Inclusive Deep Inelastic Scattering at HERA

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On behalf of
the H1 & ZEUS
collaborations

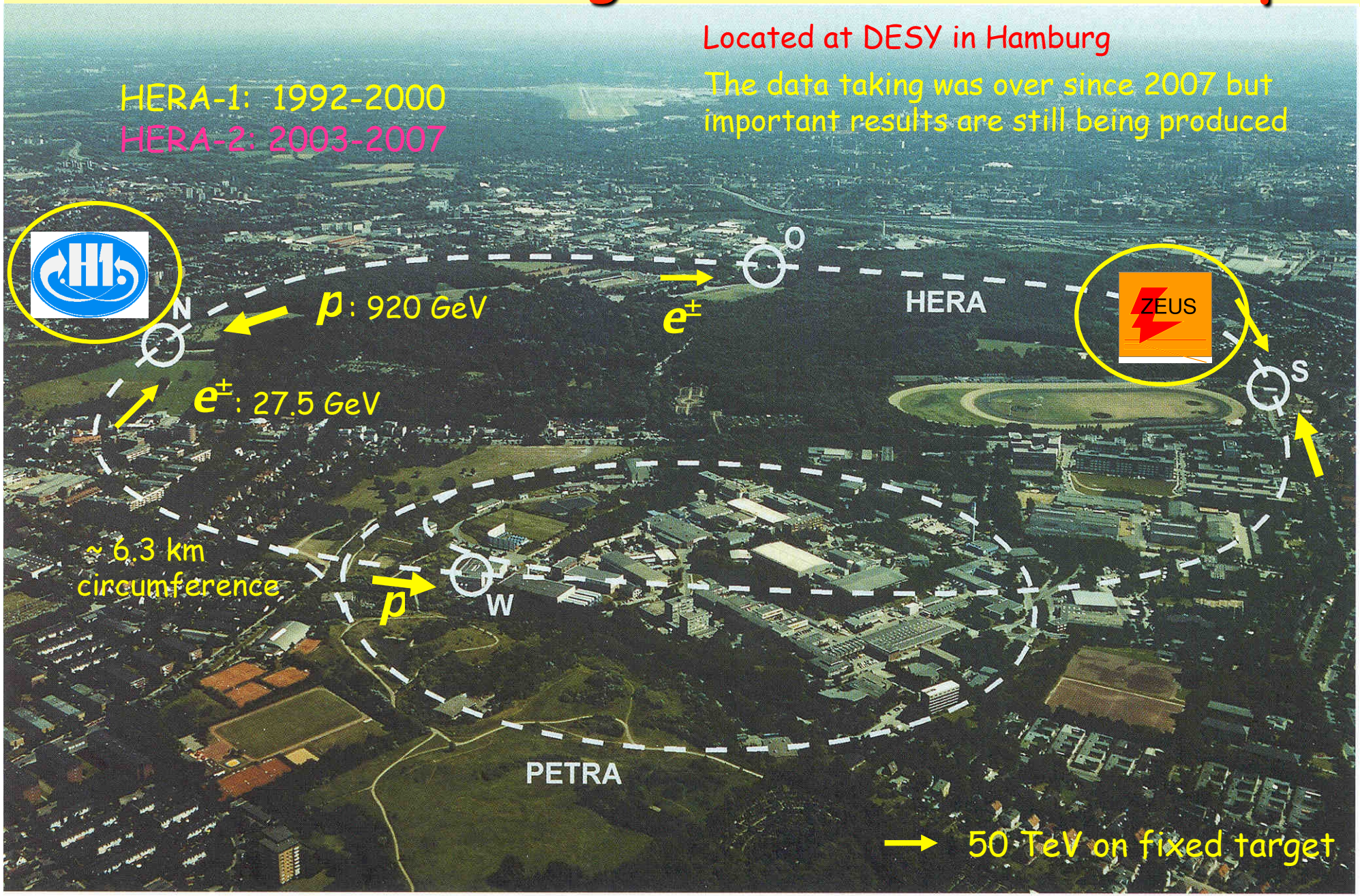
The talk covers 3 topics

1) Measurements of longitudinal structure function F_L
   H1: EPJC74 (2014) 2814, arXiv:1312.4821
   ZEUS: arXiv:1404.6376

2) Neutral current cross section at high x
   ZEUS: PRD89 (2014) 072007, arXiv:1312.4438

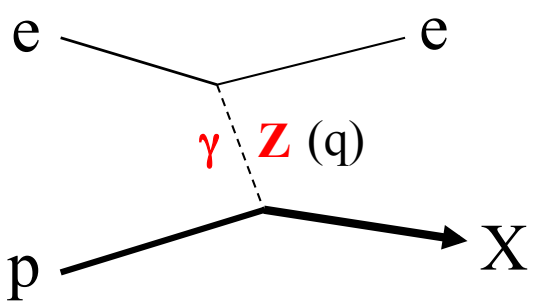
3) Preliminary H1 & ZEUS combination of HERA-1 & 2 neutral and charged current cross sections
   H1prelim-14-041
   ZEUS-prel-14-005

HERA used to be Largest Electron Microscope



Neutral and Charged Current DIS

NC $e^{\pm}p$ event



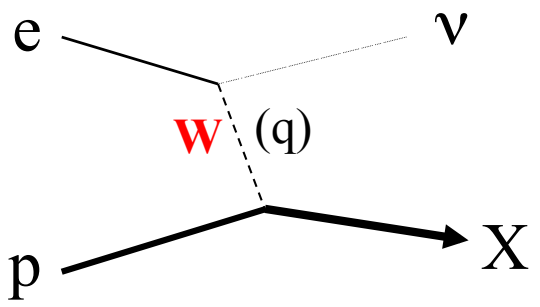
Event kinematics:

$Q^2=-q^2$: Boson virtuality

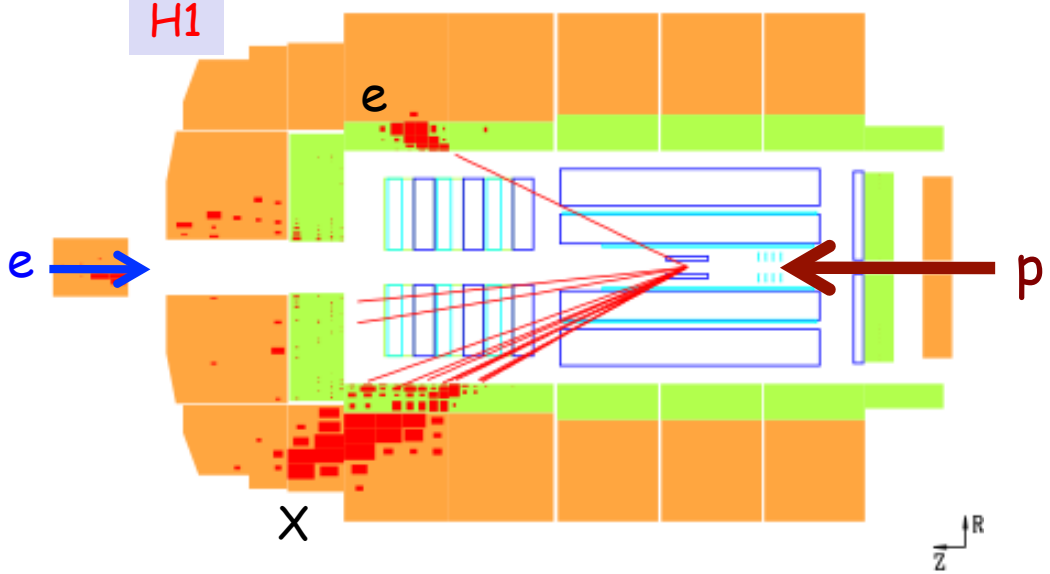
x: momentum fraction of struck parton

$y=Q^2/sx$: inelasticity

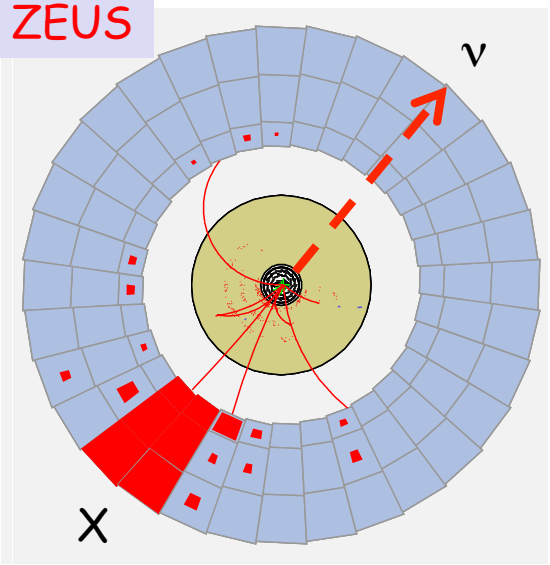
CC $e^{\pm}p$ event



H1



ZEUS



Final states e & X balanced in transverse plane

Unbalanced due to missing ν

Cross Sections, Structure Functions, PDFs

Parton Distribution Functions

$$\frac{d^2\sigma^{\pm}_{\rm NC}}{dxdQ^2} \sim Y_+\tilde{F}_2 \mp Y_-\tilde{F}_3 - y^2\tilde{F}_L \qquad \text{with} \quad Y_\pm = 1 \pm (1-y)^2$$

γ exchange γZ interference Z exchange

$$\tilde{F}_2 = F_2 - (v_e - P_e a_e)\kappa_Z F_2^{\gamma Z} + (v_e^2 + a_e^2 - 2P_e v_e a_e)\kappa_Z^2 F_2^Z$$

$v_e \sim 0$, ➔ some of the terms are negligible

$$x\tilde{F}_3 = -(a_e - P_e v_e)\kappa_Z x F_3^{\gamma Z} + \left[2v_e a_e - P_e(v_e^2 + a_e^2)\right]\kappa_Z^2 x F_3^Z$$

$$\left[F_2, F_2^{\gamma Z}, F_2^Z\right] = x\sum_q \left[e_q^2, 2e_q v_q, v_q^2 + a_q^2\right]\{q + \bar{q}\}$$

$$\left[xF_3^{\gamma Z}, xF_3^Z\right] = 2x\sum_q \left[e_q a_q, v_q a_q\right]\{q - \bar{q}\}$$

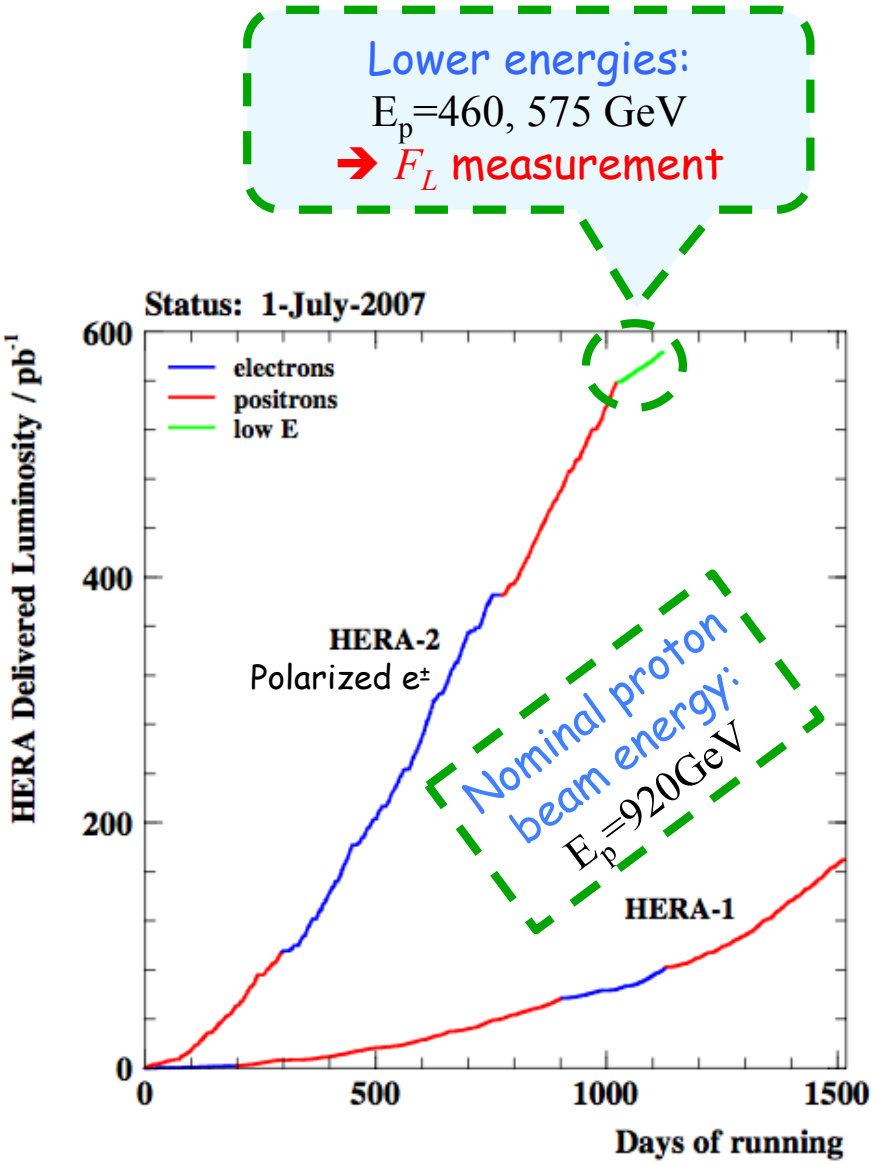
$$\kappa_Z^{-1} = \frac{2\sqrt{2}\pi\alpha}{G_F M_Z^2}\frac{Q^2 + M_Z^2}{Q^2}$$

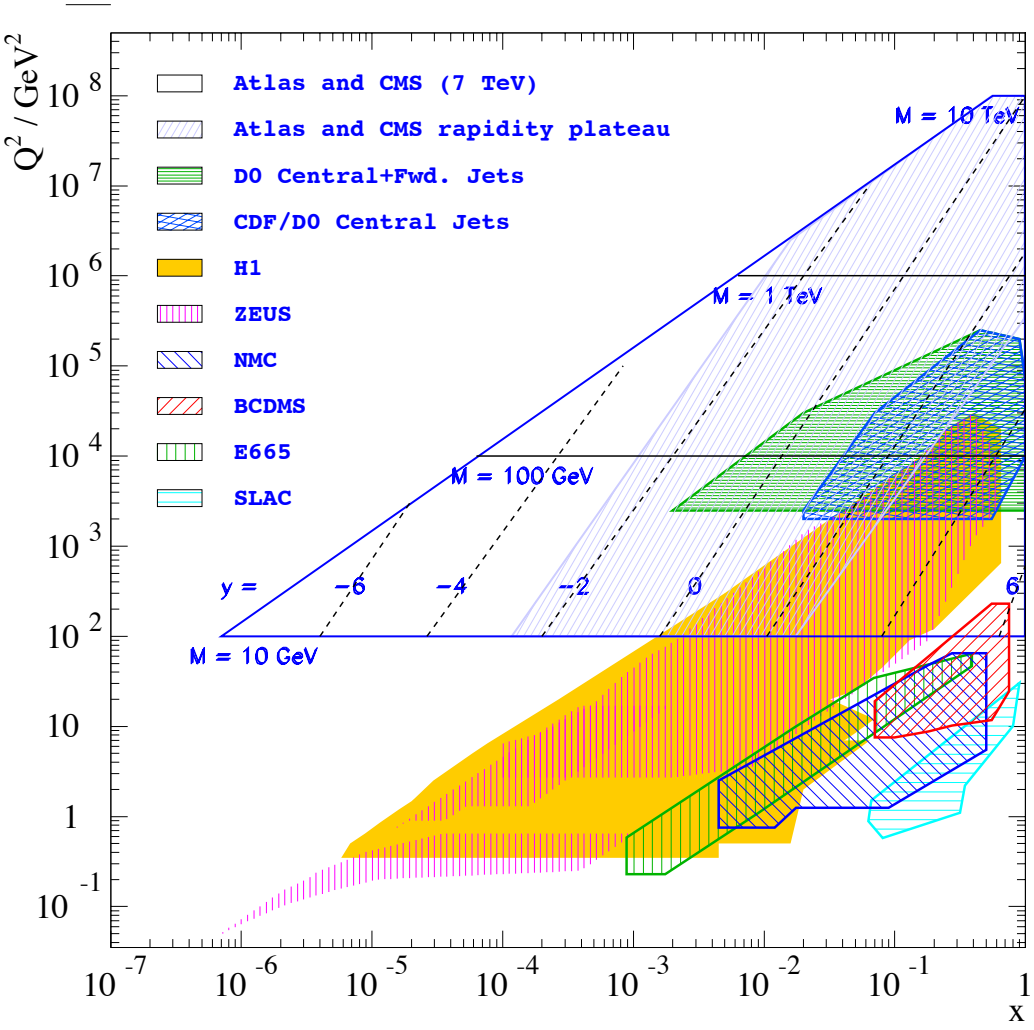
Structure function formulae given for e^-p scattering, for e^+p, $P_e \rightarrow -P_e$

