Diffractive Structure Functions with H1

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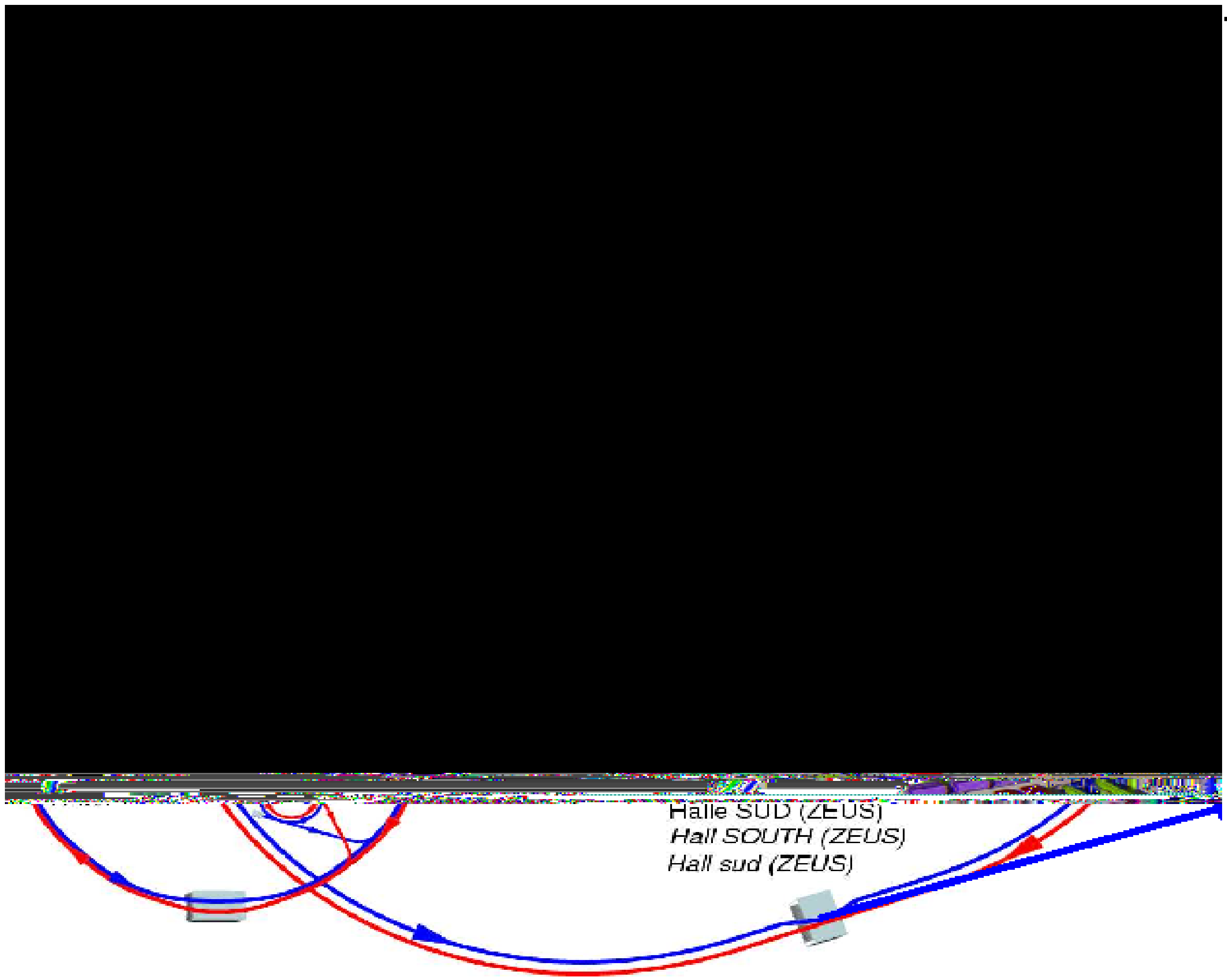
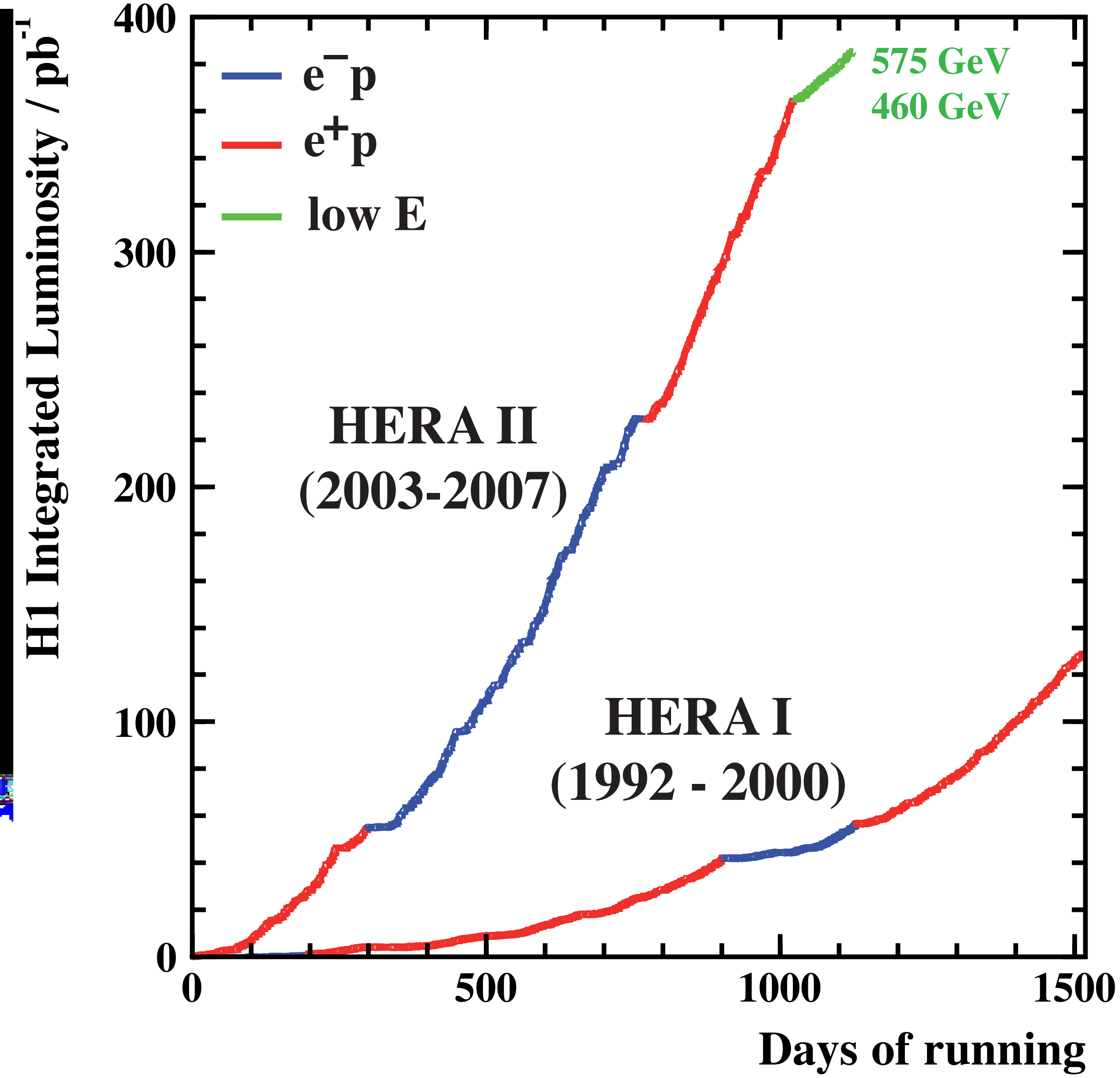
Thursday 21st July 2011
HEP 2011, Grenoble, France

- HERA datasets
- Diffractive DIS
- F_L^D and F_2^D

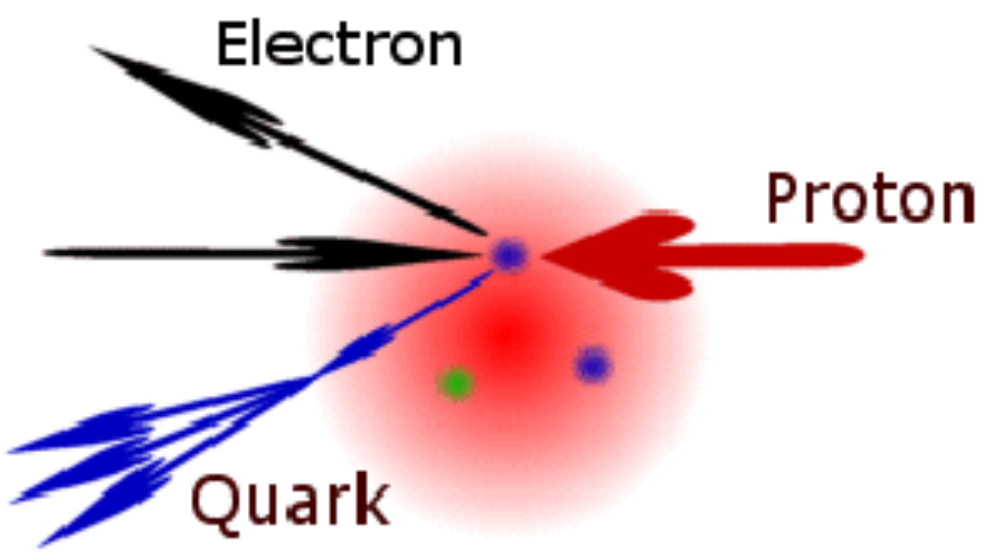
HERA, collider experiments and data

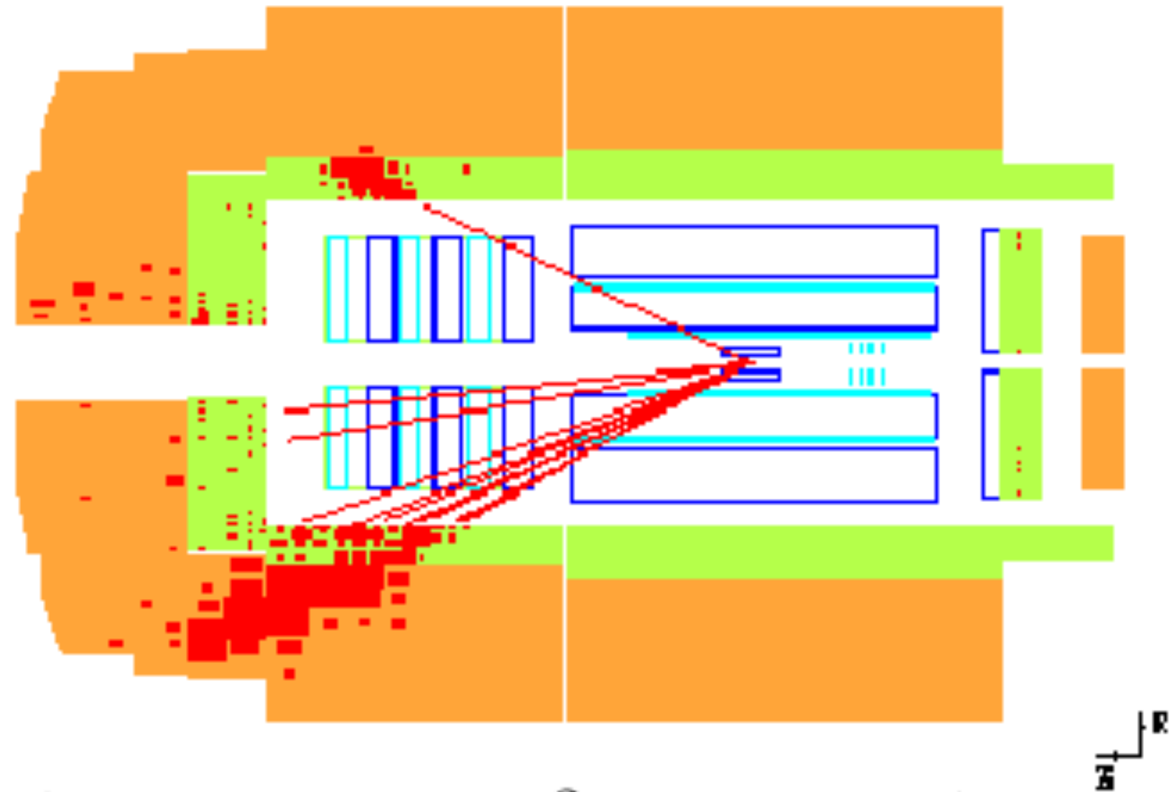




- The unique HERA machine collided 27.5 GeV electrons or positrons with protons of 460, 575, 820 and 920 GeV providing 0.5 fb^{-1} to H1
- The final precision analyses of this data are being delivered

Deep-inelastic Scattering





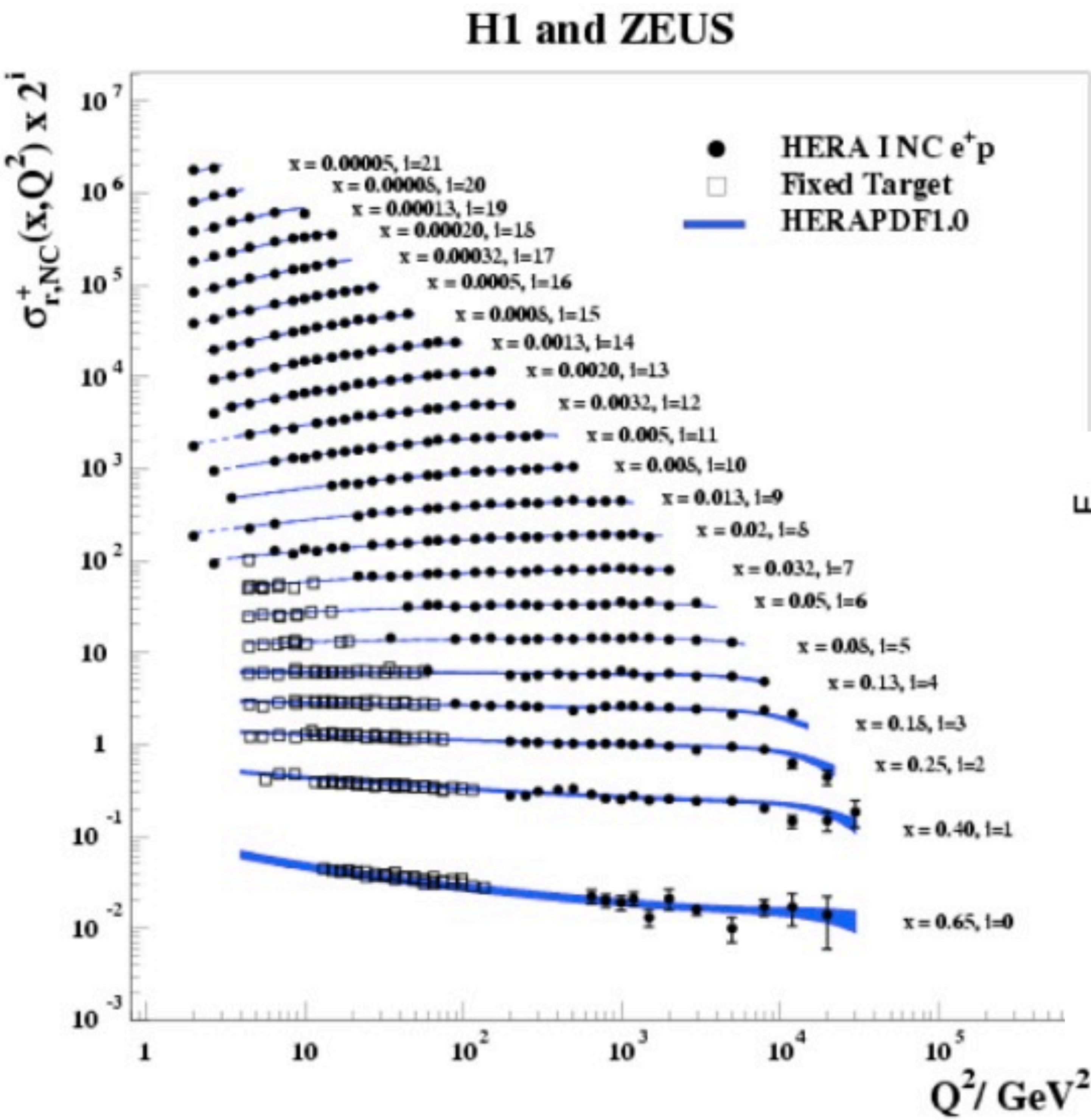
Measure:

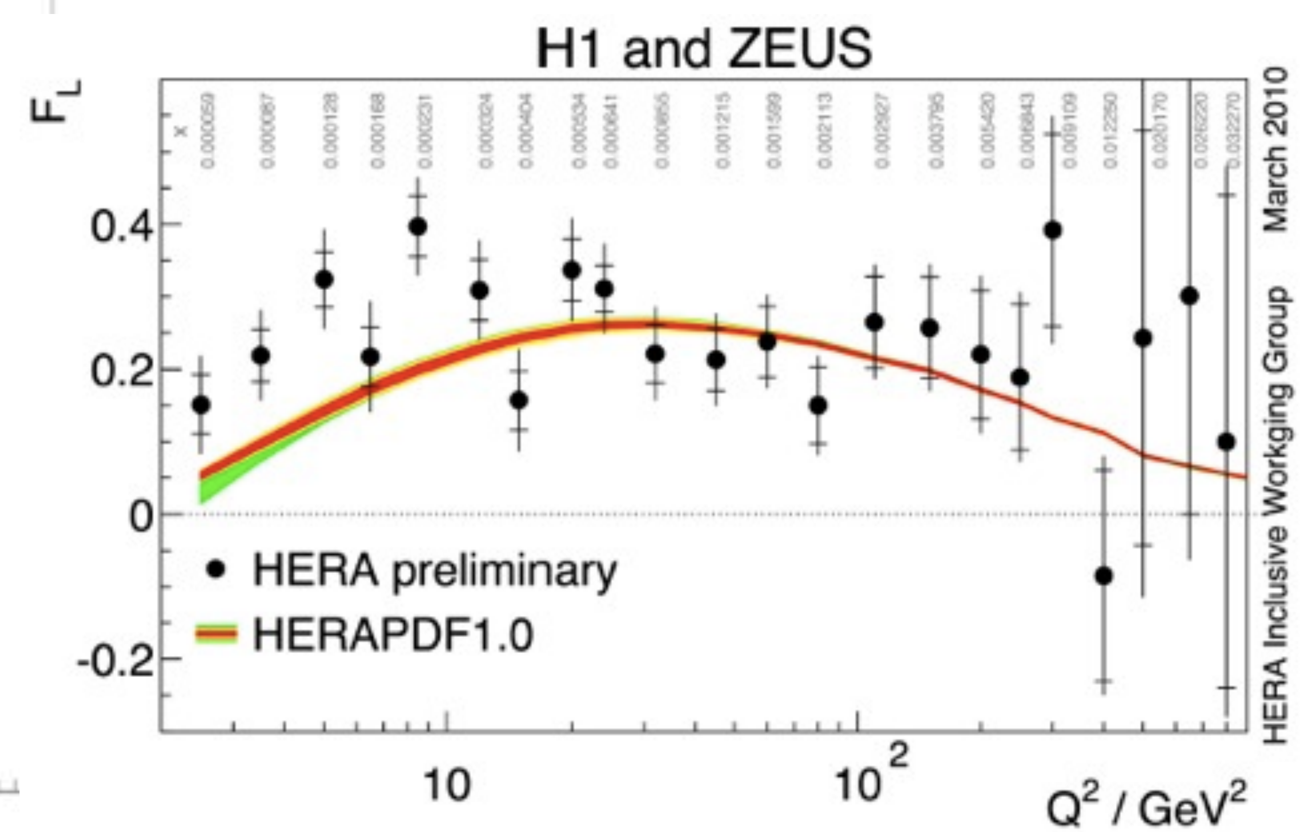
$$\frac{d^2\sigma^{ep}_{NC}}{dx\,dQ^2} = \frac{2\pi\alpha^2 Y_+}{xQ^4}\left(F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2)\right)$$

Extract:

- F_2 directly related to (PDFs) quark content: $F_2 \sim x\Sigma e^2(q+q)$
- $dF_2/d\ln Q^2$ (scaling violations) sensitive to gluon content
- F_L only non-zero in higher order QCD – independent access to gluon density and QCD dynamics

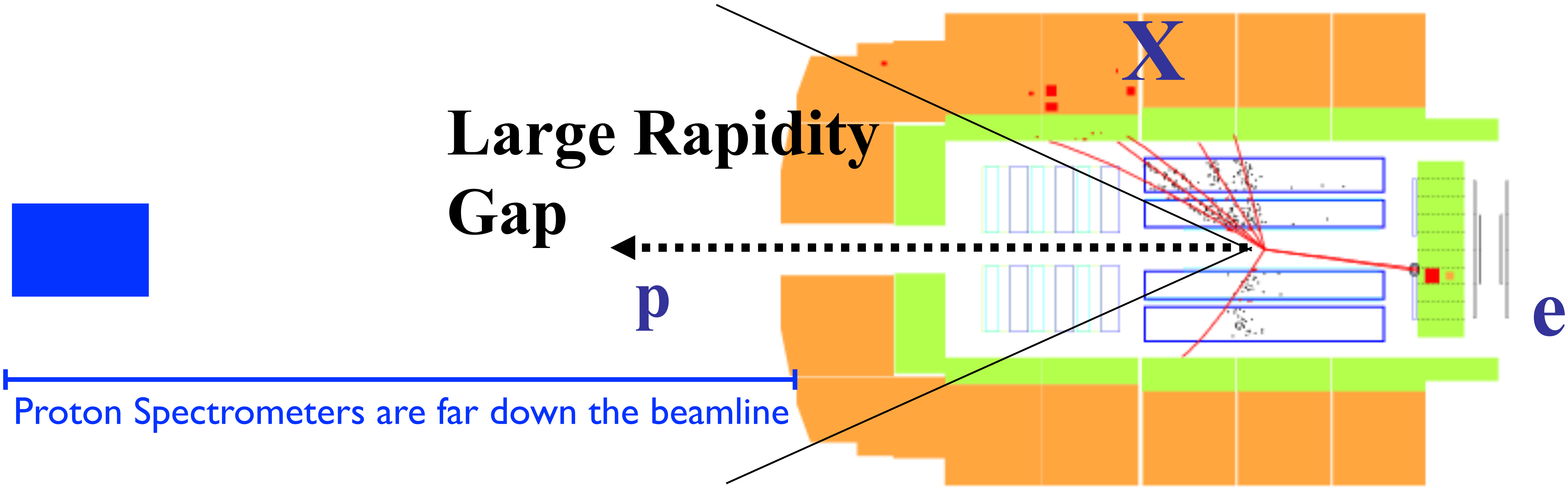
Inclusive F_2 and F_L





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

Diffractive Deep Inelastic Scattering: $ep \rightarrow epX$



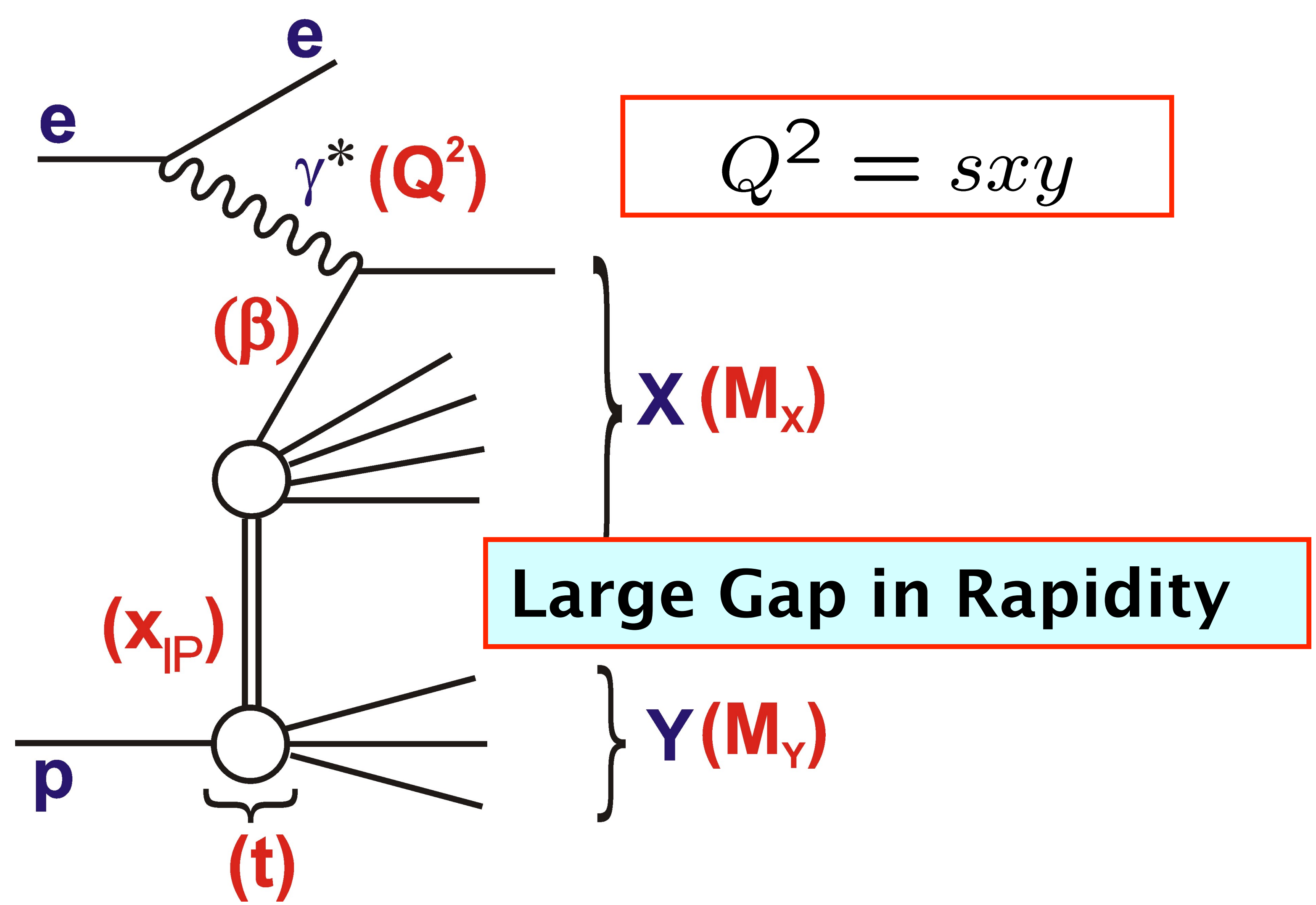
- Quasi-elastic scattering involving a colour singlet exchange
- Select events based on the Large Rapidity Gap topology or alternatively detect the elastically-scattered proton in a **Proton Spectrometer**
- The experimental mandate is simple - measure the kinematic dependences of the cross section for the process

