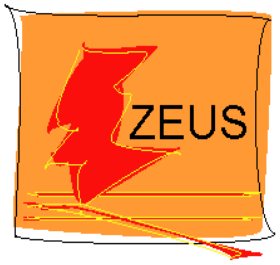


ZEUS physics results for summer 2013

Misha Lisovyi (DESY)

on behalf of the ZEUS and H1 Collaborations

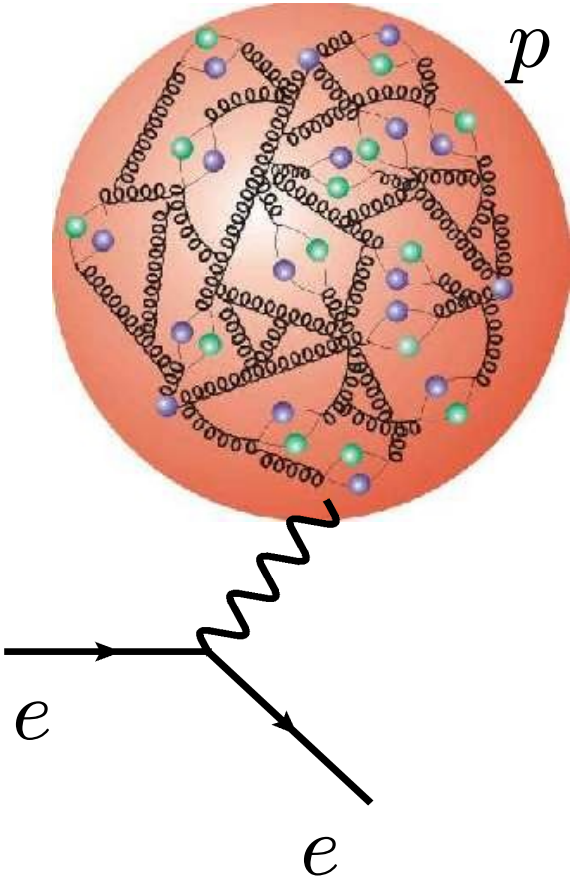
HERA Forum

18.06.2013

HERA physics

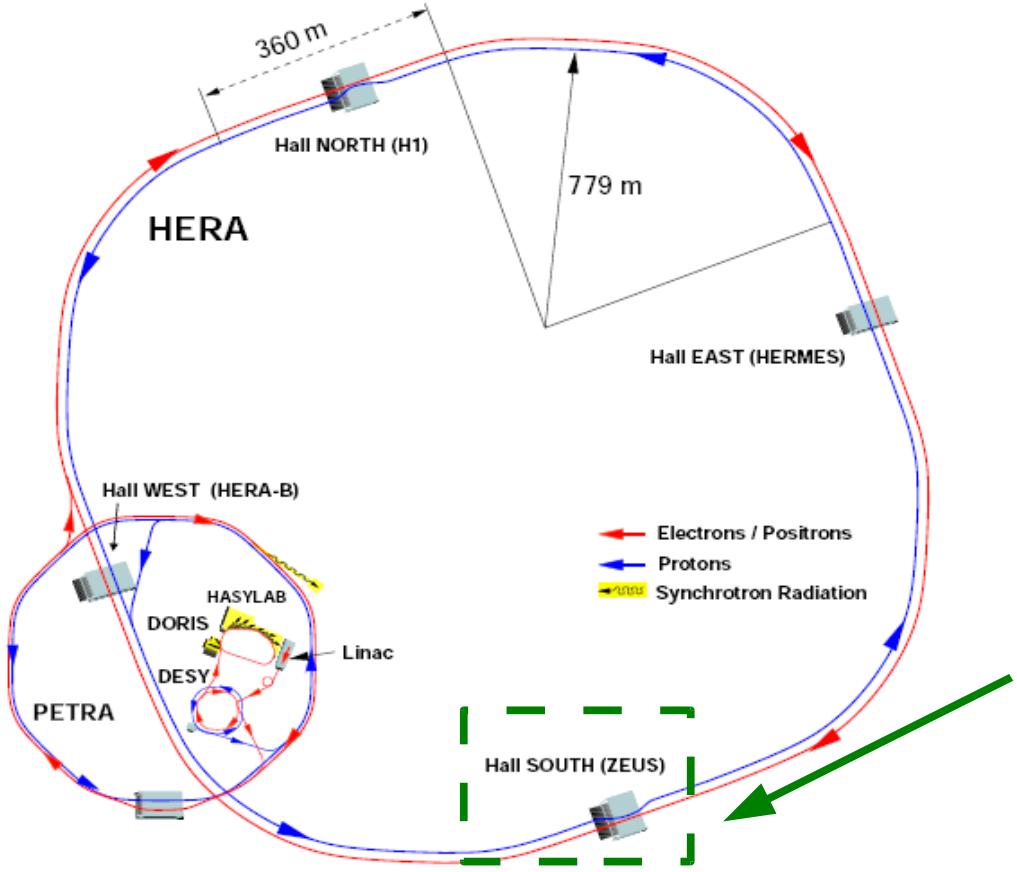
HERA physics:

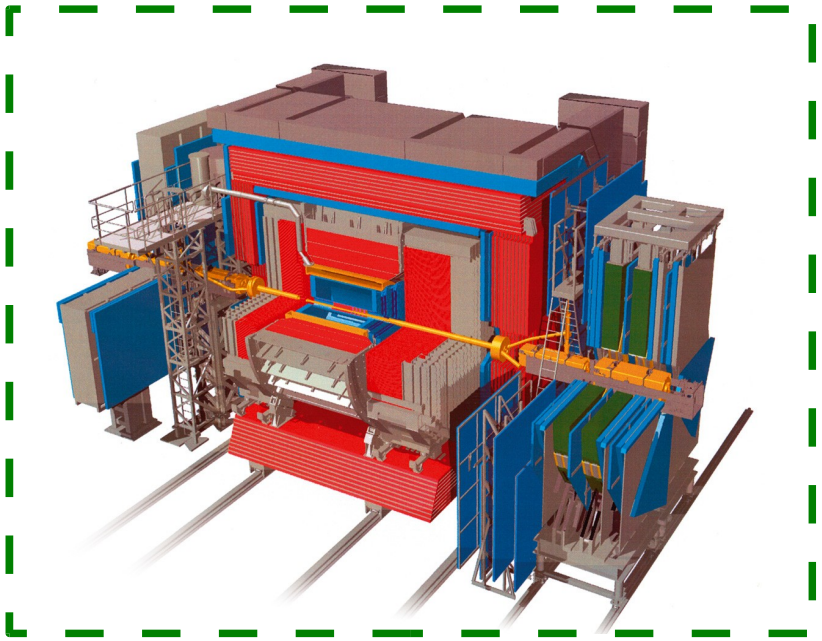
- Structure functions and electro weak effects
- QCD and hadronic final states
- Heavy flavours (c,b)
- Exotics and beyond the SM
- Diffraction



Final goal: ultimate precision. => Combined data as the HERA heritage.

HERA





$E_p = 920\,GeV \qquad E_e = 27.5\,GeV$

$\sqrt{s} = 318\,GeV$

HERA I: 1996-2000 (~120 pb^{-1})

HERA II: 2003-2007 (~370 pb^{-1})

Full: ~ 0.5 fb^{-1}

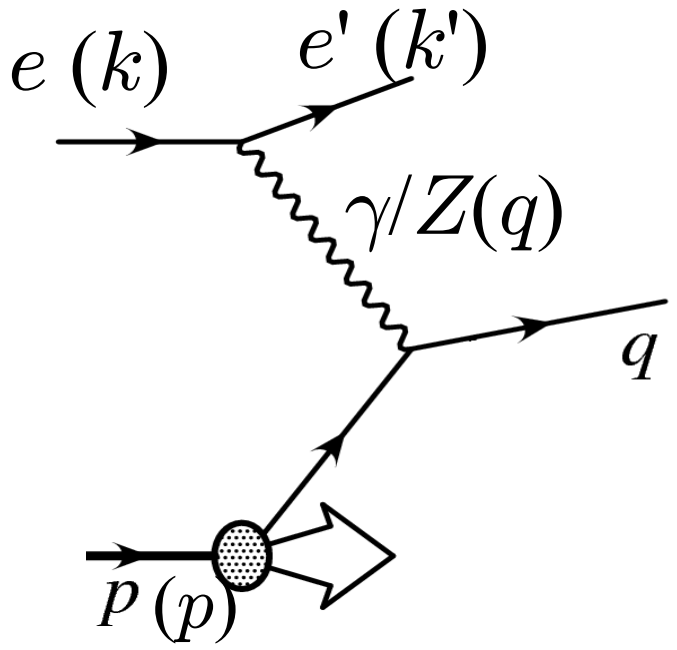
Inelastic NC ep collisions

Q^2 : photon virtuality

x : Bjorken scaling variable

y : inelasticity

s : center-of-mass energy squared



$$Q^2 = -q^2 = -(k - k')^2 \qquad Q^2 = sxy$$

$$x = \frac{Q^2}{2\, q \cdot p} \qquad y = \frac{p \cdot q}{q \cdot k} \qquad s = (k + p)^2$$

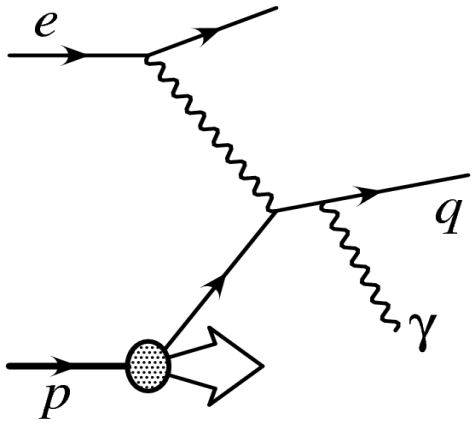
γ, Z^0: Neutral current (NC)

$Q^2 \approx 0$ GeV^2 : Photoproduction (PHP)

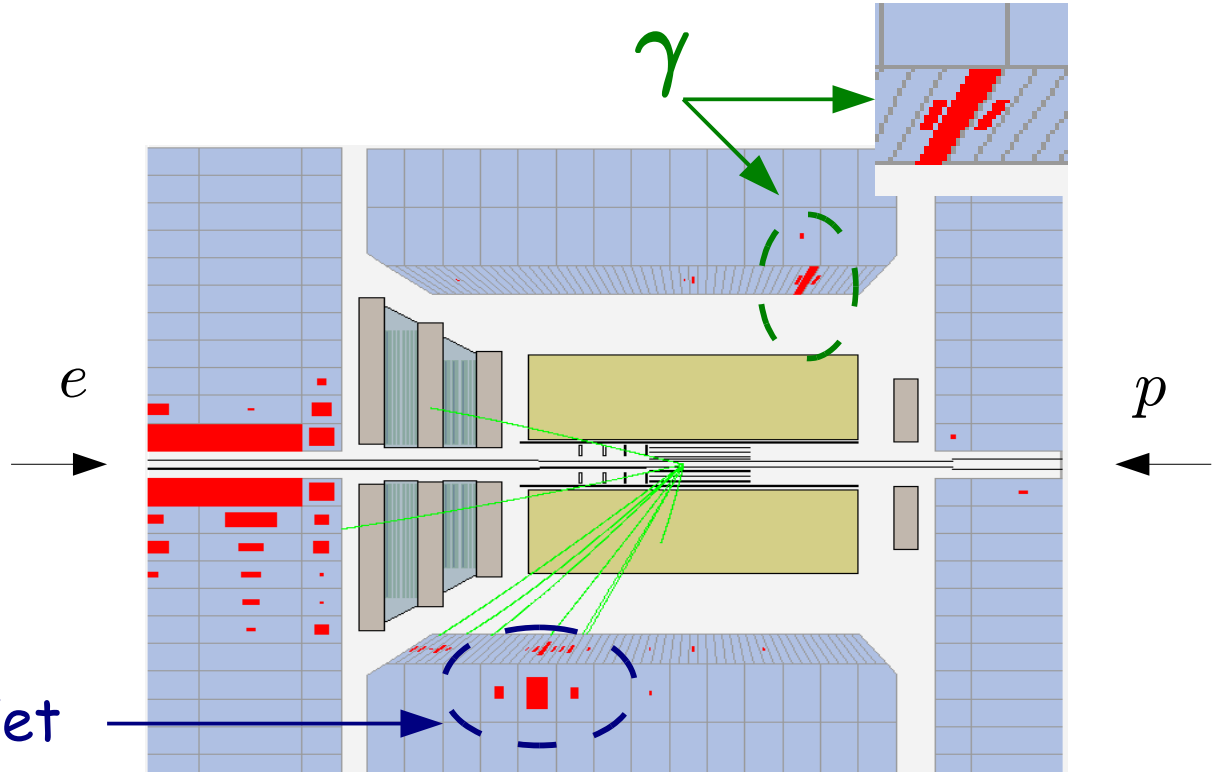
$Q^2 > 1$ GeV^2 : Deep Inelastic Scattering (DIS)

