Charm fragmentation fractions in photoproduction

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On behalf of the **ZEUS collaboration**

Contents

- Motivation
- Signal extraction
- Fragmentation fraction determination
- Results

Motivation

Fragmentation — transition of partons to hadrons

Charm Fragmentation fraction – the probability of c-quark to hadronize into particular charm meson

Charm production

e^+e^- ep

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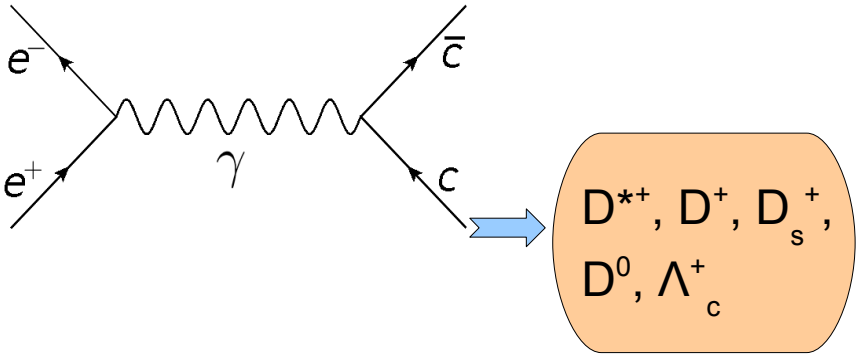

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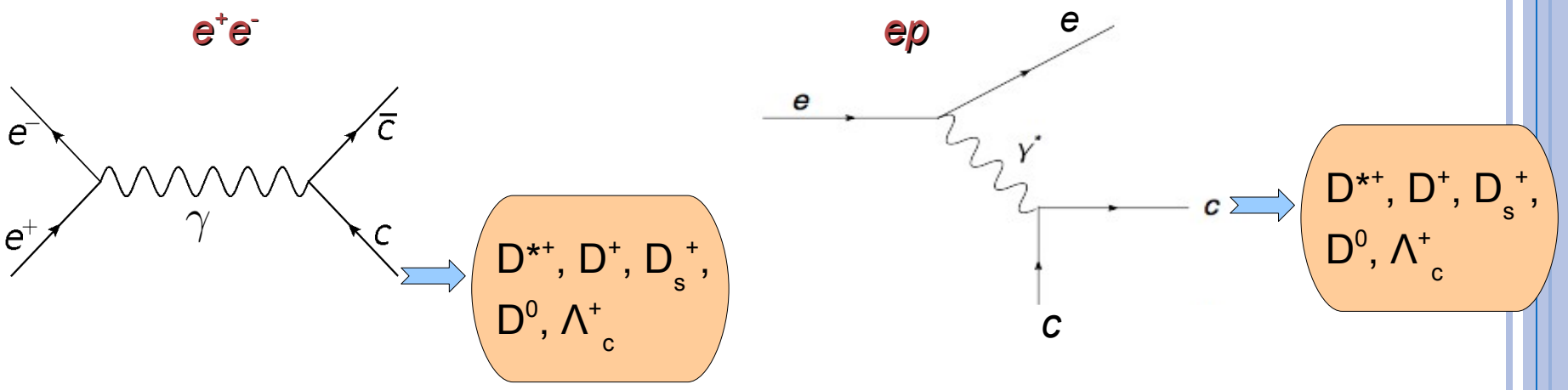
Fragmentation — transition of partons to hadrons

Charm Fragmentation fraction – the probability of c-quark to hadronize into particular charm meson

Charm production

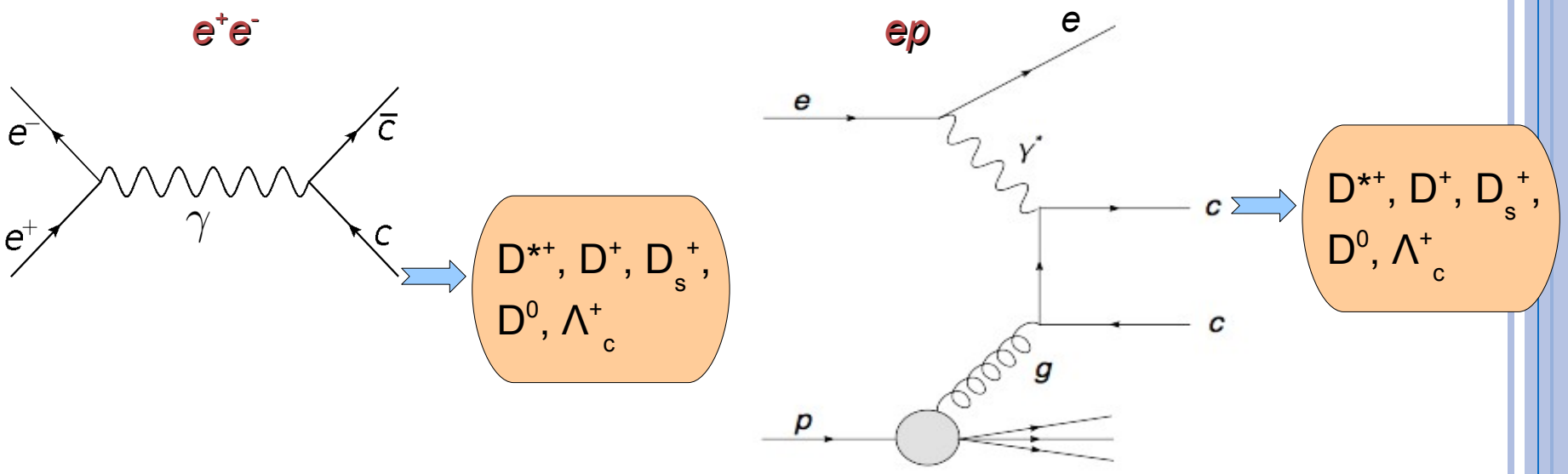


Motivation

Fragmentation — transition of partons to hadrons

Charm Fragmentation fraction – the probability of c-quark to hadronize into particular charm meson

Charm production



Is fragmentation universal?

