Recent COMPASS results on the polarized structure function g_1^d of the deuteron

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Abstract. The study of the spin dependent structure functions of the deuteron is part of a broad physics program addressed by the COMPASS collaboration at CERN. The longitudinal spin asymmetry A_1^d is evaluated from data on inelastic scattering of longitudinally polarised muons off a large ^{6}LiD polarised target. Recent results on g_1^d both for low and high Q^2 are presented. The obtained values for the first moment Γ_1^d and the flavor-singlet axial current a_0 are also shown.

Keywords: Deep Inelastic Scattering; Nucleon Spin; A_1 asymmetry; g_1^d structure function
PACS: 13.88.+e; 24.85.+p

The COMPASS experiment at CERN uses the inelastic scattering of polarized muons on longitudinally polarized deuterons from a solid state target to study the A_1^d asymmetry. A muon beam of 160 GeV and ≈–80% average polarization impinges on a ^6LiD target. Two target cells are used simultaneously, each 60 cm long and 3 cm in diameter. They are oppositely polarized using the dynamic nuclear polarization technique, which allows to reach ≈50% polarization. Detectors placed upstream of the polarized target system measure each beam muon's momentum. The COMPASS spectrometer includes a large number of tracking planes, disposed before and after each of the two dipole magnets of the experiment. The angular acceptance of the spectrometer is limited by the target solenoid aperture of 70 mrad along the beam direction. Particle identification is done using a RICH detector, as well as muon filters, hadron and electromagnetic calorimeters.

The kinematic range covered by the experiment includes the very low Bjorken-x region, poorly known up to now. The analyses here presented concern two distinct physics regions: a $Q^2 > 1$ (GeV/c)^2 sample, with a total of 88 million deep inelastic scattering events (data taken from 2002 to 2004); and a $Q^2 < 1$ (GeV/c)^2 sample, with 280 million quasi-real photon interaction events (2002 and 2003 data).

The COMPASS trigger system selects inclusive events (by conditions on the scattered muon). Additionally, hadron triggers are also used in the analyses. These may be semi-inclusive events, with at least one hadron in addition to the scattered muon; or purely hadronic triggers, i.e. events with a minimum deposit of energy in the hadron calorimeters.

To ensure flux and acceptance cancellation in the asymmetry calculations, the spin directions in the target cells are reversed every eight hours, by rotating the magnetic field of the target solenoid. Furthermore, a full repolarization of the cells in opposite configurations is done at least once per year. Target geometric cuts are applied to guarantee that the beam crosses both cells. Specific selection criteria are applied in each

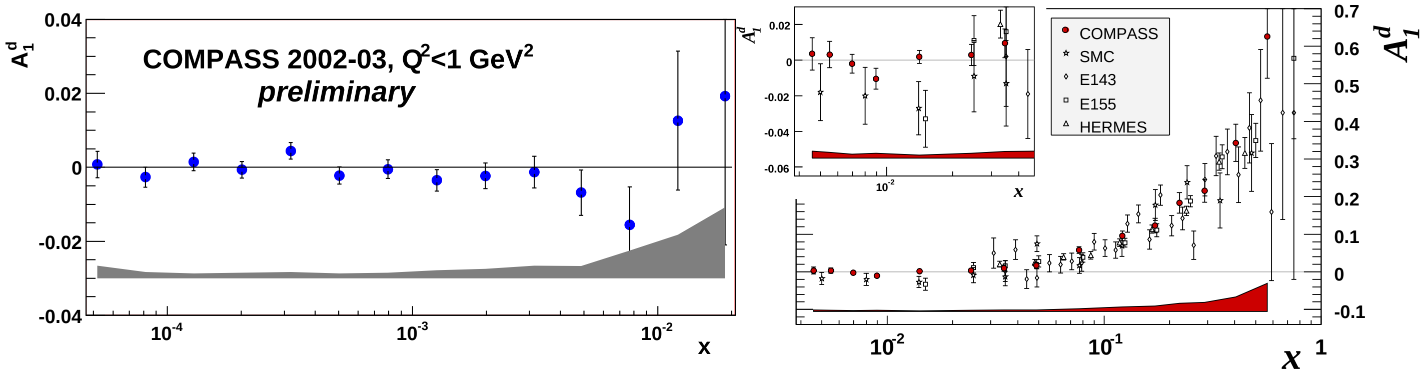

FIGURE 1. A_1^d asymmetry as a function of x. COMPASS results for $Q^2 < 1$ (GeV/c)^2 (left), and $Q^2 > 1$ (GeV/c)^2 (right) compared to other experiments.

of the analyses, like requiring the fraction of energy taken by the virtual photon, y, to be in the range $0.1 < y < 0.9$.