Prompt γ+jets in PHP

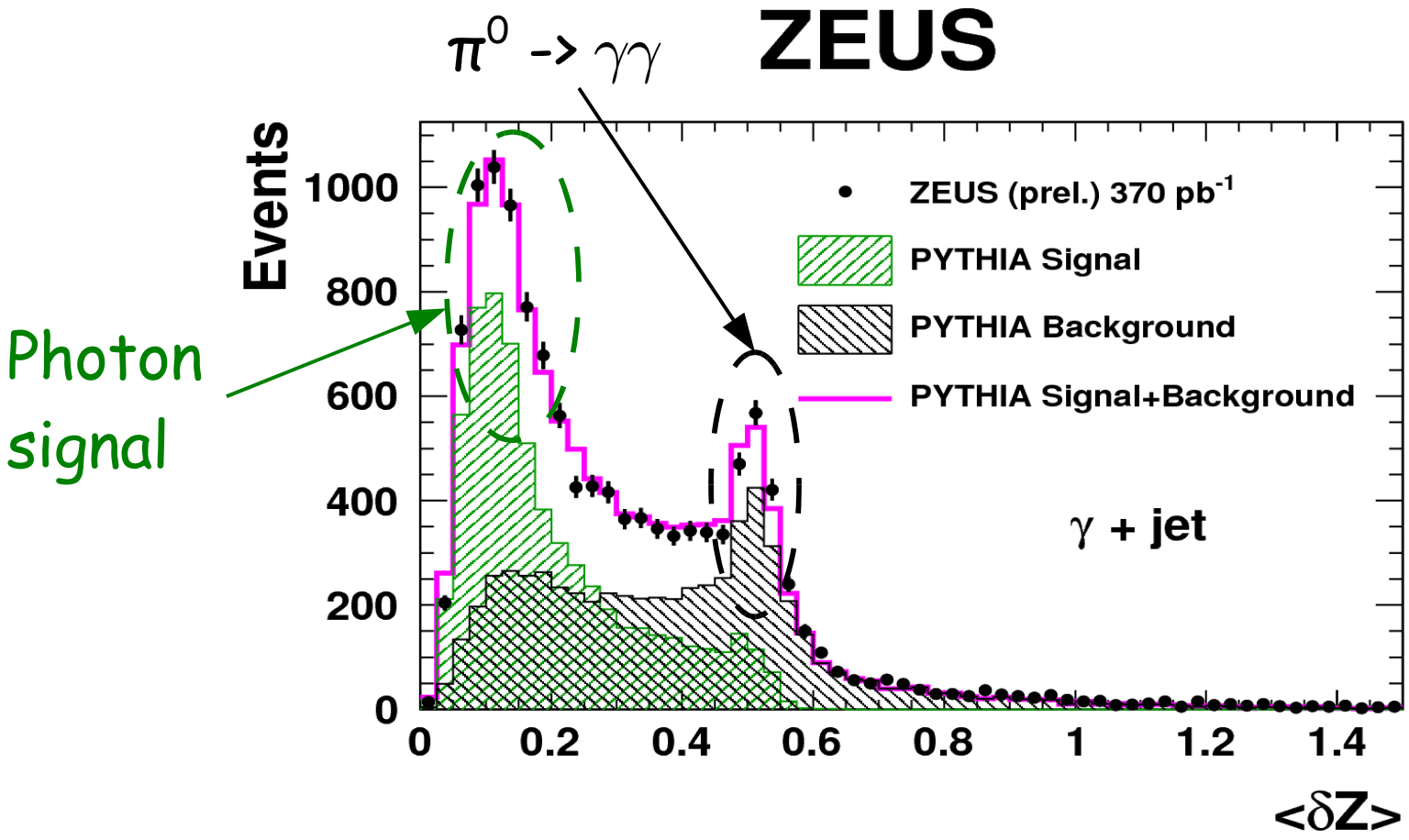
ZEUS-prel-2013-001



- γ emissions are not affected by hadronisation
  => a direct probe of the parton dynamics
- sensitivity to the quark charge: u/d separation

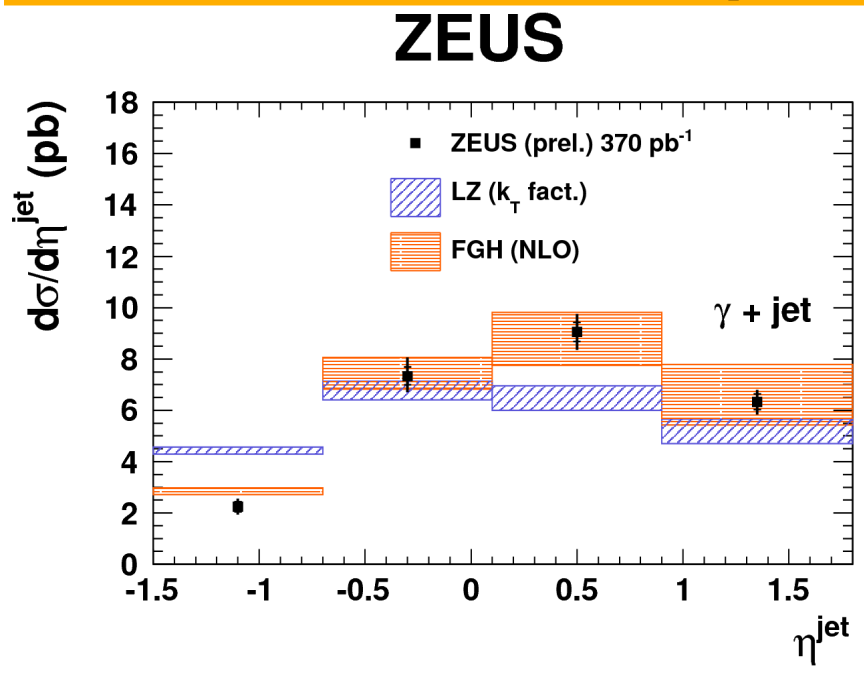


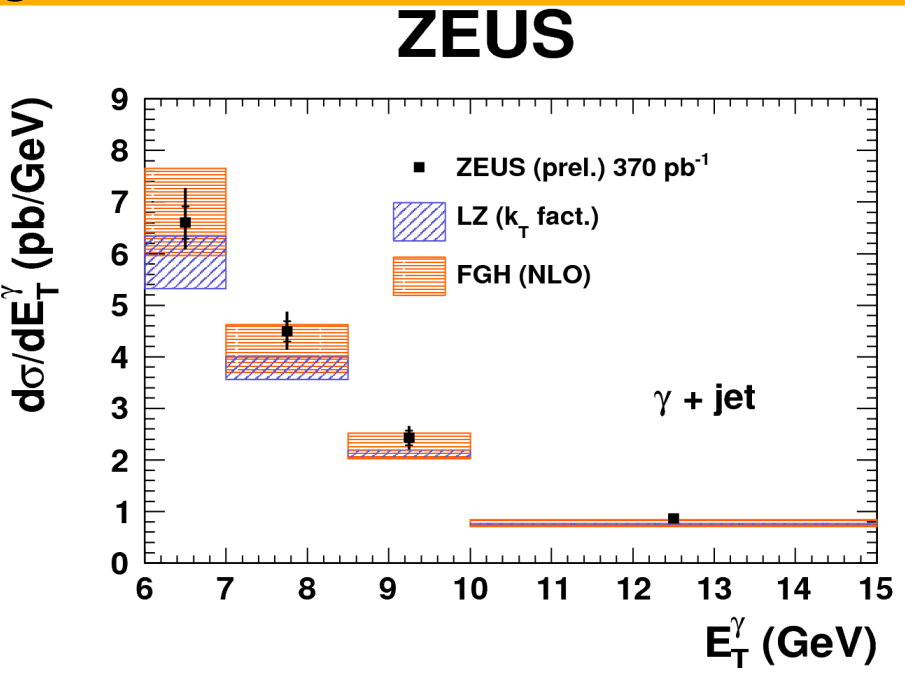
Prompt γ+jets in PHP

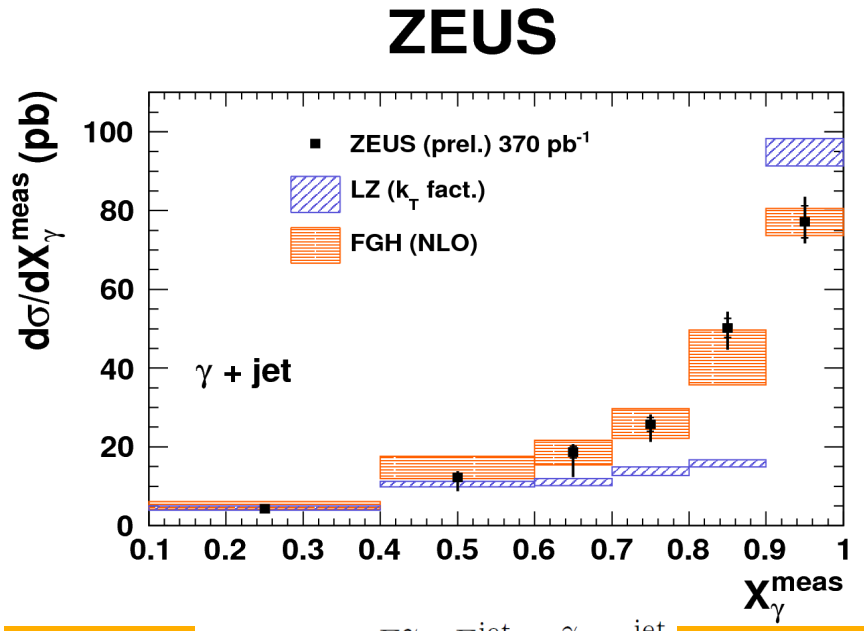


Template fit for the shower shape variable <δZ> (energy-weighted width of the EMC cluster): $< \delta Z > = \frac{\sum_i E_i |Z_i - Z_{cluster}|}{w_{cell} \sum_i E_i}$

Prompt γ+jets in PHP





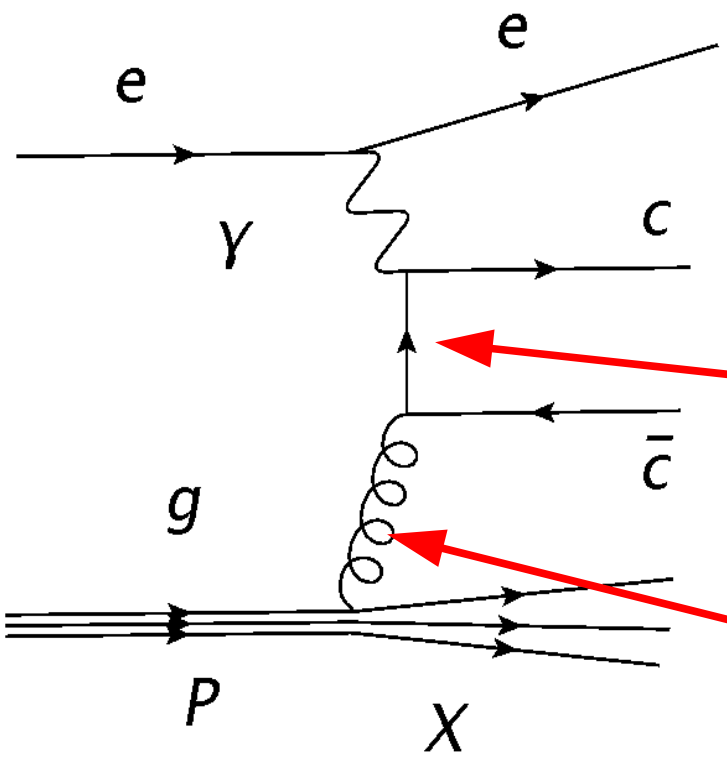


NLO gives a good description.
kT-factorisation reasonably describes the data, but better predictions are on the way.

