COMPASS Spin Dependent Longitudinal Asymmetries on Deuteron Target

Marcin Stolarski
On behalf of COMPASS Collaboration

Physikalisches Institut der Universität Freiburg
D-79104 Freiburg, Hermann-Herder-Str. 3

Abstract

The COMPASS results of double spin longitudinal asymmetries obtained in the inclusive and semi-inclusive inelastic scattering of a polarized 160 GeV/c muon beam off a polarized deuteron target are presented. The data were collected in the years 2002-2004. The slides can be found in [1].

1 Introduction

COMPASS is an experiment at CERN focusing on the spin structure of the nucleon and hadron spectroscopy. Between 2002 and 2004, a 160 GeV/c polarized muon beam and a two cell polarized ^{6}LiD target were used [2] for spin studies. Here we present results for the deuteron longitudinal cross-section asymmetry A_1^d and spin dependent structure function g_1^d for the non-perturbative region $Q^2 < 1$ (GeV/c)^2 [3], and the DIS region $Q^2 > 1$ (GeV/c)^2 [4]. The former data were used in a global QCD analysis.

The DIS region was measured in several other experiments [5], [6], [7], [8], [9] while non-perturbative region at low x was only exploited by the SMC [8]. Results of the semi-inclusive analysis, which allows to separate valence and sea quark contribution to the nucleon spin [10] are also presented. Similar measurements were performed by the SMC [11], [12] and HERMES [13] collaborations. In three COMPASS analyses a large improvement of the statistical error with respect to previous measurements is seen in the low x domain.

2 Event selection

An incoming and a scattered muon as well as an interaction vertex in the target are required for each event. The kinematic cuts $0.1 < y < 0.9$ and $Q^2 < 1(\mathrm{GeV}/c)^2$ or $Q^2 > 1(\mathrm{GeV}/c)^2$ are applied. In case of the low x and low Q^2 analysis at least one additional (charged) hadron track in the interaction vertex is required. In case of the semi-inclusive analysis for every hadron a cut $0.2 < E_h/\nu < 1.0$ is applied; no hadron identification is performed. For additional details *c.f.* [3], [4], [10].

3 A_1^d and g_1^d in the low x and low Q^2 region

The cross-section asymmetry $A^d = (\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow})/(\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow})$ [a] is related to the virtual photon–deuteron asymmetry A_1^d by[b]:

$$A^d \simeq D\ A_1^d \tag{1}$$

where the so called virtual photon depolarization factor, D, depends on the event kinematics. The spin dependent structure function g_1^d is given by[b]

$$g_1^d \simeq \frac{F_2^d}{2x(1+R)} A_1^d \tag{2}$$

[a] arrows correspond to relative orientation of the incoming muon and the target deuteron spins

[b] all factors which contain A_2^d were neglected since they are small in this analysis

where F_2^d and R are spin independent structure functions. Details of the used F_2 and R parameterizations can be found in [8]. The procedure which relates the observed number of muon–nucleon interactions to A_1^d is described in [14].

In this analysis data from the years 2002-2003 were used. Total data sample is 300 million events. The results for A_1^d and g_1^d as functions of x are presented in Figures 1 and 2. The error bars mark statistical errors, the shaded band indicates the systematic ones. Most of the systematic uncertainty results from possible false asymmetries estimated in a way similar to [14]. The values of A_1^d and g_1^d were found to be consistent with 0 in the investigated x range. In the overlapping region the COMPASS results agree with the SMC [8] and HERMES [9] ones. The statistical precision of A_1^d and g_1^d in COMPASS is ten times better than in the SMC.

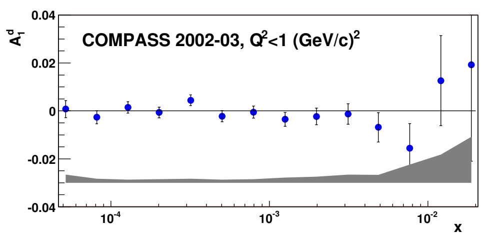

Figure 1: The COMPASS results of the A_1^d in the low x and low Q^2 region versus x.

