Fragmentation of Charm into D^+,D^0, D_s^+,D^* and the Charm Fragmentation Function

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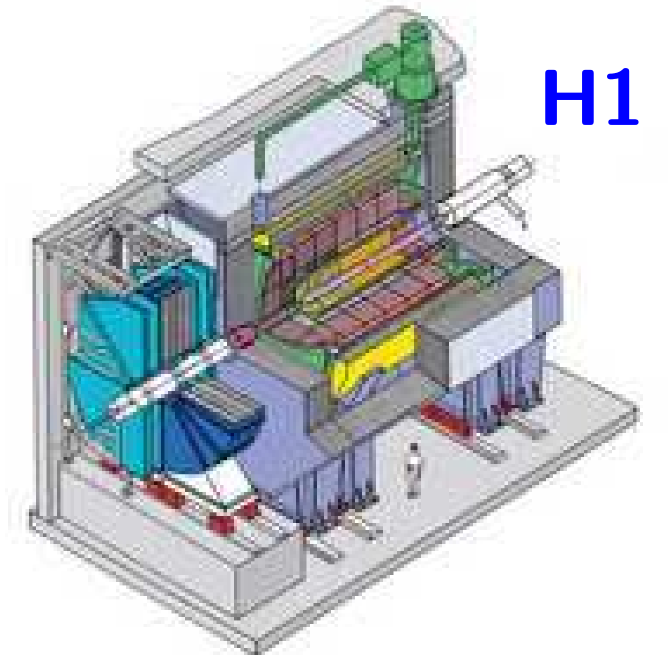
- Motivation for fragmentation study
- Fragmentation fractions (D^+, D^0, D_s^+, D^*)
- Fragmentation function (D^*)
- Conclusions



Why Fragmentation?

Inclusive production cross-section of charm mesons:

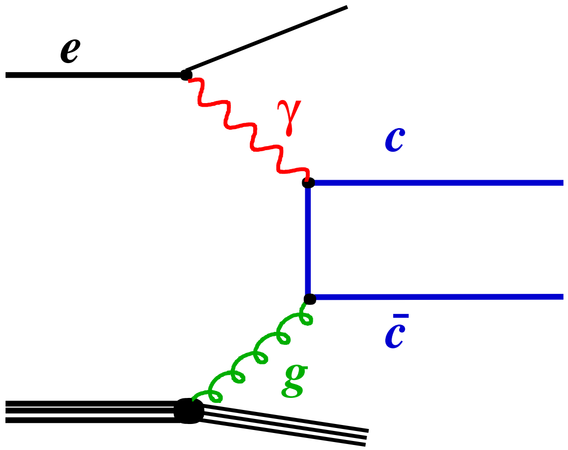
$$\sigma(D) \sim f_{g/p}(x,\mu) \otimes ME \otimes D_{D/c}(x,\mu)$$

Gluon Density Function

Experimentally determined

Hard Scattering

(perturbative)



Fragmentation Function

Experimentally determined

Experimental Study of Fragmentation

Fragmentation

▷ nonperturbative process (transition from quark to hadron)
$\Longrightarrow$ needs experimental study

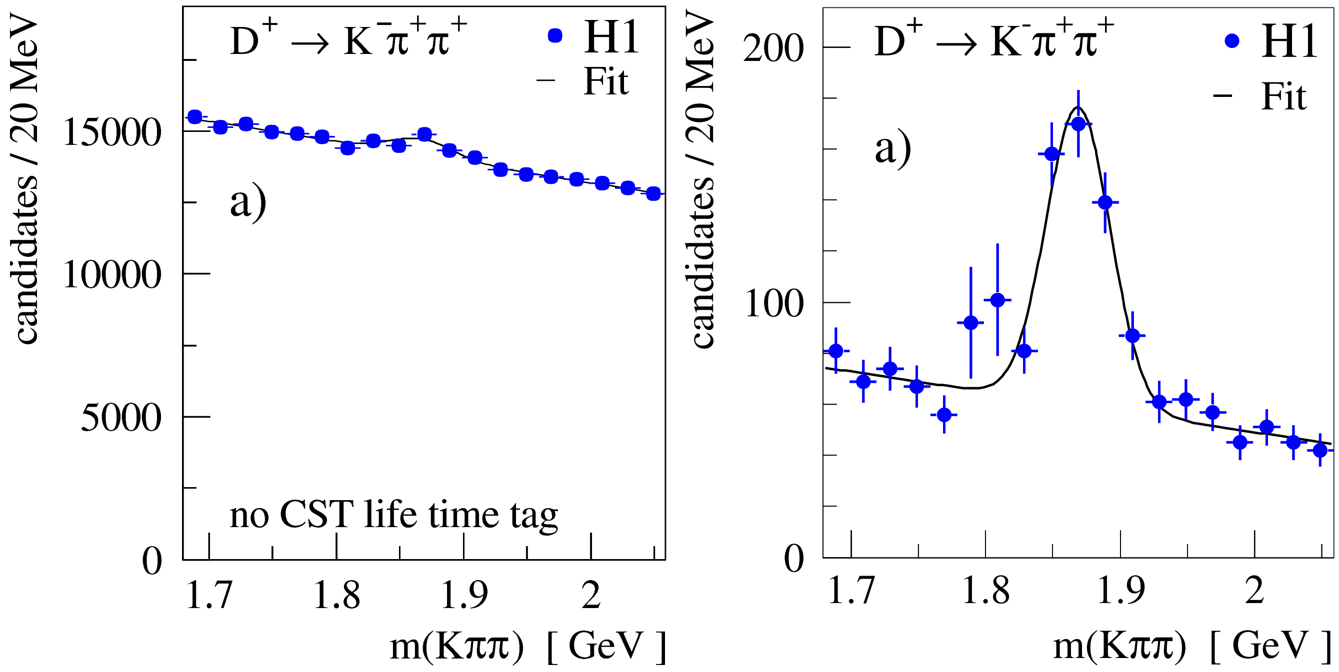
Questions to be addressed :