Diffractive Structure Functions

$$x = x_{\mathbb{P}}\beta$$

$$\beta = \frac{Q^2}{Q^2+M_X^2}$$

$$x_{\mathbb{P}} = \frac{Q^2+M_X^2}{Q^2+W^2}$$



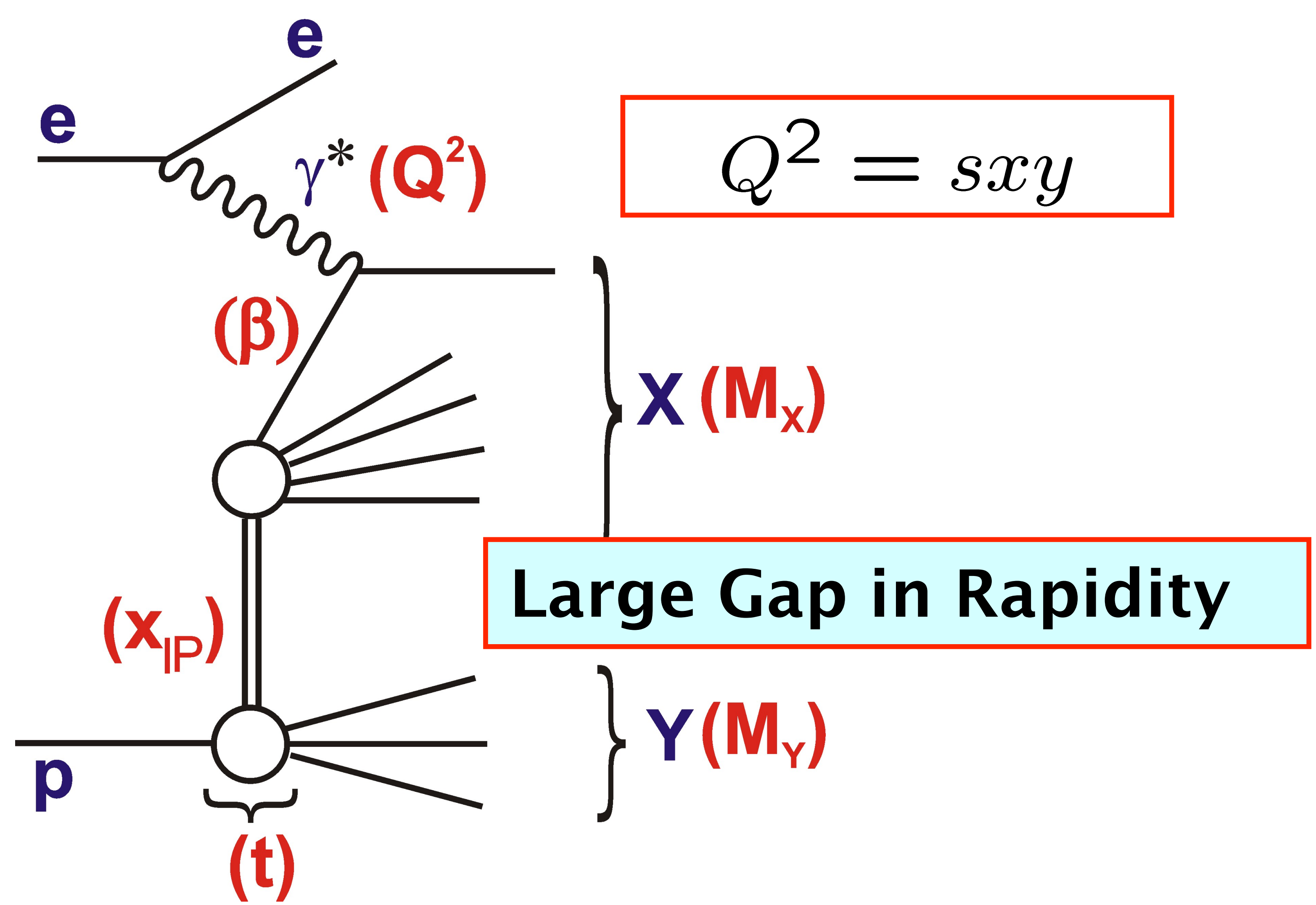
$$Q^2 = sxy$$

Diffractive Structure Functions

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

$$\beta = \frac{Q^2}{Q^2+M_X^2}$$

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



$$Q^2 = sxy$$

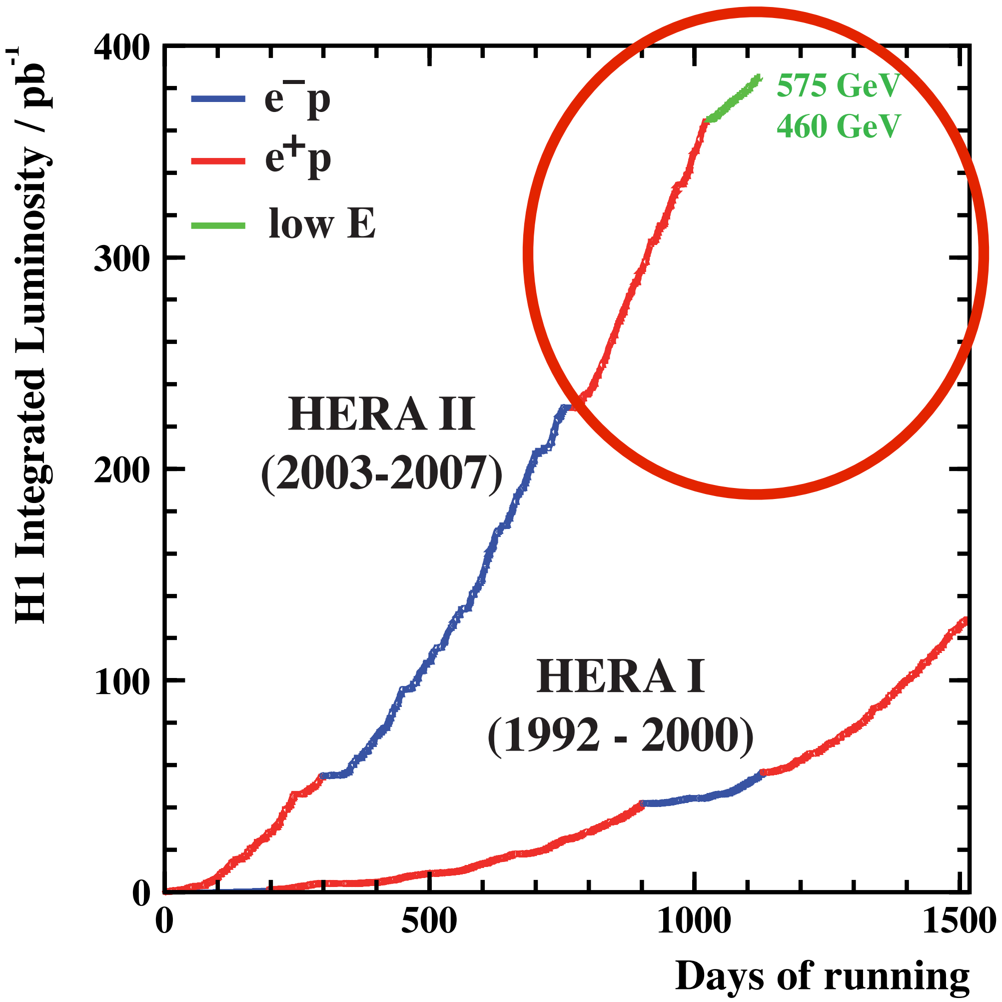
$$Y_+ = 1 + (1-y)^2$$

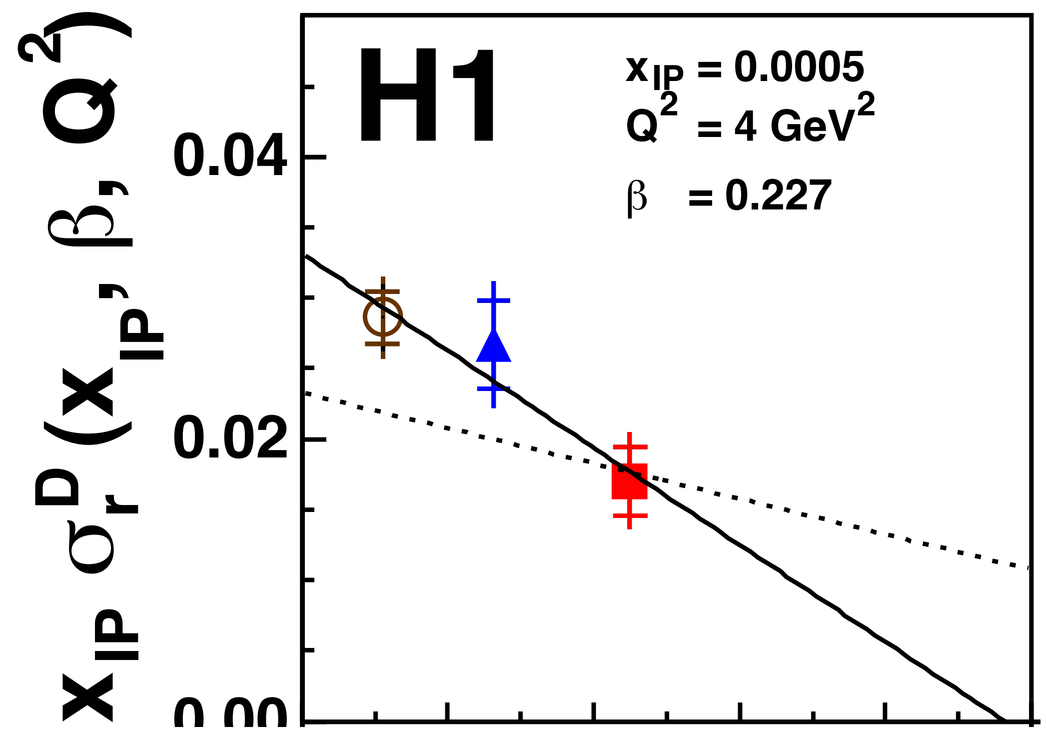
Cross section: $\frac{d^4\sigma^{ep\to eXp}}{dx dQ^2 dx_{I\!P} dt} = \frac{4\pi\alpha^2}{xQ^4} Y_+ \sigma_r^{D(4)}(x, Q^2, x_{I\!P}, t)$

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

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

F_L^D using H1 data



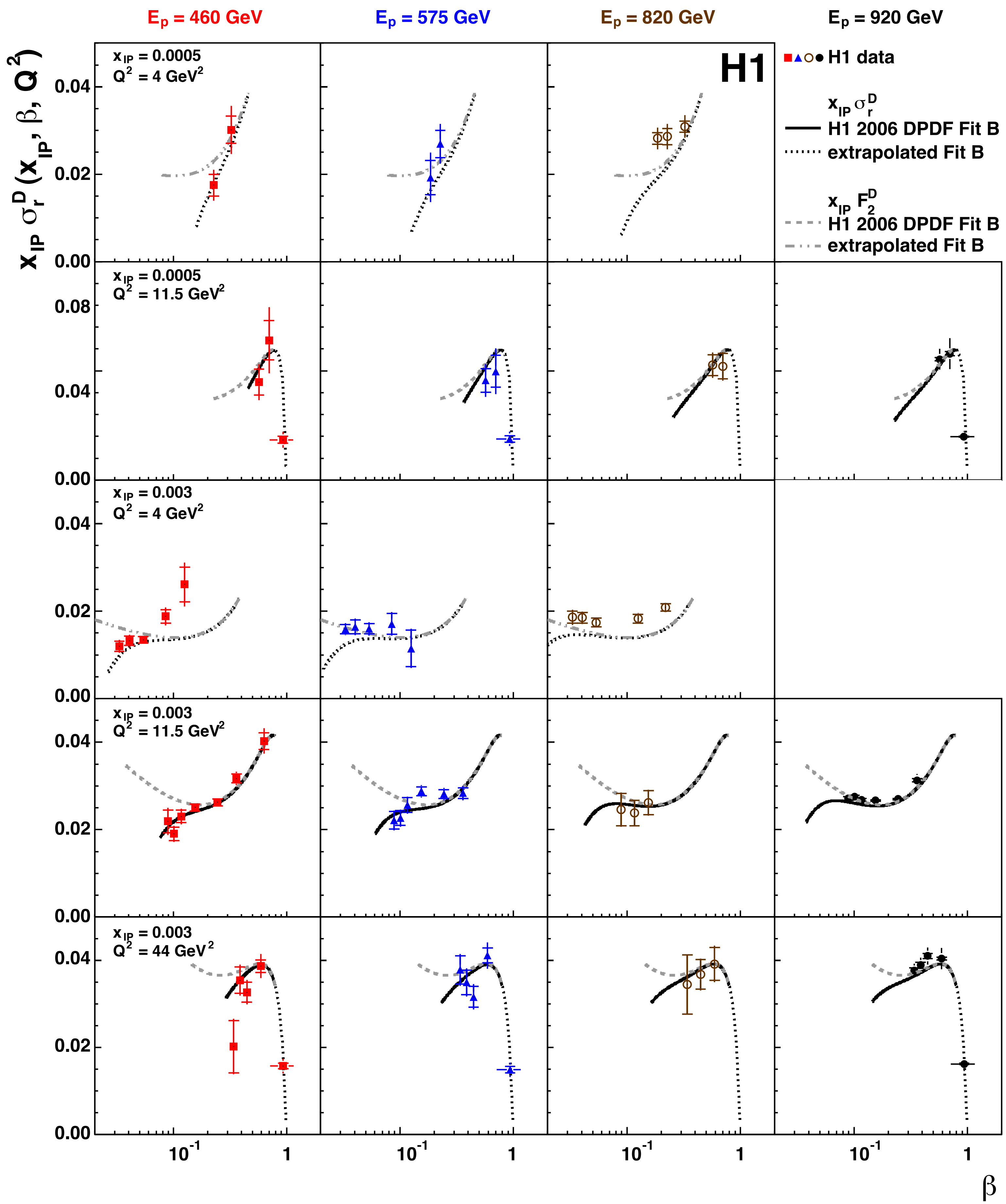


$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{Y_+} F_L^{D(4)}$$

- Measure cross sections at fixed x_{IP}, β, Q^2 and different y values using H1 data with different proton beam energies → F_L^D
- Analysis now published on the full kinematic range $Q^2 > 2.5$ GeV^2

arXiv:1107.3420

Diffractive cross sections at medium and high y

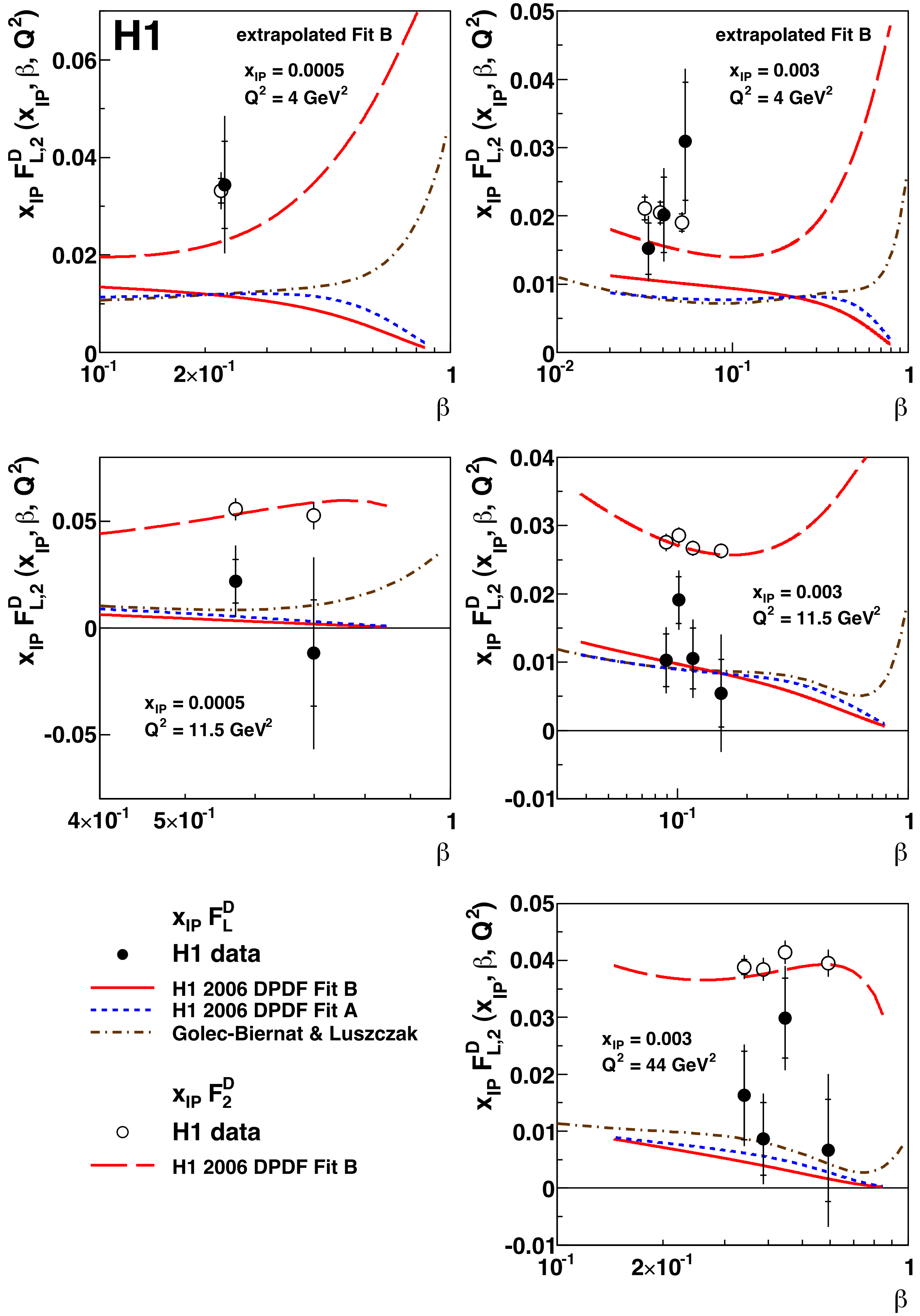


New diffractive cross sections using E_p = 920 GeV, E_p = 575 GeV, E_p = 460 GeV and previously ***published*** data (hep-ex/0606004) using E_p = 820 GeV, all compared to H1 2006 DPDF Fit B

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 in that fit)

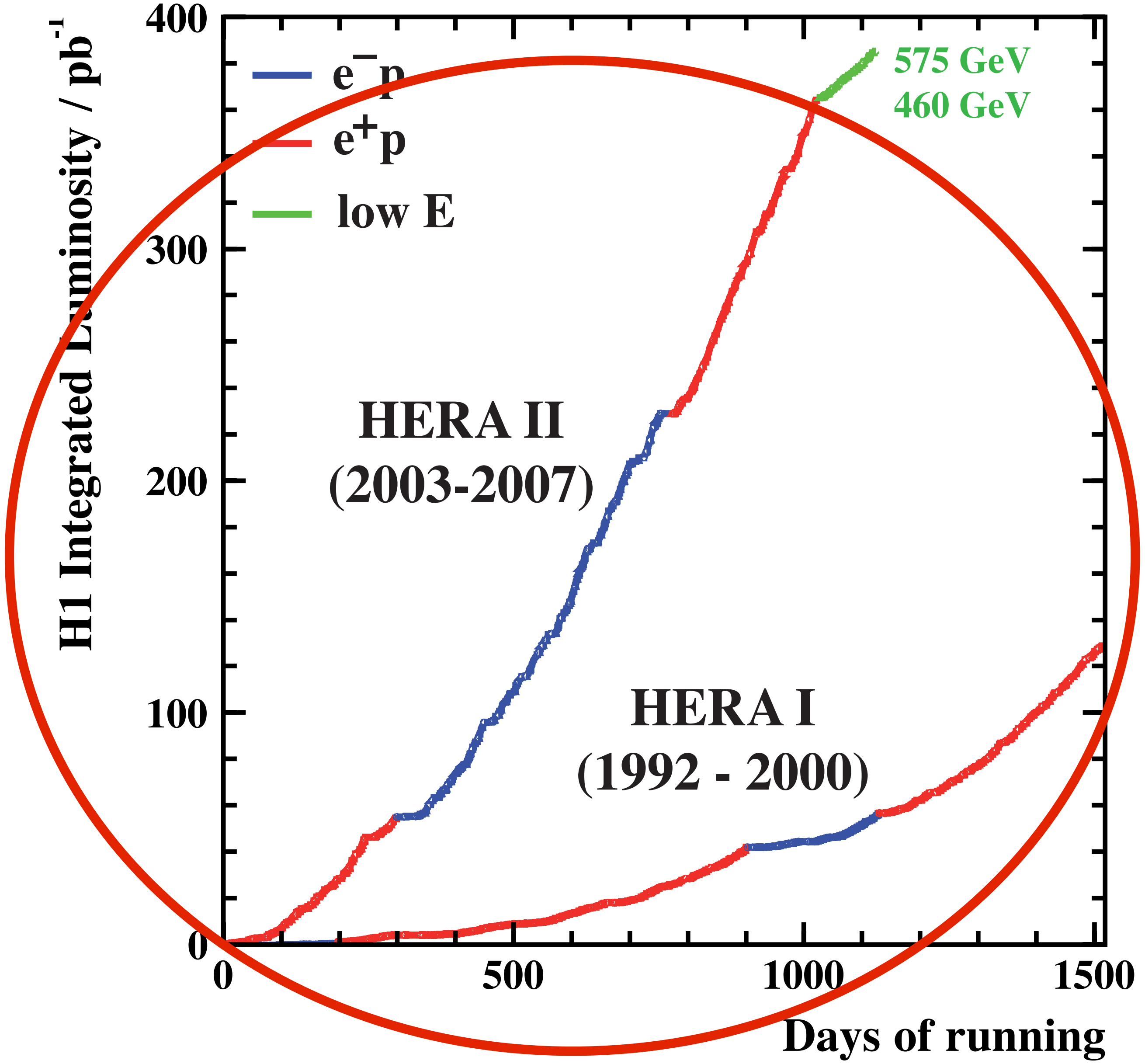
Cross-sections binned coarsely in order to optimise F_L^D extraction

