Charm Fragmentation Function in DIS

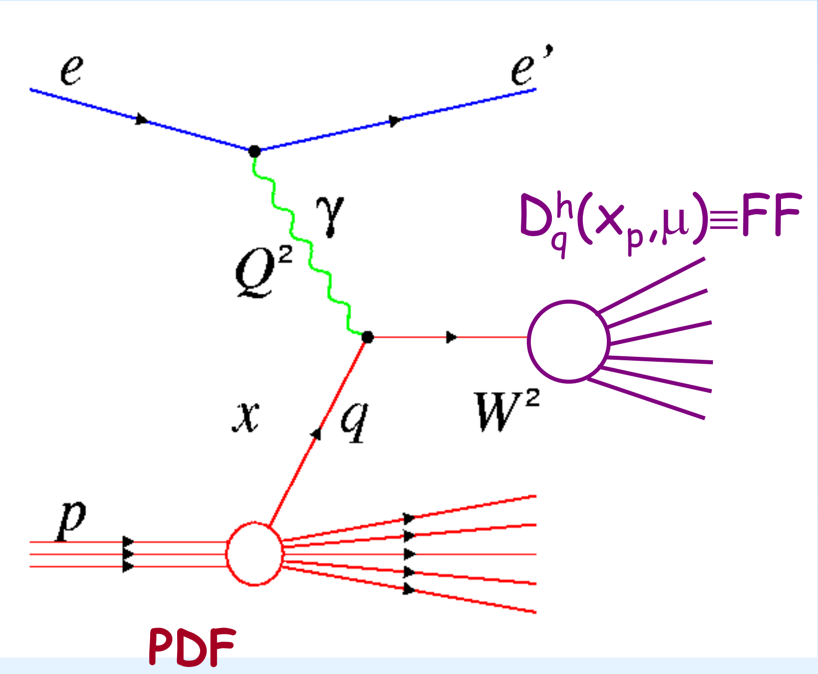
Karin Daum – Wuppertal

Outline:

- Introduction into the problem
- Experimental method
- Extraction of the fragmentation parameters
- Discussion of results
- Conclusions

The need for understanding charm fragmentation

$$\sigma^h = \mathrm{PDF} \otimes \mathrm{M.E.} \otimes \mathrm{FF}$$



Need to understand this to be able to learn something about PDF and M.E.

The problem of getting the observed fragmentation function in ep scattering

Measure observed fragmentation functions:

Definition in e^+e^- is easy:

$$z(D^*)=2 \cdot E(D^*)/\sqrt{s}$$

(includes gluon radiation)

More complicated in case of ep scattering:

How to get the energy of the parent charm quark?

- **via jet reconstruction**

draw back: only small region of phase space accessible

- **find a method which works at threshold and has similarities to e^+e^-**

$\Rightarrow$ infer the non-perturbative FF from the observable

Fragmentation observable using jets

-Momentum of the charm quark approximated by a jet containing the D* meson

$$z_{jet} = \frac{(E+p_L)_{D^*}}{(E+p)_{jet}}$$

- inclusive $k_\perp$ algorithm applied in the γp frame

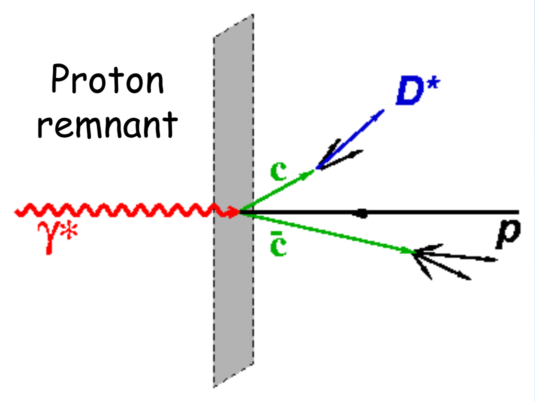
  require: E_T(D*-jet)>3 GeV

  significant contribution only from $\hat{s}$ > 100 GeV²
  (factor 10 above threshold)

