ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Catania

INFN/BE-76/3
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(d, α) REACTION ON ^{15}N AT E_d < 3 MeV.

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1. - INTRODUCTION. -

This work was undertaken to continue the study of the reaction mechanisms in the deuteron induced reactions on light nuclei at low energies(1). To this aim we have performed absolute measurements of differential cross sections of the (d, d), (d, p) and (d, α) reactions for E_d = 1.2 - 2.7 MeV.

In the present paper however, we report about the results of the excitation functions of the (d, α) reaction on ^{15}N for θ_{lab} = 71°, 109°, 128° and 146°.

2. - EXPERIMENTAL PROCEDURE. -

A gas target, enriched to 99.5% in ^{15}N, was used to make absolute measurements of differential cross-sections. The ^{15}N was enclosed in a gas cell, separated from the scattering chamber by a thin Nichel foil (Fig. 1).

During the experiment the temperature of the gas was kept at 300°K within 0.3%, while the pressure was maintained at 5.4 mbar within 1%. The target thickness was 10 keV at E_d = 1.5 MeV.

The incident particles were accelerated by the 2.8 MeV Van de Graaff of the Centro Siciliano di Fisica Nucleare e di Struttura della Materia of Catania. The energy of deuterons was varied from E_d = 1.19 MeV to E_d = 2.70 MeV in steps of about 10 keV. The energy of the particles was controlled whithin 1 keV by a NMR gaussmeter.

The outgoing particles were detected by four solid-state detectors, equipped with a collimating system that allows us to obtain an angular resolution of 1°.

The pulses produced in the detectors were analysed after amplification through Ortec chains.

The reduction of data was performed by means of a HP-2100 computer.

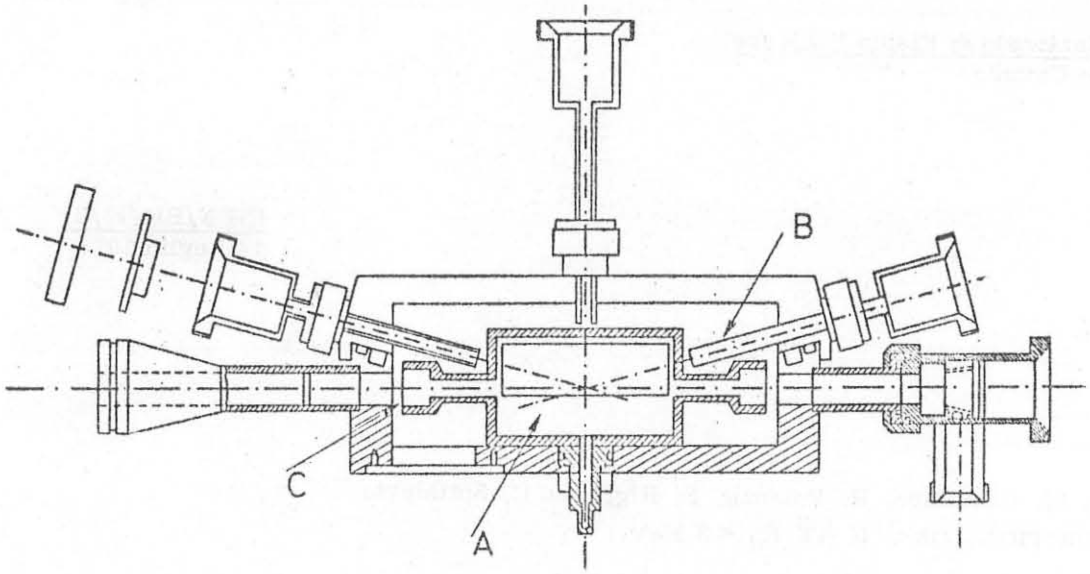

Fig. 1 - Scattering chamber and gas cell: A = gas cell, B = collimator, C = Nichel foil.

2. - EXPERIMENTAL RESULTS. -

In Fig. 2 is shown a typical spectrum of particles arising from the 2.0 MeV deuteron bombardment of the target at $\theta_{lab} = 146^o$. As one can see the groups α_3 and α_2 were not separated; in ref. (2) a description is given of the system of automatic analysis that we have adopted for the separation of the various groups.

