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THE $J^{\pi}=1/2^{+}$, T=1/2 LEVEL IN THE ^{5}He AND ^{5}Li MIRROR NUCLEI

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ABSTRACT - Despite the fact that the shell-model predicts a $J^{\pi}=1/2^{+}$, T=1/2 state for both ^{5}Li and ^{5}He there is no experimental evidence for this last nucleus . All this is probably due to a very low formation cross-section and to a large width of the above state. Since the analogous in the ^{5}Li mirror nucleus is a broad level the ^{5}He$(1/2^{+},1/2)$ state should decay through $\alpha + n$ or $t + d$ in the relative S state.

The knowledge of the low-lying level spectroscopic parameters in light nuclei constitutes the most remarkable test for the validity of the nuclear model. Therefore a precise determination of the excitation energy and width of the above states from the experimental data is very important.

Actually the shell-model calculation, in the case of the A=5 systems, predicts a $J^\pi=1/2^+$, T=1/2 state for both ^{5}He and ^{5}Li nuclei at an excitation energy of about 18 MeV$^{1)}$. On the contrary all scattering or reaction experiments performed to populate the ^{5}He nucleus show no evidence for the above state$^{2)}$.

The existence of the $(1/2^+,1/2)$ ^{5}Li level is instead invoked to interpret the results of α-p scattering$^{3)}$, ^{3}He(d,p)^{4}He, ^{2}H(^{3}H,γ)^{5}Li and ^{6}Li(^{3}He,αp)^{4}He reactions$^{4\text{-}6)}$. The present situation is summarized in Table I : the experimental data coming from the α-p, ^{3}He+d and ^{2}H+^{3}He reactions show a certain evidence of the $(1/2^+,1/2)$ ^{5}Li level but no measure of the E_x and Γ spectroscopic parameters of the above state was furnished$^{3\text{-}5)}$. The αα spectra

Table I. Evidence of the $J^\pi=1/2^+,T=1/2$ ^{5}Li level: experimental results and shell model prediction.

Reaction or scattering	E_{inc}(MeV)	Results	Ref.
$\alpha - p$	$25 \div 29$	Evidence of the $1/2^+$ ^{5}Li level	3
^{3}He(d,p)^{4}He	$2.8 \div 11.5$		4
^{2}H(^{3}He,γ)^{5}Li	$2 \div 26$		5
^{6}Li(^{3}He,αp)^{4}He	11, 13, 14	$E_x=(17.9 \pm 0.4)$ MeV $\Gamma = (3.5 \pm 0.8)$ MeV	6
Theoretical prediction:		$J^\pi=1/2^+$, T=1/2 E_x=18.4 MeV	1
Current literature:		$E_x=(18 \pm 1)$MeV *broad width*	2

