CHARM PRODUCTION AT HERA*

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Measurements of charm production in ep collisions at a centre of mass energy of $\sqrt{s} = 318\,\text{GeV}$ performed by the ZEUS and H1 experiments at HERA are presented. Final states containing D mesons are used to identify charm production. Measurements cover both the photoproduction (γp), *i.e.* $Q^2 \sim 0$, and deep inelastic scattering (DIS), *i.e.* large Q^2, kinematic regimes. Experimental results are compared to QCD predictions.

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1. Introduction

The production of heavy flavours in ep collisions is dominated at leading order (LO) by the boson gluon fusion (BGF) process, $\gamma g \to c\bar{c}$, where a virtual photon emitted by the electron interacts with a gluon in the proton producing a heavy quark pair $q\bar{q}$. In γp, *resolved processes* where the photon exhibits a partonic structure, are expected to play a significant role. Theoretical calculations for heavy flavour production are mainly done in two schemes: the massless and the massive approach, depending on whether the heavy quark is considered as part of the structure functions or not, respectively.

2. Inclusive $D^{*\pm}$ meson production in γp

Two different ways are used to select γp events at HERA. The ZEUS experiment selects events where the outgoing electron is not detected [1]. The H1 experiment selects events in which the outgoing electron is detected in the electron tagger located 33 m down stream from the interaction point [2]. $D^{*\pm}$ mesons are identified by the decay chain $D^{*\pm} \to D^0\pi^{\pm}$,

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$D^0 \to K^{\mp}\pi^{\pm}$. In the analysis from the H1 experiment the cross sections are determined in the kinematic region $171 < W < 256\,\text{GeV}$, $Q^2 < 0.01\,\text{GeV}^2$, $p_{\text{T}}(D^*) > 2.5\,\text{GeV}$ and $\eta(D^*) < 1.5$ as a function of $p_{\text{T}}(D^*)$, $\eta(D^*)$ and W. They have been compared to NLO QCD calculation in the "3-flavour massive" and in the "4-flavour massless" schemes. None of the calculations is able to predict the shape of the $d\sigma/d\eta$, but the shape of $d\sigma/dW$ is described by all, as shown in Fig. 1.

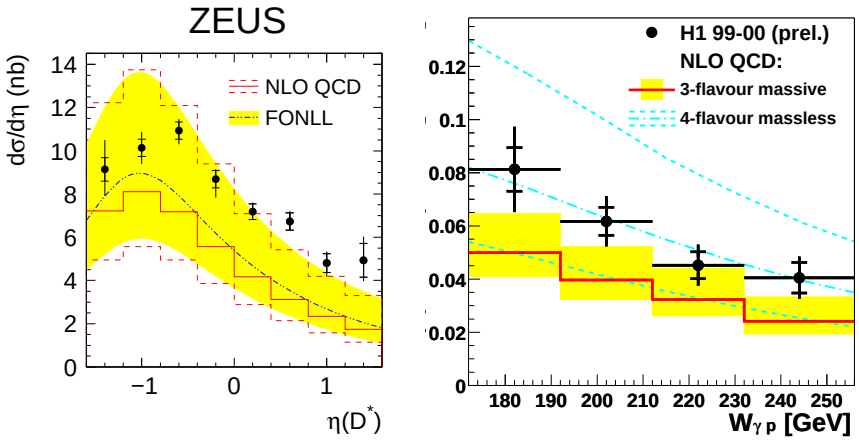

Fig. 1. Differential cross sections $d\sigma(ep \to eD^{*\pm}X)/dW$ (left) and $d\sigma(ep \to eD^{*\pm}X)/d\eta$ (right) compared to NLO QCD massive and massless calculations.

3. $D^{*\pm}$ γp inclusive jet cross sections and dijet correlations

The study of jet events in $D^{*\pm}$ photoproduction is an efficient tool for the investigation of the details of the charm production mechanism. Inclusive jet cross sections with a D^* in the final state have been measured by ZEUS [3] as a function of $E_{\text{T}}^{\text{jet}}$ and η^{jet}. The use of jets as an approximation to a parton is expected to reduce the dependence of the cross section on uncertainties due to hadronisation effects. The pQCD predictions generally reproduce the shape of all distributions. However, the central pQCD predictions underestimate the data over the whole range in $E_{\text{T}}^{\text{jet}}$ and η^{jet}. Angular correlations between tagged and untaged jets provide a test of high order QCD contributions, *i.e.* gluon emission. Measurements of angular distributions and together with the NLO QCD and Monte Carlo models predictions are shown in Fig. 2, separately for a resolved enhanced sample ($x_\gamma < 0.75$) and for a direct enriched sample ($x_\gamma > 0.75$). The observed discrepancies indicate the need of further theoretical development.

