

BEAUTY & CHARM PHYSICS AT HERA

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The most recent beauty and charm results from the ZEUS and H1 collaborations are presented.

1 Introduction

Heavy quark production in electron-proton collisions at HERA is dominated by Boson Gluon Fusion at leading order ($\gamma g \rightarrow q\bar{q}$) in which a virtual photon coming from the electron vertex interacts with a gluon from the proton to produce a heavy quark pair. There are two main kinematic regimes, Deep Inelastic Scattering (DIS) for photon virtualities $Q^2 > 1 \text{ GeV}^2$ and photoproduction (γp) for $Q^2 \simeq 0 \text{ GeV}^2$. Studying the production of heavy quarks enables comparison of the experimental results to theoretical Next to Leading Order (NLO) Quantum Chromodynamics (QCD) calculations. The experimental results can also be compared to Leading Order (LO) plus parton shower Monte Carlo (MC) programmes.

2 Charm

Measuring the D^* cross section at low Q^2 is a test of the NLO calculation for charm production in the transition region from DIS to γp . Q^2 values in the range $0.05 < Q^2 < 0.7 \text{ GeV}^2$ are reached by measuring the scattered electron in the Beam Pipe Calorimeter (BPC) [1]. The measured cross section is well described by the predictions of NLO QCD (figure 1) showing that this kinematic region is well understood theoretically.

Charm mesons have long lifetimes enabling them to be tagged via their displaced secondary vertices [2]. Selecting tracks depending on their decay length significance (S_1)

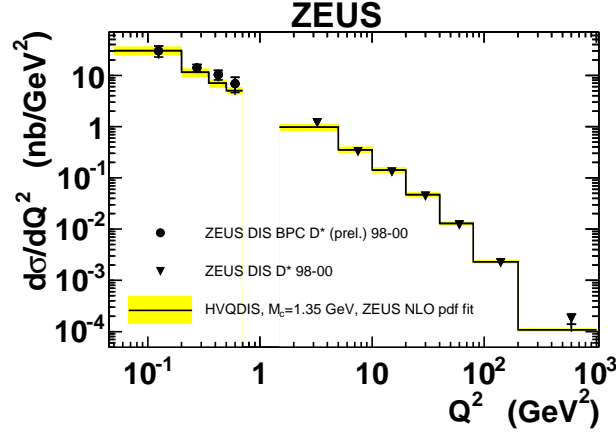


Figure 1: Differential D^* cross section as a function of Q^2 .

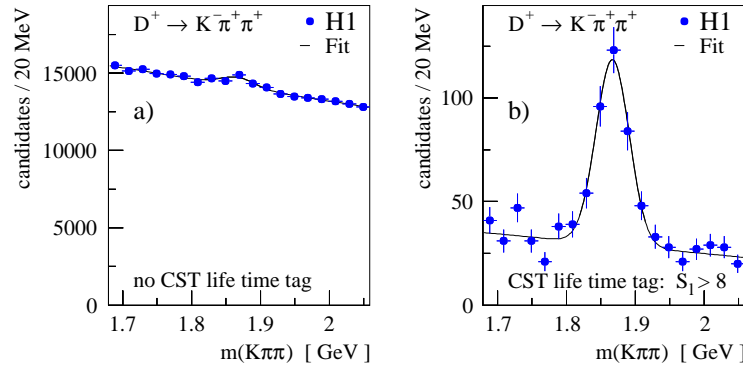


Figure 2: Invariant mass distributions $m(K\pi\pi)$ for $D^+ \rightarrow K^-\pi^+\pi^+$ decay candidates (left) before and (right) after a cut on the decay length significance $S_l > 8$.

greatly improves the purity of the signal. For $S_l > 8$, the D^+ signal to background ratio improves by factor of 50, and 20% of the signal is kept (figure 2).

For events containing a D^* and two jets in γp , correlations can be studied between the jets to allow detailed comparisons with QCD calculations [3]. x_γ^{obs} is the fraction of the photon's four momentum, manifest in the two highest p_T jets, entering the hard dijet subprocess. The NLO calculation describes shape of the data for direct γp ($x_\gamma^{\text{obs}} > 0.75$), with the data favouring a lower charm mass. The shape is not as well described

by the NLO calculation for resolved γp ($x_\gamma^{\text{obs}} < 0.75$), indicating a need for higher order corrections to the NLO calculations. The LO + parton shower MCs particularly HERWIG fit the data well for both direct and resolved γp (figure 3). Similar results have been found looking at correlations between the D^* and a jet not containing the D^* [4].

