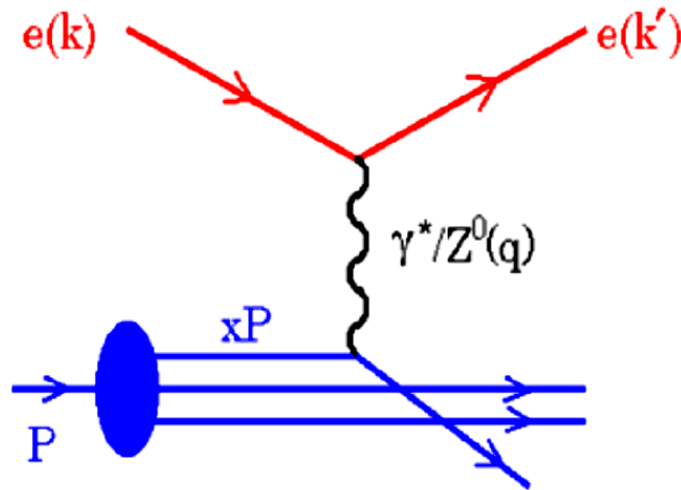# Measurement of $\mathbf{F_L}$ at low $\mathbf{Q^2}$ by the H1 collaboration

DIS09, Madrid

S. Glazov, DESY

DIS kinematics

For low Q^2:

$$\frac{d^2\sigma}{dx dQ^2} = \frac{2\pi\alpha^2 Y_+}{Q^4 x}\sigma_r =$$

$$= \frac{2\pi\alpha^2 Y_+}{Q^4 x}\left[F_2(x, Q^2) - \frac{y^2}{Y_+}F_L(x, Q^2)\right]$$

where factors $Y_+ = 1 + (1 - y)^2$ and y^2 define polarization of the exchanged photon and $y = Q^2/(sx)$.
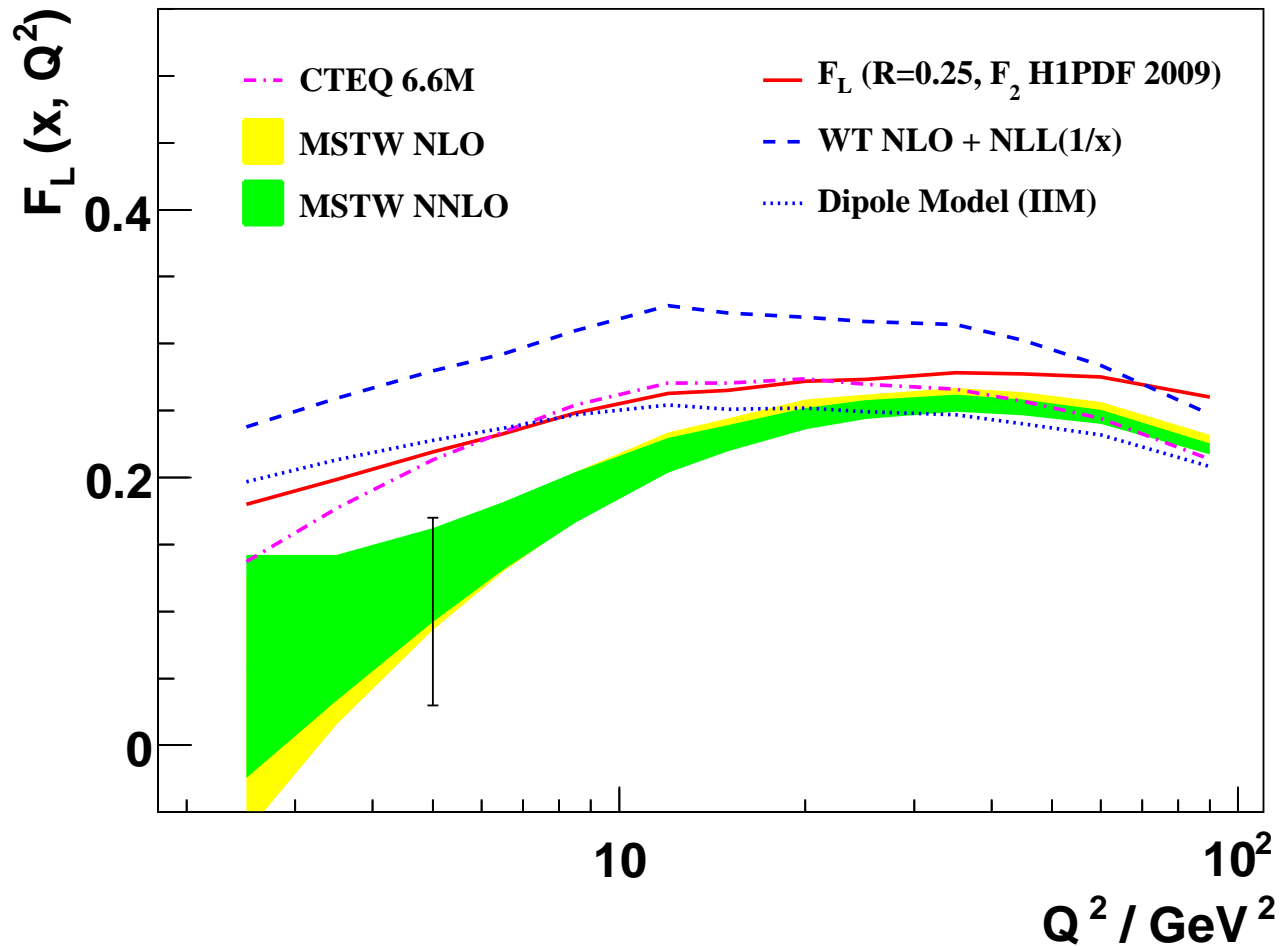
$$F_2 \sim \sigma_L + \sigma_T \quad F_L \sim \sigma_L$$

which implies $0 \le F_L \le F_2$.

One can define $R = \sigma_L/\sigma_T$, i.e. $F_L = \frac{R}{1 + R}F_2$

- In Quark-Parton Model $F_L = 0$ for spin $1/2$ quarks.

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

- At low x, sea quark and gluon density are measured using F_2 and its scaling violation, $dF_2/d\log Q^2$.
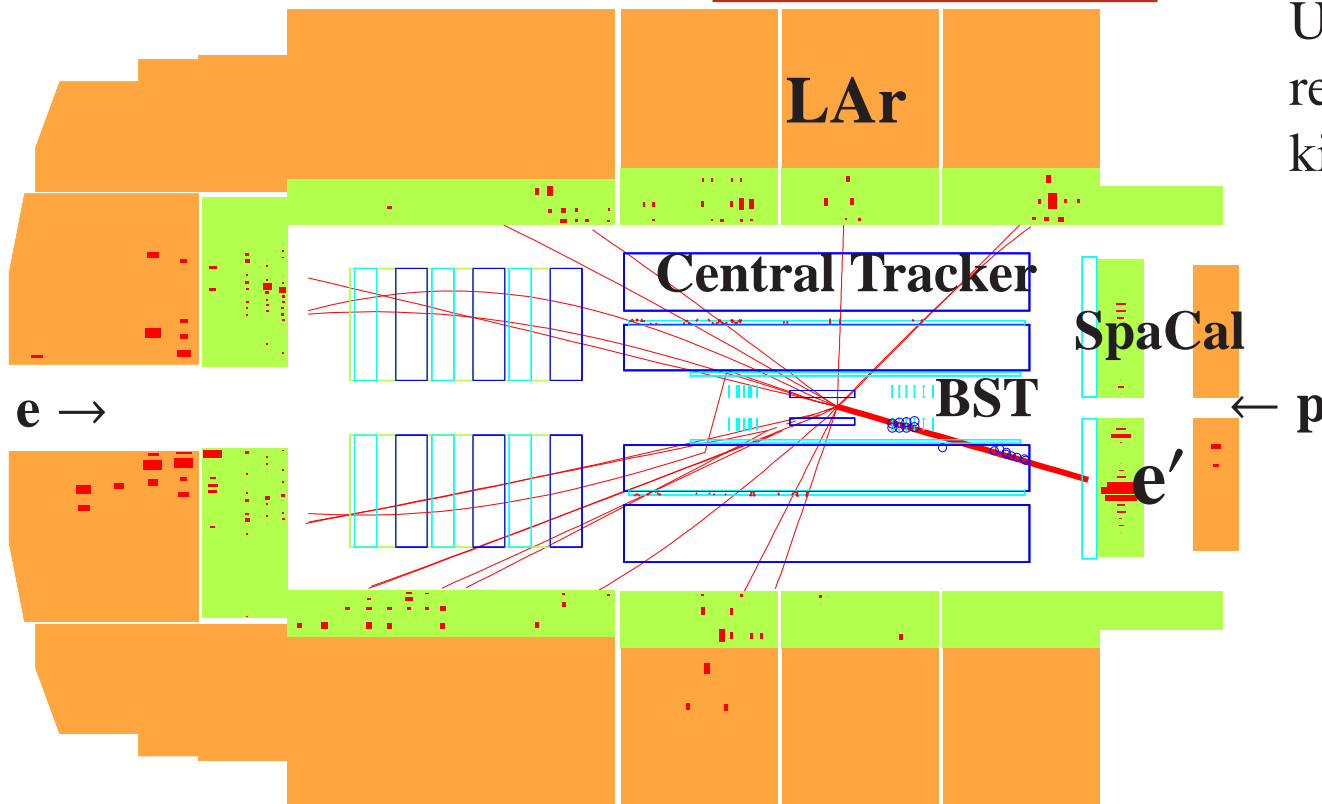 F_L measures gluon via cross section polarization decomposition.

