Neutral and Charged Current Cross Sections at High Q^2 at HERA

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Neutral and charged current deep inelastic scattering at high Q^2 has been studied with the H1 and ZEUS detectors at HERA. e^+p data have been collected from 1994 to 1997 corresponding to an integrated luminosity of 37 pb^{-1} (H1) and 47.7 pb^{-1} (ZEUS). e^-p preliminary results from 1998/99 are based on an integrated luminosity of 5.6 pb^{-1} (H1) and 6.3 pb^{-1} (ZEUS). The measured cross sections are in agreement with the Standard Model. A difference in the e^-p and e^+p neutral current cross sections at high Q^2 due to γZ^0 interference was observed. The propagator mass M_W has been determined in a spacelike region from the Q^2 dependence of the e^+p charged current cross section.

1. INTRODUCTION

From 1994 to 1997, HERA was running with 27.5 GeV positrons colliding with 820 GeV protons ($\sqrt{s} = 300$ GeV). The e^+p neutral and charged current cross sections were measured using 37 pb^{-1} and 47.7 pb^{-1} of data collected by H1 [1] and ZEUS [2,3], respectively. In 1998, HERA switched to 27.5 GeV electrons colliding with 920 GeV protons ($\sqrt{s} = 320$ GeV). The e^-p preliminary results presented are based on an integrated luminosity of 5.6 pb^{-1} (H1) and 6.3 pb^{-1} (ZEUS).

2. NEUTRAL CURRENT CROSS SECTIONS

The neutral current (NC) Born cross section is given by

$$\frac{d^2\sigma(e^\pm p \to e^\pm X)}{dx\,dQ^2} = \frac{2\pi\alpha^2}{x\,Q^4}\left[Y_+ F_2(x,Q^2) - y^2 F_L(x,Q^2) \mp Y_- xF_3(x,Q^2)\right], \qquad (1)$$

where x is the Bjorken scaling variable, Q^2 is the four–momentum transfer squared, α is the fine structure constant and $Y_\pm = 1 \pm (1-y)^2$ with $y = Q^2/xs$. The dominant contribution is the proton structure function F_2. The contribution of the longitudinal structure function F_L is negligible for small y. The parity violating structure function xF_3 becomes significant only at high Q^2 and contributes with different sign for electrons and positrons. In Figure 1, the e^+p reduced NC cross section

$$\tilde{\sigma}_{NC}(x,Q^2) = \frac{x\,Q^4}{2\pi\alpha^2}\,\frac{1}{Y_+}\,\frac{d^2\sigma_{NC}}{dx\,dQ^2} \qquad (2)$$

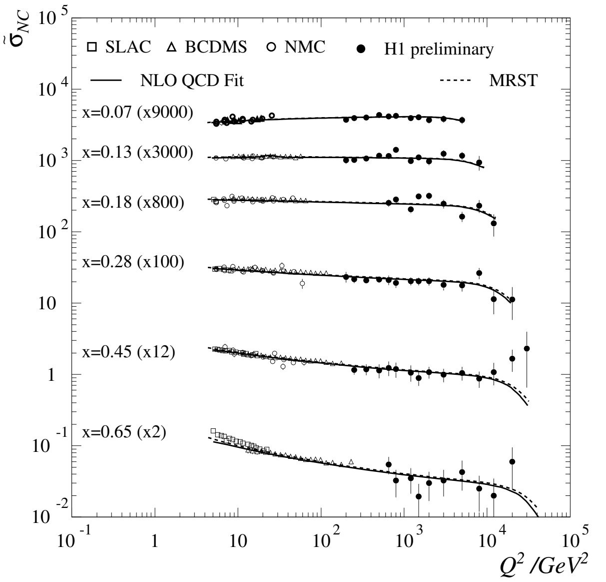

Figure 1. The e^+p reduced neutral current cross section at high x compared with the Standard Model prediction from MRST and the H1 NLO QCD fit.

