Charm in the Breit Frame of DIS

Sergei Chekanov (ANL)
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- Motivations;
- Charm kinematics in the Breit frame;
- Selection, mass distributions;
- Uncorrected distributions and MC models;
- Comparisons to LO and NLO calculations;
- Conclusions.

Motivations

- To set a limit on charm behaving as an active flavour:

  Theoretical descriptions:

  1) $Q \sim m_c \longrightarrow$ Fixed-flavour-number (FFN) scheme:

  ◦ Charm created from BGF alone ($m_c \neq 0$)

  ◦ Kinematics from RAPGAP/AROMA/HVQDIS

  2) $Q >> m_c \longrightarrow$ Zero-mass variable-flavour-number (ZM-VFN) scheme:

  ◦ Charm is 4th active flavour ($m_c = 0$)

  ◦ Implemented in CTEQ and MRS approaches

  ◦ Kinematics from DJANGON/LEPTO (without BGF)

  3) ACOT (RT) scheme:

  ◦ Combines ZM-VFN with FFN

- Intrinsic Charm (IC) study:

  ◦ Non-perturbative contribution to valence quarks

- Comparisons with NLO calculations (HVQDIS)

- Study of charm contribution to inclusive DIS current-region spectra:

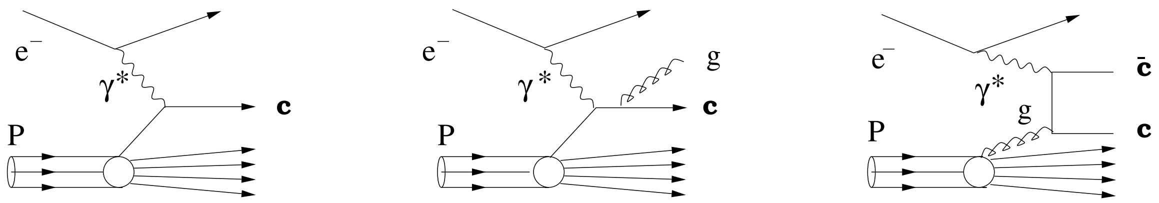
  ◦ Important for comparisons with e^+e^-.

- Studies of charm fragmentation:

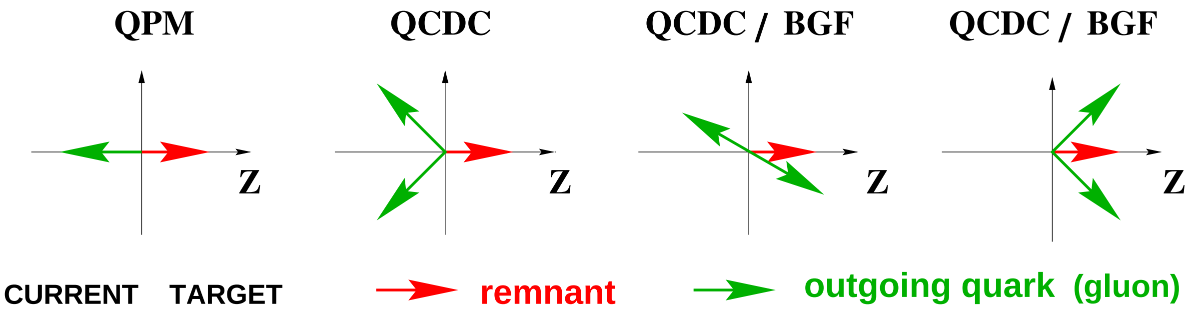
  ◦ Peterson fragmentation (PF) (HVQDIS)

  ◦ DGLAP + LUND string hadronisation (Djangon/Rapgap)

Breit Frame Kinematics



a) QPM b) QCDC c) BGF



- FFN scheme $\equiv$ BGF kinematics:

  Large P_0
  (probability for no charm emission to the current region);

  Hard $P_t^{current}(D^*)$ spectrum;

  $\eta(D^*)$ shifted to positive values;

  large $\langle N_t \rangle / \langle N_c \rangle$;

- ZM-VFN scheme/IC model$\equiv$ QPM/QCDC kinematics:

  Small P_0;

  Soft $P_t^{current}(D^*)$ spectrum;

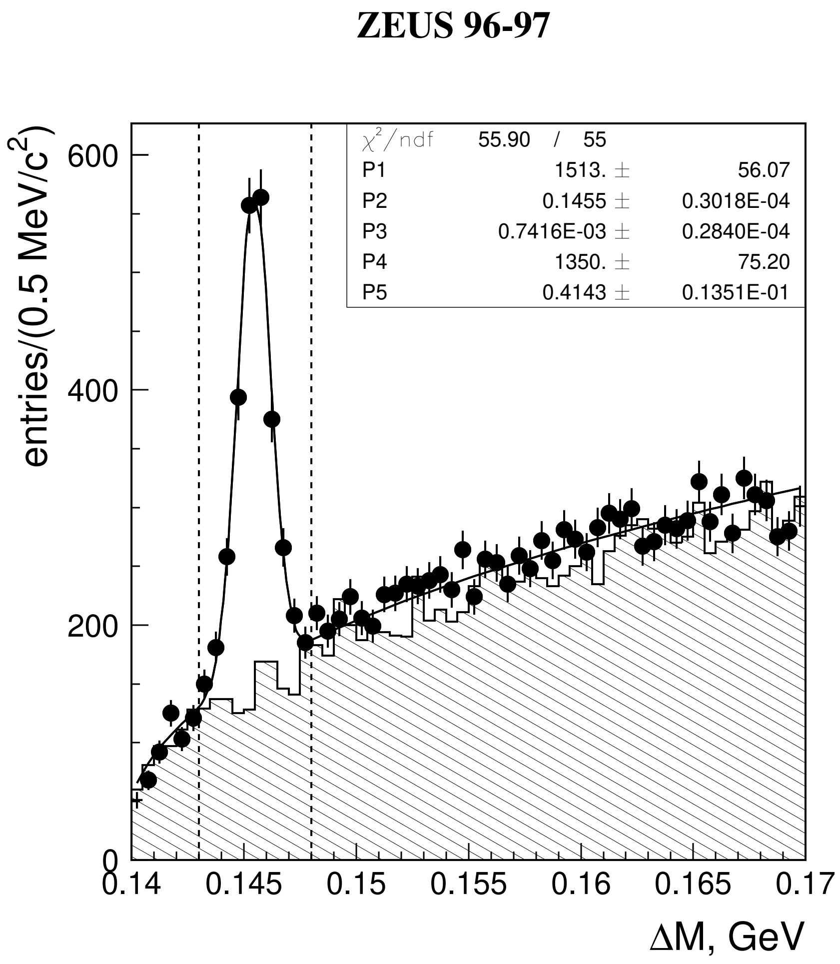
  $\eta(D^*)$ shifted to negative values;

