Heavy Flavor Production at the electron-proton collider HERA

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Abstract. An overview over the recent heavy flavor results of the H1 and ZEUS collaborations is presented. Various techniques to tag the heavy quark, which allow to explore different phase space regions, are employed. Predictions of pertubative QCD are compared to the charm and beauty production data. Charm and beauty fractions of the proton structure function F_2 are extracted.

1. Introduction

The investigation of heavy quark production is one of the main research topics at the ep collider HERA. Heavy quarks are predominantly produced via boson gluon fusion. The mass of the heavy quark provides a large scale which allows a calculation of the parton scattering cross section ($g\gamma \rightarrow c\bar{c}$) in pertubative QCD. The process $ep \rightarrow c\bar{c}(b\bar{b})$ is calculated by a convolution of the parton density functions of the proton (non pertubative part), the parton scattering cross section (pertubative part) and the fragmentation functions (non pertubative part), which describe the transition from the heavy quark to a meson. The measurement of heavy quarks is of interest since it allows a test of pertubative QCD. Heavy quark provide a sizeable contribution to the proton structure. Cross section measurements for heavy quark production and the extraction of the charm and beauty contribution to the proton structure function F_2, will be presented and compared with theoretical pQCD predictions.

2. Fragmentation

The fragmentation function of charm quarks to $D^{\star}$ mesons are determined as a function of z, which is defined as the ratio of the energy of the meson to the energy of the heavy quark. The fragmentation has been measured by the H1 and ZEUS collaborations [1, 2] where the charm quark momentum is approximated by using two different methods. In one method the charm quark is approximated by the jet containing the $D^{\star}$-meson, this method works far above the production threshold. Within the other method the charm quark's energy is approximated by the energy in the $D^{\star}$ meson's hemisphere; this method is applicable close to the production threshold. Figure 1 a) and b) shows the ZEUS and H1 fragmentation measurements as function a of the variable z, for the case that the $D^{\star}$-meson is measured together with a jet. These distributions are reasonably well described by the QCD model and similar Kartvelishvili fragmentation parameters α [3] are determind by H1 and ZEUS. Figure 1 c) shows the H1 measurement, by using the hemisphere method, for the sample where no jet is found. In this sample a harder fragmentation parameter is needed to describe the data. No single parameter set describes the fragmentation in the whole phase space.

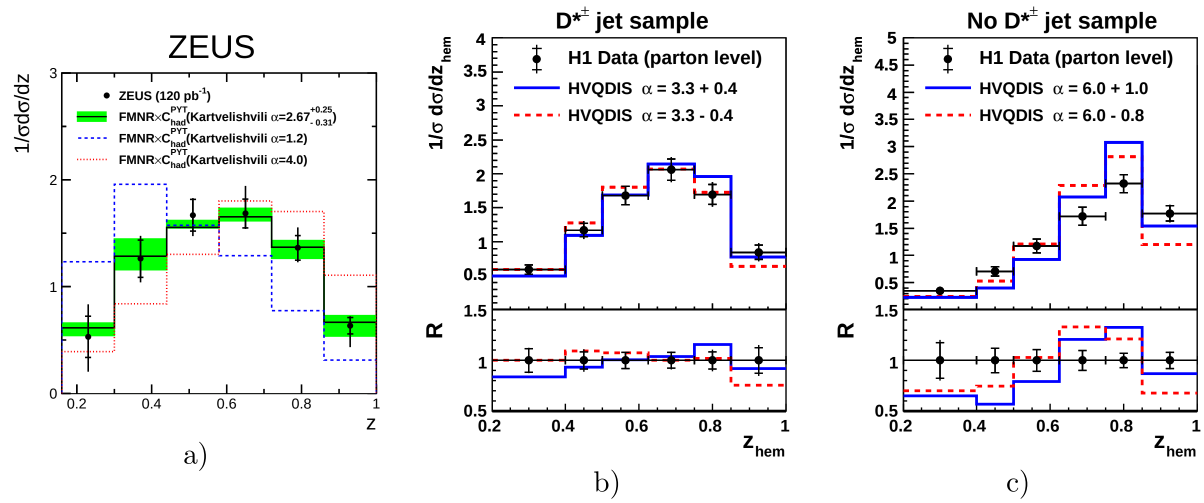


Figure 1. *Measurement of the charm fragmentation function by the H1 and ZEUS collaborations as a function of the variable z. Figure a) and b) shows the measurement for the case that the $D^\star$ meson is measured together with a jet. Figure c) shows the measurement for the case that no jet is reconstructed in the event. The measurements are compared to predictions provided by the NLO program HVQDIS.*

