D^+, D^0 and Λ_c^+ production in deep inelastic scattering at HERA

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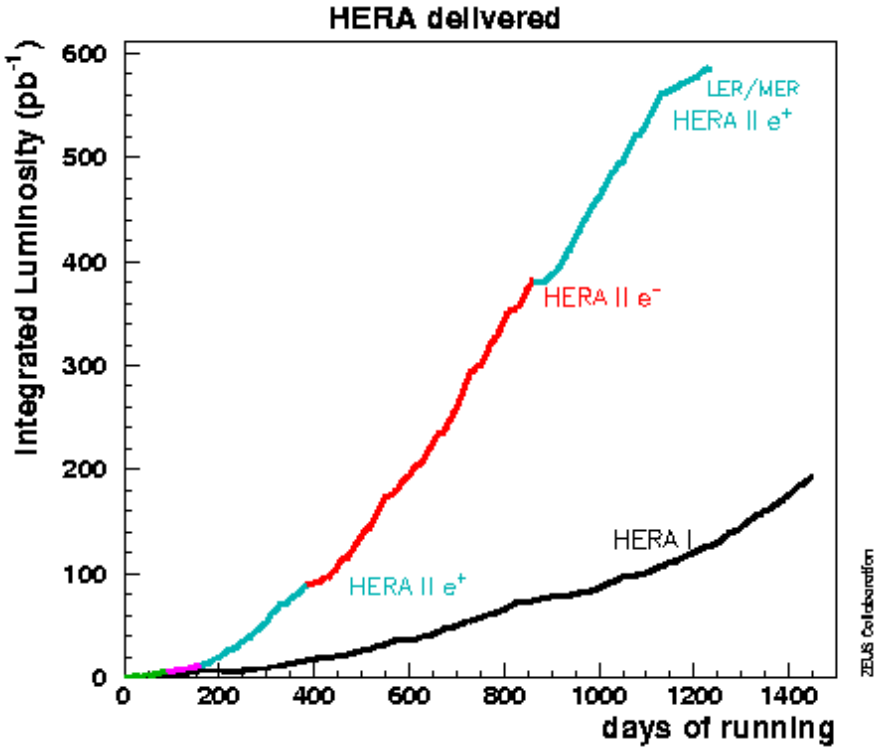
35th International Conference on High Energy Physics
ICHEP 2010, 22-28 July 2010, Paris

Outline

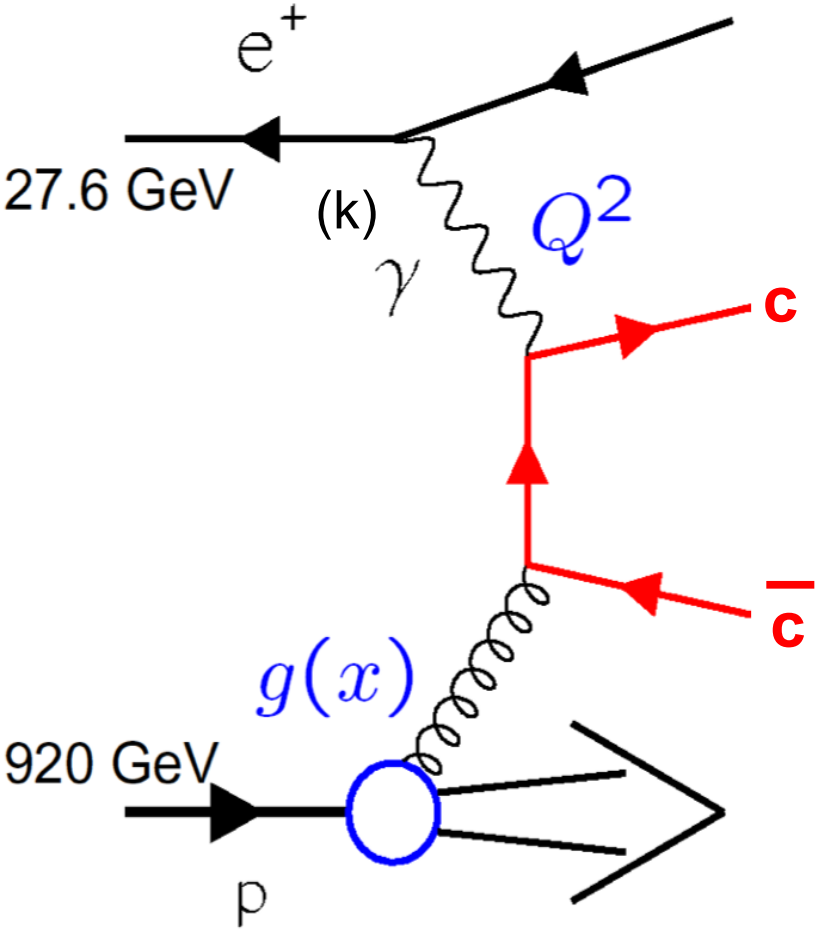
This talk:
Measurements of charm production in DIS at HERA:

- **HERA I data:**
D^+ at threshold and
Λ_c^+ production (DESY-10-064)

- **HERA II data:**
D^+ and D^0 cross sections with high precision, extraction of F_2^c
(ZEUS-prel-10-005,
Eur. Phys. J. C 63: 171)



Charm production in DIS at HERA



- Dominant process for charm production in DIS (Q^2 > a few GeV^2): Boson-Gluon-Fusion (BGF)
- Multiple hard scales: $\mu^2 = m_c^2, p_T^2, Q^2$
- The charm contribution to the inclusive DIS cross section is up to 30%
- The double differential cross section for the production of open charm can be written as:

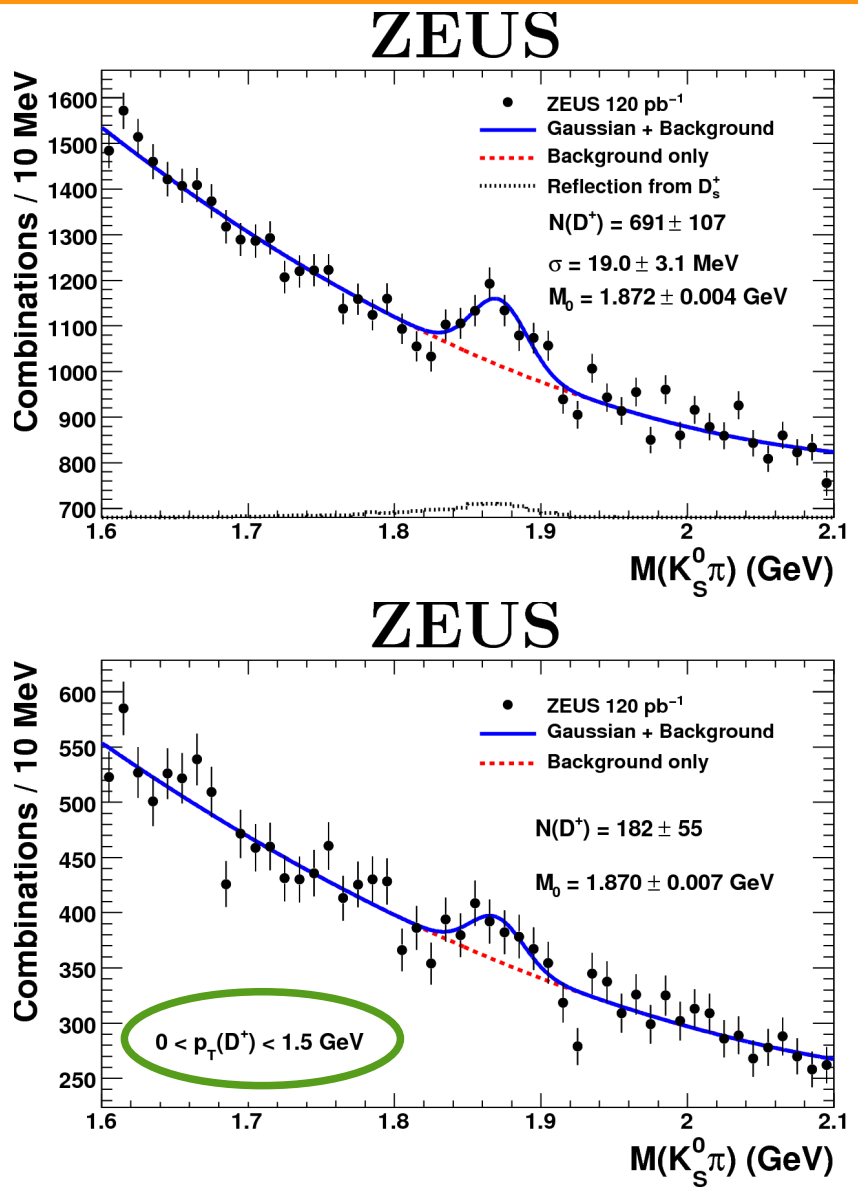
$$\frac{d^2\sigma^{c\bar{c}}(x,Q^2)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\{[1+(1-y)^2]F_2^{c\bar{c}}(x,Q^2) - y^2 F_L^{c\bar{c}}(x,Q^2)\}$$

Newly analysed decay channel: $D^+ \to K^0_S \pi^+$

New decay channel:
K^0_S in the final state
→ Reduction of background
→ Access to the low transverse momentum region

Kinematic region:
$0 < p_T(D^+) < 10$ GeV
$|\eta(D^+)| < 1.6$
$1.5 < Q^2 < 1000$ GeV^2
$0.02 < y < 0.7$

Data sample:
120 pb^{-1} (1996-2000),
only 17 pb^{-1} for $Q^2 < 20$ GeV^2

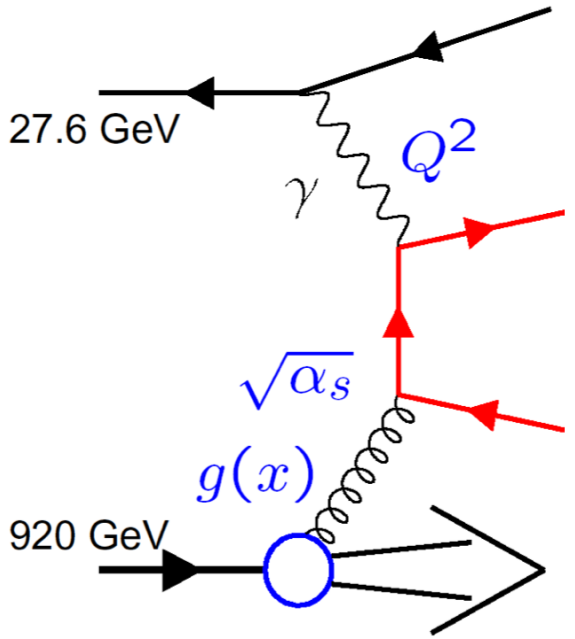


NLO QCD predictions from HVQDIS

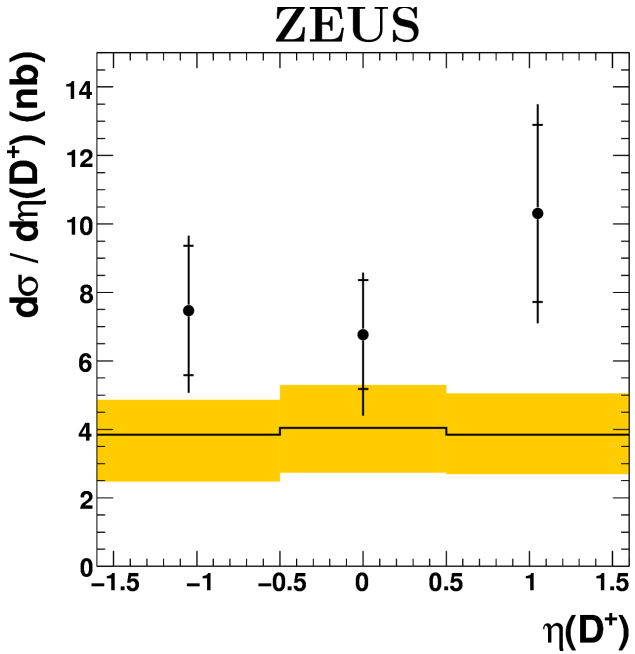
Visible cross sections are compared to predictions obtained using the HVQDIS program (Harris & Smith)

