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Σ^+ decay and polarization properties in $K^-p \to \Sigma^+\pi^-$

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Results are presented on a new measurement of αP for the decay of Σ^+ hyperons produced in the reaction $K^-p \to \Sigma^+\pi^-$ at beam momenta around 460 MeV/c, where α is the decay asymmetry parameter and P is the hyperon polarization. The present analysis is based on 20479 events. The ratio of the usual Σ^+ decay parameters, α_+ and α_0, is found to be -0.104 ± 0.028; this should be compared with the present world average of -0.067 ± 0.016.

New results are presented on the measurement of αP for Σ^+ hyperons from the reactions $K^-p \to \Sigma^+\pi^-$, $\Sigma^+ \to p\pi^0$ and $K^-p \to \Sigma^+\pi^-$, $\Sigma^+ \to n\pi^+$, where α is the decay asymmetry parameter and P is the hyperon polarization. The kaon transport momenta for the experiment were 440, 460, 480, and 500 MeV/c. These data have statistical weight comparable to the world average based on all earlier experiments, and they have the further advantage that, owing to the different detector geometry, they are not subject to the same possible systematic error. The data were obtained at the CERN Proton Synchrotron using the specially designed bubble chamber HYBUC, whose geometry[1] is particularly suited for these polarization measurements; events with decay-particle momentum parallel to the magnetic field do not bias the αP results. In addition, the ratio of the asymmetry parameters for the $n\pi^+$ and $p\pi^0$ modes (α_+ and α_0) does not depend on the value of the polarization since each decay mode has identical polarization.

The hyperon bubble chamber, HYBUC, is a hydrogen bubble chamber equipped with an 11.7-T superconducting solenoid. The chamber fiducial volume is approximately cylindrical in shape with a length of 32 cm and a diameter of about 11 cm. The optical system consists of Scotchlite[2] illumination and of five objectives with optical axes parallel to the chamber axis, four situated 10 cm from the chamber axis and one on the axis. The beam enters along the magnetic field in order to have the polarization perpendicular to the field for all production planes. More details of the HYBUC hardware system are published elsewhere.[3]

The film is being scanned on all five views and is measured manually with image- and film-plane digitizers. Scanning criteria are very liberal in order to minimize losses of Σ events. The present work is based on the measurement of 29 851 Σ^+ candidates; the events were reconstructed using the advanced CERN analysis package HYDRA GEOMETRY and KINEMATICS. The average deviation of measured points from the reconstructed track, ϵ, is approximately 80μ in the plane of the chamber window. Approximately 20% failed to give an acceptable Σ^+ multivertex fit. The rejects are presently under study and preliminary results indicate that about $\frac{1}{2}$ of them are non-Σ events (e.g., double scatters, $\Lambda\pi^+\pi^-$ events, glass and wall interactions, etc.), about $\frac{1}{4}$ are found to be unmeasurable (e.g., very short Σ length), and the remainder are being remeasured.

Events with production vertex within 3 cm of the chamber window were not included in the present analysis. These events often have large measurement errors and the fraction of ambiguous kinematic fits is much higher. Also excluded from this analysis were events with a Σ track length less than 2 mm; such events show significant losses. A small fraction ($\approx 5\%$) of the Σ^+ events gave good kinematic fits to both $\Sigma^+ \to p\pi^0$ and $\Sigma^+ \to n\pi^+$ decay modes. The decision between the two decay modes was made on the basis of relative fit probability *unless* the proton hypothesis was consistent with a stopping proton, in which case the $\Sigma^+ \to p\pi^0$ mode was chosen. Studies with the ambiguous events and with Monte Carlo events have shown that the present results are not biased by wrong fit decisions.

After cuts and fit decisions, 20 479 acceptable Σ events remained. For one magnetic-field direction there were 5337 $\Sigma^+ \to p\pi^0$ and 5468 $\Sigma^+ \to n\pi^+$ events, and for the reversed field direction 4877 $\Sigma^+ \to p\pi^0$ and 4797 $\Sigma^+ \to n\pi^+$.

