Measurement of transverse Λ and $\overline{\Lambda}$ polarization at COMPASS

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Abstract. New data on hyperon polarization in semi-inclusive deep inelastic scattering have been collected by the COMPASS collaboration at CERN during the years 2002-2004, using a beam of longitudinally polarized muons of 160 GeV/c and a ^{6}LiD target that can be polarized both longitudinally and transversely. The various combinations of beam and target polarizations allow for the study of a wide variety of hyperon polarization effects. Here we present preliminary results on the transverse polarization of Λ and $\overline{\Lambda}$ produced both with unpolarized and transversely polarized deuteron targets.

INTRODUCTION

The polarization of Λ hyperons was studied for the first time in the inclusive reaction $pN \rightarrow \Lambda X$ at Fermilab [1]. The large spontaneous polarization observed along the normal to the production plane, reaching up to about 30% at Λ transverse momenta $p_T > 1.5$ GeV/c, was completely unexpected, as polarization effects were thought to be vanishing in inclusive hadro-production at large energies [2, 3]. This first result was confirmed by later hadronic scattering experiments, performing systematic studies of hyperon polarization with different hadron beams (see for example [4], and references therein). The Λ polarization is in most of the cases found to be negative, rising linearly with the transverse momentum p_T up to $p_T \approx 1$ GeV/c were a plateau is reached. An exception is represented by the positive polarization, with a similar rise with p_T, observed in $K^- p$ scattering. In the plateau region the polarization rises almost linearly with the Feynman variable x_F of the hyperon, and is basically independent of the beam energy. $\overline{\Lambda}$ produced by anti-protons show a similar behavior as Λ produced in proton scattering, while they are found to be unpolarized in $pN \rightarrow \overline{\Lambda} X$.

Presently very little experimental information on the spontaneous hyperon polarization exists in photo- and lepto-production. The effect was investigated about 20 years ago in photo-production at CERN [5] and SLAC [6], with photon energies varying from 20 GeV to 70 GeV, but the results are statistically quite poor. The process has been more recently been investigated by the NOMAD colaboration in ν_μ scattering [7], were the spontaneous Λ polarization was found to be negative for all x_F, while the $\overline{\Lambda}$ polarization was found compatible with zero. New data have also been collected by the HERMES collaboration using 27.5 GeV electron and positron beams. The Λ spontaneous polarization is found to be positive and more pronounced for values of the light cone momentum faction of the beam $\zeta < 0.25$ [8]; in the same kinematical region, the $\overline{\Lambda}$ polarization has the opposite sign.

Λ polarization in deep inelastic lepton-nucleon scattering has also been proposed as a tool to investigate the transverse spin structure of the nucleons (see [9, 10, 11, 12]). When a lepton interacts with one of the valence quarks of a transversely polarized nucleon, the scattered quark leaves the nucleon in a polarization state that is determined by its transverse spin distribution function inside the nucleon ($\Delta_T q(x)$) and the kinematics of the lepton-photon vertex. The outgoing quark has a certain probability to fragment into a Λ hyperon and to transfer part of its polarization in the process. Therefore, the measurement of the spin correlation between the Λ and the transversely polarized target can provide information on the transverse quark spin distributions [13].

The COMPASS experiment [14] has collected a large sample of μN scattering events, both in the quasi-real photo-production and in the Deep Inelastic Scattering (DIS) regimes. A fraction of about 20% of the data was collected with the polarized target in the transverse spin configuration. In the following sections the preliminary COMPASS results on the spontaneous Λ and $\overline{\Lambda}$ polarization and on the transverse spin correlation are presented.

SPONTANEOUS Λ AND $\overline{\Lambda}$ POLARIZATION

The analysis of the spontaneous Λ and $\overline{\Lambda}$ polarization is based on the data sets collected by the COMPASS experiment during the years 2002 and 2003. As no selection on the Q^2 of the primary reaction is applied to the data, the sample is dominated by the quasi-real photo-production peak of the cross-section at $Q^2 \approx 0$ (GeV/c)^2.

