New Measurements of F_2^D and F_L^D with H1 at HERA
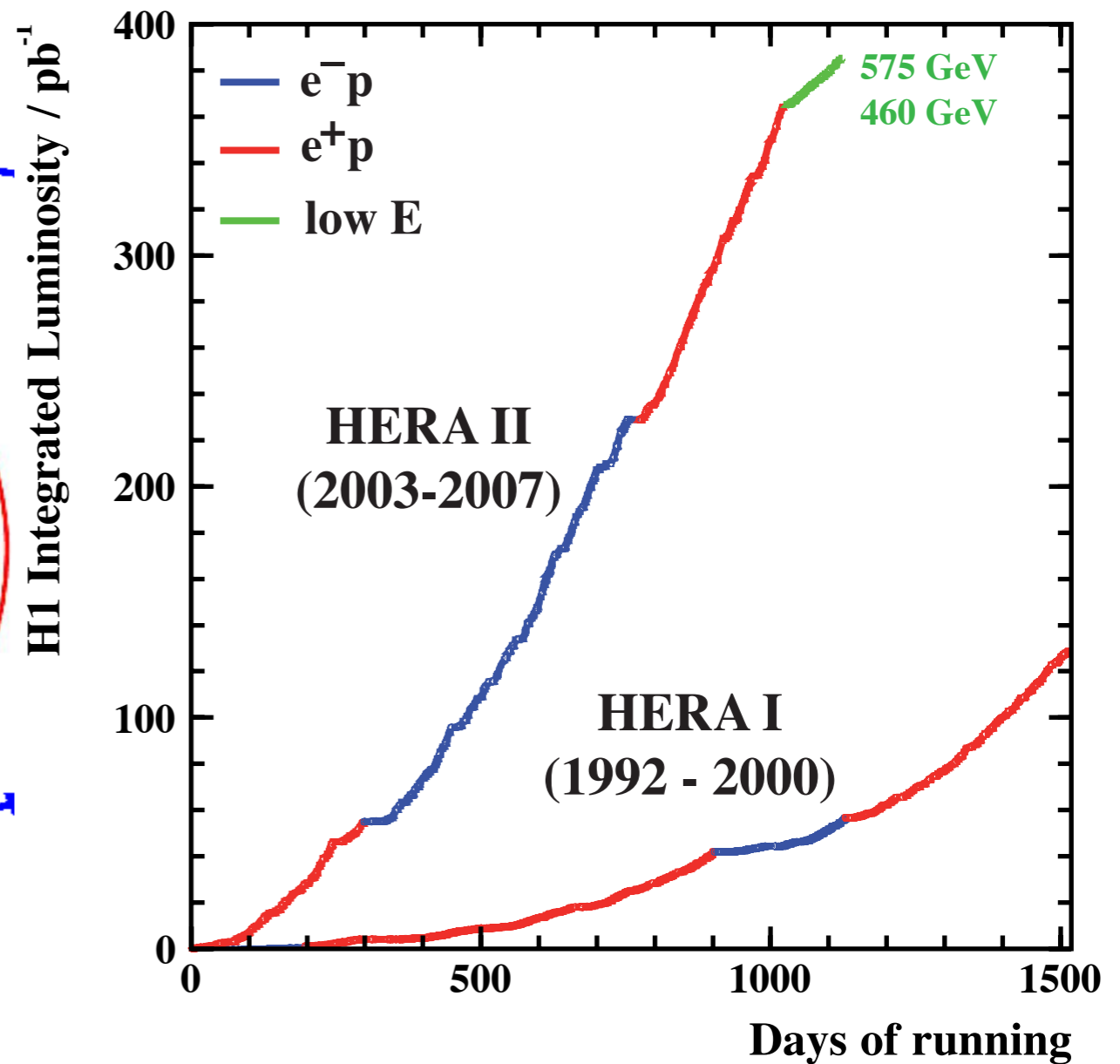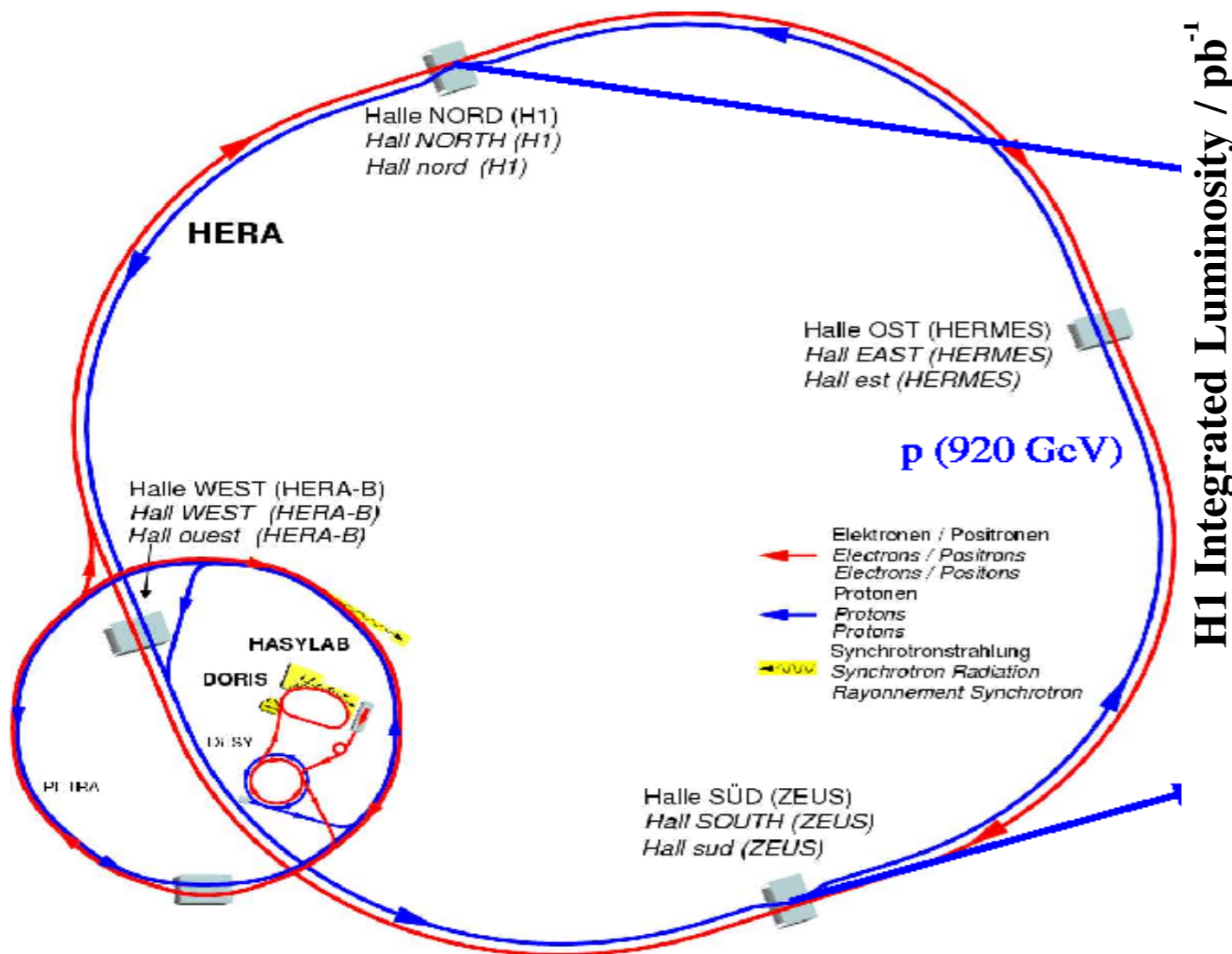
Paul Laycock
Thursday 24th June 2010
Low x 2010, Kavala, Greece

- HERA datasets

- Diffractive DIS
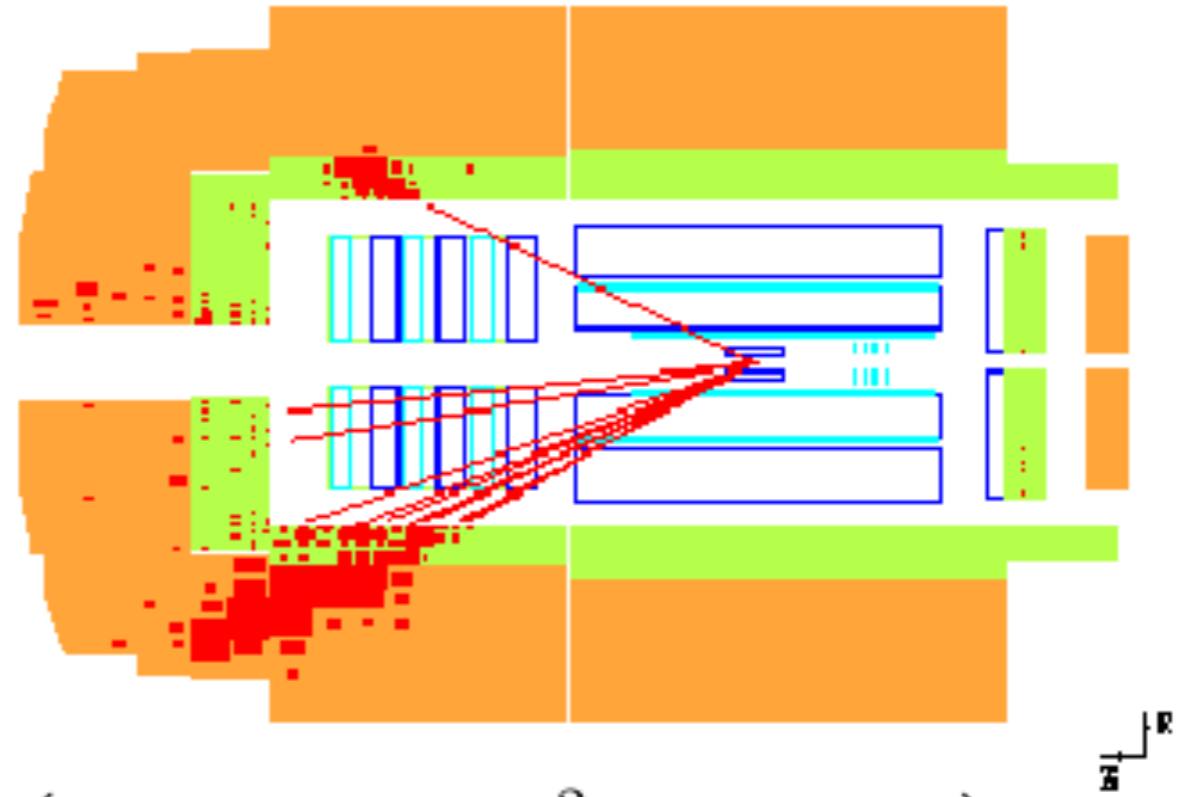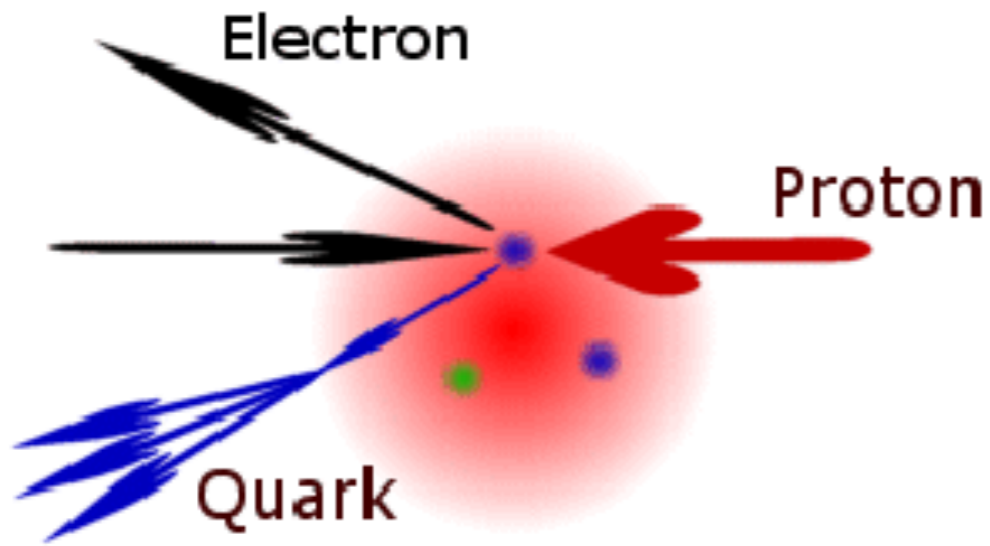
- F_L^D and F_2^D

HERA, collider experiments and data

- The unique HERA machine collided 27.5 GeV electrons or positrons with protons of 460, 575, 820 and 920 GeV providing 0.5 fb^{-1} to H1

- The final precision analyses of this data are being delivered
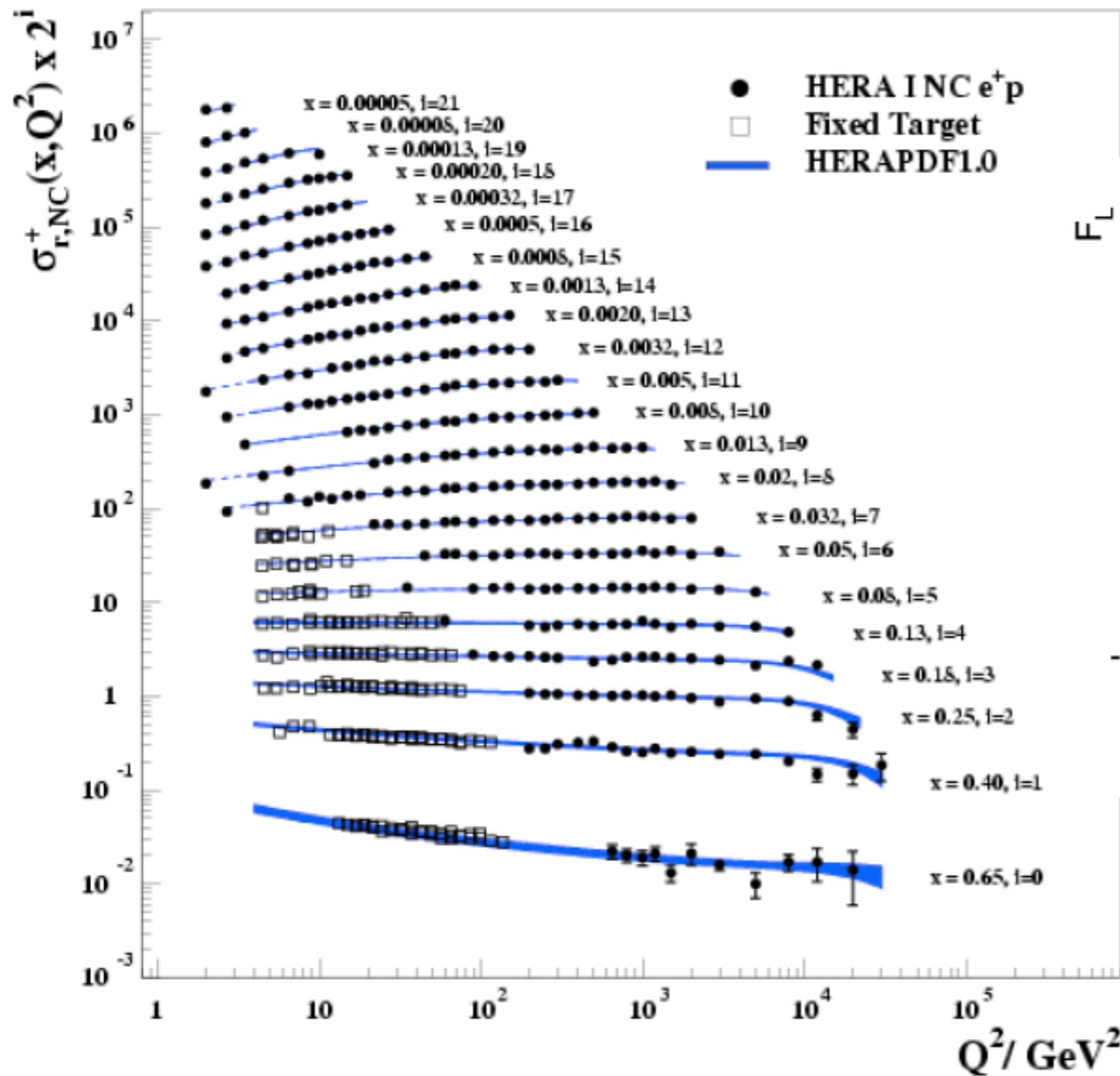
Deep-inelastic Scattering

