

# Charm fragmentation fractions in photoproduction

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On behalf of the **ZEUS** collaboration



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# Motivation

**Fragmentation** — transition of partons to hadrons

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

## Charm production

$e^+e^-$

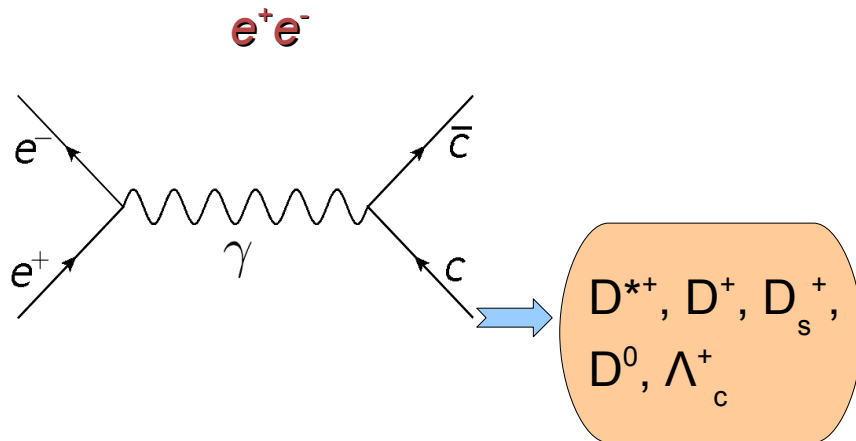
$ep$

# Motivation

**Fragmentation** — transition of partons to hadrons

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

## Charm production

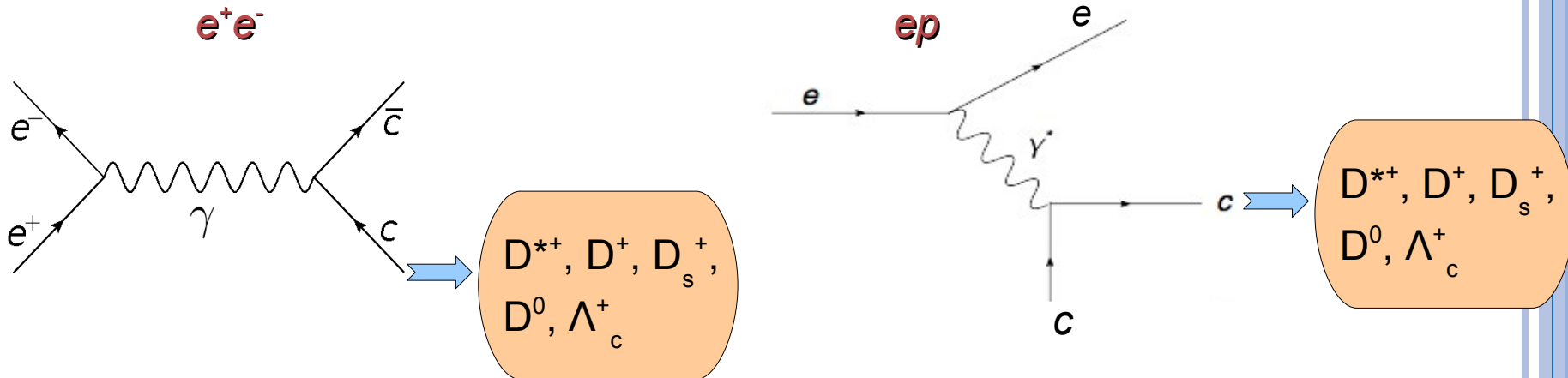


# Motivation

**Fragmentation** — transition of partons to hadrons

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

## Charm production

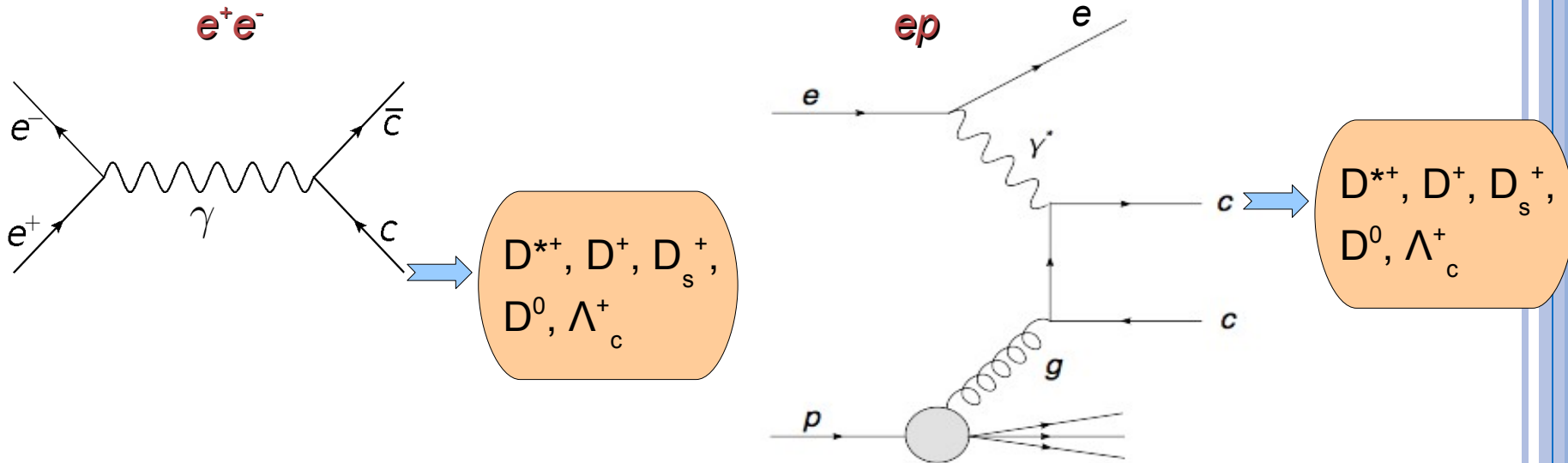


# Motivation

**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:

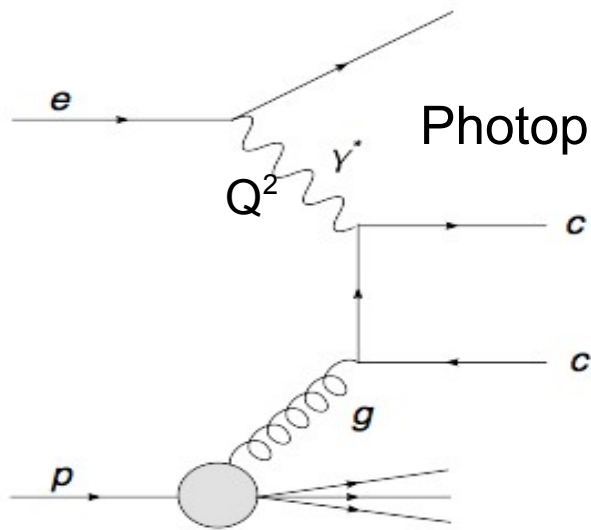
$$f(c \rightarrow D, \dots, \Lambda_c) = \frac{\sigma_{D, \Lambda_c}}{\sigma_{gs}}$$

- $\sigma_{D, \Lambda}$  - production cross section for the hadron
