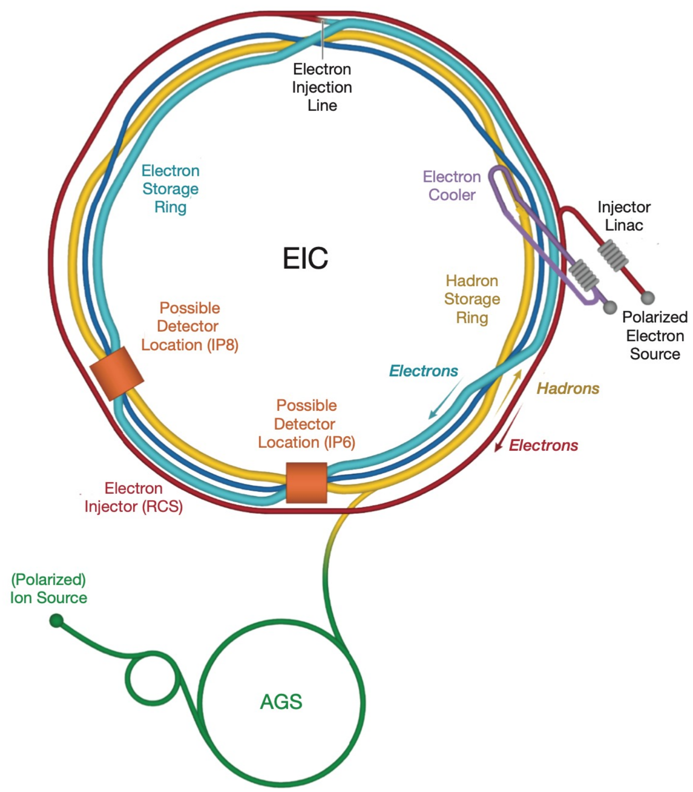


Small x and diffraction at the EIC

Anna Staśto
Penn State University

Outline

- **Small x**
  - EIC kinematics. Evolution equations DGLAP vs BFKL
  - Resummation at small x
  - Nonlinear evolution: parton saturation. Opportunities at EIC
- **Inclusive diffraction at EIC**
  - Longitudinal diffractive structure function
  - Extraction of Pomeron and Reggeon, estimate of uncertainties

What is EIC ?

EIC: Electron-Ion Collider facility that will be built at Brookhaven National Laboratory using and upgrading existing RHIC complex. Partnership between BNL and Jefferson Lab.

Capabilities of EIC

High luminosity $10^{33} - 10^{34} cm^{-2} s^{-1}$
(100-1000 times more than HERA)

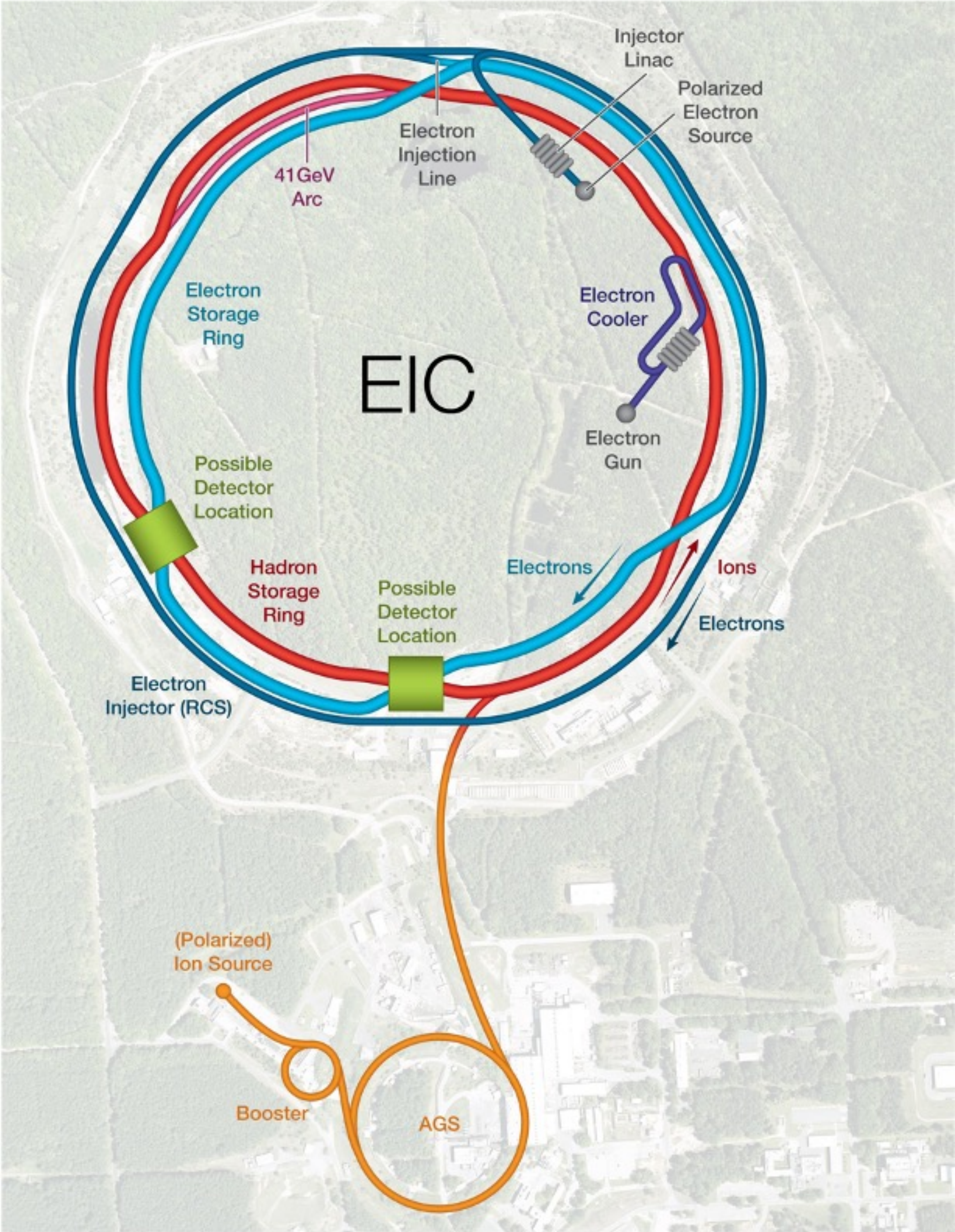
Variable center of mass energies 20 -140 GeV

Beams with different A: from light nuclei (proton) to the heaviest nuclei (uranium)

Polarized electron and proton beams.
Possibility of polarized light ions.

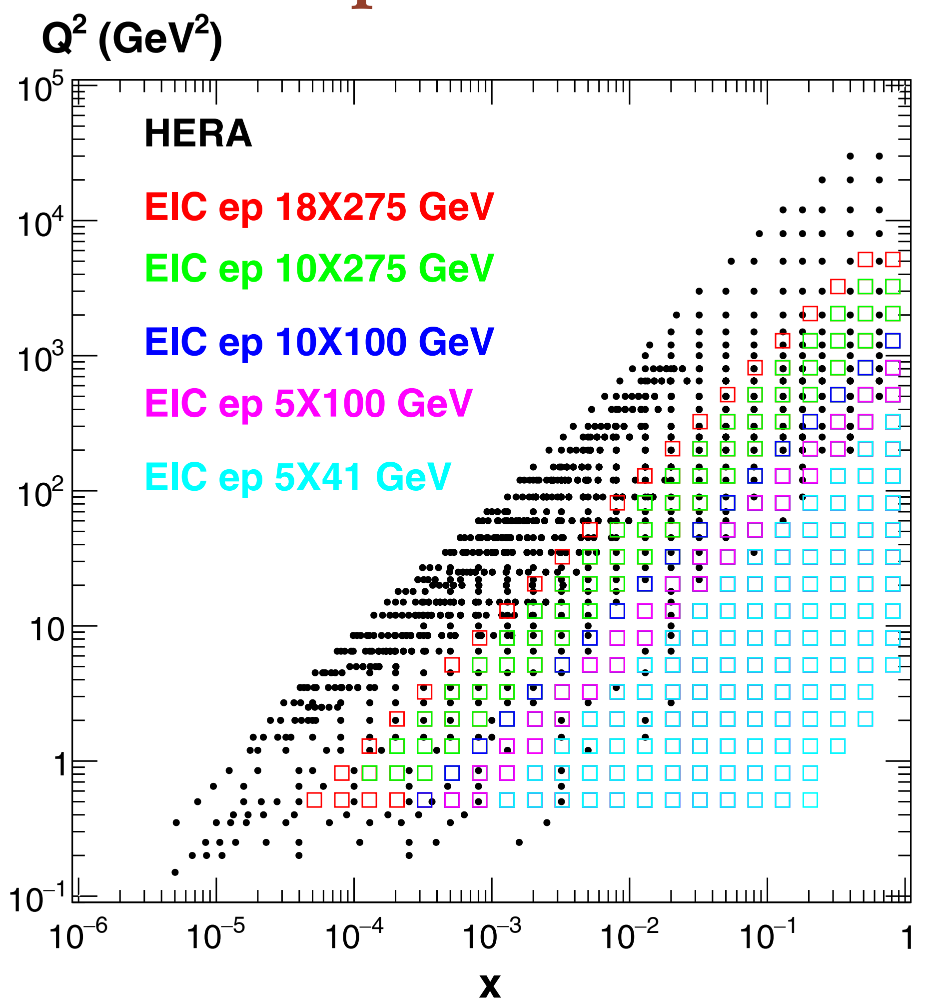
Dedicated forward instrumentation: proton tagging (essential for diffraction)

Up to two interaction regions

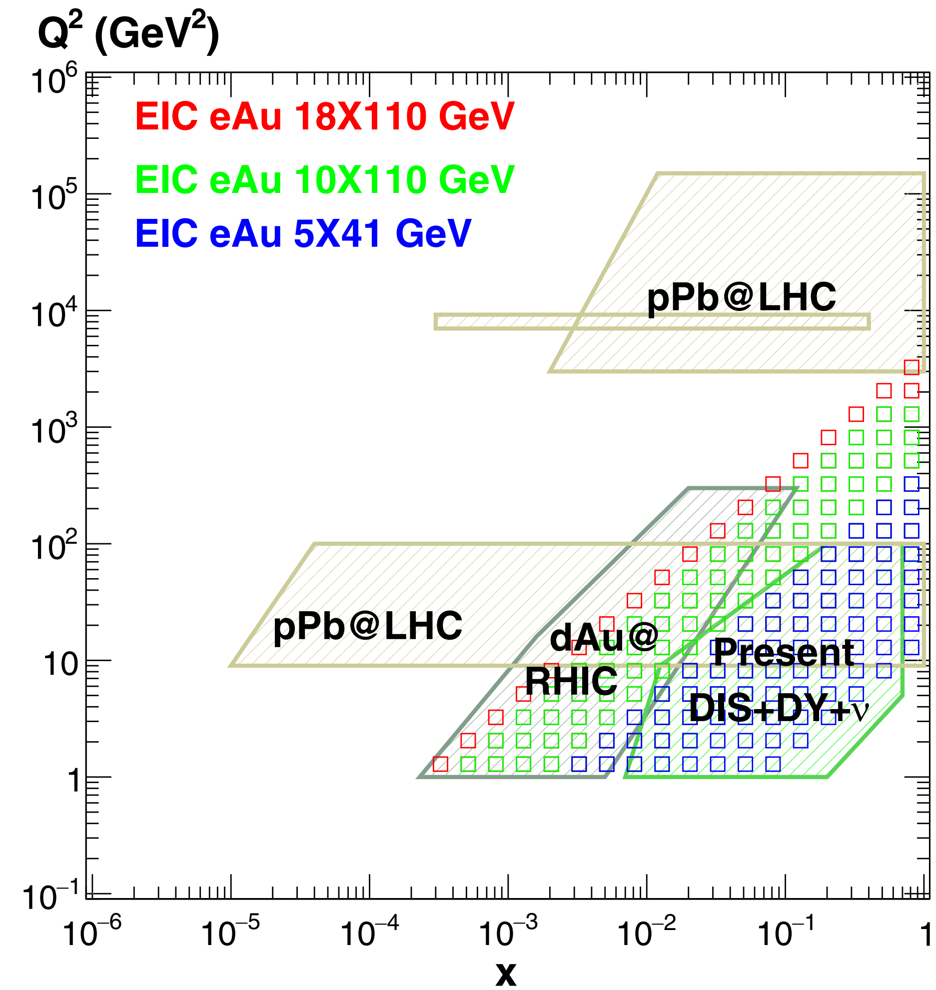


Kinematic range at EIC

proton



nucleus: Pb



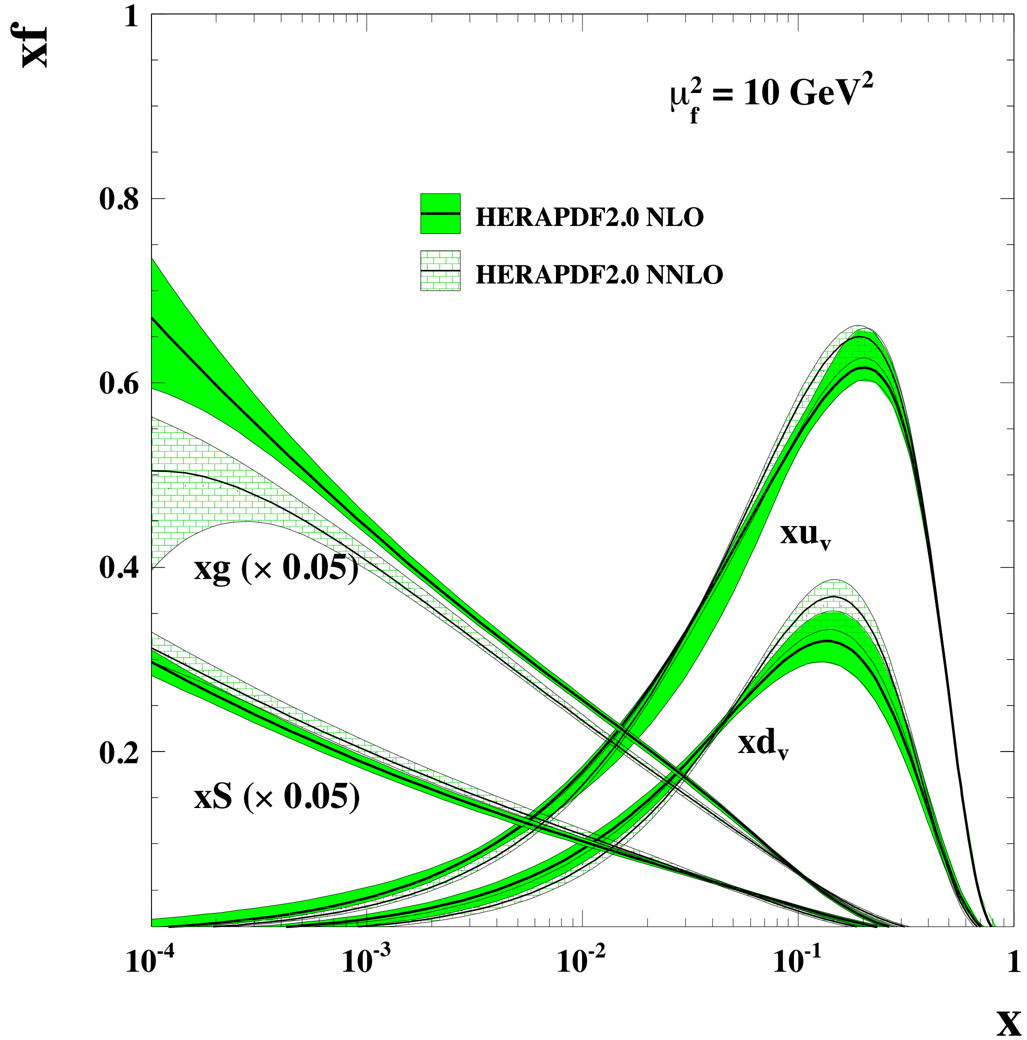
plots from : Armesto, Cridge, Giuli, Harland-Lang, Newman, Schmookler, Thorne, Wichmann

