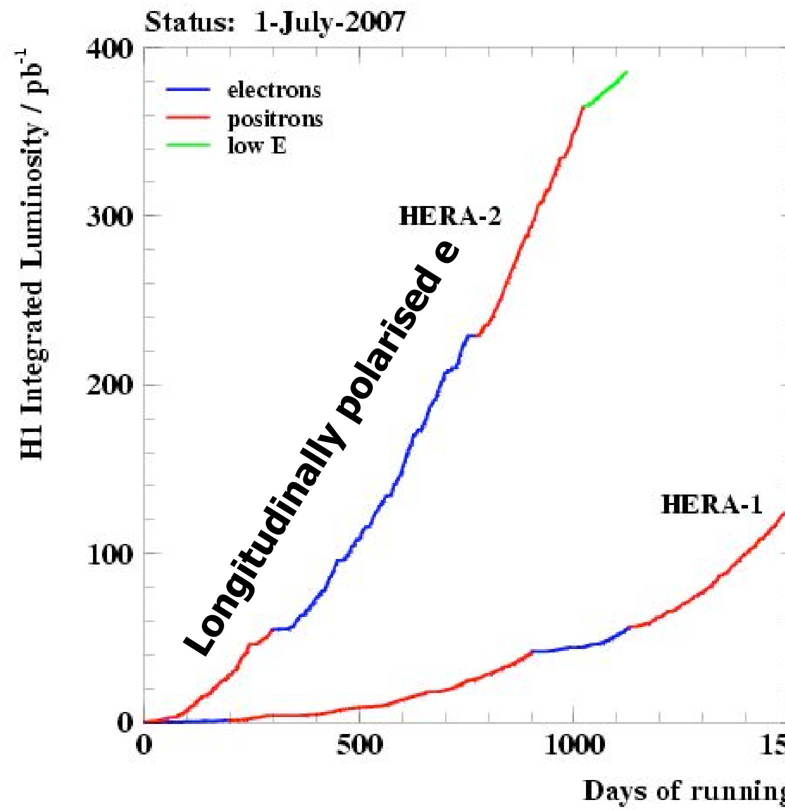
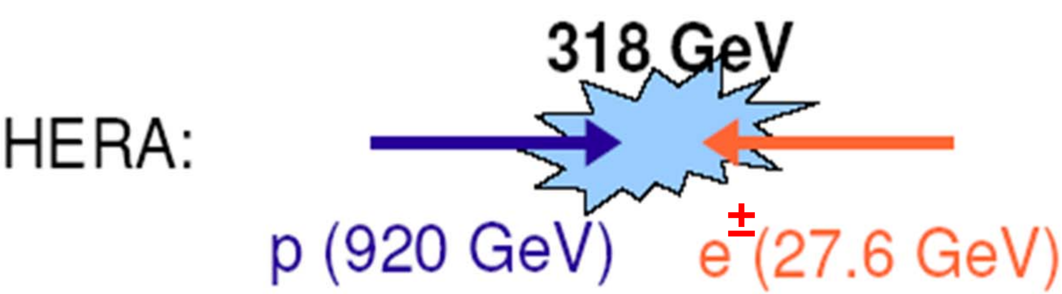
Recent *charm* production measurements at HERA

Low x workshop 2013, Eilat, Israel
3th june 2013

Olaf Behnke (DESY)
on behalf of

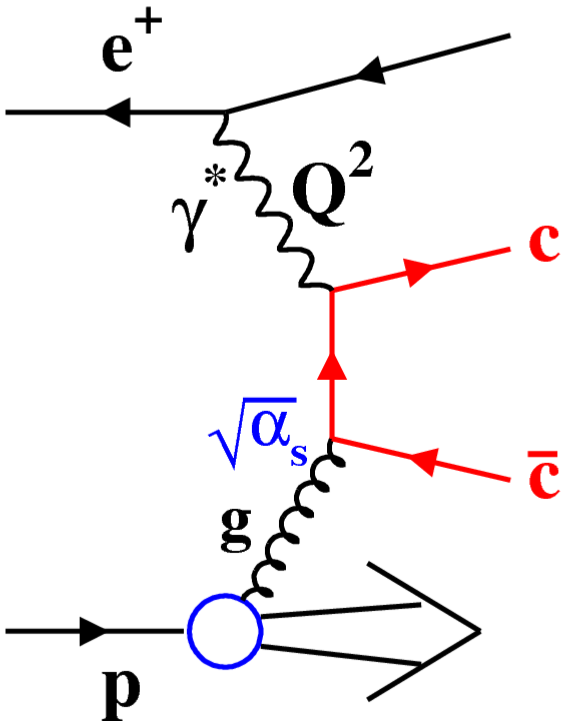
The HERA ep collider (1992-2007)





~0.5 fb^{-1} per experiment

Charm production at HERA

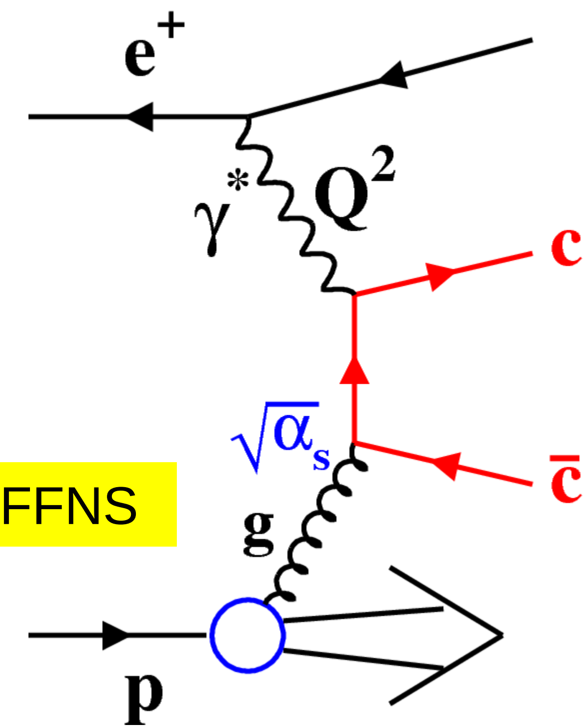


- Large contributions to incl. DIS
- Sensitive to g(x)

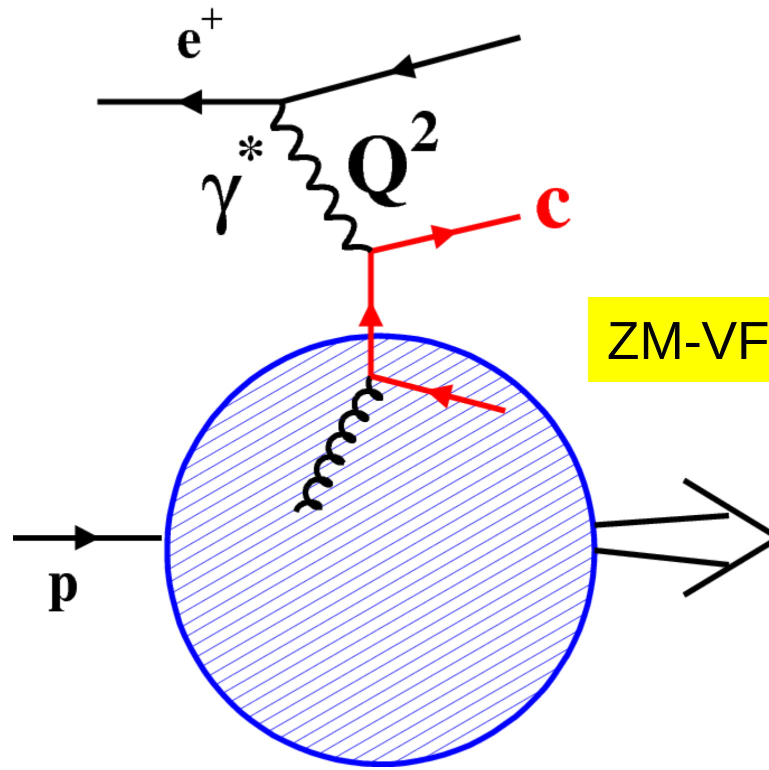
HFL schemes

Massive scheme: $Q^2 \sim m_c^2$

Massless scheme: $Q^2 >> m_c^2$



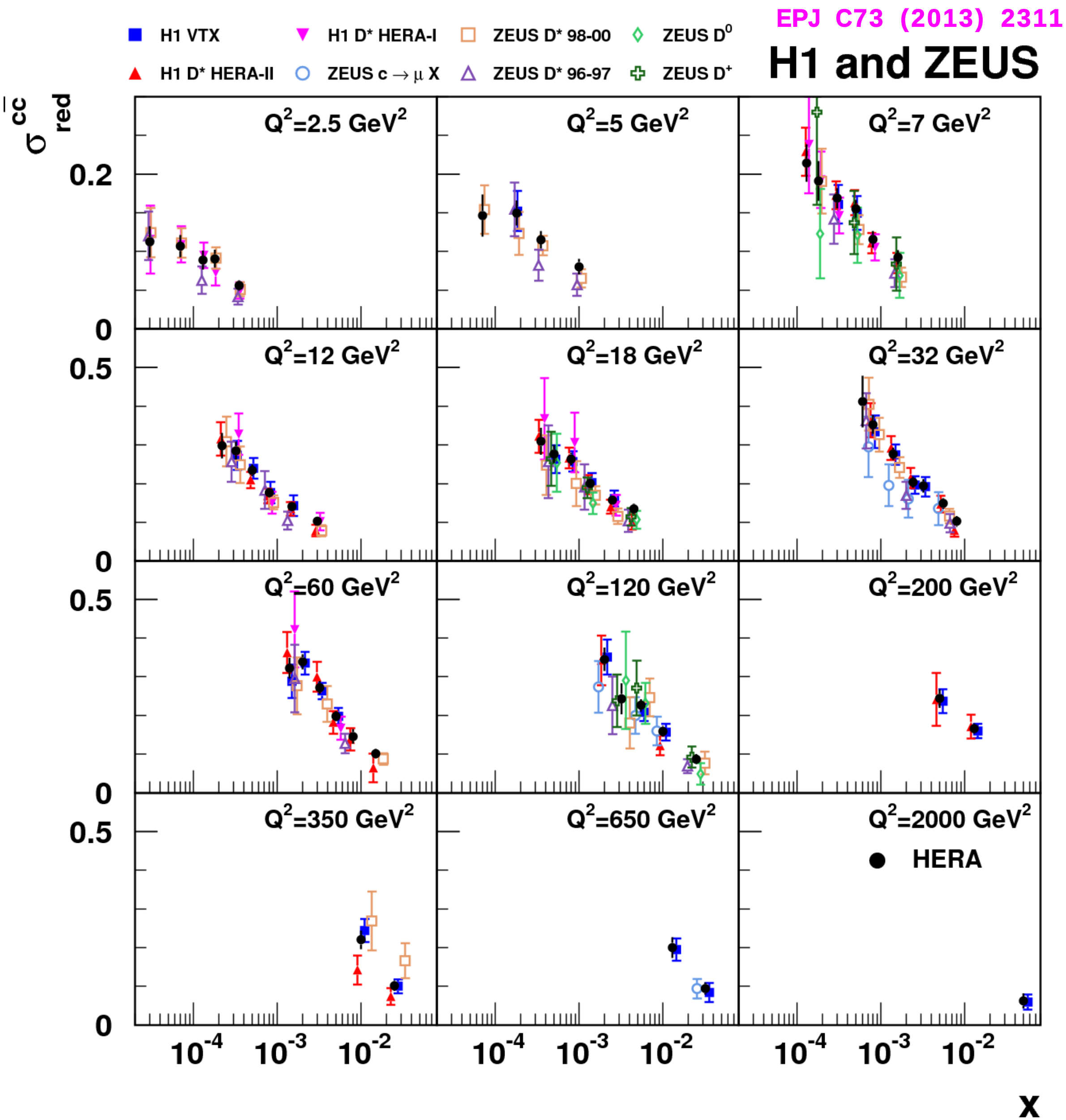
FFNS



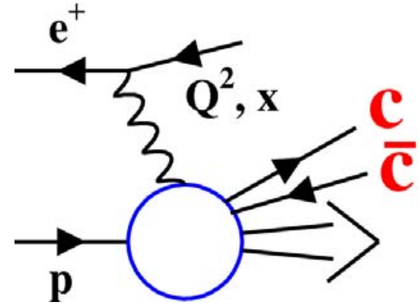
ZM-VFNS

Mixed schemes: interpolate, but how to do transition? → numerous variants GM-VFNS

