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Measurement of the spin structure functions and latest results on quark helicity distributions from Deep-Inelastic Scattering at HERMES

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Abstract

The HERMES experiment at DESY is a second generation experiment to provide a precise measurement of the nucleon spin structure in deep-inelastic lepton scattering. Using the 27.5 GeV longitudinal polarised lepton beam at HERA and longitudinally polarized hydrogen and deuterium gasous targets, the HERMES experiment can probe the longitudinal spin structure functions $g_1^{p,d,n}$ and the quark helicity distributions. An overview of most recent results is given.

1 Introduction

The spin structure of the nucleon has been one of the most important subjects in Quantum ChromoDynamics (QCD) since the European Muon Collaboration [1] reported that the quark spin contribution to the proton spin is small, an observation which commonly refered to as *Proton Spin Puzzle.* The nucleon spin can be decomposed conceptually into the angular momentum contributions of its constituents according to equation

$$S^N = \frac{1}{2} = \frac{1}{2}\triangle\Sigma + L_g + J_g, \tag{1}$$

where the three terms give the contributions to the nucleon spin from the quark spins, the quark orbital angular momentum, and the total angular momentum of the gluons, respectively. The objective of these studies is to determine the fraction of the nucleon spin which is carried by the quarks. Detailed information on $\triangle\Sigma$ and its flavor decomposition can be obtained from various

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sources. The HERMES experiment at DESY uses the 27.5 GeV polarized lepton beam of the HERA collider and pure polarized gaseous targets (hydrogen or deuterium). With a large forward acceptance of the HERMES spectrometer and its reliable particle identification [2] it is possible to measure not only inclusive reactions in deep-inelastic scattering, where only the scattered lepton is detected, but also semi-inclusive DIS events where hadrons are detected in coincidence with the lepton. For the hydrogen data set, pions could be identified using the information from a threshold Cherenkov counter (1996-1997 years). For the deuterium data a Ring-Imaging Cherenkov (RICH, 1998-2000 years) detector provided identification of pions and kaons over the kinematic range of 2-15 GeV/c.

2 Spin Structure Function g_1

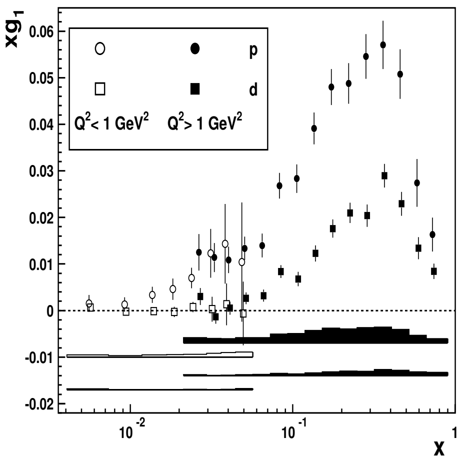

Fig.1. HERMES result for xg_1 vs x for the proton and the deutron

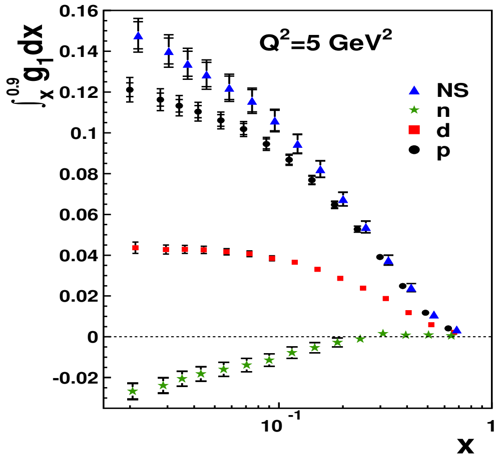

Fig.2. Integrals of $g_1^{p,d,n,NS}$ over the range $0.021 \leq x \leq 0.9$.

The polarised structure functions $g_1^{p,d}$ can be extracted from double-spin asymmetries $A_{||}^{p,d}$ in inclusive deep-inelastic scattering (DIS) using

$$g_1(x,Q^2) = \frac{1}{1-\frac{y}{2}-\frac{y^2}{4}\gamma^2} \times \left[\frac{Q^4}{8\pi\alpha^2 y} \frac{d^2\sigma_{UU}(x,Q^2)}{dxdQ^2} A_{||}(x,Q^2) + \frac{y}{2}\gamma^2 g_2(x,Q^2) \right] \tag{2}$$

