Σ^- DECAY PARAMETERS

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We have measured the decay parameters of $\Sigma^- \to n + \pi^-$. We find $\alpha_- = -0.104 \pm 0.04$. Defining φ by $\beta_- = (1-\alpha_-^2)^{-1/2}\sin\varphi$, $\gamma_- = (1-\alpha_-^2)^{-1/2}\cos\varphi$, we find $\varphi = -22° \pm 30°$, i.e., the decay occurs mainly through the S-wave channel.

We have measured the parameters α_-, β_-, and γ_- characterizing the decay

$$\Sigma^- \to n + \pi^-. \tag{1}$$

The parameters are defined by Berley et al.[1]; we follow the convention that α_- is equal to the neutron helicity. Previous experiments find α_- small and consistent with zero[2]; α_0 (the decay asymmetry parameter for the decay $\Sigma^+ \to p + \pi^0$) is near unity[2,3]; and the $\Sigma^+ \to n + \pi^+$ decay has been found to be predominantly spin flip ($\gamma_+ \approx -1$).[1,4] Given these facts and the known decay rates, the $\Delta I = \frac{1}{2}$ rule predicts $\gamma_- \approx +1$. Evaluation of the final-state interaction indicates that if time-reversal invariance holds, β_- is expected to be small.[5] Neither γ_- nor β_- has been measured.

From the analysis of Watson, Ferro-Luzzi, and Tripp (WFT),[6] the Σ^- hyperons produced by

$$K^- + p \to \Sigma^- + \pi^+ \tag{2}$$

in the vicinity of the $Y_0^*(1520)$ resonance are predicted to be highly polarized. Accordingly, we have taken 500 000 exposures in the Columbia-Brookhaven 30-in. hydrogen bubble chamber, with the K^- beam energy centered at 410 MeV/c. We scanned for examples of Reaction (2), with no criteria being applied at the production vertex other than minimum lengths for the K^- and π^+. All events were discarded which did not have a visible proton recoil of at least 5-mm projected length within 35° projected angle of the sigma direction, lying on the opposite side of the sigma from the decay pion. In order to reject decays having low-energy neutrons, it was also required that the decay pion make a projected angle of at least 20° with the sigma direction.

There is one very significant difference between the analysis in this experiment and that which was done in the similar experiment reported earlier on the $\Sigma^+ \to n + \pi^+$ decay mode.[1] It is possible to make a direct measurement of the Σ^+ polarization by studying the asymmetry in the decay $\Sigma^+ \to p + \pi^0$. No such measurement is possible in this case, and we are forced to rely heavily on the results of WFT. However, our experiment does indicate that the general form of the Σ^- polarization prediction is probably correct, though a change of sign is not excluded. If the sign of the sigma polarization is reversed, we find similar results but with the sign of γ_- also changed.

Measurement of α_-.—A sample of 6068 events of Type (1) was used in studying the decay asymmetry. The events were divided into four subsamples according to the sigma polarization predicted for each event from WFT. The quantity $\alpha_- P_\Sigma$, where P_Σ is the sigma polarization, was determined in two ways: first by the usual "up-versus-down" method, second by a maximum-likelihood calculation. A maximum-likelihood calculation was also made for α_-, with the sigma polarization as given by WFT assumed. The results are summarized in Table I. The four subsamples give similar results, with the exception of sample 3. However, sample 3 has a relatively flat likelihood function, and therefore it has little effect on the over-all result. Combining all the events, one obtains $\alpha_- = -0.104 \pm 0.04$. Previous experiments give -0.017 ± 0.042.[2]

Measurement of β_- and γ_-.—In order to obtain β_- and γ_-, it is necessary to study the correlation between the neutron polarization direction and the direction of polarization of

Table I. P_{WFT} is the sigma polarization predicted from WFT. P_S is the value for the sigma polarization obtained from the n-p scattering asymmetry when $\gamma_-=+1$ is assumed. The subscript "L" indicates that the quantities were obtained from a likelihood function calculation.

