Neutral and Charged Current Cross Sections at HERA

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Abstract. The Q^2, y and x dependence of cross sections for charged and neutral current deep inelastic processes are measured in e^+p reactions using the H1 detector for transverse momenta of the outgoing lepton $p_T \geq 12.5$ GeV and $0.1 < y < 0.9$. The W-mass determined in the framework of the standard model is consistent with the mass of directly produced W's with an uncertainty of 1 GeV. From the helicity structure of the charged current the y dependence of the measured cross section can be shown to receive contribution from scattering on quarks and anti quarks (90% C.L.). QCD evolution of parton densities yields a good description of the data at high Q^2. Good agreement with Standard Model expectations is found.

INTRODUCTION

Charged Current interactions played a key role in establishing the standard model and were also used 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 : $e^{\pm}p \to e^{\pm} + X$) and charged current (CC : $e^{\pm}p \to \overset{(-)}{\nu}_e + X$) processes. X denotes the hadronic system recoiling against the lepton. For CC processes the lowest order cross section can be written as:

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

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 s the center of mass energy. The quark and anti-quark densities (u,d,s,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 $Q^2 \approx m^2_{Z^0}$. Therefore electroweak effects in NC processes are statistically less significant in the present data. In this report the dependence of the charged and neutral current cross section on Q^2 and on x, y are presented as measured by the H1 collaboration based on a total luminosity of $6.8 pb^{-1}$.

DATA

The event selection for the CC and NC analyses is based on information of the hadronic final state. Energies and directions are measured by the H1 liquid Argon calorimeter [1]. From that the hadronic transverse momentum sum $p_{T,h}$ as well as the 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 is the positron beam energy. Events are selected by $p_{T,h} > 12.5$GeV and $0.1 \leq y_h \leq 0.9$. The final state kinematics is fully specified by these two independent variables [2]. Q^2 and x are given by $Q^2_h = p^2_{T,h}/1 - y_h$, $x_h = Q^2_h/sy_h$. All experimental details concerning backgrounds and efficiency determination are described in [3–5]. Measured data is unfolded for detector effects. The parton densities used for the model predictions are from [6] (MRSH). The systematic errors are all dominated by the uncertainty of the hadronic energy scale.

RESULTS

The total cross section within cuts is $\sigma^{e^+p}_{CC} = 25.2 \pm 2.5 \pm 0.8\ pb$. Variation of the W mass in the propagator term (c.f. eq. 1) results in an uncertainty for this mass of ≈ 10 GeV. Using m_W as a free parameter of the standard model and taking all other boson and fermion masses, including the top quark mass, as experimental input, HERA measures m_W with a residual small dependence on the, yet unknown, Higgs mass [7]. Interpreting the total CC cross section this way the W mass measured in this space like process is consistent with the W mass measured by direct W production at $p\bar{p}$-colliders [8]. The uncertainty is ≈ 1 GeV. Consistency of the standard model requires these masses to coincide, deviations would hint to new physics. A measurement with longitudinally polarized e^- beams will give a sensitivity of 50 MeV on the W mass [7].

Fig. 1a shows Q^2 differential cross sections taken in e^-p collisions for NC and CC processes. They are of comparable size above $Q^2 \succeq m^2_W$ [5]. For e^+p data ($p_T > 12.5$ GeV, fig. 1b) the CC data stays for all Q^2 below the NC cross section, due to the different quark densities of the u and d quark in the proton.

The differential x distributions are shown in Fig 2a. At low x scattering on the sea quarks dominates the cross sections whereas at $x > 0.2$ scattering on valence quarks becomes important. Parton densities are determined from low

