New Measurement of DVCS Cross Section at HERA

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Abstract. A new measurement is presented of elastic deeply virtual Compton scattering based on data taken by the H1 detector at HERA [1]. For the first time the cross section dependence is reported on the momentum transfer squared at the proton vertex, t. The data is well described by the QCD based calculations.

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INTRODUCTION

Compton scattering processes, $ep \to e\gamma p$, is one of the most used reactions at HERA. The QED elastic Compton scattering, Bethe-Heitler (BH) process, is utilized to determine the luminosity. The inelastic Compton scattering process is employed to measure the F_2 structure function in extended kinematic range [2, 3].

Recently the focus has been on measuring of the deeply virtual Compton scattering process (DVCS). One of the remarkable properties of this process is factorisation: in the presence of a hard scale, here photon virtuality Q^2, the DVCS scattering amplitude factorises [4, 5, 6] into a hard part, which can be calculated in perturbative QCD, and so-called generalized parton distribution functions (GPDs) which contain the non-perturbative proton structure effects. GPDs correspond to a natural extension of the usual parton density functions (PDFs), they add information about correlations between partons and partons transverse motion [7, 8, 4]. The new degrees of freedom, additional to the Bjorken-x, are so-called skewedness ξ, which measures the fractional momenta difference between emitted and absorbed parton and t.

This paper presents a measurement of DVCS cross section based on 46.5 pb^{-1} of data collected with the H1 detector at HERA in years 1996 to 2000 [1]. The cross section is presented as a function of Q^2, of the invariant mass of $\gamma^* p$ system, W, and of t.

DATA ANALYSIS

The elastic Compton scattering events have very distinct features making them very precious experimental commodity, see Figure 1. The event kinematics can be redundantly determined using the two reconstructed electromagnetic clusters. The fraction of DVCS events with respect to ordinary QED Compton scattering is enhanced requiring the scattered photon to be reconstructed in the central region. A typical signal to background ratio for the DVCS analysis is 10 to 1.

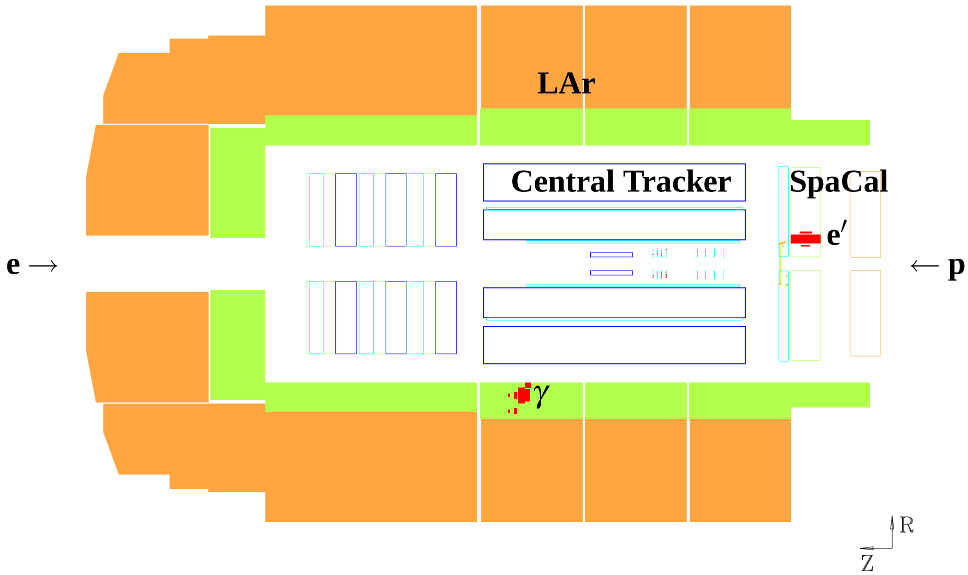

FIGURE 1. A typical DVCS event candidate recorded by the H1 detector. The Z axis is defined by the proton beam directions. The beam pipe which is located in the center of the detector (not shown in the figure) is surrounded by the central silicon tracker, central drift chamber tracker and the liquid argon calorimeter (LAr). The particles scattered in the backward direction are measured in the backward silicon tracker, backward drift chamber and the lead scintillating fiber calorimeter (SpaCal). Both calorimeters contain electromagnetic and hadronic compartments. The dark (red) areas in the calorimeters represent two electromagnetic clusters. The cluster in the LAr calorimeter is associated with the scattered photon (γ) since there is no matching track in the central tracker. The cluster in SpaCal us associated with the scattered electron (e'). The scattered proton escapes in the forward beam pipe.

