

TRANSVERSITY RESULTS FROM HERMES

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Preliminary results from the HERMES experiment on azimuthal single-spin asymmetries in semi-inclusive electroproduction of charged hadrons in deep-inelastic scattering of positrons on a transversely polarised hydrogen target are presented. The Collins and Sivers azimuthal moments are extracted for the first time for charged kaons, as a function of x , z and $P_{h\perp}$.

1. Introduction

After averaging over the quark transverse momentum p_T , three parton distribution functions are needed at leading twist for a complete description of the momentum and spin distributions of the quarks within the nucleon. Two of these have been experimentally explored in some detail: the well known momentum (or unpolarised) distribution $q(x, Q^2)$, reflecting the probability to find quarks within the nucleon carrying a fraction x of the nucleon momentum at photon virtuality Q^2 , and the helicity distribution $\Delta q(x, Q^2)$ reflecting, in the helicity basis, the difference in probabilities to find quarks in a longitudinally polarised nucleon with their spin aligned to the spin of the nucleon and quarks with their spins anti-aligned¹. Viewed in the same helicity basis, the third distribution $\delta q(x, Q^2)$, known as transversity^{2,3,4}, is related to a forward scattering amplitude involving helicity flip of both quark and target nucleon ($N^{\Rightarrow}q^{\leftarrow} \rightarrow N^{\leftarrow}q^{\Rightarrow}$) and has no probabilistic interpretation. However, in a basis of transverse spin eigenstates it becomes a number density reflecting the difference in probabilities to find quarks in a transversely polarised nucleon with their spin aligned to the spin of the nucleon and quarks with their spins anti-aligned. Since hard interactions conserve chirality, transversity has so far remained unmeasured in inclusive processes due to its chiral-odd nature.

At HERMES, the so called *Collins moments*, in which transversity is con-

volved with the chiral-odd Collins fragmentation function, are accessible through azimuthal single-spin asymmetries (SSA) in semi-inclusive DIS on a transversely polarised proton target. In such events, the scattered lepton is required to be detected in coincidence with at least one of the hadrons produced in the fragmentation of the struck quark. The Collins function describes the correlation between the transverse spin of the struck quark and the transverse momentum $P_{h\perp}$ of the produced hadron ⁵. The transverse polarisation of the struck quark can indeed influence the transverse (with respect to the virtual photon direction) component of the hadron momentum, leading to a left-right asymmetry in the momentum distribution of the produced hadrons in the direction transverse to the nucleon spin (*Collins mechanism*) ⁶. However such asymmetries might also arise from a completely different mechanism involving a correlation between the transverse polarisation of the target nucleon and the transverse momentum p_T of quarks (*Sivers mechanism*) ⁷. This correlation is represented by the Sivers distribution function f_{1T}^\perp , which, being related to a forward scattering amplitude involving helicity flip of only the target nucleon ($N \Rightarrow q^{\leftarrow} \rightarrow N^{\leftarrow} q^{\leftarrow}$), must involve orbital angular momentum of the quarks ⁸. The so called *Sivers moments*, which are proportional to a convolution of the Sivers function times the unpolarised fragmentation function, are also accessible at HERMES in semi-inclusive DIS events.

2. The HERMES experiment

The data reported here were recorded during the 2002–2004 running period of the HERMES experiment ⁹ using a transversely nuclear-polarised hydrogen gas target internal to the HERA positron storage ring at DESY. The 27.5 GeV positron beam was unpolarised at this time. The average value of the proton polarisation P_z was 0.754 ± 0.050 . Positrons were identified with an efficiency exceeding 98% and a negligible hadron contamination. In addition, very good hadron separation between pions, kaons and protons was achieved thanks to the dual-radiator ring-imaging Čerenkov detector.

3. Extraction of Collins and Sivers moments

Events were selected subject to the kinematical requirements $W^2 > 10 \text{ GeV}^2$, $0.1 < y < 0.85$ and $Q^2 > 1 \text{ GeV}^2$, where W is the invariant mass of the initial photon-nucleon system and y is the fractional energy transfer to the target. Coincident hadrons were accepted if $0.2 < z < 0.7$ and $\theta_{\gamma^*h} > 0.02$ rad, where z is the energy fraction of the hadron and θ_{γ^*h}

is the angle between the directions of the virtual photon and the hadron. For each hadron type h , the cross section asymmetry with respect to the target polarisation was evaluated as a two-dimensional distribution in ϕ and ϕ_S :

$$A_{\text{UT}}^h(\phi, \phi_S) = \frac{1}{|P_z|} \frac{N_h^{\uparrow}(\phi, \phi_S) - N_h^{\downarrow}(\phi, \phi_S)}{N_h^{\uparrow}(\phi, \phi_S) + N_h^{\downarrow}(\phi, \phi_S)}, \quad (1)$$

where $N_{h\pm}^{\uparrow(\downarrow)}$ represents the semi-inclusive yield in the target spin state “ \uparrow (\downarrow)”. The azimuthal angles ϕ and ϕ_S , defined with respect to the lepton scattering plane, are shown in Fig. 1.

