BEAUTY PRODUCTION AT HERA
H1 RESULTS

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The results of beauty quark production measurements in *ep* collisions with the H1 detector at HERA are summarized. The measured cross sections are confronted with perturbative QCD calculations performed at Leading or Next-to-leading order.

1 Introduction

The study of heavy quark production in positron-proton scattering at HERA, with a center of mass energy of 300-318 GeV, provides an important testing ground for QCD. The dominant beauty production mechanism is the *direct* boson gluon fusion (BGF) process (Fig. 1a)), which is directly sensitive to the gluon density in the proton. Further contributions are expected from *resolved* processes (Fig. 1b)), in which the photon initially fluctuates into hadronic

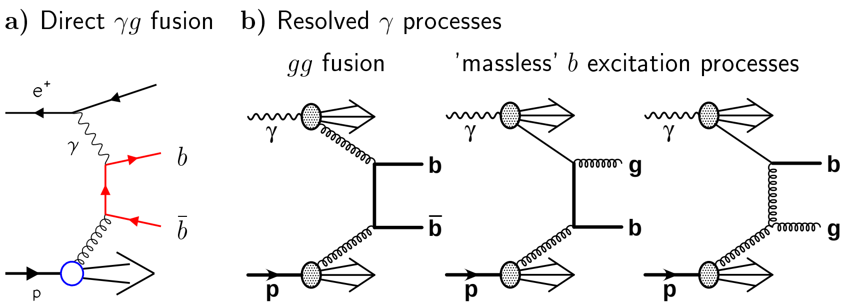

Figure 1: Beauty production processes in leading order pQCD

objects, with one of these participating in the hard interaction.

The large mass of the b-quark introduces a hard scale, which renders a sufficiently small coupling constant α_s, at the hard subprocess, so that perturbative QCD (pQCD) is applicable. Further hard scales can be present in the process by the virtuality Q^2 of the exchanged photon and also by the transvere momentum p_T of the outgoing b-quark. Q^2 varies from the photoproduction regime (γp), where $Q^2 < 1$ GeV^2 to the deep inelastic scattering regime (DIS), where Q^2 ranges from about 1 GeV^2 to $Q^2 \gg m_b^2$. It is expected that the resolved processes are suppressed in DIS towards larger values of Q^2.

One distinguishes between two approaches for pQCD calculations:

- In the *massive* or *fixed order* scheme[1] u,d and s are the only active flavors in the proton and in the photon, and charm and beauty are dynamically produced in the hard scattering (Fig. 1). It is expected that this approach works well for the kinematic region $p_T \leq m_b$ which is dominant at HERA.

- At higher transverse momenta the *massless* or *resummed* approach[2] should be applicable, where charm and beauty are regarded as active flavors (massless partons) in the proton and in the photon and fragmented only after the hard process into massive quarks. This ansatz incorporates excitation processes (Fig. 1 b)).

In the following we will review the measurements of beauty production with the H1 detector at HERA and compare them with calculations in the massive scheme performed at Next-to-leading order (NLO). The results presented here are based on analyses exploiting partial or full statistics of the HERA I data from the years 1996-2000.

2 Open Beauty in Photoproduction

Dijet γp events with an identified muon associated with one of the jets are analysed[3, 4]. The measurements are performed in the kinematical region $Q^2 < 1$ GeV^2, $0.1 < y < 0.8$, $p_{T,\mu} > 2$ GeV, $35^\circ < \theta_\mu < 130^\circ$ and $E_T^{jet_{1,2}} > 5$ GeV. Here y stands for the photon inelasticity. The resulting event sample contains predominantly muons from semileptonic charm or beauty decays, but also muons or misidentified hadrons from events with light quark or gluon jets (fake muon events), due to pion or kaon decays in–flight or hadronic energy leakage (punchthrough), respectively.

To separate beauty, charm and fake muon events, two observables are used, which exploit the large mass and the long lifetime of the b-quark:

1. The transverse momentum p_T^{rel} of the muon with respect to the axis of the

associated jet exhibits for muons from b-decays a much harder spectrum than for the other two sources.

2. The impact parameter δ of the muon track with respect to the primary event vertex, is shifted for muons from b-decays towards larger values as compared to the other two sources.

The relative contributions of beauty and background in the data are determined from a likelihood fit to the distributions of δ and p_T^{rel} (Fig. 2). The separation

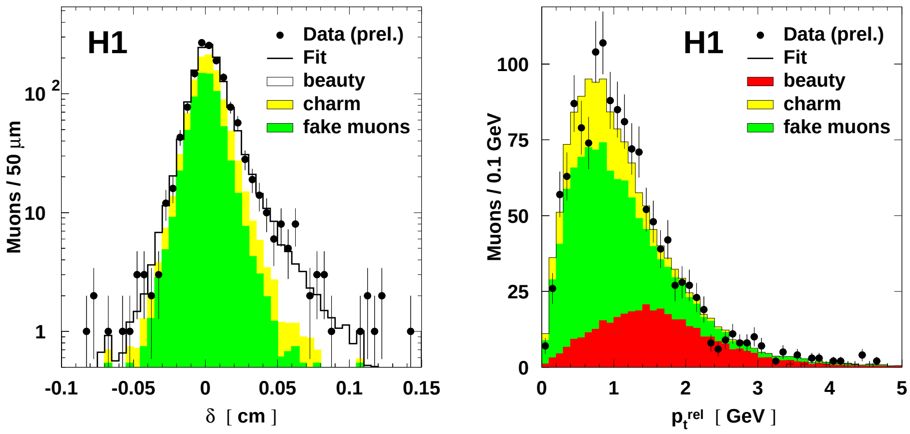

Figure 2: Distributions of the muon impact parameter (left) and p_T^{rel} (right), with decomposition from the likelihood fit.

