ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Catania

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## 1. - INTRODUCTION -

The $^{11}B+p \rightarrow 3\alpha$ reaction has been studied by various authors$^{(1\div6)}$, who detected the bidimensional spectra of two $\alpha$-particles at various pairs of angles and at various incident energies for $E_p < \sim 5$ MeV. It has been recognized since many years that the dominant mechanism in producing the three $\alpha$-particles in this energy range is a sequential one involving well known states of the $^8Be$ nucleus.

Indeed many theoretical analyses involve a double sequential mechanism of the type $^{11}B+p \rightarrow {}^{12}C \rightarrow \alpha + {}^8Be \rightarrow \alpha + \alpha + \alpha$, at least when well defined states of $^{12}C$ are involved$^{(1\div5)(7\div9)}$. However this last mechanism does not explain completely$^{(9)}$ the aspects of the reaction in the regions where the data on the angular distribution of the $\alpha$-particles from the $^{11}B(p, \alpha)^8Be$ reaction$^{(9\div11)}$ show the contribution of not isolated levels of $^{12}C$ superimposed on a broad background, that is in the region where $E_p > 1.5$ MeV.

One of the method to put into evidence the particular aspects of the reaction mechanism not necessarily involving a double sequential decay is to study the symmetry properties of the angular correlation of two $\alpha$-particles in the system where the decaying $^8Be$ nucleus is at rest (the Recoil-Centre-of Mass System$^{(1)}$, or RCM).

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## 2. - EXPERIMENTAL RESULTS -

To obtain these $\alpha\alpha$ angular correlations we detected the bidimensional spectra of two $\alpha$-particles emitted from a $B_2O_2$ target, isotopically enriched at 99.5% in $^{11}B$.

The protons were produced from the Van de Graaff accelerator of the CSFN and SM Laboratories in Catania. The target thickness was 200 KeV at $E_p = 1.0$ MeV.

The two surface barrier detectors subtended angles $\Delta\theta \leq 2^o$.

The fixed one was placed at $\theta_1 = 88.4^o$ with respect to the proton beam. The movable one was placed at various angles from $\theta_2 = 42^o$ to $\theta_2 = 130^o$ in the opposite half plane, that is at $\phi_2 = 180^o$.

The runs were done at constant charge collected by a Faraday cup and the fixed detector was used also as a monitor to control the constancy of the target thickness.

The bidimensional spectra of the reaction were detected and the part involving the 2.9 MeV state of $^8Be$ was extracted.

The angular correlations of the two $\alpha$-particles in the Laboratory System (LS) are reported in fig. 1 at $E_p = 0.9$ MeV and $E_p = 1.95$ MeV for the process involving that state of the $^8Be$ nucleus. As in ref. (6) the counts produced when the $\alpha$-particle emitted from the recoiling $^8Be$ nucleus goes toward the movable detector (process I) are not distinguishable in the explored angular range from those produced when this $\alpha$-particle goes toward the fixed detector (process II). So one has to expect interference effects in the spectra.

## 3. - RECOIL CENTRE OF MASS SYSTEM. -

Owing to the finite width of the involved $^8Be$ state, to transform correctly the angular correlations to the RCM it would have been necessary to take into account that, at given laboratory angles, the various parts of the LS peak pertain to different angles in the RCM and require different values of the jacobians for the transformation. However in the explored angular range the half width of the RCM angular spread for each LS angle is $(\Delta\theta_{R})_1 \leq 5^o$ and the half variation of the jacobians does not exceed 3% of the value at the maximum of the RCM energy peak.

Furthermore, each part of the LS peak gives rise to two different values of the RCM angle and of the jacobians, due to the presence of the processes I and II. In this case, however, the two values of the RCM angle differ of $(\Delta\theta^o_R)_2 \leq 0.3^o$. So we assumed that all the counts in a given bidimensional spectrum be transformed using the values of the jacobians pertaining to centre of the RCM energy peak in the hypothesis of process I and II respectively and that all the counts could be attributed to the same average RCM angle.

The procedure to realize the transformations was the following.

