New Measurements of $\Delta G/G$ at COMPASS

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Abstract. The COMPASS experiment at the CERN SPS is investigating the spin structure of the nucleon via scattering of polarised muons off polarised nucleons. Using a longitudinally polarised ^{6}LiD target inclusive asymmetries and asymmetries for the photon gluon fusion process were determined.

From the inclusive asymmetries the spin structure function, $g_1^{\rm d}$, is extracted in a wide kinematical range of x and Q^2. The results are used in a subsequent NLO pQCD analysis of all existing g_1 data to determine the contribution of the quarks to the nucleon spin and to estimate the gluon contribution.

The photon gluon fusion process allows a direct measurement of the gluon contribution. Here, two different channels, open charm production and the production of high $p_{\rm T}$ hadron pairs, are investigated. Preliminary results from both LO analyses using all COMPASS data from 2002 to 2004 are presented. They point to a small gluon contribution in agreement with the results from the QCD analysis.

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INTRODUCTION

In the recent years much effort was put into experiments investigating the spin structure of the nucleon by deep inelastic scattering (DIS) of polarised leptons off polarised nucleons. Initially the measurements were started in the seventies at SLAC and CERN. One of the exciting results was that the contribution of quarks to the nucleon spin is much smaller than anticipated before [1] which was confirmed in a series of experiments at SLAC, CERN and DESY.

The decomposition of the nucleon spin among its constituents can be written as $\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_{\rm q} + L_{\rm G}$ with $\Delta\Sigma = \Delta u + \Delta d + \Delta s$ the contribution of quarks, ΔG the contribution of gluons and $L_{\rm q} + L_{\rm G}$ their orbital angular momenta. Predictions from the naive quark parton model (QPM) resulted in a large polarisation of quarks of $\Delta\Sigma \sim 0.6$ while the DIS measurements show that the singlet axial matrix element a_0 is of the order of 20 to 30%. In the QPM $a_0 = \Delta\Sigma$ but in QCD the relation between a_0 and $\Delta\Sigma$ is scheme dependent e.g. $a_0 = \Delta\Sigma - (3\alpha_{\rm s}/2\pi)\Delta G$ in some schemes. Thus, a large value of ΔG could help restoring $\Delta\Sigma = 0.6$

The COMPASS collaboration studies both aspects by measuring inclusive scattering to extract the spin structure function g_1 from inclusive asymmetries and by investigating the gluon polarisation via the direct measurement of the photon gluon fusion process (PGF).

THE COMPASS EXPERIMENT

The COMPASS experiment has been set up at the M2 muon beam line of the CERN SPS [2]. Polarised 160 GeV muons with an intensity of $2 \cdot 10^8\,\mu/4.8\,\mathrm{s}$ spill and a polarisation, P_{B}, of 80% are scattered off a polarised deuteron target. The ^{6}LiD target material was chosen for its high dilution factor (fraction of polarised nucleons), f, of about 40%. To reduce false asymmetries, two 60 cm long target cells are polarised in opposite directions to $P_{\mathrm{T}} \sim 50\%$ using dynamic nuclear polarisation and the target polarised is reversed every 8 h by rotating the solenoid holding field.

The COMPASS spectrometer is a large acceptance two-stage spectrometer which covers the kinematic range from quasi-real photo production to the DIS region (see fig. 1 left). Both stages use hadronic calorimeters and absorber walls for muon identification. The first stage is equipped with a RICH detector for π/K separation up to 50 GeV, while an electromagnetic calorimeter is available since 2004 in the second stage. The data presented here were taken during 3 years from 2002 to 2004.

INCLUSIVE ASYMMETRIES AND QCD ANALYSIS

Using the data with the longitudinally polarised target the muon nucleon cross section asymmetry $A_{\parallel}$ is measured in a large kinematic range of x and Q^2. From $A_{\parallel}$ the photon nucleon asymmetry, A_1^{d}, and the spin structure function, g_1^{d}, can be extracted using $A_1 \approx A_{\parallel}/D$ and $g_1 = A_1 \cdot F_2/(2x(1+R))$ where D is the polarisation transfer from the lepton to the virtual photon and F2 and R the unpolarised structure functions. Results are presented for the data taken in 2002/2003.