HERA Charm data combination



- Combine D^*, D^+, D^0, μ and lifetime tag data
- take correlated systematics fully into account



$\sim\sigma^{cc}_{red}$

HERA Charm data combination

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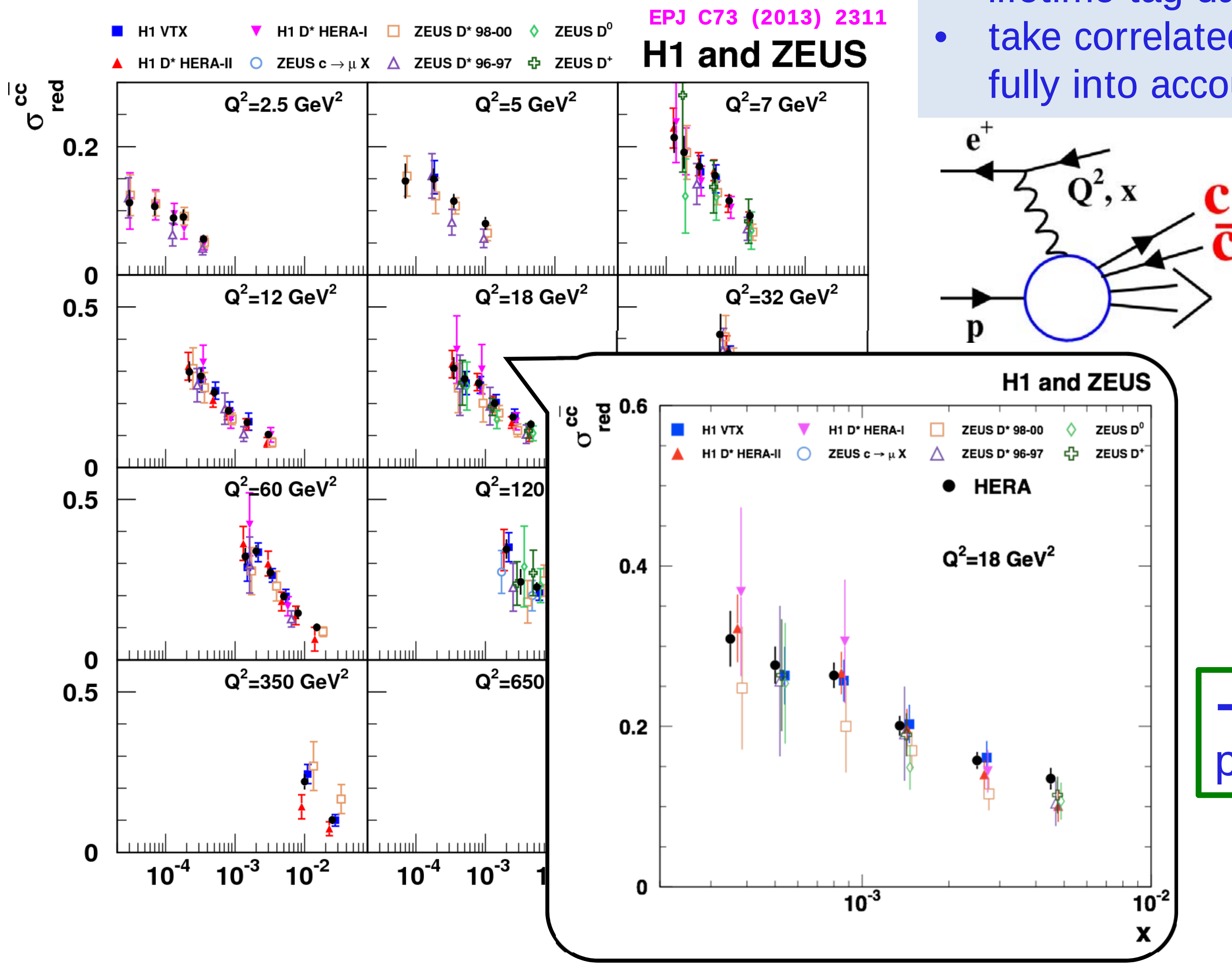


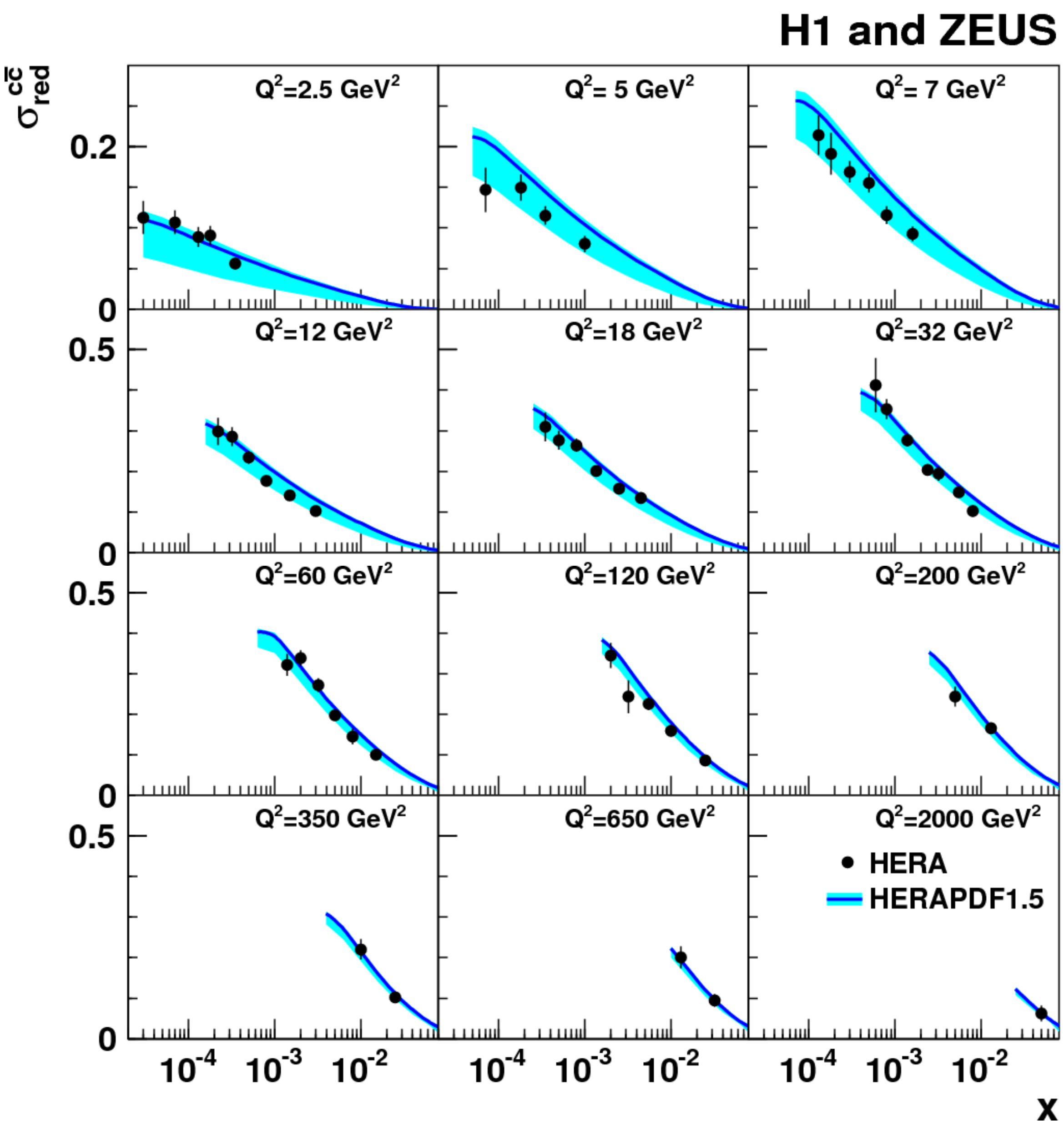
$\sim\sigma^{c\bar{c}}_{red}$

→ Best precision: ~5%

How well does the mixed massive-massless scheme (GM-VFNS) work?

Combined charm data vs NLO GM-VFNS

EPJ C73 (2013) 2311



HERAPDF1.5:

- only inclusive DIS data
- RT standard scheme

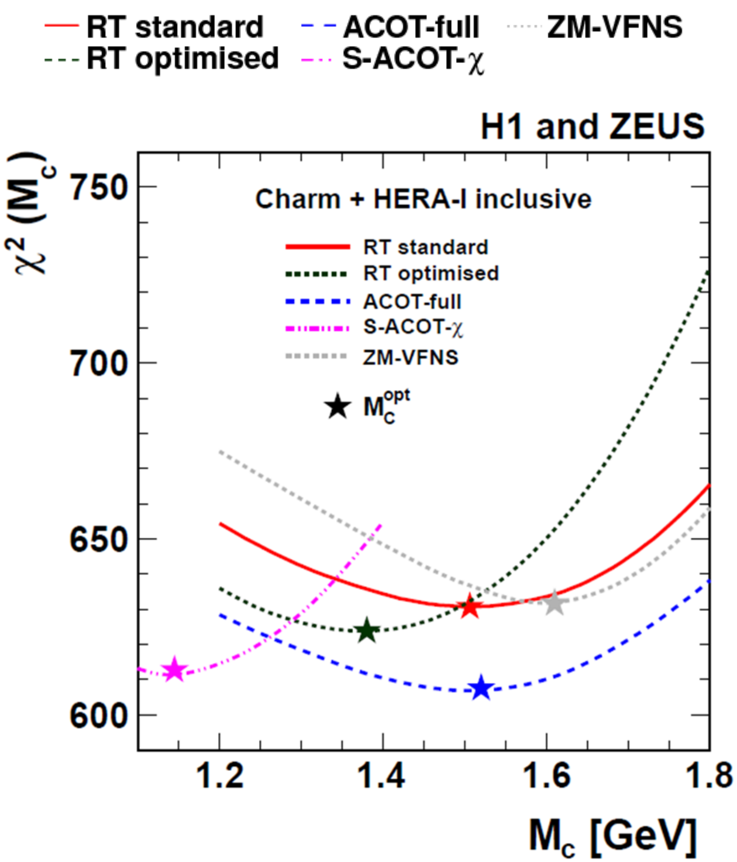
➔ NLO GM-VFNS ok ☺

➔large theory uncertainty dominated by m_c variation ☹

PDF plus charm mass parameter fit

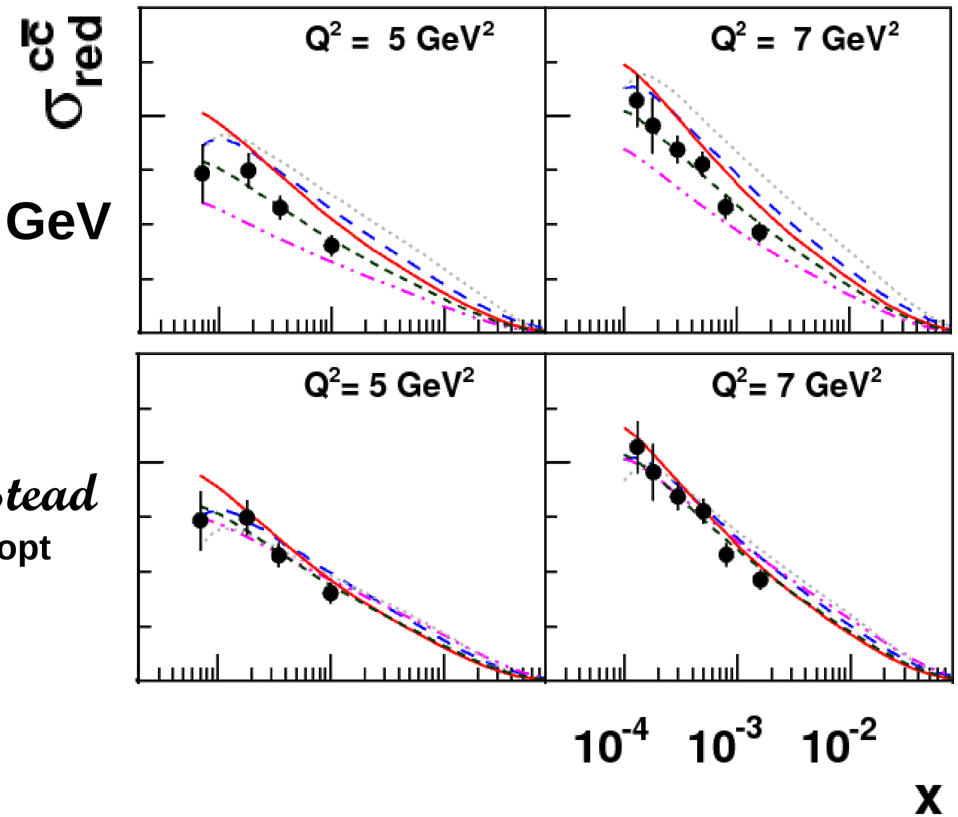
EPJ C73 (2013) 2311

- Fit **combined charm** and inclusive DIS data
- GMVFN-schemes with **charm pole mass M_c**



M_c = 1.4 GeV

Using instead
$M_c = M_c^{opt}$



→ Various GM-VFNS: interpolate differently between massive and massless schemes
→ different quality of charm data description for fixed M_c → compensate by M_c^{opt} values
→ stabilises flavour mixture in PDF → stabilises LHC predictions (W,Z)

Z,W cross section predictions for LHC

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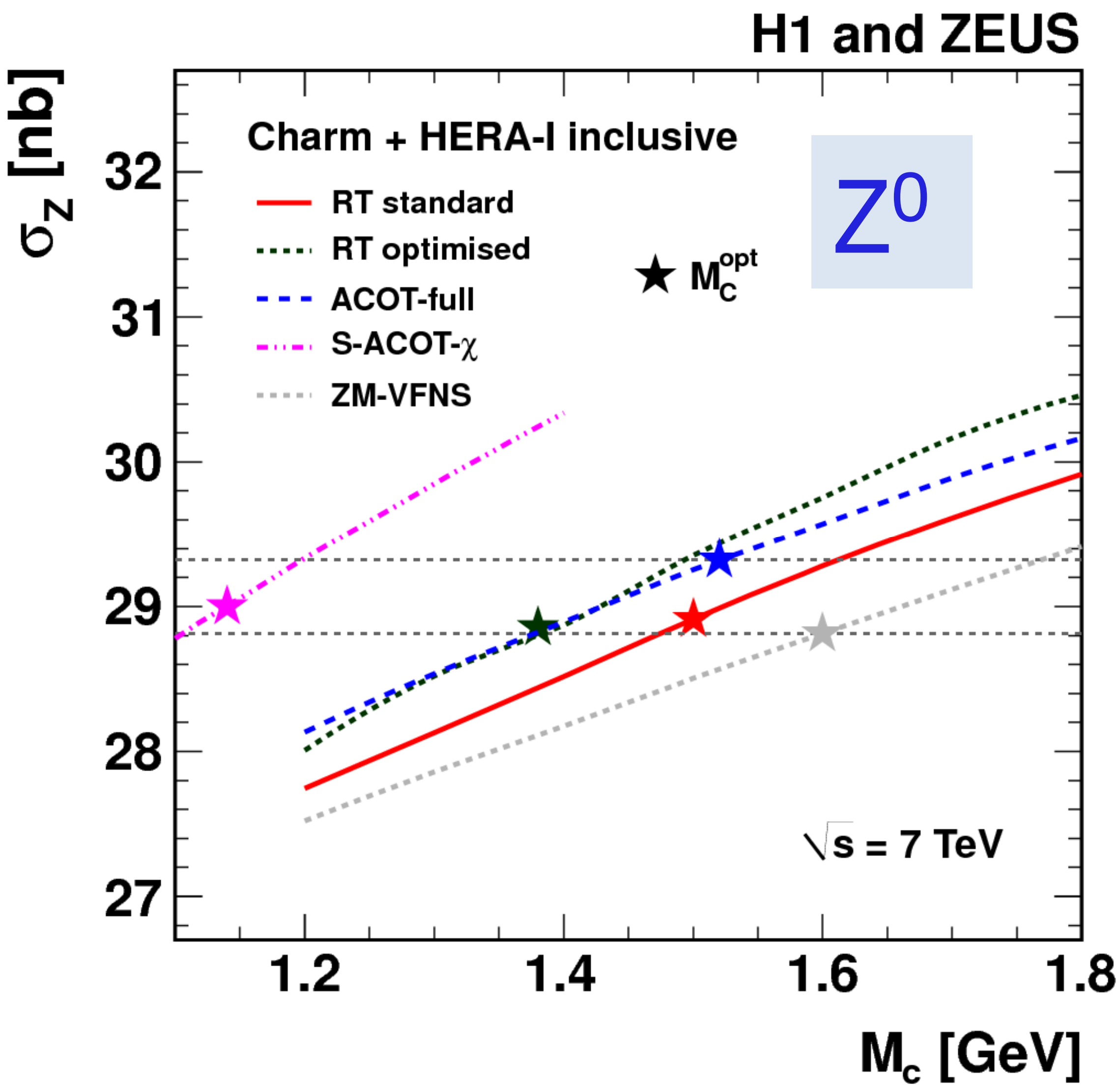

