POLARIZATION OF INCLUSIVELY PRODUCED HYPERONS

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Abstract

We report here polarization results from a series of Fermilab experiments from the years 1974 through 1980, with some preliminary data from a high p_T polarization experiment completed in February 1982. The Λ polarization has a remarkably simple and interesting behavior when expressed as a function of x_F and p_T.

The discovery of Λ polarization from 300 GeV inclusive proton-nucleon reactions[1] initiated a series of successful experiments at Fermilab which measured polarizations and magnetic moments for Λ, Ξ^0, Ξ^-, Σ^+, and Σ^- hyperons[2,3,4] The Λ data is by far the most extensive and well studied with over 10^7 events reconstucted to date at many production angles. Hence for the Λ's a detailed behavior of inclusive polarization with respect to the kinematic variables can be determined from the data.

The experimental apparatus is described in detail in References 2 and 3. Briefly, it consists of a system of magnets to pitch the proton beam on target at a specific production angle, followed by a collimation system imbedded in a primary beam dump magnet which defines the secondary hyperon beam. The hyperons are detected by a conventional proportional chamber spectrometer. For the high p_T experiment, the production angle, θ_p, could be varied from 0 to +25 milliradians. Most of the data was taken with θ_p set to +20, +12, +10, and +6 milliradians, although only 20

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and 12 milliradian data is presented here. For all results given here the reaction is

$$p + A \longrightarrow h + X$$

where the target, A, is hydrogen, beryllium, copper, or lead, and h is the particular hyperon being studied.

The behavior of Λ polarization as a function of p_T ($p_T \lesssim 2$ GeV) for fixed production angle, θ_p, is now well known . The magnitude of the polarization, $|P|$, increases monotonically with p_T. This trend, in itself, is not very illuminating since the important scaling variable x_F is not fixed for constant θ_p. To map out the polarization as a function of both p_T and x_F one needs to have many sets of data with each at a different production angle. A large sample of Λ's with 9 different values of θ_p has already been studied and reported[5,6]. This data and the preliminary results from the latest higher p_T experiment, are compltetely consistent and support the observations given below.

The magnitude of the Λ polarization , $|P|$, as a function of x_F for three ranges of p_T is shown in Figure 1. A linear fit to the data points constrained to pass through the origin is indicated with the determined slope. The behavior can be written

$$|P| = C(p_T)\ x_F$$

where $C(p_T)$, the slope, depends only on the transverse momentum.

The same data as in Figure 1 is also shown in Figure 2, however the polarization is plotted as a function of p_T for four bins of x_F. The most noteworthy feature is that $|P|$ is independent of p_T for $p_T \gtrsim 1$ GeV/c. In addition, the value of $|P|$ at which the polarization "saturates", i.e. $p_T > 1$ GeV/c, increases linearly with x_F, as shown in Figure 3. The preliminary data points are indicated by the open circles and show the highest p_T, 3.4 GeV/c, that can be attained with the present (incomplete) data sample. Once the data analysis is complete a measurement of polarization near 4 GeV/c will be possible.

It must be pointed out that no distinction has been made between directly produced Λ's and the daughter Λ's from Σ^0, Σ^{0*} or other resonance decays. The polarization of the Σ^0 is not yet known and hence the measured Λ polarization is diluted by some undetermined factor. This factor, proportional to the ratio of Λ and Σ^0 cross sections, should not have a strong p_T dependence, hence daughter Λ contamination is not beleived to have much effect on the qualitative behavior described above.

The data from Reference 3 is also shown on Figures 1 & 2 to illustrate the similarity of the results. The Ξ^0 data includes three production angles, and so offers the second best independent polarization sample for mapping out the x_F and p_T trends.

The charged hyperon polarizations show the same qualitative trend as the Λ's but since there is far less data taken at different production angles it is hard to draw the same conclusions as in the data. The results of the polarization analyses for Ξ^-, Σ^+, Σ^-, are shown in Figure 4, at fixed θ_p instead of fixed x_F. For comparison, the Λ polarization at θ_p = 5 milliradians is shown by the dashed line. The sign is important: both Σ^+, and Σ^- are polarized in the opposite sense relative to the Λ, Ξ^0, and Ξ^-. The data for both the Σ^+ and Σ^- was obtained with only one value for the magnetic field in the precession magnet which implies that the sign of the polarization cannot be unambiguously determined without some other reference. For the Σ^+, the magnetic moment is known well enough to constrain the initial polarization [7], and for the Σ^- the preliminary data from the Charged Hyperon Group at Fermilab provides the necessary constraint [8,9].

One must remember, though, that polarization is not a universal feature of inclusive hyperon production. Data for $\bar{\Lambda}$'s produced from a proton beam shows no measurable signal at $p_T \leq 1$ GeV/c and preliminary results at higher p_T also show $|P_{\bar{\Lambda}}|$ consistent with zero up to $p_T \approx 2.2$ GeV/c.

