Recent Results from HERA on Inclusive Diffraction

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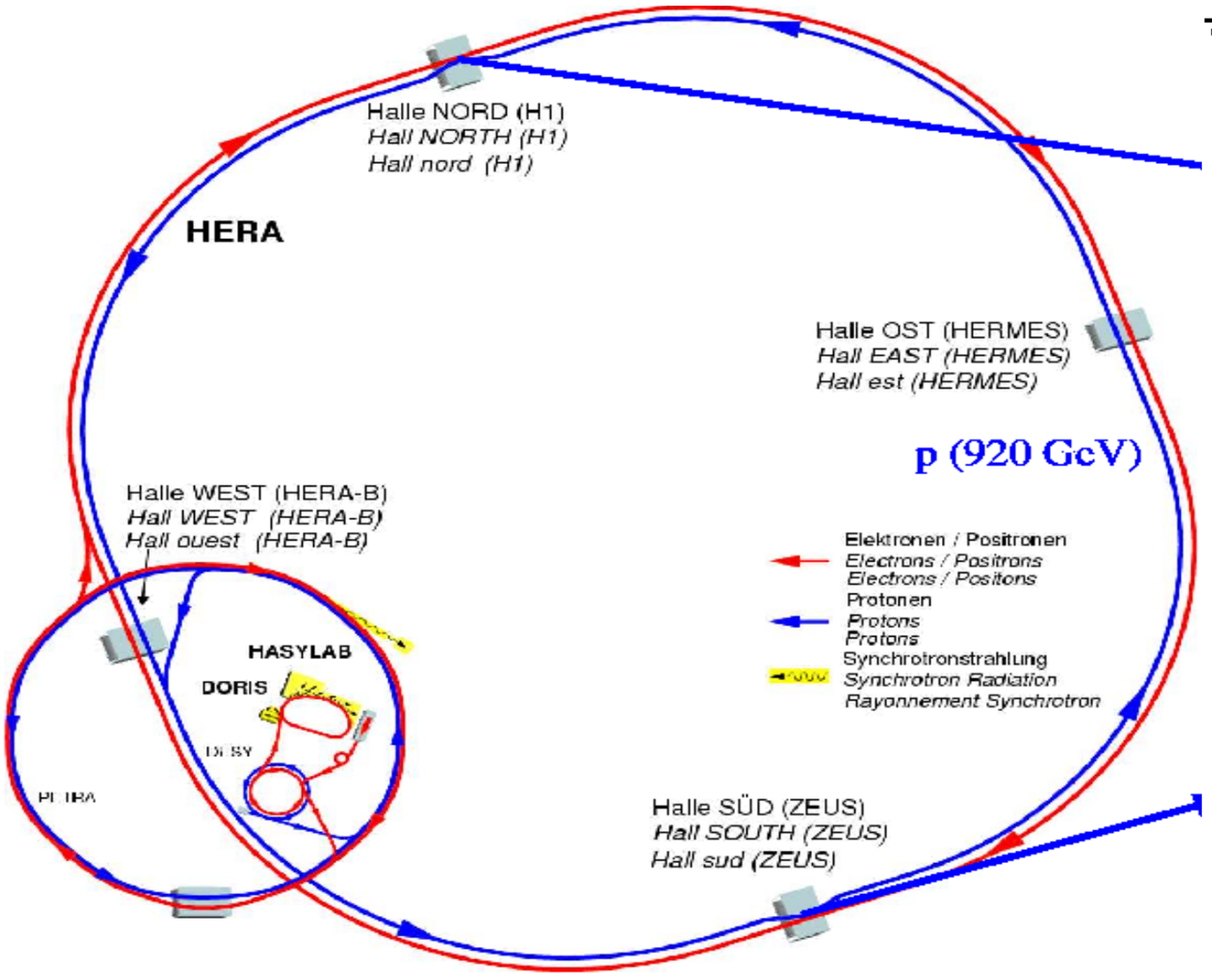
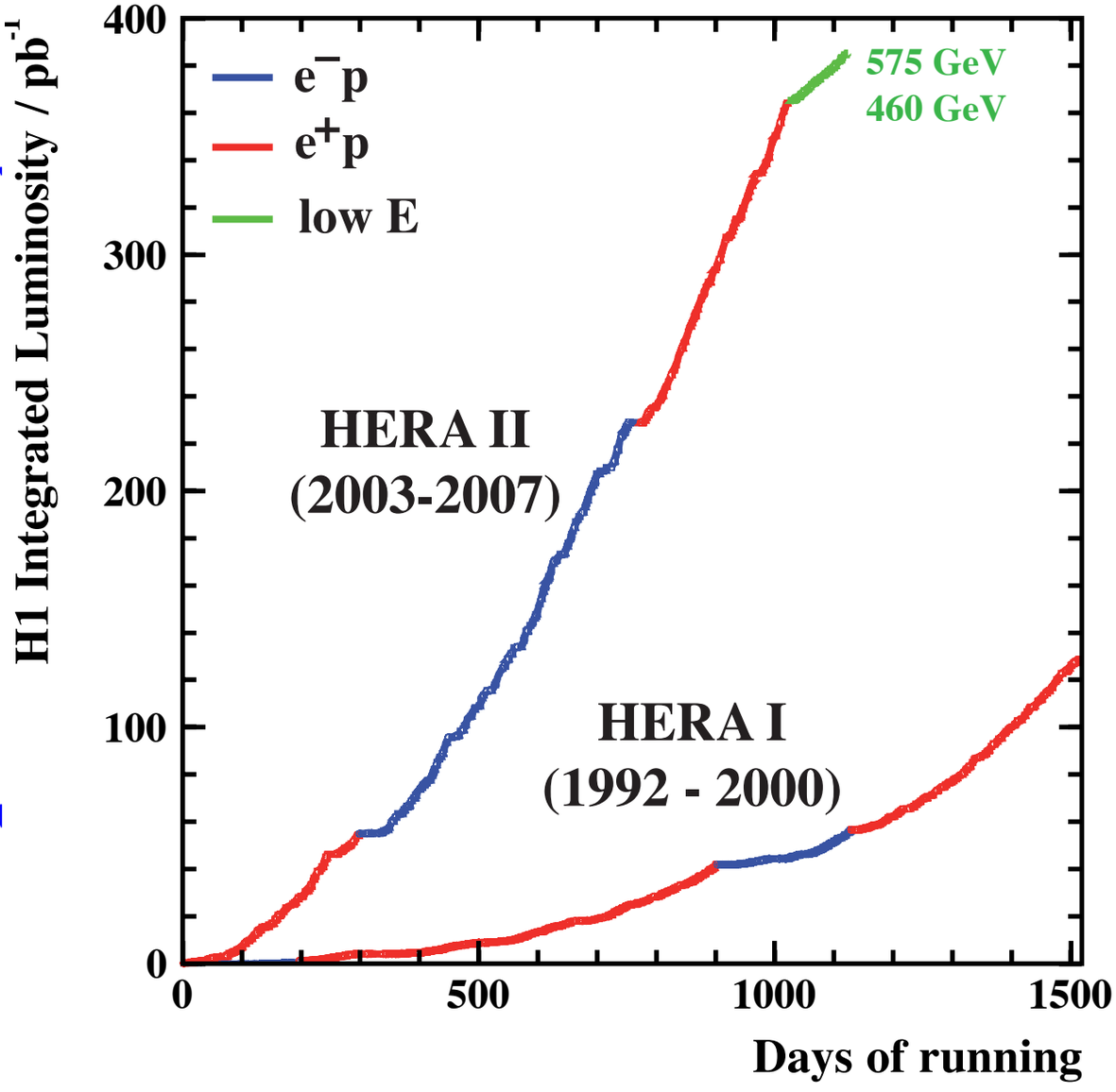
UNIVERSITY OF LIVERPOOL

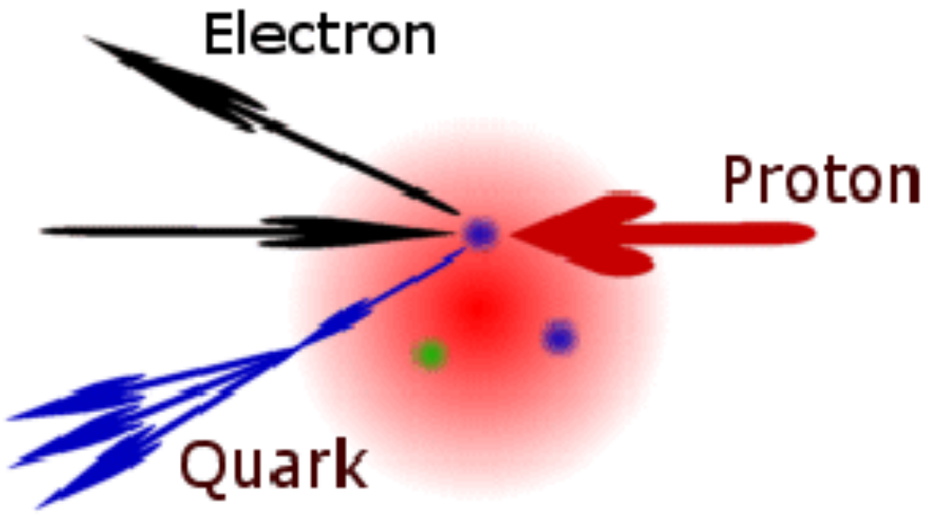
HERA, collider experiments and data

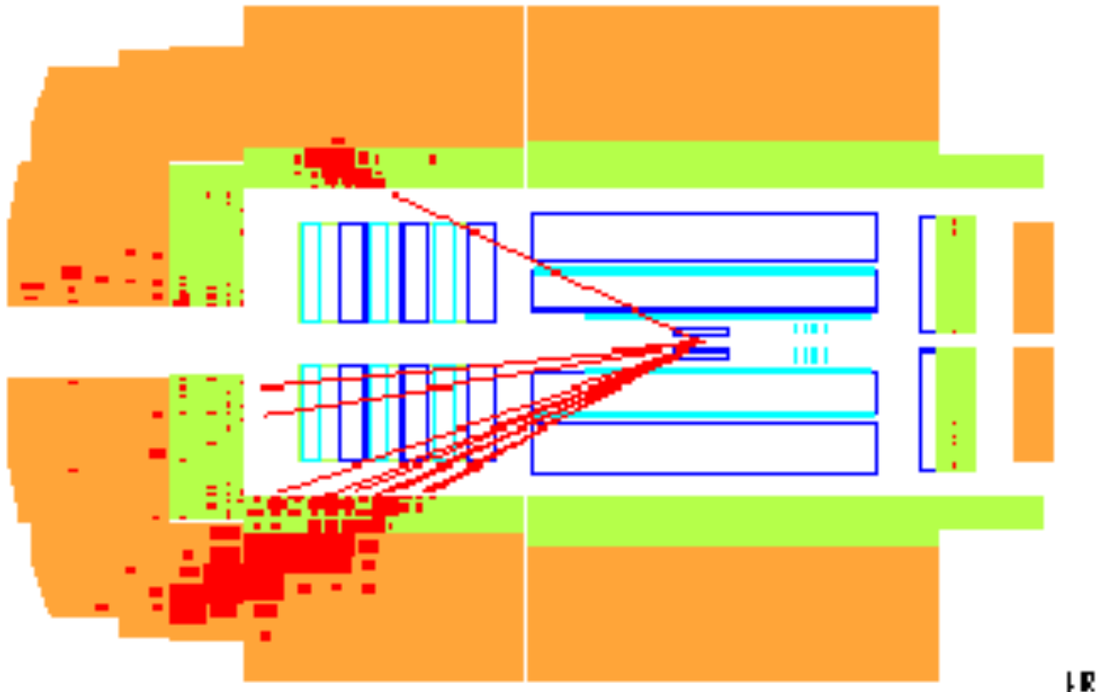




- The unique HERA machine collided 27.5 GeV electrons or positrons with protons of 460, 575, 820 and 920 GeV providing 0.5 fb^{-1} to H1 and ZEUS
- The final precision analyses of this data are being delivered