The diffractive structure functions



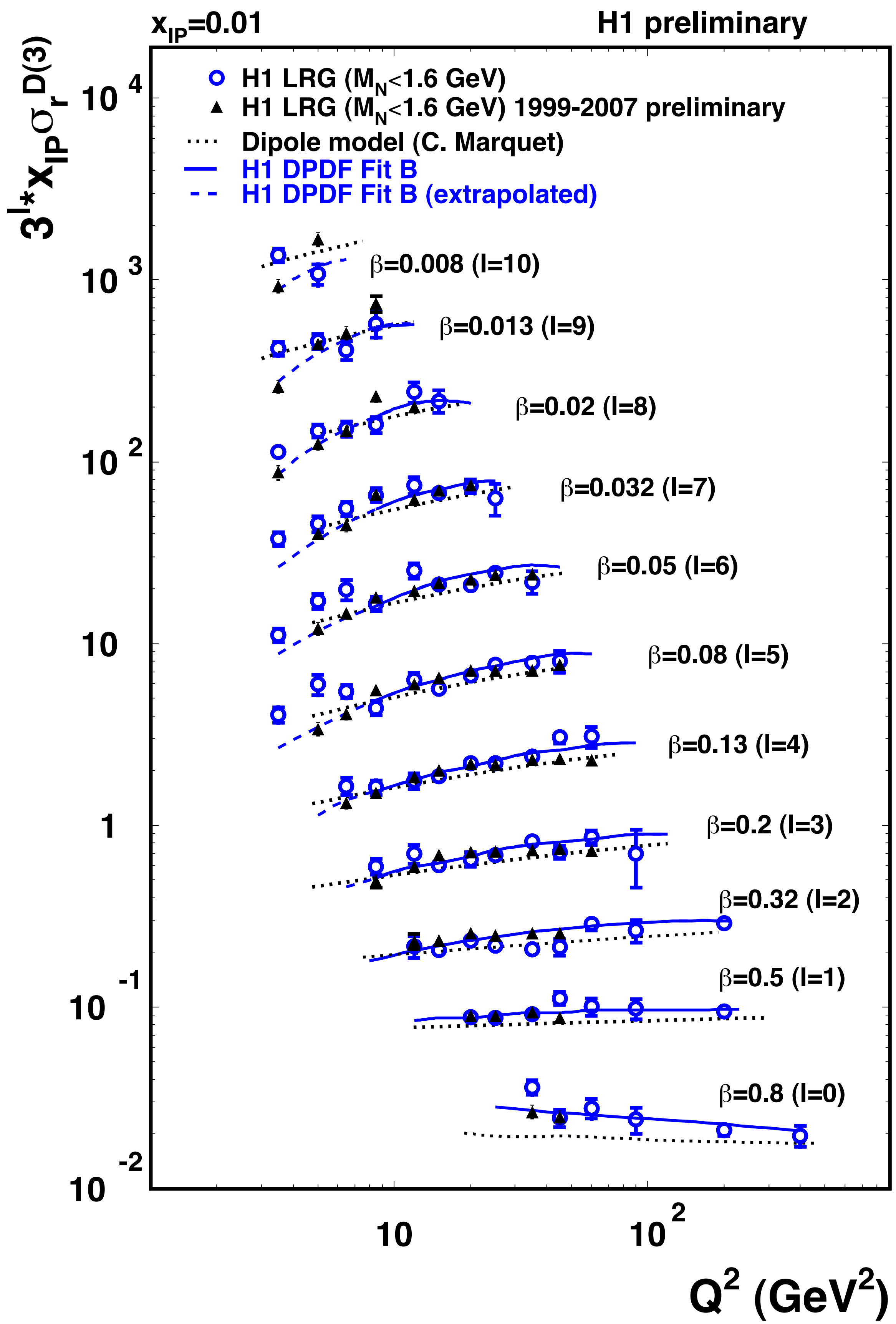
- F_2^D and F_L^D extracted simultaneously for three bins in Q^2 (= 4, 11.5, 44 GeV^2) and two bins in x_{IP} (=0.0005, 0.003) as a function of β
- The data are consistent with the hypothesis $0 < F_L^D < F_2^D$
- The F_2^D and F_L^D data agree well with the prediction of H1 2006 DPDF Fit B
- The F_L^D data also compare well with a modified colour dipole model of Golec-Biernat & Luszczak

F_2^D using all H1 data



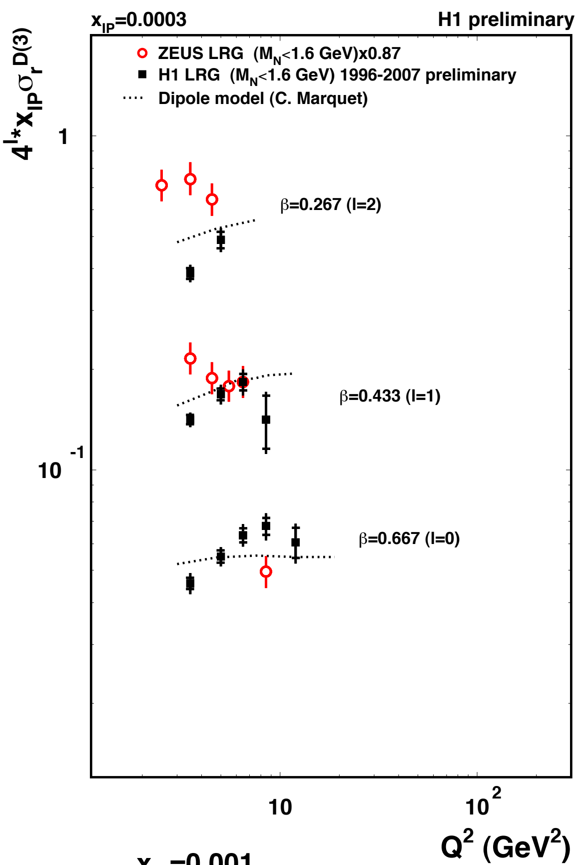
- The full HERA data sample, including both HERA I and HERA II datasets, has been analysed in order to measure σ_r^D to the best precision possible
- Question: can we also produce those classic scaling violation plots?

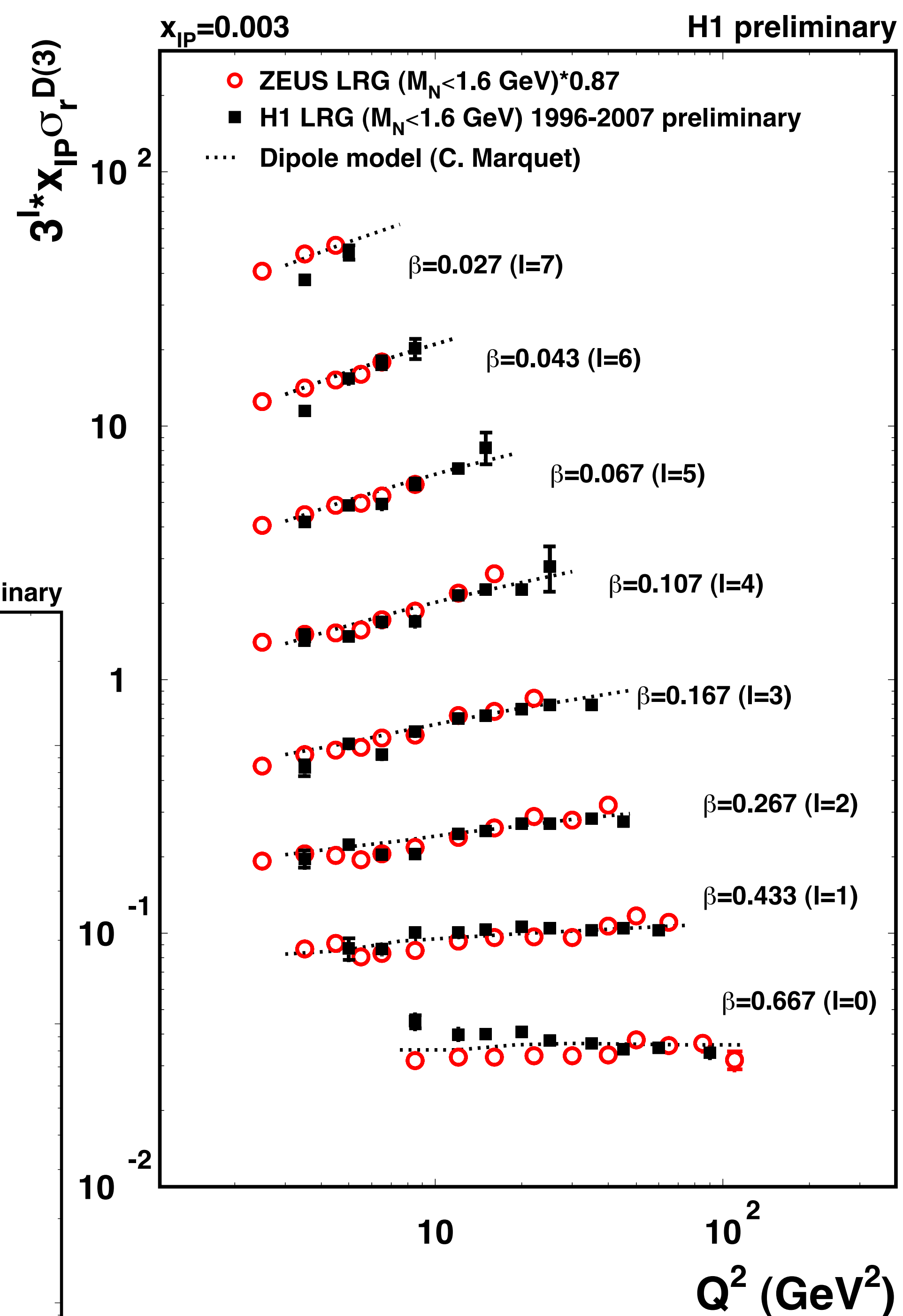
New H1LRG data - σ_r^D at fixed x_{IP}

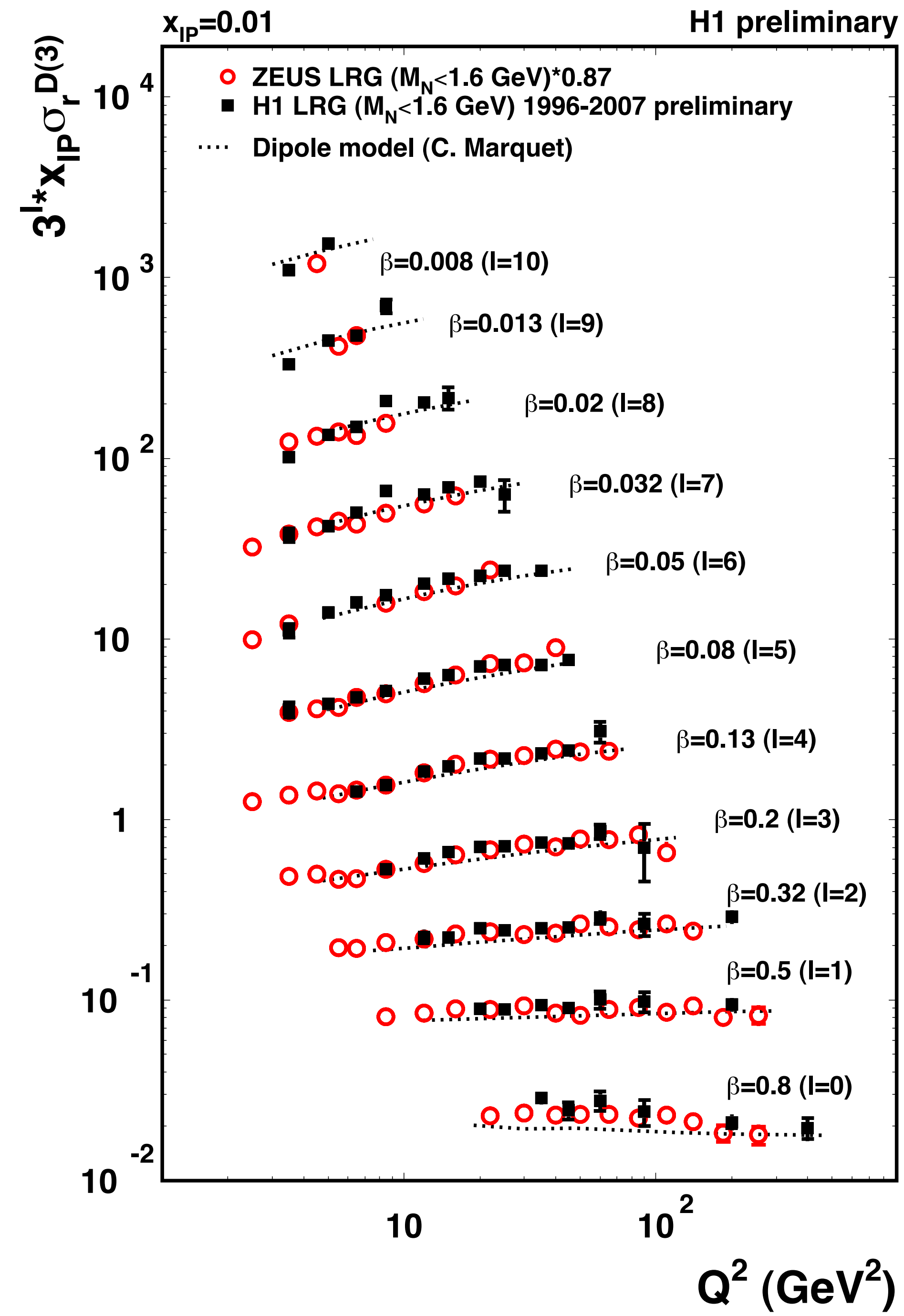


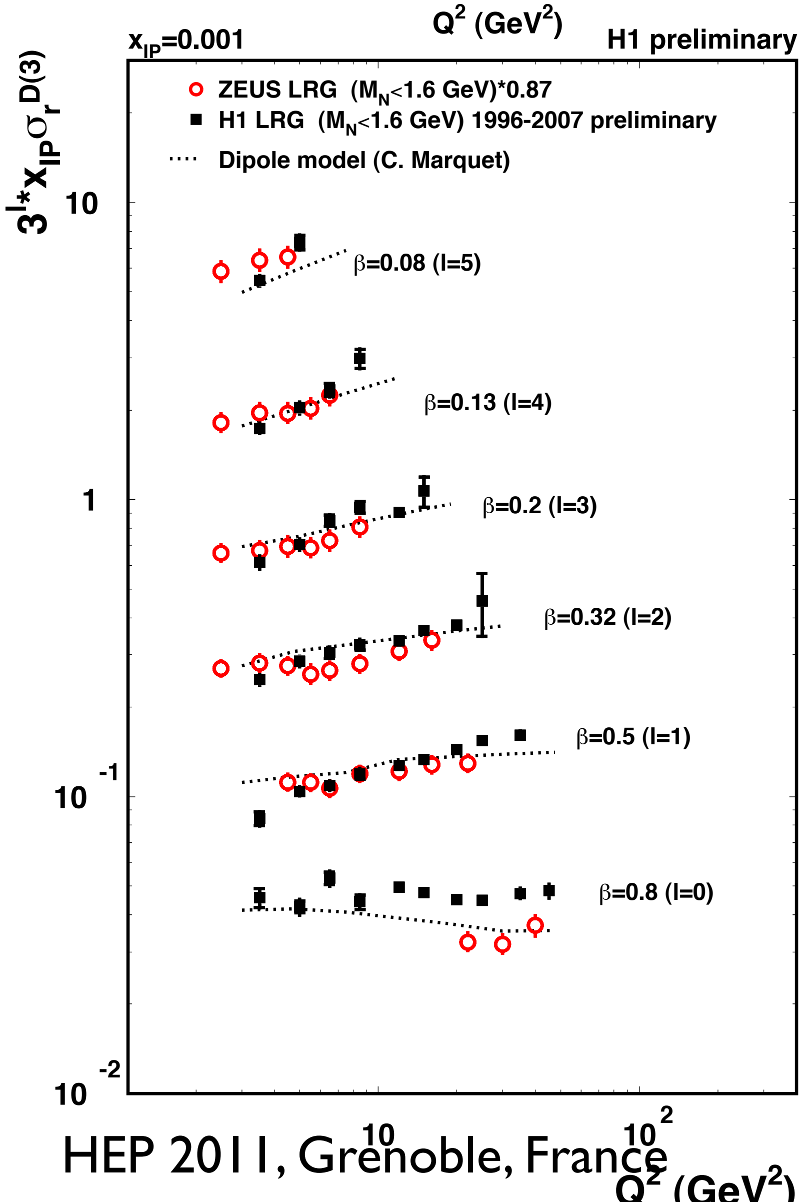
- The published data (**blue**) compared to the latest analysis of H1 LRG data (**black**)
- The larger dataset allow a more precise extraction of the reduced cross section compared to the published data
- Very precise measurements of the classic scaling violations for diffraction