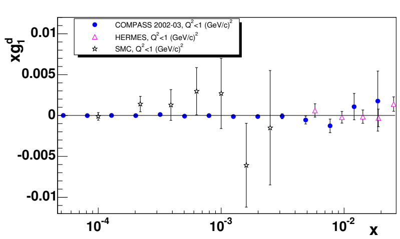

Figure 2: The g_1^d world data in the low x region for $Q^2 < 1$ GeV^2. Note the large error decrease for COMPASS.

4 A_1^d and g_1^d in the DIS region, QCD fit to world g_1 data

The asymmetry A_1^d and the structure function g_1^d were extracted in the same way as in the low x region. Terms connected with the A_2 asymmetry were neglected. The total sample used in the analysis was 89 millions events. The results were published in [4]. They are presented in Figure 3 together with results of previous experiments. The measured asymmetry is consistent with 0 for $x < 0.03$, and the negative trend observed in the SMC data is not confirmed. Note that error bars in COMPASS are greatly improved compared to the SMC ones in the low x region. For $x > 0.03$ a positive asymmetry is observed and results are compatible with those from previous experiments.

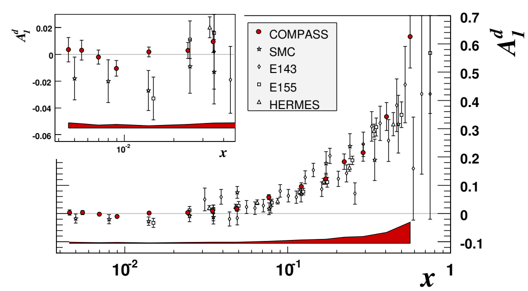

Figure 3: World data A_1^d in DIS region versus x.

A new NLO QCD fit to world g_1 data was performed. The data from proton, deuteron and ^{3}He targets were used [4]. In total, there were 230 data points available out of which 43 were from COMPASS. The $\overline{MS}$ scheme with input parameterizations at $Q^2 = 3$ (GeV/c)^2 was used. The quark singlet distribution $\Delta\Sigma(x)$, the non-singlet distributions $\Delta q_3(x)$ and $\Delta q_8(x)$ and the gluon distribution $\Delta G(x)$ were parameterized as: $\eta_k \frac{x^\alpha(1-x)^\beta(1+\gamma x)}{\int_0^1 x^\alpha(1-x)^\beta(1+\gamma x)dx}$ where $\eta_k = \int_0^1 \Delta k\, dx$. The evolution was done according to the DGLAP equations. The γ factor was only used for the singlet distribution. First moments of η_3 and η_8 were fixed by the baryon decay constants [15] under the assumption of $SU(3)_f$ symmetry. The factor β_G was also fixed as it is poorly constrained by the data. Finally, there were 10 parameters which were fitted to the data. To keep parameters in the physical range a positivity condition were required at all values of Q^2 for the polarized parton distributions. The fit was performed using two different programs [7], [16], and both gave similar results and χ^2 probabilities. In each of them two solutions for negative and positive η_G were found. The absolute value of the first moment of the polarized gluon distribution was found to be about $|\eta_G| \approx 0.2 - 0.3$. The results of the fit for the two η_G solutions are presented in Figure 4.

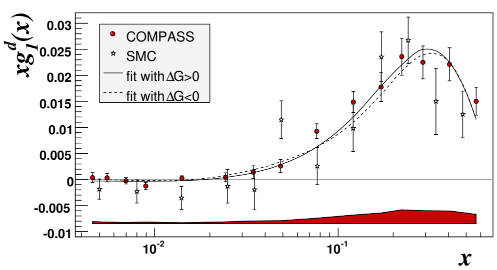

Figure 4: The COMPASS results of the g_1^d in the DIS region versus x.