Sample	P_{WFT}	No. Σ decays	No. genuine recoils	$\langle P_{WFT}\rangle$	$\langle P_S\rangle$	$\langle \alpha P\rangle_{up-down}$	$\langle \alpha_- P_\Sigma\rangle_L$	$\langle \alpha_-\rangle_L$
1	−1.0 to −0.5	686	92	−0.730	−1.58 ± 0.72	+0.14 ± 0.07	+0.114 ± 0.062	−0.16 ± 0.08
2	−0.5 to 0.0	1481	209	−0.210	−0.69 ± 0.54	+0.036 ± 0.052	+0.078 ± 0.040	−0.30 ± 0.16
3	0.0 to 0.5	2096	304	+0.209	−0.42 ± 0.42	+0.14 ± 0.04	+0.093 ± 0.035	+0.125 ± 0.14
4	0.5 to 1.0	1805	401	+0.768	+0.42 ± 0.29	−0.052 ± 0.047	−0.062 ± 0.039	−0.093 ± 0.05
	All	6068	1006					−0.104 ± 0.04

the sigma from which it was produced. As in the α_- analysis, we have used the results of WFT to obtain the Σ^- polarization. The neutron polarization is obtained by studying the asymmetry in the subsequent n-p scatters in the chamber. The genuine recoils were chosen by means of a three-constraint decay fit; additional discrimination against background

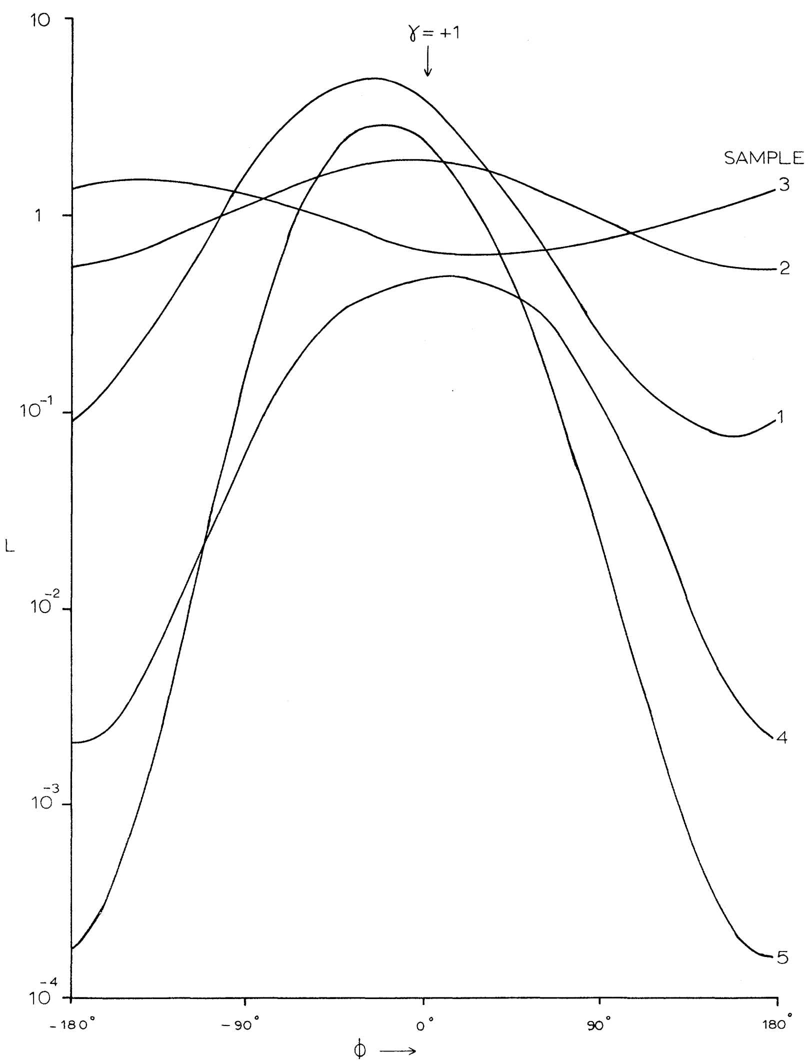

FIG. 1. Likelihood functions for samples 1-5 as a function of the parameter φ, drawn for $\alpha_-=0$. $\beta_-=(1-\alpha_-^2)^{-1/2}\times\sin\varphi$, $\gamma_-=(1-\alpha_-^2)^{-1/2}\cos\varphi$.

was provided by making an n-p scattering fit.

