Measurement of the neutral current DIS cross section at H1

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Abstract. New preliminary measurements of the inclusive neutral current ep scattering cross sections from the H1 experiment at HERA are presented.

The inclusive ep scattering cross ection is measured in the region of low negative four-momentum transfer squared, $0.2 \leq Q^2 \leq 12$ GeV^2, and low Bjorken x, $5{\cdot}10^{-6} \leq x \leq 0.02$. The result is based on two data sets collected in dedicated runs at beam energies of 27.5 GeV for positrons and 920 GeV for protons and covers the transition region from quasi-real photoproduction to deep inelastic scattering. A combination with data used in results previously published by H1 leads to an accuracy of a few percent on the resulting cross section measurement.

Measurements of the $e^{\pm}p$ inclusive cross sections are presented in the region of high inelasticity $y > 0.6$ at low ($8 \leq Q^2 \leq 50$ GeV^2) and medium ($65 \leq Q^2 \leq 800$ GeV^2) values of Q^2. At high values of inelasticity the cross section is sensitive to the longitudinal structure function F_L and thus provides additional constraints on DGLAP evolution. These results are based on data collected during the years 2003-2007 (HERA-II) which correspond to an integrated luminosity of 315 pb^{-1}. About equal luminosities obtained for the e^+p and e^-p samples allow for a high precision control of background processes.

1. Introduction

Inclusive deep inelastic scattering (DIS) cross section measurements of $e^{\pm}p$ interactions are the main source for our knowledge of proton structure. These measurements played a key role in the development of Quantum Chromodynamics (QCD). The HERA collider experiments, H1 and ZEUS, cover the largest kinematic phase space for such inclusive measurements to date.

The neutral current process takes place via the exchange of a virtual photon or Z^0 propagator. For low values of negative four momentum transfer squared, Q^2, photon exchange dominates, while Z^0 exchange contributes significantly only for very high values of Q^2, $Q^2 \geq {M_Z}^2$, where M_Z is the mass of the Z^0.

The inclusive neutral current $e^{\pm}p$ double-differential cross section at low values of Q^2, in the one-photon exchange approximation, can be expressed as

$$\frac{d^2\sigma}{dxdQ^2} \cdot \frac{Q^4 x}{2\pi\alpha^2[1+(1-y)^2]} = \sigma_r = F_2(x,Q^2) - f(y) \cdot F_L(x,Q^2) \ , \qquad (1)$$

where α is the fine structure constant and $f(y) = y^2/[1+(1-y)^2]$. The inelasticity y is related to Q^2, to the centre of mass energy squared of the electron[1]-proton system s and to the Bjorken

[1] The term *electron* in the text is used to denote both electrons and positrons.

scaling variable x by $y = Q^2/sx$. The two structure functions F_2 and F_L obey the relation $0 \le F_L \le F_2$ due to the positivity of the cross sections for transversely and longitudinally polarised photons scattering off protons. Therefore, the longitudinal structure function, F_L, gives a sizable contribution to the cross section only at large values of the inelasticity y. In lowest order QCD, F_L takes the value of zero but due to gluon radiation gets a non-zero value in perturbative QCD (pQCD). The measurement of F_L can thus provide additional constraints on the gluon density function and on DGLAP evolution[1, 2, 3].

For $Q^2 \le 2$ GeV^2 non-perturbative effects begin to dominate since higher order corrections to the perturbative expansion become large as the strong coupling constant $\alpha_s(Q^2)$ increases; this leads to the breakdown of pQCD calculations. A study of the transition region probes soft hadronic physics, which is currently described by QCD inspired or by purely phenomenological models. To provide better understanding of soft hadronic processes and to study these models, it is thus important to perform high precision measurements of ep scattering cross sections over the complete transition region.

Figure 1 illustrates the kinematic regions in which inclusive measurements have been made at H1, as well as at ZEUS and fixed target experiments. Results presented in this paper correspond to the region labeled with "H1 SVX, NVX" (at very low Q^2) and to the region with high inelasticity, $y > 0.6$, and Q^2 up to 800 GeV^2.

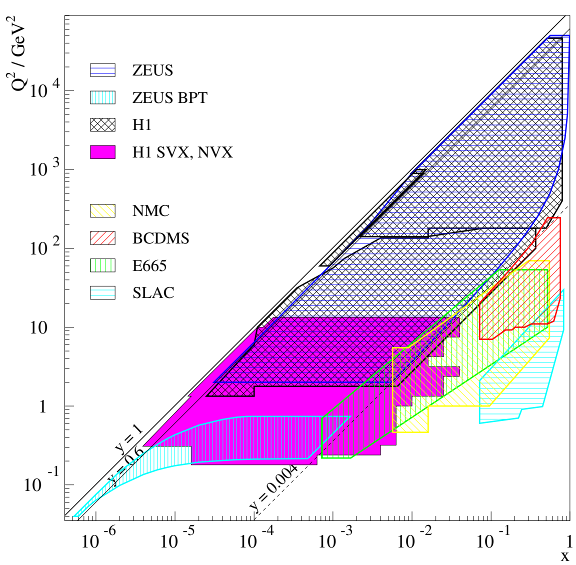

Figure 1. The kinematic plane in x and Q^2 covered by H1, ZEUS and fixed target inclusive DIS measurements. The line at inelasticity $y = 1$ represents the kinematic limit.

