SINGLE-SPIN ASYMMETRIES FOR EXCLUSIVE ELECTROPRODUCTION OF π^+ AND ρ^0 MESONS

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Target Spin Asymmetries measured with the longitudinally polarized target of the HERMES experiment are presented for exclusive electroproduction of π^+ and ρ^0 mesons.

1 Introduction

In the last years the interest in Generalized Parton Distributions (GPDs) which contain new information on the structure of hadrons has increased considerably. All four GPDs are accessible through hard exclusive electroproduction reactions. In leading twist four GPDs H, E, $\tilde{H}$, and $\tilde{E}$ can be related to the vector (H), tensor (E), axial-vector ($\tilde{H}$), and pseudo-scalar ($\tilde{E}$) transitions. In leading order perturbative QCD the two polarized GPDs $\tilde{H}$ and $\tilde{E}$ can be probed with exclusive pseudo-scalar meson production [1]. On the other hand, the unpolarized GPDs H and E can be accessed through exclusive production of longitudinally polarized vector mesons.

According to the QCD factorization theorem for longitudinally polarized virtual photons [1] the same universal GPDs enter in the hard exclusive electroproduction of mesons as in different hard electroproduction processes. This allows one to relate the different processes to each other. No factorization theorem for transversely polarized virtual photons is proven yet, but transverse photons are generally suppressed by $1/Q^2$ compared to longitudinally polarized photons.

Relevant observables for hard exclusive electroproduction of mesons are the cross section and the transverse target spin azimuthal asymmetry. For the HERMES kinematics a large transverse target spin asymmetry of order unity is predicted using phenomenological parametrizations of the GPDs [2] for the electroproduction of π^+. Other models like the chiral quark-soliton model lead to comparable predictions [3]. For the production of longitudinally polarized ρ^0 a smaller asymmetry on the order of a few percent is predicted [2].

2 π^+ and ρ^0 Meson Identification at HERMES

The data used for the presented analysis were collected using the 27.6 GeV lepton beam of the HERA storage ring at DESY and the longitudinally polarized gaseous target of the HERMES experiment [4]. The scattered lepton and the produced pions were detected with the HERMES spectrometer. This provides a lepton identification with an average efficiency of 99% at a hadron contamination of less than 1%. Until 1998 pion identification was done with a threshold Cerenkov detector. In 1998 this detector was replaced by a Ring-Imaging Čerenkov detector (RICH) which allows the efficient identification efficiency of pions, kaons, and protons over almost the complete momentum range and hence further reduces the contamination of the pion sample.

The analysis of exclusive π^+ production was performed using data accumulated with a Hydrogen target in the year 1997 [5]. The recoiling neutron was not detected, and so to ensure the exclusivity of the event it was required that the missing mass M_X of the reaction $e^+ + p \rightarrow e^+ + \pi^+ + X$ is less than 1.05 GeV. The background was estimated using the normalized number of π^- events passing all the cuts applied to π^+ events as discussed in Ref. [5].

In the years 1998 until 2000 the HERMES experiment took data with a longitudinally polarized Deuterium target. This sample was used for the analysis of exclusive ρ^0 production. For the ρ^0 identification only events were taken with exactly one lepton and two pions. The two pions had to fulfill certain conditions to ensure ρ^0 identification and exclusivity. The invariant mass $M_{2\pi}$ had to be in the range $0.6 < M_{2\pi} < 1.0$ GeV around the ρ^0 mass. In order to further suppress misidentification an additional invariant mass cut $M_{2K} > 1.06$ GeV assuming the pions are kaons was applied. Furthermore the missing mass was restricted to values below 1.4 GeV. Diffractive processes were selected with the quantity $t' = t - t_0$, where t is the squared four-momentum transfer to the hadronic vertex and t_0 its maximum kinematically allowed value. $-t'$ is small for diffractive processes, and so it was required to be less than 0.4 GeV^2.