Measure:

$$\frac{\mathrm{d}^2\sigma_{NC}^{ep}}{\mathrm{d}x\,\mathrm{d}Q^2} = \frac{2\pi\alpha^2 Y_+}{xQ^4}\left(F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2)\right)$$
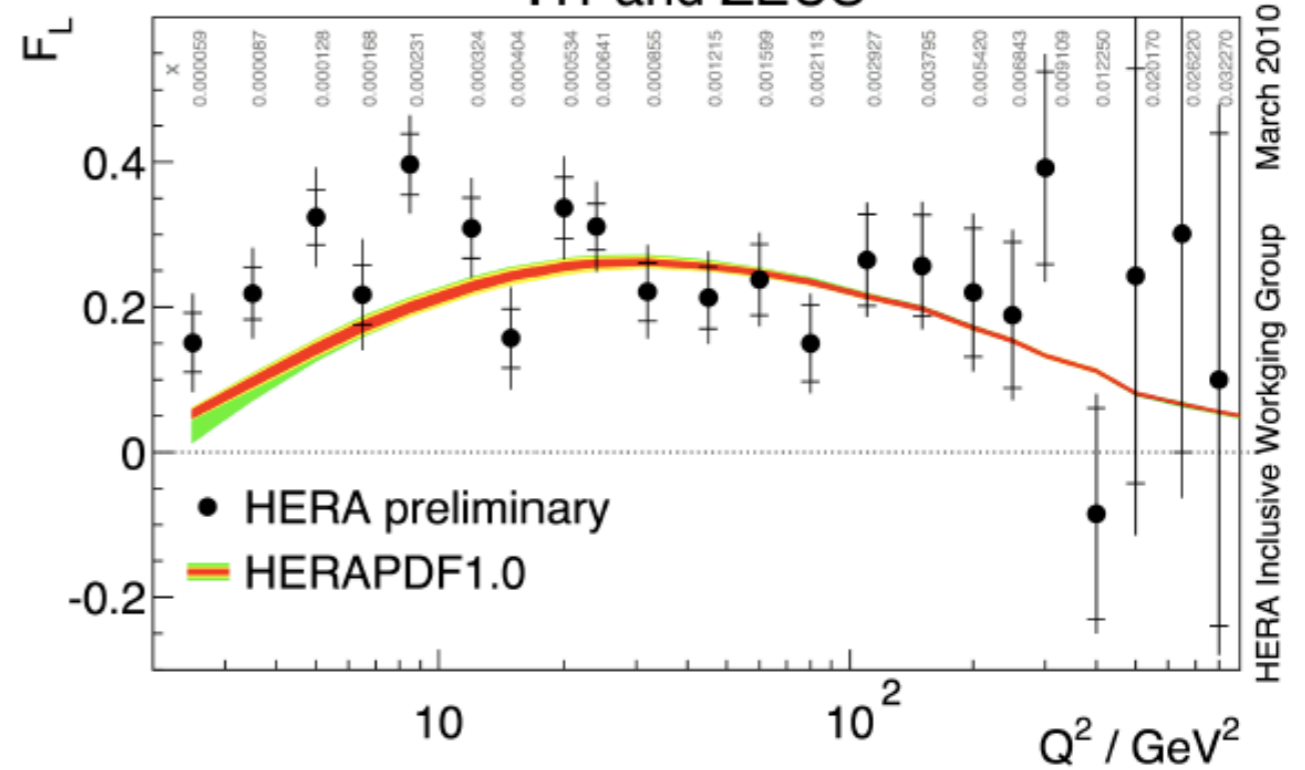
Extract:

- F_2 directly related to (PDFs) quark content: $F_2 \sim x\Sigma e^2(q+\bar{q})$

- $dF_2/d\ln Q^2$ (scaling violations) sensitive to gluon content

- F_L only non-zero in higher order QCD – independent access to gluon density and QCD dynamics
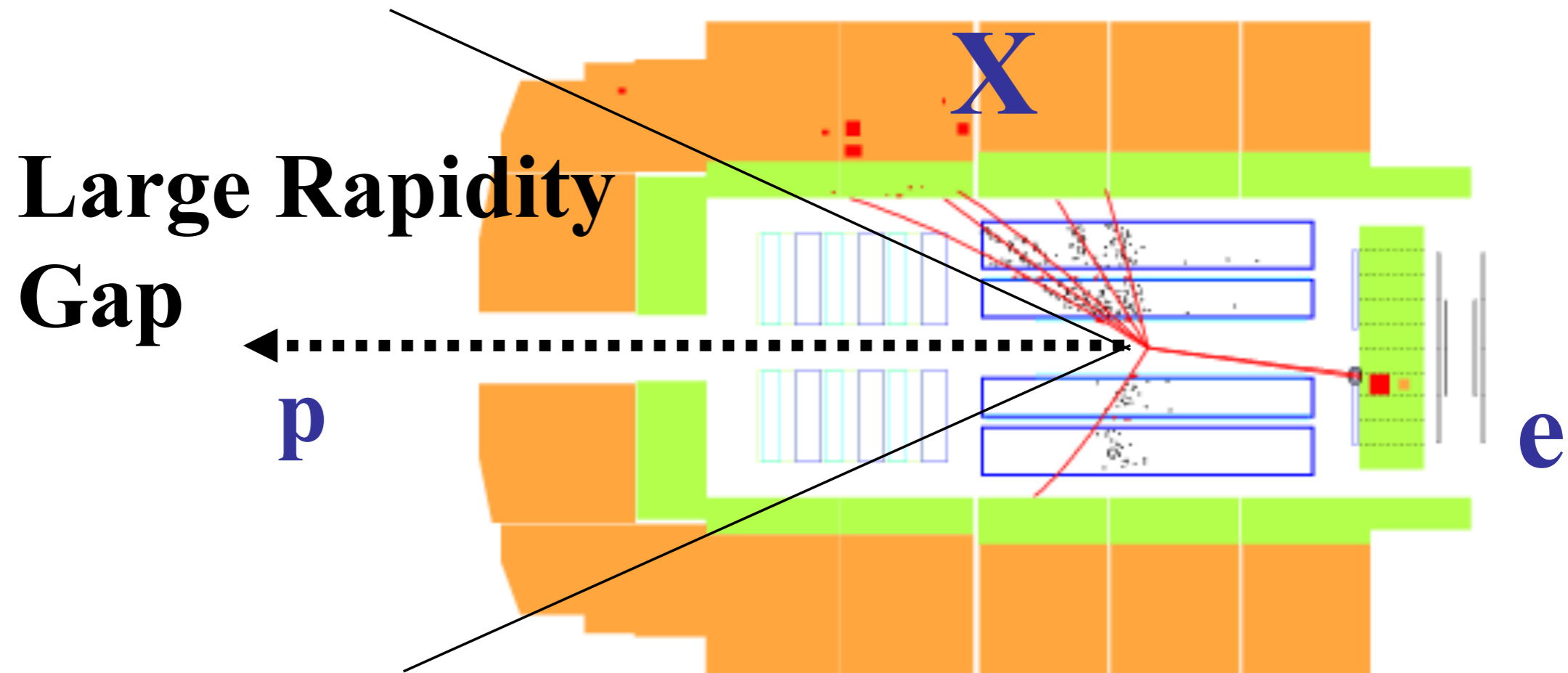
Inclusive F$_2$ and F$_L$

- Experimental confirmation of the DGLAP picture of inclusive DIS
- Target is to repeat this for diffraction
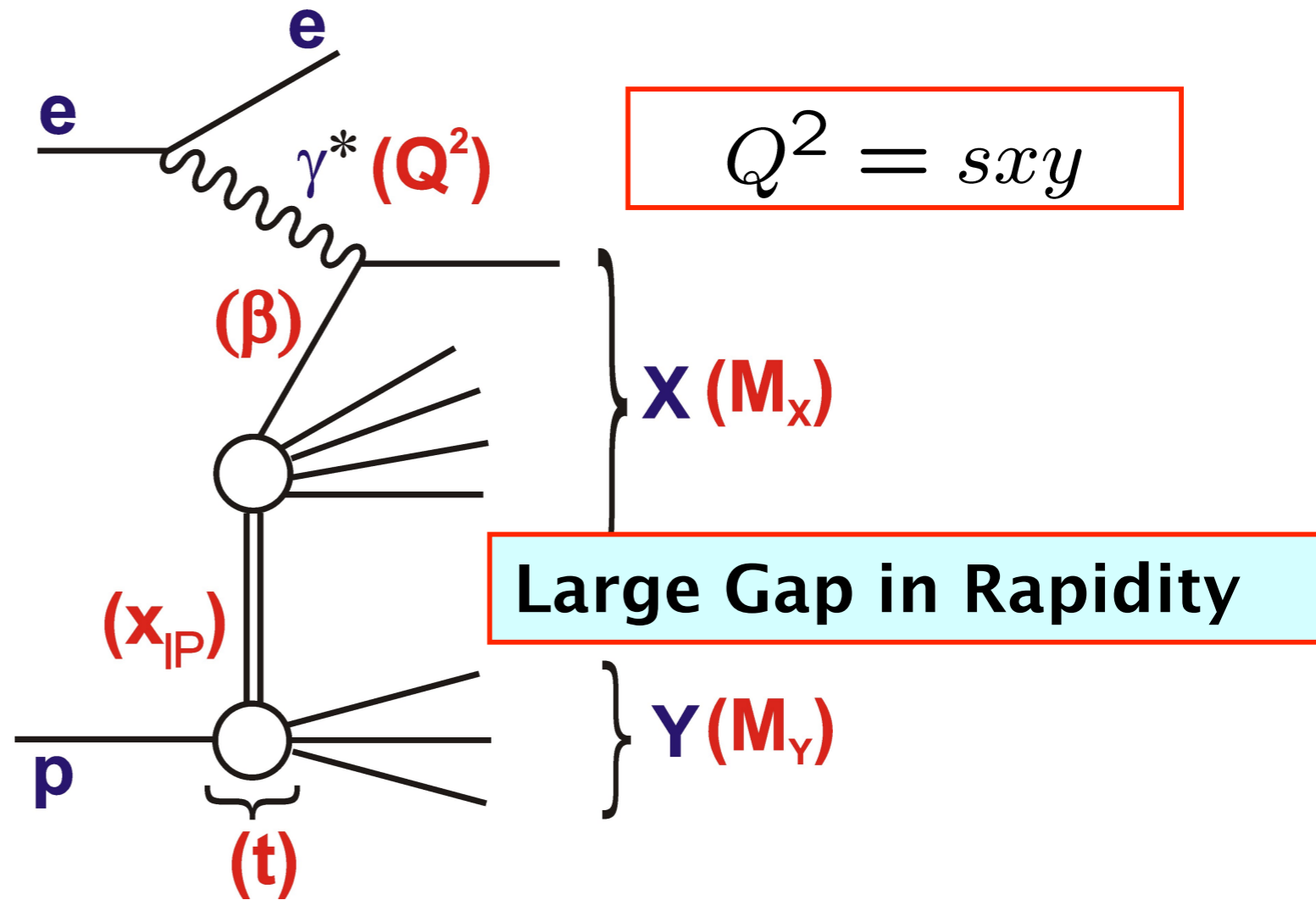
Diffractive Deep Inelastic Scattering

- Quasi-elastic scattering involving a colour singlet exchange

- Select events based on the Large Rapidity Gap topology

- The experimental mandate is simple - measure the kinematic dependences of the cross section for the process

Diffractive Structure Functions

$$x = x_{I\!P}\beta$$

$$\beta = \frac{Q^2}{Q^2 + M_X^2}$$
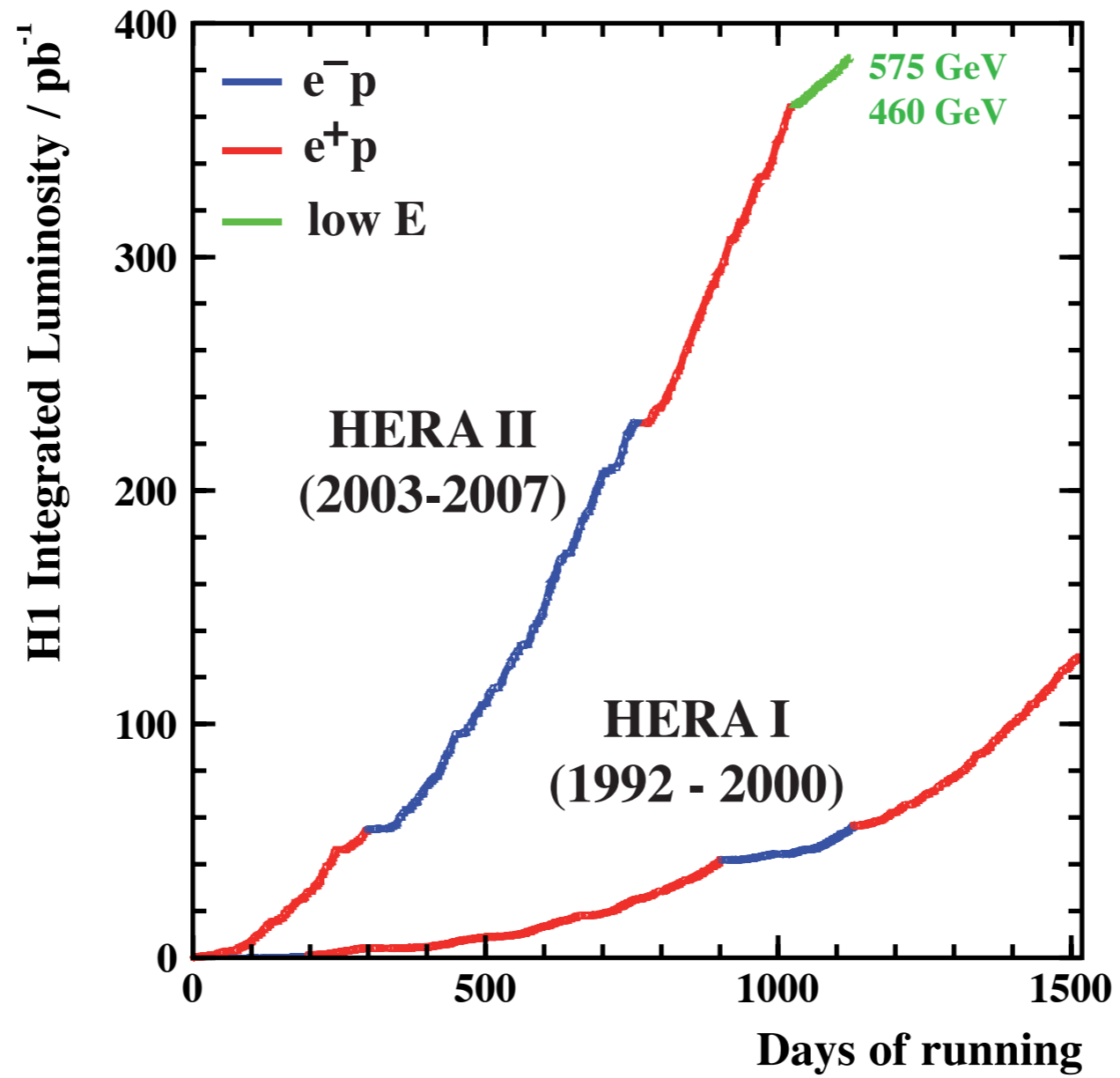
$$x_{I\!P} = \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

$$Q^2 = sxy$$

e

e

γ^* **(Q²)**

(β)

