Longitudinal polarization of Λ and $\bar{\Lambda}$ hyperons in DIS at COMPASS

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Abstract. Λ and $\bar{\Lambda}$ production in deep-inelastic scattering of 160 GeV/c polarized muons on a polarized ^{6}LiD target is under study in the COMPASS experiment. Preliminary results from data collected during 2002 beam period are presented.

The study of polarization of $\Lambda(\bar{\Lambda})$ hyperons in the deep-inelastic scattering (DIS) can provide an information on the fundamental properties of the nucleon, such as polarization of the strange quarks in the nucleon [1] and to determine the mechanism of spin transfer from polarized quark to a polarized baryon [2]-[6].

The polarized nucleon intrinsic strangeness model [7, 8] predicts negative longitudinal polarization of Λ hyperons produced in the target fragmentation region ($x_F < 0$). Main assumption of the model is the negative polarization of the strange quarks and antiquarks in the nucleon. The meson cloud model [9] predicts that in the target fragmentation region the polarization of Λ should be anticorrelated with the target polarization. Therefore, it is expected that $P_\Lambda \sim 0$ for production on unpolarized target.

The measurement of the longitudinal Λ polarization in the current fragmentation region $x_F > 0$ is traditionally connected with investigation of spin transfer from quark to hadron [2]-[6]. 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. It means that the longitudinal polarization of Λ produced in DIS is $P_\Lambda \sim 0$. In [2], using $SU(3)_f$ symmetry and experimental data for the spin-dependent quark distributions in the proton, the contributions of u and d quarks in the Λ spin was found to be negative and substantial, on the level of 20% for each light quark. Contrary to this conclusion the $SU(6)$ based quark-diquark model [10] predicts a large positive polarization of the u and d quarks in the Λ at x>0.3. In [8] it was shown that the beam energies of the current experiments on Λ production is too small to study real spin transfer from the quark to baryon. It turns out that even at the COMPASS energy of 160 GeV most Λ, even in the $x_F > 0$ region, are produced from the diquark fragmentation. It is predicted that in the COMPASS kinematics the longitudinal Λ polarization is $P_\Lambda = -0.004, -0.07$, depending on the fragmentation model.

It is important to note that a significant part (up to 30-40%) of the observed Λ is from decays of heavy hyperons. such as Σ^0 and Σ^*. More clear situation is with analysis of the $\bar{\Lambda}$ production, however up to now the statistics of $\bar{\Lambda}$ produced in the DIS experiments was marginal.

The experimental situation with measurements of Λ and $\bar{\Lambda}$ longitudinal polarization $P_\Lambda(P_{\bar{\Lambda}})$ in DIS is summarized in the Table 1.

One can see that in the target fragmentation region the Λ polarization is indeed negative. The spin transfer for current fragmentation region seems small, however the experimental data are quite scarce, especially for $\bar{\Lambda}$.

We have studied Λ and $\bar{\Lambda}$ production by polarized μ^+ of 160 GeV/c on a polarized ^{6}LiD target of the COMPASS spectrometer constructed in the framework of CERN experiment NA58. A detailed description of the COMPASS experimental setup is in the talk of L.Schmitt at this Conference. This analysis uses data collected during the 2002 run. Total amount of the acquired data is about 260 TB. The analysis comprises about $1.7 \cdot 10^8$ DIS events, which correspond to 60% of the total 2002 statistics.

The V^0 events ($V^0 \equiv \Lambda$, $\bar{\Lambda}$ and K_s^0) were selected by requiring the outgoing muon tracks together with two hadron tracks of opposite charge. The primary vertex should be inside the target. The polarized ^{6}LiD target consists of two oppositively polarized 60 cm long cells. The data presented here are averaged on target polarization.

The secondary vertex must be downstream of the both target cells. The angle between vector of V^0 momentum and

TABLE 1. Summary of experimental measurements of $\Lambda(\bar{\Lambda})$ longitudinal polarization in DIS. Sign of polarization is given with respect to virtual photon momentum.