Deep-inelastic Scattering





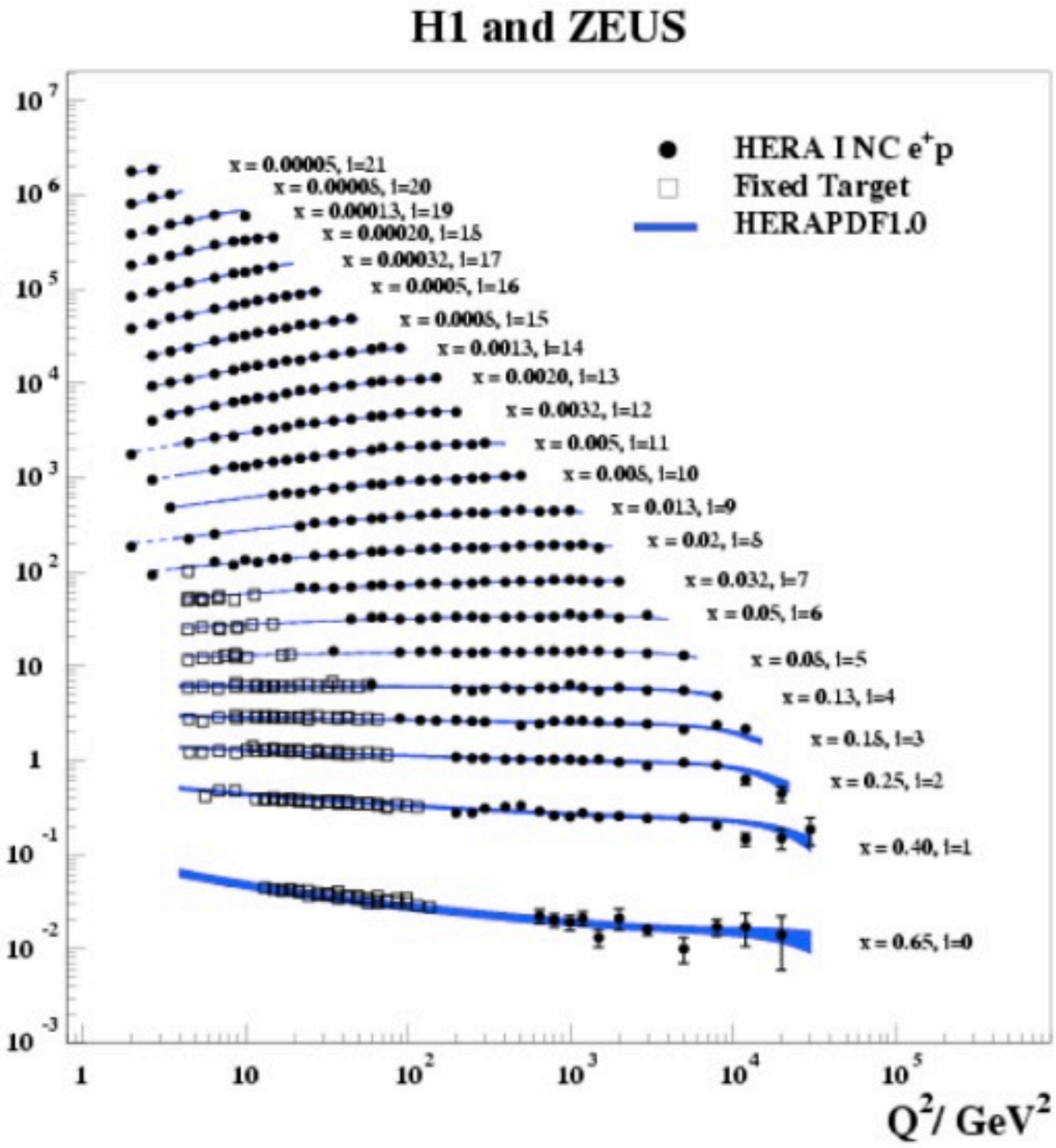
Measure:

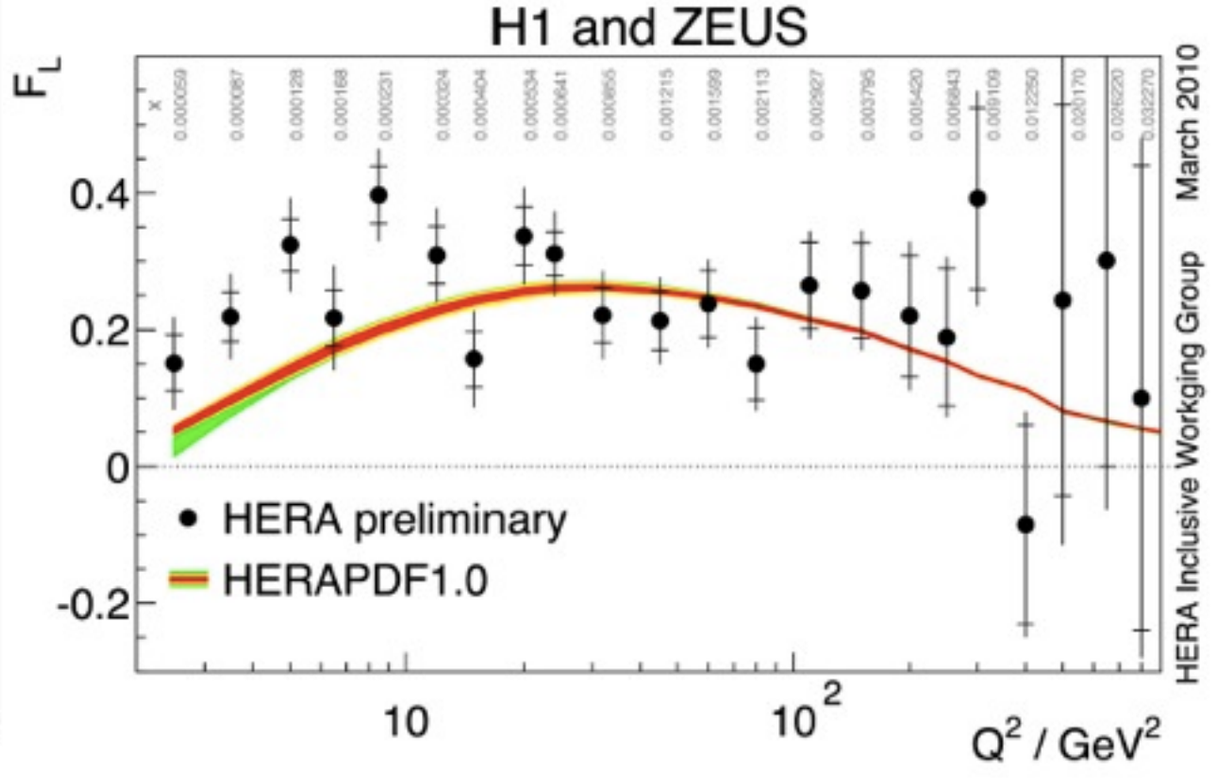
$$\frac{\mathrm{d}^2\sigma^{ep}_{NC}}{\mathrm{d}x\mathrm{d}Q^2} = \frac{2\pi\alpha^2 Y_+}{xQ^4}\left(F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2)\right)$$

Extract:

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

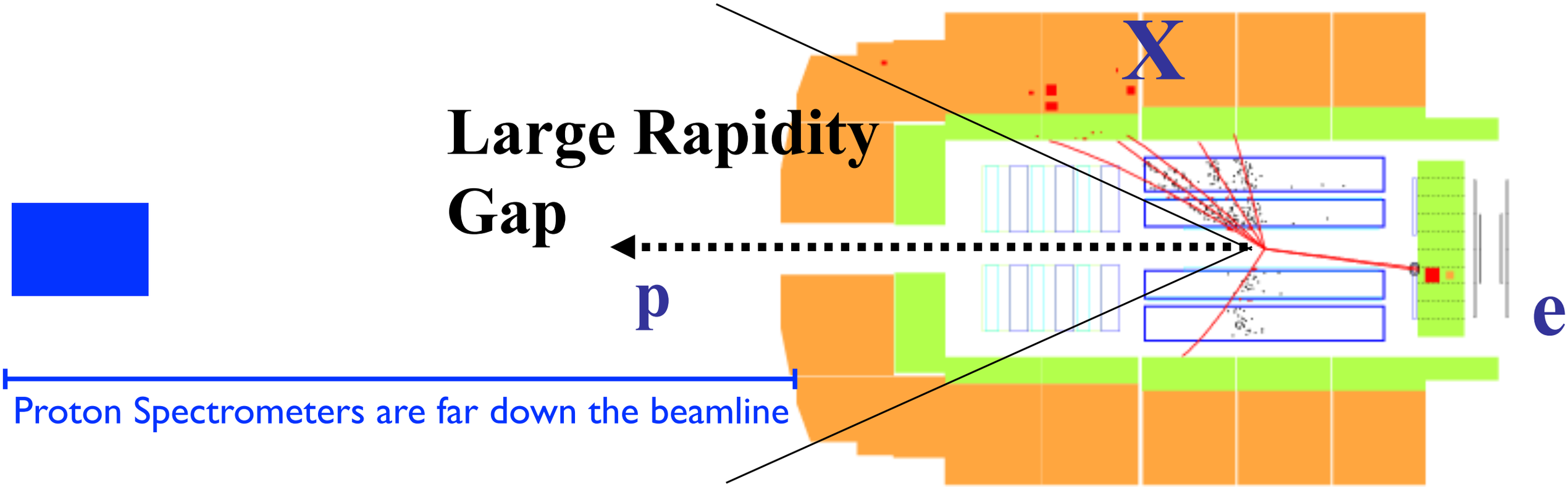
Inclusive F_2 and F_L





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

Diffractive Deep Inelastic Scattering: $ep \rightarrow epX$



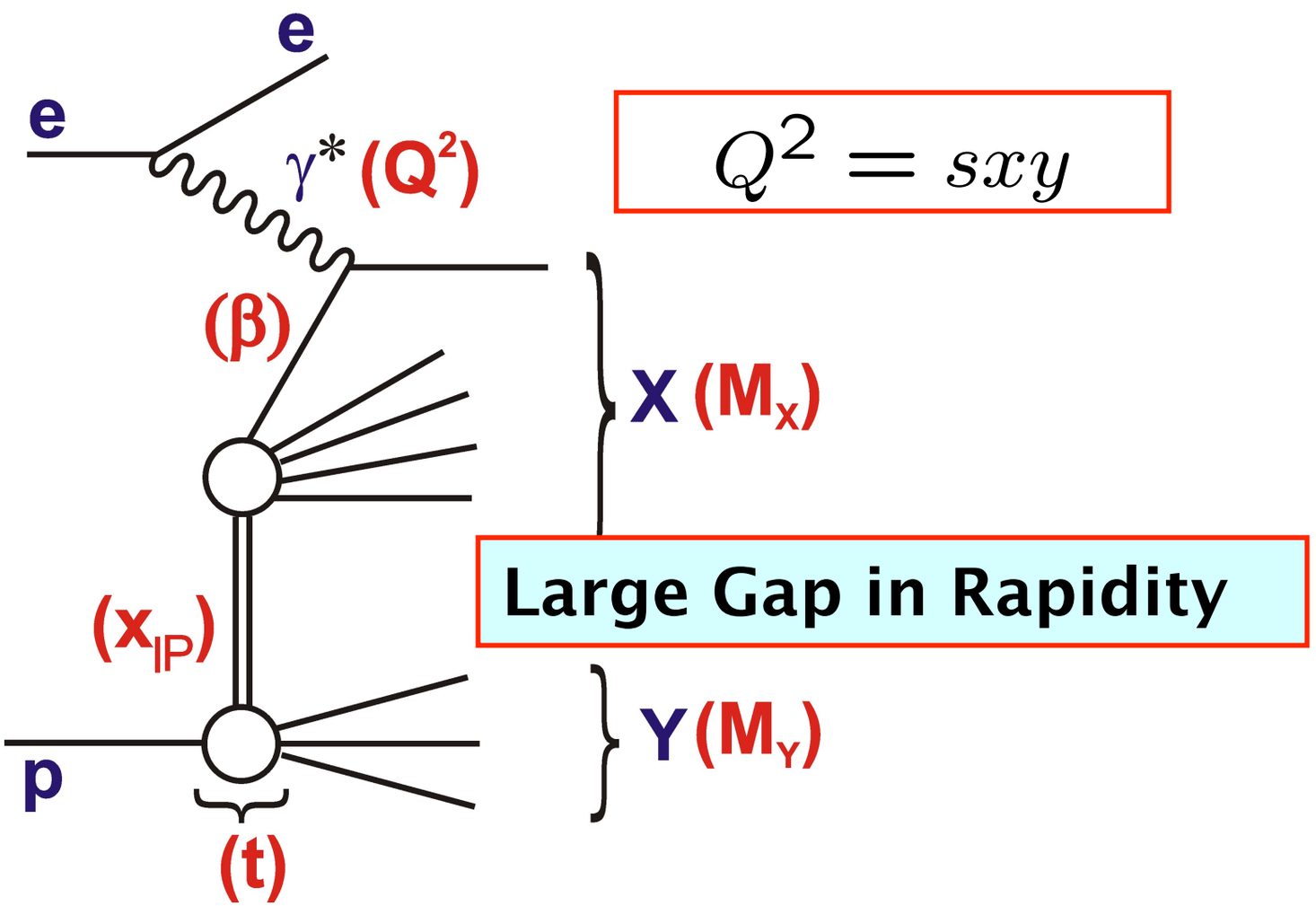
- Quasi-elastic scattering involving a colour singlet exchange
- Select events based on the Large Rapidity Gap topology or alternatively detect the elastically-scattered proton in a **Proton Spectrometer**
- The experimental mandate is simple - measure the kinematic dependences of the cross section for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

