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To cite this article: Kolata, J., Goldberg, V., Grigorenko, L., Becchetti Jr, F., Deyoung, P., Hinnefeld, J., Lamm, L., Lupton, J., O'Doonnell, T., Roberts, D., & Shaheen, S. (2003). Final state interaction or a 3H excited state? *Physical Review C*, *68*, 024602. https://doi.org/10.1103/PhysRevC.68.024602

Final state interaction or a ^{3}H excited state?

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(Received 24 April 2003; published 15 August 2003)

An inclusive α-particle spectrum from the ^{1}H(^{6}He,α) reaction has been measured at a ^{6}He laboratory energy of 23.9 MeV. A resonancelike structure is observed at an α-particle lab energy of about 20 MeV, which corresponds to an energy of E_{nd}=0.6 MeV in the n-d channel. An analysis of the spectrum shows that it cannot be explained by the effect of binary final-state interactions. The hypotheses that this structure represents (a) a new excited state of tritium or (b) a three-body final-state interaction are discussed.

DOI: 10.1103/PhysRevC.68.024602 PACS number(s): 25.60.Je, 27.10.+h

I. INTRODUCTION

There have been numerous attempts to identify resonances in the three-nucleon system. All experimental data available up to 1989 are summarized in Refs. [1–3]. According to these reviews, no unambiguous evidence for resonances in the three-nucleon system has been obtained, and only two levels are presently known: the ground states of ^{3}H and ^{3}He. In a few cases where deviation from phase space was observed and interpreted as resonances, there was always ground for skepticism. For example, it was shown that resonant structure found in the ^{3}He(π^-,π^+)3n reaction [4] could be the result of two-particle final-state interactions (FSI) [5].

Recently, resonancelike structure observed in the ^{1}H(^{6}He,α) reaction [6] was interpreted as an excited state of ^{3}H, having a width $\Gamma=0.6\pm0.3$ MeV and an excitation energy of 7.0 ± 0.3 MeV. This energy is 0.8 MeV above the n-d threshold and the state is wide enough to be readily visible in the n-d total reaction cross section, but the existing experimental data [7,8] show no evidence for comparable structure in n-d scattering. Modern theoretical studies of bound and continuum states of the three-nucleon systems have achieved a very high degree of precision (see, e.g., Refs. [9–11]), and are in very good agreement with the experimental scattering data. They show no indication for low-lying states in the N-d continuum (N here denotes a nucleon). However, it was shown in Ref. [12] that low-energy n-d scattering can be interpreted in terms of a virtual state in the vicinity of the n-d threshold, though this work leaves open the question of the observability of such a structure. Another interesting idea was put forward in Ref. [6] and discussed in detail by Barabanov [13]. It was suggested that the existence of a previously unknown excited state of tritium would not be in contradiction with the available experimental data if a very special structure was assumed for this resonance. Specifically, it must primarily consist of a "dineutron" bound to a proton (see Ref. [13] for detailed discussion of properties of such state).

The aim of the present work was twofold. First of all, the importance of the main conclusion of Ref. [6], viz., the existence of an unknown state in one of the best-studied nuclear systems, cannot be overestimated. However, the previous experiment was not without problems and it is desirable to confirm the results with a better experimental setup and over a broader range of excitation energy in ^{3}H. The second question that must be carefully considered is, whether the aspects of the reaction dynamics other than the interaction in the n-d channel can lead to resonancelike behavior. A detailed analysis of this question was not presented in Ref. [6].

The main results of the present work are as follows: (i) the measured spectrum is in good agreement with the results reported in Ref. [6] (there is a peak in the α-particle spectrum corresponding to low energy in the n-d channel); (ii) none of the individual pairwise final-state interactions in the system, except for a hypothetical state in the triton, can describe the experimental data; (iii) the peak can however be qualitatively explained by taking three-body final-state interactions into account, together with the fact that the total energy available for the three particles (α,n,d) in the final state is limited and rather low. The latter explanation, if correct, is of some importance as a novel and unexpected effect of final-state interactions for weakly bound nuclear systems.

