^{2}H(^{8}He,^{3}He) 2004Go26,2023Ni06

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	K. Setoodehnia, J. H. Kelley, J. E. Purcell	ENSDF	28-September-2023

2004Go26: Deduced that the lower limit for the ^{7}H breakup energy is 50-100 keV above the ^{3}H+4n threshold. They estimated that the lifetime of ^{7}H is τ<1 ns. This limit was deduced based on an upper limit of 3 nb/sr for the ^{7}H production cross section.

2007Te12: Structure in missing mass spectrum includes possible ^{7}H state in 0-3 MeV range. Low statistics only allows for a limit to be placed on the cross section of the d(^{8}He, ^{3}He) reaction near the ^{3}H+4n threshold: cross section is below 0.02 mb/sr in $\theta_{c.m.}=9°-21°$.

2007GoZY: No clear evidence for ^{7}H resonances is seen.

2007FoZY, 2007FoZX, D. Baumel *et al.*, International Symposium on Physics of Unstable Nuclei, ISPUN07, July 2007, Hoi An, Vietnam, ISBN 9789814472487, 2007, pp. 18-25: A 15.3 MeV/nucleon ^{8}He beam is produced, at the GANIL-SPIRAL facility, by fragmentation of a ^{13}C bombarding a thick carbon target. The ^{8}He beam impinged on an isotopically enriched deuterated polypropylene target. The missing mass spectrum of ^{7}H is deduced from kinetic energies and emission angles of the ^{3}He ejectiles detected by the Silicon array MUST. The earlier analysis of these data by (2007FoZY, 2007FoZX) indicated that a broad structure was observed at ~2 MeV above the ^{3}H+4n emission threshold, which was proposed to be the ground state of ^{7}H. Two months later, Baumel *et al*. reported a candidate resonance observed at 1.56 MeV *27* above the ^{3}H+4n mass with a width of Γ=1.74 MeV *72*. These results have not been published in a peer-reviewed journal. Also, unlike more modern measurements, these inclusive ^{2}H(^{8}He,^{3}He) results did not require an exclusive triton coincidence with the ^{3}He reaction products, which would select the correct ^{7}H decay channel (^{3}H+4n). Therefore, these results were excluded from the Adopted Levels of ^{7}H presented in this evaluation.

2010Ni10, 2010NiZT: The missing mass spectrum exhibits a shoulder at around 2 MeV as well as a maximum around 10.5 MeV, relative to the ^{3}H+4n threshold. The maximum at 10.5 MeV could be an indication of a ^{7}H continuum excitation. They estimate the cross section of ~30 μb/sr in the center of mass frame at $\theta_{c.m.}=6°-14°$ for the reaction populating the low energy part of the ^{7}H spectrum.

The above experiments did not show conclusive evidences. The first quantitative results from studying the ^{2}H(^{8}He, ^{3}He) reaction comes from the (2020Be01) measurement.

2020Be01: A 26 MeV/nucleon ^{8}He beam is produced using the ACCULINNA-2 fragment separator at the Flerov Laboratory of Nuclear Reactions (JINR) to study the ^{2}H(^{8}He, ^{3}He)^{7}H reaction. The ^{3}He reaction products and the tritons from the decay of ^{7}H are momentum analyzed by a set of position sensitive ΔE-E-E telescopes covering an angular range of $\theta=8°-26°$, and a position sensitive silicon detector backed by a set of CsI(Tl) crystals coupled to PMTs positioned at $\theta=0°$, respectively. A total of 105 [later changed to 119 in (2021Mu04)] ^{3}He-^{3}H events are measured in coincidence mode.

Analysis of the ^{7}H missing mass spectrum with a 1.1 MeV resolution (FWHM) and two binning factors (events/0.3 MeV and events/1.25 MeV) is performed. The missing mass spectrum with the events/1.25 MeV binning factor shows peaks at (i) E_T=1.8 MeV *5* (5 events) with Γ<300 keV (E_T is energy relative to the ^{3}H+4n threshold), (ii) E_T=6.5 MeV *5* with Γ=2.0 MeV *5* (27 events), and (iii) E_T=12 MeV with Γ=4 MeV. The experimenters interpret the E_T=1.8 MeV peak as the ground state of ^{7}H with an experimental cross section of ~25 μb/sr in the $\theta_{c.m.}=17°-27°$. They consider the peak at E_T=6.5 MeV to be the first excited state of ^{7}H and conclude that this state is either a $J^{\pi}=3/2^{+}$ or $5/2^{+}$ state, or an unresolved doublet encompassing both of these states built upon the 2^{+} excitation of valence neutrons. The average experimental cross section of this state is estimated to be 30 μb/sr over $\theta_{c.m.}=10°-45°$. The authors advise that the peak at E_T=12 MeV could be produced as a result of a rapid decrease in the detection efficiency combined with growing 5-body (from the decay of ^{7}H) phase space effects, which would complicate the spectrum. This study deduced theoretical differential cross sections using FRESCO for a $J^{\pi}=1/2^{+}$ for the ground state and a $J^{\pi}=3/2^{+}$ and $5/2^{+}$ for the first excited state. As a result, spectroscopic factors of ~0.08-0.12 for the ^{7}H ground state and ~1 for the population of the ^{7}H first excited state are deduced. However, due to very low statistics for both states, these results may not be reliable.

