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BEAUTY IN DIS WITH ZEUS

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The results of measurement of beauty quark production at HERA performed by the H1 and ZEUS collaborations are presented. Total visible cross sections and the differential cross sections have been measured in the deep inelastic scattering regime. The results are compared with the NLO QCD calculations.

1 Introduction

The measurement of the production of heavy quarks can be used to probe Quantum Chromodynamics (QCD) and to understand the structure of the proton and photon. The large beauty (b) quark mass provides a hard scale that ensures perturbative QCD (pQCD) is applicable and makes such calculations more reliable than for light quarks. Additionally, the production of b quarks is a source of background for many searches for new physics at existing and future experiments.

The cross sections for b-quark production in strong interactions have been measured in proton-antiproton collisions at the Sp$\bar{\text{p}}$S [1] and the Tevatron [2] and, more recently, in two-photon interactions at LEP [3] and in γp interactions at HERA [4]. Some of the b-production cross sections are significantly above the QCD expectations calculated to next-to-leading order (NLO) in the strong coupling constant, α_s.

This analysis presents results of the measurement of b-quark production in DIS obtained with the ZEUS detector at HERA, in the reaction with at least one hard jet in the Breit frame and a muon, from a b decay, in the final state: $ep \rightarrow e\, b\, \bar{b}\, X \rightarrow e+\text{jet}+\mu+X$. Experimental procedures rely on signatures or features characteristic of b production and decay. The one used in the presented analysis is a measurement of the transverse momentum, p_T^{rel}, of the muon produced in the semi-leptonic decay with respect to the axis of the closest jet. The fact that this spectrum is harder for b quarks than for c or light quarks allows a statistical separation of the signal and the background. Total visible cross sections and the differential cross sections have been measured. The results are compared with the NLO QCD calculations and MC Models.

2 Total Cross Section

The total visible cross section, $\sigma_{b\bar{b}}$, was determined in the kinematic range $Q^2 > 2\ \text{GeV}^2$, $0.05 < y < 0.7$ with at least one hadron-level jet in the Breit frame with $E_{T,\text{jet}}^{\text{Breit}} > 6$ GeV and $-2 < \eta_{\text{jet}}^{\text{lab}} < 2.5$ and with a muon fulfilling the following conditions: $-0.9 < \eta^{\mu} < 1.3$ and $p_T^{\mu} > 2$ GeV or $-1.6 < \eta^{\mu} < -0.9$ and $p^{\mu} > 2$ GeV. The muons coming from direct and indirect b decays are matched to any jet in the event. The measured cross section is $\sigma_{b\bar{b}} = 40.9 \pm 5.7$ (stat.)$^{+6.0}_{-4.4}$ (syst.) pb.

This measurement has been corrected for electroweak radiative effects using HERACLES [10]. The result has been compared with a NLO QCD calculation implemented in the HVQDIS program [5], after folding the b quark momentum spectrum with a Peterson fragmentation function and subsequently with a spectrum of the semi-leptonic muon momentum taken from JETSET [6]. The NLO QCD prediction with hadronisation corrections is $20.6^{+3.1}_{-2.2}$ pb, which is about 2.5 standard deviations lower than the measured total cross section. The CASCADE [7] MC program, which implements a calculation based on the CCFM evolution equations [8] and uses a k_T-dependent gluon density, gives $\sigma_{b\bar{b}} = 28$ pb.

3 Differential Cross Sections

The differential cross sections were calculated in the same restricted kinematic range as the total cross section and the electroweak radiative corrections were evaluated in each bin. Figures 1a and 1b show the differential cross sections as functions of Q^2 and x, respectively, compared to the NLO QCD calculation. The NLO QCD predictions generally agree with the data; in the lowest Q^2 and lowest x bins, the data are about two standard deviations higher. Figures 1c and 1d show the same differential cross sections compared with the RAPGAP [9] and CASCADE MC simulations. CASCADE agrees with the data except for the lowest Q^2 and lowest x bin. RAPGAP is well below the data in all bins.

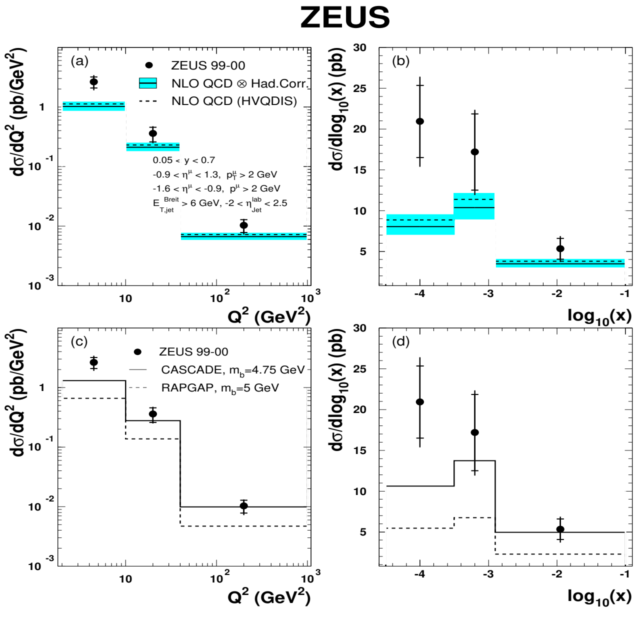

Figure 1. Differential b-quark cross section as a function of (a) Q^2 and (b) Bjorken x. The solid line shows the NLO QCD calculations with the hadronisation corrections and the dashed line the same calculation without the hadronisation corrections. Differential b-quark cross sections as a function of (c) Q^2 and (d) Bjorken x, compared with the LO QCD MC programs CASCADE (solid line) and RAPGAP (dashed line).

