RECENT HERMES RESULTS ON DVCS ASSOCIATED ASYMMETRIES*

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(Received July 3, 2002)

The latest HERMES measurements of the beam–spin and beam–charge azimuthal asymmetries in the hard exclusive electroproduction of photons are reported. The asymmetries are associated with the Deeply Virtual Compton Scattering (DVCS) process and can provide new information on the structure of the nucleon.

PACS numbers: 13.60.Hb, 13.60.Le, 13.60.–r

1. Introduction

One of the main motivations for the recent interest in Deeply Virtual Compton Scattering (DVCS) is the theoretical observation that the total angular momentum J^q carried by quarks q in the nucleon (*i.e.* the sum of intrinsic and orbital angular momenta) can be expressed via a sum rule [1]:

$$\lim_{t\to 0} \frac{1}{2} \int_{-1}^{+1} dx\, x \, \left[H^q(x,\xi,t) + E^q(x,\xi,t)\right] = J^q \, . \tag{1}$$

Here $H^q(x,\xi,t)$ and $E^q(x,\xi,t)$ are new, twist two, generalized parton distribution (GPD) functions. These functions depend on the Bjorken scaling variable x, a skewedness parameter ξ and the squared 4-momentum transfer t between the initial and final state nucleon. The GPD formalism [2] encompasses a wide range of observables, such as electromagnetic form factors, conventional parton distributions and hard exclusive cross sections.

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* Presented at the X International Workshop on Deep Inelastic Scattering (DIS2002) Cracow, Poland, 30 April–4 May, 2002.

DVCS is an exclusive process whereby a single multi-GeV real photon is produced by virtual photon–quark scattering, and is the cleanest reaction available for the measurement of GPD's. While it is impossible to distinguish between exclusive photons produced by the DVCS and Bethe–Heitler (BH) processes, DVCS–BH interference can be isolated by the measurement of beam–spin and beam–charge asymmetries. Such measurements can provide information on DVCS amplitudes and hence on GPD's [3]. Despite significant theoretical progress [4], experimental information on DVCS is still scant. First measurements of the beam–spin asymmetry were recently published by the HERMES [5] and CLAS [6] collaborations. Unpolarized DVCS was also observed by the HERA collider experiments [7], in the measurements of single photon production rates. This paper presents the latest HERMES results on DVCS associated asymmetries, including the first measurement of the beam–charge asymmetry.

2. The HERMES experiment

The asymmetries presented here are based on lepton–proton scattering data collected by the HERMES experiment using the HERA 27.6 GeV longitudinally polarized lepton (positron or electron) beam at DESY. The beam polarization had an average value of 0.55 with a fractional uncertainty of 3.8% [8]. The scattered leptons and coincident photons were detected by the HERMES spectrometer [9] in the polar-angle range of 40 to 220 mrad. The electrons and positrons were identified with an average efficiency of 99%, with hadron contamination less than 1%. Photons were identified by the detection of an energy deposition in the calorimeter and preshower counter with no associated signal in the tracking system.

Single-photon electroproduction events $ep \to e'\gamma X$ were selected by calculating the missing mass $M_X \equiv \sqrt{(q + P_p - k)^2}$ with q, P_p and k being the four-momenta of the virtual photon, the target proton and the produced real photon, respectively. The missing mass resolution $\sigma(M_x)$ was obtained from Monte Carlo calculations, and was found to be ~ 0.8 GeV. An exclusive interval of $M_X < 1.7$ GeV was chosen, with the upper limit lying 1 σ in resolution above the nucleon mass $M_x = M_N$. The contamination of background events (mainly due to $\pi^0 \to \gamma\gamma$) was found to be less then 10% in the exclusive interval. In addition, the following requirements were placed on the scattered lepton: $Q^2 > 1$ GeV^2, $W^2 > 4$ GeV^2, and $\nu < 24$ GeV, where Q^2 is the negative square of the virtual photon 4-momentum, ν is the virtual photon energy and W is the invariant mass of the photon–nucleon system.

