PROCEEDINGS OF SCIENCE

New results on the proton spin-dependent structure function g_1^p at COMPASS with $E = 200$ GeV

Elena Zemlyanichkina* **(on behalf of the COMPASS collaboration)**
Joint Institute for Nuclear Research – Joliot-Curie str., bld. 6, Dubna, Moscow region, Russia
E-mail: Elena.Zemlyanichkina@cern.ch

New results of the double spin asymmetry A_1^p and the spin-dependent structure function of the proton g_1^p as a function of x_{Bj} and Q^2 will be presented. New COMPASS data on longitudinal polarized NH_3 target were collected during the year 2011 with a beam of positive muons with energy $E = 200$ GeV. It allows us to cover low x region down to 0.0025 in the range $Q^2 > 1$ GeV$/c^2$ for the first time.

The European Physical Society Conference on High Energy Physics -EPS-HEP2013
18-24 July 2013
Stockholm, Sweden

*Speaker.

PoS(EPS-HEP 2013)473

The direct evidence for existence of quarks inside the nucleon is provided by deep inelastic scattering (DIS). The idea is to accelerate leptons to very high energies, then allow them to interact with a stationary nucleon, and investigate what happens. At the constituent level, spin effects in DIS can be intuitively understood by the fact that a quark having its spin projection along the reference axis (+OZ) can absorb a virtual photon which has its spin projection along (-OZ) and flip its spin, while no absorption can occur when the two spins in the initial state are oriented in the same direction. Defining $q_i^+(x)$ and $q_i^-(x)$ as the distributions of quarks of flavor i with spin along or opposite the nucleon spin, where x is the Bjorken scaling variable, we see that the absorption cross section for virtual photons with spin projection opposite to the nucleon spin ($\sigma_{1/2}$) will be proportional to q_i^+ while the absorption cross section for virtual photons with spin parallel to the nucleon spin ($\sigma_{3/2}$) will be proportional to $q_i^-(x)$. In the quark parton model the virtual photon asymmetry is obtained by summing over the quark flavors i and multiplying each term by the square of the quark charge expressed in units of the electron charge ($e_i^2 = 4/9$ or $1/9$):

$$A_1 = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \cong \frac{\sum e_i^2 (q_i^+(x) - q_i^-(x))}{\sum e_i^2 (q_i^+(x) + q_i^-(x))} \, . \tag{1}$$

The denominator in the previous expression shows the well known decomposition of spin averaged structure function $F_1(x)$, known from unpolarized experiments, in terms of quark flavors. The numerator provides the corresponding decomposition of spin-dependent structure function $g_1(x)$ in terms of the quark spin distributions $\Delta q_i(x) = q_i^+(x) - q_i^-(x)$. So Eq. (1) could be rewritten as

$$A_1 = \frac{g_1(x)}{F_1(x)}. \tag{2}$$

In an experiment with a polarised beam and a polarised target the double spin asymmetry (or the cross section asymmetry) is defined by

$$A_{||} = \frac{\sigma^{\rightleftarrows} - \sigma^{\leftleftarrows}}{\sigma^{\rightleftarrows} + \sigma^{\leftleftarrows}} \, , \tag{3}$$

where the arrows indicate relative directions of the spin of a beam particle and of the spin of the target. Using Eq. (2) and the relation between unpolarised structure functions F_1 and F_2, i.e. $F_1(x) = \frac{F_2(x)}{2x(1+R)}$, Eq. (3) can then be written as

$$A_{||} \cong D \frac{g_1(x,Q^2)}{F_1(x,Q^2)} = D \frac{2x(1+R)}{F_2(x,Q^2)} g_1(x,Q^2) \, . \tag{4}$$

Comparing Eq. (4) with the definition of A_1 given in Eq. (1) one can see that the factor D can be considered as the depolarization of the virtual photon. This factor depends mainly on the fraction y of the beam energy taken away by the virtual photon and is close to 1 for virtual photons carrying nearly the total energy of the incoming leptons.

