

Inclusive Deep Inelastic Scattering at HERA



Z. Zhang
LAL, Orsay

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

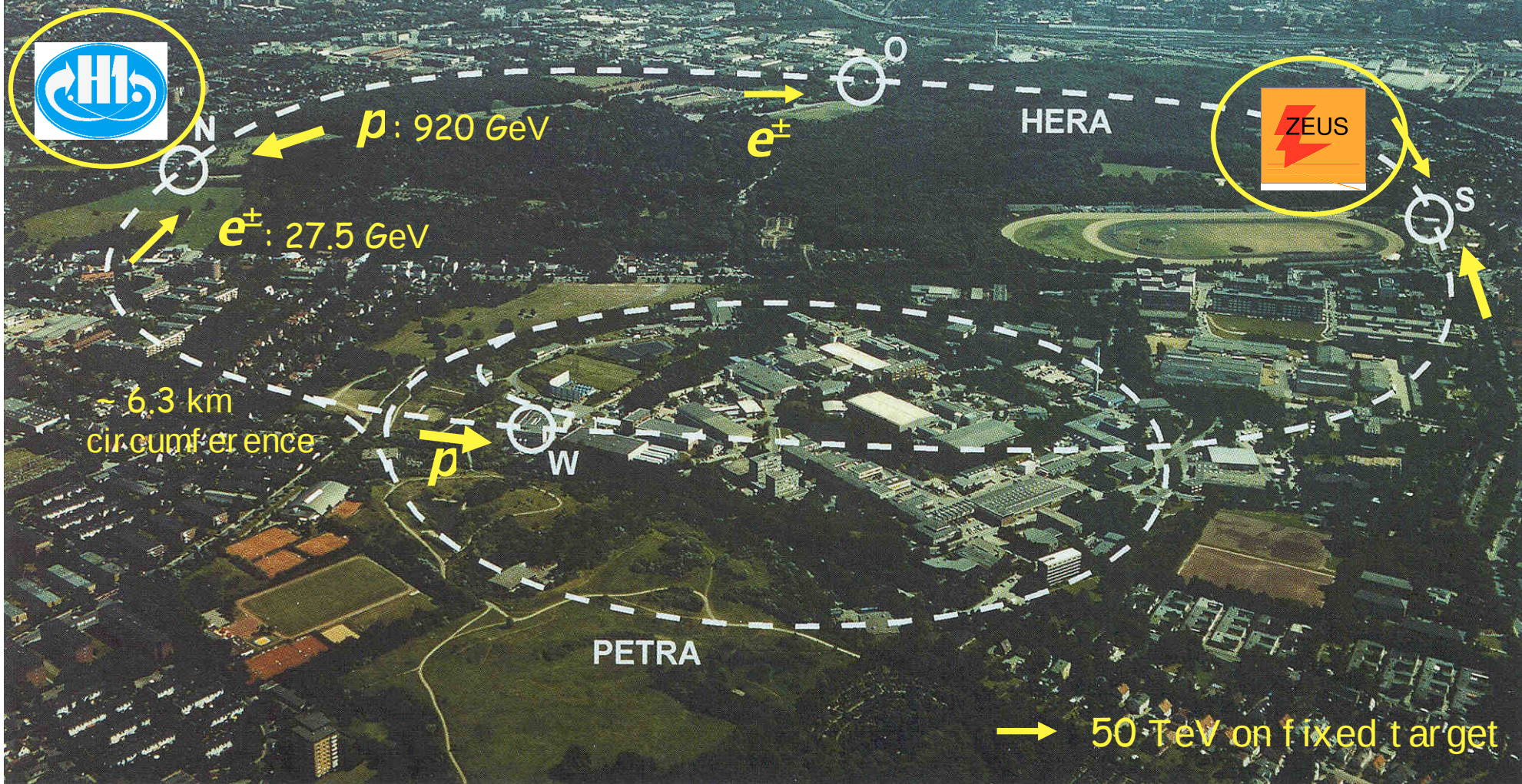
HERA used to be Largest Electron Microscope

Located at DESY in Hamburg

The data taking was over since 2007 but important results are still being produced

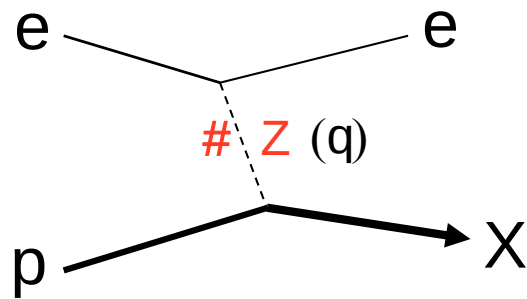
HERA-1: 1992-2000

HERA-2: 2003-2007



Neutral and Charged Current DIS

NC $e^\pm p$ event



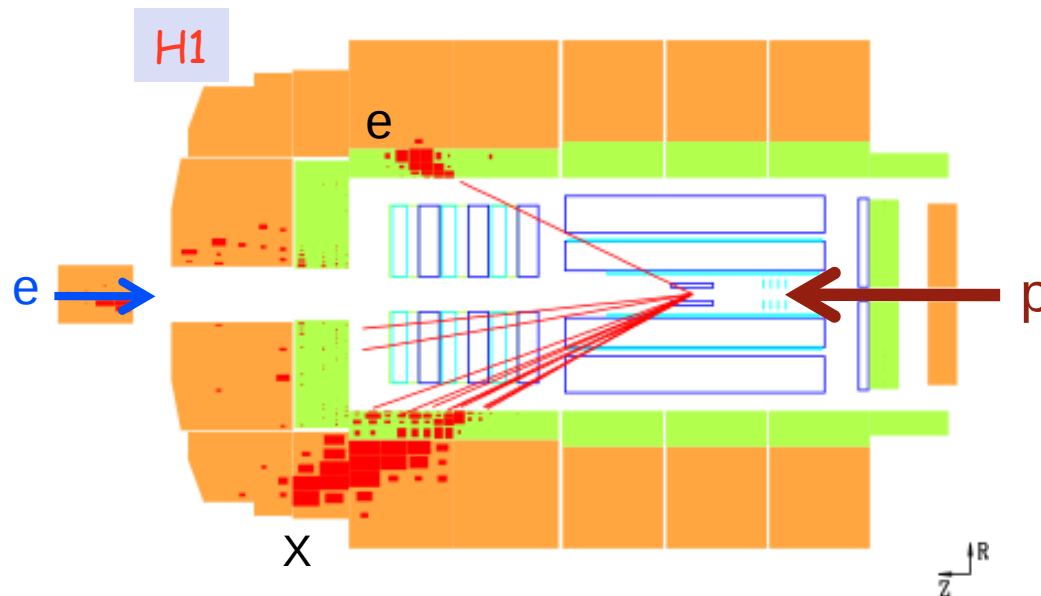
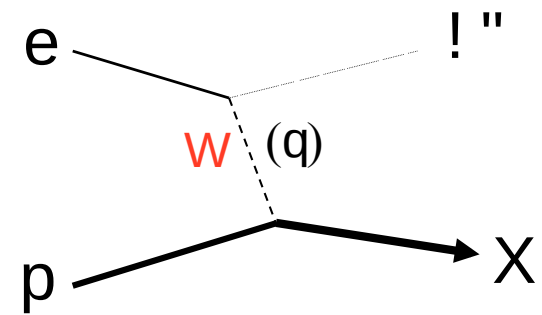
Event kinematics:

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

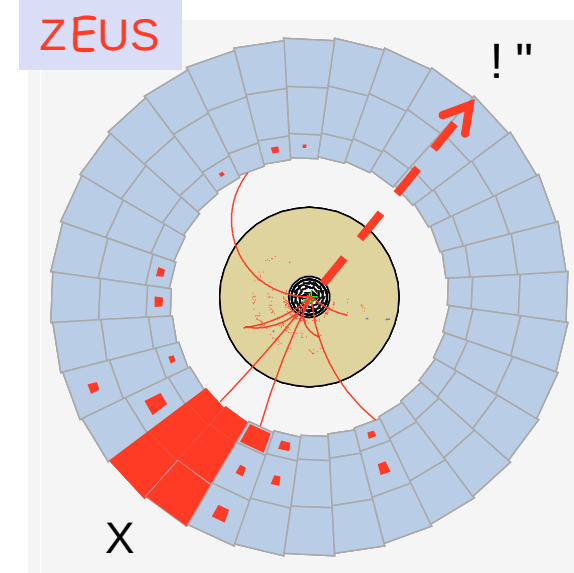
x : momentum fraction of struck parton

$y = Q^2/sx$: inelasticity

CC $e^\pm p$ event



Final states e & X balanced in transverse plane



Unbalanced due to missing ν

Cross Sections, Structure Functions, PDFs

Part on Distribution Functions

$$\frac{d^2\sigma_{\text{NC}}^{\pm}}{dx dQ^2} \sim Y_+ \tilde{F}_2 \mp Y_- \tilde{F}_3 - y^2 \tilde{F}_L \quad \text{with}$$

#exchange

#\$ interference

\$ exchange

~~P_e~~ ~~P_e~~ ~~P_e~~
 $v_e \sim 0$, " some of the terms are negligible
 ~~P_e~~ ~~P_e~~ ~~P_e~~

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

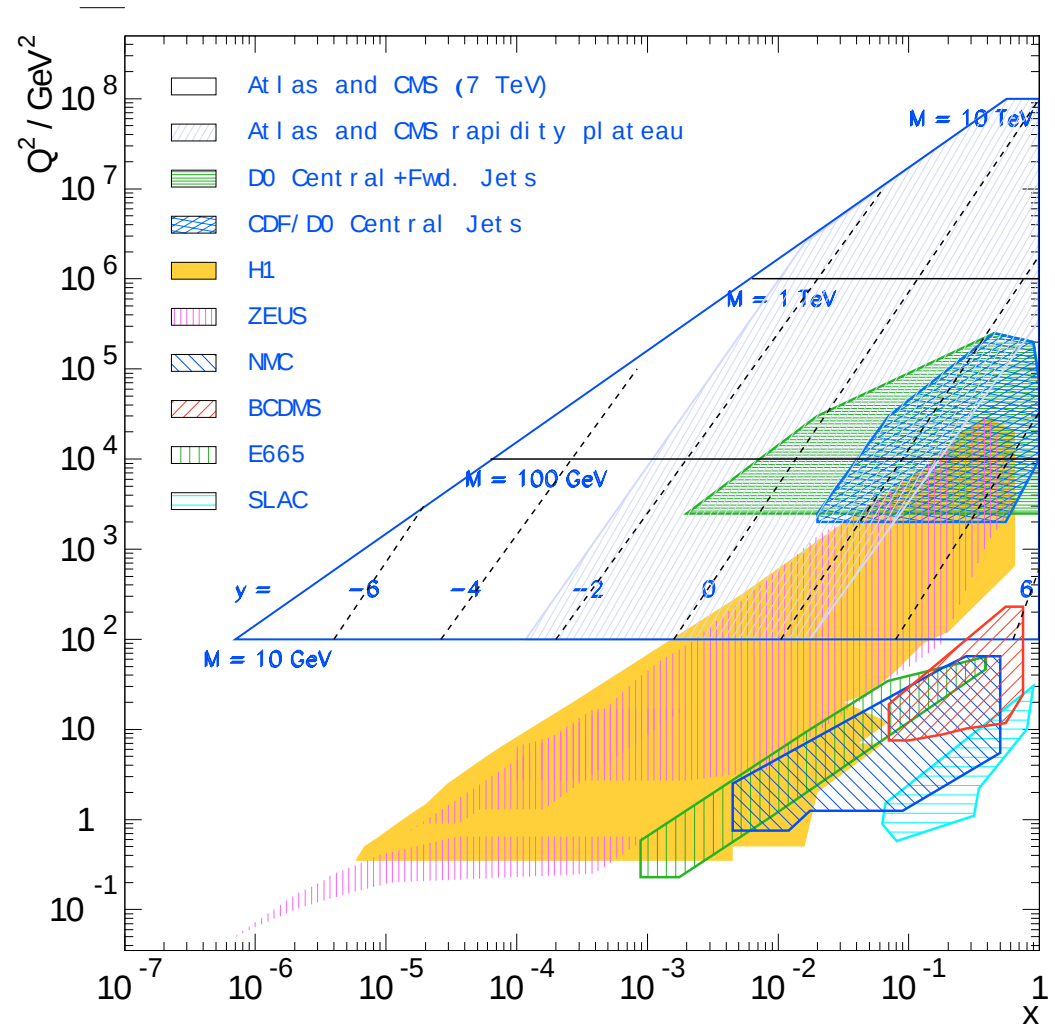
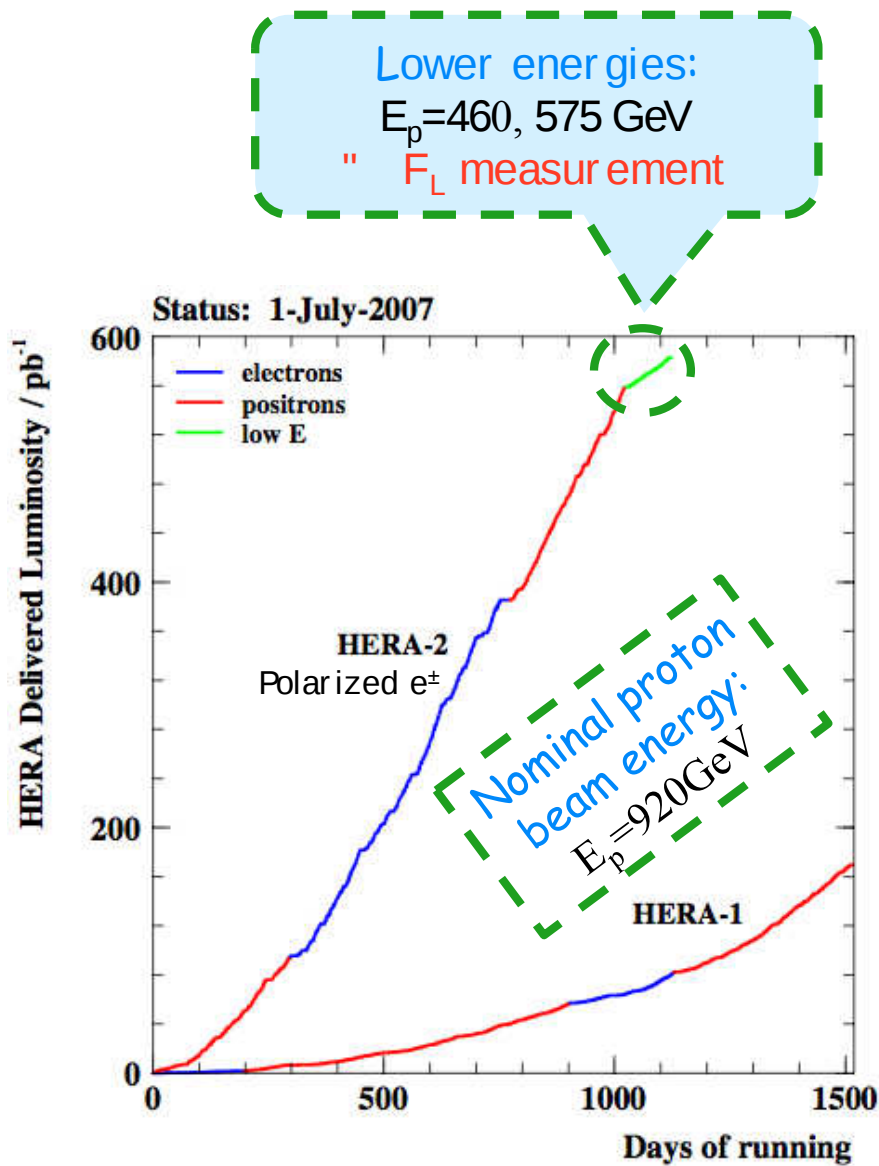
$$\left[xF_3^{\gamma Z}, xF_3^Z \right] = 2x \sum_q \left[e_q a_q, v_q a_q \right] \{ q - \bar{q} \}$$

