Determination of $\Delta G\,/\,G$ from Open Charm Events at COMPASS

S. Koblitz *

Universität Mainz - Institut für Kernphysik
Becherweg 45, 55099 Mainz - Germany

One of the main goals of the COMPASS experiment at CERN is the determination of the gluon polarisation in the nucleon, $\Delta G\,/\,G$. It is determined from spin asymmetries in the scattering of 160 GeV/c polarised muons on a polarised LiD target. The gluon polarisation is accessed by the selection of photon-gluon fusion (PGF) events. A very clean selection of PGF events can be obtained with charmed mesons in the final state. Their detection is based on the reconstruction of $D^\star$ and D^0 mesons in the COMPASS spectrometer. The analysis method for the first measurement of $\Delta G/G$ from the open charm channel is described. The result from COMPASS for the 2002-2004 data taking period is shown.

1 Introduction

In the framework of QCD, the spin of the nucleon is composed of the contributions from the quark spin, $\Delta\Sigma$, and the gluon spin, ΔG, as well as the orbital angular momenta of quarks, L_q, and gluons, L_g: $S_N = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$. The discovery, that the quark contribution $\Delta\Sigma$ is small [2], led to a series of measurements to determine the other spin contributions. Since QCD fits only give weak constraints on ΔG, it has to be measured directly. First investigations were performed by the HERMES [3] and the SMC[4] collaborations using high p_t hadron pairs in the final state. The primary goal of the COMPASS experiment is to perform a precise measurement of $\frac{\Delta G}{G}$ also with a new approach. Therefore charmed meson production is studied, since the selection of charmed mesons in the final state provides an event sample of photon-gluon fusion (PGF) events with no background from other physical processes.

2 D-Meson reconstruction

The PGF process is the main reaction for the production of charm quarks in DIS. Due to the high charm mass, the charm content of the nucleon can be neglected as well as the production of charm quarks during fragmentation. In the independent fragmentation of a $c\bar{c}$ pair most frequently D mesons are produced. On average 1.2 D^0 mesons are produced per each $c\bar{c}$ pair [5].
The D^0 mesons are reconstructed from their $K\,\pi$ decay which has a branching ratio of 3.8 %. The reconstruction is done using tracks reconstructed in the COMPASS spectrometer. A detailed description of the spectrometer can be found in [6]. The thick nucleon target of the COMPASS experiment does not allow a separation of production and decay vertex of the charmed meson. Thus, the reconstruction of D mesons is done on a combinatorial basis. For each oppositely charged track pair in a given event the invariant mass is calculated using

*supported by BMBF.

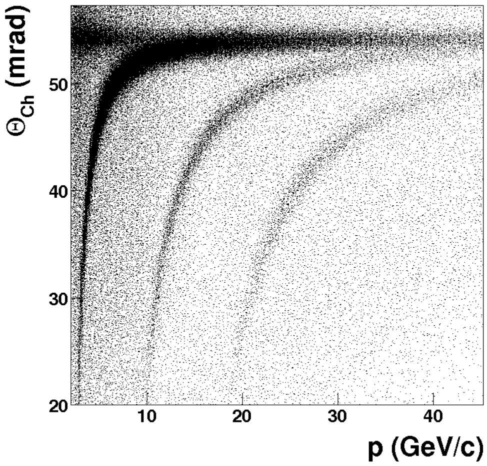

Figure 1: Cherenkov angles measured with RICH-1 vs. particle momenta. The histogram content in the kaon region is multiplied by a factor 30, in the proton region by a factor 150.

