EPS-HEP 2013
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Measurement of charm production in DIS and extraction of $F_2^{c\bar{c}}$ with ZEUS

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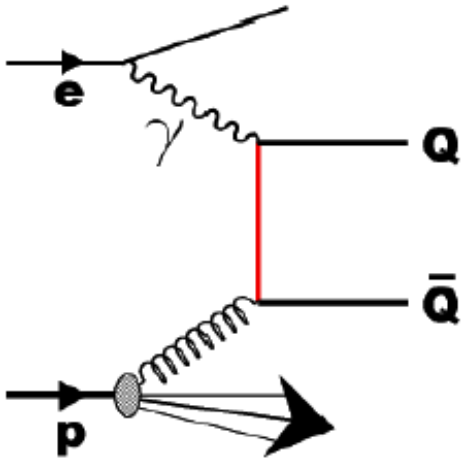
on behalf of the ZEUS Collaboration

-Introduction
- D*
- D^+
- jet vertices
- extraction of $\sigma_{red}^{c\bar{c}}$ and $F_2^{c\bar{c}}$
- conclusions

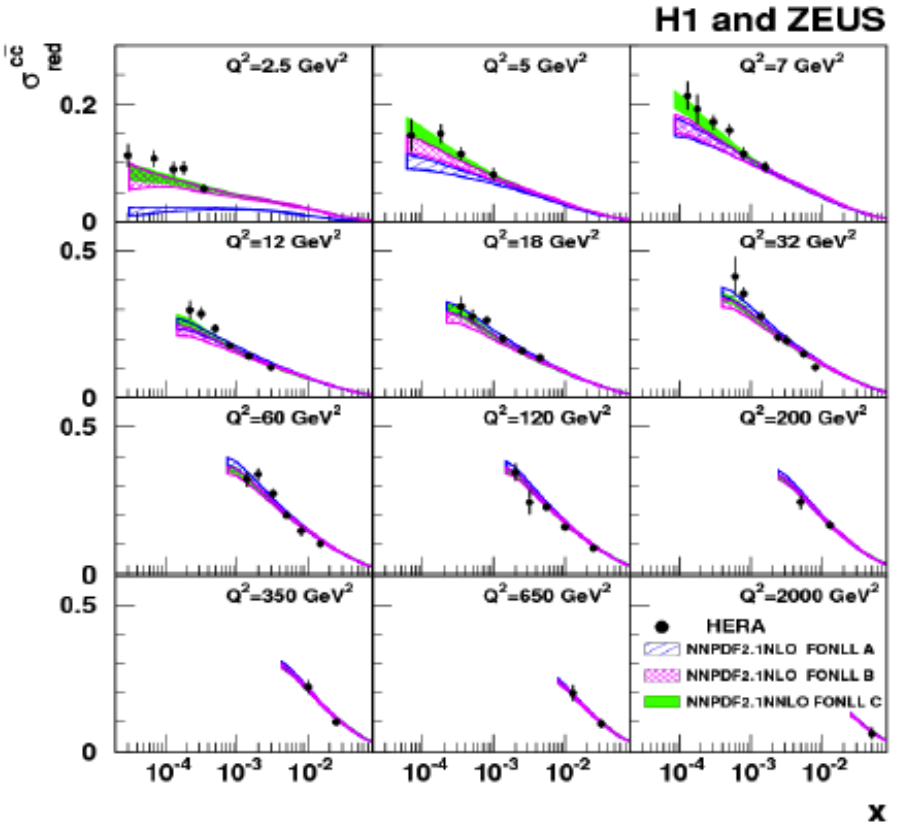
Introduction

- Charm production in DIS
  LO : Boson-gluon fusion (BGF)

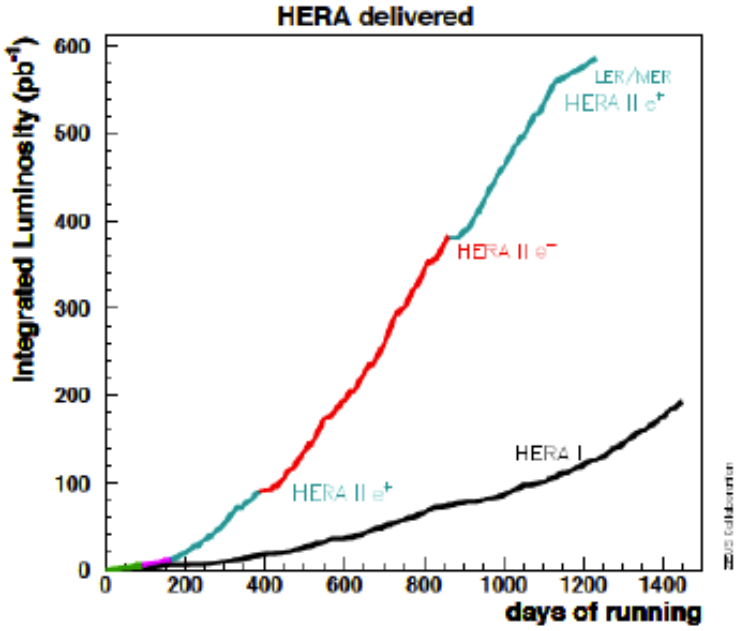


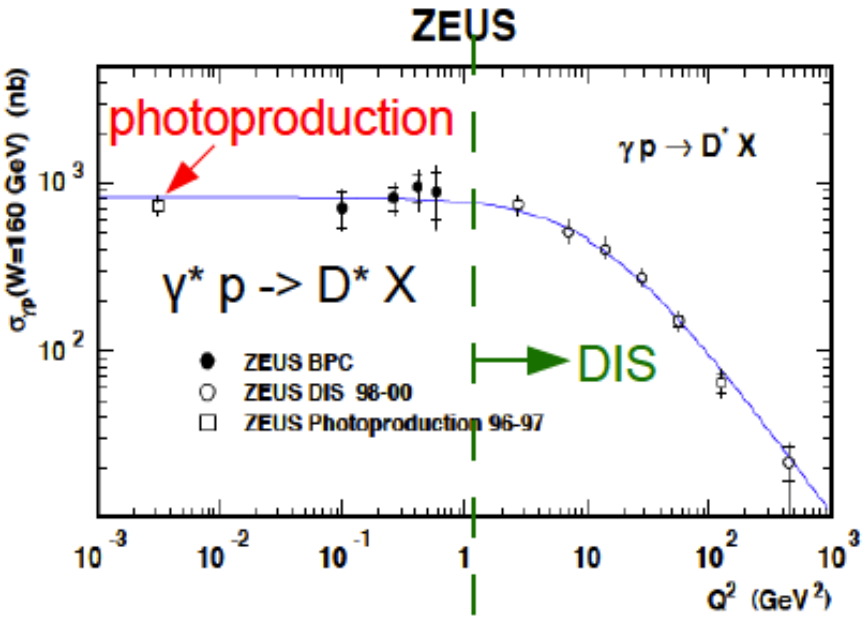
- Access to g(x)
- Sensitivity to m_c
- Test of general-mass variable-flavour-number schemes
  GM-VFNS used
  in global PDF fits

- HERA combined data:
  sensitivity on HQ scheme and m_c
  (see talk by K. Lipka)
- Can we improve it ?



ZEUS data





- ZEUS Total physics luminosity 0.5 fb^{-1}
- HERA-I : 1992-2000
- HERA-II: 2003-2007

Charm production measurements in DIS:

Included in HERA combination:
- HERA-I data: D* L= 119 pb^{-1}
- '05 e$^-$p data: D^0, D$^+$, μ L= 134 pb^{-1}

NEW (this presentation):
- HERA-II D* (JHEP05(2013)097) L= 363 pb^{-1}
- HERA-II D$^+$ (JHEP05(2013)023) L= 354 pb^{-1}
- Inclusive lifetime tagging (ZEUS-prel-12-002) L=354 pb^{-1}

--> factor 3 increase in luminosity for D*, D$^+$ + new method

$D^{*+/-}$ channel

"Golden" decay channel: $D^{*+} \to \pi_s^+ D^0 (\to K^- \pi^+)$

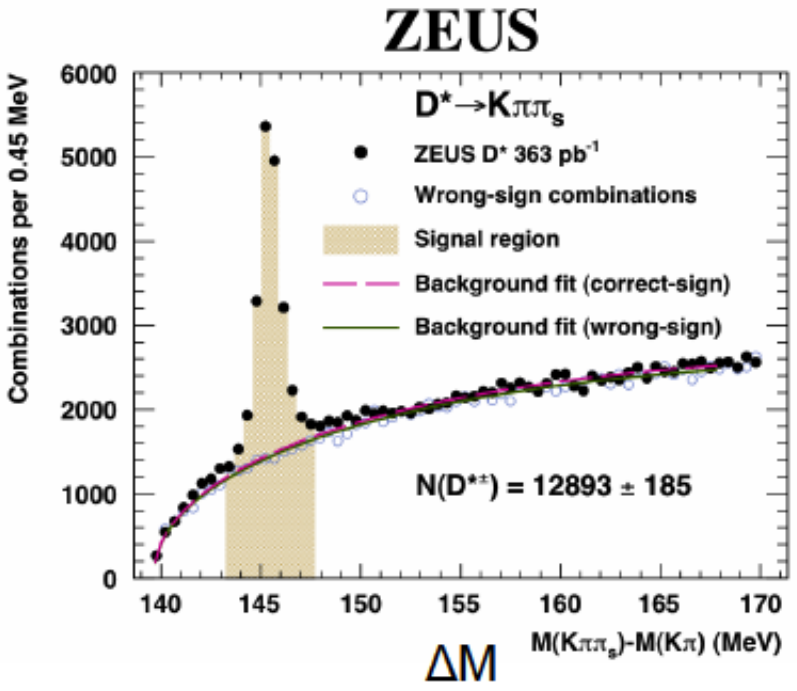
Kinematic range:
- $1.5 < p_T(D^*) < 15$ GeV, $|\eta(D^*)| < 1.5$
- $5 < Q^2 < 1000$ GeV^2, $0.02 < y < 0.7$