Events of the type $\mu N \rightarrow \mu' \Lambda X$ ($\mu N \rightarrow \mu' \overline{\Lambda} X$), with the subsequent weak decay $\Lambda \rightarrow p\pi^-$ ($\overline{\Lambda} \rightarrow \overline{p}\pi^+$) were selected by requiring a reconstructed secondary vertex from oppositely charged hadron tracks, in coincidence with a primary interaction vertex. Only events with an interaction vertex inside the fiducial volume of the target cells and with associated beam and scattered muon tracks were kept. The reconstructed position of secondary vertices was required to be downstream of the target center and at least 20 cm away from the primary interaction. A significant fraction of the combinatorial background was suppressed by a cut on the collinearity between the hyperon momentum vector and the line connecting the primary and the secondary vertices; this angle was required to be smaller than 15 mrad. Background from e^+e^- decays was reduced by requiring a minimum transverse momentum of the decay products of 100 MeV. The remaining background is mostly coming from misidentified K_s^0 decays.

The Λ polarization is extracted from the measured asymmetry of the decay products along the normal to the production plane $\hat{n} = p_{\gamma^*} \times p_\Lambda$, according to the angular distribution given by

$$\frac{dN}{\cos\theta_p} = \frac{N_0}{2} A(\cos\theta_p)(1 + \alpha P_{\hat{n}}^{\Lambda} \cos\theta_p), \qquad (1)$$

where N_0 is the total number of produced Λ, θ_p is the proton emission angle with respect to the polarization axis $\hat{n}$, $\alpha = 0.642 \pm 0.013$ [15] is the analyzing power of the parity-violating decay, and $A(\cos\theta)$ denotes the effective acceptance function. In the case of $\overline{\Lambda}$ decays, the anti-proton angular distribution is used, and an opposite sign is attributed to the analyzing power.

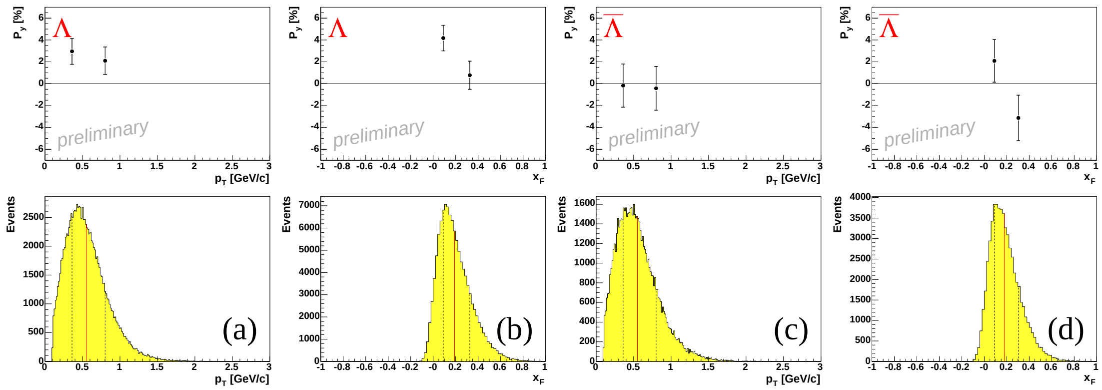

FIGURE 1. Measured transverse polarization: a) Λ polarization as a function of the transverse momentum; b) Λ polarization as a function of the Feynmann variable x_F; c) $\overline{\Lambda}$ polarization as a function of the transverse momentum; d) $\overline{\Lambda}$ polarization as a function of the Feynmann x. The corresponding p_T and x_F distributions are shown in the lower plots; the bin ranges (dashed lines) and the mean p_T and x_F values in each bin are marked by vertical lines.

To measure the polarization, the experimental data is divided into 8 bins in $\cos(\theta)$, and the Λ ($\overline{\Lambda}$) invariant mass is fitted with a Gaussian peak and a quadratic polynomial function in order to extract the number of hyperon decays and subtract the background. The distortion due to the experimental acceptance is corrected with a bias-cancellation method that exploits the up-down symmetry of the experimental apparatus, as described in [16]. The polarization is given by the slope of the corrected data points as a function of $\cos(\theta_p)$.

