Time-reversal-odd asymmetry in pion leptoproduction at HERMES

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Abstract

We estimate the size of the azimuthal asymmetry of the semi-inclusive pion production in the deep-inelastic scattering of a polarized lepton beam off an unpolarized nucleon target for the produced hadron, arising due to both nonperturbative and perturbative effects.

We analyse numerically the dependence of the azimuthal asymmetry of single inclusive charged pion production in $\vec{e}p$-scattering, shows up as a $\langle \sin\phi \rangle$ (related to the time-reversal-odd structures) on the transverse momentum cutoff P_C at HERMES energies, with taking into account nonperturbative higher-twist [1] and perturbative α_S^2-order QCD [2] contributions.

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 $\gamma^* q \to qg$ and $\gamma^* g \to q\bar{q}$ subprocesses [2]. Although that predicted P_T integrated asymmetry, $\langle \sin\phi \rangle$, is formally free from mass singularities, it may not be free from ambiguities due to the nonperturbative hadronic final-state interactions [1] which could be significant in small-P_T regions. In this respect, introduction of a cutoff in outgoing hadron's transverse momentum P_T [3] may be desirable not only from the experimental, but also from the theoretical point of view.

The single asymmetry, $\langle \sin\phi \rangle$, in the outgoing hadron momentum distribution with respect to the lepton scattering plan is related to the left $(0 < \phi < \pi)$-right $(\pi < \phi < 2\pi)$ asymmetry

$$A(Q^2, x_H, y, z_H, \vec{P}_T) = \frac{\frac{d\sigma(left)}{dx_H dy dz_H dP_T^2} - \frac{d\sigma(right)}{dx_H dy dz_H dP_T^2}}{\frac{d\sigma(left)}{dx_H dy dz_H dP_T^2} + \frac{d\sigma(right)}{dx_H dy dz_H dP_T^2}},$$

which is simply $4/\pi$ times $\langle \sin\phi \rangle$.

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Let us define the quantity $\langle \sin\phi \rangle$ as

$$\langle \sin\phi \rangle = \frac{\int d\sigma^{(HT)} \sin\phi + \int d\sigma^{(2)} \sin\phi}{\int d\sigma^{(0)} + \int d\sigma^{(1)}}, \tag{1}$$

where $d\sigma^{(HT)}$, $d\sigma^{(0)}$, $d\sigma^{(1)}$ and $d\sigma^{(2)}$ are the higher twist, lowest-order, first-order and second-order in α_S hadronic scattering cross sections expressed as a convolution of the partonic cross section and the distribution and fragmentation functions.

In order to estimate the expected asymmetry at HERMES defined by Eq(1), we have used the distribution functions [4] and the hadronic fragmentation functions [5] with Gaussian parametrization. For calculation of the higher twist contributions to the "time-odd" asymmetry [1], we have used the twist-tree distribution and twist-two "time-odd" fragmentation function [6] [1]. Our numerical results for the left-handed electron at HERMES energies are shown in Fig.1. The asymmetry for the right-handed electron scattering is obtained by just reversing the sign in the figure. The measurement of such a single spin asymmetry can allow to determine the naively-time-odd quark fragmentation functions. It is important, however, to have good particle identification and sufficient azimuthal resolution in the forward direction.

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[1] in combination with Collins parameterization [7]