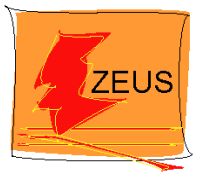
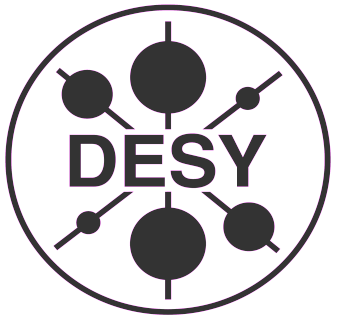




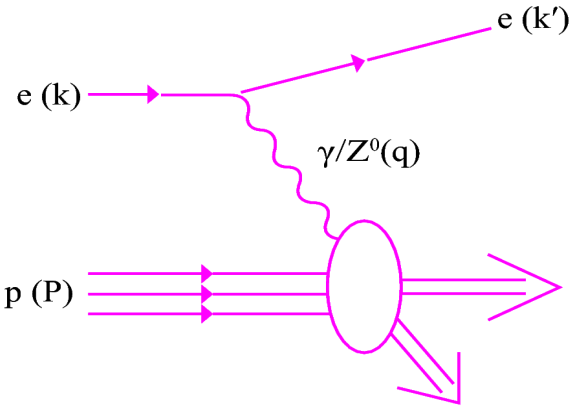
Measurement of the longitudinal structure function F_L with the ZEUS detector

Julia Grebenyuk
on behalf of the ZEUS collaboration

DIS09 conference, Madrid, Spain
27 April 2009

DIS and structure functions

Deep Inelastic Scatteling is a key tool for studing structure of the proton



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

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

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

Q^2 – virtuality of exchanged photon
x – Bjorken scaling variable
y – inelasticity
s – center-of-mass energy

The structure functions:

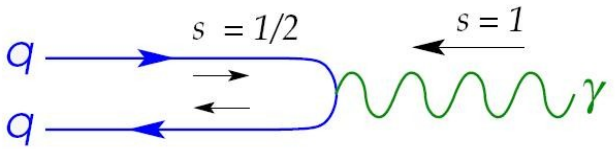
→ F_2 - dominant term, contains quark and gluon contributions

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

Longitudinal structure function F_L

- F_L is an independent structure function
- F_L is proportional to proton/longitudinally polarised photons cross section

- In the Quark-Parton model $F_L = 0$ (helicity and angular momentum conservation for spin-1/2 quarks)



- In QCD $F_L > 0$ due to gluon radiation

  $\rightarrow$ F_L is directly sensitive to gluon densities

  $\rightarrow$ F_L is a QCD effect

Motivation

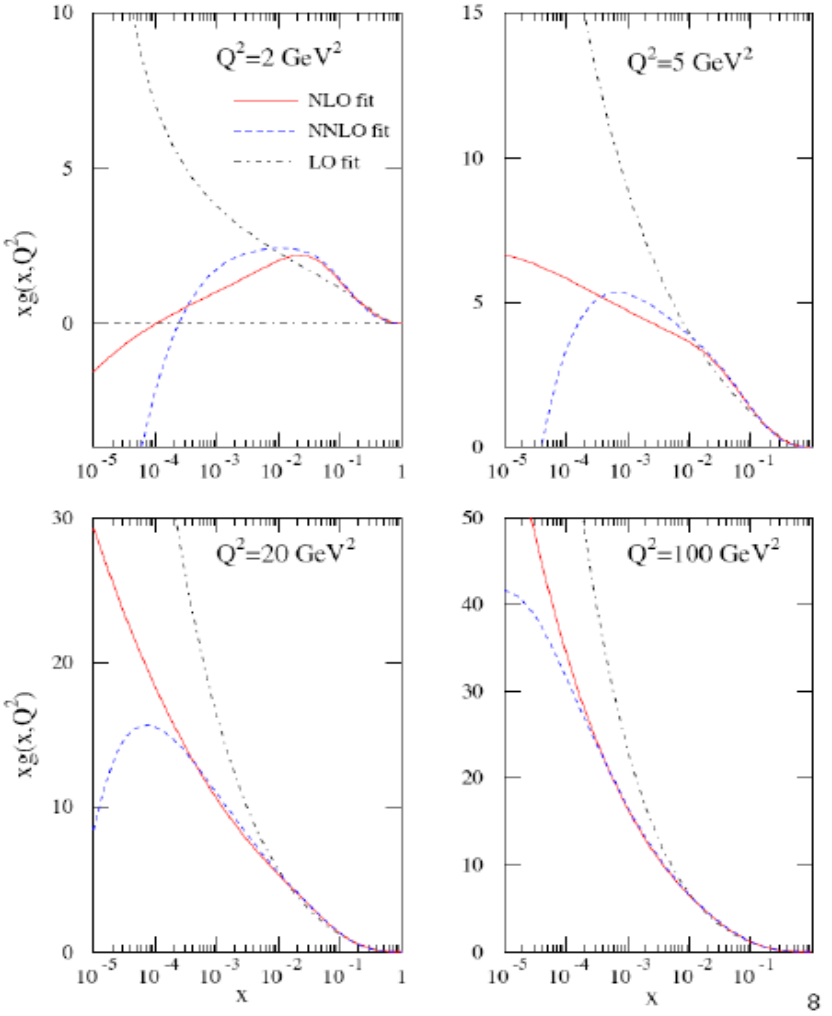
- F_2 is extracted from measured cross sections:

  → Previous F_2 extractions depend on assumptions about F_L

  → Need model independent way to extract F_2

- Theoretical predictions for gluon densities differ at low x and low Q^2

⇒ Need to measure F_L

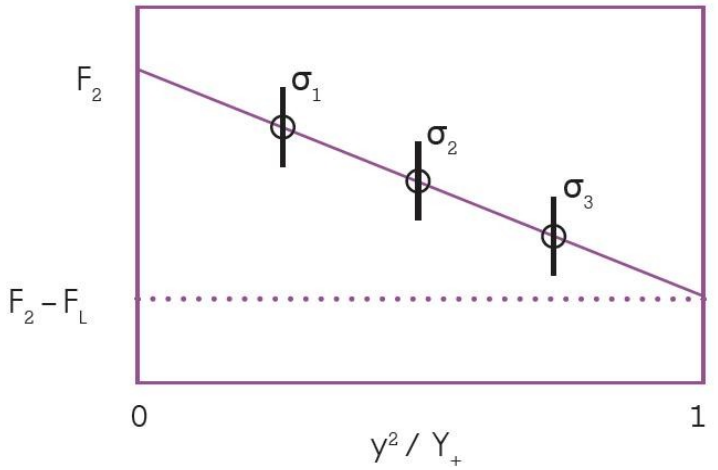


MSTW

Analysis strategy

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

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



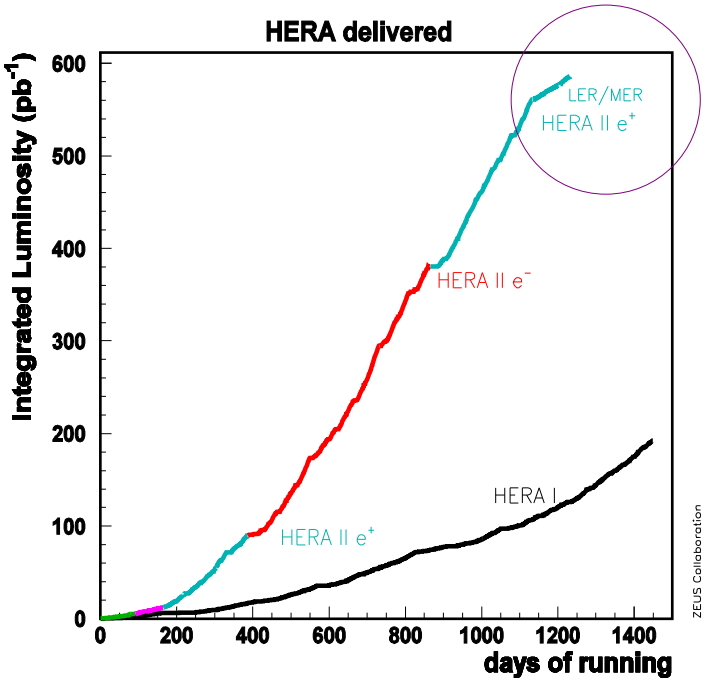
- Larger difference in y → better sensitivity to F_L (bigger "lever arm")

At given x and Q^2:
→ F_2 is the intercept at y-axis
→ F_L is the negative slope

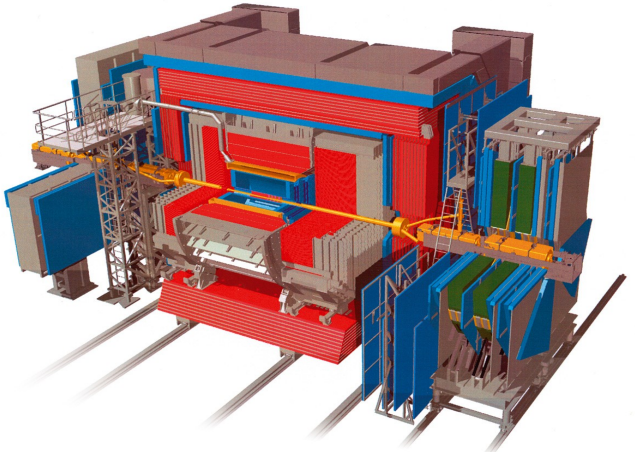
- **$Q^2 = xys$**: different y → different s → different beam energies
- Direct F_L measurement only possible if HERA operates with different proton beam energies

Experimental setup

- HERA is an ep-collider in Hamburg, Germany
- 2 colliding beam experiments: ZEUS, H1
- Most luminosity taken with E_e = **27.5** GeV, E_p = **920** GeV
- In the last year of running HERA operated with lowered proton beam energies: **460** GeV and **575** GeV



ZEUS detector:



Data used for F_L analysis:

920 GeV $\rightarrow$ 44 pb^{-1}

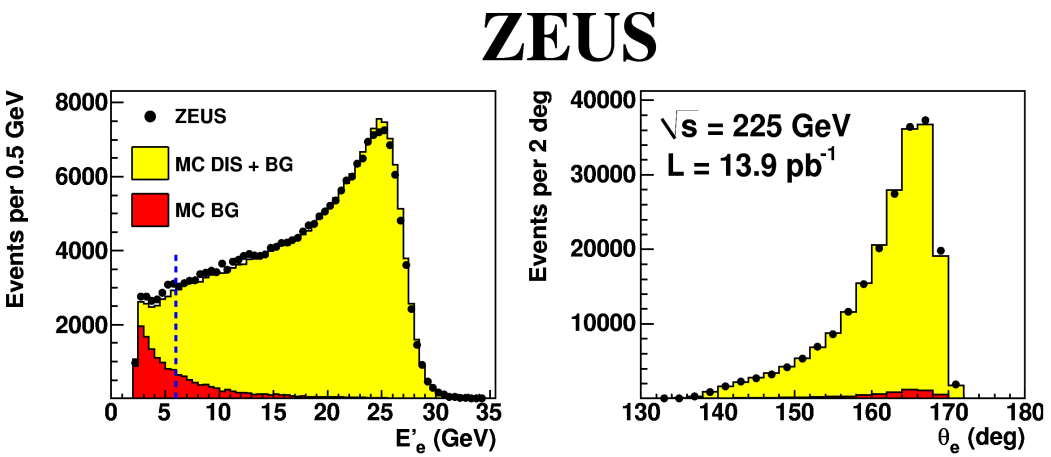
460 GeV $\rightarrow$ 14 pb^{-1}

575 GeV $\rightarrow$ 7 pb^{-1}

Reconstructing the kinematics

Information from scattered electron (E'_e, Θ'_e) is used to reconstruct the kinematics:

$$y = 1 - \frac{E'_e}{E_e}\sin^2\frac{\theta_e}{2}\,, \quad Q^2 = \frac{E'^2_e \sin^2\theta_e}{1-y}$$



Low-y high-s

→ high energy well separated scattered electron

→ almost no background

High-y low-s

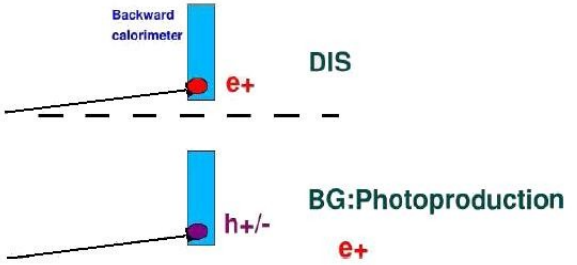
→ low energy scattered electron

→ lot of hadronic activity around scattered electron

→ large background

Photoproduction background

- Main background for the measurement is photoproduction:
  - Electron escapes down the beam pipe
  - A hadron or a photon is misidentified as scattered electron



- Photoproduction events are rejected with cuts and the rest are subtracted statistically using MC

- Neutral background is rejected with track requirement. ZEUS tracking system acceptance is limited to $\theta<154°$

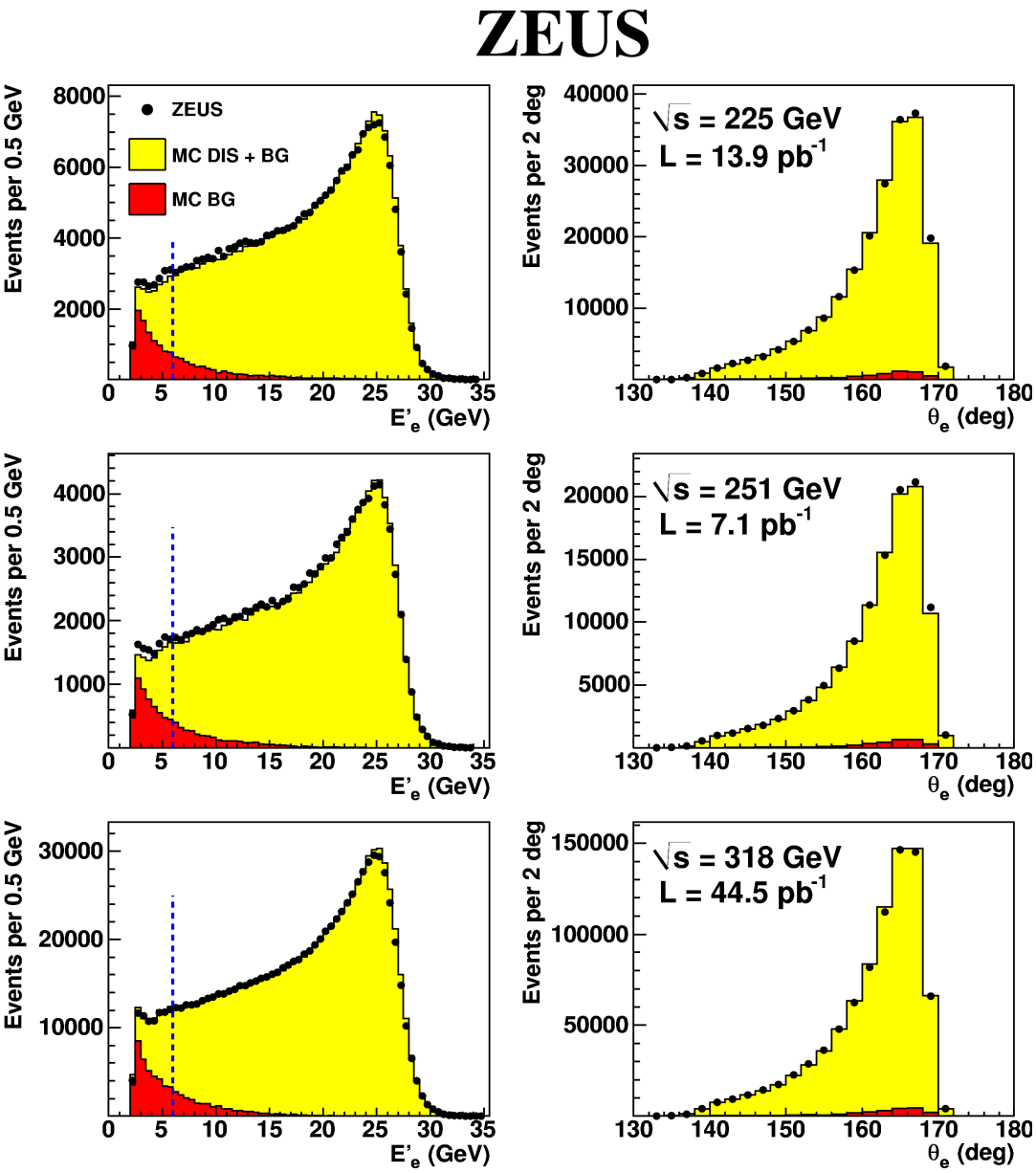
  $\rightarrow$ However, the information about single hits in the tracking detectors can be used up to $\theta<168\,^{\circ}$ (but with no information about the charge)

