# Possible $E_x \approx 18$ MeV state in $^7$Li

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The inclusive $\alpha$ spectra from the reaction $^9$Be(d,$\alpha$) have been measured at $E_d = 50$ MeV. The spectra were analyzed with a combination of phase space distributions and resonances. The result of the analysis suggests the evidence for a broad level in $^7$Li at $E_x \sim 18$ MeV. The position and width correspond to the analog state found in $^7$Be at $\sim 17$ MeV excitation.

Despite the large efforts in the determination of the levels in light nuclei, the situation is far from satisfactory, especially in cases of levels with large widths. In the present work we have investigated the existence of the isobaric analog of the $\frac{1}{2}^-$ state in $^7$Be found in phase shift analyses of elastic $^3$He-$\alpha$ (Refs. 1 and 2) at $E_x \sim 16.7$ MeV with a width of 6.5 MeV. In the case of $^7$Li similar data for t-$\alpha$ scattering do not exist, and therefore the evidence for the existence of the state in question relies solely on the results of the excitation function for the ($\gamma$, n) reaction.[3] In Ref. 1 the level was tentatively indicated, but in the latest compilation[4] it was erased from the scheme. The success achieved in describing the inclusive spectra of light particles as a combination of resonances and of statistical breakups[5] has induced us to examine inclusive $\alpha$ spectra of the reaction $^9$Be(d,$\alpha$) in the search for the level at $\sim 17$ MeV excitation.

The experiment was performed using the 50 MeV d beam from the isochronous cyclotron JULIC. The target was a 2.7 mg/cm$^2$ foil of beryllium. The alpha particles were detected by a $\Delta E$-$E$ telescope placed inside a one meter scattering chamber. The $\Delta E$ counter was a commercial Si surface barrier detector 400 $\mu$m thick. A side entry 31 mm thick Ge(Li) detector mounted in a separate cryostat[7] served as an $E$ counter. Coincident signals from the $\Delta E$ and $E$ counters of each telescope were fed separately, via standard electronics, into an ND 6660 multichannel analyzer where particle identification was performed and energy spectra for various outgoing charged particle types were produced. The measurements were taken in the angular range 7–30 deg.

The analysis was performed using a linear combination of the $\alpha\alpha$t, $\alpha$d $^5$He, and $\alpha\alpha$dn phase space distributions including in the fits the resonances at $E_x = 4.63$, 6.68, 7.46, 9.67, and 9.85 MeV with the widths quoted in Ref. 4. The transition to the 11.24 MeV $T = \frac{3}{2}$ state was not observed, a result consistent with isospin conservation. The procedure used is the same as previously applied in the analysis of inclusive spectra (Refs. 5 and 6, and references therein). The only difference from the earlier analysis is the inclusion of one additional component which stems from the decay of $^5$He "particles" emitted in the $\alpha_1$d $^5$He($\alpha_2$+n) breakup. In Fig. 1 we show the result of a Monte Carlo simulation that exhibits separately the $\alpha_1$ spectrum (from $^9$Be+d$\rightarrow\alpha_1$+d+$^5$He) and the $\alpha_2$ spectrum [from $^9$Be+d$\rightarrow\alpha_1$+d+$^5$He($\alpha_2$+n)] at 15 deg. The simulation was made under the assumption of isotropic angular distribution for the $^5$He decay. The fitting procedure was made in two steps. At the start we included in the fit the allowed phase spaces and the known resonances ($E_x < 10$ MeV). This procedure yielded a satisfactory fit only for the spectrum at 7° [Fig. 2(a)]. At larger angles no fit in the excitation range 12–22 MeV could be attained by the above method. Figures 2(b)–2(f) illustrate that in this region of excitation the phase space contribution (solid line) along cannot account for the experimental spectrum in the spectra at 15°, 20°, and 23°. Therefore the introduction of one or more resonances in this region is the only way to achieve a fit to the experimental data. Under the assumption that this departure is from the analog of the 16.8 MeV state in $^7$Be, we introduced one state in the fitting procedure. The best fit was achieved (dashed curves in Figs. 2) for $E_x = 18 \pm 1$ MeV and $\Gamma = 5 \pm 1$ MeV.