CC cross sections have similar but different structure functions and PDF combinations

F_L=0 in LO parton model, $F_L \sim g$ at NLO

HERA-1/2 & Its Kinematic Coverage

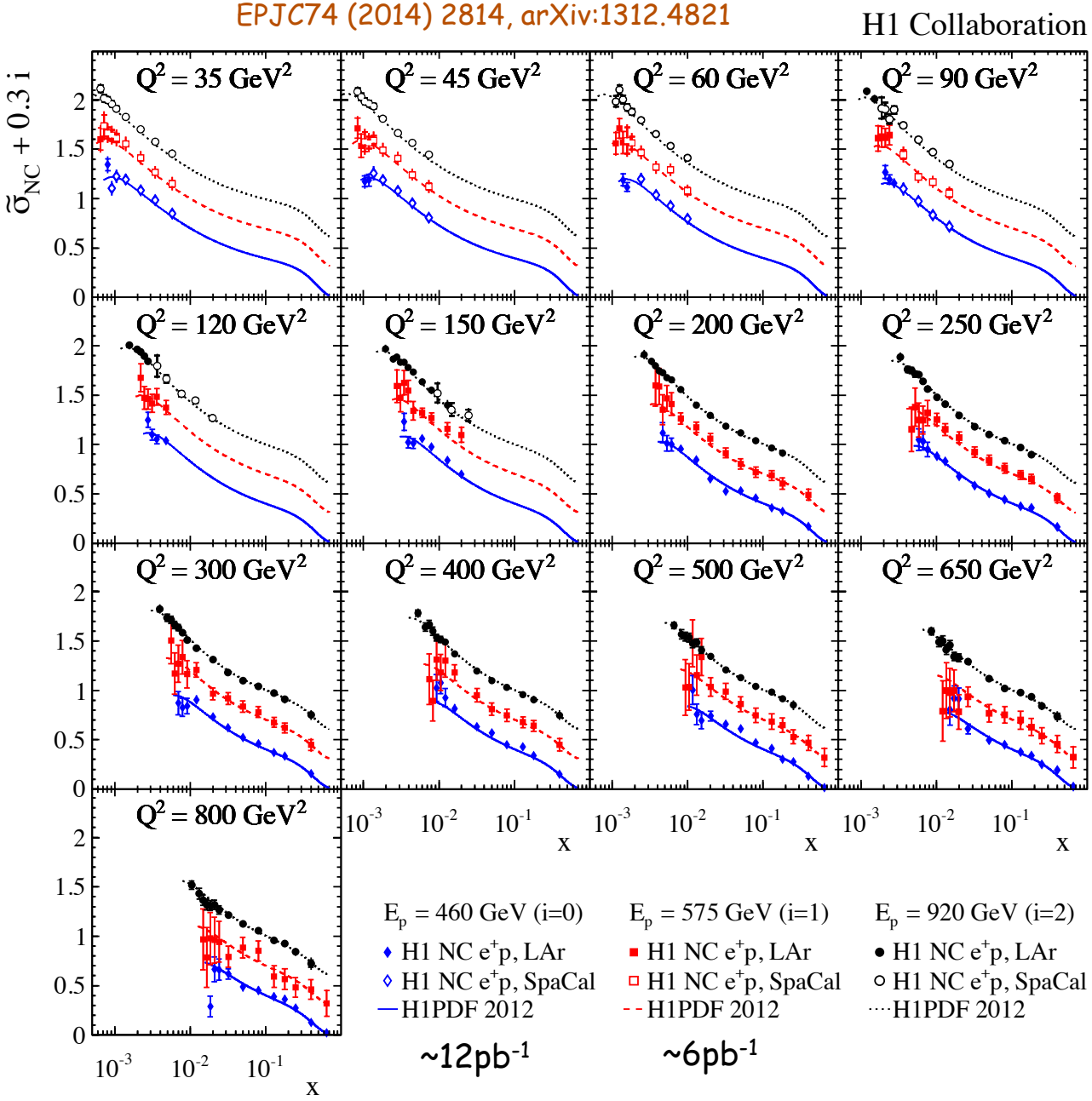




➔ The relevance & importance of HERA inclusive NC & CC σ measurements in providing PDFs for LHC physics

Dedicated H1 NC σ Measurements for F_L

EPJC74 (2014) 2814, arXiv:1312.4821



3 sets of inclusive σ_{NC} Corresponding to E_p=460, 575, 920GeV measured covering

