Measurements of Charmed Hadrons Production in DIS with ZEUS

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on behalf of the ZEUS Collaboration

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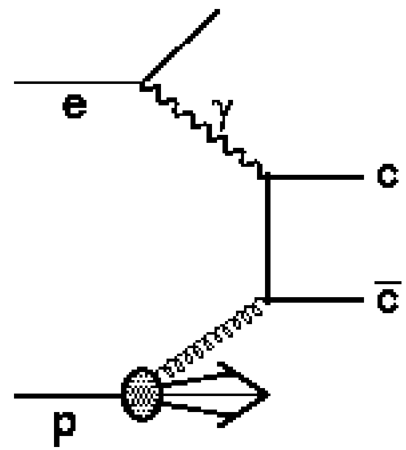
Introduction

Reconstruct the charm mesons D^0, $D^{*\pm}$, $D^{\pm}$, $D_s^{\pm}$, and the $\Lambda_c^{\pm}$ baryons in deep inelastic ep-scattering at HERA with the ZEUS detector.



Charm production via BGF

Obtain the charm fragmention ratios and fractions:

- ratio of neutral and charged D meson production rates: $R_{u/d} = c\bar{u}/c\bar{d}$;
- s-quark suppression factor: $\gamma_s = 2c\bar{s}/(c\bar{d} + c\bar{u})$;
- fraction of D mesons produced in a vector state: $P_V = V/(PS + V)$;
- fractions of c-quarks hadronising in a charm hadron: $f(c \to D, \Lambda_c) = N(D)/N(c)$

Are the charm fragmentation characteristics universal?

Comparison with ZEUS γp for consistency, and with ep, e^+e^- experiments.

Event selection and Procedure

- ZEUS data 1998-2000 (98-00: $\mathcal{L} = 81.74$ pb^{-1}, 99-00: $\mathcal{L} = 65.06$ pb^{-1})
- Tracks from primary vertex; $|Z_{\text{vertex}}| < 50$ cm;
- scattered electron energy $E'_e > 10$ GeV;
- $y_e \leq 0.95$; $y_{JB} \geq 0.02$;
- $40 < (E - p_z) < 65$ GeV;
- $1.5 < Q^2 < 1000$ GeV^2
  (Σ-method to reconstruct Q^2: $Q^2_\Sigma = \frac{E'^2_e \sin^2(\theta'_e)}{1-y_\Sigma}$, $y_\Sigma = \frac{(E-p_z)_{hadron}}{(E-p_z)_{total}}$);
- $p_T(D, \Lambda_c) > 3$ GeV;
- $|\eta(D, \Lambda_c)| < 1.6$;

Event selection and Procedure

- Kinematic region:
  - $1.5 < Q^2 < 1000$ GeV^2
  - $0.02 < y < 0.7$
  - $p_T(D, \Lambda_c) > 3$ GeV
  - $|\eta(D, \Lambda_c)| < 1.6$

Signal extraction: the mass distributions were fitted with a "modified" gaussian function,

$$Gauss^{mod} \propto \frac{N_{events}}{\sigma} \exp(-0.5x^{1+\frac{1}{1+0.5x}}),$$

where $x = |(M - M_D)/\sigma|$, to describe the signal shape plus a background function.

MC sample: RAPGAP 2.08/18

Remarks on D^0 and $D^{*\pm}$ signals

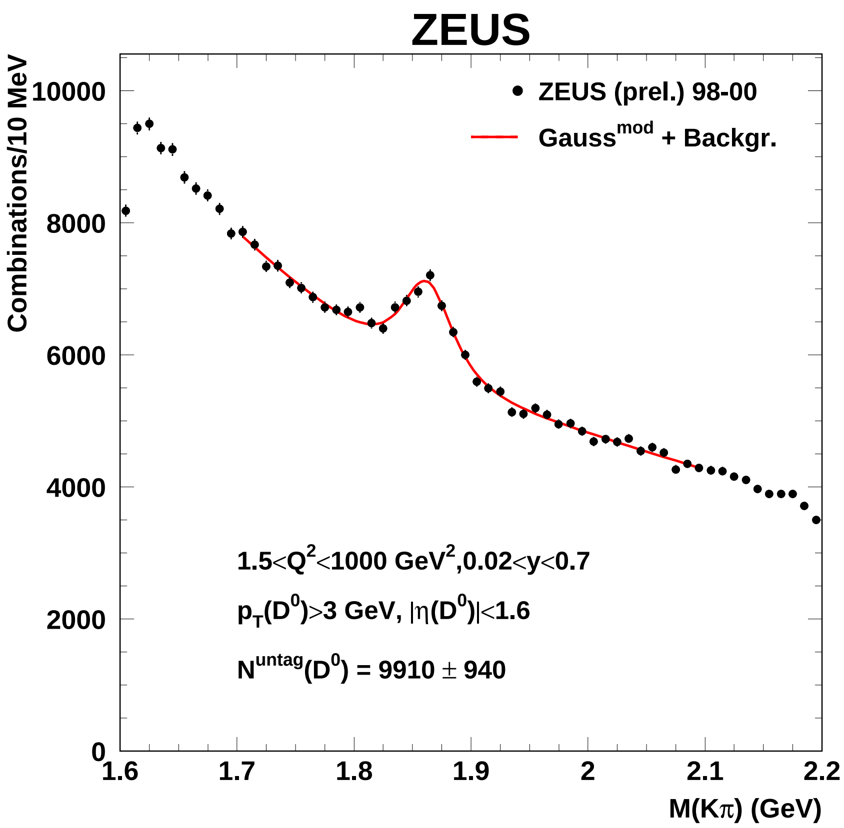
To avoid correlations, the D^0 and $D^{*\pm}$ signals are splitted in:

- D^0 not coming from D^* (D^0(untag))
- D^0 from D^* (D^0(tag)), $\sim D^*$ with D^0 in kinematic range
- "Additional" D^*, together with D^0(tag) gives the D^* with D^* in kinematic range