- MC normalisation is checked with 6m-tagger

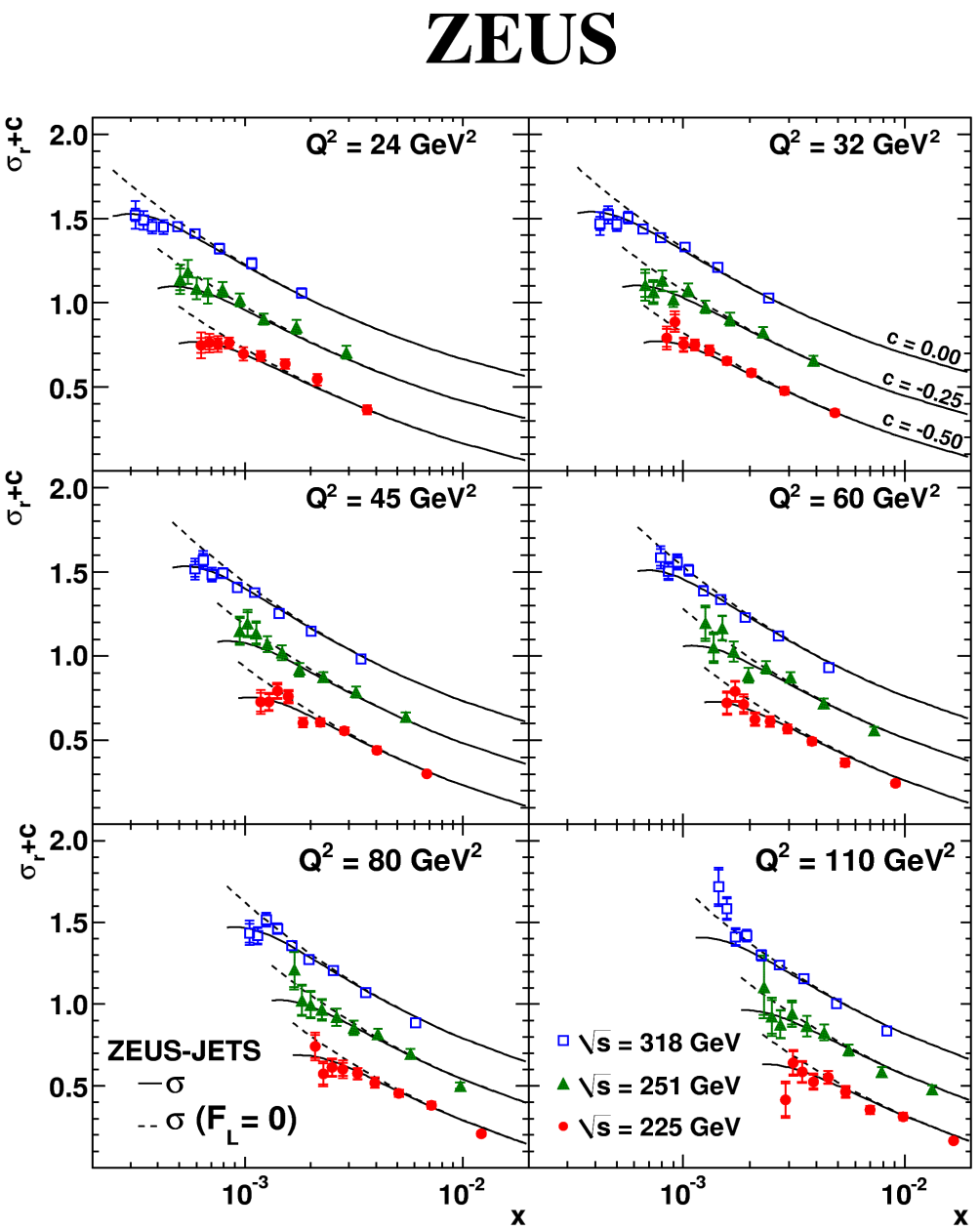
Control distributions

- 3 data sets are used for the measurement
- Center-of-mass energies:
  - 225 GeV (LER)
  - 251 GeV (MER)
  - 318 GeV (HER)

- Final data samle: 97% signal, 3% background
  - Background contribution is 16% in most affected bin (at low Q^2 and high y)



Measured reduced cross sections



Kinematic region:

$20\ \text{GeV}^2 < Q^2 < 130\ \text{GeV}^2$

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

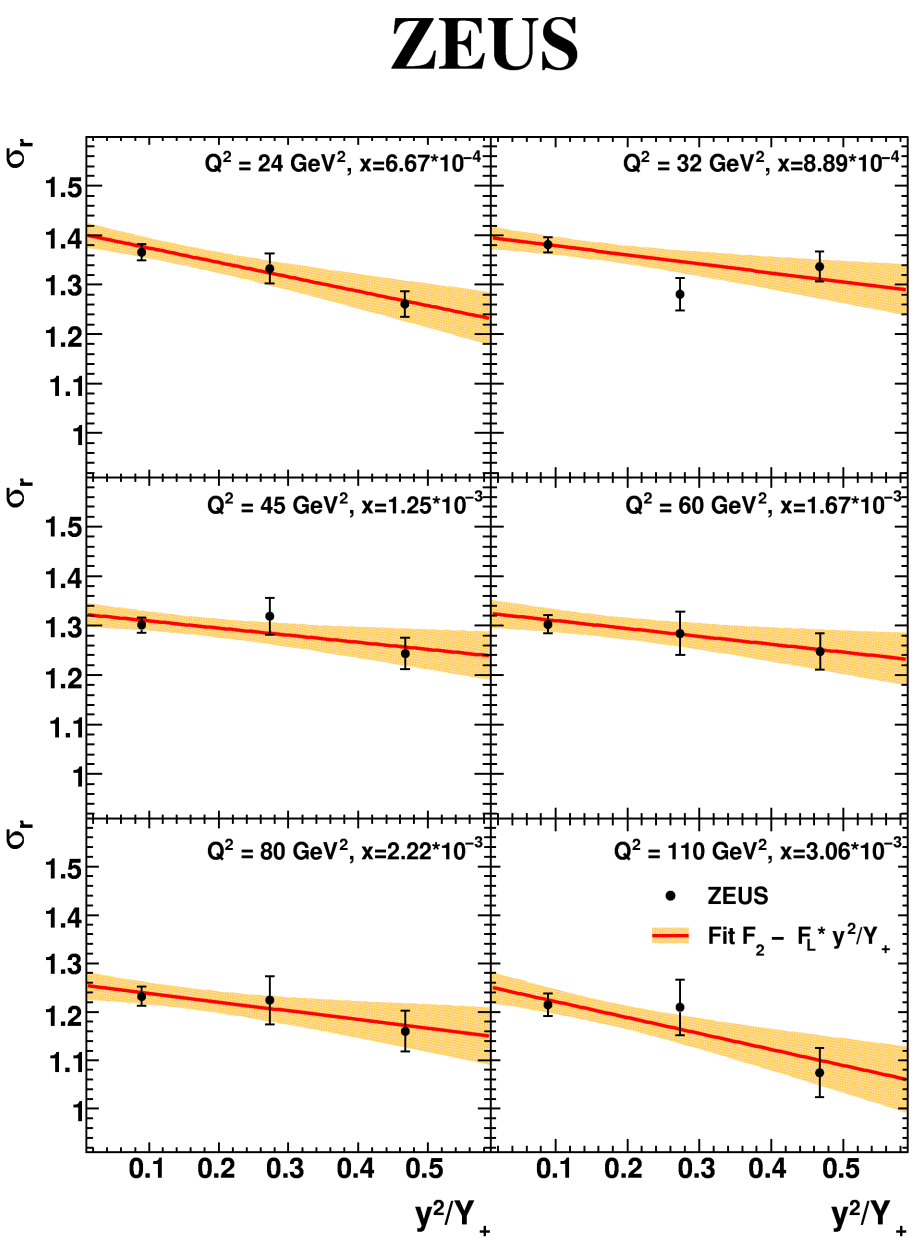
- First ZEUS F_L publication available
- Most precise cross section measurement from ZEUS in the kinematic region studied
- Measured cross sections are published and available for fits
- Measured cross sections compared to ZEUS-JETS with and without F_L
- **Turnover at low x small but visible**

