Proton Structure at high $\mathbf{Q}^2$

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The proton structure is explored with high precision in deep inelastic scattering at high momentum transfer in $e^{\pm}p$ collisions at HERA. Electro-weak and quark flavour effects have been observed in a new kinematic domain.

1 Introduction

At HERA, electrons or positrons collide with protons at centre of mass energies $\sqrt{s} = 300$ and 318 GeV. Deep inelastic scattering (DIS) charged current (CC) and neutral current (NC) processes allow to probe the proton structure with resolutions never attained before, down to 10^{-18} m. The corresponding inclusive cross-section is measured as function of the fraction of momentum (x) carried by the struck quark and of the exchanged boson virtuality (Q^2). The kinematic range explored at HERA include a very high Q^2 domain ($Q^2 \simeq M_Z^2$) where electro-weak effects due to Z boson exchange can play an important role in NC processes. The flavour dependence of the CC and NC interactions in the high x and high Q^2 range bring a new sensitivity to the proton quark content.

The data presented here have been accumulated in the period 1994-1999 in e^+p and e^-p collison modes [1,2,3,4,5,6]. In this paper the inclusive CC and NC cross-section measurements based on this data as well as the investigations of the proton structure at high Q^2 and x are discussed.

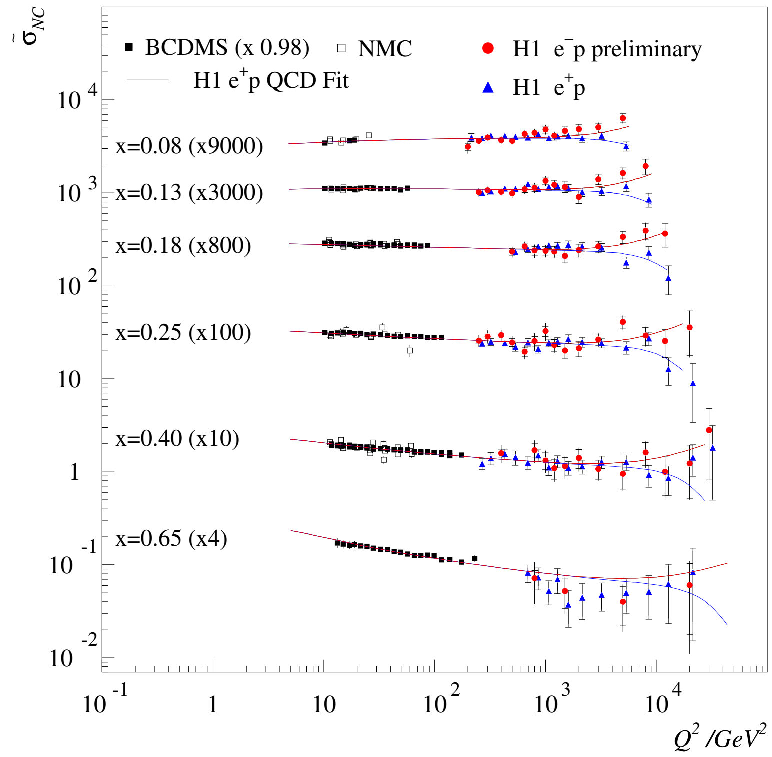

Figure 1: Reduced DIS NC cross-section measured for e$^+$p and e$^-$p collisions at HERA and comparison to respective Standard Model predictions based on a NLO QCD fit.

2 Inclusive Cross-sections at High x and Q^2

2.1 Neutral Currents

The NC double differential cross-section in e$^\pm$p collisions ($d^2\sigma^{\pm}_{\rm NC}/dxdQ^2$) as a function of x and Q^2 can be expressed in terms of three structure functions F_2, F_L and F_3:

$$\frac{d^2\sigma^{\pm}_{\rm NC}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+F_2(x,Q^2) - y^2F_L(x,Q^2) \mp Y_-xF_3(x,Q^2)\right] \tag{1}$$

where y is the inelasticity and $Y_\pm \equiv 1 \pm (1-y)^2$. The longitudinal structure function F_L has a negligible effect for the present analysis while the $\gamma - Z$ interference contribute at high Q^2 through the F_3 term. The main contribution to the NC cross-section is given by $F_2 = F_2^{em}(1+\delta_Z)$. This term is dominated by the photon contribution F_2^{em} therefore being independent on beam polarity. The Z exchange contribution δ_Z becomes non-negligible in the range Q$^2 \simeq M_Z^2$. The measurement is presented in form of the reduced cross-section $\tilde{\sigma}_{NC} \simeq F_2 \mp (Y_-/Y_+)xF_3$ so that the Q^2 dependence due to the propagator is removed.