F_L at low x and low Q^2

Significant spread of predictions for low Q^2 and low x compared to the experimental precision.

3

H1 Detector

Use the scattered electron to reconstruct event kinematics

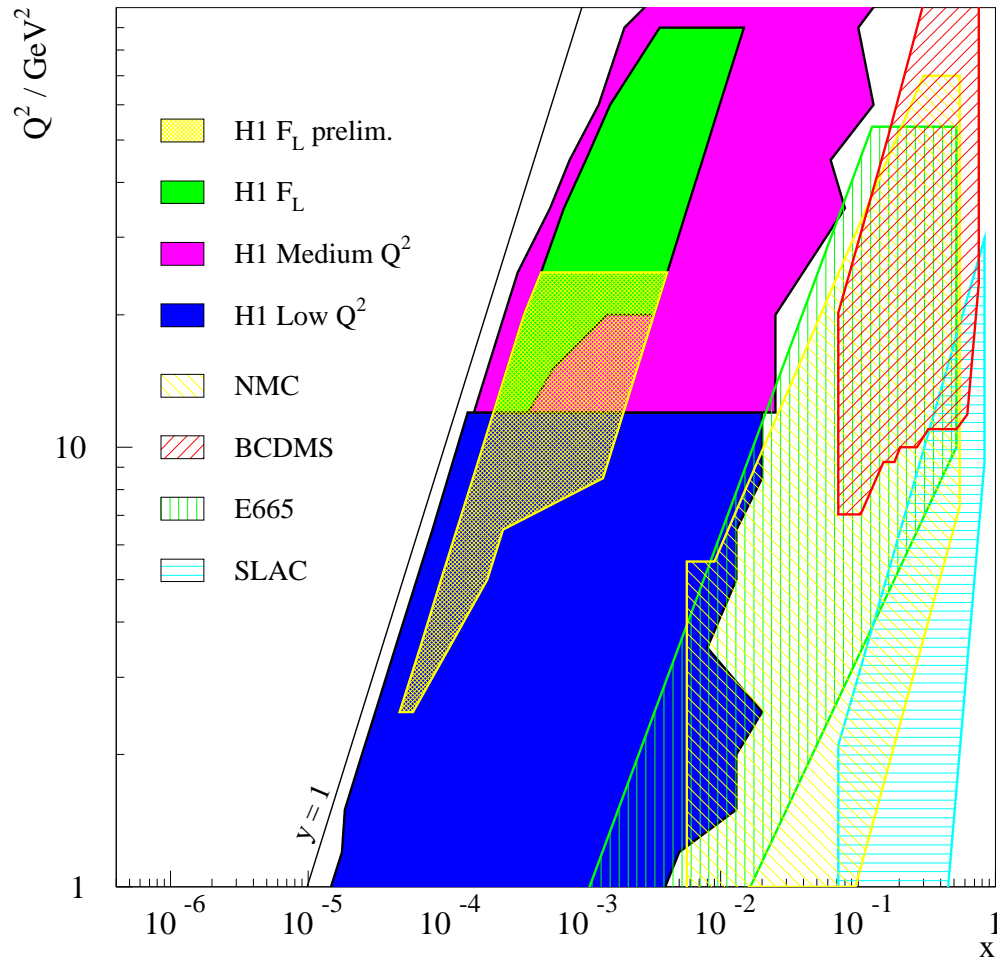$$Q^2 = 4 E_e E'_e \cos^2 \frac{\theta_e}{2}$$

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

$$x = \frac{Q^2}{S y}$$

Three separate measurements, defined by electron measurement techniques:

- Medium Q^2, $12 \leq Q^2 \leq 90$ GeV^2, SpaCal+CT, Phys.Lett.**B**665:139 (2008)
- High Q^2, $35 \leq Q^2 \leq 800$ GeV^2, LAr + CT (H1 preliminary).
- low Q^2, $2.5 \leq Q^2 \leq 25$ GeV^2, SpaCal+BST+CT.
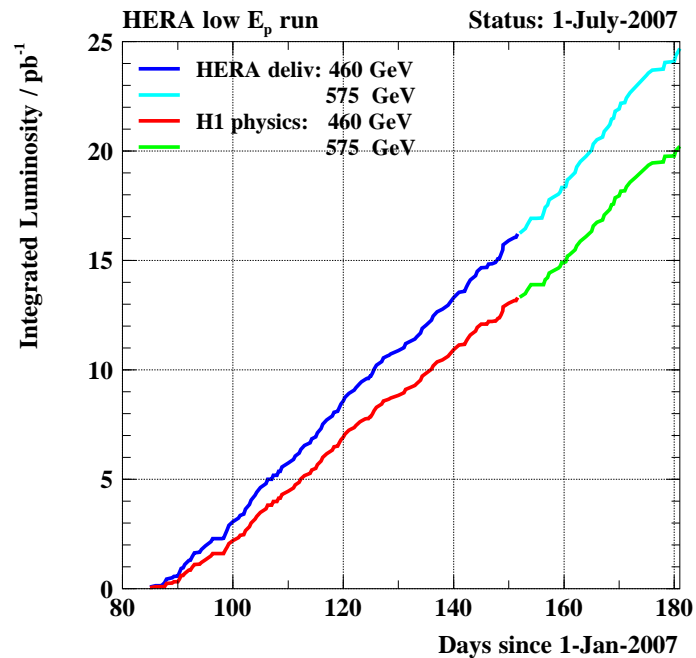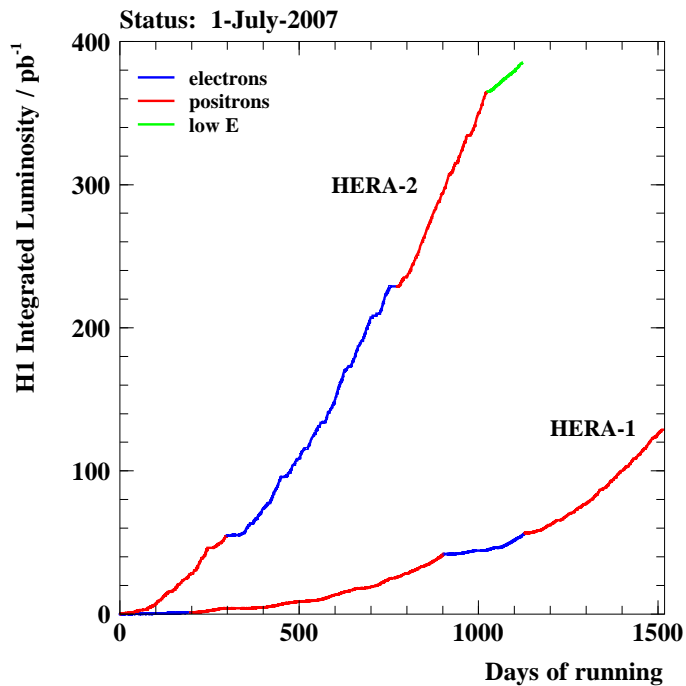
4

Kinematic Coverage

- Measure in the domain already covered by HERA DIS cross section measurements.

- Use data sets with 3 proton beam energies: E_p=460, 575 and 920 GeV. E_p=920 GeV sample comes from HERA-I 99-00 (see talks of J.Kretzschmar and A. Petrukhin). This gives
  - Extension of F_L measurement to $Q^2 < 6.5$ GeV^2
  - Highest precision at low y.

- BST-CJC-SpaCal measurement for $2.5 \leq Q^2 \leq 25$ GeV^2.

- Combined measurement using SpaCal and LAr for $Q^2 \geq 35$ GeV^2 range.

