THE CHARM CONTRIBUTION TO THE STRUCTURE FUNCTION OF THE PROTON

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Measurements of the open charm production cross section in deep inelastic scattering performed by the H1 and ZEUS experiments at HERA are presented. Final states containing open charm are identified either by full reconstruction of $D^{*\pm}$ mesons or via the semileptonic decay into electrons. The resulting differential cross sections are compared to theoretical calculations and the charm contribution to the proton structure function, $F_2^c(x, Q^2)$, is determined.

1 Introduction

Heavy quark production in electron proton scattering proceeds, in QCD, almost exclusively via the photon gluon fusion mechanism: a photon, emitted by the incoming electron, interacts with a gluon in the proton to form a quark-antiquark pair i.e. $\gamma g \to c\bar{c}$.

The kinematics of the ep interaction is described by three independent variables: the centre of mass energy $\sqrt{s}$; the squared four momentum transfer of the photon $q^2 = -Q^2$ and either one of the scaling variables $y = (q \cdot P/l \cdot P)$, the inelasticity of the ep-interaction, or Bjorken $x = Q^2/(2P \cdot l)$. Here, P and l denote the four-momenta of the proton and the electron, respectively.

The results[1,2,3] presented here are based on 34 pb^{-1} and 18.6 pb^{-1} recorded in 1996 and 1997 with the ZEUS and H1 detectors respectively.

2 Open charm production

Several schemes are used to perform the calculations. All approaches assume the scale to be hard enough to apply pQCD and to guarantee the validity of the factorisation theorem. Here, for the NLO calculations in the DGLAP scheme, the massive approach is adopted which is a fixed order (in α_s) calculation with massive quarks assuming three active flavours in the proton. The heavy quark is only produced at the perturbative level via boson-gluon fusion[4]. Based on the NLO calculations, the Monte Carlo integration program HVQDIS[5] provides the four-momenta of the outgoing partons. Charmed quarks are fragmented into charmed hadrons according to the Peterson fragmentation funcion[6].

Recently the CCFM model[7] has also been available for comparisons to the data. Here, in the parton cascade, gluons are emitted only in an angular ordered region. Due to this ordering, the unintegrated gluon distribution depends on the maximum allowed angle as well as the momentum fraction x and the transverse momentum of the propagator gluon.

3 Cross Sections

The charm content of the events is detected either by the reconstruction of $D^{*\pm}$ mesons or the identification of electrons from the semileptonic decay. $D^{*\pm}$ mesons are reconstructed in the decay $D^{*+} \to D^0\pi^+$ with $D^0 \to K^-\pi^+$ or $D^0 \to K^-\pi^+\pi^+\pi^-$.

Differential cross sections for the process $ep \to D^{*+}X$ have been measured by both ZEUS[1] and H1[3]. The inclusive D^{*+} differential cross sections in the kinematic region $1 < Q^2 < 100\ GeV^2$, $0.05 < y < 0.7$ and $p_{TD^*} > 1.5\ GeV/c$, $|\eta_{D^*}| < 1.5$ are shown in Figure 1 for the H1 data as a function of the kinematical quantities W, x_{Bj} and Q^2 and as a function of the D^{*+} observables p_{TD^*}, η_{D^*} and $z_{D^*} = (E - p_z)_{D^*}/2yE_e$. A bin by bin correction due to QED radiation has been applied using the HECTOR program[8]. The data points are compared to the expectation of the NLO QCD calculations using the HVQDIS program[5] with the GRV98-HO[9] parton density parametrization. The uncertainty in the calculation due to the variation of the c-quark mass and due to the fragmentation is shown as light shaded area. Figure 1 also includes the prediction of the CCFM calculations using the CASCADE program, which has been made available recently, with the gluon density taken from the fit to the H1 inclusive F_2 data. For the CCFM prediction, the dark shaded band reflects the uncertainty introduced by the charm mass. The agreement in the shape of the differential cross sections of both predictions with the data is reasonable. The expectations from the CASCADE program are found to agree better in normalisation with the H1 data especially in the forward η region. The ZEUS data[1,2] agree with the expectations from the HVQDIS program using the structure function from their fit to inclusive F_2 data.

Using the semileptonic decay into electrons to tag charm events [2], a higher statistics sample is obtained, making it possible to extend the kinematic region to $1 < Q^2 < 1000$ GeV^2.

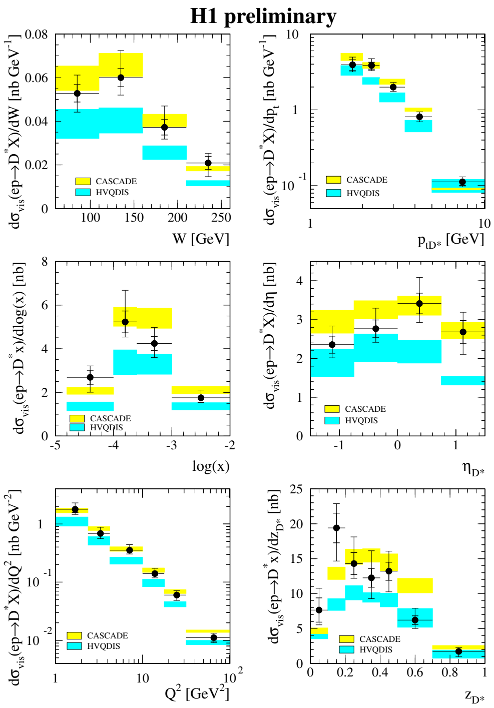

Figure 1. Differential cross section $\sigma(ep \to eD^{*+}X)$ versus W, x_{Bj}, Q^2 and p_{T,D^*}, η_{D^*}, z_{D^*}.The inner error bars account for the statistical errors and the outer error bars for the total error. The curves are described in the text.

