ANALYSIS OF THE DECAY $K^+ \to \pi^0 + e^+ + \nu$ *

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We have studied the decay

$$K^+ \to \pi^0 + e^+ + \nu \quad \Big| \to 2\gamma \to 2e^{\pm} \qquad (1)$$

using stopping K^+ mesons in the Berkeley 30-inch heavy liquid bubble chamber. The chamber filling was freon, C_3F_8 having a density 1.22 gm cm^{-3} and radiation length 28 cm. A total of 250,000 pictures containing 2.9×10^6 stopped K^+'s was taken. A two-constraint fit for the Ke_3 hypothesis was made for each event. A total of 242 events, from 15% of the film, fitted the hypothesis.

The most general form of the matrix element for Ke_3 decay is

$$M \sim \Sigma \bar{u}_\nu O_j u_e A_j$$

where the O_j's are the Dirac matrices corresponding to the three possible types of coupling scalar, vector, and tensor, and $\bar{u}_\nu O_j u_e$ is the lepton current. The strong-interaction currents A_j are of the form:

Scalar $A_j \sim f_s$;
Vector $A_j \sim f_+(P_K + P_\pi) - f_-(P_K - P_\pi)$;
Tensor $A_j \sim f_t P_K P_\pi$.

The P's are 4-momenta, and the f's are dimensionless form factors that depend on the pion energy alone.

The distribution in $\cos\alpha$ (the angle between the direction of the neutrino or positron momentum in the dilepton center-of-mass system and the direction of the pion) is independent of the energy dependence of the form factors and provides a sensitive test of the nature of the interaction [1]. In Fig. 1 the sum of the experimental distributions in $\cos\alpha_{e\pi}$ and $\cos\alpha_{\nu\pi}$ is compared with the distributions predicted for pure vector, scalar, and tensor.

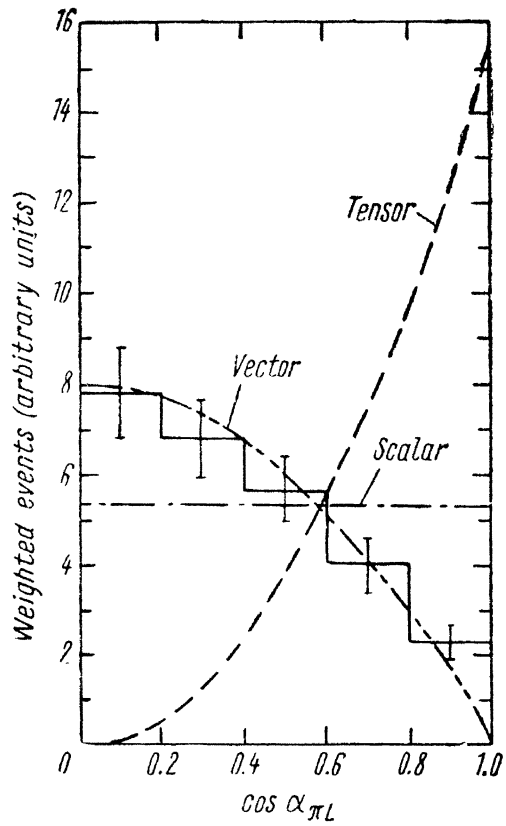

Fig. 1 The sum of the weighted distributions in $\cos\alpha_{\pi e}$ and $\cos\alpha_{\pi\nu}$. The smooth curves are the distributions predicted for a pure vector, scalar, and tensor interaction. The distribution is symmetrical about $\cos\alpha_{\pi L} = 0$.

The distribution is shown for only $0 \leqslant \cos\alpha \leqslant +1$ since the distribution from $0 > \cos\alpha \geqslant -1$ is a mirror image of the former ($\cos\alpha_{e\pi} = -\cos\alpha_{\nu\pi}$). Vector is very strongly favored in arrangement with the $V - A$ theory of weak interactions. A (V, S) or (V, T) mixture is also possible but less likely than pure vector.

