Effects of beam polarization on Λ and K^0 inclusive production in pp interactions at 12 GeV/c

R. L. Eisner,* W. J. Fickinger, J. A. Malko,† D. K. Robinson, and V. A. Sreedhar
Case Western Reserve University, Cleveland, Ohio 44106

S. Dado,‡ A. Engler, G. S. Keyes,* T. Kikuchi, and R. W. Kraemer
Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213

(Received 25 July 1979)

Inclusive production of Λ and K^0 in pp interactions at 12 GeV/c has been studied in an exposure of the Argonne National Laboratory 12-foot bubble chamber to a 50% transversely polarized proton beam. Beam-polarization-induced asymmetries are observed for both K^0 and Λ production in the forward direction.

In a recent publication[1] we presented data on Λ and K^0 inclusive production by polarized protons in pp interactions at 6 GeV/c. The present communication reports a similar study at 12-GeV/c incident momentum. At the lower energy we observed a clear beam-polarization-induced negative asymmetry in K^0 production over all center-of-mass (c.m.) production angles and some indication of a positive asymmetry in the forward production of Λ's (for $x > 0.5$, where x is the usual Feynman scaling variable). A paper on a counter experiment[2] performed in the same polarized proton beam, which described the angular distributions of forward produced Λ's in pp collisions at 6 GeV/c, reported a *negative* asymmetry parameter for Λ's produced in the extreme forward direction ($x > 0.8$). Since our bubble-chamber experiment included very few events in this region, we were unable to confirm the observation made in the counter experiment. The counter experiment measured essentially zero asymmetry in the $0.5 < x < 0.8$ region where we observed a positive asymmetry.

The various t-channel exchange structures in inclusive Λ production by polarized proton beams have been discussed by Owens.[3] In that paper, it is pointed out that a pure triple-Regge-pole model predicts that the asymmetry A and the Λ polarization P should be zero unless there are certain interference terms. Large values for A and P should result from interferences between $K(J^{PC} = 0^{-+})$ and $K_A(1^{++})$ or between $K_B(1^{+-})$ and $K_Z(2^{--})$. Calculations of these interference terms predict that $P = -A$. Since the polarization has been measured to be positive (for large x) in both the counter experiment[2] and the bubble-chamber experiment,[1] the observation of a positive asymmetry in our 6-GeV/c experiment cannot easily be understood. The experimental energy may indeed be too low to allow comparison with a Regge-pole model.

Given this experimental and theoretical situation, we have undertaken the measurement of the 12-GeV/c Λ and K^0 events to examine the behavior of the asymmetries at the higher energy. Both the 6- and 12-GeV/c bubble-chamber experiments entailed the analysis of about 120 000 photographs in the Argonne National Laboratory 12-foot hydrogen bubble chamber. The transversely polarized proton beam was produced by the Argonne Zero Gradient Synchrotron (ZGS). The average beam polarization, monitored by a double scattering polarimeter in the opposite ZGS beam line, averaged 60% at 6 GeV/c and 50% at 12 GeV/c. In the 12-GeV/c exposure, the beam polarization was reversed on each accelerator pulse and the polarity indicated on the film for each frame. The scanning, event measurement, fit selection criteria, and event weighting procedures were identical to those described in the 6-GeV/c paper.[1] The resulting numbers of observed Λ and K^0 decays are 2683 and 1431, respectively. The corresponding corrected cross sections are 873 ± 43 and 883 ± 54 μb.

We have performed maximum-likelihood fits to determine the asymmetry A for both the Λ and the K^0 samples, using the form

$$W(\phi_A) = \frac{1}{2\pi}(1 + P_A A \sin\phi_A) .$$

The angle ϕ_A is the azimuthal angle of the beam polarization vector in a coordinate system with the beam line of flight as polar axis and the y axis taken as the direction of the normal to the production plane: $\hat{y} = \hat{p}_{\text{beam}} \times \hat{p}_{\text{out}}$, where $\hat{p}_{\text{out}}$ is the unit vector for the Λ or K^0 momentum. The magnitude of the beam polarization is fixed at $P_A = 0.5$.

