# $^{11}$B($^{3}$He,p),($^{3}$He,p$\gamma$),($\alpha$,d)

History

| Type | Author | Citation | Literature Cutoff Date |
|---|---|---|---|
| Full Evaluation | J. H. Kelley, C. G. Sheu and J. E. Purcell | NDS 198,1 (2024) | 1-Aug-2024 |

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 $\theta$=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 $\theta$=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 $\theta$=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 $E_\gamma$, p$\gamma$-coin. $^{13}$C deduced levels, level-width, isobaric analog, $\gamma$-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 $\sigma$, $\sigma$(E), $\sigma(\theta)$, $E_\gamma$, $I_\gamma$, 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 $\Gamma_\gamma/\Gamma$=(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, $\pi$. 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($\gamma$), 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,p$\gamma$); measured p$\gamma$-coin.

1975Va19: $^{11}$B($\alpha$,d) E=15-25 MeV.

1977Ma16: $^{11}$B($^{3}$He,p$\gamma$) E=5.3 MeV; measured particle $\gamma$-coin. $^{13}$C levels deduced partial, total $\Gamma$, B($\lambda$).

1975MaXS: $^{11}$B($^{3}$He,p$\gamma$), measured $\gamma$-spectra, proton decays. $^{13}$C deduced levels.

1983Va28: $^{11}$B($\alpha$,d) E=25-30 MeV; measured $\sigma(\theta)$; deduced reaction mechanism, optical model parameters, residual level production $\sigma$. $^{13}$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($\alpha$,d) E=30.1 MeV; analyzed $\sigma(\theta)$; deduced optical model parameters, exchange process role.

## $^{11}$B($^{3}$He,p),($^{3}$He,p$\gamma$),($\alpha$,d) (continued)

### $^{13}$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). |
| 6871 *12* | <10 keV | 1+3 | E(level): From (1959Yo25).<br>Branching ratio of the decay $^{13}$C*(6.87 MeV)→$^{12}C_{g.s.}$+n=0.99 *9* (1973Ad02). See also $\Gamma_n/\Gamma$=1.05 *11* (1969Ad01). |
| 7500 *12* | <5 keV | | E(level): From (1959Yo25).<br>E(level): Unresolved (1958Mo99: $E_x$=7.55 MeV; 1973Wu01).<br>Γ: $\Gamma_\gamma/\Gamma$=0.3% *1* (1971HiZF). |
| 7554 *12* | <5 keV | | E(level): From (1959Yo25).<br>E(level): See also $E_x$=7580 *60* (1957Ga01) and 7550 *40* (1958Mo99).<br>E(level): Unresolved (1973Wu01).<br>Γ: $\Gamma_\gamma/\Gamma$<0.1% (1971HiZF). |
| 7694 *14* | 72 keV *10* | 1+3 | E(level): From (1959Yo25).<br>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).<br>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).<br>Branching ratio of the decay $^{13}$C*(9.989)→$^{12}C_{g.s.}$+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).<br>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)<br>Γ: (1968Co27) measured $\Gamma_{\gamma0}/\Gamma$=0.53% *6*. Using this and $\Gamma_{\gamma0}$(M1)=25 eV *7* from (1967Pe07:$^{13}$C(e,e′)) and $\delta^2$=E2/M1=0.009 *+18−8* (1968Di04: $^{12}$C(p,$\gamma$)) they deduced Γ=4.7 keV.<br>Γ: (1969Ad01) measured $\Gamma_{n0}/\Gamma$=0.065 *14* and $\Gamma_{n1}/\Gamma$=0.250 *36*.<br>Γ: (1973Ad02) measured $\Gamma_{n0}/\Gamma$=0.070 *18*, $\Gamma_{n1}/\Gamma$=0.261 *30* and $\Gamma_{n2}/\Gamma$=0.026 *18*.<br>Γ: (1975Ma21,1977Ma16) measured $\Gamma_{\gamma0}/\Gamma$=0.396% *30* and the relative $\gamma_0$, $\gamma_1$ and $\gamma_{2+3}$ intensities. They combined with $\Gamma_{\gamma0}$(M1)=22.7 eV *27* from (1969Wi22,1970Wi04:$^{13}$C(e,e′)) and $\delta^2$=E2/M1=0.009 *+18−8* (1968Di04: $^{12}$C(p,$\gamma$)) 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 $\Gamma_{\gamma(7.55\ MeV)}$<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).

Continued on next page (footnotes at end of table)

## $^{11}$B($^{3}$He,p),($^{3}$He,p$\gamma$),($\alpha$,d) (continued)

### $^{13}$C Levels (continued)

[&] 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.

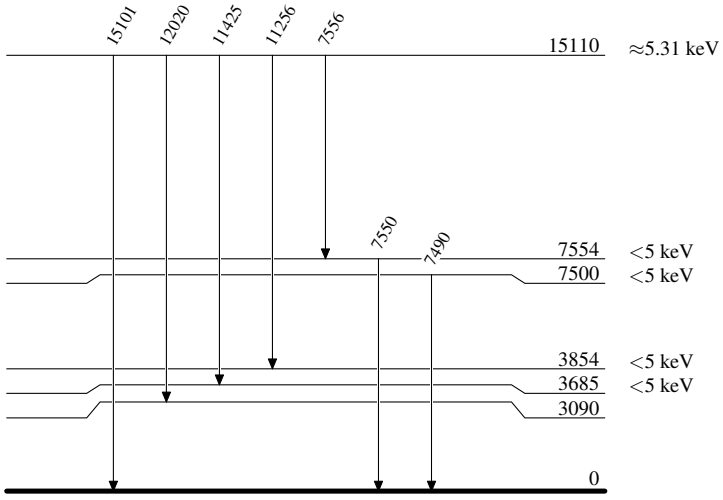
### $\gamma$($^{13}$C)

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

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

## $^{11}$B($^{3}$He,p),($^{3}$He,p$\gamma$),($\alpha$,d)

### Level Scheme




$^{13}_{6}C_{7}$