Fragmentation observable - Hemisphere method

-Find an experimental setup close to e+e-

γp-system



cut:η>0

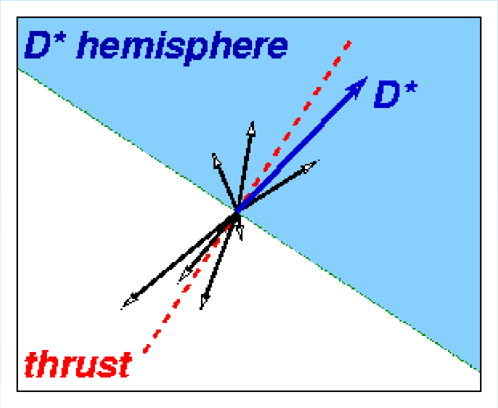
-Take all particles going in the γ-direction

-Project onto the plane Perpendicular to the photon

-Get Thrust axis

-Sum momenta of all particles in the D* hemisphere

Perpendicular to the γ-direction

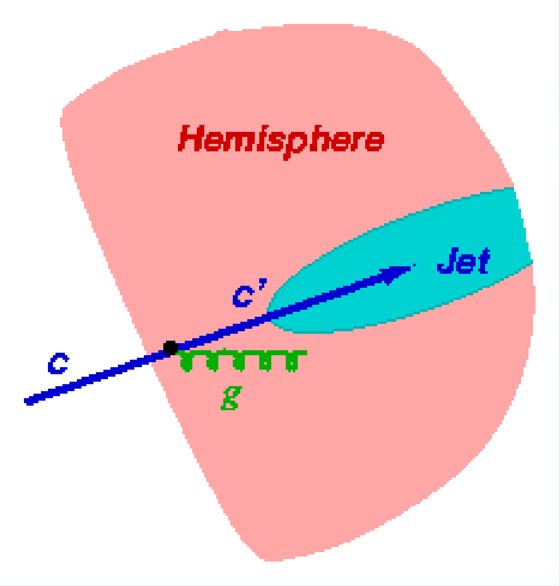


- Charm quark momentum approximated by the D*hemisphere

$$z_{hem} = \frac{(E+p_L)_{D^*}}{(E+p)_{hem}}$$

- applicable also at charm production threshold $\hat{s} \approx 4m_c^2$

Fragmentation observable - Differences



- Hemisphere method should include more final state gluon radiation than jet method

$\Rightarrow$ Measured distributions of the fragmentation variable should be different

- Extracted parameters of the non-perturbative fragmentation function should agree (if QCD evolution understood)

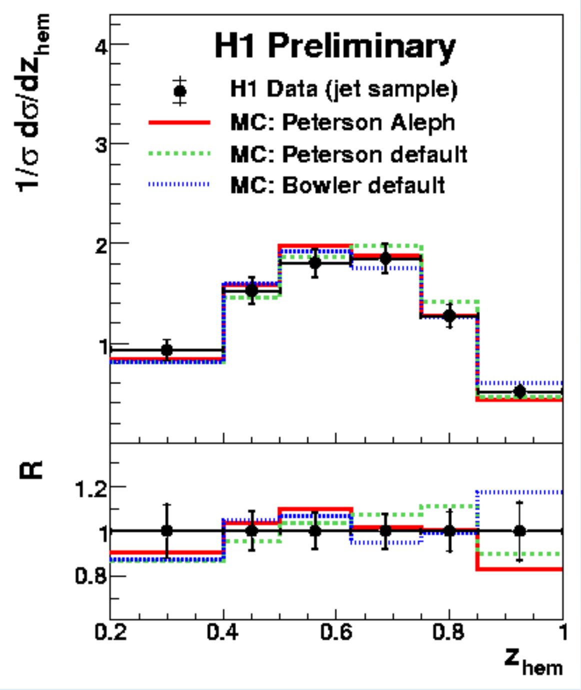
Strategy of the Analysis

- **Use both fragmentation observables in the common phase space by requiring the presence of a jet containing the D* with E_T>3 GeV**
- **Extract parameters for non-perturbative fragmentation functions using RAPGAP, CASCADE and HVQDIS**
  Parameters are expected:
  - **to agree for the different observables**
  - **to be different for the MCs and HVQDIS**
- **See what happens close to threshold (absence of a D*-jet)**