The COMPASS experiment was conceived as a "COmmon Muon and Proton Apparatus for Structure and Spectroscopy", capable of addressing a large variety of open problems in both hadron structure and spectroscopy. Detailed description of the COMPASS project can be found in Ref. [1]. The muon COMPASS setup associates the high energy CERN muon beam, a large polarised target and a spectrometer providing good track resolution and particle identification over a large phase space. The high polarisation of the incident muons and of the target protons (or deuterons) creates ideal conditions for double spin asymmetry measurements. The high incident beam energy allows studying polarised deep inelastic scattering (DIS) at x values down to about 0.0025. The identification of final state particles gives access to semi-inclusive hadron asymmetries in the DIS region (SIDIS). These features are unique in the world.

Between 2002 and 2006, COMPASS has taken very precise data with a polarised deuteron target. In addition to the initial goal of a direct measurement of ΔG at $x \approx 0.1$ in various channels, several other important physics results have been achieved. Indeed thanks to the increased luminosity in COMPASS compared to the previous SMC experiment, all deuteron DIS and SIDIS observables have been measured with an unprecedented statistical accuracy. In the low x region, unaccessible for other experiments, the error bars have been reduce by about a factor three compared to previous existing data. This is best seen in the comparison of the values of $g_1^d(x)$ for 3 years of COMPASS data [2] (Fig. 1 (left)). Although, the Q^2 of various points are quite different within the data range going from 2 GeV to 100 GeV, the points are rather compatible, confirming the very weak Q^2 dependence. These new values have led to an improved determination of the spin structure function $g_1^d(x)$ in the low x region where only the SMC measurements existed before [3].

The first sample of proton data was taken at 160 GeV beam energy in 2007. Combined with the deuteron data, it provided new physics results, especially the non-singlet spin structure function $g_1^{NS}(x) = g_1^p(x) - g_1^n(x)$, where g_1^n was extracted from g_1^p and g_1^d, and a new test of the Bjorken sum rule [4]. Due to the lack of low x proton data these topics had not been addressed since the SMC studies in 1997-98 [3].

The new proton data were collected during the year 2011. All events are required to have a reconstructed primary interaction vertex defined by the incoming and the scattered muons. For the canceling of the muon flux in the asymmetry calculation the trajectory of an incoming muon with an energy in the interval $180 < E_\mu < 220$ GeV is required to cross all target cells. Scaling variable x in a range from 0.0025 to 0.7 is limited by the kinematical threshold $Q^2 \geq 1$ $(\mathrm{GeV}/c)^2$ and the fractional energy, y, transfered from the incident muon to the virtual photon $0.1 < y < 0.9$. To measure "inclusive" asymmetry a full data sample was combined from 3 trigger sets. For most events the trigger is based on a combination of hodoscopes fired by the scattered muon. In addition to these "inclusive triggers", low x events are also selected by an additional condition on the energy deposit in the hadron calorimeter, which is then used as a "semi-inclusive trigger". At large x and Q^2 most events are selected by conditions on the calorimeter signal only, without any input from hodoscopes. For this "calorimeter-only trigger" as well as for the semi-inclusive one, the presence of a reconstructed hadron track is required. The asymmetries obtained for hadronic events are statistically compatible with the inclusive ones and their differences do not show any hint of a systematic dependence on x. This observation agrees with the Monte Carlo study of Ref. [3] which also shows that the selection of hadronic events has no sizeable effect on the evaluation of A_1 for interactions on a deuteron target within the kinematic range and the hadron acceptance of the present experiment.

The total statistics accumulated during the 2011 data taking is at $79 \cdot 10^6$ DIS events, compared to $85.3 \cdot 10^6$ DIS events available in 2007. In case of the 2011 data a slightly different binning in x has been introduced compared to previous COMPASS results. With the increased beam energy in 2011, it was possible to measure an additional point in the x interval: $0.0025 < x < 0.004$.

