



Charm production in DIS and the measurement of F_2^{CC} at ZEUS

U+H



DIS 2009
 XVII International Workshop on Deep-Inelastic Scattering and Related Subjects
 26-30 April 2009, Palacio de Congresos de Madrid
<http://www.ft.uam.es/DIS2009>

Topics
 Structure Functions and Low-x
 Diffraction and Vector Mesons
 Electroweak Physics and BSM
 Hadronic Final States and QCD
 Heavy Flavours
 Spin Physics
 Future Facilities



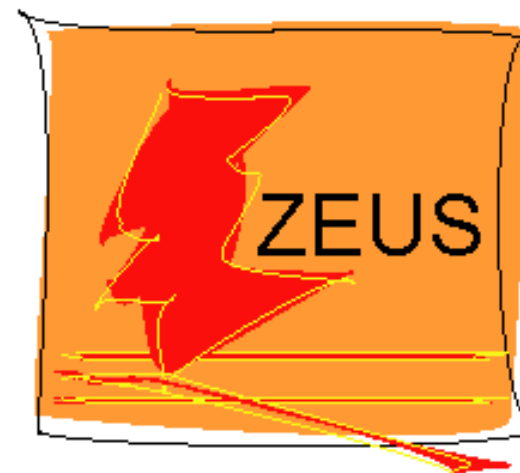
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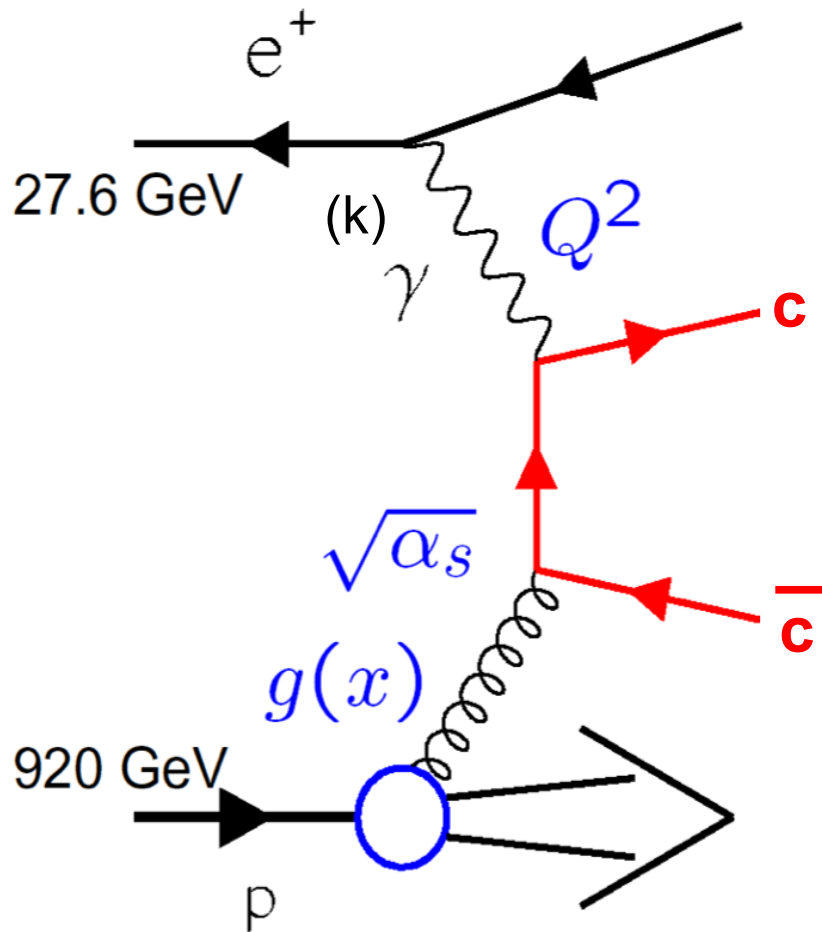


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Outline

- Introduction
- Measurement of D^\pm and D^0 production (DESY-08-201)
- Charm from decays into muons (DESY-09-056)
- Extraction of F_2^{cc}
- Summary

Charm production at HERA



- Dominant process for charm production in DIS ($Q^2 >$ a few GeV^2): **Boson-Gluon-Fusion (BGF)**

- This process is directly sensitive to the gluon content of the proton

- Multiple hard scales: $\mu^2 = m^2(c), p_T^2(c), Q^2$

- The double differential cross section for the production of open charm can be written as:

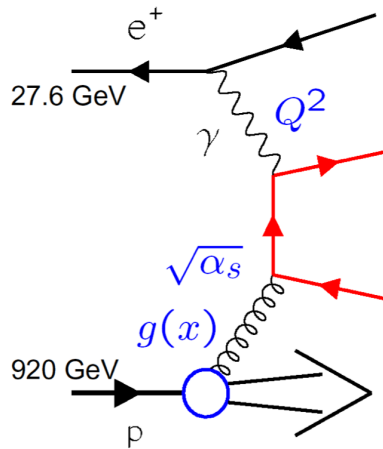
$$\frac{d^2 \sigma^{c\bar{c}}(x, Q^2)}{dx dQ^2} = \frac{2\pi \alpha^2}{x Q^4} \left\{ [1 + (1-y)^2] F_2^{c\bar{c}}(x, Q^2) - y^2 F_L^{c\bar{c}}(x, Q^2) \right\}$$

pQCD Treatment of charm (and beauty) production in DIS

Massive, FFNS:

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

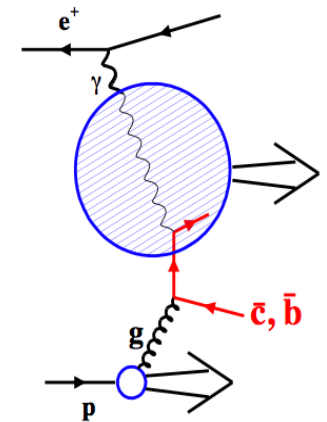
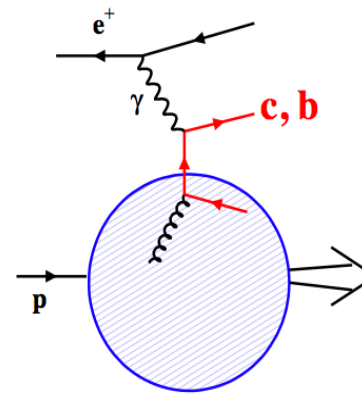
- c, b massive
- Neglects $[\alpha_s \ln(\mu^2 / m^2)]^n$
- Valid at threshold



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 $\mu^2 \gg m^2$



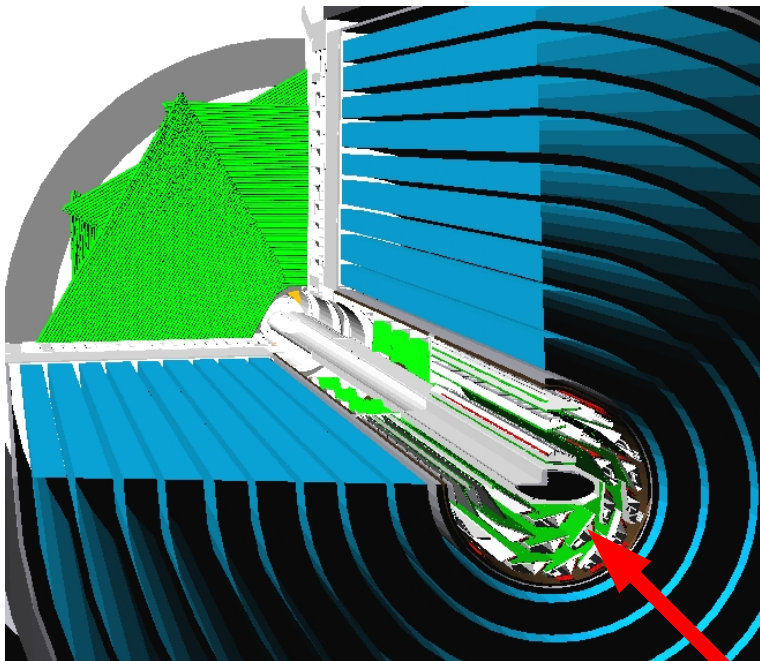
Variable Flavour Number Scheme, (GM)-VFNS:

Interpolates / matches between both approaches

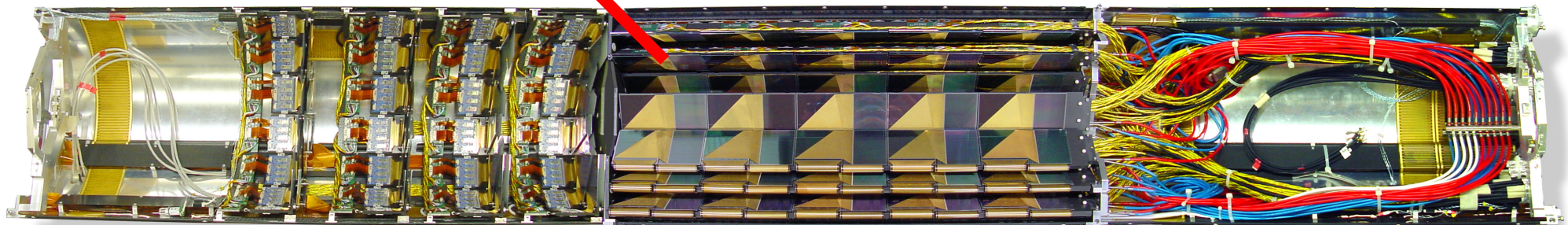
- **Massive at low Q^2 , massless at high Q^2**

Tracking at ZEUS in HERA II

ZEUS Tracking



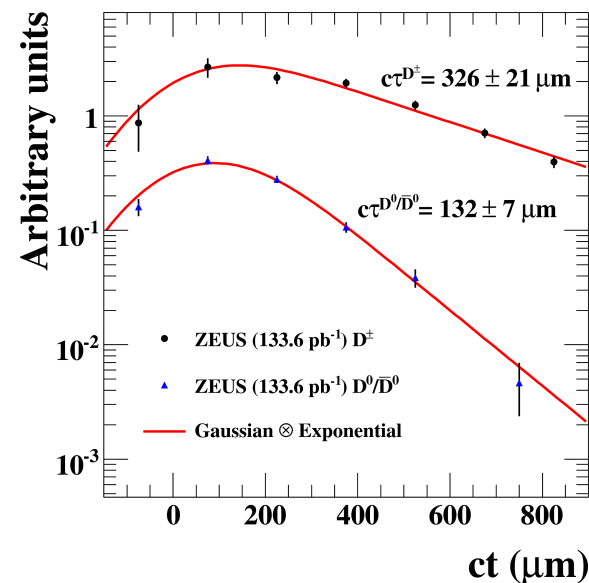
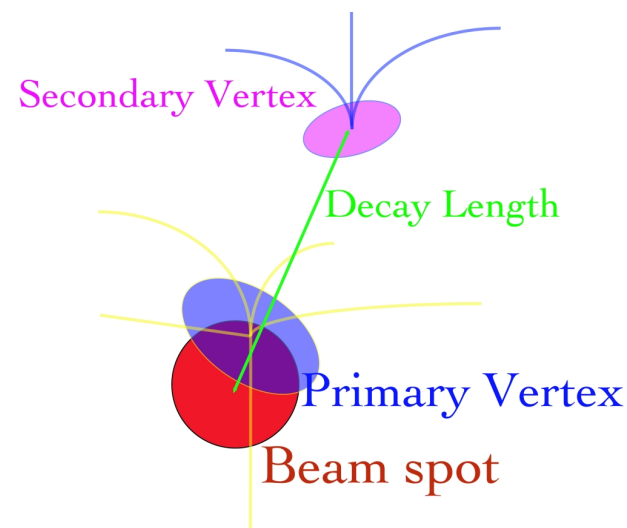
- For HERA II ZEUS was equipped with a silicon Micro Vertex Detector (MVD)
- Barrel region (**BMVD**):
3 layers of strip sensors
- Forward region (**FMVD**):
4 wheels of strip sensors
- BMVD resolution after alignment: **25 μm**
- CTD (wire chamber) + BMVD
impact parameter resolution: **100 μm**
(Intermediate state of the data,
better precision has been achieved)



BOTTOM MICRO VERTEX DETECTOR

Measurement of D^\pm and D^0 production

- Charmed mesons are tagged in the decays $D^+ \rightarrow K^- \pi^+ \pi^+ (+c.c.)$ and $D^0 \rightarrow K^- \pi^+ (+c.c.)$
- The secondary vertices of these decays can be reconstructed
- L_{XY} : 2D distance between the secondary vertex and the primary interaction point projected onto the D meson momentum vector
- $S_1 = L_{XY} / \sigma(L_{XY})$:
Positive for charm decays



Reconstruction and simulation of secondary vertices

- **Cuts for D^\pm :**

$\chi^2(\text{decay vertex}) < 9$ for
3 degrees of freedom

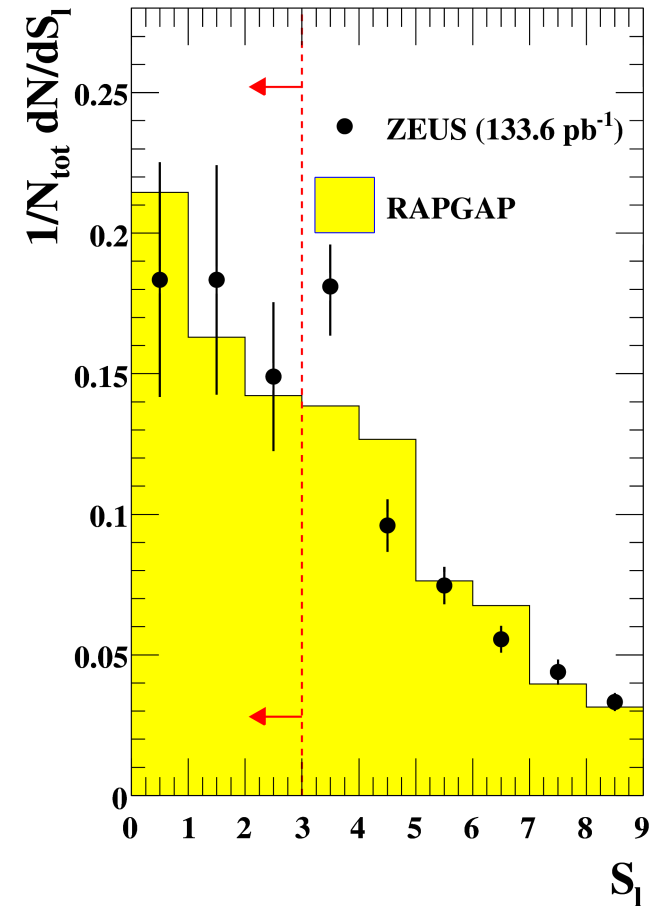
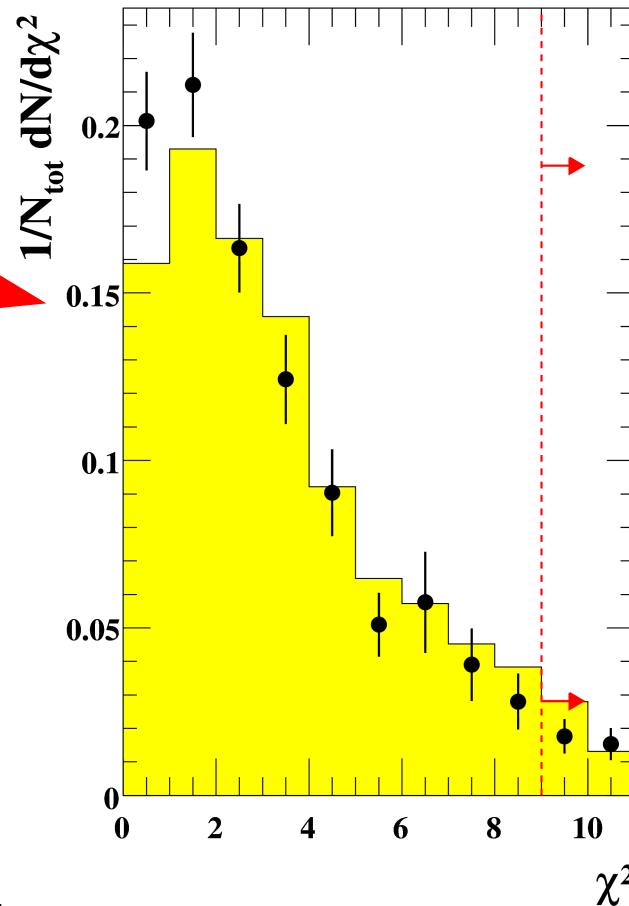
$S_1 > 3$

- **Cuts for D^0 :**

$\chi^2(\text{decay vertex}) < 8$ for
1 degree of freedom

$S_1 > 1$

- The dominant systematic uncertainty is related to the simulation of the MVD resolution

