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

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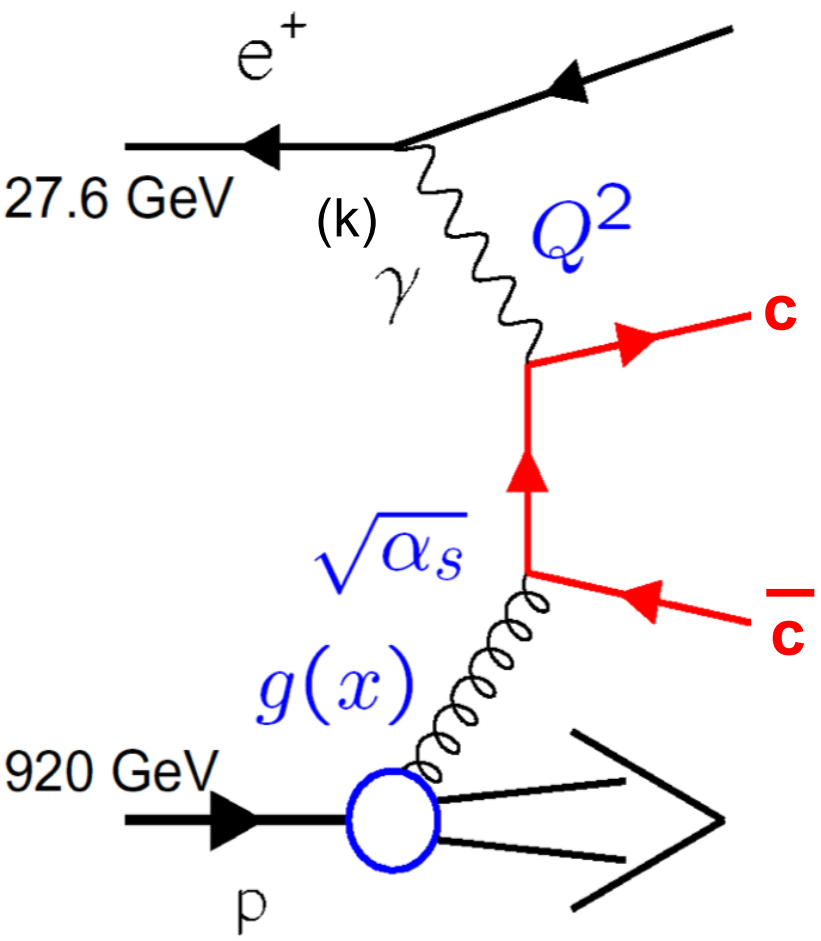
Outline

- 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:

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

pQCD Treatment of charm (and beauty) production in DIS

Massive, FFNS:

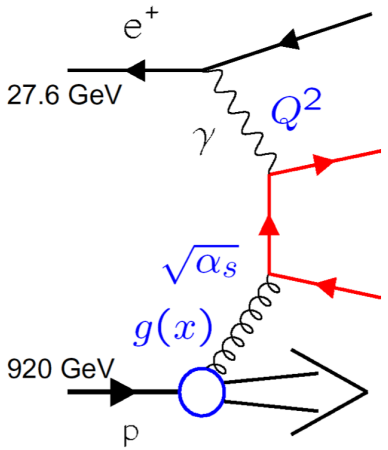
c and b produced dynamically
(not part of proton or photon)

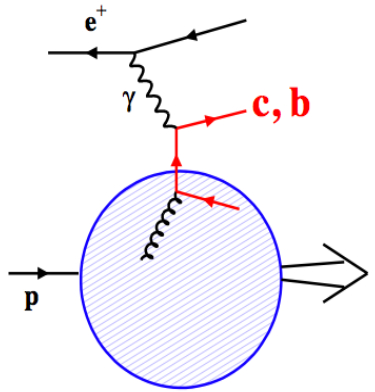
- c, b massive
- Neglects $[\alpha_s \ln(\mu^2 / m^2)]^n$
- Valid at threshold

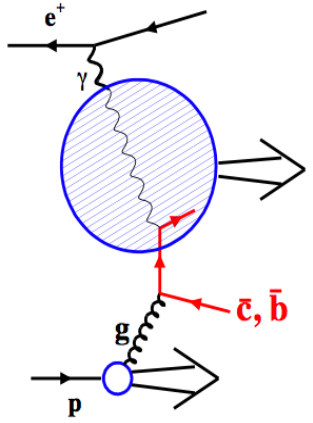
Massless, ZM-VFNS:

c and b massless partons in proton and photon

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







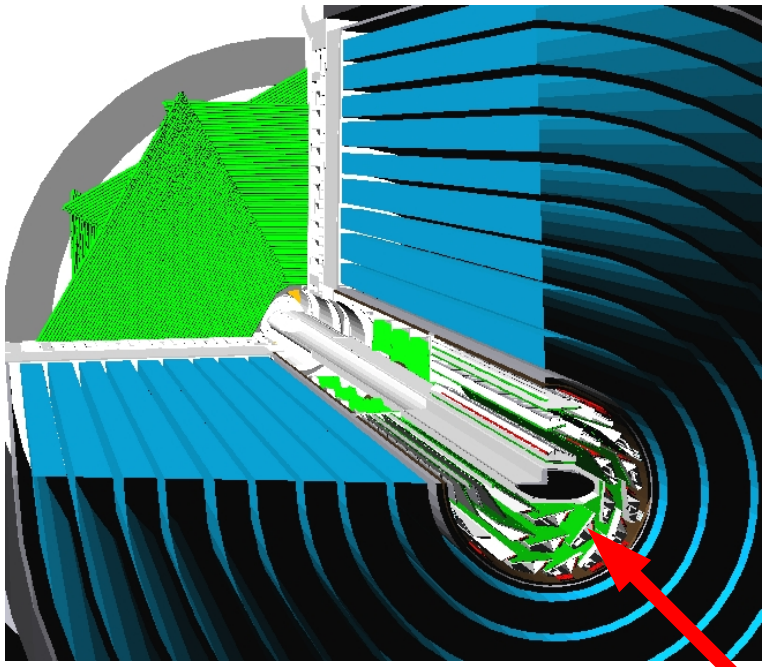
Variable Flavour Number Scheme, (GM)-VFNS:

Interpolates / matches between both approaches

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

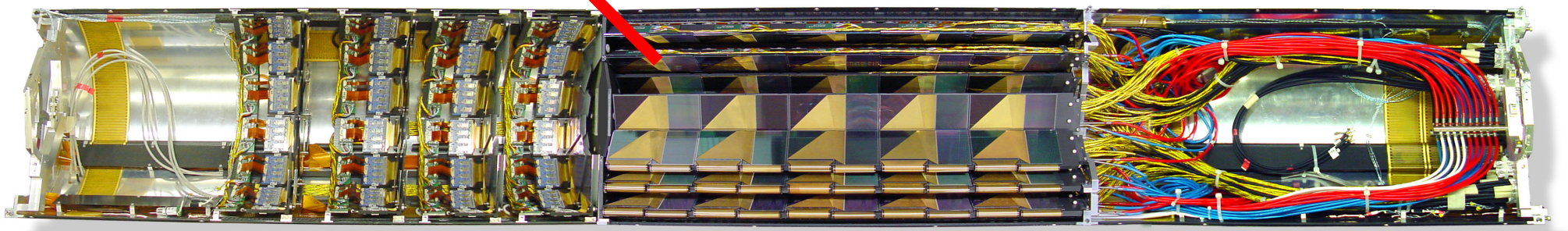
Tracking at ZEUS in HERA II

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)



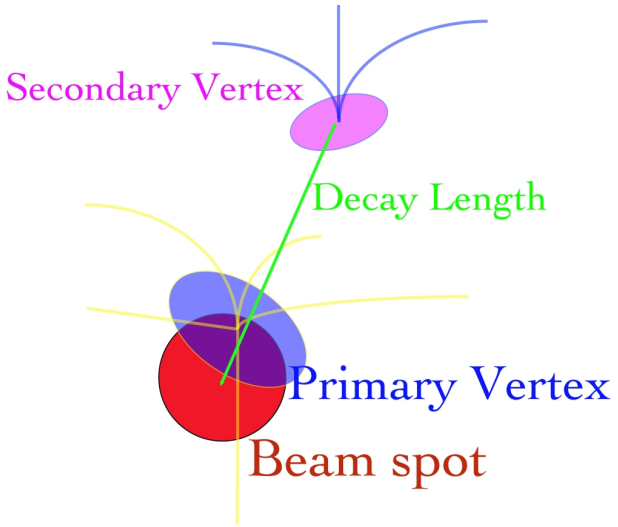
Measurement of $D^{\pm}$ and D^0 production

