$D^*\mu$ CORRELATIONS AND D MESON PRODUCTION IN ep SCATTERING AT HERA*

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$D^*\mu$ coincidences are studied using data taken with the H1 detector at HERA during the years 1997 to 2000, corresponding to an integrated luminosity of about 90 pb^{-1}. With the aid of charge and angle correlations between the D^* and the muon, a separation of charm and beauty production contributions is possible. Total charm and beauty production cross sections are shown as well as differential cross sections of several $D^*\mu$ quantities and compared with the prediction of Leading Order (LO) Monte Carlo calculations. In a separate analysis inclusive charm production is studied using e^+p data taken with the H1 detector during the years 1999 to 2000, corresponding to an integrated luminosity of about 48 pb^{-1}. For the charmed mesons D^*, D^0, D_s and D^+ total production cross sections are determined and differential distributions are measured for the D^+ and D^0 mesons, whereby lifetime information is used to improve the signal qualities. The results are compared with predictions, based on LO Monte Carlo simulations. The measured production cross sections are used to determine fragmentation ratios, which are then compared with values measured *e.g.* at e^+e^- colliders.

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1. Introduction

In electron proton collisions heavy quarks are predominantly produced via the Photon Gluon Fusion (PGF) mechanism, where a photon emitted by the incoming electron interacts with a gluon in the proton forming a quark–anti-quark pair. The major contribution is due to the exchange of almost real photons corresponding to a photon virtuality $Q^2 \approx 0$ (photoproduction). In Deep Inelastic Scattering (DIS) Q^2 is large, usually defined experimentally by $Q^2 > 2$ GeV^2. This article reports on two recent measurements of heavy quark production performed by the H1 experiment at the HERA ep collider.

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2. $D^*\mu$ correlations

In this analysis events with at least one D^*, reconstructed via the decay channel[1] $D^{*+} \to D^0\pi_s^+ \to K^-\pi^+\pi_s^+$, and at least one muon are selected. Thus both heavy quarks of the BGF process are detected (double tagging).

In the kinematical region defined by $p_t(D^*) > 1.5$ GeV$/c$, $|\eta(D^*)| < 1.5$, $p_t(\mu) > 1.0$ GeV$/c$, $|\eta(\mu)| < 1.74$ and $0.05 < y < 0.75$ the beauty fraction is strongly enriched mainly due to the p_t cut on the muon. p_t (η) denotes the tranverse momentum (pseudorapidity) of the D^* meson and the muon and y indicates the elasticity.

A separation of charm and beauty is possible exploiting the charge and angle correlations of the D^* and the muon. With the azimuthal angle difference $\Delta\Phi^*$ of the D^* and the muon in the γp centre of mass frame and the charges Q of the D^* and the muon, the following four correlation regions can be defined:

- $Q(D^*) = Q(\mu)$, $\Delta\Phi^* \leq 90°$: no charm, few beauty
- $Q(D^*) = Q(\mu)$, $\Delta\Phi^* \geq 90°$: no charm, beauty
- $Q(D^*) \neq Q(\mu)$, $\Delta\Phi^* \leq 90°$: few charm, beauty
- $Q(D^*) \neq Q(\mu)$, $\Delta\Phi^* \geq 90°$: charm, beauty

Beauty events contribute in all four regions due to the fact, that beauty hadrons usually decay via charm hadrons and the muon can come either from a charm or a beauty hadron. To separate charm and beauty a 2 dimensional log-likelihood-fit is performed in the variables $\Delta M = m_{K\pi\pi_s} - m_{K\pi}$, the mass difference of the D^* and the D^0 candidate, and the correlation regions. In order to remove background contributions, a simultaneous fit of right $(K^-\pi^+\pi_s^+)$ and wrong $(K^+\pi^+\pi_s^-)$ charge combinations is performed. In Fig. 1 the result of the fit is presented in the form of the distribution of the four correlation regions. The distributions contain hadrons misidentified as muons and muons from the decay of light hadrons. For charm the fraction of such muons is about 30% and for beauty 5%, which is subtracted from the data after the fit.

For the total $D^*\mu$ production cross sections in the quoted kinematic region values of $\sigma^c_{\rm vis}(ep \to e'D^*\mu X) = 720 \pm 115$ (stat.) $\pm$ 245 (syst.) pb and of $\sigma^b_{\rm vis}(ep \to e'D^*\mu X) = 380 \pm 120$ (stat.) $\pm$ 130 (syst.) pb are obtained for charm and beauty production, respectively. The values are larger than the Leading Order (LO) matrix element + Parton Shower (PS) prediction (AROMA Monte Carlo [4]) by a factor 1.8 for charm and a factor of 3.6 for beauty. These measurements are compatible with previous results [5, 6]. Normalised differential $D^*\mu$ cross sections for $p_t^2(D^*\mu)$, $\hat{y}(D^*\mu)$, $M(D^*\mu)$

[1] Henceforth, charge conjugate states are always implicitly included.