- $\sigma_{gs}$  - sum of all production  $\sigma$  of all charm ground states decaying weakly  
—  $D^+, D^0, D_s, \Lambda_c, \Xi_c^+, \Xi_c^0, \Omega_c^0$
- **Charm-strange baryons  $\Xi_c^+, \Xi_c^0$  and  $\Omega_c^0 \sim 14\%$  of  $\Lambda_c$**

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

The determination of production cross sections is needed

# Measurement in Photoproduction



Photoproduction means  $Q^2 \approx 0 \text{ GeV}^2$

## Investigated channels

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

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

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

$$\Lambda_c^+ \rightarrow p K^- \pi^+$$

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

### Previous ZEUS measurement:

➤ *European Physical Journal C* 44 (2005) 351-366

Based on HERA I ( $79 \text{ pb}^{-1}$ )



# Data samples and Monte Carlo

Measurement was performed using HERA II data sample:

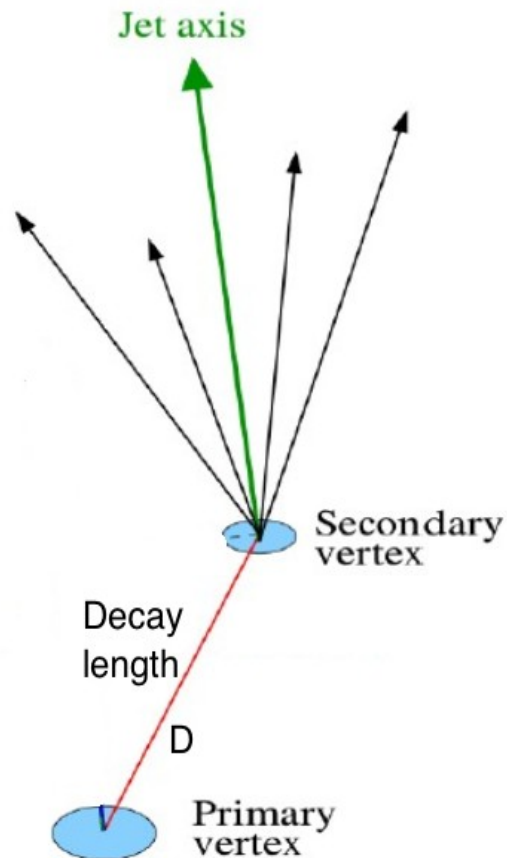
**2003-2007** run period  
Luminosity – **372 pb<sup>-1</sup>**

The MC simulation was used for acceptance calculation:

**Pythia 6.2** generator  
**Geant 3.21** – for detector simulation

# Selection criteria

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



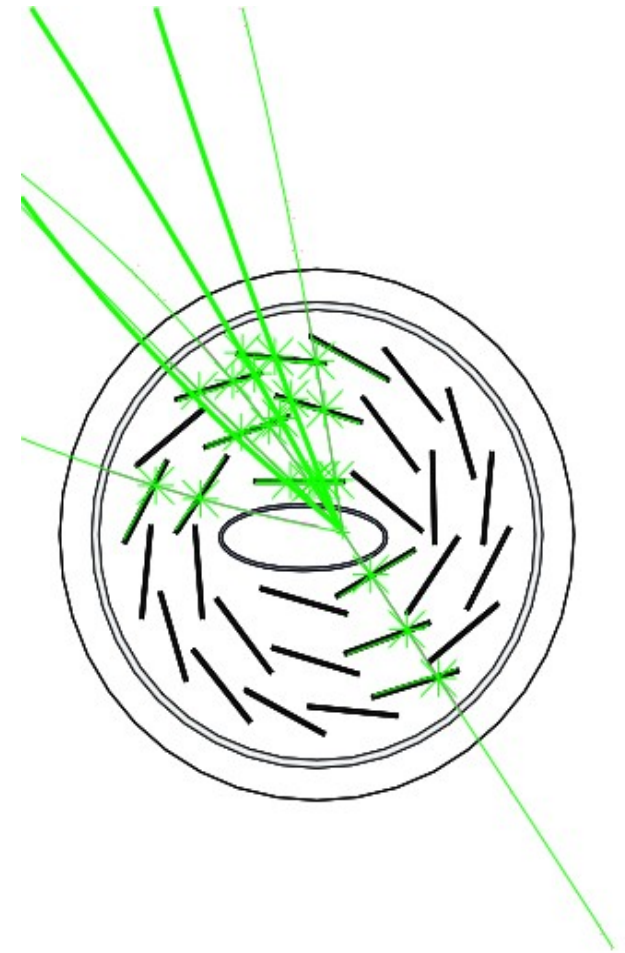
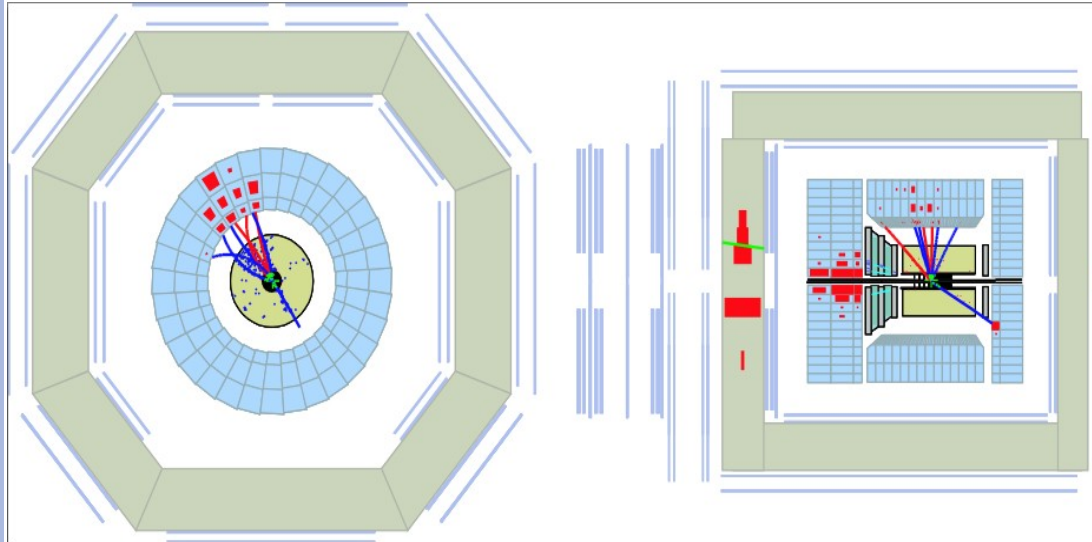
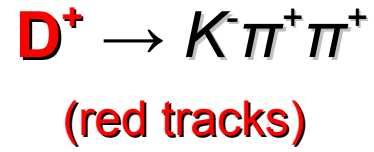
For D mesons the restriction on **decay length significance** was applied