1.) what is the probability of c-quark to fragment to different charmed mesons (fragmentation fractions)

2.) what fraction of the c-quark's energy is transferred to the charmed meson (fragmentation function)

Fragmentation Fractions of D^+, D^0, D_s^+, D^*

- Charm tagging: reconstruction of secondary vertex with the central silicon tracker
- signal to background ratio can be improved significantly by cut on decay length significance ($S_l = l/\sigma_l$)



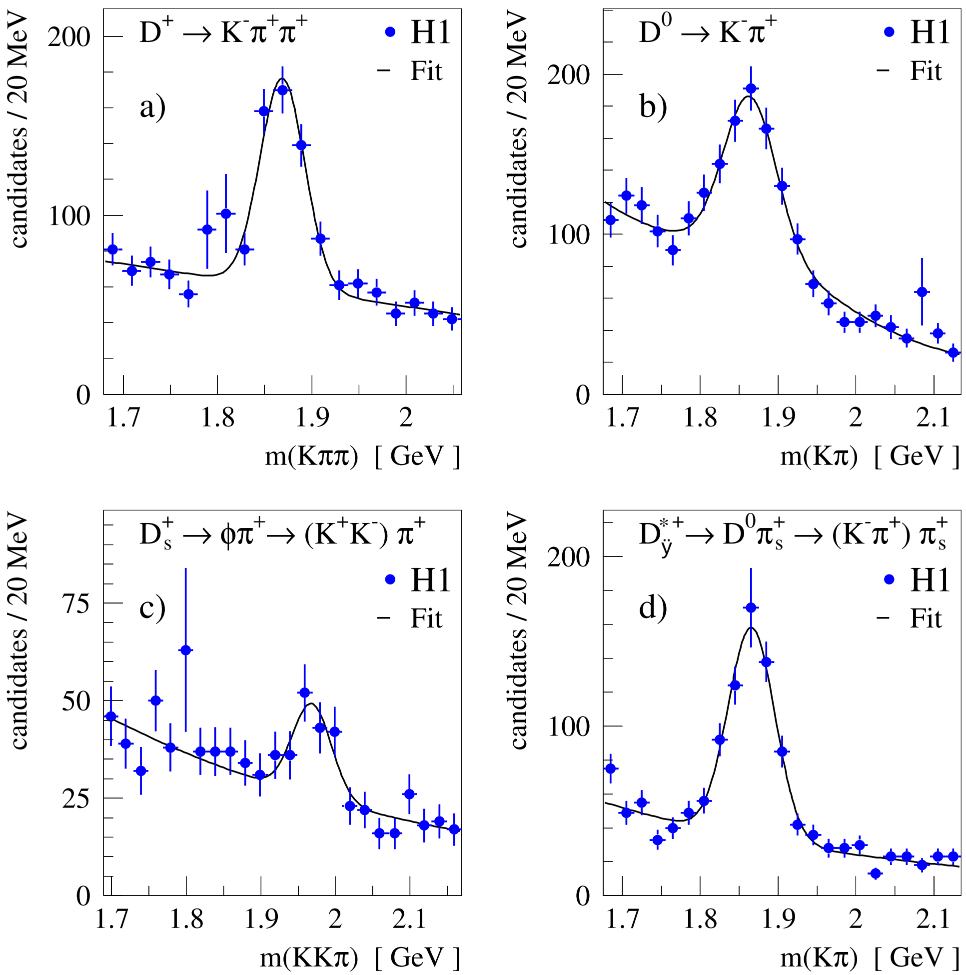
D Meson Signals

- ▷ Kinematic region:
  $2 < Q^2 < 100$ GeV^2
  $0.05 < y < 0.7$
  $p_t(D) > 2.5$ GeV
  $|\eta(D)| < 1.5$

