



Combined HERA F_L measurement

New measurement of the NC e^+p cross sections with the **ZEUS** detector at HERA

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on behalf of H1 and ZEUS collaborations

*DIS10 conference, Florence, Italy
20 April 2010*

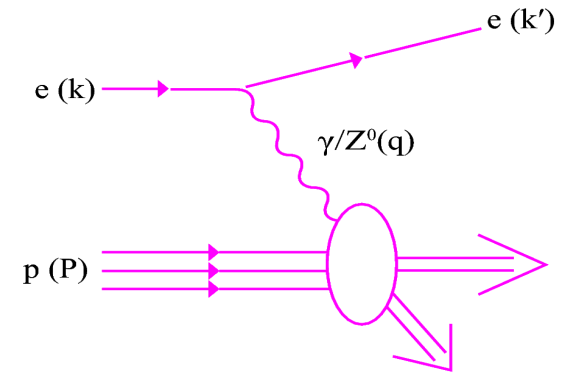
DIS and structure functions

Deep Inelastic Scattering (DIS) is a key tool for studying structure of the proton

NC DIS cross section at low Q^2 in reduced form can be written via **structure functions**:

$$\sigma_r(x, Q^2, y) = \frac{d^2 \sigma_{NC}^{ep}}{dx dQ^2} / \left(\frac{2\pi\alpha^2 Y_+}{x Q^4} \right) = F_2(x, Q^2) - \frac{Y_-^2}{Y_+} F_L(x, Q^2)$$

where $Y_{\pm} = 1 \pm (1 - y)^2$



Q^2 – virtuality of exchanged photon
 x – Bjorken scaling variable
 y – inelasticity
 s – center-of-mass energy, $s = 4E_e E_p$
 $Q^2 = xys$

→ **F_2** – dominant term, contains quark and gluon contributions

→ **F_L** – reflects the gluon contribution, non-negligible at high y

→ F_L is directly sensitive to **gluon densities**

→ F_L is a pure **QCD** effect

F_L measurement

Direct F_L measurement requires reduced cross sections at **same x and Q^2 but different y** :

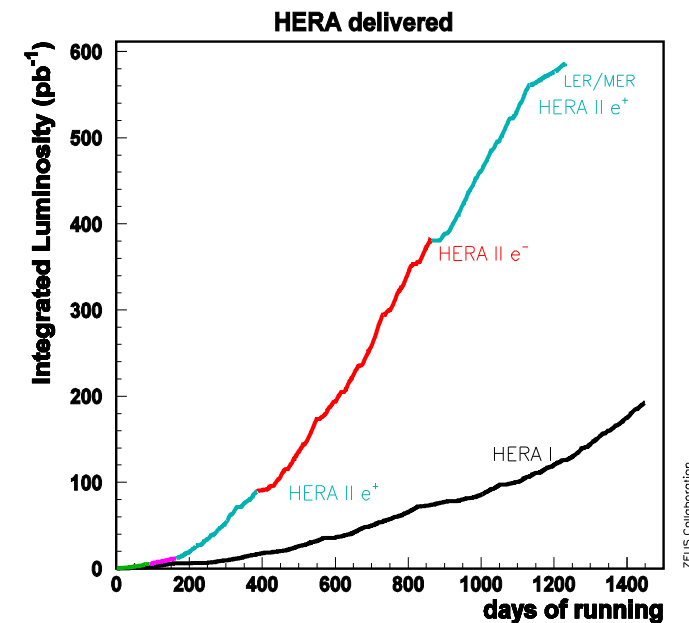
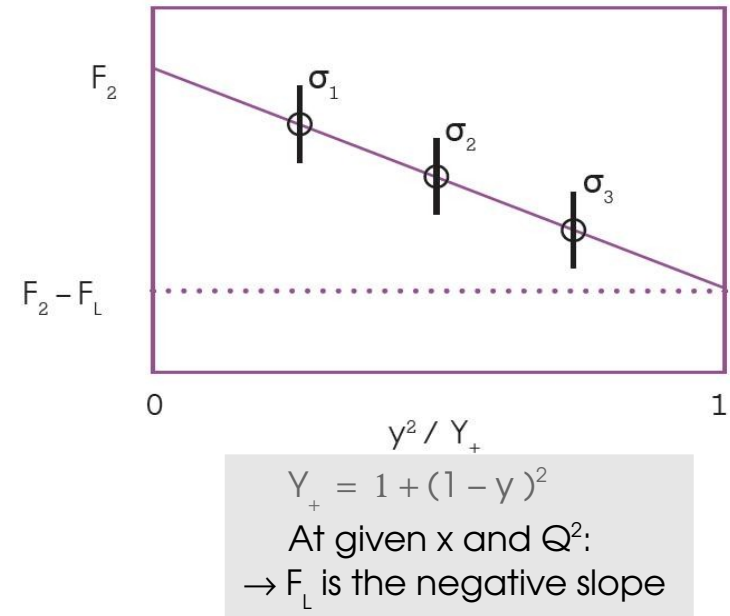
$$\sigma_r(x, Q^2, y) = F_2(x, Q^2) - \frac{y^2}{Y_+} F_L(x, Q^2)$$

$Q^2 = xys$: different $y \rightarrow$ different s (CME)
 \rightarrow different beam energies

Larger difference in $y \rightarrow$ better sensitivity to F_L

Direct F_L measurement only possible if HERA operates with different proton beam energies

- Most luminosity taken with $E_e = 27.5$ GeV, $E_p = 920$ GeV
- In the last year of running data taking with lowered beam energies: $E_p = 460$ and 575 GeV



Analysis strategy

Inclusive DIS measurement

Information from the **scattered electron** (energy E_e and scattering angle θ_e) is used to **reconstruct the kinematics**:

$$y = 1 - \frac{E_e}{E_{e_{beam}}} (1 - \cos \theta_e), \quad Q^2 = 2 E_e E_{e_{beam}} (1 - \cos \theta_e)$$

