

Combined HERA F_L measurement

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on behalf of H1 and ZEUS Collaborations

low- x Workshop
Kavala, Greece
23 June 2010

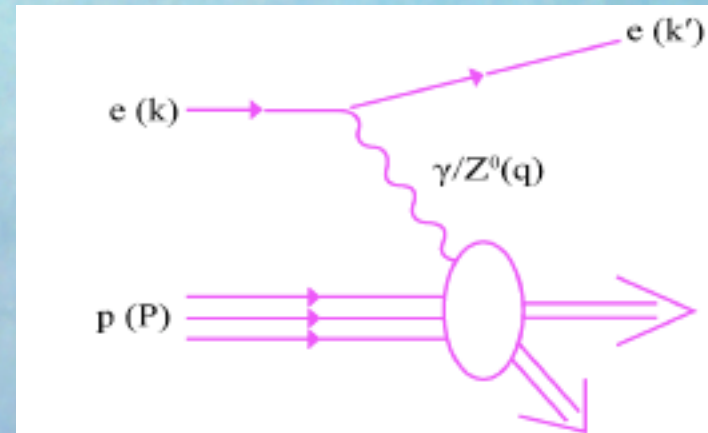
Measurement of structure functions F_2 and F_L determines the quark and gluon densities in a proton

- ✓ mandatory input for studying physics at LHC
- ✓ F_2 and F_L at low- x provide a key to the gluonic structure of matter

$$\frac{d^2\sigma_{NC}^{ep}}{dx dQ^2} = \frac{xQ^4}{2\pi\alpha^2 Y_+} \sigma_r(x, Q^2, y)$$

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

$$Y_+ = 1 + (1 - y)^2$$

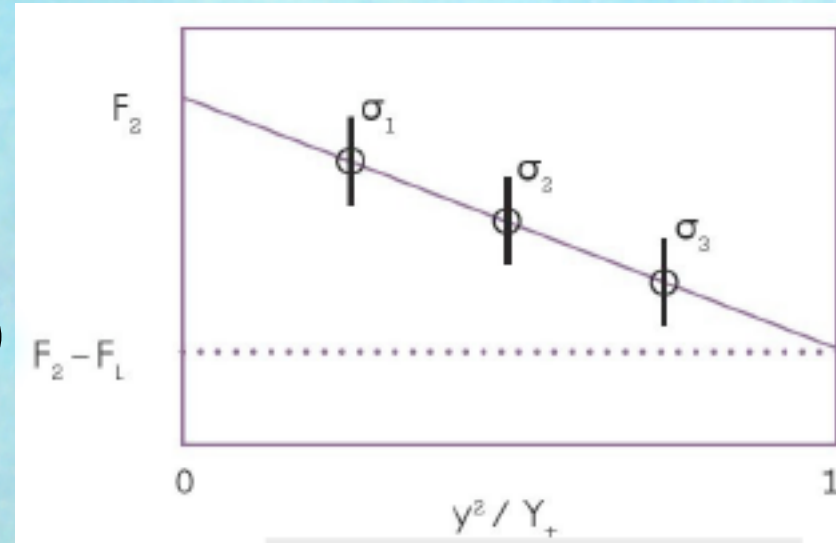


Q^2 – virtuality of exchanged photon
 x – Bjorken scaling variable
 y – inelasticity
 s – center-of-mass energy, $s=4E_e E_p$
 $Q^2 = xys$

F_L determination requires the measurements at the same Q^2 and x but different y

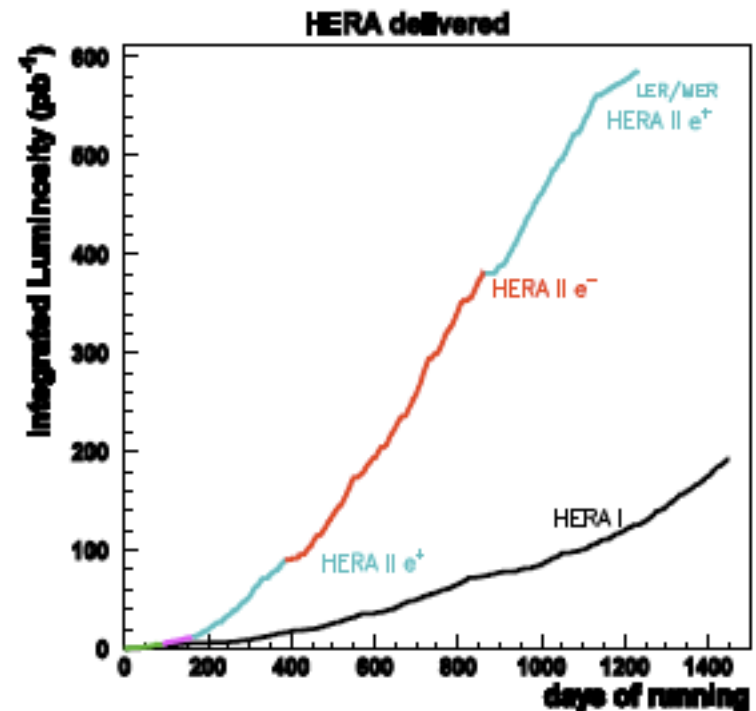
$$\sigma_r(x, Q^2, y) = F_2(x, Q^2) + \frac{y^2}{Y_+} F_L(x, Q^2)$$

$$y = \frac{Q^2}{xs} \quad \text{changing } y \text{ requires changing } s$$



Direct F_L measurement requires different beam energies

- Most luminosity taken with $E_e = 27.5$ GeV and $E_p = 920$ GeV
- Last three month $E_p = 460$ GeV and $E_p = 575$ GeV