Figure 1 shows the distribution of the fitted beam momenta at the Σ production vertex for each field direction. The variation of the αP values with beam momentum has been checked, but the variations are not significant at the present statistical level. The data from different field directions have also been analyzed separately, as any differences here could uncover systematic effects. The results from the two directions are consistent with each other. Thus for the present study all the data from both field directions and for all beam momenta have been added together, so that the results refer to the total data sets of 10 214 $\Sigma^+ \to p\pi^0$ and 10 265 $\Sigma^+ \to n\pi^+$ events.

Figure 2 shows the distribution of $\cos\theta^*$ for all Σ^+ events, where θ^* is the production angle of the π^- with respect to the incident K^- in the c.m. system. This distribution is in good agreement with that of Armenteros *et al.*[4] for the same momentum region, although the data in Fig. 2 have not yet been corrected for losses due to short or stopping Σ^+ and small decay angles. The close agreement gives confidence that any systematic corrections to the final data sample will be small. Such corrections in any case should not affect the results for αP.

The nucleon angular distribution from the Σ decay is given by $dN/d(\cos\xi) = (N/2)(1+\alpha P \cos\xi)$, where N is the number of events, $\cos\ \xi = \hat{n}\cdot\hat{p}$, $\hat{n}$ is the unit vector normal to the production plane, and $\hat{p}$ is the unit vector in the direction of the decay nucleon in the Σ rest frame. Thus $\hat{n} = -(\hat{K}\times\hat{\Sigma})/|\hat{K}\times\hat{\Sigma}|$, where $\hat{K}$ is the direction of the incoming K^-, and $\hat{\Sigma}$ is the direction of the outgoing Σ^+, taken at the decay point in order to account for the precession of the Σ Dirac magnetic moment in the magnetic field. A straight line was fitted to the $\cos\xi$ distribution, and from its slope αP was calculated. The standard notation is used here; α_0 is the asymmetry parameter for the $\Sigma^+ \to p\pi^0$ decay mode and α_+ is that for $\Sigma^+ \to n\pi^+$.

The $\Sigma^+ \to p\pi^0$ events were divided into 10 $\cos\theta^*$ intervals, and for each subsample $\alpha_0 P$ was calculated.[5] The results are shown in Fig. 3. Again the agreement with Armenteros *et al.*[4] is very

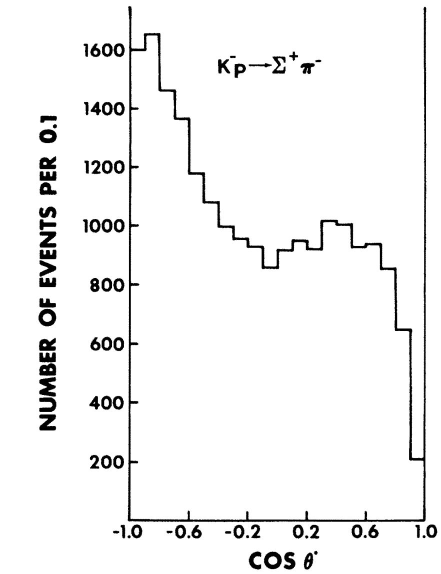

FIG. 2. Distribution of $\cos\theta^*$, the cosine of the pion production angle in the c.m. system of the reaction $K^-p \to \Sigma^+\pi^-$.

good. It should be noted that in the αP determination no account has been taken of the anomalous Σ moment. To investigate the effect of this, the entire analysis was repeated using Σ-production quantities rather than Σ-decay quantities to define the initial polarization direction. This procedure reduced the αP values by less than $\approx 1\%$ owing to the increased depolarization caused by the Σ total

