Λ^0 Polarization in proton-proton Interactions from $\sqrt{s} = 31$ to 62 GeV

(R608 Collaboration)

A.M. Smith
CERN, 1211 Geneva 23, Switzerland.

R. Bonino¹, A. Castellina², S. Erhan, M. Medinnis,
P.E. Schlein, P. Sherwood, S. Vernetto², J.G. Zweizig
University of California^{*)}, Los Angeles, California 90024, USA.

J. Alitti, J.B. Cheze, A. Montag³, J. Zsembery
Centre d'Etudes Nucleaires - Saclay, 91191 Gif-sur-Yvette, France.

L. Meritet, F. Vazeille
LPC - IN2P3, Universite de Clermont-Ferrand, 63 Aubiere, France.

Abstract

We report Λ^0 -hyperon polarization measurements at the CERN Intersecting Storage Rings from $\sqrt{s}$ of 31 to 62 GeV. P_{Λ^0} changes insignificantly, $+(0.8 \pm 1.7)\%$, over this range of $\sqrt{s}$. However, P_{Λ^0} is observed to grow with Feynman- x_F and with transverse momentum. At an average p_t of 1.1 GeV/c, P_{Λ^0} depends linearly on x_F and approaches -40% at $x_F = 0.8$.

Submitted to Physics Letters B

^{*)} Supported in part by U.S. National Science Foundation grants PHY79-24766 and PHY85-09175

¹⁾ now at University of Birmingham, U. K.

²⁾ now at Istituto di Cosmogeofisica del C.N.R., Torino, Italy

³⁾ now at Weizmann Institute, Rehovoth, Israel

Λ^0 hyperons which emerge from high energy pp interactions are observed to possess a large polarization perpendicular to the production plane, as allowed by parity conservation in the production process. Similar Λ^0 polarization observed in both proton-nucleus interactions[1] at $\sqrt{s} = 23$ GeV and pp interactions[2] at $\sqrt{s} = 53$ and 62 GeV shows that the Λ^0 polarization is a consequence of the beam-proton fragmentation mechanism and has little to do with the nature of the target particle.

The large production cross section of Λ^0 's in pp interactions[3] and its relatively flat dependence on Feynman- x_F , approximately $(1 - x_F)^1$, are undoubtedly due to the fact that the isoscalar spin-zero ud diquark system in the Λ^0 is a spectator valence diquark state from the beam proton. Such a diquark system becomes a Λ^0 with the pickup of an s-quark. Because the spin of the Λ^0 is that of its valence s-quark, the Λ^0 polarization is an excellent tracer of the spin properties of the hadronization mechanism which produces the s-quark.

Andersson et al.[4] have argued that polarization of forward-going Λ^0 's is a natural consequence of $s\bar{s}$ pair production in a confining color force field. In interactions where there is a valence diquark-quark separation in a proton resulting in creation of an $s\bar{s}$ pair, a characteristic string energy density of 1 GeV/fermi causes the $s\bar{s}$ pair to typically possess up to one unit of angular momentum. Local conservation of angular momentum requires the s (and $\bar{s}$) quark spin to be opposite to the orbital angular momentum. This accounts for the observed Λ^0 polarization. Other models for hyperon polarization also exist[5].

In a follow-up experiment to Ref. [1] at $\sqrt{s} = 27$ GeV, the Λ^0 polarization was observed[6] to be independent of Λ^0 transverse momentum between 1 and 3.8 GeV/c. Perturbative QCD is unable to account for this polarization[7].

In the present letter, we present final results from measurements at the CERN Intersecting Storage Rings (ISR) of inclusive Λ^0 polarization, P_{Λ^0} , in the reaction:

$$pp \rightarrow \Lambda^0 + X. \quad (1)$$

The detected Λ^0 's are produced in the forward direction with center-of-mass polar angles in the range $0.023 < \theta < 0.150$ radians. We give the dependence of P_{Λ^0} on center-of-mass energy, $\sqrt{s}$, of the pp interaction and also on Feynman- $x_F = 2p_\ell/\sqrt{s}$ and transverse momentum, p_t of the Λ^0 . Precise

knowledge of how P_{Λ^0} depends on these variables should lead to an increased understanding of the basic $s\bar{s}$ production mechanism.

