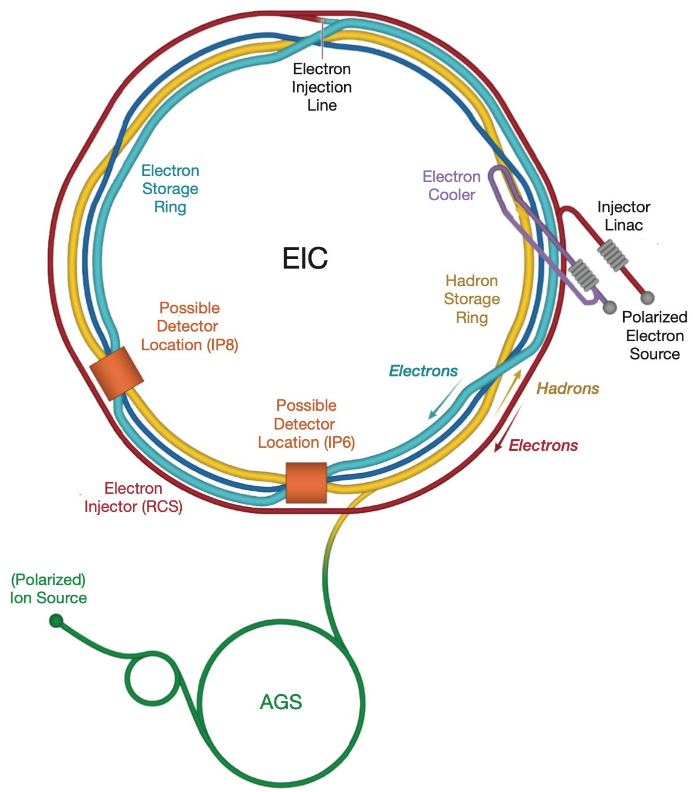


# Possibilities for inclusive diffraction at the Electron Ion Collider

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collaboration with **Nestor Armesto, Paul Newman** and **Wojciech Słomiński**

BNL, May 23, 2024

# Outline

- **Simulations of $F_L^{D(3)}$ for EIC**
    - Motivation: why is $F_L^{D(3)}$ interesting ?
    - H1 measurement
    - Proton tagging as a method for diffraction at EIC
    - Pseudodata simulation, energy beam scenarios
    - Extraction by linear fit. Kinematic range and precision
    - $F_L^{D(3)}$ and $R^{D(3)}$ ratio of longitudinal to transverse cross section
- **4D diffractive cross section and Reggeon extraction at EIC**
    - EIC pseudodata for 4D diffractive cross section with t dependence
    - Extraction of Pomeron and Reggeon partonic structure, estimate of uncertainties

Series of works on diffraction at ep/eA machines:

*Inclusive diffraction in future electron-proton and electron-ion colliders* e-Print: 1901.09076

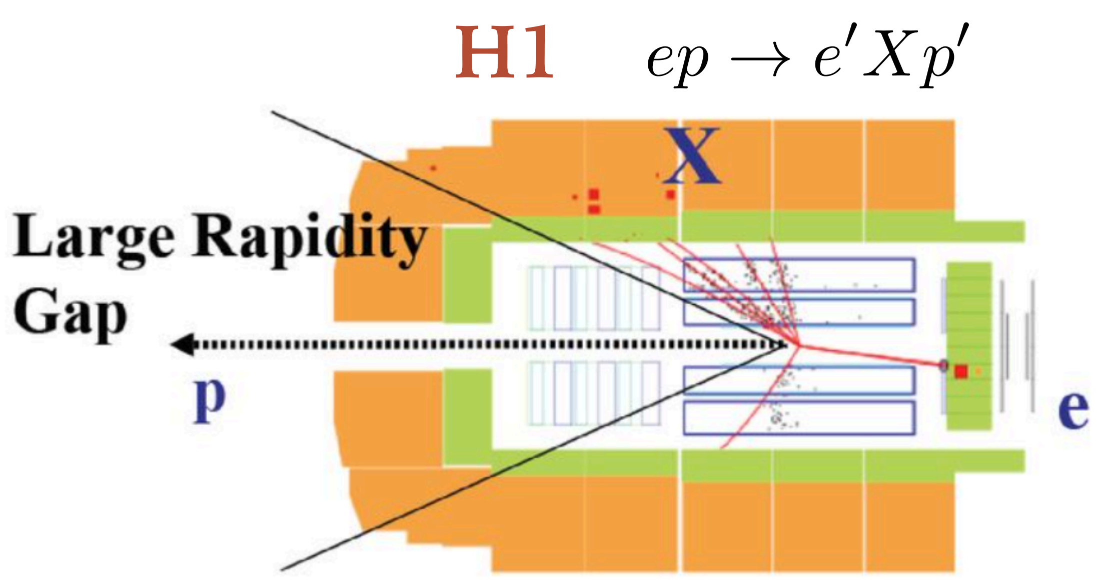
*Diffractive longitudinal structure function at Electron Ion Collider* e-Print: 2112.06839

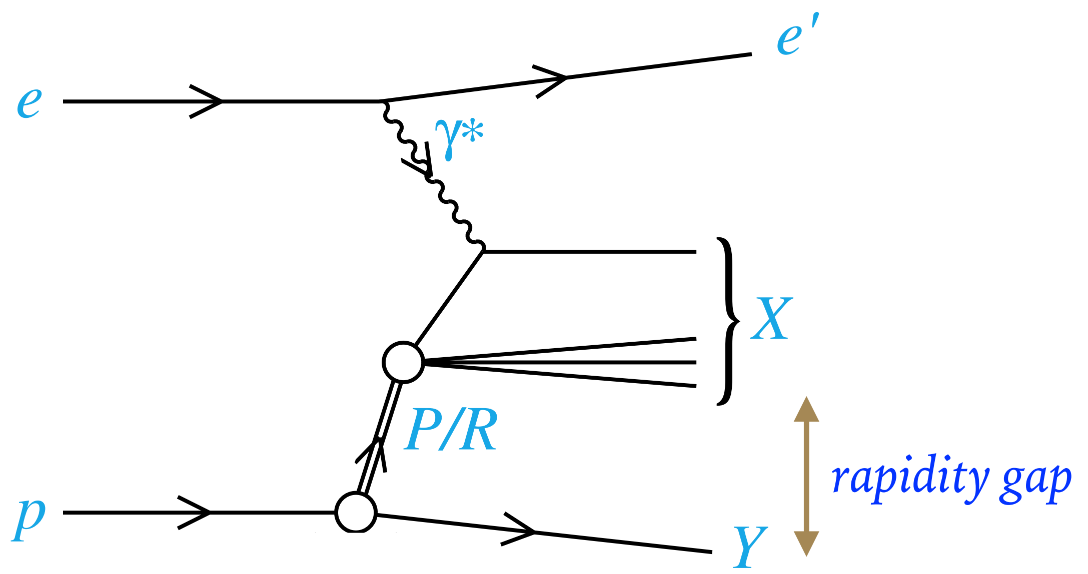
*Extracting the partonic structure of colorless exchanges at Electron Ion Collider* e-Print: to appear soon

also EIC Yellow Report, Sec. 7.1.6, 8.5.7

# Diffraction in DIS

- Diffractive characterized by the **rapidity gap**: no activity in part of the detector
- At HERA in electron-proton collisions: about 10% events diffractive
- Interpretation of diffraction : need **colorless exchange**

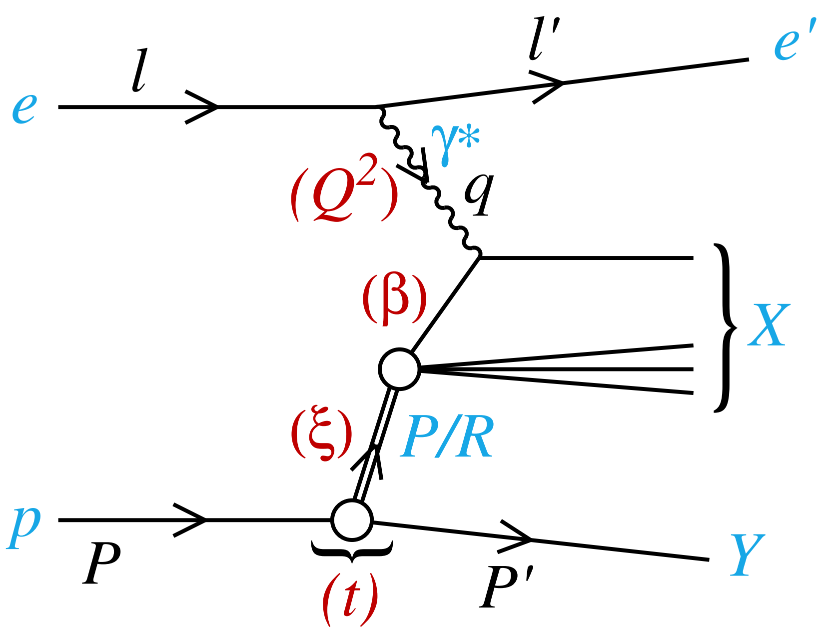



**Questions:**

- What is the nature of this exchange ? Partonic composition ?
- One, two, or more exchanges ? Pomeron $I\!P$, Reggeon $I\!R$ ?
- Evolution ? Relation to saturation, higher twists ?
- Energy, momentum transfer dependence ?

# Diffractive kinematics in DIS




$$\boxed{x = \xi\beta}$$

## Standard DIS variables:

electron-proton
cms energy squared:

$$s = (l+P)^2$$

photon-proton
cms energy squared:

$$W^2 = (q+P)^2$$

inelasticity

$$y = \frac{P \cdot q}{P \cdot l}$$

Bjorken x

$$x = \frac{Q^2}{2P \cdot q} = \frac{Q^2}{ys} = \frac{Q^2}{Q^2 + W^2}$$

(minus) photon virtuality

$$Q^2 = -q^2$$

## Diffractive DIS variables:

$$\xi = x_{IP} = \frac{x}{\beta} = \frac{Q^2 + M_X^2 - t}{Q^2 + W^2}$$

momentum fraction of the Pomeron w.r.t hadron

$$\beta = \frac{Q^2}{2(P - P') \cdot q} = \frac{Q^2}{Q^2 + M_X^2 - t}$$

momentum fraction of parton w.r.t Pomeron

$$t = (P' - P)^2$$

4-momentum transfer squared

# Diffractive cross section, structure functions

Diffractive cross section depends on **4 variables $(\xi, \beta, Q^2, t)$:**

$$\frac{d^4\sigma^D}{d\xi d\beta dQ^2 dt} = \frac{2\pi\alpha_{\rm em}^2}{\beta Q^4} Y_+ \, \sigma_{\rm r}^{\rm D(4)}(\xi,\beta,Q^2,t)$$

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

**Reduced** cross section depends on two **structure functions:**

$$\sigma_{\rm r}^{\rm D(4)}(\xi,\beta,Q^2,t) = F_2^{\rm D(4)}(\xi,\beta,Q^2,t) - \frac{y^2}{Y_+} F_L^{\rm D(4)}(\xi,\beta,Q^2,t)$$

Upon integration over $t$:

$$F_{2,L}^{\rm D(3)}(\xi,\beta,Q^2) = \int_{-\infty}^{0} dt \, F_{2,L}^{\rm D(4)}(\xi,\beta,Q^2,t)$$

$$\sigma_{\rm r}^{\rm D(3)}(\xi,\beta,Q^2) = F_2^{\rm D(3)}(\xi,\beta,Q^2) - \frac{y^2}{Y_+} F_L^{\rm D(3)}(\xi,\beta,Q^2)$$

When $y \ll 1$

$$\sigma_{\rm r}^{\rm D(4,3)} \simeq F_2^{\rm D(4,3)}$$

Dimensions:

$[\sigma_{\rm r}^{\rm D(4)}] = {\rm GeV}^{-2}$

$\sigma_{\rm r}^{\rm D(3)}$ Dimensionless

# Why $F_L^{D(3)}$ is interesting?

$F_L^D$ vanishes in the parton model, similarly to inclusive case

Gets non-vanishing contributions in QCD

As in inclusive case, particularly sensitive to the diffractive **gluon density**

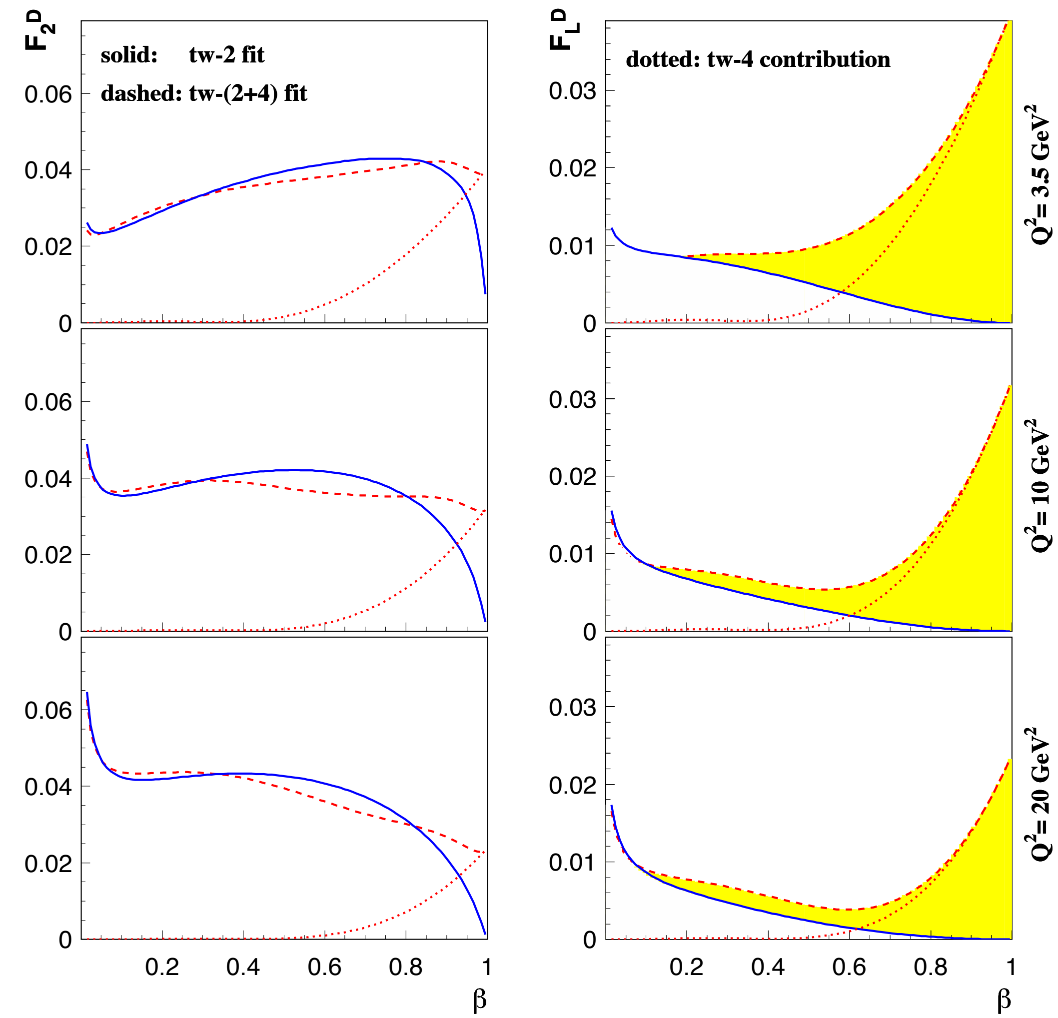
Expected large **higher twists**, provides test of the **non-linear, saturation phenomena**

*Golec-Biernat, Łuszczak*

Theoretical studies indicate important role of twist 4 contributions to $F_L^D$

$F_2^D$ affected less by higher twists

$x_{I\!P} \equiv \xi = 10^{-3}$



# $F_L^{D(3)}$ at HERA

Measurement requires several beam energies

$F_L^D$ strongest when $y \to 1$. Low electron energies

***Experimentally challenging…***

Eur. Phys. J. C (2011) 71:1836
DOI 10.1140/epjc/s10052-011-1836-6

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

**Measurement of the diffractive longitudinal structure function $F_L^D$ at HERA**

**H1 Collaboration**

1107.3420[hep-ex]

**H1 measurement:** 4 energies, $E_p$=920, 820, 575, 460 GeV, positron beam $E_e$=27.6 GeV

| $E_p$ (GeV) | $\sqrt{s}$ (GeV) | $Q^2$ range (GeV$^2$) | $y$ range | Luminosity (pb$^{-1}$) |
|---|---|---|---|---|
| 460 | 225 | $2.5 < Q^2 < 100$ | $0.1 < y < 0.9$ | 8.5 |
| 575 | 252 | $2.5 < Q^2 < 100$ | $0.1 < y < 0.9$ | 5.2 |
| 920 | 319 | $7.0 < Q^2 < 100$ | $0.1 < y < 0.56$ | 126.8 |

| $Q^2$ range | Data Set | Proton Energy $E_p$ | Luminosity |
|---|---|---|---|
| $3 < Q^2 < 13.5$ GeV$^2$ | 1997 MB | 820 GeV | 2.0 pb$^{-1}$ |
| $13.5 < Q^2 < 105$ GeV$^2$ | 1997 all | 820 GeV | 10.6 pb$^{-1}$ |

$M_Y < 1.6\,\mathrm{GeV},\ |t| < 1.0\,\mathrm{GeV}^2$

Large errors, limited by statistics at HERA

Careful evaluation of systematics. Best precision 4%, with uncorrelated sources as low as 2%