II. EXPERIMENT

The experiment was carried out with the *TwinSol* radioactive nuclear beam facility [14] at the University of Notre Dame. The ^{1}H(^{6}He,α) reaction was used, as in Ref. [6]. The experimental setup is illustrated in Fig. 1. A radioactive beam

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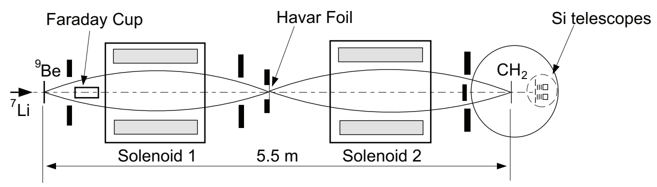

FIG. 1. *TwinSol* experimental setup.

of ^{6}He was produced via a technique similar to that described in more detail in Ref. [15]. A primary ^{7}Li beam with intensity of about 100 electrical nA and energy 35 MeV was incident on a ^{9}Be target of thickness 12 μm. The target was cooled by He gas from one side, and the primary beam was captured in a Faraday cup. Two large superconducting solenoids act as thick lenses to separate ^{6}He from other reaction products and the scattered primary beam. A 5-μm Havar degrader placed at the crossover point between the two solenoids was used to obtain better separation of ions having the same magnetic rigidity but different Z by exploiting differential energy loss. The second solenoid then focused the reaction products into a 5 mm diameter spot on the secondary target. Under these conditions, a ^{6}He beam was obtained with an intensity of 2×10^4 particles per sec, an energy of 26.3 MeV, and an energy spread of 750 keV full width at half maximum. The composition of the secondary beam was ^{6}He: 48%, ^{3}H: 41%, ^{2}H: 6%, ^{4}He: 5%.

To separate ^{6}He events from events associated with ^{4}He and ^{2}H, the primary ^{7}Li beam was bunched. The time between the bunches was 100 ns and the bunch width was 3 ns. A two-dimensional time-of-flight (TOF) spectrum, plotted vs energy deposited in a Si detector placed at the target position, is shown in Fig. 2. The TOF was obtained in reference to the radio-frequency (RF) signal from the buncher. (The intensity of the primary beam was reduced by a factor of 1000 to obtain this spectrum. Note that the Si detector was too thin to stop all but the ^{6}He ions.) As clearly seen, the ^{4}He and ^{2}H events are very well separated in TOF from ^{6}He events. ^{3}H has the same timing as ^{6}He since the Z/A ratio is the same for these two species, but it does not contribute to the ^{4}He spectrum measured in this experiment, as will be discussed below.

A polyethylene (CH_2) target having thickness 11.47 mg/cm^2 was used. The ^{6}He ions deposited 5 MeV in this target, so that their mean energy at its center was 23.9 MeV. A natural carbon target with thickness 15.8 mg/cm^2, which has the same energy loss, was used for background measurements.

Two ΔE-E Si telescopes placed symmetrically at ±5 deg relative to the beam axis were used to detect charged particles coming from the secondary target. To avoid misidentification of ^{6}He as ^{4}He in the ΔE-E telescope (due to statistical fluctuations of energy loss in the ΔE detector), a set of three ΔE detectors was used instead of just one. The thicknesses of the detectors in each telescope were 55, 45, 20, and 1000 μm (in that order). The total solid angle covered by the two telescopes was 4.6×10^{-3} sr.

A spectrum of α particles from the reactions of ^{6}He on the polyethylene target is shown by circles in Fig. 3(a). The

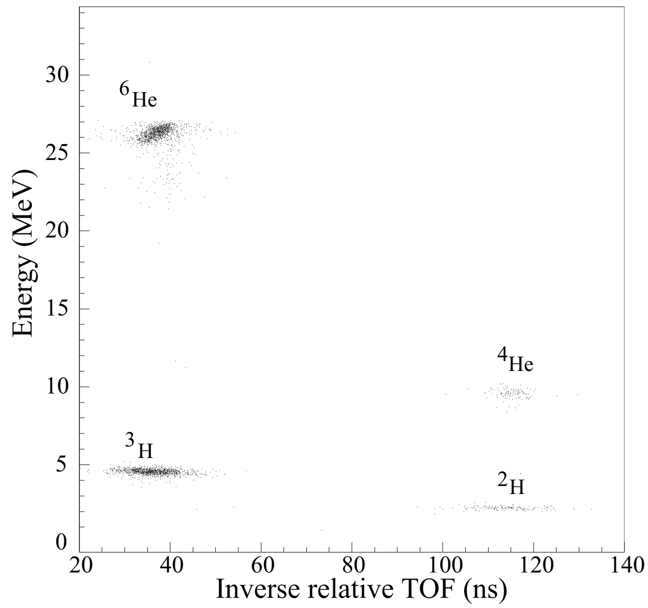

FIG. 2. Composition of the secondary beam, obtained with a Si detector at the secondary target position. The start signal for the TOF measurements was taken from this detector, and the stop signal came from the RF of the buncher.

