HIGH Q^2 NEUTRAL CURRENTS IN POLARISED $e^{\pm}p$ COLLISIONS AT HERA II

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The inclusive single differential cross section $d\sigma/dQ^2$ and the double differential cross section $d^2\sigma/dQ^2dx$ are presented for the neutral current process $e^{\pm}p \to e^{\pm}X$ in interactions of unpolarised proton beam with longitudinally polarised lepton beam. The cross sections are measured in the region of large negative four-momentum transfer squared $Q^2 \geq 200$ GeV^2 and inelasticity $y < 0.9$. The data are consistent with the expected polarisation dependence of the cross sections, albeit with the limited statistical precision of the data. The HERA II data are combined together with previously published data from HERA I to determine the structure function $x\tilde{F}_3$ with improved precision. The data are found to be in agreement with the Standard Model predictions.

1. Introduction

Data taking of the second, high luminosity phase of the HERA program (HERA II) started in October 2003. An increase of the specific luminosity after the HERA upgrade has been achieved by placing strong superconducting focusing magnets inside the H1 detector, close to the interaction point. A major additional feature of HERA II is the ability to collide longitudinally polarised electrons (positrons) with with unpolarised protons.

Neutral current (NC) interactions, $ep \to eX$, are measured at HERA and provide information on the QCD and electroweak parts of the Standard Model. The cross section is defined in terms of two kinematic variables, taken amongst the negative four-momentum transfer squared Q^2, the Bjorken x variable, and the inelasticity variable y. The kinematic variables are related via $Q^2 = sxy$, where $\sqrt{s}$ is the ep centre-of-mass energy.

The NC cross section measurements using e^+p 2003-04 data and e^-p 2005 data taken with the proton beam energy of $E_p = 920$ GeV and the electron beam energy of $E_e = 27.5$ GeV ($\sqrt{s} = 318$ GeV) are presented here. Both e^+p and e^-p data sets are subdivided into samples of positive and negative longitudinal polarisation, $P_e = (N_R - N_L)/(N_R + N_L)$, where $N_R(N_L)$ is the number of right (left) handed polarised leptons in the beam. The corresponding integrated luminosities $\mathcal{L}$ and average longitudinal lepton beam polarisations are given in the following table:

	2003-04 e^+p		2005 e^-p	
P_e	$(+33.6\pm0.7)\%$	$(-40.2 \pm 1.1)\%$	$(+37.0\pm1.8)\%$	$(-27.0\pm1.3)\%$
$\mathcal{L}$	26.9 pb^{-1}	20.7 pb^{-1}	29.6 pb^{-1}	68.6 pb^{-1}

2. The Neutral Current Cross Section

The Born cross section for the NC process $e^\pm p \to e^\pm X$ is given by

$$\frac{d^2\sigma^\pm_{NC}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}(Y_+\tilde{F}_2^\pm(x,Q^2) \mp Y_- x\tilde{F}_3^\pm(x,Q^2) - y^2\tilde{F}_L^\pm(x,Q^2)), \quad (1)$$

and the reduced cross section is defined by

$$\tilde{\sigma}^\pm(x,Q^2) \equiv \frac{d^2\sigma^\pm_{NC}}{dxdQ^2}\frac{xQ^4}{2\pi\alpha^2}\frac{1}{Y_+}. \quad (2)$$

The helicity dependence of the electroweak interactions is contained in $Y_\pm = 1 \pm (1-y^2)$.

The $x\tilde{F}_3$ term is significant only at large x and Q^2 where it substantially reduces the e^+p cross section, while increasing the cross section for e^-p scattering. The contribution from $\tilde{F}_L$ is only important at large y and is expected to be negligible at large x and Q^2. The generalised proton structure functions $\tilde{F}_2$ and $x\tilde{F}_3$ may be written as linear combinations of the hadronic structure functions F_2, $F_{2,3}^{\gamma Z}$ and $F_{2,3}^Z$, associated to pure photon exchange, to photon-Z^0 interference and to pure Z^0 exchange:

$$\tilde{F_2^\pm} = F_2 - (v_e \pm P_e a_e)\eta_Z F_2^{\gamma Z} + (v_e^2 + a_e^2 \pm 2P_e v_e a_e)\eta_Z^2 F_2^Z, \quad (3)$$

$$x\tilde{F_3^\pm} = -(a_e \pm P_e v_e)\eta_Z xF_3^{\gamma Z} + (2v_e a_e \pm P_e(v_e^2 + a_e^2))\eta_Z^2 xF_3^Z, \quad (4)$$

with $\eta_Z = \frac{\kappa Q^2}{Q^2+M_Z^2}$, $\kappa^{-1} = 4\frac{M_W^2}{M_Z^2}(1-\frac{M_W^2}{M_Z^2})$, where M_W and M_Z are the vector boson masses, v_e and a_e are the vector and axial-vector couplings of the electron to the Z^0 [1].

3. Results

The dependence of the NC cross section on the polarisation arises mainly from the γZ interference terms. The bulk of the cross sections is dominated by γ exchange and thus is independent of P_e and is the same for e^+p and e^-p scattering. Only at highest Q^2 sensitivity to polarisation shows up: the NC cross section becomes dependent on both the helicity and electric charge of the lepton. In Fig. 1 the ratio of measured NC $d\sigma/dQ^2$ cross sections for positive to negative longitudinal polarisation is shown. This ratio rises for e^+p and falls for e^-p scattering due to different signs in Eq.(3),(4). The data are consistent with the expected Q^2 dependence of polarised cross sections, albeit with the limited statistical precision.

