Small-x Physics with the LHeC

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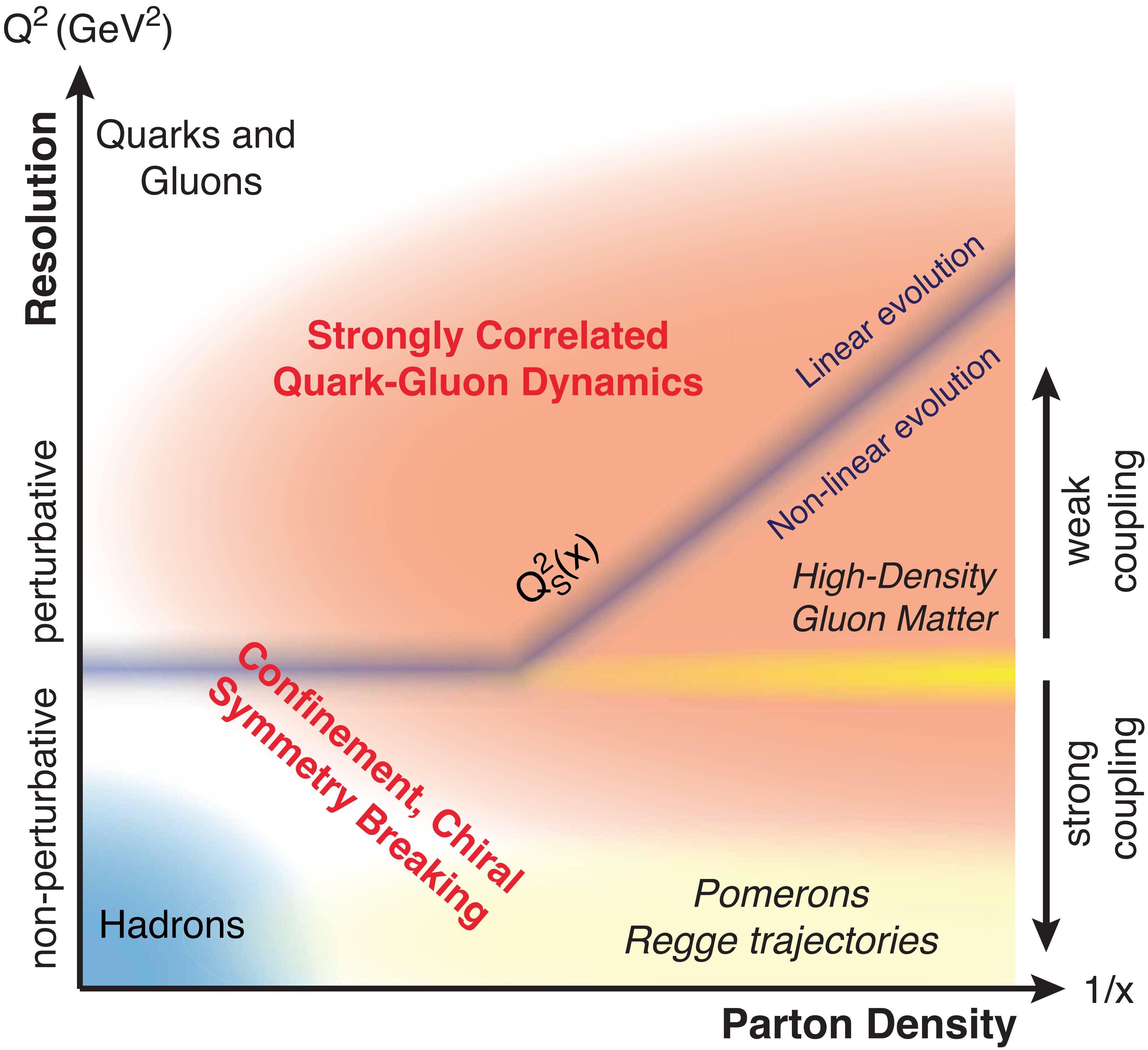
Based on J. Phys. G39, 075001

Hard Probes 2018

Cold QCD landscape



LHeC:

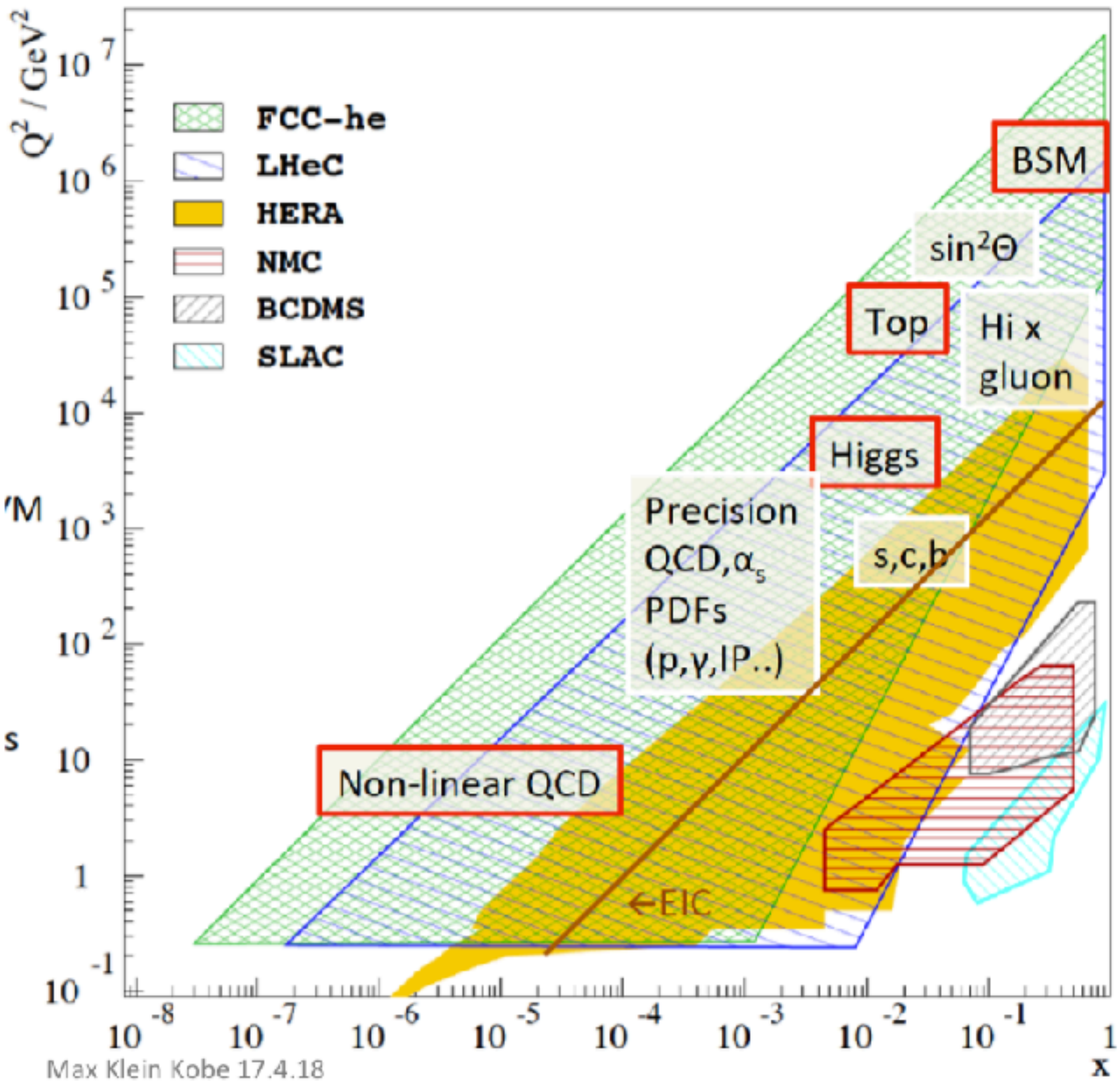
$W \gtrsim 1TeV$

Unique access to non-linear part of the QCD phase diagram

Observe non-linear evolution (BK, JIMLWK) in high-density gluon matter!