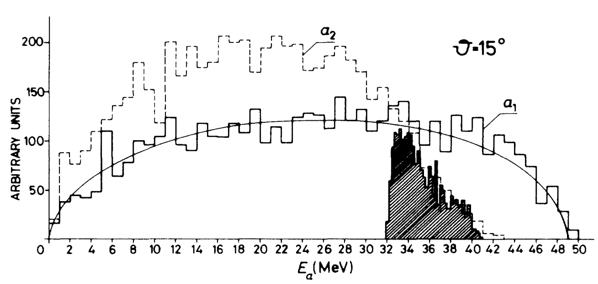


FIG. 1. Monte Carlo simulation of the energy spectrum of $\alpha_1$ particles emitted in the $\alpha_1$d $^5$He simultaneous breakup (solid histogram) and $\alpha_2$ particles emitted in sequential $\alpha_1$d $^5$He ($\alpha_2$+n) breakup (dashed histogram). The solid line represents the analytical three-body $\alpha_1$d $^5$He phase space distribution. The shaded area represents the contribution of the $\alpha_2$ particles in the experimental spectrum described in the text.

 

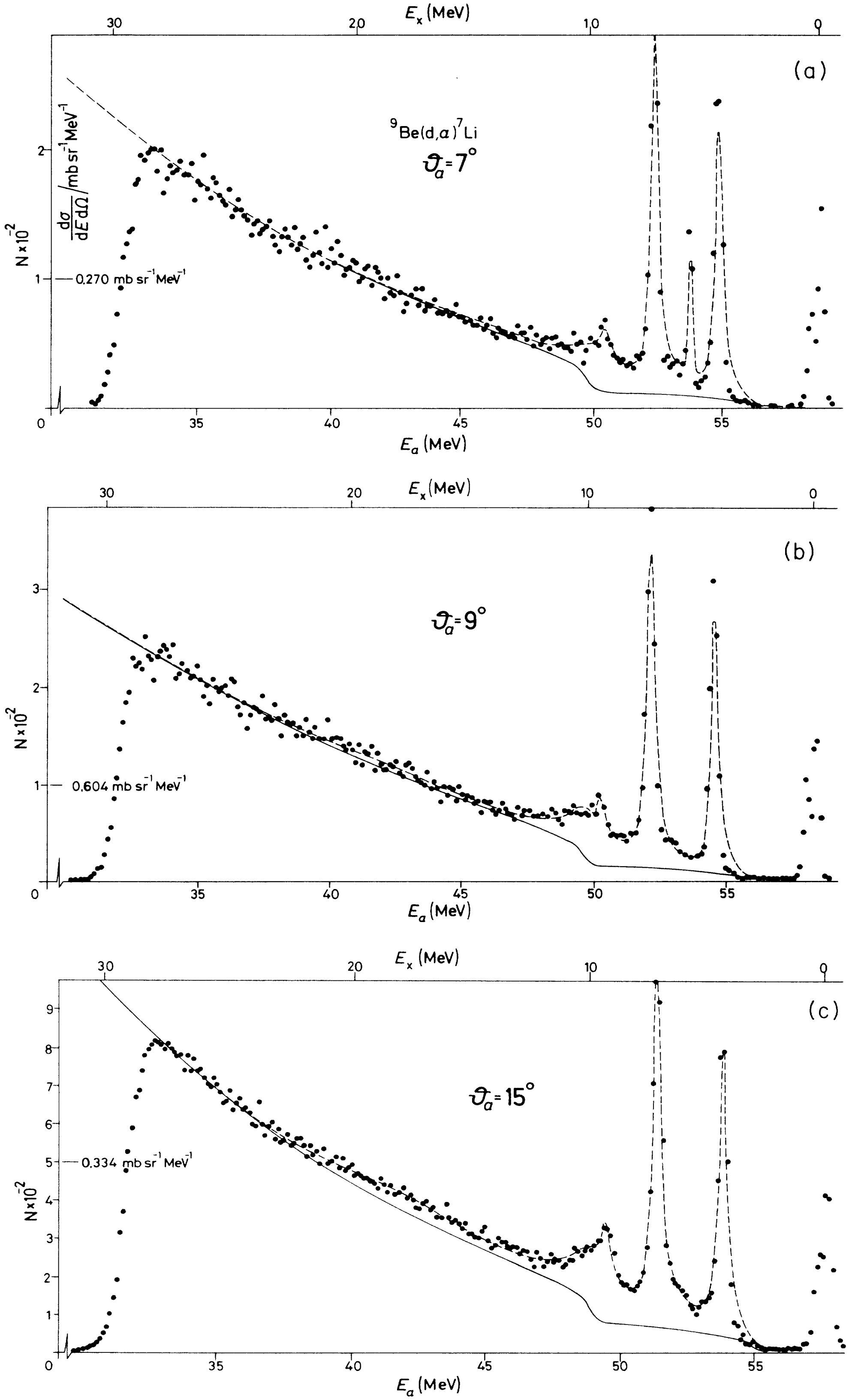


FIG. 2. (a)–(f) The total experimental spectra at 7, 9, 15, 20, 23, and 30 deg. The solid and dashed lines represent fits obtained with (a) a combination of phase space distributions (including the $\alpha_2$ component belonging to the $^5$He decay) and (b) the complete fit obtained including the contributions of the resonances at 4.63, 6.68, 7.46, 9.67, 9.85, and 18 MeV, respectively.

