

# Polarisation Dependence of the Total CC $e^\pm p$ Cross Section

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**Abstract.** Data taken with the H1 detector, with longitudinally polarised electrons and positrons in collision with unpolarised protons at HERA, are used to measure the charged current cross section  $\sigma_{\text{CC}}^{\text{tot}}$  for  $Q^2 > 400 \text{ GeV}^2$  and inelasticity  $y < 0.9$ . The polarisation dependence of the measured cross section is in agreement with the Standard Model predictions.

**Keywords:** Charged current, electroweak, cross section, polarisation, deep inelastic scattering  
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## INTRODUCTION

Data taking of the second, high luminosity phase of the HERA program (HERA II) started in October 2003. An increase of specific luminosity after the HERA upgrade has been achieved by placing strong super-conducting focusing magnets inside the H1 and ZEUS detectors, close to the interaction point. A major success at HERA II is a longitudinal polarisation of the electron beam which collides with protons inside the H1 and ZEUS detectors.

Both, neutral current (NC),  $ep \rightarrow eX$ , and charged current (CC) interactions,  $ep \rightarrow \nu X$ , can be measured at HERA and provide complementary information. In the Standard Model, there is clear prediction on polarisation dependence of these cross sections. Specifically, the  $e^+p$  CC cross section for a left handed positron and  $e^-p$  CC cross section for right handed electron should be zero and should have full strength for opposite helicities. This follows from absence of right handed weak charged currents in the Standard Model. Thus, for unpolarised electrons (positrons), the cross section is a half of the one for left handed electron (right handed positron).

The incident electron (positron) beam energy is 27.6 GeV, whilst the unpolarised proton beam energy is 920 GeV. This yields a center-of-mass energy of  $\sqrt{s} = 319 \text{ GeV}$ . The  $e^+p$  data collected in 2003 and 2004 consist of two periods with positive and negative polarisations. The first period has a mean polarisation of  $(33.0 \pm 0.7)\%$  and integrated luminosity of  $(15.3 \pm 0.4) \text{ pb}^{-1}$ . The second period, with negative polarisation, has  $(-40.2 \pm 0.6)\%$  and  $(21.7 \pm 0.6) \text{ pb}^{-1}$ . The 2005  $e^-p$  data set has a mean polarisation of  $(-25.4 \pm 0.4)\%$  and an integrated luminosity of  $(17.8 \pm 0.2) \text{ pb}^{-1}$ .

The double differential CC cross section for collisions of polarised leptons with unpolarised protons corrected for QED radiative effects can be written as

$$\frac{d^2\sigma_{CC}^{e^\pm p}}{dx dQ^2} = [1 \pm P_e] \frac{G_F^2}{2\pi x} \left[ \frac{M_W^2}{Q^2 + M_W^2} \right]^2 \Phi_{CC}^\pm, \quad (1)$$

where  $G_F$  is the Fermi coupling constant,  $M_W$  is the mass of the  $W$  boson.  $\Phi_{CC}^\pm$  is the term depending on the partonic content of the proton and can be expressed as follows:

$$\Phi_{CC}^+ = \bar{u} + \bar{c} + (1-y)^2(d+s+b), \quad (2)$$

$$\Phi_{CC}^- = u + c + (1-y)^2(\bar{d} + \bar{s} + \bar{b}). \quad (3)$$

Here,  $P_e$  is the degree of longitudinal polarisation defined as  $P_e = (N_R - N_L)/(N_R + N_L)$  with  $N_R(N_L)$  being the number of right (left) handed polarised leptons in the beam. The cross section has a linear dependence on the polarisation of the lepton beam. For positrons (electrons) with positive (negative) polarisation it is enlarged, whilst the cross section for negative (positive) polarised positrons (electrons) is diminished. For  $P_e = -1$  ( $P_e = +1$ ) the  $e^+p$  ( $e^-p$ ) CC cross section is identically equal to zero in the Standard Model.

## EXPERIMENTAL TECHNIQUE

The H1 detector components most relevant for this analysis are the LAr calorimeter, which measures energies of charged and neutral particles over the polar<sup>1</sup> angular range  $4^\circ < \theta < 154^\circ$ , and the inner tracking detectors which measure the angles and momenta of charged particles over the range  $7^\circ < \theta < 165^\circ$ . A full description of the detector can be found in [3].

Transverse polarisation of the electron beam at HERA arises naturally through synchrotron radiation via the Sokolov-Ternov effect [4]. In 2000 pairs of spin rotators were installed in the beamline around the H1 detector transforming transversely polarised positrons into longitudinally polarised. The polarisation is continuously measured using two independent polarimeters TPOL [5] and LPOL [6].

In order to determine acceptance corrections and background contributions for the CC cross section measurements, the detector response for events generated by various Monte Carlo programs is simulated in detail [2].

The selection and analysis of deep inelastic scattering processes with charged current interactions follows closely that of published unpolarised data [2]. The CC events are identified as having missing transverse momentum,  $P_{T,h}$ , where  $P_{T,h} = \sqrt{(\sum_i p_{x,i})^2 + (\sum_i p_{y,i})^2}$  and is summed over all particles of the hadronic final state.

The CC kinematics quantities are determined using hadronic final state [7]:

$$y_h = \frac{\Sigma}{2 E_e}, \quad Q_h^2 = \frac{P_{T,h}^2}{1 - y_h}, \quad x_h = \frac{Q_h^2}{s y_h}, \quad (4)$$

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<sup>1</sup> The polar angle  $\theta$  is defined with respect to the direction of the outgoing proton beam.

where  $\Sigma \equiv \sum_i E_i - p_{z,i}$  and  $E_e$  is the incident electron (positron) beam energy.

