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TRANSVERSITY MEASUREMENTS AT HERMES

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Single Spin azimuthal Asymmetries (SSA) in semi-inclusive deep-inelastic lepton-nucleon scattering can in general be produced by time reversal odd (T-odd) distribution or fragmentation functions. In the case of an unpolarised positron beam and a longitudinally or transversely polarised target, SSAs can have two origins: the chiral odd transversity distribution $\delta q(x)$ in conjunction with the chiral odd Collins fragmentation function $H_1^\perp(z)$ and the T-odd Sivers distribution function $f_{1T}^\perp(x)$ in conjunction with a spin-independent fragmentation function. In the case of a longitudinally polarised target both mechanisms contribute to the same asymmetry, whereas in case of transverse target polarisation they give rise to different angular dependences and can therefore be measured separately. The first results of HERMES data taking with a transversely polarised proton are presented.

1 Transverse momentum dependent Distribution and Fragmentation Functions

In semi-inclusive deep-inelastic scattering (SIDIS) only 3 Parton-distribution functions (DF) remain at leading twist after integration over the intrinsic transverse momentum of the quarks in the nucleon. These are the well known momentum DF $q(x)$, the helicity DF $\Delta q(x)$ and the as yet unmeasured transversity DF $\delta q(x)$. The latter describes the difference between the probability to find a transversely polarised quark parallel and antiparallel to the transversely polarised nucleon [Jaf92]. Here x is the Bjorken scaling variable, representing the fraction of the target momentum carried by the parton. In addition, also transverse momentum dependent DFs exist with as the most prominent example the Sivers Function $f_{1T}^\perp(x, p_T)$. This DF describes the probability to find an unpolarised quark in a transversely polarised nucleon [Siv90]. Only recently was it realized that the transverse momentum dependent functions can be understood in terms of a final-state interaction. This creates an interference of amplitudes giving rise to the T-odd nature of some of these functions and resulting in observable Single Spin Asymmetries (SSA) [Bro02,Ji02,Col02,Bel03] .
Since all hard interactions conserve chirality, the chiral odd transversity DF can only be probed in conjunction with another chiral odd object. In the Drell-Yan process this can be a second transversity distribution, whereas in SIDIS the 2nd chiral-odd structure has to be associated with the fragmentation process leading to the production of the detected hadron from the struck quark. The fragmentation function (FF) $H_1^\perp$, known as the Collins Function, is indeed chiral odd and it is also T-odd which results in a Single Spin Asymmetry.

2 Longitudinally polarised vs. transversely polarised target

The Collins and Sivers effect both result in a SSA. These azimuthal asymmetries are characterised by the Fourier components of the involved azimuthal angles ϕ and ϕ_s, where ϕ describes the angle between the lepton scattering plane and the hadron production plane along the direction of the virtual photon and ϕ_s is the angle between the transverse component of the target spin, relative to the virtual photon, and the lepton scattering plane. The $\sin(\phi+\phi_s)$ moment of the asymmetry A_{UT} of an unpolarised lepton beam and a transversely polarised target contains in leading twist $\delta q(x)$ in conjunction with the Collins FF $H_1^{\perp}(z)$, while its $\sin(\phi-\phi_s)$ moment contains the Sivers function $f_{1T}^{\perp}(x)$ in conjunction with the unpolarised FF $D_1(z)$. Here, $z \stackrel{lab}{=} E_h/\nu$ is the energy fraction of the transferred energy ν that the hadron h carries.
The previous measurements of HERMES made use of a longitudinally polarised target [Air00,Air01,Air03] and therefore the azimuthal target angle ϕ_s was always either 0 or π as the spin of the target was parallel to the incoming beam and thus its transverse component always stayed in the lepton scattering plane. For that reason both mechanisms contributed to the same SSA. On the other hand, if a transversely polarised target is used, the two mechanisms can be distinguished as the $\sin(\phi-\phi_s)$ and $\sin(\phi+\phi_s)$ moments are different.

3 Azimuthal asymmetries and moment reconstruction

The raw asymmetries were calculated by the DIS normalised count rate differences between the two opposite spin states ($\uparrow,\downarrow$) and either additionally weighted with the transverse hadron momentum ($w_i = \frac{P_{h\perp,i}}{M_h}$) or left unweighted ($w_i = 1$):

$$A_{UT}(\phi,\phi_S) = \frac{1}{S_T}\frac{\sum_i^{N^\uparrow(\phi,\phi_S)} w_i - \sum_i^{N^\downarrow(\phi,\phi_S)} w_i}{N^\uparrow(\phi,\phi_S) + N^\downarrow(\phi,\phi_S)} \quad , \tag{1}$$