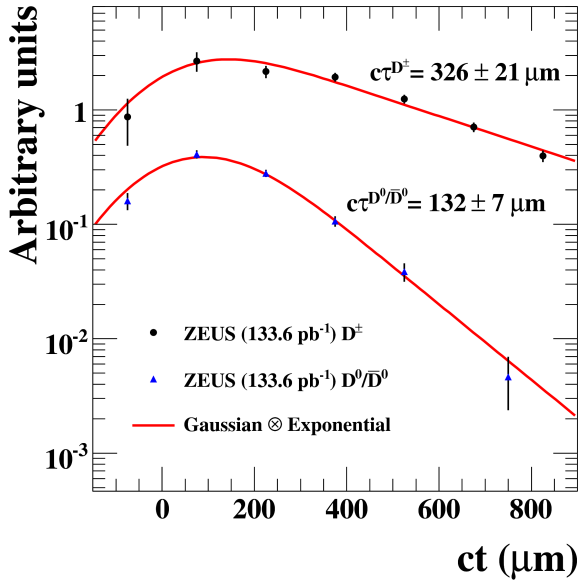
- Charmed mesons are tagged in the decays $D^+ \rightarrow K^-\pi^+\pi^+$ (+c.c.) and $D^0 \rightarrow K^-\pi^+$ (+c.c.)