A likelihood function calculation was made to determine β_- and γ_-. Since α, β, and γ are related by

$$\alpha^2+\beta^2+\gamma^2=1 \tag{3}$$

we found it convenient to express β and γ in terms of a parameter φ:

$$\beta=(1-\alpha^2)^{-1/2}\sin\varphi, \tag{4}$$

$$\gamma=(1-\alpha^2)^{-1/2}\cos\varphi. \tag{5}$$

The likelihood function is then, for a given α, a function of φ alone and has the form

$$L(\varphi)=\Pi_i(1+\alpha\vec{P}_{\Sigma i}\cdot\hat{n}_i)[1+A_i\vec{P}_{ni}(\varphi)\cdot\hat{S}_i]. \tag{6}$$

$\vec{P}_{\Sigma i}$ is the sigma polarization for the event i; and $\hat{n}_i$ is a unit vector in the direction of the neutron flight. The values for the n-p scattering asymmetry A_i were obtained from fits to n-p scattering data furnished by Hull et al.[7] The neutron polarization in the sigma c.m. system is given in terms of the decay parameters by

$$\vec{P}_n=(1+\alpha\vec{P}_\Sigma\cdot\hat{n})^{-1}\{[\alpha+\vec{P}_\Sigma\cdot\hat{n}(1-\gamma)]\hat{n}+\gamma\vec{P}_\Sigma+\beta(\vec{P}_\Sigma\times\hat{n})\}. \tag{7}$$

$\hat{S}_i$ is the normal to the scattering plane, defined by

$$\hat{S}=\hat{n}\times\hat{n}'/|\hat{n}\times\hat{n}'|, \tag{8}$$

where $\hat{n}'$ is the neutron direction after scattering.

The results of the calculation are displayed in Fig. 1. One finds that a rather large nonzero value of α_- (up to $\alpha_-=-0.25$) has virtually no effect on the value of φ obtained; the curves are drawn for $\alpha_-=0$. For the complete sample we obtain

$$\varphi=-22°\pm30°$$

with a likelihood ratio for $\gamma=+1$ to $\gamma=-1$ of 1.4×10^4. That there is indeed a change of sign in the polarization roughly as predicted by WFT is seen by comparing the likelihood functions for the two samples with large negative and positive polarizations. If the polarization did not change sign as assumed, these would give opposite signs for γ_-. It is notable that sample 3 gives $\varphi\approx220°$ ($\gamma_-\approx-1$) instead of $\varphi\approx0°$ ($\gamma_-\approx+1$), in contrast to the results for the other three samples. As in an α_- calculation, this is what one would expect if the events in the sample had predominantly negatively polarized sigmas, contrary to the prediction.

