Measurements of charm production at HERA with the H1 experiment

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Abstract. The study of charm production at the *ep* collider HERA is particularly interesting since it provides sensitivity to the gluon density in the proton and it allows different models and schemes of pQCD to be tested. New measurements, which are based on part of the HERA II data and correspond to an integrated luminosity of more than 220 pb^{-1} are presented for the inclusive production of $D^\star$ mesons in deep inelastic scattering and for inelastic electroproduction of charmonium. The data are compared to theoretical calculations and to predictions from Monte Carlo programs in leading and next to leading order.

1. Introduction

At the *ep* collider HERA heavy quarks are predominantly produced in the boson gluon fusion process. The study of charm production is particularly interesting since it provides sensitivity to the gluon density in the proton. The large charm quark mass makes the application of perturbative QCD possible and permits the study of theoretically interesting multi scale situations, when other hard scales, like Q^2 or p_t^2 are also present.

2. Open charm production

Open charm production is tagged by reconstructing the decay of $D^\star$ mesons in the golden decay channel $D^{\star\pm} \rightarrow D^0\pi^\pm_{\mathrm{slow}} \rightarrow K^\mp\pi^\pm\pi^\pm_{\mathrm{slow}}$. The increased HERA II statistics in the region of deep inelastic scattering ($5 < Q^2 < 100$ GeV^2, $0.05 < y < 0.6$), which corresponds to an integrated luminosity of $\mathcal{L} = 222$ pb^{-1} [1] allow detailed comparisons with a variety of theoretical predictions. In figure 1 the measured differential $D^\star$ cross section as a function of pseudorapidity $\eta(D^\star)$ is compared to theoretical calculations (HVQDIS) in next to leading order (NLO) and to predictions of leading order (LO) Monte Carlo programs (RAPGAP, based on the DGLAP evolution and CASCADE, based on the CCFM evolution) supplemented with parton showers. While CASCADE is able to describe the data reasonably well, it can be observed that the predictions of HVQDIS are too low for $\eta > 0.5$ and those of RAPGAP too high for $\eta < -1$. In order to identify regions of phase space, where the discrepancies are most pronounced figure 2 shows the comparison double differentially in $\eta(D^\star)$ and $p_T(D^\star)$. Discrepancies in the forward direction are seen for HVQDIS, which undershoots the data for $p_T < 2.5$ GeV and for CASCADE, which slightly overestimates the data for $p_T > 2.5$ GeV. The overshoot of RAPGAP in the backward direction is concentrated at $p_T > 3.5$ GeV. In summary, none of the predictions is able to describe all aspects of the data and even more precise data are needed to further differentiate between the models.

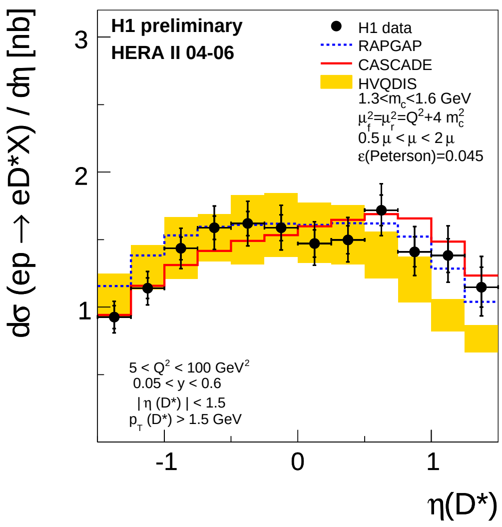

Figure 1. Single differential $D^{\star}$ cross section as a function of $\eta(D^{\star})$.

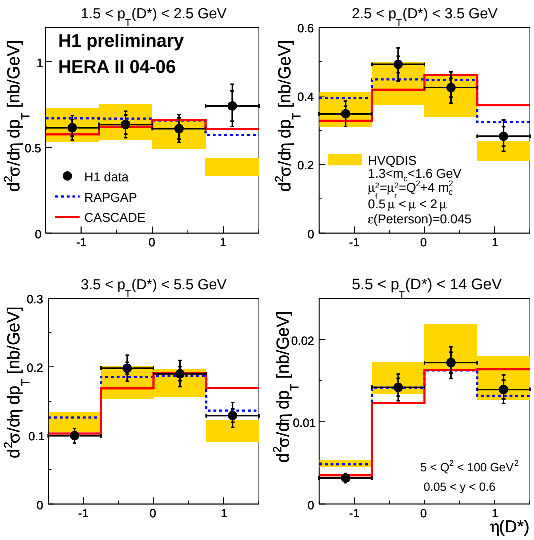

Figure 2. Double differential $D^{\star}$ cross section as a function of $\eta(D^{\star})$ and $p_T(D^{\star})$.

3. Inelastic electroproduction of charmonium

In the factorization ansatz of non-relativistic quantum chromodynamics (NRQCD) colour octet (CO) as well as colour singlet (CS) $c\bar{c}$ states contribute to the charmonium production cross section. While it was found that both CS and CO contributions as implemented in NRQCD are required to describe data obtained at the Tevatron, measurements of J/Ψ production in DIS at HERA generally are in good agreement with predictions from CS models in LO alone [2, 3]. New measurements of inelastic J/Ψ electroproduction in the kinematic range $3.6 < Q^2 < 100$ GeV^2, $50 < W_{\gamma p} < 225$ GeV, $0.3 < z_{J/\Psi} < 0.9$ and $p_T^{\star}(J/\Psi) > 1$ GeV, corresponding to an integrated luminosity $\mathcal{L} = 258$ pb^{-1} have been performed [4]. In figure 3 the differential cross section