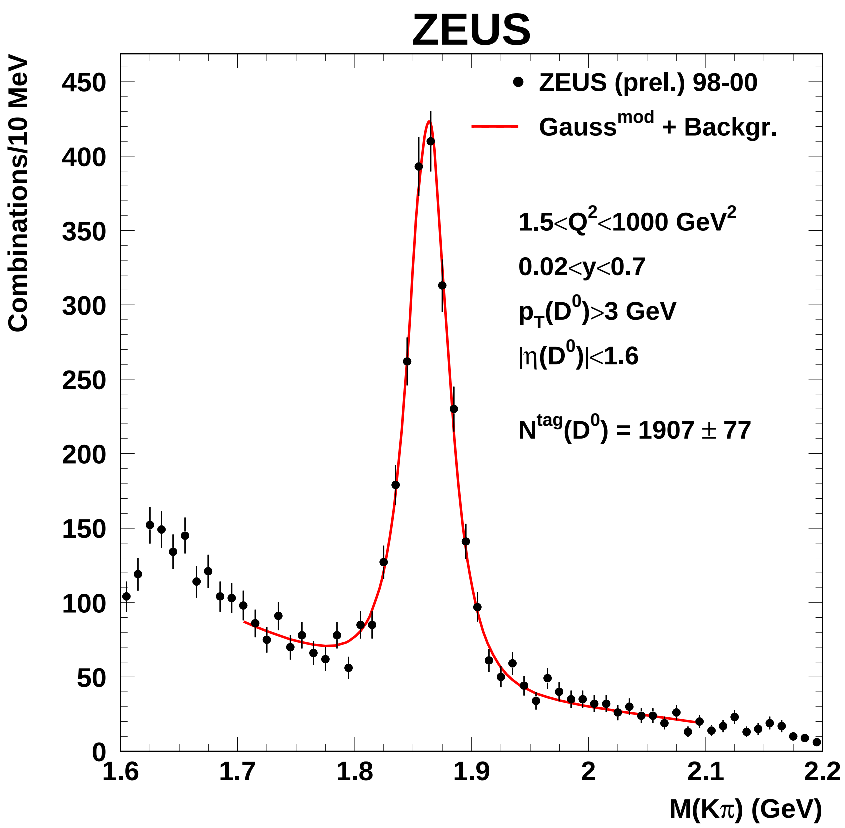
$D^0 \to K\pi$ signal

- Event has at least 2 tracks;
- $p_T(K,\pi) > 0.8$ GeV
- $|\cos\theta^*(K)| < 0.85$, where $\theta^*(K)$ = angle(K in D rest frame, D in LAB);
- reflections are subtracted;

- 3^{rd} track combined with D^0
- $p_T(\pi_s) > 0.2$ GeV, $p_T(\pi_s) > 0.25$ GeV (for a period of smaller efficiency);
- $0.143 < \Delta M < 0.148$ GeV;



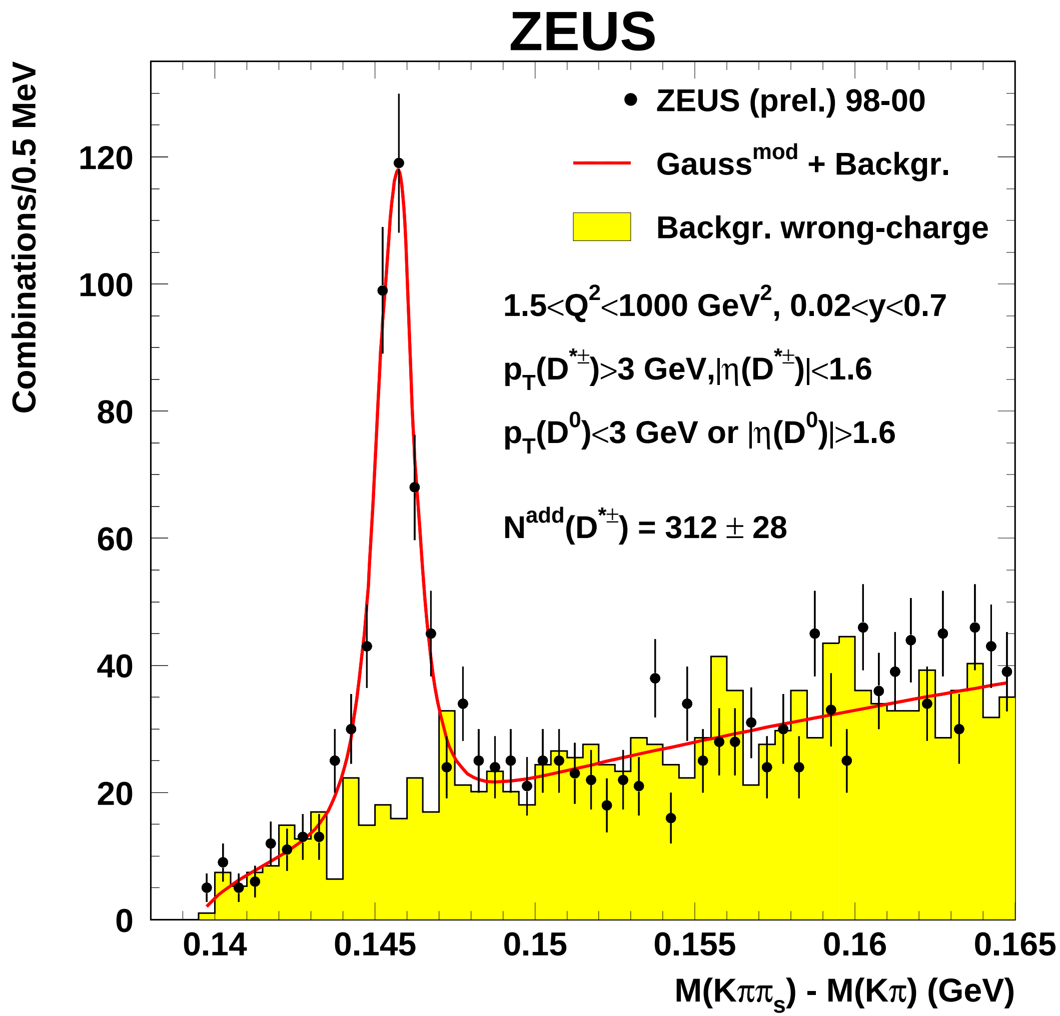
D^0(untag)