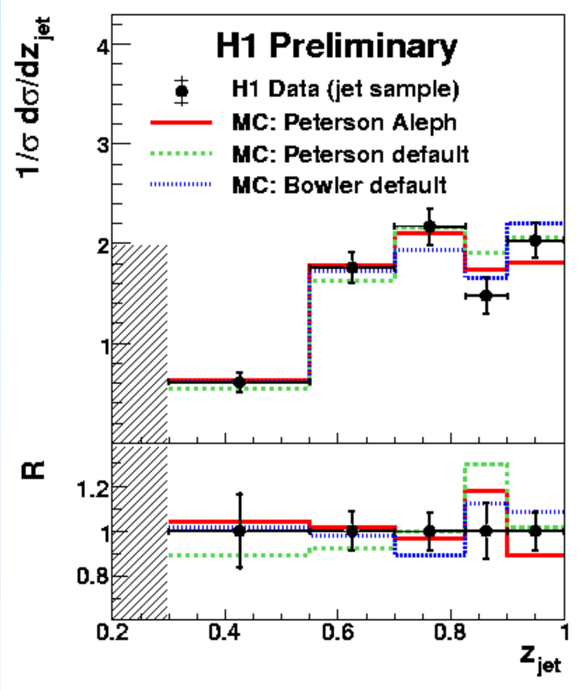
-RAPGAP & CASCADE: JETSET string fragmentation with "ALEPH" tuning, i.e. D*s from excited D-mesons, (RAPGAP with resolved contribution)
-HVQDIS independent fragmentation in γp-frame including $p_\perp$(D*) w.r.t. the charm quark

Measurement of z_{hem} & z_{jet} with $E_T^{D^*\text{-}jet}$>3GeV

Hemisphere method



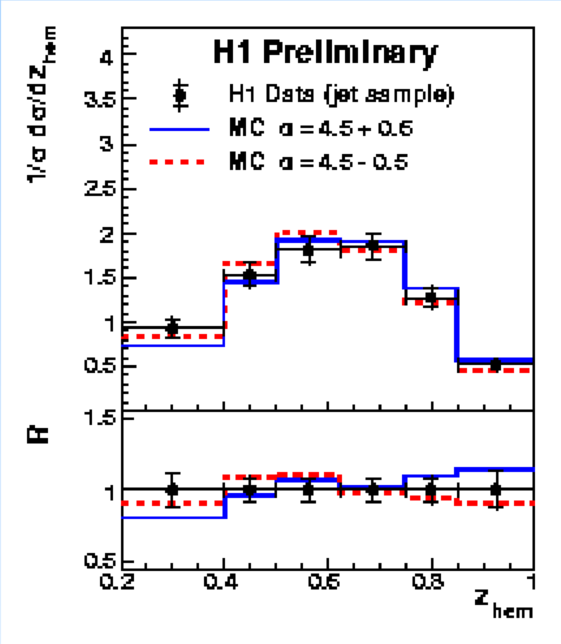
Jet method



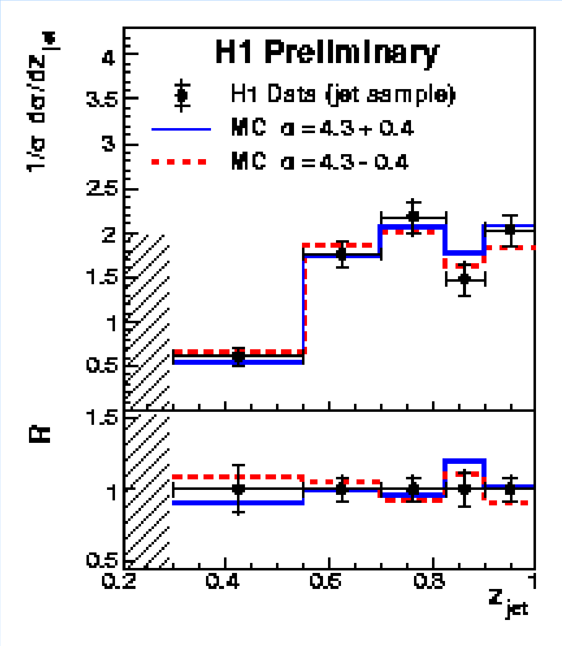
- Distributions on hadron level look different (as expected)
- MC (Rapgap) with standard n.p. FF yield reasonable description of data