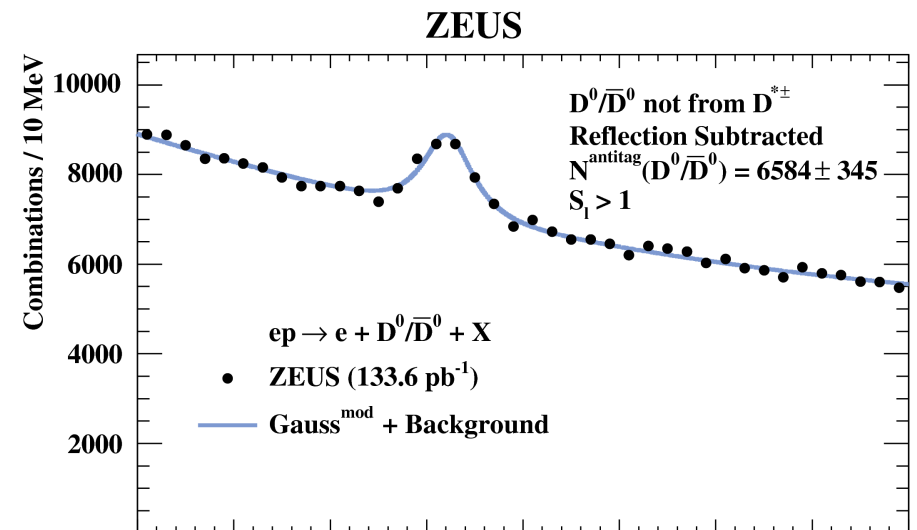
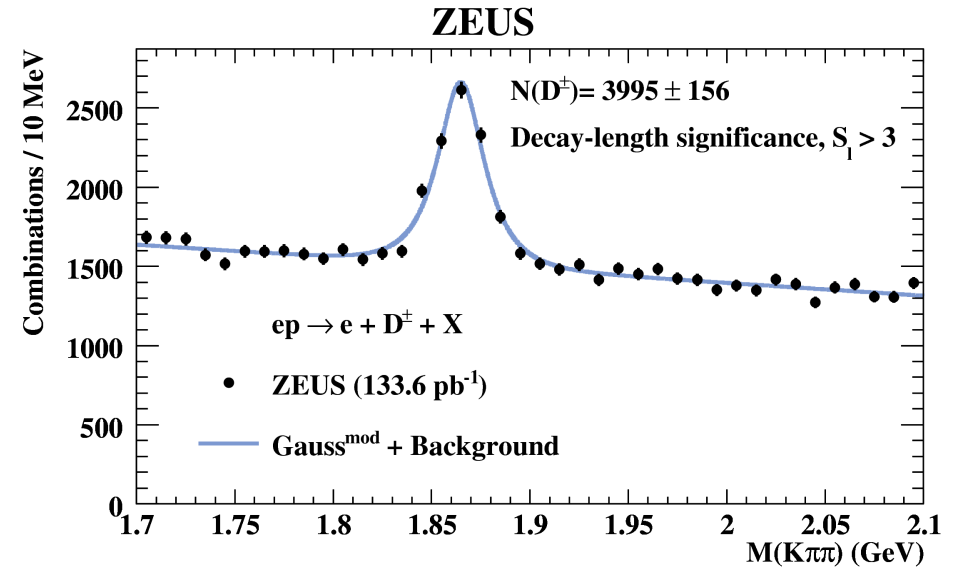


D^{\pm} and D^0 reconstruction and selection

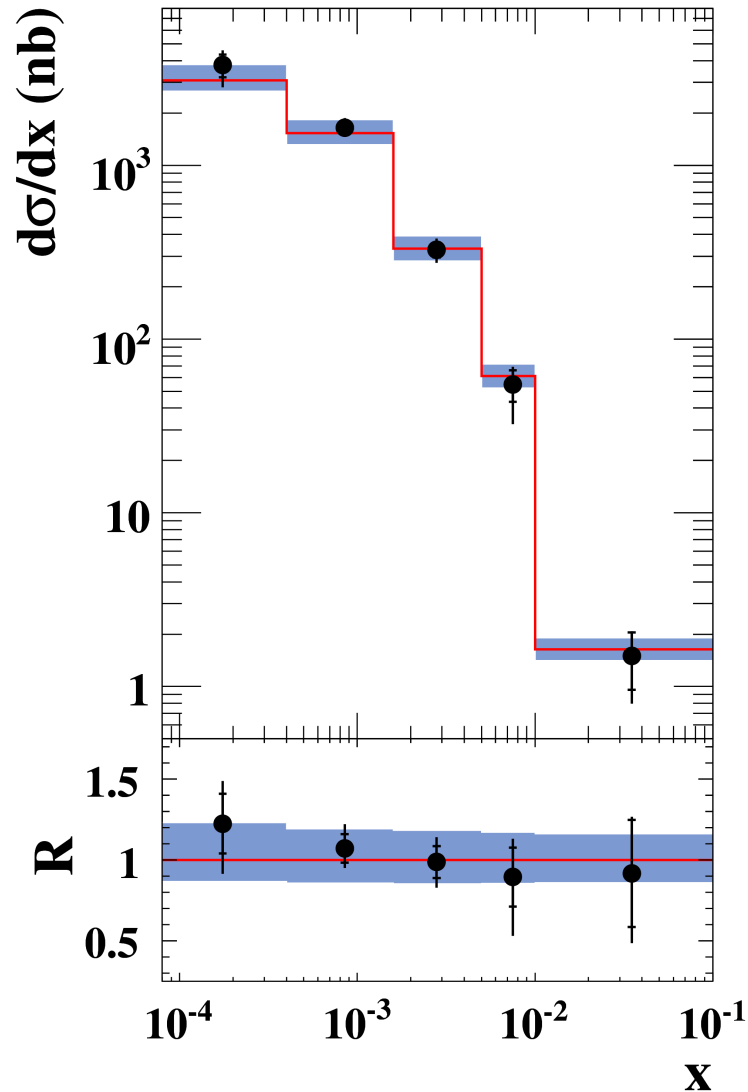
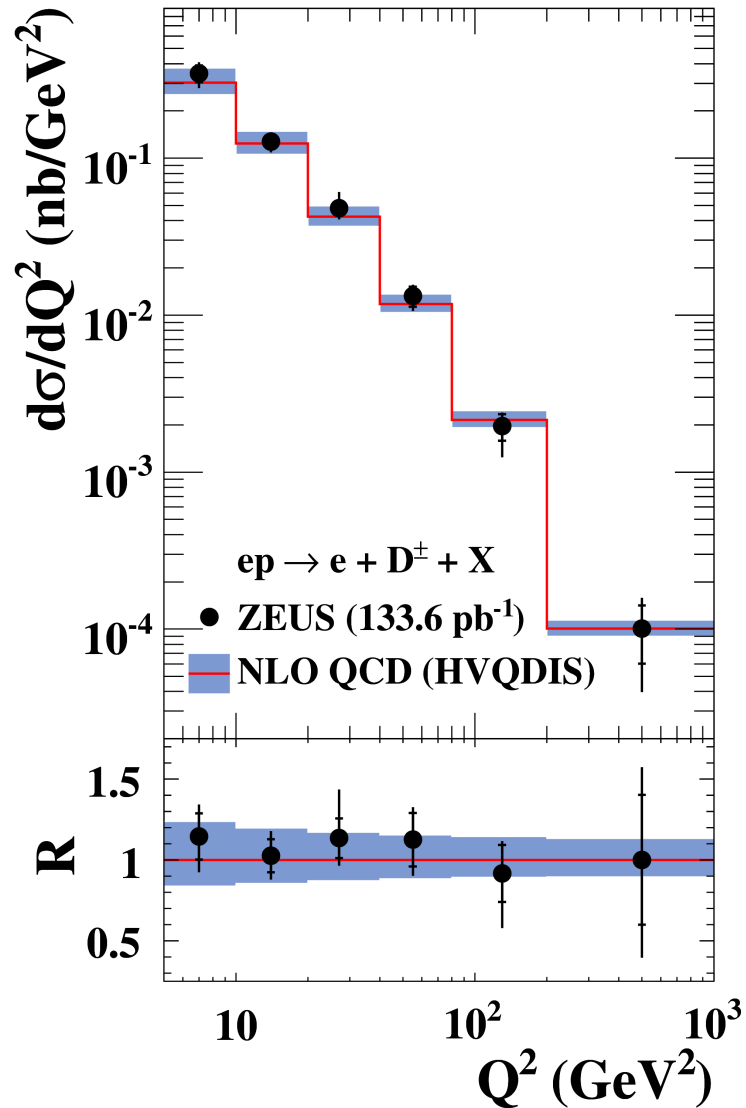
- **Kinematic range:**
 $5 < Q^2 < 1000 \text{ GeV}^2$
 $0.02 < y < 0.7$
 $1.5 < p_T(D) < 15 \text{ GeV}$
 $|\eta(D)| < 1.6$

- **Data sample:**
 133.6 pb^{-1}
HERA II
 e^-p (2004/05)

- D^0 mesons not originating from $D^{*\pm}$ decays were used for the cross section measurement