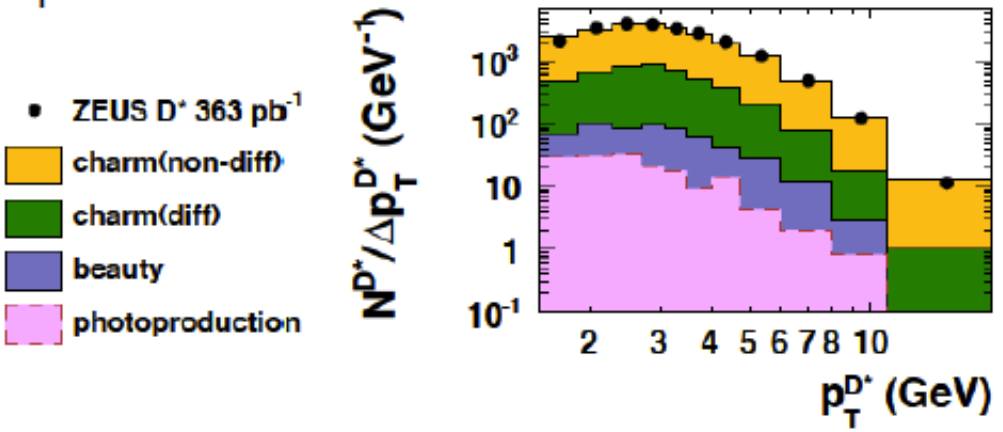
Bkg estimated from fit to wrong-sign and correct-sign sidebands.

Rapgap MC, reweighted in η, p_T, Q^2 used for acceptance corrections

Syst. uncertainty: total ~5%
(depending on bin, increasing at low y and low p_T)
Including:
- track efficiency (~2%),
- signal extraction (~2.5%),
- MC modelling (~3.5%),

Normalization: Lumi (±1.9%), BR (±1.5%)





D*+/- channel

- Differential cross sections in "visible" fiducial region, after QED radiative corrections.

- Compared to HVQDIS fixed flavour-number scheme (FFNS) NLO prediction and Rapgap LO MC

Hvqdis parameters:

$m_c = 1.5 \pm 0.15$ GeV;

$\mu_f = \mu_r = \sqrt{Q^2 + 4m_c^2}$

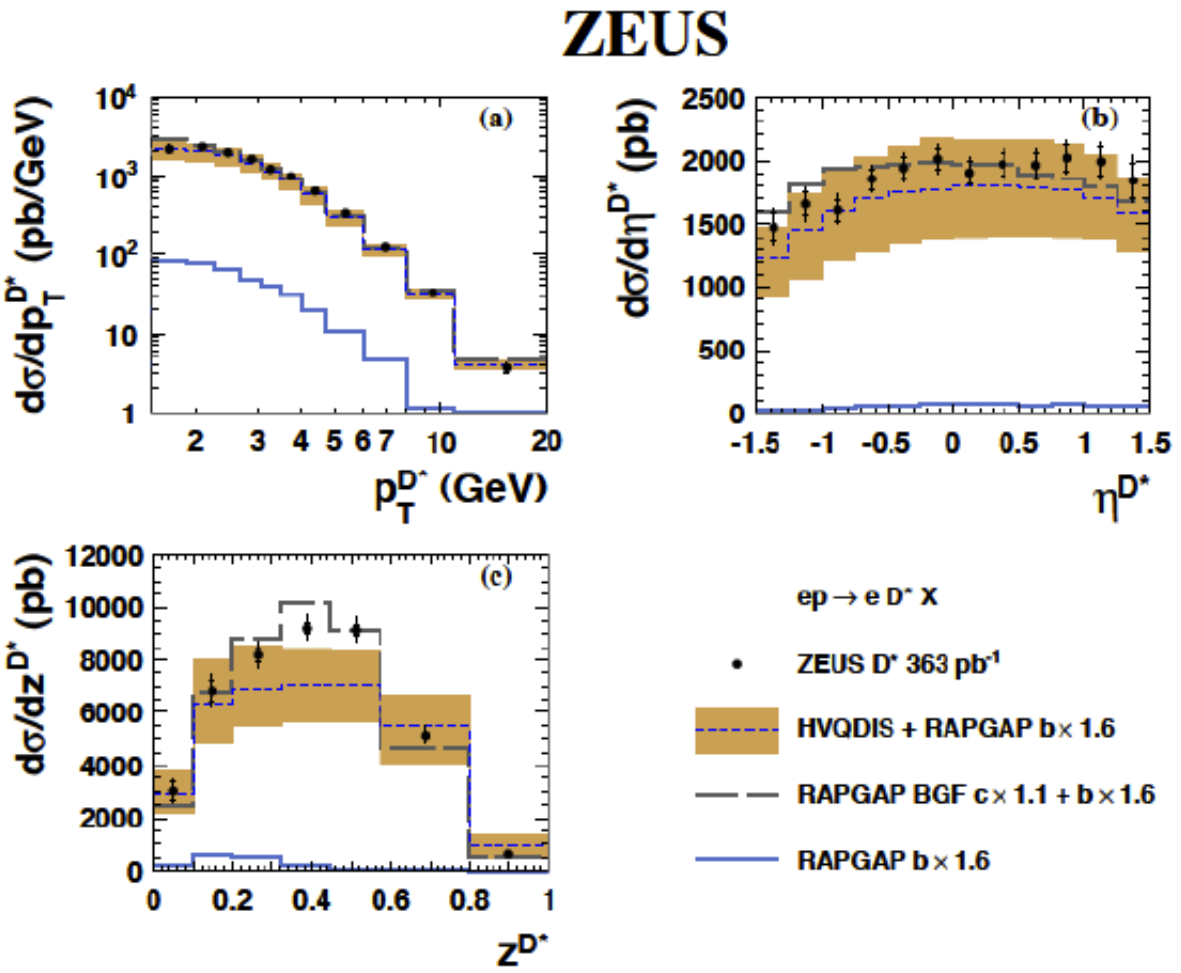
(varied independently by *2, 1/2*)

$\alpha_s^{n_f=3}(M_Z) = 0.105 \pm 0.002$.

HERAPDF1.0 (FFNS variant)

Charm fragmentation-function: Kartvelishvili, scale dependent, fit to *ep* mesurements

D-meson fragmentation fractions: from average of e^+e^- and *ep* data



- Data agree well with FFNS NLO

- Z^{D^*} = fraction of γ* momentum taken by the D* between Hvqdis and Rapgap (sensitive to fragment.)

$D^{+/-}$ channel

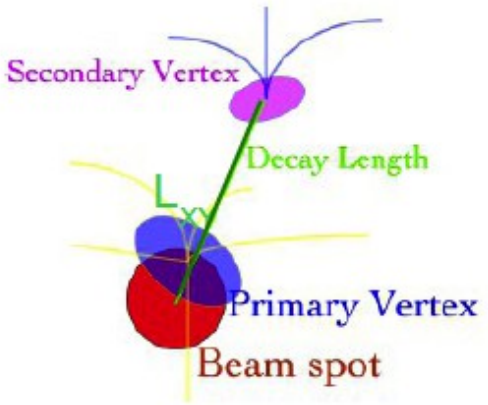
- Decay channel: $D^+ \rightarrow K^- \pi^+ \pi^+$

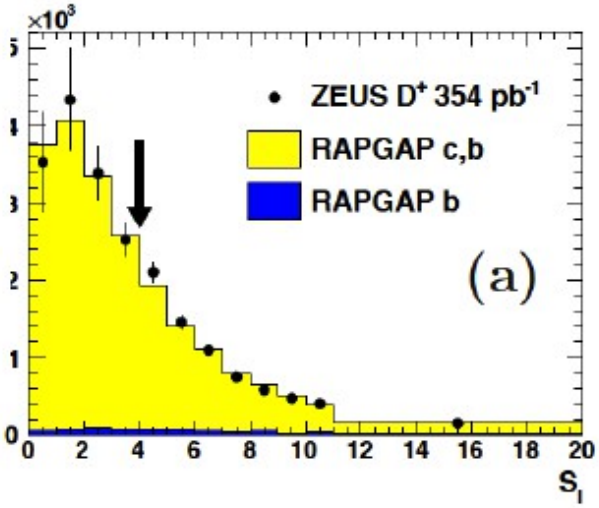
- Kinematic range
  $1.5 < p_T(D^+) < 15$ GeV, $|\eta(D^+)| < 1.6$
  $5 < Q^2 < 1000$ GeV^2, $0.02 < y < 0.7$

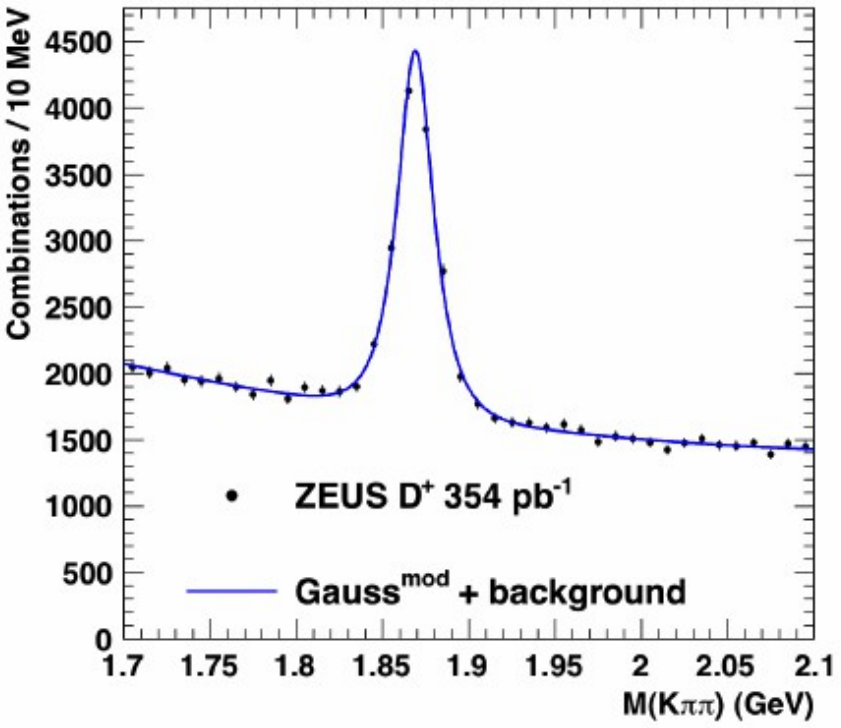
- Cut on decay length significance
  $S_l = L_{XY}/\sigma_{XY} > 4$