Structure function formulae
given for e-p scattering,
for e⁺p, P_e ! -P_e

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

F_L=0 in LO parton model,
F_L~g at NLO

HERA-1/2 & Its Kinematic Coverage

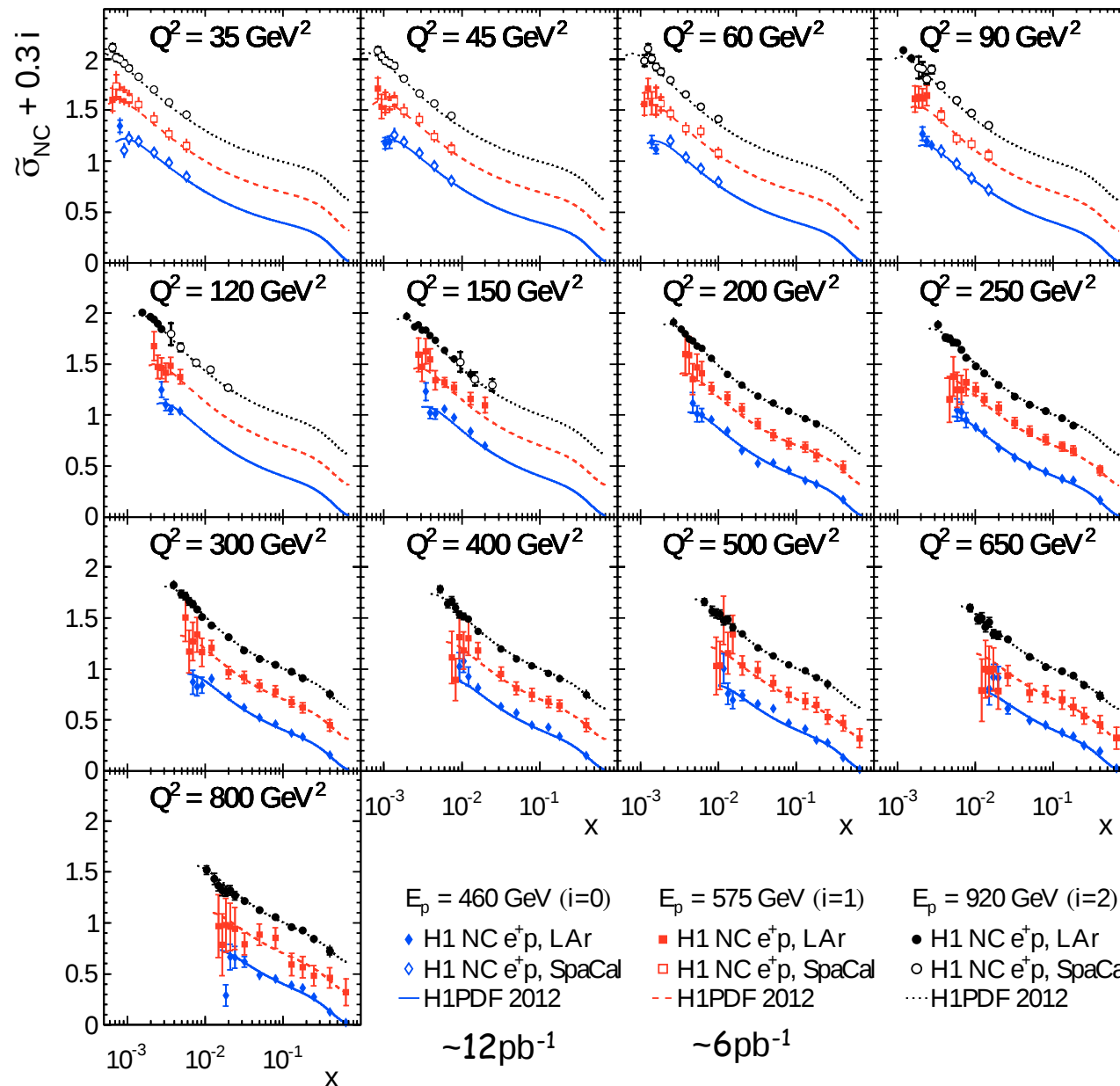


" !The relevance & importance of HERA inclusive NC & CC %measurements in providing PDFs for LHC physics

