Charm Photoproduction in ep Collisions at HERA

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We report the latest results of the ZEUS collaboration on the photoproduction of D^* mesons in a low W range. Differential cross sections as function of $p_\perp^{D^*}$ and η^{D^*} are measured and compared with several recent NLO pQCD calculations. The differential cross-sections in a restricted kinematical region are higher than the NLO calculations, in particular in the forward (proton) direction. A recent pQCD model (BKL) describes the data reasonably well.

1. INTRODUCTION

Heavy quark photoproduction can be used to probe pQCD calculations with a hard scale given by the heavy quark mass and the high transverse momentum of the produced parton ($m_Q \gg \Lambda_{QCD}$). Two types of NLO calculations with different approaches are available for comparison with measurements of charm photoproduction at HERA. The massive charm approach [1] assumes light quarks to be the only active flavours within the structure functions of the proton and the photon, while the massless charm approach [2,3] also treats charm as an active flavour and is thus only valid for $p_\perp \gg m_c$.

The data taken by the ZEUS collaboration during 1996/1997 corresponds to an integrated luminosity of about $37\,\mathrm{pb}^{-1}$. In a subsample of about $17\,\mathrm{pb}^{-1}$ a small calorimeter positioned along the beam pipe was used to tag low W events, $80 < W_{\gamma p} < 120\,\mathrm{GeV}$. The results of the high W region ($130 < W_{\gamma p} < 280\,\mathrm{GeV}$) have been published before [4] and will not be shown here. This is the first presentation of our low W results. Charm was identified by the observation of $D^*(2010)$ mesons, which were reconstructed in the following decay modes: $D^{*+} \to D^0\pi_s^+ \to (K^-\pi^+)\pi_s^+$ ($Br = 0.0262 \pm 0.0010$) and $D^{*+} \to D^0\pi_s^+ \to (K^-\pi^+\pi^+\pi^-)\pi_s^+$ ($Br = 0.051 \pm 0.003$) and charge conjugates. The kinematic range studied was $p_\perp^{D^*} > 2$ GeV and $-1.5 < \eta^{D^*} < 1.5$ for the high W region, and $2 < p_\perp^{D^*} < 8$ GeV and $-1.0 < \eta^{D^*} < 1.5$ for the low W region. The pseudorapidity is $\eta^{D^*} = -\ln(\tan\frac{\theta}{2})$, where θ is the polar angle with respect to the proton beam direction.

Charged tracks were measured in the central tracking detector. Cross sections were calculated in the photoproduction range of photon virtualities $Q^2 < 1\,\mathrm{GeV}^2$ ($Q^2 < 0.015\,\mathrm{GeV}^2$ for the tagged data).

2. D^* RECONSTRUCTION

D^* events have been selected by means of the mass difference (ΔM) method [5]. In the high W region we have observed [4] 3702 ± 136 D^*'s in the $D^0 \to (K\pi)$ decay mode with $p_\perp^{D^*} > 2\,\mathrm{GeV}$, and 1397 ± 108 in the $(K\pi\pi\pi)$ decay mode with $p_\perp^{D^*} > 4\,\mathrm{GeV}$ ($M(D^0) = 1.80$–$1.92\,\mathrm{GeV}$). In the low W region we triggered only the $(K\pi)$ decay mode, and observed 550 ± 36 D^* events in the range $2 < p_\perp^{D^*} < 8$ GeV (Fig. 1). All tracks were assumed to be pions and kaons in turn; wrong charge D^* combinations [4] were used as a background distribution (dashed curve in Fig. 1), normalized outside the signal region.

3. D^* CROSS SECTIONS AND COMPARISON WITH CALCULATIONS

The D^* differential cross sections in the low W region are shown in Fig. 2 to 5. For comparing the

*Supported by the German Israeli Foundation and by the Minerva Foundation.

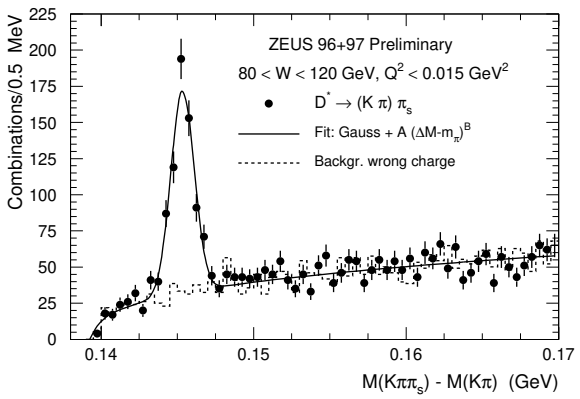

Figure 1. ΔM distribution for the events inside the D^o mass region. The wrong charge distribution is shown as a dashed histogram.

