2^+$ and $5/2^-$, respectively. For 5.88 MeV, Γ_{lab}=70 keV and Γ_{p0}/Γ=0.08 are deduced. The resonance at 9.13 MeV is identified as two overlapping states whose energies differ by less than 2 keV. The states have J^π=$5/2^-$ with Γ_{lab}=33 keV and Γ_{p0}/Γ=0.26 and J^π=$7/2^-$ with Γ_{lab}=82 keV and Γ_{p0}/Γ=0.81.

1968Sl01: ^{12}C(pol. p,p) E=1-3 MeV; measured induced proton polarization.

1968Te05: ^{12}C(pol. p,p) E=4.6 to 7.2 MeV; measured polarization observables for θ≈40° to 165°. Data is analyzed in (1968Be31).

1969Fa04: ^{12}C(p,p),(p,p′) E=11-22.7 MeV; measured polarization observables at θ=55°.

1969Fu07: ^{12}C(p,p) E=61.4 MeV; measured $\sigma(\theta)$ for θ=15° to 110°. For a broad collection of targets they deduced OM potential parameters.

1969Gu02: ^{12}C(p,p) E=7 MeV; measured $\sigma(\theta)$ and polarization observables for θ=20° to 160°. Deduced OM parameters.

1969Ko07: ^{12}C(p,p′) E=9-20 MeV; measured $\sigma(\theta)$ for θ=30° to 160°. Deduced spin-flip probabilities.

^{12}C(p,p) (continued)

1969Le18: ^{12}C(p,p) E≈9.4-21.5 MeV. Measured $\sigma(E,\theta)$ for θ=25° to 165°. Deduced resonances in $\alpha_{0,1}$ and $p_{0,1}$. In (1970Aj04) the full collection of states given in Table 1 of (1969Le18) are associated with the (p,α) reaction; but this seems arbitrary given their θ=60° data shown in Fig 7. Isospin values are discussed. The results shown in Table 1 include ^{13}N states from E_x=13.96 to 19.88 MeV that were studied via phase-shift analysis. The complex of states around E_p=10.5 to 11 MeV were analyzed, but the no results could be obtained.

1970Bl03: ^{12}C(pol. p, p),(pol. p, p′) E=20.3 MeV; measured polarization observables for θ≈40° to 160°.

1970Di08: ^{12}C(p,p) E=9.9-19.5 MeV; measured attenuation. Deduced broad levels near E_p≈10.4 and 13.8 MeV.

1970Gi04: ^{12}C(pol. p,p) E=20-30 MeV; measured $\sigma(E,\theta)$ for θ=20° to 150°. Results are combined with ^{10}B(^{3}He,α) at E(^{3}He)=1-10 MeV; deduced resonances at E_{res}(^{3}He)=3, 5.8, and 8 MeV (^{13}N(24, 26.1, 28 MeV)) with Γ= 0.75 *25*, 1.35 *15* and 2.25 *25* MeV and J^{π}=7/2^{-}, 7/2^{-} and 9/2^{+}, respectively. See ^{10}B(^{3}He,α).

1970Ko15: ^{12}C(p,p′γ(4.44)) E=12-14 MeV; measured $\sigma(\theta)$ for θ=30° to 160°; analyzed spin-flip probability. Focused on the region around E_{res}=13.1 MeV.

1970Ts03: ^{12}C(p,p) E=41-50 MeV; measured polarization observables.

1971Na29: ^{12}C(p,p) E≈4.81 MeV; measured polarization observables around the E_p=4.81 MeV resonance at θ=50° and 137.5°.

1972Ba14: ^{12}C(p,p) E=14.2 MeV; measured σ(E) for θ=165° near the E_x=15.07 MeV T=3/2 resonance. Deduced change in resonance shape attributed to molecular ion beams.

1972Be15: ^{12}C(p,pγ) E≈8.2 MeV; measured elastic, inelastic and spin-flip cross sections for θ≈30° to 160°. Analyzed resonance and found E_{res}=8.18 MeV, Γ_{lab}≈28 keV and Γ_{p1}/Γ=0.72. Deduced resonance is a proton coupled to ^{12}C*(4.44 MeV).

1972Dz05: ^{12}C(p,p) E≈14.23 MeV; measured $\sigma(\theta)$ at θ=40°, 140° and 165°. Used the observed width, FWHM=1.6 keV, and previously reported width, Γ=1.22 keV to estimated their systems's resolution function.

1972Gr02: ^{12}C(pol. p, p),(pol. p, p′) E=30.4 MeV; measured $\sigma(\theta)$ and polarization observables for θ=20° to 170°. Deduced effective interactions.

1972Ja07: ^{12}C(p,p) E=144 MeV; measured $\sigma(\theta)$. Deduced scattering amplitudes and OM parameters.

1972Vo20: ^{12}C(p,p) E=1 GeV; measured induced proton polarization for θ<13°.

1972Wi24: ^{12}C(p,p) E=46 MeV measured $\sigma(\theta)$. Deduced OM parameters.

1972Wi26: ^{12}C(pol p,p) E=9.95-10.90 MeV; measured $\sigma(\theta)$, $A_y(\theta)$ for θ=50° to 150°. Deduced phase shifts, resonances. Tabular data. Resonances at E_{res}=10.25 MeV *10*, 10.51 MeV *2*, 10.54 MeV *5* and 10.70 MeV *5* (^{13}N*(11.40, 11.64, 11.67, 11.82 MeV), with J^{π}=5/2^{+}, 5/2^{-}, 3/2^{-}, 3/2^{+}, and with Γ=0.45 MeV *10*, 120 keV *30*, 230 keV *50*, 250 keV *50*, and with Γ_{p0}/Γ= 0.65 *15*, 0.55 *5*, 0.45 *10* and 0.62 *10*, respectively.

1973Be29: ^{12}C(p,p), (p,p′) E=1.04 GeV; measured $\sigma(\theta)$ for θ≈4° to 35°.

1973Be37: ^{12}C(p,p), (p,p′) E=7-8 MeV; measured σ(E). As in (1972Be15), measured elastic, inelastic and spin-flip cross sections for θ≈45° to 165°. Analyzed resonance and found E_{res}=7.575 (assumed) with Γ=0.25 MeV. They find the decay is dominated by f-wave proton emission.

1973Ha59: 12C(p,p) E=2.0-4.5 MeV; measured A_y.

1973Hu07,1974Hu15: 12C(p,p) E≈14.2 MeV; measured σ(E). Find T=3/2 resonance at E_p=14230.75 keV *20*.

1973Me03: ^{12}C(pol. p,p), (pol. p,p′) E=9.5-11.5 MeV, measured $\sigma(\theta)$, $A_y(\theta)$ for θ=20° to 160°. Phase-shift analysis. Deduced resonances with E_{res}=10.35 MeV *5*, 10.58 MeV *3*, 10.62 MeV *4*, 10.62 MeV *5*, 10.75 MeV *4* and 11.05 MeV *5* (^{13}N(11.49, 11.71, 11.75, 11.75, 11.86, 12.14 MeV), with J^{π}=5/2^{+}, 5/2^{-}, 3/2^{+}, 3/2^{-}, 1/2^{+} and 7/2^{-}, with $\Gamma_{c.m.}$= 430 keV *35*, 115 keV *30*, 250 keV *30*, 530 keV *80*, 380 keV *50* and 250 keV *30*, and with Γ_p/Γ=0.70 *5*, 0.60 *4*, 0.30 *5*, 0.55 *5*, 0.35 *5* and 0.30 *5*. See further discussion on reduced widths.

1973Me12: ^{12}C(p,p′γ) E=9-24 MeV; measured E_γ, I_γ excitation function capture γs and ^{12}C*(12.7, 15.11 MeV) de-excitation. A high background has resulted in multiple solutions for deduced widths in the γ_0 capture analysis; the preferred option is listed. For 12C(p,γ_0) resonances at E_p=9.01 MeV *15*, 10.62 MeV *12*, 12.5 MeV *2*, 13.12 MeV *9* 14.5 MeV *2* for ^{13}N*(10.25, 11.74, 13.0, 14.04, 15.3 MeV), with J^{π}=3/2^{+}, (3/2^{+},1/2^{+}), 3/2^{+}, 3/2^{+}, (3/2^{+}), and with Γ=0.28 MeV *10*, 220 keV *50*, 7 MeV, 170 keV *20* and 0.38 MeV *15*, and with $\Gamma_{\gamma0}$ ≥0.6 eV, 4.2 eV, ≥1.1 keV, 76 eV *28* and ≥0.5 eV. See further discussion in text. Levels in 12C(p,p′γ) are found at E_p=15.27 MeV *3* (E_x=16.02) with Γ=130 keV *30*, Γ_{p0}≈7.5 keV, $\Gamma_{p12.71}$≈30 keV; E_p=19.35 MeV *20* (E_x=19.77) with J^{π}=(5/2^{+}), Γ=800 keV, Γ_{p0}≈80 keV, $\Gamma_{p15.11}$≈300 keV (*Not accepted*); E_p=20.55 MeV *30* (E_x=20.87) with J^{π}=(5/2^{+}), Γ=1.1 MeV, Γ_{p0}≈110 keV, $\Gamma_{p15.11}$≈400 keV; E_p=22.2 MeV *5* (E_x=22.7) with J^{π}=(7/2^{+}), Γ=2 MeV, Γ_{p0}≈200 keV, $\Gamma_{p15.11}$≈450 keV. Significant comparison with literature values.

1974Ae01: ^{12}C(p,p) E=399-576 MeV; measured $A_y(\theta)$ for θ=4° to 10°.

1974Al31: ^{12}C(p,p), (pol. p,p) E=4.6-6 MeV; measured $\sigma(\theta)$ and $A_y(\theta)$.

1974Co09: ^{12}C(p,p) E=156 MeV; measured $\sigma(\theta)$ for θ=5° to 65°. Deduced OM parameters.

1974Fe08: ^{12}C(p,p), (p,p′) E=24 MeV; measured $\sigma(\theta)$.

^{12}C(p,p) (continued)

1974Gu04: ^{12}C(p,p) E=5.8-6.3 MeV; measured induced proton polarization.
1974Ja25: ^{12}C(p,p) E=10-20 MeV; measured $\sigma(\theta)$ for θ=15° to 70°.
1974Lo19: ^{12}C(p,p) E≈4.8 MeV; measured $\sigma(E_p)$. Analyzed E_{res}=4.8 MeV level properties.
1974Ro42: ^{12}C(pol. p,p) E=6.2 MeV; measured $A_y(\theta)$.
1975Cr06: ^{12}C(p,p) E=1770, 1900 keV; measured $\sigma(E_\gamma)$. Analyzed proton induced bremsstrahlung spectrum for near-resonance energies.
1975De26: ^{12}C(p,p), (p,p′) E=6 MeV; measured $\sigma(E_{p'},\theta)$.
1975De32: ^{12}C(p,p′γ) E=15.9-37.6 MeV; measured $\sigma(E_{p'},\theta)$. for θ=40° to 170°. Observed resonances at E_p=20 and 29 MeV. Suggest E1 and E2, respectively.
1975Ge15: ^{12}C(p,p′γ) E=22.5-45 MeV; measured $\sigma(E_{p'},\theta)$. for θ=20° to 160°.
1975Go03: ^{12}C(p,p) E=14.22-14.24 MeV; measured σ(E) around the T=3/2 resonance using a broad range spectrometer to determine the proton energy. Various thin targets from 10-20 μg/cm^2 were utilized. Deduced E_{res}=14232.5 keV *22* from phase-shift analysis. The value Γ_p/Γ≈0.18 was used in their fit.
1975Hi07: ^{12}C(p,p),(p,p′),(p,α) E=14.222-14.242 MeV; measured σ(E) at θ=175°. Analyzed ^{13}N(15.07) mainly from (p,p) analysis. They deduced Γ=1.10 keV *9*, Γ_p=210 eV *11* and Γ_p/Γ=0.191 *17*. Analyzed other level decay properties such as partial widths, but they used branching ratios from (1973Ad02) with their Γ and Γ_p.
1975Sl02: ^{12}C(p,p) E=20-44 MeV; measured total σ(E). Observed structures at E_p=23.8 and 25.9 MeV.
1976Be28: ^{12}C(p,pγ(12.71,15.11)) E≤24 MeV; measured σ(E) for θ=90° and 55°. States at E_p=17.87, 18.46, 19.5 MeV and 20.5 MeV are observed in E_γ(15.11) excitation spectrum (seems shifted). E_x=18.456 MeV *15* for the E_p=17.87 state. For E_γ(12.71), structures are seen at E_p=15.27, 16.8, 20.5 MeV. They suggest the 20.5 could be (3/2$^+$), but express uncertainty.
1976Cu08: ^{12}C(p,p) E=1.5-4.0 MeV; measured $\sigma(E,\theta)$ for θ=5° to 41°. Deduced OM parameters.
1976Fe11: ^{12}C(p,p′γ(4.44,12.7,15.1)), ^{12}C(p,$\gamma_{0,2,3}$) E=16-40 MeV; measured σ(E). Observed resonances at E_p=20, 27, 32 MeV (E_x≈20.4, 26.8, 31.5 MeV). The 20 MeV resonance is seen in all channels, while the 27 MeV state is not seen in capture reactions. The 32 MeV resonance is seen in ^{12}C(p,p′γ(4.44)).
1976Ma06,1976Ma55: ^{12}C(p,p) E=1.765, 1.795, 1.895 MeV. Analyzed proton induced bremsstrahlung spectrum for near-resonance energies.
1976Me18: ^{12}C(pol. p,p) E=11.5-18.1 MeV; measured $\sigma(\theta)$, $A_y(\theta)$ for θ≈20° to 160°. Phase-shift analysis. Deduced resonances at E_p=13.13 MeV *2*, 15.24 MeV *4*, 17.58 MeV *3* and 17.60 MeV *2* (^{13}N*(14.06, 16.00, 18.16, 18.18 MeV)) with J^π=3/2$^+$, 7/2$^+$, 3/2$^+$, 1/2$^-$, and with $\Gamma_{c.m.}$=180 keV *35*, 135 keV *90*, 322 keV *75*, 225 keV *50*, and with Γ_p/Γ=0.29 *7*, 0.05 *4*, 0.08 *2* and 0.24 *6*. See further discussion on reduced widths and other fitting parameters. They suggest systematic errors in (1969Le18) that require ≤70 keV energy shifts.
1976Me22: ^{12}C(p,p) E=0.3-2.0 MeV; measured $\sigma(\theta)$ for θ=89.1°, 118.7° and 146.9°. R-Matrix analysis deduced levels at $E_{c.m.}$= 424 , 1558, 1604 keV with $\Gamma_{c.m.}$=33, 55, 50 keV. These data were included in a reanalysis given in (2023Ke11); see discussion in ^{12}C(p,γ). Of particular relevance was the description of the E_p=1735.5 keV *5* resonance with J^π=5/2$^+$, and Γ=49.0 keV *5*.
1976So02: ^{12}C(p,p) E=8.0-8.3 MeV, 8.909.4 MeV; measured $\sigma(\theta)$ for θ=87.4°. Analyzed the region around the E_{res}=9.14 MeV doublet by analyzing cross sections and spin-flip probability.
1977Bl09: ^{12}C(p,p) E=0.8 GeV; measured $\sigma(\theta)$ and $A_y(\theta)$ for θ≈1° to 30°.
1977Ma16: ^{12}C(p,p) E=14.23 MeV, ^{13}N(15.066 MeV T=3/2). Observed p decay to ^{12}C(0,4.4, 7.65, 9.65) and associated γ rays.
1978Cu04: ^{12}C(p,p) E=3.0, 49.48 MeV; measured $\sigma(\theta)$ for θ= 3° to 90°. Deduced OM parameters.
1978Fr12,1978Ho05: ^{12}C(pol. p,p) E=800 MeV; measured $\sigma(\theta)$ and A(θ) for θ=2° to 30°.
1979Al26: ^{12}C(p,p) E=1 GeV; measured $\sigma(\theta)$ for θ=5° to 25°. Analyzed nuclear density. Discussed quadrupole moments.
1979Be44: ^{12}C(pol. p,p) E=300-560 MeV; measured A(θ) for θ=5° to 20°.
1979Bo03: ^{12}C(p,p) E=3-61.4 MeV; measured and analyzed literature $\sigma(\theta)$. Deduced α-cluster structure in ^{12}C.
1979Ga13: ^{12}C(pol. p,p),(pol. p,p′) E=19.15-23.34 MeV; measured $\sigma(\theta)$ and $A_y(\theta)$ for θ=20° to 160° and for protons to ^{12}C(0, 4.4, 12.7 MeV). Deduced resonances at E_x= (≥19.5 MeV), 19.9 MeV, 20.2, 20.9, 21.4 and 22.4 MeV with J^π=1/2$^+$, 7/2$^+$, 5/2$^-$, 1/2$^+$, 5/2$^-$,1/2$^+$, and with Γ=(≥1.0), 0.75, 1.0, 1.2, 0.75 and (1.0) MeV. Evidence for additional states around 21.7 with J^π=3/2$^+$ and above 22.7 with 3/2$^+$ was discussed. They give an overview comparison of their results for this region with those of (1966Lo16, 1964Tamura, 1967Sc11, 1969Le18).
1979Kr18: ^{12}C(pol. p,p) E=450-600 KeV; measured A(θ) for θ=90° and 120°. Deduced evidence for Mott-Schwinger interaction.
1979Pr04: ^{12}C(p,p), (p,p′) E=6.9 MeV; measured $\sigma(\theta)$. Analyzed spin-flip probability. Deduced reaction mechanism.
1980Al09: ^{12}C(p,p) E=1 GeV; measured polarization observables for θ=3° to 19° Deduced spin-orbit amplitude parameters.
1980Co05: ^{12}C(p,p), (p,p′) E=122 MeV; measured $\sigma(E_P,\theta)$ for θ=10° to 60°. DWIA analysis. Analyzed spin-orbit tensor effective interaction.

^{12}C(p,p) (continued)

1980Fa07: ^{12}C(p,p), (p,p′) E=35.2 MeV; measured $\sigma(\theta)$ for θ= 30° to 170°. Deduced OM parameters.
1980Ka02: ^{12}C(p,p) E=40-75 MeV; measured $\sigma(\theta)$ and polarization observables forθ=47.5°. Presented measurements for θ=15° to 115° at E_p=65 MeV.
1980Th05: ^{12}C(pol p,p) E=14.226-14.236 MeV; measured $\sigma(\theta)$, $A_y(\theta)$ for θ=60° to 160°. For ^{13}N(15.07) deduced Γ_{lab}=1010 eV *30* and Γ_{p-lab}=285 eV *15* with a beam energy resolution of 850 eV; analyzed atomic excitation effects for the E_p=14230.75 keV state.
1980Tr03: ^{12}C(p,p) E≈1.7 MeV; measured σ(E). Analyzed interaction of proton induced bremsstrahlung with resonance.
1981Dy03: ^{12}C(p,p′γ(4.44)) E≈5-23 MeV; measured σ(E).
1981Me02, 1981Me11: ^{12}C(pol. p,p) E=200 MeV; measured $\sigma(\theta)$ and $A_y(\theta)$ for θ=6° to 115°.
1982Al18: ^{12}C(p,p) E=1 GeV; measured induced proton polarization, deduced spin-orbit parameters.
1981Fu12: ^{12}C(pol p,p′γ) E=22-29 MeV; measured polarization observables θ=45° to 150°.
1982Le03: ^{12}C(p,p) E=591, 696, 796 keV. Analyzed interaction of proton induced bremsstrahlung with resonance.
1982Ta09,1982Ta11: ^{12}C(p,p) E≈1.7 MeV; measured σ(E). Analyzed interaction of proton induced bremsstrahlung with resonance.
1983Ba57: ^{12}C(p,p′), (p,p) E=135 MeV; measured $\sigma(\theta)$ for θ=10° to 70°. Deduced OM parameters.
1983Me02: ^{12}C(pol. p,p) E=122, 160 MeV; measured $\sigma(\theta)$, A(θ) for θ=5° to 154°. Deduced OM parameters.
1983Ta12: ^{12}C(pol. p,p′(4.44)) E=159.4 MeV; measured $\sigma(\theta)$ and $A_y(\theta)$ for θ=7.5° to 45° DWBA/DWIA analyses.
1985Al16: ^{12}C(p,p) E=1 GeV; measured $\sigma(\theta)$ for θ=5° to 26°. Deduced OM parameters, analyzed density distribution.
1986Er06,1987Er01,1990Er02: ^{12}C(p,p) E ≈1.7 MeV; measured σ(E). Analyzed interaction of proton induced bremsstrahlung with resonances. Deduced reaction duration time and discussed $T_{1/2}$ for ^{13}N*(3.5 MeV) doublet.
1986Ho26: ^{12}C(p,p) E=350-550 keV; measured σ(E) for θ=95°, 124° and 152°.
1986Vu02: ^{12}C(pol. p,p) E=4-8 MeV; measured $A_y(\theta)$ for θ=20° to 165°.
1988Me02: ^{12}C(pol. p,p) E=200-300 MeV; measured $\sigma(\theta)$, $A_y(\theta)$ for θ=5° to 100°. Deduced OM parameters.
1989Vo05: ^{12}C(pol. p,p) E=72 MeV; measured $\sigma(\theta)$, $A_y(\theta)$ for θ≈15° to 160°. Deduced OM parameters.
1990Ev01: ^{12}C(pol. p,p) E=71.2 MeV; measured $A_y(\theta)$ for θ=40° to 48°.
1990Ho06: ^{12}C(pol. p,p) E=494 MeV; measured $\sigma(\theta)$, polarization observables for θ=5° to 37°.
1991Ba45: ^{12}C(pol. p,p) E=500 MeV; measured $A_y(\theta)$ and spin-rotation depolarization parameters for θ=10°, 15° and 20°.
1991Ka12: ^{12}C(p,p), (p,p′) E≈11-13 MeV; measured $\sigma(\theta$, E) Deduced levels and level parameters *Not accesible*.
1991Ya10: ^{12}C(p,p) E=2.5-3.6 MeV; measured $\sigma(\theta$=170°).
1992Ba30: ^{12}C(pol. p,p) E=1-2.1 MeV; measured analyzing powers $A_y(\theta)$ for θ=40° to 160°. Phase-shift analysis. Deduced E_{res}=1685 keV *6* and 1736 keV *8* for ^{13}N(3.499,3.546).
1992Wi01: ^{12}C(pol. p,p) E=189 MeV; measured $A_y(\theta)$ for θ=16.3°, 17.3° and 18.3°.
1992Wi13: ^{12}C(pol. p,p), E ≈14.231 MeV; reported $\sigma(\theta)$, $A_y(\theta)$ as in (1980Th05). See also (1983Wi04).
1993Ba37: ^{12}C(pol. p,p), (pol. p,p′) E=318 MeV; measured $\sigma(\theta)$ and polarization observables. RPA, DWIA analyses.
1993Da16: ^{12}C(p,p) E=1.5-1.8 MeV; measured σ(E). Analyzed interaction of proton induced bremsstrahlung with resonances. Discussed total collision duration.
1993Sy01: ^{12}C(pol. p,p) E=3.5-7.5 MeV; measured $\sigma(\theta)$, $A_y(\theta)$ and polarization observables for θ=30° to 145°.
1994Ai04: ^{12}C(p,p) E≈16.5-20 MeV; measured $\sigma(\theta)$.
1994Fa05: ^{12}C(p,p) E=1.80, 1.83 MeV; measured $\sigma(\theta)$, Analyzed interaction of proton induced bremsstrahlung with resonances.
1996Ho08: ^{12}C(pol. p,p) E=500 MeV; measured polarization transfer parameter.
1999Ta22: ^{12}C(pol. p,p) E=392 MeV; measured polarization observables for θ=0°.
2001Op01: ^{12}C(pol. p,p′) E=198 MeV; measured polarization observables for θ=7° to 22°.
2003Ha12: ^{12}C(pol. p,p) E=150 MeV; measured polarization observables for θ≈5° to 30°.
2006Ca19: ^{12}C(p,p) E=3-7 MeV; measured $\sigma(\theta)$ for θ=150°.
2007Be47: ^{12}C(p,p′γ) E=5-25 MeV; measured E_γ, I_γ, $\sigma(\theta)$ for θ=45° to 157.5°.
2010To03: ^{12}C(p,p) E=4.9-6.1 MeV; measured scattered protons. Deduced yields, stopping σ, sharp backscattering resonance at E_p=4808 keV.
2011Ab05: ^{12}C(p,p) E=2.7-7 MeV; measured backscattered protons for θ=140° to 170°. Analyzed utility for elastic spectroscopy.
2011Gu31: ^{12}C(p,p) E=1-2, 8 MeV measured $\sigma(\theta)$ for 30° to 170°.
theoretical analysis:
1971Au02: Computed partial proton width for E_x=15.07 MeV T=3/2 state.
1973An07: ^{12}C(p,p) E=1.5-3 MeV; analyzed E≈3.5 MeV resonances.
1977Al25: ^{12}C(p,p) E=1 GeV; analyzed induced proton polarization.
1981Pe06: ^{12}C(p,p) E_p≈1.7 MeV; calculated $\sigma(\theta)$.