Fontannaz, Guillet, Heinrich; Lipatov, Zotov

$$x_\gamma^{meas} = \frac{E^\gamma + E^{\rm jet} - p_Z^\gamma - p_Z^{\rm jet}}{E^{\rm event} - p_Z^{\rm event}}$$

Charm production in DIS



Important test of QCD.

Up to 30% of the inclusive ep cross section at HERA.

Multiple scales (Q^2, m_c, $p_T(c)$): a challenge for pQCD due to presence of log terms, e.g. ~ $\ln(Q^2/m_c)$.

Direct probe of the gluon in the proton:

dominant production mechanism is the Boson-Gluon Fusion(BGF).

pQCD approximations

Massive scheme (FFNS):

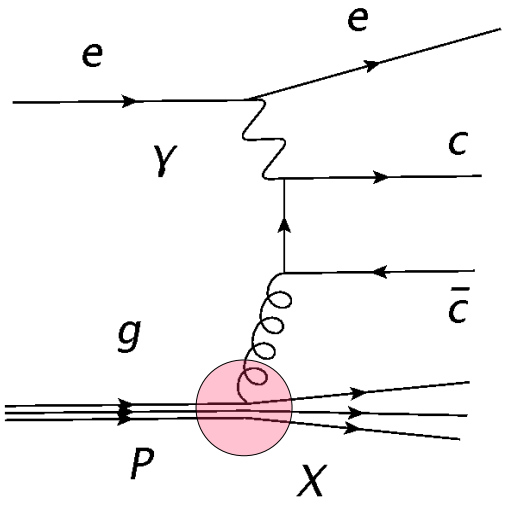
- c quarks are massive;
- valid for $Q^2 \sim M^2_c$;

➔ c produced perturbatively

Massless scheme (ZM-VFNS):

- c mass neglected;
- valid for $Q^2 \gg M^2_c$;

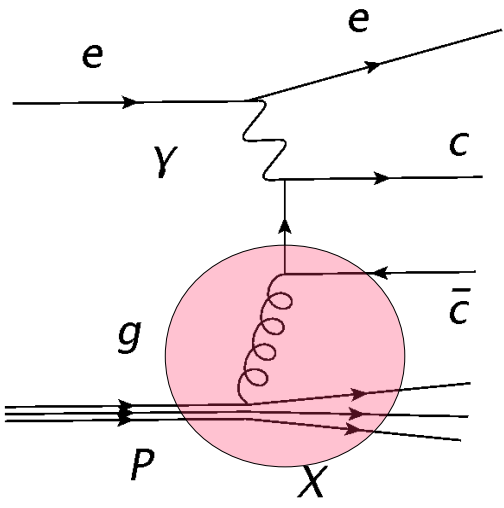
➔ c present in proton



Variable FNS (GM-VFNS):

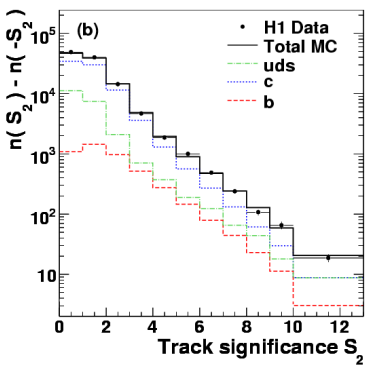
- equivalent to massive at small Q^2;
- equivalent to massless at high Q^2;

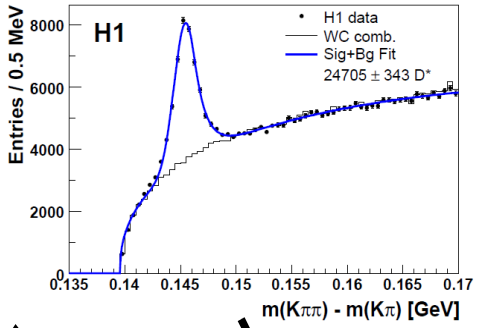
➔ c present in proton starting from a certain scale

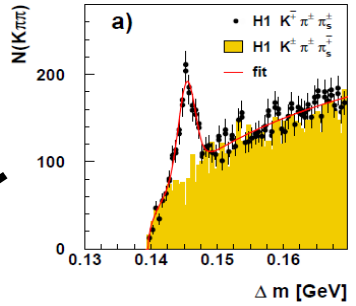


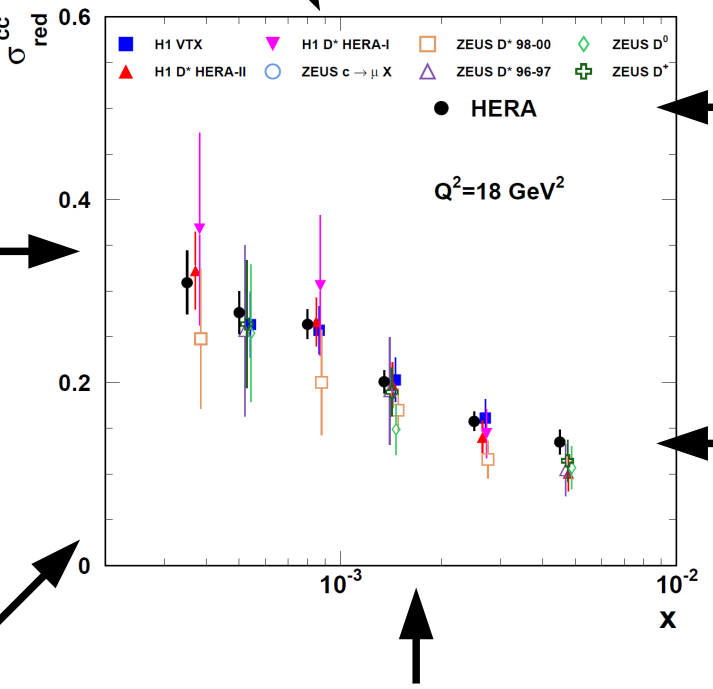
Charm measurements in DIS

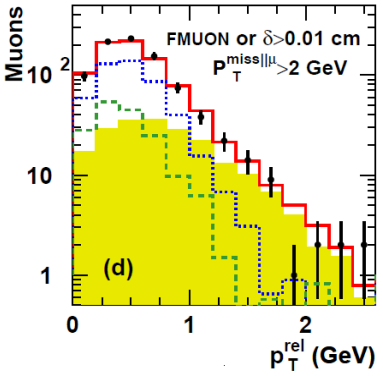
EPJ C73 (2013) 2311

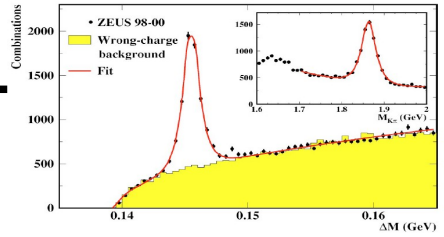


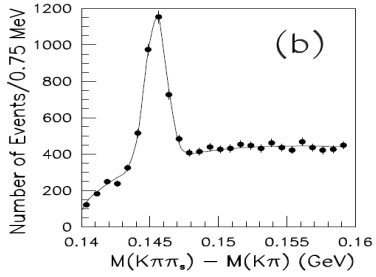


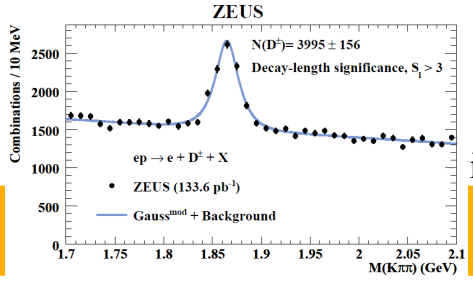


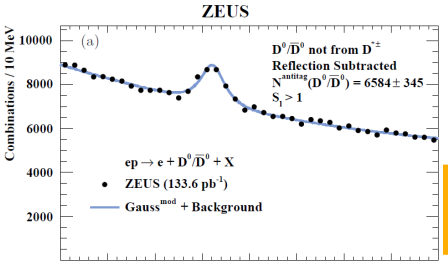






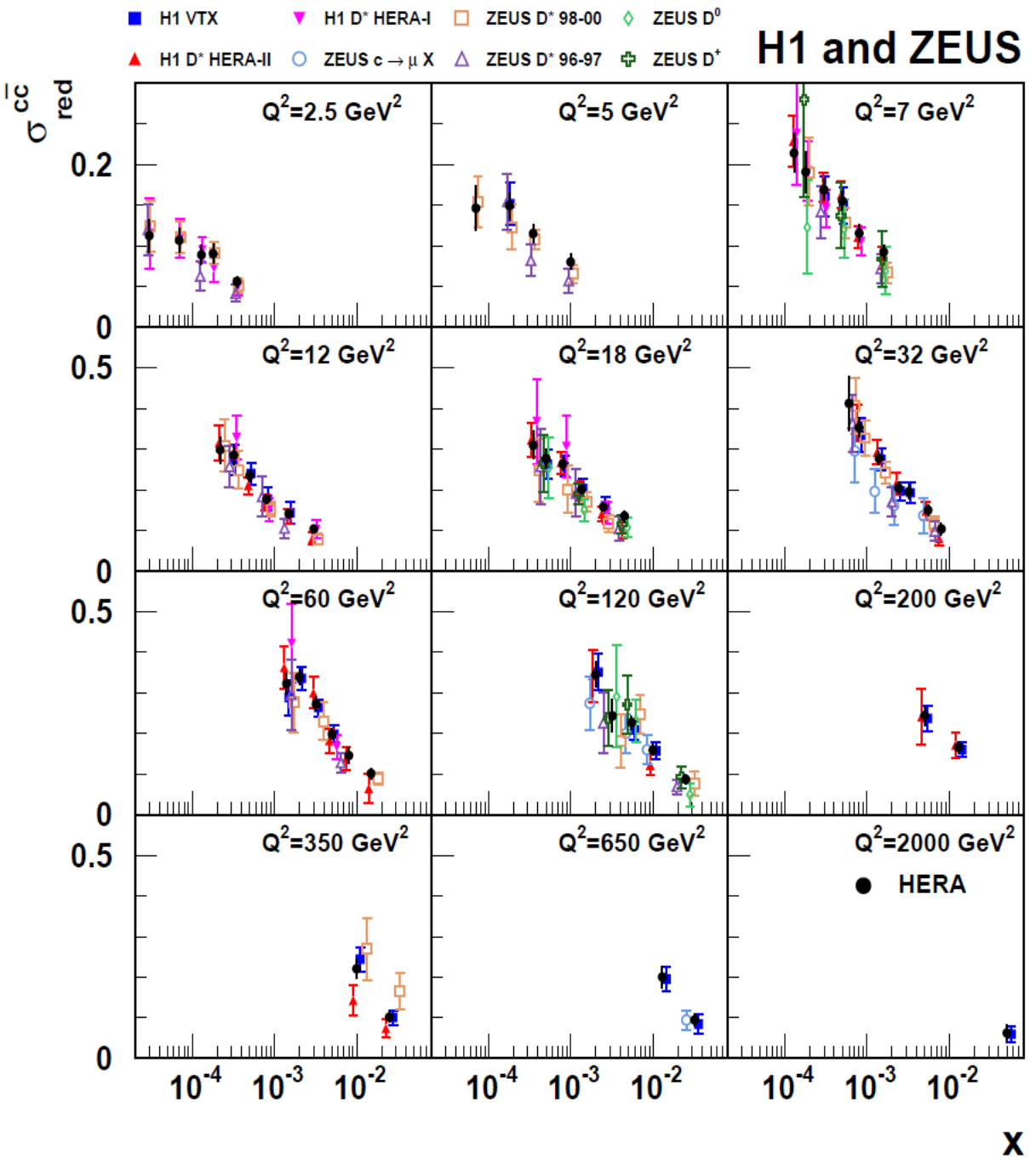






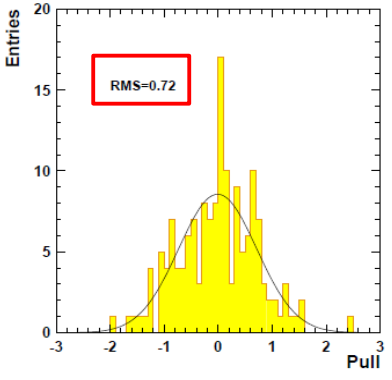
- 9 data sets
- 5 different tagging methods