challenge: measurement at high y

determine Q^2 and y from the scattered electron angle and energy

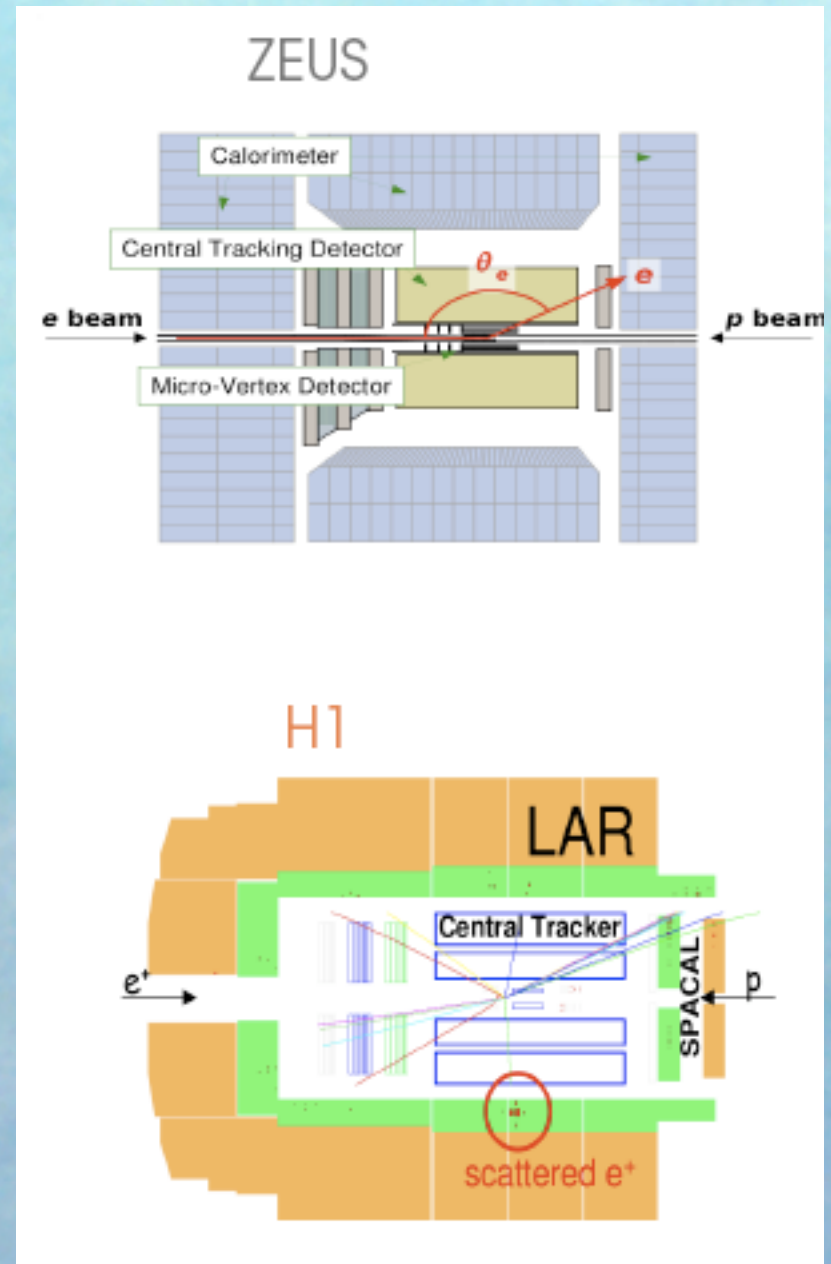
$$y = 1 - \frac{2E_e}{E_{e_{beam}}} (1 - \cos \theta_e)$$

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

High- y

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

Main background at high y photoproduction



Combining ZEUS and H1 F_L data

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

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

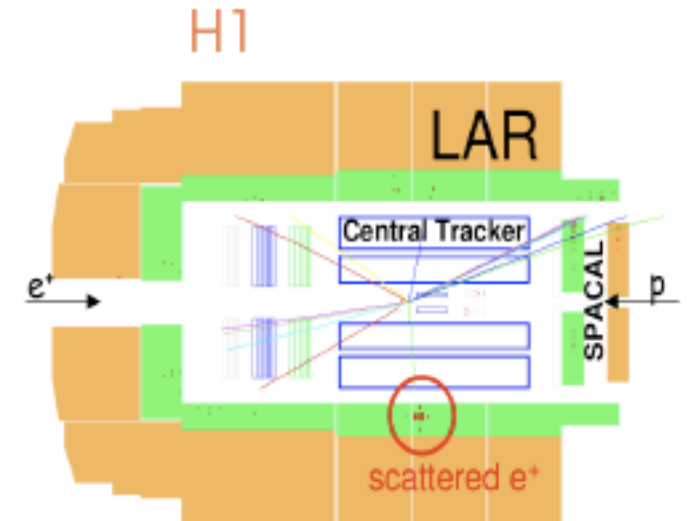
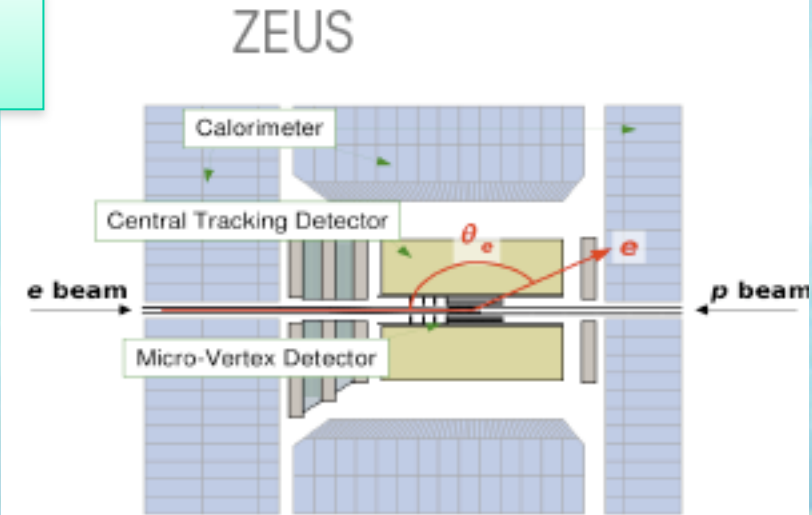
Phys. Lett. B682, 8 (2009)

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

Combining ZEUS and H1 F₂ data

Improved statistical precision by $\sim 1/\sqrt{2}$
Improved systematic precision
H1 and ZEUS detectors and data analysis are quite different.

➔ The H1 and ZEUS cross-sections have different sensitivities to similar sources of correlated systematic uncertainties



Combination Method

Swim H1 and ZEUS data to the same grid points:

$$\sigma_{\text{H1}}(x_{\text{H1}}, Q_{\text{H1}}^2) \rightarrow \sigma_{\text{H1}}(x, Q^2) \quad ; \quad \sigma_{\text{ZEUS}}(x_{\text{ZEUS}}, Q_{\text{ZEUS}}^2) \rightarrow \sigma_{\text{ZEUS}}(x, Q^2)$$

New measurements are obtained by building the χ^2 estimate:

Combination at point i
 [Estimate of 1 true cross section]

$$\chi_{\text{exp}}^2(m, b) = \sum_i \frac{[m^i - \sum_j \gamma_j^i m^j b_j - \mu^i]^2}{\delta_{i,\text{stat}}^2 \mu^i (m^i - \sum_j \gamma_j^i m^j b_j) + (\delta_{i,\text{uncor}} m^i)^2} + \sum_j b_j^2$$

Sensitivity of the cross section to the j^{th} source of correlated uncertainty.

