Diffractive DIS at LHeC & FCC-he

A case study of DPDFs accuracy

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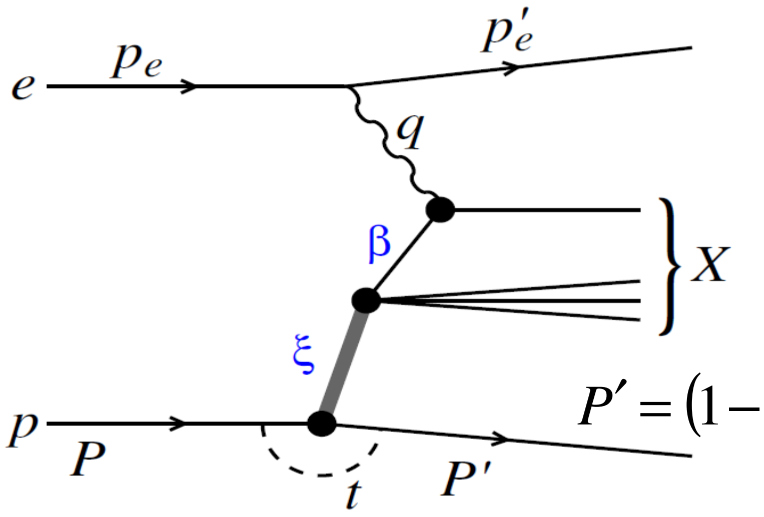
- Diffractive DIS and DPDFs from HERA
- Phase-space of LHeC & FCC-he
- Data simulation
- DPDFs from fits to the simulated data

PDFs and Low x at LHeC/FCC-he WG meeting 2017-11-15

Inclusive diffractive DIS



notation
$\xi \equiv x_{IP}$

$$\beta = \frac{Q^2}{2(p-p')q}$$

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

t-integrated cross section

$$\frac{d\sigma}{d\beta dQ^2 d\xi} = \frac{2\pi\alpha^2}{\beta Q^4}\left[1+(1-y)^2\right]\sigma_{\rm red}^{D(3)}(\beta, Q^2, \xi)$$

diffractive

structure functions

and PDFs

$$\sigma_{\rm red}^{D(3)} = F_2^{D(3)} - \frac{y^2}{1+(1-y)^2} F_{\rm L}^{D(3)}$$

$$F_N^{D(3)} = \sum_{k=q,g} C_{Nk} \otimes f_k^{D(3)} \qquad N = 2, \mathrm{L}, \mathrm{T}$$

A model for diffractive PDFs used in HERA fits

Regge factorization assumption

$$f_k^{D(3)}(z, Q^2, \xi) = \Phi_{\mathbf{P}}(\xi)\, f_k^{\mathbf{P}}(z, Q^2) + \Phi_{\mathbf{R}}(\xi)\, f_k^{\mathbf{R}}(z, Q^2)$$