σ_r^D at fixed x_{IP} - H1 and Zeus



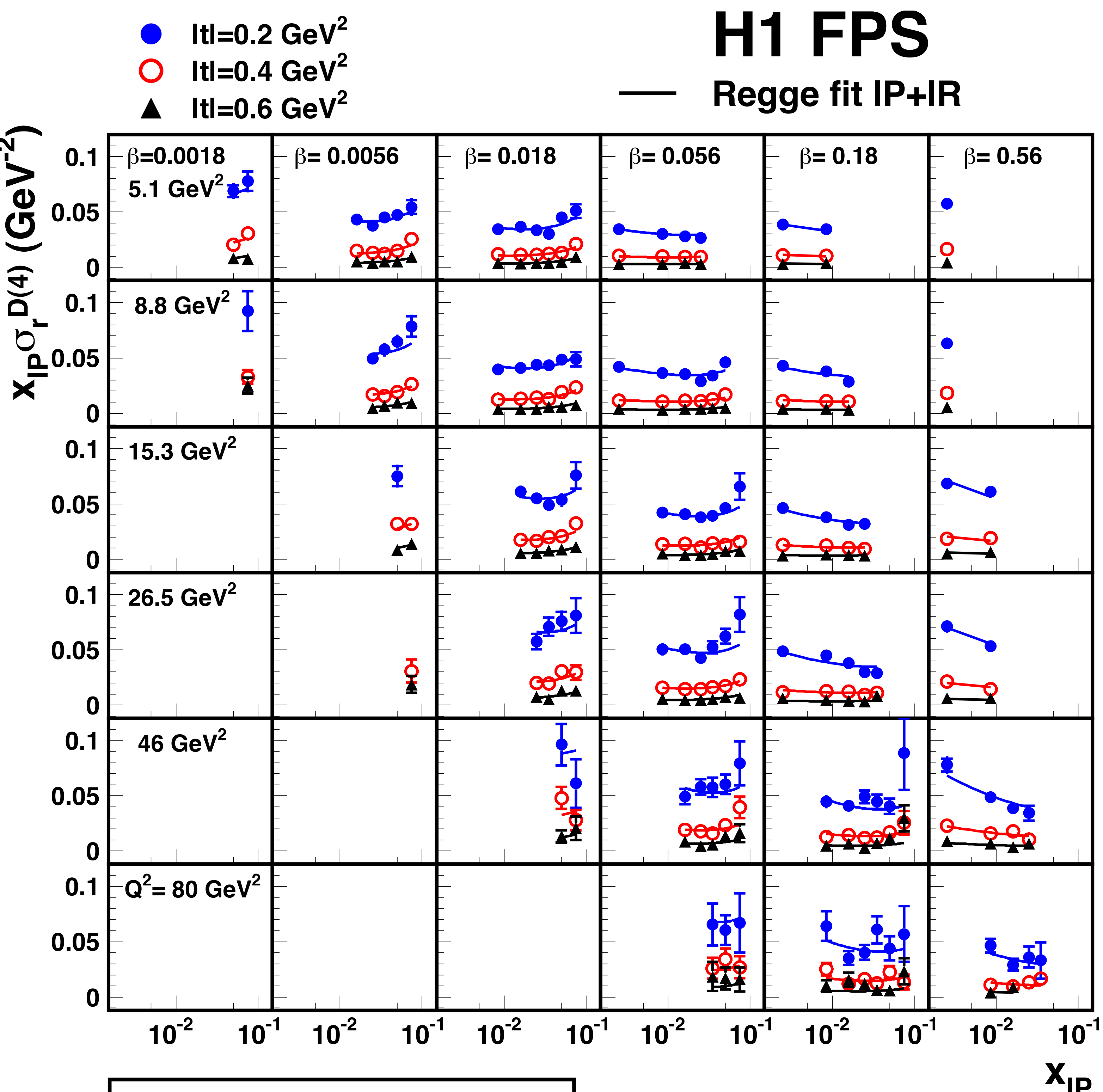


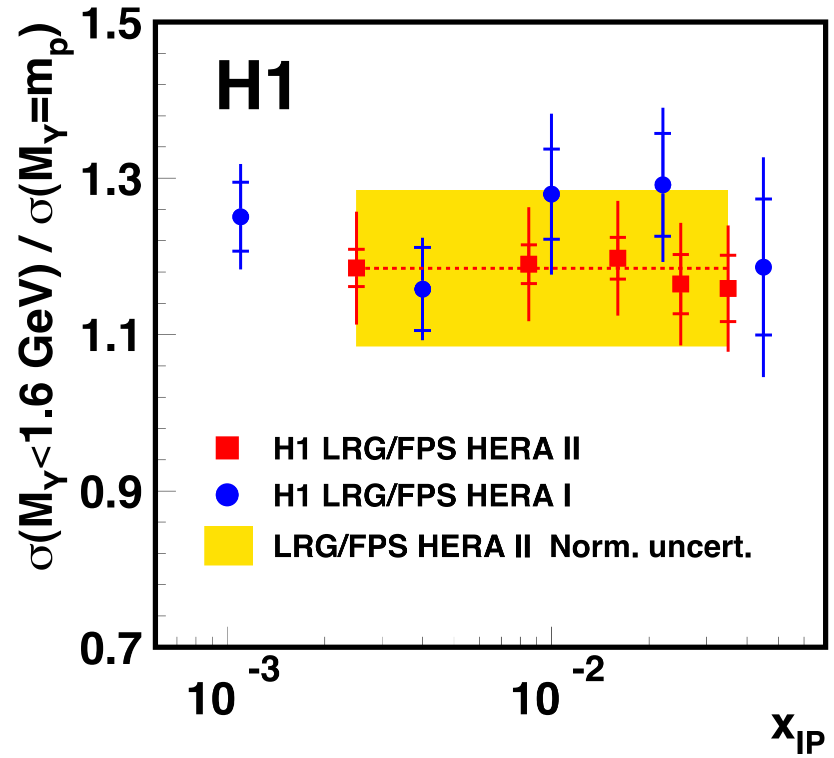




Good agreement between two high precision measurements

Factorisation and t using the FPS

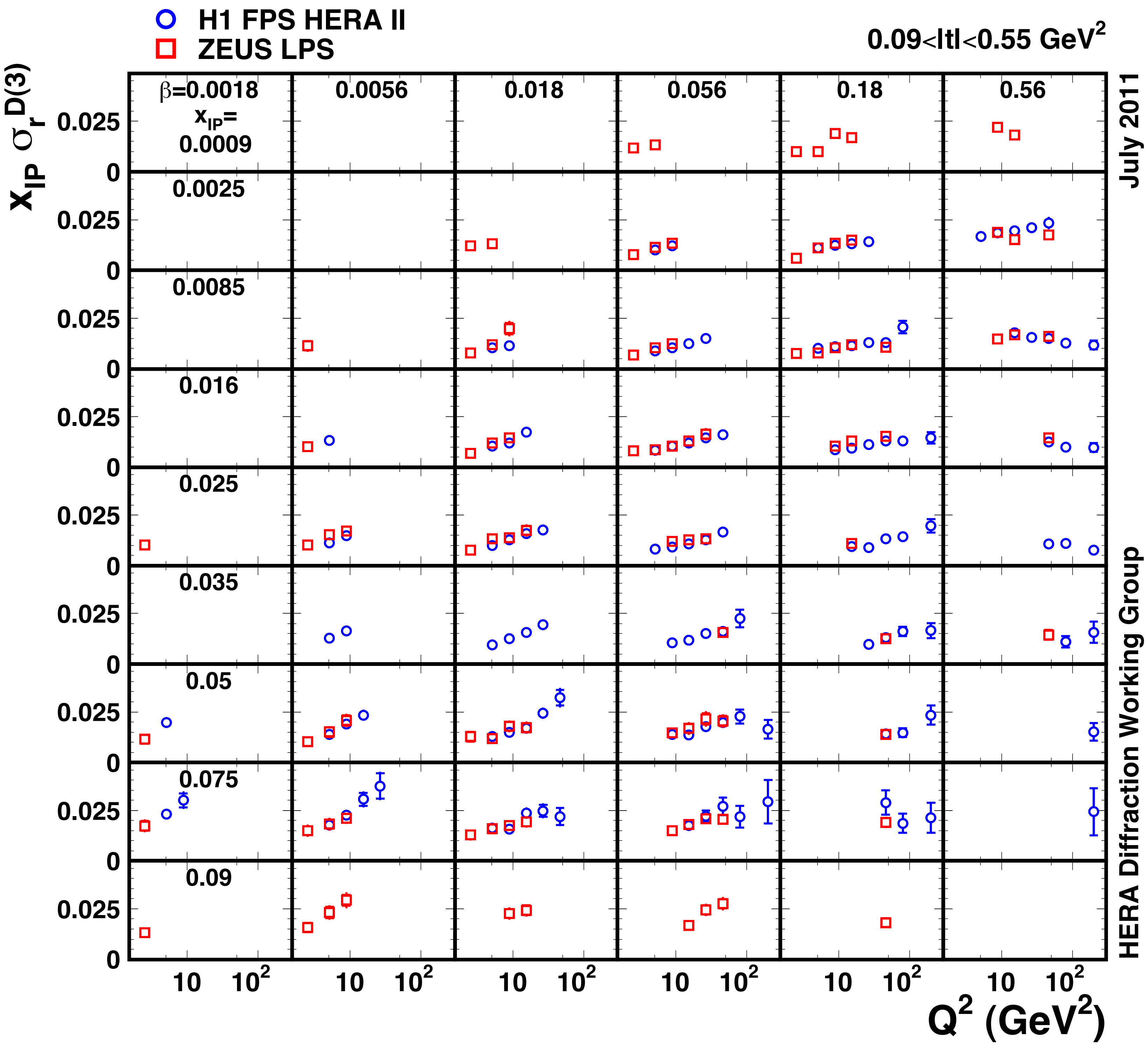




arXiv:1010.1476

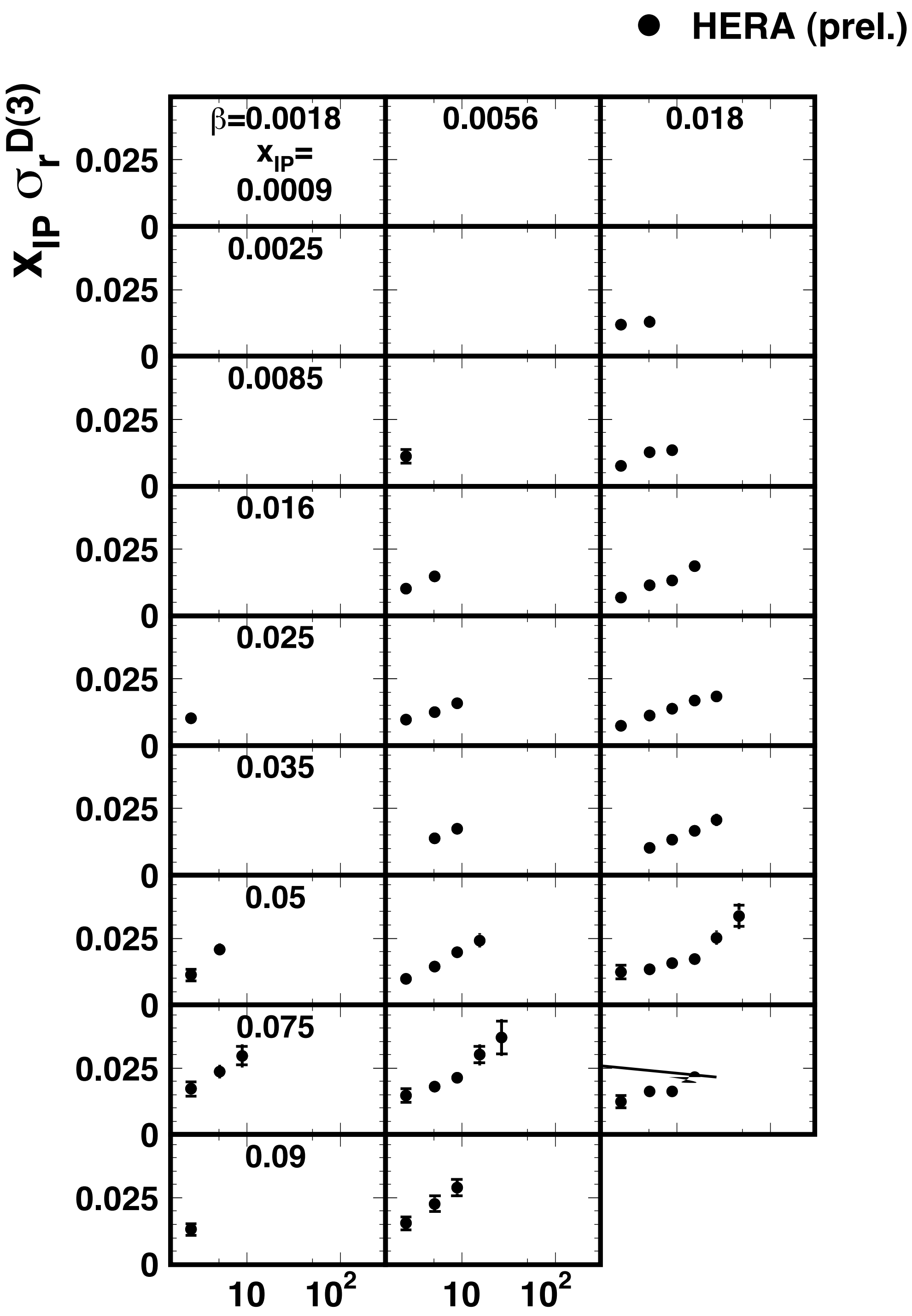
- Using the proton spectrometer allows the dependence of the cross section on t to be studied
- Integrating over t, the proton spectrometer and LRG measurements agree very well up to a normalisation (different M_Y range)

H1 and Zeus Combinations



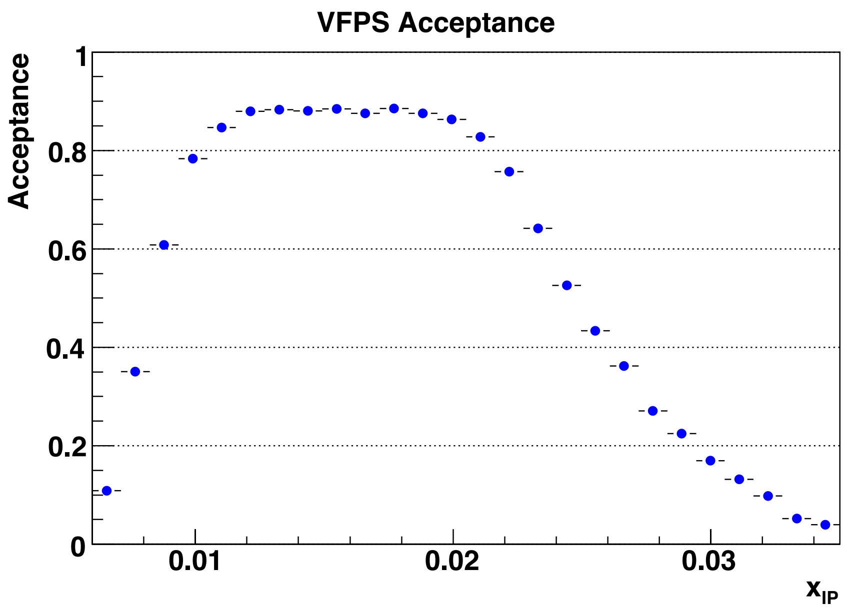
Take the two published proton spectrometer datasets from H1 and Zeus...

