Deeply Virtual Compton Scattering at H1 and ZEUS

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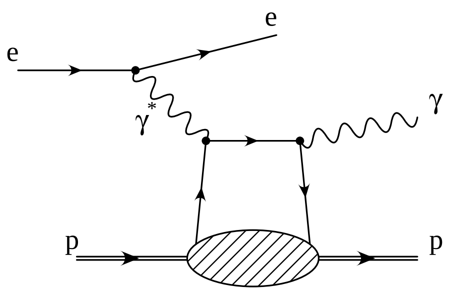
Results on Deeply Virtual Compton Scattering at HERA measured by the H1 and ZEUS Collaborations are presented. The cross section, measured for the first time, is reported for by H1 and ZEUS for Q^2 above a few GeV^2 in the low x region. The measured cross section is discussed and compared to different predictions.

1. INTRODUCTION

At the high energy of $\sqrt{s} \simeq 300$ GeV delivered by HERA using colliding electron (27.5 GeV) and proton beams (820 GeV), the Deeply Virtual Compton Scattering process (DVCS) $ep \to e\gamma p$ is of diffractive nature. Comparing to the lower energy experiments CLAS[1] and HERMES[2,3], additionally to the direct quark contribution (LO contribution shown in Fig. 1a), the color singlet two gluon exchange is also expected to have a sizable contribution (NLO - Fig. 1b).



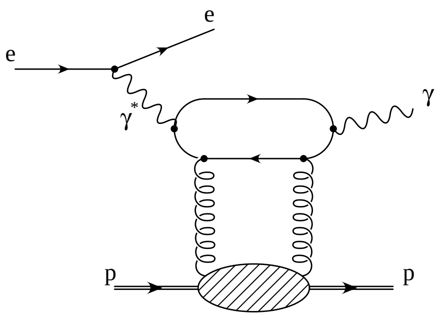


Figure 1. The DVCS **a)** at LO **b)** at NLO.

A considerable interest of the DVCS comes from the particular access it gives to Generalised Parton Distributions (GPD) through the interference term with the Bethe-Heitler process. The high energy situation of H1 and ZEUS experiments give them the unique opportunity to constrain the gluon contribution to GPDs and to study the evolution in Q^2 of the quark and gluon distributions.

Here we report the first cross section measurement of the Deeply Virtual Compton Scattering, performed by the H1 and ZEUS experiments. The cross section measurement are compared to the theoretical predictions and future plans for the DVCS measurement at HERA are briefly presented.

2. ANALYSIS STRATEGY

Both H1 and ZEUS adopted the same analysis strategy. Around the interaction region, H1 and ZEUS are equipped with tracking devices surrounded by calorimeters. Since the proton escapes the main detector through the beam pipe only the scattered electron and photon are measured. Therefore the event selection is based on demanding two electromagnetic clusters, one in the backward (i.e. the direction of the incoming electron, $\theta = 0$) and one in the central or the forward part of the detector ($\theta \lesssim 140^o$). If a track can be reconstructed it has to be associated to one of the clusters and determines the electron candidate. These events are then subdivided into two mutually exclusive samples. The *control sample* (Fig. 2.a) contains events with the electron candidate detected in the central or the forward part of the detector. This sample is largely dominated by Bethe–Heitler events, although some additional backgrounds due to dilepton production by photon-photon interaction and due to diffractive ρ electroproduction have to be considered [4]. The DVCS contribution is kinematically suppressed by the large Q^2 value. The *enriched DVCS sample* (Fig. 2.b), complementary to the control sample, contains both DVCS and Bethe–Heitler events, and a small background contribution due to ω and ϕ diffractive electroproduction.

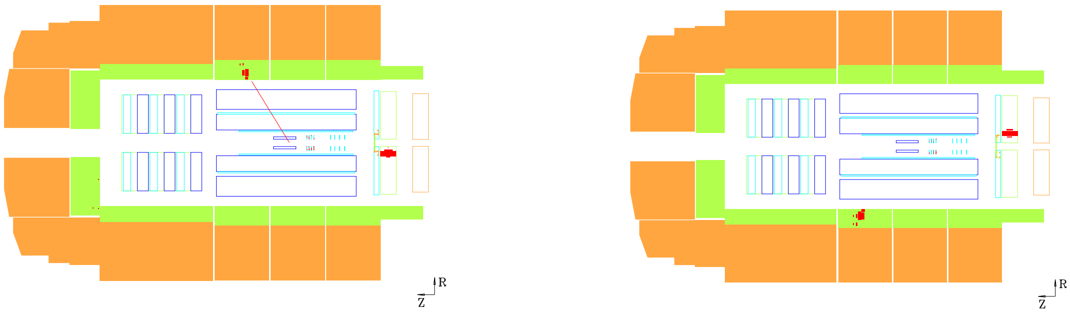


Figure 2. **a)** Control sample topology. **b)** Enriched DVCS sample topology.

