Measurement of Beauty and Charm Photoproduction at H1 using inclusive lifetime tagging

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Abstract. A measurement of the charm and beauty photoproduction cross sections at the ep collider HERA is presented. The lifetime signature of c and b-flavoured hadrons is exploited to determine the fractions of events in the sample containing charm or beauty. Differential cross sections as a function of the jet transverse momentum, the rapidity and x_γ^{obs} are measured in the photoproduction region $Q^2 < 1$ GeV^2, with inelasticity $0.15 < y < 0.8$. The results are compared with calculations in next-to-leading order perturbative QCD and Monte Carlo models as implemented in PYTHIA and CASCADE.

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INTRODUCTION

A measurement of differential charm and beauty dijet photoproduction cross sections in ep collisions at HERA is presented here. The analysis covers the photoproduction region, where the virtuality of the photon emitted from the incoming positron is small, $Q^2 \sim 0$. In this process, the production of heavy quarks is expected to be dominated by photon-gluon fusion, $\gamma g \to c\bar{c}$ or $\gamma g \to b\bar{b}$, where the photon interacts with a gluon from the proton to produce heavy quarks in the final state. The measurements are compared to calculations in perturbative QCD (pQCD) at next-to-leading order (NLO) in which the mass of the heavy quarks provides a hard scale.

The charm and beauty cross sections are determined using a fit to the lifetime signature of charged particles in jets. This inclusive method yields measurements of differential cross sections that extend to larger values of transverse momenta than in previous HERA analyses in which leptons from beauty quark decays were used to measure beauty cross sections [1, 2, 3, 4, 5, 6].

EXPERIMENTAL METHOD

The analysis is based on a photoproduction dijet sample, corresponding to an integrated luminosity of 57.7pb^{-1}, taken in the years 1999-2000, when HERA was operated in unpolarised e^+p mode, with an ep centre of mass energy of $\sqrt{s}$=319 GeV. Events with two jets and large transverse momenta, $p_t^{jet_{1(2)}} > 11(8)$ GeV, in the central rapidity range, $-0.88 < \eta^{jet} < 1.3$ are selected.

For the final sample only those events which have at least 1 reconstructed track with hits from the central silicon tracker CST [7] with polar angle $30^\circ < \Theta_{track} < 150^\circ$ and a minimum transverse momentum of 0.5 GeV, and which are associated to one of the two highest p_t jets are used. In this analysis, the signed track impact parameter (DCA) with respect to the event vertex is used to separate the different quark flavours. The signed impact parameter is defined as positive if the angle between the jet axis and the line between the vertex and distance of closest approach of the track to the vertex is less than 90°, and is defined as negative otherwise. Tracks from the decays of long lived particles will mainly have positive true DCA, whilst those produced at the event vertex will have zero true DCA. Tracks reconstructed with negative DCA values mainly result from detector resolution.

The separation of charm and beauty events is further enhanced by using different significance distributions for events with different track multiplicities. The first significance S_1 is defined for events with exactly one CST track associated to a jet and is simply the significance of this track. The second significance S_2 is defined for events with two or more CST tracks associated to one of the two jets and is the significance of the track with the second highest absolute significance. Events in which the tracks with the first and second highest absolute significance in a jet have different signs are removed from the S_2 distribution. This latter condition removes around 50% of events from the S_2 distribution, predominantly from the light quark event sample. In order to considerably 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 b, c and light quark fractions in the data are extracted by simultaneously fitting the subtracted S_1 and S_2 distributions and the total number of events with the Monte Carlo beauty, charm and light quark distributions used as templates in each interval of the measurement. This procedure was originally proposed by a recent H1 measurement in [8].

Consistent results in all bins are obtained using an alternative method to separate the quark flavours also based on the use of the significance distributions of the selected tracks. The method was employed by the ALEPH collaboration [9].

RESULTS

From the fit results scale factors for charm and beauty are determined for the samples in each bin.

