

New measurement of charge asymmetry xF_3 from HERA

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Abstract. After presenting the recent measurements of neutral current cross section in DIS at HERA, we explain the effect of the $\gamma - Z_0$ interference at the electro-weak scale, visible on these data. Then, the beam charge difference xF_3 is measured and the interference itself is extracted. Results are discussed in the context of perturbative QCD.

Keywords: DIS, Neutral current, xF_3

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INTRODUCTION

HERA was a collider, located at the DESY laboratory in Hamburg, with the capability to scatter (polarised) electrons and positrons off protons, at a center of mass energy, \sqrt{s} , of about 320 GeV. The first HERA data were taken in summer 1992. It ceased operations in June 2007. The total luminosity collected by both experiments H1 and ZEUS is $\sim 0.9 \text{ fb}^{-1}$. The core results of HERA (with H1 and ZEUS experiments) are related to deep inelastic lepton-proton scattering (DIS), where the proton structure is probed by a virtual photon (γ^*), or weak bosons (Z_0 or W^\pm). The typical resolution scale is then inversely proportional to the momentum of the exchanged boson $\sim 1/\sqrt{Q^2 + M_{Z,W}^2}$. Main results concerning measurements of DIS cross sections are summarised in Fig. 1 [1, 2]. The Neutral Current (NC) and Charge Current (CC) cross sections in DIS are displayed. A NC process corresponds to the reaction $ep \rightarrow eX$, where the incoming lepton is scattered with a change in momentum. Then, the exchanged boson is a (neutral) virtual photon at low Q^2 and a virtual photon or a Z_0 boson at large Q^2 ($Q^2 > M_Z^2$). In a CC process, the lepton is scattered as a neutrino, $ep \rightarrow \nu X$, which means that the exchanged boson is charged, namely W^\pm . That's why values of CC cross sections are a few orders of magnitude below the NC ones at low Q^2 and become of comparable size at large Q^2 , when Q^2 is above M_Z^2 or M_W^2 . This is a fundamental observation, visible in Fig. 1. This corresponds exactly to the Electro-Weak (EW) unification in the Standard Model.

EXPERIMENTAL RESULTS

In Fig. 1, we also present cross section measurements for e^+p and e^-p collisions separately. For CC processes, the difference between both lepton beam charges is obvious. In e^+p and e^-p collisions, W^+ or W^- bosons are exchanged (respectively). Then, the reactions at the proton vertex do not probe the same parton densities. Quarks of types u