To enhance the DVCS contribution in comparison to the Bethe-Heitler process the phase space has to be restricted by demanding the photon candidate in the forward part of the detector.

The H1 analysis selects more specifically the elastic component by using, in addition, forward detectors, placed close to the beam pipe, are used to identify particles originating from proton dissociation processes.

Both experiments compare their results to the prediction of L. L. Frankfurt, A. Freund and M. Strikman (FFS) [5] calculated in QCD at LO and leading twist. It is important to notice that, into this approximation, the interference term cancels out when integrating over the azimuth angle of the final state photon (as in the analysis here below). Therefore the pure DVCS cross section can be measured subtracting the Bethe-Heitler contribution to the enriched DVCS sample.

3. ZEUS RESULTS

This analysis [6] is based on a sample corresponding to an integrated luminosity of 37 pb^{-1}. The backward electromagnetic cluster is required with an energy above 10 GeV, and the central or forward cluster ($-0.6 < \eta < 1.0$) with more than 3 GeV. The photon virtuality $Q^2 > 5\,\text{GeV}^2$ is demanded, the $\gamma^* - p$ energy, W, is such that $40 < W < 140\,\text{GeV}$. The $e-p$ DVCS (preliminary) cross section is shown as a function of Q^2 and of W in Fig. 3 and is compared to the FFS prediction. The measurement is well described by the FFS prediction assuming a value of $b = 4.5$ GeV^{-2} for the exponential t slope. It has to be noted that the background from the proton dissociation (around 20%) has not been subtracted.

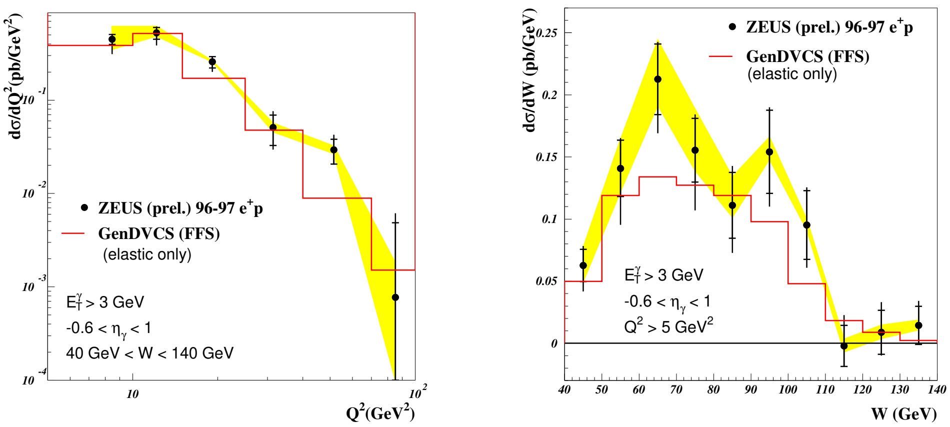


Figure 3. DVCS contribution to the $ep \to e\gamma p$ cross section as a function of Q^2 (left) and of W (right). The measurement is compared to the FFS prediction.

4. H1 RESULTS

In the H1 analysis [7], corresponding to an integrated luminosity of 8 pb^{-1}, the DVCS cross section is measured in the kinematic region: $2 < Q^2 < 20\,\text{GeV}^2$, $|t| < 1\,\text{GeV}^2$ and $30 < W < 120\,\text{GeV}$. The proton dissociation background has been estimated to of $16\% \pm 8\%$ and is subtracted statistically assuming the same W and Q^2 dependence as for the elastic component.

It may be worth to comment on possible π^o contamination as suffer the DVCS measurements of HERMES and CLAS. Due to the high energy regime, the direct π^o production (via Regge pole exchange) is suppressed, and the possible π^o contamination from tails of low multiplicity DIS events is suppressed by the large rapidity gap requirement (see detailed study in [4]).

In Fig. 4 the total cross sections of the reaction $ep \to e\gamma p$ is shown differentialy in Q^2 and in W. The data are compared with the Bethe-Heitler prediction alone (normalised on the integrated luminosity).