triangles illustrate the background spectrum measured with the carbon target. It was found that carbon in the polyethylene target is responsible for only 20% (maximum) of the total number of events in the α particle spectrum. As mentioned above, we were unable to separate tritium-induced event from ^{6}He-induced event using the TOF technique. However, if there is any tritium-induced background in the α-particle spectrum, it can only come from $^{12}C(t,\alpha)$. Hence, subtraction of the carbon spectrum from the CH_2 spectrum will eliminate this background, and background from the $^{12}C(^6He,\alpha)$ reaction as well.

A comment should be made on the α-particle spectrum measured with the carbon target. There is a peak in this spec-

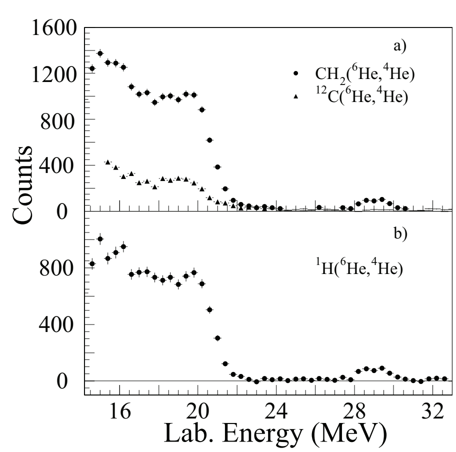

FIG. 3. Energy spectra of α particles from the reactions of ^{6}He on a polyethylene target [(a), circles] and on a carbon target [(a), triangles]. The spectrum obtained after subtraction of the latter from the former (b).

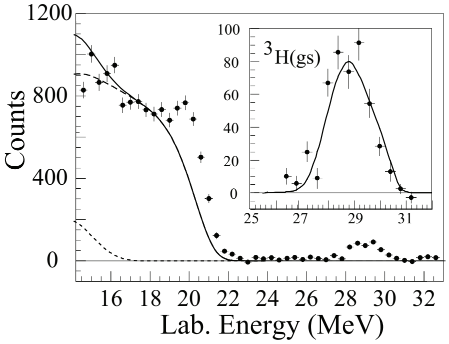

FIG. 4. Three- and four-particle phase space for the ^{1}H(^{6}He,α) reaction, normalized to the experimental data. The inset gives a Monte Carlo prediction for population of the ^{3}H ground state, compared with the experimental data.

trum at an energy of about 19 MeV (see Fig. 3). This peak is a result of the interaction of ^{6}He with ^{12}C, since the α-particle energy from the ^{12}C(t,α) reaction is considerably lower. Several explanations for this peak are possible. The most probable are the ^{12}C(^{6}He,^{5}He) reaction with excitation of the 3.85-MeV ($5/2^+$) level in ^{13}C, and the ^{12}C(^{6}He,α) reaction with excitation of levels in ^{14}C in the vicinity of 10 MeV of excitation energy. A more detailed analysis of the origin of this group is not possible on the basis of the available data.

Figure 3(b), the result of subtraction of the carbon background from the spectrum obtained with the polyethylene target, represents the spectrum of α particles corresponding to the (^{6}He, α) reaction on hydrogen alone. Since the energy losses in the two targets are very closely matched, it was not necessary to make any corrections to the background spectrum prior to subtraction.