γ_j^i defined as the relative change of the measurement for a 1 sigma shift of the error source

$\delta_{i,\text{stat}} / \delta_{i,\text{uncor}}$

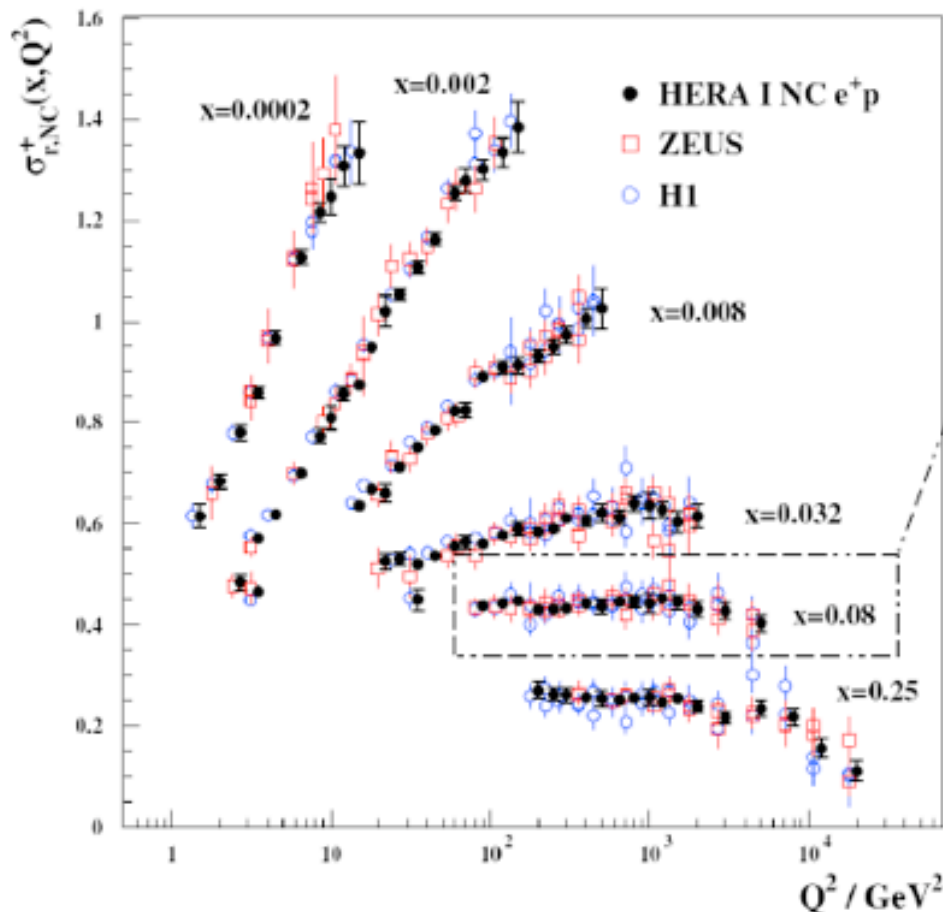
Relative stat. / syst. error on the measurement

Measurement at point i

Shift of the j^{th} source of correlated uncertainty

- 1402 measurements with 110 correlated sources of uncertainty combined to 741 cross sections.
- $\chi^2 / \text{dof} = 636.5 / 656$; No tension in Pulls ; $|b_j| < 2 \Rightarrow$ **H1 and ZEUS Agree!**

H1 and ZEUS



$x=0.08$

Systematic Uncertainty:

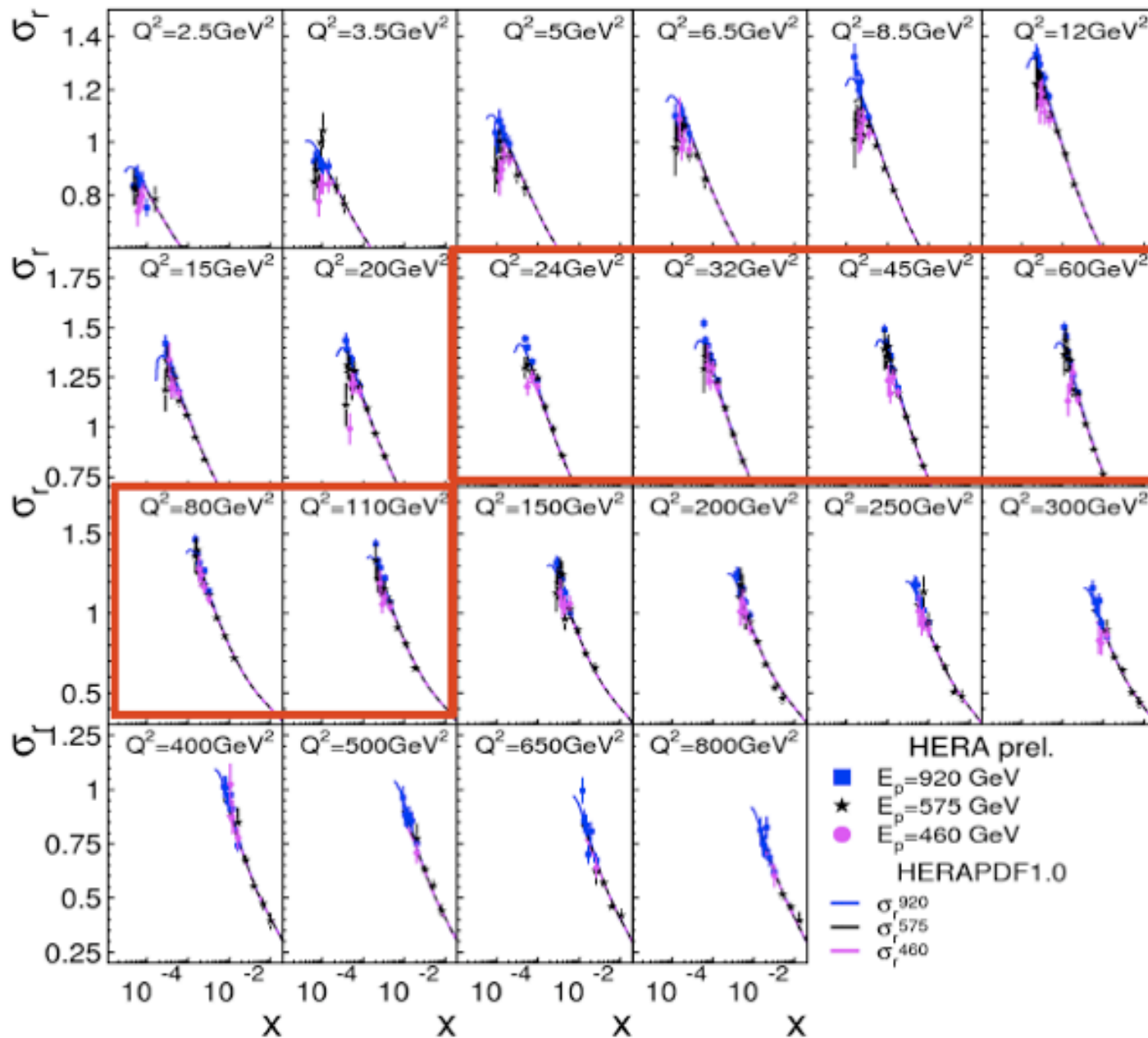
- $\delta_{\text{H1 LAR}} \rightarrow 0.45 \delta_{\text{H1 LAR}}$
- $\delta_{\text{ZEUS BG}} \rightarrow 0.35 \delta_{\text{ZEUS BG}}$