- Signal extraction from fit

- Typical syst. uncertainties 5-7%

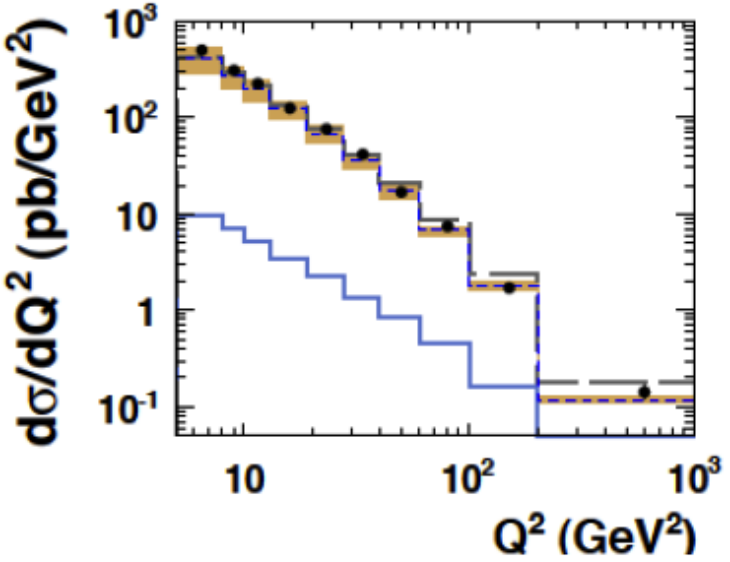


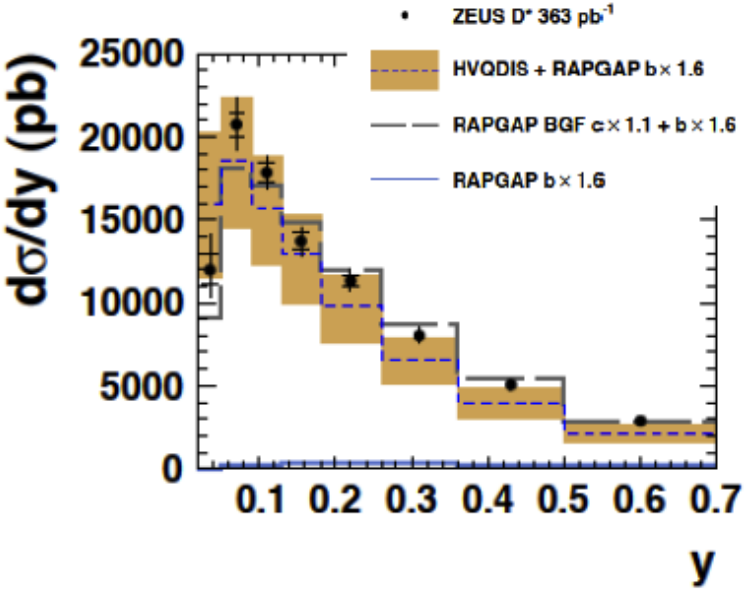


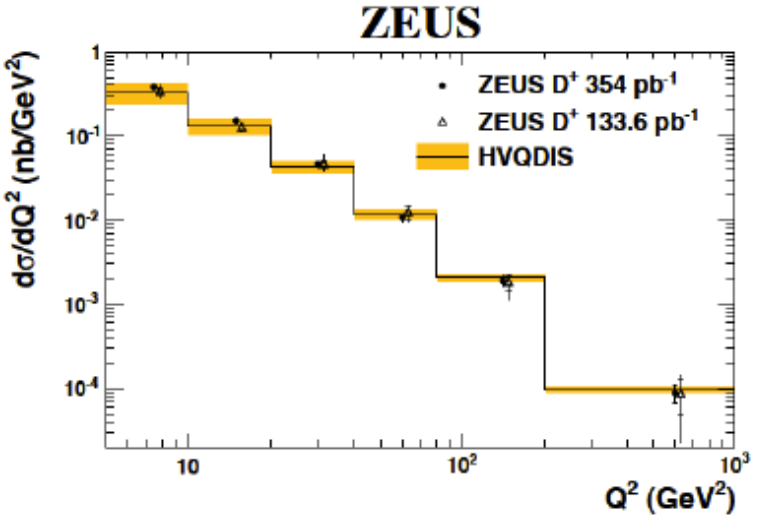


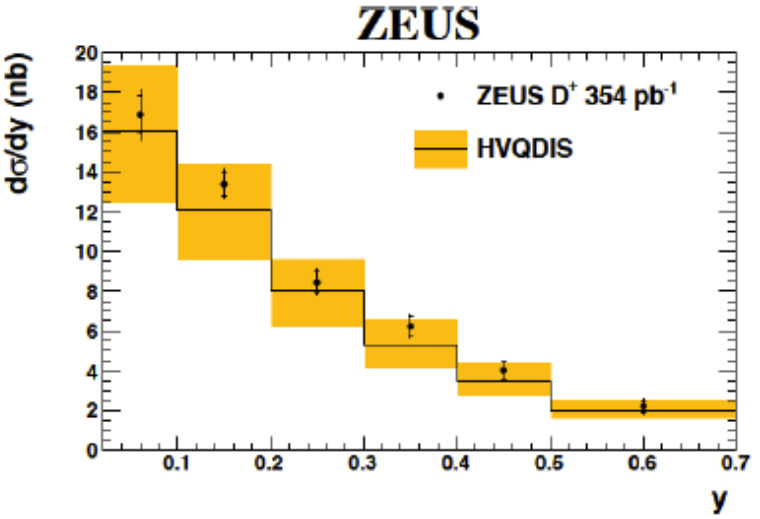
Differential cross sections vs Q^2, y

- D+ and D* agreement with HVQDIS
- Both on the upper side of theoretical uncertainty band







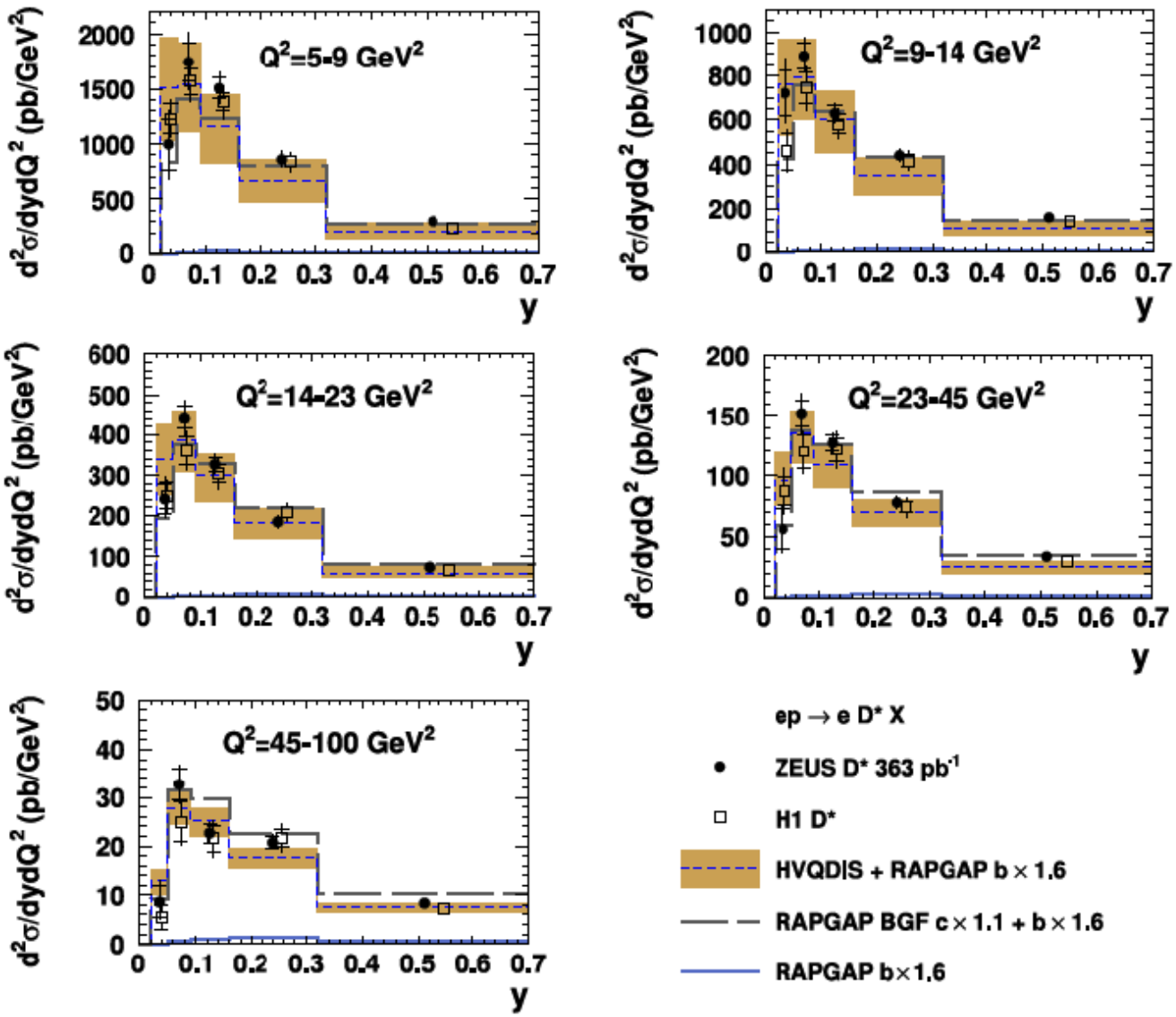


Double differential cross sections in Q^2, y

- Cross sections are mesured in bins of y and Q^2

- Agreement with H1 HERA-II data, similar precision (see also K. Lipka's talk)