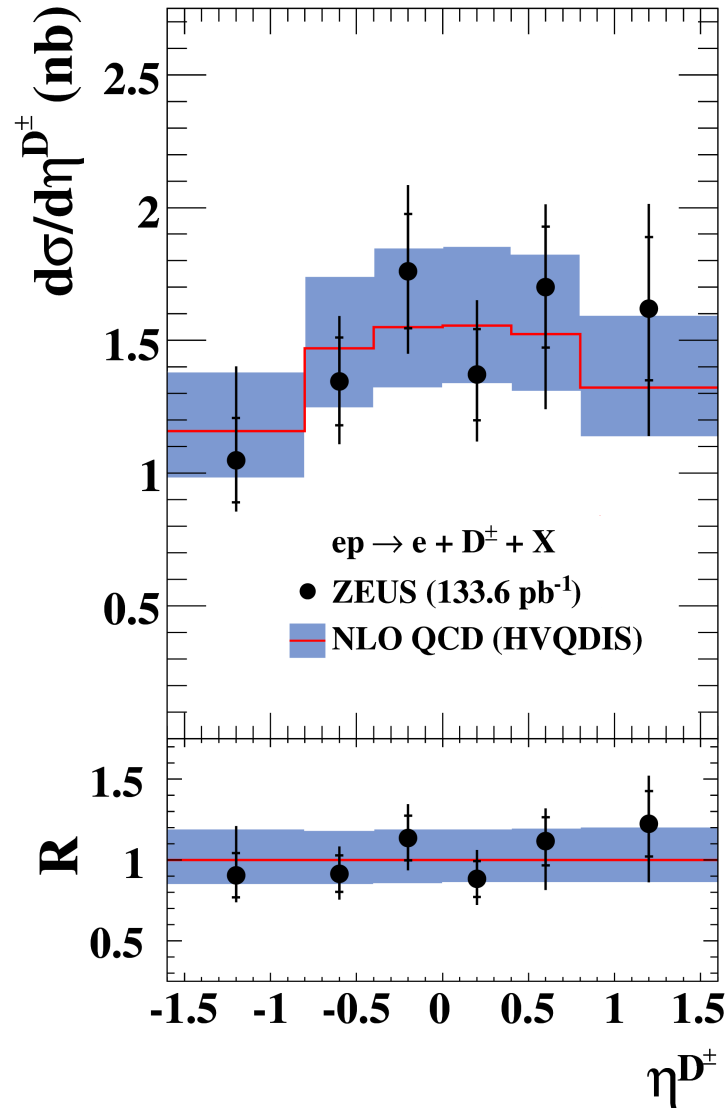
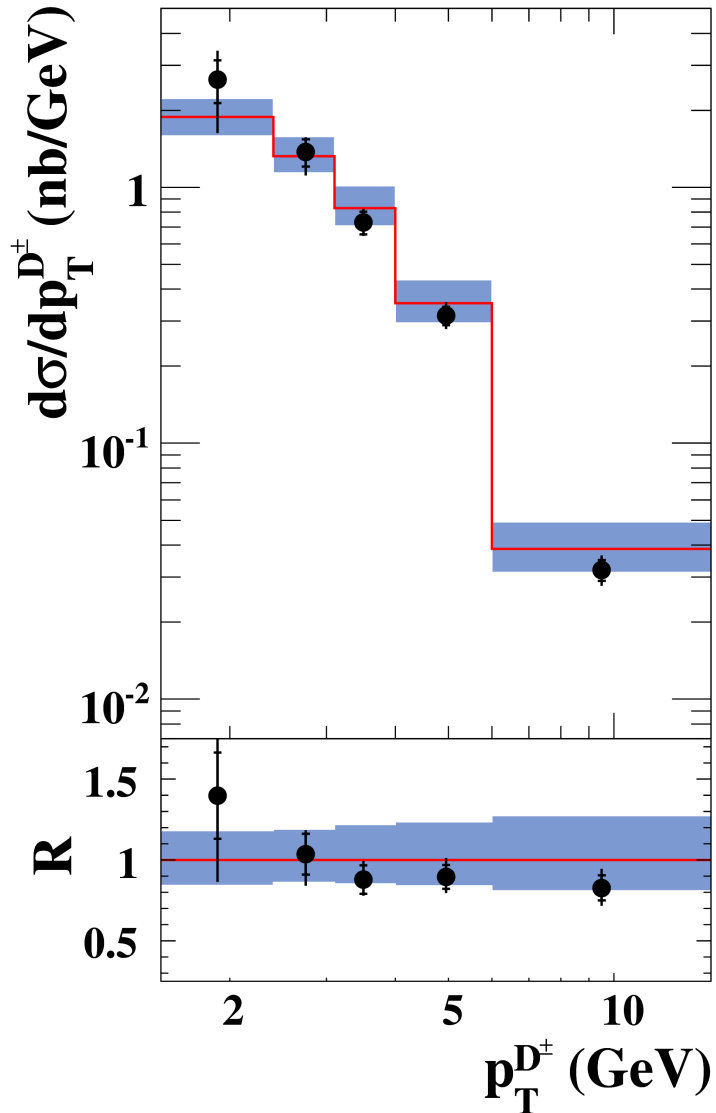


D^\pm cross sections: Q^2 and x



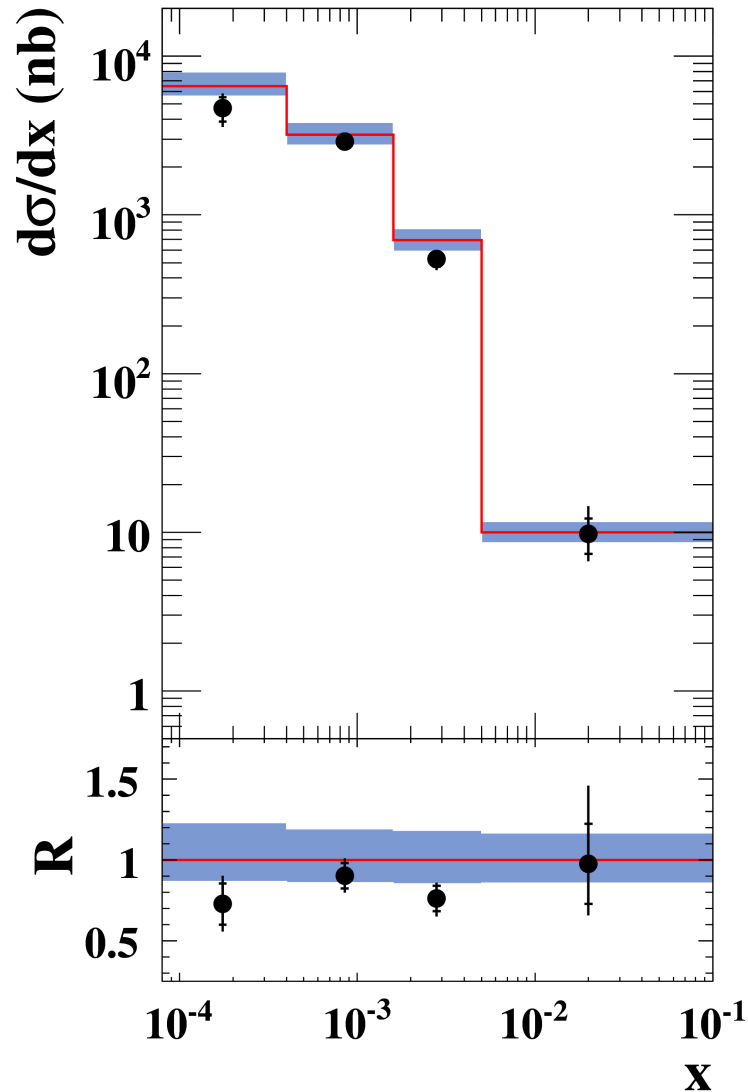
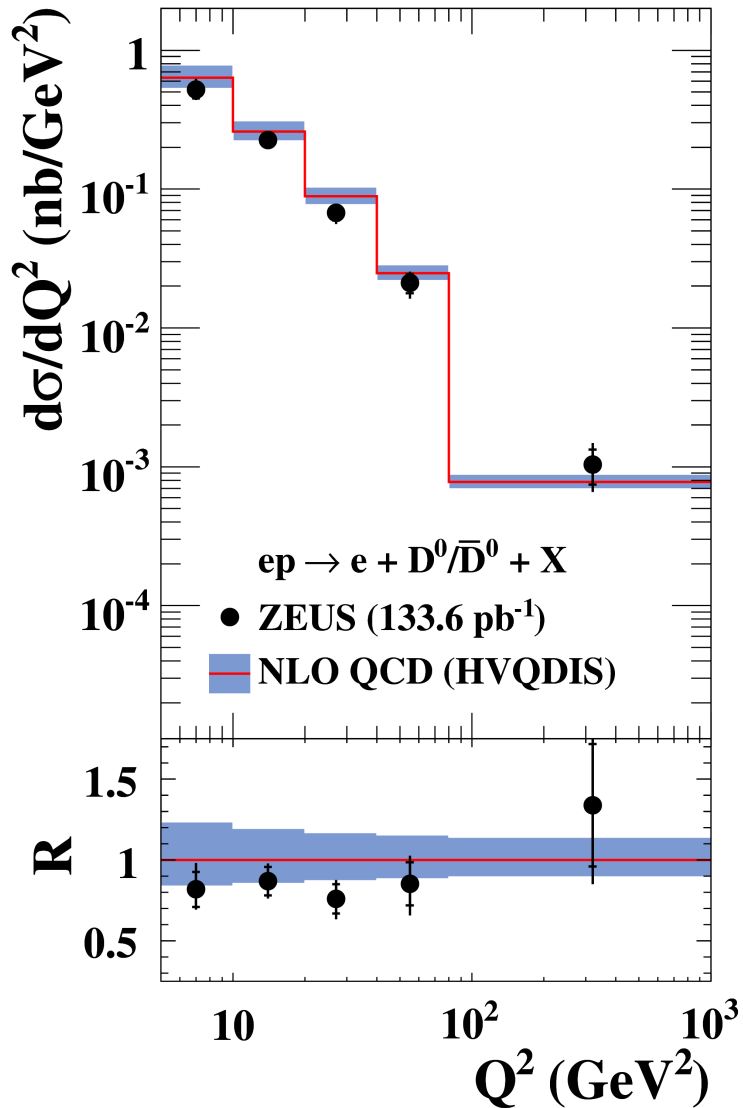
Good description by the HVQDIS NLO QCD prediction (FFNS)

