e+A Physics at the Large Hadron-electron Collider

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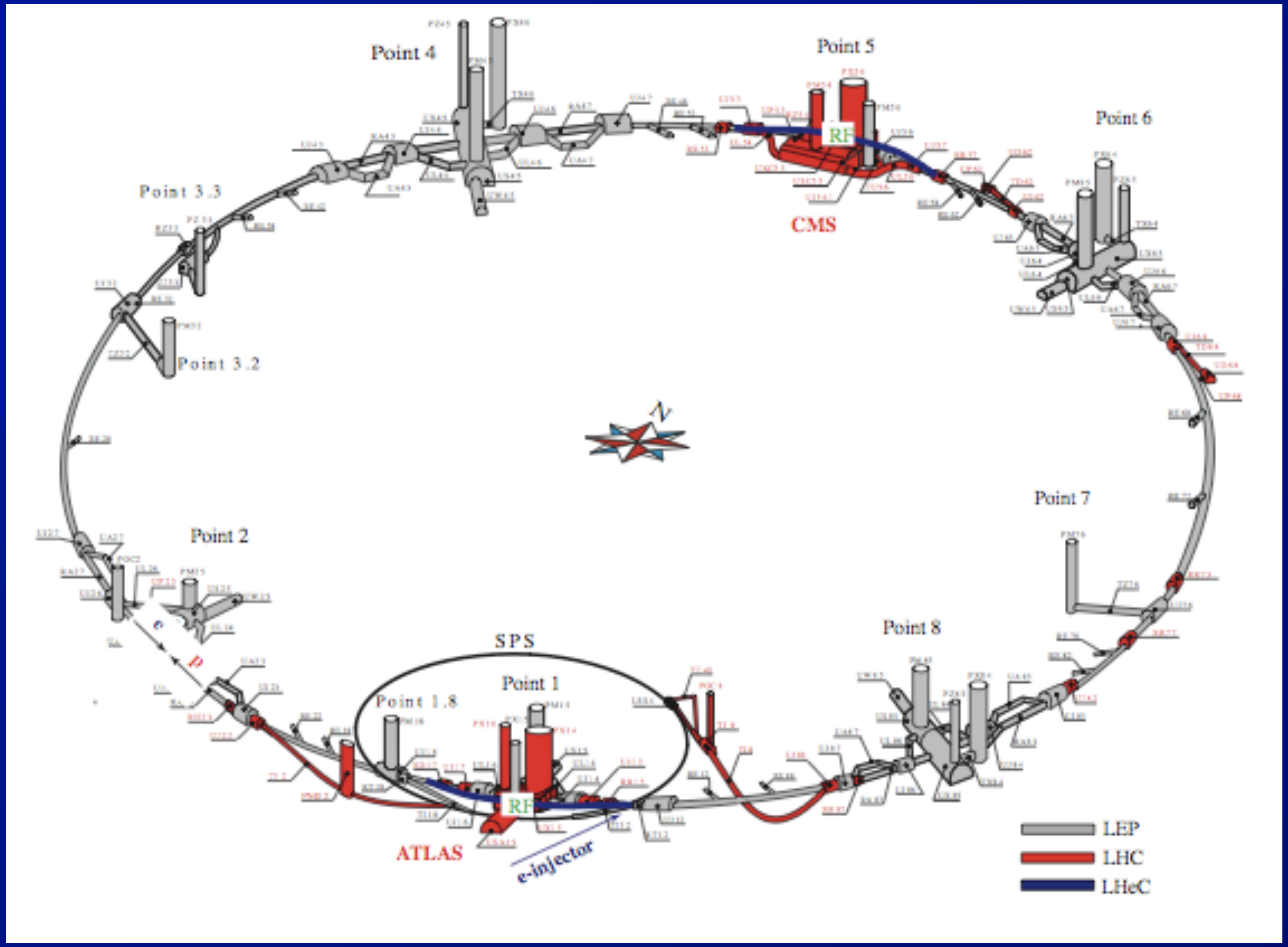