III. BINARY FSI ANALYSIS

The peak in the α-particle spectrum at 29 MeV laboratory energy corresponds to population of ^{3}H in its ground state. The differential cross section for this reaction was found to be 10.5 ± 0.8 mb/sr, in agreement with the 14 mb/sr obtained in Ref. [6] (taking into account the lower energy of the ^{6}He beam used in that work). The position and shape of this peak is very well reproduced by a GEANT 3.21 [16] Monte Carlo calculation, which takes into account the geometry of the experimental setup and the known parameters of the incident beam (see inset in Fig. 4). No structure was observed in the energy range between the ^{3}H ground state and 21.0 MeV, which corresponds to the α-n-d threshold. Hence, except for the ground-state population, all the α particles, in Fig. 4, come from the three- and four-body (α-p-n-n) continuum. The comparison of inclusive experimental spectra with theoretical predictions becomes model dependent if more than two particles are present in the final state. Our starting point is the approximation of noninteracting particles, or phase space. Three- and four-particle phase spaces produce very different α-particle spectra, as shown in Fig. 4. The dashed curve corresponds to α-n-d and the dotted curve represents the α-p-n-n phase space (which has its threshold at 17.0 MeV). These curves were obtained using the same Monte Carlo calculation that reproduced the ^{3}H ground state, which ensures that not only the kinematics but also the real conditions of the measurement were fully taken into account. Using this result, we can draw the general conclusion that most of the events belong to the three-particle continuum. The four-particle continuum can contribute significantly only at energies below about 17 MeV. Also, it is evident that the phase-space approximation alone fails to describe the experimental data. The relatively narrow peak at 20 MeV is a clear indication that additional hypotheses have to be introduced. Note that this structure would correspond to a ^{3}H state at 6.8 MeV, in agreement with the 7.0 ± 0.3 MeV reported in Ref. [6]. The width of the observed structure corresponds to the experimental resolution. Thus, only an upper limit could be established for the width of the state in our experiment, which is 1 MeV.

FSI could be responsible for resonancelike structures in the inclusive spectra. Our center-of-momentum (cm) energy is low enough so that we can take into account all the eight open channels having an α particle in the final state to see if any of these can produce a sharp structure in the spectrum at the appropriate energy. Each of these channels is discussed below.

A. The (p,d) reaction

The (p,d) reaction is the main (if not the only) source of "background" α particles at energies above 17 MeV. At the ^{6}He energy of the present experiment, it can lead to the population of ^{5}He in the ground and first-excited states. However, the population of the $1/2^-$ first-excited state can be ignored due to its high 4-MeV excitation energy. This gives a reaction threshold at 3.6-MeV cm, which is above the beam energy at the center of the target (3.4-MeV cm). Also, the very large width of the resonance (4-MeV) is an indication of a weak α-n interaction in the $1/2^-$ channel. Hence, the α-particle spectrum from this process should not be very much different from the three-particle phase space. The ground state of ^{5}He is a relatively sharp $3/2^-$ resonance ($\Gamma=600$ keV) unbound relative to neutron decay by 0.9 MeV. The cross section for the ^{6}He(p,d)^{5}He($3/2^-$) reaction was obtained with the full finite-range, nonlocal coupled-channels (CCBA) method using the code FRESCO [17]. The optical-model parameters (Table I) were taken from Rosario-Garcia and Benenson [18], who studied neutron-induced charged particle reactions on ^{6}Li. The ^{6}He$+p$ elastic-scattering cross section computed with this optical-model potential is very similar to that obtained in a cluster-model microscopic calculation [19]. The result of the CCBA calculation is shown in Fig. 5. The angular distribution of this reaction is forward peaked, and its shape is rather insensitive to variations of the optical-model parameters. However, the absolute yield is very large, which led us to use the CCBA calculation rather than the distorted-wave Born approximation (DWBA). The inclusion of back coupling to the incident channel significantly reduced the magnitude of the angular distribution predicted in the DWBA, without materially affecting its shape.

TABLE I. Optical-model parameters. The same geometry was used for the real and spin-orbit potentials.

System	V_R (MeV)	V_{so} (MeV)	r_R (fm)	a_R (fm)	W_s (MeV)[a]	r_s (fm)	a_s (fm)	r_C (fm)
^{6}He+p	56.0	4.25	1.45	0.35	3.00	2.54	0.10	1.20
^{5}He+d	140.	6.25	1.30	0.80	5.75	1.80	0.31	1.40
^{5}He+n	52.9[b]	6.25	1.25	0.65				
$p+n$	71.8[c]			0.86[d]				

[a]Surface imaginary potential.
[b]Adjusted to obtain the correct neutron binding energy.
[c]Gaussian potential. Adjusted to the correct binding energy.
[d]Standard deviation of the Gaussian.

The neutron-decay angular distribution for ^{5}He was assumed to be isotropic in its cm system. The alignment of ^{5}He, which will influence the angular distribution of its decay, is given by the CCBA calculation. As expected, this calculation predicts the highest degree of alignment for the emission of ^{5}He at zero degrees, because all the orbital angular momenta involved have zero projection on the ^{5}He direction. However, the geometry of the experiment and the angular distribution of the transfer reaction are such that ^{5}He particles emitted at 20 deg in the cm system have the highest probability to be detected. For this angle the alignment is much smaller, resulting in a nearly isotropic distribution for ^{5}He decay.