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

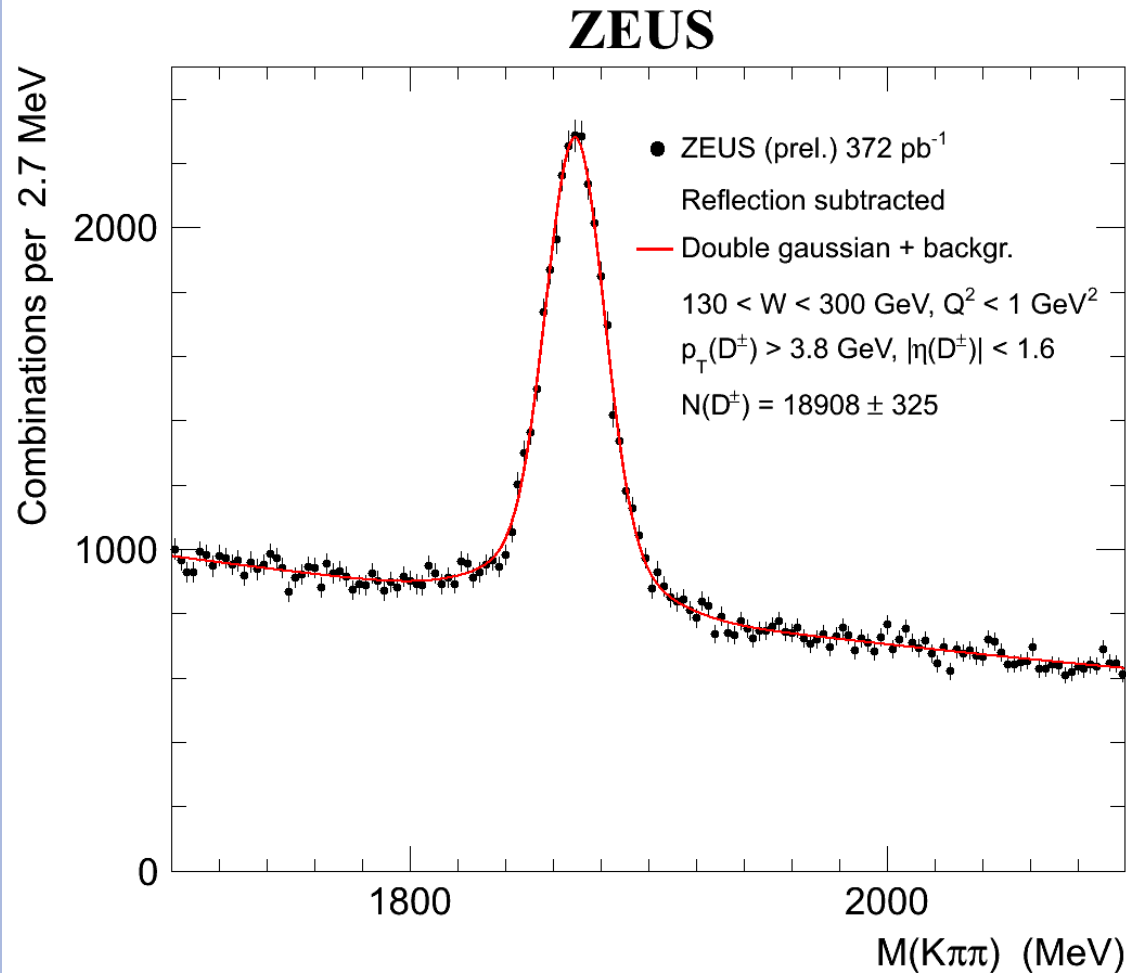
$l$  — decay length

Improvement in **signal-to-background ratio**

# Event display



# $D^\pm$ meson reconstruction

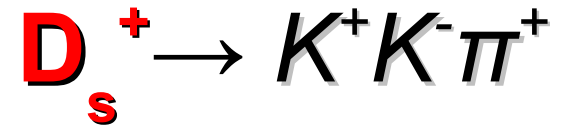
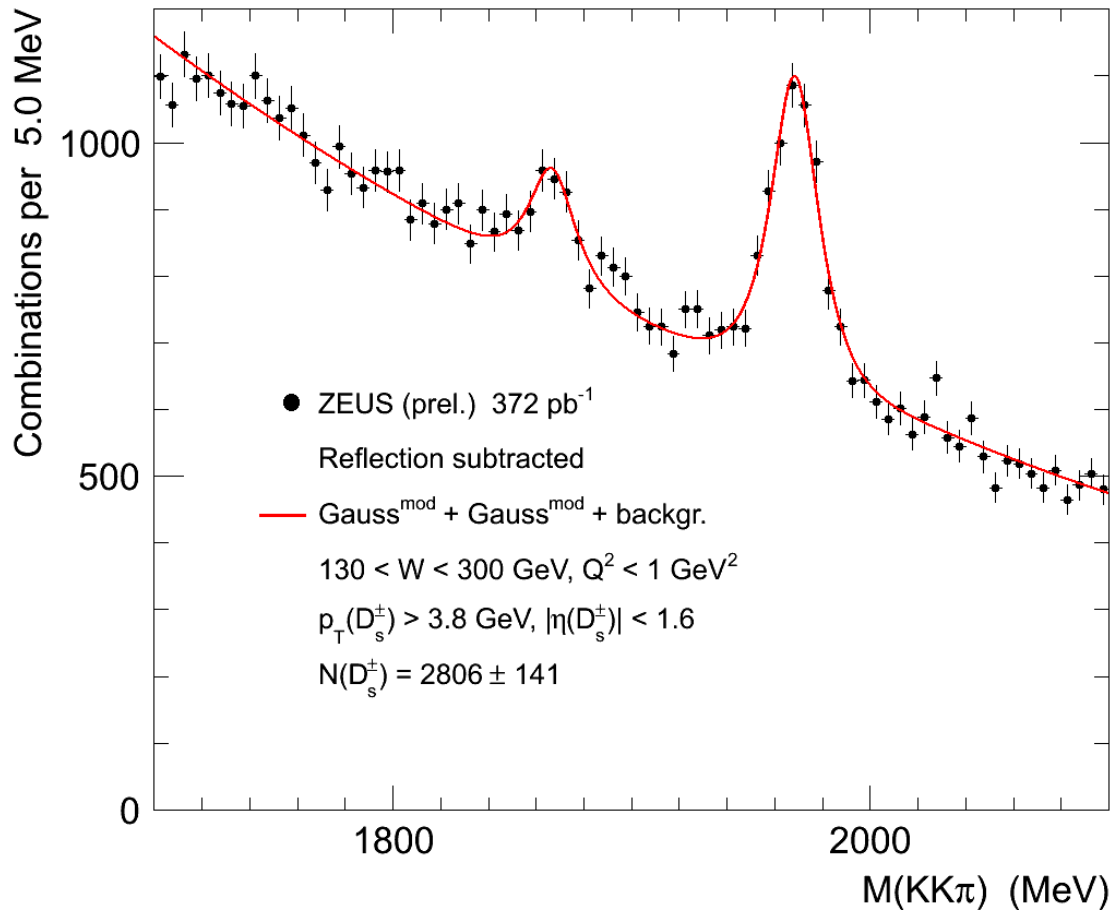