The muon-deuteron asymmetry is related with the difference between the number of events from the two target cells, which are longitudinally polarized in opposite directions, according to:

$$A^{\mu d} = \frac{1}{f P_B P_T} \left(\frac{N^{\leftrightarrows} - N^{\leftleftarrows}}{N^{\leftrightarrows} + N^{\leftleftarrows}} \right), \tag{1}$$

with f being the target dilution factor (i.e. the fraction of polarizable nucleons in the target material); and P_B and P_T the beam and target polarizations, respectively. This measured asymmetry relates to the longitudinal (A_1^d) and transverse (A_2^d) virtual photon-deuteron asymmetries:

$$A^{\mu d}/D = A_1^d + \eta A_2^d, \tag{2}$$

where D is the virtual photon depolarization factor. Both D and η depend on kinematics and, in the COMPASS covered range, η is small. A_2^d was measured by SLAC experiments as well as by SMC, and is shown to be also small. For these reasons, one can safely assume that

$$A^{\mu d}/D \approx A_1^d. \tag{3}$$

Although the asymmetry A_1^d is evaluated separately from inclusive and from hadronic events (and corrected in each case for radiative effects), the results are statistically compatible and no systematic effects are observed.

The COMPASS results on the A_1^d asymmetry [1] are shown in figure 1. The study of the $Q^2 > 1$ (GeV/c)^2 sample in 15 x bins (obtained from the total range $0.004 < x < 0.7$) and 3 Q^2 bins shows that A_1^d has no significant dependence on Q^2. On the contrary, a strong dependence is seen with Bjorken-x, the asymmetry being compatible with zero at $x < 0.003$, and increasingly large at large x (figure 1, right). The uncertainties on the P_B, P_T and f measurements lead to 10% systematic error. Radiative corrections have a very small contribution to the systematics. Several studies performed to evaluate the

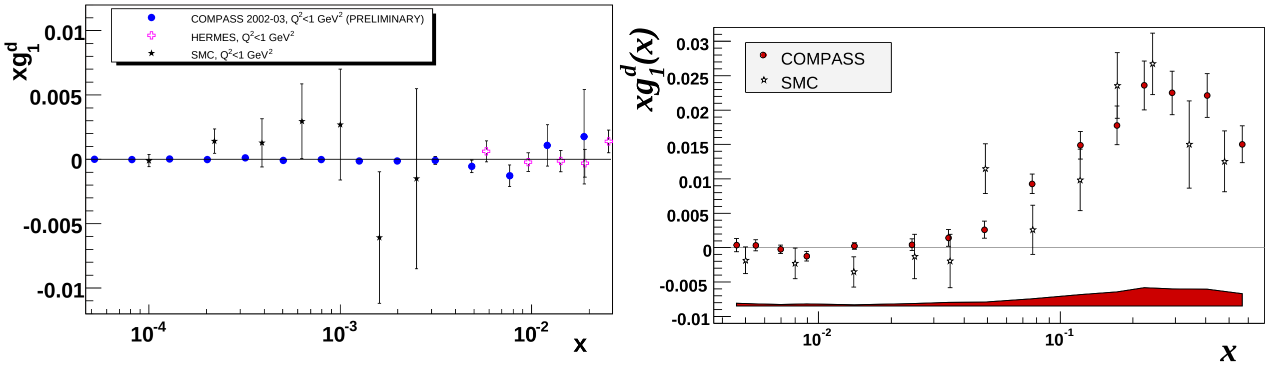

FIGURE 2. xg_1^d as a function of x. COMPASS result for $Q^2 < 1$ (GeV/c)^2 (left) and $Q^2 > 1$ (GeV/c)^2 (right), compared to the SMC and HERMES results.

systematic effects that may arise from instabilities of the apparatus over time (the so-called false asymmetries) show that these contribute with less than 50% of the statistical error on the asymmetry measurement. In the large x region, the COMPASS result is in good agreement with the observations from other experiments, while improving significantly the measurement precision in the low x region. The tendency towards negative asymmetry at $0.004 < x < 0.04$, that the SMC result suggests, is not confirmed by the COMPASS DIS data.

