MEASUREMENT OF CHARM AND BEAUTY DIJET CROSS SECTIONS IN PHOTOPRODUCTION AT HERA USING THE H1 VERTEX DETECTOR

L. FINKE
University of Hamburg, Germany

A measurement of charm and beauty dijet 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 dijet cross sections for charm and beauty, and their relative contributions to the flavour inclusive dijet photoproduction cross section, are measured. Taking into account the theoretical uncertainties, the charm cross sections are consistent with a QCD calculation in next-to-leading order, the predicted cross sections for beauty production being somewhat lower than the measurement.

A measurement is presented of charm and beauty production in *ep* collisions at HERA using events with two or more jets at high transverse momentum [1]. Events containing heavy quarks are determined using a fit to the lifetime signature of charged particles in jets. This analysis provides the first simultaneous measurement of charm and beauty in photoproduction at HERA, extending to larger values of transverse jet momentum than previous measurements.

The analysis covers the photoproduction region, where the virtuality of the photon emitted from the incoming positron is small, $Q^2 \sim 0$. In pQCD calculations, the photoproduction of charm and beauty proceeds dominantly via the direct photon-gluon fusion process $\gamma g \rightarrow c\bar{c}$ or $b\bar{b}$, where the photon interacts with a gluon from the proton to produce a pair of heavy quarks in the final state.

The measurement is based on an integrated luminosity of 56.8pb^{-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, $p_{\mathrm{t}}^{\mathrm{jet}_{1(2)}} > 11(8)$ GeV, in the central rapidity range, $-0.9 < \eta^{\mathrm{jet}_{1(2)}} < 1.3$ are selected. For the final sample only those events which have at least 1 well measured track with hits from the central silicon tracker CST [2] with polar angle $30^\circ < \Theta_{track} < 150^\circ$ and a minimum transverse momentum of 0.5 GeV, and where the tracks are associated to one of the two highest p_t jets are used. In order to separate the different quark flavours, the two significance distributions S_1 and S_2 are used where the significance is defined as the ratio of the impact parameter to its error. 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. 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. For jets contributing to the distribution of S_2 it is required that the tracks with the first and second highest absolute significance in the jet have the same sign of the impact parameter. The c, b and light quark fractions in the data are extracted using a simultaneous least squares fit of simulated reference distributions for c, b and light quark events, obtained from the PYTHIA Monte Carlo simulation, to the measured (subtracted) S_1 and S_2 distributions.

From the fit results scale factors for charm and beauty are determined for the samples in each bin. The differential cross section in this bin is obtained by multiplying the bin-averaged cross section predictions of the PYTHIA Monte Carlo simulation by the scale factor, divided by the respective bin size.

The total dijet charm photoproduction cross section in the range $Q^2 < 1\,\mathrm{GeV}^2$, $0.15 < y < 0.8$, $p_{\mathrm{t}}^{\mathrm{jet}_{1(2)}} > 11(8)$ GeV and $-0.9 < \eta^{\mathrm{jet}_{1(2)}} < 1.3$ is measured to be $\sigma(ep \rightarrow ec\bar{c}X \rightarrow ejjX) = 702 \pm 67(stat.) \pm 95(syst.)\mathrm{pb}$. For the same kinematic range, the measured beauty cross section is $\sigma(ep \rightarrow eb\bar{b}X \rightarrow ejjX) = 150 \pm 17(stat.) \pm 33(syst.)\mathrm{pb}$. In comparison a NLO QCD calculation using the program FMNR yields total cross sections for charm and beauty of 500^{+173}_{-99} pb and 83^{+19}_{-14} pb, respectively.

Figure 1 shows the measured differential cross sections for both, charm and beauty, as functions of $p_t^{jet_1}$ 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. 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. Both Monte Carlo simulations imple-