Proton: EIC kinematic range overlaps with HERA, extends to larger x

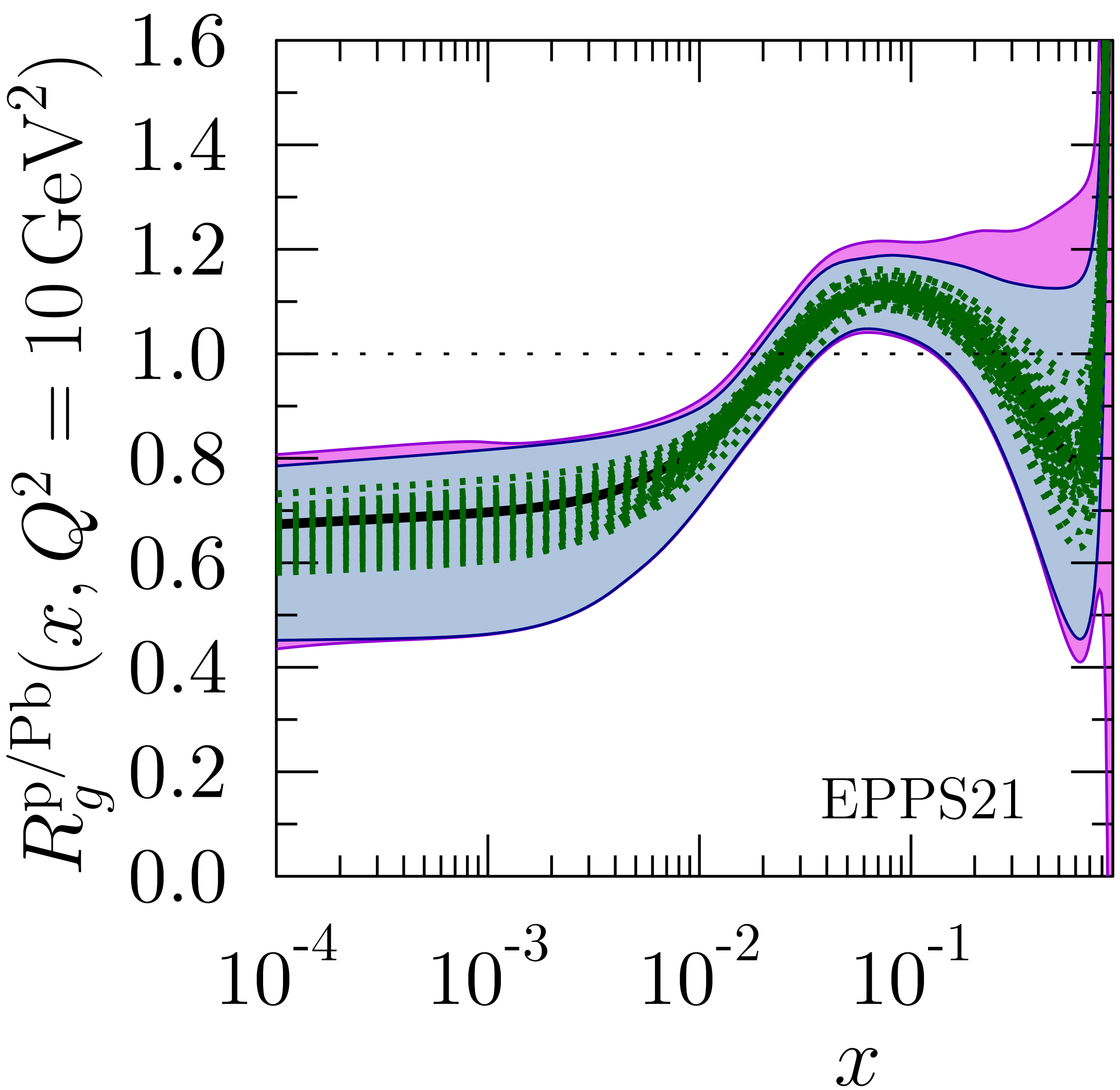
Nucleus: EIC the only DIS machine to extend down to small x

Gluon density in proton and nuclei

proton



nucleus: Pb



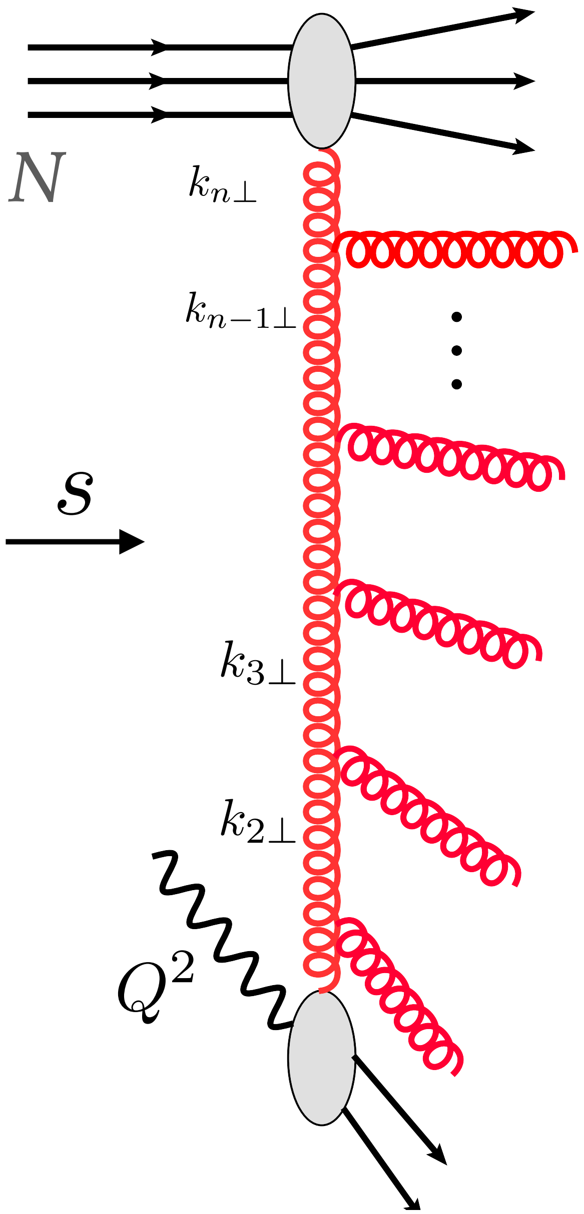
Gluon density dominates at small x
What happens at small x (high energy) ?
How nuclear environment modifies PDFs ?

$$x = \frac{Q^2}{Q^2 + W^2}$$

$$W^2 = s_{\gamma^* p}$$

Collinear limit and DGLAP evolution

$\gamma^* N$ as a template



Focusing on gluon emissions

Large parameter

$$Q^2 \to \infty$$

Probing small distances

Strong ordering in transverse momenta

$$Q^2 \gg k_{1\perp}^2 \gg k_{2\perp}^2 \gg k_{3\perp}^2 \cdots \gg k_{n\perp}^2$$

Collinear dynamics

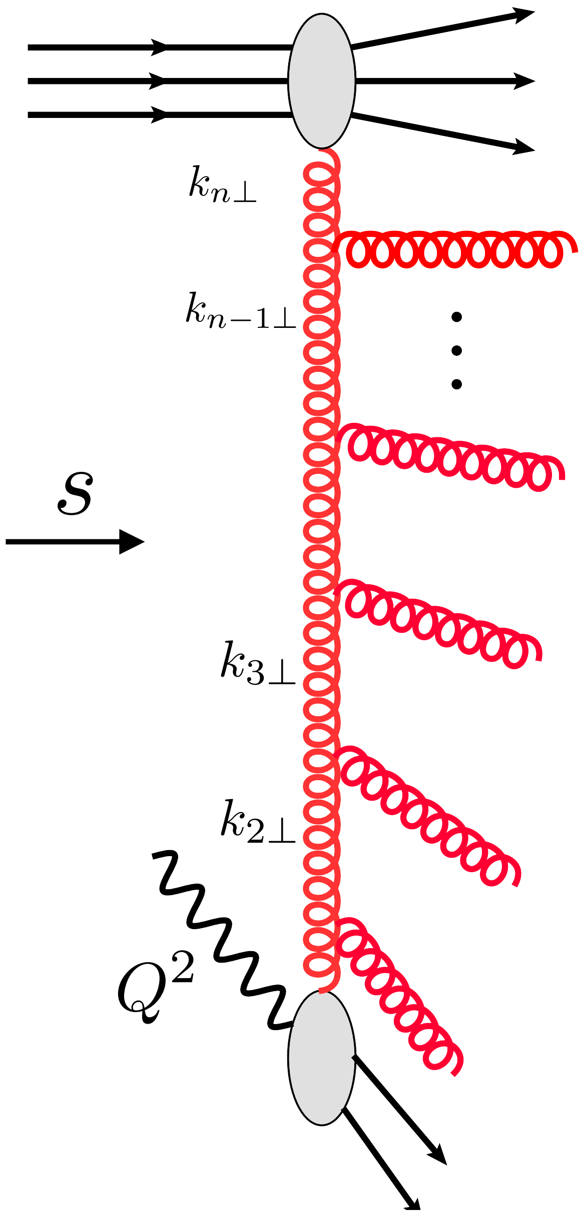
Resummation of large logarithms

$$\int_{\mu_0^2}^{Q^2} \frac{dk_{1\perp}^2}{k_{1\perp}^2} g^2 \int_{\mu_0^2}^{k_{1\perp}^2} \frac{dk_{2\perp}^2}{k_{2\perp}^2} g^2 \int_{\mu_0^2}^{k_{2\perp}^2} \frac{dk_{3\perp}^2}{k_{3\perp}^2} g^2 \cdots \int_{\mu_0^2}^{k_{n-1\perp}^2} \frac{dk_{n\perp}^2}{k_{n\perp}^2} g^2 \simeq \left(g^2 \log \frac{Q^2}{\mu_0^2} \right)^n$$

$$\alpha_s = \frac{g^2}{4\pi}$$

DGLAP evolution

Dokshitzer-Gribov-Lipatov-Altarelli-Parisi



DGLAP evolution equations for parton densities

$$\mu^2 \frac{\partial}{\partial \mu^2} \begin{pmatrix} q_i(x,\mu^2) \\ g(x,\mu^2) \end{pmatrix} = \sum_j \int_x^1 \frac{dz}{z} \begin{pmatrix} P_{q_i q_j}(z,\alpha_s) & P_{q_i g}(z,\alpha_s) \\ P_{g q_j}(z,\alpha_s) & P_{gg}(z,\alpha_s) \end{pmatrix} \begin{pmatrix} q_j(\frac{x}{z},\mu^2) \\ g(\frac{x}{z},\mu^2) \end{pmatrix}$$

q_j : quark density, g : gluon density

Splitting functions calculated perturbatively

$$P_{ab}(z,\alpha_s) \equiv P_{b\to a}(z,\alpha_s) = \frac{\alpha_s}{2\pi} P^{(0)}_{ab}(z) + \left(\frac{\alpha_s}{2\pi}\right)^2 P^{(1)}_{ab}(z) + \left(\frac{\alpha_s}{2\pi}\right)^3 P^{(2)}_{ab}(z) + \dots$$

LO NLO NNLO

Leading order splitting functions

$$P^{(0)}_{qq}(z) = C_F\left[\frac{1+z^2}{(1-z)_+} + \frac{3}{2}\delta(1-z)\right]$$

$$P^{(0)}_{qg}(z) = T_R\left[z^2 + (1-z)^2\right]$$

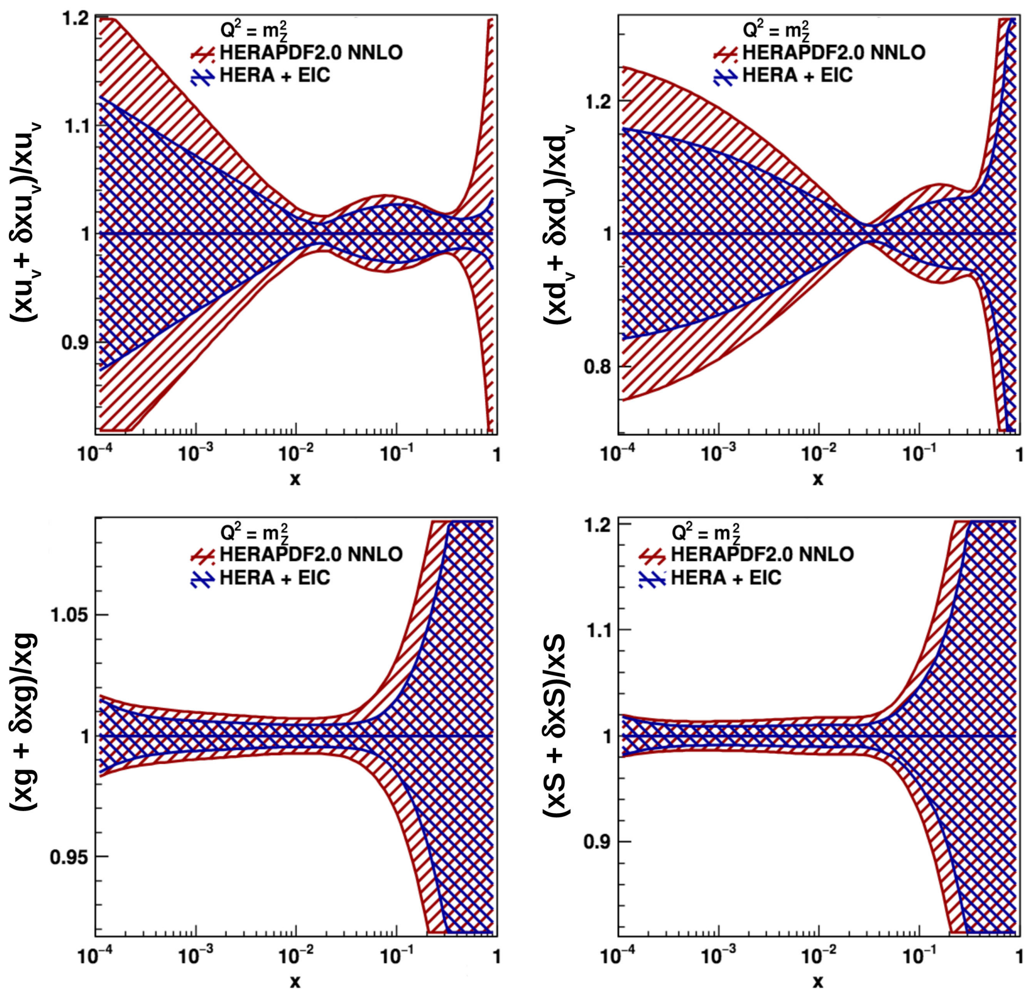
$$P^{(0)}_{gq}(z) = C_F\left[\frac{z^2 + (1-z)^2}{z}\right]$$

$$P^{(0)}_{gg}(z) = 2C_A\left[\frac{z}{(1-z)_+} + \frac{1-z}{z} + z(1-z) + \delta(1-z)\frac{11C_A - 4n_f T_R}{6}\right]$$

dominant at small z(x)