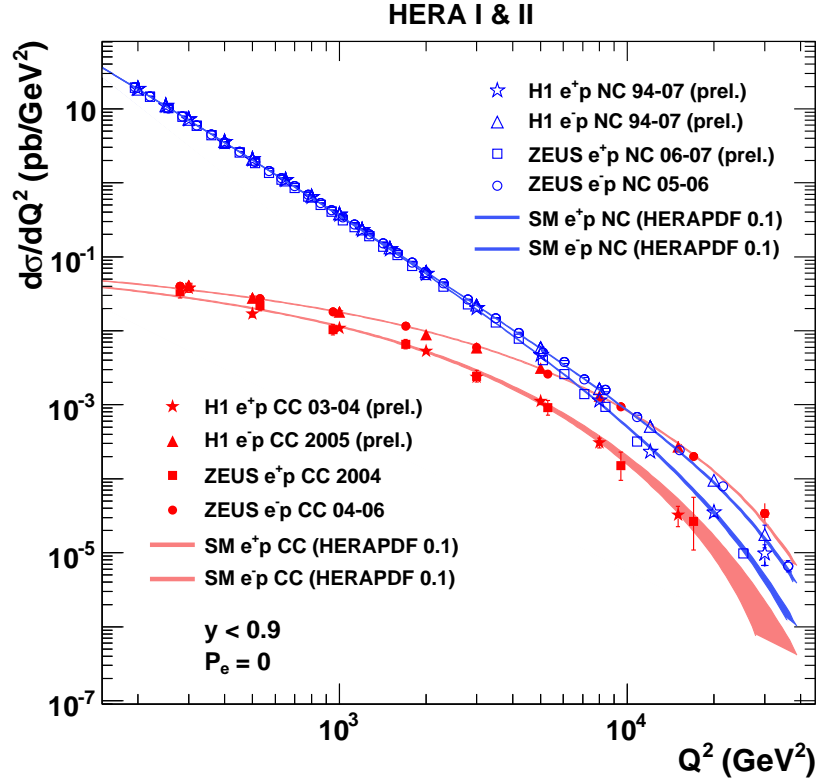


FIGURE 1. Neutral Current (NC) and Charge Current (CC) cross sections in DIS (Q^2 dependence) as measured by H1 and ZEUS experiments at HERA. Cross sections obtained from electron-proton and positron-proton collisions are shown (see Ref. [1] for a complete presentation of these results).

and d are probed with W^- boson and quarks of types \bar{u} and \bar{d} in the case of W^+ boson exchange.

For NC cross sections, we also observe a difference with the lepton beam charges. This last observation is less trivial to explain. At large Q^2 , for $Q^2 > M_Z^2$, measured values of $e^- p \rightarrow e^- X$ (NC cross section) are greater than values for $e^+ p \rightarrow e^+ X$. And the effect is more and more sizable when increasing Q^2 . This effect of beam charge asymmetry for measurements of NC cross section at large Q^2 is resulting from the interference between interactions mediated by virtual photon and Z_0 boson. Indeed, at large Q^2 , both are contributing to the production of NC events with the same final state. Therefore they can interfere and the effect of this interference is producing the different values observed for $e^+ p$ and $e^- p$ values of NC cross section. We define the function $x\tilde{F}_3$ as follows

$$\frac{d^2\sigma_{NC}^-}{dx dQ^2} - \frac{d^2\sigma_{NC}^+}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4} [2x\tilde{F}_3], \quad (1)$$

with

$$x\tilde{F}_3 \simeq -a_e \frac{\kappa_w Q^2}{Q^2 + M_Z^2} xF_3^{\gamma Z}. \quad (2)$$

In this expression, $\kappa_w^{-1} = 4M_W^2/M_Z^2 (1 - M_W^2/M_Z^2)$. Parameters v_e and a_e are the vector and axial vector couplings of the lepton to the Z^0 boson. They are related to the weak isospin of the lepton. Namely, $v_e = -1/2 + 2\sin^2\theta_w$ and $a_e = -1/2$ where θ_w is the electroweak mixing angle.

Of course, measurements of NC cross section, illustrated in Fig. 1 in bins of Q^2 , can be done more differentially in Bjorken x and Q^2 . This is shown in Fig. 2 for large Q^2 , when the effect of $x\tilde{F}_3$ is sizeable [1, 2]. From the difference between e^-p and e^+p measurements, we can extract directly the function $x\tilde{F}_3$, using its definition in Eq. (1) (see Fig. 2). As discussed above, this is a direct measurement of the $\gamma - Z_0$ interference and its impact on NC cross section at the EW scale is observed. In this case, HERA is used as an interferometer at the EW scale. This is obviously a highly non trivial experimental issue. From Eq. (2), we can then compute directly the interference term, apart from EW propagators, $xF_3^{\gamma Z}$, which gives the magnitude of this interference. Results are presented in Fig. 3.