The asymmetries were studied as a function of ϕ, the azimuthal angle of the final-state photon with respect to the lepton scattering plane. In order to have an almost full 2π coverage in ϕ, a cut of $15 < \theta_{\gamma\gamma^*} < 70$ mrad was imposed on the angle $\theta_{\gamma\gamma^*}$ between the directions of the virtual and real photons.

3. The beam–spin asymmetry

The beam–spin azimuthal asymmetry $A_{\rm LU}$ was defined as follows:

$$A_{\rm LU}(\phi) = \frac{1}{\langle |P_l| \rangle} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)} \,. \tag{2}$$

Here N^+ and N^- represent the luminosity-normalized yields of events in the two beam helicity states, $\langle |P_l| \rangle$ is the average magnitude of the beam polarization, and the subscripts L and U denote the use of a longitudinally polarized beam and an unpolarized target.

The results obtained for $A_{\rm LU}(\phi)$ in the exclusive interval are presented in figure 1(a). A clear $\sin\phi$ behaviour is observed, as shown by the superimposed dashed curve with a best-fit amplitude of -0.23. The solid curve shows the GPD model calculation from Ref. [10] computed at the average kinematics of the HERMES experiment. The systematic uncertainty of the measurement is represented by the error band at the bottom of the figure.

To explore the behavior of the asymmetry as a function of missing mass, the asymmetry moment $A_{\rm LU}^{\sin\phi}$ (also termed 'analyzing power') was calculated in a variety of M_X bins:

$$A_{\rm LU}^{\sin\phi} = \frac{2}{N} \sum_{i=1}^{N} \frac{\sin\phi_i}{(P_l)_i} \,, \tag{3}$$

where $N \equiv N^+ + N^-$. The difference of moments between the two beam helicity states is implicity contained in this formula via the sign of the beam polarization P_l. The results are are presented in Fig. 1(b). All bins in the M_X region bellow 2.5 GeV show a similar negative asymmetry, while $A_{\rm LU}^{\sin\phi}$ is consistent with zero for large (non-exclusive) M_X values. The systematic error band takes into account a possible false asymmetry due to acceptance effects (at most 2.6%) and the uncertainty due to π^0 contamination (estimated to be 12.5%). By combining the values measured in the exclusive region $M_X < 1.7$ GeV, as in Fig. 1(a), the following average value was obtained: $A_{\rm LU}^{\sin\phi}$=-0.23 $\pm$ 0.04 (stat) $\pm$ 0.03 (syst).

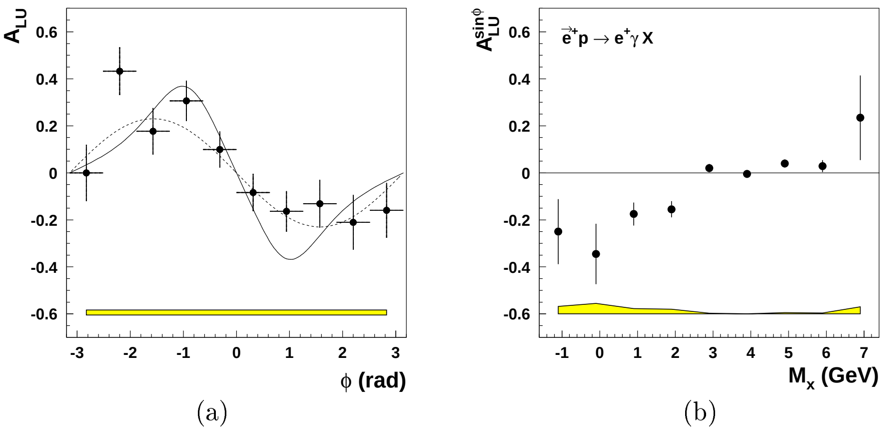


Fig. 1. (a) The beam–spin azimuthal asymmetry $A_{\rm LU}(\phi)$ for hard electroproduction of photons in the exclusive interval $M_X < 1.7$ GeV. (b) The beam–spin analyzing power $A_{\rm LU}^{\sin\phi}$ measured *versus* missing mass M_X.