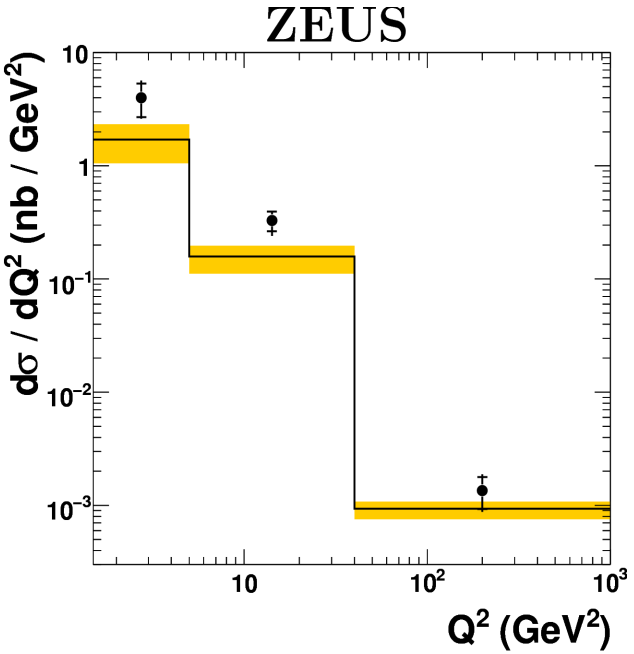
→ Fully differential NLO QCD prediction
in the **Fixed Flavour number scheme** (FFNS):

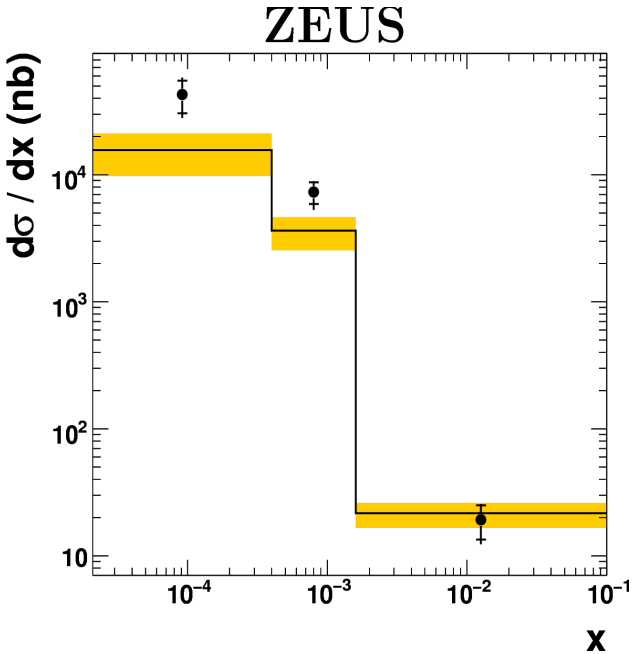
- Charm (and beauty) are produced dynamically
(not part of proton or photon)
- c, b massive
- Neglects $[\alpha_s \ln(\mu^2 / m^2)]^n$
- Valid at threshold



Cross sections: $d\sigma/d\eta(D^+)$, $d\sigma/dQ^2$, $d\sigma/dx$







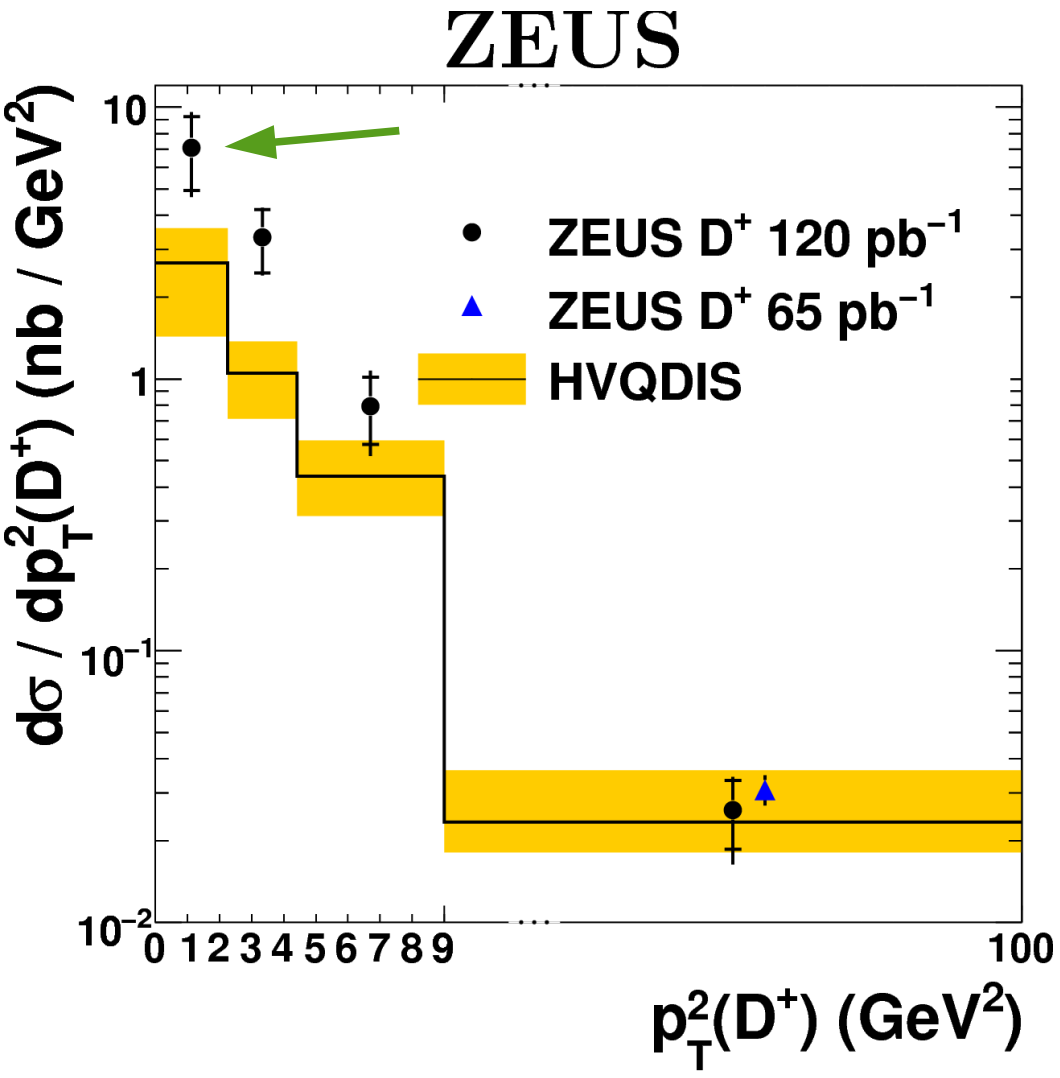
- **ZEUS D^+ 120 pb^{-1}**
- **HVQDIS**

The data are reasonably described by HVQDIS

Parameters and variations:

- ZEUS-S FFNS PDF (varied within uncertainty)
- m_c = 1.5 GeV (1.35 – 1.65 GeV)
- $\mu_R^2 = \mu_F^2 = Q^2 + 4m_c^2$ (separately multiplied by 4 and 0.25)
- Peterson ε = 0.079 (0.01 - 0.1)

Cross sections: $d\sigma/dp_T^2(D^+)$



- The data are in good agreement with a previous ZEUS measurement (using $D^+ \rightarrow K^-\pi^+\pi^+$) for $p_T(D^+) > 3$ GeV

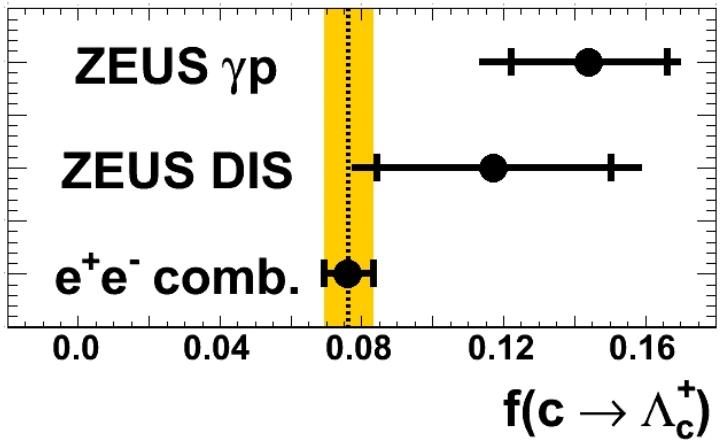
- The data are in reasonable agreement with HVQDIS

$f(c \to \Lambda_c^+)$ in DIS

Motivation:

- Test fragmentation universality
- Affects knowledge of $f(c \to D^+, D^*, \ldots)$

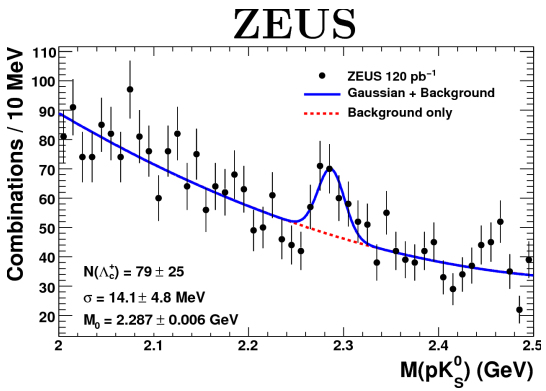
$\to$ Important for precise F_2^c from D mesons



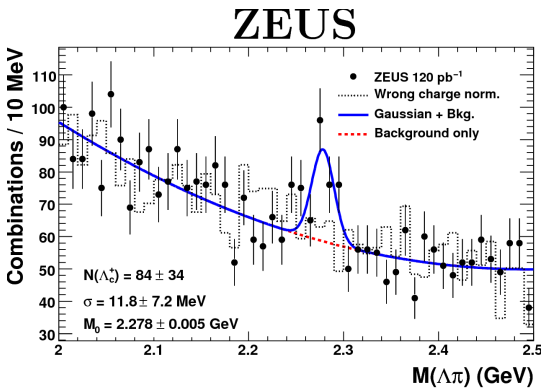
Difficult measurement at HERA (statistics!)

$\to$ Combine two decay channels

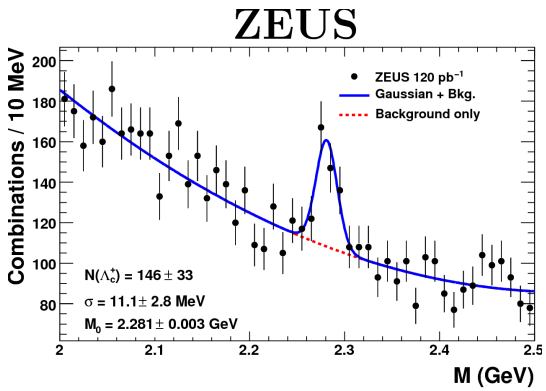
(same kinematic range as for $D^+ \to K^0_S \pi^+$)