Fragmentation fraction

Fragmentation fraction – is given by:

$$f(c \to D, \ldots, \Lambda_c) = \frac{\sigma_{D,\Lambda_c}}{\sigma_{gs}}$$

- $\sigma_{D,\Lambda}$ - production cross section for the hadron
- σ_{gs} - sum of all production σ of all charm ground states decaying weakly

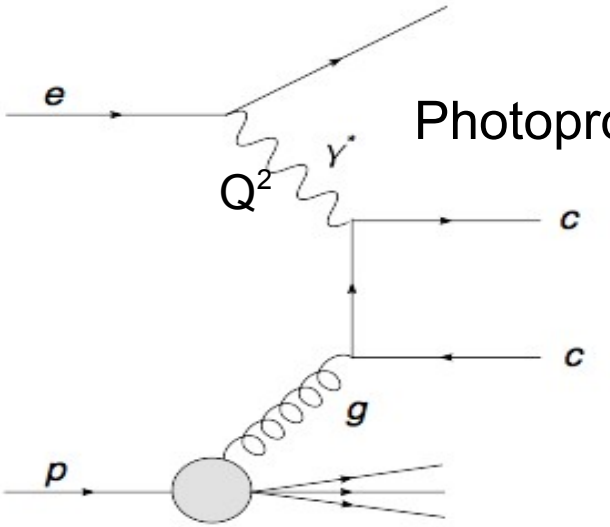
— D^+, D^0, D_s, Λ_c, Ξ_c^+, Ξ_c^0, Ω_c^0

- **Charm-strange baryons Ξ_c^+, Ξ_c^0 and Ω_c^0 ~ 14% of Λ_c**

$$\sigma_{gs} = \sigma^{eq}(D^+) + \sigma^{eq}(D^0) + \sigma(D_s^+) + \sigma(\Lambda_c^+) \cdot 1.14$$

The determination of production cross sections is needed

Measurement in Photoproduction



Photoproduction means $Q^2 \approx 0\ GeV^2$

Investigated channels

$D^+ \rightarrow K^-\pi^+\pi^+$

$D^0 \rightarrow K^-\pi^+$

$D_s^+ \rightarrow \Phi^0\pi^+ \rightarrow K^+K^-\pi^+$

$\Lambda_c^+ \rightarrow pK^-\pi^+$

$D^{*+} \rightarrow D^0\pi_s^+ \rightarrow K^-\pi^+\pi_s^+$

Previous ZEUS measurement:

- *European Physical Journal C44 (2005) 351-366*

Based on **HERA I** (79 pb^{-1})

Data samples and Monte Carlo

Measurement was performed using HERA II data sample:

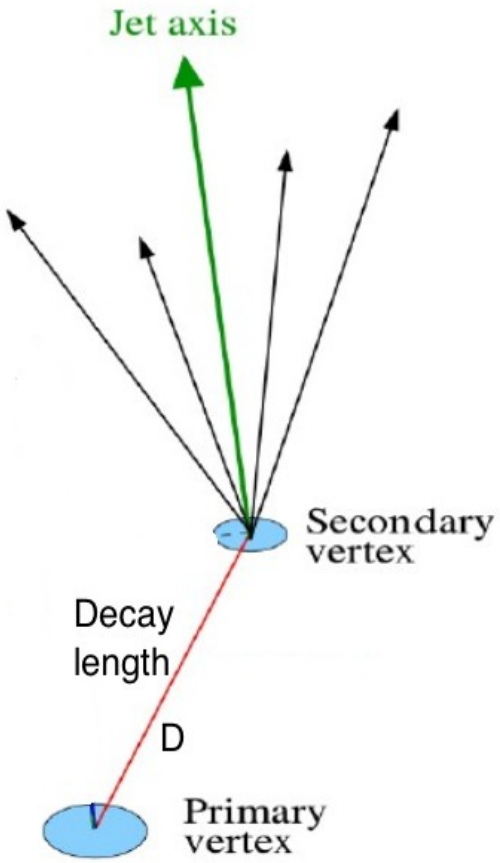
2003-2007 run period
Luminosity – 372 pb^{-1}

The MC simulation was used for acceptance calculation:

Pythia 6.2 generator
Geant 3.21 – for detector simulation

Selection criteria

- $p_t(D,\Lambda) > 3.8$ GeV
- $|\eta(D,\Lambda)| < 1.6$
- $130 < W < 300$ GeV



*For D mesons the restriction on **decay length significance** was applied*

$$S_l = \frac{l}{\sigma_l}$$

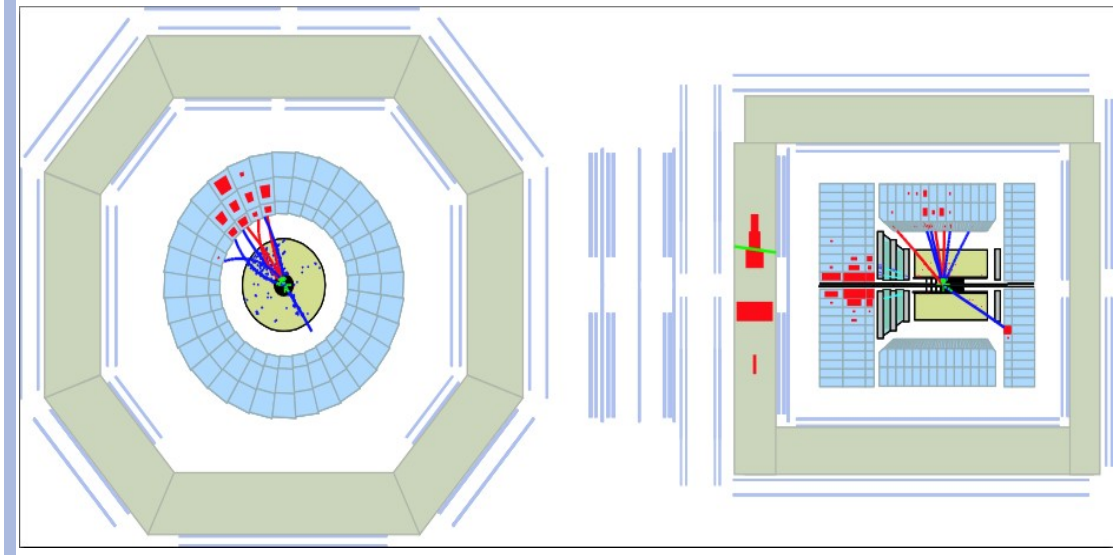
l — decay length

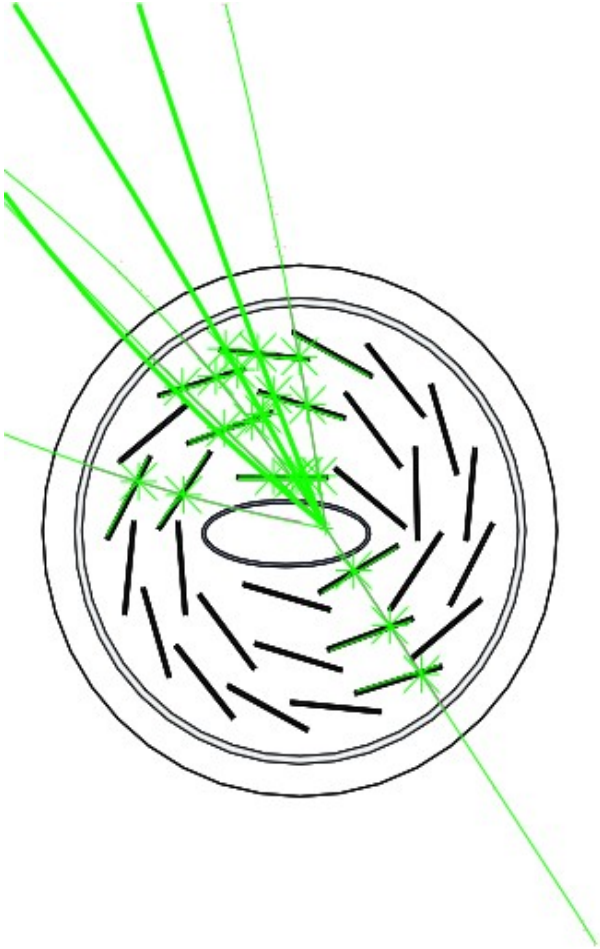
Improvement in signal-to-background ratio

