ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Catania

INFN/BE-80/10
30 Novembre 1980

N. Arena, Seb. Cavallaro, V. D'Amico, G. Fazio, G. Giardina and F. Mezzanares: ON THE $^{13}D_1$ ^6Li STATE AT ABOUT 5.7 MeV EXCITATION ENERGY.

Servizio Documentazione
dei Laboratori Nazionali di Frascati

Istituto Nazionale di Fisica Nucleare
Sezione di Catania

INFN/BE-80/10
30 Novembre 1980

ON THE $^{13}D_1$ ^{6}Li STATE AT ABOUT 5.7 MeV EXCITATION ENERGY (x)

N. Arena and Seb. Cavallaro
Istituto di Fisica dell'Università di Catania,
INFN, Sezione di Catania, and
Centro Siciliano di Fisica Nucleare e di Struttura della Materia, Catania

V. D'Amico, G. Fazio, G. Giardina and F. Mezzanares
Istituto di Fisica dell'Università di Messina,
INFN, Sezione di Catania, Gruppo di Messina

ABSTRACT.

The α-d bidimensional spectra for the ^{7}Li(^{3}He, $\alpha\alpha$d) reaction at $E_{^3He}$ = 5 MeV and at various detection angles have been measured. The peak corresponding to an α-d relative energy of about 5.7 MeV, found in the spectra, has been analyzed. By taking this peak to be mainly contributed by the $^{13}D_1$ ^{6}Li state at 5.7 MeV, an estimate of the excitation energy and width of this state is given.

The existence of a ^{6}Li state with $J^\pi = 1^+$, T = 0 at an excitation energy of about 5.7 MeV, spectroscopically indicated with the notation $^{13}D_1$, has been evidenced by the phase shifts analysis of the d-^{4}He elastic scattering(1-3). However, if one excludes the Allen's experiment(4), the contribution of this state is not clearly discernible in any one of the particle spectra measured in the kinematically incomplete experiments carried out on the ^{7}Li (^{3}He, $\alpha\alpha$d) and ^{6}Li(p, pαd) reactions(5, 6), which produce the ^{6}Li nucleus as a result of the α-d interaction in the final state. In fact, due to the large background and the high yield peak from the 5.37 MeV ^{6}Li state, the contribution of the $^{13}D_1$ state is obscured in the above mentioned spectra.

(x) This work was supported in part by INFN, CRRN and CSFN/SM.

Although the low T = 0 admisture in the 5.37 MeV state forbids the decay of this state in the α-d channel, the $^{13}D_1$ state contribution is not clearly seen even in the α-d or p-α spectra measured in the kinematically complete experiments performed on the same reactions(7-10). Thus while some authors only mention the $^{13}D_1$ state contribution as a shoulder in their spectra, others do not mention it at all. The most explicit outline of the above state is found in the work of Von Witsch et al.(9). Although the $^{13}D_1$ state contribution is not evident enough even in their spectra, these authors give an estimate of its excitation energy and width.

In order to attempt to evince the contribution of this state at the best we decided to perform a systematic study of the $^7Li(^3He, \alpha\alpha d)$ reaction. We began by measuring the α-d bidimensional spectra with the two detectors arranged in the ordinary left-right geometry and by using a ^3He bombarding energy of 5 MeV, an energy where no kinematically complete experiment has been performed on the $^7Li(^3He, \alpha\alpha d)$ reaction until now.

The Fig. 1 shows the used experimental apparatus. The 5 MeV ^3He beam was produced by the 7.5 MV Van de Graaff accelerator of the Legnaro National Laboratories. The ^7Li target, obtained by evaporating LiF (99.9 % enriched in ^7Li) onto a carbon backing of 40 $\mu g/cm^2$, was 0.5 mg/cm^2 thick. The detector 1, fixed at $\theta_1 = 90^o$ and $\phi_1 = 0^o$, was a telescope consisting of a totally depleted solid state detector ΔE 100 μm thick and a surface barrier solid state detector E 1000 μm thick; the ΔE detector, while stopping the α-particles, let the deuterons pass. This prevented the α-α events detection and has simplified the data analysis. The surface barrier solid state detector 2 was allowed to rotate between $\theta_2 = 10^o$ and $\theta_2 = 170^o$ at $\phi_2 = 180^o$ and its 300 μm thick depletion region stopped all the α-particles produced in the reaction. In order to measure correctly the deuterons energy and at the same time to reduce the effects of energy straggling suffered by the deuterons in ΔE detector, the pulses produced in ΔE and E detectors were summed by the Σ circuit. A triple fast-slow 30 ns resolving time coincidence circuit was set up to gate a 4096 channels analyzer and a remarkable reduction of the random coincidences was obtained in the bidimensional spectra measured.

