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A FIRST EVIDENCE OF A RADIATIVE DECAY MODE OF THE INTERMEDIATE PION RESONANCE (M~550 MeV)

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(presented by G. Salvini)

I. INTRODUCTION

The experimental results we are reporting here are the first part of a program we have undertaken at Frascati with the 1100 MeV electron synchrotron in order to observe the possible radiative decay modes of the η particle [1-3]:

$$\begin{aligned} \eta &\to \pi^0 + \gamma \\ \eta &\to \gamma + \gamma \end{aligned} \tag{1}$$

This resonance has been studied by us in the photo-nuclear reaction:

$$\gamma + p \to \eta + p \tag{2}$$

with particular regard to the mass values in the interval

$$500 \leqq M \leqq 580 \text{ MeV} \tag{3}$$

As we shall see in the following, we have observed a radiative decay of type (1) for a value of M close to 550. We must underline that we cannot distinguish between an η and a ζ_0 particle, if a ζ particle exists [2,4]. We will use in the following for η, ζ_0: the collective R.

II. 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 $R+\Delta R$) are detected by the proton telescope. We count the coincidences

$$P + (C_2 - A) \tag{4}$$

between the proton and a γ-ray entering the integral (lead glass) Čerenkov 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 *et al.* [5] The energy resolution of C_2 is $\pm 15\%$.

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 the η is a function only of its mass. It follows that, for a given value of the mass, the single γ-ray emitted in the decay of the η in the mode $\pi^0+\gamma$ (or $\gamma+\gamma$) has an energy which depends only on its angle of emission.

Thus the presence of a radiative decay of a single mass M_R will 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.

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

In fact the peak should disappear when the energy of the synchrotron is brought below the threshold

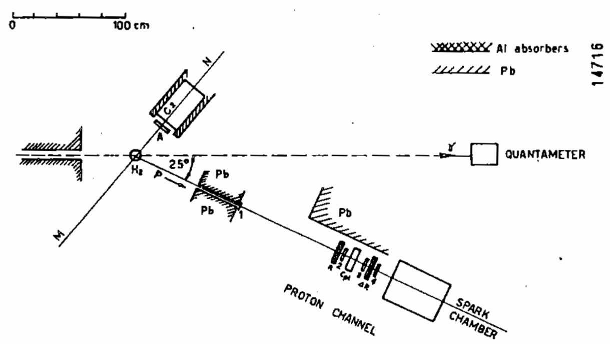

Fig. 1 Frascati η_0 experimental disposition.

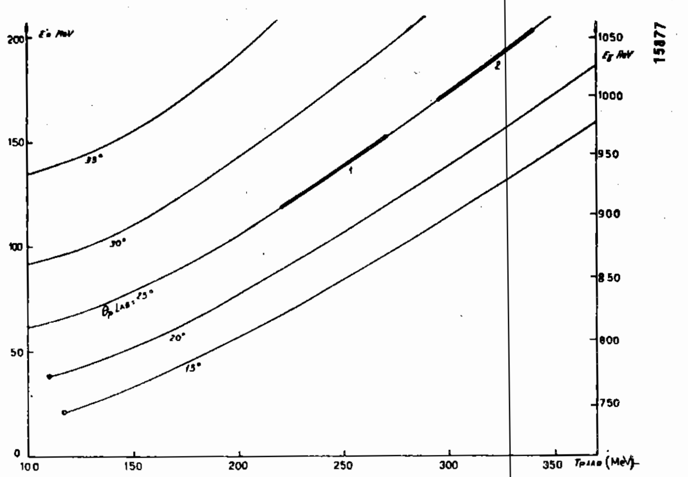

Fig. 2 Kinematics of the reaction $\gamma+p\rightarrow\eta^0+p$ for a mass $m_\eta = 550$ MeV. Ordinates: (left) kinetic energy in the c.m.s.; (right) energy of the γ. Abscissa: laborat. proton kinetic energy.

for production of η, 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).

III. RESULTS

Our results are reported in Fig. 3; the four different kinetic conditions are summarized in the Table I.

TABLE I

Kinematics of the experiments whose results are reported in Fig. 2a, b, c, d. By ΔE we mean the energy interval of the photons producing the R particle. Yes (no) means that the R particle can (cannot) be produced.

Fig.	Maximum energy of the γ-ray beam (MeV)	Proton energy (MeV)	ΔE	R ($M_R = 550\pm30$)
2*a*	1000	221-270	60 MeV	yes
2*b*	900	221-270		no
2*c*	1070	295-340	60 MeV	yes
2*d*	1000	295-340		no

In the abscissa we report the decay γ-ray energy ω_γ which is linear to the channel number on a large interval.

The continuous lines in 3b, 3d are the best fits of the experimental data up to the third degree in ω_γ.

The events of Fig. 3 b, 3 d, which are below the threshold (see Table I) must mainly be due to the processes

$$\gamma+p \rightarrow p+\pi^0+\pi^0 \qquad (5a)$$

$$\gamma+p \rightarrow p+\pi^0+\pi^++\pi^- \qquad (5b)$$

(the single photoproduction $\gamma+p\rightarrow p+\pi^0$ gives photons which at our angle are less than 100 MeV).