Event display

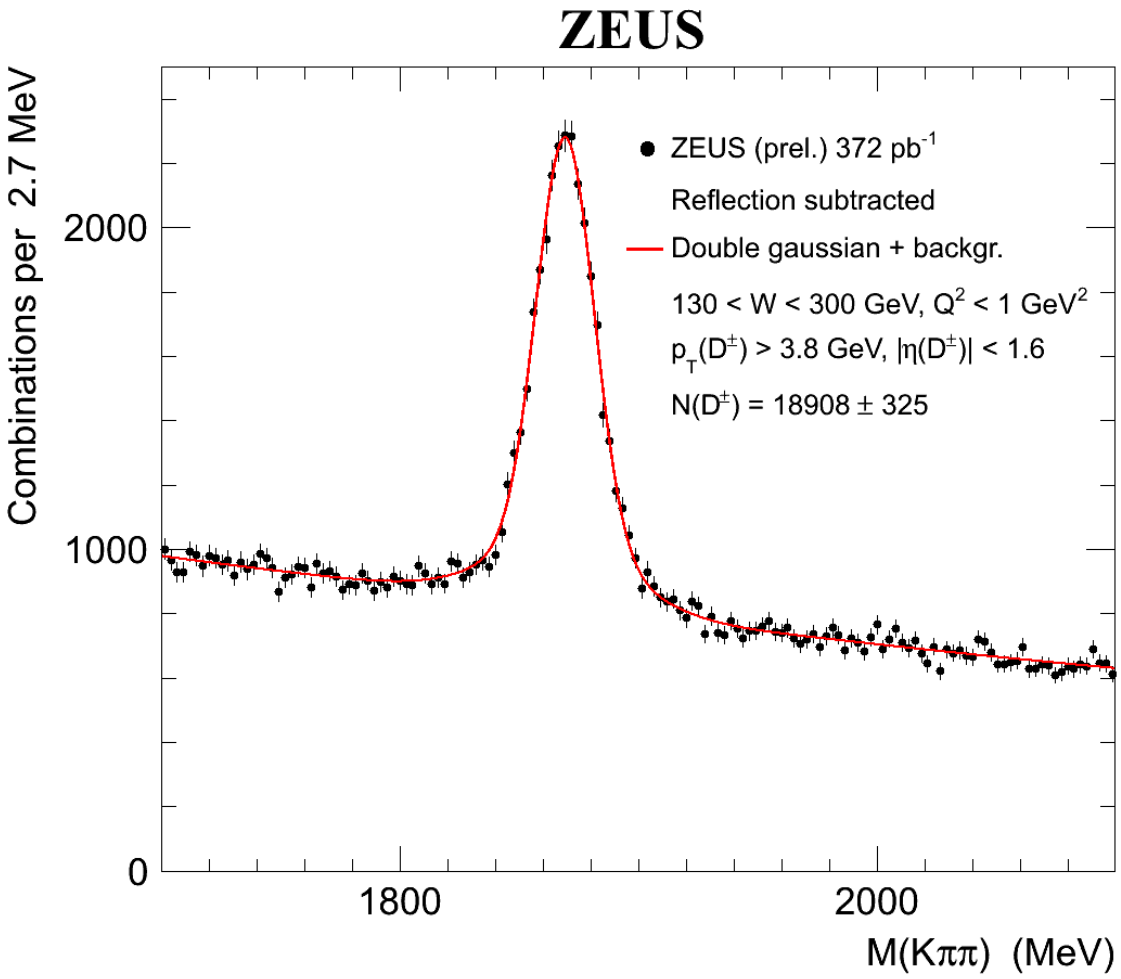
$D^+ \rightarrow K^-\pi^+\pi^+$

(red tracks)





