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Heavy Quark Production at the H1 Experiment at HERA

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Recent measurements of charm and beauty production at the H1 Experiment at the ep collider HERA are presented. The measurements of b-quarks in photoproduction indicate a generally good understanding of the production process. The new charm measurements achieve a new level of detail and experimental precision. The data are used to determine the structure functions $F_2^{c\bar{c}}$ of charm quark contributions in the proton and the results are compared with predictions from perturbative QCD calculations.

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1. Introduction

Measurements of heavy quark production are a powerful means to exploring the dynamics of the strong interaction described by perturbative QCD. Quantitative predictions of cross sections for the production of heavy hadrons in ep-collisions assume factorization of a number of ingredients: the parton distributions of the proton, the hard matrix element, as well as hadronization and fragmentation effects. For the calculation of the matrix elements the largeness of the heavy quark mass provides an additional energy scale which interplays with other scales, such as the virtuality Q^2 of the exchanged photon, or the transverse momentum p_t of the outgoing heavy quarks. Precise measurements allow for a verification of the factorization approach and a quantitative determination of the non-calculable ingredients. Theoretical calculations are generally available to next-to-leading order (NLO) [1, 2, 3]. Calculations of the inclusive c and b contributions are available to next-to-next-to-leading order (NNLO) [4, 5, 6].

The H1 experiment was operated in the years 1992-2007 and collected a total integrated luminosity of about 0.5 fb^{-1}. The hermetic multi-purpose H1 detector has a cylindric geometry and consists of central drift chambers, surrounded by calorimeters and muon systems, allowing for the complete reconstruction of the events in the final state.

2. Beauty Production

A new measurement of b production at the production threshold has been performed in the channel $b\bar{b} \rightarrow eeX$ [7]. In this analysis, events with pairs of low momentum (>1 GeV) electrons in the final state are collected using a combination of the H1 Fast Track Trigger [8] and the Jet Trigger [9]. No jet selection is applied. The distribution of the invariant mass of the electron pair multiplied with their charge is used to determine the fraction of events with b quark pairs. The

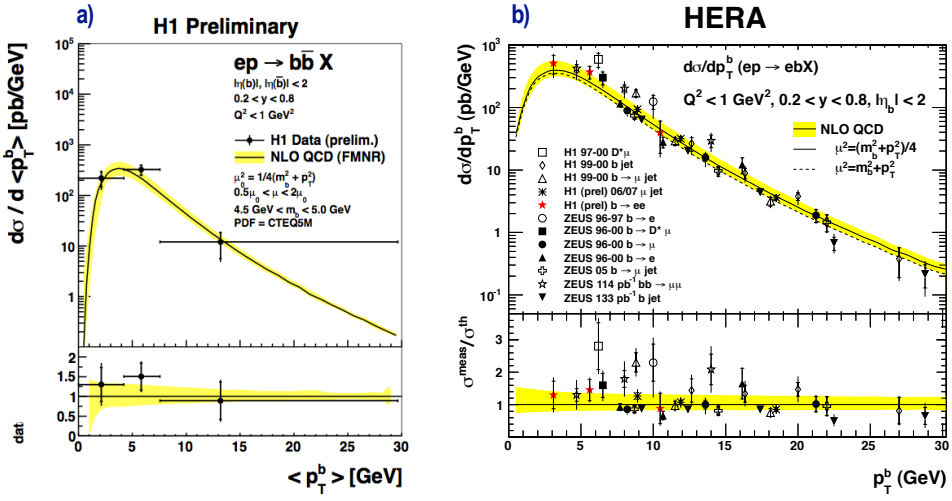

Figure 1: a) Photoproduction cross section for $b\bar{b}$-pairs [7]. b) Compilation of b-quark photoproduction cross section measurements as a function of the average transverse momentum of the b-quark. In both figures the band represents the result from the same theoretical NLO calculation [1].