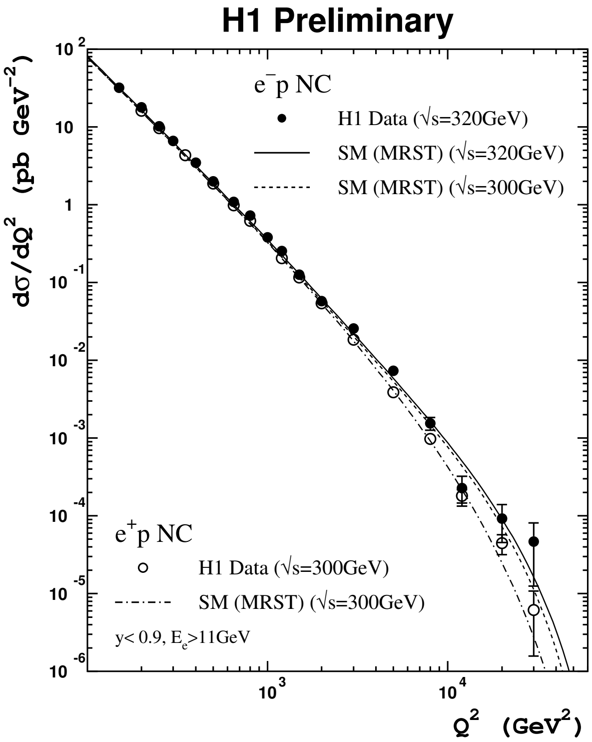

Figure 2. The single differential cross sections $d\sigma/dQ^2$ for e^-p and e^+p neutral current scattering compared with the Standard Model prediction.

measured by H1 is shown, together with measurements from fixed target experiments, as a function of Q^2 at fixed values of x between 0.07 and 0.65. The measured cross section is compared to the MRST parton densities [4] and to the H1 NLO QCD fit, which is up to 5 % lower than MRST in the high x domain. At $x = 0.45$, a slight excess of the data over the Standard Model prediction is visible for the highest Q^2 values.

The H1 single differential cross sections $d\sigma/dQ^2$ for e^-p and e^+p neutral current scattering are shown in Figure 2. The decrease of the cross sections with Q^2 by about 6 orders of magnitude is well reproduced by the Standard Model prediction, evaluated using the MRST parton densities. At high Q^2, the neutral current cross section becomes sensitive to electroweak effects. In agreement with a positive (negative) γZ^0 interference in e^-p (e^+p) neutral current scattering, the e^-p cross section is above the e^+p cross section for $Q^2 \geq 3000$ GeV^2. The small effect of the increased center of mass energy on the e^-p cross section is also shown.

3. CHARGED CURRENT CROSS SECTIONS

In leading order QCD and neglecting the effect of quark mixing, the charged current (CC) Born cross section is given by

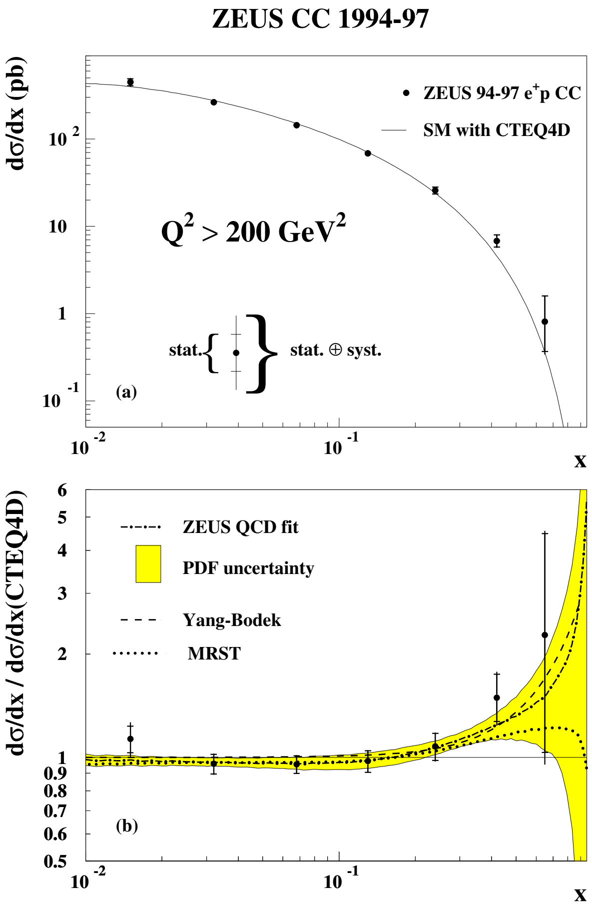

Figure 3. The e^+p single differential charged current cross section $d\sigma/dx$. The ratio of the measured cross section to the Standard Model expectation, evaluated using CTEQ4D, is shown in the bottom plot.

