Combined HERA F_L measurement

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on behalf of H1 and ZEUS Collaborations

low-x Workshop
Kavala, Greece
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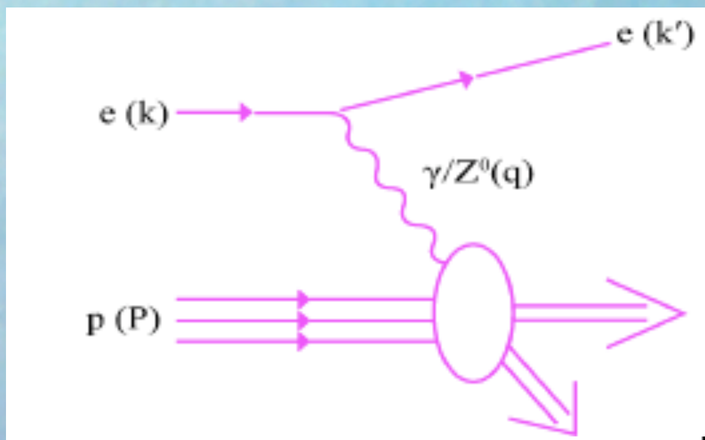
Measurement of structure functions F_2 and F_L determines the quark and gluon densities in a proton

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

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

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

$$Y_+ = 1 + (1 \quad y)^2$$

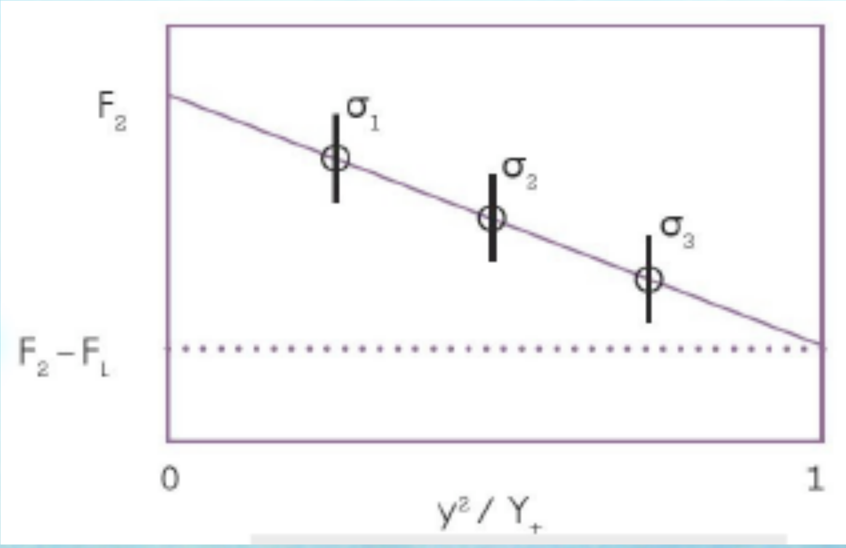


Q^2 – virtuality of exchanged photon
x – Bjorken scaling variable
y – inelasticity
s – center-of-mass energy, $s=4E_eE_p$

$Q^2 = xys$

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

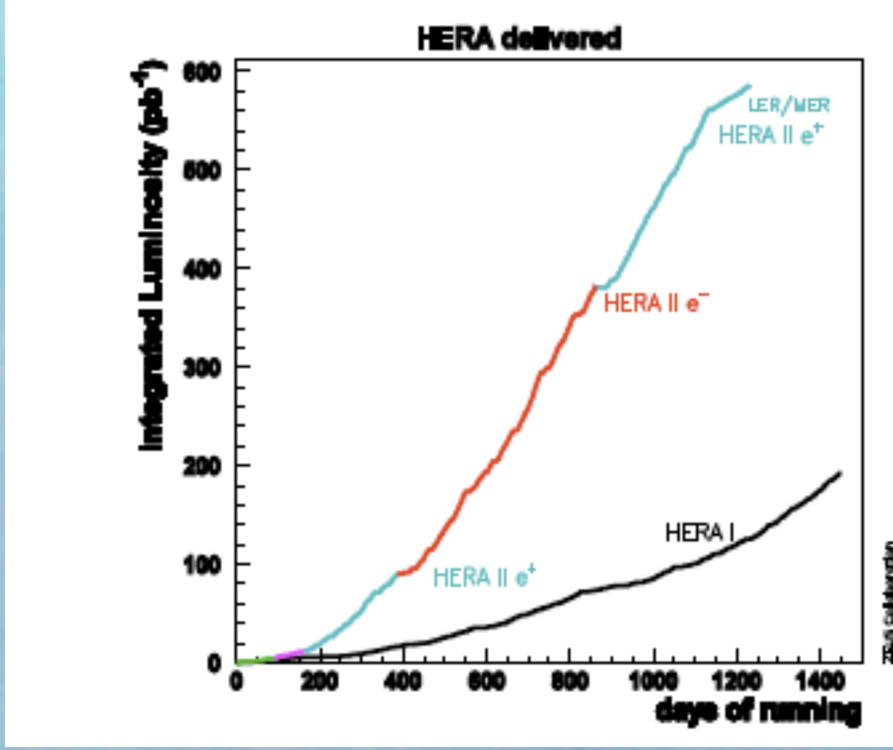
$$\sigma_r(x,Q^2,y) = F_2(x,Q^2) + \frac{y^2}{Y_+} F_L(x,Q^2)$$



$$y = \frac{Q^2}{xs}$$ **changing y 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