Q^2: 35-800GeV^2

x: 6.5×10^{-4}-0.65

y: up to 0.85

Given the relation*

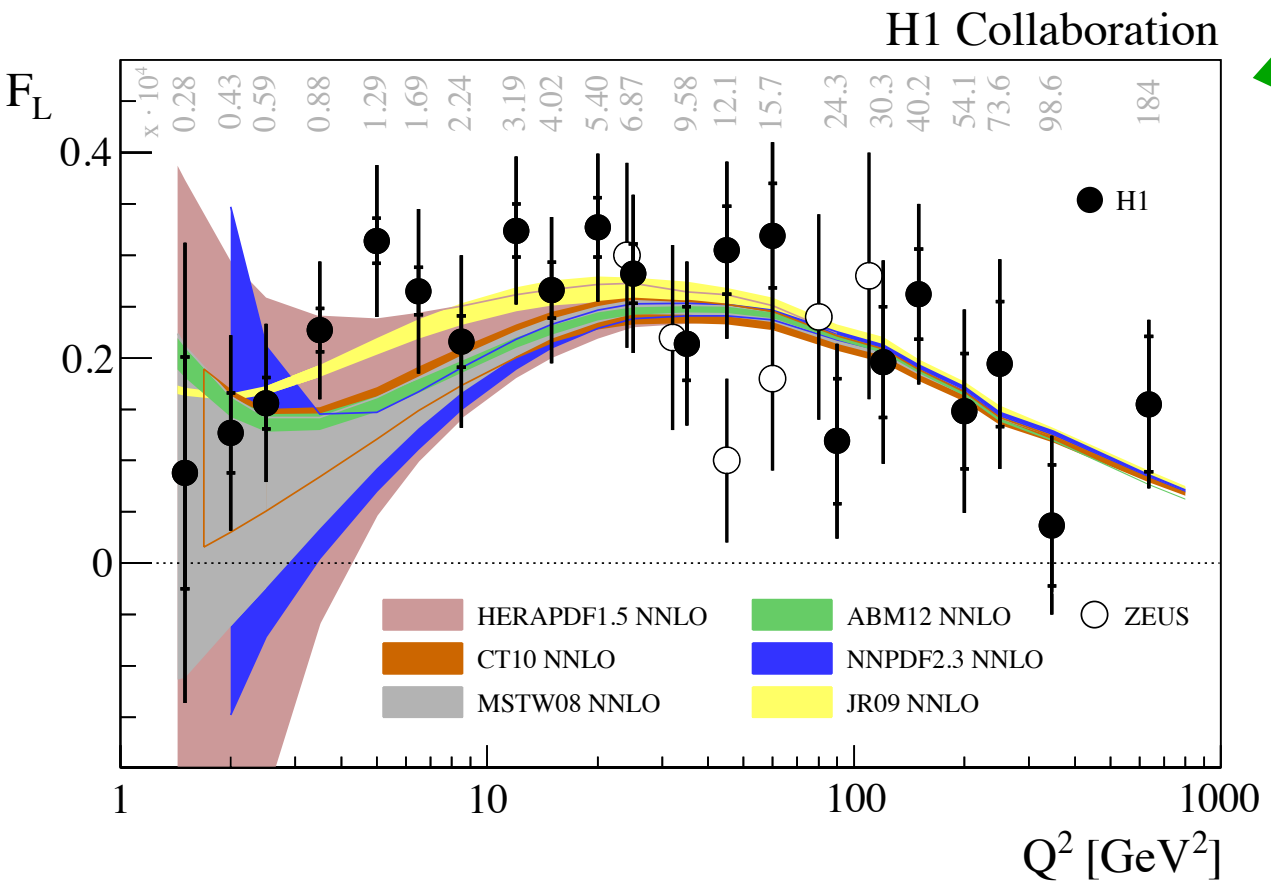
$$\sigma_{\mathrm{NC}} \sim F_2 - \frac{y^2}{Y_+} F_L$$

F_L can thus be extracted

* At this Q^2 range, xF_3 & Z change contribution are small

F_L Measurements from H1

This measurement combined with
Previous measurement: EPJC71 (2011) 2579, arXiv:1012.4355



Direct F_L measurement in agreement with pert. NNLO QCD expectation (scaling violation of F_2)

Since $F_L \sim xg$ at low Q^2, x

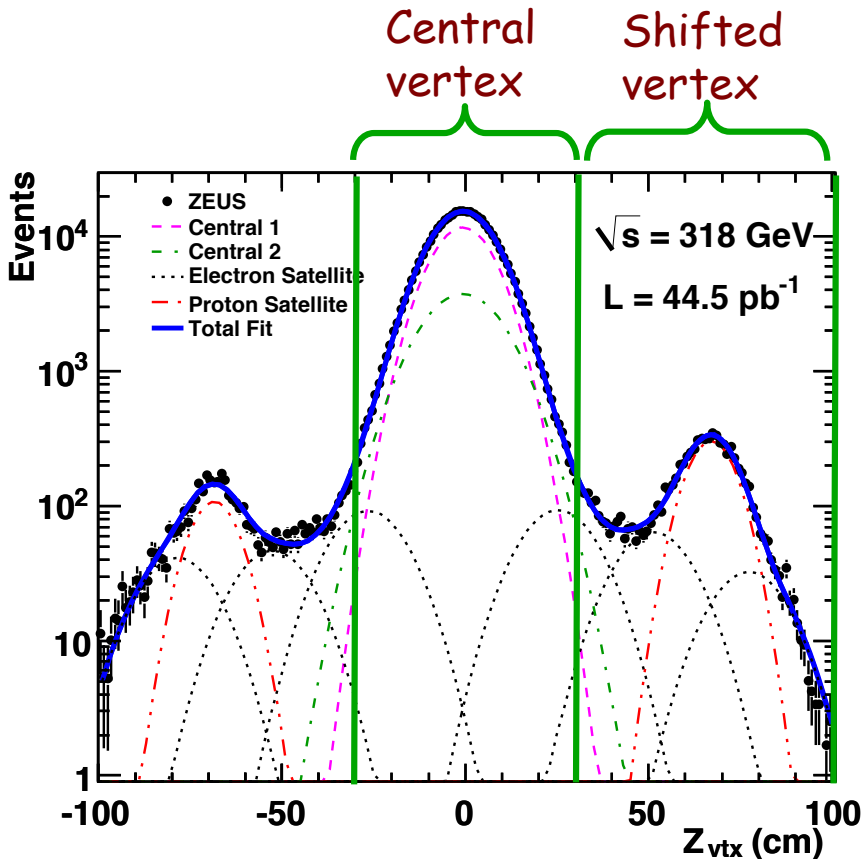
➔ HERA data provide a direct constraint of gluon density of the proton

H1 measurement in good agreement with (old) ZEUS measurement

New F_L Measurement from ZEUS

The new measurement: arXiv:1404.6376 supersedes the old measurement: PLB682 (2009) 8, arXiv:0904.1092 with

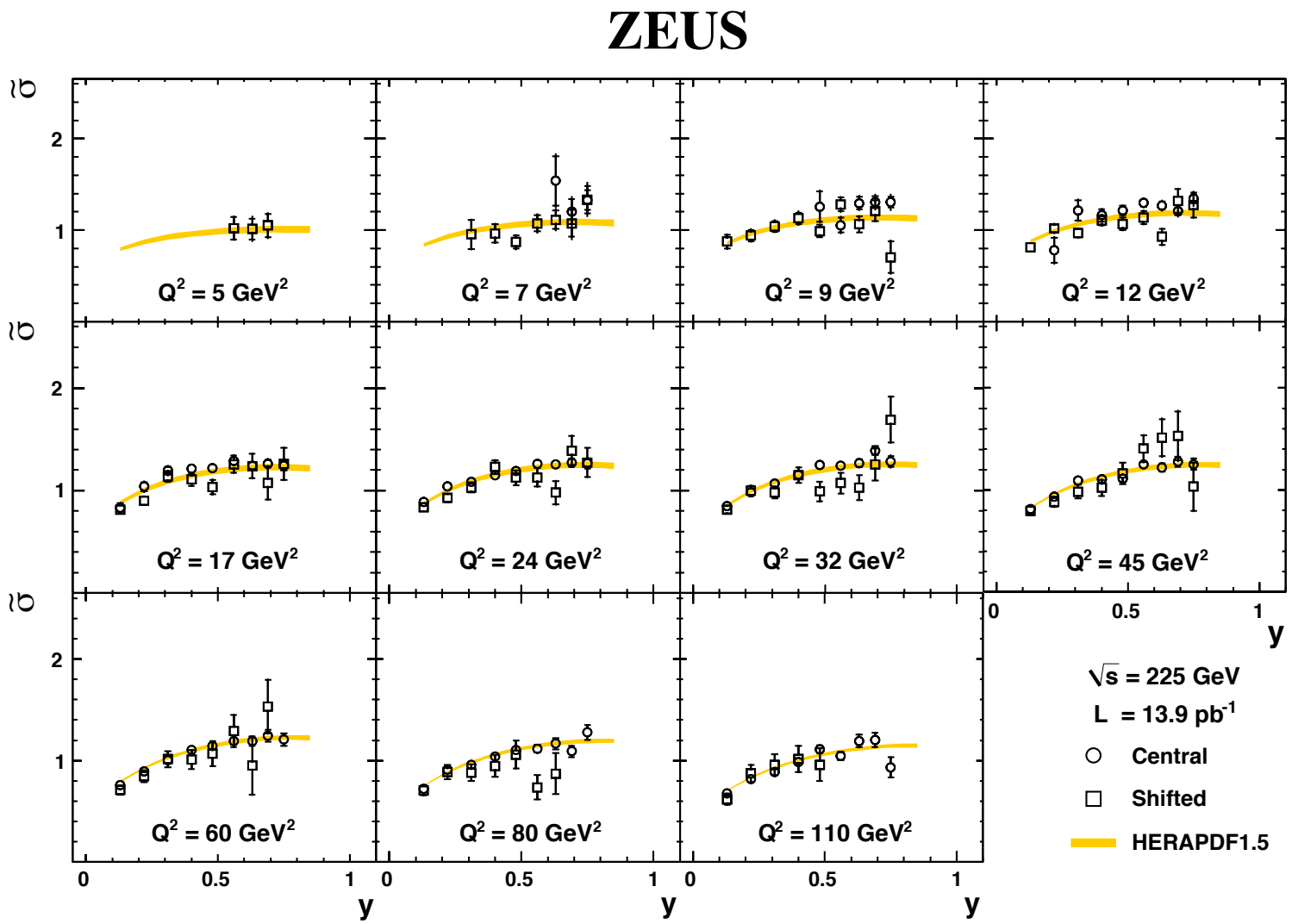
- Extension to lower Q^2 (using events with shifted vertex)
- Improved analysis techniques
- Better understanding of systematic uncertainties



