

ZEUS high- y Cross Section Measurement and Preparation for Low Energy Running

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HERA is the only place to provide information on F_L in the gluon dominated region of ep interactions. The ZEUS experiment has extended its cross section measurement to the high- y region, where the F_L contribution can be sizable. In this report, details of the measurement and the first look on data from the Low Energy Running, which allows separation of F_2 and F_L , are presented.

1 Introduction

The ep collider HERA has played a crucial role in the investigation of proton structure, especially in the low- x region where gluons are dominant in the proton. The ZEUS experiment performed a precise measurement of Deep Inelastic Scattering (DIS) reduced cross sections using data collected in 1996 and 1997 [2]. The kinematics of lepton-proton DIS is described by x , the Bjorken scaling variable, Q^2 , the negative square of the invariant mass of the virtual exchanged boson, and y , the inelasticity. The reduced cross sections can be defined as

$$\tilde{\sigma} \equiv \frac{xQ^4}{2\pi\alpha^2 Y_+} \frac{d^2\sigma}{dx dQ^2} = F_2(x, Q^2) - \frac{y^2}{Y_+} F_L(x, Q^2), \quad (1)$$

where $Y_+ = 1 + (1 - y)^2$. Since the contribution of F_L to the cross section is sizable only at high y , the measurement provided information mainly on F_2 , which is sensitive to the total number of quarks and anti-quarks in the proton. A measurement of F_2 also allows to determine a gluon distribution indirectly from the scaling violation, $\frac{\partial F_2}{\partial \ln Q^2}$.

The longitudinal structure function of the proton, F_L , is directly sensitive to gluon dynamics in the proton. Since high- y corresponds to the low- x region, F_L with gluon dominance can be investigated at HERA. The ZEUS experiment has performed a new cross section measurement, which is optimized for the high- y region, with data collected in 2006. A special trigger was prepared for this measurement, which takes events in a new kinematic region of high y . The measurement requires a good understanding of the scattered electron energy and a good control of background contamination, since events with higher y have lower energy of the scattered electron^a, which is more difficult to identify. Details and results of the measurement are presented.

For separation of F_2 and F_L , cross sections at the same (x, Q^2) but different y values need to be measured (See Eq. 1). This requires measurements with different center-of-mass (CM) energies because of the relation $s = Q^2/xy$, where s is the ep center-of-mass energy. For that reason, HERA started the operation with lowered proton beam energy, called Low Energy Run (LER), in March 2007. Also shown in this report are the first LER data collected by the ZEUS experiment.

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^aThe word *electron* is used for both electron and positron in this paper.

2 High- γ cross section measurement

2.1 Details of the analysis

The data were collected with the CM energy of 318 GeV, where proton and positron beam energies were 920 GeV and 27.5 GeV, respectively. The total luminosity was 29.5 pb^{-1} .

For online event selection, two independent trigger-logic were prepared to take events with low scattered electron energy. One required a scattered electron with energy above 4 GeV. The second logic required $\Sigma_{\text{total}}(E - p_z)_i > 30 \text{ GeV}$ and $\Sigma_{\theta_i \lesssim 165^\circ} (E - p_z)_i > 20 \text{ GeV}$, where E_i and p_{z_i} ^b are energy and longitudinal momentum of the i -th cell of the calorimeter and each sum runs over all the cells and the cells excluding the ones in the rear, close to the beam pipe, respectively. Events satisfying at least one of the two triggers were selected.

For offline event selection, the following conditions were applied:

- $|Z_{\text{vtx}}| < 50 \text{ cm}$, where Z_{vtx} is the z position of an event vertex.
- $\Sigma_{\text{total}}(E - p_z)_i > 38 \text{ GeV}$
- The presence of an electron candidate found in the calorimeter with energy ($E_e > 5 \text{ GeV}$) and angle ($\theta_e \lesssim 170^\circ$). For $\theta_e \lesssim 151^\circ$, a track was required to be matched to the candidate.

