Cross section measurements in DIS

K. Papageorgiou
University of the Aegean, Greece

(on behalf of the H1 and ZEUS Collaborations)

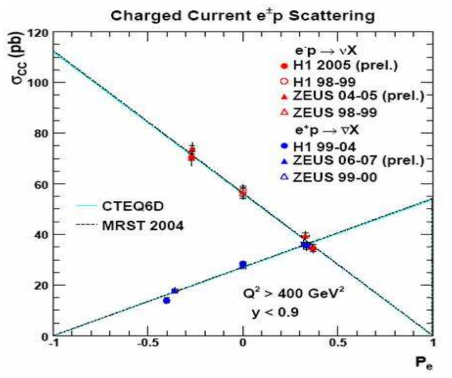
DOI: http://dx.doi.org/10.3204/DESY-PROC-2009-01/36

Abstract

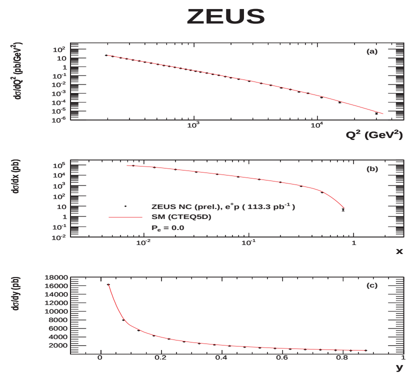
Several topics from the wide field of cross section measurements for Deep Inelastic Scattering (DIS) in ep collissions at HERA are addressed. They include measurements of the Neutral Current (NC) DIS cross section with particular emphasis on the direct determination of the longitudinal proton structure function F_L. Additionally measurements of the Charged Current (CC) e^-p and the Neutral Current (NC) e^+p cross sections from both H1 and ZEUS Collaborations are also presented.

1 Introduction

Studies of the deep inelastic lepton-nucleon scattering has been a very powerfull tool to improve our understanding of the parton structure of the nucleons and also in establishing and testing QCD. The HERA ep collider, having a centre-of-mass energy of 318 GeV in nominal runs, functions like a super microscope with the world's sharpest view of the protons interior, allowing for the first time the direct observation of weak effects in ep DIS at high values of the virtuality Q^2, of the intermediative boson. During the last 3 month's of it's operation (from March to June of 2007), HERA had performed also some special runs with reduced proton beam energies of 460 GeV and 575 GeV dedicated to the direct measurement of the longitudinal polarised structure function F_L. Two different kinds of particle interactions can taken place at HERA: the Neutral Current (NC) and the Charged Current (CC). In the Standard Model (SM), the NC process is mediated by photons or Z- boson, while the CC DIS process is mediated by the exchange of the W-boson. However, at leading order only up and down type of valence quarks contribute to e^-p CC DIS interactions, making these processes valuable for studying flavour specific parton distributions. Chiral structure of weak interactions is directly visible as a function of polarization. The polarization scales linearly with the unpolarised cross section as $\sigma_{CC}^{e^{\pm}p}(P_e) = (1 \pm P_e)\sigma_{CC}^{e^{\pm}p}(P_e = 0)$. Measurements of the CC DIS cross section in $e^{\pm}p$ collissions by both ZEUS [1] and H1 Collaborations revealed a clear and large effect at HERA as depicted in figure 1a. The results are consistent with SM predictions of $\sigma_{CC}^{RH} = 0$ and the absence of RH currents. Measurements of the NC DIS cross sections in e^+p collisions with a longitudinal polarised positron beam, have been previousely published by the ZEUS and the H1 Collaborations [2]. Recent results from ZEUS [3] for the single differential cross sections $\frac{d\sigma}{dQ^2}$,$\frac{d\sigma}{dx}$ and $\frac{d\sigma}{dy}$ for $Q^2 > 185GeV^2$ and $y < 0.95$ based on data corresponding to a luminosity of $L = 113.3pb^{-1}$ at $\sqrt{s} = 318GeV$ and corrected for zero polarization, are presented in figure 1b. Measured cross sections are consistent with SM predictions evaluated using the ZEUS-JETS PDF's.



(a)



(b)

Fig. 1: (a) Cross section of CC $e^{\pm}p$ DIS as a function of polarization from the ZEUS (triangles) and the H1 (circles) Collaborations. The results are consistent with SM predictions of $\sigma_{CC}^{RH} = 0$ (b). Single differential NC $e^{+}p$ cross section as a function of Q^2, Bjorken-x and y from the ZEUS Collaboration. The measured cross sections are consistent with SM predictions evaluated using the ZEUS-JETS PDF's.

