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P. Cuzzocrea, A. De Rosa, G. Inglima, E. Perillo, E. Rosato, M. Sandoli and G. Spadaccini : THE $^{19}F(p,\alpha)^{16}O$ REACTION AND THE QUARTET MODEL.

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1. - INTRODUCTION.

The quartet model, proposed some years ago by Danos and Gillet(1), has received some experimental support, essentially from the transfer reactions of α, ^{8}Be and ^{12}C clusters on N=Z even-even targets(2).

This work investigates the possibility to produce, through the $^{19}F(p,\alpha)^{16}O$ reaction, $|211|$ quartet states in ^{20}Ne, involving excitations of quartets from the (Op) to the (Of, 1p) shell.

^{20}Ne states with large components of quartet structure should decay preferentially by α-emission and therefore produce resonances in the $^{19}F(p,\alpha)$ excitation functions. In particular $|211|$ states should exhibit for the α_π-line reduced widths larger than for the α_0 one (see Fig. 1), as this last process involves more complicated decays with quartet scattering, i.e.

$$\langle ^{20}Ne\ 211 \,||\, ^{16}O\ 210 + \alpha_\pi \rangle > \langle ^{20}Ne\ 211 \,||\, ^{16}O\ 300 + \alpha_0 \rangle .$$

The energy range of the incident protons was initially taken as $0.70 \lesssim E_p \lesssim 1.55$ MeV, as the model(3) locates the O^+ band-head of the $|211|$ configuration at an excitation energy $E_x = (13.3 + V_{p,pf})$ MeV, with $V_{p,pf} < 1$ MeV (see Fig. 1).

In this range only a O^+ resonance was found (at $E_p = 0.845$ MeV), but it is not due to quartet excitations(4). On the other hand Middleton et al.(5) located the $|220|$ O^+ band-head at $E_x = 7.195$ MeV in ^{20}Ne, instead of the predicted(3) value of 5.1 MeV (this difference of $\sim 40\%$ gives the degree of reliability of one of the fundamental hypotheses of the model, i.e. the independence of the quartet-quartet hole interaction potentials from the mass number). The measurements were therefore extended to higher energies. Partial results previously published(6) have shown that the O^+ state at $E_x = 14.467$ MeV has some quartet component. This state was tentatively identified with the $|211|$ band-head essentially because other O^+ states in literature seemed to be very far in energy and identifying one of them with the claimed band-head would require a big change in the interaction potentials. On the other hand, the investigation of the high excitation region of ^{16}O ($E_x = 21$-25 MeV) through the $^{14}N(d,\alpha)^{12}C$ reaction(7), provided no evidence of quartet states.

In this paper the results of the analysis of other resonances are presented, also including some 2^+ levels, in order to investigate the possible production of other members of quasi-rotational quartet bands and to collect some other information on this complex situation.

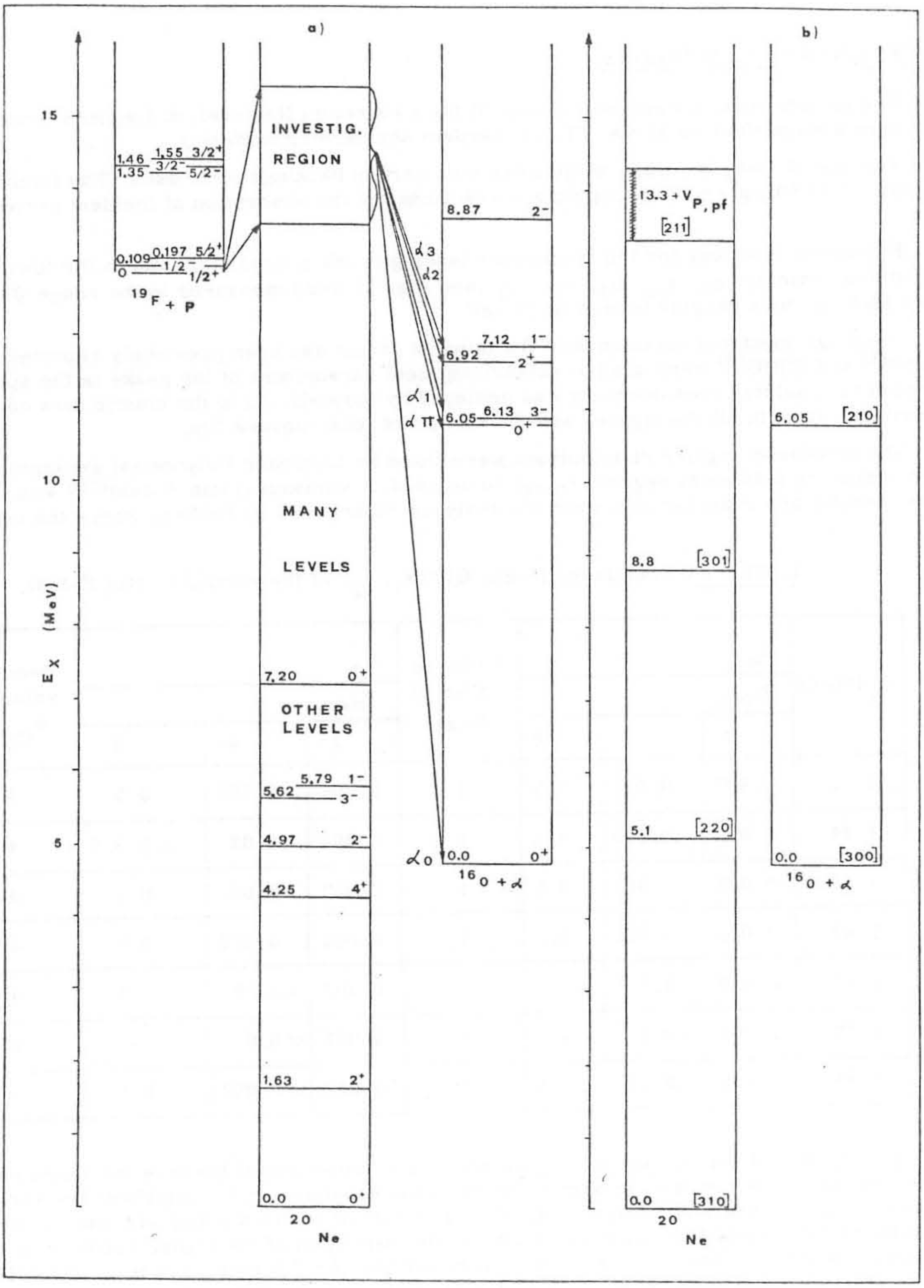

FIG. 1 - a) Schematic illustration of the reaction $^{19}F(p,\alpha)^{16}O$. b) The previsions of the quartet model(3) for the ^{20}Ne and ^{16}O nuclei.

Moreover, this paper presents the results obtained on three other α-lines, studied in order to obtain information about the ways of decay of the ^{20}Ne intermediate states.

2. - EXPERIMENTAL METHODS.

The measuremerts were carried out at the Laboratori Nazionali di Legnaro (Padova). Some tests were also performed at the TTT-3 Tandem accelerator in Napoli.

Targets of CaF_2 or BaF_2 evaporated onto carbon backings were used. The thicknesses ranged from 10 to 50 $\mu g/cm^2$; appropriate corrections for the absorption of incident protons were made.

Excitation functions for the transitions leading to the ground state and to the lowest four excited states, namely α_0, α_π, α_1, α_2, α_3 (see Fig. 1) were measured in the range $0.70 \leq E_p \leq 2.68$ MeV in steps ranging from 5 to 50 keV.

A typical spectrum obtained with the thinnest target has been previously reported(4). Codes TALPA(8) and SIRIO(9) were used to extract physical parameters of the peaks in the spectra; the reduction to absolute cross-sections was achieved by normalizing to the elastic data on Ca or Ba. The errors shown in all the figures are the results of least-square fits.

The measured angular distributions were fitted by Legendre Polynomial expansions. In order to obtain the maximum degree (ν_{max}) to be used, a variance-ratio F-test(10) was used everywhere; results are reported only near the analysed resonances in Table I, where the confidence

TABLE I - Confidence levels $Q(F/\nu_1, \nu_2)$ of the variance ratio F-test.

E_p(MeV)	α_o ν_{max} 2	4	6	Deduced value of ν_{max}	α_π ν_{max} 2	4	6	Deduced value of ν_{max}
1.12	0.002	0.01	0.5	4	0.002	0.002	0.5	4
1.34	0.002	0.002	0.5	4	0.002	<0.02	0.2-0.5	4
1.36	0.002	0.002	0.5	4	0.002	0.05	0.5	4
2.09	0.002	0.002	0.5	4	0.002	0.002	0.5	4
2.13	0.002	0.5	-	2	0.002	<0.05	0.5	4
2.18	0.002	>0.1	-	2	0.002	≃0.5	-	2
2.35	0.002	0.002	≃0.5	4	0.002	0.002	0.1	4

levels $Q(F/\nu_1, \nu_2)$ of performing a 1st type error (i.e. rejection of the true null-hypothesis that the introduction of the assumed maximum order in the expansion is not justified) are shown. These values of ν_{max} were also used to draw the curves in all the cases they are shown. The obtained values do not exceed 4 in any case. An accurate inspection of the higher coefficients (ν =5, 6) has ensured us that no casual cancellation occurs for the ℓ = 3 terms; this is consistent with the hypothesis(11) that at these low incident proton energies only s, p and d partial waves take part to the reactions and permits an analysis of the angular distributions in terms of the first five coefficients of the expansion:

$$\sigma(\Theta_{C.M.}) = \sum_{\nu=0}^{4} B_\nu \cos^\nu(\Theta_{C.M.}) \tag{1}$$

where the B_ν are directly connected to the contributions of the single partial waves[11]. For the α_o and α_π groups the final channel spin is 0 and the knowledge of the transferred orbital angular momentum uniquely defines the J^π of the intermediate levels ; these values are reported in the analysis of the single resonances.

3. - RESULTS.

The results are reported separately for the lower and the higher energy region.

3. 1. - Energy region $0.70 \leq E_p \leq 1.55$ MeV.

The partial yields, measured at eight different angles, are shown in Figs. 2-6. In this energy range complete angular distributions were measured only near even-parity observed resonances for α_o and α_π($E_p \simeq 0.845$, 1.115, 1.355 MeV). The resonance at $E_p \simeq 0.845$ MeV has already been analysed[4]. The angular distributions relative to the other two resonances are shown in Figs. 7, 8. Odd-parity resonances were not analysed, as they cannot be due to quartet excitations[1].

The results on α_1, α_2, α_3 are in very good agreement with those reported in refs. (12, 15). Also for α_o and α_π a good agreement is obtained with the data of refs. (11, 12, 13, 14, 16) for what concerns the yields, the cross-sections at the resonances and the angular distributions too, when reported.