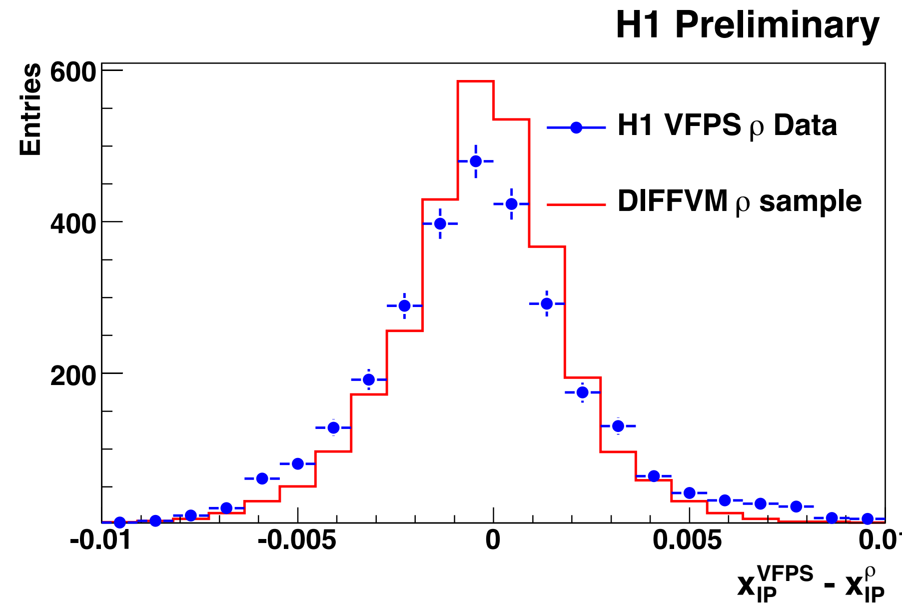
H1 and Zeus Combinations

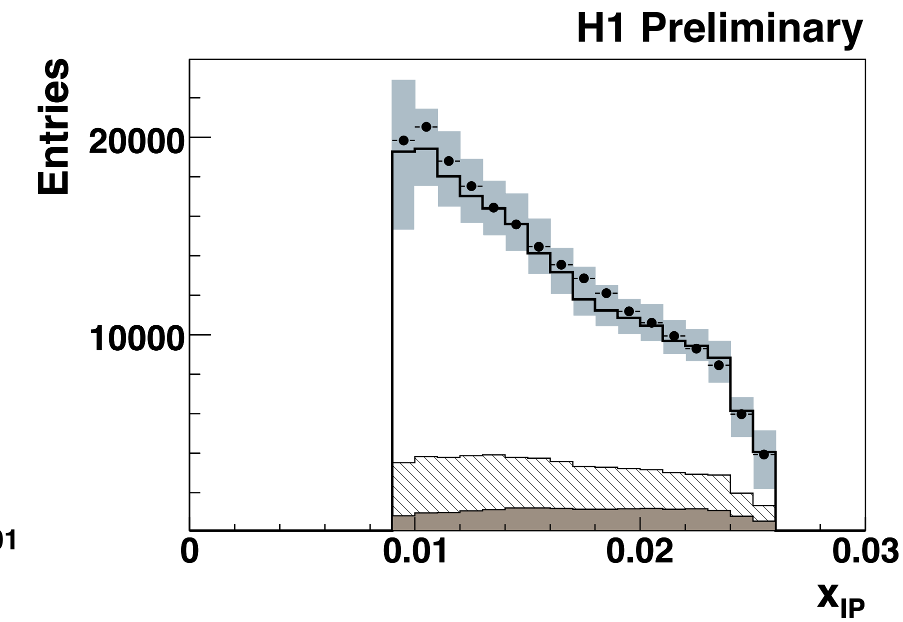


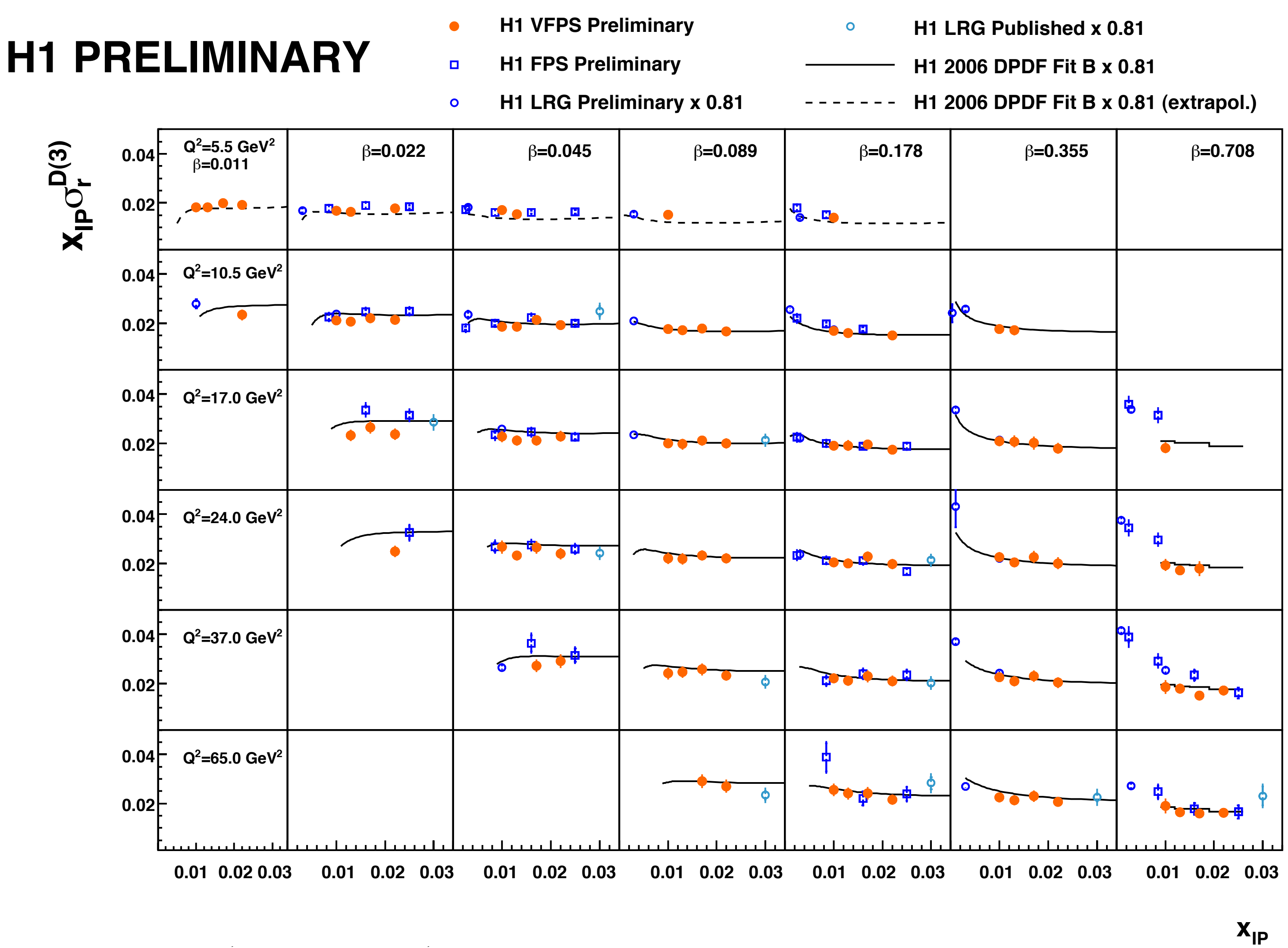
See poster of Marta Ruspa for details

High acceptance proton spectrometer - the H1 VFPS



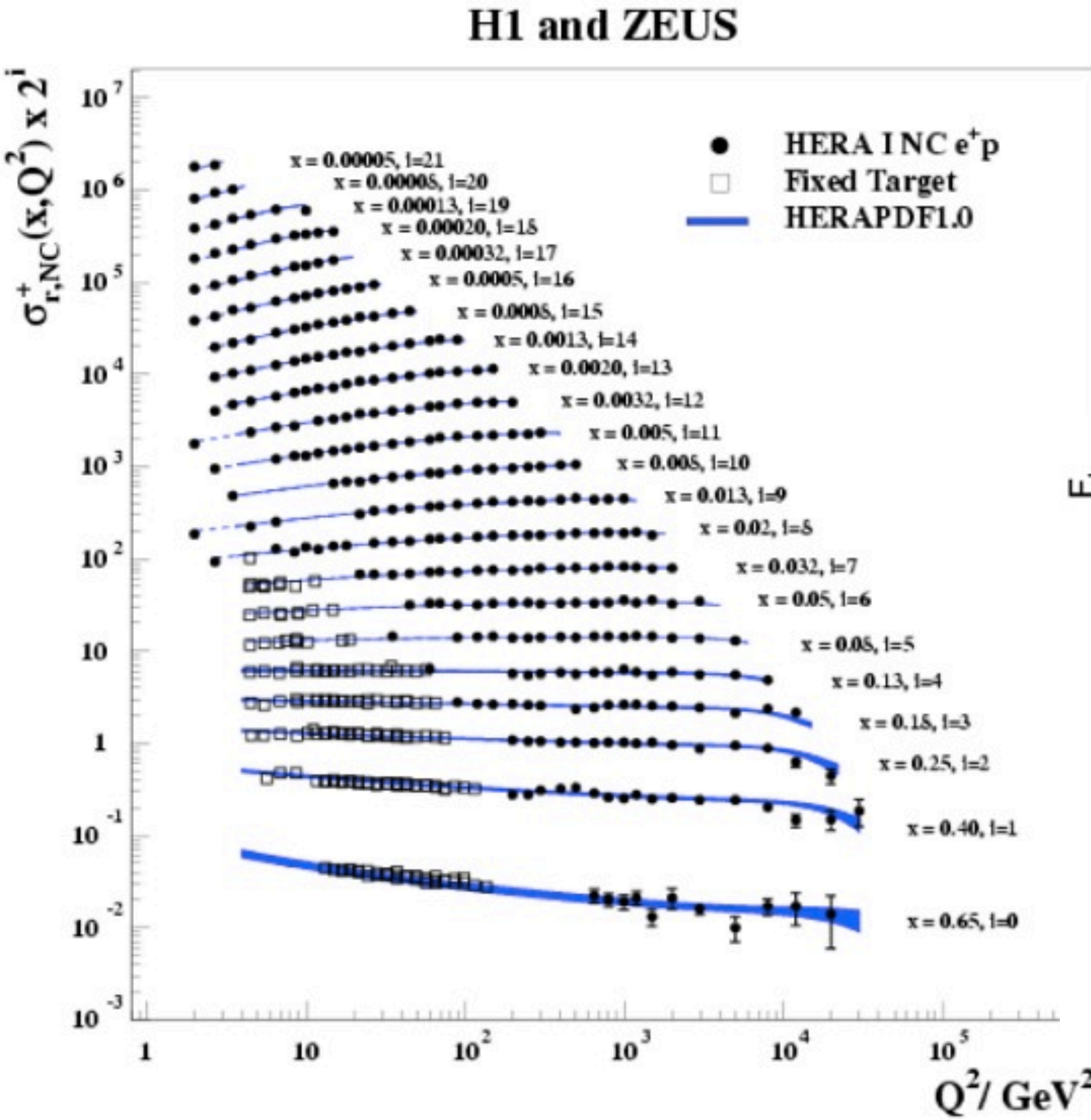


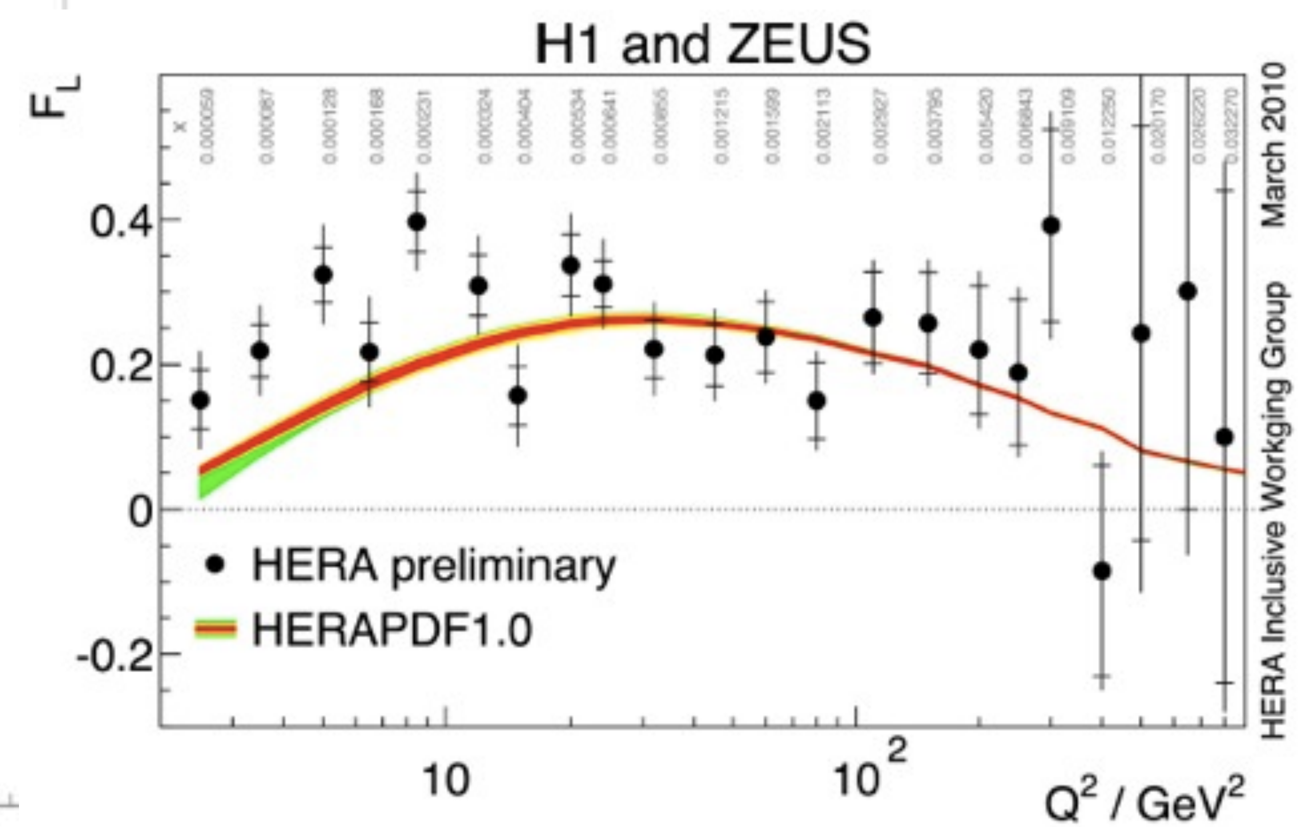




- The VFPS has high acceptance over a window in x_{IP}
- Calibrated using exclusive rho production, resulting in a well understood, high acceptance proton spectrometer
- Allows a high precision measurement over this x_{IP} range