- 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

- $S_l = L_{XY} / \sigma(L_{XY})$: Positive for charm decays





Reconstruction and simulation of secondary vertices

- **Cuts for $D^{\pm}$:**

χ^2(decay vertex) < 9 for 3 degrees of freedom

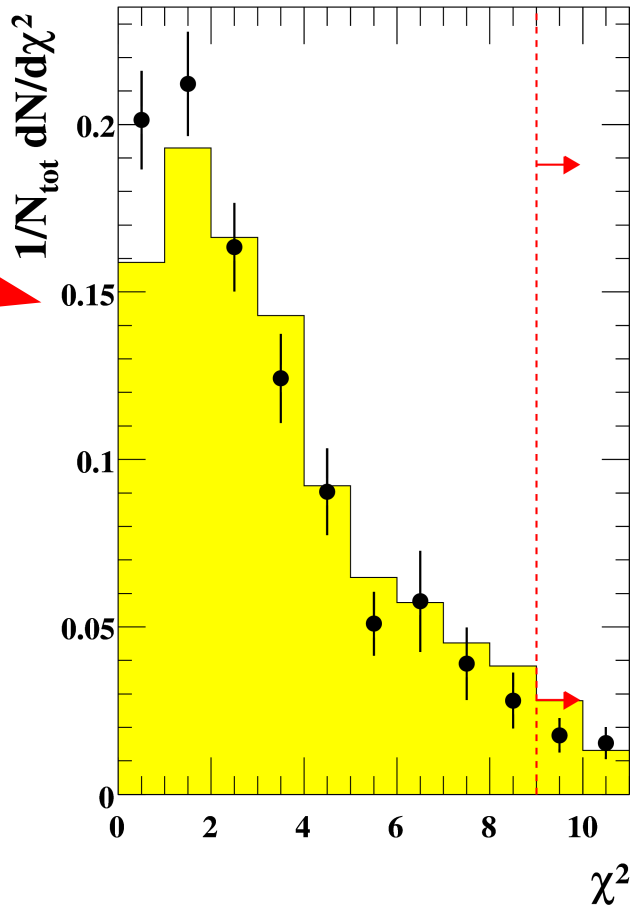
$S_l > 3$

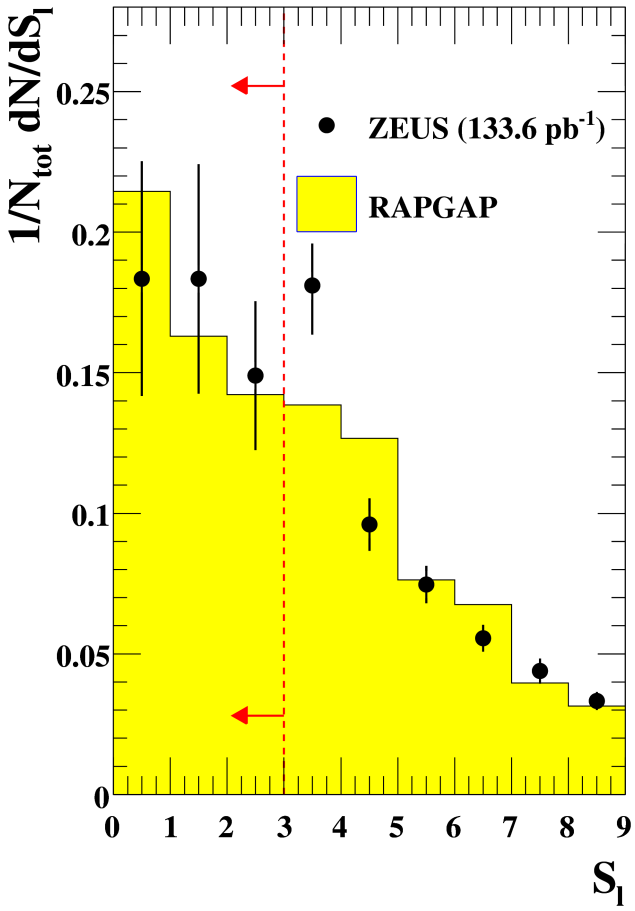
- **Cuts for D^0:**

χ^2(decay vertex) < 8 for 1 degree of freedom

$S_l > 1$

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





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

- **Kinematic range:**

$5 < Q^2 < 1000\ \text{GeV}^2$

$0.02 < y < 0.7$

$1.5 < p_T(D) < 15\ \text{GeV}$

$|\eta(D)| < 1.6$

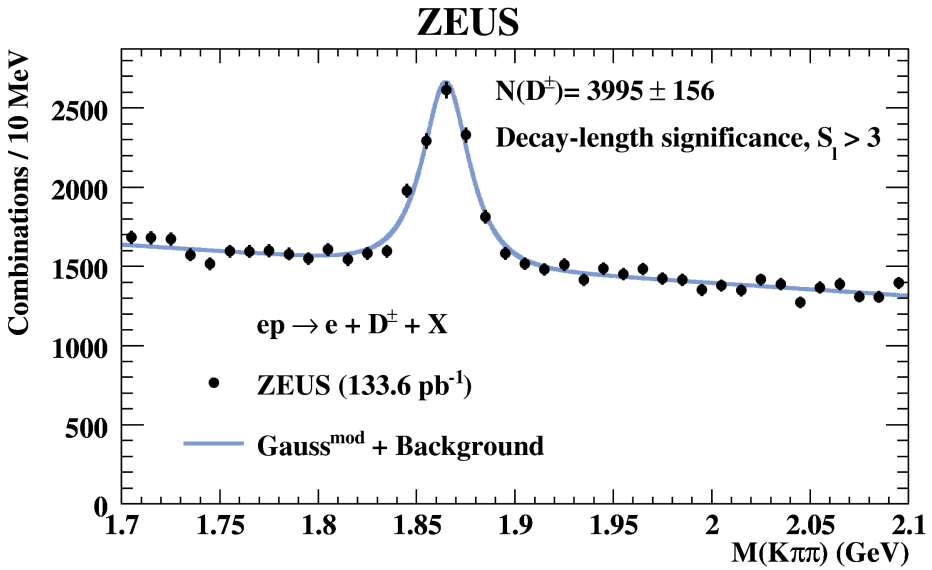
- **Data sample:**

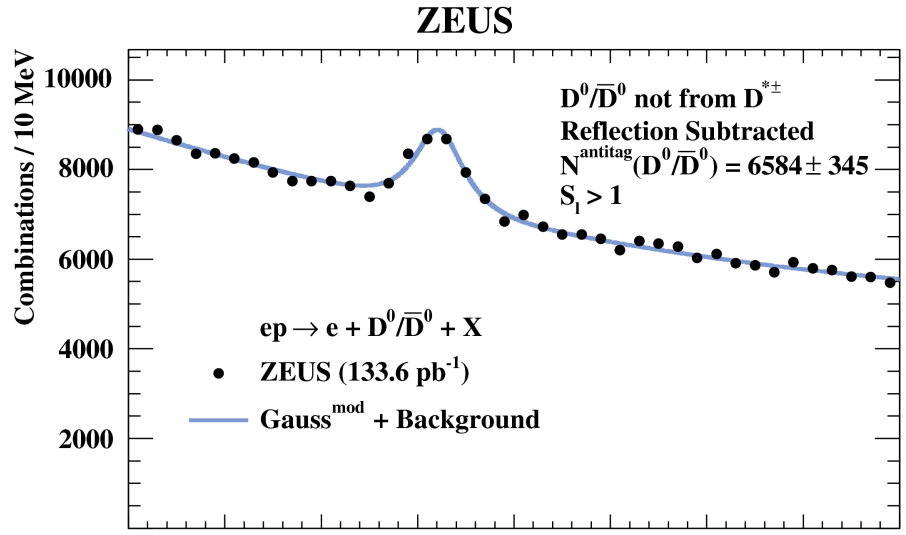
$133.6\ \text{pb}^{-1}$

HERA II

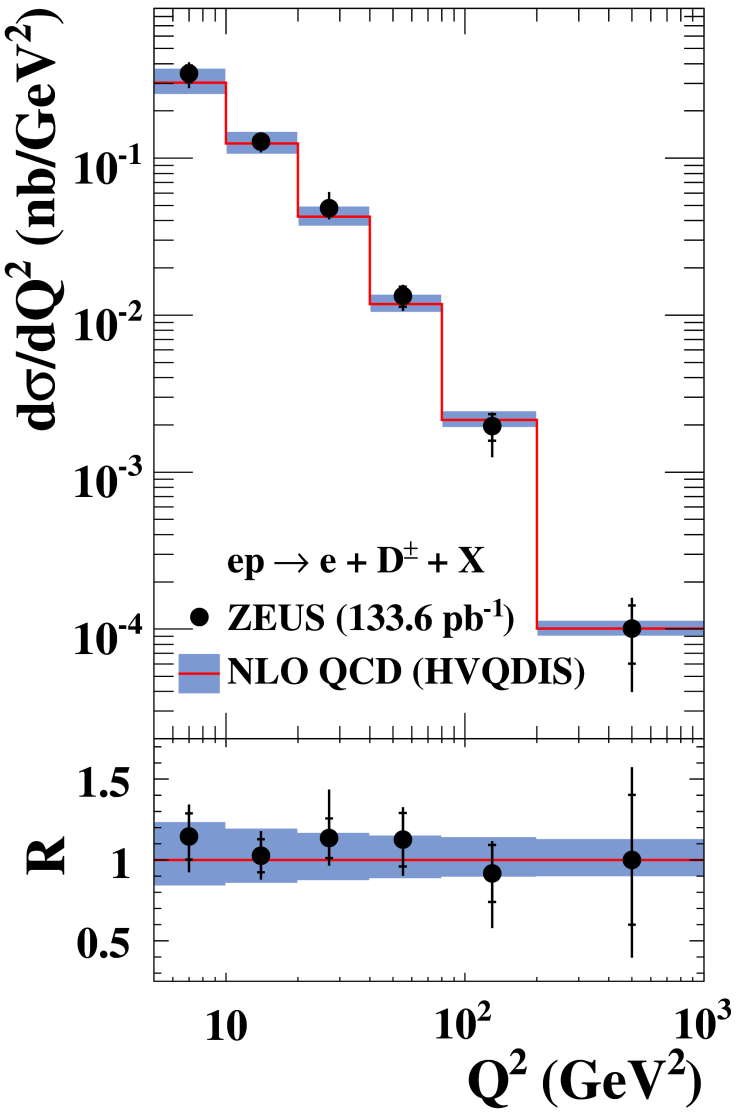
e^-p (2004/05)

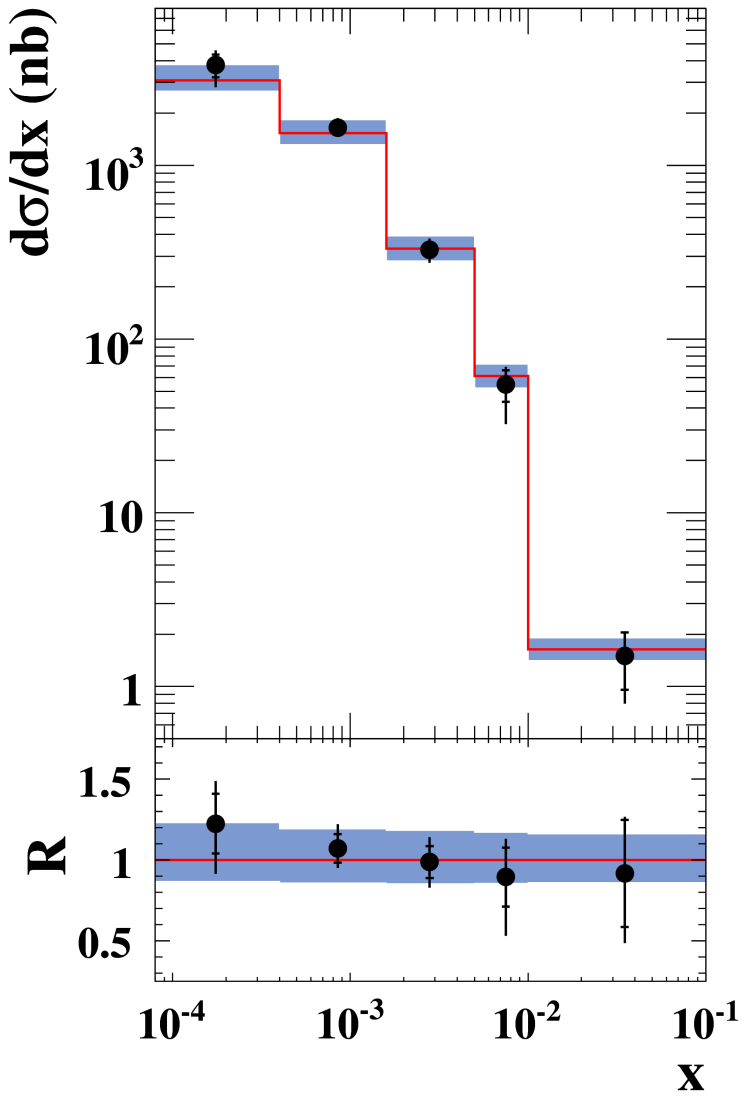
- D^0 mesons not originating from $D^{*\pm}$ decays were used for the cross section measurement





