NEUTRAL CURRENT CROSS SECTIONS WITH
POLARISED LEPTON BEAM AT ZEUS

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Measurements of the neutral current cross sections for deep inelastic scattering in $e^\pm p$ collisions with longitudinally polarised lepton beams are presented. The single differential cross section $d\sigma/dQ^2$ is presented for $e^\pm p$. For the $e^- p$ data set, the double differential cross section in $Q^2$ and $x$ is shown and the structure function $xF_3$ is extracted using previously measured unpolarised $e^+ p$ measurements. The polarised $e^+ p$ measurements are based on an integrated luminosity of 23.8 pb$^{-1}$ taken by the ZEUS detector in 2004. The polarised $e^- p$ data has an integrated luminosity of 122 pb$^{-1}$ taken in 2004 and 2005. During both running periods, leptons and protons were collided at HERA with a centre-of-mass energy of 318 GeV. The Standard Model agrees well with all measurements, with the $d\sigma/dQ^2$ measurement showing clear evidence of parity violation.

Introduction

Deep inelastic scattering (DIS) of leptons off nucleons is a key tool to probe the structure of matter at small distance scales. The neutral current (NC) DIS interaction at HERA, $e^\pm p \rightarrow e^\pm X$, proceeds via the exchange of a photon or a $Z^0$ boson.

The kinematics of NC DIS can be defined in terms of the variables $x$, $y$ and $Q^2$. The variable $Q^2$ is defined to be $Q^2 = -q^2 = -(k - k')^2$ where $k$ and $k'$ are the four-momenta of the incoming and scattered lepton, respectively. Bjorken $x$ is defined by $x = Q^2 / 2E \cdot q$ where $E$ is the four-momentum of the incoming proton. The variables $x$, $y$ and $Q^2$ are related by $Q^2 = s xy$, where $s = 4E_e E_p$ is the square of the lepton-proton centre-of-mass energy (neglecting the masses of the incoming particles).

The Standard Model (SM) predicts that the cross section for $e^\pm p$ NC DIS should exhibit a dependence on the polarisation of the incoming lepton due to the parity violating nature of the weak interaction. Therefore, this polarisation effect should be most significant at high $Q^2$ where the $Z^0$ boson
exchange becomes important.

These proceedings present the cross section measurements for $e^\pm p$ NC DIS with longitudinally polarised lepton beams. The $e^+p$ measurements [1] are based on data with an integrated luminosity of $23.8 \text{ pb}^{-1}$ collected at a mean luminosity weighted polarisation of $+0.32$ and $-0.41$ with the ZEUS detector in 2004. The $e^-p$ data has an integrated luminosity of $122 \text{ pb}^{-1}$ with a mean luminosity weighted polarisation of $+0.33$ and $-0.27$ collected in 2004 and 2005. During both running periods HERA collided protons of energy 920 GeV with positrons or electrons of energy 27.5 GeV, yielding collisions at a centre-of-mass energy of 318 GeV.

Cross sections

The unpolarised electroweak Born-level cross section for the $e^\pm p$ NC interaction can be written as

$$\frac{d^2\sigma(e^\pm p)}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4} H^\pm$$

where $\alpha$ is the fine-structure constant and $H^\pm$ is defined by

$$H^\pm \equiv Y_+ F_2(x, Q^2) \mp Y_- x F_3(x, Q^2)$$

where $Y_\pm \equiv 1 \pm (1 - y)^2$. The structure functions $F_2$ and $xF_3$ contain the sums and differences of the quark and anti-quark parton density functions (PDFs). The longitudinal structure function $F_L$ is ignored as it is small in the kinematic region considered.

The reduced cross section is defined as

$$\tilde{\sigma}^{e^\pm p} = \frac{xQ^4}{2\pi\alpha^2} \frac{1}{Y_+} \frac{d^2\sigma(e^\pm p)}{dx dQ^2} = F_2(x, Q^2) \mp \frac{Y_-}{Y_+} x F_3(x, Q^2)$$

which is used in this analysis to extract $xF_3$.

The NC cross section is modified when the incoming lepton beam is longitudinally polarised. The longitudinal polarisation is defined as

$$P_e = \frac{N_R - N_L}{N_R + N_L}$$

where $N_R$ and $N_L$ are the numbers of right and left-handed leptons in the beam. By including the polarisation, the Born $e^\pm p$ NC cross section defined by Eq. (1) can be generalised as

$$\frac{d^2\sigma(e^\pm p)}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4} [H^\pm + P_e H^\pm_{P_e}]$$

where $H^\pm_{P_e}$ contains the polarised structure functions.
Results

The cross section $d\sigma/dQ^2$ for $e^+p$ NC DIS is shown in Fig. 1 for positively and negatively longitudinally polarised lepton beams. Only statistical uncertainties were considered when taking the ratio of the cross sections with the two polarisations. A clear indication of parity violation is seen as the cross section ratio deviates from unity and is well described by the SM evaluated using the ZEUS-JETS PDFs.

Figure 2 presents the reduced cross sections for unpolarised $e^\pm p$ and the $xF_3$ measurements. The unpolarised $e^-p$ reduced cross sections are measured by combining the positive and negative polarisation samples, and correcting the residual polarisation of -0.06. The reduced cross sections are compared with previously measured unpolarised $e^+p$ reduced cross sections taken in 1999 and 2000 [2]. A significant difference between the two data sets is seen at high $Q^2$ due to the $xF_3$ contribution. The structure function $xF_3$ is extracted using the unpolarised $e^\pm p$ reduced cross sections and is reproduced well by the SM.
Summary

The single differential cross section $d\sigma/dQ^2$ is presented for $e^\pm p$ NC DIS separately for positively and negatively longitudinally polarised leptons. The $e^- p$ reduced cross sections corrected to zero polarisation are presented and have been combined with previously measured unpolarised $e^+ p$ reduced cross sections to extract $xF_3$. The SM predictions describe the measurements well and this is the first time at ZEUS that parity violation can clearly be seen in the $d\sigma/dQ^2$ measurement.

References