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SIGMA SPIN AND PARITY CONSERVATION IN $K^- + p \rightarrow E^{++} + n^-$

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$$\text{IN } K^- + p \rightarrow \Sigma^+ + \pi^-$$

Jack Leitner, Paul Nordin, Jr., Arthur H. Rosenfeld,
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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 " Σ_+^+ " 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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¹On leave from Syracuse University, New York.

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 spin⁴ 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 n_0 and n_1 states. Since the capture probability from n_0 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 :

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

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

$$1 + a P_{\Sigma} \cos \theta,$$

where a 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 $a_{\pi^0} \geq 0.7 \pm 0.3$. It follows, then, that for Σ^+ of polarization P_{Σ} we should observe an asymmetry $\geq (0.7 \pm 0.3) P_{\Sigma}$ 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

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

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

We check our procedure by noting that Cochl 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 bion.

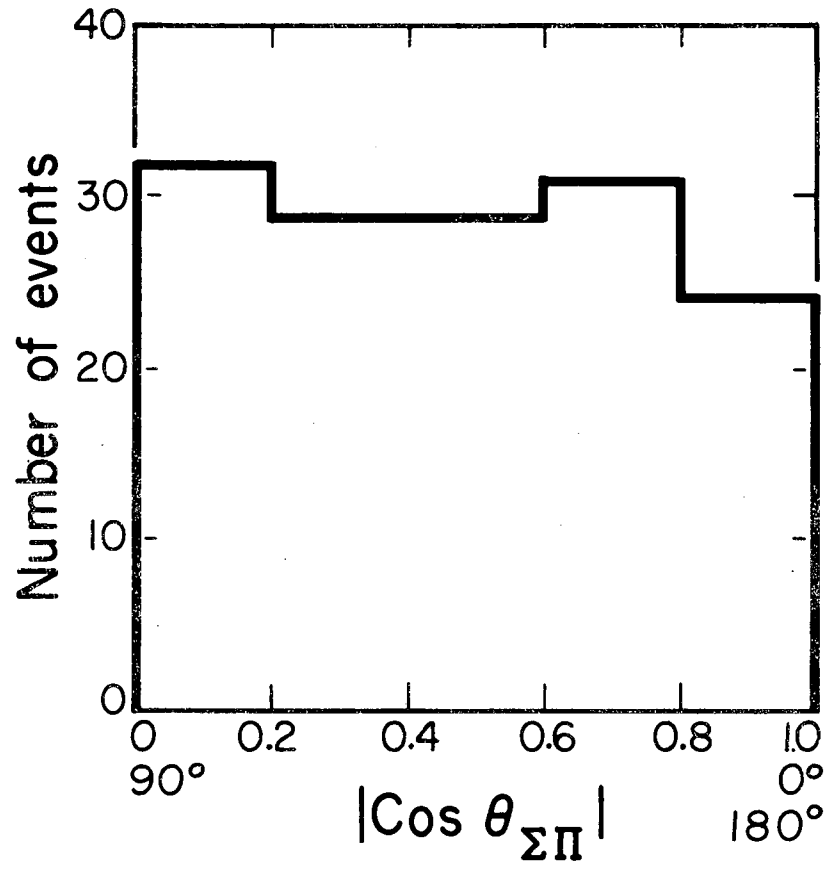
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2. Alvarez, Bradner, Rosenfeld, Solmits, and Tripp, Nuovo cimento, Ser.10, 5, 1026 (1956).
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For a rather complete evaluation of this evidence see F. Eicler et al. (reference 8).
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6. 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, Solmits, 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).
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Figure Captions

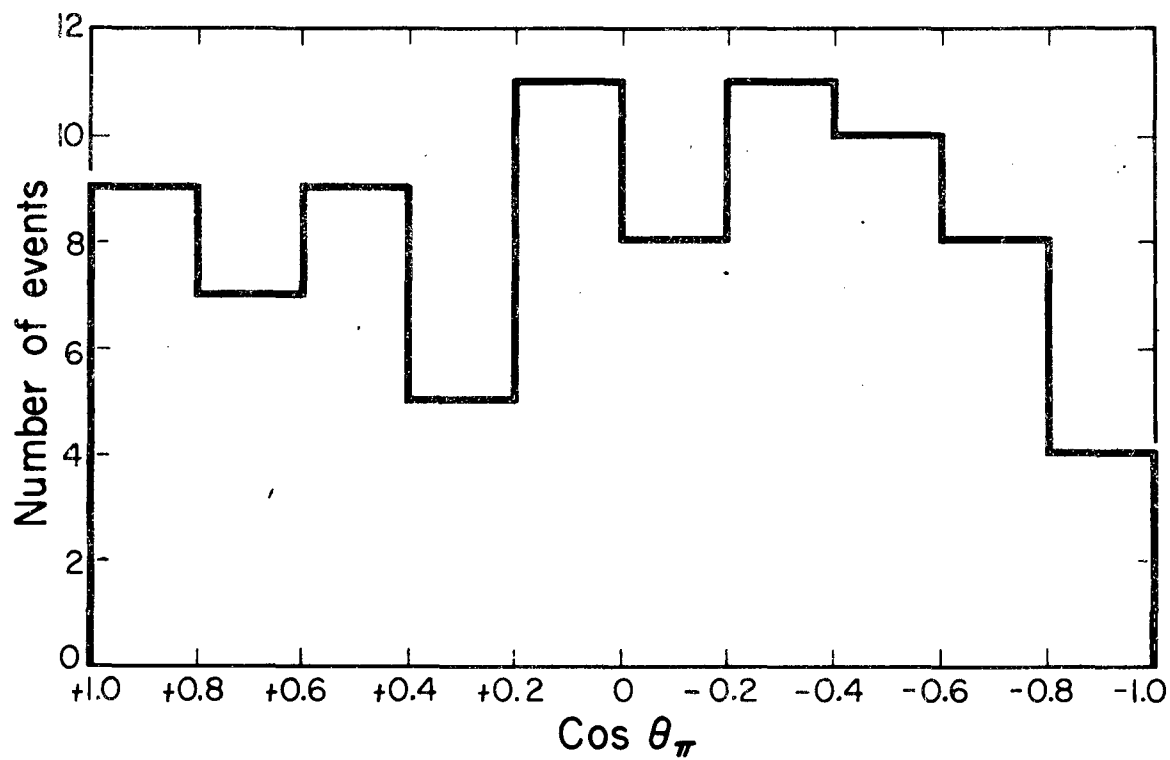
Fig. 1. Folded angular distribution of all Σ^+ decays (145 events).

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.

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