# $F_L^{D(3)}$ at HERA: extraction from linear fit

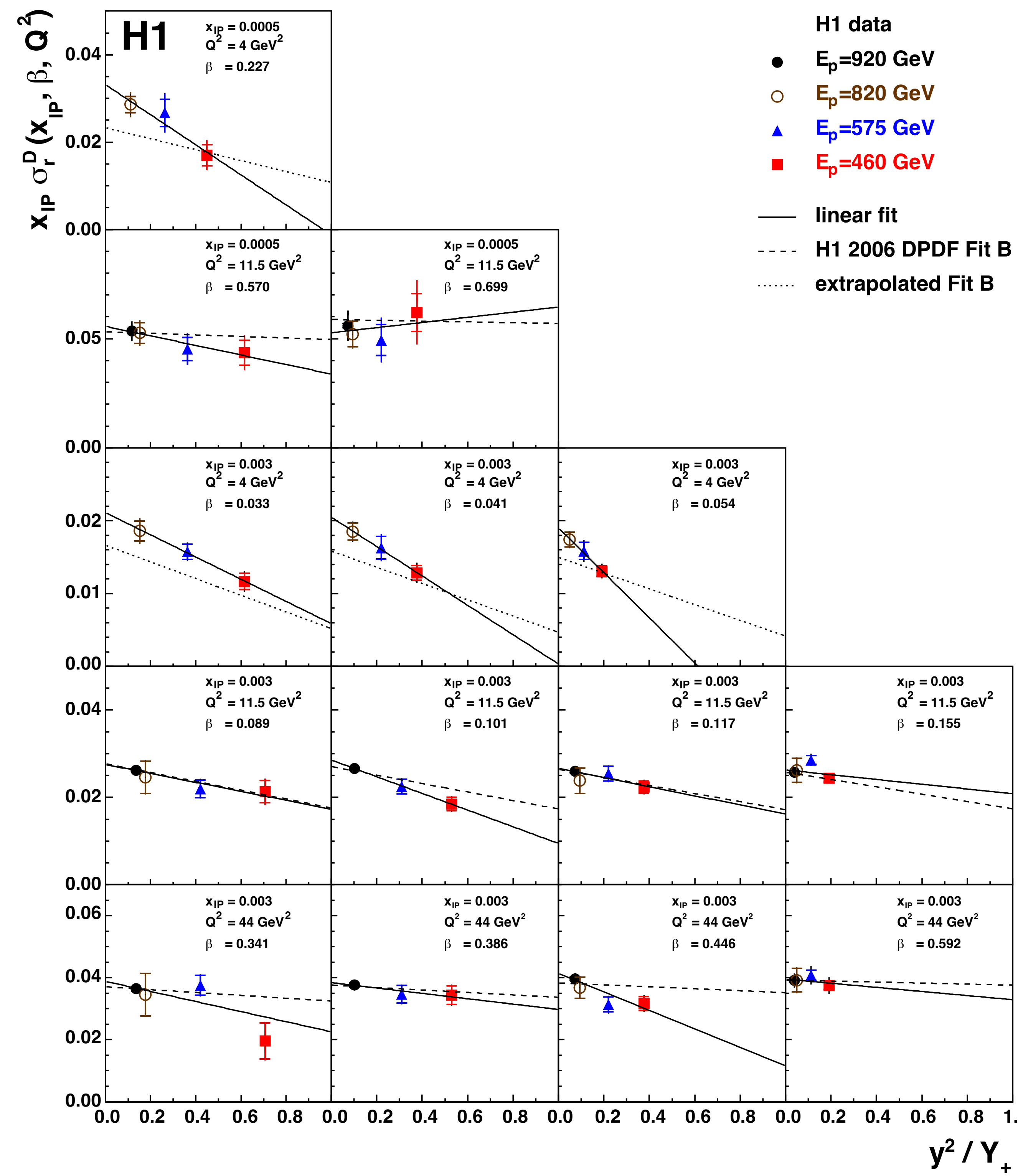
H1 analysis

$x_{IP}\,\sigma_r^D$ as a function of $y^2/Y_+$

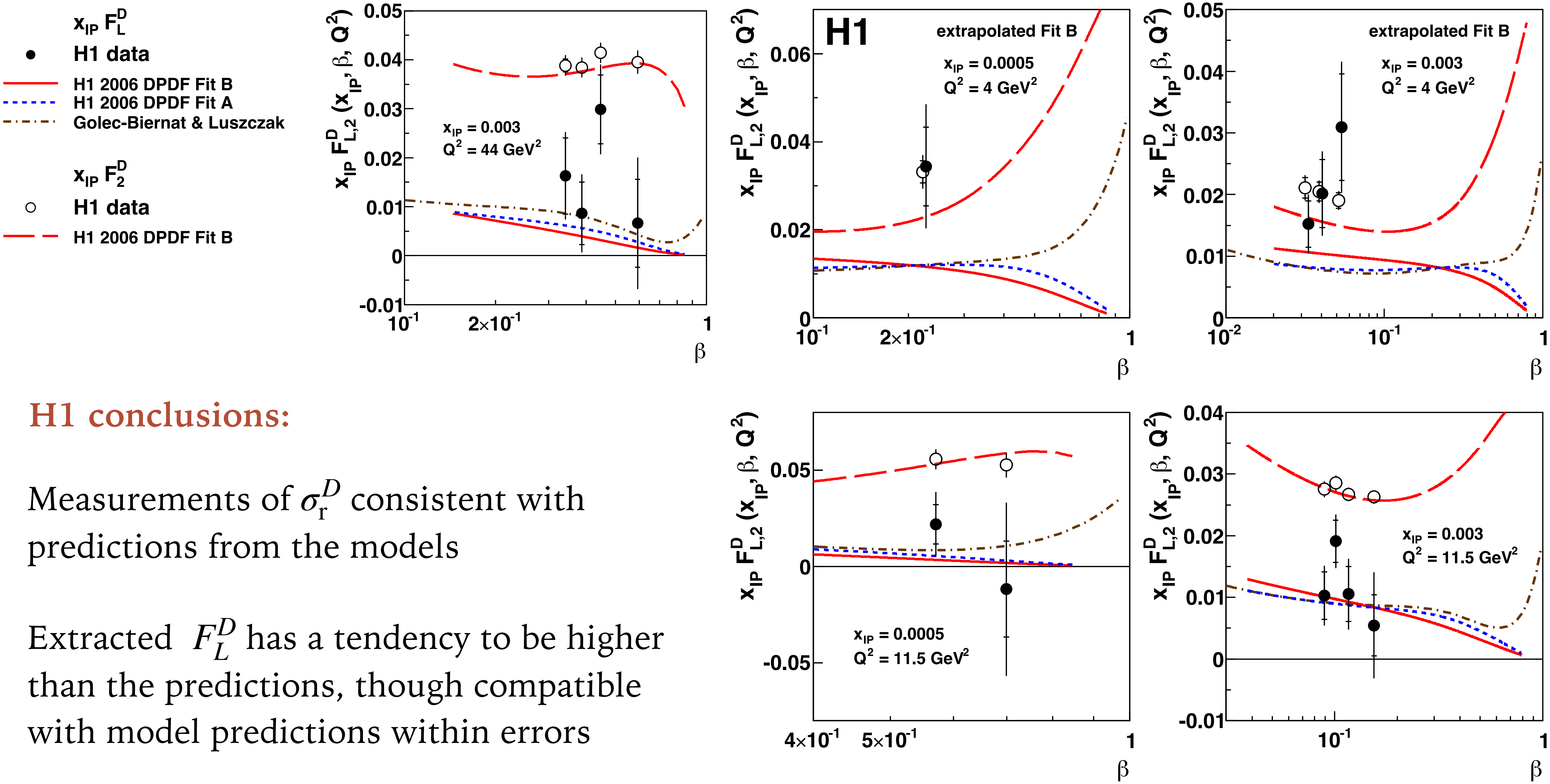
Inner bars: statistical errors

Data show linear dependence

Linear fit (solid line), the slope gives $F_L^D$



# $F_L^{D(3)}$ at HERA




## H1 conclusions:

Measurements of $\sigma_r^D$ consistent with predictions from the models

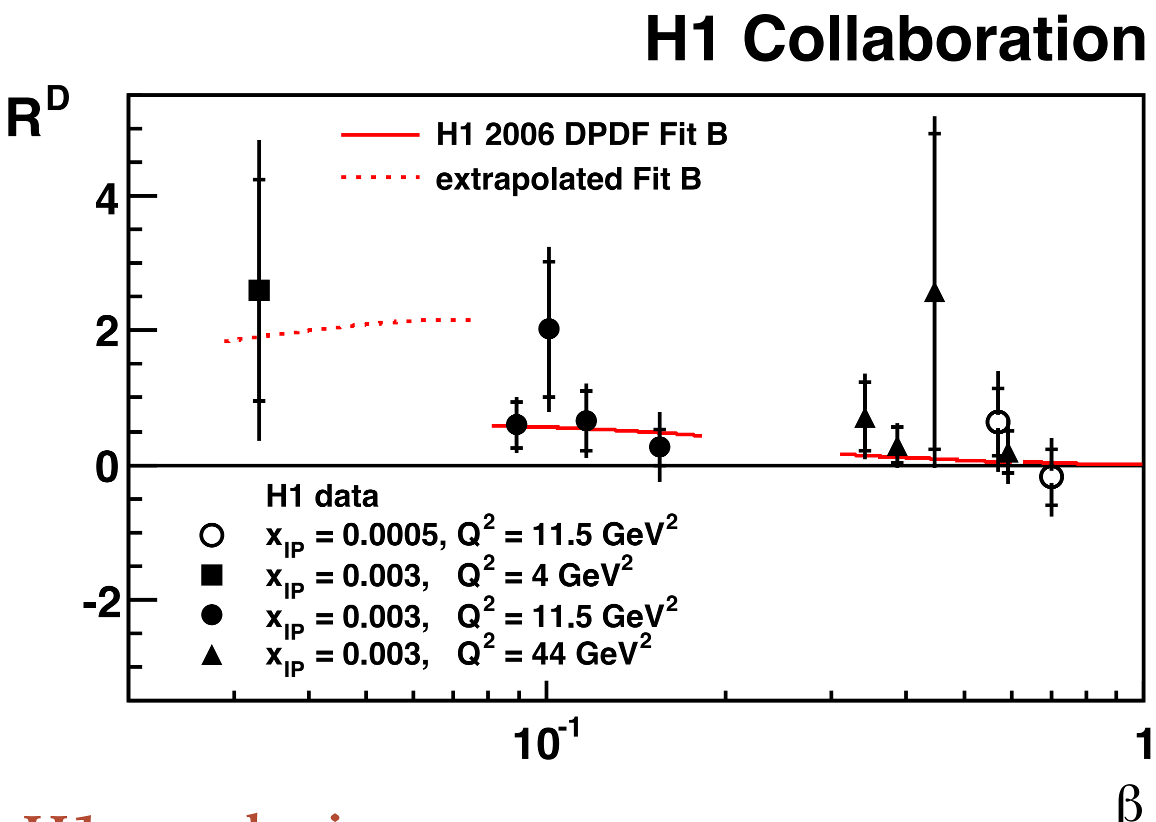
Extracted $F_L^D$ has a tendency to be higher than the predictions, though compatible with model predictions within errors

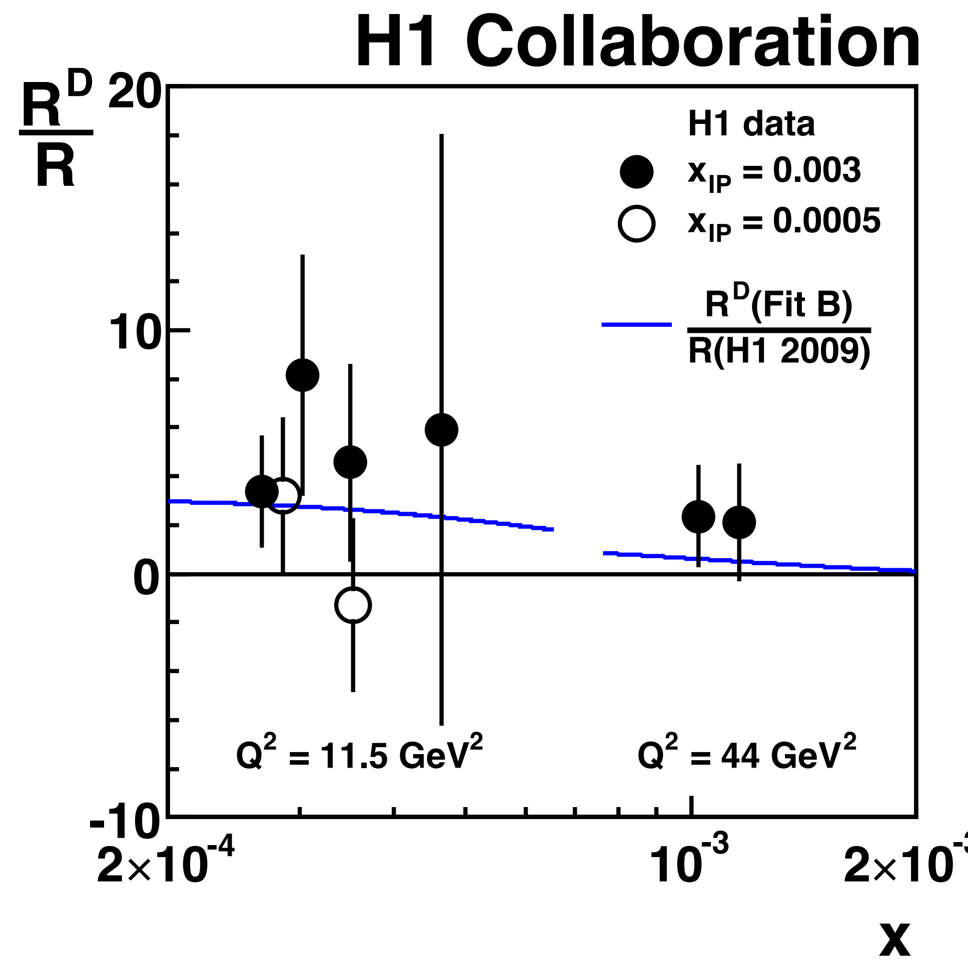
Overall: $0 < F_L^D < F_2^D$

# Diffractive ratio $R^D = F_L^D / F_T^D$ at HERA

Ratio $R^D = F_L^D/(F_2^D - F_L^D)$ longitudinal to transverse

Ratio of ratios : diffractive $R^D$ to inclusive $R$




**H1 conclusions:**

Data compatible with the theoretical predictions

Transverse and longitudinal polarised cross sections are of the same order of magnitude for $Q^2 = 11.5\,\mathrm{GeV}^2$

Ratio of ratios $R^D/R$ larger than 1, average value 2.8.

$R^D/R$ data indicate than longitudinally polarised cross section plays a larger role in the diffractive case than in inclusive case