Aschenauer et al, arXiv:1708.01527

Large kinematical reach of the LHeC



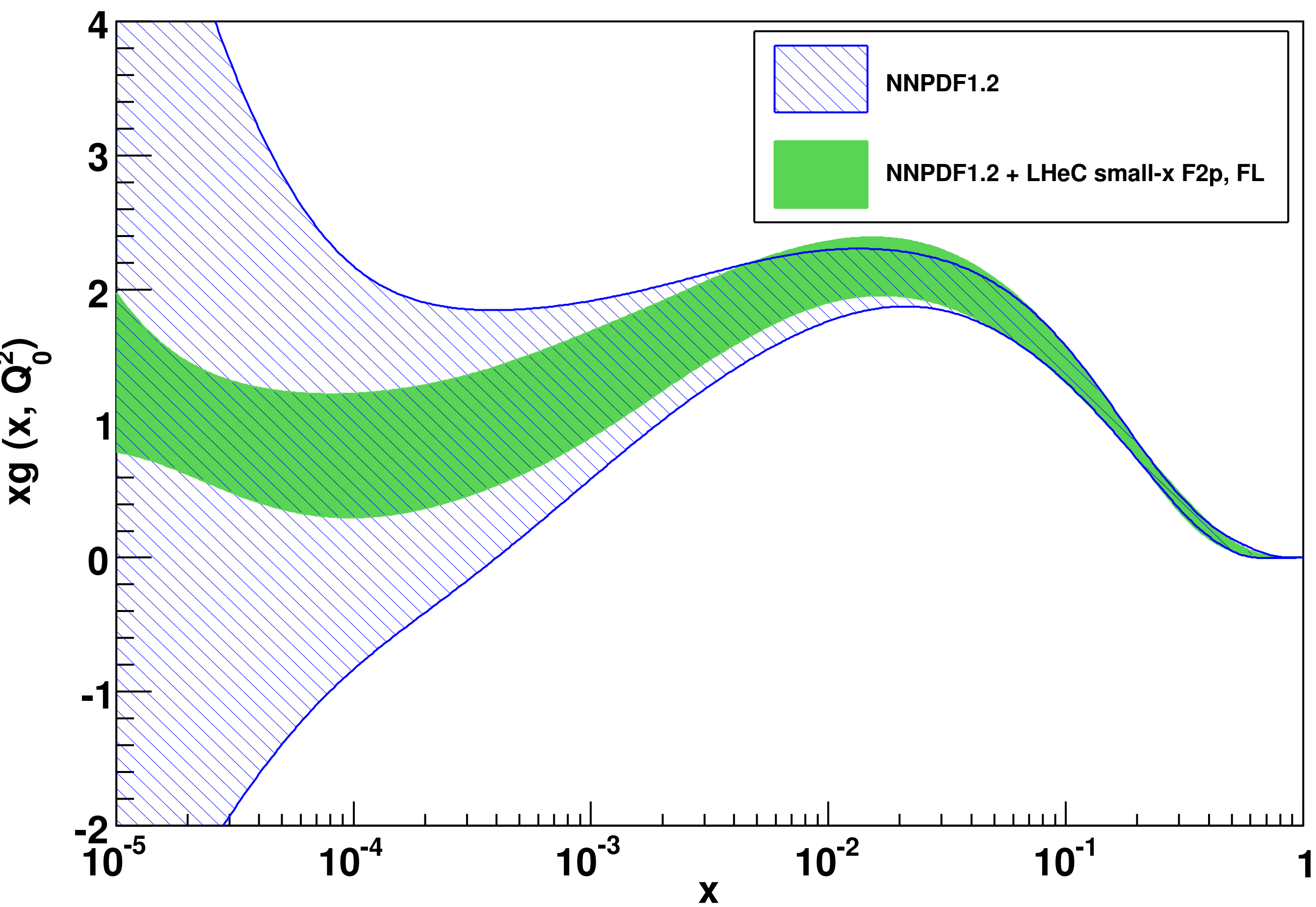
Kinematical reach in ep down to $x \sim 10^{-7}$

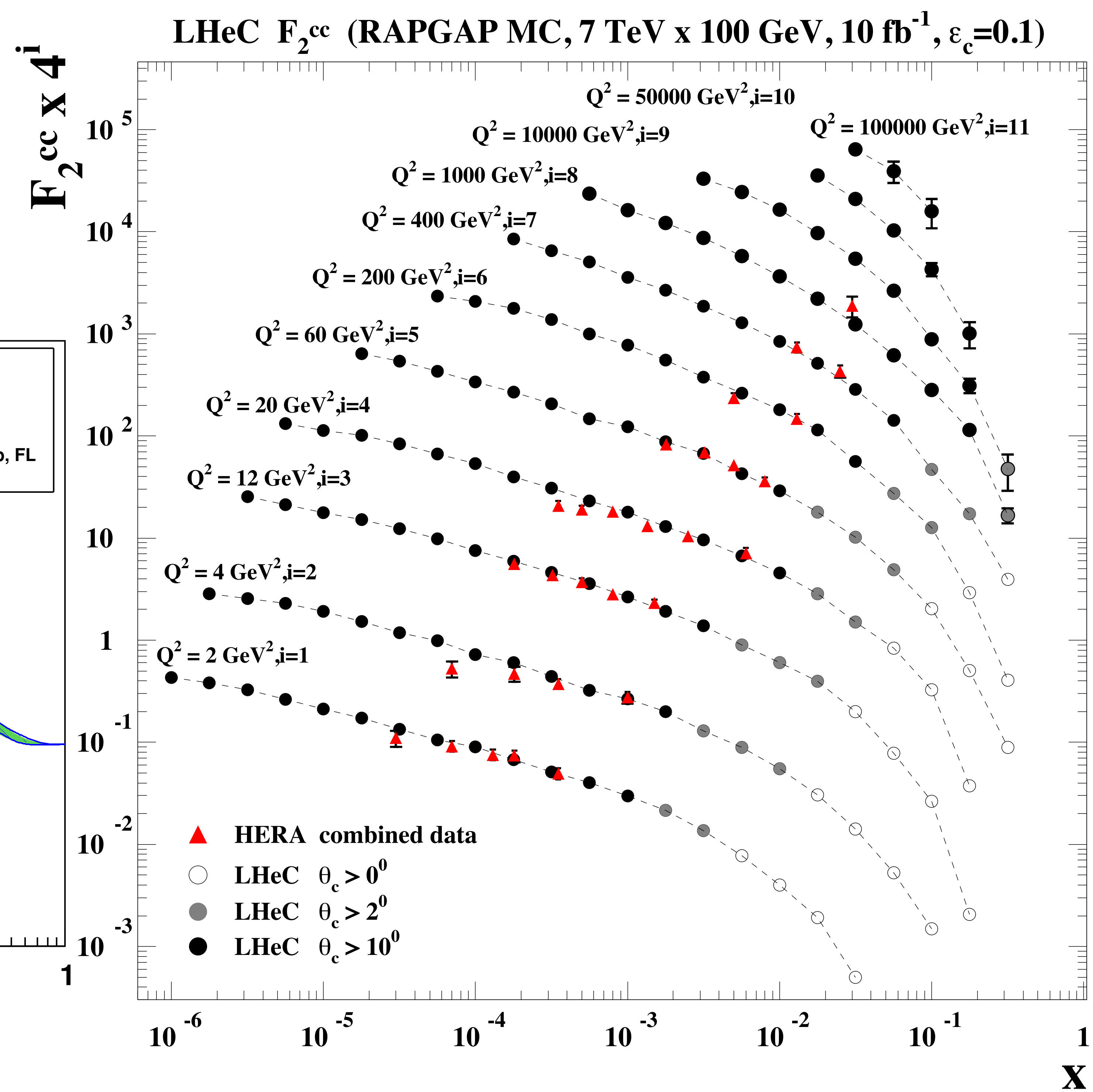
Significant extension to HERA and EIC

Partonic structure of the proton

Proton pdfs have large uncertainties at small x

Example: charm-F2 constraints small-x gluon





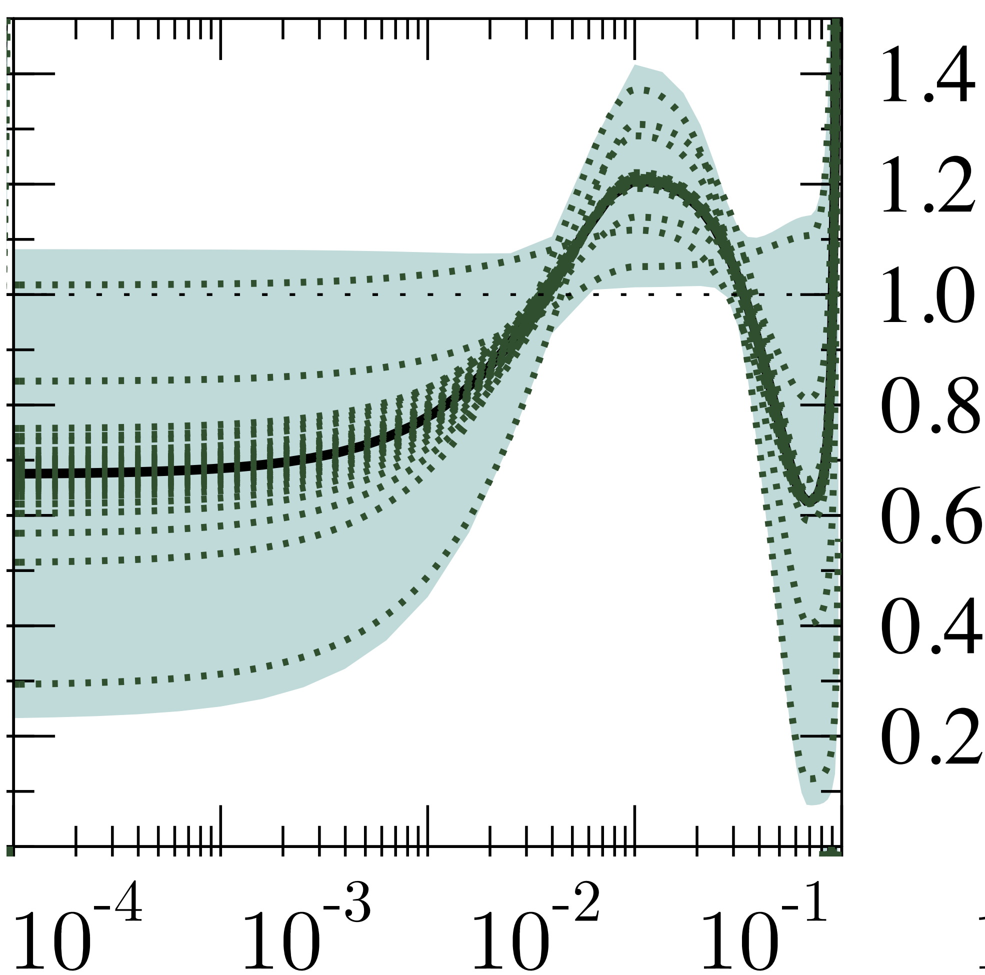
Reduce (dominant) uncertainty in many LHC studies!