  small $\langle N_t \rangle / \langle N_c \rangle$

Selection

- 1996+1997 data, CTD tracks only
- $Q^2_{DA} > 5$ GeV^2 $\quad E_{e'} > 10$ GeV
  $Prob > 0.9 \quad y_e \leq 0.95 \quad y_{jb} \geq 0.04$
  $|Z_{vertex}| < 50$ cm $\quad 40 \leq \delta \leq 60$
- Final D^* reconstruction:
  $D^{*\pm} \to D^0 \pi_s^\pm \to K^- \pi^+ \pi_s^\pm$ (+c.c.)
  For all tracks:
  $p_t > 0.12$ GeV $\quad | \eta | < 1.75$
  For reconstructed D^*:
  $p_t(D^*) > 1.5$ GeV $\quad p_t(K, \pi) > 0.4$ GeV $\quad | \eta(D^*) | < 1.5$
- Signal regions ($\Delta M \equiv M_{K\pi\pi_s} - M_{K\pi}$):
  $1.80 < M(D_0) < 1.92$ GeV $\quad 143 < \Delta M < 148$ MeV
- Breit frame reconstructed according to:
  SIRA method for $5 \leq Q^2 \leq 80$ **GeV**^{2}
  DA method for $Q^2 > 80$ **GeV**^{2}
  to achieve good resolution for $E_{e'}$

Mass Distribution for $Q^2 > 5$ GeV^2



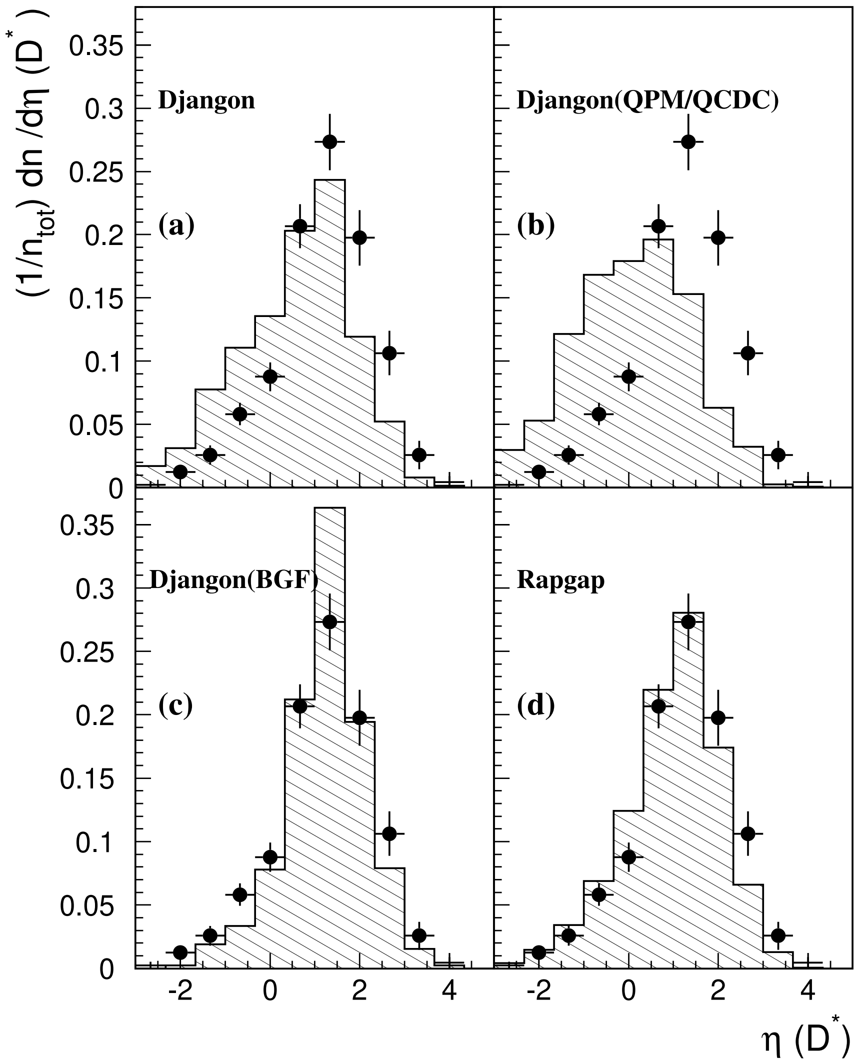
$$F(\Delta M) = [P1/(\sqrt{2\pi} \cdot P3)] \times \text{binwidth}$$
$$\times \exp\left[0.5 \cdot (\Delta M - P2)^2/P3\right]$$
$$+P4 \cdot (\Delta M - m_\pi)^{P5}$$

- 1513 events from the fit
- 1521 events from subtraction

$\eta^{Breit}(D^*)$ for $Q^2 > 5$ GeV^2

Monte Carlo model	Implemented kinematics
Djangon (QPM/QCDC)	ZM-VFN scheme $(m_c = 0)$
Djangon (BGF)	FFN scheme $(m_c = 0)$
Rapgap	FFN scheme $(m_c \neq 0)$