Diffractive Structure Functions

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

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

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



$$Q^2 = sxy$$

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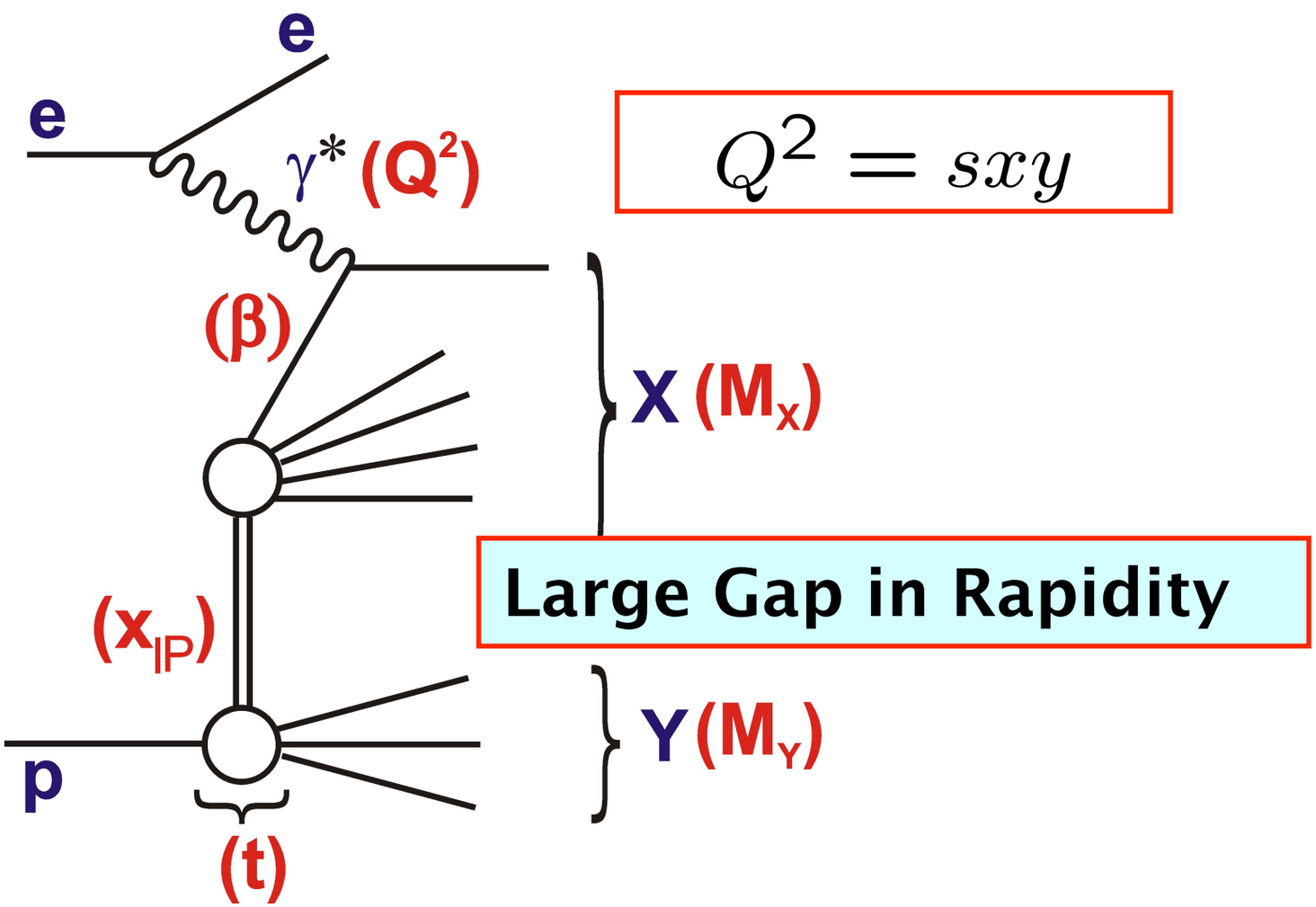


$$Q^2 = sxy$$

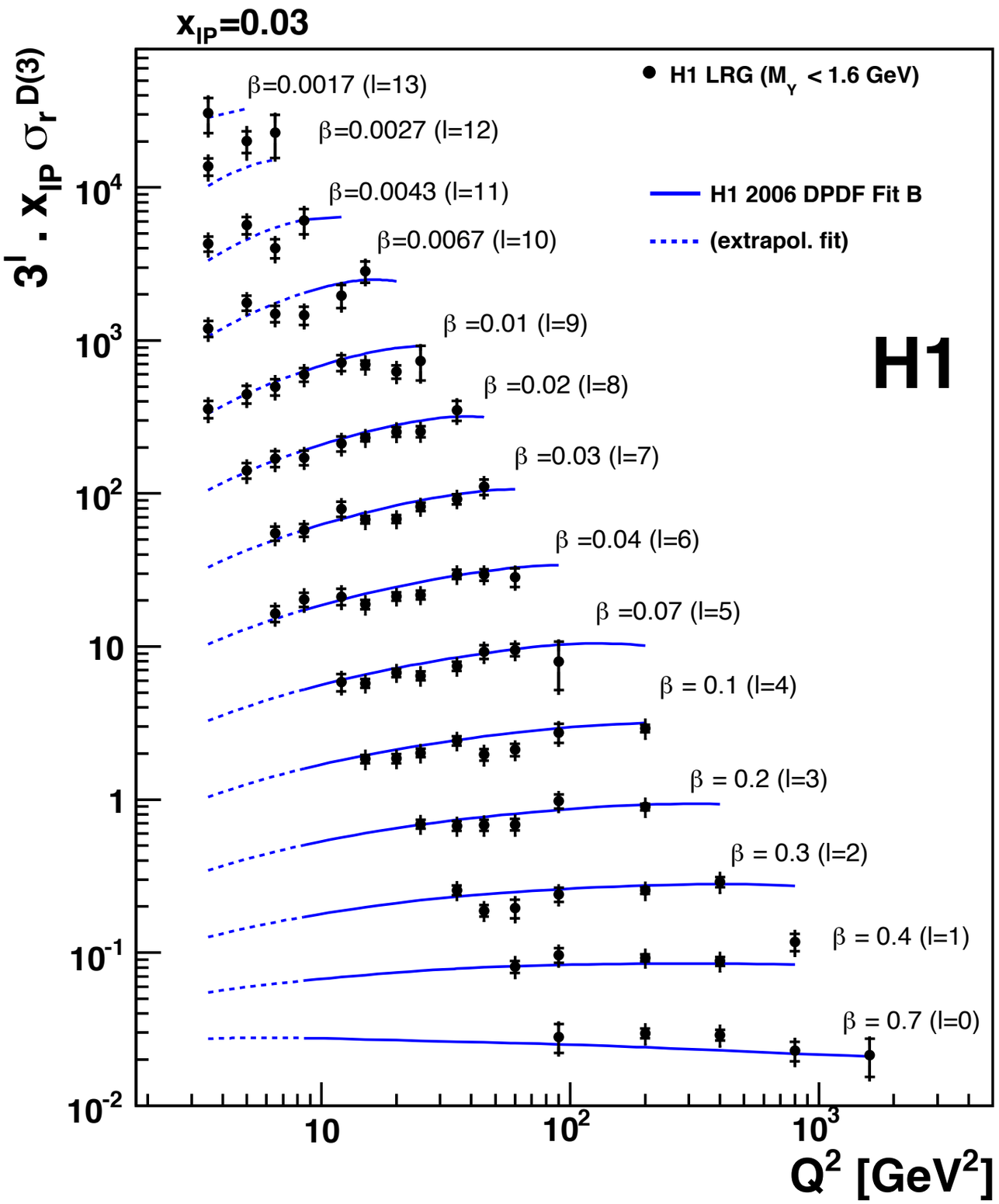
$$Y_+ = 1 + (1-y)^2$$

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

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

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

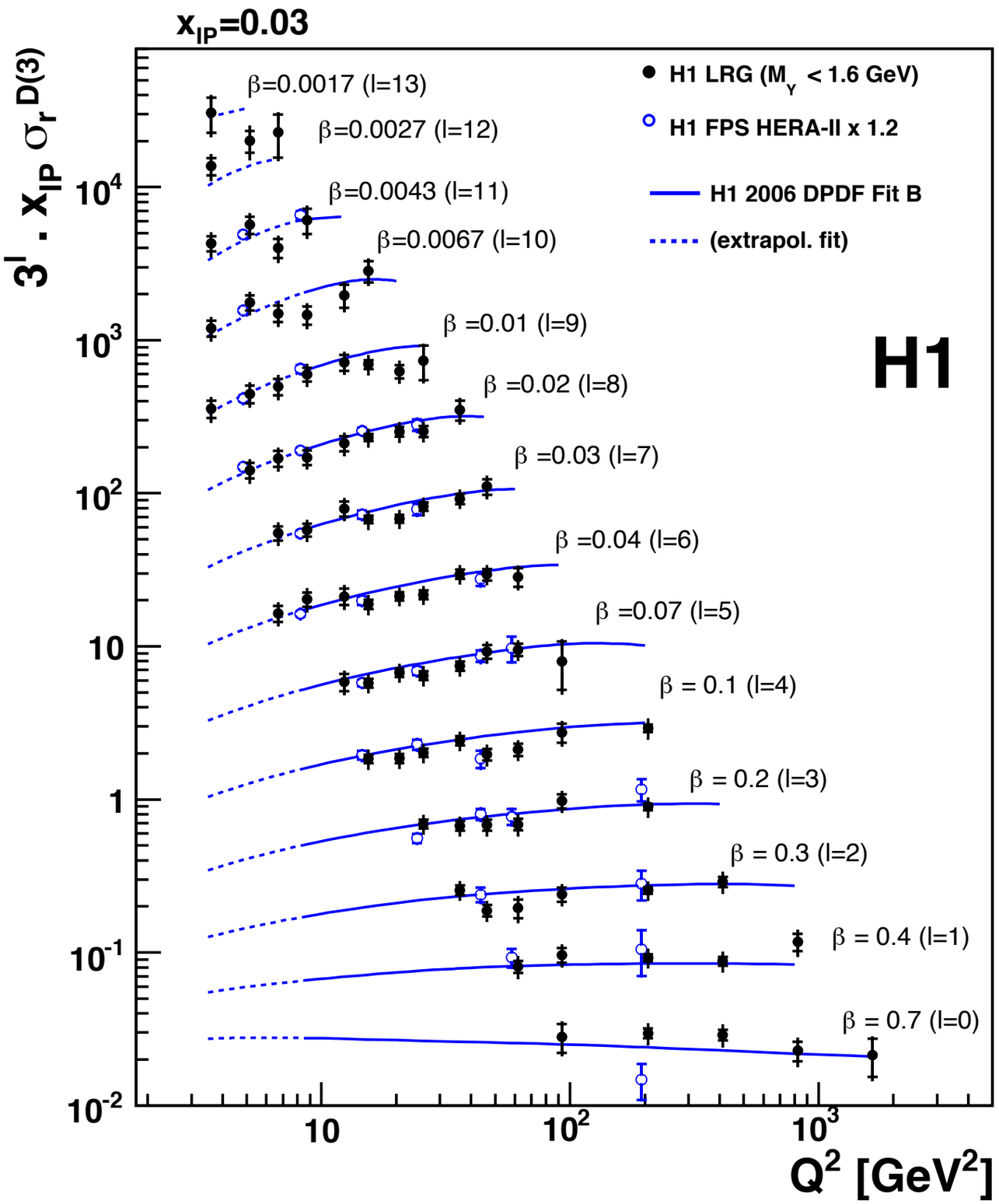
New H1LRG data - σ_r^D at fixed x_{IP}



Combination performed with existing H1 data to use the complete HERA dataset

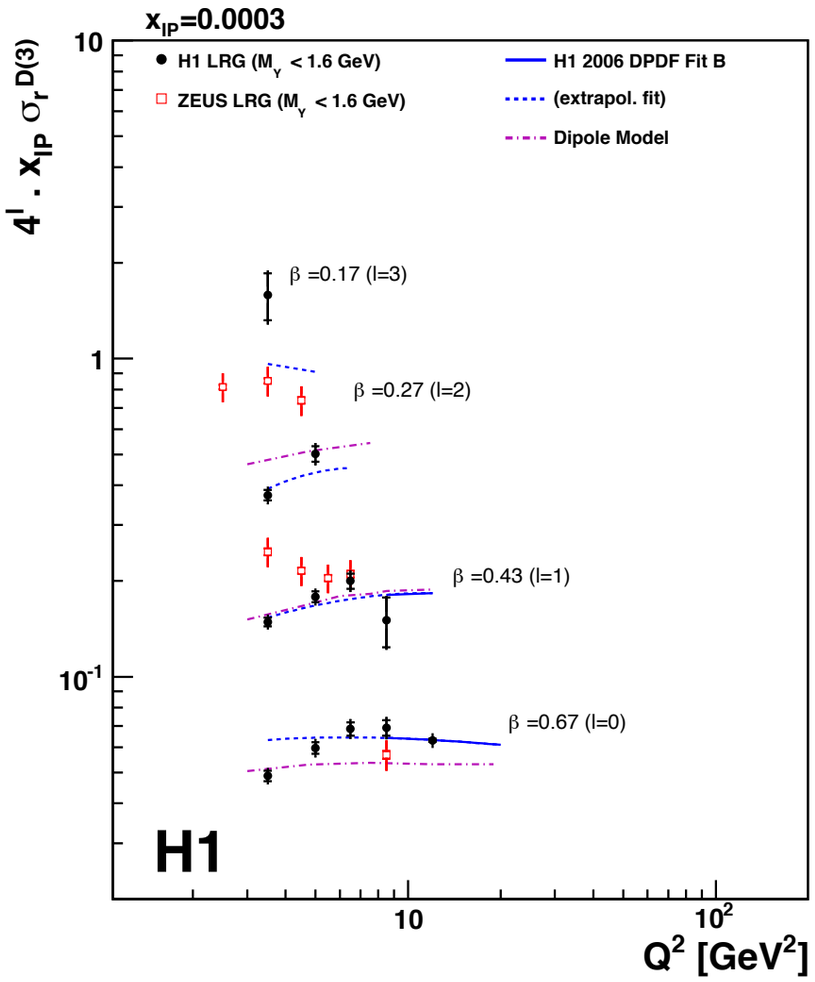
Precision measurements of the classic scaling violations for diffraction, covering a large kinematic range

