Precise Results on g_1^{p} and g_1^{d} and First Measurement of the Tensor Structure Function b_1^{d} with the HERMES-Experiment

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Abstract. Precise results on the spin-dependent structure functions $g_1^{\mathrm{p}}(x,Q^2)$ and $g_1^{\mathrm{d}}(x,Q^2)$ over the kinematic range $0.0021 < x < 0.9$ and $0.1 < Q^2 < 20$ GeV^2 are presented. The analyses base on data collected at the HERMES experiment at DESY in polarized deep-inelastic scattering and make use of an unfolding algorithm in order to correct for radiation and detector smearing. Furthermore, final results of the first measurement of the tensor asymmetry A_{zz} and the tensor structure function $b_1^{\mathrm{d}}(x,Q^2)$ are provided.

Keywords: HERMES at DESY, spin-dependent structure functions, tensor structure function.
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At leading twist, polarized inclusive deep-inelastic scattering (DIS) of charged leptons off a proton (spin $1/2$) is described by the spin-dependent structure function $g_1(x,Q^2)$. In case of a deuteron target (spin 1), the parametrization of the hadronic part of the interaction contains the additional structure function $b_1(x,Q^2)$ [1].

In the Quark-Parton Model the structure function g_1 describes the imbalance in the distribution of quarks with the same or opposite helicity with respect to that of the parent hadron and can be measured when both beam and target are polarized. The function g_1 is extracted through the ratio g_1/F_1, which is approximately equal to the virtual photon asymmetry A_1 that is measured via the longitudinal cross section asymmetry $A_{\|}$ [2].

The tensor structure function b_1 represents the difference in the quark distribution between the helicity-0 and the averaged non-zero helicity states of the deuteron. Its measurement does not require a polarized beam and it is obtained from the ratio b_1/F_1 determined via the tensor asymmetry A_{zz} [3]. As a nuclear-polarized deuteron target always carries a large tensor polarization, it is a priori not justified to neglect the effect of the tensor asymmetry during the measurement of g_1^{d}.

HERMES is a fixed-target experiment exploiting the 27.6 GeV lepton beam of the HERA storage ring. The beam is transversely self-polarized, for the reported data reaching an average polarization of 0.53; longitudinal beam polarization in the interaction region is obtained by employing a pair of spin rotators. The HERMES polarized internal hydrogen/deuterium gas target [4] consists of an Atomic Beam Source (ABS) to generate and a Breit Rabi Polarimeter to measure nuclear polarization; a tubular open-ended, cooled storage cell is mounted inside the beam pipe confining the gas fed from the ABS. Gas targets offer significant advantages over solid state targets for spin experiment as they provide a high degree of polarization ($|P_z| \simeq 0.85$ for most of the data considered in the g_1 analyses), they are free of dilution and they can invert the spin of the atoms within milliseconds, thereby substantially reducing the systematic uncertainties of asymmetry measurements. Moreover, the HERMES deuterium ABS allowed the injection of a pure tensor polarized gas ($|P_{zz}| \simeq 0.83$ with $|P_z| \simeq 0.01$), making it possible to decouple the b_1 from the g_1 measurement.

HERMES employs a conventional forward magnetic spectrometer [5] including tracking chambers and particle identification detectors. The achieved momentum resolution is of the order of 2%, while a very efficient discrimination between electrons and hadrons, carried out by means of a likelihood method based on the combination of four detectors [6], brings the hadron contamination of the inclusive sample down to less than 1%.

The final HERMES g_1 results base on data taken with longitudinally polarized hydrogen (1996-97) and deuterium (2000) targets (4 resp. $11.5 \cdot 10^6$ DIS events), the b_1 results on a separate data set with a tensor-polarized deuterium target ($2.4 \cdot 10^6$ DIS events).

During these analyses an unfolding method has been applied which corrects within one step both for the (quasi)-elastic radiative background and for the intra-bin migration caused by radiative DIS events and detector smearing. This procedure makes use of a Monte Carlo model in order to keep track of how events migrate from a Born bin j to an experimental bin i due to changes in their kinematics and describes this effect by means of a (jxi) matrix. The Born Asymmetry, retrieved by inverting this matrix and multiplying it by the experimental data, depends only on the experimentally measured asymmetry, on the known unpolarized cross sections and on the Monte Carlo models for background and detector behavior. Unfolding implies the elimination of the systematic correlations between different kinematic bins introducing at the same time statistical correlations between them. Therefore, the HERMES results presented here must always be considered along with their correlation matrices when performing QCD fits or moments calculations. The true statistical power of a data set can be seen from the uncertainties of the moments. More analysis details can be found in [7] and [8].