- ▷ Invariant mass spectra fitted:
  Gaussian + background

- ▷ Visible cross-sections were determined

[Eur.Phys.J.C38:447-459,2005]



Fragmentation Fractions

▷ Fragmentation fractions $f(c \to D)$ deduced from measured σ_{vis} using AROMA Monte Carlo:

$$f(c \to D) = \frac{\sigma_{vis}(c\bar{c} \to D) - \sigma_{vis}^{MC}(b\bar{b} \to D)}{\sigma_{vis}^{MC}(c\bar{c} \to D)} . f_{MC}(c \to D)$$

[Eur.Phys.J.C38:447-459,2005]

Fragmentation factors	D^+	D^0	D_s^+	D^*
H1: $f(c \to D)$	0.203 $\pm$ 0.026	0.560 $\pm$ 0.046	0.151 $\pm$ 0.055	0.263 $\pm$ 0.032
World Average: $f(c \to D)$	0.232 $\pm$ 0.018	0.549 $\pm$ 0.026	0.101 $\pm$ 0.027	0.235 $\pm$ 0.010

Results compatible with world average values.

Fragmentation Ratios

- ▷ Ratio of u to d: $R_{u/d} = c\bar{u}/c\bar{d}$
- ▷ Strangeness suppression factor: $\gamma_s = 2c\bar{s}/(c\bar{u} + c\bar{d})$
- ▷ Fraction of vector D mesons: $P_V = V/(V + PS)$

[Eur.Phys.J.C38:447-459,2005]

Ratio	H1 measurement				e^+e^- experiments		
	value	stat.error	syst.error	theo.error	value	error	ref.
P_V^d	0.693	$\pm\,0.045$	$\pm\,0.004$	$\pm\,0.009$	0.595	$\pm\,0.045$	[42]
P_V^{u+d}	0.613	$\pm\,0.061$	$\pm\,0.033$	$\pm\,0.008$	0.620	$\pm\,0.014$	[43]
$R_{u/d}$	1.26	$\pm\,0.20$	$\pm\,0.11$	$\pm\,0.04$	1.02	$\pm\,0.12$	[42]
γ_s	0.36	$\pm\,0.10$	$\pm\,0.01$	$\pm\,0.08$	0.31	$\pm\,0.07$	[44]

H1 ep data agree with e^+e^-
$\Longrightarrow$ universality of charm fragmentation fractions

Fragmentation Function

Fragmentation function describes the energy transfer from quark to a given meson.

e^+e^- collisions

- natural choice $$z = \frac{E_{D^*}}{\sqrt{s}/2} = \frac{E_{D^*}}{E_{beam}}$$
- assuming LO processes - direct measurement of non perturbative fragmentation function

ep collisions

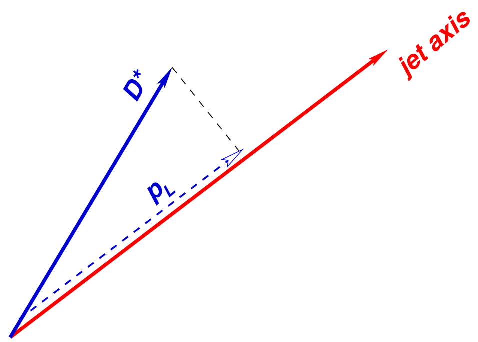
- choice of z observable not so obvious
- differences: IPS contribution,
  different kinematics

The Experimental Methods

Jet Method :

▷ the energy of c-quark is approximated by the energy of the reconstructed D^* jet