Dedicated H1 NC σ Measurements for F_L

EPJC74 (2014) 2814, arXiv:1312.4821

H1 Collaboration



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

Q^2 : 35-800 GeV²
 x : $6.5 \cdot 10^{-4}$ -0.65
 y : up to 0.85

Given the relation*

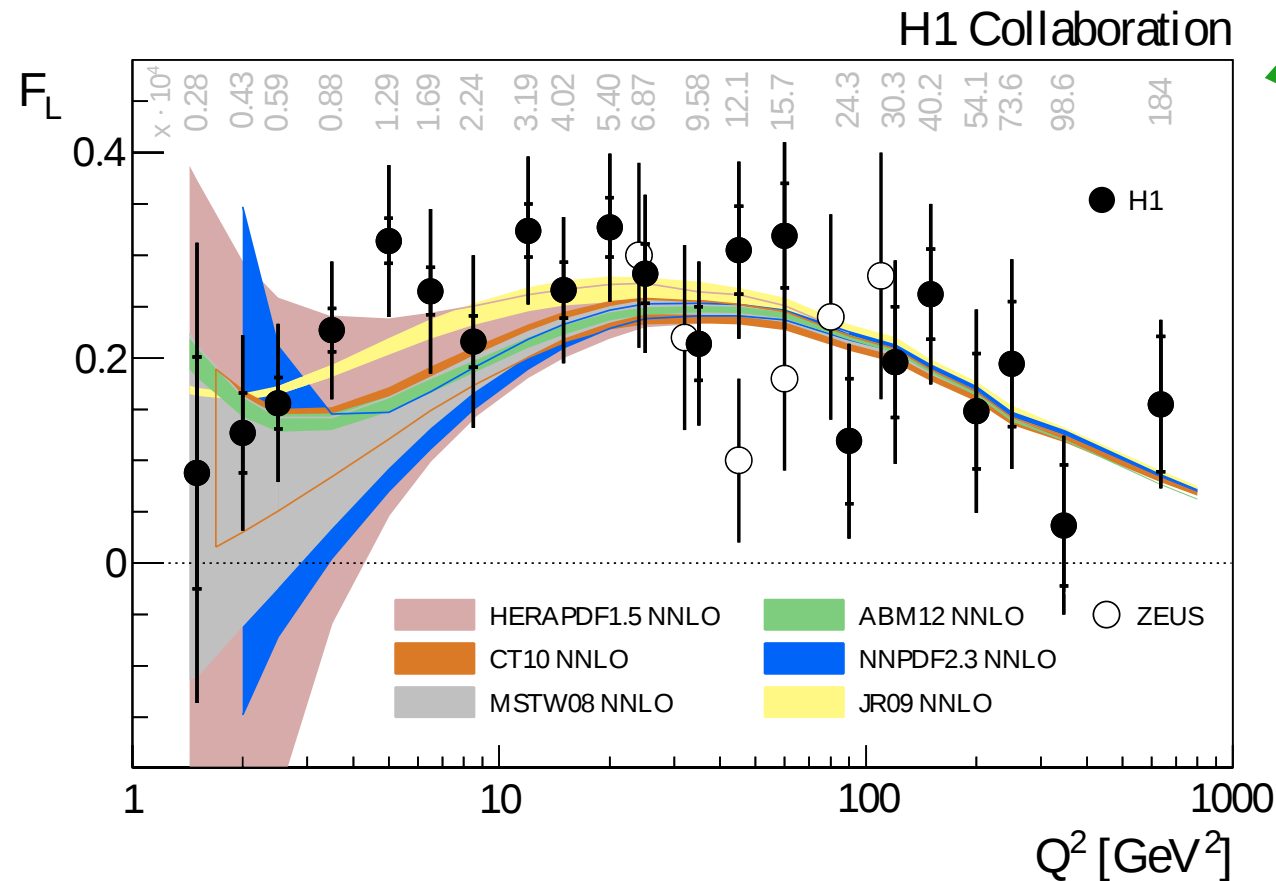
$$\sigma_{\text{NC}} \sim F_2 - \frac{y^2}{Y_+} F_L$$

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)

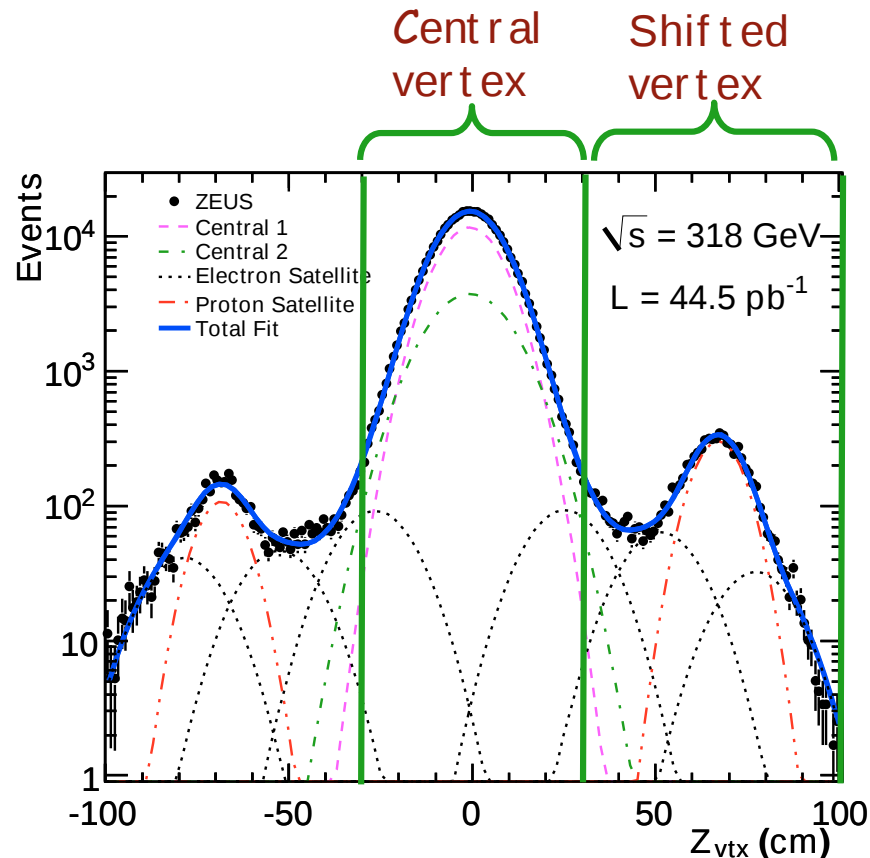
Since $F_L \sim xg$ at low Q^2 , x
" !HERA data provide a
direct constraint of
gluon density of the
proton

H1 measurement in good agreement with (old) ZEUS measurement

New F_L Measurement from ZEUS

The new measurement : arXiv:1404.6376 super sedes
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