Low-y

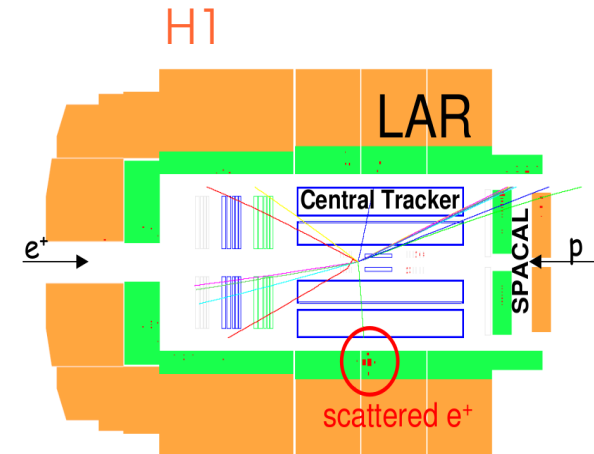
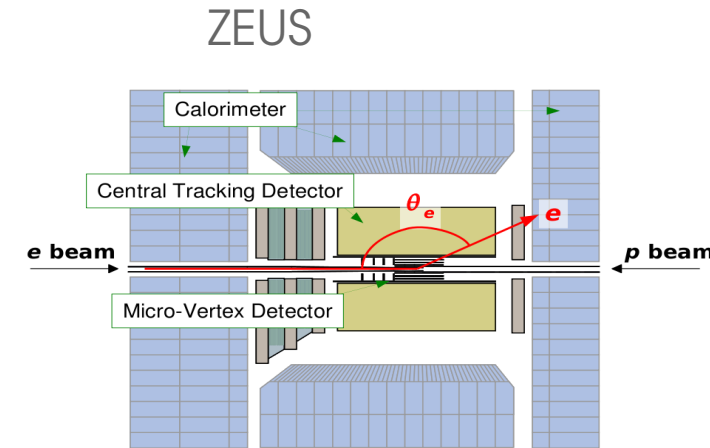
- high energy well separated scattered electron
- almost no background

High-y

- low energy scattered electron
- lot of hadronic activity around scattered electron
- large background

Experimentally challenging: low scattered electron energy (low y) and low scattering angles (low Q^2)

Main background: **photoproduction events**



Data combination

NC cross sections used for combination:

H1

$$2.5 < Q^2 < 800 \text{ GeV}^2$$

Eur. Phys. J. C63, 625 (2009)

Eur. Phys. J. C64, 561 (2009)

H1prelim: 09-044, 08-042

ZEUS

$$24 < Q^2 < 110 \text{ GeV}^2$$

Phys. Lett. B682, 8 (2009)

In the H1/ZEUS
kinematic overlap
region: *comparable
precision; combining
data will improve
precision*

Method of combination:

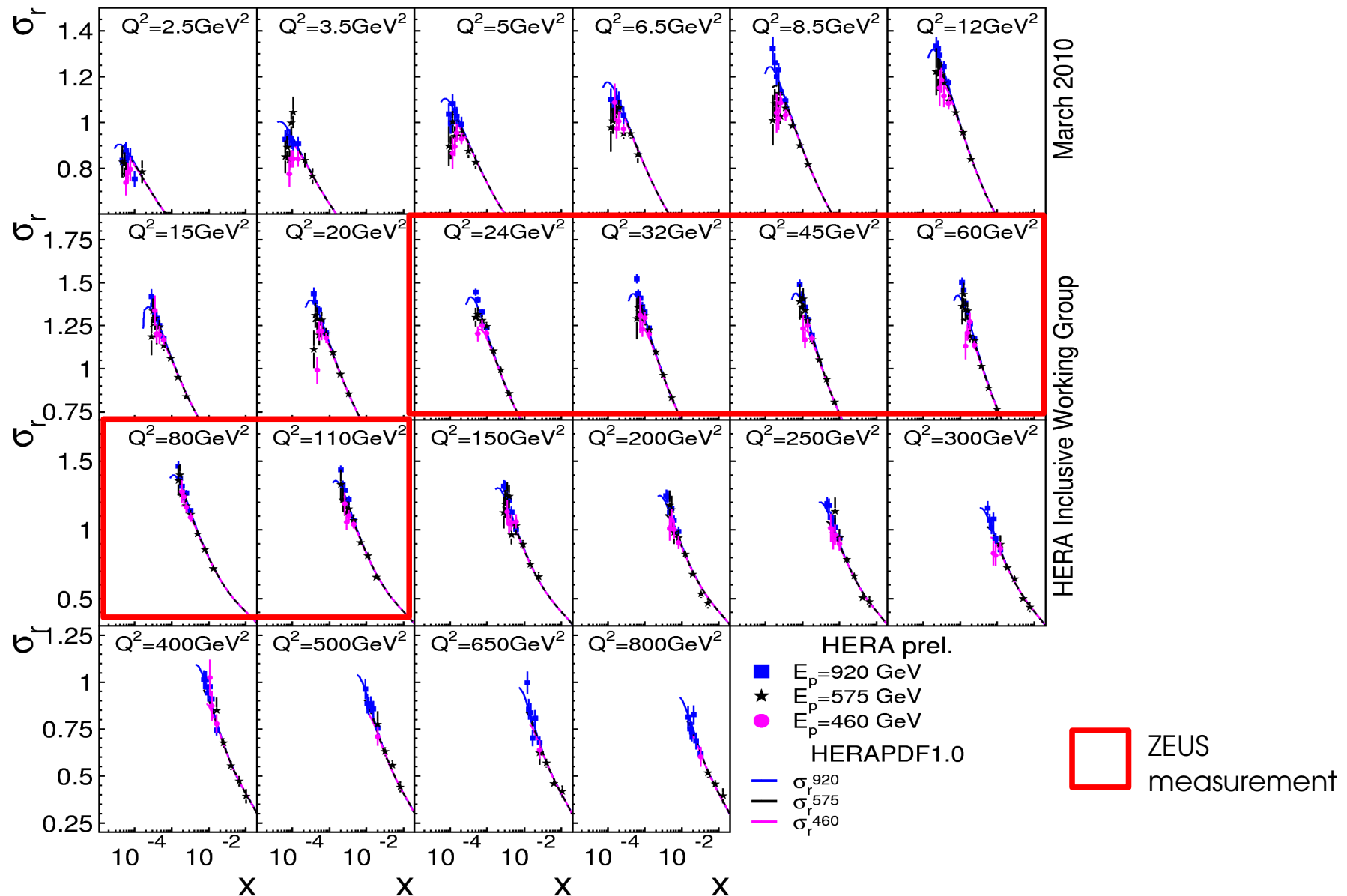
- same as for previous HERA data combinations (*see talk by S. Habib*)

Procedure:

- Move cross sections to common grid
- Average cross sections (minimum χ^2)
- extract F_L from combined cross sections