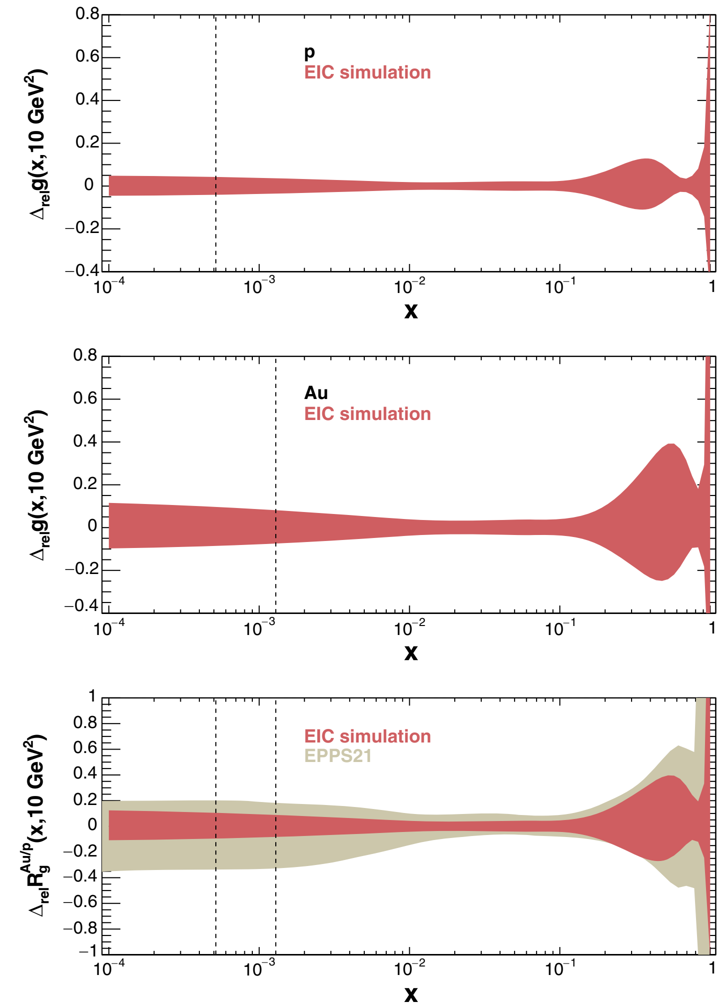
Impact of EIC on collinear PDFs

proton



nucleus: Au

Ratio

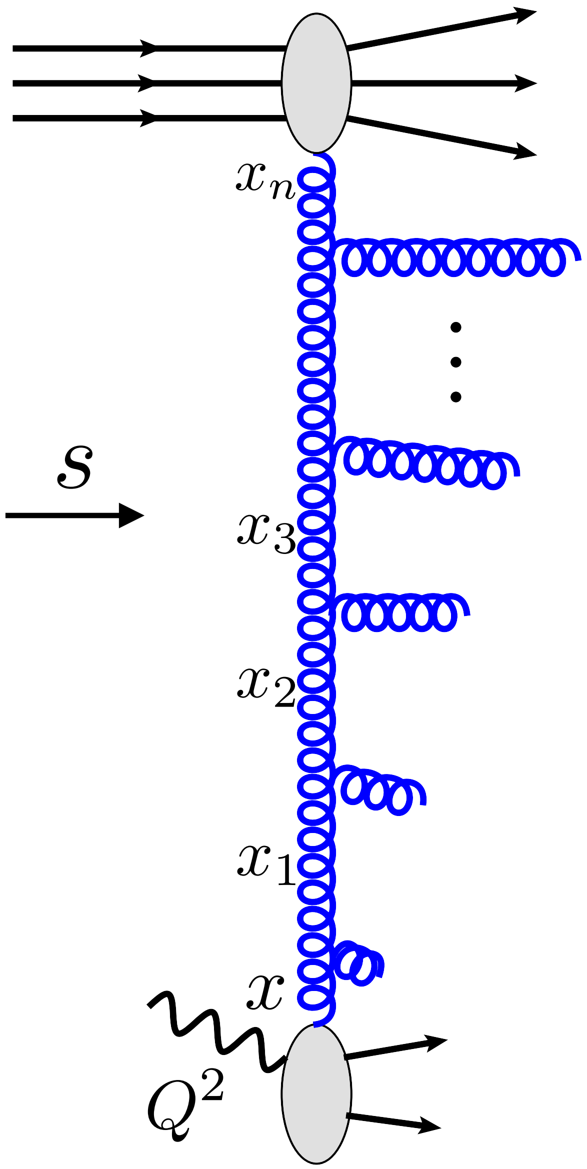


Armesto, Cridge, Giuli, Harland-Lang, Newman, Schmookler, Thorne, Wichmann

Proton : Combining HERA and EIC. EIC impact mostly large but also moderate and small x. Biggest changes in valence distribution (smaller impact on global analyses like MSHT20)

Nucleus: EIC has large impact at small x for all parton species

High energy / Regge / small Bjorken x limit



Large parameter

$s \to \infty$

High energy or Regge limit

$s \gg Q^2 \gg \Lambda^2$

Q^2 fixed, perturbative

Light cone proton momentum

$p^+ = p^0 + p^z \qquad k_i^+ = x_i p^+$

Strong ordering in longitudinal momenta

$x \ll x_1 \ll x_2 \ll \cdots \ll x_n$

Perturbative coupling but large logarithm

$\bar{\alpha}_s \ll 1 \qquad \ln \frac{1}{x} \simeq \ln \frac{s}{Q^2} \gg 1$

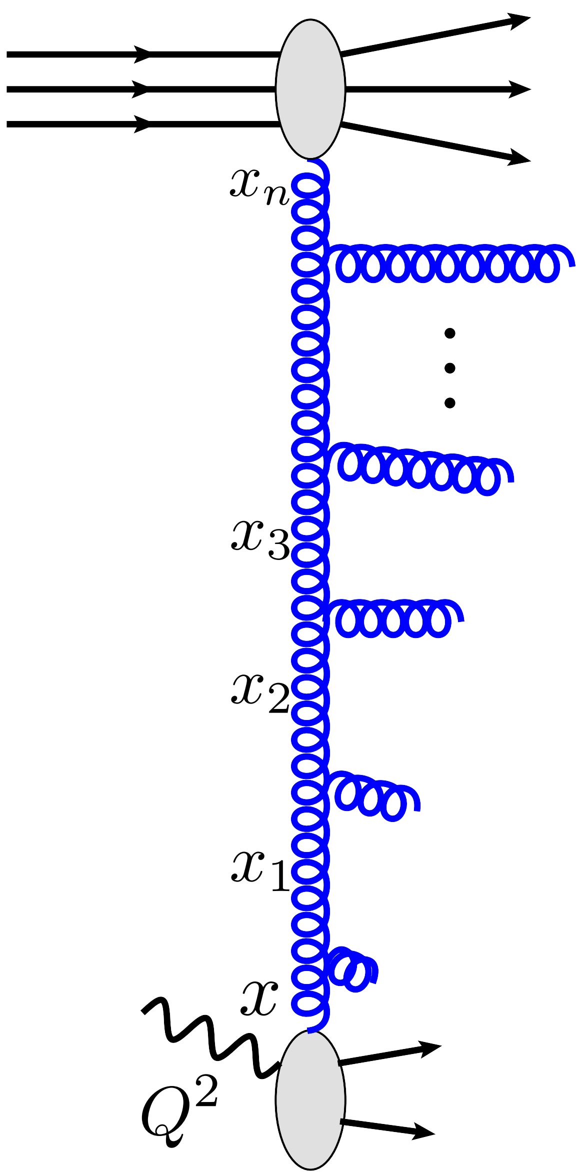
Large logarithms

$$\frac{\alpha_s N_c}{\pi} \int_x^1 \frac{dz}{z} = \frac{\alpha_s N_c}{\pi} \ln \frac{1}{x} = \bar{\alpha}_s \ln \frac{1}{x}$$

Leading logarithmic LL resummation

$$\left(\bar{\alpha}_s \ln \frac{1}{x}\right)^n \qquad \left(\bar{\alpha}_s \ln \frac{s}{s_0}\right)^n$$

High energy / Regge / small Bjorken x limit



compare with DGLAP-collinear approach

Resummation performed by BFKL evolution equation

Balitskii, Fadin, Kuraev, Lipatov

$$\frac{\partial}{\partial \ln 1/x} f_g(x, \boldsymbol{k}) = \int d^2\boldsymbol{k}' \, K(\alpha_s, \boldsymbol{k}, \boldsymbol{k}') \, f_g(x, \boldsymbol{k}')$$

Branching kernel (perturbative expansion)

$$K(\alpha_s, \boldsymbol{k}, \boldsymbol{k}') = \alpha_s K_0(\boldsymbol{k}, \boldsymbol{k}') + \alpha_s^2 K_1(\boldsymbol{k}, \boldsymbol{k}') + \mathcal{O}(\alpha_s^3)$$

QCD: LL, NLL sYM: LL, NLL, NNLL

unintegrated (transverse momentum dependent) gluon density $f_g(x, \boldsymbol{k})$

$$\frac{\partial f_i(x, Q^2)}{\partial \log(Q^2)} = \sum_j \int_x^1 \frac{dz}{z} P_{j \to i}(z) f_j(\frac{x}{z}, Q^2)$$

$f_j(x, Q^2)$ **integrated (collinear)** parton distribution function (PDF)

BFKL at NLL

$$\frac{\partial}{\partial \ln 1/x} f_g(x, \boldsymbol{k}) = \int d^2\boldsymbol{k}' \, K(\alpha_s, \boldsymbol{k}, \boldsymbol{k}') \, f_g(x, \boldsymbol{k}')$$

NLL corrections to BFKL $K = \alpha_s K_0 + \alpha_s^2 K_1 + \ldots$

Fadin, Lipatov
Camici, Ciafaloni

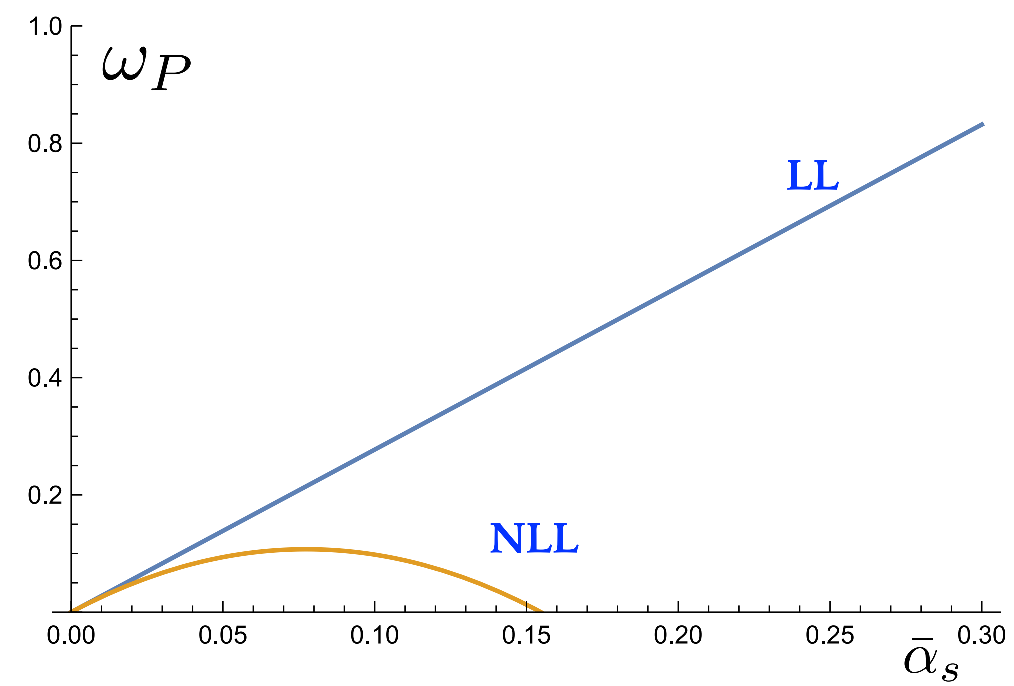
$$\omega_P \simeq \overline{\alpha}_s 4 \ln 2 (1 - 6.5 \overline{\alpha}_s)$$

$$\overline{\alpha}_s = \frac{\alpha_s N_c}{\pi}$$

NLL corrections to BFKL equation are **large** and **negative**

Main sources:

- **running coupling**
- **kinematical effects**
- **DGLAP anomalous dimension**



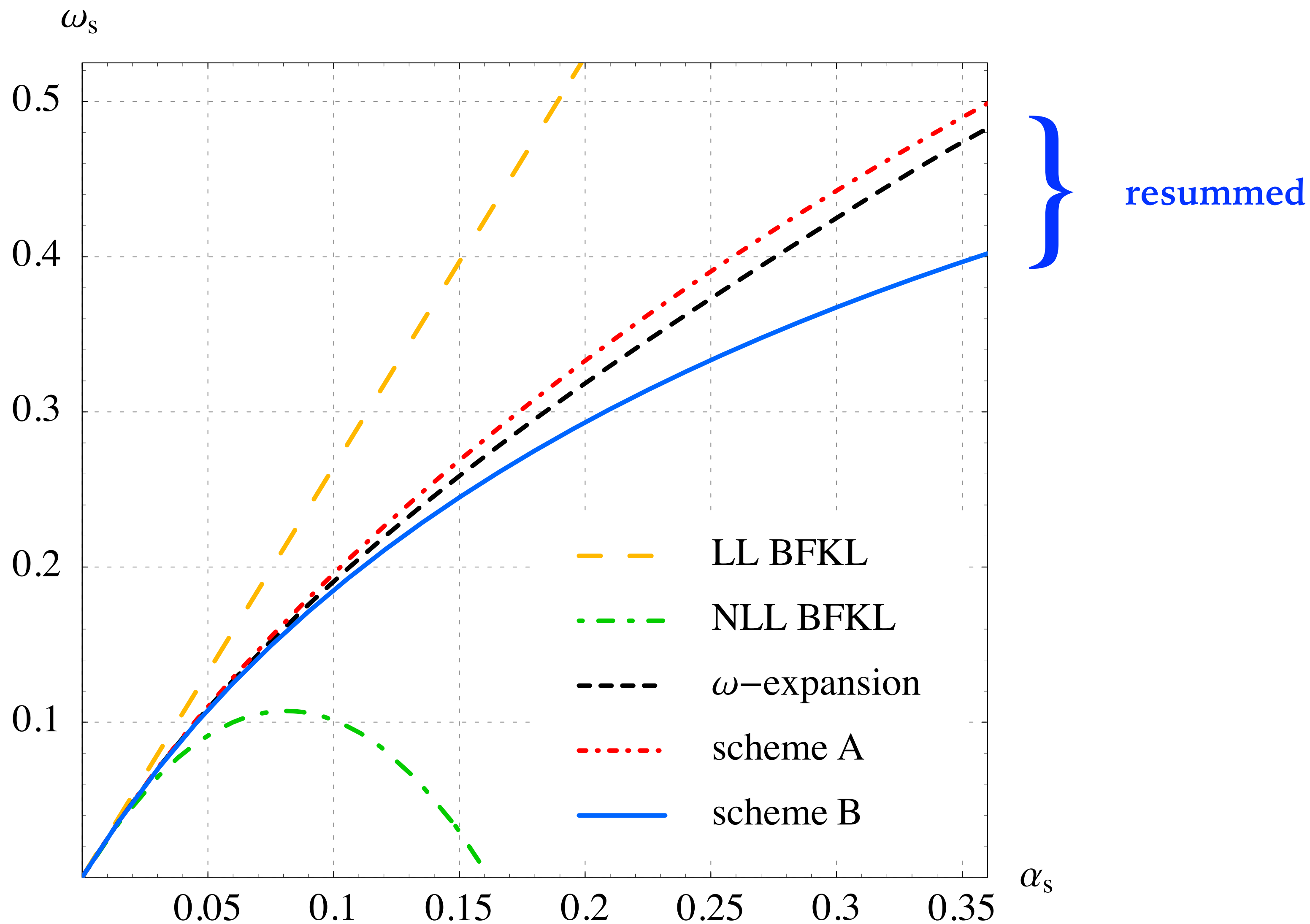
Need resummation at small x !

