Proceedings of the DIS'2004, Štrbské Pleso, Slovakia

GLUON POLARIZATION MEASUREMENTS AT COMPASS

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The COMPASS experiment at CERN is studying the nucleon spin structure in polarized deep inelastic muon scattering. COMPASS is using a 160 GeV/c muon beam on a polarized LiD target. The gluon polarization in the nucleon is accessible via the photon-gluon fusion process. The latter can be tagged either by the production of open charm or by pairs of light hadrons with high transverse momenta. The talk presents the analysis methods, the status of the reconstruction of open charm via D-mesons, and the status of the asymmetry measurement for pairs of hadrons with high transverse momenta.

1 Introduction

The COMPASS experiment [1] covers a broad physics programme ranging from measurements of the gluon polarization in the nucleon, the determination of the flavor dependent quark helicity distribution functions, the transverse quark spin distributions functions, the polarized Λ fragmentation as well as production of vector mesons in semi inclusive deep inelastic scattering [2]. In addition hadron spectroscopy using hadron beams is foreseen. To reach these demanding goals a collaboration consisting of 28 institutes with over 230 physicists from 12 countries have constructed the COMPASS detector and taken data since 2002.

One of the main goals of the experiment is to understand how the constituents of the nucleon contribute to the total spin of $\frac{1}{2}\hbar$. It is known from previous experiments at CERN, SLAC and DESY that the sum of the helicity of the quarks contribute to about one third. First estimates of the contribution of the gluons have been tried by a QCD analysis of the Q^2 dependence of the polarized structure function g_1. However, the polarized structure function g_1 is measured only for two orders in magnitude in Q^2, much less than the unpolarized measurements of F_2. Thus the uncertainties from applying the DGLAP evolution are fairly large.

Therefore at COMPASS a more direct measurement is performed by analyzing the photon-gluon fusion process through open charm or the detection of hadron pairs with high transverse momenta.

Additional contributions to the total spin of the nucleon may come from orbital angular momenta of the quarks and gluons. Some ideas exists on determining the orbital angular momentum of the quarks from generalized parton distributions. These measurements may be attacked in a future extension of the COMPASS experiment.

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2 The COMPASS experiment

At COMPASS a 160 GeV/c muon beam is scattered off a polarized target. A high flux of $2 \cdot 10^8$ muons per 4.8 s spill in a cycle of 16.8 s is reached. The ^{6}LiD targets are located inside two 60 cm long target cells inside a superconducting solenoid of 2.5 T. For the measurement of the gluon polarization both targets are longitudinally polarized in opposite directions with values above 50% and a fraction of polarized material of about 40%. Trigger hodoscopes are set up in a way to select the event kinematics based on the scattered muon down to very low values of Q^2.