the kaon mass hypothesis for one of the tracks.
To suppress the high combinatorial background several cuts are applied on the track pair. The most important requirement is the particle identification for the kaon candidate from the Ring Imaging CHerenkov detector. The RICH allows to separate π, K and p in a momentum range from the particle's Cherenkov threshold to about 50 GeV. Figure 1 shows the RICH response for these three particle types as a function of their momenta. As can be seen, kaons can be identified starting from the kaon threshold around 9 GeV.
Due to the large charm mass the fraction of energy from the virtual photon that is carried by the meson, z, is expected to be higher for a real charmed meson than for combinatorial background. Therefore a cut of $z > 0.25$ is applied on the D^0 candidates. A third cut to reduce the combinatorial background is applied on the angle between the D^0 flight direction and the K momentum vector in the D^0 rest frame, $|\cos\theta_K^\star| < 0.5$.
With these cuts the ratio of open charm events to combinatorial background is still in the order of 1 : 10 (cf. Fig. 2). Therefore, a second more exclusive channel is also studied: $D^\star \to D^0\pi \to K\pi\pi$. Due to the small mass difference between $D^\star$ and D^0, combinatorial background can be very much suppressed by a cut on the mass difference: $3.1\,\text{MeV} < M_{K\pi\pi} - M_{K\pi} - M_\pi < 9.1\,\text{MeV}$. Here, $M_{K\pi\pi}$ denotes the mass of the $D^\star$ candidate and $M_{K\pi}$ the mass of the D^0 candidate. Since this so-called $D^\star$ tag is very effective in the reduction of combinatorial background, the z and the $\cos\theta^\star$ cuts can be relaxed. With $z > 0.2$ and $|\cos\theta^\star| < 0.85$ for $D^\star$ tagged D^0 mesons a signal to background ratio of 1:1 can be obtained (cf. Fig. 2).

3 Analysing Power

The ΔG measurement at COMPASS is based on the Photon Gluon Fusion (PGF) process. In this process the photon emitted by the incoming muon interacts with a gluon embedded in the nucleon. The interaction occurs via the exchange of a virtual quark resulting in a $q\bar{q}$ pair in the final state. Studying the scattering of a polarised muon beam off a polarised target gives access to experimental muon-nucleon asymmetries of the tagged PGF process. To access the gluon polarisation ΔG information about the hard subprocess is needed, which is combined in the analysing power a_{LL}. It contains the information about the partonic asymmetries from the muon-gluon scattering process. To determine a_{LL} the kinematic variables of the hard subprocess are needed.
Since only one of the two mesons is reconstructed, the full kinematics of the PGF process is not known for each single event. Thus, a parametrisation based on measured quantities was introduced, providing an estimation of a_{LL} for each open charm event. The parametrisation was obtained by training a neural network with an event sample generated with the

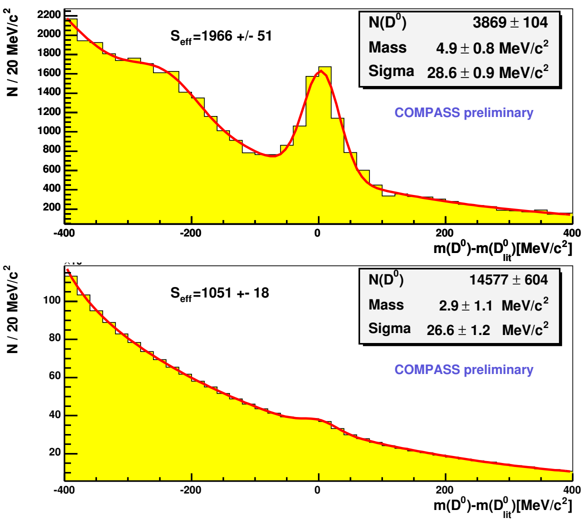

Figure 2: Kπ mass spectra for $D^\star$ tagged events (upper plot) and the sample without $D^\star$ tag ($S_{eff} = S^2/(B+S)$ is the effective signal)

AROMA generator in leading order QCD. For these events the full PGF kinematics were available as well as the reconstructed observables from the D^0 mesons. The correlation between the a_{LL} values coming directly from the generated quantities and the reconstructed a_{LL} from the parametrisation is about 82%. This procedure allows an evaluation of the analysing power for every event entering the $\Delta G/G$ determination.

4 Analysis Method

The data analysis leading to $\Delta G/G$ is based on event rates for scattering from a polarised muon beam off a polarised target. Since a separation between the remaining background events and the signal events in the final event sample is not possible, the signal purity of the event sample, $\sigma_{PGF}/\sigma_{PGF} + \sigma_B$, has to be introduced. It is determined from a fit to the final mass spectra. To optimise the description of the signal purity, this fit is done separately for events from the two target cells and for different bins of a_{LL}.

