Inclusive diffraction in DIS

What can we learn beyond HERA?

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Extension of studies in
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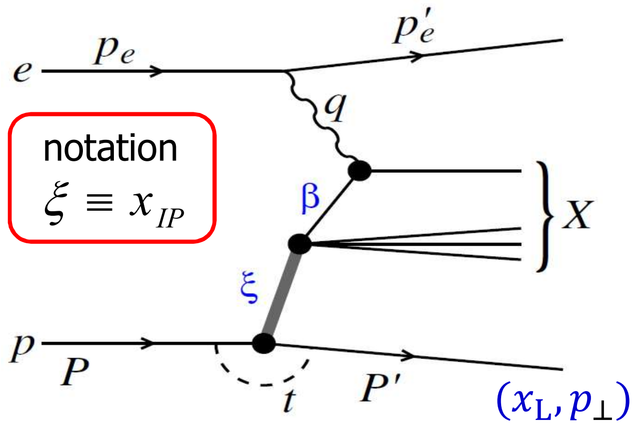
- Diffractive DIS framework
- Data simulation
- Preliminary studies

Diffraction and Tagging WG meeting 2020-05-07

Inclusive diffractive DIS



$$\xi \equiv x_{IP} = \frac{(P-P')\cdot q}{P\cdot q} = \frac{Q^2+M_X^2-t}{Q^2+W^2-m_p^2}$$

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

$$x = \xi\beta$$

Incoming proton along z axis in both std. hadron frame = CM(γ,p) and LAB = collinear (e,p).

Outgoing proton momentum given in terms of $(x_L, p_\perp)$ with $P'_+ = x_L P_+ \quad (x_L \approx x_F)$.

Note that $(x_L, p_\perp)$ are not Lorentz invariant but in both frames, for small ξ and $p_\perp$,

$x_L \approx 1 - \xi$. The corrections grow with $xp_\perp/Q$.

E.g. in LAB, for $\xi = 0.4$ and $p_T < 2$ GeV , $x_L \in [0.45, 0.75]$.

cross section, reduced cross section, diffractive structure functions

$$\frac{d\sigma}{d\beta dQ^2 d\xi dt} = \frac{2\pi\alpha^2}{\beta Q^4}\left[1+(1-y)^2\right]\sigma_{\mathrm{red}}^{D(4)}(\beta, Q^2, \xi, t)$$

dim = GeV^{-2}

$$\sigma_{\mathrm{red}}^D = F_2^D - \frac{y^2}{1+(1-y)^2}F_L^D$$

Upon integration over t
$\sigma_{\mathrm{red}}^{D(3)}$, $F_{2,L}^{D(3)}$
become dimensionless

Two component model for diffractive SFs (as used in the HERA fits)

Regge factorization works at low ξ (< 0.01).
At higher ξ, subleading exchanges (reggeons/mesons) enter the game
— they are all parametrized by a single additional term

$$F^{D(4)}(z,Q^2,\xi,t) = \varphi_{\mathbf{P}}(\xi,t)\, F^{\mathbf{P}}(z,Q^2) + \varphi_{\mathbf{R}}(\xi,t)\, F^{\mathbf{R}}(z,Q^2)$$

"Reggeon" SF ∝ pion, $F^{\mathbf{R}} = A_{\mathbf{R}}\, F^{\pi}$

$\varphi_{\mathbf{P},\mathbf{R}}$ = Regge-type flux:

$$\varphi(\xi,t) \sim \frac{e^{Bt}}{\xi^{2\alpha(t)-1}}$$ with $\alpha(t) = \alpha_0 + \alpha' t$