Fit of n.p. FF parameters to z_{hem} & z_{jet} with $E_T^{D^*\text{-jet}}$>3GeV

Hemisphere method



Jet method

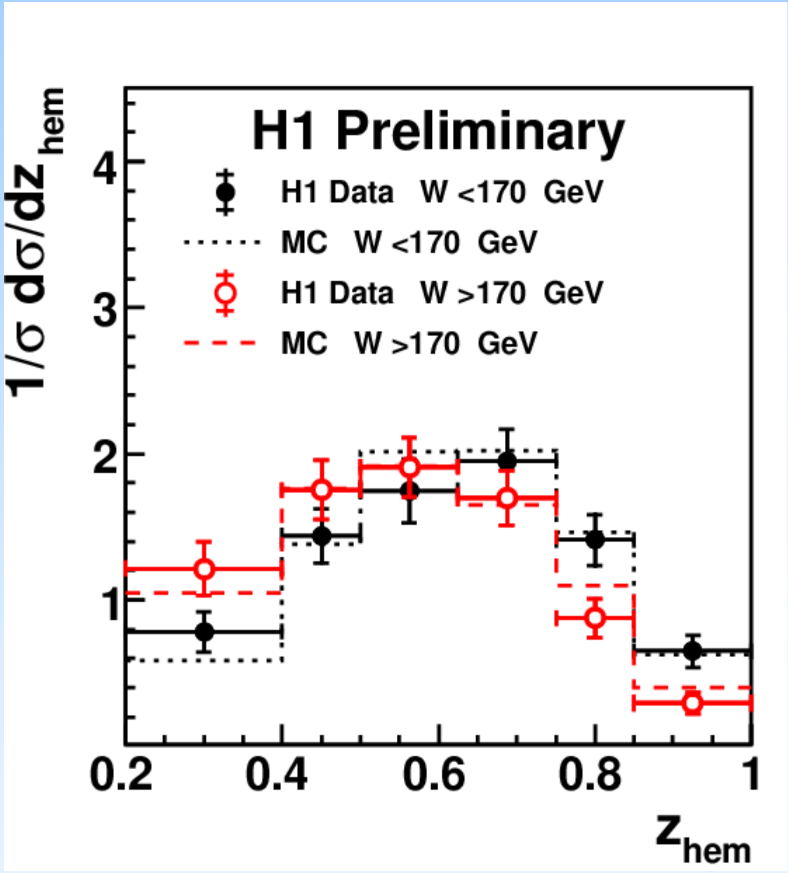


- **Extracted n.p. FF parameters from z_{hem} (α=4.5±0.6) and z_{jet} (α=4.3±0.4) agree well**

(Rapgap, ALEPH steering, Kartvilishvili)

z_{hem} with $E_T^{D^*\text{-}jet}>3GeV$ vs. $W_{\gamma p}$

Hemisphere method



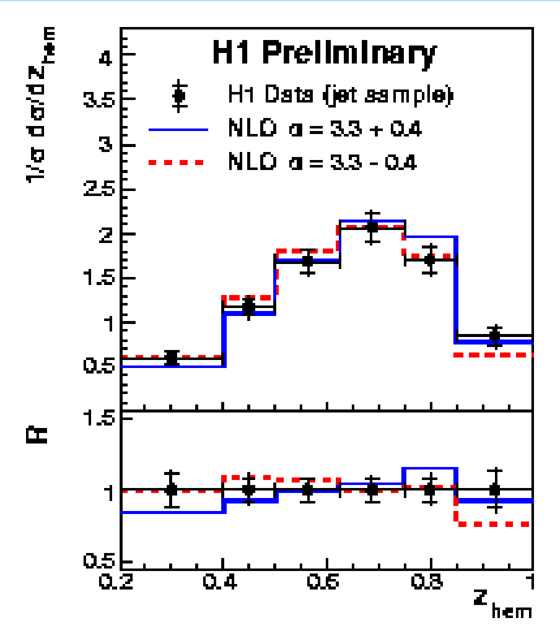
- **Significant change of the z_{hem} distribution with $W\gamma p$**
- **Change well reproduced by Monte Carlo with α fixed.**
  (similar conclusions for z_{jet})