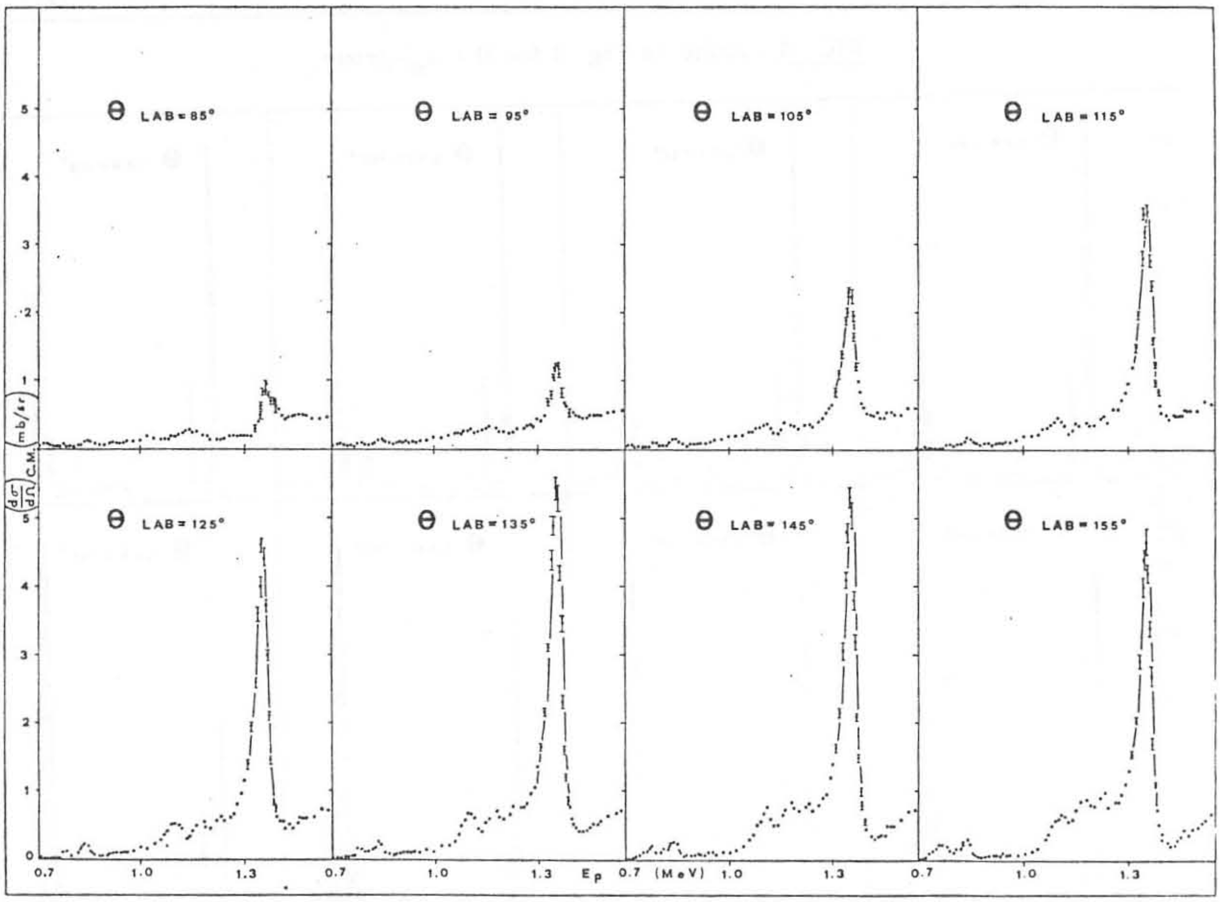

FIG. 2 - Excitation functions of α_o-group at eight lab. angles. The broken curves are intended as a guide for the eye.

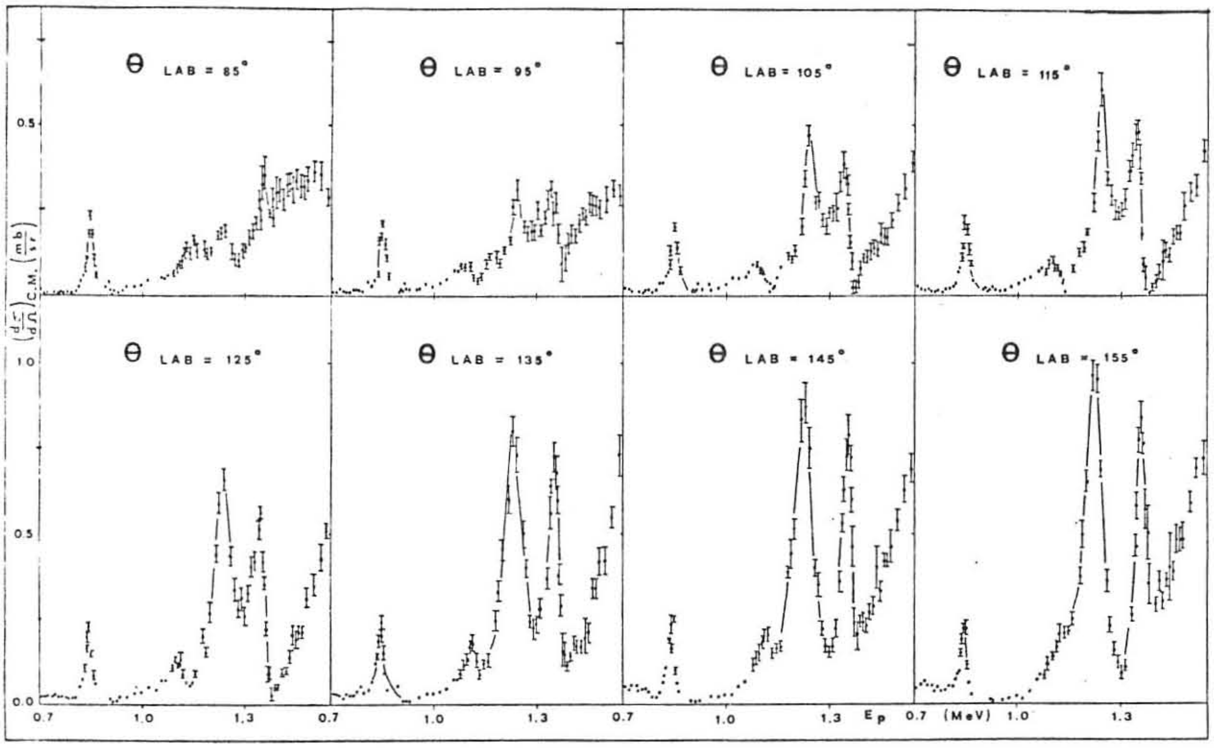

FIG. 3 - Same as Fig. 2 for the α_π-group.

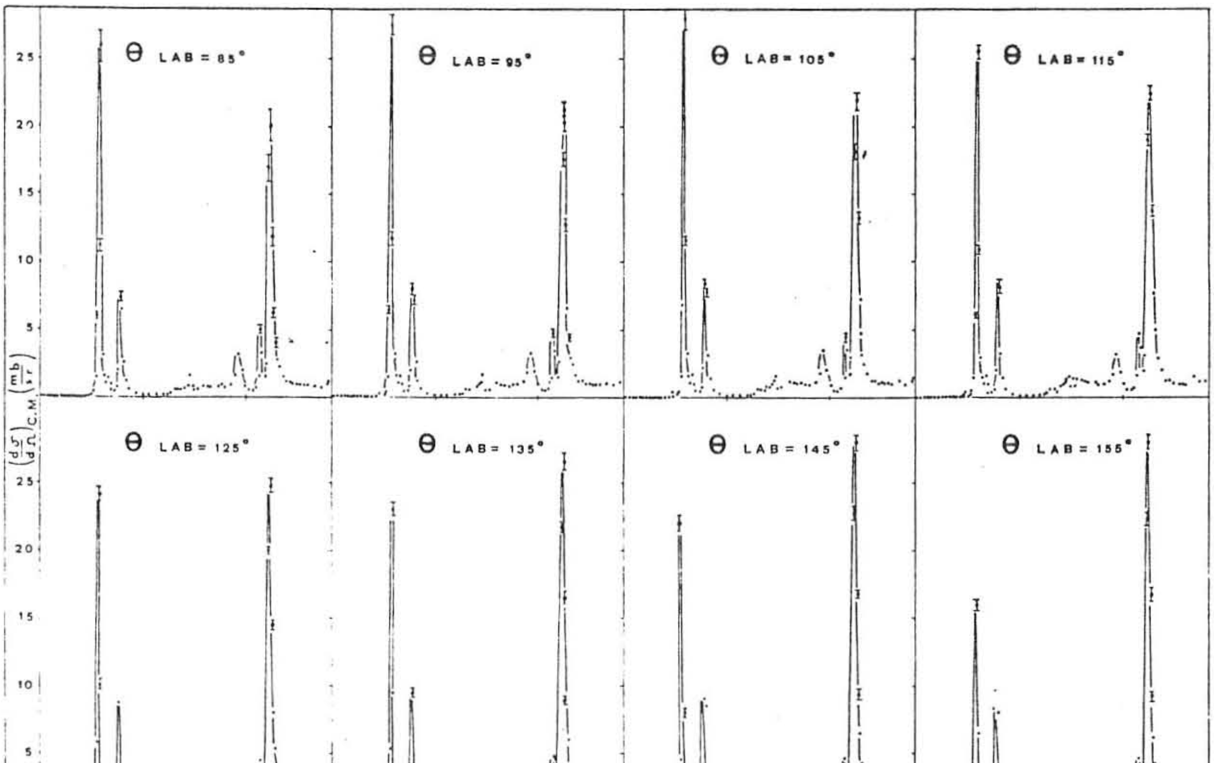

FIG. 4 - Same as Fig. 2 for the α_1-group.