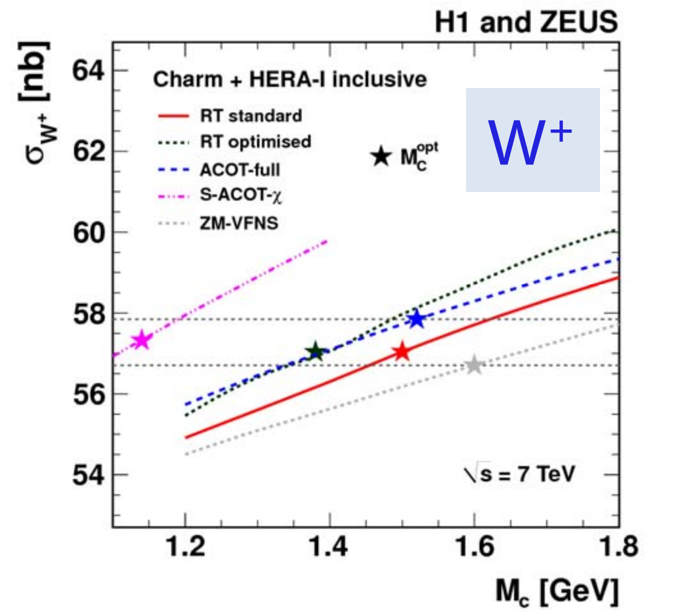

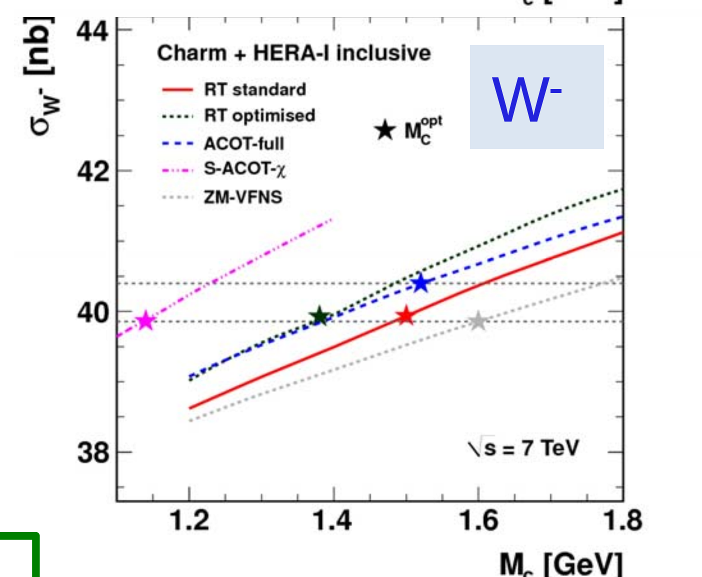

➔ optimal M_c reduces significantly uncertainty

Impact of charm data on PDF

Example: RT optimal scheme

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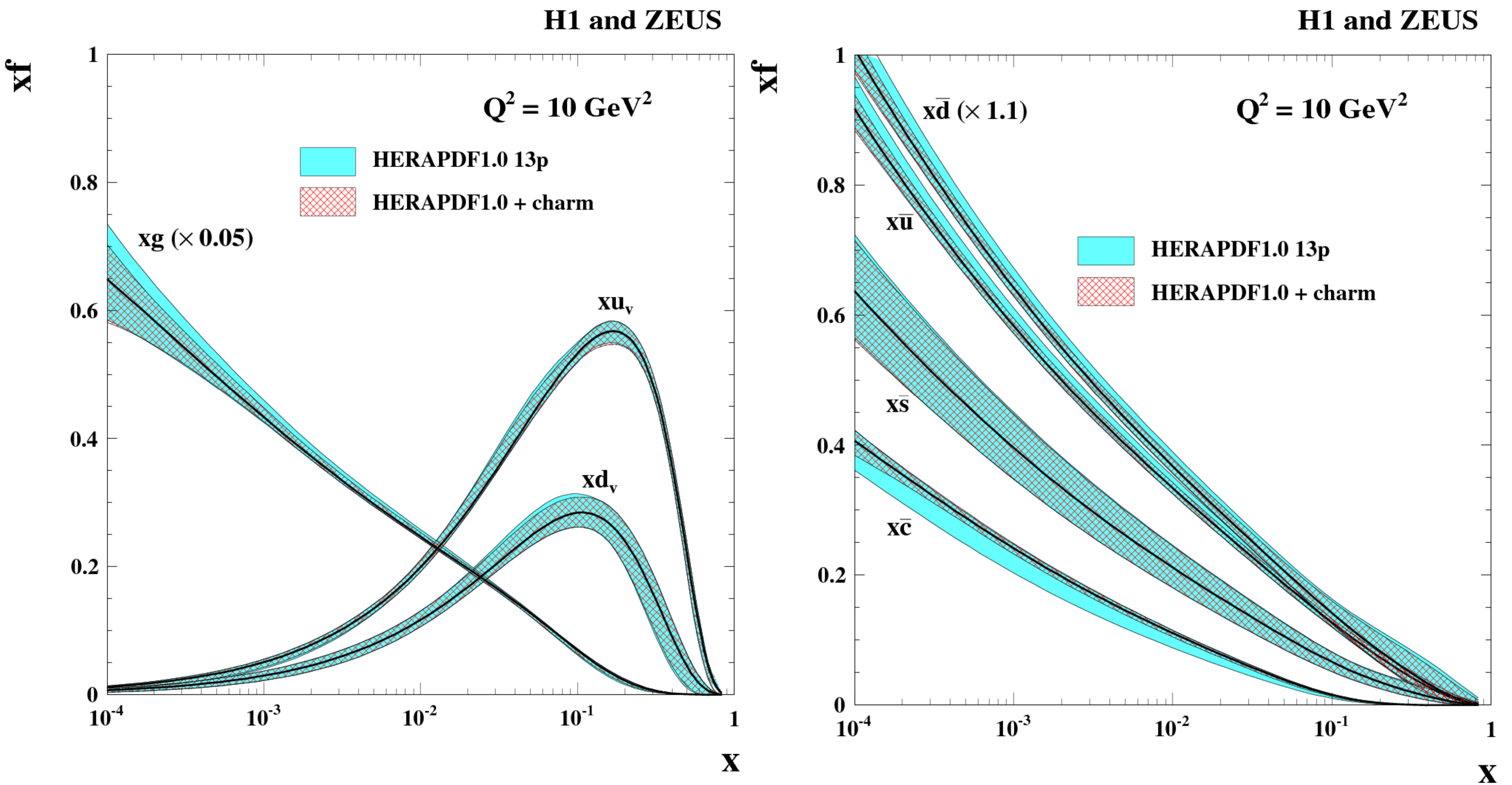

➔ stabilise the sea flavour composition

Impact of charm data on PDF

Example: RT optimal scheme

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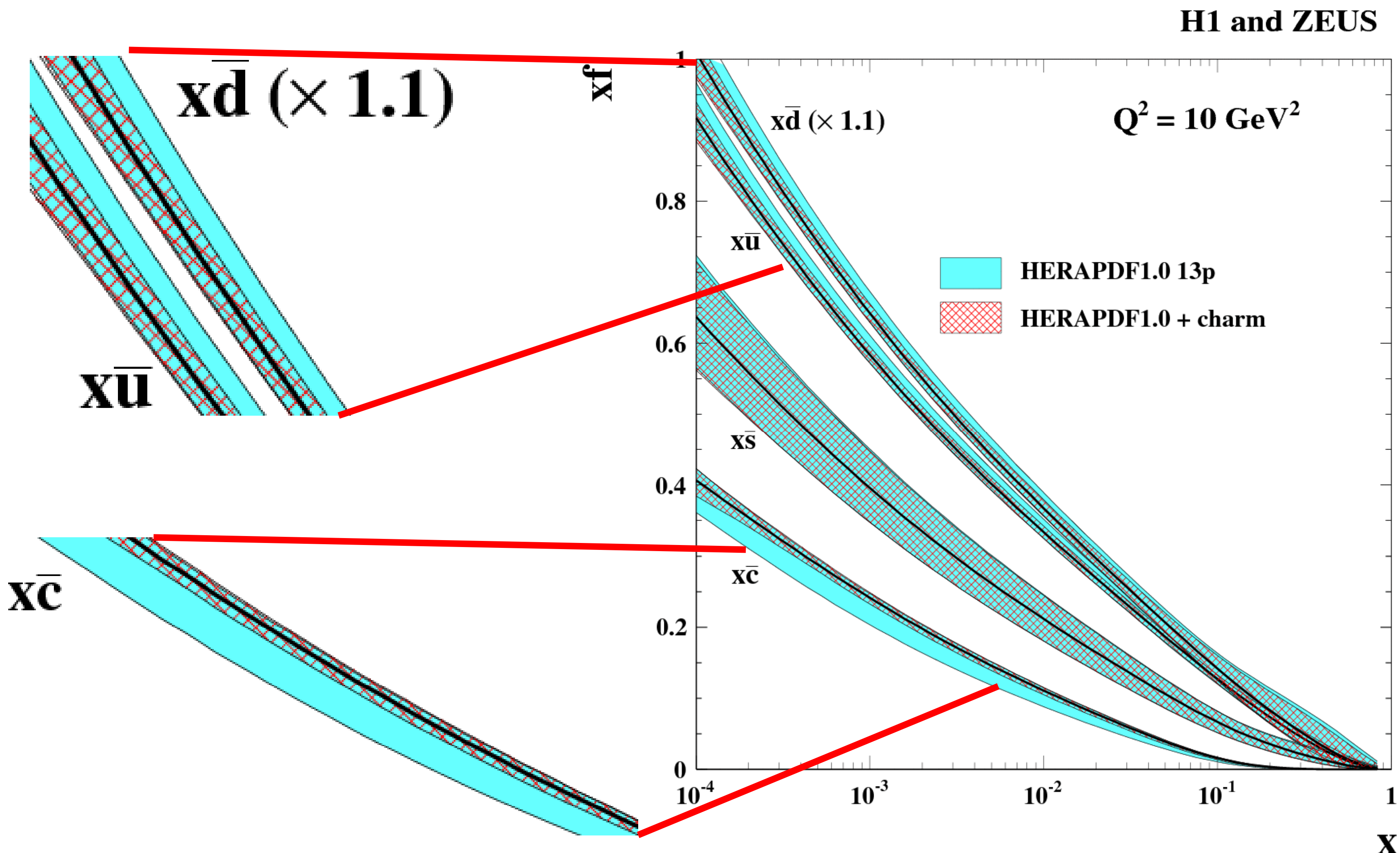

➔ stabilise the sea flavour composition

How well does the rigorous massive scheme (FFNS) work?

Combined charm data vs ABM FFNS prediction

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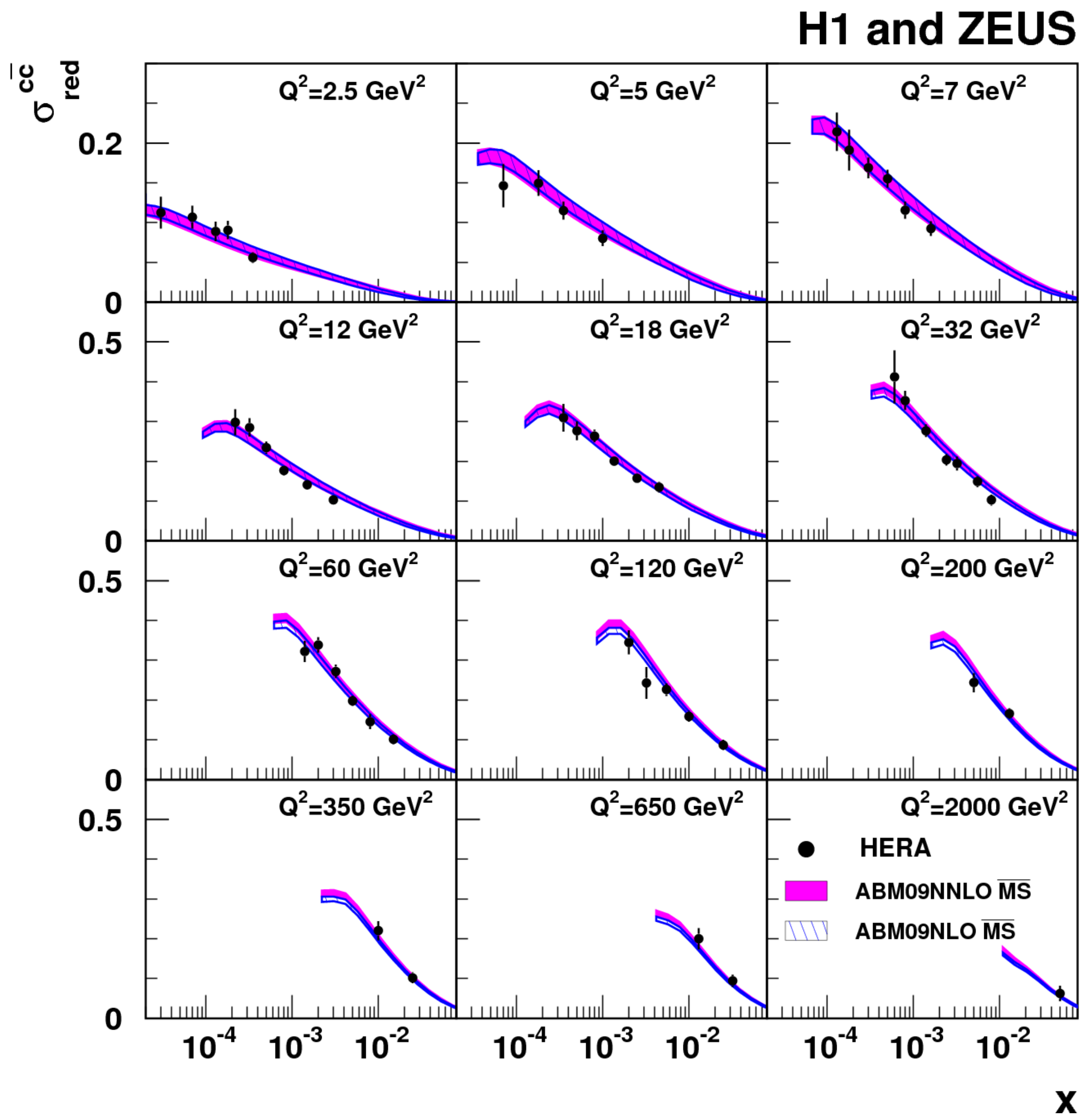