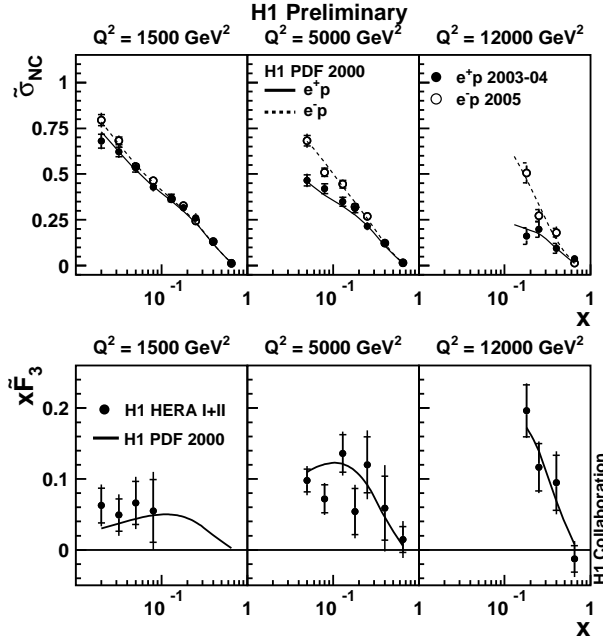


FIGURE 2. $x\tilde{F}_3$ extracted from measurements of NC DIS cross section at large Q^2 (see text).

DISCUSSION AND OUTLOOK

Finally, we can discuss the interest of this beam charge asymmetry at the EW scale in the context of parton densities. The main interest of $xF_3^{\gamma Z}$ comes from its expression in terms of quarks densities

$$xF_3^{\gamma Z} \simeq 2u_v + d_v \quad (3)$$

where u_v and d_v are the valence distributions for u and d quarks. In global fits of parton densities, valence type distributions are essentially constrained by fixed target

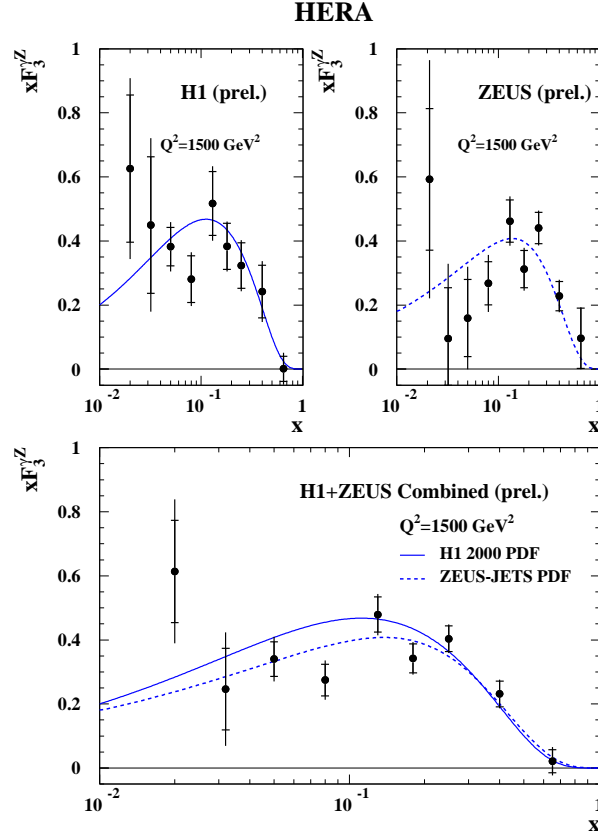


FIGURE 3. The interference term $x\tilde{F}_3^{\gamma Z}$ (see Eq. 2) extracted by H1 and ZEUS experiments, and the combined values.

experiments (BCDMS and NMC) in the kinematic domain $x < 0.2$ and $Q^2 < 150 \text{ GeV}^2$. With $x\tilde{F}_3$ measurements, we get the valence distribution $2u_v + d_v$ (and its dependence in x) at very large Q^2 , above the EW scale. This provides reference data points for valence distributions that complements their determination from fixed target experiments. The statistical uncertainty on $x\tilde{F}_3$ is still large (see Fig. 2). However, as displayed in Fig. 3, a combination of H1 and ZEUS results is of great interest in order to reduce errors. The present result is still preliminary, with only a part of the statistics on tape analysed [2]. Therefore, in a near future, we expect more accurate measurements of $x\tilde{F}_3$ and a greater impact on PDFs determination.

REFERENCES

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