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If the coupling in Ke_3 decay is pure vector, the distribution in pion kinetic energy is given by

$$N(T_\pi)\,dT_\pi \sim F_+^2 P_\pi^3\,dT_\pi \qquad (2)$$

and hence can be used to investigate the energy dependence of the form factor f_+. The term containing f_- is negligible in K_{e3} decay. It is

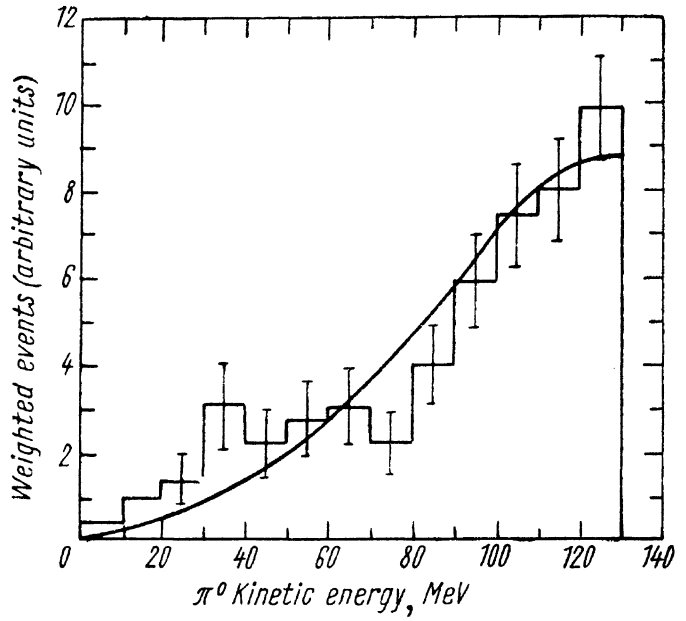

Fig. 2. Weighted pion-kinetic-energy spectrum. The smooth curve is a best fit of our data to Eq. (2), with the error spread in pion energy folded in.

generally believed that f_+ is a slowly varying function of the 4-momentum transfer $q^2 = M_K^2 + M_\pi^2 - 2M_K E_\pi$ and it may, therefore, be explained in a power series in q^2. We have fitted the π^0 energy spectrum, Fig. 2, to Eq. (2) with $f_+ \sim 1 + q^2/M_\pi^2$ and with the experimental error distribution folded in. The χ^2 probability for the fit is 5%. The poor fit is due to an excess of events at low pion momenta and may arise from a tail in the π^0 momentum error distribution. The value of λ, which minimizes χ^2, is $\lambda = 0.02^{+0.04}_{-0.03}$. Since only the high-momentum end of the spectrum is sensitive to the possible energy dependence of the form factor, the value of λ is almost independent of the low-energy tail.

Fig. 3 shows the combined electron- and neutrino-momentum spectrum, the distribution is in excellent agreement with the hypothesis of a pure vector interaction with constant form factor.

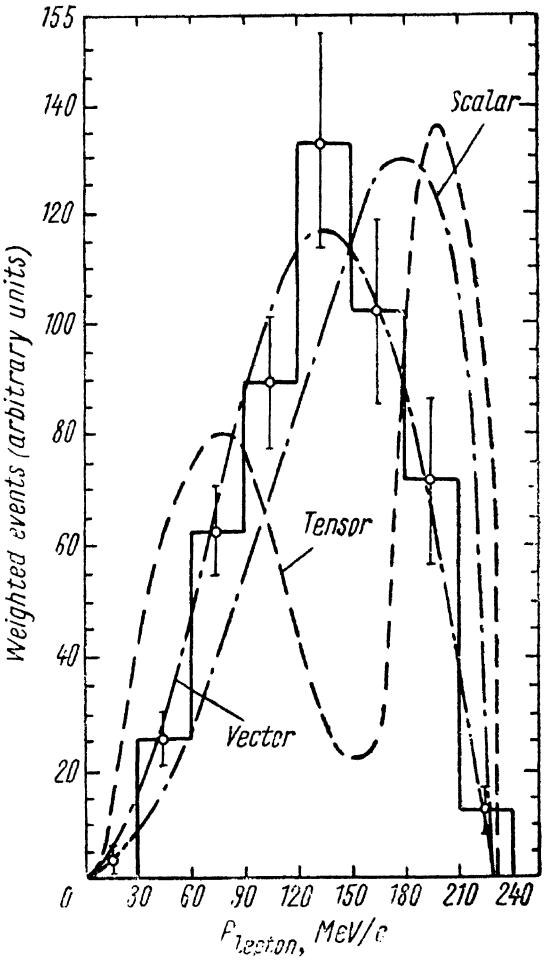

Fig. 3. Sum of the weighted positron and neutrino momentum distributions. The curve shows the distributions for a pure vector, scalar, and tensor interaction, assuming a constant form factor.

Our results are in good agreement with the previous study of Ke_3^+ decay [2]. However, in contrast to this previous experiment, our events are kinematically over-determined and hence have been completely reconstructed.

REFERENCES

1. Mac Dowell S. W. Ann. Phys., **18**, 171 (1962).
2. Brown J. L. et al. Phys. Rev. Lett., **7**, 423 (1961); Phys. Rev. Lett., 8, 450 (1962).