Submitted to the 30th International Conference on High-Energy Physics ICHEP2000,
Osaka, Japan, July 2000

Measurement of the Deeply Virtual Compton Scattering at HERA

H1 Collaboration

Abstract

A measurement is presented of Deeply Virtual Compton Scattering at HERA. The cross section is measured as a function of Q^2 and W. The data are compared to LO QCD calculations based on the two gluon exchange model.

Abstract: 966
Parallel session: 02
Plenary talk: 12

1 Introduction

Deeply Virtual Compton Scattering (DVCS) is the hard diffractive scattering of a virtual photon off a proton. The QCD interpretation, based on the two gluon exchange model, of this process can be seen in figure 1. The virtual photon emitted by the incoming electron is coupling via a quark–loop to the two gluons which are coupling to the incoming proton. A real photon is emitted from the quark loop.

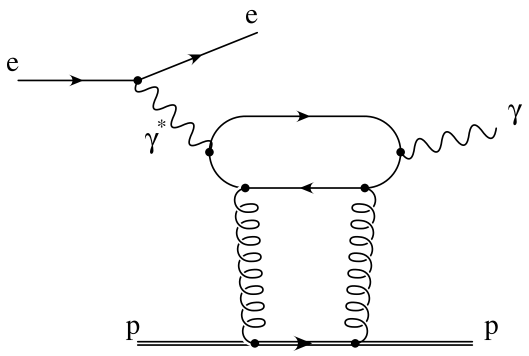

Figure 1: DVCS diagram in QCD picture.

DVCS offers a new and comparatively clean way to study diffraction at HERA. In comparison to vector-meson production it avoids large uncertainties on the vector-meson wave-function. The largest interest comes from the access it provides to the skewed parton distributions of the proton[1].

DVCS contributes to the reaction $e^+p \longrightarrow e^+\gamma p$, whose total cross section is dominated by the purely electromagnetic Bethe–Heitler process. The diagrams corresponding to this process are shown in figure 2. The real photon in the final state is either emitted from the incoming or outgoing electron line.

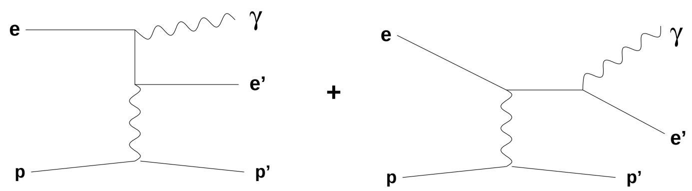

Figure 2: Diagrams contributing to the Bethe–Heitler process.

In the presence of a large scale the DVCS process can be calculated in perturbative QCD. In the present case the scale is given by the photon virtuality Q^2 above a few GeV^2. LO QCD calculations exist, based on the two gluon exchange model[2]. These calculations, including the interference between DVCS and Bethe–Heitler processes, are embedded into a MC generator used in the analysis.

Since for the DVCS process the virtual photon is scattered onto mass shell in the final state it is necessary to transfer longitudinal momentum from the proton to the photon. In the picture of the two gluon exchange the fractional momenta of the gluons x_1 and x_2 are therefore not equal which leads to the concept of the skewed parton distribution, which are generalised parton distributions. The DVCS process provides in principle the possibility to extract these distributions from experimental data[3].

2 Event selection

The analysis is based on data taken in 1997 corresponding to an integrated luminosity of $8\,\mathrm{pb}^{-1}$. A detailed description of the H1–detector can be found elsewhere[4]. The main components of the detector which are used in this analysis are the tracking system, the LAr calorimeter which covers the central and forward part of the detector, a Spaghetti calorimeter which covers the backward part of the detector, the Forward Muon Detector (FMD) and the Proton remnant tagger (PRT). The forward direction is defined as the direction of the incoming proton.

Since the total $e^+p \longrightarrow e^+\gamma p$ cross section is dominated by the Bethe–Heitler process the selected phase space has to be chosen in a way that the DVCS contribution becomes sizeable; in practice the photon will be required to be in the forward region.

