HEAVY-FLAVOURED JETS AT HERA

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Heavy-flavoured jets have been studied in photoproduction at HERA. This includes the first measurement of dijet angular distributions in D* photoproduction and the ratio of the vector/(vector + pseudoscalar) production rate for charm mesons.

1 Introduction

The study of heavy-flavoured jets allows a detailed investigation of pQCD and the potential to understand the heavy quark production mechanism. In this paper only charm is considered. Measurements relating to the universality of charm fragmentation fraction are made. Measurements of both inclusive jets and dijets with a charm meson have been performed to probe the dynamics and the contents of the photon and proton at HERA.

2 Heavy Flavour (charm) Production and Fragmentation

Charm mesons in the ground state can be in either a vector state (V) or a pseudoscalar state (PS) corresponding to D* or D meson[a] with spin 1 or 0, respectively. Their relative production P_v = V/(V + PS) is sensitive to non-perturbative effects in the hadronisation process and cannot be calculated exactly. The value P_v is calculated with respect to the ground-state charm mesons via the decay channels $D^{*+} \to D^0\pi_s^+ \to (K^-\pi^+)\pi_s^+(+c.c.)$ and $D^0 \to K^-\pi^+(+c.c.)$. It is assumed that the $D^{*\pm}$ and D^0 are produced with equal probabilities and only in fragmentation and D^0 is produced either directly ($f(c) \to D^0 + X$) or via D* decays. This leads to:

$$P_v = \frac{1}{(\sigma_{tot}(D^0)/\sigma_{tot}(D^{*+})) - BR(D^{*+} \to D^0\pi^+)} \tag{1}$$

where BR is the branching ratio and σ_{tot} is the measured cross section.

In this paper, the analysis [1] is based on $D^{*\pm}$ and D^0 events with an almost real photon (virtuality, $Q^2 \approx 3.10^{-4}$ GeV^2) in a photon-proton center of mass energy, W, in the range 130 < W < 295 GeV. Using the $\triangle$M = M(D*) -

[a] $D^{*\pm}(2010)$ is referred to as D* for the rest of this paper.

M(D^0) tag the sample is then further divided into D^0 mesons arising from and not from D* mesons. After this division there were 1180 ± 39 events with a D^0 meson from a D* and 5223 ± 185 inclusive D^0 meson events and the resulting value for P_v in the full phase space is:

$$P_v = 0.546 \pm 0.045(stat)^{+0.028}_{-0.028}(syst).$$

This is in good agreement with the values of 0.57 ± 0.05 and 0.595 ± 0.045 [2] measured in e^+e^- annihilations.

3 Charm with Jets

In order to understand charm production further, the inclusive jet cross section for events containing a D* meson has been measured. Here the non-perturbative effects, which are currently poorly understood, are more suppressed than in inclusive charm production. Cross sections as a function of the pseudorapidity (η^{jet}) for D* jet and non-D* jet samples are shown in