Overall Precision:

- 2% for $3 < Q^2 < 500 \text{ GeV}^2$
- 1% for $2 < Q^2 < 100 \text{ GeV}^2$



H1 and ZEUS



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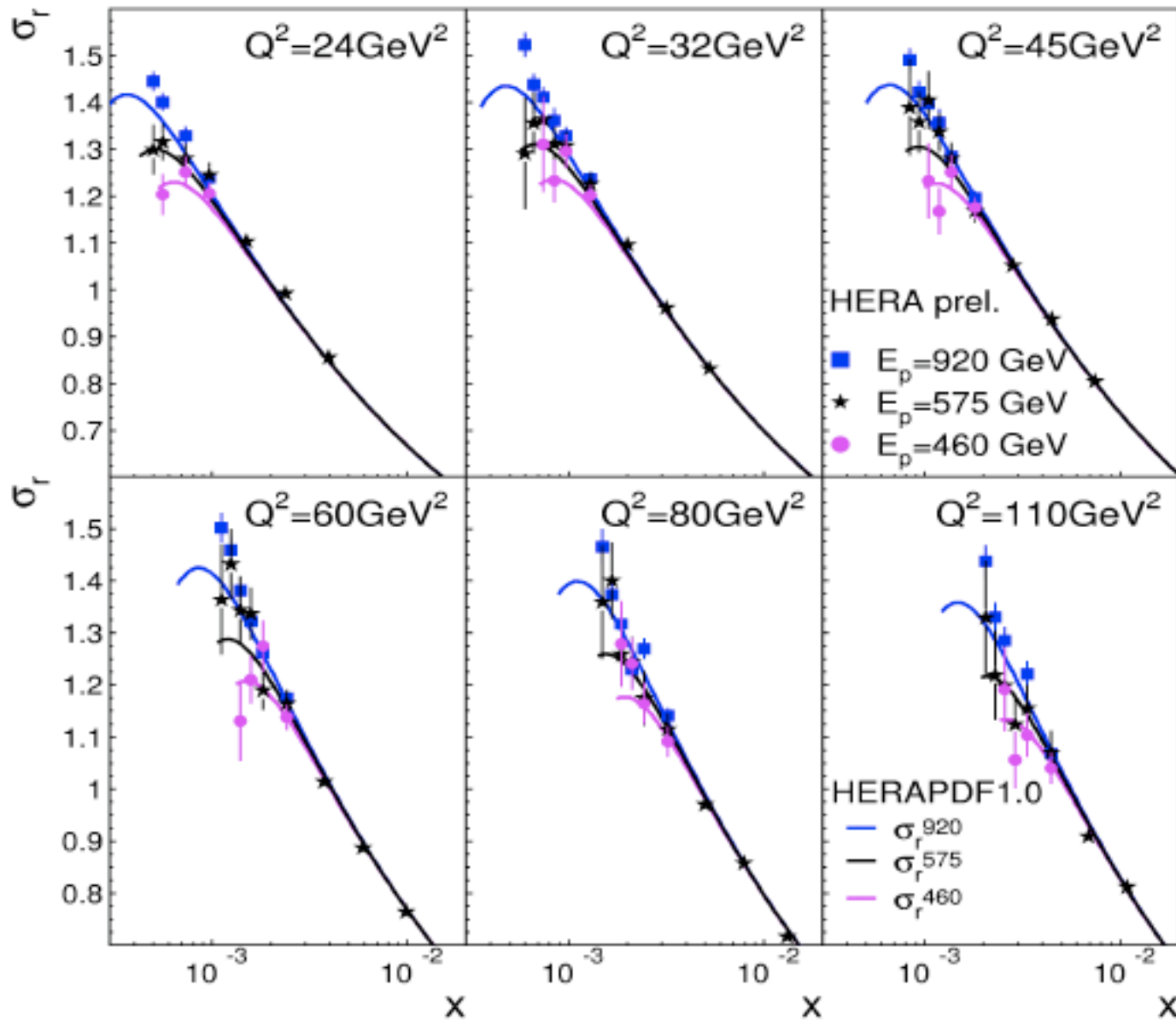
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Combined cross-sections

HERA prel.
 ■ $E_p=920$ GeV
 ★ $E_p=575$ GeV
 ● $E_p=460$ GeV
 HERAPDF1.0
 — σ_r^{920}
 — σ_r^{575}
 — σ_r^{460}

