Measurement of the gluon polarization Δg/g from Open Charm at COMPASS

Fabienne Kunne[a], on behalf of the COMPASS collaboration

[a]*IRFU SPhN, CEA Saclay, F91191 Gif/Yvette, France*

Abstract. We have measured the gluon polarization in the nucleon by detecting charm production via D^0 meson decay to charged K and π in polarized muon scattering off a longitudinally polarized deuteron target. The dominant process for charm production is the photon gluon fusion into a charm anti-charm quark pair. By using all deuteron statistics from COMPASS accumulated between 2002 and 2006, we extract double spin asymmetries in bins of the transverse momentum and the energy of the D^0 meson and we perform a leading order analysis of the data to extract the gluon polarization $\langle\Delta g/g\rangle=-0.49 \pm 0.27$ (stat) ± 0.11 (syst) at a QCD scale $\mu^2= 13$ GeV^2 and at a gluon momentum fraction $\langle x\rangle=0.11$.

Keywords: Spin of the nucleon; Gluon Polarization
PACS:

INTRODUCTION

The main objective of the COMPASS muon physics program is the study of the nucleon spin, and in particular the measurement of the gluon polarization ΔG and of the quark spin distributions, longitudinal and transverse. The nucleon spin can be decomposed into the contributions from the quarks, the gluons and the orbital angular momentum as $\frac{1}{2} = \frac{1}{2}\, \Delta\Sigma + \Delta G + L_z$. Predictions from the naive quark parton model as well as from a QCD approach (neglecting strange quark polarization) lead to a large polarization of the quarks, *i.e.* ΔΣ=0.60. On the contrary, measurements from the last decades show that a_0, the singlet axial matrix element related to ΔΣ, is small, ~0.30. In fact, in some QCD schemes, $a_0= \Delta\Sigma - (3\alpha_s/2\pi)\, \Delta G$. Thus a large value of ΔG could help restoring ΔΣ ~0.6. This fact, together with the ½ nucleon spin sum rule, has motivated the efforts for direct measurements of ΔG.

THE MEASUREMENT OF ΔG/G

At COMPASS, the direct measurement of the gluon polarization is performed via the double spin asymmetry of photon gluon fusion (PGF) events (Fig.1). PGF events are searched for in two distinct channels: the *'open charm'* channel, discussed here, where the outgoing quarks are charmed quarks ($c\bar{c}$ pairs), and the '*high* p_T *hadron pair'* channel, where the two outgoing quarks can be light quarks and hadronize with high transverse momentum p_T. The second channel ('*high p_T*') has high statistics but suffers from physical background and requires dedicated Monte Carlo study to estimate the contributions from the competing processes[1].

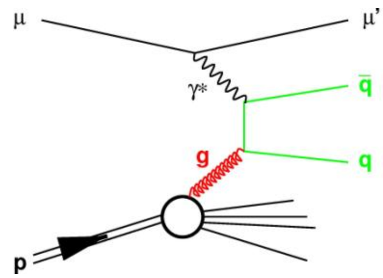

FIGURE 1: Photon Gluon Fusion process.

In the contrary the *open charm* channel provides a clean but rare signature of the PGF process since there is basically no contamination from other physics channels. In particular there is no intrinsic charm in the nucleon in this kinematical domain. The hard QCD scale is set by the mass of the charm quark. The presence of an outgoing charm quark is signed by the production of a charmed D^0 meson decaying into a $K\pi$ pair. However, the combinatorial background and the limited statistics due to the small charm cross section and the low branching ratio of D^0 decay, makes the experiment difficult. The analysis is therefore based on a weighted approach in order to minimize the statistical error. The double spin asymmetries between PGF cross sections with opposite target polarizations are related to the gluon polarization $\Delta g/g$ through the PGF analyzing power a_{LL}^{PGF}.