^{12}C(p,p) (continued)

1983Ol04: ^{12}C(p,p) E<4.5 MeV; calculated σ(E). S-matrix formalism.
1984Ko37: ^{12}C(vec p,p$_0$) analyzed data for states up to E$_x$=7.8 MeV.
1984Ph02: ^{12}C(pol. p,p) E=800 MeV; analyzed LANL $\sigma(\theta)$ and A$_y(\theta)$ data to obtain OM parameters. See also (1985Bl22).
1993By02: ^{12}C(p,p) E=64.9, 72, 83.4 MeV; calculated $\sigma(\theta)$ for θ=20°−80°. Analyzed N-N interaction.
2019Ma89: ^{12}C(p,p′γ) E=8-22 MeV; measured $\sigma(\theta)$ for θ=50° to 140°.
2005Pi16: ^{12}C(p,p) E≈1-7 MeV. Calculated $\sigma(\theta)$ and predicted level energies.
2015Be12: ^{12}C(p,p) E < 200 MeV. Cluster model analysis of proton scattering.

^{13}N Levels

E(level)[†]	J$^\pi$	Γ	L	Comments
2369 *3*	1/2$^+$	31 keV	0	E(level),J$^\pi$,Γ: From E$_{res}$=461 keV *3* (1953Jackson). θ^2=0.54 (1953Jackson × 0.66). (1951Ja21): E$_x$=2379 keV, Γ=33 keV. (1953Jackson): E$_{res}$=461 keV *3*, J$^\pi$=1/2$^+$ and Γ=31 keV from phase-shift analysis. (1954Mi05): E$_{res}$=462 keV *4* and Γ$_{c.m.}$=32 keV. (1976Me22): E$_{c.m.}$=424 keV with Γ$_{c.m.}$=33 keV (1976Me22).
3499 *6*	3/2$^-$	63 keV	1	θ^2=0.031 (1953Jackson value × 0.66). E(level),J$^\pi$,Γ: From E$_p$=1686 keV *6* (1966Ar03). (1951Ja21): E$_x$=3501 keV, Γ=42 keV. (1953Jackson) E$_{res}$=1698 keV, J$^\pi$=3/2$^-$ and Γ=55 keV. (1966Ar03): E$_p$=1686 keV *6*, J$^\pi$=3/2$^-$ and Γ=63 keV. They also report ΔE(3/2$^-$,5/2$^+$)=48 keV *2* and reduced width values. (1976Me22): E$_{c.m.}$=1558 keV with Γ$_{c.m.}$=55 keV. (1992Ba30): E$_{res}$=1685 keV *6* J=3/2$^-$ from phase-shift analysis.
3544.4 *5*	5/2$^+$	49.0 keV *5*	2	E(level): E$_{res}$=1735.5 keV *5* from the average of E$_p$=1734 keV *6* (1966Ar03), E$_p$=1736 keV *8* (1992Ba30) and E$_p$=1735.5 keV *5* from the (2023Ke11) analysis of (1976Me22). J$^\pi$,Γ: From the (2023Ke11) R-matrix analysis of (1976Me22). θ^2=0.21 (1953Jackson value × 0.66). (1951Ja21): E$_x$=3549 keV, Γ=40 keV (1951Ja21). (1953Jackson) E$_{res}$=1748 keV, J$^\pi$=5/2$^+$ and Γ=61 keV, (1966Ar03): E$_p$=1734 keV *6*, J$^\pi$=5/2$^+$ and Γ=74 keV. They also report ΔE(3/2$^-$,5/2$^+$)=48 keV *2* and reduced width values. (1976Me22): E$_{c.m.}$=1604 keV with Γ$_{c.m.}$=50 keV. A subsequent reanalysis in (2023Ke11) resulted in E$_p$=1735.5 keV *5* with J$^\pi$=5/2$^+$, and Γ=49.0 keV *5*. (1992Ba30): E$_{res}$=1736 keV *8* J=5/2$^+$ from phase-shift analysis.
6378 *8*	5/2$^+$	11 keV	2	E(level),J$^\pi$,Γ: From E$_{res}$=4808 keV *8* (1956Re39). θ^2=0.0031 (1956Re39). (1956Re39): E$_{res}$=4808 keV *8*, J$^\pi$=5/2$^+$, Γ$_{lab}$=12 keV and θ^2=0.0031 from phase-shift analysis. (1966Ba35): E$_{res}$=4.80 MeV, J$^\pi$=5/2$^+$ and Γ$_{lab}$=12 keV See also (1967Barnard).
6890 *6*	3/2$^+$	115 keV *5*	2	Γ$_{p0}$=51 keV (1963Ba36); Γ$_{p1}$=63 keV (1963Ba36) θ^2=0.13 (1963Ba36). E(level): from E$_{res}$=5363 keV *6* from the average of E$_{res}$=5370 keV *8* (1956Re39), E$_{res}$=5.35 MeV *1* (1963Ba36) and E$_p$=5374 keV *20* (1967Duval). J$^\pi$: from phase-shift analysis of angular distributions and σ(E) in (1956Re39) ^{12}C(p,p),(p,p$_1\gamma(\theta)$). See also (1965Be12). Γ: From (1963Ni05). Γ$_{p0}$: See also Γ$_{p0}$=46 keV (1963Ni05). (1956Re39): E$_{res}$=5370 keV *8*, J$^\pi$=3/2$^+$ and Γ$_{lab}$=125 keV. (1956Sc29): E$_{res}$=5.30 keV, L:J$^\pi$=2:3/2$^+$, Γ=50 keV. See unpublished results in (1959Aj76). (1960Yo05): E$_{res}$=5.37 MeV.

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^{12}C(p,p) (continued)

^{13}N Levels (continued)

E(level)†	J^{π}	Γ	L	Comments
				(1961Ad04): E_{res}=5.63 MeV and Γ_{lab}=140 keV. (1962Sh22): E_{res}=5.38 MeV, $J^{\pi}=3/2^{+}$, Γ=115 keV and θ^{2}=0.01 from phase-shift analysis. (1961Ba25, 1961Mc11): E_{res}=5.4 MeV. (1963Ba36): E_{res}=5.35 MeV *1*, $J^{\pi}=3/2^{+}$, $\Gamma_{c.m.}$=114 keV Γ_{p0}=51 keV, Γ_{p1}=63 keV. (1963Ni05): E_{p}=5.38 MeV, $J^{\pi}=3/2^{+}$, $\Gamma_{c.m.}$=115 keV *5* and Γ_{p0}=46 keV (1963Ni05). (1966Ba35): E_{res}=5.30 MeV, $J^{\pi}=3/2^{+}$ and Γ_{lab}=74 keV. (1967Duval): E_{p}=5374 keV *20*. (1968Be31): E_{res}=5.38 MeV, $J^{\pi}=3/2^{+}$.
7155 *9*	$7/2^{+}$	9.0 keV *5*	4	Γ_{p0}=0.36 keV; Γ_{p1}=8.64 keV *50* E(level),J^{π}: from E_{res}=5.65 MeV *1* (1963Ba36). Γ,Γ_{p1}: From (1963Ni05). θ^{2}=0.016 (1963Ba36). (1960Yo05): E_{res}=5.69 MeV (1960Yo05). (1963Ba36): E_{res}=5.65 MeV *1*, $J^{\pi}=7/2^{+}$, $\Gamma_{c.m.}$=7.7 keV Γ_{p0}=0.03 keV, Γ_{p1}=7.4 keV. Γ_{p0}=0.03 keV may be a typo since the value Γ_{p0}=0.3 keV give the better accounting. Phase-shift and interference analysis. (1963Ni05) E_{p}=5.68 MeV, $J^{\pi}=(7/2^{+})$, $\Gamma_{c.m.}$=9.0 keV *5* and Γ_{p0}=0.36 keV. Phase-shift analysis.
7.38×10^{3}	$5/2^{-}$	69 keV *5*	3	Γ_{p0}=6.9 keV E(level): From (1956Re39), for example. J^{π}: From polarization data in (1968Be31). See discussion in (1966Sh10). Γ,Γ_{p0}: From (1963Ni05). See also $\Gamma_{c.m.}$=61 keV, Γ_{p0}=5.0 keV, Γ_{p1}=56 keV (1963Ba36) and Γ_{lab}=70 keV and Γ_{p0}/Γ=0.08 (1968Be31). θ^{2}=0.069 (1963Ba36). (1956Br27) E_{res}=5891 keV, Γ_{lab}= 55 keV. (1956Sc29): E_{res}=5.85 keV, L:J^{π}=1:$3/2^{-}$, Γ=50 keV. See unpublished results in (1959Aj76). (1960Yo05): E_{res}=5.93 MeV. (1961Ad04): E_{res}=5.89 MeV, Γ_{lab}=70 keV. (1961Ba25,1961Mc11): E_{res}=5.9 MeV. (1962Sh22): E_{res}=5.90 MeV, $J^{\pi}=5/2^{+}$, Γ=80 keV and θ^{2}=0.01 from phase-shift analysis. (1963Ba36): E_{res}=5.89 MeV *1*, $J^{\pi}=(5/2^{-},7/2^{-})$, $\Gamma_{c.m.}$=61 keV, Γ_{p0}=5.0 keV, Γ_{p1}=56 keV. (1963Ni05): E_{p}=5.90 MeV, $J^{\pi}=5/2^{-}$, $\Gamma_{c.m.}$=69 keV *5* and Γ_{p0}=6.9 keV. (note:Γ_{lab}=75 keV 5 is listed in the abstract as $\Gamma_{c.m.}$. The issue is clear in the conclusions paragraph). (1966Ba35): E_{res}=5.88 MeV, $J^{\pi}=5/2^{-}$ and Γ_{lab}=70 keV. (1968Be31): E_{res}=5.88 MeV, $J^{\pi}=5/2^{-}$, Γ_{lab}=70 keV and Γ_{p0}/Γ=0.08.
8.0×10^{3}	$3/2^{+}$	≈1.5 MeV	2	E(level): E_{res}≈6530 from average of E_{res}=6.65, 6.6, 6.35 MeV. J^{π}: From (1962Sh22,1966Ba35). Γ: From average of Γ=1400 keV (1962Sh22) and Γ_{lab}=1.72 MeV (1966Ba35). See also Γ=350 keV (1956Sc29). θ^{2}=0.14 (1962Sh22). (1956Sc29): E_{res}=6.65 keV, L:J^{π}=2:$3/2^{+}$, Γ=350 keV. (1961Ba25, 1961Mc11): E_{res}=6.65 MeV. (1961Na02): E_{res}=(6.65) MeV. (1962Sh22): E_{res}=6.6 MeV, $J^{\pi}=3/2^{+}$, Γ=1400 keV and θ^{2}=0.14 from phase-shift analysis. (1966Ba35): E_{res}=6.35 MeV, $J^{\pi}=3/2^{+}$ and Γ_{lab}=1.72 MeV.
8.90×10^{3}	$1/2^{-}$	230 keV	1	E(level),Γ: From E_{res}≈7540 keV, Γ from Γ_{lab}≈250 keV. θ^{2}=0.02 (1962Sh22). (1961Ad04): E_{res}=7.55 MeV, Γ_{lab}=255 keV.

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^{12}C(p,p) (continued)

^{13}N Levels (continued)

E(level)†	J^{π}	Γ	L	Comments
				(1961Ba25, 1961Mc11, 1961Mc16): E_{res}=7.6 MeV. (1962Sh22): E_{res}=7.53 MeV, J^{π}=1/2^{-}, Γ=225 keV and θ^2=0.02 from phase-shift analysis. (1966Ba35): E_{res}=7.53 MeV, J^{π}=1/2^{-} and Γ_{lab}=250 keV. (1973Be37): $E_{res.}$=7575 keV and Γ=0.25 MeV.
9.48×10^3	3/2^{-}	30 keV	1	E(level): From E_{res}=8170 keV. θ^2=0.001 (1962Sh22). Γ_{p1}/Γ=0.72 (1972Be15). (1961Ad04): E_{res}=8.17 MeV, Γ_{lab}=38 keV. (1961Ba25, 1961Mc11, 1961Mc16): E_{res}=8.2 MeV. (1962Sh22): E_{res}=8.17 MeV, J^{π}=3/2^{-}, Γ=30 keV and θ^2=0.001 from phase-shift analysis. (1966Ba35): E_{res}=8.16 MeV, J^{π}=3/2^{-} and Γ_{lab}=30 keV. (1972Be15): E_{res}=8.18, $\Gamma_{lab}\approx$28 keV and Γ_{p1}/Γ=0.72.
10.37×10^3	5/2^{-}	30 keV	3	Γ_{p0}/Γ=0.26 (1968Be31). E(level),J^{π},Γ: From $E_{res}\approx$9130 keV (1968Be31). E(level): In (1966Sw04) a doublet was identified around E_{res}=9.12 MeV. Previously, only the J^{π}=7/2^{-} state had been identified. Later, 1967Swindt identified the doublet members at E_p= 9145 and 9152 keV via phase-shift analysis with J^{π}=5/2^{-} and 7/2^{-} and with Γ_{lab}=12 and 90 keV, respectively. E(level): In (1968Be31) E_{res}=9.13 MeV, J^{π}=5/2^{-} from polarization data , Γ_{lab}=33 keV and Γ_{p0}/Γ=0.26. The level energies of the doublet states differ by less than 2 keV. (1961Ad04): E_{res}=9.12 MeV, Γ_{lab}=70 keV. (1961Ba25, 1961Mc11, 1961Mc16): E_{res}=9.2 MeV. (1961Na02): E_{res}=9.1 MeV, Γ=150 keV.
10.37×10^3	7/2^{-}	76 keV	3	Γ_{p0}/Γ=0.81 (1968Be31). E(level),J^{π},Γ: From $E_{res}\approx$9130 keV (1968Be31). E(level): In (1966Sw04) a doublet was identified around E_{res}=9.12 MeV. Previously, only the J^{π}=7/2^{-} state had been identified. Later, 1967Swindt identified the doublet members at E_p=9145 and 9152 keV via phase-shift analysis with J^{π}=5/2^{-} and 7/2^{-} and with Γ_{lab}=12 and 90 keV, respectively. E(level): In (1968Be31) E_{res}=9.13 MeV, J^{π}=7/2^{-} from polarization data, Γ_{lab}=82 keV and Γ_{p0}/Γ=0.81. (1961Ad04): E_{res}=9.12 MeV, Γ_{lab}=70 keV. (1961Ba25, 1961Mc11, 1961Mc16): E_{res}=9.2 MeV. (1961Na02): E_{res}=9.1 MeV, Γ=150 keV. (1962Sh22): E_{res}=9.14 MeV, J^{π}=7/2^{-}, Γ=73 keV and θ^2=0.01 from phase-shift analysis. (1966Ba35): E_{res}=9.13 MeV, J^{π}=7/2^{-} and Γ_{lab}=84 keV.
11.49×10^3 *5*	5/2^{+}	430 keV *35*	2	Γ_{p0}/Γ=0.70 *5* (1973Me03) E(level),J^{π},Γ: from E_{res}=10.35 MeV *5* (1973Me03). In (1976Aj04) values from the E_p=9.5-11.5 MeV phase-shift analysis of (1973Me03) were accepted; we continue this acceptance and note that averaging with other values would have little impact. (1961Mc16): E_{res}=10.3 MeV. (1961Na02): E_{res}=10.5 MeV, Γ=700 keV. (1972Wi26): E_{res}=10.25 MeV *10*, J^{π}=5/2^{+}, Γ=0.45 MeV *10* and Γ_{p0}/Γ=0.65 *15*. (1973Me03): E_{res}=10.35 MeV *5*, J^{π}=5/2^{+}, $\Gamma_{c.m.}$=430 keV *35* and Γ_{p0}/Γ=0.70 *5*.
11.70×10^3 *3*	5/2^{-}	115 keV *30*	3	Γ_{p0}/Γ=0.60 *4* (1973Me03) E(level),J^{π},Γ: E_{res}=10.58 MeV *3* (1973Me03). The E_p=9.5-11.5 MeV

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^{12}C(p,p) (continued)

^{13}N Levels (continued)

E(level)[†]	J^π	Γ	L	Comments
				phase-shift analysis of (1973Me03) is accepted. See comment on E_x=10.49 MeV. (1961Ad04): E_{res}=10.51 MeV, Γ_{lab}=85 keV. (1961Ba25, 1961Mc11, 1961Mc16): E_{res}=10.5 MeV. (1972Wi26): E_{res}=10.51 MeV *2*, J^π=5/2$^-$, Γ=120 keV *30* and Γ_{p0}/Γ=0.55 *5*. (1973Me03): E_{res}=10.58 MeV *3*, J^π=5/2$^-$, $\Gamma_{c.m.}$=115 keV *30* and Γ_{p0}/Γ=0.60 *4*.
11.74×10^3 *4*	3/2$^+$	250 keV *30*	2	Γ_{p0}/Γ=0.30 *5* (1973Me03) E(level),J^π,Γ: E_{res}=10.62 MeV *4*, J^π=3/2$^+$, $\Gamma_{c.m.}$=250 keV *30* and Γ_{p0}/Γ=0.30 *5* from the E_p=9.5-11.5 MeV phase-shift analysis of (1973Me03) are acccepted. See comment on E_x=10.49 MeV. See also E_{res}=10.70 MeV *5*, J^π=3/2$^+$, Γ=250 keV 50 and Γ_{p0}/Γ=0.62 *10* (1972Wi26).
11.74×10^3 *5*	3/2$^-$	530 keV *80*	1	Γ_{p0}/Γ=0.55 *5* (1973Me03) E(level),J^π,Γ: E_{res}=10.62 MeV *5*, J^π=3/2$^-$, $\Gamma_{c.m.}$=530 keV *80* and Γ_{p0}/Γ=0.55 *5* from the E_p=9.5-11.5 MeV phase-shift analysis of (1973Me03) are acccepted. See comment on E_x=10.49 MeV. See also E_{res}=10.54 MeV *50*, J^π=3/2$^-$, Γ=230 keV *50* and Γ_{p0}/Γ=0.45 *10* (1972Wi26).
11.86×10^3 *4*	1/2$^+$	380 keV *50*	0	Γ_{p0}/Γ=0.35 *5* (1973Me03) E(level),J^π,Γ: E_{res}=10.75 MeV *4*, J^π=1/2$^+$, $\Gamma_{c.m.}$=380 keV *50* and Γ_{p0}/Γ=0.35 *5* from the E_p=9.5-11.5 MeV phase-shift analysis of (1973Me03) are acccepted. See comment on E_x=10.49 MeV. See also E_{res}=10.74 MeV, Γ_{lab}=140 keV (1961Ad04).
12.13×10^3 *5*	7/2$^-$	250 keV *30*	3	Γ_{p0}/Γ=0.30 *5* (1973Me03) E(level): From E_{res}=11.05 MeV *5* (1973Me03). The E_p=9.5-11.5 MeV phase-shift analysis of (1973Me03) is acccepted. See comment on E_x=10.49 MeV. (1961Ad04): E_{res}=10.99 MeV, Γ_{lab}= 150 keV. (1961Mc16) E_{res}=11.0 MeV. (1973Me03): E_{res}=11.05 MeV *5*, J^π=7/2$^-$, $\Gamma_{c.m.}$=250 keV *30* and Γ_{p0}/Γ=0.30 *5*.
13.5×10^3		≈500 keV		E(level),Γ: From E_p=12.5 and Γ=500 keV (1961Na02).
14.05×10^3 *2*	3/2$^+$	180 keV *35*	2	T=1/2; Γ_{p0}/Γ=0.29 *7* E(level),J^π,Γ: From E_{res}=13.13 MeV *2*, J^π=3/2$^+$, $\Gamma_{c.m.}$=180 keV *35* and Γ_{p0}/Γ=0.29 *7* phase-shift analysis (1976Me18). The authors suggest a ≤70 keV systematic error in (1969Le18). See also E_{res}=13.2 MeV, Γ=500 keV (1961Na02).
14.7×10^3?		≈500 keV		E(level): See E_{res}=13.7 MeV, Γ=500 keV (1961Na02). This resonance does not appear in the (1981Aj01) evaluation or later.
15064.56 *40*	3/2$^-$	0.932 keV *28*	1	T=3/2 Γ_p=263 eV *14* (1980Th05) E(level),T: From E_p=14230.75 keV *20* and T=3/2 (1973Hu07). E(level): See also E_p=14232.5 keV *22* (1975Go03); Γ_p/Γ=0.18 was used in the fit. Γ: From Γ=1010 eV *30* and Γ_p=285 eV *15* (both lab frame) (1980Th05). Atomic excitations were taken into account, See also (1983Wi04,1992Wi13). Γ: See also $\Gamma_{c.m.}$=1.10 keV *9*, Γ_p=210 eV *11* and Γ_p/Γ=0.191 *17* (1975Hi07). J^π: From phase-shift analysis in (1969Le18). p decay to ^{12}C(0,4.4, 7.65, 9.65) is observed in (1977Ma16).
16.01×10^3 *4*	7/2$^+$	135 keV *90*	4	T=1/2; Γ_{p0}/Γ=0.05 *4* E(level): From average of E_{res}=15.27 MeV *3* (1973Me12) and E_{res}=15.24 MeV *4* (1976Me18). J^π: From phase-shift analysis in (1969Le18).

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^{12}C(p,p) (continued)

^{13}N Levels (continued)

E(level)[†]	J^π	Γ	L	Comments
				Γ: From (1973Me12). See also (1976Me18). E(level): A second state near E_x=16 MeV with Γ≈500 keV had previously been adopted, apparently based on (1964Da03) and (1961Na02); however this seemes unwarranted. In (1964Da03) the authors indicate improved data are necessary, and in (1961Na02,1967Ku02,1976Be28) the associated peaks are rather narrow. (1973Me12): E_{res}=15.27 MeV *3*, $\Gamma_{c.m.}$=130 keV *30* and Γ_p(12.71)=30 keV. (1976Me18): E_{res}=15.24 MeV *4*, J^π=7/2$^+$, $\Gamma_{c.m.}$=135 keV *90* and Γ_{p0}/Γ=0.05 *4*. (1961Na02): E_{res}=15.1 MeV (1961Na02). (1967Ku02): E_p=15.2 MeV and T=(1/2) (1967Ku02). (1976Be28) E_p=15.27 MeV (1976Be28).
17.4×10^3				E(level): From E_p=16.8 MeV (1976Be28).
18.15×10^3 *3*	3/2$^+$	322 keV *75*	2	T=1/2; Γ_{p0}/Γ=0.08 *2* E(level),J^π,Γ: From E_{res}=17.58 MeV *3* phase-shift analysis in (1976Me18). (1962Wa31): E_p=17.5 MeV and $\Gamma_{c.m.}$=0.33 MeV *10*. (1976Me18): E_{res}=17.58 MeV *3*, J^π=3/2$^+$, $\Gamma_{c.m.}$=322 keV *75* and Γ_{p0}/Γ=0.08 *2*. See also table 13.25 of (1970Aj04) where Ep=17.27 MeV *5* and $\Gamma_{c.m.}$≈400 keV from Snover BAPS **13** (1968) 1662 and a 1968 Private Communication are referenced.
18.17×10^3 *2*	1/2$^-$	225 keV *50*	1	T=1/2; Γ_{p0}/Γ=0.24 *6* E(level),J^π,Γ: From E_{res}=17.60 MeV *2*, J^π=1/2$^-$, $\Gamma_{c.m.}$=225 keV *50* and Γ_{p0}/Γ=0.24 *6* phase-shift analysis in (1976Me18). E(level): See also E_p=17.6 MeV and T=(1/2) (1967Ku02).
18405 *5*	3/2$^+$	66 keV *8*	2	T=3/2 E(level),Γ: from E_p=17.857 MeV in (1970Aj04) Table 13.25. E(level): In (1970Aj04), E_p=17857 keV *5* and Γ=66 keV *8* are given in Table 13.25; the values appear connected with Snover BAPS **13** (1968) 1662 and a 1968 Private Communication. J^π: From phase-shift analysis in (1969Le18). (1967Ku02): E_x=18.43 MeV *2*, Γ≈30 and T=3/2. (1962Wa31): E_p=18.05 MeV and $\Gamma_{c.m.}$≤200 keV. (1976Be28): E_p=17.87 MeV.
18960 *9*	3/2$^-$ or 7/2$^+$	23 keV *5*		T=3/2 E(level),Γ: from E_p=18.460 MeV in (1970Aj04) Table 13.25. E(level): In (1970Aj04), E_p=18460 keV *10* and Γ=23 keV *5* are given in Table 13.25; the values appear connected with Snover BAPS **13** (1968) 1662 and a 1968 Private Communication. J^π: From phase-shift analysis in (1969Le18). (1967Ku02): E_x=18.98 MeV *2*, Γ≈10 keV, L=(1) and T=3/2. (1976Be28): E_p=18.46 MeV.
19.9×10^3	7/2$^+$	750 keV	4	T=1/2 E(level),J^π,Γ: From E_x=19.9 MeV, J^π=7/2$^+$, Γ=0.75 MeV polarization data in (1979Ga13); see also E_p=19.3 MeV and $\Gamma_{c.m.}$≤200 keV (1962Wa31). E(level): Several earlier Ajzenberg-Selove evaluations associate this state with resonances observed near $E_{c.m.}$=19.8 MeV; see (1965Ma26,1966Lo16,1967Sc11), but these appear to be misplaced.
20.2×10^3	5/2$^-$	1000 keV		E(level),J^π,Γ: From E_x=20.2 MeV, J^π=5/2$^-$, Γ=1.0 MeV polarization data in (1979Ga13). E(level): See also (1963Me04) who suggested resonances near E_p=20

