MEASUREMENT OF THE Σ^- ASYMMETRY PARAMETER*

Robert D. Tripp, Mason B. Watson, and Massimiliano Ferro-Luzzi†
Lawrence Radiation Laboratory, University of California, Berkeley, California
(Received May 31, 1962)

In a previous Letter we reported a hydrogen bubble-chamber experiment in which the existence of an excited 1520-MeV hyperon was established.[1] Moreover, a study of the angular distributions and polarizations of Σ hyperons from the reaction $K^-p \to \Sigma\pi$ in the vicinity of this resonance showed the $KN\Sigma$ parity to the negative.[2] A further study of this reaction permits us to determine the asymmetry parameters α in $\Sigma^\pm$ decay by means of their decay asymmetries. The α for $\Sigma_+^+ \to n\pi^+$ (called α_+) and $\Sigma_0^+ \to p\pi^0$ (called α_0) have already been well established, and our measurements are in good agreement with the published values, although statistically less accurate. The α_- for $\Sigma_-^- \to n\pi^-$ has, however, resisted measurement via the Σ^- decay asymmetry due to uncertainty in Σ^- polarization. Since the procedure described in reference 2 yields a relatively precisely specified and rather large value for the $\sin\theta\cos\theta$ term in Σ^- polarization over the K^- momentum range 350 to 450 MeV/c, we have been able to determine the helicity $\alpha_- = -0.16 \pm 0.21$.[3]

Figure 1 shows the measurements, as a function of momentum, of $(\alpha\overline{P})_{\sin\theta\cos\theta}$ for the reaction $K^-p \to \Sigma^-\pi^+$, where θ is the c.m. angle between the K^- and π^+, and $\overline{P}$ is the average value of the Σ^- polarization over the angular interval $0.95 > |\cos\theta| > 0.30$ as described in reference 2. The solid curve shows the value of $\overline{P}$ for this reaction, calculated using a least-squares fitting program to determine the S-, P-, and D-wave amplitudes.[4] These amplitudes are essentially those of reference 2. The dashed curve shows a maximum-likelihood fit to $\alpha\overline{P}$ over the previously noted momentum range, resulting in the value of α_- quoted above. Similar procedures applied to Σ_+^+ and Σ_0^+ decays yield the values shown in column 2 of Table I. The uncertainties are statistical and correspond to standard deviations for a Gaussian likelihood function ($e^{-1/2}$ points on the likelihood curve). The uncertainties in the calculated Σ polarization are small relative to this. From our experiment, α_+, α_-, and α_0 all have the same sign. The over-all sign is determined by the sign of α_0 as measured by Beall et al.[5] Column 3 gives α as measured by other experimenters.[6,7]

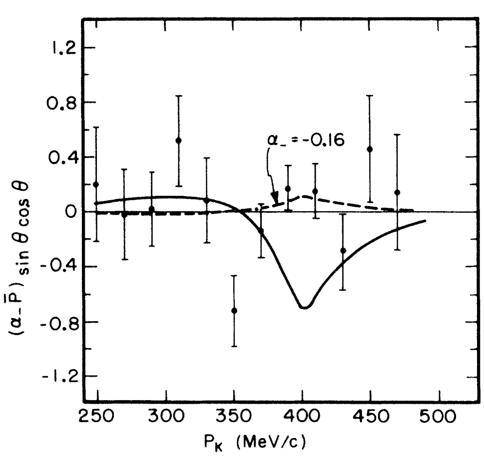

FIG. 1. Experimental values of $(\alpha\overline{P})_{\sin\theta\cos\theta}$ as a function of K^- laboratory momentum for the reaction $K^- + p \to \Sigma^- + \pi^+$ (462 events). The dashed curve is the maximum likelihood fit to the data from 350 to 450 MeV/c; the solid line is the calculated behavior of $(\overline{P})_{\sin\theta\cos\theta}$.

We shall now describe these asymmetries in terms of the $|\Delta\vec{T}| = \frac{1}{2}$ triangular relationship of Gell-Mann and Rosenfeld.[8] In their notation, $\vec{N}_+ + \sqrt{2}\,\vec{N}_0 = \vec{N}_-$, where $\vec{N}_{\pm,0}$ signifies the decay amplitudes for $\Sigma_{\pm,0}^{\pm}$. For spin-$\frac{1}{2}$ hyperons decaying into S and P states with amplitudes S and P, we have $\vec{N} = \vec{S} + \vec{P}$ and

$$\alpha = \frac{2\,\mathrm{Re}\,S^*P}{|S|^2 + |P|^2} \approx \frac{2SP}{S^2 + P^2}. \tag{1}$$

Here we have used time-reversal invariance to relate the phases of these amplitudes to the πN-

Table I. Asymmetry parameters (helicities) in Σ decay.

	This experiment	Other experiments	Combined
α_-	-0.16 ± 0.21		-0.16 ± 0.21
α_+	-0.20 ± 0.24	-0.03 ± 0.08[a]	-0.05 ± 0.08
α_0	-0.90 ± 0.25	$-0.78^{+0.09}_{-0.08}$[b]	$-0.79^{+0.09}_{-0.08}$

[a]See reference 6.
[b]See reference 7.