The counts in a given bidimensional spectrum can be written as

$$(1) \qquad N(\theta_2)=n_I(\theta_2)+n_{II}(\theta_2)+n_{int}(\theta_2)$$

where $\theta_2$ is the variable LS angle and $n_I$, $n_{II}$ and $n_{int}$ are the contributions of process I and II and of the interference term. If one makes the assumption that the angular correlation is independent from the angle of emission of the first $\alpha$-particle, one can also write

$$(2) \qquad \frac{n_I(\theta_2)}{J_I(\theta_2)\sigma(\theta_1)} = \frac{n_{II}(\theta_2)}{J_{II}(\theta_2)\sigma(\theta_2)} = n(\theta_R)$$

where $n(\theta_R)$ is the transformed angular correlation and $J_I$ and $J_{II}$ are the values of the jacobians pertaining to the two processes and $\sigma(\theta)$ is the cross section for the $^{11}B(p, \alpha_1)^8Be^*$ process in the L.S.

From rels. (1) and (2) one has

$$(3) \qquad n(\theta_R) = \frac{N(\theta_2)}{J_I(\theta_2)\sigma(\theta_1)+J_{II}(\theta_2)\sigma(\theta_2)} \left(1- \frac{n_{int}(\theta_2)}{N(\theta_2)}\right)$$

To obtain the ratio $\left[n_{int}(\theta_2)\right]/\left[N(\theta_2)\right]$ we assumed a pure Lorentzian distribution

$$n(E,\theta_R) \propto \frac{n(\theta_R)}{(E-E_o)^2+\frac{\Gamma^2}{4}} = n(\theta_R)g(E)$$

