FIRST RESULTS ON OPEN CHARM PRODUCTION IN DEEP INELASTIC SCATTERING FROM H1

K. DAUM
for the H1 Collaboration
Rechenzentrum, Universität Wuppertal,D-42097 Wuppertal , Germany

Results on the inclusive D^0 and $D^{*\pm}$ production in deep inelastic ep scattering are reported from the H1 experiment at HERA . Inclusive D meson and charm production cross sections in deep inelastic ep scattering in the kinematic range 10 GeV$^2 \leq Q^2 \leq 100$ GeV^2 and $0.01 < y < 0.7$ are presented. Differential cross sections are found to agree well with the QCD predictions for boson gluon fusion. An upper limit on a charm sea in the proton of 5% at 95% C.L. is deduced. A first measurement of $F_2^{c\bar{c}}\left(x, Q^2\right)$ for $8 \cdot 10^{-4} \leq x \leq 8 \cdot 10^{-3}$ is described.

1 Introduction

The study of charm production in deep inelastic lepton nucleon scattering *(DIS)* is of importance for the understanding of the parton densities in the nucleon [1,2]. In accordance with measurements by the EMC collaboration [3], neutral current heavy quark production is ecpected to be dominated by the *boson gluon fusion (BGF)* process $\gamma(Z^0)g \rightarrow c\bar{c}$, whereas charm quark contributions to the proton *(QPM)*, i.e. $\gamma(Z^0)c \rightarrow cX$, are expected to be small. D meson production either from fragmentation and gluon splitting or via B meson decay is suppressed by heavy quark masses.

In modern parton density calculations charm is either included in the massless quark evolution [4] accounting for the charm quark mass by introducing a threshold below which no charm will be generated [5] or it is produced via BGF only taking into account the charm quark mass [6]. Both approaches may lead to similar results for the charm contribution $F_2^{c\bar{c}}(x, Q^2)$ to the structure function of the proton, but they will differ in the momentum spectrum of the charm quarks, and of D mesons, in the hadronic center of mass system $(\gamma^* p)$, which allows to test the charm production mechanism with high sensitivity.

If the charm data may be described by BGF exclusively inclusive D production is a unique probe for the gluon density $x\, g(x, Q^2)$ in the proton.

2 Data Analysis

The analyses [7] are based on the data collected with the H1 detector [8] at HERA in the 1994 running period corresponding to an integrated luminosity of $\mathcal{L}_{int} = 2.97 \pm 0.04$ pb^{-1}.

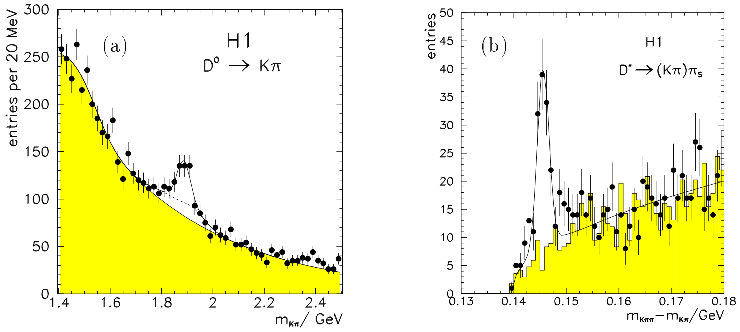

Figure 1: Distribution (a) of $m_{K\pi}$ from the D^0 analysis and (b) of Δm from the D^{*+} analysis by requiring $|m_{K\pi} - m_{D^0}| < 90$ MeV. The shaded areas show the background expectations. The full lines are the results of fits to the data.

Tagging of charm events is performed by reconstructing D^0 and D^{*+} mesons[a] via their decays into $D^0 \to K^-\pi^+$ and $D^{*+} \to D^0\pi_s^+ \to (K^-\pi^+)\pi_s^+$, respectively. Satisfactory suppression of the combinatorial background is obtained by making use of the hard fragmentation of charm quarks. Furthermore, for the D^{*+} analysis the mass difference $\Delta m = m(D^{*+}) - m(D^0)$, being very close to the π^+ mass, leads to a better resolution and signal to background ratio than the D^{*+} mass itself. In Fig. 1 the inclusive D^0 and D^{*+} signals are shown. Fits to the data result in inclusive yields of 144 ± 19 D^0 and 103 ± 13 D^{*+} mesons with 8 ± 3 events being in common in both analyses.