3 parameters per flux

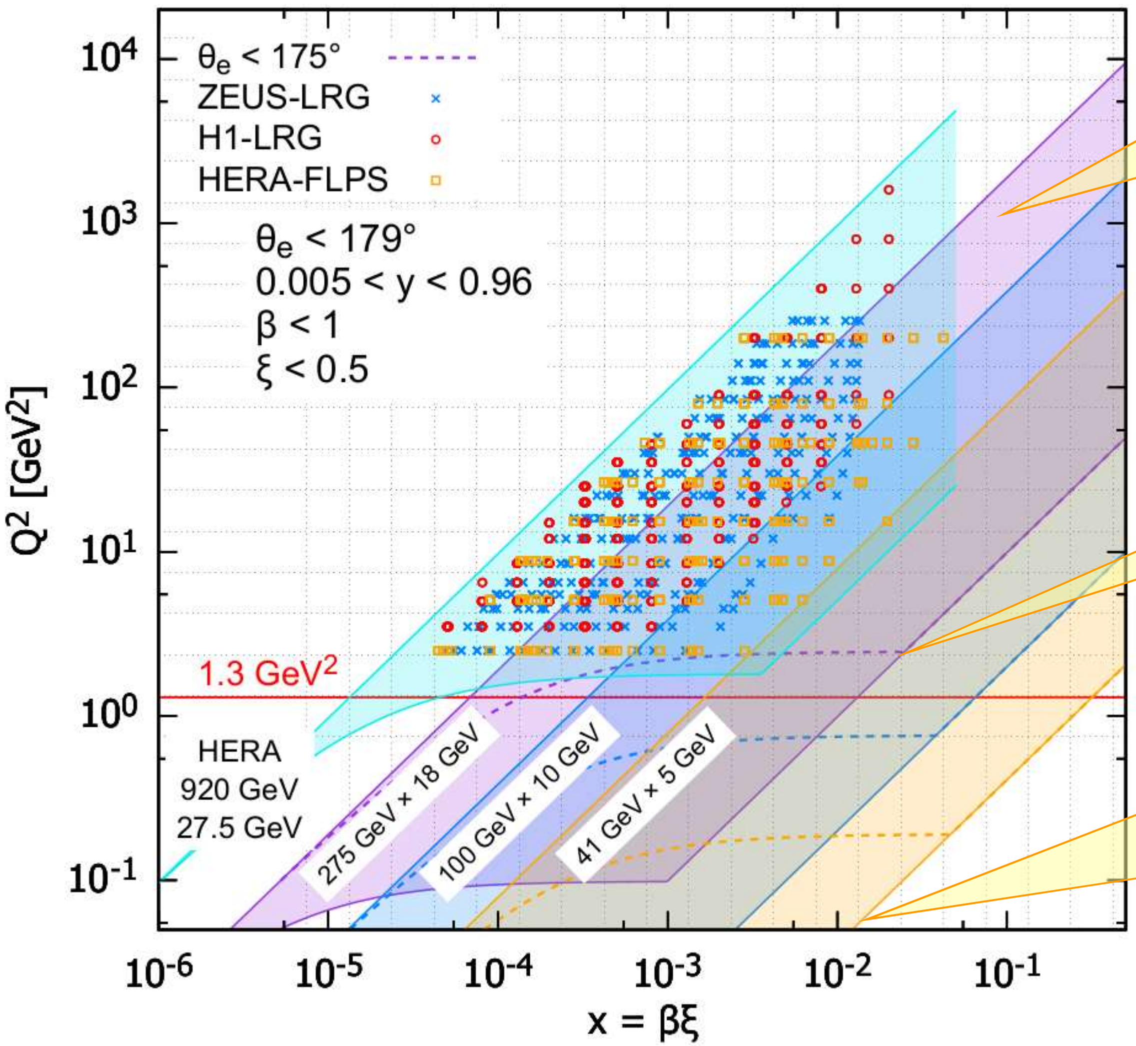
$F^{\mathbf{P}}$ from Pomeron PDFs via NLO DGLAP evolution starting at μ_0^2 = 1.8 GeV^2

$$f_k^{\mathbf{P}}(z) = A_k z^{B_k}(1-z)^{C_k}, \qquad k = g, q$$

6 parameters

$q = d = u = s$

x, Q^2 range — EIC and HERA



The grid shows binning of 4 bins per order of magnitude in each β, Q^2, ξ

Dashed lines show boundaries for max $\theta_e = 175°$

x range gets shifted up by a factor ~5 when going from HERA through the EIC beam settings: 275×18, 100×10, 41×5.