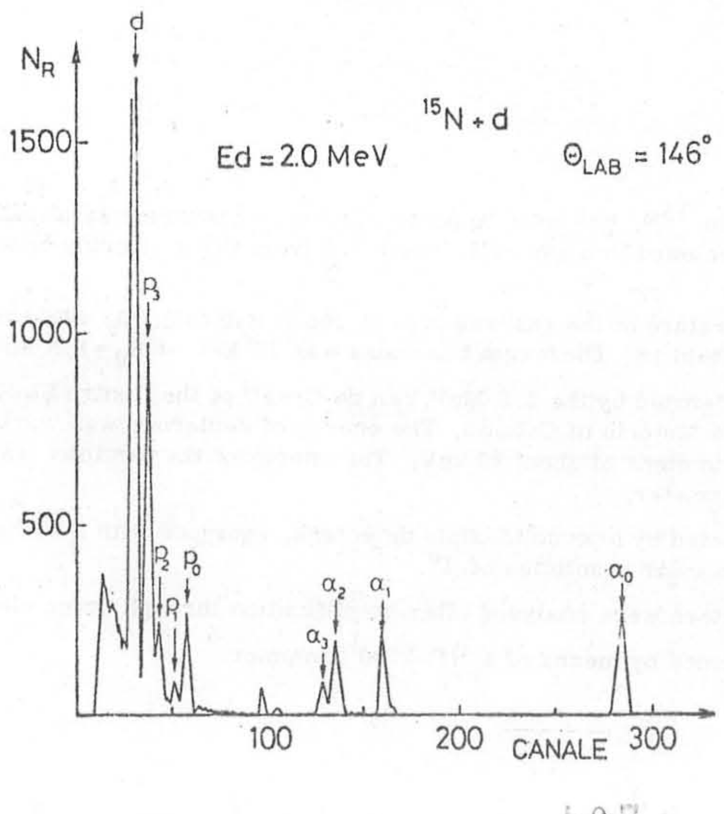

Fig. 2 - Typical pulse spectrum of the particles produced by ^{15}N+d reaction at E_d=2.0 MeV and θ_{lab}=146°. The arrows sormounting the different peaks indicate the positions as determined by the identification program.

In Figs. 3, 4, 5, 6 the excitation functions of the various groups are reported, for $\theta_{lab} = 71^o, 109^o, 128^o$ and 146^o.

The statistical error for these reactions is of the order of a few per cent, while the total error on the absolute value of the cross-sections is about 6-7%.

We have tested the presence of sistematic errors by the 2 MeV angular distribution of the elastic scattering of deuterons on ^{40}A.

We have performed a preliminary analysis of the excitation functions, computing the auto-correlation and the correlation functions given by[4]:

$$C_\alpha(\varepsilon) = \overline{\left[\frac{\sigma_\alpha(E)}{<\sigma_\alpha(E)>} - 1\right]\left[\frac{\sigma_\alpha(E+\varepsilon)}{<\sigma_\alpha(E+\varepsilon)>} - 1\right]} , \qquad (1)$$

$$C_{\alpha\alpha'}(\varepsilon) = \frac{1}{\sqrt{c_\alpha(0)\cdot c_{\alpha'}(0)}} \overline{\left[\frac{\sigma_\alpha(E+\varepsilon)}{<\sigma_\alpha(E+\varepsilon)>} - 1\right]\left[\frac{\sigma_{\alpha'}(E)}{<\sigma_{\alpha'}(E)>} - 1\right]} , \qquad (2)$$

where σ_α and $\sigma_{\alpha'}$ are the experimental differential cross-sections of the various processes.

To compute these functions it is necessary to evaluate the average $<\sigma(E)>$ over the available energy range. We decided to obtain these averages by fitting the excitation functions with a polinomial curve of the first degree.

The function $C(\varepsilon)$ shows a lorentzian shape as predicted by theory[5]; the fluctuations around this shape are a consequence of the finite range (FRD) errors.

The values of Γ obtained for the various α groups at different angles are reported in Table I.

TABLE I

Autocorrelation coefficients for the various processes.

