PROCEEDINGS OF SCIENCE

Recent measurement of $\Delta G/G$ at COMPASS

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The determination of the gluon polarization in the nucleon is one of the main goals of the COMPASS experiment at CERN. To do this, we collide a polarized 160 GeV muon beam on a nucleon in a polarized ^{6}LiD target, and compute the resulting helicity asymmetry. $\frac{\Delta G}{G}$ is related to this asymmetry via the Photon-Gluon Fusion process, in which the virtual photon emitted by the muon interacts with a gluon from the nucleon to give a quark-antiquark pair. These processes are tagged either by the detection of a charmed D meson, or by requiring 2 hadrons with high transverse momentum in the final state. From the measured asymmetry of the latter channel, based on a preliminary analysis of 2002 and 2003 data, we were able to obtain the most precise direct estimation up to now of $\frac{\Delta G}{G}(x)$ at a nucleon momentum fraction x carried by the gluon around 0.1.

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The decomposition of the nucleon spin in terms of the contributions of its constituents has been a central topic in polarized deep-inelastic scattering (DIS) experiments for the last 20 years. The first exciting result was obtained by the EMC [1] experiment at CERN, which showed that the spin of the quarks only contributes to a small fraction $\Delta\Sigma$ of the proton spin. Other experiments confirmed this result, establishing $\Delta\Sigma$ between 20 and 30%, i.e. in contradiction with the 60% expected in the quark-parton model. Another contribution to the nucleon spin, ΔG, comes from the spin of the gluons. Up to recently, it can only be determined in inclusive DIS, using the Q^2 dependence of the polarized structure function g_1. Unfortunately, the precision of such a determination is in practice strongly limited by the small Q^2 range of existing data. In polarized semi-inclusive DIS, however, a direct measurement of the polarization $\Delta G/G$ of gluons, carrying a fraction x of the nucleon momentum, can be obtained from the cross-section helicity asymmetry of the photon-gluon fusion (PGF), $\gamma^* g \rightarrow q\bar{q}$. The COMPASS experiment at CERN uses 2 procedures to tag this process. One consists in selecting open-charm events, providing a pure but small sample of PGF events.The other selects events with 2 hadrons with high transverse momentum p_T with respect to the virtual photon direction [2]. In this case, the statistics is much larger, but a non-negligeable fraction of background processes is still present in the selected sample. This means that the measured asymmetry $A_{||}$ does not only contain the contribution of PGF events, but also the asymmetry of the background events:

$$A_{||} = R_{PGF}\,\hat{a}_{LL}^{PGF}\,\frac{\Delta G}{G} + A_{backgd} \tag{1}$$

$\hat{a}_{LL}^{PGF}$ is the helicity asymmetry of the hard lepton-gluon scattering cross-section, and R_{PGF} is the fraction of PGF events in the selected sample. The former can be calculated in pertubative QCD, whereas the latter, as well as A_{backgd}, can only be estimated using a Monte Carlo simulation, thus introducing a model dependence in our determination of $\Delta G/G$. Note that the expression we use for $A_{||}$ assumes that the factorization holds, thus requiring an hard scale in the selected events. In practice, this hard scale is provided either by Q^2 or by the p_T of the outgoing partons.

The present analysis deals with data collected during the 2002 and 2003 runs on deuteron target. The selected events are required to contain at least 2 charged hadrons associated to the primary vertex, in addition to the incident and scattered muons. Since the generator we use, PYTHIA, provides a reliable model for interactions of virtual photons with nucleons in the low virtuality region [4], we select events with $Q^2 < 1$ GeV^2. To enhance the fraction of PGF events in our sample, we also require the transverse momentum of the 2 hadrons to be large: $p_T^{h1} > 0.7$ GeV/c, $p_T^{h2} > 0.7$ GeV/c and $(p_T^{h1})^2 + (p_T^{h2})^2 > 2.5$ (GeV/c)^2, as in the SMC high p_T analysis [3]. In total, around 250,000 events remain after these cuts, defining our high-p_T sample, from which we extract the following asymmetry (as defined in [5]):

$$\left\langle \frac{A_{||}}{D} \right\rangle = +0.002 \pm 0.019(stat) \pm 0.003(syst). \tag{2}$$

The systematic error accounts for the false asymmetries related to the apparatus. Other sources of systematics errors, including the error on the beam and target polarizations, are proportional to the (small) measured asymmetry, and have been therefore neglected.

As already stated, our determination of the gluon polarization involves a Monte Carlo simulation. The events generated by PYTHIA are propagated through a GEANT model of our apparatus, and reconstructed with the same program as for real data. The cuts described above are then applied, and the selected events define our Monte Carlo high p_T sample.

In our kinematics, PYTHIA generates 2 kinds of processes. In the *direct processes*, the virtual photon directly takes part in the hard partonic interaction, whereas in the *resolved processes*, it first fluctuates to a hadronic state, from which a parton is extracted and interacts with a parton from the nucleon. These resolved processes account for nearly 60% of our Monte Carlo high p_T sample.

