extensions such as that reported on here.

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K_2^0 DECAYS AND INTERACTIONS*

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We have performed an experiment with low-energy K_2^0 mesons in the BNL 20-in. hydrogen bubble chamber. In this Letter, we wish to report results of two types: those bearing on the structure of the strangeness-changing weak interaction; and those which give information concerning K^0p and $\bar{K}^0p$ interactions.

The beam was made by 1250 ± 40 Mev/c π^- on a CH_2 target. K_2^0's at 47° in the lab were selected, and charged particles were removed by a sweeping magnet before the beam passed into the chamber, some 110 in. from the target. The direction of the K_2^0 beam in the chamber is known to ±2° but the momentum has a spread from ~200 to ~650 Mev/c, due to associated production of both Λ^0K^0 and Σ^0K^0, Fermi momentum in the target, etc.

We have made the usual assumptions (consistent with our observations) that the only common modes of K_2^0 decay into charged particles are[1]:

$$K_2^0 \to \pi^\pm + e^\mp + \nu,$$

$$K_2^0 \to \pi^\pm + \mu^\mp + \nu,$$

$$K_2^0 \to \pi^\pm + \pi^- + \pi^0,$$

which we shall call $\pi e\nu$, $\pi\mu\nu$, and $\pi\pi\pi$.

Under the present conditions, the K_2^0 momentum is calculable from measurements of the decay particles but is not overdetermined. (There is in general an ambiguity in the momentum which is not serious for the present analysis.) The most serious backgrounds, $\pi\mu$ and μe decays in flight, which might be interpreted as neutral decays, were eliminated by restrictions on the events which also threw out a small and calculable fraction of the K_2^0 decays (4 to 6% for the different decay modes).

A sample of 124 identified $\pi e\nu$ decays was obtained by identifying all electrons with momentum < 200 Mev/c by bubble density. Any track which was not clearly identified on inspection was measured by gap counting.[2] (A muon at the limiting momentum has $1/\beta^2 = 1.29$.) The remainder of the events was classified into two groups, one containing 52 events which gave a physical value of the K_2^0 momentum when interpreted as a $\pi\pi\pi$ decay, and a group of 222 events which are $\pi e\nu$ or $\pi\mu\nu$.

If polarizations are not measured, the configuration of a three-body decay is specified by two variables. We choose to use the energy of the charged particles in the center-of-mass system of the K_2^0. For each configuration, we have determined the probability of identifying a $\pi e\nu$ and of not rejecting each of the modes. This involves integrating over the uninteresting angles and over the experimentally observed K_2^0 spectrum. Given this information, we are prepared to make several comparisons with the theory.

1. The ratio $\pi^-e^+\nu/\pi^+e^-\nu = 1.16 \pm 0.17$. This ratio is one if CP is conserved, but no larger than 1.08 in any case.[3]

2. Pais and Treiman[4] have shown that the electron energy spectrum in the $\pi e\nu$ decay for a given pion energy has a form which is dependent only on the type of interaction involved. The pion spectrum is given, to be multiplied by a form factor which is expected to be roughly constant.[4-6] We have divided the Dalitz plot into three strips in T_π, each of which is subdivided as shown in Fig. 1.

We multiply the probability for observation and detection at each point times the expected distribution function for pure scalar, vector, and tensor interactions and integrate over each region. Theory and experiment are normalized to one in regions 1 and 2; 3, 4, and 5; and 6, 7, 8, and 9; thereby giving a comparison essentially