X (M_x)

Large Gap in Rapidity

(x_IP)

Y (M_Y)

p

(t)

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

Cross section: $\dfrac{d^4\sigma^{ep\to eXp}}{dx\,dQ^2\,dx_{I\!P}\,dt} = \dfrac{4\pi\alpha^2}{xQ^4}\,Y_+\,\sigma_r^{D(4)}(x, Q^2, x_{I\!P}, t)$
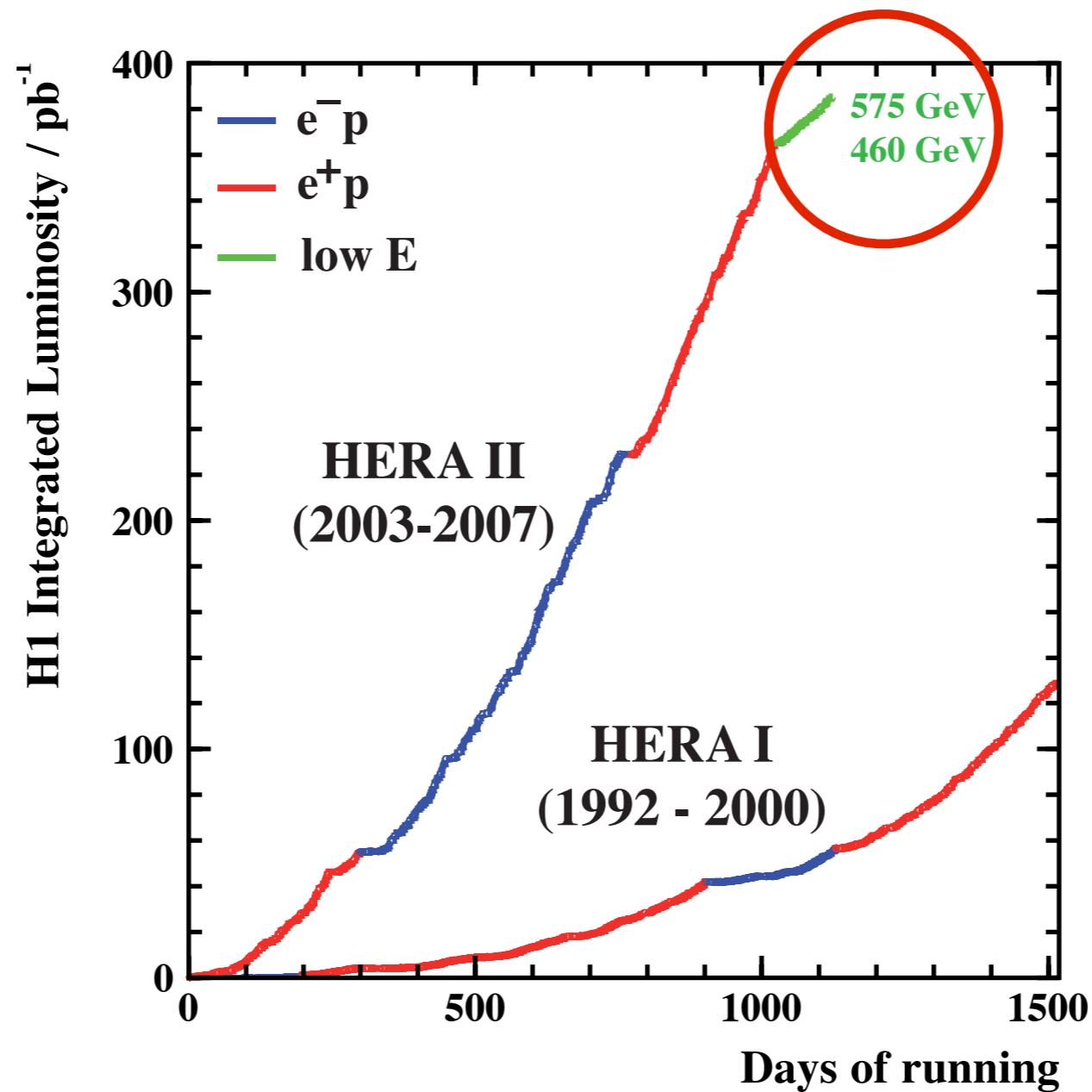
$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{Y+}F_L^{D(4)}$$

$$\sigma_r^{D(3)} = \int_{-1}^{t_{min}} \sigma_r^{D(4)}\,dt$$
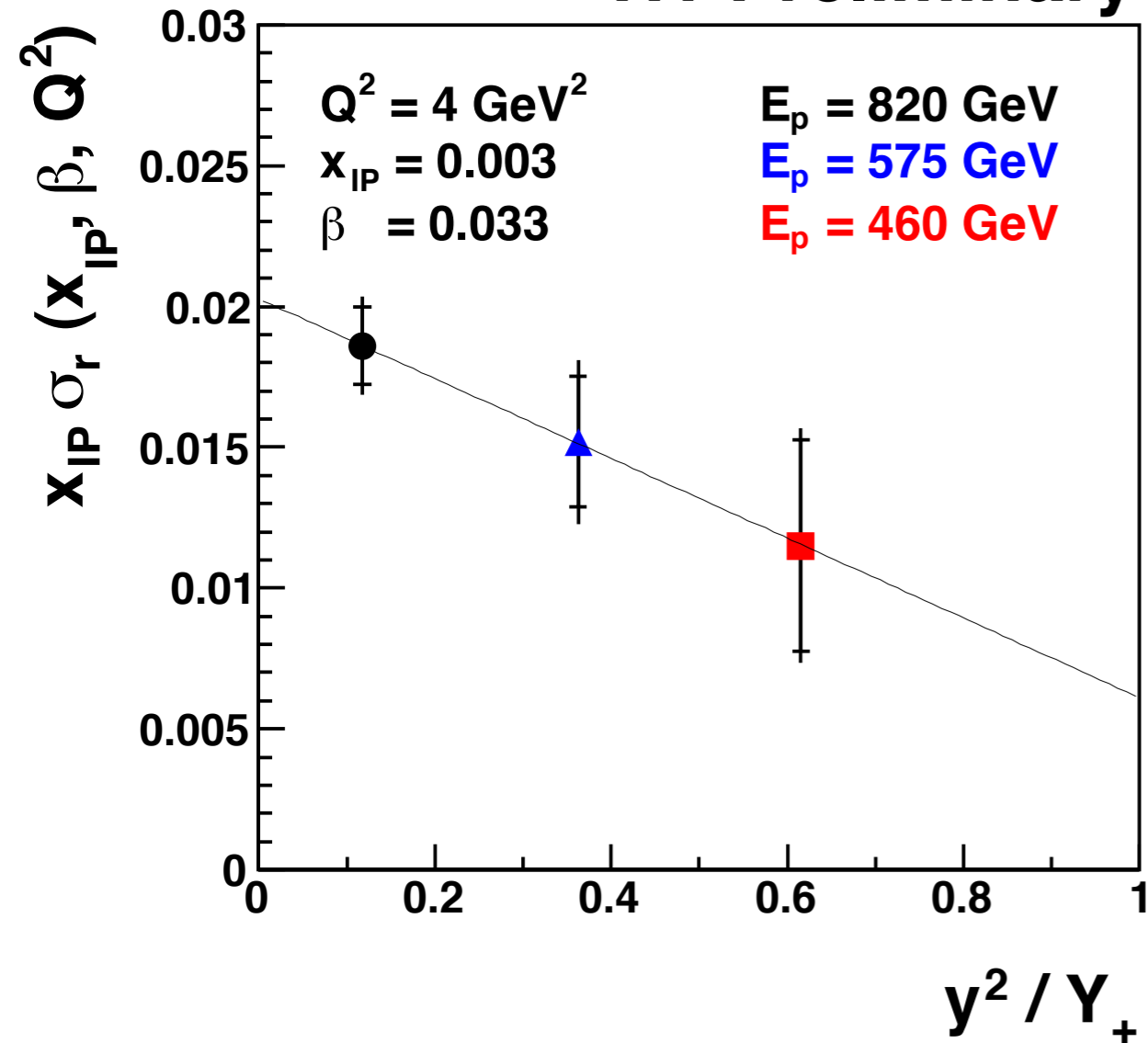
H1 data

H1 data

- Analyse the low (E_p=460 GeV) and medium (E_p=575 GeV) energy runs

- Measure cross sections at fixed x_{IP}, β, Q^2 and different $y \rightarrow F_L^D$

F_L^D Extraction

H1 Preliminary

$Q^2 = 4$ GeV^2
$x_{IP} = 0.003$
$\beta = 0.033$

$E_p = 820$ GeV
$E_p = 575$ GeV
$E_p = 460$ GeV

Y-axis: $x_{IP}\, \sigma_r\, (x_{IP}, \beta, Q^2)$
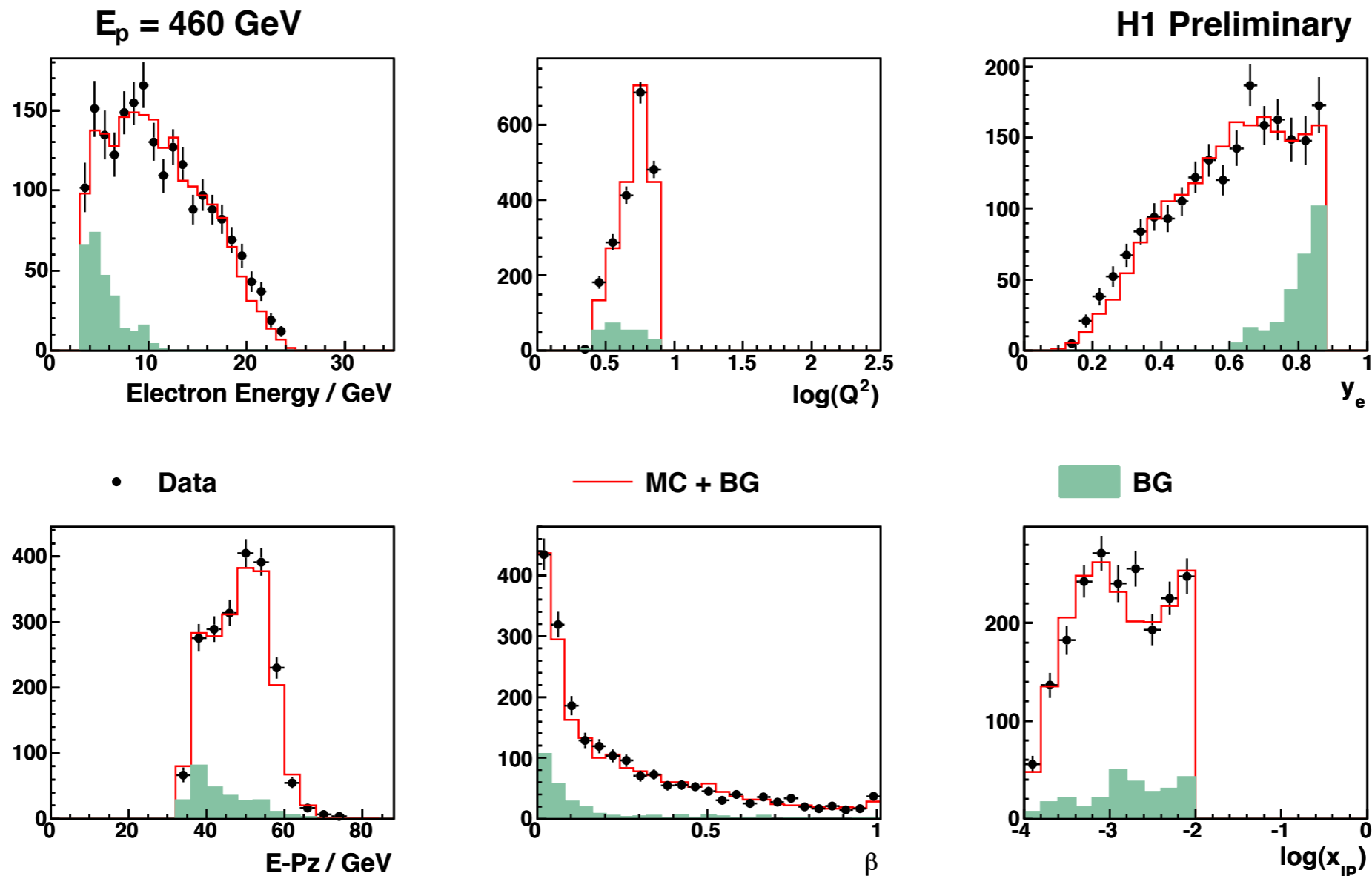
X-axis: y^2 / Y_+

- Measure reduced cross sections at three different beam energies at fixed x_{IP}, β and Q^2

$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{Y+} F_L^{D(4)}$$

- Plot as a function of y^2 / Y_+ (Rosenbluth plot)

- Extract F_L^D as the slope

- Analysis at medium $Q^2 > 7$ GeV^2 shown last year

- Extend the measurement down to $Q^2 > 2.5$ GeV^2

The low (460 GeV) energy data

- Analyse data down to Q^2 of 2.5 GeV^2 and electron energy of 3.4 GeV

- Extremely challenging measurement!