The results presented in this letter were obtained from an analysis of nearly 1 million Λ^0 events at different ISR energies, $\sqrt{s} = 31, 44, 53$ and 62 GeV. The detector was the forward multiparticle spectrometer[8,9] of experiment R608. Details of the experiment and of the inclusive trigger and analysis procedures are identical to those described in a recent publication[10] and will not be repeated here. The acceptance-correction procedures and verification tests are also identical to those used in extracting polarization results by Erhan et al.[2] in the earlier experiment R603 at the ISR.

To study the dependence of P_{Λ^0} on $\sqrt{s}$, we choose three bins of x_F - p_t , in each of which there is good Λ^0 acceptance at all energies from $\sqrt{s} = 31$ to 62 GeV. Fig. 1 displays the average polarization in each bin at each of the four energies. There is no obvious dependence on $\sqrt{s}$.

In order to obtain a quantitative statement of the dependence of P_{Λ^0} on $\sqrt{s}$, the linear function $P_{\Lambda^0} = P_{62} + R(\sqrt{s} - 62.4)$ is fit to the data points in Fig. 1. $R = d(P_{\Lambda^0})/d(\sqrt{s})$ is the quantity of interest. A joint fit of this function to the three sets of data points in Fig. 1 yields a value $R = +(0.027 \pm 0.055)\%/GeV$, corresponding to a net change over the energy range from 31 to 62 GeV of $+(0.8 \pm 1.7)\%$.

We next examine the dependences of P_{Λ^0} on x_F and p_t using our highest statistics data sample at $\sqrt{s} = 62$ GeV. Fig. 2 (and Table I) shows this dependence on p_t in four different regions of x_F . The calibration point shown in Fig. 2 is obtained by measuring the "polarization" of non- Λ^0 $p\pi^-$ pairs (i.e., those that come from a primary proton-proton interaction and which have invariant mass on either side of the Λ^0 peak). The $p\pi^-$ pairs used for the calibration have an average x_F of 0.4 and an average p_t of 0.78 GeV/c. This measurement yields a value consistent with zero, $(1.3 \pm 1.3)\%$, as required.

The most striking aspect of the results in Fig. 2 is that P_{Λ^0} grows with increasing x_F at any p_t , as has been observed in the $\sqrt{s} = 27$ GeV experiment at Fermilab[11]. However, our results do not agree with the simple parameterization of the Fermilab results discussed in Ref. [11] for which, at fixed x_F , P_{Λ^0} increases linearly from zero at $p_t = 0$ to its value at $p_t = 1$ GeV/c. In each of our three largest x_F bins, P_{Λ^0} is small at $p_t = 0.4$ GeV/c and then increases rapidly to its value at $p_t \approx 1$ GeV/c. Furthermore, in our lowest x_F bin, P_{Λ^0} levels off at $p_t \approx 0.6$ GeV/c. However, for $p_t > 0.96$, our P_{Λ^0} values are consistent with no dependence on p_t , as discussed in Ref. [11].

In order to display the x_F dependence at high p_t in more detail, the data in Fig. 2 are integrated over p_t above 0.96 GeV/c (average $p_t = 1.1$ GeV/c) and divided into six bins in x_F . The resulting values of P_{Λ^0} are shown in Fig. 3. The straight line fit to the points in Fig. 3 has the parameterization $P_{\Lambda^0} = (7.3 \pm 3.5) - (56.6 \pm 7.0)x_F$. The open circles in Fig. 3 are the $\sqrt{s} = 27$ GeV hydrogen target results from Fermilab[12] for Λ^0 's with $p_t > 0.95$ GeV/c. At x_F of 0.45 and 0.55, there is a difference of about 5% between these results and ours at $\sqrt{s} = 62$ GeV.

