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THE $J^{\pi} = 2^{+}$ AND 0^{+}, $T = 0$ ^{8}Be LEVELS AT ABOUT $E_x = 20$ MeV

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The ^{7}Li (d, $\alpha\alpha$) n reaction induced by deuterons of an incident energy of 7 MeV has been used to excite the ^{8}Be nucleus in the region of excitation energy E_x of about 20 MeV. Each of the obtained $\alpha\alpha$ coincidence spectra was fitted by an incoherent sum of the $J^{\pi} = 2^{+}$ and 0^{+}, $T = 0$ ^{8}Be levels at $E_x = 20.1$ and 20.2 MeV, respectively. The results show that the experimental data are well fitted when the Γ values deduced for these levels are 0.90 and 0.70 MeV, respectively.

1. Introduction

In a recent work[1] an appropriate choice of the beam energy and detector geometry allowed us to observe the ^{8}Be excitation energy region around 20 MeV by the ^{7}Li (d, $\alpha\alpha$) n reaction. In fact, the analysis of the $\alpha\alpha$ bidimensional spectra obtained by the above reaction at 7 MeV deuteron incident energy shows the $J^{\pi} = 2^{+}$ and 0^{+}, $T = 0$ ^{8}Be contributions at $E_x = 20.1$ and 20.2 MeV, respectively. The width values deduced[1] for the two ^{8}Be states are (0.85 ± 0.25) MeV and (0.75 ± 0.25) MeV for the 2^{+} and 0^{+} states, respectively.

These results represent the first quantitative estimate of the width of the two ^{8}Be states. Therefore, it is necessary to perform new experiments leading to the formation of both even-spin positive-parity states in the ^{8}Be excitation energy region around 20 MeV, extended the research range and improving the analysis conditions of the above-mentioned work.

In the ^{7}Li (d, $\alpha\alpha$) n experiment, performed by Arena et al.[1], the choice of 7 MeV incident energy and of detection geometries allowed us to obtain, for kinematic reasons, the $\alpha\alpha$ bidimensional spectra free from the 16.76 MeV ^{5}He state and from the contributions of ground, 3.04 and 11.4 MeV ^{8}Be states. Moreover, for dynamical reasons, the contributions of the first excited ^{5}He state were absent, while the ground state ones of the same nucleus were present at such a low level (4—5%) that no correction to the data was necessary for them. Thus the $\alpha\alpha$ coincidences region of interest can be populated by the ^{8}Be levels that fall in the E_x regions close to 17 and 20 MeV. The above mentioned ^{8}Be levels decay also in the α-channel.

Now, bearing this in mind, we analyzed the $\alpha\alpha$ bidimensional spectra coming from the ^{7}Li (d, $\alpha\alpha$) n reaction at a beam incident energy of 7 MeV in the detector configurations that populate: i) both the 17 and 20 MeV excitation energy regions; ii) the 17 MeV E_x region only. At lower deuteron incident energies it is not possible to excite the two above 2^{+} and 0^{+} ^{8}Be levels; at higher incident energies the high spin (4^{+}) ^{8}Be state at 19.86 MeV excitation energy — with a (700 $\pm$ 100) keV width[2] — can be excited and entirely populate the kinematical region of our concern. Furthermore, in the above experiment the $\alpha\alpha$ spectra were obtained by using a thinner ^{7}Li target to improve the energy resolution.

2. *Experimental details*

The ^{7}Li (d, $\alpha\alpha$) n experiment was carried out at the Van de Graaf CN accelerator of the National Laboratories in Legnaro (Padova). The intensity of the 7 MeV deuteron beam current (about 80 nA) was measured by a Faraday cup charge integrator. The target was made by evaporating LiF (enriched to 99.9% in ^{7}Li), until the thickness of 100 μg/cm^{2} was reached.

