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NEW PRECISION RESULTS ON THE SPIN STRUCTURE FUNCTION g_1^d *

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The HERMES experiment studies the spin structure of the nucleon using the 27.6 GeV longitudinally polarized positron beam of HERA and an internal target of pure gases. Recently, HERMES presented preliminary results on the deuteron spin structure function g_1^d in the kinematic range $0.0021 < x < 0.85$ and $0.1 < Q^2 < 20$ GeV ^{2} based on a restricted data set. Here, new, precise results are presented using the superior statistics of the 2000 data taking period. A reduction of the systematic uncertainty which could be achieved in this preliminary analysis relies in particular on the excellent performance of HERA and of the HERMES target. The data will be discussed in comparison with previous measurements performed at SLAC and CERN.

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1. Introduction

The HERMES experiment [1] has been designed to measure the nucleon spin structure functions from deep inelastic scatterings (DIS) of polarized positrons (electrons) on polarized gaseous targets (H, D, ^{3}He). The partonic interpretations of the leading-twist structure functions in the Quark-Parton-Model (QPM) are summarized in the following table (where the sum is over (anti)quark flavours; the dependencies on the photon squared 4-momentum $-Q^2$ and on the Bjorken scaling variable x are omitted for simplicity):

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	Proton	Deuteron
F_1	$\frac{1}{2}\sum_f e^2[q^+ + q^-]$	$\frac{1}{3}\sum_f e^2[q^+ + q^- + q^0]$
F_2	$2xF_1$	$2xF_1$
g_1	$\frac{1}{2}\sum_f e^2[q^+ - q^-]$	$\frac{1}{2}\sum_f e^2[q^+ - q^-]$
b_1	—	$\frac{1}{2}\sum_f e^2\left[2q^0 - (q^- + q^+)\right]$
b_2	—	$2xb_1$

The sum over all the helicity states of the quarks is measured with the unpolarized structure function F_1. The polarized structure function g_1 is sensitive to the spin structure of the nucleon, and measures the number of quarks with same (q^+) or opposite (q^-) helicity with respect to the nucleon they belong to. For targets of spin 1 as deuteron, the tensor structure function b_1 compares the quark momentum distribution in the 0 (q^0) or non-0 ($q^+ + q^-$) helicity state of the hadron [2]. Although b_1 is foreseen to be so small for deuterium to give negligible effects on the g_1^d measurement, it has not been measured yet for deuterium. HERMES will provide the first direct measurement of the b_1 structure function from a dedicate data set taken in 2000 with a tensor polarized target and an unpolarized beam.

2. HERMES setup

The HERMES experiment is installed in the HERA ring where the positrons self-polarize by emission of synchrotron radiation (Sokolov–Ternov effect) along the direction of the bending magnetic field. The longitudinal polarization at HERMES is obtained by two spin rotators. Two polarimeters based on Compton-back scattering of circular polarized laser light measure the beam polarization [3]. In 2000 the helicity of the positron beam was reversed every $2 \div 3$ months and average polarization values of 0.55 with an uncertainty of 0.02 could be achieved.

The peculiarity of the HERMES experiment is its gaseous target. An Atomic Beam Source (ABS) injects a polarized atomic gas into a cylindrical 40 cm long, 75 μm thick Al tube (target cell) which confines the gas along the positron beam line. In 2000 the target density and thus the luminosity could be increased by a factor of about 2 by reducing the working temperature from 100 K down to 60 K and using a cell with a smaller section. Each 90 s a diagnostic system measures the atomic and molecular abundances and the atomic polarization inside the cell, then the polarization of the injected gas is reversed. The target polarization is defined as the atomic fraction entering into the cell from the ABS (α_0) times the atomic polarization (P_a):

$$P_\mathrm{t} = \alpha_0\,[\,\alpha_\mathrm{r} + (1-\alpha_\mathrm{r})\beta\,]\,P_\mathrm{a}\,. \tag{2.1}$$

A correction factor is needed to account for the fraction of recombined atoms $(1-\alpha_{\rm r})$ that may keep a residual polarization ($\beta = P_{\rm a}/P_m$). In 2000 the recombination on the cell surface was negligible ($\alpha_{\rm r} \sim 1$). The present result is therefore not sensitive to the uncertainty on the β value, yet not directly measured. Running conditions were very stable during 2000 and led to an average polarization of 85 %. In contrast to the solid targets used by other experiments, the HERMES gaseous target does not suffer from radiation damage (flowed gas), its polarization can be continuously measured and rapidly reversed, and is not diluted by non-polarizable material.

