**Longitudinal spin structure of the nucleon at COMPASS (SPS CERN)**[1]

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**Abstract**

We present new results on longitudinal inclusive double-spin asymmetry $A_{1,p}(x)$ in deep-inelastic muon-proton scattering and proton spin-dependent structure function $g_1^p(x, Q^2)$. New COMPASS data on longitudinal polarised $NH_3$ target were collected during the year 2011 with beam of positive muons with energy $E = 200$ GeV. Kinematical threshold $Q^2 \geq 1$ $(\mathrm{GeV}/c)^2$ and the fractional energy $0.1 < y < 0.9$ allow us to cover low $x$ region up to 0.025.

The longitudinal virtual-photon proton (deuteron) asymmetry, $A_{1,p(d)}$, is evaluated from the numbers of events collected in the different target cells by the method described in Ref. [1]. Neighbouring target cells are polarised in opposite directions and data from both target spin orientations are thus recorded simultaneously. The lengths of the cells are chosen so that the two samples collected with opposite spin orientations have in average the same acceptance, which limits the risk of false asymmetries. The target spin directions are reversed once a day by rotating the magnetic field and a few times a year by changing the microwave frequencies used for dynamic nuclear polarisation. The asymmetries are calculated from the numbers of events in cells with opposite spin orientations collected before and after a field rotation so that flux and acceptance factors cancel out. A description of COMPASS experiment has been presented in Ref. [2].

The pion data extend the measured region by an order of magnitude towards small Bjorken scaling variable $x$, while the kaon asymmetries for the proton were measured for the first time. The published in Ref [3, 4, 5, 6, 7] results on inclusive, $A_{1,p(d)}$, and semi-inclusive, $A^{\pi+}_{1,p(d)}$, $A^{\pi-}_{1,p(d)}$, $A^{K+}_{1,p(d)}$, and $A^{K-}_{1,p(d)}$, double-spin asymmetries in deep-inelastic muon-proton (muon-deuteron) scattering (DIS) have been obtained with data collected in 2002 – 04 and 2006 for the longitudinal polarised $^6$LiD solid target and in 2007

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for the longitudinal polarised $NH_3$ solid target. Beam of polarised positive muons with energy $E = 160$ GeV have been used.

The deuteron data provided an accurate evaluation for $\Gamma_1^d$, the first moment of $g_1^d(x)$, and for the matrix element of the singlet axial current $a_0$. The results of QCD fits in the next to leading order (NLO) on all $g_1$ deep inelastic scattering data proposed two solutions with the gluon spin distribution function $\Delta G$ positive or negative, which described the data equally well. In both cases, at $Q^2 = 3(\mathrm{GeV}/c)^2$ the first moment of $\Delta G$ was found to be of the order of $0.2 - 0.3$ in absolute value. With COMPASS data alone, at the order $\alpha_s^3$, it has been found that $a_0(Q^2 \to \infty) = 0.33 \pm 0.03(\mathrm{stat.}) \pm 0.05(\mathrm{syst.})$ and the first moment of the strange quark distribution $(\Delta s + \Delta\bar{s})_{Q^2\to\infty} = 0.08 \pm 0.01(\mathrm{stat.}) \pm 0.02(\mathrm{syst.})$ [3].

The 2007 data improved the statistical precision in the low $x$ region by a factor of 2-3 and showed no evidence either for an increase or a decrease of the spin structure function $g_1^p$ in this region. In combination with the previously published results on the deuteron, the 2007 data improved the evaluation of the non-singlet spin structure function $g_1^{NS}$. The isovector quark density, $\Delta q_3(x, Q^2)$, was evaluated from a NLO QCD fit of $g_1^{NS}$. The first moment of $\Delta q_3$ is in good agreement with the value predicted by the Bjorken sum rule and corresponds to a ratio of the axial and vector coupling constants $|g_A/g_V| = 1.28 \pm 0.07(\mathrm{stat.}) \pm 0.10(\mathrm{syst.})$ [4].

