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MEASUREMENTS OF THE GLUON POLARIZATION IN THE NUCLEON AT COMPASS

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Abstract

One of the main goals of the COMPASS experiment at CERN is the determination of the gluon polarization in the nucleon, $\Delta G/G$, from double spin asymmetries in deep inelastic scattering of polarized muons on a polarized ^{6}LiD target. The gluon polarization is accessible in photon–gluon fusion (PGF) events, either tagging them by open charm production or enriching them in the inclusive production of hadron pairs with high transverse momentum. The analysis method is outlined and results from the data taking periods of 2002–2004 are shown.

1 Introduction

In the framework of QCD, the spin of the nucleon is composed of the contributions from quark and gluon spins, $\Delta\Sigma$ and ΔG, and their orbital angular momenta, L_q and L_g.

$$J_N = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

With $\Delta\Sigma$ of the order of $\frac{1}{3}$ [1], and because QCD fits only weakly constrain ΔG, direct measurements of the gluon polarization are necessary. The method of high p_T hadron pairs outlined below has been used by the HERMES [2] and SMC [3] collaborations. In addition to improving the accuracy of the data set, COMPASS [4] provides a qualitatively new measurement in the form of the open charm method.

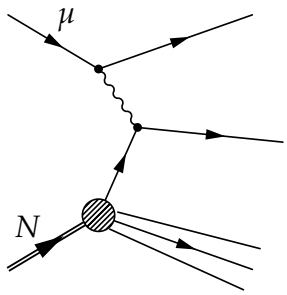

Figure 1: Leading process in deep inelastic scattering.

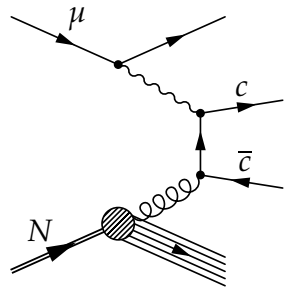

Figure 2: The photon–gluon fusion process in leading order.

2 High p_T

The leading process in deep inelastic scattering is depicted in fig. 1. Transverse momentum is either generated in the fragmentation process or stems from intrinsic k_T of the quark in the nucleon. Since both of these effects amount to $\lesssim 1\mathrm{GeV}/c$, requiring the hadron in the final state to have high transverse momentum reduces the contribution of the leading process in favor of the photon–gluon fusion shown in fig. 2. Using the fact that the latter process produces two outgoing quarks, COMPASS requires two hadrons, each with $p_{T,i} > 0.7\mathrm{GeV}/c$ and in total $\sum_i p_{T,i}^2 > 2.5\mathrm{GeV}^2/c^2$. Contributions from resonances are suppressed by restricting the invariant mass of the 2-hadron system to be larger than $1.5\mathrm{GeV}/c^2$. The target fragmentation region is excluded by $x_F > 0.1$, and hadrons are positively identified using the hadron calorimeters.

The analysis is done in two kinematic regimes. For $Q^2 > 1\mathrm{GeV}^2/c^2$, resolved photon processes can be neglected, leaving at leading order only the QCD compton scattering besides the already discussed processes. Using the LEPTO generator, the fraction of photon–gluon fusion in this sample has been determined to $R_{PGF} = 0.34 \pm 0.07$. Given the smallness of A_1 for $x_B < 0.05$, the other processes can be regarded as unpolarized background, leading to

$$A^{\gamma^* N \to hh} = R_{PGF} a_{LL}^{PGF} \frac{\Delta G}{G}$$

with the virtual photon–nucleon asymmetry $A^{\gamma^* N \to hh}$ and the analyzing power a_{LL}^{PGF}. From the data of 2002 and 2003 the preliminary value

$$\left.\frac{\Delta G}{G}\right|_{\langle x_g \rangle \approx 0.13, \mu^2 = 3\mathrm{GeV}^2/c^2} = 0.06 \pm 0.31_{\mathrm{stat}} \pm 0.06_{\mathrm{syst}}$$

The statistical uncertainty estimated for the full sample 2002–2006 is 0.14.

