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Heavy flavours in DIS using muon tags at HERA

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The production of charm and beauty quarks in ep interactions has been measured with the ZEUS detector at HERA for squared four-momentum exchange $Q^2 > 20$ GeV^2, using an integrated luminosity of 126 pb^{-1}. Charm and beauty quarks were identified through their decays into muons. Cross sections are presented for muon transverse momenta $p_T^\mu > 1.5$ GeV and pseudorapidities $-1.6 < \eta^\mu < 2.3$. The charm and beauty contributions to the proton structure function F_2 were also extracted. The results agree with previous measurements based on independent techniques and are well described by QCD predictions.

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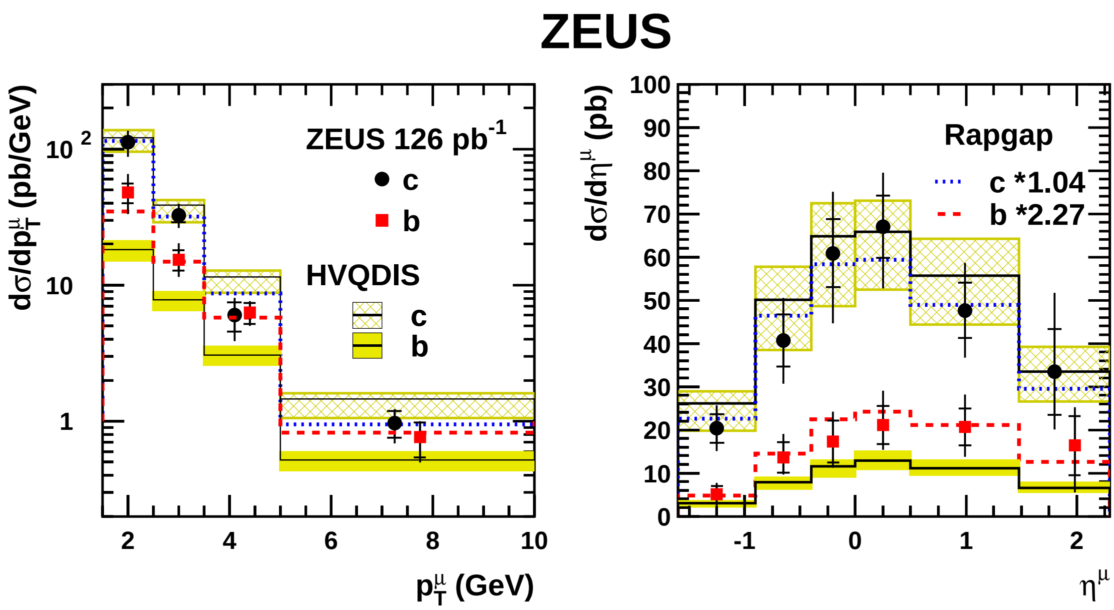

Figure 1: Differential cross sections for muons from charm (c) and beauty (b) as a function of p_T^μ (left panel) and η^μ (right panel). The data are compared to the NLO QCD predictions obtained with the HVQDIS program and to the RAPGAP Monte Carlo scaled by a factor 1.04 and 2.27 respectively for c and b.

1. Introduction

The production of heavy quarks (HQ) in deep inelastic scattering (DIS), $ep \to eQ\bar{Q}X$, provides a test of QCD in the presence of multiple hard scales such as the squared four momentum exchange Q^2 and the quark mass m_Q. HQ production is directly sensitive to the gluon parton density function (PDF) of the proton since it occurs, at leading order, thorugh the boson-gluon fusion subprocess $\gamma^* g \to Q\bar{Q}$. Different methods have been used to tag charm and beauty production in DIS: reconstructed D mesons, inclusive lifetime tag analyses and the leptons from semileptonic HQ decays. We present here a recent ZEUS measurement [1] of charm and beauty production from their decays into muons. It is the first time that leptonic tags are used for charm measurements at HERA.