- Good control of the data, using data (wrong-charge events) to understand the significant photoproduction background in the region of interest at high y

The medium (575 GeV) energy data
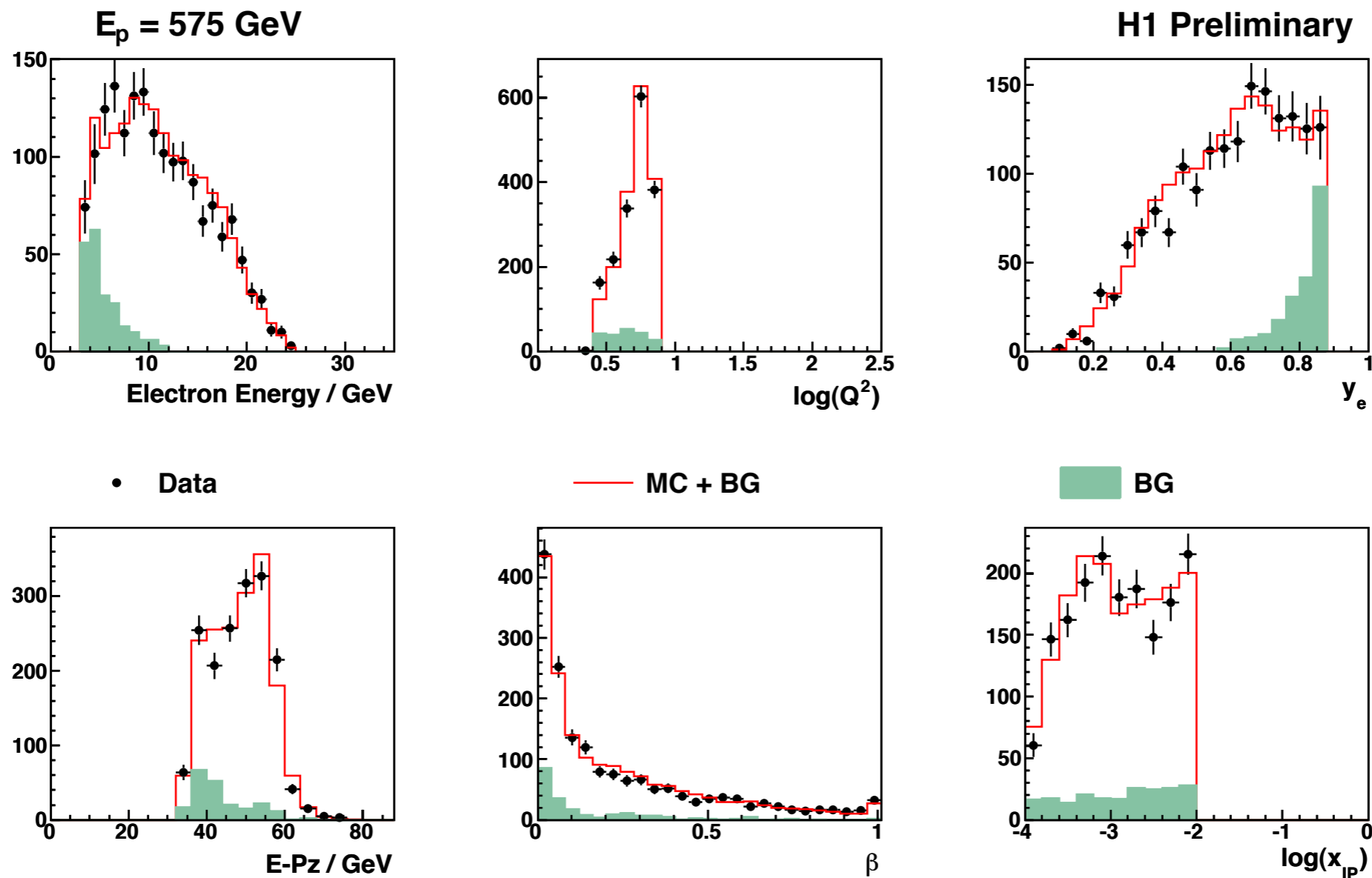
- Analyse data down to Q^2 of 2.5 GeV^2 and electron energy of 3.4 GeV

- Extremely challenging measurement!

- Good control of the data, using data (wrong-charge events) to understand the significant photoproduction background in the region of interest at high y
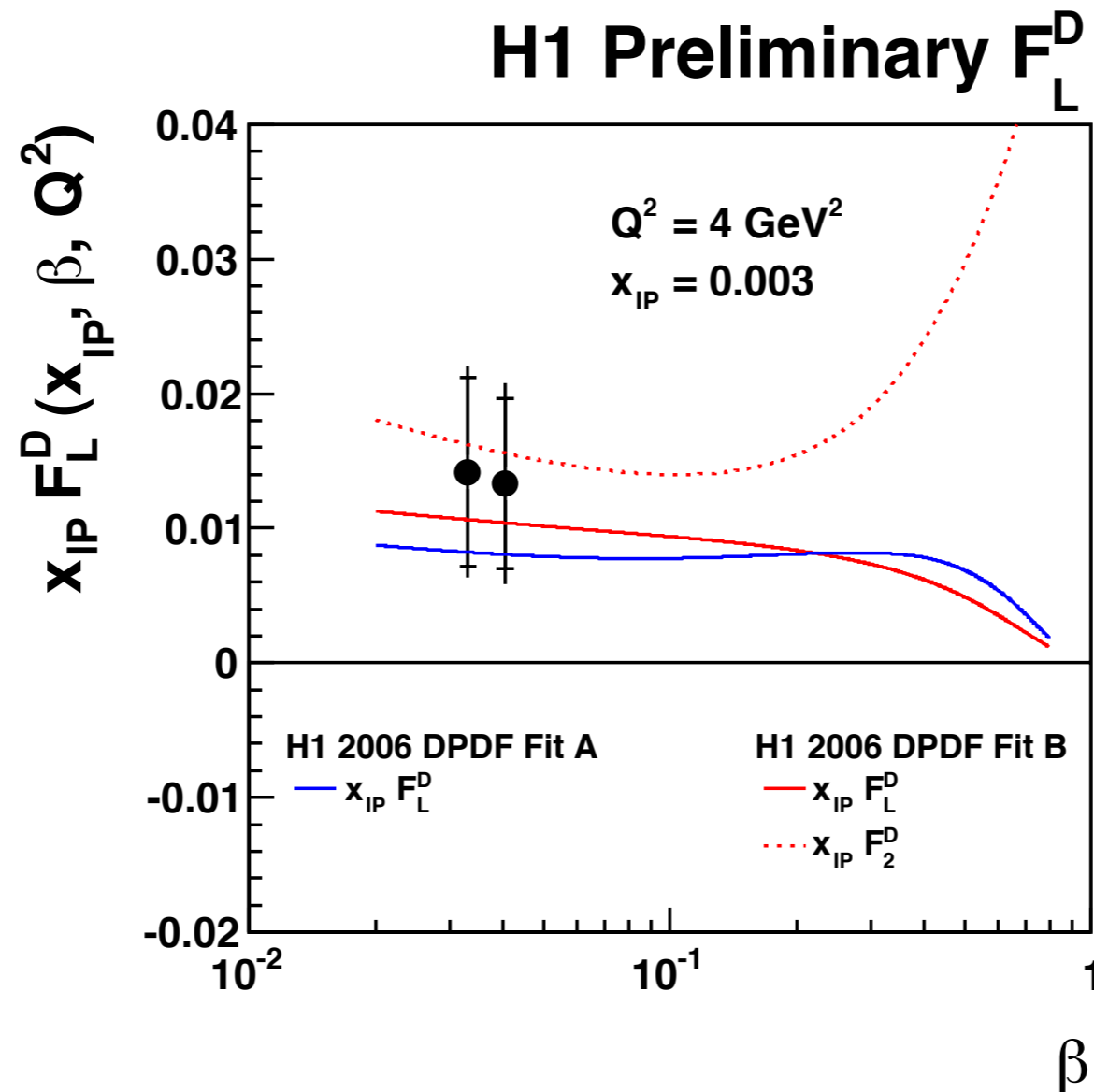
Diffractive cross sections at low Q^2 and high y
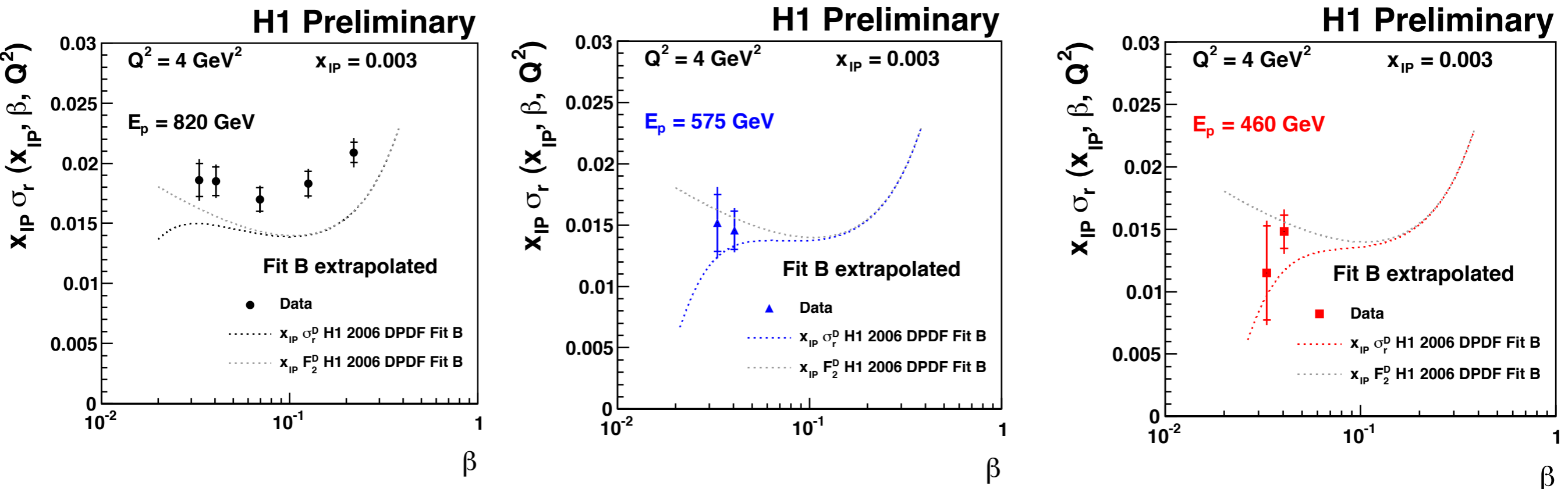
- Left are *published* data (hep-ex/0606004) with $E_p = 820$ GeV

- The extrapolation of Fit B for F_2^D (upper curve) and σ_r^D is shown - it undershoots the data at low Q^2 (only data with $Q^2 >= 8.5$ GeV^2 were included)

- New low Q^2 (=4 GeV^2) diffractive cross sections at $E_p = 575$ GeV (centre, blue) and $E_p = 460$ GeV (right, red) compared to extrapolated Fit B

F_L^D extraction
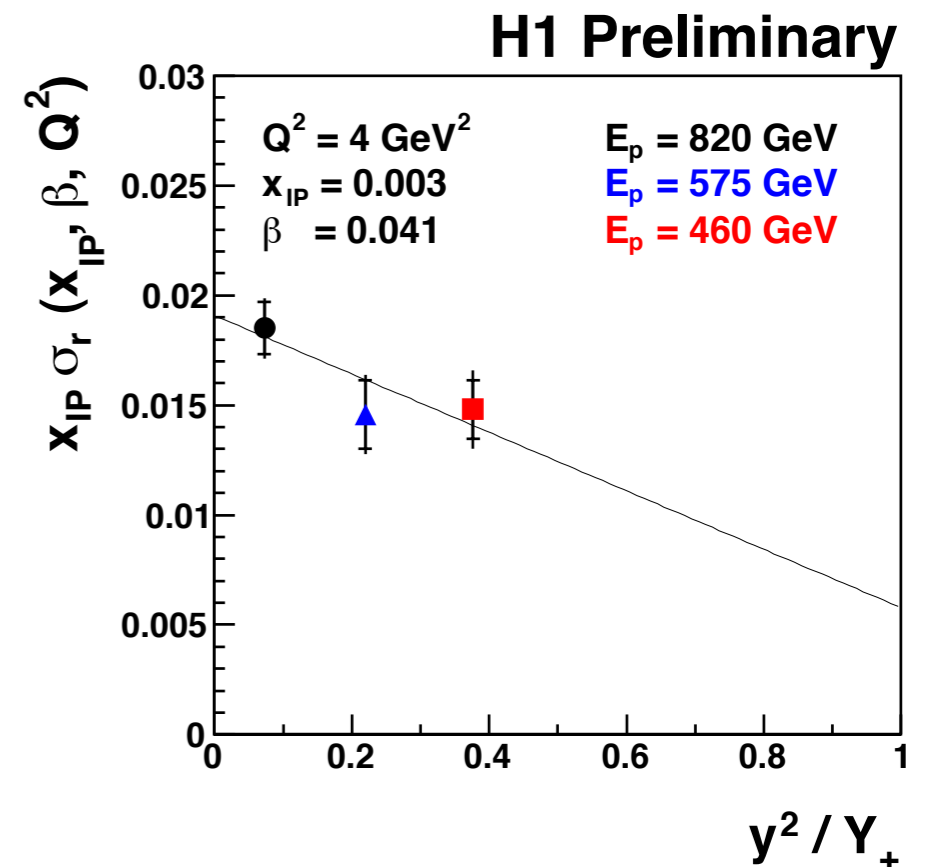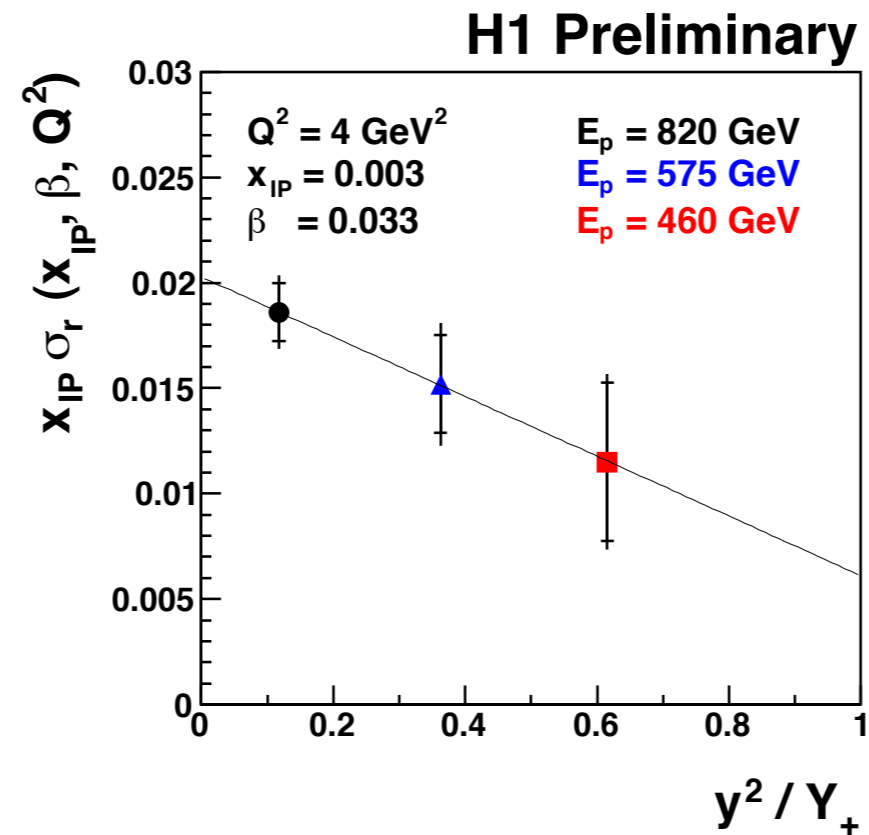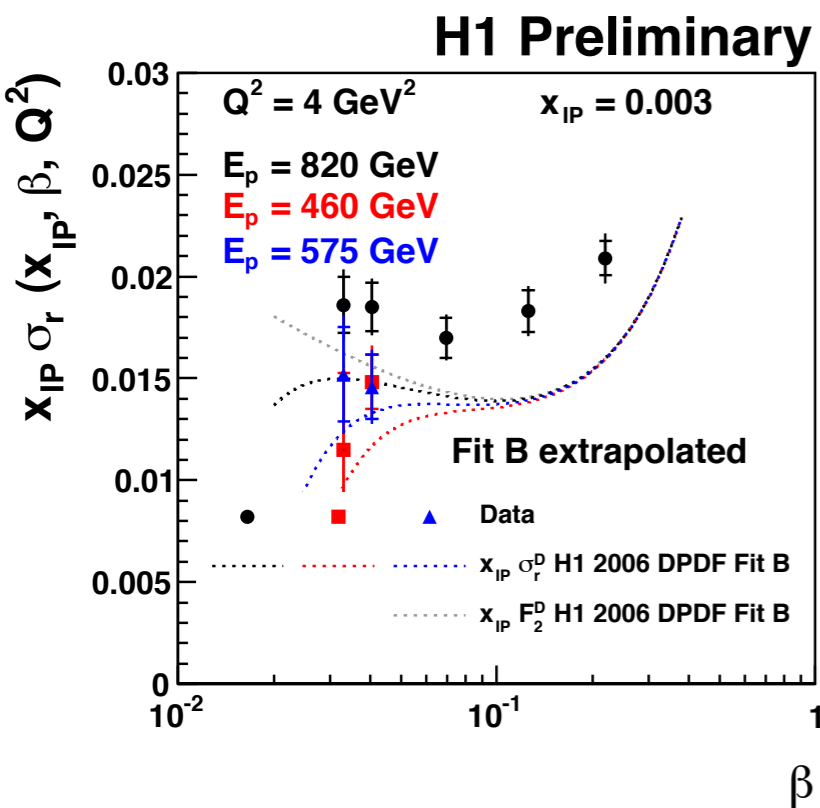
- The linear fits to the Rosenbluth plots for the two highest y bins are shown, allowing two new measurements at low Q^2 to be made