The electron energy scale and the dead material corrections are well understood based on the investigation of three data samples, namely exclusive J/Ψ photoproduction ($E_e \lesssim 5 \text{ GeV}$), QED Compton ($5 \text{ GeV} < E_e < 25 \text{ GeV}$) and DIS ($10 \text{ GeV} < E_e < 35 \text{ GeV}$). The uncertainty on the electron energy scale is assigned a value of $\pm 2\%$.

The main source of contamination to the DIS sample are photoproduction (γp) events, $\gamma p \rightarrow X$, where the electron emits a quasi-real photon and disappears down the beam pipe. The photon interacts with the proton producing in particular π^0 and low energy π^\pm , which may be misidentified as electron in the calorimeter. The contamination is severe at high- y , where the energy of the scattered electron is small. To understand the γp background, two analyses were performed. The first analysis was done with events tagged by the 6m tagger, which is a detector placed downstream of the electron beam and which can directly detect an escaping electron. The sample is reasonably described by the γp MC except for the

^bIn the ZEUS coordinate, proton beam direction is in the z direction.

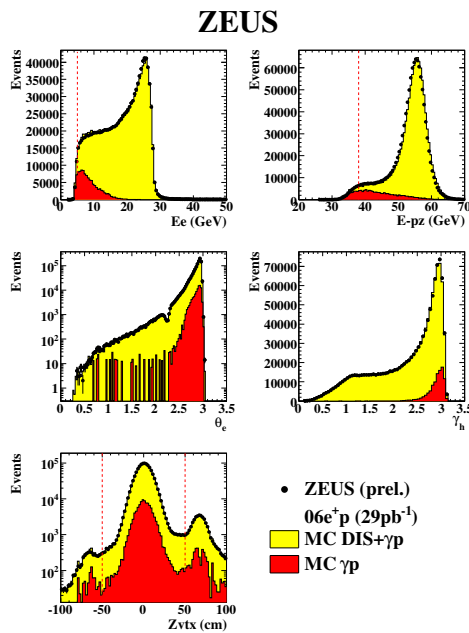


Figure 1: Distributions of measured quantities, E_e , $\Sigma_{\text{total}}(E - p_z)_i$, θ_e , hadronic angle (γ_h) and Z_{vtx} , compared to MC prediction as described in the figure.

overall normalization. The second analysis was done with a γp enriched sample, in which a low quality scattered electron was found, based on its calorimeter shower shape. In this sample, the difference between the data and the DIS MC is described by the scaled γp MC. The normalization factor for the γp MC was extracted for each sample separately and the two values agreed within 5%. Considering the imperfect description of the shape of the considered distributions by the γp MC, an uncertainty of $\pm 10\%$ was conservatively assigned to the normalization factor.

Distributions of measured quantities for selected DIS events are shown in Fig. 1. They are well described by MC prediction in which the normalization factor described above is applied to the γp MC.

2.2 Reduced cross sections

Kinematic variables are reconstructed using the energy and the angle of the scattered electron. Bins are defined in the (y, Q^2) plane for good coverage of the high- y region. In the region where reduced cross sections were extracted, most of the bins had acceptance above 60% and the contamination of γp events was estimated to be less than 40% in each bin.

Reduced cross sections are extracted as,

$$\tilde{\sigma} = \frac{N_{\text{data}} - N_{\gamma p \text{ MC}}}{N_{\text{DIS MC}}} \cdot \tilde{\sigma}_{\text{theory}}^{\text{BORN}} \quad (2)$$

The following systematic sources were taken into account:

- electron energy scale ($\pm 2\%$),
- γp MC normalization factor ($\pm 10\%$),
- electron finding inefficiency ($\pm 10\%$),
- $\Sigma_{\text{total}}(E-p_z)_i$ threshold (± 2 GeV).

The effect on the cross section measurement was evaluated by varying the value of each systematic source by a factor in brackets. At highest y , for low Q^2 ($Q^2 < 50$ GeV²), the systematic uncertainty from the γp MC normalization factor was largest, giving $\sim 5\%$ uncertainty on the cross section.