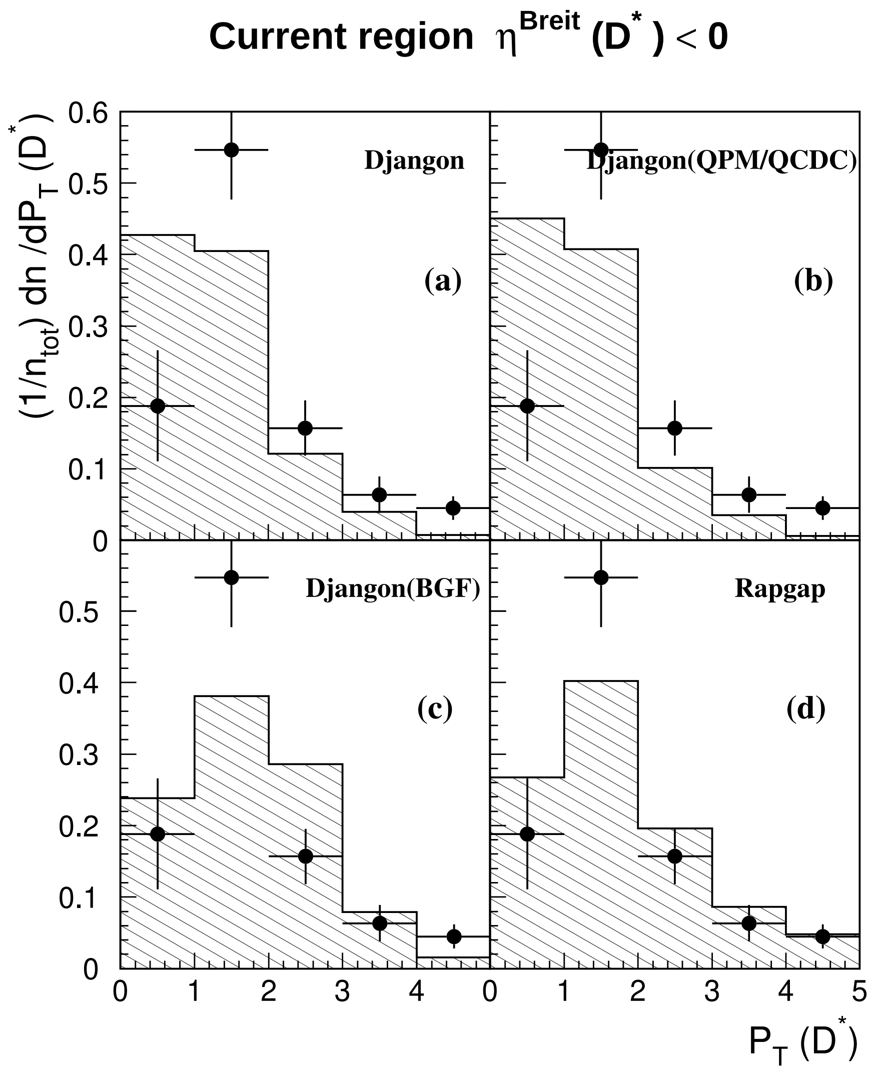
Detector level



- Best description by Rapgap
- No need for QPM/QCDC mechanism

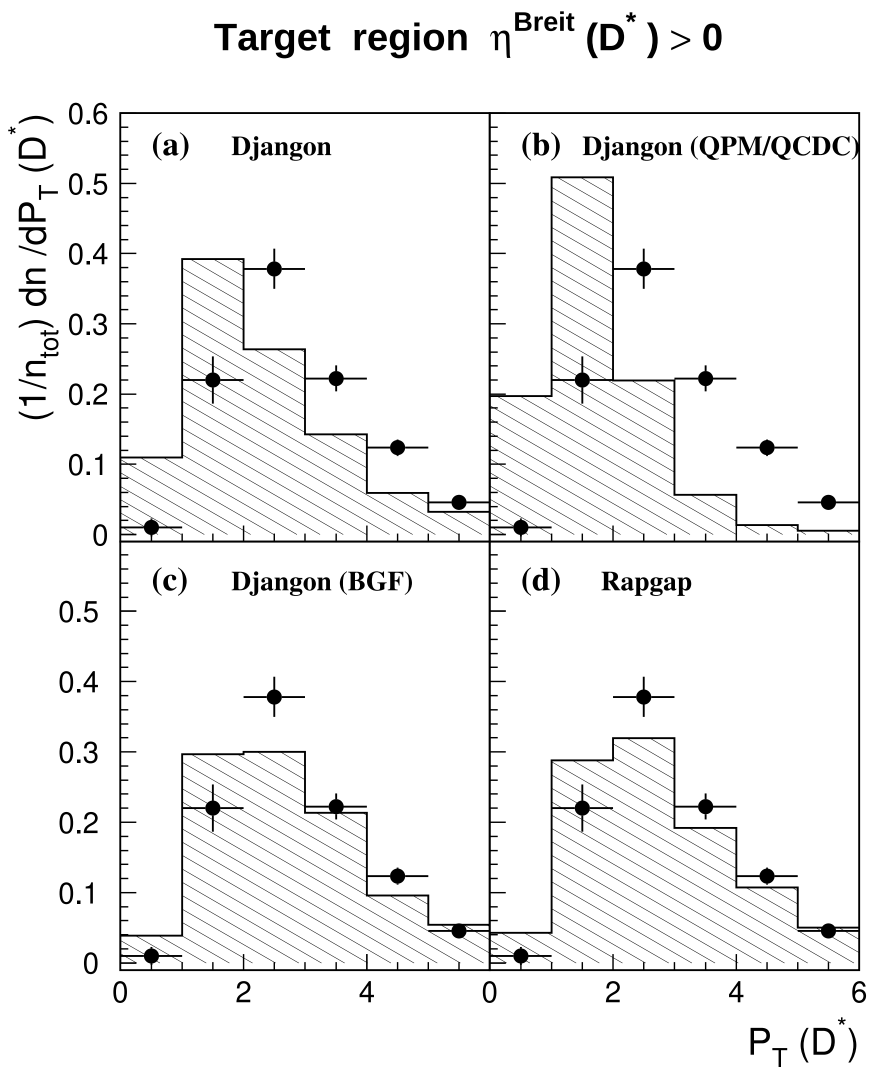
$P_t^{Breit}(D^*)$ for $Q^2 > 5$ GeV^2

Detector level



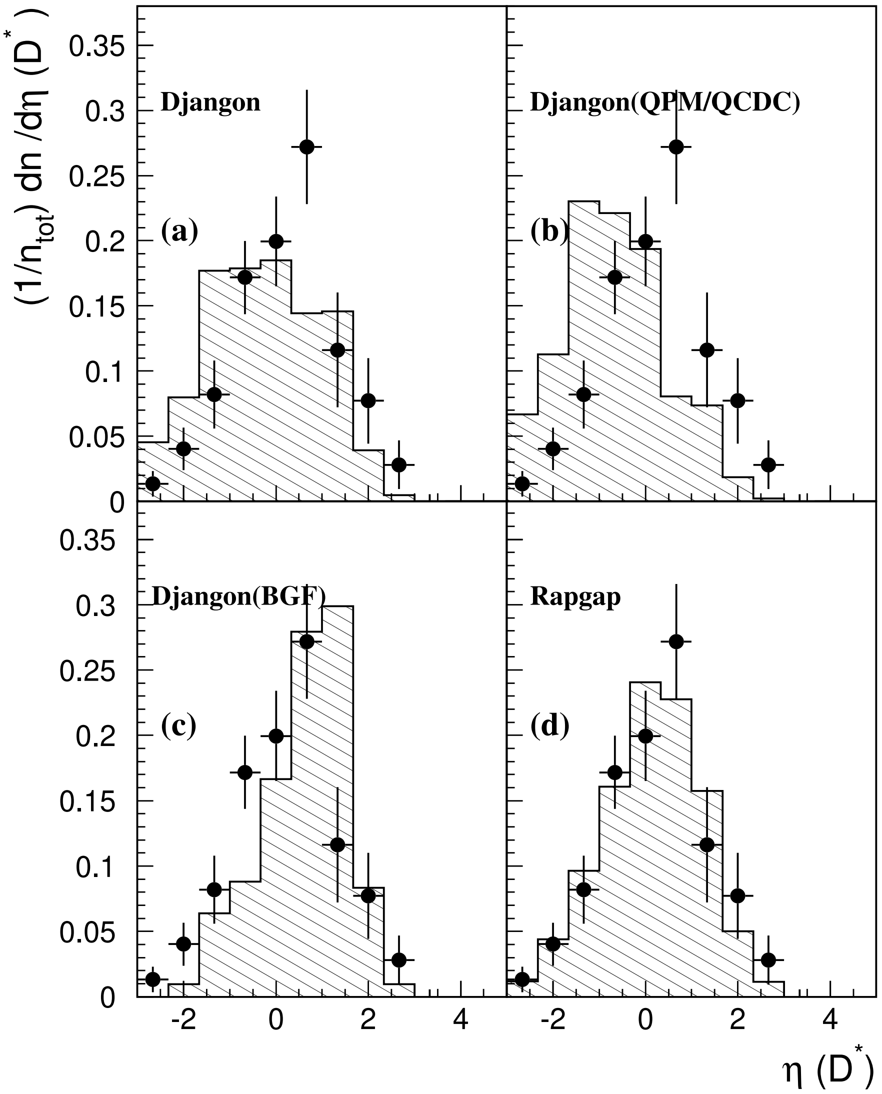
P_T^{Breit} for $Q^2 > 5$ GeV^2

Detector level



$\eta^{Breit}(D^*)$ **for** $Q^2 > 30$ **GeV^2**