# Phase space $(x, Q^2)$ EIC–HERA

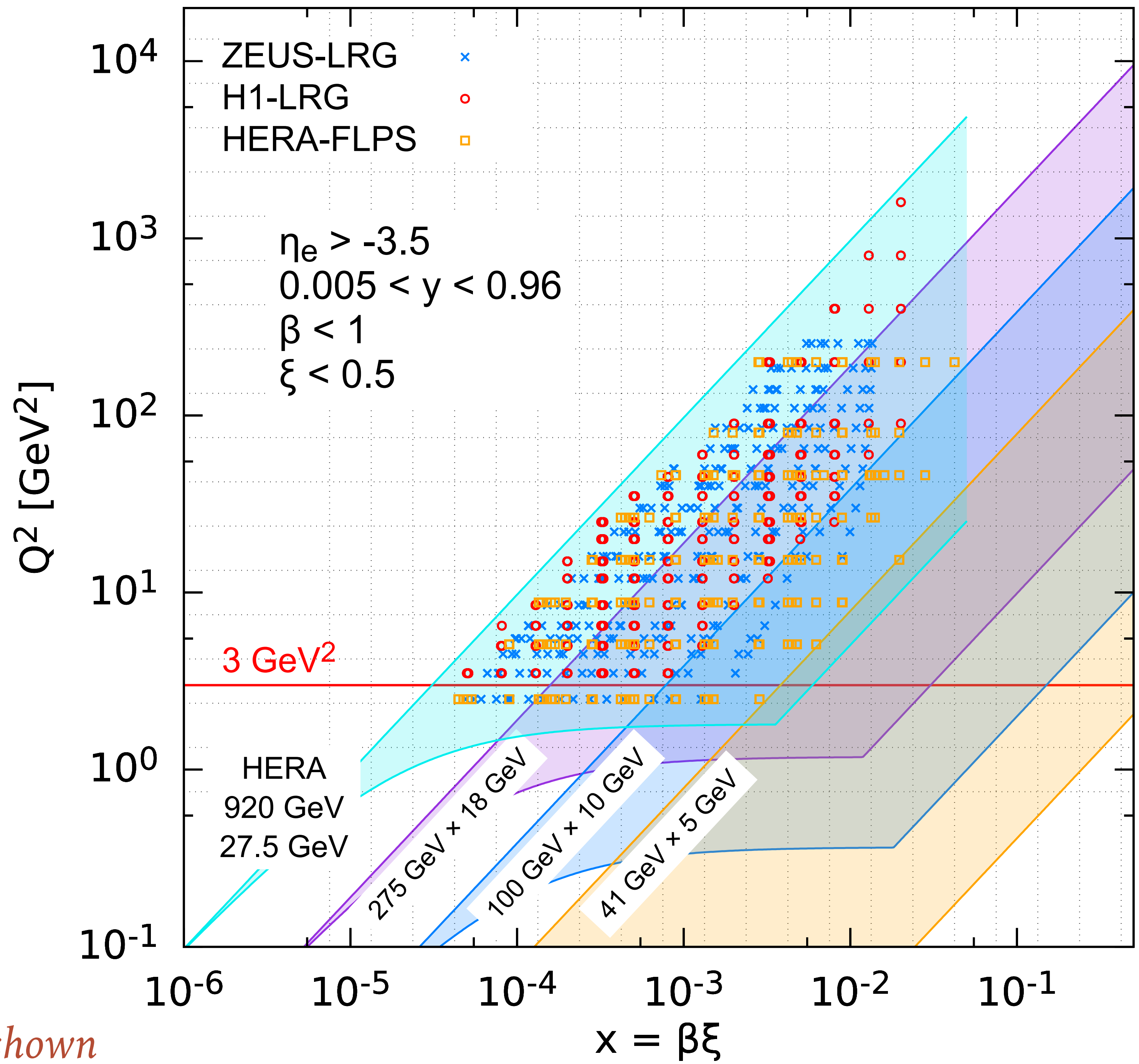
EIC 3 scenarios - HERA

EIC can operate at various energy combinations

Can cover wide range of x

Large instantaneous luminosity

Statistics should not be a limiting factor

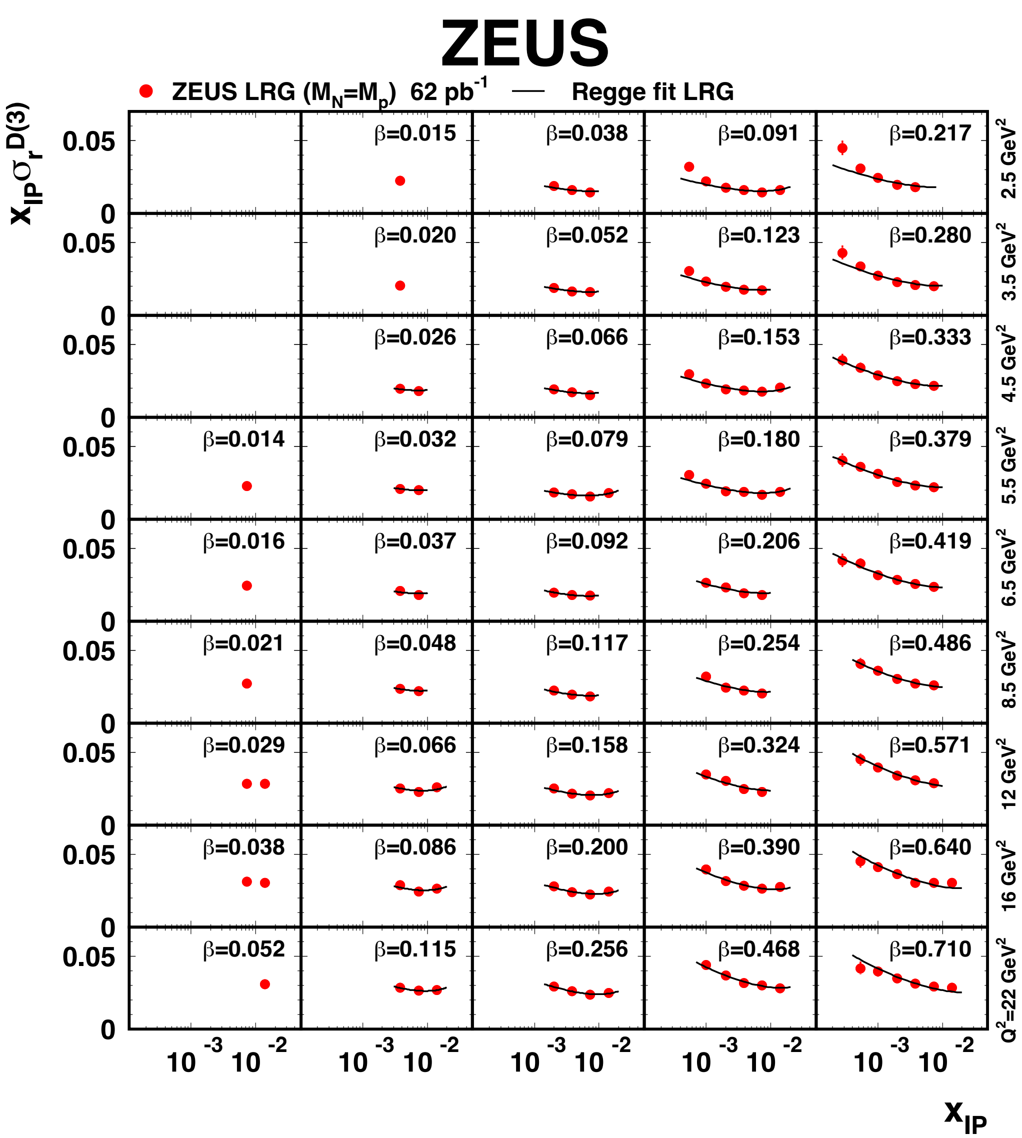


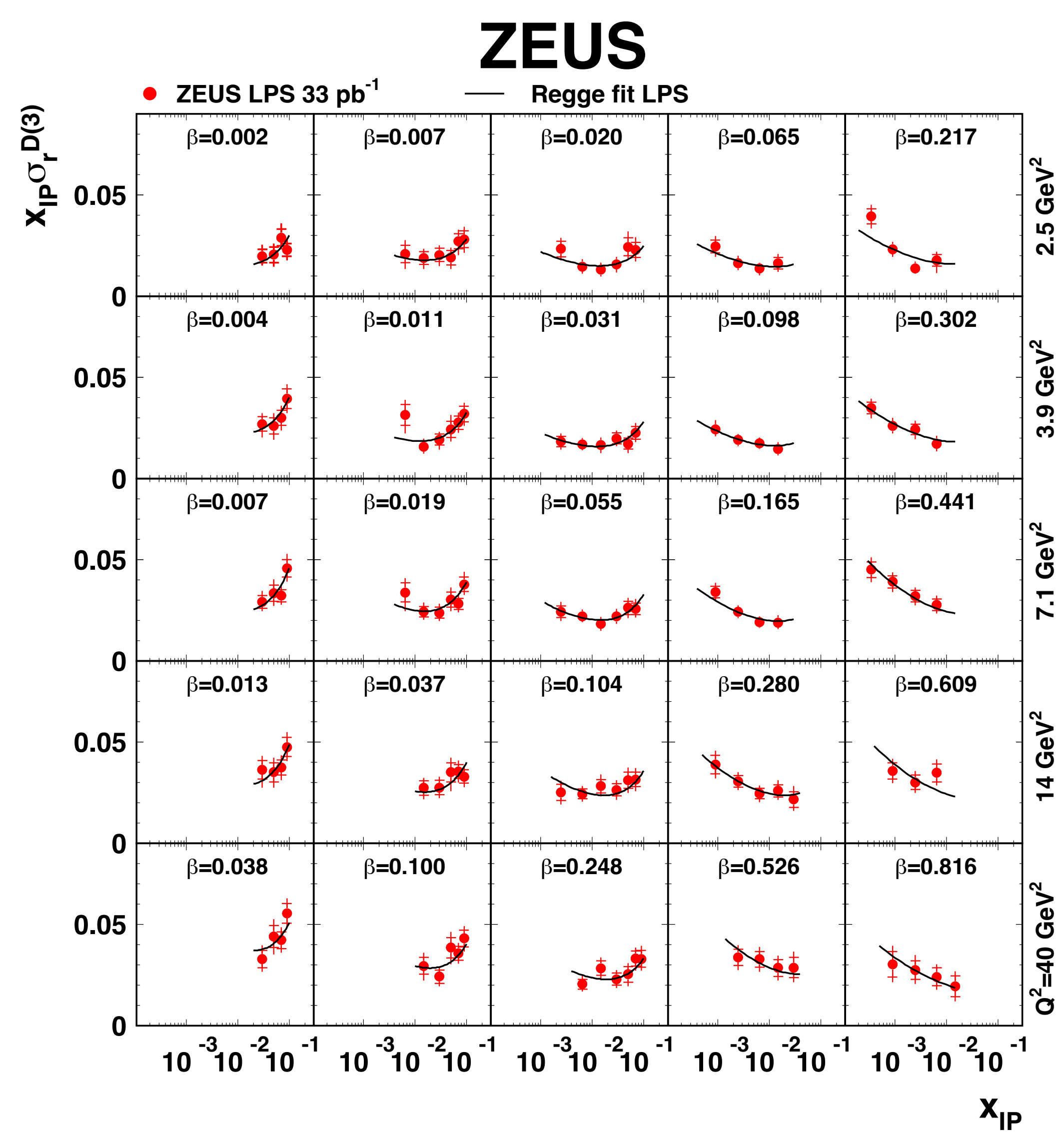

*Only selected energy scenarios at EIC shown*

# Measurement methods: LRG vs LP

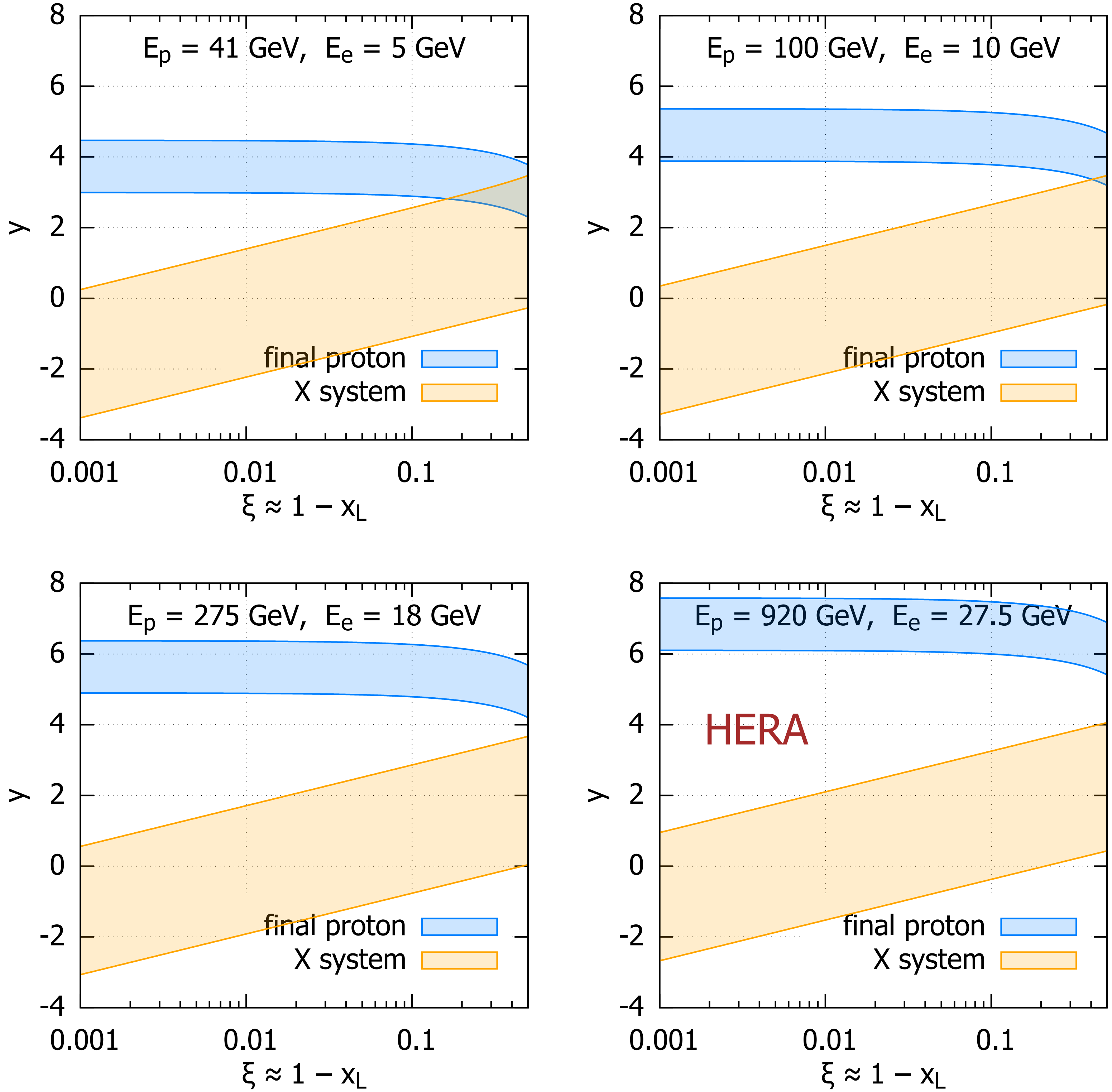
**Large Rapidity Gap method:**
request a large rapidity gap (ex. ZEUS 2009 $\xi<0.02$)

**Proton Tagging (Leading Proton) method:**
detection of a leading proton (ex. Leading Proton Spectrometer in ZEUS, Forward Proton Spectrometer in H1, can go to higher $\xi<0.1$)



# Rapidity range at EIC in diffraction




Rapidity range of proton and undecayed diffractive system X

$p_T^{proton} < 4\,\mathrm{GeV}$

$0.1 < \beta < 0.9$

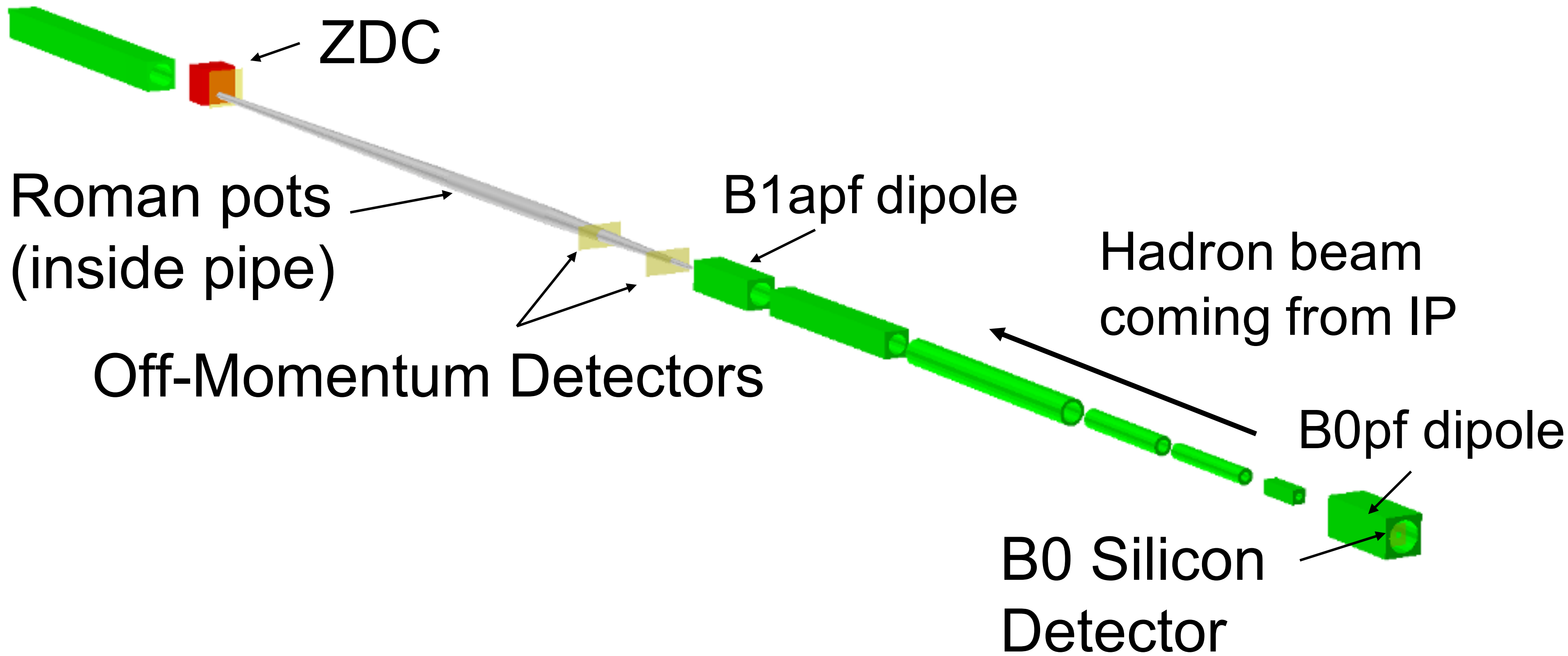
$0.005 < y < 0.96$

HERA: LRG method reliable for gaps > 3 units of rapidity

EIC: fairly large gaps ( $\Delta\eta \geq 4$ ) exist for smallest $\xi$ and largest $s$

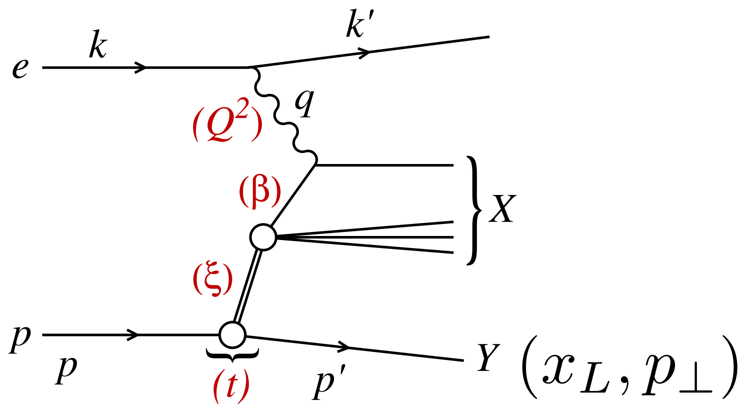
However, through most region LRG method may be challenging at EIC