Another interesting feature of inclusive polarization is that it appears to be independent of target material at Fermilab energies ($\sqrt{s}$ = 27 GeV). However, polarization data at lower energy ($\sqrt{s}$ = 5 GeV) seems to show a strong dependence on target material. There does, however, seem to be a strong dependence on target material at lower energies [10].

Conclusion

The previously analyzed data and the preliminary data from the higher p_T polarization experiment are consistent with each other and the properties of inclusive polarization can be summarized with these important points:

(1) For inclusive Λ polarization the x_F behavior is striking and can be expressed as

$$|P| = C(p_T)\ x_F$$

(2) Λ inclusive polarization becomes essentially independent of p_T for $p_T \gtrsim 1$ GeV/c.

(3) Charged hyperons show the same qualitative polarization behavior as Λ's and Ξ^0's.

(4) $\bar{\Lambda}$'s show no measurable polarization for p_T up to 2.2 GeV/c (preliminary result).

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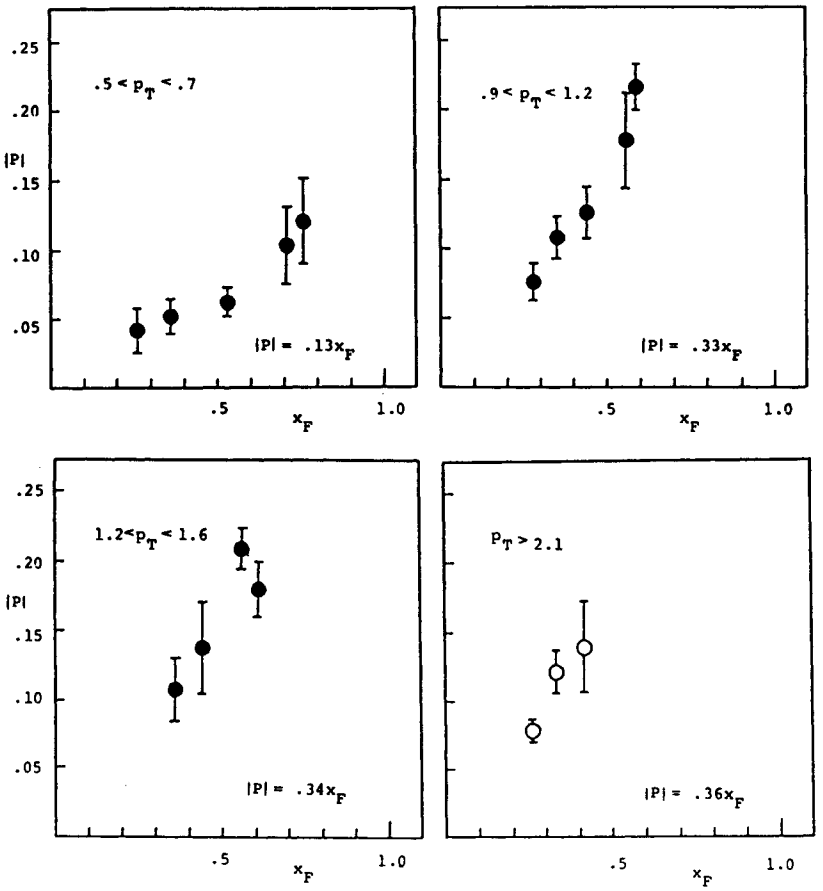

Fig. 1. The magnitude of inclusive Λ^O polarization, |P| , as a function of x_F for different bins of p_T (in GeV/c). The open circles are based on preliminary data. A linear fit to the data points constrained to go through the origin was made for each p_T range and is indicated on the graphs.