$\Rightarrow$ **Parameter α of n.p. FF independent of $W\gamma p$**

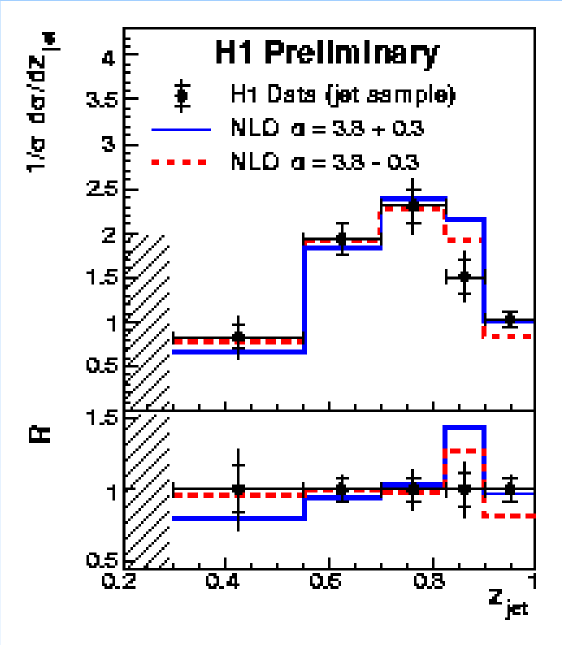
(as expect if everything is well modeled and n.p. FF universal)

Fit of n.p. FF parameters to z_{hem} & z_{jet} with $E_T^{D^*\text{-}jet}$>3GeV

Hemisphere method



Jet method



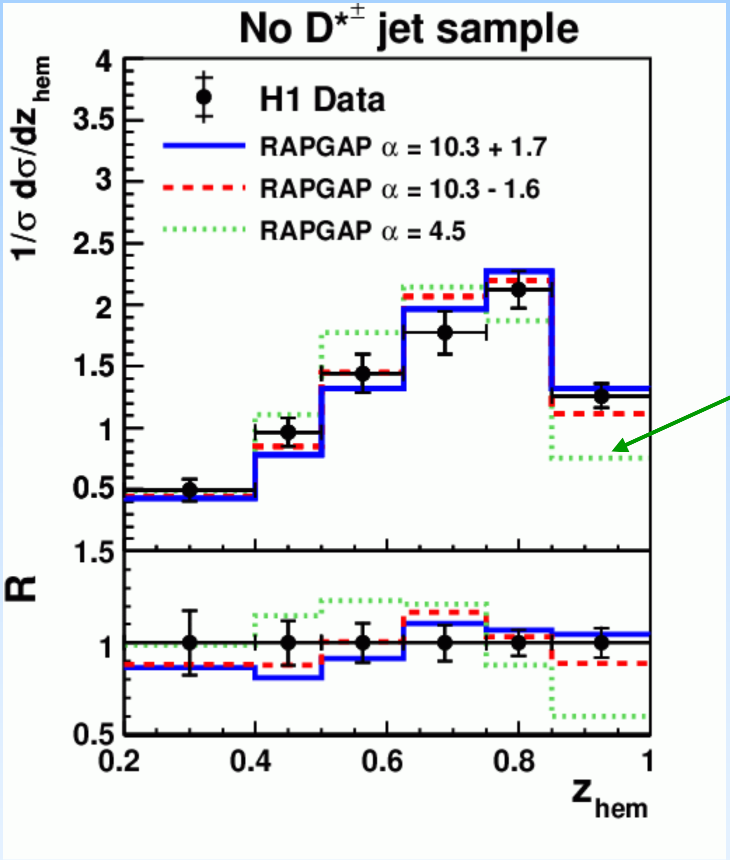
HVQDIS
parton level

- **Extracted n.p. FF parameters from z_{hem} (α=3.3±0.4) and z_{jet} (α=3.3±0.3) agree well**

