Measurement of charm production in DIS with $D^*$ mesons and extraction of $F_2^{c\bar{c}}$

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Charm production has been measured with the ZEUS detector in deep inelastic $ep$ scattering at HERA. The measurement is based on the full reconstruction of the decay chain $D^* \rightarrow D^0 \pi$, $D^0 \rightarrow K \pi$ and exploits the full HERA II statistics with integrated luminosity $L = 357 \text{ pb}^{-1}$. Differential cross-sections have been measured. The kinematic range is $1.5 \text{ GeV} < Q^2 < 1000 \text{ GeV}^2 \text{ and } 0.02 < y < 0.7$. The observed cross sections were extrapolated to the full $P_t(D^*)$ and $\eta(D^*)$ range in order to determine the open-charm contribution, $F_2^{c\bar{c}}(x,Q^2)$ to the proton structure function $F_2$.

1 Introduction

The production of heavy quarks at HERA proceeds dominantly via the direct boson-gluon fusion (BGF) process $\gamma g \rightarrow c\bar{c} (\gamma g \rightarrow b\bar{b})$. The measurement of processes involving heavy flavour production gives a test of perturbative QCD calculations and information on the gluon content of proton. The measurement of the charm contribution $F_2^{c\bar{c}}$ to the proton structure function allows to test parton density functions. Information about gluon and heavy quark distribution in the region of low Bjorken $x$ is important for measurement of Standard Model and new physics processes at hadron-hadron colliders such as LHC.

In this paper recent measurements on the charm production in neutral current deep inelastic scattering (NC DIS) obtained from the reconstruction of $D^*$ mesons at HERA by the ZEUS experiment are presented. The analysis is based on $e^+p$ and $e^-p$ data collected by ZEUS from 2004 to 2007 at a center of mass energy $\sqrt{s} = 318 \text{ GeV}$. 

2 Analysis Techniques

In this analysis charmed hadrons were detected by reconstructing the decay products of $D^{*\pm}$ mesons in the central tracking detector using $D^* \rightarrow K\pi\pi$ decay channel. The kinematic range of measurement is $5 < Q^2 < 1000 \text{ GeV}^2$, $|\eta(D^*)| < 1.5 \text{, } 1.5 < P_t(D^*) < 20 \text{ GeV}, \text{ and } 0.02 < y < 0.7$. The invariant mass difference $M(K\pi\pi) - M(K\pi)$ for $D^0$ candidates in the range $1.8 < M(K\pi) < 1.92 \text{ GeV}$ is shown in Fig.1. Background was estimated by using combination of tracks with wrong charge of reconstructed $D^0$. Both combinations, right and wrong charge were normalized in background region $[150,168] \text{ MeV}$. The shaded area indicates the signal mass window. $D^*$ mesons can also originate from beauty hadrons, but contribution is only a
few %. For acceptance calculation RAPGAP Monte Carlo samples (charm and beauty) were used.

3 D* differential cross-sections

On Fig.2 measured double-differential cross-sections (black dots) are compared to NLO QCD calculation made with the HVQDIS program [1] (dashed line) and measurements of the H1 collaboration [2] (empty symbols). The beauty contribution to $D^{*\pm}$ production (continuous line) was calculated with the RAPGAP [3] Monte Carlo, scaled by 1.52 in agreement with ZEUS measurements. For all cross-sections QED corrections were applied. Presented measurements are in good agreement with theoretical prediction.

Figure 1: $D^*$ signal

![Figure 1: $D^*$ signal](image)

Figure 2: Double-differential cross-sections in bins of $Q^2$ and $y$, compared to recent H1 data [?] and to the HVQDIS calculation.

![Figure 2: Double-differential cross-sections](image)
4 $F_2^{c\bar{c}}$ measurement

The $F_2^{c\bar{c}}$ ratio was evaluated as:

$$F_2^{c\bar{c}} = \frac{\sigma_{\text{vis}}^{\text{bin}}}{\sigma_{\text{theory}}^{\text{bin}}} \left( \frac{F_2^{c\bar{c}}(x,Q^2)}{\sigma_{\text{vis}}^{\text{bin}}} \right)_{\text{theory}}$$

where $\sigma_{\text{vis}}^{\text{bin}}$ is the $D^*$ visible cross-section in a $Q^2$, $y$ bin after substraction of the beauty contribution. On Fig.3 is measured charm structure function $F_2^{c\bar{c}}$ (filled circles) compared to the recent $D^+$ ZEUS result (filled squares) and preliminary combination of H1 and ZEUS data (empty circles).

![Figure 3: Measured charmed structure function $F_2^{c\bar{c}}$ compared to previous HERA results and HERAPDF 1.0](image)

The $\frac{F_2^{c\bar{c}}(x,Q^2)}{\sigma_{\text{vis}}^{\text{bin}}}_{\text{theory}}$ ratio were obtained using HVQDIS program and cross-section extrapolation on full phase space were performed with following parameters:

**Scales**: the renormalization ($\mu_R$) and factorization ($\mu_F$) scales set to $\mu_F = \mu_R = \sqrt{Q^2 + 4m_c^2}$
and varied simultaneously by a factor two up and down. The scales were varied both in HVQDIS and in the PDF fit.

**Mass:** the charm quark mass ($m_c$) is set to $1.5 \pm 0.15$ GeV, varied simultaneously in HVQDIS and in the PDF fit.

**PDF:** the HERAPDF 1.0 PDF fit performed with the fixed flavour number scheme (FFNS), with scales and masses in agreement with those used in HVQDIS.

**Fragmentation function:** fragmentation is performed in the $\gamma^* - p$ frame using Kartvelishvili fragmentation function with the parameter $\alpha_K$ dependent on the photon-parton center of mass energy squared, based on [6] and [7].

**Fragmentation fraction:** the probability that a c quark produces a $D^{**}$ meson is set to $f(c \rightarrow D^{**}) = 0.2287$.

The theoretical band shown in Fig. 3 is RT GM-VFNS heavy flavour scheme at NLO based on the HERAPDF 1.0 densities. The band corresponds to a variation of $m_c$ from 1.3 to 1.65 GeV.

## 5 Summary

A measurement of the heavy flavour content of the proton in DIS at HERA have been presented. $D^*$ cross-sections and $F_{2c\bar{c}}$ measurements were made using information from ZEUS detector with $D^* \rightarrow K \pi \pi_{\text{slow}}$ decay channel. The $D^*$ cross-sections are found to be well described by the predictions of perturbative QCD at NLO. Measured $F_{2c\bar{c}}$ are in good agreement with previous HERA measurements and HERAPDF 1.0. Measured $F_{2c\bar{c}}$ will improve precision of H1-ZEUS combination.

## References


[4] ZEUS Collaboration, Measurement of charm production with $D^\pm$ in DIS at HERAII, ZEUS-prel-10-005,

[5] H1 and ZEUS collaborations, Combination of $F_2 c$ from DIS measurements at HERA, H1prelim-09-171, ZEUS-prel-09-015,
