Measurement of Beauty Photoproduction from Inclusive Secondary Vertexing at HERA

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Photoproduction of beauty quarks in events with two jets has been measured with the ZEUS detector at HERA using an integrated luminosity of $[128]pb^{-1}$. The beauty content was extracted using the decay-length significance of the b hadrons and the invariant mass of the decay vertices. Differential cross sections in $P_{\mathrm{T}}^{\mathrm{Jet}}$ and η^{Jet} are compared with the PYTHIA leading order plus parton shower (LO+PS) Monte Carlo and QCD predictions calculated at next-to-leading order. Furthermore the differential cross section as a function of η^{Jet} is compared to a previously published HERA I result.

1 Introduction

The production of beauty quarks in $e^{\pm}p$ collisions at HERA provides a good testing ground of perturbative Quantum Chromodynamics (QCD), as the large b-quark mass ($m_b \sim [5]GeV$) provides a hard scale that should ensure reliable predictions.

In contrast to previous measurements, in this analysis no requirements were imposed on the final state of the b decay. The measurement is therefore kept fully inclusive and benefits from the increase in statistics compared to the exclusive $b \to \mu$ and $b \to e$ analyses.

2 Event and candidate selection

A sample of photoproduction events ($Q^2 < [1]GeV$) was selected from $e^{+}p$ collisions collected during 2006 and 2007 with the ZEUS detector, corresponding to an integrated luminosity of $\mathcal{L} \approx [128]pb^{-1}$. At least two jets with a pseudorapidity $|\eta^{\mathrm{Jet}}| < 2.5$ and a transverse momentum $P_{\mathrm{T}}^{\mathrm{Jet}} > [7(6)]GeV$ were required in the event. Standard cuts were applied to reject the contribution from deep inelastic scattering (DIS) events, corresponding to an effective cut of $Q^2 < [1]GeV^2$ and $0.2 < y < 0.8$, where y is the event inelasticity.

In order to reconstruct the b-hadron decay vertices, tracks were selected which had a transverse momentum $p_t \geq [0.5]GeV$ and were well reconstructed in the central tracking detector (CTD) and the microvertex detector (MVD). They were associated to one of the two highest energetic jets if they were within a cone of $\Delta R < 1$ with respect to the jet axis, with $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$. If two or more such tracks were associated to the selected jet, a candidate vertex was fitted from all associated tracks. Only vertices made of tracks with $\eta < 1.5$ were considered in the analysis. Finally, vertices with $\chi^2/\mathrm{dof} < 6$ and a distance from the interaction point $d_{XY} < [1]cm$ in the X-Y-plane (perpendicular to the beam axis) and $d_Z < [30]cm$ in Z (along the beam axis) were selected for the extraction of the beauty signal.

The same event and candidate selection was applied to Monte Carlo (MC) samples of beauty (b), charm (c) and light flavour (lf) events generated with PYTHIA 6.2 [1].

3 Determination of the b content

The heavy flavour content of the selected sample was determined by means of the decay-length significance, S, which is defined as the component of the decay length, d, projected on the X-Y-plane, along the jet-axis divided by its error δd. The decay-length significance distribution was divided into several bins of the invariant mass of the secondary vertex tracks providing almost pure beauty region at $[2]GeV \leq m_{vtx} < [7.5]GeV$, while the lower mass bins are dominated by charm. Figure 1 (left) shows S for the highest m_{vtx} range. In order to cancel potential systematic effects and to reduce the light flavour contribution, the left side of the significance (S^-, $S < 0$) was mirrored onto and subtracted from the right side (S^+, $S > 0$).

In order to extract the contributions from b and c quarks in the sample a binned χ^2 fit of the mirrored significance distributions ($S^+ - S^-$) was performed simultaneously in all three mass bins. The overall MC normalisation was constrained by adjusting the relative normalisation of the three MC subsamples to be consistent with the normalisation of the data in the unmirrored significance distribution. Figure 1 (right) shows $S^+ - S^-$ in three mass bins after the fit. The same fit was done in bins of $P_{\mathrm{T}}^{\mathrm{Jet}}$ and η^{Jet} for the extraction of the b content in the differential cross sections.

Requiring $m_{vtx} > [2]GeV$ and $S^+ - S^- > 8$ it was possible to obtain an almost pure beauty sample, for which good agreement between data and MC was found.