2 DIS Kinematics

Deep Inelastic Scattering can be described in terms of the kinematical variables x and Q^2. The variable Q^2 is the squared momentum transfer between the lepton and the nucleon and is defined as $Q^2 = -q^2 = -(k-k')^2$, where k and k' denote the four-momenta of the incoming and scattered electron, respectively. The variable x is the Bjorken scaling factor corresponds to the fraction of proton's momentum carried by the struck quark. It is defined by the relation $x = \frac{Q^2}{2P.q}$ where P denotes the four momentum of the incoming proton. The variable $y = \frac{P.q}{P.k}$ is the inelasticity representing the energy fraction transferred from the lepton in the proton rest frame. Bjorken-x and inelasticity are not independent from each other as $Q^2 = sxy$ where s is the total center of mass energy of the ep interaction.
The NC DIS cross section in terms of structure functions can be expressed as following

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

where $Y\pm = 1 \pm (1-y)^2$ and x and Q^2 are defined at the hadronic vertex and α is the fine structure constant. In this equation F_2 is the dominant contribution to the cross section for most of the kinematical range and its measurement has been the main ingredient for the PDF's extractions. The H1 and ZEUS Collaborations have presented high statistics measurements of the NC DIS cross section and extracted F_2. The revealed steep rise of F_2 towards low-x values corresponds to the strong scaling violations due to the increase of the gluon density. The data from the two experiments are in very good agreement with each other and with earlier fixed target experiments. In the structure function xF_3 the parity-violating term arising from Z^0 e xchange and has contributions exclusively from the weak force. Experimentally it can be extracted by measuring the $\frac{d^2\sigma(e^-p)}{dxdQ^2} - \frac{d^2\sigma(e^+p)}{dxdQ^2}$, and is negligible at small Q^2. However, at large y values, the contribution of the longitudinal polarised structure function F_L to the total cross section becomes significant and it cannot be omitted. In addition due to its origin, F_L is directly sensitive to gluon dynamics in the proton and therefore its measurement provides a sensitive test of QCD at low x values.

3 Method for direct F_L measurement

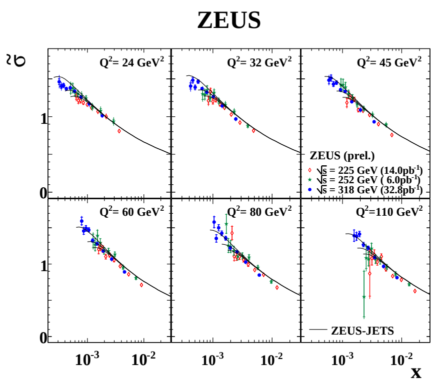
The ep cross section is usually written in the "reduced" form as $\tilde{\sigma}_r = F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2)$, ignoring xF_3 which is negligible at high Q^2. In order to separate F_2 and F_L without any theory assumption one needs to measure the cross section at fixed x and Q^2 and different values of inelasticity, therefore at different beam energies. Then F_L can be extracted as

$$F_L(x,Q^2) = \frac{\tilde{\sigma}_r(x,Q^2,y_1) - \tilde{\sigma}_r(x,Q^2,y_2)}{\frac{y_2^2}{Y_{2+}} - \frac{y_1^2}{Y_{1+}}} \tag{2}$$

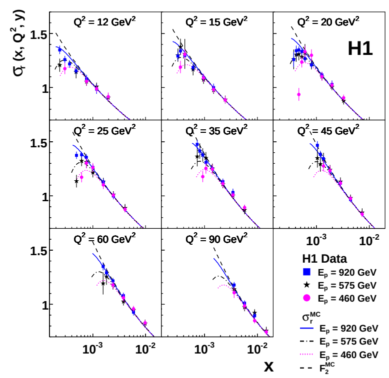
The larger the difference in the y values (level arm) or the more measurements of the $\tilde{\sigma}_r$ at intermediate beam energies, the higher the accuracy in the F_L measurement. The experimental challenge in order to measure cross sections at high y values, is related to the identification of the low energy electron in the calorimeter, where a lot of hadronic activity is present. In addition the large photoproduction background at low Q^2 is needed to be controlled and subtracted in order to extract the genuine DIS events. At low y values the high energy electron in the calorimeter is well separated. The DIS events selection criteria for ZEUS experiment, are based on the Uranium Calorimeter for the identification of the electron with energy down to 6 GeV, the use of the CTD and MVD detectors to reject neutrals, and on cuts applied on the z coordinate of the event interaction vertex and also on the longitudinal energy-momemtum variable $E - P_z$ which is calculated using the energy deposits and angles measured with the calorimeter, in order to further reduce the photoproduction background and the radiative corrections. For the H1 Collaboration, the electron identification with energies down to 3GeV relies on the SpaCal and the LAr calorimeter, the use of the CT and BST detectors to reject neutrals, and on cuts applied to the event interaction vertex and to the $E - P_z$ variable as well.