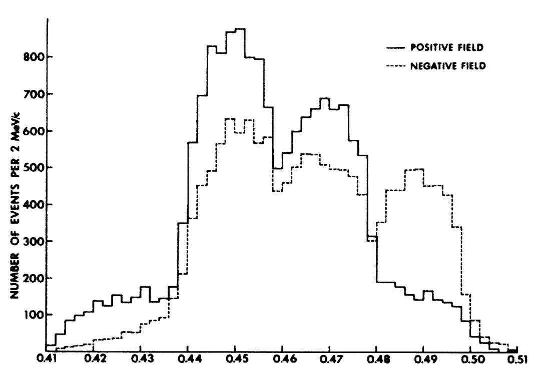

FIG. 1. Distributions of the fitted beam momenta for the two field directions.

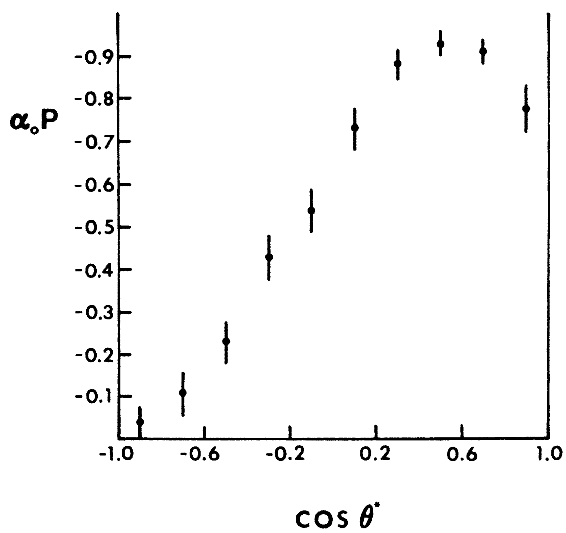

FIG. 3. Variation of αP with $\cos\theta^*$ for the $\Sigma^+ \to p\pi^0$ events. The depolarization effect caused by the anomalous part of the Σ magnetic moment has not been taken into account. The stated values for αP are therefore underestimated by a few percent.

moment. This indicates that the αP values given in Fig. 3 are underestimated by $\approx 2\%$.

For the $\Sigma^+ \to n\pi^+$ events, α_+ and thus the corresponding αP values are an order of magnitude smaller than those of the $\Sigma^+ \to p\pi^0$ events.[6] Therefore the $\cos\theta^*$ intervals were chosen larger in order to have a significant αP measurement with the present statistics. The $\cos\xi$ distributions for the division into *two* $\cos\theta^*$ intervals are shown in Fig. 4; the steeper slopes correspond to $\cos\theta^* > 0$. The straight-line fits to the distributions, excluding the shaded regions which have losses, are also shown, and the corresponding αP results are given in the figure caption. The αP results for the subdivision of $\cos\theta^*$ into *four* intervals are listed in Table I. For these results the same $\cos\xi$ region as in Fig. 4 has been excluded from the fits.

The losses in the shaded regions of Fig. 4 are due to events for which (a) the decay-particle direction makes a small angle with respect to the Σ direction in the laboratory system, (b) the decay proton is very short-ranged and thus not seen, or (c) the decay-particle momentum is unmeasurable because it is parallel to the field direction. Losses (a) and (b) are naturally distributed symmetrically about, and near, $\cos\xi = 0$ and therefore do not bias the αP result. Fitted events of category (c) tend to have kinematically ambiguous decay hypotheses. It is a unique advantage of the HYBUC geometry that these events also have $\cos\xi$ near zero and do not bias the αP measurement. Values of αP were determined excluding events within several intervals symmetric about $\cos\xi = 0$. The values with and without ambiguous events, and for the fits with zero and the maximum cut ($-0.4 < \cos\xi < +0.4$) differed by at most 0.01. The interval excluded for the results presented here is $-0.2 < \cos\xi < +0.2$; this choice gives good χ^2 values for the straight-line fits.