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



The H1 LRG data are in very good agreement with the H1 proton spectrometer data

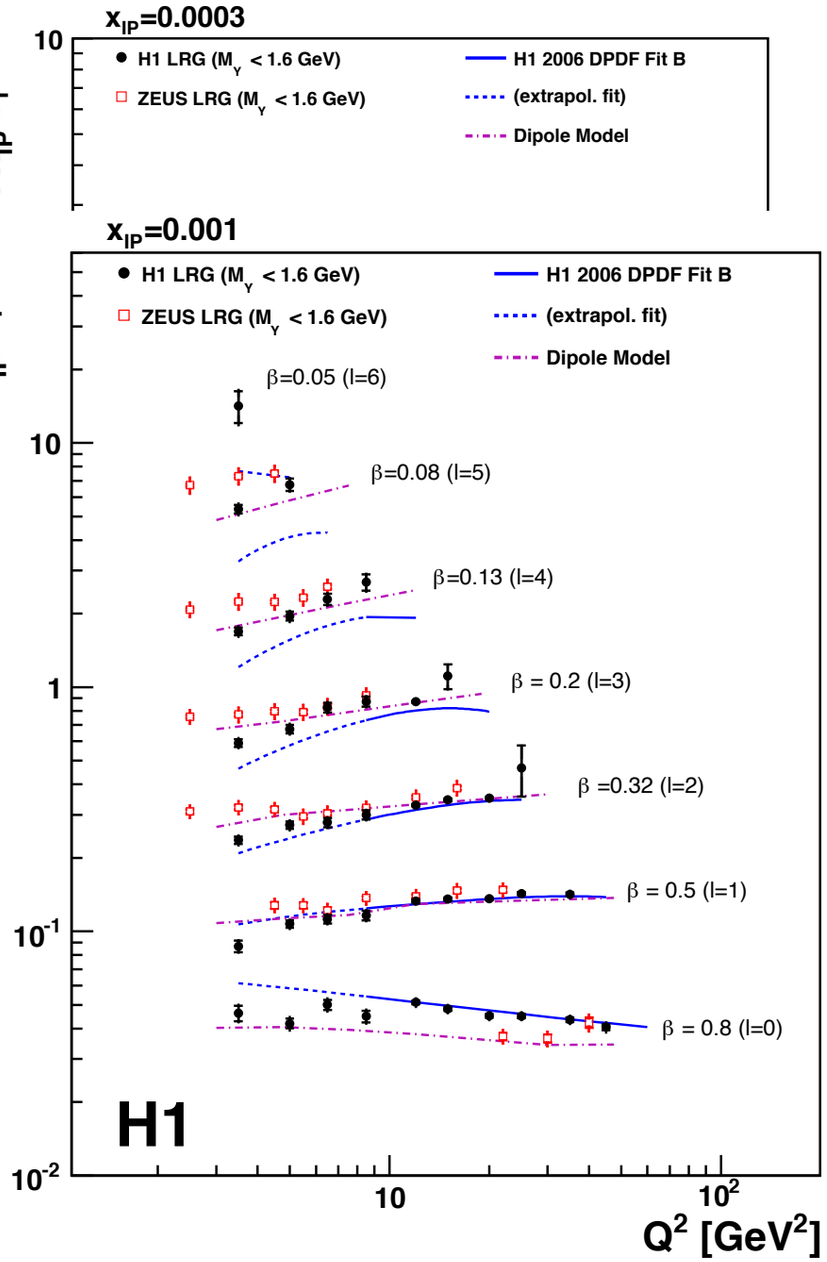
σ_r^D at fixed x_{IP} - H1 and Zeus



Both collaborations measure the reduced cross section in bins of fixed x_{IP}

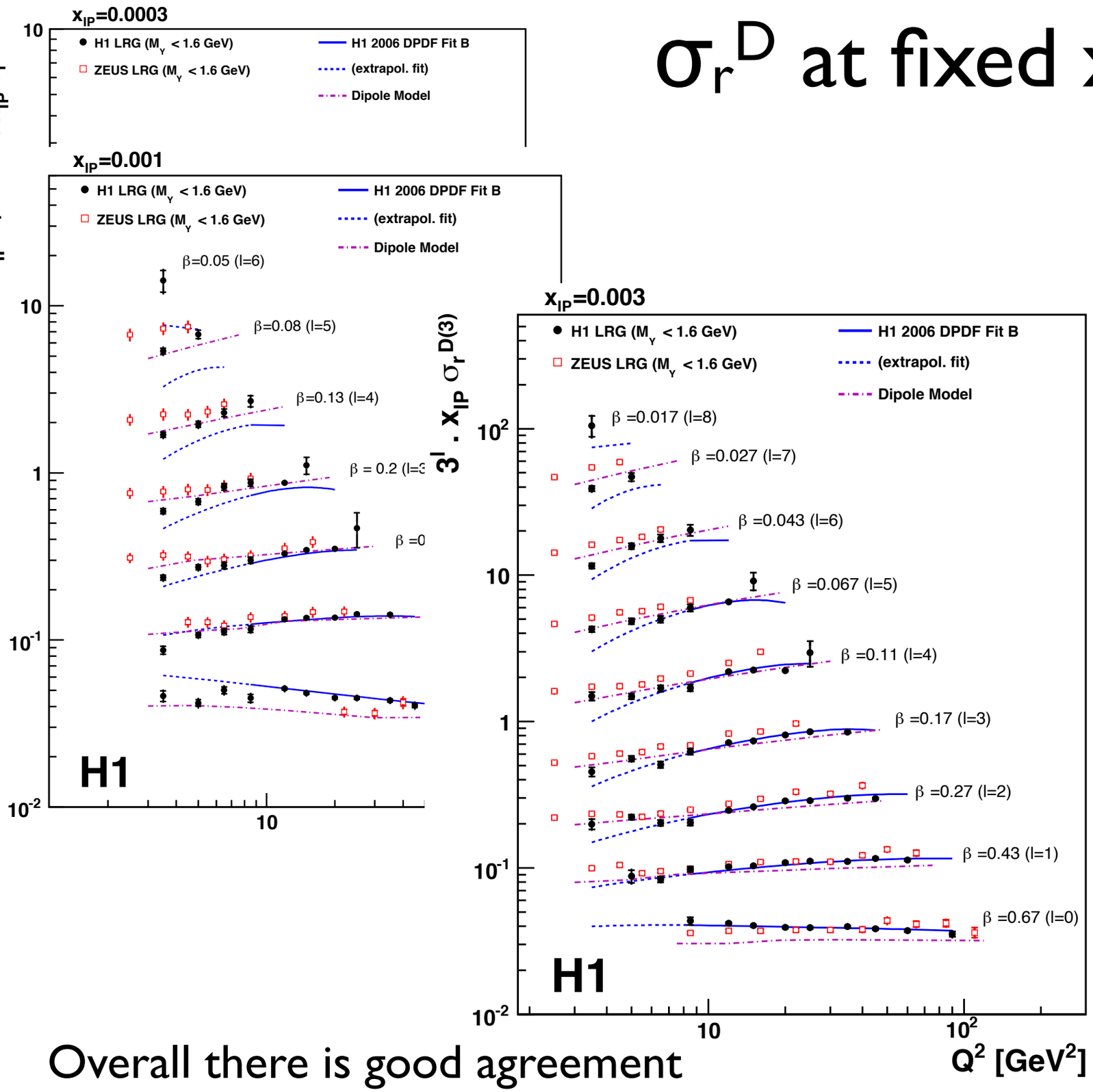
The measurements cover a large kinematic range and agreement isn't perfect everywhere

σ_r^D at fixed x_{IP} - H1 and Zeus



Overall there is good agreement between these two high precision measurements

σ_r^D at fixed x_{IP} - H1 and Zeus



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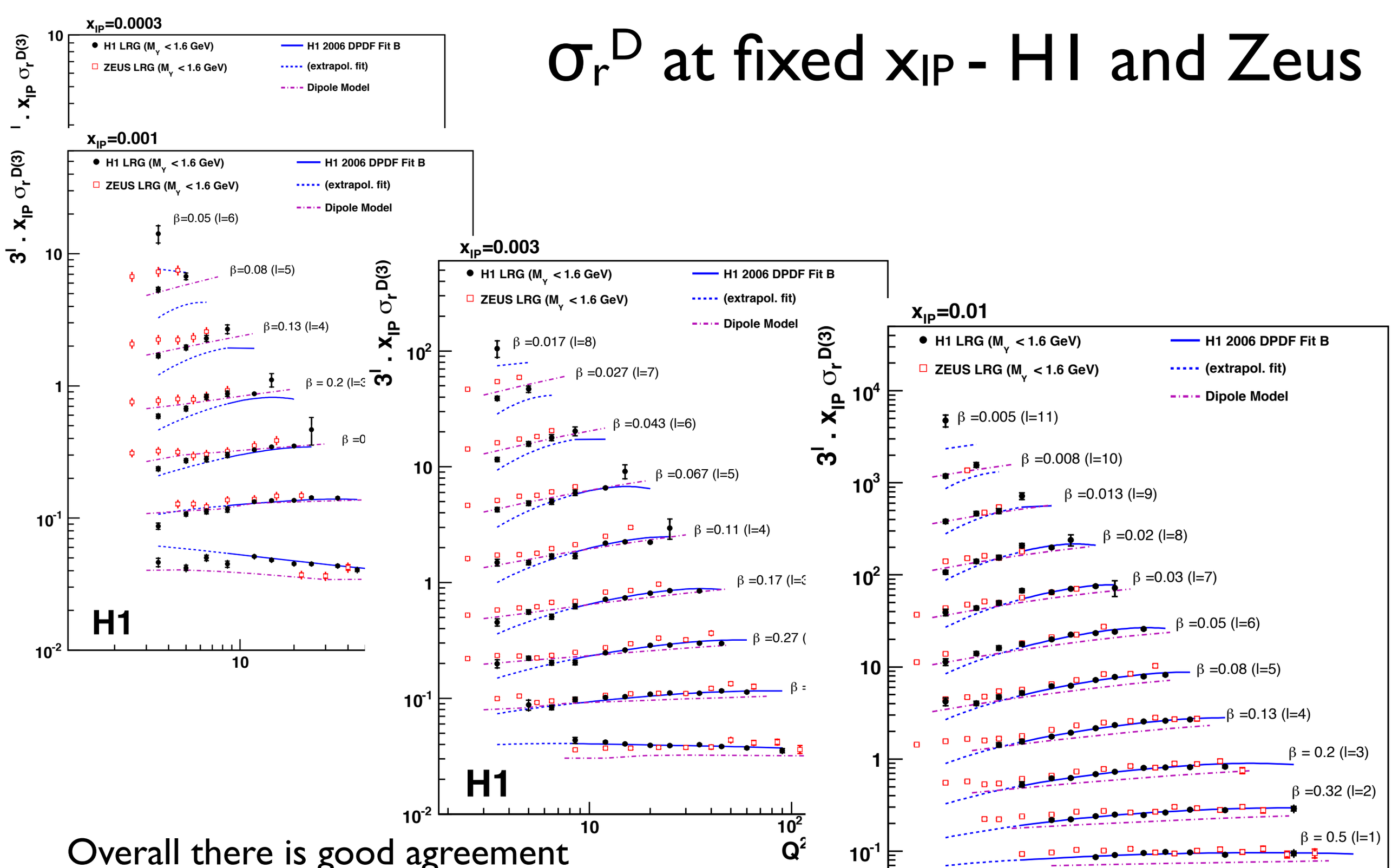
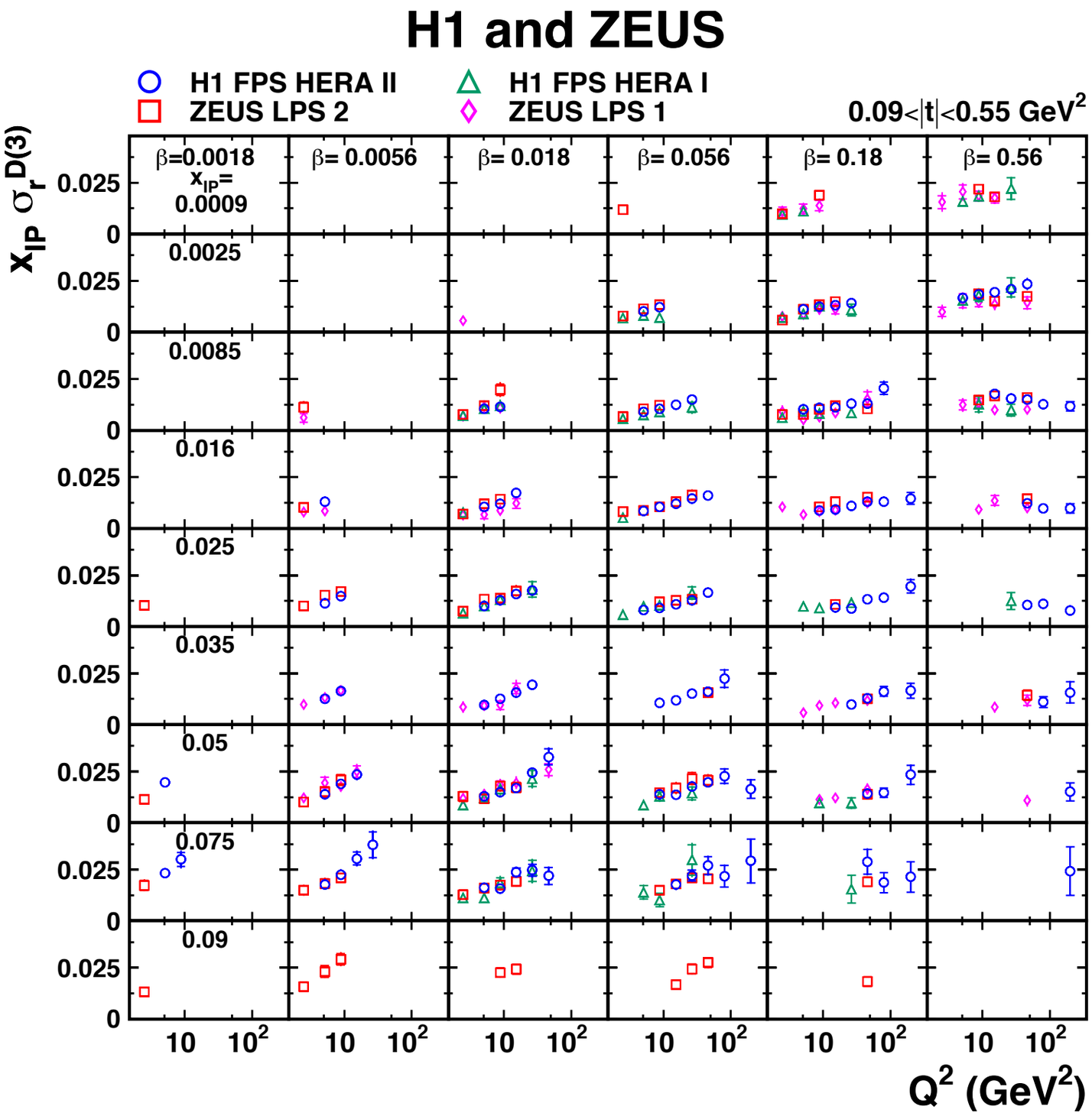


