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SIGMA SPIN AND PARITY CONSERVATION IN $K^- + p \rightarrow \Sigma^+ + \pi^-$

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Day, Snow, and Sucher have recently shown that when K^- mesons come to rest in liquid hydrogen, they are captured from s orbits.[1] Such s-state capture leads to Σ-decay angular distributions that are unique functions of the Σ spin. On the basis of an analysis of 145 Σ^+ hyperons produced in K^- absorption,[2] we find very strong evidence for a spin-1/2 sigma. We also report a check on the hypothesis of parity conservation in the reaction $K^- + p \rightarrow \Sigma^+ + \pi^-$.

The sample considered here consisted of 82 "Σ_0^+" events (i.e., $\Sigma^+ \rightarrow \pi^0 + p$) and 63 "$\Sigma_+^+$" events (i.e., $\Sigma^+ \rightarrow \pi^+ + n$), 95% of which came from K^- absorption at rest. In order to eliminate biases and avoid confusing various possible reactions, only Σ^+ events longer than 0.9 mm were accepted in the analyzed sample. Possible confusion of the event types Σ_0^+ and Σ_+^+, where the decay secondary is too short to provide a reliable ionization estimate, is eliminated by submitting the event to a full kinematic analysis. Events in which the Σ^+ and primary π^- were clearly noncollinear were discarded, since in these cases the K definitely interacted in flight.

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The observed center-of-mass angular distribution, folded through 90°, for all Σ^{+} decay-pions is shown in Fig. 1. In order to determine the Σ spin from this distribution, certain assumptions must be made, since the most general form of the Σ-decay angular distribution contains undetermined parameters.[3] If we assume that the K meson has zero spin[4] and is captured from an s-state, the maximum component of angular momentum that the Σ can have along its direction of flight is 1/2. Further, if the Σ has spin greater than 1/2, this leads to an alignment of its spin, J, perpendicular to its direction of motion. The decay angular distribution, $f_J(\theta)$, is thus unique for a given value of J.[5]

The crucial assumption of s-state capture has recently been investigated by Day, Snow, and Sucher.[1] They consider hydrogen atoms in an excited state with large quantum number, n, colliding with protons in liquid hydrogen. They point out that the Stark effect serves to oscillate the kaon wave function between ns and np states. Since the capture probability from ns states is large compared to the radiative transition probability from all l states of the n level, kaons presumably do not cascade to the 2p level, but rather are captured directly from s-states. Quantitatively, Day et al. estimate that about 99% of all K-p absorptions occurs from s-states. We, therefore, feel that the assumption of s-state capture is well grounded.[6]

With these assumptions,[7] the folded distributions $f_J(|\cos\theta|)$ become $f_{1/2} = 1$, $f_{3/2} = 1/2(1 + 3\cos^2\theta)$. The forms for higher spin values are given by Adair.[3] For practical purposes, since the observed distribution is quite isotropic, we have analyzed the data in terms of the normalized function, F:

$$F(|\cos\theta|) = 1/2(1 + A\cos^2\theta)\,(1 + A/3)^{-1}. \qquad (1)$$

An approximate maximum-likelihood solution of Eq. (1) for the best-fit value of A, gives $A = +0.12 \pm 0.14$. This is clearly consistent with J = 1/2, and

moreover is over 20 standard deviations from the expected value of 3 for spin 3/2. This constitutes the strongest evidence to date that the sigma spin is 1/2.[8]

Next, we describe a search for evidence of parity nonconservation in the reaction $K^- + p \rightarrow \Sigma^+ + \pi^-$, using the Σ_0^+ decay mode as an analyzer. Parity conservation in strong, strange-particle-producing reactions has been carefully checked only for the reaction $\pi^- + p \rightarrow \Lambda + K^0$, observed in the associated-production experiments of Crawford et al.[9] The question of parity conservation in other strong, strange particle producing interactions is still unsettled and is a subject of much theoretical interest.[10]

To detect parity violation, we look for a nonzero average value of a pseudoscalar variable, - namely, the component of the Σ spin in the direction of its momentum. Because the Σ spin is 1/2, the angular distribution of the Σ decay products in the Σ rest frame can be written in the form

$$1 + \alpha P_\Sigma \cos\theta,$$

where α is the decay-asymmetry parameter and P_Σ is the component of polarization along the axis from which θ is measured.