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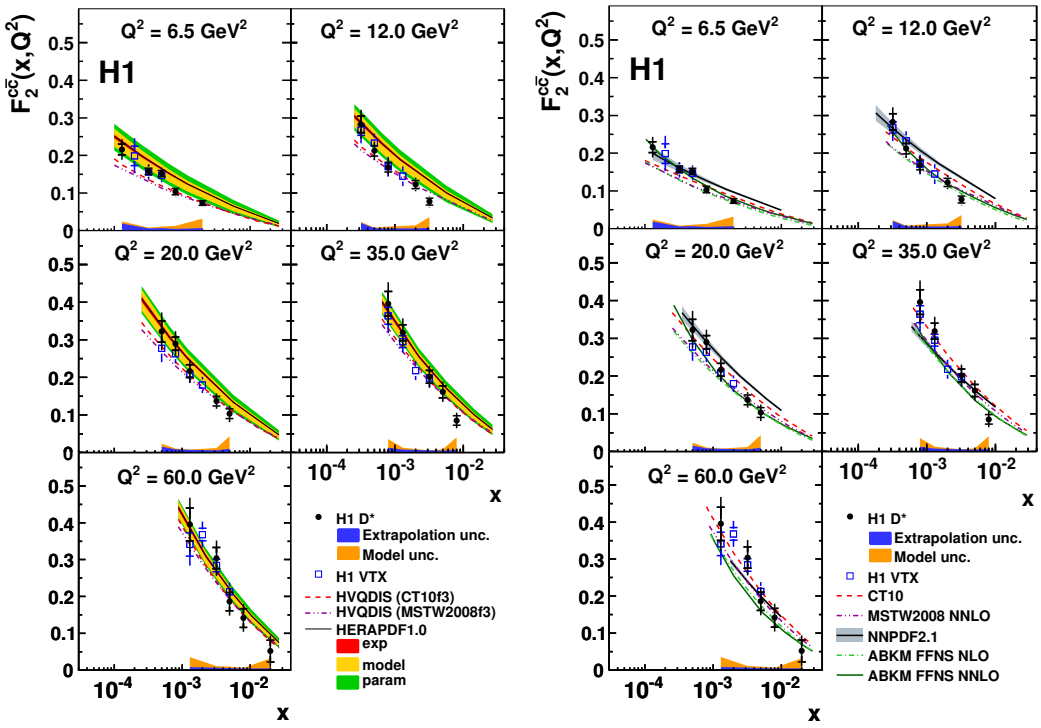

Figure 2: Left: The charm contribution $F_2^{c\bar{c}}$ as derived from $D^\star$ data with HVQDIS (points) and from an inclusive measurement using the H1 vertex detector [14] (open squares). The extrapolation uncertainty within the HVQDIS model is shown as blue band at the bottom of the plots. The outer (orange) band shows the model uncertainty. The data are compared to DGLAP predictions from HVQDIS using two different proton PDFs, and to the $F_2^{c\bar{c}}$ prediction of HERAPDF1.0 [15]. Right: The same data are compared to PDFs from several different groups.

differential cross section as a function of the average transverse b-quark momentum is shown in Figure 1a. Good agreement of the theory with the data is observed. This measurement adds to the wealth of existing measurements of photoproduction of beauty quarks from HERA (Figure 1b) which utilize a variety of experimental techniques, ranging from inclusive lifetime tag measurements to using lepton tags or angular and charge correlations. Comparison of the NLO calculation [1] with the data indicates a small trend of the calculation to be somewhat lower than the data, in particular towards small transverse b-quark momenta.

3. Charm Production

A new precise measurement of differential D^* meson production cross sections in ep collisions has been performed using the large data sample collected at the H1 Experiment between 2004 and 2007, corresponding to an integrated luminosity of 348 pb^{-1} [10, 11]. The measurement extends previous measurements in statistical and systematic precision. The results from the measurement are used to determine the charm structure function $F_2^{c\bar{c}} \propto d^2\sigma(ep \to c\bar{c}X)/dxdQ^2$, describing the inclusive charm cross section as a function of the scaling variable x and the photon virtuality Q^2, in

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analogy to the proton structure function $F_2(x,Q^2)$. In Figure 2, the results of the new measurement are shown together with an earlier complementary measurement, in which the lifetime signatures of inclusive tracks from charm and beauty quarks are exploited to determine their relative contributions to the inclusive ep cross section [12]. The data show good agreement with each other. The QCD predictions reproduce the data within uncertainties. At this level of precision, the data are able constrain the theory as calculated from QCD fits to the inclusive structure function data [4, 13].

Charm production has also been measured in photoproduction using a sample with D^* mesons and at least two jets [14]. Comparisons of the results with NLO QCD calculations show general agreement. There are however indications that contributions beyond NLO are necessary for an optimal description of the data.

4. Summary

Several new results of charm and beauty production have been presented. The charm measurements provide important constraints for the determination of the structure of the proton. Many different beauty measurements are available from HERA, exploiting different analysis techniques and covering a wide phase space. The theory calculations show general agreement with the data. Towards small transverse momenta of the b-quarks there is a trend of the theory to be somewhat lower than the data.

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