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Measurement of Deeply Virtual Compton Scattering at HERA II

H1 Collaboration

Abstract

A measurement[1] is presented of elastic deeply virtual Compton scattering $\gamma^* p \to \gamma p$ using e^+p and e^-p collision data recorded with the H1 detector at HERA. The analysed data samples correspond to integrated luminosities of 146 pb^{-1} and 145 pb^{-1} recorded in e^+p and e^-p collisions, respectively. Cross sections are measured as a function of the virtuality Q^2 of the exchanged photon and the centre-of-mass energy of the $\gamma^* p$ system, W, in the kinematic domain $6.5 < Q^2 < 80$ GeV^2, $30 < W < 140$ GeV and $|t| < 1$ GeV^2, where t denotes the squared momentum transfer at the proton vertex. For the first time, a beam charged asymmetry is obtained in a colliding mode, using data recorded in e^+p and e^-p. A significant non zero value is measured. It is related to the interference of QCD and QED processes, namely deeply virtual Compton scattering and Bethe-Heitler, respectively.

[1]The analysis of e^-p data was published since the first release of this preliminary result, therefore some of the original figures are now included as final in the publication [10]

1 Introduction

Measurements of inclusive deep-inelastic scattering (DIS) of leptons and nucleons allow the extraction of Parton Distribution Functions (PDFs) which describe the longitudinal momentum carried by the quarks, anti-quarks and gluons that make up the nucleon. As a shortfall of this picture, the PDFs contain neither information on the correlations between partons nor on their transverse motion. This missing information can be provided by measurements of processes in which the nucleon remains intact and the four momentum transfer squared at the nucleon vertex, t, is non-zero [1–6].

The simplest such reaction is deeply virtual Compton scattering (DVCS), the diffractive scattering of a virtual photon off a proton $\gamma^* p \to \gamma p$. In the present analysis DVCS is accessed through the reaction $e^{\pm}p \to e^{\pm}\gamma p$ in high energy electron-proton collisions at HERA [7–10]. This reaction receives also contribution from the purely electromagnetic Bethe-Heitler (BH) process, where the photon is emitted from the electron. The BH cross section is precisely calculable in QED and can be subtracted from the total process rate to extract the DVCS cross section. In addition, an interference term contributes to the cross section due to the identical final states of both DVCS and BH processes. In the leading twist approximation, the main contribution resulting from the interference of the BH and DVCS processes is proportional to the cosine of the azimuthal angle ϕ of the photon [1, 11]. This ϕ angle is defined in the proton rest frame as the angle between the plane formed by the incoming and scattered electron and that formed by the γ^* and the scattered proton. Cross section measurements which are integrated over ϕ are not sensitive to the interference term. But the interference term can be singled out in the measurement of a cross section asymmetry with respect to the lepton beam charge.

This paper presents a new measurement of single differential DVCS cross sections as a function of Q^2 and W using e^+p data. The data were recorded during the HERA II running period with the H1 detector when HERA collided protons of 920 GeV energy with 27.6 GeV positrons. The sample corresponds to an integrated luminosity of 146 pb^{-1} recorded in e^+p collisions. This analysis complements the recent H1 measurement [10] of DVCS performed using e^-p data. The measurement is carried out in the kinematic range $6.5 < Q^2 < 80$ GeV^2, $30 < W < 140$ GeV and $|t| < 1$ GeV^2 and the same analysis strategy as described in [10] is followed. Both e^+p and e^-p data sets from this analysis and from [10], respectively, are used to extract the beam charge asymmetry (BCA) of the interference term between DVCS and BH processes.

2 Results

2.1 Cross Sections as a function of Q^2 and W

As a first step, the complete DVCS sample is used to extract the W dependence of the DVCS cross section over the whole Q^2 range, corrected to a bin center value of $Q^2 = 8$ GeV^2. The Q^2 dependence is also extracted over the whole W range and expressed at $W = 82$ GeV. The results for both e^+p and e^-p data sets are displayed in figure 1. The new e^+p cross sections are in agreement within errors with the previous measurements [8–10]. The steep and approximately linear rise of the cross section with W is an indication of the presence of a hard underlying process [12].

2.2 Measurement of the Beam Charge Asymmetry

Differential cross sections of the process $\gamma^* p \to \gamma p$ are measured as a function of the azimuthal angle ϕ, separately in e^+p and e^-p data samples. The BCA is then derived by building the asymmetry

$$\text{BCA} = \frac{d\sigma^+/d\phi - d\sigma^-/d\phi}{d\sigma^+/d\phi + d\sigma^-/d\phi} \tag{1}$$

where $d\sigma^+/d\phi$ and $d\sigma^-/d\phi$ are differential cross sections measured in e^+p and e^-p, respectively. Due to the experimental resolution on t, the angle ϕ can not be defined when $|t| < 0.05$ GeV^2. The BCA measurement is thus explicitely restricted to the range $0.05 < |t| < 1$ GeV^2. For the definition of the angle ϕ the convention from [11] is used. The result is presented in figure 2. The result of the fit of a $p_1 \cos\phi$ function to the measured points is also displayed. The experimental resolution on ϕ is of the order of $15°$ for $\phi = 0°$ and $180°$ and goes up to $40°$ for $\phi = 90°$. A deconvolution method is therefore needed to extract the real BCA amplitude from the measurement presented in figure 2 After applying such a deconvolution, the amplitude of the $\cos\phi$ term is found to be $p_1^{cor.} = 0.17 \pm 0.03$ (stat.) ± 0.05 (sys.).

