ΔG from high p_T events at SMC and high p_T analysis at COMPASS

K.Kurek[a] *
On behalf of SMC and COMPASS Collaborations

[a]Andrzej Sołtan Institute for Nuclear Studies,
Hoża 69, 00-681 Warsaw, Poland.

Measurements of the longitudinal spin cross section asymmetry for deep inelastic muon-nucleon interactions with two high transverse momentum hadrons ($p_T > 0.7$ GeV) in the final state are presented for SMC data for polarized proton and deuteron and for data on polarized deuteron from COMPASS taken in 2002 and 2003. The muon asymmetries determined with a cut on $Q^2 > 1$ GeV^2 in SMC are: $A_p = 0.03 \pm 0.057 \pm 0.01$ and $A_d = 0.070 \pm 0.076 \pm 0.010$, respectively. From these values a gluon polarization $\Delta G/G = -0.20 \pm 0.28 \pm 0.10$ was obtained at an average fraction of nucleon momentum carried by gluons $\eta = 0.07$. The measured asymmetry (with cut on $Q^2 > 1$ GeV^2) in COMPASS is $(A_d/D) = -0.015 \pm 0.08 \pm 0.013$ where D is depolarization factor and the gluon polarization $\Delta G/G = 0.06 \pm 0.31 \pm 0.06$ was obtained at $\eta = 0.13 \pm 0.08$.

1. Introduction.

The measurement of the asymmetry for the pairs of hadrons with the high transverse momenta is a way of direct measurement of the gluon polarization via the Photon Gluon Fusion (PGF) process [1,2]. Requiring two hadrons with high transverse momenta in the final state the PGF process contribution, originally small in DIS, can be increased.

The cross section asymmetry with the production of at least two hadrons with large transverse momenta, $A^{\ell N \to \ell h h X}$, at the parton level consists of three terms corresponding to the contributions from three lowest order processes: leading process (LP), PGF and QCD Compton process (QCDC):

$$A^{\ell N \to \ell h h X} = \frac{\Delta q}{q}(\langle \hat{a}_{LL} \rangle^{LP} R_{LP} + \langle \hat{a}_{LL} \rangle^{QCDC} R_{QCDC}) + \frac{\Delta G}{G} \langle \hat{a}_{LL} \rangle^{PGF} R_{PGF} \ . \qquad (1)$$

The relevant diagrams are schematically shown in Fig.1.

In the asymmetry formula $\langle \hat{a}_{LL} \rangle$ is the average partonic asymmetry for a given process and R the ratio of its cross section with respect to the total cross section for the selected sample of events. The measurement of the asymmetry $A^{\ell N \to \ell h h X}$ thus permits an evaluation of the gluon polarization, $\Delta G/G$, if all other elements in Eq. (1) are known. The quark asymmetry $\Delta q/q$ can be approximated from the value of A_1 obtained in inclusive measurements. The partonic asymmetries $\hat{a}_{LL}$ and the ratios R are calculated for Monte Carlo simulated events in the kinematic region covered by the data. The applicability

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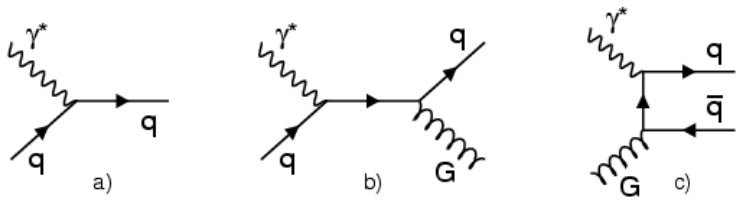

Figure 1. Lowest order diagrams for DIS γ^* absorption: a) leading process (LP), b) gluon radiation (QCDC), c) photon-gluon fusion (PGF).

of the presented method is based on the assumption that three considered processes can be separated and therefore it is limited to the leading order QCD approximation. The description of hadron production in DIS muon interaction, in terms of the three processes showed in Fig. 1 using Monte Carlo event generator LEPTO has been successfully tested in EMC and E665 experiments. Other processes, such as those involving resolved photon contribution, are expected to have small contributions for Q^2 above 1 GeV^2 and have not been taken into account in the presented analysis.

