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Missing mass spectroscopy of ^{8}He and ^{10}He by (d,^{3}He) reaction

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We present the first missing mass spectrum of the unbound system ^{10}He obtained from one nucleon transfer ^{11}Li(d,^{3}He) reaction at 50 A MeV. We found rather large yields for the 6He+4n decay channel especially for higher excitation energy, which suggest the importance of the ^{6}He+4n structure in 10He.

KEYWORDS: resonance, transfer reaction, nuclear structure

1. Introduction

All studies in which ^{10}He has been populated by proton removal from ^{11}Li and observed in invariant-mass spectroscopy agree that E ∼ 1.2-1.6 MeV [1–4]. Recently, the analysis of the missing-mass spectrum from the transfer reaction ^{8}He(t,p)^{10}He [5] lead to a sizeably higher value, E ∼ 2.1 MeV.

Our experiment, performed in July 2010 at the RIKEN RIPS facility, used a secondary beam of ^{11}Li at 50 AMeV on a CD_2 target. At forward angle, a wall of four MUST2 telescopes [6] were coupled with four 20 μm thick silicon detectors in order to perform an E-ΔE identification of the light particles, and separation of ^{4}He and ^{3}He. At zero degree, a fifth MUST2 telescope and a two stages plastic detector were used for identification of heavy residues of reaction in coincidences. Around 90° an additional MUST2 telescope was used to measure the (d,d) elastic scattering of the beam particles. In addition a ^{9}Li beam at 50 AMeV was used to perform a reference experiment populating the ground state of ^{8}He. The later was correctly reconstructed, validating our experimental technique.

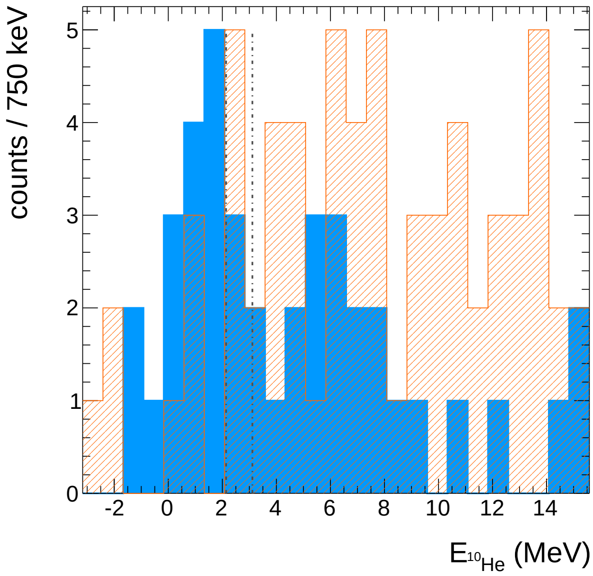

Fig. 1. The ^{10}He spectrum measured from ^{11}Li(d,^{3}He) reaction data in coincidences between ^{3}He and ^{8}He *(solid blue)* and ^{6}He *(dashed orange)*. The two vertical dashed lines indicate the positions of the ^{6}He+4n and ^{4}He+6n thresholds.

The final excitation spectrum of the unbound ^{10}He, reconstructed in coincidence with ^{8}He decay products (Fig.1), exhibits two clean resonances located respectively at 1.3(3) MeV and 6.3(6) MeV above the two neutron threshold, with natural widths of 1.1(6) MeV and 2.7(7) MeV respectively. In addition the spectrum obtained in coincidence with the ^{6}He decay products (Fig.1) is showing a preferred decay to the ^{6}He+4n channel when possible. This could be inferred to the important role played by the ^{8}He(2+) excited state in the ^{10}He structure, arguing for the development of models beyond the three-body approach.

The associate differential cross section has been obtained for the ^{8}He ground state (Fig. 2.a) and the ^{10}He ground state resonance (Fig. 2.b) in coincidence with ^{8}He decay products around zero degrees. Finite-range DWBA calculations were performed using the DWUCK5 code [7]. Parameters for the d+^{9,11}Li potentials (Table I), were adjusted to fit the experimental cross-sections presented in Fig.3.

Nucl.	V	r_V	a_V	W	r_W	a_W	W_D	V_{so}	r_{so}	a_{so}
^{9}Li	90.90	1.189	0.85	4.68	1.28	1.85	3.00	8.96	1.53	0.35
^{11}Li	77.13	0.89	1.22	18.48	1.19	0.97	7.48	8.91	0.80	0.30

Table I. Optical model parameters (defined in Ref. [10]) fitted to reproduce the d+^{9,11}Li data shown in Fig. 3.

The ^{3}He optical potentials were taken from Ref. [8]. The $\langle d|^3\text{He}\rangle$ overlap has been taken from the latest *ab initio* calculations [9]. The overlap functions $\langle ^{11}\text{Li}|^{10}\text{He}\rangle$ were represented by single-particle (s.p.) wave functions obtained in a standard potential model (SPM) with the Woods-Saxon potential of reduced radius $r_0 = 1.25$ fm and diffuseness $a = 0.65$ fm.

