Combination of D* measurements in Deep Inelastic Scattering at HERA

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for the H1 and ZEUS collaborations

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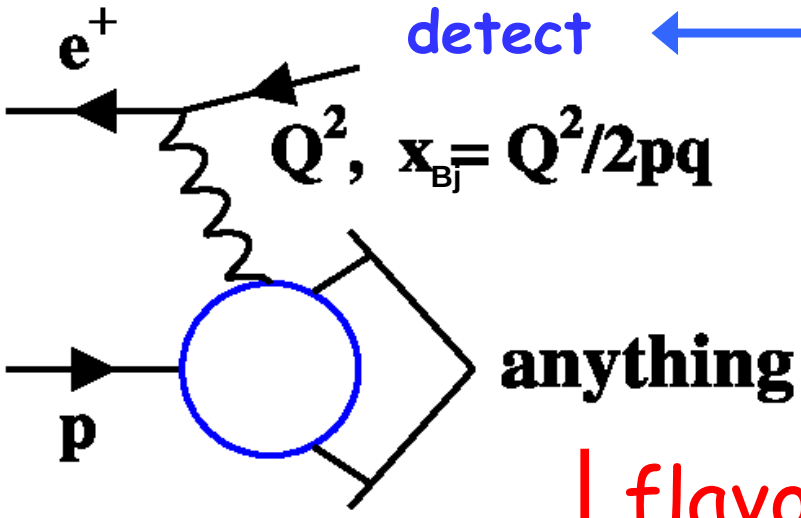
- Introduction
- Combination of D* cross sections
- Comparison with NLO QCD
- Interpretation of results
- Conclusions

arXiv: 1503.06042, JHEP 09 (2015) 149

review of all (other) HERA charm + beauty results
arXiv:1506.07519
Prog.Part.Nucl.Phys. 84 (2015) 1

Heavy flavour contributions to DIS

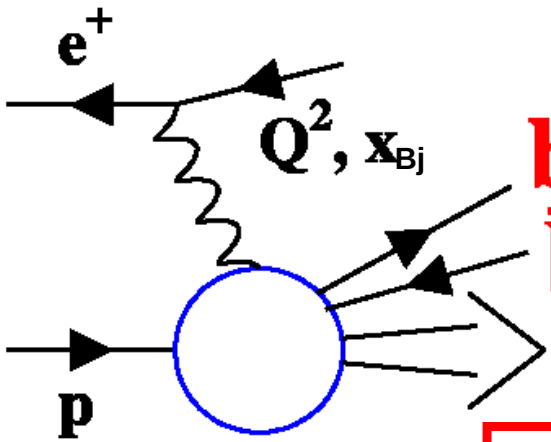


detect ⟷

Measure cross section

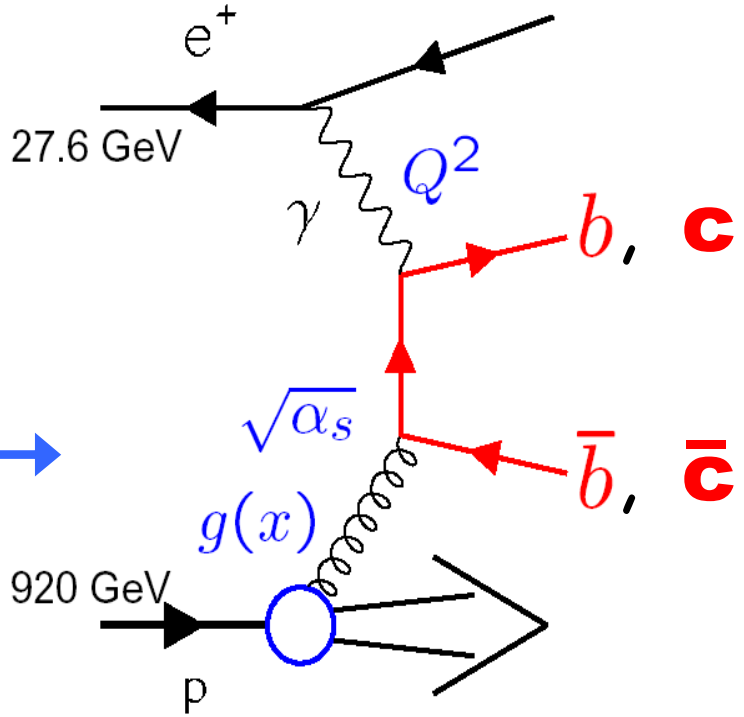
$$\frac{d^2\sigma}{dx_{Bj}dQ^2} \cong \frac{2\pi\alpha^2}{Q^4 x_{Bj}}\left[1+(1-y)^2\right] \sigma_{red}$$

flavour tagging (D*)



$\mathbf{b}\ \bar{\mathbf{b}}$ or $\mathbf{c}\ \bar{\mathbf{c}}$

QCD ⟷



→ P_T(D*), etc.

Why are heavy flavours important?

- charm contribution to inclusive DIS data ~10-30%!
- **kinematic effect of mass, fragmentation effects**
- **competing scales for perturbative expansion**

e.g. m, Q^2, p_T -> terms $\log Q^2/m^2$

$\log p_T^2/m^2$ etc.

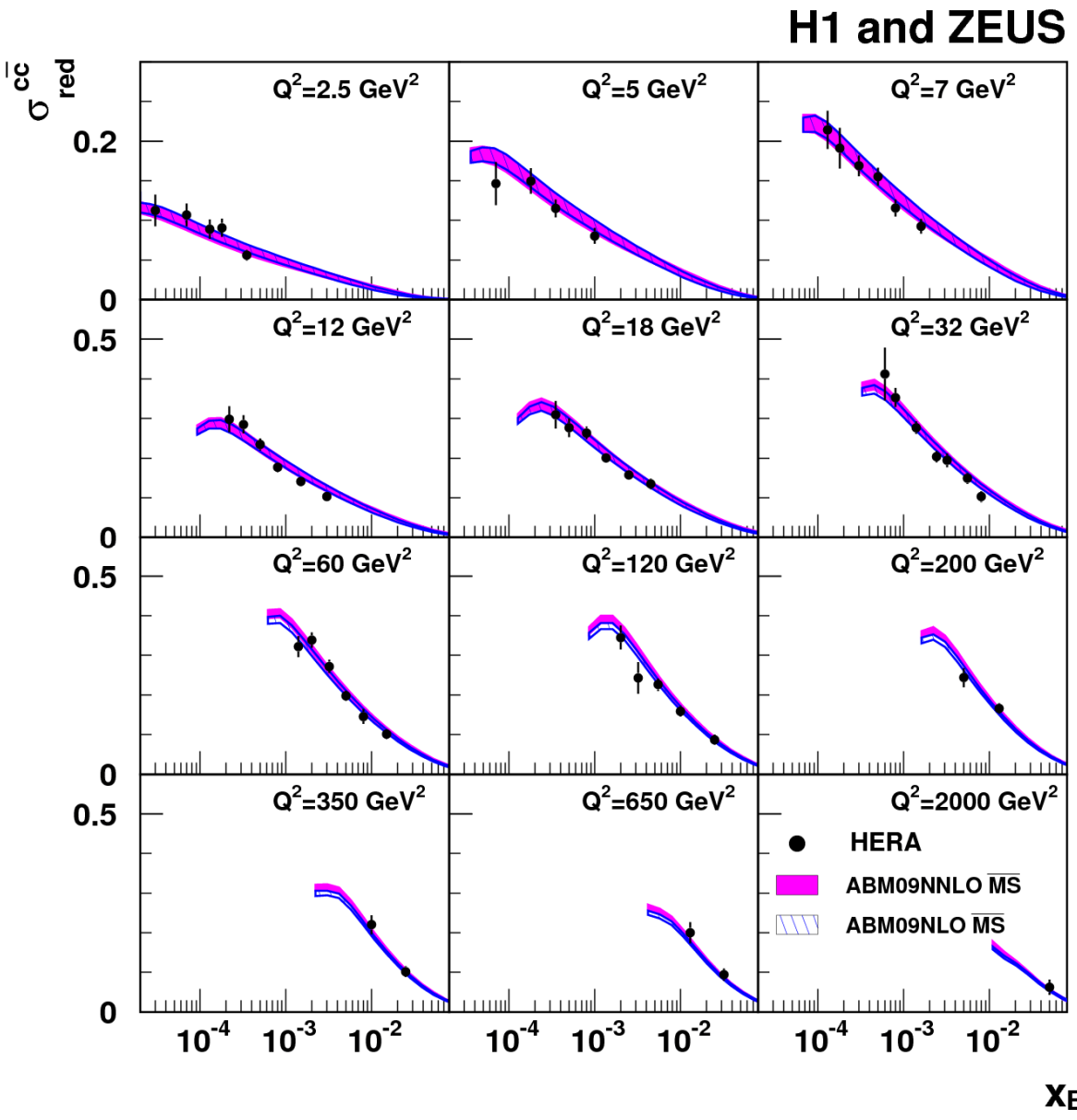
⇒ "**massless**" treatment allows resummation beyond NLO,
but fails near "mass threshold" -> avoid !