● Reflections from  $D_s^+$  and  $\Lambda_c^+$  to 3 charged particles subtracted

●  $S_l > 3$

# $D_s^\pm$ meson reconstruction

ZEUS

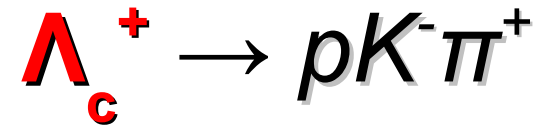
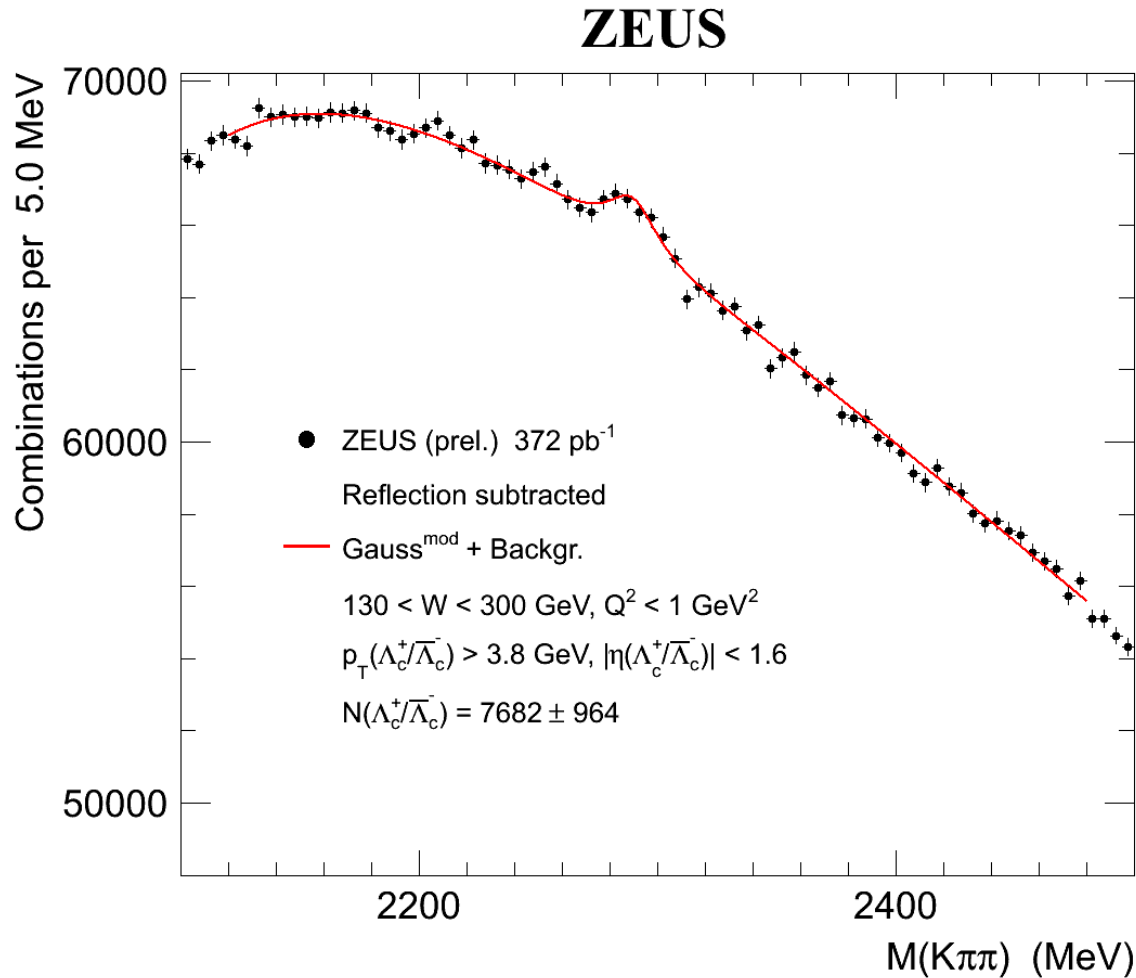