4 Reduced cross section measurement and F_L extraction

Recent measurements of the reduced cross section as a function of x, for various fixed Q^2 values, perfomed separately by the ZEUS [4] and H1 [5] Collaborations and based on data collected at three different center of mass energies ($\sqrt{s} = 318, 252, 225)$ GeV), are shown in figures 2a and 2b respectively. The results are compared with the predictions of ZEUS-JETS PDF's and F_2 H1 PDF2000. Visible differences between the data sets and the turn over of the cross sections at low x values are observed, while the cross sections at high-x values are consistent for all data sets.
Direct measurements of the longitudinally polarised structure function F_L perfomed for the first time separately by ZEUS [4] and H1 [5] Collaborations, as a function of Bjorken-x for fixed Q^2 values are depicted in figures 3a and 3b respectively. The results are consistent with the prediction of ZEUS-JETS PDF's and H_1 PDF. The x-averaged F_L measurements from the H1 Collaboration [5] as a function of Q^2 values in the range of $12 < Q^2 < 110 GeV^2$, are depicted

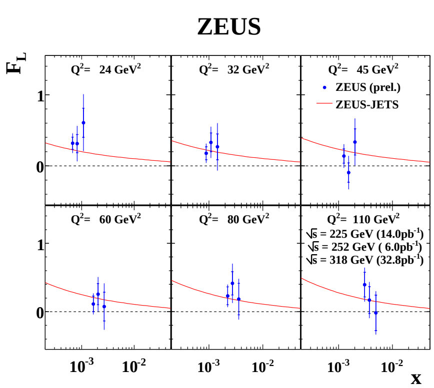


(a) ZEUS

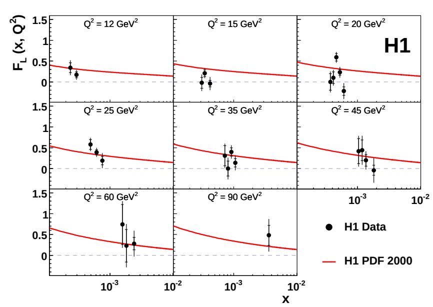


(b) H1

Fig. 2: Reduced cross section as a function of Bjorken x for various fixed Q^2 values (a) from ZEUS and (b) from $H1$. The lines are predictions using ZEUS-JETS PDF's and $H1$ PDF2000 respectively.



(a) ZEUS



(b) H1

Fig. 3: F_L measurements as a function of Bjorken x for various fixed Q^2 values (a) from the ZEUS and (b) from the H1 Collaborations. Lines are predictions using ZEUS-JETS PDF's and H1 PDF2000 respectively.

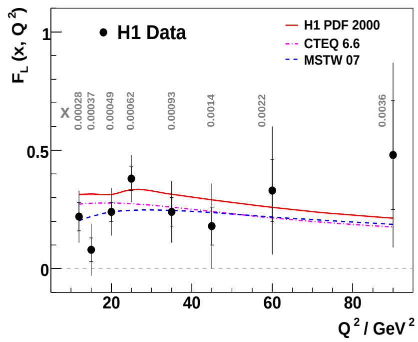


Fig. 4: The x-averaged F_L measurements performed by the H1 Collaboration as a function of the Q^2. The results are consistent with the H1 PDF 2000 fit (red line) and with expectations from other models, CTEQ 6.6 (pink line) and MSTW (blue line) at higher order pertubation theory.

in Figure 4. The results are consistent with the H1 PDF 2000 fit and with the expectations from global parton distribution fits at higher order pertubation theory.

5 Conclusions

The HERA experiments provide unique information on the proton structure over a wide range of Bjorken-x values, an important precision input for physics at LHC. First direct measurements of the longitudinally polarised structure function F_L performed in a new kinematical range of x and Q^2 separately by both the ZEUS ($24 < Q^2 < 110 GeV^2$ and $0.0006 < x < 0.005$) and H1 Collaborations ($12 < Q^2 < 90 GeV^2$ and $0.00024 < x < 0.0036$) are presented here. In general the data are in good agreement with higher order pQCD predictions, although deviations at smaller Q^2 values are visible. The analysis is ongoing, thus it can be expected to further constrain low-x region.

References

[1] ZEUS Collaboration, "Measurement of high-Q^2 charged current deep inelastic scattering cross section with a longitudinally polarised electron beam at HERA", XXXIII International Conference on High Energy Physics, July 26-August 2 , Moscow (Russia).

[2] ZEUS Collaboration, S.Chekanov *et al.*, Phys.Lett. **B637**, 210 (2006).

[3] ZEUS Collaboration, "Measurement of high-Q^2 neutral current deep inelastic e^+p scattering cross sections with longitudinallly polarised electrons at HERA", ZEUS-prel-08-005 (2008).

[4] A. Caldwell, International Workshop on Diffraction in High Energy Physics, DIFFRACTION 2008, 9-14 Sep 2008 , La Londe-les-Maures (France).

[5] H1 Collaboration, Phys.Lett. **B665**, 139 (2008).