In 2000 the extremely good and stable performances of both HERA beam and HERMES target allowed the collection of about 10 million positron DIS candidates, a statistics 5 times higher than any of the previous data-taking years.

The HERMES detector is a forward spectrometer with a dipole magnet providing a field integral of 1.3 Tm. A horizontal iron plate shields the HERA beam lines against the field thus dividing the spectrometer into two identical halves with a minimum vertical acceptance of ± 40 mrad. The acceptance extends to ± 140 mrad vertically and to ± 170 mrad horizontally. Tracking in each detector half is accomplished by 42 drift chamber planes and 6 microstrip gas chamber planes. In this analysis positron identification is accomplished using a probability method based on signals of three sub-systems: the lead-glass block calorimeter, a transition-radiation detector and a preshower hodoscope. For positrons in the momentum range of 2.5 to 27 GeV, the identification efficiency exceeds 98 % with a negligible hadron contamination, the average polar angle resolution is 0.6 mrad, and the average momentum resolution is $1 \div 2$ %.

3. g_1^d measurement

The kinematic range of this measurement is limited by resolution and trigger requirements, therefore accessing a range in the Bjorken variables of $0.0021 < x < 0.85$ and $0.1 < y < 0.91$. Inclusive events are selected by the requirements: $Q^2 > 0.1$ GeV ^{2} and $W^2 > 3.24$ GeV ^{2} (where $-Q^2$ and W^2 are the photon and hadron squared 4-momenta). For each of the 2-dimensional $[x, y]$ bins the kinematic range is divided in, the asymmetry between cross-sections of parallel ($\rightrightarrows$) or antiparallel ($\rightleftarrows$) helicities of the beam and the target is calculated:

$$A_{||} = \frac{\sigma^{\rightleftarrows} - \sigma^{\rightrightarrows}}{\sigma^{\rightleftarrows} + \sigma^{\rightrightarrows}} = \frac{1}{P_{\rm b} P_{\rm t}} \frac{(N/L)^{\rightleftarrows} - (N/L)^{\rightrightarrows}}{(N/L)^{\rightleftarrows} + (N/L)^{\rightrightarrows}} \,. \tag{3.1}$$

The number of events selected (N) are corrected per spin state for the background arising from charge symmetric processes. The corresponding luminosities (L) used for normalization are measured with Bhabha scattering where the rate is corrected for a spin-dependent contribution due to a residual polarization of the target gas electrons. $P_{\rm b}$ ($P_{\rm t}$) is the beam (target) polarization. The radiative corrections are calculated using POLRAD [4]. The statistical error had to be enlarged to account for radiative background by even a factor near 2 at low x. The spin structure function g_1^d is extracted according to

$$g_1^d = \frac{1}{1+\gamma^2}\left[\frac{A_{||}}{D} + (\gamma-\eta)A_2^d\right] \times \frac{(1+\gamma^2)F_2^d}{2x(1+R)} . \tag{3.2}$$

The first term is the virtual-photon asymmetry, where D is the effective polarization of the virtual-photon, γ and η are kinematic factors, A_2^d is parameterized using the Wandzura–Wilczek relation [5]. The second term is the structure function F_1^d in terms of the ratio $R = \sigma_{\rm L}/\sigma_{\rm T}$ [6] and the structure function F_2^d, the latter is formed by $F_2^d = F_2^p\,(1 + F_2^n/F_2^p)$, using parameterizations for F_2^p [7] and F_2^n/F_2^p [8].

