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C. Mencuccini, R. Querzoli, G. Salvini, V. Silvestrini:
PHOTOPRODUCTION AND RADIATIVE DECAY MODE OF THE 550 MeV PION RESONANCE (η PARTICLE).
(Presented to the 1962 International Conference on High Energy Physics at CERN).

Nota interna: n° 152
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SUMMARY

It is reported a first experimental evidence in favour of the existence of the photoproduction process

$$\gamma + p \rightarrow (\eta \text{ and/or } \zeta^0) + p$$

with the produced particle decaying into a radiative mode ($\gamma + \gamma$ or $\pi^0 + \gamma$).

The cross section observed for this process is of the order of 3-5 x 10^{-32} cm^2/ster.

1. - INTRODUCTION

The experimental results we are reporting here are the first part of a program we have undertaken at Frascati with the 1100 MeV electronsynchrotron in order to observe the possible radiative decay modes of some of the new "particles" (η, ζ, etc.: we will use in the following the collective R) which have been recently observed(1-3):

$$R \rightarrow \pi^0 + \gamma$$
(1)
$$R \rightarrow \gamma + \gamma$$

These resonances R have been studied by us in the photonuclear reaction

(2) $$\gamma + p \rightarrow R + p$$

with particular regard to the mass values in the interval

(3) $$500 \leq M_R \leq 580 \text{ MeV}$$

As we shall see in the following, we have observed a radiative decay of type (1) for a value of M_R close to 550. Considering that such radiative modes, so often proposed[4] were never observed before; and that their existence may allow a first conclusion on the relative position of the η and ζ resonances, we consider convenient to report here our results.

2. - EXPERIMENTAL DISPOSITION

Our results come until now mainly from the experimental disposition reported in fig. 1. Protons of a given energy (Range between R and R + ΔR) are detected by the proton telescope, which separates the protons from the pions through Cerenkov threshold in Cpl and measurements of ionization losses in counter 3,4. We count the coincidences

(4) $$P + (C_2 - A)$$

between the proton and a γ-ray entering the integral (lead glass) Cerenkov Counter C_2. The size of the pulse in C_2 is registered on a multichannel analyzer, using a technique similar to that used by Gomez and coll.[5].

Once the momentum (range and direction) of the proton has been fixed, the energy of the initial photon as well as the line of flight MN (see fig. 1) and the energy of R are a function only of M_R. It follows that, for a