The experimental apparatus was the same as the one shown in a previous work[3]. Now, in order to perform kinematically complete measurements, the $\alpha\alpha$ coincidence spectra are obtained by two solid state detectors (100 μm thick) placed at ϑ_1 and ϑ_2 angles on the opposite sides with respect to the beam direction. The different detector configurations were chosen in the order to allow formation of the two $J^{\pi} = 2^{+}$ and 0^{+}, $T = 0$ ^{8}Be levels at $E_x = 20.1$ and 20.2 MeV, respectively, by the ^{7}Li (d, $\alpha\alpha$) n reaction. We measured the energy of the two α particles and the time-of-flight difference by means of a standard electronic set-up. The energy of each event was corrected for the loss in the target and spurious coincidences were suppressed by the time window of 10 ns selected off-line.

The true events were projected onto the central kinematical curve (the one corresponding — in the E_1, E_2 plane — to the ϑ_1 and ϑ_2 angles defined by the beam direction and detector axes) by standard tecniques[4]. In such a way one easily takes into account the effects coming from the finite geometry and energy resolution of the detectors.

3. *Results and discussion*

Fig. 1 shows the $\alpha\alpha$ coincidence distribution versus the curvilinear abscissa s — representing the arclength of the rectified kinematical curve — at $\vartheta_1 = 82°$ and $\vartheta_2 = 80°$. Owing to the identity of the detector particles (α particles), in our spectra any contributions due to a resonant state are present in two peaks. Each of these peaks is contributed by the unresolved ^{8}Be levels at $E_x = 16.6$ and 16.9 MeV (see E_{1-2} curve representing the relative energy of the $\alpha\alpha$ system), while the spectrum is free from the $^5\mathrm{He}_{g.s.}$ contributions (see E_{1-3} and E_{2-3} curves representing the relative energy of the αn system when the ^{5}He decay α-particle, in coincidence with the other α-particle emitted at the first step of the reaction, is

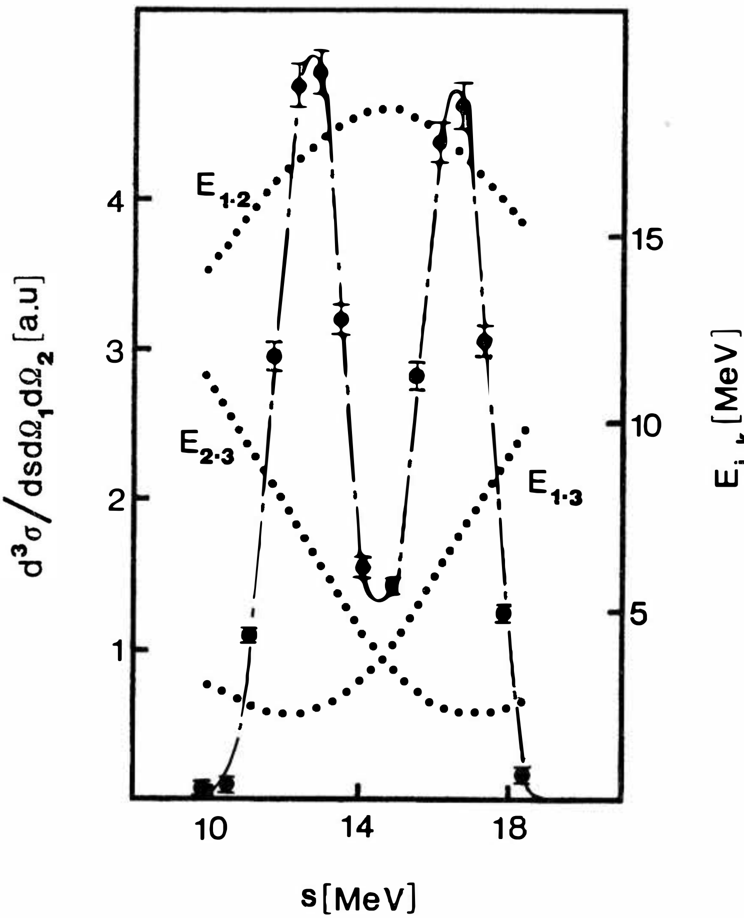

Fig. 1. Distribution of the $\alpha\alpha$ coincidences along the rectified central kinematical curve versus curvilinear abscissa s for the ^{7}Li (d, $\alpha\alpha$) n reaction at $E_d = 7$ MeV, $\vartheta_1 = 82°$ and $\vartheta_2 = 80°$. For the meaning of the dotted lines labelled with E_{1-2}, E_{1-3} and E_{2-3}, see text. Dash-dotted line is a guide to the eye.

detected at the angles ϑ_1 and ϑ_2, respectively). Here the error bars represent only the statistical error.