θ_{LAB}		$\alpha_0-\alpha_1$	$\alpha_1-\alpha_2$	$\alpha_2-\alpha_3$
146°	$C_{\alpha\alpha'}(0)$	0.447	0.770	0.530
	$\Gamma_{\alpha\alpha'}$	300 keV	225 keV	250 keV
128°	$C_{\alpha\alpha'}(0)$	0.660	0.390	0.190
	$\Gamma_{\alpha\alpha'}$	300 keV	225 keV	300 keV
109°	$C_{\alpha\alpha'}(0)$	0.590	0.160	-0.040
	$\Gamma_{\alpha\alpha'}$	300 keV	600 keV	280 keV
71°	$C_{\alpha\alpha'}(0)$	0.550	0.510	0.170
	$\Gamma_{\alpha\alpha'}$	250 keV	250 keV	225 keV

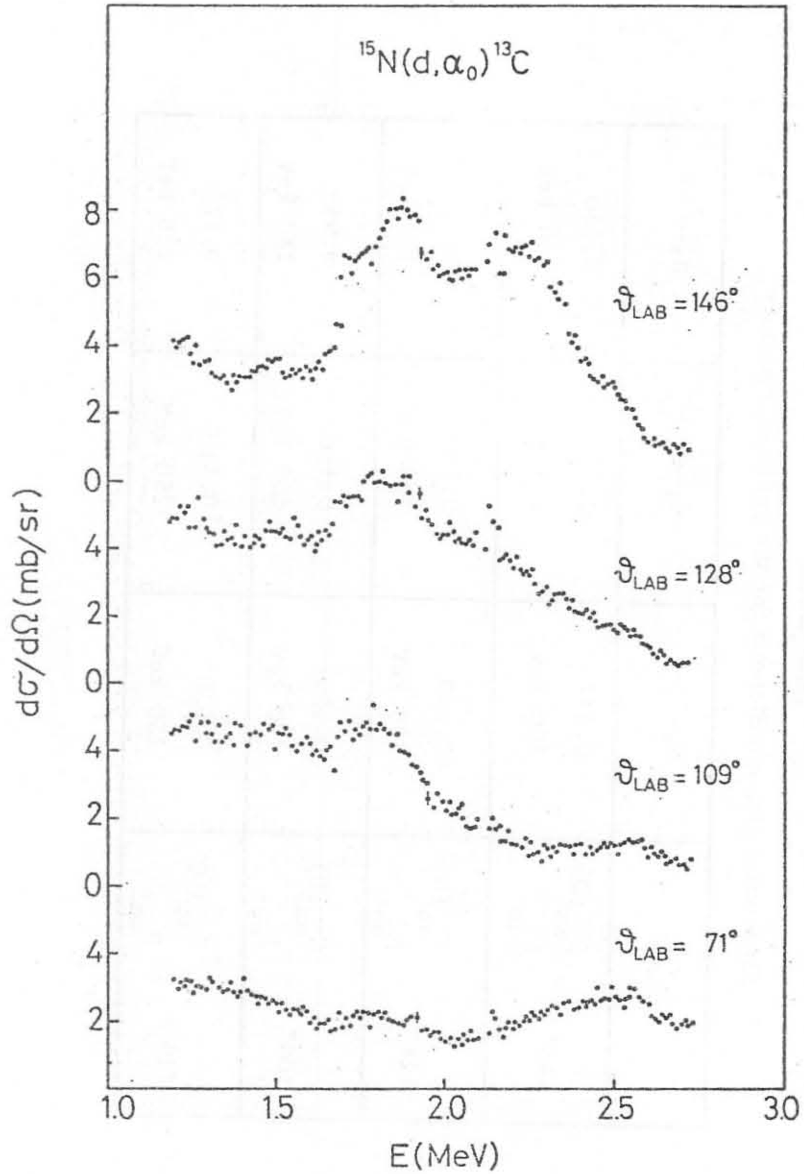

Fig. 3 - Excitation functions for the $^{15}N(d, \alpha_0)^{13}C$ reaction at θ_{lab} = 71°, 109°, 128°, 146°.

