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Λ^0 Polarization in 800 GeV/c pp $\rightarrow$ p$_f$(Λ^0K$^+$)

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Λ^0 Polarization in 800 GeV/c $pp \to p_f(\Lambda^0 K^+)$

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We report preliminary results from a study of Λ^0 polarization in the exclusive reaction $pp \to p_f(\Lambda^0 K^+)$ at 800 GeV/c. These data are a part of the 5×10^9 diffractive event sample collected by Fermilab E690. We observe a large dependence of the polarization on the $\Lambda^0 K^+$ invariant mass. This observation confirms the result of the CERN ISR R608 experiment and extends the range over which the effect is observed.

1. INTRODUCTION

The polarization of Λ^0 hyperons at high energy is well established [1]. Most of the experimental observations at high energy have been of *inclusive* Λ^0 production. Despite this work, an understanding of the source of the polarization remains elusive. Several experiments have measured Λ^0 polarization in *exclusive* events [2–6]. The main motivation of these studies is the hope that important clues might be uncovered regarding the origin of the polarization by studies of specific final states.

We report here the preliminary results of a study of Λ^0 polarization in the diffractive reaction:

$$pp \to p_f(\Lambda^0 K^+), \tag{1}$$

at a beam momentum of 800 GeV/c. These data were collected by Fermilab E690 during the 1991 fixed target run using a multiparticle spectrometer located in Lab G of the Neutrino Lab in conjunction with a beam spectrometer system. A detailed description of this apparatus can be found in [4]. In what follows we will discuss the method used to isolate the particular final state, delineate the procedure for determining the Λ^0 polarization and present the polarization measured in this analysis.

2. EXCLUSIVE EVENTS

This analysis of E690 data is performed after the track and vertex reconstruction stage of the data analysis. The 2.4×10^9 events used in this analysis represent roughly 50% of the total data sample. A further selection requires: that the event has 3 reconstructed tracks, that both a primary and secondary vertex are reconstructed, that the secondary vertex is uniquely identified as a $\Lambda^0 \to p\pi^-$ decay, that the secondary vertex points back to the primary vertex and that the third charged particle is also assigned to the primary and has a positive charge. Another requirement of the event is that the outgoing "fast" proton (p_f) is reconstructed in the beam spectrometer system and has interacted in the target. The above selection reduces the sample size to 87,233 events.

An additional selection is performed on this reduced sample. Two event variables are used: $(\Delta p_T)^2$, the square of the difference of the initial beam $\mathbf{p_T}$ and the sum of the final state particle $\mathbf{p_T}$, and $\Delta(E - p_L)$, the difference of the initial $E - p_L$ and the sum of the final state $E - p_L$. These two variables should be zero if energy and momentum are conserved in the event, *i.e.* if all of the particles in the event have been observed. The exclusive isolation cuts are: $(\Delta p_T)^2 < 0.001$ (GeV/c)^2 and -0.020 GeV $< \Delta(E - p_L) < 0.015$ GeV. Figure 1 and figure 2 show the distributions of these variables before and after the cuts. These plots also indicate that backgrounds from other event topologies are small. The final sample size is 17,683 events.

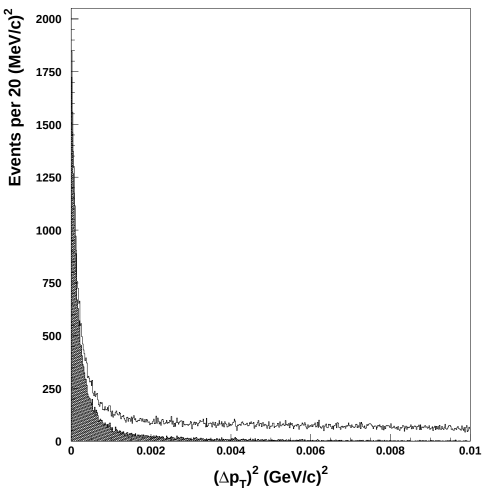

Figure 1. The $(\Delta \mathbf{p_T})^2$ distribution before (open) and after (shaded) the $\Delta(E - p_L)$ cut.

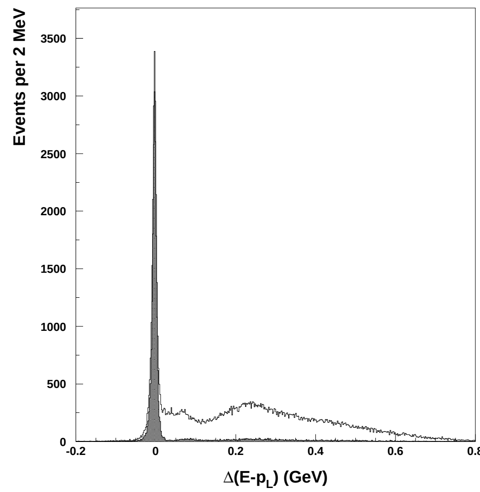

Figure 2. The $\Delta(E - p_L)$ distribution before (open) and after (shaded) the $(\Delta \mathbf{p_T})^2$ cut.