Analysis is done separately in the DIS range ($Q^2 > 1\,(\mathrm{GeV/c})^2$) and at low Q^2 ($Q^2 < 1\,(\mathrm{GeV/c})^2$). Figure 1 right shows the preliminary result for the low Q^2 data [3] and the published data in the DIS range [4] compared to previous experiments. The COMPASS data extend towards much lower x than the SMC data [5] and improve the error bars at small x by an order of magnitude. For $x < 0.03$ the asymmetry as well as the extracted g_1 are compatible with zero. The interpretation of the results for g_1 in the DIS region is done in terms of a next-to-leading order (NLO) perturbative QCD analysis. The DGLAP evolution equations for the polarised parton densities are used to describe the Q^2 dependence of g_1 in terms of the polarised singlet, $\Delta\Sigma$, the non-singlet, Δq_{NS}, and the gluon distribution, ΔG. The fit using all existing inclusive DIS data is shown in fig. 2 together with the 2002/2003 COMPASS DIS data obtained after correcting for the D-state admixture in the deuteron. The QCD analysis confirms the value of $\Delta\Sigma \sim 0.25$ and points to a gluon polarisation of the order of $\Delta G \sim 0.4$. The results from the full statistics including the 2004 data will be available soon [6].

GLUON POLARISATION

In lepton nucleon scattering the gluon polarisation is accessible via the spin asymmetry in the photon gluon fusion process. Two channels are investigated: In the open charm channel the outgoing c and $\overline{\mathrm{c}}$ quarks are tagged by requiring charmed mesons (D^0, D^*) in

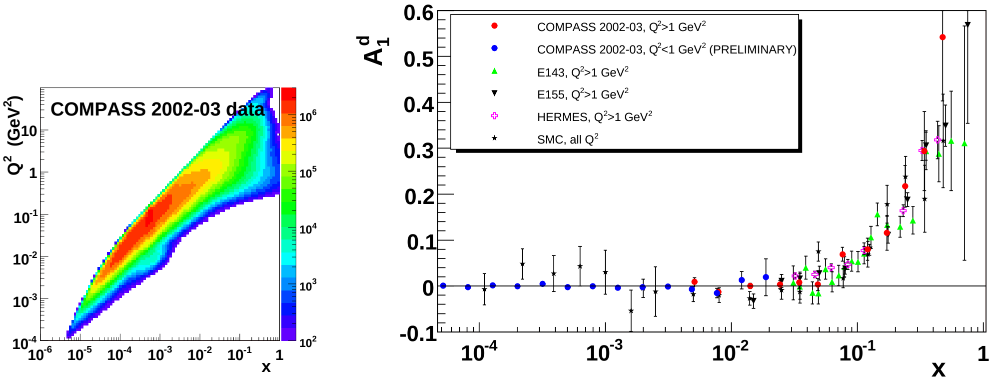

FIGURE 1. left: The kinematic range in x and Q^2, right: the deuteron asymmetry, A_1^{d}, for $Q^2 < 1\,(\mathrm{GeV/c})^2$ compared to previous experimental results.