Use $\overline{MS}$ running mass
NLO+ partial NNLO

→ Very good description everywhere

Fit: PDF plus $\overline{\text{MS}}$ *running* charm mass

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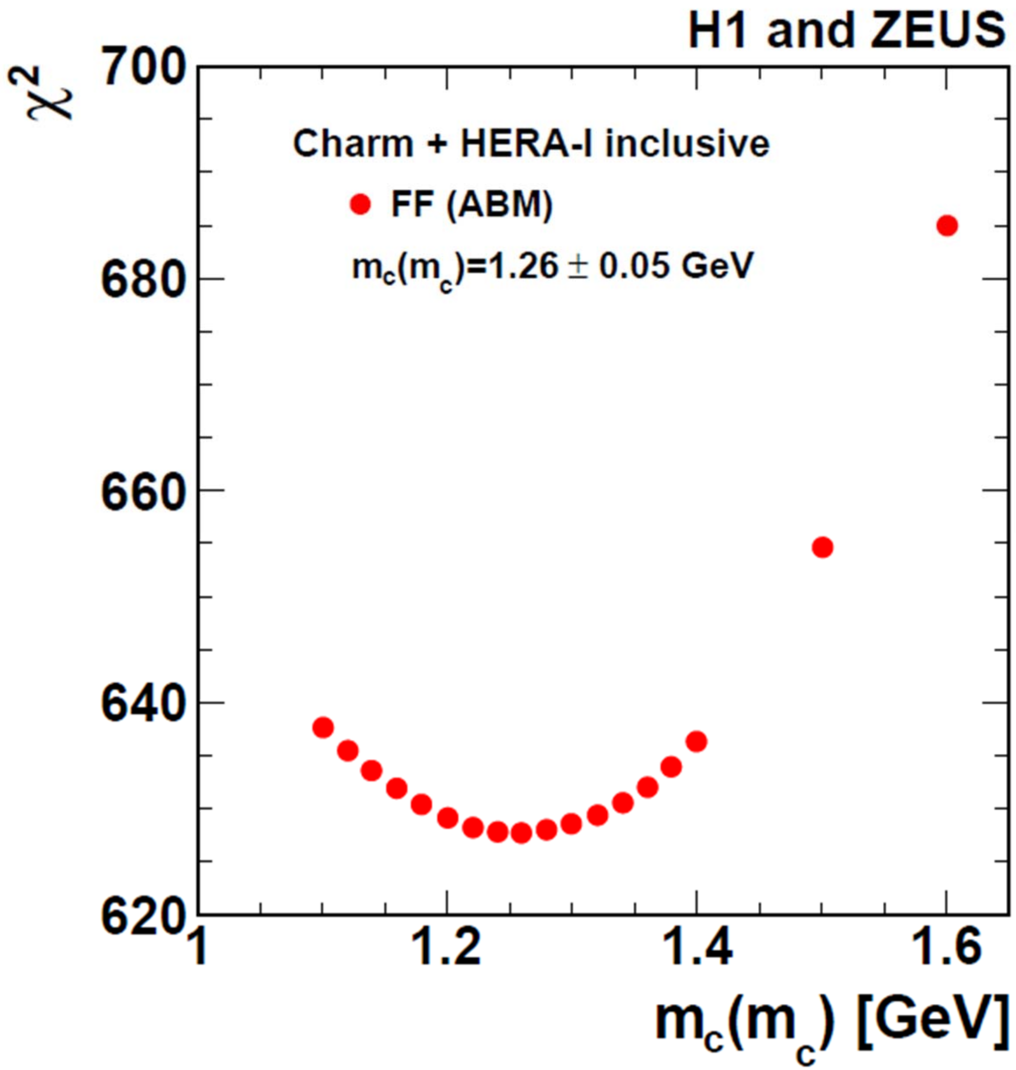


- Fit **combined charm** and inclusive DIS data
- **use ABM FFNS**

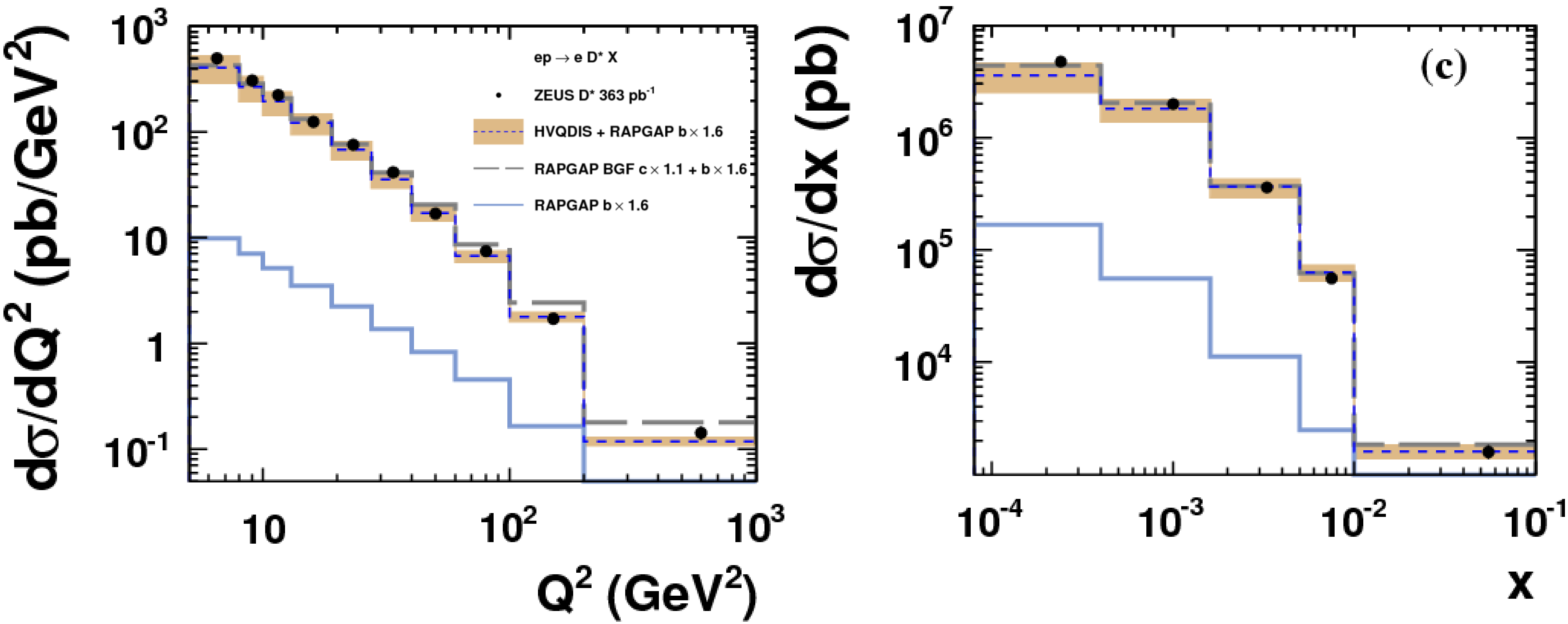
$m_c(m_c) = 1.26 \pm 0.05_{exp} \pm 0.03_{mod} \pm 0.02_{\alpha s}$ GeV (NLO)

➔ precise result

PDG: 1.275 ±0.025 GeV (lattice QCD + time-like processes) (NNLO)

Brand new ZEUS results in DIS: D* production

DESY-13-054

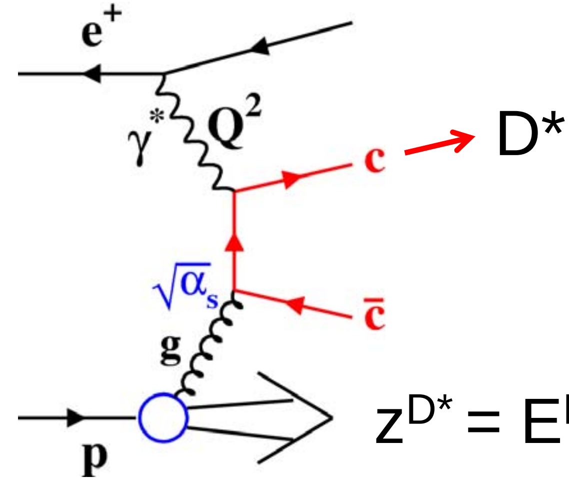


➔ Most precise ZEUS charm measurement

➔ well described by massive NLO (HVQDIS) ⊗ fragmentation model over the whole Q^2 and x range