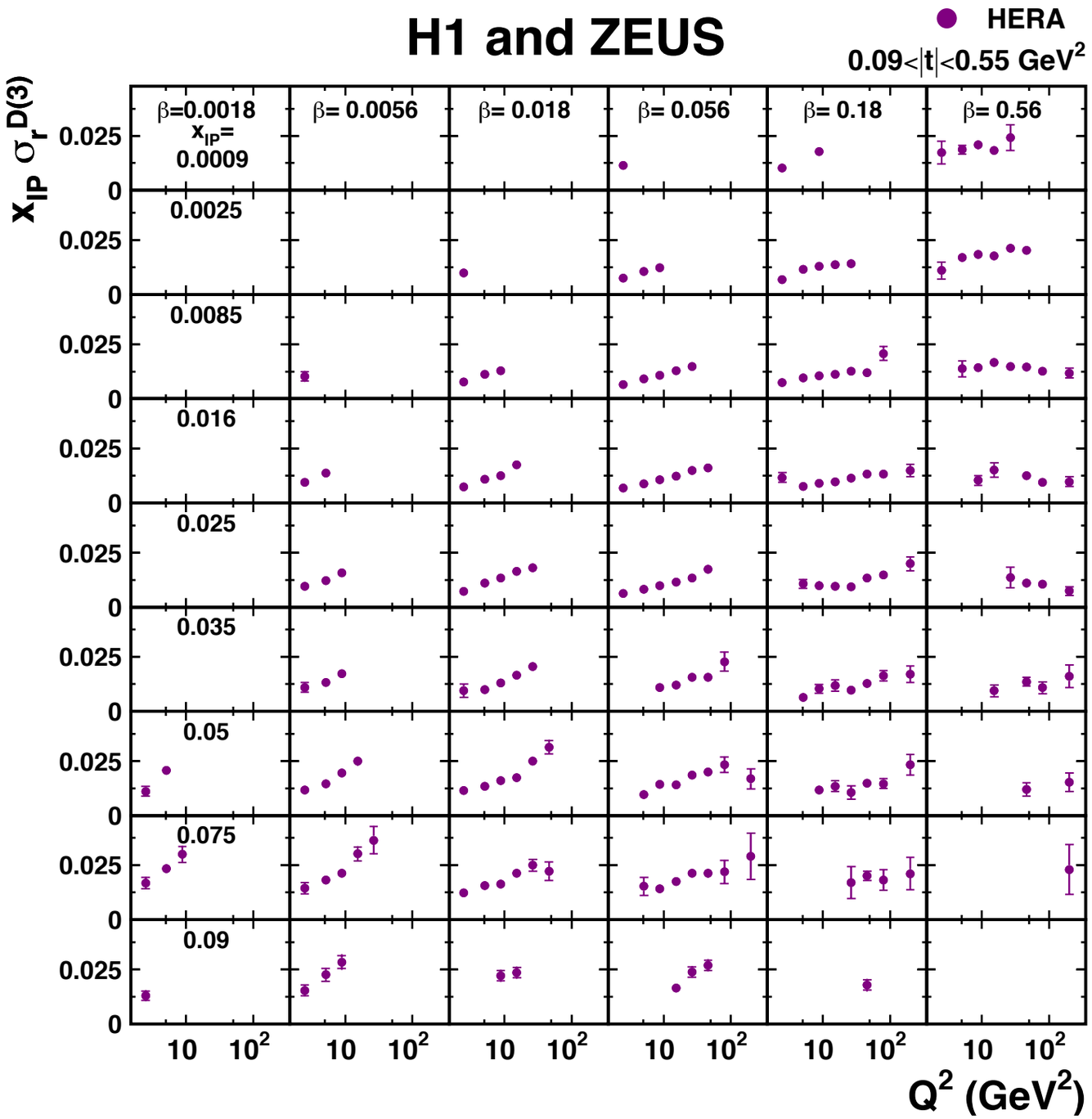
Overall there is good agreement between these two high precision measurements

H1 and ZEUS Spectrometer Data



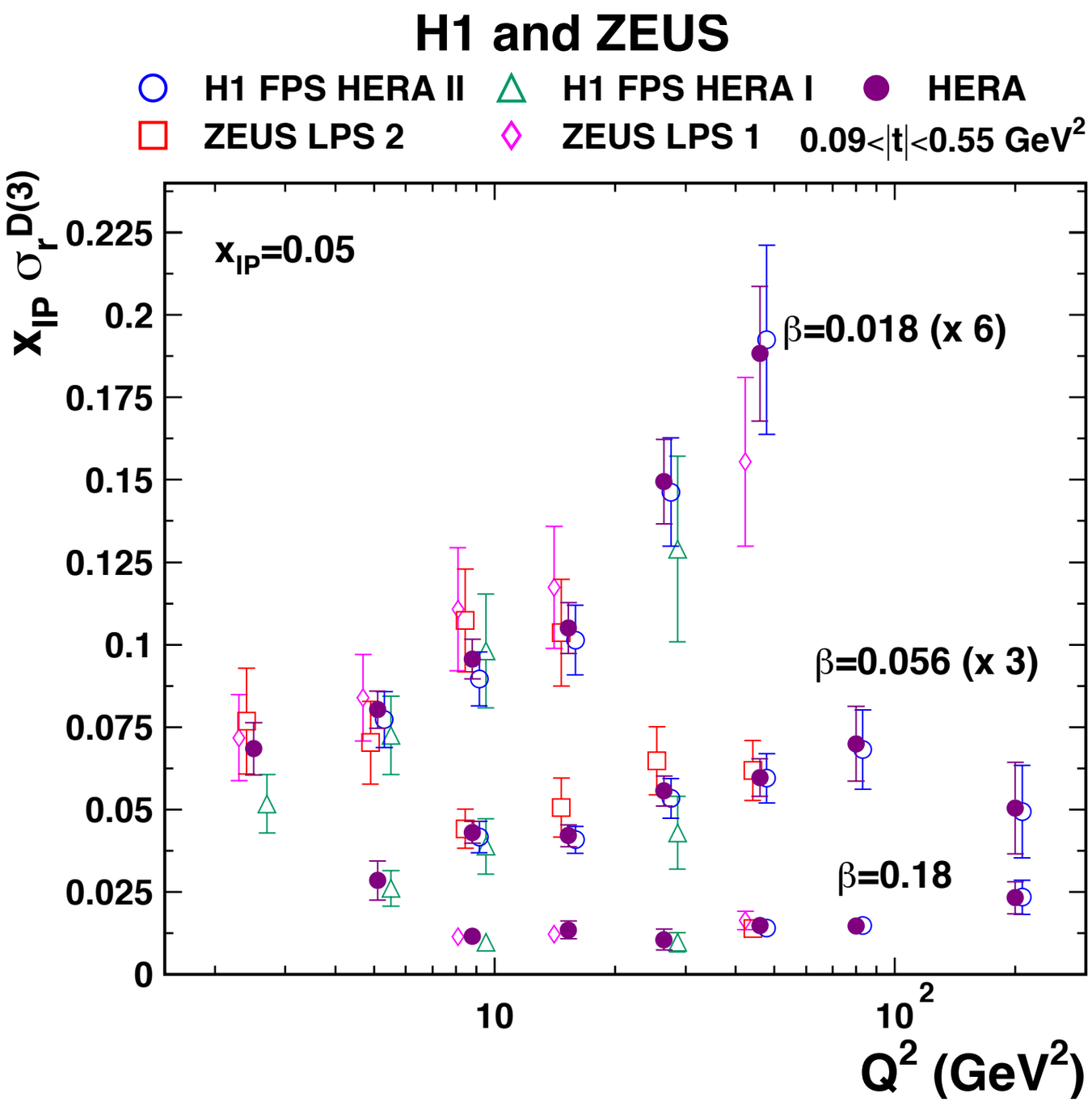
Both experiments have published their proton spectrometer data...

H1 and Zeus Combinations



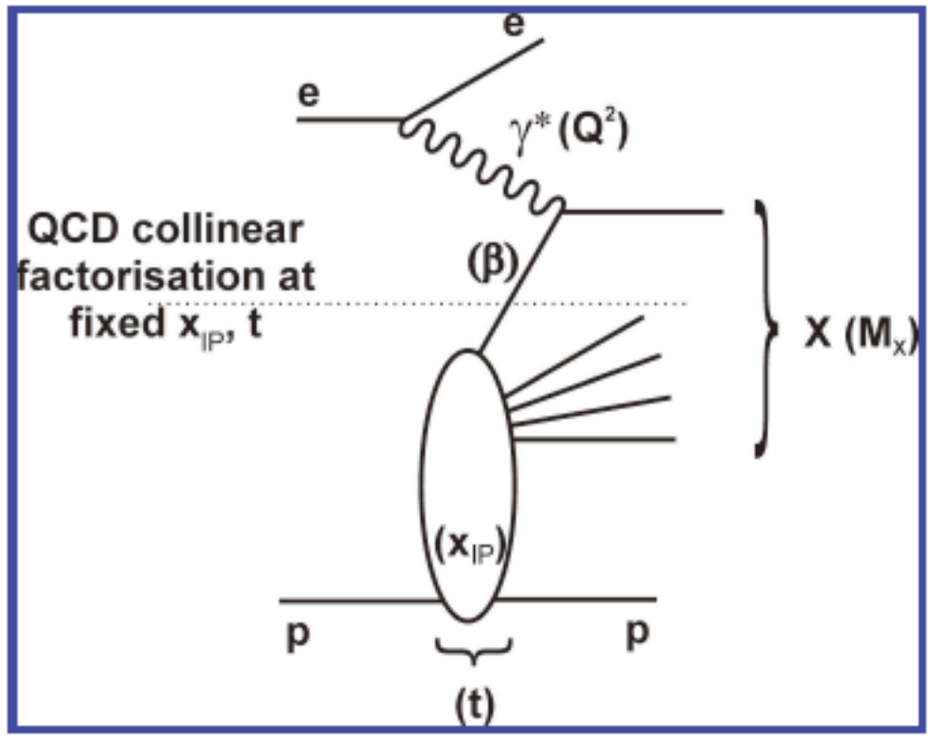
All of the proton spectrometer datasets have been combined to produce the first HERA diffractive dataset