2. Cross section measurements

The analysis is based on the first part of the HERA II data, corresponding to an integrated luminosity of 126 pb^{-1}. A sample of muons with $p_T^\mu > 2.5$ GeV and $-1.6 < \eta^\mu < 2.3$ was selected in DIS events with $Q^2 > 20$ GeV^2 and $0.01 < y < 0.7$. The sample contains muons from charm, beauty and light flavour (LF) events. The muons from LF events originate from in–flight decays of charged K and π mesons and from leakages of hadronic showers into the muon chambers. The c, b and LF content of the muon sample was obtained exploiting three discriminating variables: δ, the signed impact parameter of the muon with respect to the primary vertex; $p_T^{\rm rel}$, the transverse momentum of the muon with respect to the associated jet axis; and $P_T^{{\rm miss}||\mu}$ the event missing transverse momentum in the muon direction.

The measured cross section for muons coming from charm and beauty decays are $\sigma^c = 164 \pm 10({\rm stat.})^{+30}_{-31}({\rm syst.})$ pb and $\sigma^b = 63 \pm 7({\rm stat.})^{+18}_{-11}({\rm syst.})$ pb. The corresponding QCD next-

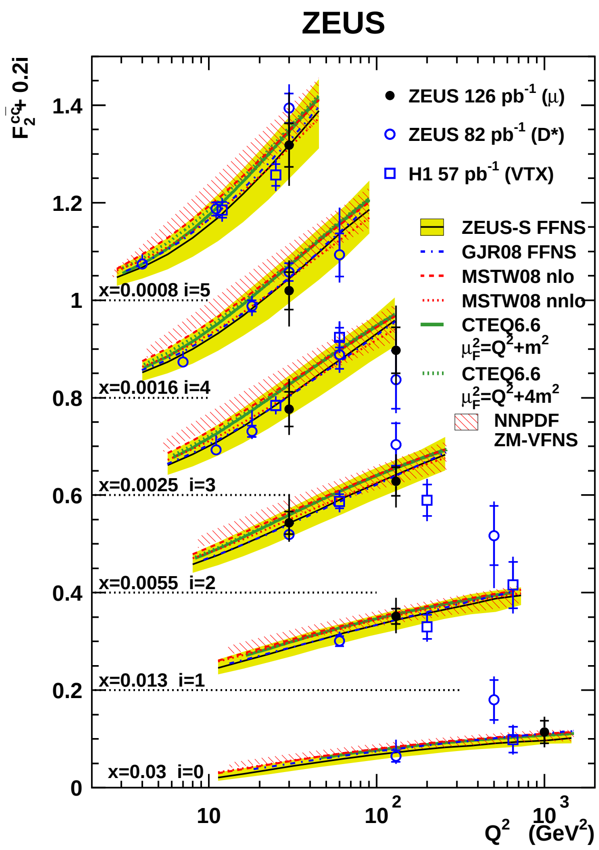

Figure 2: $F_2^{c\bar{c}}$ extracted from the ZEUS muon [1] (μ) and D^* [2] (D^*) data and from the H1 inclusive lifetime analysis [3] (VTX). The data are shown as a function of Q^2 for fixed x values. The band represents the NLO calculation in the fixed-flavour-number scheme (FFNS) based on the ZEUS-S PDF fit and its uncertainty obtained from variations of the renormalisation and factorisation scales, of the charm mass and of the PDFs. The different curves show the NLO FFNS calculation of [4] (GJR08), the GM-VFNS NLO and NNLO calculations of [5] (MSTW08) and the NLO GM-VFNS calculations of [6] (CTEQ6.6) with two different choices of the factorisation scale μ_F. The dashed area shows a ZM-VFNS calculation based on the NNPDF1.0 [7] with the corresponding uncertainty.

to-leading order (NLO) predictions are $\sigma^c_{\rm nlo} = 184^{+26}_{-40}$ pb and $\sigma^b_{\rm nlo} = 33 \pm 5$ pb. The charm cross section is in good agreement with the QCD result while the beauty cross section is about two standard deviations above the theoretical value. Differential muon cross sections as a function of p_T^μ and η^μ are shown in Fig. 1, compared to the NLO predicitions. The shape of the distributions is well reproduced by the QCD calculations.

