A Measurement of Polarization in $\pi^- p \rightarrow K^0 \Lambda^0$ at 5 GeV/c[†]

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Abstract

We have measured the Λ^0 polarization in $\pi^- p \rightarrow K^0 \Lambda^0$ at 5 GeV/c, using 3709 events where the decay products of both the K^0 and the Λ^0 were observed. We find that the polarization is small and positive for small $-t$, passes through zero near $-t = 0.3 \text{ (GeV/c)}^2$, and becomes large and negative at larger $-t$, consistent with a value of -1.0 for $-t \geq 0.7 \text{ (GeV/c)}^2$.

We present the results of a measurement of the Λ^0 polarization in $\pi^- p \rightarrow K^0 \Lambda^0$ at 5 GeV/c, using 3709 events where the products of the decay $\Lambda^0 \rightarrow p \pi^-$ were detected. The polarization measurements were part of an experiment⁽¹⁾ performed at the Argonne ZGS accelerator with the Argonne Effective Mass Spectrometer.

The experimental apparatus is shown in Fig. 1; it has been described in reference 1. The $\pi^+ \pi^-$ decay of K_s^0 's produced in the forward direction were selected by requiring a total anticoincidence in an array of veto counters just downstream of the hydrogen target, followed by charged particles producing a signal in counter CM located 51 cm further downstream. For the Λ^0 polarization measurements, a set of four magnetostrictive wire spark chambers were placed on the right side of the hydrogen target to observe the decay products of the recoiling Λ^0 . The active area of these chambers was 55 cm x 91 cm, and the first chamber of the set was located 31 cm from the center of the hydrogen target. The veto counter to the right of the beam was removed to allow Λ^0 decay products to enter the recoil chambers without vetoing the event, and the right-hand half of the counter hodoscope was removed from the trigger to prevent triggering on events with final state charged particles passing to the right of the beam line.

For π^- -induced events with at least one successfully reconstructed track of each charge, pion masses were assumed for both particles and the $\pi^+ \pi^-$ effective mass was calculated. A peak with an RMS width of $3 \text{ MeV}/c^2$ was found at the K^0 mass. Events in the peak region were fitted to the hypothesis $K^0 \rightarrow \pi^+ \pi^-$, and the missing mass squared of each event was calculated. A good separation of $\pi^- p \rightarrow K^0 \Lambda^0$ from $\pi^- p \rightarrow K^0 \Sigma^0$ could be made by a cut on the

calculated missing mass, illustrated in Figure 2. Less than 5% of the events selected were from the $K^0 \Sigma^0$ reaction.

Events selected by the missing mass cut were used in the polarization analysis if one or more tracks were found in the recoil spark chambers. A Z-C fit to the production hypothesis was made, and the limit of the small cone angles around the fitted Λ^0 direction allowed for the proton from $\Lambda^0 \rightarrow p\pi^-$ was calculated. If the recoil chamber track lying closest to the calculated Λ^0 direction fell within this cone, it was identified as the Λ^0 decay proton. A total of 3709 events were identified in this manner as having $\Lambda^0 \rightarrow p\pi^-$ decays. The calibration of the track angle measurements in the recoil spark chambers was performed using recoil protons from $\pi^- p$ elastic scattering.

The events with identified Λ^0 decays were divided according to whether the decay proton had been emitted up or down with respect to the Λ^0 production plane. The "up" direction was taken along the production plane normal $\hat{\pi} \times \hat{K}$. The Λ^0 polarization was determined from the up-down asymmetry by

$$P = \frac{2}{a} \left(\frac{U - D}{U + D} \right)$$

where $a = 0.645$. Our results are shown in Fig. 3 and in Table 1. The polarization is small and positive for small t ; it crosses zero near $-t = 0.3$ $(\text{GeV}/c)^2$ and becomes large and negative. For $-t$ beyond 0.7 $(\text{GeV}/c)^2$ the polarization is consistent with being constant and equal to -1.0 . These qualitative features are in agreement with earlier data⁽²⁾.

The three measured polarization values above 0.8 $(\text{GeV}/c)^2$ exceed 1.0 in absolute value. The possibility that this was due to systematic

measurement errors was carefully investigated. Monte Carlo calculations showed that only small acceptance corrections to the measured values of the polarization were required (less than .01 at all values of t). Events with more than one recoil chamber track could be fitted to the 4-C production and decay hypothesis $\pi^- p \rightarrow K^0 \Lambda^0$, $\Lambda^0 \rightarrow p \pi^-$, and the Λ^0 decay proton identified by the result of the fit. More than half the events with $-t \geq 0.8$ $(\text{GeV}/c)^2$ were of this type. There was no significant difference between the polarization determined by the 2-C and 4-C methods for these events, nor did the fitted recoil chamber track angles show any systematic shifts from the measured values. Instrumental asymmetries in the recoil chambers were looked for in several groups of data where the recoil chamber tracks could not come from hyperon decays. No statistically significant non-zero asymmetry could be found, either overall or as a function of t . Neither could any evidence of systematic alignment errors or dead areas in the recoil chambers be found. It was concluded that the measured polarizations greater than 1.0 in absolute value could only be explained as statistical fluctuations in the measured up-down asymmetry, with the real Λ^0 polarization being close to -1.0 in the interval 0.8 to 1.6 $(\text{GeV}/c)^2$.

Also plotted in Fig. 3 is the polarization observed in $\pi^+ p \rightarrow K^+ \Sigma^+$ at 5 GeV/c .⁽³⁾ Hand-drawn curves indicate the general features of the results for the two reactions. The mirror symmetry between the polarizations in $\pi^+ p \rightarrow K^+ \Sigma^+$ and $\pi^- p \rightarrow K^0 \Lambda^0$ is striking. It can be understood as the result of an SU(3) octet coupling relation between the s -channel helicity amplitudes for the two processes.⁽⁴⁾

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Table 1

Polarization in
 $\pi^- p \rightarrow K^0 \Lambda^0$ at 5 GeV/c

<u>-t Interval</u> <u>(GeV/c)²</u>	<u>Polarization</u>
.01 - .10	.04 ± .08
.10 - .20	.17 ± .09
.20 - .30	.36 ± .14
.30 - .40	-.63 ± .20
.40 - .60	-.56 ± .20
.60 - .80	-.92 ± .30
.80 - 1.0	-1.57 ± .30
1.0 - 1.2	-1.59 ± .42
1.2 - 1.6	-1.55 ± .45

Figure Captions

1. The Argonne Effective Mass Spectrometer.
2. Missing mass squared distribution from K^0 's at 5 GeV/c. The shaded region shows the events selected for polarization analysis.
3. Polarization in $\pi^- p \rightarrow K^0 \Lambda^0$, measured in this experiment, and in $\pi^+ p \rightarrow K^+ \Sigma^+$, from reference 3.

Figure 1.

Figure 2

Figure 3