# Far forward detectors at EIC



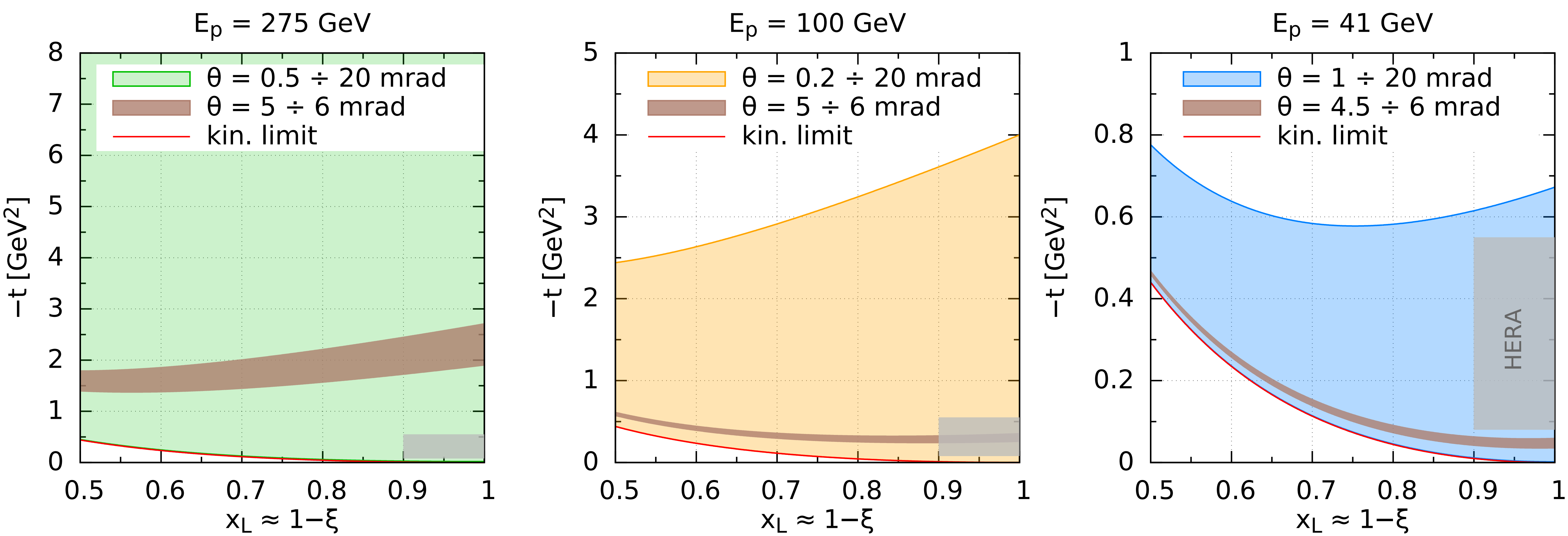

| Detector | Angle | Position [m] |
|---|---|---|
| ZDC | θ<5.5 mrad | 37.5 |
| Roman Pots | 0.5<θ<5.0 mrad | 26.0, 28.0 |
| Off-momentum detectors | θ<5.0 mrad | 22.5, 25.5 |
| B0 | 6.0<θ<20.0 mrad | 5.4<z<6.4 |

# Final proton tagging




Small angle acceptance i.e. Roman pots

$(x_L, p_\perp, \theta)$ measured in LAB, collinear (e,p) frame



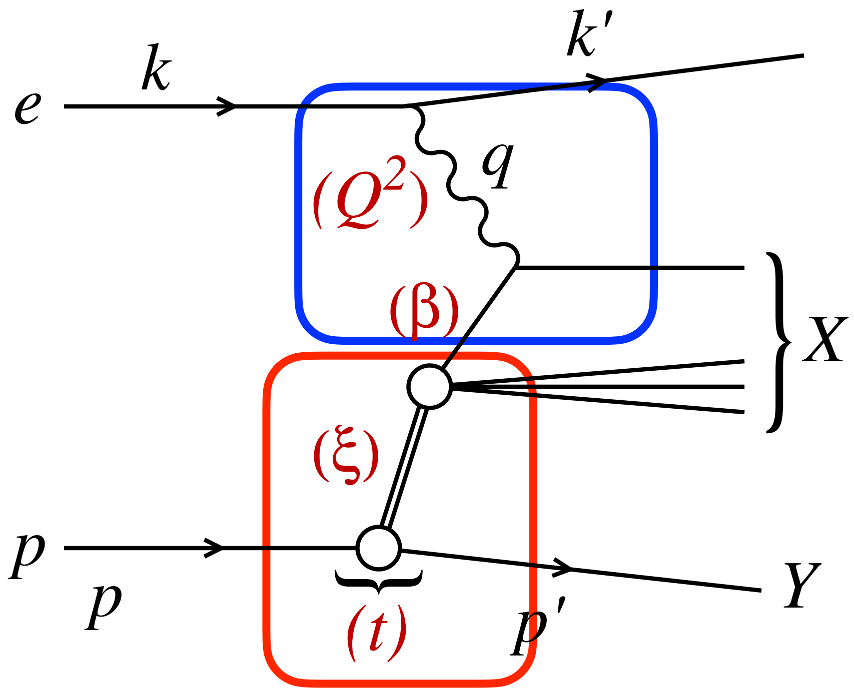

**Much better than at HERA**

**Best way to select diffractive events through proton tagging**

$$t = -\frac{p_\perp^2}{x_L} - \frac{(1-x_L)^2}{x_L} m_p^2$$

# Pseudodata generation: collinear factorization for diffraction

Use the collinear factorization for the description of HERA and pseudodata simulation




Collins

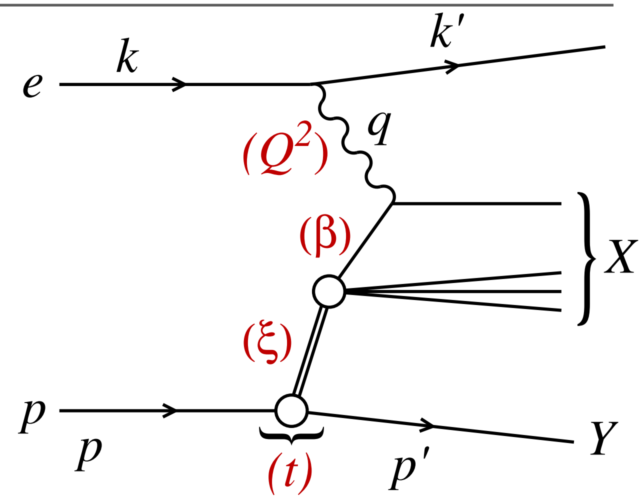
Collinear factorization in diffractive DIS

$$F_{2/L}^{D(4)}(\beta, \xi, Q^2, t) = \sum_i \int_\beta^1 \frac{dz}{z} C_{2/L,i}\left(\frac{\beta}{z}, Q^2\right) f_i^{\mathrm{D}}(z, \xi, Q^2, t)$$

- Diffractive cross section can be factorized into the convolution of the perturbatively calculable **partonic cross sections** and **diffractive parton distributions (DPDFs)**
- Partonic cross sections are the **same as in the inclusive DIS**
- The DPDFs are non-perturbative objects, but evolved perturbatively with **DGLAP**

# Pseudodata generation: model for diffractive structure functions

- Parametrization of the DPDFs as in H1 and ZEUS analysis
- **Regge factorization** assumed
- ($\beta$(or $z$), $Q^2$) dependence in parton distribution of diffractive exchange factorized from flux factors with ($t, \xi$) dependence
- Dominant term **'Pomeron'**, at low $\xi$
- At higher $\xi$ additional exchanges **'Reggeons'** need to be included




$$f_i^{D(4)}(z,\xi,Q^2,t) = \underbrace{f_{I\!P}^p(\xi,t)\, f_i^{I\!P}(z,Q^2)}_{\text{Pomeron}} + \underbrace{f_{I\!R}^p(\xi,t)\, f_i^{I\!R}(z,Q^2)}_{\text{Reggeon}}$$

Regge type flux:

$$f^p_{I\!P,I\!R}(\xi,t) = A_{I\!P,I\!R}\frac{e^{B_{I\!P,I\!R}t}}{\xi^{2\alpha_{I\!P,I\!R}(t)-1}}$$

Trajectory:

$$\alpha_{I\!P,I\!R}(t) = \alpha_{I\!P,I\!R}(0) + \alpha'_{I\!P,I\!R}\, t.$$

For t-integrated case

$$f_i^{D(3)}(z,\xi,Q^2) = \phi_{I\!P}^p(\xi)\, f_i^{I\!P}(z,Q^2) + \phi_{I\!R}^p(\xi)\, f_i^{I\!R}(z,Q^2)$$

Integrated flux:

$$\phi^p_{I\!P,I\!R}(\xi) = \int dt\; f^p_{I\!P,I\!R}(\xi,t)$$

Pomeron PDFs obtained via NLO DGLAP evolution starting at initial scale $\mu_0^2 = 1.8$ GeV$^2$

$$z f_i(z,\mu_0^2) = A_i z^{B_i}(1-z)^{C_i} \qquad i=q,g$$

Reggeon PDFs taken from the GRV fits to the pion structure function (***could also be determined at EIC!***)

# Pseudodata generation: energy choice

$$\sigma_{\rm red}^{\rm D(3)} = F_2^{\rm D(3)}(\beta,\xi,Q^2) - Y_{\rm L}\, F_{\rm L}^{\rm D(3)}(\beta,\xi,Q^2)$$

Integrated over t-momentum transfer

$$Y_{\rm L} = \frac{y^2}{Y_+} = \frac{y^2}{1+(1-y)^2}$$

**Can disentangle $F_2^{D(3)}$ from $F_L^{D(3)}$ by varying energy and performing the linear fit in $Y_L$.**

$$y = \frac{Q^2}{xs} = \frac{Q^2}{\beta\xi s}$$

Need to vary the energy $\sqrt{s}$ to change y for fixed (β,ξ,Q²)

EIC energies for electron and proton:

$E_e = 5,10,18$ GeV

$E_p = 41,100,120,165,180,275$ GeV

| $E_e$ [GeV] \ $E_p$ [GeV] | 41 | 100 | 120 | 165 | 180 | 275 |
|---|---|---|---|---|---|---|
| 5 | **29** | **45** | 49 | **57** | 60 | 74 |
| 10 | 40 | **63** | 69 | **81** | 85 | **105** |
| 18 | 54 | **85** | 93 | **109** | 114 | **141** |

S-17 all 17 combinations

S-9 **9 - bold red**

S-5 5 - green (EIC preferred)

# Pseudodata generation

## Binning and cuts

Uniform logarithmic binning, 4 bins per order of magnitude in each $\beta, Q^2, \xi$

Bins in $(\xi, \beta, Q^2)$, common to at least four beam setups

$Q^2 > 3\ \mathrm{GeV}^2$ both H1 and ZEUS fits indicate deterioration of fits for low $Q^2$

$0.96 > y > 0.005$ expected coverage of the experiment

## Simulations

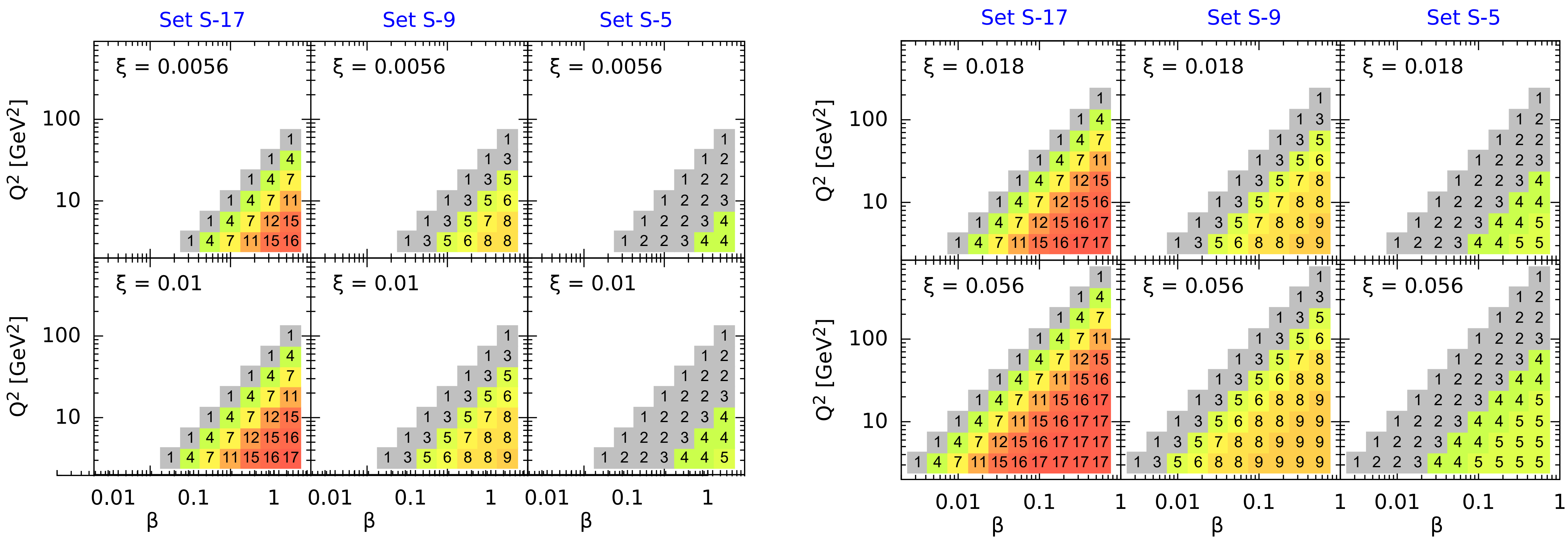
Cross section generation from ZEUS-SJ diffractive PDFs evolved with DGLAP

Assumed $\delta_{sys}$=1-2%, extrapolated from HERA 2% uncorrelated systematics; normalization/correlated systematics negligible effect on extraction of $F_L^D$