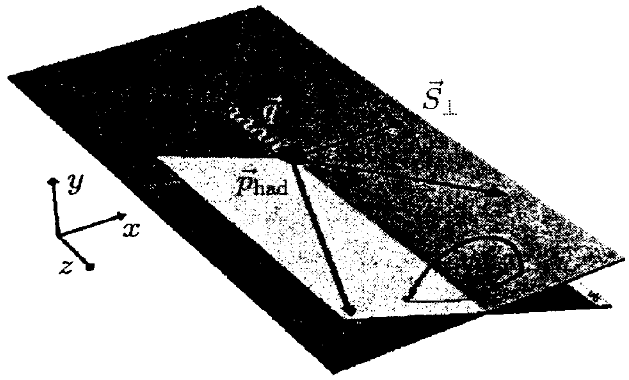

Figure 1: The definition of the azimuthal angle ϕ.

3 The Target Spin Azimuthal Asymmetry

Azimuthal asymmetries depend on the azimuthal angle ϕ between the scattering and the hadron production plane as indicated in Fig. 1. The relevant observable in this analysis is the transverse spin azimuthal asymmetry because it is a leading order observable. For the measurement of this asymmetry a target polarization perpendicular to the virtual photon direction is essential. In the case of a target longitudinally polarized w.r.t. the lepton beam momentum there appears w.r.t. the direction of the virtual photon not only the dominant longitudinal component ($S_{\|}$) of the spin but also a small transverse component ($S_\perp$) (see Fig. 1). For the kinematics of the HERMES experiment this component is on the order of 10%. Hence the polarized cross section consists of two parts [6]

$$\sigma_S \sim [S_\perp \sigma_{\mathcal{L}} + S_{\|}\sigma_{\mathcal{L}\mathcal{T}}] A_{\rm UL}^{\sin\phi} \sin\phi, \tag{1}$$

where $A_{\rm UL}^{\sin\phi}$ is the $\sin\phi$ moment of the azimuthal asymmetry. The subscript UL denotes the use of an unpolarized beam and a longitudinally polarized target. The second component of σ_S contains the interference of longitudinal ($\mathcal{L}$) and transverse ($\mathcal{T}$) virtual photon amplitudes. As a factorization theorem is proven only for longitudinal virtual photons, calculations in next-to-leading twist are necessary for quantitative predictions.

The azimuthal asymmetry is defined by

$$A_{UL}(\phi) = \frac{1}{\langle S \rangle} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}, \tag{2}$$

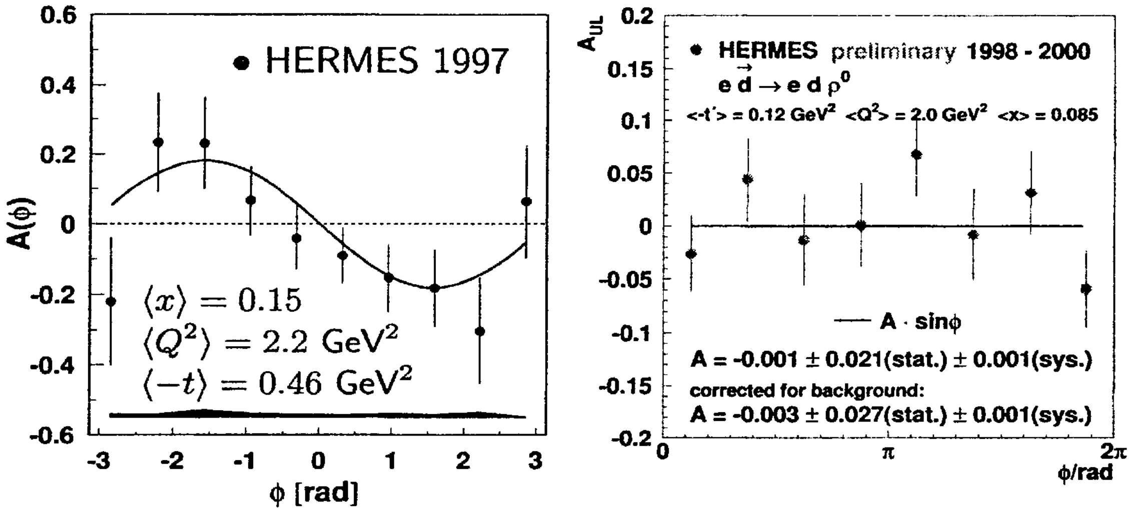

Figure 2: Azimuthal asymmetries $A_{UL}(\phi)$ averaged over x, Q^2, and t for the reactions $e^+ + \vec{p} \to e^+ + n + \pi^+$ (left panel) and $e + \vec{d} \to e + d + \rho^0$ (right panel). The curves represent the $\sin\phi$ fits to the data.