ZEUS + H1 measurement

H1 and ZEUS



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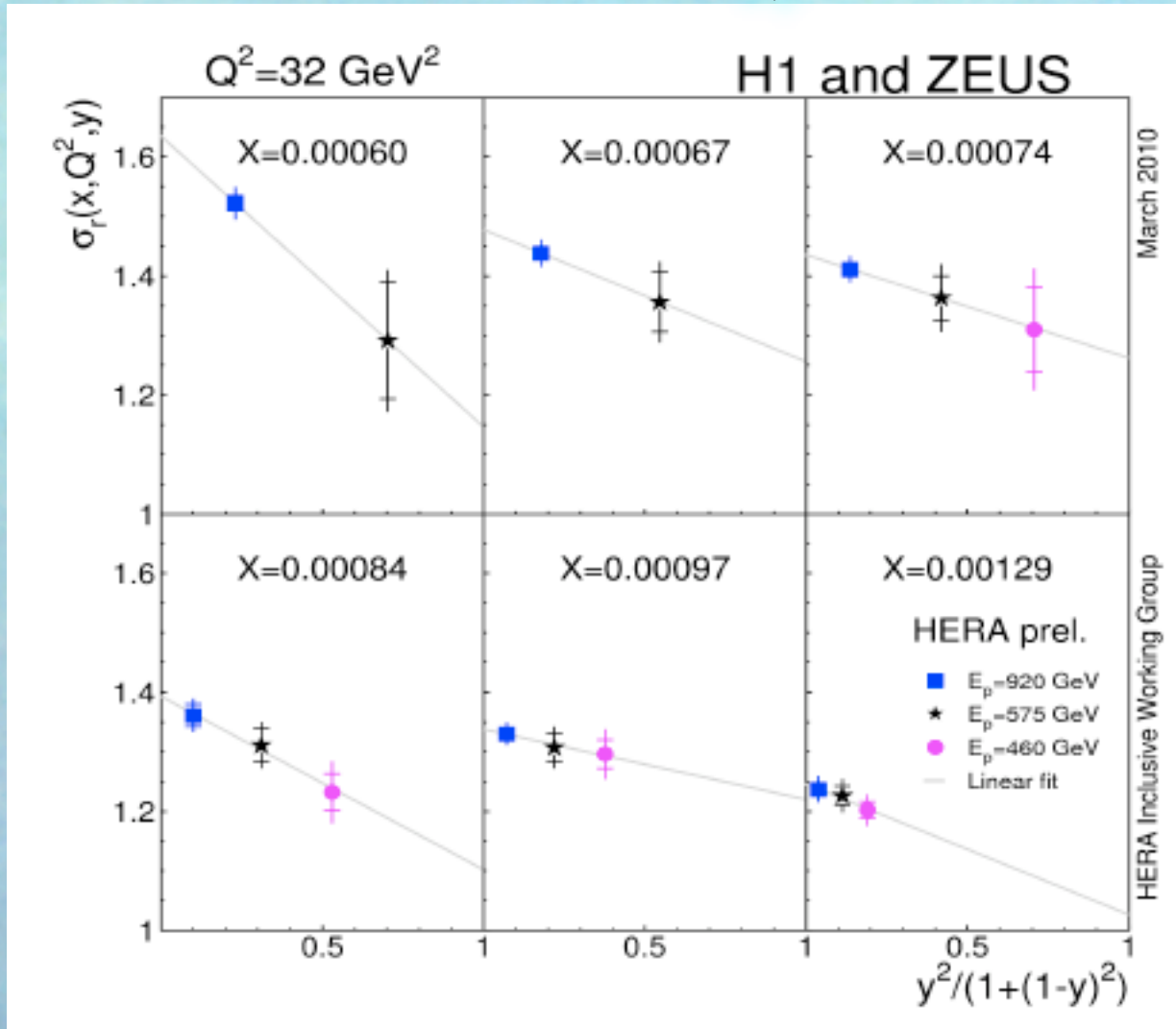
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Combined cross-sections

