TRANSVERSE SPIN PHYSICS AT HERMES*

Ingrid-Maria Gregor

for the Hermes Collaboration
DESY, Platanenallee 6, 15738 Zeuthen, Germany

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The main focus of the Hermes experiment is the experimental investigation of the spin structure of the nucleon. For Run II of Hermes one of the main topics is the study of the transverse spin structure of the nucleon. Using a transversely polarised hydrogen target single-spin asymmetries are measured in semi-inclusive electro-production of charged and neutral pions in deep inelastic scattering. Two different azimuthal dependences that can be related to the transversity distribution are extracted.

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1. Introduction

The Hermes experiment at the DESY laboratory has accomplished important contributions to the study of the nucleon spin structure. Since 2001 Hermes is taking data with a transversely polarised internal gas target to study the "transverse" spin structure of the nucleon. In this contribution a short overview of the quantity transversity is given and first results obtained with the transversely polarised target are summarised.

A quark of a given flavour is characterised by three twist-two parton distributions, providing a complete description of the nucleon at the quark level. The first one, q, is the spin-independent quark number density while the helicity distribution Δq reflects the probability of finding the helicity of the quark to be the same as that of the target nucleon. The third distribution, δq, is the transversity distribution and describes in a transversely polarised basis the probability to find a quark with its spin parallel or antiparallel to the spin of the nucleon that is polarised transversely to its momentum

$$\delta q(x) = q^{\uparrow}(x) - q^{\downarrow}(x)\,. \tag{1}$$

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Here x is the dimensionless Bjorken scaling variable representing the momentum fraction of the target carried by the parton.

The quark number density q has been measured quite accurately [1,2], while the helicity distribution Δq was very recently well measured for u and d quarks [3]. No data to access the transversity distribution δq was available until very recently. However, a number of properties were known from theoretical calculations: due to the positivity of the correlation matrix in helicity space the absolute of the transversity is smaller than the helicity density ($|\delta q| \leq \Delta q$) and the Soffer bound [4] gives:

$$2|\delta q(x)| \leq q(x) + \Delta q\,. \tag{2}$$

In the non-relativistic case where boosts and rotations commute, δq and Δq would be identical. Hence the difference between Δq and δq allows an insight to the relativistic nature of the quarks. From angular momentum conservation it can be derived that the transversity has no gluon component and, therefore, the QCD evolution is expected to be the same for δq as compared to Δq. Furthermore, quarks and antiquarks contribute with opposite sign to δq which leads to a predominant sensitivity to the valence quark polarisation. The common unpolarised and longitudinally polarised quark distributions q and Δq are related to the matrix elements of vector and axial-vector currents, respectively, which preserve chirality, *i.e.* are chiral even. The transversity δq is related to the tensor current and is a chiral odd object, *i.e.*, transversity is associated with a helicity flip. Since chirality is conserved in all hard QCD and electroweak processes there is no access to transversity in fully inclusive deeply inelastic scattering. However, it might be accessed by a process involving some additional chiral odd structure. This additional partner, a second chiral odd distribution function or a chiral odd fragmentation function, would regain the chirality conservation [4]. This is illustrated in the handbag diagram in Fig. 1. Such a necessary object leads to a single spin asymmetry (SSA).

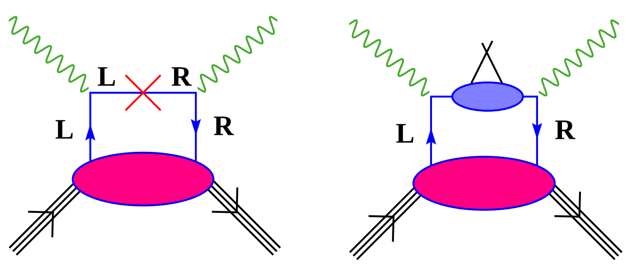

Fig. 1. Left-hand side: the chirality flip is forbidden by chirality conservation. Right-hand side: a chiral odd object preserves chirality.