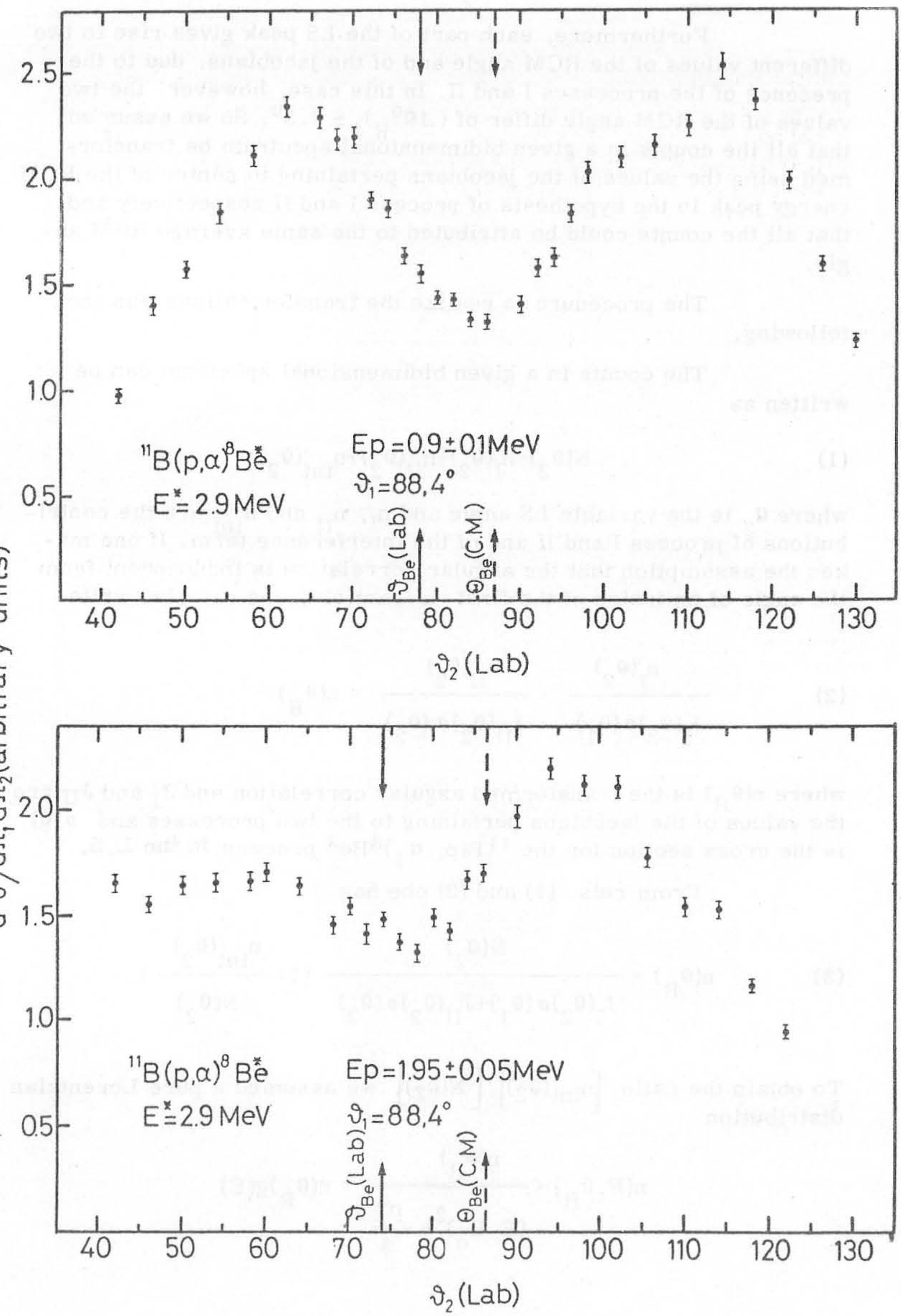


FIG. 1 - Angular correlations of two particles in the $^{11}B+p \rightarrow 3\alpha$ reaction in the laboratory system at $\theta_1 = 88.4$, $E_p = 0.9$ MeV and $E_p = 1.95$ MeV.

for the RCM energy peak and a phase $\varphi(E) = \tan^{-1}(E_o - E)/\Gamma$ for the resonant amplitude. Putting

$$I(\theta_2) = \sqrt{J_I(\theta_2)J_{II}(\theta_2)\sigma(\theta_1)\sigma(\theta_2)} \int_o^\infty \sqrt{g(E_I)g(E_{II})}\cos\left[\varphi(E_I) - (E_{II})\right] dE_I$$

we had

$$\frac{n_{int}}{N(\theta_2)} = \frac{I(\theta_2)}{\left[J_I(\theta_2)\sigma(\theta_1) + J_{II}(\theta_2)\sigma(\theta_2)\right] \int_o^\infty g(E)dE + I(\theta_2)}$$

where $E_{II} = E_{II}(E_I)$ is the equation of the kinematic curve.

The angular correlations so obtained are reported in Fig. 2. To compute the correction for the interference term, we used $\Gamma = 1.4$ MeV and $E_o = 3$ MeV.

The error bars contain the statistical errors together with those produced by the outlined procedure, which are of about 3%. The angular indetermination is about $\Delta\theta_R \lesssim 7^o$.

## 4. - DISCUSSIONS AND CONCLUSION -

The 2 $\alpha$- state giving rise to the measured angular correlations is certainly a definite parity state, due to the identity of the particles.

So it is to expect a $180^o$ periodicity in the angular correlations. Furthermore, a first insight to fig. 2 seems to indicate that these angular correlations are symmetric with respect to a single axis, whose angle with respect to the $\theta_R = 0^o$ direction we call $\theta_S$.

So, as made in ref. (6), we tried to fit the correlations by

$$W(\theta) \propto 1 + A_2P_2(\theta_R - \theta_s) + A_4P_4(\theta_R - \theta_s) \tag{4}$$

The curves obtained by the least square method are reported in fig. 2. The values of the parameters are reported in table I.

The fact that $\theta_s \sim 0^o$ at both energies is characteristic of a double sequential decay involving the formation of $^{12}C$ compound nucleus.