Ciafaloni, Colferai, Salam, AS
Altarelli, Ball, Forte; Thorne, White; Sabio Vera

Resummation at small x

Ciafaloni, Colferai, Salam, AS

- Include **kinematical constraint: limits on transverse momenta, resum double transverse logarithms**
- Include DGLAP **splitting function** and **running coupling** in the leading part
- **S**ubtractions to avoid double counting, guarantee **momentum sum** rule
- The **integro-differential** equation becomes double integral equation
- **Transverse** and **longitudinal** momenta no longer factorized



Resummation stabilizes the BFKL expansion

Intercept, and therefore the resulting growth with 1/x is slowed down

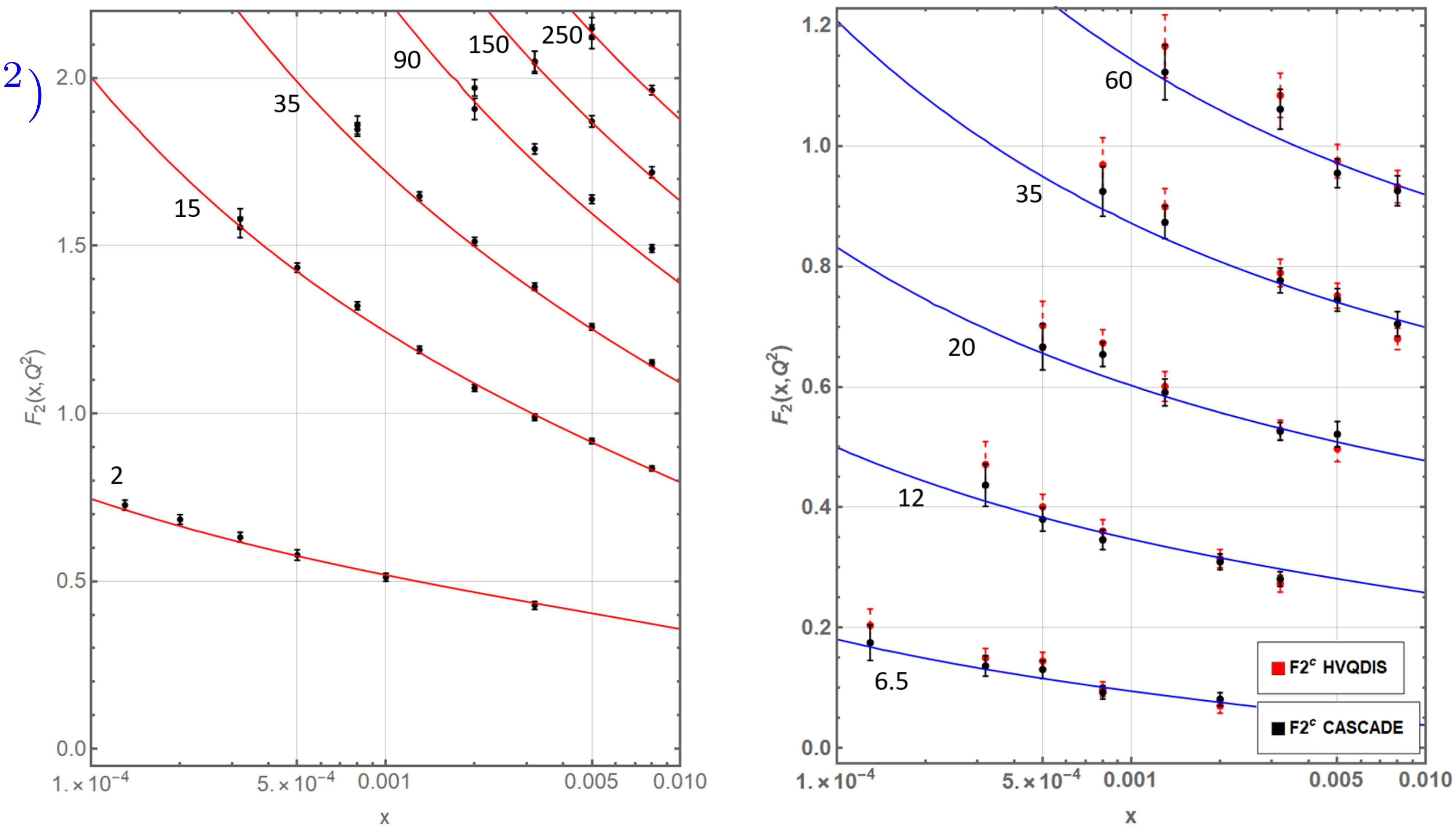
Strong preasymptotic effects. Need DGLAP terms with BFKL

More consistent with phenomenology

Resummation at small x : phenomenology

Example : structure functions at HERA

$F_2(x, Q^2)$



$F_2^c(x, Q^2)$

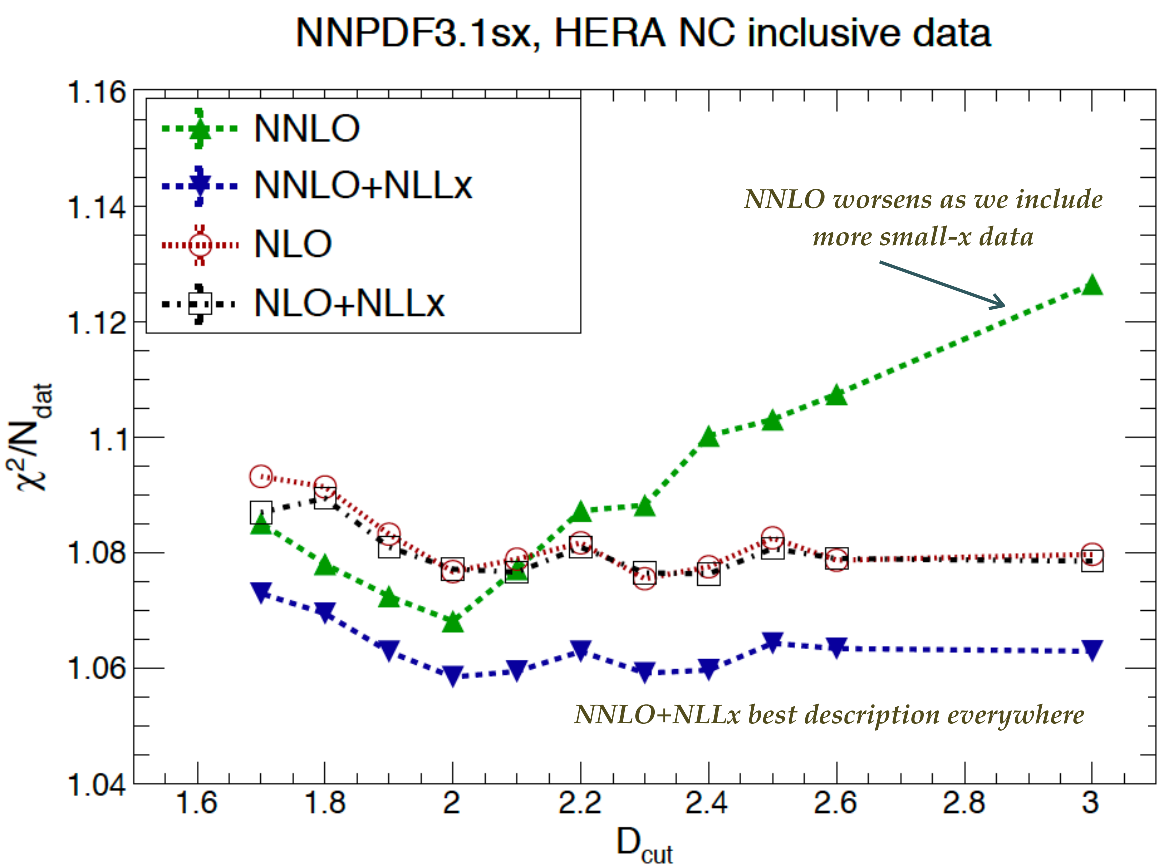
Li, AS

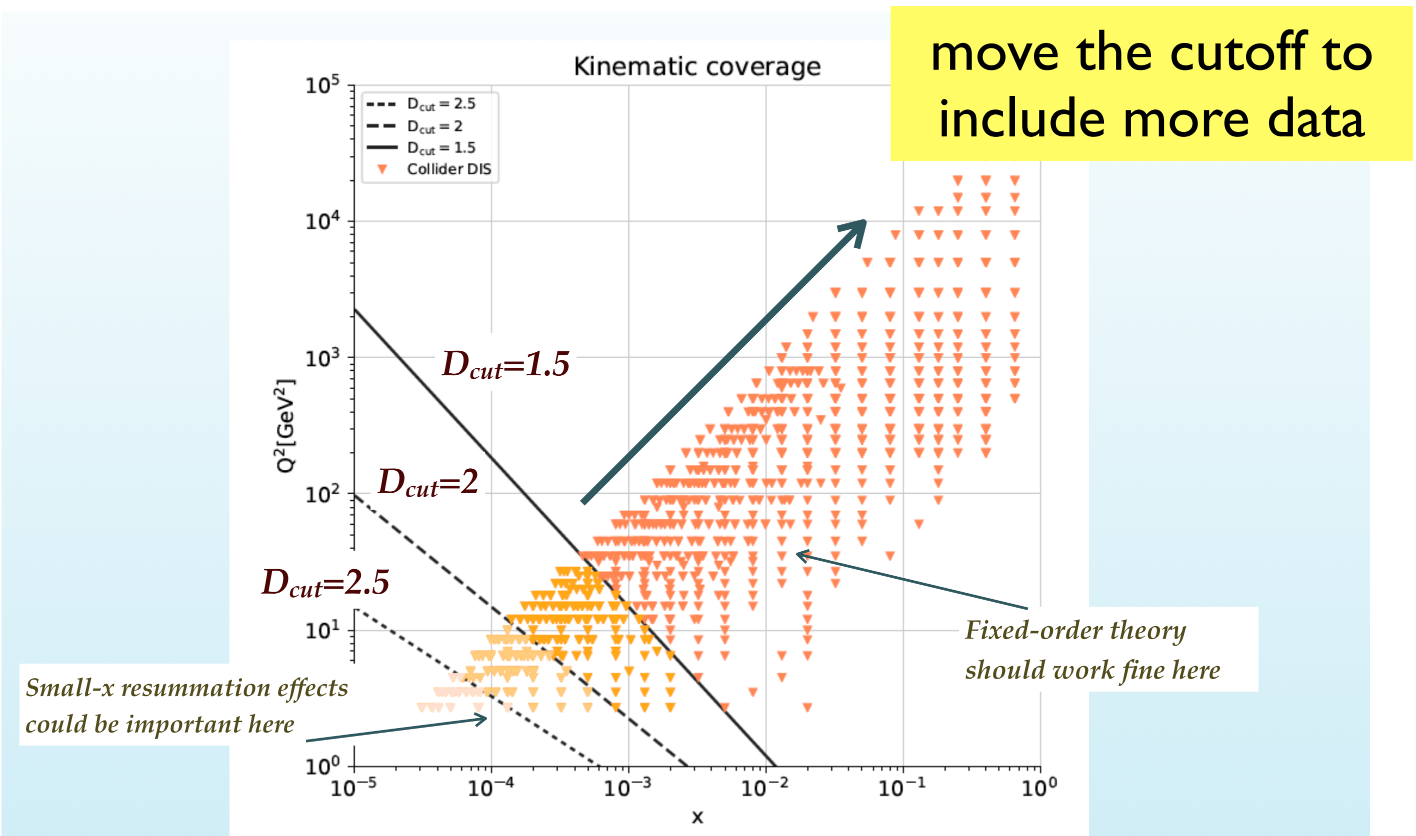
- Application of the CCSS resummation to phenomenology of deep inelastic scattering
- Very good simultaneous description of F_2, F_2^c at small x

Evidence for BFKL at HERA ?

Ball,Bertoni,Bonvini,Marzani,Rojo,Rottoli

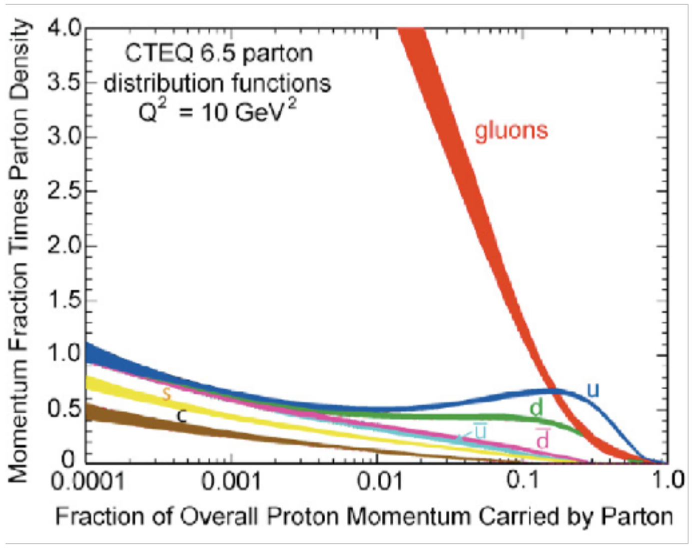
- Used small x resummation method of *Altarelli, Ball, Forte*
- Perform fits to data with the **cut** on small x/small Q region
- Observe the variation or lack of variation in χ^2





- χ^2changes for DGLAP at NNLO at **low x**
- **NNLO+NNLLx** gives **best** description
- Interestingly NLO and NLO+NLLx do not differ by a lot (flat splitting function at NLO?)
- **Resummation important for consistent description from large to small x**

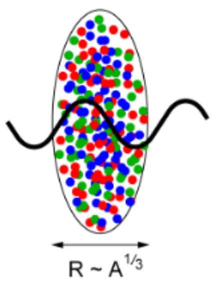
Another small x problem: saturation



Does the rise of gluon $xg(x, Q^2)$ get tamed?

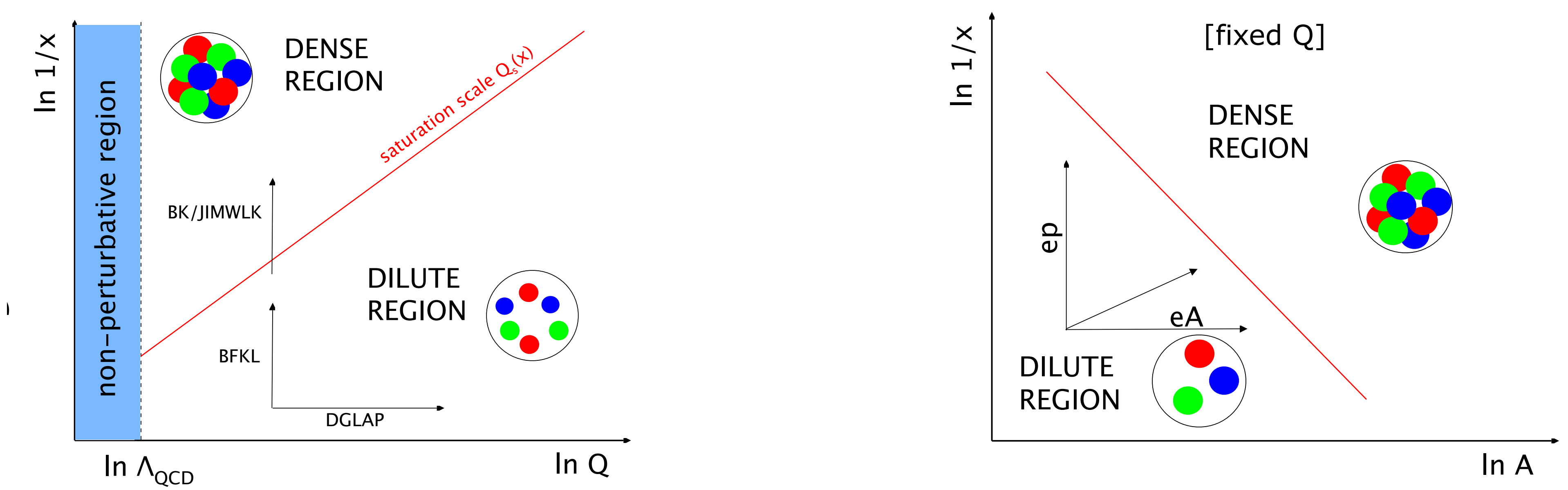
Important to understand for initial conditions in heavy ion collisions

Probe interacts coherently with nucleons



QCD at high energy (low x) and/or high density (large A) predicts **saturation** of gluons

$$Q_s^2(x, A) \sim \frac{A^{1/3}}{x^\lambda}$$



Nuclei provide enhancement of the density : opportunities to test saturation at EIC