While 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. A cluster with an energy above $15\,\mathrm{GeV}$ has to be found in the backward calorimeter. A second cluster has to be in the central part of the LAr calorimeter with a transverse energy with respect to to the incoming proton direction of $p_t > 1\,\mathrm{GeV}$. To reject background (incl. inelastic DVCS contributions) no further clusters with energy above $0.5\,\mathrm{GeV}$ are allowed.

If a track can be reconstructed it has to be associated to one of the clusters and determines the electron candidate. If no track is reconstructed the backward cluster is assumed to be the electron. If more than one track is reconstructed, the event is rejected.

In order to reject inelastic and proton dissociation events where all additional particles escape detection by the LAr calorimeter at small polar angles, counters close to the beam pipe (PRT, FMD) are used as veto.

To reduce the effect of QED radiative corrections a cut on the balance of longitudinal momentum is applied; $\sum(E - P_z) > 45\,\mathrm{GeV}$, where the sum runs on the two selected clusters.

From the selected events two event samples are built:

- **Control sample:** The photon candidate is demanded to be in the backward calorimeter. The electron candidate has to be found in the central part of the detector.
- **DVCS candidates:** The photon candidate is requested to be in the central part of the detector and the electron candidate in the backward.

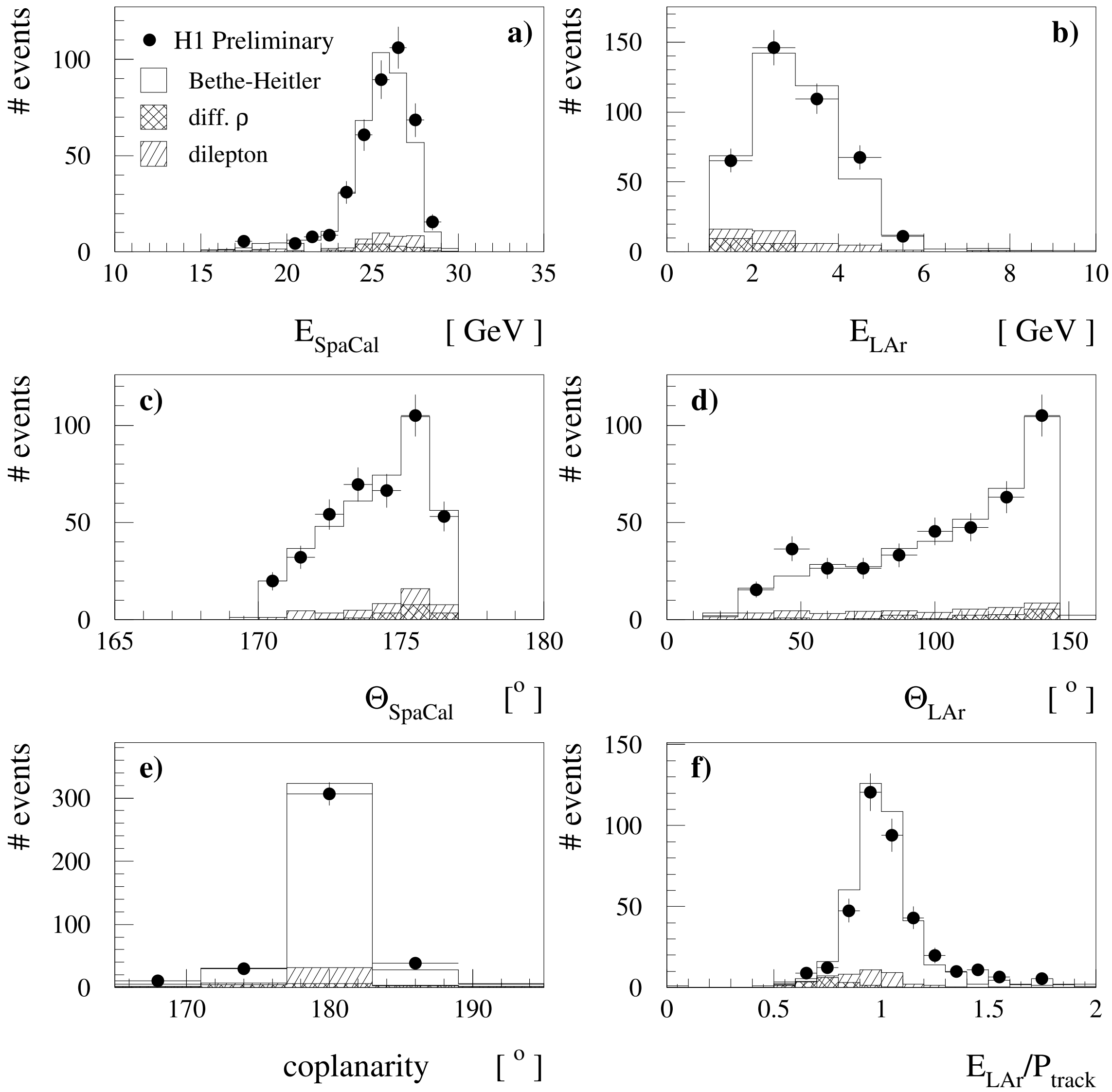

Figure 3: Event distributions (uncorrected) of the control sample. The data are compared to the sum of the prediction for the Bethe–Heitler process, elastic dilepton production and diffractive ρ production. a) energy of the cluster in the Spaghetti calorimeter (backward) , b) energy of the cluster in the LAr calorimeter (central), c) polar angle of the cluster in the Spaghetti calorimeter, d) polar angle of the cluster in the LAr calorimeter, e) coplanarity; difference in the azimuthal angle of the two clusters, f) ratio of the energy of the cluster and the momentum measured by the tracking detector for the electron candidate.

3 Control sample

This sample is dominated by the Bethe–Heitler process. Due to the large scattering angle of the electron the DVCS process is highly suppressed and therefore negligible. Two additional background sources can give such a configuration in the detector. These are the elastic electro–production of ρ–mesons and the elastic production of electron pairs by photon–photon processes.

