Heavy Flavours in Photoproduction at HERA

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Differential cross sections, $d\sigma/dx^{OBS}$, for dijet photoproduction events with a tagged $D^*$ meson are presented, where $x^{OBS}$ is the fraction of the photon energy contributing to the two highest transverse energy jets. Results on open beauty cross sections (from semileptonic decays) compared to LO Monte Carlo predictions are also presented.

1 Photoproduction

The photon structure is being probed in new kinematic regimes at HERA. Tagging of charmed mesons or semileptonic decays in photoproduction events is providing a wealth of information on charm in the photon and the processes involved in its production. Since photoproduction of charm and beauty is much less affected by non-perturbative and higher-order effects than hadroproduction cross sections, the HERA measurements can provide important tests of the heavy-flavour production dynamics.

In photoproduction at leading order (LO), two types of process contribute to the hard scatter: direct photoproduction, where the photon enters directly into the hard subprocess, and resolved photoproduction, where the photon acts as a source of partons, which in turn interact in the hard subprocess. At next-to-leading order (NLO), only the sum of direct and resolved processes is unambiguously defined.
Figure 1: The \(x_{\gamma}^{\text{OBS}}\) distribution for tagged \(D^*\) decays from charm, beauty and light quarks. The points are ZEUS preliminary data for the 1996 and 1997 data sample. The inner error bars are the statistical errors and the outer error bars are the statistical and systematic errors added in quadrature. The shaded curve represents the uncertainty due to the energy scale of the jets. In (a) the shaded histograms show the direct and resolved contributions as predicted by HERWIG 5.9. The solid line is the two contributions added together. In (b) the same data are shown (rebinned into four bins) compared to a NLO calculation with two choices of parameters.

2 Photoproduction of Charm

H1 and ZEUS have published measurements of \(D^*\) mesons in photoproduction. In photoproduction events with two or more jets it is possible to define an observable

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x_{\gamma}^{\text{OBS}} = \frac{\sum_{\text{jets}} E_{T,jet} e^{-\eta_{\text{jet}}}}{2yE_{\gamma}},
\]

where the sum is over the two jets with highest transverse energy. In LO, \(x_{\gamma}^{\text{OBS}}\) can be interpreted as an observable related to the fraction of the photon’s momentum participating in the hard-scale interaction. At higher \(x_{\gamma}^{\text{OBS}} > 0.75\), the direct processes dominate, while at lower \(x_{\gamma}^{\text{OBS}}\) the resolved processes dominate.

ZEUS have published a measurement of \(x_{\gamma}^{\text{OBS}}\) with a tagged \(D^*\) meson, for the kinematic regime, \(Q^2 < 1 \text{ GeV}^2\), \(130 < W_{\gamma P} < 280\), two jets with \(E_T > 7,6 \text{ GeV}\) and \(|\eta| < 2.4\), and a \(D^*\) in the final state with \(p_T > 3.0 \text{ GeV}\) and \(|\eta| < 1.5\). This is shown in Figure 1. This shows a clear tail to low \(x_{\gamma}^{\text{OBS}}\), which in terms of LO Monte Carlo programs can only be explained by a large (40%) component of LO-resolved processes. This is heavily dependent on the amount of charm in the parton density function used. A NLO calculation, performed in a factorization scheme where heavy quarks are exclusively generated in the hard subprocess, cannot describe this long tail and falls below both the data and the LO Monte Carlo.
3 Photoproduction of Beauty

H1 have released a preliminary beauty cross section and comparison with the LO theory. They have used the $p_{T}^{rel}$ method to separate the beauty component. In this method, $p_{T}^{rel}$ is the momentum of the muon transverse to the thrust axis of the constituent particles (minus the muon) of the closest jet. The muons from beauty decays are expected to dominate at high $p_{T}^{rel}$ because of the large beauty mass. The relative composition of the data sample is determined from an unconstrained fit and amounts to $f_b = 51.4 \pm 4.4\%$ (beauty), $f_c = 23.5 \pm 4.3\%$ (charm) and $f_{\text{fake}} = 23.5\%$ (background, fixed). For the kinematic range, $Q^2 < 1 \text{ GeV}^2$, $0.1 < y < 0.8$, $p_T > 2.0 \text{ GeV}$ and $35^\circ < \theta^\mu < 130^\circ$, H1 quote a preliminary visible cross section of $\sigma_{\text{vis}}^{ep \rightarrow e+b\bar{b}+X} = 0.93 \pm 0.08^{+0.21}_{-0.12} \text{ nb}$ and also quote a predicted cross section from AROMA 2.2 of $\sigma_{\text{vis}}^{ep \rightarrow e+b\bar{b}+X} = 0.191 \text{ nb}$. Thus the preliminary measurement of the cross section of open beauty is up to a factor of 5 higher than the LO theory as predicted by the Monte Carlo AROMA. It should be noted that AROMA only produces a direct component. Another additional resolved component should therefore be taken into account in the comparison.

ZEUS have also released a preliminary result of a beauty measurement by the study of semileptonic decays to electrons. The measurement is an inclusive electron measurement, $e^+p \rightarrow e^- + \text{dijets} + X$ in the kinematic region; $Q^2 < 1 \text{ GeV}^2$, $0.2 < y < 0.8$, two jets with $E_T > 7.6 \text{ GeV}$ and $|\eta| < 2.4$ and an electron in the final state with $p_T > 1.6 \text{ GeV}$ and $|\eta| < 1.1$. This measurement includes the contributions from all beauty, charm and light-quark decays, but with conversion electrons removed. The $x^{OBS}_\gamma$ distribution (Figure 2) shows, similar to the $D^*$ study, a clear tail to low $x^{OBS}_\gamma$, which can only be described by a significant fraction of resolved LO Monte Carlo. The $x^{OBS}_\gamma$ distribution also peaks at high values, which is consistent with the observation.
Figure 3: The $p_T^{rel}$ distribution for tagged semileptonic decays as measured in ZEUS. The points are ZEUS preliminary 1996 and 1997 data. The inner error bars are the statistical errors and the outer error bars are the statistical and systematic errors added in quadrature. The shaded curve represents the uncertainty due to the energy scale of the jets. The shaded histograms show the direct and resolved contributions for charm, beauty and light quarks as predicted by HERWIG 5.9. The solid line shown is the sum of the contributions.

of direct processes. The preliminary fit on the fraction of the LO resolved contribution yields $35 \pm 6\%$ and agrees well with the HERWIG 5.9 prediction of 40%. The agreement in shape between the data and the LO Monte Carlo is good.

A constrained fit was done to the $p_T^{rel}$ distribution allowing the fraction of beauty to vary with respect to the charm and light quarks contribution (fixed in the ratios given by HERWIG). ZEUS define $p_T^{rel}$ as the momentum of the electron transverse to the jet axis. A beauty fraction of $20 \pm 6^{+12}_{-7}\%$ is needed to fit the data (assuming a 40% resolved component), in agreement with the HERWIG prediction of 17%. The HERWIG prediction is about a factor 4 smaller than the data (using GRV-LO for the photon structure function and a beauty mass of 4.95 GeV). ZEUS quotes a preliminary visible cross section for beauty production of $\sigma^{vis}_{bb}(e^+p \to e^- + dijet + X) = 39 \pm 11^{+23}_{-16}$ pb in the kinematic region described above.

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