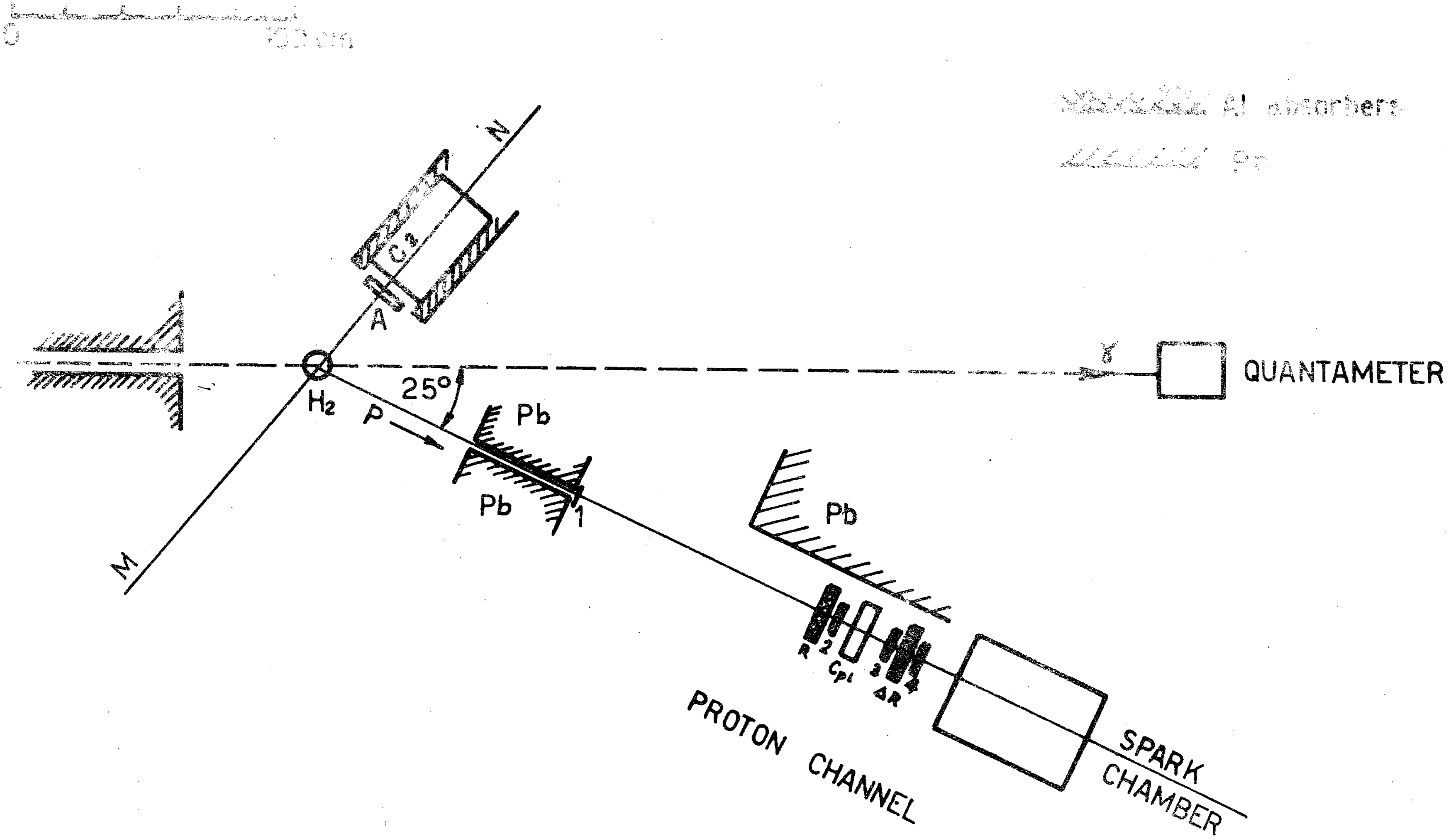

FIG. 1 – FRASCATI η_0 – EXPERIMENTAL DISPOSITION

given value of M_R, the single γ-ray emitted in the decay of a R particle in the mode $\gamma+\gamma$ (or $\pi^0+\gamma$) has an energy which depends only on its angle of emission.

Thus the presence of a radiative decay of a single mass M_R shall appear in the pulse height distribution in C_2 as a peak, whose width will depend on the spatial and energy resolution of the experimental disposition. In our case the experimental width is due almost completely to the energy resolution of the Cerenkov C_2. The energy of the peak is of course connected with the mass M_R.

The disposition was prepared and calculated for an interval of masses as given in (3), without any apriori selection in favour of the existing particles.

If a "mass" decaying in a $\pi^0+\gamma$ or $\gamma+\gamma$ mode has been suggested by this kind of measurements we can cheek its existence by an excitation curve[5,6].

In fact the peak should desappear when the energy of the synchrotron is brought below the threshold for production of R, with the recoil proton at the fixed energy and angle.

Our measurements were taken above and below this threshold at both of the two kinematical conditions chosen, shown in fig. 2 (heavy lines labelled 1 and 2).

3. - RESULTS

Our results are reported in fig. 3a, b, c, d; the four different kinetic conditions are summarized in the table I. In the abscissa we report the decay γ-ray energy ω_γ. It is important to know that our Cerenkov C_2 was calibrated with monochromatic electrons up to 660 MeV, and the energy resolution of this counter resulted to be ± 15% at 500 MeV. In the ordinate we give the yield (number of counts)