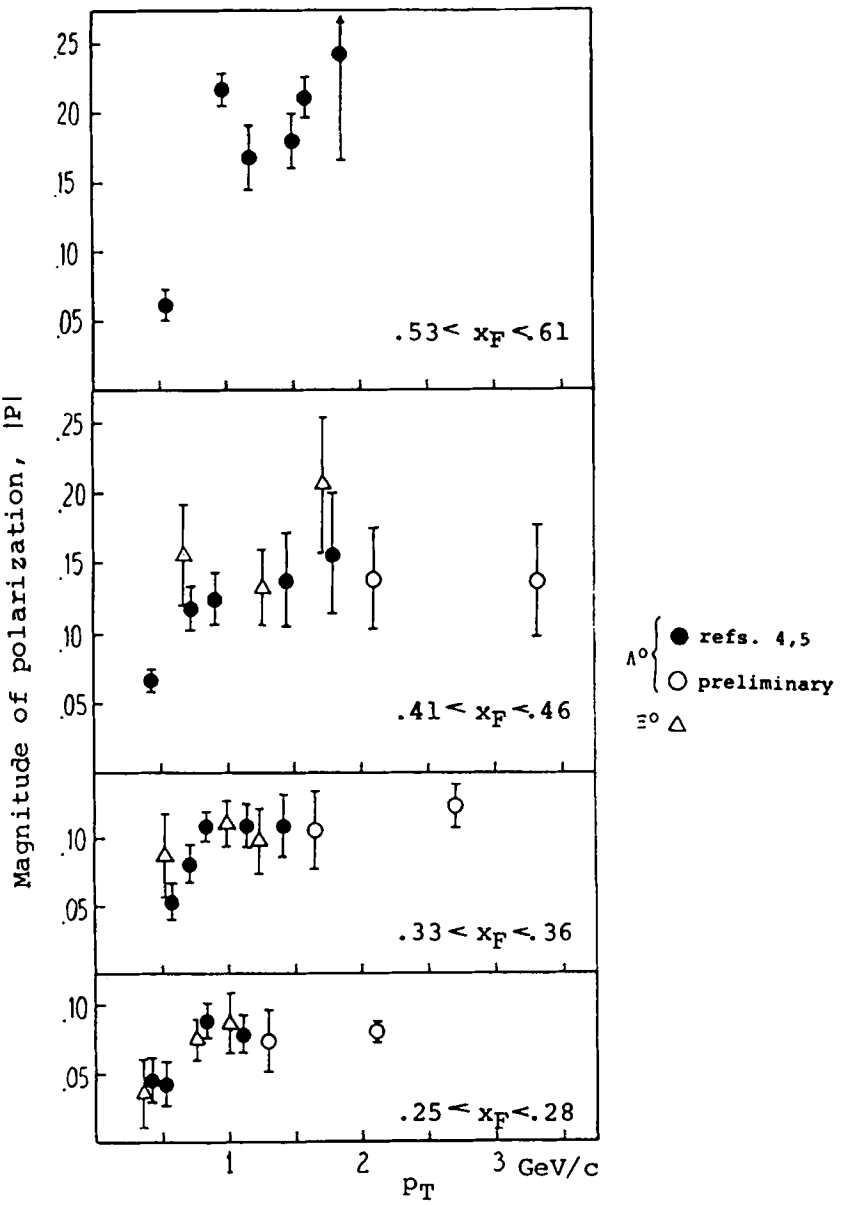

Fig. 2. The magnitude of inclusive Λ^o and Ξ^o polarization, |P| , is shown as a function of p_T for a fixed range of x_F. For Λ^o's it is clear that the polarization "saturates" for $p_T \gtrsim 1$ GeV/c.

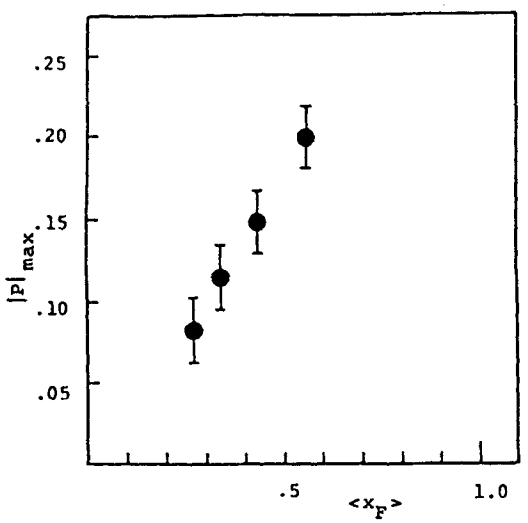

Fig. 3. The value of the maximum or "saturated" polarization for each x_F range is determined by the mean value of |P| for those data points in Fig. 2 with $p_T > 1$ GeV/c. This maximum value, $|P|_{max}$ is plotted as a function of the mean value of x_F.

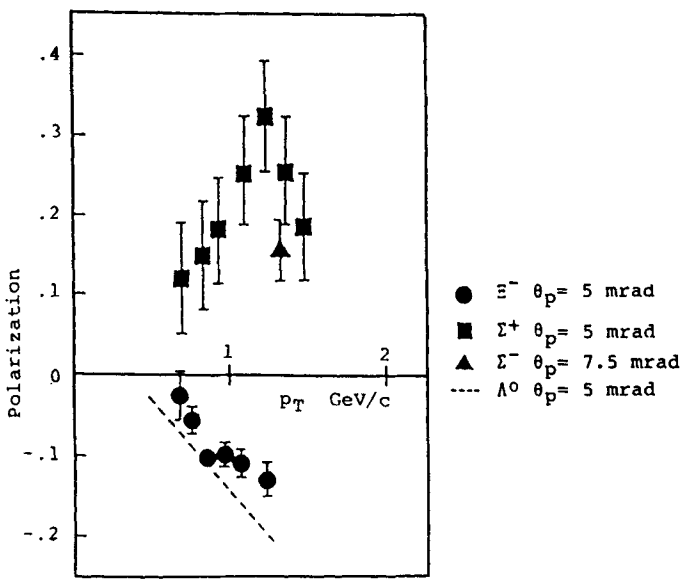

Fig. 4. Polarization of the charged hyperons for fixed production angle, θ_p. For comparison a linear fit to the Λ^o polarization at θ_p = 5 milliradians is also shown.