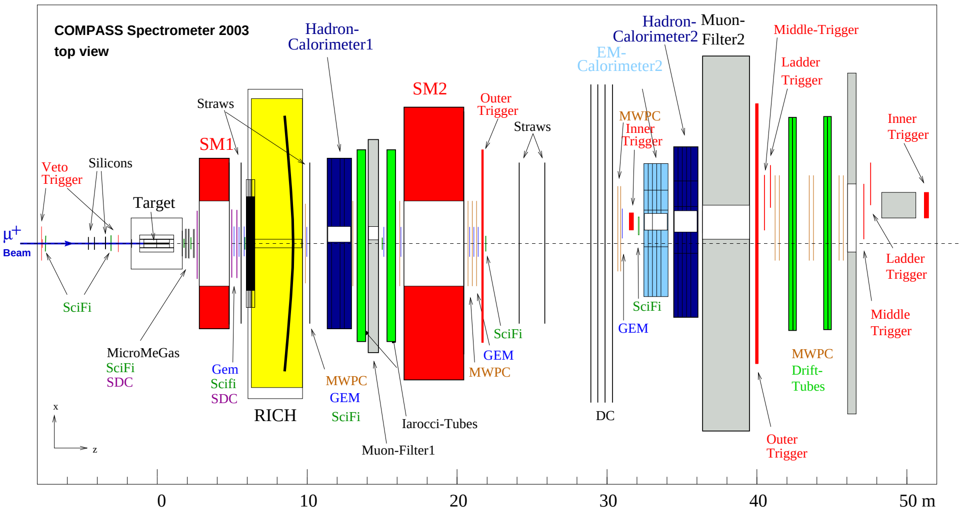

Figure 1. The COMPASS detector at CERN. Shown are the polarized target, two spectrometer magnets (SM1, SM2), small angle tracking detectors (SciFi, Silicon, MicroMeGas, GEM), large angle tracking detectors (SDC, Straws, MWPC) and particle identification detectors: RICH, hadron calorimeters and muon filter.

The COMPASS experiment is layed out as a two stage spectrometer (Fig. 1). The first part allows to measure large scattering angles and low momenta tracks, the second the high momenta tracks. Several type of tracking detectors are used to cover the different rate requirements. Scintillating fibers and silicon detectors measure the highest particle flux in the central region. These are surrounded by novel micromesh gas chambers (Micromegas) and gas electron multipliers (GEMs). The larger regions are covered by drift chambers, MWPCs and straw drift tubes. A ring imaging cherenkov detector allows pion and kaon separation in a large momentum range up to 50 GeV/c. This is essential for the reconstruction of D-mesons. The muons and hadrons can be distinguished by their energy deposit in the hadron calorimeters and the penetration depth in the muon filters. High rate capable frontend electronics and a pipelined DAQ system has been designed to read event rates of up to 100 kHz [3].

3 Gluon polarization measurement by open charm

The open-charm events (Fig. 2) are identified by the reconstruction of D^0 and D^* mesons from their hadronic decay products: $D^0 \to K^-\pi^+$ and $D^{*+} \to D^0\pi_s^+ \to (K^-\pi^+)\pi_s^+$ (and the charge conjugated processes). Experimentally the helicity dependent cross section asymmetry for charm production is measured by the counting rate asymmetry:

$$A_{exp} = \frac{N_{c\bar{c}}^{\uparrow\downarrow} - N_{c\bar{c}}^{\uparrow\uparrow}}{N_{c\bar{c}}^{\uparrow\downarrow} + N_{c\bar{c}}^{\uparrow\uparrow}} = P_\mu P_T f D(y) A^{\gamma N \to c\bar{c}X}, \tag{1}$$

where the beam polarization $P_\mu \approx 0.8$, the target polarization $P_T \approx 0.5$, the dilution factor $f \approx 0.4$ and the depolarization factor $D(y)$ enters. The gluon polarization $\Delta G/G$ can the be deduced according to:

$$A^{\gamma N \to c\bar{c}X} = \frac{\Delta\sigma^{\gamma N \to c\bar{c}X}}{\sigma^{\gamma N \to c\bar{c}X}} = \frac{\int d\hat{s}\, \Delta\sigma^{\mathrm{PGF}}\, \Delta G(x_g, \hat{s})}{\int d\hat{s}\, \sigma^{\mathrm{PGF}}\, G(x_g, \hat{s})} \approx \langle a_{LL} \rangle \left\langle \frac{\Delta G}{G} \right\rangle \tag{2}$$

where $\hat{s} = (p_\gamma + p_g)^2$. The polarized photon-gluon cross section $\Delta\sigma^{\mathrm{PGF}}$ has been calculated up to NLO by two groups [4,5].

The D^* mesons can be tagged through their decay into $D^0\pi_s$. A cut on the momentum fraction of the D-meson $z_D = E_D/E_\gamma > 0.2$ and the decay angle distribution $|cos\Theta^*|$ removes background. A selection of the kaon momentum in the region between 10 and 35 GeV/c allows proper particle identification by the RICH. By selecting the D* meson by a cut on the energy release $M(K\pi\pi_s) - M(K\pi) - m_\pi$ one can project on the $M(K\pi)$ invariant mass and observes a clear D^0 peak corresponding to 317 D^0 from 80% of the 2002 data set (Fig. 2). The reconstruction is very challenging because no decay vertex reconstruction is possible inside the massive polarized target and the event rate is small compared to the background. Ongoing improvements in the reconstruction algorithms, the analysis methods and including the 2003 and expected 2004 data sets will lead to a projected error on the gluon polarization of 0.24 before COMPASS will continue data taking in 2006.