H1 and Zeus Combinations



The precision of the combined dataset is a significant improvement

Factorisation in Diffractive DIS

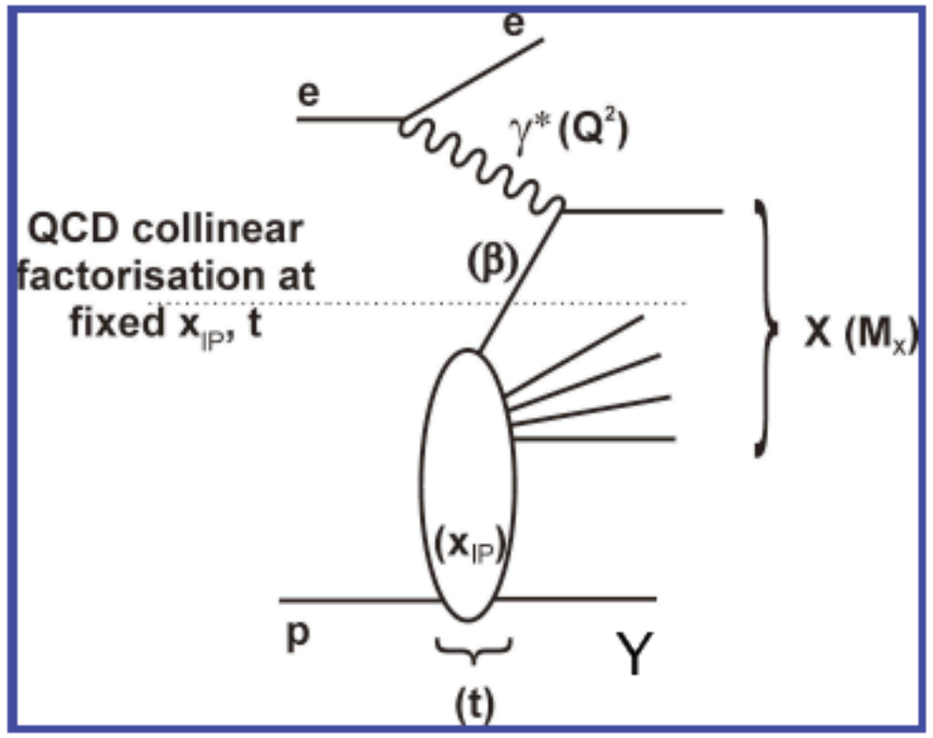


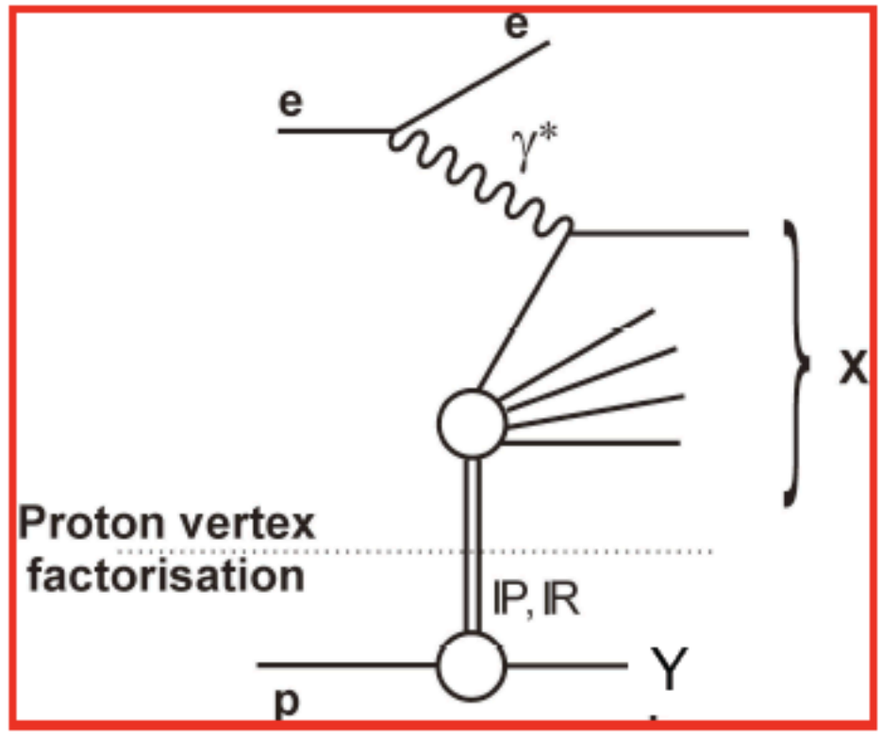
QCD hard scattering collinear factorisation (Collins) at fixed x_{IP} and t

$$d\sigma_{partoni}(ep \to eXY) = f_i^D(x, Q^2, x_{I\!P}, t) \otimes d\sigma^{ei}(x, Q^2)$$

Applied after integration over measured M_Y and t ranges

Factorisation in Diffractive DIS





QCD hard scattering collinear factorisation (Collins) at fixed $x_{I\!P}$ and t

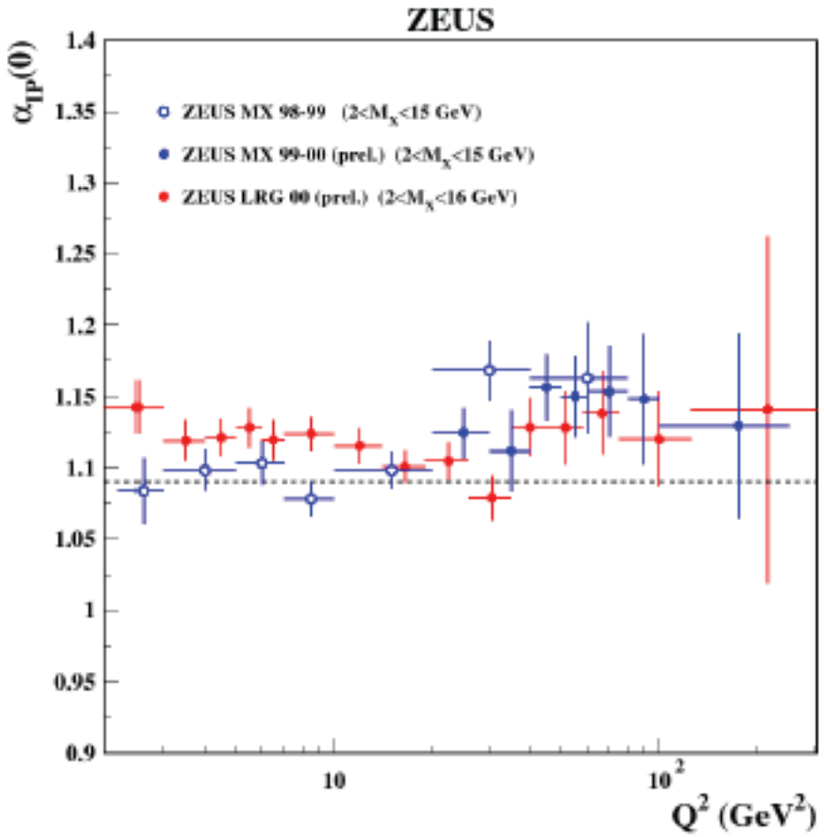
$$d\sigma_{partoni}(ep \to eXY) = f_i^D(x, Q^2, x_{I\!P}, t) \quad \otimes d\sigma^{ei}(x, Q^2)$$

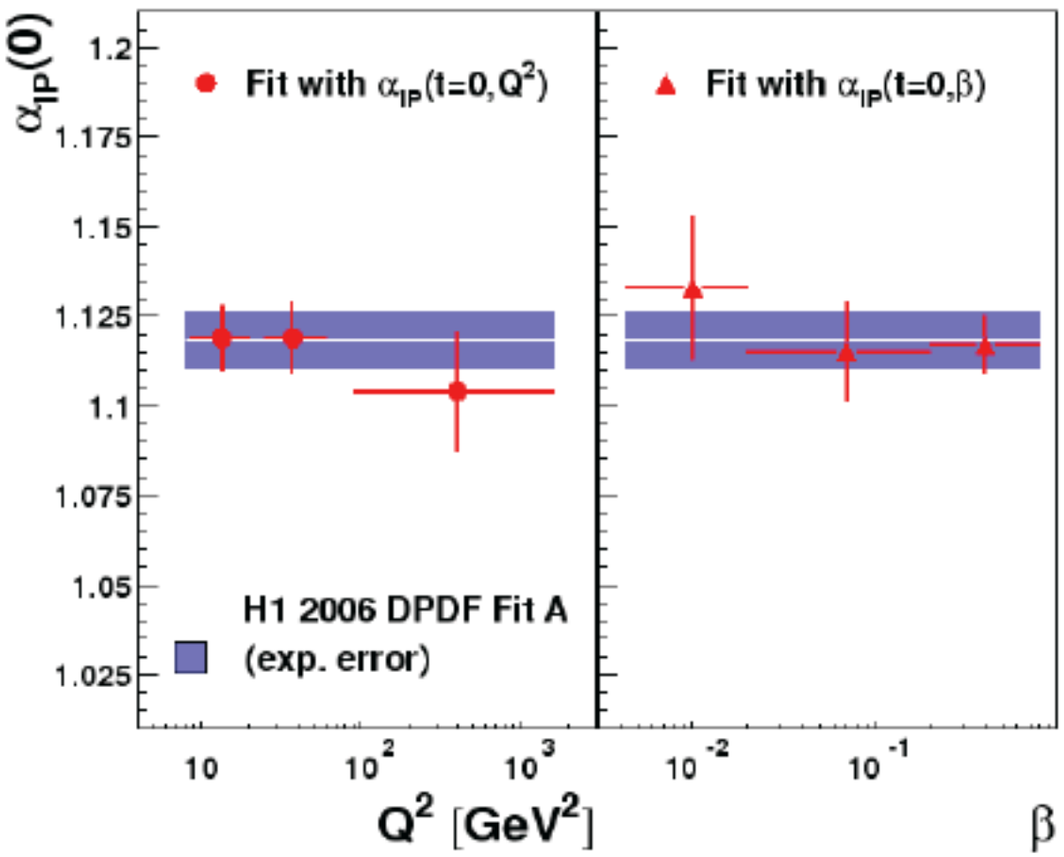
Applied after integration over measured M_Y and t ranges

`Proton vertex' factorisation of β and Q^2 from $x_{I\!P}$, t, and M_Y dependences

$$f_i^D(x, Q^2, x_{I\!P}, t) = f_{I\!P/p}(x_{I\!P}, t) \cdot f_i^{I\!P}(\beta = \frac{x}{x_{I\!P}}, Q^2)$$

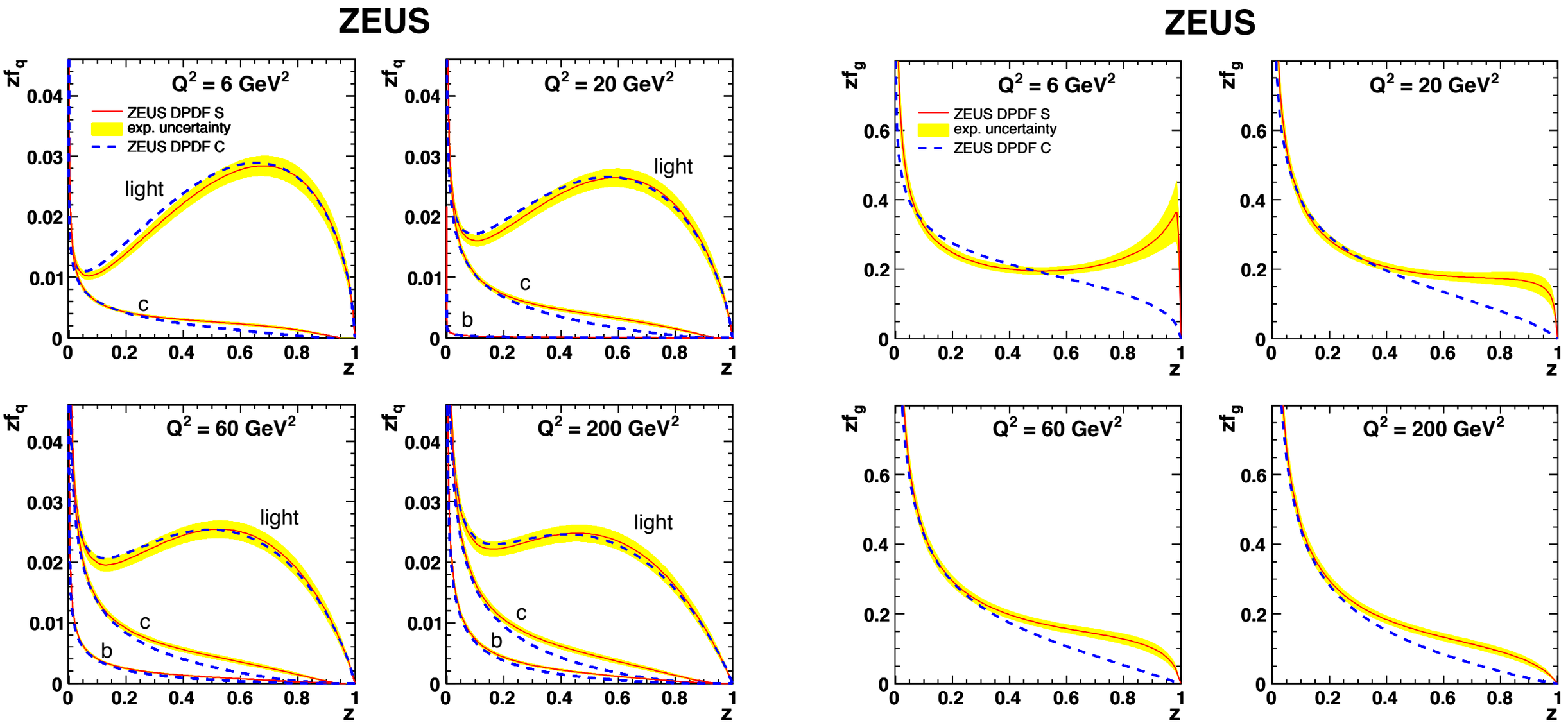
Proton Vertex Factorisation Tests

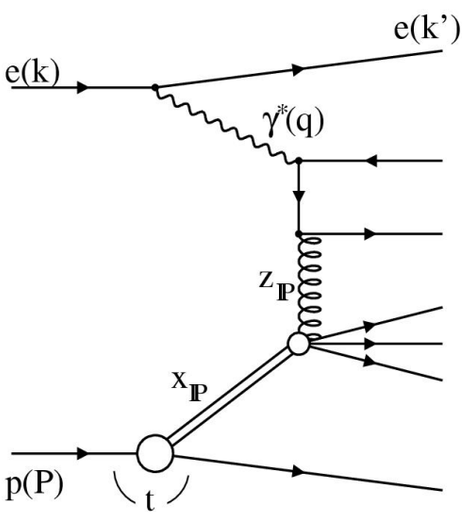




- Measure the x_{IP} dependence of the data as a function of β and Q^2
- The proton vertex factorisation approximation holds within the experimental precision
- This allows an NLO QCD analysis of the β and Q^2 dependences

