SEARCH FOR ANOMALOUS π^+ DECAY AMONG τ^+ DECAY SECONDARIES*

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A recent Letter by Cvijanovich, Jeannet, and Sudarshan[1] proposes that the apparent CP nonconservation in K_2^0 meson decay could be explained if there existed a particle of mass close to the pion mass but with nonzero spin, and if at least one of the secondaries in the "two-pion" decay mode of K_2^0 were one of these new particles. The authors cite the experiment of Cvijanovich and Jeannet[2] as suggestive of the existence of such a new particle.[3] In that experiment, the 448 π^+'s from 224 τ^+ decays, $K^+ \to \pi^+ + \pi^+ + \pi^-$, were examined. For each pion, the angle between the initial pion direction and the initial direction of the decay muon was measured. Each pion energy was also measured. The over-all angular distribution of the $\pi \to \mu$ decays was found to be isotropic, but the average initial energy of pions with forward muons, $\bar{E}_F$, was found to differ from the average initial energy of pions with backward muons, $\bar{E}_B$, such that $\bar{E}_F - \bar{E}_B = 3.0 \pm 1.1$ MeV.[4] The authors of reference 1 state that this asymmetry could be explained by an admixture of at least 5% of the new particles. They also point out that the new particle, having nonzero spin, would be expected to have more or less equal decay rates into electrons and muons, and hence that at least 3% of all positive "pions" from τ's would decay into electrons.

The present Letter reports the results of the examination of the decays of 1190 π^+'s from τ^+ decay, all in the energy range 0-12 MeV (approximately the lower quarter of the energy range available.) No statistically significant evidence for asymmetry in the decays is observed. No $\pi \to e$ decays were observed among these π^+ decays.

An unbiased total sample of 3345 τ^+ decays at rest in nuclear emulsion have been located as part of a systematic study of τ^+ decays.[5] The Ilford G5 emulsions were exposed to a 300-MeV/c separated K^+ beam at the Bevatron of the Lawrence Radiation Laboratory of the University of California. As part of the τ^+ study, each τ^+ decay was treated in the following manner: Angular measurements were made on the secondary tracks at the K^+ decay point, and secondary tracks were followed until the π^- was identified. The measured ranges and angles were then used to calculate the energies of the three pion secondaries.

In the present experiment, it was desired to investigate the asymmetry effect reported in reference 2. Since the reported asymmetry is dependent on the pion initial energy, it was decided to measure the π-μ angles for pions emitted from the K decay with low energy. From the sample of 3345 τ^+ decays, 1190 π^+'s had energies of 12 MeV or less, corresponding to approximately one-quarter or less of the maximum possible π^+ energy. Each of these secondaries was re-examined. The projected and dip angles of the pion were measured at the τ^+ decay point, the pion was followed until it decayed, and the projected and dip angles of the muon were measured at the π^+ decay point. All angle measurements were rechecked. The measured angles were then used as input data for the IBM 1620 computer at the Stevens Computer Center to calculate the space angle between the initial pion direction and the initial muon direction. The results are, for the number of muons emitted in the backward or forward directions, respectively, $N_B = 592 \pm 17$ and $N_F = 598 \pm 17$, where the error is the standard deviation of the binomial distribution, assuming no asymmetry. The data are entirely consistent with isotropic distribution of the muons.

It was also desired to test the prediction of reference 1, that if the proposed new particle exists, the branching ratio of "pion" decay to electrons should be increased. In the present experiment, no example of $\pi \to e$ decay exists among the 1190 low-energy π^+'s examined. (Since a $\pi \to e$ decay might accidentally be misidentified as a π^- ending, all negative pions in the same low-energy range 0-12 MeV were also re-examined.) In the total sample of 3345 τ^+ decays studied in the τ^+ decay analysis, roughly an additional 3000 π^+ endings were examined, although no careful search for $\pi \to e$ decays was made. One example of $\pi \to e$ decay was found.

In summary, the experimental data show

no indication of asymmetry in the $\pi^+ \to \mu^+$ decay angle for π^+'s in the energy range 0-12 MeV originating in τ^+ decay. Furthermore, the data show no evidence for an anomalously large branching ratio for $\pi^+ \to e^+$ decay for pions originating in τ^+ decay. Hence the experiment provides no evidence for the existence of a new particle with nonzero spin, of approximately the pion mass.

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[1]G. B. Cvijanovich, E. A. Jeannet, and E. C. G. Sudarshan, Phys. Rev. Letters 14, 117 (1965).

[2]G. B. Cvijanovich and E. Jeannet, Helv. Phys. Acta 37, 211 (1964).

[3]See also R. L. Garwin, G. Gidal, L. M. Lederman, and M. Weinrich, Phys. Rev. 108, 1589 (1957).

[4]Private communication from G. B. Cvijanovich and E. A. Jeannet indicates that the effect is still present after a considerably larger number of events have been measured.

[5]Preliminary data on the τ^+ study were reported in Bull. Am. Phys. Soc. 9, 23 (1964).

ABSORPTIVE CORRECTIONS TO THE ONE-MESON-EXCHANGE MODEL IN S-MATRIX THEORY*

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The one-meson-exchange (OME) model modified by the inclusion of absorptive corrections has met with impressive success, at least for scalar meson exchanges.[1-7] The formula used by Sopkovich,[4] Durand and Chiu,[2] and Gottfried and Jackson[1] is to expand the OME scattering amplitude $B(W)$ in partial waves $B^J(W)$ and to make the replacement

$$B^J(W) \to [S_{11}^J(W)]^{1/2} B^J(W) [S_{22}^J(W)]^{1/2}, \qquad (1)$$

where W is the total energy in the c.m. system, S_{11}^J is the partial-wave S-matrix in the incident channel (1), and S_{22}^J is the partial-wave S matrix in the final channel (2). This formula has been derived under the following assumptions[1]: (i) the applicability of a complex potential to high-energy elementary-particle reactions; (ii) the neglect of "indirect" reactions from channel 1 to 2 via an intermediate state of channel n, $n > 2$; (iii) the neglect of the effect of the reaction $1 \to 2$ on the 11 and 22 amplitudes; (iv) the validity of the high-energy (eikonal) approximation; and either (v) that the interactions in channel 1 and 2 are the same, $S_{11} = S_{22}$, or (v′) that the range of the interaction giving rise to B is small compared to the range of the interactions in channel 1 and 2. Whether one questions assumption (i) is a matter of taste, but assumption (v) is quite questionable. In fact, (v′) is not satisfied in any of the reactions studied, and (v) seems arbitrary.

We present here a derivation of Eq. (1) within the framework of S-matrix theory. Our reasons for presenting this derivation are twofold: Firstly, the dubious assumption (v) or (v′) is not necessary; and secondly, more accurate formulas are found which should permit one to evaluate some corrections to Eq. (1).[8,9]

Let the reaction amplitude that we wish to calculate be designated M_{12}, which we analyze into partial waves M_{12}^J, suppressing for simplicity the labels referring to helicity and isospin. The unitary condition for M_{12}^J can be written in the form

$$\mathrm{Im} M_{12}^J = M_{11}^{J*} \rho_1 M_{12}^J \theta(W-W_1) + M_{12}^{J*} \rho_2 M_{22}^J \theta(W-W_2) + \sum_{n>2} M_{1n}^{J*} \rho_n M_{n2}^{*} \theta(W-W_n), \qquad (2)$$