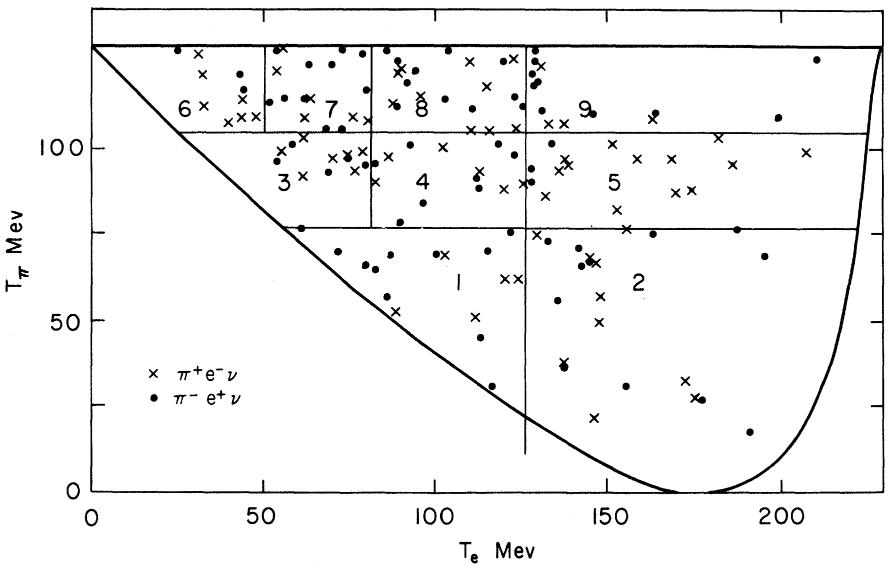

FIG. 1. Regions on Dalitz plot for $\pi e\nu$ to be used for comparison with experiment are shown, together with the distribution of events.

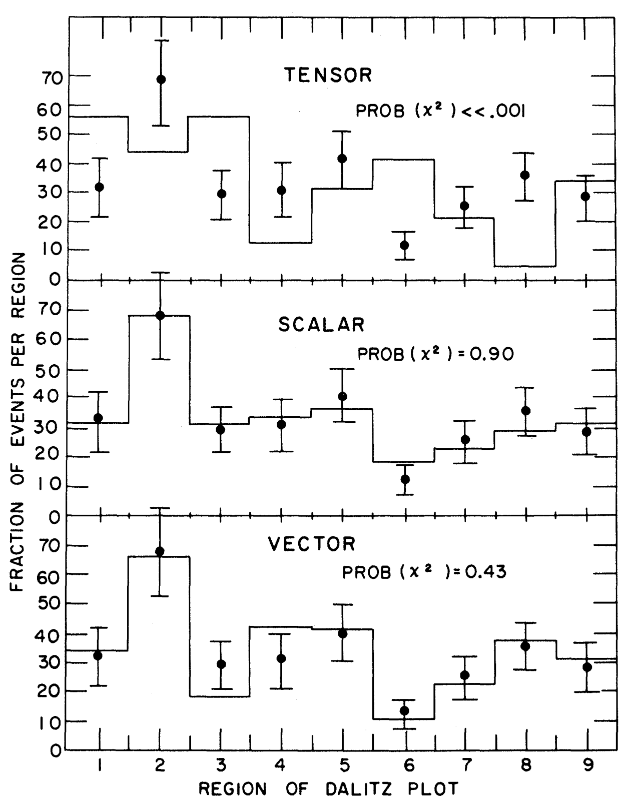

FIG. 2. Comparison of $\pi e\nu$ events with theory. Histograms represent the theoretical distribution of events, corrected for detection efficiency and normalized in each set of regions with the same range of T_π.

independent of the form factor. The results are shown in Fig. 2. Tensor is excluded; scalar and vector are allowed.

3. If the interaction is assumed to be scalar, the form factor is found to increase by a factor of ~14 from the region with $T_\pi < 76$ Mev to the region with $T_\pi > 104$ Mev. Such a large increase with pion energy is not expected, and probably allows this interaction to be excluded.

4. The vector form factor (Fig. 3) is roughly constant. The conclusion, then, is that the data are consistent with a pure vector interaction—in agreement with the universal V-A theory.[7]

5. If that part of the form factor due to strong interactions is constant, and an intermediate boson exists, the energy dependence of the form factor may be given in terms of the boson mass,[8] as shown by the curves on Fig. 3. From the present data a boson with mass >500 Mev/c^2 cannot be excluded.

6. The detection and identification probabilities may be integrated over all the decay configurations with weights appropriate to the vector interaction. This allows the $\pi e\nu$ branching ratio to be determined. The number of $\pi e\nu$ (0.1%) and $\pi\mu\nu$ (4.4%) in the sample fitting $\pi\pi\pi$ may be calculated. This allows a complete set of K_2^0 branching ratios into charged modes to be given in Table I.