$5 < Q^2 < 100\ \text{GeV}^2$



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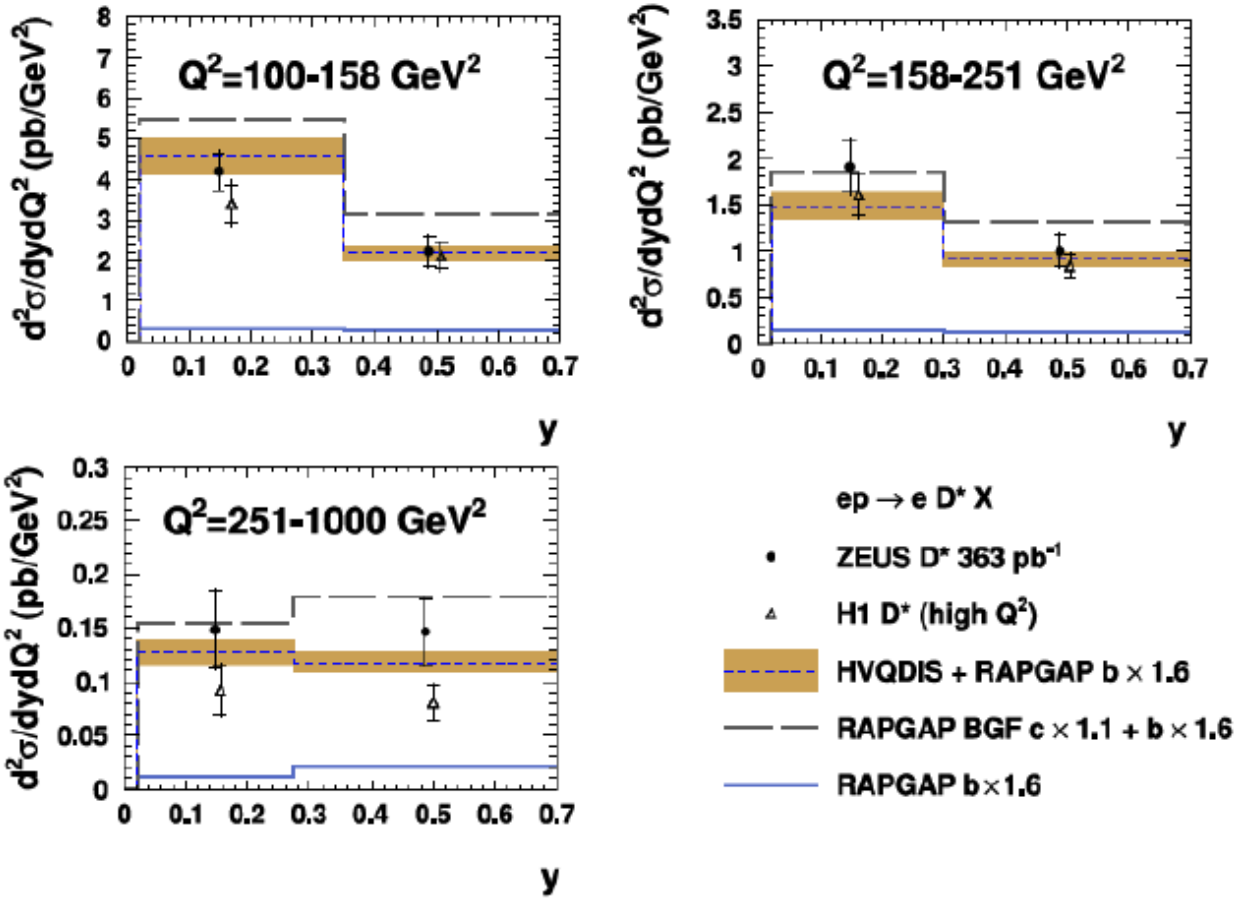


Jet vertices : method

Charm and beauty jet tagging

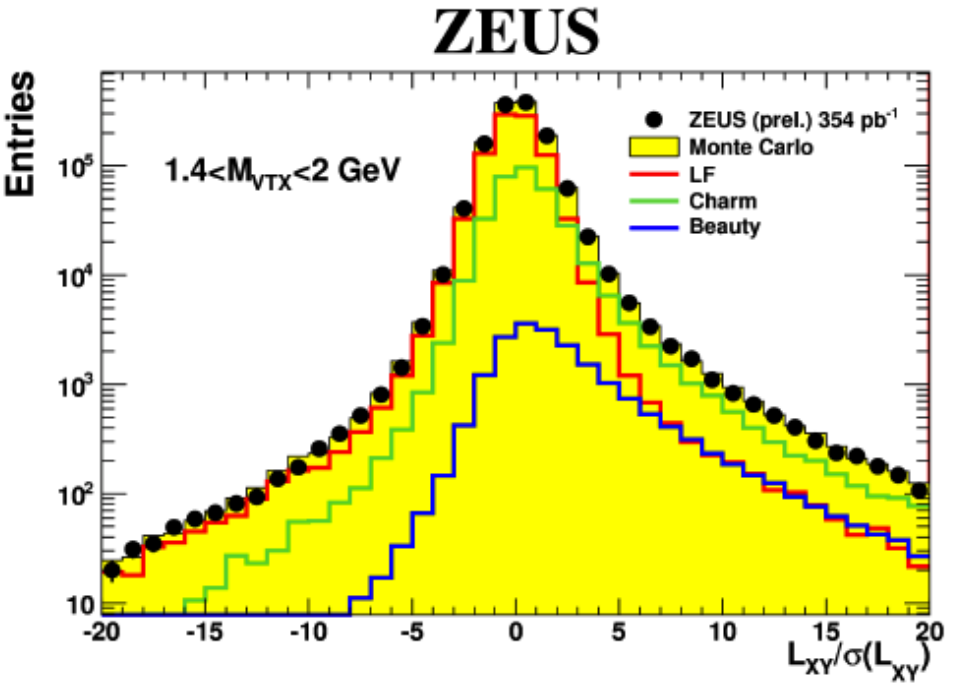
Jets with E_T>4.2 GeV (k_T, massive)

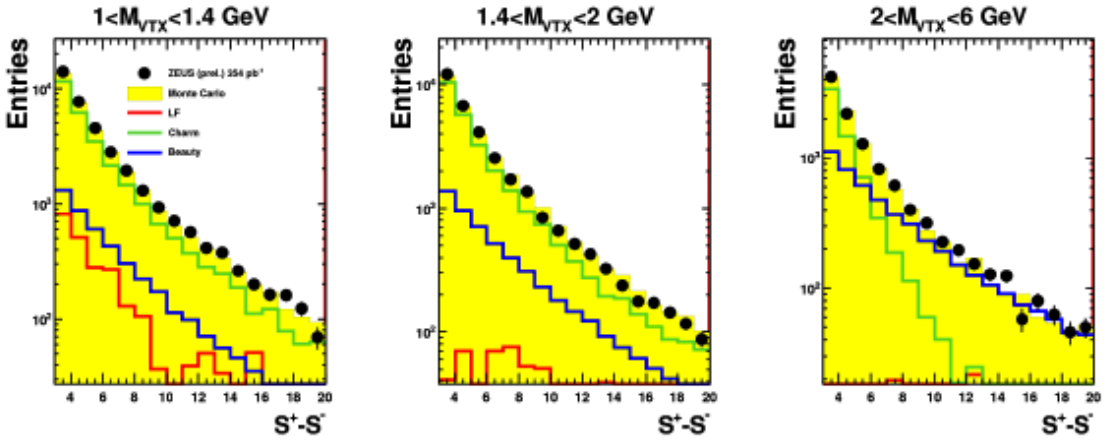
Flavour decomposition based on "jet vertex" from tracks in cone ΔR<1 with p_T>0.5 GeV, exploiting