The final HERMES results for the polarized structure function g_1 [3] from all data taken with longitudinally polarized hydrogen and deuterium targets are presented in Fig. 1. The statistical precision of the HERMES proton data is comparable to that of the hitherto most precise data from CERN and SLAC in the same x range. The HERMES deuteron data provide the most precise determination of the spin structure function $g_1^d(x, Q^2)$. In the region $x < 0.03$ the SMC data favor negative values, while the HERMES deuteron data are compatible with zero, as are the recent COMPASS data. As shown in Fig.2, integrals of the spin structure function g_1 of proton, deuteron and neutron were evaluated. The HERMES deuteron integral appears to saturate at $x < 0.04$. Based on saturation of the integral of g_1^d and using the assumption of SU(3) flavor symmetry in the hyperon decays in the spin-$\frac{1}{2}$ baryon octet, the flavor-singlet axial charge a_0 has been determined:

$$a_0(Q^2 = 5GeV^2) = 0.330 \pm 0.011(theo.) \pm 0.025(exp.) \pm 0.028(evol.). \quad (3)$$

In the $\overline{MS}$ scheme which was used in this analysis, a_0 can be interpreted as the contribution of quark helicities to the nucleon helicity. A value of 1/3 acquires still major contribution from gluons and/or orbital angular momenta of quarks and gluons.

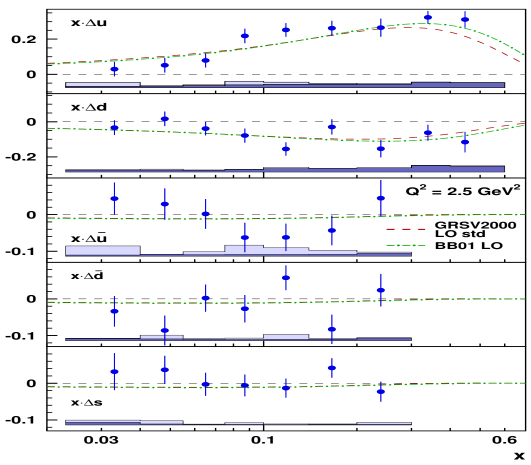

Fig.3. Quark helicity distributions $x\triangle q(x, Q_0^2)$ at $Q_0^2 = 2.5GeV^2$. The curves show LO QCD global analysis [6].

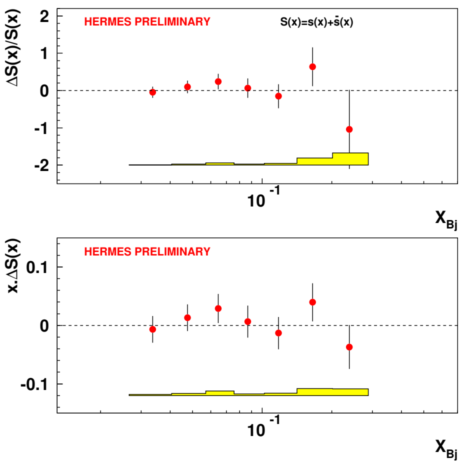

Fig.4. Strange quark helicity distributions at $Q^2 = 2.5GeV^2$ as a function of x.

3 Quark Helicity Distribution

Semi-inclusive DIS (SIDIS) is a powerful tool to determine the separate contributions $\triangle q_f(x)$ of the quarks and antiquarks of flavor f to the total spin of the nucleon. The hadron asymmetries $A_1^h(x)$ are related to the quark polarization distributions $\triangle q_f(x)$ through the so-called purity matrix P_f^h. A combined analysis of the inclusive and semi-inclusive spin asymmetries for

π^+, π^-, K^+ and K^- has been carried out for the longitudinally polarized hydrogen and deuterium targets [4]. Figure 3 shows the results for the x-weighted distributions $x\triangle q(x)$. Note that in contrast to the LO QCD fits to inclusive data overlaid in Fig.4, in the HERMES analysis no assumptions were made on the symmetry of the sea quark polarizations, except $\triangle\overline{s}/\overline{s}$ is assumed to be zero. The systematic error bands include uncertainties in addition to the experimental error of the asymmetries (used pdf's, tune for extracting purities). For $x > 0.3$, the polarization of the sea flavors was set to zero, the small uncertainties for the non-sea flavors arising from this as well as from setting $\triangle\overline{s}/\overline{s} \equiv 0$ were also included in the systematic error. As expected the helicity density of the u quark is found to be positive and large at $x > 0.1$, and that of the d quark is negative and rather flat in x. The helicity densities of the light sea quarks are all found to be compatible with zero. For sea quarks, within the experimental uncertainties, there is no disagreement with the QCD fits.

4 Isoscalar method

An alternative analysis was performed on the extractions of $\triangle s(x) + \triangle\overline{s}(x)$ [5]. Because the strange quark helicity $\triangle s(x) + \triangle\overline{s}(x)$ has no isospin, it can be extracted from the isoscalar deuteron target alone. A simple purity matrix can be computed extracting the needed purities for kaons from the measured HERMES multiplicities. The strange helicity distributions obtained in the HERMES leading-order analysis are presented in Fig.4. The integral over the measured region of x is consistent with zero.

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