7. Given the $\Delta I = \frac{1}{2}$ rule,[9] the $\Delta I = \frac{1}{2}$ current rule,[10] and the K^+ branching ratios[11] and lifetime, the K_2^0 branching ratios may be predicted, Table I. There is reasonable agreement with the exper-

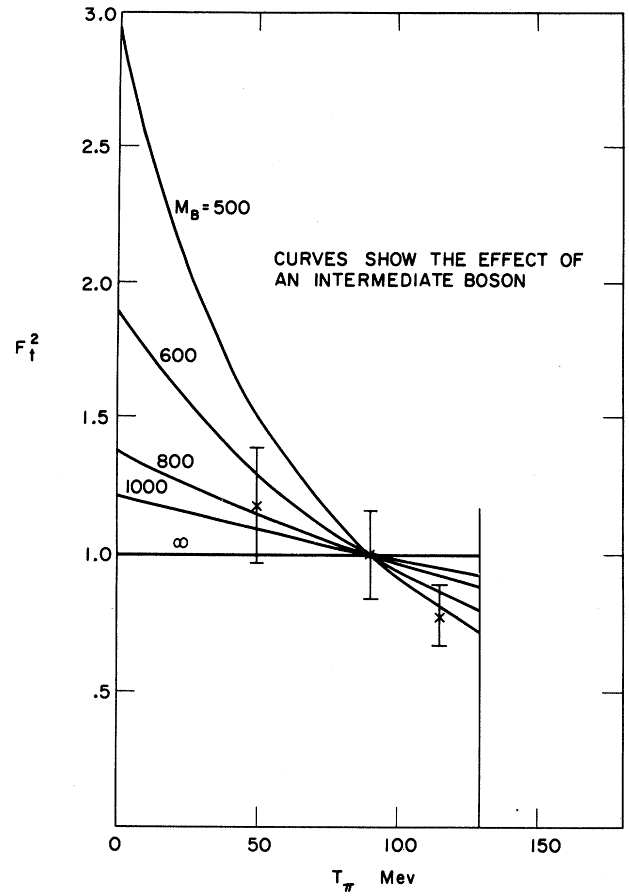

FIG. 3. The square of the form factor for $\pi e \nu$ decay with vector interaction. The curves show the form-factor dependence due to a possible intermediate boson.

imental numbers. If a $\Delta I = \frac{3}{2}$ current is assumed, together with $\Delta S = \Delta Q$,[10] the numbers obtained, also in Table II, are in disagreement with the experiment. Since there is evidence for $\Delta I = \frac{1}{2}$, but little information concerning the currents, we see this as a test of the current rule.

8. The π^0 energy spectrum in $\pi\pi\pi$ decay has been given by Weinberg[12] and Sawyer and Wali[13] as $W(T_{\pi^0}) = (1 + aT_{\pi^0})$(phase space). Using the $\Delta I = \frac{1}{2}$ rule, he predicts $a = -0.0109 \pm 0.022$. We find $a = 0.0171 \pm 0.0065$.

We turn now to the interactions. We have observed 111 events representing comparable numbers of

$$K_2^0 + p \to K_1^0 + p,$$
$$K_2^0 + p \to \Lambda^0 + \pi^+,$$
$$K_2^0 + p \to \Sigma^0 + \pi^+.$$

Biswas[14] has pointed out that a measurement of $K_1^0 p/(\Lambda^0\pi^+ + 2\Sigma^0\pi^+)$ provides a method for distinguishing among the various scattering length solutions for $\bar{K}p$ interactions, if the K^+-N scattering is known.

Unfortunately, most of our K_2^0's have a momentum greater than the limit of applicability of the zero-range theory (estimated to lie between 200 and 300 Mev/c).[15] The results are given in Fig. 4. Also shown are shaded regions indicating the result which might be expected, within the errors on the scattering lengths, using the $\bar{K}$ scattering lengths given by a recent χ^2 analysis of K^--p interactions.[16] Also shown are the range of expected values for the ratio at 175 Mev/c, using the four Dalitz solutions[17] to the same data: The momentum dependence is similar to that of solutions (1) and (2). Our data would seem to agree better

Table II. Values of the quantity $\epsilon = \Lambda^0/(\Lambda^0 + \Sigma)$, $T = 1$.