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

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

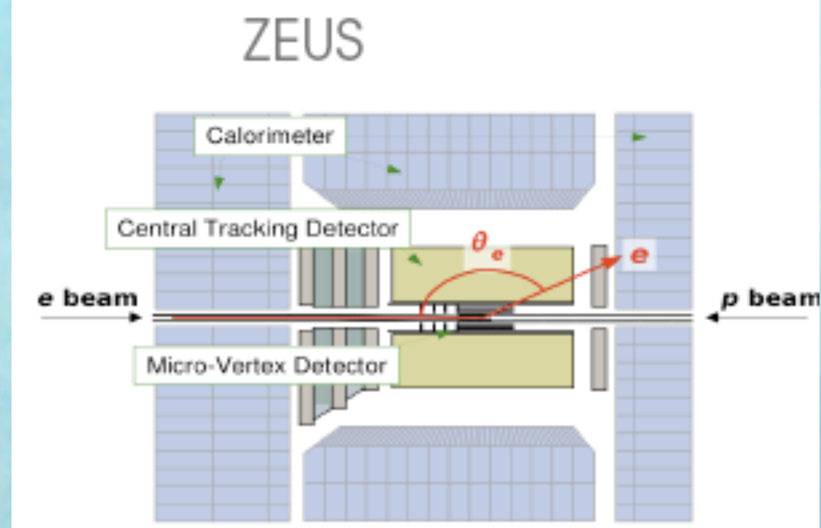
High-y

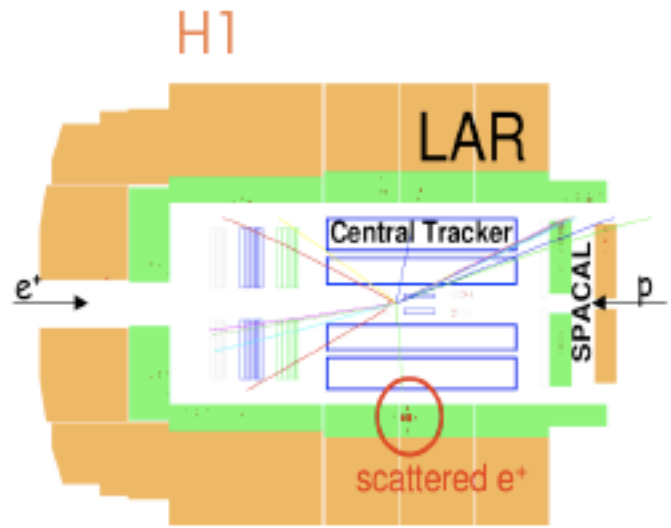
→ low energy scattered electron

→ 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:

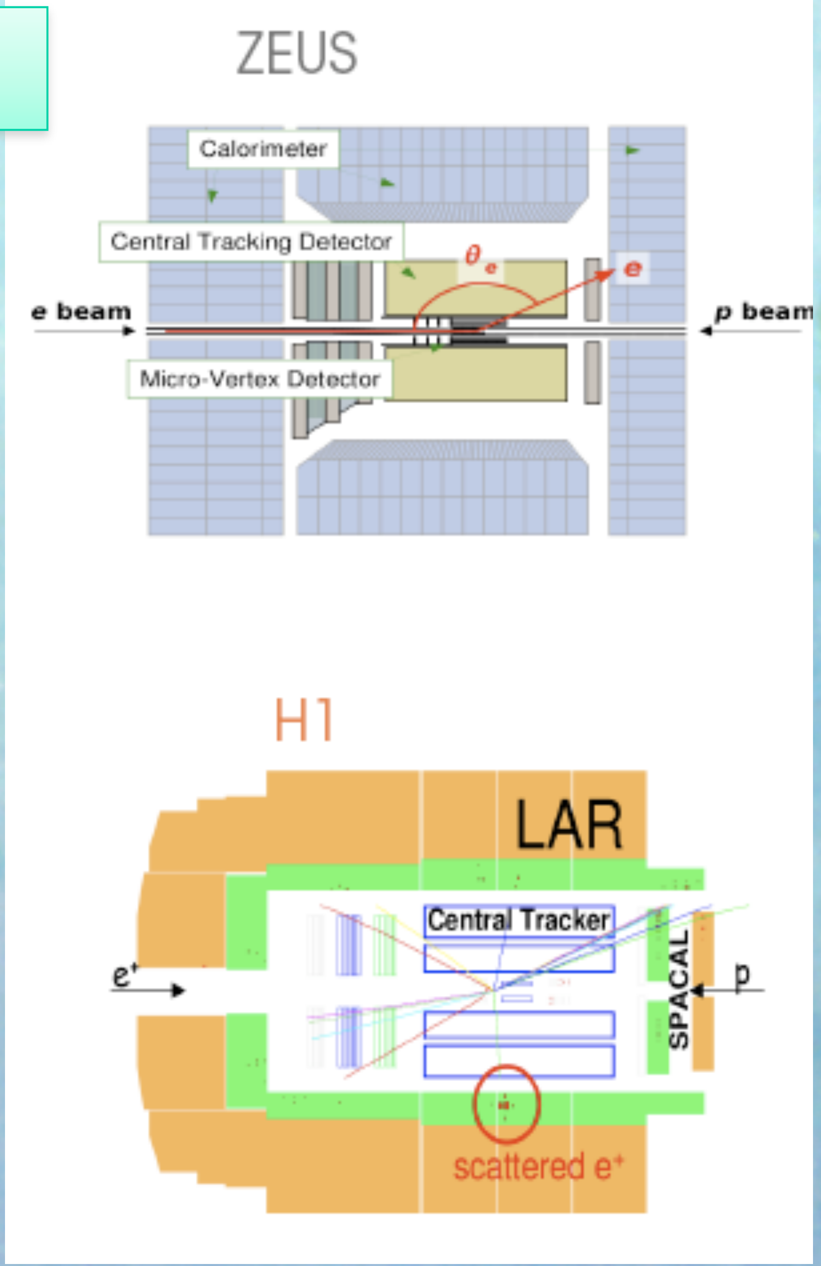
H1	ZEUS
$2.5 < Q^2 < 800$ GeV^2	$24 < Q^2 < 110$ GeV^2
Eur. Phys. J. C63, 625 (2009)	Phys. Lett. B682, 8 (2009)
Eur. Phys. J. C64, 561 (2009)	
H1prelim: 09-044, 08-042	

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

Combining ZEUS and H1 F_2 data

Improved statistical precision by ~ $1/\sqrt{2}$
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:

$$\sigma_{H1}\left(x_{H1}, Q^2_{H1}\right) \rightarrow \sigma_{H1}\left(x, Q^2\right) \quad ; \quad \sigma_{ZEUS}\left(x_{ZEUS}, Q^2_{ZEUS}\right) \rightarrow \sigma_{ZEUS}\left(x, Q^2\right)$$

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

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

Measurement at point i

$$\chi^2_{\mathrm{exp}}(\boldsymbol{m}, \boldsymbol{b}) = \sum_i \frac{\left[m^i - \sum_j \gamma^i_j m^i b_j - \mu^i\right]^2}{\delta^2_{i,\mathrm{stat}}\, \mu^i \left(m^i - \sum_j \gamma^i_j m^i b_j\right) + \left(\delta_{i,\mathrm{uncor}}\, m^i\right)^2} + \sum_j b_j^2$$