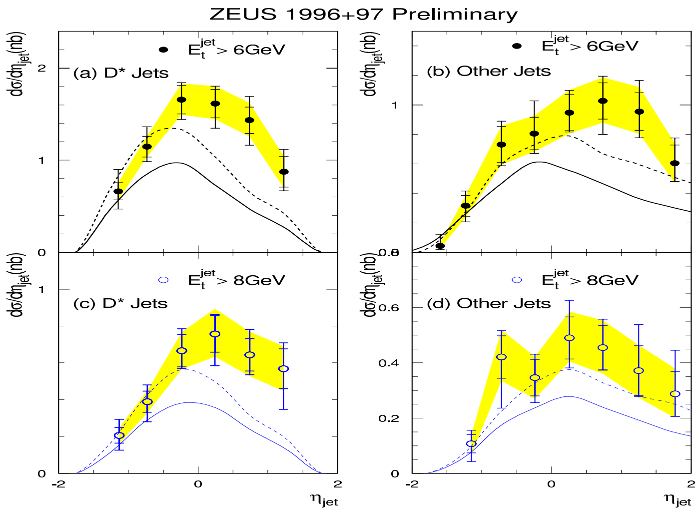


Figure 1. *D* and non-D* jet cross sections $d\sigma/d\eta_{jet}$ of D* photoproduction events with the kinematic cuts: $Q^2 < 1$ GeV^2, $130 < W < 280$ GeV, $p_\perp^{D*} > 3$ GeV and $|\eta^{D*}| < 1.5$. The upper plots (a) and (b) are for $E_t^{jet} > 6$ GeV and the lower plots (c) and (d) are for $E_t^{jet} > 8$ GeV. The inner error bars represent the statistical errors, and the outer bars the quadratic sum of statistical and systematic uncertainties. The solid and dotted curves are NLO predictions using renormalisation and factorisation scales set to $\mu_R = m_\perp; \mu_F = 2m_\perp$ with charm mass $m_c = 1.5$ GeV and $\mu_R = 0.5m_\perp$, $m_c = 1.2$ GeV respectively.*

Fig. 1. The D* jet is defined to be that jet nearest to the D* in $\eta - \phi$ ($\triangle R \equiv \sqrt{(\phi_{jet} - \phi_{D*})^2 + (\eta_{jet} - \eta_{D*})^2} < 0.6$) space. The remaining jets in the

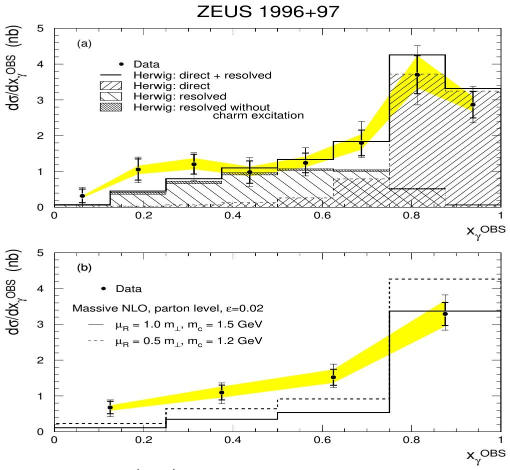
event are called non-D* jets. In Fig. 1, the NLO ("massive charm" scheme [3]) calculations underestimate both jet cross sections by approximately a factor of two. Even with an extreme set of parameters, NLO fails to describe both the shape and the absolute cross section. The differences in shape and normalization for both D* and non-D* jet cross sections cannot be accounted for by the hadronisation corrections.

4 Charm with Dijets

Given the discrepancies between data and the NLO prediction, it is of interest to probe the kinematics of charm production in more detail, by measuring the dijet cross section. The variable (x_γ^{OBS}) related to the momentum fraction of the parton from the photon, is defined as the fraction of the photon's energy participating in the production of the two highest transverse energy jets:

$$x_\gamma^{OBS} = \frac{\sum_{jet1,2} E_T^{jet} e^{-\eta^{jet}}}{2yE_e} \qquad (2)$$

where yE_e is the initial photon energy. The measured differential cross section, $d\sigma/dx_\gamma^{OBS}$ is compared with HERWIG MC (normalised to the data) and predictions from NLO massive charm calculation [3] in Fig. 2. There is a substantial tail at low x_γ^{OBS}, which requires a LO-resolved component to describe the data. The predictions from NLO, where charm is not treated as an active flavour in the photon structure function, significantly underestimates the data at low x_γ^{OBS}. Using an extreme set of parameters in the calculation yields a larger cross section at low x_γ^{OBS}, but is still below the data. Further studies were made to probe more directly the production mechanism. This was done by considering the differential distribution [4] $dN/d|\cos\theta^*|$, where θ^* is the angle between the jet-jet axis and the beam direction in the dijet rest frame. This distribution is sensitive to the parton dynamics of the underlying subprocesses. The distribution was considered for direct-enriched ($x_\gamma^{OBS} > 0.75$) and resolved-enriched ($x_\gamma^{OBS} < 0.75$) samples. Additional cuts (as shown in Fig. 3) on the dijet invariant mass, M_{jj}, and the average pseudorapidity of the jets, $|\overline{\eta}|$, were checked to ensure an unbiased phase space region. The measured differential distributions $dN/d|\cos\theta^*|$ for both $x_\gamma^{OBS} < 0.75$ and $x_\gamma^{OBS} > 0.75$ are shown in Fig. 3. They are significantly different, which reflects the different spins of the quark and gluon propagator. This is well reproduced by the PYTHIA prediction. The steep rise towards high $|\cos\theta^*|$ values of the resolved dijet charm events, consistent with gluon exchange, provides strong evidence that the bulk of the resolved contribution is due to charm excitation in the photon, rather than to the more conventional resolved process $gg \to c\overline{c}$.



