Determination of the gluon polarisation in COMPASS experiment at CERN.

Adam Mielech on behalf of the COMPASS collaboration.
INFN, Padriciano 99, 34100 Trieste, Italy

Determining of the gluon polarisation in the nucleon, by measurement of the double spin asymmetry of the photon-gluon fusion process is the main goal of the COMPASS experiment at CERN. Experiment uses 160 GeV polarized muon beam and polarised ^{6}LiD target. Photon-gluon fusion events are selected using charmed mesons and hadron pairs at large p_T. Preliminary results on charm signal extraction, and spin asymmetry $A^{\gamma^* d}$ of the cross sections for high p_T hadron pairs production are presented.

1. Nucleon spin structure

The spin of the nucleon can be understood in terms of its constituents, according to the sum rule:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_{zq} + L_{zg}, \tag{1}$$

where $\Delta\Sigma$ and ΔG are the quark and the gluon spin contributions to the nucleon spin, L_{zq} is the orbital momentum of quarks and L_{zg} orbital momentum of gluons.

In the quark parton model, the singlet matrix element of the axial vector current a_0 is proportional to the sum of the spin contributions carried by quarks, $\Delta\Sigma$. Element a_0 can be evaluated from the integral of the spin structure function $g_1(x, Q^2)$, measured by number of experiments at CERN (EMC, SMC) and SLAC giving consistent results. The value $\Delta\Sigma = 0.27 \pm 0.13$ [1] indicates that only a small fraction of the nucleon spin is carried by quarks. The ΔG up to now was determined with large uncertainties either indirectly from the QCD evolution of $g_1(x, Q^2)$ structure function [2] or from the PGF process tagged by hadrons at large p_T [3],[4]. More precise determination of ΔG from direct processes is the main goal of COMPASS [5] and of experiments at RHIC [6].

2. COMPASS experiment

COMPASS experiment covers a broad physics program with the muon and the hadron beam. The main subject of the muon beam program is the determination of ΔG but also includes the flavour dependent helicity distribution functions, transverse quark spin distribution functions, the polarised Λ fragmentation and vector meson production.

The experimental setup of the COMPASS for the muon program consists of the longitudinaly (or transversaly) polarised target, two-stage magnetic spectrometer, particle identification and hadron calorimeters.

The target consists of two 60 cm long cells filled with ^6LiD which has a dilution factor of 40%. The cells are in the superconducting magnet at a field of 2.5 T. Through DNP, the target material is polarised to about 50% in the longitudinal mode (transvere polarisation is obtained with the use of a dipole magnet). Directions of the polarisation vectors of cells are opposite, and periodicaly reversed. This configuration allows cancellation of the flux and acceptance effects in the measured asymmetry (2).

The first stage of the COMPASS spectrometer is used for the low momenta and large angle tracks reconstruction. High momentum tracks, mainly scattered muons, are reconstructed in the second stage. Tracking system consists of various type and size detectors and include small ($50 \times 70\,\mathrm{mm}^2$) silicon and scintilating fiber planes, set in the beam region, medium size drift, proportional and novel micromesh chambers and large ($3.2 \times 2.8\,\mathrm{m}^2$) straw tube trackers. Trigger is based on the scattering muon angle measurement in the set of hodoscopes and the energy deposited in the hadron calorimeter. Particle identification, very important for the extraction of charmed meson signal, is provided by the RICH detector filled with C_4F_{10}. Is allows to distinguish pion, kaon and proton tracks for the momenta above 3, 10 and 17 GeV respectively. Muon identification procedure uses muon filter detectors and the hadron calorimeter signal.

3. Asymmetry determination

The $\frac{\Delta G}{G}$ is extracted from the asymmetry of the number of events (N), with paralell and antiparalel beam-target spin configurations:

$$A_{\parallel} = \frac{N^{(\leftarrow\Leftarrow)} - N^{(\leftarrow\Rightarrow)}}{N^{(\leftarrow\Leftarrow)} + N^{(\leftarrow\Rightarrow)}}. \tag{2}$$

Asymmetry is calculated for two signatures of the PGF process: open charm and high p_T hadron pair production.

Processes contributing to the leading order Deep Inelastic Scattering are shown on the figure 1.

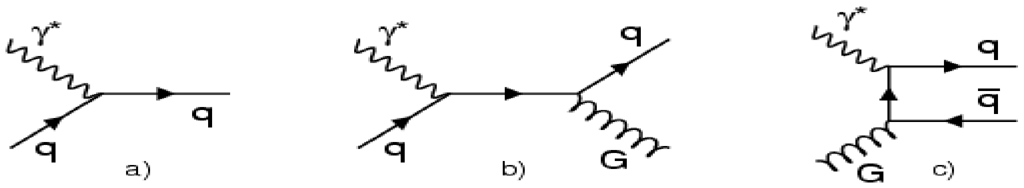

Figure 1. *Lowest order diagrams for DIS γ^* absorption: a) leading process, b) gluon radiation (QCD Compton scattering), c) photon-gluon fusion (PGF).*

3.1. Open charm production

Due to a large mass of c quark, its contribution to the nucleon sea is negligible. Apperance of the charm particle in the final state is a clean signature for PGF process, as it is the only mechanism for producing those particles in the leading order (see Fig.1).