5

Measurement Strategy

$$\sigma_r(x, Q^2; y) = F_2(x, Q^2) - \frac{y^2}{1 + (1 - y)^2} F_L(x, Q^2)$$

- Measure at the same x, Q^2, different y — use different E_p

- Increase sensitivity by using largest spread in
  $f(y) = y^2/(1 + (1 - y)^2)$: $E_p^{max}/E_p^{min} \to$ max, $y \to 1$.

6

High y Experimental Challenge

Measurement at both low and high y are required. High y is much more difficult.

$$y \approx 1 - \frac{E'_e}{E_e}$$

Measurement extends down to $E'_e = 3.4$ GeV.

- Trigger efficiency/rate
- Electron identification
- Radiative corrections
- Background

Background Estimation

Measure particle charge using curvature of the associated track.
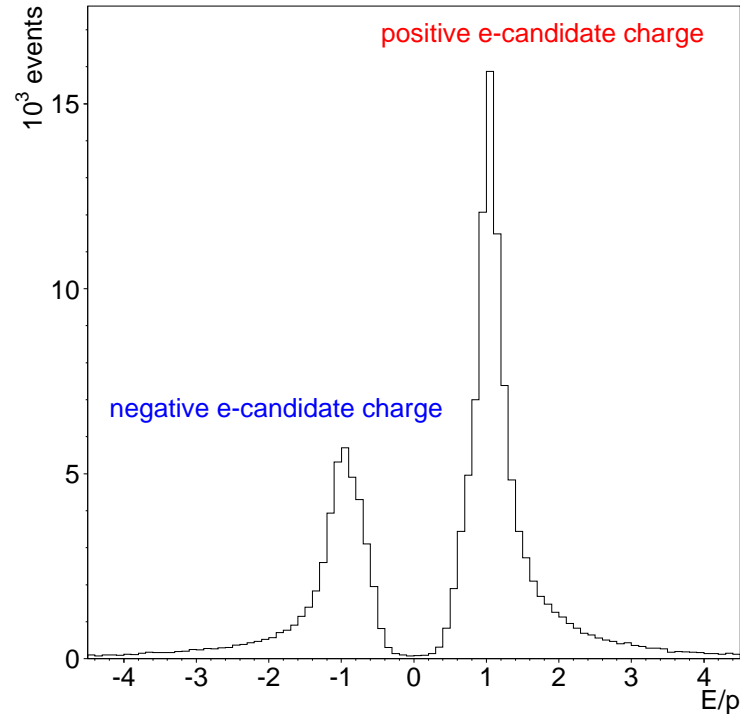
$e^+ p$ scattering:

+ Scattered lepton has the beam charge (positive).

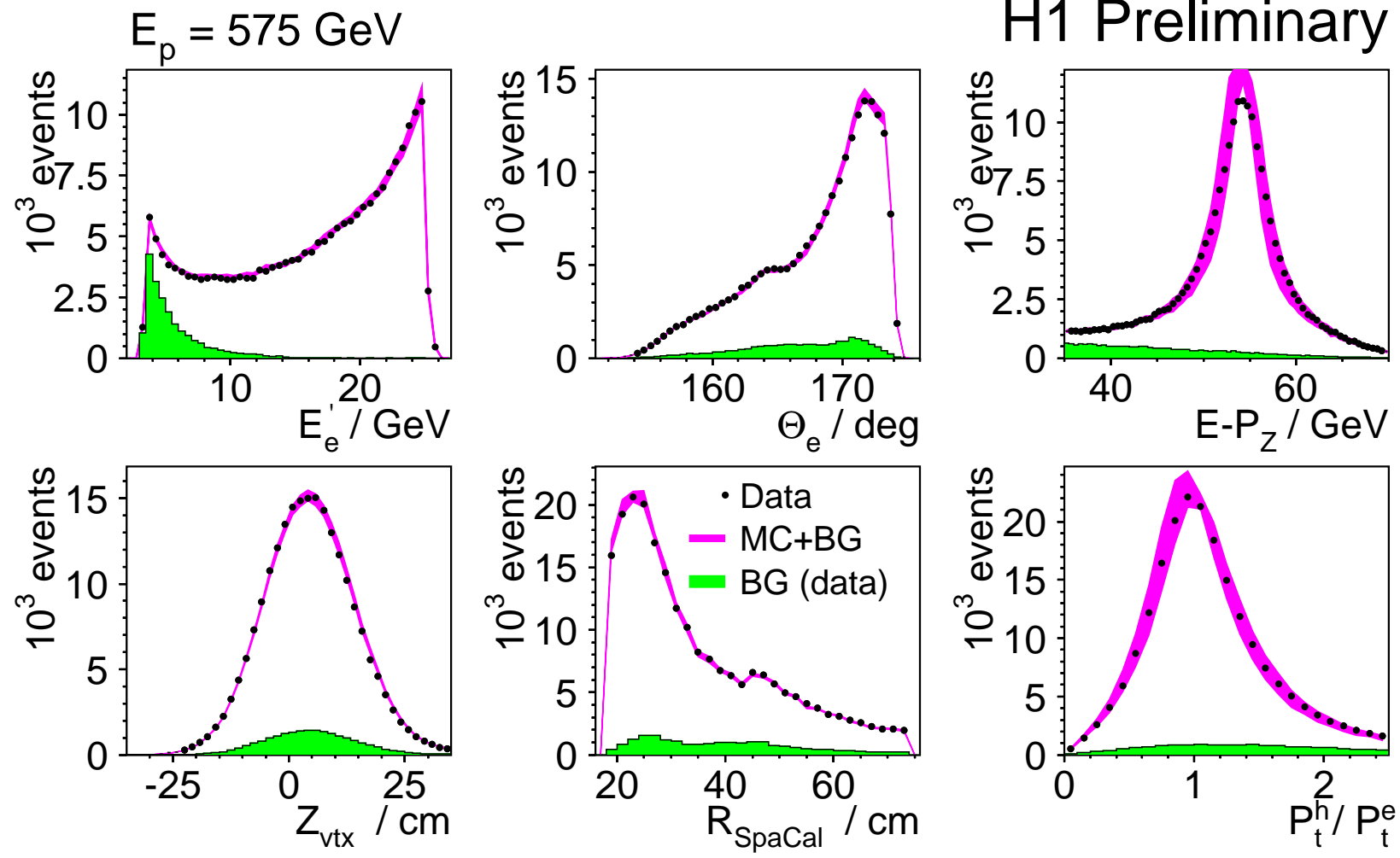− Background from hadronic particles, γ conversions is almost charge symmetric:
$$N_{bg}^+ \approx N_{bg}^-$$

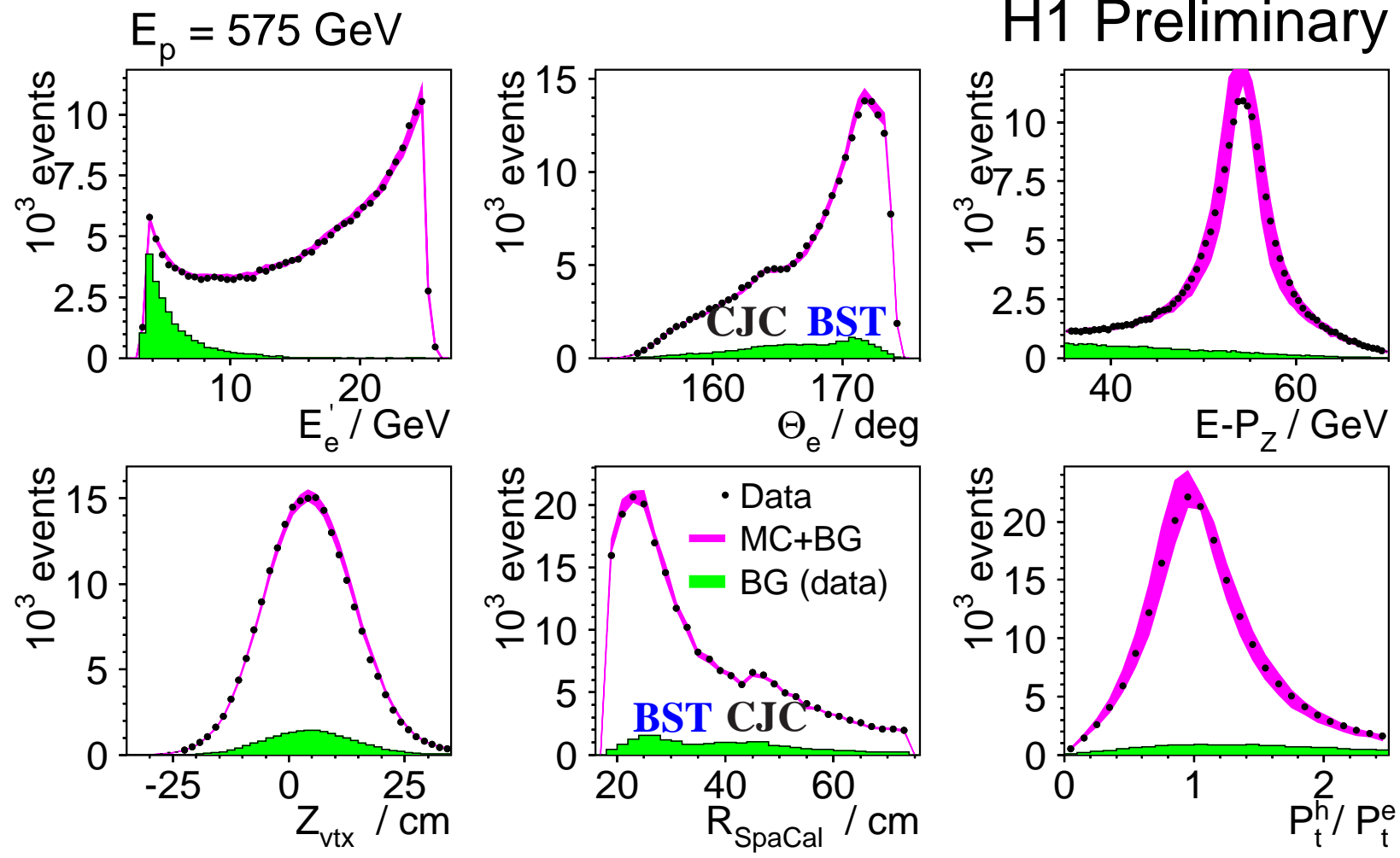→ require positive charge for the signal sample. Estimate remaining background using negative sample.