The cross section asymmetry, $A^{\ell N \to \ell h h X}$, is related to the counting rate asymmetry, A^{exp}, by: $A^{exp} = P_B P_T f A^{\ell N \to \ell h h X}$, where f is the effective dilution factor, which takes into account the dilution of spin asymmetries by unpolarized nuclei in the target and by radiative effects on the nucleon, P_B and P_T stand for beam and target polarization, respectively.

2. Data selection.

Event sample for further studies was defined by requiring 2 hadrons with transverse momenta above 0.7 GeV and energy fraction z above 0.1 (to reduce target fragmentation contribution). Also selection on event kinematics, including $Q^2 \geq 1$ GeV^2 and vertex position were applied.

The SMC experiment has used polarized muon beam of CERN SPS with energy 190 GeV scattered off polarized proton (butanol or amonia) and deuteron (deuterated butanol) targets. The high intensity polarized muon beam with energy 160 GeV is used in COMPASS experiment together with polarized ^{6}LiD target. The ^{6}LiD target with higher dilution factor f (larger fraction of the polarized deuterons inside the target) and high muon intensity beam allow to increase the precision of the asymmetry measurement in COMPASS.

In the SMC experiment after all selections the total number of remaining events amounts to about 80k for the proton and 70k for the deuteron sample. The detailed discussion of the SMC analysis is presented in [3].

The data after selection were compared with the MC sample generated with LEPTO and the experimental conditions have been taken into account. In order to describe the data, it was found necessary to change the values of two parameters describing the quark fragmentation in JETSET [3]. The statistical precision of the gluon polarization

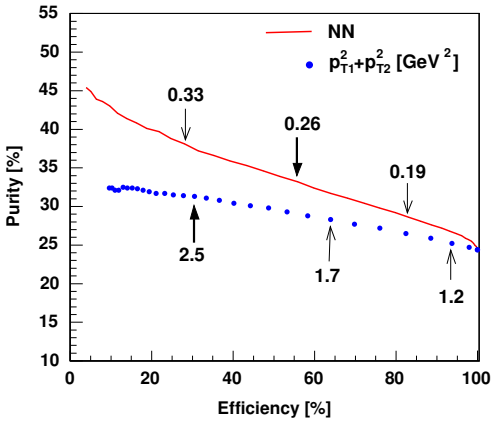

Figure 2. Purity and efficiency obtained in the selection of the PGF process with the methods based on the cut on $\sum p_T^2$ and the NN response, applied to simulated events for SMC experiment.

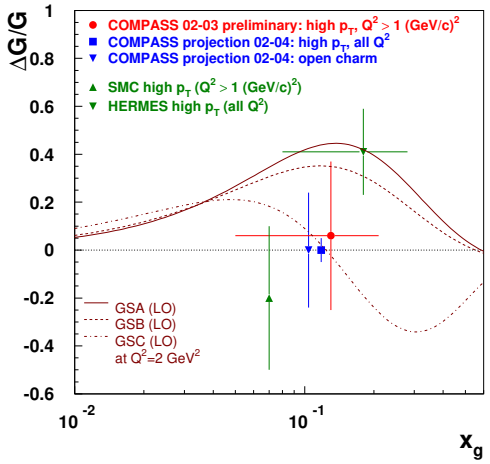

Figure 3. SMC and COMPASS results for $\Delta G/G$ from high p_T hadron pairs with $Q^2 > 1$ GeV^2 compared with Hermes result (all Q^2). In additon projected errors for open charm and high p_T hadron pairs for all Q^2 from COMPASS 2002-2004 data are shown.

determined from Eq. (1) depends on the precision of the measured asymmetry $A^{\ell N\to\ell hhX}$ and on the fraction of PGF events (R_{PGF}) in the final sample. Several methods of additional selections were tried to obtain a finale sample large enough and with a maximal contribution of PGF events.

