Combination of D^* differential cross sections measurements in DIS at HERA

DIS2015, Dallas, USA, 28th april 2015

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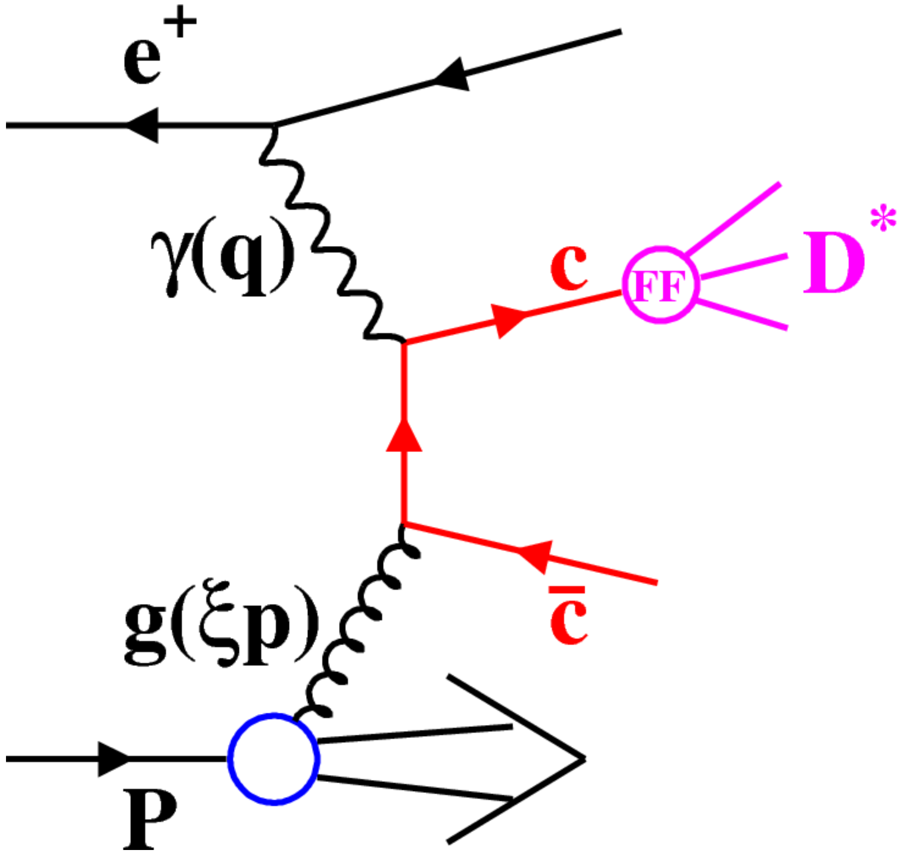
on behalf of

Results published as DESY-15-037, submitted to JHEP (arXiv:1503.06042)

Charm production in DIS at HERA



Photon kinematics:
$Q^2 = -q^2$
$y = (E_\gamma/E_e)|$p-frame

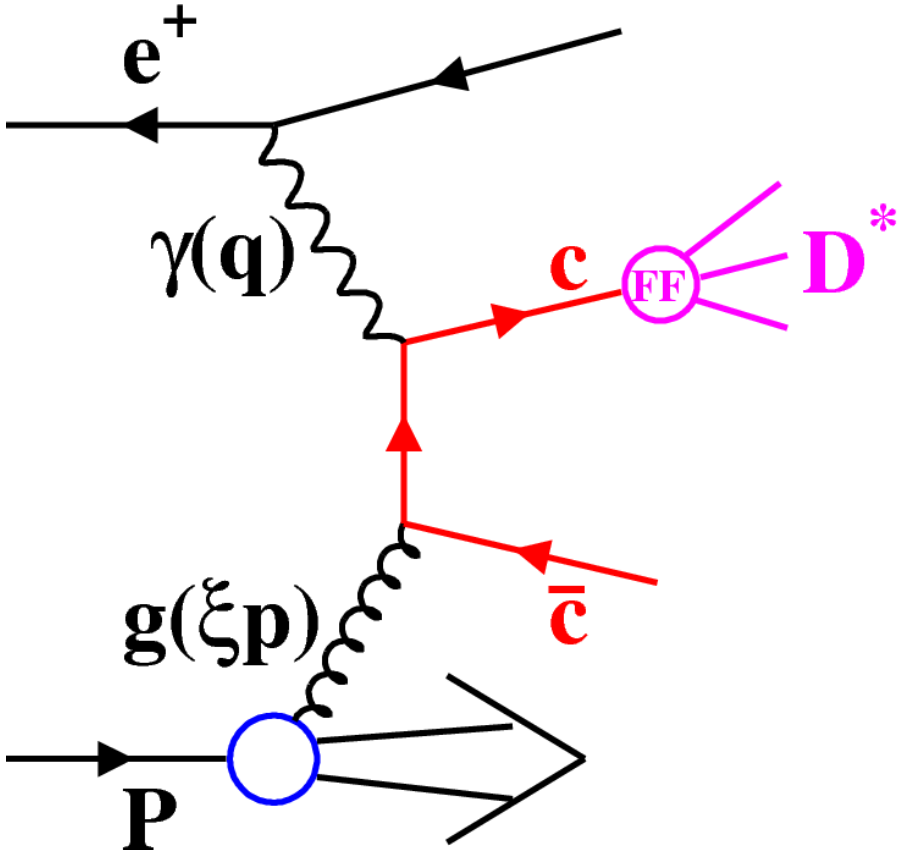
DIS: $Q^2 >$ few GeV^2

Motivation:

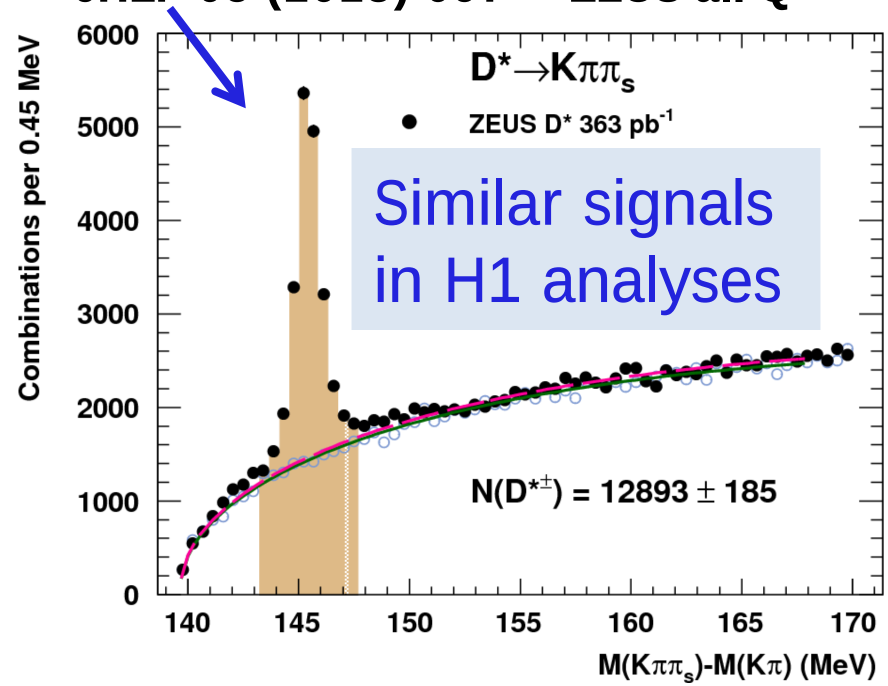
- Test of pQCD (multiple hard scales: Q^2, $p_T(c)$, m_c)
- Sensitive to gluon density in p and to m_c

