

¹Y. Akimov *et al.*, "Proton-Deuteron Elastic Scattering at Small Momentum Transfer from 50 to 400 GeV/c" (to be published).

²Y. Akimov *et al.*, preceding Letter [Phys. Rev. Lett. **35**, 763 (1975)].

³This is justified by the near factorization of the form factor in elastic scattering (Ref. 1) and by the factorization of the diffractive vertex in the low-mass region (Ref. 2). In a fit of our inelastic data where c was treated as a free parameter, we obtained $c = 64.3 \pm 11.4$ (GeV/c)⁻⁴ in agreement with the (more accurate) value of 62.3 ± 1.1 given by the deuteron form factor.

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

A. Lesnik and D. M. Schwartz†
Ohio State University, Columbus, Ohio 43210

and

I. Ambats, E. Hayes, W. T. Meyer,‡ and C. E. W. Ward
Argonne National Laboratory, Argonne, Illinois 60439

and

T. M. Knasel,§ E. G. Swallow, and R. Winston||
Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637

and

T. A. Romanowski
Argonne National Laboratory, Argonne, Illinois 60439, and Ohio State University, Columbus, Ohio 43210
(Received 7 July 1975)

We have measured the polarization, analyzing power, and depolarization parameter for forward Λ^0 's produced with a 6-GeV/c polarized-proton beam at the Argonne National Laboratory zero-gradient synchrotron. We collected a sample of 15 281 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.

Parity-conserving inclusive processes of the form spin $\frac{1}{2}$ (polarized) + unpolarized \rightarrow spin $\frac{1}{2}$ (analyzed) + anything can be described¹ 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:

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

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

Here $\vec{\epsilon}$ is the initial (beam) polarization vector; \vec{f} is the final (Λ^0) polarization vector; \hat{n} is the production-plane unit normal (along $\vec{p}_{\text{beam}} \times \vec{p}_{\Lambda}$); and σ_0 is the cross section for unpolarized protons. $P + P'$ measures the component of the final state baryon polarization along the production plane normal that is produced independently of

the beam polarization. $P - P'$ measures the left-right production asymmetry of the final-state baryon when the incident beam is vertically polarized. D measures the component of the beam polarization along the production-plane normal that is retained by the final-state baryon. 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 Λ^0 's 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 beam⁵ and the effective-mass spectrometer⁶ (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 at least 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. Noninteracting beam particles were suppressed by a small veto counter just behind this hodoscope. Thus our trigger was

$$\text{trigger} = \text{beam} \cdot (\text{beam veto}) \\ \cdot \text{PWC}(\Delta N \geq 2) \cdot H(\geq 2).$$

During data taking, the sign of the (vertical) beam polarization was reversed approximately every 2 h. 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 15 281 Λ^0 events.

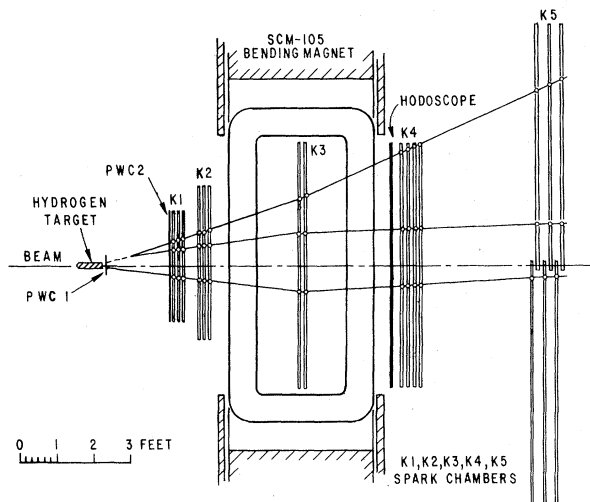


FIG. 1. Plan view of the experimental apparatus.

