QCD AND EW ANALYSIS OF THE ZEUS NC/CC INCLUSIVE AND JET CROSS SECTONS

SHIMA SHIMIZU
ON BEHALF OF THE ZEUS COLLABORATION

University of Tokyo
E-mail: shima@mail.desy.de

The large kinematic coverage of HERA gives high sensitivity to EW parameters besides the proton PDFs. The precisely measured HERA-II data with polarized electrons increase the sensitivity. In this contribution, a combined analysis of QCD and EW parameters, which exploits fully the potential of HERA, is presented.

1. Introduction

The *ep* collider HERA has played a crucial role in the determination of the Parton Distribution Functions (PDFs) of the proton. The PDFs are essential to understand any physics process involving protons. The ZEUS experiment performed precise measurements of neutral- (NC) and charged-current (CC) Deep Inelastic Scattering (DIS) cross sections and jet cross sections using data collected in the years 1994-2000 (HERA-I). The PDFs were successfully extracted from these ZEUS data only [1].

Following the luminosity upgrade, HERA provides longitudinally polarized lepton beams (HERA-II). ZEUS has measured NC and CC inclusive double differential cross sections with polarized electrons [2]. Increased luminosity with polarized leptons brings not only improved determination of the PDFs but also improved sensitivity to electroweak (EW) parameters. In this paper, the first results from a combined QCD and EW analysis on HERA-II cross sections are presented.

2. DIS cross sections and QCD analysis

The kinematics of lepton-proton DIS are described by x, the Bjorken scaling variable, Q^2, the negative square of the invariant mass of the virtual exchanged boson, and y, the fractional energy transfer from the lepton to the hadron system.

The NC interaction, $ep \to eX$, proceeds by exchange of a γ^* or Z^0. The double differential NC DIS cross sections with lepton polarization P are given in terms of structure functions by

$$\frac{d^2\sigma^{NC}(e^\pm p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}[H_0^\pm \mp PH_P^\pm], \quad H_{0,P}^\pm = Y_+F_2^{0,P} - y^2F_L^{0,P} \mp Y_- xF_3^{0,P}, \tag{1}$$

where $Y_\pm = 1 \pm (1-y)^2$. F_2 and xF_3 directly reflect the quark distributions,

$$F_2^{0,P} = \sum_i A_i^{0,P}[xq_i + x\bar{q}_i], \quad xF_3^{0,P} = \sum_i B_i^{0,P}[xq_i - x\bar{q}_i], \tag{2}$$

where $A_i^{0,P}$ and $B_i^{0,P}$ contain quark and lepton couplings to virtual bosons.

The double differential cross sections for CC DIS, $ep \to \nu X$, which proceeds by exchange of $W^\pm$, are given by

$$\frac{d^2\sigma^{CC}(e^\pm p)}{dxdQ^2} = (1 \pm P)\frac{G_F^2}{4\pi x}\frac{M_W^4}{(Q^2 + M_W^2)^2}[Y_+F_2^{CC} - y^2F_L^{CC} \mp Y_- xF_3^{CC}]. \tag{3}$$

Due to its charge-selecting nature, CC DIS is sensitive to the flavour of quarks. The e^-p and e^+p cross sections give information of u- and d-quark PDFs, respectively.

A combined QCD and EW analysis was performed in the framework of the ZEUS-JETS fit [1]. The PDFs are parameterized, at $Q_0^2 = 7\text{GeV}^2$, by the form $xf(x) = p_1 x^{p_2}(1-x)^{p_3}(1+p_4 x)$, and in total 11 free parameters describe the PDFs. They are evolved by the DGLAP equation at NLO in the $\overline{MS}$ scheme. Heavy quarks are treated in the general-mass variable flavour-number scheme of Throne and Roberts [3]. The correlated experimental uncertainties are evaluated using the OFFSET method [4].

3. Results

3.1. *QCD only analysis; ZEUS-pol fit*

First the data are analyzed with fixed EW parameters to investigate the impact of HERA-II data on the PDF determination. The new polarized DIS cross sections are well described by the fit. The central values of the PDFs are almost unchanged by the addition of the HERA-II data. However, the uncertainties are reduced, especially for u-valence PDF in the high-x region, for example, there is a $\sim 25\%$ reduction at $x = 0.8$ and $Q^2 = 10$ GeV. This is due to the increase of statistics of electron data in the high-Q^2 region.

3.2. *Combined analysis of QCD and EW parameters*

The stability of the extraction of the PDFs allows the determination of both the PDFs and EW parameters simultaneously. The advantage of this combined analysis of QCD and EW parameters is that the correlations between them are taken into account automatically in the fit.