Nuclear small-x gluon: pA is not enough

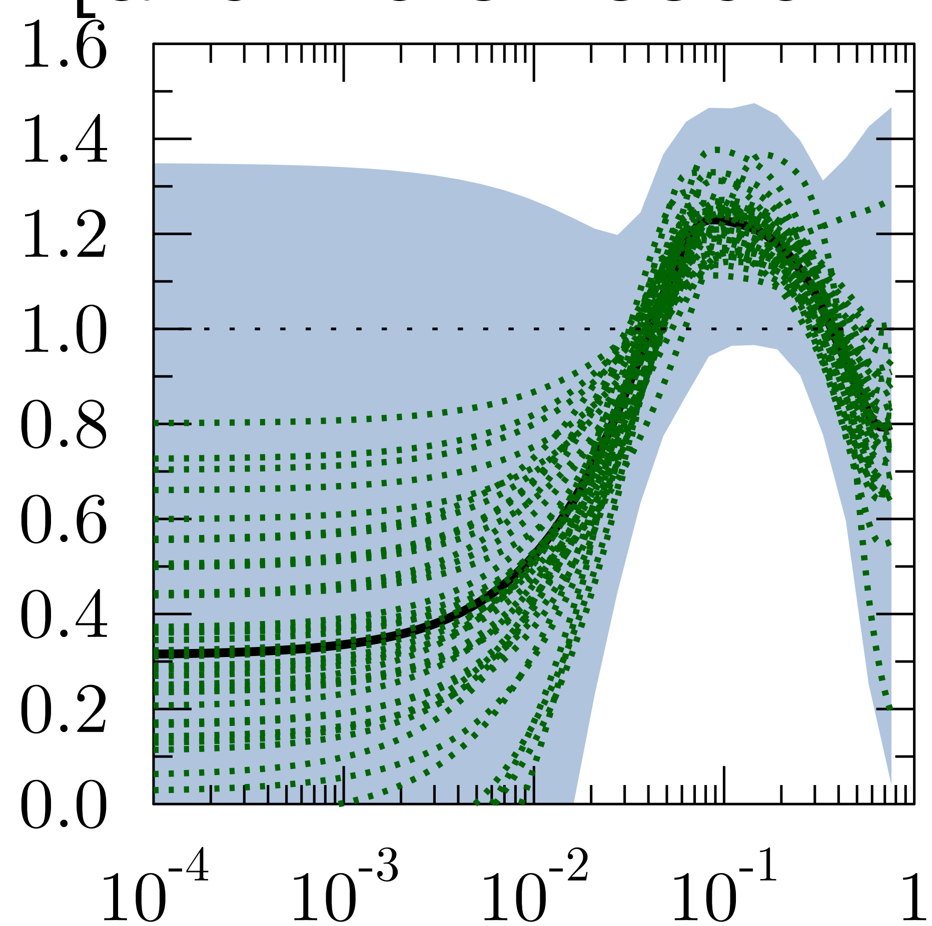
Modification to gluon PDF $R_g(x, Q^2 = 1.69^2\ \mathrm{GeV}^2)$

EPS09: fixed target DIS
+ RHIC pions

Eskola et al, JHEP 0904 (2009) 065



EPPS16*: including
some LHC data (dijets in pA)
[and more freedom in fit]



Eskola et al, Eur.Phys.J. C77 (2017) no.3, 163

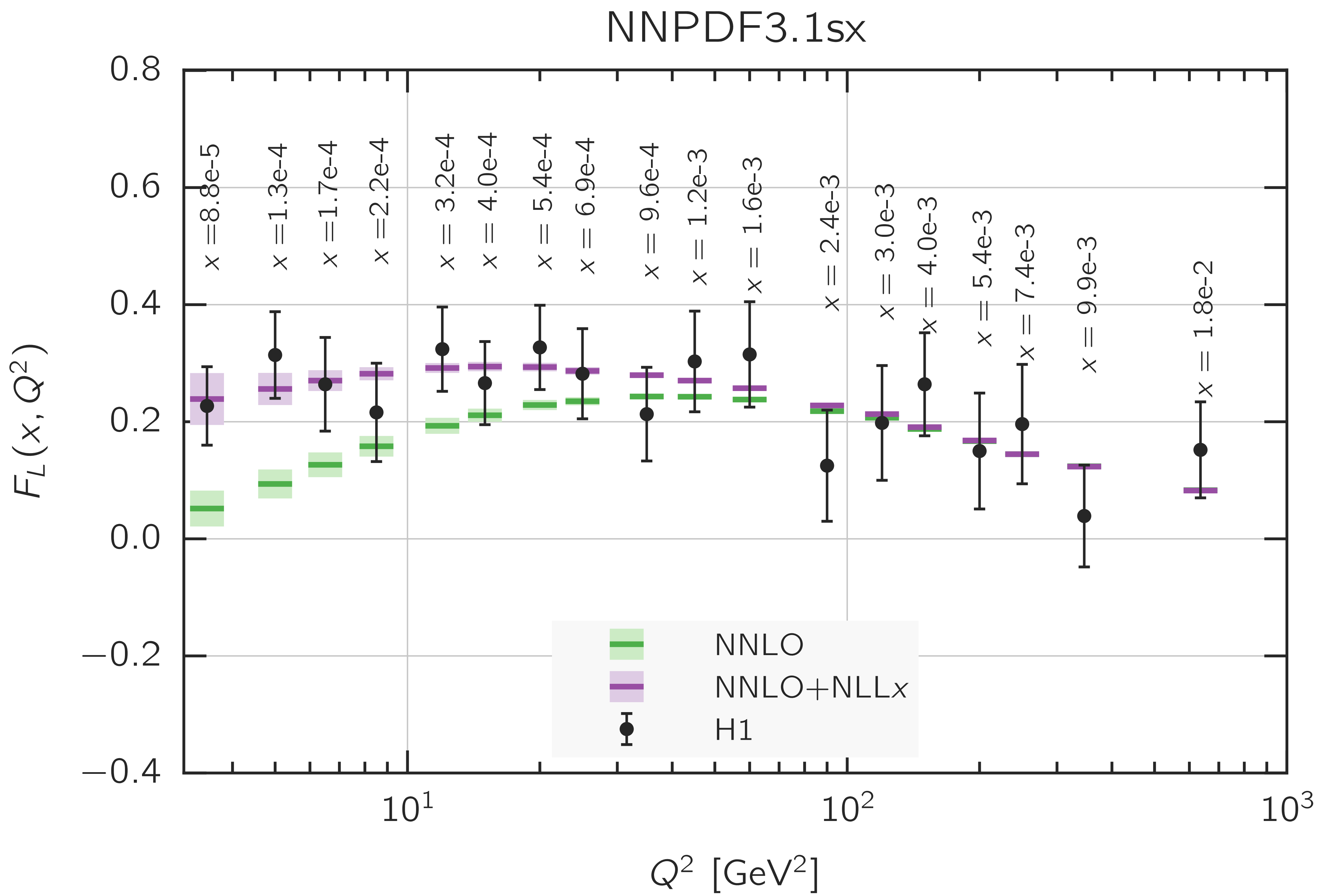
Precise access to gluon requires an eA collider

See N. Armesto on Wednesday

Beyond fixed order calculations

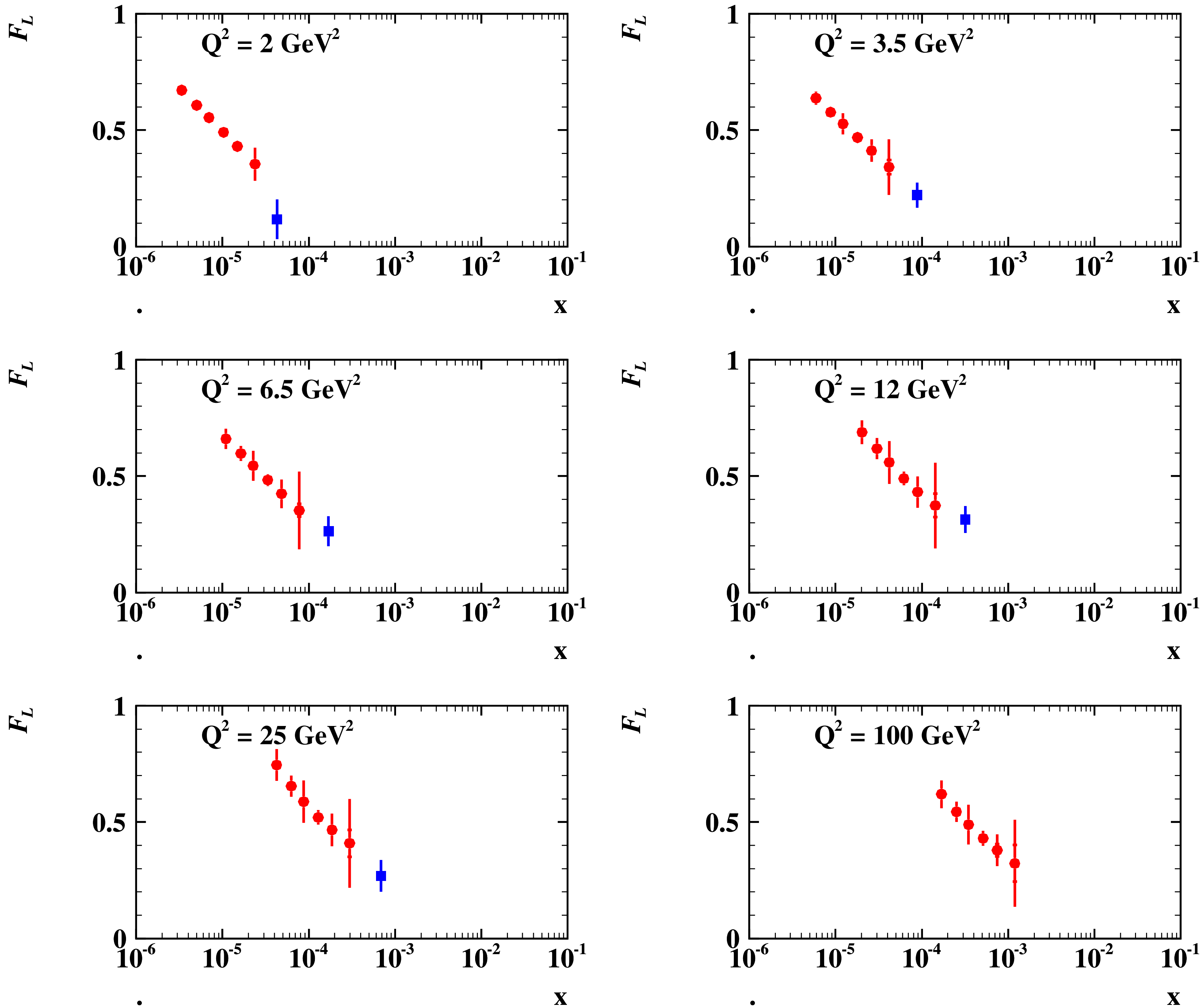
At small x, gluon density ~ inverse coupling, and resummation of large logarithms of $\alpha_s \ln 1/x$ is necessary