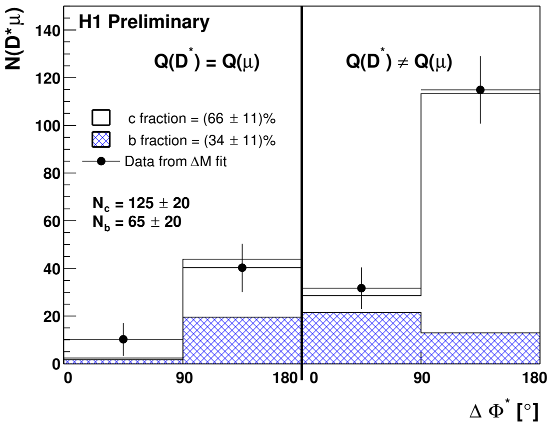

Fig. 1. Distribution of the four charge and angle correlation regions. The solid points are the result of a fit to the ΔM distribution in each correlation region. The black line shows the sum of charm and beauty $D^*\mu$ signal events as obtained from the 2 dimensional fit. The hatched histogram represents the beauty contribution.

and $\Delta\Phi$ are shown in Fig. 2 in comparison with the LO+PS prediction. For charm the LO prediction is multiplied by a factor 1.8 and for beauty by 3.6. $p_{\mathrm{t}}(D^*\mu)$, $M(D^*\mu)$ and $\hat{y}(D^*\mu)$ denote the transverse momentum, the invariant mass and the rapidity of the $D^*\mu$ pair and $\Delta\Phi$ is the azimuthal angle difference of the $D^*\mu$ pair in the lab frame. $p_{\mathrm{t}}(D^*\mu)$, $\Delta\Phi$ and $\hat{y}(D^*\mu)$ can be used to study non perturbative effects. $M(D^*\mu)$ and $\hat{y}(D^*\mu)$ are needed to determine the momentum fraction x_g of the gluon to the proton momentum. The LO+PS prediction describes the shape of the distributions quite well.

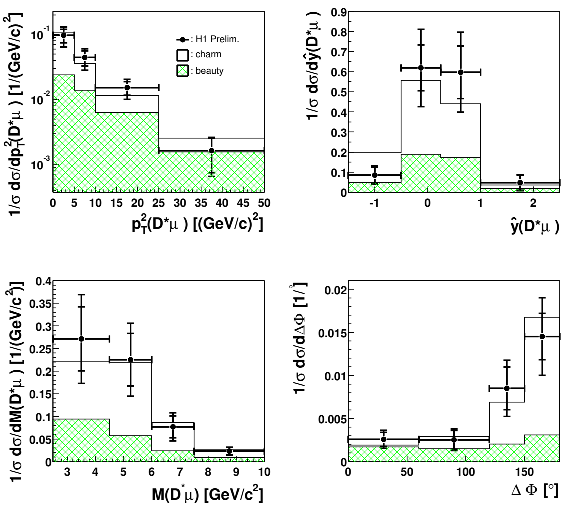

Fig. 2. Normalised differential visible $D^*\mu$ cross sections.

3. D meson production

To test the universality of fragmentation [2,3] in the charm sector the production of the four different D mesons, D^+, D^0, D_s^+ and D^{*+} is measured in DIS. The D^{*+} meson is reconstructed via the decay channel described above, the D^+ via $D^+ \to K^-\pi^+\pi^+$, the D^0 via $D^0 \to K^-\pi^+$ and the D_s^+ via $D_s^+ \to \Phi\pi^+ \to (K^+K^-)\pi^+$. All four D mesons are identified with a common method, so that for ratios the systematic uncertainties mostly cancel. The kinematical region in this analysis is defined by $p_t(D) > 2.5$ GeV/c, $|\eta(D)| < 1.5$, $2 < Q^2 < 100$ GeV^2 and $0.05 < y < 0.7$. The central silicon vertex detector (CST) is used to measure the lifetime of the D mesons. Thus the large combinatorial background especially of the D^+ meson can be strongly reduced by exploiting the long lifetime ($c\tau_{D^+} = 315\ \mu$m). The most important variable for the lifetime tagging is the decay length significance S_l defined as the ratio of decay length and the error of the decay length. Fig. 3 shows the signal improvement if a cut on the decay length significance of $S_l > 8$ is applied. With this vertex information the background is suppressed by a factor $\mathcal{O}(300)$ and the signal to background ratio is improved by a factor $\mathcal{O}(50)$. The relatively small CST tag efficiency is checked carefully and it is ensured that the Monte Carlo simulation describes the data well.