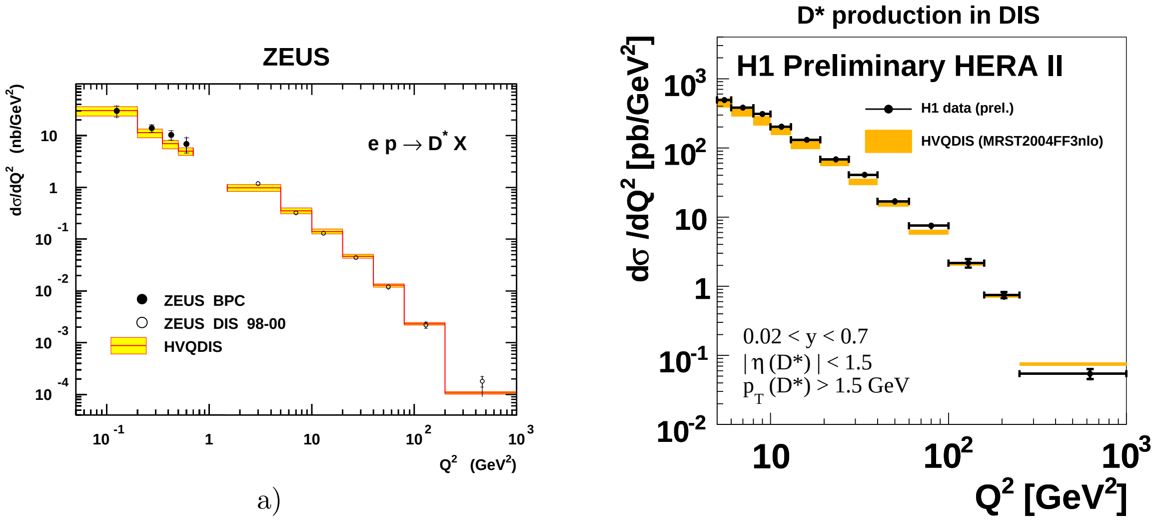
3. $D^\star$ meson production

Charm production can be identified by the presence of $D^\star$ mesons, which are reconstructed in the decay channel $D^{\star\pm} \rightarrow D^0\pi^\pm_{slow} \rightarrow K^\mp\pi^\pm\pi^\pm_{slow}$. These measurements are performed in a restricted η[1] and p_t range, which corresponds to the acceptance of the used detector devices. The cross section measurement of $D^\star$ mesons as a function of squared momentum transfer from the electron to the proton Q^2, measured in the kinematic region of deep inelastic scattering (DIS) by the H1 and ZEUS collaboration [4, 5] is shown in figure 2. The data is compared to pQCD calculations provided by the program HVQDIS [6]. A good agreement with the theory prediction is found over four orders of magnitude in Q^2. A similar measurement has been performed in photoproduction by the H1 collaboration [7]. The precision of these measurements is much higher than the accuracy of the NLO calculations. The theoretical uncertainties are estimated by scale variations and correspond to missing higher order terms.

4. Measurement from semileptonic decays and inclusive lifetime tag

The measurement of beauty production is based on the detection of semileptonic decays, lifetime information or a combination of both methods. These methods allow the measurement of charm production at the same time. In contrast to the $D^\star$ analyses, both methods are sensitive to lower p_t of the heavy quark. The ZEUS collaboration has performed a measurement of beauty production in the DIS kinematic regime based on two electrons in the final state $b \rightarrow ee$ [8] and a measurement which is based on semileptonic decays of beauty $b \rightarrow \mu x$ [9]. The H1 collaboration performed a similar measurement, based on semileptonic decays, in the photoproduction regime [10]. A measurement which employs the lifetime information of the event has been performed by the H1 collaboration [11]. In all these measurements a good agreement of the beauty production with pertubative QCD is found.