(HVQDIS, independent fragmentation, Kartvilishvili)

Fit of n.p. FF parameters to z_{hem} –no D*-jet with E_T>3GeV

Hemisphere method



RAPGAP hadron level

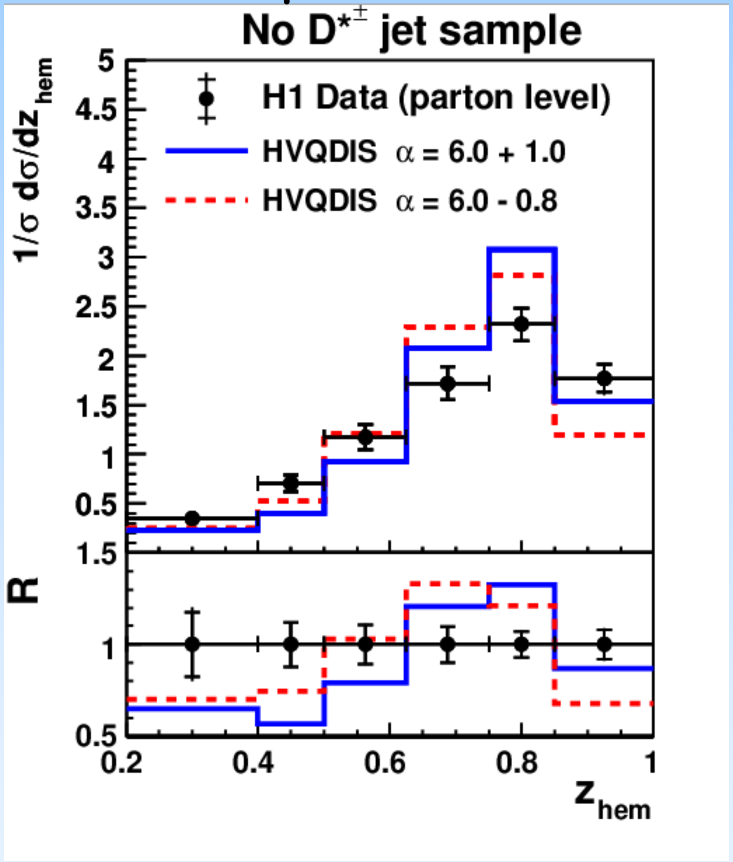
- Extracted parameters of the 'non-jet' sample (α=10.3 $^{+1.7}_{-1.6}$) inconsistent with the parameters obtained for the jet-sample (α=4.5±0.6)

Fragmentation at threshold is significantly harder than expected from the jet-sample (Events are quite empty – but not diffraction)

⇒there is a lack of understanding of fragmentation in the full phase space of charm production in ep-scattering