Figures 2a and 2b show the differential cross sections as functions of the transverse momentum, p_T^μ, and pseudorapidity, η^μ, of the muon, compared to the NLO QCD calculation. They generally agree with the data; in the lowest p_T^μ bin and the high η^μ bin, the NLO QCD prediction is about two standard deviations below the data. Figures 2c and 2d show the same differential distributions compared with CASCADE and RAPGAP. CASCADE describes the measured cross sections well except for the lowest p_T^μ bin, while RAPGAP lies below the data.

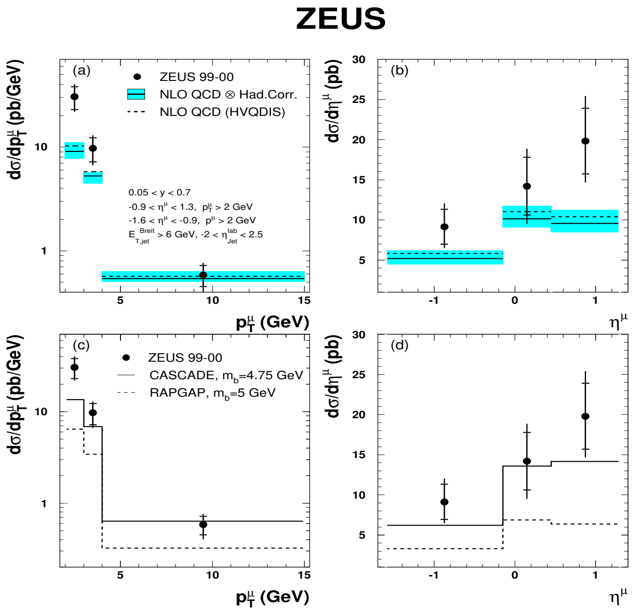

Figure 2. Differential b-quark cross section as a function of (a) p_T^μ and (b) η^μ. The solid line shows the NLO QCD calculations with the hadronisation corrections and the dashed line the same calculation without the hadronisation corrections. Differential b-quark cross sections as a function of (c) p_T^μ and (d) η^μ, compared with the LO QCD MC programs CASCADE (solid line) and RAPGAP (dashed line).

Figure 3a shows the differential cross section as a function of $E_{T,\mathrm{jet}}^{\mathrm{Breit}}$ of the leading jet compared to the NLO QCD calculation. The NLO QCD prediction agrees with the data reasonably well, though it is systematically below. For the highest $E_{T,\mathrm{jet}}^{\mathrm{Breit}}$ bin the difference is about two standard deviations. Figure 3b shows the same differential distribution compared with CASCADE and RAPGAP. For all $E_{T,\mathrm{jet}}^{\mathrm{Breit}}$ values, CASCADE reproduces the measured cross section reasonably well while RAPGAP lies below the data.

4 Summary

The production of b quarks in the DIS process $ep \to e\ \mu$ jet X has been measured with the ZEUS detector at HERA. The NLO QCD prediction for the visible cross section lies about 2.5 standard deviations below the measured value.

The differential cross sections are in general consistent with the NLO QCD predictions; however at low values of Q^2, Bjorken x, and muon transverse momentum, and high values of jet transverse energy and muon pseudorapidity, the prediction is about two standard deviations below the data.

The CASCADE MC program, implementing the CCFM QCD evolution equations, gives a good description of the measured cross sections. It is, however, below the data for low values of the transverse momenta, low Q^2 and low values of x. RAPGAP is well below the data for all measured cross sections.

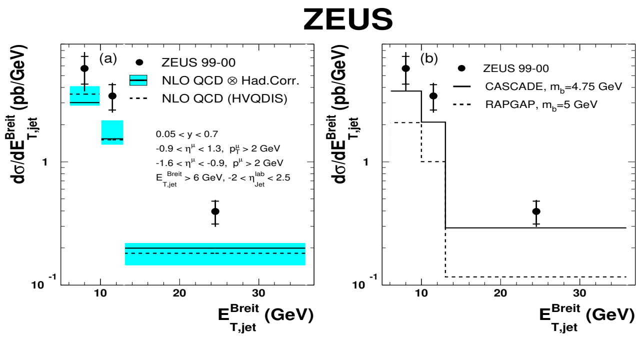

Figure 3. Differential b-quark cross section as a function of (a) $E_{T,\mathrm{jet}}^{\mathrm{Breit}}$. The solid line shows the NLO QCD calculations with the hadronisation corrections and the dashed line the same calculation without the hadronisation corrections. Differential b-quark cross sections as a function of (c) $E_{T,\mathrm{jet}}^{\mathrm{Breit}}$, compared with the LO QCD MC programs CASCADE (solid line) and RAPGAP (dashed line).

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