D* combination

Combine most precise D* measurements in DIS

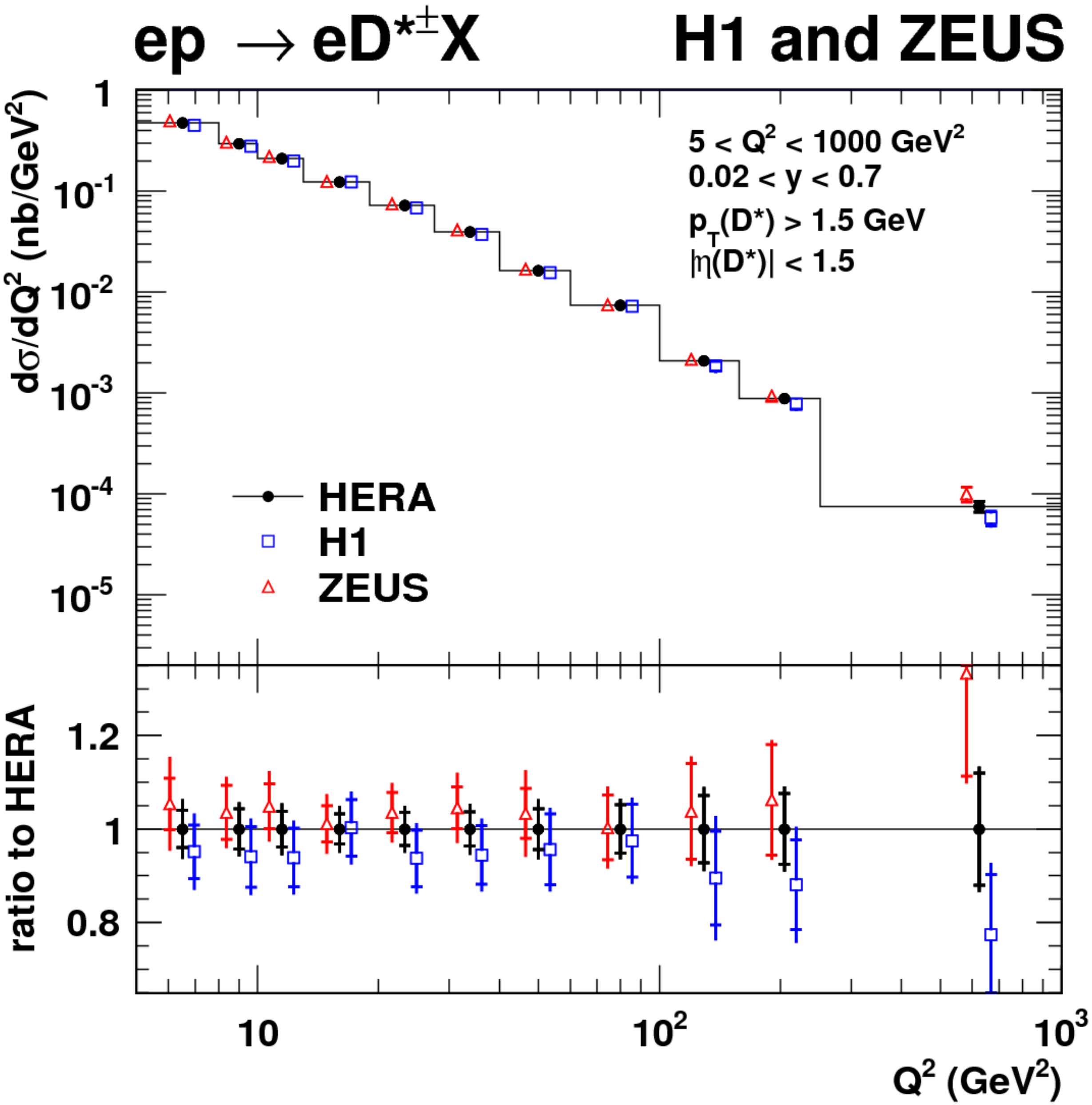


EPJ C71 (2011) 1769 H1 medium Q^2
PL B686 (2010) 91 H1 high Q^2
JHEP 05 (2013) 097 ZEUS all Q^2



- Combine D* visible cross sections
- Common phase space: $1.5<p_T(D^*)<20$ GeV, $|\eta(D^*)|<1.5$, $5<Q^2<1000$ GeV^2, $0.02<y<0.07$
- Small extrapolation uncertainties (unlike full phase space combi EPJ C73 (2013) 2311)
- Compare to HVQDIS NLO QCD (also used to calculate small phase space corrections)

Combination example: Q^2



Performed with HERAverager code

Systematics:

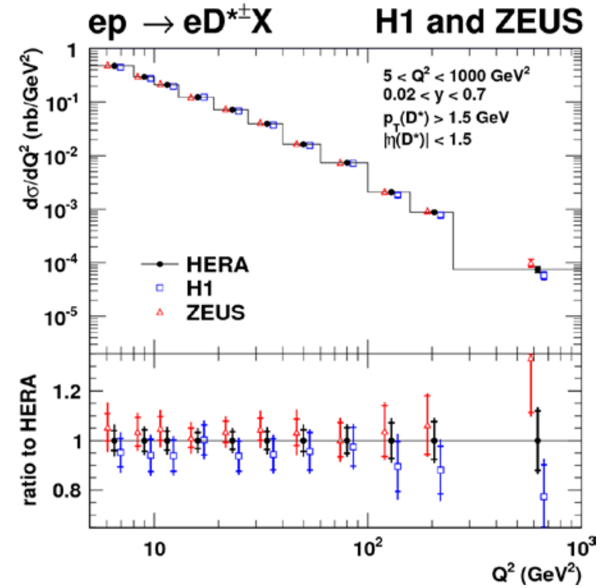
- Correlations: fully taken into account
- Experimental: uncorrelated between H1 and ZEUS
- Theoretical: very small