[1] The pseudorapidity η is defined via the relation $\eta = -\ln(\tan\theta/2)$, where θ is the polar angle with respect to the proton direction.



a) b)

Figure 2. *Measurement of the $D^\star$ cross section as a function of Q^2 performed by the H1 and ZEUS collaborations. The measurements are compared to predictions provided by the NLO program HVQDIS [6].*

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

The structure functions $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ are defined in analogy to F_2 and describe the fraction of charm (beauty) in the final state. In order to extract $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ from the measurements described above the cross sections are extrapolated to the full phase space. The extrapolation factors can be calculated in pQCD, for which a good understanding of the fragmentation is required. The structure functions are universal and hence can be used to compare experimental results from different analysis techniques. Figure 3 shows a summary of the measurement of the proton structure function $F_2^{c\bar{c}}$ as a function of Q^2 for different values of x and $F_2^{b\bar{b}}$ in bins of Q^2 as a function of x. Clear scaling violations are observed towards large Q^2 at low values of x. A good agreement between the various analysis techniques and different data sets is found. The data is compared to pQCD calculations, the precision of the charm data is high enough to resolve between different PDF sets at low Q^2 and x. In general a good agreement with the pQCD prediction is found.

6. Acknowledgements

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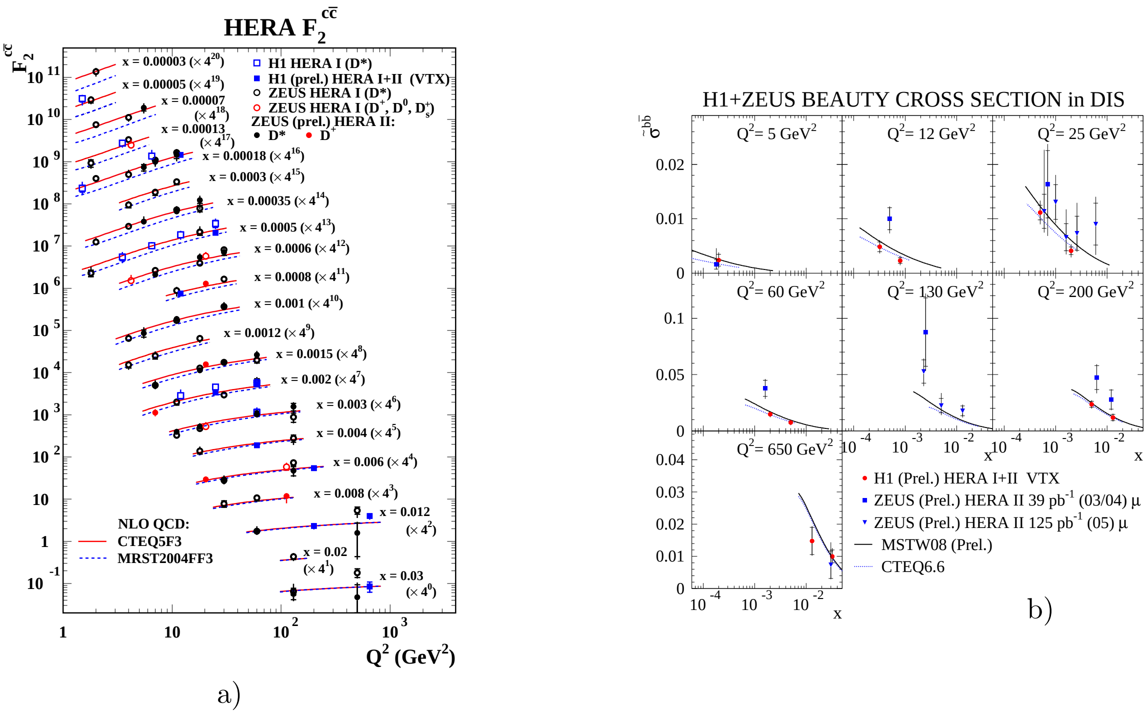

Figure 3. *a) The structure function $F_2^{c\bar{c}}$ as a function of Q^2 for various x values. b) The measured averaged reduced cross section $\tilde{\sigma}_{b\bar{b}}$ shown as a function of x for different Q^2 values. The inner error bars show the statistical error, the outer error bars represent the statistical and systematic errors added in quadrature. The data is compared to predictions of pertubative QCD.*

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