Similar distributions also available for $\sqrt{s}$=225, 251GeV

Measured Cross Sections

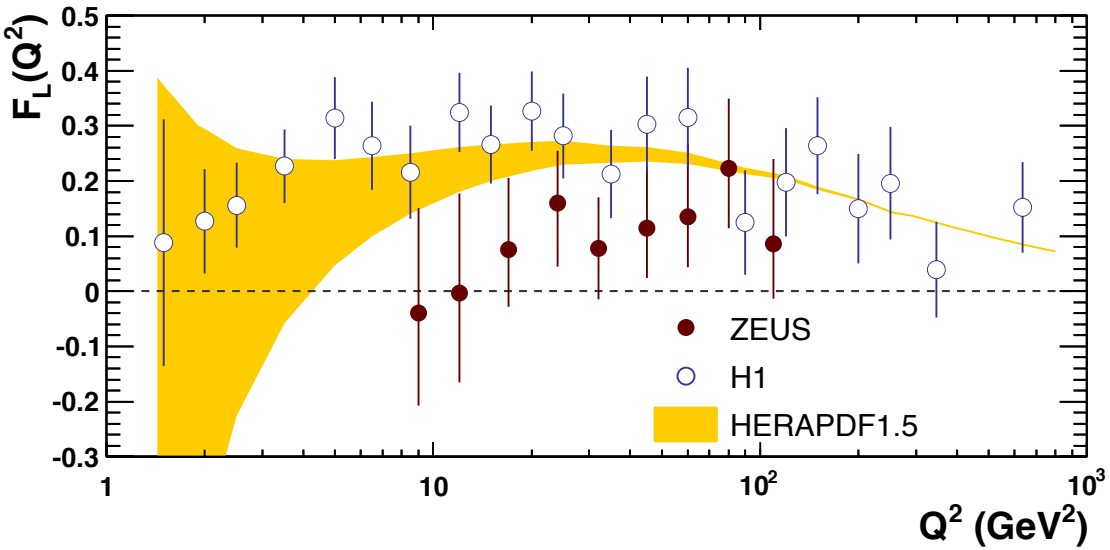
Covering Q^2: 5-110GeV^2, y: 0.13-0.75

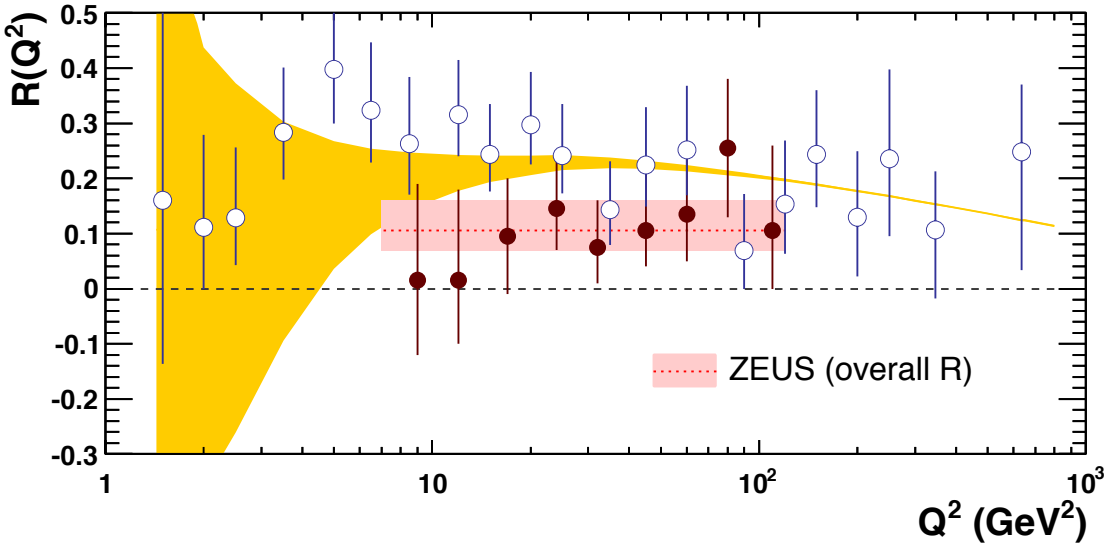


Shown for $\sqrt{s}$=225GeV, similar measurements also made for $\sqrt{s}$=251, 318GeV

Results and Comparison with H1

ZEUS





New ZEUS results extend to lower Q^2 but are lower than previous results due to changes in

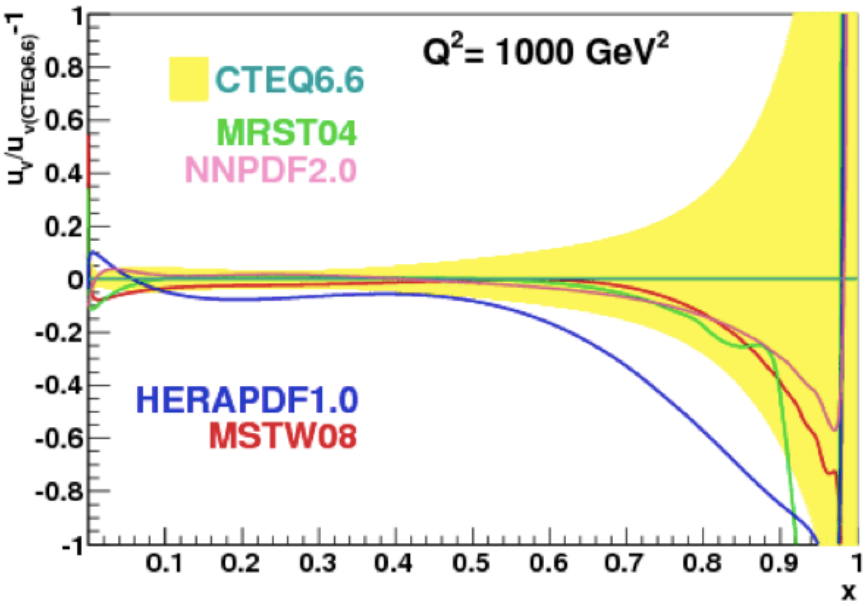
- the treatment of diffractive event simulation
- Electron validation at small scattering angles

$R=F_L/(F_2-F_L)\sim\sigma_L/\sigma_T$

ZEUS measurement lower than H1 measurement & HERAPDF1.5 NLO prediction

ZEUS' NC Cross Section at High x

New measurements: PRD89 (2014) 072007, arXiv:1312.4438 supersede
old measurements: EPJC49 (2007) 523, hep-ex/0608014