The selected DVCS sample contains 1243 events. To extract the cross section, the data are corrected for detector acceptance and initial state radiation using the Monte Carlo simulation (MC). The generation of MC is based on MILOU program [9] and then the events are passed through a detailed simulation of the H1 detector response.

The measured $e^+p \to e^+\gamma p$ cross section is converted to the $\gamma^* p \to \gamma p$ cross section using equivalent photon approximation:

$$\frac{d^3\sigma(ep \to e\gamma p)}{dydQ^2dt}(Q^2,y,t) = \Gamma(Q^2,y)\frac{d\sigma(\gamma^* p \to \gamma p)}{dt}(Q^2,y,t). \qquad (1)$$

Here inelasticity y is calculated as $y = (W^2 + Q^2)/s$ (s is the square of the ep centre-of-mass energy) and the transverse photon flux Γ is [10]

$$\Gamma = \frac{\alpha(1-y+y^2/2)}{\pi y Q^2}. \qquad (2)$$

RESULTS

For the triggering reasons, the cross sections are measured separately in 1996-1997 and 1999-2000, covering different Q^2 ranges, and are then combined. The differential

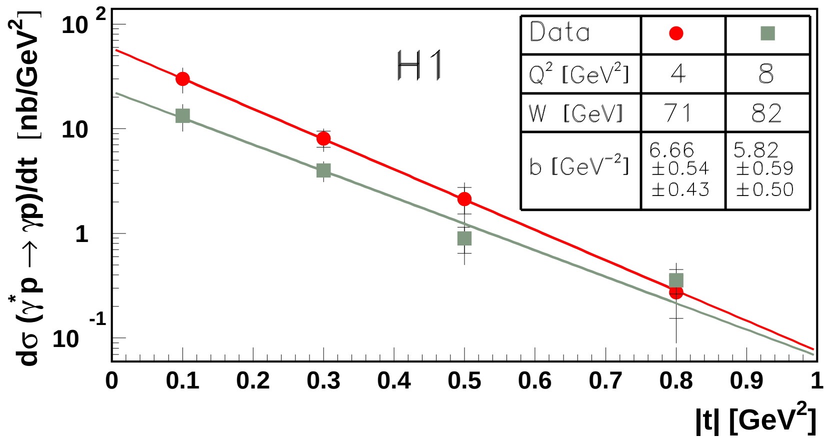

FIGURE 2. The differential cross section $d\sigma(\gamma^* p \to \gamma p)/d|t|$ for $Q^2 = 4$ GeV^2 at $W = 71$ GeV and $Q^2 = 8$ GeV^2 at $W = 82$ GeV. The inner error bars represent the statistical and the full error bars the total uncertainties. The lines show the results of fits $e^{-b|t|}$, the corresponding values of b are given in the insert.

$d\sigma(\gamma^* p)/d|t|$ cross section is shown in Fig. 2. The data points are fitted with the exponential form $e^{-b|t|}$, which gives $b = 6.66 \pm 0.54_{\text{stat}} \pm 0.43_{\text{sys}}$ GeV^{-2} at $Q^2 = 4$ GeV^2 and $b = 5.82 \pm 0.59_{\text{stat}} \pm 0.50_{\text{sys}}$ GeV^{-2} at $Q^2 = 8$ GeV^2. Since the measurements agree within the experimental errors, they are averaged to obtain $b = 6.02 \pm 0.35_{\text{stat}} \pm 0.39_{\text{sys}}$ GeV^{-2} for $Q^2 = 8$ GeV^2 and $W = 82$ GeV.