Detailed binning 100x10 275x18

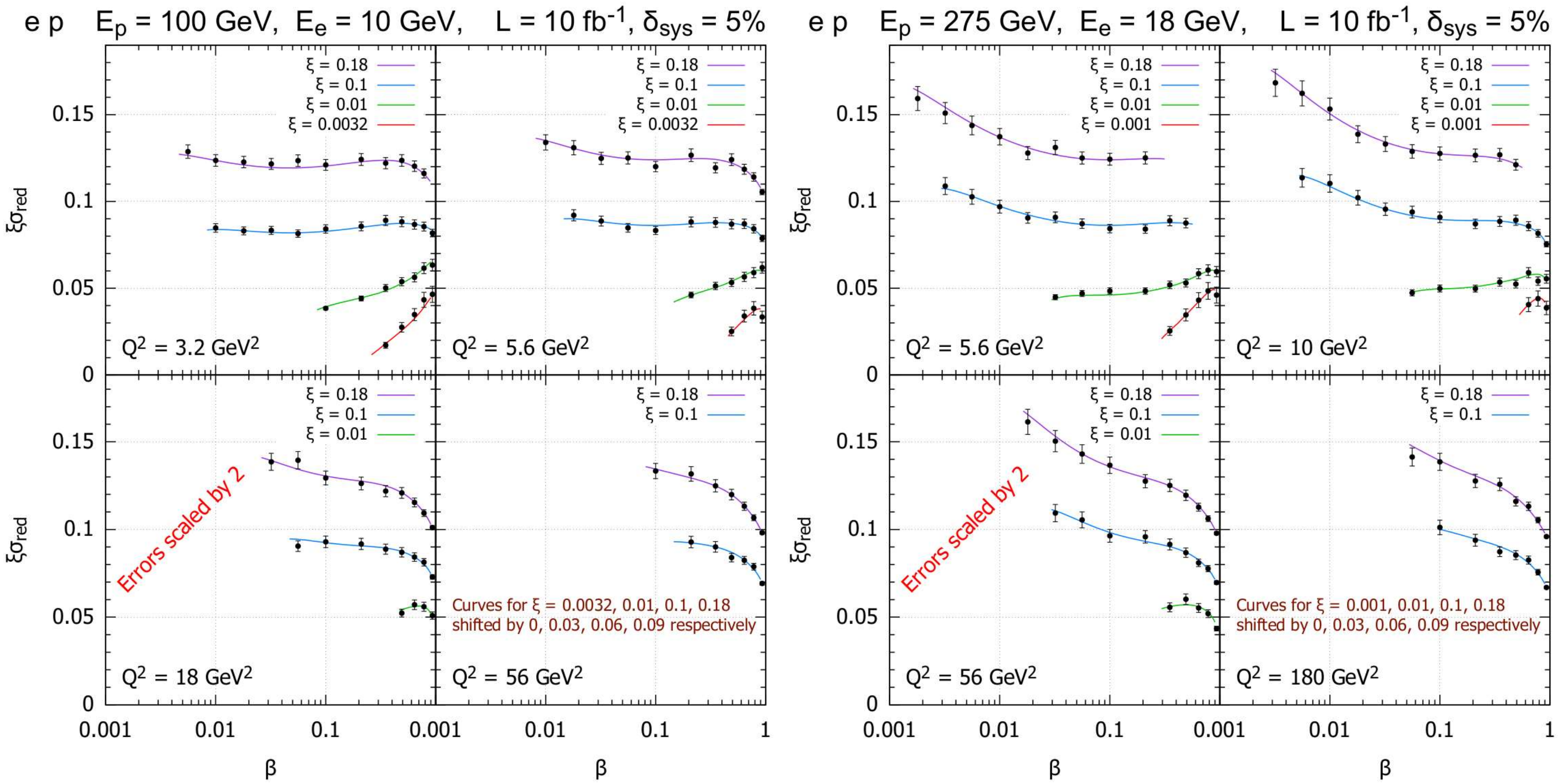
New, high x region to explore

Simulation and fits

- Pseudo-data generation
  - binning: 4 bins per order of magnitude in each β, Q^2, ξ;
    linear binning for $\beta > 0.3$ (6 bins in 0.1÷1 range)
  - extrapolation from ZEUS-SJ DPDFs
  - random Gaussian smearing from 5% syst. + Poissonian from lumi
  - several samples, *aka* MC-replicas
- Fits
  - Two basic types of fits
    - S (Standard) — all A_k, B_k, C_k free
    - C (Constant gluon) — $B_g = C_g \equiv 0$
  - Both equally good for $x > 10^{-5}$
    - large ambiguity for gluon
    - inclusion of dijet data crucial for gluon determination

