Measurement of the spin structure of the deuteron at COMPASS

Jürgen Hannappel*,† and COMPASS collaboration**

*Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, Johann-Joachim-Becher-Weg 45, D-55099 Mainz
†CERN, CH-1211 Genève 23, Switzerland
**http://wwwcompass.cern.ch/compass/organisation/members.html

Abstract. A new measurement of the longitudinal spin asymmetry A_1^d and the spin dependent structure function g_1^d of the deuteron is presented in the Q^2 range from $1\mathrm{GeV}^2$ to $100\mathrm{GeV}^2$ and the x range from 0.004 to 0.7. The data were taken in 2002 and 2003 with the COMPASS experiment at CERN, scattering 160 GeV^2 polarised muons off a large polarised ^{6}LiD target. While significantly improving statistical accuracy in the low x region the data agree nicely with previous experiments.

Keywords: Deep inelastic scattering; Structure functions
PACS: 13.60.Hb; 13.88.+e

INTRODUCTION

Most of the work presented here is described in more detail in [1]. First results on the deuteron spin asymmetry A_1^d and the spin dependent structure finction g_1^d are presented.

The data were taken with the COMPASS spectrometer, which is located on the M2 beam line of the SPS at CERN. A polarized muon beam (naturally polarized to $\approx -75\%$) of $160\mathrm{GeV}/c$ (the momentum of each individual muon is measured in the beamline) impinges on a ^{6}LiD polarized target, the reaction products are analyzed in a two stage spectrometer, as seen in Fig. 1 and described in more detail in [2].

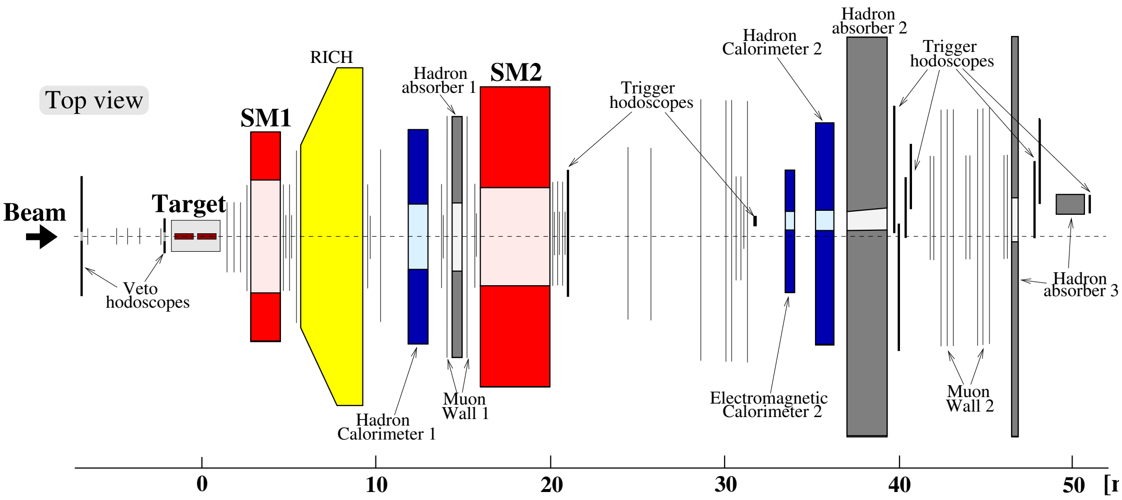


FIGURE 1. Layout of the COMPASS spectrometer in 2002 and 2003

The target consists of two cells of 60cm length each and 3cm diameter, separated by 10 cm. Each of the cells has its own microwave system for dynamic nuclear polarisation (DNP)[3], so that the two cells are polarized in opposite direction, reaching +54% and -50% of polarisation. Every 8 hours the spin directions in both cells are reversed by rotating the magnetic field direction. This is done to ensure that the variations of flux and acceptance cancel out in the asymmetry calculations. This method is carried further by reversing the sign of the polarisation in each cell several times a year by changing the DNP microwave frequencies.

Data recording is triggered by the detection of the scattered muons. This is done by several sets of hodoscopes, which cover different kinematical ranges. For the large Q^2 range this inclusive triggering is sufficient, but for smaller Q^2 it was necessary to have also triggers that also take into account the muon energy loss in the target and additionally require some hadronic energy to be detected in the hadron calorimeters, while the very large Q^2 range is covered by a trigger on a hadron signal in the calorimeters alone. For more details see [4].

