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RECENT RESULTS ON THE HELICITY STRUCTURE OF THE NUCLEON FROM HERMES*

M.C. Simani

For the HERMES Collaboration

Vrije Universiteit/NIKHEF, Amsterdam, The Netherlands

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The HERMES experiment at DESY uses the HERA polarized positron beam of 27.6 GeV in combination with internal polarized gas targets in order to investigate the spin structure of the nucleon via deep inelastic scattering. Inclusive and semi-inclusive double-spin asymmetries from polarized hydrogen and deuterium targets have been measured in the kinematic range $0.023 < x < 0.6$ and $1\,\mathrm{GeV}^2 < Q^2 < 10\,\mathrm{GeV}^2$. The installation of a Ring Imaging Čerenkov (RICH) detector in 1998 allowed for the first time the measurement of charged kaon asymmetries. Based on the measured set of hydrogen and deuterium asymmetries, the polarized quark and anti-quark distributions in the proton were extracted in leading-order pQCD as a function of x for all flavors separately. In particular, the first measurement of the light-antiquark asymmetry $\Delta\bar{u} - \Delta\bar{d}$ is presented.

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1. Semi-inclusive asymmetries

The study of the spin structure of the nucleon has attracted great interest since the EMC experiment [1] reported that only a small fraction of the spin of the proton is carried by the spins of the quarks. The HERMES experiment [2, 3] at DESY employs the 27.6 GeV longitudinally polarized positron beam of the HERA accelerator and longitudinally polarized gas targets to measure inclusive and semi-inclusive spin dependent deep inelastic scattering observables. The central goal of these measurements is to determine the polarizations of the individual quark flavors within the proton.

The study of the semi-inclusive channel, in which a final state hadron is detected in coincidence with the scattered lepton, is particularly important in this endeavor as the identity of fast hadrons from the fragmentation

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process is correlated with the flavor of the struck quark. This "flavor-tagging" correlation can then be used to determine the polarization Parton Distribution Functions (PDF) for each quark flavor. The polarized PDF's are written as follows:

$$\Delta q_f(x, Q^2) = q_f^{\uparrow}(x, Q^2) - q_f^{\downarrow}(x, Q^2)\ . \tag{1}$$

Here, $q_f^{\uparrow,(\downarrow)}$ is the number density for quarks of flavor f with spin aligned (anti-aligned) with the spin of the nucleon. The PDF's depend on the Bjorken scaling variable x and the squared four-momentum of the virtual photon Q^2.

Assuming factorization of the hard scattering and fragmentation processes, the photo-absorption spin asymmetry A_1^h for the production of a hadron of type h is related to the polarized PDF's as follows

$$A_1^h\left(x, z, Q^2\right) = C_R\ \frac{\sum_f e_f^2 \Delta q_f\left(x, Q^2\right) D_f^h\left(z, Q^2\right)}{\sum_f e_f^2 q_f\left(x, Q^2\right) D_f^h\left(z, Q^2\right)}\ . \tag{2}$$

Here, $C_R = (1 + R(x, Q^2))/(1 + \gamma^2)$ where $R = \sigma_{\mathrm{L}}/\sigma_{\mathrm{T}}$ is the ratio of the longitudinal (σ_{L}) and transverse (σ_{T}) virtual photon absorption cross-sections. The symbol e_f denotes the charge of a quark of flavor f, and $q_f(x, Q^2)$ are the unpolarized quark distributions. The fragmentation functions $D_f^h(z, Q^2)$ represent the probability that a struck quark of flavor f fragments into a hadron of type h with energy E_h and fractional energy $z = E_h/\nu$, where ν is the energy of the virtual photon. The fragmentation functions are assumed to be independent of the spin orientations of the beam and target.

For the asymmetry analysis, DIS positrons were selected by imposing the kinematical constraints $Q^2 > 1$ GeV^2, $W^2 > 10$ GeV^2 and $y < 0.85$. The average Q^2 of the data sample was 2.5 GeV^2. To enhance the contribution of hadrons from the current fragmentation region, the selection criteria $0.2 < z < 0.8$ and $x_{\mathrm{F}} > 0.1$ were applied. (The upper z cut suppresses contributions from exclusive events.) A Monte Carlo simulation was used to correct the asymmetries for kinematic smearing in the variable x due to instrumental resolution and QED radiative effects.