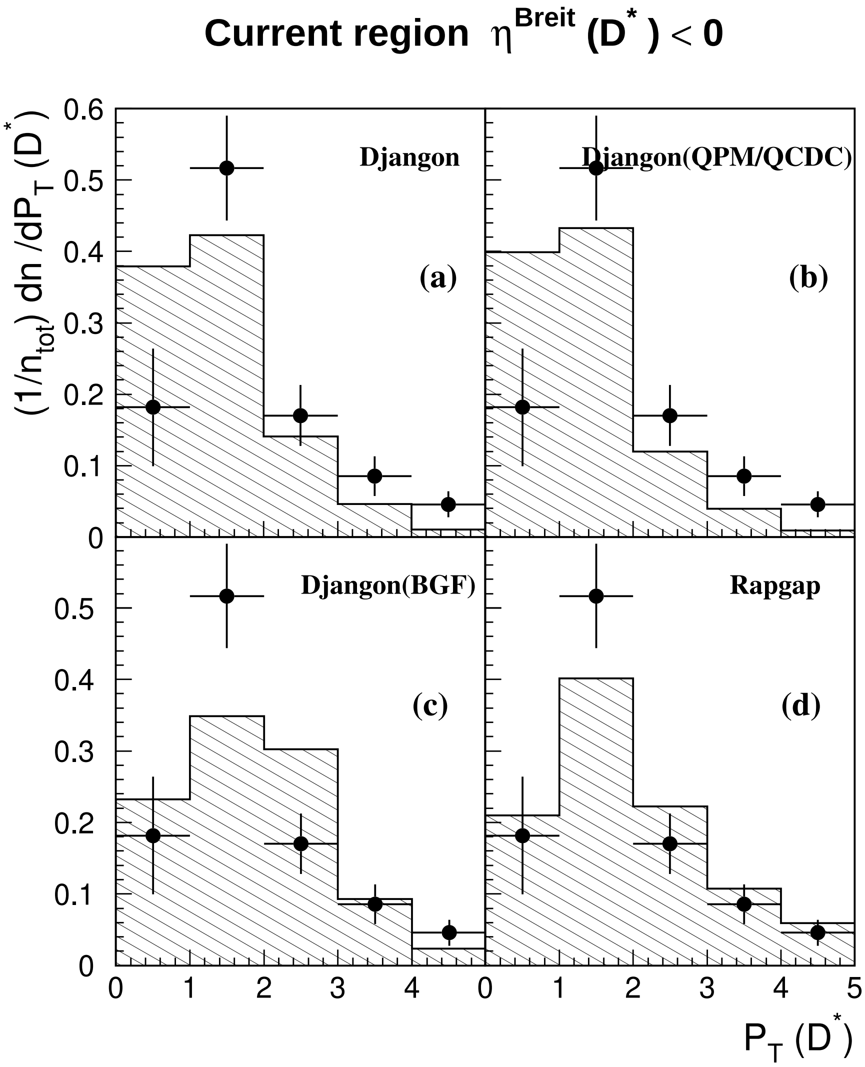
Detector level



- QPM/QCDC is expected to work ($Q >> m_c$) !
- BGF still describes the data

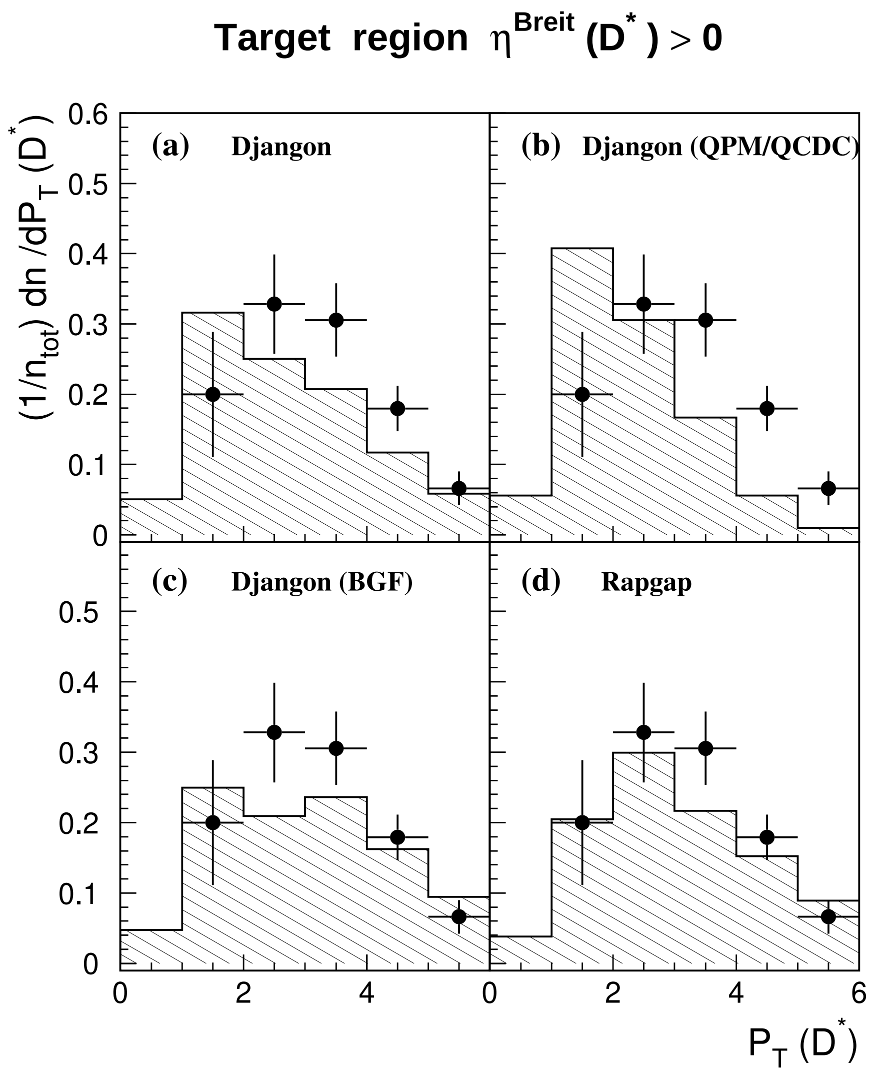
$P_T^{Breit}(D^*)$ for $Q^2 > 30$ GeV^2

Detector level



P_T^{Breit} for $Q^2 > 30$ GeV^2

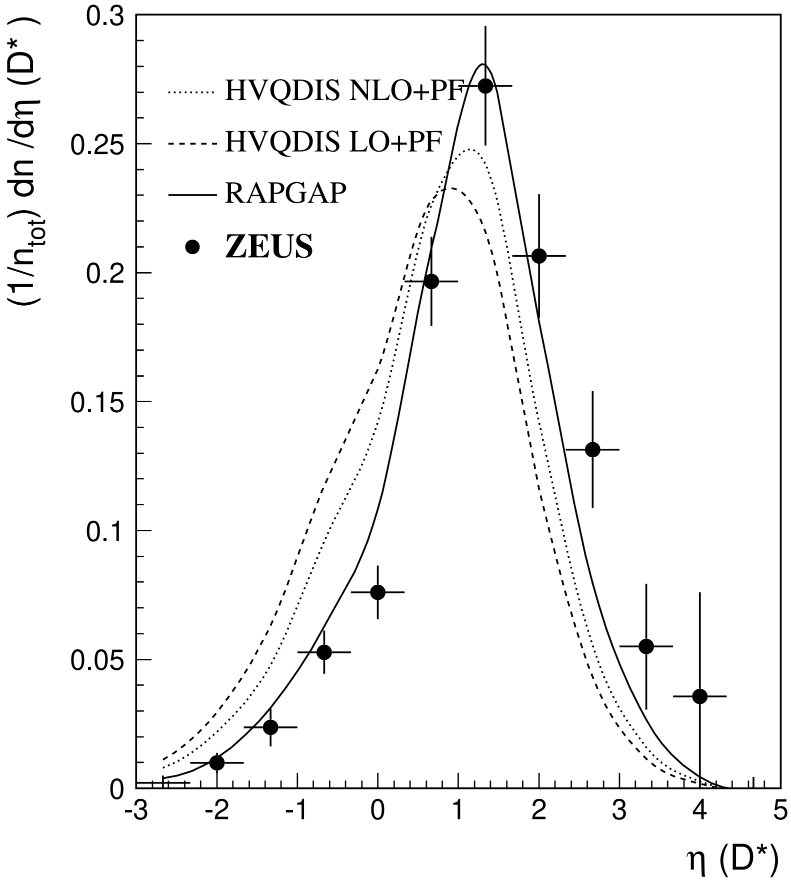
Detector level



$\eta^{Breit}(D^*)$ for $Q^2 > 5$ GeV^2