The first moment of $g_1^d(x)$ was estimated from COMPASS data evolved to $Q^2 = 3$ $(\mathrm{GeV}/c)^2$ with the NLO fit. The obtained value is $\Gamma_1^N = 0.050 \pm 0.003(stat.) \pm 0.003(evol.) \pm 0.005(syst.)$. The flavor-singlet axial current matrix element, a_0, was found to be $a_0 = 0.35 \pm 0.03(stat.) \pm 0.05(syst.)$. Here, a value of $a_8 = 0.585 \pm 0.025$ was assumed [15]. These results point toward significantly negative strange quark polarization in the nucleon, $(\Delta s + \Delta \bar{s}) = \frac{1}{3}(a_{0|Q^2 \to \inf} - a_8) = -0.08 \pm 0.01(stat) \pm 0.02(syst)$. A direct measurement of the strange quarks polarization is possible in semi-inclusive analysis of kaons asymmetries. This analysis is currently in progress in COMPASS.

5 Semi-inclusive analysis, valence quarks polarization

The valence quark helicity distributions were measured previously in the SMC [11],[12] and HERMES [13]. Knowledge of them helps to determine properties of the polarized nucleon sea. The following relation holds:

$$\Delta\bar{u} + \Delta\bar{d} = (\Delta s + \Delta\bar{s}) + 0.5(a_8 - \Gamma_v) \quad (3)$$

where Γ_v is the first moment of the valence quark distribution.

To obtain the valence quark polarization the so called difference asymmetry, which is determined from the difference of cross sections of positive (h^+) and negative hadrons (h^-), is used. This method was developed in [17]. It was shown that in LO approximation for the deuteron target the fragmentation functions cancel out so that systematic uncertainties are greatly reduced. Moreover as hadron identification is not needed there is no additional data loss. The difference asymmetry can be obtained from single hadron asymmetries via the relation:

$$A^{+-} = \frac{1}{1-r}(A^{h+} - rA^{h-}) \quad (4)$$

where r is the cross sections ratio for negative and positive hadrons. This number was calculated using the ratio of the number of hadrons observed in the data corrected by the ratio of their acceptances taken from Monte–Carlo.

The values of $\Delta u_v + \Delta d_v$ are obtained using:

$$\Delta u_v + \Delta d_v = A^{+-}\frac{(u_v + d_v)}{(1+R)(1-1.5\omega_D)} \quad (5)$$

where unpolarized PDF comes from MRST2004 at LO [18]. Note that all but the ω_D factor in Eq. 5 depend upon x and Q^2. To estimate the first moment of $\Delta u_v + \Delta d_v$

the distribution $\Delta u_v(x,Q^2) + \Delta d_v(x,Q^2)$ was evolved to a common Q^2 using DNS parametrization at LO [19]. For $x > 0.3$ the unpolarized sea contribution to F_2 can be neglected. In this region one can use inclusive g_1^d measurements, which have smaller statistical errors compared to this analysis. Additional systematic uncertainties due to the neglected sea contribution were taken into account[c].

In this analysis the total data sample was about 55 millions hadrons. The results are presented in Figure 5 together with the DNS fit prediction [19]. The systematic errors indicated as a shadowed band mainly come from the estimation of false asymmetries and from the neglected sea contribution for inclusive g_1^d measurement at high x. The measured Γ_v at $Q^2 = 10$ (GeV/c)^2 is $\Gamma_v(0.006 < x < 0.7) = 0.40 \pm 0.07(stat.) \pm 0.05(syst.)$. This value favors a non-symmetric sea with $\Delta\bar{u} = -\Delta\bar{d}$, when $(\Delta s + \Delta\bar{s})$ is used from [4]; instead of symmetric sea $\Delta\bar{u} = \Delta\bar{d} = \Delta\bar{s} = \Delta s$. Contributions to Γ_v from unmeasured regions are expected to be negligible. Results of COMPASS, SMC and HERMES are compatible.