$$f_k^{\mathbf{P}}(z) = A_k z^{B_k}(1-z)^{C_k}, \quad k = g, q$$

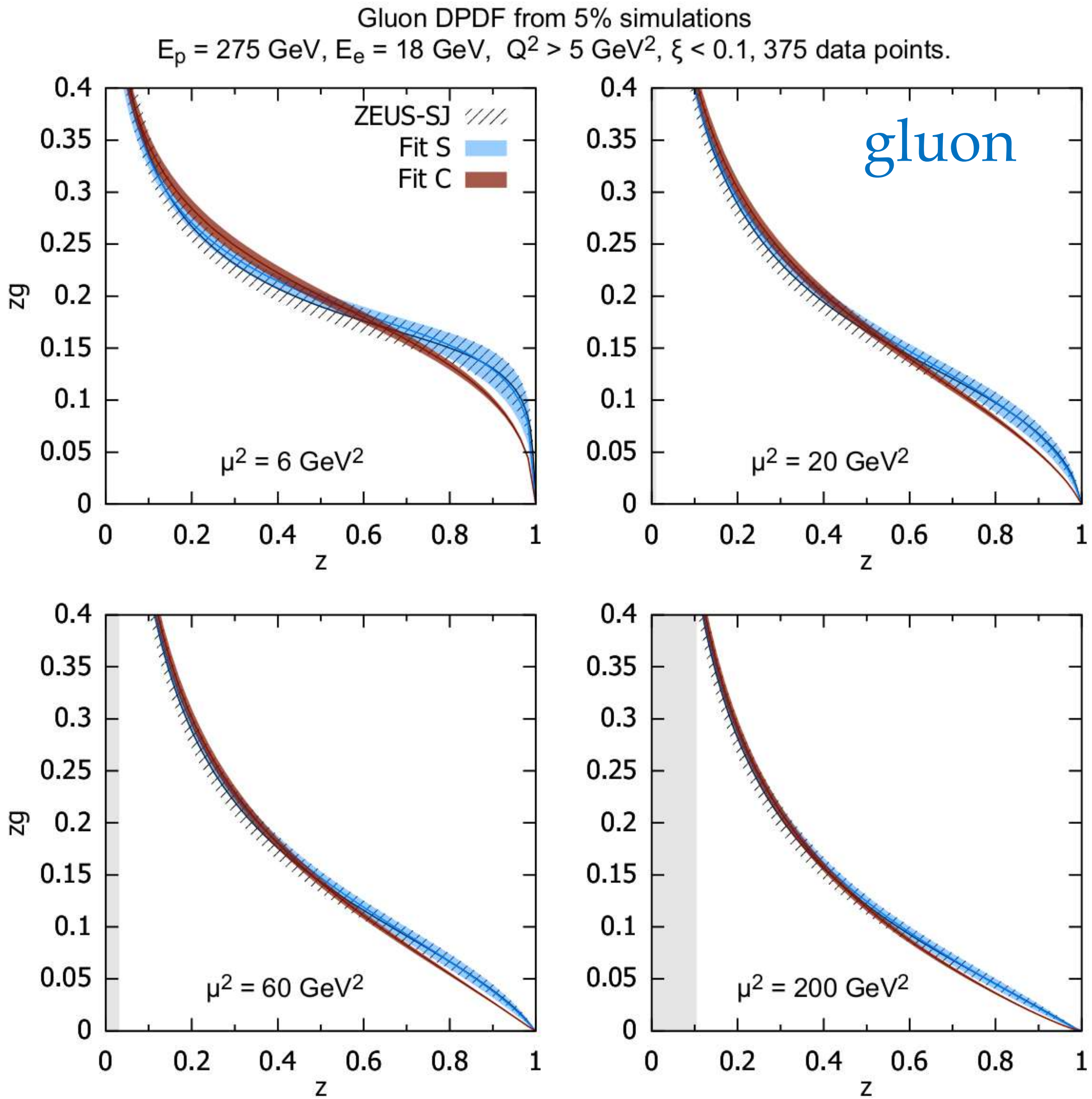
Pseudo-data examples



In total:
482 points for $1.3 < Q^2 < 1330\ \mathrm{GeV}^2$

In total:
792 points for $1.3 < Q^2 < 4220\ \mathrm{GeV}^2$

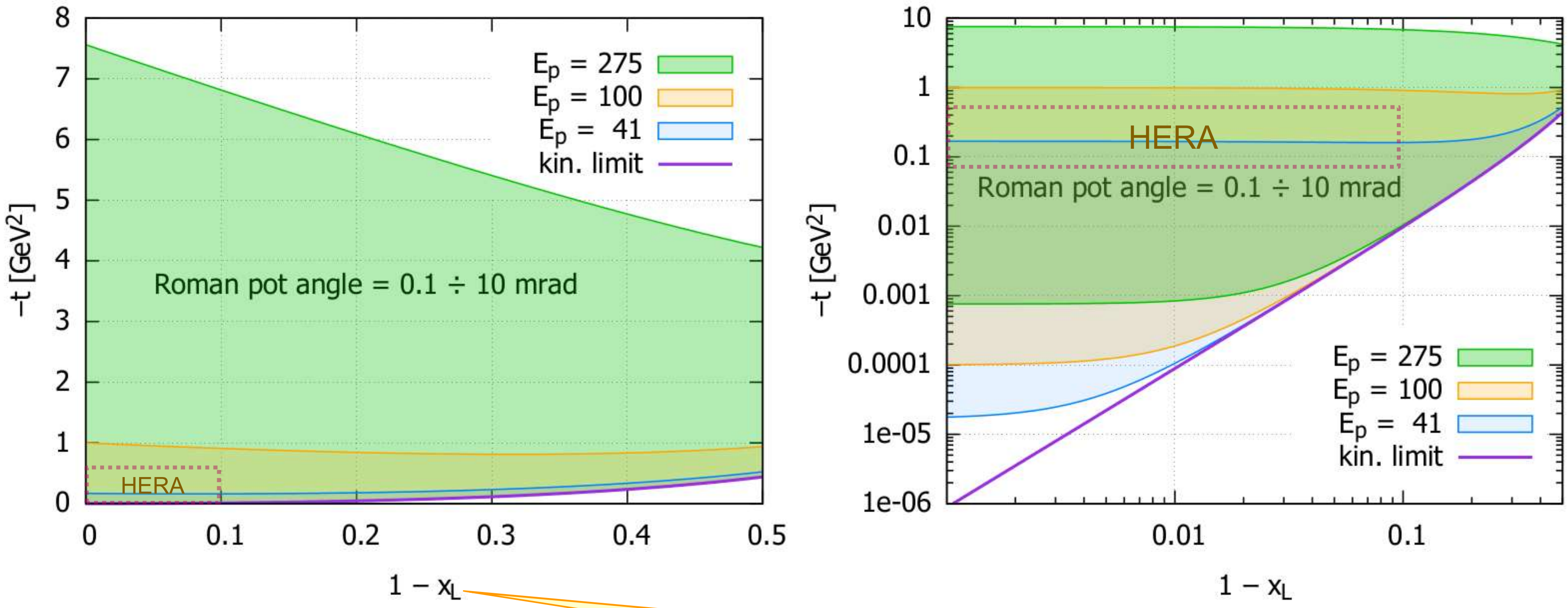
Gluon DPDFs form C and S fits



Data selection
$Q^2 > 5\ \mathrm{GeV}^2$
$\xi < 0.1$

- Both C and S fits give $\chi^2 \approx 1$
- Fixing gluon from inclusive DDIS requires $x \lesssim 10^{-6}$
- Here $x > 10^{-4}$
- Some other, gluon-sensitive process needed – e.g. dijet production, dominated by BGF

