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MEASUREMENT OF $F_2^{C\bar{C}}$ AND $F_2^{B\bar{B}}$ AT HIGH Q^2 USING THE H1 VERTEX DETECTOR AT HERA

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Measurements are presented of inclusive charm and beauty cross sections in e^+p collisions for values of $Q^2 > 110$ GeV^2 and $0.07 < y < 0.7$, using a method based on the distance of closest approach, in the transverse plane, of tracks to the primary vertex as measured by the H1 vertex detector. The data are divided into three intervals in Q^2 and Bjorken x and values for the structure functions $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ are obtained. The results are found to be compatible with the predictions of perturbative quantum chromodynamics.

1 Introduction

Heavy quark production is an important process to study quantum chromodynamics (QCD). It is expected that perturbative QCD (pQCD) at next-to-leading order (NLO) should give a good description of heavy flavour production in deep-inelastic scattering (DIS), especially at values of the negative square of the four momentum of the exchanged boson Q^2 greater than the square of the heavy quark masses. In this analysis, events containing heavy quarks can be distinguished from light quark events by the long lifetimes of charm (c) and beauty (b) hadrons, which lead to displacements of tracks from the primary vertex. The distance of a track to the primary vertex is reconstructed using precise spatial information from the H1 vertex detector [1].

2 Experimental Method

The analysis is based on a high Q^2 sample of neutral current (NC) events, taken in the years 1999-2000, when HERA was operated in unpolarised e^+p mode, with an ep centre of mass energy squared $s = 101200$ GeV^2. The events are selected in a similar manner to that described in [2], and correspond to an integrated luminosity of 57.4 pb^{-1}.

Only those events which have at least 1 reconstructed track with hits from the central silicon tracker (CST) with polar angle $30 < \theta_{\text{track}} < 150°$ and a minimum transverse momentum of 0.5 GeV are used. In this analysis the transverse distance of closest approach (DCA) of the track to the primary vertex point is used to separate the different quark flavours. To identify long lived hadrons a 'jet axis' is defined for each event in order to calculate a signed DCA for every track. In the Q^2 range of this paper, the vector sum of all HFS particles in the laboratory frame always has a transverse momentum greater than 5 GeV and 97% of the events have the jet axis defined by a reconstructed jet, and the remaining 3% have the jet axis defined by the 'direction of the struck quark in the quark parton model'. CST tracks are associated to the jet axis if they lie within a cone of size 1 in η–ϕ space centred about the jet axis. The DCA is defined as positive if the angle between the jet axis and the line joining the vertex to the point of DCA is less than 90°, and is defined as negative otherwise. Tracks from the decays of long lived particles will mainly have a positive true DCA, whilst those produced at the primary vertex will have zero true DCA. Tracks reconstructed with negative DCA values mainly result from detector resolution.

In order to optimise the separation of the quark flavours use is made of the significance, defined as the ratio of the DCA to its error. A further optimisation is made by using different significance distributions for events with different multiplicities. The first significance distribution S_1 is defined for events where only 1 reconstructed CST track is linked to the jet, and is simply the significance of the track. The second significance distribution S_2 is defined for events with two or more tracks associated with the jet and is the significance of the track with the second highest absolute significance. In order to substantially reduce the uncertainty due to the DCA resolution and the light quark normalisation the negative bins in the S_1 and S_2 distributions are subtracted from the positive.

The fractions of c, b and light quarks of the data, are extracted in each x–Q^2 interval using a simultaneous fit to the subtracted S_1 and S_2 distributions and the total number of inclusive events before track selection, using c, b and light quark (uds) Monte Carlo samples as templates. A standard least squares fit is used. The Monte Carlo c, b and uds distributions in each x–Q^2 interval are allowed to be modified by the scale factors P_c, P_b and P_l, respectively.