One possible chiral odd object preserving the chirality of the interaction was proposed by Collins: the Collins effect describes the process where the quark fragments into a pion; the spin of the quark is transformed into orbital angular momentum during the fragmentation process [5]. This results in a correlation to the transverse momentum of the produced hadron and can give it an additional transverse momentum which may lead to a single spin asymmetry. The Collins function $H_1^{\perp(1)q}$ enters the cross section combined with the transversity distribution δq. By measuring the afore mentioned asymmetry, the transversity distribution could be accessed when the Collins fragmentation function is known.

There exists a completely different possible mechanism for producing target single-spin asymmetries, described by the Sivers function $f_{1\mathrm{T}}^{\perp(1)q}$ [6]. Here, in a transverse polarised target nucleon a quark with correlated primordial transverse momentum is found. The observed asymmetry is attributed to the interaction of the struck quark with the target remnants through the exchange of a single gluon. The Sivers function appears in the cross section together with the unpolarised fragmentation function D_1^q.

In the case of transversity the Collins and Sivers effects are both directly resulting in an azimuthal asymmetry. It can be measured via the difference of the polarisation states of the detected hadrons, normalised by its sum and the average polarisation

$$A(\phi) = \frac{1}{\langle P \rangle} \, \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)} \,. \tag{3}$$

In Fig. 2 the scattering plane and the different angles are shown for the case of a transversely polarised target.

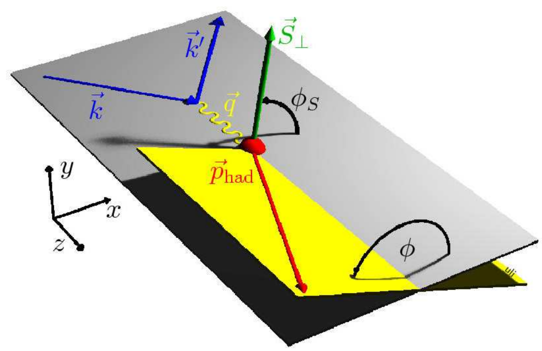

Fig. 2. Definition of the angles: the angle ϕ (ϕ_S) is the azimuthal angle of the scattered hadron (the target spin vector) around the virtual photon with respect to the lepton scattering plane.

The asymmetry can be written as the sum of two sine functions:

$$A(\phi) = A_{\mathrm{UT}}^{\sin(\phi+\phi_S)} \sin(\phi+\phi_S) + A_{\mathrm{UT}}^{\sin(\phi-\phi_S)} \sin(\phi-\phi_S)\,. \tag{4}$$

The amplitudes of each sine term are in leading order proportional to the product of a distribution function and a fragmentation function, respectively,

$$A_{\mathrm{UT}}^{\sin(\phi+\phi_S)} \sim \sum_q e_q^2\, \delta q\, H_1^{\perp(1)q}(z)\,, \tag{5}$$

and

$$A_{\mathrm{UT}}^{\sin(\phi-\phi_S)} \sim \sum_q e_q^2\, f_{1\mathrm{T}}^{\perp(1)q}(x)\, D_1^q(z)\,. \tag{6}$$

2. Results obtained with the Hermes transversely polarised target

The data reported here were recorded during the 2002–2003 running period of the Hermes experiment using a transversely polarised hydrogen gas target [7] internal to the 27.5 GeV Hera positron storage ring at DESY. Scattered beam leptons and any coincident hadrons are detected by the Hermes spectrometer [8]. Azimuthal asymmetries of produced hadrons were measured to unfold the Collins and the Sivers term (*cf.* Eq. (4)). This is only possible with a large data set. The single spin asymmetries $A_{\mathrm{UT}}^{\sin(\phi+\phi_S)}$ and $A_{\mathrm{UT}}^{\sin(\phi-\phi_S)}$ are shown for the production of π^+, π^-, and π^0 in Fig. 3 and 4, respectively. The results for the Collins asymmetry are quite surprising as the asymmetry for π^- is larger than the one for π^+ assuming a behaviour for the transversity distribution similar to that of the helicity distribution [9]. The Sivers asymmetry $A_{\mathrm{UT}}^{\sin(\phi-\phi_S)}$ is found slightly positive for π^+ and π^0 while it is consistent with zero for π^-. A detailed physics interpretation of this data can be found in Ref. [10]. It appears that the fragmentation which is disfavoured in terms of quark flavour has a surprising importance in case of the Collins related asymmetry. It enters with a sign opposite to that of the favoured case. An interesting explanation of a non-zero Sivers function is a non-vanishing orbital angular momentum of the quarks [11].

