Measurement of ΔS in the nucleon at HERMES from semi-inclusive DIS

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Abstract. The helicity density of the strange quark sea in the proton has been extracted from measurements of polarized semi-inclusive production of charged kaons in deep-inelastic scattering of positrons from a polarized deuteron target. In the region of measurement of x $>$ 0.02 the helicity density is zero within experimental error and the measured first moment of the density is 0.006$\pm$0.029(stat.)$\pm$0.007(sys.). The first moment of the axial charge in the measured region is substantially less than that inferred from hyperon semi-leptonic decays.

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INTRODUCTION

The helicity distribution of the strange quark sea is of great interest as a probe of the spin properties of the quark sea in the nucleon. Because strange quarks carry no isospin, the total strange quark helicity density $\Delta S(x) \equiv \Delta s(x) + \Delta\bar{s}(x)$ can be extracted from measurements of scattering off the deuteron alone which is isoscalar. In effect, measurements of the inclusive spin asymmetries provide an estimate of the helicity density $\Delta Q(x) \equiv \Delta u(x) + \Delta\bar{u}(x) + \Delta d(x) + \Delta\bar{d}(x)$ of the non-strange sea. Using the spin asymmetries measured for the charged kaons as the second measured quantity, it is possible to extract $\Delta S(x)$. By measuring the charged kaon multiplicites with the same data set, the fragmentation functions relevant to the extraction process can be obtained without resort to other experiments. Aside from that of isospin symmetry between the proton and the neutron, the only assumption required in the analysis is charge-conjugation invariance in the fragmentation process. A precise “isoscalar” extraction of $\Delta S(x)$ using semi-inclusive DIS on the deuteron at HERMES [1] is presented here.

THE EXPERIMENT

In leading-order (LO), the semi-inclusive virtual photon double-spin asymmetry A_1^K in semi-inclusive production of a Kaon is given by

$$A_1^K(x,z) = \frac{\sigma_{1/2}^K - \sigma_{3/2}^K}{\sigma_{1/2}^K + \sigma_{3/2}^K} = \frac{\sum_q e_q^2\, \Delta q(x)\, D_q^K(z)}{\sum_q e_q^2\, q(x)\, D_q^K(z)}\,, \tag{1}$$

The asymmetries for the analysis reported here were recorded by the HERMES experiment using a longitudinally nuclear-polarized deuteron gas target internal to the E =

27.6 GeV HERA positron storage ring at DESY. The self-induced beam polarization is measured continuously with Compton back-scattering of circularly polarized laser beams [2, 3]. The open-ended target cell is fed by an atomic-beam source based on Stern-Gerlach separation [4] with hyperfine transitions. The nuclear polarization of the atoms is flipped at 90 s time intervals, while both this polarization and the atomic fraction inside the target cell are continuously measured [5, 6].

Scattered beam leptons and coincident hadrons are detected by the HERMES spectrometer [7]. Leptons are identified with an efficiency exceeding 98% and a hadron contamination of less than 1% using an electromagnetic calorimeter, a transition-radiation detector, a preshower scintillation counter and a Čerenkov detector. Charged kaons are identified using a dual-radiator ring-imaging Čerenkov detector [8]. Events were selected subject to the kinematic requirements $Q^2 > 1\,\mathrm{GeV}^2$, $W^2 > 10\,\mathrm{GeV}^2$ and $y < 0.85$, where W is the invariant mass of the photon-nucleon system, ν is the virtual photon energy, and $y = \nu/E$. Coincident hadrons were accepted if $0.2 < z < 0.8$ where $z = E_{hadron}/\nu$, and $x_F \approx 2p_L/W > 0.1$, where p_L is the longitudinal momentum of the hadron with respect to the photon direction in the photon-nucleon center of mass frame.

