High Q^2 neutral current cross sections in e^+p DIS*

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Measurements of cross sections for neutral current deep inelastic scattering at HERA are presented and the proton structure-function F_2^{em} extracted. The measurements are found to be in agreement with the Standard Model expectations.

1 Introduction

Deep inelastic scattering (DIS) of leptons off nucleons probes the structure of matter at small distance scales. Two types of DIS interactions are possible at HERA: neutral current (NC) reactions $e^-p \to e^-X$ and $e^+p \to e^+X$, where a photon or Z^0 boson is exchanged and charged current (CC) interactions $e^-p \to \nu X$ and $e^+p \to \bar{\nu}X$, where a $W^\pm$ boson is exchanged.

The kinematics of charged current and neutral current deep inelastic scattering processes are defined by the four-momenta of the incoming lepton (k), the incoming proton (P), the outgoing lepton (k') and the hadronic final state (P'). The four-momentum transfer between the electron and the proton is given by $q = k - k' = P' - P$. The square of the centre-of-mass energy is given by $s = (k + P)^2$. The description of DIS is usually given in terms of three Lorentz invariant quantities, which may be defined in terms of the four-momenta k, P and q:

- $Q^2 = -q^2$, the negative square of the four-momentum transfer,
- $x = \frac{Q^2}{2P\cdot q}$, the Bjorken scaling variable,
- $y = \frac{q\cdot P}{k\cdot P}$, the fraction of the energy transferred to the proton in its rest frame.

These variables are related by $Q^2 = xys$, when the masses of the incoming particles can be neglected.

This paper presents measurements of the e^+p neutral current deep inelastic scattering cross sections as functions of x and Q^2 and the proton electromagnetic structure-function F_2^{em}. The measurements are based on data taken by the ZEUS detector in 1999 and 2000, corresponding to an integrated luminosity of 63.2 pb^{-1} at a centre-of-mass energy of ~ 320 GeV.

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2 Cross sections

The double-differential Born-level cross section for the neutral current deep inelastic scattering processes $e^-p \to e^-X$ and $e^+p \to e^+X$, with longitudinally unpolarised beams, is given by:

$$\frac{d^2\sigma_{\rm Born}(e^\pm p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}[Y_+F_2(x,Q^2) - y^2F_L(x,Q^2) \mp Y_-xF_3(x,Q^2)],$$

where $Y_\pm = 1 \pm (1-y)^2$, and α is the QED coupling constant. The neutral current structure functions in the quark parton model are given by:

$$F_2(x,Q^2) = \frac{1}{2}\sum_q [(V_q^L)^2 + (V_q^R)^2 + (A_q^L)^2 + (A_q^R)^2][xq(x,Q^2) + x\bar{q}(x,Q^2)],$$

$$xF_3(x,Q^2) = \sum_q [V_q^L A_q^L - V_q^R A_q^R][xq(x,Q^2) - x\bar{q}(x,Q^2)],$$

where the sums run over all quarks, q, in the proton. In the quark parton model F_L is zero. At next-to-leading order in QCD however quarks interact through gluons, which can split to quark-antiquark pairs or gluon pairs. In this way the struck quarks can have transverse momentum leading to a non-zero contribtuion from F_L. Thus, F_L is a direct probe of the gluon density in the proton. The structure-function xF_3 has contributions from the interference between the photon and Z^0 exchange amplitudes, and pure Z^0 exchange. The functions V_q and A_q contain the couplings of the electron to the photon and Z^0. The NC reduced cross section, $\tilde{\sigma}_{NC}$, is defined to be:

$$\tilde{\sigma}_{NC}(x,Q^2) = \frac{1}{Y_+}\frac{xQ^4}{2\pi\alpha^2}\frac{d^2\sigma^{NC}_{Born}}{dxdQ^2}.$$

3 Results

Figure 3 shows the single differential cross-sections (a) $d\sigma/dQ^2$ and (b) $d\sigma/dx$. It can be seen that the cross section for e^-p [1] scattering is higher than that for e^+p [2]. The Standard Model predicts a higher cross section for e^-p interactions, due to constructive interference between the photon and Z^0 exchange amplitudes, compared to e^+p interactions where destructive interference is expected. The cross sections are well described by the Standard Model predictions evaluated using the ZEUS-S [3] PDFs.

Figure 2 shows the measured reduced cross sections as a function of x in bins of fixed Q^2. The data span a Q^2 range from 200 GeV^2 to 30000 GeV^2 and an x range of 0.005 to 0.65. The results are compared to the Standard Model predictions and found to be in good agreement.

