Measurement of charm fragmentation fractions in photoproduction at HERA

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Overview

Agenda

- Why charm fragmentation fractions?
- ZEUS experiment
- Data selection
- To obtain invariant mass distributions
- Measured signals:
  D^0, D^{*+}, D^+, D_s^+, Λ_c^+ and their antiparticles
- Systematic uncertainties
- Calculation of cross section ratios
- Fragmention fractions
- Summary and conclusions

Why charm fragmentation fractions?

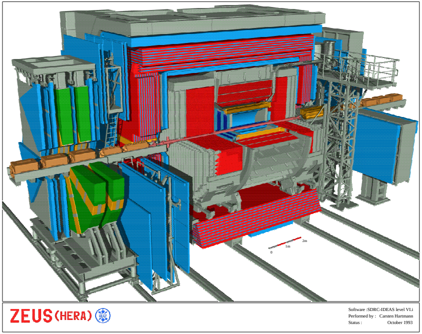
Definition

- Charm fragmentation fraction:
  f(c $\rightarrow$ charm particle)
  $= \sigma$(charm particle)/σ(total charm production)

Physics issues

- Test of fragmentation fraction universality
  with charm particle production
- Fragmentation fractions are parameters for MC simulations of pQCD predictions

ZEUS experiment



HERA

- *ep* collider at DESY
- colliding beams:
  920 GeV p
  and 27.5 GeV $e^{\pm}$
- $\sqrt{s} = 318$ GeV
- data from data taking:
  2004 - 2007
- integrated luminosity:
  372 pb^{-1}

ZEUS

- MVD and CTD $\rightarrow$ reconstruction of charged particle tracks
- MVD $\rightarrow$ reconstruction of decay vertices of charm particles

Event selection

Selection of photoproduction events

- No scattered electron with energy above 5 GeV in the calorimeter

Range of γp cms energy

- $130 < W_{\gamma p} < 300$ GeV

Cuts to ensure good acceptance of charm particles and low background

- $p_T > 3.8$ GeV and $\eta < 1.6$ for all charm hadron candidates
- $p_T / E_T^{\theta > 10^o} > 0.2(0.25)$ for D, D^* (Λ_c^+) candidates

To obtain invariant mass distributions

Decay mode of D^0

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

requirement for D^0 candidates

- Reconstructed decay vertex
- Decay length significance $S_l = l/\sigma_l > 1$

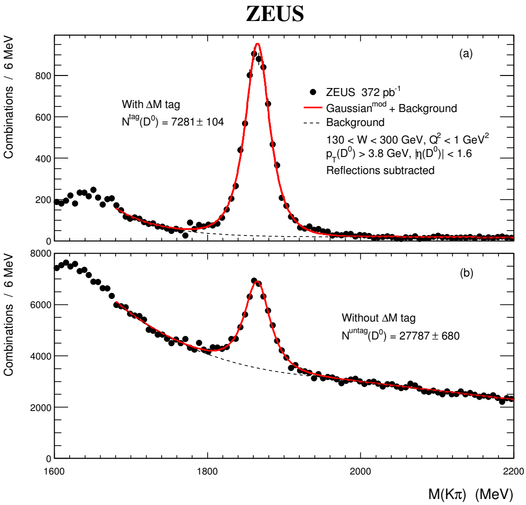
For each $K\pi$ pair two entries into mass spectrum

