High Q^2 Charged Current Charm Production at HERA II

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motivation for CC charm production studies at HERA

- in general: experimental test of SM and pQCD

- measurements of strange distribution: $s(x, Q^2)$, $s - \bar{s}$, polarized strange densities

- theoretical aspects of pQCD: what heavy flavour scheme should be applied in what regime, is transition region correctly described (unlike in NC: no initial-state m_q)

- V_{cd} — flavour mixing at HERA?

heavy flavour schemes

zero-mass variable-flavour number scheme (ZM-VFNS):

- $m_c = 0$
- partons: $g, u, d, s, \delta(\mu_f - Q_0)c$
- transition $n_f = 3 \to 4$: finite transformation
- perturbative boundary cond. $f_p^{c(4)}(x, Q_0^2 = m_c^2) = 0$

$\Rightarrow$

- $m_c = 0$ technically simple
- miss $\frac{m_c^2}{p_T^2}$ terms (threshold behaviour)
- general factorization theorem holds
- resummation of collinear logs in $D_c^{D^\star}(x, \mu^2)$, $f_p^c(x, \mu^2)$
- valid only for $p_T^2 \gg m_c^2$

$(n_f = 3)$ fixed-flavour number scheme (3-FFNS):

- $m_c \neq 0$
- partons: g, u, d, s
- quasi-collinear logs $\log(\frac{s}{m_c})$ purely perturbative
- no evolution of $D_c^{D^\star}$, f_p^c perturbative

$\Rightarrow$

- m_c terms are kept, i.e. more complicated
- therefore threshold behaviour ok
- description of FF ad hoc , no universal factorization
- valid only for $p_T^2 \approx m_c^2$ no resummation

general-mass variable flavour number scheme (GM-VFNS):

- $m_c \neq 0$
- partons: g, u, d, s, c
- quasi-collinear logs $\log(\frac{s}{m_c})$ re-summed
- $D_c^{D^\star}(x, \mu^2)$, $f_p^c(x, \mu^2)$ DGLAP evlolved

$\Rightarrow$

- $m_c \neq 0$ more complicated
- mass factorization for finite m_q
- $\frac{m_c^2}{p_T^2}$ terms included
- non-perturbative charm component included
- valid for $p_T^2 \approx m_c^2$ and $p_T^2 \gg m_c^2$

for a more detailed comparison of heavy flavour schemes see I. Schienbein's talk at Ringberg 03

existing NLO calculations and an experimental analysis in progress

NLO calculations for CC charm production at HERA

Gottschalk (1981) Glück, Kretzer, Reya (1996)	3-FFNS	fully inclusive structure function
Glück, Kretzer, Reya (1997) Kretzer, Schienbein (1997, 1998, 1999)	GM-VFNS (ACOT)	semi-inclusive structure functions

$\Rightarrow$ at this moment: no ready-to-use NLO prediction for CC DIS charm production at HERA with $m_c \neq 0$ available!

analysis in progress

analysis of charm production in CC DIS underway C. Grab, S. Mangano; ETHZ:

- 1-, 2- or 3-track reconstruction of secondary vertex
  and lifetime tag with $c\tau \approx 300\mu\mathrm{m}$

- $p_T^{\mathrm{miss}} > 12\mathrm{GeV}$

- angular cuts: $4^\circ < \theta_{\mathrm{miss}}^{\mathrm{Lab}} < 154^\circ$ and $25^\circ < \theta_c^{\mathrm{Lab}} < 155^\circ$

unofficial present status (DO NOT QUOTE!): S. Mangano

	MC charm/BG	MC total	data
sample		1531	1521
1 track	7.7/9.5	17.2	19
2 tracks	3.5/2.1	5.6	7
3 tracks	2.1/3.5	4.6	5

if at NLO p_T^{miss} balanced by g radiation in QS (final state s in BGF)

then soft D-meson production included and $m_c \neq 0$ potentially important

$\Rightarrow$ work in progress in collaboration with Kretzer and Schienbein:

full NLO analysis of CC DIS charm production at HERA

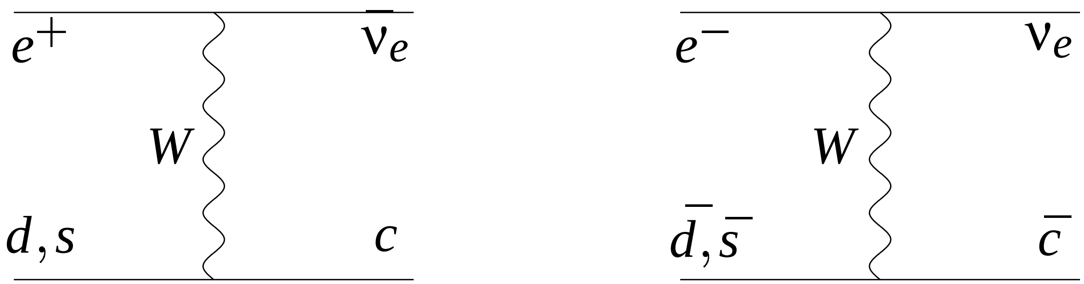
including $m_c \neq 0$ effects in GM-VFNS

can V_{cd} be measured at HERA II?