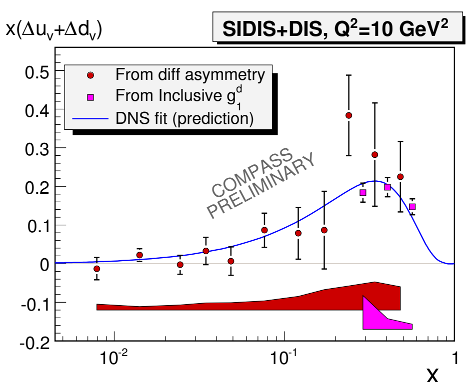

Figure 5: Polarized valence quark contribution from COMPASS at $Q^2 = 10$ (GeV/c)^2.

[c] $\Delta u_v + \Delta d_v = 36/5(g_1^d/(1-1.5\omega_d)) - [2(\Delta\bar{u} + \Delta\bar{d}) + \frac{2}{5}(\Delta s + \Delta\bar{s})]$, where the term in square parenthesis is neglected.

6 Summary and outlook

COMPASS results of inclusive and semi-inclusive analyses were presented. The analysis of identified hadron samples is in progress, which will allow to directly measure the $\Delta s + \Delta\bar{s}$ contribution to the nucleon spin. In 2007 COMPASS is taking data with a polarized NH_3 target. These data allow flavor separation using COMPASS data only.

References

[1] `http://indico.cern.ch/materialDisplay.py?contribId=4&sessionId=34&materialId=slides&confId=3841`.

[2] **COMPASS** Collaboration, P. Abbon *et al.*, *Nucl. Instrum. Meth.* **A577** (2007) 455–518.

[3] **COMPASS** Collaboration, E. S. Ageev *et al.*, *Phys. Lett.* **B647** (2007) 330–340.

[4] **COMPASS** Collaboration, V. Y. Alexakhin *et al.*, *Phys. Lett.* **B647** (2007) 8–17.

[5] **E143** Collaboration, K. Abe *et al.*, *Phys. Rev. Lett.* **75** (1995) 25–28.

[6] **E155** Collaboration, P. L. Anthony *et al.*, *Phys. Lett.* **B463** (1999) 339–345.

[7] **Spin Muon** Collaboration, B. Adeva *et al.*, *Phys. Rev.* **D58** (1998) 112002.

[8] **Spin Muon** Collaboration, B. Adeva *et al.*, *Phys. Rev.* **D60** (1999) 072004.

[9] **HERMES** Collaboration, A. Airapetian *et al.*, *Phys. Rev.* **D75** (2007) 012007.

[10] **COMPASS**. Collaboration, arXiv:0707.4077v1 [hep-ex], submited to PLB.

[11] **Spin Muon** Collaboration, B. Adeva *et al.*, *Phys. Lett.* **B369** (1996) 93–100.

[12] **Spin Muon** Collaboration, B. Adeva *et al.*, *Phys. Lett.* **B420** (1998) 180–190.

[13] **HERMES** Collaboration, A. Airapetian *et al.*, *Phys. Rev.* **D71** (2005) 012003.

[14] **COMPASS** Collaboration, V. Y. Alexakhin *et al.*, *Phys. Rev. Lett.* **94** (2005) 202002.

[15] **Asymmetry Analysis** Collaboration, Y. Goto *et al.*, *Phys. Rev.* **D62** (2000) 034017.

[16] A. N. Sissakian, O. Y. Shevchenko and O. N. Ivanov, *Phys. Rev.* **D70** (2004) 074032.

[17] L. L. Frankfurt *et al.*, *Phys. Lett.* **B230** (1989) 141.

[18] A. D. Martin, W. J. Stirling and R. S. Thorne, *Phys. Lett.* **B636** (2006) 259–264.

[19] D. de Florian, G. A. Navarro and R. Sassot, *Phys. Rev.* **D71** (2005) 094018.