2. Neutral current cross section measurement at very low Q^2

In this paper a new measurement of the inclusive ep cross section in the range $Q^2 \le 12$ GeV^2 and $5 \cdot 10^{-6} \le x \le 0.02$ is presented. The data was collected by the H1 detector in two positron-proton running periods with dedicated settings of the inclusive positron triggers. One data set (termed as minimum bias '99, "MB '99") was collected in 1999 and corresponds to an integrated luminosity of 2.1 pb^{-1}. The other was collected in 2000, with the interaction region shifted along the proton beam direction by +70 cm (termed shifted vertex, "SVX 00"), and corresponds to 505 nb^{-1}. This shifting of the interaction region provided detection of the scattered electron at larger polar angles[2]. In this way events with $Q^2 \le 2$ GeV^2 are detected within the H1 detector. In comparison to the previous shifted vertex H1 measurement [4],

[2] In the H1 coordinate system the z axis points along the proton beam direction and thus large electron polar angles correspond to very small angles with respect to the incoming electron direction.

an improvement in precision is reached using the higher luminosity of the new data as well as exploiting a new backward detector of the H1, the Backward Silicon Tracker (BST). The vertex reconstructed using the electron track in the BST allows extension of the kinematic range at low Q^2. These measurements are combined with previously published data [5] taken at a proton beam energy of 820 GeV in the region $Q^2 \geq 2$ GeV^2 with a luminosity of 1.8 pb^{-1} (minimum bias '97 - "MB'97"). The combination takes into account the correlations of the systematic uncertainties.

Figure 2 shows the x dependence of the combined H1 ep reduced cross section for Q^2 ranging from 0.2 GeV^2 to 12 GeV^2. The measurement is compared to the fractal model [6]. The total accuracy of the combined datasets is 2-3 % in the bulk region of the measurement. For $Q^2 > 5$ GeV^2 precision reaches 1.5 %.

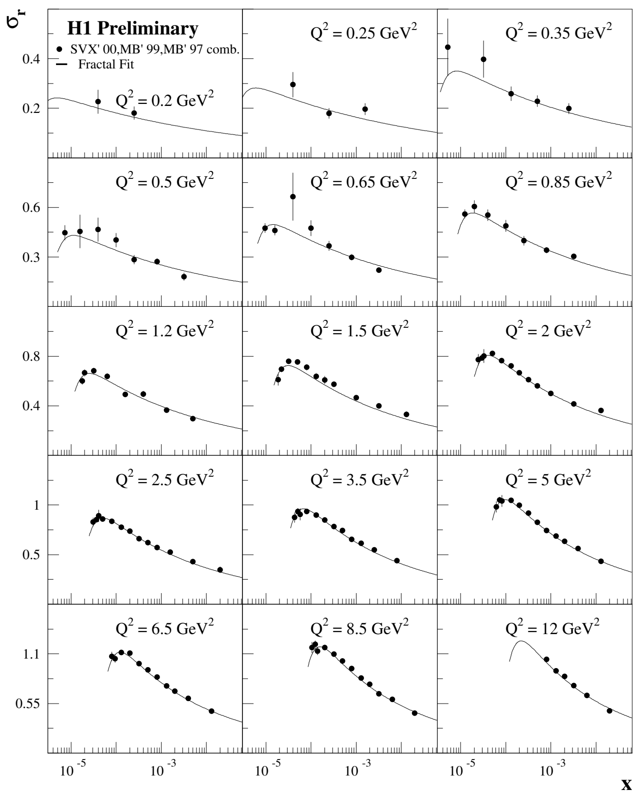

Figure 2. The reduced cross section measured at the H1 experiment in the region of very low Q^2 as a function of x compared to the fractal model fit. The errors represent the statistical and systematic errors added in quadrature.

3. Measurements at high y

At high y the event kinematics is best reconstructed using the electron method which uses the energy of the scattered electron, $E_e{}'$, and its polar angle, θ_e, according to the relations

$$y = 1 - \frac{E_e{}'}{E_e} sin^2(\theta_e/2), \qquad Q^2 = \frac{E_e{}'^2 sin^2\theta_e}{1-y}. \tag{2}$$

Thus for a given value of Q^2, measurements at high values of y correspond to low electron energies.