The diffractive longitudinal structure function

H1 Preliminary F_L^D

$Q^2 = 4 \text{ GeV}^2$
$x_{IP} = 0.003$

H1 2006 DPDF Fit A
— $x_{IP} F_L^D$

H1 2006 DPDF Fit B
— $x_{IP} F_L^D$
⋯ $x_{IP} F_2^D$

- At low Q^2, the extrapolation of the NLO QCD fit predicts that F_L^D is approximately half the size of F_2^D

- The measurements are consistent with the extrapolation of Fit B

# The diffractive longitudinal structure function
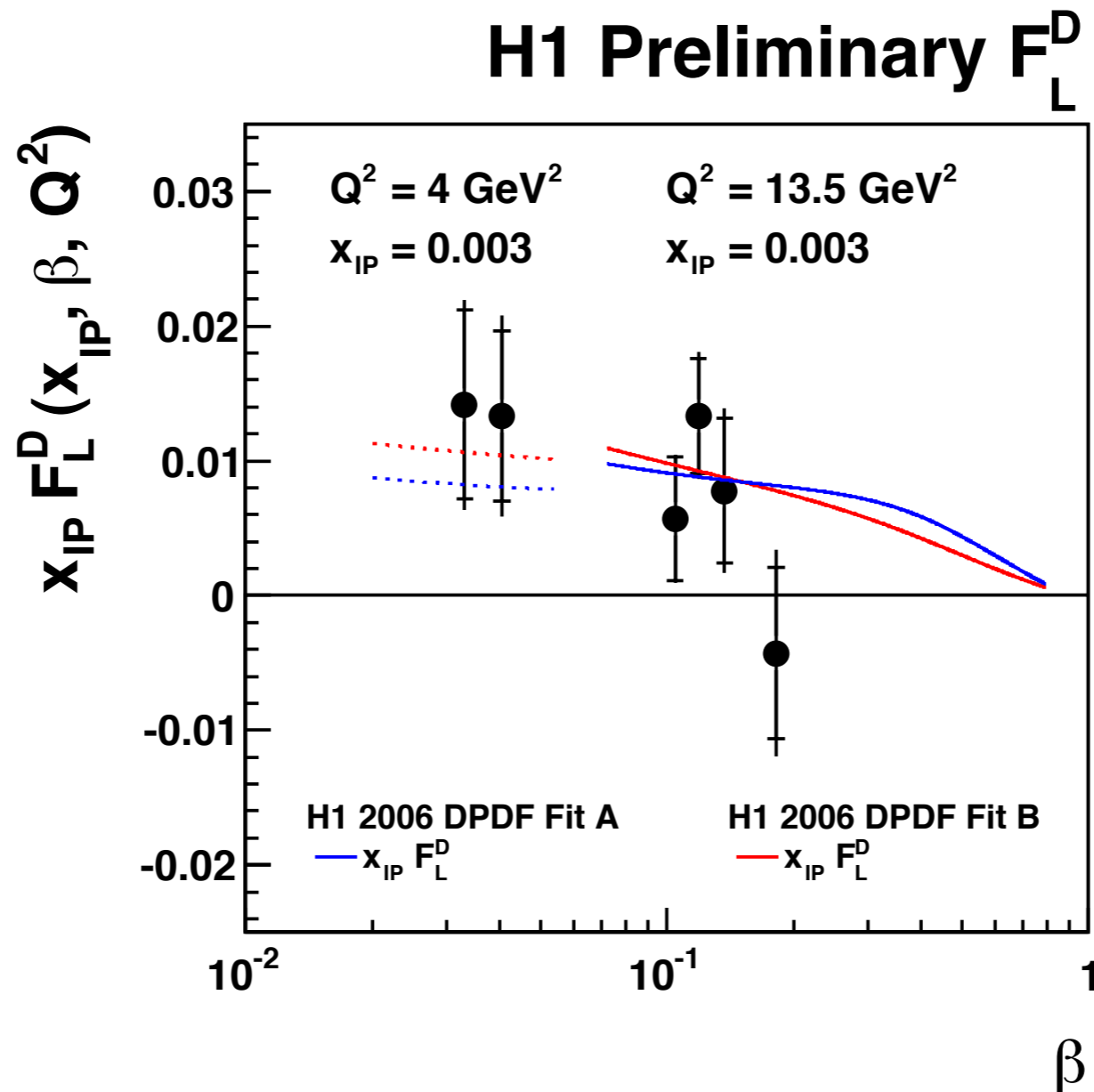
- The new measurements at low Q^2, shown together with the previous measurement of F_L^D at medium Q^2

- The measurements are consistent with the extrapolation of Fit B

H1 data

H1 data
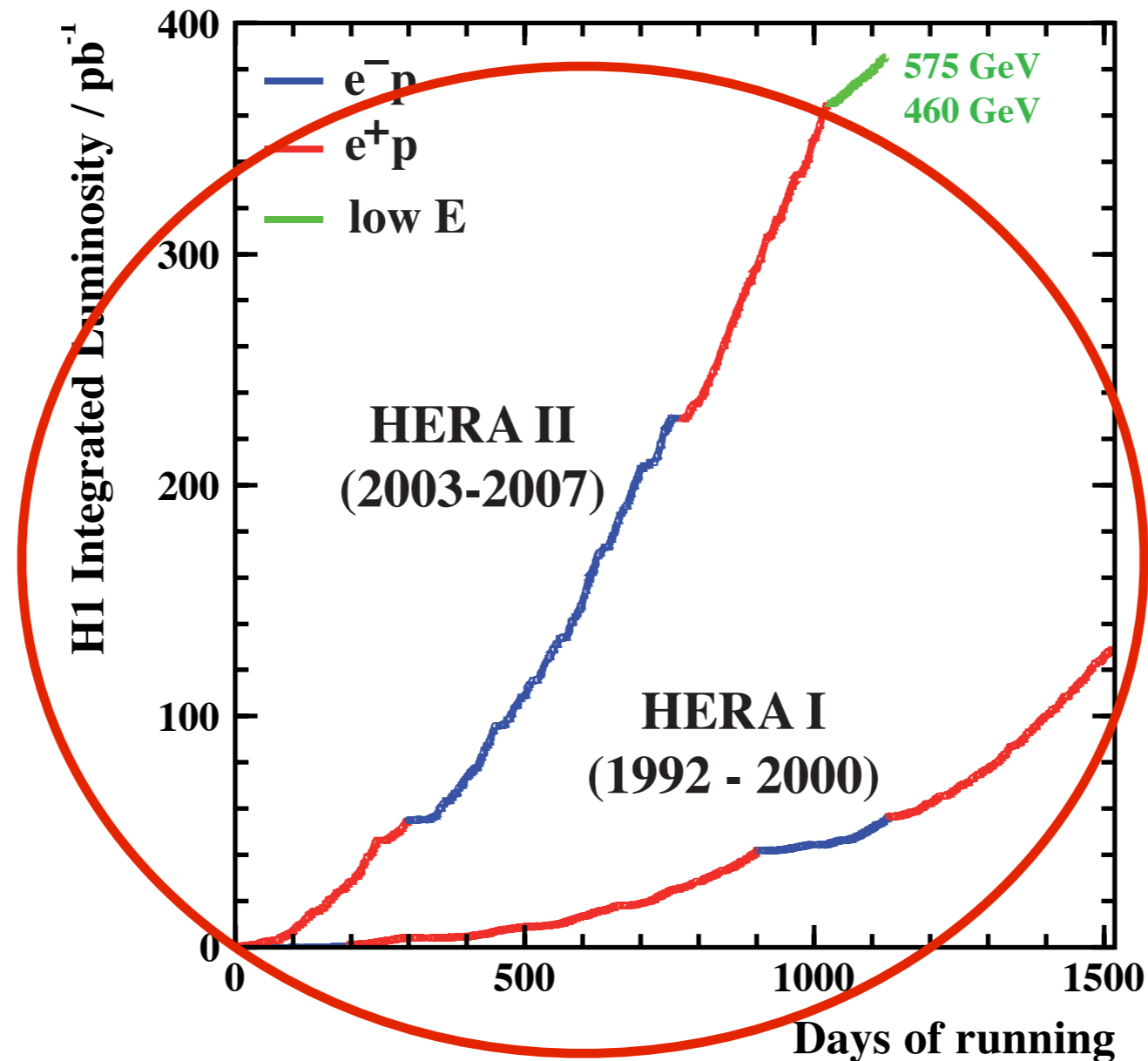
- The full HERA data sample, including both HERA I and HERA II datasets, has been analysed in order to measure σ_r^D to the best precision possible

- Question, can we also produce those classic scaling violation plots?

New H1LRG data - σ_r^D at fixed x_{IP}
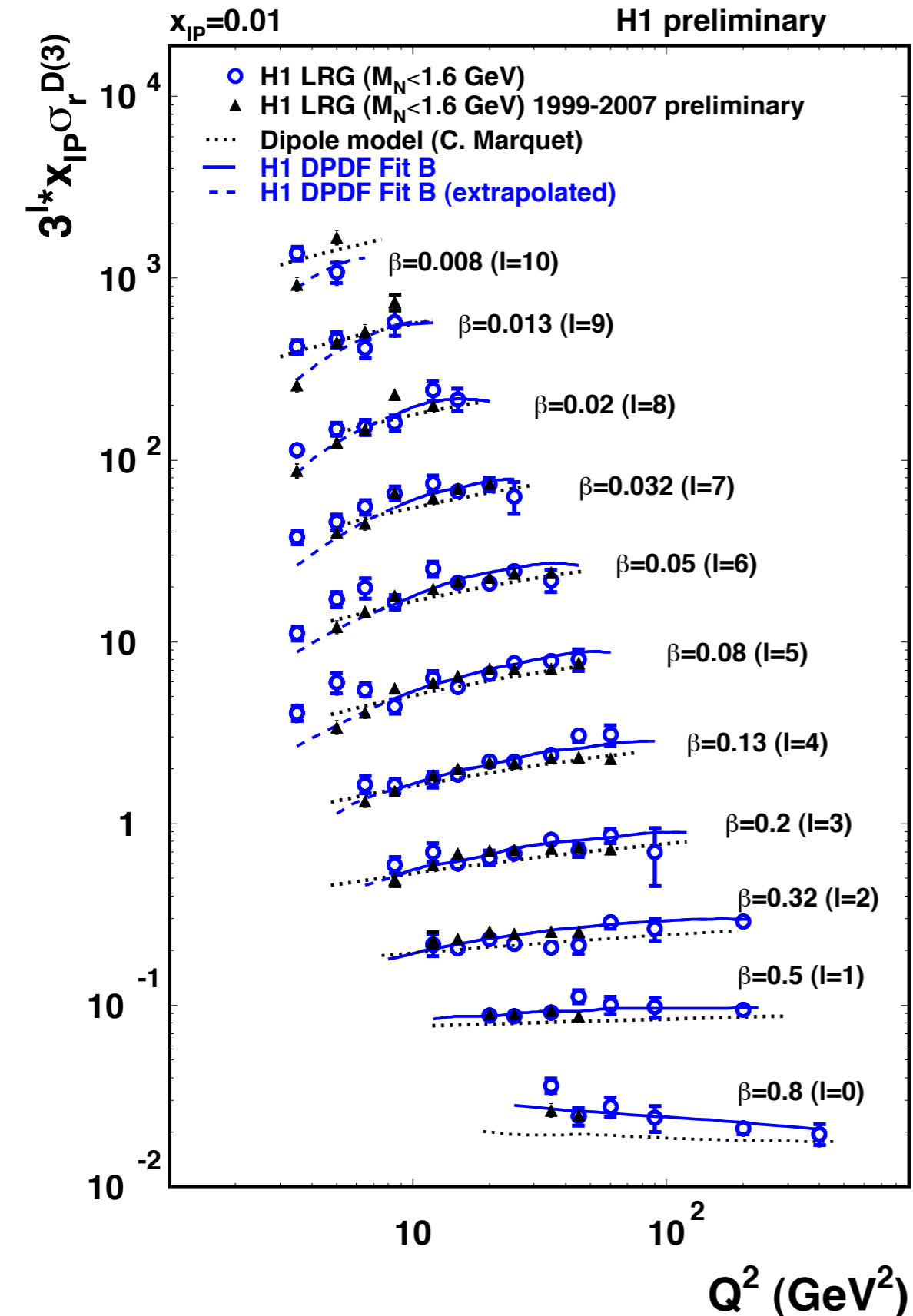

- The published data (**blue**) compared to the latest analysis of H1 LRG data (**black**)

- The larger dataset allow a more precise extraction of the reduced cross section compared to the published data

