Charm production at HERA: Experimental overview

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September 16, 2008

Abstract

Recent preliminary results on charm production at HERA from the H1 and ZEUS collaboration are summarized.

1 Introduction

Several new measurements of open charm production have been performed by the H1 and ZEUS collaboration:

H1:

- $D^{*\pm}$ Production at low Q^2 with the H1 Detector
- Measurement of the $D^{*\pm}$ Production cross section in Photoproduction with the H1 Detector using HERA II data
- Study of Charm Fragmentation into $D^{*\pm}$ Mesons in Deep-Inelastic Scattering at HERA

In case of the H1 single differential D^* cross section measurement at the bottom of the distributions the ratio between data and the predictions normalised to the respective total visible cross section is shown in order to better judge on the shape of the distribution.

ZEUS:

- $D^{*\pm}$ in DIS and Measurement of F_2^c
- Measurement of $D^{*\pm}$ Meson Production in DIS ep Scattering at low Q^2
- Measurement of excited charm and charm-strange mesons production at HERA
- Measurement of the Charm Fragmentation function

The details of the measurements like the visible range will not be discussed here as they are given in the literature cited for each measurement. For both experiments high statistic charm event samples are tagged by $D^{*\pm}$ mesons reconstructed in the golden decay channel: $D^{*\pm} \rightarrow D^0\pi^\pm_{\rm slow} \rightarrow K^\mp\pi^\pm\pi^\pm_{\rm slow}$. The well known mass difference method reduces symmetric systematic uncertainties and allows the extraction of the D^* meson signal by fits out of the background dominated data samples. In addition to that method charmed mesons like D^+, D_s^+ mesons are tagged via lifetime measurements from the high resolution silicon vertex detectors used by both experiments in HERAII.

2 Results of open charm production

The H1 photoproduction analysis [1] makes use of the H1 Fast Track Trigger (FTT) [2, 3] which enhanced the capabilities of heavy flavor measurements at H1 by a selective on-line track based event reconstruction [4]. By that the phase space and the available statistic of the measurement has been significantly enlarged compared to the previous H1 photoproduction analysis [5].
The large statistic allows precise double differential measurements. For the H1 photoproduction measurement the data are reasonably well described except for special regions of the phase space and correlations. Especially the $W_{\gamma P}$ dependence is not described by the NLO prediction using the FFNS. The correlation between η and p_T as shown in Figure 1 (right) is compared to the NLO QCD predictions in the FFNS [6] and GM-VFNS; it turns out that the NLO QCD predictions are able to describe the correlation between η and p_T in photoproduction. Nevertheless the NLO predictions show an increasing deficit at forward $\eta > 0$ which is largest at high p_T where the D^* data prefer the upper edge of the error band. For the photoproduction regime the relatively large theoretical uncertainty especially at small p_T arises from the scale variation. For comparison also the double differential measurement in DIS from H1 is shown on the left side of Figure 1. The H1 DIS analysis [7] uses the full HERAII luminosity. Because of the large

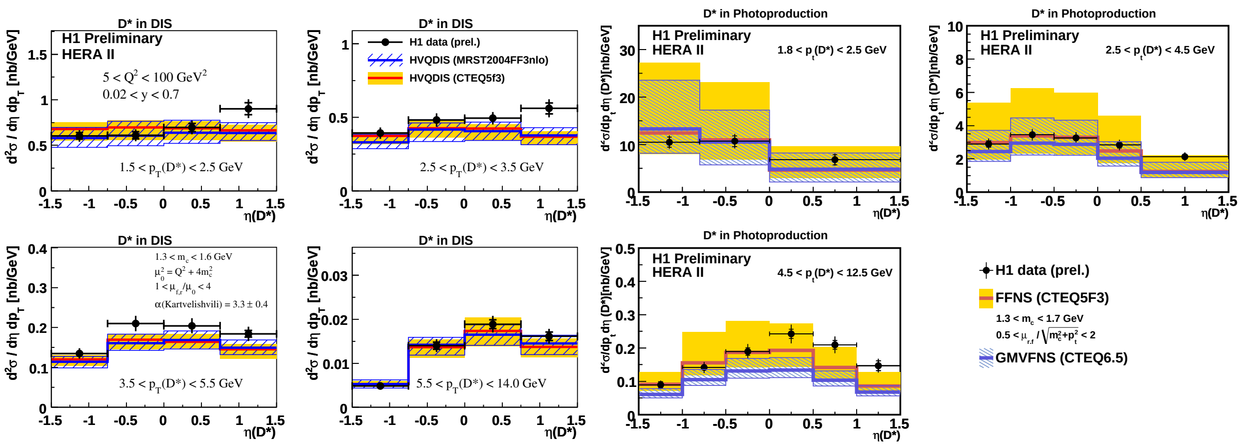


Figure 1: The double differential cross section in $\eta(D^*)$ and $p_T(D^*)$ for the DIS (left) and photoproduction (right) regime compared to the NLO QCD predictions.