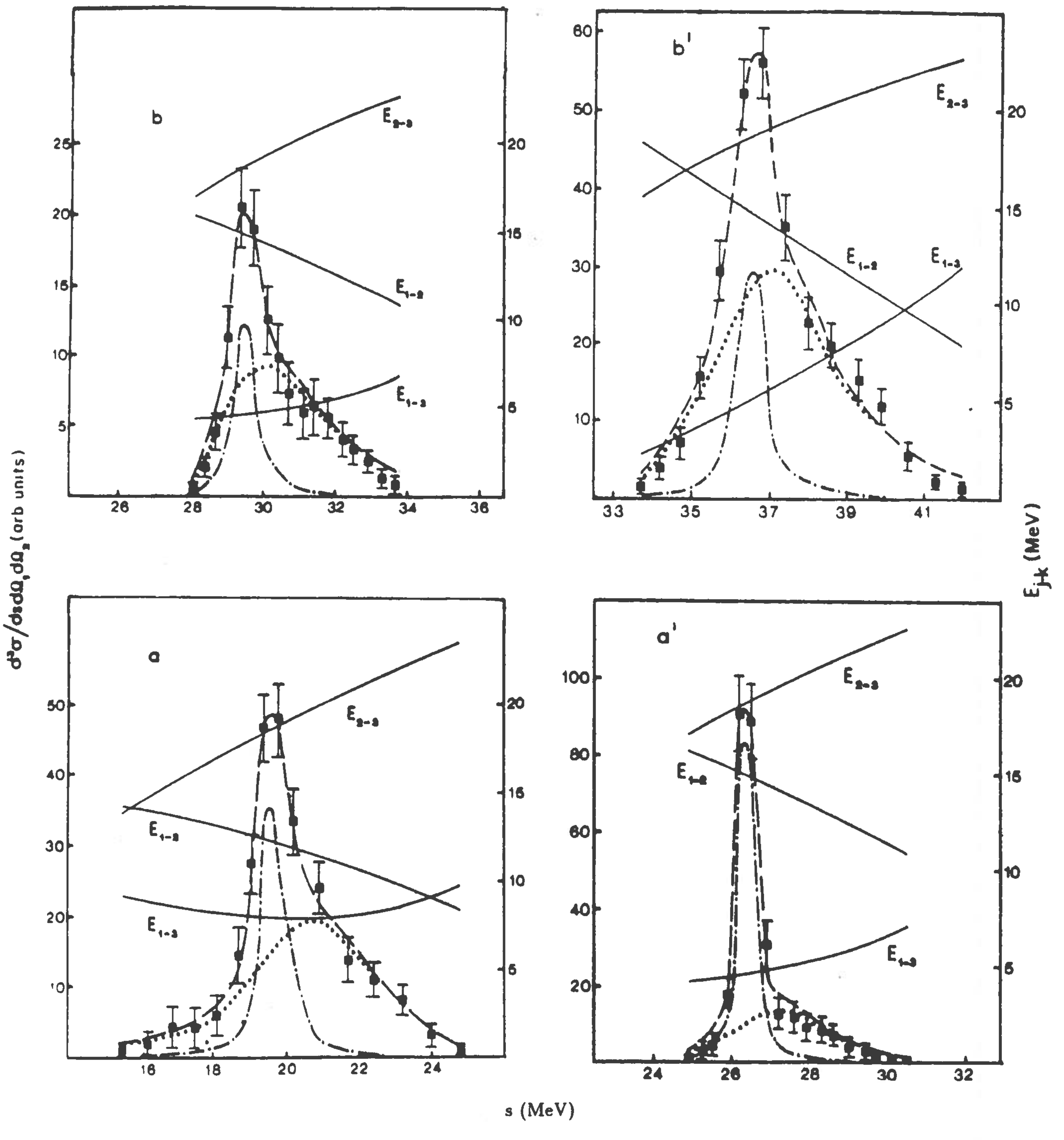

Fig. 1 — Distribution of the $\alpha\alpha$ coincidences along the rectified central kinematical curve versus arclenght s for the ^{6}Li(^{3}He,αp)^{4}He reaction at θ_2=90° and (a) E(^{3}He)=13 MeV, θ_1=20°; (b) E(^{3}He)=13 MeV, θ_1=30°; (a') E(^{3}He)=14 MeV, θ_1=30°; (b') E(^{3}He)=14 MeV, θ_1=50°. The E_{1-2} curve refers to the relative energy of the $\alpha\alpha$ system while the E_{1-3} and E_{2-3} ones refer to the αp system. The dotted line represents the $(1/2^+,1/2)$ ^{5}Li contribution, the dashed-dotted line represent the contribution of the 16.66 MeV ^{5}Li state, the dashed one is the sum of these contributions.

(Fig.1) coming from the ^{6}Li(^{3}He,αp)^{4}He experiment, performed by some of us and others at various incident energies and detector geometries, provides for the above level the excitation energy and the first quantitative estimate of the width$^{6)}$.

As one can observe, the E_x values, as predicted by Bevelacqua$^{1)}$ and deduced by us$^{6)}$, are in line with the one adopted by Ajzenberg-Selove$^{2)}$.

For the $(1/2^+,1/2)$ ^{5}He level, only the shell-model predictions (E_x=18.0 MeV) appear in literature. We believe that the production of the above $1/2^+$state in a three-body reaction might possibly be somewhat favourable than in a two-body process. In this way a kinematically complete, rather than incomplete, experiment can be used in order to reduce the background contributed by:

i) other states of the ^{5}He nucleus;

ii) particles coming from the decay of other nuclei produced in competing reaction channels;

iii) the statistical three-body break-up.

The analysis of the α-particle spectra obtained by the ^{7}Li(d,α)^{5}He reaction carried out at E(d)=24 MeV shows in fact no evidence of the above $1/2^+$ ^{5}He state. This contribution is probably obscured by the presence of a strong background$^{7)}$.

Recently some of us *et al.*$^{8)}$ studied the ^{7}Li(d,αn)^{4}He reaction, using a 7 MeV deuteron beam coming from the Van de Graaf CN machine of the National Laboratories of Legnaro (Padova). The $\alpha\alpha$ bidimensional spectra, deduced at various θ_1 and θ_2 polar angles, did not provide sure evidence of the above ^{5}He excited state. This state of affairs can be explained by assuming that for the $(1/2^+, 1/2)$ ^{5}He state:

a) the formation cross-section is very low;

b) the probable large width makes the experimental investigations relatively difficult.

Now, since the ^{5}He state at $E_x \simeq 18$ MeV has spin 1/2 and positive parity, we could expect contributions from three possible bifragmented structures: $\alpha+n$ in the relative S state and $t+d$ in the relative S or D state. If the Γ $(1/2^+$ ^{5}He) width is expected to be large, as for the analog state in the ^{5}Li mirror nucleus[6)], the S-state hypothesis could be favoured. On the contrary in the case of the D-state hypothesis the centrifugal barrier should delay the $t+d$ decay with consequent narrowing of the width of our concern.

With this situation it is necessary to carry out new kinematically complete experiments of the $a + A \rightarrow b + {}^5$He kind. In this way the following ^{5}He $(1/2^+)$ decay in $\alpha+n$ or $t+d$ or both the above channels will allow us to obtain bidimensional spectra between the b spectator particle and another particle coming from the ^{5}He decay.

In our ^{7}Li(d,αn)^{4}He experiment[8)] the spectator is the first emitted α-particle and we studied the $\alpha\alpha$ coincidence spectra between the above α particle and the one coming from the ^{5}He $(1/2^+)$ decay. If the above decay occurs in the $t+d$ fragments (in the relative S or D state) it is necessary to obtain αt or αd or both coincidence spectra besides to evaluating the angular distribution in order to get information on the l-value in which the resonance mainly occurs. Therefore, in the case of this reaction, it is proper to perform a kinematically complete experiment at an incident energy enough to populate the above ^{5}He state to obtain $\alpha\alpha$ or αn and αt or αd coincidence spectra.

Other reactions leading to three bodies in the final state (n+^{6}Li → d+^{5}He; d+^{6}Li → ^{3}He+^{5}He; γ+^{7}Li → d+^{5}He; n+^{7}Li → t+^{5}He; p+^{7}Li → ^{3}He+^{5}He) could be performed to populate the ^{5}He state with an excitation energy of about 18 MeV. Now, while the d+^{7}Li → α+^{5}He reaction has a Q-value of 14.23 MeV, the above five reactions have Q-values below 1 MeV or quite negative. In these cases, higher incident energies are required and, consequently, processes in competition could arise with the probable result of obscuring the contribution of our interest making the extraction of the spectroscopic parameters more difficult.

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