- Very precise measurements of the classic scaling violations for diffraction

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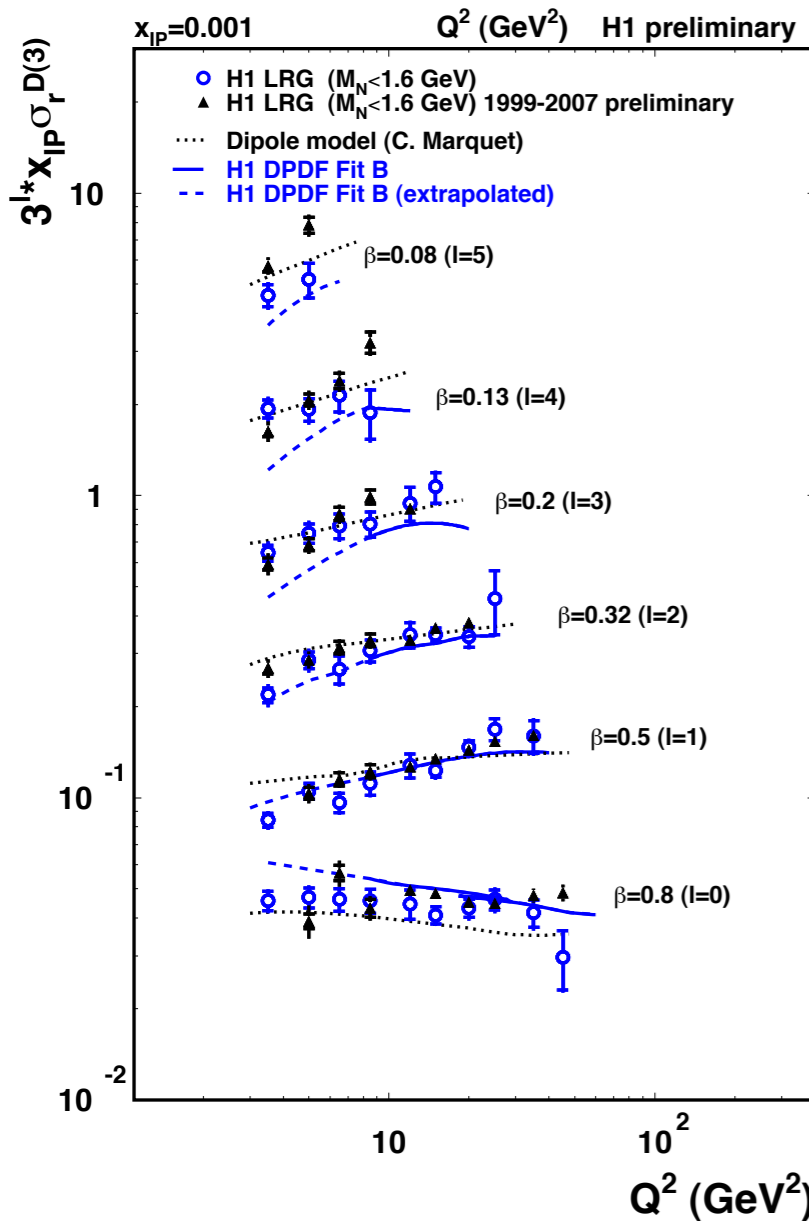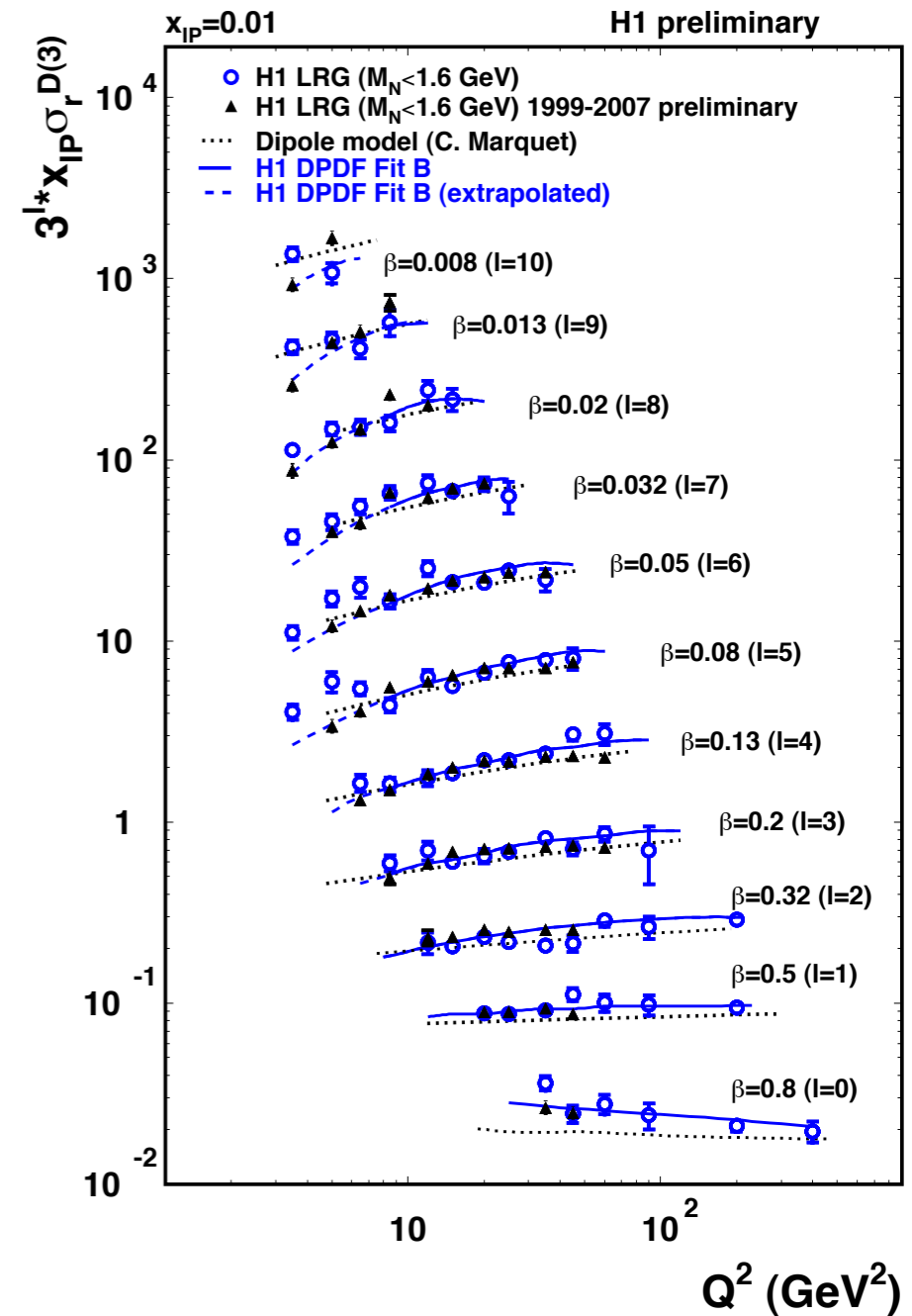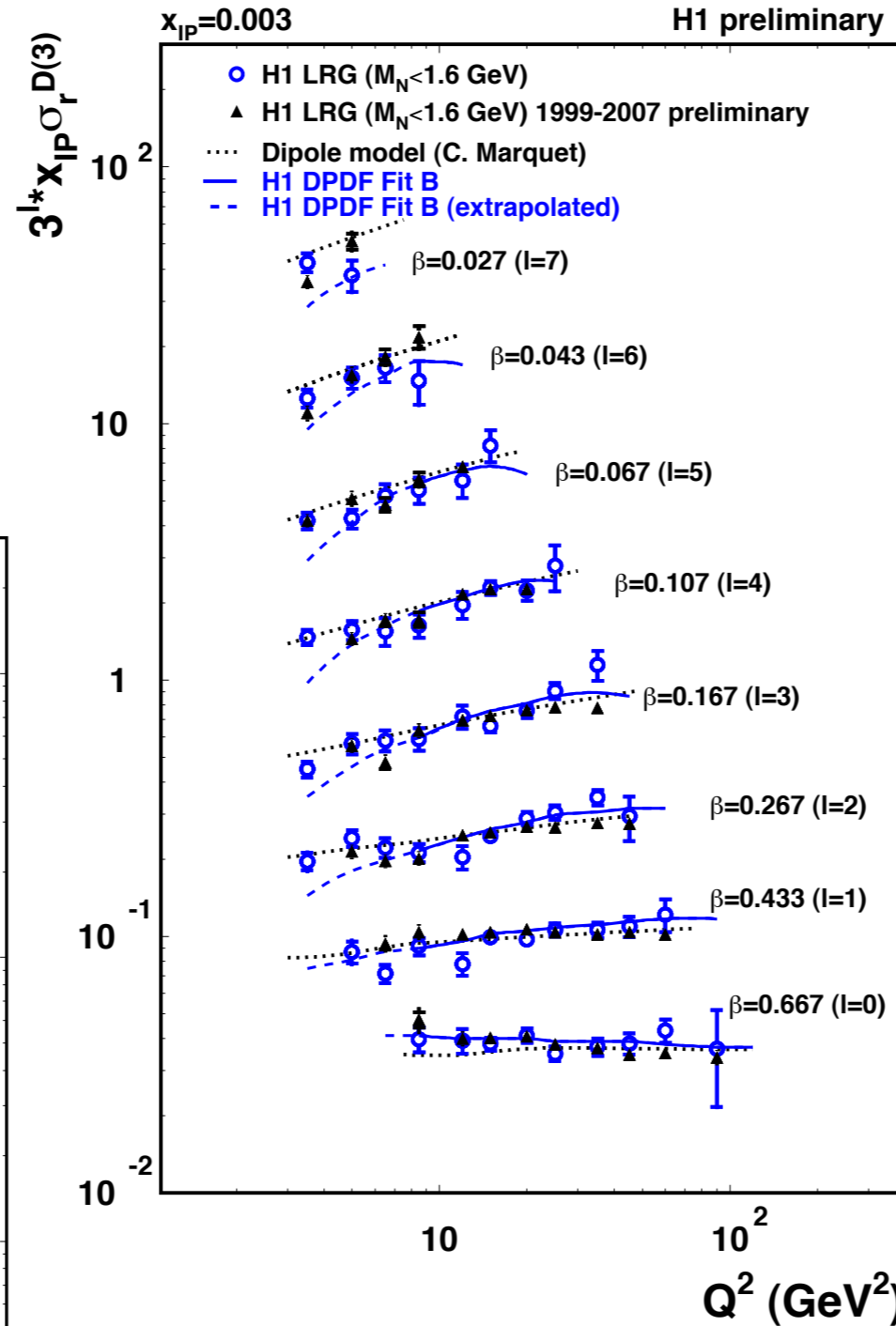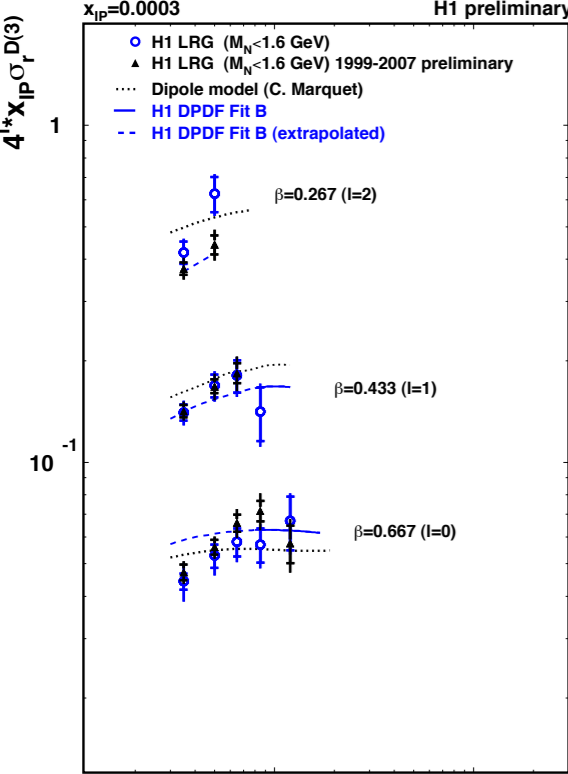# New H1LRG data - σ_r^D at fixed x_{IP}
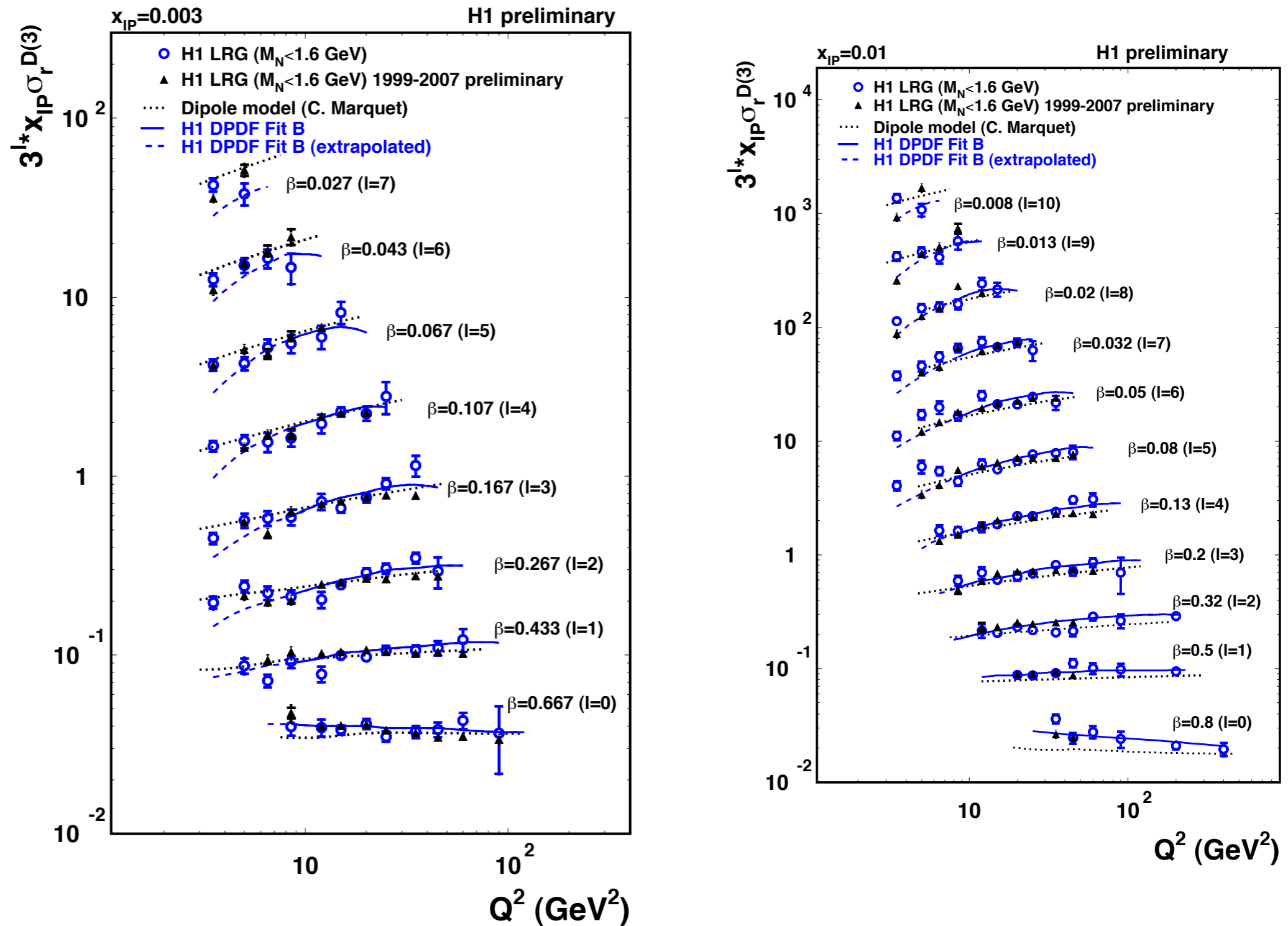
Similarly good precision in the next lowest x_{IP} bin

New H1 LRG data - σ_r^D at fixed x_{IP}
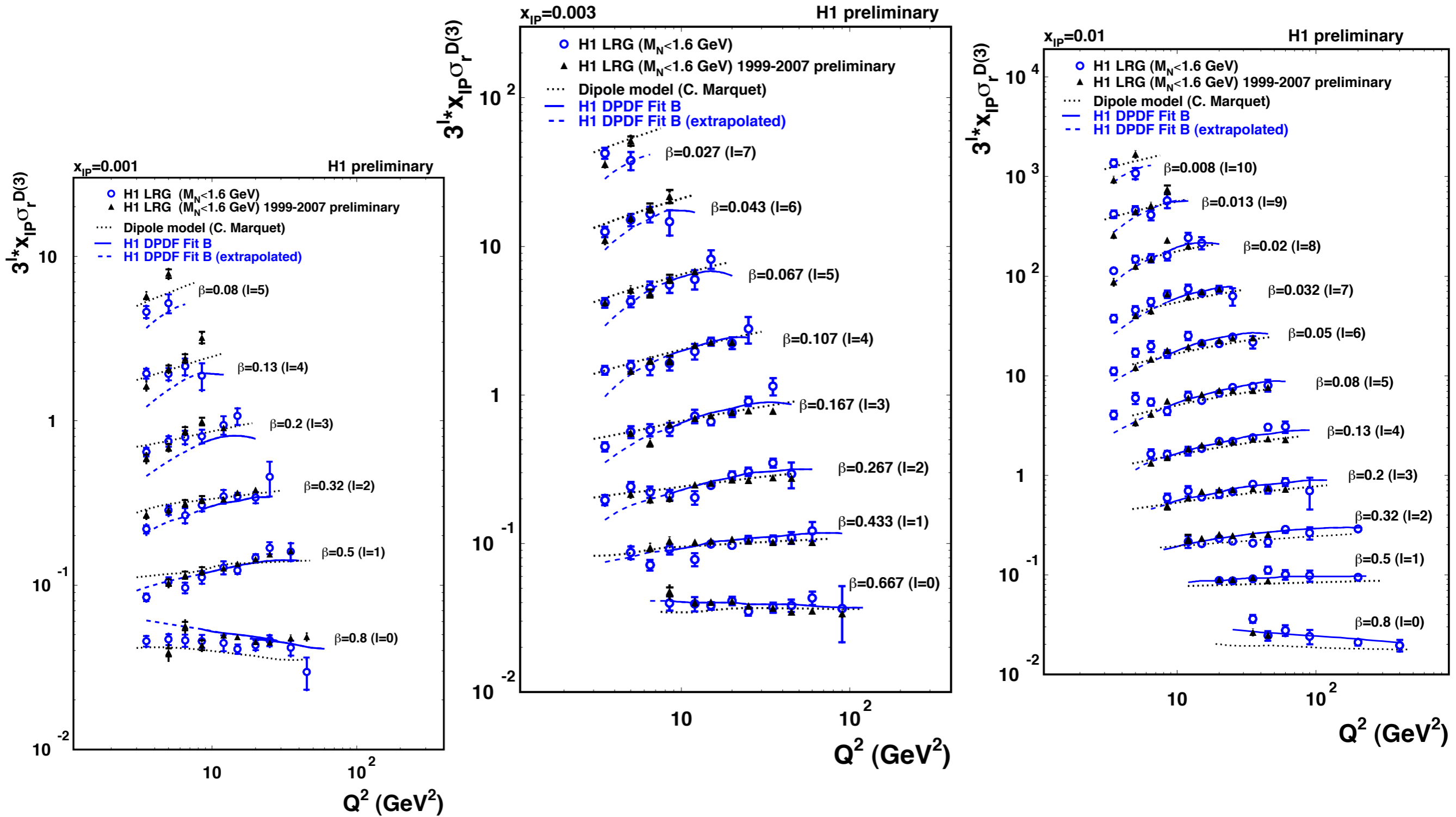
... and lower x_{IP}...