statistics the analysis is almost everywhere dominated by the systematic error which is why the its reduction was one of the main focus of the presented H1 analysis. The use of electron and hadron quantities combined in the $e\Sigma$ reconstruction method [8] for the reconstruction of the kinematic variables allows lower inelasticities and smaller systematic uncertainties compared to previous H1 DIS analyses [9].
The measured single and double differential D^* production cross sections are in general well described by the next-to-leading order QCD predictions in the FFNS. The theoretical uncertainty of the predictions is dominated by the mass variation of the charm quark but is in general smaller as in photoproduction because of the additional scale Q^2. The small excess in data at forward directions $\eta > 0$ (seen previously by H1 [9]) turns out to be located at low p_T as it can be seen in comparison to the NLO prediction for the double differential distribution (see Figure 1 left). The data are above the predictions for the low p_T region at forward directions which is different to the photoproduction region where the data prefer the upper edge of the prediction at large p_T.
The small discrepancy at forward directions can already be seen in the single differential $\eta(D^*)$ distribution in comparison to the NLO QCD prediction as shown in Figure 2 left. The recent D^* measurement from the ZEUS collaboration [10] measures the same $p_T(D^*)$ and y region but covers a slightly larger range in $\eta(D^*)$ and goes up to larger Q^2. Nevertheless ZEUS observes that the measured D^* data prefer the upper edge of the NLO QCD predictions at forward directions as it can be seen in figure 2 right and by

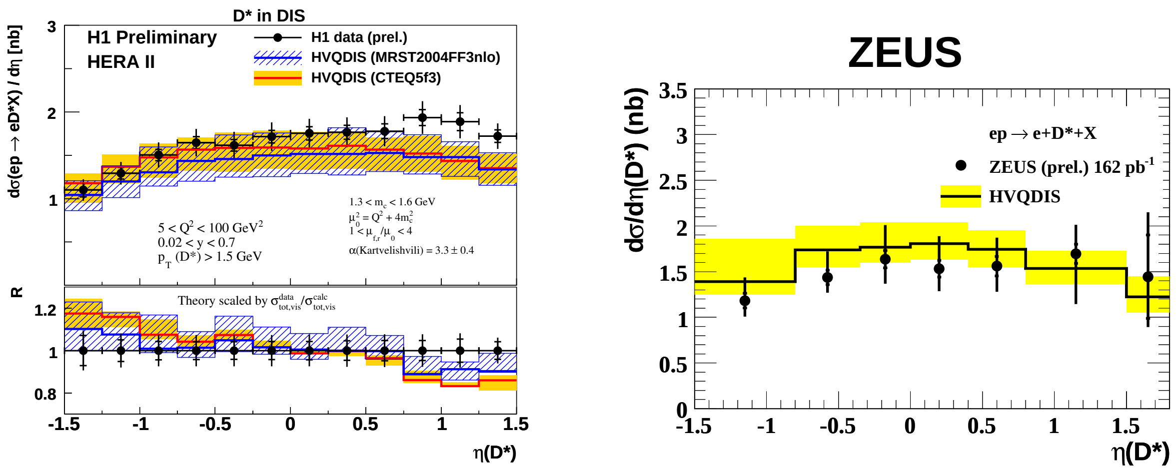
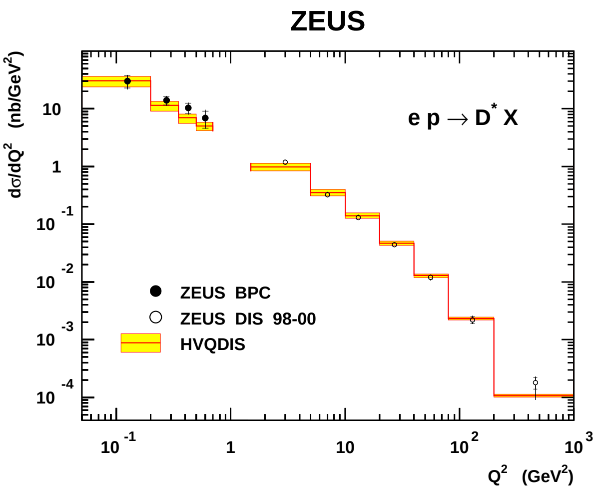