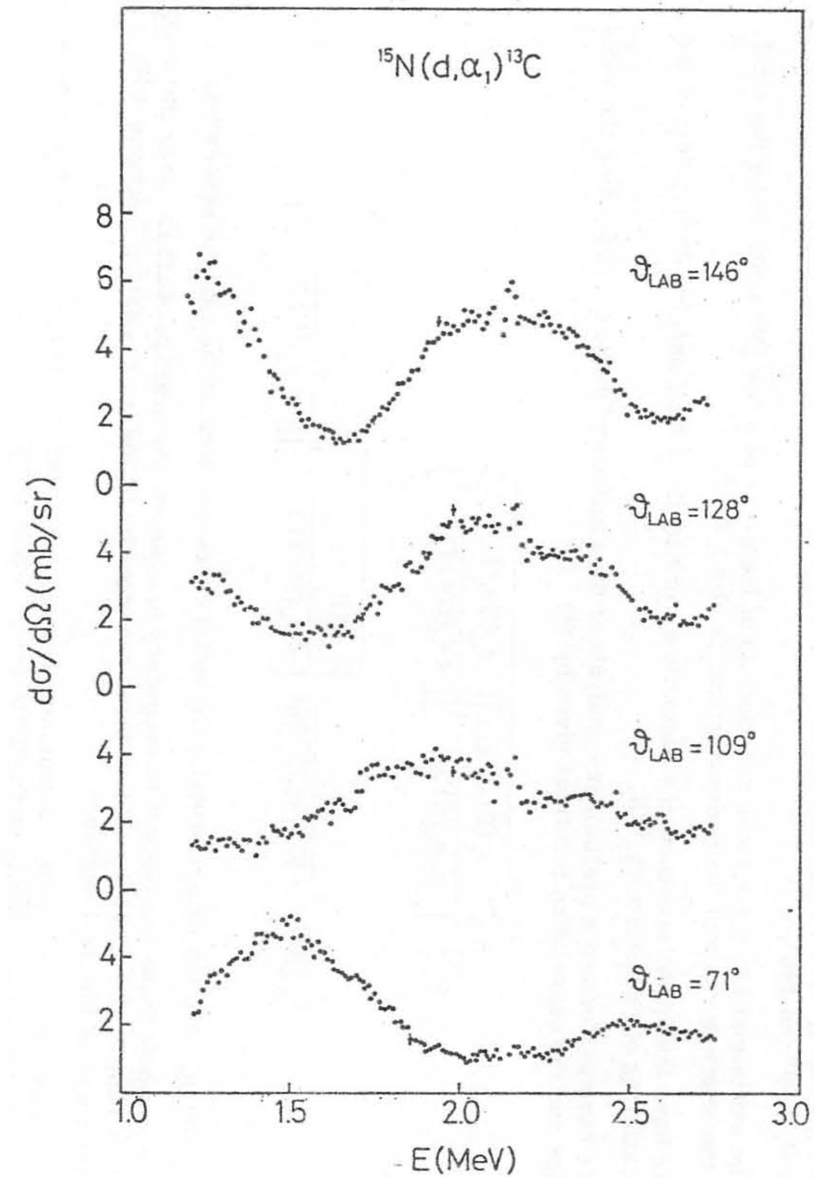

Fig. 4 - As in fig. 3, for $^{15}N(d, \alpha_1)^{13}C$ reaction.

