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Measurements of the Differential Neutral and Charged Current Cross Sections at HERA in the Range for Q^2 from 800 to 13000 $\mathrm{GeV}^2/\mathrm{c}^2$

H1 Collaboration

Abstract

Charged and neutral current differential cross sections are measured in e^+p deep inelastic scattering using the H1 detector at HERA. Results are presented for Q^2 from 800 to 13000 $\mathrm{GeV}^2/\mathrm{c}^2$ for transverse momenta of the outgoing lepton $p_T \geq 12.5$ GeV/c and $0.1 < y < 0.9$.

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Introduction

Charged Current interactions played a key role in establishing the standard model and to unravel the structure of the nucleon. With the advent of the HERA ep collider tests of the electroweak theory as well as studies of QCD are performed in an unexplored kinematic regime at large Q^2 using neutral current ($NC : e^+p \to e^+ + X$) and charged current ($CC : e^+p \to \bar{\nu}_e + X$) processes. X denotes the hadronic system recoiling against the lepton. For the CC process the lowest order cross section can be written as:

$$\frac{\mathrm{d}^2\sigma_{\mathrm{CC}}^{e^+}}{\mathrm{d}x\mathrm{d}Q^2} = \frac{G_\mu^2}{2\pi}\frac{1}{(1+Q^2/m_W^2)^2}\left[\bar{u}+\bar{c}+(1-y)^2(d+s)\right], \tag{1}$$

where G_μ is the Fermi constant. Here x and y are the Bjorken scaling variables which are related by $Q^2 = sxy$. Q^2 is the four momentum squared and $\sqrt{s} = 300$ GeV the center of mass energy. The quark and anti-quark densities ($\bar{u}$,d,s,$\bar{c}$) all depend on x and Q^2. In the propagator term m_W denotes the mass of the W boson which mediates the weak force.

The NC cross section is dominated by the photon propagator. The relative Z^0 exchange contribution grows with Q^2, but is still small for $Q^2 \approx m_{Z^0}^2$. Therefore electroweak effects in the NC process are statistically not significant in the present data. In this report the Q^2, x and y dependences of the charged and neutral current cross sections are presented. The results are obtained after a full unfolding of the experimental resolution. This analysis is based on data taken in 1994 and 1995 in e^+p scattering, which corresponds to an integrated luminosity of 6.6 pb^{-1}. This measurement extends to a smaller transverse momentum $p_{T,min} = 12.5$ GeV/c compared to the previous analysis [1]. The kinematic variables are derived from the measurement of final state hadrons for both processes; this ensures a similar resolution.

Selection of neutral and charged current events

Selection of CC and NC events is based on information of the hadronic final state. Energies and directions are measured using data from the H1 liquid Argon calorimeter [2]. The hadronic transverse momentum sum $p_{T,h}$ and the fractional energy transfer

$$y_h = (E_h - p_{h,z})/2E_e$$

are measured. Here E_h is the total calorimetric energy, $p_{h,z}$ the longitudinal component of it and $E_e = 27.5$ GeV is the positron beam energy. Events are selected by $p_{T,h} > 12.5$ GeV/c and $0.1 \le y_h \le 0.9$. Note that for this analysis the selection and analysis cut is lowered substantially in comparison to our previous publications [3, 4, 1]. The final state kinematics is fully specified by two independent variables here $p_{T,h}$ and y_h [5]. Q^2 and x are then given by

$$Q_h^2 = p_{T,h}^2/(1-y_h), x_h = Q_h^2/sy_h.$$

The resolution for Q_h^2 is about 20% in contrast to the Q^2 resolution of 3% obtainable by using the information of the scattered positron [1]. In order to ensure a reliable determination of the CC cross sections the hadronic variables are as well used for the NC process.

For the lowered $p_{T,h}$ cut a detailed study of the photoproduction background is performed. Topology of events from this process exhibits a large multiplicity of hadrons. Imperfect measurement of their energy in the liquid argon calorimeter leads to missing transverse momentum. Events then enter the CC sample but are discriminated by means of a variable A that measures in the transverse plane the ratio of transverse momenta pointing into the direction of the outgoing neutrino and transverse momenta measured on the opposite side. Fig. 1 shows the distribution of A for the CC sample and also tagged photoproduction events where the scattered positron was detected in a magnetic spectrometer. The simulated distributions for A are also shown for CC and the photoproduction case. CC events are selected requiring $A < 0.13$. All further experimental details concerning backgrounds and efficiency determination are described in previous publications [3, 4, 1].