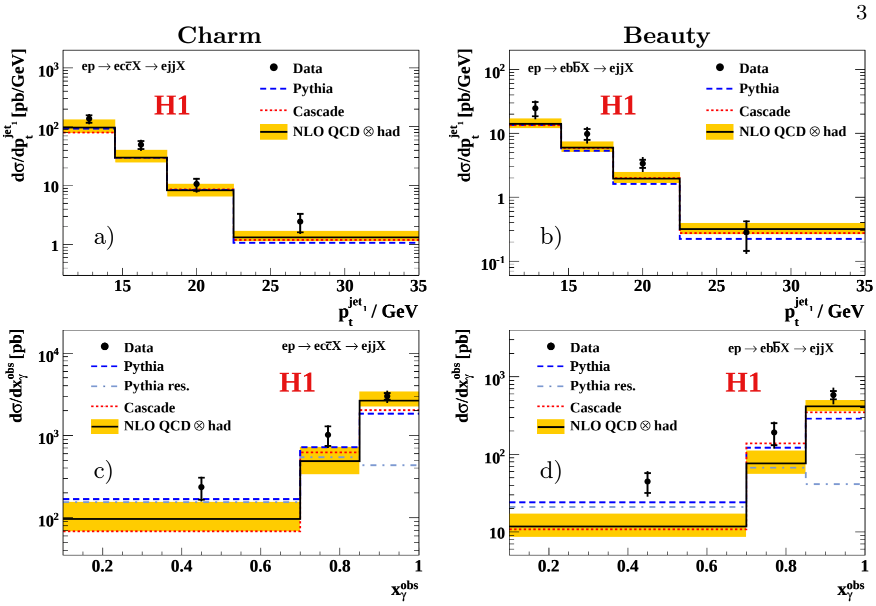

Figure 1. Differential charm (left column) and beauty (right column) photoproduction cross sections a, b) $d\sigma/dp_t^{\mathrm{jet}_1}$ and c, d) $d\sigma/dx_\gamma^{\mathrm{obs}}$ for the process $ep \to e(c\bar{c}$ or $b\bar{b})X \to ejjX$. The inner error bars indicate the statistical uncertainty and the outer error bars show the statistical and systematic errors added in quadrature. The data is compared to various QCD predictions.

ment leading order matrix elements and contributions from higher orders are approximated using parton showers.

Both the charm and beauty data are reasonably well described in shape by FMNR. Towards small values of x_γ^{obs} (figure 1c and d) the prediction tends to be below the data (for beauty $\sim 2\sigma$ in the lowest bin). In this region, PYTHIA predicts a large contribution from events with resolved photons, in which the photon acts as a source of partons. According to PYTHIA a large fraction of these resolved photon processes is due to heavy quark excitation, in which one of the partons that enters the hard interaction is a heavy quark (c or b) originating from the resolved photon or the proton. PYTHIA describes the shapes of the charm and beauty data distributions, while the normalisations are low. The CASCADE prediction is too small in the region of small x_γ^{obs}, but approaches the measurement in the region $x_\gamma^{\mathrm{obs}} > 0.85$.

To obtain the fractional contributions of events containing charm and beauty quarks, the measured differential cross sections for charm and beauty dijet production are divided by the corresponding flavour inclu-

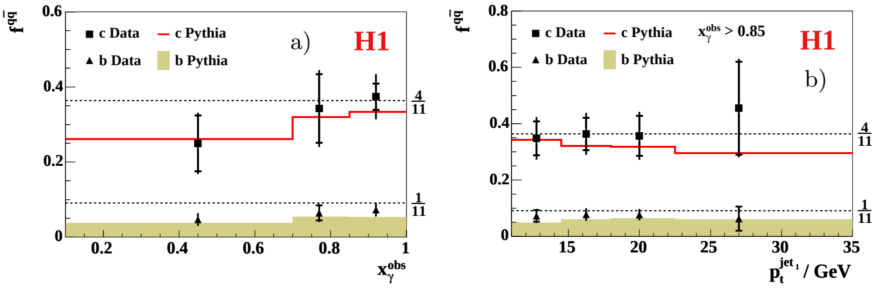

Figure 2. Relative contributions from charm (squares) and beauty events (triangles) as a function of a) the observable $x_\gamma^{\rm obs}$ and b) the transverse momentum of the leading jet $p_{\rm t}^{\rm jet_1}$ for the region $x_\gamma^{\rm obs} > 0.85$. The solid line (shaded area) indicates the absolute prediction from PYTHIA for charm (beauty). The dashed line corresponds to the absolute prediction from naïve quark charge counting.

sive cross sections. In figure 2a, the relative contributions are shown as a function of $x_\gamma^{\rm obs}$. The data are compared with the PYTHIA Monte Carlo simulation which predicts an increase of the relative charm and beauty contributions towards large $x_\gamma^{\rm obs}$ where direct photon-gluon fusion processes dominate. Assuming the charm and beauty quarks to be light, naïve quark charge counting predicts a value of four for the relative production rates of charm to beauty dijets in direct photon-gluon fusion processes. In comparison, the measurement in the region $x_\gamma^{\rm obs} > 0.85$ yields a ratio of 5.1 ± 1.1 (stat.). In figure 2b the relative contributions to the dijet cross section are shown for the region $x_\gamma^{\rm obs} > 0.85$ as a function of $p_{\rm t}^{\rm jet_1}$. The ratios are constant within their uncertainties.

In conclusion, the charm cross sections are consistent both in normalisation and shape with a calculation in perturbative QCD to next-to-leading order. For beauty, the NLO calculations tend to be somewhat lower than the data, by 1.6σ for the total cross section, with an increased difference observed in the region of $x_\gamma^{\rm obs} < 0.85$ where processes involving resolved photons or higher order contributions are expected to be enhanced. In the region $x_\gamma^{\rm obs} > 0.85$, the relative charm and beauty fractions are found to be in agreement within errors with values of 4/11 and 1/11, i.e. the naïve expectation for the direct photon-gluon fusion process, assuming all quarks to be massless.

References

1. A. Aktas *et al.* [H1 Collaboration], to appear in Eur. Phys. J. C., [hep-ex/0605016].
2. D. Pitzl *et al.*, Nucl. Instrum. Meth. A **454** (2000) 334 [hep-ex/0002044].