Observation of a Difference Between Polarization and Analyzing Power in Λ^0 Production with 6 GeV/c Polarized Protons*

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ABSTRACT

We have measured the polarization, analyzing power, and depolarization parameter for forward lambdas produced with a 6 GeV/c polarized proton beam at the Argonne National Laboratory Zero Gradient Synchrotron. We collected a sample of 15281 Λ^0 production events with subsequent $p\pi^-$ decays. There is a clear difference between the polarization and analyzing power for events with Feynman scaling variable x greater than 0.8. This is the first observation of this phenomenon at high energy.

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Parity conserving inclusive processes of the form spin $\frac{1}{2}$ (polarized) + unpolarized $\rightarrow$ spin $(\frac{1}{2})$ (analyzed) + anything can be described⁽¹⁾ by observables which are a generalization of the Wolfenstein spin rotation parameters for proton-proton elastic scattering.⁽²⁾ The polarization $(P+P')$, the analyzing power $(P-P')$, the depolarization parameter D , and the differential cross section σ are related as follows:

$$\sigma = \sigma_0 [1 + (P-P') \vec{e} \cdot \hat{n}] \quad (1)$$

$$\sigma \vec{f} \cdot \hat{n} = \sigma_0 [(P+P') + D \vec{e} \cdot \hat{n}]. \quad (2)$$

Here $\vec{e}$ is the initial (beam) polarization vector; $\vec{f}$ is the final (Λ^0) polarization vector; and $\hat{n}$ is the production plane unit normal (along beam $\times \vec{\Lambda}^0$). $(P+P')$ measures the component of final-state baryon polarization along the production plane normal that does not depend on the beam polarization. $(P-P')$ measures the left-right production asymmetry of the final-state baryon, and D measures the extent to which it retains the beam polarization. For elastic scattering, time reversal invariance constrains the polarization to be equal to the analyzing power. However, for inelastic processes like inclusive Λ^0 production the two parameters are not required to be equal.⁽³⁾ Differences between polarization and analyzing power have previously been observed only in low energy nuclear reactions.⁽⁴⁾ We report here the first observation of this effect at high energy.

We have measured $(P-P')$, $(P+P')$, and D for lambdas produced in the forward direction by transversely polarized 6 GeV/c protons incident on a 20 cm

liquid hydrogen target. This experiment was performed at the Argonne National Laboratory Zero Gradient Synchrotron using the polarized proton beam⁽⁵⁾ and the Effective Mass Spectrometer⁽⁶⁾ (Fig. 1). Two multiwire proportional chambers (PWC's) were incorporated into the trigger logic as multiplicity sensing hodoscopes; the trigger requirement was that there be two more charged particles at PWC2 than at PWC1. This requirement favored $\Lambda^0 \rightarrow p\pi^-$ decays which occurred between the two PWC's. Chamber sizes were chosen to minimize triggering biases which depend on event multiplicity. We also required at least two particles in the counter hodoscope behind the spectrometer magnet. Non-interacting beam particles were suppressed by a small veto counter just behind this hodoscope. Thus our trigger was

$$\text{Trigger} = \text{Beam} \cdot \overline{\text{Beam Veto}} \cdot \text{PWC}(\Delta N \geq 2) \cdot H(\geq 2).$$

During data taking, the sign of the (vertical) beam polarization was reversed approximately every two hours. The analyzing magnet polarity was also reversed several times.

In our data analysis, the $p\pi^-$ invariant mass was calculated for all plus-minus charge combinations. This distribution is shown as a solid histogram in Fig. 2. Cuts on the quality and position of the production and decay vertices reduced the background under the Λ^0 mass peak to less than 1% (see dashed histogram in Fig. 2). The RMS mass resolution was about 1 MeV. The surviving data sample contained 15281 Λ^0 events.

The analyzing power (P-P') in equation (1) gives rise to a left-right production asymmetry. By counting the number of lambdas produced left and

right, for the beam polarization up or down, and for opposite polarities of the spectrometer magnet, we can express the analyzing power as a pure ratio,

$$P-P' = \frac{1}{e'} \cdot \frac{G_L - G_R}{G_L + G_R} \quad (3)$$

Here G_L (Geometric left) $\equiv \{ (L\uparrow+) (R\downarrow+) (L\uparrow-) (R\downarrow-) \}^{1/4}$, G_R (Geometric right) $\equiv \{ (R\uparrow+) (L\downarrow+) (R\uparrow-) (L\downarrow-) \}^{1/4}$, e' is the magnitude of the mean beam polarization along the production plane normal and, for example, $(L\uparrow+)$ denotes the number of detected lambdas produced to the left when the beam polarization was up and the spectrometer magnet polarity was positive. To extract the parameters $(P+P')$ and D from the data, we made use of the polarization analyzing properties of the $\Lambda^0 \rightarrow p\pi^-$ decay. Thus each category like $(L\uparrow+)$ was further subdivided according to whether the decay proton was emitted above or below the production plane. Ratios similar to (3) were then constructed, yielding the parameters $(P+P')$ and D . All terms containing beam intensity, target density, geometric detection efficiency, and production cross section cancel in these ratios. (7)

In order to monitor the beam polarization we continuously recorded proton-proton elastic scattering events along with our Λ^0 data. By taking the beam polarization to be $(60 \pm 3)\%$, we obtain values for the elastic analyzing power which agree very well with those obtained from polarized target experiments. (8)

A number of consistency checks have been performed to establish that no spurious effects are present. We compared the results from data taken at different times during the run and verified that there were no significant differences.

We found no dependence of our results on the polarity of the analyzing magnet. As an additional check we determined the same parameters for non- Λ^0 low effective mass background events. They are consistent with zero over our entire x range.

Our results for the polarization ($P+P'$), the analyzing power ($P-P'$) and the depolarization parameter D are shown in Figure 3(a), 3(b), and 3(c), respectively. There is structure in all three parameters for x greater than 0.8. We particularly point out the difference between ($P+P'$) and ($P-P'$). The integrated difference between the polarization and analyzing power for $x > 0.8$ has the value 0.465 ± 0.082 .

This structure in the spin parameters can be qualitatively understood in terms of t -channel exchange properties of the production amplitudes. The fact that P' is non-zero and D is negative implies that unnatural parity exchange contributions are dominant. ⁽³⁾ However, P is also finite, and D is certainly not -1 , indicating that natural parity exchanges also contribute.

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Figure Captions

1. Plan view of the experiment.
2. Distribution of $p\pi^-$ effective mass. The solid (dashed) histogram is the uncut (cut) data sample.
3. Values of the spin parameters versus the Feynman scaling variable x :
(a) polarization ($P+P'$); (b) analyzing power ($P-P'$); (c) depolarization (D).