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NEUTRAL AND CHARGED CURRENTS AT HIGH Q^2 IN COLLISIONS OF LONGITUDINALLY POLARIZED POSITRONS WITH PROTONS AT HERA II

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The First measurement of the total cross section for charged current deep inelastic scattering in e^+p collisions with a longitudinally polarized positron beam is presented and compared with the Standard Model prediction.

1 Introduction

Measurement of deep inelastic scattering (DIS) of leptons on nuclei has been a valuable method in understanding the structure of nucleons. Two kinds of DIS can be measured at HERA, neutral current DIS (NC: $e^{+(-)}p \rightarrow e^{+(-)}X$) and charged current DIS (CC: $e^{+(-)}p \rightarrow \overline{\nu_e}(\nu_e)X$). A total integrated luminosity of about 100 pb^{-1}(15 pb^{-1}) was collected with unpolarized positron (electron) beam from 1994 until 2000 (HERA I). NC and CC DIS cross sections with unpolarized positron (electron) beam have been measured [1–9].
The HERA accelerator was upgraded in 2001-2002 to provide high luminosity and longitudinal polarized lepton for the collider experiments. HERA II e^+p collisions with a longitudinally polarized positron beam started in 2003. By measuring the CC DIS cross sections, a test of the Standard Model in the weak sector is possible through its dependence on the lepton polarization.
In CC DIS, a W boson is exchanged between the positron and proton. Only right-handed positrons (or left-handed electrons) contribute to the reaction since only the left-handed charged current exists in the Standard Model. The total cross section for e^+p CC DIS as a function of the positron beam polarization (P) is written as:

$$\sigma^{CC}(P) = (1+P)\,\sigma^{CC}_{unpol.}\ , \tag{1}$$

where $\sigma^{CC}_{unpol.}$ is the CC DIS cross section for an unpolarized positron beam. The longitudinal polarization of the positron beam is defined as $P = \frac{N_R - N_L}{N_R + N_L}$, where N_R and N_L are the numbers of right and left-handed positrons in the positron beam. Measurements of the dependence of the CC DIS cross-section on the longitudinal polarization of the lepton beam therefore lead to a test of the Standard Model and a search for new physics beyond the Standard Model, such as right-handed charged currents. In this paper, the first measurement of the total CC DIS cross section in e^+p collisions with a longitudinally polarized positron beam is presented.

2 Kinematic reconstruction and event selection

Data corresponding to an integrated luminosity of 6.6 pb^{-1}, which was taken from 2003 fall with polarized positrons, were analyzed. The luminosity-weighted average polarization of the positron beam was $+(33 \pm 2)$ %. CC DIS kinematic variables can be reconstructed by using only the information of the hadronic system (the Jacquet-Blondel method). The quality of the reconstruction was checked using a NC DIS sample. The NC DIS kinematic variables were reconstructed by the double-angle method, in which the polar angles of both the scattered positron and the hadronic system were used.
NC events were selected by finding a positron with requiring energy $E_e > 10$ GeV and the presence of a track that matched to the positron position in the calorimeter. About 15000 NC events were observed for $Q^2 > 200$ GeV^2. Fig.1 shows distributions of the kinematic variables in the NC events. Reconstruction of the hadronic system is seen to be good in the distribution of the transverse momentum, $P_{T,h}$, and the polar angle of the hadronic system, γ_h. Also the luminosity normalization was satisfactory for the study of CC DIS events.
In the CC analysis, events were first classified into high-γ ($\gamma > 23°$) and low-γ ($\gamma < 23°$) events. Missing transverse momentum, $\not{P}_T$ due to the escaping neutrino is a key in the CC DIS selection. For high-γ events, $\not{P}_T > 12$ GeV was required. For low-γ events, a tighter requirement of $\not{P}_T > 14$ GeV was made to suppress beam-gas background, since the information from the central tracking detector can't be used. The z coordinate of the event vertex was required to be $|Z_{VTX}| < 50\ cm$ for high-γ events and was set to $Z_{VTX} = 0$ for low-γ events. To reject photoproduction (γp), $\not{P}_T/E_T > 0.4$ (0.55) was required for high-γ events with $20 < \not{P}_T < 30$ GeV ($\not{P}_T < 30$ GeV). Non-ep backgrounds such as cosmic and halo-muon events were rejected by pattern recognition using calorimeter information. CC DIS events were measured in the region $Q^2 > 400$ GeV^2. Fig.2 shows a comparison between data and expectation from CC DIS Monte Carlo (MC) simulation reweighted with $P = +33\%$. The MC describes the data well.

