Longitudinal Polarization of Λ and $\bar{\Lambda}$ Hyperons in Deep-Inelastic Scattering at COMPASS

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Abstract. The longitudinal polarization of Λ and $\bar{\Lambda}$ hyperons produced in deep-inelastic scattering of 160 GeV/c polarized positive muons is studied in the COMPASS (CERN NA58) experiment. Preliminary results on the longitudinal polarization of Λ and $\bar{\Lambda}$ from data collected during the 2003 run are presented.

Keywords: longitudinal polarization, hyperons, deep-inelastic scattering
PACS: 13.60.Rj Baryon production, 13.88.+e Polarization in interactions and scattering.

INTRODUCTION

The study of longitudinal polarization of Λ and $\bar{\Lambda}$ hyperons in the deep-inelastic scattering (DIS) is important for understanding the role of the strange quarks in the nucleon and obtaining information about the spin structure of the Λ hyperon. The longitudinal polarizations of Λ and $\bar{\Lambda}$ produced in DIS is sensitive to the strange quark polarized and unnpolarized parton distributions.

The polarized nucleon intrinsic strangeness model [1, 2] predicts negative longitudinal polarization of Λ hyperons produced in the target fragmentation region [3, 4]. The main assumption of the model is the negative polarization of the strange quarks and antiquarks in the nucleon. This assumption was inspired by the results of EMC and subsequent experiments on inclusive deep-inelastic scattering, which gave indication that the $s\bar{s}$ pairs in the nucleon are negatively polarized with respect to the nucleon spin. Recent COMPASS result [5], based on the new measurement of the g_1^d structure function and NLO QCD fit of all g_1 data from proton, deuteron and ^{3}He targets, is

$$\Delta s \equiv \int_0^1 dx[s_\uparrow(x) - s_\downarrow(x) + \bar{s}_\uparrow(x) - \bar{s}_\downarrow(x)] = -0.08 \pm 0.01(stat.) \pm 0.02(syst.). \quad (1)$$

A similar value is reported by the HERMES collaboration: $\Delta s = -0.085 \pm 0.013(th.) \pm 0.008(exp.) \pm 0.009(evol.)$ from analysis of the inclusive DIS [6].

The prediction of the nucleon intrinsic strangeness model [1, 2] was confirmed in the neutrino DIS experiments, where a large and negative longitudinal polarization P_Λ of the Λ hyperons in the target fragmentation region was found [7]. However the question about polarization of the nucleon strange quarks can not be considered to be solved. The HERMES collaboration, after analysis of the semi-inclusive DIS channels in the LO approximation, found that $\Delta s = 0.028 \pm 0.033 \pm 0.009$ [8], i.e. consistent with zero within the errors (for the discussion of the HERMES result, see [9],[10]). Recent HERMES data of deutron SIDIS [11] confirms this result with the better precision: $\Delta s = 0.006 \pm 0.029 \pm 0.007$. Therefore, the possibility to obtain an information on Δs from data on longitudinal polarization of Λ and $\bar{\Lambda}$ is quite important.

Another important subject is the spin structure of Λ hyperon. According to the naive quark model the spin of Λ is carried by the s quark and the spin transfer from the u and d quarks to Λ is equal to zero. This picture was questioned by a number of models [12]-[16], which differ in the absolute value and the sign of the polarization of the light quarks in the Λ. The precise measurements of Λ and $\bar{\Lambda}$ spin transfer will help to disentangle between these models.

EXPERIMENTAL SETUP AND SELECTION CRITERIA

We have studied Λ and $\bar{\Lambda}$ production by polarized μ^+ of 160 GeV on a polarized ^{6}LiD target using the spectrometer constructed in the framework of COMPASS experiment (NA58) at CERN. The muon beam polarization is $P_b = -0.76 \pm 0.04$. The polarized target consists of two oppositively polarized cells, each 60 cm long. For this analysis the data are averaged over the target polarization. A detailed description of the COMPASS experimental setup is given elsewhere [17] (see, also talks of A.Magnon and G.Mallot at this conference). The COMPASS data taking was going on in 2002-2004.

