Measurement of $D^{\pm}$ Meson Cross Sections in Deep Inelastic Scattering using the ZEUS Micro Vertex Detector

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Measurments of charm production in deep inelastic scattering (DIS) have been carried out by the ZEUS collaboration at HERA. Results using integrated luminosities of 135 pb^{-1} of HERA II running are presented. Single differential cross sections are compared to perturbative QCD predictions. Charm cross sections are in reasonable agreement with QCD calculations. The charm contribution to the proton structure function F_2^{cc} has also been measured, and is also in reasonable agreement with QCD fits.

1 Introduction

The electron/positron-proton collider HERA at the DESY laboratory is a unique facility to test Quantum Chromo Dynamics (QCD). Charm production in deep inelastic scattering (DIS) has been extensively studied at HERA[2, 3, 4, 5, 6, 7]. These measurements are consistent with pQCD calculations indicating boson-gluon fusion (BGF) as the dominant mechanism of charm production. Charm is mainly tagged in the 'golden' decay channel of the D^* meson $D^{*+} \rightarrow K^+\pi^-\pi^-$(+c.c.). More advanced instrumentation using secondary vertex tagging have been used to measure other charm cross sections at H1[8]. ZEUS results by tagging $D^{\pm}$ mesons using the micro-vertex detector from the 2005 running phase of HERA II are reported.

2 Analysis

The measurement of $D^{\pm}$ mesons cross sections in DIS has been performed using $135\,\mathrm{pb}^{-1}$ of e^-p data collected by the ZEUS detector in the 2005 running period.

The deep inelastic scattering regime in which the measurements were made is characterised by $Q^2 > 1\,\mathrm{GeV}^2$, where Q^2 is the virtuality of the exchanged photon.

Tagging of the $D^{\pm}$ mesons was performed by reconstructing a candidate $D^{\pm}$ meson in its decay mode, $D^{\pm} \rightarrow K^+\pi{-}\pi^-$ (+c.c). Tracks in the pseudorapidity region $|\eta^{\mathrm{track}}| < 1.6$ with transverse momentum $p_T > 0.7$ GeV for the kaon and $p_T > 0.5$ GeV for the pions were required. The $D^{\pm}$ mesons were reconstructed in the region, $3 < p_T^{D^{\pm}} < 20\,\mathrm{GeV}$ and $|\eta^{D^{\pm}}| < 1.6$. The purity of the $D^{\pm}$ tagging was improved by utilising the precision tracking provided by the ZEUS microvertex detector (MVD).

The increased purity was achieved through the use of the signed two dimensional decay length significance (S_{DL}). This is defined to be the two dimensional distance from the secondary vertex to the primary interaction point projected onto the $D^{\pm}$ momentum vector divided by the error on this distance. Figure 1 shows the improvement in the reconstructed $D^{\pm}$ signal from using a cut on the S_{DL} variable. The uncertainty on the number of re-

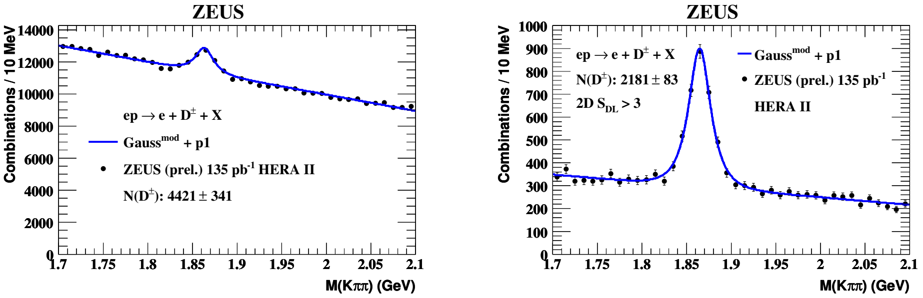

Figure 1: The effect of the S_{DL} cut on the precision of the reconstructed $D^{\pm}$ meson signal. The data (dots) are fitted with a modified gaussian.

constructed $D^{\pm}$ mesons is reduced from 7.7% to 3.8% by rejecting $D^{\pm}$ candidates with a $S_{DL} < 3$. After all cuts 2181 ± 83 candidates were selected.

3 Differential $D^{\pm}$ meson cross sections in DIS

Differential cross sections have been measured for the process $ep \to e + D^{\pm} + X$ as functions of Q^2, $p_T^{D^{\pm}}$, $\eta^{D^{\pm}}$ and the Bjorken scaling variable x. By definition this cross section includes contributions from beauty production though these contributions are expected to be small. The measurements are compared to the NLO QCD calculation performed in the massive scheme by Harris and Smith [9]. The $D^{\pm}$ momentum is simulated using the Peterson function for charm fragmentation. The central theoretical prediction was calculated using a charm mass of $m_c = 1.35\,\mathrm{GeV}$ and renormalisation and factorisation scales, $\mu_R = \mu_F = \sqrt{Q^2 + 4m_c^2}$. The Peterson fragmentation function parameter (ϵ) was set to 0.035. Upper and lower bounds were estimated by independently changing the charm mass, fragmentation and renormalisation scales, Peterson ϵ parameter and the input PDFs used for the calculation [1]. The resulting deviations from the central value were then added in quadtrature to obtain the total theoretical uncertainty.

The single differential cross sections are presented in fig. 2. The beauty contribution as estimated using RAPGAP is generally small contributing most at low $p_T^{D^{\pm}}$ and small values of the scaling variable x. Previous ZEUS results from the HERA I running period are shown for comparison on the Q^2 figure, these again show the improved precision resulting from the use of the MVD. All measurements are well described by the NLO QCD prediction obtained from HVQDIS.