3 Results

The Born-level CC DIS cross section at polarization, P was determined as follows:

$$\sigma^{CC}_{Born}(P) = \frac{N^{CC}_{data}}{N^{unpol.}_{MC}}\ \sigma^{unpol.CC}_{Born(SM)}\ , \tag{2}$$

where N^{CC}_{data} denotes the number of CC DIS events measured, $N^{unpol.}_{MC}$ and $\sigma^{unpol.CC}_{Born(SM)}$ are the numbers of CC DIS events expected from MC and the Standard

Model CC DIS cross section prediction at $P = 0$. The level of background was estimated to be negligible. The largest source of systematic uncertainty came from the variation of the selection thresholds. The uncertainty was estimated by shifting all cut thresholds by 10 %, which is a reasonable match with the resolution. The largest uncertainty was due to shifting the threshold of the photoproduction background rejection. The total CC DIS cross section in the kinematic region $Q^2 > 400$ GeV^2 for positrons with a longitudinal polarization of +33 %, was measured to be:

$$\sigma_{CCtot}^{Q^2>400\mathrm{GeV}^2} = 38.1 \pm 2.9(stat.) \pm 0.8(syst.) \pm 2.0(lumi.) \pm 0.8(pol.)\ \mathrm{pb}\ , \quad (3)$$

Fig.3 shows the total cross section for CC DIS as a function of the longitudinal polarization of the positron beam. The uncertainty of polarization measurement was included in the horizontal error bar. The measured total cross section is 2.8 standard deviations above the HERA I result [8] with an unpolarized positron beam and consistent with the Standard Model prediction of a linear rise with polarization, clearly showing the left-handed nature of the charged current interaction.

4 Conclusion

The total cross section for charged current deep inelastic scattering in e^+p with longitudinally polarized positrons from data of integrated luminosity 6.6 pb^{-1} was presented. The ZEUS result was in good agreement and was described by the prediction of the Standard Model with the pure left-handed nature of charged current interaction. Collisions with e^+p using left-handed polarized positron beams started from April of 2004. The CC DIS cross section for oppositely polarized beams will be measured and a more precise test of the Standard Model will be performed.

References

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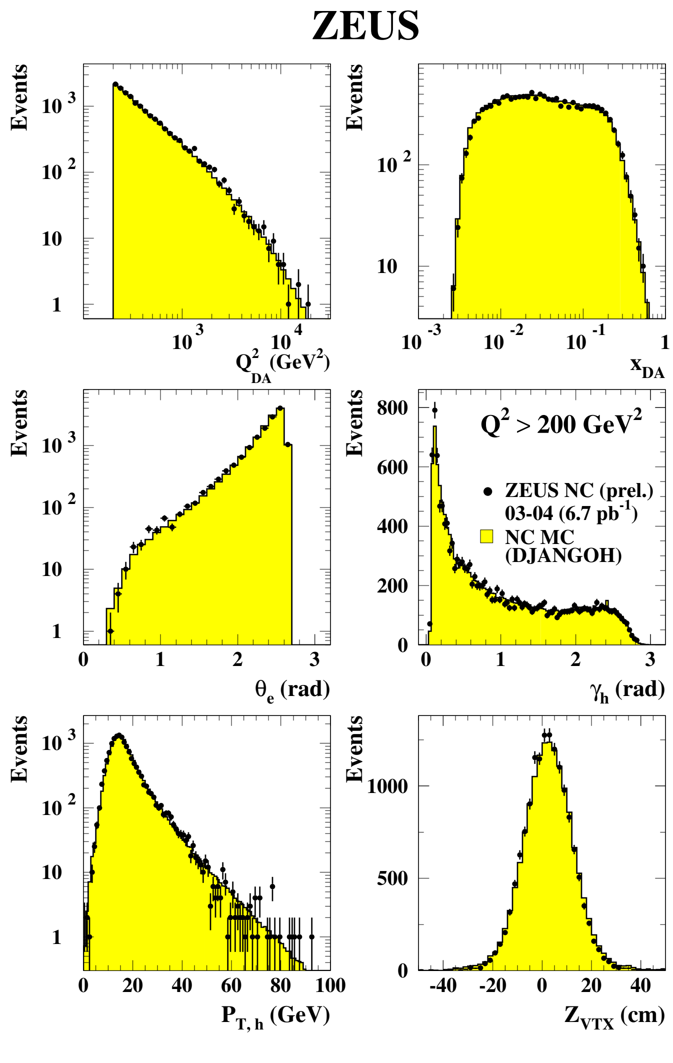

Figure 1. Various distributions for NC events; the reconstructed variables Q^2 and x from the double-angle method (Q^2_{DA} (top left) and x_{DA} (top right)), the polar angles of the scattered positron θ_e (middle left) and the hadronic system γ_h (middle right), the transverse momentum of the hadronic system $P_{T,h}$ (bottom left) and Z coordinate of the event vertex Z_{VTX}(bottom right). The closed circles and the solid histograms denote the data and the NC MC, respectively.

