POSSIBILITIES OF COMPASS SPECTROMETER FOR THE Λ HYPERONS POLARISATION MEASUREMENTS*

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The possibilities of the COMPASS spectrometer for the measurement of Λ polarisation were investigated. The COMPASS experiment can provide Λ polarisation measurement in the deep-inelastic scattering process with high precision, which is comparable to the most precise existing data.

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1. Introduction

In recent years many models were proposed for the longitudinal polarisation of Lambda baryons produced in deep-inelastic lepton scattering, a list of references can be found in work [1]. Also many efforts were done from the experimental side and new precise data appeared [2–5]. Addressed questions of these studies are the following: if strange quarks in the nucleon indeed polarised as suggested by the Deep Inelastic Scattering (DIS) data, and what is the spin content of other baryons?

We would like to check predictions on Λ polarisation of the model based on static SU(6) quark–diquark wave functions and polarised intrinsic strangeness in the nucleon associated with individual valence quarks [1]. For COMPASS kinematics and $x_{\rm F} > -0.2$ ($x_{\rm F} = 2p^*_{\rm L}/W$) model predicts Λ polarisation of $\approx -7.3\%$.

For this we have investigated the possibilities of the COMPASS spectrometer constructing in framework of CERN experiment NA-58 [6] for the measurement of Λ polarisation.

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2. COMPASS experiment

The COMPASS apparatus set-up comprises two spectrometers: Large Angle Spectrometer (LAS) and Small Angle Spectrometer (SAS). The design of two spectrometers is similar and along the beam comprises a magnet, SM1/2, a ring imaging Cherenkov counter, RICH1, an electromagnetic calorimeter, ECAL1/2, a hadron calorimeter, HCAL1/2 and finally a muon filter, μ-wall 1/2, where 1 and 2 refer to the LAS and SAS, respectively.

The main features of the COMPASS spectrometer are as follows:

- Ability to work with high intensity beams. For the muon beam of 160 GeV an intensity of $10^8 \mu^+$ per second is used. It is 5 times higher than in the previous NA47 (SMC) experiment on deep-inelastic scattering. For the proton beam of 300 GeV an intensity of 4×10^7 particles per second is planned. It is 10 times higher than in typical experiment WA102 on central production performed earlier at CERN.

- Good particle identification. Ring imaging Cherenkov counter RICH1 is foreseen to separate pions, kaons and protons in the momentum interval 3–65 GeV/c.

3. Simulation of the detector efficiencies for Λ production

We have investigated the possibilities of the COMPASS spectrometer for measurements of Λ production. The interactions of 160 GeV 80% negatively polarised μ^+ beam with ^{6}LiD target were considered. To simulate the Λ production in DIS, 10^5 events were generated using LEPTO 6.5.1 code. To ensure a high spin transfer in the lepton–quark scattering, the cut $0.5 < y < 0.9$ on $y = (E_\mu - E_\mu^{'})/E_\mu$ was applied in addition to the standard kinematical DIS cut $Q^2 > 1\,(\mathrm{GeV}/c)^2$. Additional cut on Λ momentum $P_\Lambda > 2$ GeV/c was applied for better simulation efficiency.

The acceptance of the proposed apparatus for the Λ detection has been investigated using the COMPASS Monte Carlo code COMGEANT. Track reconstruction efficiency for realistic events (including beam pile-up, beam halo and secondary interactions simulation) was estimated using dedicated COMPASS off-line program.

A Λ event was considered as accepted if tracks of the pion and the proton from the Λ decay passed through tracking chambers upstream and tracking chambers downstream of the SM1 or SM2 magnets.

The following cut on the Λ decay vertex was implemented to suppress the background: $r/\sigma_r > 3$ or $z/\sigma_z > 3$, where r and z are radial and longitudinal distances between primary and Λ decay vertices and σ_r and σ_z are the errors of the corresponding values.

Λ effective mass resolution was found to be about $\sigma(m_\Lambda) \approx 3\,\mathrm{MeV}/c^2$, with strong dependence on Λ-decay vertex position because of large amount of target material. Precision of the fractional longitudinal centre-of-mass momentum variable $x_{\mathrm{F}} = 2p^*_{\mathrm{L}}/W$ determination was found to be about 0.003. The x_{F} distribution for generated (solid line), accepted (dashed line) and reconstructed (hatched histogram) events is shown in Fig. 1.

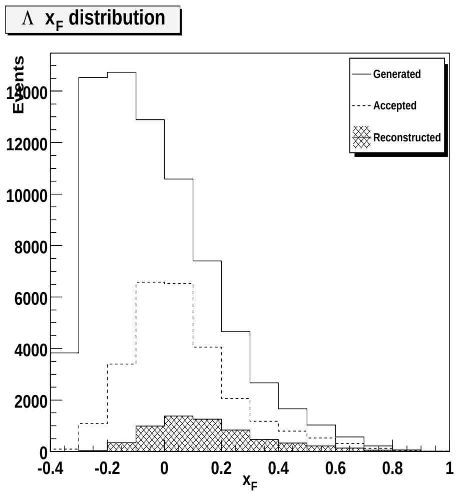

Fig. 1. x_{F} distribution of Λ hyperons. Solid line shows distribution for generated events, dashed line for accepted events, hatched histogram for reconstructed events.