Combined HERA NC e+p cross sections

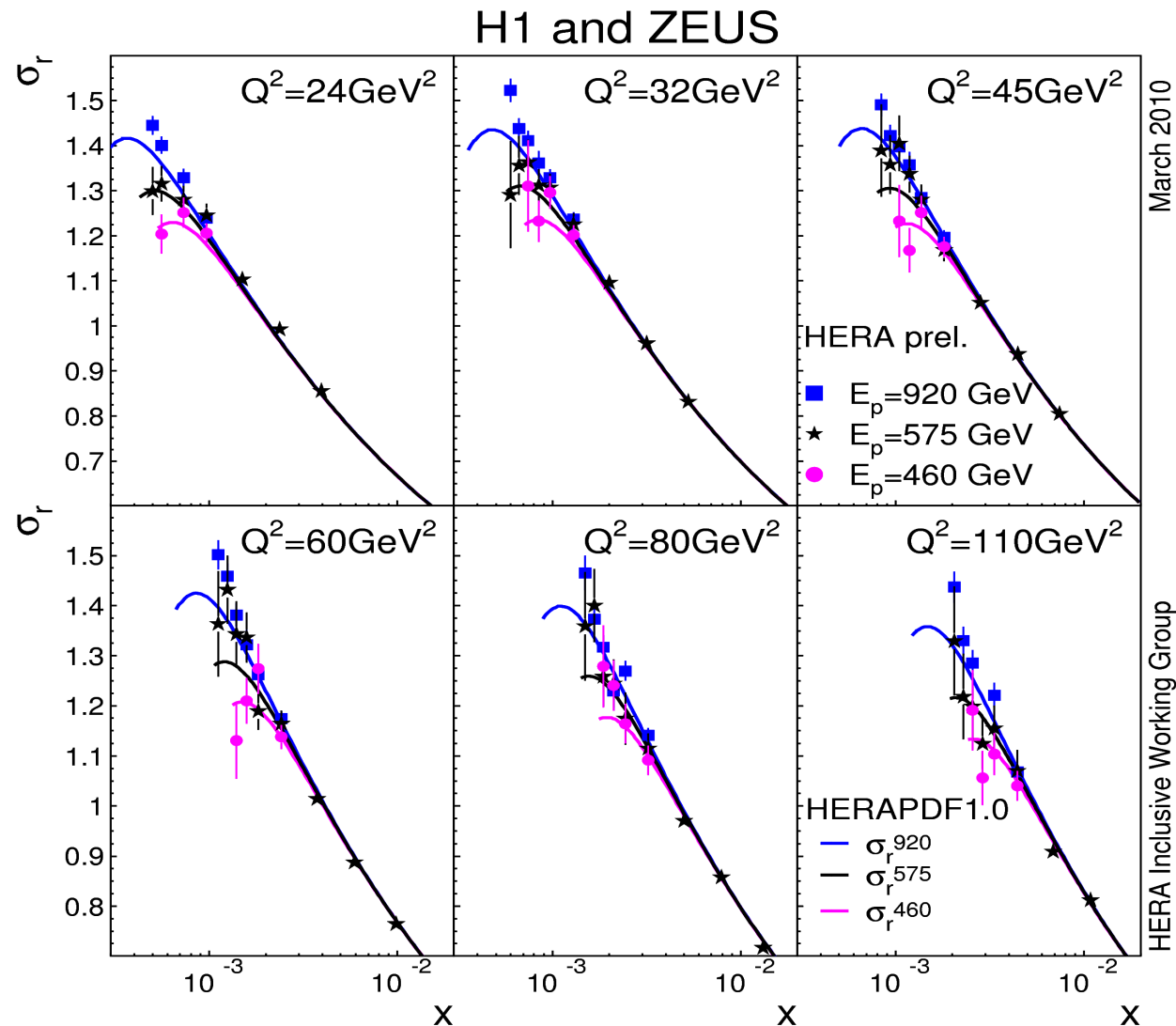
H1 and ZEUS



Combined cross sections are an input for further QCD analysis (see talk by V. Radescu)