We remain grateful to the ISR Operations and Experimental Support Groups for their invaluable efforts, and to the CERN administration for their support. We thank L. Pondrom for providing us with the FNAL hydrogen-target results[12] used in Fig. 3.

TABLE I: Inclusive Λ^0 Polarization^{a)} at $\sqrt{s} = 62$ GeV

x_F	Transverse Momentum p_t (GeV/c)					
	0.41 ^{b)}	0.60 ^{c)}	0.76	0.89	1.02	1.26
0.25	-2.7 ± 1.0	-5.6 ± 0.9	-5.8 ± 1.4	-5.1 ± 1.9		
0.38	-2.7 ± 1.0	-7.5 ± 0.8	-11.8 ± 1.1	-13.6 ± 1.3	-15.9 ± 1.5	-14.8 ± 1.5
0.58	-4.6 ± 2.9	-7.3 ± 1.4	-14.9 ± 1.7	-20.0 ± 1.9	-24.8 ± 2.3	-25.4 ± 2.2
0.77		-15.1 ± 4.2	-21.9 ± 4.0	-29.7 ± 4.3	-37.1 ± 5.0	-37.5 ± 4.6

^{a)} P_{Λ^0} values given in percent.

^{b)} $p_t = 0.46$ GeV/c for the largest x_F point in this column, as plotted in Fig. 2.

^{c)} $p_t = 0.63$ GeV/c for the largest x_F point in this column, as plotted in Fig. 2.

References

- [1] G. Bunce et al., Phys. Rev. Letters 36 (1976) 1113.
- [2] S. Erhan et al., Phys. Letters 82B (1979) 301.
- [3] S. Erhan et al., Phys. Letters 85B (1979) 447.
- [4] B. Andersson et al., Phys. Letters 85B (1979) 417.
- [5] T.A. DeGrand and H.I. Miettinen, Phys. Rev. D 24 (1981) 2419; J. Szwed, Phys. Letters 105B (1981) 403.
- [6] B. Lundberg et al., High Energy Spin Physics, 1982, edited by G. Bunce (American Institute of Physics Conference Proceedings No. 95), p. 83.
- [7] G. L. Kane et al., Phys. Rev. Letters 41 (1978) 1689.
- [8] P. Chauvat et al., The Performance of a 16,000 Wire Mini Drift MWPC System; CERN-EP/82-198; Proceedings of the 1983 DPF Workshop on Collider Detectors (LBL-15973), p. 81; and contribution to XXI International Conference on High Energy Physics, Paris, July 1982.
- [9] P. Chauvat et al., Phys. Letters 127B (1983) 384.
- [10] P. Chauvat et al., Phys. Letters 163B (1985) 273.
- [11] K. Heller, Journal de Physique, Colloque C2, supplement au N^o 2, Tome 46, fevrier 1985, page C2-121 (Proceedings of Marseilles Conference, 1984).
- [12] R. Grobel, Univ. of Wisconsin Thesis (1981), unpublished;
B. Lundberg, Univ. of Wisconsin Thesis (1984), unpublished;
see L. Pondrom, Phys. Reports 122 (1985) 57, for references to earlier work.

Figure Captions

- 1. Inclusive Λ^0 polarization vs. $\sqrt{s}$ for three x_F - p_t bins. Horizontal lines are drawn at the average P_{Λ^0} values for each bin.
- 2. Λ^0 polarization ($\sqrt{s} = 62$ GeV data) vs. transverse momentum for fixed x_F . As explained in the text, the calibration point, $(1.3 \pm 1.3)\%$, is calculated using $p\pi^-$ pairs which do not arise from Λ^0 's.
- 3. P_{Λ^0} vs. x_F for those data in Fig. 2 with $p_t > 0.96$ GeV/c (the average $p_t = 1.14$ GeV/c). The straight line is the fit discussed in the text. The open circles are Fermilab results from Ref. [12] with $p_t > 0.95$ GeV/c.

Figure 1

Figure 2

Figure 3