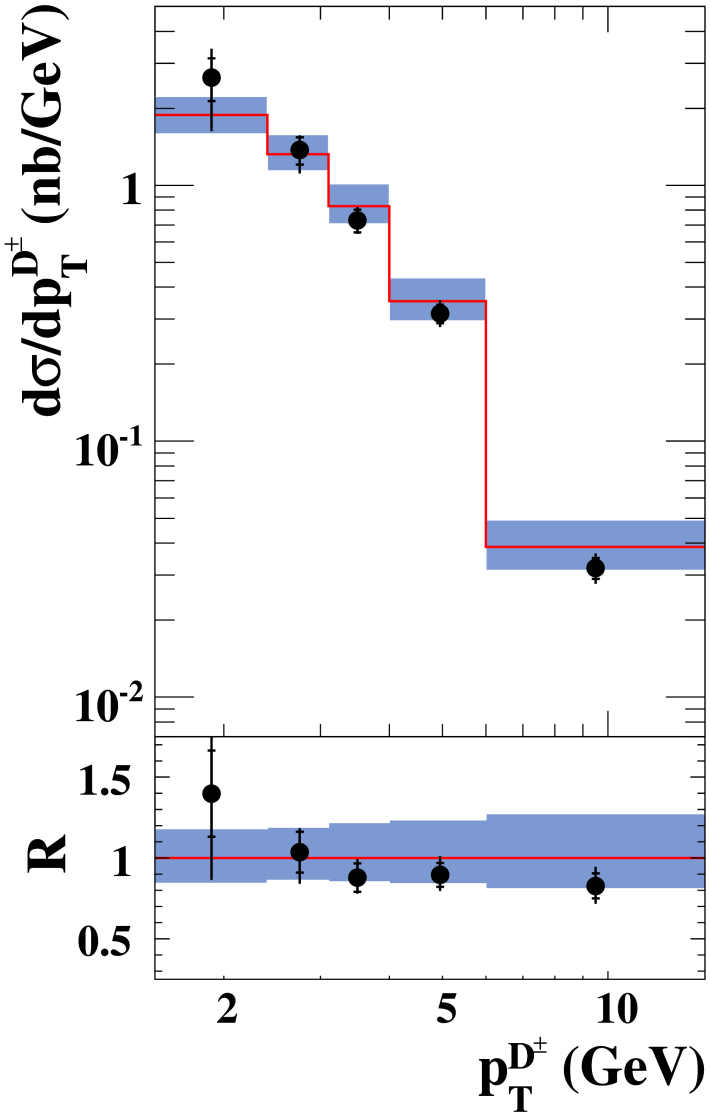
$D^{\pm}$ cross sections: Q^2 and x

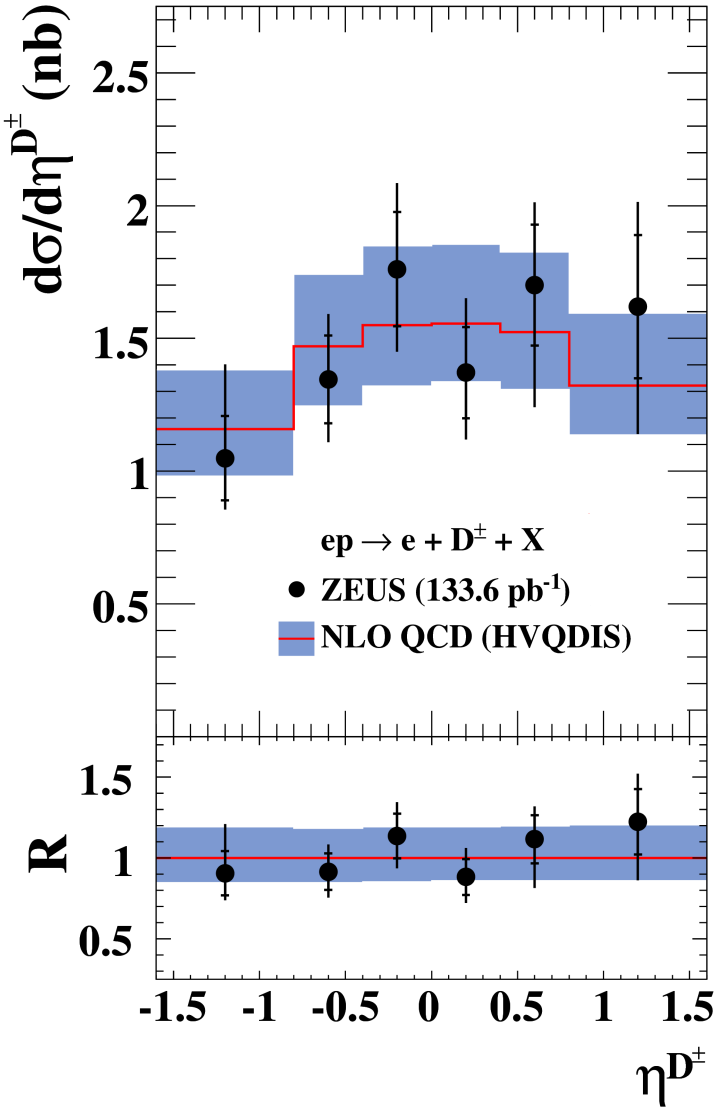




Good description by the HVQDIS NLO QCD prediction (FFNS)

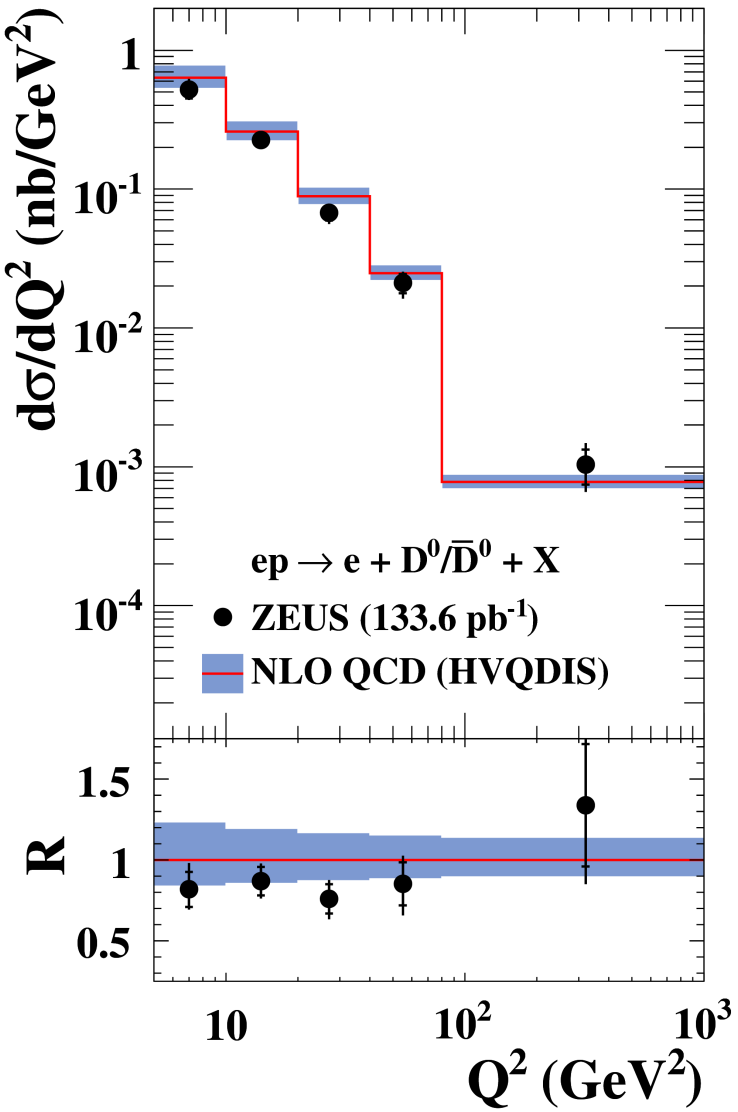
$D^{\pm}$ cross sections: $p_T(D^{\pm})$ and $\eta(D^{\pm})$