Final proton tagging – x_{L}, t range



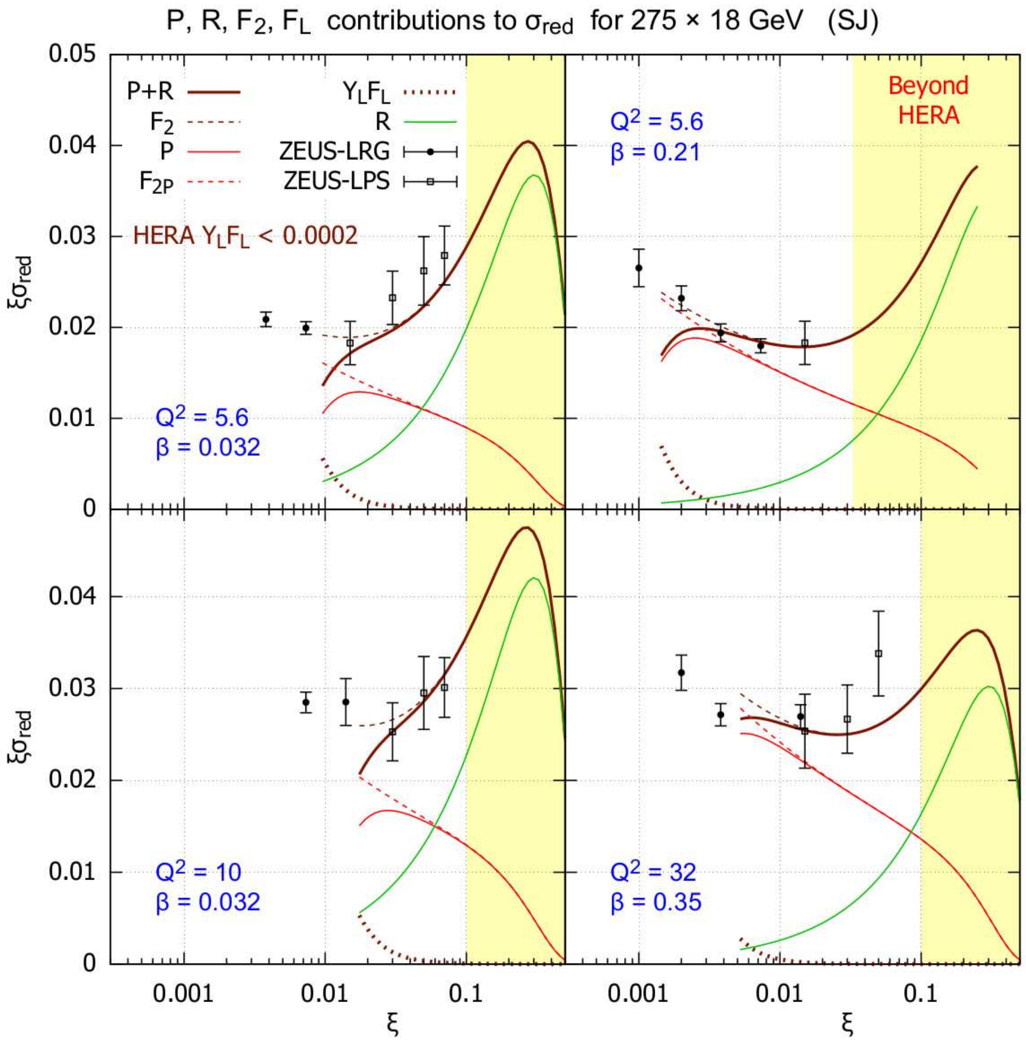
x_{L} measured in LAB = collinear (e,p) frame

$$t = -\frac{p_{\perp}^2}{x_{\mathrm{L}}} - \frac{(1-x_{\mathrm{L}})^2\, m_p^2}{x_{\mathrm{L}}}$$

HERA data taken at $0.08 < -t < 0.55\ \mathrm{GeV}^2$ and $0.9 < x_{\mathrm{L}} < 1$