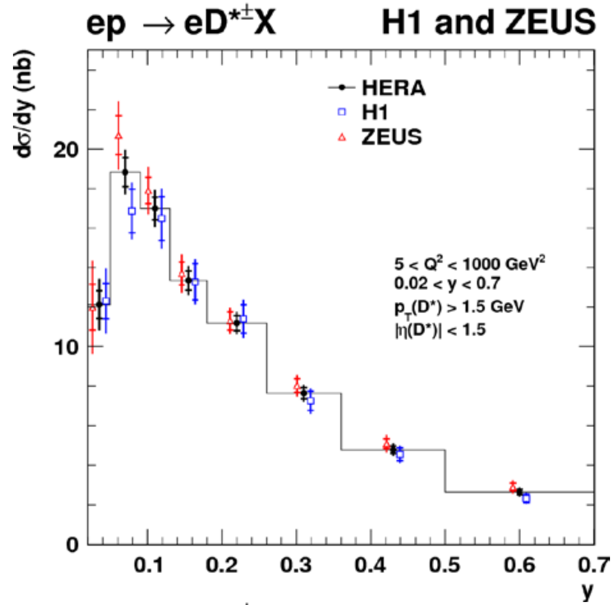
➔ Consistent data

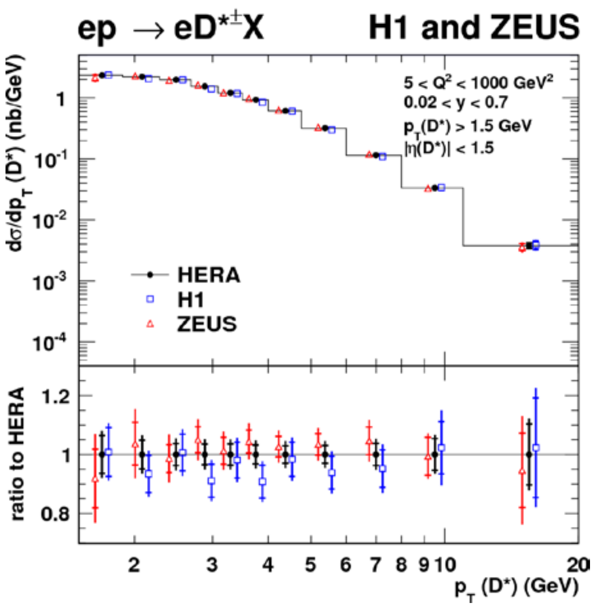
➔ Combined data reach precision of ~5%

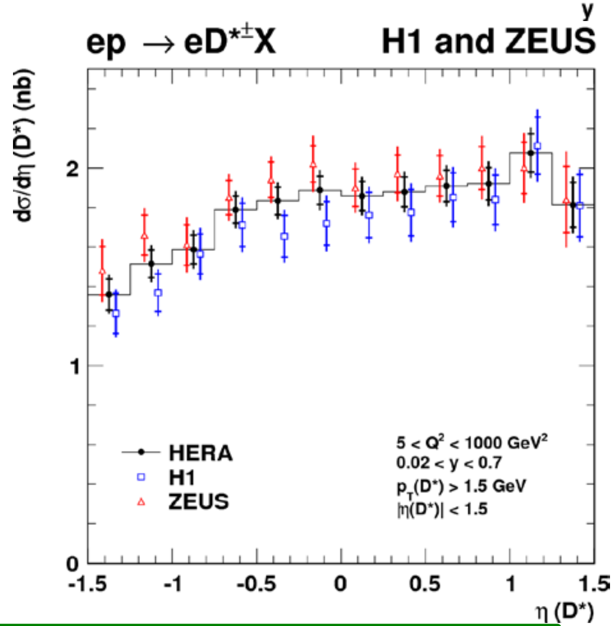
Combinations:

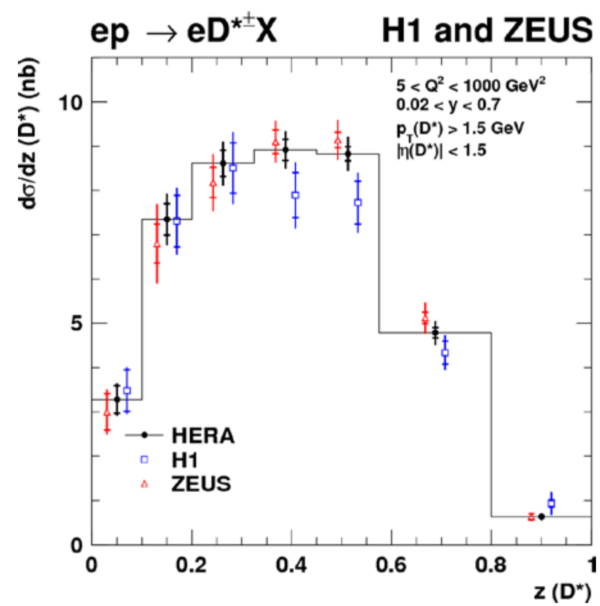
Performed separately for each variable











➔ Consistent data
➔ Combined data reach precision ~5%

NLO QCD predictions: HVQDIS

Massive scheme → only light flavours in pdf: u,d,s,g;   NLO = $o(\alpha_s^2)$

HVQDIS setup for ep →cc X→D*X (uncertainties):

- $\mu_r = \mu_f = \sqrt{Q^2 + 4m_c^2}$ vary independently by factor 0.5 and 2
- $\mathrm{m_c^{pole}} = 1.50 \pm 0.15$ GeV
- $\alpha_s^{nf=3}(\mathrm{m_Z}) = 0.105 \pm 0.002$ (corresponds to $\alpha_s^{nf=5}(\mathrm{m_Z}) = 0.116 \pm 0.002$)
- HERAPDF1.0 FFNS
- Fragmentation:
  - Longitudinal: Karvelishvili FF with $\alpha_K(D^*)$

$\hat{s}$ range	$\alpha_K(D^*)$
$\hat{s} \leq \hat{s}_1$	6.1 ± 0.9
$\hat{s}_1 < \hat{s} \leq \hat{s}_2$	3.3 ± 0.4
$\hat{s} > \hat{s}_2$	2.67 ± 0.31

$\hat{s}_1 = 70 \pm 40\ \mathrm{GeV}^2$
$\hat{s}_2 = 324\ \mathrm{GeV}^2$

  - Transverse: $f(k_T) = k_T \exp(-\frac{2k_T}{\langle k_T \rangle})$; $\langle k_T \rangle = 0.35 \pm 0.15$ GeV
  - $f(c \to D^*) = 0.2287 \pm 0.0056$

Use HVQDIS also to predict small additional component: ep → bb X → D* X

Customised NLO QCD predictions: HVQDIS

Try to find parameters such that calculation describes normalisation & shapes of all differential cross sections presented in the following

- $\mu_r = \sqrt{Q^2 + 4m_c^2}$ → $\mathbf{0.5\sqrt{Q^2 + 4m_c^2}}$ → Increase cross section
- $m_c^{pole} = 1.50$ GeV → **1.40 GeV** → Increase cross section
- Fragmentation:
  - Longitudinal: Karvelishvili FF with $\alpha_K(D^*)$

$\hat{s}$ range	$\alpha_K(D^*)$
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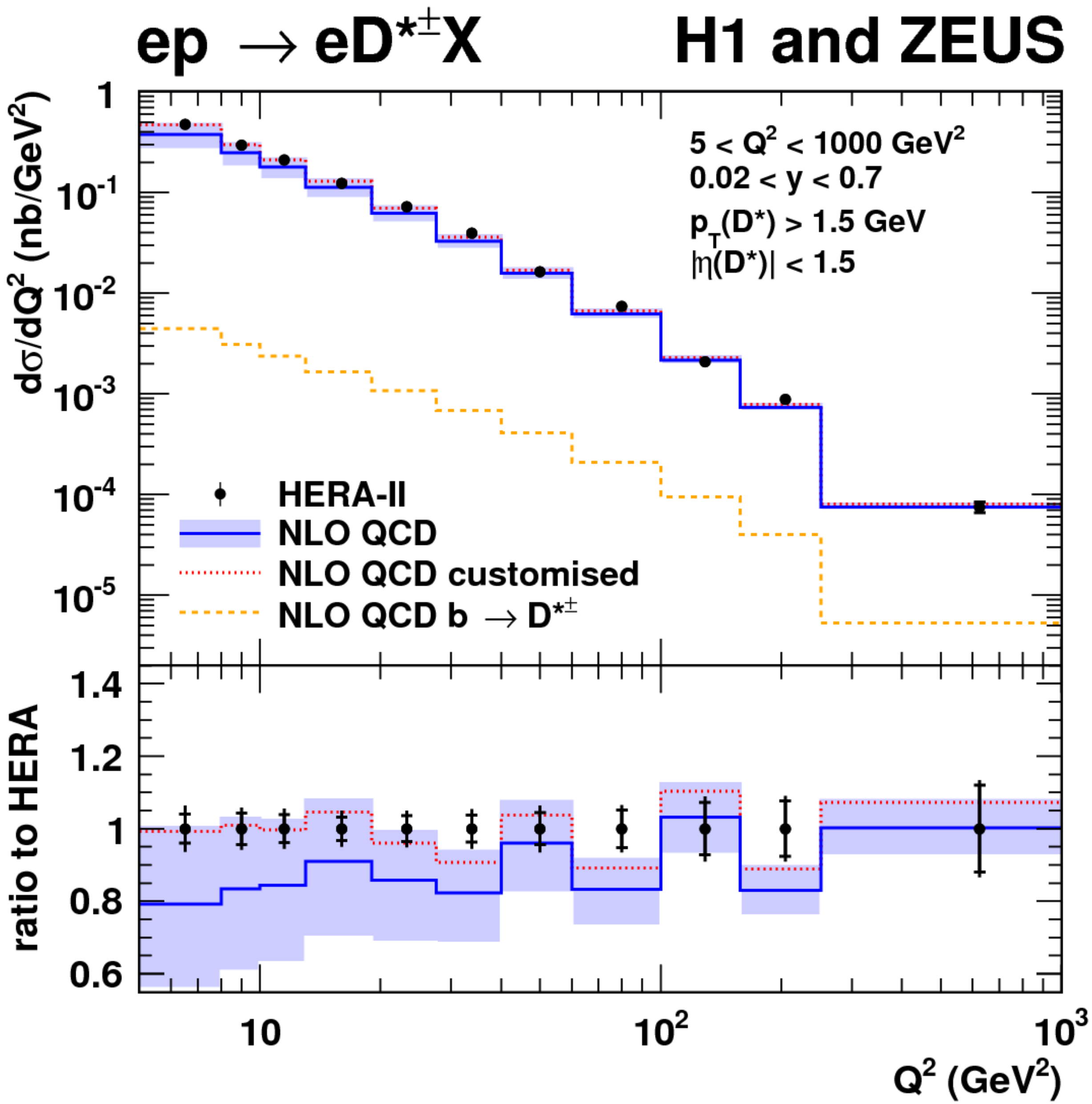
- $\hat{s}_1 = 70$ GeV^2 → **30 GeV^2** → Soften fragmentation