D^0(tag)

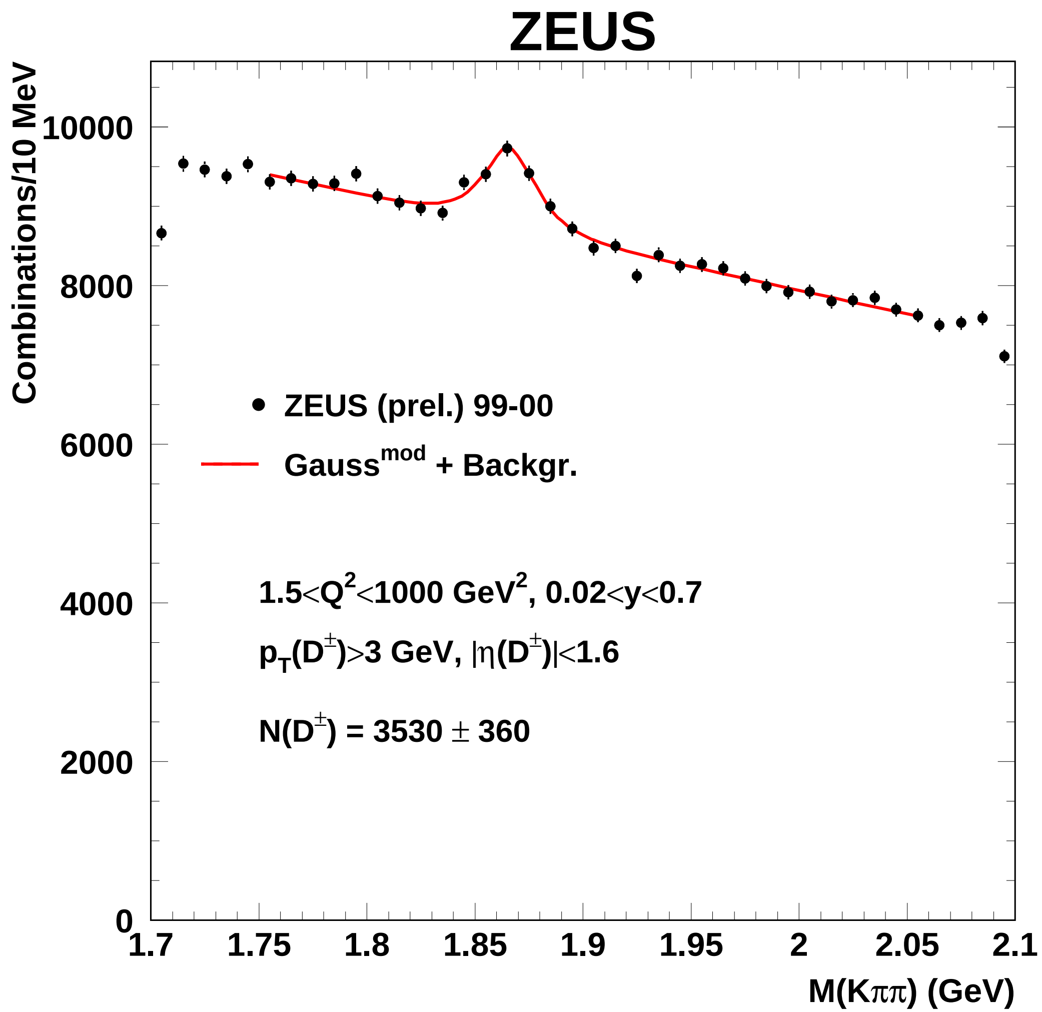
"Additional" $D^{*\pm} \to D^0\pi_s \to K\pi\pi_s$ signal

- Event has at least 3 tracks;
- $p_T(K,\pi) > 0.4$ GeV
- $p_T(\pi_s) > 0.2$ GeV
  $p_T(\pi_s) > 0.25$ GeV (for a period of smaller efficiency);
- $0.143 < \Delta M < 0.148$ GeV;
- $1.8 < M(K\pi) < 1.92$ GeV;
- $p_T(K\pi) < 3$ GeV or
  $|\eta(K\pi)| > 1.6$