2021Mu04, 2023Ni06: These studies have an improved experimental setup in comparison with the (2020Be01) experiment. A beam of 26 MeV/nucleon ^{8}He ions, produced by fragmentation of a ^{11}B primary beam at the FLNR/JINR/ACCULINNA-2 (Dubna) fragment separator, impinged on a windowed gas target filled with 1.13 atm (thick-mode) and 0.56 atm (thin-mode) D_2 gas maintained at 27 K. It was assumed that beam interacted with the target in the middle plane of the target. The detection system was modified to increase angular coverage at lower angles. The ^{3}He reaction products and tritons from the decay of ^{7}H were detected in coincidence (378 events) using 4 ΔE-E-E (last one used as veto) telescopes consisting of single sided silicon strip detectors covering an angular range of $\theta_{lab}=6°-24°$ and a ΔE-E telescope placed at $\theta_{lab}=0°$ consisting of a double sided position sensitive silicon strip detector backed by 16 CsI(Tl) crystals coupled to PMTs, respectively. An array of 48 organic scintillator neutron

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detectors with 12 cm distance between each two were positioned along θ=0°. This array had a 15% efficiency for single neutrons and a 2% efficiency for neutrons in coincidence with charged particles. The resolution of the array was 4.5%. The experimental resolution was deduced using Monte Carlo simulation validated by an independent reference measurement of d(^{10}Be, ^{3}He)^{9}Li using the same setup. This reference measurement was also used to calibrate the ^{7}H missing mass spectrum.

The missing mass spectrum was deduced from momenta of ^{3}H and ^{3}He particles. Eight events were produced from the requirements of ^{3}He+^{3}H+n triple coincidences. The experimenters applied a cut on the data for $\theta_{c.m.}$>18° because angular resolution rapidly degrades at higher angles. Moreover, data at higher angles are more affected by the background. The missing mass spectrum reported in (2023Ni06) shows two clear peaks as well as evidence for a higher energy third peak. These peaks are evident in the spectrum of (2021Mu04). Furthermore, in (2021Mu04), there is evidence of an additional higher energy peak.

The first peak – $^{7}H_{g.s.}$: It exists at E $_{T}$=2.2 MeV *5*, where E_T is decay energy above the ^{3}H+4n threshold. This peak is constructed from 9 events (2 events are from triple ^{3}He-^{3}H-n coincidences) associated to the $^{7}H_{g.s.}$ with a theoretically estimated width (2011Gr13) of Γ≤1 keV. The measured angular distribution is consistent with a one-step FRESCO calculation assuming a J^{π}=1/2^{+} state and an extreme peripheral transfer.

The second and third peaks fitted as one peak: The next region of interest of the missing mass spectrum is the 3.5 ≤ E_T ≤ 9.5 MeV region. If the events in this region are fitted with only one peak, the result would be a peak at E_T=5.7 MeV with a width of Γ=1.5 MeV corresponding to the first excited state of ^{7}H. However, assuming that this state decays via the sequential decay of $^{5}H_{g.s.}$ + 2n, where ^{5}H decays, in turn, via ^{3}H+2n, the 1.5 MeV width of the 5.7 MeV state would be twice as large as the upper limit width of the $^{5}H_{g.s.}$ decay (Grigorenko, unpublished). Therefore, a more reasonable analysis involves fitting two peaks for the events in the 3.5 ≤ E_T ≤ 9.5 MeV region of the missing mass spectrum.