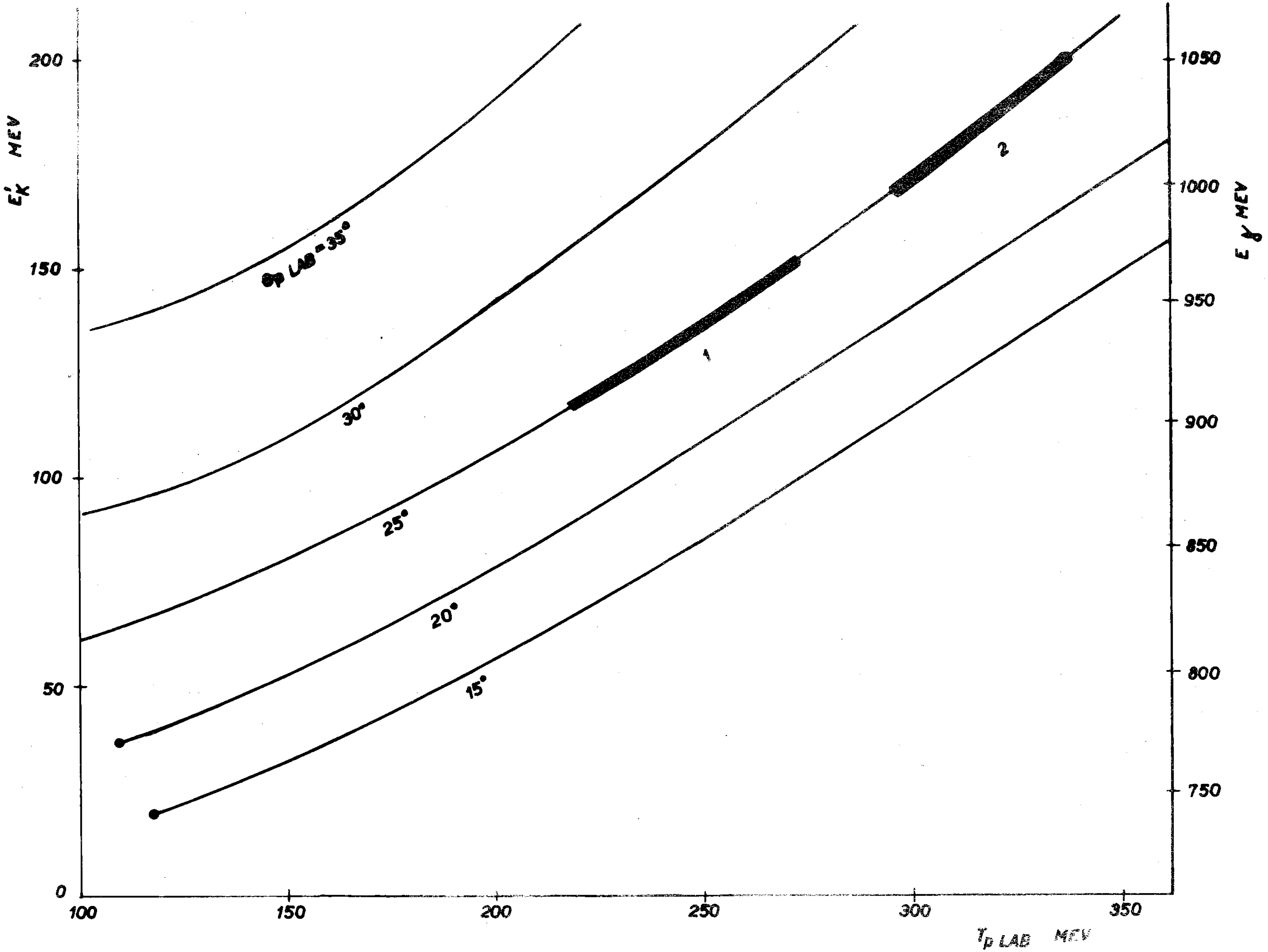

FIG. 2 - KINEMATICS OF THE REACTION, $\gamma + p \longrightarrow \eta^{\circ} + p$ FOR A MASS m_η = 550 MeV.
ORDINATES : LEFT KINETIC ENERGY IN THE C.M.S. ; RIGHT ENERGY OF THE γ
ABSCISSA : LABORAT. PROTON KINETIC ENERGY

TABLE I

Kinematics of the experiments whose results are reported in fig. 3a, 3b, c, d, By ΔE we mean the energy interval of the photons producing the R particle. Yies (no) means that the R particle can (cannot) be produced.

Fig.	Maximum energy of the ray beam (MeV)	Proton energy (MeV)	E	R (M_R 550$\pm$30)
3 a	1000	221 ⟷ 270	60 MeV	yes
3 b	900	221 ⟷ 270		no
3 c	1070	295 ⟷ 340	60 MeV	yes
3 d	1000	295 ⟷ 340		no