Reaction Exp.	$< E_b >$ (GeV)	$< x_F >$	N_Λ	P_Λ	$N_{\bar{\Lambda}}$	$< x_F >$	$P_{\bar{\Lambda}}$
$\bar{\nu_\mu} Ne$ WA59[11]	40	-0.47 > 0	403 66	-0.59 ± 0.14 -0.11 ± 0.45			
μN E665 [12]	470	0.15 0.44	750	1.2 ± 0.5 0.32 ± 0.7	650	0.15 0.44	-0.26 ± 0.6 -1.1 ± 0.8
$\nu_\mu N$ NOMAD [13]	43.8	-0.36 0.21	5608 2479	-0.21 ± 0.04 -0.09 ± 0.06	248 401	-0.2 0.18	0.23 ± 0.20 -0.23 ± 0.15
eN HERMES [14]*	27.5	0.30	10568	$S_\Lambda =$ 0.06 ± 0.09	1687		

* The results were presented in terms of the spin transfer $S_\Lambda = \frac{P_\Lambda}{P_b D}$, where P_b is the beam polarization and D is the depolarization factor.

vector between primary and V^0 vertices should be $\theta_{col} < 0.01$ rad. Cut on transverse momentum 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 seen as the band at the bottom of the Armenteros plot shown in Fig.1.

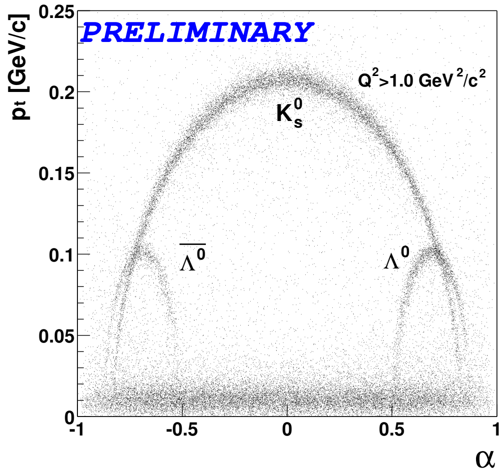

FIGURE 1. The Armenteros plot: p_t is the transverse momentum of the V^0 decay products with respect to the direction of V^0 momentum, $\alpha = \frac{p_L^+ - p_L^-}{p_L^+ + p_L^-}$, where p_L is the longitudinal momentum of the V^0 decay particle.

The typical elliptical bands from the K_s^0, Λ and $\bar{\Lambda}$ decays are seen in Fig.1. Both Λ and $\bar{\Lambda}$ signals stand out clearly. The large number of produced $\bar{\Lambda}$ is a specific feature of the COMPASS experiment.

The standard DIS cut $Q^2 > 1$ $(\mathrm{GeV}/c)^2$ and $0.2 < y < 0.8$ have been used. After background subtraction the experimental sample contains about 10800 Λ and 5900 $\bar{\Lambda}$.

The kinematical characteristics of produced Λ, $\bar{\Lambda}$ and K_s^0 are shown in Fig.2 and Fig.3. The x_F and Q^2 experimental distributions are compared to Monte-Carlo ones in Fig. 2. One can see that we are able to access mainly current fragmentation region. The averaged value of x_F is $< x_F >= 0.21$, whereas for the Bjorken scaling variable x it is $< x >= 0.02$.

The momenta of V^0 particles and of their decay products are shown on Fig.3. The mean Λ momentum is 12 GeV/c, while decay pion momentum is 2 GeV/c. Both figures shows reasonable agreement between the experimental data and the Monte-Carlo simulations.