The fit results are converted to a measurement of the differential c cross section using:

$$\frac{\mathrm{d}\sigma^{c\bar{c}}}{\mathrm{d}x\mathrm{d}Q^2} = \frac{\mathrm{d}\sigma}{\mathrm{d}x\mathrm{d}Q^2} \frac{P_c N_c^{\mathrm{MCgen}}}{P_c N_c^{\mathrm{MCgen}} + P_b N_b^{\mathrm{MCgen}} + P_l N_l^{\mathrm{MCgen}}}, \tag{1}$$

where $\mathrm{d}\sigma/\mathrm{d}x\mathrm{d}Q^2$ is the measured inclusive differential cross section from H1 [2] and N_c^{MCgen}, N_b^{MCgen} and N_l^{MCgen} are the generated number of c, b and light quark events from the Monte Carlo in each bin, respectively.

The structure function $F_2^{c\bar{c}}$ is then evaluated from the cross section by estimating the longitudinal structure function $F_L^{c\bar{c}}$ using the NLO QCD expectation [2]. The differential b cross section and $F_2^{b\bar{b}}$ are evaluated in the same manner.

2.1 Results

The measurements of $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$ are shown in figure 2.1 as a function of x for two values of Q^2. The H1 data for $F_2^{c\bar{c}}$ are compared with the results of the ZEUS collaboration [3], where the cross sections were obtained from the measurement of $D^{*\pm}$ mesons. The results of the two measurements for $F_2^{c\bar{c}}$ are in good agreement. The data are also compared with the prediction from the H1 PDF 2000 fit[2] in which the c and b quarks are treated in the 'massless' scheme. The QCD prediction is compatible with the data.