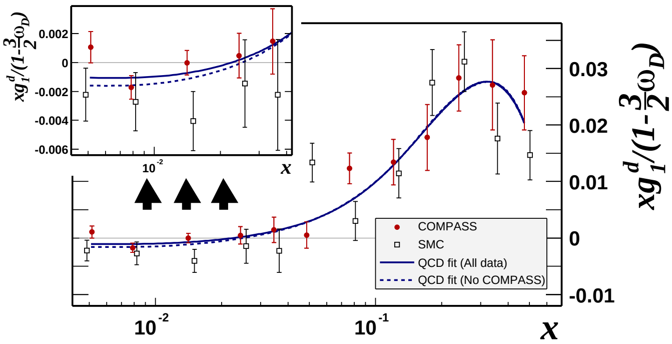

FIGURE 2. COMPASS results for $xg_1^{\mathrm{d}}(x)$ vs x compared to SMC results. The error bars are statistical errors. The COMPASS data are given at the measured Q^2, the SMC data are evolved to the same Q^2 and are slightly shifted in x for clarity. The curves are the results of QCD analyses of the world data with and without the COMPASS data.

the final state. The charm mass serves as the hard scale for the pQCD interpretation. In the hadron pair channel outgoing light quarks are selected by requiring a pair of hadrons with high transverse momentum, p_{T}.

Open charm analysis

The open charm channel is a background free process because the PGF subprocess is the only possible mechanism for charm production in LO QCD. On the other hand charmed mesons have to be reconstructed through their decay in $\mathrm{D}^0 \to \mathrm{K}\pi$ and $\mathrm{D}^* \to \mathrm{K}\pi\pi_{\mathrm{slow}}$ so that statistics generally is low. In addition, reconstruction of the D meson decay vertex is not possible due to multiple scattering in the long solid state target so that charmed mesons have to be reconstructed from their invariant mass distribution only. Here, particle identification with the RICH is essential. For D^0 this method is hampered by a huge combinatorial background (see fig. 3 left). Selecting D^* first by adding a slow

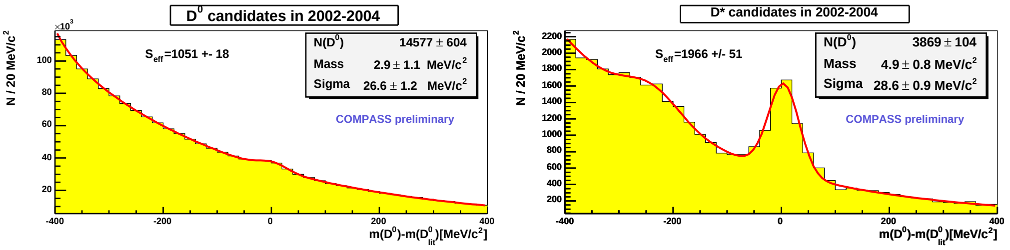

FIGURE 3. Invariant mass distributions in the D^0 mass range using $\mathrm{D}^0 \to \mathrm{K}\pi$ candidates (left) and after cutting on the invariant mass of $\mathrm{D}^* \to \mathrm{K}\pi\pi_{\mathrm{slow}}$ events in the D^* region (right). The effective signal is given by $S_{\mathrm{eff}} = S/(1+S/B)$.

π suppresses much of the background (see fig. 3 right). The gluon polarisation is then calculated from the experimental asymmetry $A_{\mathrm{exp}} = P_{\mathrm{B}} P_{\mathrm{T}}\, f\, a_{\mathrm{LL}} \frac{S}{S+B} \frac{\Delta G}{G}$. The analysing power a_{LL} has to be determined from a Monte Carlo simulation, as the kinematics of the PGF event is not fully known because only one of the two charmed mesons is reconstructed. A parametrisation of a_{LL} is obtained with a neural network trained on a Monte Carlo sample generated by the AROMA generator and reconstructed as for the real data. Using all 2002–2004 data a preliminary value of $\frac{\Delta G}{G} = -0.57 \pm 0.41(\mathrm{stat})$ at $\langle x_g \rangle = 0.15$ is obtained at a scale of $\langle \mu^2 \rangle = 13\,(\mathrm{GeV/c})^2$ [8].

