Time-reversal-odd asymmetries at HERA

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Abstract: Longitudinal polarization of the HERA electron beam allows the study of spatial asymmetries in the final state of single inclusive hadron production in $\vec{e}p$-collisions. We estimate the size of a particular production asymmetry which is related to the time reversal properties of the underlying parton level subprocess.

Despite the experimental success of QCD, some of its basic interaction properties are yet undetermined. In particular, only little is known about the behaviour of QCD interactions under discrete symmetry operations. It was shown in [1] that time-reversal properties of a particular interaction can be tested by measuring experimental observables which are odd under the time-reversal operation. Assuming invariance under T, these T-odd observables vanish at tree level but receive contributions from the absorptive part of higher order loop corrections, yielding in general a non-zero effect. The first measurement of a T-odd QCD observable was carried out in hadronic Z^0 decays by the SLD collaboration [2]. Due to the presence of T-odd contributions from QCD and electroweak interactions [3] at $\sqrt{s} = M_Z$, this measurement fails to provide a clean probe of the T-properties of QCD. A complimentary measurement of a T-odd observable in deep inelastic scattering at moderate Q^2 would on the contrary be insensitive to electroweak effects. Such an observable is suggested in [4, 5]: the azimuthal angle between the momenta of the outgoing electron and an outgoing hadron in the plane transverse to the current direction in the target rest frame. This angle can be expressed as a triple product

$$\sin\phi = \frac{\vec{s}\times\vec{k}'\cdot\vec{P_T}'}{|\vec{s}\times\vec{k}'||\vec{P_T}'|}\ ,$$

where $\vec{s}$ denotes the incoming electron spin, $\vec{k}'$ the momentum of the outgoing electron and $\vec{P_T}'$ the transverse momentum of the outgoing hadron relative to the current direction. The leading non-zero contribution inducing a $\sin\phi$-dependence into the single hadron inclusive cross section arises from the absorptive part of the one-loop corrections to the $\gamma^\star q \to qg$ and $\gamma^\star g \to q\bar{q}$ subprocesses and was calculated in [4]. The average angle $\langle\sin\phi\rangle$ is

$$\langle\sin\phi\rangle(z) = \int \mathrm{d}x\mathrm{d}y\mathrm{d}\phi\ \sin\phi\ \frac{\mathrm{d}\sigma}{\mathrm{d}x\mathrm{d}y\mathrm{d}\phi\mathrm{d}z} \Bigg/ \int \mathrm{d}x\mathrm{d}y\mathrm{d}\phi\ \frac{\mathrm{d}\sigma}{\mathrm{d}x\mathrm{d}y\mathrm{d}\phi\mathrm{d}z}. \tag{1}$$

As the numerator is $\mathcal{O}(\alpha_s^2)$ while the denominator is $\mathcal{O}(1)$, one should expect $\langle\sin\phi\rangle$ to be rather small. The non-vanishing of $\langle\sin\phi\rangle$ is manifest as asymmetry between the left and right event hemispheres in a frame defined by the current direction and divided by the lepton scattering plane. It has to be kept in mind that this asymmetry is subleading to the up–down asymmetry

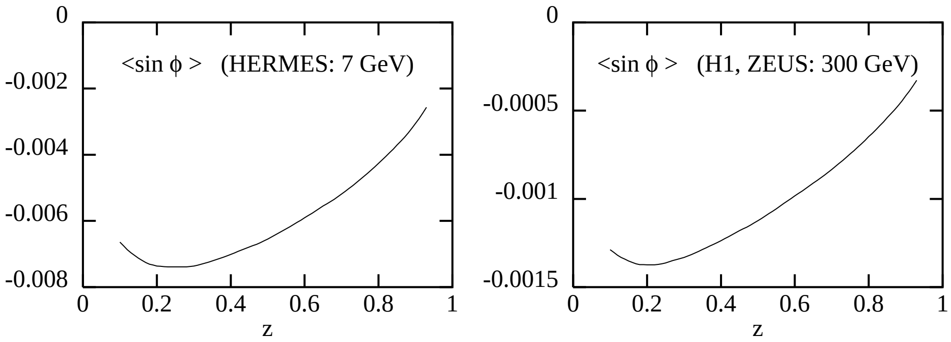

Figure 1: *Expected angular asymmetry in single inclusive hadron production with a beam of left-handed electrons.*

in the same frame, which arises from a $\cos\phi$ dependence of the cross section at $\mathcal{O}(\alpha_s)$ [6]. In order to estimate the expected asymmetries at HERA and at HERMES, we have evaluated the average angle $\langle \sin\phi \rangle$ in the single inclusive production of charged pions and kaons, using the LO parton distribution functions of [7] and the LO hadron fragmentation functions of [8]. To suppress higher twist contributions which can yield sizable T-odd asymmetries [5], we have restricted the final state to $Q^2 > 5$ GeV^2 and $W^2 > 5$ GeV^2. The resulting average angle $\langle \sin\phi \rangle$ for left-handed electrons is shown in Fig. 1 as a function of the longitudinal hadron momentum $z = (P \cdot P')/(P \cdot q)$. The asymmetry for right-handed electrons would be equal in magnitude but opposite in sign. Although the asymmetry appears small at first sight, a measurement might still be possible. The denominator of (1) can be suppressed to $\mathcal{O}(\alpha_s)$ by including only hadrons above a minimal transverse momentum in the measurement. A realistic estimate with a transverse momentum cut has to take effects due to detector resolution and geometry into account and is beyond the scope of the present study.

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