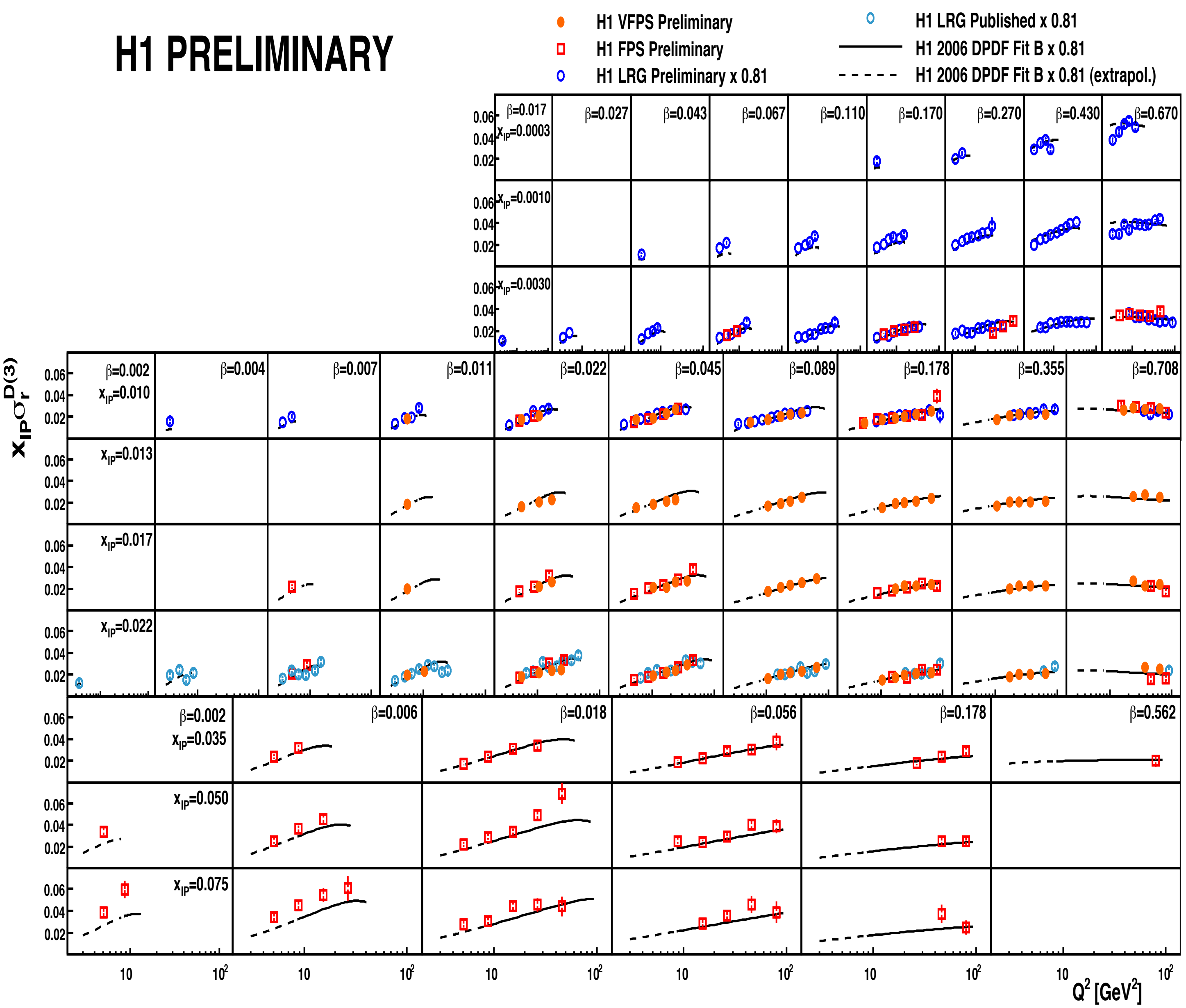
Inclusive F_2 and F_L

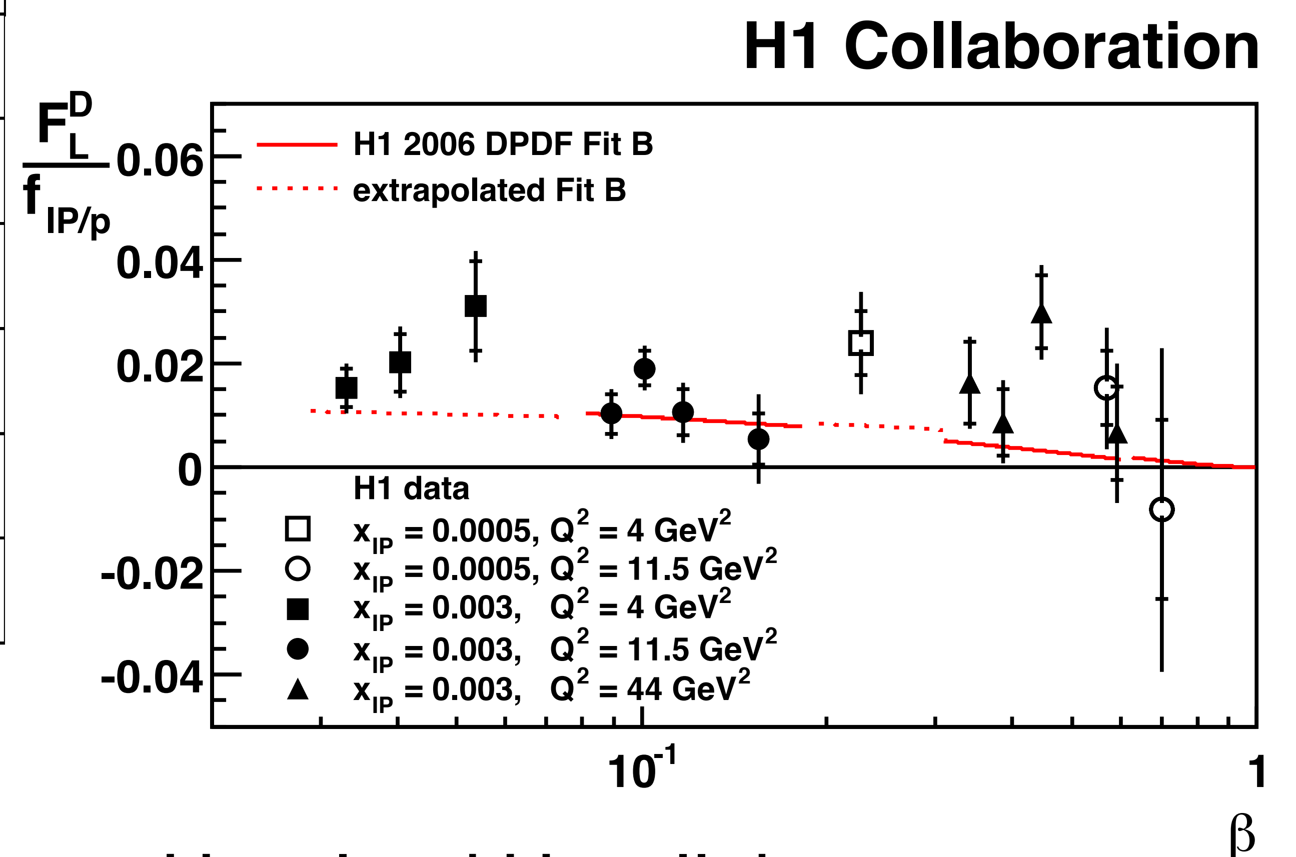




- Target is to repeat this for diffraction, how are we doing?

Summary - F_2^D and F_L^D from H1

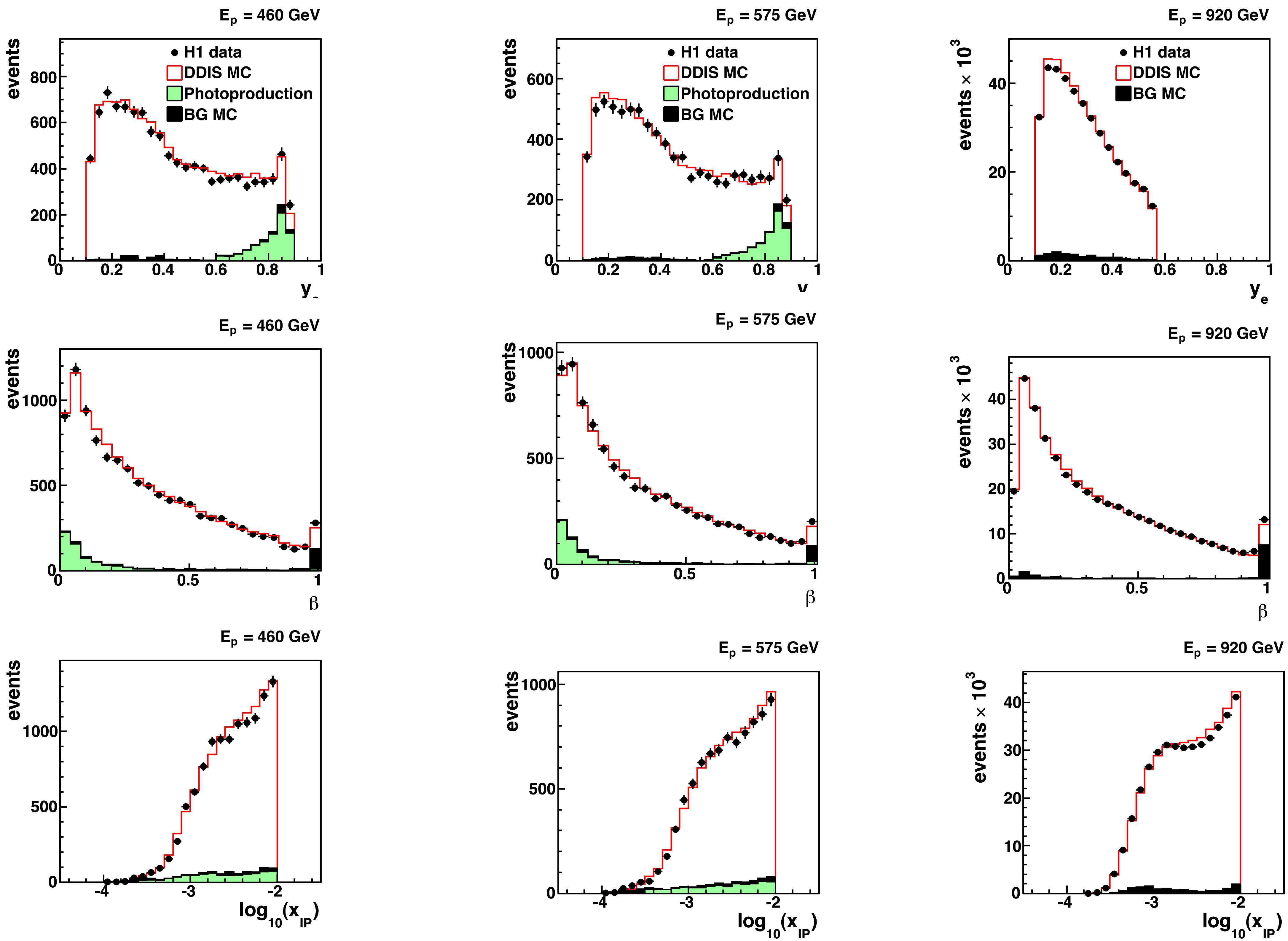




- Inclusive diffractive DIS studied in H1 using Hera I and Hera II data
- The results provide a compelling confirmation of the NLO QCD picture of diffraction, with precision over a wide kinematic range

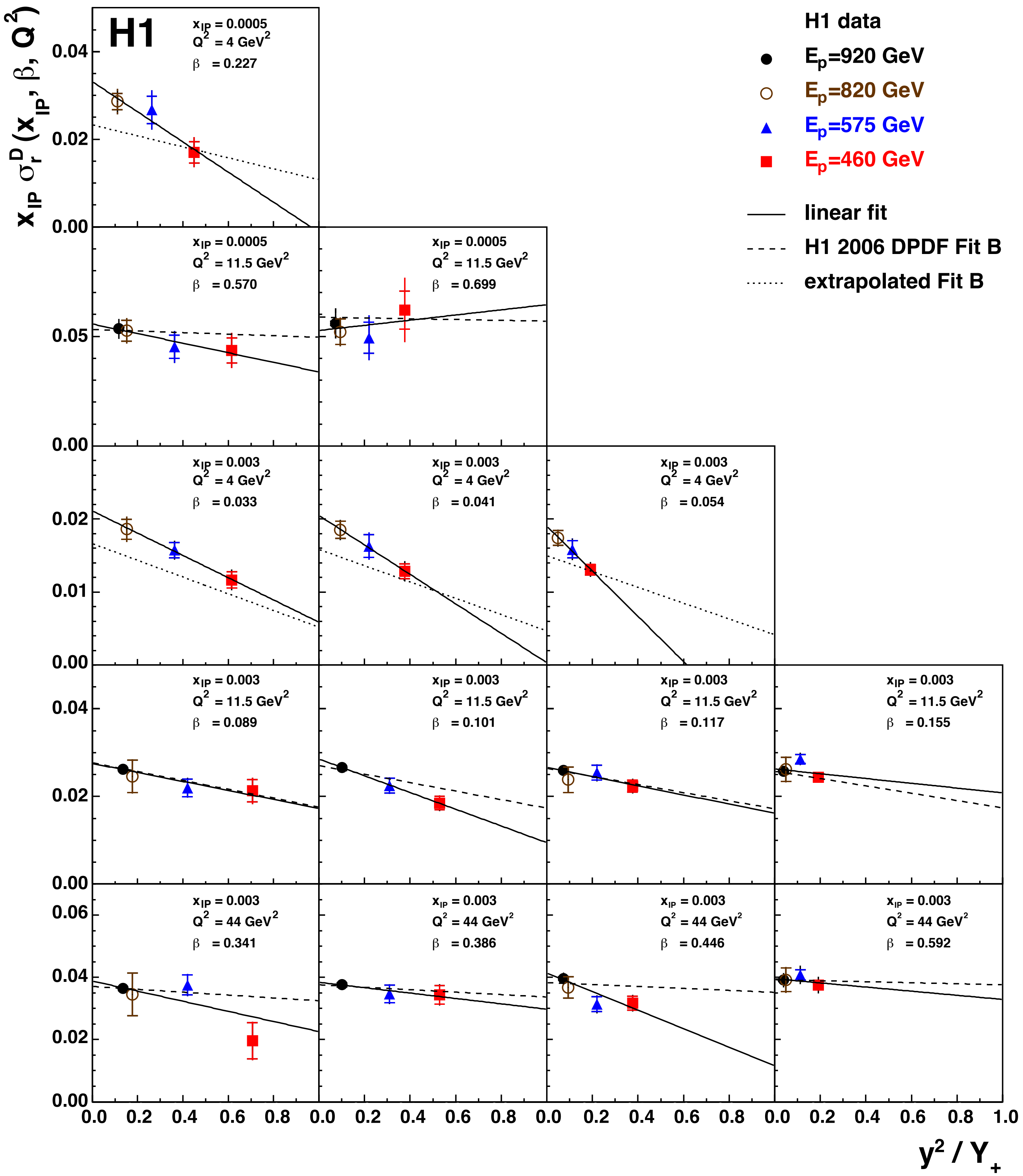
- Backup slides

The F_L^D data (Control plots)