positive e-candidate charge

negative e-candidate charge

10^3 events

E/p

8

Control plots: $E_p = 575$ GeV

$E_p = 575$ GeV

H1 Preliminary

- Data
- MC+BG
- BG (data)

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Control plots: $E_p = 575$ GeV

$E_p = 575$ GeV

H1 Preliminary

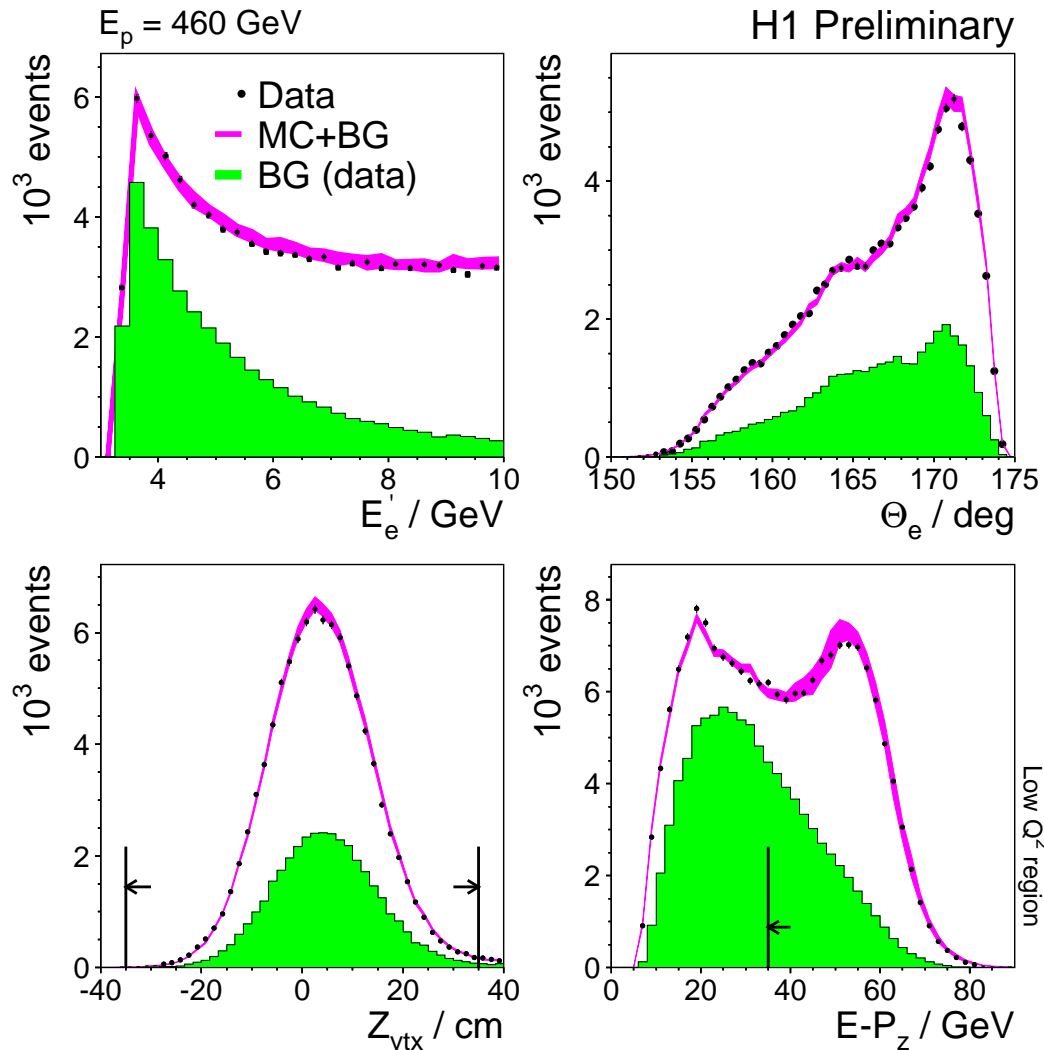Extension to $\theta_e > 165°, R_{SpaCal} < 40$ cm vs previous analysis