Testing saturation through inclusive structure functions at EIC

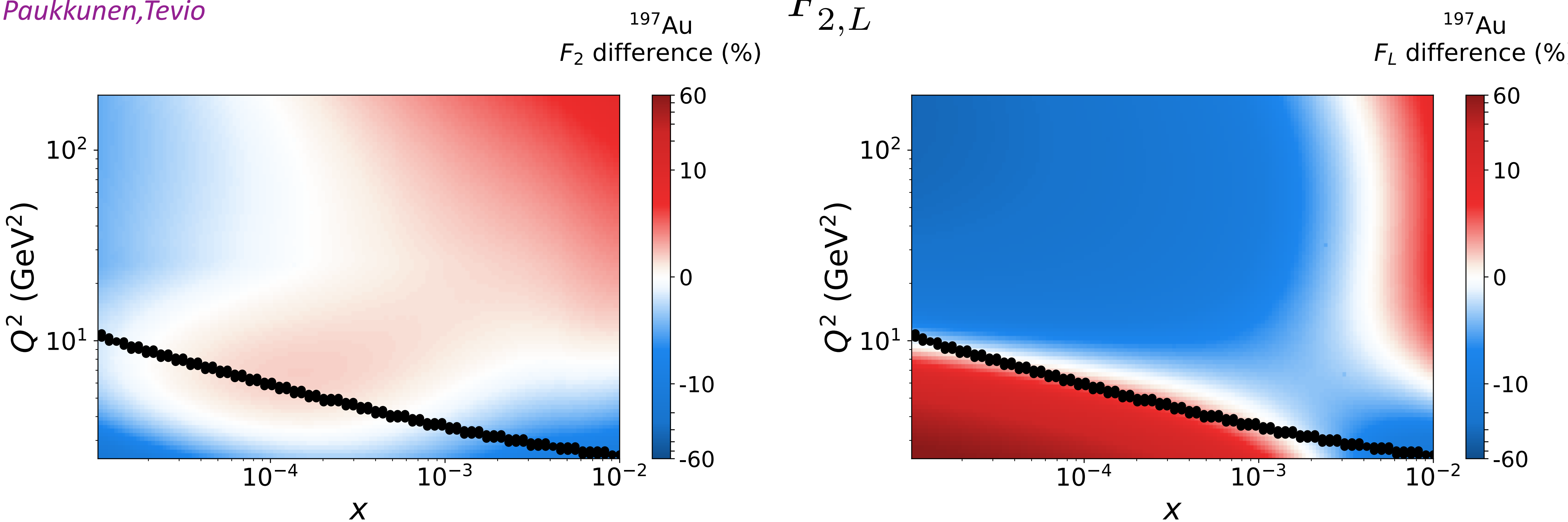
Study differences in evolution between **linear DGLAP** evolution and **nonlinear** evolution with **saturation**

Matching of both approaches in the region where saturation effects expected to be small

Quantify differences away from the matching region: **differences in evolution dynamics**

Armesto, Lappi,Mantysaari, Paukkunen,Tevio

$$\frac{F_{2,L}^{\rm BK} - F_{2,L}^{\rm Rew}}{F_{2,L}^{\rm BK}}$$



Heavy nucleus: difference between DGLAP and nonlinear are few % for F_2^A and up to 20% for F_L^A.

Longitudinal structure function can provide good sensitivity at EIC

Diffraction at EIC

- **Simulations of $F_L^{D(3)}$ for EIC**
  - Motivation: why is $F_L^{D(3)}$ interesting ? H1 measurement
  - Pseudodata simulation, energy beam scenarios. Extraction of $F_L^{D(3)}$
- **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

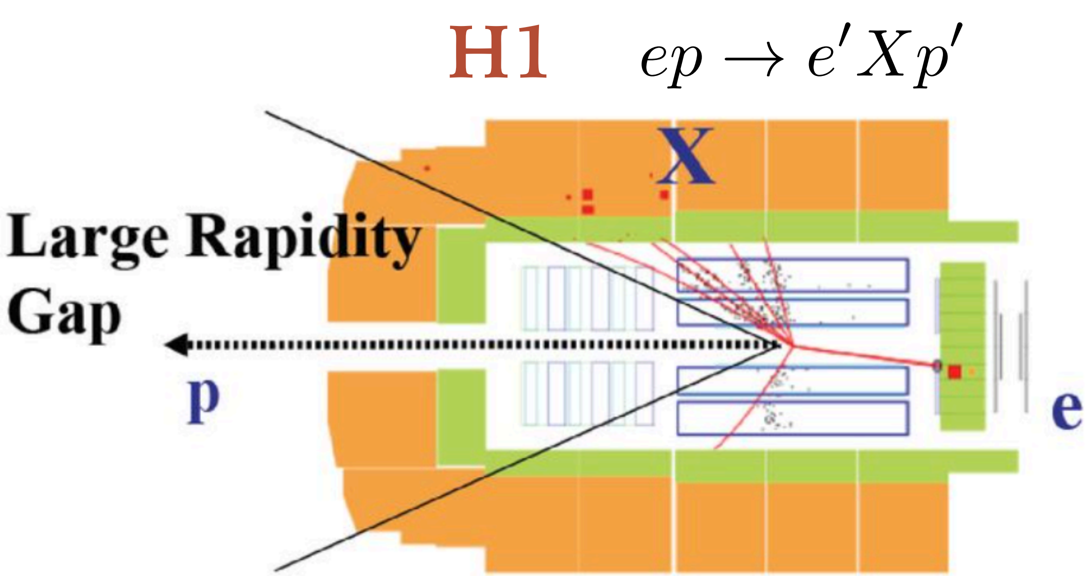
Extracting the partonic structure of colorless exchanges at Electron Ion Collider e-Print: 2406.02227

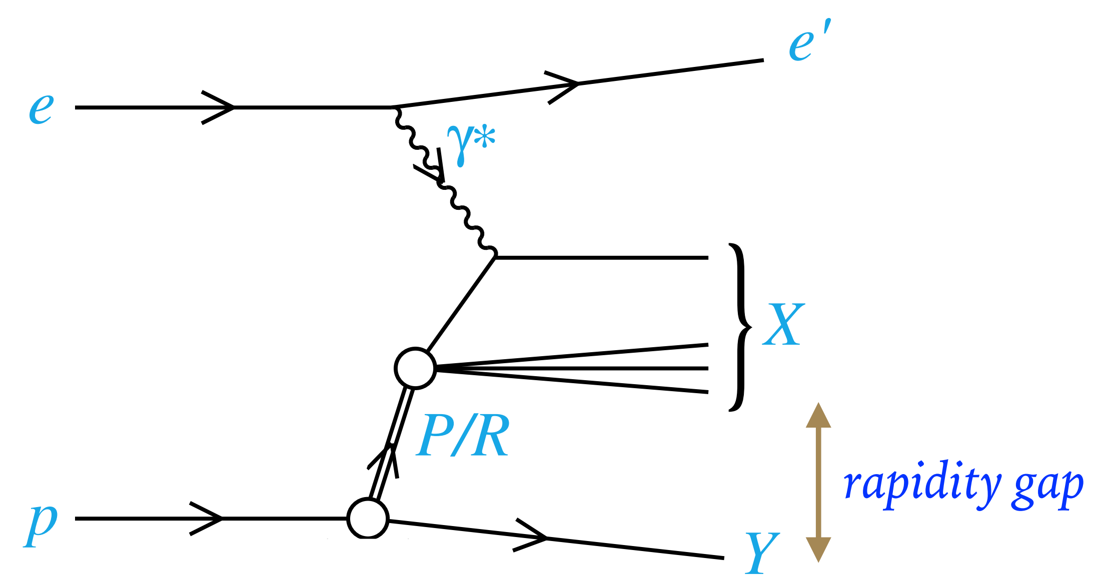
also EIC Yellow Report, Sec. 7.1.6, 8.5.7

Armesto, Newman, Słomiński, Staśto

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**

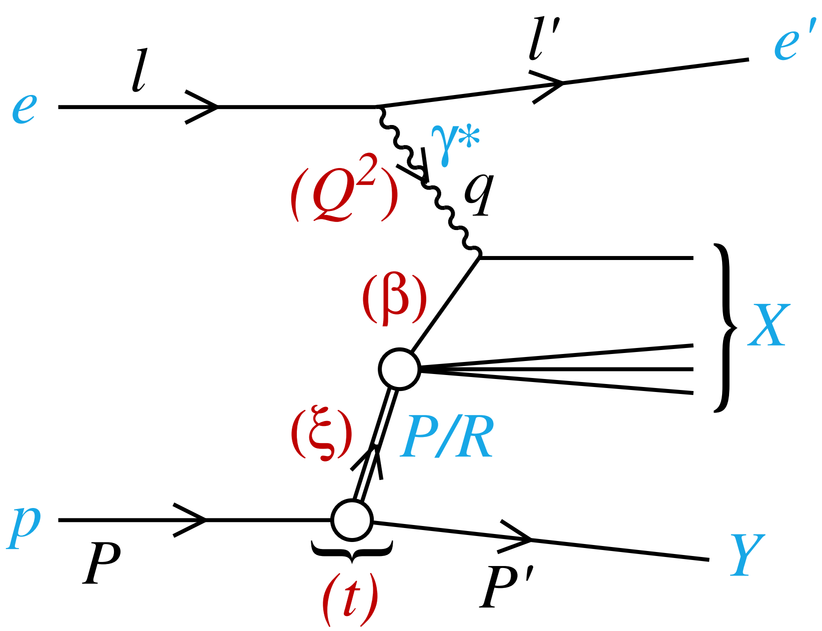




Questions:

- 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



$$x = \xi\beta$$

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 (ξ, β, 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

Phase space (x,Q^2) EIC–HERA

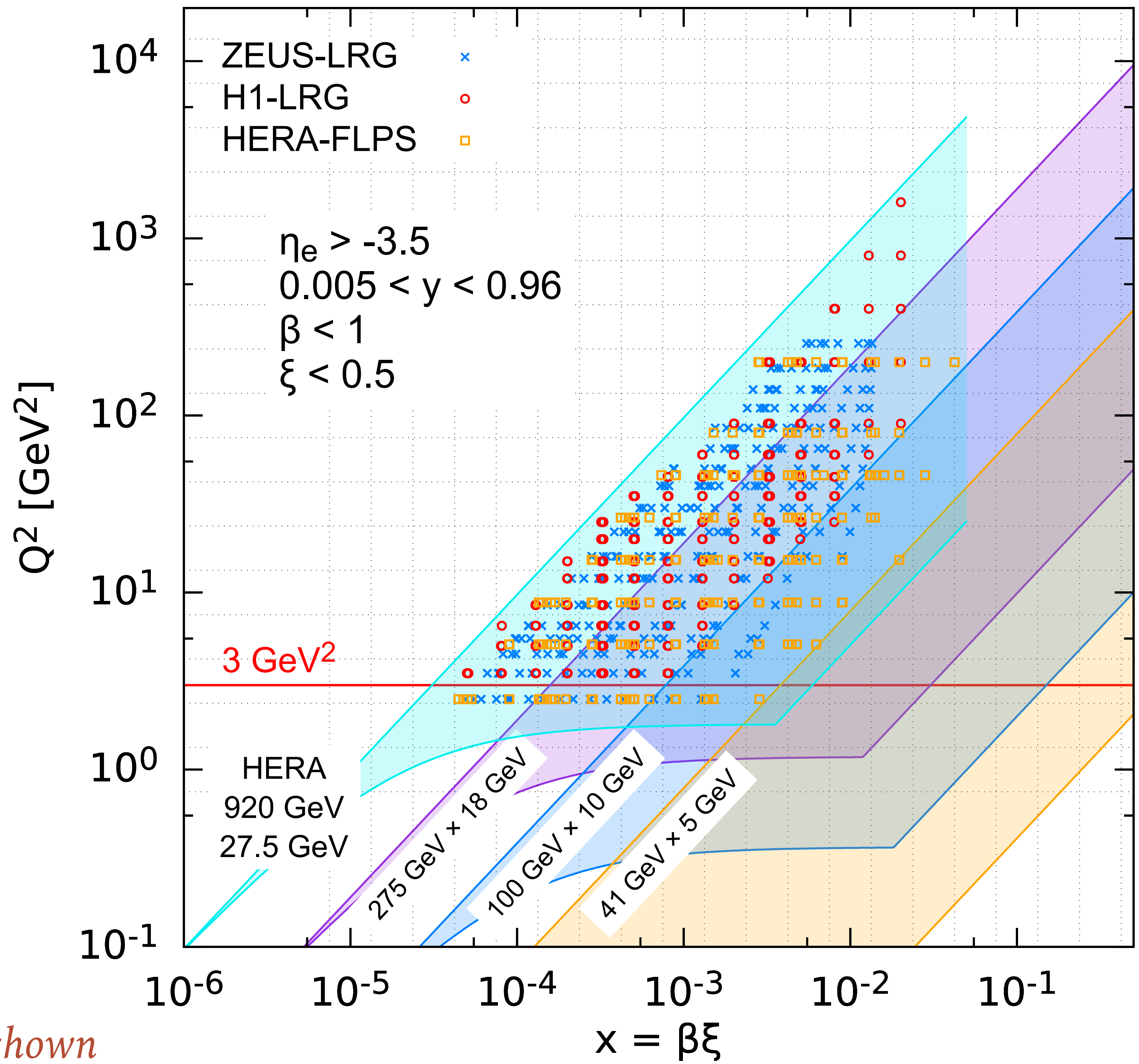
EIC can operate at various energy combinations

Can cover wide range of x

Large instantaneous luminosity

Statistics should not be a limiting factor

EIC 3 scenarios - HERA



Only selected energy scenarios at EIC shown

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

Why F_L^D 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**

Experimentally challenging…

Measurement requires several beam energies

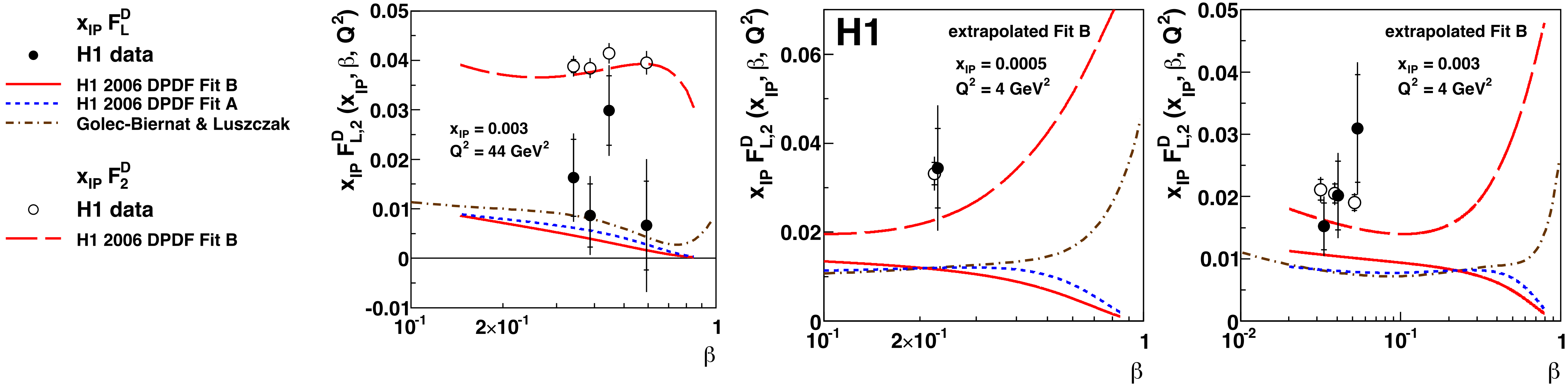
F_L^D strongest when $y \to 1$. Low electron energies

