ΔG FROM HIGH p_T EVENTS AT COMPASS

On behalf of the COMPASS collaboration
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Abstract

One of the main goals of the COMPASS experiment is a precise determination of $\Delta G/G$. This will lead to better understanding of the nucleon spin structure. The polarization of the gluons in the nucleon is measured by tagging the Photon Gluon Fusion (PGF) process in scattering of polarized muons off a polarized deuteron target. One of the methods used to tag PGF events is a selection of a pair of high p_T hadrons in the final state. In the analysis presented here, the $Q^2 < 1$ (GeV/c)^2 region is considered. The preliminary value of $\Delta G/G$, $\frac{\Delta G}{G} = 0.016 \pm 0.058(stat.) \pm 0.055(syst.)$, is currently the most precise measurement available.

1 Introduction

In the frame of the Quark Parton Model the nucleon spin is described by a sum rule:

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

where $\Delta\Sigma$ is the contribution from quark helicities, ΔG the contribution from helicities of gluons and $L_{q,g}$ are the orbital momenta of quarks and gluons, respectively. A value of $\Delta\Sigma$ was first determined by the EMC [1]. That result was confirmed by several experiments [2, 3, 4]. All measurements indicate that $\Delta\Sigma$ cannot account for the whole spin of the nucleon. Recent results show that the value of $\Delta\Sigma$ is close to 30%, e.g. $\Delta\Sigma(Q^2 = 3(\mathrm{GeV/c})^2) = 0.30 \pm 0.01(\mathrm{stat.}) \pm 0.02(\mathrm{evol.})$ [4]. Therefore it is clear that the rest of the nucleon spin originates from polarised gluons and orbital motion of partons in the nucleon. The COMPASS experiment aims to further study the nucleon spin structure. A direct measurement of the gluon polarisation is performed using cross-section asymmetries for PGF events in the scattering of polarised leptons on polarised nucleons which probes ΔG in the region of $x_g \simeq 0.1$.

In the COMPASS experiment we study interactions of a μ^+ beam of 160 GeV/c momentum and a polarisation $P_B \simeq 80\%$ with a polarised deuteron target. The target material is ^{6}LiD which provides a good compromise between the dilution factor, $f \simeq 0.4$, and the achieved deuteron polarisation of $P_T \simeq 50\%$. For more information about the COMPASS experimental setup see [5].

2 Experimental asymmetry

We measure a counting rate asymmetry as $A_{exp} = \frac{N^{\uparrow\Downarrow} - N^{\uparrow\Uparrow}}{N^{\uparrow\Downarrow} + N^{\uparrow\Uparrow}}$, where $N^{\uparrow\Downarrow(\uparrow\Uparrow)}$ are number of events with nucleons polarised anti-parallel (parallel) to muon spin direction. A two-cell target with cells polarised oppositely is used. This allows for a simultaneous measurement of both spin configurations with the same beam flux. Due to that the flux as well as many other systematic effects will cancel out in the asymmetry calculation.

The raw counting asymmetry is related to cross-section asymmetry by

$$A_{||} = f P_T P_B A_{exp}. \tag{2}$$

To decrease statistical errors a weighting method of asymmetry extraction is used [6]. In this method a weight $w = fDP_B$, where D is the depolarisation factor, is applied on an event by event basis instead of using average values.

3 $\Delta G/G$ measurement at COMPASS

A direct measurement of the gluon polarisation in the nucleon can be performed using events originating from the PGF process. In this process a virtual photon emitted by an incoming lepton interacts with a gluon from a nucleon. The photon retains a part of the lepton polarisation and thus provides a probe to sample the polarised gluons in the nucleon.

The PGF events have to be selected from a background originating from other processes. In LO QCD the following processes should be taken into account: the Leading Process (LP) where $\gamma*$ interacts with a quark from the nucleon, the QCD Compton (QCDC) process where an additional gluon is radiated and the PGF process. A hadron from LP obtains a transverse momentum with regards to the virtual gamma only from the fragmentation or from the intrinsic transverse momentum of the struck quark. This means that such hadrons will have a rather small p_T. Thus, by selecting high transverse momenta, a fraction of LP in the sample is greatly reduced.