Fig. 1 shows the smearing-unfolded g_1/F_1 and xg_1 results and their statistical correlations. The kinematic range covers $0.0021 < x < 0.9$ and $0.1 < Q^2 < 20$ GeV^2. In the range $0.03 < x < 0.8$ the measured moment for g_1^{p} (g_1^{d}) is $0.1174 \pm 0.0027_{\mathrm{stat}}$ ($0.0433 \pm 0.0013_{\mathrm{stat}}$). A compilation of world data on g_1/F_1 and xg_1 is shown in Fig. 2 [9, 10, 11].

The tensor asymmetry A_{zz}, as measured for the first time by HERMES (in the range $0.01 < x < 0.45$ and $0.5 < Q^2 < 5$ GeV^2), is shown in the left panel of Fig. 3. A_{zz} is different from zero and of the order of 1%, implying the quadrupole contribution to the measurement of g_1 to be negligible. The right plot displays the structure functions b_1^{d} and xb_1^{d} along with the associated average Q^2. The shape of b_1^{d} is in qualitative agreement with coherent double scattering models predicting contributions at low x via the nuclear shadowing mechanism [12, 13, 14]. In the measured range the b_1^{d} moment is $1.05 \pm 0.34_{\mathrm{stat}} \pm 0.35_{\mathrm{sys}}$.

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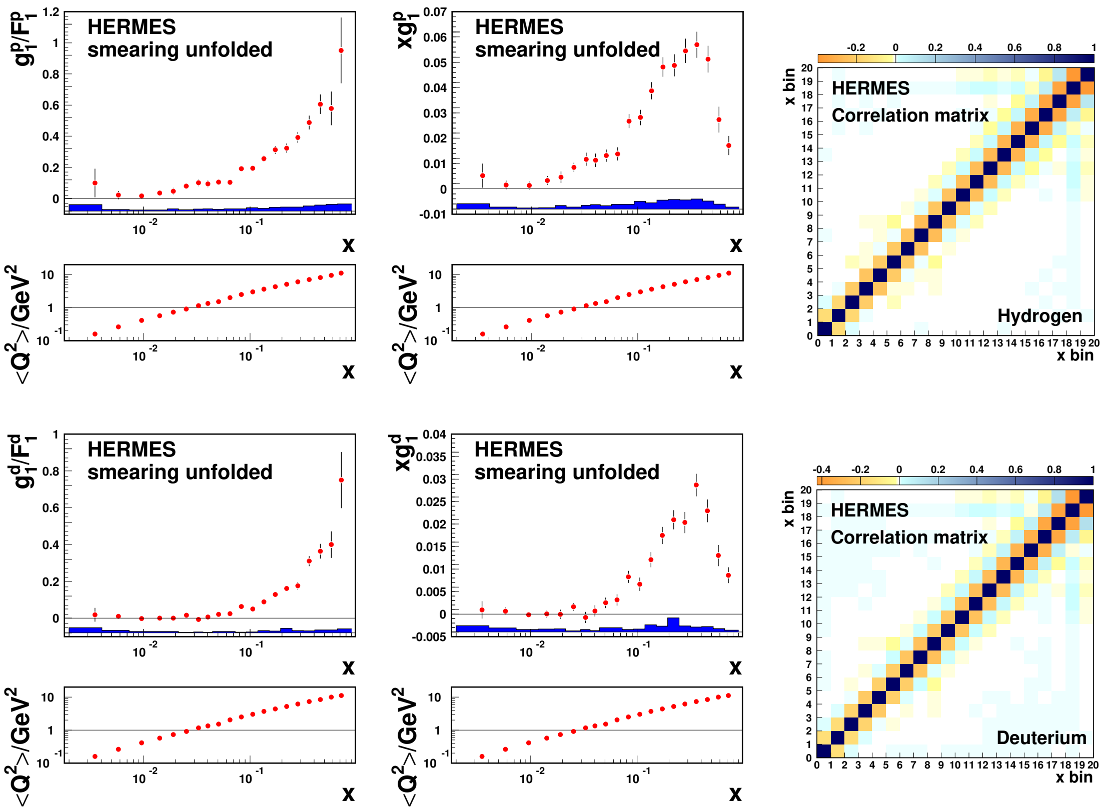

FIGURE 1. Smearing-unfolded g_1/F_1 (left) and xg_1 (middle) as measured by HERMES and the correlation matrix between statistical errors (right), for the proton (top row) and for the deuteron (bottom row). Error bars are statistical, displaying only the diagonal element of the correlation matrix, the shaded bands show the estimated systematic uncertainties