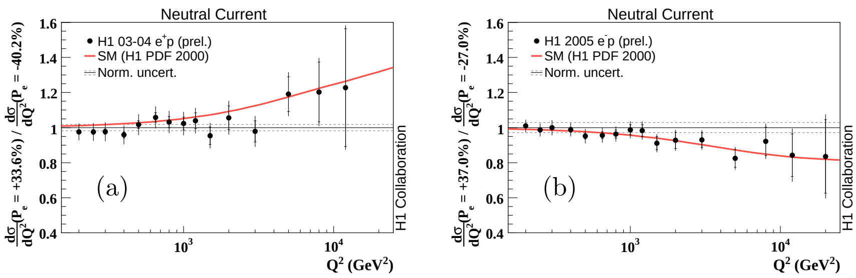

Figure 1. Ratio of NC differential cross sections for positive to negative longitudinal polarisation is shown: (a) for e^+p, (b) for e^-p. The data are compared to the Standard Model prediction based on the H1 PDF 2000 fit. The normalisation uncertainty is shown by the dashed lines.

The NC polarised data may be combined into an effectively unpolarised e^+p data set and effective unpolarised e^-p data set after correcting for the small residual polarisations. The unpolarised reduced cross sections are shown for $e^\pm p$ scattering in Fig. 2(a) and demonstrate a clear suppression of the e^+p cross section with respect to the e^-p data. The data compare well with the Standard Model prediction from the H1 PDF 2000 fit in which the observed difference arises from the generalised structure function $x\tilde{F}_3$ (see Eq. 1). Thus $x\tilde{F}_3$ may be obtained from

$$x\tilde{F}_3 = \frac{Y_+}{2Y_-}[\tilde{\sigma}^-(x,Q^2) - \tilde{\sigma}^+(x,Q^2)]. \quad (5)$$

In order to improve the statistical precision the cross section data presented here are combined with the previously published [2] unpolarised NC reduced cross sections in order to determine $x\tilde{F}_3$. The combined HERA I and HERA II data are shown in Fig. 2(b) for the region of x and Q^2 where the expected sensitivity is larger than the normalisation uncertainty of the data.

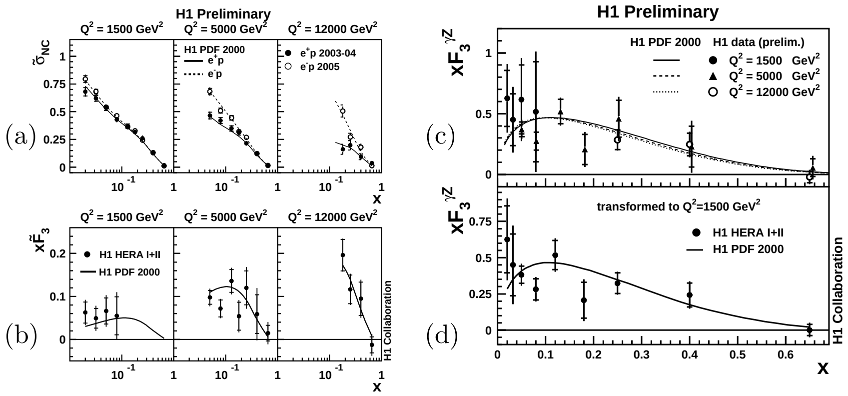

Figure 2. The HERA II measured NC reduced unpolarised cross sections $\tilde{\sigma}^{\pm}_{NC}(x, Q^2)$ (a), shown for three different Q^2 values. These cross sections are combined with HERA I results to extract the structure functions $x\tilde{F}_3$ (b) and $xF_3^{\gamma Z}$ (c). The results are compared with the corresponding Standard Model expectations determined from the H1 PDF 2000 fit. In (d), the averaged structure function $xF_3^{\gamma Z}$ for a Q^2 value of 1500 GeV^2 is compared with the expectation determined from the same fit.

The dominant contribution to $x\tilde{F}_3$ arises from γZ interference, which allows $xF_3^{\gamma Z}$ to be extracted according to $xF_3^{\gamma Z} \simeq -x\tilde{F}_3(Q^2+M_Z^2)/(a_e\kappa Q^2)$ by neglecting the pure Z exchange contribution, which is suppressed by an additional factor of $\kappa Q^2/(Q^2+M_Z^2)$ and the small vector coupling v_e. This structure function is non-singlet and has little dependence on Q^2. This is illustrated in Fig. 2(c). The measured $xF_3^{\gamma Z}$ at these Q^2 values can thus be averaged taking into account the small Q^2 dependence. The averaged $xF_3^{\gamma Z}$, determined for a Q^2 value of 1500 GeV^2, is shown Fig. 2(d) in comparison with the QCD fit result. The Standard Model prediction from the H1 PDF 2000 fit found to be in excellent agreement in both shape and magnitude with the data.

References

1. L. Alvarez-Gaume *et al.* [Particle Data Group Collaboration], "Review of Particle Physics", Phys. Lett. B **592** (2004).
2. C. Adloff *et al.* [H1 Collaboration], Eur. Phys. J. C **30** (2003) 1-32 [hep-ex/0304003].