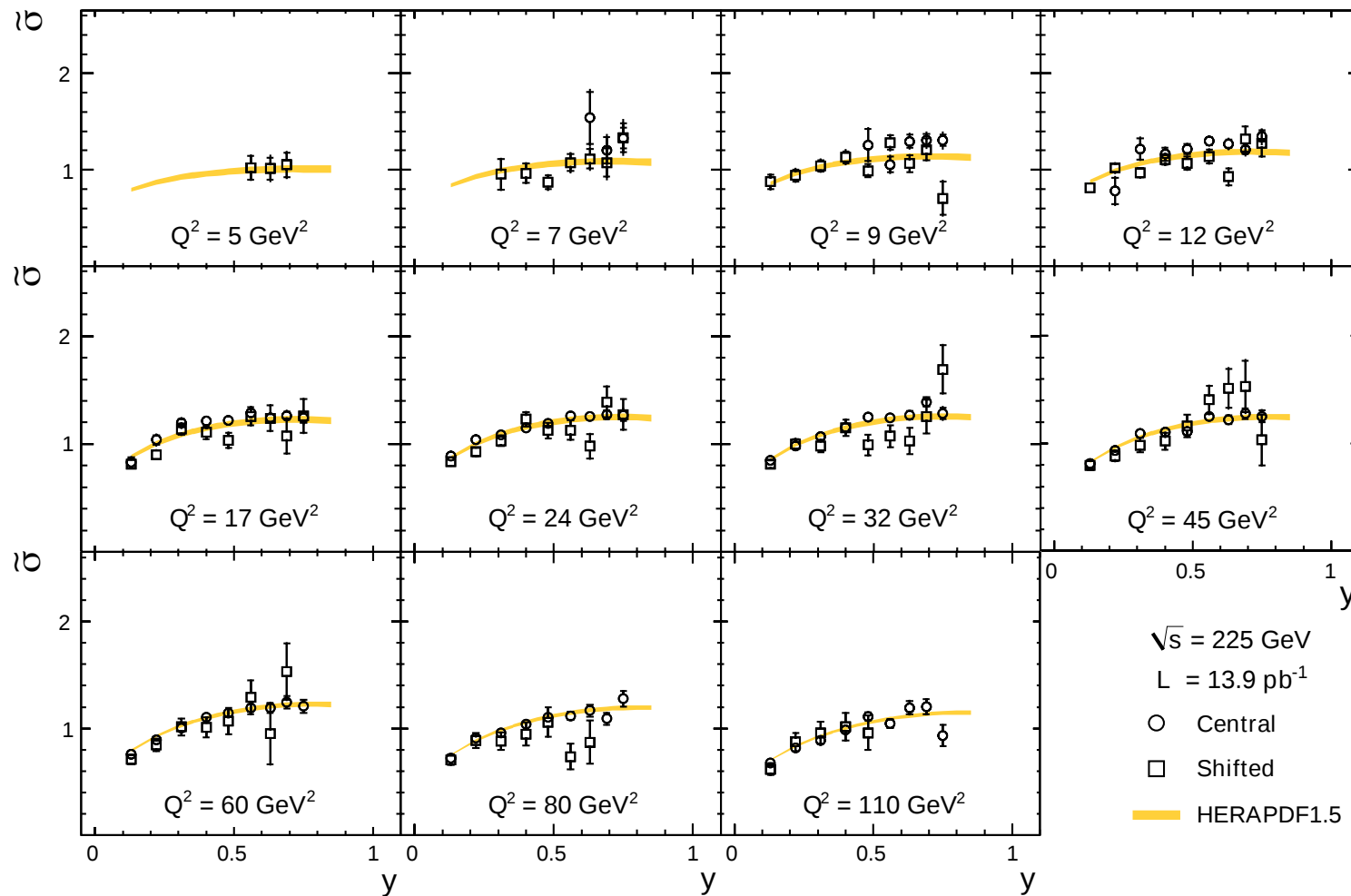


Similar distributions
also available for
 $\sqrt{s}=225, 251 \text{ GeV}$

Measured Cross Sections

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

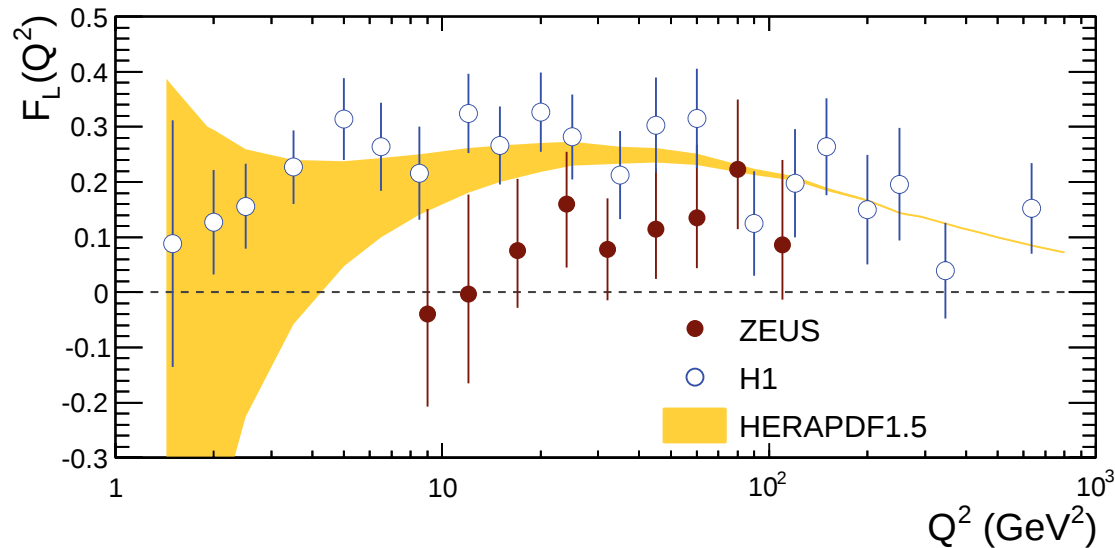
ZEUS



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

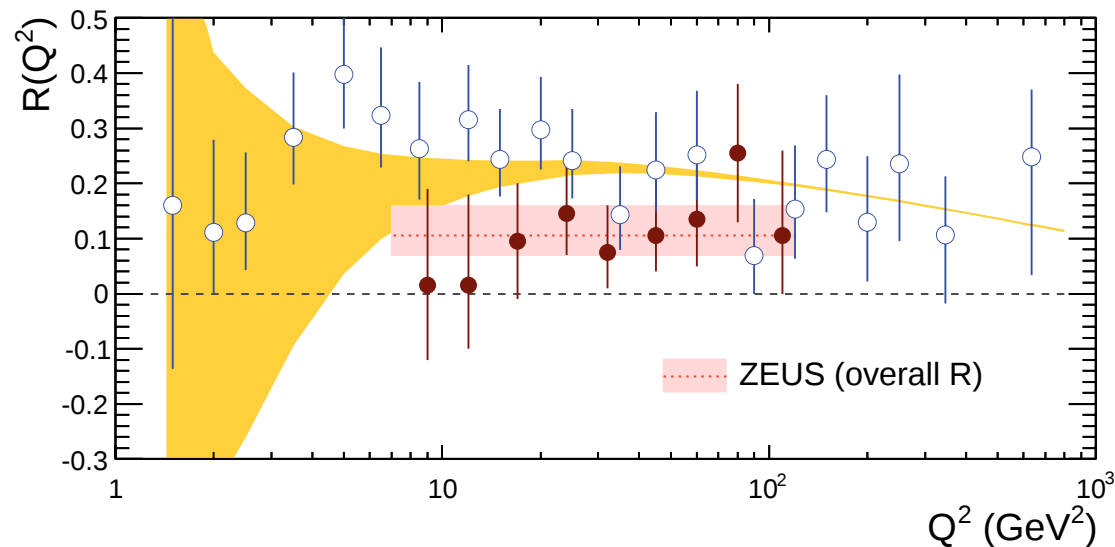
Results and Comparison with H1

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



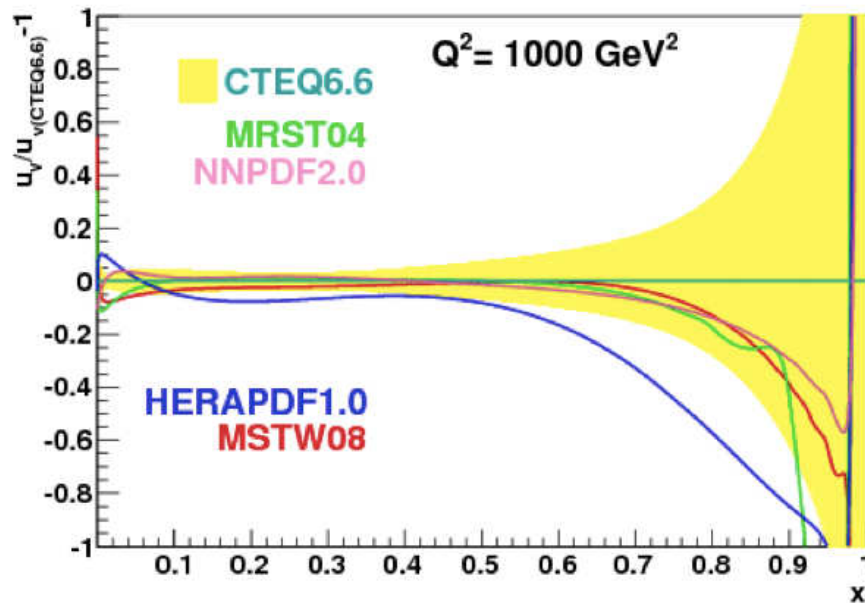
$$R = F_L / (F_2 - F_L) \sim \%_L / \%_T$$