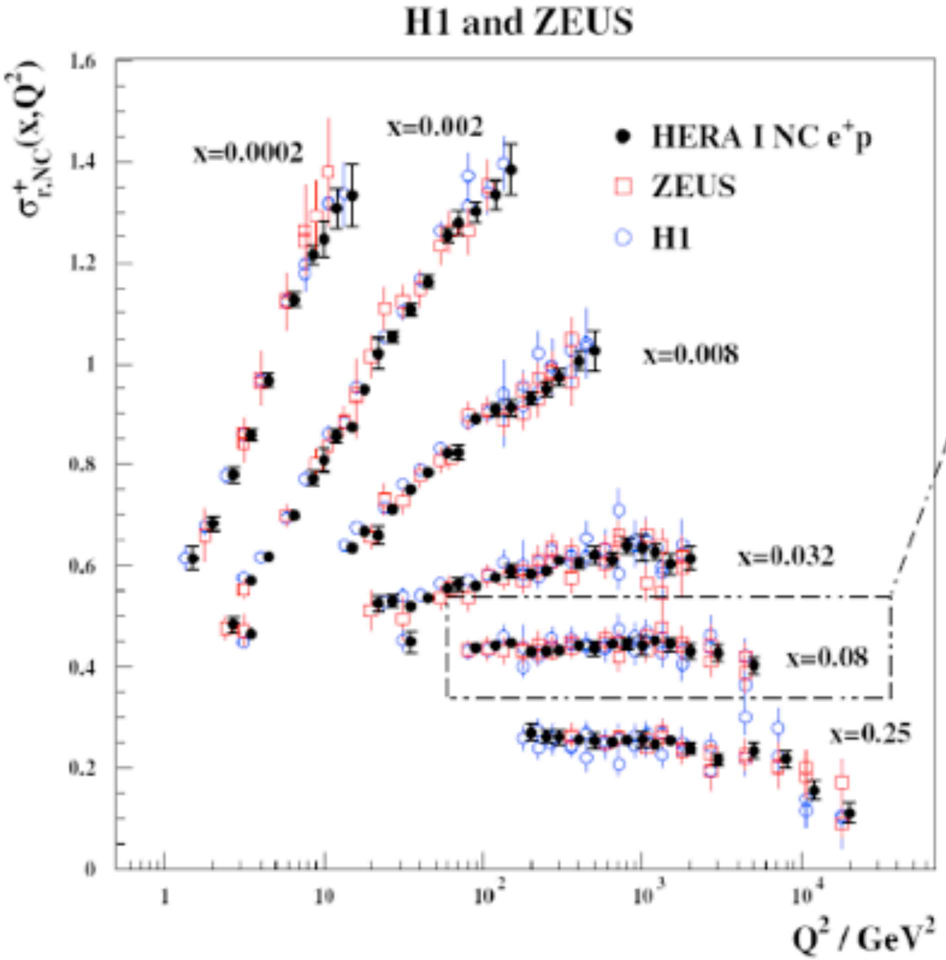
***Sensitivity** of the cross section to the j^{th} source of **correlated** uncertainty.*

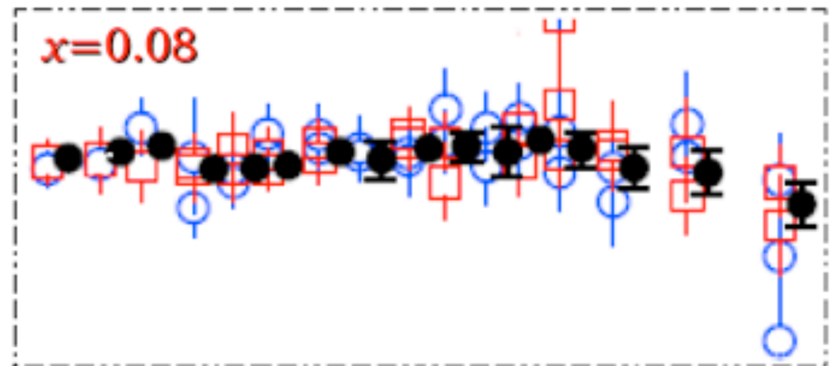
*Shift of the j^{th} source of **correlated** uncertainty*

γ^i_j *defined as the relative change of the measurement for a 1 sigma shift of the error source*

$\delta_{i,\mathrm{stat}} / \delta_{i,\mathrm{uncor}}$ *Relative stat. / syst. error on the measurement*

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





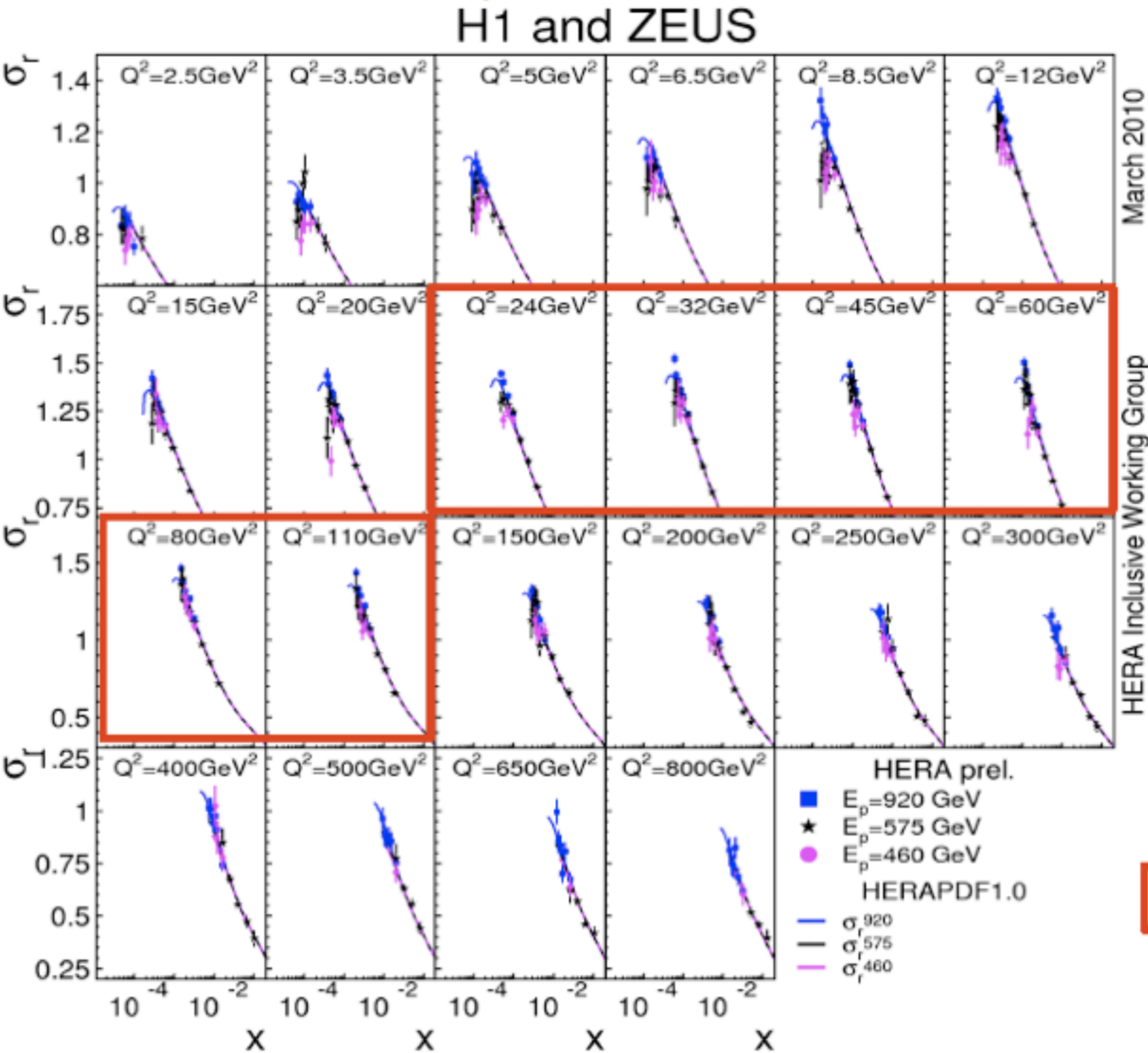
Systematic Uncertainty:

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

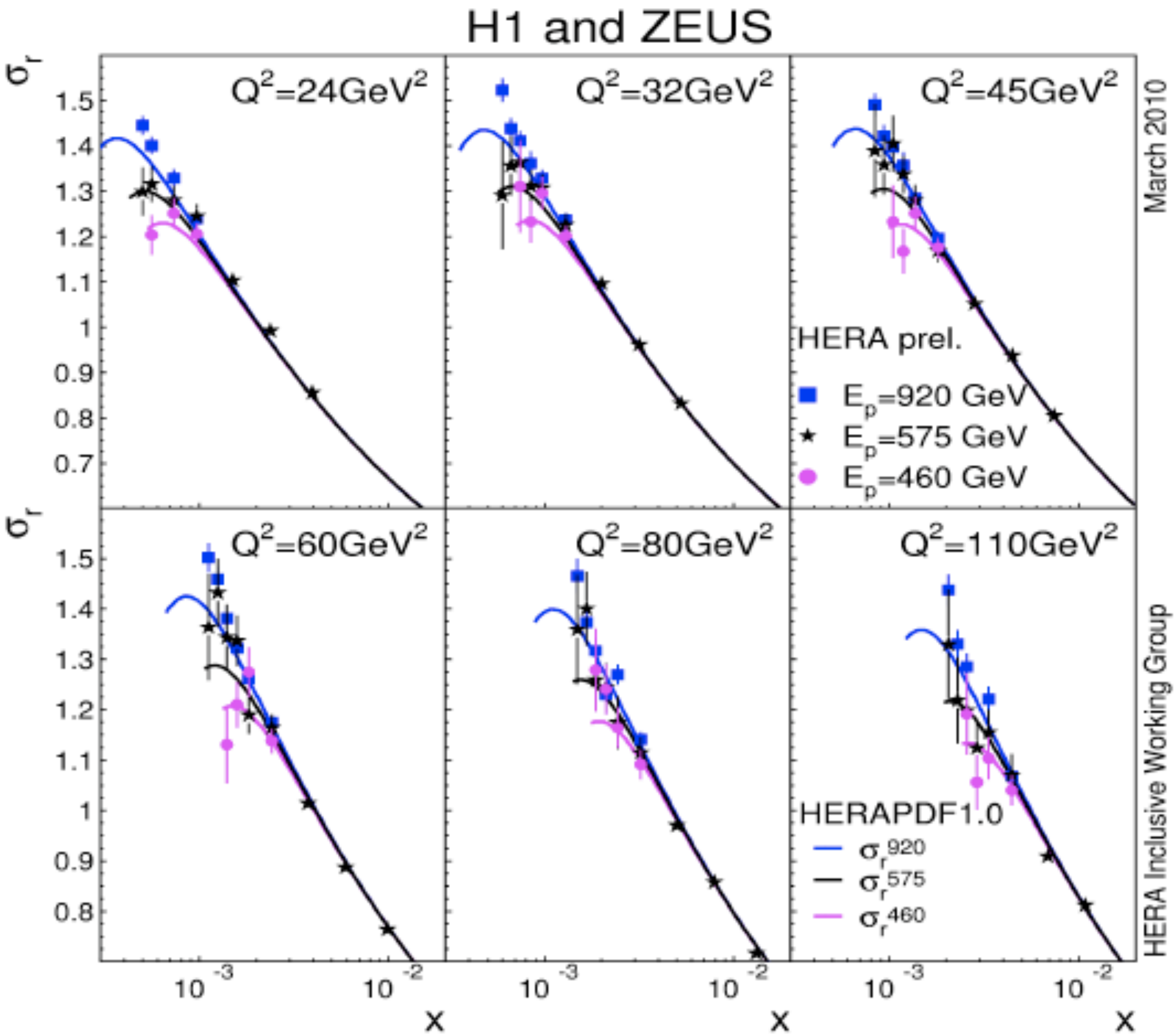
Overall Precision:

- 2% for $3 < Q^2 < 500$ GeV²
- 1% for $2 < Q^2 < 100$ GeV²

Combined cross-sections



ZEUS + H1 measurement

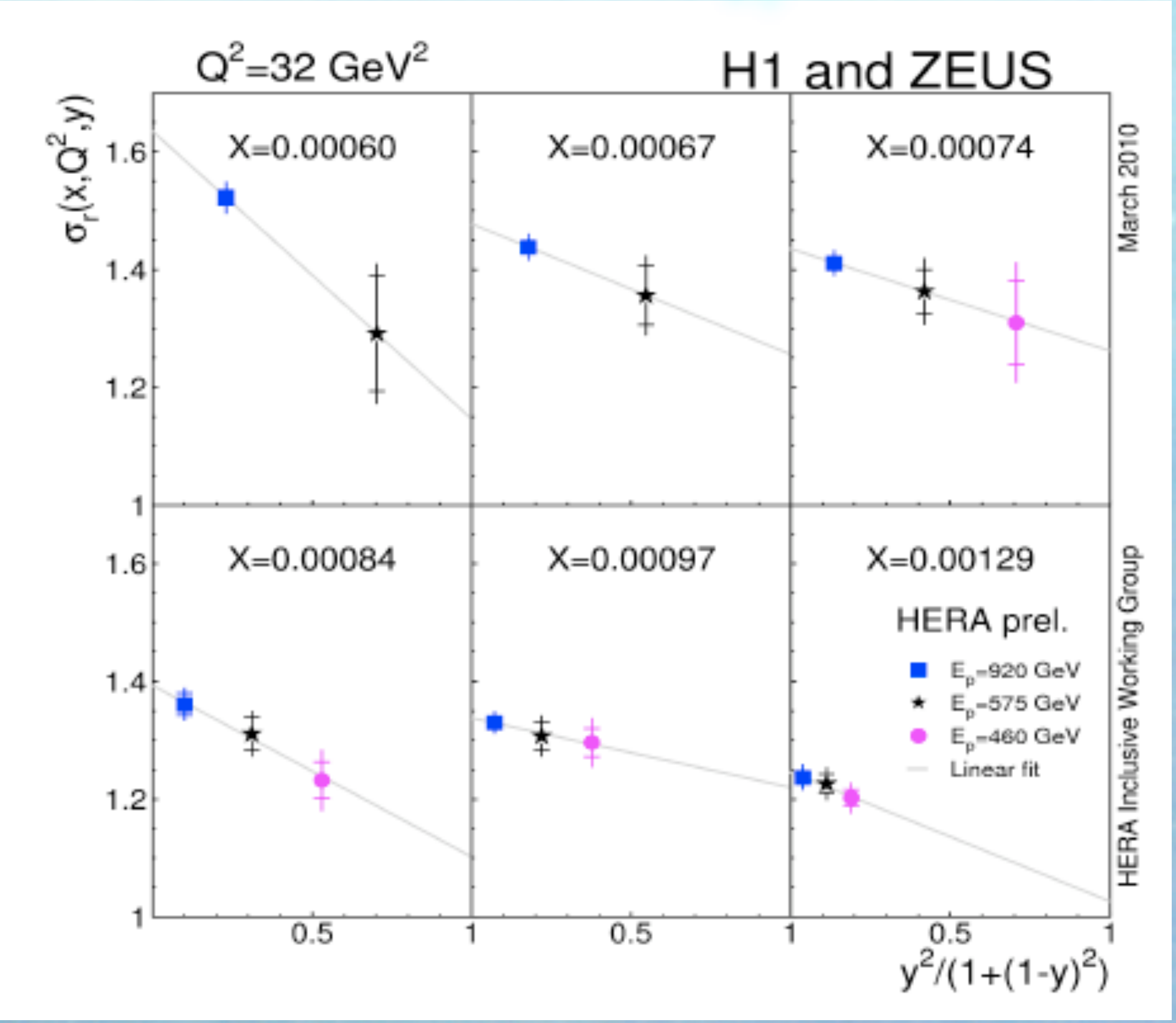


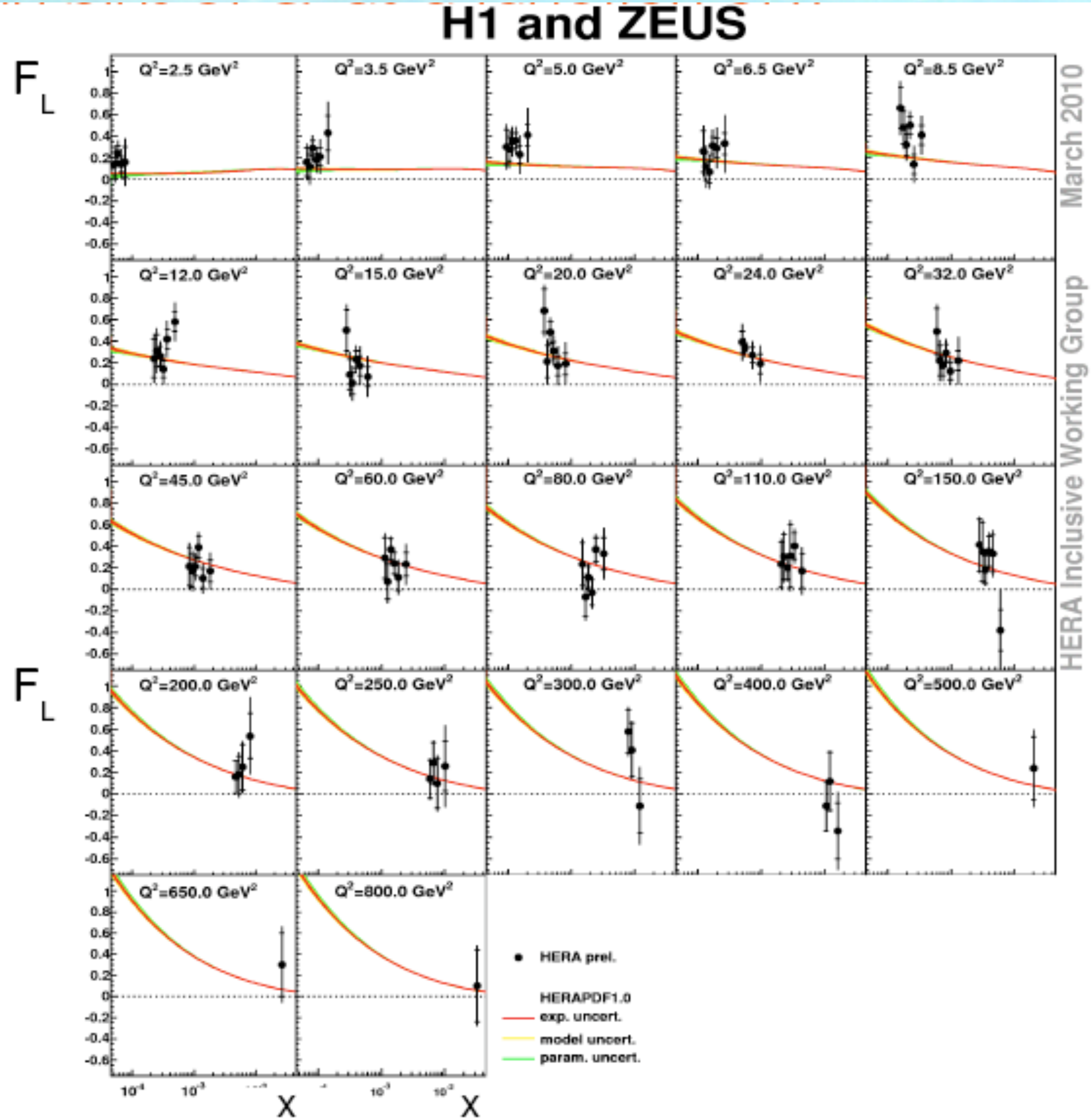
Combined cross-sections

H1 and ZEUS Overlap region

Determination of F_L

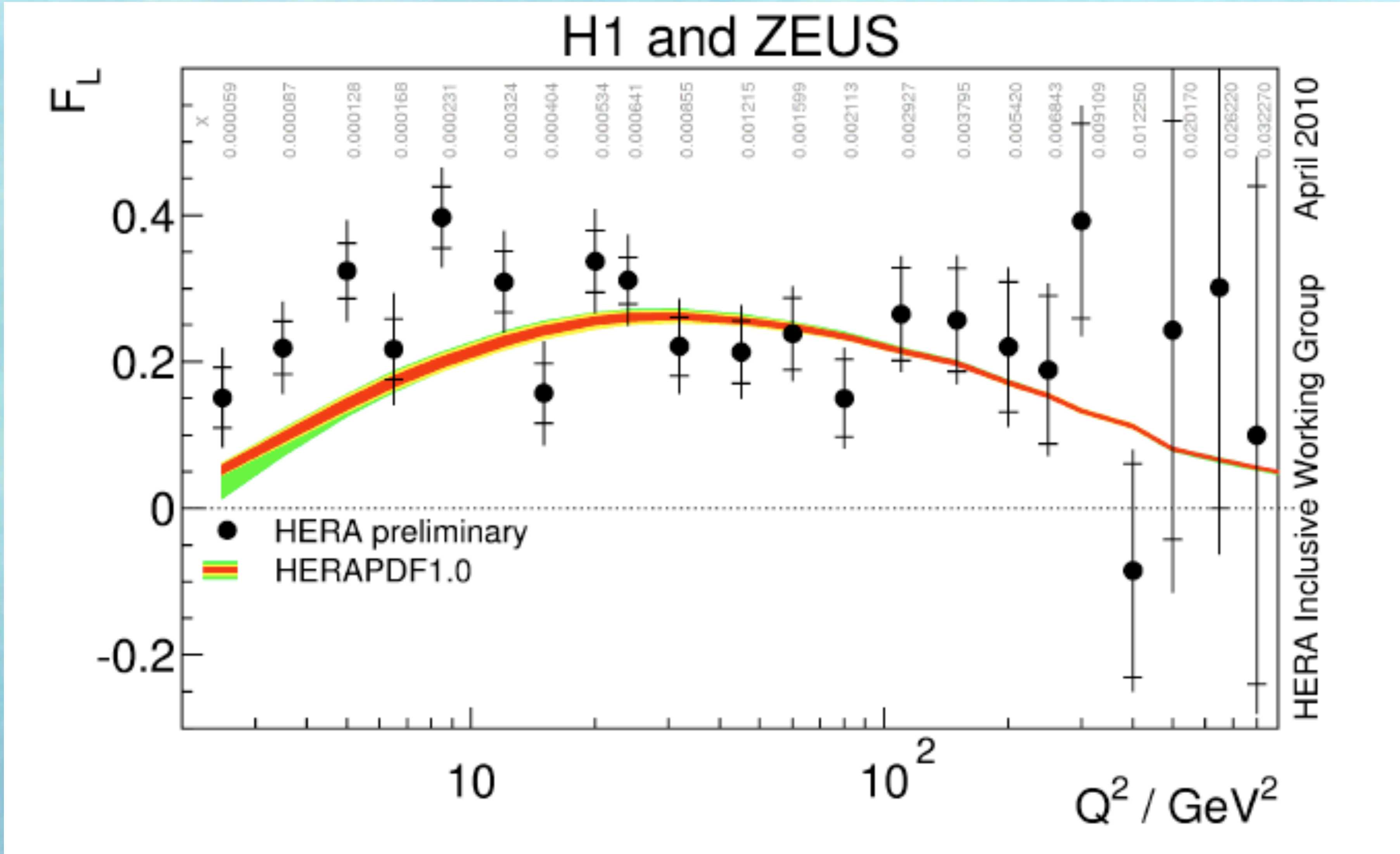
$$\sigma_r(x, Q^2, y) = F_2(x, Q^2) + \frac{y^2}{Y_+} F_L(x, Q^2)$$





H1 and ZEUS
F_L
Q²=2.5 GeV²
Q²=3.5 GeV²
Q²=5.0 GeV²
Q²=6.5 GeV²
Q²=8.5 GeV²
Q²=12.0 GeV²
Q²=15.0 GeV²
Q²=20.0 GeV²
Q²=24.0 GeV²
Q²=32.0 GeV²
Q²=45.0 GeV²
Q²=60.0 GeV²
Q²=80.0 GeV²
Q²=110.0 GeV²
Q²=150.0 GeV²
Q²=200.0 GeV²
Q²=250.0 GeV²
Q²=300.0 GeV²
Q²=400.0 GeV²
Q²=500.0 GeV²
Q²=650.0 GeV²
Q²=800.0 GeV²
HERA prel.
HERAPDF1.0
exp. uncert.
model uncert.
param. uncert.
x
HERA Inclusive Working Group
March 2010