Photoproduction often leads to electron-like low energy deposits in the calorimeter thus faking the scattered electron's signature. Since the photoproduction cross section is much greater than that of the signal, it contributes as the largest source of background. Thus the removal of the background provides the main difficulty for high y measurements. At high y and low Q^2, hadrons originating from deep inelastic scattering processes also give rise to significant background as the hadronic final state is scattered backwards.

This high level of background leads directly to an additional uncertainty from the background subtraction procedure. The background also complicates the estimation of the signal selection efficiency in an unbiased way. As Monte Carlo background estimates are unreliable, the background is better estimated using the charge of the track associated to the calorimeter cluster. The sample of candidates with a negatively charged track is taken to represent the background in the positron data sample and vice versa.

The new high y cross section measurements are based on HERA-II data. For measurements at low Q^2 ($8 \leq Q^2 \leq 50$ GeV^2), data with an integrated luminosity of 96 pb^{-1} was used, where 51 pb^{-1} is from e^+p and 45 pb^{-1} from e^-p interactions. For measurements at medium Q^2 ($65 \leq Q^2 \leq 800$ GeV^2), data with an integrated luminosity of 315 pb^{-1} was used, where 161 pb^{-1} is from e^+p and 154 pb^{-1} from e^-p interactions.

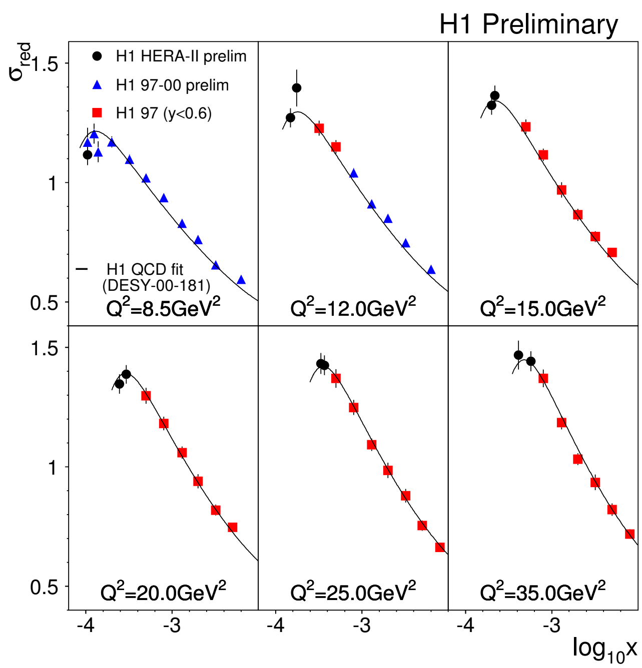

Figure 3. The reduced cross section at the H1 experiment as a function of x compared to the H1 QCD fit [5] (the line). The preliminary measurement from section 3.1 (solid circles) , the preliminary measurement from section 2 (trinagles), and the published measurement (squares) from HERA-I data [5] are shown. Error bars represent the total error.

3.1. Low Q^2

The charge assignment of the central track associated with the calorimeter cluster allows a measurement of the scattered electron energy down to 3.4 GeV corresponding to $y \leq 0.9$ in the region of low Q^2.

Figure 3 shows the x dependence of the reduced cross section measurement from high y for various values of Q^2 compared with measurements from section 2 and published cross section measurements based on HERA-I data [5]. Also shown is the H1 QCD fit [5] for comparison. Figure 3 shows that there is a turn-over of the reduced cross section for very high y which indicates the negative contribution of the F_L structure function to the cross section.

The systematic uncertainty of the new cross section measurement is 2-3 % and is dominated by the track link efficiency uncertainty which is estimated to be 1.5 %.

Figure 4 compares the new preliminary reduced cross section dependence on Q^2 at inelasticity $y = 0.825$ with the published H1 result based on HERA-I data [5]. The new measurement

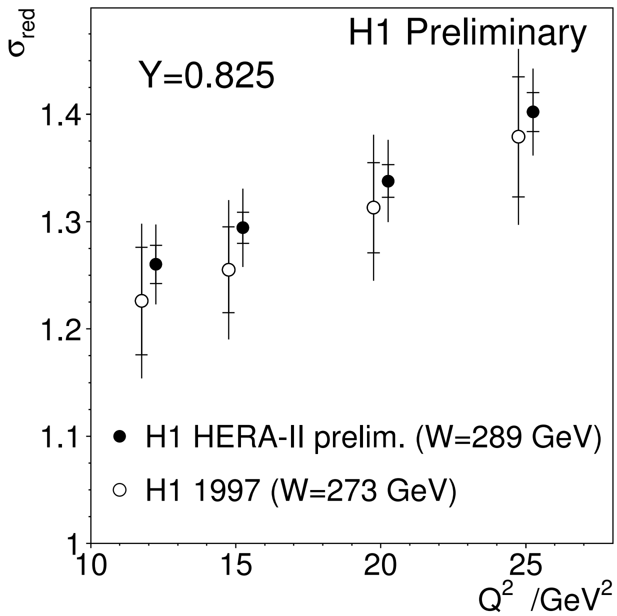

Figure 4. The Q^2 dependence of the preliminary reduced cross section (solid circles) at inelasticity $y = 0.825$ compared to the published H1 result (open circles) for low values of Q^2. The inner and outer error bars represent statistical and total errors respectively. The published data corresponds to a slightly lower center of mass energy.