D^\pm cross sections: $p_T(D^\pm)$ and $\eta(D^\pm)$



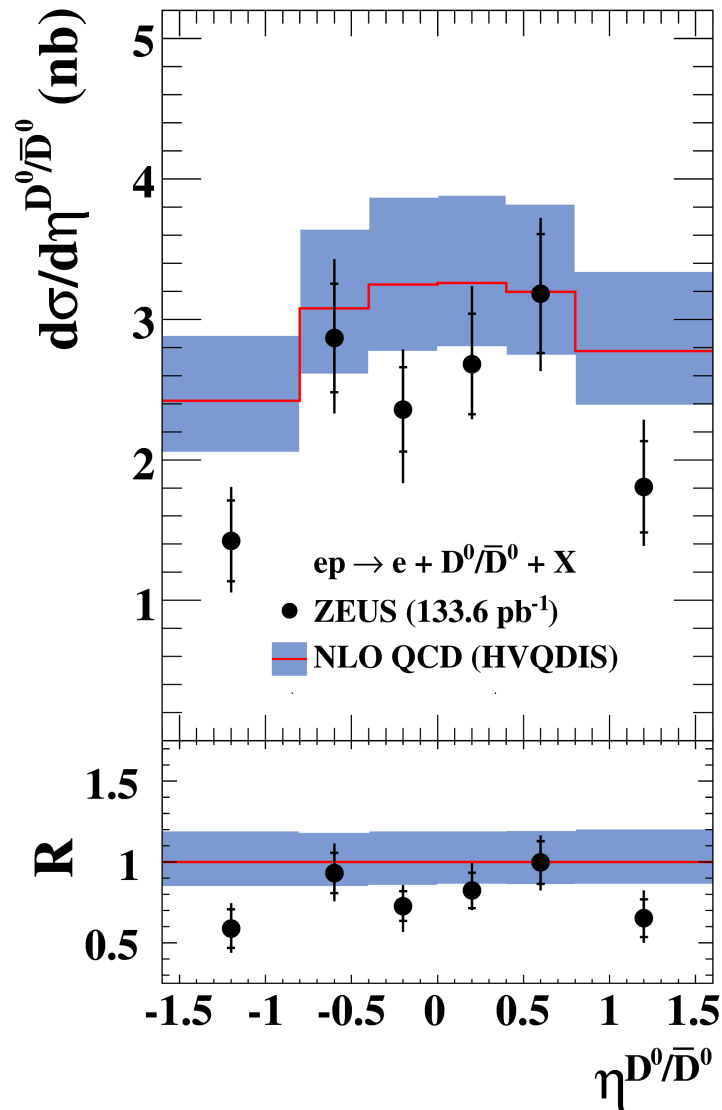
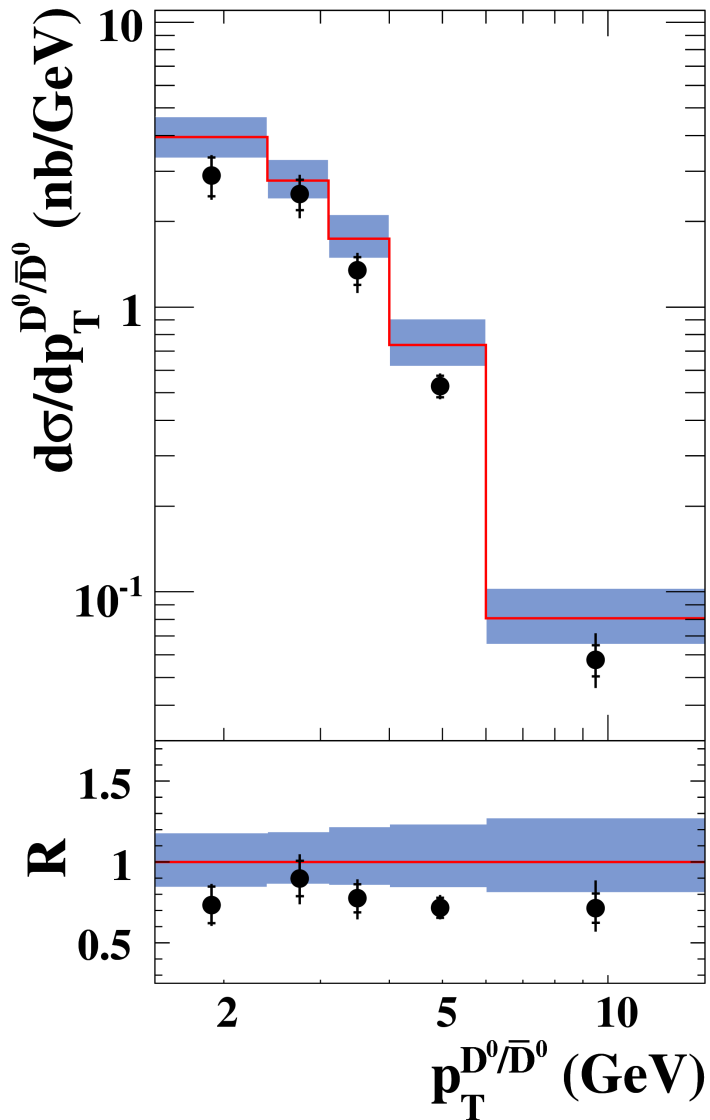
Good description by HVQDIS

D⁰ cross sections: Q² and x



Measurements described by HVQDIS

D⁰ cross sections: p_T(D⁰) and η(D⁰)



Measurements described by HVQDIS

Charm from decays into muons

The fractions of muons from charm, beauty and LF events were obtained from a **simultaneous fit of 3 discriminating variables**:

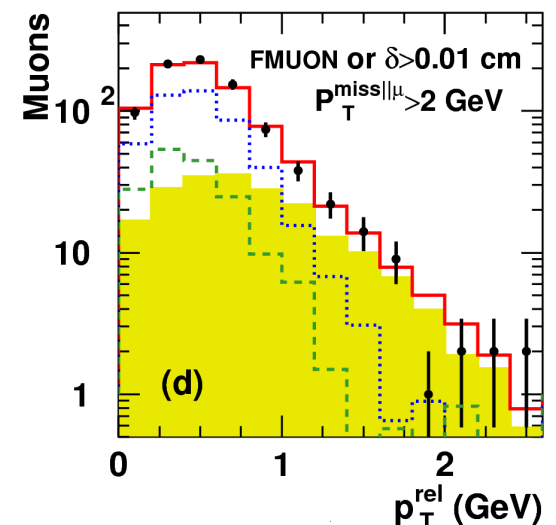
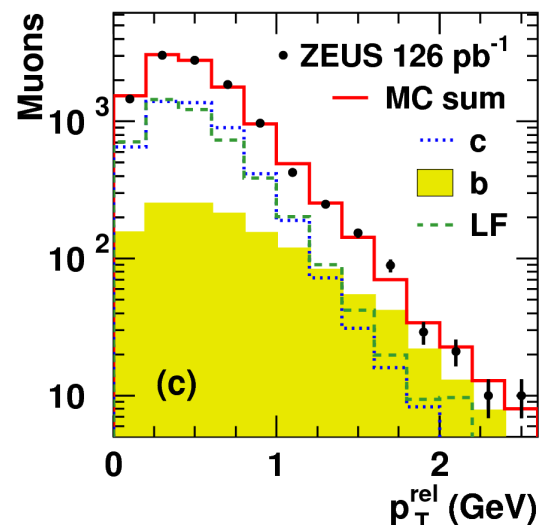
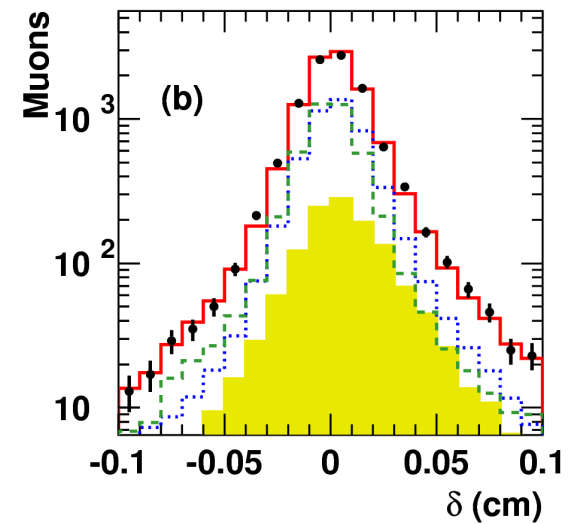
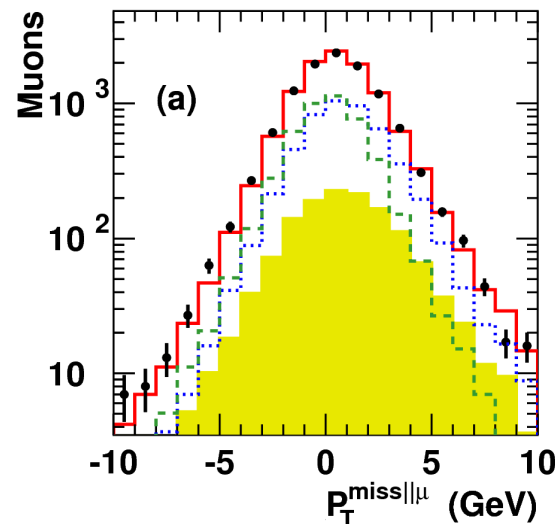
- p_T^{rel} : the muon momentum component transverse to the jet axis

- δ : the impact parameter of the muon track

- $p_T^{\text{miss}||\mu}$: the missing transverse momentum parallel to the muon direction

→ More details in talk by M. Bindi

ZEUS



Muon cross sections

- Kinematic range:

$Q^2 > 20 \text{ GeV}^2$

$0.01 < y < 0.7$

$p_T(\mu) > 1.5 \text{ GeV}$

$-1.6 < \eta(\mu) < 2.3$

- Data sample:

126.0 pb^{-1}

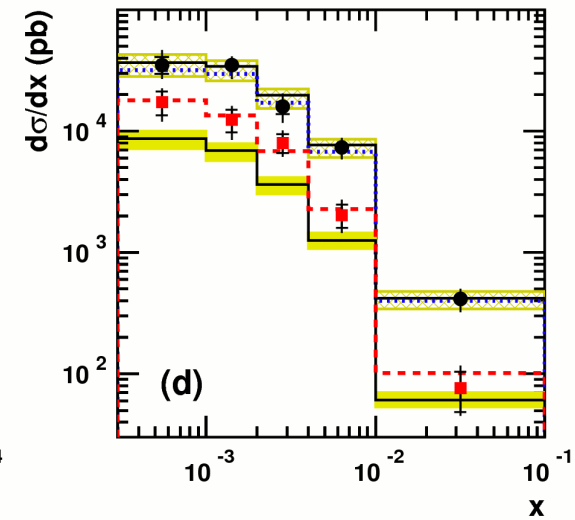
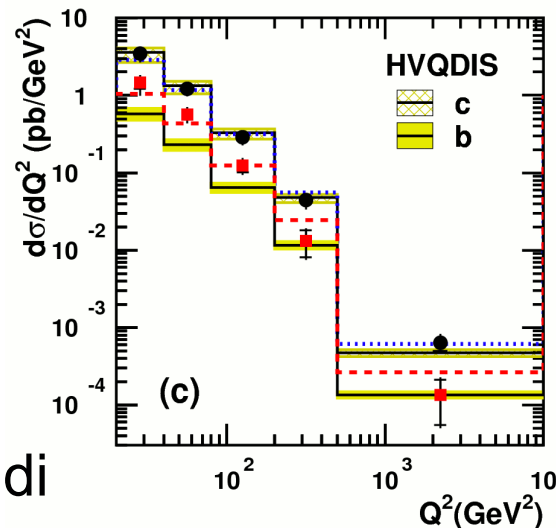
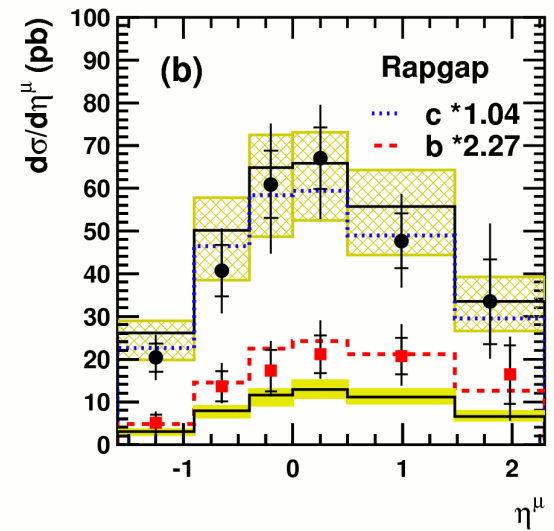
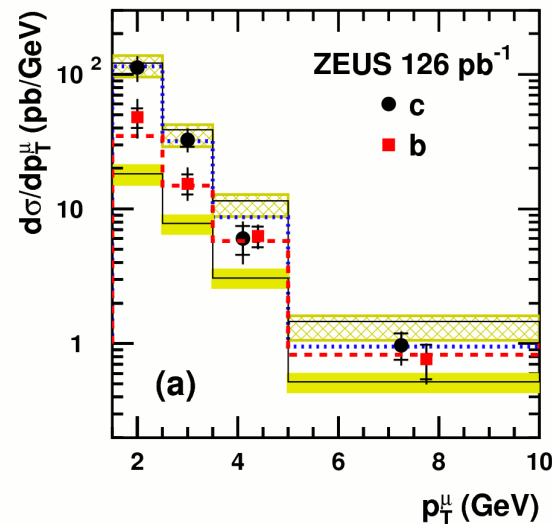
HERA II

e^-p (2004/05)

- The charm cross sections are in good agreement with the HVQDIS predictions

→ Beauty results in talk by M. Bindi

ZEUS



Extraction of $F_2^{c\bar{c}}$

Extrapolation needed:

Measured cross section
in bin i

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

Calculated using
HVQDIS (FFNS)

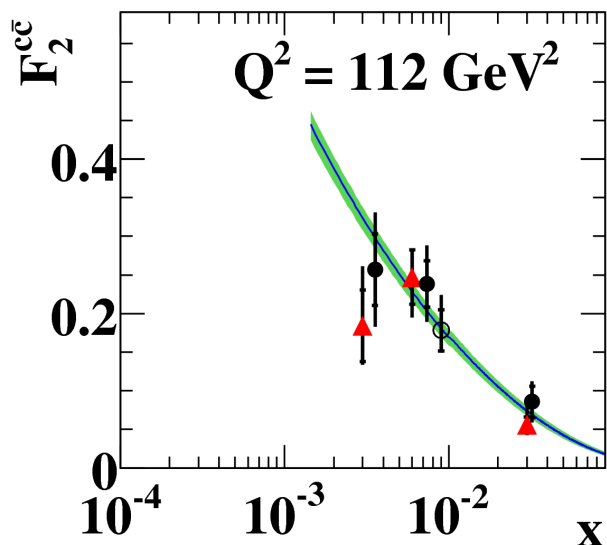
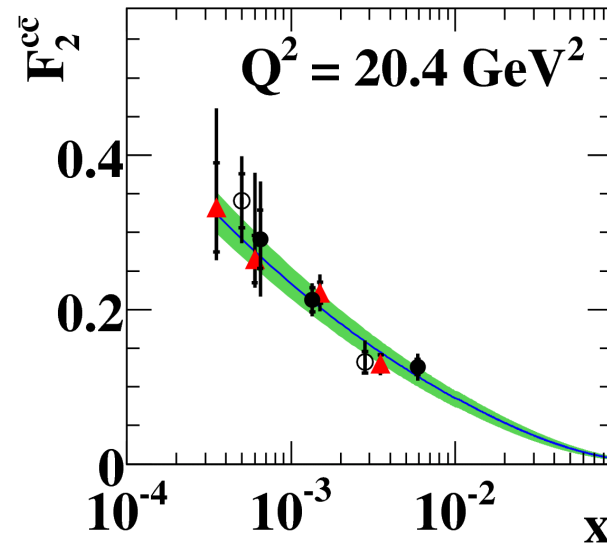
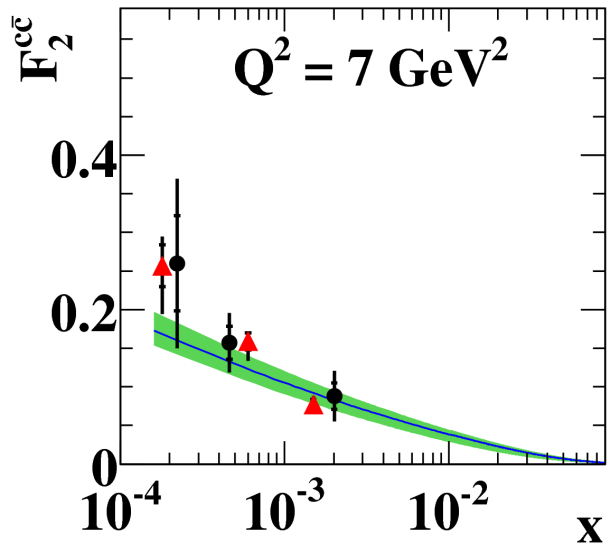
Calculated at NLO
in FFNS