Already hints in HERA data (Ball et al, arXiv:1710.05935)



LHeC: Precise data over wide (x,Q^2) range

LHeC capabilities, F_L example



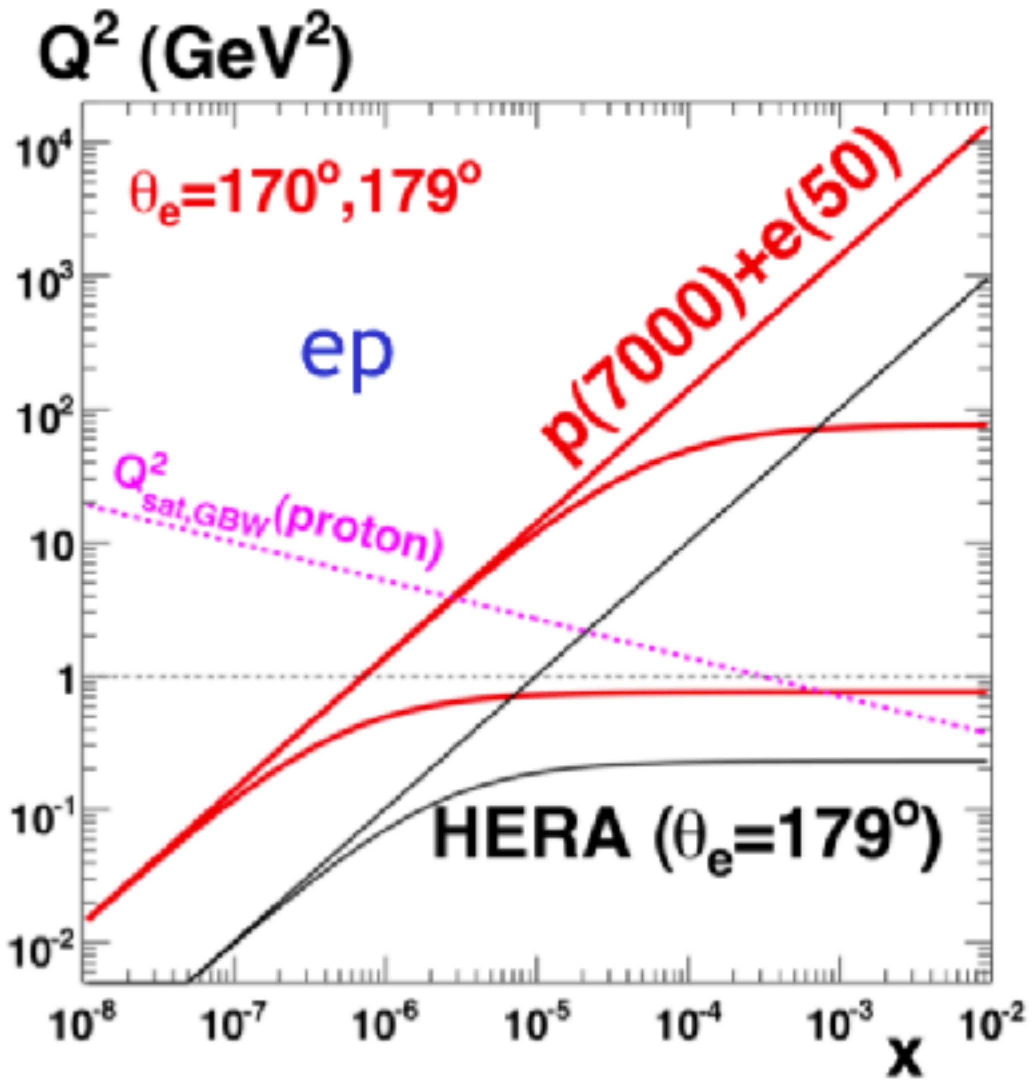
Red: LHeC, blue: HERA

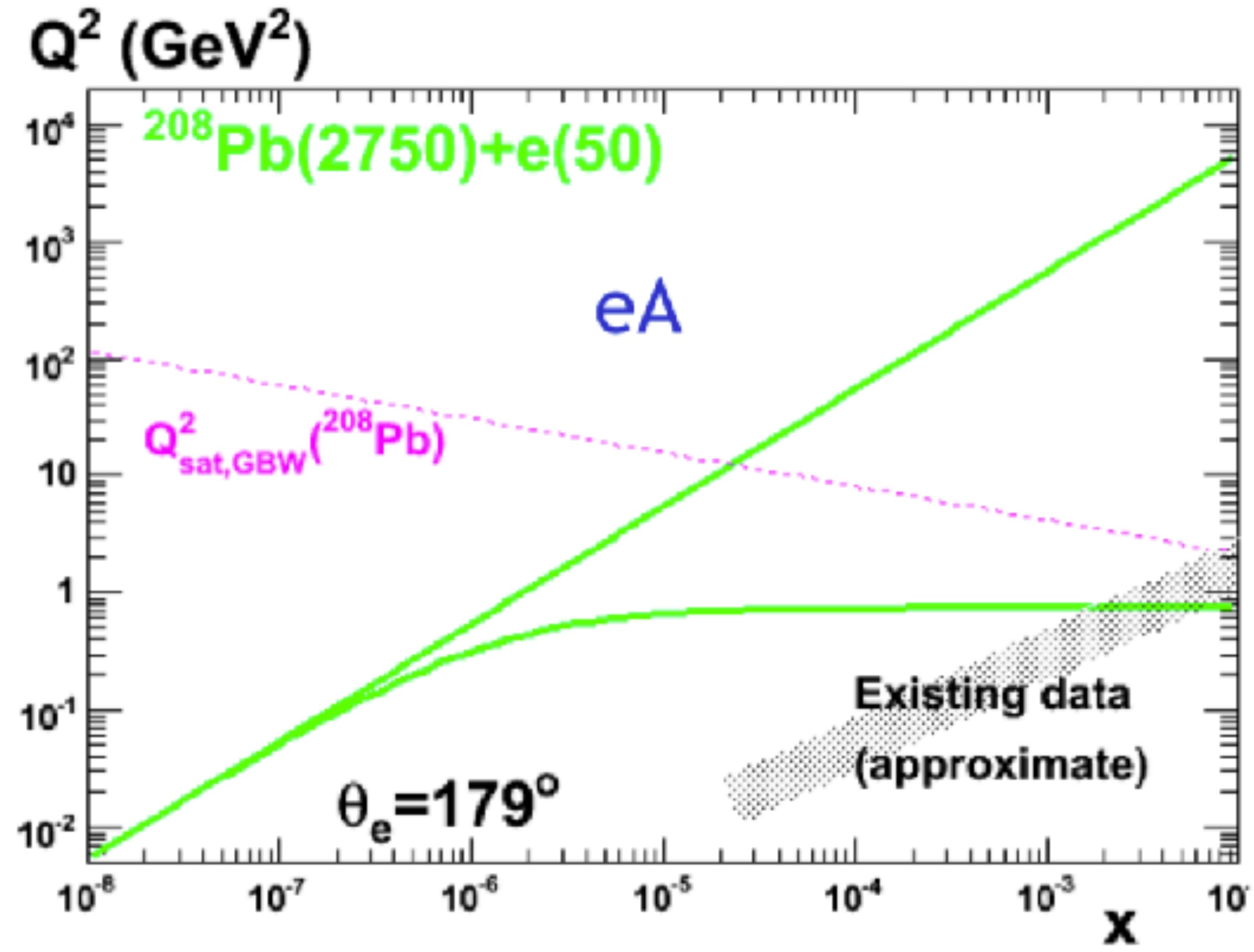
Potential to clearly see breakdown of perturbative expansion

Enhancing density effects with nuclei

Non-linear effects important at $Q^2 \sim Q_s^2 \sim A^{1/3} x^{-\lambda}$

LHeC reaches saturated region in both ep and eA!