The high p_T sample selection is based on a set of cuts. First, at least two hadron tracks are required to be reconstructed in a primary vertex. The p_T of two fastest hadrons should be above 0.7 GeV/c and their $\sum p_T^2$ exceed 2.5 $(\mathrm{GeV/c})^2$ to suppress the contribution from the LP. To remove regions with low sensitivity to ΔG and regions with large radiative corrections events with $0.35 < y < 0.9$ are selected. Finally, to ensure that mainly events from the current fragmentation region are selected and to remove the ρ resonance three additional cuts are imposed: $x_F,\ z > 0$ and $M_{inv} > 1.5$ GeV/c^2.

In the region of $Q^2 < 1$ $(\mathrm{GeV/c})^2$ there is an additional contribution from the resolved photon processes. In Fig. 1 the fractions of the contributing processes are presented. They were estimated from a MC simulation based on the PYTHIA generator [7]. Apparatus behaviour is simulated by the GEANT3 [8]. Although Q^2 is small we can treat our sample as being in the perturbative region as the hard scale is set by p_T cuts. The PGF and two resolved photon processes that probe gluons from the nucleon - gq, gg are treated as signal. LP and so called "low p_T" sample, which consists of nonperturbative processes are neglected as they contribute only a small fraction of events. Finally we obtain:

$$\begin{aligned} \frac{A_{||}}{D} &= R_{PGF}\left\langle \frac{a_{LL}^{PGF}}{D} \right\rangle \frac{\Delta G}{G} + R_{QCDC}\left\langle \frac{a_{LL}^{QCDC}}{D} \right\rangle \frac{\Delta q}{q} + R_{qq}\left\langle \frac{a_{LL}^{qq}}{D} \right\rangle \frac{\Delta q}{q}\frac{\Delta q^\gamma}{q^\gamma} \\ &+ R_{qg}\left\langle \frac{a_{LL}^{qg}}{D} \right\rangle \frac{\Delta q}{q}\frac{\Delta G^\gamma}{G^\gamma} + R_{gq}\left\langle \frac{q}{D} \right\rangle \frac{\Delta G}{G}\frac{\Delta q^\gamma}{q^\gamma} + R_{gg}\left\langle \frac{a_{LL}^{gg}}{D} \right\rangle \frac{\Delta G}{G}\frac{\Delta G^\gamma}{G^\gamma} \end{aligned} \tag{3}$$

where R_i is the fraction of the process i, a^i_{LL} is the partonic level asymmetry [9], q and Δq are the Parton Distribution Functions (PDFs) in the nucleon, q^γ, G^γ are unpolarised PDFs in the photon and Δq^γ, ΔG^γ are polarised PDFs in the photon.

In the expression (3) $\Delta G/G$ is the quantity we would like to extract, and $A_{||}$ is the measured asymmetry (2). The fractions of processes R_i and the average values of a_{LL} are taken from the MC simulation. The parton distributions in the nucleon are obtained from parameterisations to world data [10]: GRV98 and GRSV2000. Also unpolarised PDFs are taken from parameterisation [11]. For polarised PDFs in the photon there are no measurements available. From theory we know that these PDFs are sums of a nonperturbative (VMD) term, and of a perturbative (point-like) term. The point-like PDFs are calculable in QCD but the VMD part is not. To cope with that we use the minimal $\Delta f^\gamma_{VMD} = -f^\gamma_{VMD}$ and the maximal $\Delta f^\gamma_{VMD} = f^\gamma_{VMD}$ scenarios [12]. This model uncertainty is taken into account in the systematic error.