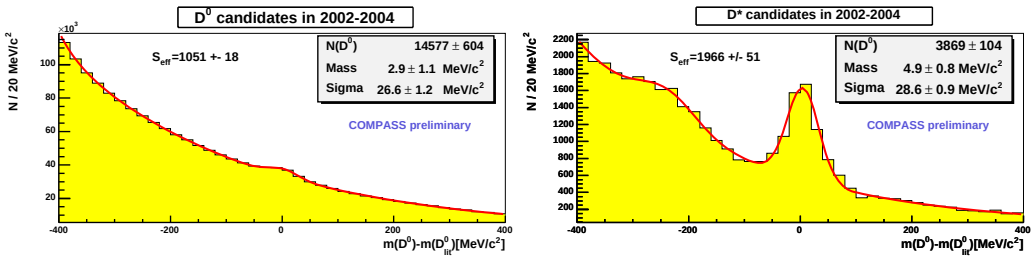

Figure 3: D mesons reconstructed from deep inelastic scattering events in 2002–2004. The left plot shows the untagged $D^0 \to \pi^{\pm}K^{\mp}$ channel while the right plot shows the events tagged with $D^{*\pm} \to D^0\pi^{\pm}$.

In the quasi-real regime $Q^2 < 1\mathrm{GeV}^2/c^2$, the statistics are about a factor 10 higher, but the sample also includes resolved photon processes. These have been taken into account using a PYTHIA simulation, see [5] for details on the analysis method. With $R_{PGF} = 0.32$, the analysis of the data from 2002–2004 yields the preliminary result

$$\left.\frac{\Delta G}{G}\right|_{\langle x_g\rangle \approx 0.085, \mu^2 = 3\mathrm{GeV}^2/c^2} = 0.016 \pm 0.058_{\mathrm{stat}} \pm 0.55_{\mathrm{syst}}$$

3 Open Charm

The photon–gluon fusion process can be selected rather cleanly by D mesons in the final state, since the intrinsic charm content of the nucleon is extremely short-lived and therefore strongly correlated with the gluonic structure. The decay channels investigated so far are $D^0 \to \pi^+K^- + c.c.$ as well as the same decay preceded by $D^{*+} \to D^0\pi^+$. The signals obtained from these channels are shown in fig. 3. The higher purity of the D^* tagged sample outweighs its lower statistics, leading to slightly lower statistical uncertainties. Possible background asymmetries are much smaller than the statistical uncertainty achieved so far, as has been checked using sideband samples, thus the connection between the measured asymmetry and the gluon polarization is

$$A^{\gamma^* N \to D} = \frac{S}{S+B} a_{LL}^{opencharm} \frac{\Delta G}{G}$$

The polarization transfer from the incoming muon to the virtual photon as well as the analyzing power $a_{LL}^{opencharm}$ strongly vary between events depending on the kinematics, wherefore the analysis is made in bins of a_{LL}. The preliminary result from 2002–2004 is

$$\frac{\Delta G}{G} = -0.57 \pm 0.41_{\mathrm{stat}} \pm 0.17_{\mathrm{syst}}$$

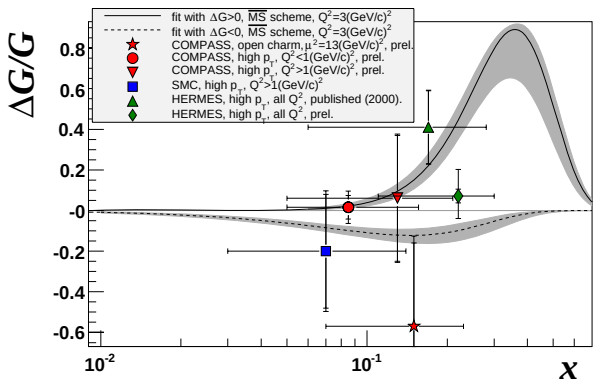

Figure 4: Gluon polarization measurements of COMPASS in comparison to measurements by HERMES and SMC. The curves are the result of a QCD fit by COMPASS [1].

at a scale $\mu^2 = 13\text{GeV}^2/c^2$ and $x_B \approx 0.15$. The statistical uncertainty estimated for the full sample 2002–2006 is 0.28.

4 Conclusion

COMPASS has investigated the polarized gluon structure of the nucleon using three complementary methods, all of which exclude a very large positive gluon polarization. On the other hand, they are consistent with QCD fits to the world data, which indicate an absolute value of $0.2 \div 0.3$ for the contribution of the gluons' spin to the spin of the nucleon.

References

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