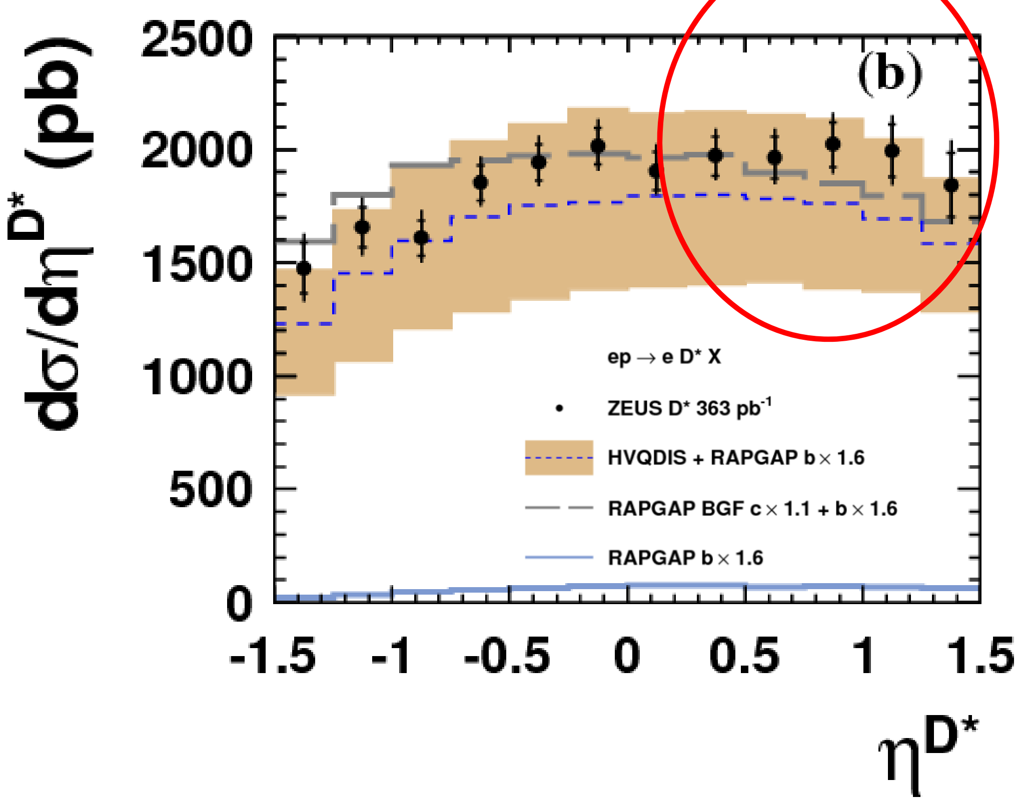
ZEUS D* in DIS *cont'd*

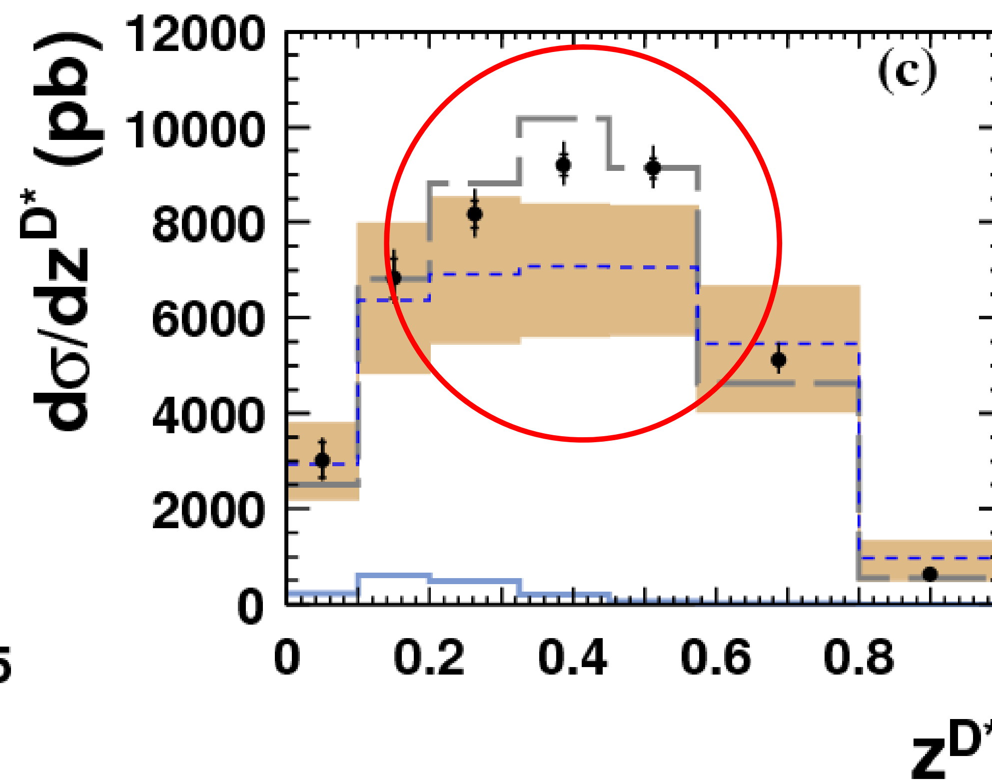
DESY-13-054



$z^{D^*} = E^{D^*}/E\gamma^*$ |p-restframe

e-direction p-direction

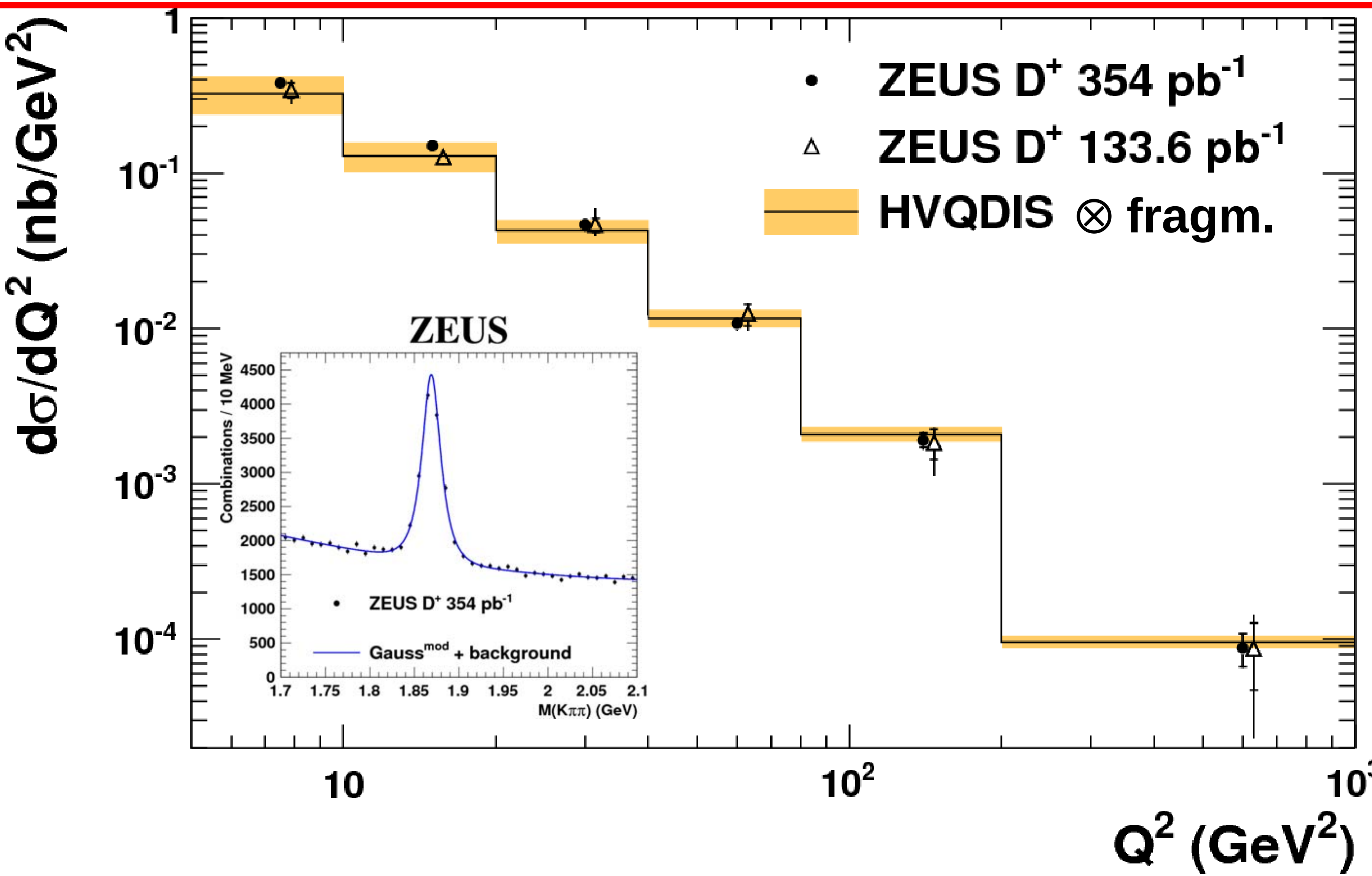




➔ Not perfect, but reasonable description by massive NLO ⊗ fragmentation model

Brand new ZEUS results in DIS: D^+ production

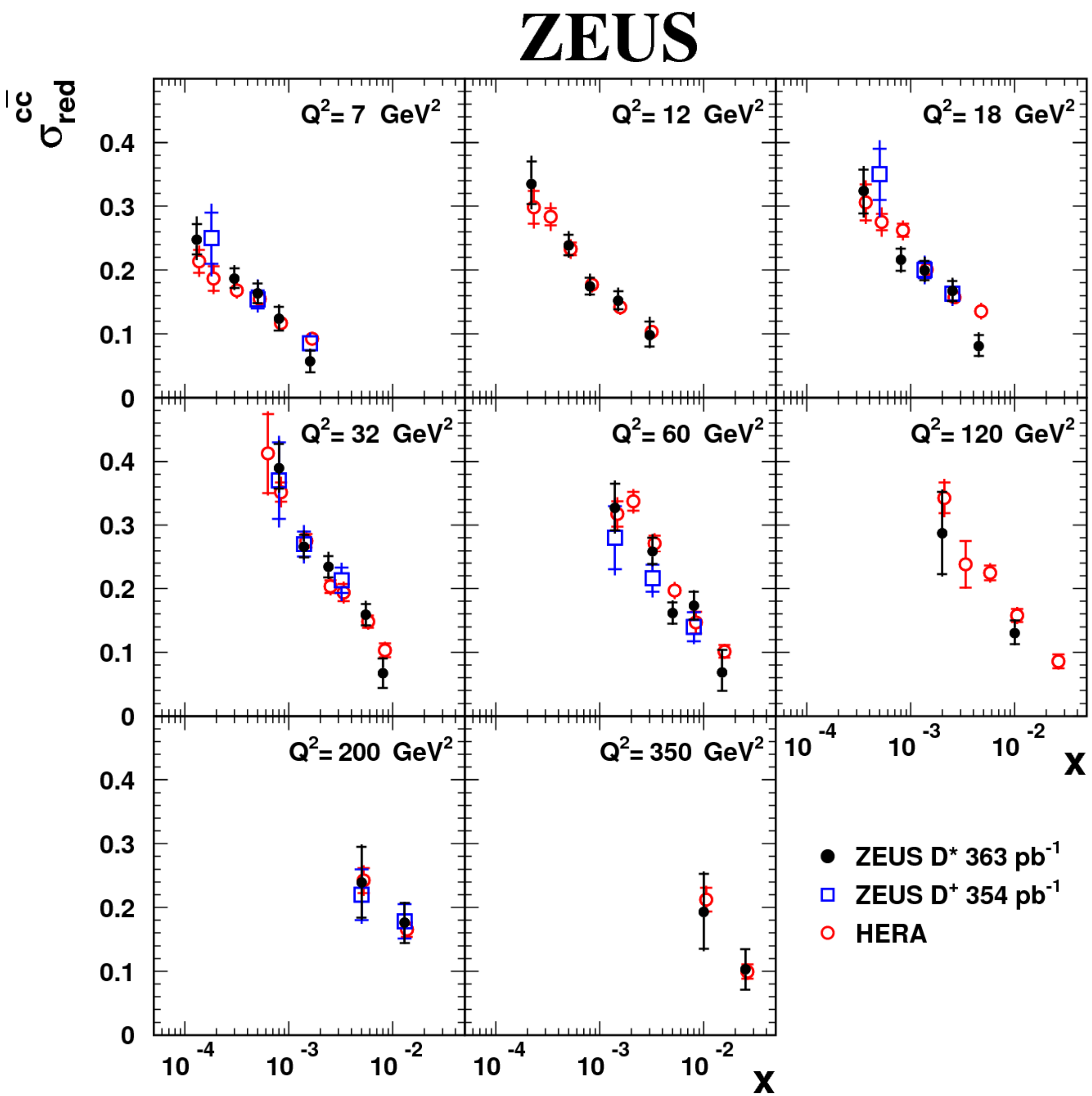
DESY-13-028

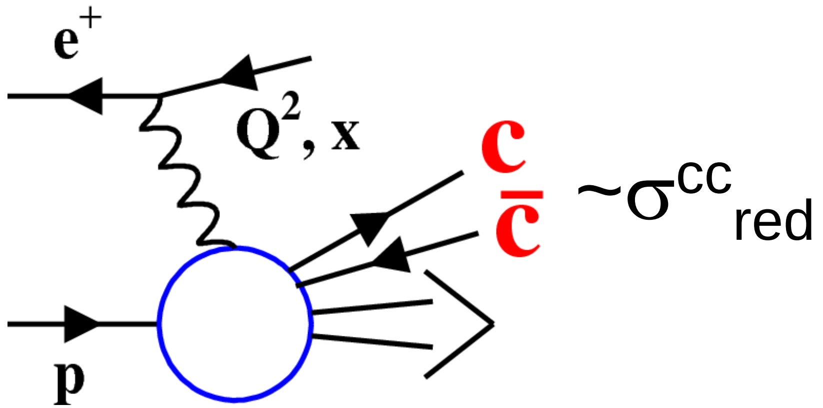


➔ The massive (NLO) scheme “prevails” up to Q^2~1000 GeV^2

Brand new charm results in DIS: D* and D+

DESY-13-054
DESY-13-028

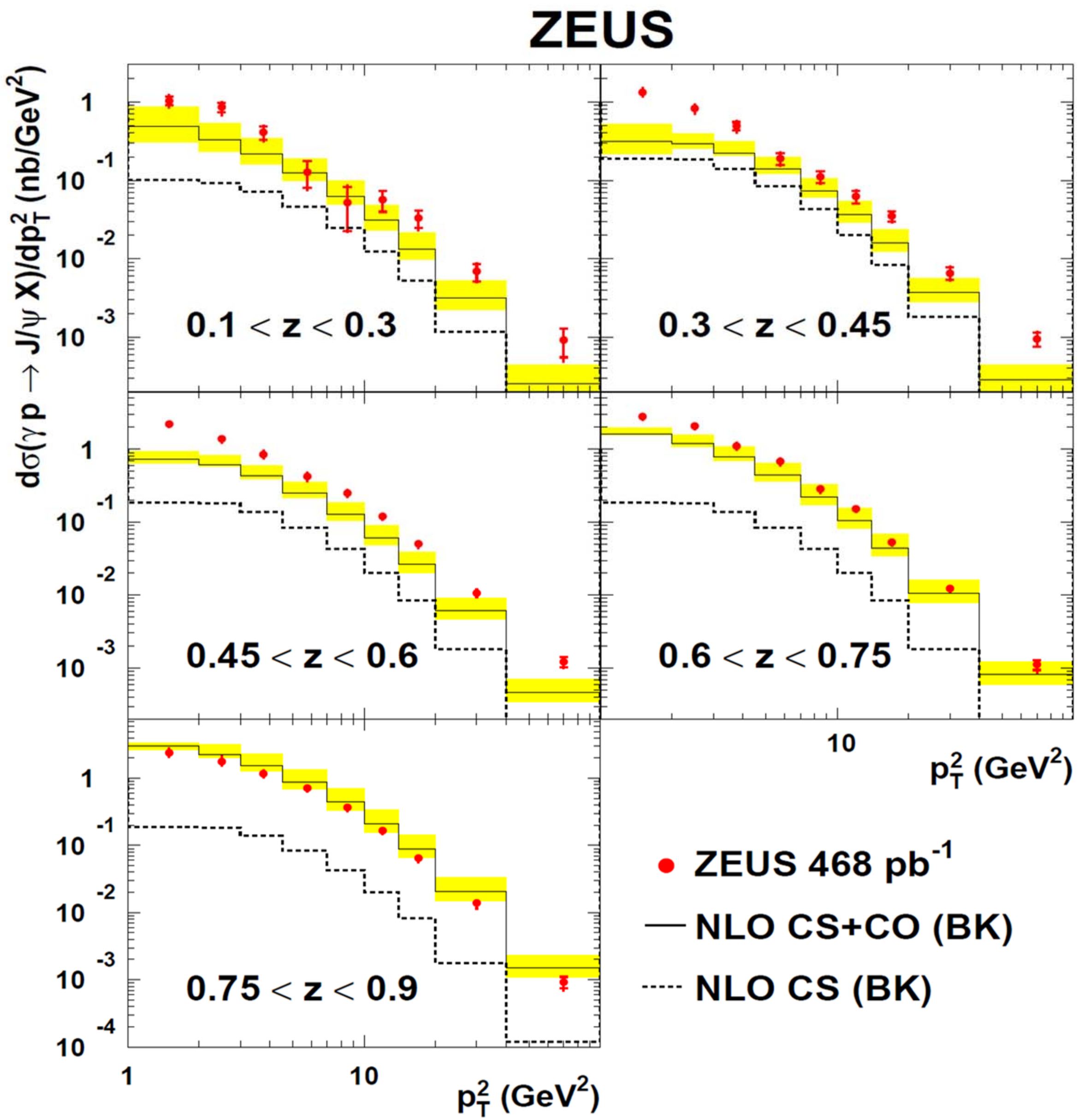




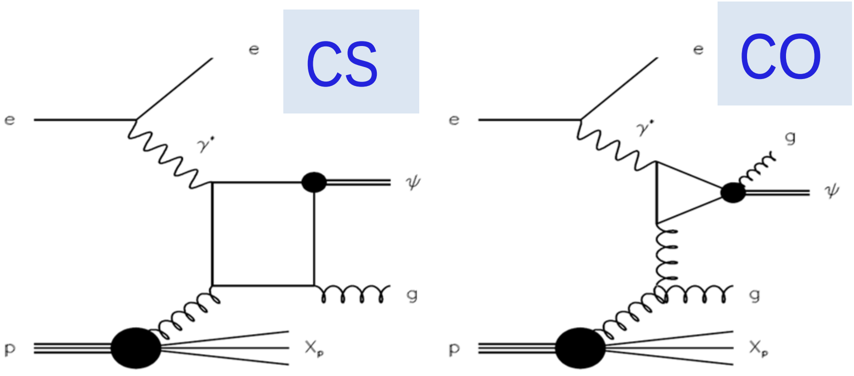
➔ Consistent findings
➔ New ZEUS results will improve combination, PDF and M_c fits

Inelastic J/ψ production in PHP

JHEP02 (2013) 071



Non relativistic QCD



$$z = \frac{(E-p_z)_{J/\Psi}}{(E-p_z)}$$

NLO calculation:

➔ **Rough** data description

➔ Color octet contribution is essential