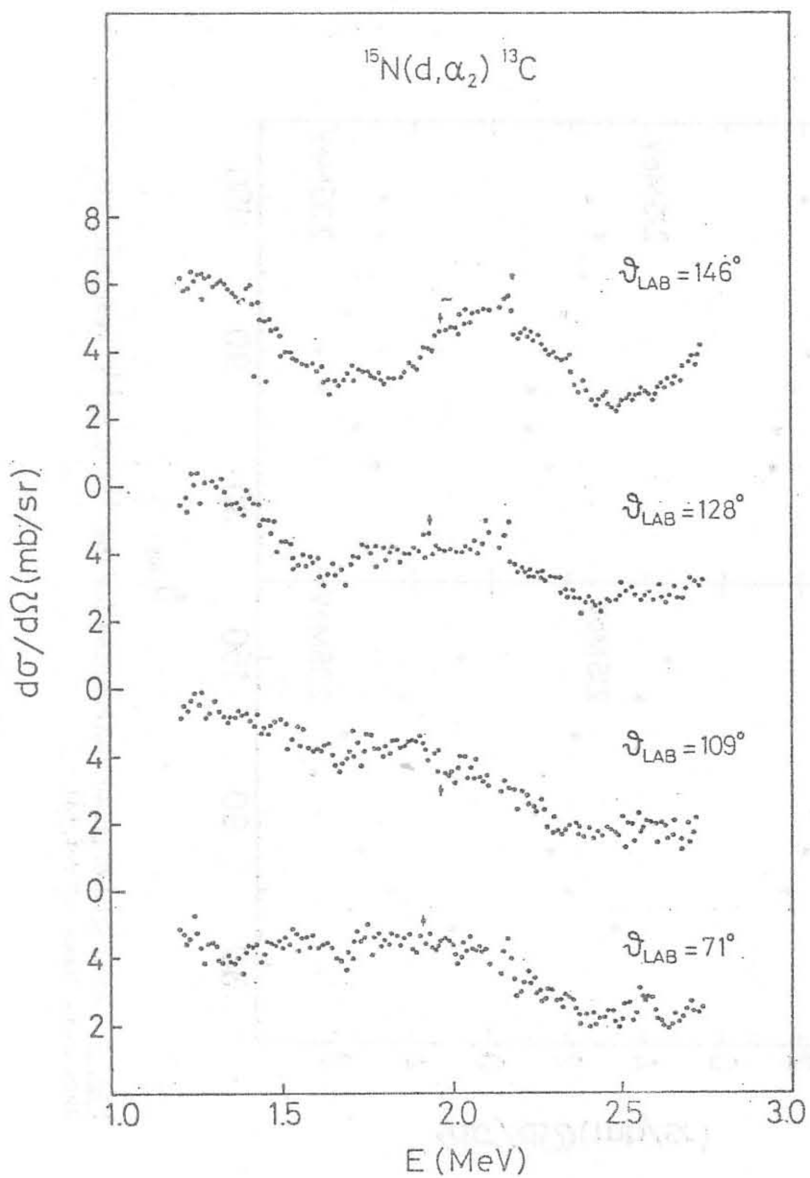

Fig. 5 - As in fig. 3, for $^{15}N(d, \alpha_2)^{13}C$ reaction.