The $\gamma^* p \to \gamma p$ DVCS cross section, derived subtracting the Bethe-Heitler contribution and dividing by the virtual photon flux, is shown as a function of Q^2 and of W in Fig. 5 and compared to FFS and Donnachie and Dosh (DD) [8] predictions. The description of the data by the calculations is good, in shape and in absolute normalisation when a t slope is chosen between 5 and 9 GeV^{-2} covering the measured range for light vector meson production. Although the shapes in Q^2 and W are similar for the ZEUS (still preliminary) and H1 measurements, the absolute cross section measurements are not fully compatible

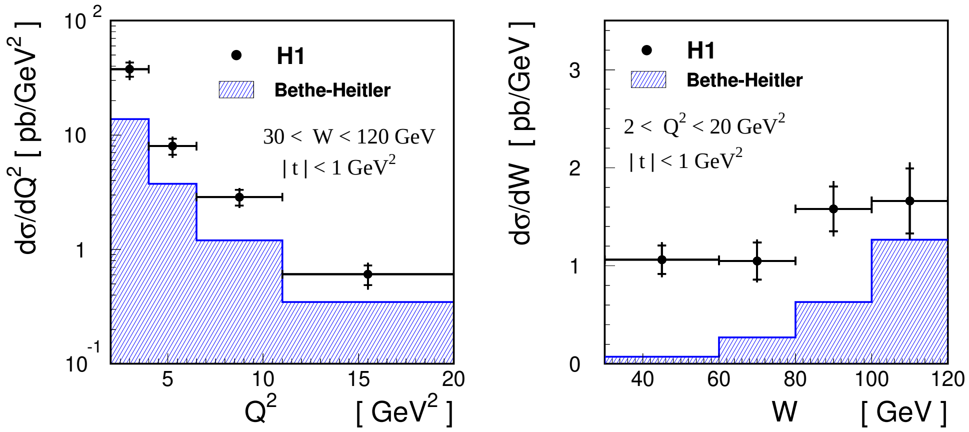


Figure 4. The measured cross sections of the reaction $e^+p \rightarrow e^+\gamma p$ differentialy in Q^2 (left) and W (right) are shown and compared to the pure Bethe-Heitler contribution.

(different b values have to be assumed in the FFS prediction to get an agreement). This underlines the importance of the t slope measurement in the future.

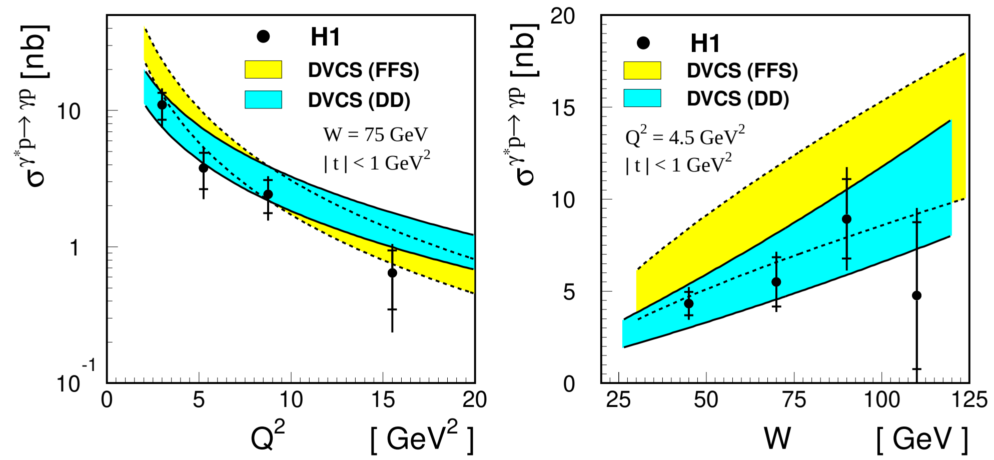


Figure 5. The measured $\gamma^*p \rightarrow \gamma p$ DVCS cross sections as a function of Q^2 and W. The data are compared to the theoretical predictions FFS [5] and DD [8]. The uncertainty in the theoretical prediction, shown here as a shaded band, is dominated by the unknown slope of the t dependence of the DVCS part of the cross section, assuming $5 < b < 9\,\mathrm{GeV}^{-2}$.