In each bin of the measurement the differential cross section is obtained by multiplying the bin-averaged cross section predicted by the Monte Carlo simulation by the scale factor and dividing by the bin size. The total dijet charm photoproduction cross section in the range $Q^2 < 1$ GeV^2, $0.15 < y < 0.8$, $p_t^{jet_{1,2}} > 11(8)$ GeV and $-0.88 < \eta^{jet_{1,2}} < 1.3$ is measured to be

$$\sigma(ep \to ec\bar{c}X \to ejjX) = 694 \pm 69(stat.) \pm 96(sys.)\text{pb}.$$

For beauty, the measurement yields a cross section for the same kinematic range

$$\sigma(ep \to eb\bar{b}X \to ejjX) = 145 \pm 18(stat.) \pm 30(sys.)\text{pb}.$$

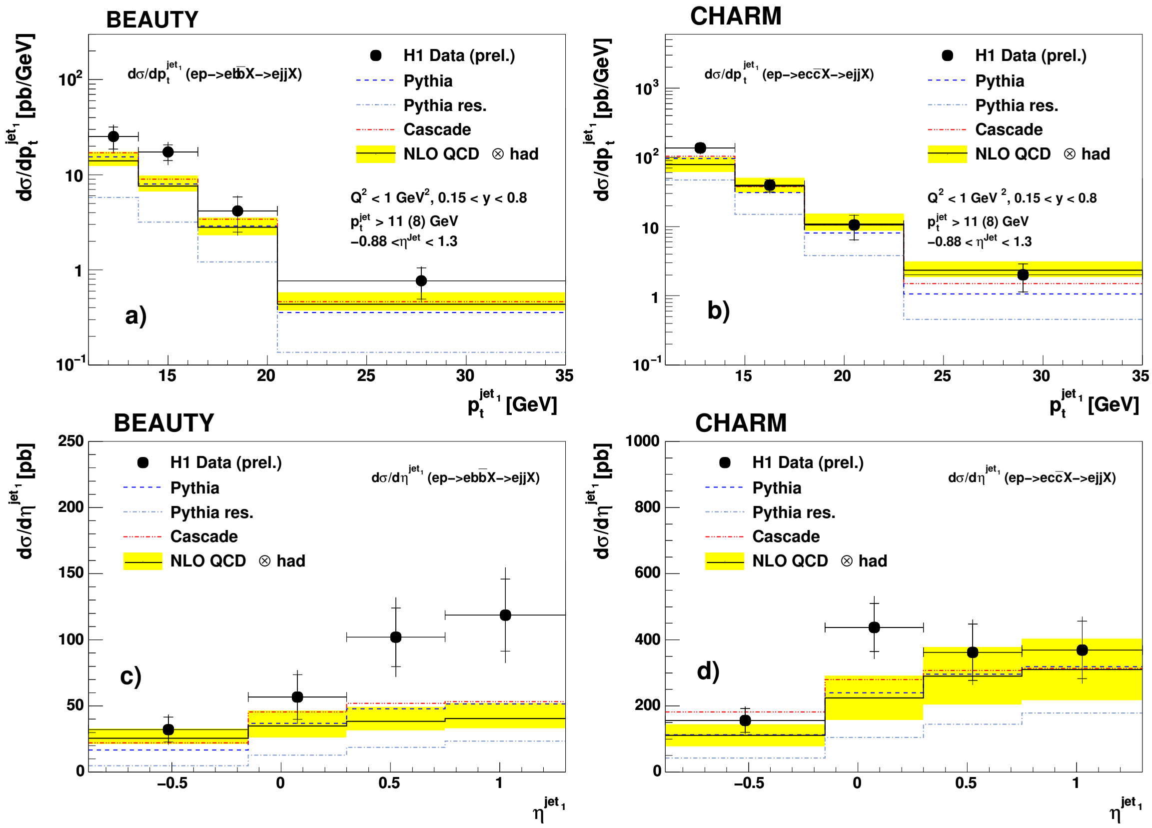

FIGURE 1. Differential charm and beauty cross sections as a function of the transverse momentum $p_t^{jet_1}$ (a and c) and of the rapidity η^{jet_1} (b and d) of the leading jet. The data is compared to the prediction from CASCADE (dotted line) and PYTHIA (dashed line). The contribution in PYTHIA from processes in which the photon is resolved is shown separately (dashed-dotted line). The solid line indicates the prediction from a NLO QCD calculation and the shaded band describes the scale uncertainty of the calculation.

