zontally, and ±0.4 deg vertically at the center of the chamber. The direction of the $K_2{}^0$ line of flight is computed from the known target and interaction positions, and this information is used in the fitting procedure.

[9]In addition, reactions $\Sigma^+ + \pi^0 (\Sigma^+ \to \pi^+ + n)$ and $K^+ n$ have been scanned for, but these events have not been fully analyzed.

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[11]M. B. Watson, M. Ferro-Luzzi, and R. D. Tripp, Phys. Rev. 131, 2248 (1963). Above 300 MeV/c, there is evidence for an asymmetry in the angular distribution in the $\Lambda^0\pi^0$ channel, in qualitative agreement with the asymmetry reported in this Letter.

[12]There is additional evidence to help resolve the ambiguity in favor of the Dalitz-Tuan interpretation. Specifically, in the $K^- p$ experiment of Ref. 11 in the momentum range 300 to 500 MeV/c, interference was observed between the $Y_0{}^*(1520)$ resonance and the S-wave background. The continuity argument of T. Akiba and R. H. Capps, Phys. Rev. Letters 8, 457 (1963), then implied that the relative phase of the isospin-0 and -1 channels was such that only one set of scattering lengths was possible. In addition, recent $K^- p$ charge-exchange experiments [G. S. Abrams and B. Sechi-Zorn, Phys. Rev. 139, B454 (1965) and W. Kittel, G. Otter, and I. Wacok, Phys. Letters 21, 349 (1966)] are consistent with only this set of solutions, as is the experiment by E. F. Beall, G. Sayer, T. V. Devlin, P. Shephard, and J. Solomon, Bull. Am. Phys. Soc. 11, 326 (1966).

[13]A phase-shift analysis, using both polarization data and the angular distributions, is currently in progress, and will include many more events than the present sample.

EXPERIMENTAL TEST OF TIME-REVERSAL INVARIANCE IN $\Sigma^0 \to \Lambda^0 + e^+ + e^-$

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Bernstein, Feinberg, and Lee[1] and S. Barshay[2] have suggested that the observed violation of time-reversal invariance (T) in $K_2{}^0$ decays[3] could be accounted for by the existence of a T-nonconserving electromagnetic interaction of the strongly interacting particles. This suggestion has been supported by recent evidence from the charged decay of the η^0.[4] Such an interaction could also give rise to a polarization of the Λ^0 in the Dalitz decay of an unpolarized Σ^0

$$\Sigma^0 \to \Lambda^0 + e^+ + e^-. \tag{1}$$

The polarization direction would be expected to be along the normal to the decay plane of process (1), defined by

$$\vec{\mathrm{N}} = \hat{p}_\Lambda \times (\hat{p}_+ + \hat{p}_-), \tag{2}$$

where $\hat{p}_\Lambda$, $\hat{p}_+$, and $\hat{p}_-$ are unit vectors along the directions of the Λ^0, the positron, and the electron in the Σ^0 center-of-mass system.

We have looked for such an effect in 907 events of this type used in our determination of the relative parity of the Σ and Λ.[5,6]

In the one-photon exchange approximation, a polarization along the normal (2) requires a violation of T but is consistent with parity conservation and with charge conjugation invariance of the electromagnetic interactions of the leptons. Polarization of the Λ^0 can also arise from the decay of polarized Σ^0 hyperons. In these experiments, the Σ^0's are thought to originate from interactions at rest of K^- mesons or Σ^- hyperons on unpolarized protons which will produce unpolarized Σ^0's. In any case, in the one-photon approximation, the direction of the normal (2) is independent of the Σ^0 spin; hence, a Λ polarization correlated with the Σ^0 spin direction will not affect our results.