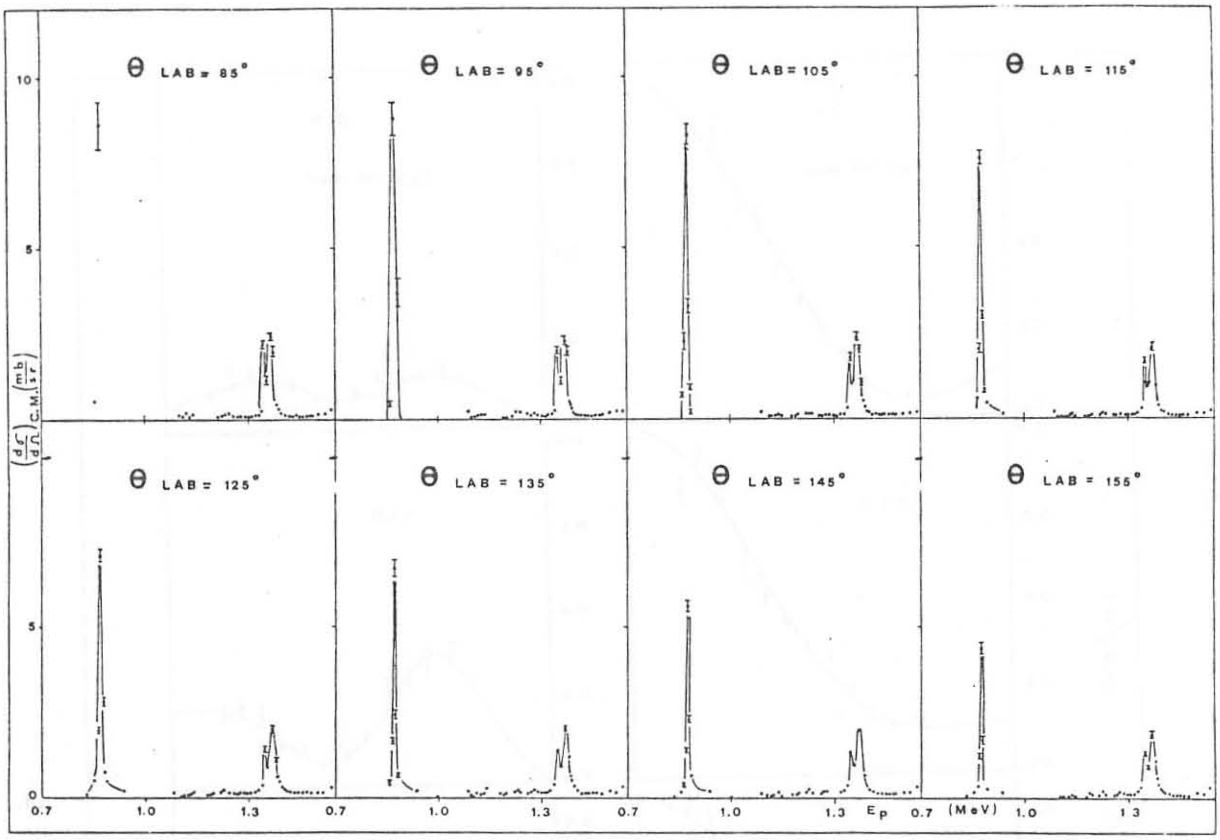

FIG. 5 - Same as Fig. 2 for the α_2-group.

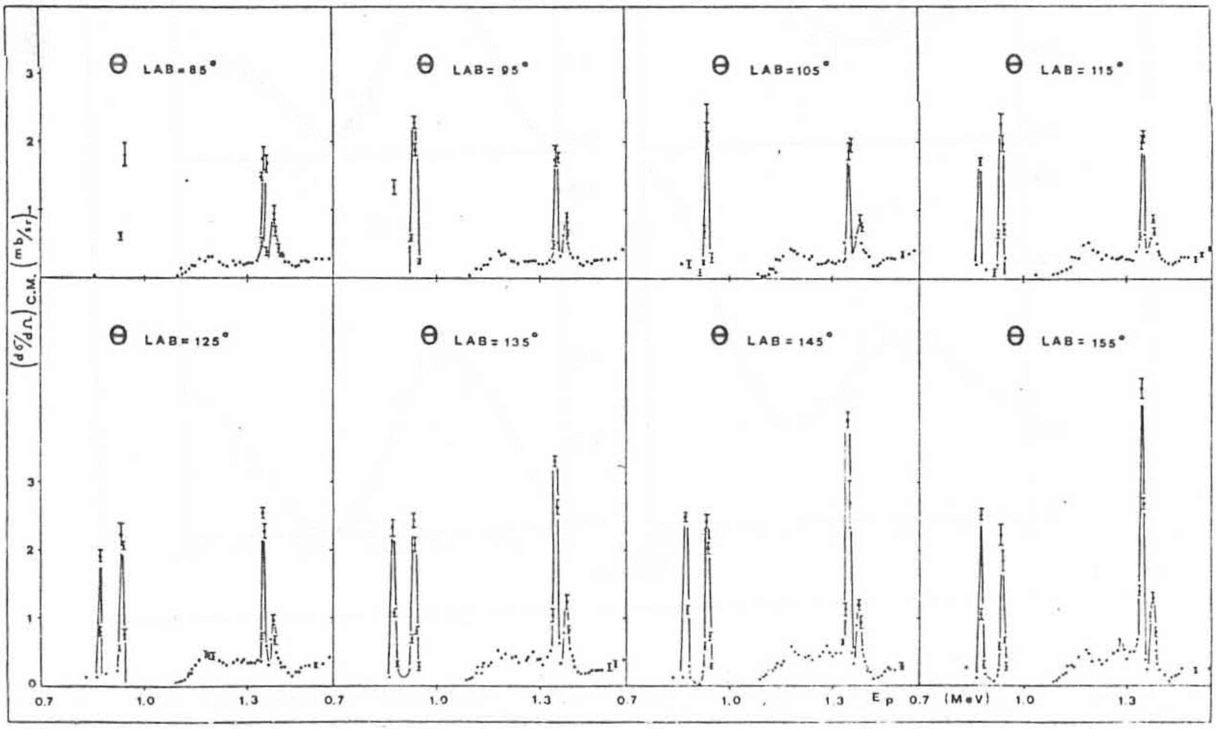

FIG. 6 - Same as Fig. 2 for the α_3-group.

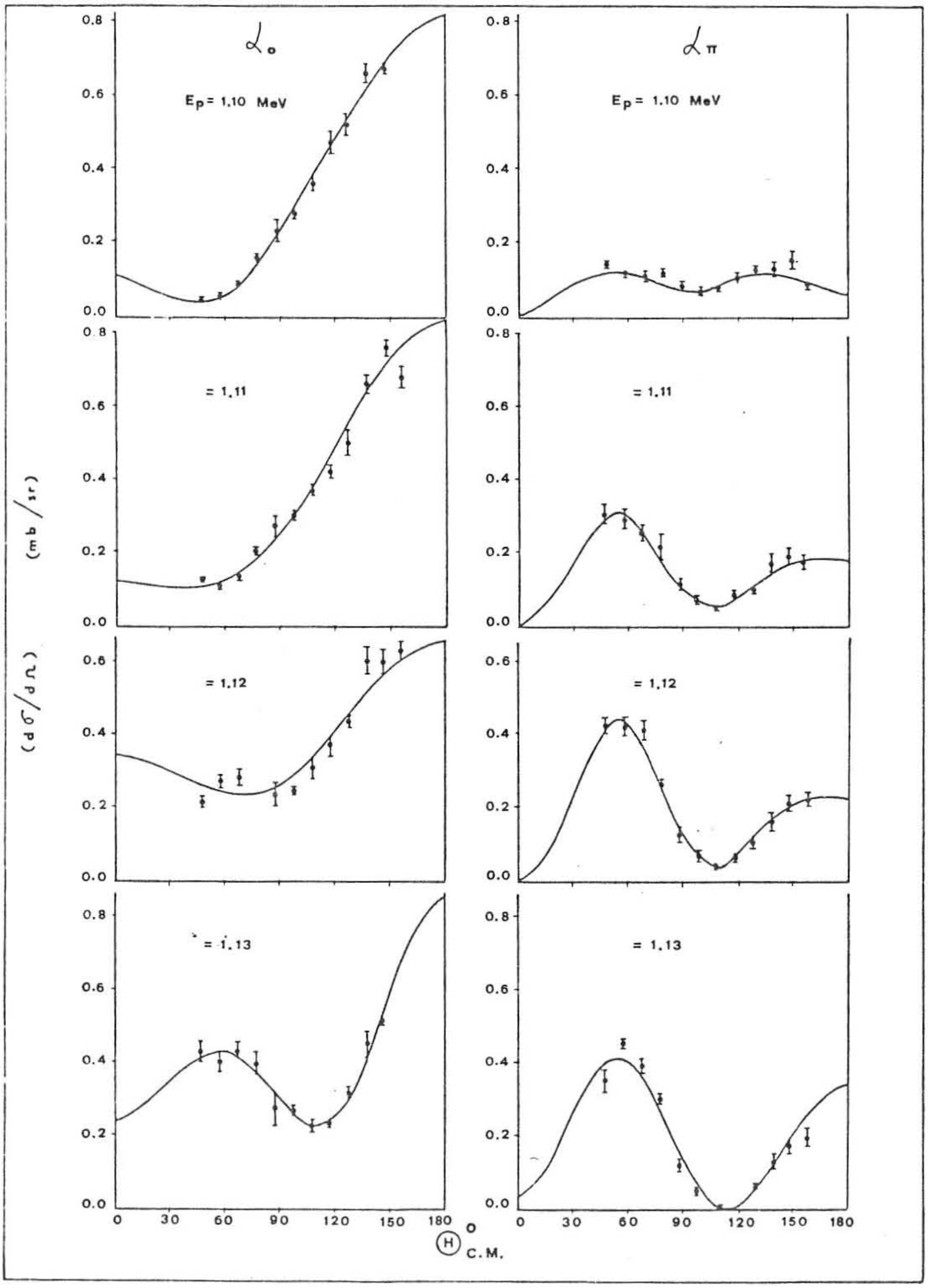

FIG. 7 - Angular distributions for the α_o (left) and α_π (right)-groups near the $E_p \simeq 1.115$ MeV resonance. The curves are Legendre Polynomial fits with $\nu^p_{max} = 4$ (see text).