A better measurement of t-dependence possible

Pomeron, Reggeon, F_2, F_L components of σ_{red}



- ❑ $\mathbb{R}$ contribution dominates at high ξ
- ❑ Significant F_L component

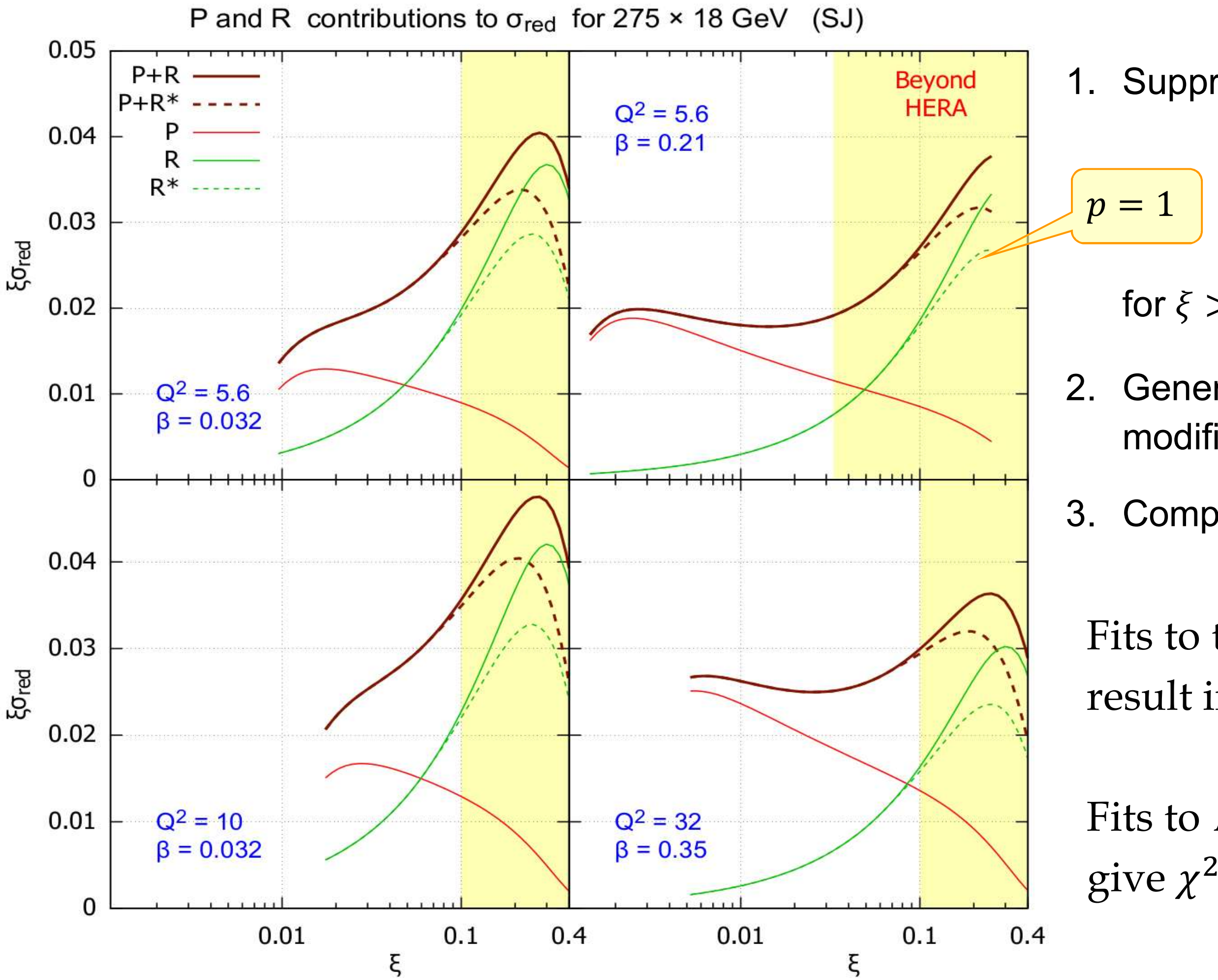
$$\sigma_{\text{red}} = F_2 \; - Y_L(y)\, F_L$$

$$Y_L(y) = \frac{y^2}{1 + (1-y)^2}$$

At fixed (x, Q^2),
$Y_L(y)$ scales stronger than $\sim 1/s^2$,
e.g. $Y_L(0.9/5)/Y_L(0.9) = 0.024$

Some intermediate beam energy settings would improve F_L measurements.

Sensitivity to the Reggeon contribution to σ_{red}



1. Suppress Reggeon by a factor

$$\left(\frac{1-\xi}{1-\xi_0}\right)^p$$

   for $\xi > \xi_0 = 0.07$,

2. Generate pseudo-data with nominal and modified $\mathbb{R}$ contribution

3. Compare results of the fits

Fits to the unmodified $\mathbb{R}$ result in $\chi^2 \approx 1$, as expected.