so far V_{cd} determined in fixed-target ν-N scattering (CCFR, CDHS):

$$|V_{cd}| = 0.224 \pm 0.016$$

at HERA:



consider: $\Delta\sigma = \sigma(e^+ p \to \bar{\nu}\, c + X) - \sigma(e^- p \to \nu\, \bar{c} + X) = \sigma_c - \sigma_{\bar{c}}$

assume: $s = \bar{s}$

then: $\Delta\sigma$ idependent of s pdf uncertainties rough estimate of relative statistical error $\delta\mathcal{O}$ of observable $\mathcal{O} = \sigma_c - \sigma_{\bar{c}}$:

for $\mathcal{L} = \mathcal{L}_{e^+} = \mathcal{L}_{e^-}$: $\quad \delta\mathcal{O} = \frac{\sqrt{(\delta\sigma_c)^2 + (\delta\sigma_{\bar{c}})^2}}{\sigma_c - \sigma_{\bar{c}}} = \frac{\sqrt{\frac{\sigma_c^2}{n_c} + \frac{\sigma_{\bar{c}}^2}{n_{\bar{c}}}}}{\sigma_c - \sigma_{\bar{c}}} = \frac{\sqrt{\sigma_c + \sigma_{\bar{c}}}}{\sqrt{\mathcal{L}}(\sigma_c - \sigma_{\bar{c}})}$

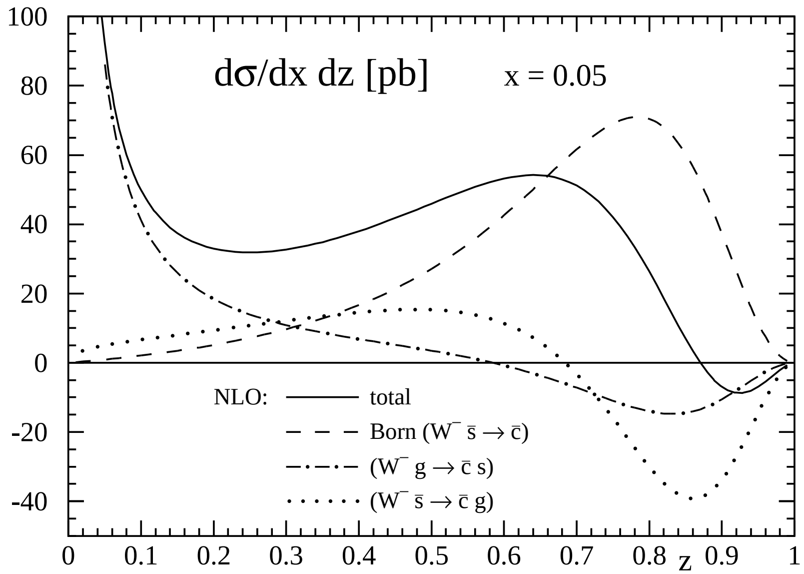
given $\delta\mathcal{O}$ need luminosity $\mathcal{L} = \frac{\sigma_c + \sigma_{\bar{c}}}{(\delta\mathcal{O})^2(\sigma_c - \sigma_{\bar{c}})^2}$

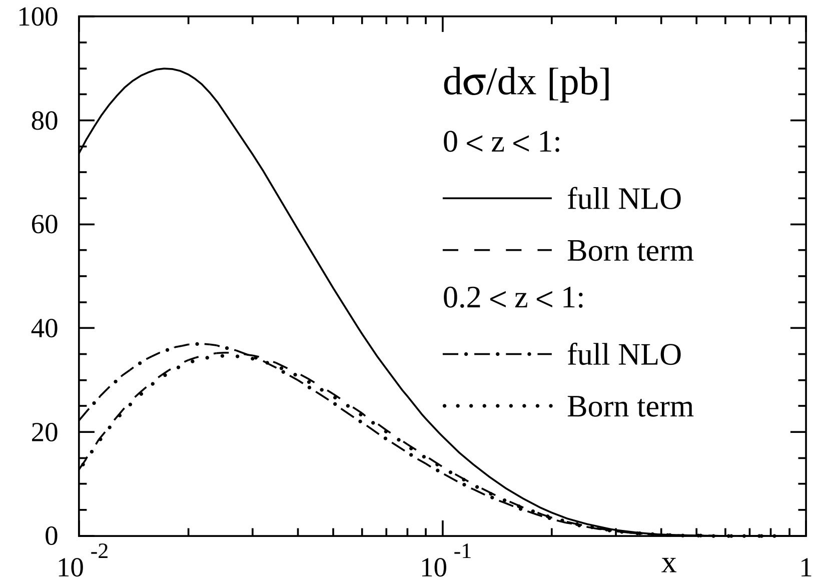
for $\delta\mathcal{O} = 10\%$ and fully integrated cross sections from 3-FFNS calculation (GRV-94):

at LO : $\quad \sigma_c \approx 4.5\text{pb}^\star, \quad \sigma_{\bar{c}} \approx 4.0\text{pb}^\star \quad \Rightarrow \quad \mathcal{L} \approx 3.4\text{fb}^{-1}$
at NLO : $\sigma_c \approx 8.4\text{pb}^\star, \quad \sigma_{\bar{c}} \approx 7.9\text{pb}^\star \quad \Rightarrow \quad \mathcal{L} \approx 6.5\text{fb}^{-1}$

$\Rightarrow$ with no efficiencies considered — hopeless case?

* S. Kretzer, priv. comm.





Kretzer, Stratmann, Eur. Phys. J. C10, (1999) 107

⇒ cuts in z-fragmentation could reduce BGF background ?

⇒ restriction to typical valence x-Bjorken could reduce sea background ?

⇒ still too ambitious ?

conclusions

- CC DIS charm production as testing ground for heavy flavour schemes (unlike NC: no initial m_q)
- GM-VFNS present suitable description of charm production from threshold to large-p_T region
- ready-to-use implementation of a GM-VFNS calculation for charm production at HERA not yet available but in preparation (D., Kretzer, Schienbein)
- V_{cd} out of reach at HERA II ?
- maybe further investigation is worthwile . . . ?