In Fig. 1 the semi-inclusive asymmetries are presented for charged hadrons and pions produced from a hydrogen target (1996–1997 data taking). Pion identification was accomplished for particles with momenta from 4.5 to 13.5 GeV using a gas threshold Čerenkov counter. Compared to the previous HERMES publication of these results [4], a new analysis of the target data was performed yielding updated values for the proton target polarization: $P_z = 0.75 \pm 0.06$ for 1996 and $P_z = 0.85 \pm 0.05$ for 1997.

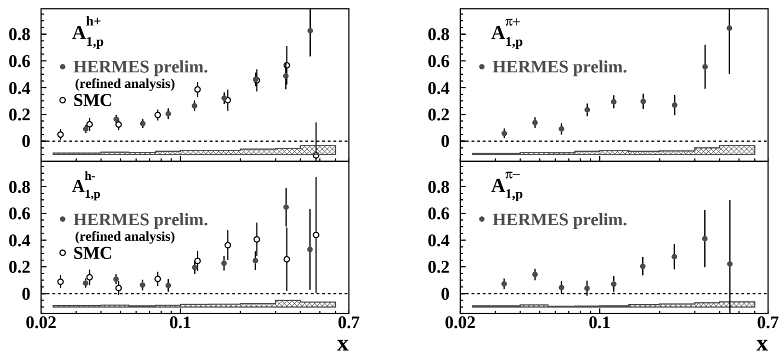

Fig. 1. Semi-inclusive asymmetries for charged hadrons on a hydrogen target.

Fig. 2 shows new results from the 1998–2000 data taking period: the semi-inclusive asymmetries for hadron production from a deuterium target. The dual-radiator ring imaging Čerenkov detector installed in 1998 permitted the separate identification of pions and kaons in this data set across the momentum range $2 < p < 15\,\mathrm{GeV}$.

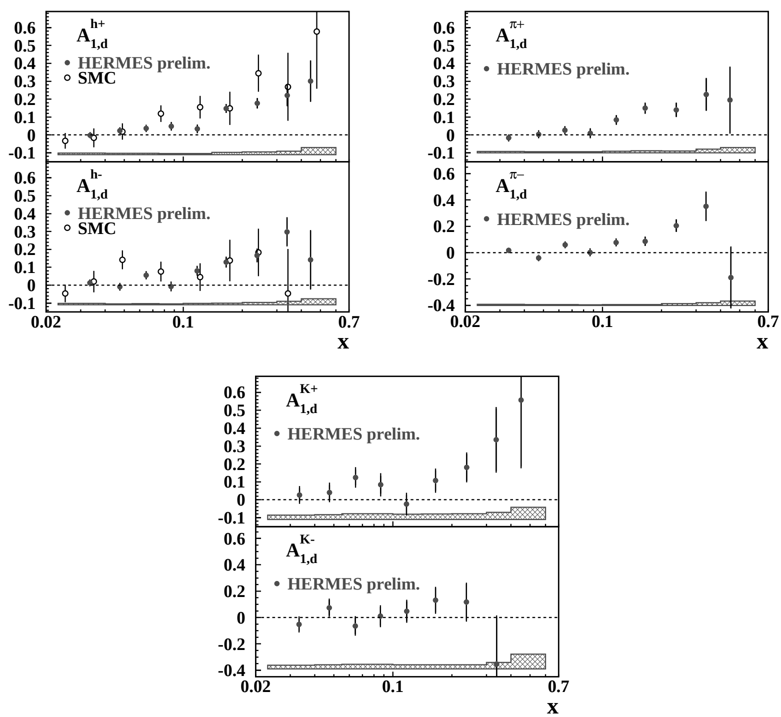

Fig. 2. Semi-inclusive asymmetries for charged hadrons on a polarized deuterium target. The error bars are statistical only, while the error bands indicate the systematic uncertainties. A comparison to results from SMC [5] is shown for the semi-inclusive hadron asymmetries.