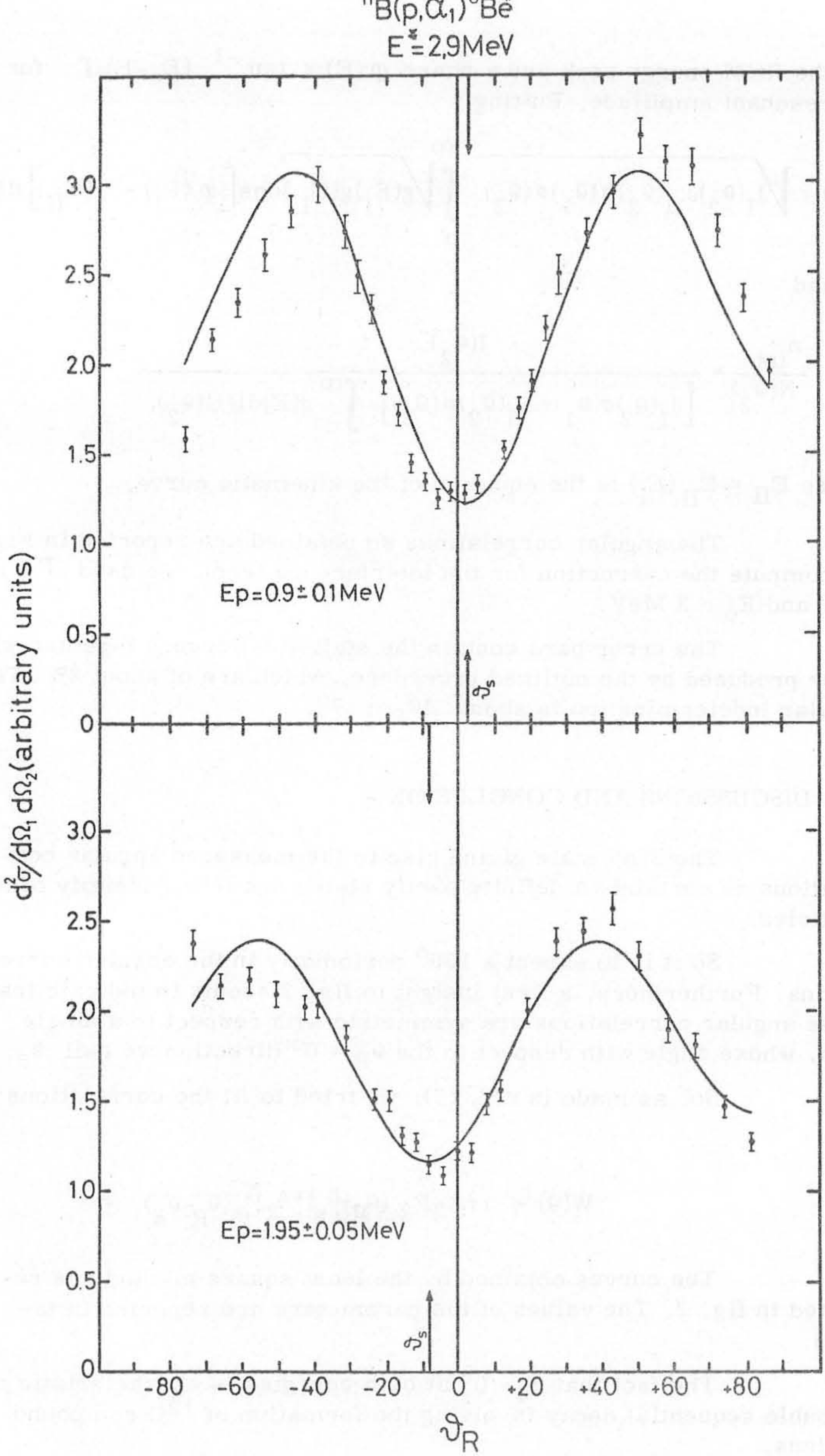


FIG. 2 - Angular correlations in the RCM system.

TABLE I

| | $E_p = 0.9$ MeV | $E_p = 1.95$ MeV |
|---|---|---|
| $A_2$ | 3.09 | 2.80 |
| $A_4$ | -3.41 | -2.99 |
| $\theta_s$ | $2.64^o$ | $-8^o$ |

The results are consistent with those obtained at $E_p <$ $< 1.4$ MeV in ref. (6).

The assumption made in sect. 3 that the angular correlations are not depending from the angle of the "first" emitted $\alpha$-particle seems conforted by the interpretation in terms of double sequential decay.

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