- decay length significance $S=L_{XY}/\sigma_{XY}$
- vertex mass M_{VTX}

"mirrored" significance to reduce resolution effects

Large statistics compared to D mesons

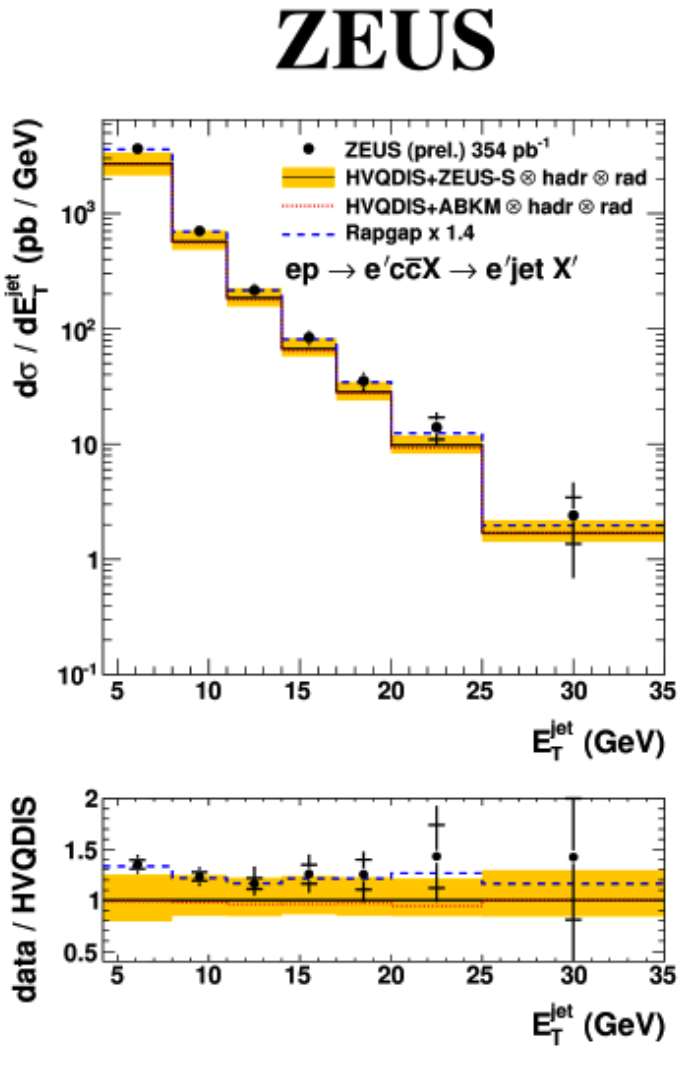


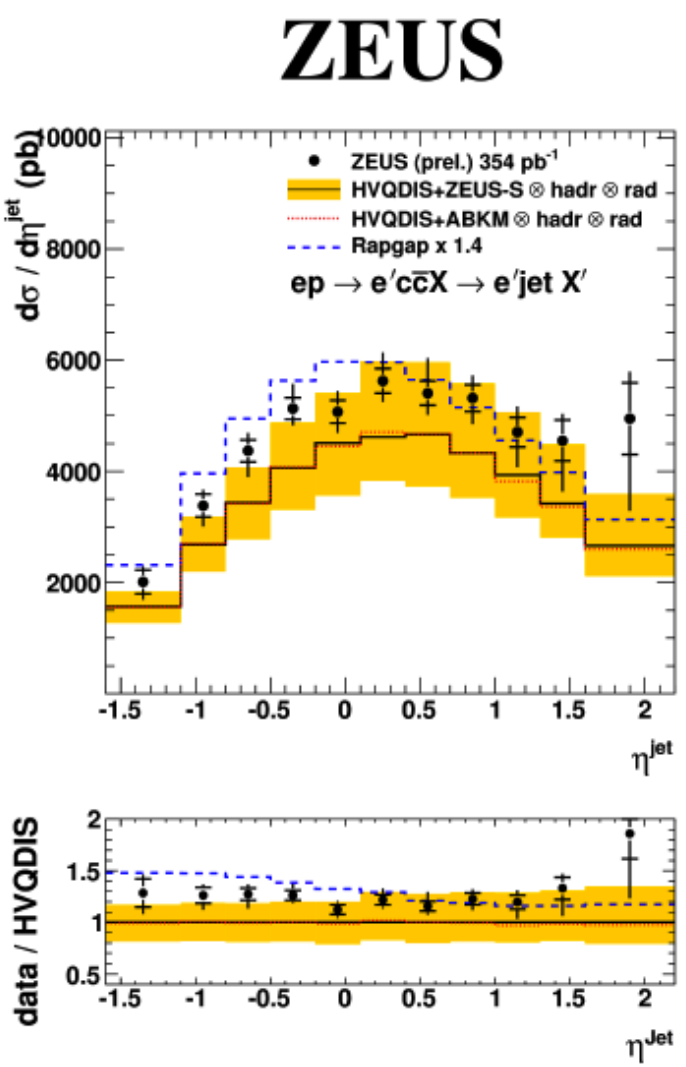


Jet vertices : results

- Charm jet cross sections: result on upper side of HVQDIS prediction (with jet hadronization corrections from Rapgap)

- Used also to extract $F_2^{c\bar{c}}$





Extraction of reduced cross section $\sigma_{red}^{c\bar{c}}$

Reduced charm cross section $\sigma_{red}^{c\bar{c}}$ and the structure functions $F_2^{c\bar{c}}$, $F_L^{c\bar{c}}$ are defined Similarly to the inclusive case but for events with charm in the final state:

$$\frac{d^2\sigma^{c\bar{c}}}{dx\,dQ^2} = \frac{2\pi\alpha_{em}^2}{xQ^4}\, Y_+\, \sigma_{\rm red}^{c\bar{c}}(x, Q^2, s), \qquad Y_+ = 1 + (1-y)^2$$

$$\sigma_{\rm red}^{c\bar{c}}(x, Q^2, s) = F_2^{c\bar{c}}(x, Q^2) - \frac{y^2}{Y_+} F_L^{c\bar{c}}(x, Q^2),$$

Obtained from cross section in visible phase space (σ_{vis}) in a [y,Q^2] bins as

$$\sigma_{\rm red}^{c\bar{c}}(x, Q^2) = \left(\sigma_{\rm vis} - \sigma_{\rm vis}^{\rm beauty}\right) \left(\frac{\sigma_{\rm red,\,HVQDIS}^{c\bar{c}}(x, Q^2)}{\sigma_{\rm vis,\,HVQDIS}}\right)$$

beauty contribution taken from Rapgap MC normalized to ZEUS measurements.

The method accounts for the extrapolation to full phase space,
D* phase-space acceptances of ~50%, from 17% (low-y) to 64% (high-Q_2).

Theoretical uncertainty obtained from the variation of HVQDIS and fragmentation parameters.

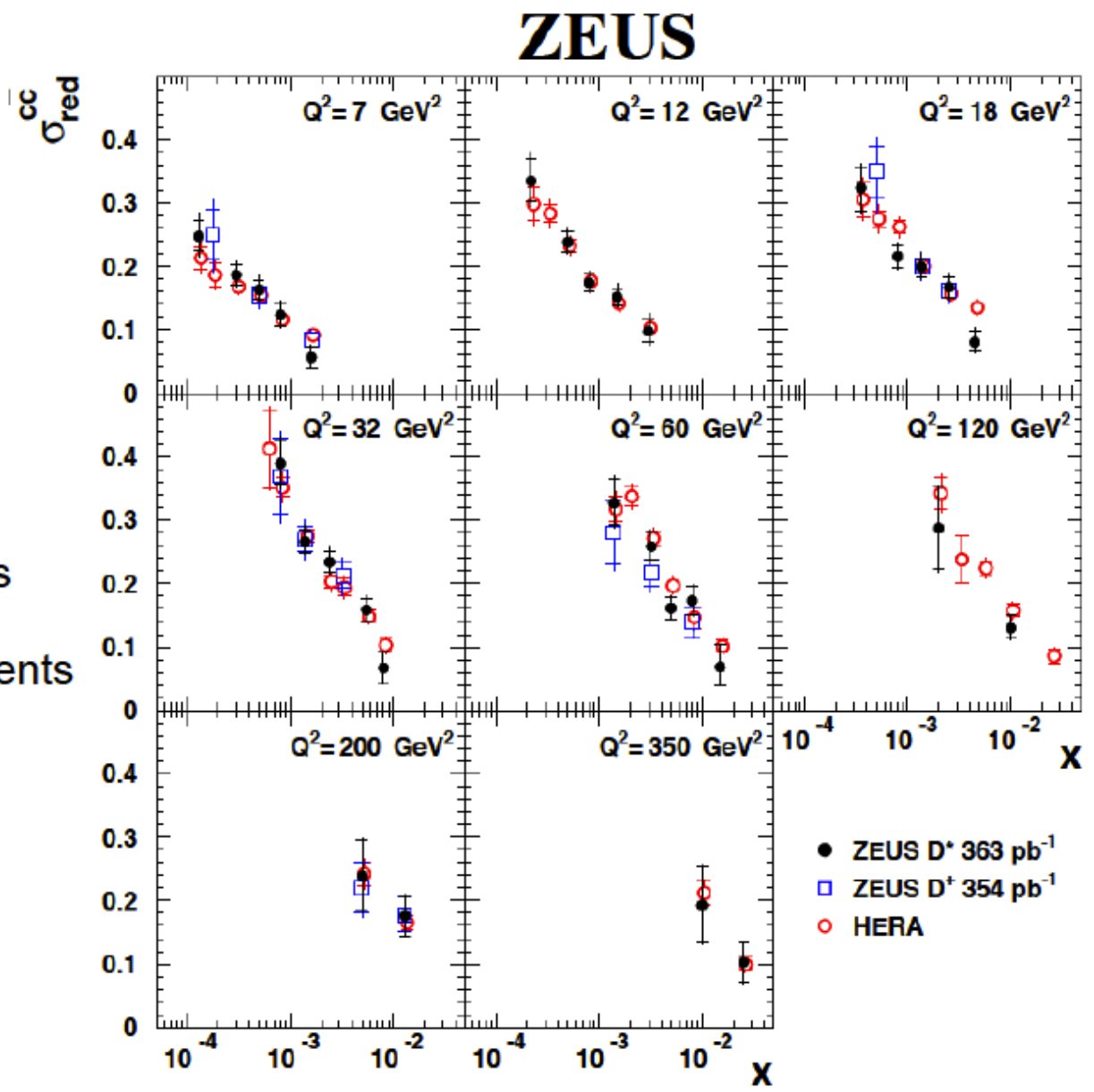
Reduced cross sections: results

- Reduced cross sections
  For D* and D^+
  compared to
  HERA charm combination
  Including previous data

- Error bars:
  inner = stat+syst.
  outer = stat.+syst.+theo.

- Good agreement of three sets

- Precision of single measurements
  comparable to combined data
  in some bins.