$\Phi_{\mathbf{P},\mathbf{R}}$ = Regge-type flux integrated over t

Reggeon PDFs ∝ pion
$f_k^{\mathbf{R}} = A_{\mathbf{R}}\, f_k^{\pi}$

$$\Phi(\xi) \sim \int dt \frac{e^{bt}}{\xi^{2\alpha(t)-1}}$$

with $\alpha(t) = \alpha(0) + \alpha' t$

3 parameters per flux

Pomeron PDFs via DGLAP evolution starting at μ_0^2 = 1.8 GeV^2

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

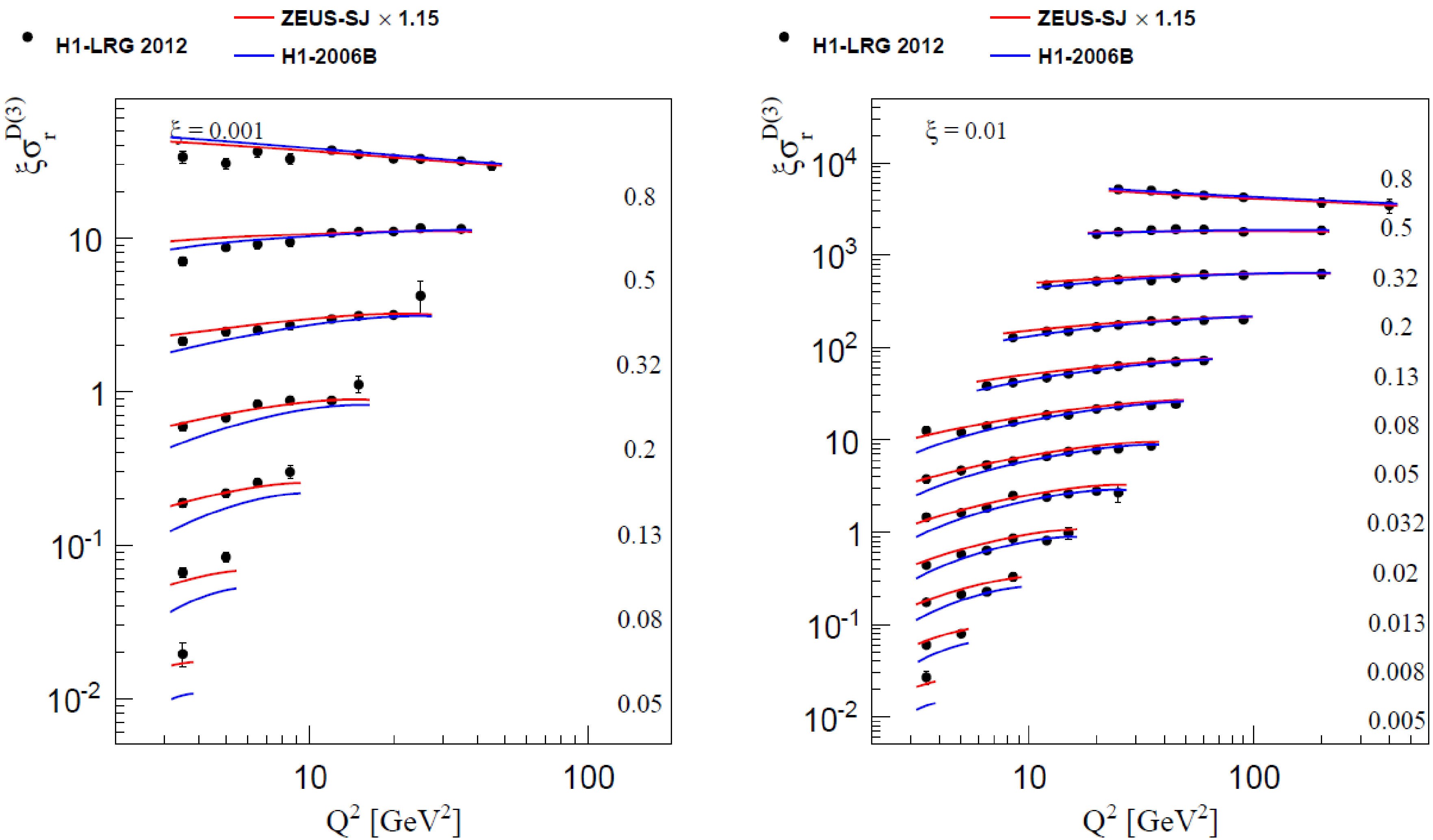
$q = d = u = s$

6 parameters

HERA DPDF fits

- Two types of fits (fixed fluxes)
  - S (standard) — all A_k, B_k, C_k free
  - C (constant gluon) — $B_g = C_g = 0$
- Both equally good for the HERA inclusive data
  - large ambiguity for gluon
  - inclusion of dijet data crucial for gluon determination
- Parametrizations with codes for DPDFs and $F_{2/L}$
  - H1-2006 — C-type fit to σ_{red}
  - ZEUS-SJ — S-type fit to σ_{red} + jets

HERA models vs. recent HERA data



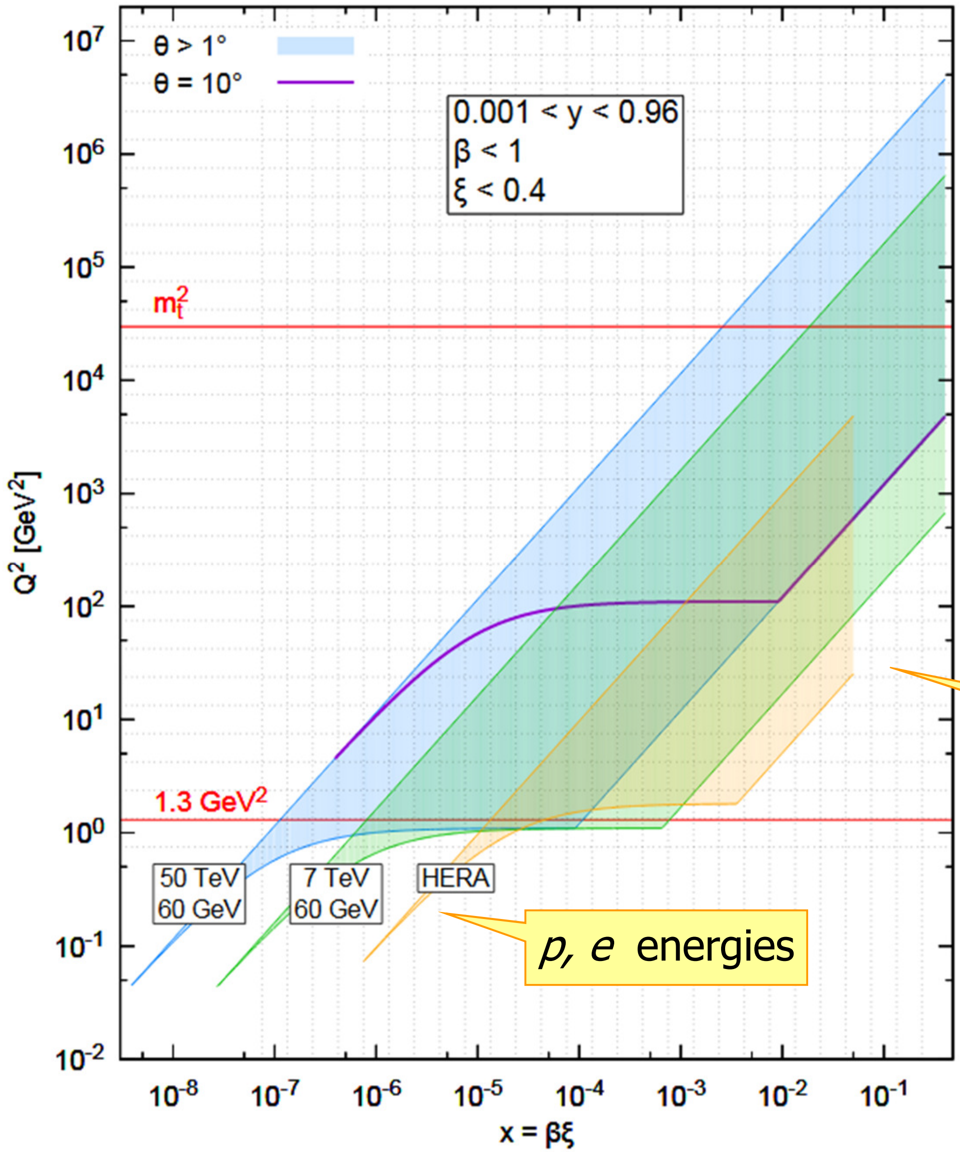
Compatible description

ZEUS-SJ chosen for simulations

Data simulation for LHeC & FCC

- Phase space of LHeC & FCC-he
  - ✓ shift to lower β, ξ and higher Q^2
  - ❖ expected experimental coverage
  - ❖ top quark contribution
- Binning
  - ✓ assumed to ensure negligible statistical errors
- Simulation
  - ✓ extrapolation from ZEUS-SJ DPDFs
  - ✓ supplemented with 5% Gaussian noise