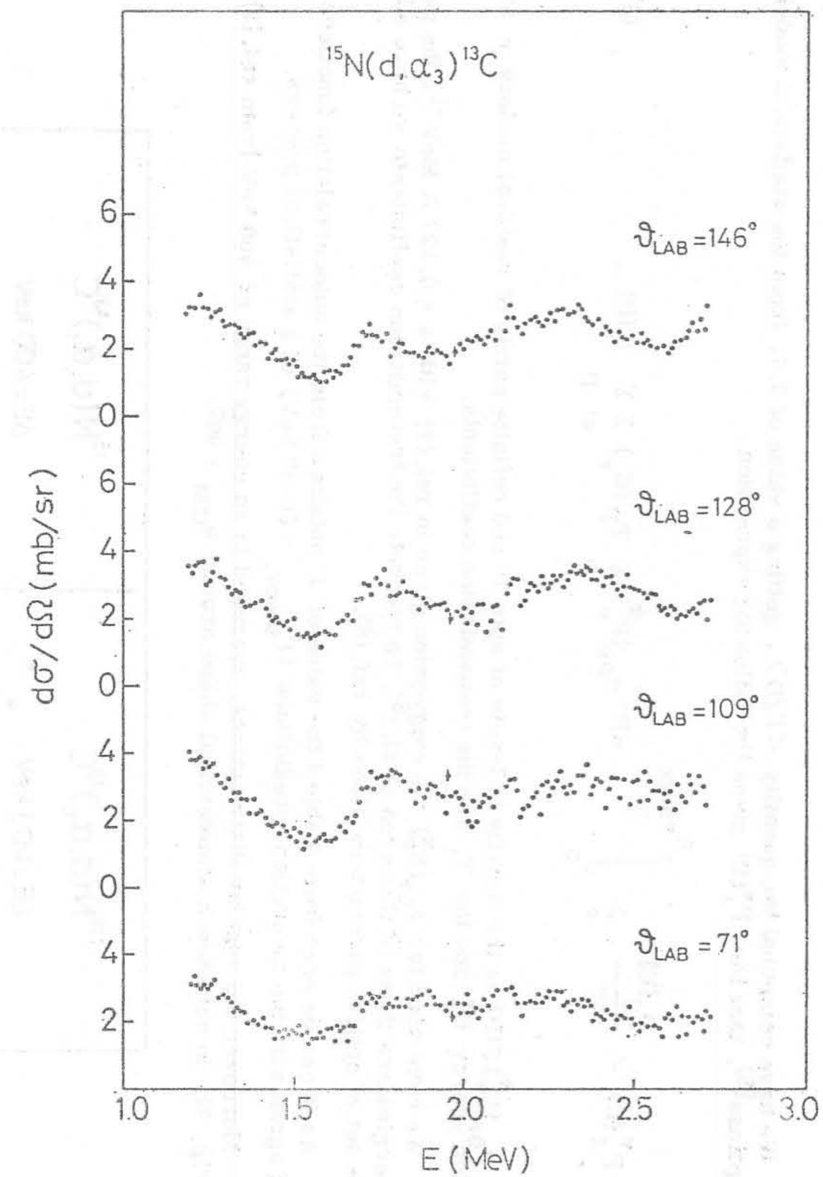

Fig. 6 - As in fig. 3, for $^{15}N(d, \alpha_3)^{13}C$ reaction

We have computed the quantity $<\Gamma/D>$, getting a value of 2.7, from the statistical model assumptions(6), that for $\Gamma_J^{\pi}(E)$ gives the following expression :

$$\Gamma_J^{\pi}(E) = \frac{D_J(E)}{2\pi} \sum_{\nu} \int_0^{E_{\nu max}} dE \cdot \rho_{0\nu'}(E_{\nu'}^{*}) \sum_{l'} T_{l'}(E_{\nu}) \sum_{s'} \sum_{I'} F(I') , \qquad (3)$$

where $\rho_{0\nu}(E_{\nu}^{*})F(I')$ is the density of levels of spin I' and definite parity of residual nucleus ν at exitation energy E_{ν}^{*} and the T_l are the transmission coefficients.

We have used for $\rho_{0\nu}(E_{\nu}^{*})$ the expression given in ref. (7) with $a = 0.127\ A\ MeV^{-1}$; the pairing energies are those of Cameron et al.(8). To compute the transmission coefficients we have adopted the set of optical parameters given by ref. (9).

As it can be seen from Table I the value of Γ obtained from the autocorrelation functions do not agree with the theoretical predictions ($\Gamma_{theor.} = 60-90$ keV) of a statistical process.

Moreover the angular distributions, averaged in an energy range of 400 keV from ref. (3) (see Fig. 7), do not show a simmetrical shape around $\theta_{CM} = 90^{o}$.