Charm combination



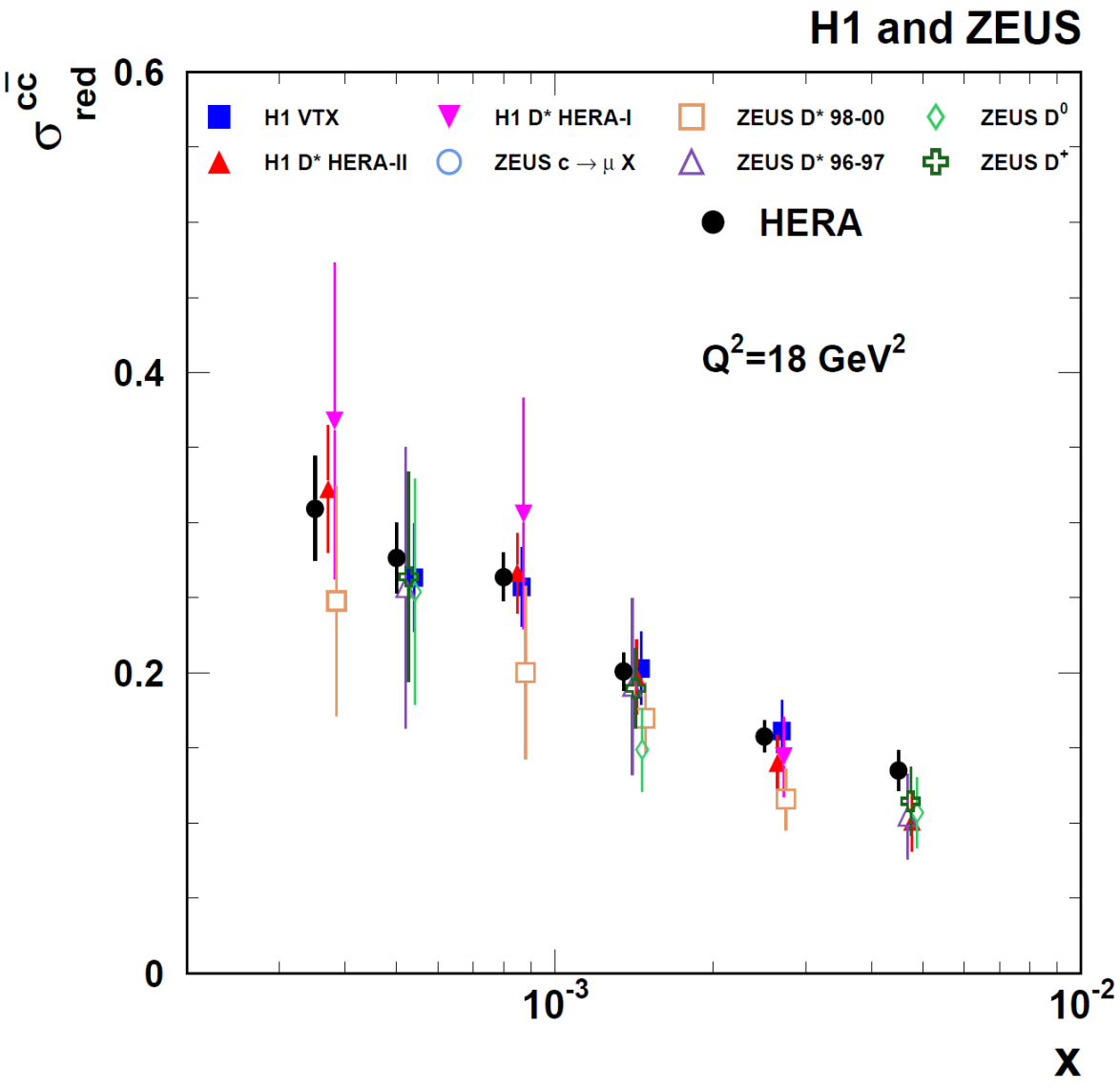
- 155 data points -> 52 combined points
- Charm reduced cross sections (in Q^2 and x):

$$\frac{d\sigma^{c\bar{c}}}{dxdQ^2} = \frac{xQ^4}{2\pi\alpha^2}\cdot[1+(1-y)^2]\cdot\sigma_{red}^{c\bar{c}}$$



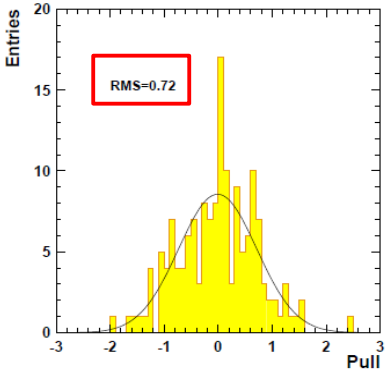
All data are consistent

Charm combination



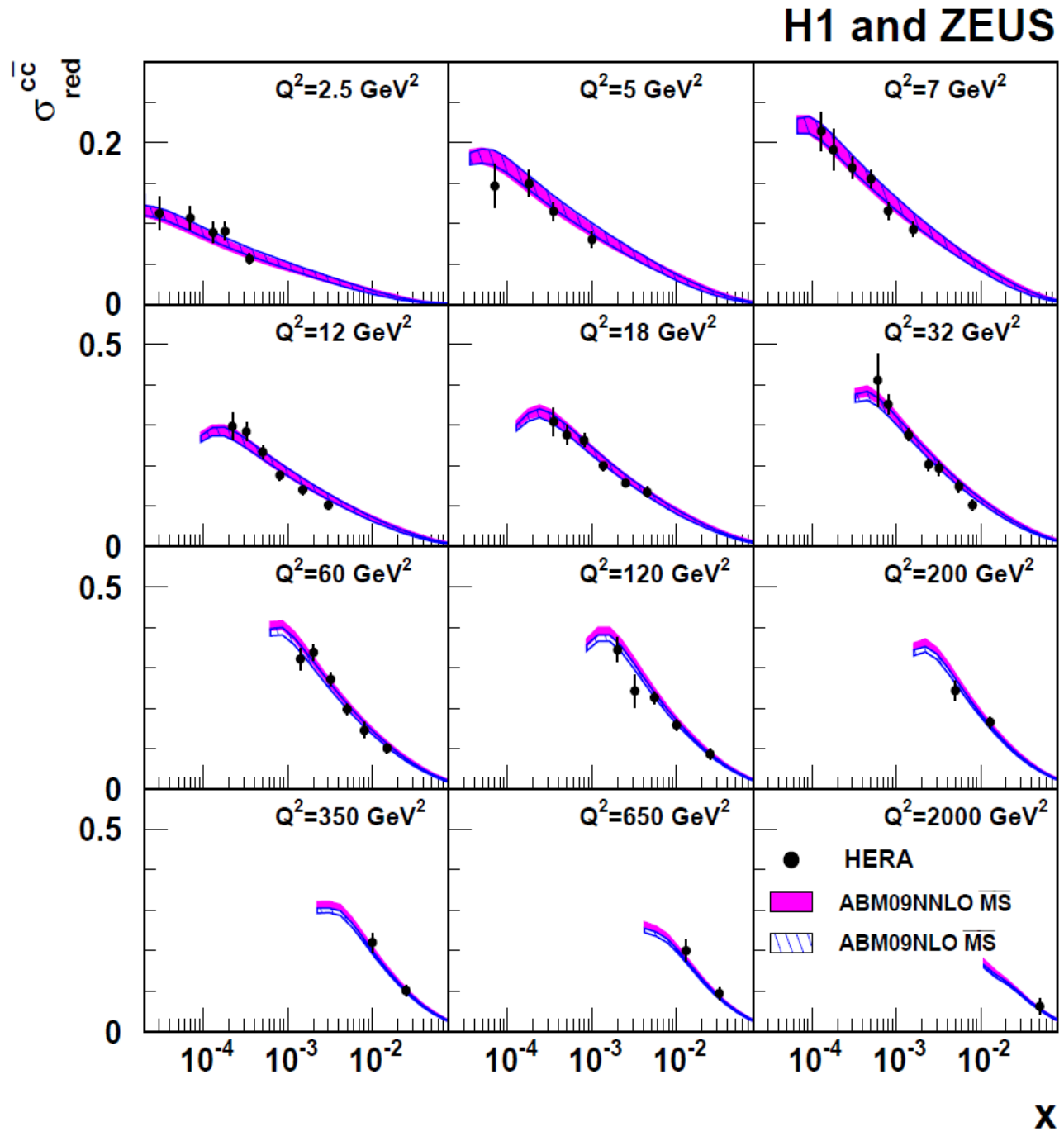
- 155 data points -> 52 combined points
- Charm reduced cross sections (in Q^2 and x):

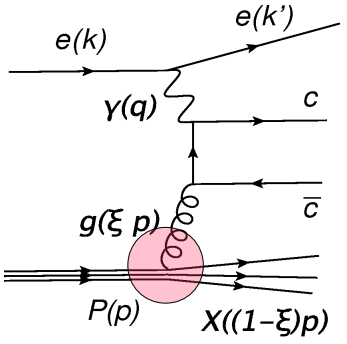
$$\frac{d\sigma^{c\bar{c}}}{dxdQ^2} = \frac{xQ^4}{2\pi\alpha^2}\cdot[1+(1-y)^2]\cdot\sigma_{red}^{c\bar{c}}$$



All data are consistent

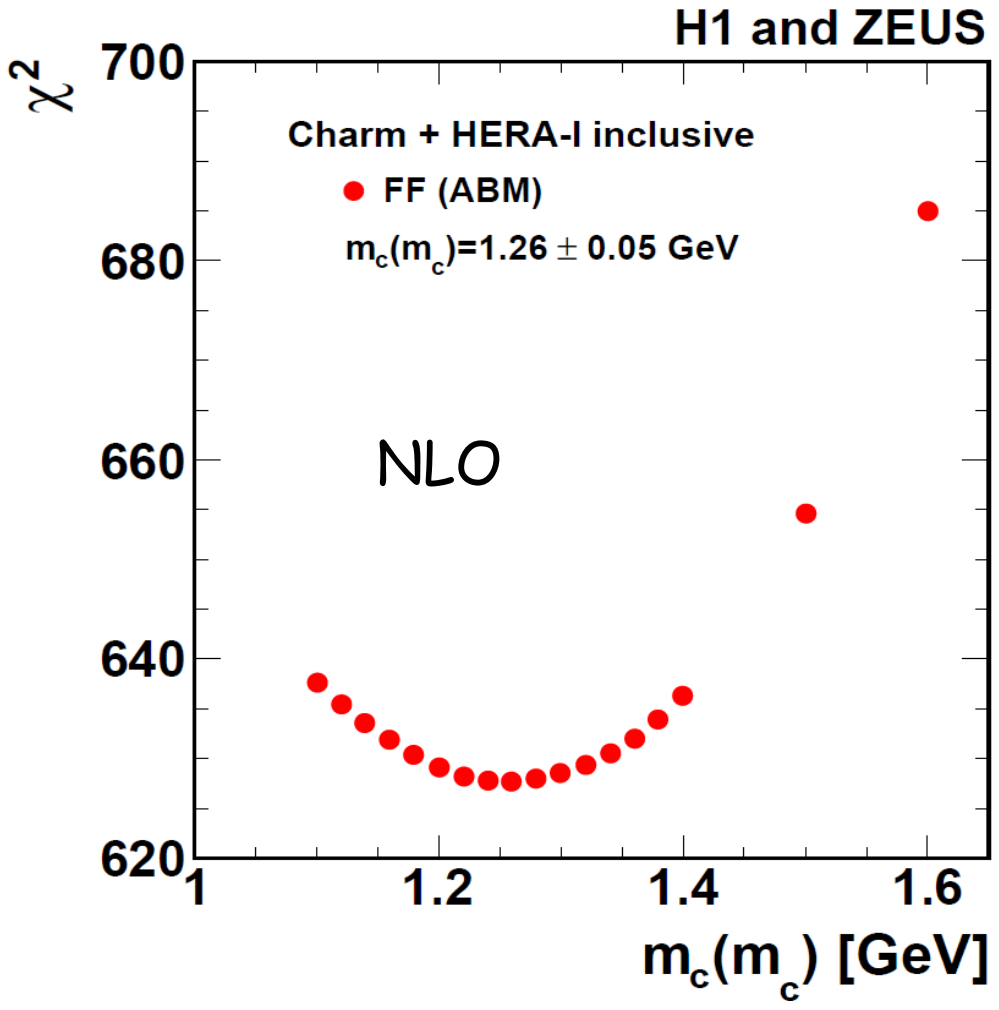
Comparison to FFNS theory





- Proper mass treatment in kinematics ($\overline{MS}$ running mass).
- Only 3 active flavours in the proton. Charm is produced perturbatively.
- NLO (α_s^2) and partial NNLO (α_s^3)