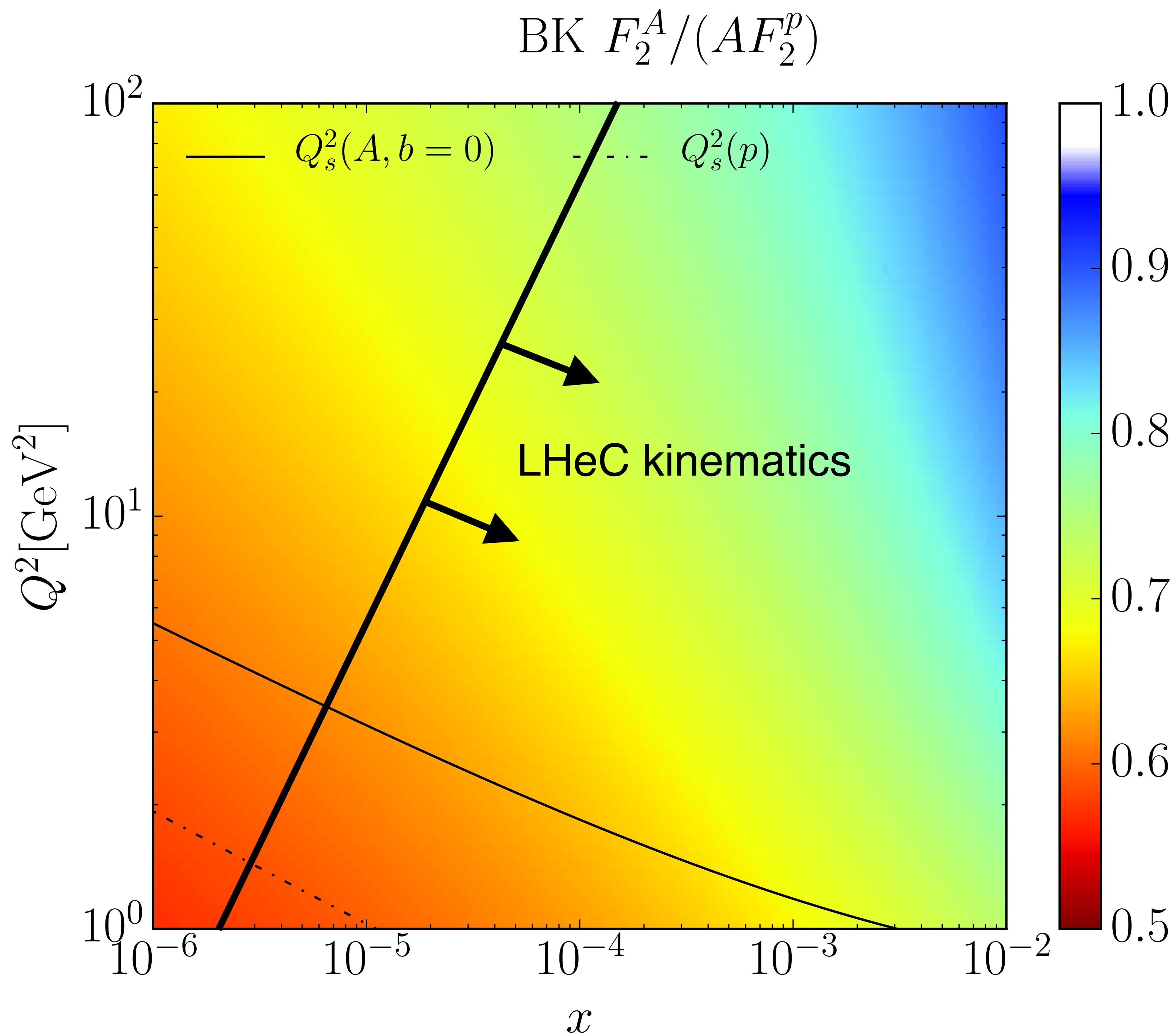




Dilute-dense-transition

Probe nuclear suppression in dilute ($Q^2 \gg Q_s^2$)
and dense region ($Q^2 \ll Q_s^2$)

