CHARGED CURRENT CROSS SECTIONS WITH POLARISED LEPTON BEAMS AT ZEUS

H. KAJI*
KEK,
1-1 Oho,
Tsukuba Ibaraki, Japan
E-mail: kajihiro@post.kek.jp

We measured the polarised CC DIS cross section by using the ZEUS detector at HERA. The cross section dependence on polarisation was well explained as the left-handed nature of the weak interaction. The right-handed cross section was extrapolated to be $\sigma^{e^-p}_{RHCC} = 0.8 \pm 3.1(\text{stat.}) \pm 5.0(\text{sys.})$ pb (prel.) and was consistent with zero as the Standard Model predicts. The cross sections were also measured in double differentially, which will bring better understanding of PDFs in the proton.

1. Introduction

Deep inelastic scattering (DIS) can be studied in the large negative four-momentum-transfer-squared, Q^2, region at the HERA collider. In this region, the charged current (CC) reaction, which is mediated by the charged $W^{\pm}$ boson, can be measured. The ZEUS collaboration have reported measurements of unpolarised cross sections using the data collected in the years 1994-2000 (HERA-I), which amounts about 100 (20) pb^{-1} for e^+p (e^-p) collision.

Since 2002, the second phase of HERA operation (HERA-II) has started to provide higher luminosity and lognitudinally polarised $e^{\pm}$ beams to the collider experiments. The polarisation of the $e^{\pm}$ beam, P, is defined as $(N_R - N_L)/(N_R + N_L)$, where N_R and N_L are the number of the right-handed and left-handed $e^{\pm}$ in the beam, respectively. Since the weak interaction is purely left-handed, cross section varies linearly as a function of P. Therefore, CC measurement with polarization give a direct approach to the right-handed weak interaction.

*on behalf of ZEUS collaboration

This paper presents the measurements of the cross sections for CC DIS using logitudinally polarised $e^{\pm}$ beams and unpolarised protons. The e^+p CC cross sections were measured[3] based on the data taken during year 2003-04, corresponding to 12.3 (11.5) pb^{-1} of luminosity at luminosity-weighted mean polarisation of $\mathsf{P} = +0.32$ (-0.41). The e^-p cross sections were measured with the latest data collected in year 2005. The luminosity of 42.7 (78.8) pb^{-1} at $\mathsf{P} = +0.329$ (-0.268) were used in this measurement.

2. CC DIS cross section

The kinematics of inclusive DIS can be defined by the three variables; Q^2, Bjorken x, and the inelasticity, y. They are related by $Q^2 = s \cdot x \cdot y$, where s is the square of the centre-of-mass energy (neglecting the masses of the incoming particles). The cross section is, therefore, described by a pair of these three variables. The cross sections for unpolarised e^+p and e^-p collisions can be written as follows:

$$\sigma^{e^+p}_{unpolCC}(Q^2,x) = \frac{G_F}{2\pi}\cdot(\frac{M_W^2}{Q^2+M_W^2})^2\cdot\sum_i[\bar{u}_i(Q^2,x)+(1-y)^2 d_i(Q^2,x)], \quad (1)$$

$$\sigma^{e^-p}_{unpolCC}(Q^2,x) = \frac{G_F}{2\pi}\cdot(\frac{M_W^2}{Q^2+M_W^2})^2\cdot\sum_i[u_i(Q^2,x)+(1-y)^2 \bar{d}_i(Q^2,x)], \quad (2)$$

where u_i and d_i denote probability distribution function (PDF) of the u-type and d-type quarks and $\bar{u}_i$ and $\bar{d}_i$ denote densities of their anti-quarks. Sum runs over every generation. Therefore, measurement of e^+p (e^-p) cross section is directly sensitive to the d-quark (u-quark) density in the proton.

The polarised cross section can be written in the Standard Model (SM) as follows:

$$\sigma^{e^{\pm}p}_{polCC}(Q^2,x) = \frac{(1 \pm \mathsf{P})}{2} \cdot \sigma^{e^{\pm}p}_{LHCC}(Q^2,x) \quad (3)$$

where σ_{LHCC} denotes left-handed component of CC DIS cross section which is related to the unpolarised one as $\sigma_{LHCC} = 2 \cdot \sigma_{unpolCC}$. If cross section is non zero at $\mathsf{P} = -1$ $(+1)$ for e^+p (e^-p) collision, it indicates evidence of right-handed component, σ_{RHCC}, which does not exist in the SM.