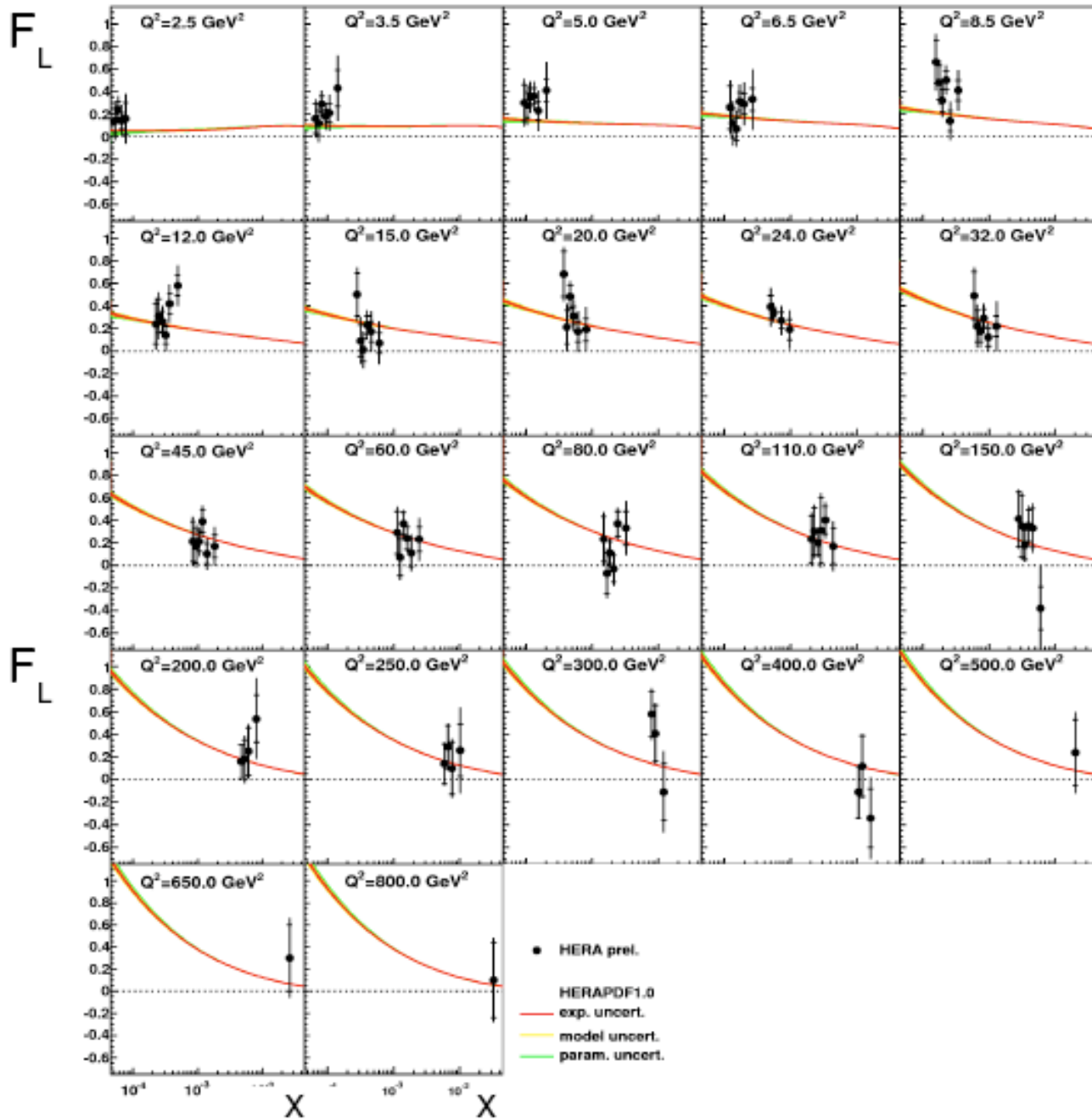
H1 and ZEUS Overlap region

Determination of F_L

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



H1 and ZEUS

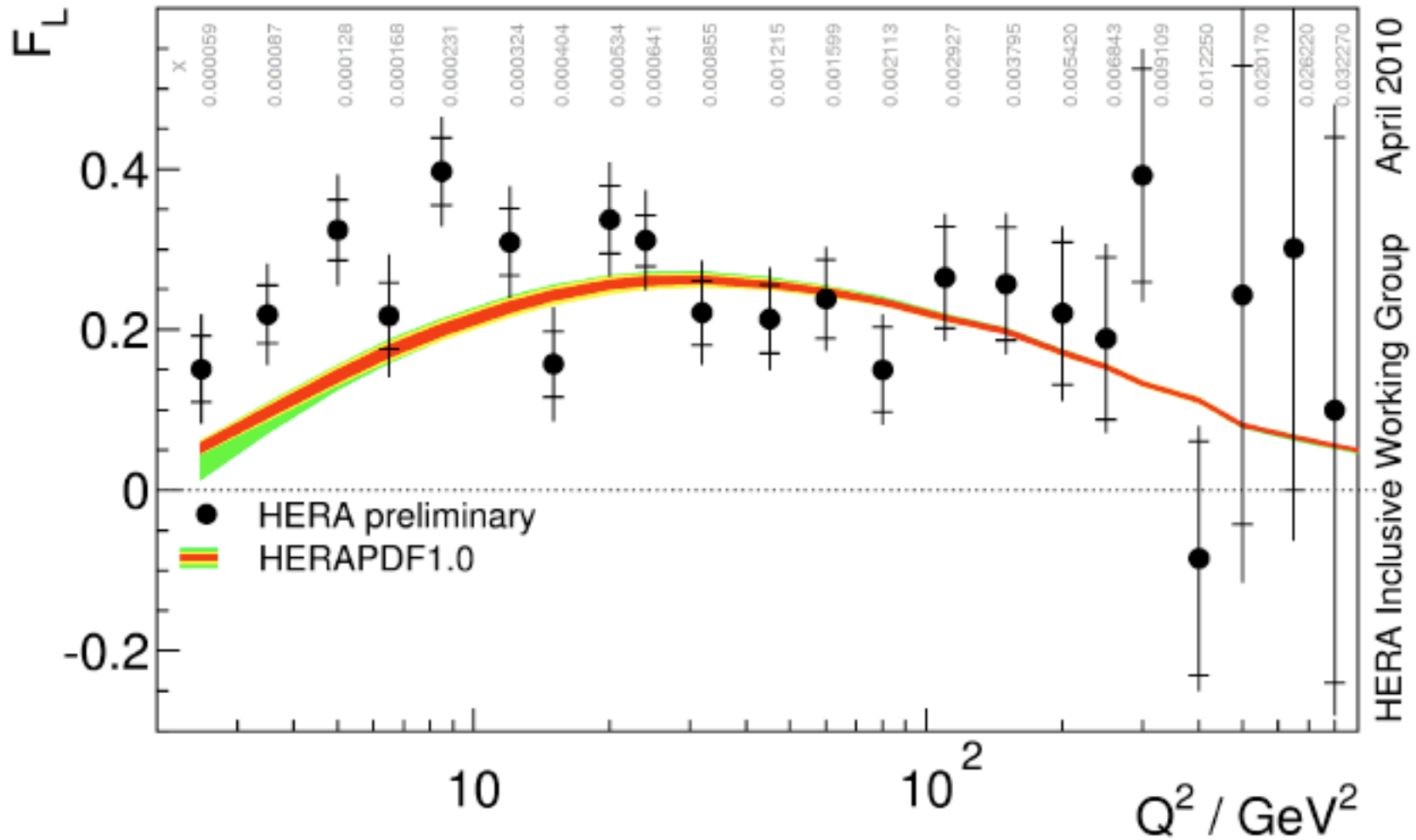


March 2010

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Averaged F_L

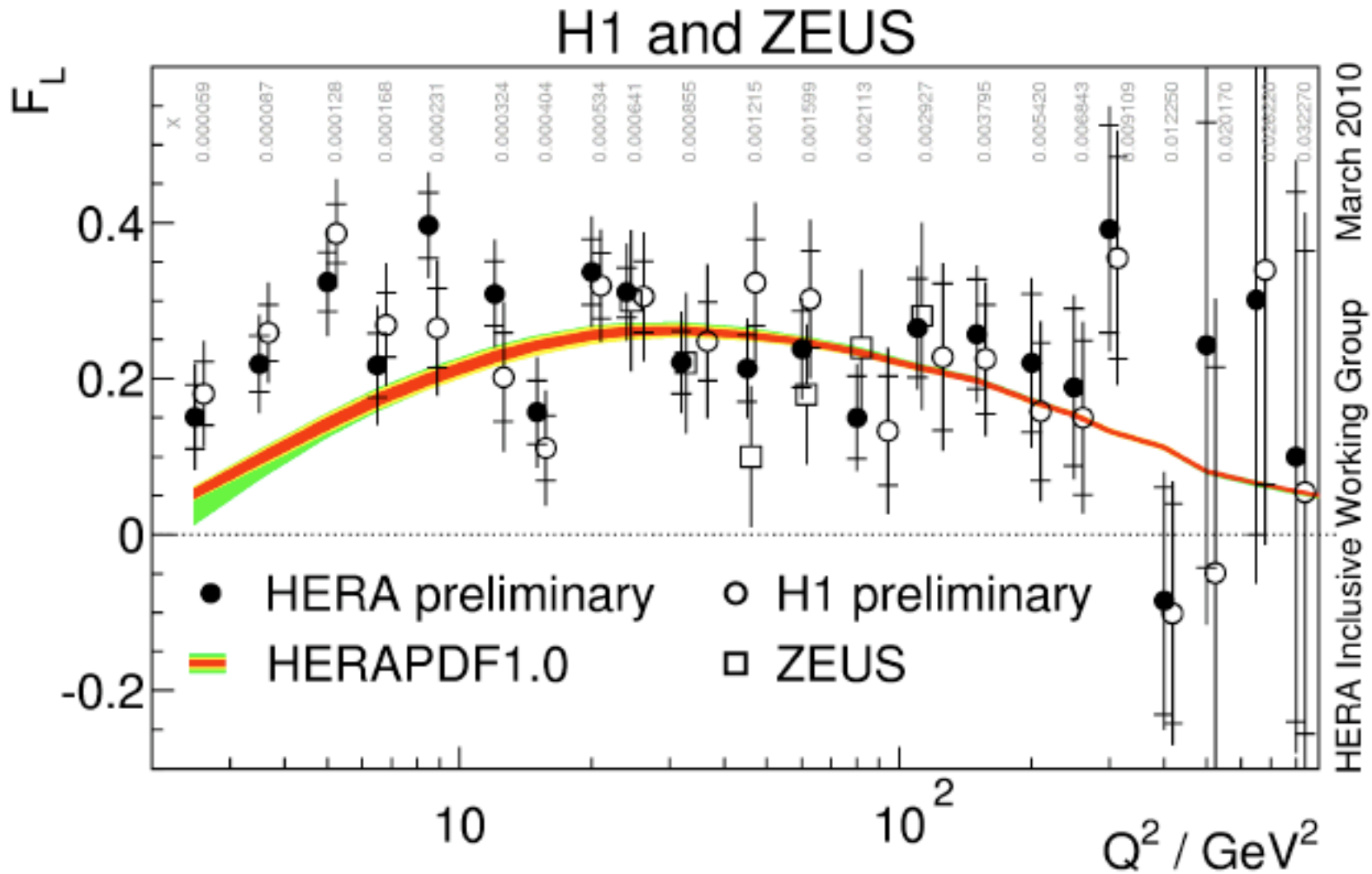
H1 and ZEUS



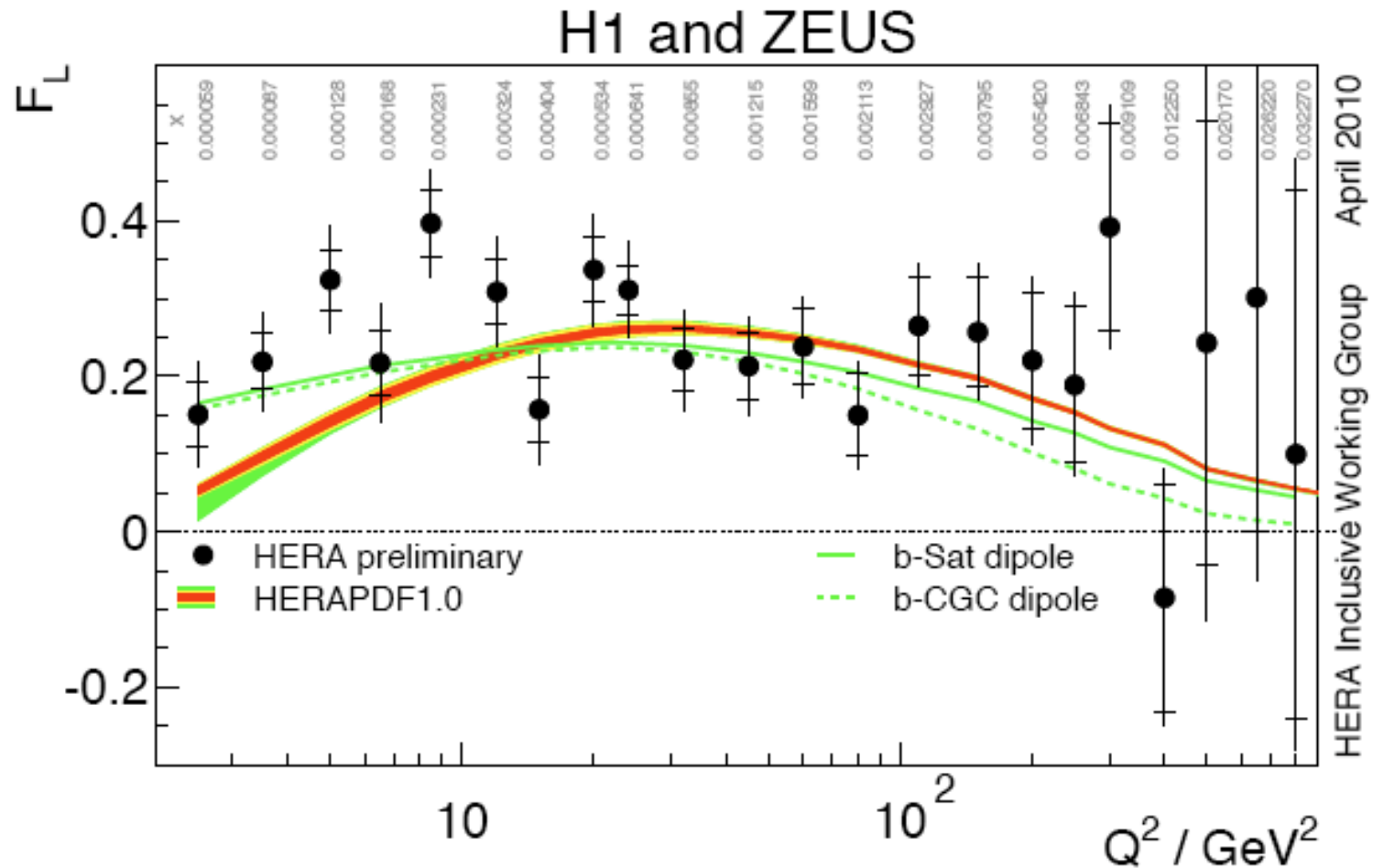
HERA Inclusive Working Group April 2010

Averaged F_L