Extraction of the running mass

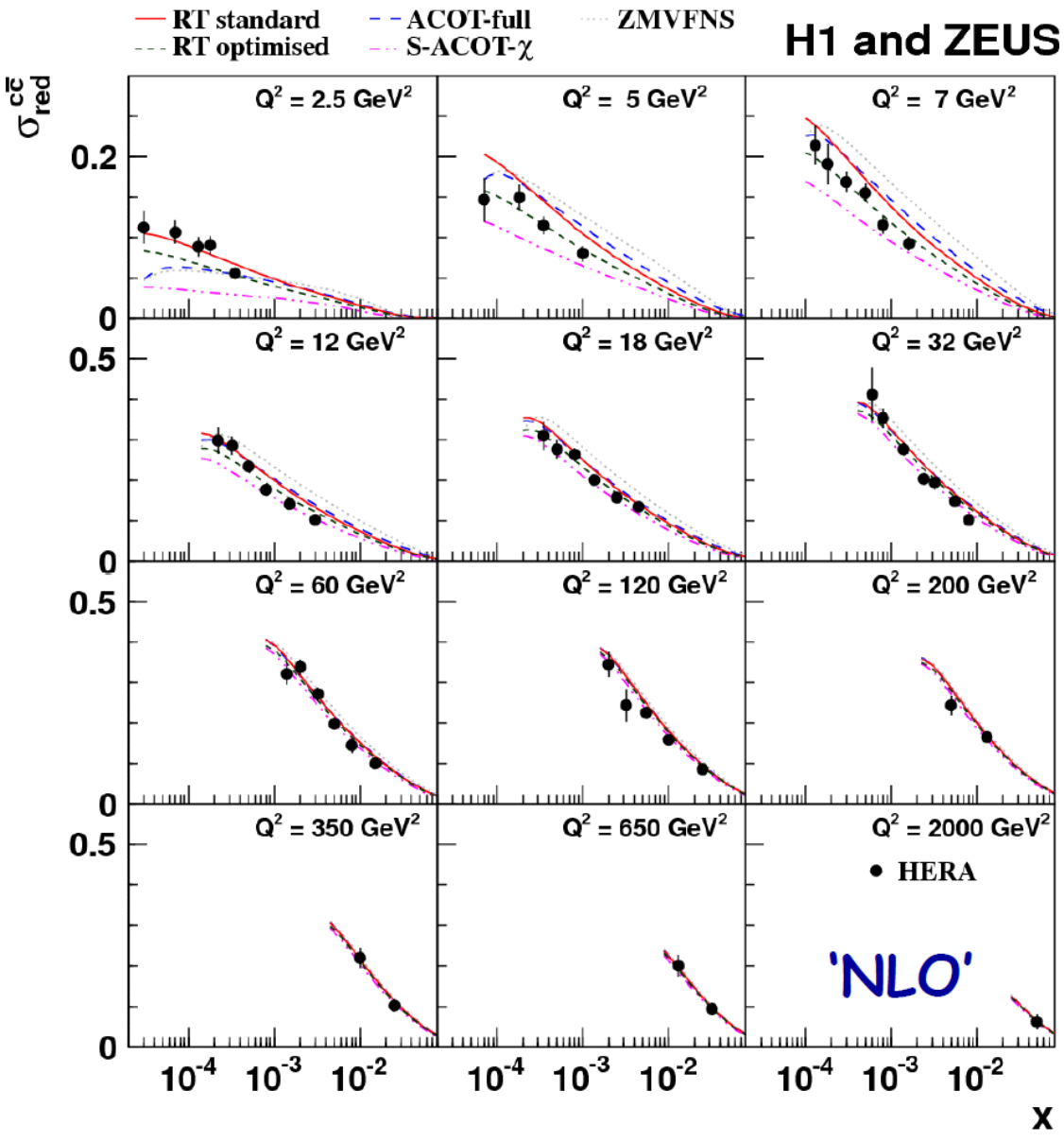


- Simultaneous fit of the combined charm and inclusive HERAI data
- χ^2/ndf = 628/626, partial charm: 44/47.

$$m_c(m_c) = 1.26 \pm 0.05_{\text{exp}} \pm 0.03_{\text{mod}} \pm 0.02_{\text{param}} \pm 0.02_{\alpha_s} \text{ GeV}$$

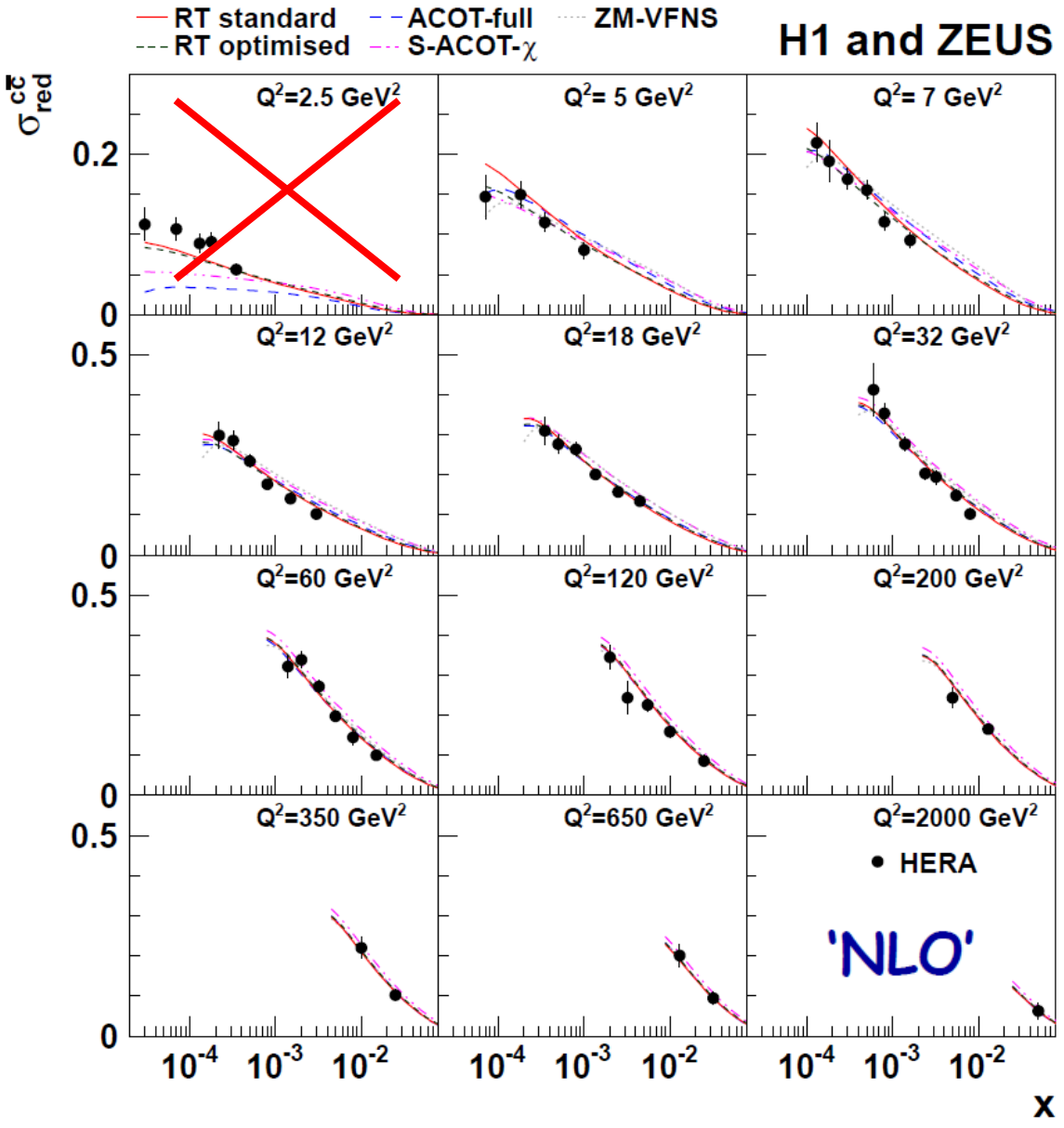
PDG 2012 : $m_c(m_c)$ = 1.275 ± 0.025 GeV (lattice QCD & time-like processes)

Comparison to GM-VFNS theories

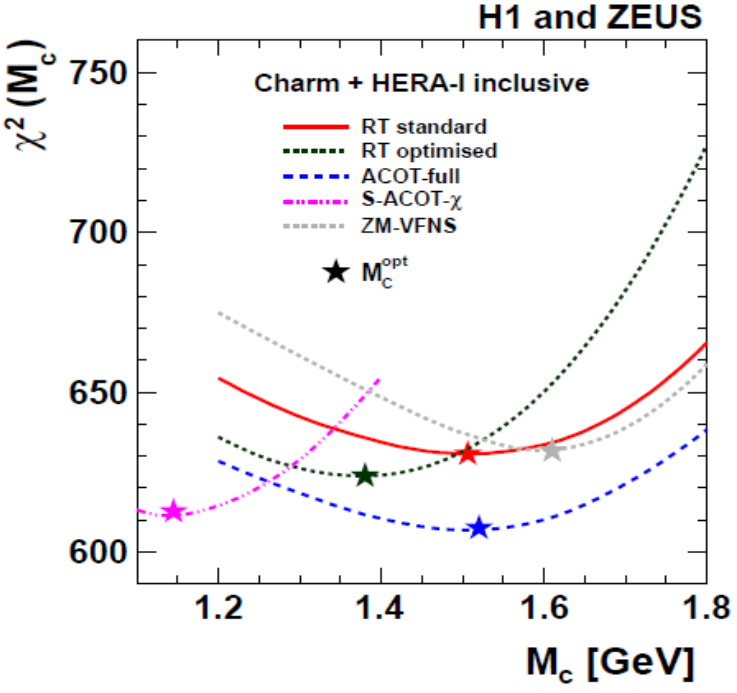


M_c (effective parameter) is fixed to 1.4 GeV.