Figure 3 shows the structure-function F_2^{em} extracted from the combined 96/97 [4] and 99/00 [2] data sets as a function of Q^2 in bins of fixed x. Also shown

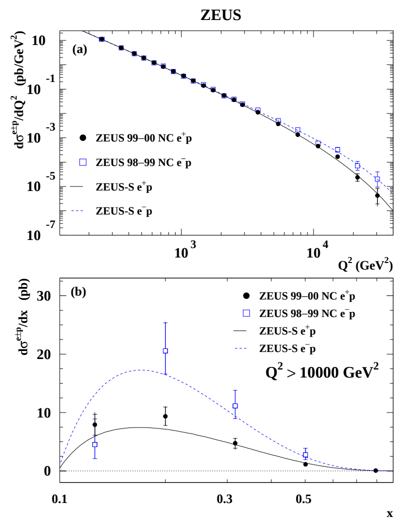

Figure 1. Single differential neutral current cross sections.

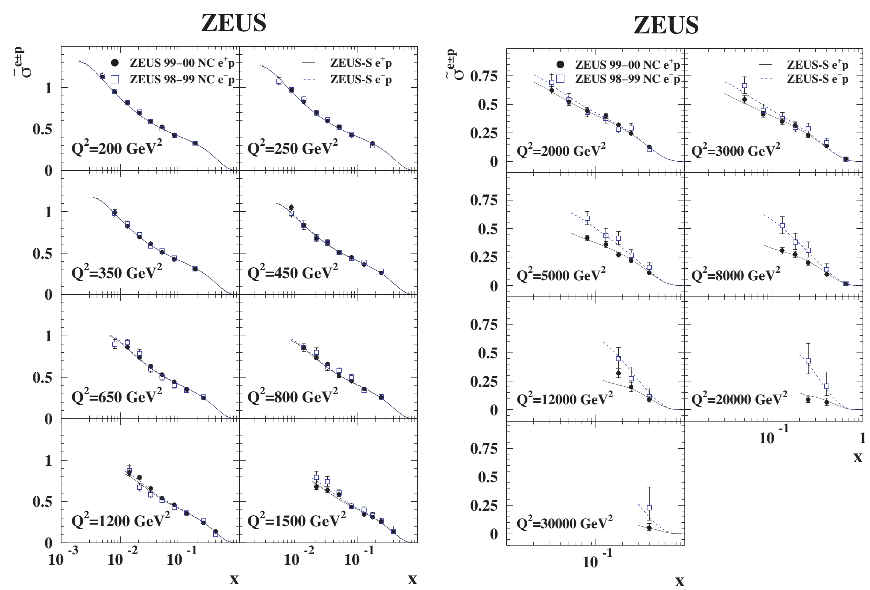

Figure 2. The reduced neutral current cross section.

are data from the H1 [5] Collaboration and fixed-target experiments. The measurements agree well. The Standard Model predictions from the ZEUS-S, MRST [6] and CTEQ [7] PDFs describe the data well.

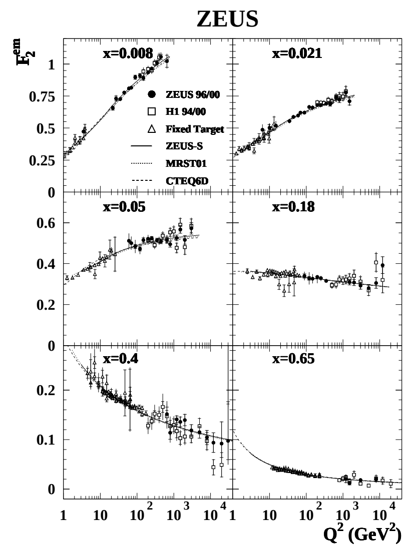

Figure 3. The F_2^{em} structure function.

4 Summary and future prospects

The cross sections for neutral current deep inelastic scattering have been measured using 63.2 pb^{-1} of data collected by the ZEUS detector during 1999 and 2000. The Standard Model predictions are in good agreement with the data. The structure function F_2^{em} was extracted from the measured cross sections and compared with the result of the H1 Collaboration and results from fixed-target experiments.

The HERA accelerator was upgraded in 2001-2002 to provide higher luminosity and longitudinally polarised lepton beams to the collider experiments. The first results from HERA II have recently been presented and in the future the precision of NC and CC DIS cross section measurements at high Q^2 will benefit from the increase in luminosity. In addition the introduction of longitudinally polarised lepton beams will allow the investigation of the chiral nature of the Standard Model in *ep* scattering.

References

1. ZEUS Collab., S. Chekanov *et al.*, Eur. Phys. J. **C28**, 2 (2002).
2. ZEUS Collab., S. Chekanov *et al.*, hep-ex/0401003, 2004. Accepted by Physical Review D.
3. ZEUS Collab., S. Chekanov *et al.*, Phys. Rev. **D67**, 012007 (2002).
4. ZEUS Collab., J.Breitweg *et al.*, Eur. Phys. J. **C12**, 3 (2000).
5. H1 Collab., C. Adloff *et al.*, Eur. Phys. J. **C30**, 1 (2003).
6. A. D. Martin *et al.*, Eur. Phys. J. **C23**, 73 (2002).
7. J. Pumplin *et al.*, JHEP 0207, 012 (2002).