4. The beam–charge asymmetry

The beam–charge asymmetry was determined as follows:

$$A_{\rm C}(\phi) = \frac{N^{e^+}(\phi) - N^{e^-}(\phi)}{N^{e^+}(\phi) + N^{e^-}(\phi)}, \tag{4}$$

where N^{e^+} and N^{e^-} are the luminosity-normalized yields collected from positron and electron beams, respectively. The electron data were only collected with negative beam helicity. In order to reduce the $\sin\phi$ dependence of $A_{\rm C}$, the e^+ sample was selected in such a way as to have the same magnitude but different sign of the beam polarization as the e^- sample.

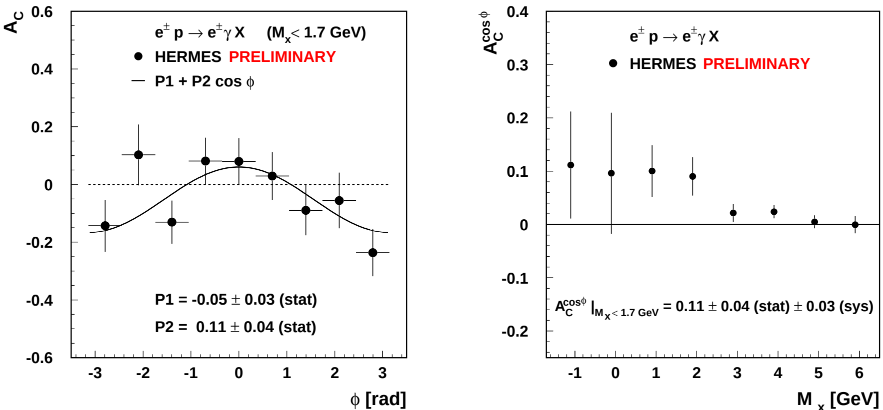
Fig. 2(a) presents the HERMES preliminary data on the asymmetry $A_{\rm C}(\phi)$, obtained from the events in the exclusive interval $M_X < 1.7$ GeV. A distinct $\cos\phi$ dependence is observed, with an amplitude of 0.11 ± 0.04.

The M_X dependence of the beam–charge analyzing power was measured by combining the $\cos\phi$ moments calculated from positron ($A^{\cos\phi^+}$) and electron ($A^{\cos\phi^-}$) data:

$$A_{\rm C}^{\cos\phi} = \frac{A^{\cos\phi^+} - A^{\cos\phi^-}}{2} \tag{5}$$

The results obtained for $A_{\rm C}^{\cos\phi}$ *versus* missing mass are presented in Fig. 2(b). As with the beam–spin asymmetry, $A_{\rm C}^{\cos\phi}$ is consistent with zero in the non-exclusive region. The average value in the exclusive interval is $A_{\rm C}^{\cos\phi} = 0.11$

± 0.04 (stat) ± 0.03 (syst). The systematic error contains the contributions discussed previously, as well as uncertainties due to instrumental effects such as trigger and calorimeter performance in the 2000 data set. A final analysis is in progress which will correct for some of these effects and provide a reduced systematic error.



(a) (b)

Fig. 2. (a) The beam–charge azimuthal asymmetry $A_{\rm C}(\phi)$ in the exclusive interval $M_X < 1.7$ GeV. (b) The beam–charge analyzing power $A_{\rm C}^{\cos\phi}$ *versus* missing mass.

5. Summary

At average kinematic values of $\langle x\rangle = 0.11$, $\langle Q^2\rangle = 2.6$ GeV^2 and $\langle -t\rangle = 0.27$ GeV^2, the HERMES collaboration has obtained the following results from measurements of hard photon production in the exclusive region: $A_{\rm LU}^{\sin\phi} = -0.23 \pm 0.04$ (stat) ± 0.03 (syst) for the beam–spin asymmetry, and a preliminary result of $A_{\rm C}^{\cos\phi} = 0.11 \pm 0.04$ (stat) ± 0.03 (syst) for the beam–charge asymmetry.

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