In the case of the elastic ρ production one of the decay pions is faking an electron signature in the calorimeter and the other pion is leaving the central detector by the beam pipe. The electron originating from this process is found to be in the backward detector. Its track is not reconstructed due to the limited acceptance of the tracking system. In the case of dilepton production a Bethe–Heitler configuration can be faked if two of the resulting three leptons are detected and the third lepton is leaving the main detector through the beam pipe. These backgrounds have been studied using a Monte Carlo simulation of vector mesons[5] and two lepton processes[6]. Since these backgrounds involve a charged particle in the central part of the detector which is detected by the tracking system, these background sources only contribute to the control sample and not to the sample of DVCS candidates.

In figure 3 distributions of the control sample are shown. The data are compared to MC predictions which include the Bethe–Heitler process, the elastic ρ production and the elastic dilepton production. A good description of the data by the sum of the different contributions is achieved showing that they are well understood and also that the detector response is well described by the simulation.

4 DVCS candidates

In this sample where the photon candidate is demanded to be in the central part of the detector the DVCS contribution is the dominating part of the cross section. In figures 4 and 5 distributions are shown where the data are compared to predictions which are based on the Bethe–Heitler process only. A large excess of events above the prediction is observed. The data are different in shape and in absolute normalisation in comparison to the Bethe–Heitler simulation. The coplanarity distribution which is the difference in azimuthal angle of the two clusters and which is a measure of the p_t–balance of the electron–photon system is found to be much broader than expected for a pure Bethe–Heitler event sample. The Bethe–Heitler process is a pure electromagnetic interaction and has a very steep t dependence, where t is the square of the four–momentum transfer at the proton vertex. The momentum transfer to the proton is small and the electron–photon system is well balanced in p_t. Diffractive events have a flatter t dependence than the purely electromagnetic Bethe–Heitler process which leads to a less p_t–balanced electron–photon system. Such an effect leads directly to a broader coplanarity distribution. The measured coplanarity distributions is already a hint for the diffractive nature of the underlying process for the excess of events which is observed.