where S_T is the average target polarisation. Several modulations are then fitted simultaneously, where the inclusion of higher moments does not affect the $sin(\phi+\phi_S)$ and $sin(\phi-\phi_S)$ moments one is most interested in. MC studies have shown that such a 2-dimensional binning of the asymmetries is least affected by acceptance effects and contamination by other moments. The data was taken during the 2002 run of the HERMES experiment, using a transversely polarised hydrogen gas target and the 27.5 GeV HERA positron beam. The average polarisation is 0.78 ± 0.04, where the systematic error gives an overall scale uncertainty of 5% for the extracted asymmetries. The HERMES spectrometer provides a lepton-hadron separation with an average lepton identification efficiency of 98% with a hadron contamination of less than 1%. Additionally the dual radiator Ring-Imaging Čerenkov counter (RICH) allows an efficient identification of charged pions, kaons and protons in the momentum range 2 GeV $< P_h <$ 15 GeV. This range was therefore taken as momentum window. Neutral pions were detected by combinations of trackless clusters in the e.m. calorimeter with deposited energies larger than 1 GeV per cluster. These clusters were required to be in the invariant mass region 0.10 GeV $< M_{\gamma\gamma} <$ 0.17 GeV, the sidebands were used to evaluate the combinatorial background and its asymmetries. The asymmetries were fit for the kinematic range $0.023 < x < 0.4$ and $0.2 < z < 0.7$, as displayed in Fig. 1. For the Collins type asymmetries one sees pos-

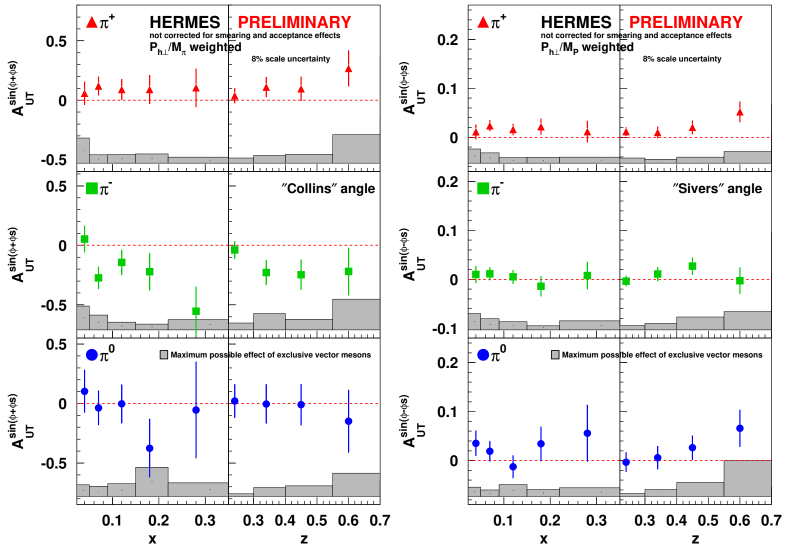

Figure 1. $P_{h\perp}$-weighted asymmetries $A_{UT}^{\sin(\phi\pm\phi_S)}$ for π^+, π^- and π^0 versus the kinematic variables x and z.

itive asymmetries for π^+ and negative asymmetries for π^-. The π^0 asymmetries are compatible with zero. The large magnitude of the π^- asymmetries wrt. the positive pions cannot be explained by the usual assumptions of u-quark dominance and mostly favoured fragmentation. One can rewrite the cross section asymmetries, taking into account only quarks of the 1^{st} generation and favoured and disfavoured fragmentation. A likelihood analysis in the ratio $\delta r := \frac{\delta d(x)+4\delta\bar{u}(x)}{\delta u(x)+1/4\delta\bar{d}(x)}$ performed by sampling asymmetries with Gaussian widths of the statistical error around its central values was performed. This analysis indicates, that these asymmetries cannot constrain the range of the light quark transversities, but do prefer a disfavoured to favoured Collins fragmentation ratio close to $\frac{H_{1,disf}^{\perp,(1)}}{H_{1,fav}^{\perp,(1)}} = -1$. This can be understood in a string fragmentation model [Art93] under the assumption of conservation of the vacuum quantum numbers by the quark-antiquark pair produced in the string breaking.

The Sivers type asymmetries show nonzero and positive asymmetries for π^+ and π^0 while they are consistent with zero for negative pions. This can be related to nonzero Sivers functions, which require a non-vanishing orbital angular momentum of the quarks in the nucleon. No numerical relation could be established as yet, but it can be seen in model calculations applying nonzero angular quark momenta to an impact parameter description of transverse momentum dependent distribution

functions [Bur02].
The grey bands represent the interpretative uncertainties originating from the dilution of exclusive vector meson (VM) decay pions in the semi-inclusive pion samples. At present, the asymmetry transfers from VM asymmetries to the decay pions were calculated with PYTHIA6, assuming maximal VM asymmetries, which would actually break positivity limits. The real asymmetries of the VMs could not be evaluated as not enough statistics are available yet.

4 Outlook

Applying a purity formalism it is possible to extract the Sivers distribution function for the light quarks from the measured asymmetries. In this case only the Sivers function is unknown, which enables a direct application of the Purity formalism [Air03a]. This extraction is in progress.
For the Collins type asymmetries, both the transversity distribution function and the Collins fragmentation functions are unknown. Therefore it is not possible to apply the Purity formalism unless one has either of these functions as additional input. HERMES has increased the data sample by a factor of 4 until now, so more precise date will be available soon.

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