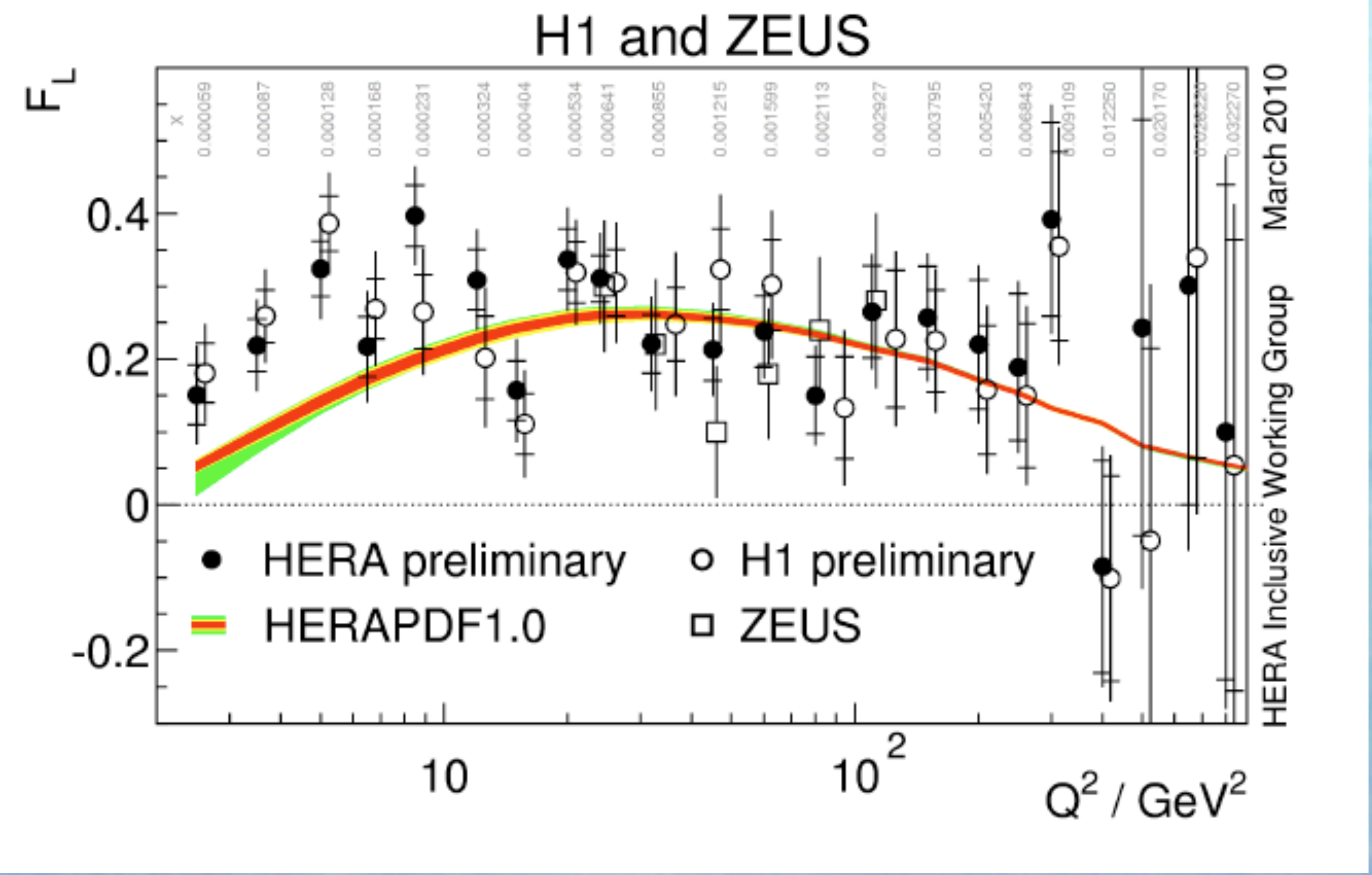
Averaged F_L



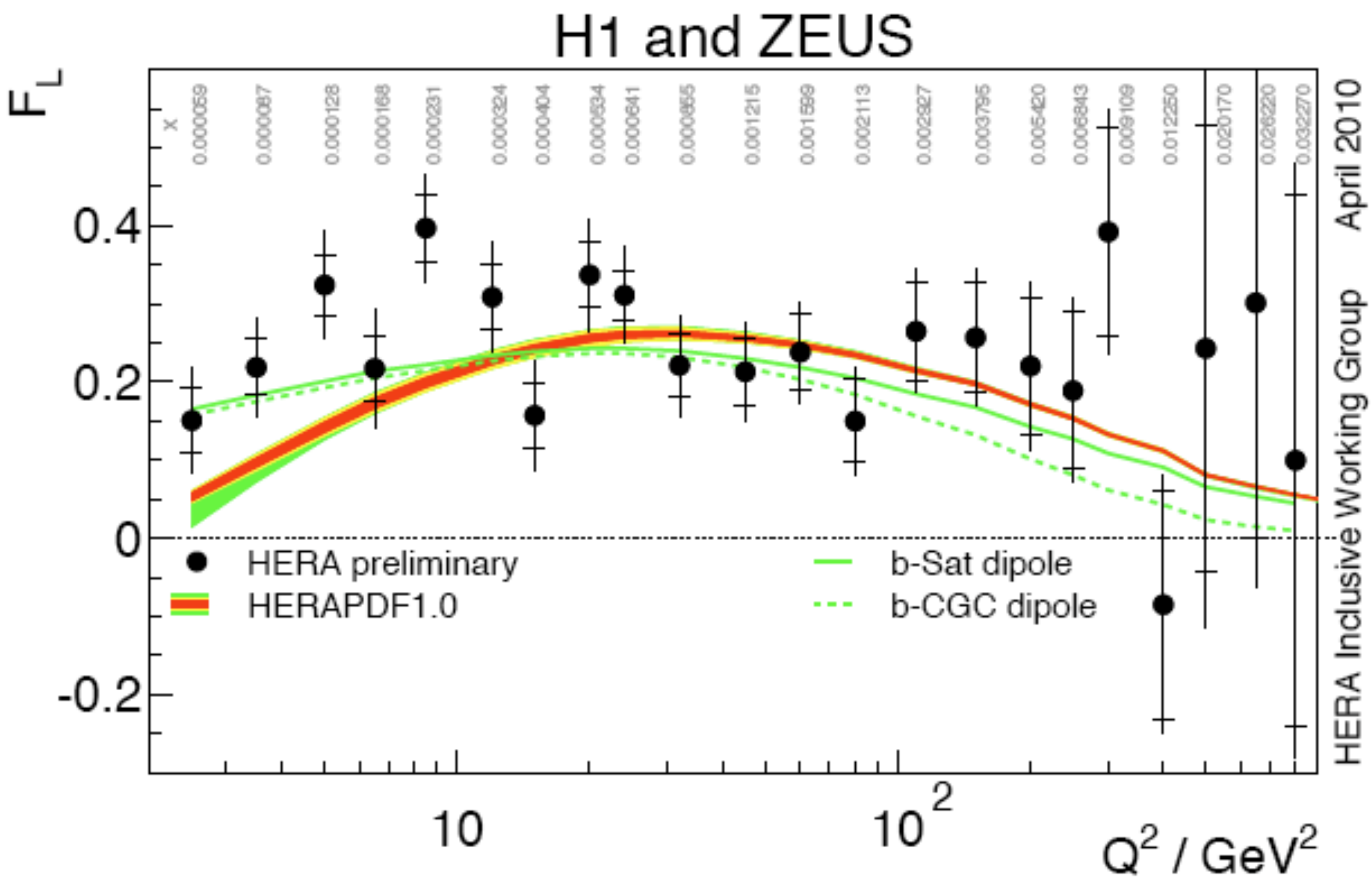
H1 and ZEUS
F_L
x
0.000059
0.000087
0.000128
0.000168
0.000231
0.000324
0.000404
0.000534
0.000641
0.000855
0.001215
0.001599
0.002113
0.002927
0.003795
0.005420
0.006843
0.009109
0.012250
0.020170
0.026220
0.032270
0.4
0.2
0
-0.2
10
10^2
Q^2 / GeV^2
HERA preliminary
HERAPDF1.0
April 2010
HERA Inclusive Working Group