=> "**massive**" treatment gets kinematics right,
but does not allow resummation (fixed flavour number schemes)
or induces ambiguities in QCD corrections near flavour threshold
(variable flavour number schemes, available for semi-inclusive only)

check theory against HERA data

Combination of inclusive charm data

Reminder:



EPJ C73 (2013) 2311

9 data sets,
5 tagging methods

very good description of combined data by fixed flavour predictions in full kinematic range, small theory uncertainties

measure charm mass

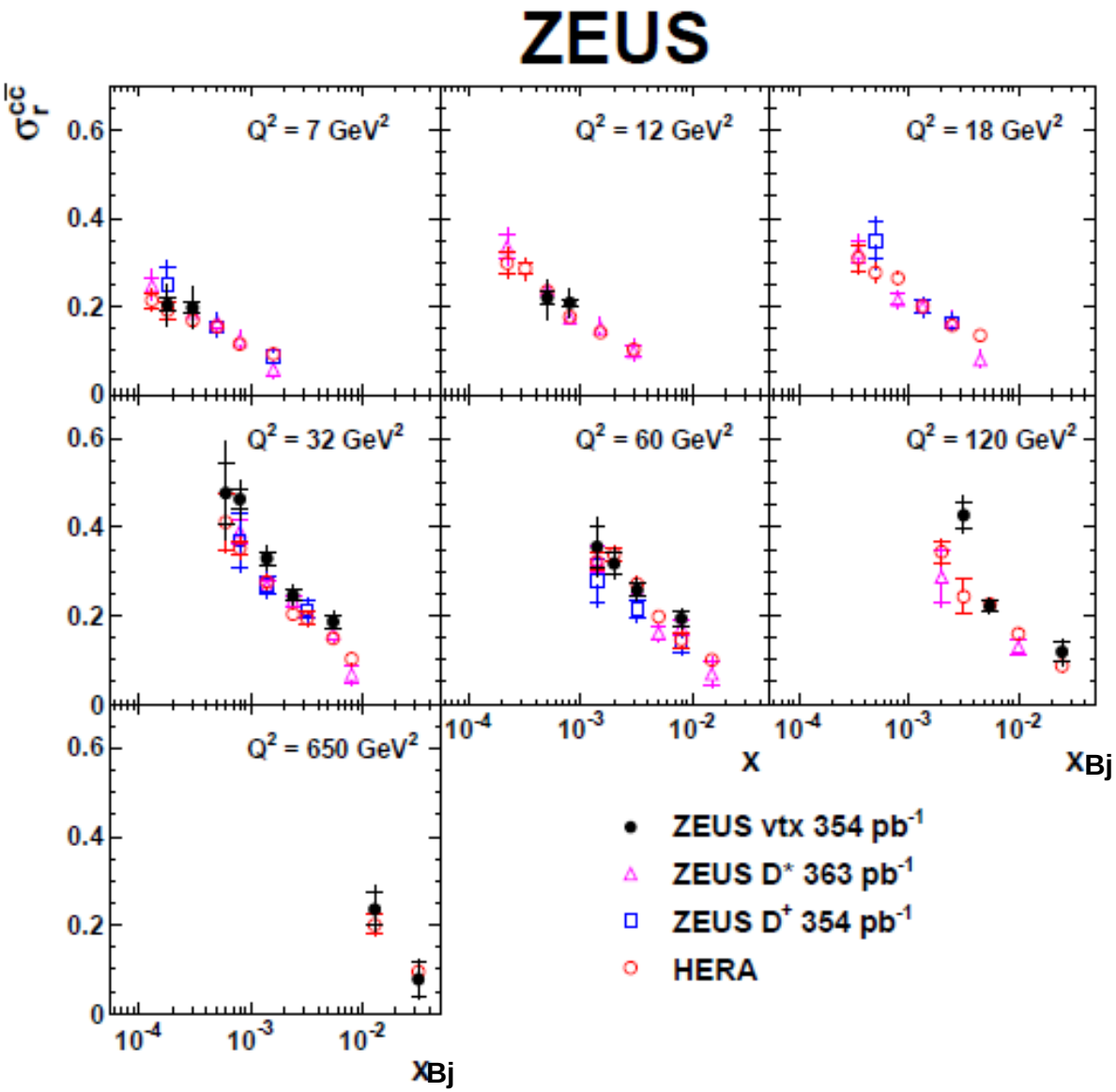
$m_c(m_c)$ = 1.26 $\pm 0.05_{exp}$ $\pm 0.03_{mod}$ $\pm 0.02_{\alpha s}$ GeV

PDG: 1.275 ±0.025 GeV
(lattice, …)

Latest charm results in DIS: D*, D⁺, vtx

JHEP 05 (2013) 023
JHEP 05 (2013) 097
JHEP 1409 (2014) 127

Reminder:



→ completes ZEUS measurements

→ consistent findings

→ will further improve combination, PDF and m_c fits

→ 1st step (new) : combine H1 and ZEUS visible differential D* cross sections

HERA D* cross section combination

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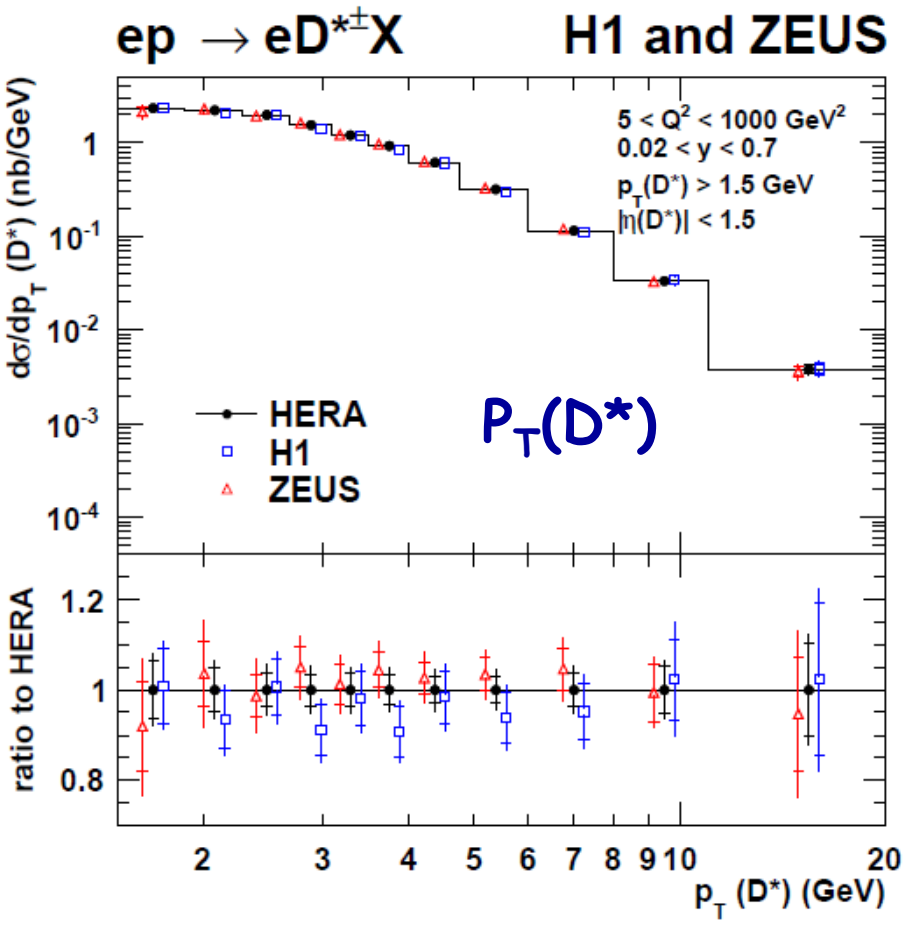
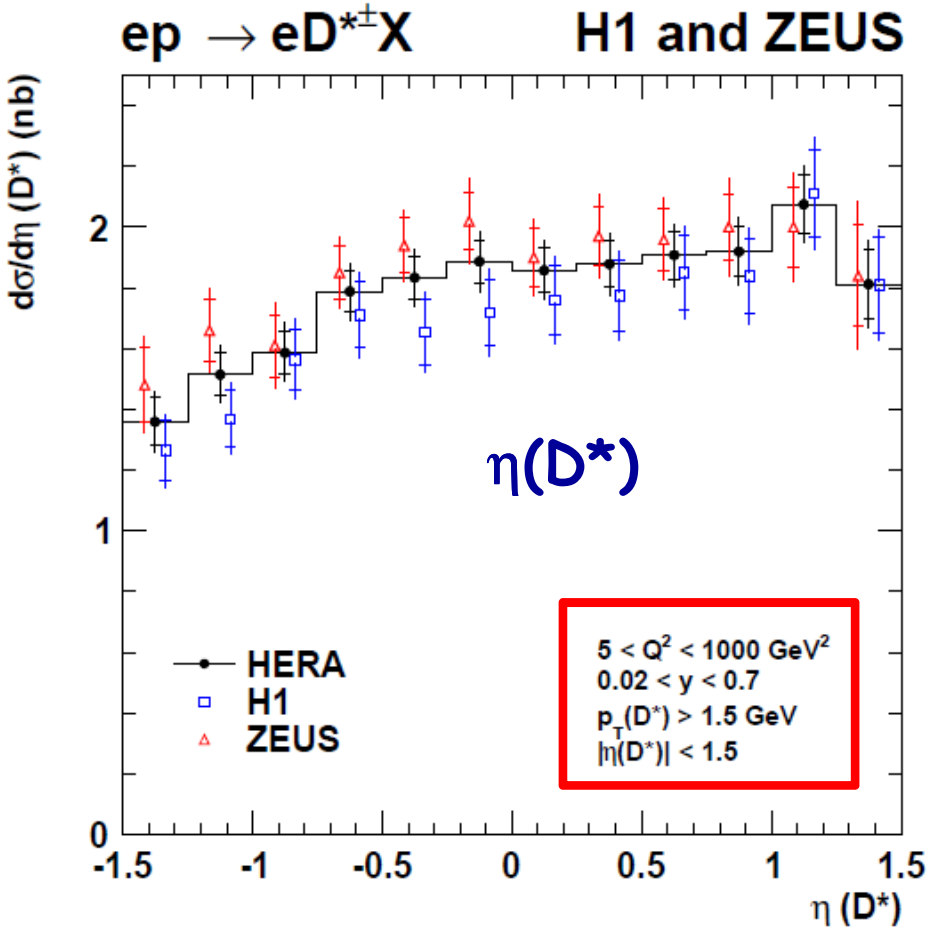
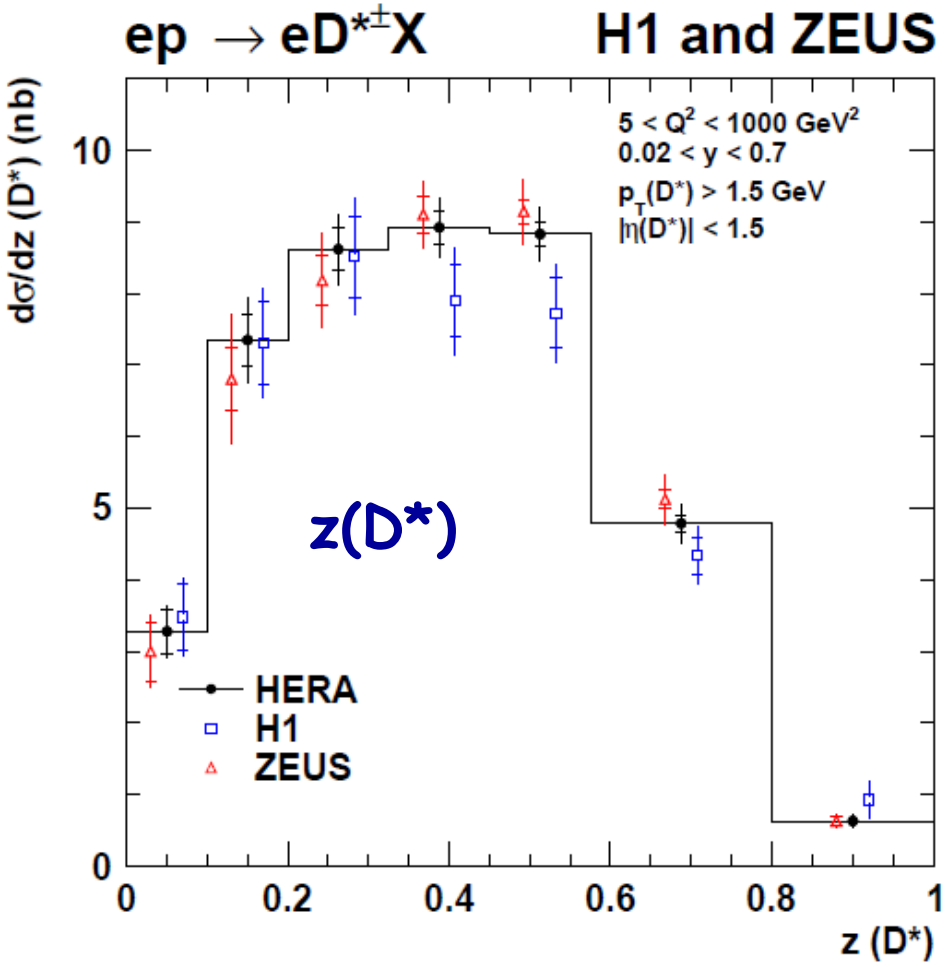
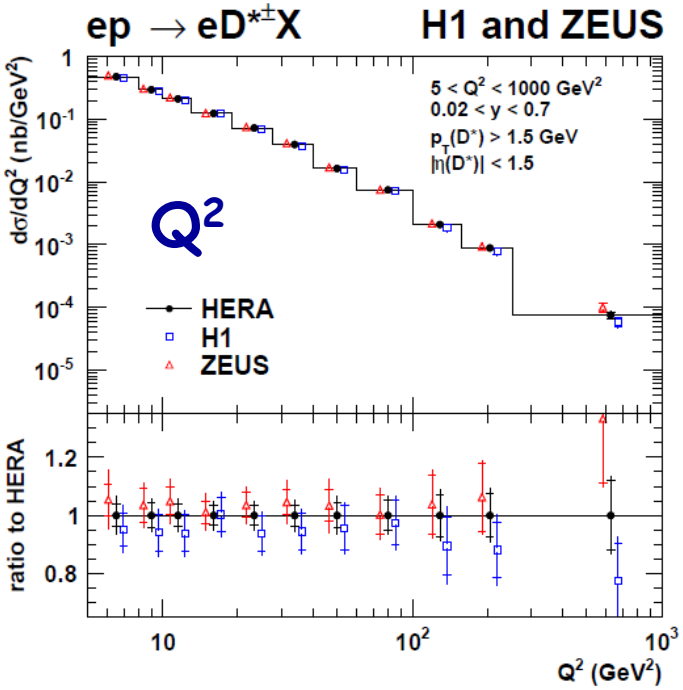