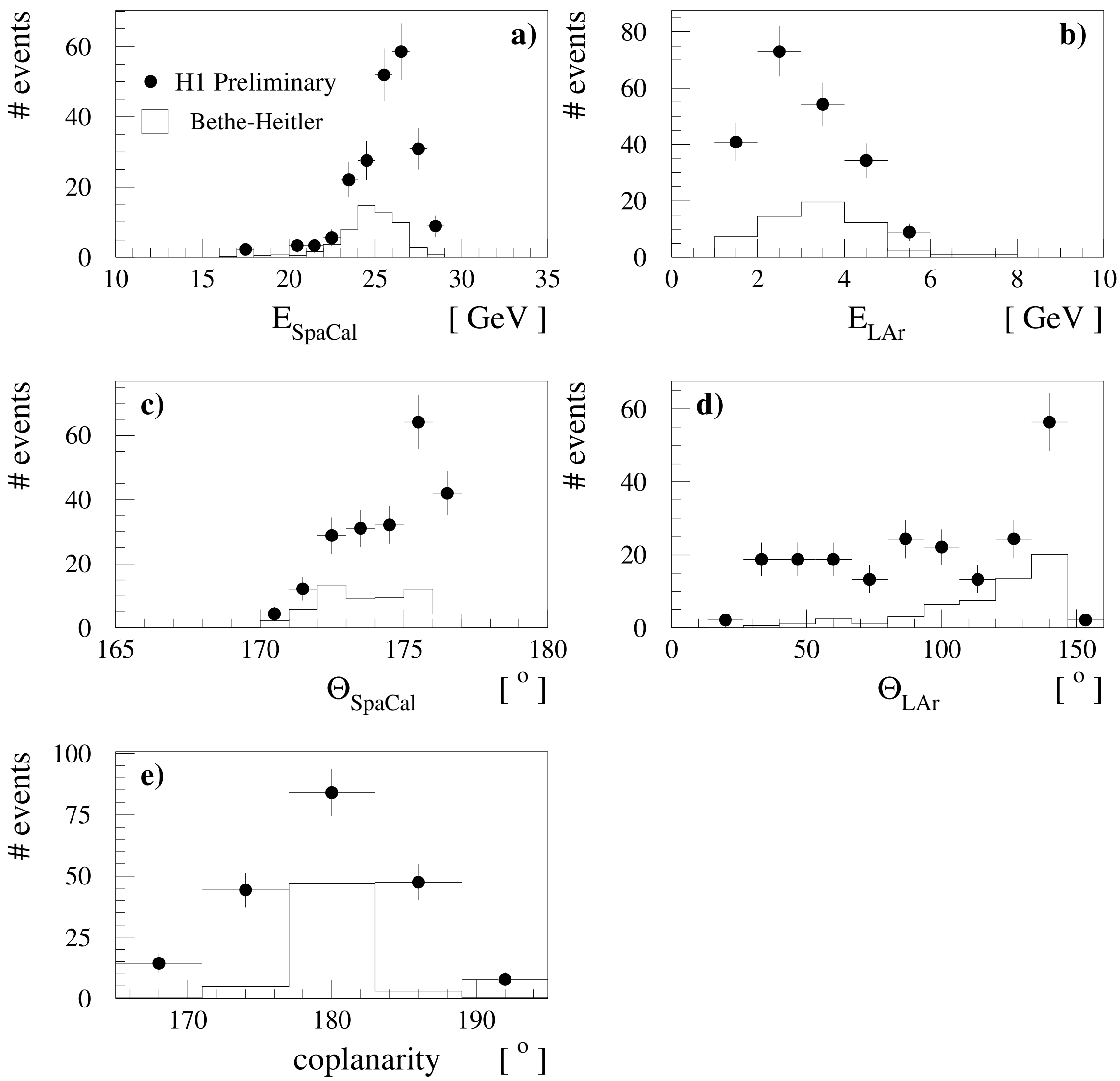

Figure 4: Event distributions (uncorrected) for the DVCS candidates. a) energy of the cluster in the Spaghetti calorimeter (backward), b) energy of the cluster in the LAr calorimeter (central), c) polar angle of the cluster in the Spaghetti calorimeter, d) polar angle of the cluster in the LAr calorimeter, e) coplanarity; difference in the azimuthal angle of the two clusters.