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^{12}C(p,p) (continued)

^{13}N Levels (continued)

E(level)[†]	J^π	Γ	Comments
			MeV based on their analysis of ^{12}C(p,p$'\gamma$(12.7,15.1).
20.90×10^3 *30*	1/2$^+$	1.2 MeV	E(level): From E$_p$=20.5 MeV *30* (1973Me12). J^π,Γ: From E$_x$=20.9 MeV polarization data in (1979Ga13). (1966Lo16): E$_{c.m.}$=19.0 MeV, J^π=(5/2,9/2) and Γ=1.5 MeV. (1967Sc11) find E$_x$=20.9 MeV, J^π=5/2$^+$, L=2,0. (1973Me12): E$_p$=20.55 MeV *30*, J^π=(5/2$^+$), Γ=1.1 MeV, Γ$_{p0}$≈110 keV, Γ$_{p15.11}$≈400 keV. (1976Fe11): E$_p$=20 MeV. (1976Be28): E$_p$=20.5 MeV, J^π=(3/2$^+$). (1979Ga13: E$_x$=20.9 MeV, J^π=1/2$^+$, Γ=1.2 MeV. See (1963Me04) who suggested a resonance near E$_p$=20 MeV Based on their analysis of ^{12}C(p,p$'\gamma$(12.7,15.1)).
21.4×10^3	5/2$^-$	750 keV	E(level),J^π,Γ: From E$_x$=21.4 MeV, J^π=5/2$^-$, Γ=0.75 MeV polarization data in (1979Ga13).
21.7×10^3	(3/2$^+$)		E(level): From E$_{c.m.}$=19.75 MeV (1964Tamura analysis of (1963Di16)). 1964Tamura analysis of (1963Di16): E$_{c.m.}$=19.75 MeV J^π=(3/2$^+$) and Γ$_{c.m.}$=2.49 MeV are deduced. (1965Ma26):See E$_{c.m.}$=19.8 MeV. (1979Ga13): polarization data suggest a state around 21.7 MeV with J^π=3/2$^+$.
22.4×10^3 *5*	1/2$^+$	≈1 MeV	E(level): From E$_p$=22.2 MeV *5* (1973Me12). J^π,Γ: From E$_x$=22.4 MeV polarization data in (1979Ga13). E(level): Resonances at several energies around E$_x$=22 MeV have in been reported (1963Di16, 1964Tamura, 1965Ma26, 1967Sc11). In (1970Aj04) Table 13.25 proton resonances were listed at E$_x$=21.99 and 22.6 MeV. However, guided by the discussion and analysis of (1979Ga13, 1981Aj01), we accept only the E$_x$=22.4 MeV J$^\pi$=1/2$^+$ state. Along with the accepted states reported in (1979Ga13), their analysis indicated additional states around 21.7 with J^π=3/2$^+$ and above 22.7 with 3/2$^+$. 1964Tamura analysis of (1963Di16): E$_{c.m.}$=20.05 MeV J^π=(5/2$^+$) and Γ$_{c.m.}$=1.46 MeV. (1965Ma26): E$_{c.m.}$=20.01 MeV. (1967Sc11): E$_x$=22.5 MeV, J^π=5/2$^-$, L=1. (1966Lo16): E$_{c.m.}$=20.8 MeV, J^π=(5/2,9/2) and Γ=0.5 MeV. (1973Me12): E$_p$=22.2 MeV *5*, J^π=(5/2$^-$), Γ≈2 MeV, Γ$_{p0}$≈200 keV, Γ$_{p15.11}$≈450 keV. (1979Ga13): E$_x$=22.4 MeV, J^π=1/2$^+$, Γ≈1.0 MeV.
24.1×10^3	7/2	<500 keV	E(level),J^π,Γ: From E$_{c.m.}$=22.2 MeV, J^π=7/2 and Γ=0.5 MeV polarization data in (1966Lo16). E(level): See also E$_p$=23.8 MeV (1975Sl02).
25.6×10^3	(3/2$^-$)		E(level): From average of E$_x$=25.5 MeV (1967Sc11) and E$_p$=25.9 MeV (1975Sl02). J$^\pi$: from E$_x$=25.5 MeV, J^π=3/2$^-$, L=1 Legendre polynomial angular correlation analysis in (1967Sc11).
26.87×10^3			E(level): from E$_{c.m.}$=24.93 MeV (1964Tamura analysis of (1963Di16)). 1964Tamura analysis of (1963Di16): E$_{c.m.}$=24.93 MeV and Γ$_{c.m.}$=2.17 MeV. (1965Ma26): E$_{c.m.}$=24.9 MeV (1965Ma26). (1976Fe11): E$_p$=27 MeV.
31.4×10^3			E(level): From E$_p$=32 MeV (1976Fe11); seen only in ^{12}C(p,p$'\gamma$(4.44)).

[†] Level energies are deduced using E$_p$(res) and ^{12}C, p and ^{13}C masses from (2021Wa16: AME-2020). E$_x$=S$_p$+E$_{c.m.}$(relativistic).

^{12}C(p,α)

1969Le18: ^{12}C(p,α) 9.4-21.5 MeV. Measured σ(E,θ) for θ=25° to 165°. Deduced resonace in $\alpha_{0,1}$ at E$_p$=14.231 MeV 4 with Γ=1.22 keV and Γ_{p0}=0.25 keV. The analysis is coupled with their associated (p,p) data. In (1970Aj04) the full collection of states given in Table 1 of (1969Le18) are associated with the (p,α) reaction; but this seems arbitrary given their θ=60° data shown in Fig 7. Isospin values are discussed. The results shown in Table 1 include ^{13}N states from E$_x$=13.96 to 19.88 MeV that were studied via phase-shift analysis. The complex of states around E$_p$=10.5 to 11 MeV were analyzed, but the no results could be obtained.

1975Hi07: ^{12}C(p,α), ^{12}C(p,p) E=14.222-14.242 MeV measured σ(E) at θ=175°. Analyzed ^{13}N(14.07) mainly from (p,p). They deduced Γ=1.10 keV *9*, Γ_p=210 eV *11* and Γ_p/Γ=0.191 *17*. Analyzed other level decay properties such as partial widths, but they used branching ratios from (1973Ad02) with their Γ and Γ_p.

See also.

1964Ba29: ^{12}C(p,α) E=12.7-18.3 MeV; studied ^{9}B states.
1965Is05: ^{12}C(p,α), (p,p′) E=13 MeV; measured σ(E$_a$,θ), σ(E$_p$,θ).
1967Ac01: ^{12}C(p,α) E=38 MeV; measured σ(E$_\alpha$,θ).
1967Cr05: ^{12}C(p,α E=30.5-45.1 MeV, σ(E$_\alpha$,θ) for $\theta\approx$20° to 173°.
1969Ga03: ^{12}C(p,α) E=38 MeV; measured σ(E$_\alpha$,θ) for $\theta\approx$20° to 180°. PWBA analysis.
1970Gu06, 1971Gu23: ^{12}C(p,α_0) E=25-45 MeV; measured σ(E,θ) θ=20° to 170°. Discussed reaction mechanism.
1970Ko25: ^{12}C(p,α) E=665 MeV; measured σ(E).
1972Ma21: ^{12}C(p,α) E=54.1 MeV; measured σ(E$_\alpha$,θ) for θ=10° to 60°.
1980Da07: ^{12}C(p,α) E=45.2 MeV; measured σ(E$_\alpha$,θ) for θ=20° to 50°. Analyzed data via finite range DWBA.
1981Do13: 12C(pol. p,α_0) E=72 MeV; measured $\sigma(\theta)$, A$_y(\theta)$ for θ=20° to 150°. Deduced reaction mechanism.
1983Pe07: ^{12}C(p,α) E=42.77 MeV; measured σ(E$_\alpha$,θ) for θ=15° to 75°. Deduced optical model parameters.
1989Gu05: ^{12}C(p,α) E=50 MeV; measured $\sigma(\theta)$.

^{13}N Levels

E(level)[†][‡]	J$^\pi$[‡]	Γ[‡]	E$_{res}$ (keV)	Comments
13962?	3/2$^+$	140 keV	13035	Γ_{p0}=126 keV (1969Le18)
15064 *4*	3/2$^-$	1.10 keV *9*	14231 *4*	Γ_{p0}=210 eV *11* T=3/2 Γ,Γ_{p0}: From (1975Hi07) analysis (p,p) and (p,α) data. E(level): From (1969Le18); see also Γ=1.22 keV and Γ_p=0.24 keV from their analysis of (p,p) and (p,α) data.
15975?	7/2$^+$	100 keV	15220	Γ_{p0}=7.5 keV (1969Le18)
18232	1/2$^-$	300 keV	17670	Γ_{p0}=120 keV (1969Le18)
18352	3/2$^+$	100 keV	17800	Γ_{p0}=25 keV (1969Le18)
18960	(3/2$^-$,7/2$^+$)	15 keV	18459	$\Gamma_{p0}\approx$0.30 keV (1969Le18)
19.83×10^3	5/2$^-$	1 MeV	19.4×10^3	Γ_{p0}=175 keV (1969Le18)
19.88×10^3	3/2$^+$	520 keV	19.46×10^3	Γ_{p0}=208 keV (1969Le18)

[†] Level energies are deduced using E$_p$(res) and ^{12}C, p and ^{13}C masses from (2021Wa16: AME-2020). E$_x$=S$_p$+E$_{c.m.}$(relativistic).
[‡] From phase-shift analysis in (1969Le18).

^{12}C(d,n)

Cook et al., Phys. Rev. **74** (1948) 502: ^{12}C(d,n) E=12 MeV at the Indiana University cyclotron. Measured β end point and deduced T$_{1/2}$=10.2 min *1*.

Grosskreutz, et al., Phys. Rev. 76 (1949) 482: ^{12}C(d,n). Reported states at E$_x$=2.29 MeV *12*, 3.48 MeV *12* and 3.74 MeV *5*.

1950Ho01: ^{12}C(d,n). Measured β spectrum and end-point energy; deduced T$_{1/2}$=10.05 M *10*.

1953Mi10: ^{12}C(d,n) E=8 MeV; measured $\sigma(\theta)$ for θ=0° to 60°. Deduced ^{13}N(0,2.38 MeV *5*,3.53 MeV *5*) with L=1, 0 and 2(doublet), respectively.

1955Ma76: 12C(d,n) E≈ 3 MeV; investigated threshold region. Deduced E$_x$=2.37 MeV *2*.

1955Wi43: 12C(d,n) E≤20 MeV; measured activation cross section. Deduced T$_{1/2}$=10.08 min *4* from analysis of the 14.1 MeV data.

1959El44: ^{12}C(d,n) E=1.45-2.95 MeV; measured $\sigma(\theta)$ for θ=0° to165°.

1957Ca02: ^{12}C(d,n$_{0,1,2+3}$) E=1.45-2.95 MeV; measured $\sigma(\theta)$ for θ<60°. Deduced level energies, L, J$^\pi$, $\sigma(\theta=0)$, reduced widths.

1957Da08, 1959Da09: ^{12}C(d,n) E=7 MeV; measured β spectrum. Deduced Fierz coefficient, *b*=0.14% *237* and T$_{1/2}$=9.96 min *3*.

1957De22: ^{12}C(p,γ) and (d,n); measured activation cross sections in the few hundred keV range. Deduced T$_{1/2}$=10.02 min *10*.

1960Bu15: ^{12}C(d,n) E=12.9 MeV; measured polarization of neutrons to various states for θ=15°.

1960Ja12: ^{12}C(d,n) measured T$_{1/2}$ of superallowed β emitters. Summarize T$_{1/2}$ early measurements on ^{13}N made between 1939 and 1958. Their work gives T$_{1/2}$=597.9 sec *3*. Measurement carries a significant weight. (German/Heidelberg text).

1961Ja08: ^{12}C(d,n$_0$) E=0.7-1.3 MeV at the Cambridge accelerator. Measured $\sigma(\theta)$ for θ=0° to 150°.

1963Bu24: ^{12}C(d,n) E=12.8 MeV; measured σ(q) for θ=0° to 150°. Deduced optical model parameters.

1963Ko24: ^{12}C(d,n) measured σ(q).

1965Ke10: ^{12}C(d,n) E=4,5,6,7,7.5 MeV; measured polarization observables for θ=20° to 80°.

1966La18: ^{12}C(d,pn) E=5.39 MeV; measured σ(E$_p$, θ_n, θ_p) deduced τ≈0.7E−20 S for states in the region of ^{13}N(3.5 MeV).

1966Gu04: ^{12}C(d,n$_0$) E$_d$=2.7-3.2 MeV. Studied ^{14}N resonances.

1966Ho11: ^{12}C(d,n$_{0,1}$) E$_d$=3.8-5.0 MeV; measured yield curves for θ=5° to 150°.

1966Sa05: ^{12}C(d,n$_0$) E$_d$=2.8-4.2 MeV; measured $\sigma(\theta)$ and polarization observables for θ=10° to 130°.

1967Fu03: ^{12}C(d,n$_0$) E$_d$=3.8-4.2 MeV; measured σ(E).

1967Wo07: ^{12}C(d,n) E=0.4-3.0 MeV; measured σ(E).

1968Do09: ^{12}C(d,n) E=5.2-6.2 MeV; measured polarization observables to ^{13}N(0, 2.37 MeV) for θ=10° to 130°.

1968Ri15: ^{12}C(d,n) E=3.0 MeV; measured T$_{1/2}$=9.963 min *9*.

1969Ch04: ^{12}C(d,n) E=0.5-0.8 MeV; measured $\sigma(\theta)$ for θ=5° to 160°. Deduced optical model parameters.

1970Ga07: ^{12}C(d,n$_0$) E=12, 15 and 17 MeV; measured $\sigma(\theta)$ for θ=30° to 150°; list tabular data. Deduced optical model parameters and spectroscopic factors. Ground state S(12 MeV)=1.35; S(15 MeV)=1.29; S(17 MeV)=0.78.

1970Ba63: ^{12}C(d,n) E=6.4 MeV; measured neutron polarization.

1971Hi09: ^{12}C(d,n$_0$) E=8.5 MeV. Measured neutron polarization for θ=2.5° to 70°.

1971Ja17: ^{12}C(d,n) E=2.17, 2.96 MeV; measured polarization observables at θ=20°.

1971Mu18: ^{12}C(d,n$_{0,1,2+3}$) E=11.8 MeV; measured σ(E,θ) for θ=20° to 170°. Deduced level energies and spectroscopic factors. Tabular data provided.

1973Cl04: ^{12}C(d,n) E=3.3,3.4 MeV; measured σ(E$_n$), deduced Γ(^{13}N(2366))=36.15 keV *54*. Discussed all previous data on Γ(2366); analyzed width dependence on reaction.

1975Ka26:^{12}C(d,n) E=1.86 MeV; measured polarization observables at θ=5°.

1975Az02: ^{12}C(d,n$_{0,1,2+3}$) 15.25 MeV; measured σ(E,θ) for θ=0.3° to 99°.

1975Bo32,1975Bo35: ^{12}C(d,n$_{0,1,2+3}$) E=6.3 MeV; measured σ(E,θ) for θ=0° to 82.5°. Analyzed shape of the ^{13}N(2364) state.

1976Te03: ^{12}C(d,n$_{0,1}$) E=5.7-9.7 MeV; measured σ(E,θ) and polarization observables over θ=5° to 35°.

1981Li23: ^{12}C(vec d,n$_{0,1}$) E=6-14 MeV; measured θ=0° polarization transfer.

1981Sh22: ^{12}C(d,n$_0$) E=7-10 MeV; measured σ(E,θ=0°): thick target yield.

1984Sc04: ^{12}C(d,n$_{0,1,2+3}$) E=7-13 MeV; measured σ(E,θ) for θ=5° to 160°; deduced optical model parameters and S=0.34 and 0.28 for ^{13}N(0, 2.36), respectively.

1987Ie02: ^{12}C(d,n$_0$) E=25 MeV; measured polarization observables for θ=10° to 90°.

1987KaZL, 1988Ka30: ^{12}C(d,n$_{0,1}$) E=18 MeV; analyzed Γ(2.36)=54 keV.

1990Mi11: ^{12}C(d,n) E=0.5-6 MeV; measured σ(E) via activation technique.

1991Fi05, 1991Fi11: ^{12}C(d,n) E=1-23 MeV; measured σ(E), thick target.

2020Ge10: ^{12}C(d,n) E=1-12 MeV; measured thick target yields.

2021Su11: ^{12}C(d,n) E≈200 MeV; analyzed neutron energy spectrum.

Theory:

^{12}C(d,n) (continued)

1958Mc63: Analyzed ^{13}C and ^{13}N ground state reduced widths. Found consistency; see additional references within.
1968Ba47: ^{12}C(d,n)E=3-12 MeV, calculated polarization observables.
1972Pe11: Analyzed spectroscopic factors between 4 and 20 MeV.
1974Bo52, 1974Bo53: ^{12}C(d,n) calculated $\sigma(\theta)$.
1978Ba21: ^{12}C(d,n$_{0,1}$) E=6.3 MeV; analyzed resonant and non-resonant $\sigma(E,\theta)$.
1983Mu13: ^{12}C(d,n), (^{3}He,d) analyzed data.
1984Bl21: ^{12}C(d,n) calculated $\sigma(\theta)$.
2015De38: ^{12}C(d,n) 3-body model analysis of (d,n) and (d,p) reactions.
2016Na23, 2016NaZT: ^{12}C(d,n) , calculated σ(E), deduced spectroscopic factors.
2016No14: ^{12}C(d,n), calculated σ(E) using TALYS.
2017De20: ^{12}C(d,n), analyzed $\sigma(\theta)$ for E=7, 12, 18 and 25 MeV.

^{13}N Levels

E(level)†	J$^{\pi}$†	T$_{1/2}$	L†	S†	Comments
0	1/2^{-}	9.963 min *9*	1	0.74	T$_{1/2}$: From T$_{1/2}$=597.9 s *3* (1960Ja12), T$_{1/2}$=9.963 min *9* (1968Ri15). S: From (1971Mu18). See also S=0.34 (1984Sc04).
2.36×10^{3} *2*	1/2^{+}	36.15 keV *54*		1.02	E(level): From (1955Ma76). T$_{1/2}$: $\Gamma_{c.m.}$ from 1973Cl04. S: From (1971Mu18). See also S=0.25 (1984Sc04).
3.51×10^{3}	(3/2^{-})			0.13	E(level): Doublet (1966La18).
3.55×10^{3}	(5/2^{+})			0.87	E(level): Doublet (1966La18).

† From DWBA analysis in (1971Mu18).

^{12}C(^{3}He,d)

1960Hi07: ^{12}C(^{3}He,d_0) E=5.98-10.14 MeV; measured angular distributions and excitation function; θ=10° to 125°.
1960Pr12: ^{12}C(^{3}He,d_0) E=13.9 MeV; measured $\sigma(\theta)$ for θ=10° to 150°.
1960We04: ^{12}C(^{3}He,d) E=21,25 MeV; measured angular distributions of ^{13}N*(0, 2.36, 3.50, 3.54) for θ=5° to 170°. Deduced L.
1967Ha21: ^{12}C(^{3}He,d) E=24.8 MeV;p measured $\sigma(\theta)$ for recoil ^{13}N nuclei, θ=10° to 40°.
1969Fo02: ^{12}C(^{3}He,d0,1,2+3,4,5,6,7) E=12−19 MeV; measured $\sigma(E,E_d,\theta)$ for θ=10° to 170°. Deduced level energies, J^π, Γ, θ_p^2.
1970Si15: ^{12}C(^{3}He,d) E=6.5-30.6 MeV; measured σ(E), failed to observe significant structure in the excitation function.
1971St21: ^{12}C(^{3}He,$d_{0,2+3}$) E=40 MeV; measured $\sigma(\theta)$ for θ=5° to 40°.
1974Bl06: ^{12}C(^{3}He,d) E=12-15 MeV; measured $\sigma(E,E_d,\theta)$ for θ=60°, 90° and 120°. Deduced resonance widths.
1976Ka23: ^{12}C(vec ^{3}He,d) E=33.3 MeV; measured $\sigma(\theta)$, A(θ). for θ=10° to 90°. Deduced ground state deduced S=0.68.
1976Ko36: ^{13}C(^{3}He,$d_{0,1,2+3}$) E=81.4 MeV; measured $\sigma(E_d,\theta)$ for θ=5° to 70°. Deduced levels, optical model parameters.
1977Bo30: ^{12}C(^{3}He,d) E=8.8-14 MeV; analyzed $\sigma(\theta)$, deduced ground state S.
1978Ma42: ^{12}C(^{3}He,d) E=70 and 90 MeV; measured $\sigma(E_d,\theta=13°)$.
1979Fu03: ^{12}C(^{3}He,d) E=36.0 MeV; measured $\sigma(E_d,\theta)$ for θ=7° to 20°, deduced reaction mechanism, level energies.
1979Se07: ^{12}C(^{3}He,d) E≈25.4 MeV analyzed $\sigma(\theta)$ for θ=0° to 50°. Deduced S for lowest four states.
1980Pe13: ^{12}C(^{3}He,d) E=43.6 MeV; measured $\sigma(E_d,\theta)$. for θ=0° to 80°. Deduced reaction mechanism, J, π, S. 2-step DWBA model analysis.
1982Co20: ^{12}C(^{3}He,d) E=36 MeV, calculated $\sigma(E_d)$, DWBA.
1983Ca07: ^{12}C(^{3}He,d) E=13 MeV; measured $\sigma(E_d,\theta)$ for θ=4.8 to 12°. Analyzed continuum region.
1983Mu13: ^{12}C(d,n), (^{3}He,d) analyzed data.
1984Ca06: ^{12}C(^{3}He,d) E=13 MeV; measured $\sigma(\theta)$ for θ=10° to 170° deduced levels, S. DWBA analysis.
1989Li06: ^{12}C(^{3}He,d) E=0.4-14 MeV; measured σ(E), activation.
1995Da08, 1995Da21: ^{12}C(^{3}He,d) E=90, 98 MeV; measured $\sigma(\theta)$ for θ≈20°−60°. Analyzed nuclear-rainbow effects.
1996Ar07: ^{12}C(^{3}He,d) E=22.3-34 MeV; measured $\sigma(E_d,\theta)$. at forward angles. DWBA analysis; deduced S, reaction mechanism.
1997Ya06: ^{12}C(^{3}He,d) E=34 MeV; analyzed 3-body Coulomb effects in proton transfer. Deduced nuclear vertex constant.
2002Ar22: ^{12}C(^{3}He,d) E=22.3 MeV; measured $\sigma(\theta)$. Analyzed 3-particle Coulomb effects. Deduced nuclear vertex constants.
2022Ko25: ^{12}C(^{3}He,d) E=81.4 MeV; calculated $\sigma(E_d,\theta)$ using eikonal approximation and folding model. Compared results with (1976Ko36).

^{13}N Levels

E(level)[†]	J^{π}[†]	Γ	L	S[†]	Comments
0[#@]	$1/2^-$[@]		1[‡]	0.48	S: See also S=0.81 (1979Se07) and S=0.76-1.13 (1984Ca06).
2368.2[#@] *28*	$1/2^+$[@]	36.1 keV *28*	0[‡]	0.14	E(level),Γ: From (1974Bl06). S: See also S=0.23 (1979Se07) and S=0.28-0.66 (1984Ca06).
3507.8[#] *76*	$3/2^-$	55 keV *12*			E(level),Γ: From (1974Bl06). S: See S=(0.69) (1979Se07) and S=0.05-0.08 (1984Ca06).
3549.1[#@] *50*	$5/2^+$[@]	46.5 keV *71*		0.53	E(level),Γ: From (1974Bl06). S: See also S=(1.76) (1979Se07) and S=0.34-0.58 (1984Ca06).
6.36×10^3[#&]	$5/2^+$			0.007	
6.89×10^3[#&]	$3/2^+$			0.015	
7.16×10^3[#&]	$7/2^+$			<0.009	J^π: See J^π=$1/2^+$ in (1969Fo02).
7.38×10^3[#&]	$5/2^-$			0.024	
8.0×10^3[@]	$3/2^+$[@]			0.13	E(level): Not seen in (1969Fo02).
8.92×10^3[#]	$1/2^-$			<0.005	
9.0×10^3	$9/2^+$	400 keV *50*		<0.005	Γ: From (1969Fo02).
9.48×10^3	$3/2^-$			<0.002	
10.36×10^3[@]	$(5/2^-,7/2^-)$[@]			<0.001	
10.78×10^3	$1/2^-$	75 keV *15*		0.064	Γ: From (1980Pe13).

Continued on next page (footnotes at end of table)

^{12}C(^{3}He,d) (continued)

^{13}N Levels (continued)

E(level)[†]	J^{π}[†]
11.1×10^3[@]	(5/2$^-$)[@]
12.08×10^3[@]	(7/2$^-$)[@]

[†] From DWBA analysis in (1980Pe13) unless indicated otherwise.
[‡] From (1960We04).
[#] Reported in (1969Fo02).
[@] Reported in (1976Ko36).
[&] Reported in (1979Fu03).