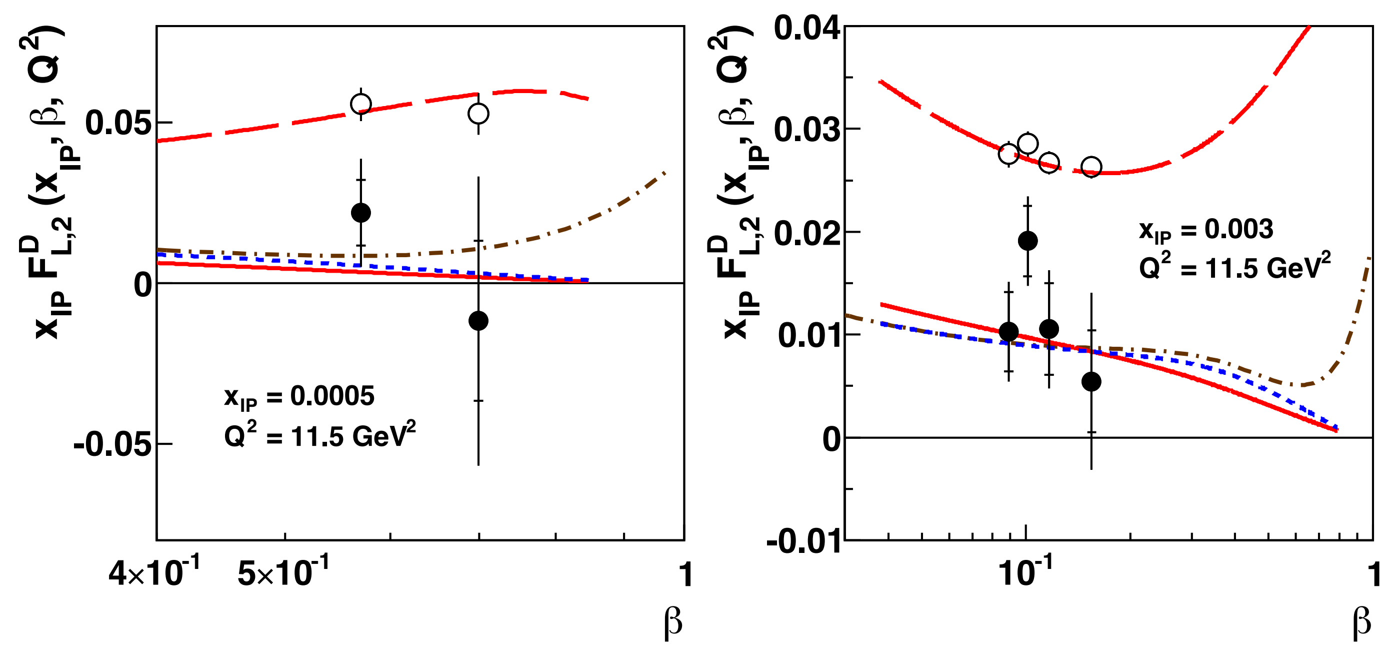
H1 measurement: 4 energies, E_p=920, 820, 575, 460 GeV, electron beam E_e=27.6 GeV

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





H1 conclusions:

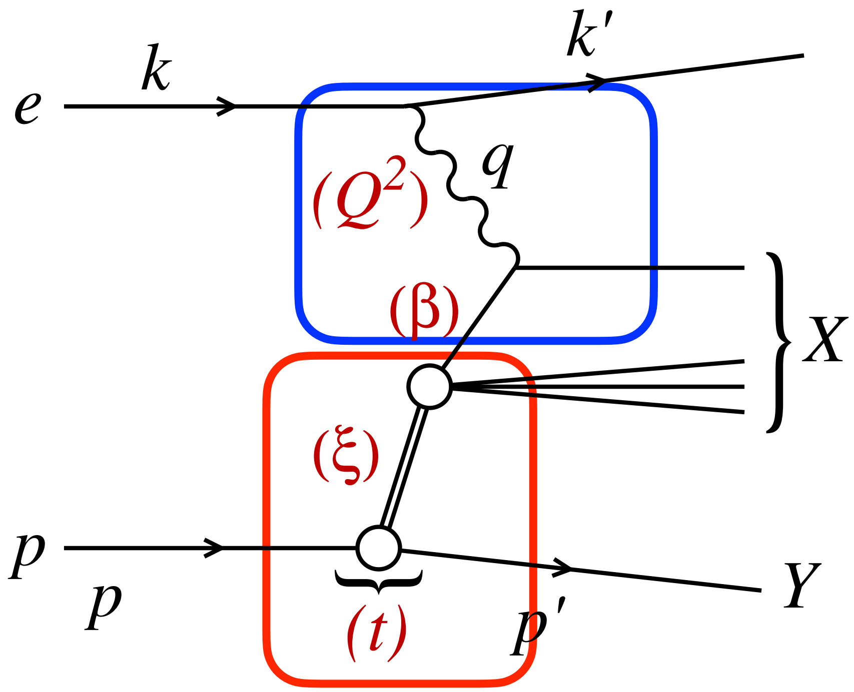
Measurements of σ_r^D consistent with predictions from the models

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

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

Pseudodata generation: collinear factorization for diffraction

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



Collins

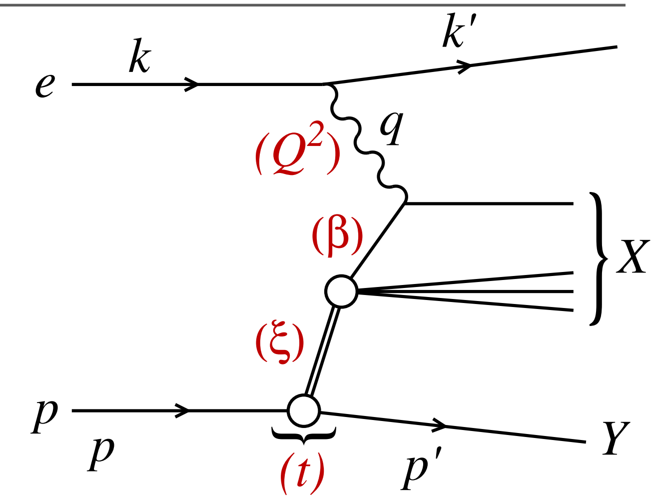
Collinear factorization in diffractive DIS

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

- 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
- (β(or z), Q^2) dependence in parton distribution of diffractive exchange factorized from flux factors with (t, ξ) dependence
- Dominant term **'Pomeron'**, at low ξ
- At higher ξ 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

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

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,Q^2)

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**

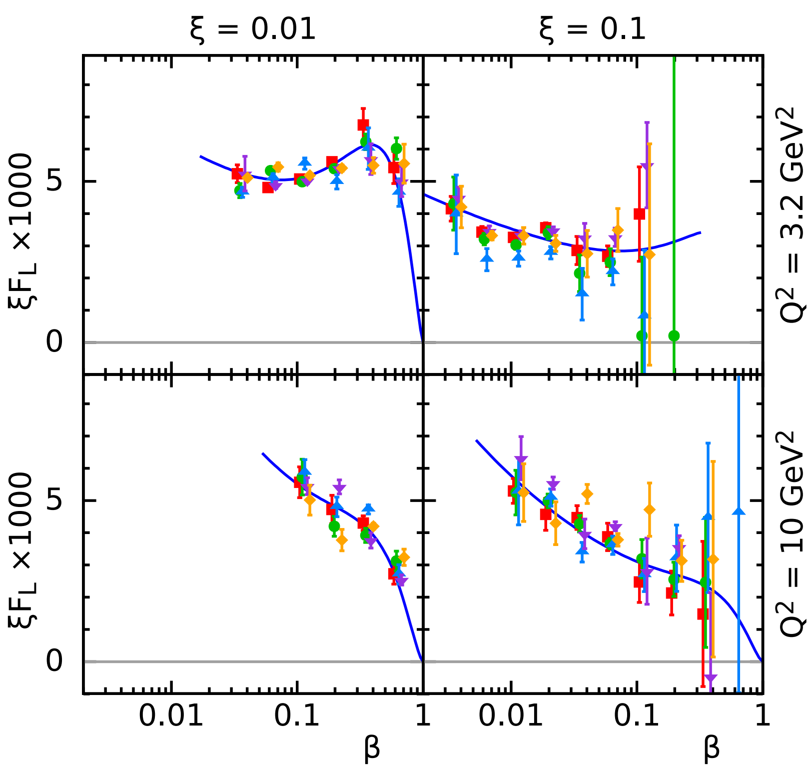
S-17 all 17 combinations

S-9 **9 - bold red**

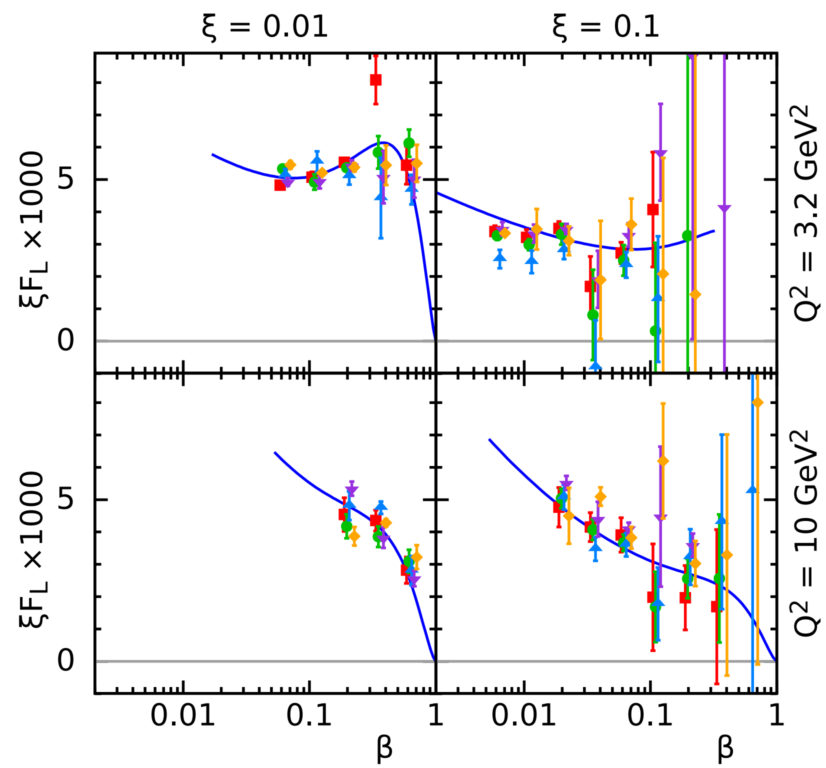
S-5 5 - green (EIC preferred)

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

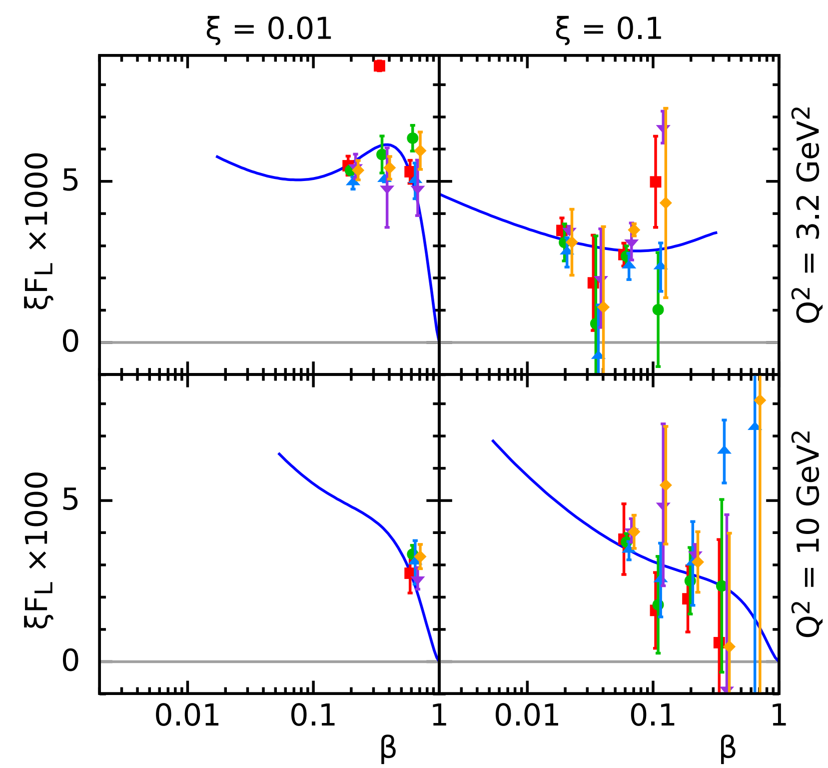
Uncorr. systematic error 1%, 5 MC samples to illustrate fluctuations



17 energies



9 energies



5 energies

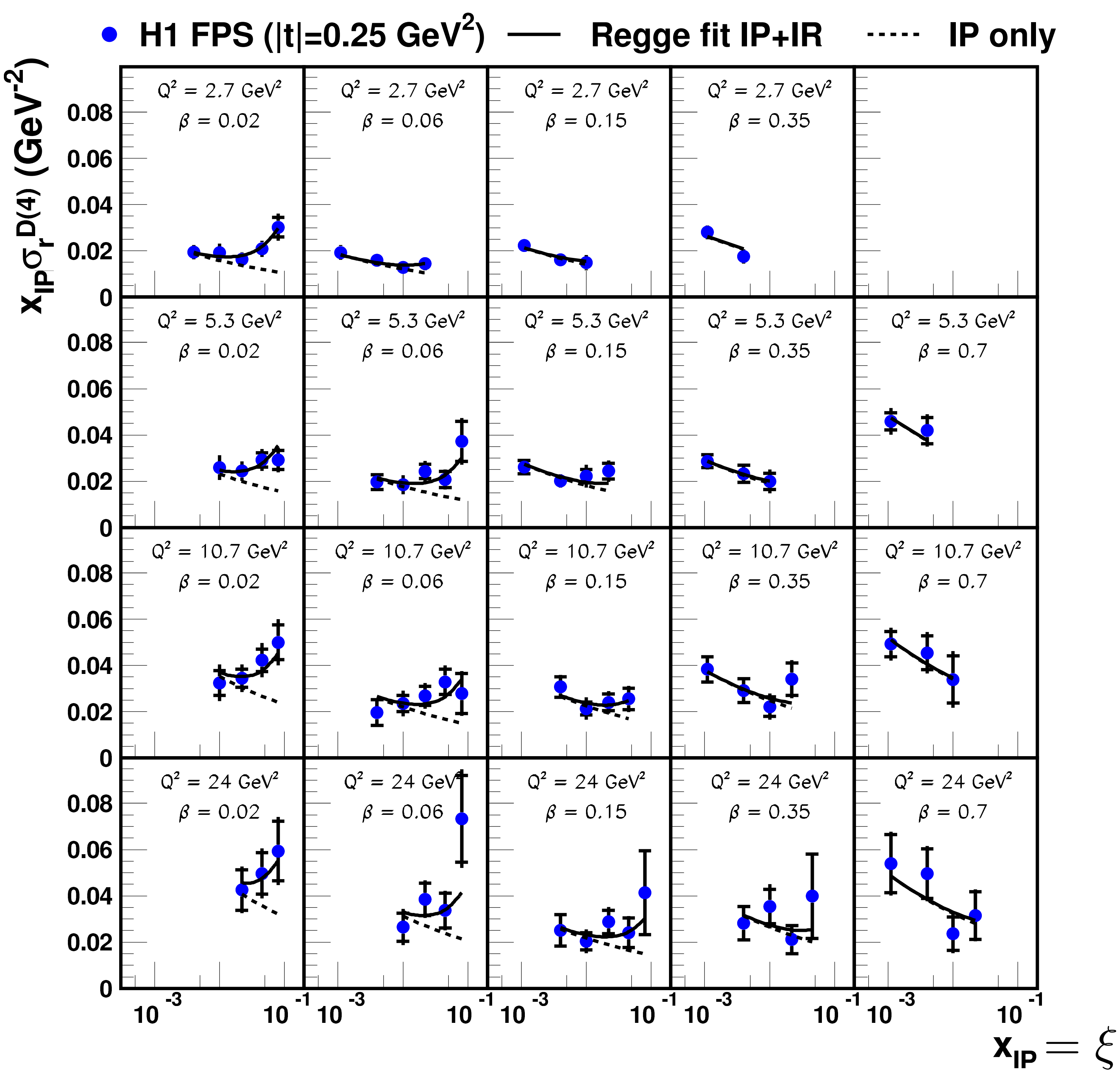
Small differences between S-17 and S-9, small reduction to range and increase in uncertainties.