Fit of n.p. FF parameters to z_{hem} –no D*-jet with E_T>3GeV

Hemisphere method



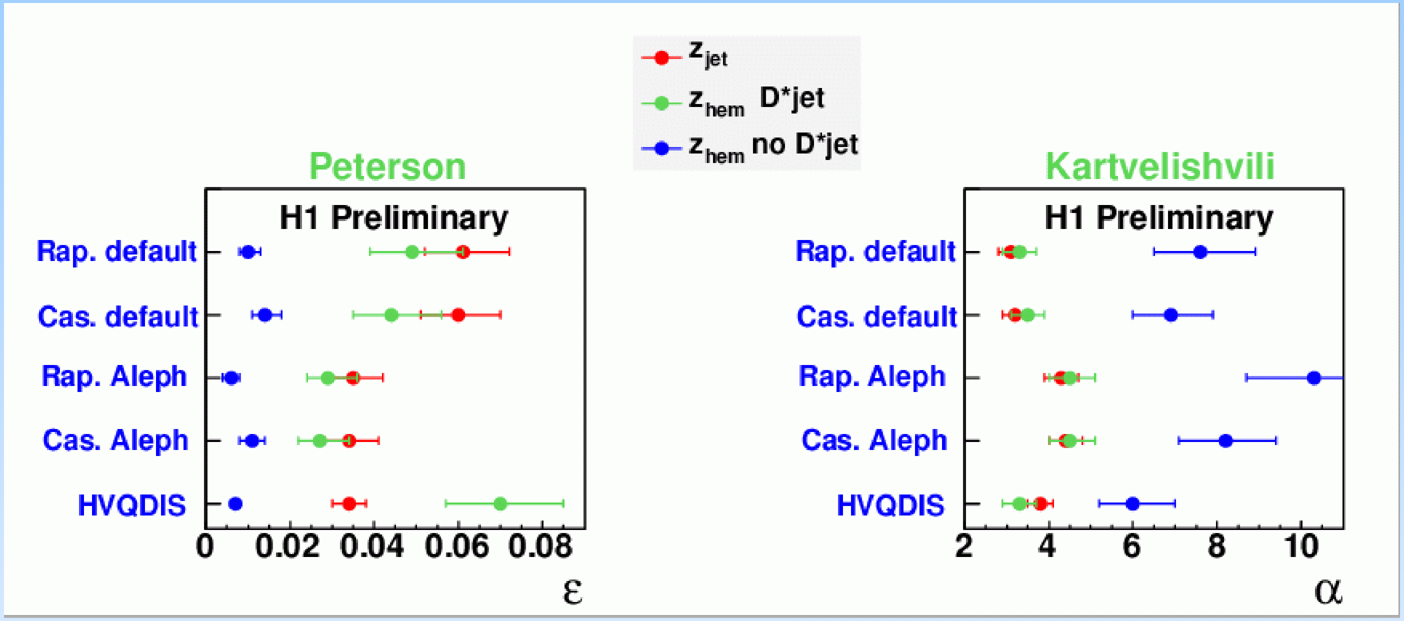
HVQDIS parton level

- **Extracted parameters of the 'non-jet' sample** ($\alpha=6.0^{+1.0}_{-0.8}$) **inconsistent with the parameters obtained for the jet-sample** ($\alpha=3.3\pm0.4$)

HVQDIS yields a very poor description of the fragmentation observable close to threshold (χ^2/NDF=11 !!)

Conclusions are the same as for RAPGAP (previous slide)

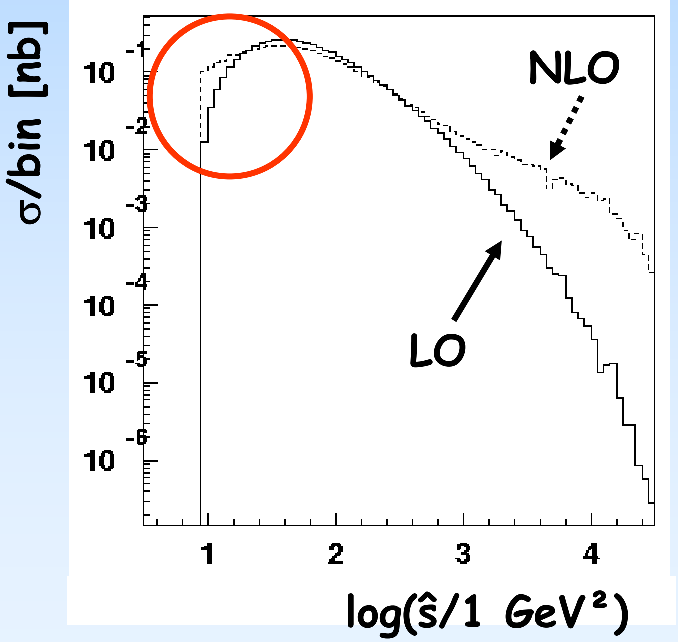
FF parameters - Results



- N.p. FF parameters extracted from the two observables agree within errors (Kartvilishvili better than Peterson)
- Parameters are model dependent
- Parameters of the jet (••) and non-jet samples (•) are always inconsistent