# New H1LRG data - σ_r^D at fixed x_{IP}

**Beautifully consistent data →
combine using weighted average**

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σ_r^D at fixed x_{IP} H1 and Zeus
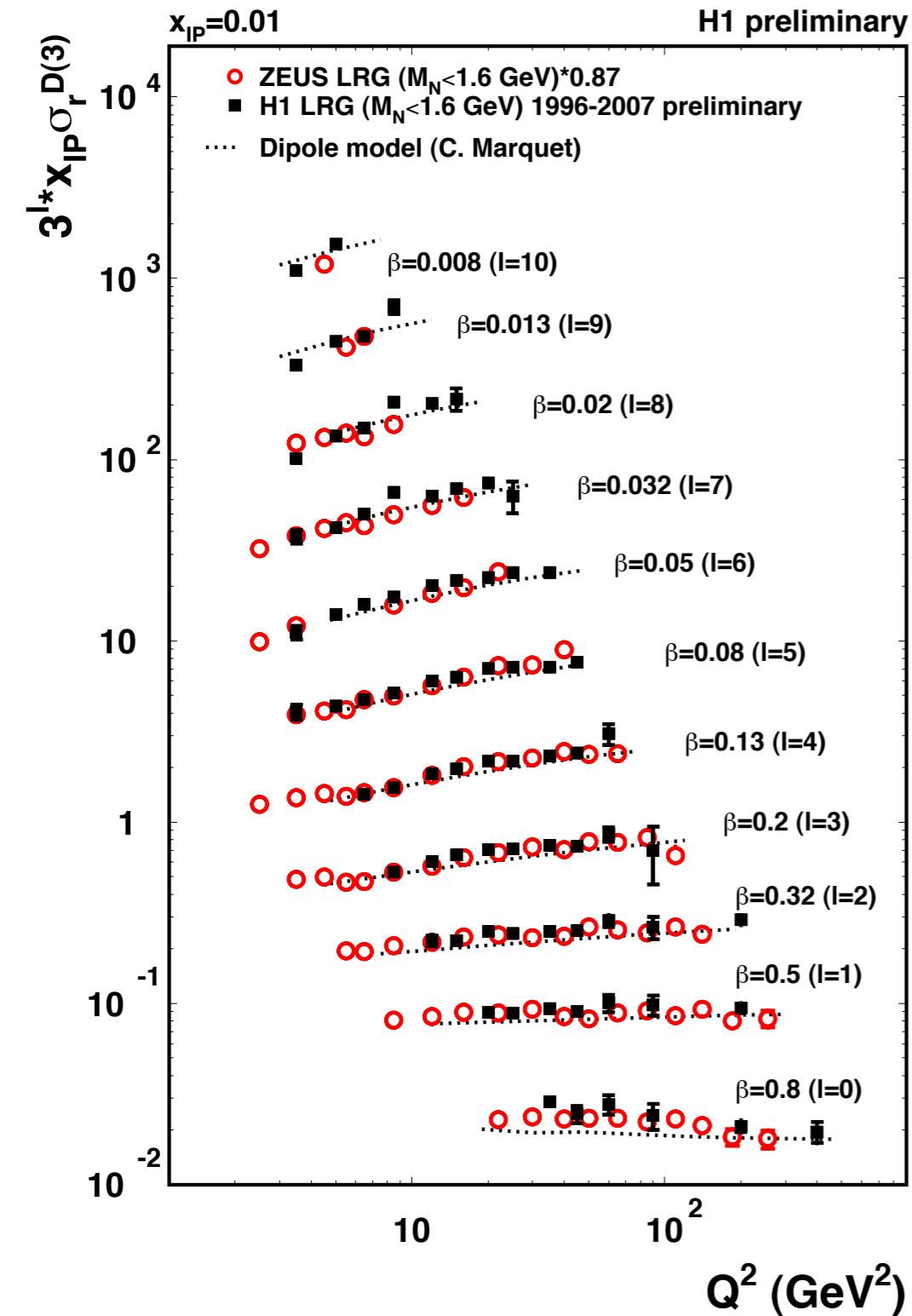
- The new H1 LRG data has been combined with the published data to create

  one combined H1 LRG dataset

- Compare H1 LRG data (**black**) to the published Zeus data (**red**) which is scaled by the "known" factor of 0.87

- Apart from the normalisation discrepancy, which is (just) consistent within large normalisation uncertainties...

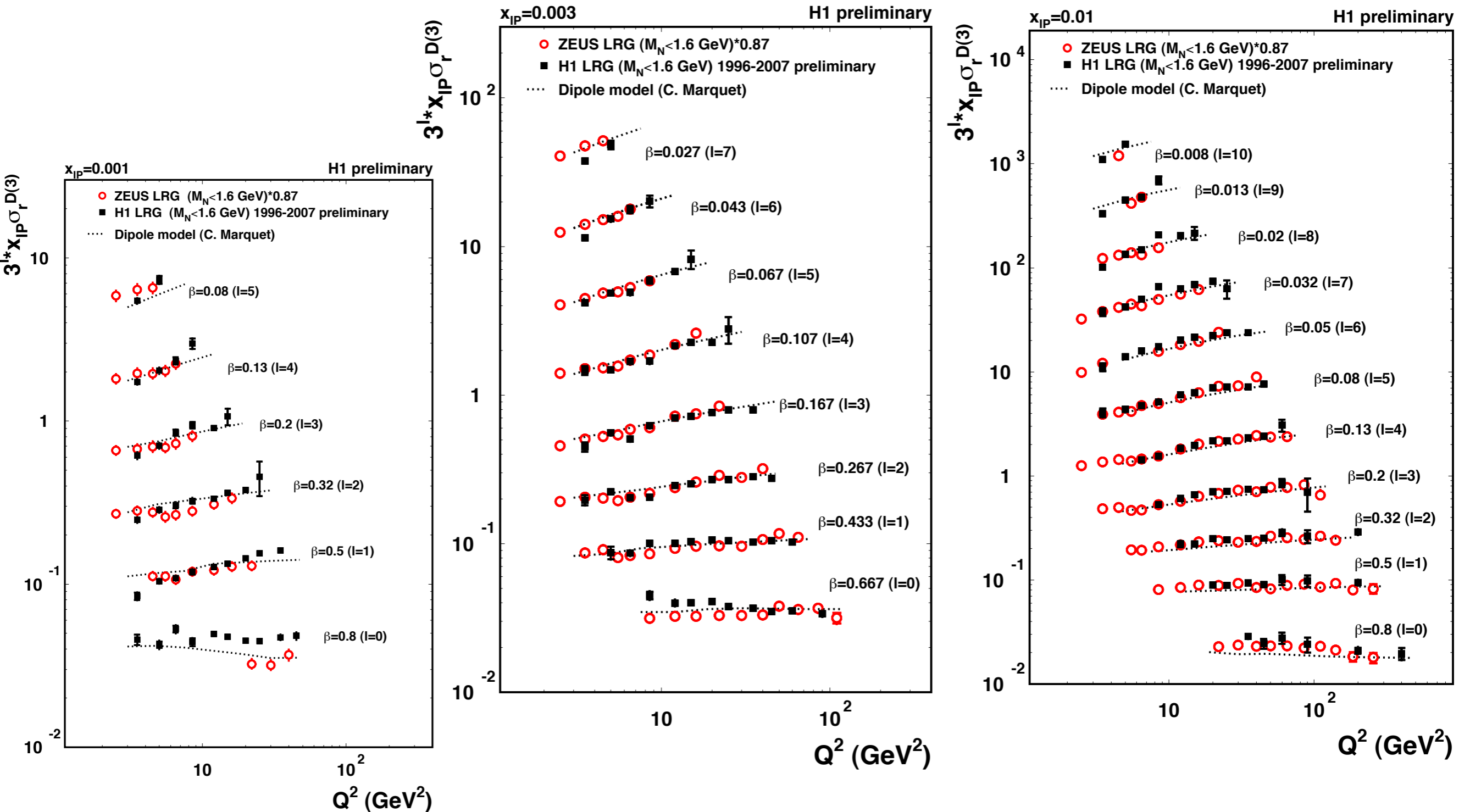- ...H1 and Zeus LRG data are in good agreement
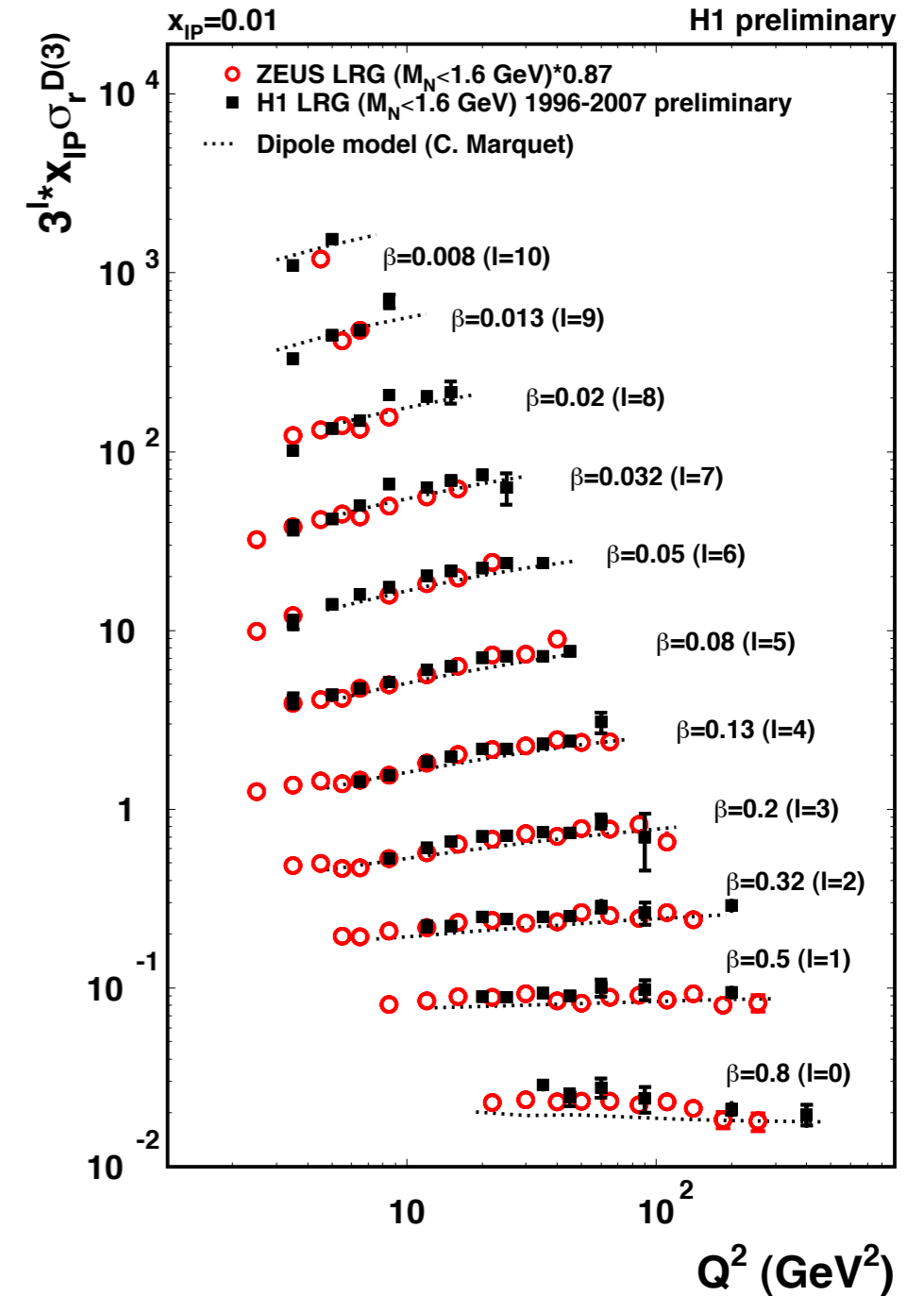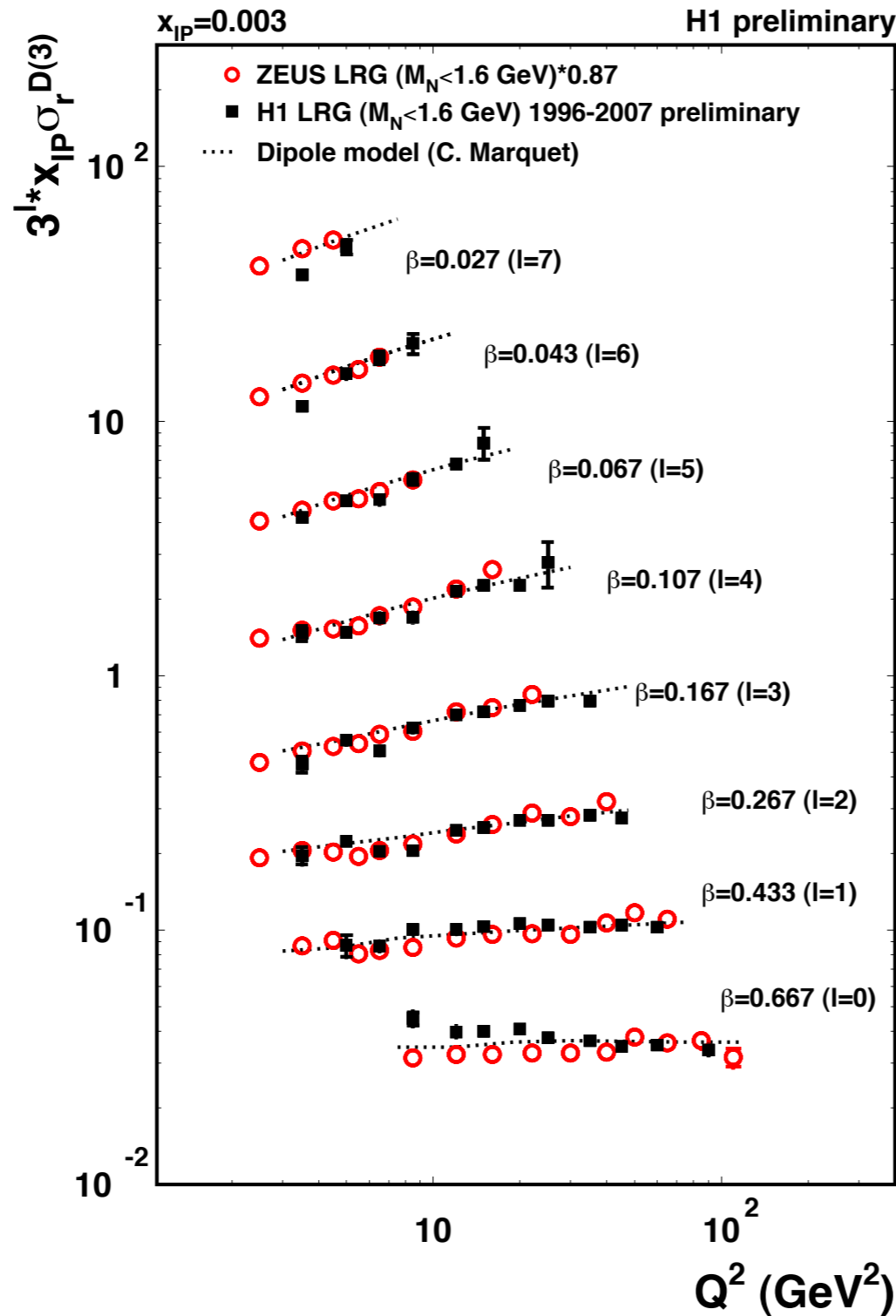
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σ_r^D at fixed x_{IP} H1 and Zeus