3. Extraction of $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$

The cross sections for muons coming from c and b in the visible kinematic range, measured in bins of x and Q^2, have been used to extract the c and b contributions to the proton structure function F_2: $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$. This extraction requires some model assumption on the kinematical distributions of c and b quarks. The uncertainty related to the model assumptions was evaluated by varying the model parameters. It is always small for beauty while it is one of the dominating uncertainties for charm at low Q^2. Figure 2 shows the extracted $F_2^{c\bar{c}}$ compared to a selection of previous results. The muon data are in good agreement with previous results and competitive at large Q^2. Figure 3 shows $F_2^{b\bar{b}}$ compared to the recent H1 preliminary results. The agreement is good. Calculations based on different QCD approaches are also shown: a NLO calculation in the fixed-flavour-number scheme (FFNS) based on the ZEUS-S PDFs; the NLO FFNS calculation of [4] (GJR08); the NLO

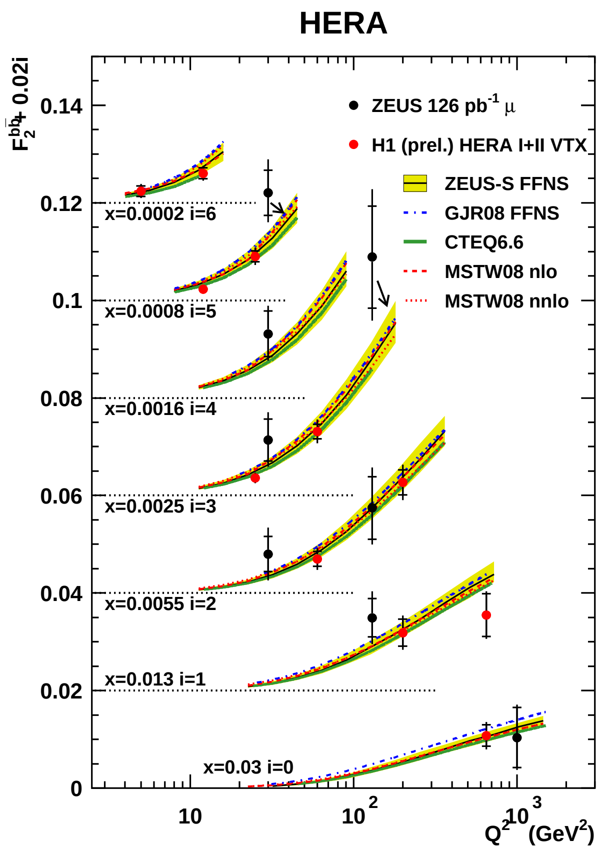

Figure 3: $F_2^{b\bar{b}}$ extracted from the ZEUS muon [1] (μ) and from the preliminary H1 combination of the HERA I and HERA II lifetime analysis [8] (VTX). The data are shown as a function of Q^2 for fixed x values. The band represents the NLO FFNS calculation based on the ZEUS-S PDF fit and its uncertainty obtained from variations of the renormalisation and factorisation scales, of the charm mass and of the PDFs. The different curves show the NLO FFNS calculation of [4] (GJR08), the NLO and NNLO calculations in the GM-VFNS of [5] (MSTW08) and the NLO GM-VFNS calculations of [6] (CTEQ6.6) with $\mu_F^2 = Q^2 + m^2$.

and NNLO calculations in the "general mass variable-flavour-number scheme" (GM-VFNS) of [5] (MSTW08); and the NLO GM-VFNS calculations of [6] (CTEQ6.6). In the charm case, a "zero-mass variable-flavour-number scheme" (ZM-VFNS) calculation based on the NNPDF1.0 [7] PDFs is also shown. All the above approaches produce similar predictions in the kinematic range under study. They are in general in good agreement with the data.

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