EVIDENCE FOR A $T=1$ PION-PION RESONANCE AT 575 Mev

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Recent experiments[1-8] have shown various resonances of multipion systems. We report here evidence for a di-pion resonance with isotopic spin $T=1$ at 575 ± 20 Mev.

Single pion production in π^+-p collisions at incident pion kinetic energies of 820, 900, and 1050 Mev were studied by means of the Saclay 35-cm hydrogen bubble chamber at the proton synchrotron Saturne. Experimental details and preliminary results have been described elsewhere.[9]

The histograms in Fig. 1 show the distribution of events as a function of the kinetic energy $Q_{\pi\pi}$ in the rest system of the two pions produced in the reaction,

$$\pi^+ + p \rightarrow \pi^+ + \pi^0 + p. \qquad (1)$$

A peak appears at all incident energies at a value of $Q_{\pi\pi} \sim 300$ Mev. For comparison we show the predictions of the isobar model[10] as a dashed curve normalized to the total number of events. At the higher energies one also notes an excess of events for $Q_{\pi\pi} \geq 400$ Mev. This is probably due to the gradual appearance of the ρ meson, for which phase space increases with incident energy. This process obscures somewhat the 300-Mev peak at 1050 Mev.

Indications of a peak around 300 Mev have also been found by Pickup et al.[1] and Erwin et al.[2]

The existence of the peak is confirmed by the variation as a function of $Q_{\pi\pi}$ of the π^0 and π^+ forward-backward asymmetry in the center-of-mass system. The isobar angular distribution at 820- and 900-Mev incident energies is peaked backwards in the c.m. system.[9] Furthermore, the isobar is predominantly doubly charged. Thus, if the main mechanism is isobar formation, one expects, in a qualitative manner, a forward peaking of the π^0's in the c.m. system for all values of $Q_{\pi\pi}$ and a much smaller asymmetry for the π^+'s. This is in fact the case, except in the vicinity of 300 Mev, where the two asymmetries are equal within the experimental errors.

To have a better idea of the $Q_{\pi\pi}$ value at the maximum of the peak, we have plotted on Fig. 1 a "densitogram." Each point in the diagram is proportional to the probability of finding an event from reaction (1) in a $Q_{\pi\pi}$ band of 10 Mev, assuming an experimental error of ±30 Mev for each determination of $Q_{\pi\pi}$. The continuous curve in Fig. 1 is a smooth curve drawn through the points of the "densitogram." The maximum of the peak is located at 300 Mev with an estimated error of ±20 Mev taking into account the error in incident energy. The experimental total width is not larger than 70 Mev.

These results indicate the existence of a dipion which we call ζ.

No similar peak was observed in the reaction,

$$\pi^+ + p \rightarrow \pi^+ + \pi^+ + n, \qquad (2)$$

which favors $T=1$ isotopic spin for ζ.

If the production of the ζ is due to peripheral collisions, one may determine its coupling to pions (assuming a coupling of the form

$$g\epsilon_{ijk}\overleftrightarrow{\partial}_\mu \varphi^j B_\mu^k,$$

where φ is the pion field, B_μ is the ζ vector field, $i,j,k=1,2,3$ are isotopic spin indices, ϵ_{ijk} is the antisymmetric tensor, and g is the π-π-ζ coupling constant) by considering the number of ζ's produced in a momentum transfer band near to zero momentum transfer.[11] This has been done at 900 Mev and leads to a value of g too large to be compatible with the experimental width of ζ. We thus conclude that ζ is directly coupled to the nucleon. This result is experimentally supported by the fact that selection of events with low-momentum transfer does not strongly enhance the proportion of ζ's.

As far as pion-nucleon scattering experiments are concerned, one should note that a weakly bound nucleon-ζ, $T=\frac{1}{2}$ (assuming a spin of 1 for ζ), S state has a mass around 1510 Mev corresponding to a kinetic energy of 595 Mev in pion-

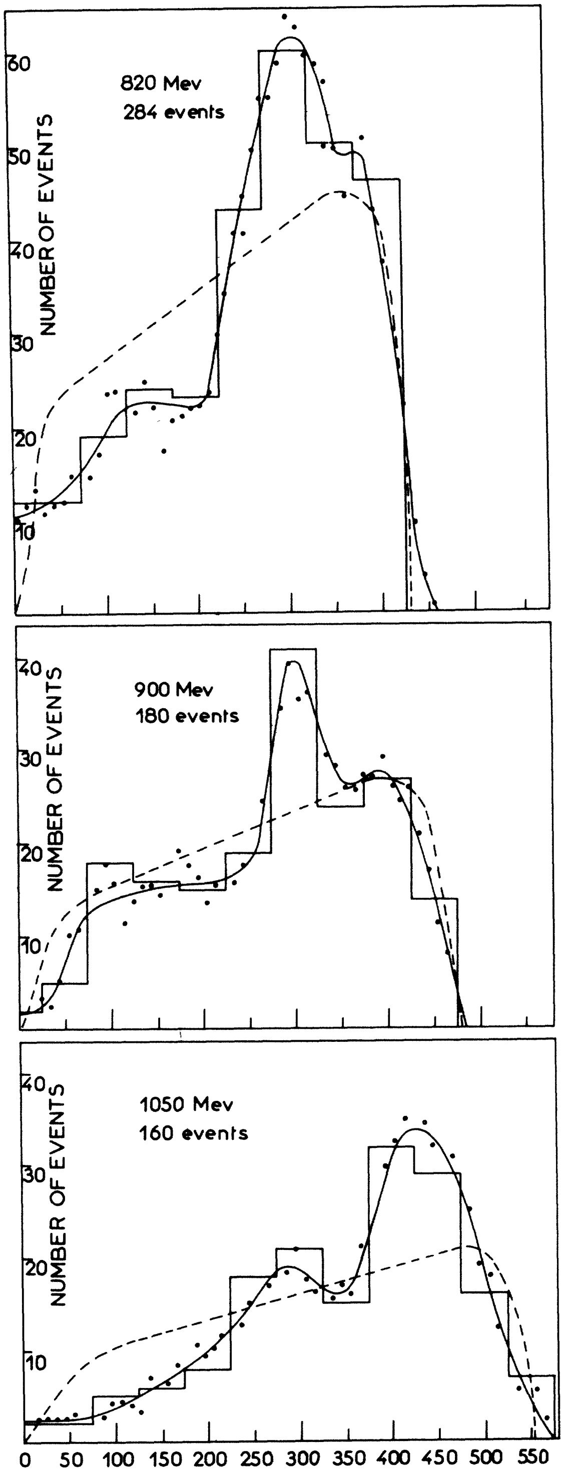

FIG. 1. Distribution of $Q_{\pi^+\pi^0}$ for incident pion energies of 820, 900, and 1050 Mev. The dashed curves show the predictions of the isobar model normalized to the total number of events.

nucleon collisions and could lead to a pion-nucleon resonance at this energy in a $D_{3/2}$ state as observed.[12] It is remarkable that a bound ρ-nucleon P state with $T=\frac{1}{2}$ could lead to an $F_{5/2}$ pion-nucleon resonance around 900 Mev.

As regards electromagnetic form factors of the nucleon, the existence of a ζ, $T=1$, $J=1$ state, with a mass equal to four pion masses, directly coupled to the nucleon, would greatly help to fit the isovector form factor by dispersion representations.[13]

One should note that the mass of ζ is approximately equal to the mass of the 3-pion state η recently observed by Pevsner et al.,[8] just as the mass of ρ is compatible with that of ω. Whether this remark has a deep significance would be made clearer by a better knowledge of the widths of all these states.

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