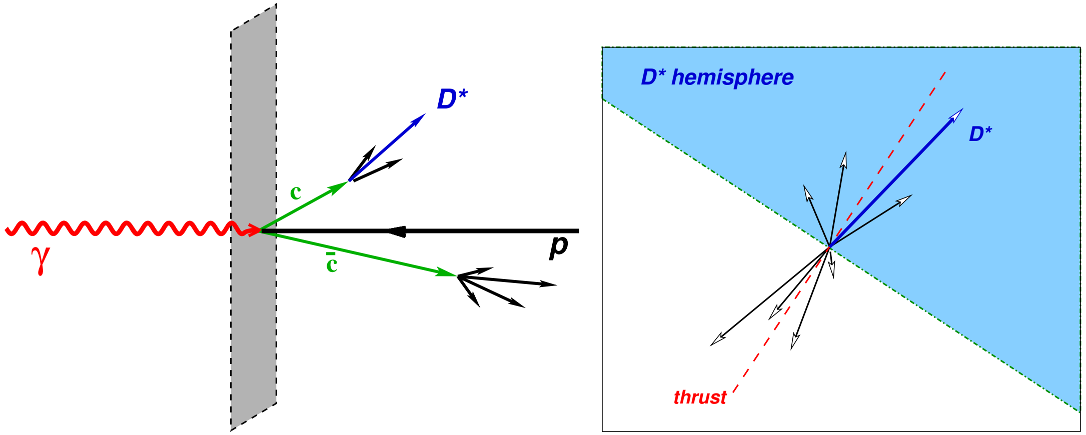
$$z_{jet} = \frac{(E+p_L)_{D^*}}{(E+p)_{jet}}$$



Hemisphere Method :

▷ in γp-frame the $c\bar{c}$ pair is balanced in p_t $\Longrightarrow$ possibility to divide event into two hemispheres

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



Aspects of z(jet) & z(hem) Methods

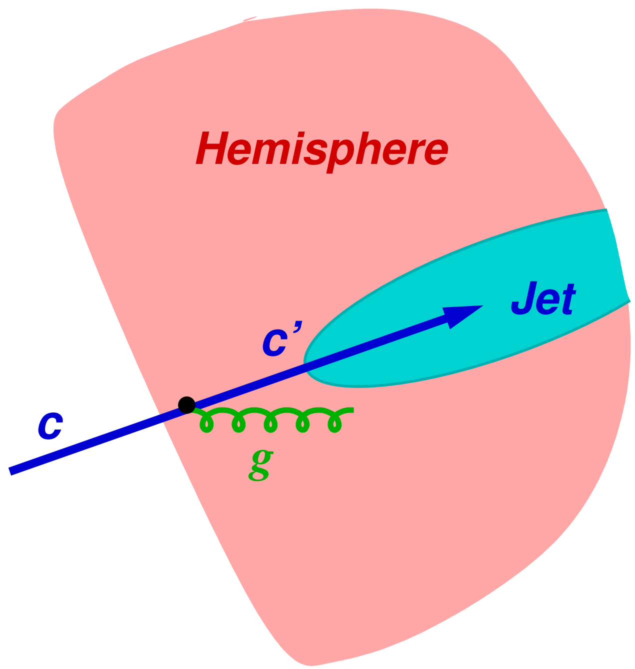
Jet method and hemisphere method differ in case of gluon radiation:

Hemisphere method:

- ▷ includes radiated gluons (fragmentation $c \longrightarrow D^*$)
- ▷ closer to e^+e^-

Jet method:

- ▷ not sensitive to hard gluons from c-quark (fragmentation $c' \longrightarrow D^*$)
- ▷ maybe closer to non-perturbative fragmentation function

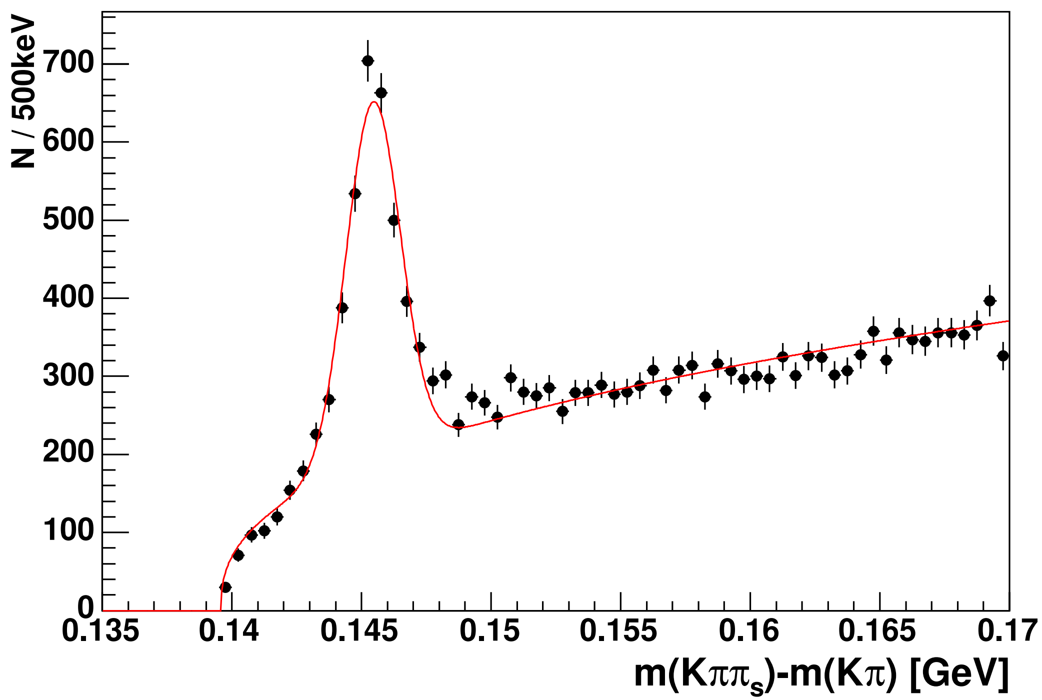


$\Longrightarrow$ **Comparison of both methods provides information about underlying physics.**

