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Structure of ^{7}He studied with the ^{7}Li(d,^{2}He) reaction

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Abstract. A search for the $J^\pi = 1/2^-$ spin-orbit partner of the $J^\pi = 3/2^-$ ground state in ^{7}He has been performed with the ^{7}Li(d,^{2}He) charge-exchange reaction. The results are incompatible with recent claims of such a state at very low excitation energy [Meister M et al 2002 *Phys. Rev. Lett.* **88** 102501] but rather suggest a resonance with parameters $E_x = (1.2^{+0.5}_{-0.4})$ MeV, $\Gamma = (1.9^{+0.8}_{-0.4})$ MeV. GT strengths deduced for the transitions to the lowest states in ^{7}He are in remarkable agreement with ab initio Quantum Monte Carlo calculations.

Information about the structure of the exotic, neutron-rich ^{7}He is scarce. The g.s. of ^{7}He is located at an energy $E_R = 0.445$ MeV above the neutron emission threshold with spin-parity $J^\pi = 3/2^-$ [1]. It is interpreted as the $1p_{3/2}$ single-particle state of the unpaired neutron relative to a ^{6}He core. Excited states at $E_x = 2.9$ MeV with likely $J^\pi = 5/2^-$ [2] and at $E_x = 5.8$ MeV [3] have been established. Recently a controversy arose about the possible observation of the $1/2^-$ spin-orbit partner of the ^{7}He ground state. An investigation of ^{6}He + n correlations after ^{8}He breakup at GSI [4] indicates such a state in ^{7}He at an unusually low excitation energy of $E_\mathrm{x} = 0.57(10)$ MeV with a small width $\Gamma = 0.75(8)$ MeV. A study of isobaric analog states of ^{7}He in the ^{6}He(p,n) compound nucleus reaction at Notre Dame [5] contradicts the finding of Ref. [4] suggesting that a possible $1/2^-$ resonance should lie above $E_\mathrm{x} \simeq 2.2$ MeV (the highest energy accessible in their experiment). However, based on continuum shell-model calculations their conclusion have been questioned by Halderson [6].

The present work, described in detail in [7], provides an alternative access to this important question by utilizing the ^{7}Li(d,^{2}He)^{7}He charge-exchange reaction at zero degrees, where GT transitions are selectively excited. This reaction at intermediate energies has been developed recently as a spectroscopic tool for the study of GT strength distributions [8]. GT transitions populating spin-orbit partners - like the $1p_{3/2}$ and $1p_{1/2}$ states - should have similar strengths. Since the g.s. is sufficiently populated in a charge-exchange reaction [9], a low-lying resonance in ^{7}He with the parameters suggested by Ref. [4] should give a clear signal.

Figure 1(a) displays the low-energy region of the ^{7}He spectrum measured at 0°. A decomposition is performed including the experimentally established resonances (short-dashed lines) and a quasifree background (long-dashed line). The latter is based on the semi-

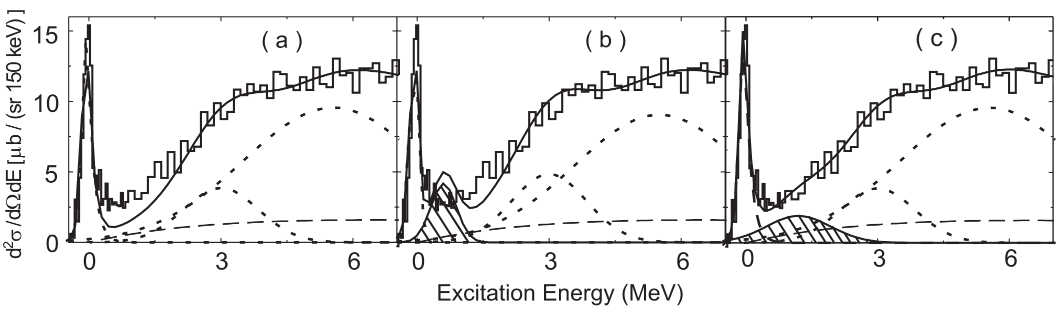

Figure 1. Decomposition of the low-energy region of the ^{7}He excitation spectrum (a) without or (b) with an additional resonance (hatched area) assuming the parameters of Ref. [4], or (c) assuming parameters $E_\mathrm{x} = 1.2$ MeV and $\Gamma = 1.9$ MeV (from [7]).

phenomenological parameterization of Ref. [10]. Its magnitude is constrained by the very good description of this model obtained for a measurement of the ^{6}Li(d,^{2}He)^{6}He reaction under the same kinematics at large scattering angles, where the quasifree cross section dominates. The g.s. and the excitation region above 2.5 MeV are well described. However, in between the data overshoot the fit, indicating the presence of a possible further resonance. Indeed, the necessity for an additional state is not only evident at 0° but also in the other spectra at larger scattering angles. Assuming an additional resonance at low E_x with the parameters of Ref. [4] (hatched area) leads to the poor fit shown in Fig. 1(b). Evidently, such a resonance should be clearly visible in the data. On the other hand, inclusion of an additional resonance with $E_x = 1.2$ MeV and $\Gamma = 1.9$ MeV provides an excellent description of the data, see Fig. 1(c).

Because of the experimental uncertainties of the other resonances [2, 3] included in the decomposition, the centroid energy of such an additional resonance cannot be determined very precisely [7]. The result is $E_x = (1.2^{+0.5}_{-0.4})$ MeV with a corresponding width $\Gamma = (1.9^{+0.8}_{-0.4})$ MeV. It is possible to extract the B(GT) strength of the lowest three states in ^{7}He from the proportionality to the (d,^{2}He) cross section at zero momentum transfer [11]. The resulting B(GT) values are in excellent agreement [7] with ab initio Quantum Monte Carlo calculations [12] using the methods described in [13]. This finding further supports the interpretation of the possible new low-energy resonance as $J^\pi = 1/2^-$ spin-orbit partner of the ^{7}He ground state.

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