^{12}C(α,t) 1972Ha08

1969Ga11: ^{12}C(α,t) E=56 MeV; measured $\sigma(\theta,E_{t0})$ for θ=10° to 60°.
1972Ha08: ^{12}C(α,t) E=104 MeV; measured $\sigma(\theta,E_{t0})$ for θ=10° to 70°. Compared with (α,^{3}He) cross sections. Deduced absolute S=1.48.
1990Go05: ^{12}C(α,t) E=160 MeV; measured $\sigma(E_{t0},\theta=20.7°)$.
1994Da32: ^{12}C(α,t) E=90 MeV; measured $\sigma(\theta,E_{t0})$ for $\theta\approx20°-80°$; analyzed nuclear rainbow effects.

^{13}N Levels

E(level)	J^{π}	L	S	Comments
0	$1/2^{-}$	1	1.82	J^{π},L,S: From DWBA analysis in (1972Ha08).

^{12}C(^{7}Li,^{6}He)

1973Sc26: ^{12}C(^{7}Li,^{6}He) E=36 MeV; measured σ(E(^{6}He),θ) for θ=15° to 60°. Deduced L, Spectroscopic factors.
1979Ze01: ^{12}C(^{7}Li,^{6}He) E=48 MeV; measured σ(E(^{6}He),θ) for θ=5° to 40°. Deduced S.
1986Co02: ^{12}C(^{7}Li,^{6}He) E=34 MeV; measured σ(E(^{6}He),θ). for θ=15° to 100°. Deduced S.
2002Ke04: ^{12}C(pol. ^{7}Li,^{6}He) E=34 MeV; measured σ(E(^{6}He),θ) and polarization observables for $\theta\approx$15°−70° to ^{13}N(0, 3.51+3.55).
2010Li38: ^{12}C(^{7}Li,^{6}He) E=44 MeV; measured σ(E(^{6}He),θ) for θ=10° to 35°. Deduced ANC and ^{12}C(p,γ) astrophysical S-factor.

^{13}N Levels

E(level)[†]	J$^{\pi}$	L	S	Comments
0	1/2^{-}	1,2	0.613	J$^{\pi}$,L,S: From finite-range DWBA (1973Sc26:E=36 MeV); see also S=0.72 from (1979Ze01:E=48 MeV) and S=0.38 *5* from (1986Co02:E=34 MeV).
2367				
3.51×10^{3}				
3.55×10^{3}				

[†] Values listed in (1973Sc26).

^{12}C(^{10}B,^{9}Be)

1965Sa07: ^{12}C(^{10}B,^{9}Be) E=105 MeV; populated ground state and unresolved states at E_x=3.5 MeV.
1974Na20: ^{12}C(^{10}B,^{9}Be) E=100 MeV. Measured $\sigma(\theta)$ for θ=10° to 40°, deduced level energies. Considered model dependencies for S.
2022Ar03: ^{12}C(^{10}B,^{9}Be) E=41.3 MeV; measured $\sigma(\theta)$ for θ=7° to 51°. Analyzed data using a modified DWBA; deduced p+^{12}C→^{13}N ANC and analyzed astrophysical reaction rates. The study included a reanalysis of the collection of low-energy (p,γ) data resulting in Γ_p=33.5 keV *10*, 46.0 keV *34* and 280 keV *50* and Γ_γ=0.63 eV *7*, 0.35 eV *8* and 2200 eV *500* for ^{13}N*(2.36, 3.50, 10.26), respectively. Note: the tail of the 10.26 MeV state is fit using data below the E_x=2 MeV region.
1975Ra13: DWBA analysis of (1974Na20) data.
1976Ku06: DWBA analysis of ^{13}N(2.37 MeV) data from (1974Na20).
2000Fe08: ^{12}C(^{10}B,^{9}Be) E=100 MeV; analyzed ANC method.

^{13}N Levels

E(level)†
0
2.37×10^3
3.51×10^3‡
3.55×10^3‡
6.9×10^3‡
7.17×10^3‡
7.39×10^3‡
8.82×10^3

† From (1974Na20).
‡ Unresolved.

$^{12}C(^{11}B,^{10}Be)$

1965Sa07, 1967Po13: $^{12}C(^{11}B,^{10}Be)$ E=116 MeV; populated ground state and unresolved states at E_x=3.5 MeV.

1974An36: E=114 MeV; measured σ. Analyzed the reaction mechanism, which was found to be mostly direct. Developed a dynamical nuclear reaction theory and compared with DWBA in this review article. Analysis includes $^{11}B(^{12}C,^{10}Be)$, $^{11}B(^{11}B,^{9}Li)$, $^{12}C(^{11}B,^{10}Be)$, $^{12}C(^{12}C,^{11}B)$, $^{12}C(^{14}N,^{13}C)$.

^{13}N Levels

E(level)	J^{π}†	L†	S†	Comments
0‡#@&a	1/2⁻	2	1.2	
3.51×10^{3}‡#@	3/2⁻	0+2		S: S(L=0)=0.334; S(L=2)=0.211.
3.56×10^{3}‡#@&a	5/2⁺	1+3		S: S(L=1)=0.40; S(L=3)=0.669.
6.9×10^{3}#@&a	3/2⁺	1+3		S: S(L=1)=0.302; S(L=1)=0.354.
7.17×10^{3}#@	7/2⁺	3	0.488	
7.9×10^{3}‡#@	3/2⁺	1+3		S: S(L=1)=0.288; S(L=3)=0.462.
9.0×10^{3}#@	(9/2⁺)	3	0.507	
12.5×10^{3}‡				

† From DWBA analysis in (1974An36).

‡ Reported in $^{12}C(^{11}B,^{10}Be)$.

\# Reported in $^{11}B(^{12}C,^{10}Be)$.

@ Reported in $^{11}B(^{11}B,^{9}Li)$.

& Reported in $^{12}C(^{12}C,^{11}B)$.

a Reported in $^{12}C(^{14}N,^{13}C)$.

^{12}C(^{12}C,^{11}B)

1979Fu04: ^{12}C(^{12}C,^{11}B) E=93.8 MeV; measured $\sigma(\theta)$ for ^{13}N(0,3.5 MeV) and θ=10° to 60°. DWBA analysis; deduced g.s. spectroscopic factor.
1992Ja10: ^{12}C(^{12}C,^{11}B) E=344.5 MeV; analyzed $\sigma(\theta)$, for θ=5° to 25°; deduced S.
1999Sz01: ^{12}C(^{12}C,^{11}B) $E_{c.m.}$=30-60 MeV; analyzed σ(E).

Related measurements on quasifree nucleon scattering are reported in (2019PaAA: panin et al, https://doi.org/10.1016/j.physletb.2019.134802) and (1988Ki05); see also (2022Li09,2023Be20).

^{13}N Levels

E(level)[†]	J^{π}[‡]	S[†]
0	$1/2^-$	0.60
3.55×10^3	$5/2^+$	0.48
7.16×10^3	$7/2^+$	0.050
7.37×10^3	$5/2^-$	0.096
9.00×10^3	$9/2^+$	0.054

[†] From DWBA analysis in (1992Ja10).
[‡] From Adopted Levels.

^{12}C(^{13}C,^{12}B)

1987Ad07: ^{12}C(^{13}C,^{12}B) E=30 MeV/nucleon; measured $\sigma(\theta)$ for θ=1.8° to 5.6°. Observed low-lying states along with E_x=16.3 and 22.1 MeV, which are suggested as the J^π=5/2$^+$ and 3/2$^+$ GDR components. The same data are discussed in (1988Vo08).

1988Vo08: ^{12}C(^{13}C,^{12}B) E=30 MeV/nucleon; measured $\sigma(\theta)$ for θ=4° to 10°. Deduced L and S values via DWBA.

1990Br25: ^{12}C(^{13}C,^{12}B) E=50 MeV/nucleon; measured $\sigma(\theta)$ for θ=0° to 6°. Discussed spectroscopic factors.

^{13}N Levels

E(level)†‡	J^π†	$T_{1/2}$	L†	S†	Comments
0	1/2$^-$		1	0.48	
2.36×10^3	1/2$^+$		0	0.14	
3.55×10^3	5/2$^+$		2	0.53	
7.1×10^3	7/2$^+$		4		
7.9×10^3	3/2$^+$		2	0.14	
8.5×10^3	(1/2$^-$)		1	0.02	
11.3×10^3	(5/2$^-$)		3	0.03	
12.6×10^3	(7/2$^-$)		3	0.03	
16.2×10^3	(5/2$^+$)	4.8 MeV	2	0.52	
22.5×10^3	(3/2$^+$)	4.2 MeV	2	0.43	J^π,L: The discussion of (1987Ad07) and (1988Vo08) associates this state with the J^π=3/2$^+$ GDR at E_x=21.7 MeV; however Table 6 of (1988Vo08) shows J;L=5/2$^+$;2, which appears to be a typo.

† Reported in DWBA analysis of (1988Vo08).

‡ (1990Br25) report poorly resolved groups at E_x=0, 2.34, 3.55, 5.4, 6.6, 7.6, 8.5, 10.5, 11.8, 13.2, 17.5, 24.0 MeV.

$^{12}C(^{13}N,^{13}N),^{13}C(^{13}N,^{13}N)$

1995Li10, 1995Li23: $^{12}C(^{13}N,^{13}N)$, $^{13}C(^{13}N,^{13}N)$ E=16.3-29.5 MeV; measured elastic $\sigma(\theta)$ for $\theta_{cm}\approx15°-145°$. Compared with $^{12}C(^{13}C,^{13}C)$.

2021Do04: Coupled-channels analysis of $^{12}C(^{13}N,^{13}N)$.

^{13}N Levels

E(level)
0

^{12}C(^{14}N,^{13}C)

1969Vo01, 1970Vo02: ^{12}C(^{14}N,^{13}C) E=78 MeV; measured $\sigma(\theta)$ for θ=5° to 40°. Compared population of ^{13}N/^{13}C IAS states. Higher-lying ^{13}N states are unresolved.
1974An36: E=114 MeV; measured σ; compared different transfer reactions.
1974De03: ^{12}C(^{14}N,^{13}C) E=100 MeV; measured $\sigma(\theta)$ for θ=10° to 30°.
1975Go14: E=78 MeV; analyzed σ.
1975Na15, 1975Vo05: E=155 MeV; measured $\sigma(\theta)$ for θ=15° to 50°. Analyzed S.
1997Zi05: ^{12}C(^{14}N,^{13}C) E=116 MeV; measured $\sigma(\theta)$ for θ=10°−60°. Coupled channels analysis of various transfer reactions.
Theory:
1973De02, 1973De35: ^{12}C(^{14}N,^{13}C) calculated impact of recoil effects on angular distributions.
1975Re04: ^{12}C(^{14}N,^{13}C) calculated impact of recoil effects on angular distributions.
1976Ku06: DWBA analysis of the reaction to ^{13}N(2.37 MeV).
1976Na09: comparison of ^{12}C(^{14}N,^{13}N) and ^{12}C(^{14}N,^{13}C) reactions at E=155 MeV.

^{13}N Levels

E(level)[†]	J^π	L	S[‡]	Comments
0	1/2$^-$	0,1	0.62	L,S: From DWBA analysis in (1975Na15).
2.37×10^3				
3.56×10^3				
6.90×10^3				

[†] From (1974An36).
[‡] $C_2^2S_2$.

^{12}C(^{16}O,^{15}N)

1979Pr07: ^{12}C(^{16}O,^{15}N) E=128 MeV; measured σ(E,θ) for θ=15° to 30°. Deduced S via DWBA.

^{13}N Levels

E(level)	J^π	S
0	$1/2^-$	0.29
2.37×10^3	$1/2^+$	0.04
3.5×10^3	$5/2^+$	0.15

^{13}C(γ,π^-)

1982Le06: ^{13}C(γ,π-) E=17, 29, 42 MeV; measured anomalously low $\sigma(E_\pi)$ to $^{13}N_{g.s.}$.
1984Du16: ^{13}C(γ,π-) E=267 MeV; discussed π detection capabilities at NIKHEF-K.
1984St16: ^{13}C(γ,π-) E=193 MeV; measured $\sigma(\theta)$ for θ=60° to 130°. Analyzed reactions to ^{13}N(0,3.51). Deduced form factor.
1986Sh13: ^{13}C(γ,π-)$^{13}N_{g.s.}$ E=165 MeV; measured $\sigma(\theta)$ for θ=50° to 150°; analyzed E0 and M1 contributions.
1987Du08: ^{13}C(γ,π-) measured $\sigma(\theta)$ in the Δ-resonance region.
1994Ch03: ^{13}C(γ,π-) E=170, 300 MeV; analyzed polarization observables for the ground state reaction.
1995Va13: ^{13}C(γ,π-) E=184 MeV; measured $\sigma(\theta)$ for θ=45°−100° and for ^{13}N(0, 3.5 MeV).
Theory:
1973Na14: Calculated $T_<$ and $T_>$ giant resonance contributions.
1983Ma40: ^{13}C(γ,π-) E=197 MeV; calculated $\sigma(\theta)$.
1984Ti02: ^{13}C(γ,π-) E=200-400 MeV; calculated $\sigma(\theta)$ in the Δ resonance region.
1985Sa06: ^{13}C(γ,π-) E=200-400 MeV; calculated $\sigma(\theta)$, form factors.
1986Dy02: ^{13}C(γ,π-) calculated $\sigma(\theta)$ analyzed in medium effects.
1987Or01: ^{13}C(γ,π-) calculated $\sigma(\theta)$.
1990Be12, 1990Be45: ^{13}C(γ,π^-) E=160-320 MeV; calculated $\sigma(\theta)$.
1990Er03: ^{13}C(γ,π-) E=170-320 MeV; calculated $\sigma(\theta)$.
1990Ko19: ^{13}C(γ,π^-) E=193,223 MeV; calculated $\sigma(\theta)$.
1991Od04: ^{13}C(γ,π^-) E=163, 190 MeV; calculated $\sigma(\theta)$.
1993Ch26: ^{13}C(γ,π-) E=170 MeV, calculated polarization observables.

^{13}N Levels

E(level)†
0
2.4×10^3
3.51×10^3
6.4×10^3

† See (1984Du16).

^{13}C(ν,μ^{-}),(ν,e)

2008Ei01: ^{13}C(ν,e^{-}) $E_{\nu}\leq52.8$ MeV; measured flux-averaged σ for neutrinos from π^{+} and μ^{+} at KArlsruhe Rutherford Medium Energy Neutrino (KARMEN). $<\sigma>=10.2\times10^{-42}$ cm^{2} *4*(stat.) *8*(sys.).

Theory:

1985Mi21: calculated σ for E<260 MeV.
1990Fu03: calculated σ for E<20 MeV.
1990Po04: calculated σ for E<280 MeV.
2000Mi14: calculated σ for E<300 MeV.
2012Su15, 2012Su29: Shell model calculation of σ(E=threshold−100 MeV).
2013Su17: Shell Model analysis of low-lying excitations.
2018Su20: See for related information on ^{16}O(ν,X).

^{13}N Levels

E(level)
0

^{13}C(π^+,π^0)

1976Sh01: ^{13}C(π^+,π^0) E_{π^+}=70-250 MeV; measured activation σ(E).
1980Ba27: ^{13}C(π^+,π^0) E_{π^+}=98 MeV; measured σ_{ave}=0.43 mb/sr *6* for θ=0° to 16°.
1980Bo03: ^{13}C(π^+,π^0) E_{π^+}=200 MeV; measured $\sigma(\theta)$ for θ=0° to 50°. Overview of LAMPF facility.
1982Do02: ^{13}C(π^+,π^0) E_{π^+}=70-180 MeV; Measured $\sigma(\theta)$ for θ=0° and 7° for ^{13}N$_{g.s.}$. Listed σ(E, θ) table.
1982Do10: ^{13}C(π^+,π^0) E_{π^+}=164 MeV; measured $\sigma(\theta)$ for θ=0° to 60° for ^{13}N$_{g.s.}$. Listed $\sigma(\theta)$ table.
1988Us01: ^{13}C(π^+,π^0) E_{π^+}=50-340 MeV; measured σ(E) for ^{13}N$_{g.s.}$. Listed σ(E) table.
1990Go36,1991Go14: ^{13}C(π^+,π^0) E_{π^+}=163 MeV; polarized ^{13}C target. Measured $\sigma(\theta)$ $A_y(\theta)$ for θ=20° to 60°. Analyzed ^{13}N$_{g.s.}$ and unresolved ^{13}N(3.5 MeV:3/2$^-$&5/2$^+$) doublet.
1994Ha41: ^{13}C(π^+,π_0), E=165 Measured $\sigma(\theta, E_\pi)$ for θ=0° to 50° at LAMPF using the π^0 spectrometer to measure the decay γ-γ photons. Analyzed π_0 to ^{13}N(0,12.8 MeV) T=1/2 states and ^{13}N(23.3 MeV) T=3/2 state.

Theory:
Calculated σ(E) or $\sigma(\theta)$: 1970Bj01: E_{π^+}=180 MeV; 1971Ka62: E_{π^+}=180 MeV; 1973Ch20: E_{π^+}=180 MeV; 1973Au06: E_{π^+}=30-90 MeV; 1974Ka07: E_{π^+}=30-200 MeV; 1976Ga06: E_{π^+}=30-200 MeV; 1976Ga21: analyzed σ(E) in $\Delta_{(3,3)}$ resonance region; 1976Gi01: E_{π^+}=20-240 MeV; 1976Li04: E_{π^+}=30-230 MeV; 1976Ni05: E_{π^+}=40-200 MeV; 1976Os06: E_{π^+}=150-250 MeV; 1977Au01: E_{π^+}=80-200 MeV; 1977Fu10; 1977Lo19: E_{π^+}=100-300 MeV; 1977Wa02, 1978Wa02: E_{π^+}=80-200 MeV; 1979La22: E_{π^+}=30-250 MeV; 1979Sa21: E_{π^+}=100-200 MeV; 1980Ch08: E_{π^+}=120-226 MeV; 1980Ei01: E_{π^+}=100-200 MeV; 1980Ga12: E_{π^+}=0-300 MeV; 1980Le02: E_{π^+}=80-240 MeV; 1980Sa04: E_{π^+}=100-200 MeV; 1981Hi06: E_{π^+}=70-230 MeV; 1981Li02: E_{π^+}=30-260 MeV; 1981Os04: E_{π^+}=130-250 MeV; 1981Po10: E_{π^+}=162 MeV; 1983Ka19: E_{π^+}=40-240 MeV; 1990Gl09: E_{π^+}=163 MeV; 1991Ka18: E_{π^+}=130-250 MeV; 1996No03: E_{π^+}=163; 1999Ta33: E_{π^+}=165.

^{13}N Levels

E(level)	Γ	Comments
0		
3.5×10^{3} †		
7.4×10^{3} †		
12.8×10^{3} ‡	7.9‡ MeV	T=1/2
23.3×10^{3} ‡	10.4‡ MeV	T=3/2

† From (1991Go14).
‡ From (1994Ha41).

$^{13}C(\pi^+,\gamma)$

1984Ma45: $^{13}C(\pi,\gamma)$ E_π=115.5 MeV; measured $\sigma(E_\gamma)$ for θ=37° to 85°.
1986Si13, 1986Si22: $^{13}C(\pi,\gamma_0)$ E_π=49, 115.5 MeV; calculated $\sigma(\theta)$.
1990Ko19, 1990Be45: $^{13}C(\pi,\gamma_0)$ E_π=115 MeV; calculated $\sigma(\theta)$.

^{13}N Levels

E(level)
0

^{13}C(p,n)

1960Da05, 1961Da09: E≤13 MeV; measured σ(E(n),θ) for θ=15° to 170°. Deduced participation of low-lying ^{13}N states. Q=3.2372 *16*.
1961Al07: ^{13}C(p,n$_0$) E=3.1 to 5.3 MeV; measured $\sigma(\theta)$.
1961Be13: ^{13}C(p,n) deduced E$_{\text{thres}}$=3.2353 MeV *15*; later revised to 3.2371 MeV *16* in (1964Bo10).
1961Wo03: ^{13}C(p,n) E=6.5-12.2 MeV; measured $\sigma(\theta_{n0})$ for θ=0° to 150°. Observed contributions from ^{13}N(0,2.37, 3.51+3.56).
Anderson, et al., Phys. Rev. **136** (1964) B118. ^{13}C(p,n$_0$) E=18.5 MeV; measured $\sigma(\theta)$ for θ≈5° to 130°.
1965Va23: ^{13}C(p,n) E=155 MeV; measured σ=1.9 mb *2*.
1966Bo20: ^{13}C(p,n) E=3.2 to 9.5 MeV; measured Yield(E), deduced E$_{\text{thres}}$=3.2354 MeV *24*.
1966Di03: ^{13}C(p,n) E=3.27 to 3.85 MeV; measured $\sigma(\theta)$ near the reaction threshold for θ=0° to 150°.
1966Ma60: recommend E$_{\text{thres}}$=3.2357 MeV 7.
1966Ri09: ^{13}C(p,n) E=3.2-9.5 MeV; measured σ. Deduced Q(^{13}N$_{\text{g.s.}}$=3004 keV *10* and E$_x$=3464 keV 10 to the 3/2$^-$ state.
1969Kr21: ^{13}C(p,n) E=thresh−40 MeV; measured activation σ.
1969Mo32: ^{13}C(p,n) E] MeV. Discussed method for correlating reaction threshold with beam energy.
1970Cl01: ^{13}C(p,n) E=30, 50 MeV; measured σ.
1974Sh06: ^{13}C(p,n) E≈3 MeV; deduced E$_{\text{thresh}}$=3235.7 keV *7*.
1975Li11: ^{13}C(p,n) E=16.3, 22.8 MeV; compared cross sections determined via direct and activation techniques.
1976Li08: ^{13}C(pol. p,n$_0$) E=7-15 MeV; measured polarization transfer coefficients along θ=0°.
1977Az01: ^{13}C(p,n): E=10-13 MeV (also ^{16}O(p,α). Measured T$_{1/2}$=597.9 s *6*.
1980Go07: ^{13}C(p,n) E=120 MeV; analyzed relation between σ(θ=0°:(p,n)) and G-T matrix element values for the g.s. transition.
1981Ba22: ^{13}C(p,n) E=4-12 MeV; measured σ(E); results are tabulated.
1981By01: ^{13}C(p,n$_{0,1,2+3}$) E=10.1-16.75 MeV Measured σ(E,θ) for θ=0° to 150°. Potential model analysis.
1982Ta03: ^{13}C(p,n) E=60-200 MeV; measured σ(θ=0°) deduced G-T transition strengths.
1983Pe14: ^{13}C(p,n) E=26.1 MeV; compared analog states populated via (p,p) and (p,n) reactions.
1984Ta07: ^{13}C(p,n) E=160 MeV; measured D$_{\text{NN}}$(θ=0°) spin-transfer coefficients.
1984He20: ^{13}C(pol. p,n$_0$) E=5.5 MeV; measured neutron polarization at θ=40°.
1985Go02: ^{13}C(p,n$_{0,2}$) E=160 MeV; measured $\sigma(\theta)$. Analyzed relation between σ(θ≈0°) and B(GT).
1985Wa24: ^{13}C(p,n$_{0,2}$) E=135 MeV; measured $\sigma(\theta)$. Analyzed relation between σ(θ≈0°) and B(GT).
1986Ki12: ^{13}C(p,n) E=800 MeV; measured $\sigma(\theta)$. Analyzed Fermi and G-T strength intensities.
1986Oh03: ^{13}C(p,n) E=35 MeV; compared low-lying analog states populated via (p,p) and (p,n) reactions.
1987Ta22: ^{13}C(pol. p,n$_0$) E=60-200 MeV; measured D$_{\text{NN}}$(θ=0°) spin-transfer coefficient.
1987Ra15, 1987Ra32: ^{13}C(p,n) E=160 MeV; measured σ(θ,E$_n$) for θ=0° to 50°. Analyzed G-T strength for ^{13}N(0, 3.51, 15.1).
1987Or01: ^{13}C(p,n) E=35 MeV; measured σ(θ,E$_n$) for θ=0° to 150°. Analyzed ΔJ=0$^-$ component to ^{13}N(2.37).
1987Li29: ^{13}C(p,n) E=800 MeV; measured σ(E$_n$). Overview of LAMPF capabilities for charge-exchange reactions.
1988Ka30: ^{13}C(p,n$_{0,1}$) E=18.6 MeV; measured $\sigma(\theta)$.
1989Ra09: ^{13}C(pol. p,pol. n$_0$) E=492,590 MeV; measured σ(E$_n$,θ=0°). Deduced B(GT) values for ^{13}N(0,3.51 MeV).
1989Wa16: ^{13}C(p,n) E=5-30 MeV; measured activation yields.
1990Dr10: ^{13}C(p,n) E$_{\text{c.m.}}$<13 MeV and θ≈0°. Analyzed monoenergetic neutron beam production.
1990Mi14: analyzed spin-flip and nonflip reactions at θ=0°.
1991Mi03: ^{13}C(p,n) E=200 MeV; measured σ(θ=0°) for ^{13}N(8.92, 9.48, 10.83, 11.88, 15.06 MeV).
1991Fi11, 1991Fi05: ^{13}C(p,n) E=1-33 MeV; measured σ(E), thick target.
1993Go15: ^{13}C(p,n) E=2.5-10.5, analyzed utility to produce ^{13}N beams.
1994Ra23: ^{13}C(pol. p,n) E=186 MeV; measured σ(E$_n$,θ=0°−50°), multipole decomposition analysis in giant resonance region.
1994Sa36: ^{13}C(pol. p,n) E=50, 80 MeV; measured polarization transfer coefficients, D$_{\text{NN}}$(θ=0°).
1994Wa22: ^{13}C(pol. p,n) E=186 MeV; measured σ(E$_n$,θ=0°−50°), analyzing powers. Analyzed quasifree scattering.
1995Ya12: ^{13}C(p,n) E=186 MeV; measured σ(E$_n$,θ=0°−50°), multipole decomposition analysis to determine ΔL=1 strength. Significant strength around E$_x$=18-24 MeV.
1995Wa16: ^{13}C(pol. p,n) E=295 MeV; measured σ(E$_n$,θ=0°−10°) for ^{13}N(0,3.51); deduced polarization transfer coefficients (D$_{\text{NN}}$(0°).
1994Wa05: ^{13}C(p,n) E=160 MeV; measured σ(E$_n$,θ=0°−20°); analyzed J^π=1/2$^-$→1/2$^+$ transition to ^{13}N(2.46).
1996Yu02: ^{13}C(p,n$_0$) E=200 MeV; measured $\sigma(\theta)$; analyzed large angle scattering.
1999Ha24: ^{13}C(p,n),(^{3}He,t),(π^+,π^0). Analyzed giant resonance features.
2000Jo17: ^{13}C(p,n$_0$) E=35 MeV; measured $\sigma(\theta)$ for θ≈5°−140°. DWBA analysis.