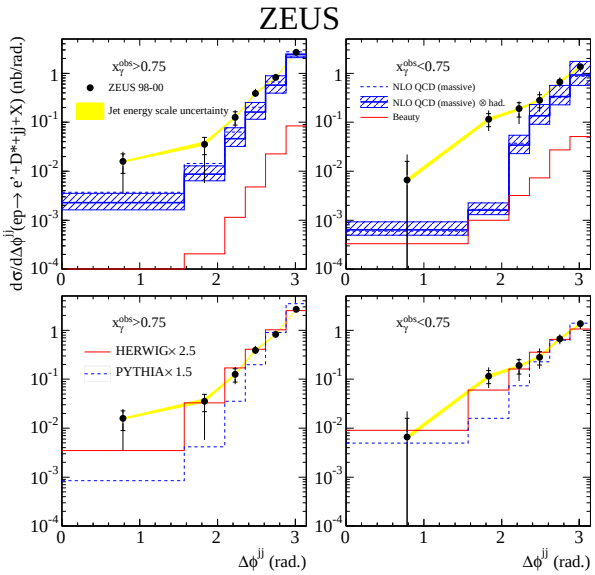

Fig. 2. Differential cross sections compared to NLO QCD massive and massless calculations for two regions of the observable x_γ.

4. Fragmentation of charm quark

Experimentally heavy quarks are not observed directly, but heavy flavoured hadrons are measured instead. The universality of fragmentation, can be tested by comparing measurements in ep collisions to e^+e^- data. Two measurements are done at HERA: fractions and ratios, and fragmentation functions. At HERA the inclusive production cross sections of the charm ground states D^0, $D^\pm$, D_s, D^* and Λ_c have been measured in the γp [5] and in the DIS [4, 6] regime. The ratio $R_{u/d} = c\bar{u}/c\bar{d}$ measures the rate of the neutral to charged D meson production. Due to the smallness of the u and d quark masses, a value close to 1 is expected. Due to the higher s quark mass, D_s mesons are expected to be less frequently produced than D^0 and $D^\pm$ mesons. This is quantified by the strangeness suppression factor $\gamma_s = 2\,c\bar{s}/(c\bar{u} + c\bar{d})$. The ratio $P_V = V/(V + P)$ of the fraction of D mesons produced in a vector state is expected to have a value of 3/4, from naive spin counting. Measurements of $R_{u/d}$, γ_s and P_V at HERA and e^+e^- collisions are shown in Fig. 3, supporting the assumption of universality. A significant strangeness suppression and a deviation from naive spin counting expected value are observed.

The fragmentation fractions of the c quarks hadronizing as particular charmed hadrons, $f(c \to D, \Lambda_c)$, can be calculated as the ratio of the production cross section of a specific charmed hadron to the sum of all charmed

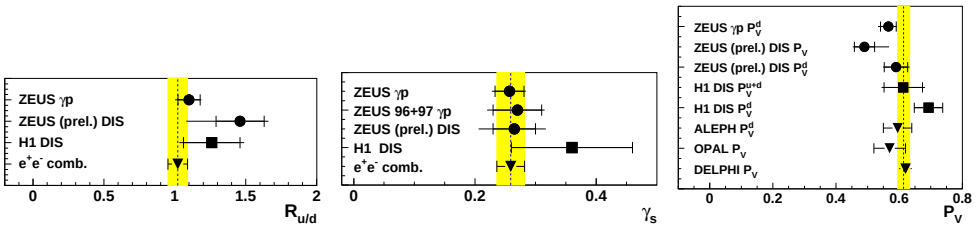

Fig. 3. The fragmentation parameters $R_{u/d}$, γ_s and P_V measured at HERA compared to e^+e^- annihilation results.

ground state hadrons. Comparison of the HERA measurements to combined values in e^+e^- collisions is in agreement with the assumption of universality.

Fragmentation functions are used to parametrise the energy transfer from quark to hadron. The H1 experiment has measured the $c \to D^*$ fragmentation function [8]. Comparison to e^+e^- data shows reasonable agreement with the assumption of universality.

5. Summary

The description of charm cross sections by QCD is good in general, but fails in the details. New measurements of charm photoproduction with jet events give more details of the final state and the event kinematic and show the need for further theoretical developments. Charm fragmentation fractions and ratios have been measured at HERA with competitive errors, showing also evidence of the universal character of charm fragmentation.

REFERENCES

[1] ZEUS Collaboration, contributed paper to the XXXIst International Conference on High Energy Physics, Amsterdam, Abstract 786, (2002).

[2] H1 Collaboration, contributed paper to the XXXIInd International Conference on High Energy Physics, Beijing, Abstract 5-0162, (2004).

[3] ZEUS Collaboration, contributed paper to the International Conference of High Energy Physics, Lisboa, Abstract 438, (2005).

[4] ZEUS Collaboration, contributed paper to the International Conference of High Energy Physics, Lisboa, Abstract 351, (2005).

[5] ZEUS Collaboration, S. Chekanov *et al.*, accepted by *Eur. Phys. J.* **C**.

[6] H1 Collaboration, A. Aktas *et al., Eur. Phys. J.* **C38**, 447 (2005).

[7] L. Gladilin, "Charm Hadron Production Fractions", `hep-ex/9912064`.

[8] H1 Collaboration, contributed paper to the XXIInd International Symposium on Lepton–Photon Interactions at High Energy, Uppsala, Abstract 407, (2005).