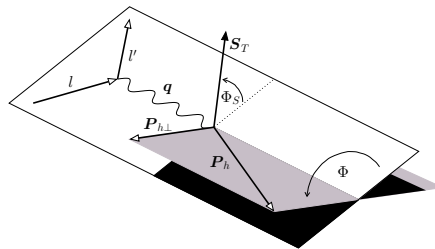


Figure 1. Kinematics of semi-inclusive DIS on a transversely polarised target.

The cross section asymmetry (Eq. 1) can be expanded in terms of several azimuthal moments modulated by the sine or the cosine of different combinations of ϕ and ϕ_S . In particular, the Collins and Sivers moments, which are both leading-twist quantities, have a distinctive azimuthal dependence: $\sin(\phi + \phi_S)$ for the Collins moments and $\sin(\phi - \phi_S)$ for the Sivers moments. A first measurement of non-zero Collins and Sivers moments for charged pions has been recently achieved by the HERMES Collaboration as a function of x , z and $P_{h\perp}$ in a least-squares fit of the cross-section asymmetry (Eq. 1) ¹⁰. These moments have now been extracted for the first time for charged kaons (Fig. 2) using a maximum-likelihood based fit. Effects of acceptance, instrumental smearing and QED radiation were all found to be negligible in Monte Carlo simulations and the largest contribution to the systematic uncertainties (error bands in figure) is due to the target polarisation. The average Collins moments for K^+ and K^- are $A_{K^+}^{\text{Coll}} = 0.0172 \pm 0.0232 \pm 0.0177$ and $A_{K^-}^{\text{Coll}} = 0.0605 \pm 0.0450 \pm 0.0220$, respectively. The average Sivers moments for K^+ and K^- are $A_{K^+}^{\text{Siv}} = 0.0925 \pm 0.0147 \pm 0.0091$ and $A_{K^-}^{\text{Siv}} = 0.0167 \pm 0.0266 \pm 0.0093$, respectively.

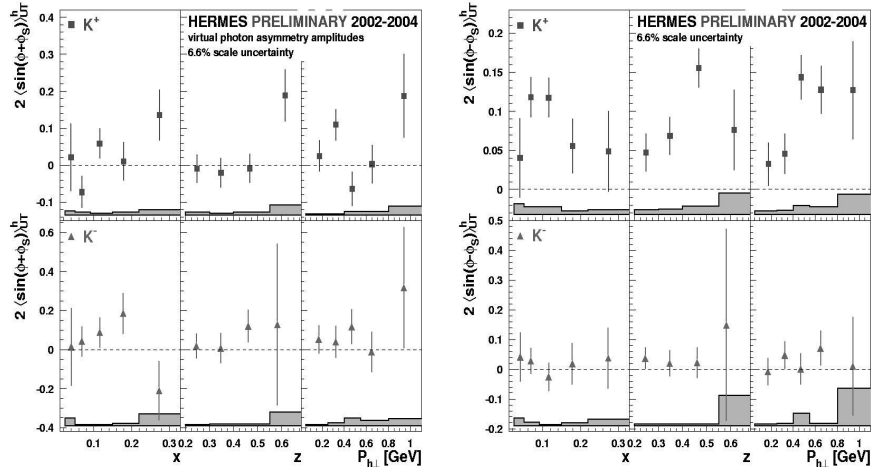


Figure 2. Virtual-photon Collins (left) and Sivers (right) moments for K^+ and K^- as a function of x , z and $P_{h\perp}$.

While there is no reason to expect a similar Collins amplitude for K^- and π^- , being the K^- a fully sea object, the u -quark dominance in DIS would suggest a similar amplitude for K^+ and π^+ . However a smaller amplitude is observed for K^+ (Fig. 2) than for π^+ ¹⁰. As in the case of unpolarised fragmentation functions, the Collins function may thus differ for fragmentation of u into K^+ and u into π^+ . On the other hand, the amplitude of the Sivers moment for K^+ (Fig. 2) is roughly twice as big as that for π^+ (Ref.¹⁰) in the region $x \approx 0.1$. This suggests that the sea quarks may provide an important contribution to the Sivers function, and so, may carry significant orbital angular momentum in the nucleon.

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