$$\text{Corrected data} = \frac{\text{true generated } D^*}{\text{det} - \text{lev reconstructed } D^*} \times \text{data}$$

Hadron level



$$\chi^2 = \sum(data - theory)^2/(\sigma^2_{data} + \sigma^2_{theory})$$

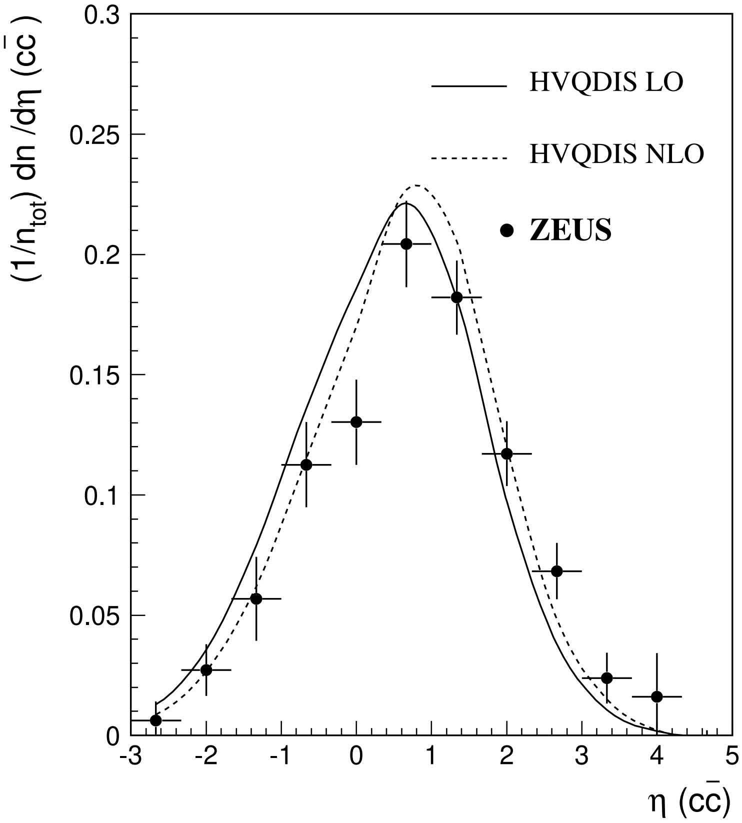
Predictions	χ^2/Ndf
RAPGAP	1.7
HVQDIS LO+PF	17.6
HVQDIS NLO+PF	8.8

Fragmentation Correction (FC)