$\Lambda_c^+ \to K^0_S p$



$\Lambda_c^+ \to \Lambda \pi^+$

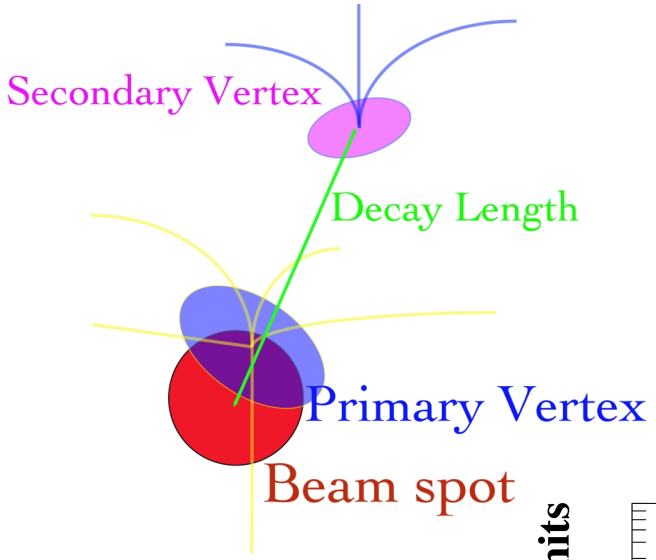


both channels

Reconstruction of D^+ and D^0 mesons using lifetime information

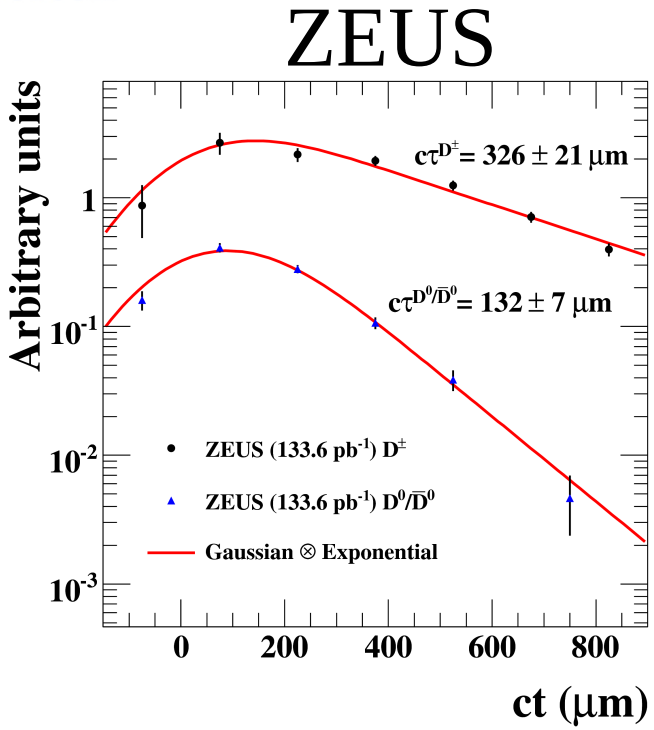
Decay channels:
$D^+ \rightarrow K^-\pi^+\pi^+$
$D^0 \rightarrow K^-\pi^+$

Micro Vertex Detector (HERA II):
→ Reconstruct secondary decay vertices



L_{XY}: 2D distance between the secondary vertex and the primary interaction point projected onto the D Meson momentum vector

$S_l = L_{XY} / \sigma(L_{XY})$



D^+ and D^0 measurement

Kinematic region:

$1.5 < p_T(D^+,D^0) < 15$ GeV

$|\eta(D^+,D^0)| < 1.6$

$5 < Q^2 < 1000$ GeV^2

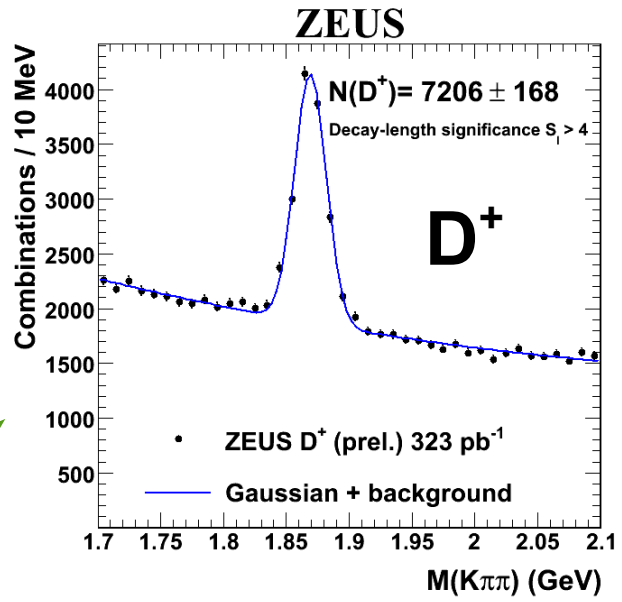
$0.02 < y < 0.7$

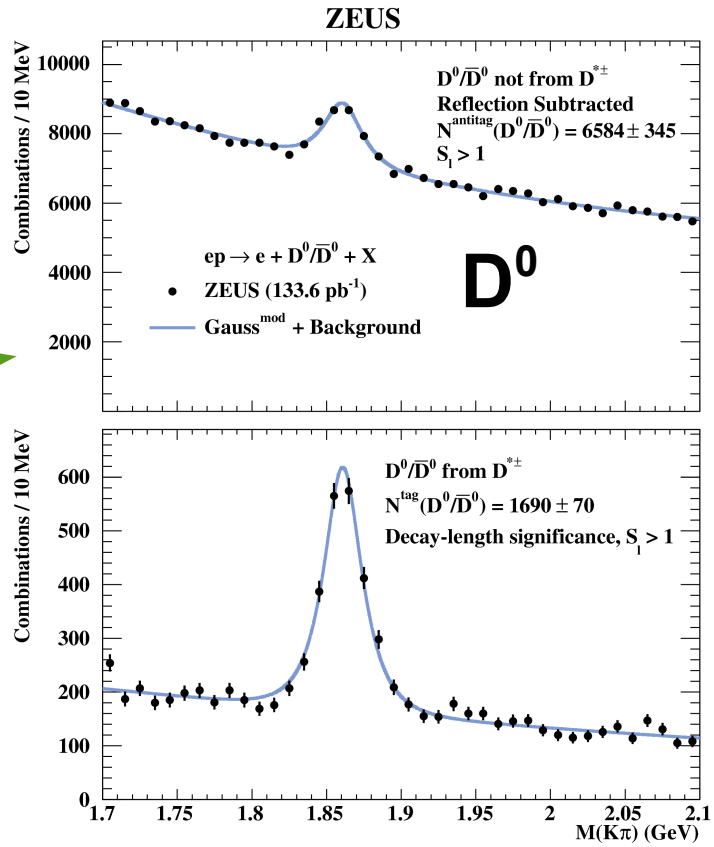
Data sample:

323 pb^{-1} (2005-2007) for D^+

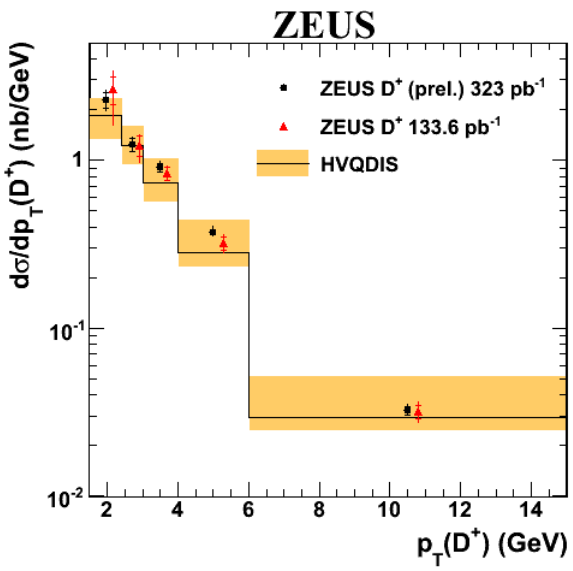
134 pb^{-1} (2005) for D^0

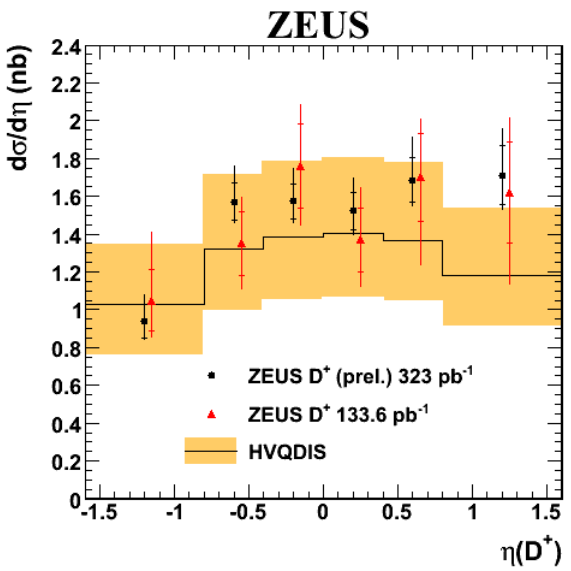
D^0 mesons not originating from D^{*+} decays were used for the cross section measurement

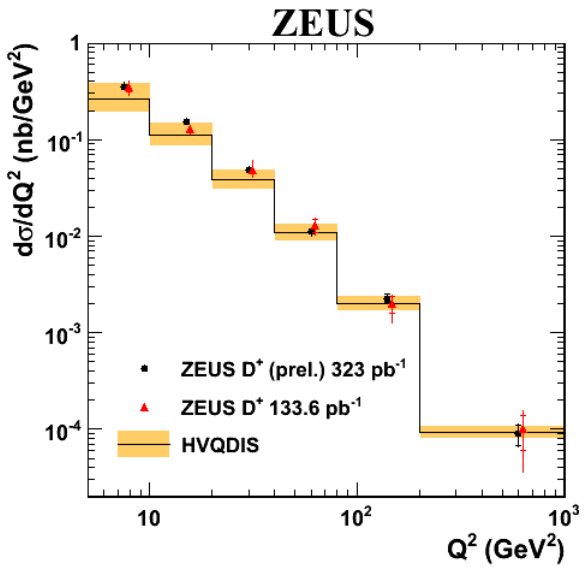


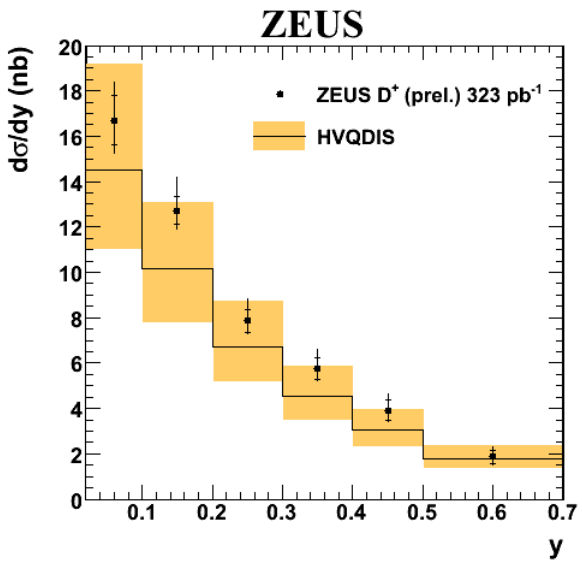


D^+ cross sections









- The measurements are described by HVQDIS (same parameters as for the HERA I analysis)

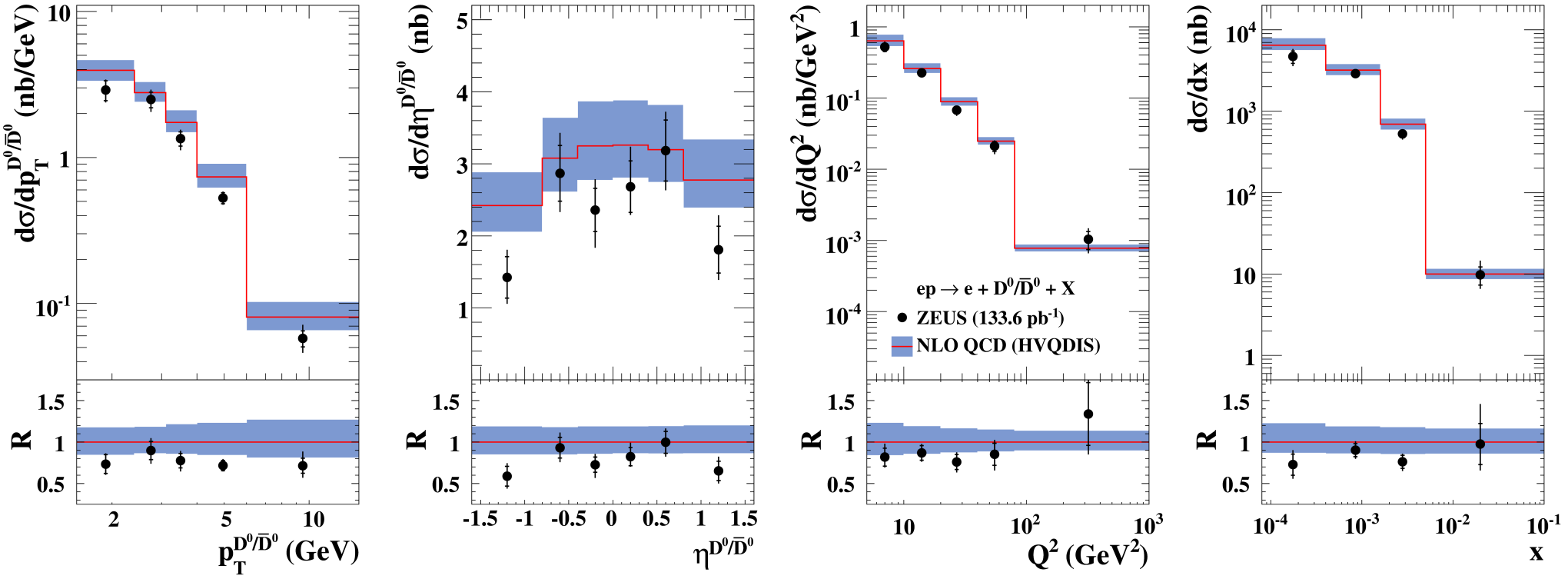
- The published (05) and preliminary (05-07) results are in good agreement and the precision has improved significantly