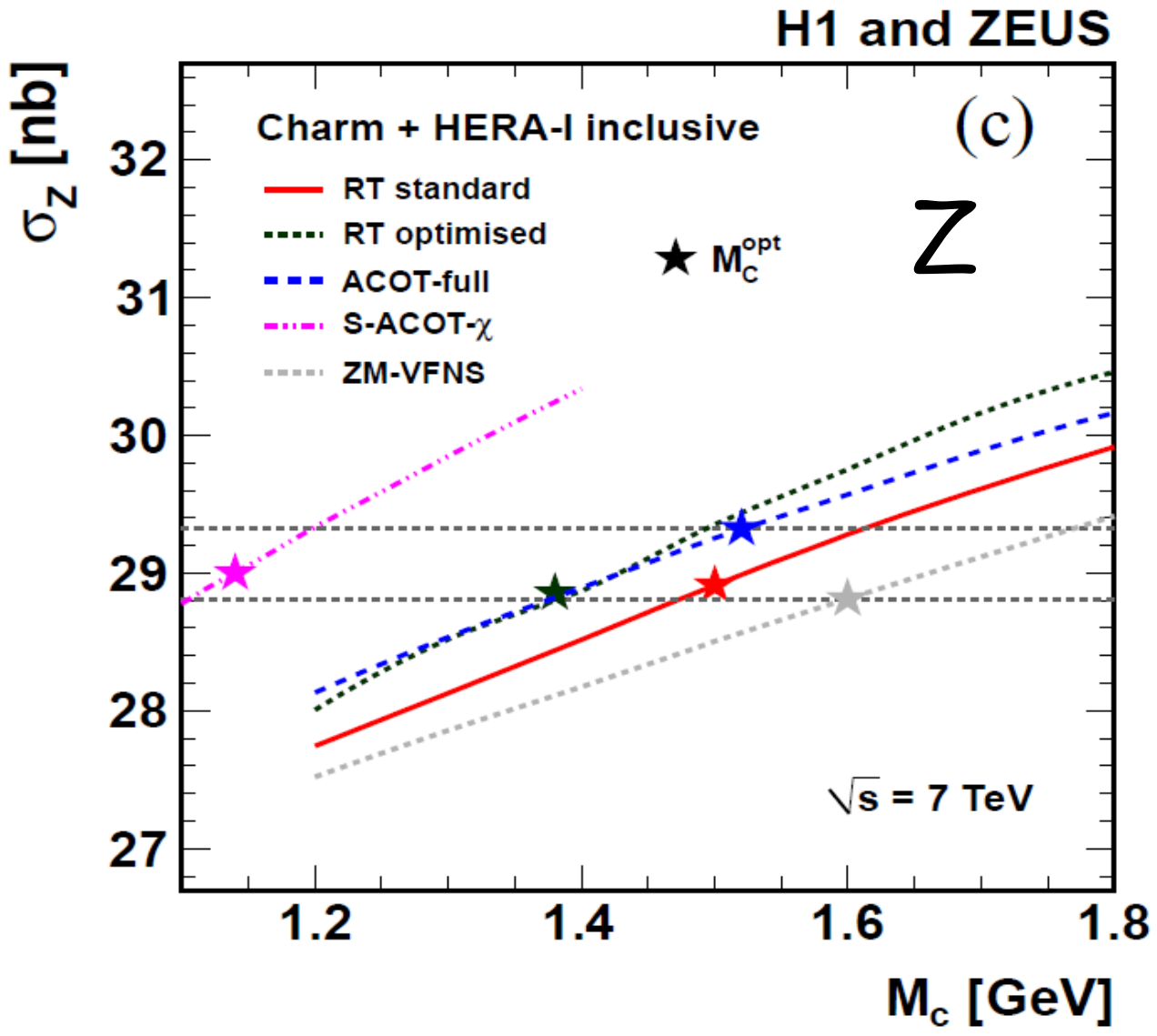
Constraints on GM-VFNS theories



Fit the optimal M_c value in each scheme (using $Q^2>3.5$ GeV^2).



Z cross sections at LHC

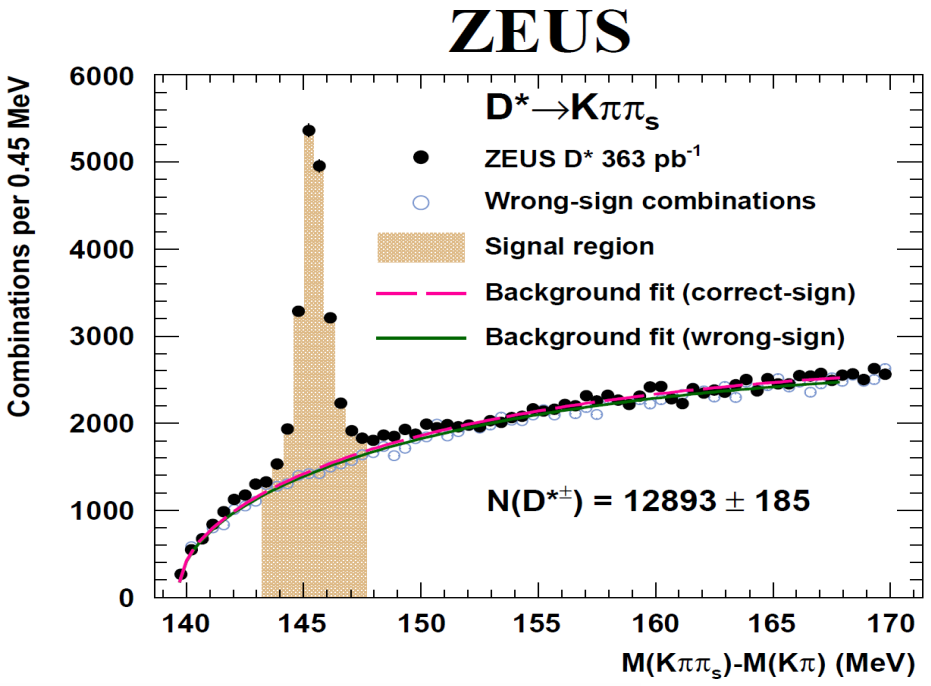


The optimal M_c reduces the uncertainty to ~2%.

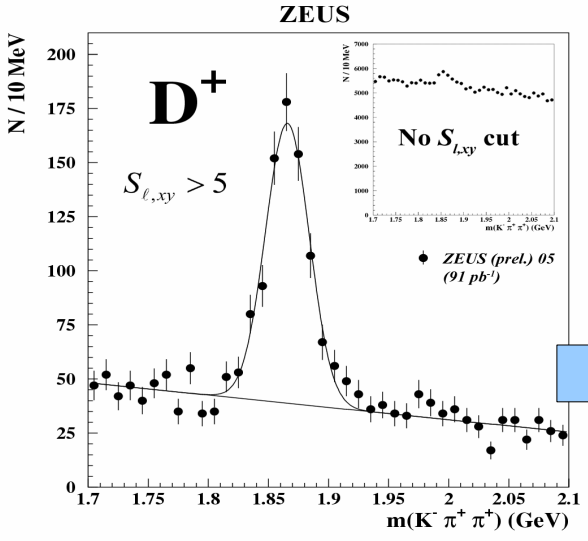
$D^{\pm}$ and $D^{*\pm}$ in DIS

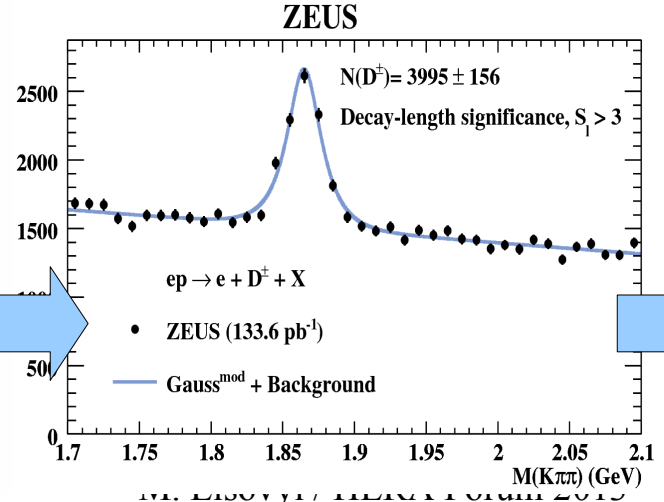
JHEP 05 (2013) 023

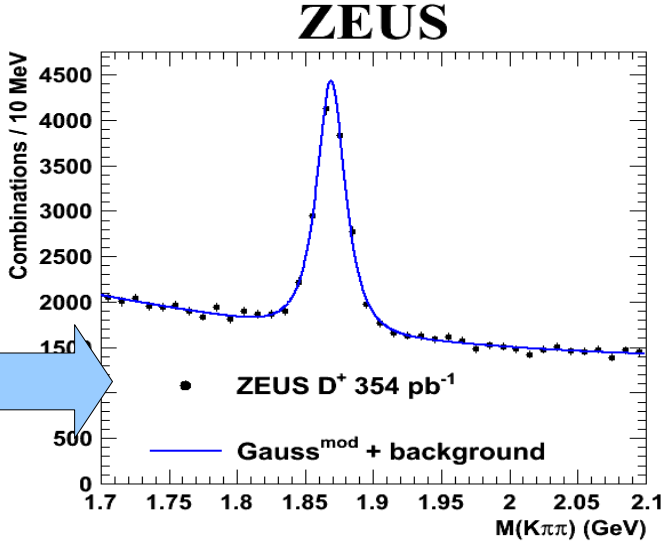
JHEP 05 (2013) 054



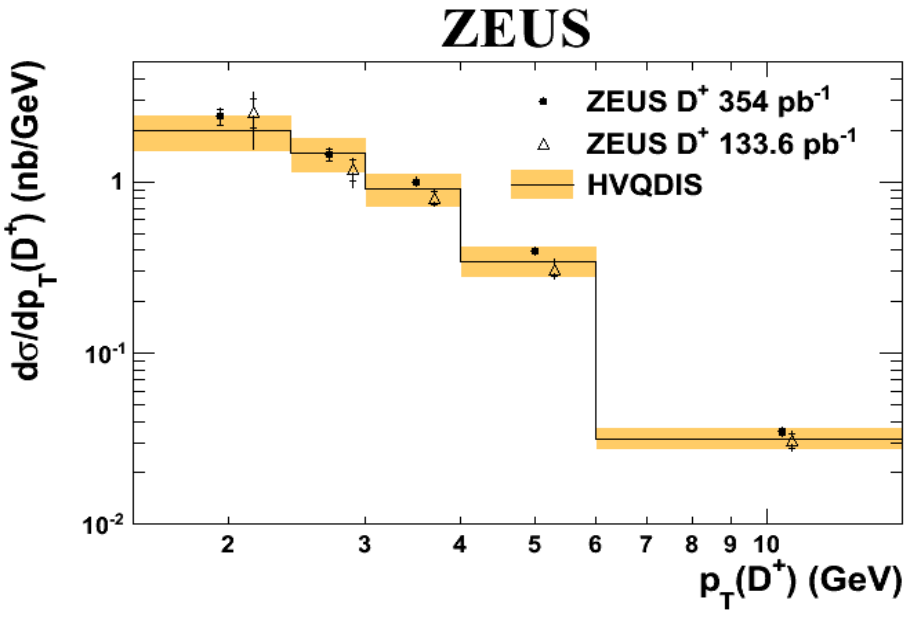
- New measurements: D^{+} and D^{*} tagging (full HERAII)