The 160 GeV polarized muon beam from CERN, with 2×10^8 muons per 4.8s spill and a polarization of 80% is scattered on a longitudinally polarized deuteron target. The target material, ^{6}LiD, has been chosen for its high dilution factor (fraction of polarized nucleons ~ 50%). To reduce false asymmetries, two 60 cm long target cells are polarized in opposite directions to about 50%. The COMPASS spectrometer[2] is a two stage spectrometer for large and small angle tracking, with precise momentum measurement and particle identification including π, K, p separation between 10 and 50 GeV thanks to a RICH detector. Data were taken during four years between 2002 and 2006. Before the 2006 run, several upgrades were performed. A new and larger solenoid magnet was installed, which increased the acceptance from 70 to 180 mrad. A three-cell target replaced the two-cell one, reducing the risk of false asymmetries. Tracking devices were added to cope with the enlarged acceptance. A major upgrade of the RICH detector (photon detectors with multi-anode PMTs in the central area, and a faster read-out system of the chambers at the periphery) improved its performance.

Since the polarized target is thick, the vertex of the D^0 (or anti-D^0) meson cannot be reconstructed, and the event selection is done by calculating the $K\pi$ invariant mass. D^0s are also identified by tagging D* mesons which decay into D^0 and a soft π. The small mass difference between the D* and the D^0 provides a strict and very effective selection cut which drastically reduces the background. Fig. 2 shows the invariant mass distribution of the Kπ pair for the untagged D^0s *(left)*, and for the D^0s tagged by a D* *(right)*.

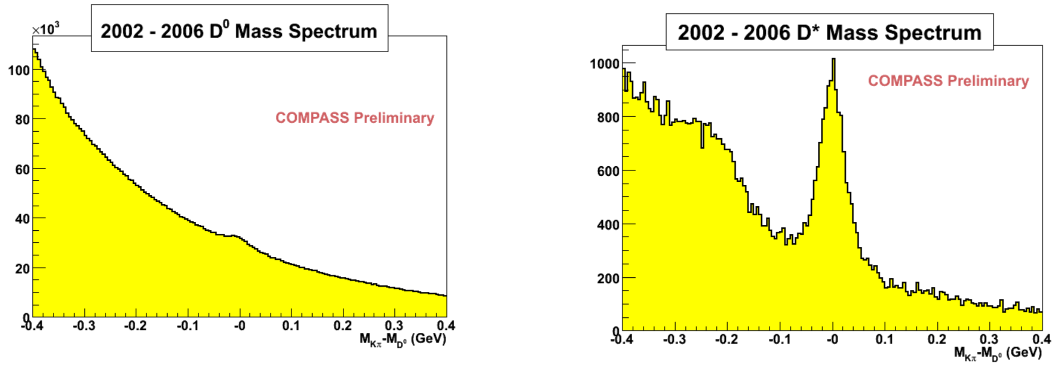

FIGURE 2. Invariant mass spectra for D^0 events *(left)* and "D^0 tagged by D*" events *(right)*. The additional bump due to D^0 decaying into K π π^0(right) is not yet used in the present analysis.

The total statistics amounts to ~37400 untagged and ~8700 tagged D^0s events. Both samples of events are independent and contribute about the same weight to the final result, the first one thanks to a higher statistics, and the second to the higher signal to background ratio *S/(S+B)*.

At LO, the experimental spin asymmetry is related to $\Delta g/g$ through the analyzing power a_{LL}^{PGF}, the signal strength $R_{PGF}=S/(S+B)$, various dilution factors (beam and target polarizations, fraction of polarisable nucleons) and the background asymmetry:

$$A_{\exp} = P_B P_T f \left[R_{PGF}\, a_{LL}^{PGF} \frac{\Delta g}{g} + (1 - R_{PGF}) A_{bkg} \right]$$

In order to account for the large variations of both a_{LL}^{PGF} (varying between -0.6 and +1) and $R_{PGF}=S/(S+B)$ in the phase-space, events are weighted in the analysis by those factors. The gain in statistics from the S/(S+B) weighting alone is +45% for D^0 which has the worse S/(S+B) ratio, and 15% for D* tagged events.

