INCLUSIVE DIS AT HIGH Q^2 AT HERA

S. Levonian[1]

[1] *DESY, Notkestraße 85, 22607 Hamburg, Germany*

Abstract

With recently published HERA II data both H1 and ZEUS collaborations completed their inclusive deep inelastic scattering (DIS) analyses. This report summarises main results of the cross sections measurements for inclusive neutral- (NC) and charged-current (CC) DIS reactions obtained using full HERA $e^{\pm}p$ samples of ~ 0.5 fb^{-1} per experiment, with the emphasis on high Q^2 regime.

1. Introduction

Deep inelastic scattering data from ep collider HERA provide unique information on the proton structure down to 10^{-18}m. At the same time these data represent a powerful laboratory to test the Standard Model both in electroweak and QCD sectors in a wide kinematic range of negative four-momentum transfer squared, Q^2, up to 50000 GeV^2 and Bjorken x down to 10^{-6}. Data of HERA I run (1992-2000) were used to measure unpolarised ep cross sections with the emphasis on low x and low and medium Q^2 regime where high precision of 1–2% was achieved, and corresponding HERAPDF 1.0 [1] has been extracted. High luminosity HERA II run (2003-2007) with 3-fold increase of e^+p and 10-fold increase of e^-p statistics allowed to improve precision of high Q^2 and high x domain, which is a topic for this

report. Together with access to $\sqrt{Q^2}$ comparable to the masses of the Z and W bosons, a longitudinal polarisation of lepton beam ($\pm 35\%$ in average) also gives an opportunity to probe the chiral structure of the electroweak interactions. In particular, the structure function $xF_3^{\gamma Z}$ is determined with improved statistical precision, and NC parity violating structure function $F_2^{\gamma Z}$ is extracted for the first time. Detailed description of the analyses and results presented below can be found in [2,3].

2. Results

At HERA II left handed (L) and right handed (R) polarised lepton beams yield polarised $e^{\pm}p$ cross sections. Still, unpolarised cross sections are also measured by merging L and R data sets and correcting remaining small polarisation using pQCD fits to obtain HERA II cross sections with $P_e = 0$. H1 combines then these new unpolarised NC and CC HERA II cross sections with previously published HERA I cross sections, taking into account correlated systematic uncertainties. A total of 854 data points are averaged to 413 cross section measurements. The data show good consistency with a total $\chi^2/\mathrm{ndf} = 412.1/441$. Finally, all H1 unpolarised cross sections undergo combined QCD analysis using HERAFitter framework [1,4] based on QCD evolution code QCDNUM, thus yielding new H1PDF 2012 parton density functions, as shown in Fig. 1. One can see, that the new high Q^2 data have a visible impact on all distributions, especially in the xD distribution (where $D = d + s$).

The polarised single differential cross sections $\mathrm{d}\sigma_{\mathrm{NC}}/\mathrm{d}Q^2$ are used to construct the asymmetry

$$A^{\pm} = \frac{2}{P_L^{\pm} - P_R^{\pm}} \cdot \frac{\sigma^{\pm}(P_L^{\pm}) - \sigma^{\pm}(P_R^{\pm})}{\sigma^{\pm}(P_L^{\pm}) + \sigma^{\pm}(P_R^{\pm})}$$