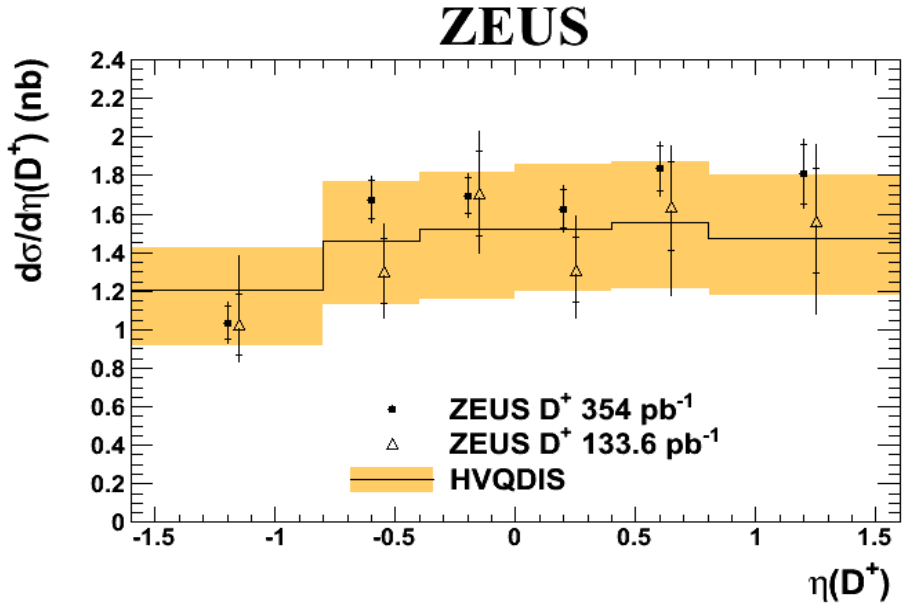






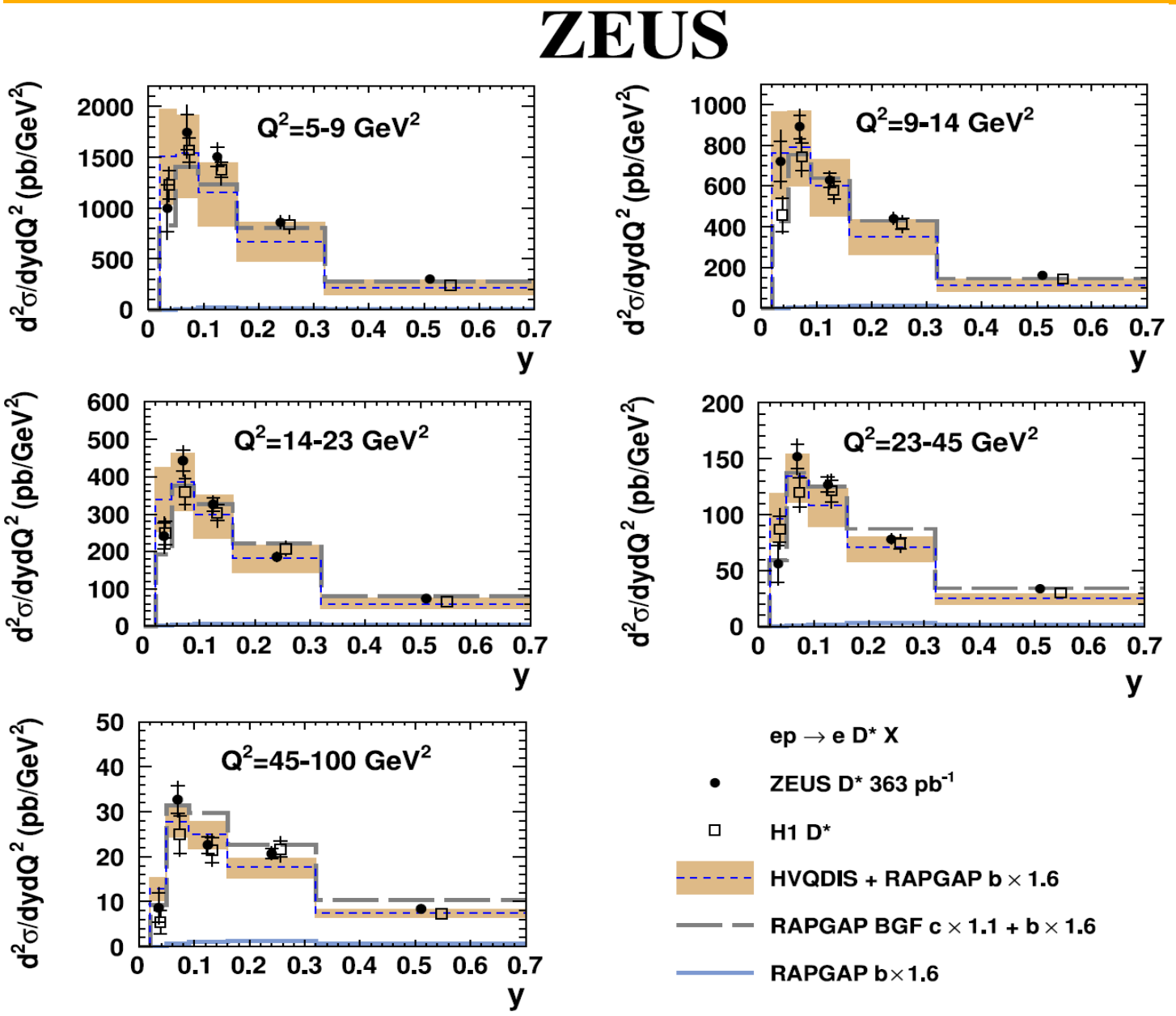
$D^{\pm}$ cross sections in DIS





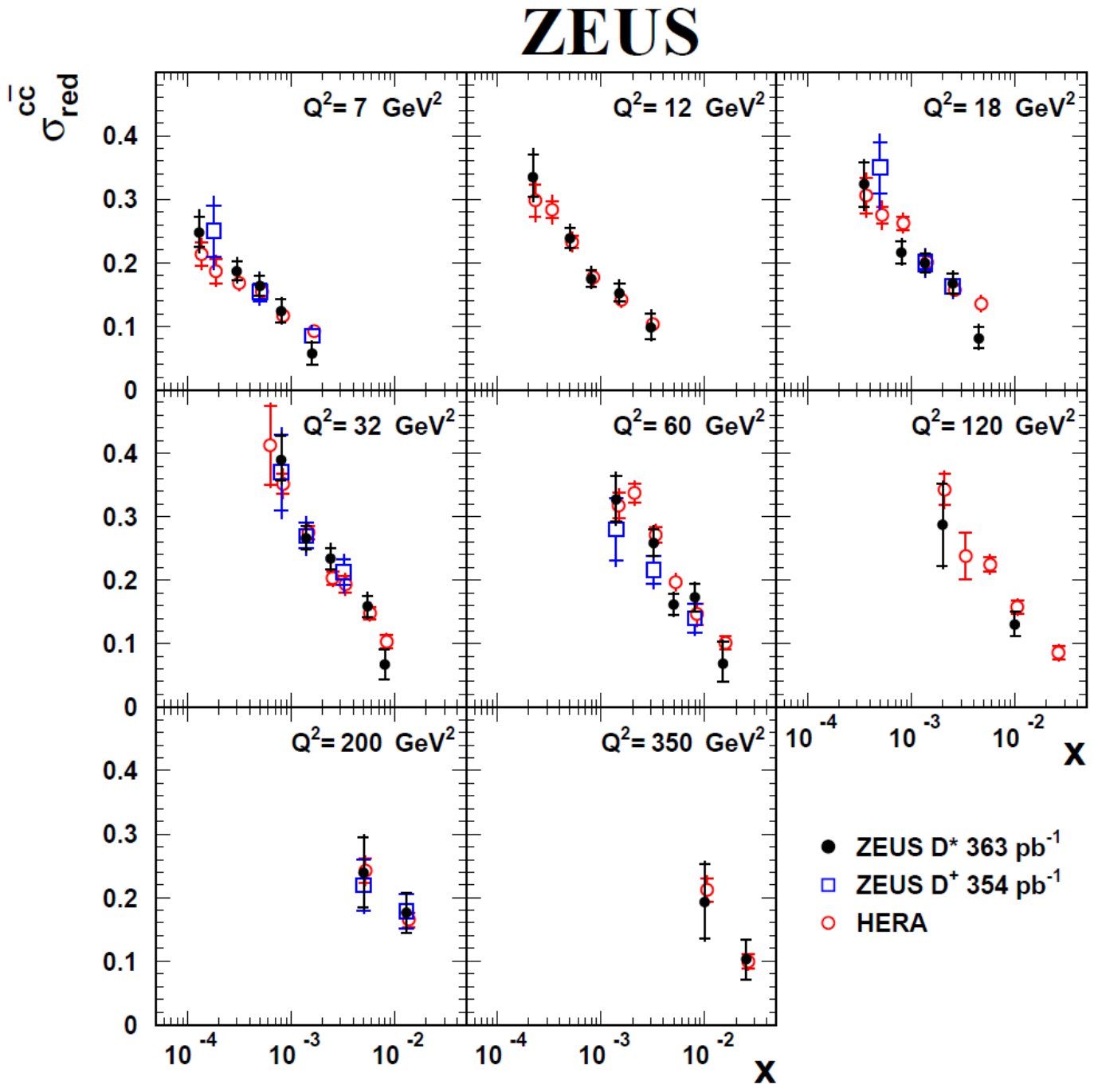
- Massive NLO QCD predictions (HVQDIS) describe the data.
- Significant improvement over the earlier $D^{\pm}$ result.

$D^{*\pm}$ cross sections in DIS



- Massive NLO QCD predictions (HVQDIS) describe the data.
- H1 and ZEUS D^* data agree and have similar precision

$D^{\pm}$ and $D^{*\pm}$ in DIS



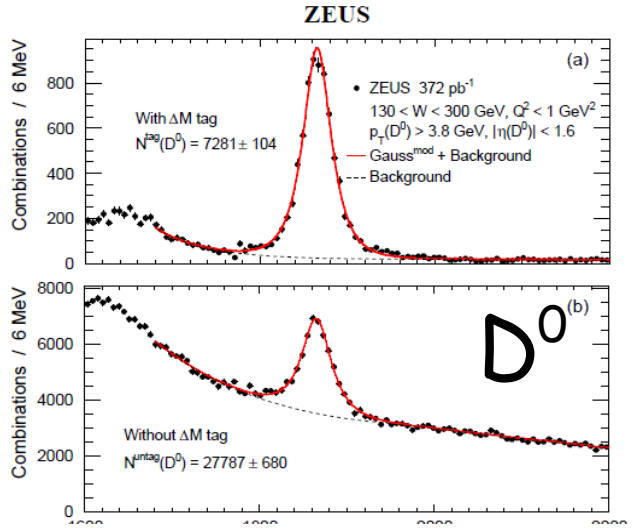
- Good agreement between new measurements and the combination
- D* measurement is the most precise charm result from ZEUS!

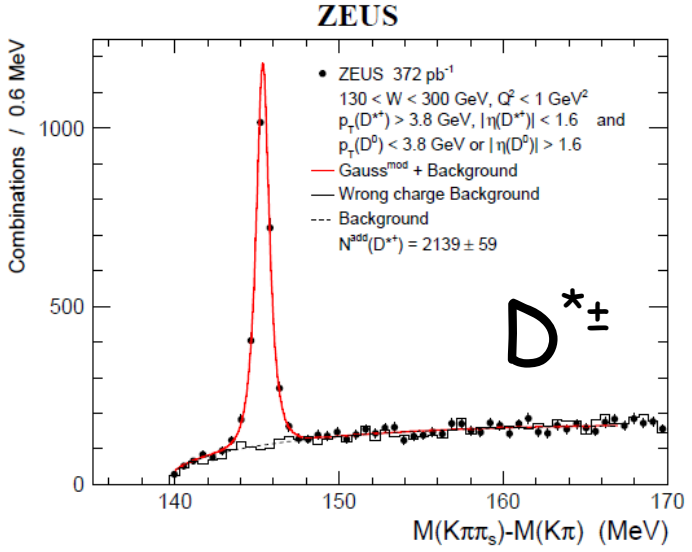
- Important new inputs to the final H1+ZEUS charm combination