K momentum (Mev/c)	ϵ
0	$0.5^{+0.35}_{-0.15}$ [a]
~175	0.40 ± 0.03 [b]
~230	0.33 ± 0.14
~360	0.19 ± 0.07
~500	0.32 ± 0.08

[a] From K^--p data, quoted in reference 17.
[b] From K^--p data, reference 16.

Table I. Experimental branching ratios for charged modes of K_2^0 decays, together with predictions based on the $\Delta I = \frac{1}{2}$ rule and the $\Delta I = \frac{1}{2}$ and $\Delta I = \frac{3}{2}$ current rules. The ratio $\pi\mu\nu/\pi e\nu$ is given because the individual errors are correlated.

Quantity	Experiment	$\Delta I = \frac{1}{2}$ current	$\Delta I = \frac{3}{2}$ current
$\pi e \nu$	48.4 ±5 %	40.5 ±4.5%	27.4 ±3%
$\pi \mu \nu$	38.2 ±8 %	43.4 ±4.5%	29.1 ±3%
$\pi\pi\pi$	13.4 ±1.8%	16.1 ±1.0%	43.5 ±4%
$\pi\mu\nu/\pi e\nu$	0.79 ±0.19	1.06 ±0.15	1.06 ±0.15

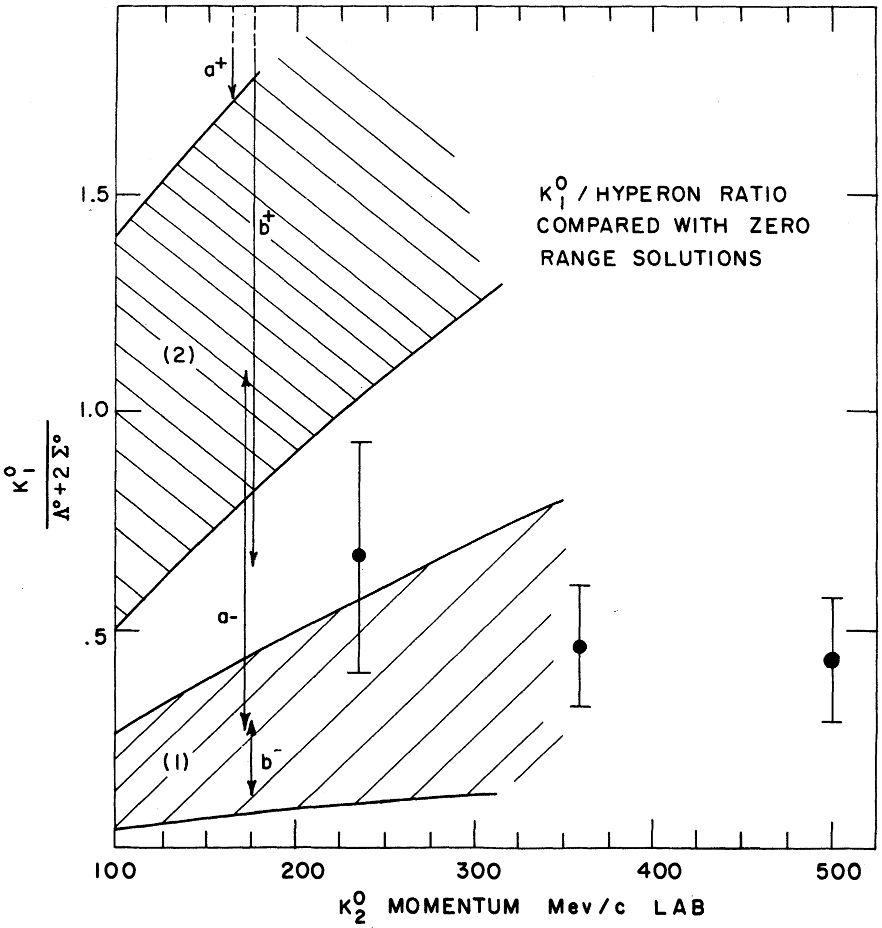

FIG. 4. The experimental values of $K_1^0/(\Lambda^0+2\Sigma^0)$ compared with the approximate values expected from K^+- and K^--nucleon scattering.

with solution (1) than with solution (2), or better with a^- or b^- than with a^+ or b^+, or, in general, with a $T=1$ scattering length which is not large and positive. A more quantitative conclusion must await consideration of effective-range effects.

