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HIGH Q^2 NEUTRAL CURRENT SCATTERING AT ZEUS*

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The cross sections for neutral current deep inelastic scattering have been measured in e^-p and e^+p collisions at a centre-of-mass energy of 318 GeV with the ZEUS detector at HERA using an integrated luminosity of 16 pb^{-1} and 63 pb^{-1}, respectively. Single and double differential cross sections at high Q^2 are presented and compared to the predictions of the Standard Model. The structure function xF_3 has been extracted by combining the e^-p data with the recent ZEUS measurement of e^+p neutral current Deep Inelastic Scattering (DIS) at a centre-of-mass energy of 300 GeV. The measured xF_3 is well described by the Standard Model using recent proton parton density functions.

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1. Introduction

Deep inelastic lepton proton scattering has played a key role in the investigation of the structure of the proton. The HERA collider offers the possibility to probe the proton structure at small resolution scales, a previously unexplored kinematic domain.

This paper presents a measurement of high Q^2 neutral current single and double differential cross sections using e^-p (e^+p) data recorded in the years 1998/1999 (1999/2000) with the ZEUS detector. In comparison to previous analyses the available centre-of-mass energy is increased to $\sqrt{s} \approx 318$ GeV and the statistical precision of the e^+p measurement is improved. The data correspond to an integrated luminosity of 63 pb^{-1} (16 pb^{-1}) for e^+p (e^-p). The weak interaction can be studied from the opposite contribution of the γ–Z^0-interference in e^-p and e^+p scattering.

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The structure function xF_3, which is a measure of the valence quark distribution, was extracted by combining the e^-p data with the recent ZEUS measurement of e^+p neutral current deep inelastic scattering at a centre-of-mass energy of 300 GeV [1].

2. Neutral current analysis

2.1. Neutral current cross section

The double differential neutral current cross section for $e^{\pm}p \to e^{\pm}X$ can be written as

$$\frac{d^2\sigma_{\rm NC}^{e^{\pm}p}}{dxdQ^2} = \frac{2\pi\alpha^2}{Q^4x}\left[Y_+F_2\left(x,Q^2\right) \mp Y_- xF_3\left(x,Q^2\right) - y^2F_{\rm L}\left(x,Q^2\right)\right], \qquad (1)$$

with $Y_{\pm} = 1 \pm (1-y)^2$ and the electro-magnetic constant α. For convenience the reduced cross section is used which is defined as follows

$$\tilde{\sigma}_{\rm NC}^{e^{\pm}p} = \frac{Q^4x}{2\pi\alpha^2}\frac{1}{Y_+}\frac{d^2\sigma_{\rm NC}^{e^{\pm}p}}{dxdQ^2} = F_2\left(x,Q^2\right) \mp \frac{Y_-}{Y_+}xF_3\left(x,Q^2\right) - \frac{y^2}{Y_+}F_{\rm L}\left(x,Q^2\right) . \quad (2)$$

The structure functions can be expressed as a combination of the parton densities inside the proton. In leading order they are

$$\begin{aligned} F_2\left(x,Q^2\right) &= \sum_f x(q_f+\bar{q}_f)A_f\,, \\ xF_3\left(x,Q^2\right) &= \sum_f x(q_f-\bar{q}_f)B_f\,, \\ F_{\rm L}\left(x,Q^2\right) &= 0\,, \end{aligned} \qquad (3)$$

where the summation runs over all quark flavours f and A_f and B_f denote the electroweak couplings. As can be seen from equations 1 and 3 neutral current DIS at high Q^2 tests both the electroweak and QCD sector of the Standard Model (SM).

2.2. Event selection and reconstruction

Neutral current events are selected by the identification of the scattered lepton. An isolated high energetic (>10 GeV) electro-magnetic energy cluster in the calorimeter is required which has to be matched with a corresponding track if within the tracking chamber acceptance. The main backgrounds occur from photoproduction and cosmic rays. They are effectively rejected by demanding a $E - p_Z$ value close to $2\,E_e = 55$ GeV and a balance in transverse momentum, respectively. The event kinematics are reconstructed using the lepton scattering polar angle θ and the hadronic polar angle γ_h. This method is, in first order, independent of the calorimeter energy scale.

2.3. Cross section results

The single differential cross sections $d\sigma/dQ^2$ for $e^{\pm}p$ data *versus* Q^2 is shown in Fig. 1 (left). In addition, the SM predictions evaluated using CTEQ5D PDFs [2] are presented. In the measured kinematic range the cross section decreases by six orders of magnitude for both e^-p and e^+p scattering. Whereas the cross sections are of similar size at lower values of Q^2 due to the dominating photon-exchange process, they differ at higher Q^2 where the exchange of the Z^0 boson becomes important. The different behaviour of the γ–Z^0-interference to e^-p and e^+p cross sections can also be seen in the measurement of $d\sigma/dx$ ($Q^2 > 10000\,\mathrm{GeV}^2$) shown in Fig. 1 (right). The interference is constructive for e^-p interactions whereas the cross section is decreased for the e^+p measurement. The high statistical precision of the e^+p data set in comparison to the e^-p data is evident.