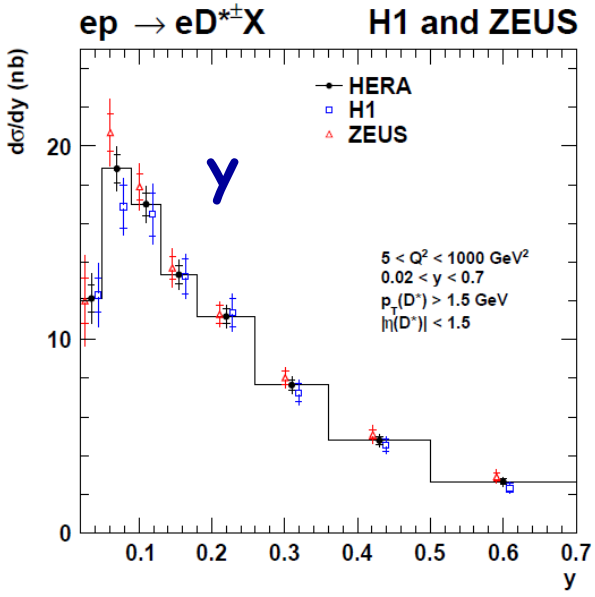


- good agreement between experiments
- full treatment of systematic correlations
- no extrapolation to full phase space
  -> data (almost) unaffected by theory uncertainties

