Beauty Production at HERA using the H1 Detector

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Abstract. Recent measurements on beauty production at HERA using the H1 experiment are presented. The cross section for beauty dijets in photoproduction and the contribution of the inclusive beauty cross section in deep-inelastic scattering (DIS) are shown. The results are based on a method using the impact parameter, in the transverse plane, of tracks to the primary vertex, as measured by the H1 vertex detector. The measurements are compared with the predictions of next-to-leading order (NLO) QCD.

1. Introduction

In perturbative QCD (pQCD) calculations, the production of beauty quarks at HERA proceeds dominantly via the direct photon-gluon fusion (PGF) process $\gamma g \rightarrow b\bar{b}$, where the photon interacts with a gluon from the proton to produce a pair of heavy quarks in the final state. Therefore, the measurement of processes involving beauty production provides a test of the understanding of the QCD production mechanism and information on the gluon content of the proton. The presence of the beauty quark mass m_b provides an additional 'hard' scale to the momentum transfer of the exchanged boson Q and the transverse momentum of the beauty quark p_T meaning the perturbative series has to be treated in different ways depending on the relative magnitude of m_b, Q and p_T. At small scales ($Q, p_T \sim m_b$) the mass of the beauty quark is taken into account via the 'massive' PGF matrix element. At high scales ($Q, p_T \gg m_b$) the quark's mass may be neglected and it is treated as a 'massless' parton.

Two recent measurements on beauty production at HERA using the H1 experiment are presented here: the cross section for beauty dijets in photoproduction [1] and the contribution of the inclusive beauty cross section in DIS [2]. In the case of the photoproduction of dijets leading order QCD models predict additional contributions from processes involving resolved photons. In such processes the quasi-real photon fluctuates into a hadronic state before the hard interaction and thus acts as a source of partons. In the case of the inclusive contribution of processes involving beauty production to the proton structure function, $F_2^{b\bar{b}}$, the understanding of the gluon and quark distributions in the region of low Bjorken x has important implications for the measurement of standard model and new physics processes at the LHC.

2. Analysis Technique

For the analyses presented here events containing heavy quarks are distinguished from light quark events by the long lifetimes of c and b flavoured hadrons, which lead to displacements of tracks from the primary vertex. The distance of a track to the primary vertex δ is reconstructed using precise spatial information from the H1 vertex detector. To further distinguish the light, charm

(c) and beauty (b) components the significance, defined as the ratio of δ to its error, is measured for jets with exactly one selected track associated to the jet (S_1) and for the second highest absolute significance in jets with two or more selected tracks (S_2). The c, b and light quark fractions in the data are extracted using a simultaneous least squares fit of simulated reference distributions, obtained from Monte Carlo simulation, to the measured S_1 and S_2 distributions.

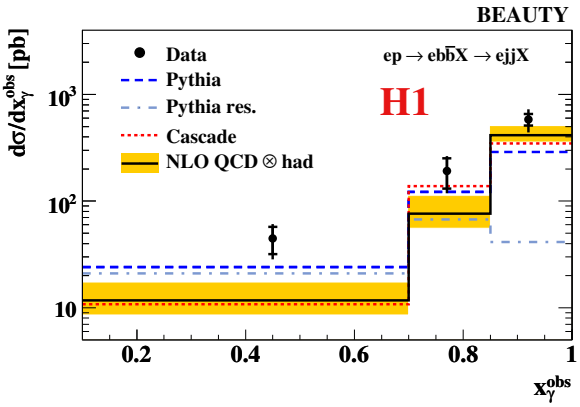

Figure 1. Differential b cross section for $d\sigma/dx_\gamma^{obs}$.

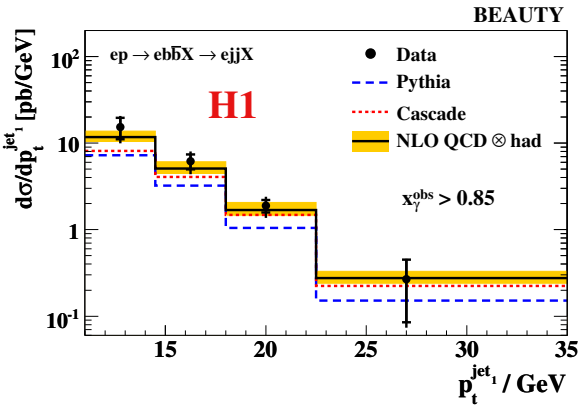

Figure 2. Differential b cross section for $d\sigma/dp_t^{jet_1}$.

3. Results

3.1. Photoproduction dijets

The total dijet beauty photoproduction cross section is measured in the range $Q^2 < 1$ GeV^2, $0.15 < y < 0.8$, $p_t^{jet_{1(2)}} > 11(8)$ GeV and $-0.9 < \eta^{jet_{1(2)}} < 1.3$. The 'massive' NLO QCD prediction of FMNR [3] is lower than the data by a factor 1.8, corresponding to 1.6 standard deviations, taking both experimental and theoretical uncertainties into account.