The sample used in the low Q^2 analysis contains events with photon virtualities $0.001 < Q^2 < 1$ (GeV/c)^2 and Bjorken-x $4\times10^{-5} < x < 2.5\times10^{-2}$, where a correlation between these two variables exists. The resulting asymmetry A_1^d is compatible with zero in the whole x range, as shown in figure 1 (left). The dominant systematic error is due to false asymmetries, whose upper limit is estimated to be of the same order as the statistical error, i.e. very low, given the very high statistics available in this analysis. The measurement, obtained with one order of magnitude better accuracy, is in good agreement with the SMC result, and extends the knowledge of the asymmetry to lower x values.

The longitudinal spin-dependent structure function g_1^d is obtained from the asymmetry A_1^d using:

$$g_1^d \approx A_1^d \frac{F_2^d}{2x(1+R)}, \qquad (4)$$

where F_2^d is the spin-independent structure function of the deuteron, and R is the ratio of longitudinal to transverse photo-absorption cross-sections. The quantities g_1^d, A_1^d, F_2^d and R depend both on x and Q^2. The SMC parameterization of F_2 as a function of x from [2] is used, F_2 being calculated for the COMPASS kinematic region. An updated parameterization of R as a function of x, obtained from the SLAC experiments and calculated in the COMPASS kinematics, is also used. Figure 2 (right) shows the $x \cdot g_1^d$ values for the analysis of $Q^2 > 1$ (GeV/c)^2 events [3], together with the SMC published results.

Figure 2 (left) presents $x \cdot g_1^d$ COMPASS result with $Q^2 < 1$ (GeV/c)^2 [4], as compared to SMC and HERMES published results. g_1^d is obtained with unprecedented precision, and found to be consistent with zero in the whole x range.

The spin structure function of the nucleon g_1^N, defined as $(g_1^p + g_1^n)/2$, can be obtained from g_1^d, by correcting for the D-wave state of the deuteron, $g_1^d = g_1^N(1 - 1.5\omega_D)$. In this conversion, the value $\omega_D = 0.05 \pm 0.01$ is used. The g_1^N datapoints obtained in the $Q^2 > 1$ (GeV/c)^2 analysis are evolved to a given fixed Q^2 value, by using a QCD fit. The value $Q^2 = 3$ (GeV/c)^2 is used, since it corresponds to the average Q^2 of the events in the sample. Several parametrizations to the g_1 world data exist, but these do not succeed to describe the COMPASS results at low x. Thus, new QCD fits, including the COMPASS data, are performed, which lead to two equally good solutions, one implying $\Delta G > 0$ and the other $\Delta G < 0$ [5].

The first moment of g_1^N, Γ_1^N, is defined as:

$$\Gamma_1^N(Q_0^2) = \int_0^1 g_1^N(x, Q_0^2)dx \tag{5}$$

The evolution of the measured points to a common Q_0^2 is done using the new QCD fit. The integral of g_1^N in the measured x range ($0.004 < x < 0.7$) amounts to 98% of Γ_1^N. The result

$$\Gamma_1^N(Q^2 = 3(GeV/c)^2) = 0.050 \pm 0.003(stat) \pm 0.002(evol) \pm 0.005(syst) \tag{6}$$

is obtained, where the second error presented is from the evolution to fixed Q^2 alone.

Γ_1^N is an interesting quantity, since it is related to the flavor-singlet axial current a_0, which can be interpreted as the quark spin contribution to the nucleon spin. At NLO, this relation has the form:

$$\Gamma_1^N(Q^2) = \frac{1}{9}\left(1 - \frac{\alpha_s(Q^2)}{\pi} + \mathcal{O}(\alpha_s^2)\right)\left(a_0(Q^2) + \frac{1}{4}a_8\right) \tag{7}$$

a_8 was measured in hyperon-β decays assuming the flavor symmetry SU(3)$_f$, to be $a_8 = 0.585 \pm 0.025$. Assuming this a_8 value, we obtain

$$a_0(Q^2 = 3(GeV/c)^2) = 0.35 \pm 0.03 \pm (stat) \pm 0.05(syst). \tag{8}$$

New COMPASS data, taken during 2006, will allow to increase the precision of these measurements even further.

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