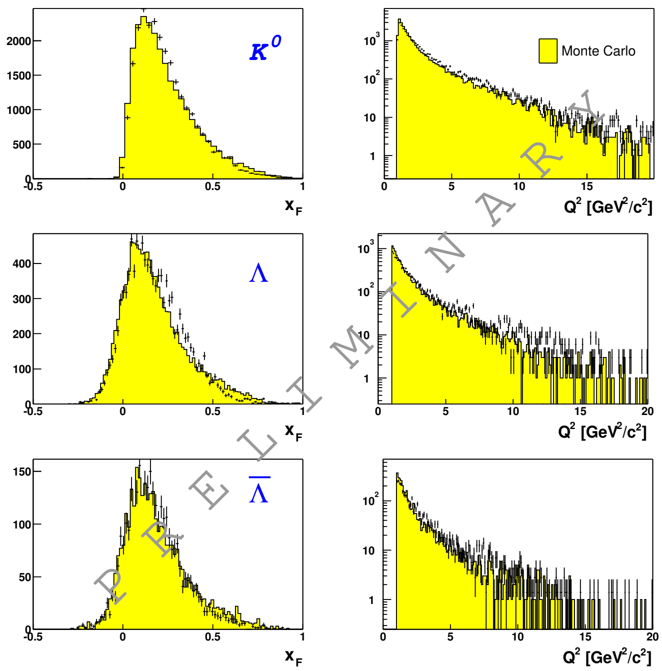

FIGURE 2. x_F (left column) and Q^2 (right column) distributions for K_s^0 (upper row), Λ (middle row) and $\bar{\Lambda}$ (lower row). The experimental data points are shown together with results of Monte-Carlo simulations (histograms).

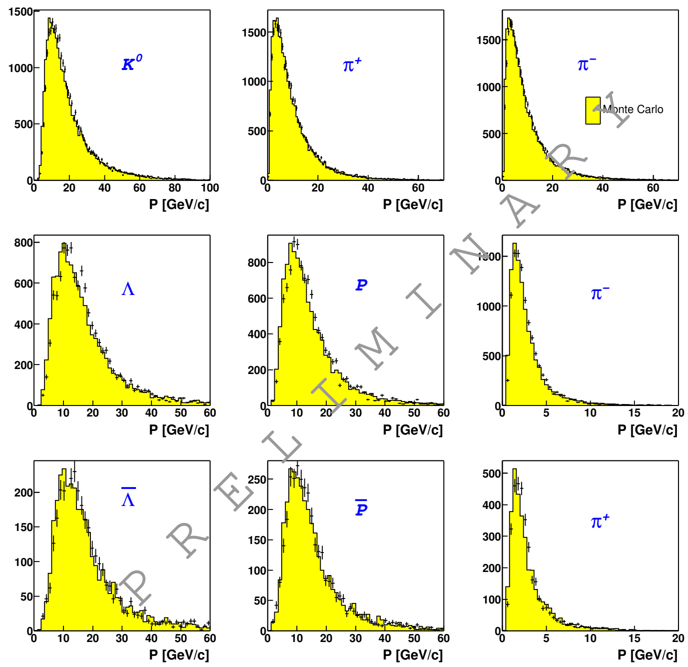

FIGURE 3. The momentum spectra for strange particles and their decay products are shown: K_s^0, π^+ and π^- in upper row; Λ, proton and π^- in middle row; and $\bar{\Lambda}$, $\bar{p}$ and π^+ in lower row. The experimental data points are shown together with results of Monte-Carlo simulations (histograms).

Λ ($\bar{\Lambda}$) hyperon polarization can be measured via the angular asymmetry of positive particle in $\Lambda \to p\pi^-$ ($\bar{\Lambda} \to \bar{p}\pi^+$) decays. Angular distribution of the positive particle in Λ ($\bar{\Lambda}$) rest frame is

$$\frac{d\sigma}{d\Omega} = N_0\,(1 + (-)\alpha P_i \cos\theta_i) \tag{1}$$

where N_0 is a normalization constant, $\alpha = 0.642 \pm 0.013$ is the decay asymmetry parameter, $P_i,\ i = x, y, z$ are the components of the polarization vector $\mathbf{P}$. The angles θ_i are between the direction of the positive decay particle and the axes of the coordinate system, which was defined using directions of virtual photon ($\mathbf{e}_\gamma$) and target nucleon ($\mathbf{e}_T$) in the Λ rest frame:

$\mathbf{n}_x = \mathbf{e}_\gamma$

$\mathbf{n}_y = \mathbf{e}_\gamma \times \mathbf{e}_T / |\mathbf{e}_\gamma \times \mathbf{e}_T|$

$\mathbf{n}_z = \mathbf{n}_x \times \mathbf{n}_y$

The analysis was performed slicing each angular distribution in 10 bins and fitting the invariant mass distribution of the V^0 decay products to determine the number of V^0 events in each bin. Fig. 4 shows measured angular distributions for K_s^0, Λ and $\bar{\Lambda}$ decays, corrected on the acceptance. The acceptance was determined by the Monte Carlo simulation of unpolarized $\Lambda(\bar{\Lambda})$ decays.