The analyzing properties of the Σ_0^+ mode have been demonstrated by Cool et al.[11] They find $\alpha_{\pi^0} \geq 0.7 \pm 0.3$. It follows, then, that for Σ^+ of polarization P_Σ, we should observe an asymmetry $\geq (0.7 \pm .3)\, P_\Sigma$ in the π^0 angular distribution. This in turn would indicate some degree of parity nonconservation in the reaction $K^- + p \rightarrow \Sigma^+ + \pi^-$.

The experimental angular distribution is shown in Fig. 2. There is no statistically significant asymmetry. Using the expression

$$\left\langle \alpha_{\pi^0} P_\Sigma \right\rangle = \frac{3}{N} \sum_{i=1}^{N} \cos\theta_i \pm \sqrt{\frac{3}{N}},$$

we obtain $\left\langle \alpha_{\pi^0} P_\Sigma \right\rangle = 0.02 \pm 0.19$. Hence we find no evidence for parity nonconservation in Σ^+ production.

We check our procedure by noting that Cool et al. find no asymmetry for the Σ_+^+ decay mode. Thus by analyzing our Σ_+^+ events in the same way as we have treated the Σ_0^+, we should find $\langle a_{\pi^+} P_\Sigma \rangle$ close to zero. We have done this and find $\langle a_{\pi^+} P_\Sigma \rangle = -0.03 \pm 0.22$, which is indeed isotropic and constitutes indirect evidence against hidden biases.

References

1. Day, Snow, and Sucher, Phys. Rev. Lett. 3, 61 (1959).
2. Alvarez, Bradner, Rosenfeld, Solmitz, and Tripp, Nuovo cimento, Ser. 10, 5, 1026 (1956).
3. R. K. Adair, Phys. Rev. 100, 1540 (1955).
4. The evidence that the K^- spin is indeed 0, although indirect, is quite strong. For a rather complete evaluation of this evidence see F. Eisler et al. (reference 8).
5. S. Trieman, Phys. Rev. 101, 1216 (1956).
6. Before the work of Day et al., analysis of our data could only give much weaker evidence for a sigma spin of 1/2. This is reported in Leitner, Nordin, Rosenfeld, Solmitz, and Tripp, Angular Distributions in Σ^+ Decay, UCRL-8737, May 1959.
7. Parity nonconservation in the Σ decay does not complicate the distribution if it is folded about 90 deg, because then all odd powers of $\cos\theta$ vanish. For details of this argument, see N. Samios, Properties of Λ^0, θ^0 Produced by 1.3-Bev π^- (thesis), Nevis Report No. 32, January 1957 (unpublished).
8. F. Eisler et al., Nuovo cimento, Ser. 10, 7, 222 (1958).
9. Crawford, Cresti, Good, Solmitz and Stevenson, Phys. Rev. Lett. 1, 618 (1958)
10. [illegible] Phys. Rev. 108, 890 [illegible] Nuclear Phys. 6, 6[illegible] (1958); A. Pais, Phys. Rev. Lett. 1, [illegible] (1958).
11. Co[illegible] Hyperon [illegible]

Figure Captions

Fig. 1. Folded angular distribution of all Σ^+ decays (145 events).

Fig. 2. Angular distribution of pions from $\Sigma^+ \rightarrow p + \pi^0$ (83 events).