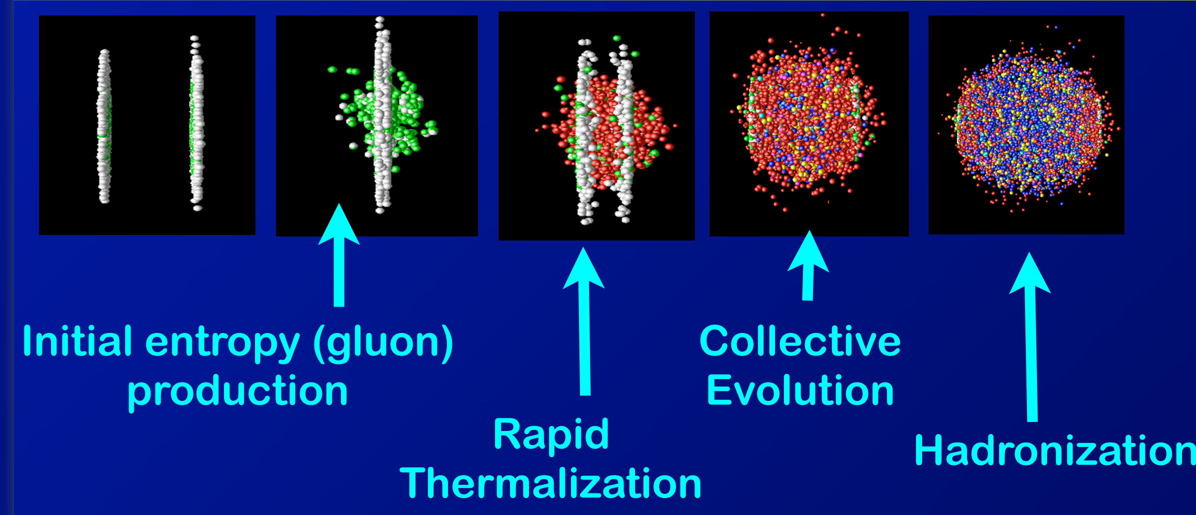
Material primarily drawn from the **High Parton Density** Chapter of the LHeC CDR

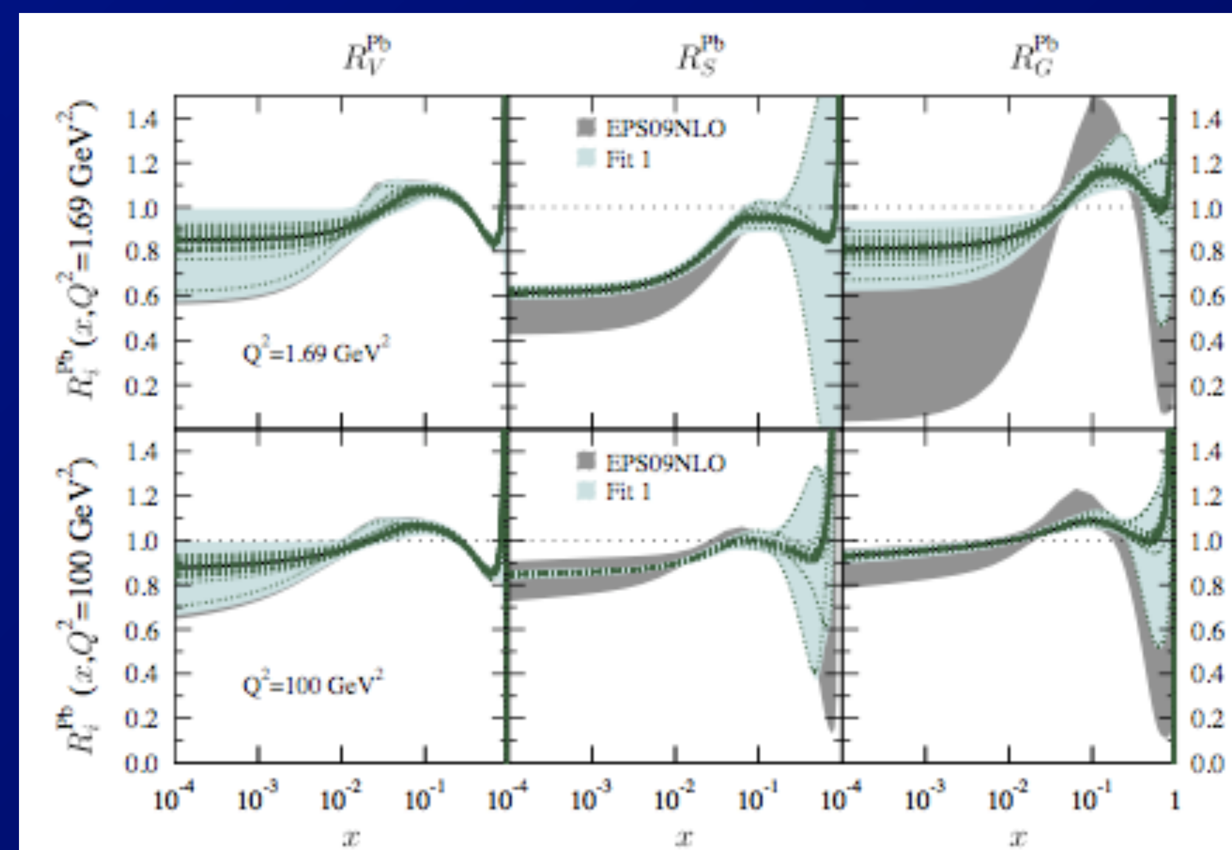
J. L. Albacete (IPhT Saclay), N. Armesto (Santiago de Compostela), J. Bartels (Hamburg), B. A. Cole (Columbia), J. C. Collins (Penn State), D. d'Enterria (CERN), K. J. Eskola (Jyvaskyla), L. Favart (IIHE Brussels), S. Forte (Milano), H. Jung (DESY), M. Klein (Liverpool), H. Kowalski (DESY), T. Lappi (Jyvaskyla), C. Marquet (CERN), P. R. Newman (Birmingham), H. Paukkunen (Santiago de Compostela), J. Rojo (Milano), C. A. Salgado (Santiago de Compostela), A. M. Stasto (Penn State), M. Strikman (Penn State), K. Tywoniuk (Lund), G. Watt (CERN), C. Weiss (JLab) and U. A. Wiedemann (CERN)