Figs. 2 and 3 show the $\alpha\alpha$ coincidence spectra at $\vartheta_1 = 82°$, $\vartheta_2 = 62°$ and 76°, respectively. As one can see, in both the spectra three well separated peaks appear. The two lateral peaks can clearly be attributed to the formation of the ^{8}Be states at excitation energies of about 17 MeV (see E_{1-2} curve). Analogously, the central can be attributed to the formation of ^{8}Be at E_x of about 20 MeV.

Now, if we rule out the 19.86 MeV ^{8}Be state formation because of the 4^+ high spin of this state and the relatively low incident energy, the ^{8}Be states which can decay into the 2α channel are the 16.6, 16.9, 20.1 and 20.2 MeV ones. However, the two lateral peaks are populated by the 16.6 and 16.9 MeV ^{8}Be levels, while the central peak is mainly populated by the two above ^{8}Be levels in the 20 MeV E_x region (the unresolved 20.1 and 20.2 MeV).

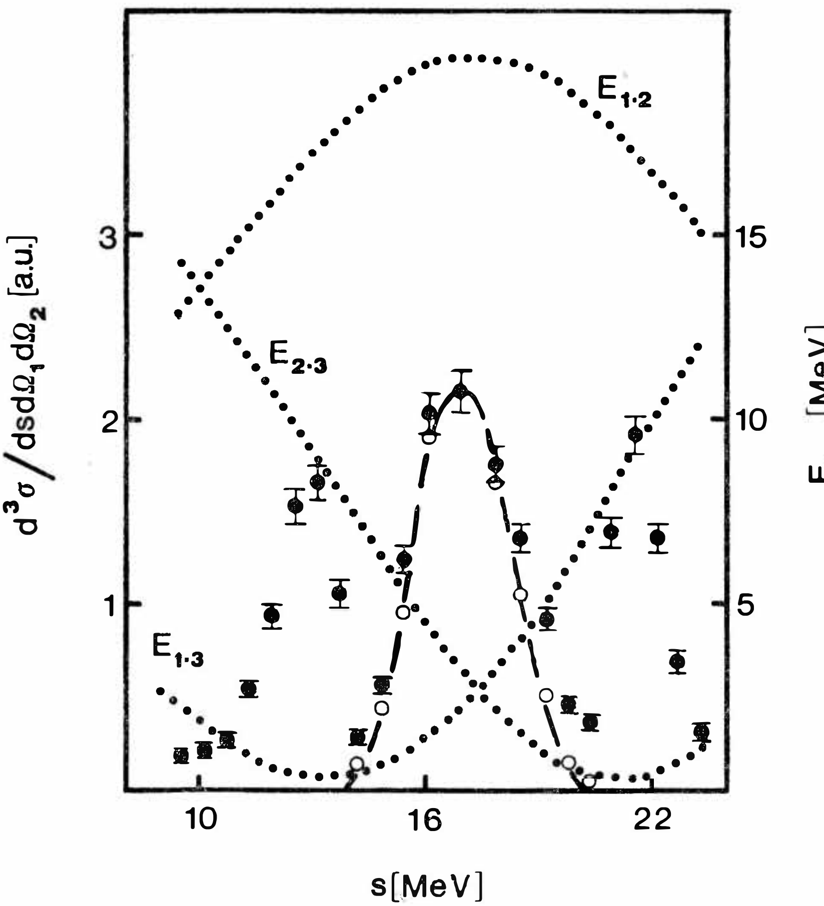

Fig. 2. Same as Fig. 1 but with $\vartheta_2 = 62°$. The dashed line is the result of the fit for the ^{8}Be levels in the region at about $E_x = 20$ MeV.