9-a

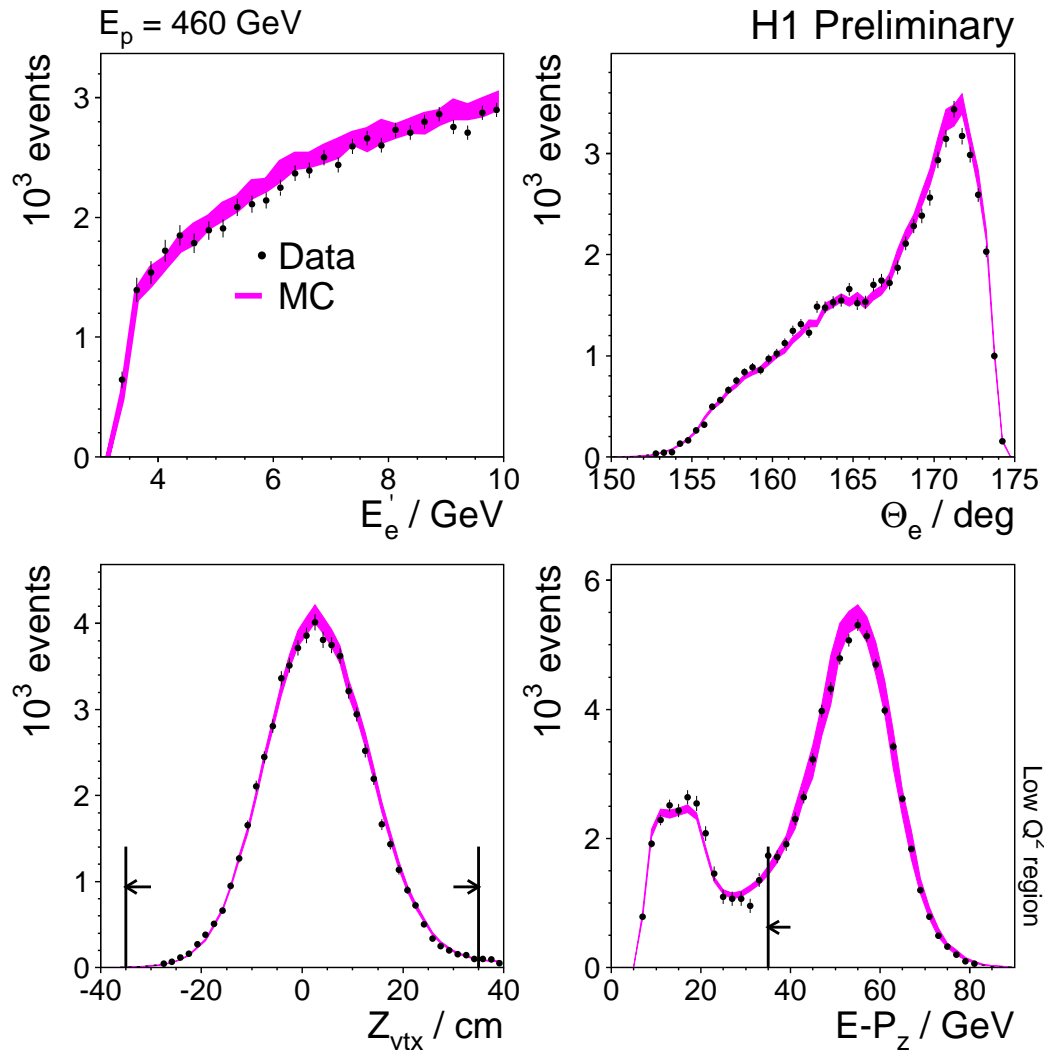# Control plots: $E_p = 460$ GeV

Band shows MC and background stat. and correlated syst. uncertaities.
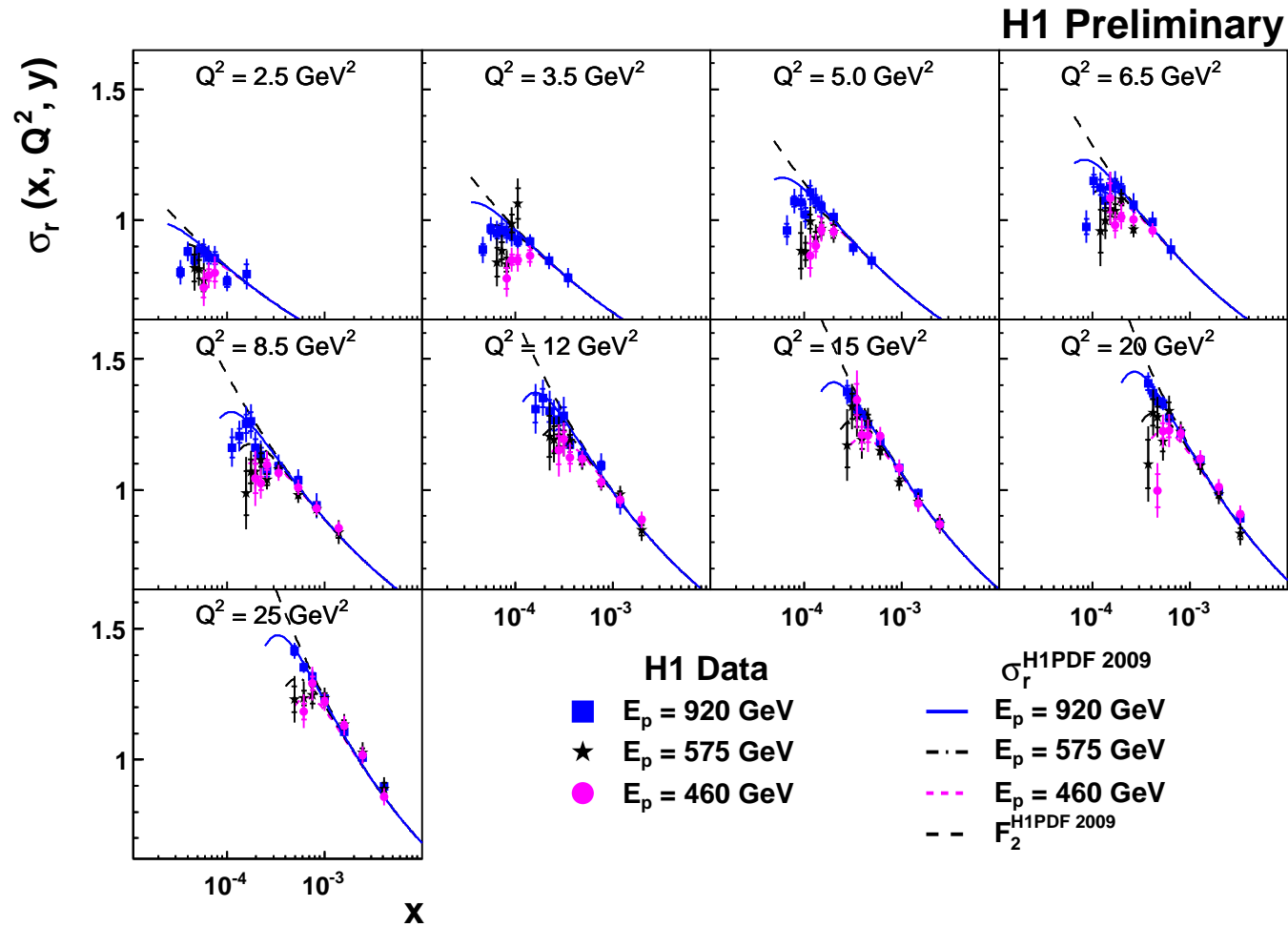
Control plots: High y

- Before background subtraction
- $E_p = 460$ GeV
- $E'_e > 3.4$ GeV.
- Lines indicate cut values
- $E - p_z$ is effective against background

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Control plots: High y

E_p = 460 GeV

H1 Preliminary

- Data
- MC

10^3 events

E'_e / GeV

10^3 events

Θ_e / deg

10^3 events

Z_{vtx} / cm

10^3 events

$E - P_z$ / GeV

Low Q^2 region

- After background subtraction
- $E_p = 460$ GeV
- $E'_e > 3.4$ GeV.
- Lines indicate cut values
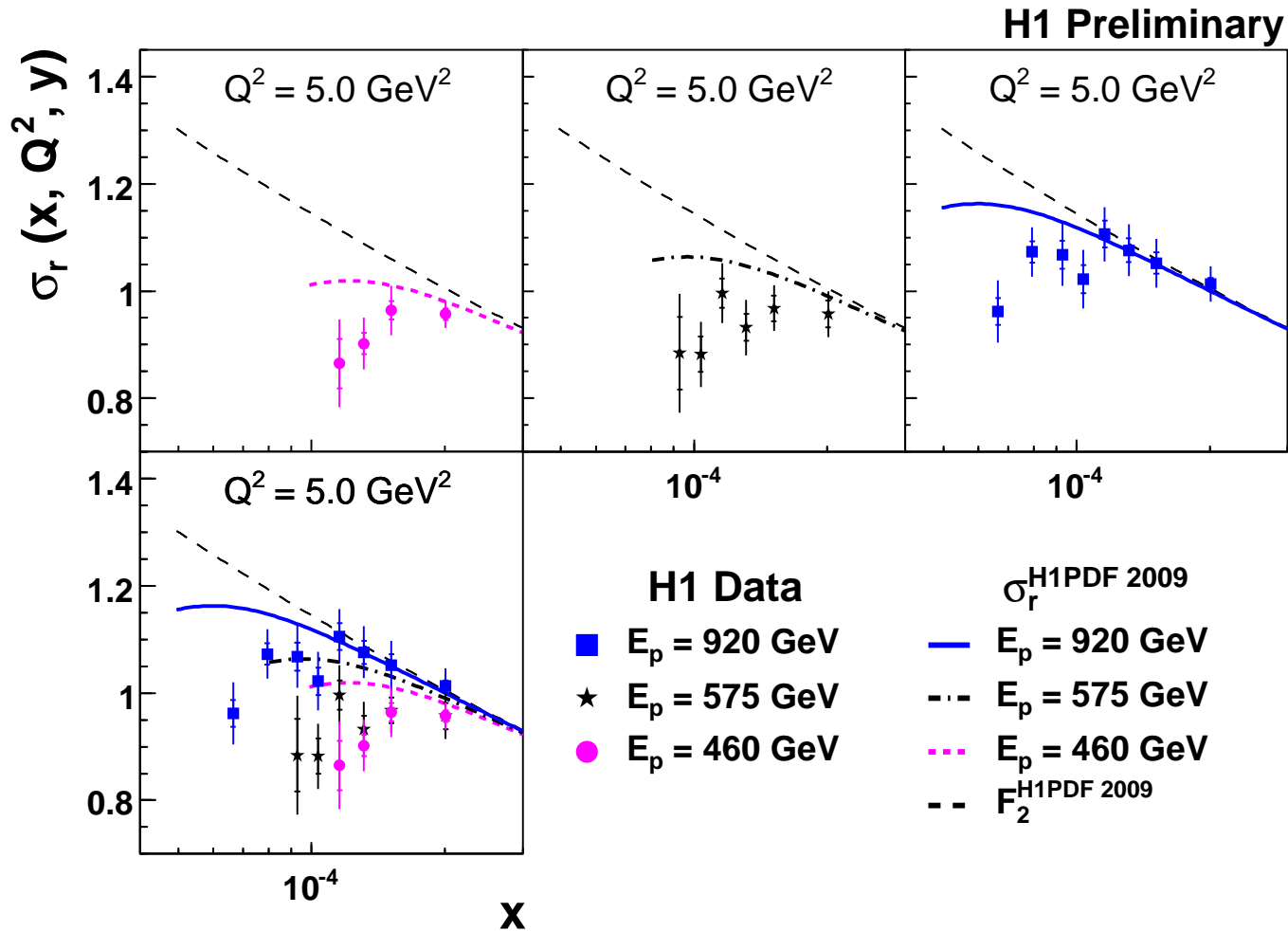- $E - p_z$ is effective against ISR radiation

