OPEN CHARM AND BEAUTY PRODUCTION AT HERA

FELIX SEFKOW
(on behalf of the H1 and ZEUS Collaborations)
Physik-Institut der Universität Zürich, Winterthurerstr. 190, CH-8057 Zürich, Switzerland
E-mail: felix.sefkow@desy.de

Selected new results from the H1 and ZEUS collaborations on ep interactions at 300 - 318 GeV centre-of-mass energy are presented. The full pre-upgrade integrated luminosity of HERA of 110 pb^{-1} is used. Charm cross sections are measured up to high values of x_B and Q^2 and are found to be well described by NLO QCD in the 3 flavour scheme. Orbitally excited D mesons are observed; radial excitations are searched for, but are not seen. The first b cross section measurement is confirmed with a lifetime based method, establishing the excess over NLO QCD.

1 Charm

Thanks to the excellent HERA performance the available statistics has strongly increased. ZEUS now has a signal of 27,000 D^* decays in the "golden" mode $D^* \to D^0\pi^+ \to K^-\pi^+\pi^+$. This wealth of data (similarly at hand for H1) allows perturbative QCD to be tested with charm production data in an extended kinematic range and opens the possibility for charm spectroscopy at HERA.

In QCD, heavy quark production in ep interactions predominantly proceeds via boson gluon fusion (BGF), where a quark anti-quark pair is created in the interaction of a photon with a gluon in the proton (3 Flavour scheme). At four-momentum transfers much higher than the charm quark mass, $Q^2 \gg m_c^2$, such a description becomes inaccurate, and a treatment in terms of charm densities in the proton may be more adequate.

The single-differential D^* cross sections measured in deep inelastic scattering (DIS) by ZEUS [1] as a function of Bjorken-x and Q^2 now cover a range up to $x_B \simeq 0.1$ and $Q^2 \simeq 1000\,\mathrm{GeV}^2$. (Fig. 1) They are compared with NLO QCD calculations in the 3 Flavour scheme [2], which use as input gluon densities from global fits [3] or a parameterization extracted from scaling violations of the proton structure function F_2, measured at HERA. Good agreement is seen, showing that the BGF picture provides an overall consistent description of charm production and inclusive DIS up to high x_B and Q^2.

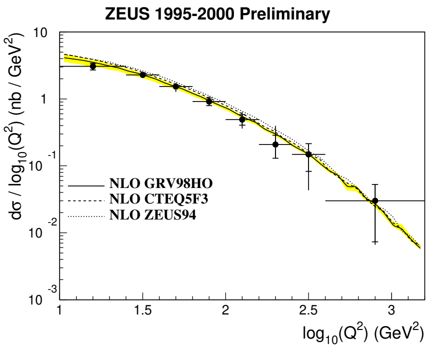

Figure 1. D^* cross section in DIS vs. NLO QCD in the 3 Flavour scheme (shaded: $m_c = 1.3 - 1.6\,\mathrm{GeV}$).

The spectrum of non-strange D mesons is only partially established experimentally. Apart from the lowest mass D and D^* states, the narrow excited P-wave mesons $D_1(2420)$ and $D_2^*(2460)$ have been firmly identified, with spin-parity $J^P = 1^+$ and 2^+. A narrow state interpreted as radially excited $D^{*\prime\pm}$ has been observed by DELPHI [4], but was not confirmed by OPAL and CLEO searches [5].

ZEUS report [6] the observation of orbitally excited D_1^0 and D_2^{*0} mesons in the decay channel $D_J^{(*)0} \to D^{*+}\pi^- +$ c.c. From a fit to the invariant mass (Fig. 2) and π^- helicity angle distributions they extract relative production rates of

$$\frac{D_1^0 \to D^{*+}\pi^-}{D^{*+}} = 3.40 \pm 0.42\,^{+0.78}_{-0.63}\,\%$$

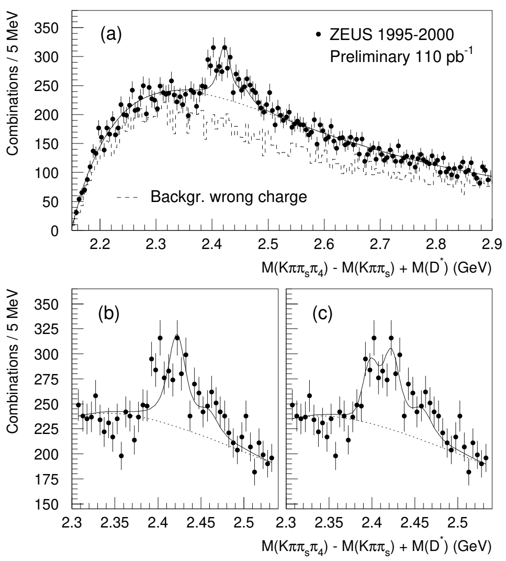

Figure 2. Mass difference distribution for D^{**0} candidates. The curves show fits using mass and helicity angle information.