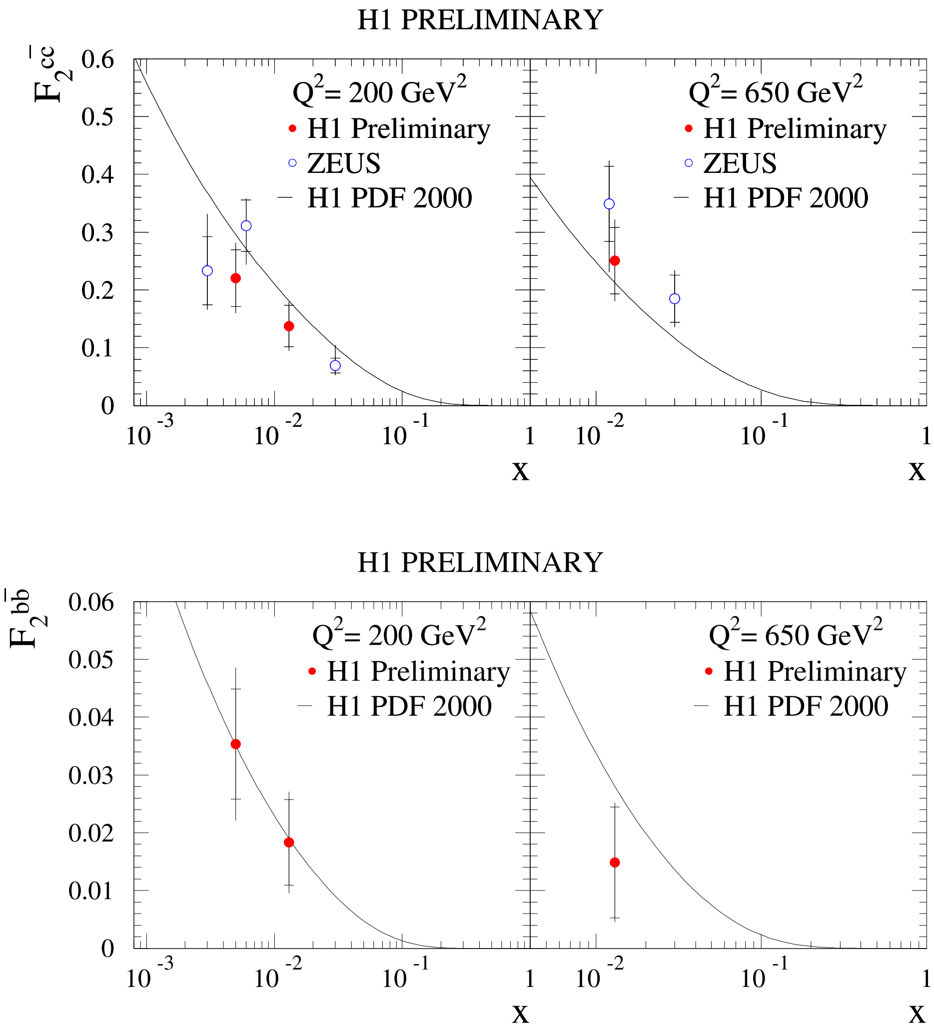

Figure 1. The measured $F_2^{c\bar{c}}$ (a) and $F_2^{b\bar{b}}$ (b) shown as a function of x for two different Q^2 values. The measurements of $F_2^{c\bar{c}}$ from ZEUS using D^*s to tag charm[3] and the prediction of a NLO QCD fit are also shown.

The measurements are also shown figure 2 in the form of the fractional contribution to the total ep cross section: $f^{c\bar{c}} = \frac{\mathrm{d}\sigma^{c\bar{c}}/\mathrm{d}x\mathrm{d}Q^2}{\mathrm{d}\sigma/\mathrm{d}x\mathrm{d}Q^2}$. The b fraction $f^{b\bar{b}}$ is defined in the same manner. NLO QCD is found to give a good description of the data, as shown by comparison with the 'massless' prediction from the H1 fit [2].

The c and b fractions and cross sections are also measured integrated over the range $Q^2 > 150$ GeV^2 and $0.1 < y < 0.7$. This is a more restricted range than

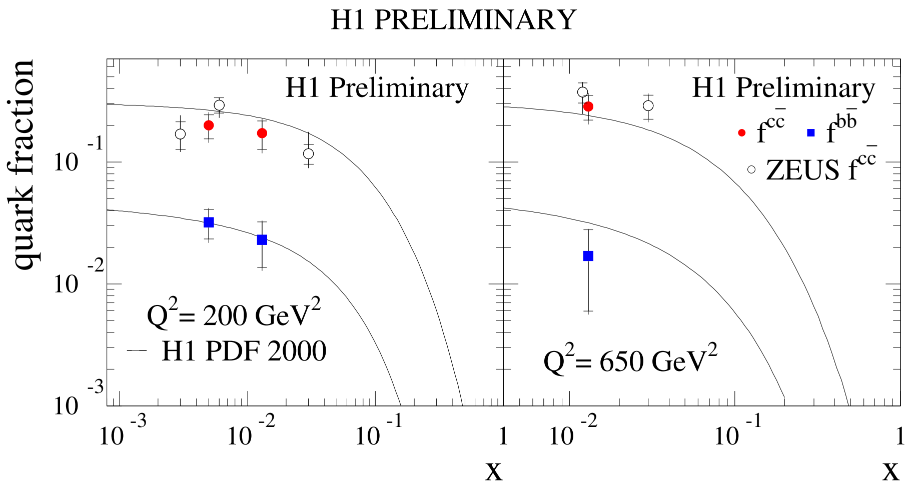

Figure 2. The ratio $f^{c\bar{c}}$ and $f^{b\bar{b}}$ shown as a function of x for two different Q^2 values. The measurements of $f^{c\bar{c}}$ from ZEUS using D^*s to tag charm[3] and the predictions of the H1 NLO QCD fit are also shown.

for the differential measurements, in order to minimise the extrapolations, and the following values are found: $\sigma^{c\bar{c}} = 431 \pm 59 \pm 69$ pb and $\sigma^{b\bar{b}} = 45 \pm 11 \pm 11$ pb. NLO QCD is found to agree well with the data. For example, the 'Variable Flavour Number Scheme' prediction from MRST [4] gives: $\sigma^{c\bar{c}} = 426$ pb and $\sigma^{b\bar{b}} = 47$ pb.

3 Conclusion

The production of c and b quarks at HERA has been studied using precise tracking information from the H1 vertex detector. The inclusive c and b cross sections are measured using a technique based on the lifetime of the heavy quark hadrons. The measurements are made using all events containing tracks with vertex detector information eliminating the need for large model dependent extrapolations to the full cross section. The predictions from perturbative QCD are found to agree well with both the integrated and differential cross sections.

References

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