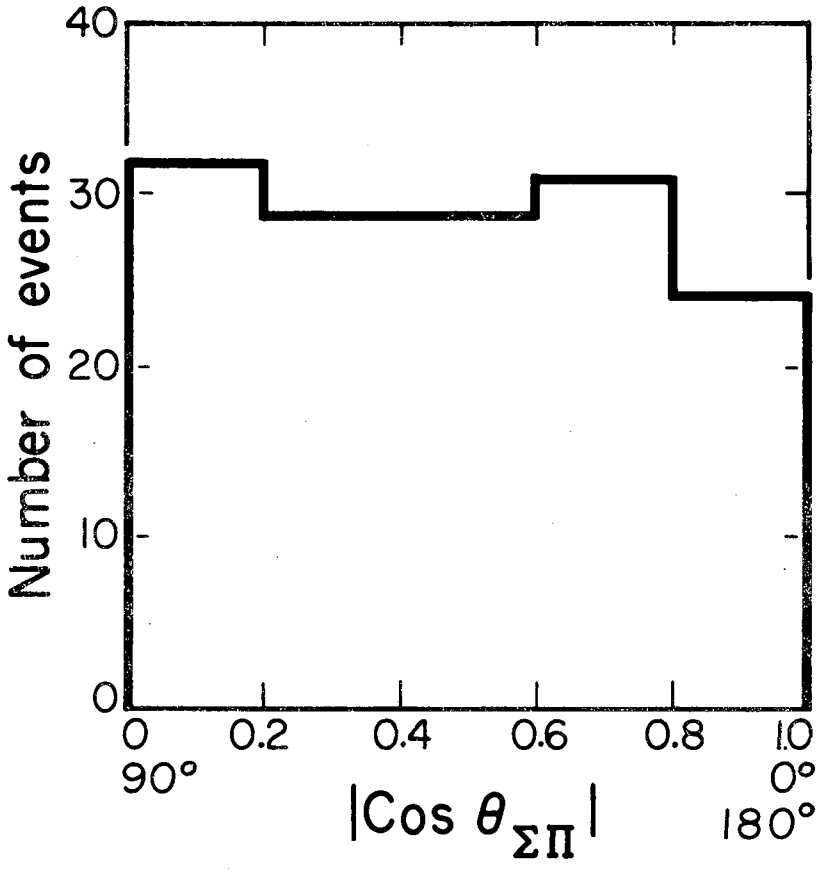

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Fig. 1

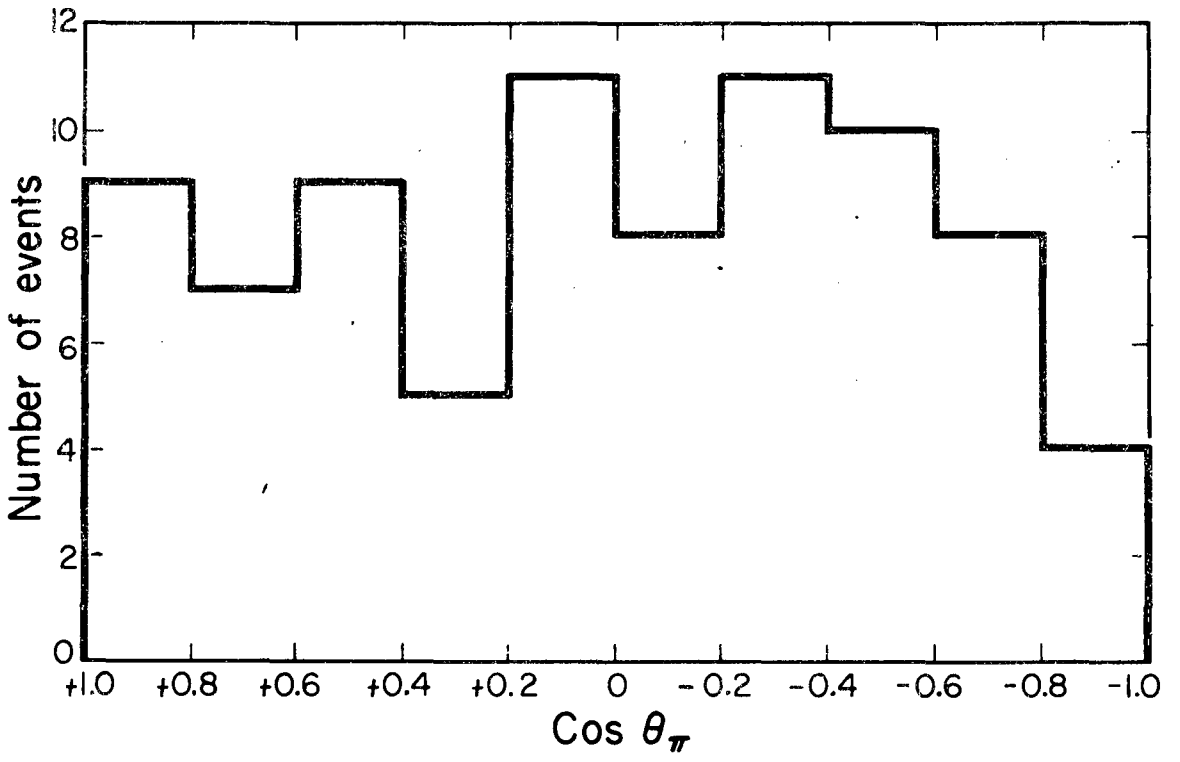

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Fig. 2.