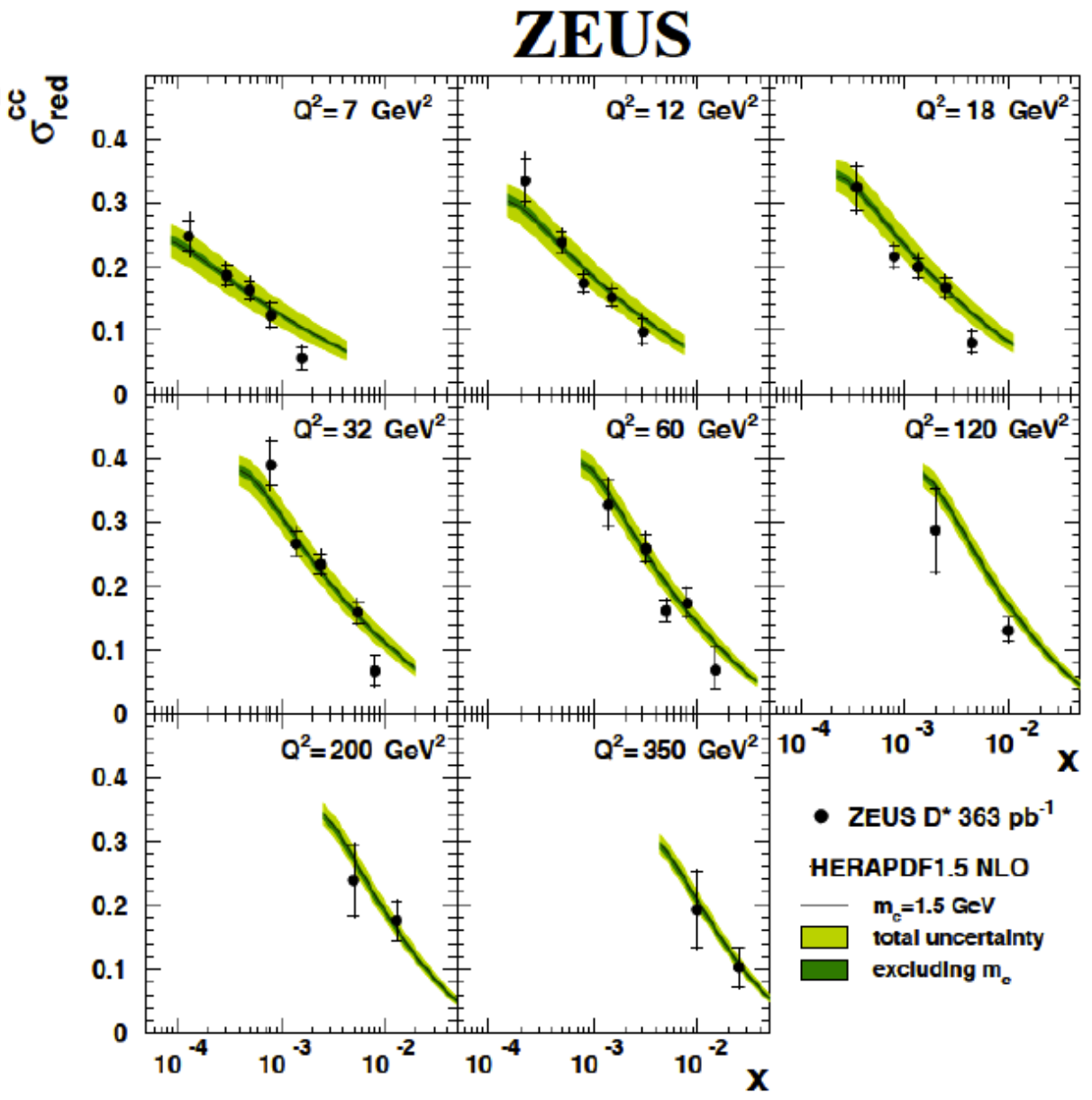
Comparison with HERAPDF1.5

- D* results compared to prediction from the HERAPDF1.5 PDF fit to inclusive HERA data

- Prediction at based on the GM-VFNS Roberts-Thorne heavy-flavour scheme at NLO

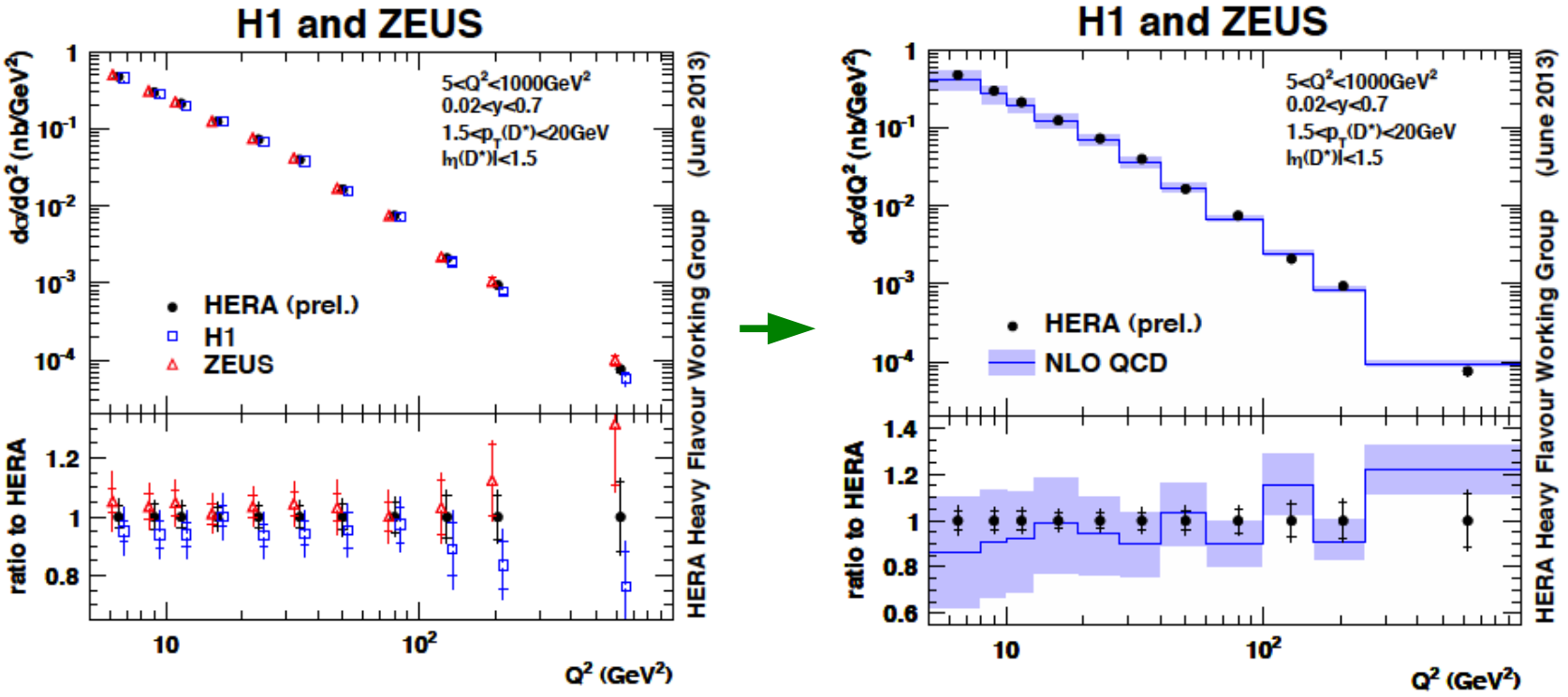
- Consistent description of charm and inclusive data

- Theory uncertainty band:
  - m_c +- 0.15 GeV
  - PDFs
  (no scale variation included)



Conclusions

- New measurements of charm production in DIS from ZEUS : D*, D^+ and jet vertices
- Agreement with NLO predictions in FFNS (HVQDIS) and in the GM-VFNS (HERAPDF1.5)
- Improvement with respect to previous ZEUS result expected reduction on HERA combined charm data of ~1/√2



BACKUP SLIDES

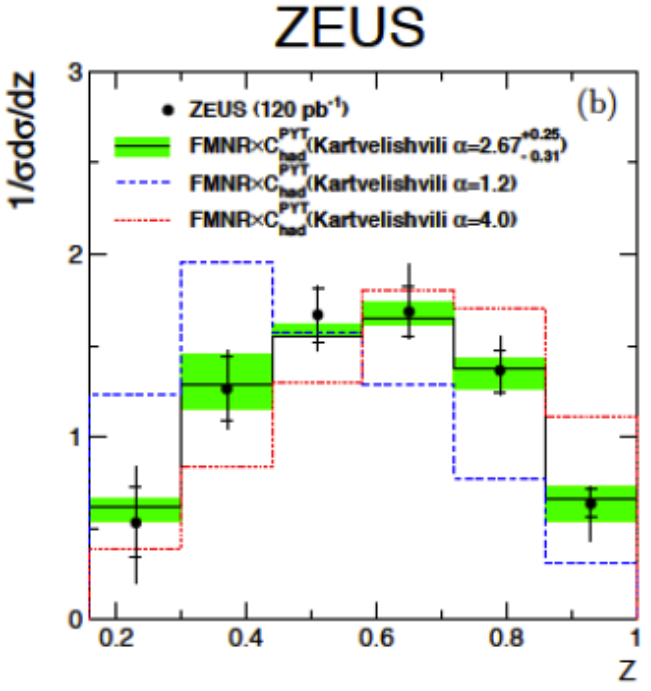
Fragmentation

To produce visible D*, D cross sections from Hvqdis a fragmentation model is used:

- Longitudinal fragmentation function : Kartvelishvili with variable α_K ($\hat{s}$)
  $\hat{s}$ = γ*g cms energy squared, same model as used for HERA charm combination

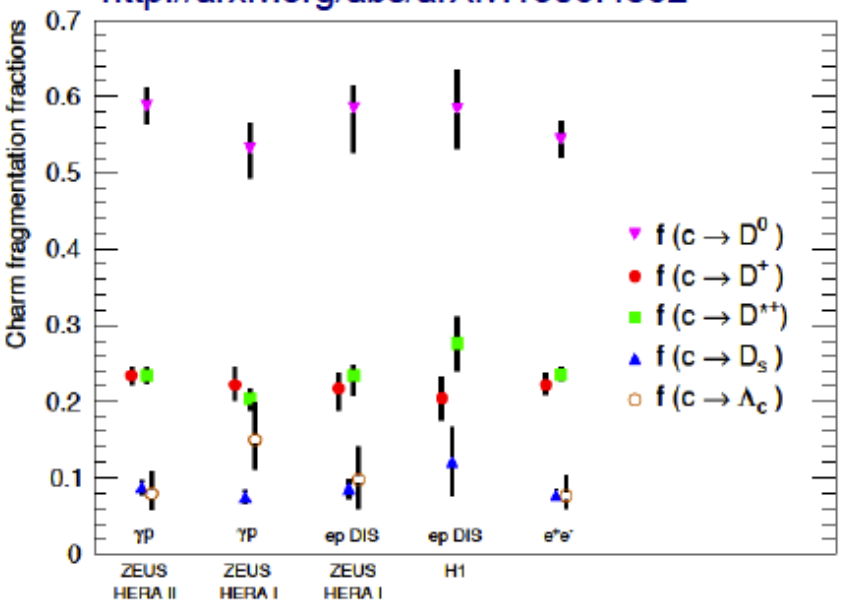
- D meson fragmentation fractions from e^+e^- and ep measurements