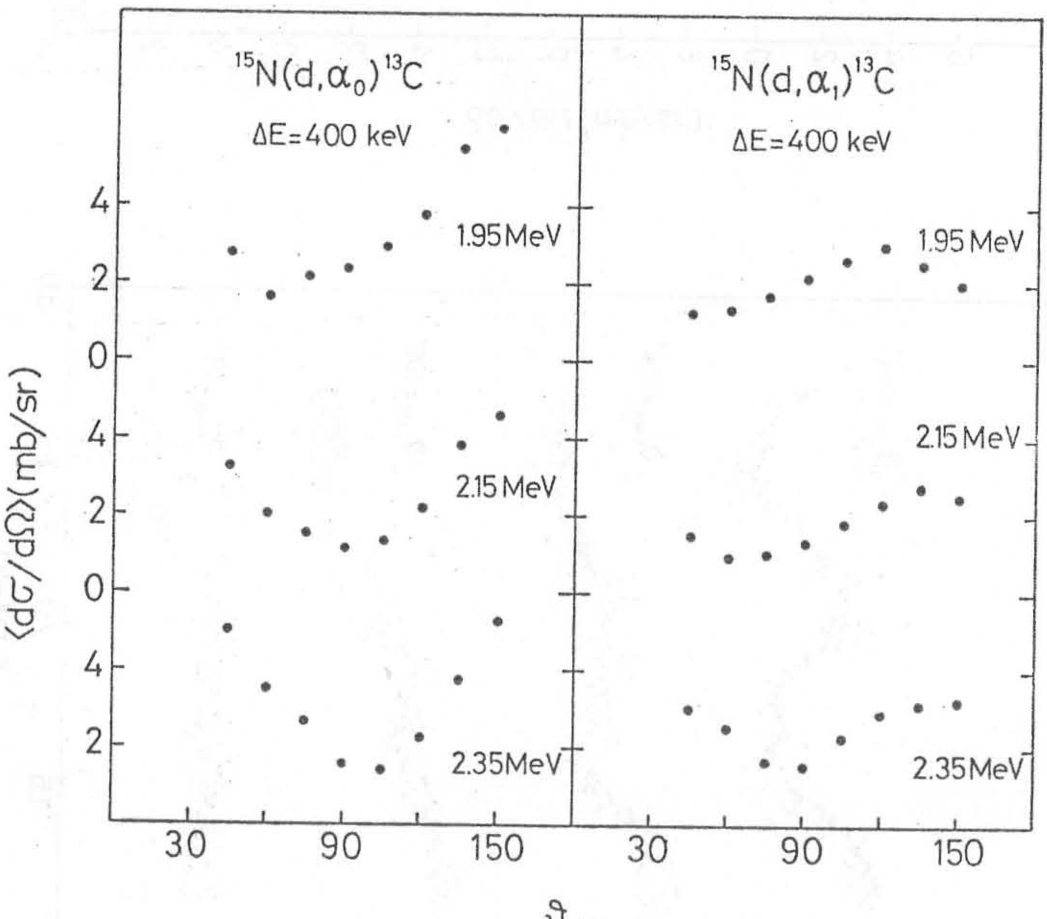

Fig. 7 - Averaged angular distribution for the $^{15}N(d,\alpha)^{13}C$ reaction. The data were those of ref. (3).

These results are in contrast with the pure assumption of a statistical process.

On the other hand the cross correlation functions, reported in Figs. 8, 9, 10 show a strong correlation, particularly for the α_0-α_1 and α_1-α_2 pairs. In Table II are reported the cross correlation coefficients $C_{\alpha\alpha'}(0)$ and the values of $\Gamma_{\alpha\alpha'}$.

TABLE II

Cross correlation coefficients and $\Gamma_{\alpha\alpha'}$ for α_0-α_1, α_1-α_2, α_2-α_3 pairs.

Group	$E^*(^{13}C)$ MeV	J^π	$\Gamma(71°)$ keV	$\Gamma(109°)$ keV	$\Gamma(128°)$ keV	$\Gamma(146°)$ keV
0	0	$\frac{1}{2}^-$	130	110	160	160
1	3.09	$\frac{1}{2}^+$	170	190	160	140
2	3.68	$\frac{3}{2}^-$	120	-	70	120
3	3.85	$\frac{5}{2}^+$	80	70	80	80

The results neither agree with the hypothesis of a statistical process nor with that of a pure direct mechanism.

To interpret these fluctuations in the excitation functions it is then possible to assume an intermediate reaction mechanism connected to the formation of a "doorway state" at $E^*(^{17}O) \simeq$ $\simeq 15.8$ MeV in the ^{17}O.

This attempt of interpretation can be supported by the fact that the alpha-particle model is very able to describe the ^{16}O ground state. The doorway state interested can in fact be supposed as formed by an hole in the ^{16}O core, coupled to two particles, as proton and a neutron in an excited state.

To hole annihilation by the proton is directly coupled with the exit of an alpha-particle from the ^{16}O core.

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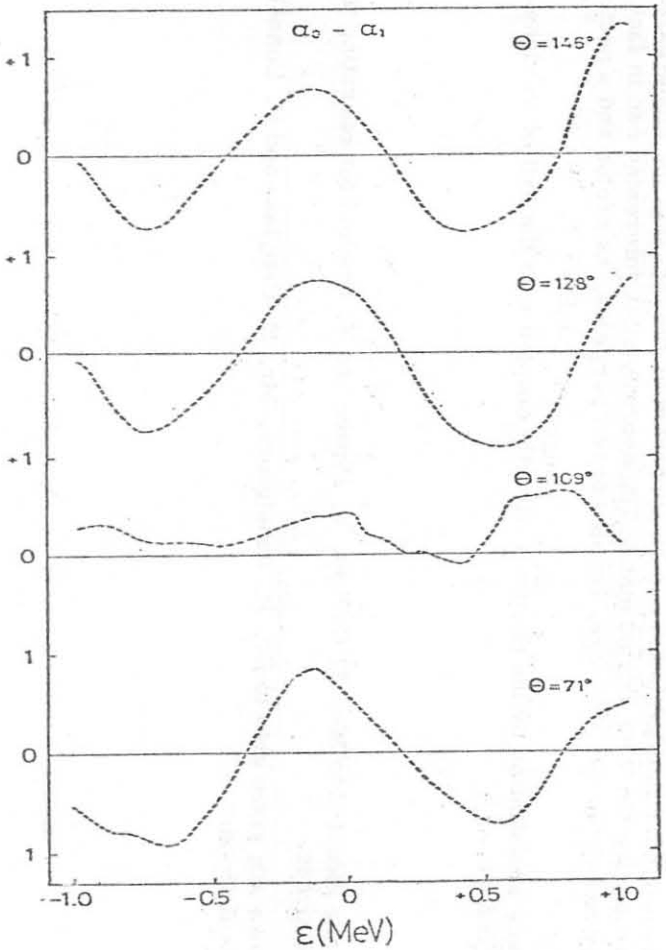