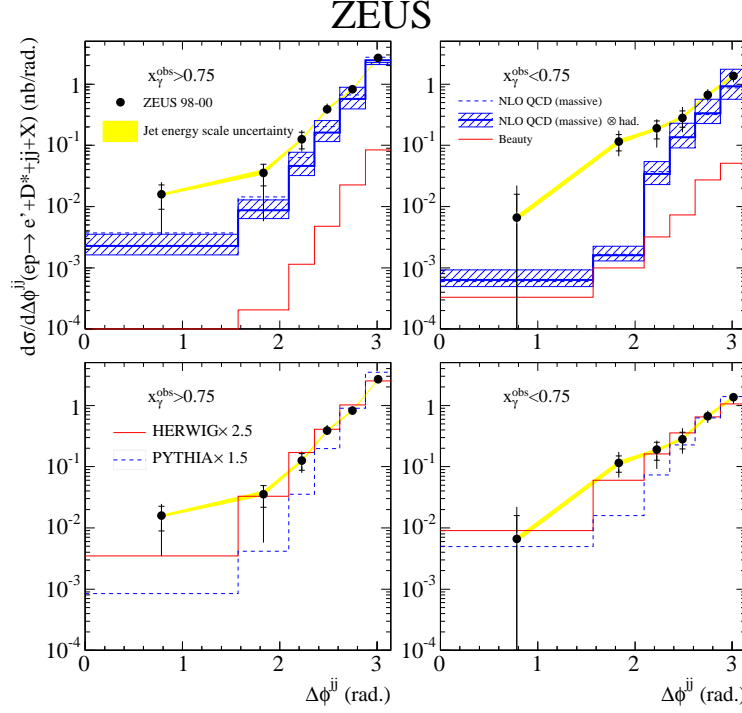


Figure 3: Cross section $d\sigma/d\Delta\phi^{jj}$ for dijets in D^* photoproduction.

3 $F_2^{c\bar{c}}$ & $F_2^{b\bar{b}}$ from Impact Parameters

Using the impact parameter significance of tracks, charm and beauty fractions can be calculated by fitting distributions in different x - Q^2 intervals [5, 6]. Differential cross sections can then be measured and the structure functions $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ evaluated from the expression

$$\frac{d^2\sigma^{c\bar{c}}}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4} \left[\left(1 + (1-y)^2\right) F_2^{c\bar{c}} - y^2 F_L^{c\bar{c}} \right]$$

(and similarly for $F_2^{b\bar{b}}$) and plotted in figure 4. The QCD calculations fit the data reasonably well with scaling violations apparent at low x .

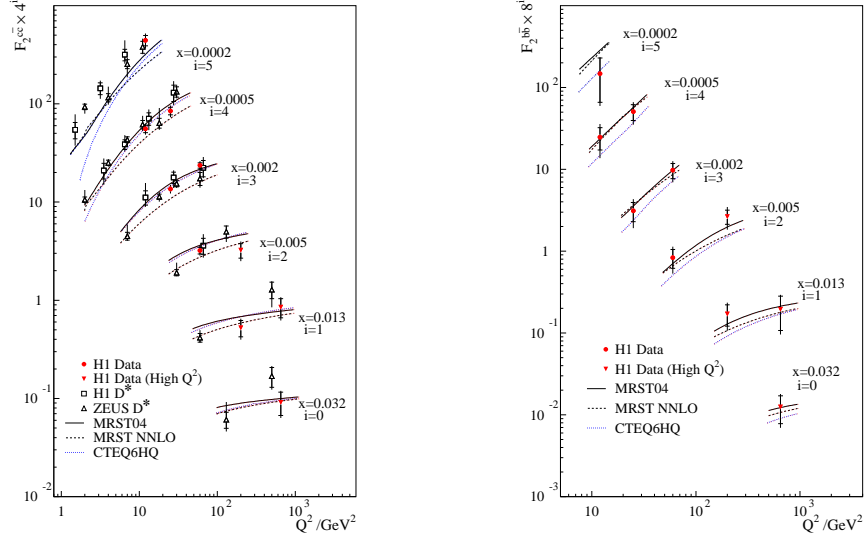


Figure 4: The measured $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ shown as a function of Q^2 for various x values.

4 Beauty

Using the semileptonic decay of a B meson to a muon with an accompanying jet, the beauty can be separated from charm and light flavours by exploiting the high mass and long lifetime of B mesons. By simultaneously fitting the impact parameter and the relative transverse momentum of the muon to the axis of the associated jet the beauty fraction can be extracted [7, 8]. The NLO calculation describes the data reasonably well, though H1 have excess of events at low p_T^μ (figure 5).