3 Results

The results on differential and integrated cross sections are presented for the range 10 GeV$^2 \leq Q^2 \leq 100$ GeV^2. Inclusive D cross sections are calculated from the observed numbers N_{obs} of D^0 and D^{*+} candidates according to

$$\sigma(ep \to eDX) = \frac{N_{obs}}{\mathcal{L}_{int} \cdot B \cdot \epsilon_{tot}}. \tag{1}$$

Here $\mathcal{L}_{int}$, B and ϵ_{tot} refer to the integrated luminosity, the branching ratios of the D^0 and the D^{*+} into the specific final states [9], and the total efficiency respectively. These cross sections are subsequently converted into charm production cross sections using the equation

$$\sigma(ep \to ec\bar{c}X) = \frac{1}{2} \cdot \frac{\sigma(ep \to eDX)}{P(c \to D) \cdot (1+\xi)}\ , \tag{2}$$

[a] Charge conjugates are always implied.

Table 1: Inclusive D meson and charm production cross sections in DIS.

	$D^0 \to K^-\pi^+$	$D^{*+} \to (K^-\pi^+)\pi^+$
$\sigma(ep \to eDX)$	$(20.4 \pm 2.7 ^{+2.7}_{-2.4} {}^{+1.6}_{-1.2})$ nb	$(7.8 \pm 1.0 ^{+1.2}_{-1.0} \pm 0.6)$ nb
$\sigma(ep \to ec\bar{c}X)$	$(19.5 \pm 2.6 ^{+2.7}_{-2.5} {}^{+1.6}_{-1.2})$ nb	$(15.1 \pm 1.8 ^{+2.4}_{-2.0} \pm 1.2)$ nb

where $P(c \to D)$ denotes the charm quark fragmentation probability into a specific D meson and ξ the correction to account for D production due to gluon splitting, fragmentation, and B meson decay, respectively. The inclusive D meson and charm production cross sections are summarized in Tab. 1. The errors refer to the statistical, the experimental systematics and the model dependent uncertainties. The latter includes the uncertainties on the charm fragmentation function and its QCD evolution, on the gluon density in the proton, and on the charm quark mass m_c. For the charm cross sections they also include an error for the estimate of the correction factor ξ.

3.1 Differential Cross Sections

Figure 2a shows the normalized differential cross section $1/\sigma \; d\sigma/dp_t(D^0)$ for the inclusive D^0 and D^{*+} production. Good agreement in the normalized $p_t(D^0)$ spectra of the two analyses is observed. The data also compare well with the BGF expectation for $m_c = 1.3$ GeV/c^2 and $m_c = 1.7$ GeV/c^2.

In order to investigate the charm production mechanism in ep-scattering the scaled D^0 momentum in the $\gamma^* p$ system is defined for both analyses according to the equation

$$x_D = (|\vec{p}_{D^0}|/|\vec{p}_p|)^{\gamma^* p} = 2 \; |\vec{p}^{\,\gamma^* p}_{D^0}|/W. \tag{3}$$

In figure 2b the corrected distribution $1/\sigma \; d\sigma/dx_D$, which is a convolution of the charm production spectrum with the fragmentation function is compared to the expectations from (a) BGF using AROMA, (b) QPM charm production according to LEPTO 6.1, and (c) νN scattering[10] where the major contribution is expected from $W^\pm$ scattering off the strange sea in the proton. For the latter the QCD evolution [4] to HERA energies is taken into account. The difference between the BGF prediction and the QPM expectations is evident. Only BGF is able to describe the data. A fit to $1/\sigma d\sigma/dx_D$ of a BGF plus QPM