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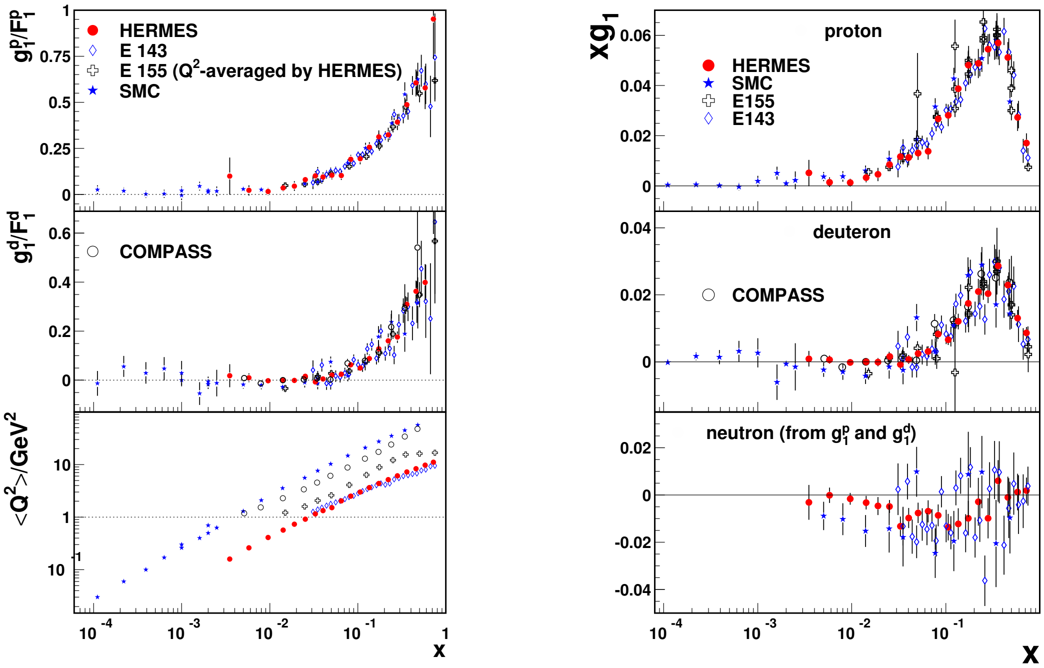

FIGURE 2. HERMES g_1/F_1 (left) and xg_1 data (right) in comparison to SLAC and CERN data for the proton (top panels) and the deuteron (middle panels) and xg_1 for the neutron, as extracted from p and d data (right bottom panel) at the measured Q^2 (left bottom). Error bars show the quadratic sum of statistical and systematic uncertainties.

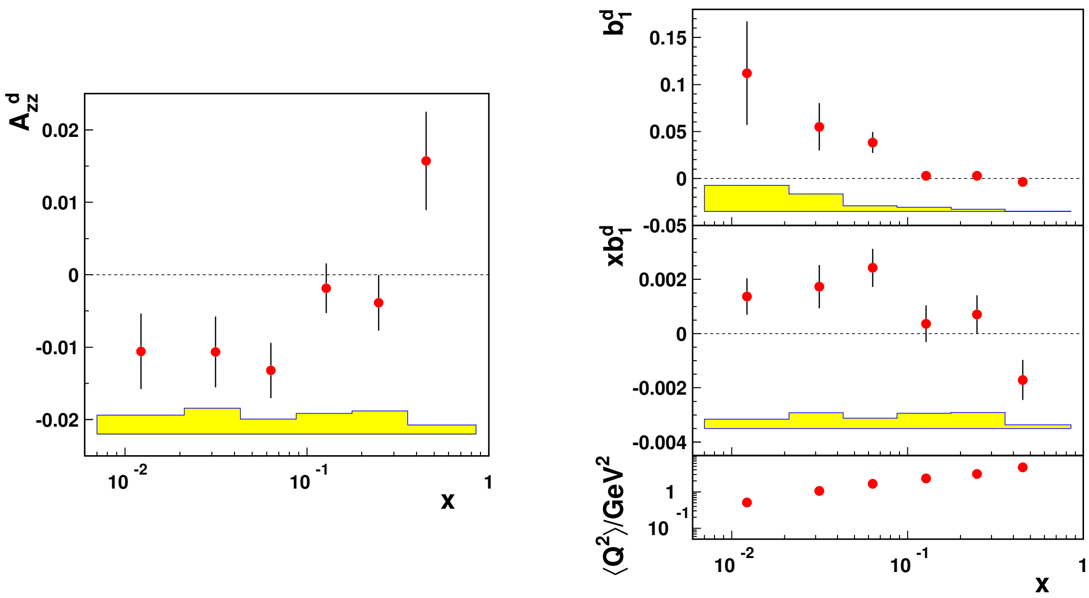

FIGURE 3. The HERMES tensor asymmetry A_{zz} (left) and tensor structure functions b_1^{d} and xb_1^{d} (right upper and middle panel respectively; lower panel: average Q^2 values). The error bars are statistical only, the shaded bands show the estimated systematic uncertainties.