4 Extraction of the charm contribution to the proton structure function, F_2^{cc}.

At low values of inelasticity (y) the charm contribution to the proton structure function can be defined in terms of the double differential $c\bar{c}$ cross section in Q^2 and x.

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

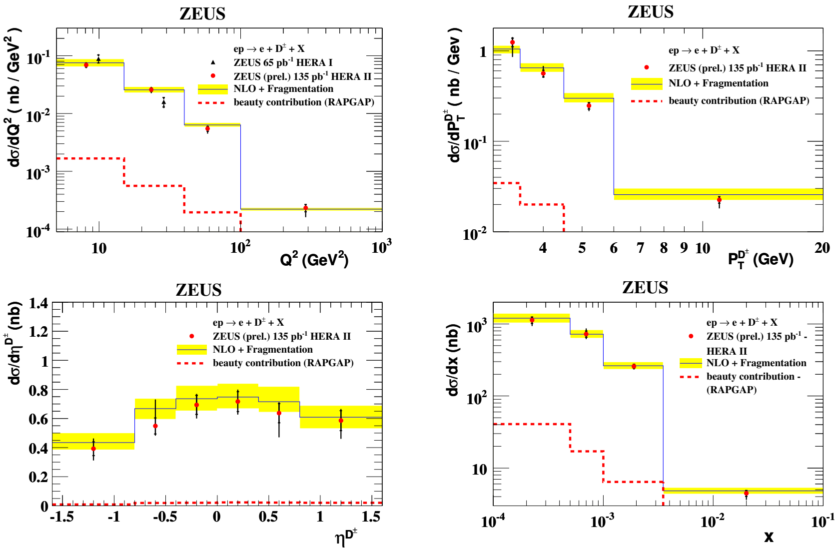

Figure 2: Single differential cross sections of the process $ep \to e + D^{\pm} + X$ as functions of Q^2, $p_T^{D^{\pm}}$, $\eta^{D^{\pm}}$ and the scaling variable x. The data (dots) are shown compared to the NLO QCD prediction with its theoretical uncertainty (yellow band). The expected beauty contribution estimated from RAPGAP (red dashed line) is also shown.

The $c\bar{c}$ cross section was obtained by measuring the $D^{\pm}$ cross section and employing the hadronisation fraction $f(c \to D^{\pm})$ to derive the total charm cross section. Since the measurement of $D^{\pm}$ mesons is only possible in a limited kinematic range a method for extrapolating to the full kinematic phase space is required. As the structure function varies only slowly it is assumed to be constant in a given Q^2 and y bin. This leads to the measured $F_2^{c\bar{c}}$ in a bin i being given by.

$$F_{2,meas}^{c\bar{c}}(x_i, Q_i^2) = \frac{\sigma_{i,\mathrm{meas}}(ep \to D^{\pm}X)}{\sigma_{i,\mathrm{theo}}(ep \to D^{\pm}X)} F_{2,\mathrm{theo}}^{c\bar{c}}(x_i, Q_i^2) \tag{2}$$

where σ_i are the cross sections in bin i in the measured kinematic region. The value of $F_{2,\mathrm{theo}}^{c\bar{c}}$ was calculated from the NLO coefficient functions [10]. The functional form of $F_{2,\mathrm{theo}}^{c\bar{c}}$ was used to quote results for $F_2^{c\bar{c}}$ at appropriate values of Q_i^2 and x_i. In this calculation the same charm mass, parton densities and factorisation and renormalisation scales have been used as for the HVQDIS calculation of the differential cross sections. The hadronisation was performed using the Peterson fragmentation function. The beauty contribution as estimated from RAPGAP was subtracted from the data. As with the differential cross sections this contribution is small.

The measured values of $F_2^{c\bar{c}}$ are shown in fig. 3. The theoretical prediction calculated from coeeficient functions along with the prediction's uncertainty are also shown. Results from the HERA I running period are shown for comparison in the two higher Q^2 bins. It can be seen that the precision of the HERA II results is comparable even though the HERA I results are obtained by a combination of measurements of three charm mesons. This demonstrates the power of lifetime tagging techniques.

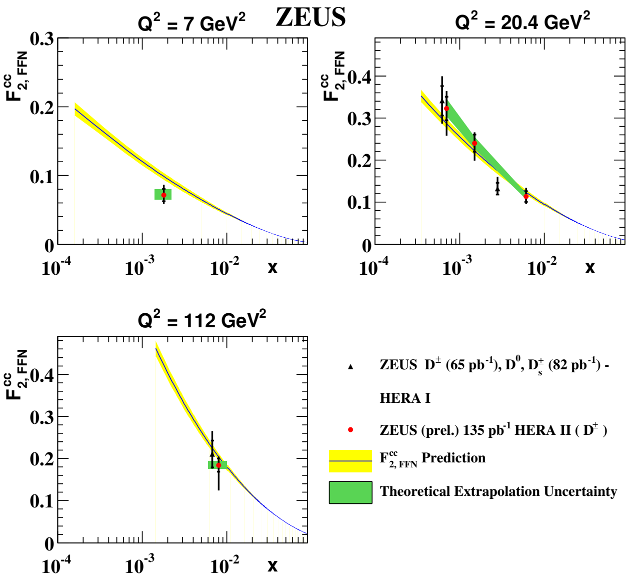

Figure 3: Measured values of the charm contribution to the proton structure function $F_2^{c\bar{c}}$ (dots) are shown along with previous ZEUS results. The uncertainty of the measurements associated with the extraction procedure is also shown (green band).

References

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