Phase space — HERA → LHeC → FCC-he

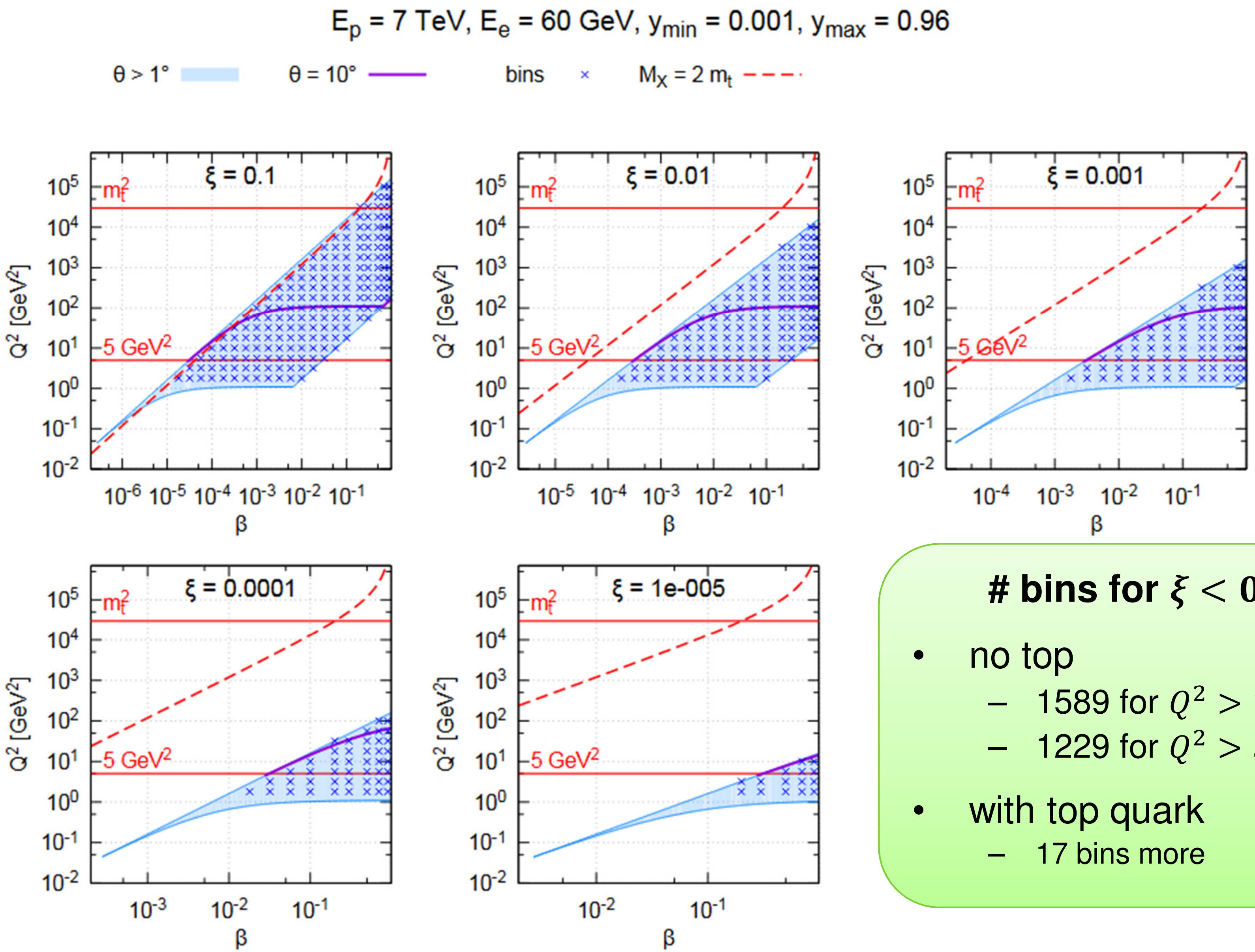


$E_e = 60\ GeV$

- $E_p = 7$ TeV vs. HERA
  - $x_{\min}$ down by factor ~20
  - $Q^2_{\max}$ up by factor ~100
- $E_p = 50$ TeV vs. 7 TeV
  - $x_{\min}$ down by factor ~10
  - $Q^2_{\max}$ up by factor ~10