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

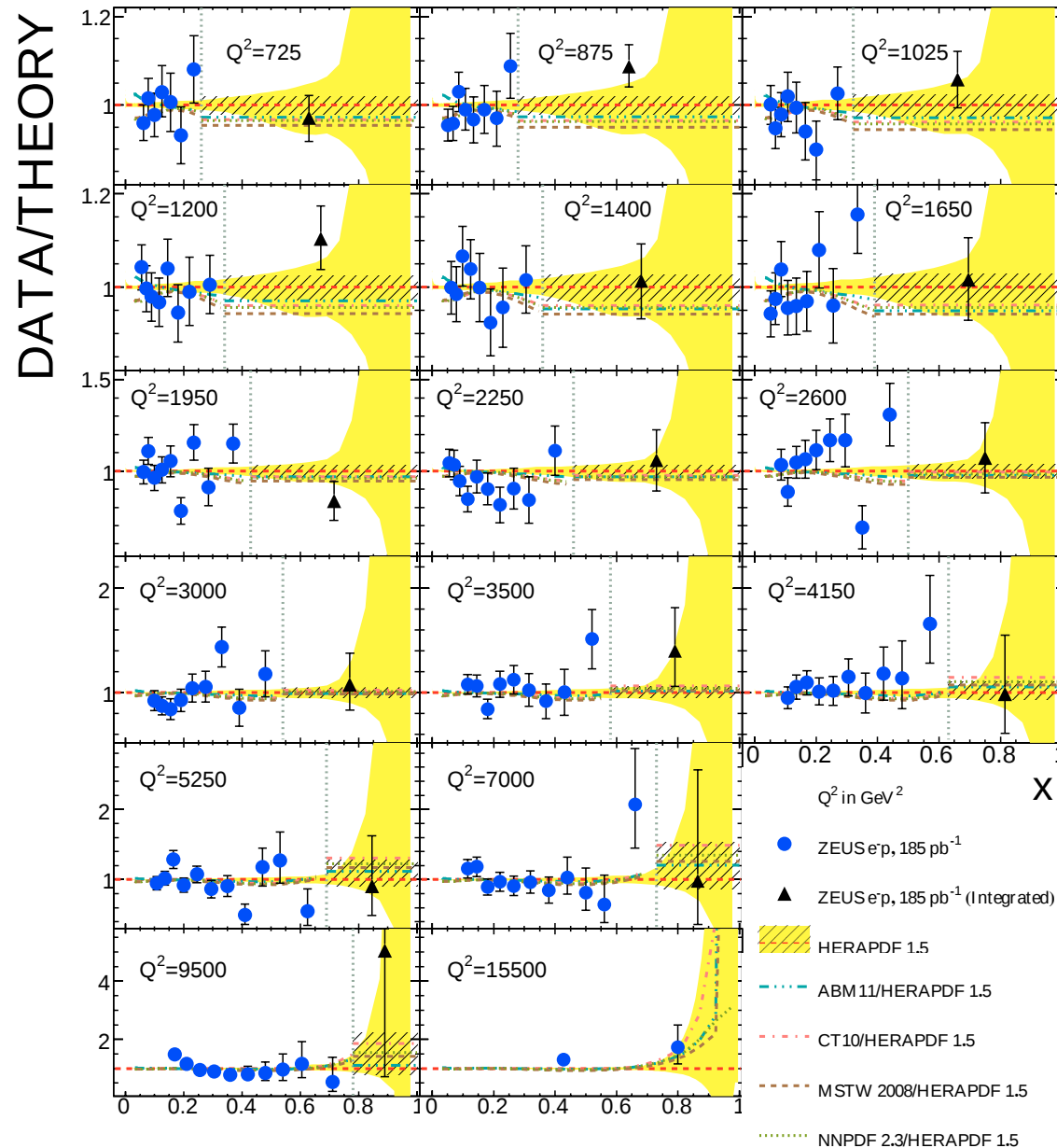
- !The PDF uncertainty at high x is large
- !The HERA measurements are mostly limited to 0.65

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

ZEUS



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 $(1-x)^n$ 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)