In addition, the bin for x between 0.01 and 0.02 has been split up into two bins. The values of $g_1^p(x, Q^2)$ have been obtained from Eq. (4), using the parametrisation of spin independent structure function F_2^p from Ref. [3] and the parametrisation of R from Ref. [5]. Fig. 1 (right) shows the results on $g_1^p(x)$ as a function of x obtained from the 2011 COMPASS data at 200 GeV compared to the 2007 results [4] at 160 GeV and to the SMC results [3] at 190 GeV for $Q^2 > 1(GeV/c)^2$. The band at the bottom indicates the systematic uncertainty. One can observe a good compatibility of these results in the overlapping region. The gain in precision with respect to the SMC data is about a factor of 2-3.

The new values of $A_1^p(x)$ as functions of Q^2 in 16 intervals of x for COMPASS data sets at 160 GeV and at 200 GeV are presented in Fig. 2. They do not show any significant Q^2 dependence in any interval of x. Fig. 3 shows the proton spin-dependent structure function g_1^p as a function of Q^2 for various x obtained from the 2011 COMPASS data at 200 GeV compared to the result of 2007 data at 160 GeV and to the world data.

To conclude, a new measurement of g_1^p at 200 GeV beam energy has been performed. The measured region was extended to lower x and larger Q^2. The new data points at very low x can be used as new inputs for global fits and indirect extraction of gluon contribution to the nucleon spin. The availability of $g_1^d(x)$ and $g_1^p(x)$ data with good and comparable precision at low x provides ideal conditions for a new evaluation of the non-singlet spin structure function $g_1^{NS}(x)$ and a new test of the Bjorken sum rule. The new data can determine the shape of $g_1^{NS}(x)$ at low x and provide a much more reliable extrapolation to $x = 0$, which in turn will reduce the systematic uncertainty in the test of the Bjorken sum rule.

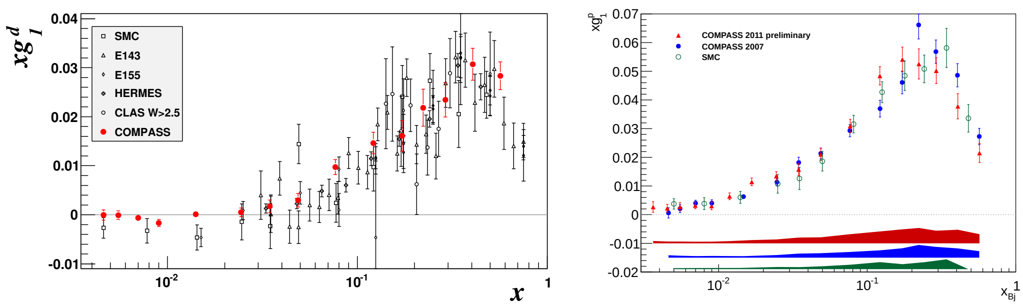

Figure 1: (left) The spin-dependent structure function of deuteron $g_1^d(x)$ as a function of x [2]. For comparison the COMPASS points are shown together with the world data. The g_1^d points correspond to full deuteron statistics. (right) The spin-dependent structure function of proton $g_1^p(x)$ as a function of x obtained from the 2011 COMPASS data at 200 GeV compared to the 2007 results [4] at 160 GeV and to the SMC results [3] at 190 GeV for $Q^2 > 1(GeV/c)^2$. The band at the bottom indicates the systematic uncertainty.

References

[1] P. Abbon *et al.* [COMPASS Collaboration], "The COMPASS experiment at CERN," Nucl. Instrum. Meth. A **577** (2007) 455 [hep-ex/0703049].

[2] V. Y. .Alexakhin *et al.* [COMPASS Collaboration], "The Deuteron Spin-dependent Structure Function g1(d) and its First Moment," Phys. Lett. B **647** (2007) 8 [hep-ex/0609038].