12

σ_r for $E_P = 460, 575$ and 920 GeV

H1 Preliminary

$\sigma_r\,(x,\,Q^2,\,y)$

Q² = 2.5 GeV² Q² = 3.5 GeV² Q² = 5.0 GeV² Q² = 6.5 GeV²

Q² = 8.5 GeV² Q² = 12 GeV² Q² = 15 GeV² Q² = 20 GeV²

Q² = 25 GeV²

H1 Data	$\sigma_r^{\text{H1PDF 2009}}$
■ E_p = 920 GeV	— E_p = 920 GeV
★ E_p = 575 GeV	–·– E_p = 575 GeV
● E_p = 460 GeV	– – E_p = 460 GeV
	– – $F_2^{\text{H1PDF 2009}}$

x

H1PDF 2009 — New fit to H1 data, see talk of J. Kretzschmar

Turn-over of the cross section from F_2 at low x is due to F_L

13

σ_r for $E_P = 460, 575$ and 920 GeV for $Q^2 = 5$ GeV^2

Data at low x is consistently lower vs H1PDF 2009 prediction.

F_L extraction

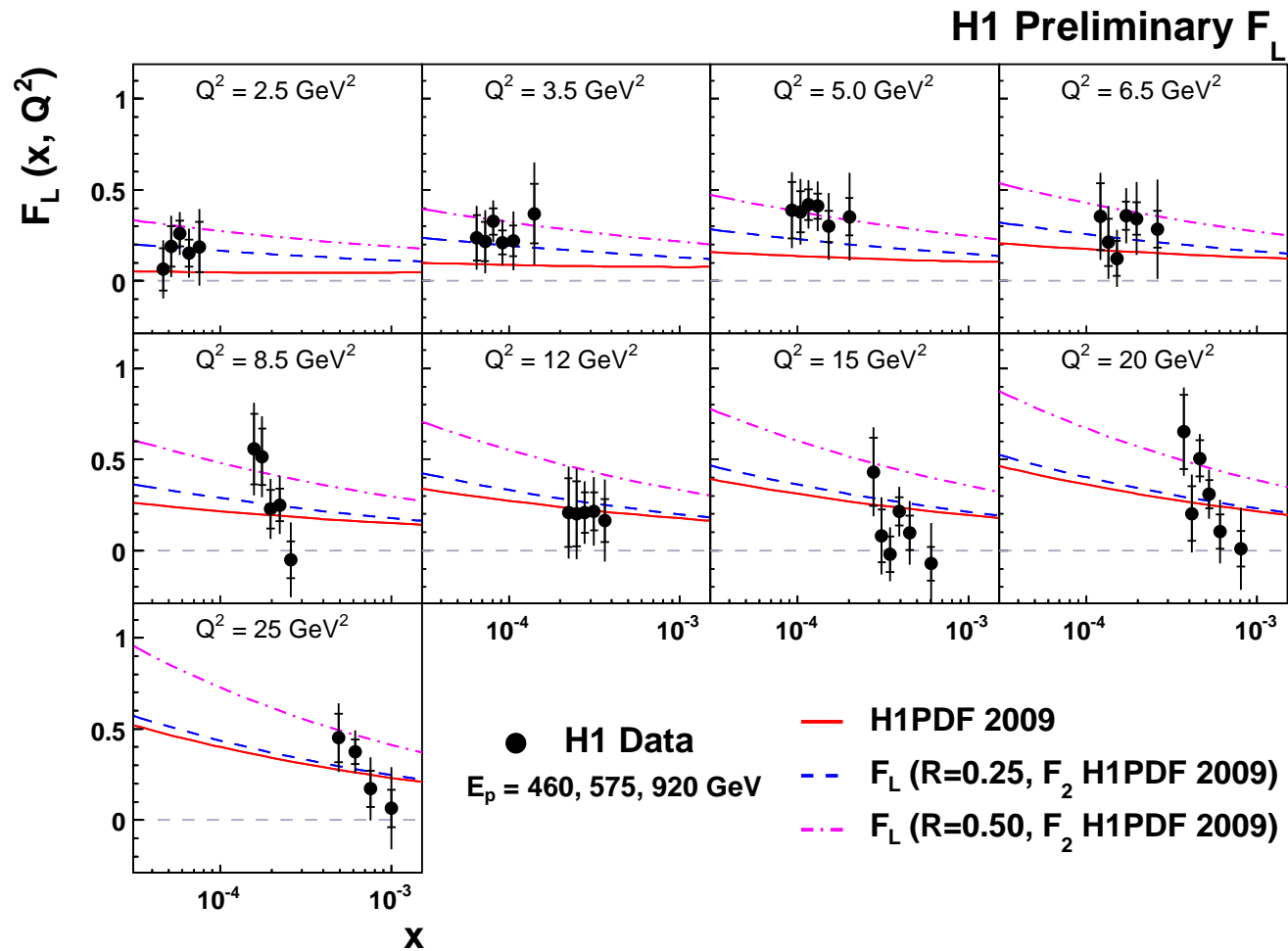$$\sigma_r(y) = F_2 - \frac{y^2}{1 + (1-y)^2} F_L$$