$$R = \frac{F_2^{eA}}{A F_2^{pA}}$$



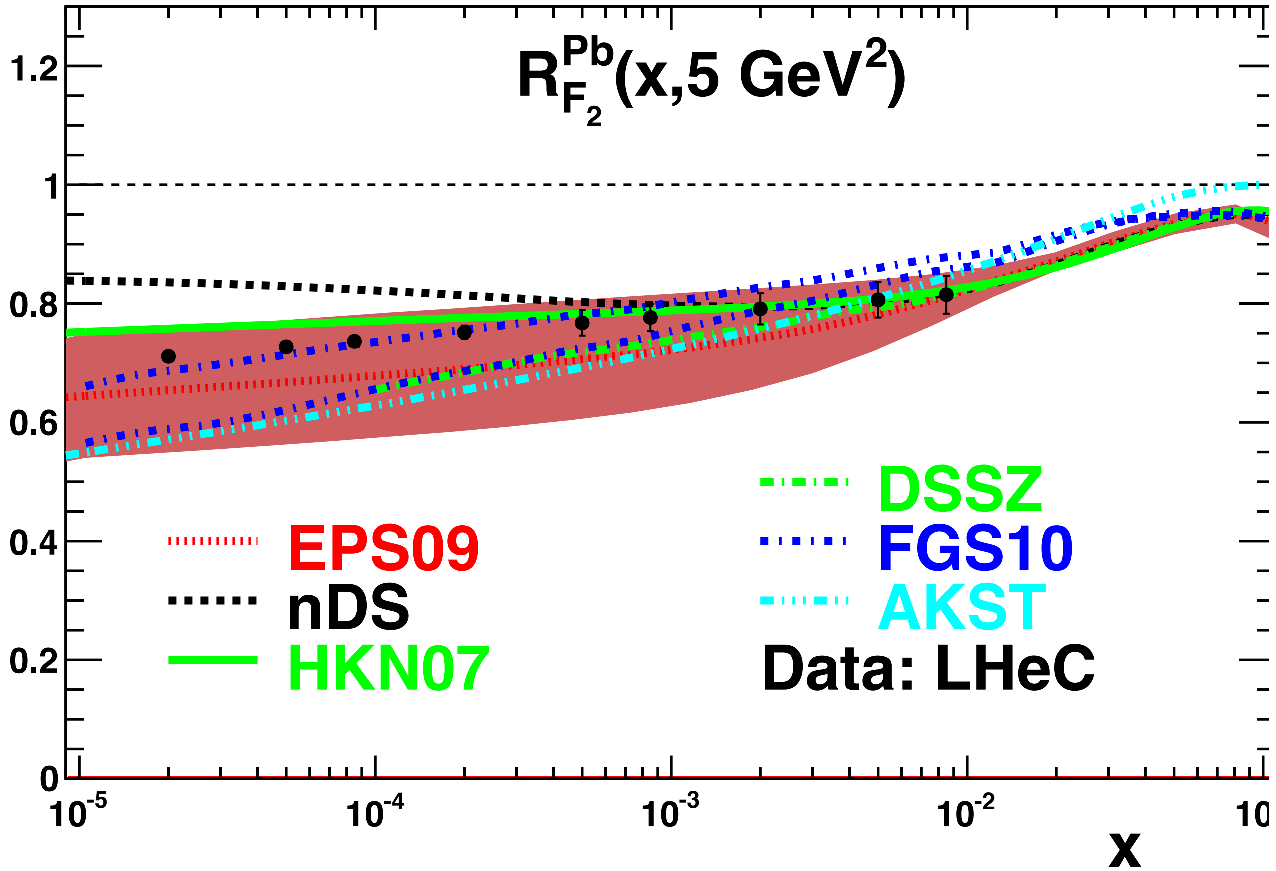
← JIMWLK/BK prediction

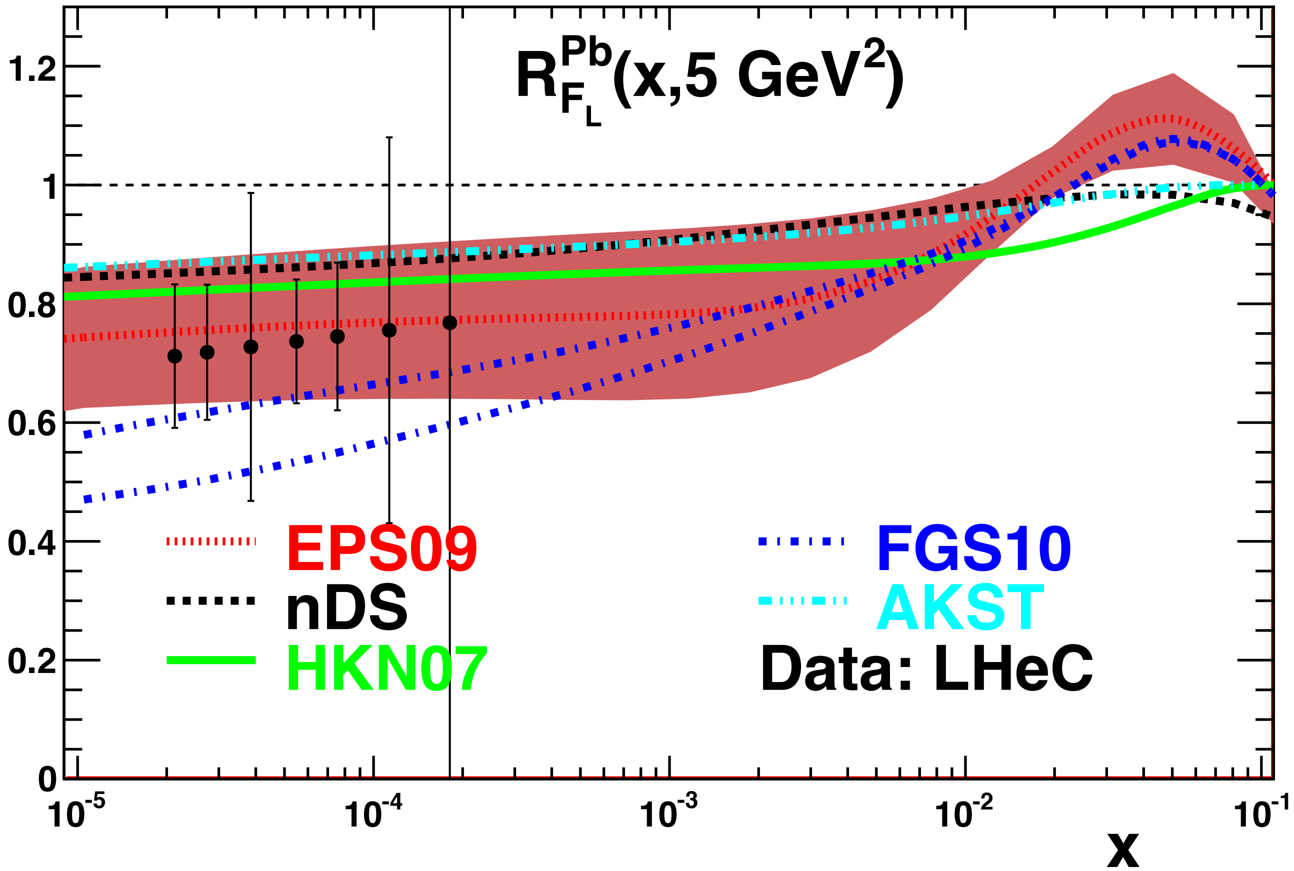
Calculation based on
H.M, T. Lappi, 1309.6963

LHeC capabilities

Precise measurements for the nuclear suppression factor for F_2 and even for F_L down to small x

$$R = \frac{F_2^{eA}}{AF_2^{pA}}$$

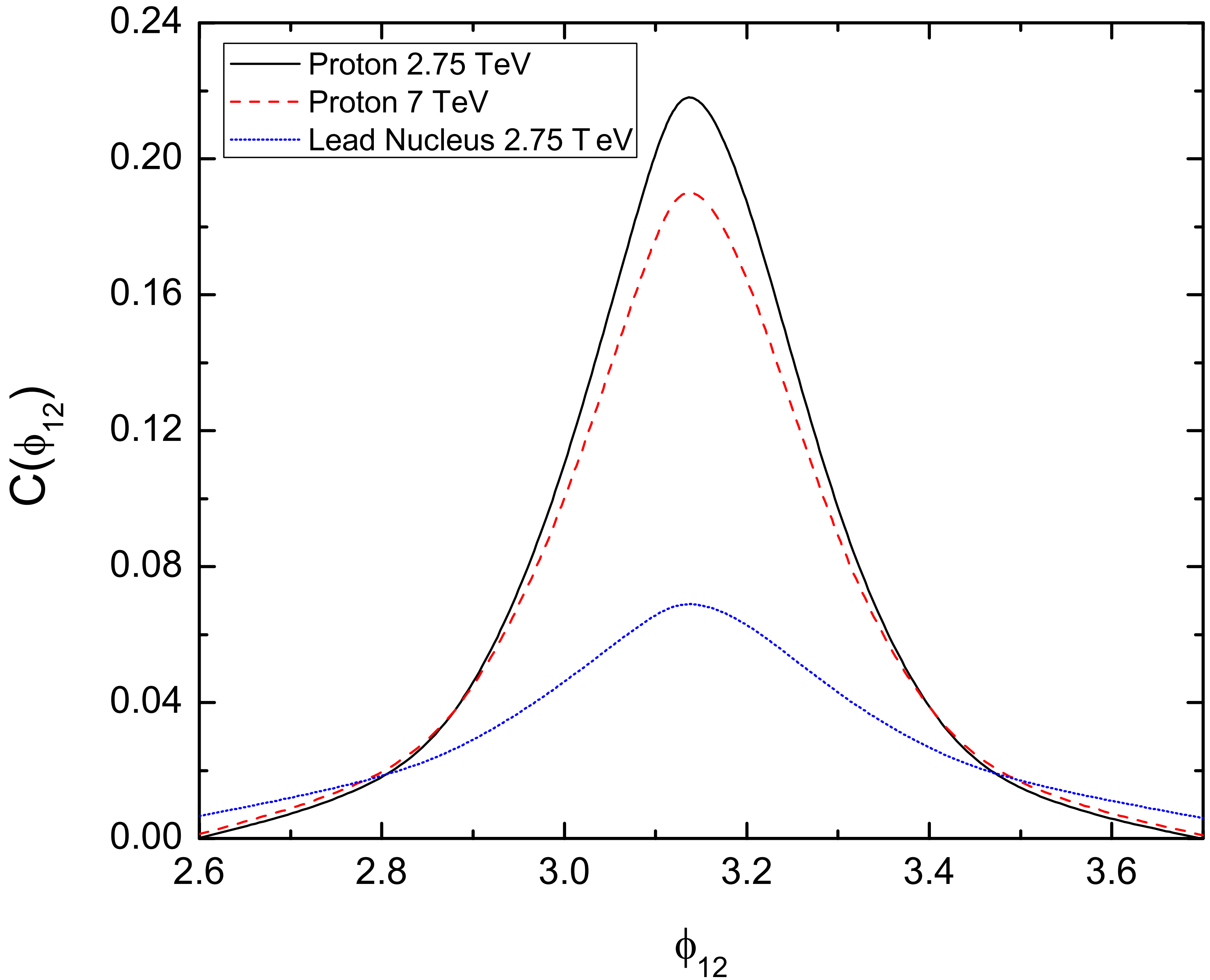


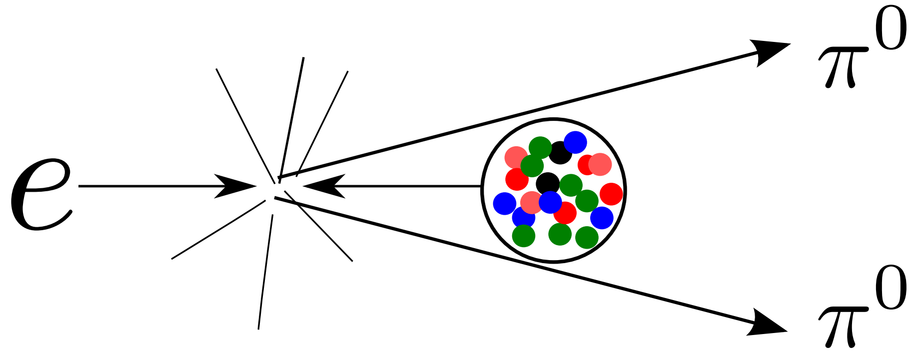


Beyond fully inclusive observables

Dihadron production:

- Produced partons are initially back-to-back: $\gamma^* \to q\bar{q}$
- $\phi_{12} = \pi$ washed out by a kick $\sim Q_s$





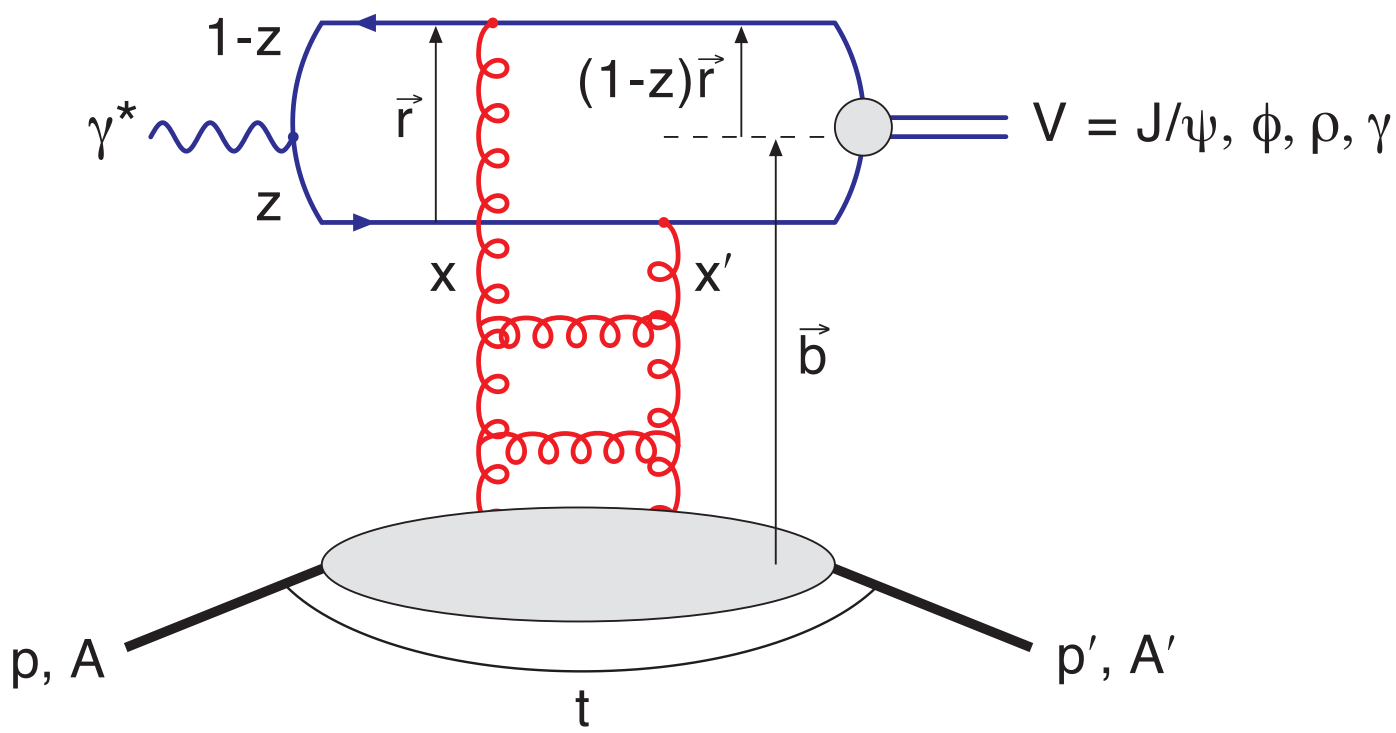
Saturation calculations Compatible with RHIC dAu data