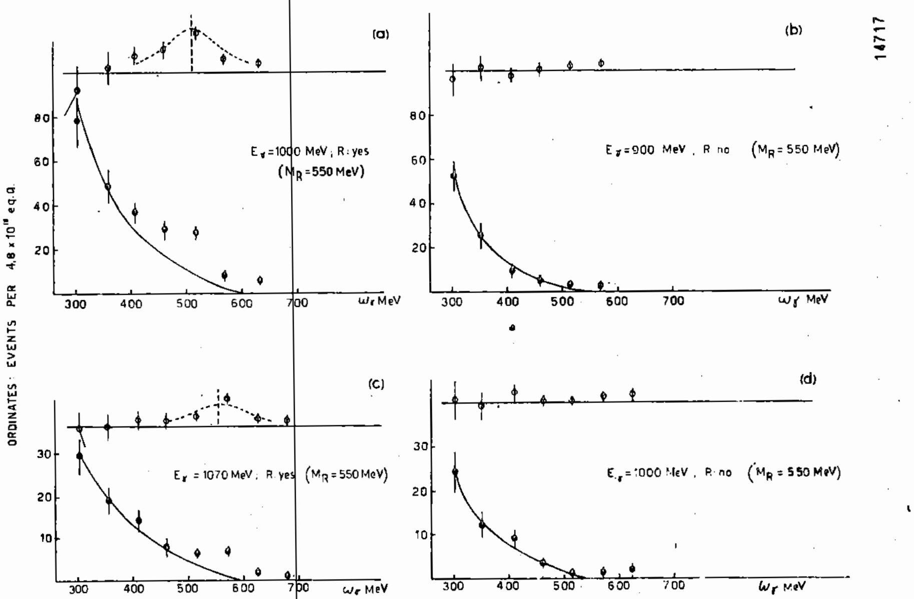

Fig. 3

In order to obtain the number of counts in 3 a which are due to the reaction (2), we must subtract all the events of Fig. 3 b (contribution A) plus the events of the same type which were produced in the energy interval 900-1000 MeV of the initial photon energy, (contribution B).

The last contribution has been calculated on the basis of a statistical model for reaction (5 a).

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

The dashed line in the upper part of Fig. 3 a, 3 c 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 an R particle, in the following cases: (6)

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 $\frac{d\sigma}{d\Omega} \cong 5\times 10^{-32}$ 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 $\frac{d\sigma}{d\Omega} \cong 3\times 10^{-32}$ cm^2/ster ;

$$M_R = 550 ;\; R \rightarrow \pi^0+\gamma$$

We cannot decide between the two alternatives, considering that the absolute calibration of the Čerenkov C_2 has an error of $\sim 6\%$.

We must point out that it would be very difficult to explain the shape of our " swelling " in any way other 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's.

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

$$\gamma+p \rightarrow p+(\gamma+\gamma) \qquad (7a)$$

$$\gamma+p \rightarrow p+(\pi^0+\gamma) \qquad (7b)$$

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

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

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).

IV. DISCUSSION OF THE RESULTS

a) From our results we can already draw the conclusion that

$$\eta \neq \zeta_0 \qquad (9)$$

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 (although perhaps the opposite was expected) 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 $\pi+\gamma$.

b) We cannot give the branching ratio between our radiative mode and the already discovered pion mode $\eta \rightarrow \pi^0+\pi^++\pi^-$. Let us say only 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) give a value not very different from the corresponding value for neutral decay [3] in strong interactions.

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

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

Ross: If the spin of η were 2, then η and ζ could still be the same; I feel however that your results show strong evidence for $T = 0$ and probably $J = 0$ for the η.

Gatto: I would like to say that the evidence reported by Salvini for an η decay into 2γ or $\pi^0+\gamma$ strongly reinforces the spin-parity assignment 0^{-+} for η. If the decay is into 2γ, this assignment is unique if spins $\geqslant 2$ are excluded. If the decay is into $\pi^0+\gamma$, two assignments are possible again for spins <2, namely 1^{+-} ($E1$ transition) and 1^{--} ($M1$ transition). Both assignments imply strong difficulties: for 1^{+-} no weak selection rule exists that makes the 3π-decay slow enough to compete with the radiative-decay. For 1^{--} the 2π-decay would not be strictly forbidden and could compete with the 3π-decay. Furthermore, the Dalitz analysis favours 0^{-+} and a mechanism favouring 3π-decay with respect to the 2π γ-decay based on a strong $\pi-\pi$ s-wave would not work for 1^{+-} or 1^{--}. My assumption is that the ζ meson does not exist or, at least, is not contaminating the experiment.

π^+-p INTERACTIONS NEAR 1 GeV

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(presented by J. Sandweiss)

This paper reports the results of a study of pion-pion and pion-proton interactions which were produced by a beam of π^+ mesons incident on hydrogen. The experiment [1] was performed at Brookhaven laboratory in the fall of 1960. An electromagnetically separated pion beam, produced from the external beam of the Cosmotron was photographed in the Brookhaven 20″ hydrogen bubble chamber. Exposures were taken with three incident pion kinetic energies—910, 1090, and 1260 MeV—in order to study interactions at energies in the leading edge of the second maximum in the π^+-p total cross-section. The momentum spread of the incident beam was determined by analysis of strange particle events and agrees at all three energies with the prediction of $\pm 1\%$. The contamination of the π^+ beam by protons and muons was measured by counters and analysis of forward δ-rays to be less than 10% at all three energies.

The exposure was scanned at a magnification of 20 for all interactions. Events which were found in this process were measured on a high precision pro-