$$\mathcal{C}_{\mathcal{FC}} = \frac{\eta^{Rapgap}(c\bar{c})}{\eta^{Rapgap}(D^*)}$$

$$\text{Data(parton level)} = \mathcal{C}_{\mathcal{FC}} \times \text{Data(hadron level)}$$

Parton level



Predictions	χ^2/Ndf
HVQDIS LO	2.0
HVQDIS NLO	0.8

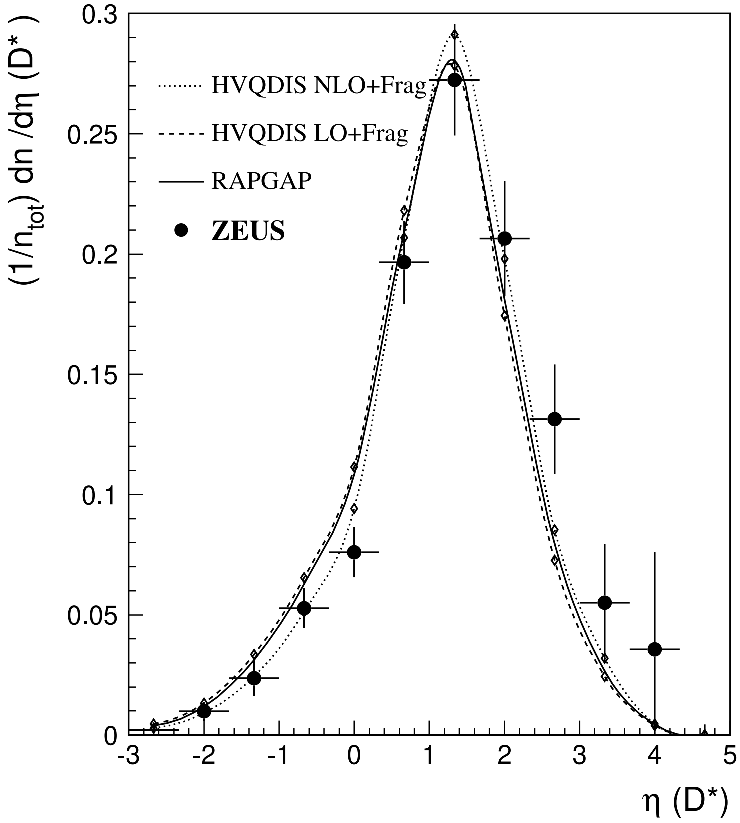
- Good agreement with NLO
- Large fragmentation correction (50%-100%)