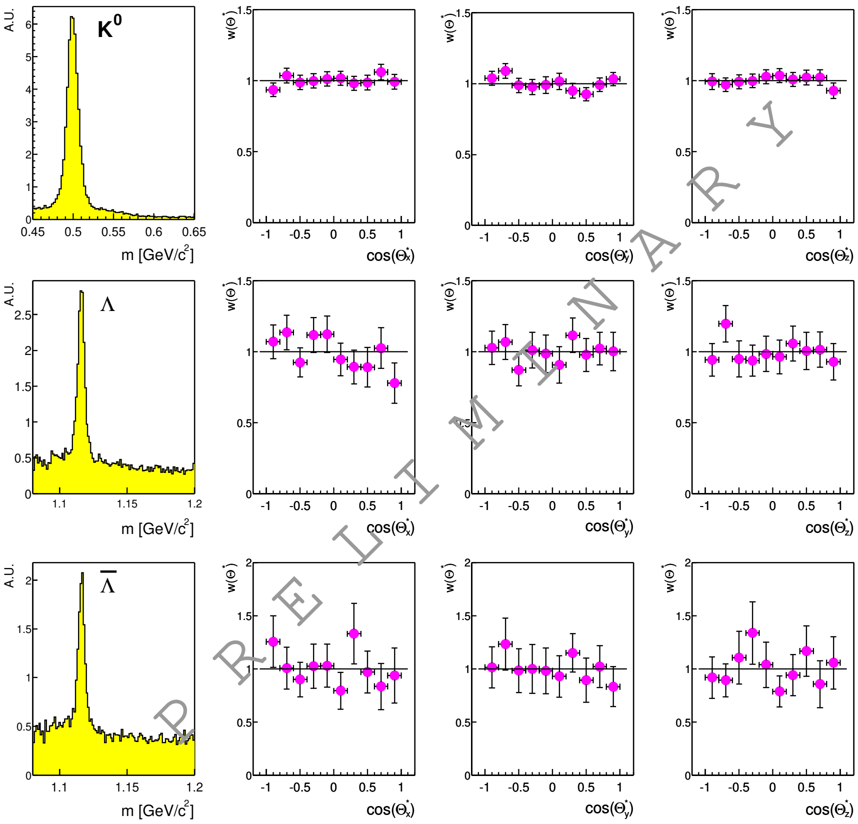

FIGURE 4. The $\cos\theta_x$ (second column) $\cos\theta_y$ (third column) and $\cos\theta_z$ (forth column) distributions for K_s^0 (upper row), Λ (middle row) and $\bar{\Lambda}$ (lower row). The first column shows invariant mass distributions for K_s^0, Λ and $\bar{\Lambda}$, respectively.

One could see that all angular distributions for K_s^0 decays are flat as expected. It means that no significant bias is introduced by the apparatus and by the analysis procedure.

The invariant mass distributions of K_s^0, Λ and $\bar{\Lambda}$ are shown in the first column of Fig.4 for a part of analyzed events. The level of the background events is not negligible and the procedure of the bin-by-bin fitting for determination of the angular distributions is essential to correct rejection of the background events.

The experimental $\cos\theta_i$ distributions are flat. It means that the Λ and $\bar{\Lambda}$ polarizations, averaged over the full kinematical range of COMPASS, are small.

Work on the determination of the polarizations and their systematic errors is continuing. The results from our 2002 data presented here demonstrate the good potential of COMPASS for measurements of Λ and $\bar{\Lambda}$ polarizations in DIS.

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