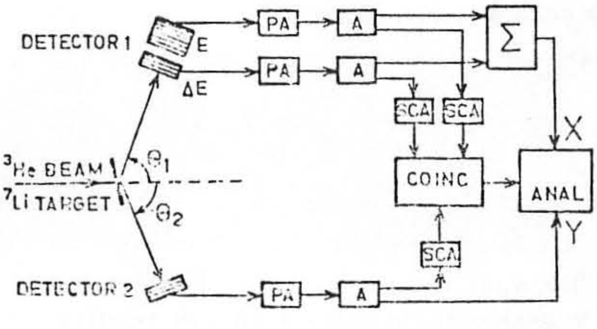

FIG. 1 - Sketch showing the experimental apparatus.

We observed in several of these spectra, in addition to two well-defined events groups corresponding to the formation of the ^8Be at the ground state and at its first excitated state, a third one which kinematically could be contributed by the α-d final state interaction in the ^6Li states at excitation energies between 5 and 6 MeV. Because, as it was said before, the isospin forbids the decay of the 5.37 MeV ^6Li state into the α-d channel, and our search for contaminations which eventually could contribute gave a negative result, we thought the above third group to be attributable to the 5.7 MeV $^{13}D_1$ ^6Li state indicated by the phase shifts of the d-^4He elastic scattering. Thus we decided to analyse the measured spectra.

The most suitable way of treatment of a bidimensional spectrum data is to project them on an axis or a curve of the E_1-E_2 plane. There are different reasons which indicate that the central kinematical curve (the one corresponding to the angles defined by the beam direction and detectors axes) is a good choice as a projection locus. In fact both the finite angular and energetic resolutions of the detecting system contribute to the spreading of the events on the E_1-E_2 plane. Therefore if the true distribution of events has to be extracted from the projected data, before projecting them, the geometrical effects have to be separated from the energetic ones.

Obviously this is not needed when the angular resolution is good with respect to the energetic one. In such a case all the events can be considered as belonging to the central kinematical curve and it is correct enough to project all of them on such a curve. This condition is best satisfied in our experiment at $\theta_1 = 90^o$ and $\theta_2 = 45^o$ detector angles. To perform the projection of the data we used the method developed by some of us et al.(11). By assuming that the finite overall energetic resolution of the detecting system produces a lorentian spreading, the method, while projecting the data, automatically operates a sort of deconvolution on them. Thus it produces a distribution of the events on the kinematical curve which should be a good approximation to the true one.

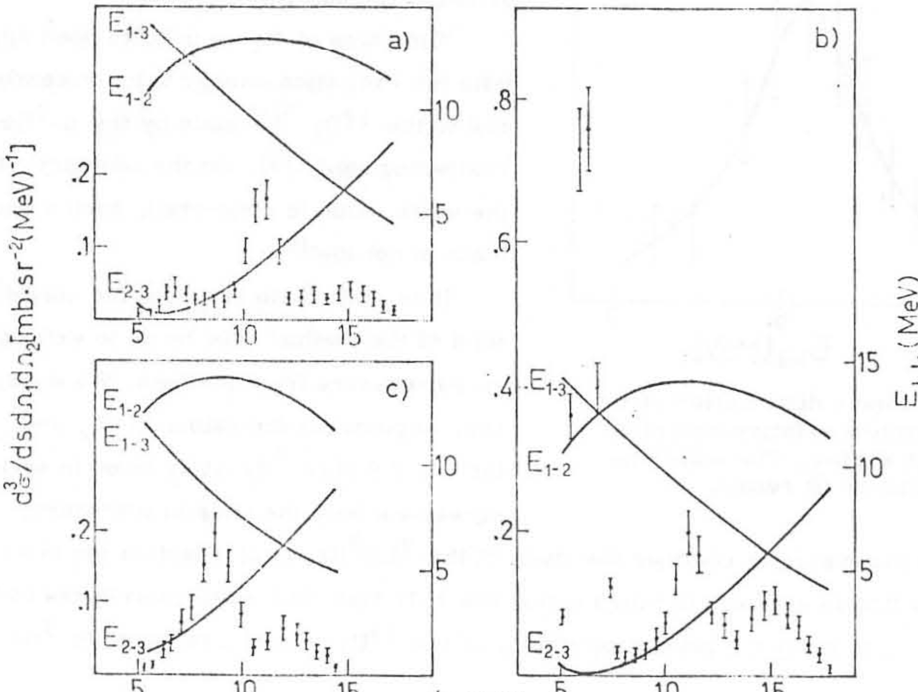

FIG. 2 - Distribution of counts along the kinematic curves at various angles for the $^7Li(^3He, \alpha\alpha d)$ reaction at $E_{^3He} = 5$ MeV : a) $\theta_1 = 90^o$, $\theta_2 = 40^o$; b) $\theta_1 = 90^o$, $\theta_2 = 45^o$; c) $\theta_1 = 90^o$, $\theta_2 = 80^o$. The curve E_{2-3} refers to the α-α system relative energy and the curves E_{1-2} and E_{1-3} refer to the d-α system relative energy. s is the arc lenght of the rectified kinematic curve.

