PROCEEDINGS OF SCIENCE

Electroweak and QCD Fits to Neutral and Charged Current HERA Data

Eram Rizvi* **on behalf of the H1 collaboration.**
Queen Mary, University of London
School of Physics and Astronomy, Mile End Road, London, E1 4NS
E-mail: e.rizvi@qmul.ac.uk

Inclusive deep inelastic scattering cross sections in the neutral and charged current channels from the H1 experiment at HERA are presented covering a Q^2 range from 100 to 30 000 GeV^2 in $e^{\pm}p$ scattering at $\sqrt{s} = 319$ GeV. The cross sections are compared to Standard Model expectations and the axial and vector couplings of up type and down type quarks are determined.

The 2011 Europhysics Conference on High Energy Physics, EPS-HEP 2011,
July 21-27, 2011
Grenoble, Rhône-Alpes, France

*Speaker.

PoS(EPS-HEP2011)368

1. Introduction

The HERA ep collider operated at a centre-of-mass energy of 319 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 almost 0.5 fb^{-1} of luminosity was collected by H1 (including unpolarised lepton scattering in 1994-2000) allowing sensitive tests of both the QCD and electroweak (EW) parts of the Standard model to be made.
In this document results are presented for the inclusive cross sections measurements in both the neutral current (NC) and charged current (CC) channels, and the determination of the EW couplings of the light quarks to the Z^0.

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. The 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 a test of the chiral structure of purely weak interactions to be tested.

The NC data constrain the singlet quark contributions arising from $\tilde{F}_2$ and the valence contributions from the $x\tilde{F}_3$ structure function at high Q^2 and high x and are presented in full in [1]. Cross section measurements at lower $Q^2 \simeq 3-100$ GeV^2 [2] constrain the gluon and sea quark distributions. The flavour decomposition of the proton is achieved by using the CC $e^{\pm}p$ data, thus the H1 data alone can be used to extract the PDFs of the proton in a NLO QCD analysis.

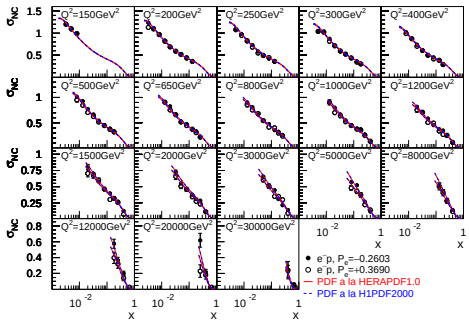

Figure 1: *High Q^2 NC e^-p scattering cross sections measured in HERA-II for left and right handed longitudinal polarisation P_e of the lepton beam.*

Fig. 1 shows an example of the H1 measurements of NC e^-p double differential reduced cross sections for left ($P_e < 0$) and right ($P_e > 0$) handed lepton polarisation. At lower values of Q^2 the difference between $P_e < 0$ and $P_e > 0$ is negligible, but as Q^2 increases a suppression of the e^-p right handed cross sections and enhancement of the e^-p left handed cross sections is visible. The data are compared to two new NLO QCD fits to previously published H1 and HERA inclusive measurements and which include the data presented here. The fits follow identically the procedures for the HERAPDF1.0 [5] and H1PDF2000 [4] QCD fits with the additional new polarised HERA-II H1 measurements. The fits are described in detail in [6]. Both fits provide a good description of the x, Q^2 dependance of the data, as well as the polarisation behaviour. Further measurements are given in [1].

The CC measurements of the reduced double differential cross sections for e^+p scattering for right handed lepton polarisation are shown in fig. 2. Further measurements for left handed and e^+p scattering are given in [3]. At fixed polarisation the data are well described by the two new NLO QCD fits. The polarisation dependance of the CC data is also well described (not shown) and consistent with the Standard Model expectation of zero cross section for left handed electron or right handed positron scattering.