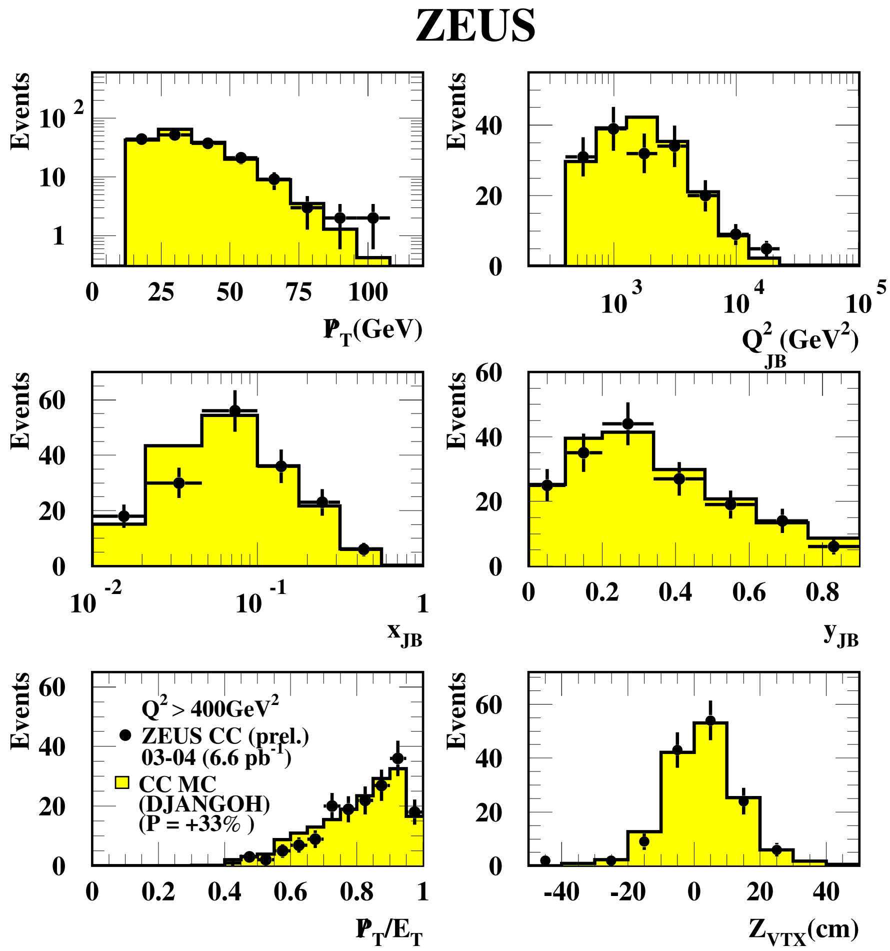

Figure 2. Various distributions for CC events; the missing transverse momentum $\not{P}_T$(top left), the reconstructed variables from the Jacquet-Blondel method (Q^2_{JB} (top right), x_{JB}(middle left) and y_{JB}(middle right)), the ratio $\not{P}_T/E_T$ and the Z coordinate of the event vertex (Z_{VTX}). Closed circles are the data and histograms are MC expectation at $P = +33$ %.

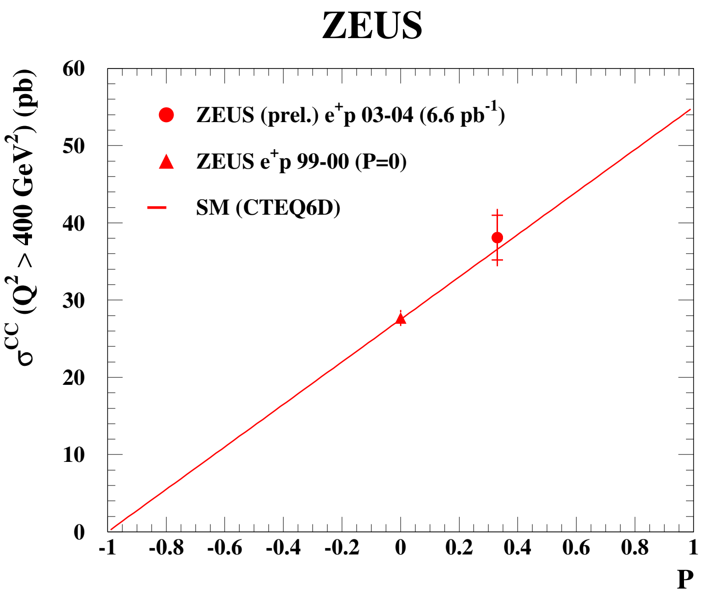

Figure 3. The total cross section for e^+p CC DIS at $Q^2 > 400$ GeV^2 as a function of the longitudinal polarization of the positron beam. The line shows the Standard Model prediction with the CTEQ6D PDFs. The closed triangle and closed circle denote the ZEUS results with unpolarized positron beam [8] and the ZEUS results with longitudinal positron beam with $P = +33$ %, respectively.