The analyzing power ($P - P'$) in Eq. (1) gives rise to a left-right production asymmetry. By counting the number of Λ^0 's 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,

$$P - P' = (1/e')(G_L - G_R)/(G_L + G_R). \quad (3)$$

Here $G_L \equiv \{(L\uparrow+)(L\uparrow-)(R\downarrow+)(R\downarrow-)\}^{1/4}$ (geometric left), $G_R \equiv \{(R\uparrow+)(R\uparrow-)(L\downarrow+)(L\downarrow-)\}^{1/4}$ (geometric right), e' is the magnitude of the mean beam polarization along the production-plane normal, and, for example, $(L\uparrow+)$ denotes the number of detected Λ^0 's 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

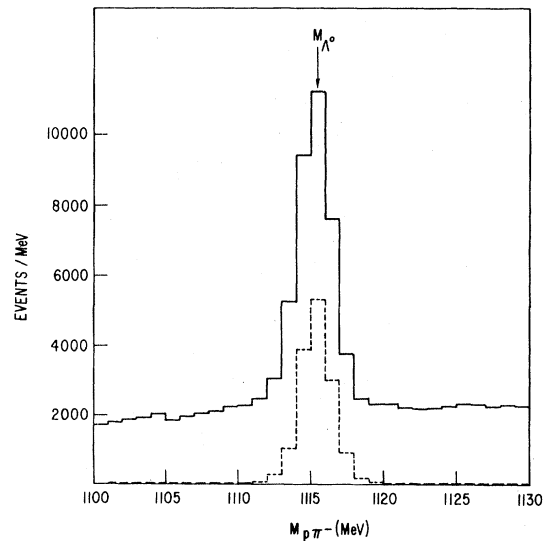


FIG. 2. Distribution of $p\pi^-$ effective mass. The solid (dashed) histogram is the uncut (cut) data sample.

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 are 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 acceptance.

Our results for the polarization ($P + P'$), the analyzing power ($P - P'$), and the depolarization parameter (D) are shown as a function of the Feynman scaling variable x in Figs. 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 nonzero 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.

It is a pleasure to acknowledge the assistance of D. S. Ayres. We also thank R. J. Jost, W. E. Keig, D. Park, T. Sullivan, and S. Usala for help during the experimental run, and S. A. Jones and S. Watson for help during the data reduction. John Heimaster was invaluable in setting up the simultaneous processing of data on several computers. Finally, we are indebted to all the zero-gradient-synchrotron-complex operating personnel for their continuing support during all phases of the experiment.

*Research supported in part by the U. S. Energy Research and Development Administration and the National Science Foundation.

†Present address: Zettler Inc., Columbus, Ohio

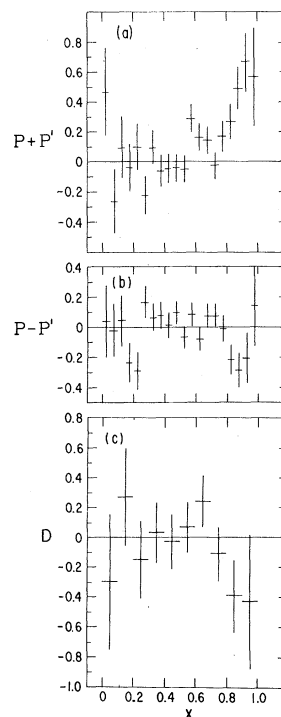


FIG. 3. Values of the spin parameters versus the Feynman scaling variable x : (a) polarization ($P + P'$); (b) analyzing power ($P - P'$); (c) depolarization (D).

43215.

‡Present address: Stanford Linear Accelerator Center, Stanford, Calif. 94305.

§Present address: Science Applications Inc., McLean, Va. 22101.

||Joint appointee at Argonne National Laboratory.

¹M. G. Doncel and A. Méndez, *Phys. Lett.* **41B**, 83 (1972).

²L. Wolfenstein, *Phys. Rev.* **96**, 1654 (1954).

³E. C. Swallow, *Phys. Lett.* **49B**, 91 (1974).

⁴R. N. Boyd *et al.*, *Phys. Rev. Lett.* **29**, 955 (1972).

⁵T. Khoe *et al.*, to be published; and also E. F. Parker *et al.*, *Phys. Rev. Lett.* **31**, 783 (1973).

⁶D. S. Ayres, in *Proceedings of the International Conference on Instrumentation for High Energy Physics, Frascati, Italy, 1973*, edited by Stanislao Stipcich (Laboratori Nazionali del Comitato Nazionale per l'Energia Nucleare, Servizio Documentazione, Frascati, Italy, 1973), p. 665.

⁷G. G. Ohlsen and P. W. Keaton, Jr., *Nucl. Instrum. Methods* **109**, 41 (1973).

⁸M. Borghini *et al.*, *Phys. Lett.* **31B**, 405 (1970).