The available statistics of about 163000 Λ and 85000 $\overline{\Lambda}$ allowed to divide the sample into two bins of the hyperon transverse momentum p_T and Feynmann variable x_F. The preliminary results for the transverse polarization are shown in Fig. 1, along with the distributions of the corresponding kinematical variables; the bin ranges (dashed lines) and the mean p_T and x_F values in each bin are also shown as vertical lines in the kinematical distributions. Only statistical errors are shown in the plots. As can be seen from the x_F distributions, the statistics in the region of $x_F < 0$ is very poor, and the data is completely dominated by the forward region.

The data seem to favor a positive polarization for the Λ hyperons, as already reported by the HERMES collaboration [8]. This tendency is in clear contrast with the negative values measured in hadron production experiments with proton beams. The zero $P_N^{\overline{\Lambda}}$ on the contrary agrees, with a large statistical error, with proton beam experiments and with the HERMES result in the forward region.

TRANSVERSE SPIN CORRELATIONS

The measurement of the transverse spin correlation between the target nucleons and the produced hyperons is based on the data sets collected during the years 2002-2004 with the transverse configuration of the polarized target. The event selection is similar to that of the spontaneous polarization analysis; however, in this case only secondary vertices

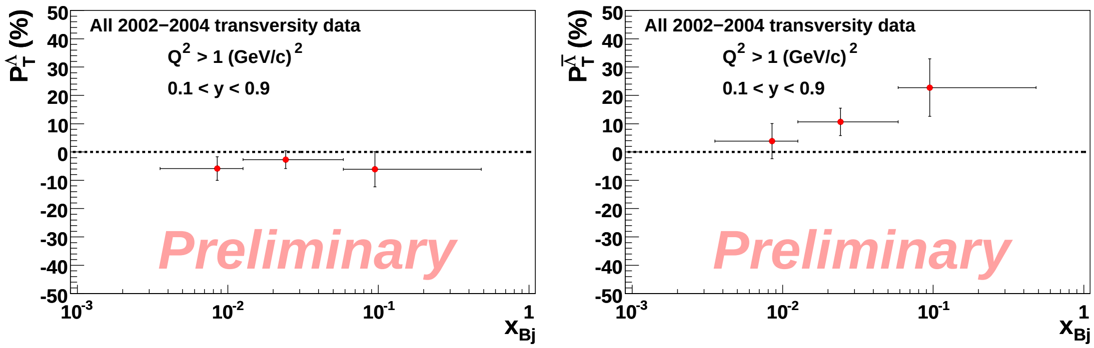

FIGURE 2. Measured Λ and $\overline{\Lambda}$ transverse spin correlations as a function of x, for the kinematical region of $Q^2 > 1$ GeV^2/c^2.

reconstructed at least 5 cm away from the downstream end of the polarized target are considered. In addition, only events with a squared four momentum transferred to the target nucleon $Q^2 > 1$ GeV^2/c^2 were considered in order to restrict the sample to the DIS region. The hyperon polarization is then measured along the direction obtained by reflecting the target polarization axis with respect to the normal to the lepton scattering plane. As this direction is completely uncorrelated with the $\hat{n}$-axis, no contribution of the spontaneous polarization is expected.

The available statistics of $\sim 45000\,\Lambda$ and $\sim 25000\,\overline{\Lambda}$ was divided into 3 bins of the Bjorken scaling variable x, and the polarization was extracted with the method described in [13]. The resulting spin correlation is shown in Fig. 2 as a function of x, for the Λ (left) and $\overline{\Lambda}$ (right) hypothesis respectively. The error bars shown include only statistical errors; the systematic errors have been estimated to be smaller than the statistical ones.

The measured spin correlation does not show unexpected deviations from the very small predicted value [11], even in the $x \approx 0.1$ region were the transversity function is expected to reach its maximum. Nevertheless, the measurement suffers from statistical accuracy, and larger data sets would be required to draw precise conclusions.

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