The measured data are unfolded for detector effects [6]. The parton densities used for the model predictions are taken from [7] (MRSH). The systematic errors are all dominated by the uncertainty of the hadronic energy scale.

Results

The total cross section for $p_{T,h} > 12.5$ GeV/c and $0.1 \leq y_h \leq 0.9$ is $\sigma_{CC}^{e^+p} = 25.2 \pm 2.5 \pm 0.8$ pb. The theoretical cross section is 23.2 ± 0.3 pb. The error comes from the uncertainty in the parton densities.

Fig. 2 shows Q^2 differential cross sections ($p_T > 12.5$ GeV/c and $0.1 < y < 0.9$) for NC and CC processes. The CC data stays for all Q^2 below the NC cross section, as expected. The measurement of the NC cross section using hadronic variables constitutes an important check for the CC analysis. The differential x distributions are shown in Fig. 3 and the differential y distributions in Fig. 4. All measured cross sections are compared with the expectation in the Standard Model based on parton densities obtained at lower Q^2 using DGLAP evolution [7] (solid lines in Fig. 2, 3 and 4). The NC and CC differential cross sections are within errors in good agreement with with the Standard Model expectations.

Acknowledgments

We are grateful to the HERA machine group whose outstanding efforts have made and continue to make this experiment possible. We thank the engineers and technicians for their work in constructing and now maintaining the H1 detector, our funding agencies for financial support, the DESY technical staff for continual assistance, and the DESY directorate for the hospitality which they extend to the non-DESY members of the collaboration.

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Figures

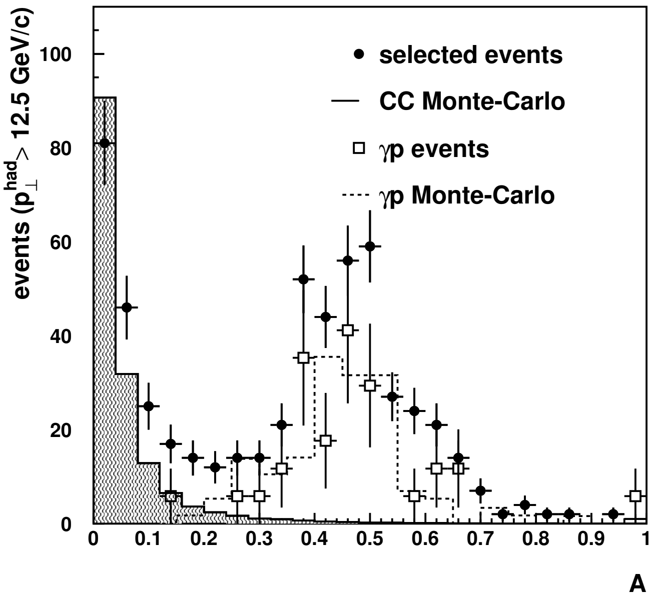

Figure 1: Distribution of the CC candidates with $p_T > 12.5$ GeV/c and $0.1 < y_h < 0.9$ of the topological variable A. This variable measures the ratio of transverse momenta in the direction of the missing $p_{T,h}$ to the transverse momentum pointing into the opposite direction.