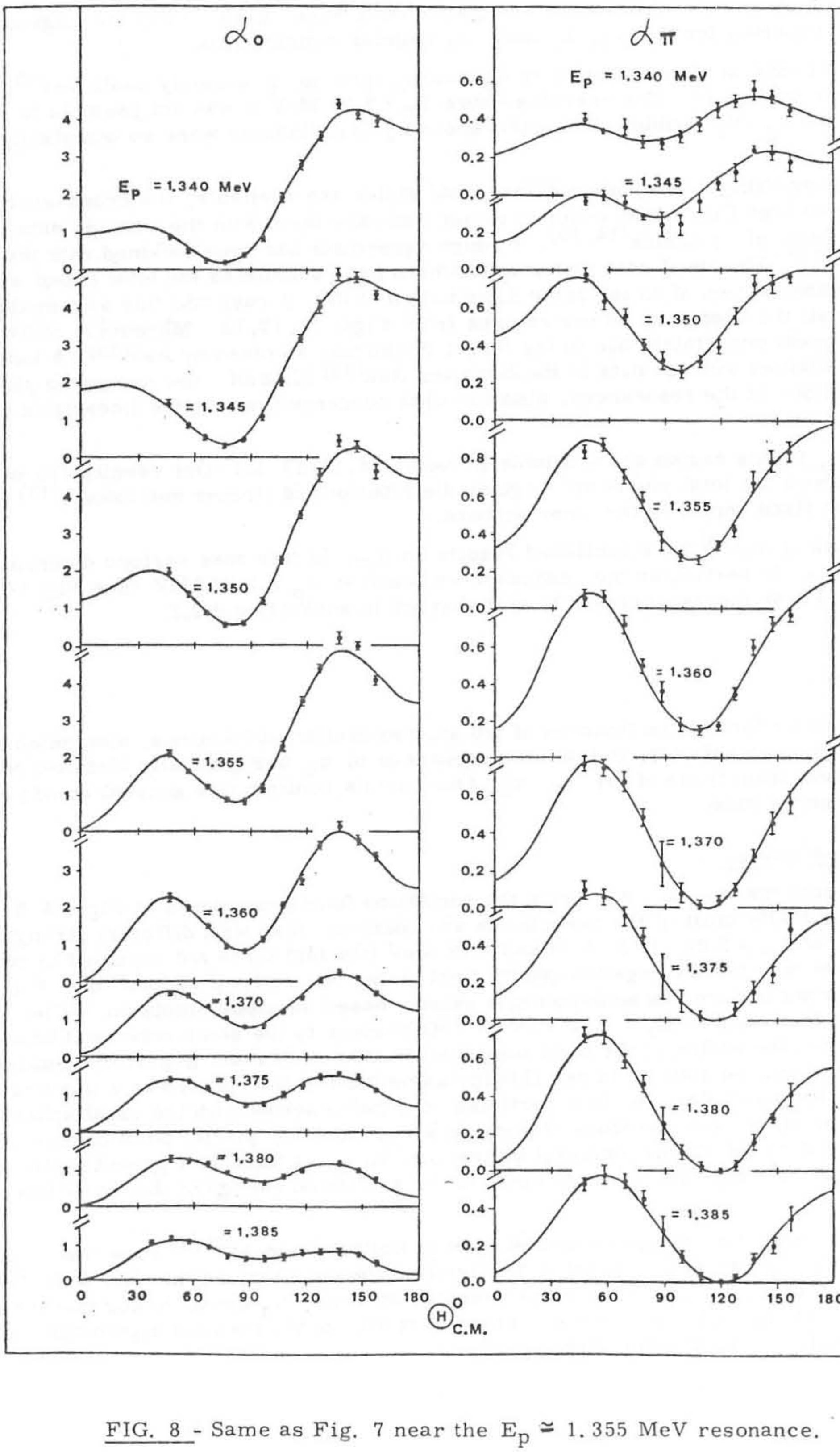

FIG. 8 - Same as Fig. 7 near the $E_p \cong 1.355$ MeV resonance.

3.2. - Energy region $1.55 \leq E_p \leq 2.68$ MeV.

The results obtained in this region are displayed in Figs. 9-14. Only the Legendre Polynomial fits were reported for the α_1, α_2 and α_3 angular distributions.

Integrated cross-sections relative to α_o and α_π-groups, previously published[6], are shown for completeness in Fig. 14. For energies above $E_p = 2.38$ MeV it was not possible to separate unambiguously the $\alpha_\pi - \alpha_1$ doublet. The corresponding contributions were so completely disregarded.

For the γ-emitting levels, when all the total yields are available, the cross-sections have been also summed (see Fig. 14) in order to better compare them with the existing data, usually reported in the form of γ-yields[14, 15]. A rough agreement has been obtained with the results of Ranken et al.[14]. One must note that these authors have calculated the total cross-sections on the basis of the assumption of an isotropic distribution of the γ-rays and this assumption is not well verified at all the energies, as one can see from Figs. 11, 12, 13. Moreover, their yield was obtained with a great uncertainty due to the target thickness, as noted by Ask[15]. A better agreement has been obtained with the data of Hellborg and Ask[15] himself, who measured yields and angular distributions at the resonances, also for what concerns the relative intensities of the three γ-lines.

Data on α_o in this region are available in refs. (14, 16, 17, 18). Our results are in very good agreement with the total yields and angular distributions of Breuer and Jahnke[17] and also with the yields at fixed angles of the other authors.

Only Ranken et al.[14] have published results on α_π. In this case serious discrepancies exist with our data. In particular the resonance we found at $E_p \simeq 2.08$ MeV (see Fig. 14) is not reported at all. These discrepancies will be discussed in subsection 4.2.2.

4. - DISCUSSION.

One of the important known features of the studied excitation functions, also noted in the review papers quoted as ref. (19), is that the resonances of α_o are generally identical to those of α_π and different from those of α_1, α_2, α_3. Our results confirm this general trend; however, some differences exist.

4.1. - γ-emitting levels.

For what concerns α_1, α_2, α_3, from the excitation functions, shown in Figs. 4, 5, 6, 14, one can see that actually most of the resonances are common, also with different strengths, but some other, viz. at $E_p = 2.03$, 1.18, 1.28 and 2.22 MeV (the last three not reported in ref. (19)) seem to be present only for the negative-parity final states (α_1 and α_3) and not for $\alpha_2(2^+)$. This is an interesting feature, as an hypothesis exists, based on experiments on $^{12}C(\alpha, \alpha)$ reaction[20], that this last state at $E_x = 6.92$ MeV in ^{16}O belongs to the same rotational band as the 0^+, 6.06 MeV state; the widths of the band suggested to the authors an α-particle cluster configuration for these excited states. In ref. (21) the same band is interpreted as a mixture of deformed two particles-two holes and four particles-four holes states with the usual spherical shell-model ground state, and therefore of great interest from the quartet point of view. (One must remember that in ref. (3) the potential interaction $V_{p, sd}$ is fixed just by setting the one quartet-one quartet hole excitation energy equal to the excitation energy of this band-head, i.e. 6.06 MeV).

On the other hand, the refined measurements of Hellborg and Ask[15] show that in some cases the 6.92 MeV γ-ray (γ_2) resonates at slightly different energies than the 6.13 MeV (γ_1) and 7.12 MeV (γ_3) ones, but not at the same energies at which α_π does. In our measurements no common decay via α_π and α_2 has been observed at all, so the claimed hypothesis cannot be confirmed at an high degree of reliability.

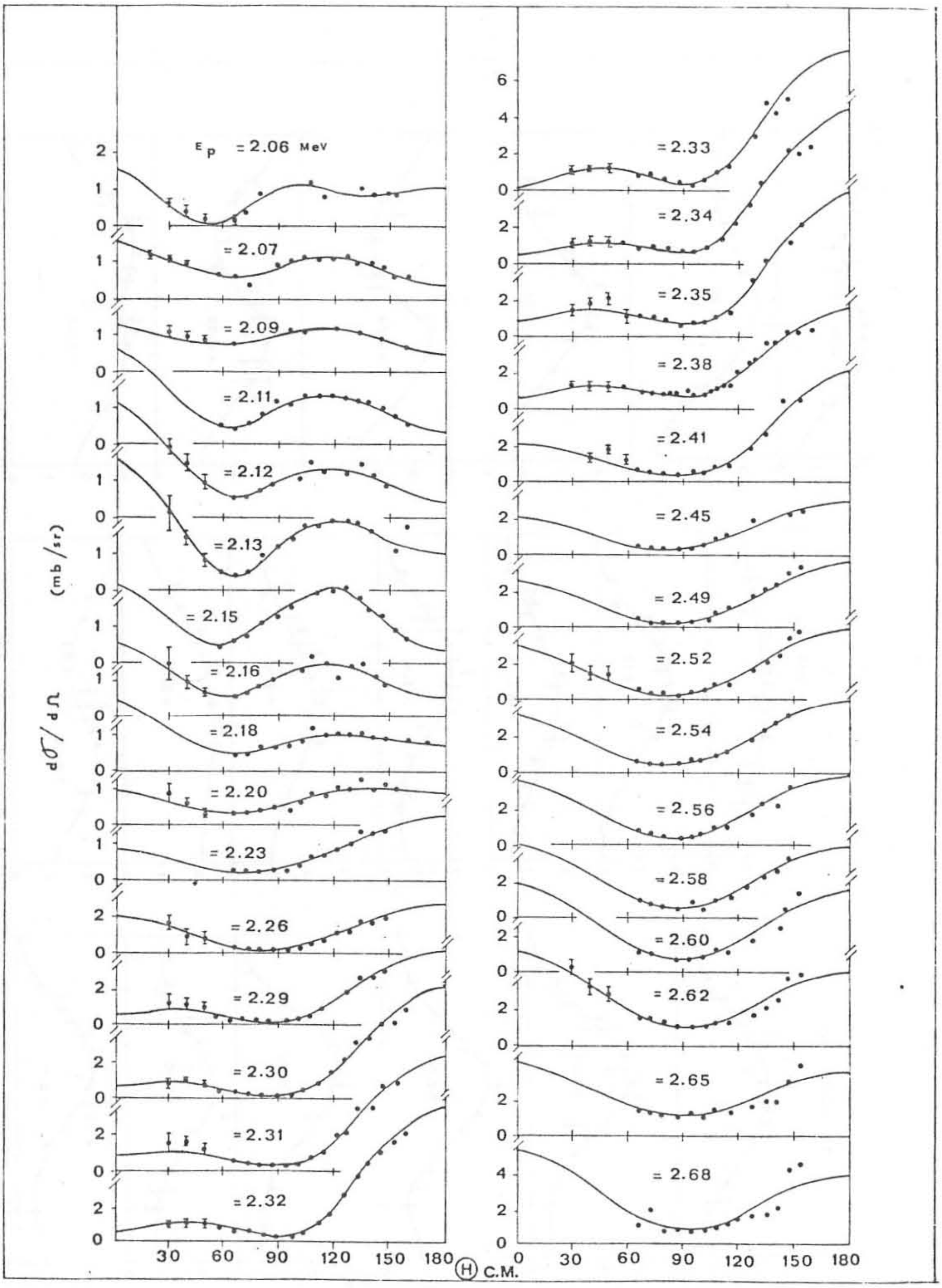

FIG. 9 - Angular distributions for the α_0-group in the energy range $2.06 \leq E_p \leq 2.68$ MeV. The curves are Legendre Polynomial fits with different values of ν_{max} (see text).