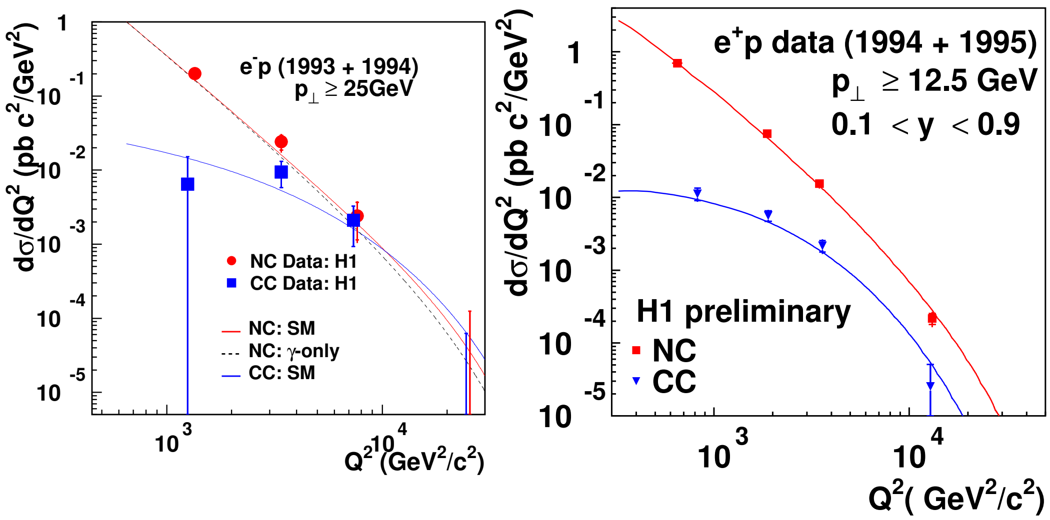

FIGURE 1. The differential cross sections $d\sigma/dQ^2$ are shown for charged and neutral current interactions with $p_T > 25$ GeV for e^-p collisions in a) and for e^+p collisions in b)with $p_T > 12.5$ GeV and $0.1 < y < 0.9$. The error bars correspond to statistical and the systematic errors added in quadrature. The lines indicate the Standard Model predictions.

Q^2 fixed target data c.f. [9]. Their Q^2–evolution probed here constitutes a test of QCD. The flavour sensitivity of the CC data due to the helicity structure of the interaction allows to disentangle quark and anti quark contributions as a function of x (c.f. eq.1). Investigation of the y-dependent CC cross-section (see fig. 2b) indicates that at 90% C.L. both quark and anti-quark contributions must contribute to the reaction. The NC x and y distributions are in good agreement with the model prediction. Note that an excess of events reported from the HERA experiments earlier this year was found for a small part of the kinematical plane and at the very highest Q^2 [10].

CONCLUSION

The x, y and Q^2 dependence of charged and neutral current processes have been measured at HERA using the H1 detector. The W mass as determined in the space like domain is, within ≈ 1 GeV, consistent with the direct measurement of the W boson mass. Quark and anti quark content of the proton are tested by means of the helicity structure of the CC process. Both contributions are needed to explain the measured cross section (90% CL). The x dependent cross sections test the QCD evolution of parton densities to large Q^2. All differential cross sections are in agreement with the Standard Model expectations. With increased luminosity future data will allow to constrain

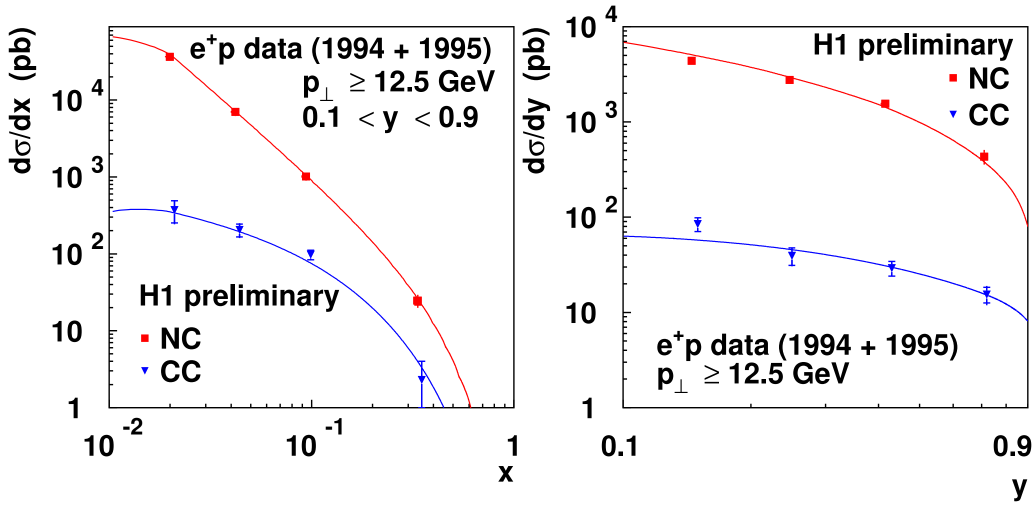

FIGURE 2. The differential cross sections of CC and NC processes $d\sigma/dx$ are shown in a) and $d\sigma/dy$ in b). The lines indicate the Standard Model predictions.

individual parton densities at large Q^2. Their knowledge is vital for W production at the Tevatron and the LHC physics program as well as for precision measurements of electroweak parameters at HERA.

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