PoS(EPS-HEP 2013)473

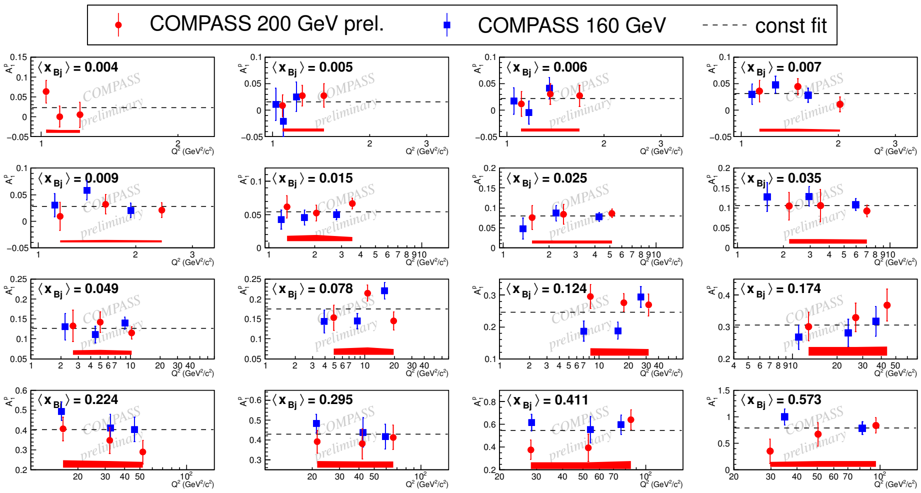

Figure 2: Values of A_1^p as a function of Q^2 in intervals of x. The dashed lines show the results of fits to a constant, the shaded areas show the size of the systematic errors.

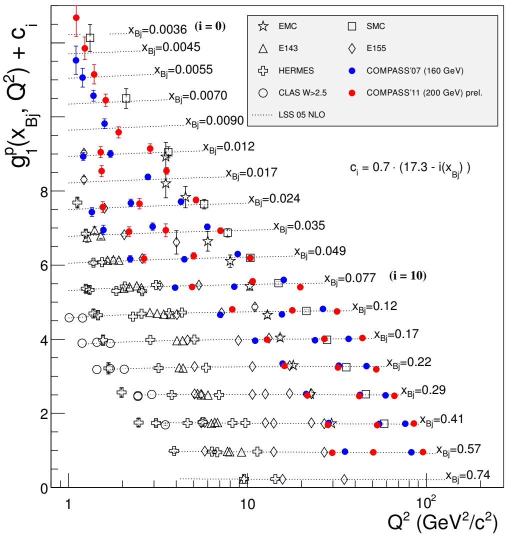

Figure 3: The proton spin-dependent structure function g_1^p as a function of Q^2 for various x obtained from the 2011 COMPASS data at 200 GeV compared to the result of 2007 data at 160 GeV and to the world data. The dashed line indicates the prediction from LSS05 [6] at NLO.

[3] B. Adeva *et al.* [Spin Muon Collaboration], "Spin asymmetries A(1) and structure functions g1 of the proton and the deuteron from polarized high-energy muon scattering," Phys. Rev. D **58** (1998) 112001.

[4] M. G. Alekseev *et al.* [COMPASS Collaboration], "The Spin-dependent Structure Function of the Proton g_1^p and a Test of the Bjorken Sum Rule," Phys. Lett. B **690** (2010) 466 [hep-ex/1001.4654].

[5] K. Abe *et al.* [E143 Collaboration], "Measurements of R = sigma(L) / sigma(T) for 0.03<x<0.1 and fit to world data," Phys. Lett. B **452** (1999) 194 [hep-ex/9808028].

[6] E. Leader, A. V. Sidorov and D. B. Stamenov, "Longitudinal polarized parton densities updated," Phys. Rev. D **73** (2006) 034023 [hep-ph/0512114].