High Q^2 DIS cross sections at HERA with longitudinally polarised positron beams

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Abstract. Measurements of the cross sections for neutral and charged current deep inelastic scattering in e^+p collisions with longitudinally polarised positron beams are presented. The total cross section for e^+p charged current deep inelastic scattering is presented at positive and negative values of positron beam longitudinal polarisation. In addition, single differential cross sections are presented for charged and neutral current deep inelastic scattering in the kinematic region $Q^2 > 200$ GeV^2. The measurements are based on data of integrated luminosity 30.5 pb^{-1} collected with the ZEUS detector in 2003 and 2004 at a centre-of-mass energy of 318 GeV. The measured cross sections are compared with the predictions of the Standard Model.

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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 Standard Model predicts that the cross sections for charged and neutral current DIS should exhibit dependence on the longitudinal polarisation of the incoming lepton beam. In the charged current case the dependence is predicted to be linear with the cross section becoming zero for right-handed (left-handed) electron (positron) beams, due to the chiral nature of the Standard Model.

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 cross sections for e^+p CC and NC DIS with longitudinally polarised positron beams. The measurements are based on 16.4 pb^{-1} of data collected at a mean luminosity weighted polarisation of -40.2%, and 14.1 pb^{-1} collected at a polarisation of 31.8% with the ZEUS detector in 2003 and 2004. During this time HERA collided protons of energy 920 GeV with positrons of energy 27.5 GeV, yielding collisions at a centre-of-mass energy of 318 GeV. The measured cross sections are compared to the Standard Model predictions.

CROSS SECTIONS

The electroweak Born-level cross-section for the CC reaction, $e^+p \rightarrow \bar{\nu}X$, with a longitudinally polarised positron beam (defined in Eqn. (2)), can be expressed as

$$\frac{d^2\sigma^{\rm CC}}{dxdQ^2} = (1+\mathscr{P})\frac{G_F^2}{4\pi x}\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2\left[Y_+F_2^{\rm CC}(x,Q^2) - Y_-xF_3^{\rm CC}(x,Q^2) - y^2F_L^{\rm CC}(x,Q^2)\right], \quad (1)$$

where G_F is the Fermi constant, M_W is the mass of the W boson and $Y_\pm = 1 \pm (1-y)^2$. The structure functions $F_2^{\rm CC}$ and $xF_3^{\rm CC}$ contain sums and differences of the quark and anti-quark parton density functions (PDFs) and $F_L^{\rm CC}$ is the longitudinal structure function. The longitudinal polarisation of the positron beam is defined as

$$\mathscr{P} = \frac{N_R - N_L}{N_R + N_L}, \quad (2)$$

where N_R and N_L are the numbers of right and left-handed positrons in the beam. Similarly the cross section for the NC reaction, $e^+p \rightarrow e^+X$, can be expressed as

$$\frac{d^2\sigma^{\rm NC}(e^+p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}[H_0^+ + \mathscr{P}H_{\mathscr{P}}^+], \quad (3)$$

where α is the QED coupling constant and H_0^+ and $H_{\mathscr{P}}^+$ contain the unpolarised and polarised structure functions, respectively.

RESULTS

The total cross section for e^+p CC DIS in the kinematic region $Q^2 > 200$ GeV^2 was measured to be

$$\sigma^{\rm CC}(\mathscr{P} = +0.318 \pm 0.009) = 46.7 \pm 2.4({\rm stat.}) \pm 1.0({\rm syst.})\ {\rm pb}, \quad (4)$$

and

$$\sigma^{\rm CC}(\mathscr{P} = -0.402 \pm 0.011) = 22.5 \pm 1.6({\rm stat.}) \pm 0.5({\rm syst.})\ {\rm pb}. \quad (5)$$

The contribution to the systematic uncertainty of 5% from the luminosity measurement is not included in the quoted systematic uncertainty. The total cross section is shown as a function of

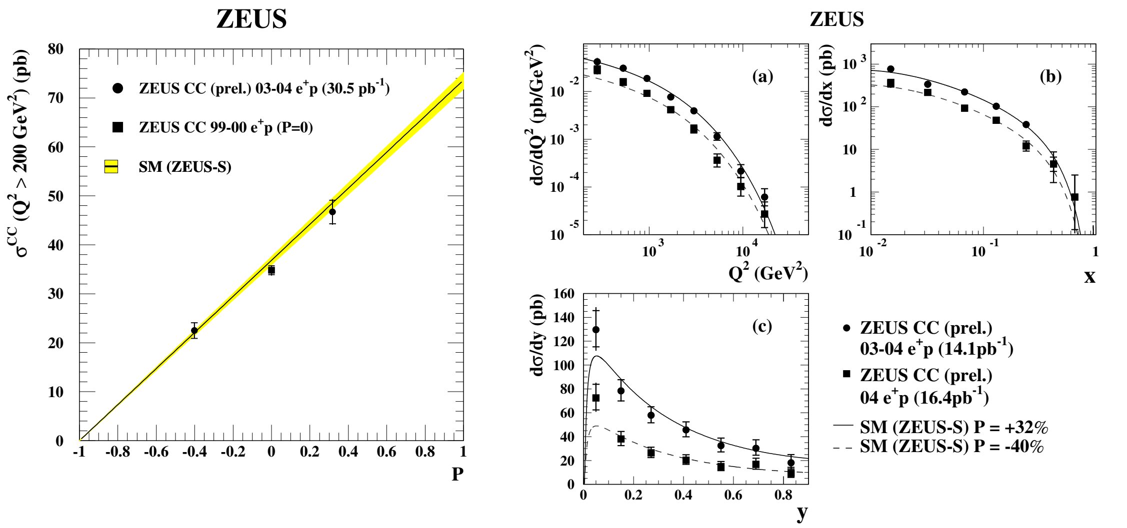

FIGURE 1. The total cross section for e^+p CC DIS as a function of the longitudinal polarisation of the positron beam is shown on the left. On the right the differential cross-sections (a) $d\sigma/dQ^2$, (b) $d\sigma/dx$ and (c) $d\sigma/dy$ are shown. The curves show the SM predictions evaluated using the ZEUS-S PDFs.

the longitudinal polarisation of the positron beam in Fig. 1 including the unpolarised ZEUS measurement from the 1999-2000 data [1]. The data are compared to the Standard Model prediction evaluated using the ZEUS-S PDFs [2]. The SM prediction describes the data well.

