EVIDENCE FOR VIOLATION OF THE $\Delta I = \frac{1}{2}$ RULE IN $K^+ \to 3\pi$ DECAY*

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A significant violation of the $\Delta I = \frac{1}{2}$ rule has been detected in $K^+ \to 3\pi$ decay. The ratio of the coefficients of the linear terms in the squared matrix elements of τ'^+ ($K^+ \to \pi^+ + 2\pi^0$) and τ^+ ($K^+ \to 2\pi^+ + \pi^-$) is found to be -2.63 ± 0.18 (as compared with the $\Delta I = \frac{1}{2}$ rule prediction of -2), when the results of the Riverside τ'^+ experiment are used together with the results of the present τ^+ experiment.

As part of an investigation of τ^+ decay, a squared matrix element of a form linear in the kinetic energy of the π^- (the "odd" pion),[1] was fitted to a sample of 17 898 τ^+ decays. The fit was found to be adequate. However, when the coefficient of the linear term is compared with the corresponding coefficient in τ'^+ decay, the ratio of the coefficients is found to be in significant violation of the $\Delta I = \frac{1}{2}$ rule. Complete details of the analysis of the τ^+ sample will be reported at a future date.

The τ^+ sample consisted of 14 310 bubble-chamber events[2] and 3588 previously reported emulsions events,[3] all decays being at rest. The bubble-chamber events were found in a systematic frame-by-frame scan and rescan of 70-mm film taken from the Columbia–Brookhaven National Laboratory 30-in. propane chamber exposed to a beam of stopping K^+ mesons at the alternating-gradient synchrotron at Brookhaven National Laboratory. Scanners searched for all multiple-secondary decays, and the events were then subjected to a series of geometrical and kinematical tests. Events outside of the fiducial volume, τ^+ decays in flight, and other recognizable K decay modes and interactions were eliminated, and remeasurements were made where necessary. Ultimately, 13 718 events passed all tests, and 592 passed relaxed tests.[4] A residue of six τ-like events failed the tests, and were eliminated. These are probably radiative τ^+ events.

Following Weinberg,[1] the data (17 898 events) were fitted with a linear approximation of the squared matrix element, of the form

$$|M|_j^2 \propto 1 + \alpha_j \left(\frac{M_j Q_j}{m^2}\right) Y \quad (j = \tau^\pm, \tau'^\pm, K_2^0),$$

where M_j is the mass of the kaon, Q_j is the Q value for the decay, m is the mass of charged pion, and Y is related[5] to the kinetic energy of the odd pion in a given decay through the Mandelstam variables

$$S_i = (M_j - m_i)^2 - 2M_j T_i \quad (i = 1, 2, 3),$$

$$3S_0 = \textstyle\sum_i S_i = \sum_i (M_j - m_i)^2 - 2M_j Q_j,$$

by

$$Y = -3(S_3 - S_0)/2M_j Q_j.$$

The data are adequately fitted with $\alpha_{\tau+} = 0.131 \pm 0.008$. χ^2 is 14.9 for ten bins and eight degrees of freedom, corresponding to a χ^2 probability of about 7%.[6] See Fig. 1. There is no evidence for higher order terms in the squared matrix element. The value of $\alpha_{\tau+}$ is in good agreement with earlier values.[3,7,8]

When the linear approximation for $|M|^2$ is valid, the $\Delta I = \frac{1}{2}$ rule predicts[1,9]

$$\alpha_{\tau'}/\alpha_\tau = -2 \text{ and } \alpha_{K_2^0}/\alpha_\tau = -2.$$

Using $\alpha_{\tau'+} = -0.344 \pm 0.012$ obtained by Davison et al.[10] and $\alpha_{K_2^0} = -0.252 \pm 0.020$ obtained by averaging the results of Basile et al.[11] and Nefkens et al.,[12] and using the present value of $\alpha_{\tau+}$, the experimental ratios are

$$\alpha_{\tau'+}/\alpha_{\tau+} = -2.63 \pm 0.18 \text{ and}$$

$$\alpha_{K_2^0}/\alpha_{\tau+} = -1.92 \pm 0.19.$$

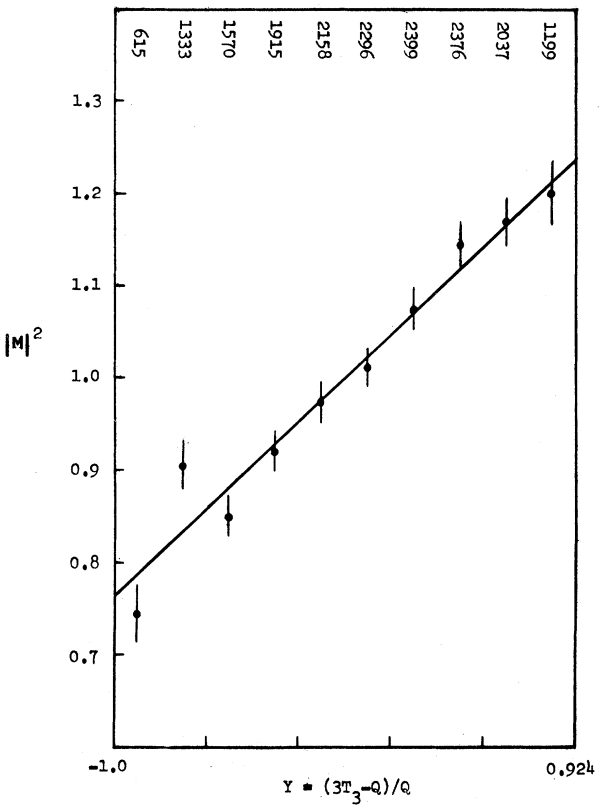

FIG. 1. Dependence of the square of the matrix element on the unlike-pion energy. The points with errors and the solid line were obtained by dividing the experimental and calculated numbers of events, respectively, by the appropriate integral over phase space, including the Coulomb correction, and renormalizing to unit area. The numbers at the top give the experimental number of events in each of the ten equal energy intervals.

Hence the first ratio indicated a violation of the $\Delta I = \frac{1}{2}$ rule in $K^+ \to 3\pi$ decay. Similar results are obtained in the experiment of Mast et al.[13] on τ^- decays where α_{τ^-} is found and compared with existing τ'^+ data. There are also indications of violation of the $\Delta I = \frac{1}{2}$ rule in $K \to 3\pi$ branching ratio experiments.[14]

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[4]The tests consisted essentially of the requirements that (1) the measured Q value of the event be within 6 MeV of the accepted Q value, (2) the measured residual momentum of the event be less than 30 MeV/c, and (3) the magnitude of the scalar triple product of unit vectors along the three secondary momenta be less than 0.16. After repeated remeasurement and reinterpretation of the event, expansions of the test criteria up to approximately 100% were permitted.

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