PROCEEDINGS OF SCIENCE

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

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Approximately 1 fb^{-1} of HERA data have been collected by the H1 and ZEUS experiments allowing the neutral and charged current cross sections to be measured at large values of momentum transfer squared Q^2 upto 30 000 GeV^2. Analysis of the data is in progress and partial data sets are used to measure the $x\tilde{F}_3$ structure function. The cross sections are compared to Standard Model expectations and the axial and vector couplings of up type and down type quarks are determined. Finally the polarisation dependance of the charged current total cross sections are used to place limits on the mass of a right handed weak boson of 208 GeV.

European Physical Society Europhysics Conference on High Energy Physics, EPS-HEP 2009,
July 16 - 22 2009
Krakow, Poland

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1. Introduction

The HERA *ep* collider operated at a centre-of-mass energy of 320 GeV in the second phase of running from 2003-2007 during which polarised electron or positron beams at 27.6 GeV were collided with unpolarised proton beams at 920 GeV. The lepton beam polarisation reached typical values of 35% to 40%. A total of approximately 1 fb^{-1} of luminosity was collected between the two experiments H1 and ZEUS allowing sensitive tests of both the QCD and electroweak parts of the Standard model to be made.

In this document recent results are presented using partial data sets to measure cross sections in both the neutral current (NC) and charged current (CC) channels.

2. Neutral and Charged Current Cross Sections

The NC cross section for the process $e^{\pm}p \to e^{\pm}X$ with polarised lepton beams and neglecting the longitudinal structure function is given by

$$\frac{\mathrm{d}^2\sigma^{\pm}_{NC}}{\mathrm{d}x\,\mathrm{d}Q^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+\tilde{F}_2^{\pm} \mp Y_- x\tilde{F}_3^{\pm}\right] \; , \tag{2.1}$$

where α is the fine structure constant taken to be $\alpha \equiv \alpha(Q^2=0)$. The helicity dependences of the electroweak interactions are contained in the terms $Y_{\pm} \equiv 1 \pm (1-y)^2$. The generalised structure functions $\tilde{F}_2$ and $x\tilde{F}_3$ are related to the quark densities as

$$\tilde{F}_2^{\pm} \approx \sum_i e_i^2(q_i+\bar{q}_i) - (v_e \pm P_e a_e)\chi_Z \sum_i 2e_i v_i (q_i+\bar{q}_i) \tag{2.2}$$

$$x\tilde{F}_3^{\pm} \approx (-a_e \mp P_e v_e)\chi_Z \sum_i 2e_i a_i (q_i-\bar{q}_i) \tag{2.3}$$

where the sum runs over quark flavours, and $\chi_Z = \frac{1}{\sin^2 2\theta_W}\frac{Q^2}{Q^2+M_Z^2}$. The quantities v_e and a_e are the vector and axial couplings of the electron to the Z^0, and P_e is the lepton beam polarisation. The functions q_i and $\bar{q}_i$ are the parton distribution functions (PDFs) for quarks and anti-quarks, e_i is the charge of quark q_i in units of the electron charge and v_i and a_i are the vector and axial-vector couplings of the quarks.

For CC interactions $e^{\pm}p \to \nu X$ the cross section may be expressed as

$$\frac{\mathrm{d}^2\sigma^{\pm}_{\mathrm{CC}}}{\mathrm{d}x\,\mathrm{d}Q^2} = (1 \pm P_e)\frac{G_F^2}{2\pi x}\left(\frac{M_W^2}{Q^2+M_W^2}\right)^2 \tilde{\sigma}^{\pm}_{CC} \quad . \tag{2.4}$$

In the quark parton model $\tilde{\sigma}^{\pm}_{CC}$ can be expressed in terms of the quark densities as

$$\tilde{\sigma}^{+}_{CC} = x\left[(\bar{u}+\bar{c}) + (1-y)^2(d+s)\right], \quad \tilde{\sigma}^{-}_{CC} = x\left[(u+c) + (1-y)^2(\bar{d}+\bar{s})\right] \tag{2.5}$$

where u, c, d, s are the quark distributions and $\bar{u}$, $\bar{c}$, $\bar{d}$, $\bar{s}$ are the anti-quark distributions. This differing quark contributions to the CC e^+p and e^-p scattering cross sections allows a flavour decomposition of the proton to be achieved. The linear dependance of the CC cross section on lepton polarisation allows limits to be placed on the existence of right handed weak currents which are forbidden in the Standard Model.

The non-singlet structure function $x\tilde{F}_3$ for unpolarised NC scattering is obtained from the difference between the electron and positron scattering cross sections as can be seen from eq. 2.1. This measurement is sensitive to the high x valence quark distributions and is shown in fig. 1 using 233 pb^{-1} of data [1]. The uncertaines are dominated by the statistical precision of the data which nevertheless constrain the valence quark densities in QCD analyses of HERA data [2].

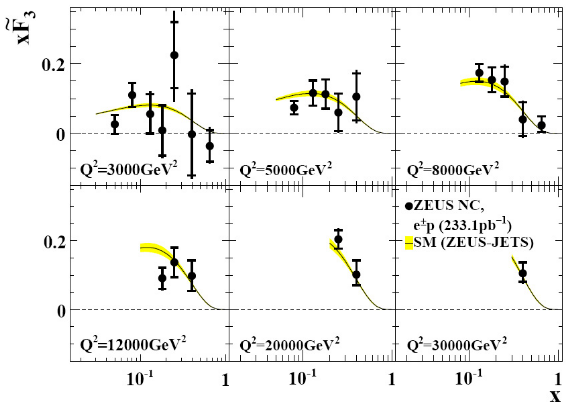

Figure 1: Measurement of the unpolarised structure function $x\tilde{F}_3$ using an integrated luminosity of 233 pb^{-1}. The statistical (inner) and total (outer) uncertainties are shown. The data are compared to a NLO QCD fit and its uncertainty (shaded band).