4 Gluon polarization measurement from high p_T hadron pairs

Another approach to identify the photon-gluon fusion process is provided by the observation of two jets with high transverse momenta p_T. This process has been used at the HERA collider experiments to determine the unpolarized gluon structure function. In COMPASS, where the energies are lower, this process is tagged by selecting a pair of charged hadrons with high p_T [6]. This means that the p_T of each hadron is required to be larger than 0.7 GeV/c and $p_{T_1}^2 + p_{T_2}^2 > 2.5$ (GeV/c)^2. To ensure that they result from current fragmentation a cut on $x_F > 0.1$ and $z > 0.1$ has been applied. A two hadron invariant mass cut above 1.5 GeV/c^2 removes contributions from resonances.

The COMPASS result obtained from the 2002 data for the spin asymmetry in the production of hadron pairs with high transverse momenta is

$$A_{LL}^{\gamma^* d} = -0.065 \pm 0.036_{stat.} \pm 0.010_{syst.}.$$

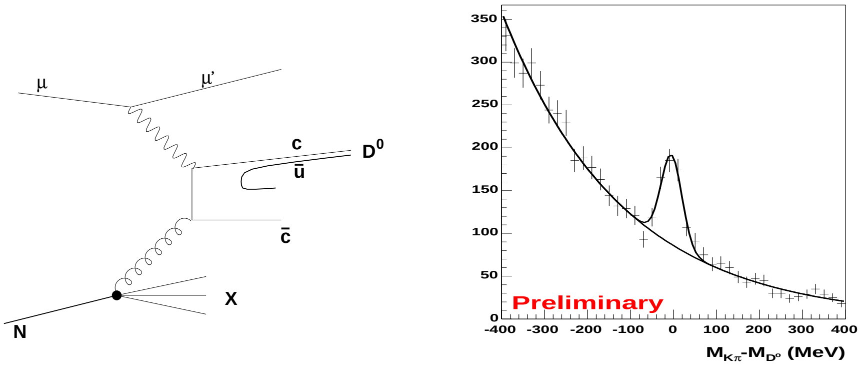

Figure 2. Left: The photon-gluon fusion process leading to open charm. Right: Reconstructed D^0 in the $K\pi$ invariant mass distribution tagged by their decay from the D^* (80% of the 2002 data set).

Presently the systematic error contains only studies on false asymmetries due to target or spectrometer effects. Including the 2003 and expected 2004 data a gain by a factor of four in the statistics is expected. From this expected statistics an error on the gluon polarization measurement of 0.05 has been projected. Here it is assumed that the fraction of photon-gluon fusion events is one quarter.

The gluon polarization can be determined from the asymmetry $A_{LL}^{\gamma^* d\to hhX}$ by subtracting background contributions according to the equation:

$$A_{LL}^{\gamma^* d} = \frac{A_{||}^{\mu d\to hhX}}{D} \approx \left\langle \frac{\hat{a}_{LL}^{PGF}}{D} \right\rangle \left\langle \frac{\Delta G}{G} \right\rangle \frac{\sigma^{PGF}}{\sigma^{tot}} + \left\langle \frac{\hat{a}_{LL}^{COM}}{D} \right\rangle \left\langle \frac{\Delta q}{q} \right\rangle \frac{\sigma^{COM}}{\sigma^{tot}} + LO.DIS$$

where the the photon-gluon fusion process PGF has an analyzing power of $\hat{a}_{LL}^{PGF} \approx -1$ and the QCD-Compton process an analyzing power of $\hat{a}_{LL}^{COM} \approx 0.5$, while the leading order DIS contributions to the asymmetry are small. A large fraction of the data stems from the $Q^2 < 1$ $(\mathrm{GeV}/c)^2$ region. Here additional contributions from the resolved photon and vector meson exchange cannot be neglected. Monte Carlo studies to determine the fractions of the various processes are in progress.

