SEARCH FOR A NEUTRAL SCALAR MESON*

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(Received 22 September 1965)

There has been speculation recently about the existence of a $J=0^+$, $T=0$ pion-pion resonance (ϵ^0) as an explanation for the symmetry observed in ρ^0 decay.[1-3] Evidence has been presented by Feldman et al.[4] for a neutral particle with a mass of about 700 MeV and width $\Gamma \simeq 50$ MeV and by Hagopian et al.[5] at a mass of about 720 MeV with $\Gamma \simeq 50$ MeV.

Under the assumption that the ρ^0 is a resonance in the $T=1$, $J=1$, $\pi\pi$ scattering amplitude, it is possible to express the total ϵ^0 cross section integrated over all mass values in terms of the ρ^0 cross section:

$$\sigma(\epsilon) = \frac{2}{9}\frac{\Gamma_\epsilon}{\Gamma_\rho}\sigma(\rho).$$

Since one-third of the di-pion decays of the ϵ^0 will be into the $\pi^0\pi^0$ mode, it should appear as a peak in the missing-mass (MM) spectrum from the reaction $\pi^+ + d \to p + p + \mathrm{MM}$. The experimental missing-mass spectrum for events with two identifiable protons from an exposure of the Brookhaven National Laboratory 20-in. deuterium chamber at 3.29 BeV/c π^+ momentum[6] is shown in Fig. 1. Peaks are seen corresponding to the neutral decay of the η, ω, and f^0 mesons. The ω peak appears at 800 MeV but this must be regarded as a fluctuation.[7] We find no evidence in this spectrum for decay into neutrals of any other particle in the mass region of 700 MeV.

From our analysis of the reaction $\pi^+ + d \to p + p + \pi^+ + \pi^- + \pi^0$ in the same exposure and the branching ratios for η and ω decay into neutrals,[8] we expect 58 η's and 22 ω's in the neutral spectrum. The effect of subtracting these events is shown by the dashed curve in Fig. 1. With the η and ω as normalization points and including the effect of our resolution of less than 100 MeV at mass 700 MeV, an upper limit of 8

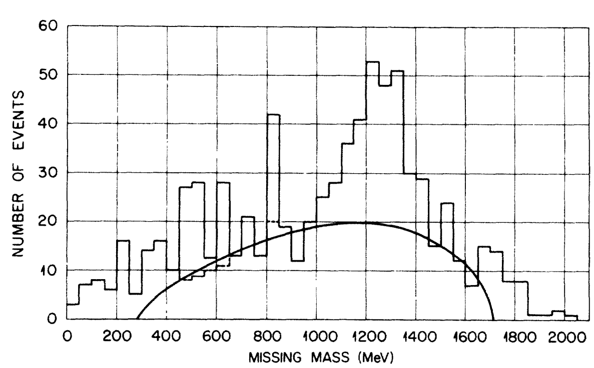

FIG. 1. Missing mass spectrum for the reaction $\pi^+ + d \to p + p + \mathrm{MM}$ for events with a measurable spectator proton. The dashed part of the histogram illustrates the effects of subtracting the expected number of η and ω decays. The smooth curve is two-body phase space.

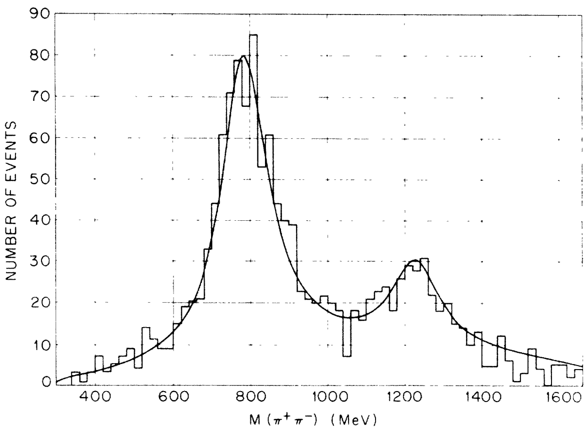

FIG. 2. Di-pion mass spectrum for events with measurable spectator proton.

events above background is obtained for the region between 650 and 800 MeV.

In order to obtain an upper limit on the ϵ^0 production cross section, we refer to the corresponding $\pi^+\pi^-$ mass spectrum from the reaction $\pi^+ + d \to p + p + \pi^+ + \pi^-$ shown in Fig. 2 where again only events with two identifiable protons are included. A fit of the form

$$\{A/[(M-M_\rho)^2+(\tfrac{1}{2}\Gamma_\rho)^2]+B/[(M-M_f)^2+(\tfrac{1}{2}\Gamma_f)^2]+C\}$$
$$\times(\text{phase space})$$

yields 820 ρ^0 events in this spectrum. Since at most eight events are observed, $\sigma(\epsilon)/\sigma(\rho) < 0.03$ and $\Gamma_\epsilon/\Gamma_\rho < 0.14$. Calculations of the ρ^0 decay asymmetry by Durand and Chiu[3] based on the one-pion exchange model with absorptive corrections yield $\sigma(\epsilon)/\sigma(\rho) \simeq 0.1$ with $\Gamma(\epsilon) = 90$ MeV and $\Gamma(\rho) = 140$ MeV. We therefore conclude that the observed upper limits on intensity and deduced width are too small to explain the ρ^0 decay asymmetry.