$\delta_{stat}$ from 10 $\mathrm{fb}^{-1}$ integrated luminosity

Several random samples are generated

# Kinematic range and number of points



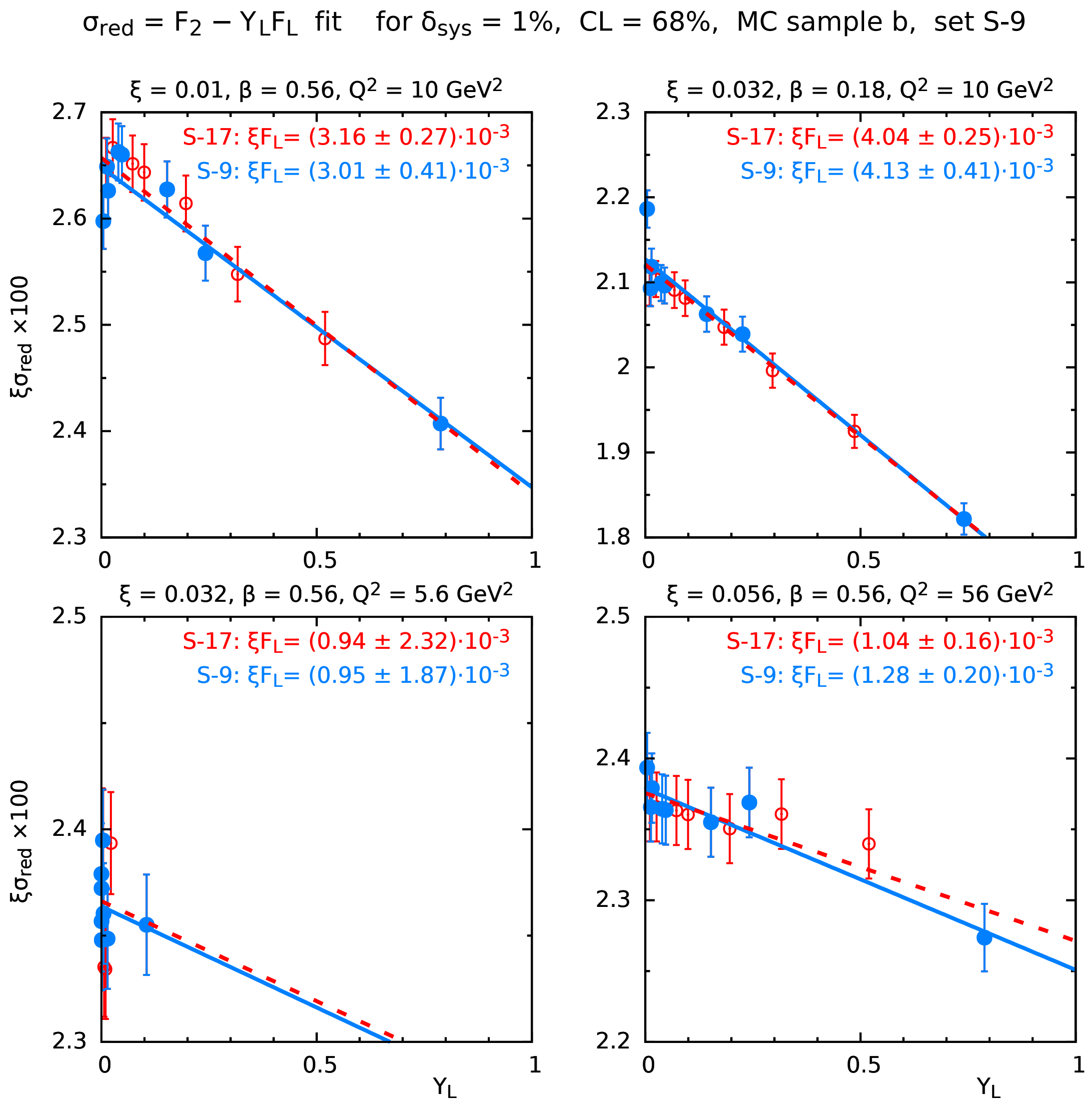

Count of different beam energy combinations for S-17, S-9, S-5

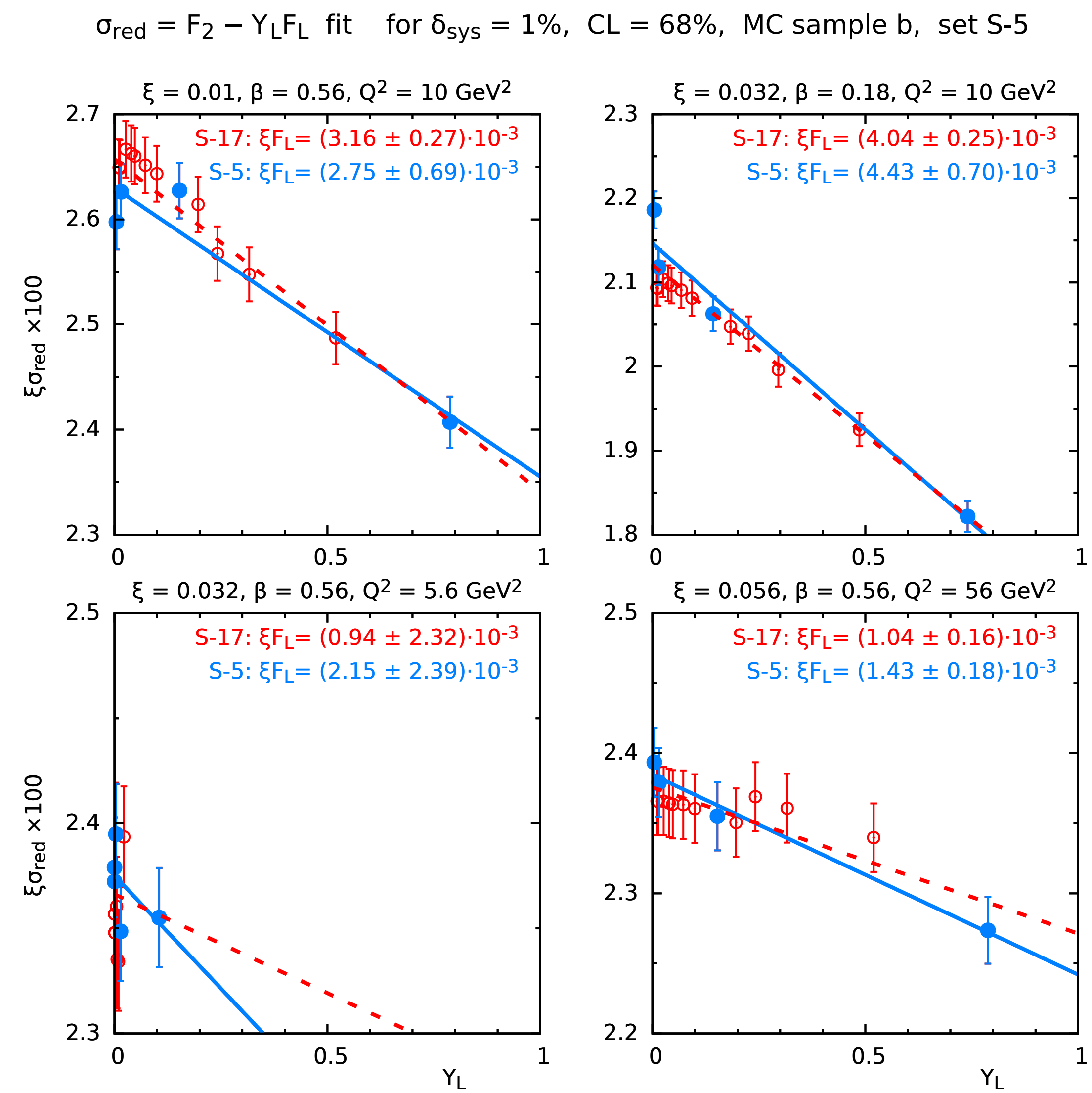
Only points with more than 4 combinations are taken for $F_L$ extraction (in H1 analysis 3 points)

Set-17: 364, set-9: 285, set-5: 160 values of $F_L$

# $F_L^{D(3)}$ extraction

$\sigma_{\rm r} = F_2(\xi,\beta,Q^2) - Y_L F_L(\xi,\beta,Q^2)$ as a function of $Y_L$ Bins in $(\xi,\beta,Q^2)$

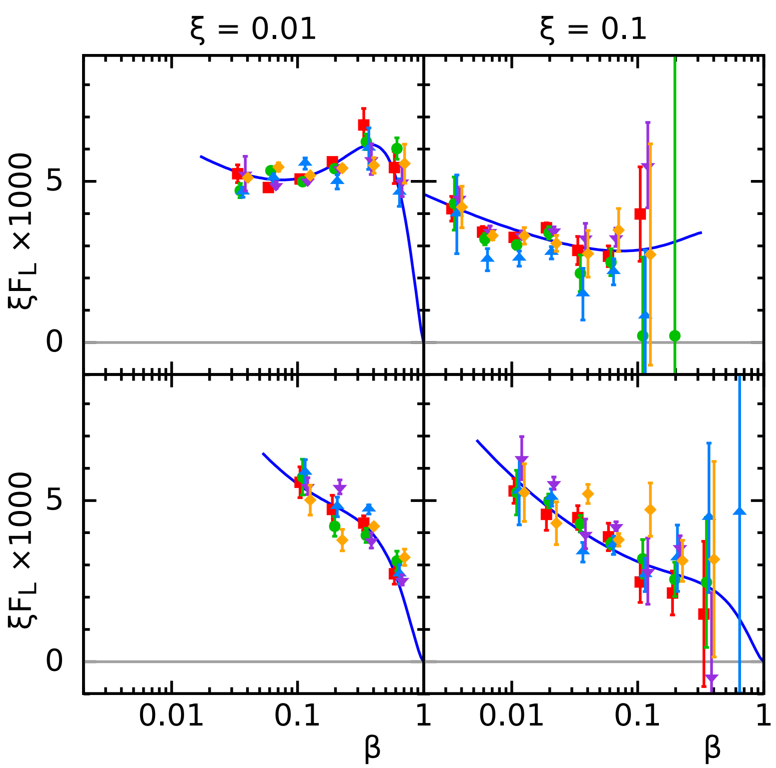


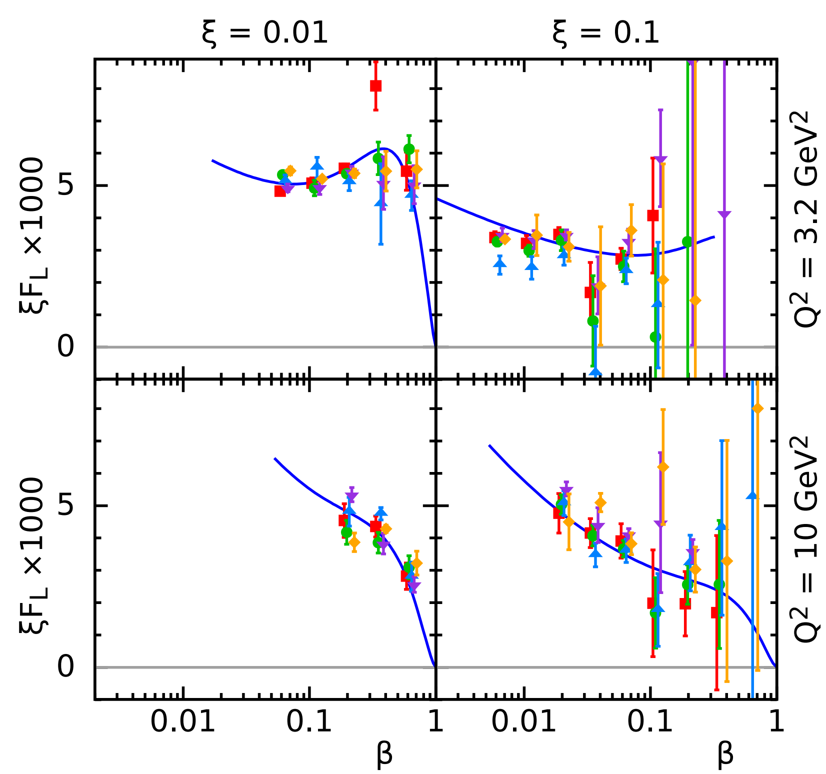

Uncorrelated systematics 1%
Differences between S-17 and S-9, S-5 small
Increase in error bar on the extraction when smaller number of energy points
Largest errors for bins with shortest range of $Y_L$

# Simulated measurement of $F_L^{D(3)}$ vs $\beta$ in bins of $(\xi, Q^2)$

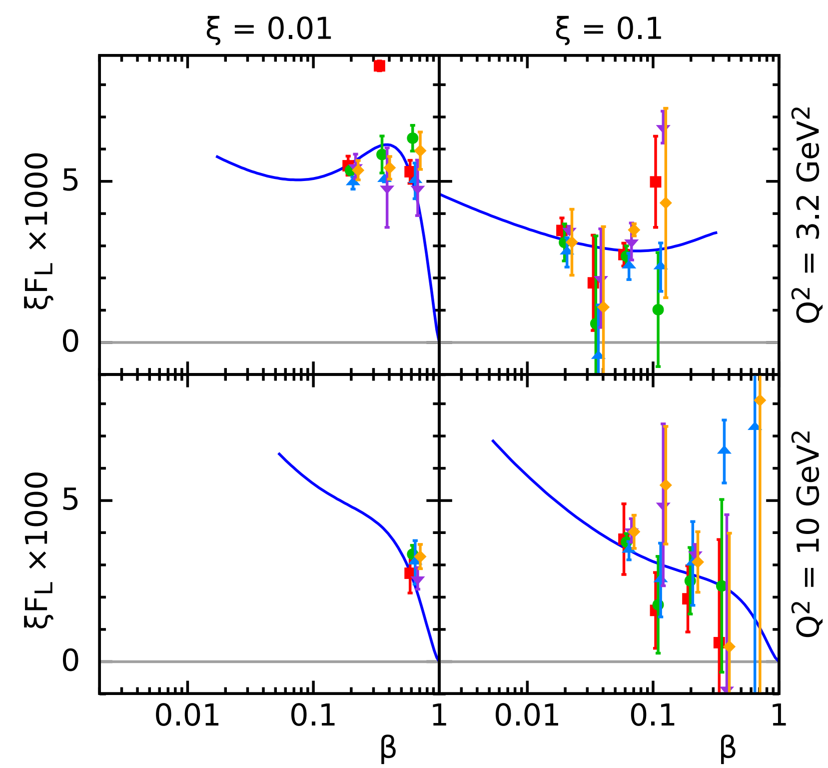
Uncorr. systematic error 1%, 5 MC samples to illustrate fluctuations




17 energies




9 energies




5 energies

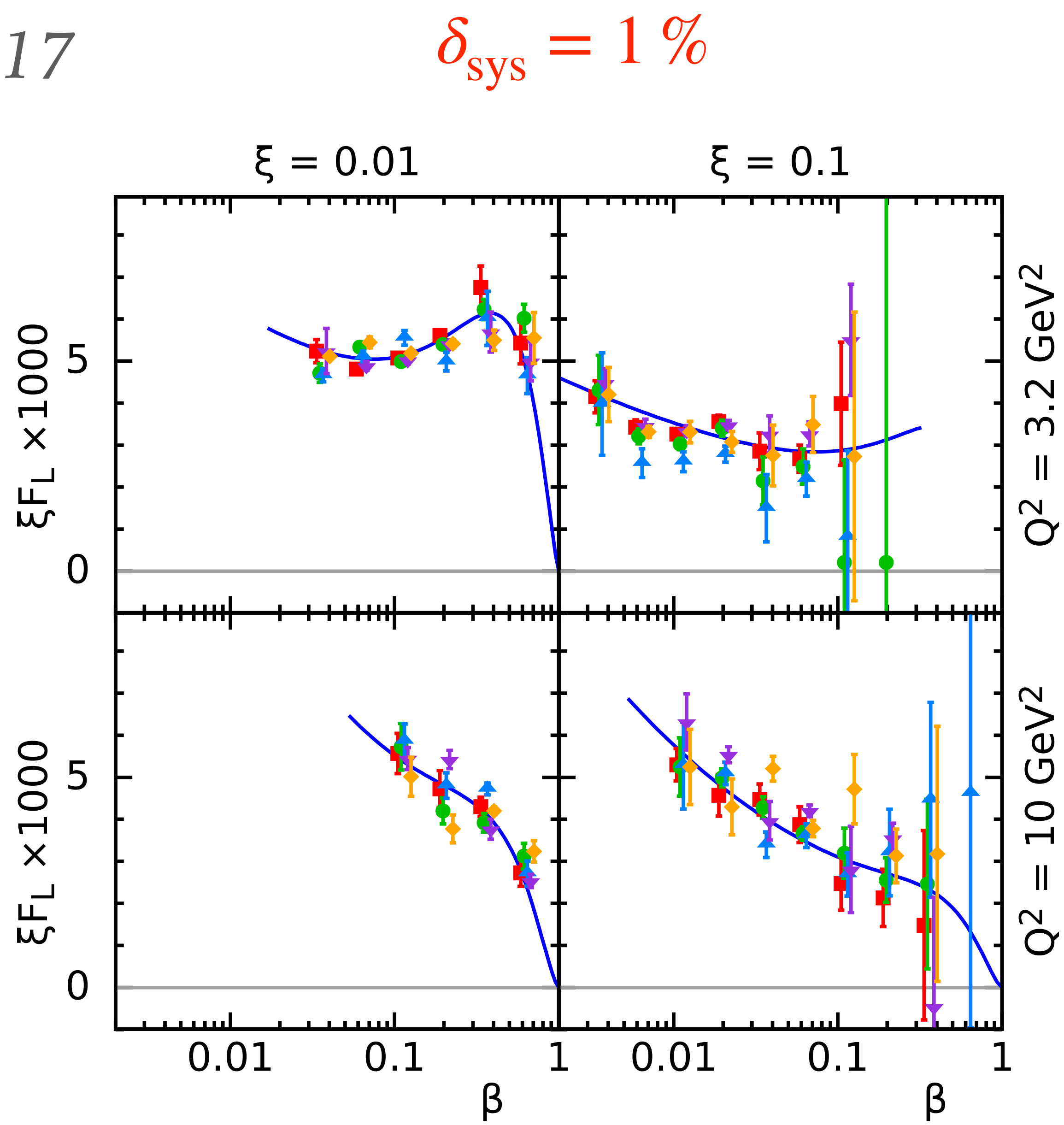
Small differences between S-17 and S-9, small reduction to range and increase in uncertainties.

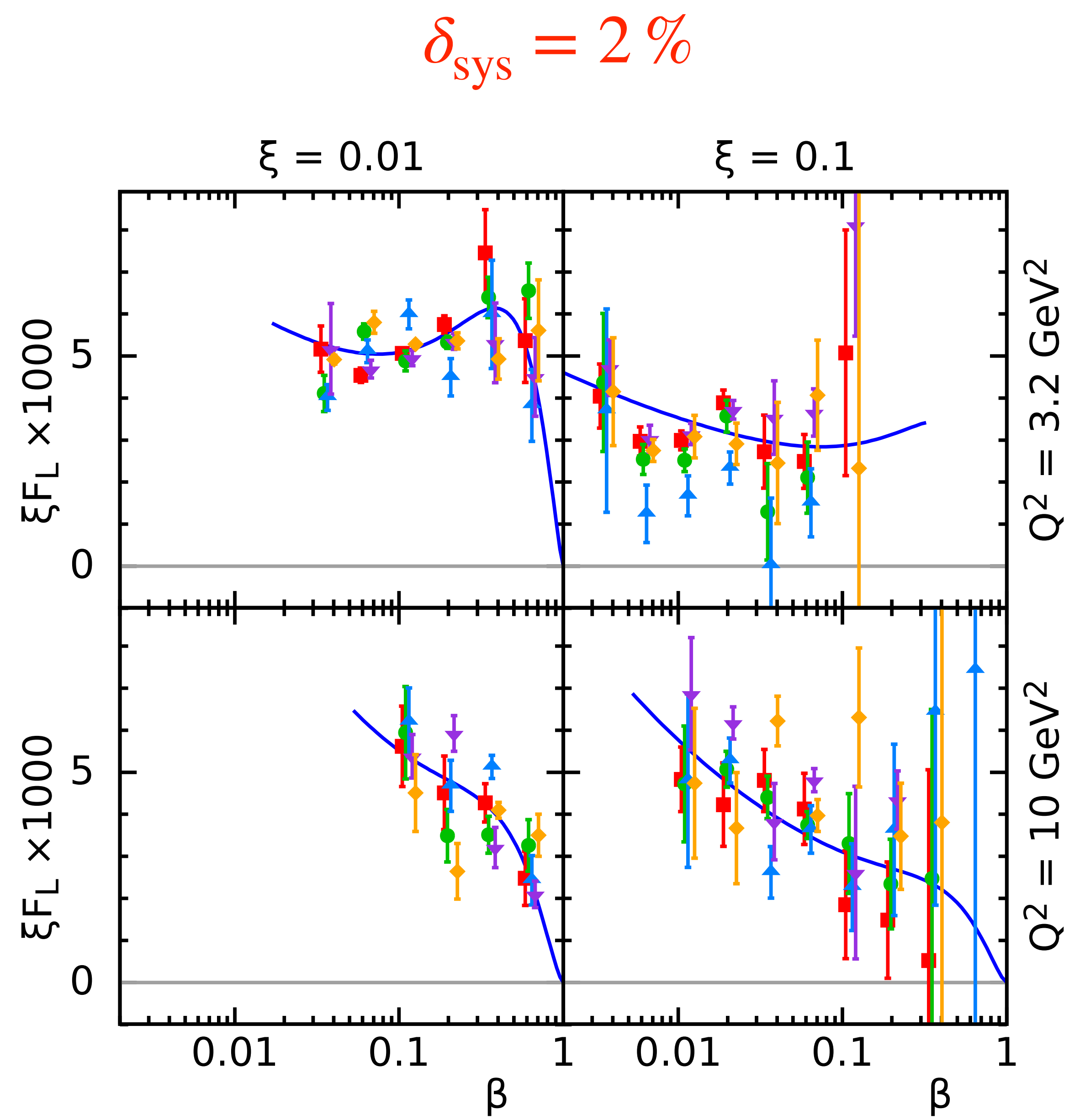
More pronounced reduction in range and higher uncertainties in S-5.