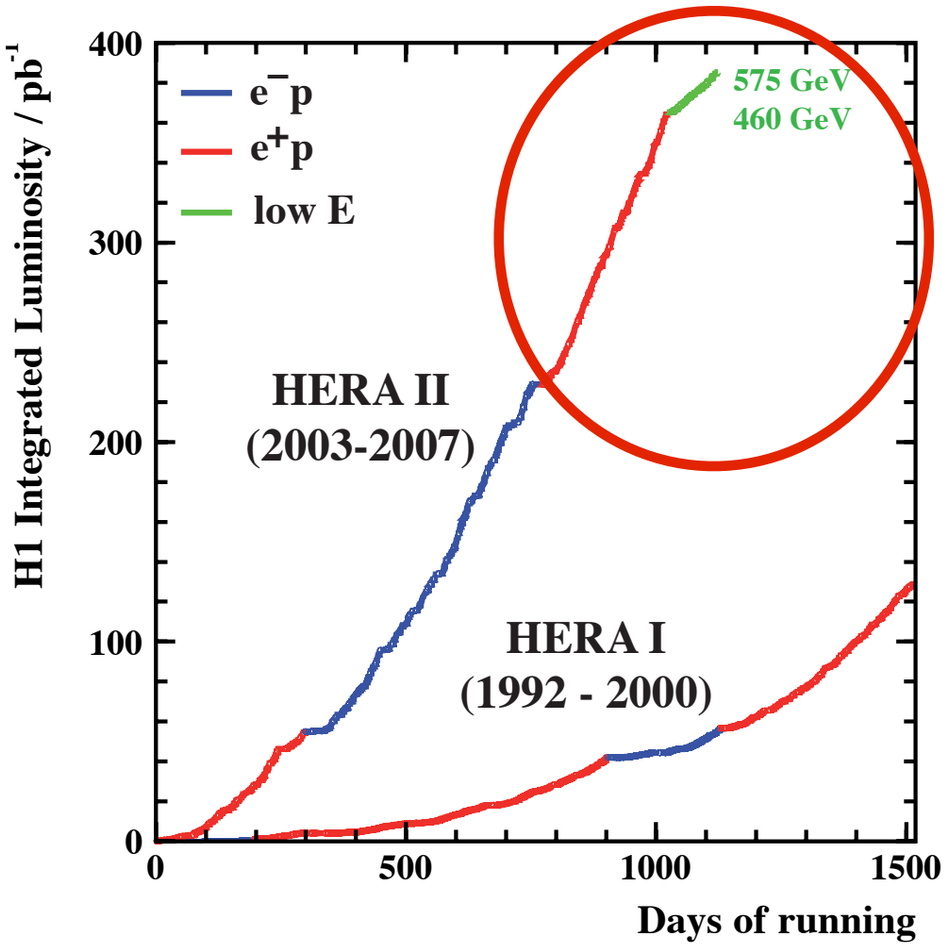
ZEUS Diffractive PDFs

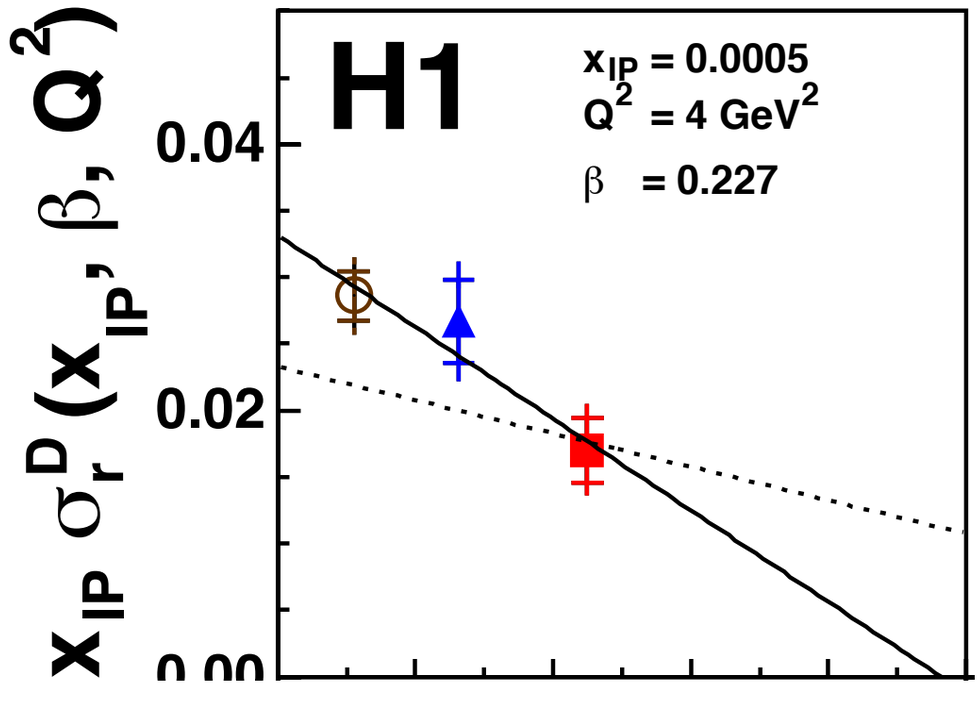




- Fit to inclusive diffractive data and diffractive dijets to provide constraints on the gluon especially at high momentum fraction
- Also includes heavy flavour treatment, see evolution with Q^2
- H1 also performed QCD fits to inclusive data, used e.g. in Pythia8 model of hard diffraction

F_L^D using H1 data

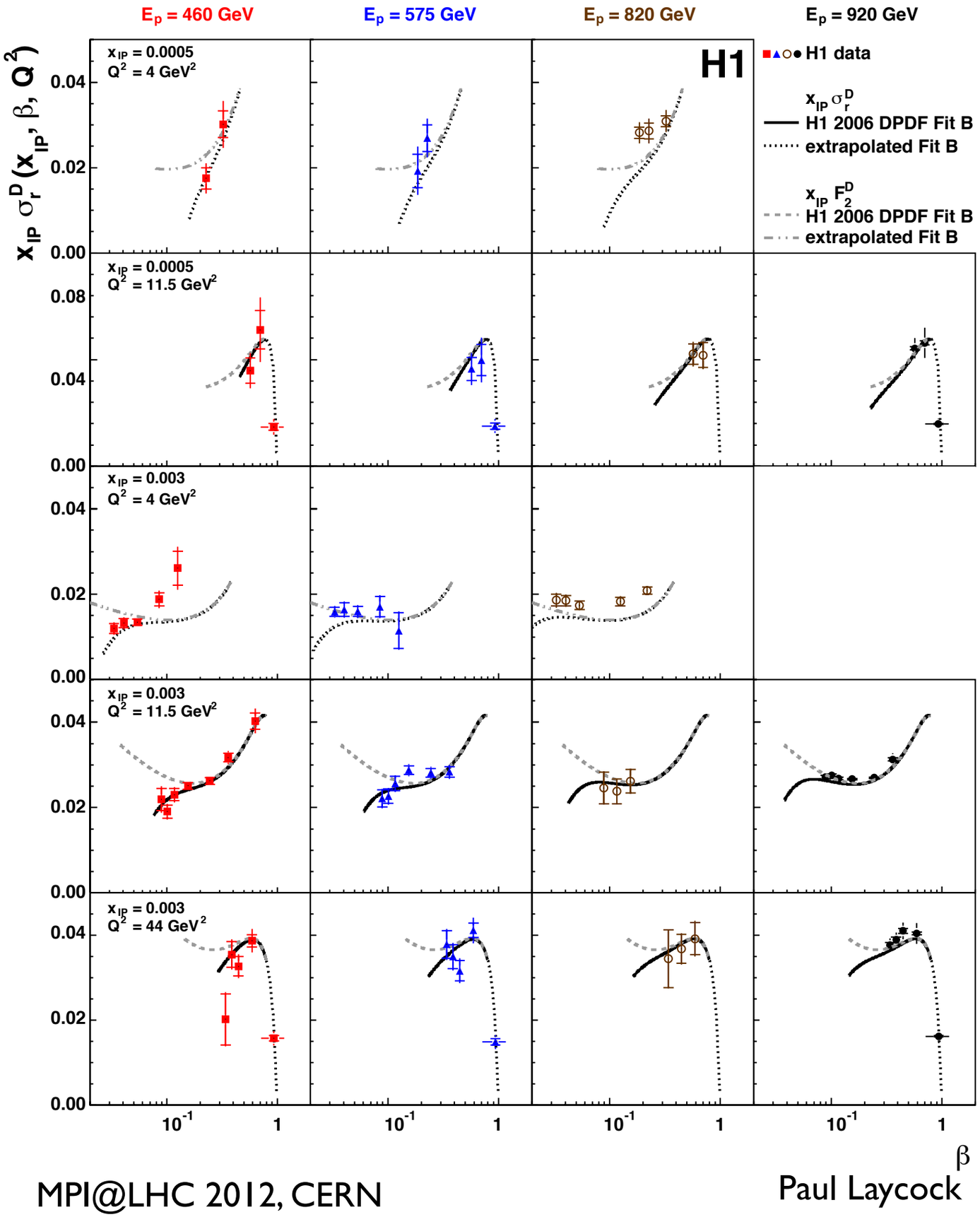




$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{Y+} F_L^{D(4)}$$

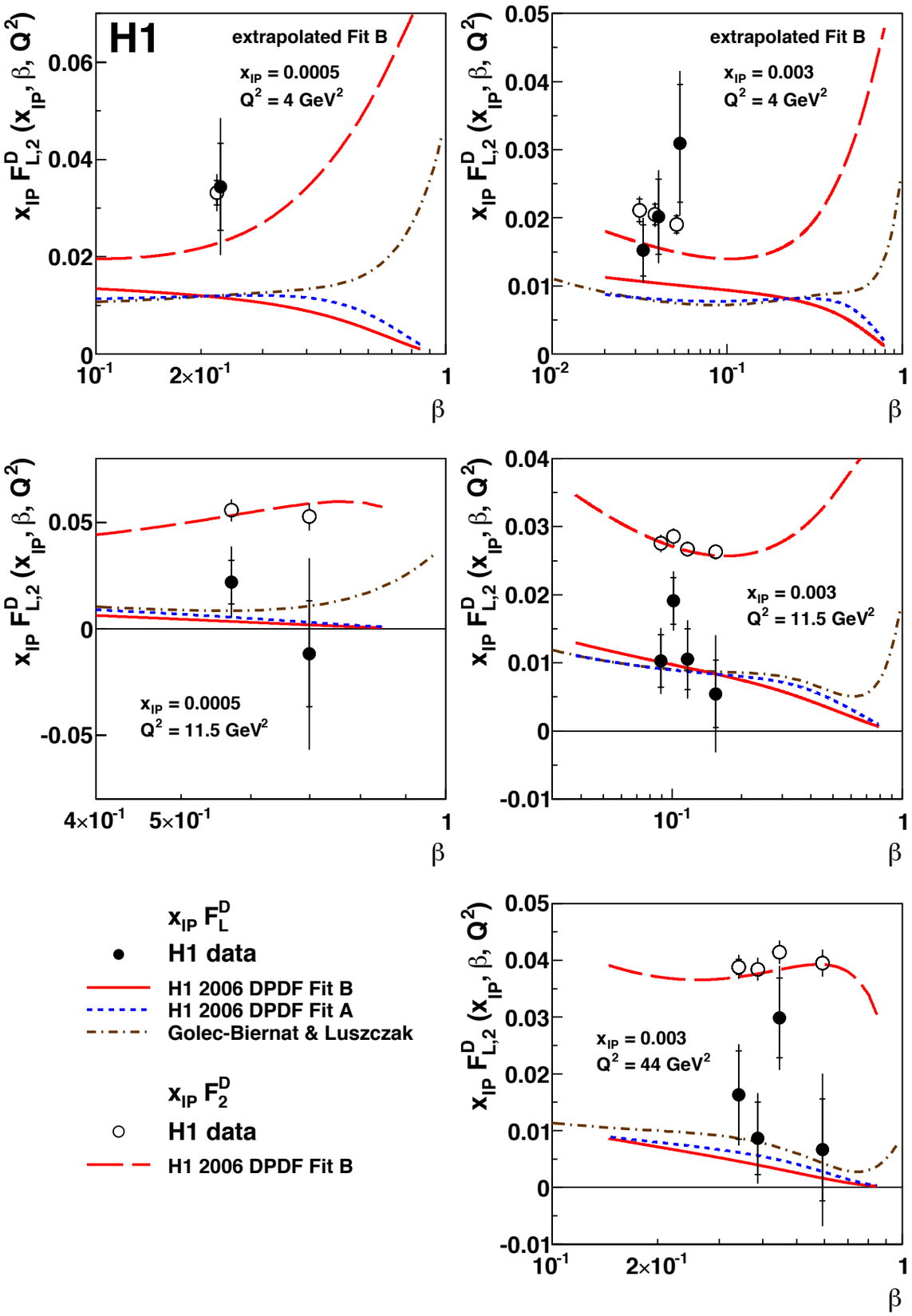
- Measure cross sections at fixed x_{IP}, β, Q^2 and different y values using H1 data with different proton beam energies → F_L^D
- Largest sensitivity to F_L^D is at highest inelasticity y
- A very challenging analysis requiring precision understanding of the calorimeter for electron ID down to 3.4 GeV, and $Q^2 > 2.5$ GeV^2

Diffractive cross sections at medium and high y



- Diffractive cross sections using E_p = 920 GeV, E_p = 575 GeV, E_p = 460 GeV and previously published data E_p = 820 GeV
- Data are compared to prediction of 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 fit)
- Cross-sections binned coarsely in order to optimise F_L^D extraction