By selecting events with two muons the background from charm and light flavours is suppressed. Separating the sample into high and low mass, isolated and non-isolated, like and unlike sign regions further constrains the background [9] and although this results in low statistics, the data agree with the theory and MC predictions (figure 6).

Figure 7 displays a summary of the beauty results from HERA showing a good coverage of measurements. There is a tendency of the data to lie above the NLO prediction though measurements with smaller errors are closer to the theory. Improved theoretical

understanding is needed to include higher orders but also improved precision from the experimental results.

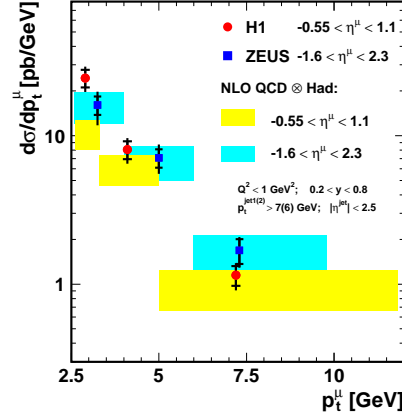


Figure 5: Differential cross section $d\sigma/dp_T$ for the γp process $ep \rightarrow e b \bar{b} X \rightarrow e j j \mu X'$.

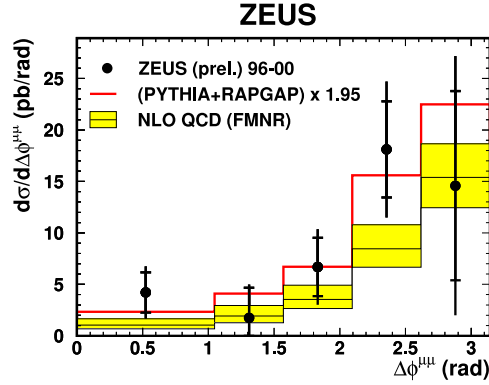


Figure 6: Cross section $d\sigma/d\Delta\phi^{\mu\mu}$ for dimuon events from $b\bar{b}$ decays in which each muon originates from a different $b(\bar{b})$ quark.

5 Conclusions

In general the charm results from HERA are in good agreement with NLO QCD. The beauty results are not as precise but tend to indicate that higher order theory calculations are needed.

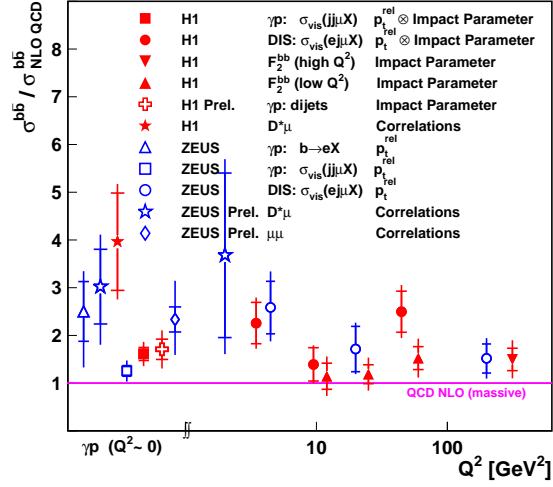


Figure 7: Ratio of beauty cross sections to the NLO QCD prediction for different measurements from HERA.

References

- [1] ZEUS Coll., Abstract 265, XXII International Symposium on Lepton-Photon Interactions at High Energy, Uppsala, Sweden, June/July 2005.
- [2] H1 Coll., A. Aktas *et al.*, Eur. Phys. J. **C38** 447 (2005).
- [3] ZEUS Coll., S. Chekanov *et al.*, Nucl. Phys. **B 729** 492 (2005).
- [4] H1 Coll., Abstract 406, XXII International Symposium on Lepton-Photon Interactions at High Energy, Uppsala, Sweden, June/July 2005.
- [5] H1 Coll., A. Aktas *et al.*, Eur. Phys. J. **C45** 23 (2006).
- [6] H1 Coll., A. Aktas *et al.*, Eur. Phys. J. **C40** 349 (2005).
- [7] ZEUS Coll., S. Chekanov *et al.*, Phys. Rev. **D70** 012008 (2004).
- [8] H1 Coll., A. Aktas *et al.*, Eur. Phys. J. **C41** 453 (2005).
- [9] ZEUS Coll., Abstract 269, XXII International Symposium on Lepton-Photon Interactions at High Energy, Uppsala, Sweden, June/July 2005.