**An extraction of $F_L^D$ possible with EIC-favored set of energy combinations**

# Simulated measurement of $F_L^{D(3)}$ vs β in bins of ($\xi$,$Q^2$)

*S-17*

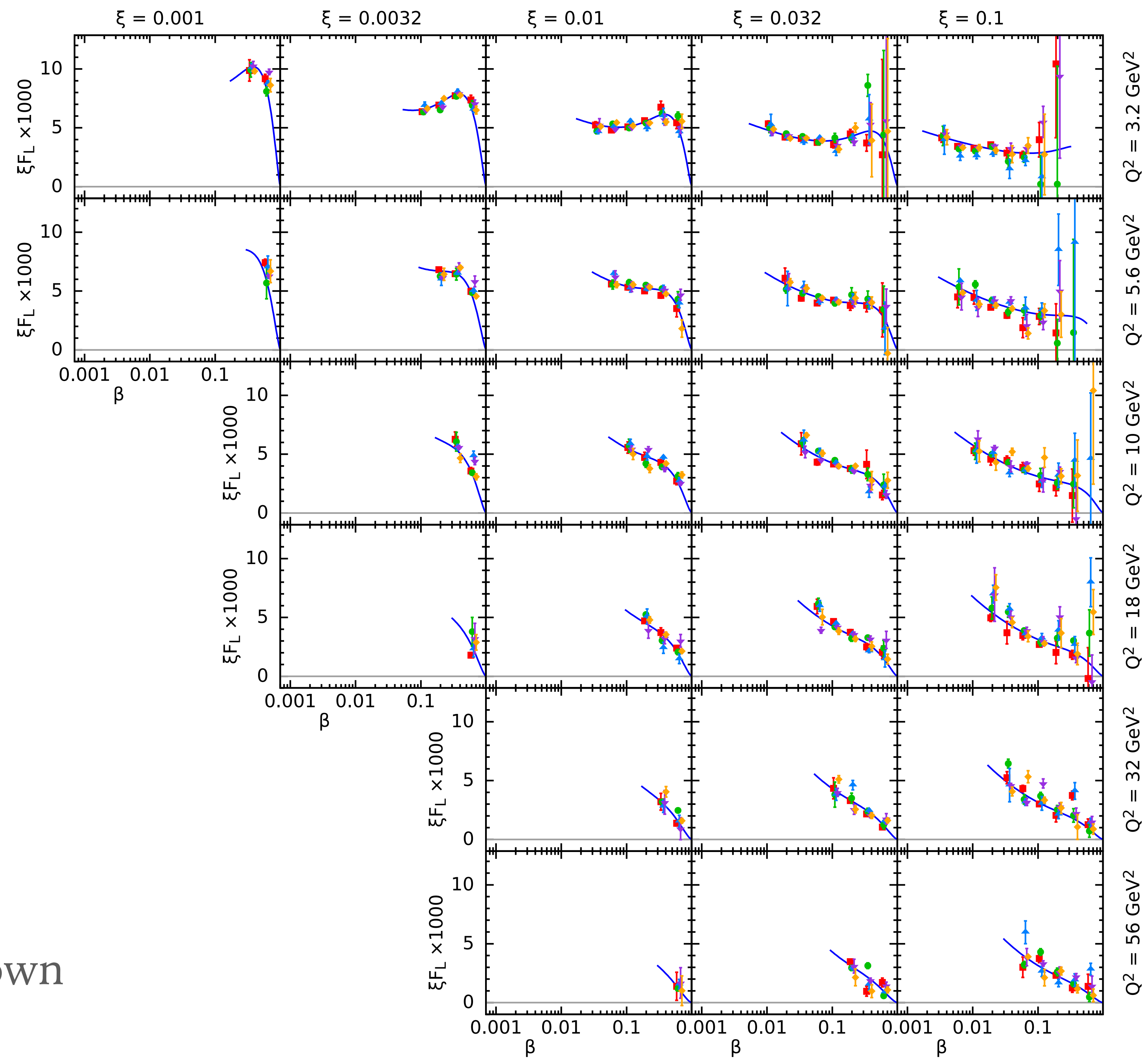



Change from 1% to 2% results in roughly twice large error bars

Statistical errors negligible

# Simulated measurement of $F_L^{D(3)}$ vs β in bins of ($\xi$,$Q^2$)




*S-17*

$\delta_{\text{sys}} = 1\ \%$

more bins shown

# $F_L^{D(3)}$ fit accuracy

Estimate the accuracy of extraction for $F_L^{D(3)}$

Generate several MC samples of pseudodata and perform fits

Use direct arithmetic averaging

*average*

$$\overline{v} = \frac{S_1}{N}$$

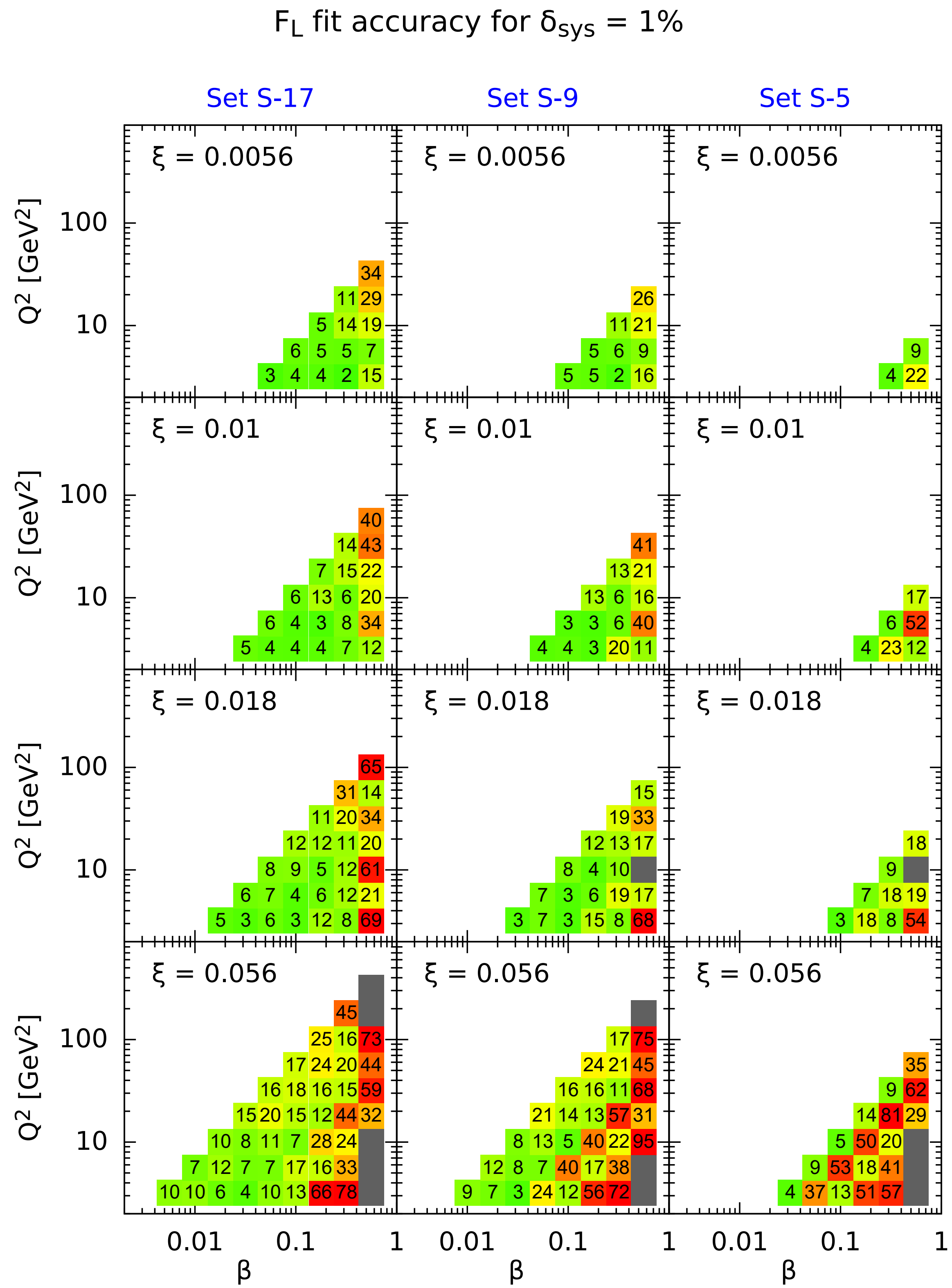
*variance*

$$(\Delta v)^2 = \frac{S_2 - S_1^2/N}{N-1}$$

$$S_n = \sum_{i=1}^{N} v_i^n$$

where $v_i$ is the value of $F_L^D$

in Monte Carlo sample i



# $R^D = F_L^D / F_T^D$ ratio of longitudinal to transverse

Ratio of cross sections for longitudinally polarized to transverse polarized photons

$$R^{D(3)} = F_L^{D(3)}/F_T^{D(3)}$$

$$F_T^{D(3)} = F_2^{D(3)} - F_L^{D(3)}$$

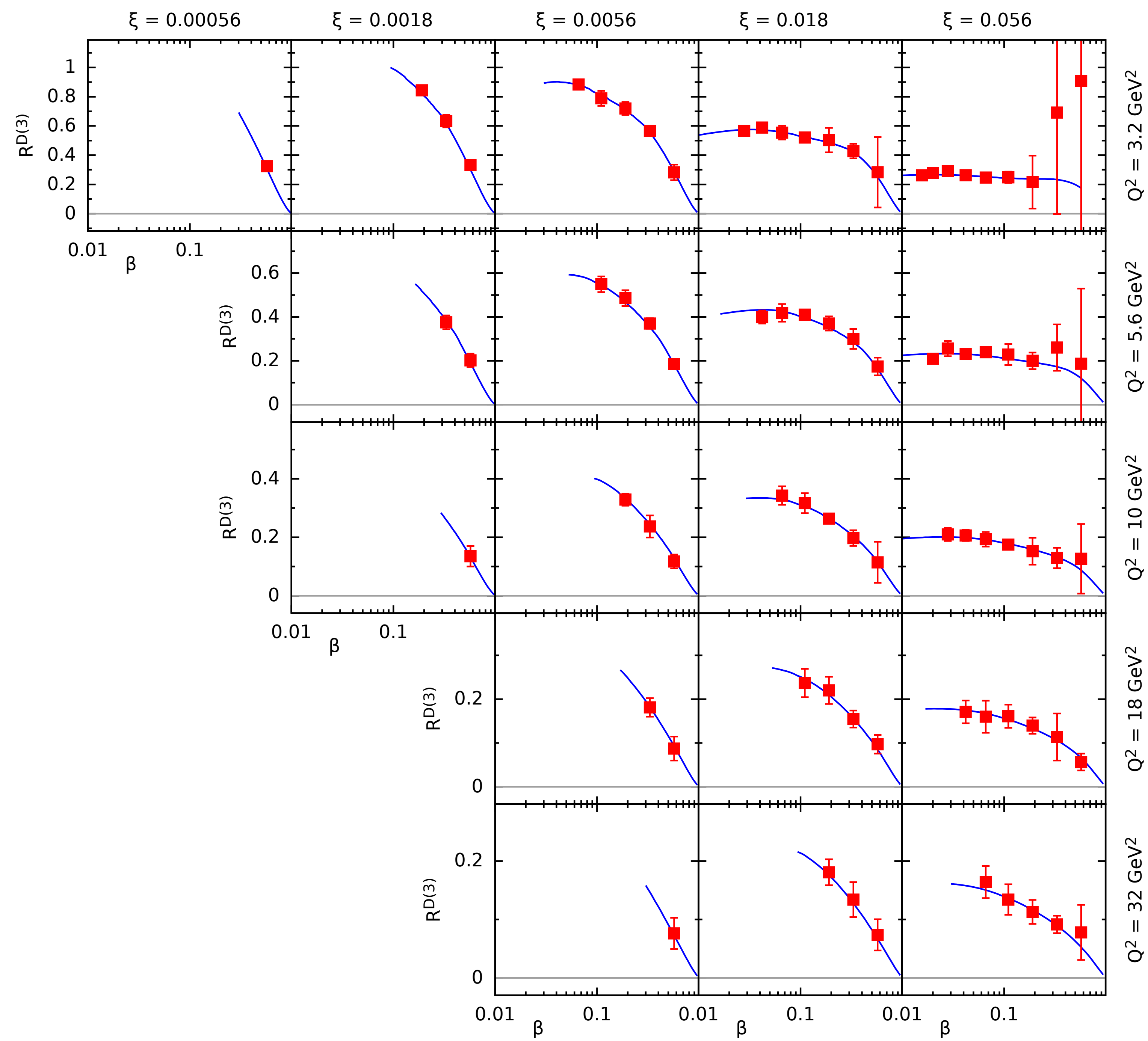
$$\sigma_{\text{red}}^{D(3)} = [1 + (1 - Y_L)R^{D(3)}]F_T^{D(3)}$$

Different form of reduced cross section

Alternative fit has different sensitivities to the uncertainties

Systematics 1%

Averaged over 10 MC samples: reduced fluctuations



# Summary on $F_L^D$

- $F_L^{D(3)}$ at EIC
  - Important quantity, sensitive to diffractive gluon density (saturation, higher twists…). Only one extraction at HERA by H1, large errors. Challenging measurement.
  - Three scenarios: 17, 9, 5 energy combinations. Pseudodata from DGLAP, assumed 1-2% systematics, 10 $fb^{-1}$ integrated luminosity. Extraction via linear fit to reduced cross section
  - Scenarios S-17 and S-9 do not differ much, S-5 reduced kinematic range
  - Precision in a given bin of ($Q^2$,ξ,β) correlates strongly with range in inelasticity y, dominated by systematics.
  - **Good prospects for $F_L^{D(3)}$ at EIC even with 5 energy combinations**

More work:

- Other models: dipole, saturation, higher twists
- $F_L^{D(4)}$ with t-dependence. Novel analysis, never measured
- Inclusive diffraction on nuclei

# Diffraction at HERA: importance of ‘Reggeon’

$\xi\sigma_r^{D(4)} \simeq \xi F_2^{D(4)}$ vs $\xi$ for fixed $|t| = 0.25\,\mathrm{GeV}^2$ in bins of $\beta, Q^2$

Described by two contributions:

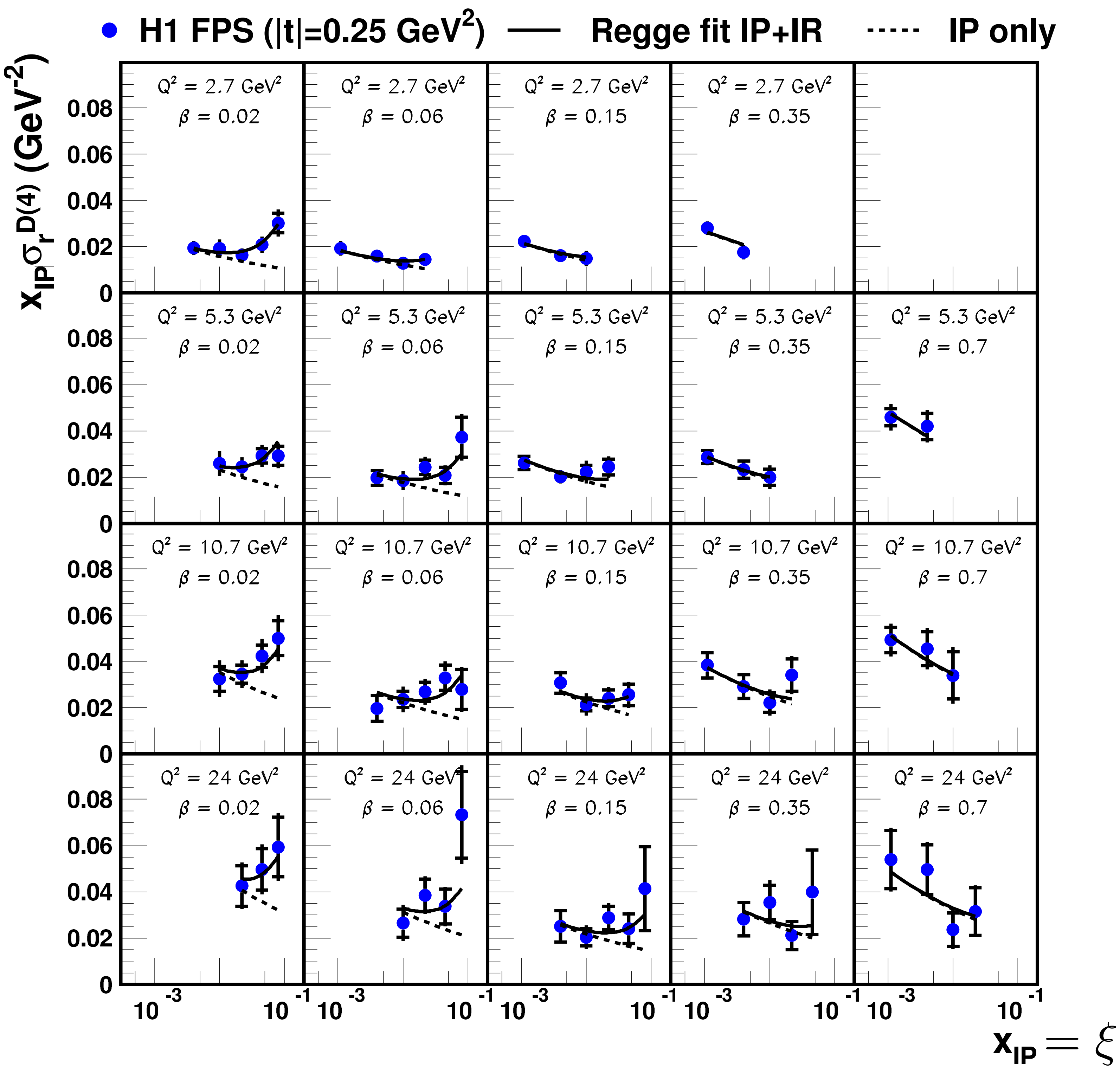
Leading ‘Pomeron’ at low $\xi$

$\xi f_{I\!P} \sim \xi^{-0.22}$

Subleading ‘Reggeon’ at high $\xi$

$\xi f_{I\!R} \sim \xi^{1.0}$

Subleading terms poorly constrained



# EIC pseudodata generation with t dependence

Use ZEUS $I\!P + I\!R$ fit with the GRV pion structure function for the $I\!R$

Pseudodata generated in all 4-variables : $(\beta = z, \xi, Q^2, t)$

**Diffractive PDF:**

$$f_k^{D(4)}(z, Q^2, \xi, t) = \phi_{I\!P}(\xi, t)\, f_k^{I\!P}(z, Q^2) + \phi_{I\!R}(\xi, t)\, f_k^{I\!R}(z, Q^2)$$