F_L fit

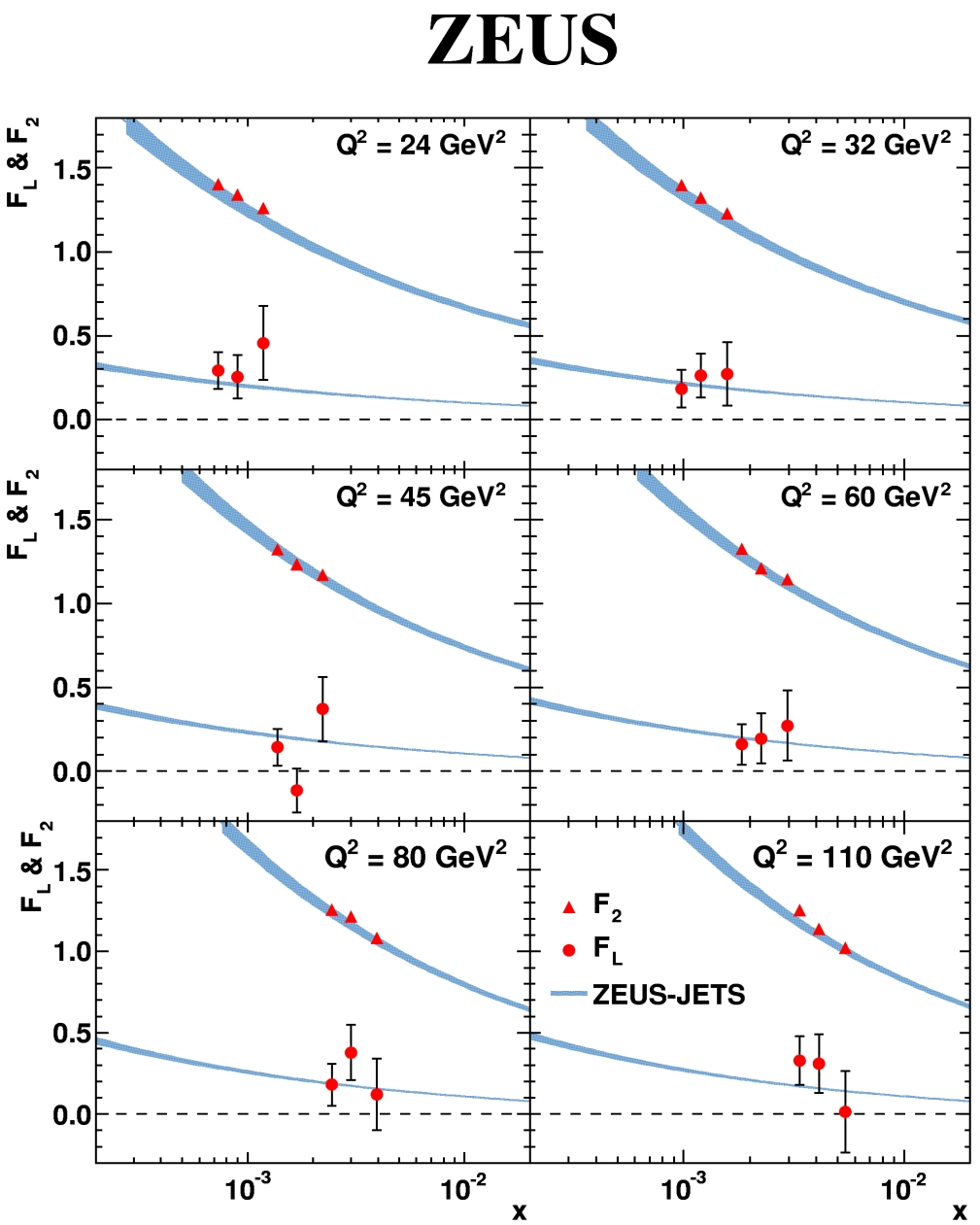
- Before fit three data sets are normalised to lunimosity-weighted average at low y (y<0.3)

- Fit was performed within Bayesian approach assuming flat prior probabilities
  - Full information about correlations is taken Into account

- To extract F_L and F_2 48 parameters were fit:
  → 18 F_2 and 18 F_L values
  → 3 uncertainties on relative normalisation factors
  → 9 systematic uncertainties