Fits to $\mathbb{R}^*$ suppressed by ~10% give $\chi^2 \approx 1.2$

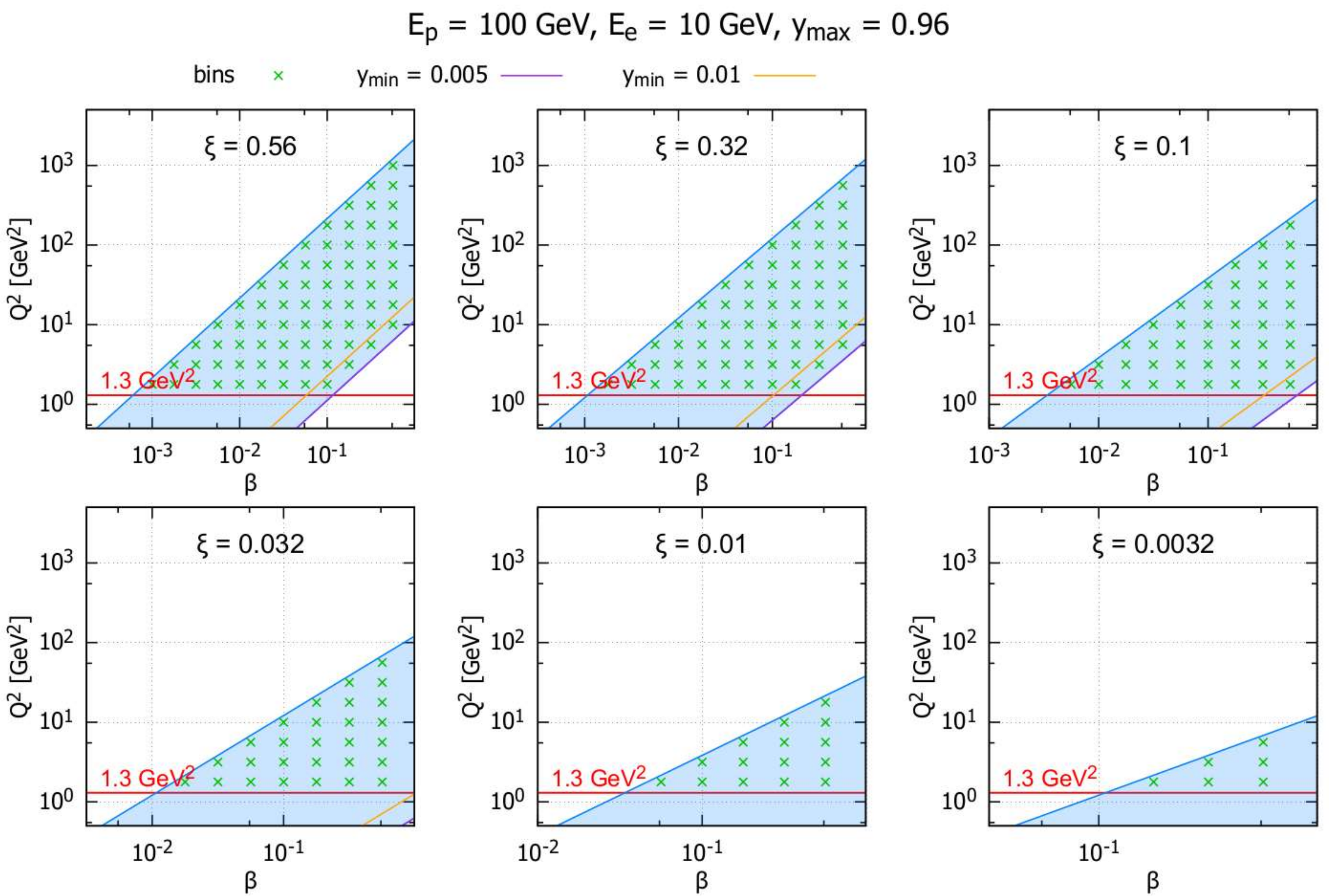
Reggeon flux $\varphi_R \sim \xi^{1-2\alpha_R}$ and α_R is a free fit parameter.
Hence the data can discriminate between two shapes in ξ.

Summary

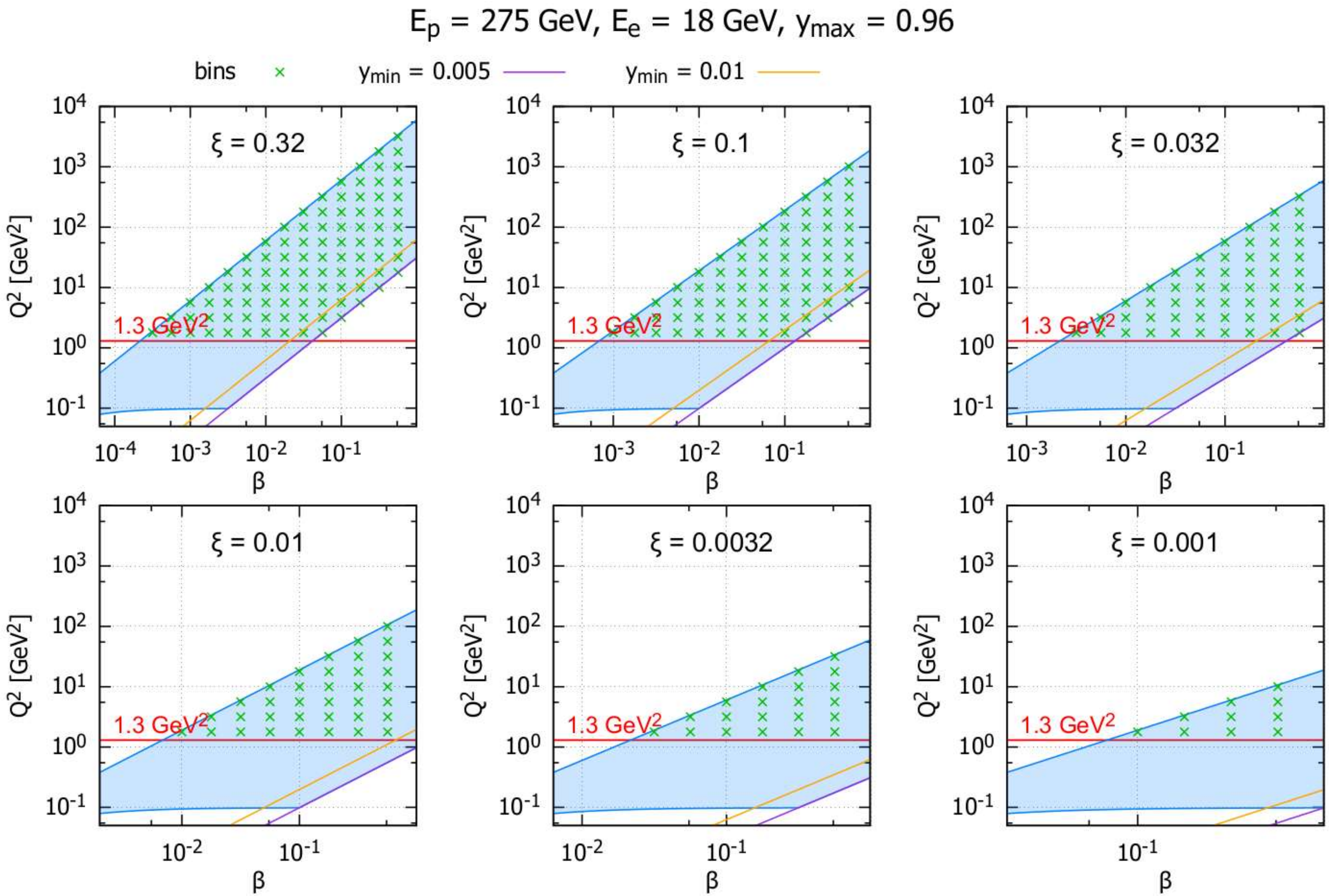
- Gluon determination requires additional data — as at HERA
- A measurement of subleading exchanges (“Reggeon”) feasible
- Diffractive F_L measurement very promising — in progress…