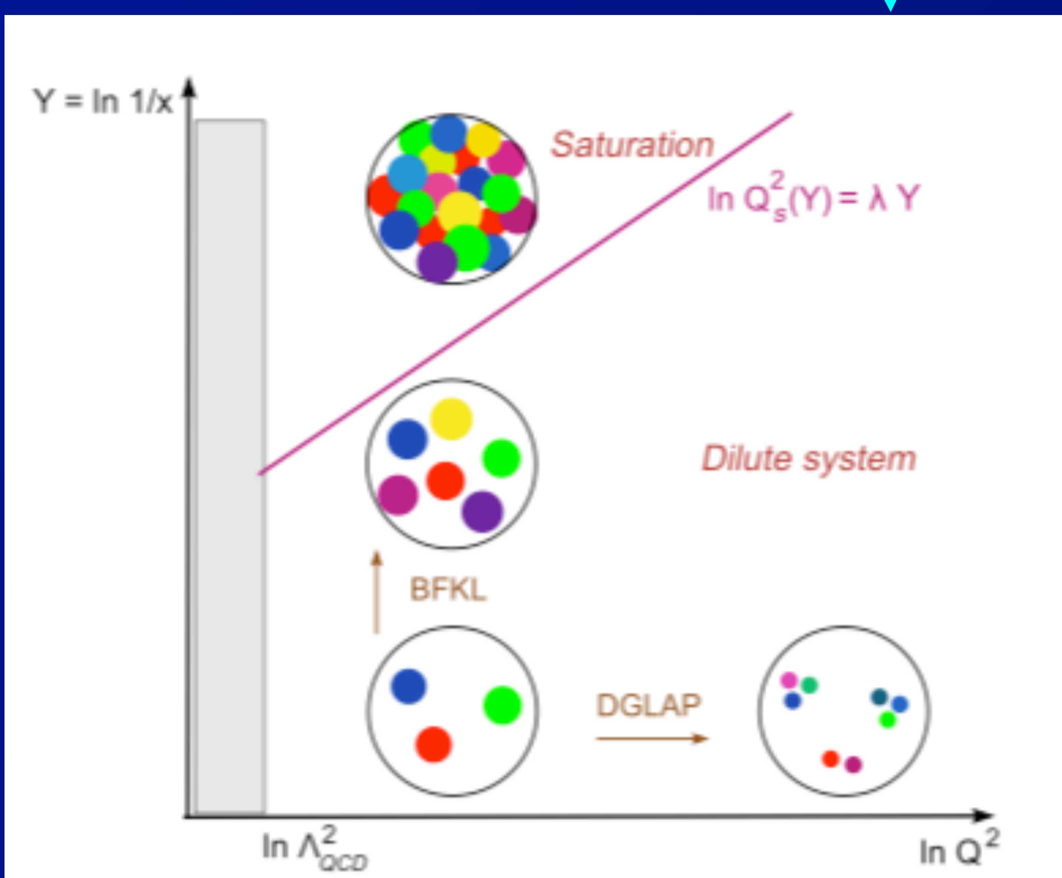
Why e-A?