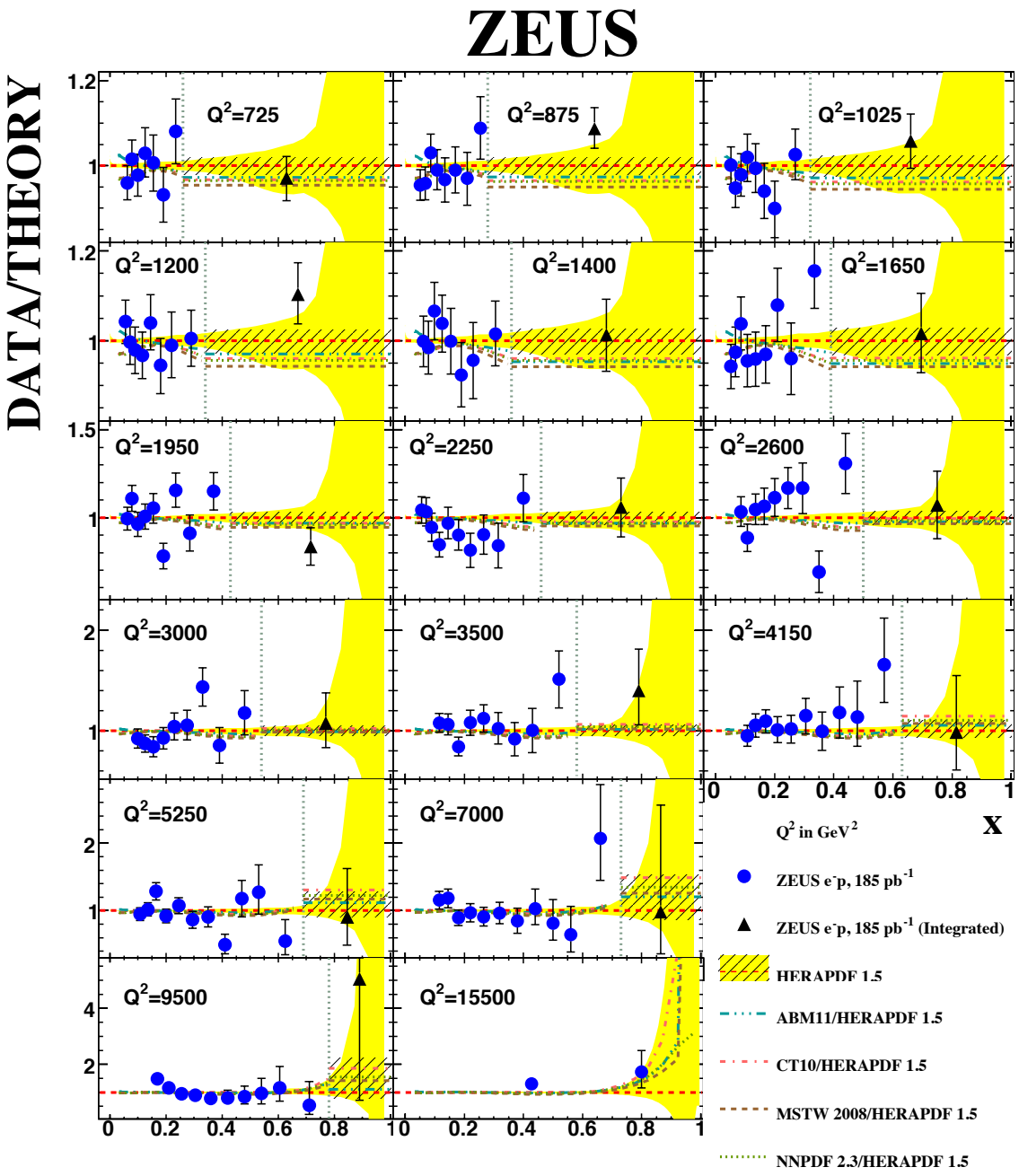
The analysis motivated by the fact

- The PDF uncertainty at high x is large
- The HERA measurements are mostly limited to 0.65

The new measurements are improved with respect to the old results with

- Larger data samples
  (10× for e^-p, 2× for e^+p)
- Novel kinematic reconstruction method

Measured Cross Sections Over Predictions



The high x measurements correspond to integrated cross section in the last x bin for each Q^2 value

The measurement is limited by statistical precision

The agreement between data and prediction is non-trivial as the latter are mostly modeled with $(1-x)^{\beta}$ parameterization

The high x data could be an additional useful constraint on PDFs if included in the fit

Preliminary HERA-1 & 2 Combination

Previously the combination of the HERA-1 data of H1/ZEUS has

- provided data samples with much improved precision both in statistical and systematic uncertainties

  (the latter was possible due to different detectors and measurement techniques)

- led to HERAPDF 1.0

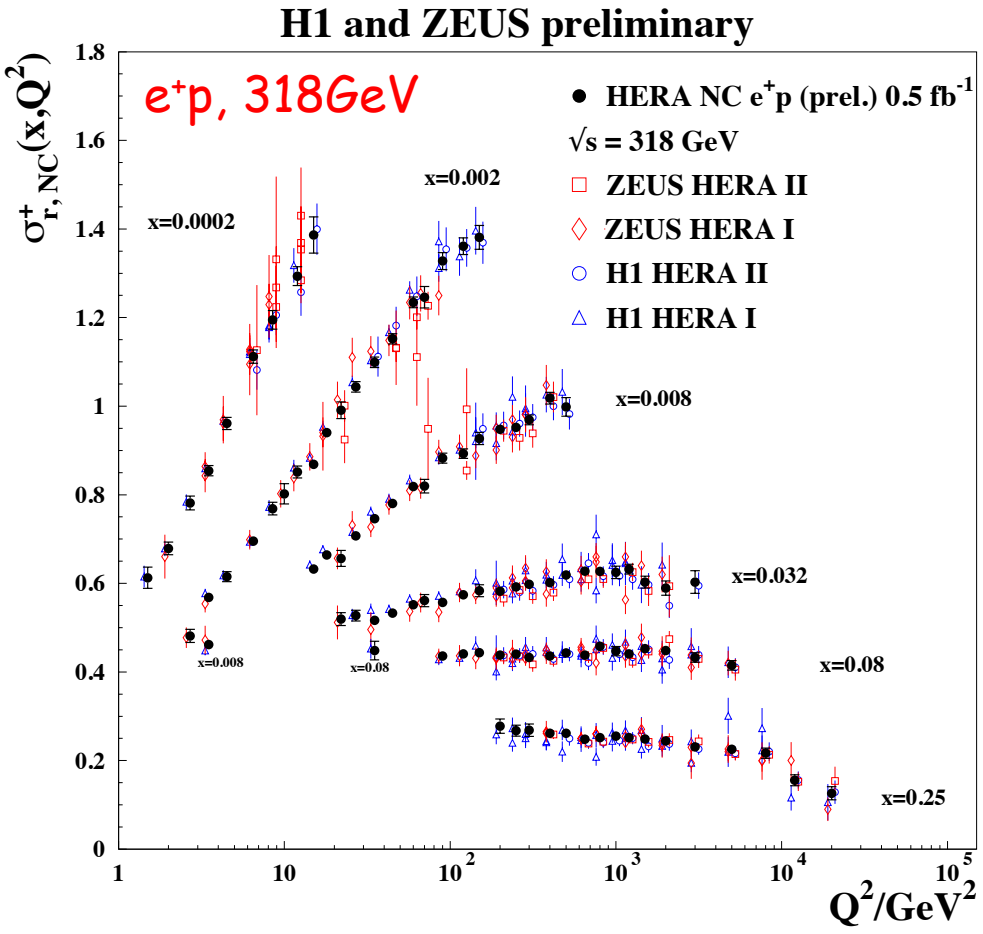
  (HERAPDF 1.5 based on combined HERA-1 data & preliminary HERA-2 data)