Good agreement between two high precision measurements

Differences to understand at high beta

$\sigma_r{}^D$ at fixed x_{IP} H1 and Zeus

Good agreement between two high precision measurements

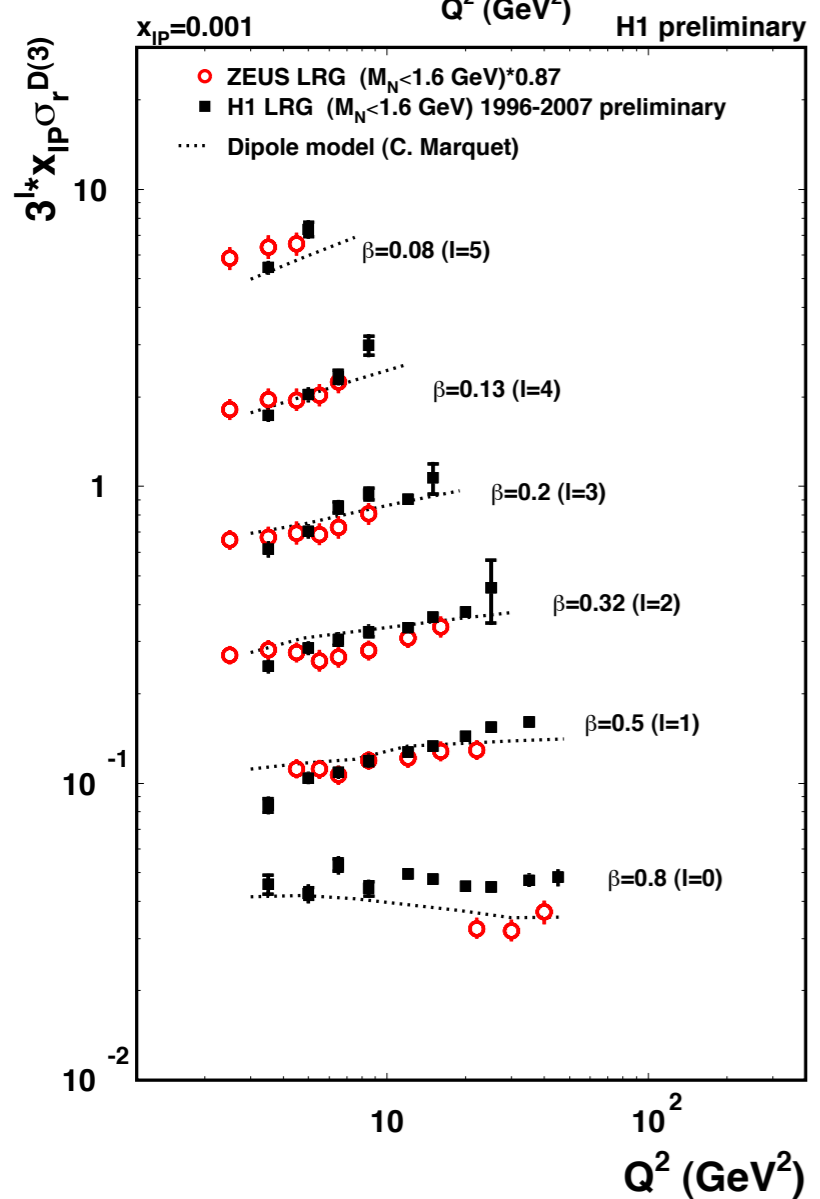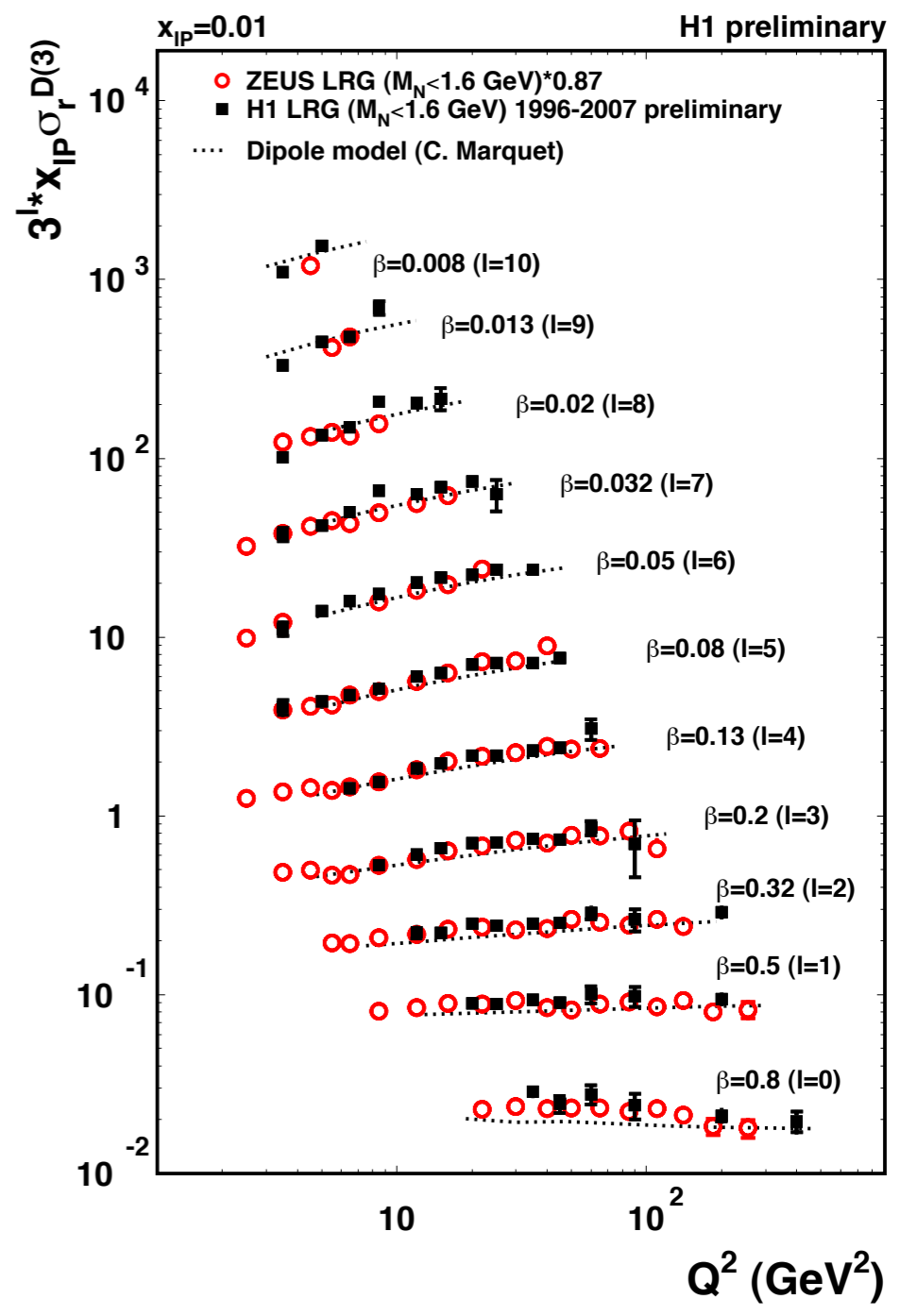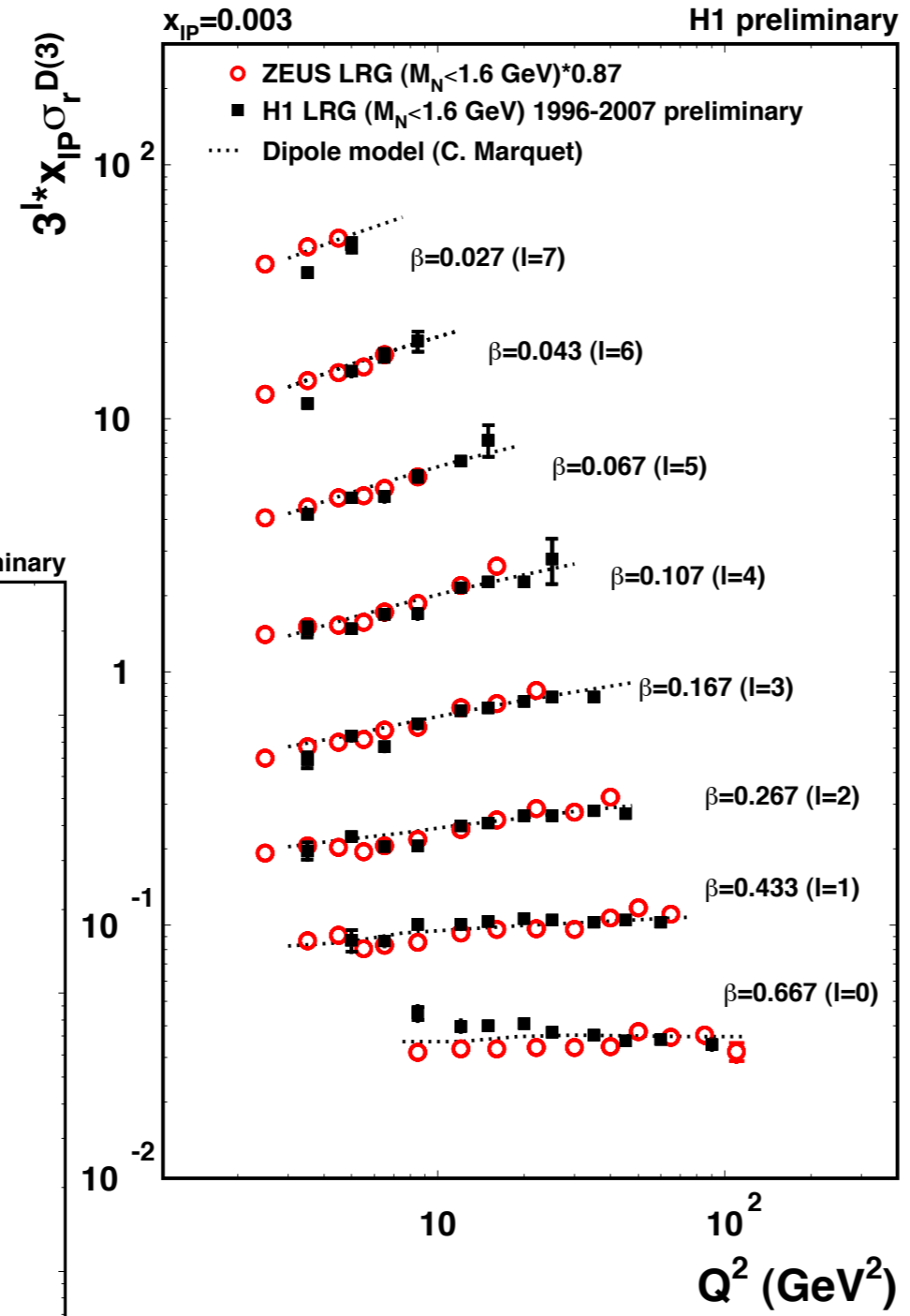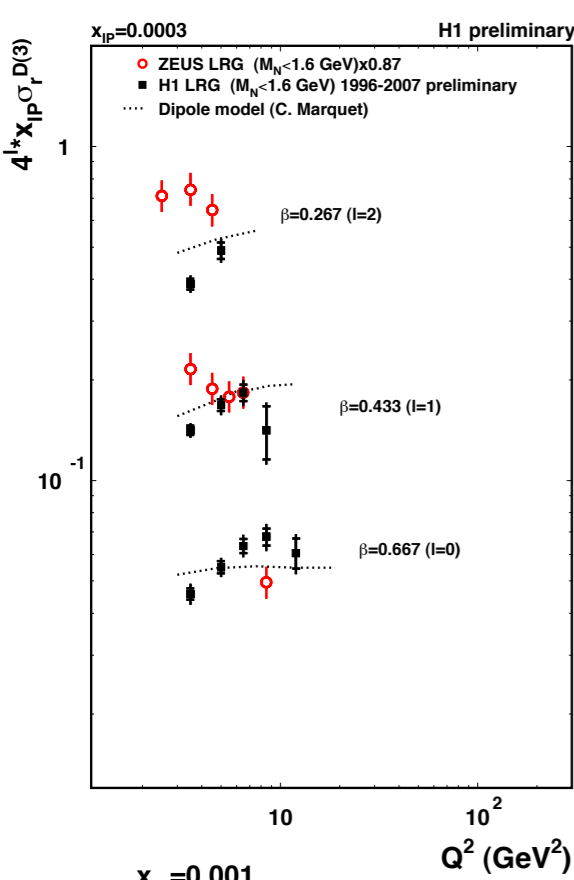Differences to understand at high beta

σ_r^D at fixed x_{IP} H1 and Zeus

Good agreement between two high precision measurements

Summary

- New measurements of the inclusive diffractive DIS cross section at low Q^2 ($Q^2 > 2.5$ GeV^2) and high y, using the low ($E_p = 460$ GeV) and medium ($E_p = 575$ GeV) energy runs from HERA have been presented

- The diffractive longitudinal structure function measurement at H1 has been extended to low Q^2

- The new results are in good agreement with the NLO QCD picture of diffraction, where F_L^D is approximately half the size of F_2^D

- The new results together with the result at medium Q^2 provide a more compelling confirmation of the NLO QCD picture of diffraction

- Inclusive diffractive DIS studied in H1 using Hera I and Hera II data

- Good agreement with the published data

- *One precise combined H1 LRG dataset*

- Backup slides