3. POLARIZATION MEASUREMENT

The polarization of the Λ^0 is determined by a linear fit to the $cos\theta$ distribution of the proton decay direction with respect to the normal vector to the Λ^0 production plane in the Λ^0 center-of-mass. This normal vector has the standard definition:

$$\hat{n} \equiv \frac{\vec{P}_{beam} \times \vec{P}_\Lambda}{|\vec{P}_{beam} \times \vec{P}_\Lambda|} \tag{2}$$

where $\vec{P}_{beam}$ and $\vec{P}_\Lambda$ are the momentum vector of the incident beam proton and of the Λ^0, respectively. The angular distribution of the proton has the following dependence on the Λ^0 polarization:

$$\mathrm{dN/d\Omega} = N_0(1 - \alpha \mathcal{P} cos\theta), \tag{3}$$

where α is the decay asymmetry parameter (equal to 0.642 ± 0.013 [7]) and $\mathcal{P}$ is the Λ^0 polarization (note the sign change which accounts for the fact that the Λ^0 is part of the target fragmentation). A Monte Carlo simulation has been run to correct the effect of the finite detector acceptance of the apparatus. The resulting fits of the $cos\theta$ distributions before and after the corrections agree.

The $cos\theta$ distribution for a particular kinematic bin ($-0.85 < x_F < -0.75$ and $0.3 < p_T < 0.5$ GeV/c) is shown in figure 3 before and after correction.

4. RESULTS

The data are binned as a function of Λ^0 x_F and $|\mathbf{p_T}|$ and the polarization is determined for the Λ^0's in each bin. The data distribution in these variables is shown in figure 4. Table 1 shows bins with large *positive* polarization which is quite surprising in view of the measurements using inclusive Λ^0's. The standard empirical functions used to describe Λ^0 polarization dependence on x_F and $|\mathbf{p_T}|$ would not adequately describe these data. Interpreting the reactions to be of the form:

$$pp \rightarrow pX \tag{4}$$

with the X system subsequently "decaying" to $\Lambda^0 K^+$ implies that there are two kinematic degrees of freedom to describe the dynamics of the reaction. We choose the perpendicular momentum, $|\mathbf{p_T}|$ and the mass, M_X of the X system. These distributions are shown in figure 5 and figure 6. Note that the distribution in $|\mathbf{p_T}|$ is indicative of the diffractive nature of these events, *i.e.* forward peaking of the scattered beam proton. We then bin the data in M_X and perform the polarization analysis; the result is found in table 2. These results are plotted along with those

Table 1
Λ^0 polarization %

p_T bins GeV/c	x_F bins $-0.95 \to -0.85$	$-0.85 \to -0.75$	$-0.75 \to -0.65$	$-0.65 \to -0.55$
$0.0 \to 0.1$		24 ± 13	-17 ± 18	
$0.1 \to 0.3$	7 ± 13	35 ± 4	38 ± 5	23 ± 14
$0.3 \to 0.5$	18 ± 37	58 ± 6	27 ± 5	2 ± 12
$0.5 \to 0.8$		67 ± 14	21 ± 9	-8 ± 15
$0.8 \to 3.0$		-35 ± 25	-49 ± 13	-53 ± 17

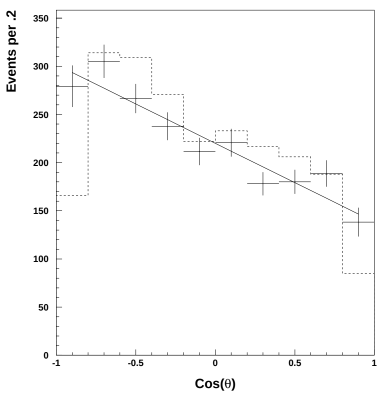

Figure 3. $cos\theta$ distribution for $-0.85 < x_F < -0.75$ and $0.3 < p_T < 0.5$ GeV/c before (dashed) and after (points with error bars) acceptance correction. Line is the result of a fit to (3).

from [2] in figure 7.

Table 2
Λ^0 polarization %

$1.5 < M_X < 1.7$ GeV/c^2	63 ± 5
$1.7 < M_X < 1.8$ GeV/c^2	30 ± 4
$1.8 < M_X < 1.95$ GeV/c^2	24 ± 5
$1.95 < M_X < 2.2$ GeV/c^2	20 ± 6
$2.2 < M_X < 2.5$ GeV/c^2	2 ± 8
$2.5 < M_X < 2.8$ GeV/c^2	-37 ± 11
$2.8 < M_X < 5.0$ GeV/c^2	-67 ± 13

5. DISCUSSION

The dependence of the Λ^0 polarization on M_X seen in our results and in those of R608 suggests that more can be learned about the origin of the polarization by studying the production dynamics of the X system (in this case, the $\Lambda^0 K^+$ two particle system). The large variation of the polarization over the kinematic range of the E690 data set and the high statistics of the data set should allow more detailed studies of the polarization. In particular it may be possible to investigate the polarization dependence on the angular momentum states of the two particle final state. Work on other exclusive final states (e.g. $\Lambda^0 K^0_s \pi^+$) may also provide additional information regarding the nature of Λ^0 polarization in high energy hadronic reactions.