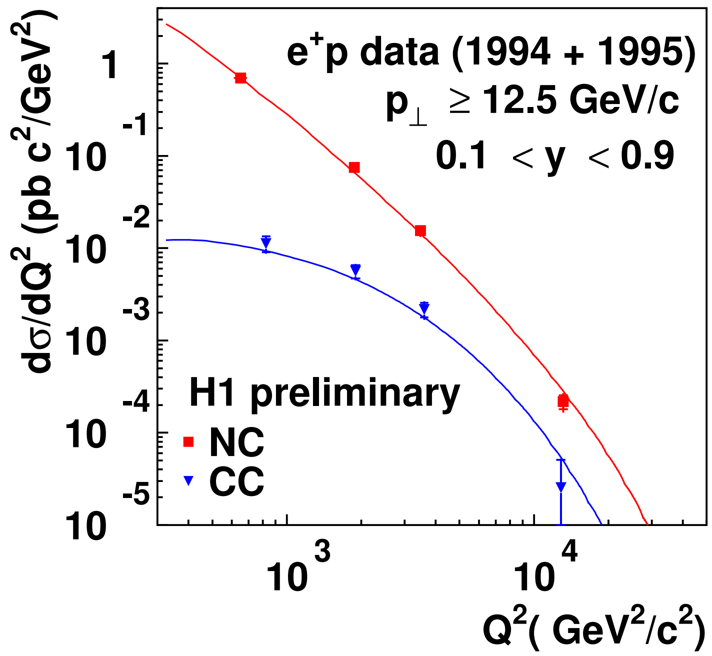

Figure 2: The differential cross sections $\mathrm{d}\sigma/\mathrm{d}Q^2$ are shown for charged and neutral current interactions in e^+p collisions with $p_T > 12.5$ GeV/c and $0.1 < y < 0.9$. The kinematics reconstruction is based on the measurement of final state hadrons. The error bars correspond to statistical and the systematic errors added in quadrature. The lines indicate the Standard Model predictions.

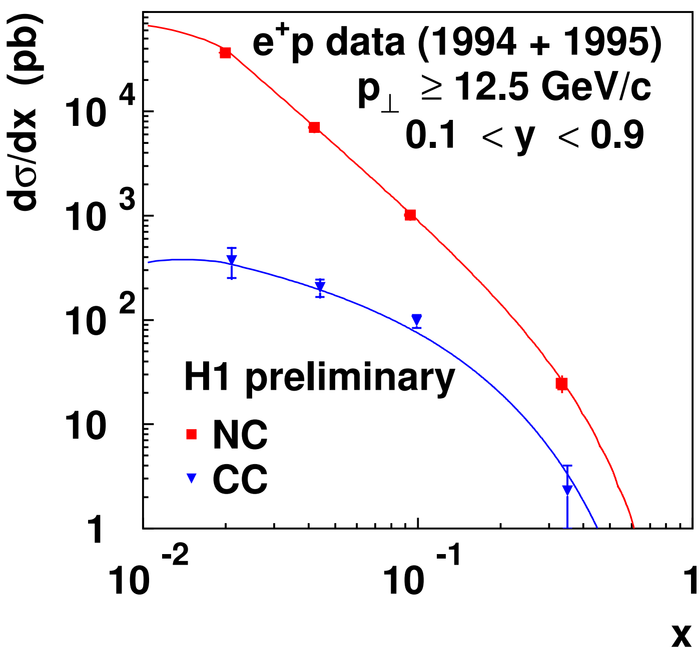

Figure 3: The differential cross sections of CC and NC processes $\mathrm{d}\sigma/\mathrm{d}x$ are shown. The kinematics reconstruction is based on the measurement of final state hadrons. The lines indicate the Standard Model predictions.

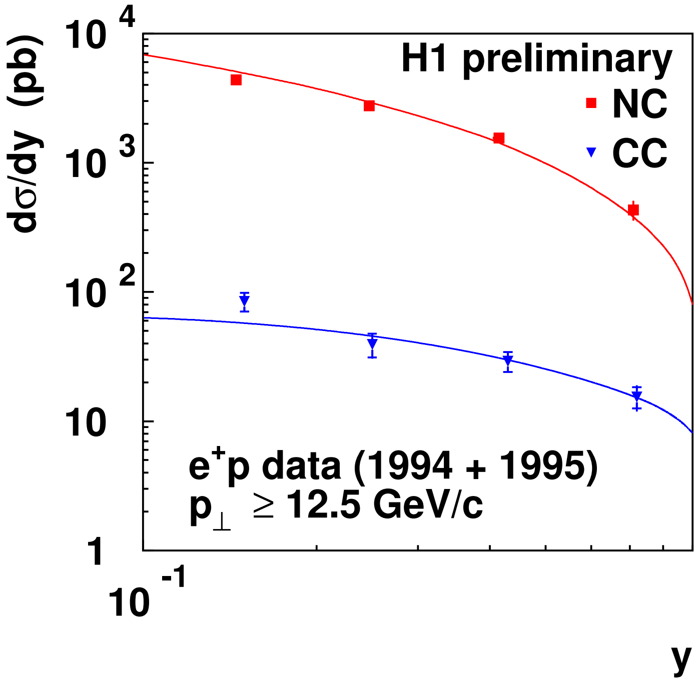

Figure 4: The differential cross sections of CC and NC processes are shown for $\mathrm{d}\sigma/\mathrm{d}y$. The kinematics reconstruction is based on the measurement of final state hadrons. The lines indicate the Standard Model predictions.