To estimate the event rate it was assumed that the expected luminosity is $L = 4.3 \times 10^{37}\,\mathrm{cm}^{-2}\,\mathrm{day}^{-1}$, as in the Proposal [6].

Λ reconstruction efficiency was found to be $\varepsilon_{\mathrm{rec}} = 0.06$, primary vertex reconstruction efficiency $\varepsilon_{\mathrm{prim}} = 0.7$.

The expected statistics for run 2002 ($t = 10$ days) was estimated. Total DIS cross section at 160 GeV is $\sigma = 41.6$ nb, the mean Λ multiplicity with $P_\Lambda > 2$ GeV$/c$ after DIS cuts $W = 0.06$. Branching $\mathrm{Br}(\pi p) = 0.64$.

$$N(\Lambda) = \varepsilon_{\mathrm{rec}}\,\varepsilon_{\mathrm{prim}}\,\sigma\,W\,\mathrm{Br}(\pi p)\,L\,t = 2.9 \times 10^4\,.$$

4. Estimation of Λ hyperons polarisation measurement errors

Two samples of Λ hyperons were generated — unpolarised and polarised with $P_\Lambda = -7.5\%$ as predicted in [1]. The $\cos\theta^*$ distribution for generated, accepted and reconstructed events is shown in Fig. 2 (left). θ^* is the angle between the momentum of the decay proton and the direction of virtual photon in the Λ rest frame.

Polarised sample was corrected with unpolarised acceptance. Correction ratio (number of reconstructed Λ divided to number of generated Λ) in $\cos\theta^*$ bins is shown in Fig. 2 (right).

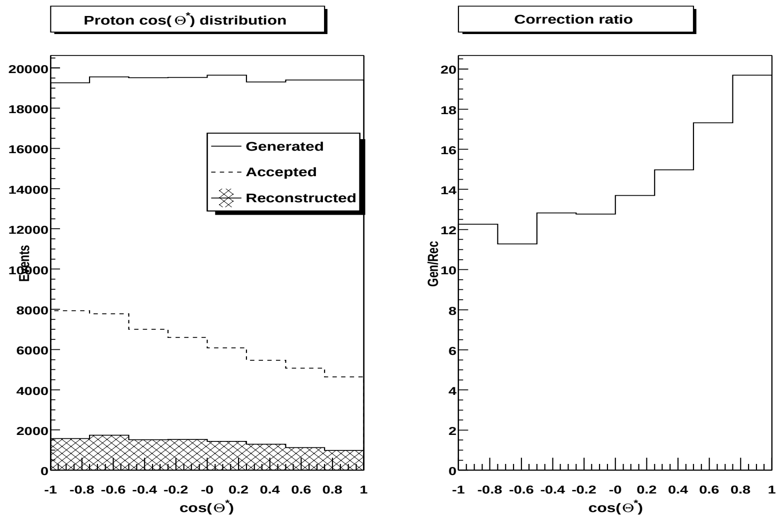

Fig. 2. Left: $\cos\theta^*$ distribution of Λ hyperons. Solid line shows distribution for generated events, dashed line for accepted events, hatched histogram for reconstructed events. Right: correction ratio (number of reconstructed Λ divided to generated).

Resulting $\cos\theta^*$ distribution as well as result of the Λ polarisation fit is shown in Fig. 3. The following function was used for the fit

$$\frac{dN}{d\cos\theta^*} = \frac{N_0}{2}\left(1 + \beta P \cos\theta^*\right) ,$$

where N_0 is the total number of the events, $\beta = 0.642 \pm 0.013$, P is Λ polarisation.

Λ polarisation obtained from the fit is $P = -5.5 \pm 3.6\%$, which is slightly different from the polarisation of generated sample (-7.5%). Error of 3.6% corresponds to 6000 reconstructed Λ. However, expected statistics for run 2002 is about 30000 reconstructed Λ hyperons. This number leads to 2% statistical accuracy in Λ polarisation measurement, in the hypothesis, that error scales as $1/\sqrt{N}$, where N is number of reconstructed Λ.

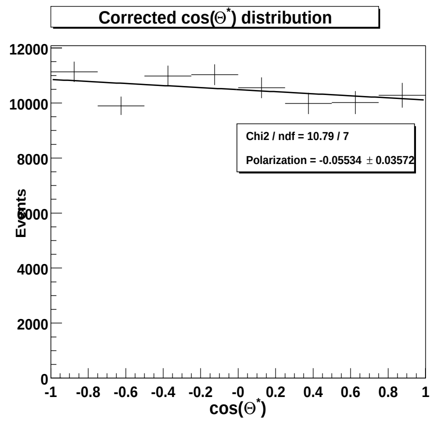

Fig. 3. Corrected $\cos\theta^*$ distribution of Λ hyperons. Solid line shows result of the straight line fit.

5. Conclusion

We have evaluated COMPASS setup 2002 possibilities for Λ polarisation measurements. Expected statistics for run 2002 is 30000 Λ which corresponds to 2% statistical accuracy in Λ polarisation measurement. Statistical error was obtained by extrapolation from simulated sample.

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