Fig. 3 shows Q^2 and W dependence of the $\gamma^* p$ cross section. Fitting the Q^2 dependence with a form $(1/Q^2)^n$ returns $n = 1.54 \pm 0.09_{\text{stat}} \pm 0.04_{\text{sys}}$. Fitting the W dependence with a form W^δ gives $\delta = 0.77 \pm 0.23_{\text{stat}} \pm 0.19_{\text{sys}}$. The steep rise of the cross section with W indicates the presence of a hard scattering process, the value of δ is similar to the value measured in exclusive J/ψ production [11, 12].

Fig. 3 also compares the data with the NLO QCD based calculation [14]. In this model, the DVCS cross section is calculated using two different GPD parameterisations. The t dependence is assumed to follow $e^{-b|t|}$ with the coefficient b taken from the H1 measurement. The two parametrisations use either MRST [16] or CTEQ [15] standard PDFs for the region $|x| > \xi$. The generalized structure functions $H^{q,g}$ are given at a starting scale μ by $H^q(x,\xi,t) = q(x)e^{-b|t|}$ for the quarks and $H^g(x,\xi,t) = xg(x)e^{-b|t|}$ for the gluons. For the larger scales, both Q^2 dependence and skewing are generated dynamically. For $|x| < \xi$, the parameterisations are modified preserving smooth transition into $|x| > \xi$ regime [14].

The theoretical estimations agree well with the data for both shape and absolute normalization. The uncertainty in the normalization for the theory is significantly reduced owing to the H1 measurement of the $\gamma^* p$ cross section t slope; this uncertainty becomes smaller than the input PDF uncertainty which is quantified comparing MRST and CTEQ PDF set based predictions.

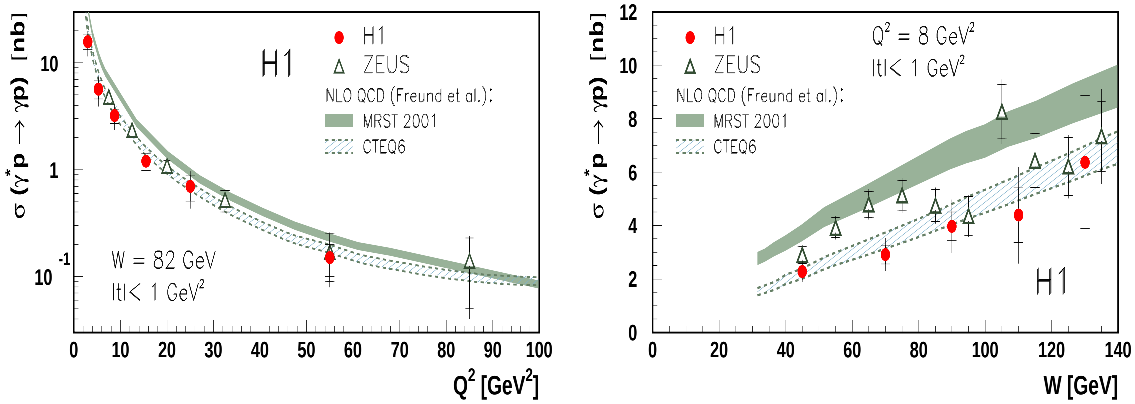

FIGURE 3. Q^2 (left) and W (right) dependence of the $\gamma^* p \to \gamma p$ cross section measured by H1 (filled circles) and ZEUS [13] (open triangles) collaborations compared to NLO QCD based calculations [14] which are performed for two different PDF sets, CTEQ6 [15] (dashed band) and MRST [16] (filled band). The inner error bars represent the statistical and the full error bars the total uncertainties. The band associated with each prediction corresponds to the uncertainty in the measured t-slope.

SUMMARY

The DVCS process are measured in the kinematic domain $30 < W < 140$ GeV, $2 < Q^2 < 80$ GeV^2 and $|t| < 1$ GeV^2 by the H1 collaboration using data collected in years 1996-2000. The $\gamma^* p \to \gamma p$ cross section is reported as a function of Q^2, W and for the first time as a function of t. The measurement of the the t dependence allows to reduce normalization uncertainties of the theoretical predictions. NLO QCD calculations provide a good description of the data.

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