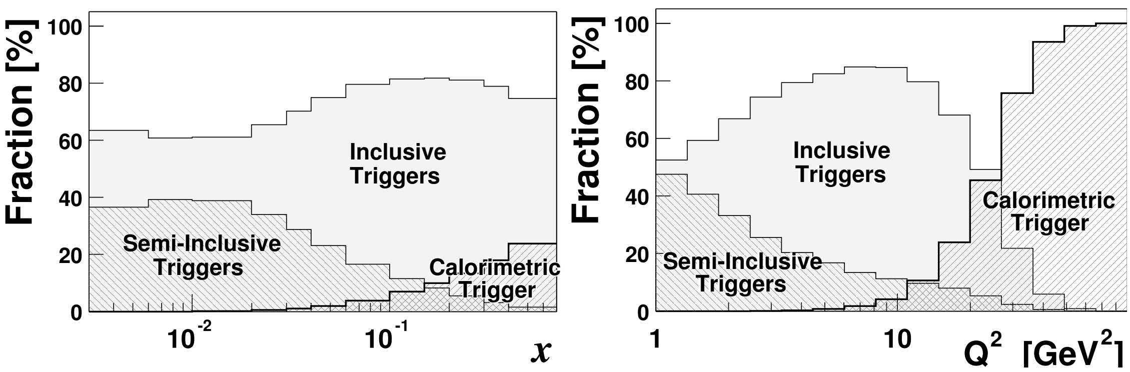


FIGURE 2. Fraction of inclusive, semi-inclusive and calorimetric triggers in the data sample as a function of x (left) and Q^2 (right)

Fig. 2 shows the different contributions of the different kinds of trigger to the data sample. Monte Carlo studies [5] show that the selection of hadronic events due to the semi-inclusive triggering method produces no large effects on the extracted A_1, so the asymmetries were calculated for both hadronic and purely inclusive data sets separately and afterward merged.

Since the measured number of events N_i for the different beam and target spin combinations is related to the asymmetry A_1^d by

$$N_i = a_i \phi_i n_i \bar{\sigma}(1 + P_T P_B f D A_1^d)$$

with a_i being the acceptance for configuration i, ϕ_i the muon flux, n_i the number of target nucleons, P_T the target polarisation, P_B the beam polarisation, f the dilution factor and D the depolarisation factor, we weight each event with $P_B f D$, each of which calculated from the event kinematics. This weighting allows us to decrease the statistical error by 10%.

To go from the asymmetry A_1^d to the structure function g_1^d we use their relation through the structure function F_2^d, which is well known from fixed target experiments [5], and the cross section ratio $R = \sigma_L/\sigma_T$, also from fixed target data [6],[7].

RESULTS

Here the combined results from the beam times in the years 2002 and 2003 are presented, which correspond to integrated luminosities of about 600 pb^{-}1 and 900 pb^{-}1.

The kinematic range covers photon virtualities in the range $1\text{GeV}^2 < Q^2 < 100\text{GeV}^2$, while the fractional energy of the virtual photon was limited to $0.1 < y < 0.9$.

Fig. 3 shows both the asymmetry A_1^d and the structure function g_1^d, the inset on the left showing more clearly the increase of precision reached in the low x region.

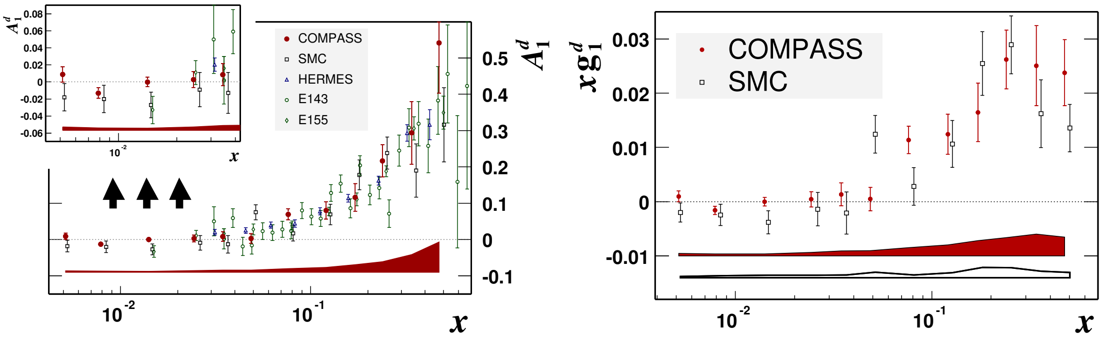
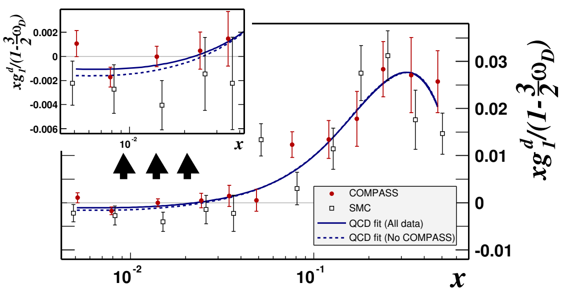


FIGURE 3. Inclusive asymmetry A_1^d (left) and structure function g_1^d (right). For g_1^d the data points are shown at the measured Q^2.