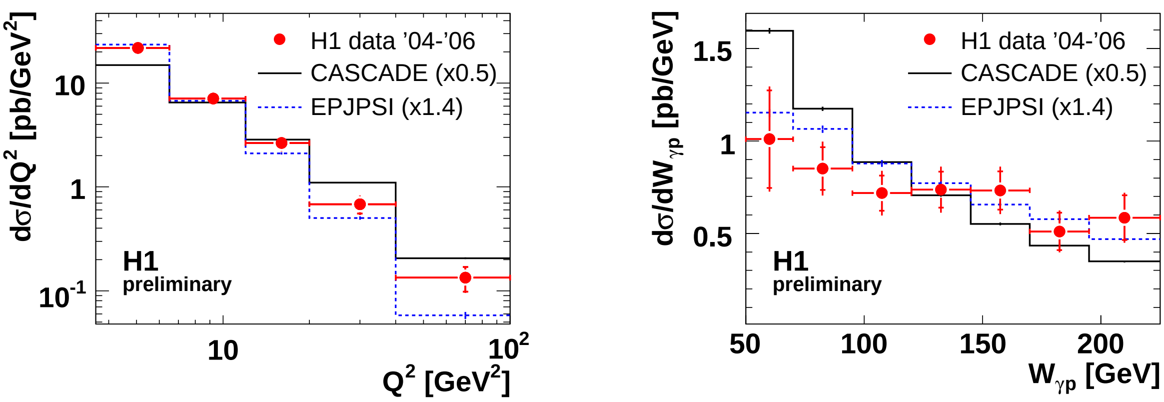

Figure 3. Measured J/Ψ cross section as a function of Q^2 (left) and of the mass of the hadronic final state, $W_{\gamma p}$, (right) in comparison with CS LO Monte Carlo predictions, which have been scaled by the factors given in the figure.

as a function of Q^2 and of the mass of the hadronic final state, $W_{\gamma p}$, are compared with predictions from the event generators CASCADE and EPJPSI, which both implement the CS model in LO. The predictions of EPJPSI, which is based on the DGLAP evolution are too low in normalization and lead to a Q^2 distribution, which is steeper than that of the data. CASCADE, on the other hand, predicts a cross section, which is a factor of two too high and exhibits a Q^2 dependence, which is harder than observed in the data. The dependence on $W_{\gamma p}$ is well described by EPSPSI but too steep in the case of CASCADE. Double differential cross section measurements as function of $p_T^{\star 2}$ and of the J/Ψ fractional energy, z, are shown in figure 4. Both programs succeed in describing the z distribution overall as well as in bins of $p_T^\star$. In particular the increase in hardness of the $p_T^\star$ spectrum with increasing z is well reproduced by both Monte Carlo programs. Also from this more detailed comparison there appears to be no need for inclusion of contributions beyond CS LO. Thus it can be concluded that additional terms, like possible CO contributions must either be much smaller in size than the CS contribution or must have a similar shape. The polarization of the J/Ψ meson is expected to be a clear signature for the presence of CO contributions. It can be accessed by measuring the decay angular distribution, however this will require analysis of the full HERA II statistics.

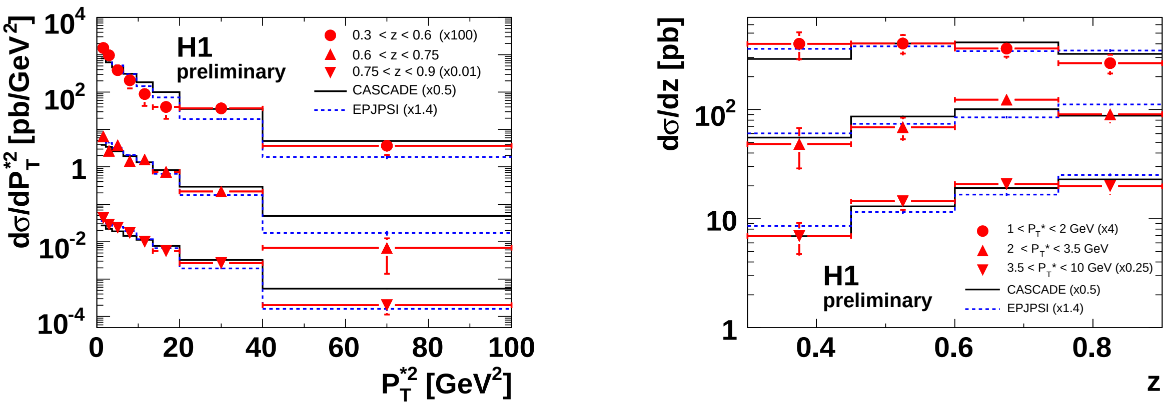

Figure 4. Differential J/Ψ cross sections as a function of $p_T^{\star 2}$ in three bins of z and as a function of z in three bins of $p_T^\star$. The data are compared with the predictions of CASCADE and EPJPSI, which have been scaled by the factors given in the figure.

4. Conclusion and outlook

The HERA II data provide a large increase in statistics for charm analyses. So far only part of the new data have been analyzed which corresponds roughly to a fourfold increase in statistics compared to published results from HERA I. Besides the increased statistical precision further qualitative improvements can be expected from the full exploitation of new vertex detectors. The present data allow to explore regions of phase space, where the models fail to describe the data in more detail than hitherto. Ultimately, with the combined full statistics of HERA I and HERA II, one will be able to study deficits of models in even greater detail. This will allow one to further differentiate between models, to tune model parameters and to improve calculations.

References

[1] H1 Collaboration 2007 *$D^\star$ Production in Deep Inelastic Scattering with the H1 Detector*, Abstract 173 submitted to this conference: `www-h1.desy.de/h1/www/publications/conf/list.EPS2007.html`

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