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

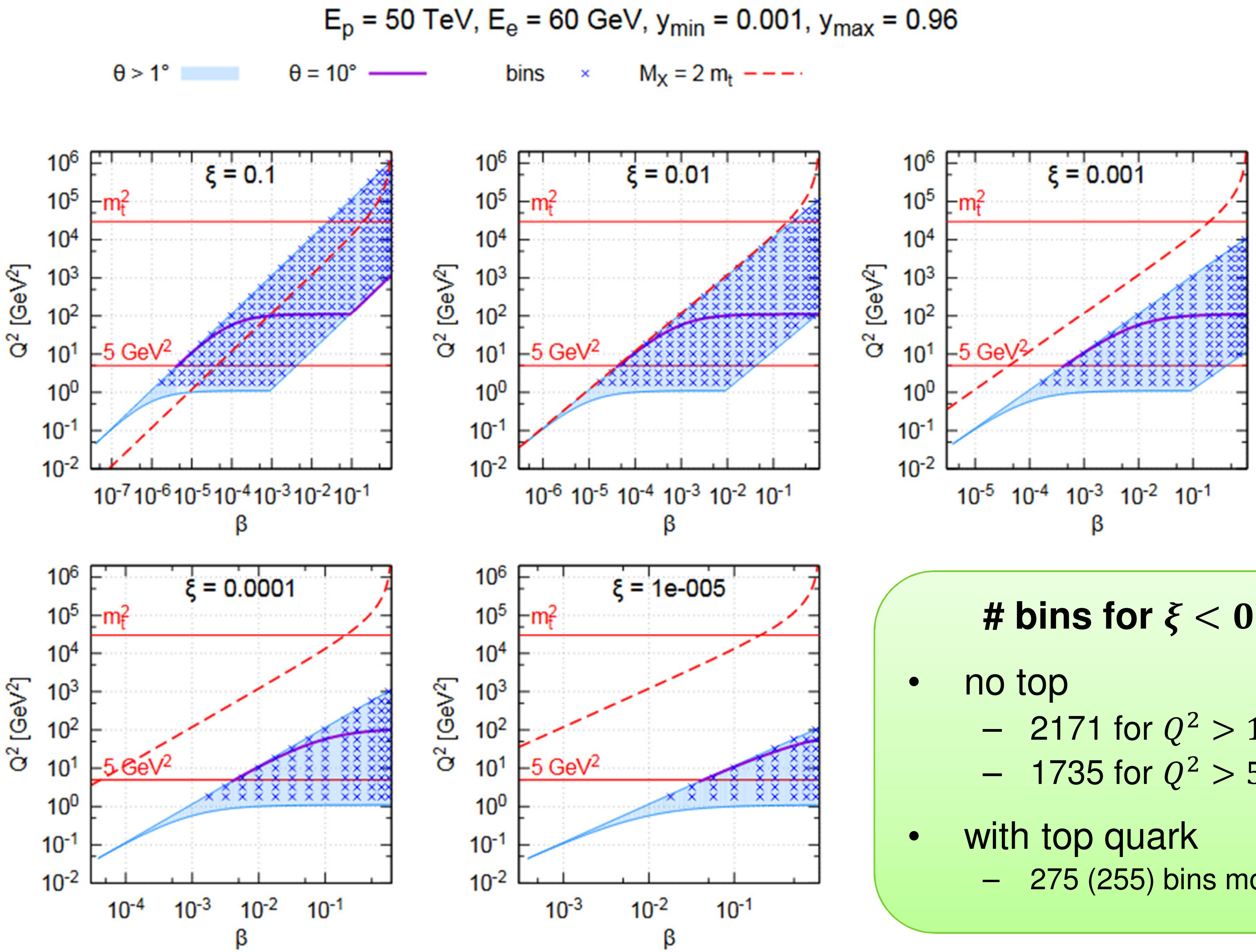
LHeC phase space — $E_p = 7$ TeV



 # bins for $\xi < 0.15$

- no top
  - 1589 for $Q^2 > 1.3\ \mathrm{GeV}^2$
  - 1229 for $Q^2 > 5\ \mathrm{GeV}^2$
- with top quark
  - 17 bins more