From the counting rate asymmetry (2), the open charm cross section asymmetry is extracted. The former one is related to the $\frac{\Delta G}{G}$ by the convolution with the partonic asymmetry: $A^{c\bar{c}}_{\gamma N} = \frac{\int d\hat{s}\Delta\sigma(\hat{s})\Delta G(x_G,\hat{s})}{\int d\hat{s}\sigma(\hat{s})G(x_G,\hat{s})} \simeq a_{LL}\frac{\Delta G}{G}$, where $\hat{s} = M^2_{c\bar{c}}$ represents the invariant mass of the photon-gluon system and x_G is the nucleon momentum fraction carried by interacting gluon. Charged D^* meson is reconstructed as a charm signature, from the following decay chain: $D^{*+} \to D^0\pi^+_s$, $D^0 \to K^-\pi^+$. The difference between D^* and D^0 mass is only 145 MeV, thus the available phase space for the π^+_s is small (s means soft) in this decay. Therefore the combinatorial background is suppressed.

Figure 2 shows the distribution of the difference ($M_{K^-\pi^+\pi^+}$ - $M_{K^-\pi^+}$ - M_π) for the sample of the data collected by the experiment during 2002 year run.

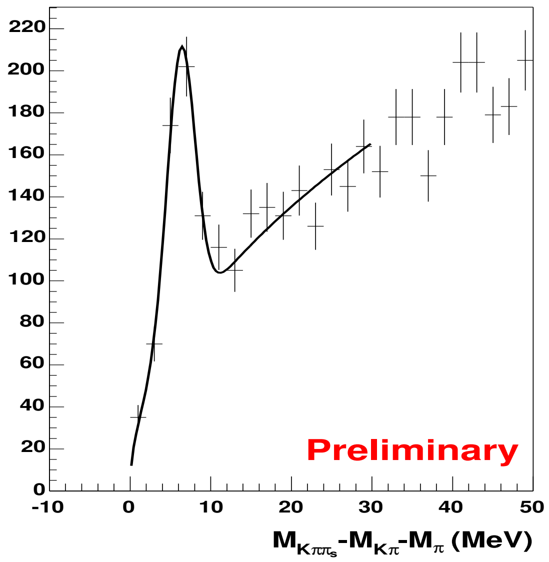

Figure 2. *$D^{*\pm}$ signal extracted from 2002 COMPASS data.*

3.2. High p_T hadron pairs

Process shown in Fig.1*a)*, involves hadron production at small p_T and it can be suppressed by requiring a pair of hadrons with relatively high transversal momenta. However, in this case, fractions of PGF, Compton and remaining contributions of leading process have to be estimated from the Monte Carlo.

In COMPASS analysis, hadrons with the transversal momenta above 0.7 GeV were selected. In addition, the cut on the sum of squared momenta of both hadrons was applied: $p_{T1}^2 + p_{T2}^2 > 2.5\,\mathrm{GeV}^2$. Cuts on $x_F = p_L^*/p_{L,max}^* > 0.1$ and $z = Pp/Pq > 0.1$, selects hadrons from the current fragmentation region (p_L^* is the longitudinal momentum in γ^*-nucleon system; P, p and q are the nucleon, hadron and virtual photon momenta respectively). The cut on $y > 0.4$, fraction of the incident muon energy carried by virtual photon, removes events with the large dilution factor $D \simeq \frac{1-(1-y^2)}{1+(1-y^2)}$. The distributions characterising selected sample are shown on the figure 3.

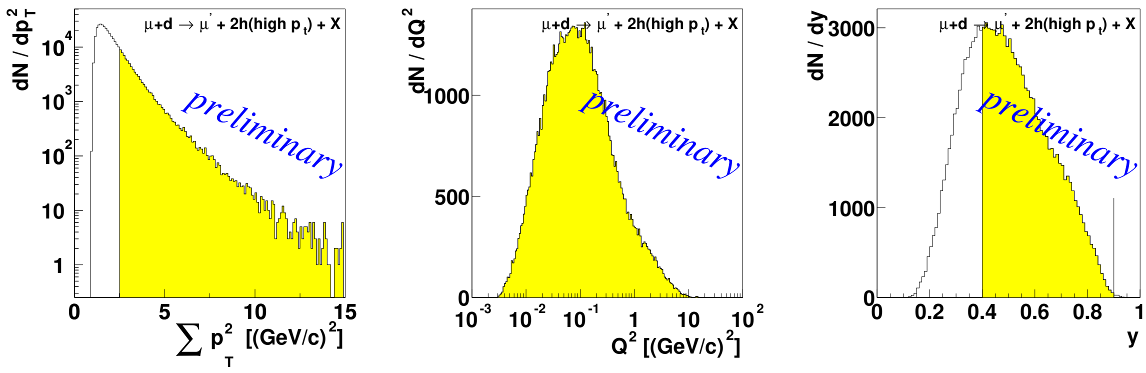

Figure 3. *Distributions of kinematical variables for the selected high p_T sample. From the left: sum of squared transversal hadron momenta, Q^2, y .*

The asymmetry evaluated from the high p_T sample of events collected in year 2002 is:

$$A^{\gamma^* d} = A_{||}^{\mu N \to hh}/D = -0.065 \pm 0.036(stat.) \pm 0.010(syst.), \tag{3}$$

where the systematic error contains only contributions from false asymmetries due to target and spectrometer effects.

4. Summary

Measurement of the cross section asymmetry for the open charm production is theoreticaly a clean way for extracting $\frac{\Delta G}{G}$. However selection of charmed mesons produced in the thick target is challenging. Signature of high p_T hadron pairs is easier to extract, but there are larger systematic uncertainties in the determination of background contributions by the Monte Carlo simulations.

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