Ξ^- and Ω^- POLARIZATION FROM A NEUTRAL HYPERON BEAM

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Introduction

The lack of understanding of the origin of hyperon polarization is a problem in high energy physics which remains nearly 20 years after its discovery[1]. Several phenomenological models exist[2-5] but their predictions are for the most part qualitative or semi-quantitative. Possible mechanisms for hyperon polarization vary. In the DeGrand-Miettinen model[2], polarization results from Thomas precession of the quark spins in the recombination process. In the Lund model[3], polarized $s\bar{s}$ pairs are produced by stretching of a color field and conservation of angular momentum leads to a preferred spin direction. There are also several Regge type models[4,5] in which polarization effects arise from interference between different production channels.

More recent data[6-8] taken to gain additional insight has, if anything, created additional confusion. For example, $\bar{\Lambda}$'s and Ω^-'s produced by protons are unpolarized while $\bar{\Xi}^+$'s and $\bar{\Sigma}^-$'s are produced with sizeable polarization. Additional data is clearly needed to untangle this picture. With this in mind we present recent results from Fermilab experiment E-800 on the polarization of Ξ^- and Ω^- produced from polarized and unpolarized neutral hyperon beams. Little data exists on the polarization of hyperons produced from strange baryon beams such as is presented here.

A simple model borrowing heavily from the DeGrand-Miettinen model[2] can be invoked to understand some features of the hyperon polarization data. Working with SU(6) wavefunctions and the quark recombination model, we assume a sufficient condition for hyperon polarization occurs when there are quarks in common between beam and target particles and when at least one s quark is picked from the sea in the recombination process. This simple model when applied to proton production "predicts" opposite signs for Λ, Ξ^-, and Ξ^0 polarization compared to Σ^+, Σ^-, and Σ^0 polarization. The model however says nothing about the P_T or x_F dependence of the polarization, anti-hyperon polarization, $K^- \longrightarrow \Lambda$ polarization, etc.

Experimental Method

E-800 used two different methods for producing Ξ^- and Ω^-particles. The first used a polarized neutral hyperon beam and was called spin transfer mode. In this mode, 800 GeV protons were incident at ± 1.8 *mrad* on a 0.37λ Be target. The secondary beam passed through a neutral collimator and consisted of polarized Λ and Ξ^0 as well as neutrons and photons. The sign of the sweeper magnetic field was along the direction of polarization and hence no spin precession occurred. This polarized neutral hyperon beam was then incident at 0 *mrad* on a second 0.37λ Be target. The resultant tertiary beam was passed through a charged collimator (hyperon magnet with field integral of 24.36 T-m) which selected negatively charged particles. This magnet also precessed the spin of the hyperons to allow a measurement of the Ω^- magnetic moment. In spin transfer mode, one would expect that polarized Ξ^- and Ω^- would be produced via the transfer of polarized s quarks from the polarized Ξ^0 and Λ particles.

The second production method was called neutral production mode. In this case, 800 GeV protons were incident at 0 *mrad*. The secondary beam again passed through the neutral collimator but now consisted of unpolarized neutral particles including Λ and Ξ^0. This unpolarized neutral beam was then used to produce a tertiary negative beam as above however in this method was incident at a production angle of ± 1.8 *mrad*. In the neutral production mode one might expect that Ξ^- and Ω^- produced from this unpolarized neutral hyperon beam would be polarized via the same (unknown) mechanism which polarizes hyperons produced from protons (since the produced particles have quarks in common with the incident beam).

The Ξ^- and Ω^- particles and their charged daughters were tracked by a magnetic spectrometer consisting of scintillation counters, 8 planes of $100\mu m$ pitch SSD's, 12 MWPC's with 1 and $2mm$ spacing, and a spectrometer magnet with a P_T kick of 1.45 GeV/c. The decays used were $\Omega^- \rightarrow \Lambda K^-$ and $\Xi^- \rightarrow \Lambda\pi^-$ where subsequently $\Lambda \rightarrow p\pi^-$. The trigger required scintillation counter hits which selected particles exiting the collimator and MWPC hits from the two most downstream chambers which selected events with at least one positively and one negatively charged track.

The offline analysis used the $2mm$ MWPC hits to find three tracks. Next a geometric fit to a three track, two vertex topology was done followed by a kinematic fit to the proton and π^- momenta constrained to the Λ mass. The $1mm$ MPWC and SSD hits were used to improve the two vertex positions. Finally mass cuts were applied under the Ξ^- or Ω^- hypothesis. In the case of the Ω^-, a set of additional kinematic cuts were applied to remove remaining Ξ^- background.

Hyperons decay weakly through the parity violating process $H \rightarrow B\pi$, where H is the hyperon and B is the daughter baryon. The hyperon polarization is found by noting the spin direction of the daughter baryon follows the spin direction of the parent hyperon. For Ω^- and Ξ^- decays, the daughter Λ polarization follows that of the parent as

$$\vec{P}_\Lambda = \gamma_\Omega \vec{P}_\Omega \tag{1}$$

and

$$\vec{P}_\Lambda = \alpha_\Xi \hat{\Lambda} + \gamma_\Xi \vec{P}_\Xi \tag{2}$$

where $\hat{\Lambda}$ is the direction of the daughter Λ in the Ξ^- rest frame.