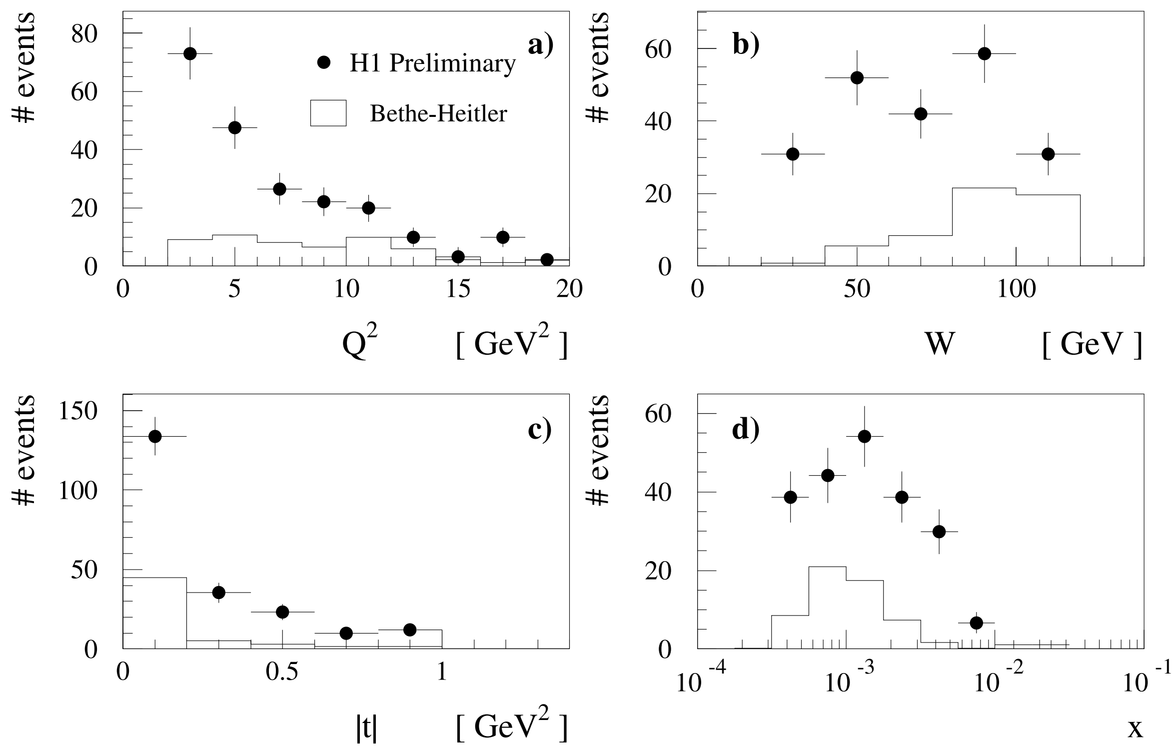

Figure 5: Event distributions (uncorrected) for the DVCS candidates. Distributions of the kinematic variables a) Q^2, b) W, c) t and d) x are shown.

5 Cross section measurement

The event kinematics was reconstructed using the polar angle of the final state electron and photon (double angle method). The phase space was restricted to the region $2 < Q^2 < 20\,\mathrm{GeV}^2$, $|t| < 1\,\mathrm{GeV}^2$ and $30 < W < 120\,\mathrm{GeV}$. W is the photon proton center of mass energy.

The data have been corrected for detector effects. The proton dissociation background has been estimated to be $10\,\%$ and subtracted. Data have been corrected for initial state radiation of real photons from the electron line. The acceptance has been determined by a MC calculation to extract the elastic cross section.

The systematic error has been estimated by varying the energy scales of the electromagnetic calorimeters and the measured angle. Additional errors originate from the noise determination of the forward detectors, the luminosity measurement and the uncertainty of the proton dissociation background. The mean total systematic error is around $15\,\%$. The main error source is due to the measurement of the scattered electron angle.