6. ACKNOWLEDGEMENTS

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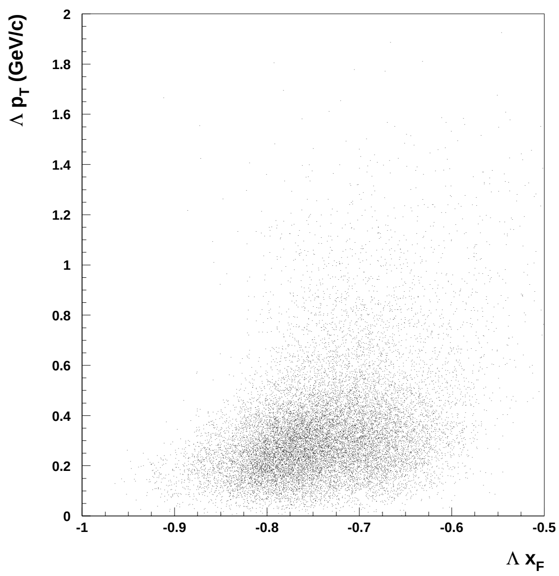

Figure 4. x_F *vs.* $|\mathbf{p_T}|$ for Λ^0's in the exclusive sample.

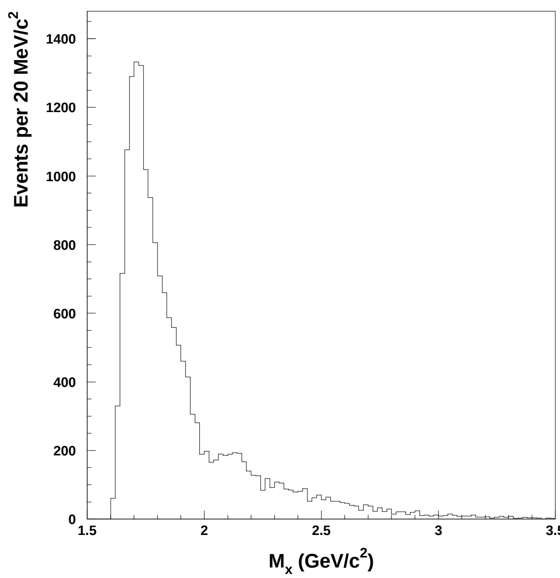

Figure 6. M_X distribution.

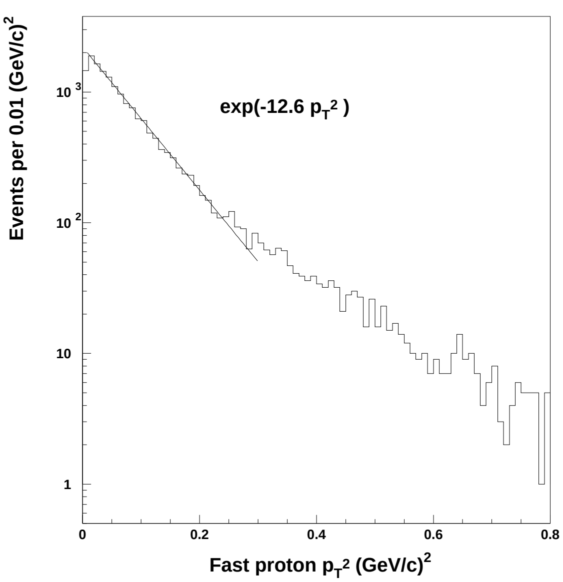

Figure 5. Fast proton p_T^2 distribution.

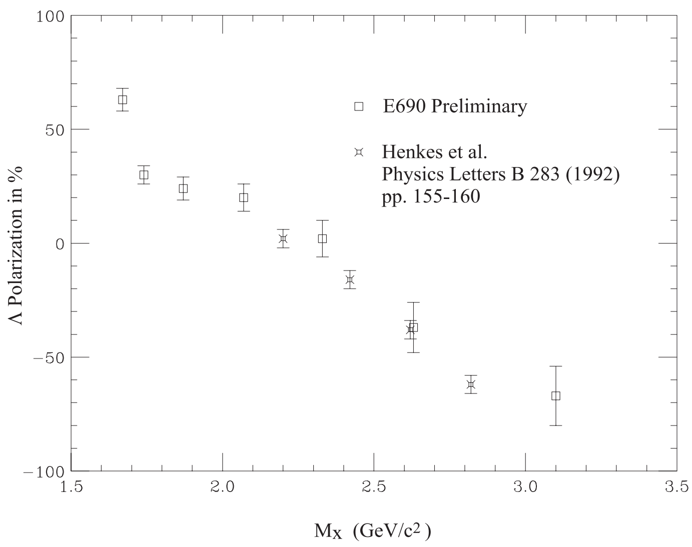

Figure 7. Λ^0 polarization as a function of M_X.