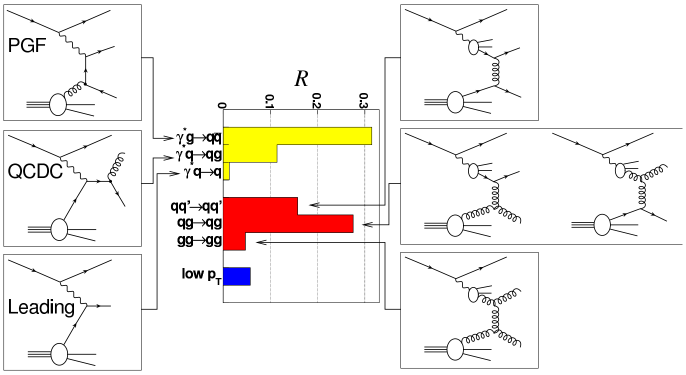

Figure 1: Relative contributions of the dominant high p_T processes at $Q^2 < 1$ (GeV/c)^2 as obtained by the PYTHIA MonteCarlo. Left: direct processes, right: resolved photon processes.

The main contribution to the experimental systematic error originates from false asymmetries. It is estimated on a sample of low p_T events with much larger statistics. Other sources of systematic errors, including the error on the beam and target polarisations, are proportional to the (small) measured asymmetry and as such were neglected.

As the $\Delta G/G$ extraction is based on quantities obtained from MC simulations, a good agreement between data and MC is crucial. It is presented in Fig. 2. In order to estimate the systematic error originating from MC simulations, the $\Delta G/G$ was determined for different values of most important parameters: parameters of the parton fragmentation model, the primordial transverse momentum of partons within the nucleon and the photon, the renormalisation and factorisation scales and swiching on and off the parton showers.

From the data collected in years 2002-2003 the following value of the gluon polarisation is measured $\Delta G/G = 0.024 \pm 0.089(stat.) \pm 0.057(syst.)$ at $x_g \approx 0.095^{+0.08}_{-0.04}$ [10]. The scale at which measurement is made was estimated to be 3(GeV/c)^2. Analysis of combined data from years 2002-2004 provides us with a more precise preliminary result:

$$\frac{\Delta G}{G} = 0.016 \pm 0.058(stat.) \pm 0.055(syst.)$$

4 Conclusions and outlook

The method for extracting $\Delta G/G$ from high p_T hadron pairs for the $Q^2 < 1$ (GeV/c)^2 was presented. The result indicates that the gluon polarisation is small, compatible with zero, in the region of $x_g \simeq 0.1$.

During a technical stop of the SPS accelerator in 2005 our spectrometer has undergone a major upgrade. The most important one for the considered channel is the installation of a new target solenoid magnet with larger aperture. Data taking was restarted in 2006 and provided a considerable gain in the collected statistics. Analysis of 2006 data is ongoing. Other means of increasing available statistics are also considered e.g using Neural Networks as a tool for selecting PGF events.

If the gluon polarisation is indeed small it would be very interesting to measure the contribution of the parton orbital angular momentum to the nucleon spin. Such a measurement using the Deeply Virtual Compton Scattering to access the Generalised Parton Distributions is considered for the COMPASS successor.

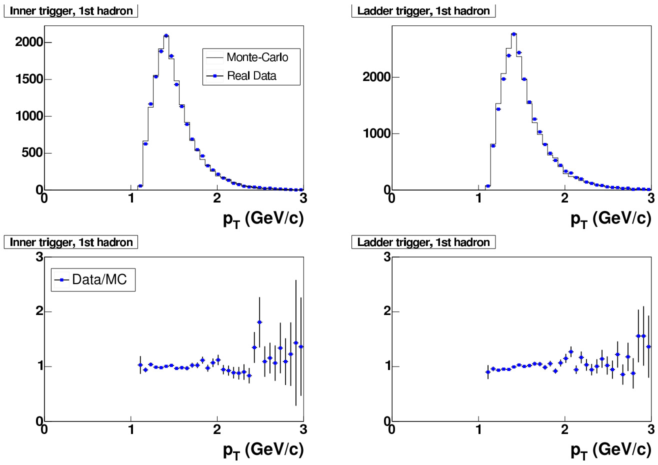

Figure 2: Comparison of data and MC for the high p_T $Q^2 < 1$ $(\text{GeV/c})^2$ sample. The upper plots present the p_T distribution of a leading hadron for two selected triggers. On the bottom plots the ratio data/MC is presented.

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