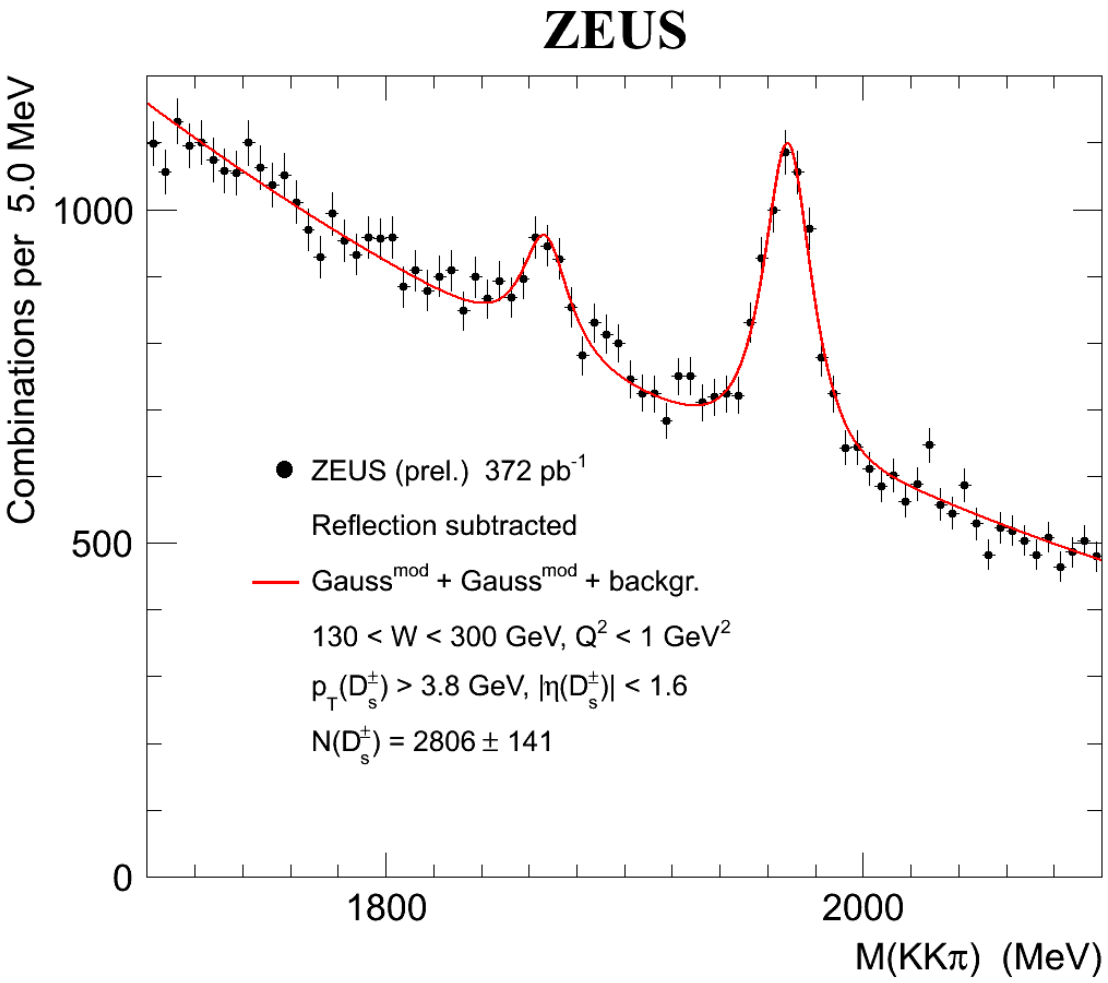
$D^{\pm}$ meson reconstruction



$D^+ \rightarrow K^-\pi^+\pi^+$

- Reflections from D^+_s and Λ^+_c to 3 charged particles subtracted
- $S_l > 3$

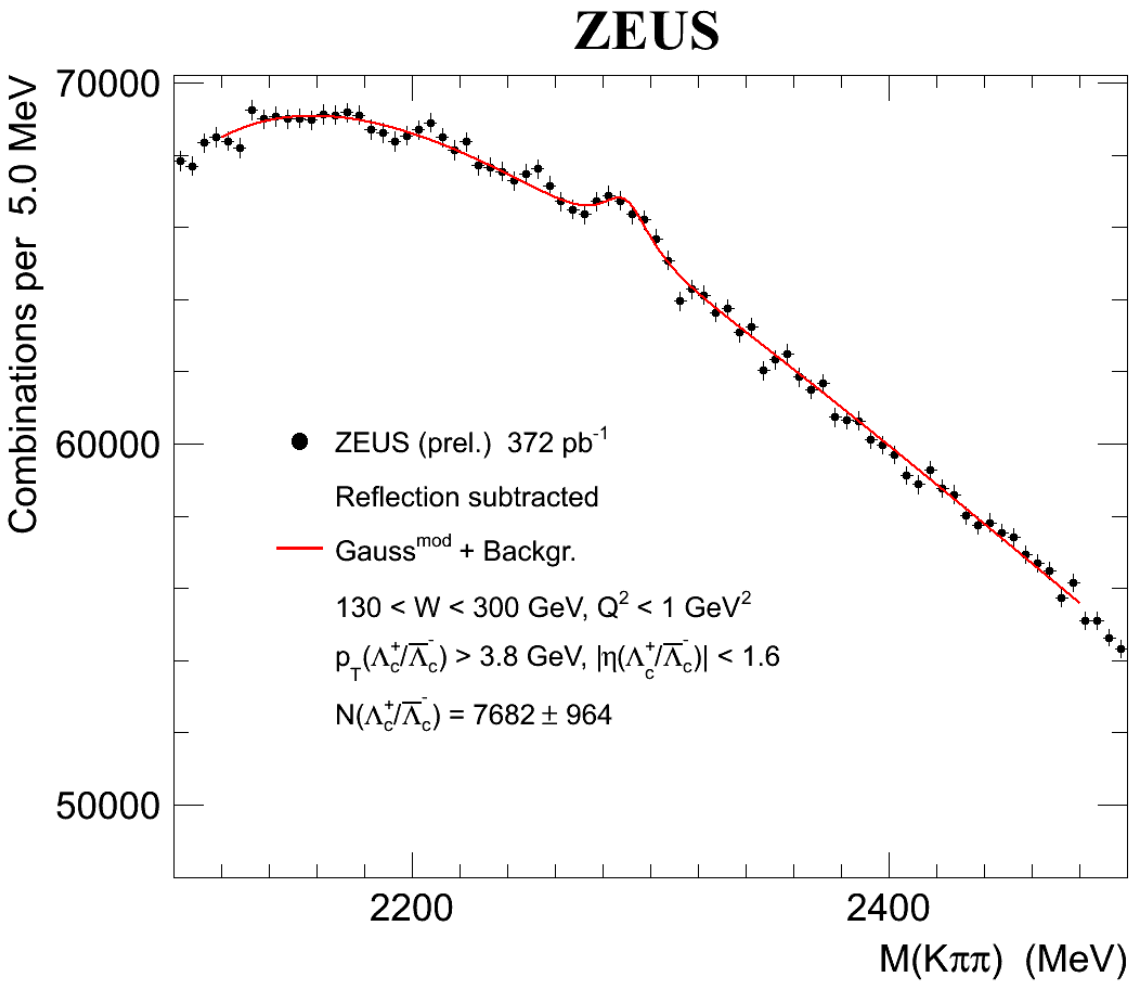
$D_s^{\pm}$ meson reconstruction



$D_s^+ \rightarrow K^+K^-\pi^+$

- Reflections from D^+ and Λ_c^+ to 3 charged particles subtracted
- Smaller signal on the left — $D^+ \rightarrow KK\pi$
- $S_l > 0$