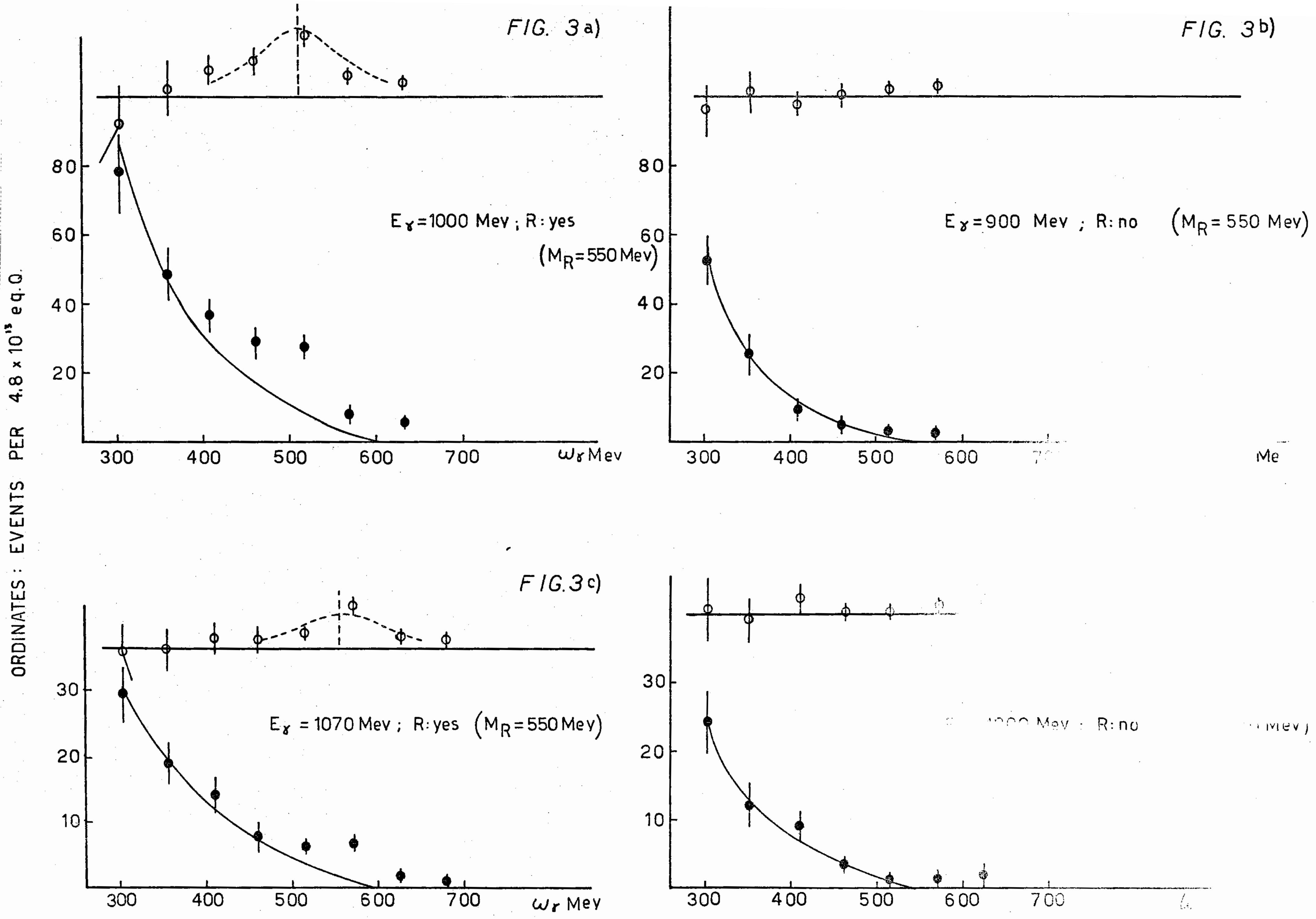
FIG. 3a)
E$_\gamma$=1000 Mev ; R: yes
(M$_R$=550 Mev)
FIG. 3b)
E$_\gamma$=900 Mev ; R: no (M$_R$=550 Mev)
FIG. 3c)
E$_\gamma$ = 1070 Mev ; R: yes (M$_R$=550 Mev)
R: no
ω_γ Mev
ORDINATES : EVENTS PER 4.8 × 10^{13} eq.Q.

similar to that measured by Cocconi[8] for the charged pions.

In this way, by adding the contributes A and B, we get the shape of the spectrum of the γ's, corresponding to the conditions of fig. 3a, due to the neutral double pion production. This spectrum normalized to the experimental points is represented from the continuous line of fig. 3a. We are confident that the difference between the experimental results and this line represents the contribute due to the reaction (2). A strictly similar procedure was used to obtain the full line of fig. 3c. In each figure 3, above, we have reported this difference, that is the contribute of reaction (2): this contribute is of course inexistent in fig. 3b, 3d, quite appreciable in 3a, 3c.