Leave all other parameters at their default values

This is no prediction → but may give hints in which direction to develop theory

Results: Q^2



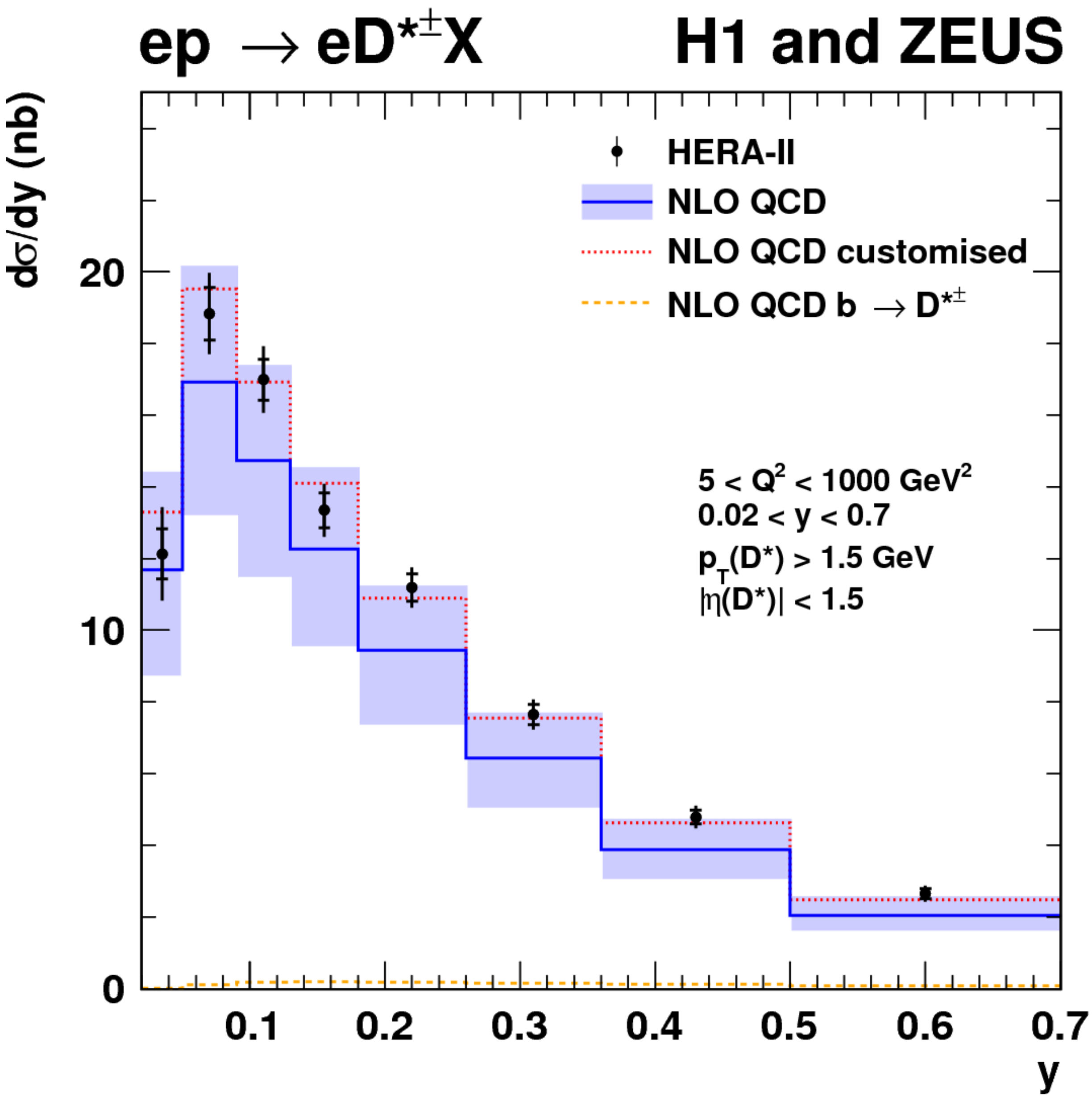
NLO prediction:

➔ describes data

➔ large uncertainties

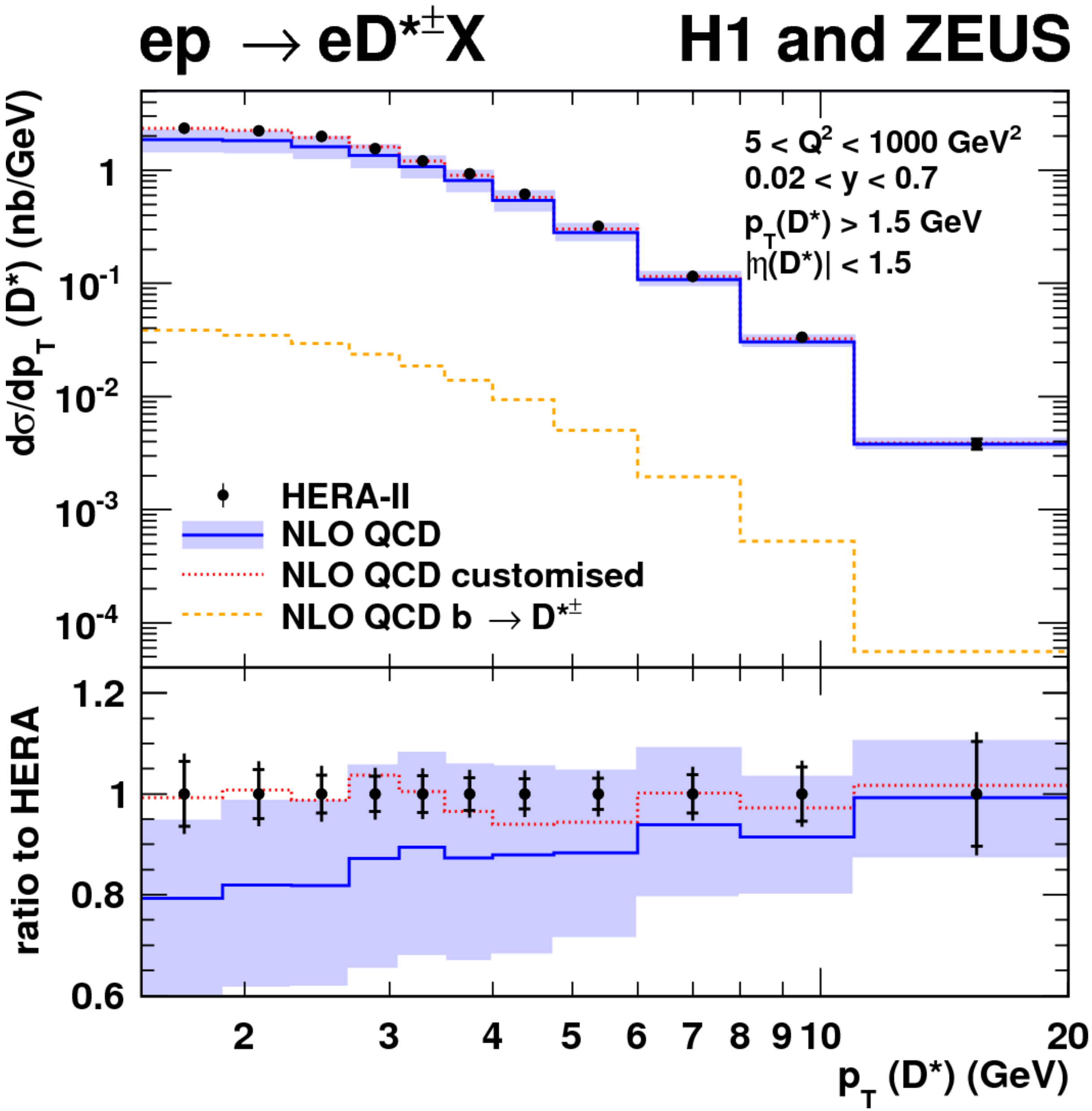
➔ customised variant:

Results: y



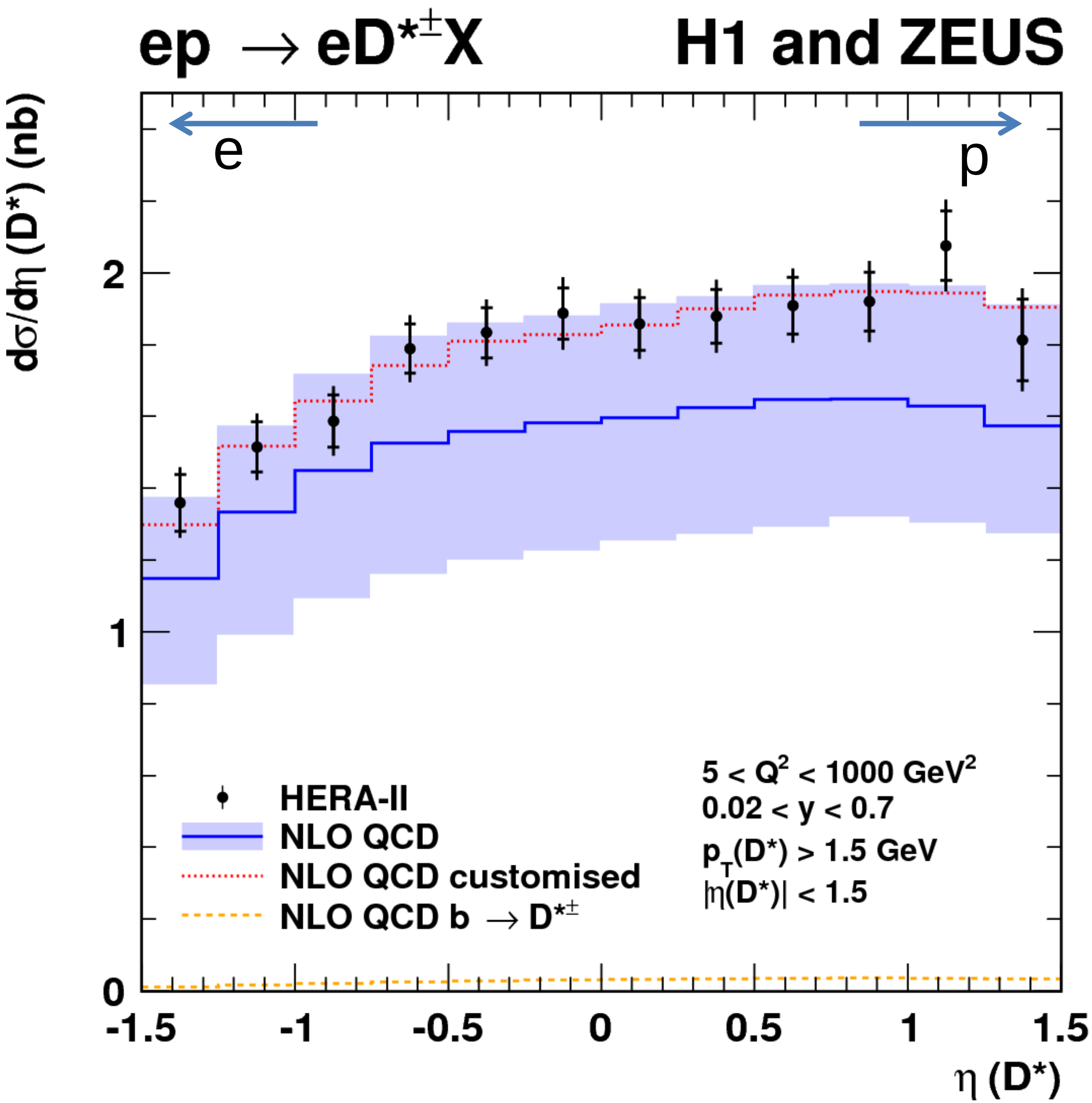
NLO prediction:
- ➔ describes data
- ➔ large uncertainties
- ➔ customised variant: ☺