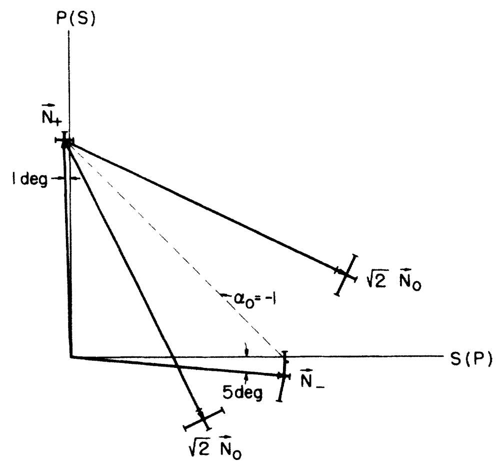

FIG. 2. The Σ-decay amplitudes in the $S-P$ plane. The $|\Delta\vec{T}| = \frac{1}{2}$ rule requires that the three amplitudes form a triangle.

scattering phase shifts. These phase shifts are listed in reference 8 and are seen to be small. Taking the amplitudes to be real (the resulting error is small relative to experimental uncertainties), one then describes the various decay amplitudes as vectors in an S-P plane. The magnitudes of the vectors are determined from the three decay rates.[9] The directions are obtained from Eq. (1) by expressing $\alpha = \sin 2\nu$, where ν is the angle with respect to the coordinate axis. Two ambiguities remain—the labeling of the S and P axes.

Using the combined values for the helicities α listed in Table I, we construct Fig. 2. The two directions for $\vec{N}_0$ arise from $|\alpha_0|$ being less than one, corresponding to S/P greater or less than one. For $\alpha_0 = -1$, the triangle would close well within experimental errors, and the triangular relationship given by the $|\Delta\vec{T}| = \frac{1}{2}$ rule would hold. The inconsistency with the $|\Delta\vec{T}| = \frac{1}{2}$ rule lies between two and three standard deviations.

---

*Work supported by the U. S. Atomic Energy Commission.

†National Academy of Sciences Fellow.

[1]M. Ferro-Luzzi, R. D. Tripp, and M. B. Watson, Phys. Rev. Letters 8, 28 (1962).

[2]R. D. Tripp, M. B. Watson, and M. Ferro-Luzzi, Phys. Rev. Letters 8, 175 (1962).

[3]The decay asymmetry is written as $1 + \alpha P_\Sigma \cos\phi$, where ϕ is the angle between the hyperon polarization, P_Σ, and the nucleon direction. This convention has the merit of having the nucleon helicity equal to the decay asymmetry parameter. The more usual, but not universal, convention of following the pion leads to an annoying minus sign relating the helicity to the asymmetry parameter.

[4]M. B. Watson, M. Ferro-Luzzi, and R. D. Tripp (to be published).

[5]E. F. Beall, Bruce Cork, D. Keefe, W. C. Murphy, and W. A. Wenzel, Phys. Rev. Letters 8, 75 (1962).

[6]Bruce Cork, L. T. Kerth, W. A. Wenzel, J. W. Cronin, and R. L. Cool, Phys. Rev. 120, 1000 (1960).

[7]See reference 5. The value we quote uses the $|\Delta\vec{T}| = \frac{1}{2}$ rule, but in only a very weak way involving the πN phase shifts. We have adjusted their uncertainties to correspond to standard deviations.

[8]M. Gell-Mann and A. H. Rosenfeld, Ann. Rev. Nuclear Sci. 7, 454 (1957).

[9]W. H. Humphrey and R. R. Ross, Phys. Rev. (to be published). The mass difference has been accounted for approximately by dividing the decay rates by the phase-space factor P/E to obtain $|N|^2$. If we assume the $|\Delta\vec{T}| = \frac{1}{2}$ rule, these decay amplitudes alone show that the triangle is nearly a right triangle (94 ± 5 deg).

CORRESPONDENCE BETWEEN τ AND η DECAYS*

Mirza A. Baqi Bég
Brookhaven National Laboratory, Upton, New York
(Received June 11, 1962)

In a recent Letter, Barton and Rosen[1] have proposed a combined test for the decay mechanism of the η meson as envisaged by Gell-Mann et al.[2] and of the adequacy of the pion pole approximation suggested earlier for τ and τ' decays.[3] The argument rests on the observation that the model of Gell-Mann et al. leads in a natural manner to the one-pion intermediate state and that, once this state has interceded, the Dalitz plot for η decay is determined by the $\pi \to 3\pi$ amplitude; in particular, if τ' decay is adequately described by the pion pole term, the π^0 spectrum in $\eta \to \pi^+\pi^-\pi^0$ is identical with the π^+ spectrum in $\tau^{+\prime}$ decay.[4]

The purpose of this note is to point out that this similarity of Dalitz plots [which, incidentally, is in reasonable agreement with the data available