- Reflections from D<sup>+</sup> and Λ<sub>c</sub><sup>+</sup> to 3 charged particles subtracted

- Smaller signal on the left — D<sup>+</sup> → KKπ

- S<sub>l</sub> > 0

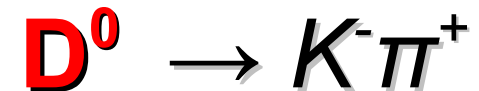
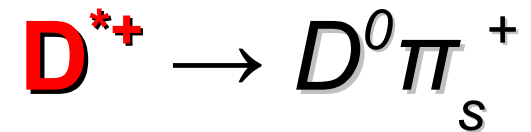
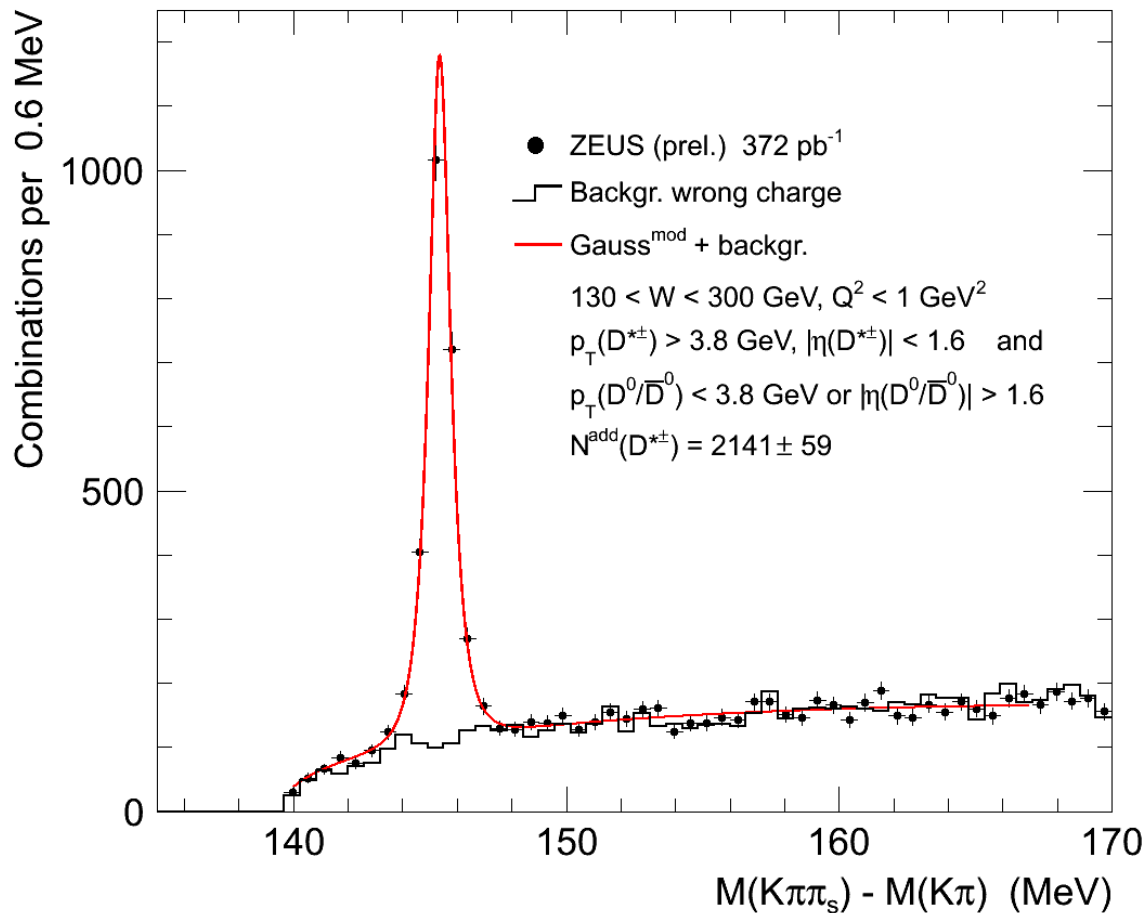
# $\Lambda_c^\pm$ baryon reconstruction



● Reflections from D<sup>+</sup> and D<sub>s</sub><sup>+</sup> to 3 charged particles subtracted