- Kaon and pion masses were assumed in turn for each track

Other charm particles

- Similar criteria to obtain the other mass distributions

$\gamma p \to D^0(\bar{D}^0) + hadrons$



D^0 signal

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

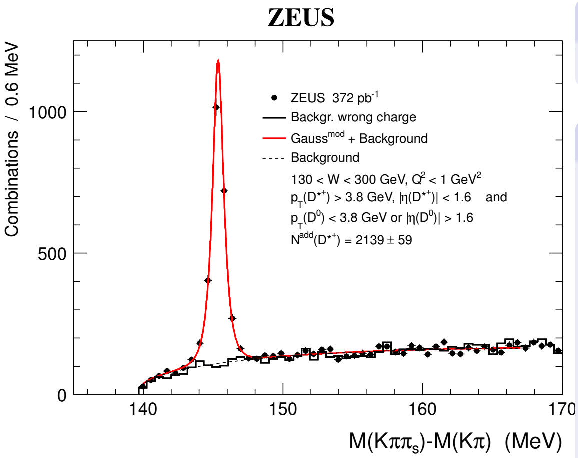
ΔM tag

- $M(K\pi\pi) - M(K\pi)$: $0.143 - 0.148\,\text{GeV}$

Subtracted signals

- $D^0 \to K^+K^-$, $D^0 \to \pi^+\pi^-$

$\gamma p \to D^{*\pm} + hadrons$



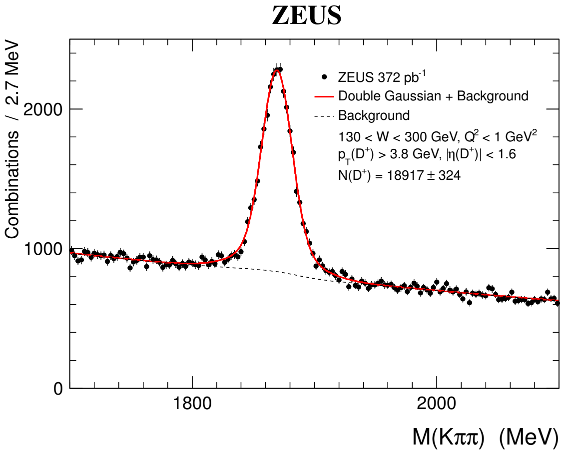
D^{*+} signal

- $D^{*+} \to D^0 \pi^+$

Sum of two peak signals

- $M(K\pi)$
  for ΔM tag sample
  $\rightarrow$previous figure
- $M(K\pi\pi) - M(K\pi)$
  additional D^{*+}
  from D^0 outside
  kinematic range
  $\rightarrow$ this figure

$\gamma p \rightarrow D^{\pm} + hadrons$



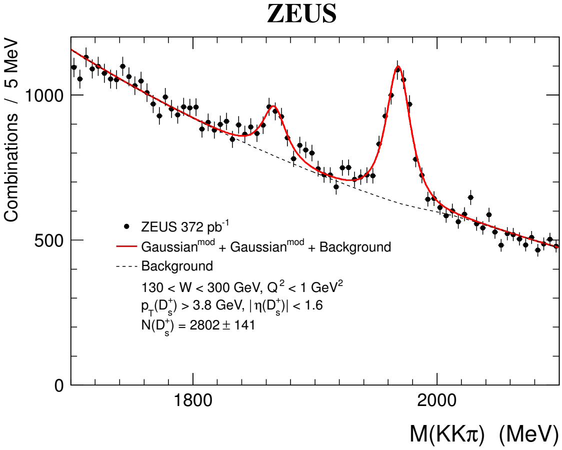
D^+ signal

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

background suppression

- mass cuts to remove D^{*+}, D_s^+ signals
- $S_l > 3$

$\gamma p \to D_s^\pm + hadrons$



D_s^+ signal

- $D_s^+ \to \phi\pi^+$, $\phi \to K^+K^-$

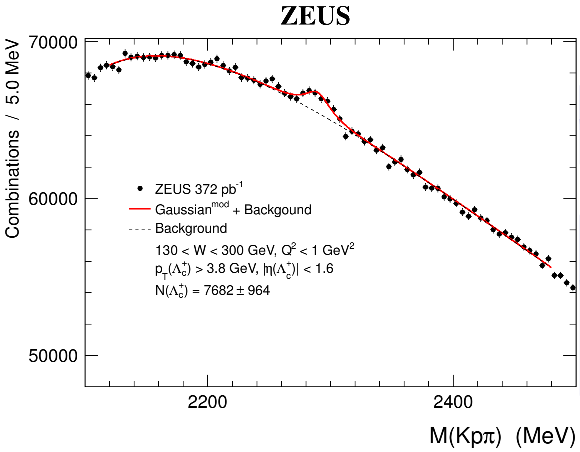
Background suppression

- $S_l > 0$

Two mass peaks

- D_s^+ at 1968 MeV
- $D^+ \to K^+K^-\pi^+$ at 1860 MeV

$\gamma p \to \Lambda_c^+/\bar{\Lambda}_c^- + hadrons$



Λ_c^+ signal

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

Subtraction of reflections

- $D^+, D_s^+ \to$ three charged particles

Systematic uncertainties

Main systematic uncertainties from signal extraction

- choice of alternative background parametrisations
- variation of fit range
- etc.