and compare it to pQCD expectation using the H1PDF 2012

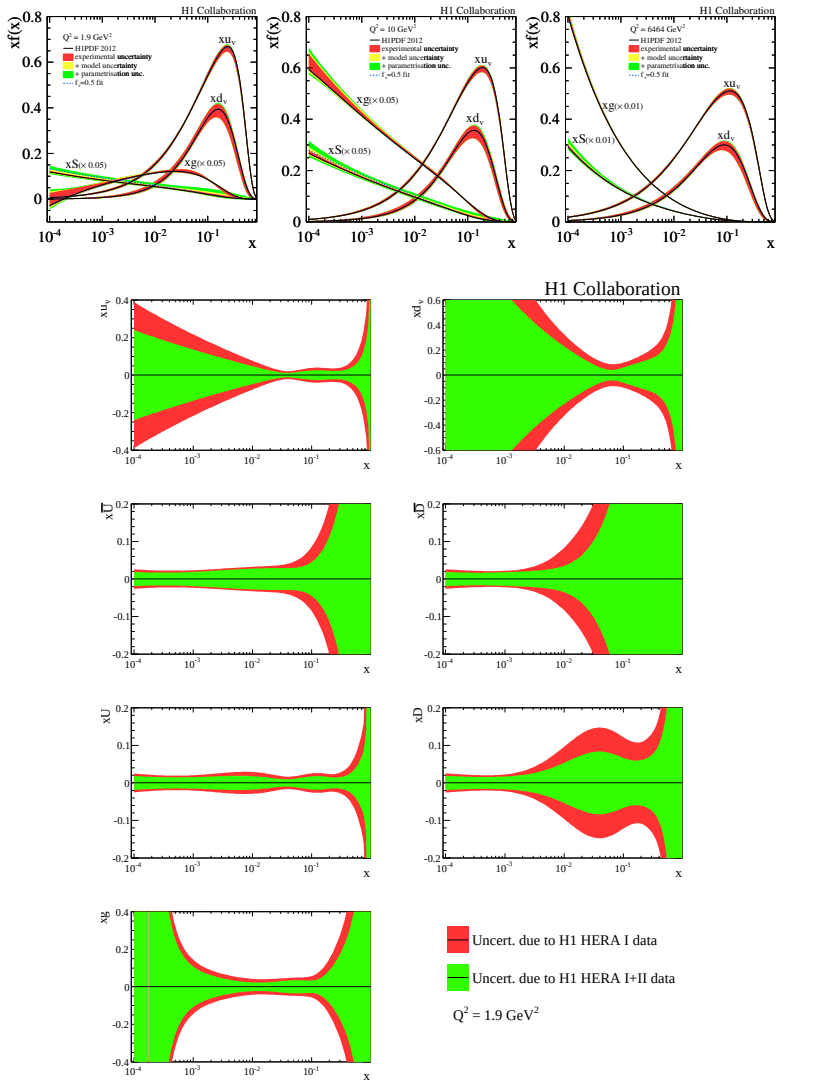

Fig. 1: H1PDF 2012. Top row: parton distribution functions at the starting scale $Q^2 = 1.9\,\mathrm{GeV}^2$ (left), at the evolved scale of $10\,\mathrm{GeV}^2$ (middle) and M_W^2 (right). Bottom part: comparison of relative experimental uncertainties of the PDFs extracted from HERA I (outer) vs HERA I+II (inner) data sets under the same fit conditions to assess the effect of the new high Q^2 measurements.

fit. The magnitude of the asymmetry is observed to increase with increasing Q^2 and is positive in e^+p and negative in e^-p scattering, thus confirming the parity violation effects of electroweak interactions at large Q^2 as predicted by the SM. Since for a given lepton charge the difference in the left and right polarised NC cross sections is sensitive to $F_2^{\gamma Z}$ as well as $xF_3^{\gamma Z}$ and xF_3^Z, it is possible to extract directly parity violating structure function $F_2^{\gamma Z}$ by taking proper differences for e^+p and e^-p data, for which $xF_3^{\gamma Z}$ and xF_3^Z terms cancel. Such measurement is performed double differentially in x and $Q^2 \geq 200$ GeV^2. To improve statistical significance the measurements are transformed to a common Q^2 value of 1500 GeV^2 and are averaged in each x bin (see Fig. 2). In turn, γZ interference term $xF_3^{\gamma Z}$ is the dominant contribution to xF_3 and is determined from new combined HERA I+II NC *unpolarised* cross sections by neglecting pure Z boson exchange term. The measurement is transformed to $Q^2 = 1500$ GeV^2 and then averaged for fixed x values. The averaged $xF_3^{\gamma Z}$ is shown in Fig. 2. Both $F_2^{\gamma Z}$ and $xF_3^{\gamma Z}$ structure functions are well described by the H1PDF 2012 fit. While the $F_2^{\gamma Z} \propto (q + \bar{q})$ reflects total parton composition in the proton, the $xF_3^{\gamma Z}$ constrains valence distribution $(2u_v + d_v)$.

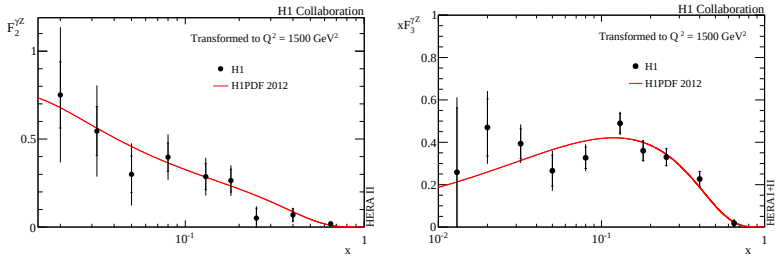

Fig. 2: Structure functions $F_2^{\gamma Z}$ (left) and $xF_3^{\gamma Z}$ (right) transformed to $Q^2 = 1\,500\,\text{GeV}^2$ for data (solid points) and the expectation from H1PDF 2012 (solid curve). The inner error bars represent the statistical uncertainties and the full error bar corresponds to the total measurement uncertainty.