Fig. 8 - Cross-correlation functions for the pairs α_0-α_1 at different angles.

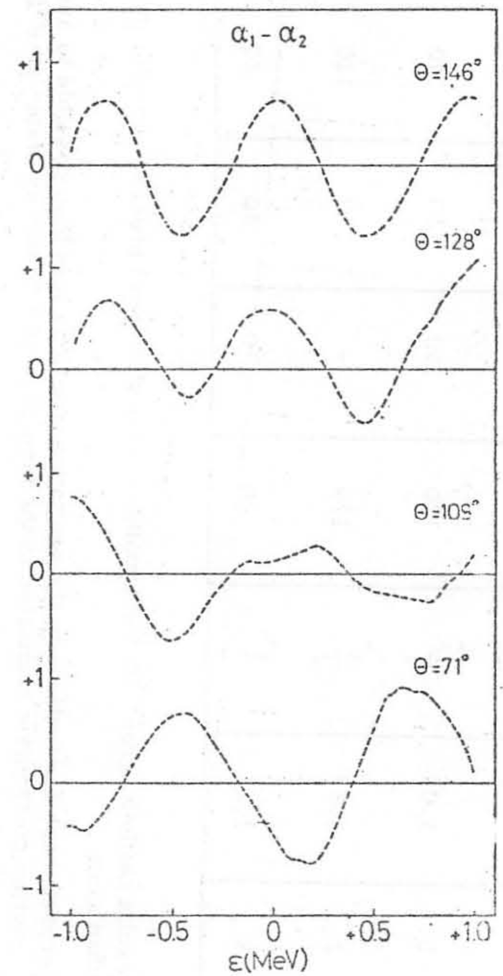

Fig. 9 - As in fig. 8, for α_1-α_2.

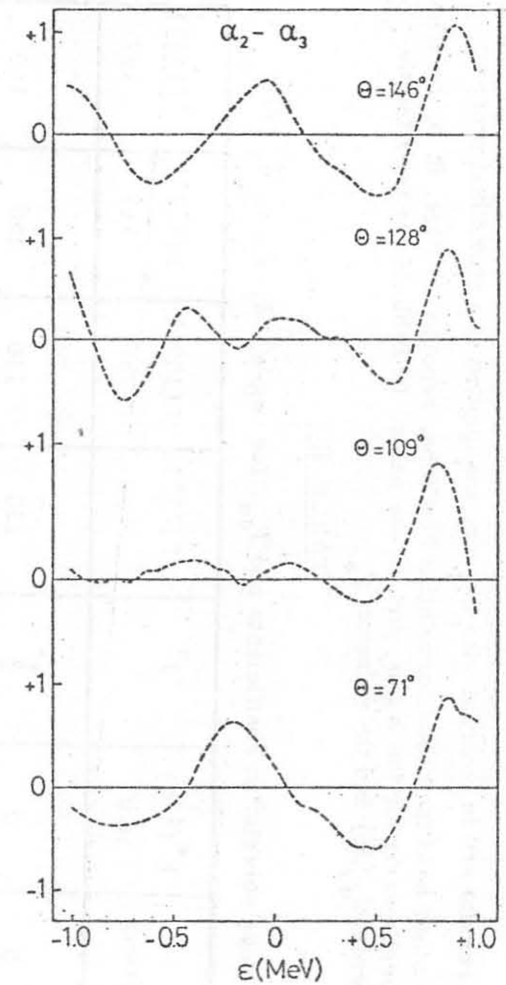

Fig. 10 - As in fig. 8, for α_2-α_3.

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