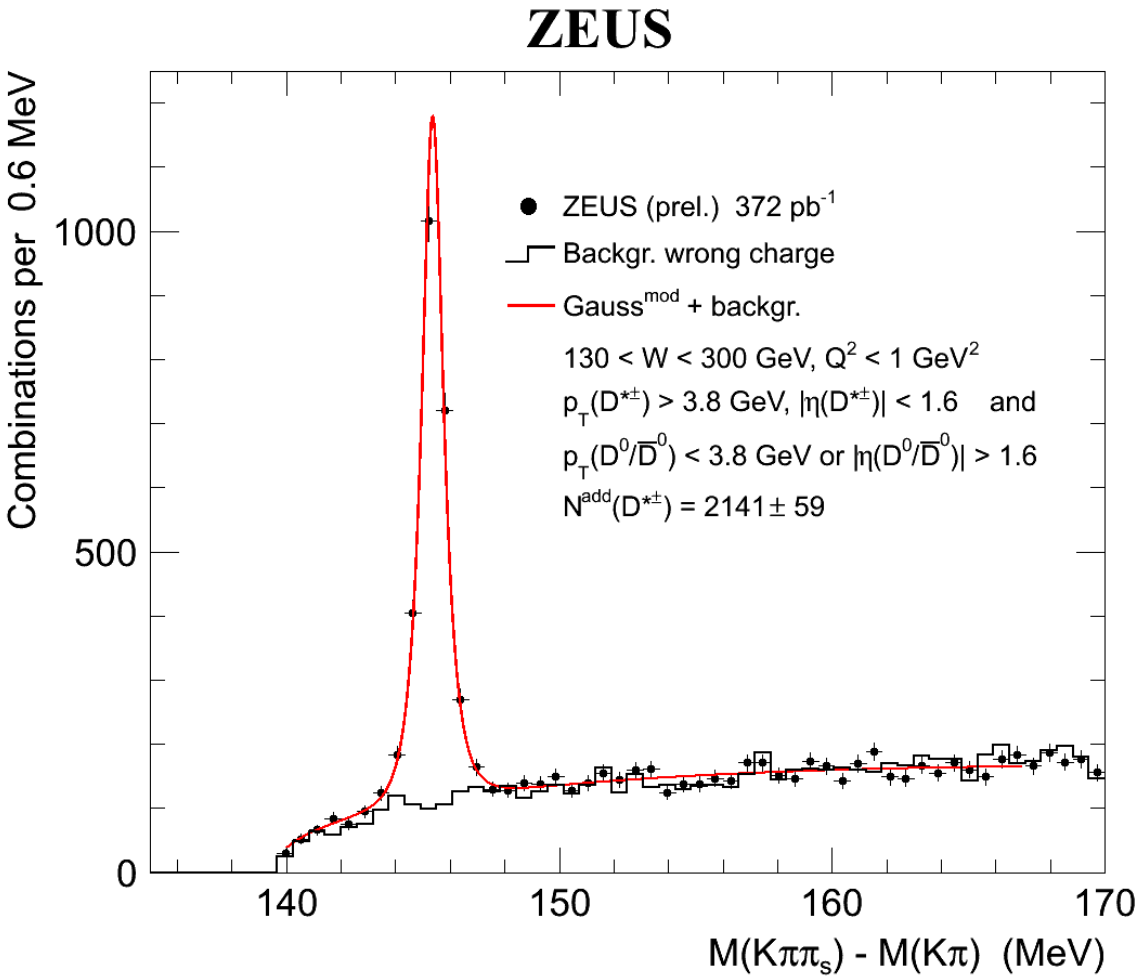
$\Lambda_c^{\pm}$ baryon reconstruction



$\Lambda_c^+ \rightarrow pK^-\pi^+$

- Reflections from D^+ and D_s^+ to 3 charged particles subtracted

$D^{*\pm}$ meson reconstruction

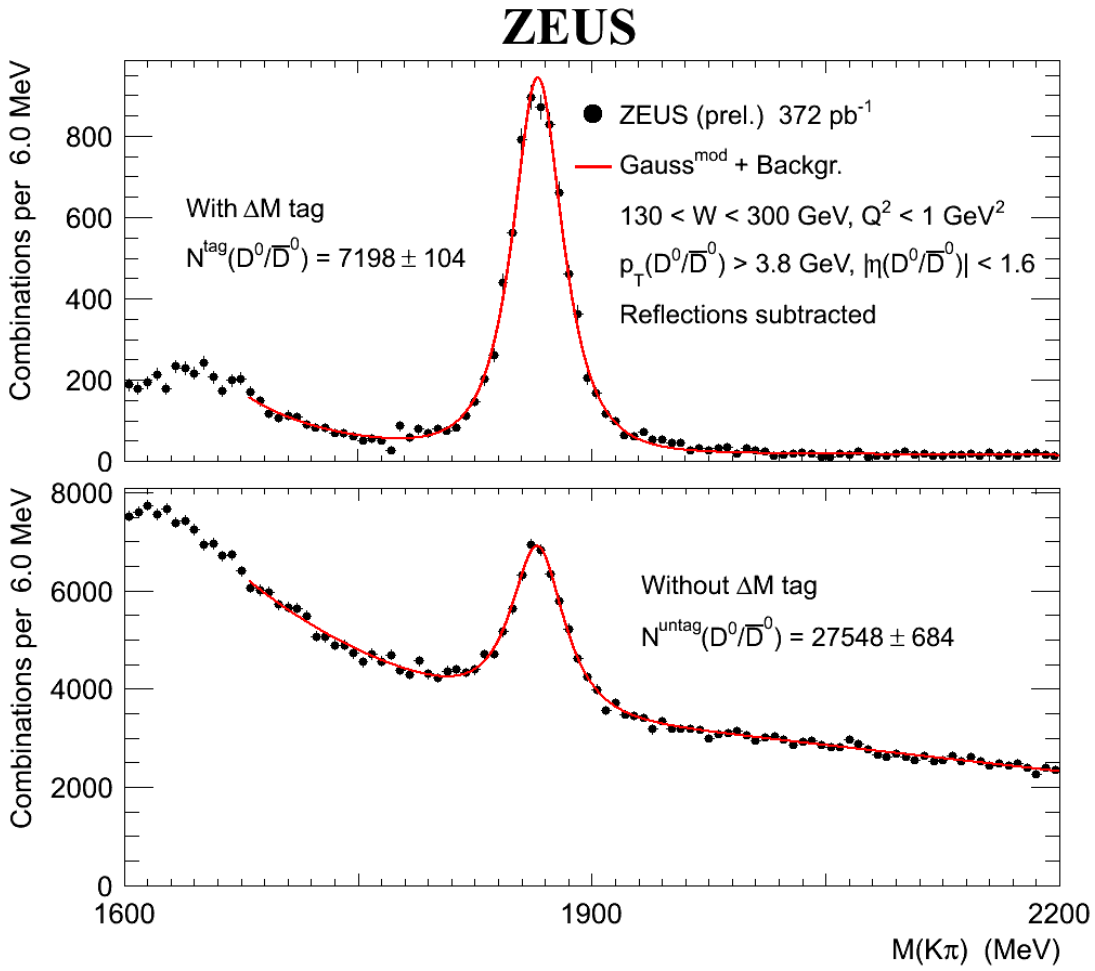


$$D^{*+} \rightarrow D^0 \pi_s^+$$

$$D^0 \rightarrow K^- \pi^+$$

- «Additional» D* sample, where D^0 has p_t<3.8 GeV or $|\eta|$>1.6
- N(D*) extracted from fit