The resulting values of A for the Λ events are shown as a function of x in Fig. 1. The scaling variable x is the ratio of the component of the Λ c.m. momentum parallel to the beam direction to the maximum allowable Λ c.m. momentum: $x = p_{\parallel}/(2.1\ \text{GeV}/c)$. A polarized-beam-induced asymmetry is indicated for forward Λ produc-

 © 1980 The American Physical Society

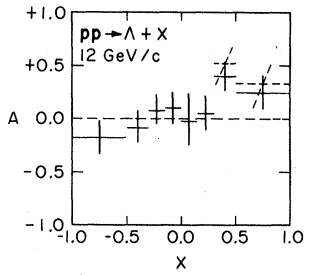

FIG. 1. The fitted beam-polarization asymmetry parameter for Λ production in $pp \to \Lambda + X$ at 12 GeV/c.

tion, i.e., for $x > 0.3$. The 316 events with $0.3 < x < 0.5$ yield a value of the asymmetry $A = 0.40 \pm 0.14$ and the 246 events with $x > 0.5$ yield $A = 0.25 \pm 0.16$. Slightly higher values of the asymmetry parameter are associated with those events with only two charged particles at the production vertex: $A = 0.52 \pm 0.18$ for $0.3 < x < 0.5$ and $A = 0.33 \pm 0.20$ for $x > 0.5$, as indicated in the figure by the dashed lines.

The measured value of the Λ polarization for those Λ's with $|x| > 0.8$ is $P = 0.41 \pm 0.28$, and, while not very well determined, is similar to the corresponding result[1] at 6 GeV/c, $P = 0.51 \pm 0.40$. We have computed the depolarization parameters[4] for this sample of Λ events, following the procedure described in Ref. 1. These parameters are less well determined than the asymmetry, and show no significant structure.

The fitted asymmetry parameters for the K^0 events are listed in Table I. The total sample shows only a 2-standard-deviation asymmetry. However, this effect is entirely associated with the two-prong main-vertex events, and in fact is seen to be preferentially due to the forward produced subset of only 152 events with two-prong main vertices and with $x > 0.2$ for which $A = -0.78 \pm 0.20$. This situation may be contrasted with the behavior of the K^0 production at 6 GeV/c, in which we found an asymmetry $A = -0.65 \pm 0.13$ for K^0 plus two-prong events over the entire range of x. An asymmetry of $A = -0.78$ with a beam polarization of 50% results in the rather remarkable experimental situation in which 70% of the K^0's scatter to the right and 30% to the left.

TABLE I. Asymmetry parameters for $p_\uparrow p \to K^0 + X$ at 12 GeV/c.

Sample	Number of events	Weighted number of events	A
All K^0	1431	1648	-0.14 ± 0.07
K^0 + (>2 prongs)	607	705	-0.05 ± 0.10
K^0 + (2 prongs)	824	943	-0.22 ± 0.09
K^0 + (2 prongs)			
$x < -0.2$	137	189	-0.24 ± 0.20
$-0.2 < x < 0.2$	535	590	-0.06 ± 0.12
$x > 0.2$	152	164	-0.78 ± 0.20

We conclude that at 12 GeV/c, there are positive (negative) polarized-beam-induced asymmetries in $\Lambda(K^0)$ inclusive production in the beam-like region, preferentially for low-charge-multiplicity production vertices. The indications of positive Λ asymmetry and positive Λ polarization at both 6 and 12 GeV/c are not understood in terms of interference effects in a Regge-pole model which predicts negative asymmetry when polarization is positive. It would certainly be interesting to pursue additional measurements of these effects in counter experiments as polarized beams become available at other accelerators, or with polarized targets. High-statistics measurements of the asymmetry parameters are essential for better understanding of the exchange characteristics of the inclusive production amplitudes.

We are grateful to the Argonne ZGS and 12-foot chamber crews and to our scanning staffs. We thank Dr. Frank Cverna for his assistance in data analysis and Dr. J. F. Owens for many useful comments. The work of the Case Western Reserve authors was supported by the U. S. National Science Foundation. The work of the Carnegie-Mellon authors was supported by the U. S. Department of Energy.

*Now at General Electric Medical Systems Division, Milwaukee, Wisconsin 53201.
†Now at Fermi National Accelerator Laboratory, Batavia, Illinois 60510.
‡Now at the Technion, Haifa, Israel.

[1] R. L. Eisner *et al.*, Nucl. Phys. B123, 361 (1977).
[2] A. Lesnik *et al.*, Phys. Rev. Lett. 35, 770 (1975).
[3] J. F. Owens, Nucl. Phys. B131, 209 (1977).
[4] G. R. Goldstein and J. F. Owens, Nucl. Phys. B103, 145 (1976).