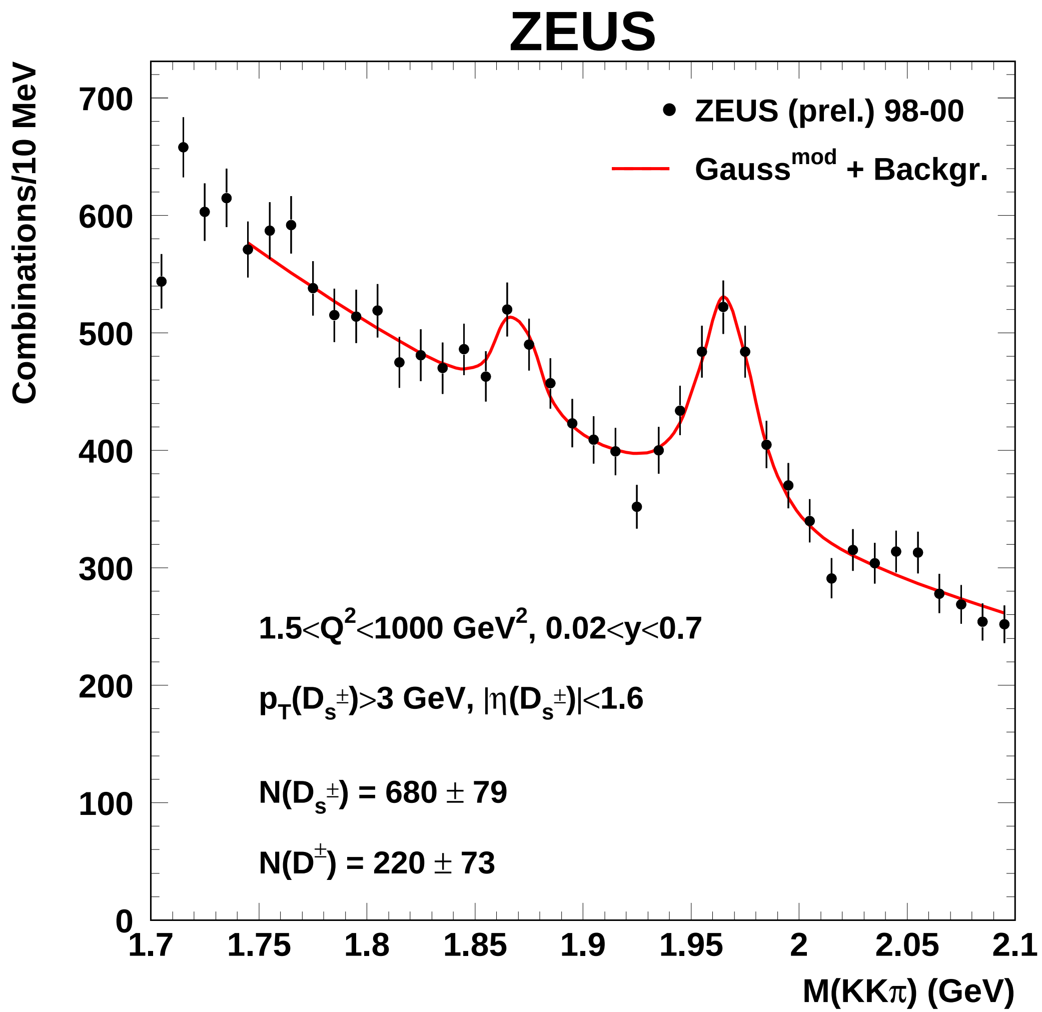
$D^{\pm} \rightarrow K\pi\pi$ signal

- Event has at least 3 tracks;
- $p_T(K) > 0.7$ GeV;
- $p_T(\pi) > 0.5$ GeV;
- $\cos\theta^*(K) > -0.75$, where $\theta^*(K) =$ angle(K in D rest frame, D in LAB);
- suppress background from $D^{*\pm}$ no combinations with $M(K\pi\pi_s) - M(K\pi) < 0.150$ GeV;
- suppress background from $D_s^{\pm}$ no pair $K^{\pm}$"$K^{\mp}$" with $1.011456 < M(KK) < 1.027456$ GeV



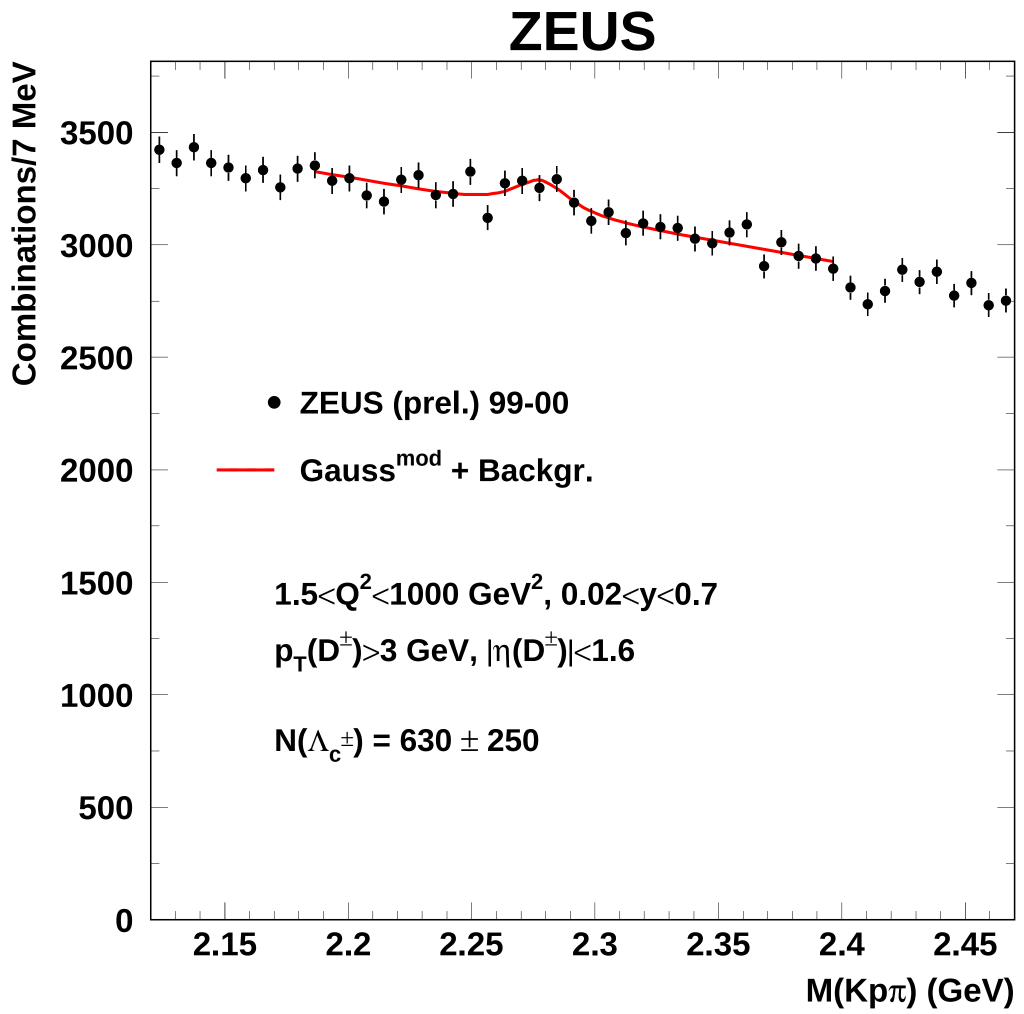
$D_s^{\pm} \rightarrow \phi\pi \rightarrow KK\pi$ signal