Fig. 2 shows the results of the projection of the laboratory system data from the $\theta_1 = 90^o$, $\theta_2 = 40^o$, 45^o, 80^o experiments, after target energy loss corrections have been done. As one can see, in addition to two well-defined maxima due to ground state and 2.9 MeV state in ^8Be, in all of the projected spectra appears a well-resolved peak which at the maximum corresponds to a relative energy for the α-d system of about 5.7 MeV. In order to extract the above peak maximum energy position and width, which should correspond to the excitation energy and width of the 1^3D_1 ^6Li state within the limits in which the peak is attributable to this ^6Li state, we reduced the data from $\theta_1 = 90^o$ and $\theta_2 = 45^o$ experiment in the Relative Coordinate System (RCS). We fitted them separately with two Breit-Wigner distributions by using the least-squares method. The first fit was done on the data between 2 and 3 MeV α-α relative energy and gave for the excitation energy and width of the 2.9 MeV ^8Be state respectively the values $E_x = 2.85 \pm 0.2$ MeV and $\Gamma = 1.46 \pm 0.3$ MeV. The second one was done on the data between 4 and 8 MeV d-α relative energy, i.e. on the data which correspond to the peak that is of our interest.

Fig. 3 reports the above last data in the RCS. The continuous curve represents the Breit-Wigner fit. This fit gave for the maximum energy position and width of the peak the values $E_x = 5.7 \pm 0.2$ MeV and $\Gamma = 1.65 \pm 0.3$ MeV respectively. The errors take into account both the statistical errors and the finite energy resolution of the analysing system.

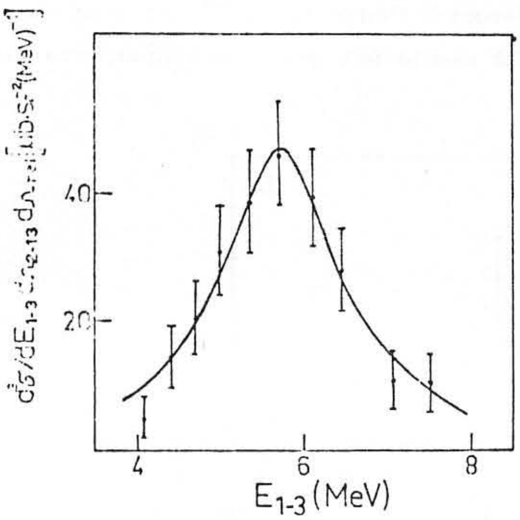

FIG. 3 - RCS counts distribution referring to d-α system relative energies between 4 and 8 MeV. The solid line is the Breit-Wigner fit result.

The value of E_x is in quite good agreement with the excitation energy value recently assigned to the 1^3D_1 ^6Li state by the d-^4He elastic scattering study[12]. On the contrary, as far as the width value is concerned, such a good agreement is not met[9].

It is difficult to estimate the confidence limits of the method used by us to extract the above parameters from the data. We wish, however, to point out the values of E_x and Γ found for the 2.9 MeV ^8Be state to be in satisfactory agreement with the ones in literature.

We think it necessary to continue the study of the $^7Li(^3He, \alpha\alpha d)$ reaction for two reasons. The first one is that to evaluate to which extent the 5.37 MeV ^6Li state contributes to the peak. The second one is to study the population change of the 1^3D_1 state by varying the ^3He bombarding energy.

REFERENCES.

(1) - L. C. McIntyre and W. Haeberly, Nuclear Phys. A91, 382 (1967).

(2) - P. A. Schmelzbach, W. Grüebler, V. König and P. Marmier, Nuclear Phys. A184, 193 (1972).

(3) - R. A. Hardekopf, W. Grüebler, B. Jenny, V. König, R. Risler, H. R. Bürgi and J. Nurzynski, Nuclear Phys. A287, 237 (1977).

(4) - K. W. Allen, E. Almqvist and C. B. Bigham, Proc. Phys. Soc. 75, 913 (1960).

(5) - C. L. Cocke, Nuclear Phys. A110, 321 (1968).

(6) - I. Link, R. Bilwes, L. Kraus, R. Seltz and D. Magnac-Valette, J. de Phys. 30, 17 (1969).

(7) - C. L. Cocke and J. C. Adloff, Nuclear Phys. A172, 417 (1971).

(8) - K. H. Bray, J. M. Cameron, H. W. Fearing, D. R. Gill and H. S. Sherif, Phys. Rev. C8, 881 (1973).

(9) - W. Von Witsch, G. S. Mutchler and D. Miljanic, Nuclear Phys. A248, 485 (1975).

(10) - H. Schwartz and C. M. Fou, J. of Phys. G1, L57 (1975).

(11) - V. D'Amico, S. Jannelli, F. Mezzanares and R. Potenza, Nuovo Cimento A15, 723 (1973).

(12) - F. Ajzenberg-Selove, Nuclear Phys. A320, 1 (1979).