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

Diffraction at HERA: importance of 'Reggeon'

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



Described by two contributions:

Leading 'Pomeron' at low ξ

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

Subleading 'Reggeon' at high ξ

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

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:

$$\alpha_{\mathbb{M}}(t) = \alpha_{\mathbb{M}}(0) + \alpha'_{\mathbb{M}}\, t$$

$\mathbb{M} = I\!P, I\!R$

Reduced cross section:

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

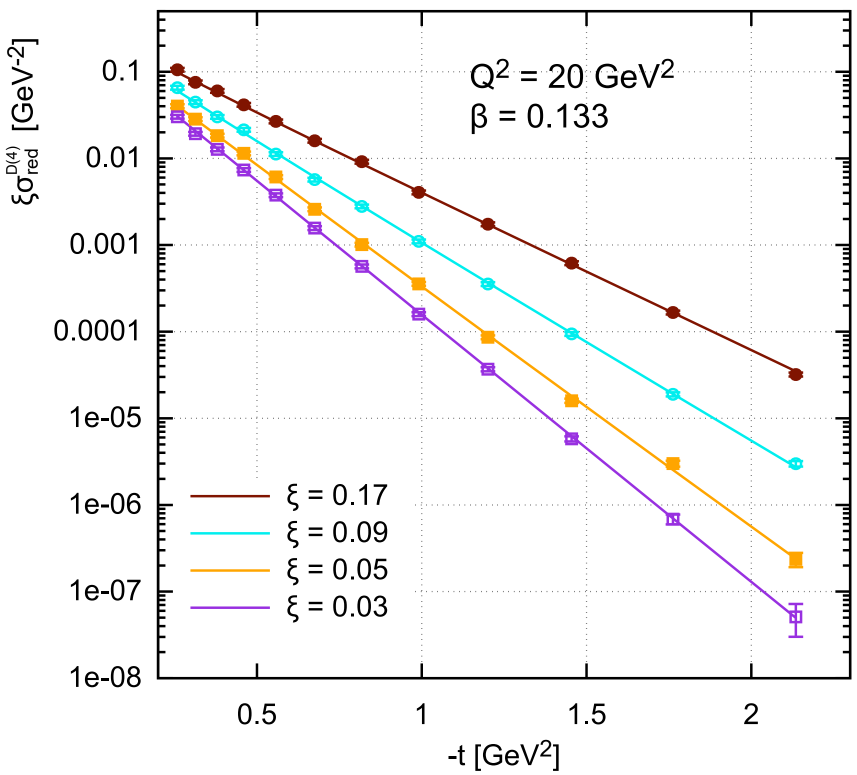
Flux parameters:

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

ZEUS fit parameters

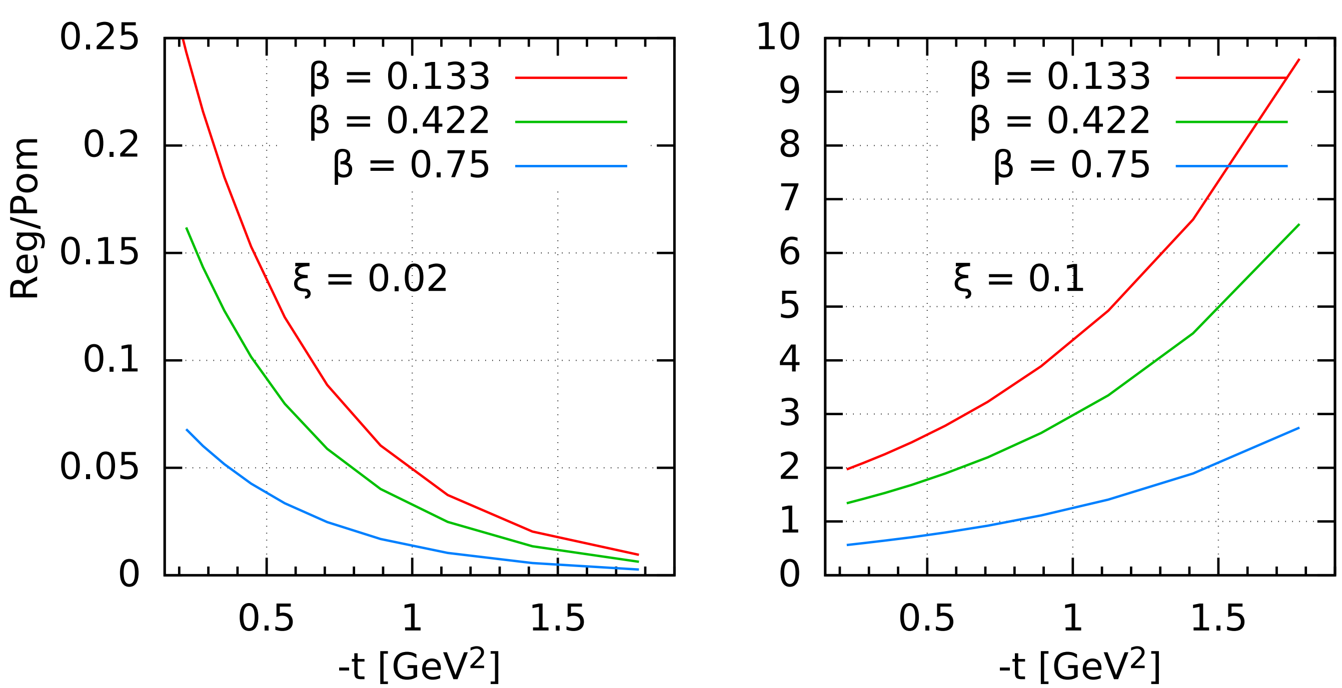
$$\xi \phi_{I\!R}(\xi, t) \ \propto\ \xi^{0.6+1.8|t|}\, e^{-2|t|} = \xi^{0.6}\, e^{(-2+1.8\ln \xi)\,|t|}$$

Reggeon and Pomeron component in cross section at EIC



4D cross section pseudodata

- Changing t slope as transitioning from Pomeron to Reggeon dominated region
- σ_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 ξ 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 $Q_0^2 = 1.8\ \mathrm{GeV}^2$:

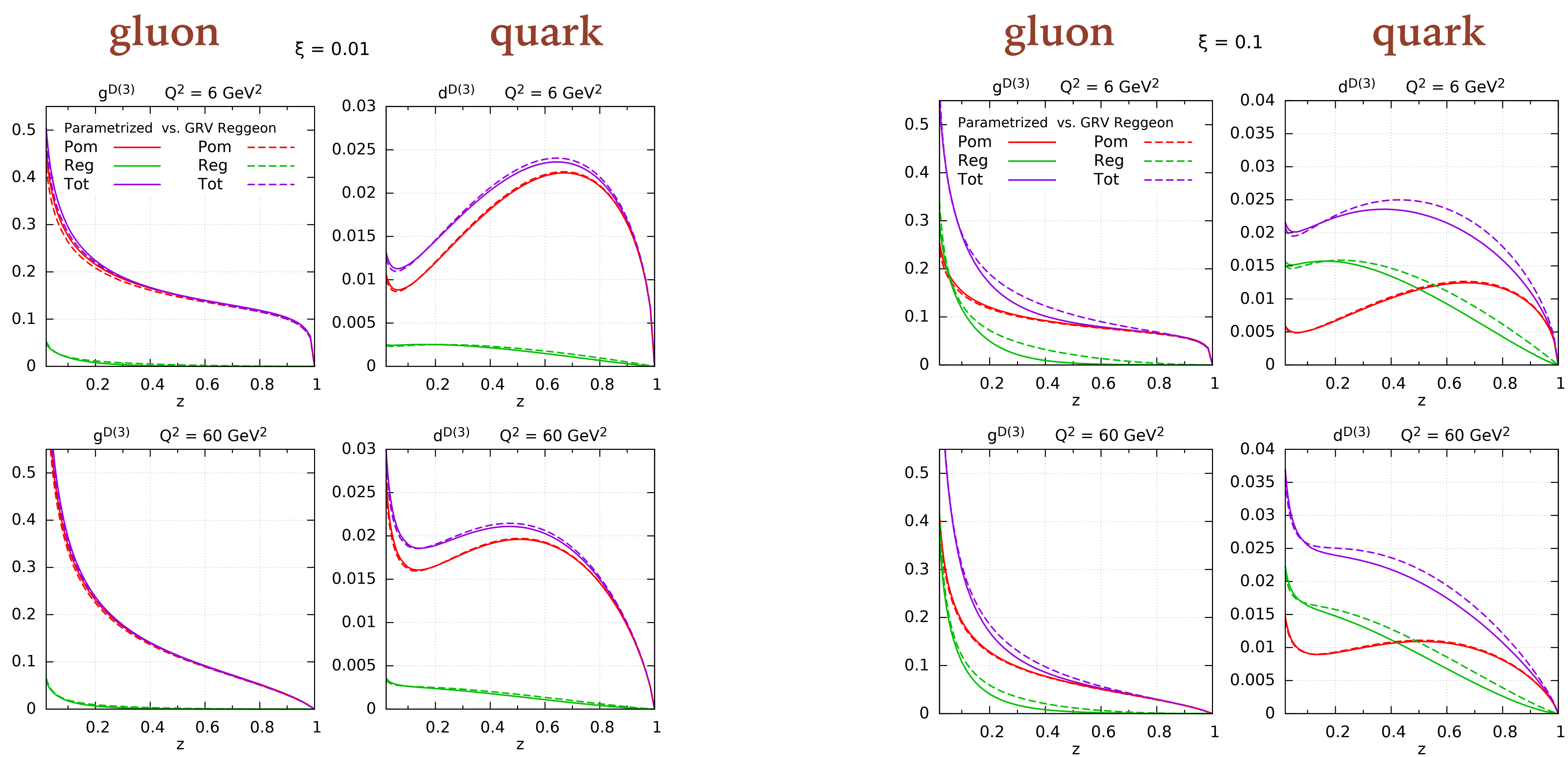
$$f_k^{(m)}(x, Q_0^2) = A_k^{(m)}\, x^{B_k^{(m)}} (1-x)^{C_k^{(m)}} (1 + D_k^{(m)}\, x^{E_k^{(m)}})$$

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



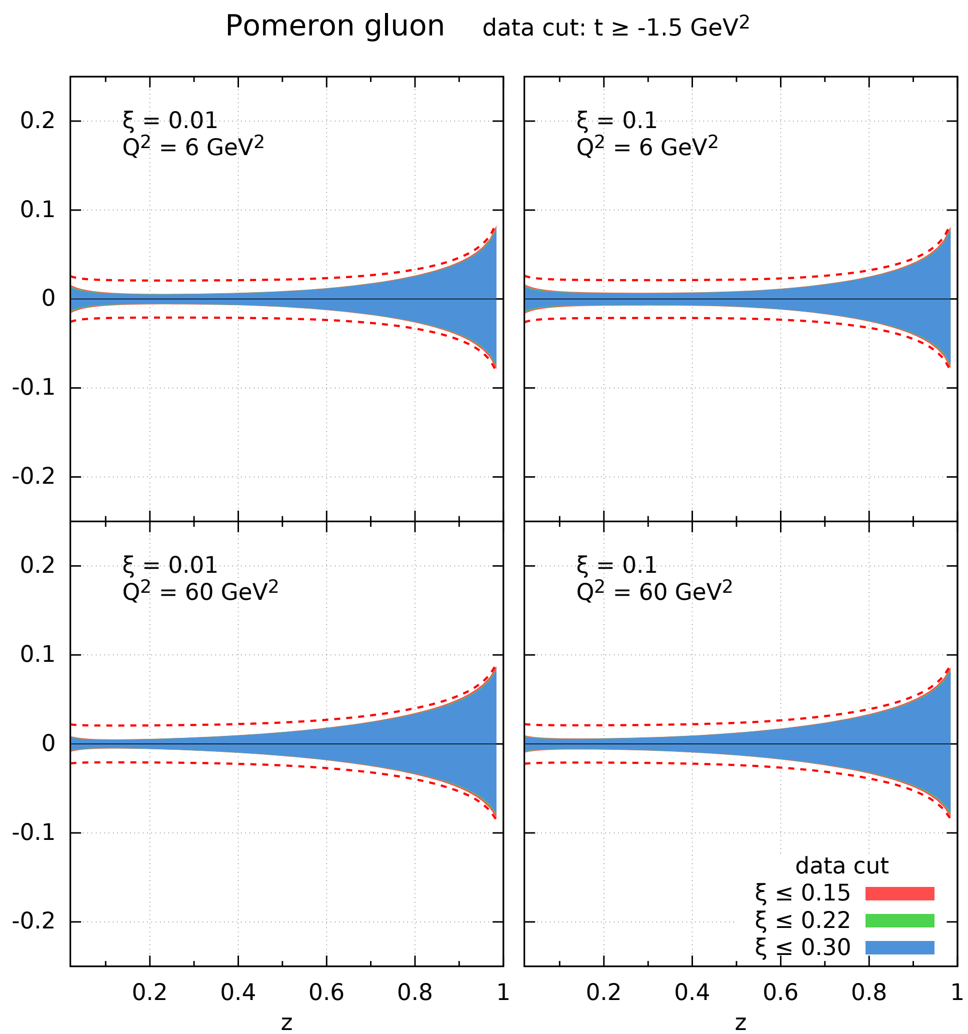
Fit results with free Reggeon parametrization (solid) made to the pseudodata based on the GRV pion structure function (dashed)