3. Results

Figure 1 shows the single differential cross section for e^-p scattering as functions of Q^2, x, and y. The cross sections have been measured at both

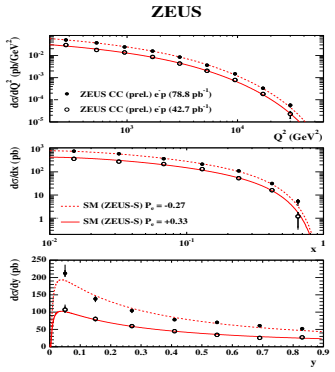

Figure 1. The e^-p single differential cross section in Q^2 (upper plot), x (middle plot), y (lower plot).

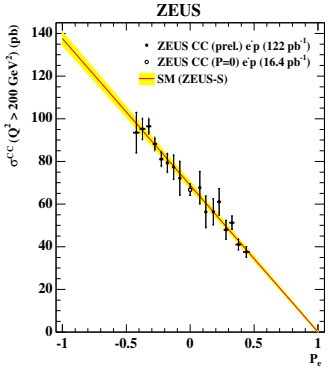

Figure 2. The e^-p total CC cross section ($Q^2 > 200\text{GeV}^2$) measred at many polarisation values

positive and negative polarisation values, separately. The lines in each plot show the polarised cross sections predicted by the SM. The cross section are shown to be in overall different between two measurements at positive and negative polarisation for each of kinematic variables and is consistent with the SM. The cross sections measured as a function of P, are shown in Figure 2. A linear relation between cross section and polarisation is clearly shown. Behavior of the cross section change can be well explained as the left-handed nature of the weak interaction.

The cross sections at $Q^2 > 200$ GeV^2 of both e^+p and e^-p scattering are shown in Figure 3. For e^-p scattering, the measured cross sections are:

$$\sigma^{e^-p}_{polCC}(\mathsf{P} = -0.268) = 87.4 \pm 1.3(\text{stat.}) \, ^{+2.6}_{-2.5}(\text{sys.}) \text{ pb (prel.)},$$

$$\sigma^{e^-p}_{polCC}(\mathsf{P} = +0.329) = 46.7 \pm 1.3(\text{stat.}) \, ^{+1.5}_{-1.3}(\text{sys.}) \text{ pb (prel.)}.$$

By exptrapolating preliminary polarised and HERA-I unpolarised e^-p results to $\mathsf{P} = +1$, the right-handed component of the CC DIS cross section is extrapolated to be

$$\sigma^{e^-p}_{RHCC} = 0.8 \pm 3.1(\text{stat.}) \pm 5.0(\text{sys.}) \text{ pb} \quad \text{(prel.)}.$$

The result is consistent with zero as the SM predicts. Therefore, upper limit of $\sigma^{e^-p}_{RHCC} < 10.6$ pb is set at 95 % C.L. This corresponds to limit of $M_{W_R} > 180$ GeV for mass of right-handed W boson.

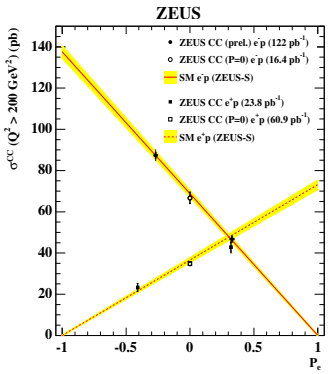

Figure 3. Total cross section

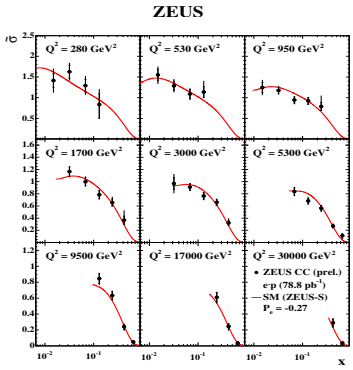

Figure 4. Double differential cross section

Taking advantage of the large luminosity of e^-p at HERA-II, cross sections were measured double differentially in Q^2 and x. Figure 4 shows these double differential cross sections in the "reduced" way defined as:

$$\tilde{\sigma} = \frac{2\pi x}{G_F^2} \cdot \frac{d^2\sigma^{e^-p}}{dQ^2 dx} = x[u_i(Q^2, x) + (1-y)^2 \bar{d}_i(Q^2, x)] \qquad (4)$$

The cross sections are measured precisely, and the covered kinematic region is extended to higher Q^2 and x regions. The result will bring better understanding of PDFs in the proton.

4. Summary

We measured CC DIS cross section of polarised $e^\pm$ and unpolarised proton scattering. The e^-p result has been updated with integrated luminosity of 122 pb^{-1}. CC DIS cross section at $P = +1$ was exptrapolated to be $\sigma^{e^-p} = 0.8 \pm 3.1(\text{stat.}) \pm 5.0(\text{sys.})$ from this result and consistent with zero as the SM predicts. The reduced cross sections which were newly measured in this time will bring better understanding of PDFs in the proton.

References

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3. ZEUS Coll., S.Chekanov et al., Phys. Lett. B 637, 210 (2006).