High p_{T} hadron pairs

The alternative approach using high p_{T} hadron pairs makes use of PGF events with light quarks. Two parallel analyses for events in DIS range with $Q^2 > 1\,(\mathrm{GeV/c})^2$ and with low $Q^2 < 1\,(\mathrm{GeV/c})^2$ are performed. In the first case Q^2 can serve as a scale for the perturbative interpretation while the sum of p_{T}^2 is used in the latter. $\Delta G/G$ is extracted from the measured cross section asymmetry $A_{\parallel} = R_{\mathrm{PGF}}\, a_{\mathrm{LL}}^{\mathrm{PGF}} \frac{\Delta G}{G} + A_{\mathrm{bkg}}$ with R_{PGF} the fraction of PGF events, $a_{\mathrm{LL}}^{\mathrm{PGF}}$ the analysing power for the PGF subprocess and A_{bkg} the asymmetry from the different background processes. The most important background contributions for the high Q^2 sample (10% of the events) stem from QCD Compton scattering and the leading order process. Due to the small A_1^{d} the background asymmetries are very small. R_{PGF} and $a_{\mathrm{LL}}^{\mathrm{PGF}}$ are determined from a Monte Carlo simulation using the LEPTO generator. The analysis of the 2002/03 data is summarised in [8], while the results from the 2004 data are expected soon. For the low Q^2 sample the data statistics is much higher but there are additional background contributions due to resolved photon processes and vector meson production. The relative contributions are determined by a Monte Carlo simulation using the PYTHIA generator. The fraction of PGF events is about 30%, half of the events are due to resolved photon processes. For the unknown polarised photon parton distributions, bounds from the unpolarised distributions are used, resulting in an additional contribution to the systematic error. The analysis for the 2002/03 data is described in [7]. Meanwhile, also the 2004 data are analysed and the preliminary results of $\frac{\Delta G}{G} = 0.016 \pm 0.058(\mathrm{stat}) \pm 0.055(\mathrm{syst})$ was obtained at $\langle x_g \rangle = 0.085$ for $\langle \mu^2 \rangle = 3\,(\mathrm{GeV/c})^2$ [9]. The systematic error includes the experimental

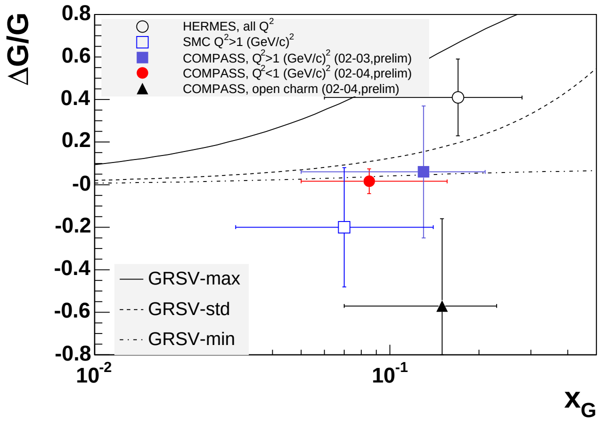

FIGURE 4. Compilation of the results for $\Delta G/G$ from high p_T hadron pairs and open charm production. The lines correspond to NLO GRSV parametrisations at $\mu^2 = 3(\mathrm{GeV/c})^2$ for $\Delta G = 2.5$, 0.6 and 0.2. The scale for the experimental points is about $3(\mathrm{GeV/c})^2$ except for the open charm point where it is $13(\mathrm{GeV/c})^2$. The error bars are statistical errors only.

systematics, the systematic error from the Monte Carlo simulation and the estimate of the resolved photon contribution. The results summarised in fig. 4 and compared to previous results from [10, 11] indicate that ΔG is small and/or has a node around $x_g \sim 0.1$.

SUMMARY

Results for inclusive asymmetries and measurements of the gluon polarisation from the first three years of the COMPASS data taking have been presented. Additional analyses using the data measured with a longitudinally polarised target were performed to study the hard exclusive ρ production and Λ polarisation.

The data taking continues in 2006 with an improved spectrometer. The most important changes are the new large acceptance solenoid available for the polarised target and the RICH detector upgrade to improve particle identification.

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