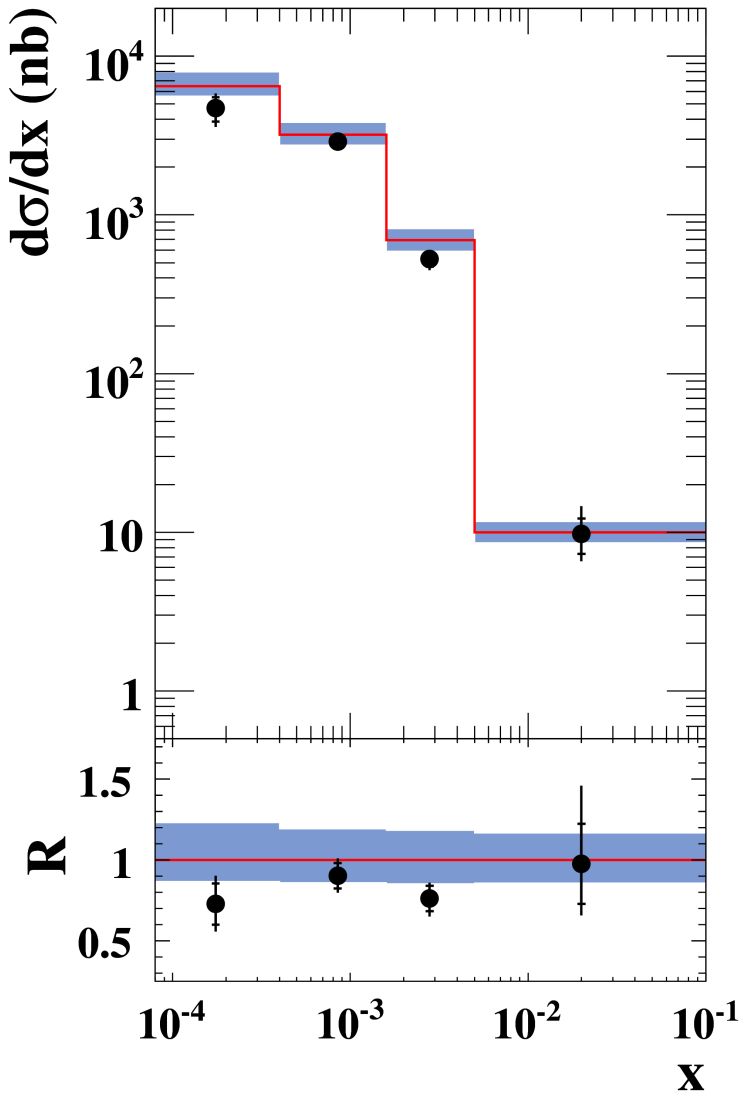




Good description by HVQDIS

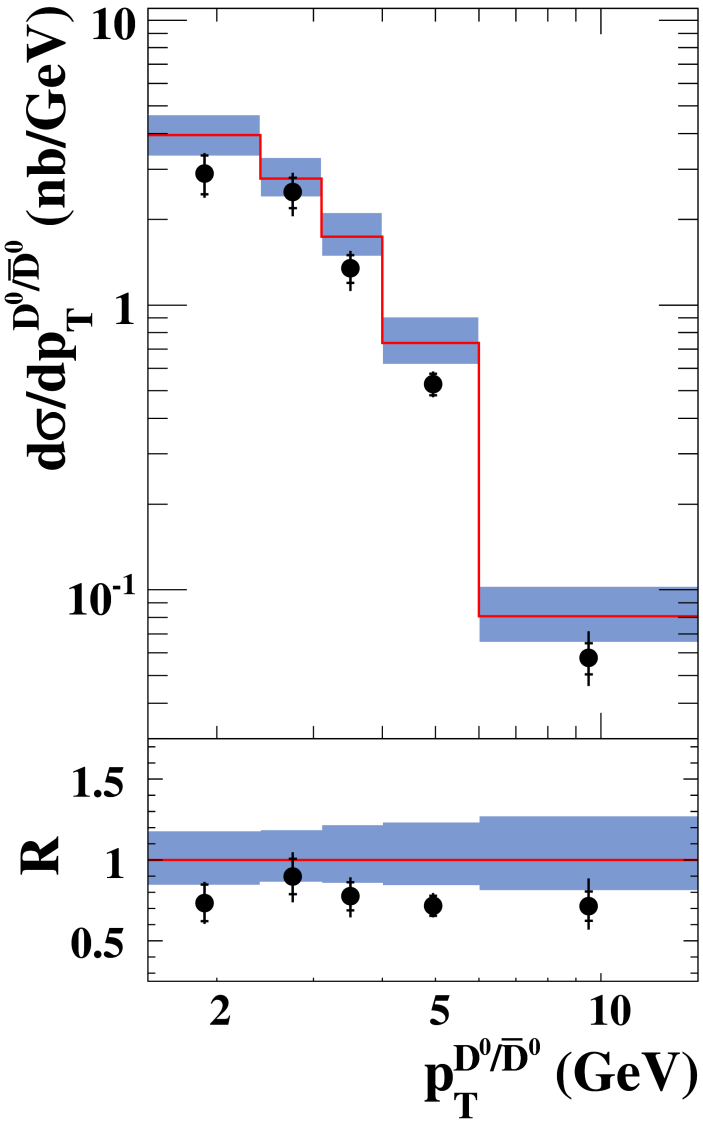
D^0 cross sections: Q^2 and x

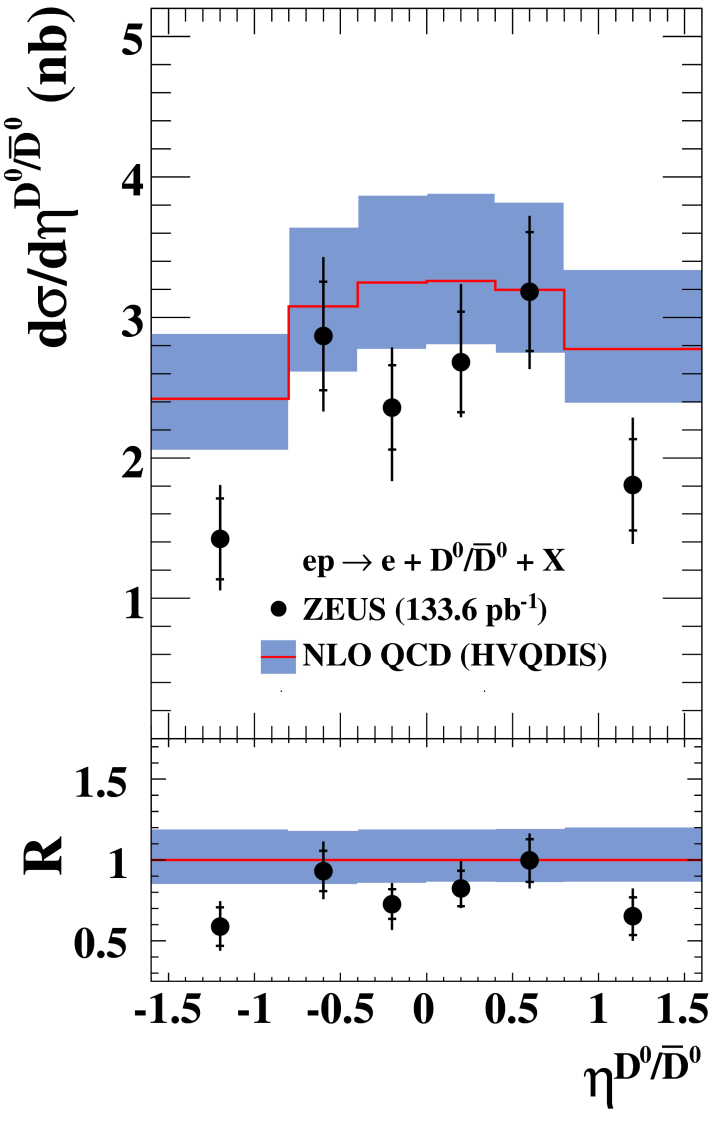




Measurements described by HVQDIS

D^0 cross sections: $p_T(D^0)$ and $\eta(D^0)$





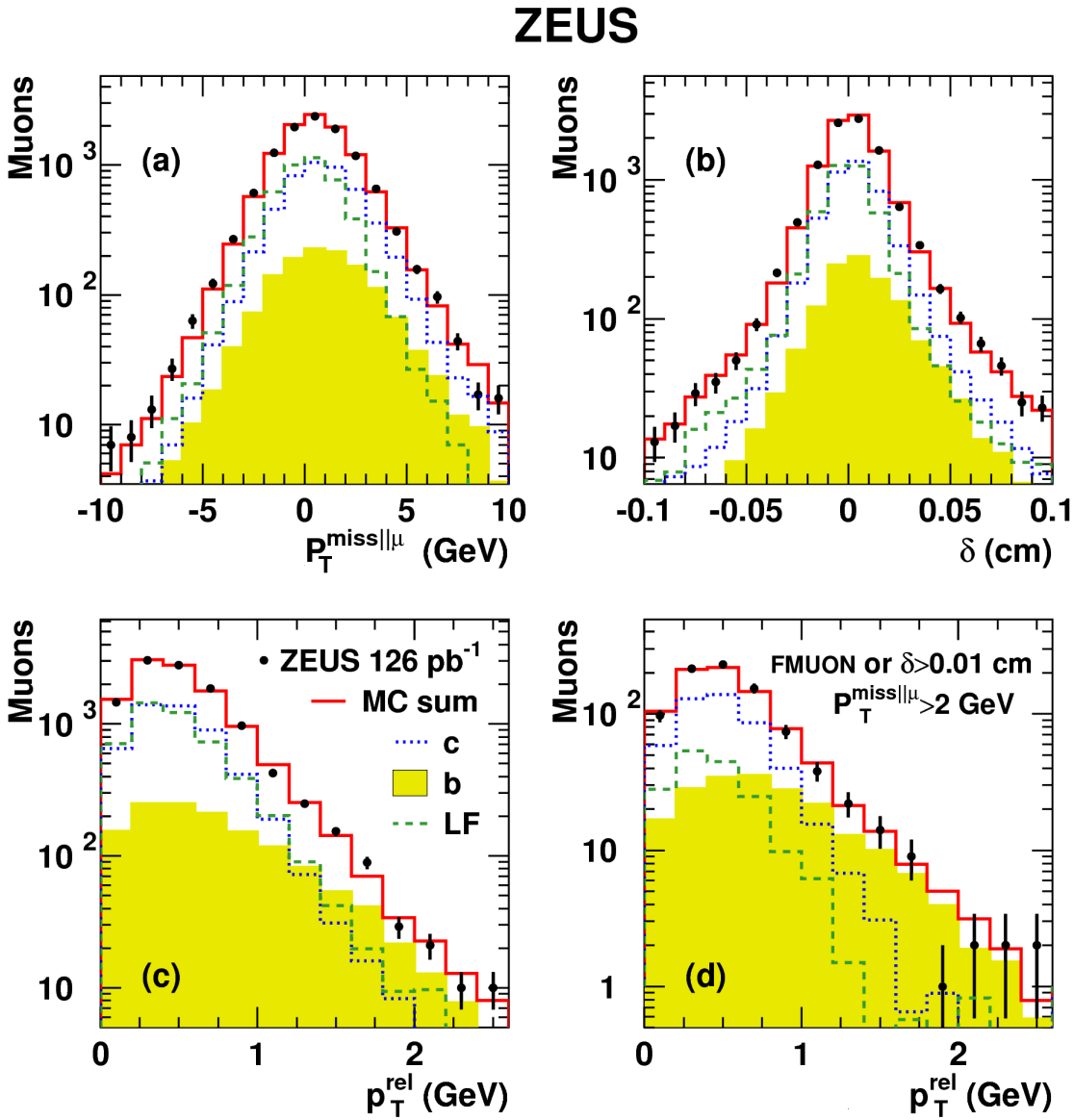
Measurements described by HVQDIS

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:

- $\mathbf{p_T^{rel}}$: the muon momentum component transverse to the jet axis
- **δ:** the impact parameter of the muon track