With these angular distributions and the Monte Carlo simulation that was used above for the ^{3}H ground state, we obtain a spectrum of α particles from the (p,d) reaction (dashed curve in Fig. 6). The predicted (p,d) cross section was renormalized by a factor of 0.88 to obtain agreement with the experimental data at energies above 22 MeV. It is clearly seen that no sharp structures appear as a result of the population of the ^{5}He ground state, so the strong enhancement in the α-particle spectrum at 20 MeV cannot be explained in this way. However, the cross section of the (p,d) reaction is so large that a major part of the observed events must be related to this process.

B. The (p,n) reaction

This charge-exchange reaction populates mainly the ground and 0^+ (3.56 MeV; $T=1$) excited states of ^{6}Li. The cross section for population of the ^{6}Li ground state can be obtained from detailed balance using the ^{6}Li$(n,p)^6$He cross section reported in Ref. [18]. This gives a maximum yield of 25 mb/sr at forward angles, which is a factor of 7 smaller than the cross section for the (p,d) reaction. The same result was obtained in a theoretical calculation by Arai *et al.* [19], who also showed that the ground-state and ^{6}He$(p,n)^6$Li(0^+) transitions have about the same cross section. Neither reaction produces an α particle in the final state, since the 0^+ state can decay only by γ-ray emission due to spin-parity conservation.

Three other excited states of ^{6}Li with isospin $T=0$ can be populated. These are: 2.18 MeV (3^+), 4.31 MeV (2^+), and 5.65 MeV (1^+). However, even if the forward-angle cross section for populating these states would be as high as 25 mb/sr, the maximum cross section for population of the ^{6}Li ground state, the contribution from the (p,n) reaction would still be negligible. The dotted curve in Fig. 6 shows the contribution of the ^{6}Li(3^+) resonance to the α-particle spectrum, assuming that the cross section is 25 mb/sr at zero degrees. Clearly, no sharp structures appear in the vicinity of 20 MeV as a result of population of these states.

There is one more ^{6}Li excited state, the 2^+ state at 5.36 MeV with isospin $T=1$, which is above the three-particle decay threshold and decays to the $\alpha+p+n$ channel due to its isospin. It was verified that the α-particle spectrum from the decay of this state is similar to the four-particle phase-space spectrum. Therefore, it can contribute to the experimental data only at energies below 17 MeV. We conclude that the overall contribution from the charge-exchange reaction is small and can be neglected. Furthermore, the energy spectrum cannot display the sharp structure seen in the data.

C. Inelastic scattering

As we learned from the phase-space analysis, inelastic scattering of ^{6}He populating the 2^+ state at 2.18 MeV can contribute to the α-particle spectrum only at energies below 18 MeV, since this state decays to two neutrons and an α particle. The Monte Carlo calculation shows that, for democratic (uncorrelated) decay of ^{6}He, the α-particle spectrum is very similar to that given by four-particle phase space. However, if we make the assumption that the 2^+ state experiences a correlated "dineutron" decay, then a peak at about 15.5 MeV would appear in the α-particle spectrum. (This type of decay for the ^{6}He first-excited state has been reported by Bochkarev *et al.* [20].) The dot-dashed curve in

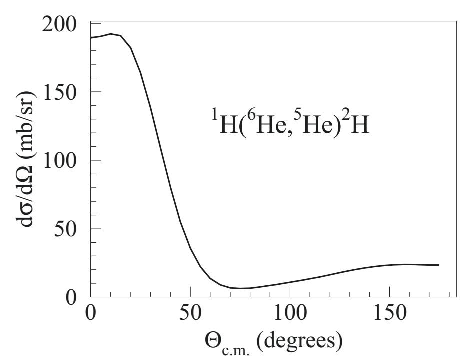

FIG. 5. Differential cross section for the ^{6}He(p,d) reaction obtained from the CCBA calculation.

