Λ POLARIZATION MEASUREMENTS AT COMPASS*

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ON BEHALF OF THE COMPASS COLLABORATION

The COMPASS experiment at the CERN SPS studies the inclusive production of polarized Λ and $\overline{\Lambda}$ hyperons with a 160 GeV/c muon beam in the quasi-real as well as in the DIS region. Since both beam and target are polarized, COMPASS is able to study various aspects of the Λ polarization. Preliminary results from three analyses are presented: The longitudinal Λ and $\overline{\Lambda}$ polarization was measured in dependence on several kinematical variables. The production of transversely polarized Λs from a transversely polarized target is connected to the transverse spin distribution functions $\Delta_T q(x)$. The Bjorken x dependence of the transverse polarization was evaluated. From hadro-production experiments it is well known that in high-energy reactions hyperons are produced polarized transversely with respect to the production plane. Up to now the mechanism of this spontaneous polarization is not understood. COMPASS extends this field to high-energy photo-production.

1. Introduction

Due to their self-analyzing weak decay, Λ hyperons are an ideal probe to study spin effects in high-energy reactions. The Λ polarization from longitudinally or transversely polarized targets or projectiles can be understood in terms of polarized distribution and fragmentation functions[1]. At twist-two level the nucleon structure is defined by three distribution functions: the momentum distributions $q(x)$, the helicity distributions $\Delta q(x)$ and the transverse spin distributions $\Delta_T q(x)$.

Being chiral-odd the spin distribution is only accessible in semi-inclusive DIS or in hadron-hadron collisions and therefore difficult to measure. COMPASS can access transversity via azimuthal asymmetries in pion production (Collins effect)[2], via two-hadron correlations[3], and via the spin transfer from transversely polarized nucleons to Λ hyperons produced in DIS[1].

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The measurement of the longitudinal Λ and $\overline{\Lambda}$ polarization provides information about about the spin transfer in the fragmentation of a polarized quark into a polarized baryon. By comparing the longitudinal polarizations of Λ and $\overline{\Lambda}$ in DIS, one can test the $q\bar{q}$ symmetry of the strange sea in the nucleon[4].

COMPASS[5] has studied the production of Λ and $\overline{\Lambda}$ hyperons by longitudinally polarized μ^+ on a longitudinally or transversely polarized solid-state ^{6}LiD target with a dilution factor f of about 40 % and a polarization $P_N \approx 50$ %. The target consists of two cells which are polarized in opposite directions so that data with both spin orientations are recorded simultaneously. The muon beam has a polarization of $P_B = 0.76 \pm 0.04$.

All three analyses reconstruct the Λ hyperons via their decay $\Lambda \to p\,\pi^-$ using only kinematical selection criteria. The detector acceptance limits the accessed kinematical region to the current fragmentation region $x_F > 0$.

2. Longitudinal Λ and $\overline{\Lambda}$ Polarization

Assuming quark fragmentation in the current fragmentation region, the longitudinal Λ polarization is given in the parton model by[6]:

$$P_L^{\Lambda} = \frac{\sum_q e_q^2 \left[P_B \cdot D_L(y) \cdot q(x) + f \cdot P_N \cdot \Delta q(x)\right] \Delta D_{\Lambda/q}(z_h)}{\sum_q e_q^2 \left[q(x) + f \cdot P_N \cdot P_B \cdot D_L(y) \cdot \Delta q(x)\right] D_{\Lambda/q}(z_h)} \qquad (1)$$

where e_q is the quark charge, $D_L(y)$ the longitudinal depolarization factor of the virtual photon, $y = \nu/E_{\text{beam}}$ the fractional energy of the virtual photon, and $z_h = E_h/\nu$ the fractional hadron energy, with ν being the virtual photon energy. $D_{\Lambda/q}(z_h)$ and $\Delta D_{\Lambda/q}(z_h)$ are the unpolarized and polarized fragmentation functions.

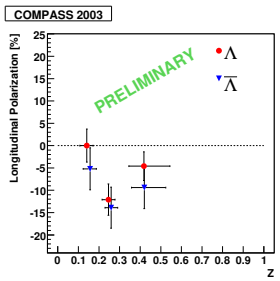

Figure 1. Longitudinal polarization of Λ and $\overline{\Lambda}$ for three bins in z_h. The error bars show only statistical errors. Systematic errors are below 5 % for each data point.

The data are averaged over the target polarization, so that $P_N = 0$ and with the known unpolarized distribution and fragmentation functions one could directly extract the polarized fragmentation functions from eq. (1). However, the above picture is more complicated since model calculations have shown that diquark fragmentation contributes significantly[7] also for $x_F > 0$ and that about 40 % of the Λs are produced via intermediate baryon states which hand down their polarization to the Λ[6].

The 2003 COMPASS data set contains about 31000 Λs and 18000 $\overline{\Lambda}$s in the DIS region with $Q^2 > 1$ GeV$^2/c^2$ and $0.2 < y < 0.9$. Details concerning the selection criteria, background subtraction, and acceptance correction can be found elsewhere[4].