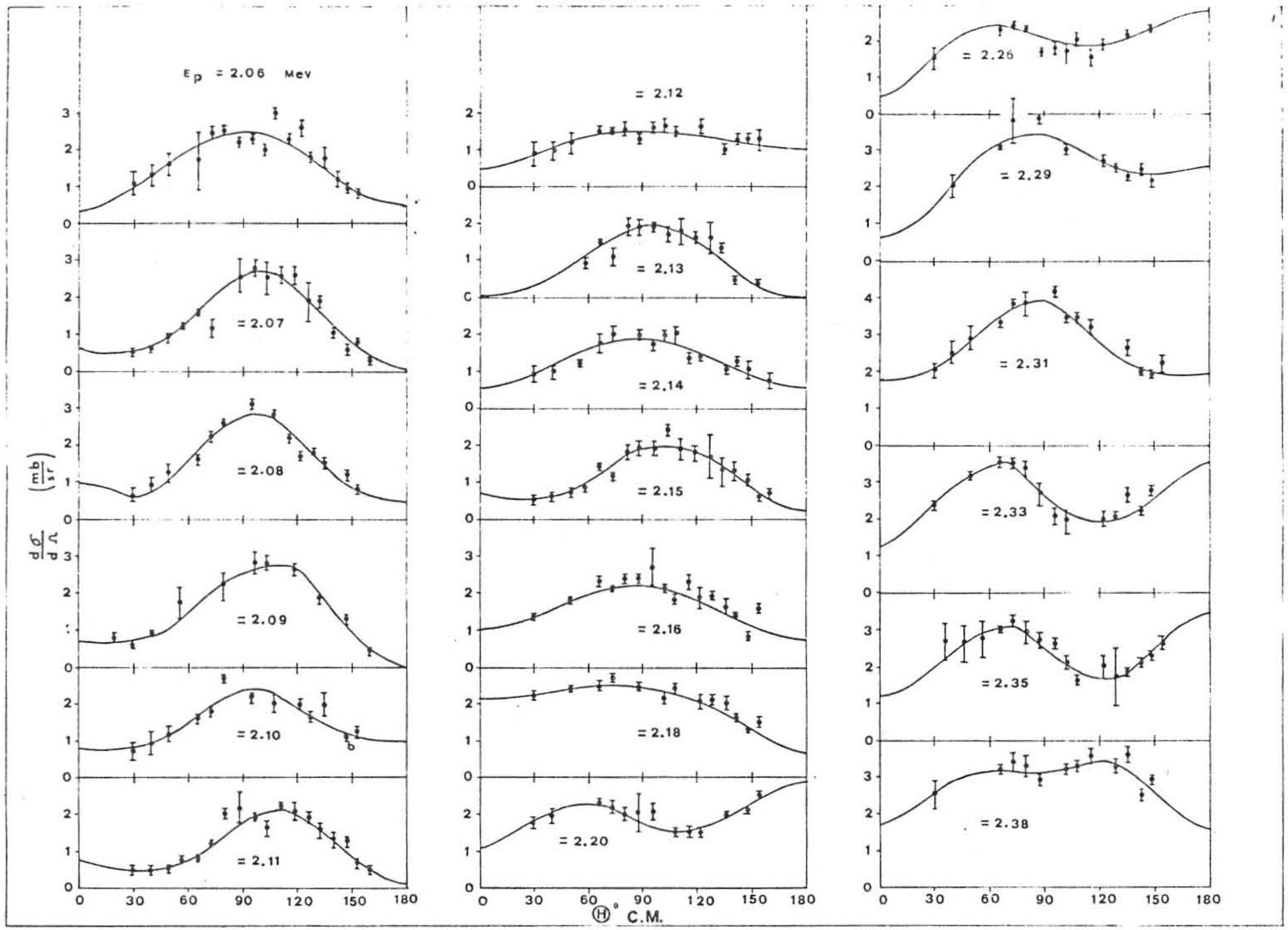

FIG. 10 - Angular distributions of the α_{π}-group in the energy range $2.06 \leq E_p \leq 2.38$ MeV. The curves are Legendre Polynomial fits with different values of ν_{max} (see text).

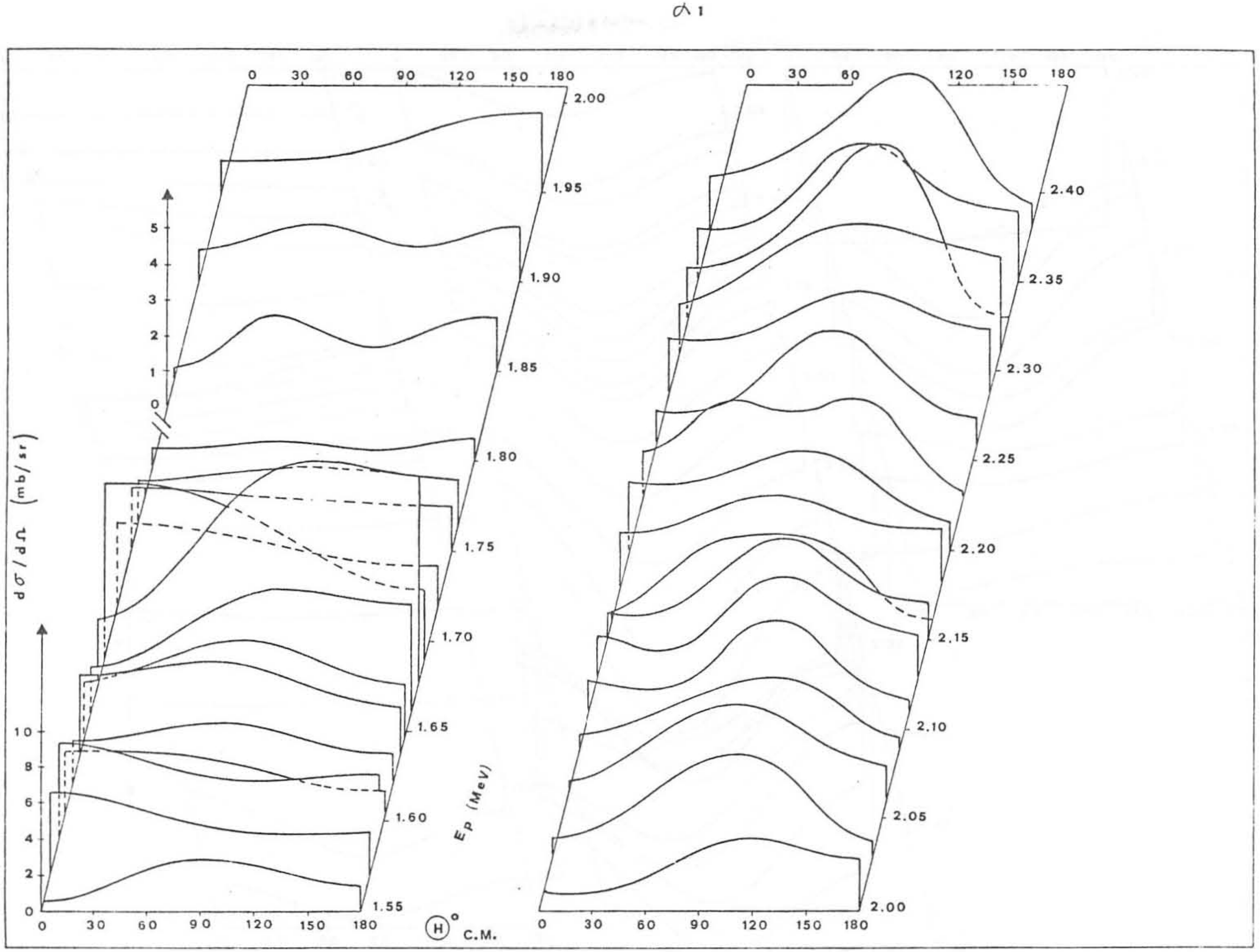

FIG. 11 - Legendre Polynomial fits with different values of ν_{max} (see text) of the angular distributions of the α_1-group, in the energy range $1.55 \leq E_p \leq 2.38$ MeV.

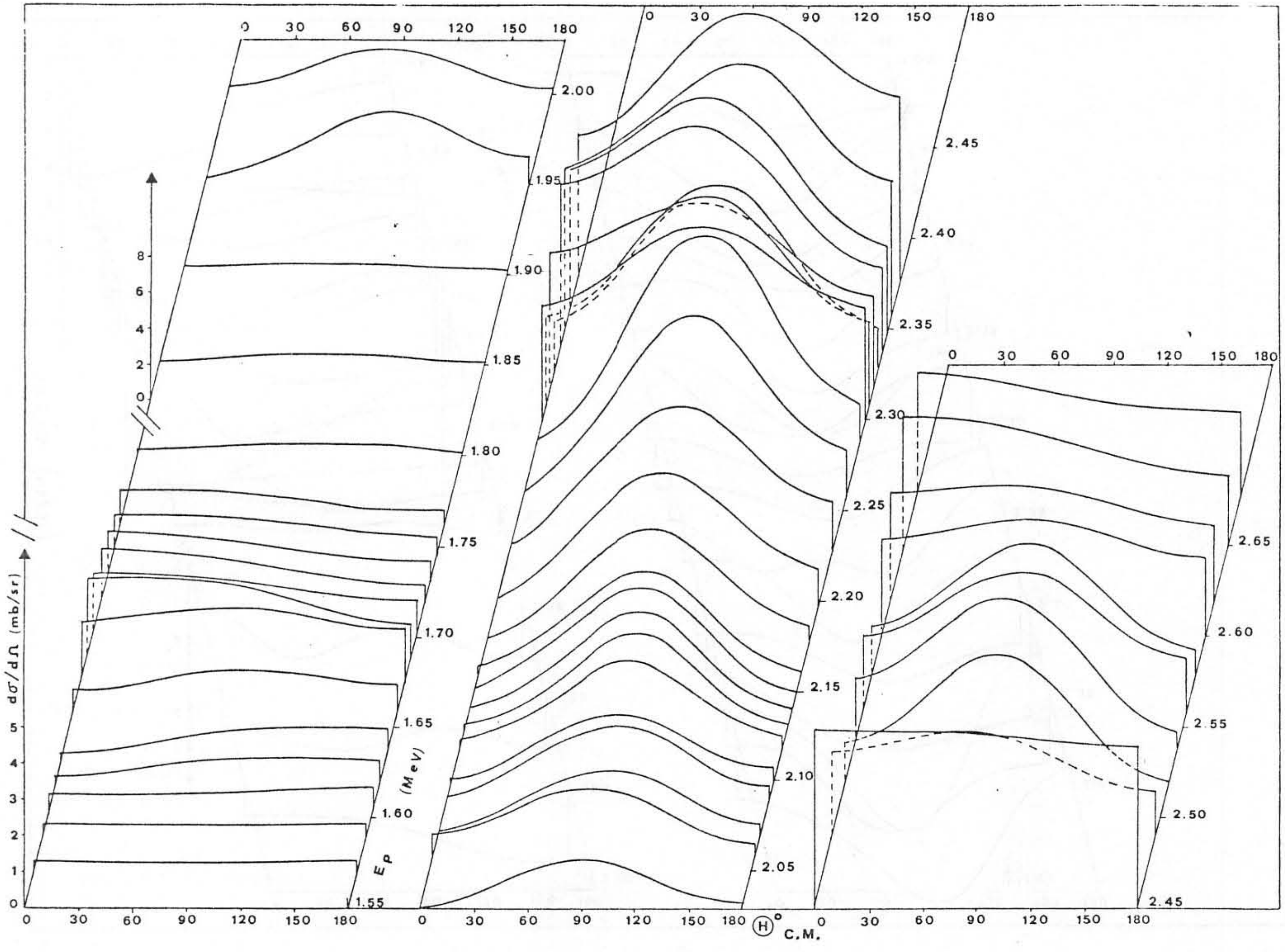

FIG. 12 - Same as Fig. 11 for the α_2-group in the energy range $1.55 \leq E_p \leq 2.68$ MeV.