- $\mathbf{p_T^{miss||\mu}}$: the missing transverse momentum parallel to the muon direction

→ More details in talk by M. Bindi



Muon cross sections

- **Kinematic range:**

$Q^2 > 20\ GeV^2$

$0.01 < y < 0.7$

$p_T(\mu) > 1.5\ GeV$

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

- **Data sample:**

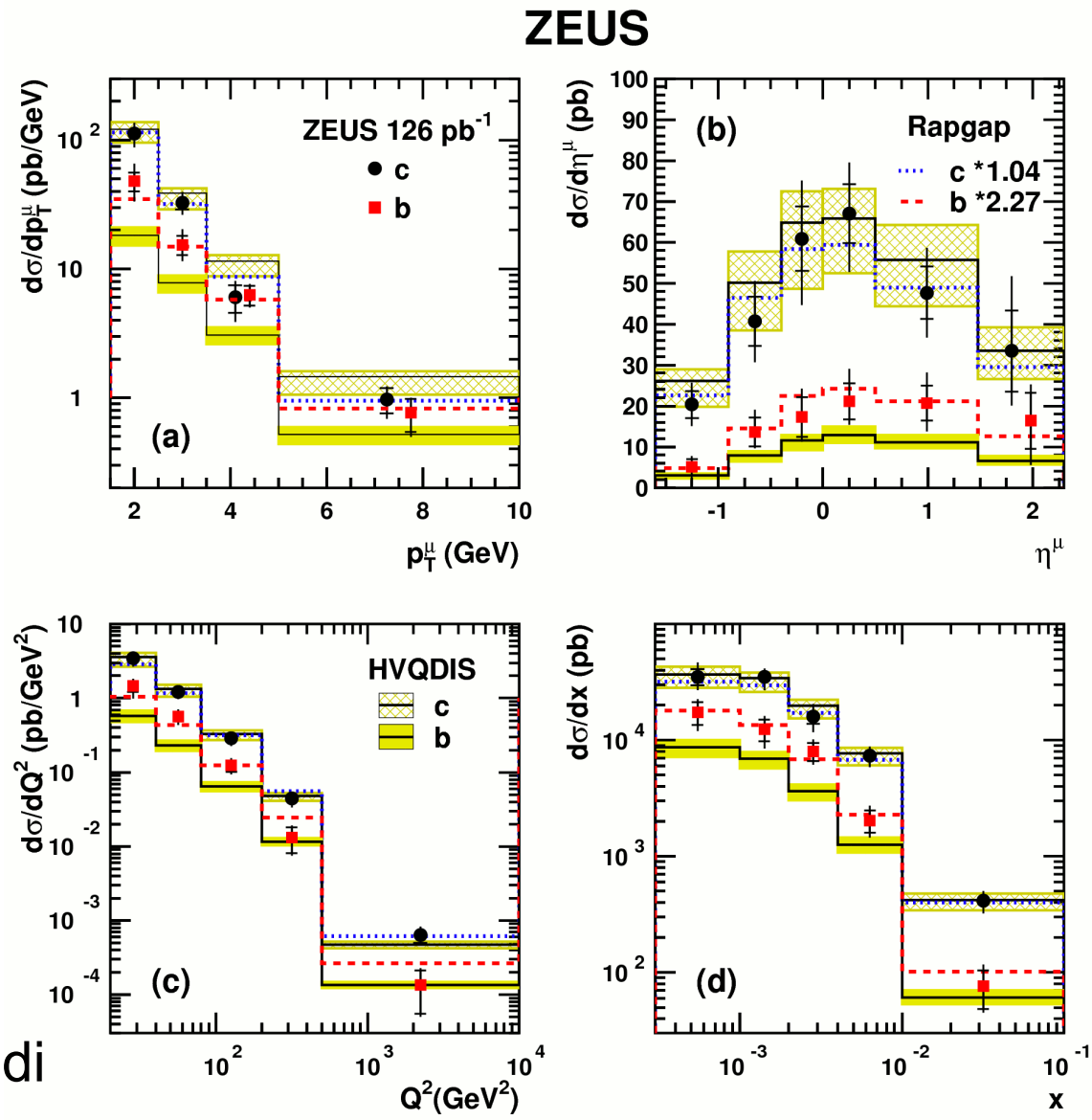
126.0 pb^{-1}

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



Extraction of F_2^{cc}

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)