- Event has at least 3 tracks;
- $p_T(K) > 0.7$ GeV;
- $p_T(\pi) > 0.5$ GeV;
- $1.011456 < M(KK) < 1.027456$ GeV;
- $\cos\theta^*(\pi) < 0.85$, where $\theta^*(\pi)$ = angle(π in D rest frame, D in LAB);
- $|\cos\theta^{**}(K)|^3 > 0.1$, where $\theta^{**}(K)$ = angle(K,π) in ϕ rest frame



$\Lambda_c^{\pm} \rightarrow Kp\pi$ signal

- Event has at least 3 tracks;
- $p_T(K) > 0.75$ GeV;
- $p_T(\pi) > 0.5$ GeV;
- $p_T(p) > 1.3$ GeV;
- $p_T(p) > p_T(\pi)$;
- $\cos\theta^*(K) > -0.9$,
- $\cos\theta^*(p) > -0.25$, where $\theta^*(K,p)$ = angle(K,p in Λ rest frame, Λ in LAB);
- $|p^*(\pi)| > 90$ MeV in Λ rest frame



Equivalent phase space treatment

- To subtract D^* contributions to D cross sections:
  $\sigma(D^* \text{ with } D^0 \text{ in kin. range}) = \sigma^{tag}(D^0)/B_{D^* \to D^0\pi}$

- D^* cross section:
  $\sigma(D^* \text{ with } D^* \text{ in kin. range}) = \sigma^{tag}(D^0)/B_{D^* \to D^0\pi} + \sigma^{add}(D^*)$

- Direct D^+ and D^0 cross section:
  $\sigma^{dir}(D^+) = \sigma(D^+) - (1 - B_{D^* \to D^0\pi}) \times \sigma^{tag}(D^0)/B_{D^* \to D^0\pi}$

  $\sigma^{dir}(D^0) = \sigma^{untag}(D^0) - \sigma^{tag}(D^0)/B_{D^* \to D^0\pi}$

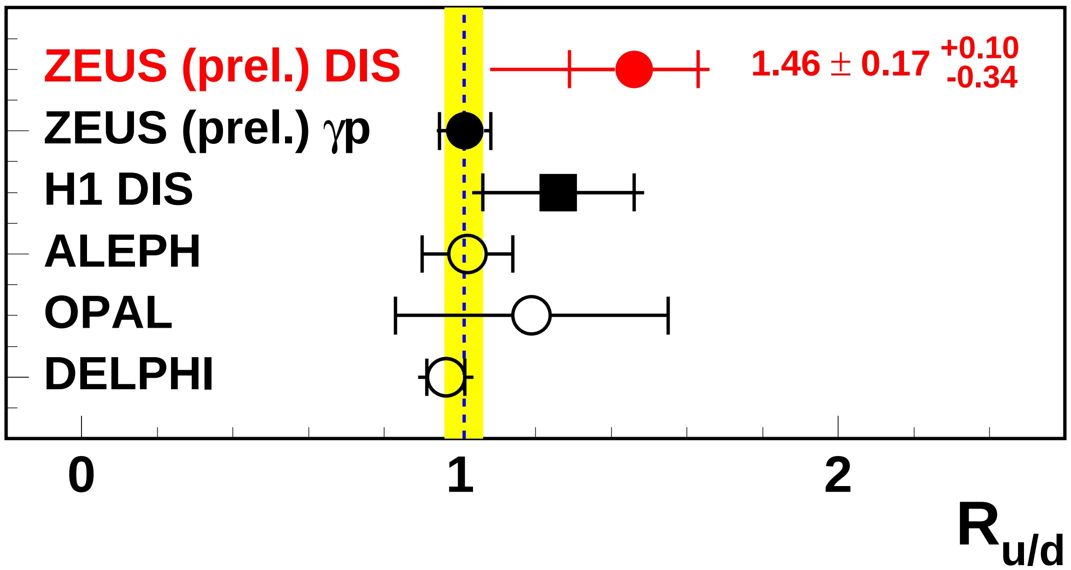
$\sigma(D^{*0}) = \sigma(D^{*+})$ is assumed in $\sigma^{dir}(D^0)$

Charm fragmentation ratios - $R_{u/d}$

- ratio of neutral and charged D meson production rates

$$R_{u/d} = \frac{\sigma^{untag}(D^0)}{\sigma(D^{\pm})+\sigma^{tag}(D^0)}$$

$$R_{u/d} = 1.46 \pm 0.17^{+0.10}_{-0.34} \quad \text{(ZEUS prel.)}$$



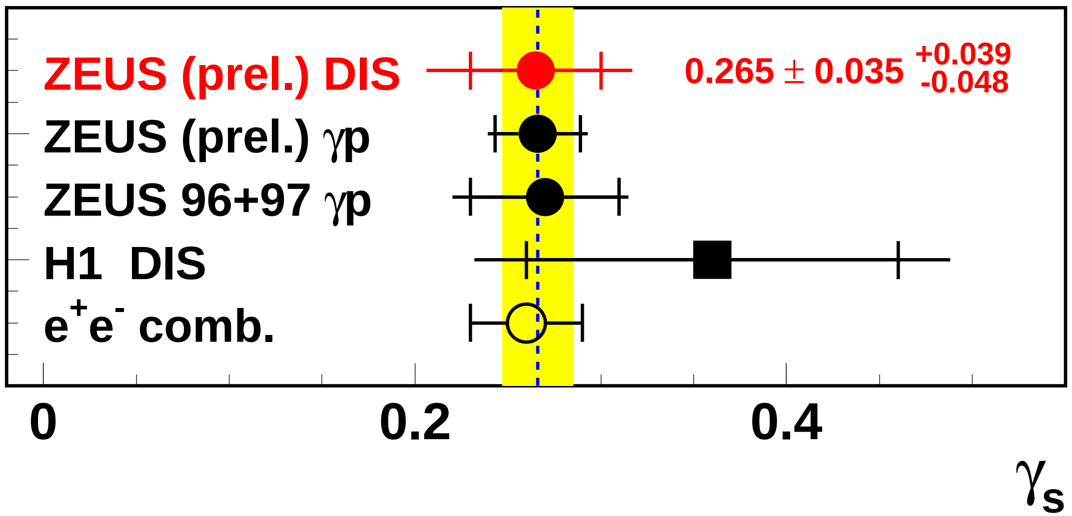
(Large systematic error from D^0(untag) signal extraction procedure, this has consequences in other measurements)