- Linear fit to get F_2 and F_L
- Relative normalization from low y data

Data at $\mathbf{E_p = 575}$ provides cross check and extends measurement to low x.
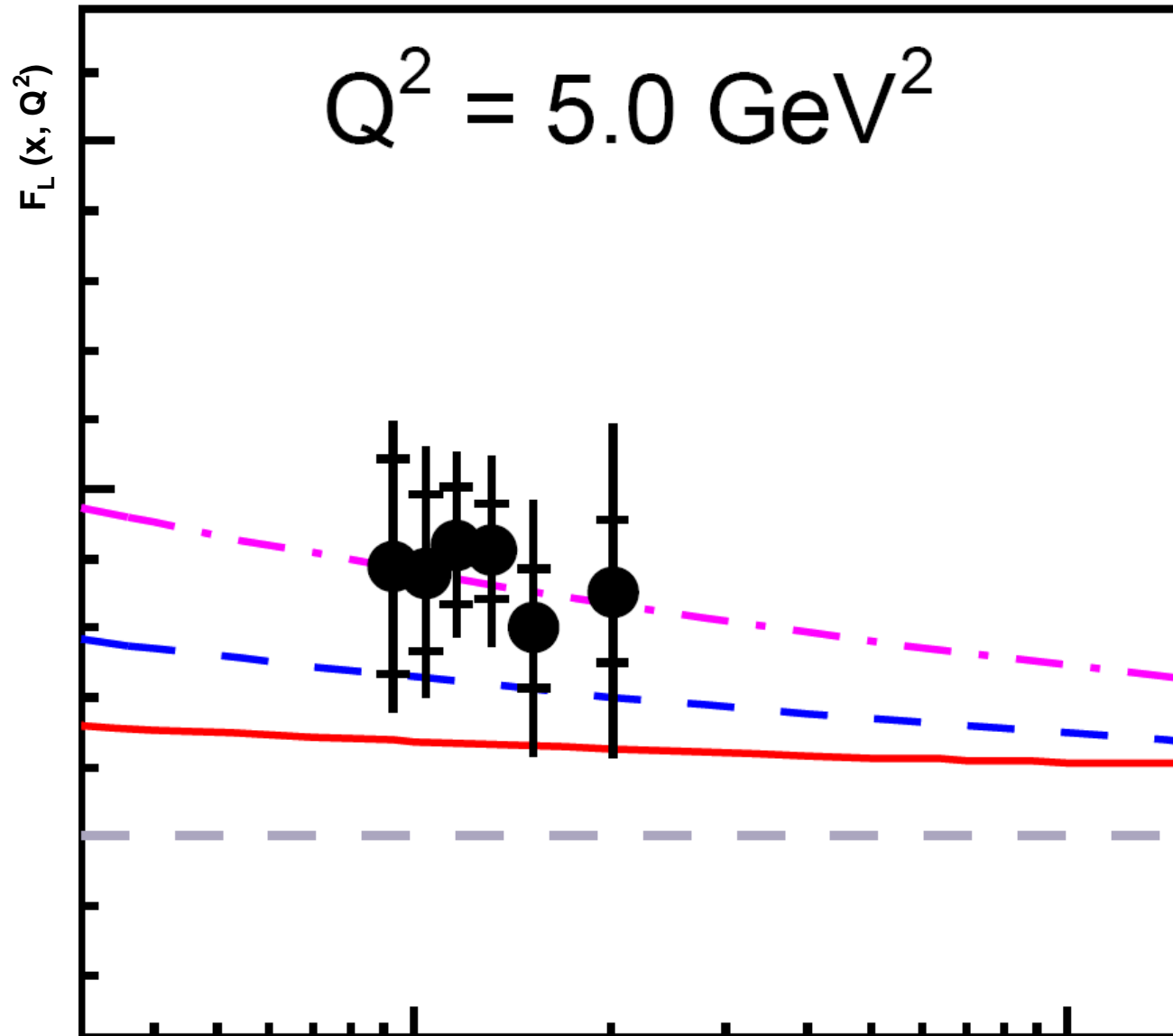
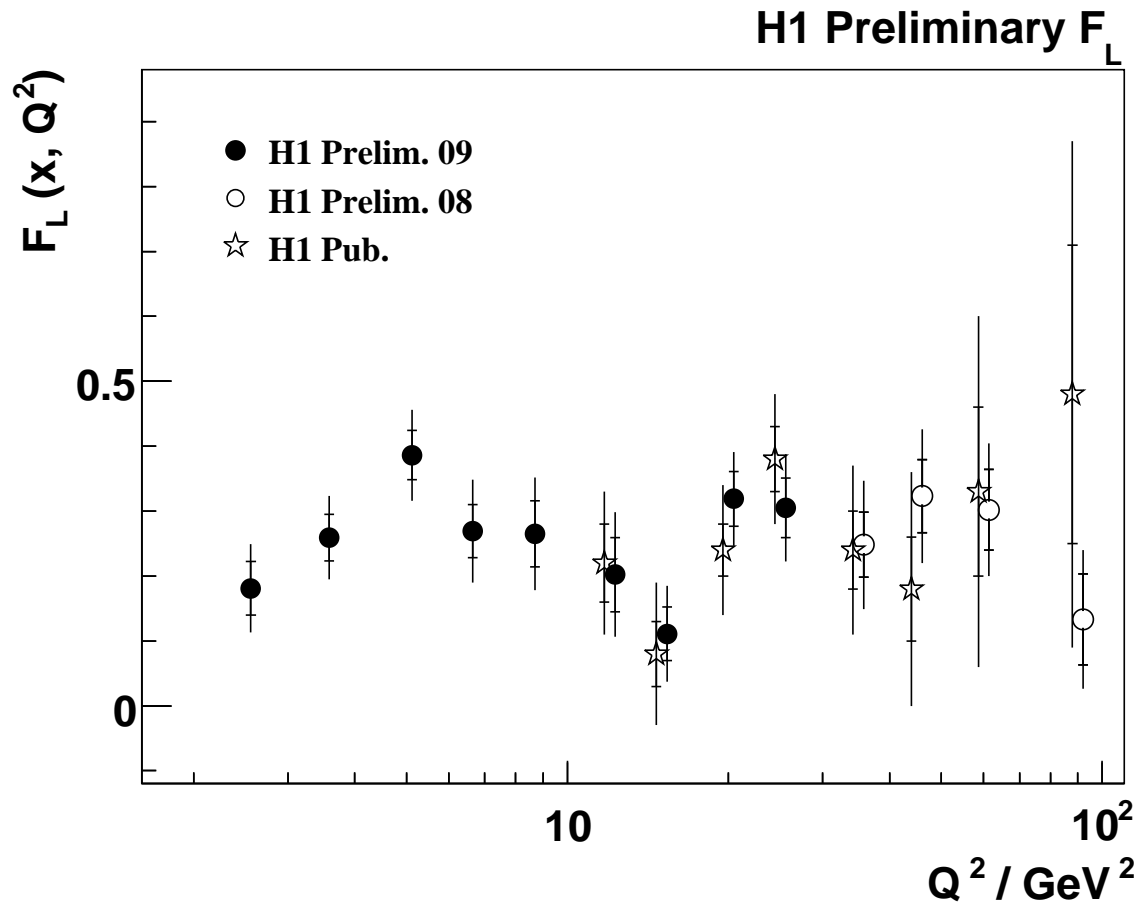Consistent slope — consistent F_L for different x bins.

F_L vs x, Q^2

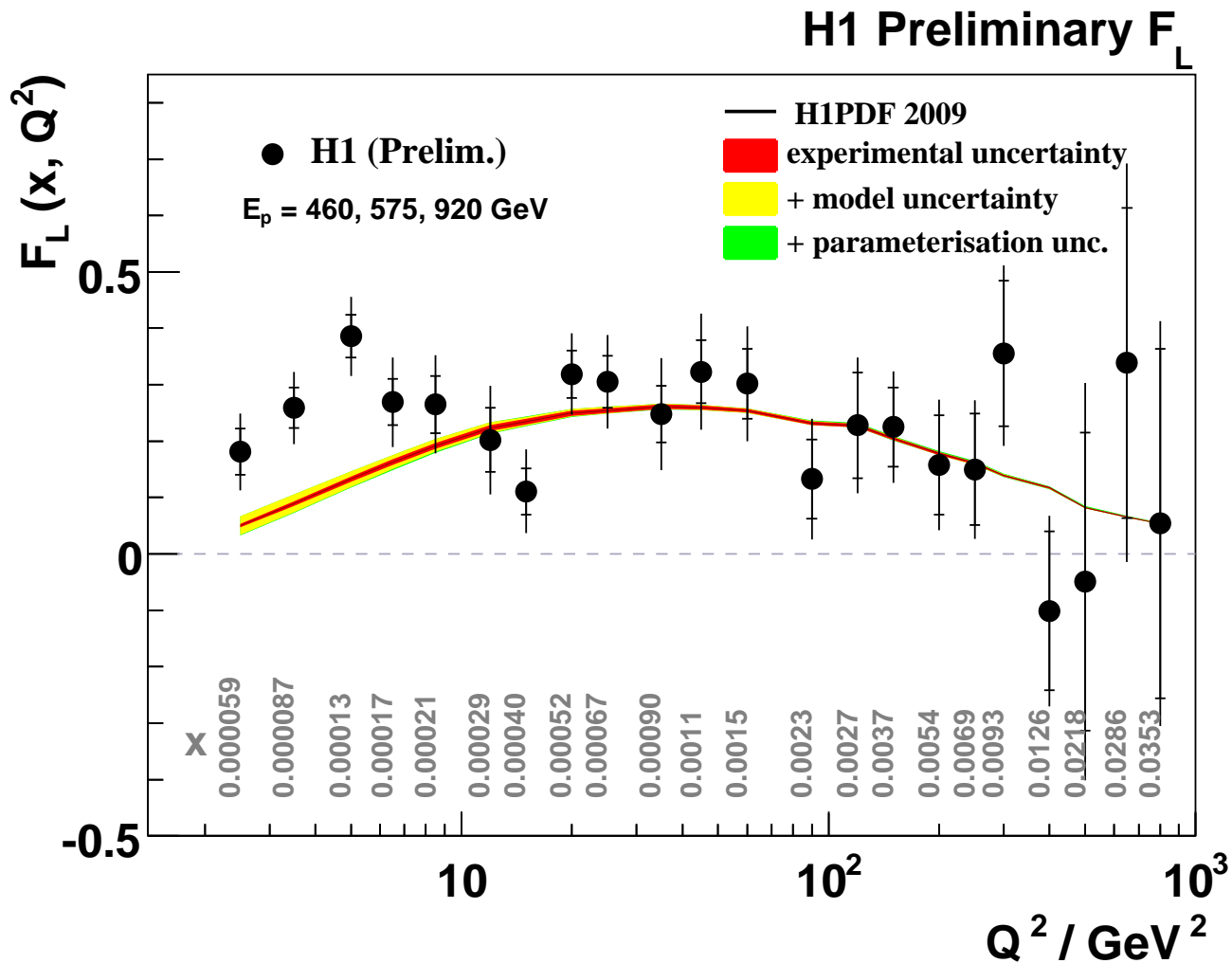Data are consistent with $R \sim 0.25$ ($F_L = 0.2 F_2$)