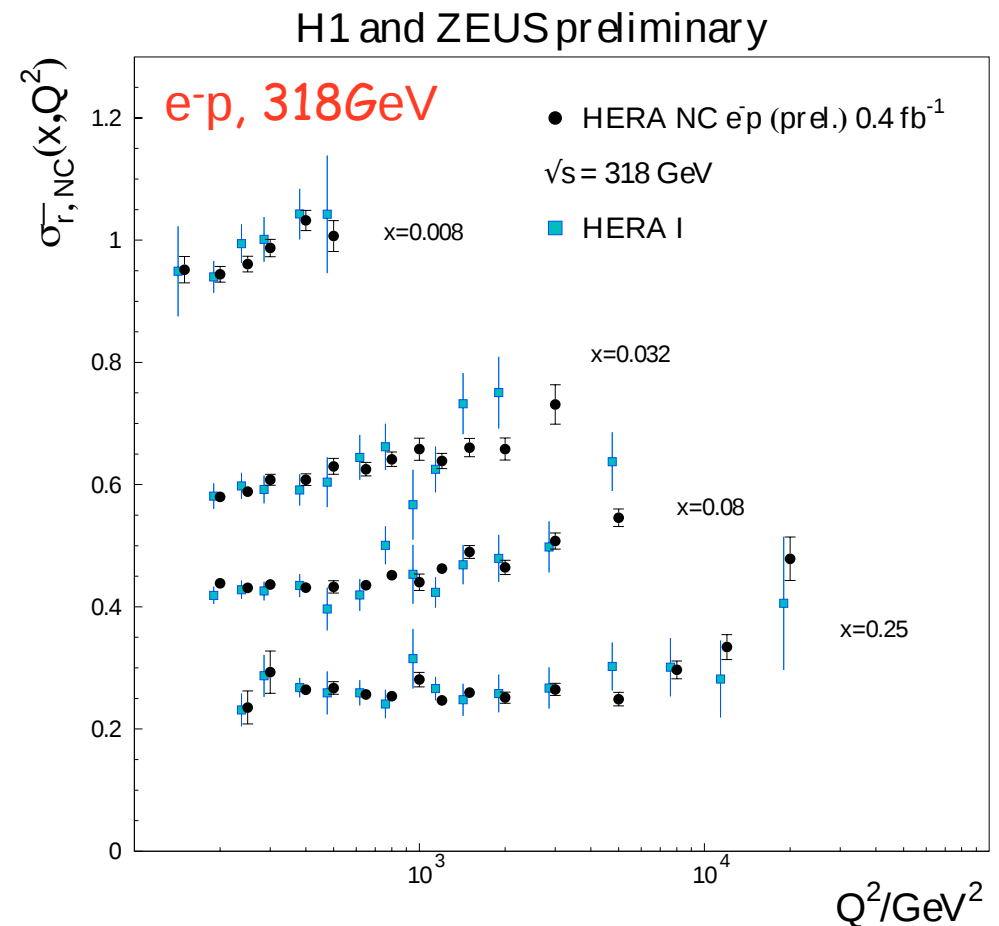
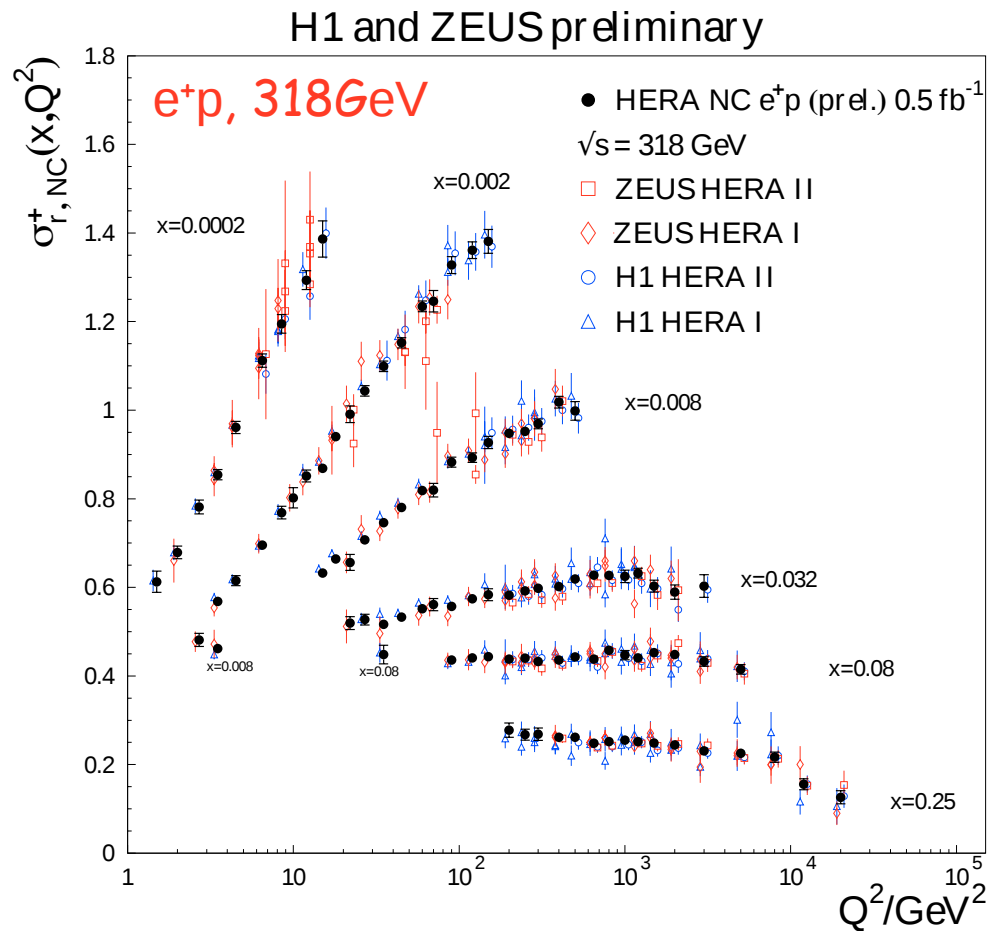
Preliminary combination of HERA-1 & 2 data has been performed
41 data sets including low E_p data; 2927 data points combined to 1307 %
measurements; Taking into account 162 correlated syst. error sources;
Spanning six orders of magnitude in Q^2 and x

- 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)

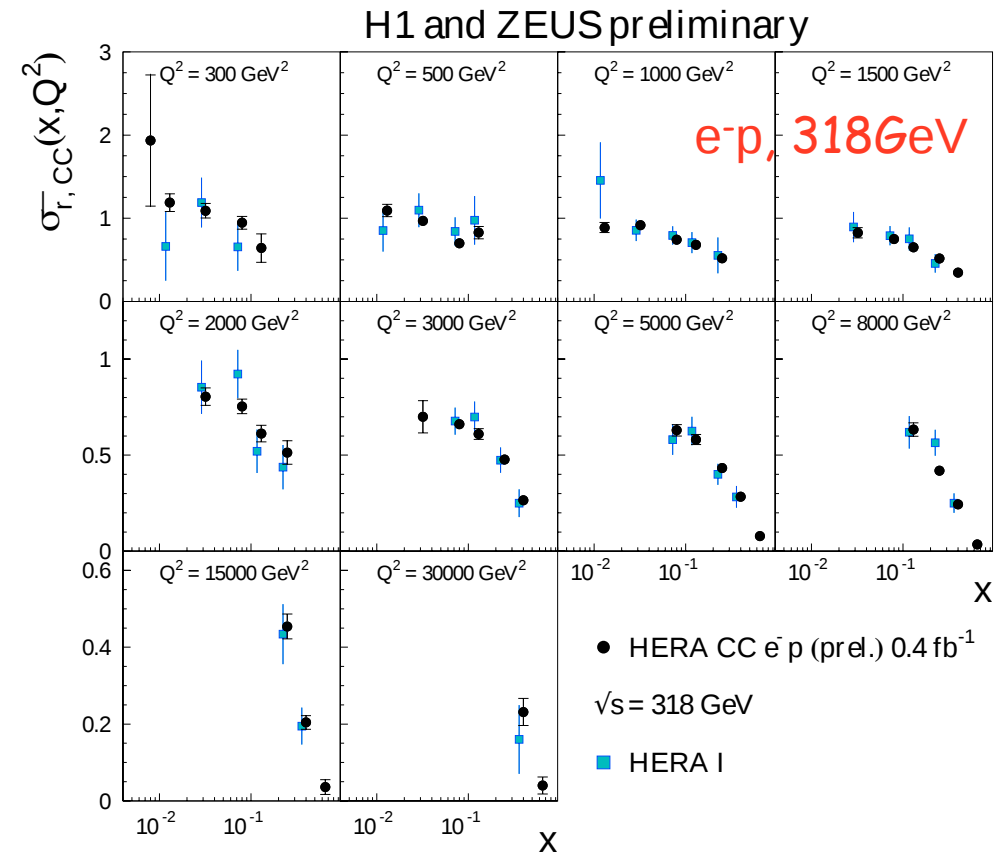
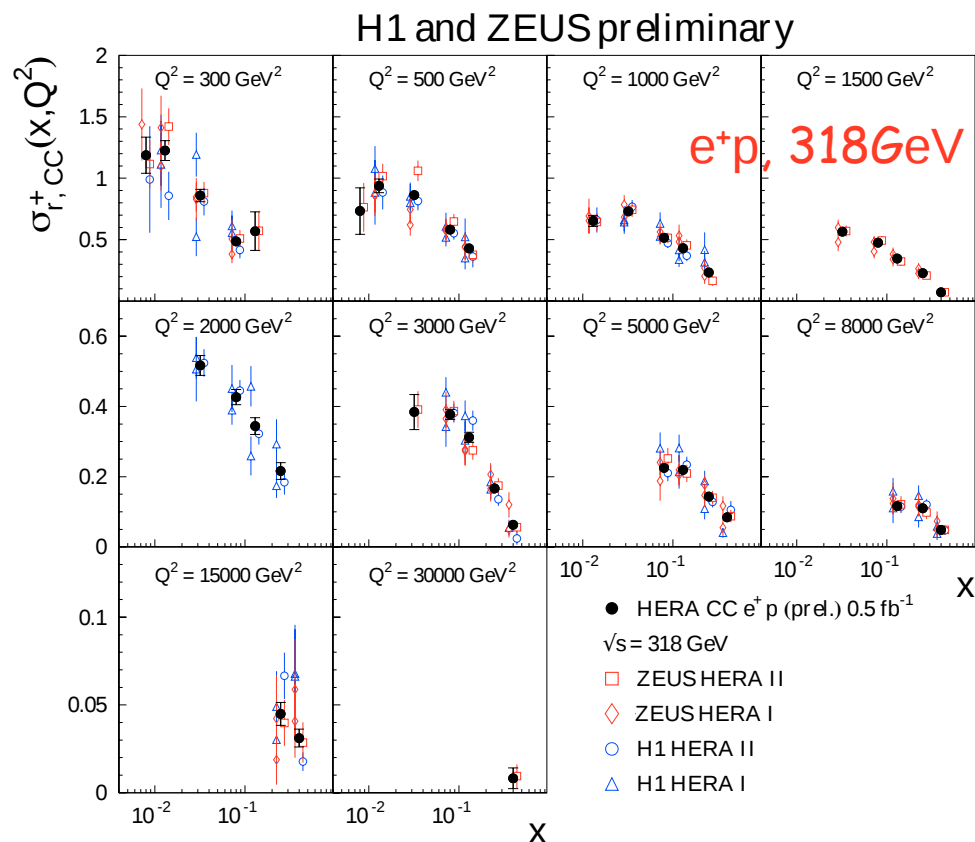
Combined vs. HERA-1 combination
(shown for high Q^2 data)