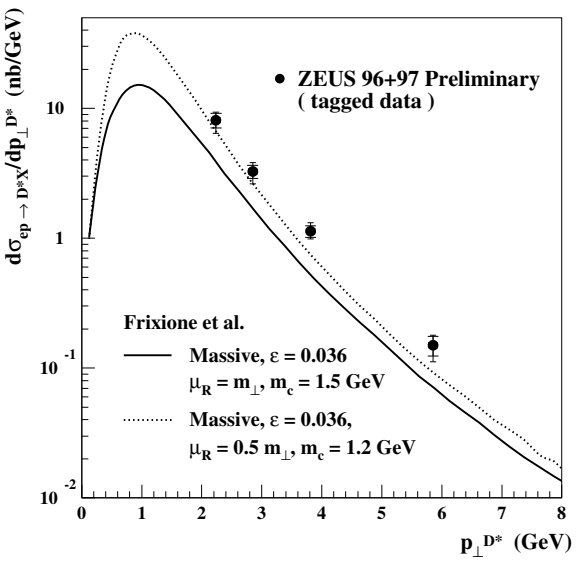

Figure 2. ZEUS tagged data compared to massive NLO calculations of $d\sigma/dp_\perp^{D^*}$.

experimental data to the NLO QCD calculations, we have used the D^* branching value measured by OPAL [6] $f(c \to D^{*+} + ...) = 0.222 \pm 0.014 \pm 0.014$. For the charm fragmentation to D^* the Peterson [7] fragmentation function was used:

$$D_c(z) = N \frac{z(1-z)^2}{[(1-z)^2 + \epsilon z]^2} , \qquad z = \frac{p_{D^*}}{p_c} .$$

In the massive calculation $\epsilon = 0.036$ was obtained from a recent fit of Nason and Oleari [8] to ARGUS data. Alternatively, the Peterson fragmentation was replaced by fragmentation effects estimated by a leading order Monte Carlo (Pythia). Initial and final state radiation were not included. The results of both calculations for the low W region are shown in Figs. 2 and 3. The cross sections are compared with NLO QCD massive calculations using MRSG for the proton structure function (SF) and GRV-G HO for the photon. The theoretical massive calculations are below the data, in particular in the forward (proton) direction, although the Pythia fragmentation slightly improves the agreement.

A comparison with massless calculations [2], which are expected to become valid mainly at higher $p_\perp^{D^*}$, is shown in Fig. 4 for several photon structure functions. Some sensitivity to the photon SF seems to be present, but the excess in the forward direction is evident. The structure function GS-G-96 HO describes the data best.

Recently Berezhnoy, Kiselev and Likhoded (BKL) have suggested a new model for describing D^* photoproduction [9]. In this tree level pQCD $O(\alpha\alpha_s^3)$ calculation, they hadronize the $(c, \bar{q})$ state produced in pQCD, taking into account higher twist terms at $p_\perp \simeq m_c$. Thus the model is supposed to be valid over the whole $p_\perp$ range studied. No explicit resolved component is used. Singlet and octet color states both contribute to D^* production. The color state ratio $O(8)/O(1)$ is a free parameter in this model and was tuned to the ZEUS untagged results [4], yielding a value of 1.3.

Comparison of these calculations, for the same Octet/Singlet mixture, with the ZEUS tagged low W data is shown in Fig. 5. A better agreement with the data is observed than that for the NLO calculations.