D* fragmentation function:



New measurement of charm frag. Fractions (not yet included in e^+e^- and ep average) :

http://arxiv.org/abs/arXiv:1306.4862



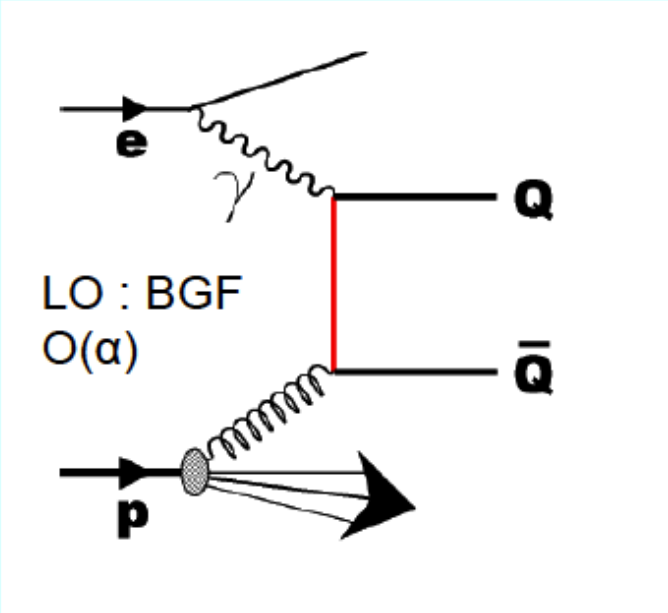
Heavy quark production in DIS

Fixed Flavour Number Scheme (FFNS)

- nf=3 active flavours in p

- heavy-quarks produced in hard scattering

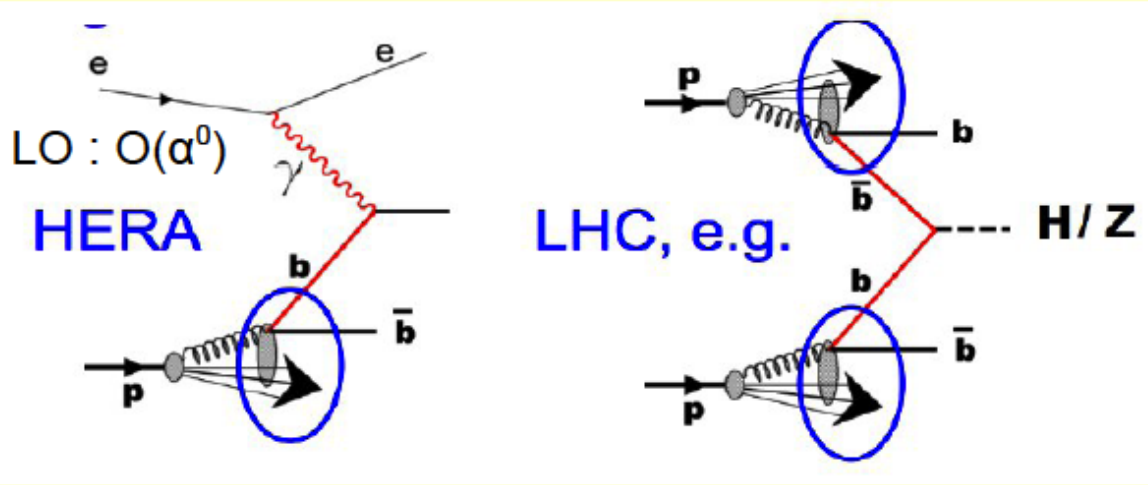
- mass effects correctly included



- spoiled by large logs of Q^2/m^2, p_T/m ...

Variable Flavour Number Scheme(s) (VFNS)

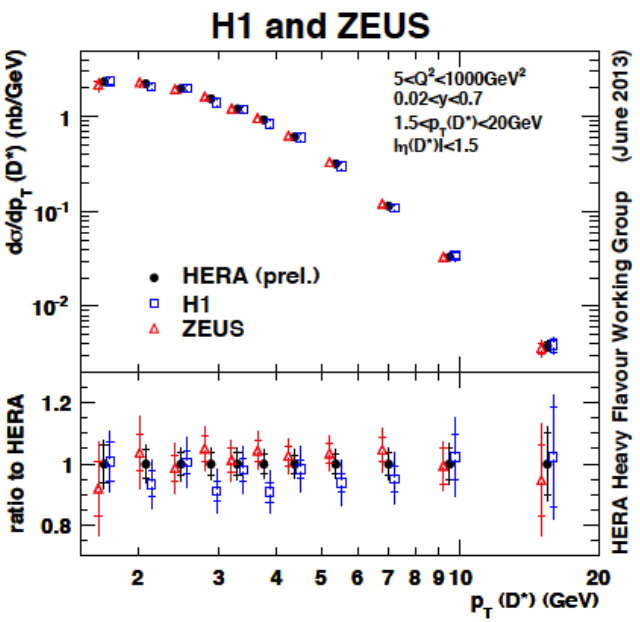
- c, b massless partons for $Q^2>m_c^2$

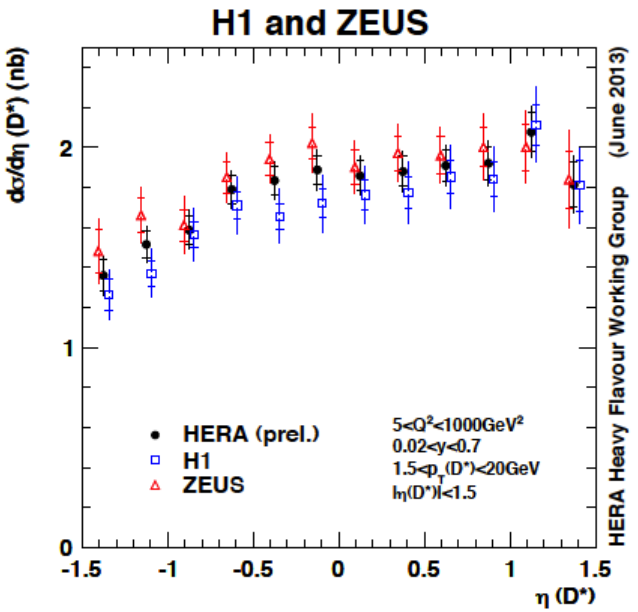


- simplifies calculations at colliders (neglecting m_c)
- resums large $\log(Q^2/m^2)$

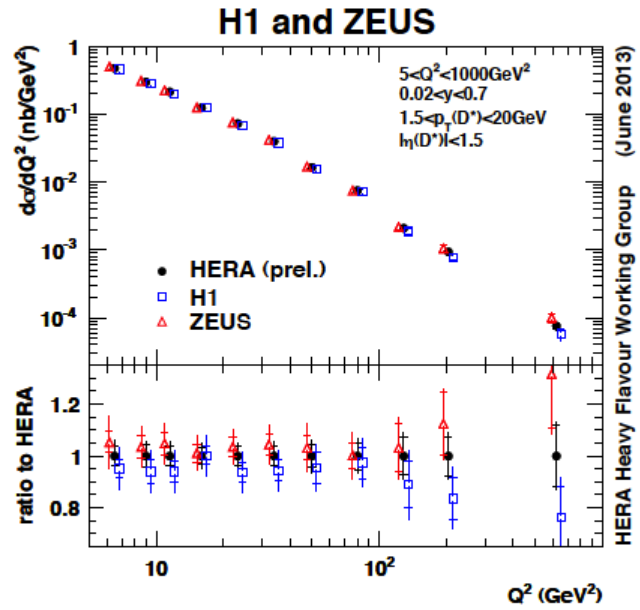
- Zero Mass (ZM) VFNS
  - neglects m_c at all Q^{2s}

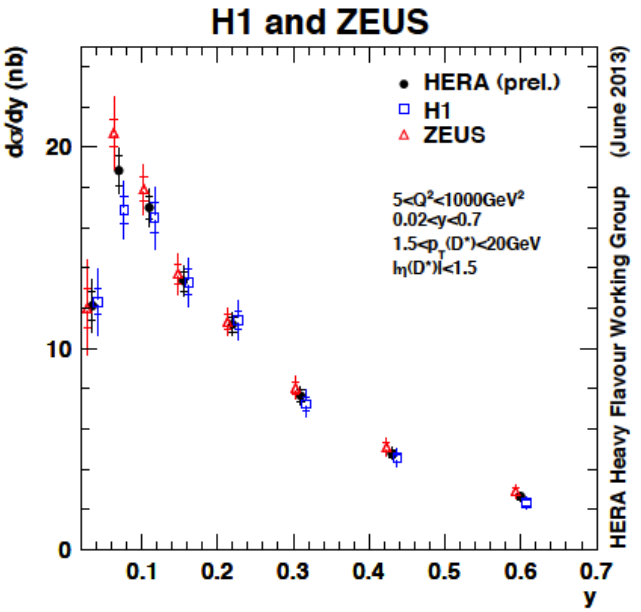
- General Mass (GM) VFNS
  - FFNS at $Q^2<m_c^2$, ZM-FNS at $Q^2>>m^2$
  - Interpolating in between
  - different prescriptions available