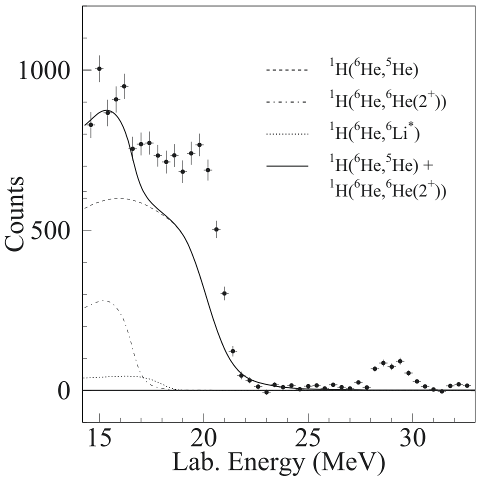

FIG. 6. Description of experimental α-particle spectra by several different processes. The dashed line is the Monte Carlo simulation of the spectrum from decay of the ^{5}He ground state populated in the ^{1}H(^{6}He,^{5}He)^{2}H reaction. The dash-dotted curve is the Monte Carlo simulation of the spectrum from the decay of the ^{6}He(2^+) excited state populated via inelastic scattering. The solid curve is the sum of the former two. The dotted curve shows the maximum possible contribution from the decay of ^{6}Li excited states to the spectrum.

Fig. 6 shows the α-particle spectrum expected from correlated "dineutron" decay of ^{6}He(2^+). Interestingly, there is an indication of a peak in the experimental data at the appropriate energy, and ^{6}He $(2^+)2n$ correlated decay is a strong candidate for this structure.

As is clearly seen from the analysis presented above, we have failed to obtain a satisfactory description of the observed spectrum of α particles from the $p+{}^6$He reaction. The resonancelike structure at 20 MeV cannot be explained by taking into account only the known binary FSI. This structure would correspond to a state at 6.8-MeV excitation energy in ^{3}H*, and it can be described as the population of a resonant state with the properties very similar to those reported in Ref. [6]. However, there may be another explanation for this structure, three-particle FSI, which has so far not been taken into account. It was shown above that the process with the largest cross section by far is ^{6}He(p,d). The residual ^{5}He nucleus is particle unstable and decays with a mean lifetime of 10^{-21} s. In such conditions, it is important to properly consider the effect of three-particle dynamics.

IV. THREE-PARTICLE FSI

Apart from a new resonance in ^{3}H, the reaction mechanisms analyzed in the preceding section cannot provide a low-energy enhancement in the d-n channel. These studies also emphasize the importance of the few-body dynamics in the reaction. A consistent description of the process would require a four-body reaction model for $p+{}^6$He. However, qualitative conclusions can be reached on the basis of a three-body α-d-n model for the composite system ^{7}Li*.

The basic idea is as follows. The comparatively low energy in the $p+{}^6$He channel means that only low J values in

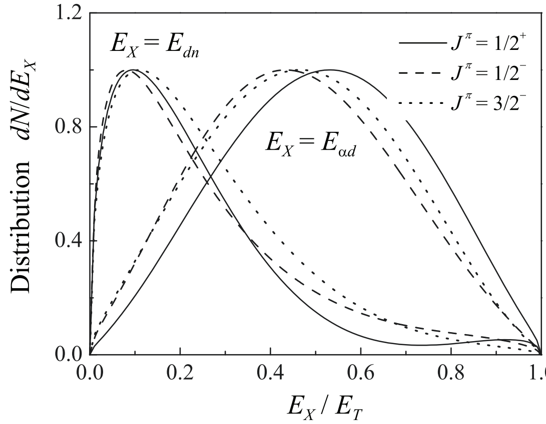

FIG. 7. Spectra of α particles and tritons connected with the isolated amplitude $A^{(3)}$ for $J^\pi = 1/2^+$, $1/2^-$, and $3/2^-$. Here, E_T is the total energy available for the three particles in the final state.

^{7}Li* are important. Assuming $\Delta l = 0,1$ and an s wave in the entrance channel, the corresponding J^π values are $1/2^+$, $1/2^-$, and $3/2^-$. The s-wave pairwise interactions are important for these configurations, and they are repulsive in both the α-d and α-n channels. Under certain conditions, this could lead to "squeezing" of the d-n spectrum to low energies even though the attraction in the d-n channel is not strong. Such hypothetical squeezing would be of importance only if the total energy E_T available for the three particles is quite small (less than 5–10 MeV as shown below). This condition is satisfied in both the current experiment and that of Ref. [6].