The measurement was done for $0.1 < y \lesssim 0.8$ and $25 \text{ GeV}^2 < Q^2 < 1300 \text{ GeV}^2$. The extracted reduced cross sections are shown in Fig. 2, as a function of y for fixed Q^2 values. They

are compared with the Standard Model predictions with CTEQ5d PDF [3] and with ZEUS-Jets PDF [4]. The measured reduced cross sections are well described by the predictions.

The measurement was successfully extended to the high- y region. The measured points are extended to higher y for $Q^2 \lesssim 300 \text{ GeV}^2$, compared to the previous measurement, and more measured points are provided at mid- y value ($y \gtrsim 0.3$).

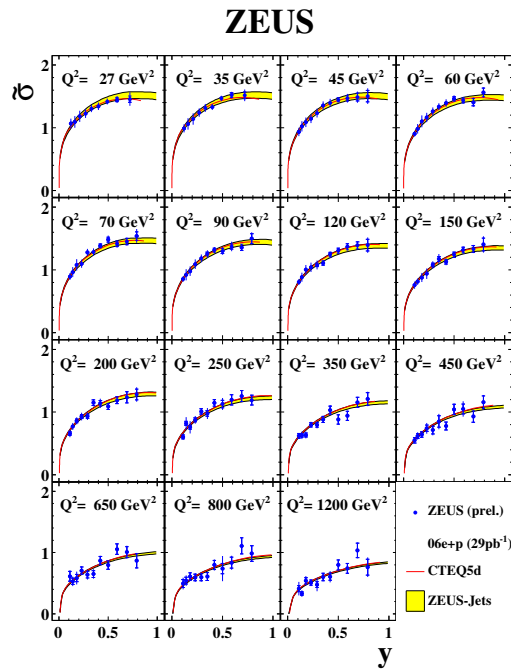


Figure 2: The reduced cross sections as a function of y for fixed Q^2 .

3 Low Energy Running (LER)

HERA ended its operation with proton beam energy of 920 GeV in March 2007. Since then, HERA started to operate with lowered proton beam energy, namely 460 GeV, for the DIS cross section measurement with different center of mass energies which will allow the extraction of F_2 and F_L .

The ZEUS experiment has performed a feasibility study for F_L measurement [5]. As can be seen in Eq. 1, larger difference in y between the measurements at different beam energies brings better precision for F_L . It can be achieved by a cross section measurement at higher y in LER data. As presented in this report, the ZEUS experiment has already extended its measurement to higher y compared to the previous measurement. The experiment started to collect LER data, as shown in Fig. 3, with a newly implemented trigger which requires $\Sigma_{\text{total}}(E - p_z)_i > 30$ GeV and has no electron finding requirement online.

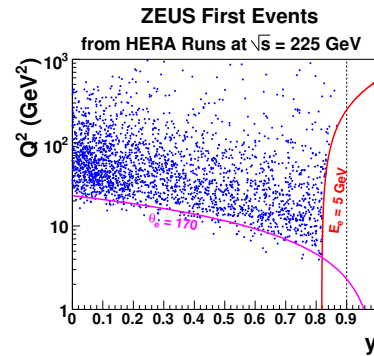


Figure 3: First look on the LER data, in the (y, Q^2) plane.

4 Summary

The ZEUS experiment performed a new cross section measurement which is optimized for the high- y region using data collected in 2006. The measurement extended to higher y in the kinematic region, compared to the previous measurement. The experiment started to collect LER data, aiming for a direct measurement of F_L .

References

- [1] Slides: <http://indico.cern.ch/contributionDisplay.py?contribId=278&sessionId=8&confId=9499>
- [2] ZEUS Coll., S. Chekanov *et al.*, Eur. Phys. J. **C21** 443 (2001).
- [3] CTEQ Coll., H.L. Lai *et al.*, Eur. Phys. J. **C12** 375 (2000).
- [4] ZEUS Coll., S. Chekanov *et al.*, Eur. Phys. J. **C42** 1 (2005).
- [5] D. Kollar, *Prospects for a measurement of F_L at HERA with the ZEUS detector*, in proceedings, DIS 2006 (2006).