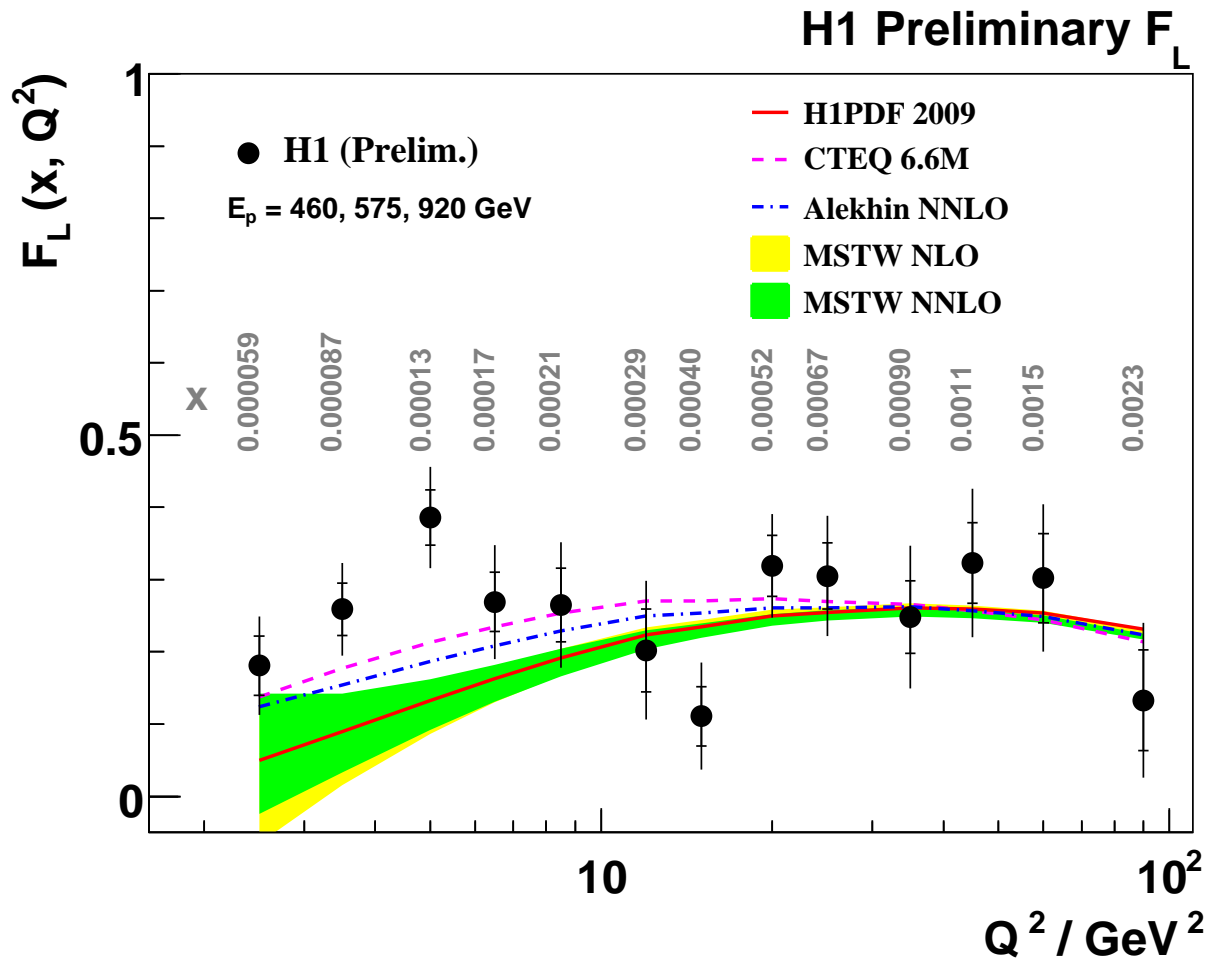F_L vs x, Q^2

$Q^2 = 5.0\ \mathrm{GeV}^2$

$F_L\,(x, Q^2)$

16-a

Averaged H1 data compared to the published CT-SpaCal and preliminary LAr-SpaCal analyeses. Significant improvement for $Q^2 \leq 15$ GeV^2.
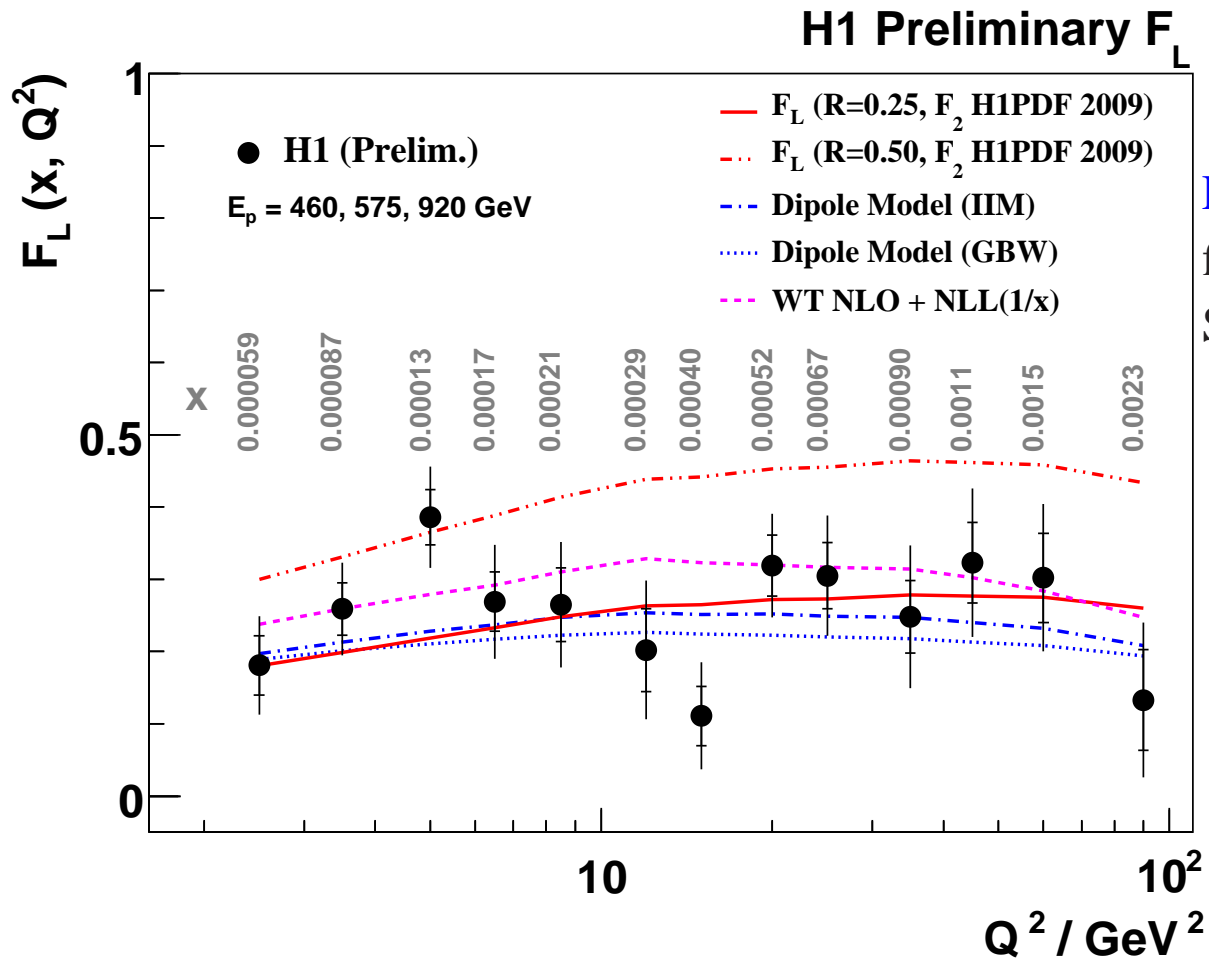
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F_L measured by H1

H1 measurements cover $2.5 \le Q^2 \le 800 \text{ GeV}^2$ and $0.00005 \le x \le 0.04$ range
For $Q^2 \ge 10 \text{ GeV}^2$, agree well with H1PDF 2009 prediction.

F_L measured at $Q^2 < 100$ GeV^2

MSTW and H1PDF 2009 predictions use the same scheme to calculate F_L.
Data agree better with calculation of CTEQ.

F_L vs phenomenological models.

Dipole Models:
fits to low Q^2 H1 data
See talk of A. Petrukhin

Data is consistent with constant $R \sim 0.25$.
Good agreement with IIM and GBW dipole models, NLL(1/x) prediction.

Summary

- F_L is measured for the first time at HERA down to $Q^2 = 2.5 \text{ GeV}^2$.

- Data are consistent with constant $R \sim 0.25$ and well described by dipole models.

- Measured F_L is higher than the predicions of MSTW at NLO and NNLO as well as H1PDF2009 for $Q^2 < 10 \text{ GeV}^2$, agree better with the CTEQ 6.6M and Alekhin NNLO predictions.