The HERMES result on g_1^d is presented in Fig. 1. The contribution to the systematic uncertainty from the experiment is dominated by the accuracy of the beam and target polarization measurements, which are 2 % and 4 % respectively. The extraction formalism adds a significant contribution at

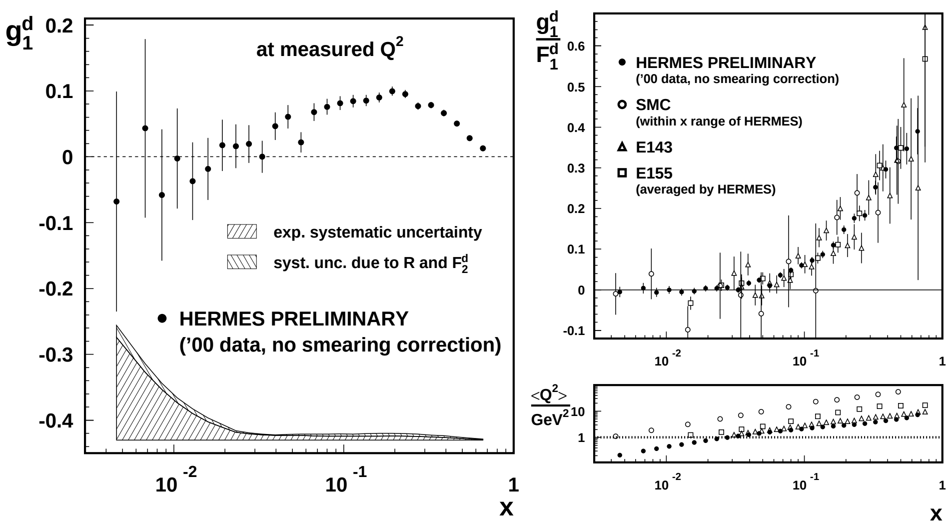

Fig. 1. HERMES result on g_1^d (left): the error bars are statistical only and the shaded histograms show the systematic uncertainty estimation. Comparison between different g_1^d/F_1^d measurements [9] (right): data are shown at the measured Q^2 and the plotted errors are the quadratic sum of the statistical and systematic uncertainties.

lowest x due to the insufficient knowledge of the radiative corrections and at most 1.8 % at highest x due to the knowledge of A_2^d. The uncertainty arising for the unpolarized structure function F_2^d is estimated to be at most 3 %, whereas the uncertainty due to R is as large as 14 % at lowest x and 2.7 % at highest x. Furthermore, the stability of the results under cut variations were studied and the data have been investigated for non-statistical fluctuations by division into sub-samples defined by relevant parameters like dead-time, beam current and time periods. No additional systematic effects could be detected beyond the statistical accuracy of the data.

The HERMES result is the most precise available measurement of g_1^d in the $0.0021 < x < 0.85$ and $0.1 < Q^2 < 20$ GeV ^{2} kinematic range, Fig. 2: it will allow the extraction of g_1^n and an accurate test of the Bjorken sum rule.

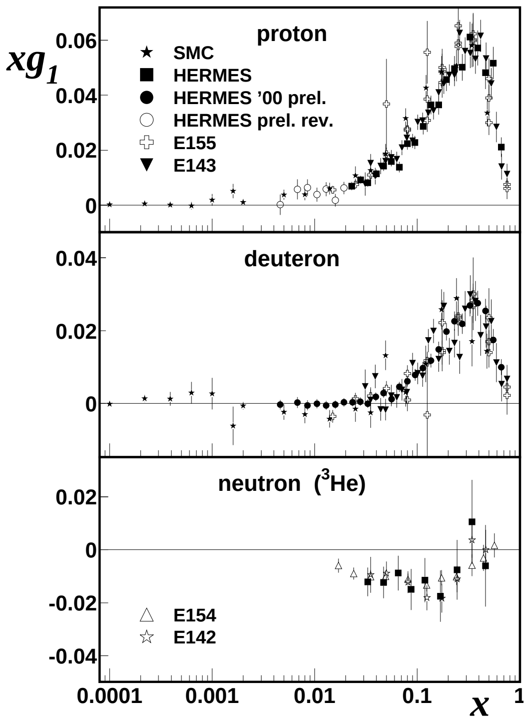

Fig. 2. World data on xg_1 [9, 10]. Data are shown at the measured Q^2 and the plotted errors are the quadratic sum of systematic and statistical uncertainties.

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