EXTRAS

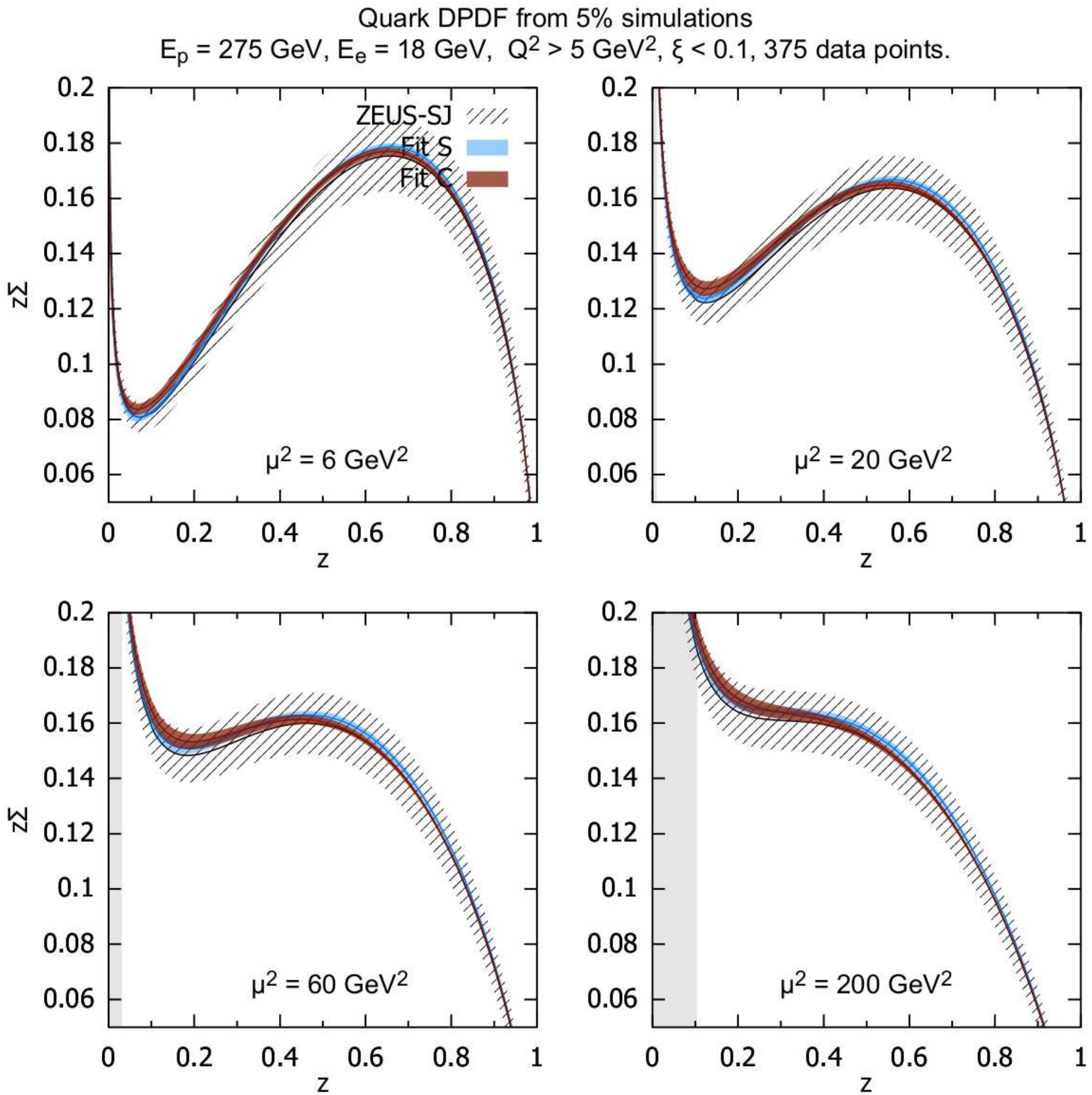
Detailed binning 100 × 10 GeV



Detailed binning 275 × 18 GeV



Quark DPDFs form C and S fits



Data selection

$Q^2 > 5\ \mathrm{GeV}^2$

$\xi < 0.1$

- As compared to HERA
  - Higher accuracy
  - More data points

THE END