The Q^2 dependence of NC and CC cross sections for $P_e = 0$ is shown in Fig. 3(left). A typical precision of these measurements are $\sim 1.5\%$ (NC) and $\sim 4\%$ (CC). The NC cross sections exceed the CC cross sections at $Q^2 \simeq 200$ GeV^2 by more than two orders of magnitude. The steep decrease of the NC cross section with increasing Q^2 is due to the dominating photon exchange cross section which is proportional to $1/Q^4$. In contrast the CC cross section is proportional to $\left[M_W^2/(Q^2+M_W^2)\right]^2$ and approaches a constant value at $Q^2 \simeq 300$ GeV^2. The NC and CC cross sections are of comparable size at $Q^2 \sim 10^4$ GeV^2, thus illustrating the unified behaviour of the electromagnetic and the weak interactions in DIS.

The total CC cross sections for $Q^2 > 400\,\mathrm{GeV}^2$ and $y < 0.9$ for the different longitudinal lepton beam polarisations are shown in Fig. 3(right) and compared to the SM expectations using the HERAPDF 1.5 parametrisation [5]. They agree within one standard deviation. For H1 data a linear fit to the polarisation dependence of the measured cross sections is performed

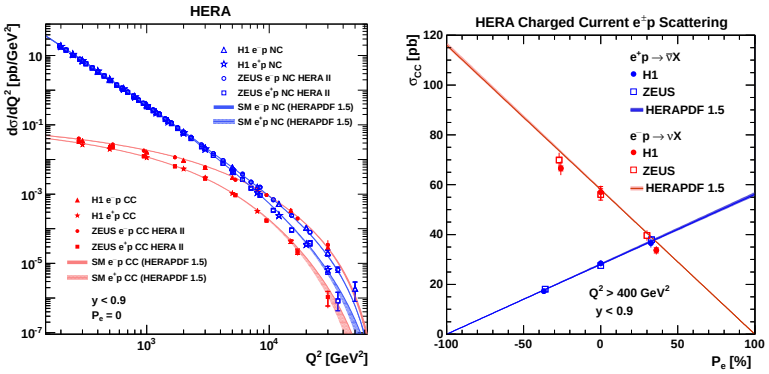

Fig. 3: Left: Q^2 dependence of the NC and CC cross sections $d\sigma/dQ^2$ for the combined HERA I+II (H1) and HERA II (ZEUS) unpolarised e^-p and e^+p data. Right: Dependence of the $e^\pm p$ CC cross sections on the longitudinal lepton beam polarisation P_e. The inner and outer error bars represent the statistical and total errors, respectively. The data are compared to the Standard Model expectation based on the HERAPDF 1.5 set [5].

taking into account the correlated systematic uncertainties between the measurements. The fit extrapolated to the point $P_e = +1$ for $e^- p$ and $P_e = -1$ for $e^+ p$ results in vanishing cross sections. This result excludes the existence of charged currents involving right handed fermions mediated by a boson of mass M_W^R below 214 and 194 GeV at 95% CL for $e^- p$ and $e^+ p$ scattering respectively, assuming SM couplings and a light ν_e^R.

3. Conclusions

With addition of HERA II data, the inclusive DIS cross sections for $e^\pm p$ interactions at $\sqrt{s} = 319\,\text{GeV}$ are now measured in the range of $0.045 \leq Q^2 \leq 50000\ \text{GeV}^2$ and $6 \cdot 10^{-7} \leq x \leq 0.65$, spanning six orders of magnitude in (x, Q^2) plane. These data allowed to extract proton PDFs with improved accuracy, especially at high x.

The NC lepton polarisation asymmetry $A^\pm$, sensitive to parity violation, is determined, and the structure function $F_2^{\gamma Z}$ is measured for the first time. At high Q^2 the structure function $xF_3^{\gamma Z}$ is determined using unpolarised NC cross sections. All these measurements are in excellent agreement with the SM predictions. A linear scaling of the polarisation dependence of the CC total cross section is observed in accordance with the SM. The data are consistent with the absence of right handed weak currents.

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