The single-differential cross-sections, $d\sigma/dQ^2$, $d\sigma/dx$ and $d\sigma/dy$ for charged current DIS are also shown in Fig. 1. A clear difference is observed between the measurements for positive and negative longitudinal polarisation, which is well described by the Standard Model evaluated using the ZEUS-S PDFs.

Figure 2 shows the cross-section $d\sigma/dQ^2$ for NC DIS with positively and negatively polarised positron beams. Ratios of the cross sections for positive and negative longitudinal polarisations to the ZEUS unpolarised measurements from the 1999-2000 data [3] are also shown in Fig. 2. In addition the ratio of the cross sections for positive and negative longitudinal polarisations is shown. Only statistical uncertainties were considered when taking ratios of the positively and negatively polarised cross sections. In taking ratios to the unpolarised cross sections the systematic uncertainties were considered uncorrelated with those of the polarised cross sections. The measurements are well described by the SM evaluated using the ZEUS-S PDFs and consistent with the expectations of the electroweak Standard Model for polarised NC DIS, although the statistical precision of the current data set does not allow the polarised effect to be conclusively observed.

SUMMARY

The cross sections for neutral and charged current deep inelastic scattering in e^+p collisions with longitudinally polarised positron beams have been measured. The measurements are based on data of integrated luminosity 30.5 pb^{-1} collected with the ZEUS detector in 2003 and 2004 at a centre-of-mass energy of 318 GeV. The total cross section for e^+p charged current deep inelastic scattering is presented at positive and negative values of positron beam longitudinal

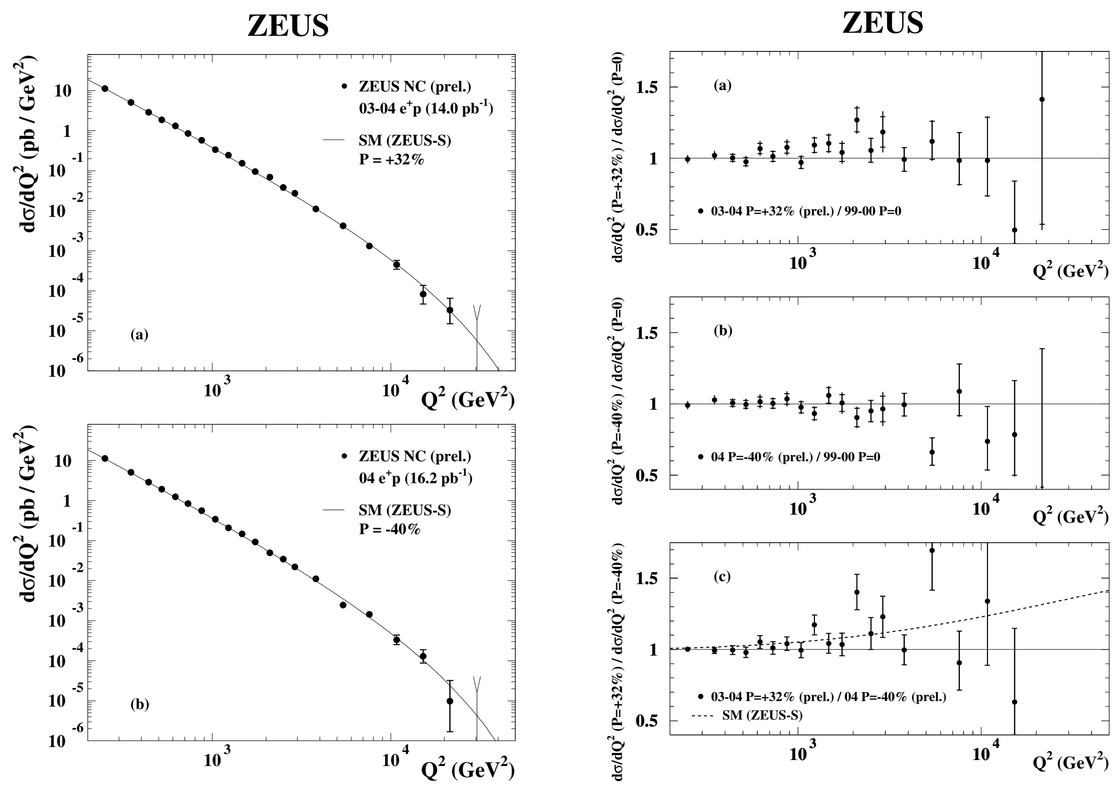

FIGURE 2. The NC DIS cross-sections $d\sigma/dQ^2$ on the left for (a) positively and (b) negatively polarised data. The curves show the SM prediction evaluated using the ZEUS-S PDFs. On the right the ratios of the cross sections for (a) positively polarised data to unpolarised data, (b) negatively polarised to unpolarised data and (c) positively polarised to negatively polarised data are shown. The dashed curve shows the SM prediction evaluated using the ZEUS-S PDFs.

polarisation. In addition, single differential cross sections are presented for charged and neutral current deep inelastic scattering in the kinematic region $Q^2 > 200$ GeV^2. The measured cross sections are well described by the predictions of the Standard Model.

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