RESULTS

The preliminary result for the gluon polarization extracted at LO from the charm channel is $\langle\Delta g/g\rangle=-0.49 \pm 0.27$ (stat) ± 0.11 (syst) at a QCD scale $\mu^2= 13$ GeV^2 and at an average gluon momentum fraction $\langle x\rangle=0.11$. In Fig.3 this result is shown together with the two preliminary '*high pT*' points from COMPASS[1] and previous '*high pT*' result from SMC[4] and HERMES[5]. Note that the μ^2 QCD scale is not identical for all data. The 3 curves are QCD NLO fits to g_1 from GRSV giving integrals of $\Delta G=$ 0.2, 0.6 and 2.4 respectively, at μ^2 =3 (GeV/C)^2. For this assumed shape of $\Delta g(x)$, COMPASS data exclude large values for the integral of ΔG. Note that recent RHIC Spin results on A_{LL} (π^0 or jet production) also favor a small ΔG.

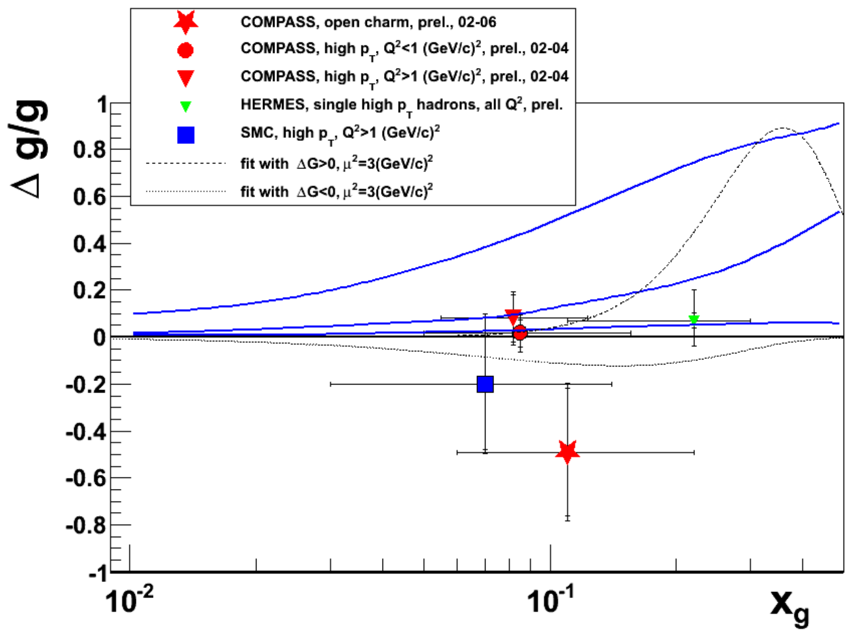

FIGURE 3. Direct measurements of <Δg/g(x)> from COMPASS open charm (prel.) [3], high p_T pairs from COMPASS[1], SMC[4] and HERMES[5]. Curves are g1 NLO fits from GRSVand COMPASS[6]

SUMMARY AND CONCLUSION

We have measured double spin asymmetries for charm D^0 meson production in the scattering of 160 GeV polarized muons off polarized deuterons. A significant improvement in statistics is obtained since our previous release, thanks to the addition of 2006 data (increased acceptance and improved PID) and to the use of S/B weighting and improved reconstruction. The model independent asymmetries, extracted in (p_T,E_D) bins, have also been produced and may be used in global NLO QCD analyses to constrain the values of $\Delta g(x)$. A direct extraction of $\Delta g/g$ using a LO approach, at $\langle x_g \rangle = 0.11$, leads to a negative value, but still less than 2σ away from zero. More statistics will come by adding 2007 proton data and events from $D^0 \rightarrow K\pi\pi^0$ decay.

REFERENCES

1. COMPASS, E.Ageev et al., Phys. Lett. B633 25 (2006). K.Kurek, theese proceedings, *Δg/g high* p_T
2. COMPASS, NIM A577 455 (2007)
3. F.Robinet, Ph.D. Thesis, Paris XI, September 2008; and proceedings of DIS2008
4. SMC, Adeva et al. Phys. Rev. D70 012002 (2004), Δg/g from high p_T hadron pairs
5. HERMES, A.Airapetian et al., Phys. Rev. D75 012007 (2007)
6. COMPASS, V. Alexakhin et al., Phys. Lett. B647 8 (2007) , g_1^d *and NLO analysis*