In figures 6 and 7 the differential cross sections as a function of Q^2 and W are shown. The data are compared with the Bethe–Heitler prediction alone and with the full calculation including Bethe–Heitler, DVCS and their interference. The description of the data by the calculations is good, both in shape and in absolute normalisation. The uncertainty in the theoretical prediction for the DVCS visible as the band for the prediction is dominated by the unknown slope of the t-dependence of the DVCS part of the cross section, assuming $7 < b < 10\,\mathrm{GeV}^{-2}$.

6 Conclusion

A clear signal of DVCS is observed at HERA. Cross sections as a function of Q^2 and W have been measured for the first time. The experimental results are well described in shape by LO QCD calculations and in normalisation if the t slope is assumed to be between 7 and $10\,\mathrm{GeV}^{-2}$.

Acknowledgments

We would like to thank M. Diehl and A. Freund for valuable discussions. We are grateful to the HERA machine group whose outstanding efforts have made and continue to make this experiment possible. We thank the engineers and technicians for their work in constructing and now maintaining the H1 detector, our funding agencies for financial support, the DESY technical staff for continual assistance, and the DESY directorate for the hospitality which they extend to the non DESY members of the collaboration.

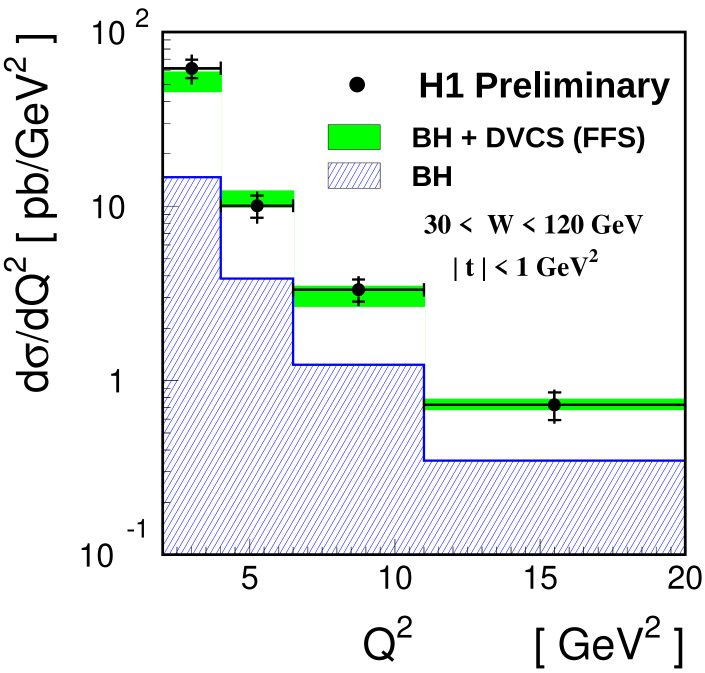

Figure 6: The measured cross sections of the reaction $e^+p \longrightarrow e^+\gamma p$ as a function of Q^2 is shown and compared to theoretical prediction (FFS)[2]. The uncertainty in the theoretical prediction for the DVCS is dominated by the unknown slope of the t-dependence of the DVCS part of the cross section, assuming $7 < b < 10\,\mathrm{GeV}^{-2}$. In addition the prediction for the Bethe–Heitler process (BH) alone is shown.

References

[1] A. V. Radyushkin *Phys. Rev.* D **56**, 5524 (1997).

[2] L. L. Frankfurt, A. Freund, M. Strikman *Phys. Rev.* D **58**, 114001 (1998) and *Phys. Rev.* D **59**, 119901E (1999).

[3] A. Freund, *Phys. Lett.* B **472**, 412 (2000).

[4] H1 Collaboration, I. Abt et al., *Nucl. Instrum. Methods* A **386** (1997) 310 and 348.

[5] B. List, Diploma Thesis, Techn. Univ. Berlin, (1993), unpublished.

