DIS Charm Cross-Sections through D^* and D Meson Tagging by the ZEUS Detector

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We summarize the results from the ZEUS experiment on D meson production in deep inelastic scattering using HERA I data and preliminary results on $D^{*\pm}$ production using HERA II data. Single differential cross sections have been measured as a function of Q^2, x, and the transverse momentum and pseudorapidity of the D meson. These measurements are compared to the prediction of next-to-leading-order QCD. Furthermore, the open charm contribution, $F_2^{c\bar{c}}$, to the proton structure function, F_2, has been extracted from the data.

1 Introduction

Charm quarks are copiously produced in deep inelastic scattering (DIS) at HERA. At sufficiently high photon virtualities, Q^2, the production of charm quarks constitutes up to 30% of the total cross section[2, 3]. The charm quark production in DIS at HERA is dominated by the interaction between the exchanged virtual photon and a gluon within the proton, the boson-gluon-fusion (BGF) mechanism. Thus, the charm cross section is directly sensitive to the gluon density in the proton.

The presented analyses were performed with data taken from 1998-2000 and 2003-2005. In these periods, HERA collided electrons or positrons with energy $E_e = 27.5$ GeV with protons of energy $E_p = 920$ GeV. The ZEUS detector is described in detail elsewhere [4]. The main components used in the presented analyzes were the compensating uranium-scintillator calorimeter, the central tracking detector and for the HERA II measurement the micro-vertex detector. The calorimeter is the major component for the reconstruction of the DIS kinematic variables.

2 D^* Cross Section Measurement using HERA II Data

HERA II data collected from 2003 to 2005 were used to measure the D^* cross section in DIS. It corresponds to an integrated luminosity of 162 pb^{-1}. The event selection of this measurement is directly comparable to previous measurements [5].

Events were required to have a reconstructed vertex within 30 cm of the nominal interaction point in z. The quantity $\delta = E - p_z = \sum_i E_i(1 - \cos\theta_i)$ was calculated using the energies, E_i, and polar angles, θ_i, and had to satisfy $30 < \delta < 60$ GeV to eliminate photoproduction events or DIS events with high-energy initial-state radiation. The photon virtuality, Q^2 and the fraction of the energy transferred to the proton in its restframe, y, were reconstructed from the energy and the angle of the scattered electron (Q^2_e,y_e) and from the hadronic system using the Jaquet-Blondel method (Q^2_{JB},y_{JB}). The kinematic region chosen for the measurement was $5 < Q^2 < 1000$ GeV^2 and $0.02 < y < 0.7$.

The selection of D^* mesons also followed the strategy used in the previous measurements [5].The D^* mesons were identified using the decay channel $D^{*+} \to D^0\pi^+$ with the subsequent decay $D^0 \to K^-\pi^+$ and the corresponding antiparticle decay. The kinematic region for the D^* candidates was $1.5 < p_T(D^*) < 15$ GeV and $|\eta(D^*)| < 1.5$. Details on the candidate reconstruction and the determination of acceptance and uncertainties can be found in a previous publication [6]. The single differential cross sections were measured as a function of Q^2, the Bjorken scaling variable, x, and the pseudorapidity and the transverse momentum of the D^* meson. The cross sections were compared to next-to-leading order (NLO) predictions from the HVQDIS program [7] using the ZEUS NLO QCD fit [8] for $m_c = 1.35$ GeV as the input parton density in the proton. As can be seen in Figure 1, the cross section $\frac{d\sigma}{dx}$ falls by about three orders of magnitude while it is still well described by the NLO calculation.

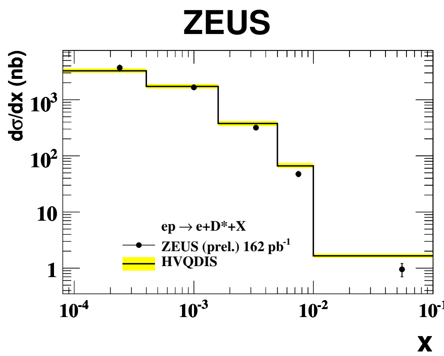

Figure 1: Differential D^* cross section as a function of the Bjorken scaling variable x. The solid points show the HERA II data while the solid line gives the NLO QCD prediction.

3 HERA I Charm Cross Section Measurements

Besides the HERA I D^* measurement [5], additional charm cross section measurements [9] were performed using an integrated luminosity of 82 pb^{-1}. Charm was tagged by reconstructing D^0, $D^\pm$ and $D_s^\pm$ charm mesons using the decay modes $D^0 \to K^-\pi+$, $D^+ \to K^-\pi^+\pi^+$, and $D_s^+ \to \phi\pi^+ \to K^+K^-\pi^+$ and their charge conjugates. The DIS kinematic region was defined by $1.5 < Q^2 < 1000$ GeV^2 and $0.02 < y < 0.7$ and charm mesons with $|\eta(D)| < 1.6$ and $p_T(D^0, D^\pm) > 3$ GeV respectively $p_T(D_s^\pm) > 2$ GeV were selected. The single differential cross sections for the different charm mesons were measured as a function of Q^2, x, $\eta(D)$, and $p_T(D)$ and agreed reasonably well with the NLO predictions [1, 9].