Results: $p_T(D^*)$



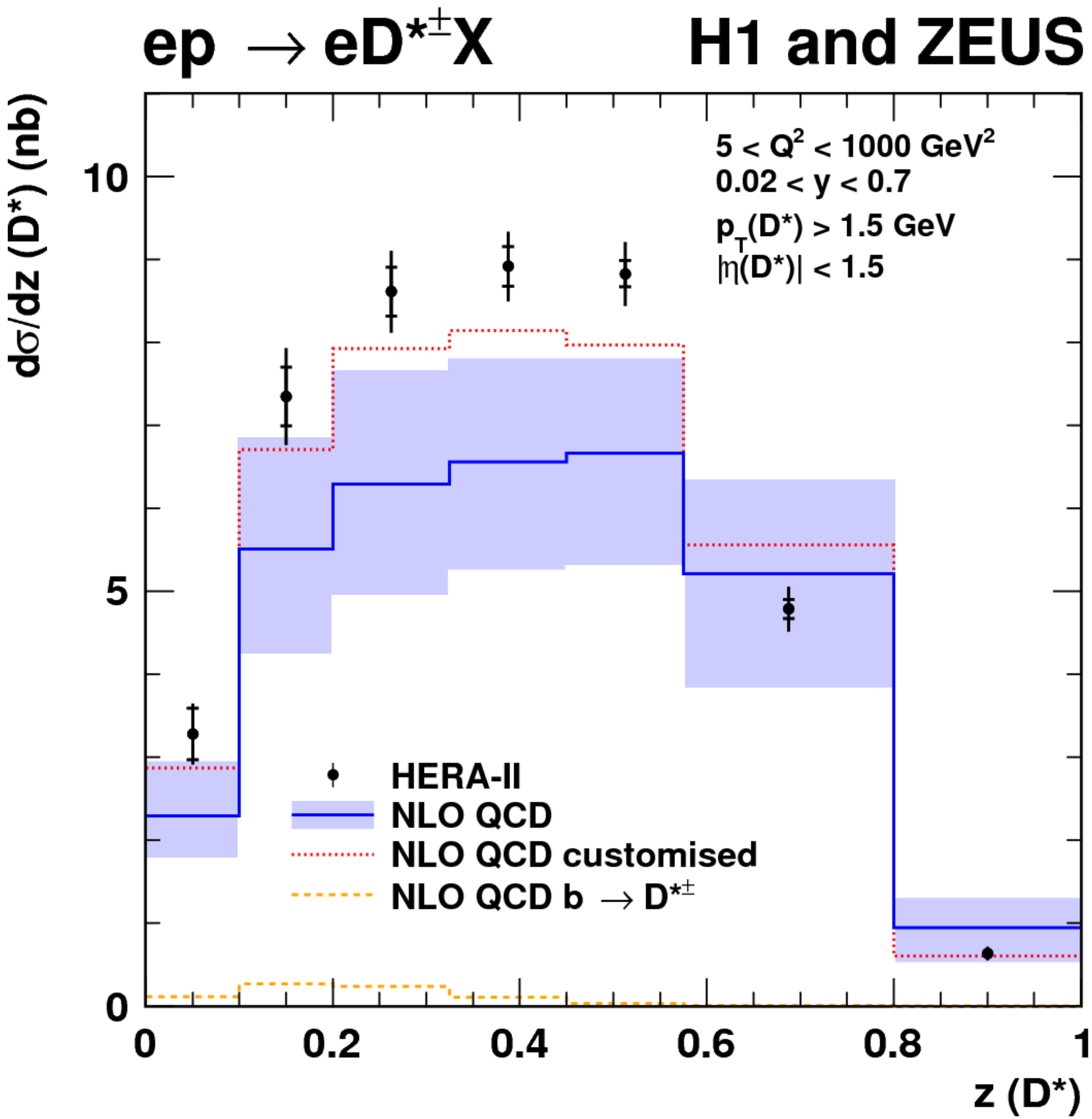
NLO prediction:
➔ describes data
➔ large uncertainties
➔ customised variant: ☺

Results: $\eta(D^*)$



NLO prediction:
➔ describes data
➔ large uncertainties
➔ customised variant: ☺

Results: $z(D^*)$

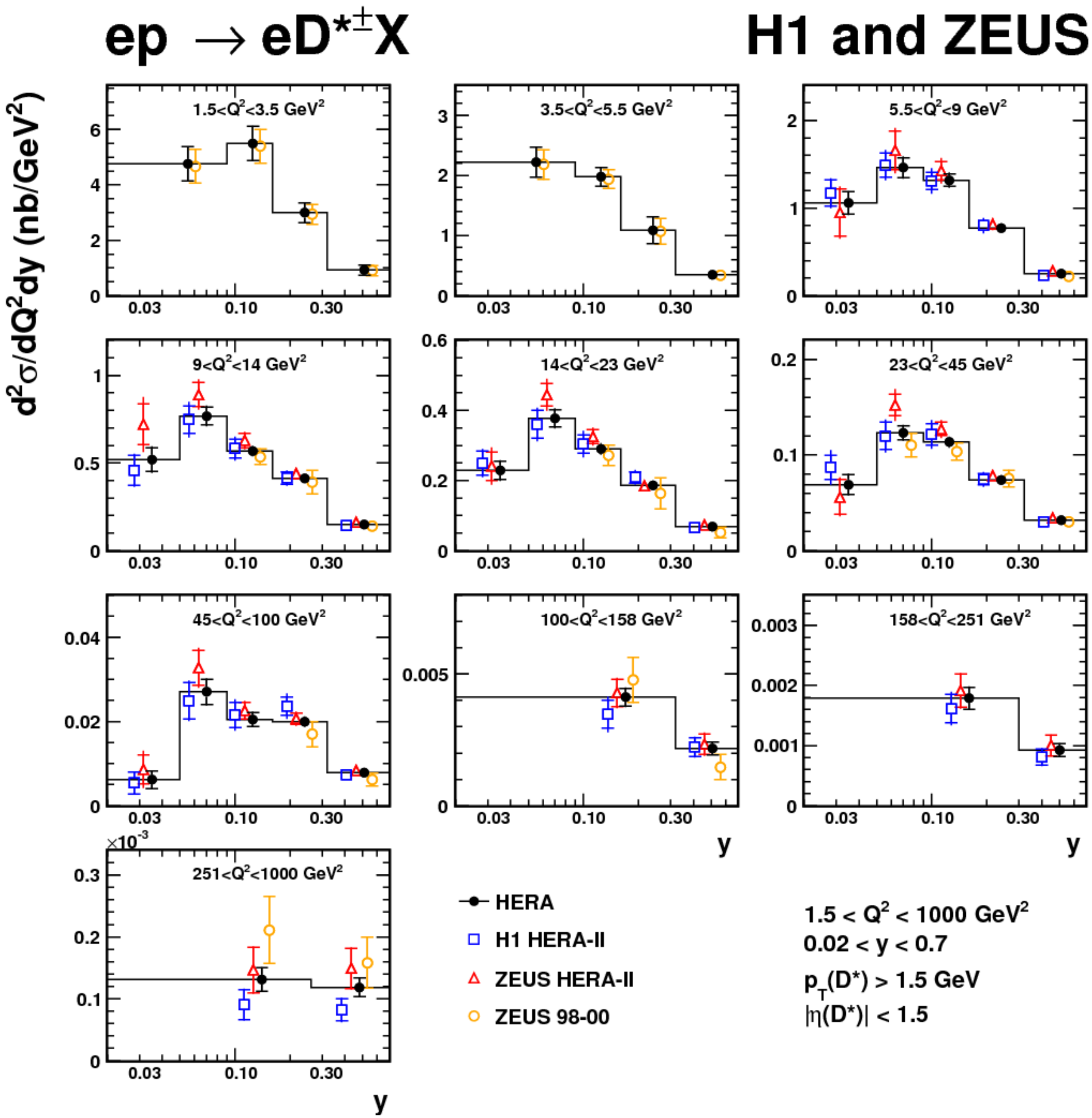


$Z(D^*) = E_{D^*}/E_{\gamma}|$p-frame

- Also sensitive to fragmentation $c \rightarrow D^*$

NLO prediction:
→ "harder" than data
→ large uncertainties
→ customised variant: better but not perfect