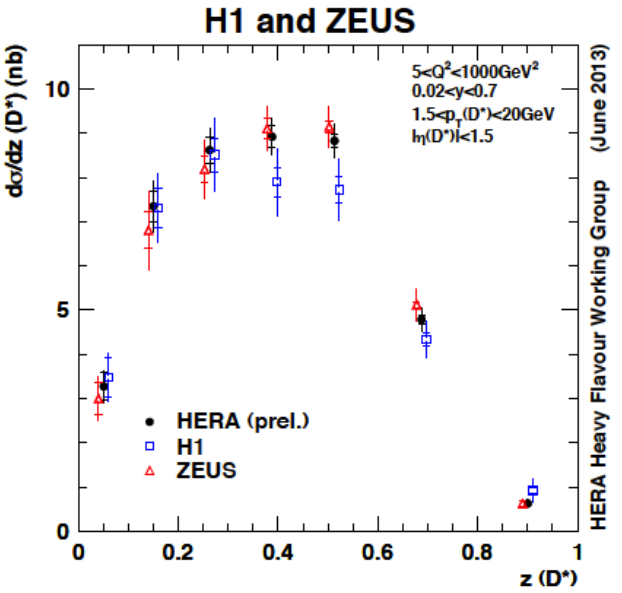




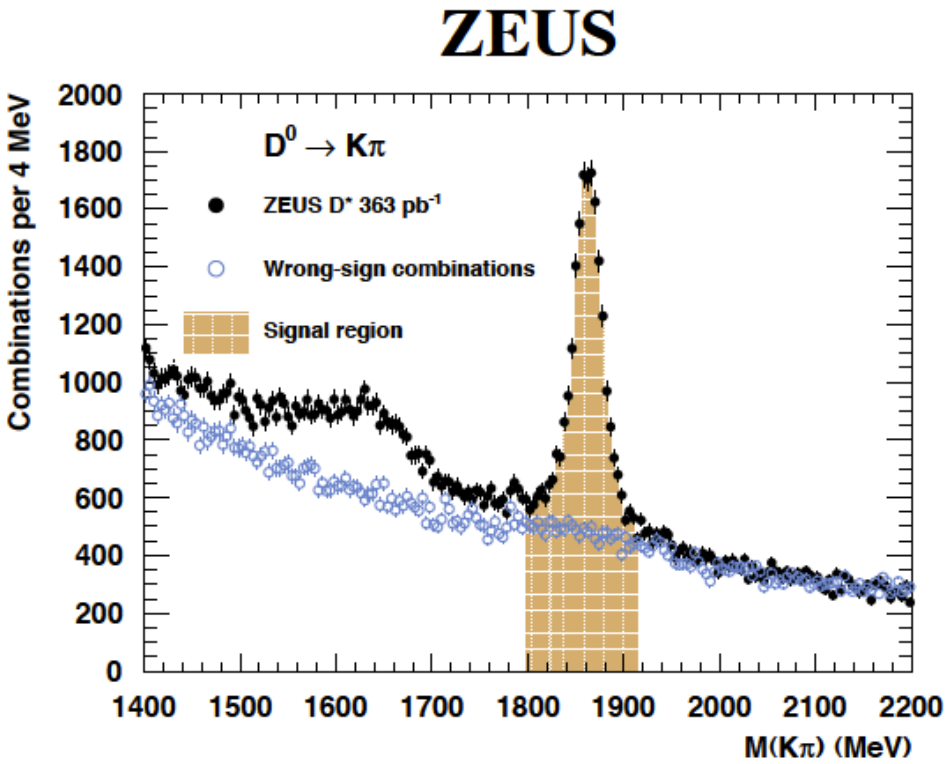
Comparison of ZEUS, H1 and combined D* data

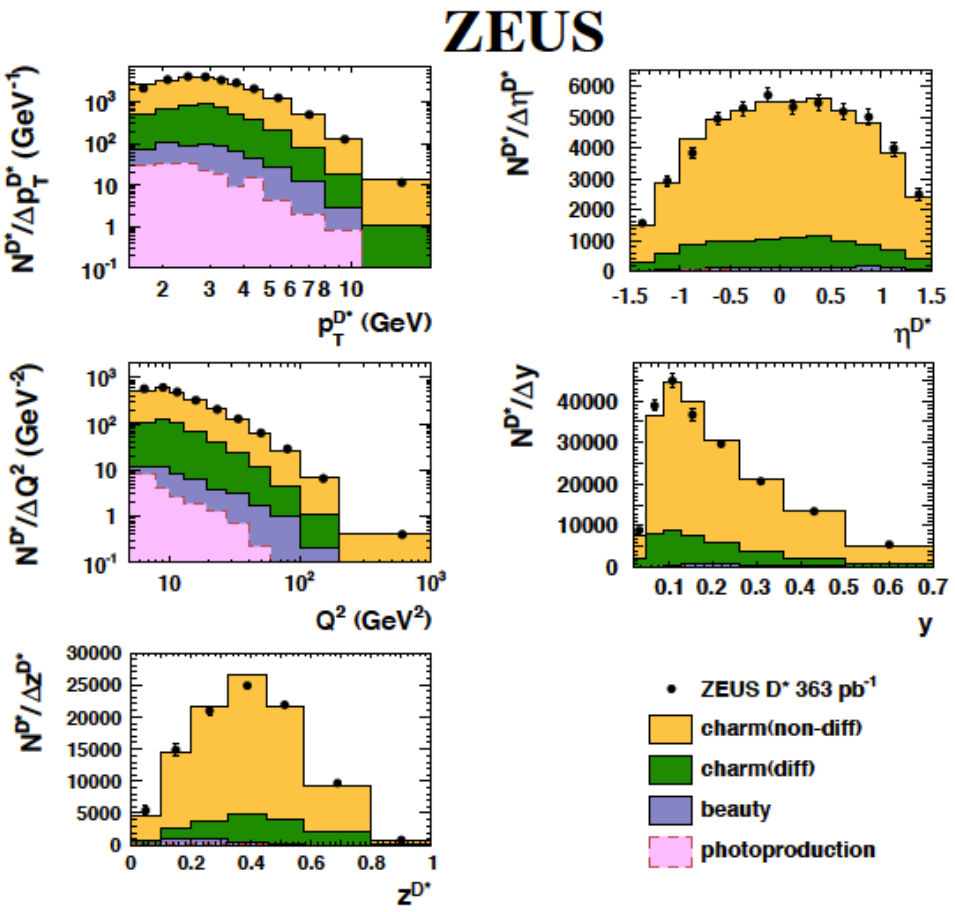




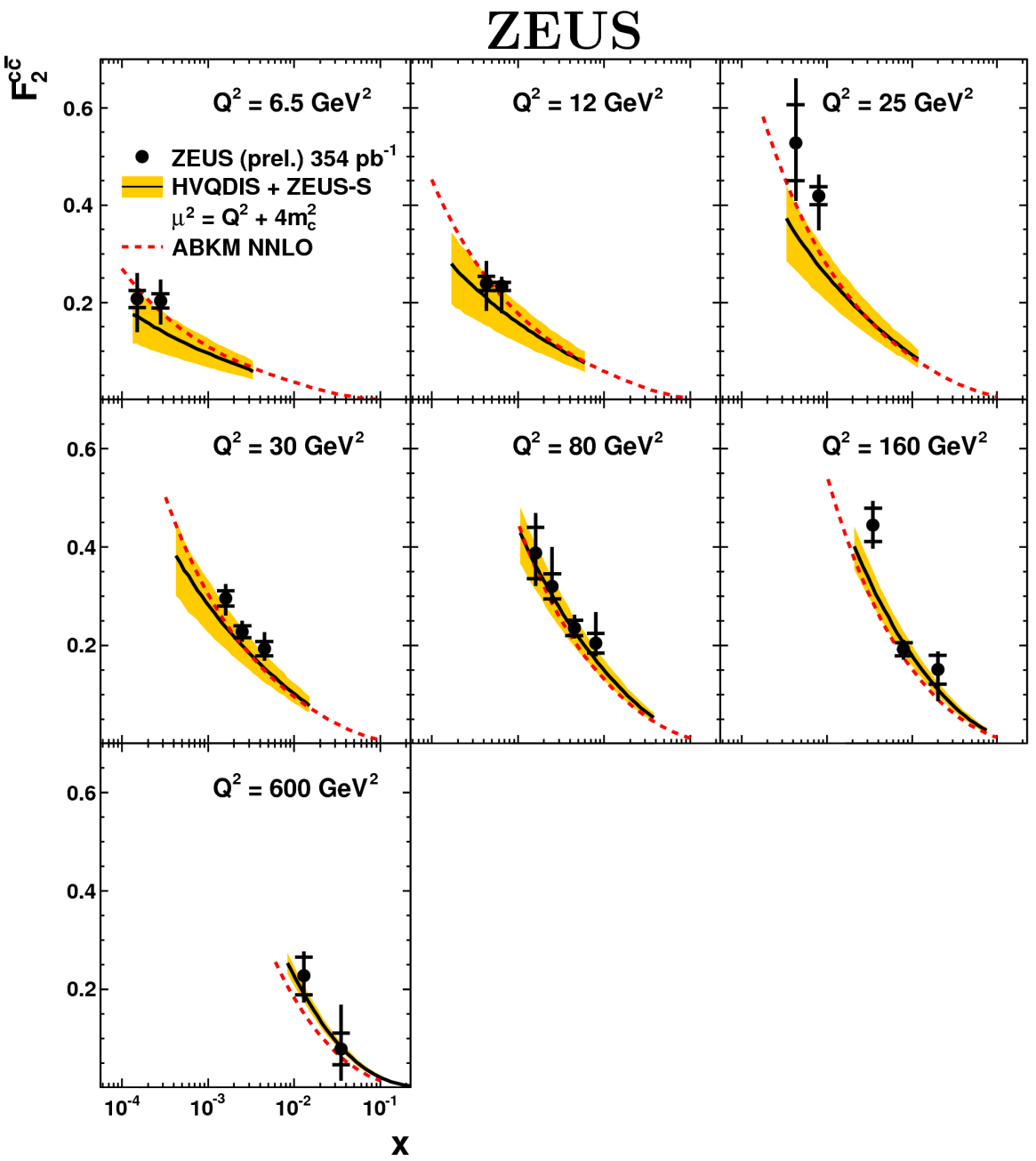


More plots from D* analysis





$F_2^{c\bar{c}}$ from jet vertex decay length



F_2^{bb} from jet vertex decay length