HERA D* cross section combination

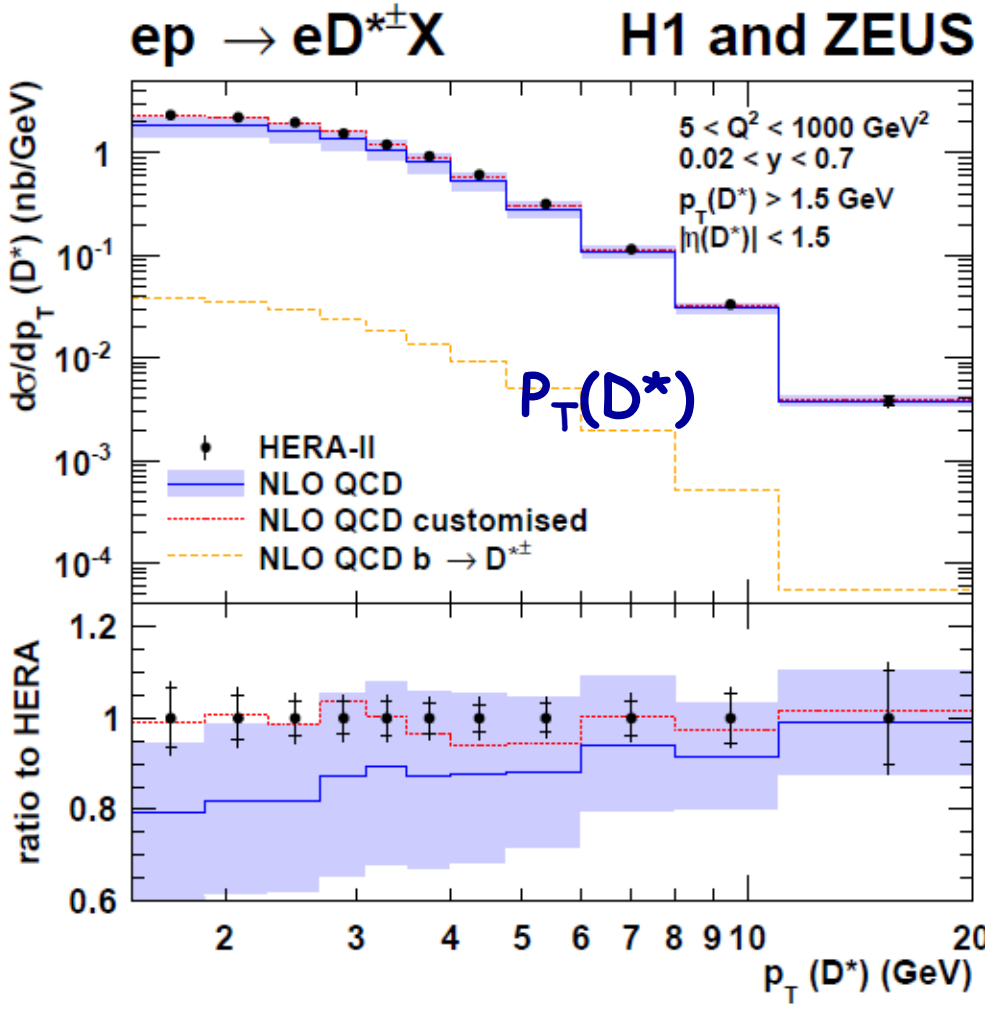


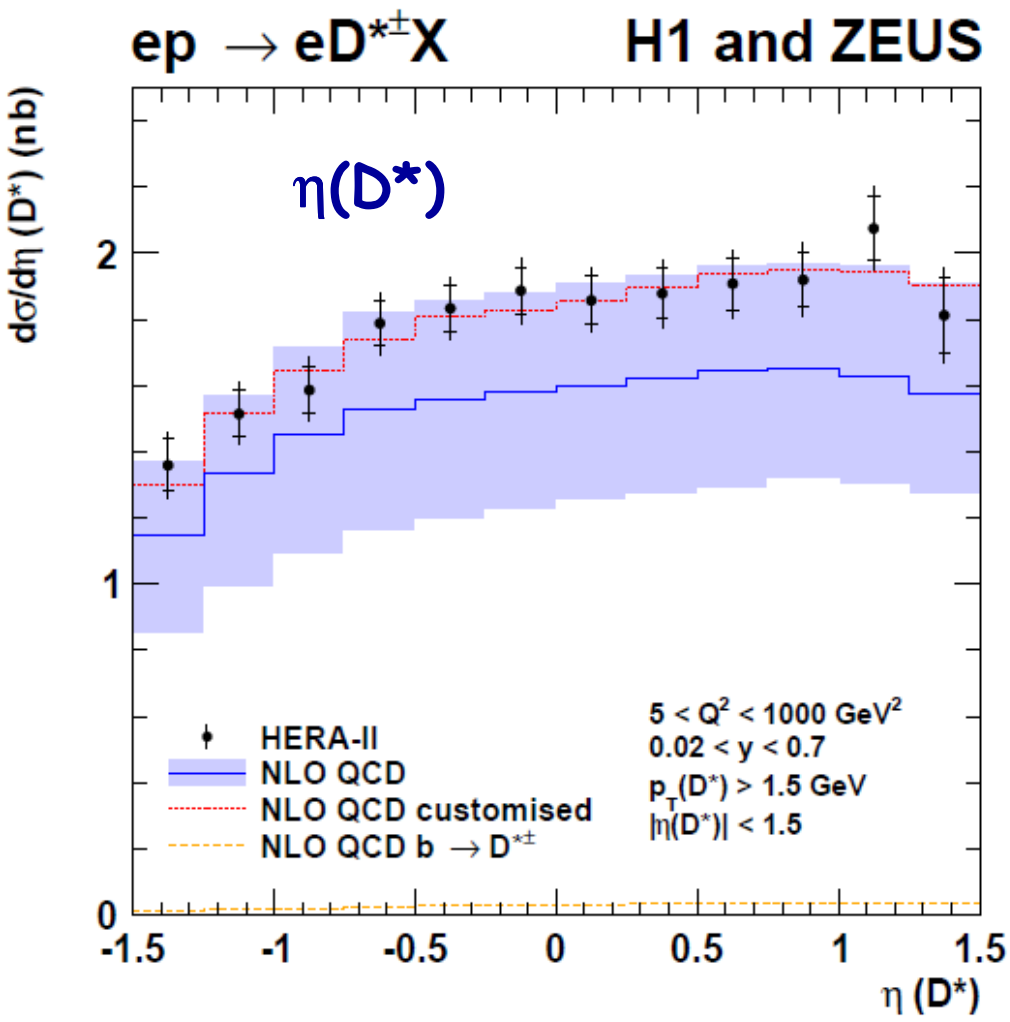




- z(D*) = (E(D*)-pZ(D*))/2Eey
- sensitive to fragmentation
- inclusive variables Q^2, y

Comparison to NLO QCD

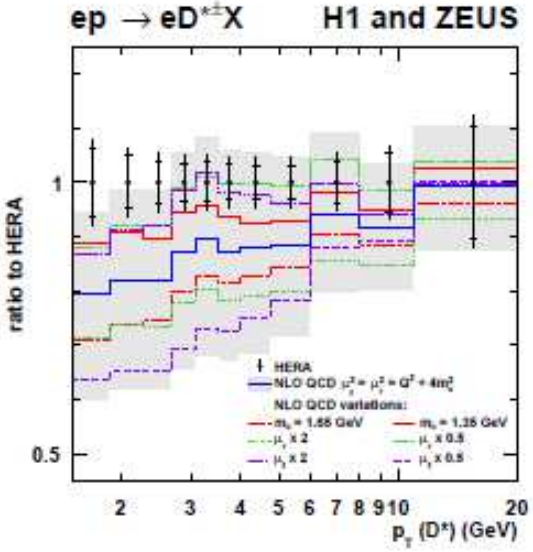




good agreement within large theory uncertainties

Comparison to NLO QCD

detailed study of theory uncertainties



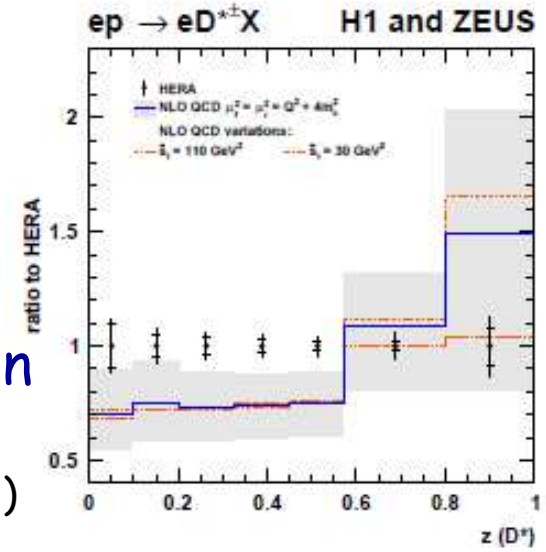
is it possible to customise (choose parameters) such that all distributions are described simultaneously?

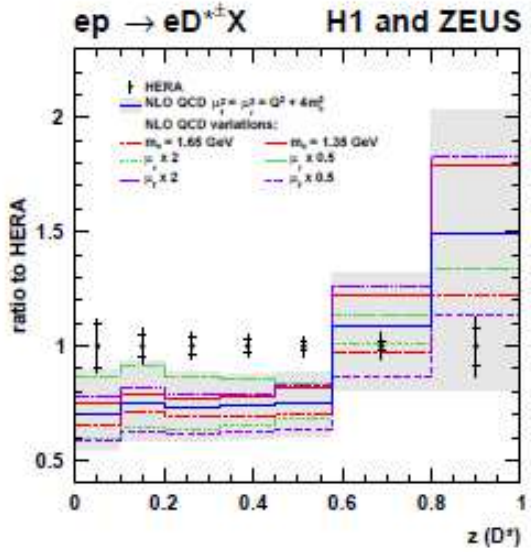
largest:

QCD scales

fragmentation

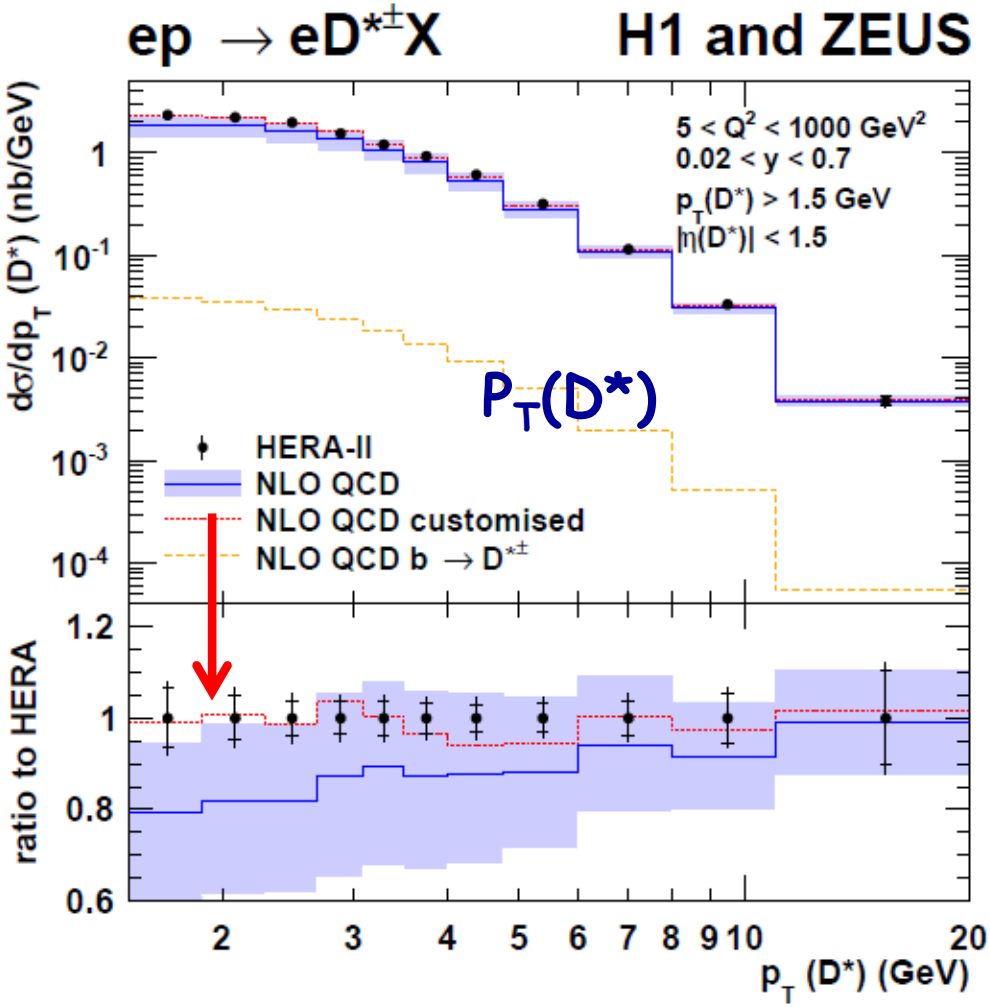
(Kartvelishvili as measured at HERA)

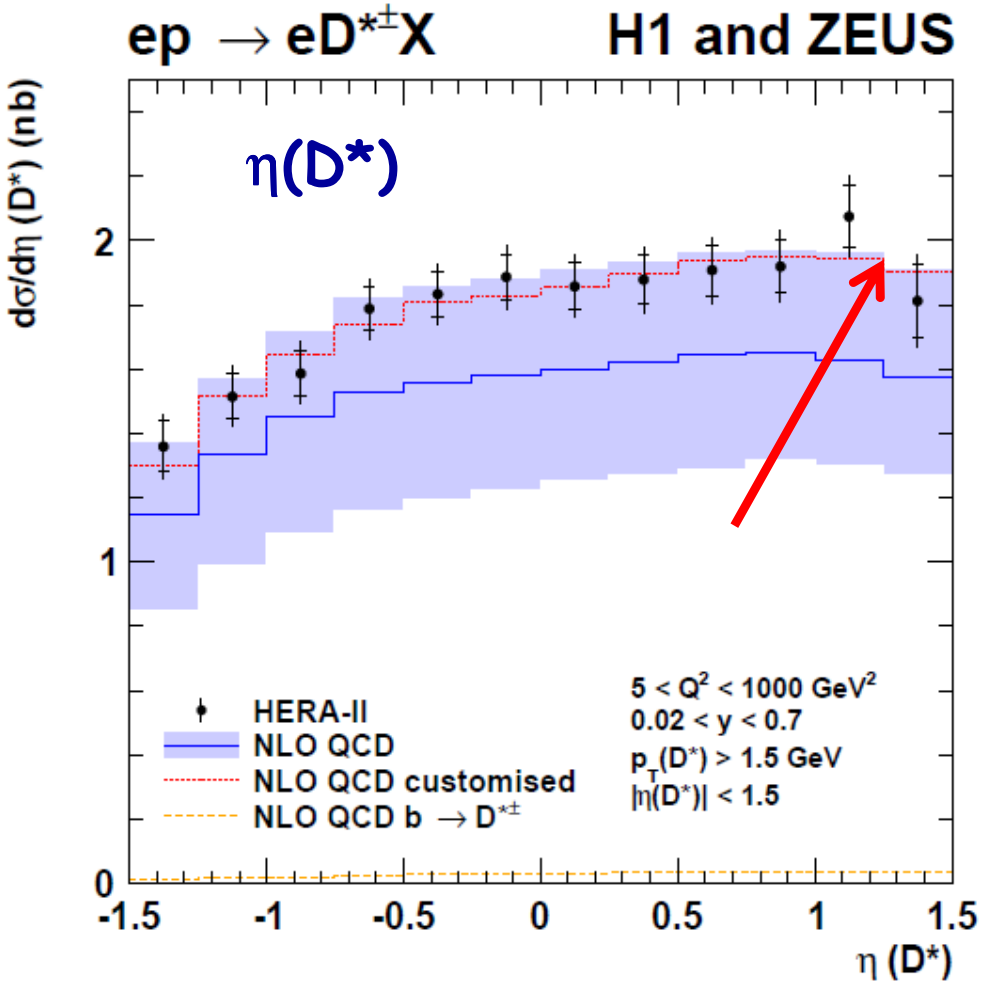




it is!