The observed event counting rates $N_{u,d}$ in the two oppositely polarised target cells of the COMPASS target are related to $\Delta G/G$ by

$$N_{u,d} = a\,\Phi\,n\,(\sigma_{PGF} + \sigma_B)(1 + P_{\rm T}\,P_{\rm B}\,f(a_{LL}\,\frac{\sigma_{PGF}}{\sigma_{PGF} + \sigma_B}\,\frac{\Delta G}{G} + a^B_{LL}\,\frac{\sigma_B}{\sigma_{PGF} + \sigma_B}\,A_B)) \quad ,$$

where $P_{\rm B}$ ($P_{\rm T}$) denotes the beam (target) polarisation and n the number of nuclei in the target. The dilution factor f describes the fraction of polarisable material in the target. For ^6LiD this dilution factor is about 50%. The beam particle is required to cross both target cells providing a cancellation of the beam flux Φ. To cancel out the acceptance difference for the two cells, the target spin orientation is reversed every eight hours, leading to a total of 4 counting rates. From their double ratio

$$\delta = \frac{N_u \cdot N'_d}{N'_u \cdot N_d}$$

$\Delta G/G$ can be determined assuming a negligible background asymmetry A_B and a stable detector performance leading to a cancellation of the acceptance factors,

$$\frac{a_u \cdot a'_d}{a_d \cdot a'_u} = 1 \quad .$$

This method is applied to the events from every data taking period as well as for the two channels separately. To improve the statistical significance of the result, event weighting is used. The final result is then calculated as the weighted mean of the results for each channel and data taking period.

5 Results

With the 2002-2004 data the preliminary result for the COMPASS open charm analysis of

$$< \frac{\Delta G}{G} > = -0.57 \pm 0.41(\text{stat}) \pm 0.17$$

was obtained. For the measured sample the average x_g is 0.15 with RMS 0.08 and the hard scale at which this result was obtained is $13\,\text{GeV}^2$.

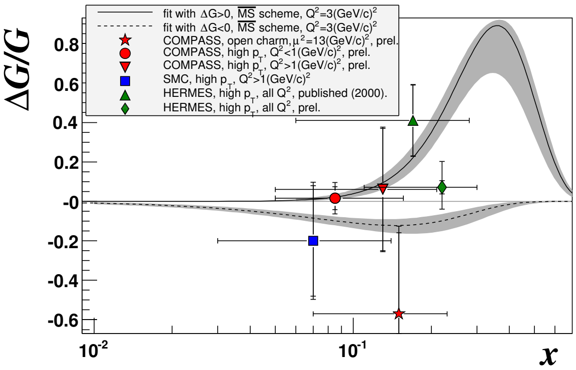

Figure 3: Comparison of the $\frac{\Delta G}{G}$ measurements from COMPASS, SMC [4] and HERMES [3]. The curves show the parametrisations at $3\,\text{GeV}^2$ in the $\overline{\text{MS}}$ scheme from [7] Note that the open charm point was obtained at a much higher scale.

The largest contributions to the systematic uncertainty of this result are possible false asymmetries (0.10), the choice of the fit function for the signal purity (0.09) and possible background asymmetries (0.07). There was no observation of any background asymmetry or false asymmetry from detector instabilities, so the actual values of these contributions are dominated by the statistical precision of the study. The influence of the choice for the fit function to describe the signal purity was estimated using different fit functions in the determination of $\Delta G/G$.
Further contributions to the systematic uncertainty are coming from the choice of Monte Carlo parameters (0.05), the number of bins for the signal-purity fit (0.04) and the uncertainties of the dilution factor (0.03) and the polarisation measurements (both 0.03).

6 Summary

The result for the first $\frac{\Delta G}{G}$ measurement from the open charm channel is presented. This is the most direct measurement of $\frac{\Delta G}{G}$ since it is only weakly dependent on Monte Carlo simulation. A comparison of the COMPASS results and other existing results is given in figure 3. The measurements are compared with the parton parametrisations from [7]. The data points give an indication that curves corresponding to small values of ΔG are favored. The analysis of the data taken in 2006 is in progress.

References

[1] Slides:
`http://indico.cern.ch/contributionDisplay.py?contribId=140&sessionId=4&confId=9499`

[2] EMC, J. Ashman et al., *Phys. Lett.* **B206**, 364 (1988).

[3] HERMES, A.Airapetian et al., *Phys. Rev. Lett.* **84**(2000) 2584.

[4] SMC, B. Adeva et al., *Phys. Rev.* **D70** (2004)012002

[5] COMPASS proposal, G. Baum et al., CERN/SPSLC 96-14.

[6] COMPASS, P. Abbon et al., CERN-PH-EP/2007-001, hep-ex/0703049, to be published in *Nucl. Inst. and Meth.*.

[7] COMPASS, E.V.Yu. Alexakhin et al., *Phys. Lett* **B647** 8 (2007).