For SMC data the best results were obtained with the selection based on the neural network (NN) approach [4]. Comparison of selection efficiency and sample purity for this method and a method using cut on the sum $p^2_{T1}+p^2_{T2}$ is shown in Fig.2. Better statistical precision was obtained with the neural network method. For COMPASS the selection $p^2_{T1}+p^2_{T2} > 2.5$ GeV^2 was used.

3. Gluon polarization determination from SMC data.

The gluon polarization has been evaluated from Eq. (1) using the measured $A^{\ell N\to\ell hhX}$ asymmetry, obtained for the samples with enhanced R_{PGF} by NN selection. The measured muon asymmetries are: $A_p = 0.03 \pm 0.057 \pm 0.01$ and $A_d = 0.070 \pm 0.076 \pm 0.010$. The partonic asymmetries $\hat{a}_{LL}$ of each sub-process have been calculated for each Monte-Carlo event and averaged. The values of the ratios R provided by the simulation for the LP, QCDC and PGF processes are 0.38, 0.29 and 0.33, respectively. The contributions of different processes for the proton and deuteron samples differ by less than 0.02.

The gluon polarization is determined for the kinematic region covered by the selected sample and corresponds to a given fraction of nucleon momentum carried by gluons η. This quantity is known for simulated events but cannot be directly determined from the data. The averaged value for the selected PGF events in the MC sample, η =0.07, is used

as the reference value for the result obtained on $\Delta G/G$.

Averaging the results for proton and deuteron obtained with the neural network selection $\Delta G/G = -0.20 \pm 0.28 \pm 0.10$ has been obtained. The accuracy is limited by the reduction to less than 1% of the DIS sample by the hadron selection requirements. The systematic errors contain dependence on the simulation parameters, scale dependence in the generation and systematic uncertainty on the measured asymmetry.

4. The high p_T analysis at COMPASS and the result for gluon polarization.

The asymmetry for the selected sample with $p_{T1}^2 + p_{T2}^2 > 2.5$ GeV^2 was calculated with the additional cut $x_B j < 0.05$. This cut selects kinematical region where asymmetry from LP and QCDC are small (proportional to A_1^d) and these processes contribute only as a dilution to the measured signal.

To remove the contribution from resonances an invariant mass of two hadrons were required to be higher than 1.5 GeV. The obtained asymmetry for events with $Q^2 > 1$ GeV^2 is $A_d/D = -0.015 \pm 0.08 \pm 0.013$, where D is a depolarization factor. The systematic uncertainty takes into account false asymmetries, the uncertanties from the measurements of the target and beam polarizations.

To determine $\Delta G/G$ from the measured asymmetry the LEPTO generator has been used with the SMC modifications in JETSET quark fragmentation functions and with radiative corrections included (RADGEN). The PGF fraction $R_{PGF} = \frac{\sigma^{PGF}}{\sigma^{tot}}$, has been found to be 0.34 ± 0.07.

The obtained gluon polarization is $\Delta G/G = 0.06 \pm 0.31 \pm 0.06$ for $\eta = 0.13 \pm 0.08$(rms).

The high p_T sample without Q^2 cut (all Q^2) contains roughly 10 times more data than the sample with $Q^2 > 1$ GeV^2. The preliminary result for asymmetry (2002 data only) gives the value $(A_d/D) = -0.065 \pm 0.036 \pm 0.01$.

5. Summary.

In the Fig. 3 SMC, COMPASS and Hermes [5] results on $\Delta G/G$ are presented together with the projected errors from open charm and high p_T hadron pairs for all Q^2 from COMPASS 2002-2004 data. The results for the gluon polarization $\Delta G/G$ from SMC and COMPASS analysis (using 2002-2003 data) with $Q^2 > 1$ GeV^2 are consistent with zero. Based on error projections, use of all Q^2 sample will allow a more precise determination of the gluon polarization on COMPASS in the near future.

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