Total systematic uncertainties

- from below 2 % for D^0
  up to 12 % for Λ_c^+

Calculation of cross section ratios

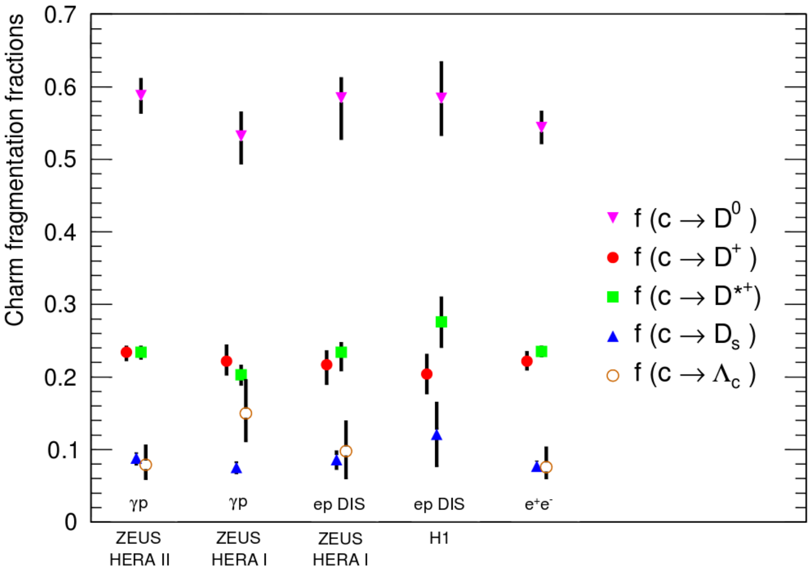
Correction factors applied to cross sections

- Subtraction of contributions from beauty-hadron decays using predictions from PYTHIA MC
- corrections to achieve equivalent phase space treatment: taking into account that only a fraction of the D^{*+} momentum is transferred to the daughters D^0 and D^+
- correction factor for not observed states: Ξ_c^+, Ξ_c^0, Ω_c^0 and their antiparticles: 1.14
- $\sigma_{tot} = \sigma^{eq}(D^0(\bar{D}^0)) + \sigma^{eq}(D^{\pm}) + \sigma(D_s^{\pm}) + \sigma(\Lambda_c^+(\bar{\Lambda}_c^-)) \cdot 1.14$

Total uncertainties

- Statistical, systematic and branching ratio uncertainties were added in quadrature

Fragmentation fractions I



Fragmentation fractions II

Fraction of charged D produced in a vector state

- $P_v^d = \sigma(D^{*+})/[\sigma(D^{*+}) + \sigma^{dir}(D^+)]$
- Result:$P_v^d = 0.595 \pm 0.020(stat.) \pm 0.015(syst.) \pm 0.011(br.)$
  consistent with previous ZEUS pub. and e^+e^-
- Comparison to predictions:
  naive spin counting: 0.75
  string fragmentation (Lund): 0.66

Strangeness suppression factor

- $\gamma_s = 2\sigma(D_s^+)/[\sigma^{eq}(D^+) + \sigma^{eq}(D^0)]$
- Result $\gamma_s = 0.214 \pm 0.013(stat.)\,^{+0.006}_{-0.017}(syst.) \pm 0.012(br.)$
- Comparison to non-charm strange particle production: 0.22 - 0.30

Summary an conclusions

Measurement

- The photoproduction of the charmed hadrons $D^0, D^{*+}, D^+, D_s^+, \Lambda_c^+$ and their antiparticles
  has been measured with the ZEUS detector
- Charm fragmentation fractions have been determined

Comparison to other data

- Charm fragmentation fractions were found to be consistent with those obtained from e^+e^- and charm production in DIS at HERA
- This supports the hypothesis that heavy-quark fragmentation is universal