The first and second excited states – the doublet: When fitting 2 peaks under the above region, the first excited state is located at E_T=5.45 MeV *3* (Γ=0.75 MeV). Two of the events from triple ^{3}He-^{3}H-n coincidences contribute to the formation of this state. For the second excited state, two equally reasonable fits were achieved both placing it at E_T=7.6 MeV *3* but with a width of Γ=0.9 MeV or Γ=2.7 MeV. Statistical arguments favor the fit with the smaller width. The authors argue that the states at E_T=5.54 MeV and 7.6 MeV could be the 5/2^{+} and 3/2^{+} observed as an unresolved doublet in (2020Be01). However, they use caution for the state at E_T~7.6 MeV since it could also originate from an asymmetric broad shoulder to the state at E_T~5.45 MeV, or from two broad overlapping states. It should be noted that only 1 ^{3}He-^{3}H-n coincident event contribute to the formation of the second excited state. But the authors point out that the observation of this state does not have reasonable statistical confidence.

Third excited state: Lastly, the final peak in the missing mass spectrum is located at E_T=11.0 MeV *3* and contains 3 ^{3}He-^{3}H-n coincidence events. This state is more prominent at $\theta_{c.m.}$ between 20°–35° but in this region the background is strong. The authors argue that this state may have a structure of a dissolved core (p+6n, where the ^{3}H core disintegrates into p+n+n). A search for decay into p+6n was performed in (2021Mu04) but no evidence was found. The authors deduced cross sections of ~24 μb/sr for $\theta_{c.m.}$=5°–9° and ~7 μb/sr for $\theta_{c.m.}$=15°–19° (both for the ground state); and ~30 μb/sr for $\theta_{c.m.}$=5°–18° and ~11 μb/sr for $\theta_{c.m.}$=18°–30° (both for the first excited state).

^{7}H Levels

E(level)[†]	J^{π}[#]	Γ	E_{res}(^{3}H+4n)(MeV)	Comments
0	(1/2^{+})	<300 keV	2.0 *4*	E_{res}(^{3}H+4n)(MeV): the weighted average between 1.8 MeV *5* (2020Be01) and 2.2 MeV *5* from (2021Mu04). Γ: The theoretical prediction is for Γ≤1 keV (2011Gr13) and Γ≈0.1 MeV (2021Li62). But the observed width in (2021Mu04) is dominated by the experimental resolution, which improves with increasing the decay energy (E_T). Γ<300 keV is from (2020Be01). dσ/dΩ=24 μb/sr between $\theta_{c.m.}$=5°–9° and ~7 μb/sr between $\theta_{c.m.}$=15°–19° from (2021Mu04); and dσ/dΩ~25 μb/sr between $\theta_{c.m.}$=17°–27° from (2020Be01). The spectroscopic factors of ~0.08-0.12 are deduced in (2020Be01) for the ^{7}H ground state. However, due to very low statistics (5 events), these results may not be reliable.
3.4×10^{3}[a] *5*	(5/2^{+})	0.75[‡] MeV	5.45[@] *3*	dσ/dΩ=30 μb/sr between $\theta_{c.m.}$=5°–18° and ~11 μb/sr between $\theta_{c.m.}$=18°–30° from (2021Mu04). Spectroscopic factors of ~1 for the population of the ^{7}H first

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^{7}H Levels (continued)

E(level)[†]	J^{π}[#]	Γ	E_{res}(^{3}H+4n)(MeV)	Comments
				excited state are deduced in (2020Be01). However, due to low statistics, these results may not be reliable. This state is expected (2021Mu04) to decay via $^{5}H_{g.s.}$+2n, where $^{5}H_{g.s.}$, in turn, decays to ^{3}H+2n. So, the decay may be sequential.
5.6×10^{3}?[a] *5*	(3/2^{+})	0.9[‡] MeV	7.6[@] *3*	E(level): the existence of this state is uncertain (2021Mu04, 2023Ni06). Γ: width of Γ=2.7 MeV can also provide a reasonable fit but the statistical arguments made by (2021Mu04) favors Γ=0.9 MeV. Also, there is no mention of Γ=2.7 MeV fit in (2023Ni06).
9.0×10^{3} *5*			11.0[&] *3*	This state may have a structure of dissolved core, where ^{3}H breaks into p+n+n resulting in a p+6n configuration. But no experimental evidence exists.

[†] E_x is deduced using E_{res}(^{3}H+4n)=2.0 MeV *4*.
[‡] From (2021Mu04, 2023Ni06).
[#] From (2020Be01) and (2021Mu04).
[@] From Fig. 15 in (2021Mu04) and Fig. 4 in (2023Ni06).
[&] From (2021Mu04).
[a] These states were unresolved in (2020Be01) and identified at E_T=6.5 MeV *5* with a width of Γ=2.0 MeV *5* and an average cross section of 30 μb/sr over $\theta_{c.m.}$=10°−45°.