Extrapolation factors for D^\pm and D^0 measurement:

1.5 (at high Q^2) – 3.2 (at low Q^2)

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

F_2^{cc} from D^\pm and D^0



- ZEUS D^\pm, D^0 (133.6 pb^{-1})
- ZEUS D^\pm (65 pb^{-1}), D^0, D_s^\pm (82 pb^{-1})
- ▲ ZEUS $D^{*\pm}$ (82 pb^{-1})
- ZEUS NLO QCD

- F_2^{cc} from D^\pm and D^0 were combined

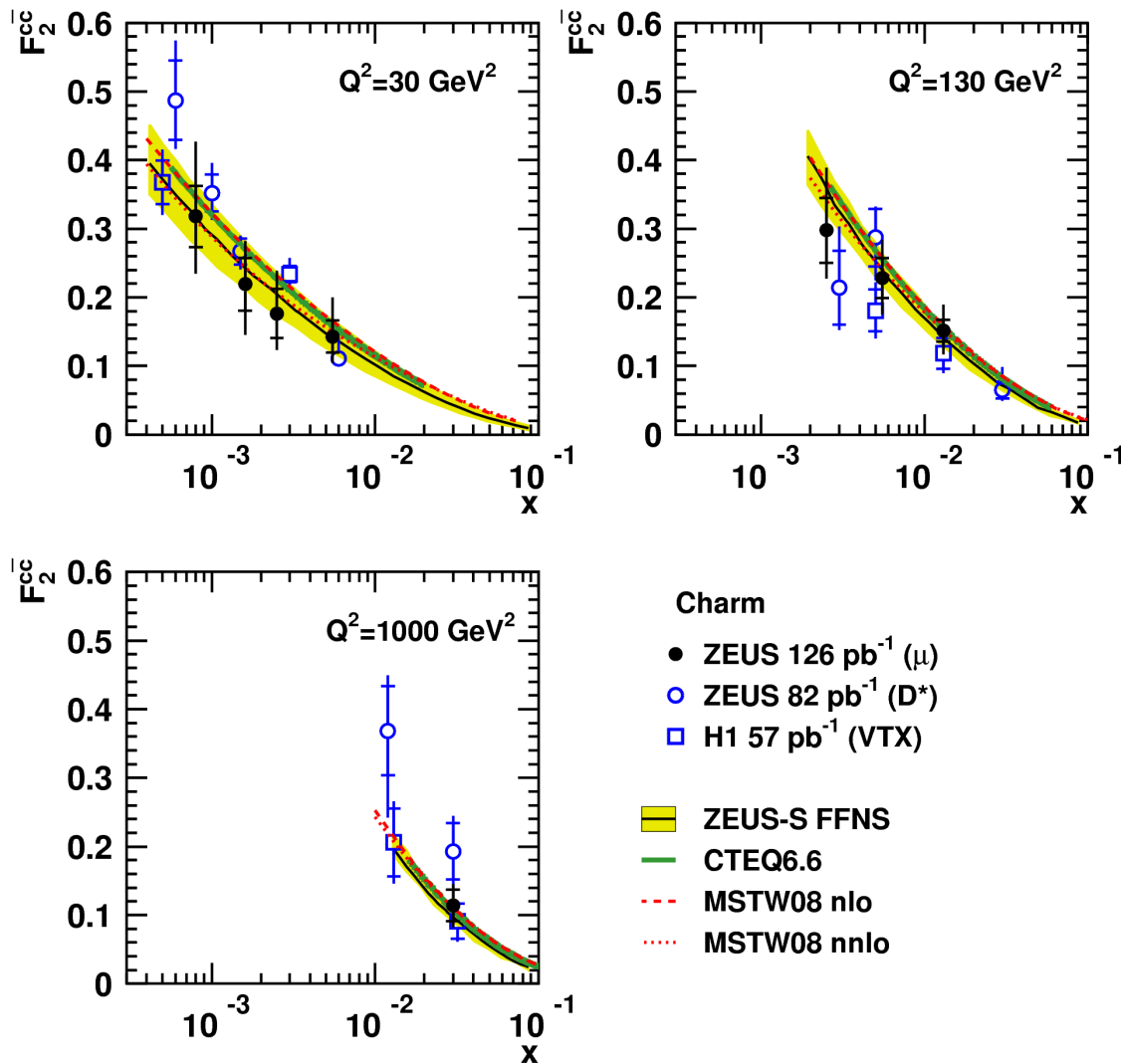
- The results are more precise than a previous measurement using the same decays channels

- At high Q^2 similar precision as D^*

- The ZEUS NLO QCD fit describes the data well

F_2^{cc} from muons

ZEUS



- The agreement between different charm tagging methods is good

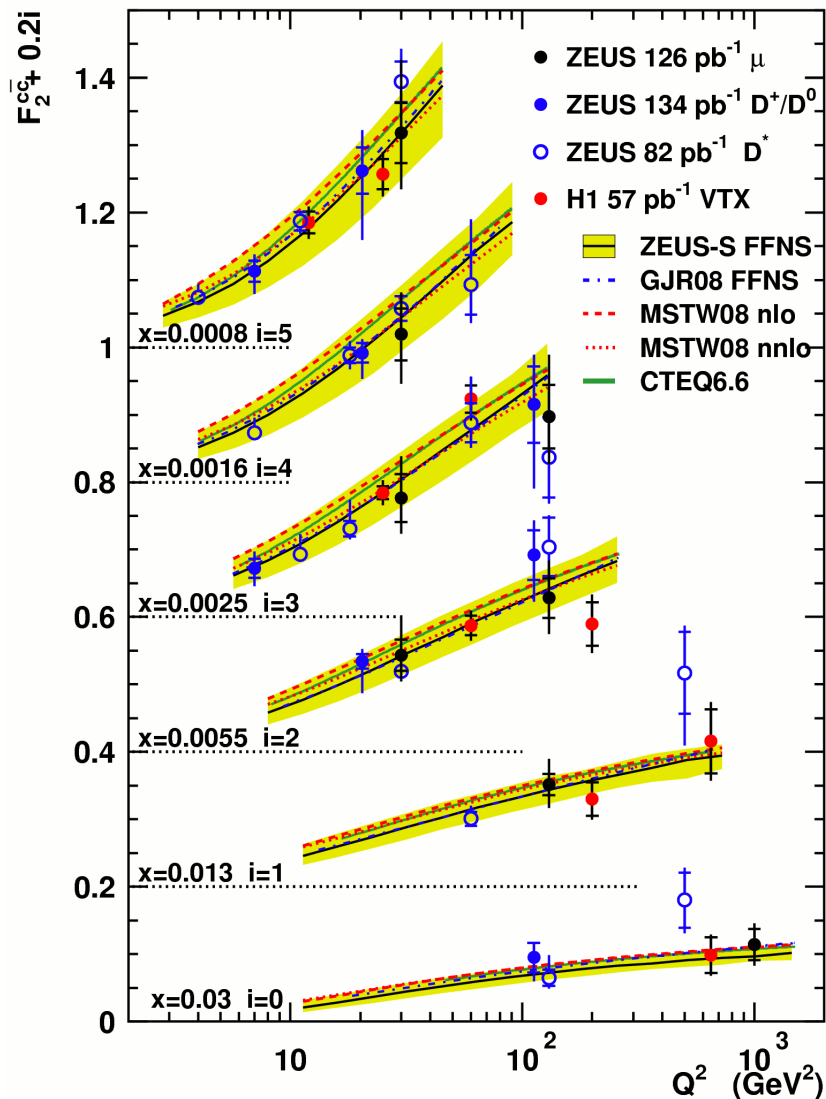
- At high Q^2 the precision of the presented data is similar or better than previous results