# D<sup>\*±</sup> meson reconstruction

ZEUS

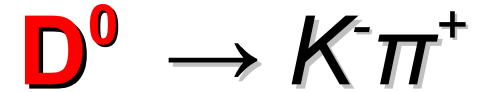
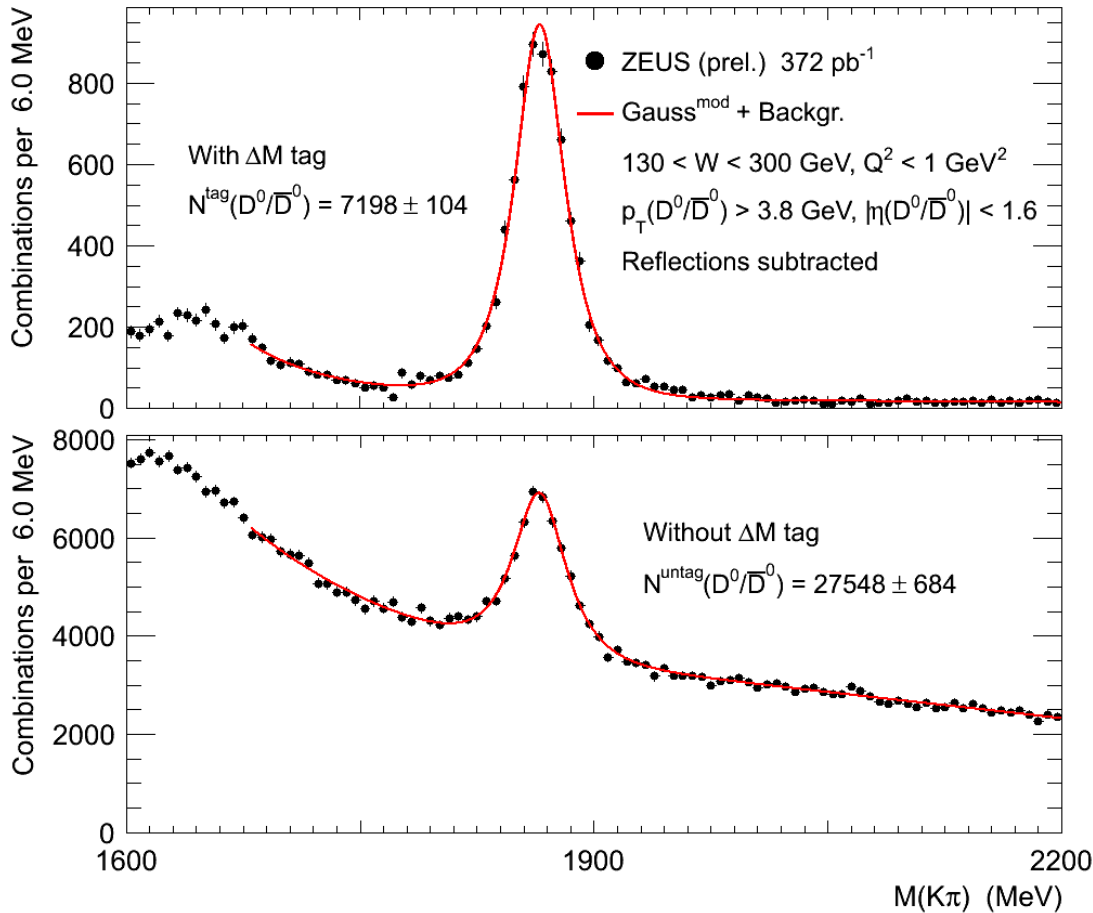


● «Additional» D\* sample, where D<sup>0</sup> has p<sub>t</sub> < 3.8 GeV or |η| > 1.6

● N(D\*) extracted from fit

# D<sup>0</sup> meson reconstruction

ZEUS



- D<sup>0</sup> 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<sup>0</sup>'s using the tagged
- $S_1 > 1$



# Equivalent phase-space

For the fragmentation fractions calculation we use the formulas:

$$f(c \rightarrow D, \dots, \Lambda_c) = \frac{\sigma_{D, \Lambda_c}}{\sigma_{\sigma c}}$$
$$\sigma_{\text{gs}} = \sigma^{\text{eq}}(D^+) + \sigma^{\text{eq}}(D^0) + \sigma(D_s^+) + \sigma(\Lambda_c^+) \cdot 1.14.$$

Here:

$$\sigma^{\text{eq}}(D^0) = \sigma^{\text{untag}}(D^0) + \sigma^{\text{tag}}(D^0) + \sigma^{\text{add}}(D^{*+}) \cdot \left( \frac{\sigma^{\text{untag}}(D^0)}{\sigma(D^+) + \sigma^{\text{tag}}(D^0)} + B_{D^{*+} \rightarrow D^0 \pi^+} \right)$$
$$\sigma^{\text{eq}}(D^+) = \sigma(D^+) + \sigma^{\text{add}}(D^{*+}) \cdot (1 - B_{D^{*+} \rightarrow D^0 \pi^+})$$