Averaged F_L

Comparison of H1 and ZEUS measurements

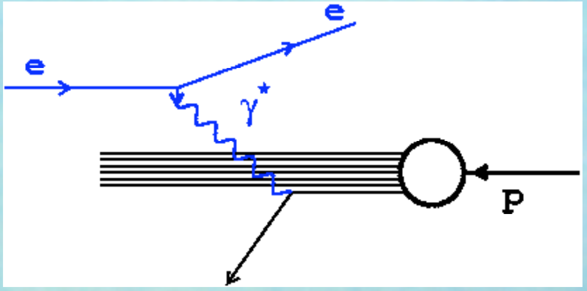


Averaged F_L

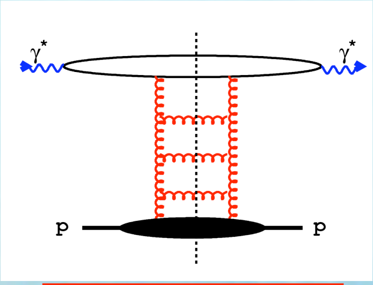


b-Sat dipole with DGLAP evolution
b-CGC dipole with CGC evolution

Gluon Density in the PDF and Dipole scheme



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



PDF

Dipole

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

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

$$\Phi_{DIS} \propto r^2(\Psi_T^2 + \Psi_L^2)$$

$\Psi_{T,L}$ transv. and longit. wave functions

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

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

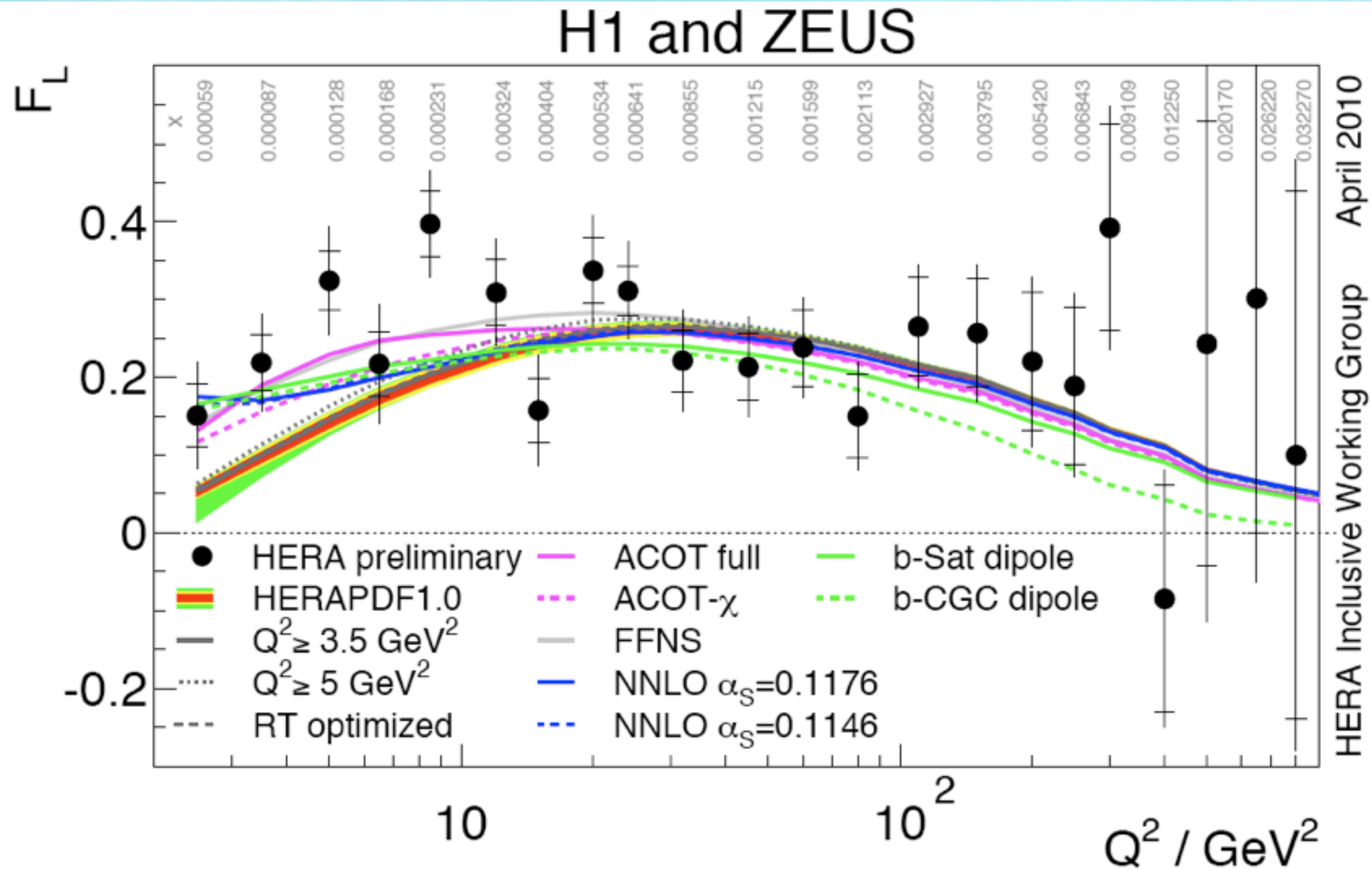
Sea quark + Gluon Density in PDF scheme ≡ Gluon Density in Dipole scheme

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



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 GeV^2 < Q^2 < 800 GeV^2

➤ precision substantially improved

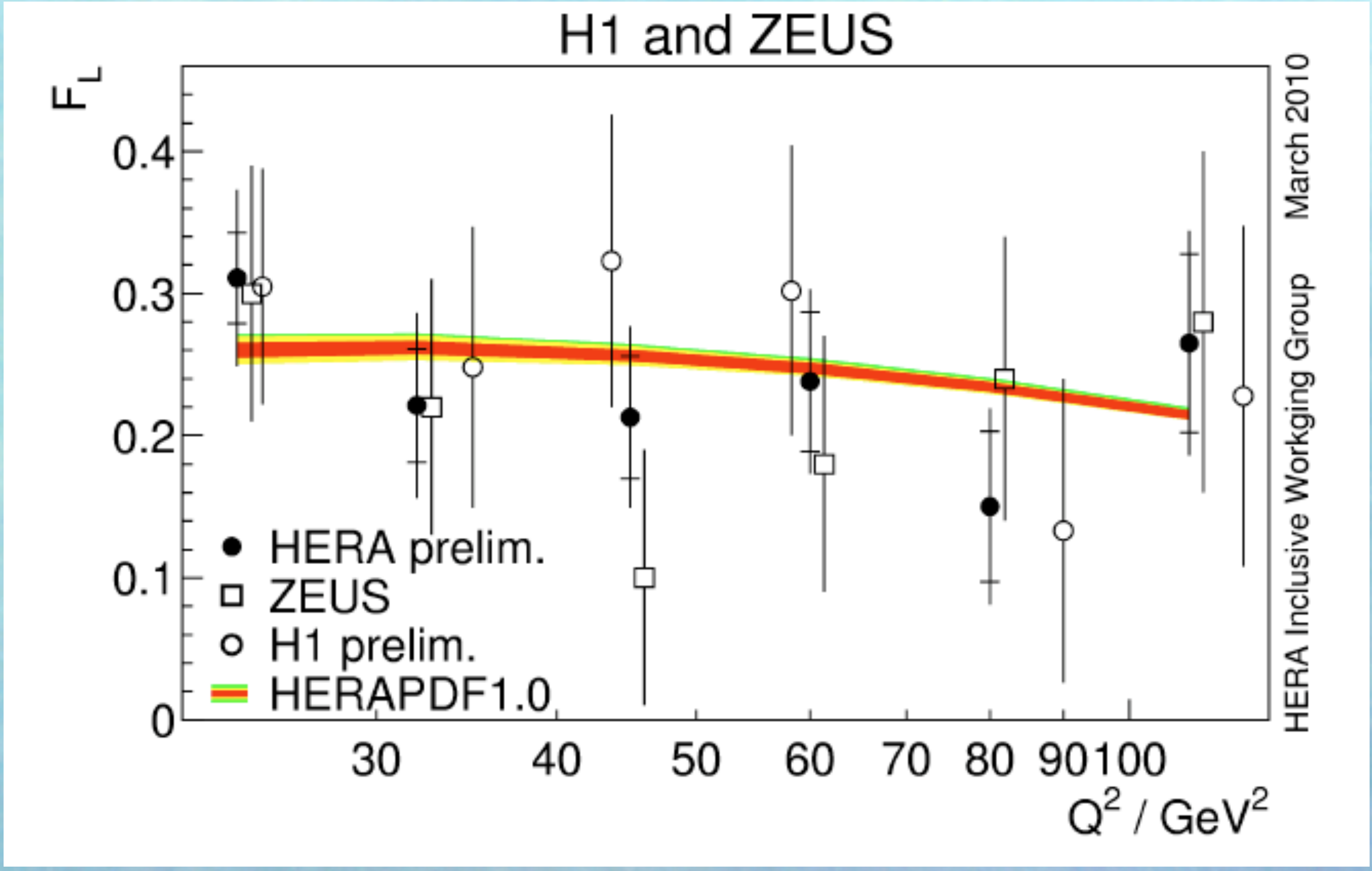
➤ joint F_L is extracted

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
F_L
0.4
0.3
0.2
0.1
0
30
40
50
60
70
80
90100
Q^2 / GeV^2
HERA prelim.
ZEUS
H1 prelim.
HERAPDF1.0
HERA Inclusive Workging Group March 2010