It is reasonable to assume that the total amplitude for the reaction above the α-d-n breakup threshold can be described as

$$A = \sum_i A_i^{(2)} + A^{(3)}, \qquad (1)$$

where $i = \{\alpha+d, \alpha+n, d+n\}$ and $A^{(3)}$ is the amplitude that takes into account all the FSI simultaneously. We have seen above that the α spectrum above the α-d-n threshold is dominated by the amplitude $A_{\alpha+n}$ for the ^{5}He $3/2^-$ state. To estimate the amplitude $A^{(3)}$, we use a three-cluster model where the continuum wave function with outgoing asymptotic $\Psi_3^{(+)}$ is obtained by solving the inhomogeneous Schrödinger equation:

$$(\hat{H}_3 - E_3)\Psi_3^{(+)} = \Phi_3^{(source)}. \qquad (2)$$

Here, $\Phi_3^{(source)}$ is a compact Gaussian source. This equation has solutions at any energy E_3 above the α-d-n threshold. The model can provide reasonable qualitative estimates of the decay amplitudes of configurations with *featureless momentum distributions* (due to the Gaussian source) populated in the ^{6}He$+p$ reaction. We assume that configurations with strong momentum correlations can be described by the pairwise amplitudes $A_i^{(2)}$. Qualitatively, Eq. (3) is then obtained as a reduction of the realistic coupled-channels problem:

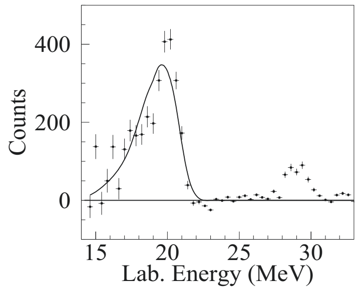

FIG. 8. α-particle spectrum after subtraction of the contribution from the binary FSI (solid line in Fig. 6). Solid curve shows the effect of the three-particle FSI. This curve was obtained based on the calculations for the $J^{\pi}=1/2^{+}$ state of the ^{7}Li* composite system with the realistic *d*-*n* potential.

$$(\hat{H}_3 - E_3)\Psi_3^{(+)} = \hat{V}\Psi_{^6\text{He}-p},$$

$$(\hat{H}_{^6\text{He}-p} - E_{^6\text{He}-p})\Psi_{^6\text{He}-p} = \hat{V}\Psi_3^{(+)}. \qquad (3)$$

The intercluster potentials used in the calculations describe the main features of pairwise scattering for the α-*n* and α-*d* subsystems. For ^{5}He, the interaction is repulsive in the *s*-wave state, and also in the $3/2^{-}$ and $1/2^{-}$ *p*-wave states. For ^{6}Li*, the effect of the ground state is simulated by an *s*-wave repulsion. The *p*-wave interaction is weak and slightly repulsive. There is also a set of low-lying *d*-wave states: 3^{+}, 2^{+}, and 1^{+}. For simplicity, a central single Gaussian potential with radius 2.5 fm is used in the *d*-*n* channel. No real states in ^{7}Li [solutions of the homogenous part of Eq. (2)] are obtained with these potentials in the vicinity of the energy used in this experiment, which is consistent with the known experimental spectrum of ^{7}Li. The calculated decay spectra for all the three low-spin configurations ($J^{\pi}=1/2^{+}$, $1/2^{-}$, $3/2^{-}$) are very similar (see Fig. 7). They feature a low-energy peak in the *d*-*n* channel at about $E_{dn}=0.4$–0.7 MeV, having width $\Gamma=0.8$–1.3 MeV. Together with the two-body amplitudes in Eq. (1), the three-body amplitude corresponding to these spectra describes the spectrum of α particles rather well, as illustrated in the Fig. 8 by solid line. The α-particle spectrum shown in Fig. 8 was obtained by subtracting the binary FSI (solid line in Fig. 6) from the total α spectrum. It is important to note that the three-body spectra do not depend very much on the spin of the configurations populated in the $^{6}\text{He}+p$ reaction.