Independent of the above analysis we have also examined our entire sample of ~2800 $pp\pi^+\pi^-$ events, including those without a visible spectator proton, for evidence of the decay mode $\epsilon^0 \to \pi^+ + \pi^-$. As noted by Hagopian et al.,[5] in the absence of absorption, the decay of a $J = 0$ meson is isotropic in the $\pi\pi$ scattering angle, while the distribution for a $J = 1$ meson is $\cos^2\theta_{\pi\pi}$, we expect the $J = 0$ meson to dominate the mass spectrum. Fig. 3 compares the $\pi^+\pi^-$ mass spectrum for all events, for low momentum-transfer (Δ^2) events, and for events with $\Delta^2 < 5m_\pi^2$ and $|\cos\theta_{\pi\pi}| \leq 0.3$. No evidence is seen for a scalar meson with a mass appreci-

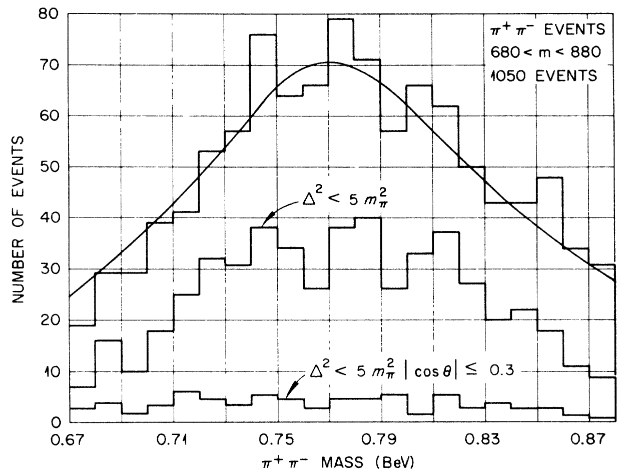

FIG. 3. Di-pion mass spectrum in ρ^0-mass region including events with zero-length spectator protons. Top histogram represents all events; middle histogram contains all events with $\Delta^2 < 5m_\pi^2$; lower histogram represents events with $\Delta^2 < 5m_\pi^2$ and $|\cos\theta_{\pi\pi}| \leq 0.3$.

ably different from ρ^0. Similarly, the scatter plots of $\cos\theta_{\pi\pi}$ versus di-pion mass and the Trieman-Yang angle versus di-pion mass offer no discontinuities indicative of the presence of any meson other than the ρ^0.

We therefore conclude that in π^+d interactions at 3.29 BeV/c, the neutral mass spectrum shows no evidence for the production of a $J = 0^+$, $T = 0$ meson with mass near 700 MeV and intensity sufficient to explain the ρ^0 decay asymmetry. Further, our data on the reaction $\pi^+ + d \to p + p + \pi^+ + \pi^-$ show none of the indications reported by Hagopian et al.[5] for a neutral scalar resonance with mass 720 MeV. It should also be pointed out that the missing-mass spectrum also rules out a $T = 1$ scalar meson ($J^{PG} = 0^{+-}$) produced with appreciable intensity in π-nucleon collisions and decaying into $\eta + \pi$ as suggested by Loebbaka and Pati.[9]

We wish to thank Professor J. Steinberger for making the bubble-chamber film available to us and for permission to include data from a previous analysis.

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*Research sponsored in part by the U. S. Atomic Energy Commission under contract with the Union Carbide Corporation.

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[2]M. M. Islam and R. Piñon, Phys. Rev. Letters 12, 310 (1964).

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[7]A histogram of the mass recoiling against the two protons for four-prong events shows no evidence for systematic error in computing the missing mass.

[8]A. H. Rosenfeld, A. Barbaro-Galtieri, W. H. Barkas, P. L. Bastien, J. Kirz, and M. Roos, Rev. Mod. Phys. 36, 977 (1964).

[9]D. Loebbaka and J. C. Pati, Phys. Rev. Letters 14, 929 (1965).

ERRATA

FURTHER DISCUSSION OF PARTICLE-MIXTURE THEORIES OF $K^0 \to 2\pi$ DECAY. P. K. Kabir and R. R. Lewis [Phys. Rev. Letters 15, 711 (1965)].

The last line of the second-last paragraph should read, "the existence of any charge asymmetry.[17]" The corresponding additional footnote is as follows:

[17]This is strictly true only insofar as one neglects interference between contributions from K_2 and Ψ_L. If such interference cannot be eliminated, either by selective absorption of one component or by averaging over a period of the Ψ_L-K_2 interference, there could be a charge asymmetry whose magnitude would depend on the unknown leptonic-decay properties of the S particle. If, for example, we assume that S cannot contribute to leptonic decays, the expected charge asymmetry would be very much smaller than in the CP-nonconserving case, since it would then arise solely from the admixture of K_+ in Ψ_L. On the other hand, detection of a charge asymmetry exceeding 5.7% would be strong evidence for the particle-mixture theory.

OFF-SHELL EQUATIONS FOR TWO-PARTICLE SCATTERING. K. L. Kowalski [Phys. Rev. Letters 15, 798 (1965)].

The quantity $(k^2-x^2)^{-1}$ (or its inverse), which appears in the definition of $\Lambda(p,q)$, Eq. (7), and the equation following (7) with $x=q,p',p$, should be $x^2(k^2-x^2)^{-1}$. Also, $\Lambda(p',p)$ should be $\Lambda(p',q)$ in the second integral equation for $\mathcal{R}_k(p,q)$.