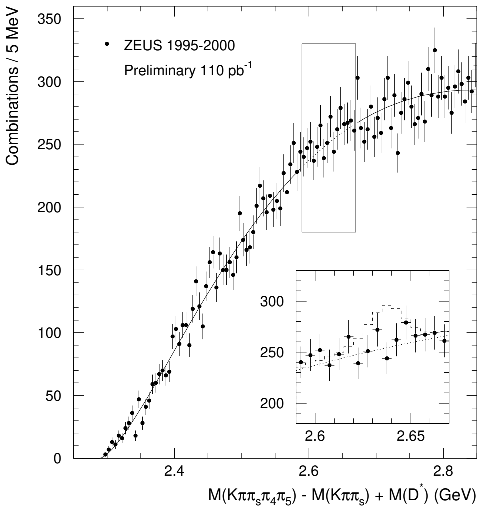

Figure 3. Mass difference distribution for $D^{*\prime\pm}$ candidates. The search region contains 91 ± 75 candidates over the fitted background. The insert shows a Monte Carlo signal normalized to the quoted limit.

$$\frac{D_2^{*0} \to D^{*+}\pi^-}{D^{*+}} = 1.37 \pm 0.40 \,^{+0.96}_{-0.33}\ \%$$

A narrow enhancement ($\sim 4\sigma$) is seen at $m_{D^*\pi} = 2398$ MeV and included in the fit (Fig. 2c), but no definite interpretation of this signal is given yet.

Radially excited states are searched for in the channel $D^{*\prime\pm} \to D^{*+}\pi^+\pi^-$ + c.c. No signal is seen (Fig. 3), so that an upper limit is quoted:

$$\frac{D^{*\prime +} \to D^{*+}\pi^+\pi^-}{D^{*+}} < 2.3\,\% \ \text{(at 95\% C.L.)}$$

which indicates that the search has a sensitivity corresponding to about the size of the claimed DELPHI signal. Since at HERA almost all charmed mesons originate from prompt charm production, and feed-down from beauty can be neglected, a rather tight limit on $D^{*\prime\pm}$ production in charm fragmentation can be set (at 95% C.L.):

$$f(c \to D^{*\prime +}) \cdot \mathrm{BR}(D^{*\prime +} \to D^{*+}\pi^+\pi^-) < 0.7\%$$

2 Beauty

Beauty production at HERA is suppressed with respect to charm by two orders of magnitude. The measurements so far rely on inclusive semi-leptonic decays, using as signature the high mass of the b quark by observing the transverse momentum p_T^{rel} of the lepton relative to a jet, and also its long lifetime by observing tracks from secondary vertices. The first measurement by H1 [7], using the p_T^{rel} method, revealed a b photoproduction cross section almost a factor of 2 above theoretical prediction [8] (Fig. 4).

The new H1 measurement [9] also uses photoproduction dijet events, where now at least one muon is measured in the two-layer silicon vertex detector. The signed impact parameter δ is determined in the plane transverse to the beam, axis, and the distribution is decomposed by a maximum likelihood fit which adjusts the relative contributions from beauty, charm and fake muons to the sample (Fig. 5). The fit describes the data well and translates into a b cross section that, using

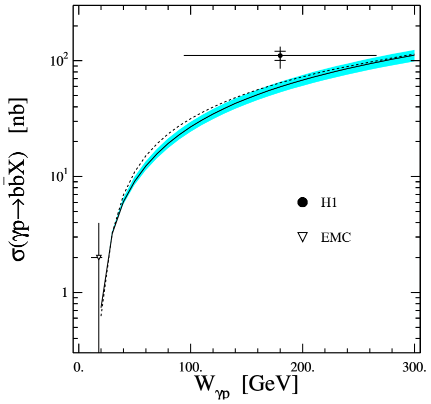

Figure 4. b photoproduction cross section vs. NLO QCD, using different proton structure functions (shaded: scale uncertainty).

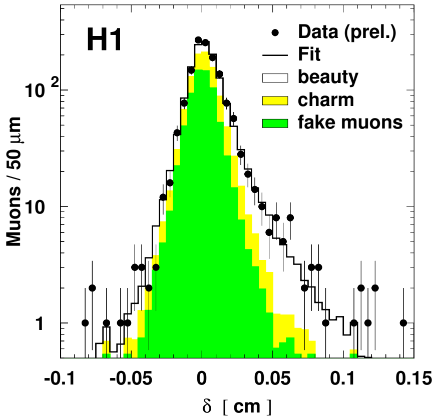

Figure 5. Signed impact parameter distribution for muons. (The sign depends on whether the track intersects the jet axis upstream or downstream (+) of the primary event vertex.)

an independent signature and new data, confirms the published result, based on 1996 data and a different set of cuts. The δ spectrum for a sample with higher b purity, obtained by a cut $p_T^{rel} > 2$ GeV (Fig. 6) agrees well with the prediction from the δ fit to the full sample. Since the two observables are consistent, they can be combined in a likelihood fit of the two-dimensional (δ, p_T^{rel}) distribution. The result, averaged with the published number, is

$$\sigma(ep \to b\bar{b}X \to \mu X) = (170 \pm 25)\,\text{pb}$$

in the range $Q^2 < 1$ GeV^2, $0.1 < y < 0.8$, $p_T(\mu) > 2$GeV, $35° < \theta(\mu) < 130°$. This is higher than the NLO QCD prediction of (104 $\pm$ 17) pb based on [8]. Such a discrepancy between experiment and NLO QCD is now established in both ep and $\bar{p}p$ interactions.

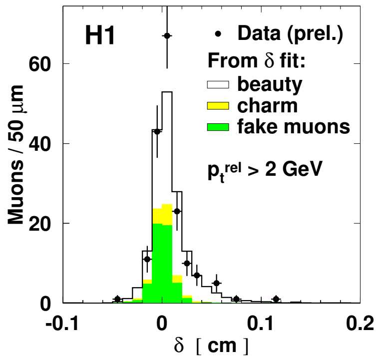

Figure 6. Impact parameter distribution for muons with $p_T^{rel} > 2$ GeV. with the absolute prediction from the fit to the full sample.

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