Figures 1 and 2 show the measured differential cross sections for both, charm and beauty, as functions of $p_t^{jet_1}$, η^{jet_1} and x_γ^{obs}, respectively. Here, x_γ^{obs} is defined as the fraction of the $(E-p_z)$ of the hadronic system that is carried by the two highest p_T jets:

$$x_\gamma^{obs} = \frac{(E-p_z)_{jet_1} + (E-p_z)_{jet_2}}{(E-p_z)_h}.$$

The data are compared with predictions from the NLO QCD calculation FMNR as well as from the Monte Carlo programs PYTHIA and CASCADE. The latter implements the CCFM evolution equation using off-shell matrix elements convoluted with k_t-unintegrated parton distributions in the proton.

While the charm data are reasonably well described in both normalization and shape, the beauty data are found to be somewhat higher than the prediction from the NLO QCD calculation. The main difference between the beauty data and the NLO calculation appears to originate in the region of positive values of rapidity, as can be seen in figure 1c, and small values of x_γ^{obs}, where the prediction lies significantly below the

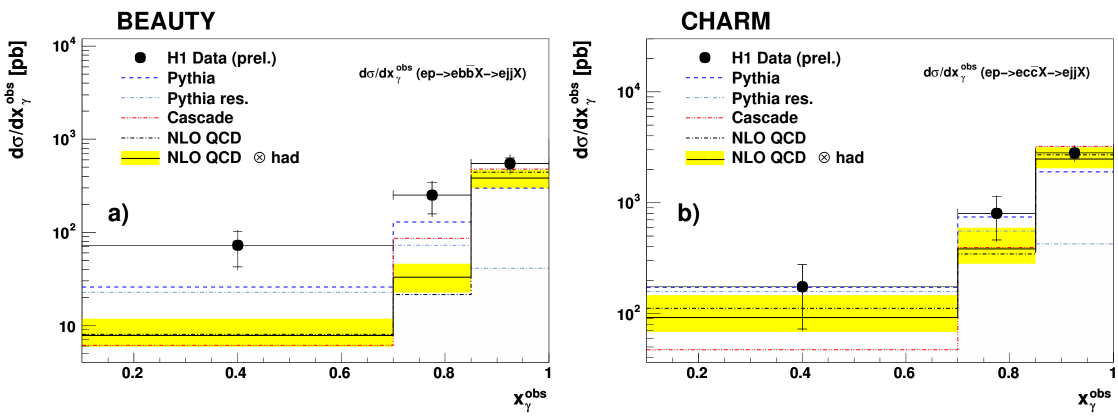

FIGURE 2. Differential charm and beauty cross section as a function of x_γ^{obs}. The data is compared to the prediction from CASCADE (dotted line) and PYTHIA (dashed line). The prediction from a NLO QCD calculation is shown before (dashed-dotted line) and after (solid line) hadronisation corrections, and the shaded band describes the scale uncertainty of the calculation.

data (figure 2a). In these regions the contribution to the cross section from events with resolved photons is particularly large. The prediction from PYTHIA for this contribution is indicated by the dashed-dotted line.

PYTHIA and CASCADE give a good description of the shapes of the data distributions. However, the beauty data are generally higher in normalisation than the PYTHIA (CASCADE) prediction by a factor ~ 1.8 (~ 1.6), respectively.

CONCLUSION

A measurement of differential charm and beauty dijet photoproduction cross sections at HERA has been presented. The measurement makes use of the precise tracking information available from the H1 vertex detector. The heavy quark cross sections are determined by making use of the lifetime distributions of charm and beauty hadrons.

While the charm cross sections are reasonably well described in both normalization and shape, the beauty cross sections are found to be somewhat higher than a calculation in perturbative QCD to next-to-leading order.

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