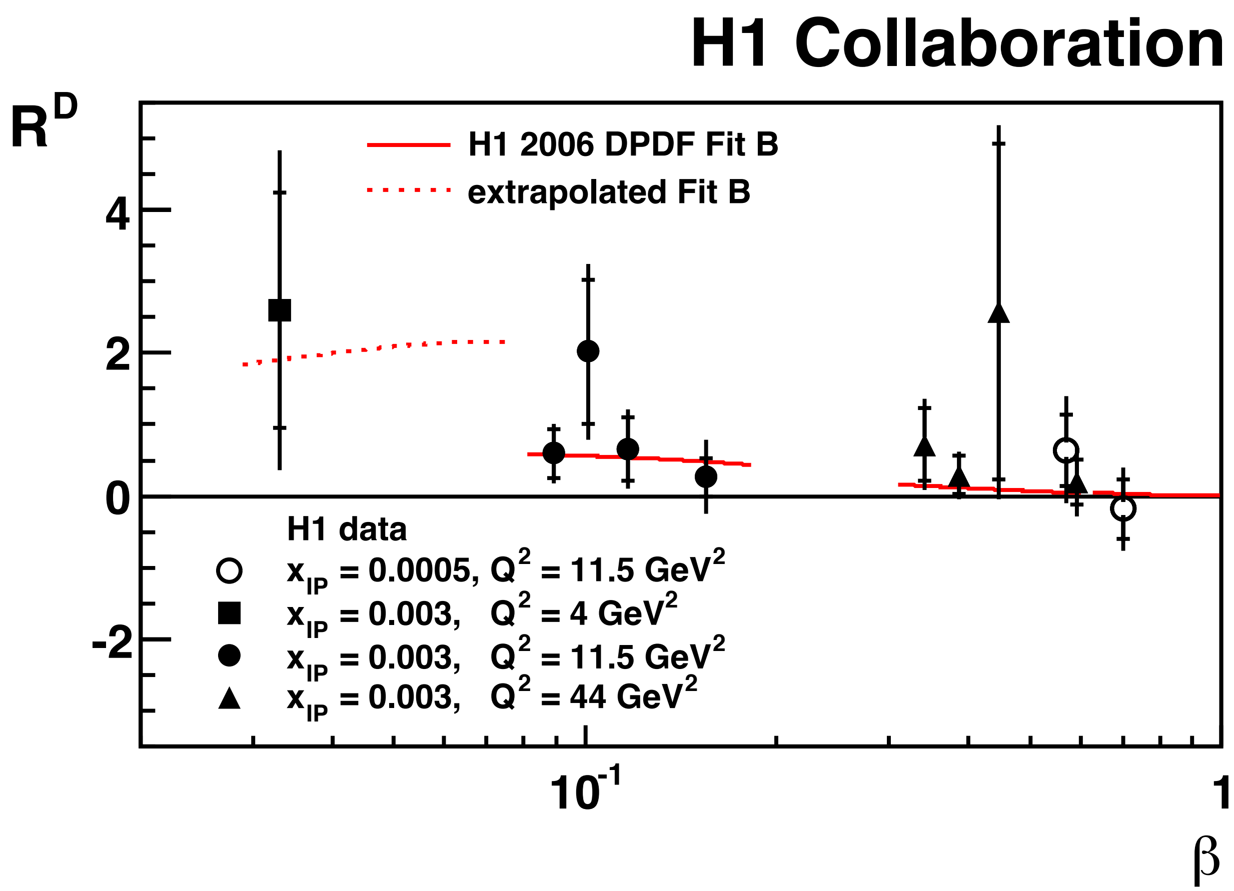


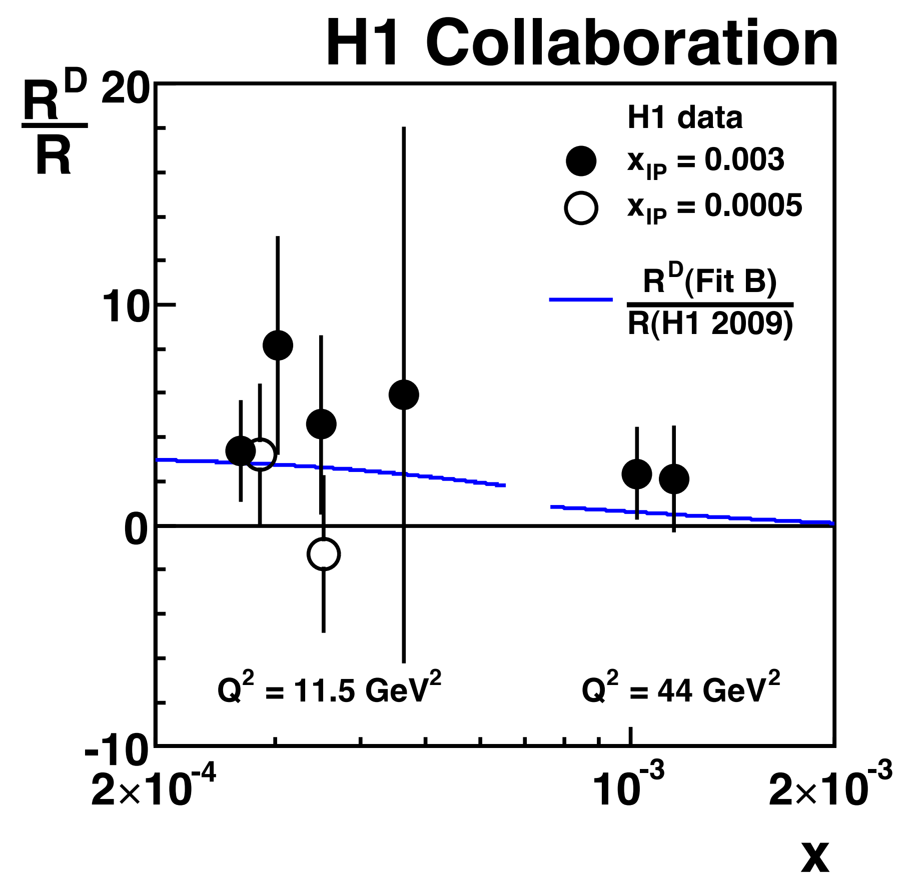
- Well understood data!

The F_L^D fits


H1
H1 data
Ep=920 GeV
Ep=820 GeV
Ep=575 GeV
Ep=460 GeV
linear fit
H1 2006 DPDF Fit B
extrapolated Fit B
xIP σr^D(xIP, β, Q²)
y² / Y+
xIP = 0.0005 Q² = 4 GeV² β = 0.227
xIP = 0.0005 Q² = 11.5 GeV² β = 0.570
xIP = 0.0005 Q² = 11.5 GeV² β = 0.699
xIP = 0.003 Q² = 4 GeV² β = 0.033
xIP = 0.003 Q² = 4 GeV² β = 0.041
xIP = 0.003 Q² = 4 GeV² β = 0.054
xIP = 0.003 Q² = 11.5 GeV² β = 0.089
xIP = 0.003 Q² = 11.5 GeV² β = 0.101
xIP = 0.003 Q² = 11.5 GeV² β = 0.117
xIP = 0.003 Q² = 11.5 GeV² β = 0.155
xIP = 0.003 Q² = 44 GeV² β = 0.341
xIP = 0.003 Q² = 44 GeV² β = 0.386
xIP = 0.003 Q² = 44 GeV² β = 0.446
xIP = 0.003 Q² = 44 GeV² β = 0.592

R^D and R^D/R



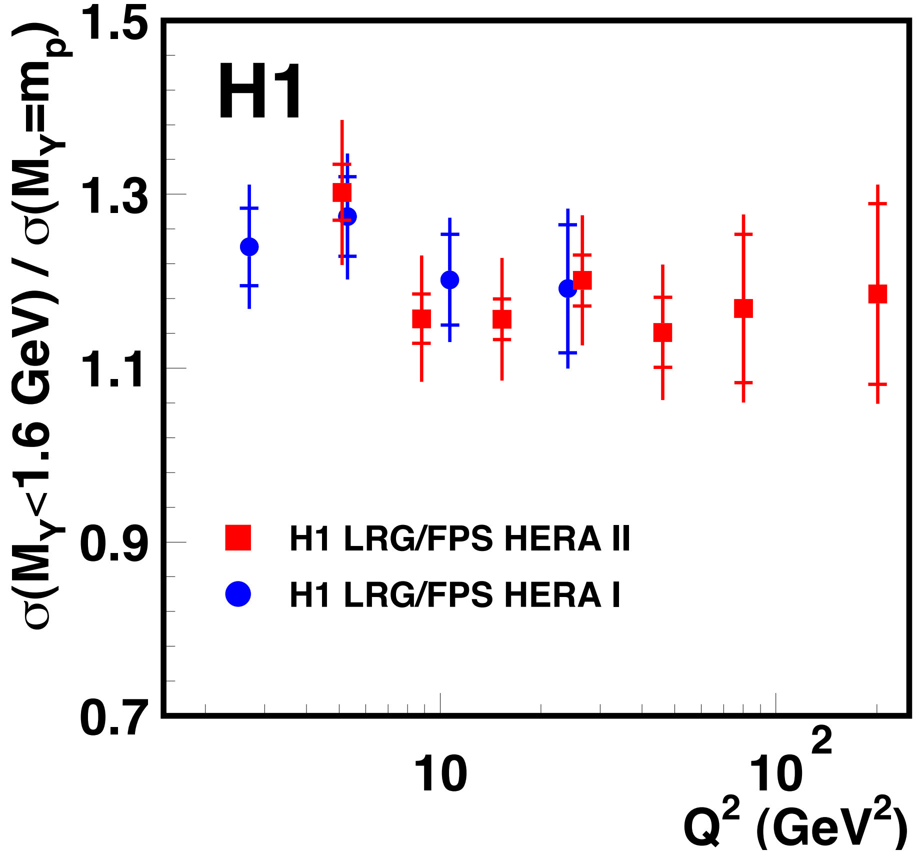


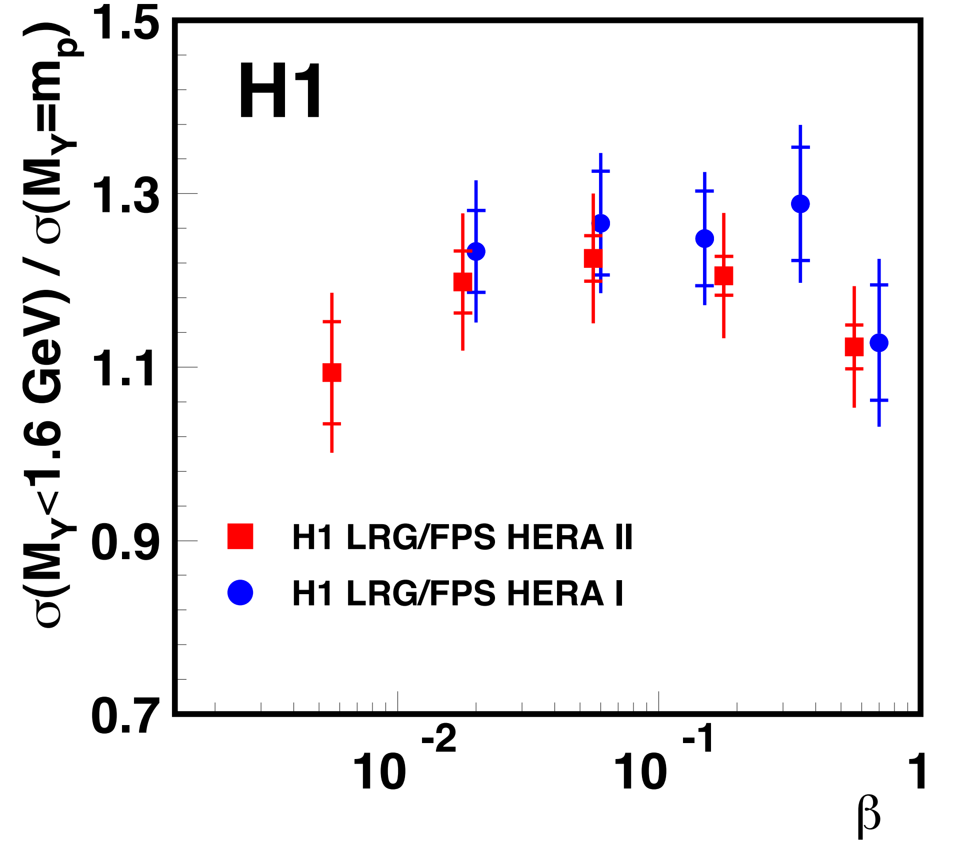
$$R = \sigma_L / \sigma_T \quad \rightarrow \quad R^D = F_L^D / (F_2^D - F_L^D)$$

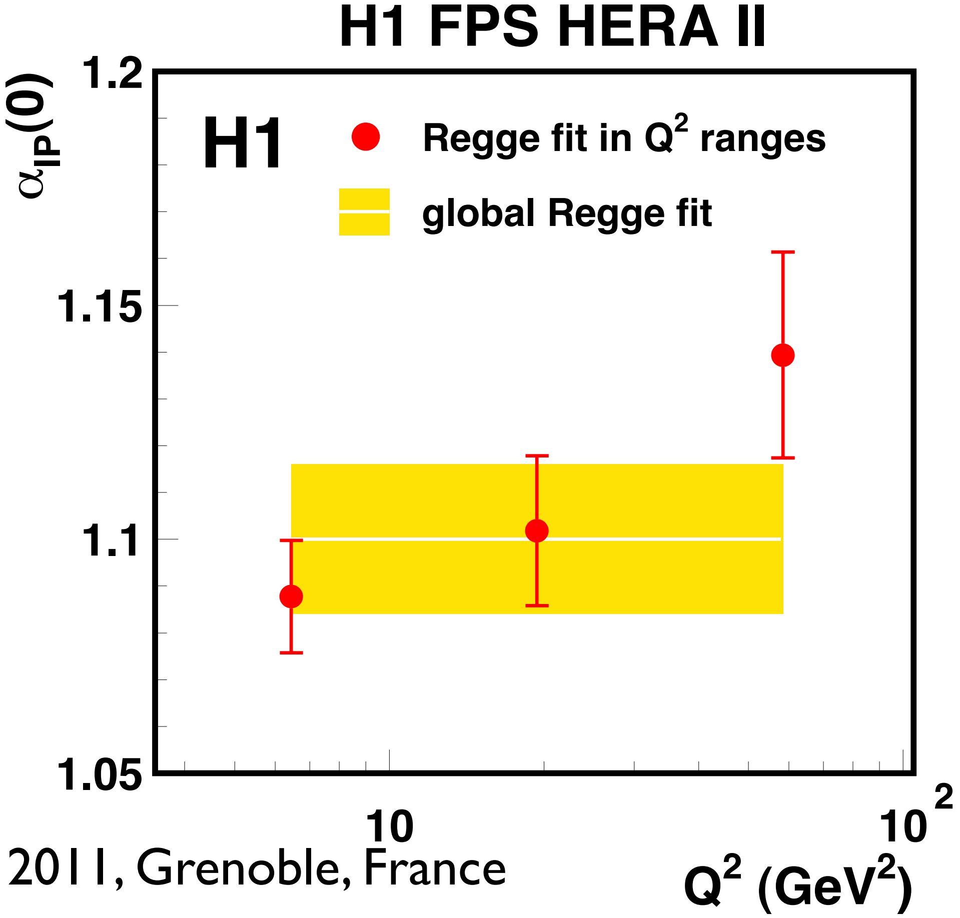
Good agreement with prediction
Two polarisation states contribute at a comparable level

Ratio of R^D to inclusive R suggests that longitudinal component is more important in diffraction

FPS factorisation







- LRG/FPS as a function of the other kinematic variables
- $\alpha_{IP}(0)$ in bins of Q^2