- Competitive precision as D* measurements in HERA I

- **ZEUS D^+ (prel.) 323 pb^{-1}**
- **ZEUS D^+ 133.6 pb^{-1}**
- **HVQDIS**

D^0 cross sections

ZEUS



All cross sections are reasonably described by HVQDIS

$ep \to e + D^0/\bar{D}^0 + X$

ZEUS (133.6 pb^{-1})

NLO QCD (HVQDIS)

Extraction of F_2^c

Extrapolation needed:

Measured cross section in bin i

$$F^{c\bar{c}}_{2,meas}(x_i, Q_i^2) = \frac{\sigma_{meas,i}}{\sigma_{theo,i}} \times F^{c\bar{c}}_{2,theo}(x_i, Q_i^2)$$

Calculated using HVQDIS (FFNS)

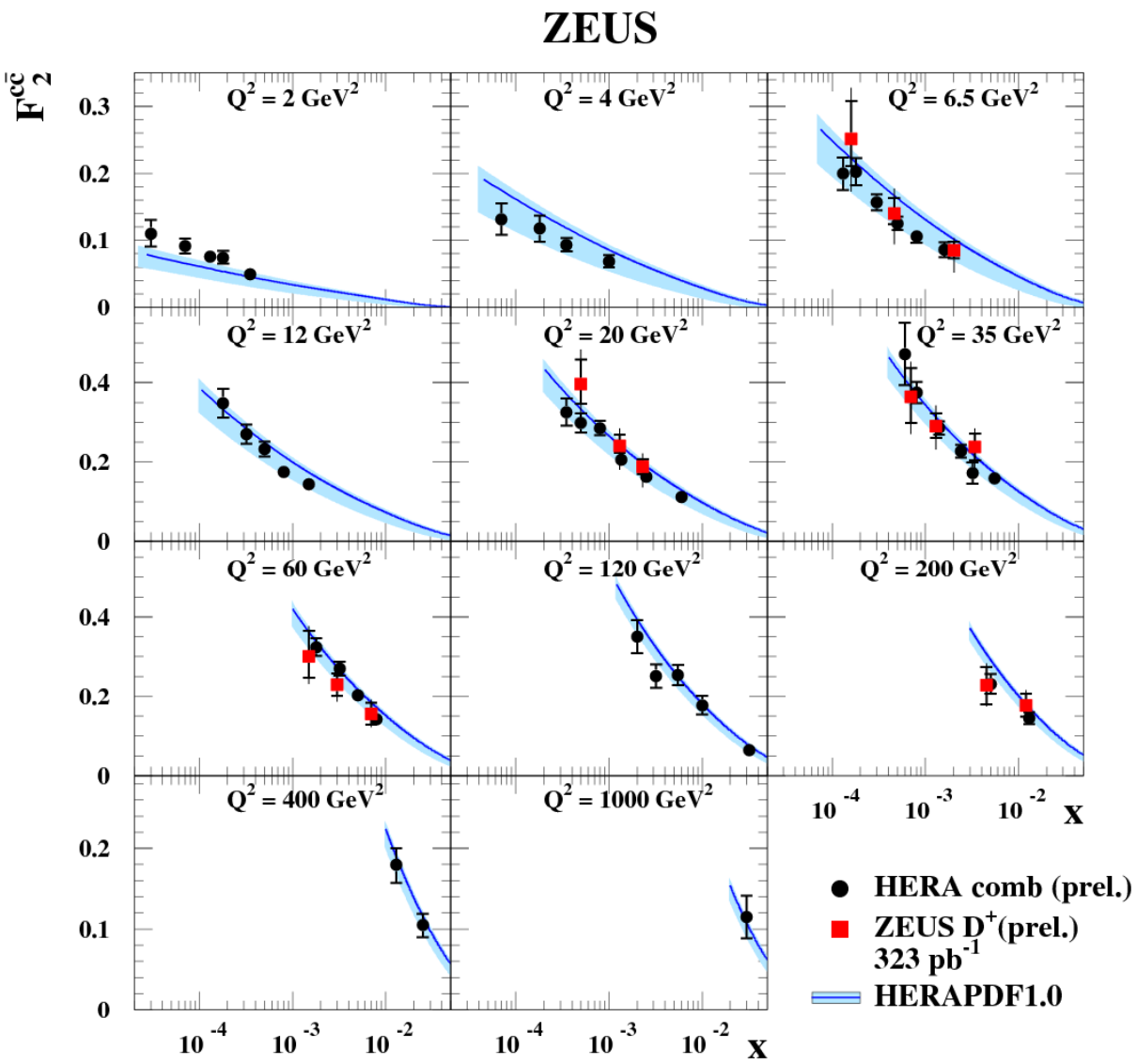
Calculated at NLO in FFNS

Extrapolation factors for D^+ and D^0 measurement:

1.5 (at high Q^2) – 3.2 (at low Q^2)

→ Lower than in previous D^+ and D^0 analysis due to lower $p_T(D^+,D^0)$ cut

F_2^c as a function of x in bins of Q^2



- Preliminary D^+ results are compared to H1+ZEUS combination of all available tagging methods (except D^+ prel.)

- For HERA combined F_2^c
→ see talk by M. Corradi

- The data are well described by HERAPDF1.0

- The black points, the red points are and HERAPDF1.0 are based on independent data sets

Summary

- The production of the charmed hadrons D^+, D^0 and Λ_c^+ in DIS has been studied in detail at HERA
- The measurements are reasonably described by NLO QCD predictions
- For the first time the threshold region and $f(c \to \Lambda_c^+)$ were investigated in DIS using new decay channels
- Precise measurements of D^+ and D^0 have been obtained using lifetime tags and the corresponding contribution to F_2 has been extracted

Backup slides

pQCD Treatment of charm (and beauty) production in DIS

Massive, FFNS:

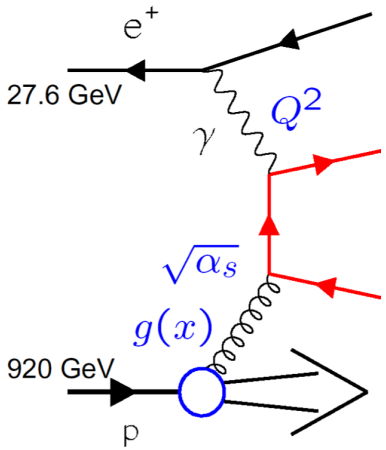
c and b produced dynamically
(not part of proton or photon)

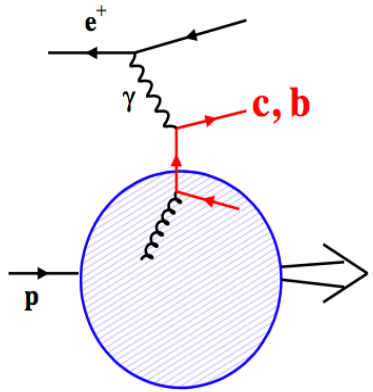
- c, b massive
- Neglects $[\alpha_s \ln(\mu^2 / m^2)]^n$
- Valid at threshold

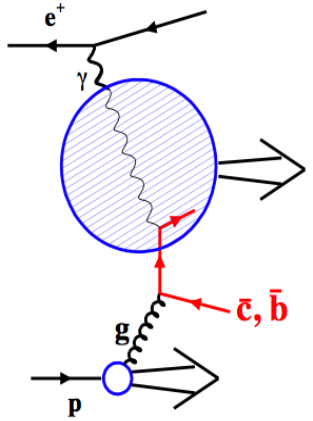
Massless, ZM-VFNS:

c and b massless partons in proton and photon

- c, b massless
- Resums $[\alpha_s \ln(\mu^2 / m^2)]^n$
- Valid for $\mu^2 >> m^2$





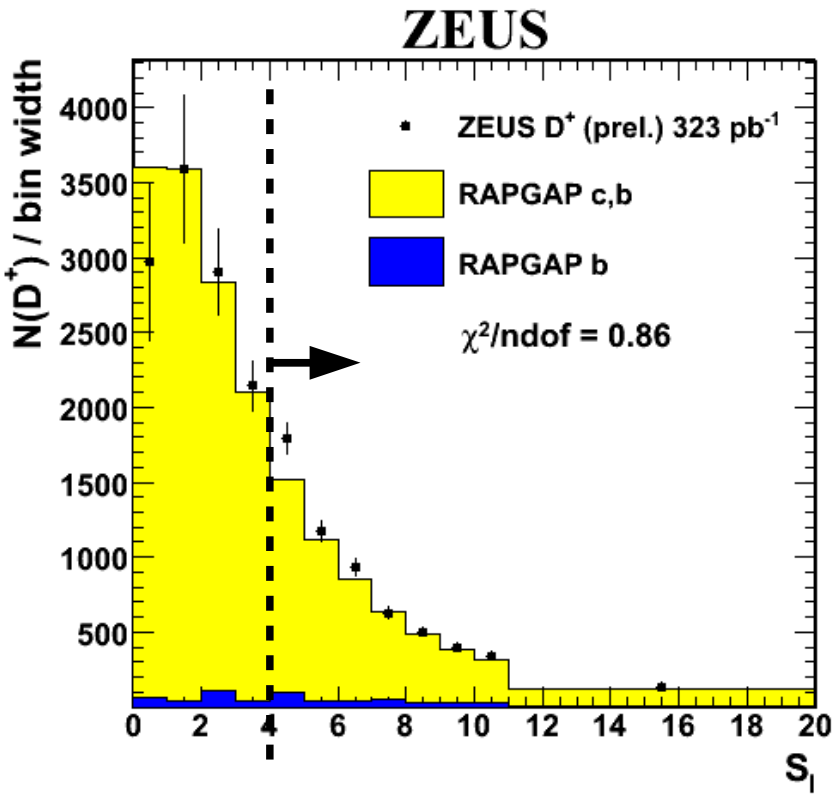


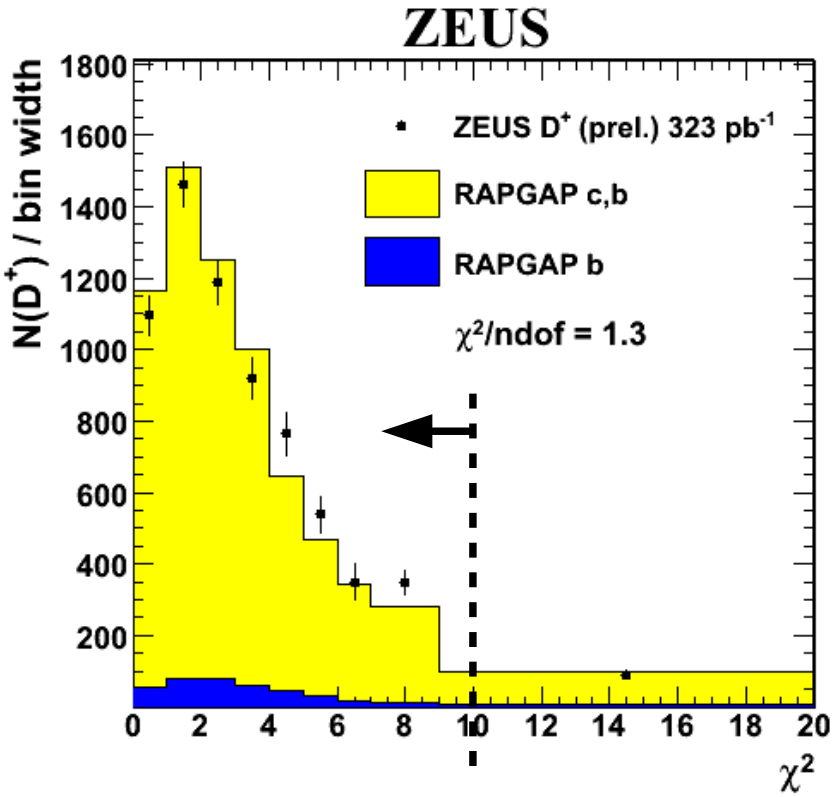
Variable Flavour Number Scheme, (GM)-VFNS:

Interpolates / matches between both approaches

- Massive at low Q^2, massless at high Q^2

Secondary vertex reconstruction





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

$S_l > 4$ **$Chi^2 < 10$**

→ Lifetime and vertex quantities are well reproduced by the MC