This statement is true because the $^{5}He_{g.s.}$ in the central region of each spectrum (the one of our concern) contributes at a low level, as already partly described in one of our previous works[1].

In fact, by using the plane wave approximation (PWA) to determine the direction of a symmetry axis for the angular correlation[5] of the α particles, for the angle ϑ_s (the angular shift with respect to the recoil ^{5}He nucleus direction) where the angular correlation shows a symmetry axis, we found the values of 14° (for the pick-up process) and 51° and −165° (for the heavy particle stripping process). Owing to these ϑ_s values the $^{5}He_{g.s.}$ contribution is at its maximum in the spectrum at about $\vartheta_2 = 60°$ — for the case of pick-up and of compound nucleus decay — and at $\vartheta_2 = 59°$ — for one ($\vartheta_s = 51°$) of the two symmetry axes predicted by the heavy particle stripping. Therefore, following the same procedure in the previously mentioned work[1], the event contribution corresponding to the $^{5}He_{g.s.}$ in the cen-

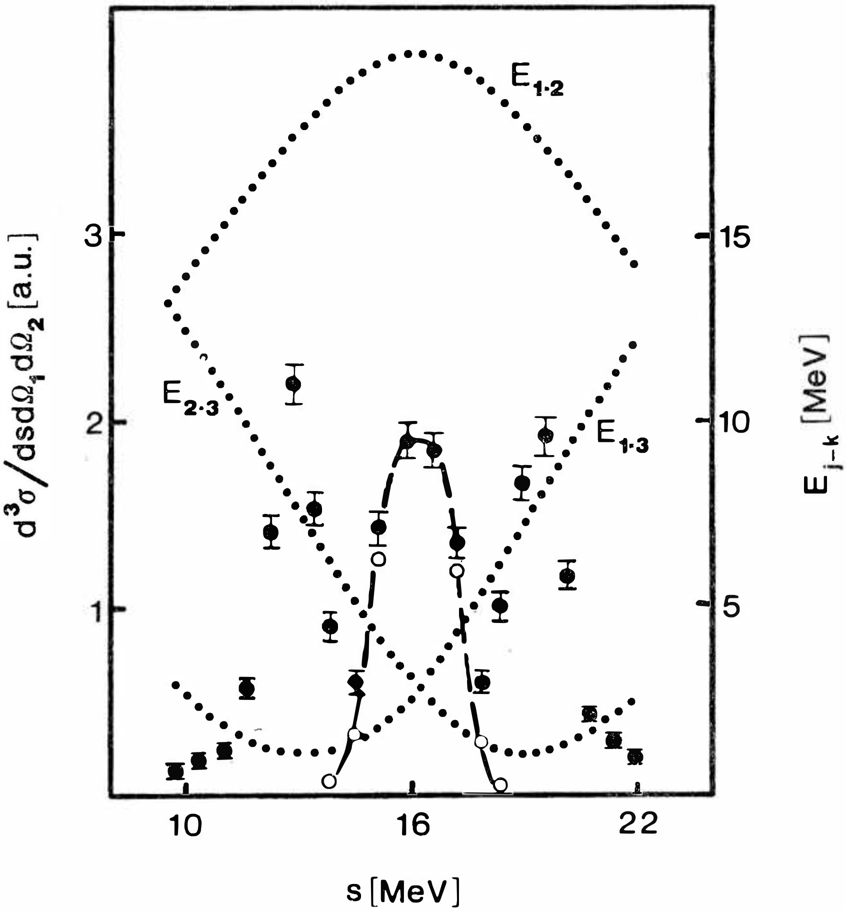

Fig. 3. Same as Fig. 2 but with $\vartheta_2 = 76°$.