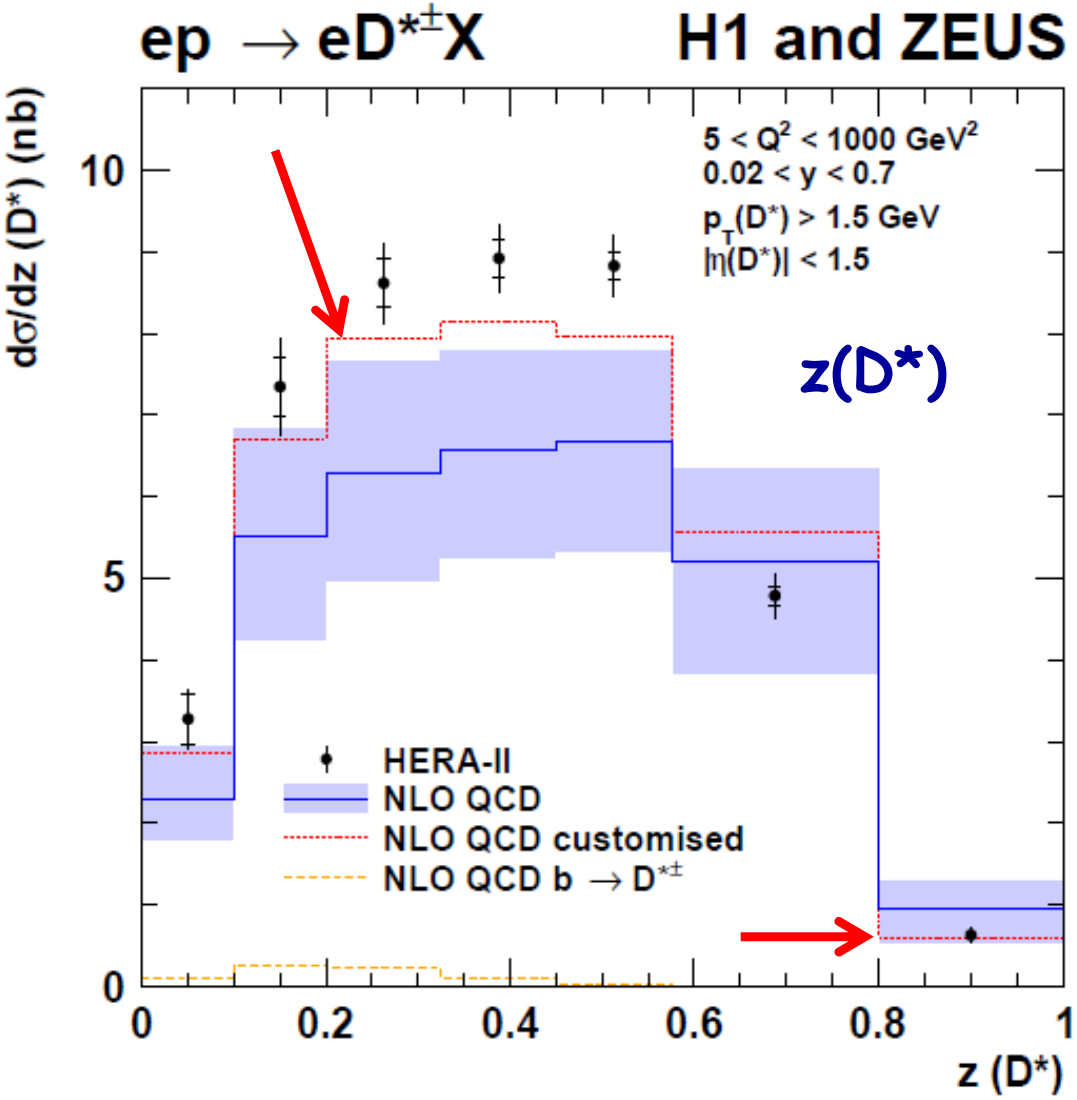
Comparison to NLO QCD





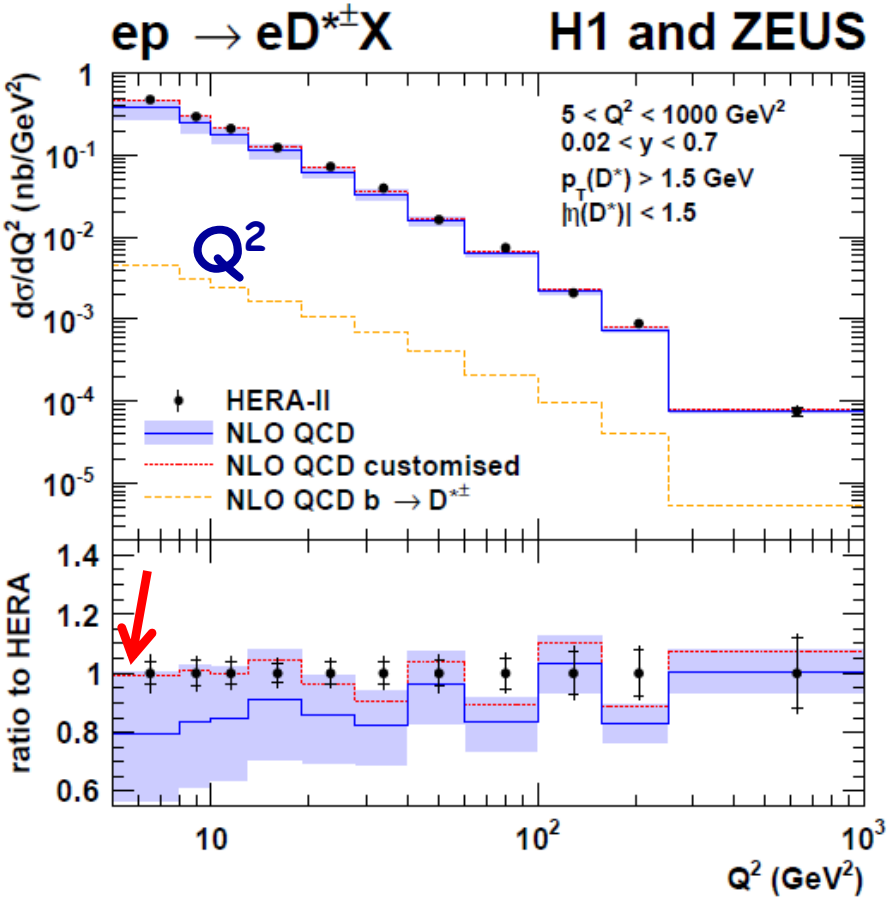
customised choice: - reduced renormalisation scale
- modified scale dependence of fragmentation
- slightly lower charm mass (all within uncertainty)