The reduced cross-section measured by H1 [1] as a function of Q^2 for different x bins is presented in figure 1 for both e$^+$p and e$^-$p data samples. The data are compared to a Standard Model fit including fixed target data at lower Q^2. Good agreement is observed over three orders of magnitude in Q^2 up to Q^2=30000 GeV^2 and for an x range from 0.08 to 0.65. The interesting high Q^2 and high x domain suffers from low statistics and will be particularly interesting for the future data taking. In particular the upward fluctuation observed in the $x = 0.4$ bin in e$^+$p collisions need more data for clarification. At high Q^2, the diference in the e$^+$p and e$^-$p

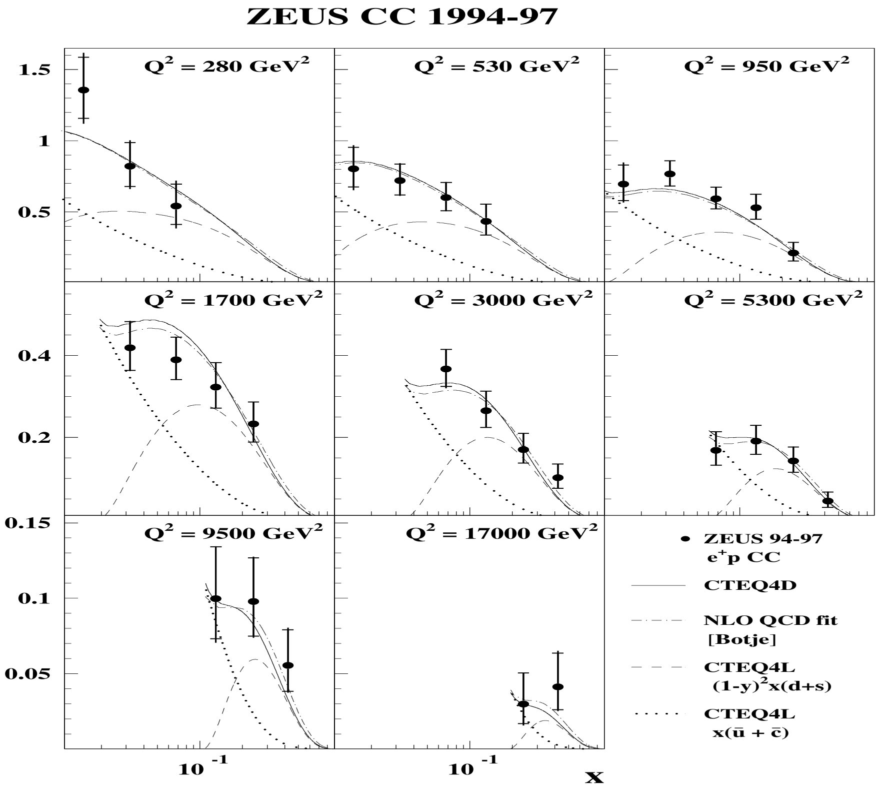

Figure 2: Double differential reduced cross-section for CC processes in e$^+$p data.

cross-sections arises from the γ-Z interference contributing with different sign (the xF_3 term in equation 1).