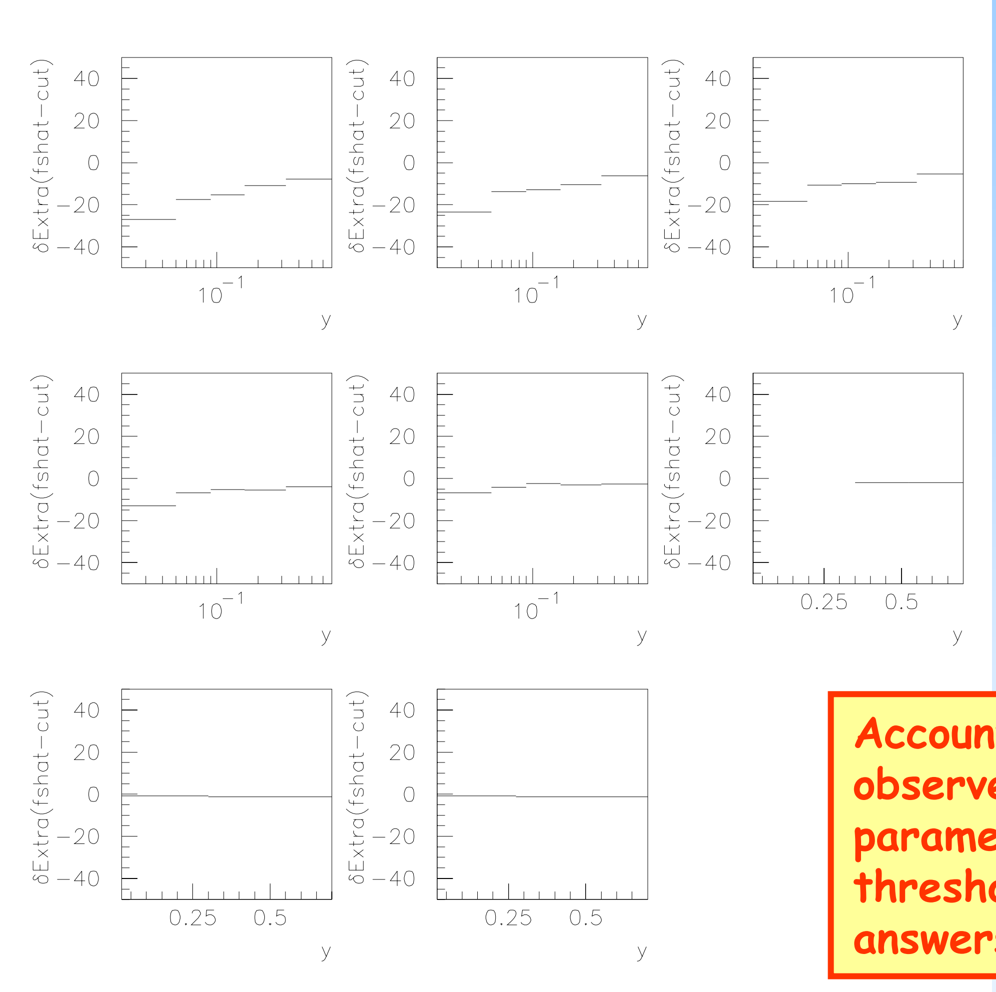
Discussion - I

- **Obviously none of the models is able to describe charm fragmentation in the full phase space accessible in DIS at HERA (3-4 σ)**
- **HVQDIS does a bad job in describing the shape of the fragmentation observable at threshold (effect of HO's?)**



Large effects from NLO also visible at threshold

Discussion - II



Ratio of extrapolation factors for F_2^{cc} using $\hat{s}$-dependent and constant fragmentation parameter

Differences up to >20% At small Q^2 and small y

Accounting for /disregarding the observed inconsistency of the np FF parameters at and well above threshold yields significantly different answers when extrapolating for F_2^{cc}

Conclusions

- From D* production different answers on the non-perturbative fragmentation parameter from the close-to and far-above threshold samples
- Fragmentation significantly harder at threshold than expected by all models investigated in the analysis. Over-estimation of gluon radiation at threshold?
- Especially HVQDIS does a bad job in describing the shape of the fragmentation observable at threshold
- The lack of understanding of fragmentation may introduce significant uncertainties when going to F_2^{cc} or comparing the visible cross section with calculations

$\Rightarrow$To better investigate the threshold region the D* phase space will be enlarged down to $p_\perp(D^*)$=0.8-1 GeV