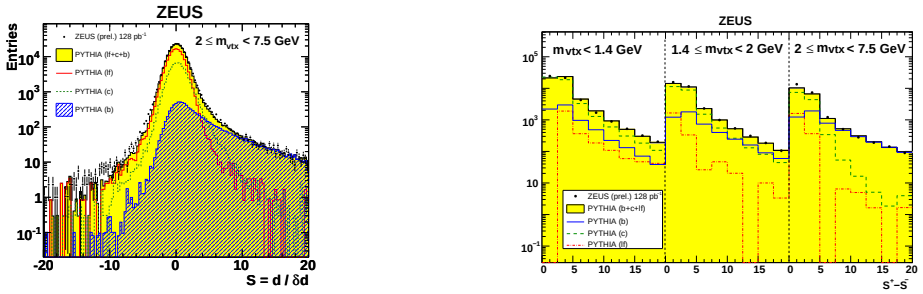

Figure 1: Distribution of decay-length significance, S, for $[2]GeV \leq m_{vtx} < [7.5]GeV$ (left) and mirrored decay-length significance in three mass bins (right) displaying the data and total MC distributions as well as the contributions from the three MC subsamples normalised according to the fractions obtained from the fit.

4 Results

The differential cross sections as a function of $P_{\mathrm{T}}^{\mathrm{Jet}}$ and η^{Jet} were measured for the process $e^+p \to e^+b\bar{b}X$ in the kinematic range $Q^2 < [1]GeV^2$, $0.2 < y < 0.8$, $P_{\mathrm{T}}^{\mathrm{Jet}\ 1(2)} > [7(6)]GeV$, $-2.5 \leq \eta^{\mathrm{Jet}\ 1(2)} < 2.5$ with at least one of the jets within $-1.6 \leq \eta^{\mathrm{Jet}\ 1(2)} < 1.3$. The results are compared to the PYTHIA LO+PS prediction as well as an NLO QCD prediction calculated

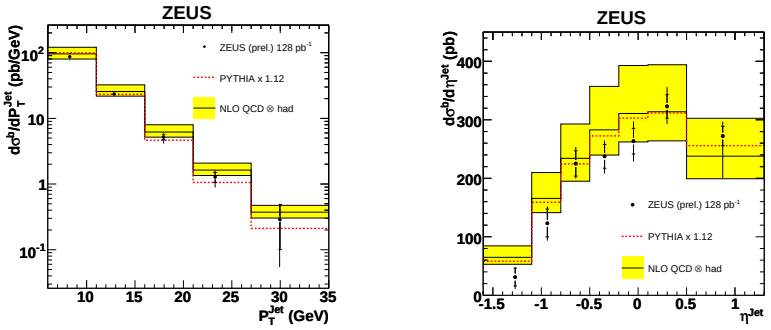

Figure 2: Differential cross section as a function of $P_T^{\rm Jet}$ (left) and $\eta^{\rm Jet}$ (right) for $Q^2 < [1]GeV^2$, $0.2 < y < 0.8$, $P_T^{Jet\ 1(2)} > [7(6)]GeV$ and $-2.5 \leq \eta^{\rm Jet\ 1(2)} < 2.5$ using jets with $-1.6 \leq \eta^{\rm Jet\ 1(2)} < 1.3$. The black points show the results from this analysis. The inner error bars are statistical uncertainties, while the outer error bars show the statistical and systematic uncertainties added in quadrature. The band represents the NLO QCD prediction with its uncertainties.

using the FMNR programme [2] as shown in Fig. 2. The FMNR settings were the same as in [3] with the default scale $\mu = \frac{1}{2}\sqrt{(p_t^b)^2 + m_b^2}$. Good agreement between the measurement and the predictions was observed. Furthermore, the cross sections as a function of $\eta^{\rm Jet}$ were compared to a previously published HERA I analysis [4]. The measurements agree well; the measurement presented here is much more precise than the previous analysis.

5 Conclusion

A measurement of beauty photoproduction using HERA II e^+p data collected in 2006 and 2007 has been presented. The decay-length significance, S, and the invariant mass, m_{vtx}, of the b hadron decay vertex have been used to determine the heavy quark contributions to the selected dijet sample. The production cross sections were found to be compatible with previous measurements and with NLO QCD predictions, while significantly improving the precision of the measurement.

References

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[4] ZEUS Collaboration; S. Chekanov et al. Bottom photoproduction measured using decays into muons in dijet events in ep collisions at $\sqrt{s} = [318]GeV$. *Phys. Rev.*, D 70:12008, 2004.