Λ^0 HYPERON POLARIZATION IN INCLUSIVE PRODUCTION BY 24 GeV PROTONS ON PLATINUM

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We report a search for Λ^0 polarization in inclusive production by 24 GeV protons on platinum made on data taken at CERN. These data show Λ^0 polarization of the same direction and magnitude and with the same p_T dependence as found at 300 GeV at Fermilab.

A recent experiment in the neutral hyperon beam at the Fermilab discovered substantial (i.e., greater than 20%) Λ^0 hyperon polarization in inclusive production by 300 GeV protons on beryllium [1]. This was an unexpected result. Since lower energy data typically showed polarizations that decreased with increasing energy to the 10% level at 10 GeV, it was expected that spin dependent effects would only be a few percent for energies in the 100 GeV region. The discovery of large Λ^0 polarization at 300 GeV raises the interesting question of the energy dependence of this effect.

We report here a search for Λ^0 polarization in inclusive production by 24 GeV protons on platinum. The analysis for the Λ^0 polarization was made on data taken from an experiment run in a neutral beam at the CERN-PS in 1974 by the CERN-Dortmund-Heidelberg collaboration. This CERN experiment measured the Σ^0 lifetime via the Primakoff effect [2] with the trigger relaxed periodically to accept Λ^0 hyperons for normalization purposes. These triggers yielded the 350, 000 Λ^0 decays used in this polarization study.

The experiment is described in ref. [2] and only the features most pertinent to the polarization study will be summarized.

Neutral particles were produced by an external proton beam of 24 GeV/c hitting a platinum target 45 mm long. A 190 cm long uranium collimator defined the production angle acceptance from 62 to 88 mrad. The collimator was embedded in a 20 kgauss horizontal bending magnet in order to sweep out charged particles. Beyond the collimator a veto counter defined the upstream limit of a 5 m decay volume. The detection apparatus consisted of a large aperture magnetic spectrometer with two multiwire proportional chambers before, and two after, an analyzing magnet. The Λ^0 trigger requirement was two and only two hits in each proportional plane of the last three chambers. The Fermilab neutral hyperon beam and detector apparatus described in ref. [1] has essentially the same features appropriately scaled for the increase in energy.

The Λ^0 polarization was found at the Fermilab to increase with transverse momentum p_T with no dependence on Feynman $x = 2p_\parallel^{cm}/\sqrt{s}$ observed. The data from the Fermilab study were in the kinematic regions $0.3 \leqslant x \leqslant 0.7$ and $0 \leqslant p_T \leqslant 1.7$ GeV/c. The table presents a comparison of the two experiments. In particular we see both experiments cover essentially the same x and p_T regions.

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Table 1
Comparison of CERN and FNAL experiments

	CERN	FNAL
Incident beam	24 GeV protons	300 GeV protons
Λ^0 momentum	6 – 21 GeV/c	60 – 290 GeV/c
θ_{lab}	62 – 88 mrad	0 – 9 mrad
x	0.2 – 0.8	0.3 – 0.7
p_T	0.4 – 1.6 GeV/c	0 – 1.7 GeV/c
Production plane	Horizontal	Vertical
$\int Bdl$	38.6 kG–m	117 kG–m
precession angle	41° in the vertical plane	122° in the horizontal plane
Number of Λ^0 events with $p_T > 0.3$ GeV/c	3.6×10^5	4.0×10^5

A Λ^0 polarization vector perpendicular to the production plane at the point of production precesses in the collimator magnet giving rise to a longitudinal component and a transverse component by the time the Λ^0 reaches the decay volume. A polarization consistent with parity conservation must lie in the vertical plane after precession.

The data were analyzed for polarization along three perpendicular axes, with the data binned in p_T and summed over x. The polarization components corresponded to an up-down Λ^0 decay asymmetry (P_y), a front-back asymmetry along the neutral beam direction (P_z), and a right-left asymmetry (P_x). The analysis program determined the polarization along each axis by comparing the observed proton decay distribution along this axis in the Λ^0 rest frame with a Monte Carlo distribution generated from the data. The polarization P was determined by weighting the Monte Carlo distribution with $1 + \alpha_\Lambda P \cos\theta^*$ to obtain the best fit to the observed proton distribution. Here θ^* is the angle between the generated decay proton in the Λ^0 center of mass and the axis, and $\alpha_\Lambda = 0.647$ [3]. The error quoted for P corresponds to the change required to increase χ^2 by one from its minimum.

To test the method, chamber hits from the decay of both polarized and unpolarized Λ^0s were generated by an independent Monte Carlo program which simulated the full experiment. These mock events were then passed through the same reconstruction and polarization analysis programs as the real events. The input polarization was accurately reproduced by the analysis.