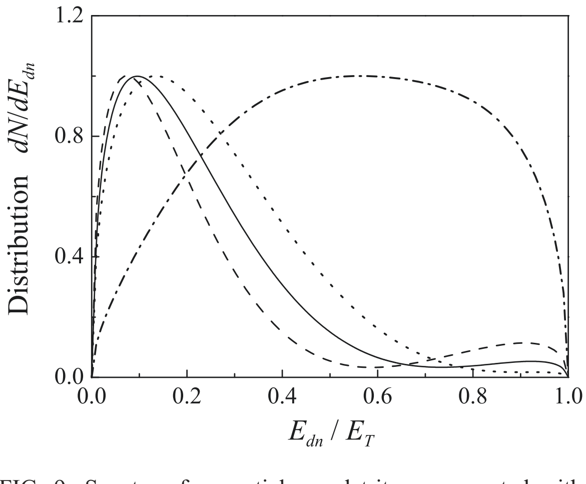

FIG. 9. Spectra of α particles and tritons connected with the isolated amplitude $A^{(3)}$, calculated with different *d*-*n* potentials and for $J^{\pi}=1/2^{+}$. The solid curve is obtained with a realistic depth for the *d*-*n* potential, which gives $\sigma(0.66)=2.2$ b for the *d*-*n* cross section at 0.66 MeV energy. The dashed curve corresponds to a "strong" potential [$\sigma(0.66)\approx 4.5$ b]. The dotted and dash-dotted curves show calculations without any interaction in the *d*-*n* channel, and with strong repulsion ($U_0=40$ MeV), respectively.

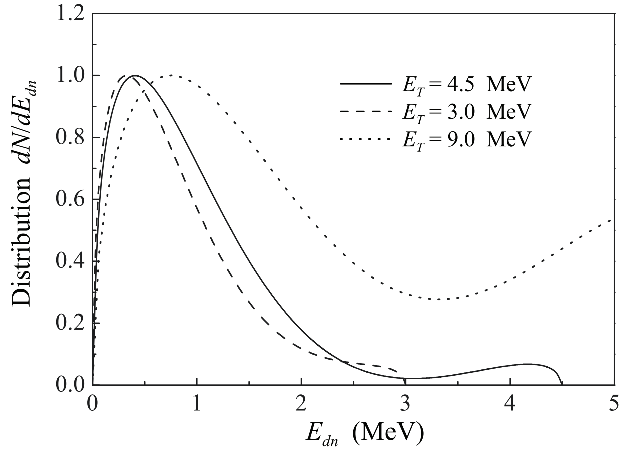

FIG. 10. Spectra of α particles and tritons connected with the isolated amplitude $A^{(3)}$ calculated for different energies E_T above the three-body α-*d*-*n* threshold.

Figure 9 shows that the three-body amplitude also has only minor sensitivity to variation of the interaction in the *d*-*n* channel. If the spectrum is already enhanced at low *d*-*n* energy, there is little change when the *d*-*n* potential is drastically altered. In fact, a broad peak at low energy appears in the *d*-*n* channel even if there is no interaction at all between the deuteron and the neutron, and the only interactions are in the α-*n* and α-*d* channels. This qualitatively confirms the idea that the main features of the spectrum are due to *s*-wave repulsion in the α-*n* and α-*d* channels, and not due to attraction in the *d*-*n* channel. The evolution of the three-body amplitude with total energy is illustrated in Fig. 10. The energy and shape of the *d*-*n* peak are stable for energies $E_T \sim 3--5$ MeV. Then, both the energy and the width rapidly grow, and the peak disappears completely at energies above 10 MeV.

V. CONCLUSION

The ^{1}H(^{6}He,α) reaction has been measured at a ^{6}He laboratory energy of 23.9 MeV. A resonancelike peak is observed at about 20-MeV laboratory α-particle energy, corresponding to an excitation energy of 0.6 MeV in the *n*-*d* channel. These results are in agreement with the work of Aleksandrov *et al.* [6]. This structure could possibly be interpreted [13] as resulting from a previously unknown excited state of ^{3}H having a unique "dineutron" wave function.

Extensive Monte Carlo simulations of the eight reaction channels open at the energy of the present experiment revealed that binary final-state interactions alone are not able to account for this peak, lending some support to the "new excited state" hypothesis. However, we have also put forward an alternative theoretical interpretation of the observed structure in terms of a three-body final-state interaction. This mechanism is something new and can be characterized as an "anti-FSI": the possibility that peaks in the missing-mass spectrum may not be due to strong FSI in one of the subsystems, rather due to repulsion in the remaining subsystems coupled with a limited total phase space. If the peak in the α spectrum corresponding to low energy in the *d-n* channel is really connected with a limited total energy above the three-body breakup threshold, then an increase in the reaction energy should gradually dissolve the effect. The theoretical considerations above are qualitative at the moment. More extensive studies are required to make a final decision about the existence of the anti-FSI phenomenon.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Antonio Moro and Dr. Ian Thompson for enlightening discussions regarding the code FRESCO. This work was supported by the National Science Foundation under Grant Nos. PHY99-01133, PHY98-04869, PHY00-72314, PHY98-70262, and PHY02-030099. One of us (L.V.G.) acknowledges the support under Russian Federation Grant Nos. RFBR 00-15-96590 and 02-02-16174.

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