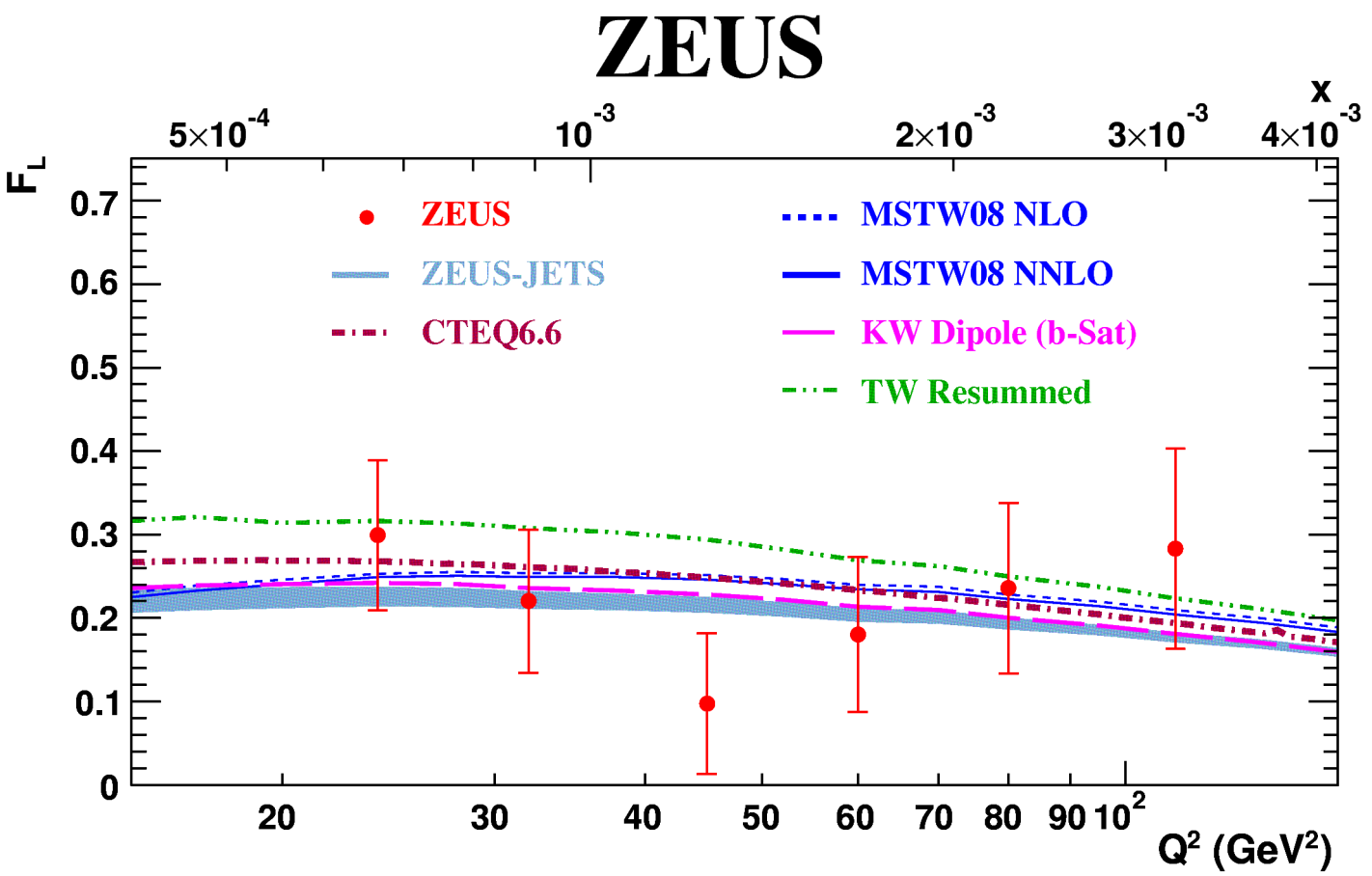
Extracted F_L and F_2



- **Most precise F_2 measurement from ZEUS at kinematic region studied**
- **First F_2 measurement without assumptions on F_L**

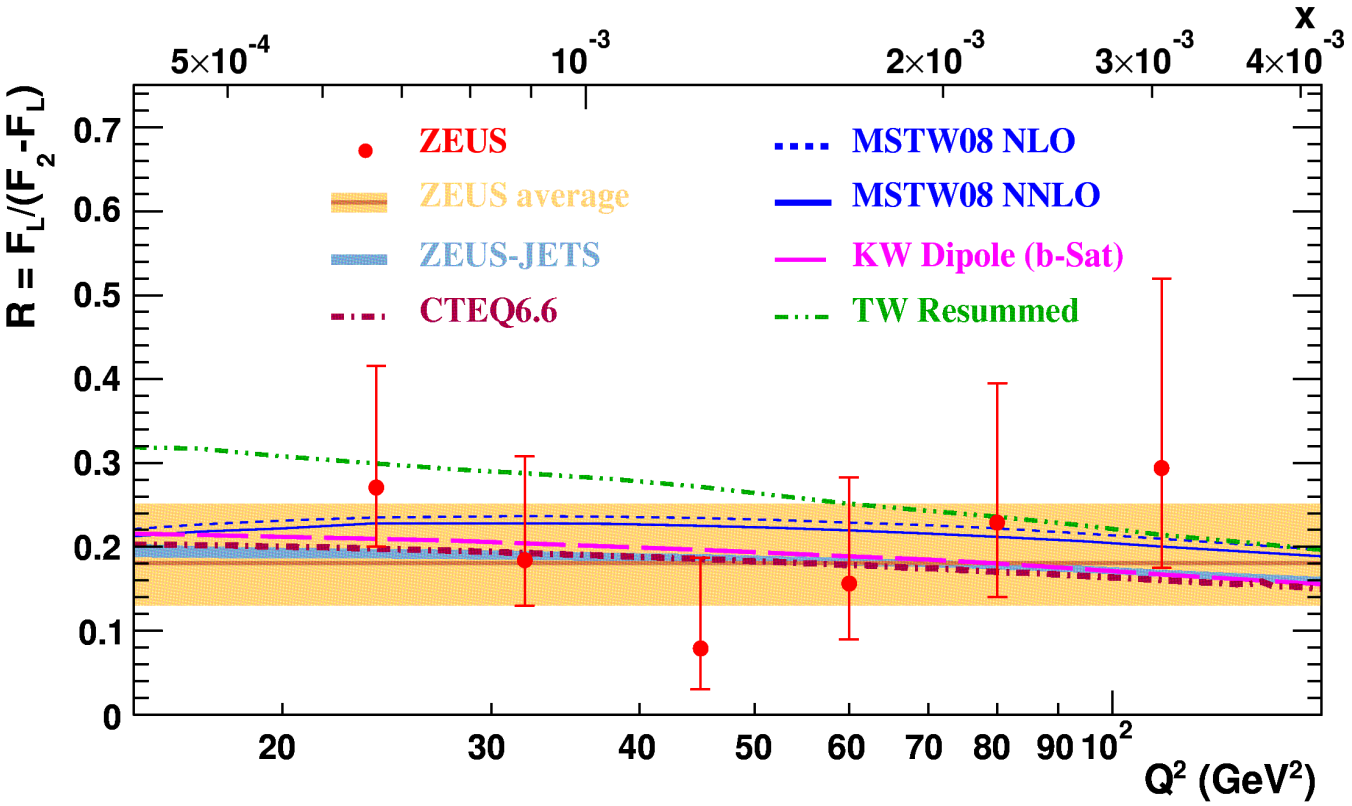
- Data support a non-zero F_L
- Predictions for F2 and FL are consistent with data