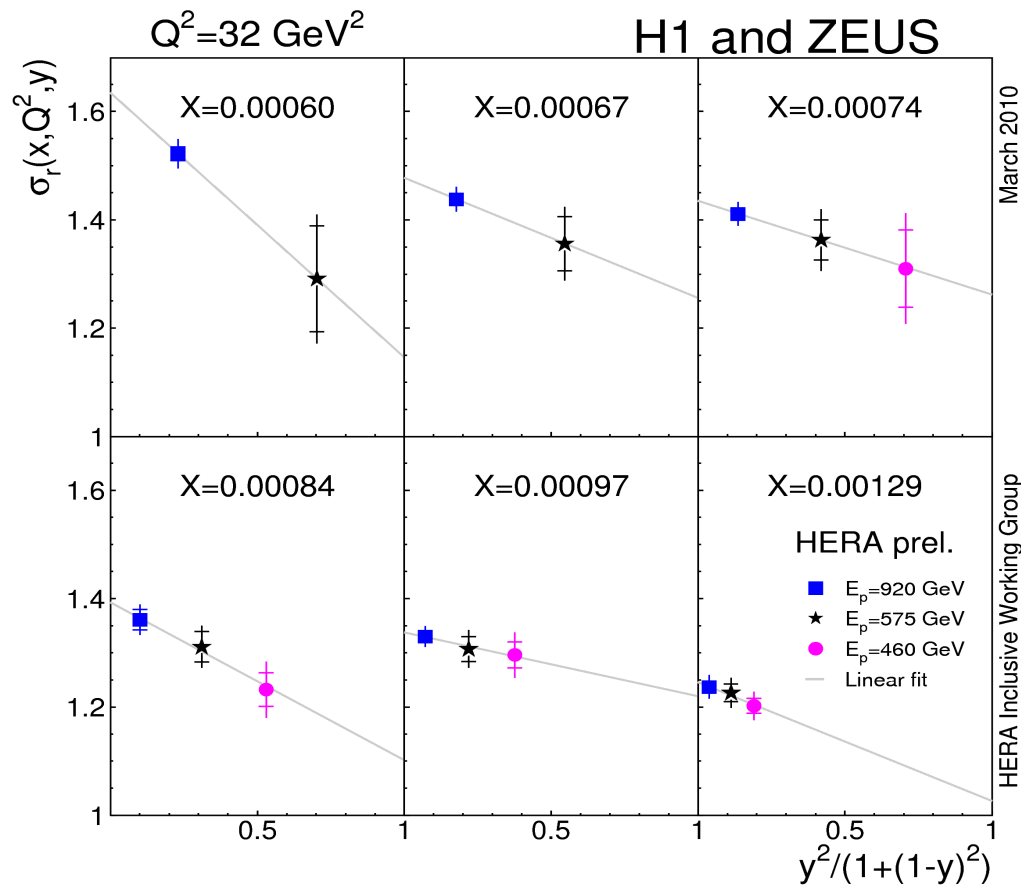
Combined HERA NC e+p cross sections

H1/ZEUS kinematic overlap region: $24 < Q^2 < 110 \text{ GeV}^2$



F_L extraction

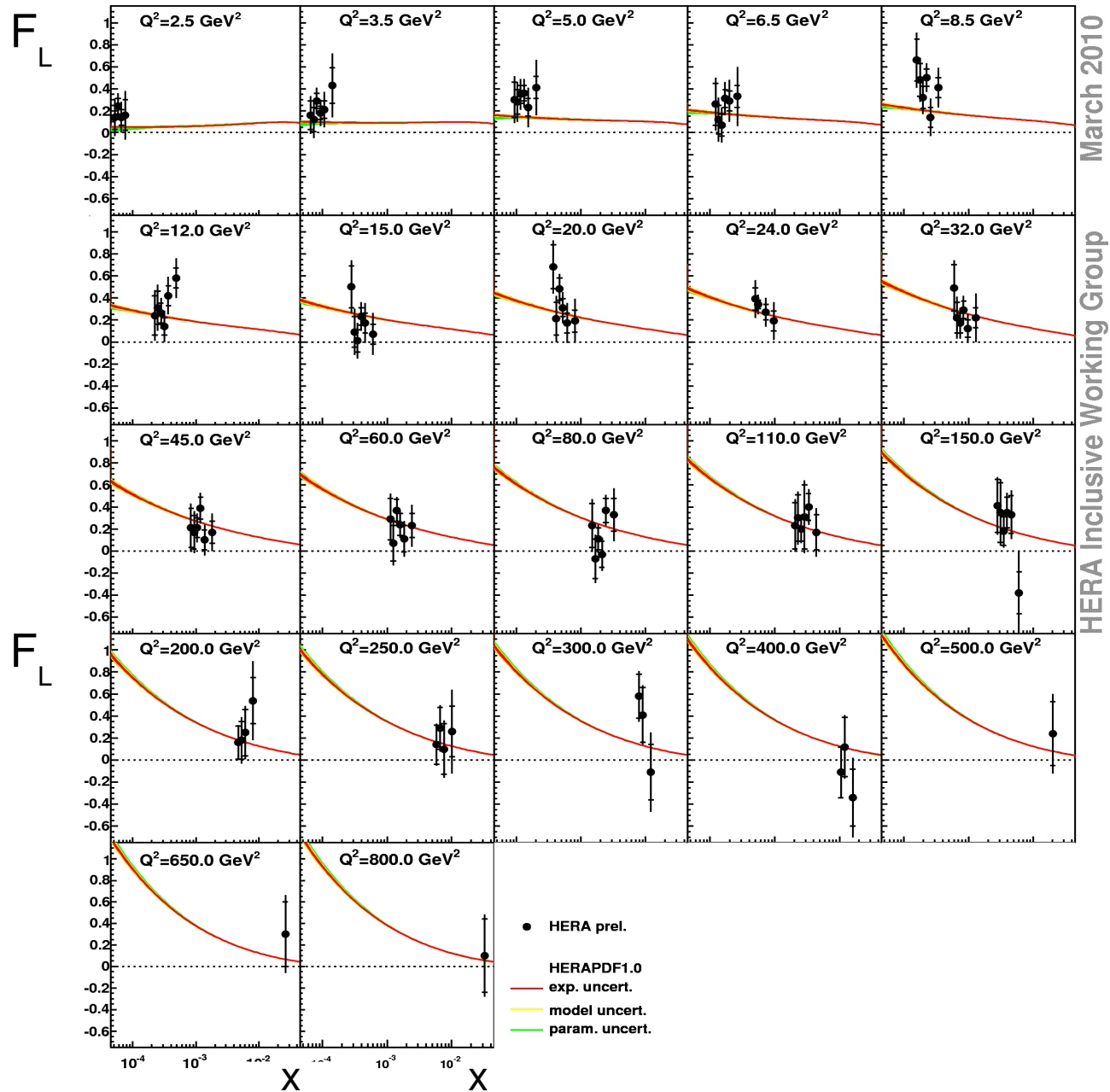
After the cross sections are combined, F_L can be extracted:



$$\sigma_r(x, Q^r, y) = F_v(x, Q^r) - \frac{Y^r}{Y_+} F_L(x, Q^r)$$

At given x and Q^2 :
 $\rightarrow F_L$ is the negative slope

HERA F_L in bins of Q^2 as a function of x H1 and ZEUS

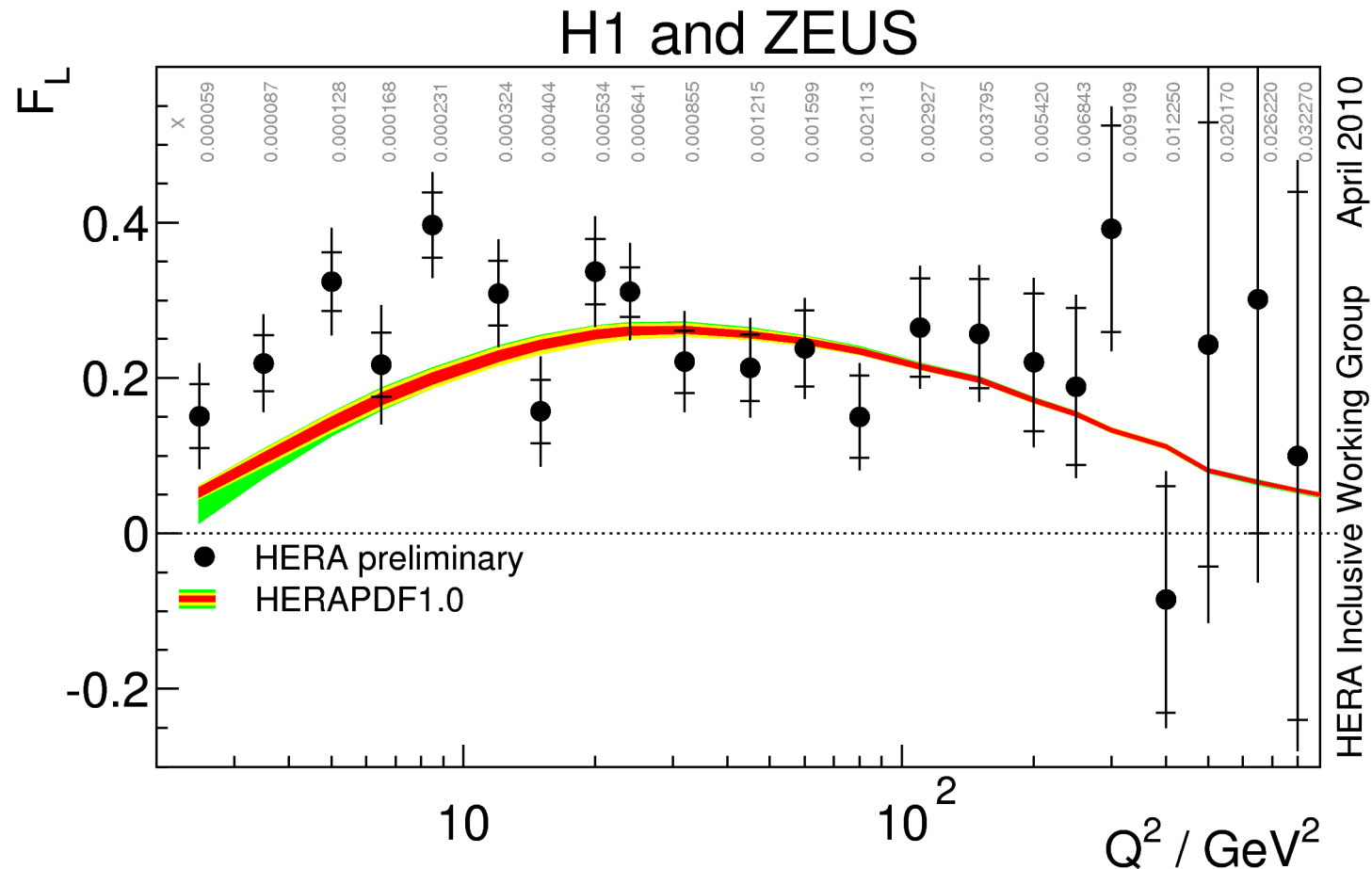


March 2010

HERA Inclusive Working Group

Averaged F_L , $2.5 < Q^2 < 800 \text{ GeV}^2$

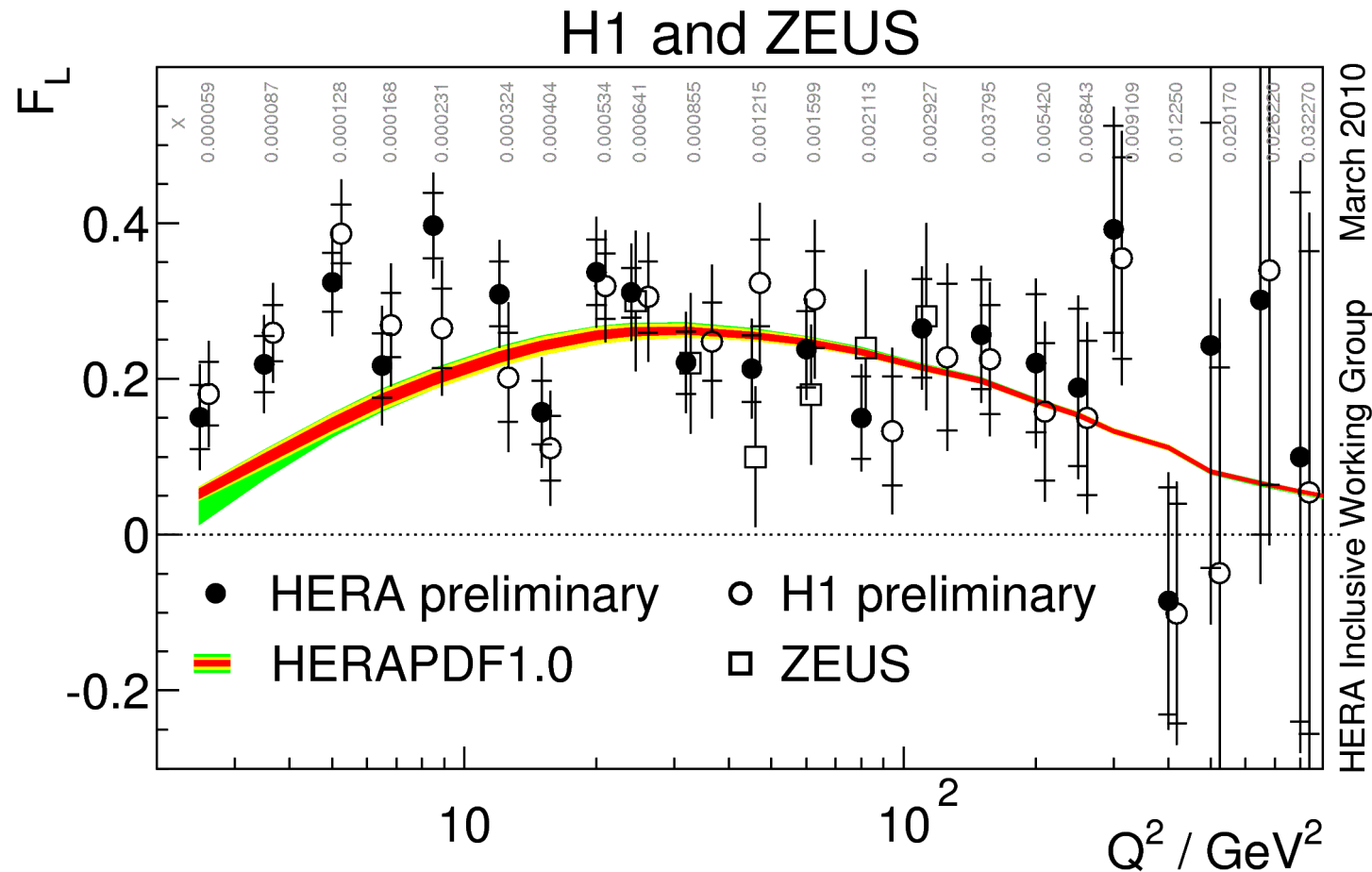
F_L , averaged over x , is obtained for each Q^2 bin:



Good agreement between data and predictions for $Q^2 > 10 \text{ GeV}^2$.
Data excess HERAPDF1.0 predictions at low- Q^2 region (see talk by V. Radescu)