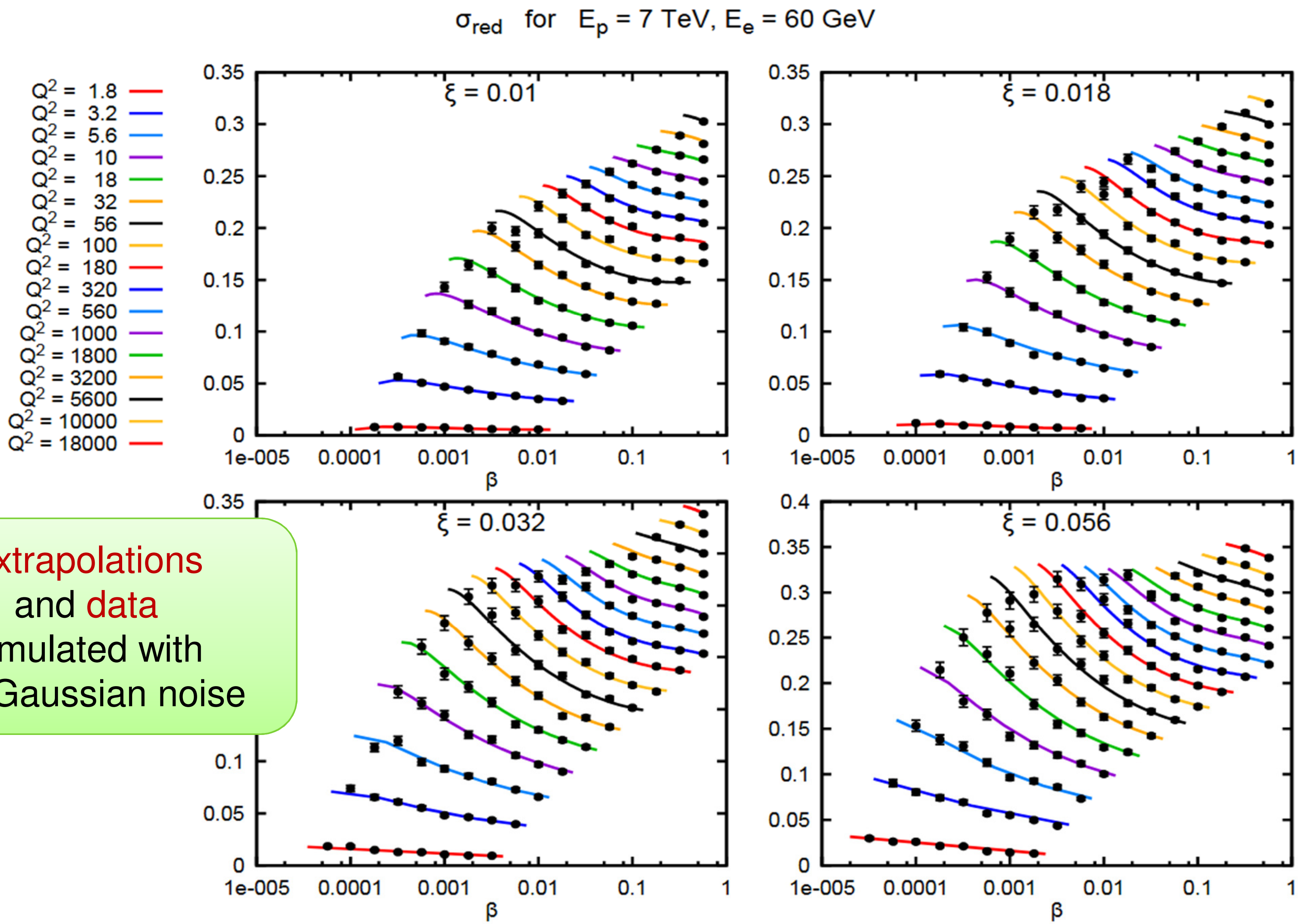
FCC-he phase space — E_p = 50 TeV



 # bins for $\xi < 0.15$

- no top
  - 2171 for $Q^2 > 1.3\ \mathrm{GeV}^2$
  - 1735 for $Q^2 > 5\ \mathrm{GeV}^2$
- with top quark
  - 275 (255) bins more

Simulated data — an example



Extrapolations
and data
simulated with
5% Gaussian noise

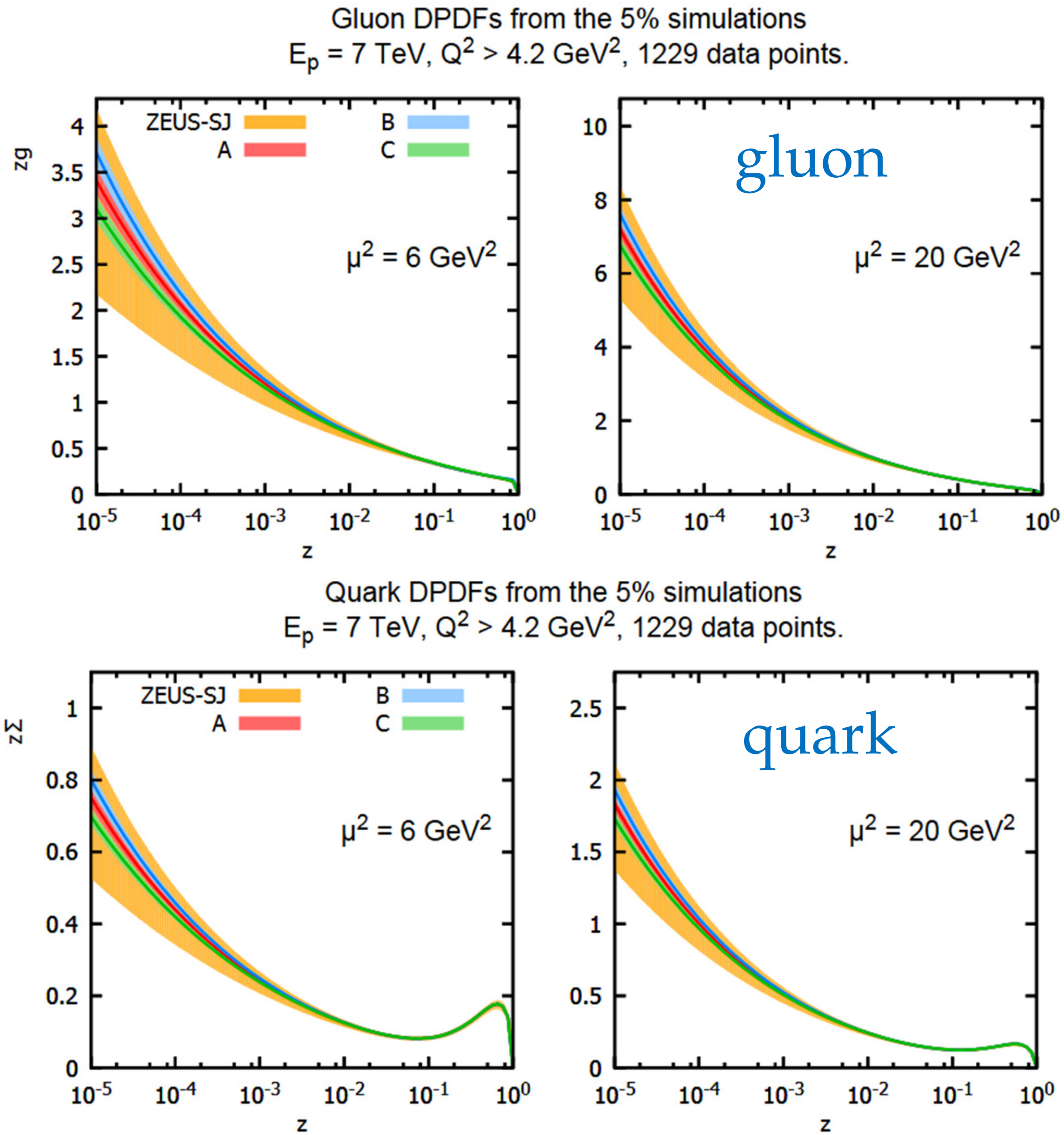
DPDFs from fits to σ_{red}

- Q^2 lower cut dependence
  - $Q^2_{\text{min}} \approx 5\ \text{GeV}^2$ safe range for DGLAP (twist 2 only)
  - $Q^2_{\text{min}} \approx 1.3\ \text{GeV}^2$ a reference base for higher-twist and/or saturation-like improvements
- Statistical properties
  - three independent data samples generated and fitted
- Measurement accuracy study
  - vs. Q^2_{min}
  - vs. E_p