The Λ polarization is determined in the usual way by measuring the angular distribution

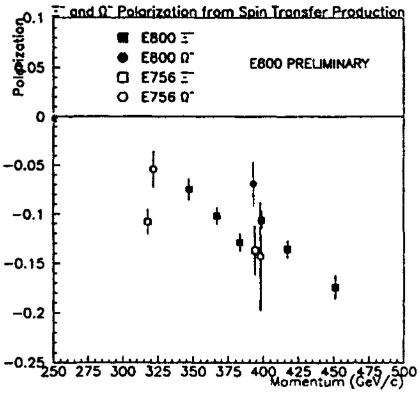

Figure 1: Ξ^- and Ω^- polarization from spin transfer production mode

of the proton in the Λ rest frame.

$$\frac{dn^{\pm}}{dcos\theta_i} = \frac{1}{2}(1 \pm \alpha_{\Lambda} P^i_{\Lambda} cos\theta_i) * \epsilon(cos\theta_i) \tag{3}$$

where $\epsilon(cos\theta_i)$ is the acceptance and the ± refer to positive and negative production angles. In practice, to account for the effect of detector acceptances on the angular distribution, a hybrid Monte Carlo technique[9] is used to determine the Λ polarization.

Results

The Ξ^- and Ω^- polarizations from the spin transfer production mode as measured by E-800 are shown in Figure 1. Also shown are earlier data from E-756. The Ξ^- polarization is large ($\approx 10\%$) and increases with momentum. The Ω^- polarization is about half as large as the Ξ^- polarization and no clear momentum dependence is observed.

These results may be described using the simple recombination model described above. Given that the polarized neutral hyperon beam contains Λ's and Ξ^0's with large, negative polarization, we expect (and observe) a large, negative polarization of Ξ^-'s via spin transfer of the polarized s quark. The same arguments can be invoked to describe the Ω^- polarization. That the Ω^- polarization is not as large as the Ξ^- polarization is difficult to understand in this model.

The Ξ^- and Ω^- polarizations from the neutral production mode are shown in Figure 2. In this mode the Ξ^- polarization is found to be consistent with zero while the Ω^- polarization is small and positive. That the Ξ^- polarization is indeed zero is seen by plotting the Ξ^- polarization components in the $\hat{x}$ and $\hat{z}$ directions. Parity conservation requires the initial polarization direction at production to be in the $\pm\hat{x}$ direction. Any real polarization would therefore be observed as a precession off this axis. In fact, the data show the precession

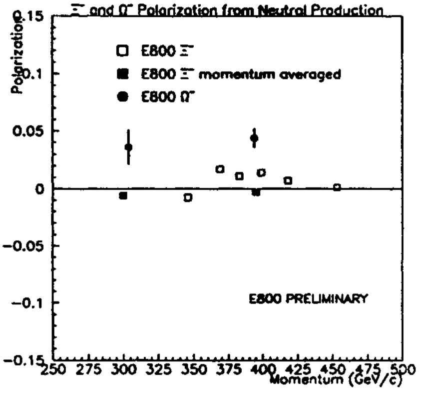

Figure 2: Ξ^- and Ω^- polarization from neutral production mode

angles to be randomly distributed. The same test may be applied to the Ω^- data. In this case, Ω^- polarization from spin transfer mode and Ω^- polarization from neutral production show the same precession angle (see Figure 3). Note that although the precession angles are the same, the directions of the initial polarization direction are opposite.

We can again turn to our simple model for interpretation of the data. Recall one of our assumed requirements for polarization was that an s quark from the sea be recombined with the fast quark(s) in common between beam and produced particle. By considering quark content, Ξ^- production from Λ's should be similar to Λ production from protons. Similarly, Ξ^- production from Ξ^0's should be similar to neutron production from protons. Making the further assumption that Ξ^- production is primarily from Ξ^0's, then we expect (and find) no Ξ^- polarization since there is no s quark picked from the sea. (Similarly one would expect neutrons to be unpolarized when produced from protons). If Ξ^- production were from Λ, one would expect a negative polarization similar to that found in $p \rightarrow \Lambda$.

For the Ω^- again assuming that most Ω^- are produced from Ξ^0's, then Ω^- polarization from $\Xi^0 \rightarrow \Omega^-$, should be similar to either $p \rightarrow \Sigma^+$ or $p \rightarrow \Lambda$. The data indicate that Ω^-'s are produced polarized similar to the former. Note that both $\Xi^0 \rightarrow \Omega^-$ and $p \rightarrow \Sigma^+$ have a diquark with identical quarks in common between beam and produced particle but in $p \rightarrow \Lambda$ the diquark consists of unlike quarks. In both cases however an s quark is produced from the sea. If Ω^- production were from Λ, one would expect a negative polarization similar to that found in $p \rightarrow \Xi^-$.

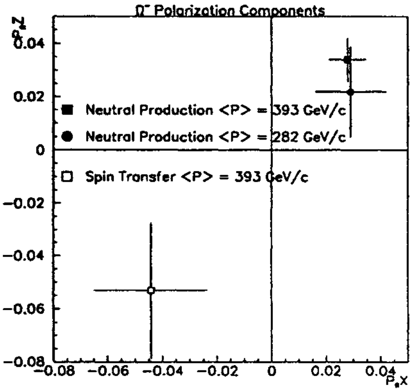

Figure 3: Ω^- polarization components from spin transfer and neutral production mode

Conclusions

E-800 has measured the polarization of Ξ^-'s and Ω^-'s produced from both polarized and unpolarized neutral hyperon beams. The negative Ξ^- and Ω^- polarizations observed in spin transfer mode are consistent with the simple quark recombination model however the small Ω^- magnitude is not understood in this context. In the neutral production mode (unpolarized neutral hyperon beam production) the Ξ^- polarization is zero and the Ω^- is small and positive. The signs of the Ξ^- and Ω^- polarizations in neutral production mode are possibly consistent with the simple quark recombination model though uncertainties in the production and polarization mechanisms weaken this argument considerably. In particular the positive Ω^- polarization is difficult to predict a priori.

A detailed understanding of hyperon polarization data continues to elude us. This problem demands additional experiments in which the quark and spin content of the beam is manipulated (such as has been pioneered by E-756 and E-800).

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