HERA F_L , compared to H1 and ZEUS measurements

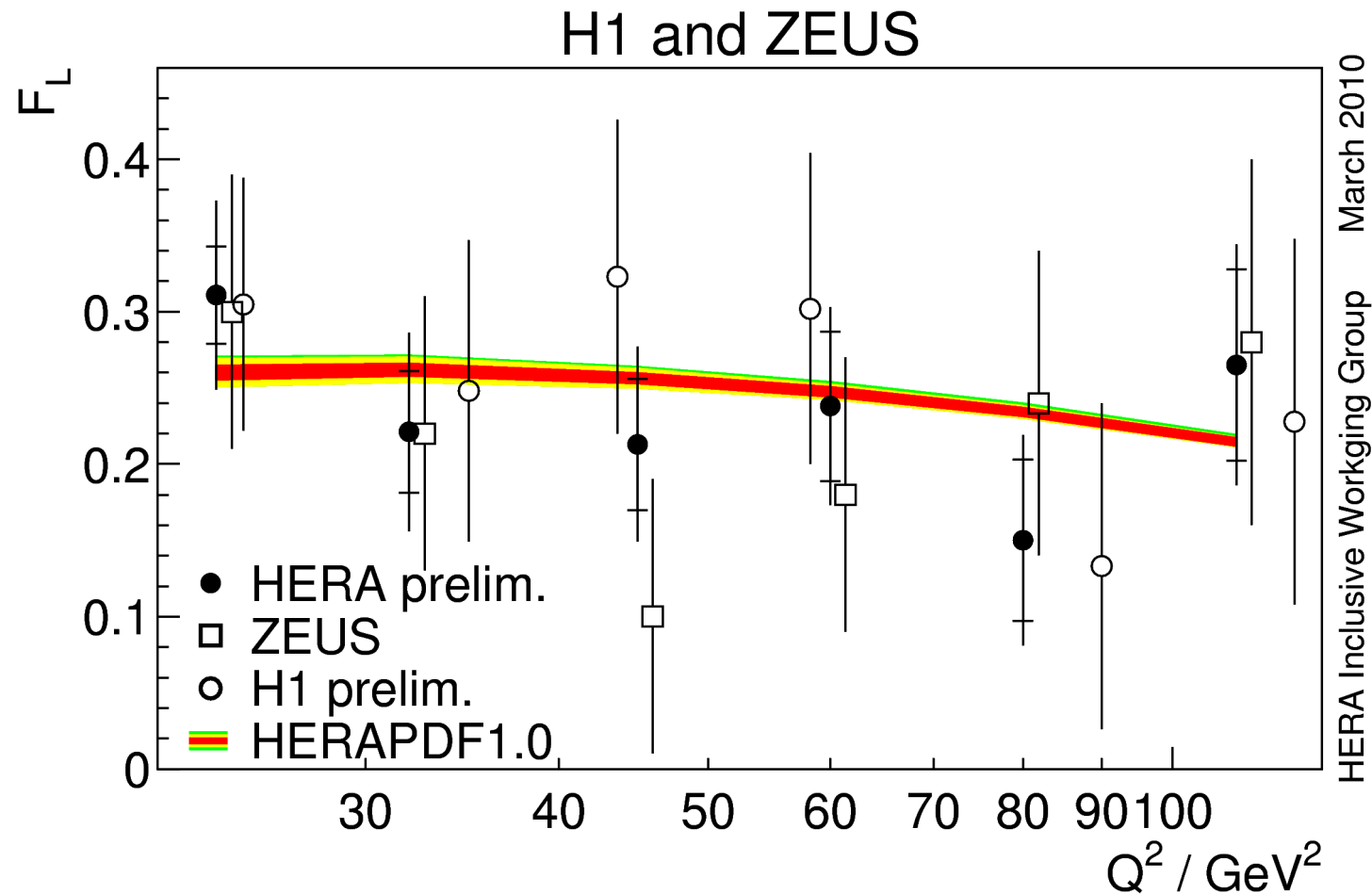
F_L , averaged over x , compared to H1 and ZEUS measurements:



Improved precision in the H1/ZEUS overlap region

HERA F_L , compared to H1 and ZEUS measurements

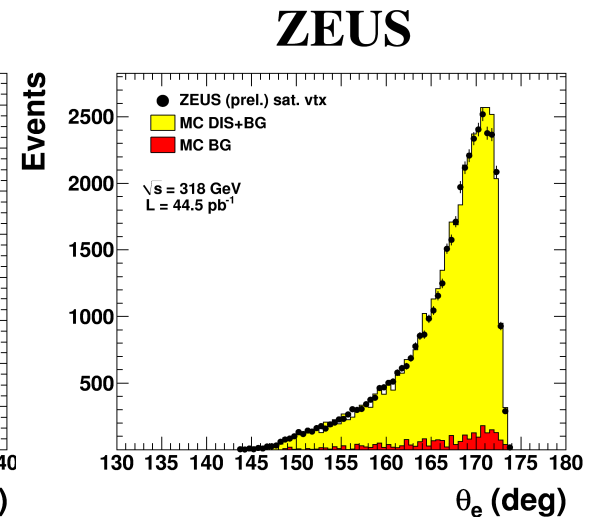
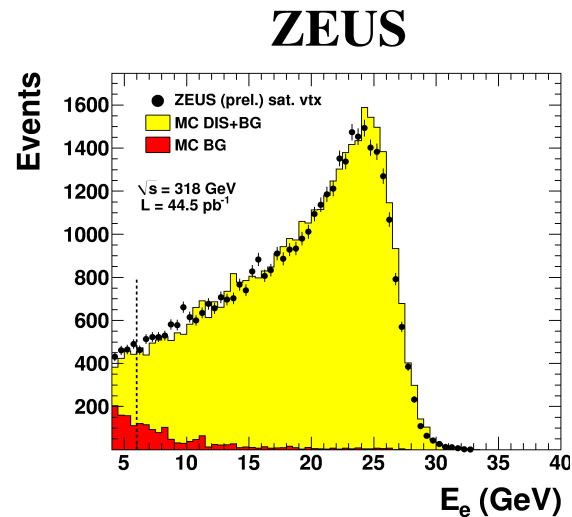
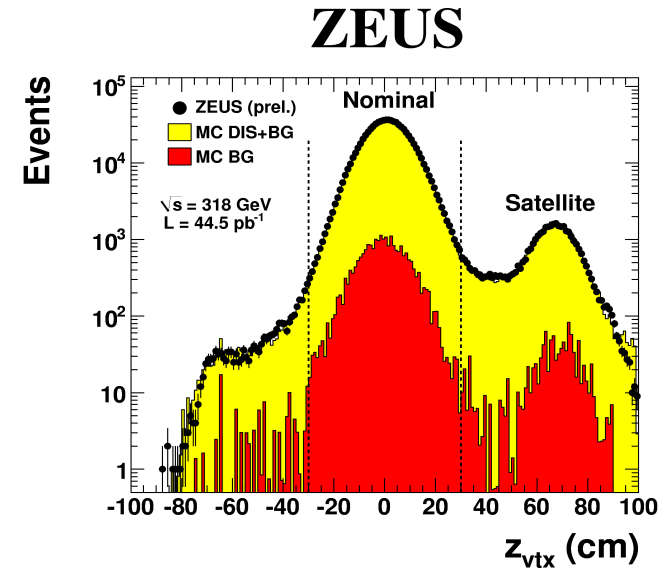
F_L in H1/ZEUS overlap region ($24 < Q^2 < 110 \text{ GeV}^2$), compared to individual measurements:



Extended to low- Q^2 region ZEUS measurement will be very useful

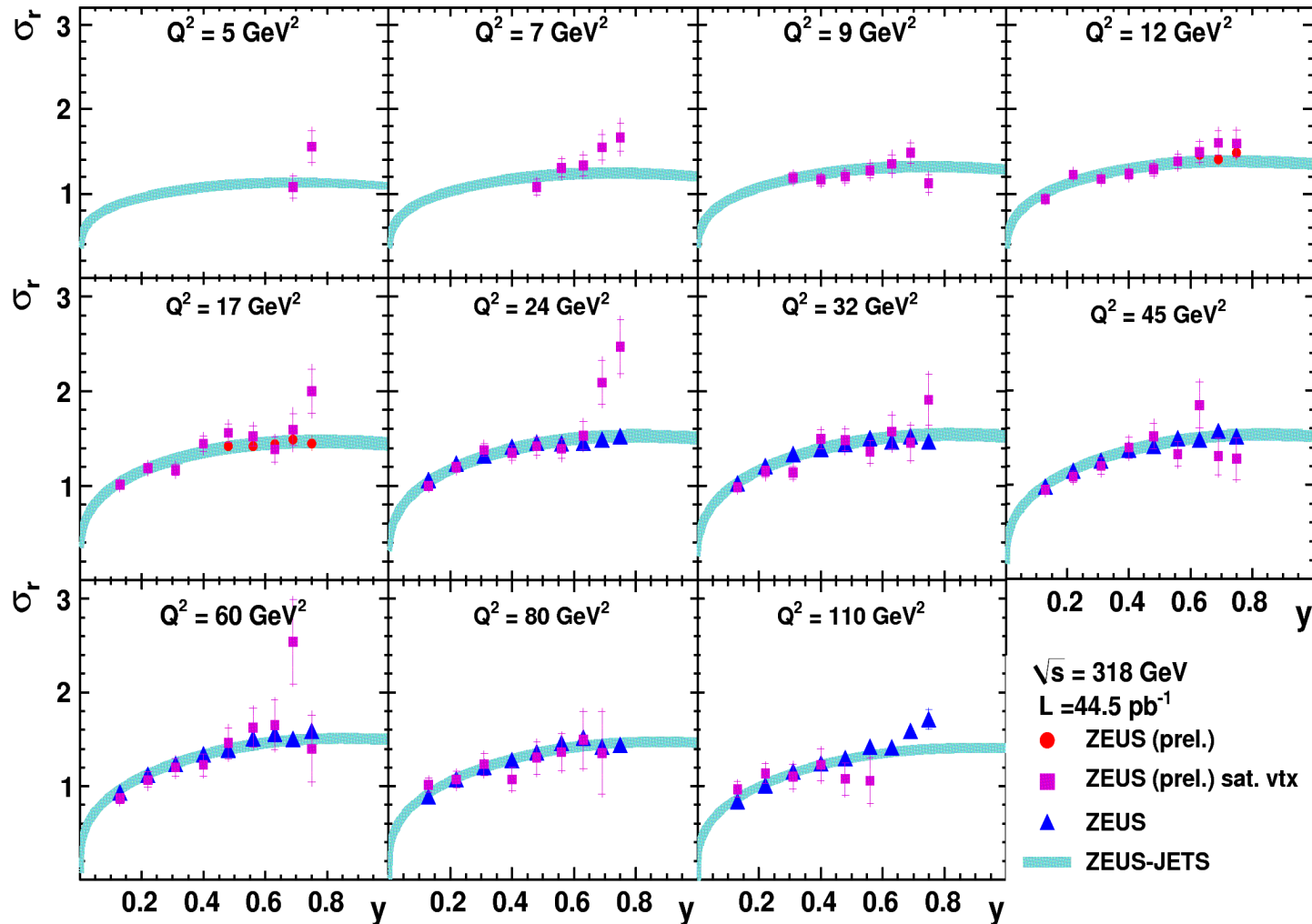
New measurement of NC cross sections at ZEUS

- NC e+p cross sections, published by ZEUS last year for $24 < Q^2 < 110 \text{ GeV}^2$
 - Lower limit in Q^2 due to tracking system acceptance
 - $E_e > 6 \text{ GeV}$
- Nominal analysis extension:
 - $Q^2 > 12 \text{ GeV}^2$
- Beam structure: presence of **satellite vertex** events:
 - can be used to access lower electron scattering angles \rightarrow lower Q^2



Measured reduced cross sections: $E_p = 920 \text{ GeV}$

ZEUS



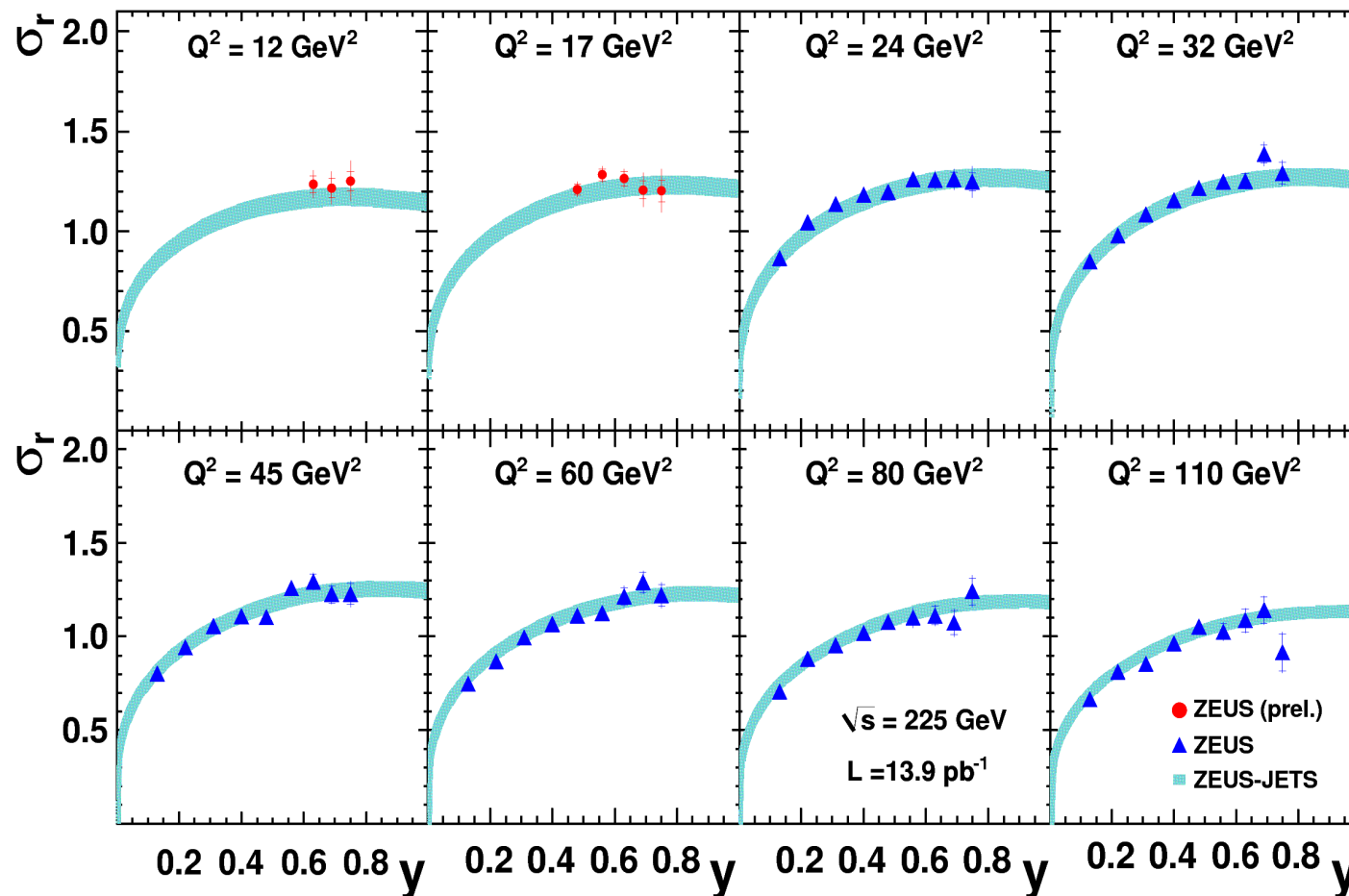
$$5 \text{ GeV}^2 < Q^2 < 110 \text{ GeV}^2$$

$$5 \cdot 10^{-4} < x < 7 \cdot 10^{-3}$$

- Shifted vertex and nominal vertex cross section measurement extended to lower Q^2
- New data agree well with previous measurements and predictions