Figure 2: The D^* cross section as a function of $\eta(D^*)$ as measured by H1 using the luminosity of the whole HERAII data taking (left) and from ZEUS as measured using the luminosity of the years $2003-2005$ (right).

that is within errors in agreement with the result from H1. Further insights are possible because of the up to know not completely used luminosity by ZEUS as well as a phase space extension by H1 towards larger values of $\eta(D^*)$. In addition if a common phase space is defined the combination of the measurement from both experiments provides another possibility for significantly reduced systematic errors because of *cross calibration effects* between the different detector setups.

A cross section measurement at very low Q^2 for D^* production in DIS has been preformed by ZEUS [11] using the beam pipe calorimeter. The overall Q^2 range including this new measurement is shown in figure 3 (left) with a nice agreement to the NLO QCD prediction. ZEUS has measured the charm production cross section of D^*, D^0, D^+, D_s^+ [12] where the differential cross section agrees well with the NLO QCD predictions. In addition the fragmentation fractions of charm into each meson can be estimated. The charm fragmentation fractions as shown in figure 3 agree with the ones extracted by H1. Because of the agreement with the fragmentation fractions from e^+e^- the conclusion is that they do not depend on the hard subprocess and are in that sense universal. For D^* meson production also the fragmentation function describing the *transition* from $c \rightarrow D^*$ itself has been measured by ZEUS [13] and H1 [14] using HERAI data with a good agreement between both experiments and e^+e^-. It should be mentionend that the H1 measurement sees problems for the QCD models and NLO predictions to describe the data at different $\hat{s}$ with the same parameters of the fragmentation function.

In addition to the test of the QCD predictions in differential distributions another stringent test of QCD is possible by the D^* measurement involving the gluon density which drives via the BGF production mechanism the D^* production. Several approaches exist to measure the gluon density. The well established approach to measure the charm structure function will be covered elsewhere. In order to have an impact on the fits of the gluon density it is necessary that the cross section data have the highest possible precision. At present stage H1 and ZEUS enter the precision era of charm measurements where a single differential distribution has at least some sensitivity to the proton PDF, e.g. the $\eta(D^*)$ distribution measured by H1 shows a better compatibility to the predictions if a proton PDF is used where a gluon density providing a less steep rise towards small x is used. Although the significance of the sensitivity is diminished by the relatively large theoretical uncertainties. The availbale D^* cross section data can also



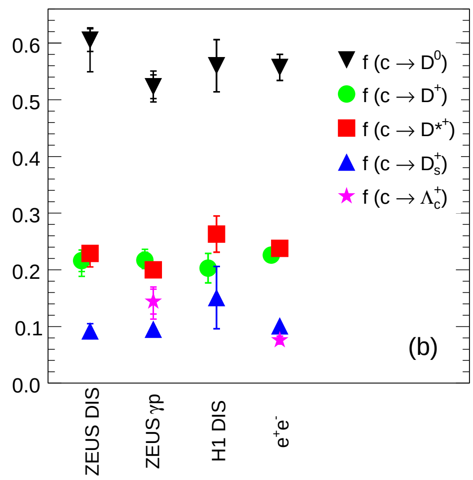


Figure 3: The Q^2 distribution including the new ZEUS measurement at very low Q^2 shown right and the fragmentation fractions as measured by ZEUS and other experiment for various D mesons.

be used to fit the gluon density directly from the differential distributions in $\eta(D^*), p_T(D^*), z(D^*), x, Q^2$ providing sensitivity and insights to the gluon density [15].
In order to further increase the data precision it is possible to combine data on the basis of (D^*) cross sections or at the level of F_2^c extractions from H1 and ZEUS. At the level of F_2^c also the combination of data within one experiment from different F_2^c measurement methods, i.e. from D^* cross sections and from lifetime measurements, provides additional information because of the cross calibration effect.

3 Conclusions

At present stage H1 and ZEUS enter the precision era of charm measurements with the large statistic of about 0.5 fb^{-1} per experiment provided by the HERAII running period. These data are currently analyzed and first preliminary results with high precision are available. In general the description by the next-to-leading order QCD predictions is reasonable except for some regions of the phase space. In order to get more insights and to have a significant impact on the fits of the PDFs the cross section data must be very precise and in addition covering the largest possible phase space where new results are expected to come.

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