Combination of 2d cross sections: Q^2,y



Input data: as before

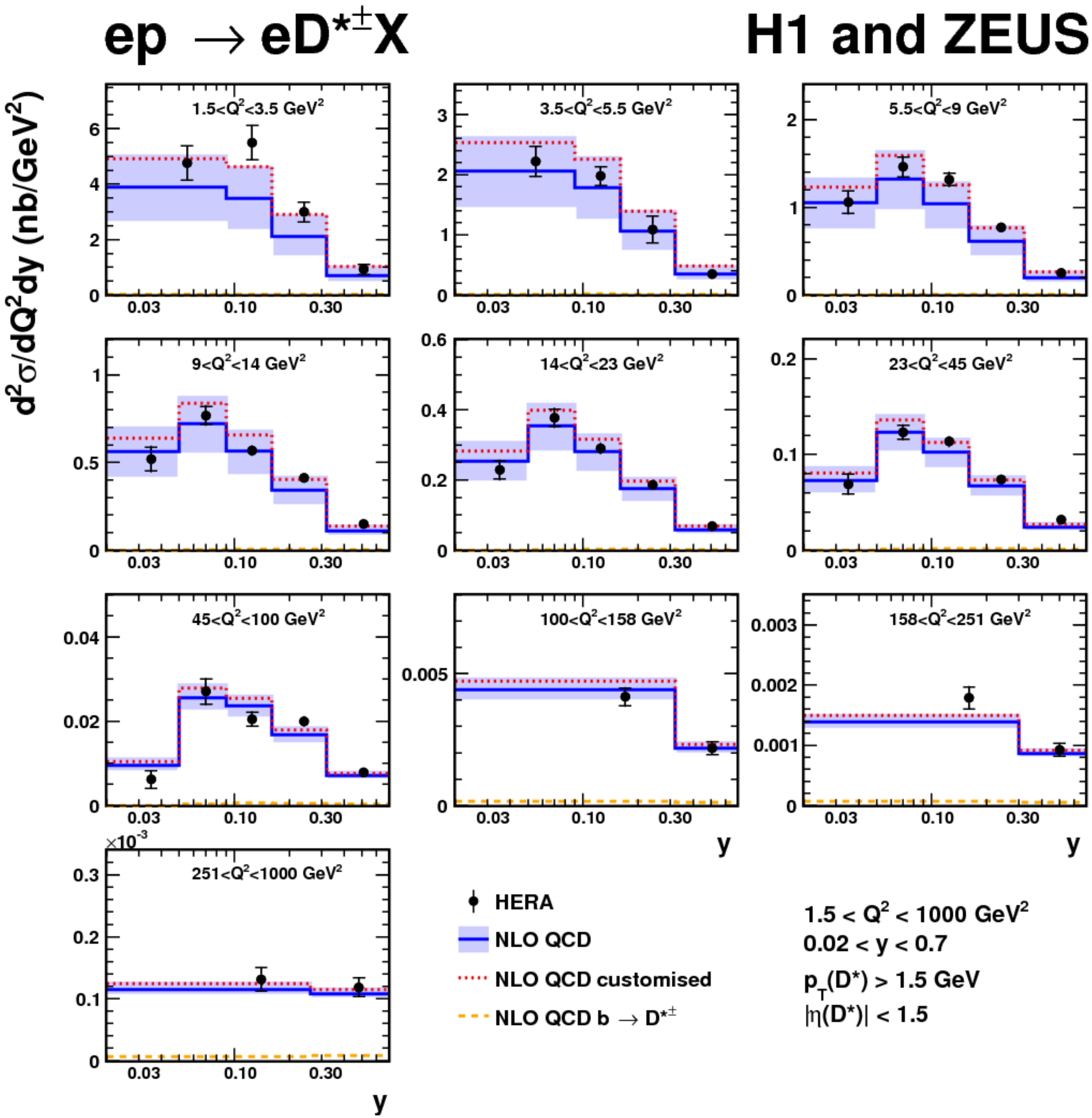
EPJ C71 (2011) 1769 H1
PL B686 (2010) 91 H1
JHEP 05 (2013) 097 ZEUS

plus ZEUS HERA I data

PR D69 (2004) 012004 ZEUS

➔ Consistent data
➔ Combined data reach precision of ~5%

Results: Q^2,y



NLO prediction:
- ➔ describes data
- ➔ large uncertainties
- ➔ customised variant: ☺

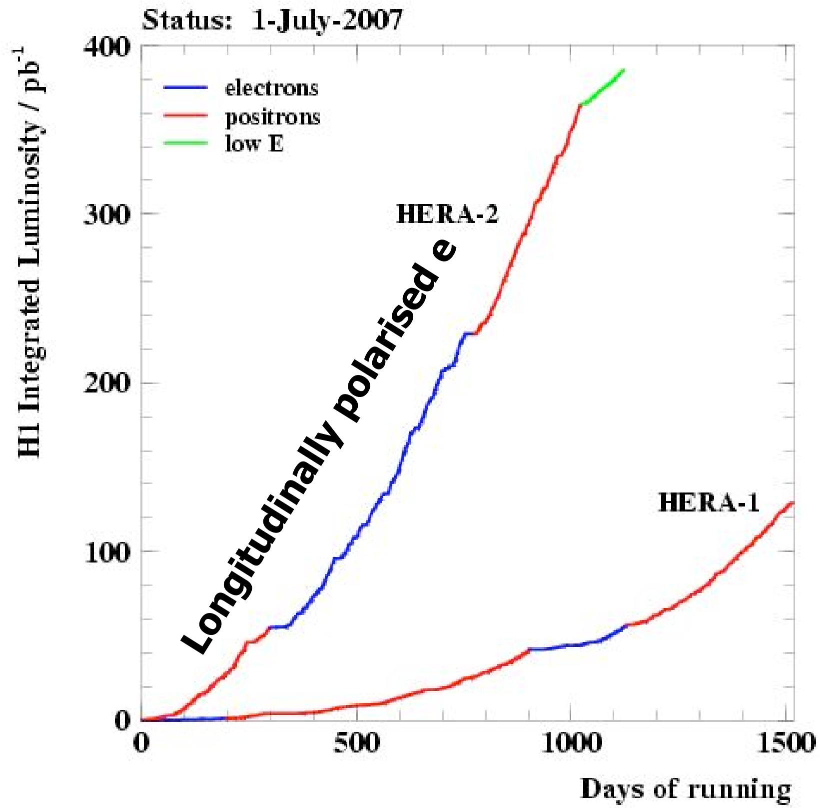
Summary

- **Most precise differential D^* measurements in DIS** by H1 and ZEUS **combined**:
  - Q^2, y and for the first time D^* final state distributions: $p_T(D^*)$, $\eta(D^*)$ and $z(D^*)$
  - Significantly improved precisions → ~5%

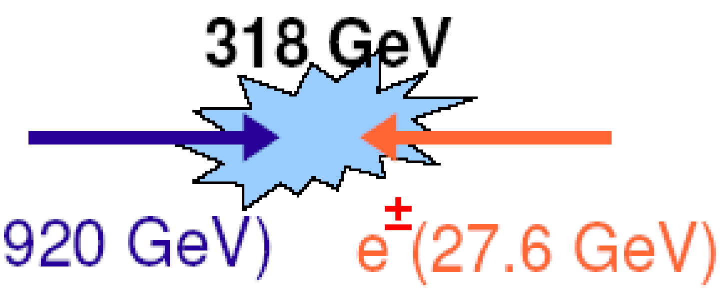
- HVQDIS NLO QCD predictions:
  - Describe data reasonably
  - Large uncertainties 10-30% → **need NNLO and improved fragmentation models**
  - Customised prediction with varied m_c, μ_r and fragmentation hardness → hints in which direction to improve the calculation

Backup slides

The HERA ep collider (1992-2007)



HERA:



~0.5 fb^{-1} per experiment

Customised NLO QCD predictions: HVQDIS

Find parameters → calculation describes norm./shapes of data

HVQDIS setup for ep →cc X→D*X (uncertainties): $\boldsymbol{\mu_r = 0.5\sqrt{Q^2 + 4m_c^2}}$