[6] T. Abe et al., in Proc. *Monte Carlo Generators for HERA physics*, Eds. A. T. Doyle, G. Grindhammer, G. Ingelman, H. Jung, DESY-PROC-1999-02, p. 566.

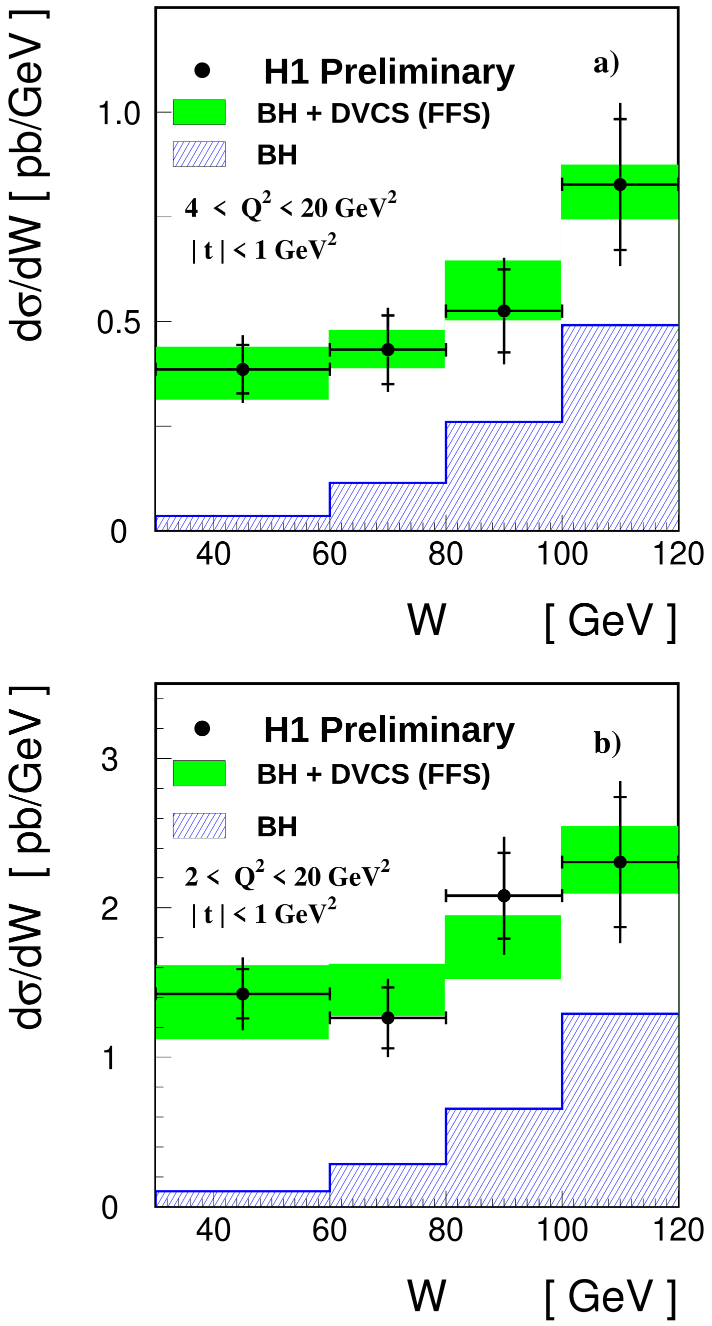

Figure 7: The measured cross section of the reaction $e^+p \longrightarrow e^+\gamma p$ as a function of W is shown and compared to the theoretical prediction (FFS)[2]. The cross section is measured in the kinematic ranges a) $4 < Q^2 < 20\,\mathrm{GeV}^2$, $|t| < 1\,\mathrm{GeV}^2$ and b) $2 < Q^2 < 20\,\mathrm{GeV}^2$, $|t| < 1\,\mathrm{GeV}^2$. The uncertainty in the theoretical prediction for the DVCS is dominated by the unknown slope of the t-dependence of the DVCS part of the cross section, assuming $7 < b < 10\,\mathrm{GeV}^{-2}$. In addition the prediction for the Bethe–Heitler process (BH) alone is shown.