In leading order QCD (LO) the deuteron semi-inclusive difference asymmetry $A_d^{h^+-h^-}$ for hadrons of opposite charge measures the valence quark polarisation and provides an evaluation of the first moment of $\Delta u_v + \Delta d_v$ which is found to be equal to $0.40 \pm 0.07(stat.) \pm 0.06(syst.)$ over the measured range of $0.006 < x < 0.7$ at $Q^2 = 10(\mathrm{GeV}/c)^2$. When combined with the first moment of $g_1^d$ previously measured on the same data, this result favours a non-symmetric polarisation of light quarks $\Delta\bar{u} = \Delta\bar{d}$ at a confidence level of two standard deviations, in contrast to the often assumed symmetric scenario $\Delta\bar{u} = \Delta\bar{d} = \Delta\bar{s} = \Delta s$ [5].

A LO evaluation of the helicity distributions for the three lightest quarks and antiquark flavours have been derived from 10 asymmetries. The resulting values of the sea quark distributions are small and do not show any sizable dependence on $x$ in the range of the measurements. No significant difference was observed between the strange and antistrange helicity distributions, both compatible with zero. The integrated value of the flavour asymmetry of the helicity distribution of the light-quark sea, $\Delta\bar{u} - \Delta\bar{d}$, is found to be slightly positive, about 1.5 standard deviations away from zero [7].

The new proton data were collected with the COMPASS spectrometer 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 0.025 to 0.7 is limited by the kinematical threshold $Q^2 \geq 1$ (GeV/$c$)$^2$ and the fractional energy, $y$, transfered from the incident muon to the virtual photon $0.1 < y < 0.9$. 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 total statistics accumulated during 2011 data taking is at $79 \cdot 10^6$ DIS events, compared to $93 \cdot 10^6$ DIS events available in 2007.

The values of $A_{1,p}$ were calculated separately for inclusive and hadron triggers. We introduced a slightly different binning in $x$ compared to our previous results. With the increased beam energy in 2011, it was possible to mesuare an additional point in the $x$ interval: $0.025 < x < 0.004$. 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

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

using the $F_2^p$ parametrisation of Ref. [8] and the parametrisation of $R$ [9] already used in the evaluation of the depolarization factor $D$ (Fig. 1, left).

A comparison between results on $g_1^p$ obtained from 2007 and 2011 data is shown in Fig. 2. One can observe that for large $x$ values results from 2011 data are below ones from 2007. The comparison of the mean values of $x$ and $Q^2$ is shown in Fig. 1, right. The mean values of $x$ and $Q^2$ have been calculated by using a weighted mean:

$$\langle x \rangle = \frac{\sum w_i^2 x_i}{\sum \omega_i^2} \;, \qquad \langle Q^2 \rangle = exp \frac{\sum \omega_i^2 log Q_i^2}{\sum \omega_i^2} \;, \tag{2}$$

where $\omega_i$ is the same weight as the one used in the asymetry calculation.

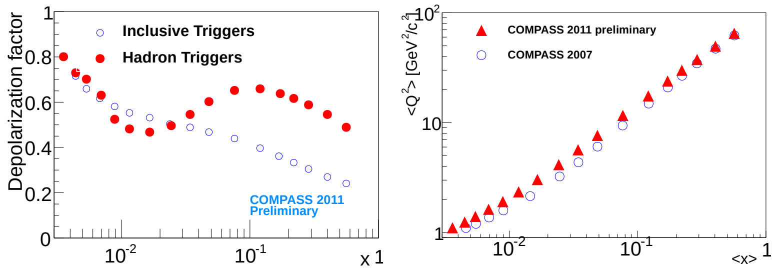


Figure 1: Left: Depolarisation factor $D$ as a function of $x$. Right: Comparison of the mean value of $x$ vs the mean value of $Q^2$ for 2011 and 2007 data.

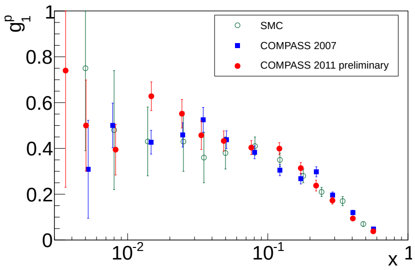


Figure 2: Comparison of $g_1^p$ versus $x$ between the COMPASS 2011 data taking at 200 GeV (filled circles), the COMPASS 2007 data taking at 160 GeV (squares) [4], and the SMC 1993 and 1996 data taking at 190 GeV (opened circles) [8].

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