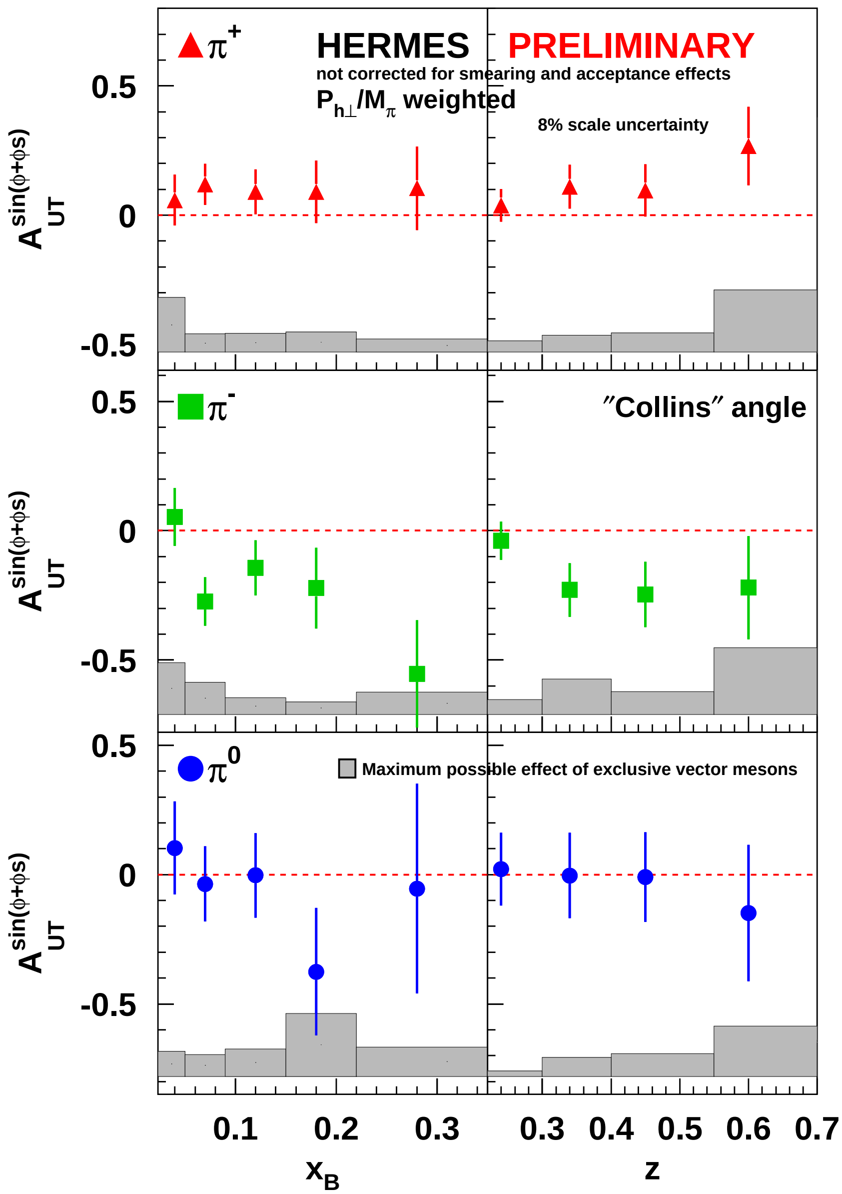

Fig. 3. Collins Asymmetries $A_{\rm UT}^{\sin(\phi+\phi_S)}$ for π^+, π^- and π^0 as a function of x and z (z is the energy fraction of the detected hadron w.r.t. the energy of the real photon). The error bars represent the statistical uncertainties, while the lower bands represent the possible interpretive uncertainties from diffractive vector meson production.