## MEASUREMENT PROCEDURE

Candidate for CC interactions are selected by requiring  $P_{T,h} > 12$  GeV. In order to ensure high efficiency of the trigger and kinematic resolution the analysis is further restricted to the domain of  $Q_h^2 > 200$  GeV<sup>2</sup> and  $0.03 < y_h < 0.85$ . The  $ep$  background is dominantly due to photoproduction events in which the scattered electron (positron) escapes undetected in the beam pipe and large missing transverse momentum is faked by fluctuations in the detector response or undetected particles. This background is suppressed using the correlation between the ratio  $V_{ap}/V_p$  and  $P_{T,h}$ .

The quantities  $V_p$  and  $V_{ap}$  are the transverse energy flow parallel and anti-parallel to the direction in which points the transverse momentum vector of the hadronic final state respectively. The residual  $ep$  background is negligible for most of the measured kinematic domain. The simulation is used to estimate this contribution, which is subtracted statistically from the CC data sample with a systematic uncertainty of 30% on the number of subtracted events.

Finally, remaining non- $ep$  background is rejected by identifying event topologies characteristic for cosmic ray and beam-induced background.

## RESULTS

The total polarised  $e^+p$  and  $e^-p$  CC cross sections are measured in the range  $Q^2 > 400$  GeV<sup>2</sup> and  $y < 0.9$ . The results are:

$$\sigma_{CC}^{e^+p}(P_e = +0.33) = 34.67 \pm 1.94_{\text{stat}} \pm 1.66_{\text{sys}} \text{ pb}, \quad (5)$$

$$\sigma_{CC}^{e^+p}(P_e = -0.40) = 13.80 \pm 1.04_{\text{stat}} \pm 0.94_{\text{sys}} \text{ pb}, \quad (6)$$

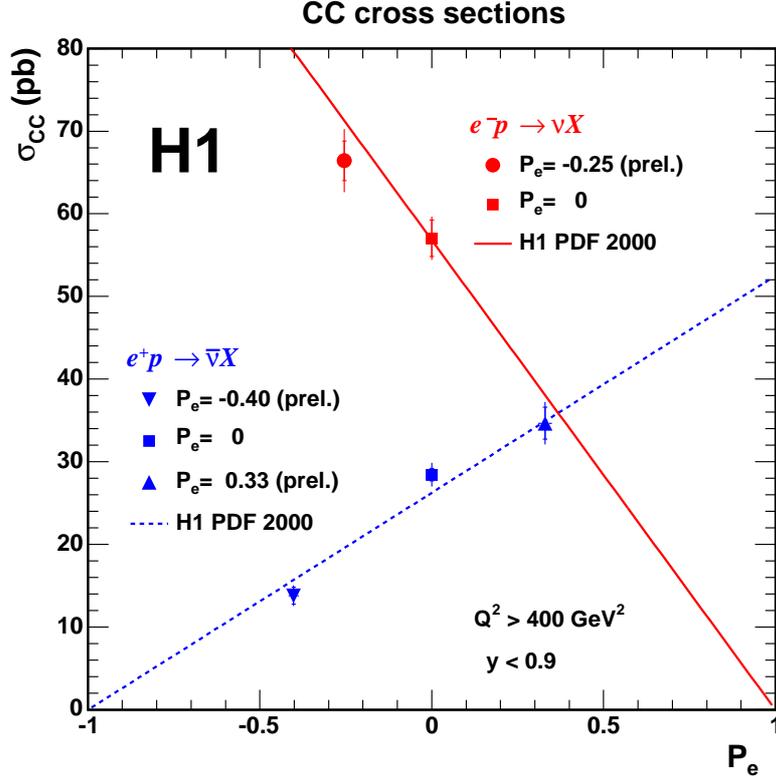
$$\sigma_{CC}^{e^-p}(P_e = -0.25) = 66.42 \pm 2.39_{\text{stat}} \pm 2.99_{\text{sys}} \text{ pb}. \quad (7)$$

The polarisation dependence of the CC cross section is shown in Fig. 1. The polarisation uncertainty, which does not directly enter in the cross section measurement, is shown in the figure as horizontal error bars. The measurements of the unpolarised CC cross section (in the same phase space regions) are also shown in Fig. 1. They are based on HERA I data with a luminosity of  $65.2 \text{ pb}^{-1}$  for  $e^+p$  and  $16.4 \text{ pb}^{-1}$  for  $e^-p$ :

$$\sigma_{CC}^{e^+p}(P_e = 0) = 28.44 \pm 0.77_{\text{stat}} \pm 1.22_{\text{sys}} \text{ pb}, \quad (8)$$

$$\sigma_{CC}^{e^-p}(P_e = 0) = 57.03 \pm 2.21_{\text{stat}} \pm 1.38_{\text{sys}} \text{ pb}. \quad (9)$$

The measured cross sections agree well the Standard Model predictions based on the H1 PDF 2000 fit. A linear fit to the polarisation dependence of the three measured  $\sigma_{CC}^{e^+p}$  cross sections is performed. The fit takes into account a correlation of systematic errors of the



**FIGURE 1.** The dependence of the  $e^+p$  and  $e^-p$  cross section with the lepton beam polarisation  $P_e$  is shown. The data are compared to the Standard Model prediction based on the H1 PDF 2000 fit.

measurements. The fit provides a reasonable description of the data with a  $\chi^2 = 2.45$ . The cross section extrapolation to  $P_e = -1.00$  yields a value:

$$\sigma_{CC}(P_e = -1.00) = -3.7 \pm 2.4_{\text{stat}} \pm 2.7_{\text{sys}} \text{ pb.} \quad (10)$$

This value is consistent with zero and indicates the absence of right handed weak charged currents, in agreement with the Standard Model.

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