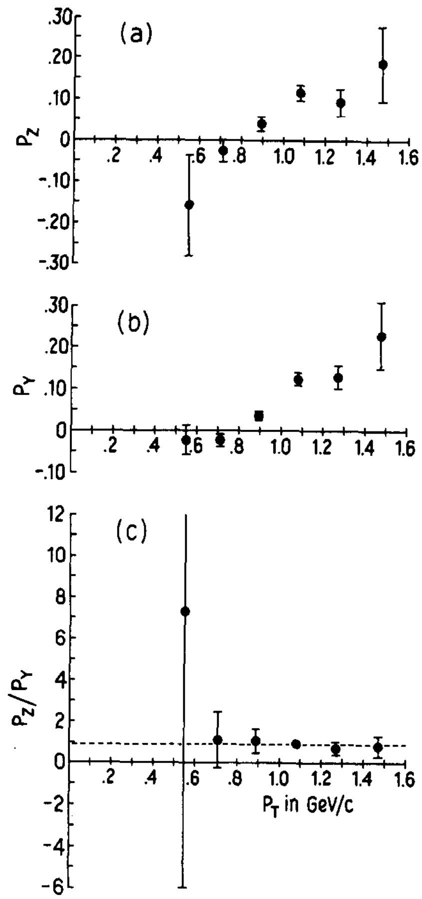

Fig. 1. (a) and (b) Components of Λ^0 polarization. (c) Ratio $P_z/P_y = \tan\Omega$. The best fit is $\Omega = 41 \pm 5°$.

The results are presented in fig. 1a for the longitudinal component P_z and in fig. 1b for the transverse component P_y ‡. Λ^0 polarization is observed for transverse momenta beyond 0.8 GeV/c which increases with p_T. Shown in fig. 1c is P_z/P_y versus p_T from which the precession angle Ω is determined to be 41 ± 5°. The projections of these components along the polariza-

‡ Because of severe acceptance problems due mainly to vertical deadened areas in the chambers, the right-left polarization, p_x, could not be measured. The program failed to find a fit to the cos θ^* distribution at the 10% level.

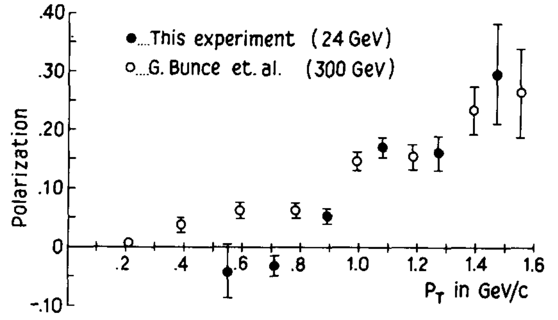

Fig. 2. Polarization as a function of Λ^0 transverse momentum. The 300 GeV data are from ref. [1].

tion direction were averaged to obtain the polarizations shown in fig. 2.

Using the measured precession angle and the collimator magnetic field integral, we obtain a Λ^0 magnetic moment $|\mu_\Lambda| = 0.59 \pm 0.07\ \mu_N$ compared with the world average $\mu_\Lambda = -0.61 \pm 0.04\ \mu_N$ ‡. This agreement, along with the good fit for the precession angle (fig. 1c), argues that no significant unknown biases exist in the individual P_y and P_z measurements ‡. A completely independent polarization analysis was done for P_y by taking the difference between numbers of the Λ^0 decays with the proton emitted up and down, corrected for the overall effect of the experimental apertures on the up-down distribution. This simple method gave the same features seen in fig. 1b. The front-back asymmetry P_z could not be measured this simple way, due to the sensitivity to the acceptance correction. Finally, the same analysis program found polarizations along different directions in the two experiments. The Fermilab experiment observed polarization in the horizontal plane consistent with parity conservation for that geometry while no vertical polarization was found.

In fig. 2 the polarizations at production for the experiment and Fermilab are compared along the direction $\boldsymbol{P}_\Lambda \times \boldsymbol{P}_p$. Both experiments give polarizations of the same sign and magnitude and generally the same p_T dependence. For low p_T the 24 GeV data appear to have smaller polarization than at 300 GeV. It should be noted that in this experiment x and p_T are strongly correlated so that these data allow no separation of the p_T and x-dependence of the effect.

Since neither experiment can separate directly produced Λ^0 hyperons from those from Σ^0 decay, the actual polarization of directly produced Λ^0 hyperons may be considerably larger than that observed. Λ^0 hyperons which come from Σ^0 decay have, on the average, $-1/3$ the polarization of the Σ^0 [6] and thus dilute the observed sample. For example, if there were equal numbers of Σ^0 and Λ^0 produced directly each with 100% polarization in the same direction, we would observe a Λ^0 polarization of 33% in this experiment.

In summary, we have found substantial polarization of Λ^0 hyperons produced by unpolarized 24 GeV protons on a platinum target, the polarization increasing with the transverse momentum of the Λ^0. Directly produced Λ^0 hyperons could have a polarization considerably larger than that observed. Since the characteristics of the polarization agree with those found at Fermilab, the production process responsible does not depend strongly on energy between 24 and 300 GeV.

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‡ Measurements of μ_Λ in nuclear magnetons are: -0.66 ± 0.07 [4] -0.73 ± 0.18 [5] and -0.57 ± 0.05 [1].

‡ From production ratios, Ξ^0 decay contributes less than 1% to the observed Λ^0 polarization.

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