D^0 meson reconstruction



$D^0 \rightarrow K^-\pi^+$

- D^0 is *tagged* if it originates from D* decay
  - All the rest are *untagged*
- Fitting two spectra simultaneously
- Reflections from wrong mass assignment is removed from untagged D^0`s using the tagged
- $S_l > 1$

Equivalent phase-space

For the fragmentation fractions calculation we use the formulas:

$$f(c \to D, \ldots, \Lambda_c) = \frac{\sigma_{D,\Lambda_c}}{\sigma_{gs}}$$

$$\sigma_{gs} = \sigma^{eq}(D^+) + \sigma^{eq}(D^0) + \sigma(D_s^+) + \sigma(\Lambda_c^+) \cdot 1.14$$

Here:

$$\sigma^{eq}(D^0) = \sigma^{untag}(D^0) + \sigma^{tag}(D^0) + \sigma^{add}(D^{*+}) \cdot \left(\frac{\sigma^{untag}(D^0)}{\sigma(D^+) + \sigma^{tag}(D^0)} + B_{D^{*+} \to D^0 \pi^+} \right)$$

$$\sigma^{eq}(D^+) = \sigma(D^+) + \sigma^{add}(D^{*+}) \cdot \left(1 - B_{D^{*+} \to D^0 \pi^+}\right)$$

«Equivalent phase-space treatment» for the non-strange D and D* mesons **minimises differences** between the fragmentation fractions measured in the accepted $p_t(D,\Lambda_c)$ and $\eta(D,\Lambda_c)$ kinematic region and those in the full phase space

Systematic uncertainties

- Systematics from b subtraction (variation of b-rates in MC) - δ1
- Varying the rates of charmed strange baryons - δ2
- Systematics from signal fitting - δ3 ⟶ ***Main source***
- Systematics from reweighting - δ4
- Trigger systematics - δ5
- Tracking effeciency (two-track vs three-track decay modes) - δ6
- Energy scale variation from CAL - δ8
- Significance cut variation - δ7

	total (%)	δ_1 (%)	δ_2 (%)	δ_3 (%)	δ_4 (%)	δ_5 (%)	δ_6 (%)	δ_7 (%)	δ_8 (%)
$f(c \to D^+)$	$^{+2.0}_{-2.7}$	$^{+0.7}_{-0.4}$	$^{+0.4}_{-0.4}$	$^{+1.4}_{-2.0}$	$^{+0.3}_{-0.3}$	$^{+0.6}_{-0.6}$	$+1.0$	$^{+0.2}_{-1.6}$	$^{+0.2}_{-0.1}$
$f(c \to D^0)$	$^{+1.9}_{-1.1}$	$^{+0.4}_{-0.4}$	$^{+0.4}_{-0.4}$	$^{+1.6}_{-0.6}$	$^{+0.1}_{-0.1}$	$^{+0.3}_{-0.3}$	-0.7	$+0.8$	$^{+0.2}_{-0.1}$
$f(c \to D_s^+)$	$^{+2.4}_{-8.2}$	$^{+1.2}_{-1.8}$	$^{+0.4}_{-0.3}$	$^{+1.3}_{-7.6}$	$^{+0.1}_{-0.1}$	$^{+0.8}_{-0.9}$	$+1.1$	$^{+0.3}_{-1.9}$	$^{+0.2}_{-0.1}$
$f(c \to \Lambda_c^+)$	$^{+6.6}_{-11.8}$	$^{+1.8}_{-1.6}$	$^{+0.4}_{-0.3}$	$^{+6.1}_{-11.6}$	$^{+0.2}_{-0.1}$	$^{+1.1}_{-0.4}$	$+1.0$	$^{+0.5}_{-0.9}$	-0.7
$f(c \to D^{*+})$	$^{+1.7}_{-1.7}$	$^{+0.5}_{-0.5}$	$^{+0.4}_{-0.4}$	$^{+1.5}_{-1.6}$	$^{+0.2}_{-0.1}$	$^{+0.4}_{-0.4}$	-0.4	$^{+0.3}_{-0.1}$	$+0.2$