To reach a good agreement between our Monte Carlo and the data, we varied many parameters of the generator, and we found that only one should be changed, i.e the width of the intrinsic transverse momentum distribution of partons in the resolved virtual photon was decreased from 1 GeV/c to 0.5 GeV/c. Fig. 1 presents a comparison between the Monte Carlo and the real data high p_T samples, and Fig. 2 gives the fractions of the various PYTHIA subprocesses in the Monte Carlo sample. Taking into account these subprocesses, the high p_T asymmetry can be approximately expressed as:

$$\left\langle \frac{A_\parallel}{D} \right\rangle = R_{PGF}\,\langle \hat{a}_{LL}^{PGF}/D\rangle \frac{\Delta G}{G} + R_{QCDC}\left\langle \hat{a}_{LL}^{QCDC}/D\right\rangle A_1 + \sum_{f,f'=u,d,s,\bar{u},\bar{d},\bar{s},g} R_{ff'}\left\langle \hat{a}_{LL}^{ff'} \left(\frac{\Delta f}{f}\right)^{d} \left(\frac{\Delta f'}{f'}\right)^{\gamma} \right\rangle . \tag{3}$$

The contribution of the PGF events to the high p_T asymmetry was found to be -0.292 × $\Delta G/G$, and the contribution of QCD Compton 0.0063, using a fit on the world data for the virtual photon deuteron asymmetry A_1. For resolved photon processes, one can see that some of them involve a gluon in the nucleon, and are thus part of the signal. Their analysing powers $\hat{a}_{LL}^{ff'}$ can be calculated in pertubative QCD [6], and the polarizations $(\Delta f/f)^d$ of the u,d and s quarks in the deuteron were estimated using the GRV98 [7] and GRSV2000 [8] parameterizations. On the other hand, the polarized PDFs of the virtual photon are presently unknown. However, theoretical considerations [9] provide a minimum and a maximum value for each $(\Delta f')^\gamma$. We were therefore able to estimate the contribution of all the resolved photon processes to be in some ($\Delta G/G$ dependent) range.

Finally, we had to estimate the systematic errors related to the use of a given Monte Carlo generator. To do this, we varied the relevant parameters of PYTHIA in a range where the agreement between

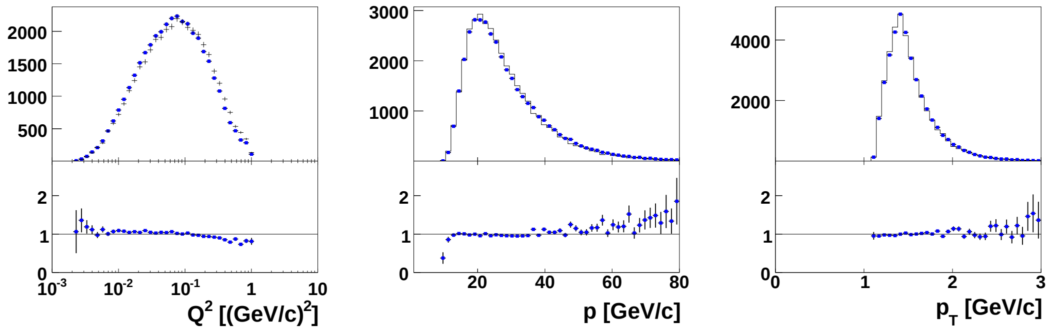

Figure 1: The upper part of these plots show a comparison between the simulated (histograms) and real data (points) samples of high p_T events, normalized to the number of events. The lower part shows the corresponding data/simulation ratio. p (p_T) is the total (transverse) momentum of the leading hadron. A similar agreement is obtained for the next-to-leading hadron.

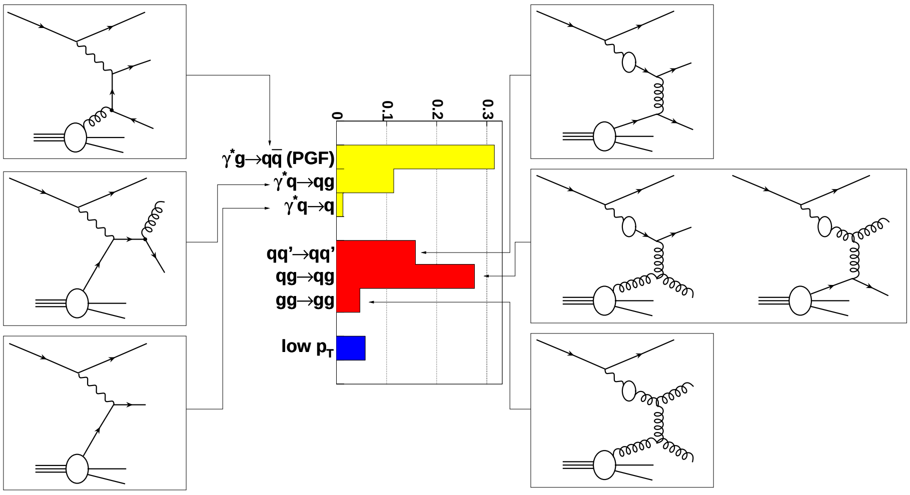

Figure 2: Contribution of each PYTHIA subprocess to the Monte Carlo sample of high p_T events. On the left: direct processes (PGF, QCD Compton, and leading process); on the right: resolved processes.

our simulation and the data remains reasonable. It appeared that the result for $\Delta G/G$ depends essentially on the width of the distribution of the intrinsic transverse momentum for partons in the resolved photon: the variation of this parameter results indeed in a variation of 30% for R_{PGF}. Gathering all the pieces, and using Eq. (2) for the measured asymmetry, we obtain:

$$\frac{\Delta G}{G}(x = 0.095, \mu^2 \approx 3GeV^2) = 0.024 \pm 0.089(stat) \pm 0.057(syst) \tag{4}$$

The nucleon momentum fraction x carried by the gluon, as well as the hard scale μ^2 on which $\Delta G/G$ depends weakly, were estimated using the simulation. This result was compared with recent GRSV parameterizations [10], resulting from QCD fits to the world g_1 data. Values between 0 and 0.6 for ΔG are clearly favored, whereas values around 3 can be already excluded. The use of our 2004 data, as well as a neural network for high p_T selection will allow us to better constrain ΔG in a near future.

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