5 Outlook

The prospects to measure the gluon polarization with COMPASS are summarized in Fig. 3 in comparison with other experiments. First explorations of the gluon polarization have been performed by the HERMES [7] and SMC [8] experiments utilizing the method of high p_T pairs. This method is experimentally easier through the fairly large statistics, however, the theoretical interpretation is quite difficult. At the RHIC collider the STAR [9] and PHENIX [10] experiments are planning to measure the gluon polarization in quark-gluon scattering and gluon-gluon fusion processes. The measurement of $\Delta G(x_g)$ in a large range of x_g by the STAR experiment may allow to determine the integral ΔG. For this the large-x_g behavior of

$\Delta G(x_g)$ must be constrained by the measurement of $\Delta G(x_g)$ using the open charm channel at the COMPASS experiment where the theory is well understood.

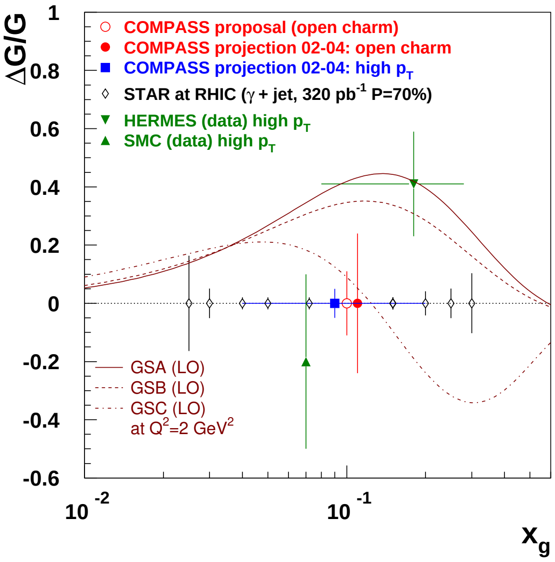

Figure 3. Comparison of experiments for the measurement of $\Delta G/G$. Shown are first measurements of HERMES ($< Q^2 >= 0.06$ (GeV/c)^2) and SMC (DIS, $Q^2 > 1$ (GeV/c)^2). For COMPASS only extrapolated errors based on the 2002 data are given. The estimates for STAR are the proposal values. The uncertainties from theory calculations is not shown and is varying largely for the different processes and experiments. The curves show the parameterizations A – C of [11].

References

1. COMPASS collaboration, CERN/SPSLC 96-14 (1996).
2. M. Leberig, these proceedings; H. Fischer, these proceedings.
3. H. Fischer *et al.*, IEEE Transaction on Nuclear Science 49 (2002) 443.
4. I. Bojak, and M. Stratmann, Nucl. Phys. B **540** (1999) 345.
5. Z. Merebashvili, A. P. Contogouris, and G. Grispos, Phys. Rev. D **62** (2000) 114509 and Phys. Rev. D **69** (2004) 019901(E).
6. A. Bravar *et al.*, Phys. Lett. B **421** (1998) 349.
7. A. Airapetian *et al.* (HERMES), Phys. Rev. Lett. **84** (2000) 2584.
8. K. Kowalik, these proceedings; B. Adeva *et al.* (SMC), hep-ex/0402010, submitted to Phys. Rev.
9. L. Bland, "Spin physics with the STAR detector" in Circum-Pan-Pacific RIKEN Symposium on High Energy Spin Physics (Wako, Japan, November 1999), RIKEN Review 28 (May, 2000).
10. C. Aidala, these proceedings.
11. T. Gehrmann, and W. J. Sterling, Z. Phys. C **65** (1994) 461.