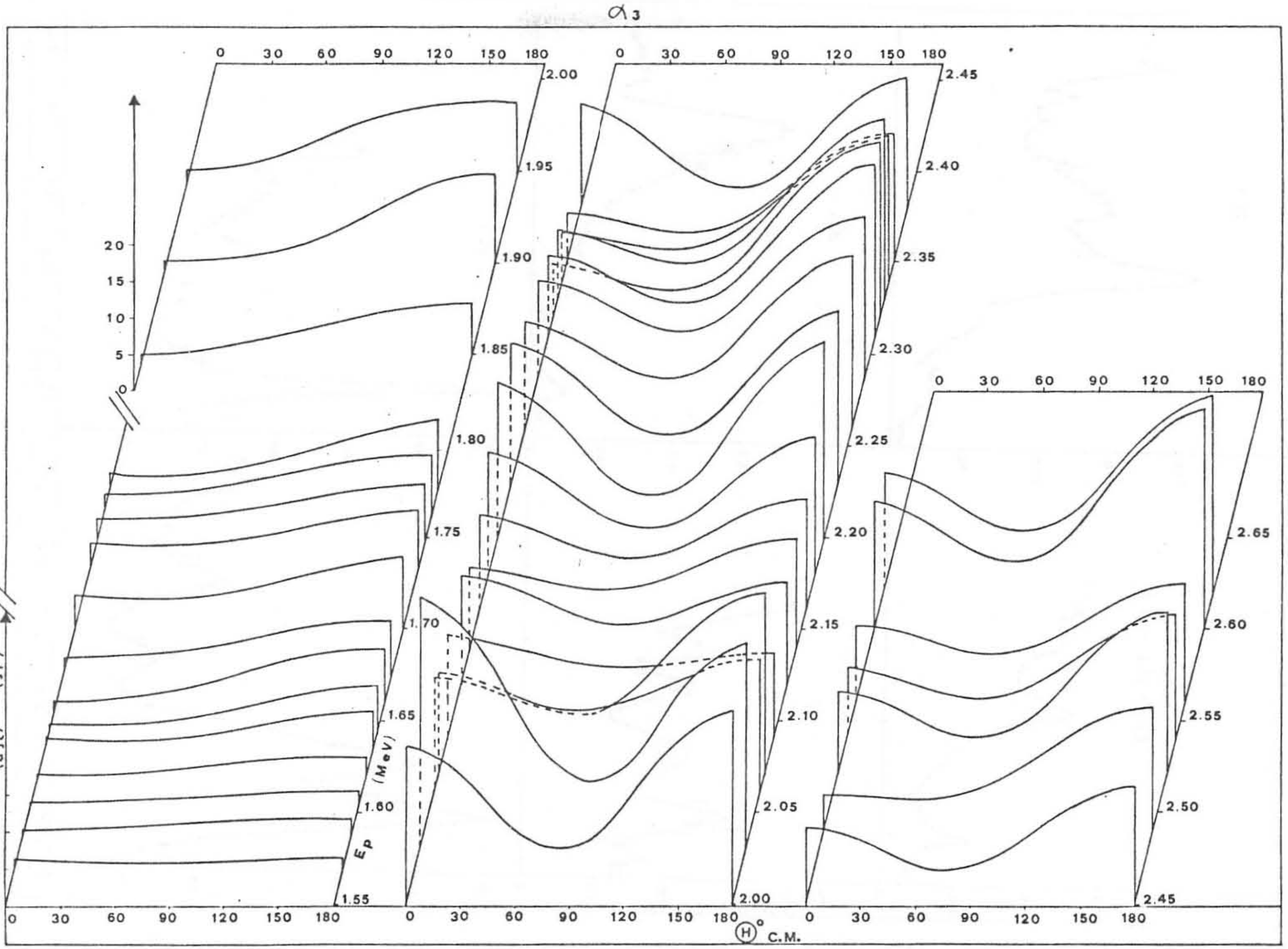

FIG. 13 - Same as Fig. 12 for the α_3-group.

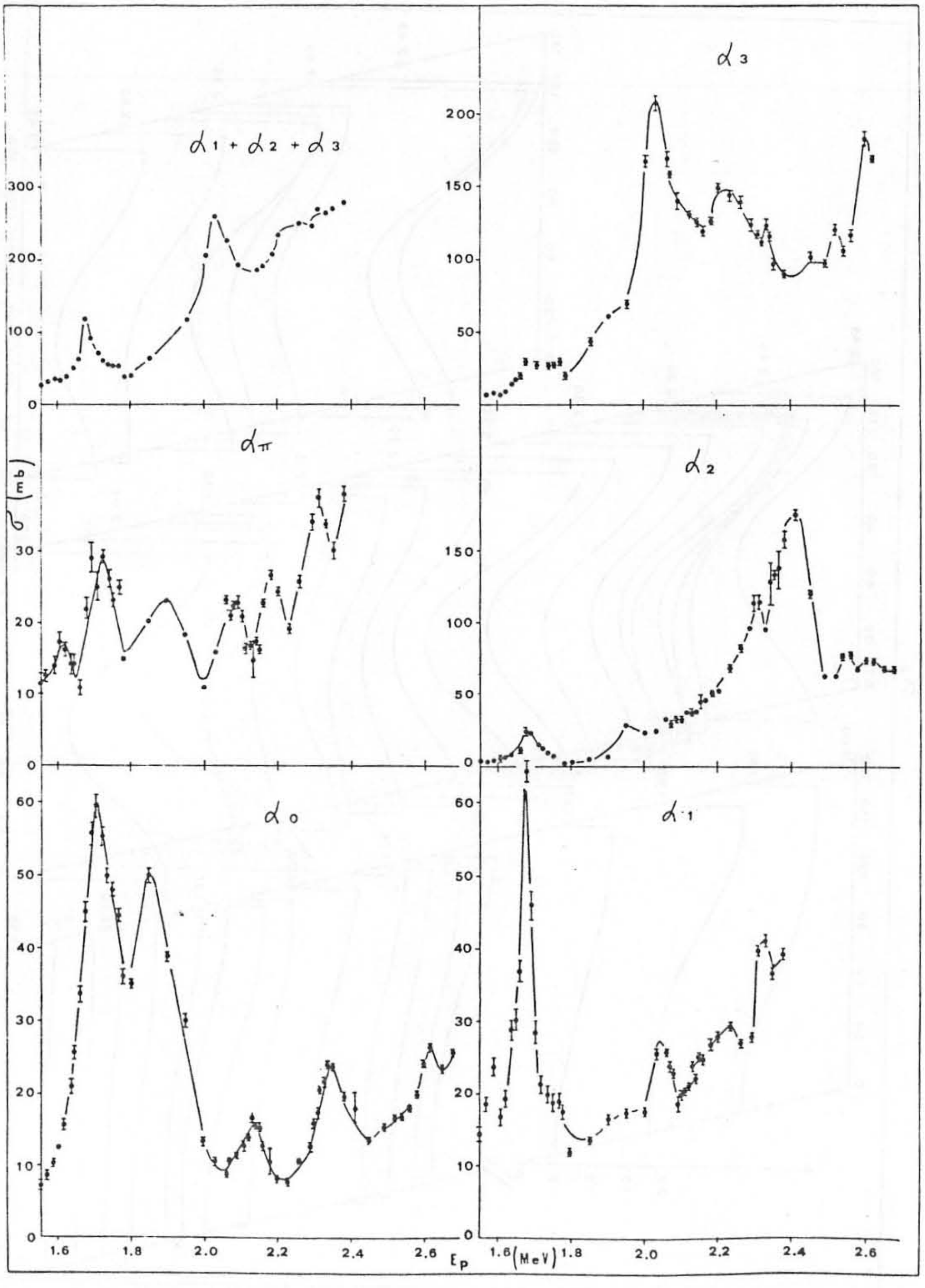

FIG. 14 - Integrated cross-sections versus the incident proton energy for the $\alpha_0, \alpha_\pi, \alpha_1, \alpha_2, \alpha_3$ and $\alpha_1 + \alpha_2 + \alpha_3$ (γ-emitting levels)-groups in the energy range $1.55 \leq E_p \leq 2.68$ MeV.

4.2. - 0^+ states.

4.2.1. - Resonances at $E_p \simeq 1.115$ and $\simeq 1.355$ MeV.

Our data in these regions are not enough to carry a complete independent analysis, but, as we pointed out in subsection 3.1, they agree well with the ones reported by Isoya et al.[11, 13]. Also the coefficients of cos $\theta_{C.M.}$, shown in Fig. 15 together with the integrated cross-sections,