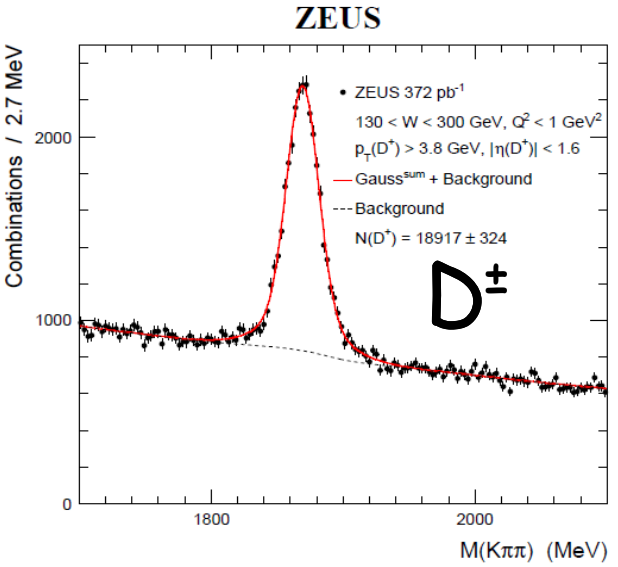
Charm fragmentation fractions

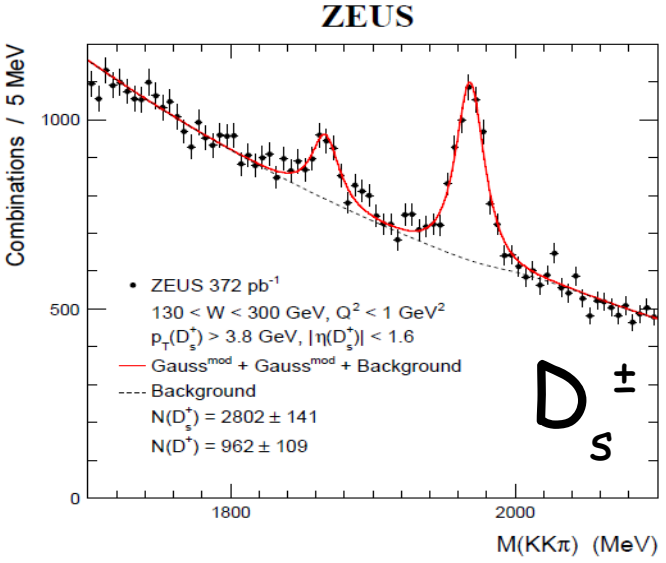
DESY-13-106

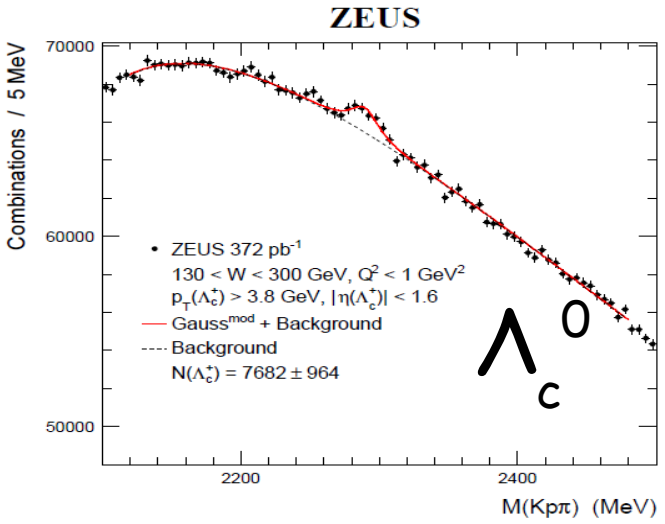
Probability of the charm quark to hadronise into a particular charm hadron => test fragmentation universality.





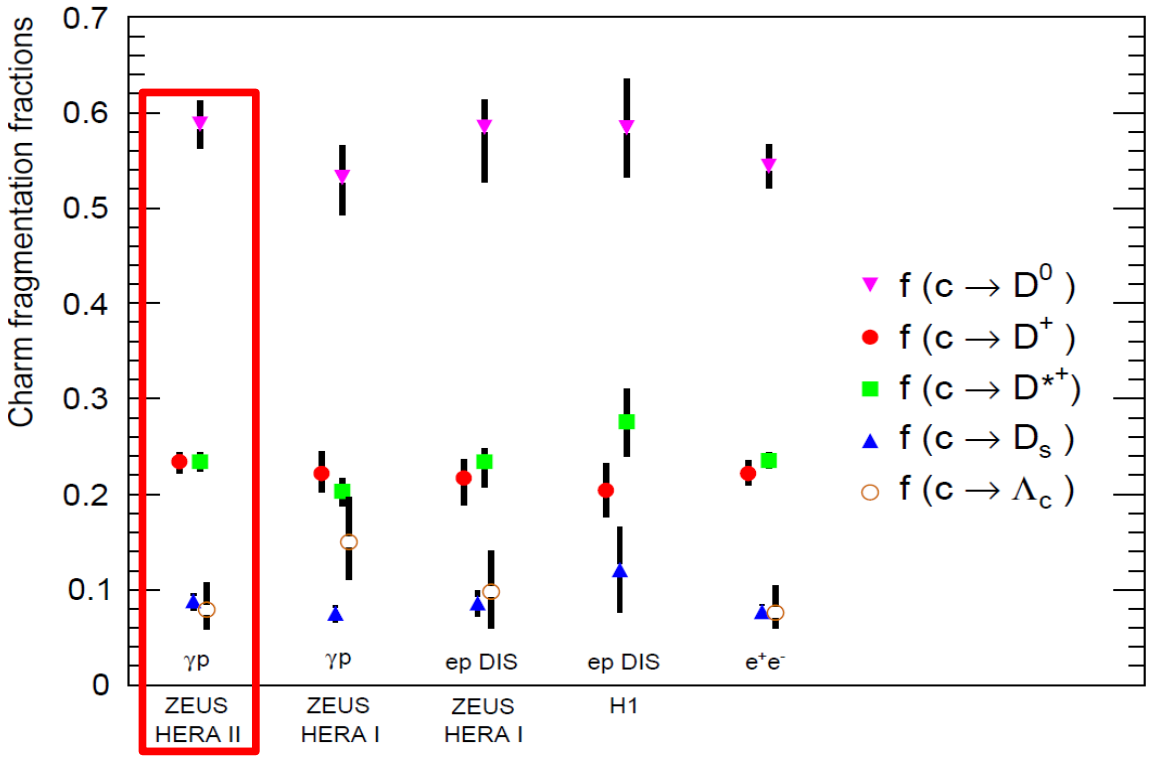






Clear charm hadron signals: using silicon-strip detector for charm vertices

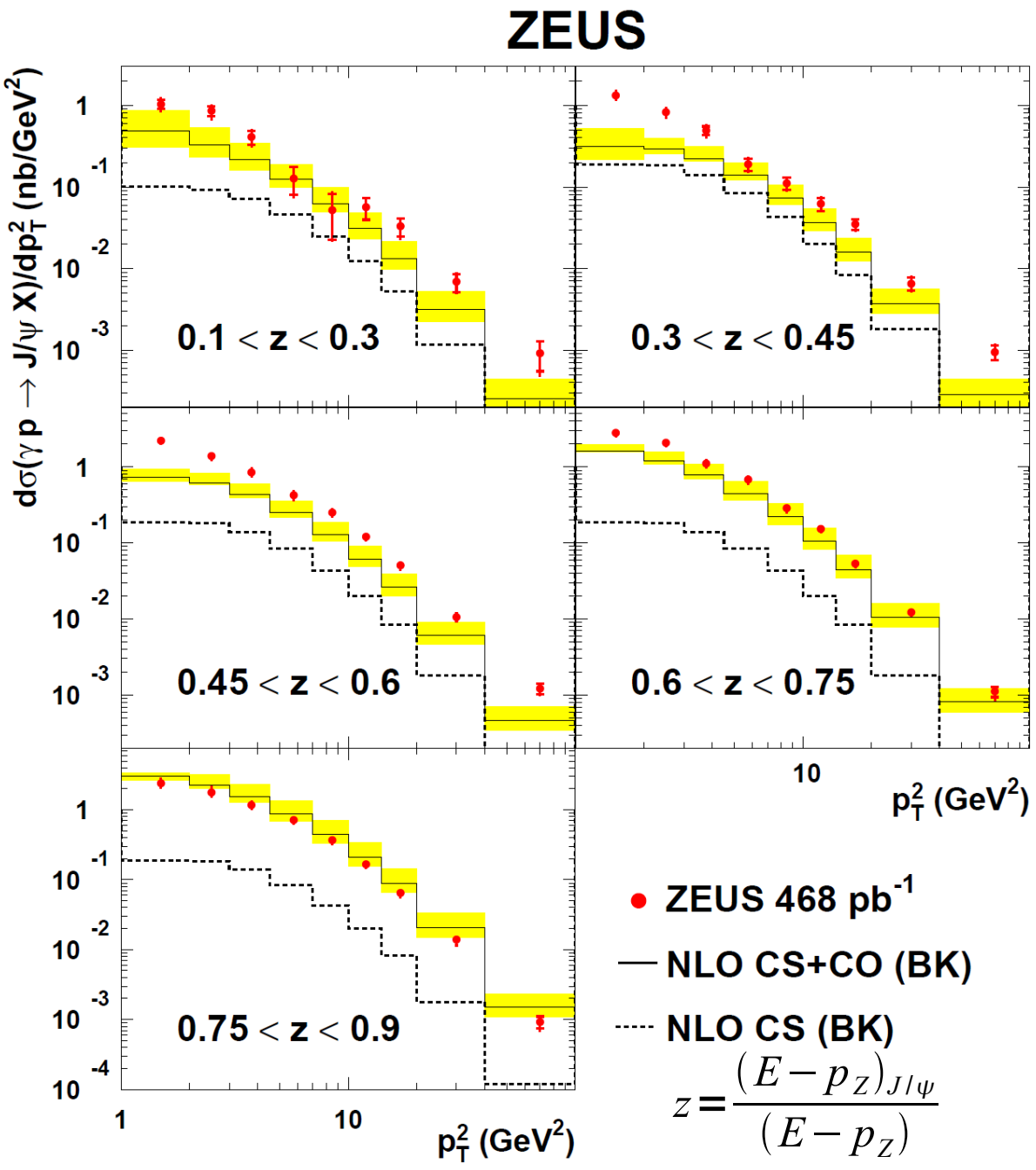
Charm fragmentation fractions



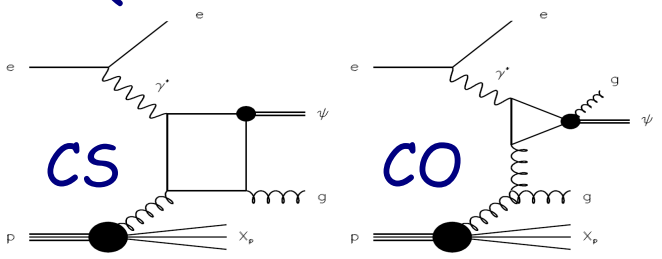
- Fragmentation universality is supported by the data.
- All measurements are in a good agreement.
- Precision competitive to the combination of e^+e^- results.

Inelastic J/ψ and ψ' in PHP

JHEP 02 (2013) 071



NRQCD:



- Stringent test of various theoretical approaches
- NLO QCD provides rough description of the data (also true for k_T-fact.).
- CO contribution is essential in the NLO framework

Summary

- Many interesting physics results.
- New prompt photon cross sections provide a stringent test of various theory approaches
- The combined charm data provide new constraints on description of the proton structure and allow a precise charm quark mass measurement.
- New precise D^* and $D^\pm$ measurements -> further improvement to HERA charm combination.
- Brand new charm fragmentation fractions support the idea of fragmentation universality and are competitive in precision with combined e^+e^- data.
- New J/ψ photoproduction: the colour-octet contribution is essential; still room for improvement of the theory predictions.

backup

New ZEUS results

- Combination and QCD Analysis of Charm Production Cross Section Measurements in Deep-Inelastic ep Scattering at HERA, DESY-12-172, EPJ C73 (2013) 2311 (shown at the last PRC)
- Measurement of the photoproduction of isolated photons with a jet at HERA, ZEUS-prel-13-001
- Measurement of Inelastic J/psi and psi' Photoproduction at HERA, DESY-12-226, JHEP 02 (2013) 071
- Measurement of $D^{\pm}$ Production in Deep Inelastic ep Scattering with the ZEUS Detector at HERA, DESY-13-028, accepted by JHEP
- Measurement of $D^{*\pm}$ Production in Deep Inelastic Scattering at HERA, DESY-13-054, submitted to JHEP
- Measurement of charm fragmentation fraction in photoproduction at HERA, read

ZEUS results for summer 2013

ZEUS talks at conferences in 2013:

- 28 talks up to now
- 44 are planed for January-September
- 8 @ EPS2013

This talk: 6 brand new results.