3 Conclusion

The cross section for deeply virtual Compton scattering $\gamma^* p \to \gamma p$ has been measured with the H1 detector at HERA. The analysis uses all e^+p and e^-p data recorded during the HERA II running period. This corresponds to a eight times higher integrated luminosity compared to the previous H1 publication based on HERA I data. The measurement is performed in the kinematic range $6.5 < Q^2 < 80$ GeV^2, $30 < W < 140$ GeV and $|t| < 1$ GeV^2.

For the first time, a beam charged asymmetry is obtained in a colliding mode, using data recorded in e^+p and e^-p. A significant non zero value is measured. It is related to the interference of QCD and QED processes, namely deeply virtual Compton scattering and Bethe-Heitler, respectively.

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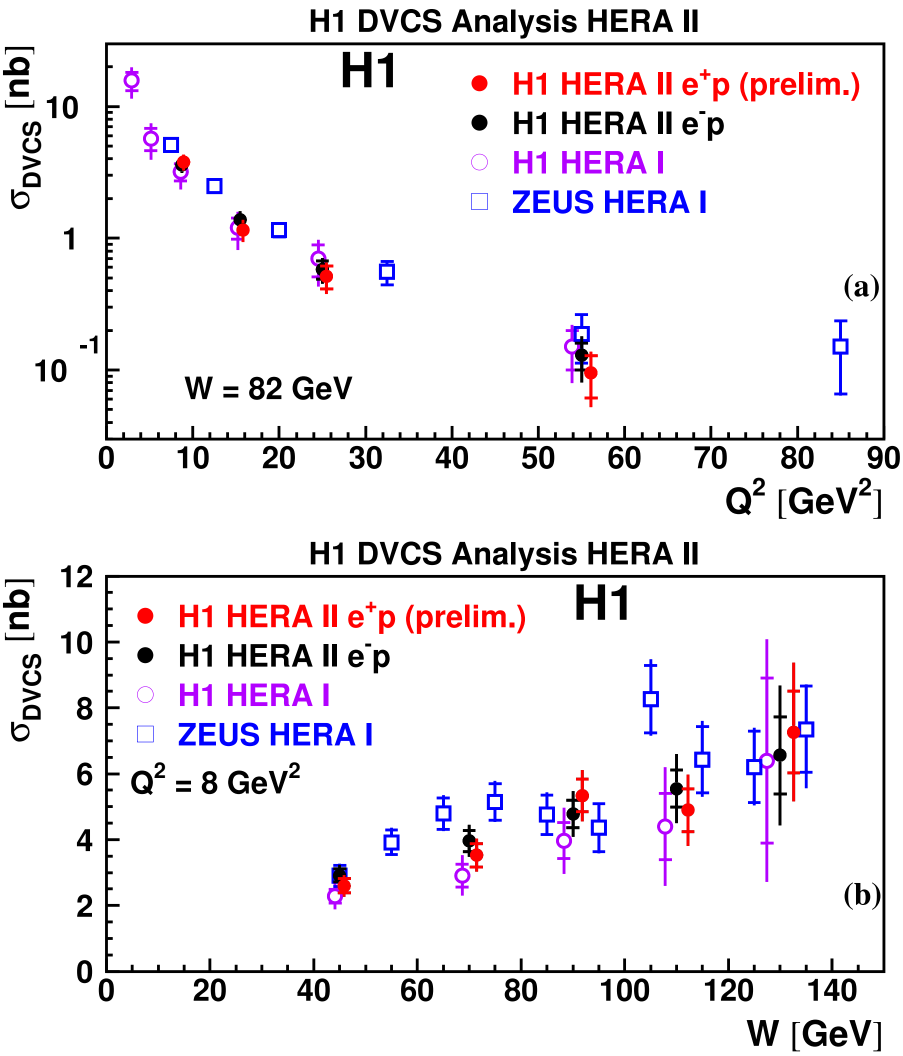

Figure 1: DVCS cross section as a function of Q^2 at $W = 82$ GeV (a), and as a function of W at $Q^2 = 8$ GeV^2 (b). The results from the previous H1 and ZEUS publications based on HERA I data [8, 9] and e^-p HERA II data [10] are also displayed. The inner error bars represent the statistical errors, the outer error bars the statistical and systematic errors added in quadrature.

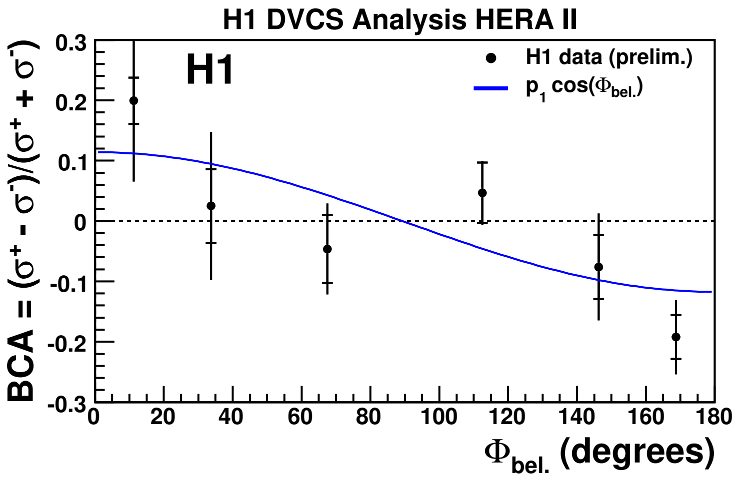

Figure 2: Beam charge asymmetry as a function of ϕ, measured in the range $0.05 < |t| < 1$ GeV^2. The line represent the result of a $p_1 \cos\phi$ fit to the data points, before deconvolution by the ϕ resolution.