Reggeon reproduced reasonably well

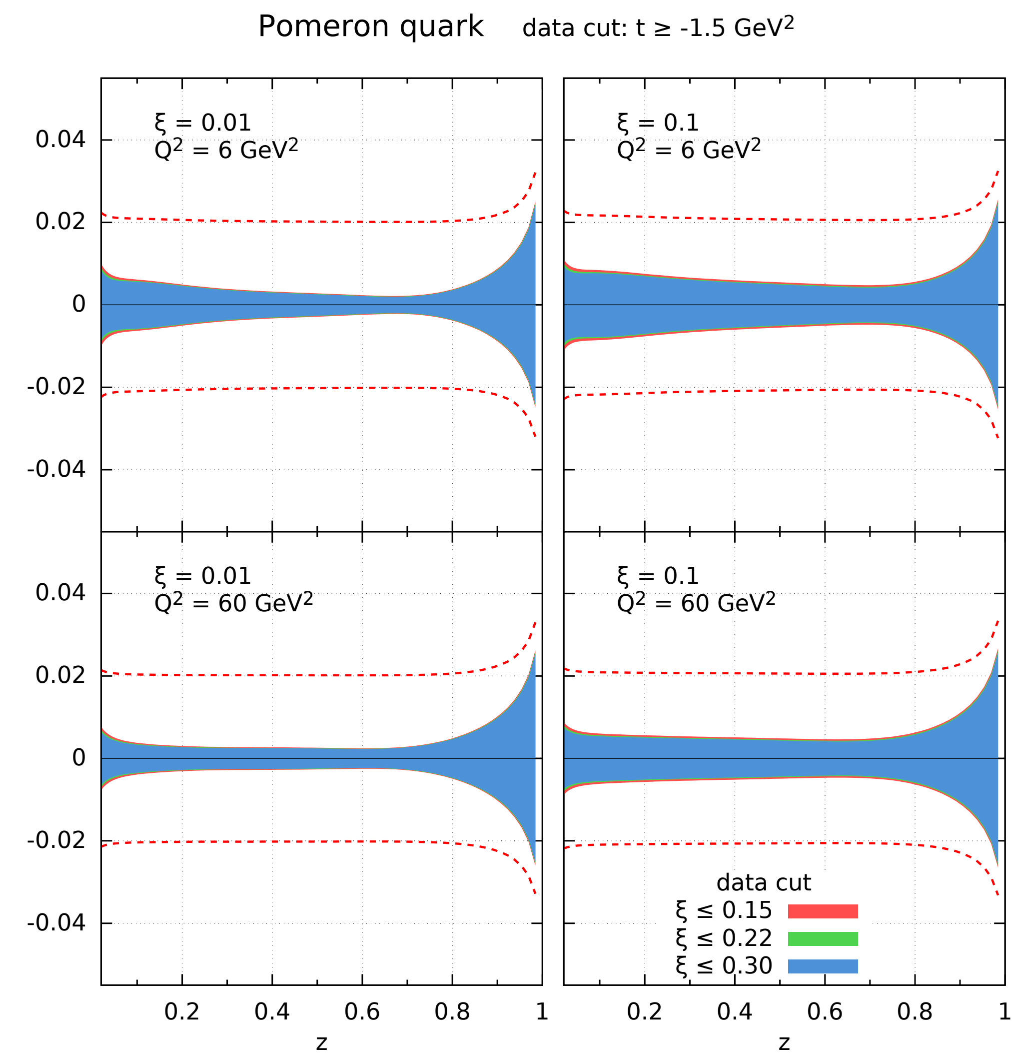
Pomeron reproduced almost perfectly

Uncertainties of diffractive PDFs: Pomeron

Pomeron gluon



Pomeron quark

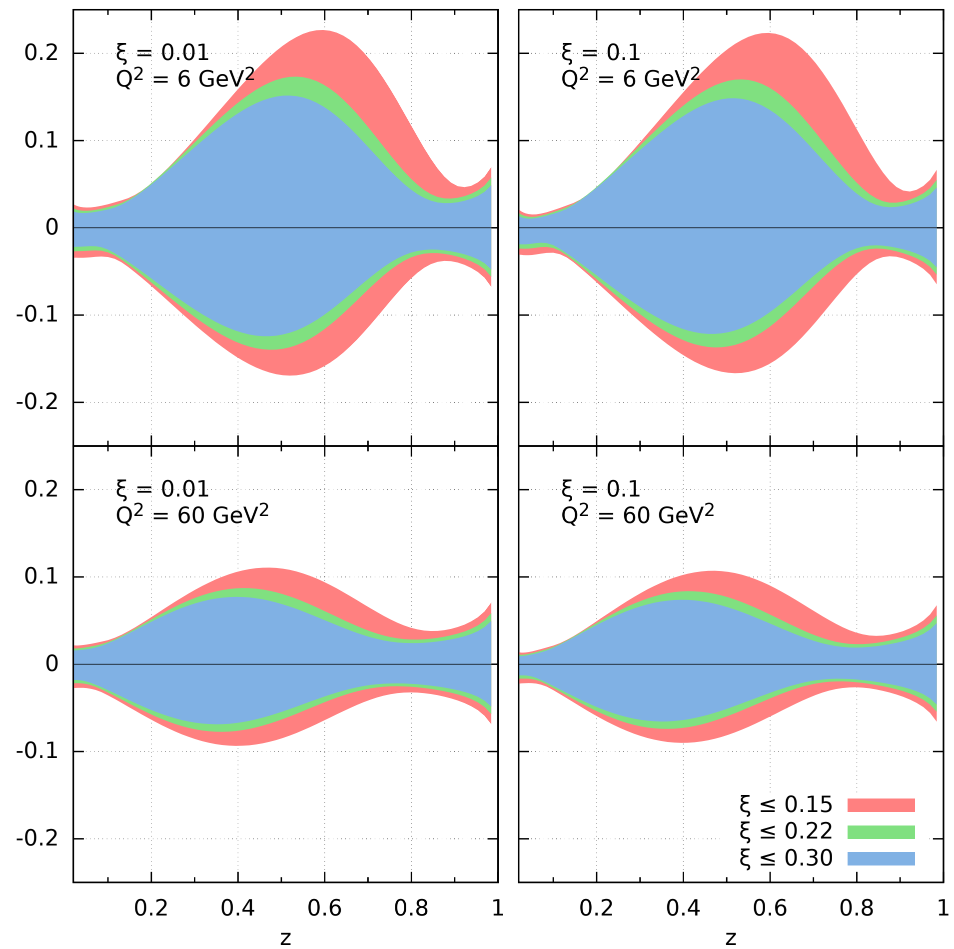


- relative uncertainty
- <few % or better in most regions
- larger uncertainty for gluon at large z (and also small z)
- normalization error at 2% is dominant at most regions (dashed red)

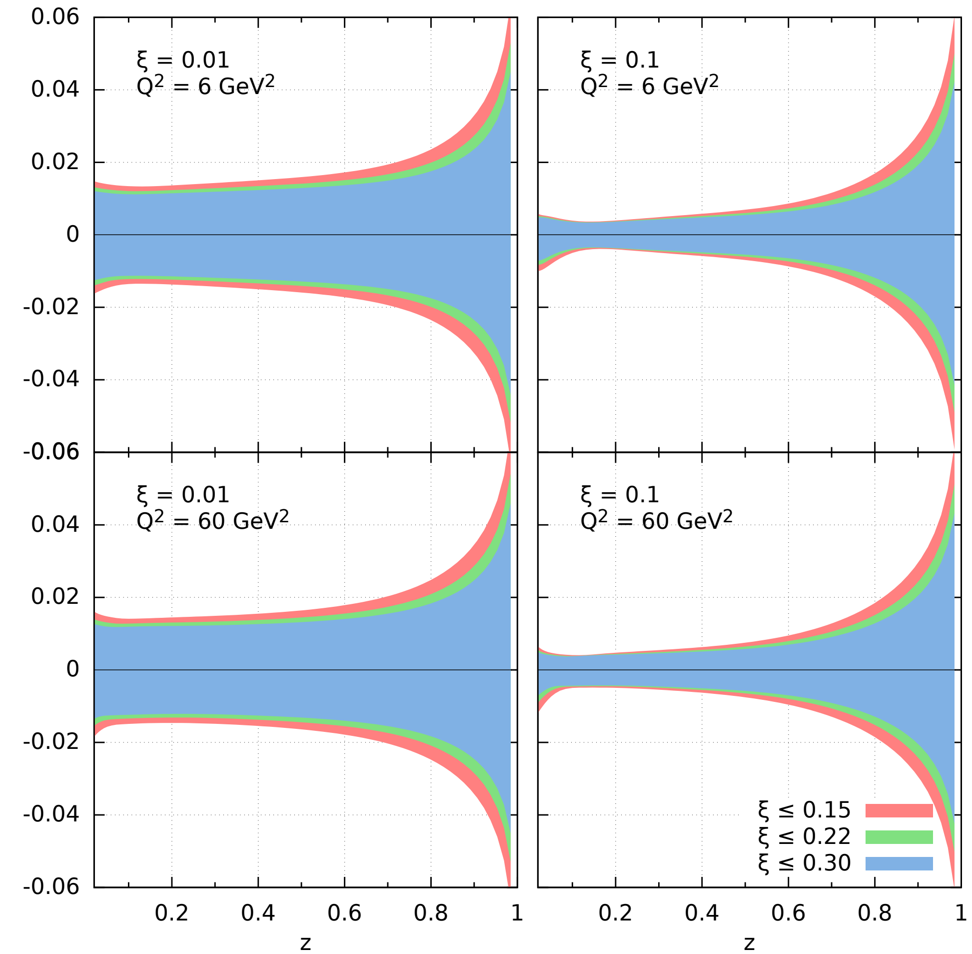
linear horizontal scale
note different vertical scale for gluons and quarks

Uncertainties of diffractive PDFs: Reggeon

Reggeon gluon



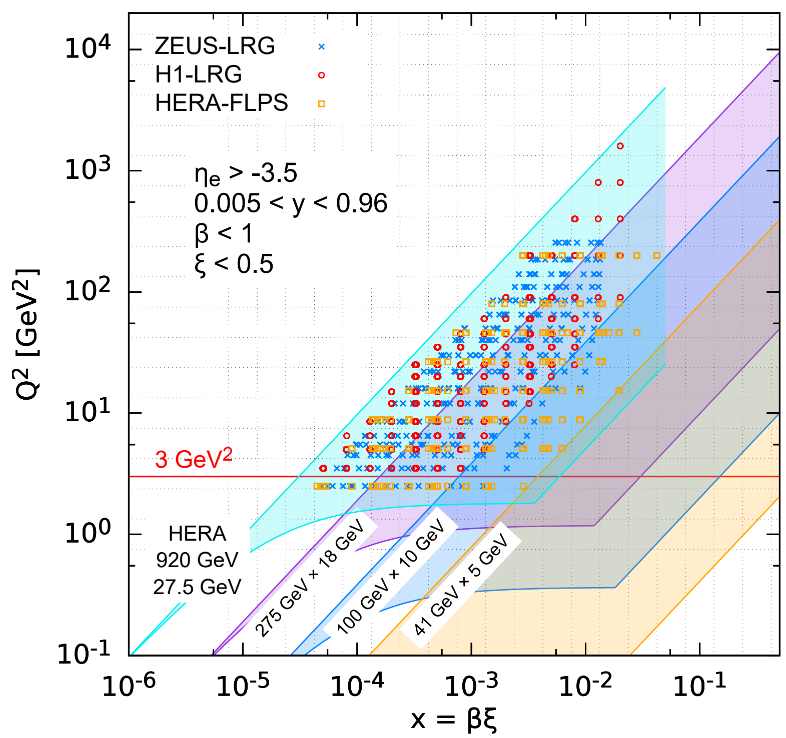
Reggeon quark

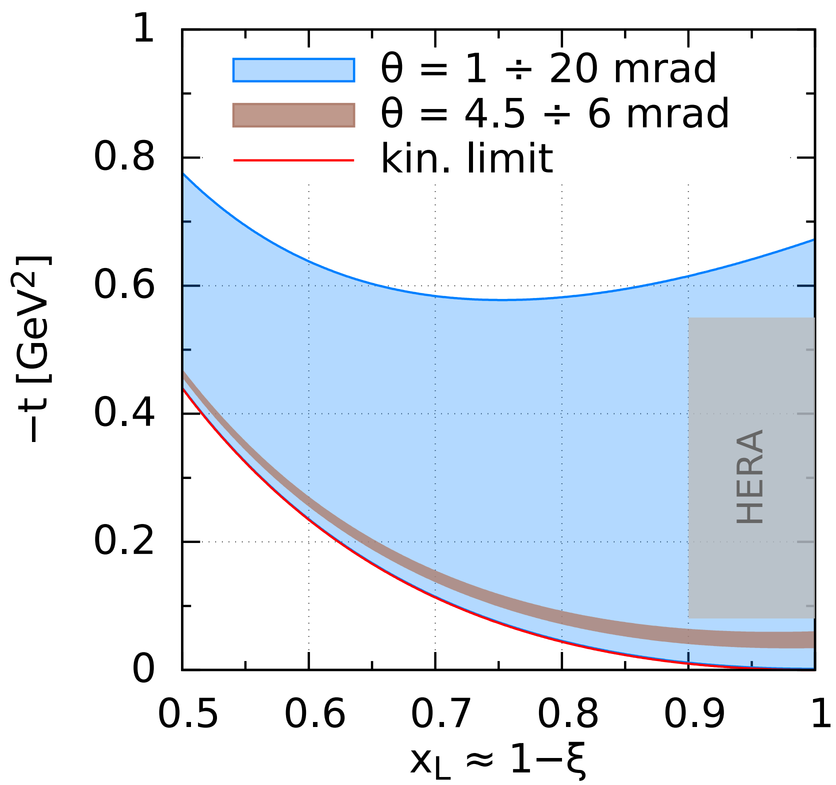


- <2 % or better in most regions for quark except at large z
- Larger uncertainty for Reggeon gluon which is much smaller than Pomeron gluon
- Mild sensitivity to the cut on ξ for gluon, quark less sensitive
- Minimal sensitivity to the cut on t, dense vs sparse binning, lower luminosity $\mathscr{L}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

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 $\xi_{\max} \simeq 0.15 \div 0.2$

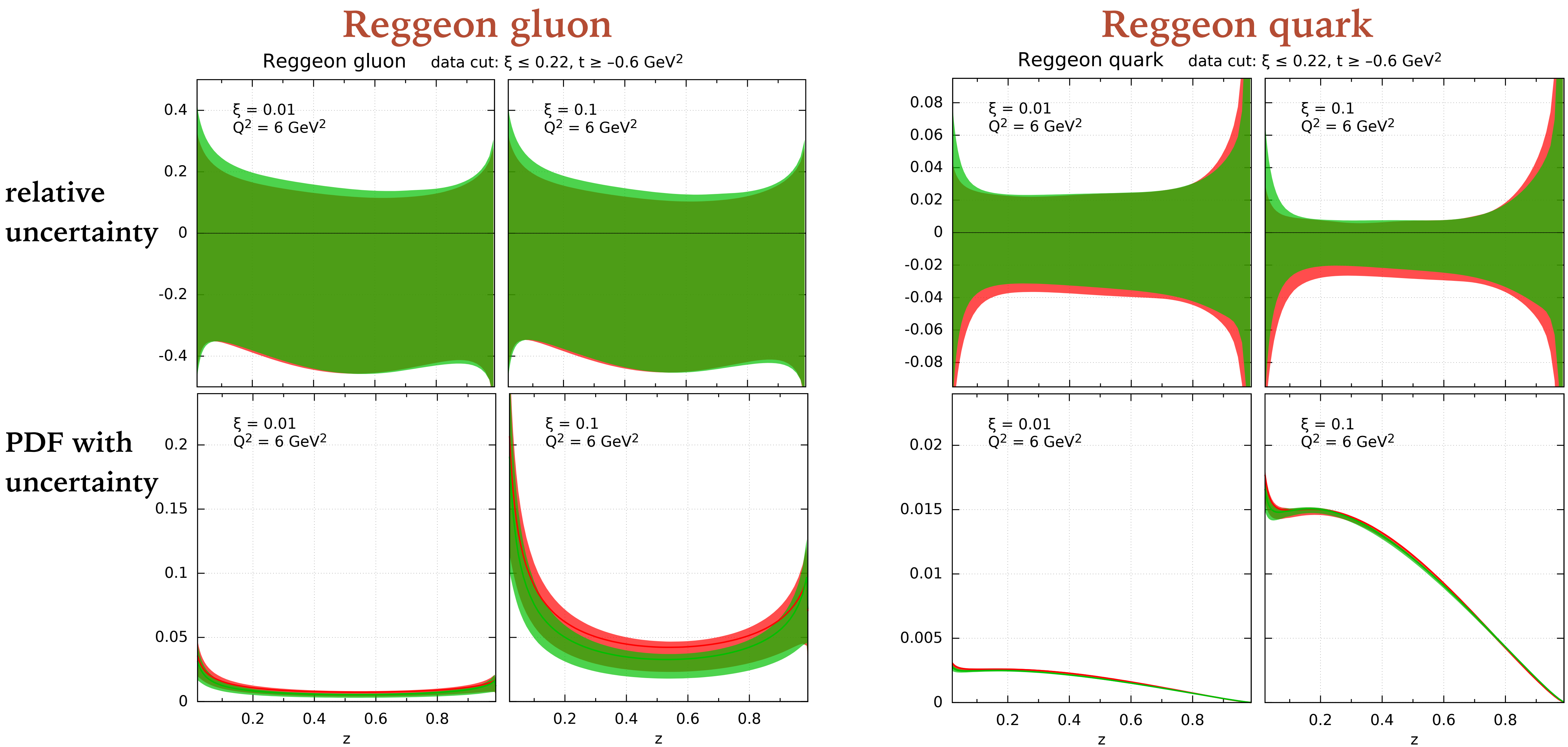
Low energy scenario: 5 GeV x 41 GeV





- 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



- 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

- Resummation at small x essential for stable results. Kinematical constraint. Combines DGLAP with BFKL.
- Strong preasymptotic effects: modifies moderate x and small x region
- EIC will allow precision tests for saturation with nuclei. Longitudinal structure function more sensitive
- Opportunities for inclusive diffraction at EIC: tagged protons
- Good prospects for measurement the diffractive longitudinal structure function
- 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