4 Charm contribution to the proton structure function $F_2^c(x, Q^2)$

Neglecting the contribution from F_L, the DIS inclusive cross section $\sigma^c(x, Q^2)$ can be expressed in terms of F_2^c:

$$\frac{d^2\sigma^c}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}(1 + (1-y)^2) \cdot F_2^c(x, Q^2)$$

where x is the Bjorken scaling variable. The visible inclusive cross sections, $\sigma_{vis}^{exp}(x, Q^2)$, in bins of x and Q^2 are converted to $F_2^{c\ exp}(x, Q^2)$ by the relation:

$$F_2^{c\ exp}(x, Q^2) = \frac{\sigma_{vis}^{exp}(x, Q^2)}{\sigma_{vis}^{theo}(x, Q^2)} \cdot F_2^{c\ theo}(x, Q^2),$$

where σ_{vis}^{theo}, $F_2^{c\ theo}$ are the theoretical predictions from the model under consideration. The HVQDIS and the Riemersma *al.*[4] programs are used to calculate these quantities by both experiments. H1 has also used the recently released CASCADE program which is based on the CCFM equation to extract F_2^c and the result is in good agreement with the one extracted with the HVQDIS program within the present statistics of the data.

In Figures 2 and 3, a compilation of the different measurements of the charm contribution to the proton structure function $F_2^c(x, Q^2)$ is shown. The experimental results are compared with the predictions of F_2^c from the H1 NLO DGLAP fit to the inclusive F_2 measurements.

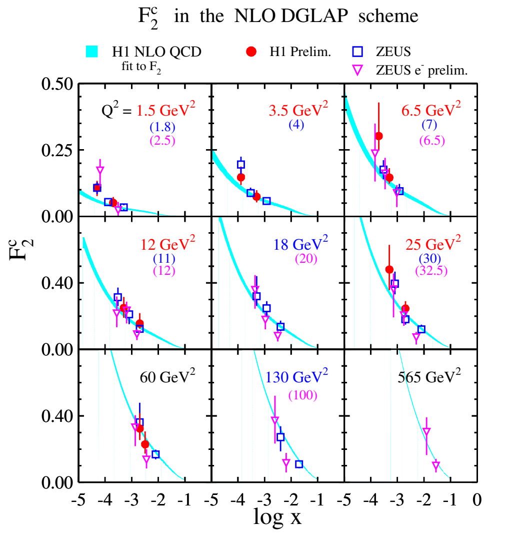

Figure 2. The charm contribution to the proton structure function F_2^c as derived from the inclusive D^{*+} meson analysis by H1 and ZEUS and from the ZEUS semileptonic decays analysis. The shaded band represents the predictions of F_2^c from the H1 NLO DGLAP fit to the inclusive F_2 measurements with m_c ranging from 1.3 to 1.5 GeV.

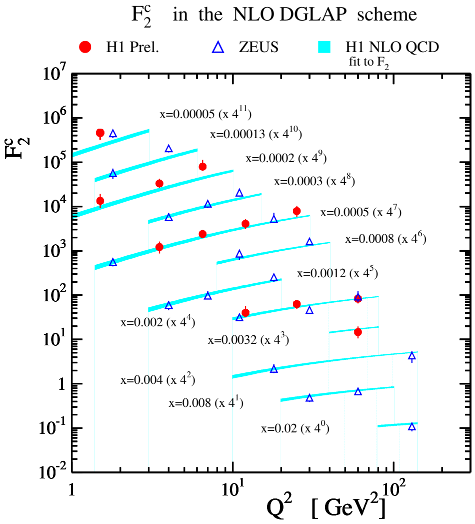

Figure 3. The charm contribution to the proton structure function F_2^c as derived from the inclusive D^{*+} meson analysis by H1 and ZEUS. The shaded band represents the predictions of F_2^c from the H1 NLO DGLAP fit to the inclusive F_2 measurements with m_c ranging from 1.3 to 1.5 GeV.

5 Conclusions

Results on open charm production in deep inelastic ep-scattering using the D^{*+} meson or the charm semileptonic decay into electrons for tagging have been reported. The resulting differential cross sections from ZEUS and H1 are in good agreement and they are reasonably well discribed by the NLO DGLAP calculation using the HVQDIS program. The comparison with the CCFM calculations, where made, shows good agreement with the data. The charm contribution to the proton structure function, F_2^c, has been extracted by extrapolating to the full p_T and η region. The measurements of F_2^c derived from the different experiments and using different methods are in good agreement.

References

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