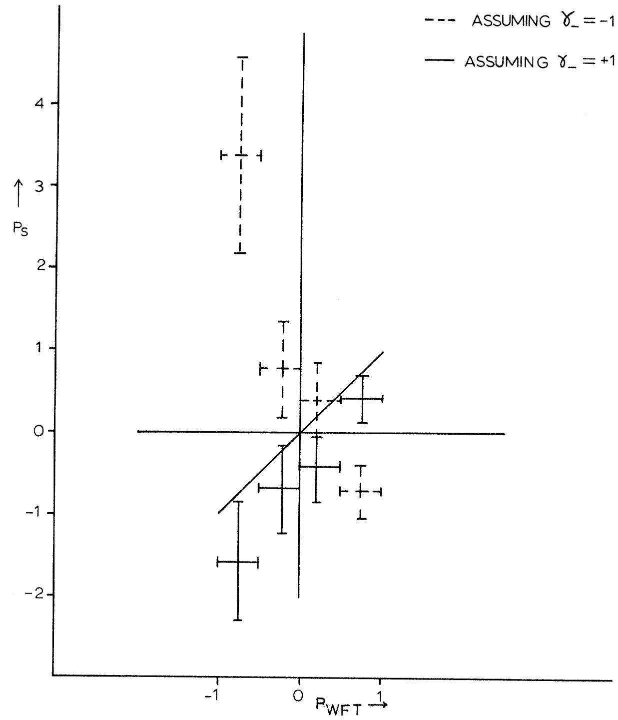

FIG. 2. The observed Σ^- polarization for four samples of events compared with the predicted average from WFT. The horizontal error bars correspond to the sample limits.

Alternatively, the Σ^- polarization can be determined assuming the decay parameters. The events were divided into the same four samples; and a likelihood function calculation was made to determine the average polarization of each sample, assuming first $\gamma_-=-1$ and then $\gamma_-=+1$. The results are referred to as P_S and are given in Table I and Fig. 2. The results for $\gamma_-=+1$ conform more closely to the prediction, although there is an over-all shift toward more negative values. For sample 1 with $\gamma_-=+1$ an unphysical value is indicated, though it is still physical within errors.

The conclusions are that $\gamma_-\approx+1$ as predicted by the $\Delta I=\frac{1}{2}$ rule, and $\beta_-\approx0$, consistent with time-reversal invariance.

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MEASUREMENT OF THE BRANCHING RATIO FOR THE DECAY $K^+ \to e^+ + \nu$

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The decay rate for the mode $K^+ \to e^+ + \nu$ has been measured. There are ten events, which include an estimated 0.34 background event only, and the branching ratio relative to $K^+ \to \mu^+ + \nu$ is found to be $R = 1.9_{-0.5}^{+0.8} \times 10^{-5}$. This is in good agreement with the prediction of the V–A theory, which is $R = 2.10 \times 10^{-5}$, including radiative corrections.

The branching ratio for $K^+ \to e^+ + \nu$ relative to $K^+ \to \mu^+ + \nu$ is predicted to be[1]

$$R_0 = \left(\frac{M_K^2 - M_e^2}{M_K^2 - M_\mu^2}\right)^2 \left|\frac{(M_e/M_K) f^A + f^P}{(M_\mu/M_K) f^A + f^P}\right|^2 \qquad (1)$$

neglecting radiative corrections and assuming (μ, e) universality. The constants f^A and f^P are for axial vector and pseudoscalar coupling, respectively. They may be relatively complex if time-reversal invariance is violated. Some special cases of Eq. (1) are the following:

$$f^A \neq 0,\ f^P = 0,\quad R_0 = 2.57 \times 10^{-5};$$

$$f^A = 0,\ f^P \neq 0,\quad R_0 = 1.10.$$

It follows that measurement of R_0 is a sensitive test for a natural pseudoscalar coupling constant. For strangeness-conserving decays, such an investigation has been made[2] by measurement of the branching ratio for $\pi^+ \to e^+ + \nu$.

Radiative corrections have been calculated[3] for the case $f^P = 0$. The branching ratio then becomes

$$R_0[1.0 - 0.185 + 0.0273 \ln(2\epsilon/M_e)]. \qquad (2)$$

The second term gives a suppression of the rate owing to virtual photons. The third term results from inner bremsstrahlung over the electron energy interval $(E_{\max} - \epsilon)$ to $E_{\max}$. In this note we define the K_{e2} branching ratio R to be given by the first two terms in expression (2), so that $R = 0.815 R_0$. In normalizing our observed rate, we have made allowance for inner bremsstrahlung according to the third term. Thus our result is independent of the resolution of the apparatus.

We have measured the K_{e2}^+ branching ratio at NIMROD, the 7-GeV proton synchrotron at the Rutherford High Energy Laboratory. Our apparatus is shown in Fig. 1. K^+ mesons from a 700-MeV/c separated beam were brought to rest in the beryllium plates of a small spark chamber at an average rate of 1500 per machine