In polarised lepton scattering the NC cross sections are sensitive to the axial and vector couplings of the quarks to the Z^0. A complete NLO QCD analysis of the HERA NC and CC data has been performed by both collaborations in order to extract the couplings [3]. The results are shown in fig. 2 separately for the up type and down type quarks. The HERA data are able to resolve the LEP sign ambiguity and achieve a greater precision than the CDF collaboration. Both H1 and ZEUS determinations are in agreement with the Standard Model.

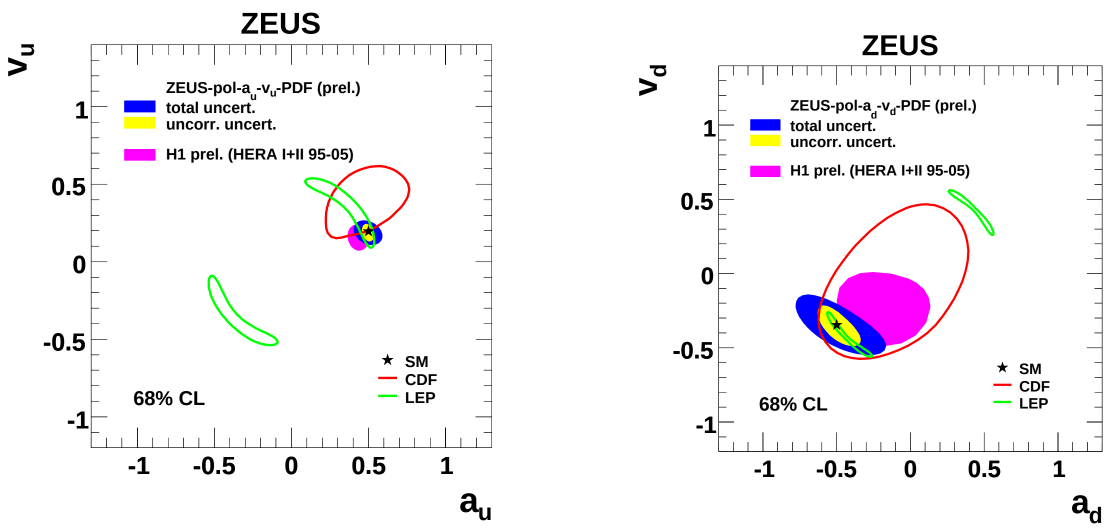

Figure 2: The 68% CL regions are shown for the determination of the axial and vector couplings of the up-type (left) and down-type (right) quarks to the Z^0. The H1 and ZEUS determinations are compared to results from LEP and the CDF collaboration.

The total $e^{\pm}p$ CC cross section measurments from H1 and ZEUS are shown in fig. 3 for the region $Q^2 > 400$ and $y < 0.9$ [4]. The data are compared to a QCD fit to the HERA data. The fit describes the data well and predicts a zero cross section for right handed electrons and left handed positrons. Deviations from zero at these limits are then sensitive to the existence of right handed weak currents, forbidded in the Standard Model. Both collaborations have analysed their data by performing linear fits to the total cross section measurements and releasing the zero cross section constraints. Assuming equal left and right handed couplings and massless right-handed neutrinos, limits are derived for a right handed W boson of 208 GeV (H1, e^+p),186 GeV (H1, e^-p) and 180 GeV (ZEUS, e^-p).

References

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[3] H1 Collab., H1prelim-07-041, Combined Electroweak and QCD Fit of inclusive NC and CC Data with Polarised Lepton Beams at HERA , International Workshop on Deep-Inelastic Scattering, Munich, Germany, April 2007; ZEUS Collab., Combined QCD and Electroweak Fits, ZEUS-prel-07-027

[4] ZEUS Collab., Measurement of high-Q2 charged current deep inelastic scattering cross sections with a longitudinally polarised positron beam at HERA, ZEUS-prel-07-023;

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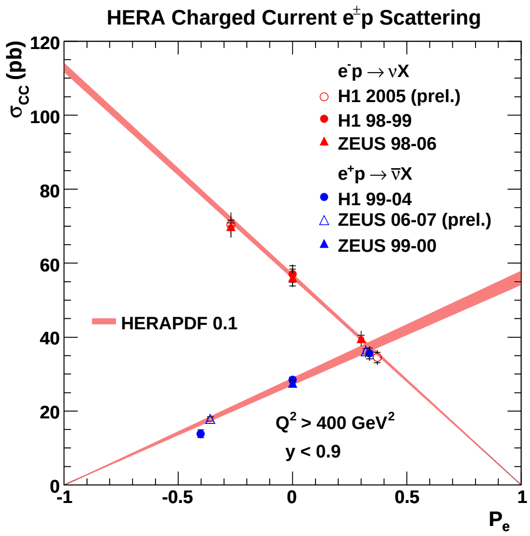

Figure 3: The polariation dependance of the total CC cross section is shown for $Q^2 > 400$ GeV^2 and $y < 0.9$ in both electron and positron scattering. The data are in good agreement and are well described by the Standard Model (shaded band)