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 with simultaneous extraction of the EW couplings [6]. The results are shown in fig. 3 separately for the up type and down type quarks, with all four couplings free in the fitting procedure. The HERA data are able to resolve the LEP sign ambiguity and achieve a greater precision than the CDF collaboration and are in agreement with the Standard Model. The precision of the extracted couplings is

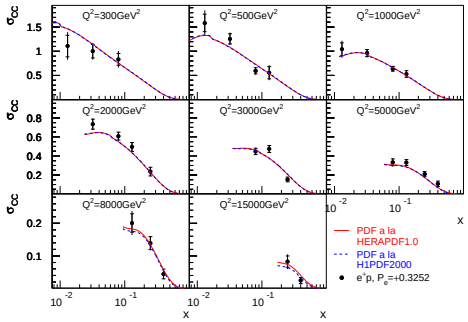

Figure 2: *High Q^2 CC e^+p scattering cross sections measured in HERA-II for right handed longitudinal polarisation P_e of the lepton beam.*

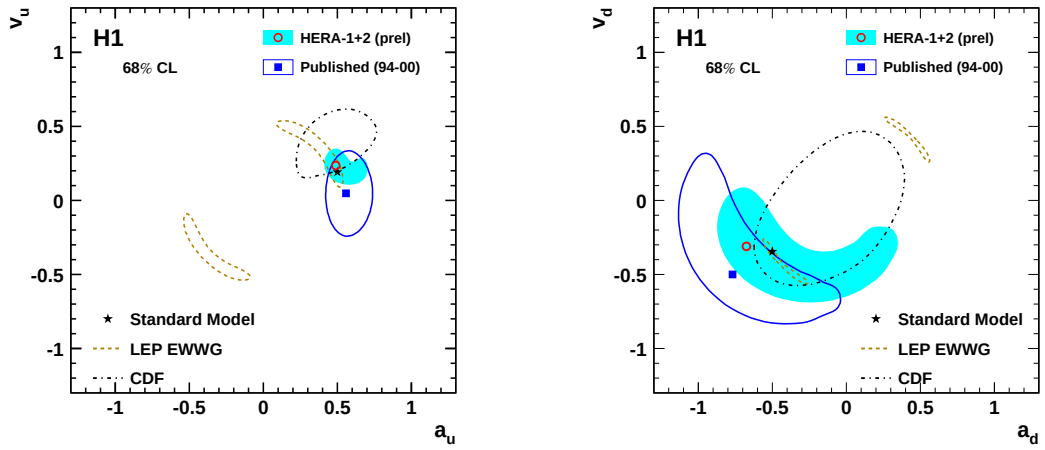

Figure 3: *The 68% CL regions are shown for the determination of the axial and vector couplings of the up-type (left) and down-type (right) quarks to the Z^0. The H1 determinations are compared to results from LEP and the CDF collaborations.*

also compared to the H1 determination using
published unpolarised NC and CC cross section data. It can be seen that the addition of the HERA-II polarised data brings a significant improvement in the determination of the vector couplings of almost a factor of two, particularly for the *u* type couplings.

References

[1] H1 Collab., H1Prelim-09-042, "Neutral current interactions in ep scattering at HERA with longitudinally polarised lepton beams"

[2] "A Precision Measurement of the Inclusive ep Scattering Cross Section at HERA" C. Adloff*et al.* [H1 Collaboration] *Eur. Phys. J.* C **64** (2009) 561-587

[3] H1 Collab., H1Prelim-09-043, "Charged current interactions in ep scattering at HERA with longitudinally polarised lepton beams"

[4] "Measurement and QCD Analysis of Neutral and Charged Current Cross Sections at HERA " C. Adloff*et al.* [H1 Collaboration] 2003 *Eur. Phys. J.* C **30** (2003) 1-32

[5] "Combined Measurement and QCD Analysis of the Inclusive e+- p Scattering Cross Sections at HERA" F.D. Aaron *et al.* [H1 and ZEUS Collaborations] *JHEP* **1001** (2010) 109

[6] H1 Collab., H1Prelim-10-042, "Combined Electroweak and QCD Fit of Inclusive Neutral and Charged Current Data with Polarized Lepton Beams at HERA"