5. RESULTS DISCUSSION

In addition to the FFS and DD predictions shown in Fig. 5, soon after publication, the H1 results have been compared to different predictions by several authors as presented in Fig. 6 (see caption for the details). From those confrontations one can conclude several things. From the dipole model prediction confrontations, a good agreement is found when one adopts an approach similar to the one of vector meson electroproduction calculations. It confirms the diffractive nature of the DVCS process and the validity of the color dipole models. The QCD calculation confrontation [9] is an important success as it consists in the first diffractive process fully calculated and in good agreement with the measurement of H1 but also with the helicity asymmetry measurements of HERMES and CLASS (see [10]). Furthermore the H1 measurement provides the first constraints on the GPDs (see [11] and [9] for details).

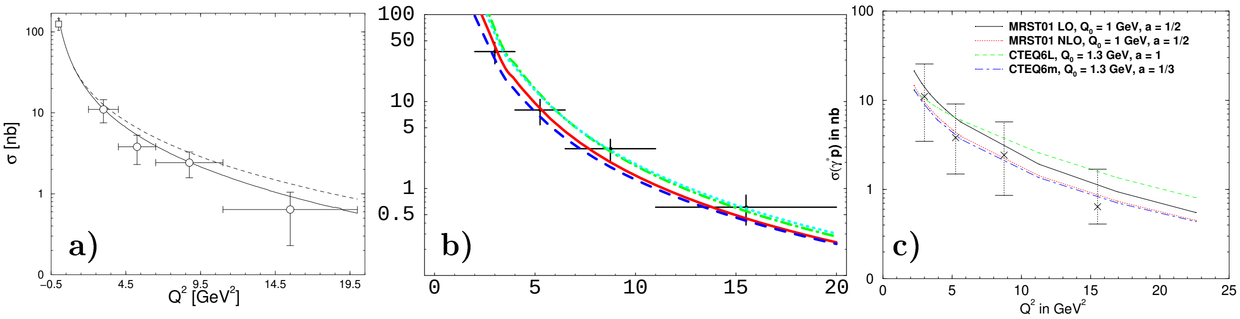


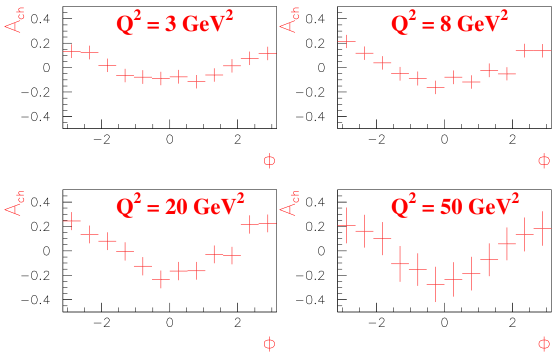
Figure 6. The $\gamma^* p \to \gamma p$ DVCS cross sections measured by H1 as a function of Q^2 is compared to different theoretical predictions:
a) the dipole models of Forshaw, Kerley and Shaw (full line) and of McDermott, Frankfurt, Guzey and Strikman (hashed line) [12];
b) the LO QCD prediction of Belitski et al. [11] going beyond the leading twist but not making a QCD evolution;
c) the NLO QCD prediction of Freund and Mc. Dermott [9] including QCD evolution of the GPDs.

6. FUTURE MEASUREMENTS

HERA is presently entering in a high luminosity regime that will accumulate up to 1 fb^{-1} until 2006, including longitudinal polarisation of the lepton beam. Additionally, the H1 detector will be completed by a high acceptance (above 80 %) proton spectrometer (VFPS) [13] for $5.10^{-3} < x_{I\!P} < 3.10^{-2}$ and $|t| \lesssim 0.5$ GeV^2, where $x_{I\!P}$ is the proton energy loss.

Within these conditions, charge and helicity asymmetry measurements will be possible giving access to the Real and the Imaginary parts of the amplitude separately. About 4000 DVCS events are expected with $Q^2 > 8$ GeV [14] amoung which about half of them will have a scattered proton measured in the VFPS. Results of a first study of the beam charge asymmetry is shown in Fig. 7 for a fraction of the full integrated luminosity (see caption for the details).

Figure 7. Beam charge asymmetry simulation for the H1 detector acceptance for different Q^2 values and $10 < W < 120$ GeV, assuming an integrated luminosity of 150 pb^{-1} for each e^+ and e^- sample. Resolution effects are not included.



CONCLUSION

The DVCS process has been observed by the H1 and ZEUS Collaborations. The first DVCS Cross section measurements derived by H1 and ZEUS have been presented. The experimental results are well described by the pure QCD calculation at NLO and by several color dipole model predictions. In the future, HERA will benefit of much larger statistics, and will yield an access to both the real and the imaginary parts of the amplitude through beam charge and helicity asymmetry measurements.

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The author is supported by the *Fonds National de la Recherche Scientifique* of Belgium.