^{13}C(p,n) (continued)

2001Go25: ^{13}C(p,n) E=120, 160 MeV; analyzed relation between $\sigma(\theta=0°)$ and Gamow-Teller strength.
2001Wa05: ^{13}C(pol. p,n$_0$) E=197 MeV; measured $\sigma(\theta=0°)$; analyzed reaction mechanism; deduced GT and Fermi contributions.
2001Wa18: ^{13}C(pol. p,n$_0$) E=135 MeV; measured $\sigma(\theta=0°)$; analyzed reaction mechanism and $\sigma(\theta=0°)$ relation to B(GT). Deduced GT and Fermi contributions.
2002Ra51, 2002Wa23: ^{13}C(pol. p,n$_0$) E=197 MeV; measured $\sigma(\theta)$ for $\theta\approx0°-33°$; analyzed polarization observables.
2009De03: ^{13}C(p,n$_0$) E=35 MeV; analyzed $\sigma(\theta)$.
2009Os01: DWBA analysis of ^{13}C(p,n$_0$) investigating the density dependence of the N-nucleus potential.
2009Sa06: ^{13}C(p,n). Analyzed Fermi and GT transitions across a broad range of targets at E=198, 297 MeV; deduced unit cross sections to connects $\sigma(\theta=0)$ with strengths.
2016Ta07: ^{1}H(^{13}C,^{13}N) and ^{12}C(^{13}C,^{13}N) at E≈950 MeV/nucleon. Measured charge changing cross sections. Compared with GT strength.

Theory:
1969Ra36: Surveyed available data for various targets.
1970Li01: ^{13}C(p,n) E=18.5 MeV, calculated $\sigma(\theta)$.
1971Ge12: ^{13}C(p,n) E=12.2,13.3 MeV, DWBA analysis of $\sigma(\theta)$.
1982Ba14: ^{13}C(p,n) E=6 MeV Calculated $\sigma(\theta)$.
1983Kr10: ^{13}C(p,n) E=150, 160, 200 MeV; calculated $\sigma(\theta)$.
1989Am02: analysis of M1 quenching.
1989Ra15: ^{13}C(pol. p,pol. n$_0$) E=500 MeV; calculated polarization tranfer coefficient.

^{13}N Levels

E(level)[‡]	J^π[#]	Comments
0	1/2$^-$	Spin transfer coefficient D$_{NN}$(0°)≈0.05 *6* (1984Ta07).
2.3×10^3 *1*		
3464[†] *10*	(3/2$^-$)	Spin transfer coefficient for J^π=3/2$^-$ state D$_{NN}$(0°)=−0.33 *5* (1984Ta07). E(level): From (1966Ri09). See also 3.5 MeV *1* (1970Cl01).
3.5×10^3[†] *1*		
4.6×10^3? *1*		
6.3×10^3 *1*		
7.2×10^3 *2*		
8.8×10^3 *2*	1/2$^-$	$\sigma(\theta=0°)$=1.30 mb/sr *8* for E$_x$=8.92 MeV (1991Mi03).
9.48×10^3	3/2$^-$	E(level): From (1991Mi03); $\sigma(\theta=0°)$=0.78 mb/sr *5*.
10.83×10^3	1/2$^-$	E(level): From (1991Mi03); $\sigma(\theta=0°)$=1.07 mb/sr *6*.
11.6×10^3 *2*	(3/2$^-$)	$\sigma(\theta=0°)$=3.27 mb/sr *20* for E$_x$=11.88 MeV (1991Mi03).
13.3×10^3[@] *2*		
15.1×10^3	(3/2$^-$)	E(level): From (1984Ta07). Spin transfer coefficient D$_{NN}$(0°)=−0.36 *8* (1984Ta07). $\sigma(\theta=0°)$=1.85 mb/sr *11* for known T=3/2 state at E$_x$=15.06 MeV.

[†] Unresolved in (1970Cl01).
[‡] From (1970Cl01).
[#] From L=0,2 transfer states populated in GT trnasitions along θ=0° (1991Mi03).
[@] Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

$^{13}C(^{3}He,t)$

1969Ba06: $^{13}C(^{3}He,t)$ E=40-50 MeV; measured $\sigma(E(t),\theta)$ for θ=20° to 75°. Deduced optical model parameters, level energies, L, J. Discussed shell configurations.
1970Nu02: $^{13}C(^{3}He,t)$ E=14 MeV; measured $\sigma(\theta)$ for $\theta\approx$10° 10 150°. Deduced optical model parameters for ^{13}N(0,2.36 MeV).
1981Pe08: $^{13}C(^{3}He,t)$ E=43.6 MeV; measured $\sigma(E(^{3}He),\theta)$, $\sigma(E_t,\theta)$ for θ=5° to 60°. Deduced $^{13}N/^{13}C$ isoscalar, isovector transition amplitude ratio, β_L deformation parameters.
1987Be25: $^{13}C(^{3}He,t)$ E=0.6-2.3 GeV; measured $\sigma(E_t,\theta)$ for θ=0° to 4°. Deduced isovector strength ratio.
1990De31: $^{13}C(^{3}He,t)$ E=39.6 MeV; analyzed $\sigma(E,\theta)$ for θ=10° to 100°. Deduced optical model parameters.
1991Ja04: $^{13}C(^{3}He,t)$ E=200 MeV; measured $\sigma(E_t,\theta=0°)$. See also (1993JaZZ).
1994Ak02: $^{13}C(^{3}He,t)$ E=450 MeV; measured $\sigma(E_t,\theta=0°)$.
1996Fu06: $^{13}C(^{3}He,t+p)$ E=450 MeV; measured proton decay from $^{13}N^{*}$ relevant to states populated in $^{13}C+\nu$ interactions. Populated ^{13}N(0, 3.51, 8.92, 10.83, 11.88, 15.06) plus SDRs at 18 and 21.5 MeV. Qualitative discussion on proton decay branches.
1996BuZZ: $^{13}C(^{3}He,t)$ E=60 MeV; measured $\sigma(\theta=0°)$ for θ=10°−100°. Analyzed diffraction effects.
2003Bu01: $^{13}C(^{3}He,t)$ E=60 MeV; measured $\sigma(E_t,\theta)$ for θ=10°−120°. DWBA analysis for ^{13}N(0, 2.36, 3.51+3.55). Discussed refractive properties.
2004Fu12: $^{13}C(^{3}He,t)$ E=150 MeV/nucleon. Measured $\sigma(E_t,\theta)$ for θ=0°−17°. Analyzed GT strengths. Measured protons from $^{13}N^{*}$ decay in coincidence with θ=0° tritons; deduced branching ratios. XUNDL dataset by McMaster (2004).
2007Ze06 , 2008Ze01: $^{13}C(^{3}He,t)$ E=420 MeV; measured $\sigma(E_t,\theta\approx0°)$. Analyzed relation between B(GT) and σ. In (2008Ze01), the B(GT) unit cross section is normalized using the σ to $^{13}N(15.1:3/2^{-})$ and B(GT)=1.37 *7* is deduced for $^{13}N(3.50:3/2^{-})$.
2011Pe12: $^{13}C(^{3}He,t)$ E=420 MeV; analyzed relation between B(GT) and $\sigma(\theta=0°)$. Global analysis of unit cross section.
2016De39, 2017De38: $^{13}C(^{3}He,t)$ analyzed ^{13}N(2.37) wavefunction. Deduced formation of a proton halo. Developed method to determine nuclear radii of excited states. See also (2023De29).
2019Li48: $^{13}C(^{3}He,t)$ Eikonal approach analysis of $\sigma(\theta)$.

^{13}N Levels

E(level)$^{†\&}$	J$^{\pi\#}$	Γ^{b}	L$^{\#\&}$	Comments
0	1/2^{-}		0$^{@}$	β_0=0.061 (1981Pe08).
2.36×10^{3}	1/2^{+}		1	β_1=0.035 (1981Pe08)
3.53×10^{3}			2	E(level): Doublet reported at 3.53 MeV *3* in (1969Ba06). %p$_0$ ($^{12}C_{g.s.}$) =71 *17* (2004Fu12).
3.55×10^{3}			3	E(level): Unresolved.
6.36×10^{3}	5/2^{+}		3	β_3=0.041 (1981Pe08)
6.89×10^{3}	3/2^{+}		1	β_1=0.025 (1981Pe08)
7.16×10^{3}	7/2^{+}		3	β_3=0.060 (1981Pe08)
7.38×10^{3}	5/2^{-}		2$^{@}$	β_2=0.056 (1981Pe08)
8920 *40*	1/2^{-}		0$^{@}$	J$^{\pi}$: From (1969Ba06). %p$_0$ ($^{12}C_{g.s.}$)=60 *9*, %p$_1$(^{12}C(4.44))=30 *5* (2004Fu12).
9.0×10^{3‡}	9/2^{+}		5	β_5=0.083 (1981Pe08)
9.48×10^{3‡}	3/2^{-}		2	%p$_0$=58 *11*, %p$_1$=43 *9* (2004Fu12).
10.36×10^{3‡}	(5/2^{-},7/2^{-})		2	β_2=0.019 (1981Pe08) E(level): Known doublet.
10780 *40*	(3/2,5/2)$^{-}$		2	β_2=0.037 (1981Pe08) E(level): Reported as 10.833 MeV in (1981Pe08). J$^{\pi}$: (1981Pe08) indicate L=2, which implies (3/2,5/2)$^{-}$, but this disagrees with their J$^{\pi}$=1/2^{-} from 12C(^{3}He,d) result in (1980Pe13). %p$_0$=5 *1*, %p$_1$=54 *9*, %p$_2$=43 *16* (2004Fu12).
11850 *40*	(3/2^{-})	98 keV	2	β_2=0.20 (1981Pe08) %p$_0$=8 *1*, %p$_1$=35 *5*, %p$_2$=10 *2* (2004Fu12).
15.07×10^{3}	3/2^{-}		2$^{@}$	T=3/2 β_2=0.065 (1981Pe08) %p$_0$=16 *2*, %p$_1$=13 *2*, %p$_2$=3 *1* (2004Fu12). E(level): (2004Fu12) report this state has a considerable amount of the isospin

Continued on next page (footnotes at end of table)

^{13}C(^{3}He,t) (continued)

^{13}N Levels (continued)

E(level)$^{\dagger\&}$	J$^{\pi\#}$	Γ^{b}	L$^{\#\&}$	Comments
				violation component in the wave function, surpassing the weak γ-ray decay rates, as the 15060, T=3/2 state in ^{13}N decays to the forbidden T=0 states in ^{12}C.
15980 *50*	7/2^{+}	163 keV	3	β_{3}=0.094 (1981Pe08)
17.68×10^{3} *3*		1212 keV *74*	1	
18.12×10^{3} *2*		276 keV *41*		
18.37×10^{3} *1*		23 keV		
19.11×10^{3} *1*		183 keV *41*		
19.83×10^{3} *2*		1542 keV *84*	[a]	
21.20×10^{3} *1*		581 keV *44*	2	
22.14×10^{3} *1*		1706 keV *82*	[a]	
24.50×10^{3} *4*		2.46 MeV *22*	[a]	
26.9×10^{3} *9*		4.38 MeV *47*		

[†] From (1969Ba06) unless otherwise indicated.
[‡] Observed in (1981Pe08).
[#] From DWBA comparison of ^{13}C and ^{13}N analog states in ^{13}C(^{3}He,^{3}He), (^{3}He,t) and ^{13}C(α,α) reactions (1981Pe08).
[@] From (1969Ba06).
[&] Above E$_{x}$=17 MeV from (2004Fu12).
[a] Assumed ΔL=1 spin-dipole resonances.
[b] From (2004Fu12).

$^{13}C(^{6}Li,^{6}He)$

1970Ch19: $^{13}C(^{6}Li,^{6}He)$ E=30.8 MeV; measured $\sigma(\theta, E(^{6}He))$ for θ=18° and 36°. Deduced levels.
1981Vi03: $^{13}C(^{6}Li,^{6}He)$ E=93 MeV; measured $\sigma(\theta=12°, E(^{6}He))$ deduced levels. See further discussion in (2010Ga19).
1984Gl06: $^{13}C(^{6}Li,^{6}He)$ E=93 MeV, $^{13}C(^{7}Li,^{6}He))$ E=78 MeV Measured $\sigma(\theta, E(^{6,7}He)$.
1989De34: $^{13}C(^{6}Li,^{6}He)$ E=93 MeV; measured $\sigma(\theta, E(^{6}He))$ for θ=20° to 60°; analyzed $^{13}N(0, 3.5)$ peaks.
1994La10: $^{13}C(^{6}Li,^{6}He)$ E=100 MeV/nucleon. Measured $\sigma(\theta\approx0°, E(^{6}He))$.
1999Ue03, 1999UeZY: $^{13}C(^{6}Li,^{6}He)$ E=100 MeV/nucleon. Measured $\sigma(\theta\approx0°, E(^{6}He))$ for $\theta_{c.m.}\leq7$ mrad. Compared yields with B(GT) from β decay.

^{13}N Levels

E(level)	J^{π}	Comments
$0^{\dagger\ddagger\#@\&}$		
$2.37\times10^{3\dagger\&}$		
$3.5\times10^{3\dagger\ddagger\#@\&}$	$(3/2^{-})$	J^{π}: From (1970Ch19). Population of $3/2^{-}$ is preferred.
$7.4\times10^{3\ddagger\#@}$		
$9.2\times10^{3\ddagger@}$		
$12.5\times10^{3\ddagger@}$		
$17.5\times10^{3\ddagger}$		
$21\times10^{3\ddagger a}$		

[†] Observed in (1970Ch19).
[‡] Observed in (1981Vi03).
[#] Observed in (1984Gl06).
[@] Observed in (1994La10).
[&] Observed in (1999Ue03).
[a] Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

^{13}C(^{13}N,^{13}C)

1996St05: ^{13}C(^{13}N,^{13}C) E=57,105 MeV; measured $\sigma(\theta=0°)$. Populated $J^{\pi}=1/2^{-}$ ground states along with single and double excitation of the ≈3.5 MeV ^{13}N and ^{13}C $3/2^{-}$ states. Analyzed GT/Fermi strengths. See also (1997Sh11).

Theory:

1993Kr01: ^{13}C(^{13}N,^{13}C) $E_{c.m.}$=7.5-10 MeV; calculated $\sigma(\theta)$ analyzed effective n-p interaction.

1997Be33: E=105 MeV/nucleon: Theory: analyzed heavy-ion charge-exchange reactions.

2020Li51: Eikonal model analysis of $\sigma(\theta)$ at E=105 MeV/nucleon.

^{13}N Levels

E(level)	J^{π}†
0	$1/2^{-}$
3.50×10^{3}	$3/2^{-}$

† From Adopted Levels.

^{13}C(^{14}N,^{14}C)

1971Ga05: ^{13}C(^{14}N,^{14}C) E=12.5-20.5 MeV; measured neutron transfer reaction σ via activation technique.
1973To05: ^{13}C(^{14}N,^{14}C) DWBA analysis of $\sigma(\theta)$.
1978Os06: ^{13}C(^{14}N,^{14}C) E=12,15 MeV; calculated σ.

^{13}N Levels

E(level)
0

^{14}N(γ,n)

1960Ki02: ^{14}N(γ,n) $E_{\beta rem}$=25 MeV; measured excitation function. Deduced $T_{1/2}$=9.93 min *5*.
1962Ko23: ^{14}N(γ,n) $E_{\beta rem}$=90 MeV; measured excitation function.
1963Fu06: ^{14}N(γ,n) $E_{\beta rem}$=30.5 MeV; measured excitation function.
1970Sh06: ^{14}N(γ,nX) $E_{\beta rem}$=15 MeV and $E_{\beta rem}$=30 MeV.
1971An08: ^{14}N(γ,n) 150<E<950 MeV. Calculated meson effects.
1971Fr11: ^{14}N(γ,n) E=100-800 MeV; measured σ(E); searched for meson effects.
1972Ge11: ^{14}N(γ,n) E=15.5-29.5 MeV; measured $\sigma(E,E_n)$.
1972Go23: ^{14}N(γ,n) E<30 MeV; calculated σ.
1978Di12: ^{14}N(γ,n) analyzed reaction dynamics.
1980Ju02: ^{14}N(γ,n_0) E=17-26 MeV; measured σ(E).
1999Ab39, 1999Ab40: ^{14}N(γ,n) $E_{\beta rem}$=20 MeV, measured yields.

^{13}N Levels

E(level)
0

^{14}N(π^+,π^+n),(π^+,p)

1973Ka19: ^{14}N(π^+,π^+n) 190 MeV; measured σ via activation at the NASA Space Radiation Effects Laboratory (SREL).
1985La20: ^{14}N(π^+,p) 170 MeV; measured yields.
1981Gi15: ^{14}N(π^+,p) 114 MeV; calculated σ.

^{13}N Levels

E(level)
0

^{14}N(n,2n)

1949Kn25: ^{14}N(n,2n) $E_n\approx90$ MeV; measured activation σ.
1951Co50: ^{14}N(n,2n) $E_n\approx0.4$-18 MeV white source, measured activation.
1961Ra06: ^{14}N(n,2n) $E_n\approx14.4$ MeV; measured activation cross section and lifetime $T_{1/2}$=12.3 min±5.4% at Argonne.
1965Bo42: ^{14}N(n,2n) E_n=12.6-18.8 MeV; measured activation cross section and lifetime $T_{1/2}$=10.05 min *5*.
1965Eb01: ^{14}N(n,2n) $E_n\approx14.7$ MeV; measured ^{13}N decay and deduced $T_{1/2}$=9.96 min *2*; compared with prior values.
1965Go18: ^{14}N(n,2n) $E_n\approx14.1$ MeV; measured cross section.
1965Gr41: ^{14}N(n,2n) $E_n\approx14.8$ MeV; measured cross section.
1967Cs02: ^{14}N(n,2n) $E_n\approx14.7$ MeV; measured cross section.
1967Pa27: ^{14}N(n,2n) $E_n\approx14.7$ MeV; measured cross section.
1973Ro29: ^{14}N(n,2n) $E_n\approx14.8$ MeV; measured cross section.
1978Ry02: ^{14}N(n,2n) E_n=14.7-19.0 MeV; measured cross section via activation technique.
Katoh et al., JAERI-M89-083 (1989) (availble online): ^{14}N(n,2n); counted 511 annihilation γ ray. Measured $T_{1/2}$=9.962 min *20*.
2001Sa27: ^{14}N(n,2n) E_n=13.4-14.9 MeV; measured cross section via activation techniques.
2011Ha04: ^{14}N(n,2n) E_n=13.4-14.9 MeV. Global analysis of reaction systematics.
2023Te01: ^{14}N(n,2n) E_n=14-15 MeV; developed imperical formalism for σ in the 14≤A≤241 region.

^{13}N Levels

E(level)	$T_{1/2}$	Comments
0	9.962 min *20*	$T_{1/2}$: From (Katoh et al., JAERI-M89-083 (1989)). See also (1961Ra06, 1965Bo42, 1965Eb01).

^{14}N(p,d) 1966Ba44,1975Ro27

1960ChZZ, 1961Ma02: ^{14}N(p,pn) E=0.4-6.2 GeV; measured activation σ.
1961Po09: ^{14}N(p,^{13}N) E=18 MeV; analyzed decay and hyperfine structure. Deduced J=1/2 and μ=0.321 *3* (μ assumed negative).
1961Be12: ^{14}N(p,d) E=16.5-18.5 MeV; measured angular distributions for $\theta \approx 10° - 60°$. Observed states with E$_x$≤3.5 MeV.
1966Ba44: ^{14}N(p,d) E=155.6 MeV; measured $\sigma(\theta)$ for θ=5° to 30°. Deduced level energies; discussed S factors.
1967Ko08: ^{14}N(p,d) E=30.3 MeV; measured $\sigma(\theta)$ for θ=10° to 160°. Deduced levels, J$^{\pi}$, S. ^{13}N(0,3.51,7.38,8.93,11.80).
1971Cu01: ^{14}N(p,d) E=14.5 MeV; measured $\sigma(\theta)$ for θ=10° to 80°. Deduced ^{13}N$_{g.s.}$ S=0.83-1.3.
1973Fa10: ^{14}N(p,d) E=185 MeV; measured $\sigma(E_d,\theta)$ analyzed deep-lying hole states around E$_x$= 50 MeV.
1974Mu17: ^{14}N(p,pn) E=11-18 MeV; measured σ(E).
1975Ro27: ^{14}N(p,d) E=65 MeV; measured $\sigma(E_d,\theta)$ for θ=10° to 60°. Deduced levels, optical model parameters, S.
1977Gu14: ^{14}N(p,d$_0$) E=16.2, 17.7, measured $\sigma(\theta)$.
1982Ao05: ^{14}N(pol. p,d$_0$) E=21 MeV; measured $\sigma(\theta)$ for θ=20° to 140°.
1987Va28: ^{14}N(pol. p,d$_0$) E=18.6 MeV; measured $\sigma(\theta)$.
1991Ab04: ^{14}N(p,d) E=30.3 MeV; measured $\sigma(\theta)$ for $\theta \approx 20°$ to 160°. Discussed configurations.
2003Ko72: ^{14}N(p,d)) E≈ 6-19 MeV; measured thick target yields.
2023Ro01: ^{14}N(p,pn)) E≈ threshold-200 MeV; measured activation σ motivated by determining dose in proton therapy treatment.

Theory:
1969Do08: calculated $\sigma(\theta)$ at E$_p$=19,30,156 MeV.
1971Mc15: calculated $\sigma(\theta)$ at E=30 MeV.
1976Wa15: ^{14}N(p,d$_0$); analyzed d$_0$ angular distribution. Deduced S=0.504.
1977Bo42: ^{14}N(p,d) E=30.3 MeV, calculated $\sigma(\theta)$.
1978Ma34: ^{14}N(p,d) E=17.7 MeV; calculated $\sigma(\theta)$.

^{13}N Levels

E(level)	J$^{\pi}$[@]	S[@]	Comments
0[†‡]	1/2$^-$	0.8 *2*	μ=0.321 *3* (1961Po09) S: See also S=0.45 (1975Ro27).
2.36×10^3	(1/2$^+$)		
3.50×10^3[†‡]	(3/2$^-$)	0.25 *5*	E(level): Observed in (1966Ba44: E$_x$=3.6 MeV *1* likely unresolved states). S: See also S=0.21 (1975Ro27).
3.55×10^3[†#]			
6.38×10^3	(5/2$^+$)		
7.38×10^3[†‡#]	(5/2$^-$)	1.5 *3*	E(level): Observed in (1966Ba44: E$_x$=7.4 MeV *1*). S: See also S=1.92 (1975Ro27).
8.92×10^3[†‡#]	(1/2$^-$)	0.30 *6*	E(level): Observed in (1966Ba44: E$_x$=9.0 MeV *2*). S: See also S=0.68 (1975Ro27).
11.86×10^3[‡#]	(3/2$^-$)	0.65 *2*	E(level): Observed in (1966Ba44: E$_x$=11.9 MeV *2*, likely unresolved states). S: See also S=1.29 (1975Ro27).
14.0×10^3			E(level): Observed in (1966Ba44: E$_x$=14.0 MeV *3*, likely unresolved states).

[†] Observed in 1966Ba44, See discussion on spectroscopic factors.
[‡] Observed in 1975Ro27, See discussion on spectroscopic factors.
[#] Reported in 1991Ab04.
[@] From (1967Ko08): J From theory, S from DWBA.