2.2 Charged Currents

The CC cross-section can be written as a product of the propagator factor and the reduced cross-section:

$$\frac{d^2\sigma^{\pm}_{\rm CC}}{dx dQ^2} = \frac{G_F^2}{4\pi x}\left(\frac{M_W^2}{M_W^2+Q^2}\right)^2 \tilde{\sigma}^{e^{\pm}p}_{CC}(x,Q^2)$$

At Born level, the reduced cross-section $\tilde{\sigma}^{e^{\pm}p}_{CC}$ is identified as proton structure term $\Phi^{e^{\pm}p}_{CC}$. For instance, in e$^+$p collisions, in leading order we have: $\Phi^{e^+p}_{CC} = x\left[(\bar{u}+\bar{c})+(1-y)^2(d+s)\right]$, where $\bar{u}, d, s, \bar{c}$ are the respective quark densities in the proton.

The double differential reduced cross-section for the CC processes measured in the e^+p data by ZEUS [5] is presented in figure 2. The Standard Model prediction describes well the data in the explored kinematic range $280 < Q^2 < 17000$ GeV^2 and $0.015 < x < 0.042$. The individual quark contributions are also shown, clearly pointing to the sensitivity of the CC processes to the d quark density in e$^+$p collisions. In a similar way, in e$^-$p collisions CC process are sensitive to the u quark density [2,6].

3 Quark Densities at High Q^2 and High x

The flavour sensitivity of DIS processes at high x can be used to further investigate the proton structure. For instance, in e$^+$p collisions the exchange of a photon (NC) mainly probes

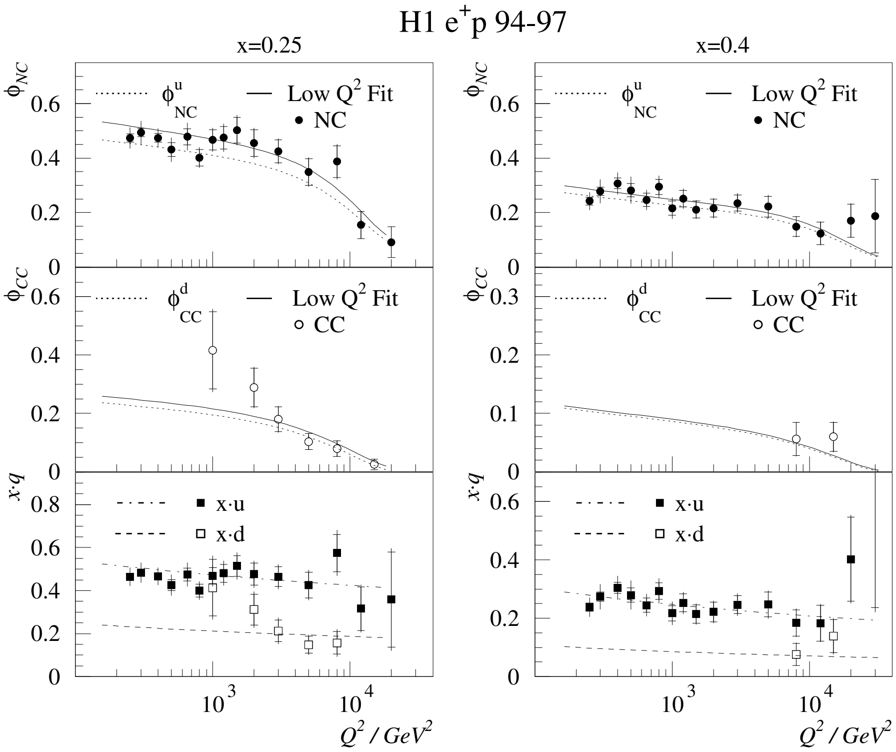

Figure 3: Structure function terms ($\Phi_{CC}^{e^+p}$ and $\Phi_{NC}^{e^+p}$) and u and d quark densities compared to low Q^2 fit.

the u quark density, while the W exchange (CC) is mainly sensitive to the d quark density [1]. Figure 3 shows the CC and NC structure function terms (reduced cross-sections at Born level) measured with e^+p data [1]. The u and d quark densities are extracted and compared to the predictions of the analysis done with lower Q^2 data sample (low Q^2 fit). Good agreement is found. In addition, the result provide an indication of the current sensitivity to the d quark density at high x which is otherwise less constrained by previously existing experimental data [7]. A more precise measurement of the d quark density at high x will be possible with an substantial increase in statistics forseen for the next data taking period at HERA.

Acknowledgments

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