FFNS: ZEUS-S
GJR08

GM-VFNS: MSTW08 NLO
MSTW08 NNLO

F_2^{cc} as a function of Q^2

HERA



• The measurements are described by the shown QCD predictions

FFNS: ZEUS-S
GJR08

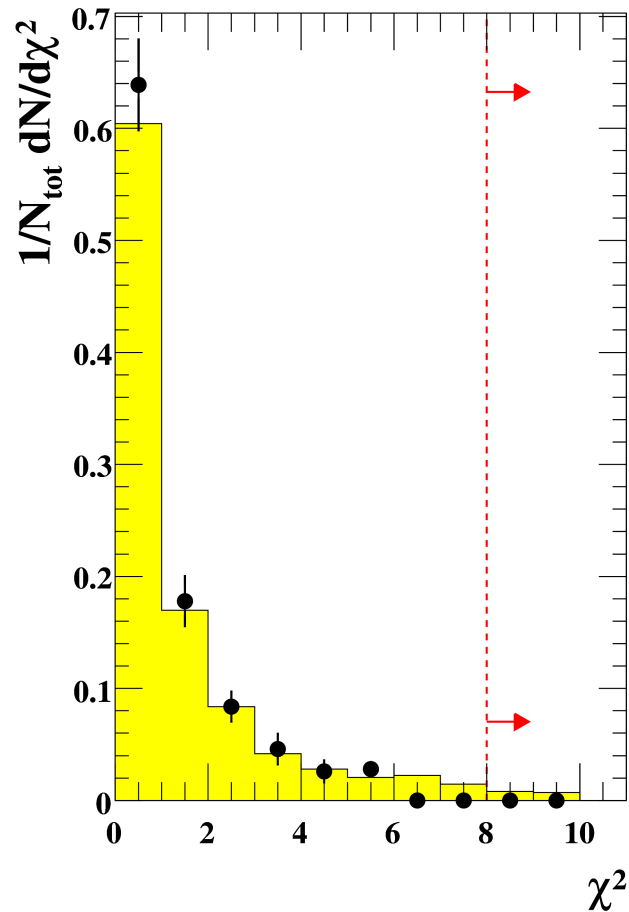
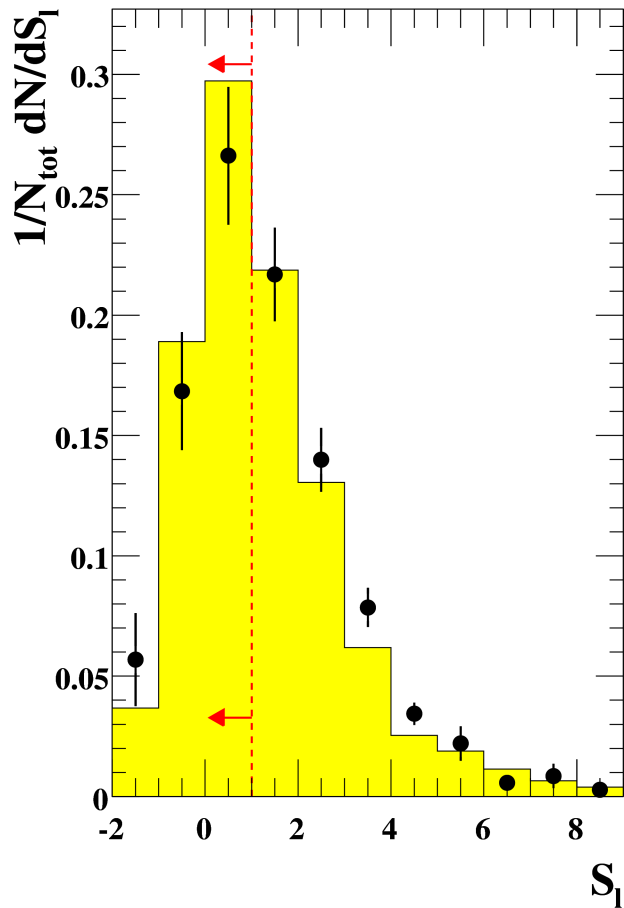
GM-VFNS: MSTW08 NLO
MSTW08 NNLO
CTEQ6.6

Summary

- Charm production has been measured using the decay channels $D^+ \rightarrow K^- \pi^+ \pi^+$ (+c.c.) and $D^0 \rightarrow K^- \pi^+$ (+c.c.) and using semileptonic decays to muons
- Single differential cross sections are in good agreement with NLO QCD predictions from HVQDIS
- F_2^{cc} was extracted and is in agreement with previous measurements and QCD predictions
- The precision will be improved further from the analysis of the full HERA II dataset ($\approx 350 \text{ pb}^{-1}$) and by combination of different charm tags

Backup

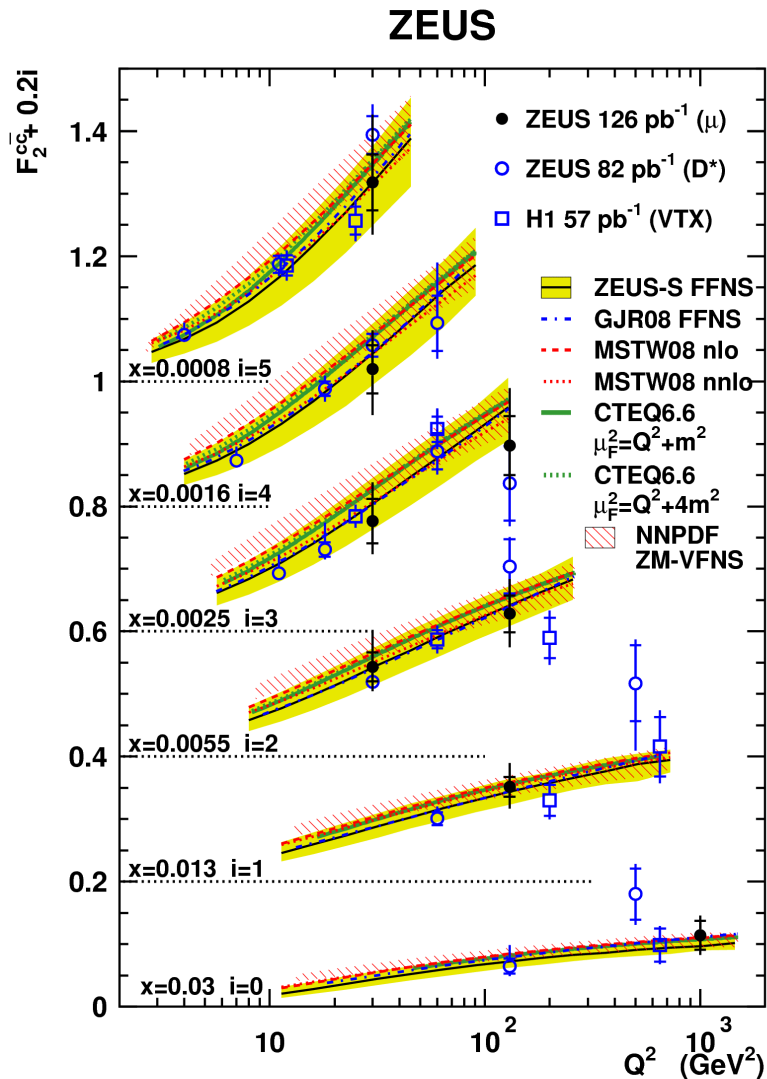
Simulation of secondary vertices: D^0



PDF schemes and parameters

PDF	Order	Scheme	μ^2	m_c [GeV]	m_b [GeV]
ZEUS NLO	α_s^2	FFNS	Q^2+4m^2	1.5	4.75
GJR08	α_s^2	FFNS	m^2	1.3	4.2
CTEQ6.6	α_s^2	GM-VFNS	$\mu_R^2 = Q^2$ $\mu_F^2 = Q^2+m^2$	1.3	4.5
MSTW08 NLO	α_s^2	GM-VFNS	Q^2	1.4	4.75
MSTW08 NNLO	α_s^3	GM-VFNS	Q^2	1.4	4.75

More predictions



FFNS:

ZEUS-S

GJR08

ZM-VFNS:

NNPDF

GM-VFNS:

CTEQ6.6

MSTW08 NLO

MSTW08 NNLO