Conclusions

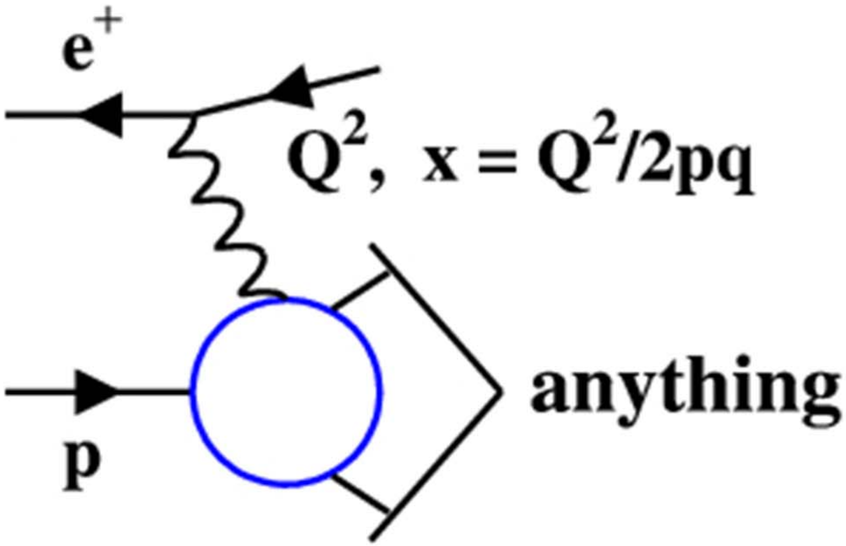
- HERA combined charm data in DIS provide unique precision data for testing treatment of **heavy quark mass terms** in pQCD:
  - variable flavour number schemes:
    - Data can separate between them
    - Can be compensated by optimal charm mass value
    - improve knowledge of sea flavour decomposition
  - Fixed flavour number scheme:
    - Provides the best data description
    - Fit running $m_c(m_c)$ = 1.26±0.06 GeV (NLO)

- Brand new ZEUS D^* and D^+ data in DIS → **precise results**, will further improve HERA charm combination

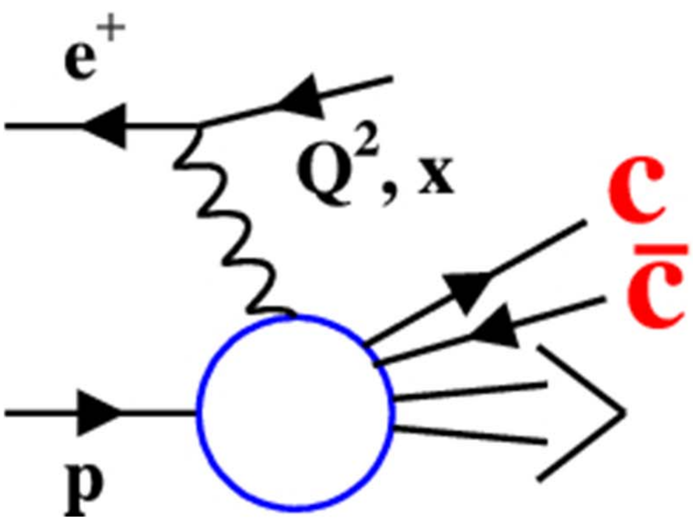
- New ZEUS J/ψ photoproduction results: colour octet terms essential in improved NRQCD NLO calculations to match the data

Backup slides

Charm contribution to DIS: F_2^{cc}

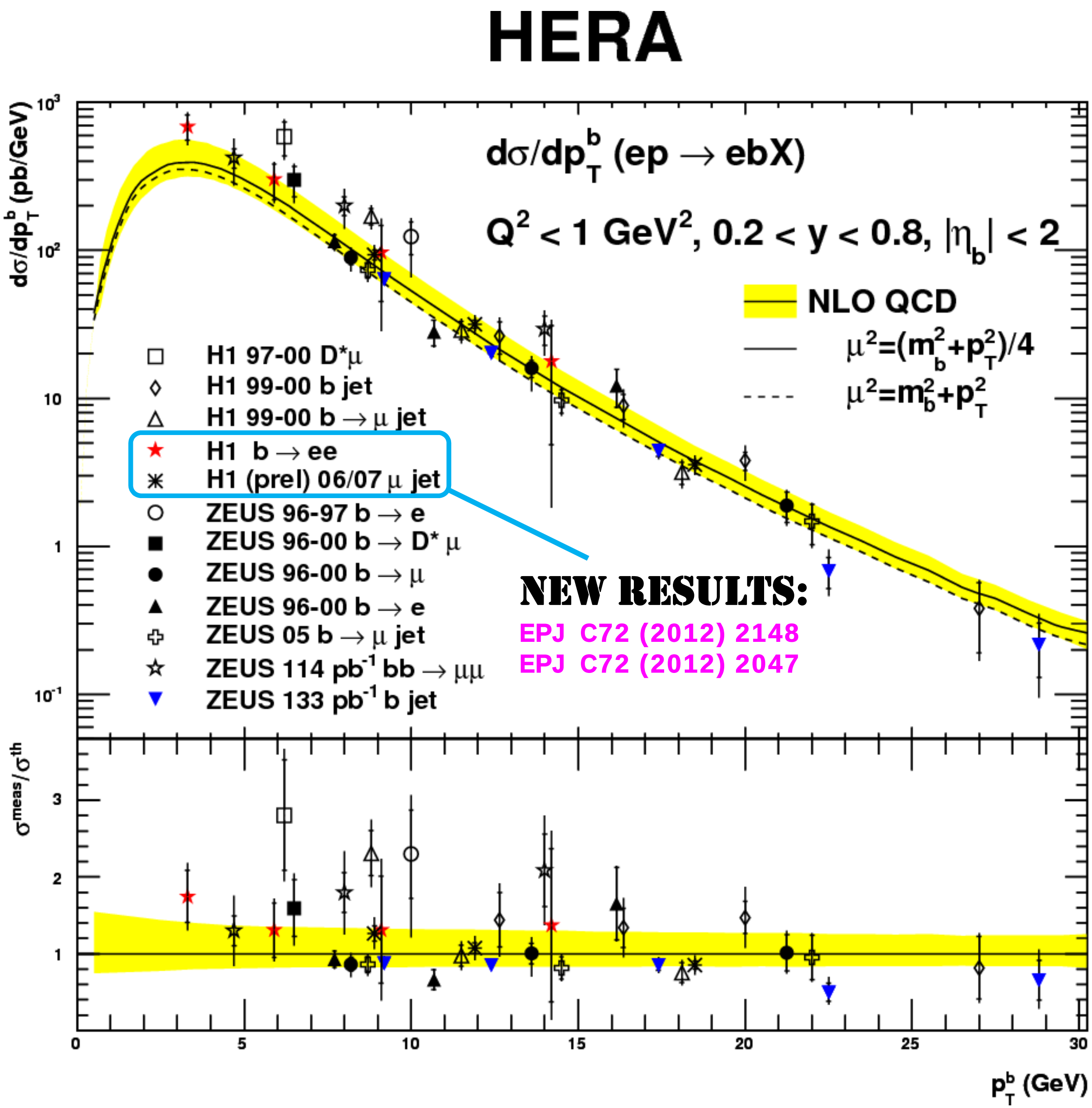


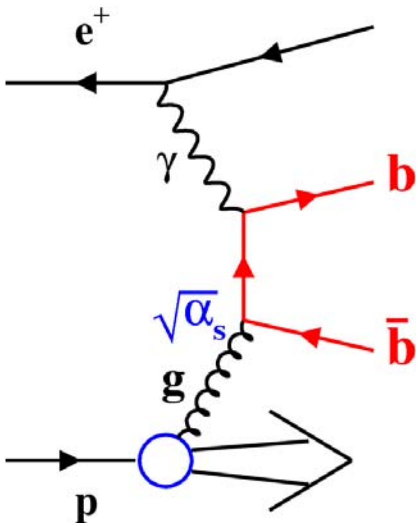
$$\frac{d^2\sigma^{ep}}{dQ^2dx} \propto F_2(x,Q^2)$$