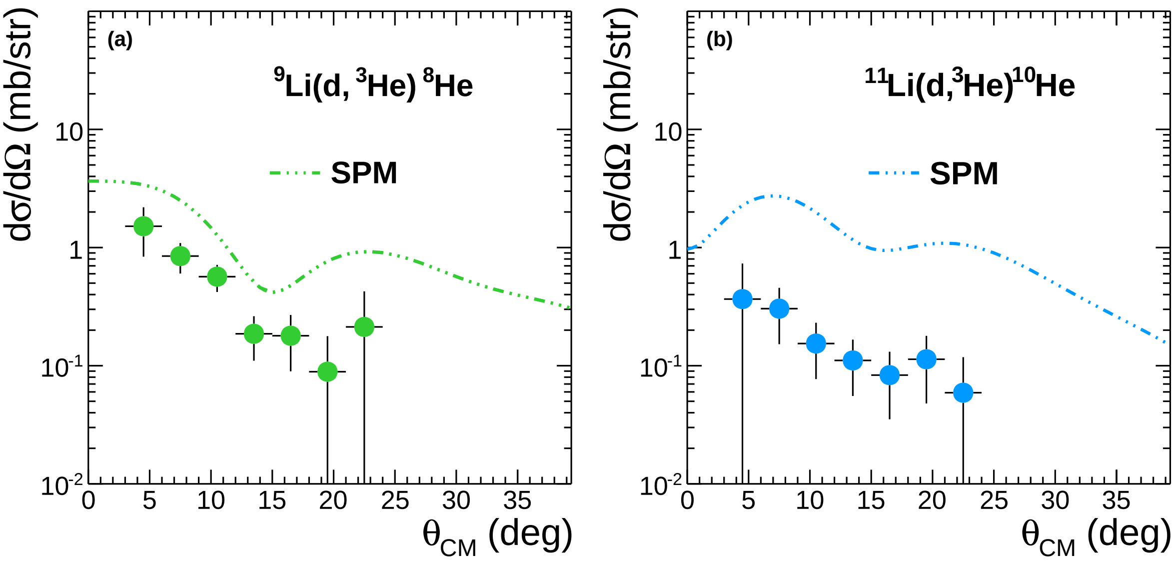

Fig. 2. Experimental differential cross section (solid dot) in coincidence with ^{8}He around zero degree against DWBA calculation using standard potential model (SPM) calculations for (*a*) ^{8}He and (*b*) ^{10}He ground states population.

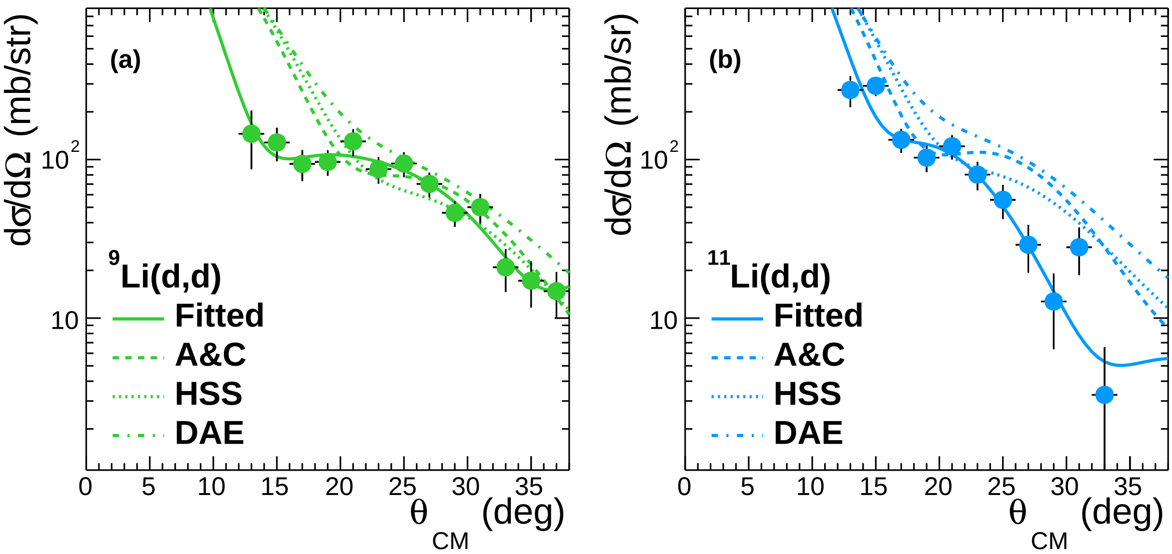

Fig. 3. Measured (*d*,*d*) cross sections from (*a*) ^{9}Li and (*b*) ^{11}Li and their fit by optical model in comparison to predictions of global optical models A&C [11], HSS [12] and DAE [10].

The ^{10}He case is showing the most extreme reduction factor R_s = 0.09(2) ever deduced from (^{3}He,*d*) and (*d*, *p*) reactions for other nuclei [13] but consistent with the systematics of R_s observed in nucleon knockout reactions in [14]. In comparaison, the ^{8}He case exhibit a reduction factor R_s = 0.38(5) close to typical values deduced from transfer reaction.

In conclusion, our experiment correctly reproduce the ground state of ^{8}He and found the ground state resonance of ^{10}He at 1.3(3) MeV above the two neutron emission threshold. In addition a second resonance is observed around 6.3(6) MeV. For the first time differential cross section associate with the ground state are presented and compared with the DWBA calculation. The deduced reduction factor using SPM form factor are the smallest ever rising question on both structure and reaction effect at stake past the neutron drip line.

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