A QCD fit to the world data ([8], [5], [1], [9], [10], [11], [12], [13], [14], [15], [16]) was made to study the impact of the new COMPASS data on our understanding of the nucleon structure. In this fit (which uses the program “2”, as it was called in the SMC notation) while DGLAP equations are solved via numerical integration a NLO calculation in the $\overline{\text{MS}}$ scheme is performed. $\Delta\Sigma$, Δq_3,Δq_8 and ΔG are parametrized as

$$\Delta f = \frac{\eta}{\int_0^1 x^\alpha (1-x)^\beta (1+\gamma x)\mathrm{d}x} x^\alpha (1-x)^\beta (1+\gamma x)$$

and then a MINUIT minimization of the deviation between measured and calculated g_1 is performed.



$$\int_0^1 \Delta\Sigma(x)\mathrm{d}x = 0.237 {+0.024 \atop -0.029} \quad \text{all data}$$

$$= 0.202 {+0.042 \atop -0.077} \quad \text{w/o COMPASS}$$

Taken at $Q^2 = 4\text{GeV}^2/c^2$.

FIGURE 4. QCD fit to word data, shown at measured Q^2

As the improved precision of data due to the COMPASS points at low x changes the curve in that region, there is also a significant change in the $\int_0^1 \Delta\Sigma(x)\mathrm{d}x$ integral, the error of which is also decreased by a factor of 2.

COMPASS being a full spectrometer with a large acceptance it is not only able to measure the scattered muon, but also to identify and measure the other reaction products. Thus asymmetries were also calculated for events in which the leading hadron has positive charge and for negative charge, represented in Fig. 5

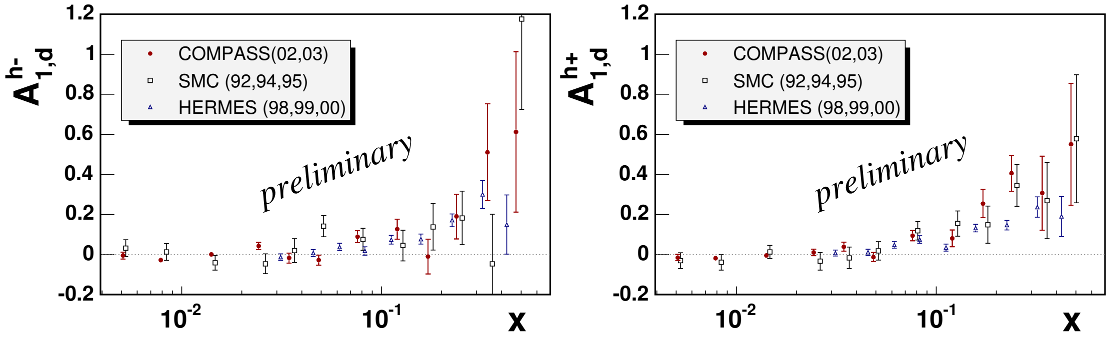


FIGURE 5. semi-inclusive asymmetries, left for negative leading hadrons, right for positive

ACKNOWLEDGMENTS

We gratefully acknowledge the support of the CERN management and staff and the skill and effort of the technicians of our collaborating institutes. Special thanks are due to V. Anosov, J.M. Demolis and V. Pesaro for their technical support during the installation and the running of this experiment. This work was made possible by the financial support of our funding agencies.

REFERENCES

1. COMPASS Collaboration, *Phys. Lett. B*, **612** (2005), 154–164.
2. G.K. Mallot, *Nucl. Instrum. Meth. A*, **518** (2004), 121
3. J. Ball *et al.*,*Nucl. Instrum. Meth. A* **498** (2003), 101.
4. J. Hannappel *et al.*, *Nucl. Instrum. Meth. A*, submitted for publication
5. B. Adeva *et al.*, *Phys. Rev. D* **58** (1998), 112001
6. NMC, M. Arneodo *et al.*, *Nucl. Phys. B* **483** (1997) 3
7. L. Whitlow *et al.*, *Phys. Lett. B* **250** (1990) 193
   K. Abe *et al.*, *Phys. Lett. b* **452** (1999) 194
8. EMC, *Nucl. Phys. B* **328** (1989) 1
9. E143, *Phys. Rev. D* **58** (1998) 112003
10. E155, *Phys. Lett. B* **463** (1999) 339
11. E155, *Phys. Lett. B* **493** (2000) 19
12. JLAB, *Phys. Rev. Lett.* **92** (2004) 012004
13. E142, *Phys. Rev. D* **54** (1996) 6620
14. E154, *Phys. Rev. Lett.* **79** (1997) 26
15. HERMES, *Phys. Lett. B* **404** (1997) 383
16. HERMES, *Phys. Rev. D* **75** (2005) 012003