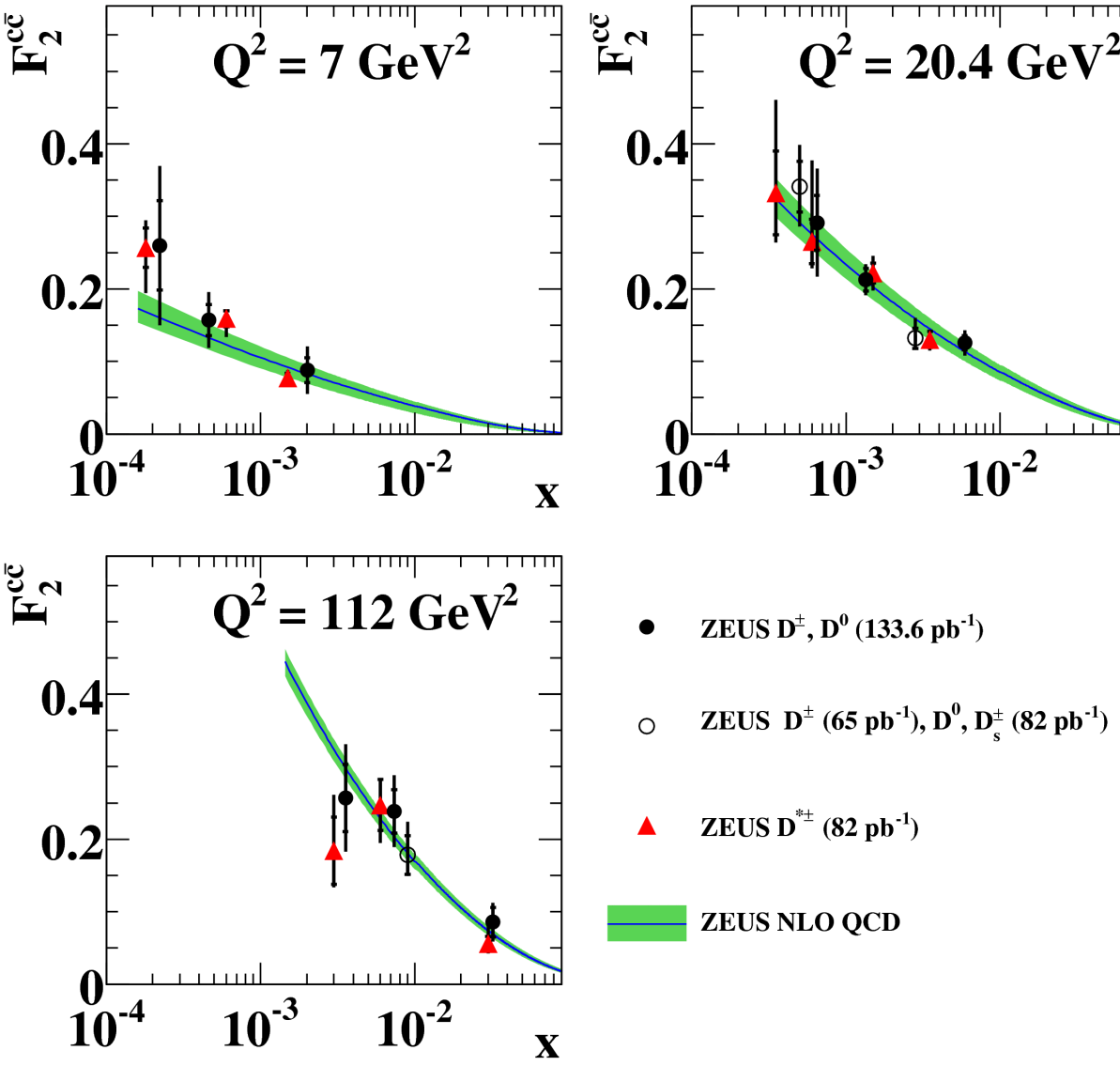
Calculated at NLO in FFNS

Extrapolation factors for $D^{\pm}$ and D^0 measurement:

1.5 (at high Q^2) – 3.2 (at low Q^2)

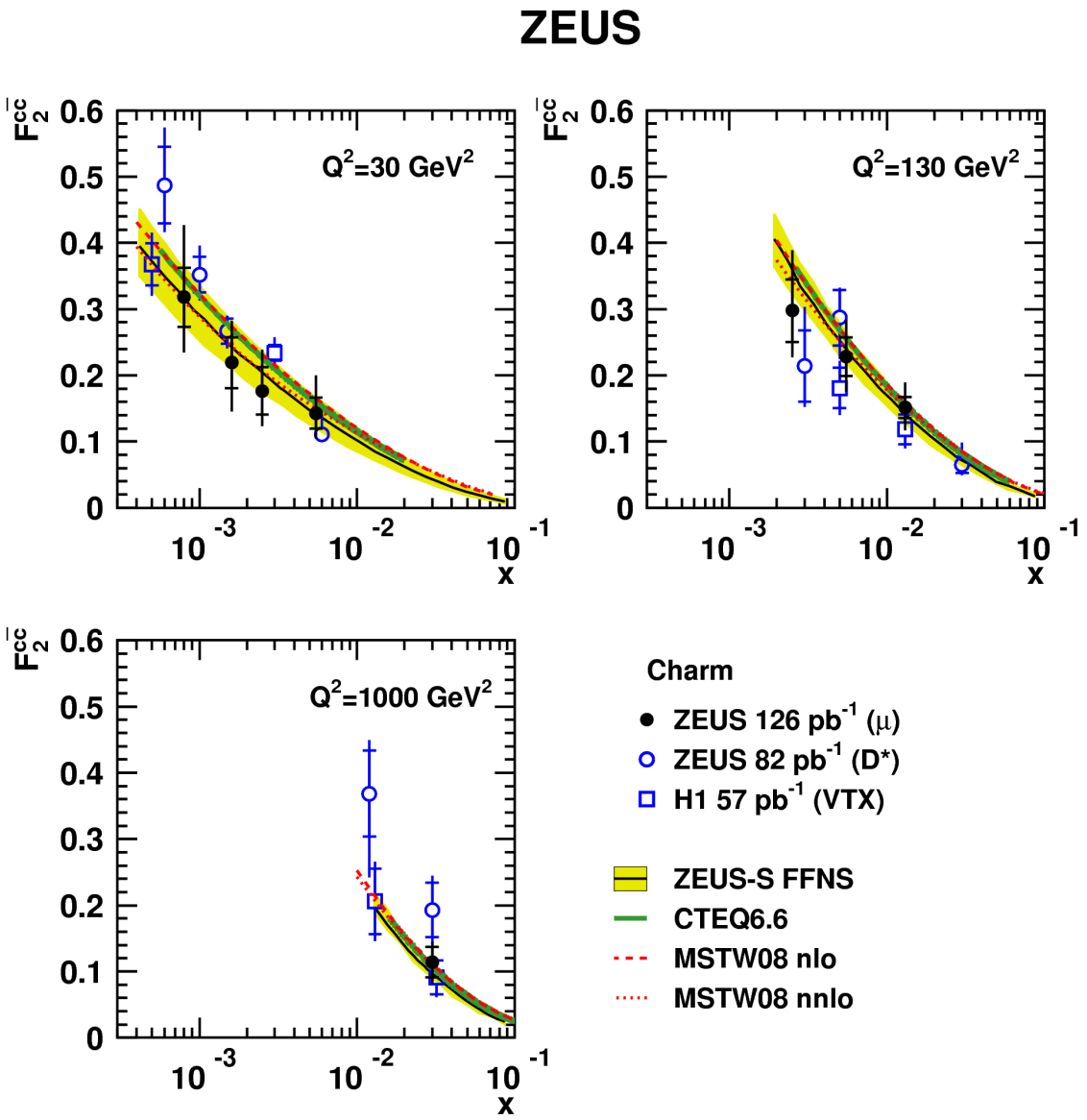
→ Lower than in previous $D^{\pm}$ and D^0 analysis due to lower $p_T(D^{\pm}, D^0)$ cut

$F_2^{c\bar{c}}$ from $D^{\pm}$ and D^0



- $F_2^{c\bar{c}}$ 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



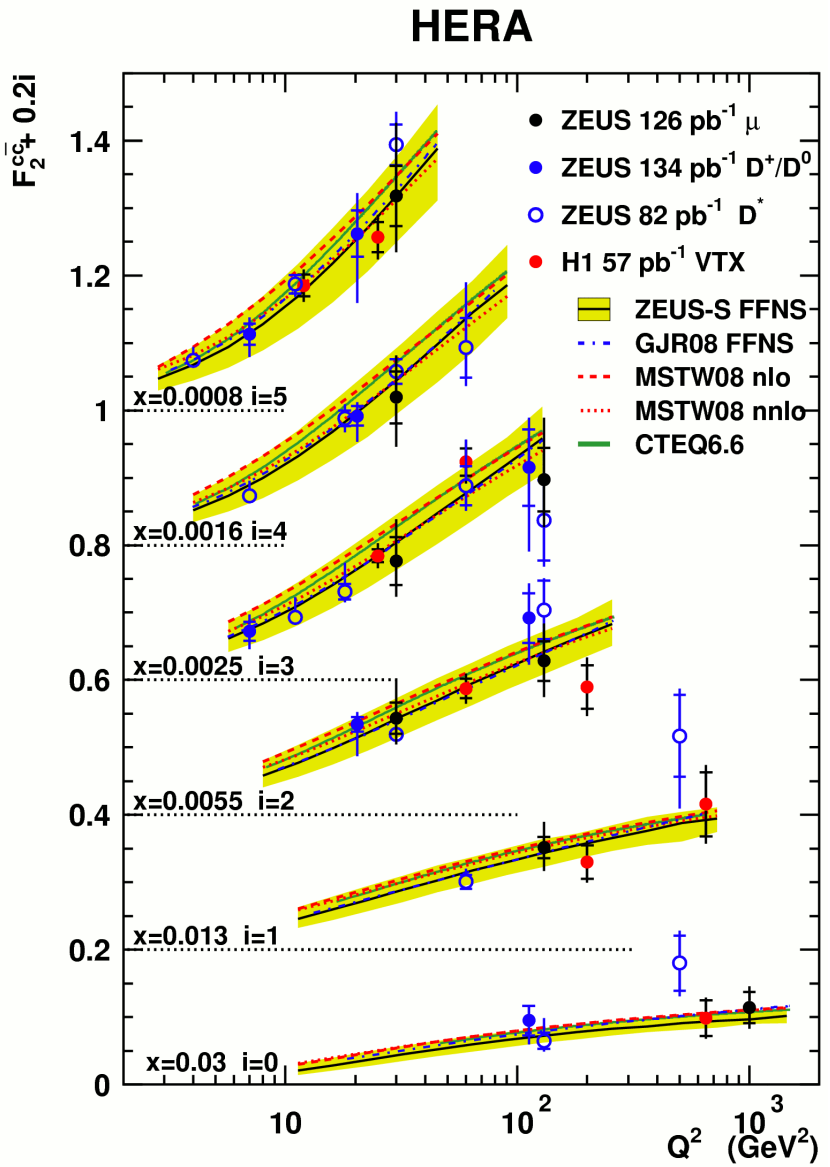
- The agreement between different charm tagging methods is good