The measured differential cross sections as functions of x_γ^{obs} and the transverse momentum of the leading jet $p_t^{jet_1}$ for $0.85 < x_\gamma^{obs} < 1$ are shown in figures 1 and 2. The variable x_γ^{obs}, in a leading order picture, corresponds to the fraction of the photon's energy in the proton rest frame that enters the hard interaction. For direct photon-gluon fusion processes $x_\gamma^{obs} \sim 1$, while for resolved photon processes x_γ^{obs} can be small. A large difference between the beauty data and the NLO QCD calculation is observed in the region of small values of x_γ^{obs} , where the prediction lies significantly below the data. The beauty cross section versus $p_t^{jet_1}$ in the range $0.85 < x_\gamma^{obs} < 1$ is reasonably well described, the agreement being significantly better than for the whole range of x_γ^{obs}.

The relative contribution of beauty to the inclusive dijet cross section is also measured. The data are compared with the PYTHIA Monte Carlo simulation which predicts an increase of the relative beauty contribution towards large x_γ^{obs} where direct photon-gluon fusion processes dominate. In the region $x_\gamma^{obs} > 0.85$, the beauty contribution is found to be consistent with the naïve quark charge counting prediction of 1/11 which assumes all quarks to be massless.

3.2. Inclusive Cross Section in DIS

The inclusive 'reduced' beauty cross section in DIS $\tilde{\sigma}^{b\bar{b}}$ ($\tilde{\sigma}^{b\bar{b}} \simeq F_2^{b\bar{b}}$) is shown as a function of x for different values of Q^2 in figure 3. The structure function $F_2^{b\bar{b}}$ is shown as a function of Q^2 for different values of x in figure 4. The data are compared with NLO QCD predictions from the MRST and CTEQ fitting groups (MRST04, CTEQ6HQ). The predictions are based on schemes

which aim to interpolate between 'massive' behaviour at low Q^2 and 'massless' behaviour at high Q^2. The difference between the two QCD calculations, which reaches a factor 2 at the lowest Q^2 and x, arises from different treatments of mass threshold effects. Within the current experimental errors the data is consistent with both QCD predictions.

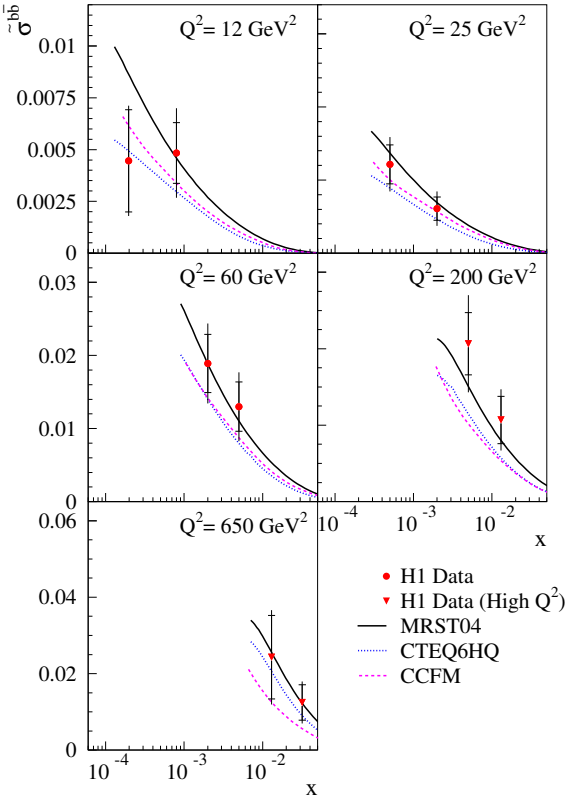

Figure 3. The measured reduced cross section $\tilde{\sigma}^{b\bar{b}}$ shown as a function of x for 5 different Q^2 values.

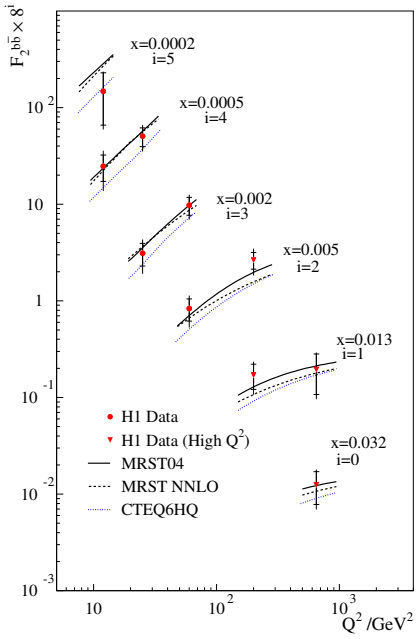

Figure 4. The measured $F_2^{b\bar{b}}$ shown as a function of Q^2 for various x values.

4. Conclusion

Measurements of the photoproduction of beauty dijets and the inclusive beauty cross section in DIS have been presented. The measurements have been made using the impact parameters of tracks from decays of long lived b hadrons as reconstructed from the H1 vertex detector. The cross sections are found to be well described by the predictions of perturbative QCD at NLO.

5. References

[1] A. Aktas *et al.* [H1 Collaboration], Eur. Phys. J. C **47** (2006) 597 [arXiv:hep-ex/0605016].

[2] A. Aktas *et al.* [H1 Collaboration], Eur. Phys. J. C **40** (2005) 349 [hep-ex/0411046];
A. Aktas *et al.* [H1 Collaboration], Eur. Phys. J. C **45** (2006) 23 [hep-ex/0507081].

[3] S. Frixione, M. L. Mangano, P. Nason and G. Ridolfi, Phys. Lett. B **348** (1995) 633 [hep-ph/9412348].