The preliminary analysis of the 2002 run was given in [18]. Here we present the preliminary analysis of data collected during the 2003 run. The data sample comprises about $8.7 \cdot 10^7$ DIS events with $Q^2 > 1$ (GeV/c)^2.

The V^0 events ($V^0 \equiv \Lambda$, $\bar{\Lambda}$ and K^0_S) were selected by requiring a primary vertex with incoming and outgoing muon tracks and at least two hadron tracks forming a secondary vertex. The primary vertex has to be inside the target. The secondary vertex must be downstream of the both target cells. The angle θ_{col} between the vector of V^0 momentum and the vector between primary and V^0 vertices should be $\theta_{col} < 0.01$ rad. Cut on transverse momentum p_t of the decay products with respect to the direction of V^0 particle $p_t > 23$ MeV/c was applied to reject e^+e^- pairs from the γ conversion. We select events with momenta of positive and negative particles greater than 1 GeV/c. The momenta of the V^0 particles have to be larger than 10 GeV/c. The DIS cuts of $Q^2 > 1$ (GeV/c)^2 and $0.2 < y < 0.9$ have been applied.

RESULTS AND DISCUSSION

To construct angular distributions of V^0 events all angular distributions were divided in several bins. In each bin the invariant mass distribution of positive and negative particles was constructed assuming the $\pi^+\pi^-$, $p\pi^-$ or $\bar{p}\pi^+$ hypothesis. The peak of the corresponding V^0 particle was fitted obtaining the number of the V^0 in the bin. This procedure allows to construct practically background-free angular distributions.

The total data sample contains about 31000 Λ and 18000 $\bar{\Lambda}$. That is significantly larger than the data sample of the 2002 run, which comprises about 9000 Λ and 5000 $\bar{\Lambda}$.