has uncertainties reduced by approximately factor two compared to the published result. Unlike the HERA-I reusult, the data used in this analysis has a large e^-p sample which provides much improved systematics arising from the charge asymmetry.

This present analysis also shows that at H1 there are advanced tools to cope with large backgrounds at low energies. This is vital for the direct and accurate measurement of the longitudinal structure function as is expected from utilizing the data from the HERA low proton energy run.

3.2. Medium Q^2

In the high y analysis at medium Q^2, electron candidates are selected in the calorimeter with an energy down to 5.5 GeV. The largest source of uncertainty on the cross section is due to the error on the trigger efficiency measurement (2-4 %), but this can be improved. The other major sources of systematic uncertainty are due to the errors on the track-link/vertex (2 %) and the electron identification (2 %) efficiencies. All other sources of uncertainty result in typically less than 1 % error on the cross section.

Figure 5 shows the new preliminary reduced cross section measured at y =0.75 as a function of Q^2 (lower scale) or equivalently x (upper scale). The H1 result based on HERA-I data [7] is also shown. Compared to HERA-I, the new measurement has significantly reduced statistical uncertainties. The cross section measurement is also extended to lower values of Q^2 giving rise to two new measurements at $Q^2 = 65$ GeV^2 and 80 GeV^2.

4. Summary

In the lowest Q^2 ($0.2 \leq Q^2 \leq 12$ GeV^2) and low Bjorken x ($5 \cdot 10^{-6} \leq x \leq 0.02$) regions, preliminary measurements were made using three data sets from H1 collected during the HERA-I period. HERA-I data will be used for the final result from H1 in this kinematic domain. The precision of the reduced cross section measurement is 2-3 % in the bulk region, while in the region of $Q^2 > 5$ GeV^2 the precision reaches 1.5 %.

At high values of inelasticity ($y > 0.6$) there are new preliminary cross section measurements

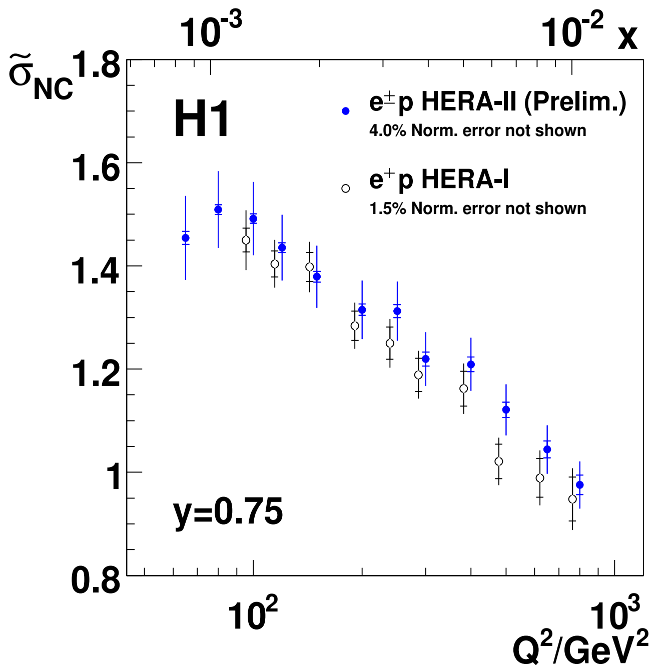

Figure 5. The new preliminary reduced cross section (solid circles) shown as a function of Q^2 (lower scale) or equivalently x (upper scale) measured at $y = 0.75$. The published HERA-I results are also shown (open circles) for comparison. The error bars are defined as in figure 4 and do not include luminosity uncertainty.

from two analyses covering the low and medium Q^2 regions which are based on HERA-II data. From the low Q^2 analysis, a precision of about 2-3 % is reached which is about a factor of two improvement compared to the corresponding published cross sections. In the medium Q^2 analysis the new preliminary result compared to the published result based on HERA-I data has significantly improved statistical uncertainty and extends towards lower values of Q^2.

HERA has accomplished its program by performing runs with low (460 GeV) and medium (575 GeV) proton beam energies. Three different center-of-mass energies will allow the direct and accurate measurement of the longitudinal structure function F_L.

References

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