The diffractive structure functions



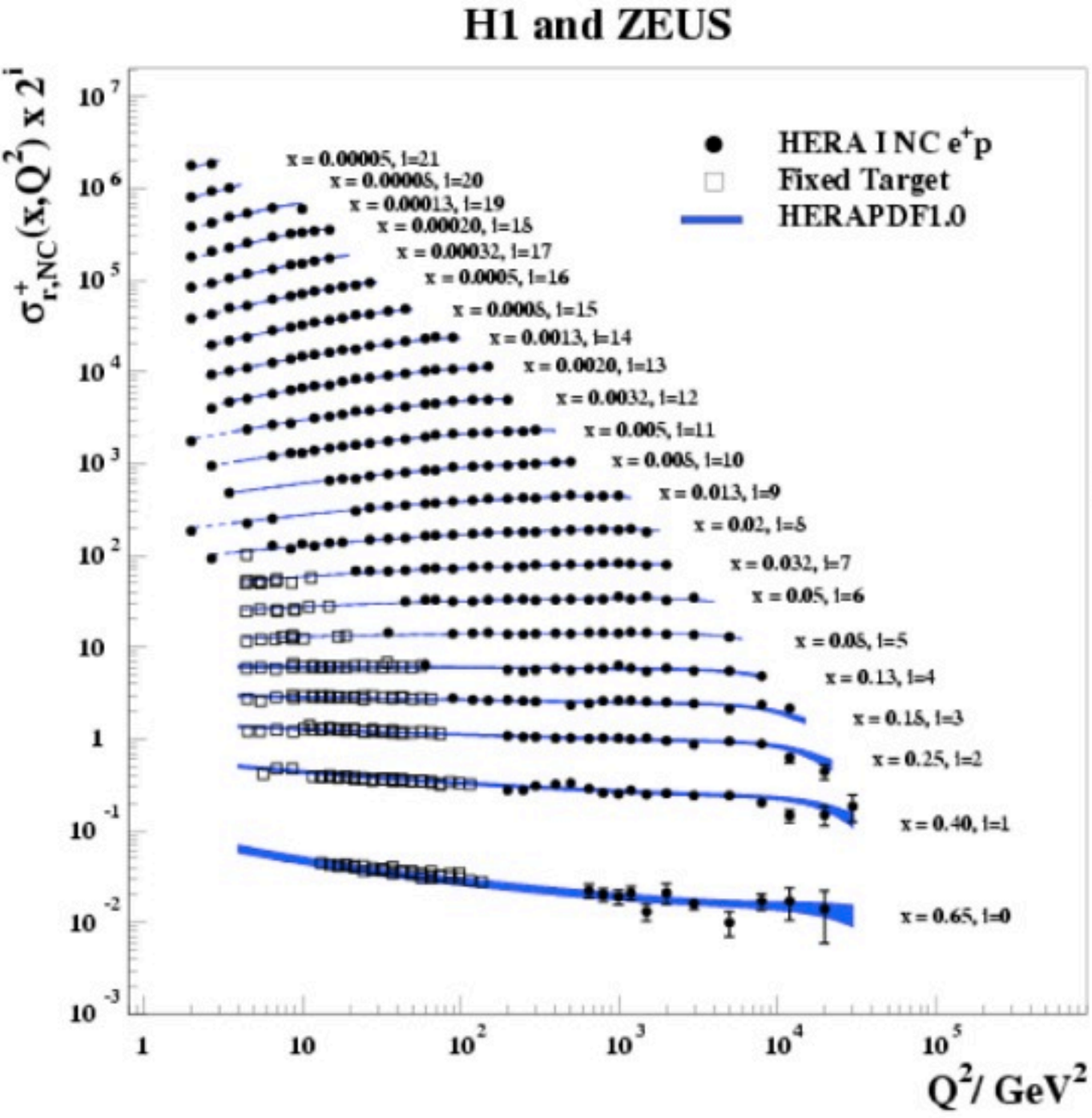
- F_2^D and F_L^D extracted simultaneously for three bins in Q^2 (= 4, 11.5, 44 GeV^2) and two bins in x_{IP} (=0.0005, 0.003) as a function of β

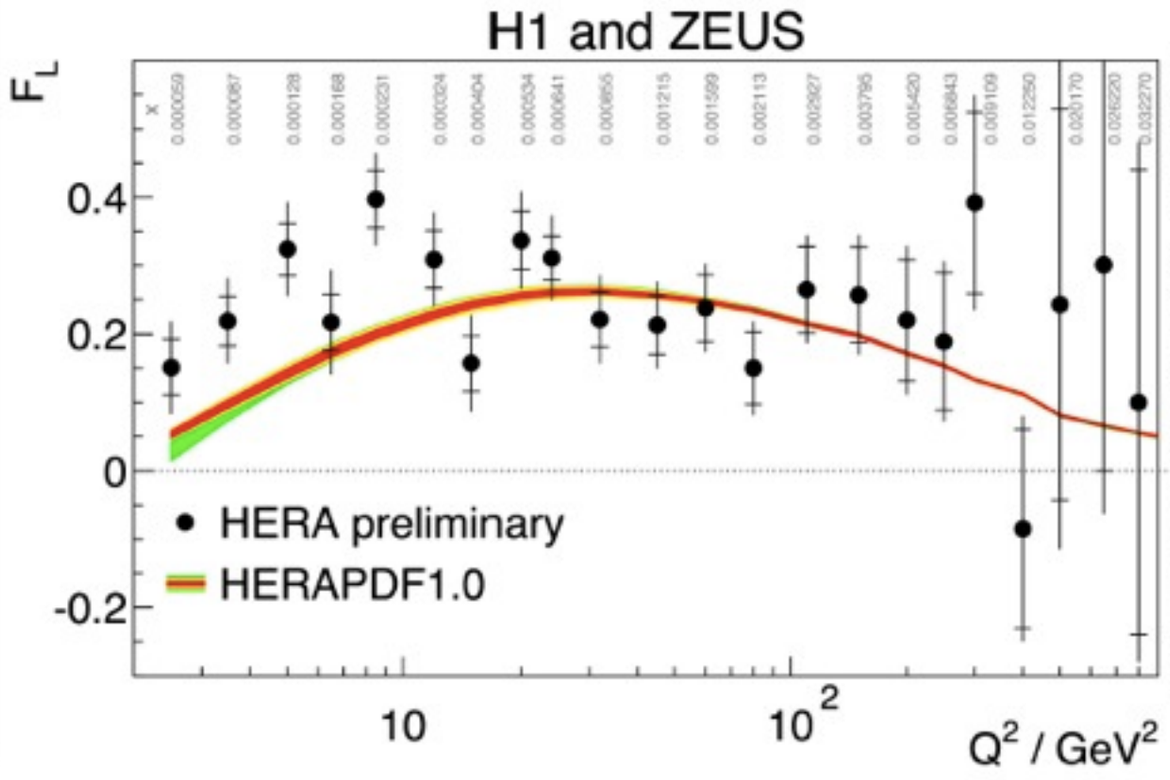
- The data are consistent with the hypothesis $0 < F_L^D < F_2^D$

- 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

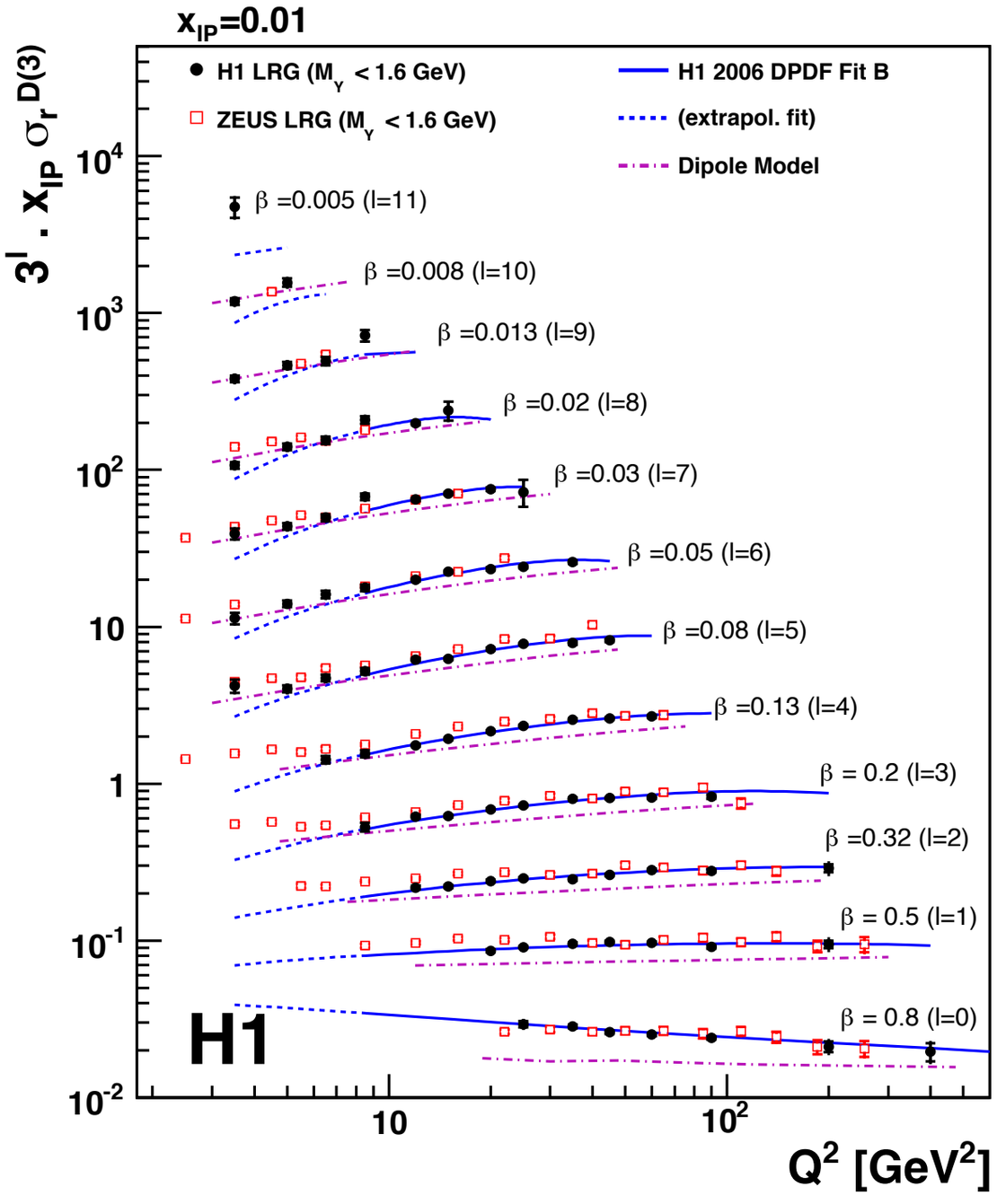
Inclusive F_2 and F_L

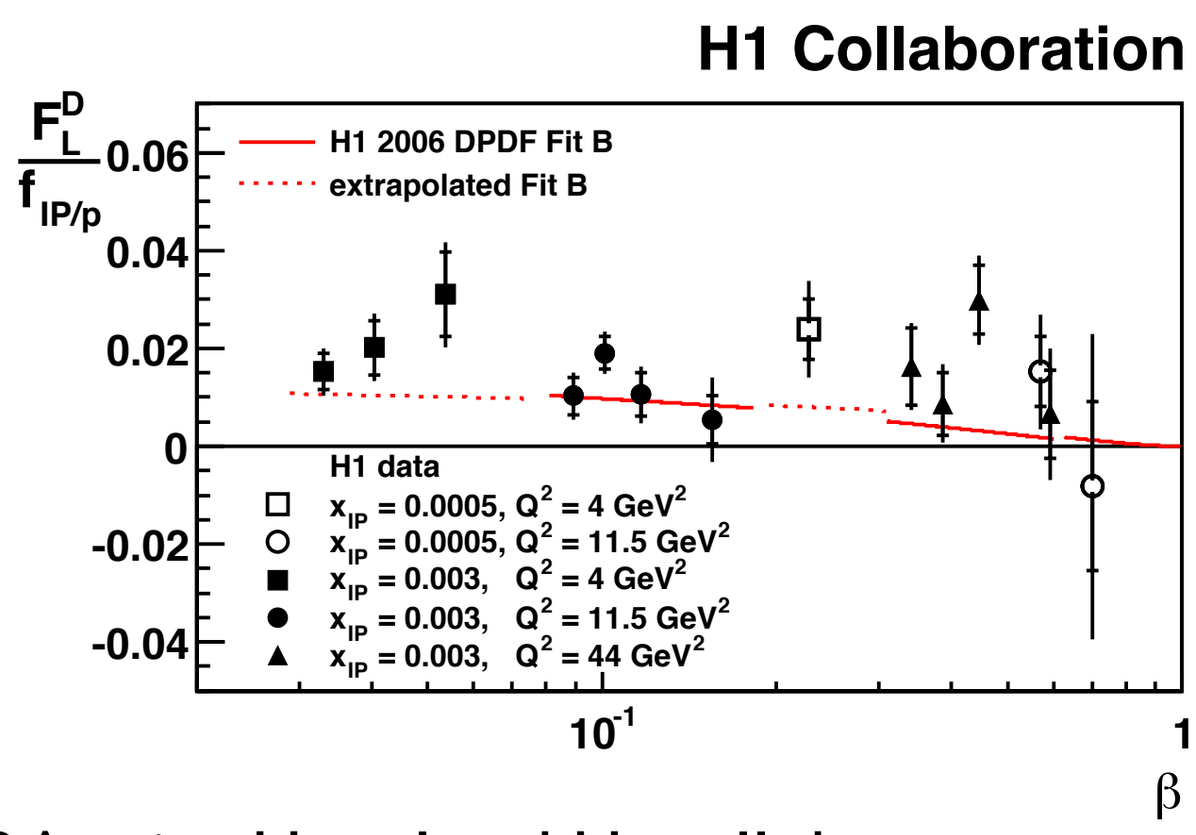




Target is to repeat this for diffraction, how are we doing?

Summary - F_2^D and F_L^D from HERA





- Inclusive diffractive DIS studied at HERA 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