Measured reduced cross sections: $E_p = 460 \text{ GeV}$

ZEUS



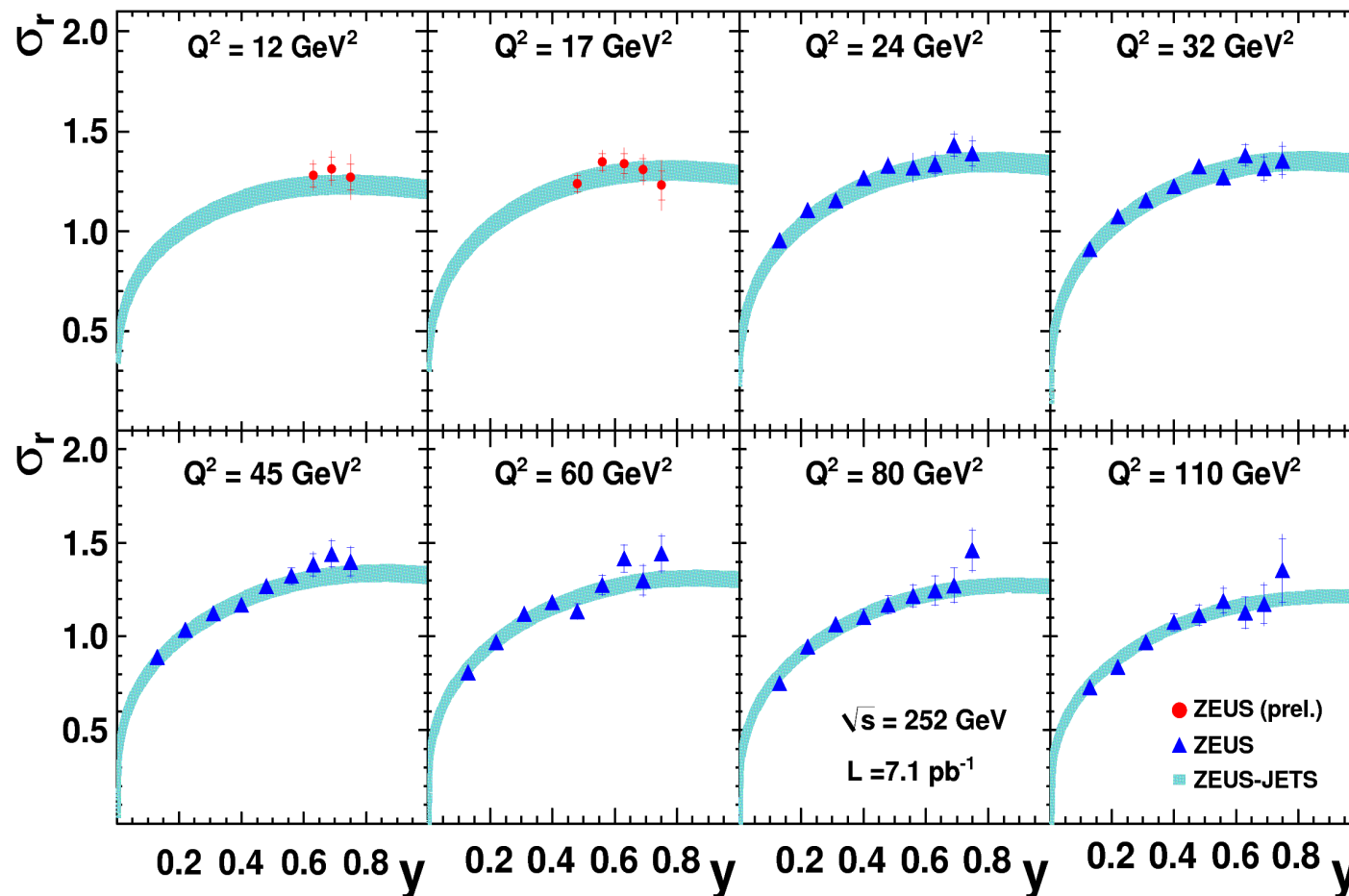
$$12 \text{ GeV}^2 < Q^2 < 110 \text{ GeV}^2$$

$$5 \cdot 10^{-4} < x < 7 \cdot 10^{-3}$$

- Nominal vertex cross section measurement extended to lower Q^2
- New data agree well with predictions

Measured reduced cross sections: $E_p = 575 \text{ GeV}$

ZEUS



$$12 \text{ GeV}^2 < Q^2 < 110 \text{ GeV}^2$$

$$5 \cdot 10^{-4} < x < 7 \cdot 10^{-3}$$

- Nominal vertex cross section measurement extended to lower Q^2
- New data agree well with predictions

Summary

- NC e+p **cross sections, measured by H1 and ZEUS, are combined** in the region of $2.5 < Q^2 < 800 \text{ GeV}^2$
 - Improved precision and check of consistency
 - Data ready for further QCD analysis
- Joint **HERA longitudinal proton structure function F_L is extracted**
- NC e+p cross sections measurement with the **ZEUS** detector is **extended to lower Q^2**
 - Satellite vertex events are used to access lower Q^2 region ($5 < Q^2 < 110 \text{ GeV}^2$)
 - Nominal analysis extended to $Q^2 > 12 \text{ GeV}^2$
 - New ZEUS measurement is ready for further combination and QCD analysis

Backup

Data combination procedure

- Cross sections are measured in bins of Q^2 as a function of x
- First H1 and ZEUS data points are **moved to common (Q^2, x) grid** (using HERAPDF1.0 to define swimming corrections)
- After swimming, **points are averaged**
 - χ^2 minimisation method used
 - For single data set χ^2 is defined as:

$$\chi^2(m, b) = \sum_i \left(\frac{(m^i - \sum_j \Gamma_j^i(m_i) b_j - \mu^i)^2}{\sigma_i(m^i, b_j)} \right) + \sum_j b_j^2$$

- Error correlations taken into account

m_i – prediction for the measurement
 μ_i – measured value
 Γ_i – correlated systematics
 σ_i – stat. and uncorr syst. uncertainties
 b_i – shifts of the correlated syst.