EXTRACTION OF HELICITY DISTRIBUTIONS

For the deuteron Eq. 1 reduces to a simple form which reflects its isoscalar character

$$A_1^K(x) \quad = \quad \frac{\Delta Q(x)\int \mathscr{D}_Q^K(z)dz + \Delta S(x)\int \mathscr{D}_S^K(z)dz}{Q(x)\int \mathscr{D}_Q^K(z)dz + S(x)\int \mathscr{D}_S^K(z)dz} \tag{2}$$

Where $\int \mathscr{D}_Q^K(z)dz = 4\int D(z)_u^{K^\pm}dz + \int D(z)_d^{K^\pm}dz$ and $\int \mathscr{D}_S^K(z)dz = 2\int D(z)_s^{K^\pm}dz$. The corresponding inclusive asymmetry is given by

$$A_1(x) = \frac{5\Delta Q(x) + 2\Delta S(x)}{5Q(x) + 2S(x)}. \tag{3}$$

The helicity distributions $\Delta Q(x)$ and $\Delta S(x)$ have been extracted directly from the measured values of $A_1(x)$ and $A_1^{K^\pm}(x)$ using the fragmentation functions defined above as measured with the same data set and the parton distributions Q(x) and S(x) taken from the latest compilations. The resulting strange and non-strange helicity distributions weighted by Bjorken x are presented in Fig. 1. The non-strange helicity distribution is in excellent agreement with that derived from the published five-component flavor decomposition [1] of the proton helicities. While of much improved precision and free of the systematic uncertainties in the fragmentation functions, the strange helicity distribution also agrees well with the results reported therein, and is consistent with zero over the measured range.

The first moment of $\Delta S(x)$ in the measured region is 0.006$\pm$ 0.029(stat.)$\pm$0.007(sys.). The result for the first moment of $\Delta Q(x)$ is 0.0286$\pm$0.026(stat.) $\pm$ 0.011(sys.) which is in excellent agreement with values previously measured at HERMES [9, 1]. The first moment of $\Delta S(x)$ is consistent with zero in the measured region. Because the very small density of strange quarks above $x = 0.3$, the contribution of any non-zero helicity

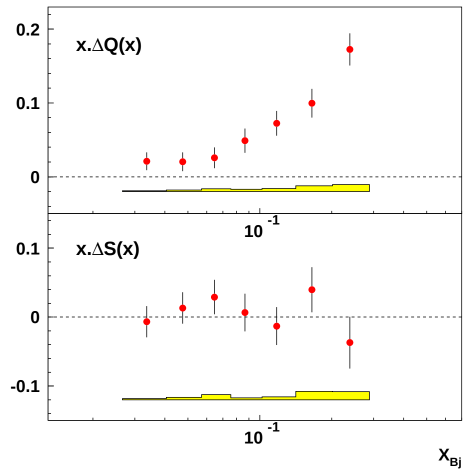

FIGURE 1. Strange and non-strange quark helicity distributions at $\langle Q^2 \rangle = 2.5\,\mathrm{GeV}^2$, as a function of Bjorken x. The error bars are statistical, and the bands at the bottom represent the systematic uncertainties.

density in this region is negligible compared to the systematic error of the measurement. Consequently, the value for S(x) can be safely taken as the moment over the Bjorken x range 0.02-1.0. The vanishing values recently reported [10] for $g_{1,d}(x)$ at lower values of x, suggest that any contribution to the first moment of $\Delta Q(x)$ below $x = 0.02$ will be very small. While an anomalously large contribution to the strange moment at $x < 0.02$ can not be ruled out, the data reported here strongly suggest that the first moment vanishes. If true the violation of the Ellis-Jaffe sum rule observed in inclusive scattering is not due to a significant negative polarization of the strange sea. The result for the first moment of the octet axial charge $a_8 = \int (\Delta Q(x) - 2\Delta S(x))dx$ is 0.0286±0.026(stat.)± 0.011(sys.), substantially less than the value inferred from hyperon decay.

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