Furthermore, the D^* charm meson production at low Q^2 was measured with 82 pb^{-1} of HERA I data [10]. The decay $D^{*+} \to D^0\pi_s^+$ with the subsequent decay $D^0 \to K^-\pi^+$ and the corresponding an-

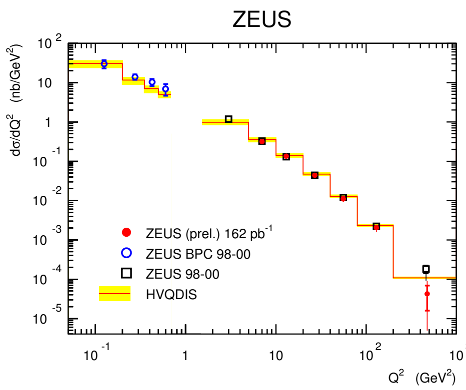

Figure 2: Differential D^* cross section as a function of the photon virtuality Q^2. The solid circles show the HERA II data while the open boxes show the results of the corresponding HERA I measurement. The open circles show the HERA I measurements using the beampipe calorimeter. The solid line gives the NLO QCD prediction with the shaded band indicating its uncertainty.

tiparticle decay were used to tag charm and the ZEUS beampipe calorimeter was used to identify the scattered electron. This allowed measurements in the kinematic region $0.05 < Q_e^2 < 0.7$ GeV and $0.02 < y < 0.7$. The D^* candidates had to satisfy $|\eta(D^*)| < 1.5$ and $1.5 < p_T(D^*) < 9.0$ GeV. This measurement combined with the other two D^* measurements allows testing of the NLO prediction over a large range of Q^2. This comparison is shown in Figure 2 and shows good agreement with the NLO QCD prediction.

4 Open Charm Contribution to the Structure Function

The extraction of the open charm contribution, $F_2^{c\bar{c}}(x, Q^2)$, to the proton structure function F_2 from the charm meson measurements was performed as described in the previous measurements [5]. $F_2^{c\bar{c}}(x, Q^2)$ can be defined in terms of the inclusive double-differential $c\bar{c}$ cross section in x and Q^2 by

$$\frac{d^2\sigma^{c\bar{c}}(x, Q^2)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\{[1 + (1 - y)^2]F_2^{c\bar{c}}(x, Q^2) - y^2 F_L^{c\bar{c}}(x, Q^2)\}.$$

As the measured cross sections are well described in the probed kinematic region, the following relation was used to extract $F_2^{c\bar{c}}(x, Q^2)$:

$$F_{2,meas}^{c\bar{c}}(x, Q^2) = \frac{\sigma_{meas}(ep \to DX)}{\sigma_{theo}(ep \to DX)} F_{2,theo}^{c\bar{c}}(x, Q^2).$$

The cross sections in the measured charm meson region were extrapolated to the full kinematic region in $p_T(D)$ and $\eta(D)$ using HVQDIS and the $c\bar{c}$ cross section was obtained using the known fragmentation fractions. Figure 3 shows the HERA I D^* [5] and D^0,$D^\pm$,D_s [9] results and the HERA II D^* result. All measurements show good agreement with each other and the ZEUS QCD NLO fit.

5 Conclusions

The ZEUS experiment has measured the charm cross section in DIS in the photon virtuality range $0.05 < Q^2 < 1000$ GeV^2. These measurements have been compared to the prediction of leading-logarithmic Monte Carlo simulations and show good agreement. Furthermore, the open charm contribution, $F_2^{c\bar{c}}$, to the proton structure function, F_2, was extracted from the data. The different measurements show good agreement with each other and the ZEUS NLO QCD fit. Further improvements to these measurements can be expected from the additional data from the 2006 to 2007 HERA running and the HERA II $D^\pm$ analysis presented in [11].

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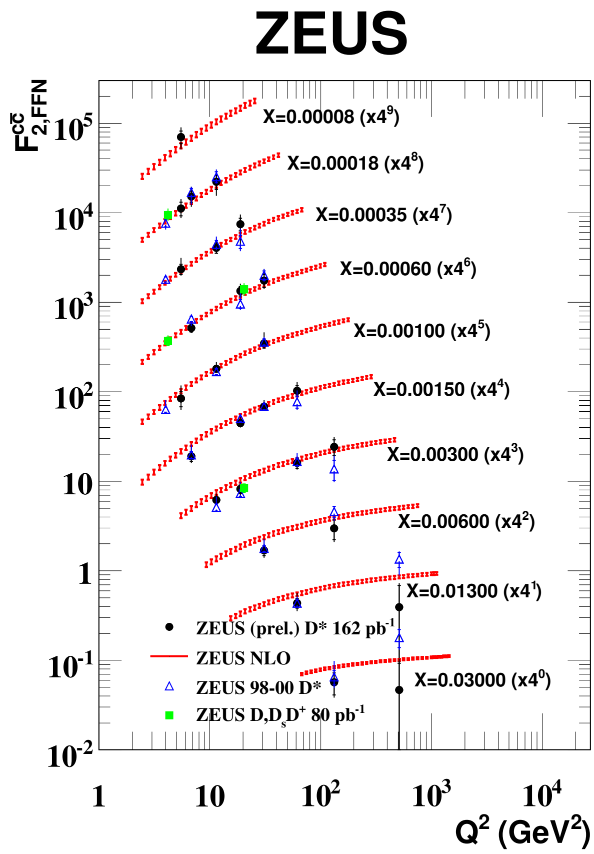

Figure 3: The measured $F_2^{c\bar{c}}$ at x values between 0.00008 and 0.03 as a function of Q^2. The circles show the HERA II D^* measurement, while the triangles show the HERA I D^* measurement. The results obtained from the HERA I measurement using D^0,$D^{\pm}$,D_s decays is shown by squares. The data are shown with statistical uncertainties (inner bars) and statistical and systematic uncertainties added in quadrature (outer bars).

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