The measured Λ and $\overline{\Lambda}$ polarizations exhibit a similar dependence on z_h (fig. 1). In the simplified picture of quark fragmentation, the z_h dependence is expected to be dominated by the polarized fragmentation function $\Delta D_{\Lambda/q}(z_h)$. The Λ and $\overline{\Lambda}$ polarizations also agree in the region where the squared invariant mass W^2 of the system recoiling against the scattered lepton is lower, but show deviations for large W^2 (fig. 2). This reflects the influence of the different production mechanisms for Λ and $\overline{\Lambda}$ which is also seen in the x and y dependences[4].

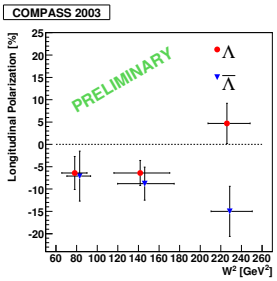

Figure 2. Longitudinal polarization of Λ and $\overline{\Lambda}$ for three bins in W^2. The error bars show only statistical errors. Systematic errors are below 5 % for each data point.

3. Λ Production from Transversely Polarized Target

For transversely polarized targets the polarization of the outgoing quark is correlated with the transverse polarization of the initial quark in the target as given by the underlying QED process. The scattered quark has a certain probability to fragment into a Λ hyperon. If at least part of its polarization is transferred in the fragmentation process, the transverse Λ polarization can provide information on the initial polarization state of the quark in the nucleon. Assuming again quark fragmentation in the current fragmentation region $x_F > 0$, the experimentally measured Λ polarization is therefore given by:

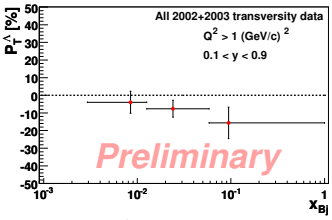

Figure 3. Λ polarization in dependence on x for the DIS region ($Q^2 > 1$ GeV$^2/c^2$ and $0.1 < y < 0.9$). The error bars show only statistical errors. Systematic errors have been estimated to be smaller than statistical ones.

$$P_T^{\Lambda} = f \cdot P_N \cdot D_T(y) \, \frac{\sum_q e_q^2 \, \Delta_T q(x) \, \Delta_T D_{\Lambda/q}(z_h)}{\sum_q e_q^2 \, q(x) \, D_{\Lambda/q}(z_h)} \qquad (2)$$

where $\Delta_T D_{\Lambda/q}(z_h)$ is the chiral odd transversity fragmentation function and $D_T(y)$ the virtual photon depolarization factor, which determines the polarization of the outgoing quark.

The analysis is based on the 2002 and 2003 data with transverse target polarization which contain about 20000 Λs. Details of the event selection, background subtraction, and acceptance correction are described elsewhere[8]. The x dependence of the transverse Λ polarization in the DIS region (fig. 3) shows a trend to negative polarizations with growing x, but the statistics is still limited in particular in the interesting region of larger x.

4. Spontaneous Transverse Hyperon Polarization

Since long time it is known that hyperons produced in unpolarized hadronic reactions exhibit a spontaneous transverse polarization[9]. Parity conservation restricts the polarization to be directed along the production plane normal.

A first preliminary analysis was performed on the 2002 data sample with longitudinally polarized target. Event selection criteria, background subtraction, and acceptance correction are described elsewhere[10]. The data sample contains 160000 Λs and 85000 $\overline{\Lambda}$s produced predominantly by quasi-real photons. COMPASS measured a positive spontaneous Λ polarization of $P_S^{\Lambda} = +2.7 \pm 0.9_{\text{stat.}} \pm 1.1_{\text{sys.}}$ which is the opposite sign as seen in proton and π^- collisions with nuclei and the same sign as in K^- beams. The $\overline{\Lambda}$ was found to be unpolarized with $P_S^{\overline{\Lambda}} = -0.3 \pm 1.4_{\text{stat.}} \pm 1.8_{\text{sys.}}$. The systematic effects were estimated from the false polarization of K_s^0s.

The analyzed sample represents only 10 % of the available statistics. A full analysis will include detailed studies of the kinematical dependencies of the spontaneous polarization.

References

1. M. Anselmino *et al.*, **hep-ph/0302008**, and references therein
2. V.Yu. Alexakhin *et al.*, *Phys. Rev. Lett.* **94**, 202002 (2005)
3. R. Joosten, *AIP Conf. Proc.* **792**, 957–960 (2005)
4. M.G. Sapozhnikov, **hep-ex/0602002**, and references therein
5. G.K. Mallot, *Nucl. Instrum. Meth.* **A518**, 121 (2004); F. Bradamante, **hep-ex/0411076**, and references therein
6. A.M. Kotzinian, A. Bravar, D. von Harrach, *Eur. Phys. J.* **C2**, 329 (1998)
7. J. Ellis *et al.*, *Eur. Phys. J.* **C25**, 603 (2002)
8. A. Ferrero, *Proc. of Transversity 2005*, Sept. 7–10, 2005, Como, Italy
9. J. Lach, *FERMILAB-Conf-92/378*, and references therein
10. J.M. Friedrich, *Proc. of Spin 2004*, Oct. 10–16, 2004, Trieste, Italy