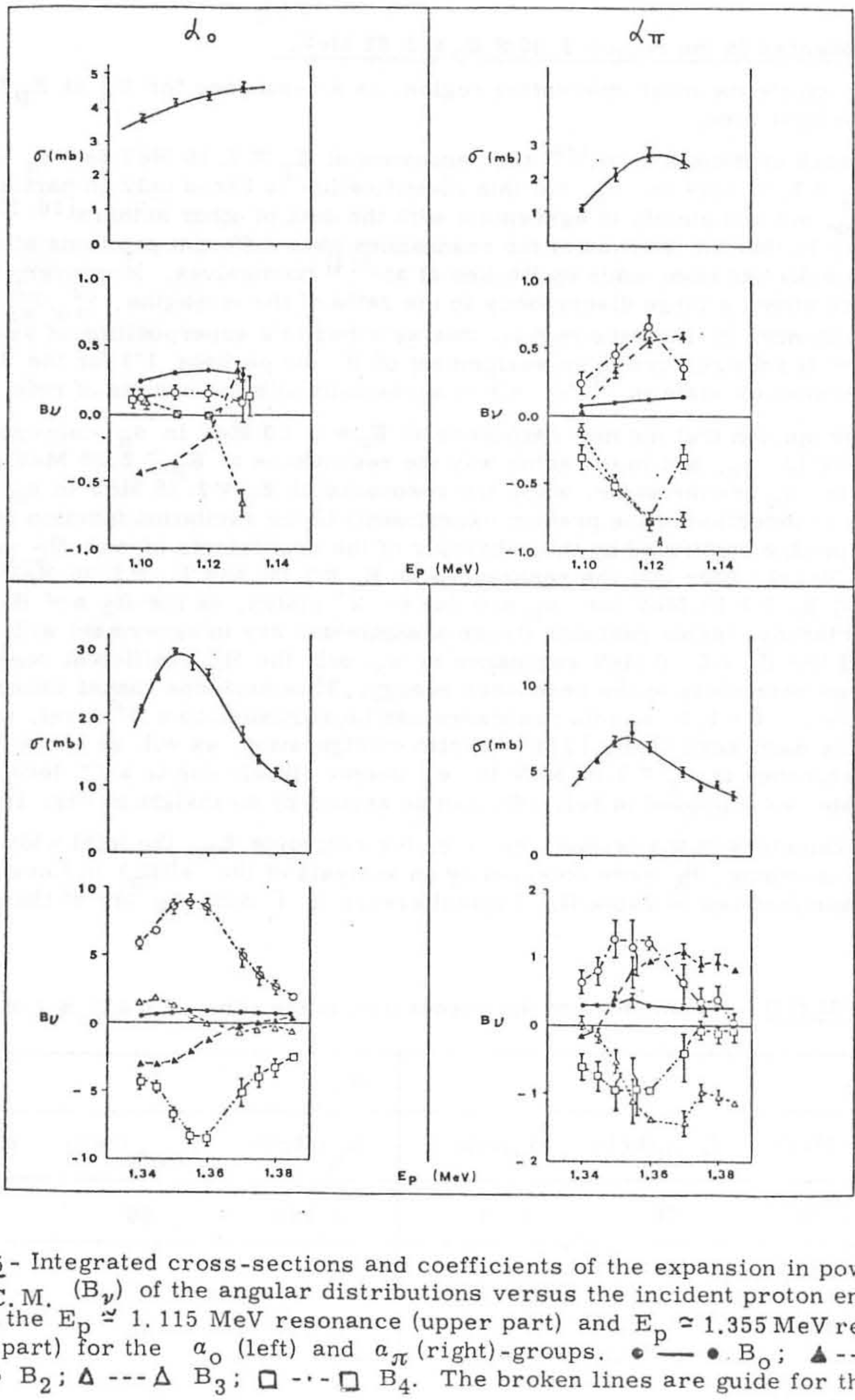

FIG. 15 - Integrated cross-sections and coefficients of the expansion in powers of cos $\theta_{C.M.}$ (B_ν) of the angular distributions versus the incident proton energy around the $E_p \simeq 1.115$ MeV resonance (upper part) and $E_p \simeq 1.355$ MeV resonance (lower part) for the α_0 (left) and α_π (right)-groups. ● —— ● B_0; ▲ --- ▲ B_1; o -·- o B_2; Δ --- Δ B_3; □ -·- □ B_4. The broken lines are guide for the eye.

have a behaviour very similar to that reported by these authors. The assignments of 2^+ for the J^{π} of both these intermediate states are therefore confirmed. The values of the partial (Γ_i) and reduced (γ_i^2) widths can be read in ref. (11). They show that, expecially in the second case, the γ_p^2 are larger than the $\gamma_{\alpha_o}^2$ and $\gamma_{\alpha_\pi}^2$.

On the other hand, no large anomalies appear in the elastic scattering data(4, 22, 23), as the ones observed in the region around E_p = 1.35 MeV are clearly ascribed(23, 24) to the neighbouring 2^- states, which produce resonances in the (p, $\alpha\gamma$) excitation function at E_p = 1.346 and E_p = 1.372 MeV. Therefore the wave functions of these states must contain large mixtures of different components.

4.2.2. - Resonances in the region $2.00 \leq E_p \leq 2.68$ MeV.

This is surely the most interesting region, as a resonance for α_π at $E_p \simeq 2.08$ MeV is reported for the first time.

In the work of Ranken et al.(14) the resonance at $E_p \simeq 2.18$ MeV for α_π is identified with the one at $E_p \simeq 2.13$ MeV in α_o, but this identification is based only on partial yield at Θ_{LAB} = 90^o for α_o, not completely in agreement with the data of other authors(16, 17). One can note from Figs. 9, 10 that the maxima of the resonances have different positions at different angles; the same remarks has been made by Ranken et al. (14) themselves. Moreover, they noted that this resonance shows a large discrepancy in the ratio of the strengths $\gamma_{\alpha_o}^2/\gamma_{\alpha_\pi}^2$ with respect to the other resonances in the same region, this ascribed to a superposition of several resonances. This argument led the authors to an assignment of 0^+ (or perhaps 1^-) for the J^π of the corresponding intermediate state in ^{20}Ne, not in agreement with the results of refs. (16, 17).

It is our opinion that the new resonance at $E_p \simeq 2.08$ MeV in α_π corresponds to that at $E_p \simeq 2.13$ MeV in α_o, and in the same way the resonances at $E_p \simeq 2.30$ MeV in α_π and at $E_p \simeq 2.35$ MeV in α_o are the same, while the resonance at $E_p \simeq 2.18$ MeV in α_π has no partners (in the limits of detection of the present experiment) in the excitation function of α_o. This interpretation is also confirmed by the behaviour of the coefficients of cos $\theta_{C.M.}$ shown in Fig. 16. One can clearly infer that the resonances at $E_p \simeq 2.08$ and $E_p \simeq 2.30$ MeV for α_π and at $E_p \simeq 2.13$ and $E_p \simeq 2.35$ MeV for α_o are due to 2^+ states, as the B_2 and B_4 coefficients and also the interference terms resonate (these assignments are in agreement with those of ref. (17)). In the case of the $E_p \simeq 2.18$ MeV resonance in α_π only the B_o coefficient resonates; all the other ones cross zero close to the resonance energy. This excludes casual cancellations of the terms relative to ℓ = 1, 2, so this resonance can be attributed to a 0^+ level, with all the characteristics of the band-head of the |211| quartet configuration, as will be clear in the following. The broad resonance at $E_p \simeq 2.62$ MeV in α_o seems clearly due to a 1^- level; no interference with a 0^+ state, as supposed in ref. (16), can be argued by an insight of Fig. 16.

The parameters of the resonances, i.e. the centroids E_R, the total widths Γ and the resonant cross-sections σ_R^i were obtained by an analysis of the $\sigma^i(E_p)$ in Lorentz functions; the results are summarized in Table II. Typical errors in Γ and σ_R are of the order of 15%.

TABLE II - Parameters of the resonances in the range $2.0 \leq E_p \leq 2.45$ MeV.

α_π			α_o		
E_R(MeV)	Γ_{LAB}(keV)	σ_R(mb)	E_R(MeV)	Γ_{LAB}(keV)	σ_R(mb)
2.080	60	12.1	2.133	80	9.5
2.180	41	12.2			
2.303	70	17.0	2.347	95	17.9

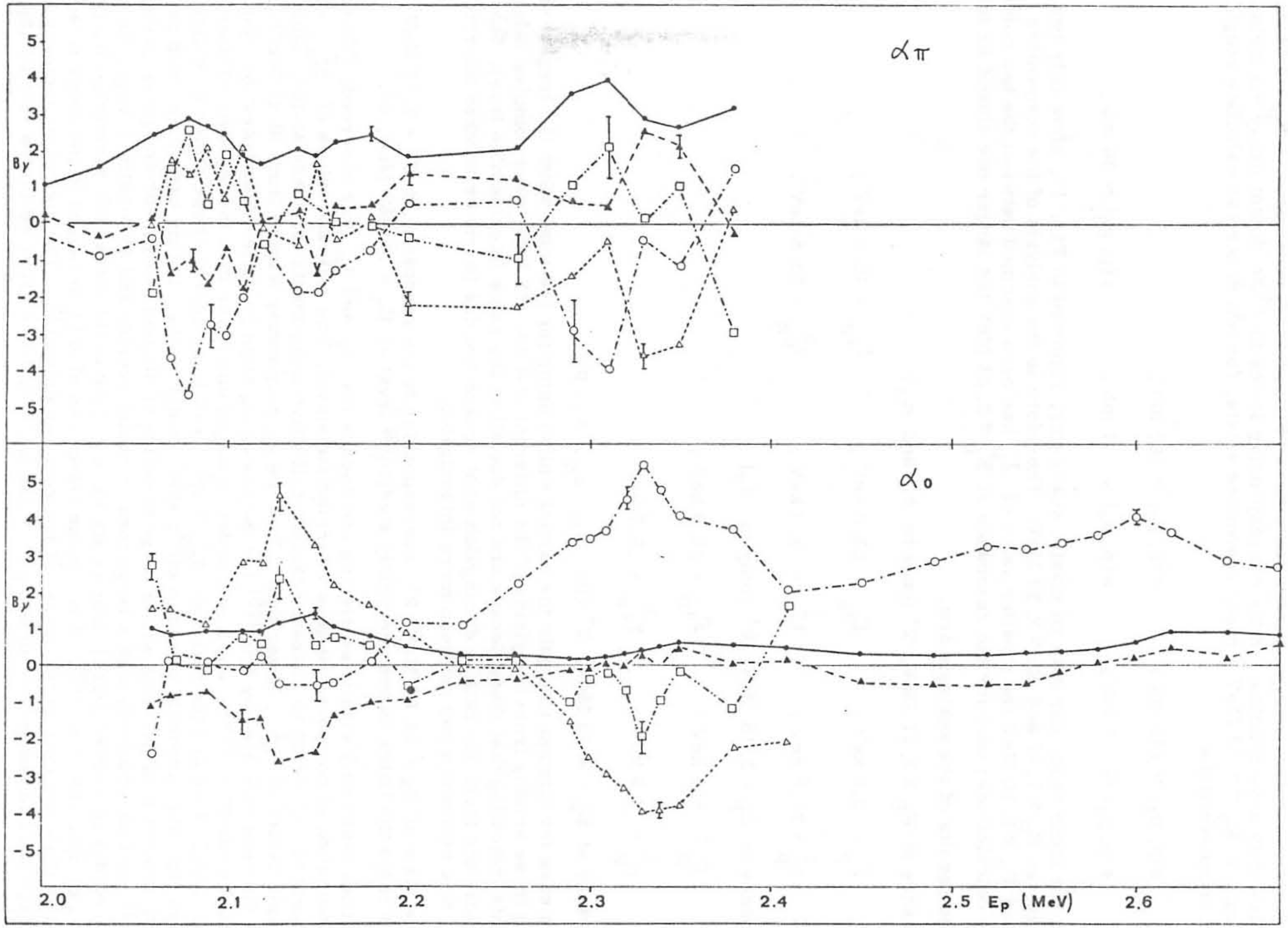

FIG. 16 - Coefficients of the expansion in powers of cos $\theta_{C.M.}$ (B_ν) of the angular distributions for the α_o (lower part) and α_π (upper part)-groups in the energy range $2.0 \leq E_p \leq 2.68$ MeV. • — • B_o ; ▲ --- ▲ B_1 ; o -.-.- o B_2 ; Δ --- Δ B_3 ; □ -..-..- □ B_4. The broken lines are intended as a guide for the eye.