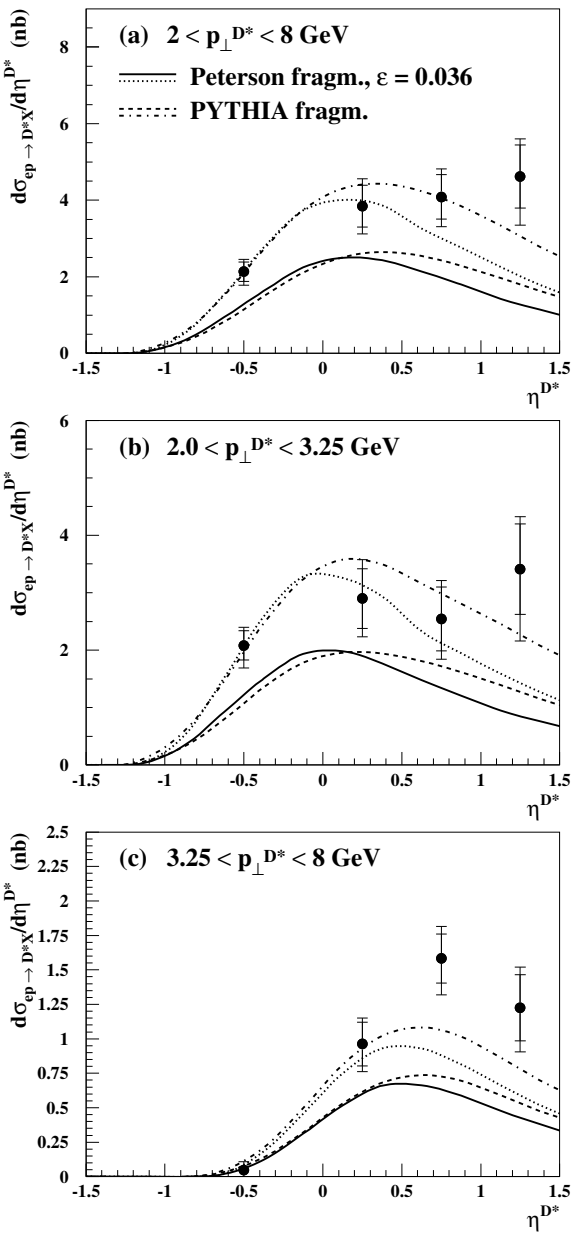

Figure 3. ZEUS differential cross sections $d\sigma/d\eta$ compared to the massive NLO predictions. The dashed/dashed-dotted lines correspond to the Pythia fragmentation. Parameter sets are as in Fig.2.

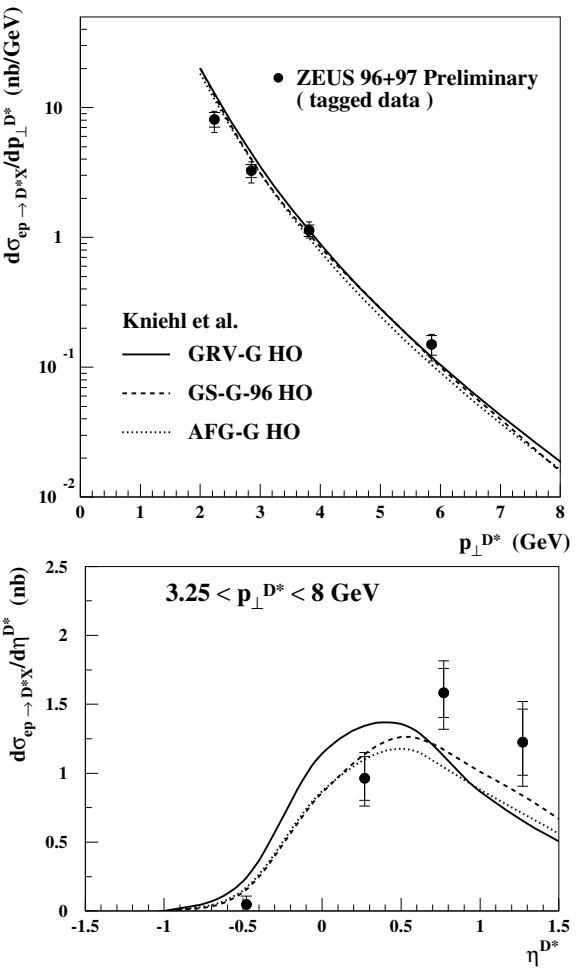

Figure 4. ZEUS data and massless NLO predictions [2] of differential cross sections for several photon structure functions. Peterson fragmentation was used with $\epsilon = 0.116$.

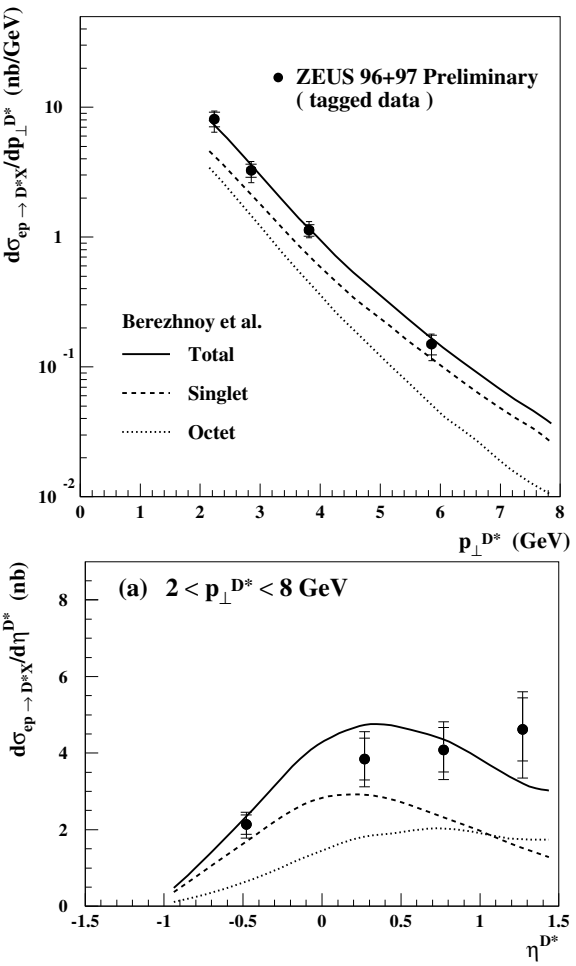

Figure 5. Comparison of the ZEUS low W data with the BKL model. The Octet/Singlet ratio is 1.3, as tuned for the high W region.

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