The ratios of the αP results for the $\Sigma^+ \to n\pi^+$ and the $\Sigma^+ \to p\pi^0$ samples for each $\cos\theta^*$ interval are given in Table I. Since the Σ^+ polarization is the same in both cases, this ratio is α_+/α_0. The results for α_+/α_0 are consistent for the different $\cos\theta^*$ intervals. The weighted mean is $\alpha_+/\alpha_0 = -0.104 \pm 0.028$, which is to be compared with the present world average of -0.067 ± 0.016.[6]

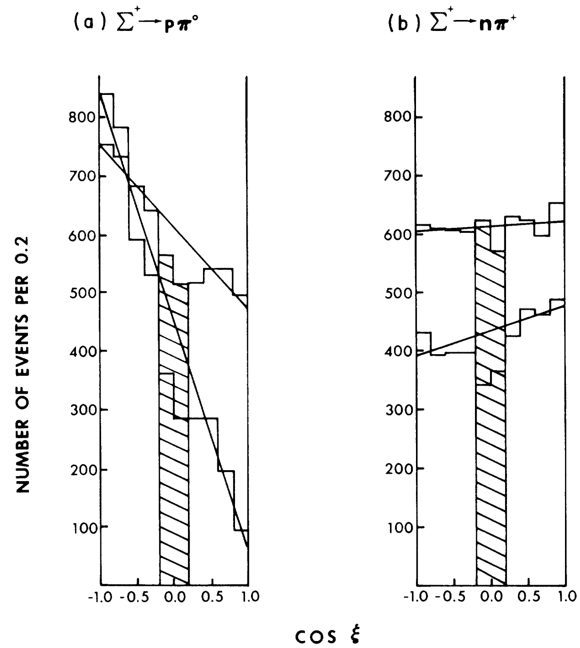

FIG. 4. Distributions of $\cos\xi$ and the corresponding straight-line fits to $dN/d(\cos\xi) = (N/2)(1+\alpha P\cos\xi)$, which yield the following αP values: (a) $\Sigma^+ \to p\pi^0$: $\cos\theta^* < 0$, $\alpha_0 P = -0.231 \pm 0.022$, $\cos\theta^* > 0$, $\alpha_0 P = -0.865 \pm 0.018$. (b) $\Sigma^+ \to n\pi^+$: $\cos\theta^* < 0$, $\alpha_+ P = 0.019 \pm 0.022$, $\cos\theta^* > 0$, $\alpha_+ P = 0.096 \pm 0.026$. The shaded regions have been excluded from these fits as discussed in the text.

The quoted error on the average has the usual meaning of a standard deviation; the denominators have negligible fractional error in three of the four determinations in Table I and the weight of the fourth ratio is very small.

We further note that measurement of this ratio also gives a direct value for α_+ since the fractional error in any reasonable estimate of α_0 is very small compared to the error in this ratio. Using the world average[6] of -0.979 ± 0.016 for α_0 gives $\alpha_+ = 0.106 \pm 0.029$.

TABLE I. Values of αP computed for (a) $\Sigma^+ \to p\pi^0$ and (b) $\Sigma^+ \to n\pi^+$ events, subdivided into four $\cos\theta^*$ intervals. The values in column (c) have been determined by dividing those in column (b) by those in column (a).

$\cos\theta^*$	(a) $\Sigma^+ \to p\pi^0$ $\alpha_0 P$	(b) $\Sigma^+ \to n\pi^+$ $\alpha_+ P$	(c) α_+/α_0
0.5 to 1.0	-0.870 ± 0.026	0.075 ± 0.040	-0.086 ± 0.046
0.0 to 0.5	-0.860 ± 0.025	0.110 ± 0.035	-0.128 ± 0.041
-0.5 to 0.0	-0.470 ± 0.032	0.032 ± 0.035	-0.068 ± 0.075
-1.0 to -0.5	-0.070 ± 0.029	0.010 ± 0.029	-0.143 ± 0.414

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[2]Scotchlite is a trademark of the 3M Company.

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