Averaged F_L



- Data support a non-zero F_L
- Predictions are consistent with data

Averaged R



Ratio R is fitted:

$$R = F_L/(F_2 + F_L)$$

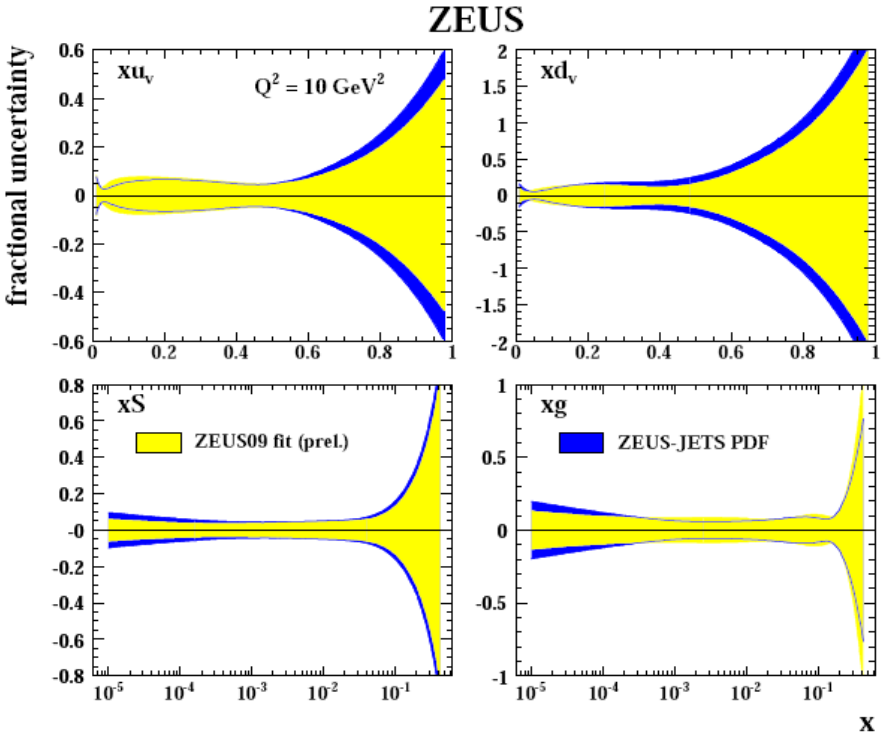
Average R from all data:

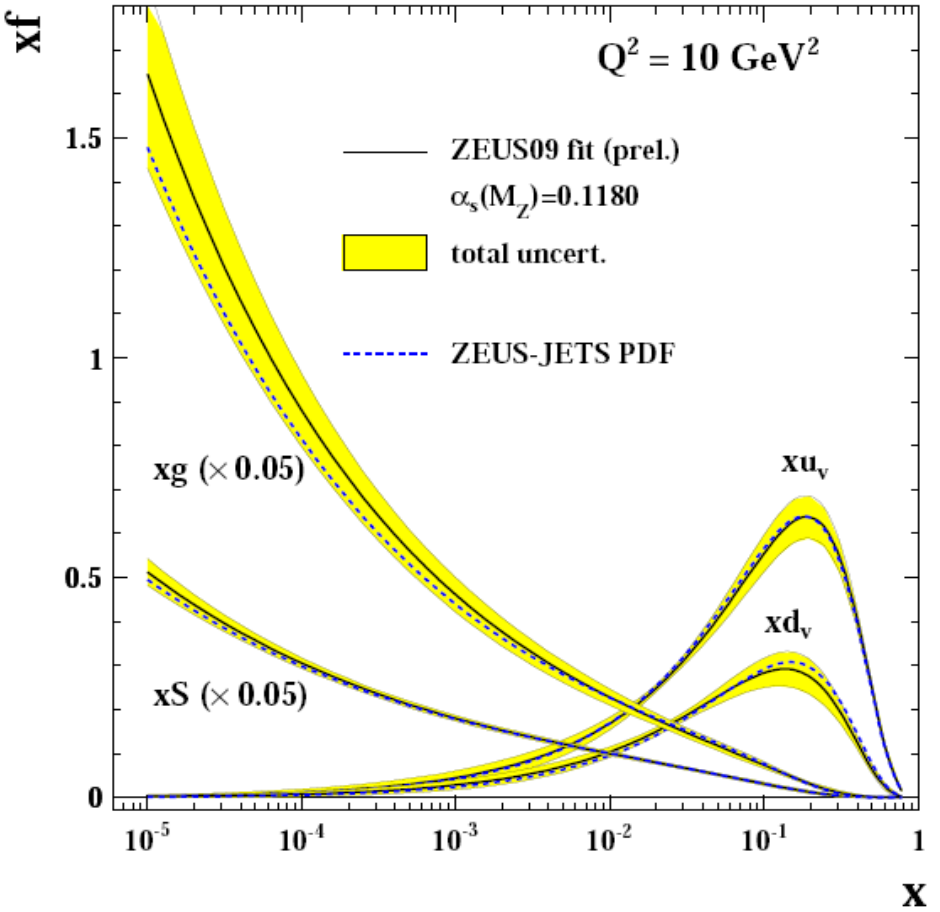
$$R = 0.18\ ^{+0.07}_{-0.05}$$

PDF fits with F_L data included

- Measured coss sections for 3 data sets (HER, LER, MER) are included in ZEUS PDF fits
- Data has impact on the low x:
  - Steeper rise of gluon at low x
  - Sea and gluon uncertainty reduced

→ **For more details see talk of A. Cooper-Sarkar**





Summary

- First F_L analysis by ZEUS published: arXiv:0904.1092v1 (hep-ex) (submitted to Phys.Lett.B)
- F_L values are extracted in the kinematic region: $5 \cdot 10^{-4} < x < 7 \cdot 10^{-3}$, $20\ \text{GeV}^2 < Q^2 < 130\ \text{GeV}^2$
  - Non-zero F_L is observed
  - QCD predictions are consistent with data

- First F_2 measurement without assumptions on F_L has been performed
  - The most precise F_2 measurement from ZEUS in the kinematic region studied

- Cross section data are published and available for fits
- Measured reduced cross sections are included in ZEUS PDF fits
  - Improvement in low-x region