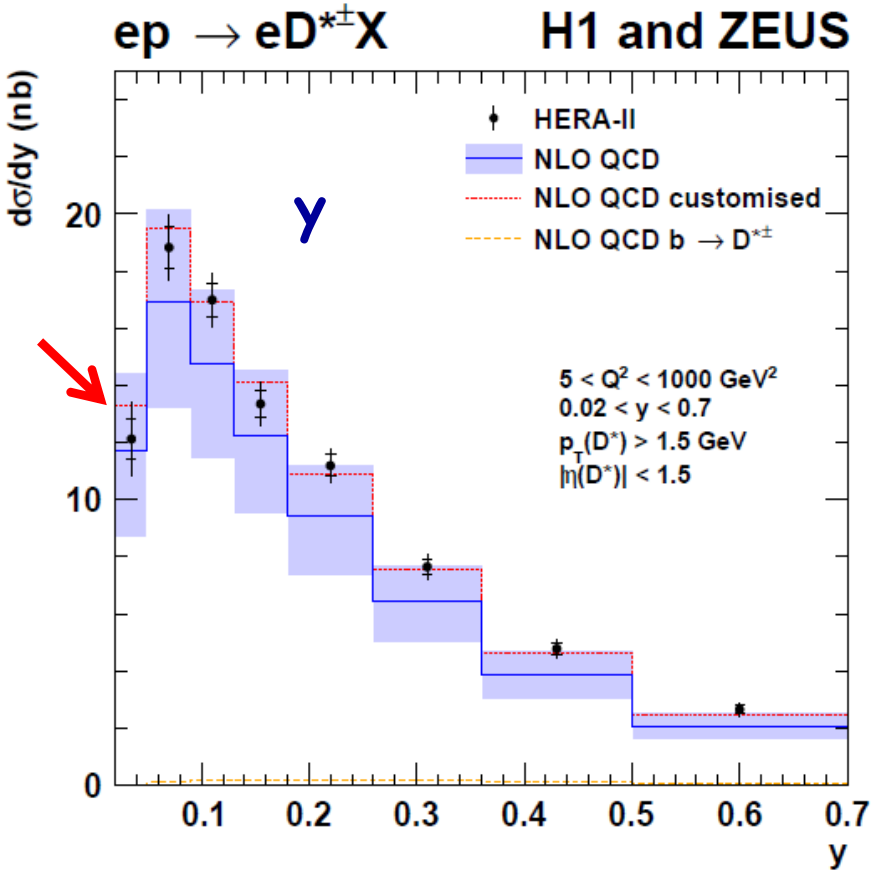
Comparison to NLO QCD



shape directly sensitive to fragmentation parameters

Comparison to NLO QCD



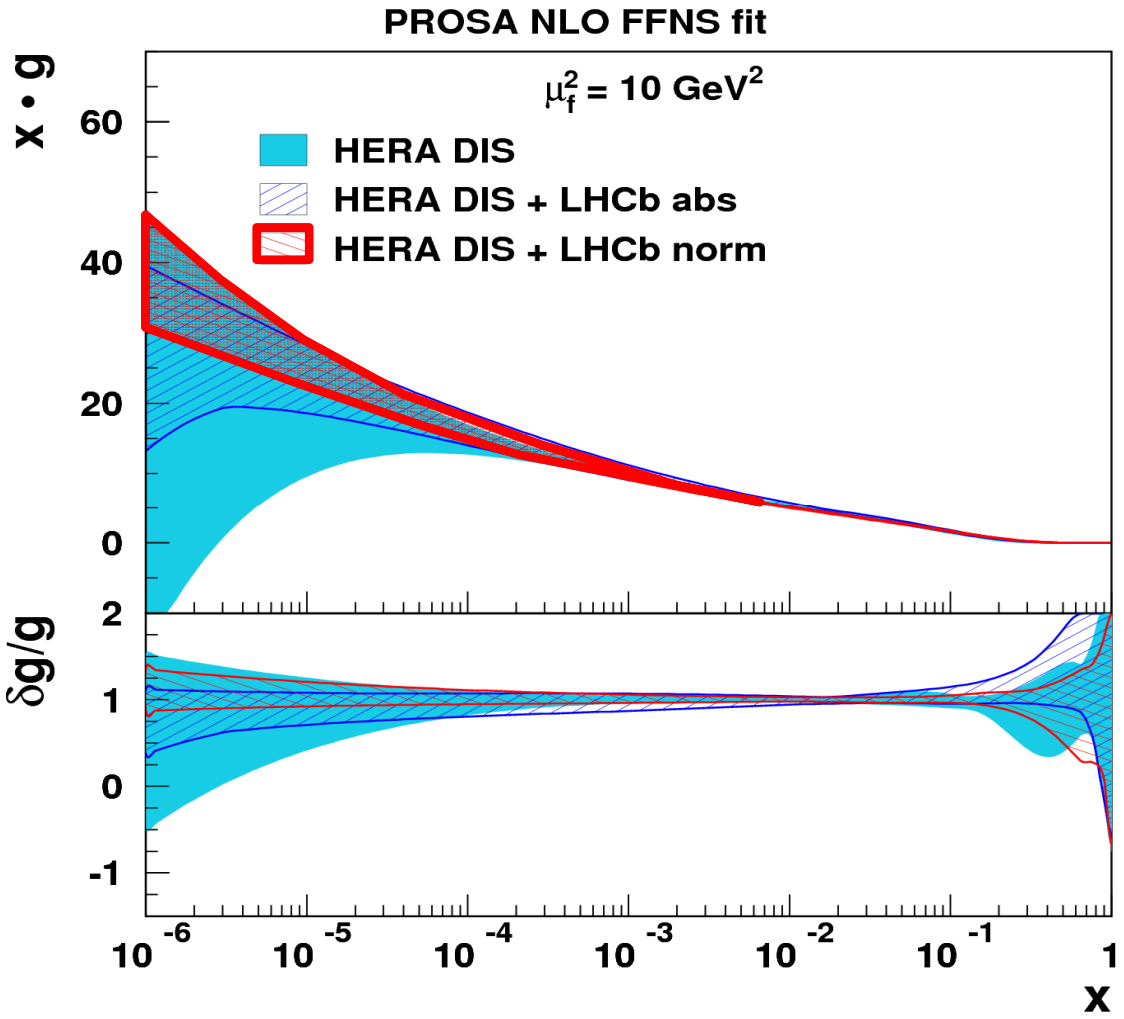


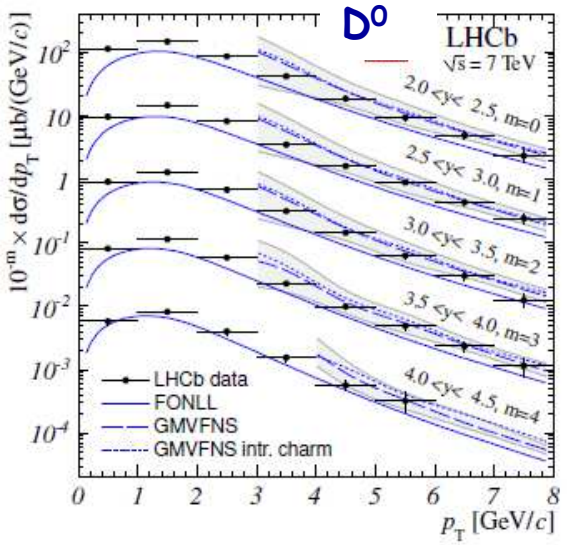
good agreement

double differential distributions see backup

Recent PROSA result from fit of **LHCb** and **inclusive** HERA charm data

arXiv 1503.04581, Eur.Phys.J. C75 (2015) 396





gluon positive and well constrained down to x ~ 10^{-6}

personal remark: merger with fit of differential HERA charm data might reduce theory uncertainties

Summary and conclusions

arXiv: 1503.06042, JHEP 09 (2015) 149

- **First H1 and ZEUS combination of differential D* distributions in DIS has been achieved -> full and final HERA statistics**
  full correlation treatment, **significant reduction of experimental uncertainties**

- **Good agreement with NLO QCD predictions within large theory uncertainties**
  (typically ~4 times larger than data uncertainties)
  -> challenge to theory to provide improved predictions

- **Detailed theory uncertainty study reveals largest potential for improvement from reduction of scale uncertainties** (NNLO predictions, difficult!)
  and improved fragmentation treatment (e.g. better treatment of c-quark/D meson mass mismatch, feasable!)

- **Customised prediction shows that such improvements lie within the range of current uncertainties.** Remaining mass uncertainty calls for differential predictions using charm running mass rather than pole mass (should be straightforward).

- Personal remark: Future simultaneous fit with other data (e.g. LHCb data) might offer additional handles for improvements and further insights

Backup

Comparison to NLO QCD