Charm fragmentation ratios – γ_s

- strangeness suppression factor

$$\gamma_s = \frac{2\sigma(D_s^\pm)}{\sigma(D^\pm)+\sigma^{untag}(D^0)+\sigma^{tag}(D^0)+2\sigma^{add}(D^{*\pm})}$$

$$\gamma_s = 0.265 \pm 0.035^{+0.039}_{-0.048} \quad \text{(ZEUS prel.)}$$



Charm fragmentation ratios - P_V

- fraction of D mesons produced in a vector state (charged+neutral)

$$P_V = \frac{2\sigma^{tag}(D^0)/B_{D^*\to D^0\pi} + 2\sigma^{add}(D^{*\pm})}{\sigma(D^\pm) + \sigma^{untag}(D^0) + \sigma^{tag}(D^0) + 2\sigma^{add}(D^{*\pm})}$$

$$P_V = 0.490 \pm 0.032^{+0.071}_{-0.019} \quad \text{(ZEUS prel.)}$$

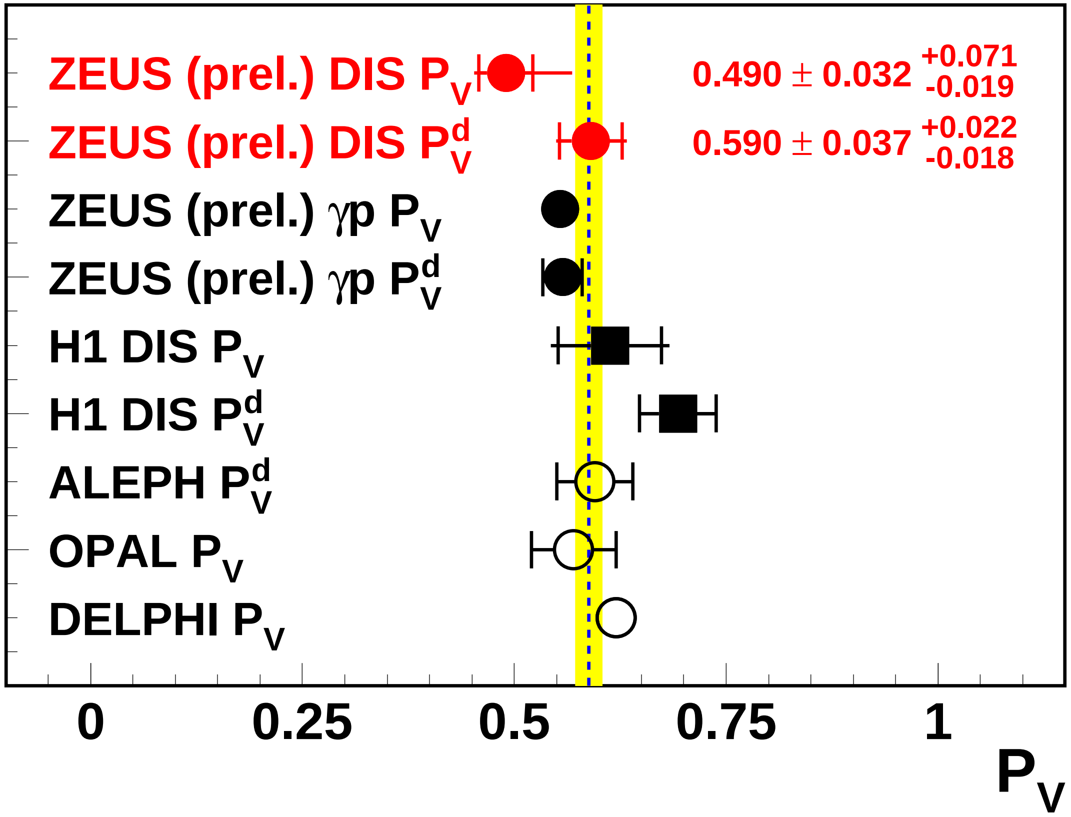
- fraction of D mesons produced in a vector state (charged)

$$P_V^d = \frac{\sigma^{tag}(D^0)/B_{D^*\to D^0\pi} + \sigma^{add}(D^{*\pm})}{\sigma(D^\pm) + \sigma^{tag}(D^0) + \sigma^{add}(D^{*\pm})}$$