Fit C — a model with “constant gluon” is excluded already at LHeC

- fit S gives χ^2/ndf = 1.05
- fit C gives χ^2/ndf = 1.4

LHeC DPDFs

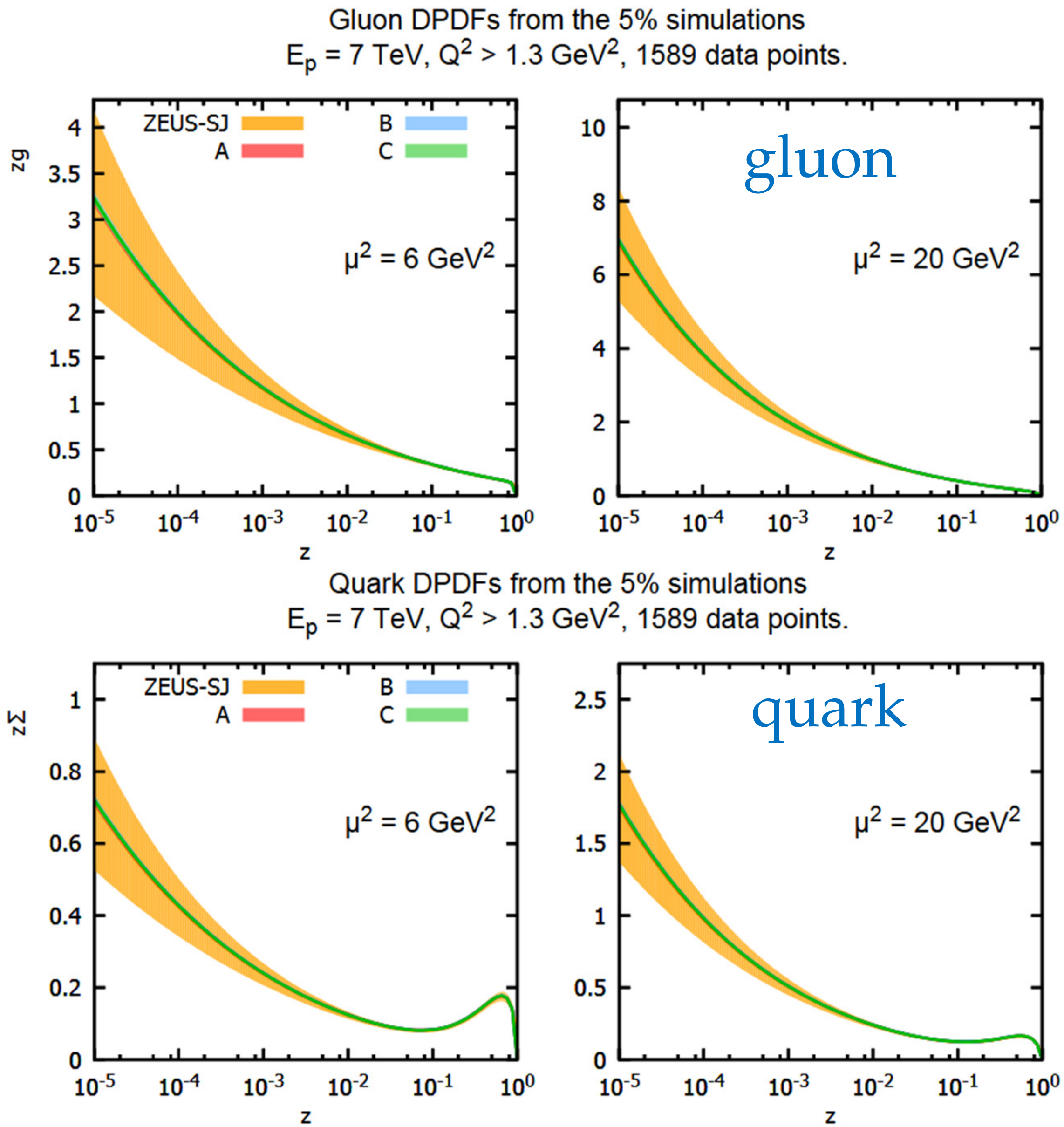


$Q^2_{\min} \approx 5\ \mathrm{GeV}^2$

$E_p = 7\ \mathrm{TeV}$

- Substantially improved accuracy wrt. HERA
- Statistical spread ~ 2 × error-band
- Statistical spreads well below error-bands for $Q^2_{\min} \approx 1.3\ \mathrm{GeV}^2$ or $E_p = 50\ \mathrm{TeV}$