The presence of a T-nonconserving interaction would, in general, give rise to a nonzero mean value for the quantity $\hat{N}\cdot\hat{p}_p$, where $\hat{N}$ is a unit vector in the direction of the normal

(2) and $\hat{p}_p$ is a unit vector in the direction of the proton momentum in the Λ^0 center of mass. As any polarization of this type is expected to appear in the Λ density matrix in the form $\sigma_\Lambda \cdot \vec{N}$ multiplied by kinematic factors, we have calculated the weighted average of this decay cosine, using the magnitude of $\vec{N}$ as the weight. Introducing the notation $\langle\cos\theta\rangle_{\vec{V}} = \Sigma\vec{V}\cdot\hat{p}_p/\Sigma|\vec{V}|$, summation over all events, for the weighted average of the decay cosine with respect to a vector $\vec{V}$, we find for $\vec{V}=\vec{N}$,

$$\langle\cos\theta\rangle_{\vec{N}} = +0.060 \pm 0.030. \tag{3}$$

This procedure requires no further assumption about the form of the interaction than those discussed above. The unweighted average of $\hat{N}\cdot\hat{p}_p$ is 0.020 ± 0.020; thus the weighting procedure described above enhances the effect as expected.

A potentially more efficient test, which requires some additional assumptions, was also made. The interaction (1) has been extensively discussed in the literature.[7,8] In the one-photon exchange approximation the polarization of the Λ^0 is given by[9]

$$\vec{P}_\Lambda = \{[Ryx^{1/2}(1-y^2)^{1/2}\sin\varphi]/[1+y^2+R^2x(1-y^2)]\}\hat{N}. \tag{4}$$

Here we follow the notation of Evans[7] with $x=-q^2/(M_\Sigma-M_\Lambda)^2$, where q^2 is the square of the four-momentum transfer to the Dalitz pair, and $y=|E_+-E_-|/p_\Lambda$, where E_+, E_-, and p_Λ are the energy of the positron, the energy of the electron, and the momentum of the Λ^0 in the Σ^0 center of mass, respectively. R is the dimensionless ratio $(M_\Sigma-M_\Lambda)|dG/dq^2|/|F|$, where $G(q^2)$ and $F(q^2)$ are the form factors described by Bernstein, Feinberg, and Lee,[1] and φ is the relative phase of F and G. T requires that φ be 0 or π, resulting in zero polarization.

We have assumed F and dG/dq^2 to be constant in the region of momentum transfer involved and have estimated R and φ with a maximum likelihood procedure. For each event we determined the likelihood function

$$f(R,\varphi,\hat{p}_p) = 1 + \alpha_\Lambda \vec{P}_\Lambda \cdot \hat{p}_p, \tag{5}$$

where $\alpha_\Lambda = 0.659$ is the decay asymmetry parameter of the Λ^0. The logarithm of the likelihood for 907 events is then

$$w(R,\varphi) = \ln\{\prod_{\text{all events}} f(R,\varphi,\hat{p}_p)\}. \tag{6}$$

Contours of constant w as functions of R and φ are shown as the solid curves in Fig. 1. The contours $R=0$ and $\varphi=0°, 180°$ are constrained, by the form of the function (5), to have $w=0$. The maximum, $w=1.6$, occurs at $R=2.7$, $\varphi=90°$. Evaluating the polarization, as given by (4) with these parameters, we find

$$\langle\cos\theta\rangle_{\vec{P}_\Lambda} = 0.048 \pm 0.026. \tag{7}$$

From the x and y values of the observed events, the expected value of this quantity, for R and φ as determined above, is 0.032.

One check on the consistency of this conclusion is to calculate the likelihood for the com-