2. Extraction of polarized quark distributions

In order to derive polarized quark distributions from the measured asymmetries, the concept of purity P_f^h must be introduced. The purity is defined as the probability that a hadron h with fractional energy z originates from an event where a quark of flavor f was struck

$$P_f^h(x) \equiv \frac{e_f^2 q_f(x) \int\limits_{0.2}^{0.8} D_f^h(z)\, dz}{\sum\limits_{f'} e_{f'}^2 q_{f'}(x) \int\limits_{0.2}^{0.8} D_{f'}^h(z')\, dz'}\,. \tag{3}$$

Using purities, the semi-inclusive asymmetry $A_1^h(x)$ can be rewritten as

$$A_1^h(x) = \sum_f P_f^h(x) \frac{\Delta q_f(x)}{q_f(x)}\, C_R\,, \tag{4}$$

where for each x-bin an integration over Q^2 was performed. The purities are purely unpolarized quantities and were determined from a Monte Carlo simulation based on the LUND string fragmentation model, with parameters tuned to the HERMES hadron multiplicities. The CTEQ5L parametrization [6] was used for the unpolarized quark distributions. The Monte Carlo simulation also involved a detailed model of the HERMES spectrometer. It is important to note that the semi-inclusive asymmetries presented in Figs. 1 and 2 are not corrected for the z-dependence of the experimental acceptance; rather, the hadronic acceptance was taken into account in the purity calculation.

For each value of x, Eq. (4) can be written in matrix form as

$$\vec{A}(x) = \mathcal{P}(x)\, \vec{Q}(x)\,. \tag{5}$$

The elements of the vector $\vec{A}(x)$ are the measured inclusive and semi-inclusive asymmetries extracted from the different targets, and the matrix $\mathcal{P}$ contains the integrated purities and C_R factor for the proton and deuteron targets. The vector $\vec{Q}(x)$ contains the quark and antiquark polarizations for each quark flavor: $\vec{Q}(x) = \left(\frac{\Delta u}{u}, \frac{\Delta d}{d}, \frac{\Delta \bar{u}}{\bar{u}}, \frac{\Delta \bar{d}}{\bar{d}}, \frac{\Delta s}{s} = \frac{\Delta \bar{s}}{\bar{s}}\right)$. Eq. (5) can be solved for $\vec{Q}(x)$ by a least squares minimization technique. In the fit procedure the polarization of the sea quarks was set to zero for $x > 0.3$ to avoid large uncertainties from correlations between the elements of $\vec{Q}(x)$.

Fig. 3 shows the resulting polarized parton densities evolved to $Q^2 = 2.5$ GeV^2 and multiplied by x. The polarization of the up quarks is positive and the down quark polarization is negative. The light sea quark

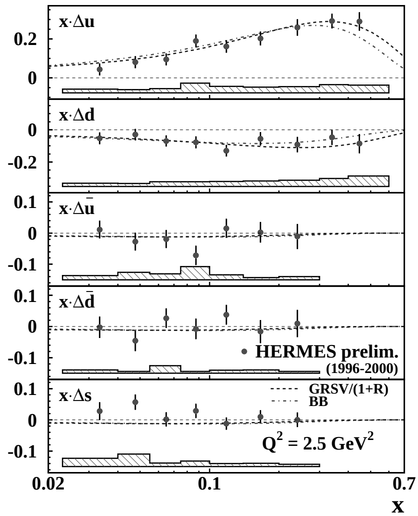

Fig. 3. Polarized quark distributions $x\,\Delta q(x)$ extracted from HERMES inclusive and semi-inclusive asymmetries on polarized hydrogen and deuterium targets. All data are evolved to $Q^2 = 2.5$ GeV^2. The dashed curves correspond to the GRSV00 parametrizations from Glück *et al.* [9], while the dot-dashed curves represent the results of a LO QCD analysis by Blümlein and Böttcher [8]. The error bars and bands correspond to the statistical and systematic uncertainties, respectively.

polarizations are consistent with zero. The result for the strange quarks, however, favors a slightly positive polarization at small values of x. Using the same fitting formalism, the value of $\Delta\bar{u} - \Delta\bar{d}$ was extracted as a function of x (see Fig. 4). No breaking of the flavor symmetry in the light sea quark polarization is observed at the present level of experimental accuracy.

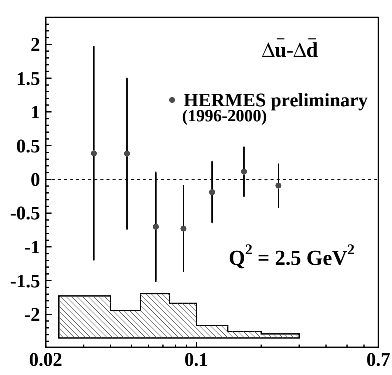

Fig. 4. Result for $\Delta\bar{u} - \Delta\bar{d}$ as a function of x at $Q^2 = 2.5$ GeV^2. The error bars correspond to the statistical uncertainties, and the error bands to the systematic uncertainties.

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