$$\frac{d^2\sigma^{ep\to c\bar{c}x}}{dQ^2dx} \propto F_2^{c\bar{c}}(x,Q^2)$$

Beauty photoproduction vs p_T^b





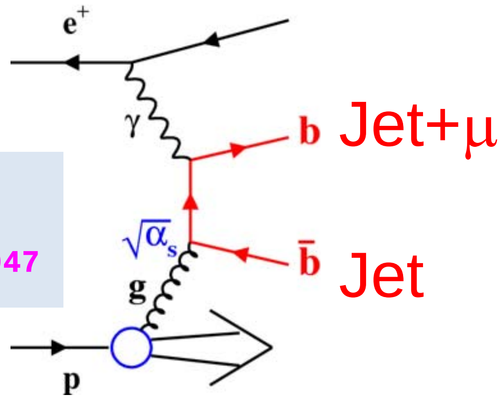
Data vs massive NLO (FMNR)

➔ Reasonable description ***from threshold to high momenta***

Beauty: HERA photo- vs LHC hadroproduction

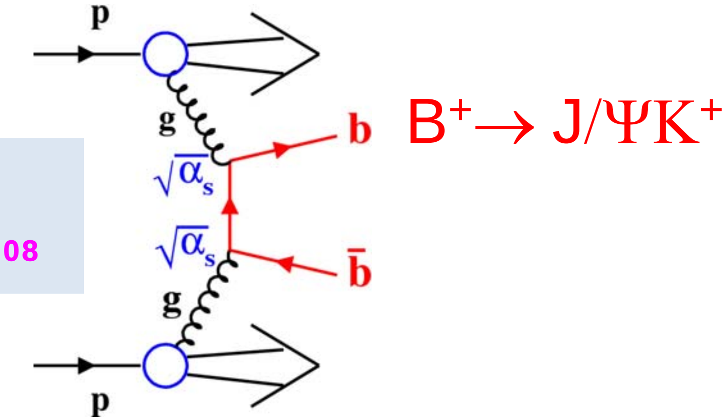
HERA

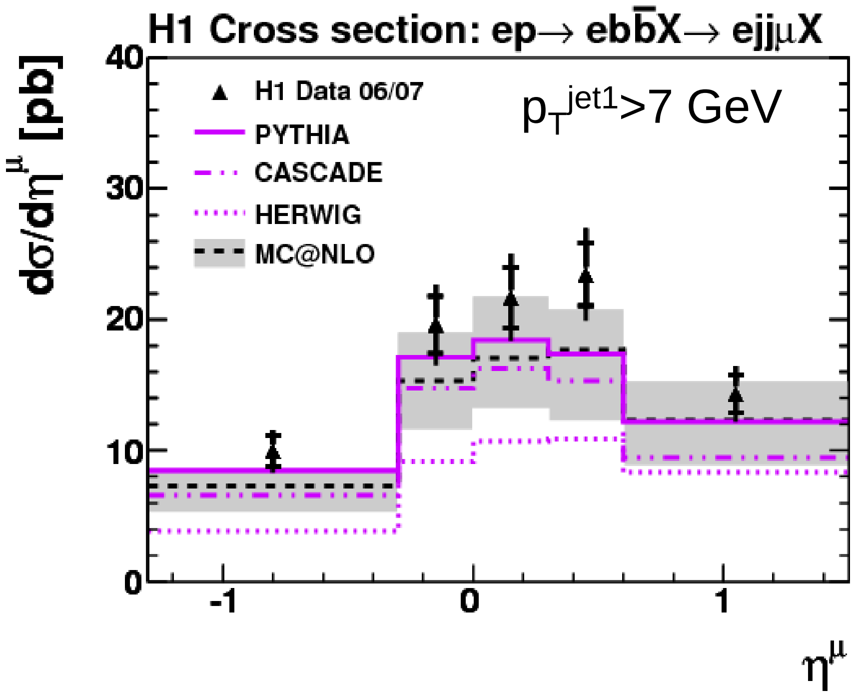
EPJ C72 (2012) 2047

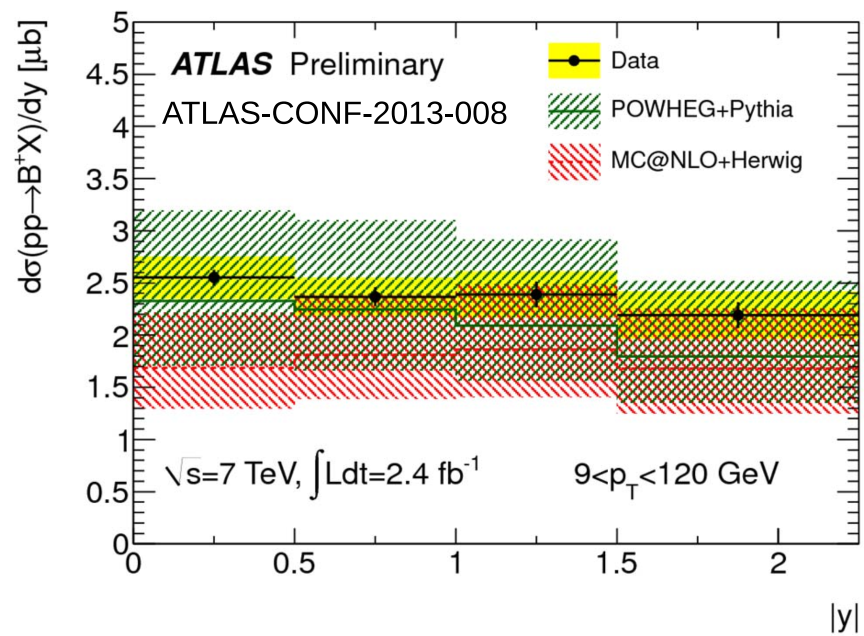


LHC

ATLAS-CONF-2013-008





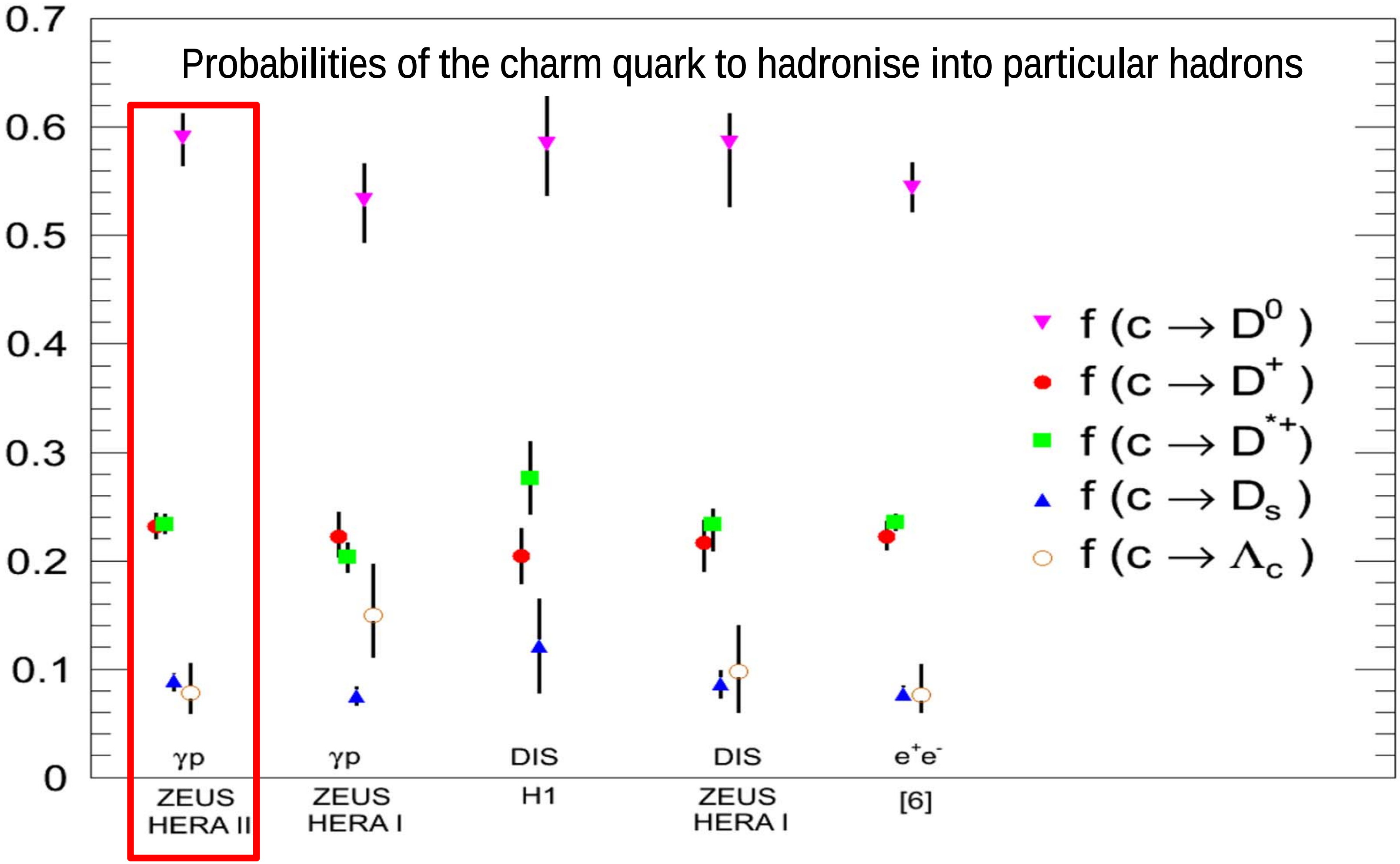


MC@NLO: - describes both data reasonably (however fails ATLAS $d^2\sigma/dpt/dy$)

- comparable (rather large) theory uncertainties

Charm fragmentation fractions in PHP

to be submitted soon for DESY preprint



➔ Competitive precision to e+e- data
➔ Confirm ***universality*** of charm fragmentation