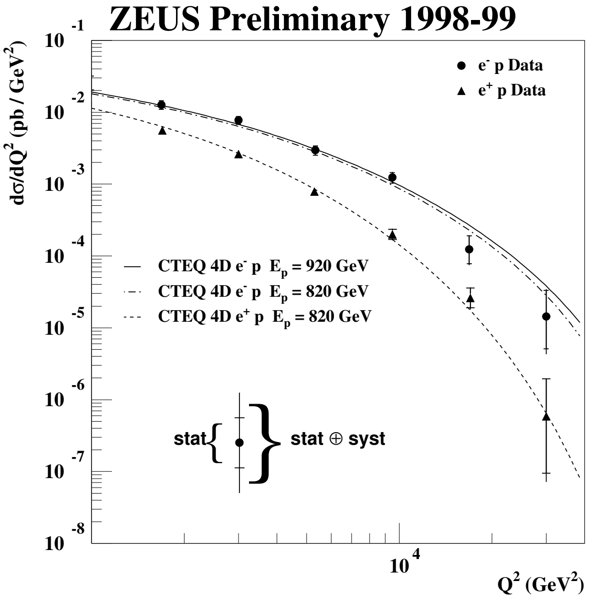

Figure 4. The single differential cross sections $d\sigma/dQ^2$ for e^-p and e^+p charged current scattering compared with the Standard Model expectation evaluated using CTEQ4D.

$$\frac{d^2\sigma(\mathrm{e^+p}\to\bar{\nu}\mathrm{X})}{dx\,dQ^2} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2\left[(\bar{u}+\bar{c})+(1-y)^2(d+s)\right], \tag{3}$$

$$\frac{d^2\sigma(\mathrm{e^-p}\to\nu\mathrm{X})}{dx\,dQ^2} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2\left[(u+c)+(1-y)^2(\bar{d}+\bar{s})\right], \tag{4}$$

where G_F is the Fermi coupling constant and M_W the mass of the W boson. The e^+p single differential CC cross section $d\sigma/dx$, measured by ZEUS, is shown in Figure 3. Also shown is the ratio of the measured cross section to the Standard Model expectation, evaluated using the CTEQ4D parton densities [5]. The data tend to lie above the Standard Model expectation at high x where the cross section is dominated by the d quark density. Both the ZEUS NLO QCD fit, which includes higher twist effects, and the Yang–Bodek parametrization [6], with a modified d/u ratio of 0.2 for $x \to 1$, give a better description of the data in the high x region than CTEQ4D.

Figure 4 shows the ZEUS preliminary single differential cross section $d\sigma/dQ^2$ for e^-p and e^+p charged current scattering. The e^-p CC cross section exceeds the e^+p cross section by almost a factor 10 at large Q^2, due to the coupling to different quark flavours (see eqn. (3) and (4)). From the Q^2 dependence of the e^+p CC cross section, the propagator mass M_W has been extracted. A constrained fit, with the value of the Fermi constant $G_F = 1.16639 \times 10^{-5}$ GeV^{-2} fixed, yields the results

$$M_W = 81.2 \pm 3.3(\text{stat.}) \pm 4.3(\text{syst.})\ \text{GeV} \quad (\text{H1}), \tag{5}$$

$$M_W = 81.4^{+2.7}_{-2.6}(\text{stat.})^{+2.0}_{-2.0}(\text{syst.})^{+3.3}_{-3.0}(\text{PDF})\ \text{GeV} \quad (\text{ZEUS}), \tag{6}$$

which are in agreement with the world average for the W boson mass ($M_W = 80.41 \pm 0.10$ GeV [7]). The agreement with the masses extracted in the timelike productions in e^+e^- and $\bar{p}p$ data confirms the Standard Model prediction in the spacelike region.

4. SUMMARY

The $e^{\pm}p$ neutral and charged current cross sections have been measured at HERA. The results are in agreement with the Standard Model prediction. In the region of high Q^2, a slight excess in the neutral current e^+p data is seen. In the comparison of the e^-p and e^+p neutral current cross sections $d\sigma/dQ^2$, a positive (negative) contribution of the γZ^0 interference to the e^-p (e^+p) cross section is observed. The measurements of the $e^{\pm}p$ charged current cross sections constrain the valence d and u quark densities at high x. From the Q^2 dependence of the e^+p charged current cross section, the propagator mass M_W has been determined.

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