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

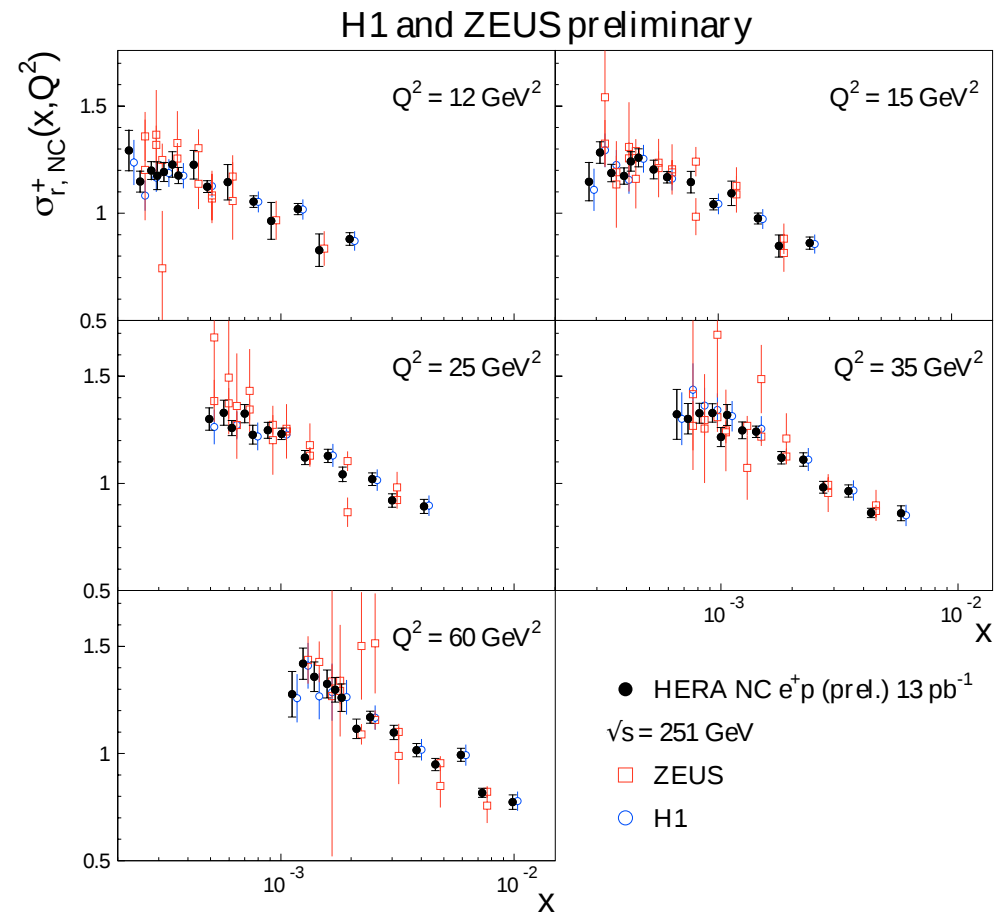
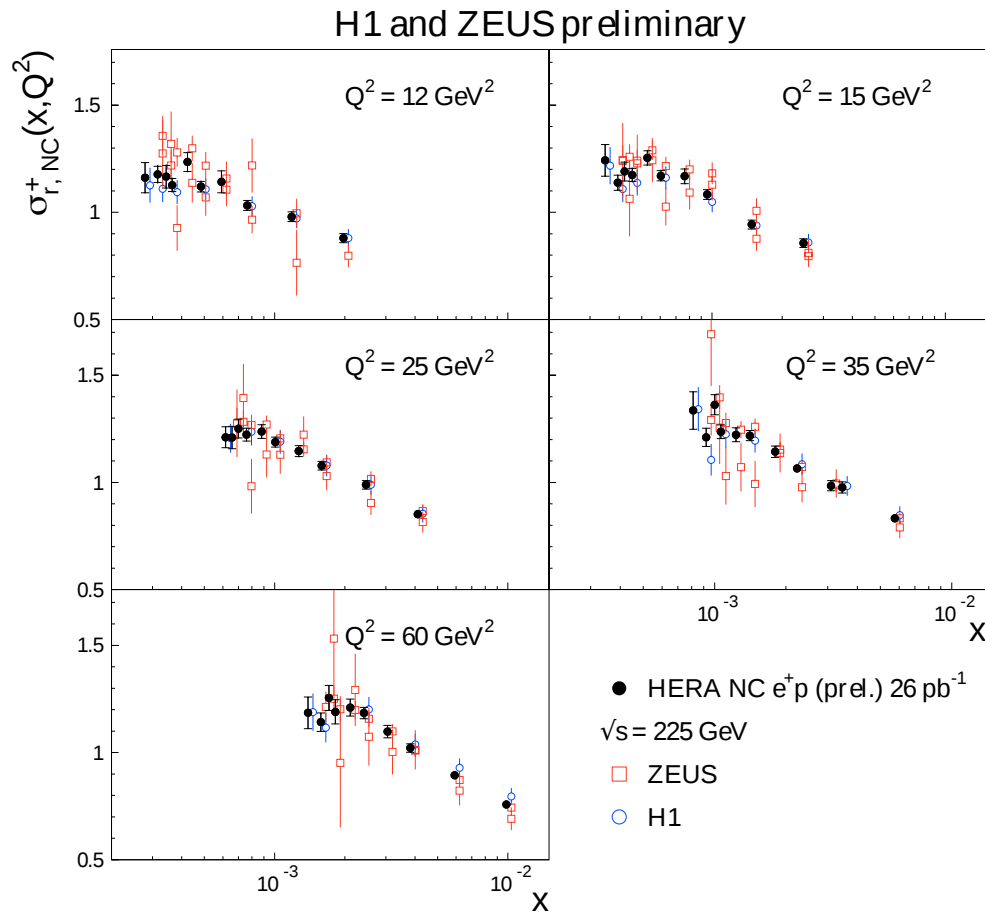


Combined vs. HERA-1 combination

Combined NC Data at Low Q^2 & E_p Energies

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

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



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: 1.5-800 GeV²

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