D^* Tagging

Golden channel:

$$D^{*\mp} \longrightarrow D^0\pi_s^\mp \longrightarrow K^\pm\pi^\mp\pi_s^\mp$$



Kinematic cuts:

$2 < Q^2 < 100$ GeV^2

$0.05 < y_e < 0.7$

$p_t(D^*) > 1.5$ GeV

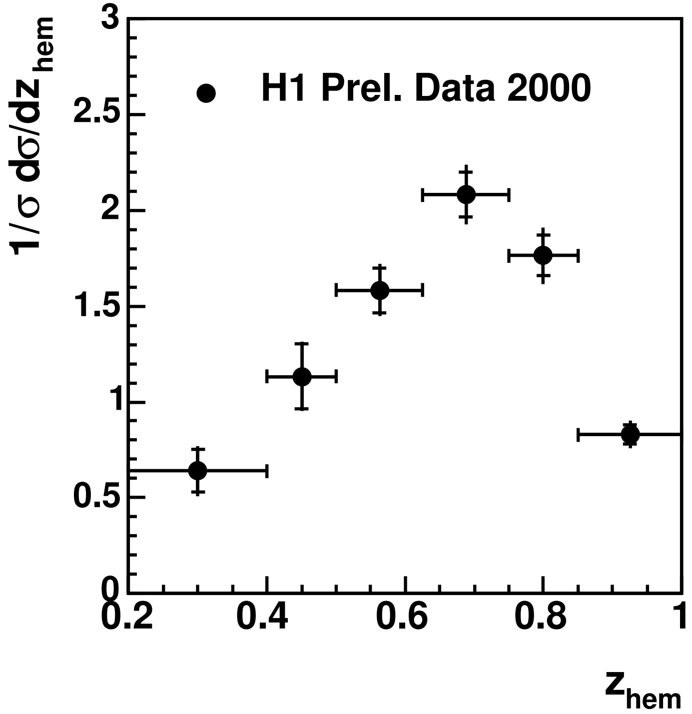
$|\eta(D^*)| < 1.5$

Jet method:

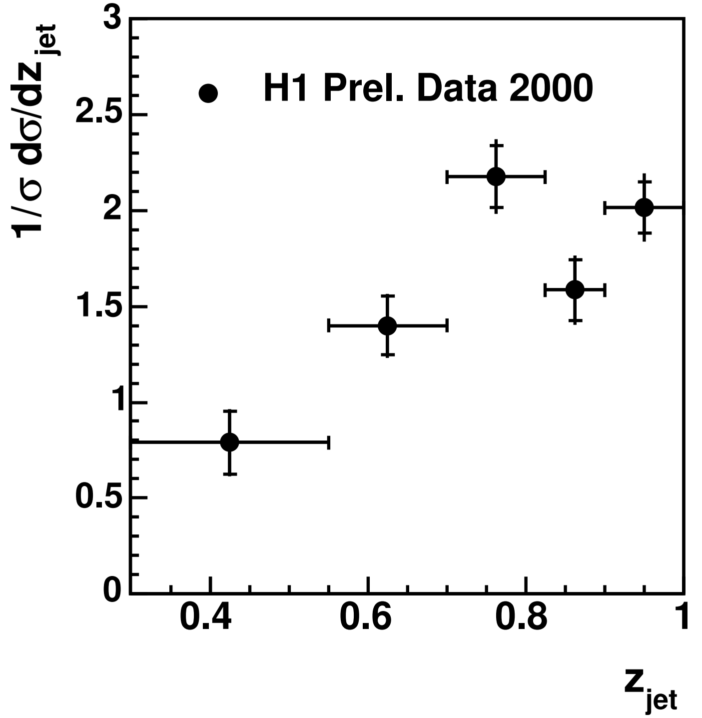
- ▷ D^* treated as stable meson
- ▷ massive k_t-cluster jet algorithm applied in γp frame

Corrected Fragmentation Spectra

Hemisphere method :



Jet method :



Visible Range:

$\eta_{\mathrm{part},\gamma p} > 0.$

$\mathrm{z} > 0.2$

$p_{\mathrm{t}}(D^{*}\mathrm{jet}) > 3$ GeV

$\mathrm{z} > 0.3$

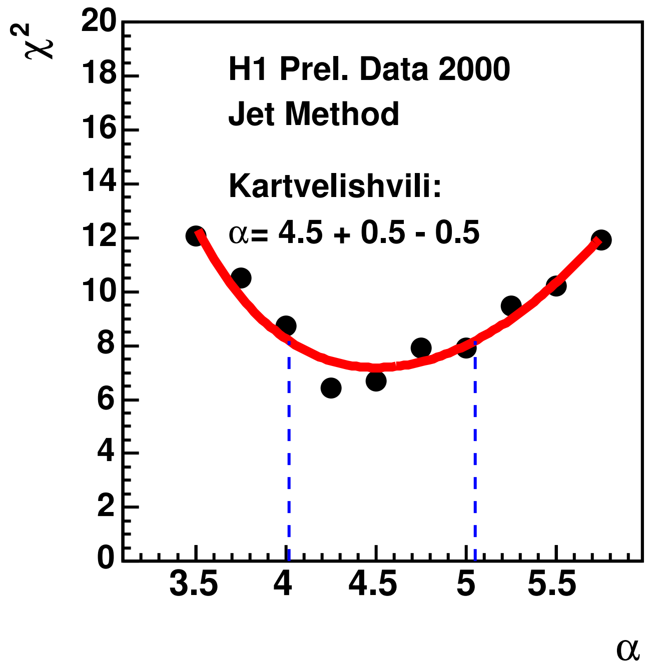
Extraction of Fragmentation Parameter

- Fragmentation parameters extracted for RAPGAP 3.1 MC (direct +resolved) with excited D-states (ALEPH tune)

- for fragmentation used: $a.)$ Peterson parametrization
  $b.)$ Kartvelishvili parametrization

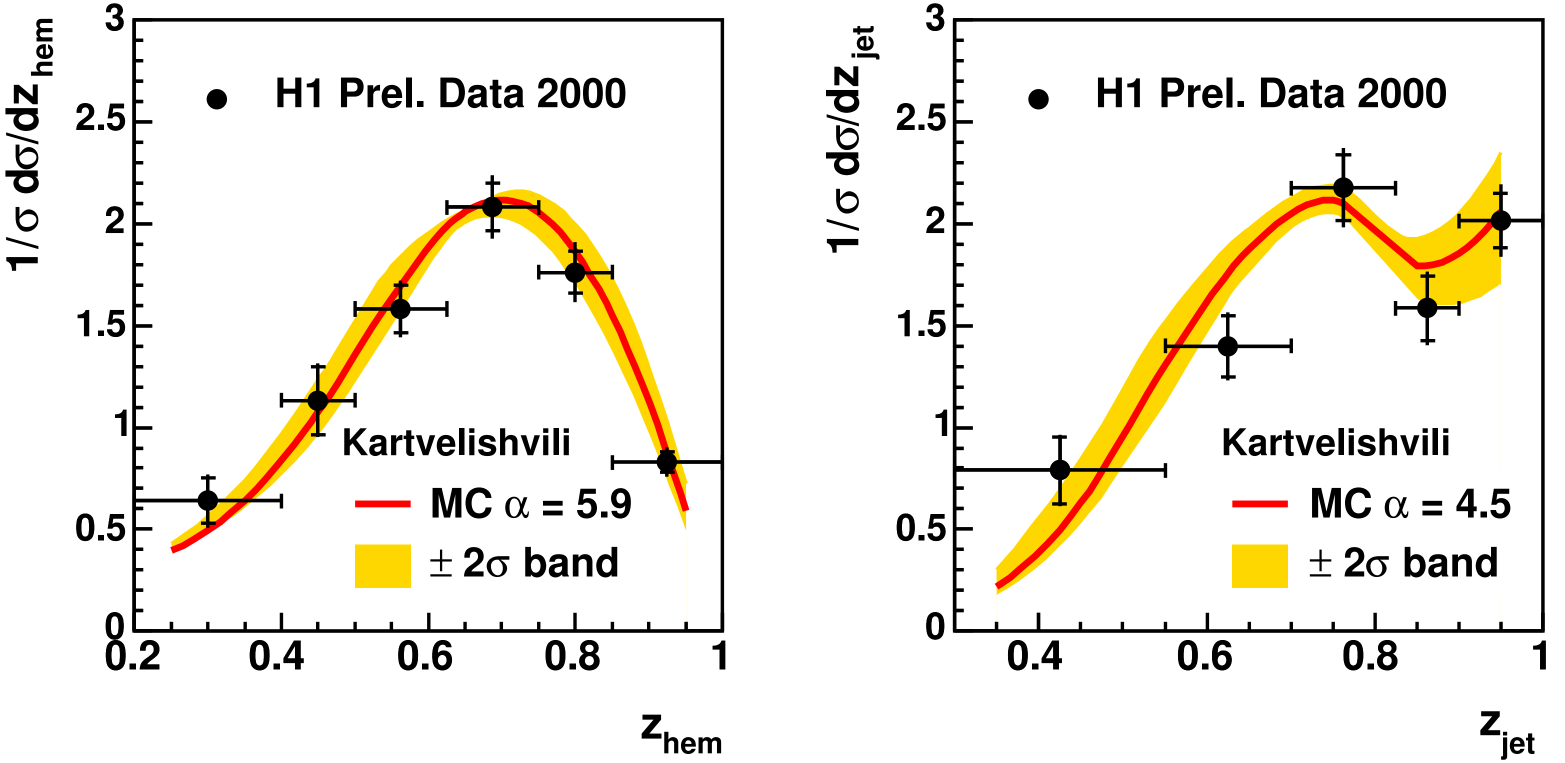
Extraction procedure:

- MC-files generated for various frag. parameters and from the χ^2 the most optimal parameter value obtained (correlated systematic errors taken into account)



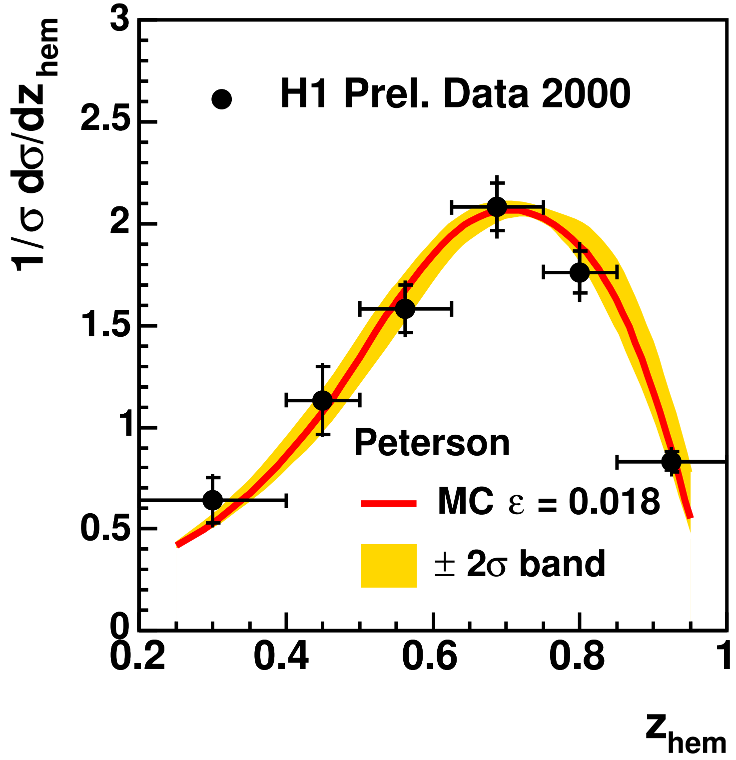
Kartvelishvili Fits

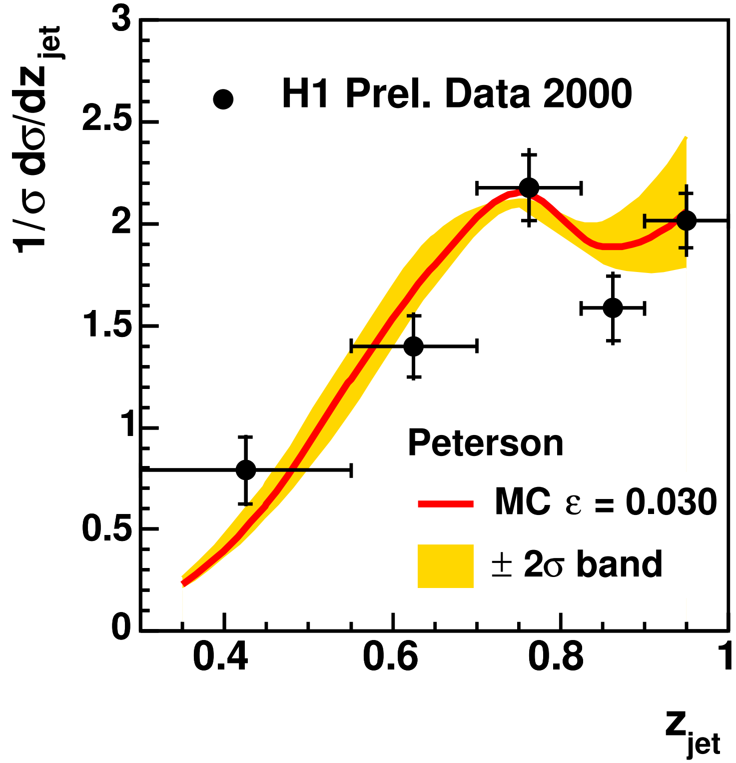
Kartvelishvili : $f(z) \sim z^{\alpha}(1-z)$