$$P_V^d = 0.590 \pm 0.037^{+0.022}_{-0.018} \quad \text{(ZEUS prel.)}$$

$P_V \neq 0.75$, *naive spin counting does not work for charm.*

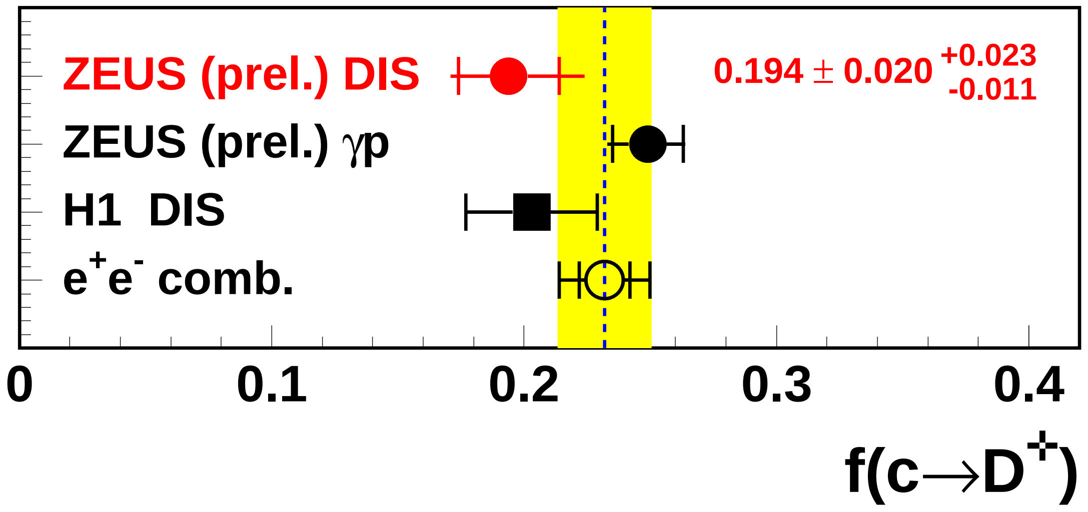
Charm fragmentation ratios - P_V



Charm fragmentation fractions - $f(c \to D^{\pm})$

$$f(c \to D^{\pm}) = \frac{\sigma(D^{\pm}) + \sigma^{add}(D^{*\pm}) * (1 - B_{D^* \to D^0 \pi})}{\Sigma_{all} \sigma_{gs}}$$

$$f(c \to D^{\pm}) = 0.194 \pm 0.020^{+0.023}_{-0.011} \quad \text{(ZEUS prel.)}$$

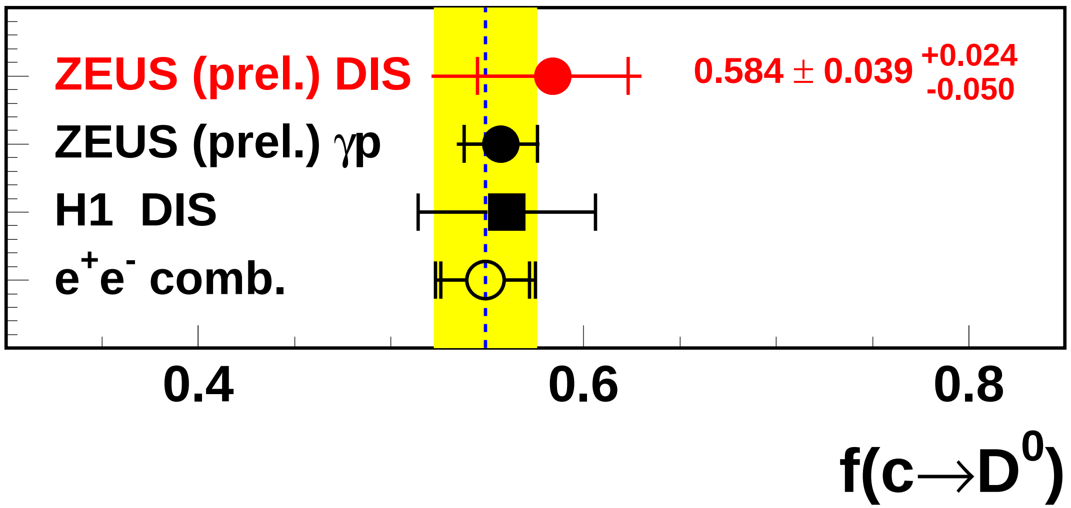


- $\Sigma_{all}\sigma_{gs}$ is the cross section of all charm ground states
- $D_s^{*\pm}$ and Σ_c cross sections are counted in $\sigma(D_s)$ and $\sigma(\Lambda_c)$.
- Rates for Ξ_c and Ω_c^0 are estimated to be 14% of Λ_c.

Charm fragmentation fractions - $f(c \to D^0)$

$$f(c \to D^0) = \frac{\sigma^{untag}(D^0)+\sigma^{tag}(D^0)+\sigma^{add}(D^{*\pm})*(1+B_{D^* \to D^0 \pi})}{\Sigma_{all}\sigma_{gs}}$$

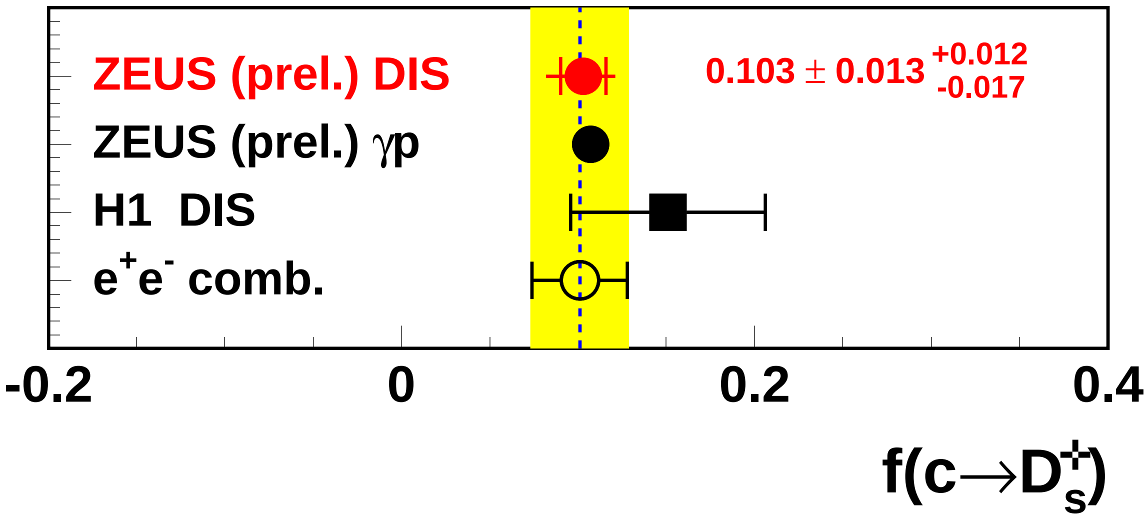
$$f(c \to D^0) = 0.584 \pm 0.039^{+0.024}_{-0.050} \quad \text{(ZEUS prel.)}$$