^{14}N(d,t)

1957Wa01: ^{14}N(d,t) E=14.8 MeV; measured yields to ^{13}N(0, 2.37, 3.5 MeV (doublet)).
1968Ga13: ^{14}N(d,t) E=28 MeV; measured $\sigma(\theta)$ for θ=10° to 70° DWBA analysis of (d,t) and (d,^{3}He) cross sections. Deduced C^2S=0.9 to $^{13}N_{g.s.}$ vs 0.88 to $^{13}C_{g.s.}$
1968Hi01: ^{14}N(d,t) E=52 MeV; measured $\sigma(E_t,\theta)$ for θ=12° to 60°. Deduced level energies, J^π. Discussed S.
1971Bo50: Theoretical analysis of spectroscopic factors.
1973Da26,1975DaYO: ^{14}N(pol. d,t) E=15 MeV; measured analyzing power A(θ) for θ=30° to 90°.
1974Lu06: ^{14}N(pl. d, t_0) E=15 MeV; measured $\sigma(E_t,\theta)$, A(θ). for θ=20° to 100°. DWBA analysis.
1985Sa35: ^{14}N(d,t), ^{15}N(p,d) Measured thick target yields.
1995Gu22: ^{14}N(d,t) E=8-50 MeV; analyzed $\sigma(\theta)$.
1998Sz01: ^{14}N(d,t) E=3.8-12.3 MeV; measured σ(E) for ^{13}N production as background radiation produced along with ^{14}N(d,n)^{15}O.

^{13}N Levels

E(level)†	J^π†	S†	Comments
0	1/2⁻	0.6	S: See also S=0.9 from (1968Ga13).
2.37×10^{3}			E(level): From (1975DaYO).
3.51×10^{3}	3/2⁻	0.25	
7.38×10^{3}	5/2⁻	1.3	
8.93×10^{3}‡	1/2⁻		
9.5×10^{3}‡	3/2⁻		
11.9×10^{3}	3/2⁻	1.25	

† From DWBA analysis in (1968Hi01).
‡ Unresolved, S(8.9+9.5 MeV)=0.7.

^{14}N(^{3}He,α)

1960Ta12: ^{14}N(^{3}He,α) E=5.2 MeV; measured $\sigma(\theta)$ for θ=10° to 100°. Deduced Q, levels, L, peak σ. Discussed reaction mechanism.
1962Cl12: ^{14}N(^{3}He,α) E=2763 MeV; measured $\sigma(\theta)$ for θ=90° and 150°. Deduced levels, Γ.
1962Se13: ^{14}N(^{3}He,α) E=29 MeV. Measuered $\sigma(\theta)$.
1965Ar07: ^{14}N(^{3}He,α) E=17.4-36.6 MeV; measured σ to $\alpha_{0,1,2+3,5+6,}$ and to ^{13}N(11.4 MeV).
1967Ha20: ^{14}N(^{3}He,α) E=6-18 MeV; measured activation σ.
1968Ar12: ^{14}N(^{3}He,α) E=19-37 MeV; measured $\sigma(E_{\alpha},\theta)$. Deduced level energies, L, S.
1968Lu03: ^{14}N(^{3}He,$\alpha_{0,1,2+3,4,6+7}$) E=13.9 MeV; measured $\sigma(\theta)$.
1969Ho13: ^{14}N(^{3}He,α) E=8 MeV.
1970Kn01: ^{14}N(^{3}He,α) E=2.5-8.5 MeV; measured $\sigma(E,E_{\alpha},\theta)$ for θ=5° to 155°. Deduced S.
1971Gu22: ^{14}N(^{3}He,$\alpha_{0,1,2+3}$) E=3.75-10.75 MeV; measured $\sigma(E,\theta)$ for θ=10° to 169°.
1972Mo39: ^{14}N(^{3}He,α) E=3.5-7.0 MeV; measured $\sigma(\theta,E_{\alpha})$ for θ=60° to 150°.
1992Ad06: ^{14}N(^{3}He,α) E=50, 60 MeV; measured $\sigma(\theta)$. Deduced optical model parameters.
1994Te04: ^{14}N(^{3}He,α) E=1.6-2.8 MeV; measured $\sigma(E,\theta)$. Evaluated utility for depth profiling.

^{13}N Levels

E(level)	J$^{\pi}$	Γ	L	S	Comments
0‡	1/2^{-}		1	0.83	S: From DWBA analysis in (1970Kn01). E(level): Q=10.029 MeV *16*, σ_{max}=1.07 mb/sr (1960Ta12).
2358‡ *10*					
3502‡#					
3547‡#					
6364#					
6886#		110 keV *15*			Γ: From (1962Cl12).
7166 *8*					E(level): From (1962Cl12).
7388† *8*		45 keV *10*			E(level),Γ: From (1962Cl12).
8.93×10^{3}†					
11.65×10^{3}†@					
11.88×10^{3}†					

† Reported in (1969Ho13).
‡ From (1960Ta12).
# Unresolved in most studies.
@ Some states are not associated with Adopted Levels because inadequate details for association are given in the literature.

^{14}N(^{6}Li,^{7}Li) 1971Gr44

1971Gr44: ^{14}N(^{6}Li,^{7}Li) E=32 MeV; measured $\sigma(\theta)$ for θ=10° to 60°.

^{13}N Levels

E(level)
0
2.36×10^{3}

^{14}N(^{10}B,^{11}B) 1975Na15

1975Na15: ^{14}N(^{10}B,^{11}B) E=97 MeV; measured $\sigma(E,\theta)$ for θ=10° to 40°. Analyzed spectroscopic factors.
1976Na09: E=97 MeV, compared ^{14}N(^{10}B,^{11}B) neutron transfer σ with the ^{14}N(^{10}B,^{11}C) proton transfer σ.

^{13}N Levels

E(level)[†]	J$^{\pi}$[†]	C^{2}S^2[†]
0	(1/2$^-$)	0.72
3.51×10^3	(3/2$^-$)	0.19
7.4×10^3		
11.9×10^3		

[†] From DWBA analysis in (1975Na15).

^{14}N(^{14}N,^{13}N)

1961To01, 1961To07: ^{14}N(^{14}N,^{13}N) E=19-28 MeV, measured $\sigma(\theta)$ for $\theta\approx6°$ to 60°.
Hiebert, et al., Phys. Rev **138** (1965) B346 ^{14}N(^{14}N,^{13}N) E= 12.3, 14, 16 and 18 MeV; measured $\sigma(\theta)$ for $\theta\approx10°$ to 100°.
Kammuri and Yoshida, Nucl. Phys. **A129** (1969) 625. DWBA analysis of data from Hiebert at E=12.3, 14, 16 and 18 MeV,
See also (1988Da12).

^{13}N Levels

E(level)
0

^{15}N(p,t) **1968Fl03**

1960ChZZ: ^{15}N(p,p2n) E=0.4-6.2 GeV; measured activation σ.
1966Ce02: ^{15}N(p,t) E=43.7 MeV; measured $\sigma(\theta)$ for θ=10° to 90° at the 88 inch. Observed ^{13}N(0, 3.51, 7.73 and 15.07 MeV). Deduced E_x=15065 keV *37*; compared IAS states.
1968Fl03: ^{15}N(p,t) E=43.7 MeV; measured $\sigma(\theta)$ for θ=10° to 90°. Deduced level energies for $E_x \leq 16$ MeV, L, J. Deduced integrated σ.
1970Ha23: ^{15}N(pol. p,t) E=44 MeV; measured $\sigma(\theta)$, A(θ) for θ=10° to 80°. Deduced L for ^{13}N(3.51, 7.38 MeV).
1971Ka04: ^{15}N(p,t) analyzed angular distributions of L=0&2 transfer reactions.
1974Ma12: ^{15}N(p,t) E=43.8 MeV; measured $\sigma(E_t,\theta)$, A(θ). for θ=10° to 60°. Analyzed distributions for ^{13}N(0,3.51, 7.39, 15.07 MeV). Deduced level energies, L.
1974Pi05: ^{15}N(p,t) E=20-45 MeV; measured $\sigma(E_t,\theta)$ for θ=12° to 126°. Deduced OM parameters. Deduced ^{13}N(0, 3.51, 7.38 MeV) levels, L, J, π.
1985Sa35: ^{14}N(d,t), ^{15}N(p,d) Measured thick target yields.

^{13}N Levels

E(level)[†]	J^{π}[†]	L[†]	Comments
0	1/2$^-$	0	
2360 *30*	1/2$^+$		
3.51×10^3	3/2$^-$	2	
6380 *30*	5/2$^+$		
7380 *20*	5/2$^-$	2	
8930 *50*	1/2$^-$	0	
10780 *60*	1/2$^-$	0	
11880 *40*	3/2$^-$	2	
15070 *20*	3/2$^-$	2	T=3/2 E(level): See also E_x=15065 keV *37* (1966Ce02).

[†] From DWBA analysis of (p,^{3}He) and (p,t) mirror partners and comparison of related differential cross sections (1968Fl08).

^{16}O(n,^{13}N)

1949Kn25: ^{16}O(n,^{13}N) $E_n \approx 90$ MeV; measured activation products.

^{13}N Levels

E(level)
0

^{16}**O(p,pt)**

1975Gr40: ^{16}O(p,pt) E=75 MeV; deduced reaction mechanism.
1977Gr04: ^{16}O(p,pt) E=75 MeV; deduced levels. Spectroscopic factors from Table VI S(0,3.51)=1.64, 2.57, respectively.
1982Sa24: ^{16}O(p,pt) E=101.3 MeV, ^{16}O(α,αt) E=139.2 MeV deduced L, S.
1983Ka37: ^{16}O(p,pt) E=670 MeV; calculated knockout reactions.
1983Go10: ^{16}O(p,pt) calculated reaction form factors.

^{13}N Levels

E(level)†	J^{π}†	S†
0	1/2⁻	1.64
2360		
3.51×10^{3}	3/2⁻	2.57

† From DWIA analysis in (1975Gr40,1977Gr04).

^{16}O(p,α)

1960Wh03: ^{16}O(p,α) E=8.59 MeV; measured reaction Q-value=−5206 keV *10*.
1960Pa14: ^{16}O(p,α) E=362 MeV; studied ^{13}N production.
1961Ma15: ^{16}O(p,α) E=13.5-18.1 MeV at the Princeton cyclotron, measured $\sigma(\theta)$ for θ=15° to 170°. Deduced E(J^{π})=0(1/2$^-$), 2.37 MeV(1/2$^+$), 3.51 MeV (3/2$^-$) and 3.56 MeV (5/2$^+$).
1964Da02: ^{16}O(p,α_0) E=7.9 to 10.2 MeV; measured $\sigma(\theta)$ for θ=33° to 166°.
1967Ac01: ^{16}O(p,α) E=38 MeV; measured $\sigma(\theta)$.
1967Ch41: E=13 MeV; measured σ to ^{13}N(0,2.36, 3.51+3.56 MeV).
1969Ga03: ^{16}O(p,α_0) E_p=38 MeV; measured $\sigma(\theta)$ for θ=15° to 170°. Deduced integrated σ=760 μb *30*. PWBA analysis.
1970Gu06: ^{16}O(p,α_0) E=25-38 MeV; measured $\sigma(\theta)$ for θ=20° to 170°.
1970Ko25: ^{16}O(p,α) E=665 MeV; measured $\sigma(E_{\alpha})$.
1971Bu05: ^{16}O(p,α) E=21.3-38.5 MeV from the UCLA sector-focused cyclotron; measured $\sigma(\theta)$ for θ=70°.
1971Gu23: ^{16}O(p,α) E=19-45 MEV, Measured $\sigma(E,\theta)$. Deduced reaction mechanism. $\alpha_{0,1,2+3,4}$.
1972Ma21: ^{16}O(p,α) E=54, 43.7, 50.5 MeV; measured $\sigma(E_{\alpha},\theta)$ for $\theta\approx$15° to 80°. Deduced level energies, L, J^{π}.
1973Mc12: ^{16}O(p,α) E=threshold=−7.7 MeV; measured σ(E) via activation technique.
1973Ne12: ^{16}O(p,α_0) E(c.m.)=5.4-9.9 MeV; measured σ(E). Deduced table of σ(E) values, and deduced astrophysical rates.
1974Sk02: ^{16}O(p,α) E=9.0-20.4 MeV; measured $\sigma(E,\theta)$ for θ=25° to 165°. Deduced ^{17}F levels.
1976Hi09: ^{16}O(p,$\alpha_{0,1}$) E=11.2-14.6 MeV; deduced ^{17}F states.
1977Gr17: ^{16}O(p,α) E=6.7-9.2 MeV; measured σ(E) via activation technique. Deduced astrophysical reaction rates.
1985Ku13: ^{16}O(p,α) E=9.1 MeV; measured thick target γ-ray yields.
1985Va14: ^{16}O(p,α) E=21 MeV; measured thick target yields.
1986Ai04: ^{16}O(p,α) E<14.7 MeV; measured residual yields.
1986Sa33: ^{16}O(p,α) E=6.5-16.5 MeV; measured thick target yields. deduced σ(E).
1989Wa16: ^{16}O(p,α) E=15-30 MeV; measured thick target yields via activation techniques. Evaluated radiopharmaceutical production.
1972Ga10: Develop pre-equilibrium emission model to explain the energy dependence of excitation functions.
1972Wo05: Computed astrophysically important reaction rates.
1999Ch50: ^{16}O(p,α) E≤250 MeV, calculated σ(E), compared with data.
2003Ta17: ^{16}O(p,α) E≈6.5-19 MeV. IAEA report on ^{13}N production cross sections. Deduced σ(E).
2021He14: ^{16}O(p,α) IAEA analysis of cross sections for PET/SPECT isotopes.

^{13}N Levels

E(level)†	J^{π}†	$T_{1/2}$†	L†	Comments
0	1/2$^-$		1	
2.36×10^3	1/2$^+$			E(level): (1967Ch41).
3.50×10^3	(3/2$^-$)			E(level): Doublet (1967Ch41).
6.38×10^3	5/2$^+$			E(level): From 1971Gu23.
7.39×10^3	5/2$^-$		3	
8.92×10^3	1/2$^-$			
9.52×10^3	3/2$^-$			
10.35×10^3	(5/2$^-$,7/2$^-$)			
11.5×10^3				
12.13×10^3 *6*	7/2$^-$	≈300 keV	3	
12.75×10^3? *6*				E(level): Probably unresolved 12.6+12.9 MeV states.
13.48×10^3?				Γ: broad: few hundred keV.

† From (1972Ma21), where a J dependence is found in the angular distributions, except where noted.

^{16}O(^{3}He,^{6}Li) **1966Ce02**

^{16}O(^{3}He,^{6}Li).

1966Ce02: ^{16}O(^{3}He,^{6}Li) E=65.3 MeV; measured $\sigma(\theta)$ for θ=12°.

1972Oh01: ^{16}O(^{3}He,^{6}Li) E=30 and 40.7 MeV; measured $\sigma(\theta)$ for θ=20° to 100°. Compared (^{3}He,^{6}Li) angular distributions measured on a variety of targets.

^{16}O(α,^{7}Li).

1972Ru03: ^{16}O(α,^{7}Li) E=42 MeV; measured angular distribution to ^{13}N$_{\text{g.s.}}$ for $\theta\approx$20° to 90°.

^{13}N Levels

E(level)[†]
0
3.5×10^{3}
6.4×10^{3}
7.4×10^{3}

[†] From (1966Ce02).

^{17}Ne $\beta^+\alpha$ decay 2002Mo19

Parent: ^{17}Ne: E=0; J^π=1/2$^-$; $T_{1/2}$=109.2 ms *6*; Q($\beta^+\alpha$)=8730.1 *4*; %$\beta^+\alpha$ decay=2.77 *19*

^{17}Ne-$T_{1/2}$: weighted mean from (1971Ha05,1988Bo39).

^{17}Ne-Q($\beta^+\alpha$): from (2021Wa16).

^{17}Ne-%$\beta^+\alpha$ decay: From (2002Mo19).

1988Bo39: A beam of ^{17}Ne ions was produced at the CERN/ISOLDE facility, using proton spallation reactions on a MgO target. Neon ions from the target were collected, post-accelerated to 60 keV and magnetically separated to obtain the ^{17}Ne beam, which was implanted in a 50 μg/cm^2 carbon foil. An annular plastic scintillator detector was placed on the upstream side of the target (w.r.t. beam) while a series of different ΔE Si surface-barrier detectors (covering ≈0.2% of 4π) were separately placed on the downstream side of the target. The Si detectors had thicknesses of 10, 15, 27 and 1000 μm and were used to characterize the proton and α groups of the delayed particle spectrum. Twenty-eight different groups of β-delayed protons and αs were identified. The lifetime was measured by collecting ^{17}Ne ions for 0.2 s and counting for 1.0 s. The value T=109.3 ms *6* was obtained. See other results on decay to ^{17}F in (1993Bo36,1993RiZY).

1997Ki19,1998Ch05,2002Ch61,2002Mo19: A series of experiments on ^{17}Ne decay were carried out at the TRIUMF/TISOL facility. The aim of the measurements was to exploit the ^{17}Ne(βp) reaction as a means to populate astrophysically important states in ^{16}O. Proton spallation of a MgO target resulted in ^{17}Ne ions that were implanted on a collection tape that was positioned at the center of various counting station configurations.

1998Ch05: A set of four ΔE-E telescopes were used to study the decay ^{17}Ne(β)^{17}F*(11193 keV)→p+^{16}O*(9590) and ^{17}Ne(β)^{17}F*(11193 keV)→α+^{13}N*(2365,3502+3547); a total of 11 decay branches were observed for the decay of ^{17}F*(11193 keV).

2002Ch61: The configuration of (1998Ch05) was improved by implementing double-sided Si strip detectors into parts of the counting station; this lowered the pile-up and random coincidence rates. It is noted that the reported branching ratios show a significant systematic dependence on the detector configuration.

2002Mo19: ^{17}Ne β delayed particle emission was studied using four different experimental techniques: proton-γ coincidences, proton-γ angular correlations, ToF spectra for the proton and α particle spectra, and a ratio cut for a clean α spectrum. Proton-γ coincidences were determined using a beam of ^{17}Ne ions at the TISOL facility at TRIUMF. The beam traveled through a four-sector annular silicon detector and was implanted onto a collection tape directly in front of a plastic scintillator and a HPGe detector that was not in the vacuum system. Counting rates were very high so only γ-ray events with energy above 4 MeV were accepted. A particle-β coincidence spectrum was also recorded by the Silicon detector.

Proton-γ angular correlations were studied using two HPGe γ-ray detectors and four ion-implanted Silicon detctors surrounding a carbon collector foil. Angular correlations between emitted protons and ^{16}O γ rays were measured. Using this method, J^π was determined for states in ^{17}F.

ToF spectra were determined for proton and α particle emissions. A beam of ^{17}Ne ions pssed through a carbon collector foil that was positioned at an angle and centered between to scitillation paddles, the beam then passed into a SSB detector. Time and pulse-height information were recorded. A clean α spectrum was not able to be produced because β-proton coincidences at low energies were very strong and obscured the weaker α decay peaks. Therefore, the ratio cut technique was used to obtain a cleaner spectrum.

A thin SSB detector was placed on the opposite side of a collector foil and a PIPS detector. Each detector had a thicker detector behind it in order to reject background events due to electrons and high energy protons. The PIPS detector recorded particle recoil and the SSB detector recorded coincident α particles. Additional background events were removed using the ratio-cut technique.

Using these methods, relative proton and α branching ratios were determined along with branching ratios for the β decay of ^{17}Ne. Using these branching ratios, reduced Gammow-Teller matrix elements were determined. β-delayed proton decay to α-unbound states in ^{16}O was also examined because of its relevance to astrophysics (helium-burning stage of stellar evolution).

The values %βp=95.4 *46* and %$\beta\alpha$=2.77 *19* are deduced from the tables given in (2002Mo19).

^{13}N Levels

E(level)†	J^π‡
0.0	1/2$^-$
2365	1/2$^+$
3502	3/2$^-$
3547	5/2$^+$

Continued on next page (footnotes at end of table)

^{17}Ne $\beta^+\alpha$ decay 2002Mo19 (continued)

^{13}N Levels (continued)

† From (2002Mo19).
‡ Drom Adopted Levels.

$\gamma({}^{13}N)$

E_γ †	E_i(level)	J^π_i	E_f	J^π_f
1137	3502	$3/2^-$	2365	$1/2^+$
2365	2365	$1/2^+$	0.0	$1/2^-$
3502	3502	$3/2^-$	0.0	$1/2^-$

† From level-energy differences.

Delayed Alphas (^{13}N)

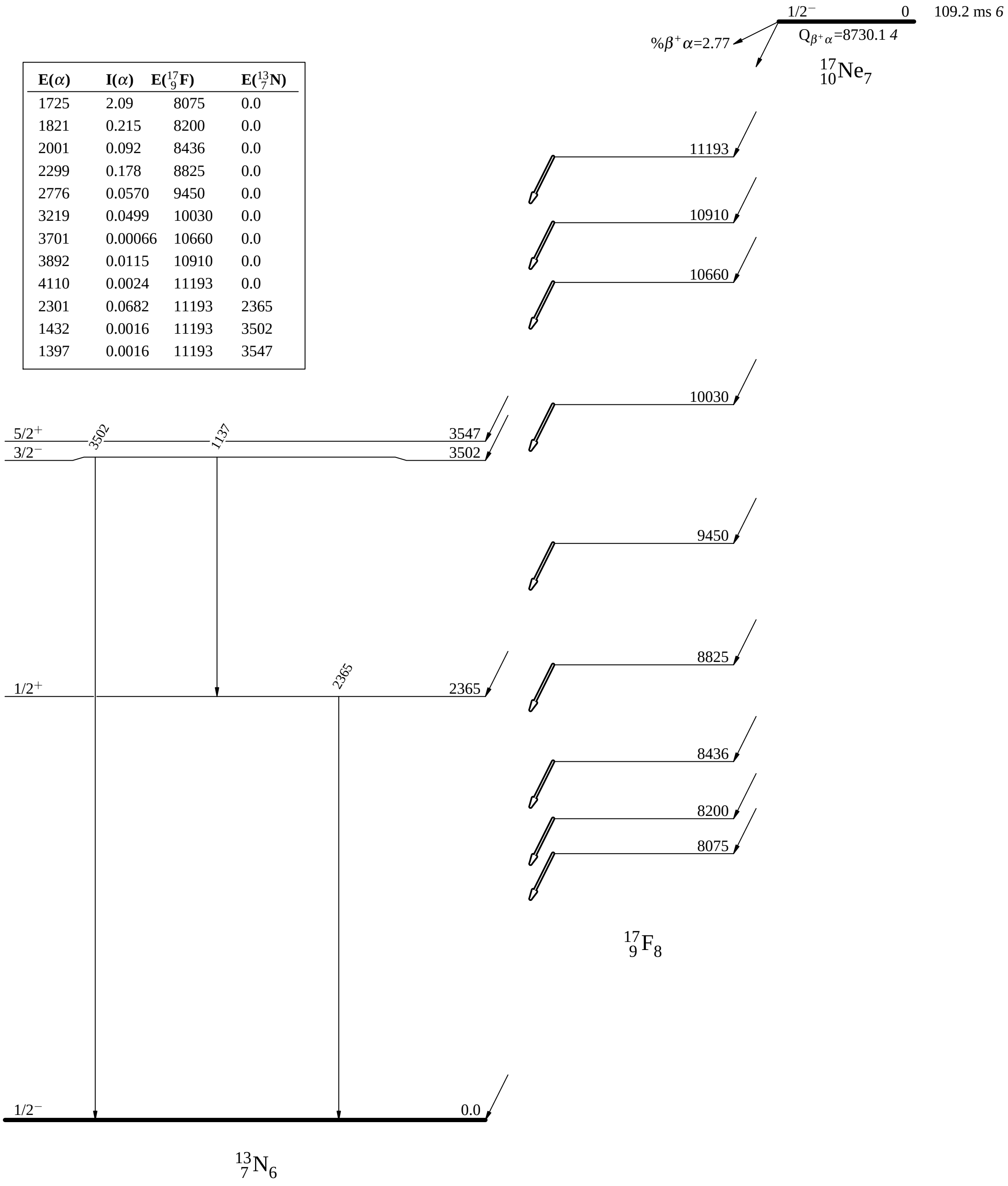
E(α)†	E(^{13}N)	I(α)†‡#	E(^{17}F)	E(α)†	E(^{13}N)	I(α)†‡#	E(^{17}F)
1397	3547	0.0016 *9*	11193	2301	2365	0.0682 *69*	11193
1432	3502	0.0016 *9*	11193	2776	0.0	0.0570 *58*	9450
1725	0.0	2.09 *18*	8075	3219	0.0	0.0499 *49*	10030
1821	0.0	0.215 *22*	8200	3701	0.0	0.00066 *58*	10660
2001	0.0	0.092 *9*	8436	3892	0.0	0.0115 *16*	10910
2299	0.0	0.178 *17*	8825	4110	0.0	0.0024 *7*	11193

† From (2002Mo19).
‡ The feeding to the particle unbound states is determined by normalizing the %β^+ strength to the relative Iβ^+-p and Iβ^+-α branching ratios using the measured β^+p, β^+pγ, $\beta^+\alpha$, $\beta^+\alpha\gamma$ observations and by assuming $I\beta^+_{g.s.}$<0.55% (1997Mi08) and Iβ^+(495 keV)=1.59% *17* (1993Bo36,1998Oz01: and including a correction for the γ-ray feeding from the 11193 keV isobaric analog state).
# Absolute intensity per 100 decays.