Preliminary combination of HERA-1 & 2 data has been performed
41 data sets including low E_p data; 2927 data points combined to 1307 σ measurements; Taking into account 162 correlated syst. error sources; Spanning six orders of magnitude in Q^2 and x

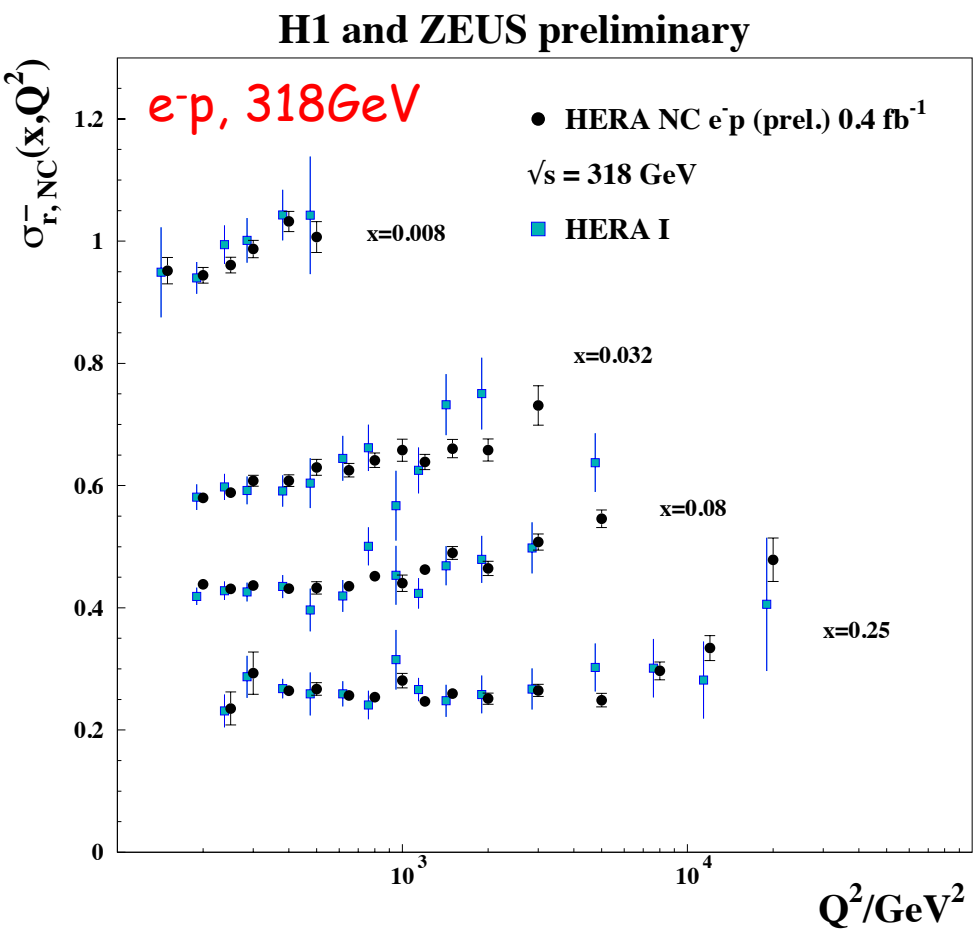
- aiming for further improved precision
- HERAPDF 2.0 (see the talk of Amanda Cooper-Sarkar)

Combined NC Data vs. Individual & HERA-1

Combined vs. individual ones
(shown for a subset)



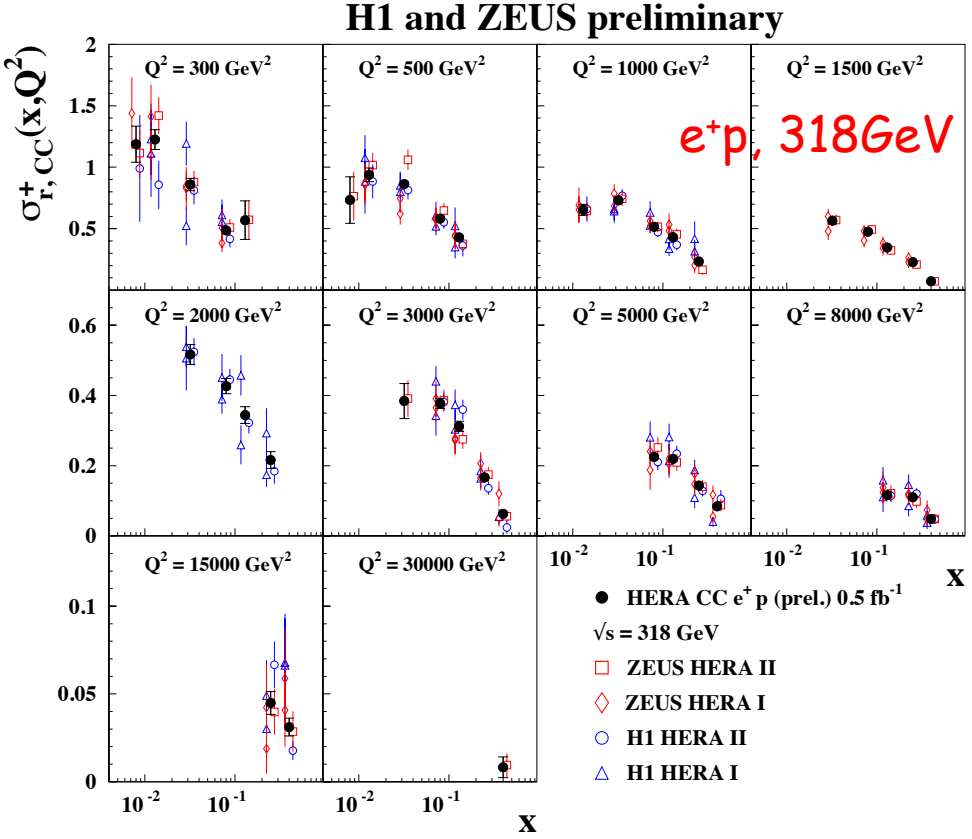
Combined vs. HERA-1 combination
(shown for high Q^2 data)

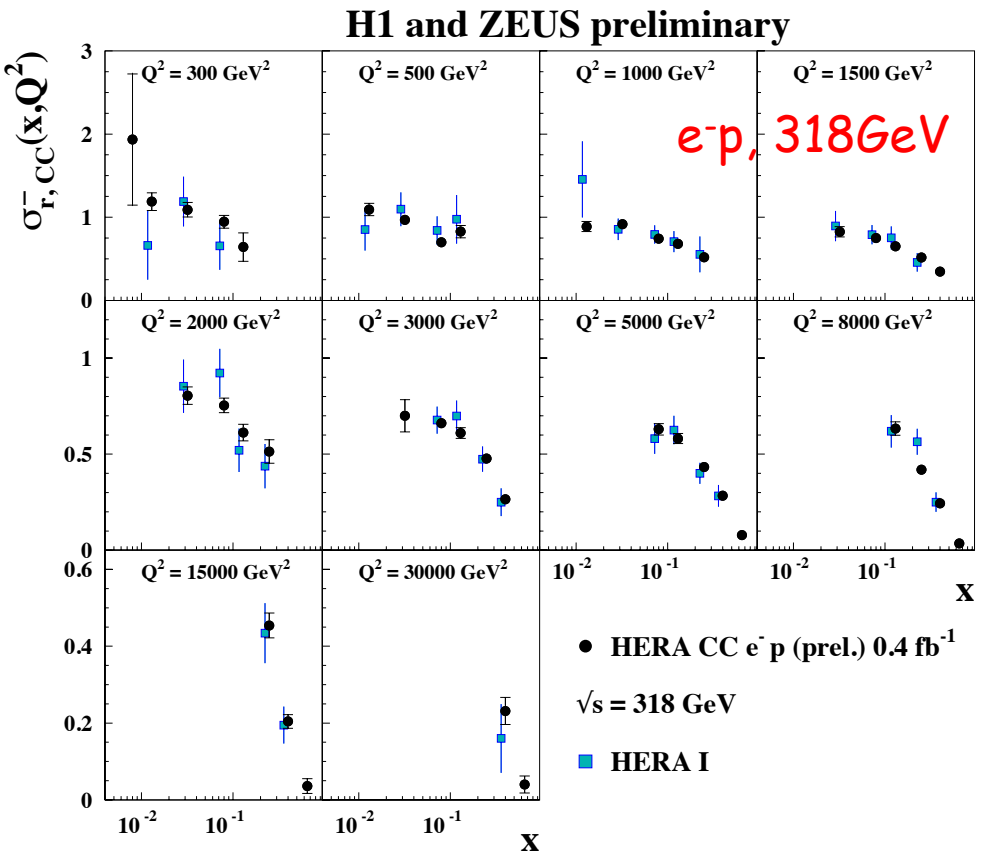


The improved precision is mainly statistical at high x and Q^2 and systematic at small x & Q^2