Comparison of H1 and ZEUS measurements

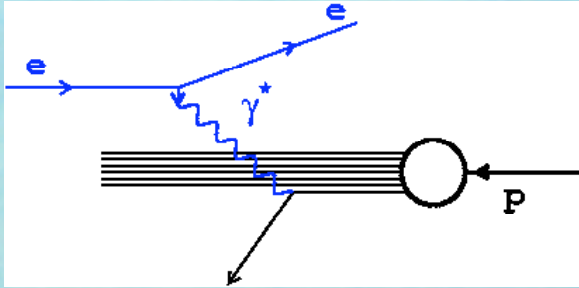


Averaged F_L



b-Sat dipole with DGLAP evolution
b-CGC dipole with CGC evolution

Gluon Density in the PDF and Dipole scheme

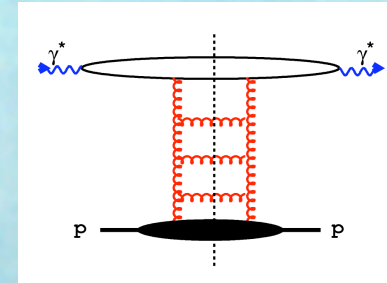


PDF

$$F_2(x, Q^2) = x \sum_q e_q^2 q(x, Q^2)$$

$$q(x, \mu^2) = q_0(x) + \frac{\alpha_s}{\pi} \int_x^1 \frac{d\xi}{\xi} q_0(\xi) \left\{ P_{qq} \left(\frac{x}{\xi} \right) \ln \mu / K + \dots \right.$$