The dashed line in the upper part of fig. 3a, 3c is an estimate of the cross section. In fact it is the expected shape (with the experimental resolution folded in) of the γ peak from the decay of a R particle, in the following cases:

1000 MeV (fig. 3a): either $\frac{d\sigma}{d\Omega} = 2.5 \times 10^{-32}$ cm^2/ster; $M_R = 520$; $R \rightarrow \gamma + \gamma$

or $\frac{d\sigma}{d\Omega} = 5 \times 10^{-32}$ cm^2/ster; $M_R = 550$; $R \rightarrow \pi^0 + \gamma$

1070 MeV (fig. 3c): either $\frac{d\sigma}{d\Omega} = 1.5 \times 10^{-32}$ cm^2/ster; $M_R = 520$; $R \rightarrow \gamma + \gamma$

or $\frac{d\sigma}{d\Omega} = 3 \times 10^{-32}$ cm^2/ster; $M_R = 550$; $R \rightarrow \pi^0 + \gamma$

We cannot decide among the two alternatives, consi dering that the absolute calibration of the Cerenkov C_2 has an error of $\sim 5\%$.

We must observe that it would be very difficult to explain the shape of our "swelling" in any other way than a process of type (2), in particular due to the well known flat shape of the spectrum of the γ's from the decay of the π^0's.

The easiest explanation of our results is therefore that we are in presence of one of the following processes:

$$(7) \qquad \begin{array}{l} \gamma + p \rightarrow p + (\gamma + \gamma) \\ \gamma + p \rightarrow p + (\pi^0 + \gamma) \end{array}$$

the ($\gamma+\gamma$) or ($\pi^0+\gamma$) group being the decay product of a R particle of a mass in the interval

$$(8) \qquad \begin{array}{ll} 500 \leq M_R \leq 550 & \text{if } \gamma + \gamma \\ 530 \leq M_R \leq 580 & \text{if } \pi^0 + \gamma \end{array} .$$

In the frame of our present knowledge we assume that R can be either an η (1-3) or a ζ^0 (2) particle (if the ζ^0 exists).

For complete information, we add that a measurement is in progress with a spark chamber on the P telescope, in the position indicated in fig. 1.

Still with poor statistics, the results are in agreement with the range measurements in fig. 3.

Another measurement is in progress, with another Cerenkov counter at 180° respect to C_2.

4. - DISCUSSION OF THE RESULTS

a) As already said, we cannot yet distinguish among the four possible modes

$$\eta \rightarrow \gamma + \gamma \qquad \eta \rightarrow \pi^0 + \gamma$$

$$\zeta^0 \rightarrow \gamma + \gamma \qquad \zeta^0 \rightarrow \pi^0 + \gamma$$

Still, from our results we can already extract the conclusion that

(9) $$\eta \neq \zeta^0$$

or, in words, that the η cannot be identified as the $T_3 = 0$ mode of the ζ particle, which seems to have definitely $T = 1$[2].

The logic of this can be found (notwithstanding the expectation was perhaps the opposite) in a recent paper by M. Ross[9]: among all the possible solutions we can have $\eta \equiv \zeta^0$ only in the case 1^-, $C = +1$ (spin 1, negative parity, positive charge conjugation), and this mode does not allow either a decay $\gamma + \gamma$ or a decay $\pi^0 + \gamma$ (x).

b) We cannot give the branching ratio between our radiative mode and the already discovered pion mode $\pi^0 + \pi^+ + \pi^-$. Let's only say that our values (6) of the cross section (whose estimate may be wrong by a factor 2), when multiplied by $\hbar c/e^2$ (our particles are photoproduced) gives a value not very different from the corresponding value for neutral decay as given by Bastian and cow.[3] for the particles produced in strong interactions. It's not excluded therefore that most of the contribute of the neutral decays is due to the radiative decay mode we observe.

c) The existence of a radiative decay excludes for the particle we observe the states $0^{\pm}$, $C = -1$; $1^{\pm}$, $C = +1$.

We are working at present to distinguish the $\gamma + \gamma$

(x) - We are grateful to Dr. N. Cabibbo for having indicated this conclusion to us.

from the $\pi^0 + \gamma$ mode. This distinction will allow the determination of the spin value (0 or 1) of the particle or resonance we are observing.

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