- 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

$F_2^{c\bar{c}}$ as a function of Q^2



- 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

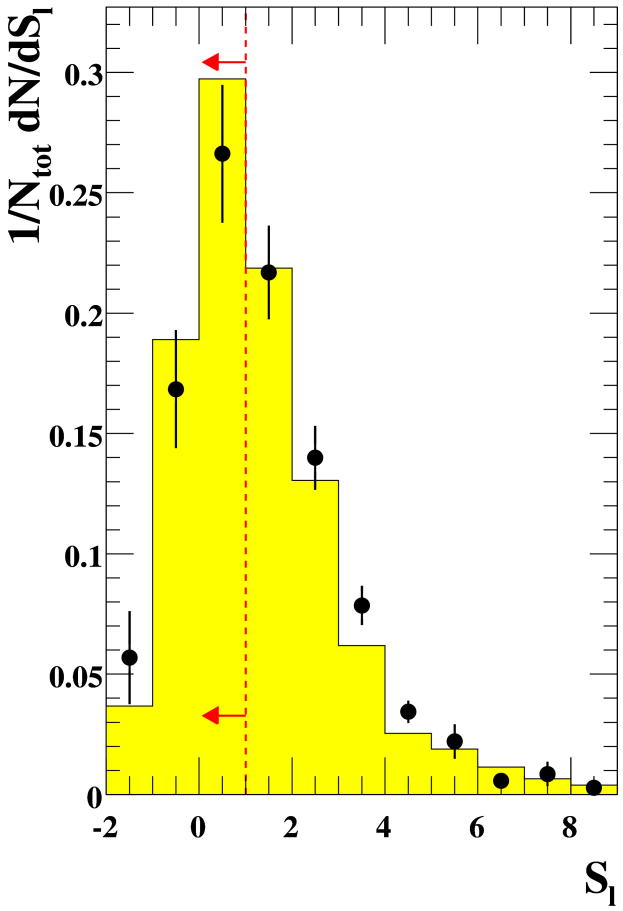
- Single differential cross sections are in good agreement with NLO QCD predictions from HVQDIS

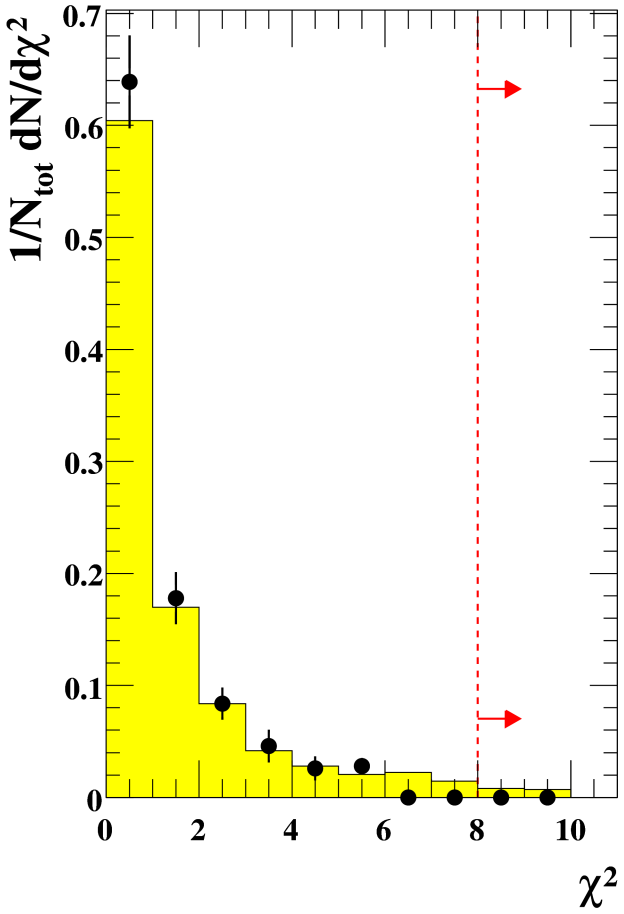
- F_2^{cc} was extracted and is in agreement with previous measurements and QCD predictions

- The precision will be improved further from the analysis of the full HERA II dataset ($\approx 350\ pb^{-1}$) and by combination of different charm tags

Backup

Simulation of secondary vertices: D^0

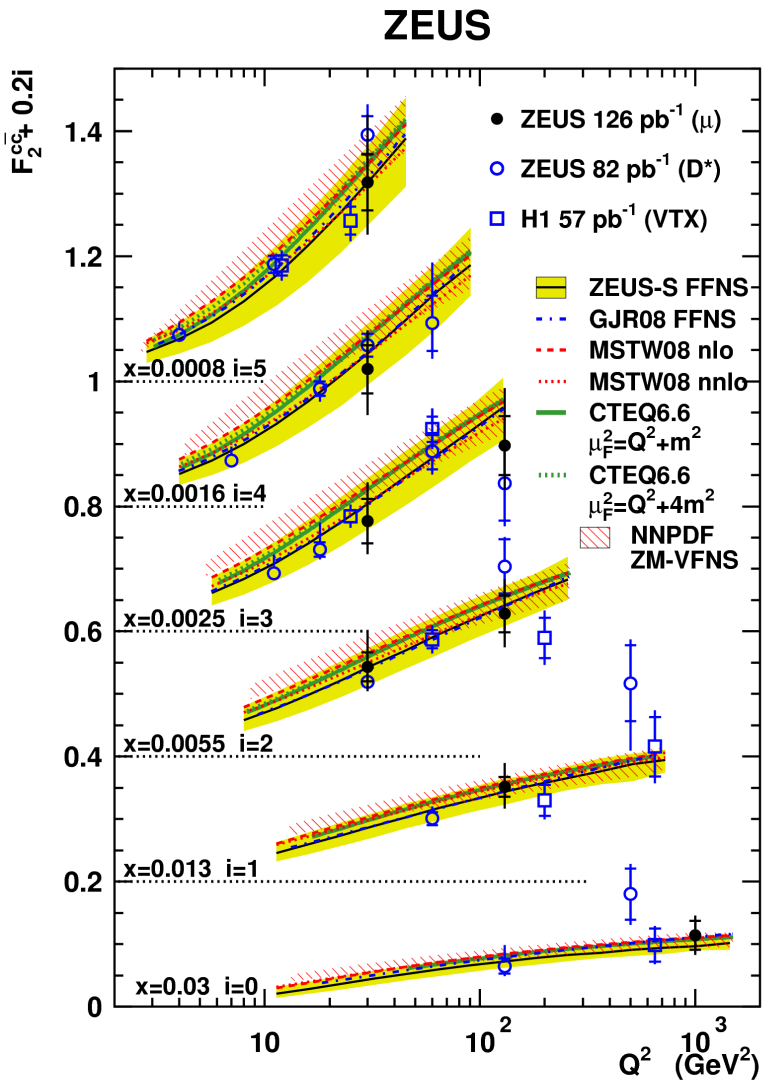




PDF schemes and parameters

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