^{17}Ne $\beta^{+}\alpha$ decay 2002Mo19

Decay Scheme

I(α) Intensities: I(α) per 100 parent decays



E(α)	**I(α)**	**E(${}^{17}_{9}$F)**	**E(${}^{13}_{7}$N)**
1725	2.09	8075	0.0
1821	0.215	8200	0.0
2001	0.092	8436	0.0
2299	0.178	8825	0.0
2776	0.0570	9450	0.0
3219	0.0499	10030	0.0
3701	0.00066	10660	0.0
3892	0.0115	10910	0.0
4110	0.0024	11193	0.0
2301	0.0682	11193	2365
1432	0.0016	11193	3502
1397	0.0016	11193	3547

^{208}Pb(^{13}N,^{13}N): coulex

2002SeZY: ^{208}Pb(^{13}N,^{12}C+p) E=76 MeV/nucleon. Measured Coulomb excitation via $^{13}N^{*}$(2.37 MeV), deduced radiative width $\Gamma_{rad.}$=0.52 eV *4*. (Preliminary RIKEN lab report).

^{13}N Levels

E(level)	Comments
0	
2.37×10^{3}	Γ_{γ}=0.52 eV *4*

^{232}Th(^{22}Ne,^{13}N),^{154}Sm(^{16}O,^{13}N)

1977Ar06: ^{232}Th(^{22}Ne,^{13}N): The transfer reaction products resulting from E(^{22}Ne)=172 MeV bombardment of a 2.5 mg/cm^{2} metallic ^{232}Th foil were measured at Dubna. The reaction products were momentum analyzed in a magnetic spectrometer positioned at either θ=12° or 40° and then focused on a ΔE-E Si detector telescope, which provided particle identification. ^{13}N was identified.

2022Ro09: ^{154}Sm(^{16}O,^{13}N) E=85 MeV; measured reaction products using a ΔE-E telescope at the Bhabha Atomic Research Centre in Mumbai. Obtained differential cross sections for $\theta_{c.m.}\approx 55°$ to 75°. Discussed multi-nucleon transfer reaction mechanism.

^{13}N Levels

E(level)
0

Adopted Levels

S(n)=17770 *10*; S(p)=1512 *10*; Q(α)=−8220 *10* 2021Wa16

Theoretical studies:
Level properties and model analyses:
1978Gu10, 1987Sa15, 2001Sa06, 2001Su10, 2002Sa12, 2008Sh16, 2010Ti04, 2011Sh21, 2013Ti05, 2013Ma60, 2016Pa05, 2017Br02, 2020So01, 2022Zo01, 2023Me02.

Charge symmetry in mirror nuclei:
1971Bl12, 1973Sa25, 1974Ch46, 1999Ba21, 2021Ca23, 2023Se01.

Magnetic moments:
1999Ba21, 2003Su04, 2003Su28, 2013De06, 2016Me17, 2021Ca23.

Analyzed β-decay, β-p decay data.
1973Ha77, 1977Ce05, 1977Ri08, 1993Ch06.

Solar and cosmogenic production rates:
2006Li57, 2018Ge07, 2019Zh29.

In the early studies of (1984Se15, 1993Wa07) using $^{13}C(\pi^+,\pi^-)$ the levels observed in the excitation spectrum appeared as broad groups with excitation energies around E_x=3, 4.5, 6 and 8.7 MeV. In the later work of (2007GuZW) using $^{16}O(^3He,^6He)$, more structures are observed revealing a collection of narrower states. Finally, in the seminal work of (2021Ch45), analysis of the decay mechanism further resolved the groups observed by (2007GuZW) into narrower states that dominantly proton decay to different ^{12}N states.

^{13}O Levels

Cross Reference (XREF) Flags

A	$^1H(^{12}N,p)$:res	F	$^9Be(^{16}O,^{13}O)$	K	$^{14}N(p,2n)$
B	$^1H(^{14}O,d)$	G	$^{12}C(p,\pi^-)$	L	$^{14}N(^{12}N,^{13}O)$
C	$^2H(^{12}N,^{13}O)$	H	$^{12}C(^{15}O,^{13}O)$	M	$^{16}O(^3He,^6He)$
D	$^2H(^{14}O,t)$	I	$^{13}C(\pi^+,\pi^-)$	N	$^{28}Si(^{13}O,X)$
E	$^9Be(^{13}O,^{13}O),(^{13}O,p^{12}N)$	J	$^{13}C(^{11}B,^{11}Li)$	O	$^{208}Pb(^{13}O,^{13}O)$

E(level)	J$^\pi$	$T_{1/2}$ or Γ	XREF	Comments
0.0	$3/2^-$	8.58 ms *5*	BCD FGHIJKLMNO	%ε+%β^+=100; %β^+p=11.3 *23* (2005Kn02) T=3/2 μ=1.3891 *3* (1996Ma38,2019StZV) Q=0.0111 *8* (2016St14,2021StZZ) Q: From reanalysis of (1999Ma46). J$^\pi$: Allowed *ft* values to ^{13}N J$^\pi$=$1/2^-$, $3/2^-$, $5/2^-$ states (1970Es03). $T_{1/2}$: From weighted average of 8.7 ms *4* (1965Mc09), 8.95 ms *20* (1970Es03) and 8.55 ms *5* (1990As01).
2428[†] *18*	$1/2^+$[&]	358 keV *19*	AB E G M	%p=100 XREF: A(2.69E3)B(2.8E3)G(2.82E3)M(2650). E(level),J$^\pi$,Γ: From (2021Ch45) $^9Be(^{13}O,^{13}O)$. See also E_x=2400 keV *50* (1991Go13,1991GoZR) $^{16}O(^3He,^6He)$, E_x=2690 keV *50* (2007Sk02) $^1H(^{12}N,p)$, and E_x=2690 keV *50* from the (2007GuZW: ΔE estimated by evaluator) $^{16}O(^3He,^6He)$

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Adopted Levels (continued)

^{13}O Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
				conference proceedings. Other values reported near this energy are E_x=2.82 MeV *24* (1978Co15) ^{12}C(p,π^-) and E_x=2.8 MeV *3* (2012Su21) ^{1}H(^{14}O,d). Γ: See also Γ=0.45 MeV *10* (2007Sk02), <300 keV (2012Su21) and <100 keV (2007GuZW: est.).
3006[†] *13*	3/2$^+$[&]	55 keV *19*	E i	%p=100 XREF: i(2750). E(level),J^{π},Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O). See also E_x=2956 keV *15* and Γ<50 keV (2013So11) ^{9}Be(^{13}O,^{13}O). Ambiguity exists in the level energies obtained from the ^{13}C(π^+,π^-) reaction. A narrow resonance is reported in (1984Se15) with E_x=2.75 MeV 4 and in (1993Wa07) with 3.10 MeV *7*; we associate this state with either or both of the E_x=3006 keV and 3051 keV states of this evaluation.
3051[‡] *16*	5/2$^+$[&]	54 keV *19*	E i m	%p=100 XREF: i(2750)m(3120). E(level),J^{π},Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O). See also E_x=3025 keV *16* and Γ<50 keV (2013So11) ^{9}Be(^{13}O,^{13}O) and E_x=3038 keV *9* (2019We11) ^{9}Be(^{13}O,^{13}O). Also see E_x=2750 keV *40* (1984Se15) and 3100 keV *70* (1993Wa07) both from ^{13}C(π^+,π^-), and 3120 keV *50* (2007GuZW:ΔE est.) ^{16}O(^{3}He,^{6}He). Γ: See also ≈0.43 MeV (2007GuZW:est.).
3290?[@] *50*	(1/2,3/2)$^-$	75 keV *30*	A m	XREF: m(3120). E(level),J^{π},Γ: From R-matrix analysis in (2007Sk02) ^{1}H(^{12}N,p). See also E_x=3120 keV *50* and Γ=0.43 MeV *10* (2007GuZW:est.) ^{16}O(^{3}He,^{6}He). E(level): This level is listed because of the significant energy difference between 3290 and the nearest level at E_x=3051 keV and because of the broad width of the group reported in (2007GuZW) that may suggest both groups were populated. But, its existence is rather uncertain.
3692[†] *13*	7/2$^+$[&]	53 keV *21*	E M	%p=100 XREF: M(3800). E(level),J^{π},Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O). See also E_x=3669 keV *13* and Γ<50 keV (2013So11) ^{9}Be(^{13}O,^{13}O), E_x=3701 keV *10* (2019We11) ^{9}Be(^{13}O,^{13}O). Also see E_x=3800 keV *50* and Γ≈160 keV (2007GuZW: ΔE and Γ est.) ^{16}O(^{3}He,^{6}He) where the unresolved ^{13}O*(3692+3721) states may have been observed.
3721[#] *16*	(3/2$^+$,5/2$^+$,5/2$^-$)[&]	10 keV *+19−10*	E M	%p=100 XREF: M(3800). E(level),J^{π},Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O). See also E_x=3800 keV *50* and Γ≈160 keV (2007GuZW: ΔE and Γ est.) ^{16}O(^{3}He,^{6}He) where the unresolved ^{13}O*(3692+3721) states may have been observed.

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Adopted Levels (continued)

^{13}O Levels (continued)

E(level)	J^{π}	$T_{1/2}$ or Γ	XREF	Comments
4287[†] *13*	$(3/2^+,5/2^+)$[&]	170 keV *25*	B E I M	%p=100 XREF: M(4410). E(level),J^{π},Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O). E(level): See also E_x=4.21 MeV (1984Se15) and 4500 keV *90* (1993Wa07) discrepant values reported in ^{13}C(π^+,π^-), 4.2 MeV 3 (2012Su21) ^{1}H(^{14}O,d) and 4410 keV 50 (2007GuZW: ΔE est.) ^{16}O(^{3}He,^{6}He). J^{π}: See also $(1/2^-,3/2,5/2^+)$ (2012Su21) and $(1/2^-)$ from (1993Wa07). Γ: See also Γ=0.6 MeV *4* (1993Wa07), <500 keV (2012Su21) and ≈0.43 MeV (2007GuZW: est.).
4866[‡] *20*	$(1/2^+,1/2^-,3/2^-)$[&]	103 keV *37*	E	%p=100 E(level),J^{π},Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O).
4892[†] *25*	$7/2^+$[&]	323 keV *27*	E M	%p=100 E(level),J^{π},Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O). See also E_x=4.95 MeV *10* and Γ≈280 keV (2007GuZW: ΔE and Γ estimated by evaluator.) ^{16}O(^{3}He,^{6}He).
5483[#] *17*	$7/2^-$[&]	204 keV *41*	E	%p=100 E(level),J^{π},Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O).
5951[‡] *18*	$(7/2^+,7/2^-)$[&]	875 keV *68*	E IJ M	%p=100 XREF: J(6E3). E(level),J^{π},Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O). E(level): (2021Ch45) suggests two states in this region: one at E_x=5951 keV *18* along with a questionable state at ≈6.2 MeV; both have broad widths of around 1 MeV. Other reactions have reported broad states near E_x≈6 MeV, but none have suggested or resolved two states. We associate all firm states reported in this region with the lower level reported in (2021Ch45), but highlight that the associations may be different if both states are found to exist. Other energies reported near E_x=6 MeV are 6020 keV *80* (1984Se15) and 6100 keV *90* (1993Wa07) both from ^{13}C(π^+,π^-), 6.00 MeV 10 (2007GuZW: ΔE est.) ^{16}O(^{3}He,^{6}He) and 6 MeV (2007TaZR) ^{13}C(^{11}B,^{11}Li). Γ: Other reported widths are Γ≈1.2 MeV (1984Se15) and Γ=0.6 MeV *4* (1993Wa07) from ^{13}C(π^+,π^-); (1984Se15) suggest the group may correspond to one or more unresolved states. See also Γ≈1.0 MeV (2007GuZW: est.).
≈6.2×10^{3}?[#]			E	%p=100 $T_{1/2}$ or Γ: WIDTH=BROAD. E(level),$T_{1/2}$ or Γ: From (2021Ch45) ^{9}Be(^{13}O,^{13}O).
6.90×10^{3}[@] *10*		≈160 keV	M	From (2007GuZW: ΔE and Γ est.) ^{16}O(^{3}He,^{6}He).
8.7×10^{3}[@] *2*		3.1 MeV *5*	IJ	E(level),Γ: From (1993Wa07) ^{13}C(π^+,π^-). See

Continued on next page (footnotes at end of table)

Adopted Levels (continued)

^{13}O Levels (continued)

E(level)	J$^{\pi}$	$T_{1/2}$ or Γ	XREF	Comments
				also E_x=8.8 MeV *5* and Γ=3.0 MeV *6* (1991Mo02) and E_x=8.8 MeV (2007TaZR) ^{13}C(^{11}B,^{11}Li). E(level): Suggested GDR⊗IAS (GDR built on isobaric analog states) see (2007TaZR, 1984Se15).

[†] Decays to p+$^{12}N_{g.s.}$. See details in (2021Ch45) ^{9}Be(^{13}O,^{13}O).

[‡] Decays to p+^{12}N(961 keV:2^+). See details in (2021Ch45) ^{9}Be(^{13}O,^{13}O).

[#] Decays to p+^{12}N(1.19 keV:2^-). See details in (2021Ch45) ^{9}Be(^{13}O,^{13}O).

[@] Decay mode not specified.

[&] From (2021Ch45) analysis of the *m* sub-state distributions obtained by comparison of measured ^{12}N+p angular distributions with those expected for proton decay via the relevant *s*-, *p*- and *d*-wave components. Angular distributions are found that uniquely identify J^{π} values.

^{1}H(^{12}N,p):res **2007Sk02**

2003Te09, 2003Te12: ^{1}H(^{12}N,p) E=3.9 MeV/nucleon; Used two parallel-plate avalanche counters to tag events by nuclide and to monitor angular spread. Si detectors measured recoil proton spectra. Deduced resonance at $E_p \approx 4.5$ MeV ($E_x \approx 2.7$ MeV).

2007Sk02: ^{1}H(^{12}N,p) produced the 46 MeV $^{12}N^{7+}$ beam via ^{10}B(^{3}He,n) reaction at E(^{10}B) = 43 MeV. Used a polyethylene, CH_2, target. At E(c.m.)=0.8-2.7 MeV, measured elastic scattering E_p excitation at θ=7.5°, 22.5° and 37.5° using three Si ΔE-E detectors. Deduced ^{13}O resonance energies J^π, Γ using R-matrix analysis.

^{13}O Levels

E(level)[‡]	J^π[†‡]	Γ[‡]	L[†]	Comments
2.69×10^3 *5*	$1/2^+$	0.45 MeV *10*	0	$\Gamma=\Gamma_p$. See related discussion on ANCs and widths in (2015Mu08, 2017Mu06, 2022Mu07).
3290 *50*	$(1/2,3/2)^-$	75 keV *30*	1	E(level): Possible mirror of a shell model predicted ($1/2^-,3/2^-$) state in ^{13}B at $E_x \approx 4$ MeV.

[†] From shape of resonance and R-matrix analysis assuming a only a single-proton decay channel. The following three distant resonances were included in the R-matrix analysis to fit the background: 4550, $3/2^-$, Γ=0.24 MeV; 5000, $3/2^+$, Γ=0.78 MeV; 5700, $3/2^+$, Γ=2.0 MeV.

[‡] From 2007Sk02.

^{1}H(^{14}O,d) **2012Su21**

2012Su21: XUNDL dataset compiled by TUNL, 2012.

The authors measured ^{14}O(p,d) at E(^{14}O)=51 MeV/nucleon using a hydrogen gas target mounted in the SPEG/GANIL target chamber and using position sensitive Si strip arrays to detect the deuteron recoils (MUST2 and RIKEN Si telescope). The energy and angular distributions of deuterons were measured in coincidence with ^{13}O and ^{12}N (from ^{13}O* –>^{12}N + p) recoils. A distorted wave analysis of the angular distributions is given as well as a discussion on the breakdown of Z=8 shell closure.

2023Po05: ^{1}H(^{14}O,^{13}O) E=94 MeV/nucleon at RIKEN/RIBF; also studied ^{1}H(^{14}O,^{13}N). Measured the parallel momentum distributions and reaction cross sections. Analyzed quasifree knockout and other mechanisms. Deduced S=3.42 in DWIA analysis.

^{13}O Levels

E(level)†	J^{π}	$T_{1/2}$ or Γ	L	S	Comments
0.0	$3/2^-$	8.58 ms *5*	1	2.1 *4*	$T_{1/2}$: from Adopted Levels. E(level): observed at $E_x=-0.2$ MeV *3*.
2.8×10^3 *3*	$1/2^+$,($1/2^-$ to $5/2^+$)	<0.3 MeV	0,(1,2)		$J^{\pi}=1/2^+,(1/2^-,3/2^-,3/2^+,5/2^+)$. The authors suggest this state corresponds to the 2.7 MeV $J^{\pi}=1/2^+$ level of (2007Sk02), though participation of a second ΔL=1 or 2 state can not be ruled out. Discussion on the spectroscopic factors for the various doublet combination is given in Table 1.
4.2×10^3 *3*	($1/2^-$,3/2,$5/2^+$)	<0.5 MeV	(1,2)		Discussion on the spectroscopic factors is given in Table 1.

† Systematic uncertainty of 0.2 MeV is included.

^{2}H(^{12}N,^{13}O) 2013Gu04

2013Gu04: XUNDL dataset compiled by TUNL, 2013.

A beam of 72 MeV ^{12}N ions was produced via the ^{3}He(^{10}B,^{12}N) reaction at the RIKEN RI Beam facility. The trajectory of beam particles was tracked onto a 1.5 mg/cm^{2} deuterated polyethylene foil, where ^{2}H(^{12}N,^{13}O) reactions occurred. Interacting ^{12}N ions were identified by their time of flight relative to the cyclotron rf. The ^{13}O ejectiles were identified by ΔE-E in a telescope array.

The data are normalized by the ^{2}H(^{12}N,^{12}N) elastic scattering reaction. The code FRESCO was used to analyze the cross section angular distributions and to deduce the ANC′s. Values of $(C_{p1/2})^2$=3.4 fm^{-1} 13 and $(C_{p3/2})^2$=0.54 fm^{-1} 20 yield a total ANC of $(C_{tot})^2$=3.9 fm^{-1} 13. An earlier measurement at RIKEN is mentioned in (2010LiZW).

Discussion is given on the astrophysical implications to the ^{1}H(^{12}N,^{13}O) reaction. See also (2022Du11).

^{13}O Levels

E(level)[†]	J^{π}[†]
0.0	3/2^{-}

[†] From Adopted Levels.

$^{2}H(^{14}O,t)$ 2013Fl01

2013Fl01: XUNDL dataset compiled by TUNL, 2013.

A 18.1 MeV/nucleon ^{14}O beam was produced at the GANIL/SPIRAL facility. The beam impinged on a 1.5 mg/cm^{2} CD_2 target (elastic scattering) or a 8.5 mg/cm^{2} CD_2 target ((d,t)) and the light recoil nuclei were detected in one of six MUST2 array telescopes: four covered $\theta_{cm}\approx$15-70° for the nucleon transfer reactions while the other two were near $\theta_{lab}\approx$90° and were used to extend the elastic measurements.

The angular distributions were analyzed using the FRESCO code. Spectroscopic factors are deduced using both phenomenological and microscopic overlap functions and compared with literature results for $^{16}O(d,^{3}He)$, (d,t) and $^{18}O(d,^{3}He)$. See further analysis in (2018Fl03).

^{13}O Levels

E(level)	J^{π}	Comments
0.0	$3/2^{-}$	$C^{2}S$(phenomenological)=1.69 *17* (experimental) *20* (analysis). $C^{2}S$(microscopic)=1.89 *19* (experimental) *22* (analysis).

^{9}Be(^{13}O,^{13}O),(^{13}O,p^{12}N) 2013So11,1996Oz01

1996Oz01, 2001Oz04: ^{9}Be, C, ^{27}Al(^{13}O,^{13}O) E≈730 MeV. Measured interaction cross section. Deduced p, charge, neutron and matter radii of 2.56 fm *5*, 2.68 fm *5*, 2.48 fm *5* and 2.53 fm *5*, respectively.

2013So11: XUNDL data set compiled by TUNL, 2013.

A beam of E(^{13}O)=30.3 MeV/nucleon ions, produced via ^{1}H(^{14}N,^{13}O) reaction at the Texas A&M MARS facility, impinged on a 45.6 mg/cm^{2} ^{9}Be target. Breakup particles were detected in a 10 cm× 10 cm segmented ΔE-E telescope located on the beam axis, 18 cm from the target.

Momentum analysis of the breakup particles permitted the kinematic reconstruction of the invariant mass and determination of excitation energies for ^{12}N* and ^{13}O* states involved in the reactions. The intrinsic width resolution was roughly 50 keV and there was a 10 keV systematic uncertainty in the invariant mass energy. The excitation spectra of p+^{12}N and 2p+^{11}C events were analyzed to deduce ^{13}O excited states.

A single state was observed at E_x=2956 keV *10* in the p+^{12}N relative energy spectrum, while two states at E_x=3025 keV *6* and 3669 keV *3* were found in the 2p+^{11}C spectrum (uncertainty is statistical only, systematic uncertainty is 10 keV). The widths of ^{13}O states were found consistent with the system resolution, hence narrow widths of Γ<50 keV are assumed.

Analysis of the Jacobi T and Y systems provides insight into the decay mechanism for the 3-body breakup systems; the decays are consistent with sequential decay mainly through E_x=0.96 and 1.18 MeV unbound states in ^{12}N.

2019We11: ^{9}Be(^{13}O,^{13}O), the authors of (2013So11) measured the excitation spectra of particle unbound nuclides produced in the breakup ^{13}O ions on a ^{9}Be target, the emphasis was on ^{11,12}N and ^{12}O, but some new information on ^{13}O was presented.

A beam of 69.5 MeV/nucleon ^{13}O ions, from the NSCL/A1900 fragment separator, was purified in the Radio Frequency Fragment Separator before impinging on a 1 mm thick ^{9}Be target. The reaction products were detected using the HiRA High-Resolution position sensitive ΔE-E telescope array, which covered the polar angles θ_{lab}=2.1° to 12.1°. Peaks corresponding to ^{13}O*(3038 *9*,3701 *10*) were reported. These values are consistent with (2013So11) but more precise. See related discussion in (2019Ka50).

2021Ch45: XUNDL dataset compiled by TUNL (2022).

The authors of (2013So11, 2019We11) reported new results on unbound ^{13}O states and analyzed the associated decay proton angular distributions to obtain information on the spin values.

A beam of 69.5 MeV/nucleon ^{13}O ions from the NSCL/A1900 fragment separator was purified in the Radio Frequency Fragment Separator before impinging on a 1 mm thick ^{9}Be target. The reaction products were detected using the HiRA High-Resolution position sensitive ΔE-E telescope array, which covered the polar angles θ_{lab}=2.1° to 12.4°. The invariant-mass spectra were obtained for states decaying to p+^{12}N$_{g.s.}$ and 2p+^{11}C (resulting from p+^{12}N(1.19 MeV:2^{-}) and p+^{12}N(961 keV:2^{+}) events).

Events corresponding to low target excitations were selected, since these events are thought to possess a strong spin alignment in the ejectile that should be sensitive to the excited state′s spin value. Additionally, the breakup events having the decay protons emitted perpindicular to the beam axis were preferentially selected to enhance the excitation energy resolution. Five states were observed in the p+^{12}N$_{g.s.}$ spectrum, three states were observed in the p+^{12}N(961 keV:2^{+}) spectrum, two states were observed in the p+^{12}N(1.19 MeV:2^{-}) spectrum, and evidence for a third, difficult to interpret, broad state was also observed in the p+^{12}N(1.19 MeV:2^{-}) decay channel.

The decay proton angular distributions were analyzed and compared with a model based on DWBA calculations to gain insight into sensitivity for constraining spin values of the excited states. The model analyzed the *m*-state distribution dependence for small-angle, and all-angle scattering of the ^{13}O ejectiles. Using the *m*-state distributions, angular distributions were calculated for *s*-, *p*- and *d*-wave components that are expected in proton emission from ^{13}O. The angular distributions showed a differentiable dependence for J and π values, and they were compaired with the measured ^{13}O→^{12}N+p angular distributions to obtain J^{π} values given below.

The present results are found in reasonable agreement with prior reports. In a few instances, states at similar excitation energies are found in the different decay modes; these states are assigned to different close-lying levels with different J$^{\pi}$ values based on the analysis of the decay proton angular distributions. See discussion in text.

note: In the initial publication, Table 1 was found to have inconsistencies between the E* and E$_{c.m.}$ values given. These values were corrected in September 2022 following a private communication with R.J. Charity (June 14, 2022). However, inconsistencies persist in the published ΔE values; in the present analysis ΔE values are obtained beginning with the uncertainties on E$_{c.m.}$ values. Also, the discussion indicates J^{π}=7/2^{+} for peak 3, the Table I contains a typographycal error.