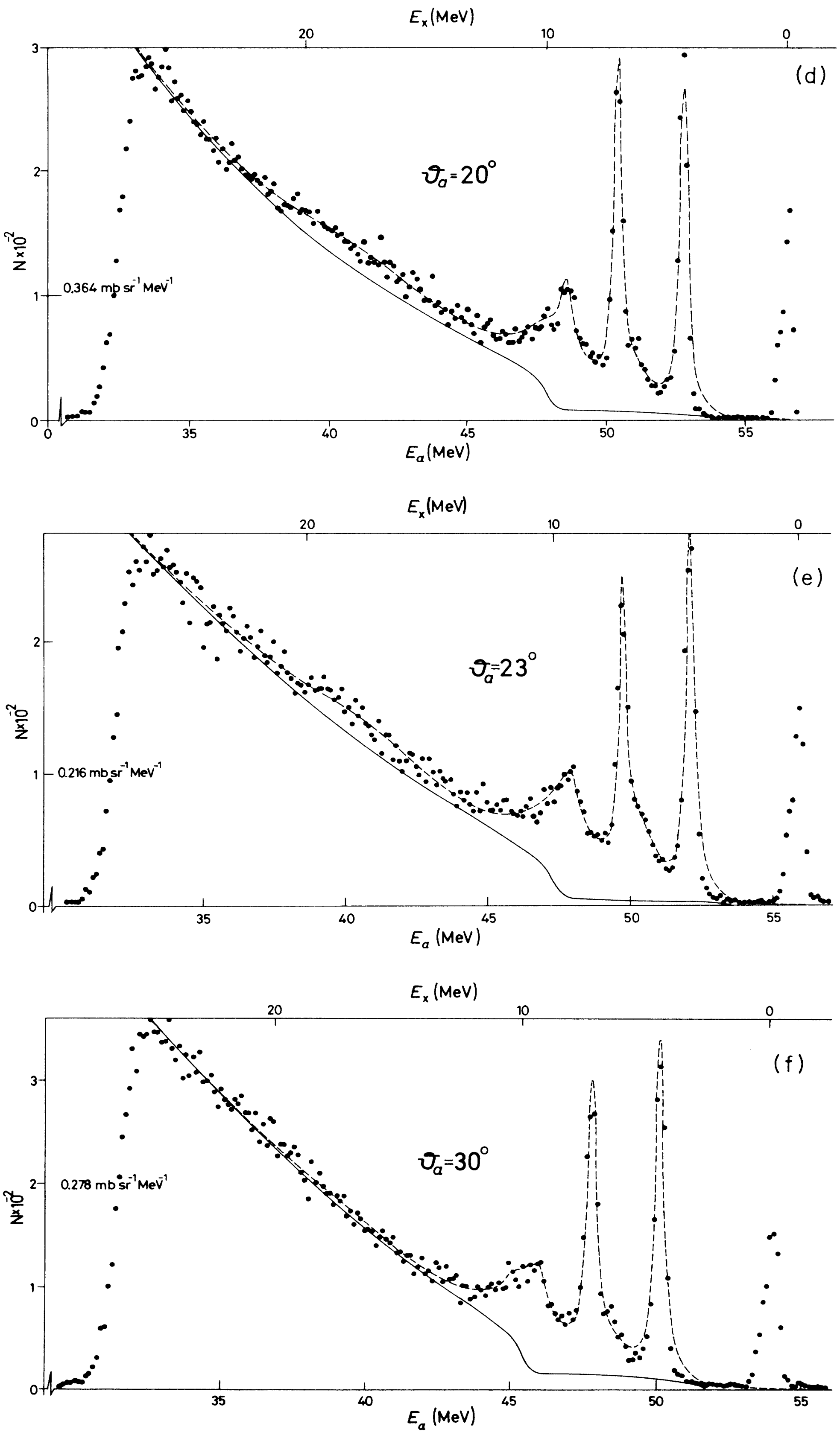


FIG. 2. (*Continued*).

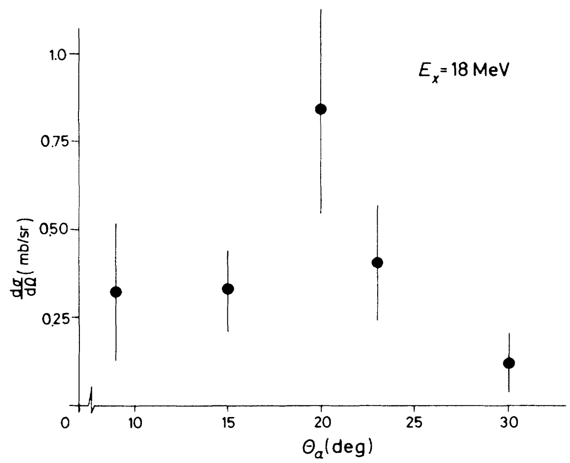


FIG. 3. The differential cross section for the 18 MeV excitation level at the measured angles.

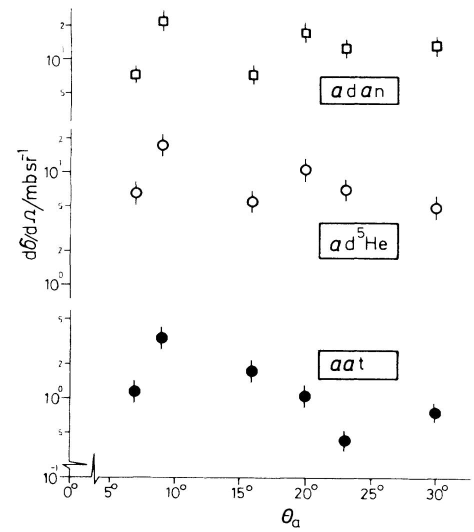


FIG. 4. The differential cross section of the $\alpha\alpha$t, $\alpha$d $^5$He, and $\alpha\alpha$dn phase space distributions.

In Figs. 2 the contribution of the Monte Carlo simulation for the $\alpha_2$ component of the $^5$He decay has been smoothed out for the sake of presentation.

The differential cross sections extracted for the 18 MeV level are shown in Fig. 3. In Fig. 4 are shown the differential cross sections for $\alpha\alpha$t, $\alpha$d $^5$He, and $\alpha\alpha$nd simultaneous breakups.

The contribution of the $\alpha_2$ component at each angle is approximately equal to the contribution of the $\alpha_1$ particles from the $\alpha_1$d $^5$He breakup. This result is illustrated in Fig. 1 by a good fit of the calculated $\alpha_2$ spectrum to the histogram representing the experimental $\alpha_2$ particle spectrum (shaded area), which is obtained by the subtraction of the $\alpha\alpha$t, $\alpha$d $^5$He, $\alpha\alpha$dn, and resonant contribution, from the total experimental spectrum.

We conclude that the present analysis enhances the already existing evidence stemming from ($\gamma$,n) data (Ref. 3) for a broad level in $^7$Li at $E_x \sim 18$ MeV. The position and width correspond to the analog state found in $^7$Be at $\sim 17$ MeV. To our knowledge this is the first observation of that state in particle-induced reactions excepting the data for the $^7$Li(n,n′) reaction,[8] which have never been subsequently published.


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