In order to obtain the reduced widths, γ_i^2, the partial widths Γ_i and therefore the cross-sections σ_R^i must be known for all the possible decays of the intermediate levels. In this energy region, besides the elastic scattering and the α-emission, the inelastic scattering to the first five low excited levels in ^{19}F is present. It has been studied again by Ranken et al.(14), who gave the excitation functions of low energy γ-rays from the $^{19}F(p, p')^{19}F^*$ reaction. At $E_p \simeq 2.11$ and $E_p \simeq 2.18$ MeV they show minima, so the corresponding states in ^{20}Ne do not decay via inelastic scattering; only at $E_p \simeq 2.33$ MeV a clear resonance exists, for which one can calculate roughly the inelastic cross-sections:

$$\sigma(p, p_1) \sim 145 \text{ mb} ; \qquad \sigma(p, p_2) \sim 100 \text{ mb} ;$$

$$\sigma(p, p_3) \sim 7 \text{ mb} ; \qquad \sigma(p, p_4) \sim 7 \text{ mb} ; \qquad \sigma(p, p_5) \sim 30 \text{ mb} .$$

On the other hand, our data on elastic scattering, reported in Fig. 17, show only two large anomalies, at $E_p \simeq 1.97$ and $E_p \simeq 2.33$ MeV. Therefore in the analysis of the resonances at $E_p \simeq 2.11$ and $E_p \simeq 2.18$ MeV the smaller value of Γ_p has been assumed between the two coming out from the calculations; only for the resonance at $E_p \simeq 2.33$ MeV the larger one should be taken.

The results of the analysis are:

a) Resonance at $E_p \simeq 2.11$ MeV, 2^+ (only in α_o and α_π)

$$\Gamma_p = 3.0 \text{ keV} ; \qquad \Gamma_{\alpha_0} = 33.0 \text{ keV} ; \qquad \Gamma_{\alpha_\pi} = 42.0 \text{ keV} ;$$

$$\gamma_p^2 = 25.0 \text{ keV} ; \qquad \gamma_{\alpha_0}^2 = 3.3 \text{ keV} ; \qquad \gamma_{\alpha_\pi}^2 = 23.5 \text{ keV} .$$

b) Resonance at $E_p = 2.18$ MeV, 0^+ (only in α_π)

$$\Gamma_p = 5.0 \text{ keV} ; \qquad \Gamma_{\alpha_\pi} = 35.0 \text{ keV} ;$$

$$\gamma_p^2 = 3.9 \text{ keV} ; \qquad \gamma_{\alpha_\pi}^2 = 9.7 \text{ keV} .$$

c) Resonance at $E_p = 2.33$ MeV, 2^+ (in α_o, α_π, α_γ, p')

In this case the attempt to obtain the partial widths using for the total width the largest value among those arising from the yields of the different α-lines (95 keV) gave complex values for Γ_p, this indicating that these decays are not due all to the same intermediate level. Since it is impossible from our data to distinguish what decays are due to one or another intermediate state, this resonance has not been more investigated.

The state at $E_x = 14.85$ MeV, 2^+, corresponding to the resonance at $E_p = 2.11$ MeV, shows the same characteristics as the previously studied(6) level at $E_x = 14.467$ MeV, 0^+.

In both cases only elastic scattering and decays via α_o and α_π are observed, this excluding the formation of compound nucleus intermediate states. The relevant values of $\gamma_{\alpha_0}^2$ and $\gamma_{\alpha_\pi}^2$ with respect to γ_p^2 seem to indicate relevant collective components for these states. Moreover, the absolute values of $\gamma_{\alpha_0}^2$, lower than 1% of the corresponding Wigner limit (0.59 MeV), are similar to the ones indicated by Vogt(25) for the low-lying eight particles-four holes (8p - 4h) rotational "super band" in ^{20}Ne, about one order of magnitude lower than the adjacent cluster (four particles) band. This and the fact that $\gamma_{\alpha_\pi}^2 > \gamma_{\alpha_0}^2$ lead to assigne to these states a configuration of the type (8p - 4h), probably mixed to other shell model states. In this case they could belong to the |220| quartet configuration with a large breaking of aligned neutron-proton pairs in the Stretch scheme(1), and consequently with a large loss of radial overlap and symmetry energy. An alternate way to obtain so excited |220| quartet states is to look at the intrashell quartet excitations, as described by Satpathy et al.(26). If so, these states can also be arranged in the same rotational band, given the similarity of the values of the reduced widths(25). The enormous moment of inertia corresponding to the energy splitting of $\simeq 380$ keV has to be expected for so excited (8p - 4h) states(25).

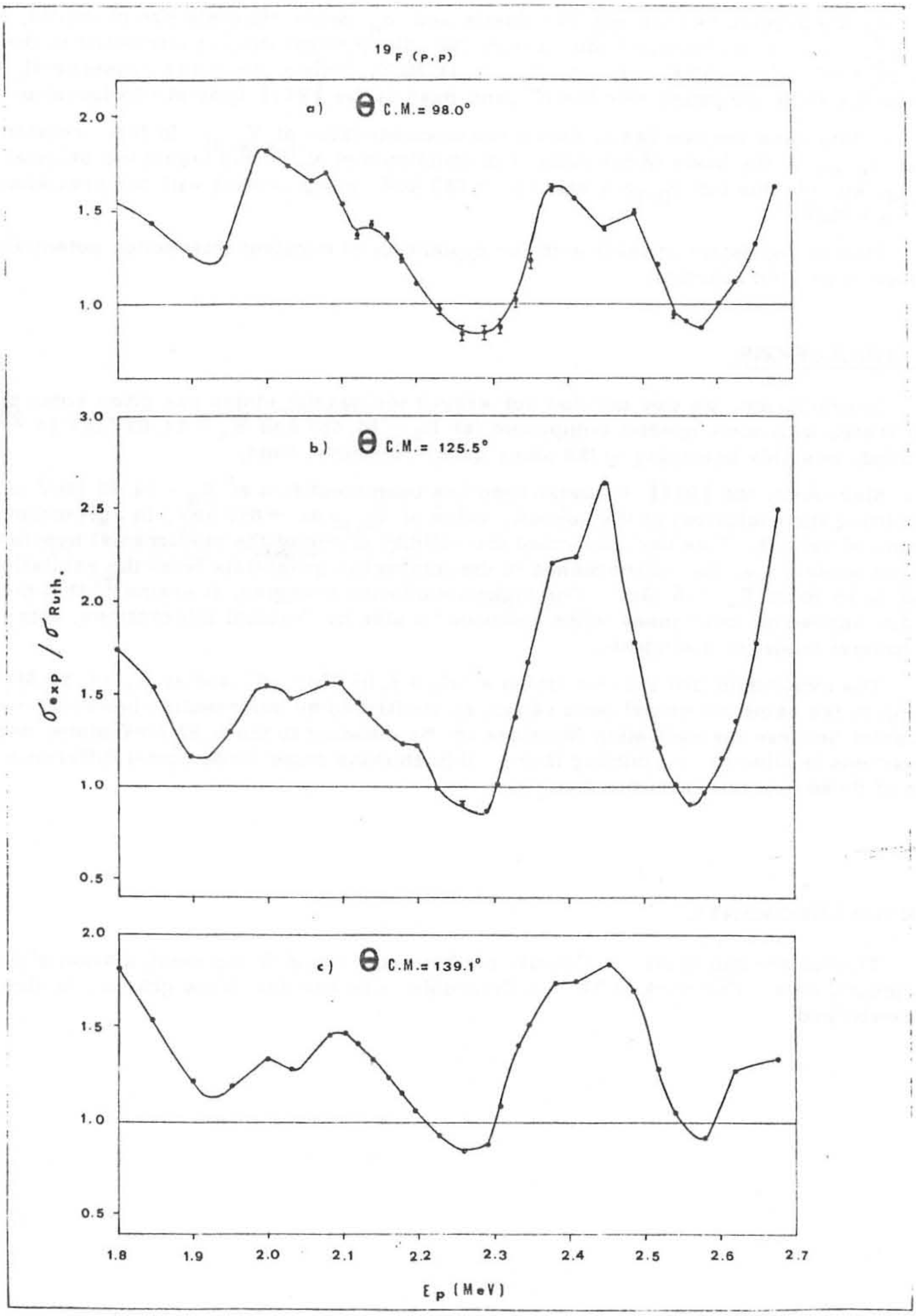

FIG. 17 - Ratio of the elastic to the Rutherford cross-section for the $^{19}F(p,p)^{19}F$ reaction in the energy range $1.8 \leq E_p \leq 2.7$ MeV at scattering angles of a) $\theta_{C.M.} = 98.0^o$, b) $\theta_{C.M.} = 125.5^o$ and c) $\theta_{C.M.} = 139.1^o$. The curves are intended only as a guide for the eye.

By the arguments that only the elastic and α_π decay channels are observed, with $\gamma^2_{\alpha_\pi} > \gamma^2_p$ and $\gamma^2_{\alpha_\pi} \sim 2\%$ of the Wigner limit, a pure (8p - 4h) configuration is attributed to the state at $E_x = 14.92$ MeV, 0^+, corresponding to E_p 2.18 MeV. This state shows consequently the highest probability to be identified with the 0^+ band-head of the $|211|$ quartet configuration.

In this case one can easily obtain the unknown value of $V_{p,pf}$. In fact, recalculating the value of $V_{p,sd}$ on the basis of the results of Middleton et al.(5) and taking the original value(3) for $V_{sd,pf}$, one obtains for $V_{p,pf}$ a value of ~ 650 keV, in agreement with the previsions of the model ($\lesssim 1$ MeV)(3).

This is consistent at least with the hypothesis of constant interaction potentials versus the number of excited quartets.

5. - CONCLUSIONS.

In conclusion, we can say that our search for quartet states has given some positive output. Two states with some quartet component (at $E_x = 14.467$ and $E_x = 14.85$ MeV in ^{20}Ne) have been found, possibly belonging to the same quasi-rotational band.

Moreover, the $|211|$ 0^+ band-head has been identified at $E_x = 14.92$ MeV in ^{20}Ne, this permitting the evaluation of the unknown value of $V_{p,pf}$ as ~ 650 keV, in agreement with the previsions of ref. (3). This has confirmed the validity of one of the fundamental hypotheses of the quartet model, i.e. the independence of the interaction potentials from the excitation energy, at least up to about $E_x = 15$ MeV. For higher excitation energies, it seems(7) that the quartet states are spread out over many other compound states by residual interactions, this implying that the quartet model is inadequate.

The hypothesis that the two states at $E_x = 6.06$ MeV, 0^+ and at $E_x = 6.92$ MeV, 2^+ in ^{16}O belong to the same rotational band cannot be confirmed by our results; however, some differences exist between the excitation functions of α_2 (leading to the 6.92 MeV state) and the other transitions leading to γ-emitting levels, this showing some fundamental difference in the structure of these opposite-parity states.

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