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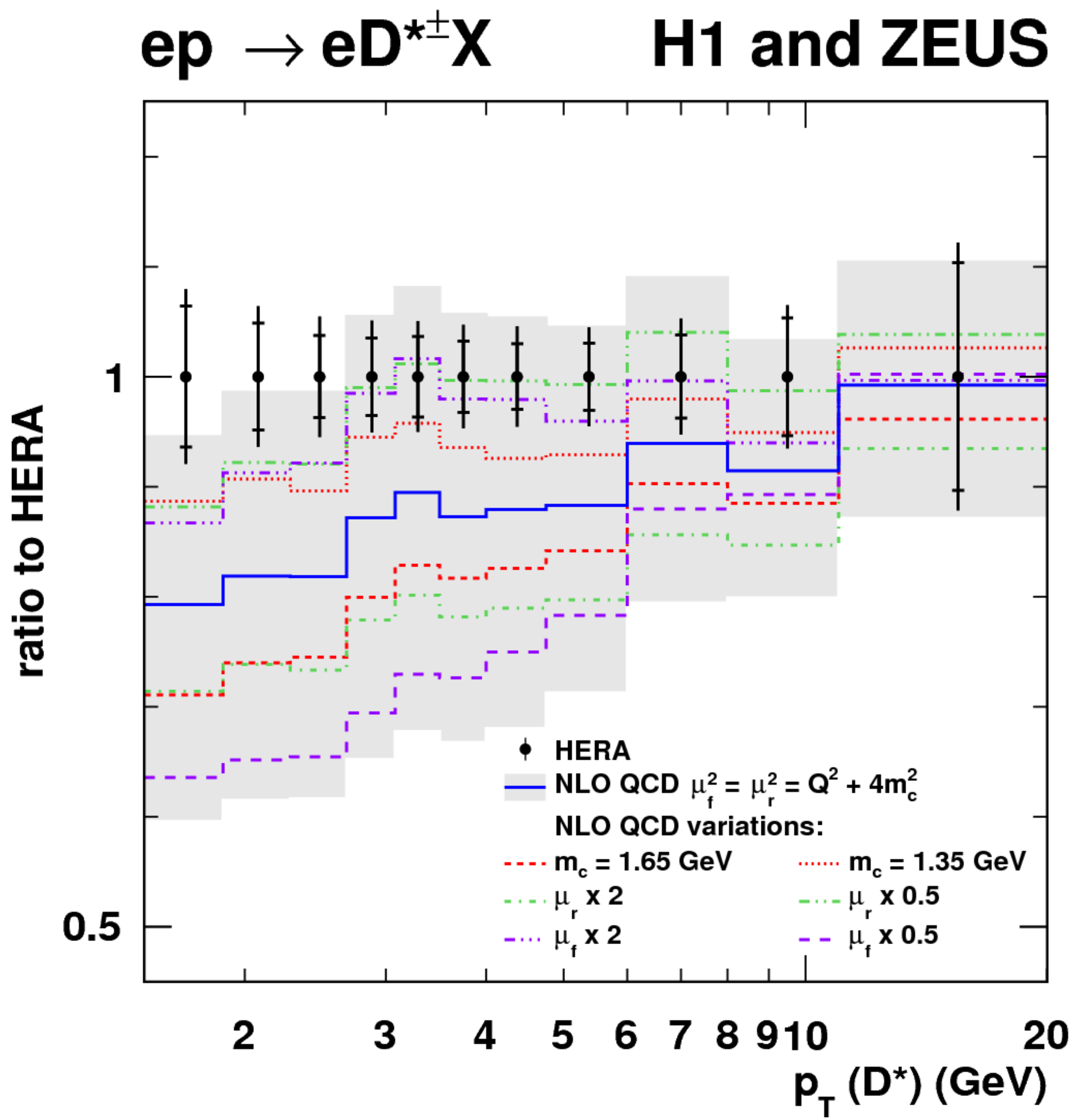
No prediction → may give hints in which direction to develop theory

Results: data vs NLO with parameter variations



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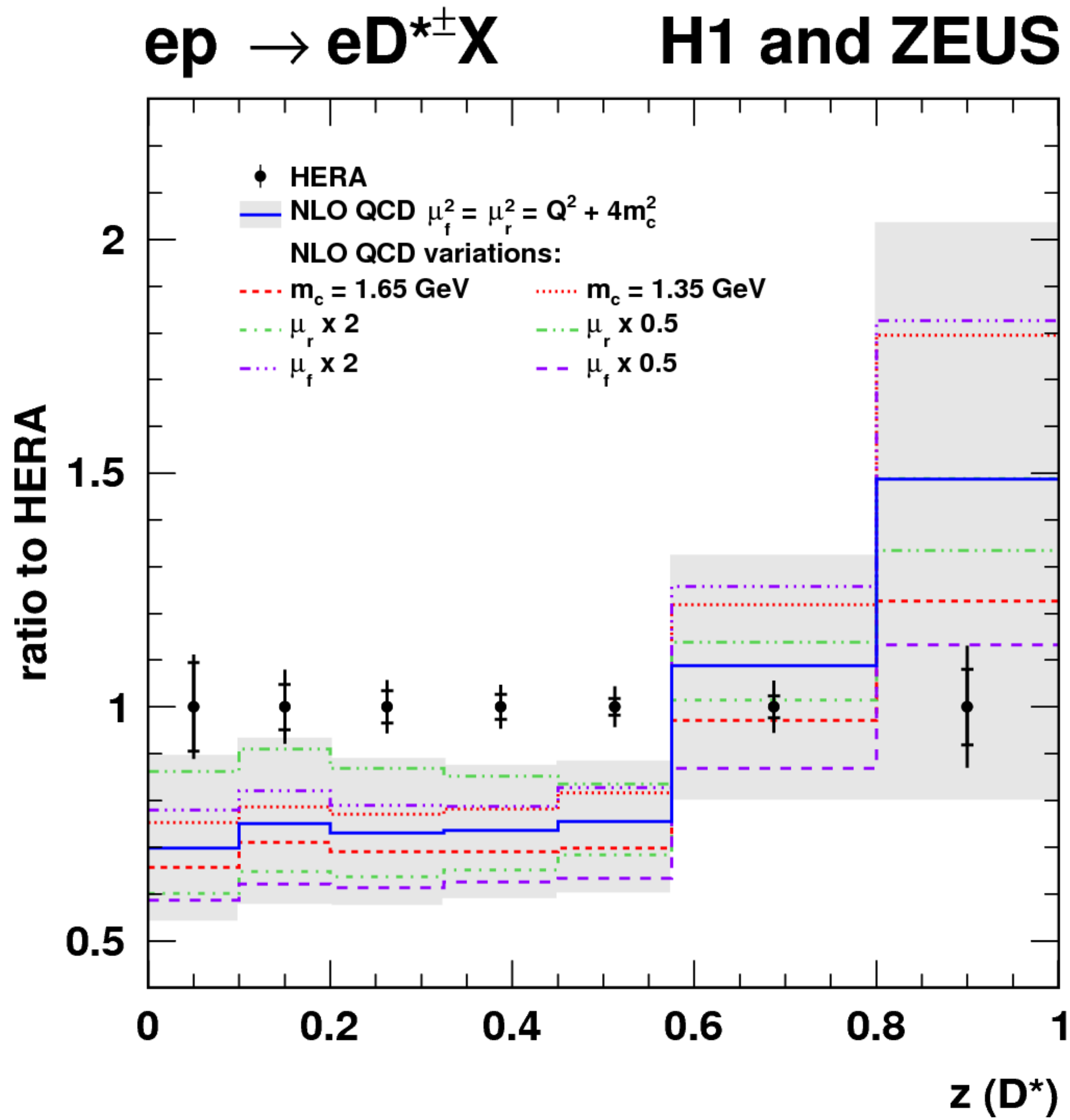

Results: data vs NLO with parameter variations