tral region of the spectrum at $\vartheta_2 = 62°$ (Fig. 2) is calculated as being small. For the other symmetry axis ($\vartheta_s = -165°$) predicted by the heavy particle stripping process, one can observe that if the correlation function is represented by the form $W(\vartheta_{ret} = K[1 + 3\sin^2(\vartheta_{ret} - \vartheta_s)]$ (where the angle ϑ_{ret} refers to the α-particle emission direction in the relative coordinate system with respect to the recoil ^{5}He nucleus axis) one has to choose the spectrum at $\vartheta_2 = 76°$ in order to have the $^5He_{g.s.}$ contribution at its maximum. But in this case one has to observe that the ^{8}Be levels at excited energies of about 17 MeV also exist (in the spectrum region contributed from the $^5He_{g.s.}$), while the central region of this spectrum at $E_x \simeq 20$ MeV is almost free from other contributions. If $W(\vartheta_{ret})$ is represented by the form $K[1 + 3\cos^2(\vartheta_{ret} - \vartheta_s)]$, one has to choose the spectrum at $\vartheta_2 = 66°$ where the $^5He_{g.s.}$ contribution appears in the central region of the spectrum entirely overlapped by the ^{8}Be levels at $E_x \simeq 20$ MeV. This spectrum has already been considered in our previous work[1].

In order to analyze the central peak present in the spectra at $\vartheta_2 = 62°$ and 76°, we separated the 20 MeV ^{8}Be contributions from the others (17 MeV ^{8}Be and $^5He_{g.s.}$ contributions). In Figs. 2 and 3 circles indicate the events pertaining to the whole of the $J^{\pi} = 2^+$ and 0^+, $T = 0$ ^{8}Be level contributions. Now, by assuming that each contribution due to the 2^+ and 0^+, $T = 0$ ^{8}Be states in its own relative coordinate system (RCS) can be represented by a Lorentzian form and that such contributions can be summed incoherently, the MINUIT code performs an autoconsistent calculation[6] and gives the normalization constant and the width of the two above ^{8}Be states as a result of the fit. Namely, each of such contributions is represented by

$$(J_{3-12})^{-1} \cdot \frac{C\Gamma^2}{(E_x - E_{1-2})^2 + (\Gamma/2)^2}$$

in the laboratory system (LS), where J_{3-12} is the LS-RCS transformation Jacobian, E_{1-2} is the relative energy of the $\alpha\alpha$ system and C a normalization constant. Now, by assuming 20.1 and 20.2 MeV for the E_x values, the fit takes the experimental data of the central peak well into account and gives the C and Γ values for the two mentioned ^{8}Be states.

The result of the fit is displayed as dashed-line in both Figs. 2 and 3 and the Γ average values deduced for the 2^+ and 0^+ ^{8}Be levels

$$\Gamma(2^+) = (0.90 \pm 0.20)\ \mathrm{MeV} \quad \text{and} \quad \Gamma(0^+) = (0.70 \pm 0.20)\ \mathrm{MeV}$$

are in line with the ones found in a previous work[1] and with the values adopted in literature[2].

As one can see, the hypothesis that the central peak in both spectra is mainly populated by the two ^{8}Be levels at excitation energies of 20.1 and 20.2 MeV is satisfactory. However, the Γ-values found by us[1] for the two mentioned ^{8}Be states are very reliable results, although in the analysis of the experimental data we summed the contributions due to the mentioned 2^+ and 0^+ states incoherently.

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STANJA $J^{\pi} = 2^{+}$ I 0^{+}, $T = 0$ ^{8}Be NA ENERGIJAMA POBUĐENJA OKO 20 MeV

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Reakcija ^{7}Li (d, $\alpha\alpha$) n inducirana deuteronima energije 7 MeV je iskorištena za proučavanje jezgre ^{8}Be na energijama pobuđenja E_x oko 20 MeV. Koincidentni $\alpha\alpha$ spektri poravnani su nekoherentnim zbrojem stanja $J^{\pi} = 2^{+}$ na $E_x = 20{,}1$ MeV i $J^{\pi} = 0^{+}$ na $E_x = 20{,}2$ MeV. Rezultati pokazuju da su eksperimentalni podaci najbolje opisani ako se za širine navedenih stanja uzmu vrijednosti 0,90 MeV odnosno 0,70 MeV.