^{9}Be(^{13}O,^{13}O),(^{13}O,p^{12}N) 2013So11,1996Oz01 (continued)

^{13}O Levels

E(level)	J^{π}[‡]	Γ[†]	$E_{c.m.}$(p+^{12}N) (keV)[†]	Comments
2428[#] *18*	1/2$^+$	358 keV *19*	916 *14*	
3006[#] *13*	3/2$^+$	55 keV *19*	1494 *8*	E(level): See also 2956 keV *15* (2013So11).
3051[@] *16*	5/2$^+$	54 keV *19*	578 *11*	E(level): See also 3025 keV *16* (2013So11) and 3038 keV *9* (2019We11).
3692[#] *13*	7/2$^+$	53 keV *21*	2180 *8*	E(level): See also 3669 keV *13* (2013So11) and 3701 keV *10* (2019We11).
3721[&] *16*	(3/2$^+$,5/2$^+$,5/2$^-$)	10 keV *+19−10*	1019 *11*	
4287[#] *13*	(3/2$^+$,5/2$^+$)	170 keV *25*	2775 *9*	
4866[@] *20*	(1/2$^+$,1/2$^-$,3/2$^-$)	103 keV *37*	2393 *16*	
4892[#] *25*	7/2$^+$	323 keV *27*	3380 *23*	
5483[&] *17*	7/2$^-$	204 keV *41*	2781 *11*	
5951[@] *18*	(7/2$^+$,7/2$^-$)	875 keV *68*	3478 *14*	
≈6.2×10^3?[&]		1.2 MeV	≈3500	Γ: from (1984Se15).

[†] From (2021Ch45). An 8 keV systematic uncertainty is combined in quadrature to the $\Delta E_{c.m.}$ decay energy values of Table 1 (labled ΔE_p in that table).

[‡] From (2021Ch45) analysis of the *m* sub-state distributions obtained by comparison of measured ^{12}N+p angular distributions with those expected for proton decay via the relevant *s*-, *p*- and *d*-wave components.

[#] $E=S(p)+E_{cm}(p+^{12}N_{g.s.})=1512$ keV *10* + $E_{c.m.}(p+^{12}N)$.

[@] $E=S(p)+E_{cm}(p+^{12}N(961\text{ keV}:2^+))=1512$ keV *10* + $E_{c.m.}(p+^{12}N)$ + 961 keV *5*.

[&] $E=S(p)+E_{cm}(p+^{12}N(1.19\text{ MeV}:2^-))=1512$ keV *10* + $E_{c.m.}(p+^{12}N)$ + 1190 keV *7*.

^{9}Be(^{16}O,^{13}O)

1996Ma38, 1999Ma46, 1999Sa75: ^{9}Be(^{16}O,^{13}O), studied β-NQR and β-NMR. Deduced ABS(μ(^{13}O))=1.3891 μ_N *3* (1996Ma38) and ABS(Q(^{13}O))=11.0 mb *13* (1999Ma46, 1999Sa75).

See preliminary and conference results in (1996MaZQ, 1998MaZK, 2002Ma43).

See theoretical analysis in (1999Ki27, 1999Ki28, 2003Sm02, 2003Su04, 2003Su28).

^{13}O Levels

E(level)
0

^{12}C(p,π^-) **1978Co15,1980Ho20**

1978Co15: ^{12}C(p,π^-) E=613 MeV from the Saclay synchrotron Saturne, measured π yields using the high-resolution magnetic spectrometer SPES I at θ=5°, 15° 25°and 35°. Deduced level at E_x=2.82 MeV *24*, enhancement at ≈5.5 MeV. 450 keV energy resolution. No Q dependence on angular distribution.

1980Ho20: ^{12}C(p,π^-) E=200 MeV from Indiana University Cyclotron Facility, measured $\sigma(\theta)$ for $^{13}O_{g.s.}$, deduced structure and reaction process interplay.

1982Ja05: ^{12}C(pol. p,π^-) E=205 MeV from the Indiana University Cyclotron Facility, measured $\sigma(E(\pi))$, $\sigma(\theta)$, and A_y vs θ FROM θ(c.m.)=31° TO 153° using the quadrupole- quadrupole split-pole spectrometer. Analyzed $^{13}O_{g.s.}$.

1985Bi04: ^{12}C(p,π^-) E= 180, 201 MeV from the Orsay synchrocyclotron, measured $\sigma(\theta,E(\pi))$. Deduced σ_{total}.

1988Ab05: ^{12}C(p,π^-) E=997(5) MeV, measured $\sigma(\theta)$ vs. π momentum from 75-950 MeV/c atθ=0° and 57.8°. Used two magnetic spectrometers π1 and π2 with angular acceptance of 0.01 sr. Total RMS error for normalisation of the differential cross section was 6% and 11% for 0° and 57.8°, respectively.

1992Ho03: ^{12}C(p,π^-) E=186, 204 MeV, θ(c.m.)=155°−180°. Observed π's emitted in backward direction corresponding to ^{13}Og.s.

2002Ha02: ^{12}C(pol. p,π^-) E=250, 300, 350 MeV, polarization of about 0.7 from the atomic beam-type polarized ion source at the Research Center for Nuclear Physics in Osaka University. Measured $\sigma(\theta)$, analyzing powers using spectrometer LAS. Focal plane detectors consisted of two vertical drift chambers and two ΔE trigger scintillators. 10% data acquistion deadtime. Most background from μ produced from π-decay. Less than 5% overall systematic uncertainties. Comparison with DWBA.

See also (theory) (1981Bu18, 1984Gu27, 1985Co11, 1991Ku07, 1992Be37, 1992No01, 1998No08, 2018No02).

^{13}O Levels

E(level)[†]	J$^\pi$[‡]
0	(3/2$^-$)
2.82×10^3 *24*	

[†] From 1978Co15.
[‡] From 1980Ho20.

^{12}C(^{15}O,^{13}O) 2022Bo01

2022Bo01: ^{12}C(^{15}O,^{13}O) E=349 MeV/nucleon. Measured fragmentation yields produced in the fragmentation of ^{15}O. In addition they measured the yields of ^{12}C(^{13}O,X) at E=397 MeV/nucleon for X=^{7,9}Be, ^{8,10,11}B, ^{9,10,11,12}C and ^{12}N.

^{13}O Levels

E(level)
0

$^{13}C(\pi^{+},\pi^{-})$ 1993Wa07

1980Bu15: $^{13}C(\pi^{+},\pi^{-})$ E=180 MeV, θ=5°, measured $\sigma(\theta)$, Q. Use of Energetic Pion Channel and Spectrometer (EPICS) to separate πs.

1984Se15, 1985SeZY: $^{13}C(\pi^{+},\pi^{-})$ E=164, 292 MeV, measured $\sigma(E(\pi),\theta)$, missing mass spectrum. 90% isotopic pure ^{13}C target. Normalization of yields with $^{1}H(\pi^{+},\pi^{+})$ at 50° and comparisons with phase-shift anlaysis. 0.9 and 0.5 MeV FWHM resolution of missing mass spectra for thick and thin targets. π's separated using EPICS. Deduced ^{13}O levels. Excited state peaks appear significantly narrower than the ground state peak, which is surprising. The energies of the observed peaks appear to be shifted lower by ≈300 keV when compared with (1993Wa07), while the g.s. seems to have a high-energy tail. The ground state and other levels are reported at E_x=2.75 MeV *4*, 4.21 MeV and 6.02 MeV *8*.

1989Mo09: $^{13}C(\pi^{+},\pi^{-})$ E=292 MeV, θ=5°, measured $\sigma(\theta)$. ^{13}O deduced GDR built on IAS.

1990Gl09: $^{13}C(\pi^{+},\pi^{-})$ E=132 MeV, compiled data.

1990Mo02: $^{13}C(\pi^{+},\pi^{-})$ E=292 MeV, θ=5°, measured $\sigma(\theta)$. ^{13}O deduced GDR built on IAS. 90% enriched ^{13}C target.

1991Mo02: $^{13}C(\pi^{+},\pi^{-})$ E=292 MeV,θ=18°, measured $\sigma(\theta(\pi),E(\pi))$. 90% isotopic pure ^{13}C target. ^{13}O deduced giant resonances, Γ, ISPIN.

1993Wa07: $^{13}C(\pi^{+},\pi^{-})$ E=140-295 MeV, measured $\sigma(\theta)$ vs E using EPICS at LAMPF. 90% isotopic pure ^{13}C target. Deduced levels, Γ, configurations from mising mass spectra. Analyzed level structures at $E_{\pi+}$=140, 180, 220, 260, 295 MeV. The ground state and other levels are reported at E_x=3.10 MeV *7*, 4.50 MeV *9*, 6.10 MeV *9* and 8.7 MeV *2*. The ground state width is reported at Γ=0.40 MeV *6*, even thought the state is known to have Γ<<1 eV. Other widths for the excited states are reported as Γ=0.6 MeV *4*, 0.6 MeV *4*, 0.6 MeV *4* and 3.1 MeV *5*, respectively.

1994Mo04, 1994Mo44: $^{13}C(\pi+,\pi-)$ E=295 MeV, compiled, reviewed $\sigma(\theta)$. Deduced GDR excitation.

1996Mo03: $^{13}C(\pi^{+},\pi^{-})$ E=140-295 MeV, θ=18° measured $\sigma(\theta)$. Analyzed various results.

See theoretical analysis in (1991Ku07).

Discussion: The level structures observed in $^{13}C(\pi^{+},\pi^{-})$ are best resolved in (1984Se15), though they did not report uncertainties for some of their results. On the other hand, (1993Wa07) also utilized EPICS at LANSCE for their measurement, and they did report experimental uncertainties, but they reported rather unreliable width values such as $\Gamma_{g.s}$=400 keV *60*. A further complication is that the reported excitation energies of (1984Se15) are systematically lower than those in (1993Wa07) suggesting the data sets should not simply be averaged. We select the excitation energies and widths of (1984Se15) for the lower-lying states since they appear better resolved, and we note that (1993Wa07) was focused on the E_x=8.7 MeV GDR⊗IAS resonance.

^{13}O Levels

E(level)†	Jπ	Γ†	Comments
0	(3/2⁻)		E(level): Q(g.s)=−18.9 MeV 1 (1993Wa07,1991Mo02). Γ: The value Γ=400 keV *60* is reported in (1993Wa07), but this would imply a particle unboud level.
2.75×10³ *4*			Γ: NARROW. E(level): From E_x=2.75 MeV *4* in (1984Se15). See also E_x=3.10 MeV *9* from Q=−22.0 MeV 6 (1993Wa07). Γ: In (1984Se15) a peak with a width narrower than the g.s. is observed; subsequent results from (2021Ch45) $^{9}Be(^{13}O,^{13}O)$ support the existence of narrow states (≈50 keV) in this region. The other width reported for this state is Γ=0.60 MeV *40* (1993Wa07).
4210	(1/2⁻)		E(level): From (1984Se15). See also E_x=4500 keV *90* from Q=−23.4 MeV (1993Wa07). Jπ: Based on similarities with $^{12}C(\pi^{+},\pi^{-})^{12}O$(g.s.) and $^{14}C(\pi^{+},\pi^{-})^{17}O$(5.9 MeV) (1984Se15). Γ: In (1984Se15) a peak with a width similar to the g.s. is observed. The only width reported for this state in $^{13}C(\pi^{+},\pi^{-})$ is Γ=0.60 MeV *40* in (1993Wa07).
6020 *80*		≈1.2 MeV	E(level): From (1984Se15). See also E_x=6.10 MeV *9* from Q=−25.0 MeV 8 (1993Wa07) and see also 5.1 MeV from Q=−24.0 MeV *5* in (1991Mo02). Γ: From (1984Se15). The other width reported for this state is Γ=0.60 MeV *40* (1993Wa07).
8.7×10³ *2*		3.1 MeV *5*	E(level),Γ: From Q=−27.6 MeV *2* (1993Wa07). See also Q=−27.7 MeV *5* and Γ=3.0

Continued on next page (footnotes at end of table)

^{13}C(π^+,π^-) 1993Wa07 (continued)

^{13}O Levels (continued)

E(level)[†]	J$^\pi$	Γ[†]	Comments
			MeV *6* (1991Mo02), and Q=−27.4 MeV *5* and Γ=2 MeV *1* (1989Mo09). Suggested GDR⊗IAS resonance.

[†] From (1984Se15).

^{13}C(^{11}B,^{11}Li)

2007TaZR: ^{13}C(^{11}B,^{11}Li) E=758 MeV, measured ^{13}O excitation spectrum at RCNP Grand Raiden spectrometer. Peaks are suggested in the spectrum, and results are compared with the ^{13}C(π^+,π^-) spectrum. The ground state is observed and there may be some evidence of levels at E_x=25.0 and 27.5 MeV. Comments on the GDR⊗IAS (GDR built on isobaric analog states) are given.

^{13}O Levels

E(level)	Comments
0	
6×10^3?	
8.8×10^3?	E(level): Possibly the GDR⊗IAS.

^{14}N(p,2n)

1963Ba63: study of residual decays from a ^{14}N(p,2n) study at the McGill synchrocyclotron. The ^{13}O nucleus was discovered based on observed β-p branches. See also (2012Th01).

1965Mc09: ^{14}N(p,2n) E=50 MeV, deduced ^{13}O β-p branches with E_p=6.06 and 6.65 MeV. $T_{1/2}$=8.7 ms *4*.

1970Es03, 1971EsZR: ^{14}N(p,2n) E=43 MeV. Measured nine ^{13}O β-p branches and $T_{1/2}$=8.95 ms 20.

1983AsZZ, 1984MiZR, 1990As01: ^{14}N(p,2n) E=45 MeV, studied ^{13}O decay. Reported $T_{1/2}$=8.50 ms *10* (1984MiZR); $T_{1/2}$=8.55 ms *5* (1984MiZR, 1990As01).

2005Kn02,2014Te01: ^{14}N(p,2n) deduced ^{13}O β-p branches.

^{13}O Levels

E(level)	$T_{1/2}$	Comments
0	8.55 ms *5*	$T_{1/2}$: From (1990As01).

^{14}N(^{12}N,^{13}O)

2009Ba09: ^{14}N(^{12}N,^{13}O) E=12 MeV/nucleon, measured particle spectra, angular distributions at TAMU/MARS spectrometer. DWBA analysis of elastic scattering channel to obtain ^{12}N(p,γ) ANC. Analyzed astrophysical reaction rate.

^{13}O Levels

E(level)
0

$^{16}O(^3He,^6He)$ 1991Go13,2007GuZW

1966Ce02: $^{16}O(^3He,^6He)$ E=65.3, θ=10-20°, deduced mass excess of 23.11 MeV *7*.
1970Me11: $^{16}O(^3He,^6He)$ E=65-75 MeV, measured M=23.107 MeV *15* at 88-inch using ΔE-E telescopes. Compared IMME.
1970Tr05, 1970TrZX, 1971Tr03: $^{16}O(3He,^6He)$ E=68-70 MeV, measured Q=−30.506 MeV *13* and ΔM=23.103 MeV *14*. Identification of particles using a position-sensitive Si surface-barrier detector in Enge spectrometer. Compared IMME.
1991Go13, 1991GoZR: $^{16}O(^3He,^6He)$ E=76.6 MeV. Used a gas target, solid SiO_2, and W_2O_5 targets to increase reliability. Collected spectra at θ=5° on a cooled semiconductor detector. Deduced levels. The article shows a spectrum with levels indicated and the text gives energy uncertainties around 50 keV, but the levels are not well resolved from other features. The peak fits appear drawn by hand via χ-by-eye technique. States at E_x=2.4 MeV *5* and 2.9 MeV *5* are deduced.
2007GuZW: $^{16}O(^3He,^6He)$ E=79.90 MeV, measured excitation spectra for θ=7° to 24° with ΔE≈250 keV (FWHM). Only one figure is shown for Θ=12° where several peaks are observed with widths that are typically 2-3 times broader than the ground state width. The data were collected along with $^{20}Ne(^3He,^6He)$ data that were published in (1998Gu10); the $^{16}O(^3He,^6He)$ data appear only in (2007GuZW). By comparison with (1998Gu10) the peak energy resolution is estimated below by the evaluator.
Measured angular distributions disagreed with DWBA calculations which may indicate higher order effects, sequential transfer and core excitations should be considered.

^{13}O Levels

E(level)[†]	J^π[@]	Γ[&]	Comments
0			
2650[‡]	(5/2$^+$)	<100 keV	E(level): See also E_x=2.40 MeV *5* (1991Go13,1991GoZR). Γ: The ≈250 keV observed width suggests Γ<100 keV.
3120[‡]	(1/2$^-$)	≈0.43 MeV	E(level): See also E_x=2.90 MeV *5* (1991Go13,1991GoZR). Γ: ≈500 keV observed width.
3800[‡]		≈160 keV	Γ: ≈300 keV observed width.
4410[‡]		≈0.43 MeV	Γ: ≈500 keV observed width.
4.95×10^3[#]		≈280 keV	Γ: ≈375 keV observed width.
6.00×10^3[#]		≈1.0 MeV	Γ: ≈1 MeV observed width.
6.90×10^3[#]		≈160 keV	Γ: ≈300 keV observed width.

[†] From (2007GuZW). As the evaluation progressed it became clear these level parameters would be more reliable if data from all nine angles had been analyzed and reported in a journal article. The weight given to these data and their uncertainties (deduced by the evaluator) is somewhat dismissed.
[‡] ΔE≈50 keV is estimated by the evaluator.
[#] ΔE≈100 keV is estimated by the evaluator.
[@] From (1991Go13,1991GoZR).
[&] : The Γ values are estimated by subtracting the FWHM=250 keV resolution from the width deduced from the spectrum in Figure 2 of (2007GuZW).

^{28}Si(^{13}O,X)

2006Wa18: ^{28}Si(^{13}O,X) E=22.5-46.8 MeV, measured total σ_{reaction} and σ_{1p}, Glauber model analysis, deduced proton, neutron and matter radii of 2.81, 2.47 and 2.69 fm, respectively. Deduced spectroscopic factors.

See other estimates of the ^{13}O nuclear density in (2005Ji04, 2017Ah08).

^{13}O Levels

E(level)
0

^{208}Pb(^{13}O,^{13}O) 2022Wa16

2022Wa16: XUNDL dataset compiled at TUNL (2022).

The authors measured elastic scattering of the ^{13}O and ^{13}B mirror nuclei on ^{208}Pb and analyzed the nucler densities obtained from optical model analyses.

A beam of 413 MeV ^{13}O ions from the HIRFL in Lanzhou impinged on a 12.24 mg/cm^2 thick ^{208}Pb target. Scattered ^{13}O ions were momentum analyzed using an array of four position sensitive ΔE-E Si-detector telescopes that covered $\theta\approx3°$ to 27°. Differential cross sections were analyzed for $\theta_{lab}=4°$ to 15°. Only the ground state is bound in ^{13}O, but participation of any ^{208}Pb excited states was unresolved.

The data were analysed using two optical model approaches: first, using the double-folding Sao Paulo potential-2 (L. Chamon, et al., Computer Physics Communications **267**, 108061 (2021)), and second using the single-folding Xu and Pang potential model (2013Xu06). The data are reasonably fit using standard global parameterization inputs. The discussion details an approach for obtaining the proton, neutron and matter rms radii. A comparison of the results may suggest a thin proton skin for ^{13}O.

^{13}O Levels

E(level)	Comments
0	$<r_p^2>^{1/2}$=3.095 fm. $<r_n^2>^{1/2}$=2.670 fm. $<r_m^2>^{1/2}$=2.939 rm.

Adopted Levels

S(p)=−2730 *syst* 2021Wa16

The ^{13}F nucleus is unbound to proton emission. A resonance is observed in (2021Ch19); however, since this resonance is reported at a higher energy than expected for the ground state, it is believed to correspond to an excited state. See also (2023Th03).

In (2013Ti01), the Kelson-Garvey mass systematics (1966Ga25) are improved to provide reliable predictions of the masses of proton-rich nuclei, based on analysis of their neutron-rich mirror nuclei. For ^{13}F, the predicted binding energy E_{bind}=53.666 MeV *16* and mass excess ΔM=43.386 MeV 16 are based on comparison with ^{13}Be.

In (2012Fo22) a potential model is developed that is informed by $^{12,13}Be$ and ^{12}O properties. The expected $J^{\pi}=1/2^{+}$ ground state is predicted near the resonance energy E_p=2.4 MeV with Γ≈0.6 MeV, relative to $^{12}O_{g.s.}$. The $J^{\pi}=5/2^{+}$ excited state is predicted near E_p≈5 MeV with Γ≈0.35 MeV. The analysis is updated in (2013Fo22) with similar results.

See (1993Po11) for earlier shell-model analysis of ground-state binding energies, including ^{13}F.

^{13}F Levels

Cross Reference (XREF) Flags

A	$^{9}Be(^{13}O,^{13}F)$

E(level)†	J^{π}	Γ	E_T (MeV)‡	XREF	Comments
x	$(5/2^{+})$	1.01 MeV *27*	7.06 *9*	A	%p=100 Analysis of the invariant-mass spectrum is consistent with sequential proton decay via $^{12}O(0{:}0^{+}_{1}$, 2.2 MeV:2^{+}_{1}, 4.8 MeV:$2^{+}_{2})$ with intensities of 40% *16*, 28% *18* and 32% *16*, respectively.

† The authors suggest the $J^{\pi}=5/2^{+}$ excited state has been observed. The $1/2^{+}$ g.s. is expected ≈3 MeV lower in energy.

‡ ^{10}C+3p Invariant Mass.

^{9}Be(^{13}O,^{13}F) 2021Ch19

2021Ch19: XUNDL dataset compiled by TUNL (2021).

The authors analyzed the excitation spectra of particle-unbound nuclides produced in ^{13}O reactions on a ^{9}Be target. The first observation of a ^{13}F resonance, produced via charge-exchange reactions, was reported.

A beam of 69.5 MeV/nucleon ^{13}O ions, from the NSCL/A1900 fragment separator, was purified in the Radio Frequency Fragment Separator before impinging on a 1 mm thick ^{9}Be target. ^{13}F nuclides were produced and decayed in-flight via $^{13}\mathrm{F}\rightarrow p+^{12}\mathrm{O}\rightarrow 3p+^{10}\mathrm{C}$ reactions. All decay products were detected using the HiRA High-Resolution position sensitive ΔE-E telescope array, which covered the polar angles $\theta_{\mathrm{lab}}=2.1°$ to $12.4°$. The invariant-mass spectrum, E_T, was deduced by analyzing the momenta of the 3p+^{10}C decay products. As in the past study of ^{11}O (2020We08), structures in the excitation spectrum are enhanced by analyzing events where ^{10}C is ejected perpendicular to the beam direction in the ^{13}F center-of-mass system.

The invariant-mass spectrum is dominated by a $\Gamma\approx1$ MeV peak around $E_T\approx7$ MeV that sits on top of a broad smooth background. For perspective, (2012Fo22) predicts a $J^{\pi}=1/2^{+}$ ground state at around $E_T=4$ MeV and a $J^{\pi}=5/2^{+}$ first excited state near $E_T=7$ MeV. No evidence is seen for a lower energy resonance; the authors suggest the lower state may have a broad width that prevents its observation in the present measurement. Comparison with the mirror ^{13}Be nucleus ground state provides ambiguous results for the measured $1/2^{+}$ width, leaving uncertainty on the expectation for ^{13}F.

A Monte Carlo simulation was developed to interpret the observed features, since the level structures of ^{12}O and ^{10}C are convoluted in the spectrum. Involvement of the ^{10}C*(3353 keV) first excited state is generally inconsistent with the observed invariant-mass spectrum so the analysis is limited to final population of $^{10}\mathrm{C}_{\mathrm{g.s.}}$. Hence the analysis focused on branching ratios for sequential decay of a $(5/2^{+})$ ^{13}F resonance through ^{12}O states that subsequently 2p decay via processes described in (2019We11), and the total decay energy was assummed to be carried in the 3p+^{10}C kinetic energies.

Sequential decays via low-lying ^{12}O states are considered in the Monte Carlo simulation. See the text for discussion and comparison of expectations based on the mirror ^{13}Be nucleus. The branching ratios to the $J^{\pi}=0^{+}_{1}$ and 2^{+}_{1} and 2^{+}_{2} ^{12}O states are found as 40% *16*, 28% *18* and 32% *16*, respectively. An alternate and reasonable fit to the data assumed zero contribution from the 2^{+}_{2} state; in this case the relative ratios for the 0^{+}_{1} and 2^{+}_{1} states remained consistent with the initial three-level fit.

^{13}F Levels

E(level)[†]	J^{π}	Γ	E_T (MeV)[‡]	Comments
x	$(5/2^{+})$	1.01 MeV *27*	7.06 *9*	Analysis of the invariant-mass spectrum is consistent with sequential proton decay via ^{12}O(0:0^{+}_{1}, 2.2 MeV:2^{+}_{1}, 4.8 MeV:2^{+}_{2}) with intensities of 40% *16*, 28% *18* and 32% *16*, respectively.

[†] The authors suggest the $J^{\pi}=5/2^{+}$ excited state has been observed. The $1/2^{+}$ g.s. is expected 3 MeV lower in energy.

[‡] Invariant Mass.

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