Using the CST for the measurement of all four D mesons D meson production cross sections in the specified kinematic range are obtained as quoted in Table I. All cross sections are in good agreement with the LO+PS (AROMA) prediction. This agreement allows a determination of fragmentation factors $f(c \to D)$ using the Monte Carlo prediction for the D meson production cross sections as normalisation. The fragmentation factors obtained by this method are in good agreement with the world averages [7].

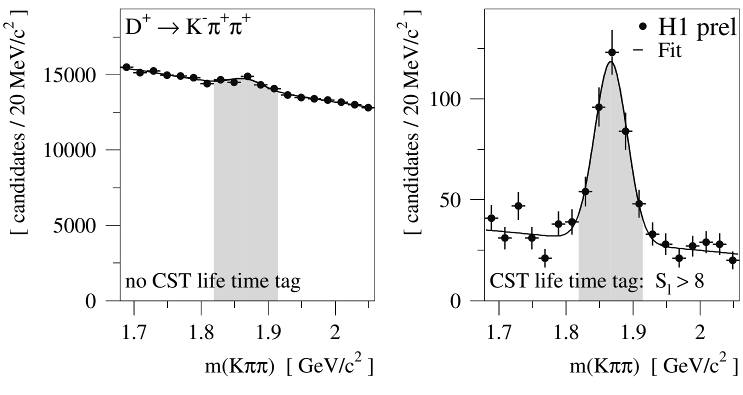

Fig. 3. Comparison of the invariant mass distributions $m_{K\pi\pi}$ for the $D^+ \to K^-\pi^+\pi^+$ decay candidates before and after a cut on the decay length significance $S_l > 8$.

TABLE I

Total visible D meson cross sections $\sigma_{\rm vis}(ep \to e'DX)$.

	D^+	D^0	$D_{\rm s}^+$	D^{*+}
$\sigma_{\rm vis}$ (nb)	2.16	6.53	1.67	2.90
stat. error	± 0.19	± 0.49	± 0.41	± 0.20
syst. error	$^{+0.46}_{-0.35}$	$^{+1.06}_{-1.30}$	$^{+0.54}_{-0.54}$	$^{+0.58}_{-0.44}$
LO+PS:	2.45	5.54	1.15	2.61
error	± 0.30	± 0.69	± 0.30	± 0.31

With these fragmentation factors it is possible to determine the fragmentation ratios, the vector to pseudoscalar ratio P_V or P'_V (additional assumption on isospin invariance), the u to d ratio $R_{u/d}$ and the strangeness suppression factor $\gamma_{\rm s}$. Here the assumptions on the Monte Carlo prediction cancel. Table II shows fragmentation ratios as determined by this method. These values are in good agreement with the world average [7].

TABLE II

Fragmentation ratios compared with the world average (WA).

	P_V	P'_V	$R_{u/d}$	$\gamma_{\rm s}$
H1 Prel.	0.693	0.613	1.26	0.36
stat. error	± 0.045	± 0.061	± 0.20	± 0.10
syst. error	± 0.004	± 0.033	± 0.13	± 0.01
theor. error	± 0.009	± 0.008	± 0.04	± 0.08
WA	0.601		1.00	0.26
error	± 0.032		± 0.09	± 0.07

The differential visible D meson cross sections in $p_{\rm t}(D)$, $\eta(D)$, Q^2 and y are again in good agreement with the LO+PS prediction, if the LO beauty prediction is multiplied by a factor 4.3 according to the H1 published values [6]. This is shown in Fig. 4 for the transverse momentum and the pseudorapidity of the D^+.

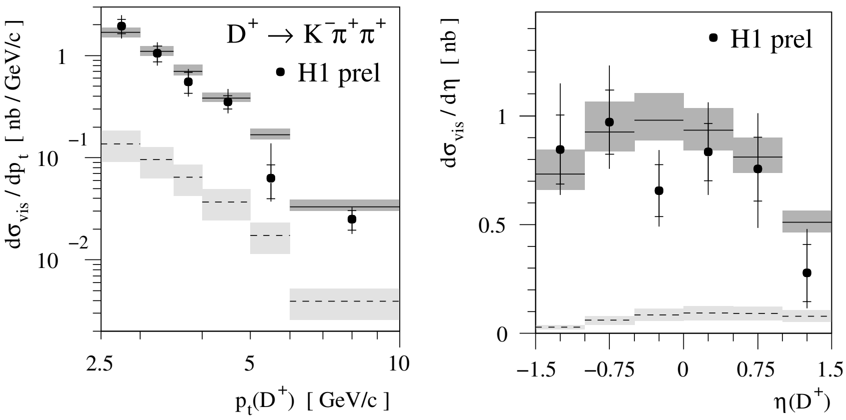

Fig. 4. Differential production cross sections for D^+ as function of D^+transverse momentum p_{t} and pseudorapidity η.

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