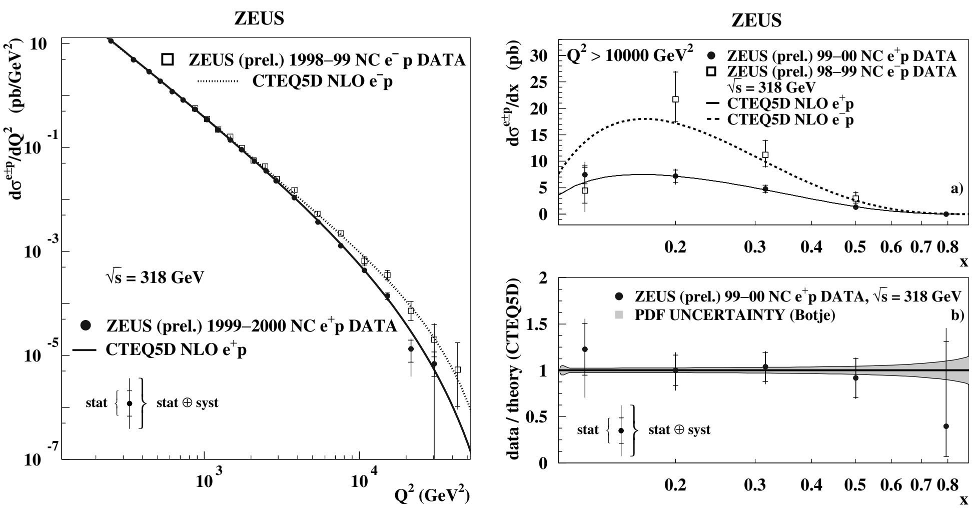

Fig. 1. The NC single differential cross sections $d\sigma/dQ^2$ (left) and $d\sigma/dx$ ($Q^2 > 10000\,\mathrm{GeV}^2$) (top right) for $e^{\pm}p$ data and SM expectation evaluated using CTEQ5D PDFs. The ratio between e^+p $d\sigma/dx$ values and the SM prediction is also shown (bottom right), where the shaded band denotes the uncertainty of Botje's fit [3].

The reduced cross section for $e^{\pm}p$ data at fixed x *versus* Q^2 and the corresponding SM expectation evaluated using PDF's from the ZEUS NLO QCD fit [4] are shown in Fig. 2 (left). Up to highest values of Q^2 the data are well described by the SM prediction. The dominating photon-exchange process resulting in similar e^-p and e^+p cross section at $Q^2 < 3000\,\mathrm{GeV}^2$ is clearly visible as well as the different behaviour at higher values of Q^2 due to different contribution of the γ–Z^0-interference. This difference can

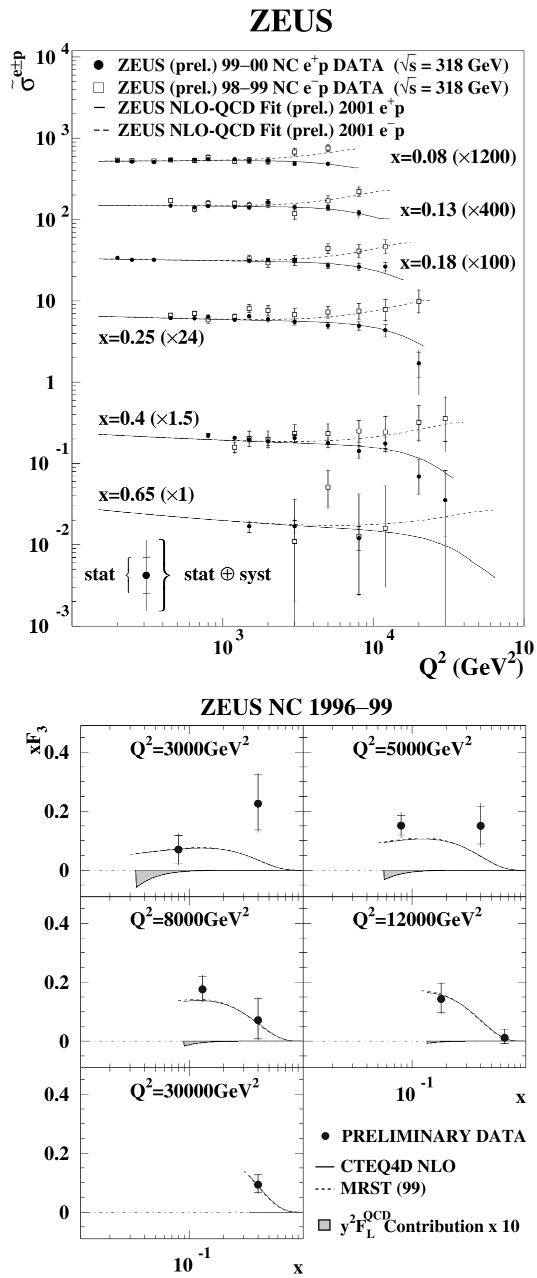

Fig. 2. The NC reduced cross section for $e^{\pm}p$ data at fixed x *versus* Q^2 and SM expectation evaluated using the ZEUS NLO QCD fit PDFs (top). The structure function xF_3 at fixed Q^2 *versus* x extracted with ZEUS 1996-99 data (bottom).

be quantified in terms of the proton structure function $xF_3\left(x, Q^2\right)$. An extraction was performed using the e^-p data set and the previous ZEUS e^+p measurement [1] using data from 96/97 which were taken at a lower centre-of-mass energy ($\sqrt{s} = 300\,\mathrm{GeV}$). The result of this extraction is shown in Fig. 2 (right). This measurement reflects the distribution of the valence quarks.

3. Summary

Measurements of the single and double differential e^-p and e^+p NC cross sections were presented. In the whole measured kinematic range the data are well described by the SM predictions. The different contribution of the Z^0 boson exchange to both cross sections was confirmed and the proton structure function xF_3 extracted.

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