HVQDIS with RAPGAP Fragmentation

$$C_{FC} = 1/\mathcal{C}_{\mathcal{FC}} = \frac{\eta^{Rapgap}(D^*)}{\eta^{Rapgap}(c\bar{c})}$$

$$\text{HVQDIS} + \text{Frag} = C_{FC} \times \text{HVQDIS}\ (c\bar{c})$$

Hadron level



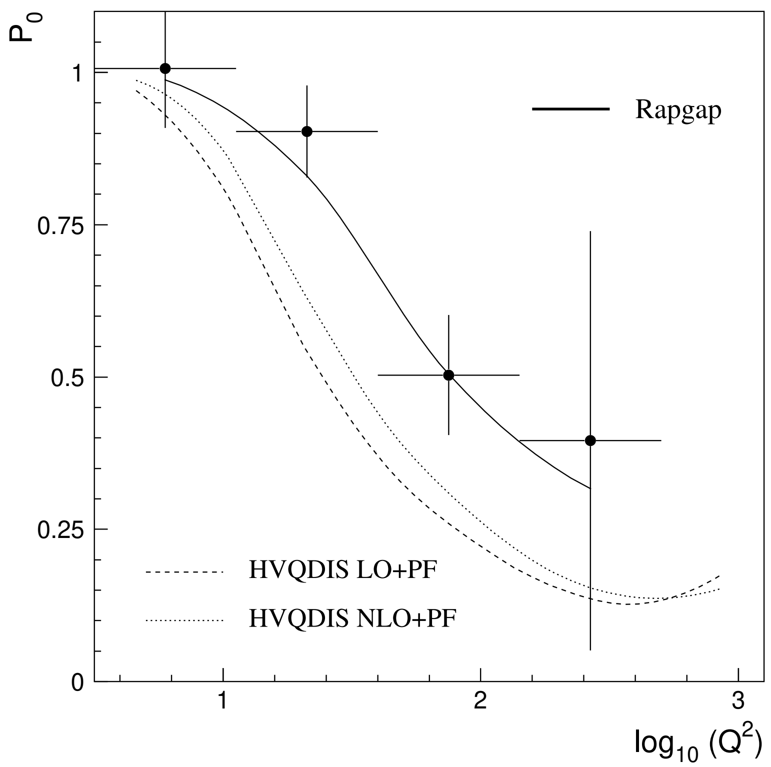
Predictions	χ^2/Ndf
RAPGAP	1.7
HVQDIS LO+Frag	1.4
HVQDIS NLO+Frag	0.8

P_0^{Breit} for $Q^2 > 5$ GeV^2

$$\text{Definition}: \quad P_0 = \frac{N_{ev}(\text{with } D^* \text{ in the target region})}{N_{ev}(\text{total})}$$

$$\text{Corrected data} = \frac{\text{true generated } D^*}{\text{det} - \text{lev reconstructed } D^*} \times \text{data}$$

Hadron level



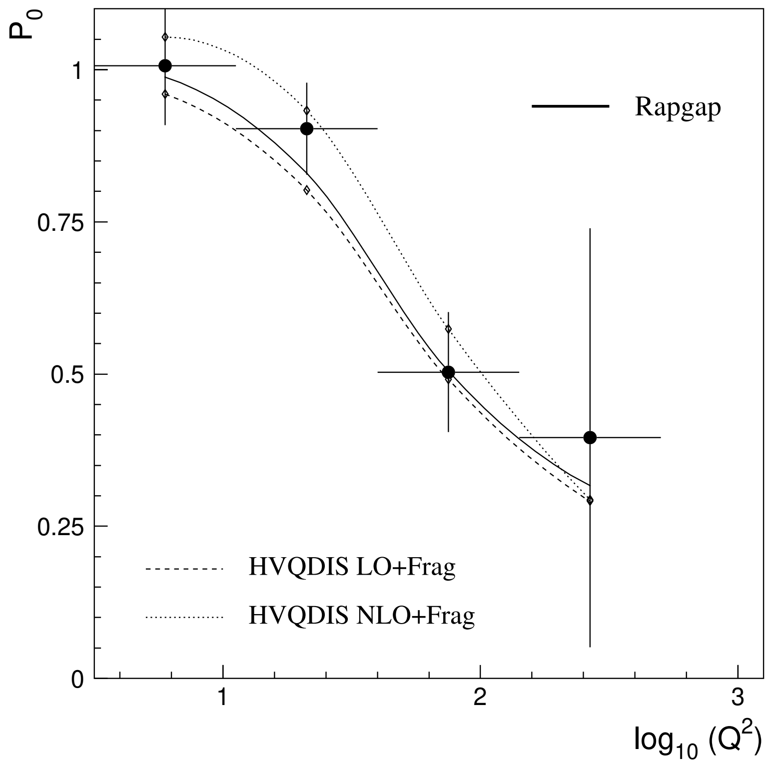
Predictions	χ^2/Ndf
RAPGAP	0.3
HVQDIS LO+PF	6.7
HVQDIS NLO+PF	3.8