Combined CC Data vs. Individual & HERA-1

Combined vs. individual ones

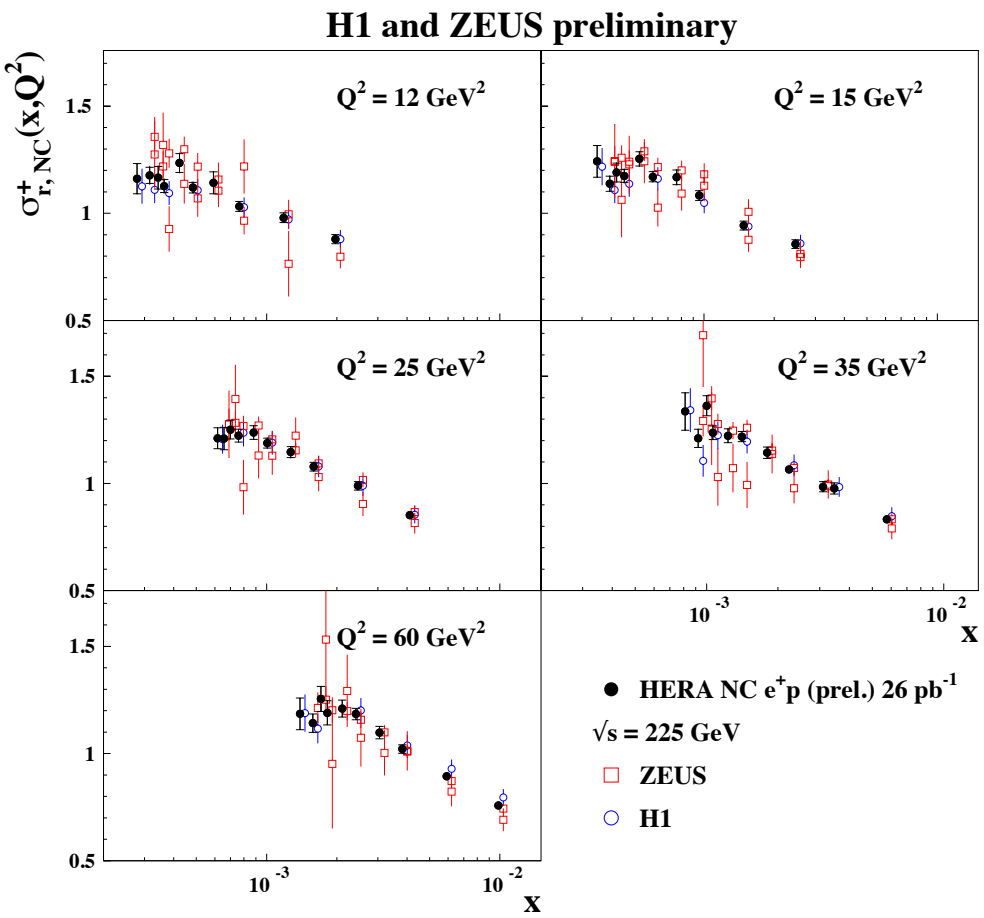




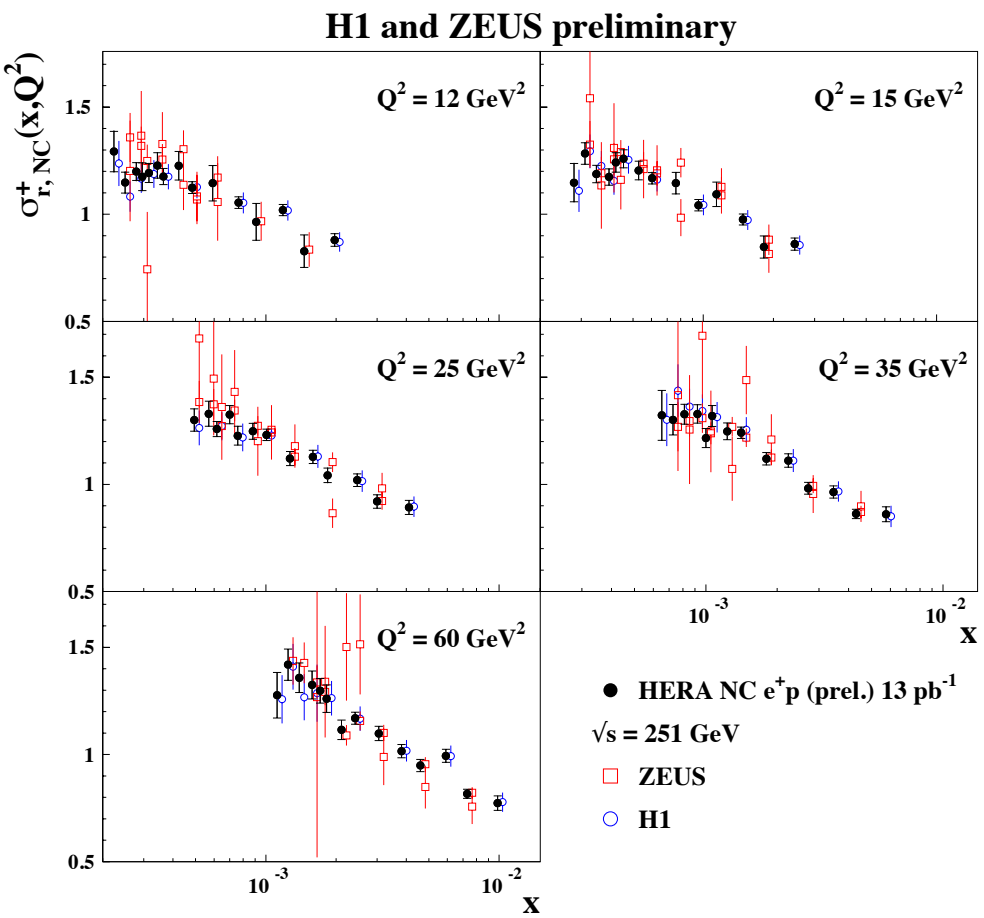
Combined vs. HERA-1 combination

Combined NC Data at Low Q^2 & E_p Energies

Combined vs. individual ones
($\sqrt{s}$=225GeV)



Combined vs. individual ones
($\sqrt{s}$=251GeV)



Summary

- Both H1 and ZEUS have measured F_L using low & nominal E_p data

  in particular the H1 measurements cover a large Q^2 range: 1.5-800GeV^2

  H1 and ZEUS data show some difference (consistent at ~20%)

  Both are however in fair agreement with (N)NLO predictions

- ZEUS has also measured integrated cross section at x close to 1

  The precision is statistically limited

  The agreement data/prediction is however non-trivial

  To be used in the future PDF fits?

- Preliminary HERA-1 & 2 combination is ready

  The combined data (over wide kinematic range) show unprecedented precision

  Inputs for HERAPDF 2.0

  Will also have important impact on other PDF sets