«**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) -  $\delta_1$
- Varying the rates of charmed strange baryons -  $\delta_2$
- Systematics from signal fitting -  $\delta_3$  —————► **Main source**
- Systematics from reweighting -  $\delta_4$
- Trigger systematics -  $\delta_5$
- Tracking efficiency (two-track vs three-track decay modes) -  $\delta_6$
- Energy scale variation from CAL -  $\delta_8$
- Significance cut variation -  $\delta_7$

	total	$\delta_1$	$\delta_2$	$\delta_3$	$\delta_4$	$\delta_5$	$\delta_6$	$\delta_7$	$\delta_8$
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
$f(c \rightarrow D^+)$	+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
$f(c \rightarrow D^0)$	+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
$f(c \rightarrow D_s^+)$	+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
$f(c \rightarrow \Lambda_c^+)$	+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
$f(c \rightarrow D^{*+})$	+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

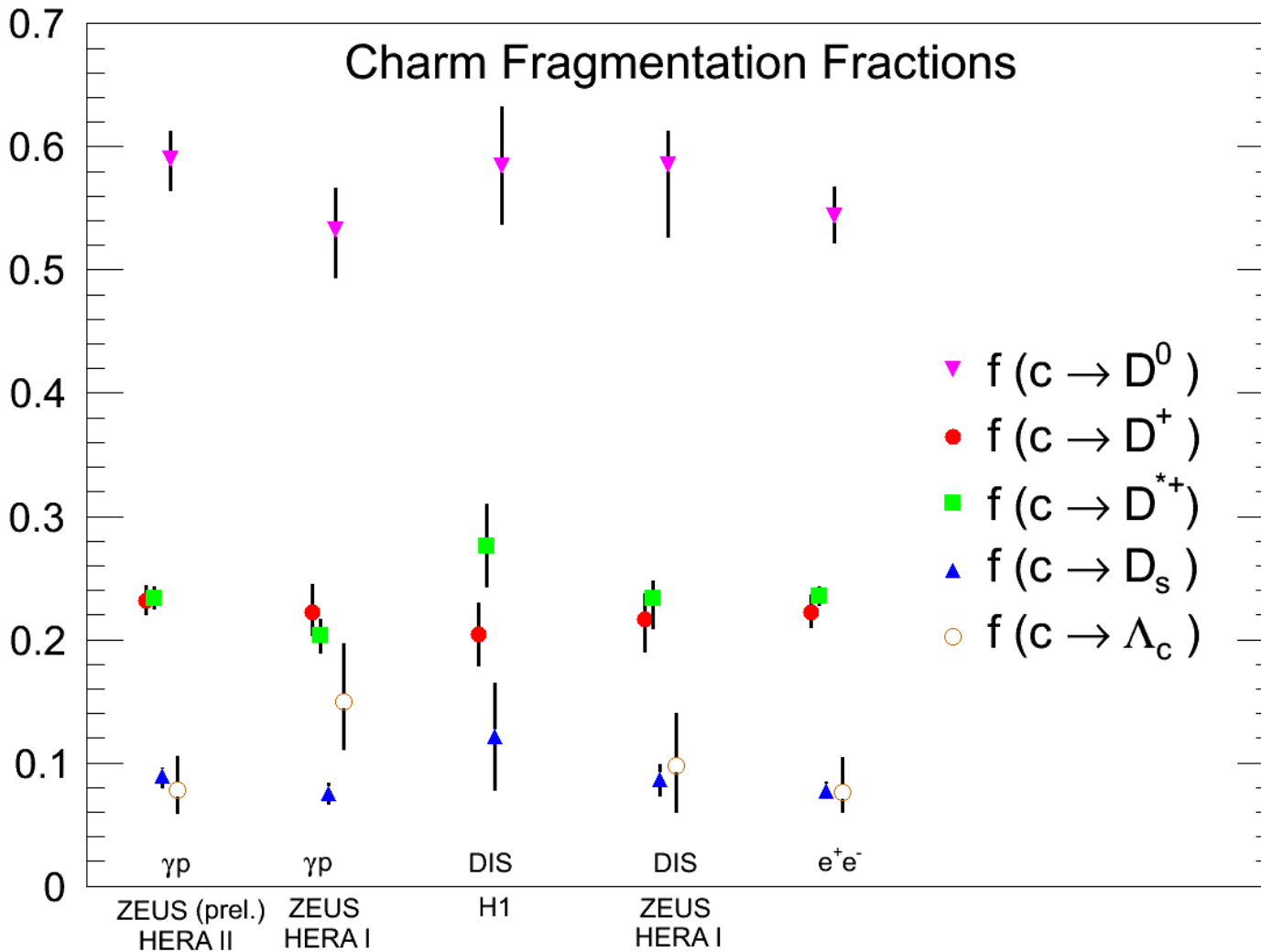
# Fragmentation fractions

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

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