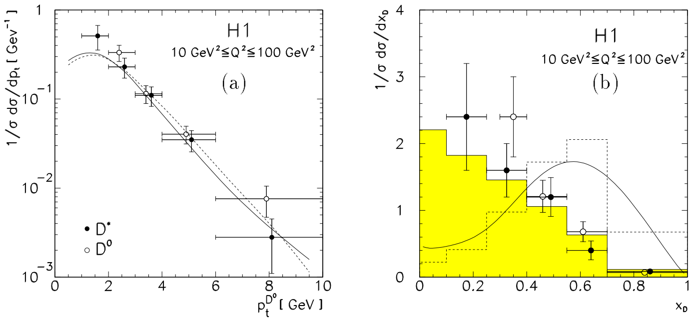

Figure 2: Fully corrected normalized distributions from the D^{*+} and the D^0 analysis: (a) $1/\sigma \;\; d\sigma/dp_t(D^0)$ compared to BGF (AROMA) with $m_c = 1.3$ GeV/c^2 (full line) $m_c = 1.7$ GeV/c^2 (dashed line), (b) $1/\sigma \;\; d\sigma/dx_D$ compared to BGF, with $m_c = 1.5$ GeV/c^2 (shaded histogram), and to QPM expectations from LEPTO (dashed histogram), and from νN scattering evolved to HERA energies (full line). The MRSH parton densities are used.

contributions in the data yields an upper limit of $\epsilon_{QPM} < 0.05$ at 95% C.L. for a QPM contribution to the charm production cross section.

3.2 Charm Contribution $F_2^{c\bar{c}}(x, Q^2)$ to the Proton Structure Function

The charm contribution $F_2^{c\bar{c}}(x, Q^2)$ to the structure function is obtained by applying the expression for the one photon exchange cross section for charm production

$$\frac{d^2\sigma^{c\bar{c}}}{dx dQ^2} = \frac{2\pi\alpha^2}{Q^4 x} \left(1 + (1-y)^2\right) \; F_2^{c\bar{c}}(x, Q^2) \; , \tag{4}$$

with the simplification that the Callan-Gross relation holds, i.e. $R = F_2/2xF_1 - 1 = 0$. Figure 3 shows $F_2^{c\bar{c}}(x, Q^2)$ as measured by H1 together with the EMC results[3]. The present measurement allows to extend the knowledge on $F_2^{c\bar{c}}(x, Q^2)$ by two orders of magnitude towards smaller x values. Together with the EMC measurement a steep rise of $F_2^{c\bar{c}}$ is observed with decreasing x. The data is also compared with NLO calculations [2] using the GRV-HO, the MRSH, and the MRSD0$'$ gluon density and $m_c = 1.5$ GeV/c^2. Since it is a priori unknown which part of the gluon density will be seen in charm production, MRSD0$'$ is still considered here, although it has already been excluded by inclusive measurements at HERA. Obviously it also fails to describe the charm production in DIS. The data also lie systematically above the other predictions. The dominant theoretical uncertainty arises from the ignorance of m_c. It turns out that a change in m_c would affect the prediction on and the measurement of $F_2^{c\bar{c}}$ nearly in the same way.

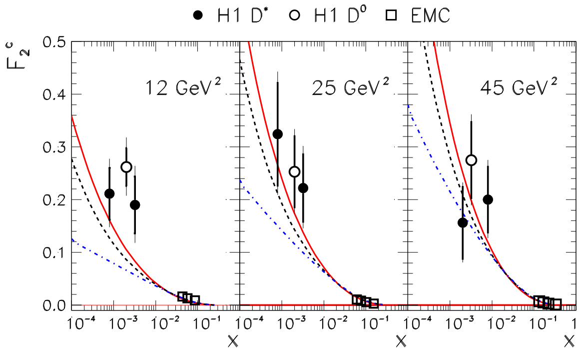

Figure 3: $F_2^{c\bar{c}}$ as derived from the D^{*+} (full dots) and D^0 analysis (open circles) in comparison with NLO predictions using GRV-HO (full line) MRSH (dashed line) and MRSD0′ (dash-dotted line) and $m_c = 1.5$ GeV/c^2. Statistical (thick) and total (thin) errors are shown. The EMC data is included (open boxes).

In conclusion the analysis of D^0 and D^{*+} meson production has shown that charm production in neutral current DIS at HERA is well described by BGF. $F_2^{c\bar{c}}$ has been measured for $8 \cdot 10^{-4} < x < 8 \cdot 10^{-3}$ for the first time. The data prefer a slightly stronger rise of $x\, g(x, Q^2)$ at small Q^2 than predicted by NLO calculations for different parameterizations.

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