Charm fragmentation fractions - $f(c \to D_s^{\pm})$

$$f(c \to D_s^{\pm}) \;=\; \frac{\sigma(D_s^{\pm})}{\Sigma_{all}\sigma_{gs}}$$

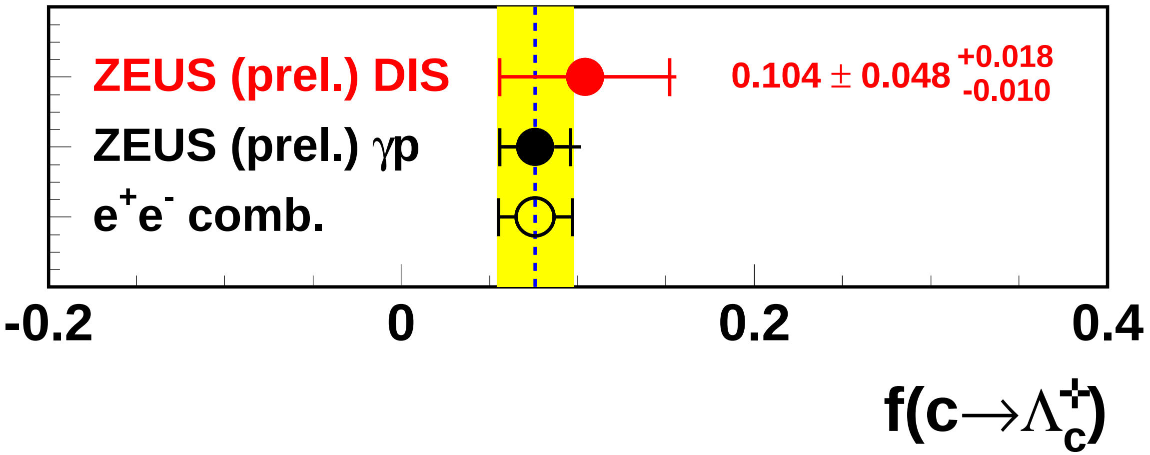
$$f(c \to D_s^{\pm}) \;=\; 0.103 \pm 0.013^{+0.012}_{-0.017} \qquad \text{(ZEUS prel.)}$$



Charm fragmentation fractions - $f(c \to \Lambda_c^{\pm})$

$$f(c \to \Lambda_c^{\pm}) = \frac{\sigma(\Lambda_c^{\pm})}{\Sigma_{all}\sigma_{gs}}$$

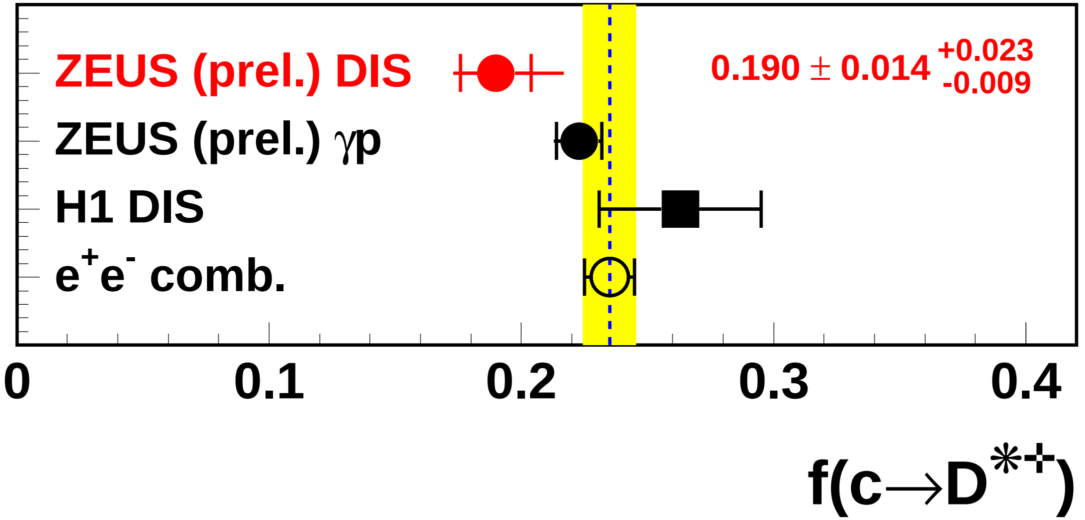
$$f(c \to \Lambda_c^{\pm}) = 0.104 \pm 0.048^{+0.018}_{-0.010} \quad \text{(ZEUS prel.)}$$



Charm fragmentation fractions - $f(c \rightarrow D^{*\pm})$

$$f(c \rightarrow D^{*\pm}) = \frac{\sigma^{tag}(D^0)/B_{D^* \rightarrow D^0 \pi} + \sigma^{add}(D^{*\pm})}{\Sigma_{all}\sigma_{gs}}$$

$$f(c \rightarrow D^{*\pm}) = 0.190 \pm 0.014^{+0.023}_{-0.009} \quad \text{(ZEUS prel.)}$$



Summary

- Charm fragmentation ratios and fractions were measured with the ZEUS detector in DIS, in the kinematic region
  - $1.5 < Q^2 < 1000$ GeV^2
  - $0.02 < y < 0.7$
  - $p_T(D, \Lambda_c) > 3$ GeV
  - $|\eta(D, \Lambda_c)| < 1.6$
- Results are in agreement with previous measurements (within errors).
- Measured ratios and fractions are consistent universality.