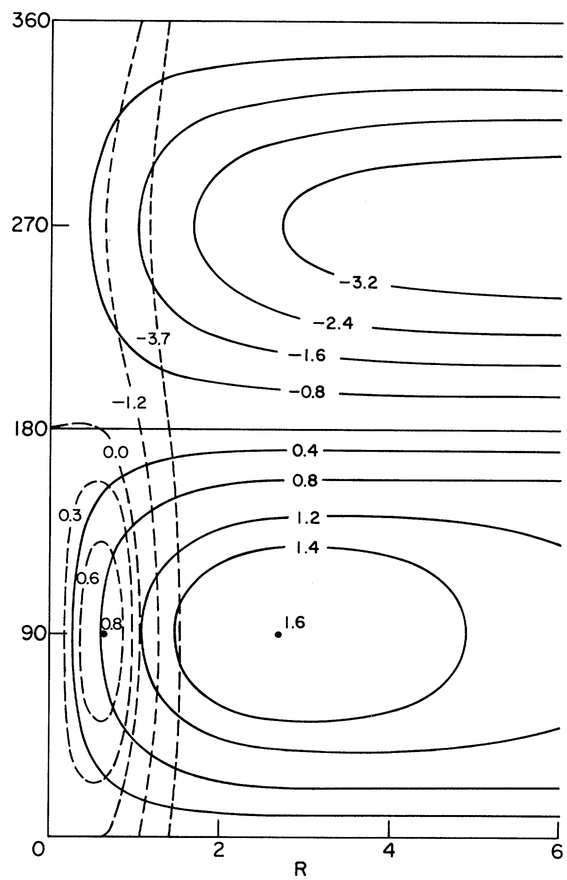

FIG. 1. Contours of constant w, the logarithm of the likelihood as a function of R and φ. The solid contours are based on the Λ^0 decay distribution alone, while the dashed contours are based on the Λ^0 decay and the pair mass distribution. In both cases the $R=0$ boundary is a contour with $w=0$.

bined observations of the distribution in x (the normalized square of the pair invariant mass as defined above) and the Λ^0 decay distribution. The expected distribution in x, as a function of R and φ, is given by[10]

$$g(R,\varphi,x)=N\left(1-\frac{x_0}{x}\right)^{1/2}\times\left(1+\frac{x_0}{2x}\right)(1-x)^{3/2}\left\{\frac{1}{x}+\tfrac{1}{2}R^2\right\}, \tag{8}$$

where $\Delta=M_\Sigma-M_\Lambda$, $M=\frac{1}{2}(M_\Sigma+M_\Lambda)$, $x_0=(2m_e/\Delta)^2$, and N is a normalizing function. We have determined the logarithm of the combined likelihood function

$$w'(R,\varphi)=\ln\{\prod_{\text{all events}} g(R,\varphi,x)f(R,\varphi,\hat{P}_p)\}. \tag{9}$$

Contours of constant w' are indicated by the dashed curves on Fig. 1. The maximum is located at $R=0.65$ and $\varphi=90°$. With w' normalized to zero for $R=0$, the maximum has the value 0.8. The parameters associated with this maximum, when inserted in the expression (4) for P_Λ, give

$$\langle\cos\theta\rangle_{P_\Lambda}=0.059\pm0.029 \tag{10}$$

with an expected value of 0.016. This disparity between the observed and expected value indicates either a strong fluctuation in the polarization data or form factors, which are strongly dependent upon q^2.

We have formed a likelihood function similar to that in expression (9) except that φ was fixed at 90° and R was of the form $R_0(1+\alpha x)$. The functions were calculated for various R_0 and α in the range −0.10 to +0.10, twice the range suggested by an estimate of Feinberg.[8] Within this range of α, we found no significant improvement in the quality of the fit or change in the best estimate of R_0. Thus, this sort of variation of the form factors does not appear to resolve the inconsistency.

We have examined the data for evidence of bias against large q^2 or for biases effecting our $\cos\theta$ distribution. No significant effect could be found. A test was made for a decay correlation along the normal $\vec{N}'=\hat{p}_+\times\hat{p}_-$. The charge-conjugation invariance of the lepton electromagnetic interaction requires that there should be no such correlation. We find

$$\langle\cos\theta\rangle_{\vec{N}'}=0.00\pm0.03 \tag{11}$$

in very good agreement with this invariance principle.

Lee has suggested that even in the presence of a significant C-nonconserving component, K_μ, in the electromagnetic current, the polarization effect discussed here might be small or zero. On the assumption of SU(3) invariance,[11] it can be shown that the effect is zero and hence might be expected to be small in the presence of breaking. In a more detailed model,[12] which calls for the existence of a charged eigenstate C_{STRONG}, the current K_μ is shown to be an isotopic singlet and hence cannot contribute to the transition $\Sigma^0\to\Lambda^0$ in the single-photon approximation. Both of these arguments are suggestive of possible explanations for no effect, but neither seems a compelling reason to expect none.

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[10]The exact expression for this distribution can be found elsewhere (for example, see Refs. 5-7). The form used here neglects terms of order Δ^2/M^2. This approximation is correct to better than $\frac{1}{2}$% at all values of x.

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