power can be combined in a likelihood fit of the two–dimensional distribution of δ and p_T^{rel}. Using both observables and combining 1996 and 1997 data, the visible cross section for the production of central muons from b decays is determined to be $\sigma_{vis} = (170 \pm 25)$ pb. The NLO QCD prediction, using a calculation in the massive scheme[7] is (54 ± 9) pb, where the error is dominated by the uncertainties of the renormalization or factorization scale, and of the fragmentation.

3 Open Beauty in DIS

The analysis in the DIS regime[5] also relies on the combination of the two observables δ and p_T^{rel}. The cross section determined for the visible kinematic range $2 < Q^2 < 100$ GeV^2, $0.05 < y < 0.7$, $p_{T,\mu} > 2$ GeV, $35^\circ < \theta_\mu < 130^\circ$ and $E_T^{jet_{1,2}} > 5$ GeV yields $\sigma_{vis} = [39 \pm 8(stat.) \pm 10(syst.)]$ pb. The result of a NLO QCD calculation in the massive scheme[8] is (11 ± 2) pb.

4 D^*-μ correlations

A double tag measurement is made[6]. Events with at least one muon and at least one D^{*+} meson, reconstructed via the decay channel $D^{*+} \to D^0\pi_s^+ \to \pi_s^+ K^-\pi^+$, are selected in the kinematic region $p_T(D^*) > 1.5$ GeV, $|\eta(D^*)| < 1.5$, $p_T(\mu) > 1$ GeV, $|\eta(\mu)| < 1.74$ and $0.05 < y < 0.75$. A separation of charm and beauty is possible exploiting the angular and charge correlation between the muon and the D^{*+} meson. For the total visible $D^*\mu$ production cross sections values of $\sigma_{vis}^c = [720 \pm 115(stat.) \pm 245(syst.)]$ pb and of $\sigma_{vis}^b = [380 \pm 120(stat.) \pm 130(syst.)]$ pb are obtained for charm and beauty production, respectively. The values are larger than the leading order (LO) +

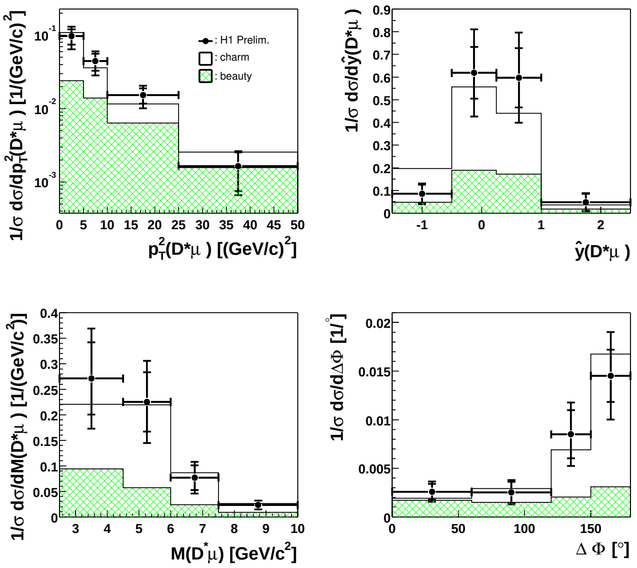

Figure 3: Normalized differential visible $D^*\mu$ cross sections.

parton shower (PS) predictions of the AROMA Monte Carlo program (direct BGF only) by a factor of 1.8 for charm and 3.6 for beauty. In Fig. 3 the normalized differential $D^*\mu$ cross sections are shown together with the AROMA predictions, where the b and c contributions are separately scaled by these factors 3.6 and 1.8, respectively. The measurements are shown as a function of the kinematic variables $p_T^2(D^*\mu), \hat{y}(D^*\mu), M(D^*\mu)$ and $\Delta\phi$, determined all in the lab frame. These variables denote the transverse momentum, the invariant mass and the rapidity of the $D^*\mu$ pair, and the azimuthal angle difference of the D^* and the muon. The LO QCD model describes the shape of the various distribution quite well.

5 Conclusions

Open beauty production at HERA has been measured with single tagged muons in the γp and the DIS regime. Both measurements are found to be above massive NLO QCD expectations. For double tagged $D^*\mu$ events the LO + PS prediction underestimate the beauty cross section by a factor of 3.6. The Monte Carlo model provides a reasonable description of the shape of various kinematic variables describing the $D^*\mu$ final state.

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