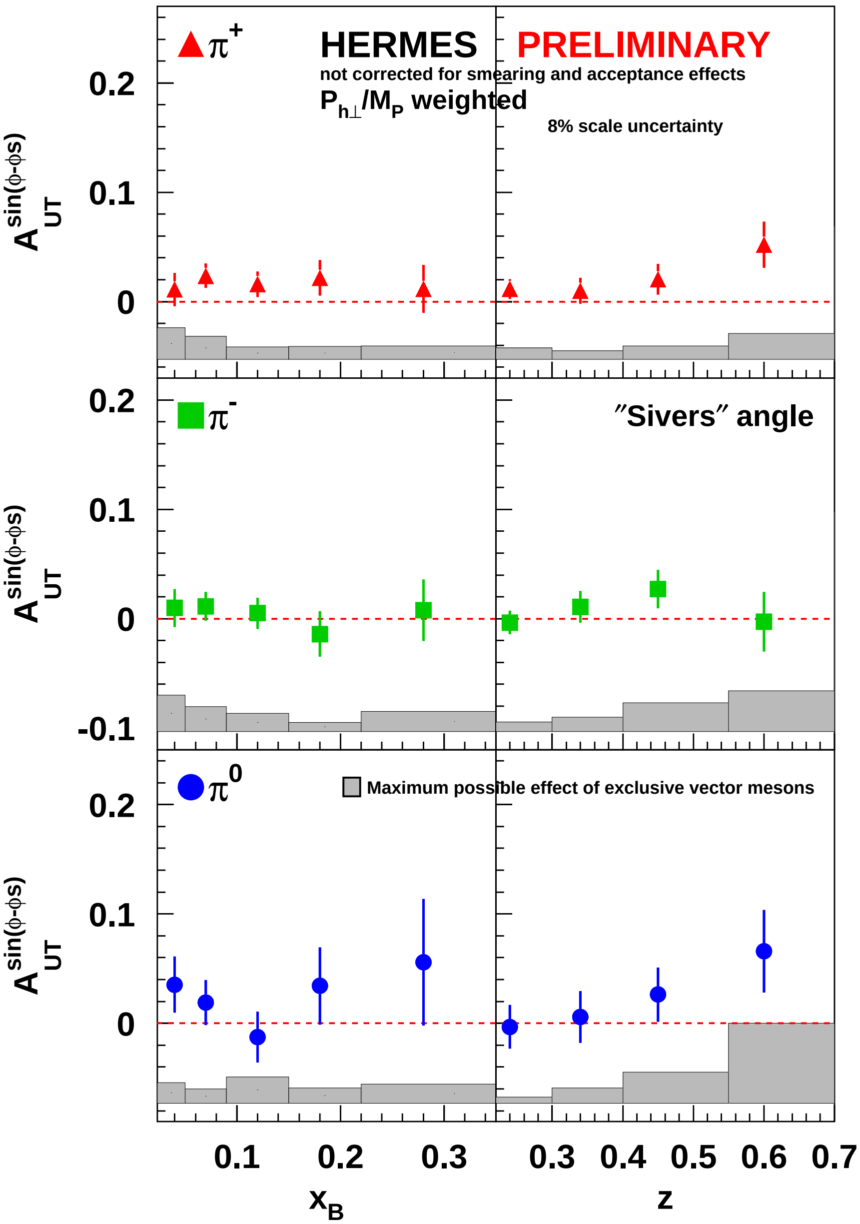

Fig. 4. Sivers asymmetries $A_{\rm UT}^{\sin(\phi-\phi_S)}$ for π^+, π^- and π^0 as a function of x and z. Notations are as in Fig. 3.

3. Outlook

The HERMES experiment is continuing data taking with the transversely polarised target until summer 2005. By then a total number of 4 million DIS events is expected to be collected. With this amount of events a significant reduction of the statistical uncertainties is expected.

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