where $N^{+/-}$ represent the yields of exclusive mesons with $+(-)$ indicating a target spin alignment anti-parallel (parallel) to the lepton beam momentum. $\langle S \rangle$ denotes the target polarization. In order to obtain the $\sin\phi$ moment $A_{\mathrm{UL}}^{\sin\phi}$, the asymmetry is fitted with a $\sin\phi$ function. The ϕ dependence of the azimuthal asymmetries for exclusive π^+ and ρ^0 production is shown in Fig. 2 together with the $\sin\phi$ fits. After subtraction of the background and integration over the experimental acceptance a $\sin\phi$ moment of $-0.18 \pm 0.05(\mathrm{stat.}) \pm 0.02(\mathrm{sys.})$ is measured for the electroproduction of exclusive π^+. The $\sin\phi$ moment $A_{\mathrm{UL}}^{\sin\phi} = -0.003 \pm 0.027(\mathrm{stat.}) \pm 0.001(\mathrm{sys.})$ for exclusive ρ^0 production is much smaller and compatible with zero.

The dependence of $A_{\mathrm{UL}}^{\sin\phi}$ on the individual kinematic variables x, Q^2, and t is plotted in Fig. 3 for both reactions. Although the amount of Hydrogen data is less, significant $\sin\phi$ moments of the target spin azimuthal asymmetry for exclusive π^+ production are measured. On the other hand, for the production of ρ^0 vector-mesons $A_{\mathrm{UL}}^{\sin\phi}$ is always compatible with zero, only for large Q^2 the $\sin\phi$ moment seems to reach a value in the region of the overall π^+ moment.

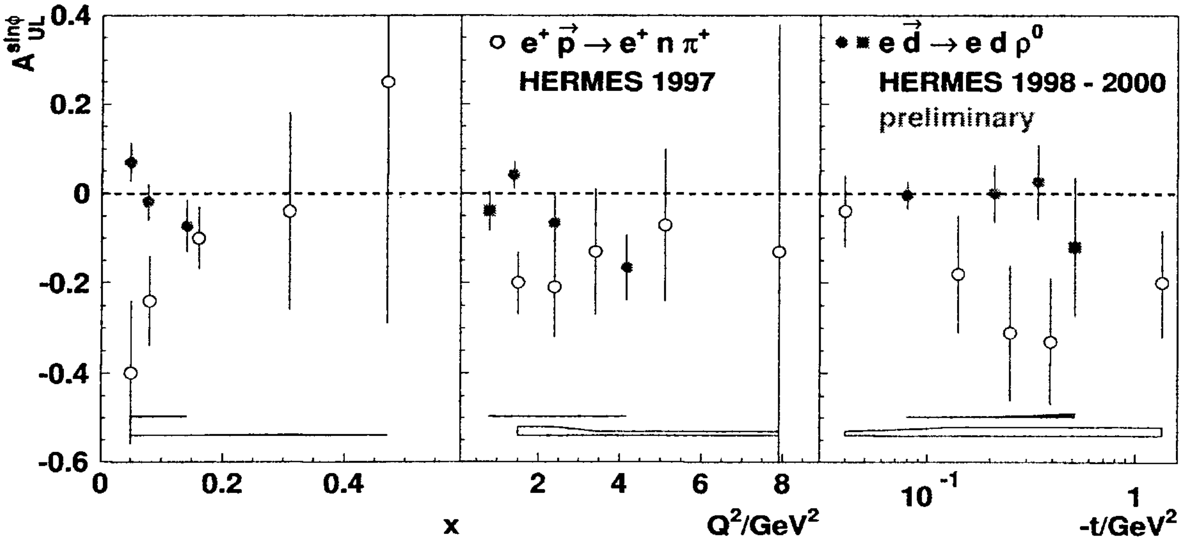

Figure 3: Kinematic dependence of the $\sin\phi$ moments $A_{UL}^{\sin\phi}$ for the reactions $e^+ + \vec{p} \rightarrow e^+ + n + \pi^+$ and $e + \vec{d} \rightarrow e + d + \rho^0$. The full squares indicate data points outside the integration limits of the kinematic variables used for the overall asymmetry (see right panel of Fig. 2).

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