LHeC DPDFs — low Q^2 included



$E_p = 7$ TeV

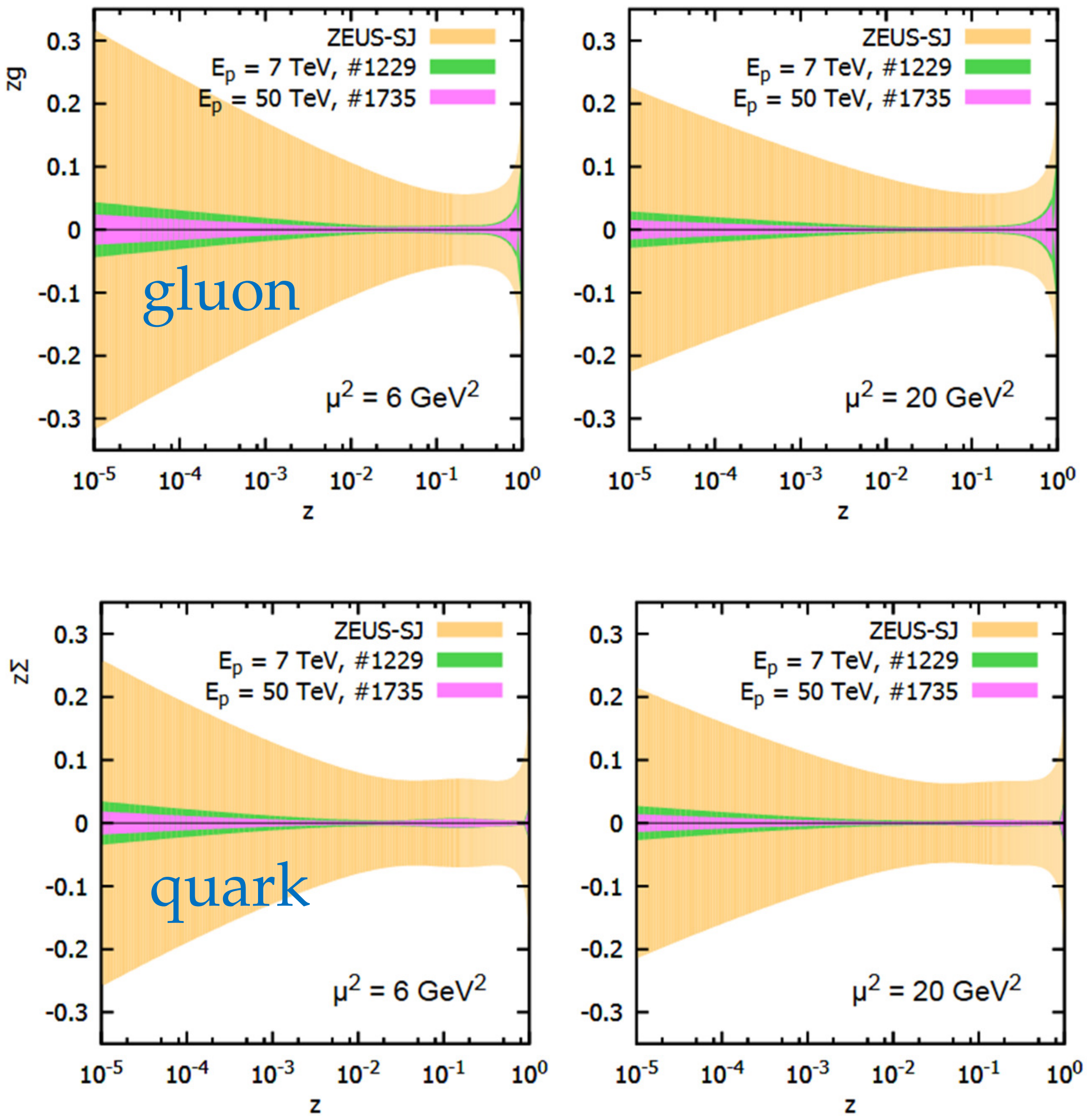
$Q^2_{\text{min}} \approx 1.3$ GeV^2

- Still better accuracy
- Statistical spreads well below error-bands

Same picture for $E_p = 50$ TeV and both $Q^2_{\text{min}} \approx 1.3$ and 5 GeV^2

