Charm Photoproduction in ep Collisions at HERA

Yehuda Eisenberg*a
On behalf of the ZEUS Collaboration

*aWeizmann Institute of Science, Particle Physics Department, Rehovot, ISRAEL
email: yehuda@mail.desy.de

We report the latest results of the ZEUS collaboration on the photoproduction of $D^*$ mesons in a wide $W$ range. The results are compared with several recent NLO pQCD calculations. The differential cross-sections in a restricted kinematical region are higher then 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 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 pb$^{-1}$. In a subsample of about 17 pb$^{-1}$ the ZEUS 44m tagger, having an acceptance of 30-90%, was used to select events with $80 < W_{\gamma p} < 120$ GeV. The results of the high $W$ region $(130 < W_{\gamma p} < 280$ GeV) has been published [4] and 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: $D^{*+} \rightarrow D^0 \pi^+_s \rightarrow (K^-\pi^+)\pi^+_s$ ($Br = 0.0262 \pm 0.0010$) and $D^{*+} \rightarrow D^0 \pi^+_s \rightarrow (K^-\pi^+\pi^-\pi^-)\pi^+_s$ ($Br = 0.051 \pm 0.003$) 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 $p_{\perp}^{D^*} = 2.8$ GeV and $-1.0 < \eta^{D^*} < 1.5$ for the low $W$ region. The pseudorapidity is $\eta^{D^*} = -\ln(\tan(\theta/2))$, where $\theta$ 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 $Q^2 < 1$ GeV$^2$ ($Q^2 < 0.015$ GeV$^2$ for the tagged data).

2. $D^*$ PHOTOPRODUCTION

$D^*$ events have been selected by means of the mass difference ($\Delta M$) method [5]. In the high $W$ region we have observed [4] 3702 ± 136 $D^*$'s in the $D^0 \rightarrow (K\pi)$ decay mode with $p_{\perp}^{D^*} > 2$ GeV, and 1397 ± 108 in the $(K\pi\pi)$ decay mode with $p_{\perp}^{D^*} > 4$ GeV ($M(D^0) = 1.80 \pm 1.92$ GeV). In the low $W$ region we triggered only the $(K\pi)$ decay mode, and observed 550 ± 36 $D^*$ events in the range $p_{\perp}^{D^*} = 2-8$ 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. COMPARISON WITH THEORETICAL CALCULATIONS

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

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fragmentation to $D^*$ the Peterson fragmentation function was used:

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

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 Fig. 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, though the Pythia fragmentation slightly improves the agreement.

A comparison with massless calculations [2,3], which are expected to become valid mainly at higher $p_{D^*}^2$, is shown in Fig. 4 for several photon structure functions. Some sensitivity to the photon SF seems to be present, but the access in the forward direction is always 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 calculation, they hadronize the $(c, \bar{q})$ state produced in pQCD, taking into account higher twist terms at $p_{D^*} \approx m_c$. Thus the model is supposed to be valid over the whole $p_{D^*}$ range studied. No explicit resolved component is used. Singlet and octet color states both contribute to $D^*$ production. The contribution 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, to the 44m tagged low $W$ data is shown in Fig. 5. A better agreement with the data is observed than for the NLO calculations.

REFERENCES

Figure 3. ZEUS differential cross sections $d\sigma_{ep\to D^*X}/d\eta_{D^*}$ compared to the massive NLO predictions. The dashed lines correspond to the Pythia fragmentation.

Figure 4. ZEUS data and massless NLO predictions [2,3] 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.