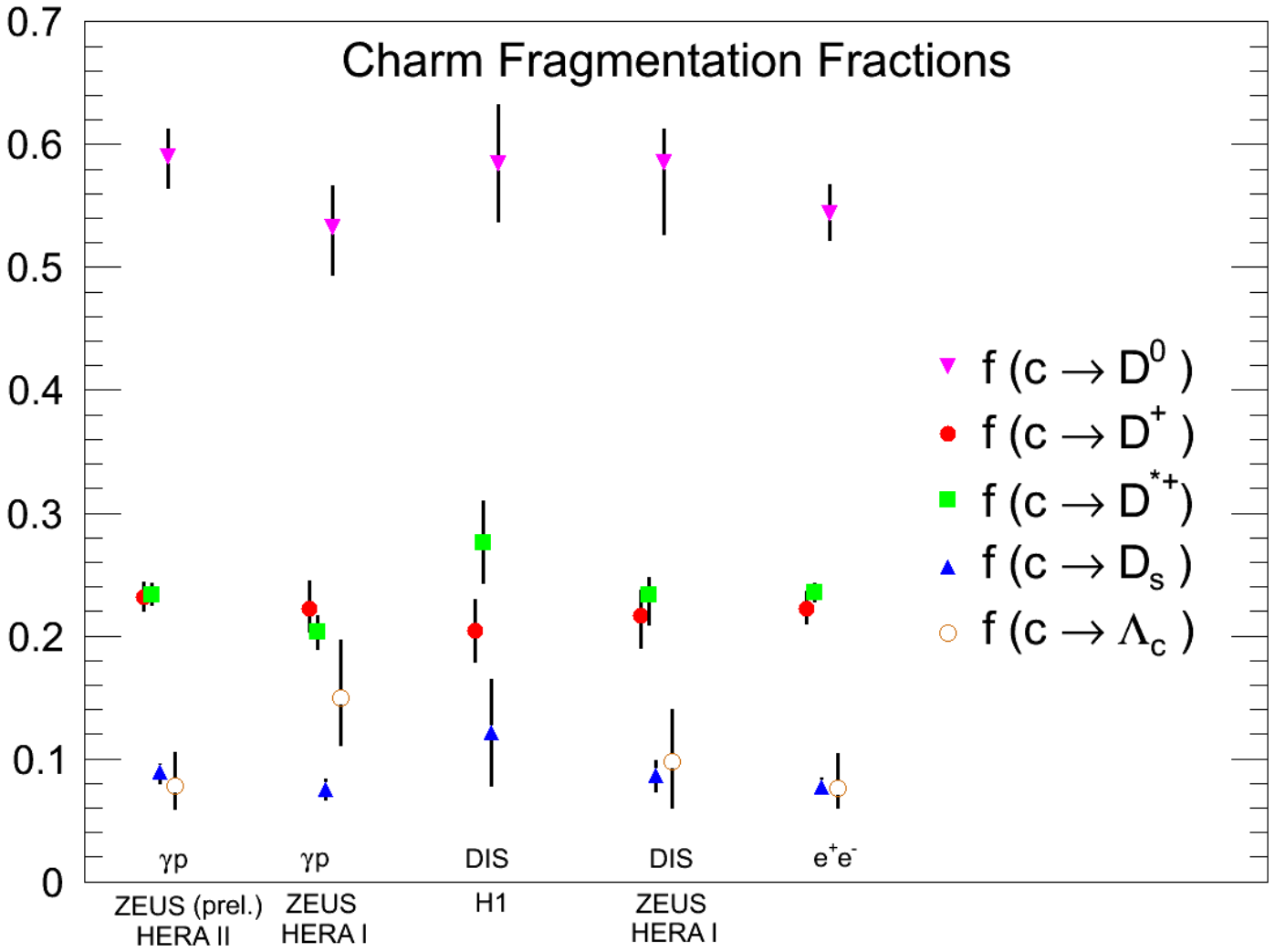
Fragmentation fractions

	ZEUS (γp) (prel.) HERA II	ZEUS (γp) HERA I	H1 (DIS)	ZEUS (DIS) HERA I	Combined e^+e^- data
	stat. syst. br.	stat. syst. br.	stat.⊕syst. br.	stat. syst. br.	stat.⊕syst. br.
$f(c \to D^+)$	$0.232 \pm 0.006\ ^{+0.005}_{-0.006}\ ^{+0.009}_{-0.010}$	$0.222 \pm 0.015\ ^{+0.014}_{-0.005}\ ^{+0.011}_{-0.013}$	$0.204 \pm 0.026\ ^{+0.009}_{-0.010}$	$0.217 \pm 0.018\ ^{+0.002}_{-0.019}\ ^{+0.009}_{-0.010}$	$0.222 \pm 0.010\ ^{+0.010}_{-0.009}$
$f(c \to D^0)$	$0.590 \pm 0.016\ ^{+0.011}_{-0.007}\ ^{+0.013}_{-0.019}$	$0.532 \pm 0.022\ ^{+0.018}_{-0.017}\ ^{+0.019}_{-0.028}$	$0.584 \pm 0.048\ ^{+0.018}_{-0.019}$	$0.585 \pm 0.019\ ^{+0.009}_{-0.052}\ ^{+0.018}_{-0.019}$	$0.544 \pm 0.022\ ^{+0.007}_{-0.007}$
$f(c \to D_s^+)$	$0.089 \pm 0.005\ ^{+0.002}_{-0.007}\ ^{+0.005}_{-0.005}$	$0.075 \pm 0.007\ ^{+0.004}_{-0.004}\ ^{+0.005}_{-0.005}$	$0.121 \pm 0.044\ ^{+0.008}_{-0.008}$	$0.086 \pm 0.010\ ^{+0.007}_{-0.008}\ ^{+0.005}_{-0.005}$	$0.077 \pm 0.006\ ^{+0.005}_{-0.004}$
$f(c \to \Lambda_c^+)$	$0.078 \pm 0.012\ ^{+0.005}_{-0.009}\ ^{+0.024}_{-0.014}$	$0.150 \pm 0.023\ ^{+0.014}_{-0.022}\ ^{+0.038}_{-0.025}$		$0.098 \pm 0.027\ ^{+0.020}_{-0.017}\ ^{+0.025}_{-0.023}$	$0.076 \pm 0.007\ ^{+0.027}_{-0.016}$
$f(c \to D^{*+})$	$0.234 \pm 0.006\ ^{+0.004}_{-0.004}\ ^{+0.005}_{-0.007}$	$0.203 \pm 0.009\ ^{+0.008}_{-0.006}\ ^{+0.007}_{-0.010}$	$0.276 \pm 0.034\ ^{+0.009}_{-0.012}$	$0.234 \pm 0.011\ ^{+0.006}_{-0.021}\ ^{+0.007}_{-0.010}$	$0.235 \pm 0.007\ ^{+0.003}_{-0.003}$

All the previous results are corrected for updated Branching Ratios

- eprint arXiv:1112.3757

Fragmentation fractions



Conclusions

- Fragmentation fractions with HERA II data on ZEUS were measured
- Fragmentation universality was confirmed