F_2 is only weakly sensitive to GD
 F_L is strongly sensitive to GD
 ➤ F_L measures GD
 $F_L = 0$ in LO,
 $F_L \neq 0$ in NLO and NNLO



Dipole

$$q(x, Q) = \int_0^Q \frac{dk}{k} \Phi_{DIS}(Q, k) xg(xk)$$

$\Phi_{DIS} \propto r^2 (\Psi_T^2 + \Psi_L^2)$
 $\Psi_{T,L}$ transv. and longit.
 wave functions

F_L and F_2 are both equally sensitive to Gluon D.
 ➤ F_2 and F_L measures GD

Gluon Density in the PDF scheme corresponds to the high virtuality part of the GD in the Dipole scheme

Sea quark + Gluon Density in PDF scheme \equiv Gluon Density in Dipole scheme

**Advantage of the PDF scheme:
quarks and gluon densities
treated in a similar way**

- **precise predictions for LHC
and Tevatron**

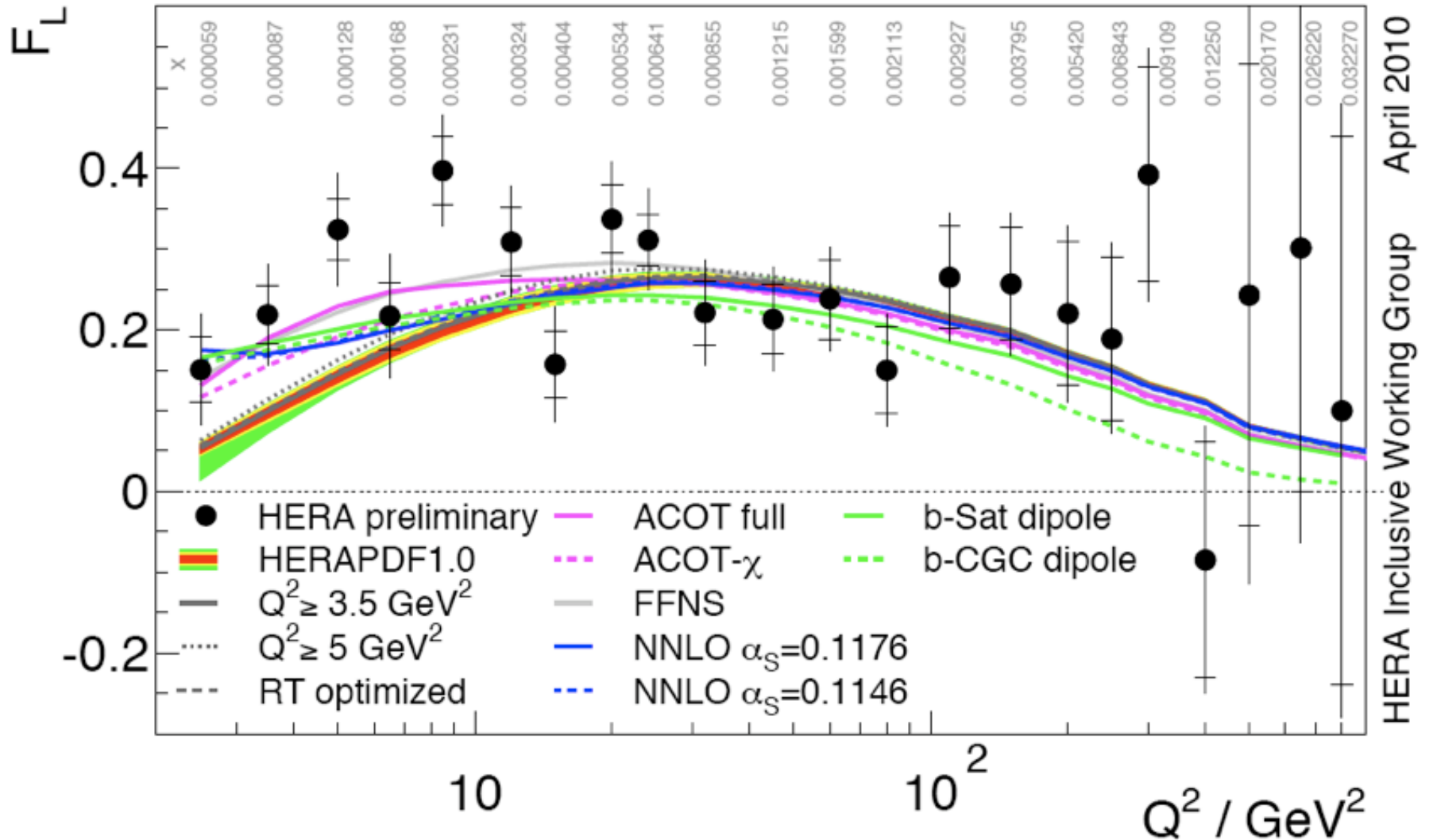
**Advantage of the Dipole scheme:
more complete treatment of
Gluon Density**

- **bridge to the gluon high
density physics at RHIC,
bridge to the gluonic structure
of matter at EIC, LHeC +**

**Precise knowledge of F_2 and F_L is necessary for LHC
physics (Higgs and Supersymmetry) and
for the future investigations of saturation and gluonic
structure phenomena**

Averaged F_L

H1 and ZEUS



ACOT= Aivazis-Collins-Olness-Tung - CTEQ scheme
 RT = Roberts-Thorne - MSTW scheme

Conclusions

Combined NC cross sections are determined from the H1 and ZEUS measurements for $2.5 \text{ GeV}^2 < Q^2 < 800 \text{ GeV}^2$

➤ precision substantially improved

➤ joint F_L is extracted

Good F_L description, in the PDF scheme, is sensitive to the choice of the gluon density/charm scheme at NLO and/or NNLO corrections (see talk by Voica Radescu)

equally good F_L description is obtained in LO Dipole approach

Backup slides

Averaged F_L

H1 and ZEUS

