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Pion spectrum in decay of $\psi'(3.7)$ to $\psi(3.1)$

(high energy/hadrons/unstable particles/chiral symmetry/propagation functions)

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ABSTRACT **The decay of $\psi' \to \psi + \pi\pi$ is described by a chiral ϵ model. The general features of the observed dipion spectrum are well reproduced. Comparison with the hadronic decay $\rho' \to \rho + \pi\pi$ indicates that the $\psi'\psi\epsilon$ coupling is relatively suppressed by a factor $\sim 10^{-2}$.**

Soon after the discovery (1) of the significant decay mode of the second narrow ψ resonance, $\psi'(3.7) \to \psi(3.1) + \pi\pi$, with its isotropic π angular distribution, it was remarked by one of us (see footnote 17 in ref. 2) that some theoretical arguments favored the following interpretation of this decay: $\psi' \to \psi + (\epsilon \to \pi + \pi)$. Here ϵ indicates a zero spin and isotopic spin resonance, which is very broad ($\Gamma_\epsilon \gtrsim 600$ MeV), and is located roughly at the mass $\mu \lesssim 700$ MeV (3). It is plausible that ϵ is also a chiral scalar, so that chiral invariance of the $\epsilon\pi\pi$ coupling requires that the π fields occur only in derivative form. That feature will suppress the low energy end of the π spectrum, whereas the approximate coincidence between the ϵ mass and the energy available in this decay, 600 MeV, will enhance the high energy end of the dipion spectrum. Such are the experimental characteristics of this spectrum that have been recently announced (4), and, accordingly, we propose to give a quantitative comparison between the spectrum predicted by the ϵ model and the experimental observations.

The $\epsilon\pi\pi$ coupling, written for charged pions as

$$(f/\mu)\epsilon\partial^\mu\pi^+\partial_\mu\pi^- \qquad [1]$$

is combined with a $\psi'\psi\epsilon$ coupling

$$gm'\psi'^\mu\psi_\mu\epsilon \qquad [2]$$

where a tensor form would be essentially equivalent, to give the partial width for the decay $\psi' \to \psi + \pi^+\pi^-$:

$$\Gamma(\psi' \longrightarrow \psi + \pi^+\pi^-) = \frac{g^2}{4\pi}\int_{2m_\pi}^{m'-m} dM\, S(M) \qquad [3]$$

Here, we find that

$$S(M) = \frac{1}{3\pi}(m + m')M\left[\left(1 - \frac{m}{m'}\right)^2 - \frac{M^2}{m'^2}\right]^{1/2}\gamma|\Delta|^2 \qquad [4]$$

in which

$$\Delta = [(\mu^2 - M^2)(1 + \delta) - i\gamma]^{-1} \qquad [5]$$

the ϵ propagation function, is characterized by

$$\gamma = \mu\Gamma_\epsilon\left(1 - \frac{4m_\pi^2}{\mu^2}\right)^{-1/2}(\mu^2 - 2m_\pi^2)^{-2} \times \left(1 - \frac{4m_\pi^2}{M^2}\right)^{1/2}(M^2 - 2m_\pi^2)^2 \qquad [6]$$

while δ does not exceed 0.05.

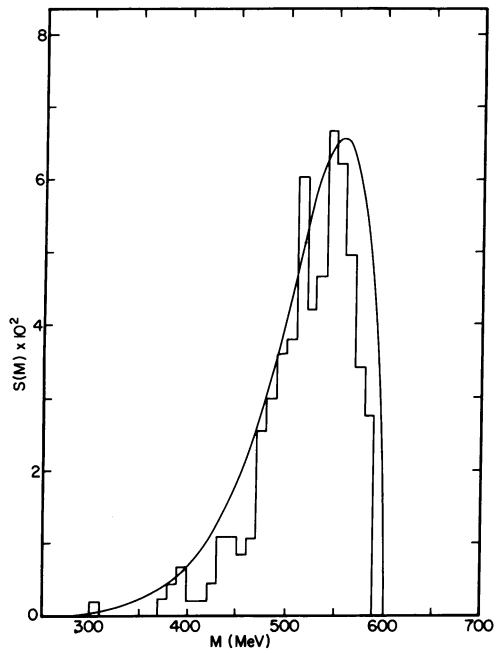

FIG. 1. Spectral distribution as a function of dipion mass. The curve is the theoretical distribution given by Eq. 4.

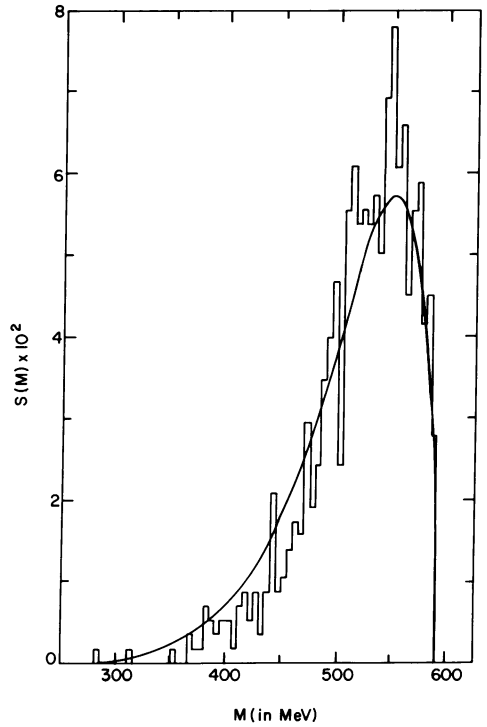

FIG. 2. Dipion distribution for the parameters $\Gamma = 600$ MeV, $\mu = 700$ MeV, $m = 3095$ MeV, and $m' = 3684$ MeV.

The dipion mass distribution function $S(M)$ is computed for $\Gamma_\epsilon = 600$ MeV, $\mu = 700$ MeV and compared with the experiment in Fig. 1. There is substantial support for the chiral ϵ model in the general agreement of the two distributions. We also find the coupling constant g of Eq. 2 to be

$$g^2/4\pi \simeq 0.01 \qquad [7]$$

when a nominal value of 100 keV is assumed for $\Gamma(\psi' \to \psi + \pi^+\pi^-)$. This gives a quantitative measure of the suppression of this hadronic decay mode, one that is emphasized by comparison with the somewhat analogous hadronic decay $\rho'(1600) \to \rho(770) + \pi\pi$, which has a partial width of the order of 100 MeV. An ϵ model for the $\rho'\rho\epsilon$ coupling yields the coupling constant $g^2/4\pi \simeq 2$, so that the relative suppression of the $\psi'\psi\epsilon$ coupling is $\sim 10^{-2}$.

Note Added in Proof. New data were presented at the 1975 International Symposium on Lepton and Photon Interactions at High Energies, Stanford University, August 21–27, 1975. The partial width is now estimated to be 70 keV; the dipion distribution is exhibited in Fig. 2. We have not attempted here, as in Fig. 1, to correct for the experimental acceptance of the apparatus. Unlike Fig. 1, however, we used precise mass values in Fig. 2 and we normalized the curves being compared to equal areas.

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