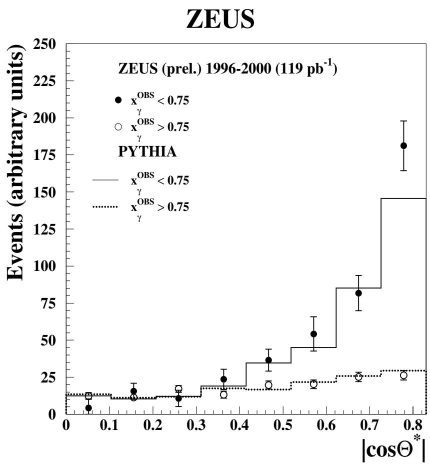


Figure 2. *(left) The differential cross section $d\sigma/dx_\gamma^{OBS}$ for dijets with an associated D^* meson with $p_\perp^{D*} > 3$ GeV, $|\eta^{D*}| < 1.5$, $130 < W < 280$ GeV, $|\eta^{jet}| < 2.4$, $E_T^{jet1} > 7$ GeV and $E_T^{jet2} > 6$ GeV. The experimental data (dots) are compared to (a) HERWIG MC and (b) a parton level NLO calculation with the parameters shown in the plot.*

Figure 3. *(right) The differential distributions $dN/d|cos\theta^*|$ of the data (dots) with $p_\perp^{D*} > 3$ GeV, $|\eta^{D*}| < 1.5$, $130 < W < 280$ GeV, $|\eta^{jet}| < 2.4$, $E_T^{jet1,2} > 5$ GeV, $M_{jj} > 18$ GeV, $|\overline{\eta}| < 1.2$ and of PYTHIA MC simulations (lines). Results are given separately for direct photon (open dots/dashed lines) and for resolved photon (black dots/full histogram) events. All the distributions are normalised to the resolved data distribution in the lowest 4 bins.*

5 Conclusions

Heavy-flavoured jets provide an important tool for understanding the heavy quark production mechanism. Measurement of P_v confirms the universality of the charm fragmentation. However inadequacies in current NLO calculations in describing heavy-flavour jet production are clearly evident. The $|\cos\theta^*|$ distribution for dijet events with a D* shows a clear signature of gluon propagator for events with $x_\gamma^{OBS} < 0.75$, suggesting strong evidence of charm in the photon.

References

1. ZEUS Coll., *Study of Inclusive D^0 Photoproduction at HERA*. Paper 501, EPS HEP01, Budapest, Hungary, July 12-18, 2001.
2. OPAL Coll., K.Ackerstaff *et al*, *Eur. Phys. J.* C **5**, 1 (1998);
   ALEPH Coll., R.Barate *et al*, *Eur. Phys. J.* C **16**, 597 (2000).
3. S.Frixione *et al*, *Phys. Lett.* B **384**, 633 (1995);
   S.Frixione *et al*, *Nucl. Phys.* B **454**, 3 (1995).
4. ZEUS Coll., *Dijet Angular Distributions in D* Photoproduction at HERA*. Paper 499, EPS HEP01, Budapest, Hungary, July 12-18, 2001.