HVQDIS with RAPGAP Fragmentation

$$C_{FC} = \frac{P_0^{Rapgap}(D^*)}{P_0^{Rapgap}(c\bar{c})}$$

$$\text{HVQDIS} + \text{Frag} = C_{FC} \times \text{HVQDIS}\ (c\bar{c})$$

Hadron level

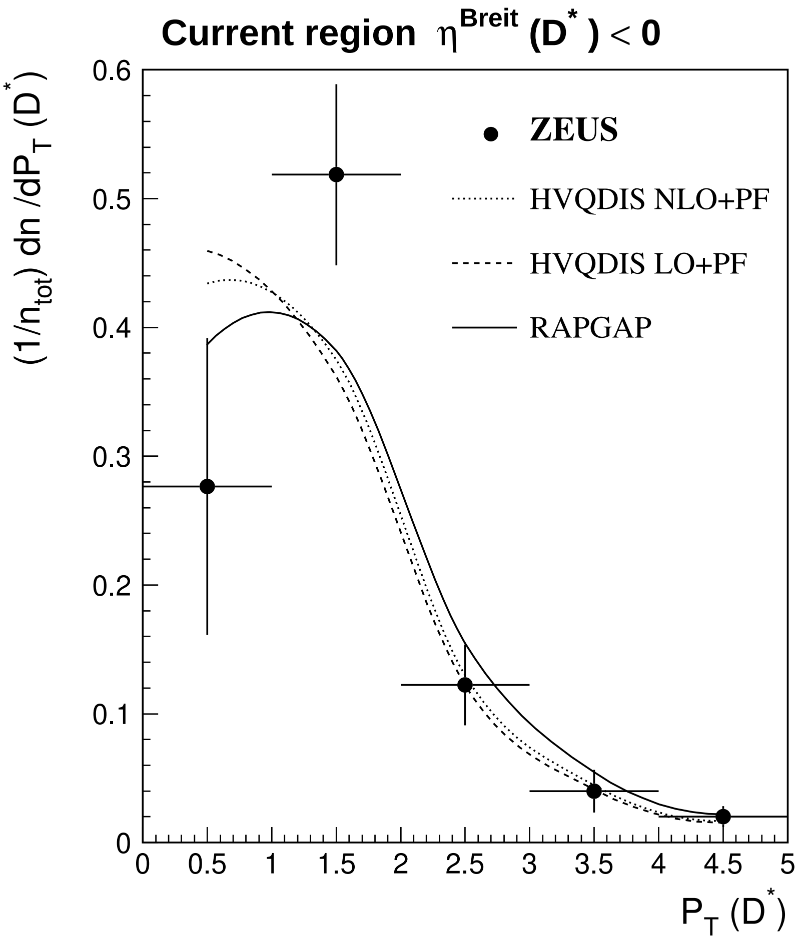


Predictions	χ^2/Ndf
RAPGAP	0.26
HVQDIS LO+Frag	0.27
HVQDIS NLO+Frag	0.25

$P_T^{Breit}(D^*)$ for $Q^2 > 5$ GeV^2

$$\text{Corrected data} = \frac{\text{true generated } D^*}{\text{det} - \text{lev reconstructed } D^*} \times \text{data}$$

Hadron level

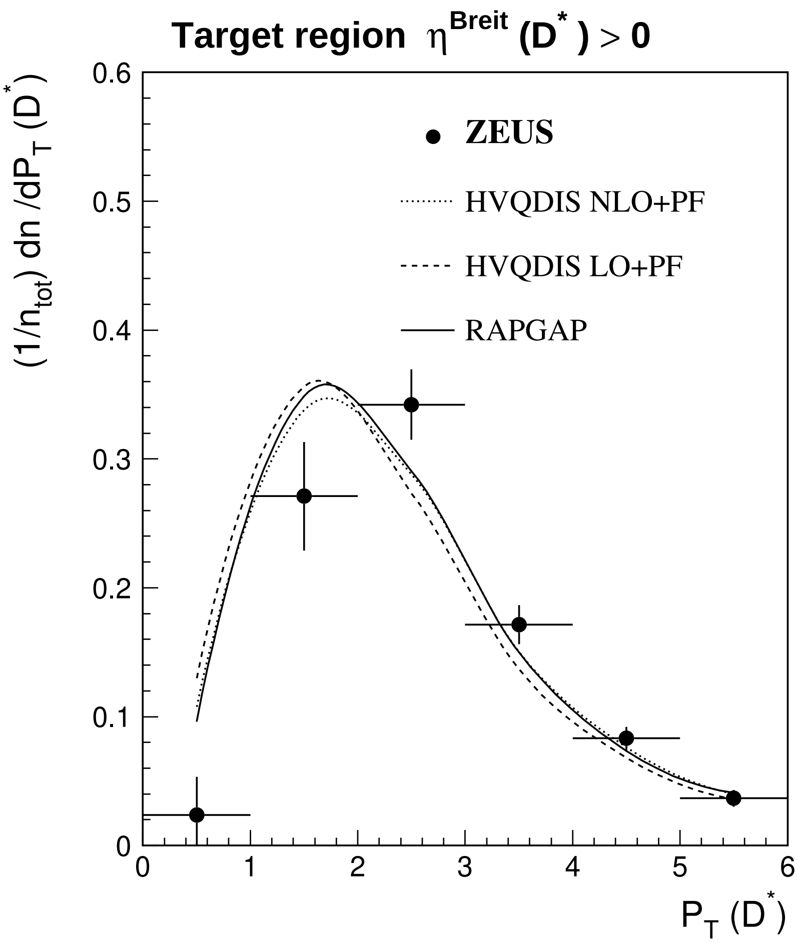


Predictions	χ^2/Ndf
RAPGAP	1.3
HVQDIS LO+PF	1.6
HVQDIS NLO+PF	1.3

$P_T^{Breit}(D^*)$ for $Q^2 > 5$ GeV^2

$$\text{Corrected data} = \frac{\text{true generated } D^*}{\text{det} - \text{lev reconstructed } D^*} \times \text{data}$$

Hadron level



Predictions	χ^2/Ndf
RAPGAP	3.4
HVQDIS LO+PF	6.0
HVQDIS NLO+PF	3.5

Conclusions

- RAPGAP gives the best description
  .. but data show stronger η shift to the target region:
  - NLO effect (see HVQDIS NLO) ?
  - "Beam drag" from hadronisation?
  - Non-BGF charm source ?

- BGF mechanism describes "high" Q^2 ($>$ 30 GeV^2); QPM/QCDC with active charm does't:

  ZM-VFN approach is not necessary even at $Q >> m_c$!

- Data for η and P_0 disfavor the Peterson fragmentation

- Good agreement with HVQDIS can be achieved only after inclusion of RAPGAP fragmentation

- NLO gives better description for all distributions

- No evidence for intrinsic charm

- Second analysis is needed