Since DIS is a space-like process, the CC cross sections give information on the propagator mass. A fit in which M_W, the general coupling g (= $G_F M_W^2$ in SM) and the PDF parameters are free gives[a],

$$M_W = 82.8 \pm 1.5 \pm 1.3 \text{ GeV}, \quad g = 7.72 \pm 0.21 \pm 0.19 \ \times 10^{-2}. \tag{4}$$

If we assume the universality of the CC interaction, G_F can be fixed to the world average value (as precisely measured by muon decay experiments). In this case, M_W is extracted as $M_W = 79.1 \pm 0.77 \pm 0.99$ GeV. One should note that in the SM formalism the value of M_W also contributes to the normalization of cross sections since G_F is fixed (see Eq. 3). All extracted values are in good agreement with Standard Model (SM).

The NC cross sections in HERA-II reduce the statistical uncertainties on xF_3 and introduce terms related to lepton polarization into F_2 and xF_3. Thus the analysis has increased sensitivity to the quark couplings to Z^0, which appear in the coefficients $A_i^{0,P}$ and $B_i^{0,P}$ of Eq 2. Further details are given elsewhere [5]. The axial (a_q) and vector (v_q) couplings are dominant in unpolarized xF_3 and polarized F_2, respectively. Figure 1 shows results from the determinations of a_q and v_q for u- and d- type quarks. The two parameters are fitted simultaneously with the PDF parameters. Comparing with the results of similar determinations from other experiments [6-8], the present analysis gives the best determination of a_q and v_q using light quarks.

The fit described above determines a_q and v_q with as little model dependence as possible. However, in the SM formalism, the couplings are related to weak isospin [6],

$$a_q = T^3_{q,L} + T^3_{q,R}, \quad v_q = T^3_{q,L} - T^3_{q,R} - 2e_q \sin^2\theta_W, \tag{5}$$

where $T_{q,L}$ and $T_{q,R} = 0$ are left and right handed components of weak isospin, respectivelly. A fit is made to extract SM parameters (note that $\sin^2\theta_W$ also enters the Z^0 propagator). The values determined are;

$$\begin{aligned} &T^3_{u,L} = 0.47 \pm 0.05 \pm 0.13, \qquad T^3_{d,L} = -0.55 \pm 0.18 \pm 0.35, \\ &\sin^2\theta_W = 0.231 \pm 0.024 \pm 0.070, \end{aligned} \tag{6}$$

[a] The first and second uncertainties are [statistical and uncorrelated systematic errors added in quadrature] and [correlated systematic error], respectively.

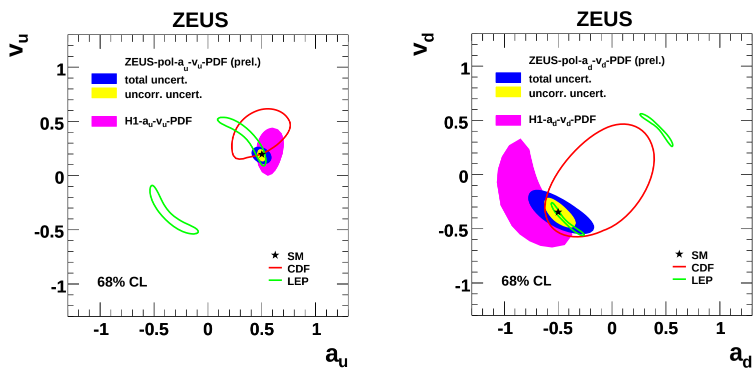

Figure 1. The extracted general quark couplings to Z^0 (left: u-, right: d-type).

which are in good agreement with SM values. Furthermore, another fit can be done to access deviations from SM more directly, by freeing $T_{q,R}$ to be determined, with $T^3_{q,L}$ fixed to SM values.

$$\begin{aligned} &T^3_{u,R} = -0.07 \pm 0.07 \pm 0.07, \qquad T^3_{d,R} = -0.26 \pm 0.19 \pm 0.19, \\ &\sin^2\theta_W = 0.238 \pm 0.011 \pm 0.023. \end{aligned} \tag{7}$$

The value of $\sin^2\theta_W$ is also freed to allow right handed contributions in the propagator term of Z^0 bosons. The fit shows no deviation from SM.

4. Summary

A combined analysis of QCD and EW parameters is performed on the ZEUS data. The new HERA-II data, which have large luminosity with polarized electrons, bring not only improved determination of the PDFs but also an excellent extraction of the EW parameters.

References

1. ZEUS Coll., S. Chekanov et al., *Eur. Phys. J.* **C42**, 1 (2005).
2. Contributions to this Conference. Given by U. Noor and H. Kaji.
3. R.G. Roberts and R.S. Thorne, *Phys. Rev.* **D57**, 6871 (1998).
4. ZEUS coll., S. Chekanov et al., *Phys. Rev.* **D67**, 012007 (2003).
5. J. Blümlein, M. Klein and T.Riemann, *Proceedings of the HERA Workshop*, 687 (1987).
6. H1 Coll., A. Aktas et al., *Phys. Lett.* **B632**, 35 (2006).
7. CDF Coll., D. Acosta et al., *Phys. Rev.* **D71**, 052002 (2005).
8. The LEP Electroweak Working Group, the SLD Electroweak and Heavy Flavour Groups, *Phys. Rep.* **427**, 257 (2006).