We have also measured the ratio $\epsilon=\Lambda^0/(\Lambda^0+\Sigma)$, $T=1$, using the charge-independent relation $\Sigma^0\pi^+=\Sigma^+\pi^0$ for $\bar{K}^0$-p, which is a pure $T=1$ state. The results, with some K^--p values,[16,17] are given in Table II.

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METHOD FOR DETERMINING THE SPIN OF THE K-π RESONANCE

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In order to understand the recently observed[1] resonance in the K-π system, which is here labeled K^*, it is essential to determine its spin. Recently there have appeared arguments[2] favoring a spin of 1 and a proposal[3] for determining the spin. The appearance of the latter has prompted the writing of this note describing a method of spin determination which may be simpler experimentally and can perhaps provide more information than that of reference 3. It has been tacitly assumed in that paper that the measurements[1] limit the K^* spin to 0 or 1 and the isotopic spin to 1/2, and that because the decay $K^* \rightarrow K + \pi$ is seen to be rapid, parity is conserved and hence the K^* has either spin 0 and parity opposite to that of the K, or spin 1 and the same parity as the K. Under these same restrictions, if one observes the process

$$K + He^4 \rightarrow K^* + He^4, \quad (1)$$

then the K^* must have spin 1, since for the spin 0 case angular momentum and parity cannot be conserved in this reaction. If (1) is not seen, the K^* spin assignment can be checked by observing

$$K + He^4 \rightarrow K^* + He^4 + \pi, \quad (2)$$

and looking at the K^*-decay distribution.

There are two circumstances under which (1) will be forbidden and a third reason why it would be inhibited, however. Thus if (1) is observed, surely (a) the spin of the K^* is greater than zero (and presumably one) and (b) the isotopic spin of the K^* is the same as that of the K, which is 1/2. If the K^* had an isotopic spin of 3/2, which is allowed by its decay into $K + \pi$, then (1) would not occur, and hence this point can be checked for a nonzero spin K^*.

The inhibition of (1) will be discussed shortly, but first let us investigate what could in principle be learned from observing the decay angular distributions from the K^* produced by (1). These results will then be applied to (2), which is not inhibited, but which is more difficult to discuss.

It is well known[4] that one can obtain information on the spin of an unstable particle if one observes such particles produced near the beam direction. A reaction like (1) is, however, particularly useful for this purpose because the decay angular distribution for the K^* is uniquely determined by its spin, and because most of the observed reactions could be utilized for this analysis. In justifying the first of these statements, let us begin by considering the initial state of (1): There can be no orbital angular momentum (l) about the direction (z) of the incident K, and since there is no spin, the total angular momentum in that direction (j_z) is zero also. Therefore in the final state $j_z = 0$ too, and since for forward production $l_z = 0$, then the spin (S) can have no component in z direction. Thus for a K^* of any possible spin, if the K^* is produced forward there will be a unique angular distribution[5] for its decay, given by the spherical harmonic $|Y_{S,0}(\theta)|^2$, where θ is the angle between the direction of the incoming K and the decay momentum in the center-of-mass system of the K^*. According to the uncertainty principle, the decay distribution should not change appreciably over K^* emission angles of the order of the reciprocal of the largest orbital angular momentum contributing to the production process, which is $\sim\hbar/pR$, where p is the incident K momentum and R is the "radius" of He^4. This, however, is just the typical emission angle for events in which the He^4 stays bound. To keep the He^4 together, the momentum transferred to the He^4, q, must be kept small. From the uncertainty principle, $q \sim \hbar/R \sim 0.2$ Bev/c. To satisfy this condition,