Peterson Fits

Peterson : $f(z) \sim z^{-1}[1 - \frac{1}{z} - \frac{\varepsilon}{1-z}]^{-2}$





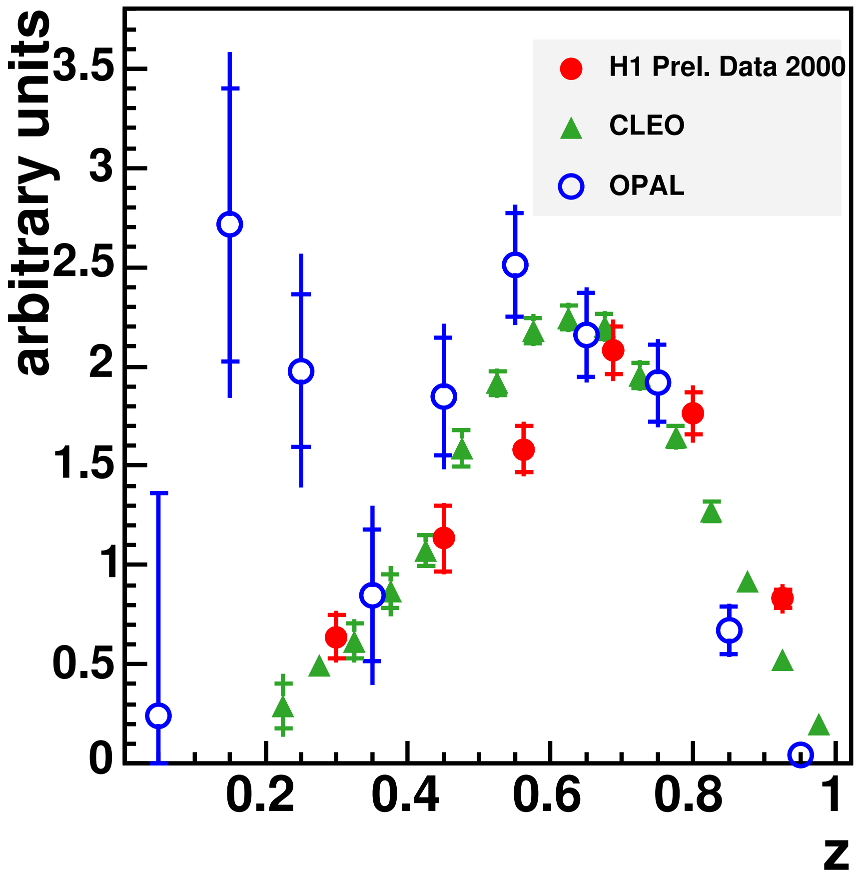
Summary of the Fragmentation Function Results

- Kartvelishvili and Peterson parametrizations provide equally good descriptions of the data
- hemisphere method appears to give harder fragmentation function than the jet method
- difference ($< 3\sigma$) between hemisphere and jet method result may indicate imperfect MC description of hadronic final state in charm events

H1 Prel. Data 2000

parametrization		Hemisphere method	Jet method
Peterson	ε	$0.018^{+0.004}_{-0.004}$	$0.030^{+0.006}_{-0.005}$
Kartvelishvili	α	$5.9^{+0.7}_{-0.6}$	$4.5^{+0.5}_{-0.5}$

Comparison with e^+e^- Experiments



H1 hemisphere method

$<\sqrt{s}> \approx 10$ GeV,

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

CLEO $\sqrt{s} \approx 10$ GeV,

$$z = p_{D^*}/p_{max}$$

OPAL $\sqrt{s} = 91.2$ GeV,

$$z = 2E_{D^*}/\sqrt{s}$$

▷ although different observable definitions, spectra similar in shape

Conclusions

- charm fragmentation has been studied
- extracted fragmentation fractions are in agreement with e^+e^-
- fragmentation function for D^* was measured using two different methods (hemisphere and jet)
- parameters of Peterson and Kartvelishvili functions were extracted for LO+PS MC RAPGAP
- the observed differences in extracted parameters for the two methods indicate inadequances in the description of the data by the model
- uncertainties due to charm fragmentation in other HERA measurements can be reduced (e.g. $F_2^{c\bar{c}}$)