**Fluxes:**

$$\phi_{\mathbb{M}}(\xi, t) = \frac{e^{B_{\mathbb{M}} t}}{\xi^{2\alpha_{\mathbb{M}}(t)-1}}$$

**Trajectories:**

$$\alpha_{\mathbb{M}}(t) = \alpha_{\mathbb{M}}(0) + \alpha'_{\mathbb{M}}\, t \qquad \mathbb{M} = I\!P, I\!R$$

**Reduced cross section:**

$$\sigma_{\rm red}^{D(4)} = \phi_{I\!P}(\xi, t)\, \mathcal{F}_2^{I\!P}(\beta, Q^2) + \phi_{I\!R}(\xi, t)\, \mathcal{F}_2^{I\!R}(\beta, Q^2)$$
$$-\frac{y^2}{Y_+}\left[\phi_{I\!P}(\xi, t)\, \mathcal{F}_L^{I\!P}(\beta, Q^2) + \phi_{I\!R}(\xi, t)\, \mathcal{F}_L^{I\!R}(\beta, Q^2)\right]$$

**Flux parameters:**

$$\xi\phi_{I\!P}(\xi, t) \;\propto\; \xi^{-0.22}\, e^{-7|t|}$$

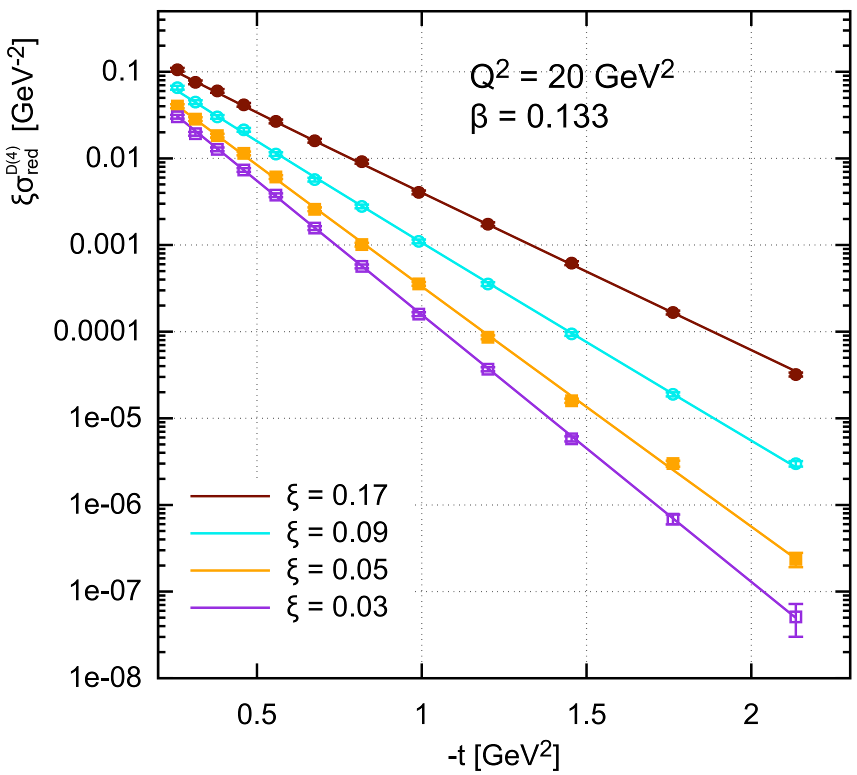
**ZEUS fit parameters**

$$\xi\phi_{I\!R}(\xi, t) \;\propto\; \xi^{0.6+1.8|t|}\, e^{-2|t|} = \xi^{0.6}\, e^{(-2+1.8\ln\xi)\,|t|}$$

# EIC pseudodata generation: lumi, energy, errors

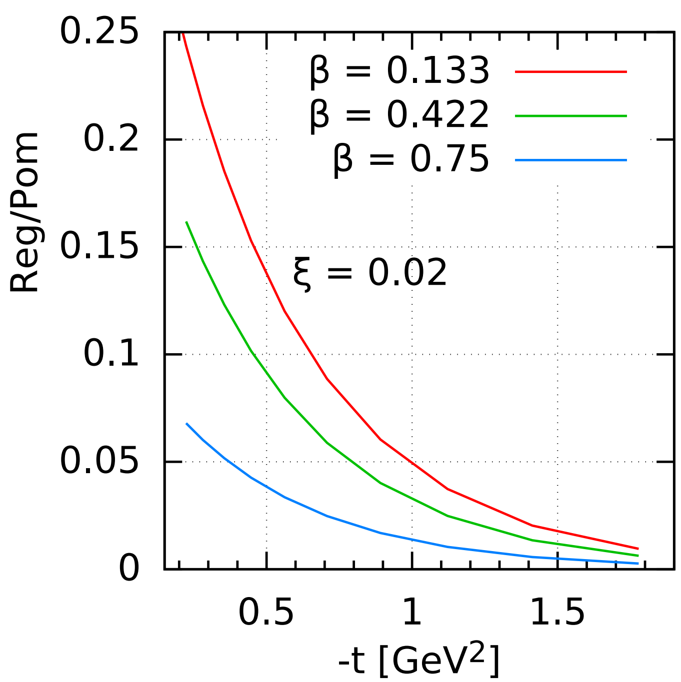
- Use NC simulations for EIC (no HERA nor CC yet)
- Three scenarios for integrated luminosity and energy :
  - $\mathscr{L} = 100\,\mathrm{fb}^{-1}$ at high energy $E_e = 18\,\mathrm{GeV}\ \times\ E_p = 275\,\mathrm{GeV}$
  - $\mathscr{L} = 10\,\mathrm{fb}^{-1}$ at high energy $E_e = 18\,\mathrm{GeV}\ \times\ E_p = 275\,\mathrm{GeV}$
  - $\mathscr{L} = 10\,\mathrm{fb}^{-1}$ at low energy $E_e = 5\,\mathrm{GeV}\ \times\ E_p = 41\,\mathrm{GeV}$
- Require $0.005 < y < 0.96$
- Sparse and dense binning scenarios
- 5% uncorrelated systematics, 2% normalization error on top
- Randomly fluctuate each data point according to the uncertainties

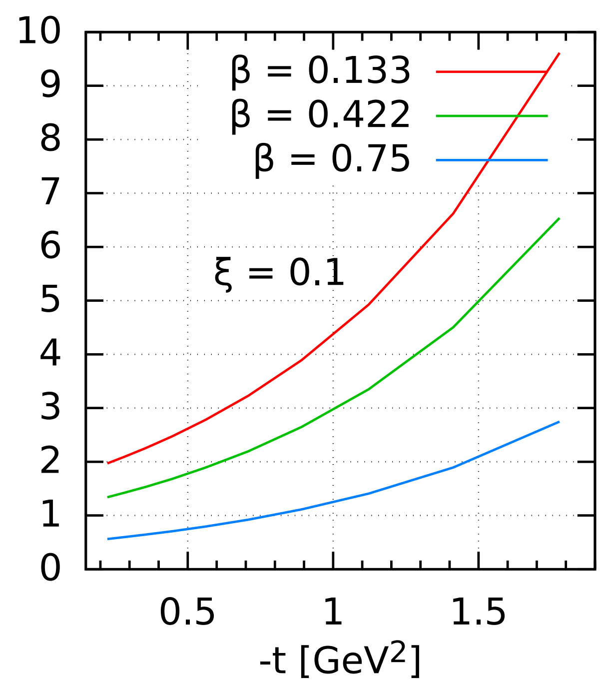
# Reggeon and Pomeron component in cross section at EIC




## 4D cross section pseudodata

- Changing $t$ slope as transitioning from Pomeron to Reggeon dominated region
- $\sigma_r^D$ slowly varying with $Q^2$




## $I\!\!R/I\!\!P$ ratio vs $-t$ for $\xi = 0.01, 0.1$

- Change of ratio for small vs large $\xi$ as a function of $-t$: different slope
- $I\!\!R/I\!\!P < 1$ for small $\xi \sim 0.02$
- $I\!\!R/I\!\!P > 1$ for larger $\xi \geq 0.1$ : not accessible at HERA

# Parametrisation for fitting the pseudodata: full 4D fit IP+IR

- Treat the Pomeron and Reggeon contributions as symmetrically as possible
- Light quark separation not possible with only inclusive NC fits
- For both $I\!P$ and $I\!R$ fit the gluon and the sum of quarks
- Generic parametrization at $Q_0^2 = 1.8$ GeV$^2$ :

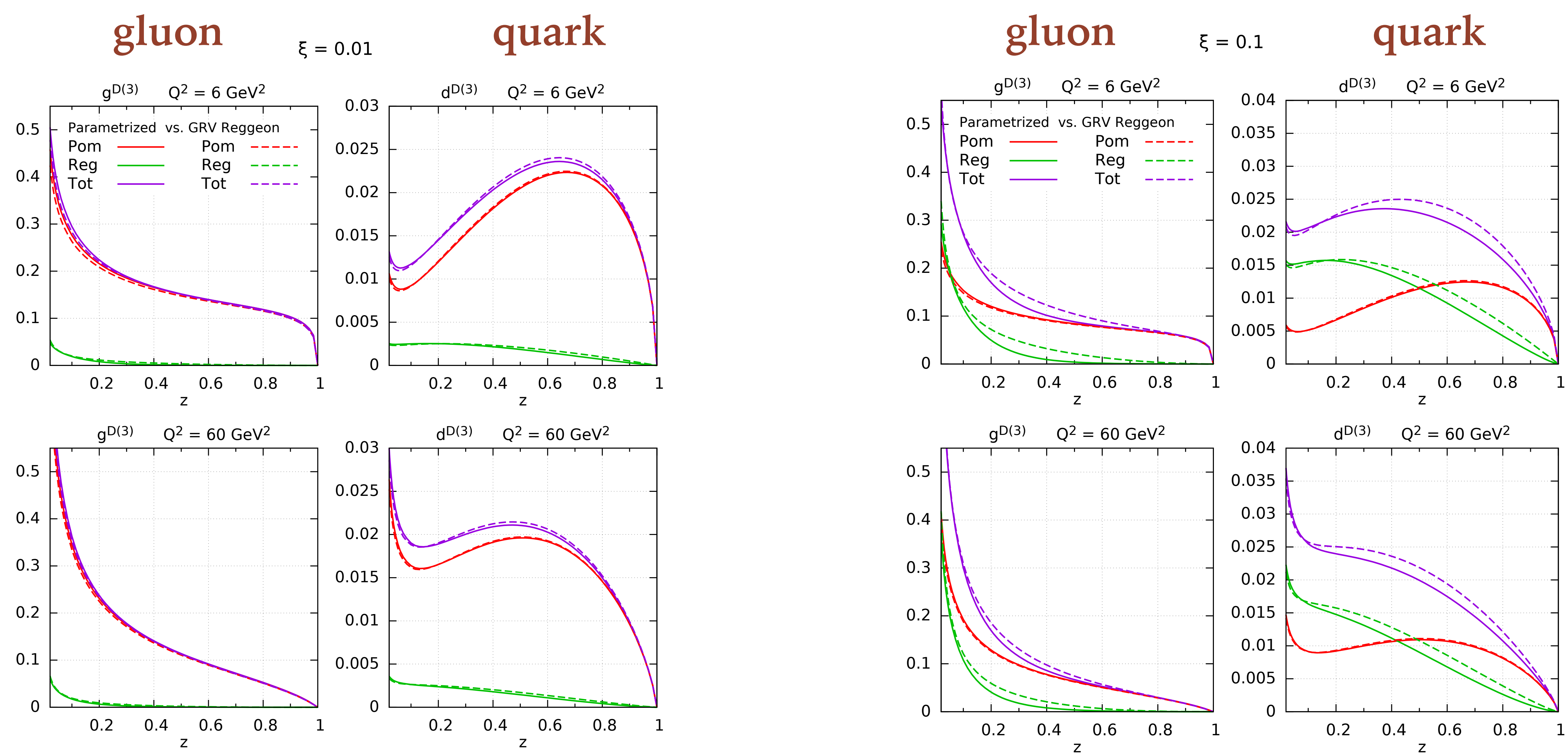
$$f_k^{(m)}(x, Q_0^2) = A_k^{(m)}\, x^{B_k^{(m)}} (1-x)^{C_k^{(m)}} (1 + D_k^{(m)}\, x^{E_k^{(m)}})$$

where $k = q, g$ and $m = I\!P, I\!R$

- Following sensitivity studies a suitable choice is:
  - $f_q^{I\!P}$ has A,B,C parameters
  - $f_g^{I\!P}$ has A,B,C parameters
  - $f_q^{I\!R}$ has A,B,C,D parameters
  - $f_g^{I\!R}$ has A,B,C parameters
- In addition fit for the parameters of the fluxes for $I\!P$ and $I\!R$: $\alpha(0), \alpha', B$

$$\frac{e^{B^{(m)}t}}{\xi^{2\alpha^{(m)}(t)-1}} \qquad \alpha^{(m)}(t) = \alpha^{(m)}(0) + \alpha^{'(m)} t$$

# Recovering the Pomeron and Reggeon inputs



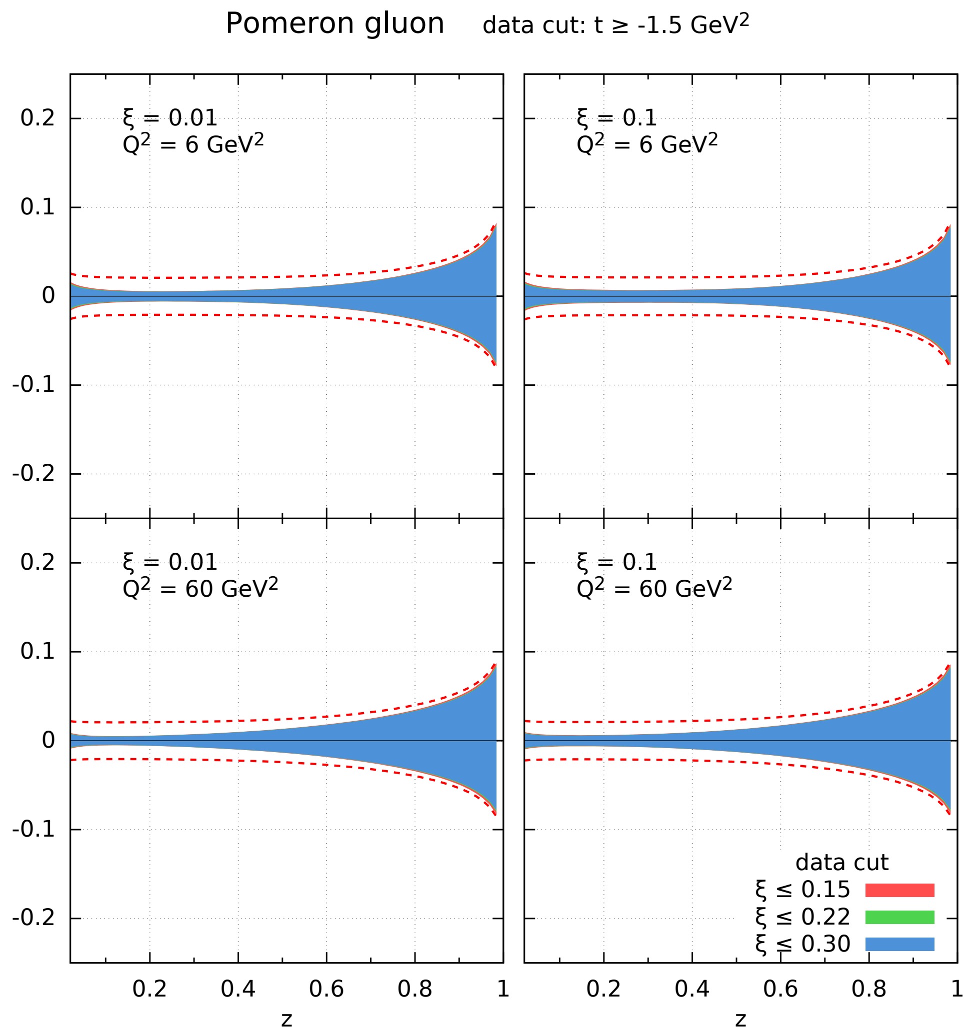

Fit results with free Reggeon parametrization (solid) made to the pseudodata based on the GRV pion structure function (dashed)