Marquet, 2007
Lappi, H.M, 2012

Diffraction: powerful probe at small x

Benefits of diffraction

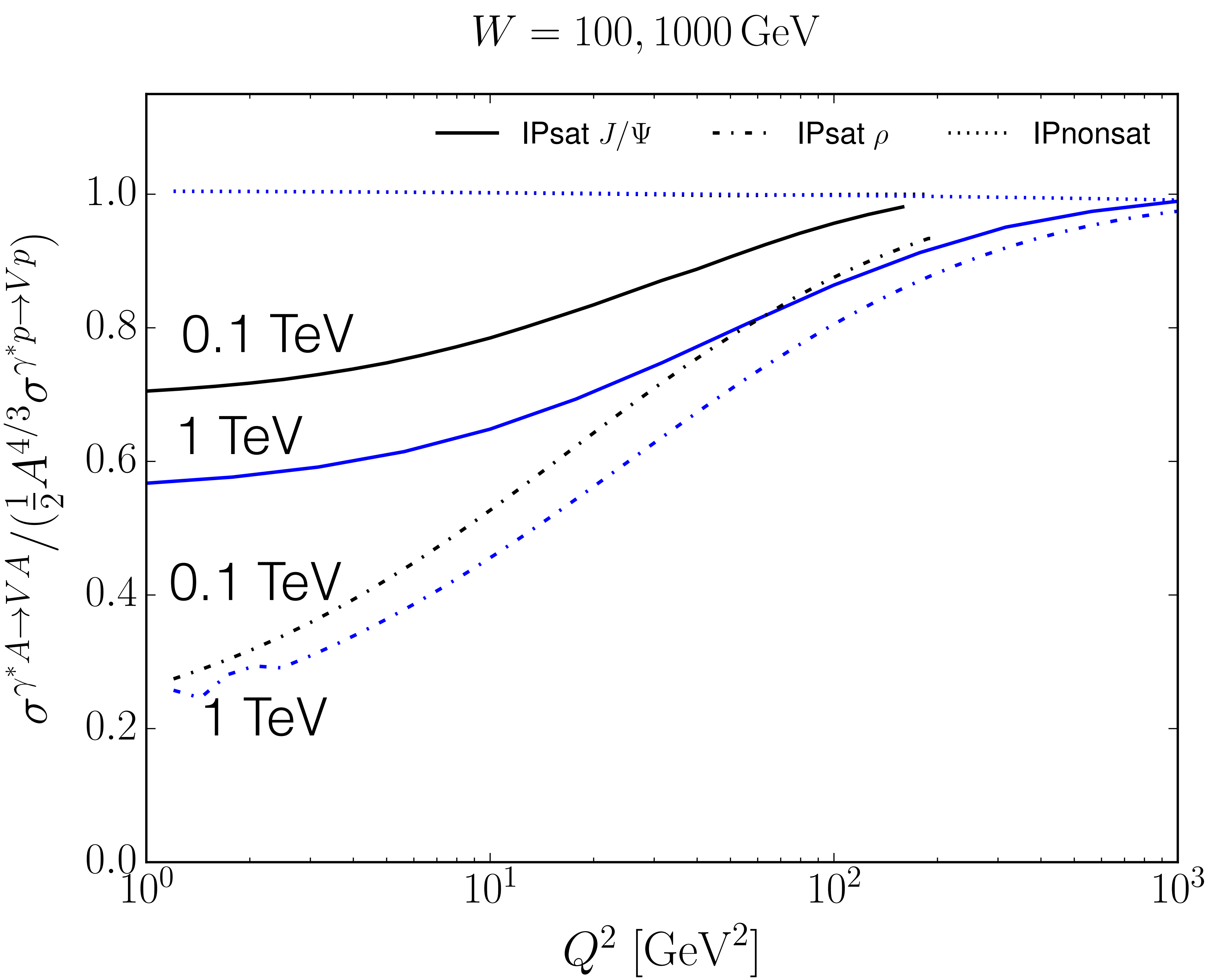
- At LO 2 gluon exchange, probes gluon density²
- Can measure total momentum transfer *t*, access to geometry via Fourier transform



$$-t = (p_A - p_{A'})^2 \approx \Delta^2 = p_T^{VM,2}$$

Strong nuclear effects

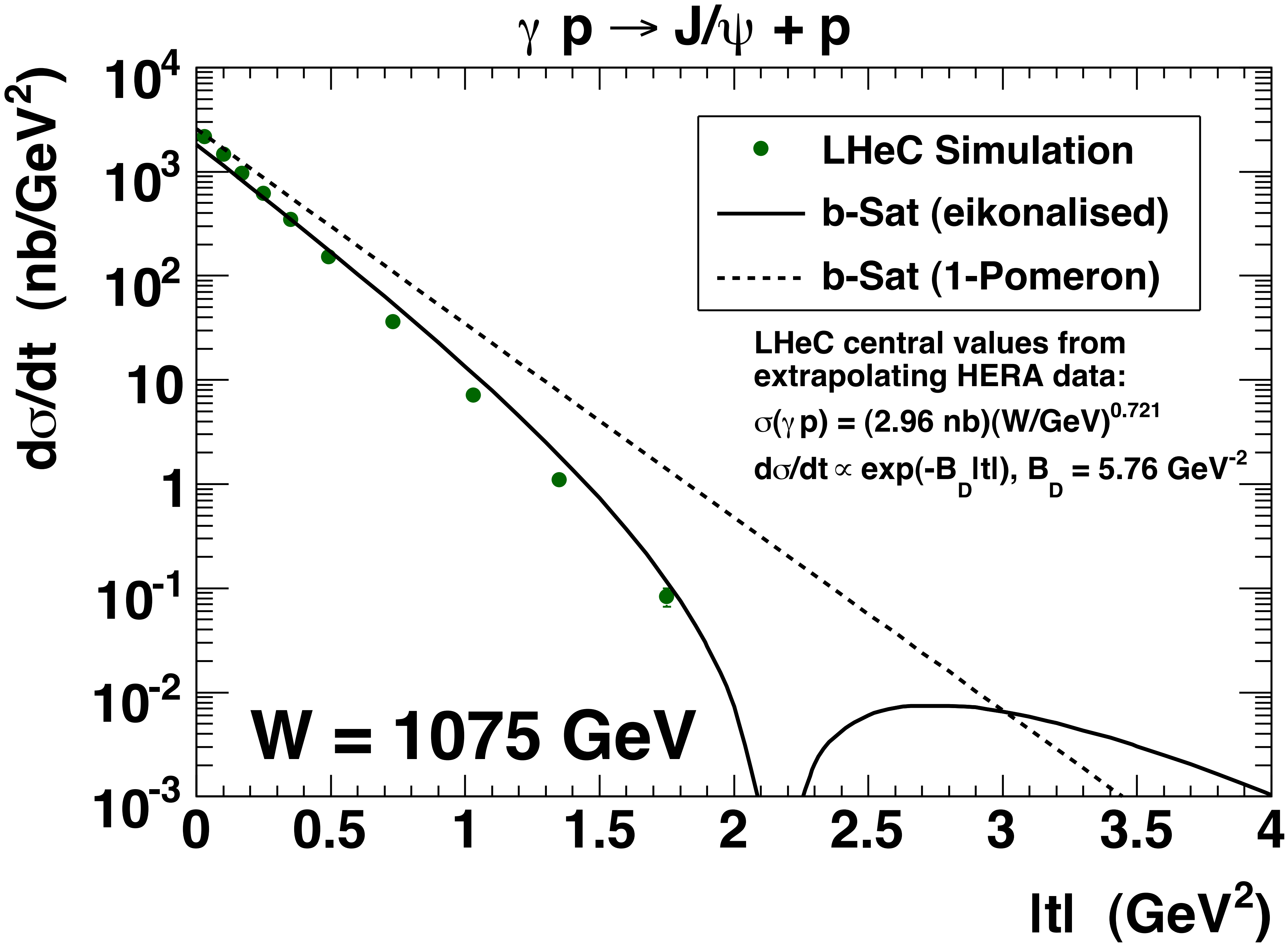
Vector meson production~gluon², sensitive to gluon saturation