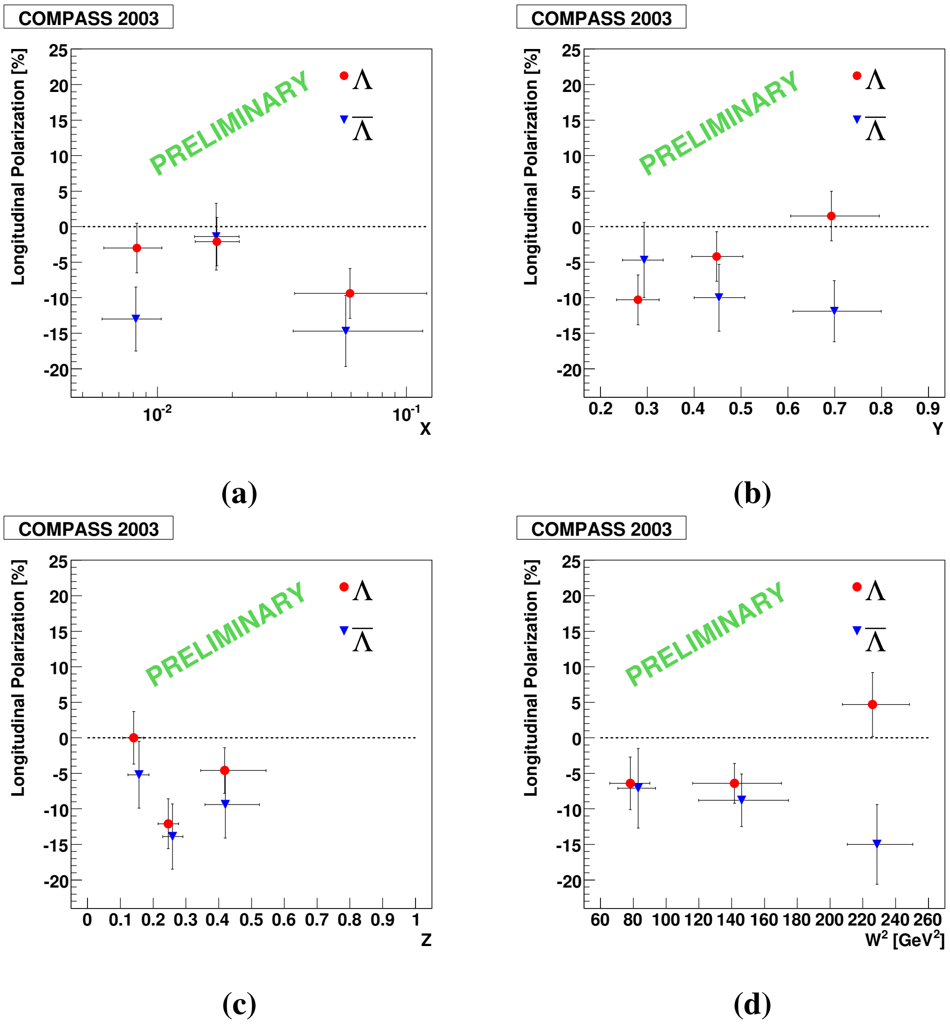

FIGURE 1. The $x-$ (a), $y-$ (b), $z-$ (c) and W^2- (d) dependencies of the longitudinal polarization of Λ and $\bar{\Lambda}$. The errors are statistical.

The COMPASS spectrometer selects Λ and $\bar{\Lambda}$ in the current fragmentation region, at relatively small x. The averaged values are $\bar{x}_F = 0.23$ and $\bar{x} = 2.8 \cdot 10^{-2}$.

The longitudinal polarization of Λ and $\bar{\Lambda}$ for data of the 2003 run is shown in Fig.1. The errors on the plots are statistical. The systematic errors have been evaluated to be not larger than 5% for each data point.

The x-dependence of the longitudinal polarization is shown in Fig. 1a. One could see that the polarization of Λ and $\bar{\Lambda}$ is the same except, probably, the region of small $x < 10^{-2}$.

The y-dependence of the longitudinal polarizations of Λ and $\bar{\Lambda}$ (Fig. 1b) is also similar. The exception is the region of large y, where there is an indication that the polarization of Λ and $\bar{\Lambda}$ is different. For the scattering on the unpolarized target, assuming that only one quark flavor dominates, one may expect that the polarization of a hyperon will be proportional to the depolarization factor $D(y) = \frac{1-(1-y)^2}{1+(1-y)^2}$. The depolarization factor $D(y)$ increases with y, therefore one should expect that the P_Λ will also grow up with y. However in the Fig. 1b we see that the data demonstrates opposite trend to the one, expected from the simple quark fragmentation: the Λ polarization is large at small y and decreases with y. The $\bar{\Lambda}$ polarization seems to be constant or slightly increases with y. The statistics is not enough for a definite conclusion, but an indication on different mechanisms of Λ and $\bar{\Lambda}$ production and polarization exists.

The z-dependence of the longitudinal polarizations is shown in Fig. 1c. It demonstrates similar behaviour for Λ and $\bar{\Lambda}$. It is interesting that we have not seen increasing of the polarization with z, as it was expected in some models. However more statistics, especially for the $\bar{\Lambda}$, is needed for the definite conclusion.

The W^2-dependence of the longitudinal polarizations Fig. 1d demonstrates the same effect as the y-dependence. At large W^2 the difference between the Λ and $\bar{\Lambda}$ polarizations starts to be significant.

In general, one may conclude that the longitudinal polarizations of Λ and $\bar{\Lambda}$ in DIS at the COMPASS energy seems to be the same, at least, in the low y-region. Nevertheless, the production mechanisms of Λ and $\bar{\Lambda}$ are different. The Λ hyperons, even in the current fragmentation region $x_F > 0$, are produced with a large contribution from the diquark fragmentation, which destroys typical y-dependence of the quark fragmentation and leads to a small spin transfer from the polarized lepton to Λ.

In future, the analysis of the 2004 run data will increase the statistics of at least a factor 2. The polarization of $\bar{\Lambda}$ seems to be more promising for investigation of the mechanisms of spin transfer from quark to hyperon. Theoretical calculations of Λ and $\bar{\Lambda}$ longitudinal polarizations at the COMPASS conditions are highly desirable.

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