Reggeon reproduced reasonably well

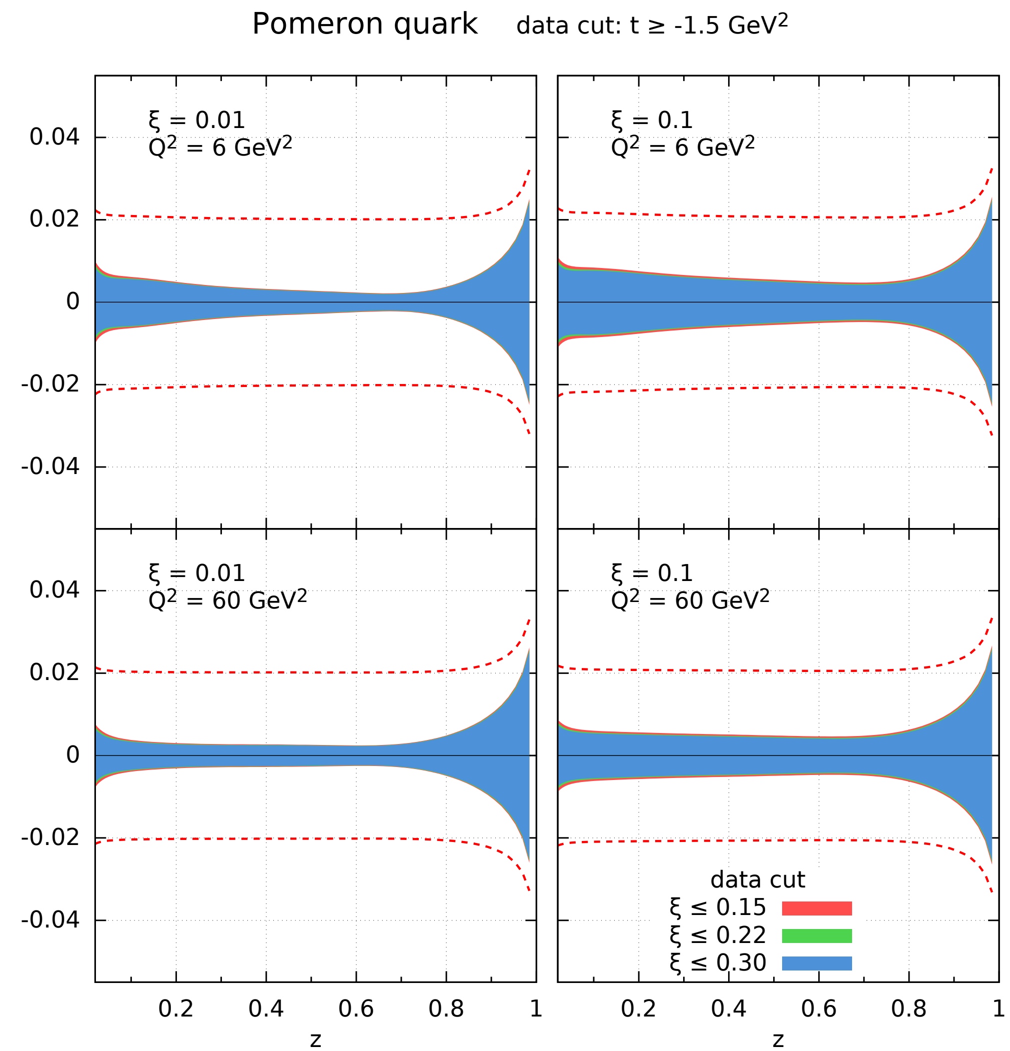
Pomeron reproduced almost perfectly

# Uncertainties of diffractive PDFs: Pomeron

## Pomeron gluon



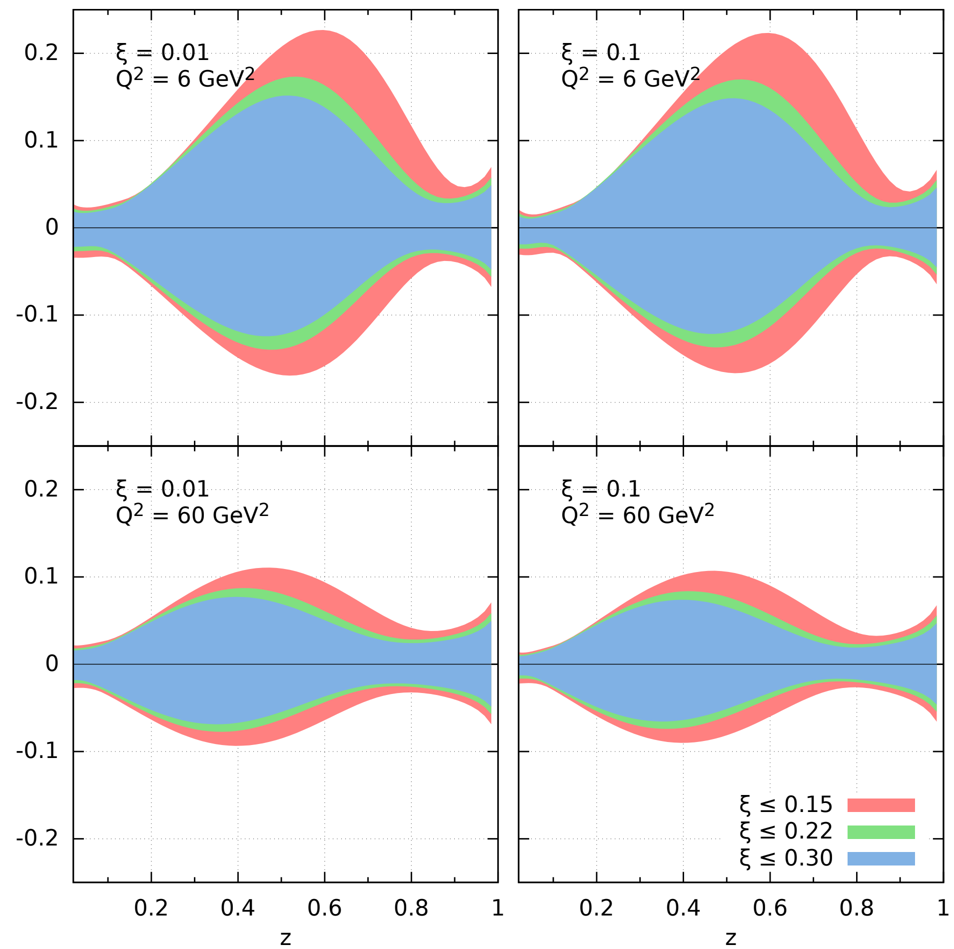

## Pomeron quark

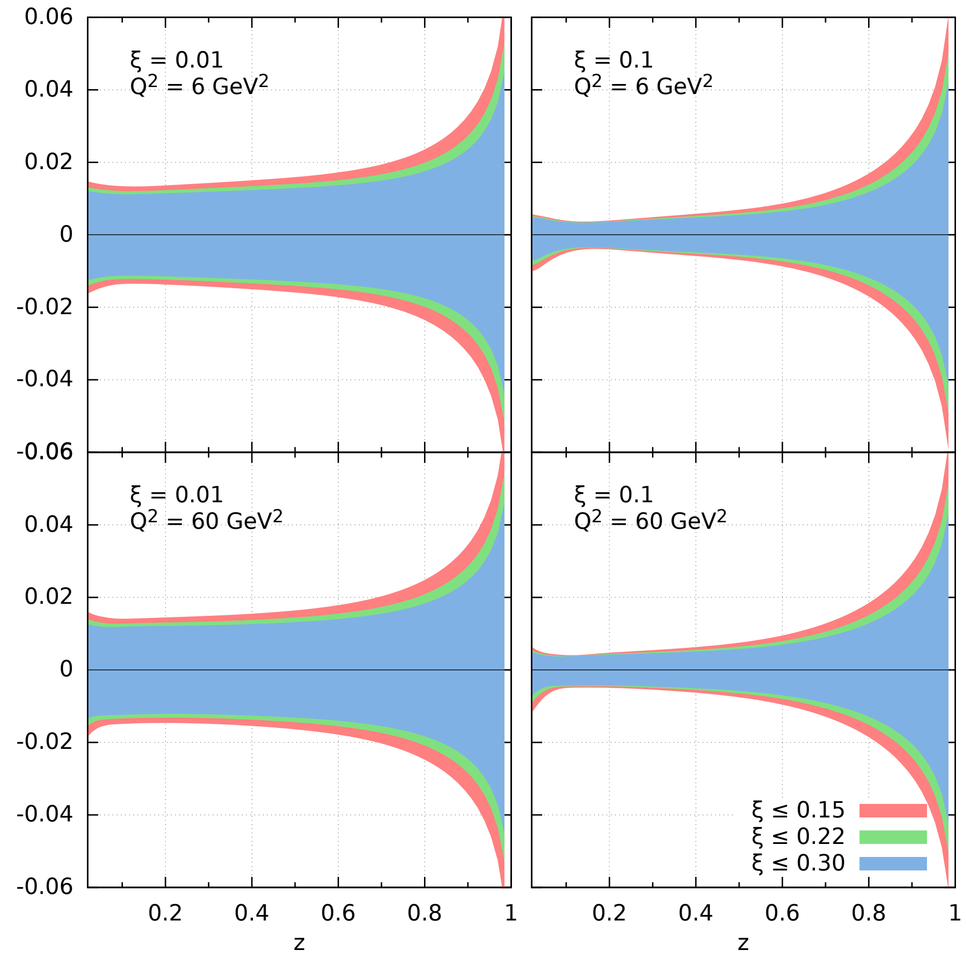



- relative uncertainty
- <few % or better in most regions
- larger uncertainty for gluon at large z (and also small z)
- normalization error at 2% is dominant at most regions (dashed red)

*linear horizontal scale*
*note different vertical scale for gluons and quarks*

# Uncertainties of diffractive PDFs: Reggeon

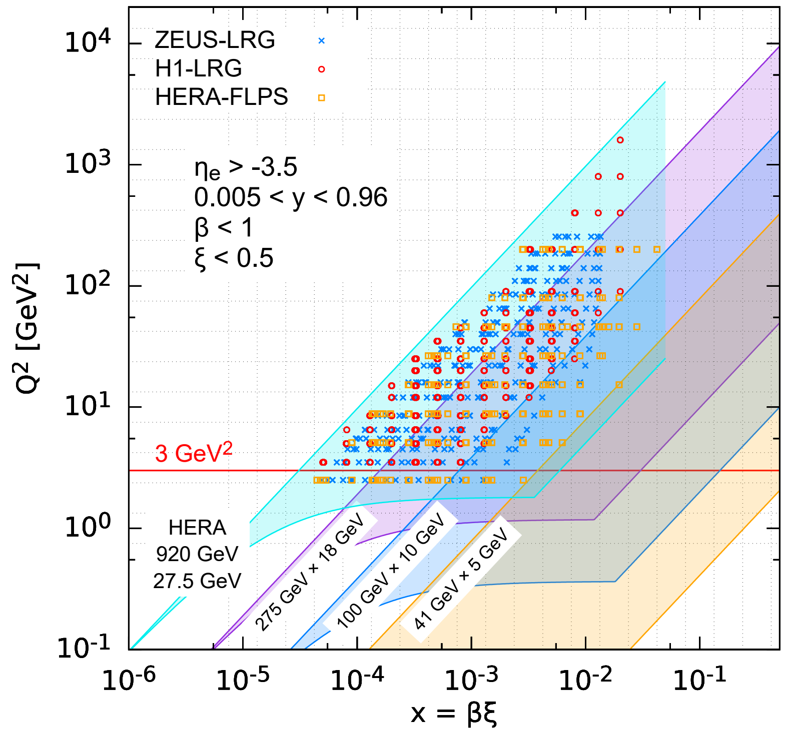


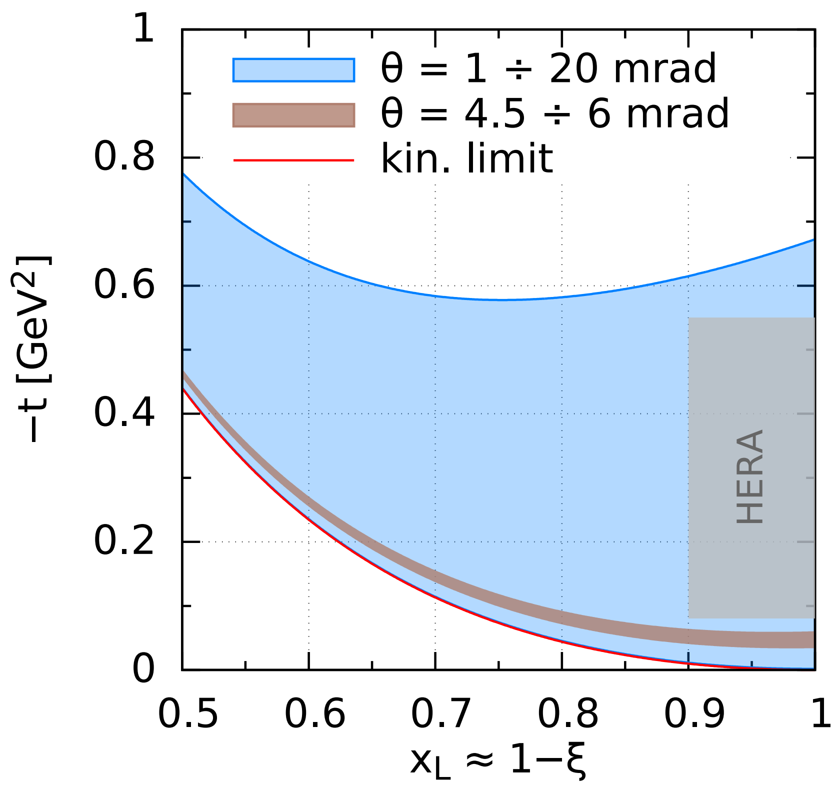




- <2 % or better in most regions for quark except at large z
- Larger uncertainty for Reggeon gluon which is much smaller than Pomeron gluon
- Mild sensitivity to the cut on $\xi$ for gluon, quark less sensitive
- Minimal sensitivity to the cut on $t$, dense vs sparse binning, lower luminosity $\mathscr{L} = 10\,\mathrm{fb}^{-1}$

**EIC can constrain Reggeon at similar level of precision as the Pomeron**
**even when restricting data to $|t| \leq 0.5\ \mathrm{GeV}^2$ and $\xi_{\max} \simeq 0.15 \div 0.2$**

# Low energy scenario: 5 GeV x 41 GeV



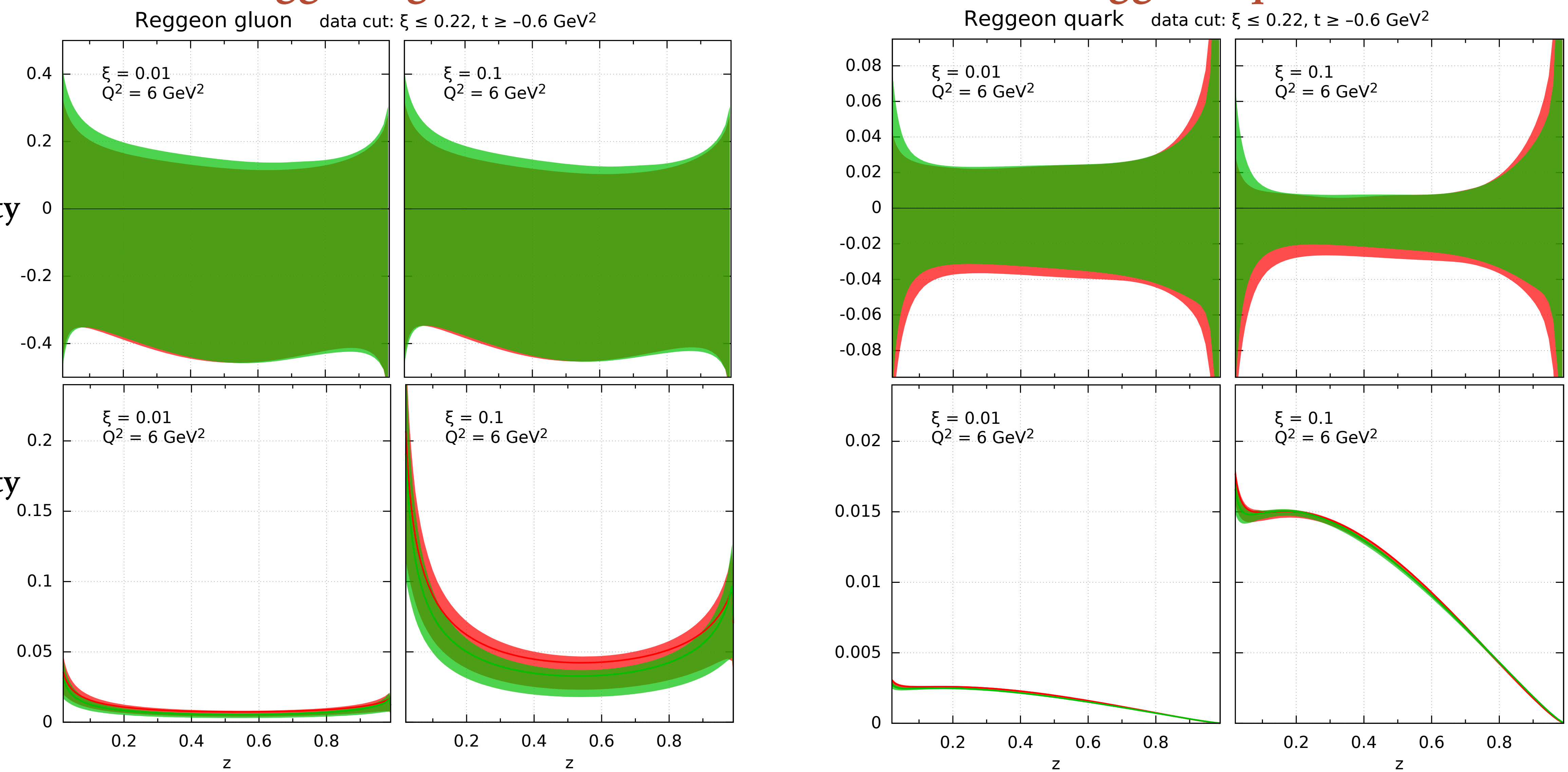

- Low energy scenario: $E_e = 5\,\text{GeV} \times E_p = 41\,\text{GeV}$
- Kinematics restricted:
  - $\xi \geq 0.01$ , by cms energy
  - $t \geq -0.6\ \text{GeV}^2$, forward detector acceptance
- Reggeon dominated
- Fix Pomeron from HERA and fit only Reggeon
- Luminosity $\mathscr{L} = 10\,\text{fb}^{-1}$

# Low energy: Reggeon DPDFs and uncertainties

**Reggeon gluon** **Reggeon quark**

relative uncertainty

PDF with uncertainty




- Quark Reggeon constrained very well
- Larger uncertainty for Reggeon gluon which is much smaller than Pomeron gluon
- Two bands indicate sensitivity to two Monte Carlo samples: small variation

**Low energy data at EIC can already determine Reggeon**

# Summary on 4D fit and Reggeon

- 4-D fit with Pomeron and Reggeon to the diffractive pseudodata
- EIC can extract flux parameters and partonic structure of the subleading ‘Reggeon’ exchange with similar precision to the leading ‘Pomeron’ exchange
- Constraints on Reggeon already from low energy run

More work needed on uncertainties:

- Experimental (correlated systematics)
- Theoretical (model dependence, parton parametrization)

Ideas for further studies:

- Combined HERA and EIC fits
- Charged current contribution