Substantial contribution expected form higher-twist, saturation, …

Accuracy improvement wrt. HERA

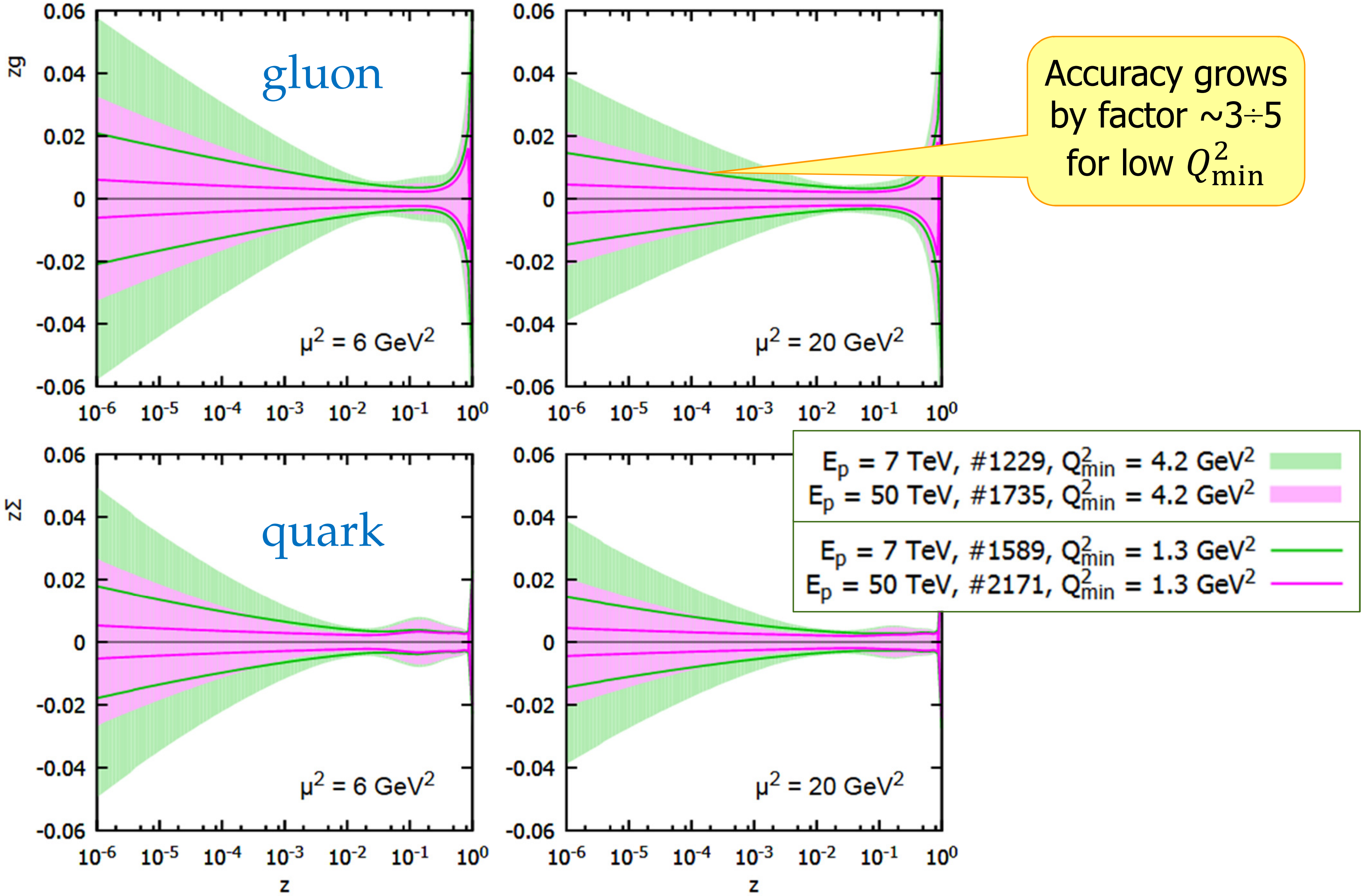


$Q^2_{\min} \approx 5\ \mathrm{GeV}^2$

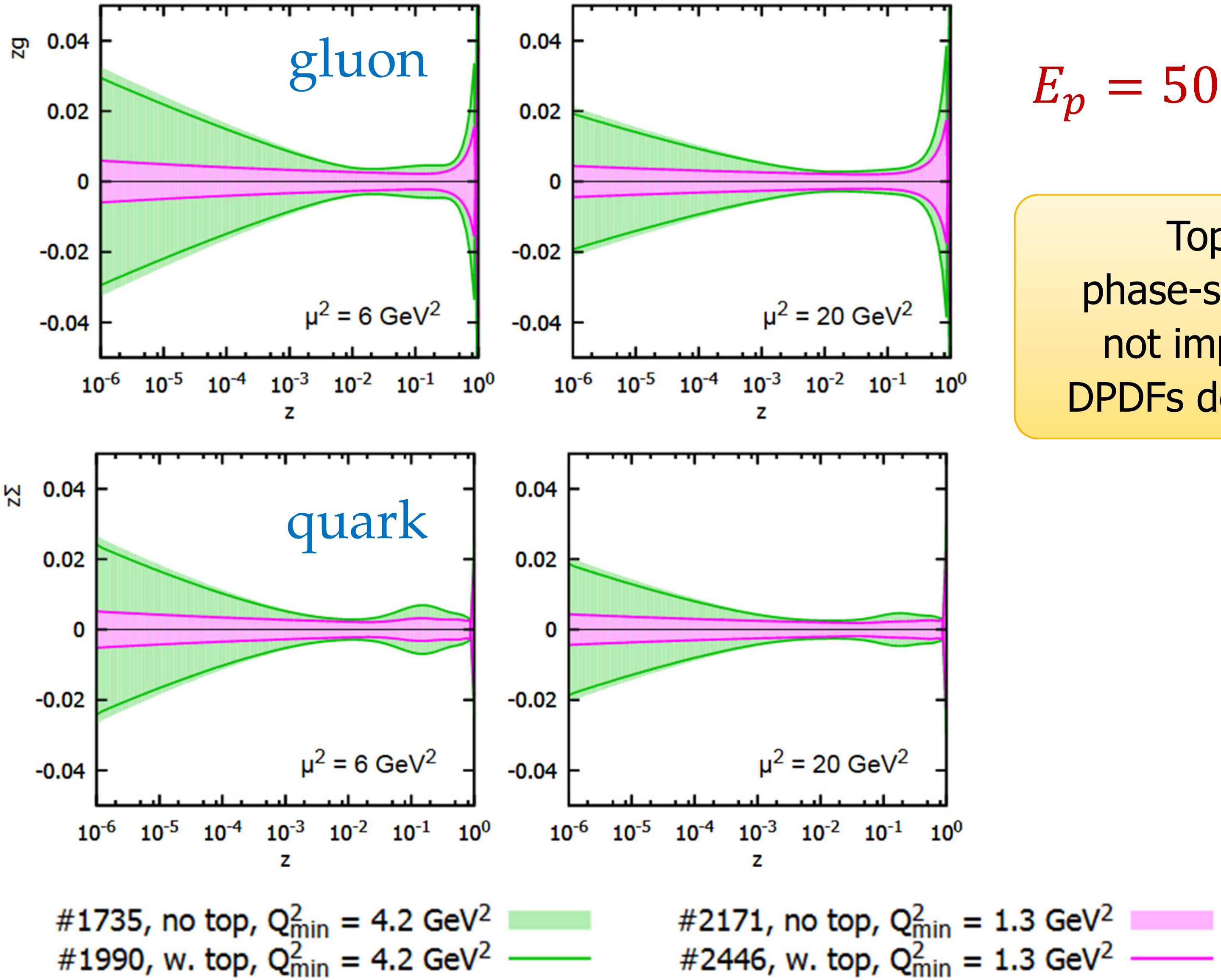
Accuracy increased by

- ✓ factor ~10 for LHeC
- ✓ factor ~20 for FCC-he

DPDFs accuracy vs. E_p and $Q^2_{\min}$



DPDFs accuracy — top quark contribution



$E_p = 50$ TeV

Top quark phase-space region not important for DPDFs determination

Summary & outlook

- Gluon determination possible from the inclusive data alone
- DPDFs measurement accuracy increased by
  - factor ~ 10 for LHeC
  - factor ~ 20 for FCC-he
- PDFs practically not sensible to the top quark region

TODO

- Fits with more free DPDFs parameters
- Higher twists, saturation
- D4 — *t*-dependence of DDIS cross-sections
- e-Pb DIS
- … … … …

THE END