H. M, P. Zurita, 1804.05311

LHeC accuracy in exclusive scattering

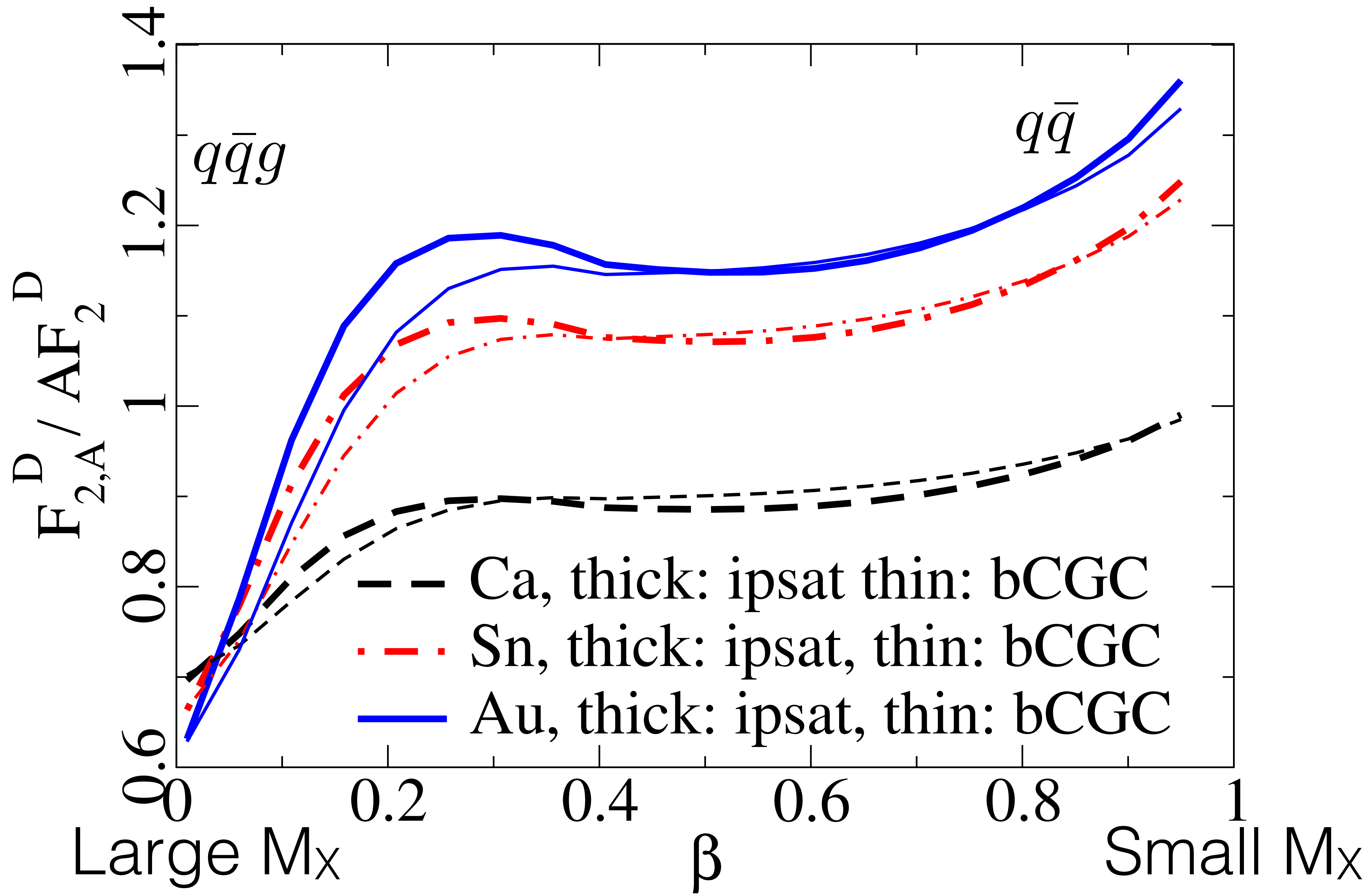
High precision differential cross section measurements



Inclusive diffraction

HERA surprise: ~15% of the events diffractive!

Saturation model prediction: suppression and enhancement with nuclei. To see this, need large energy/β lever arm)



Kowalski,Lappi,Marquet,Venugopalan

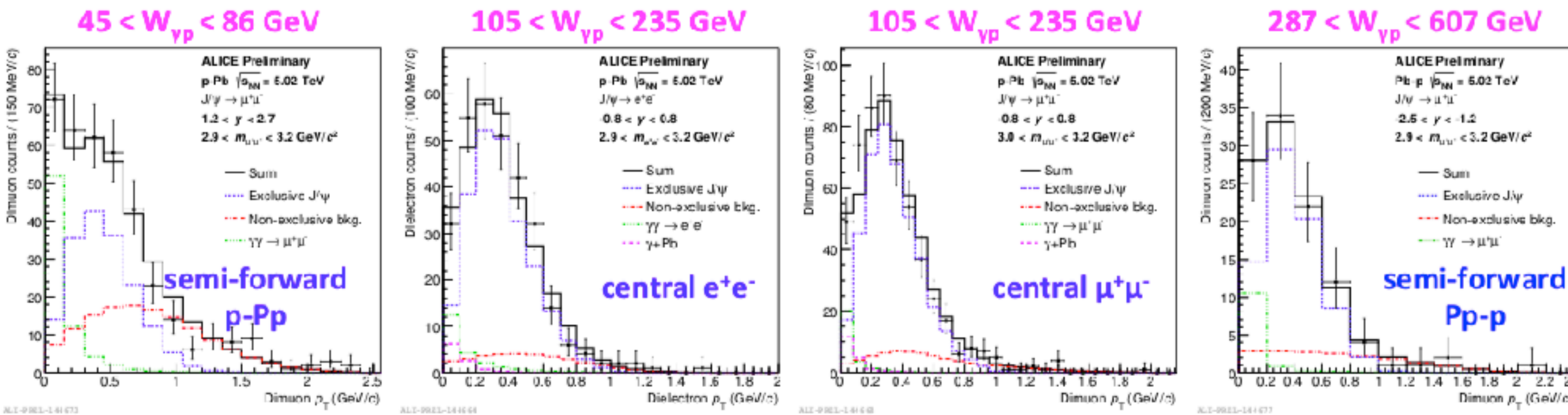
Conclusions

- Unique kinematical coverage of LHeC allows us to enter deep in the saturation region
- Nuclear beams are necessary to enhance non-linearities (and save €€€)
- With the LHeC, we (hopefully)
  - Constrain proton and nuclear PDFs to a new level, reduce uncertainties in LHC searches
  - See breakdown of fixed order perturbative expansion
  - Can study precisely non-linear effects in the nuclear wave function
  - And much more…

BACKUPS

Intriguing UPC results

Incoherent J/ψ production (~fluctuations in proton density) disappears at high energy, approaching black disk limit?

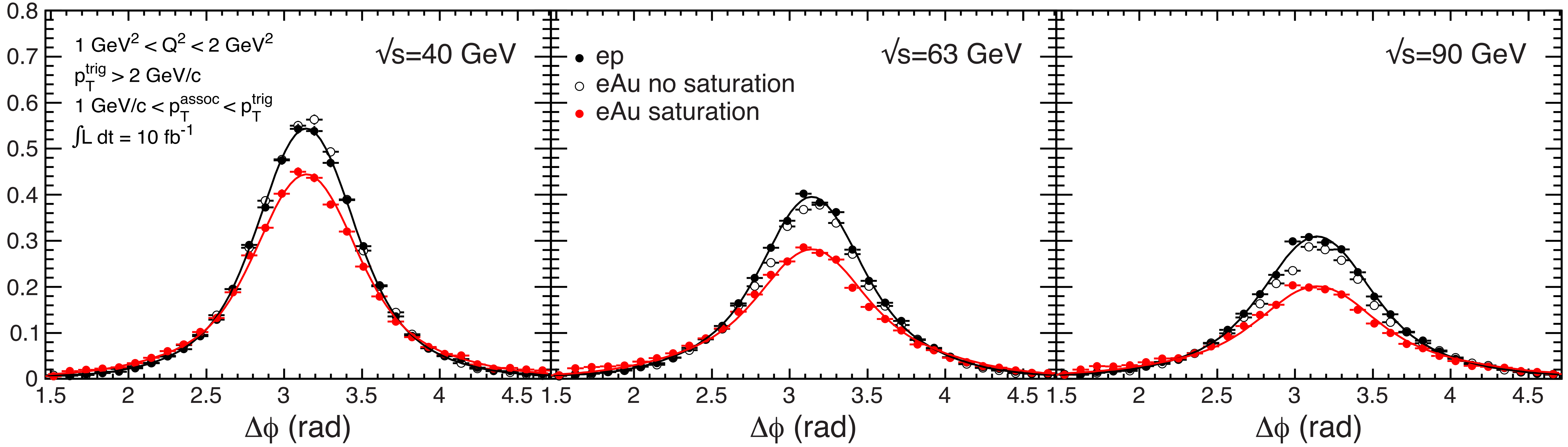


ALICE, QM2018, theory prediction: H.M, Schenke, 1806.06783

Dihadron correlations in eA

Energy dependence of back-to-back correlation

⇒ Energy dependence of Q_s



EIC simulation, theory by Bo-Wen, Feng, et al.