- Nucleus+Nucleus initial conditions
- Nuclear parton distributions
- QCD at high parton density.

Pb+Pb (Canonical) Time History

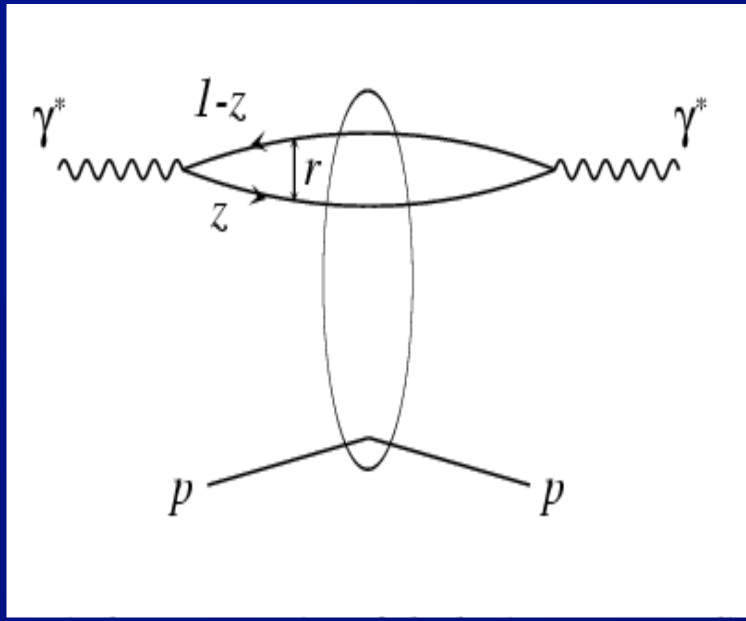




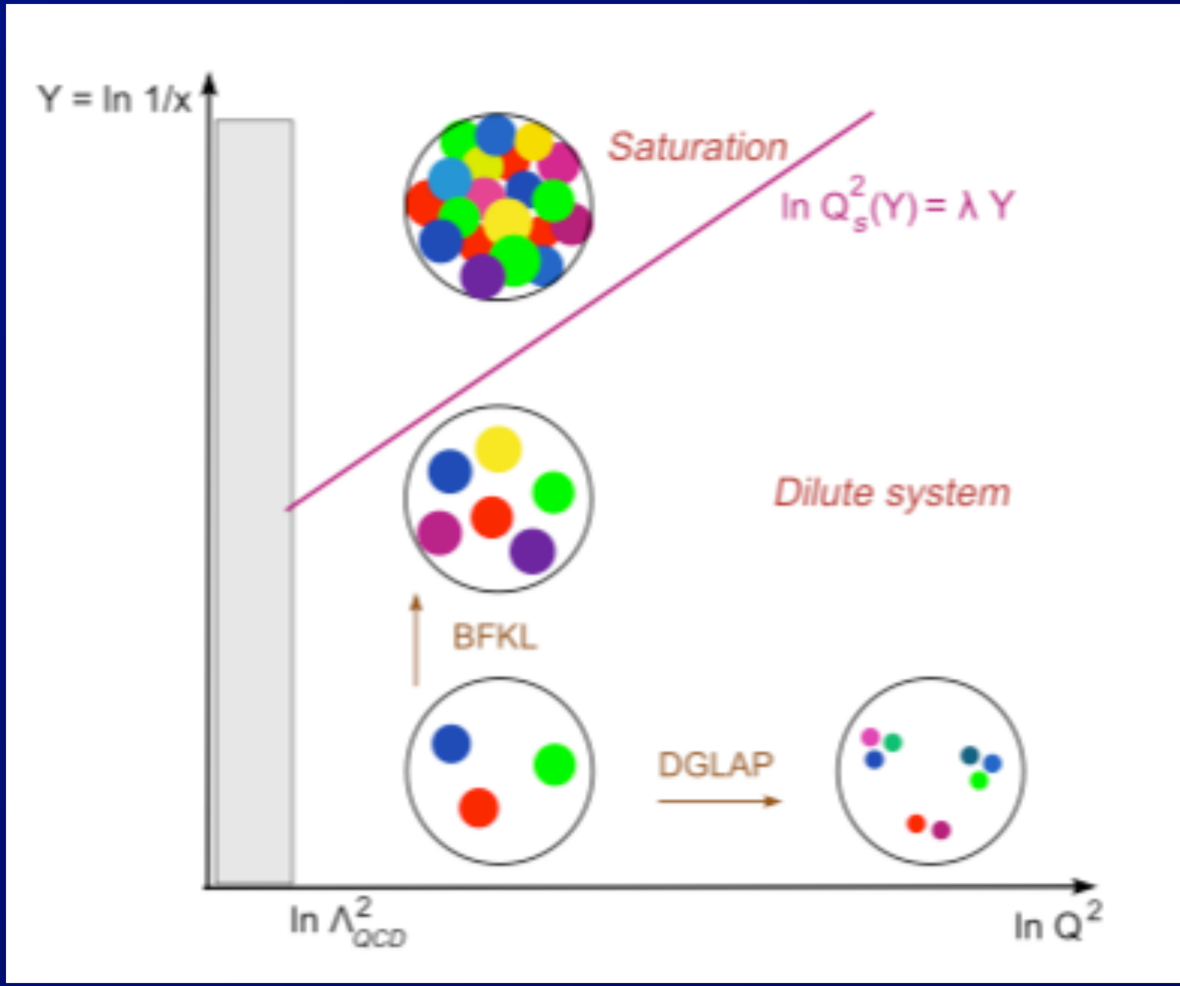


High Parton Density

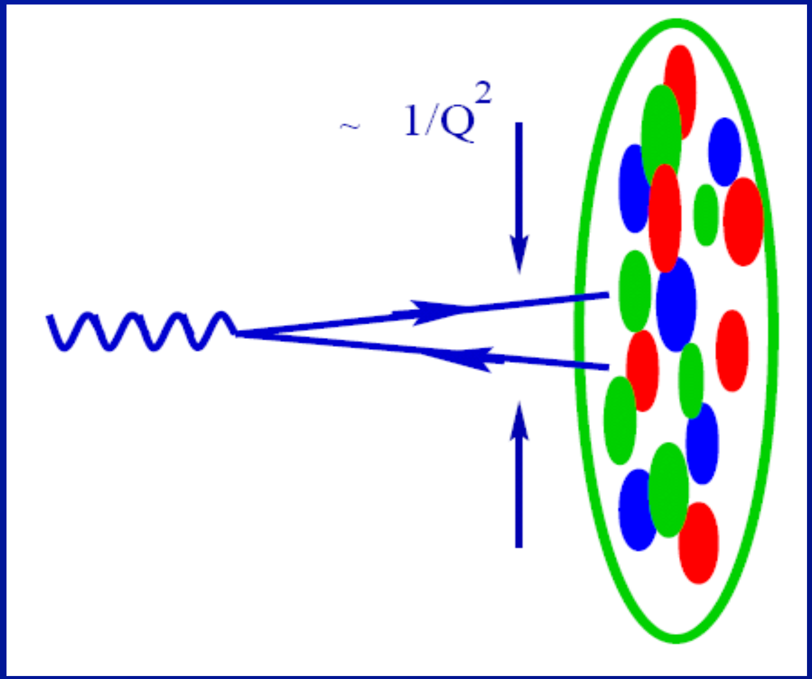
- **Why are we (am I) interested in high parton density QCD?**
  - Understand how a fundamental theory like QCD manifests unitarity
    - ⇒At large enough Q^2 for the physics to have a partonic interpretation (?).
    - ⇒e.g. non-linear evolution via recombination

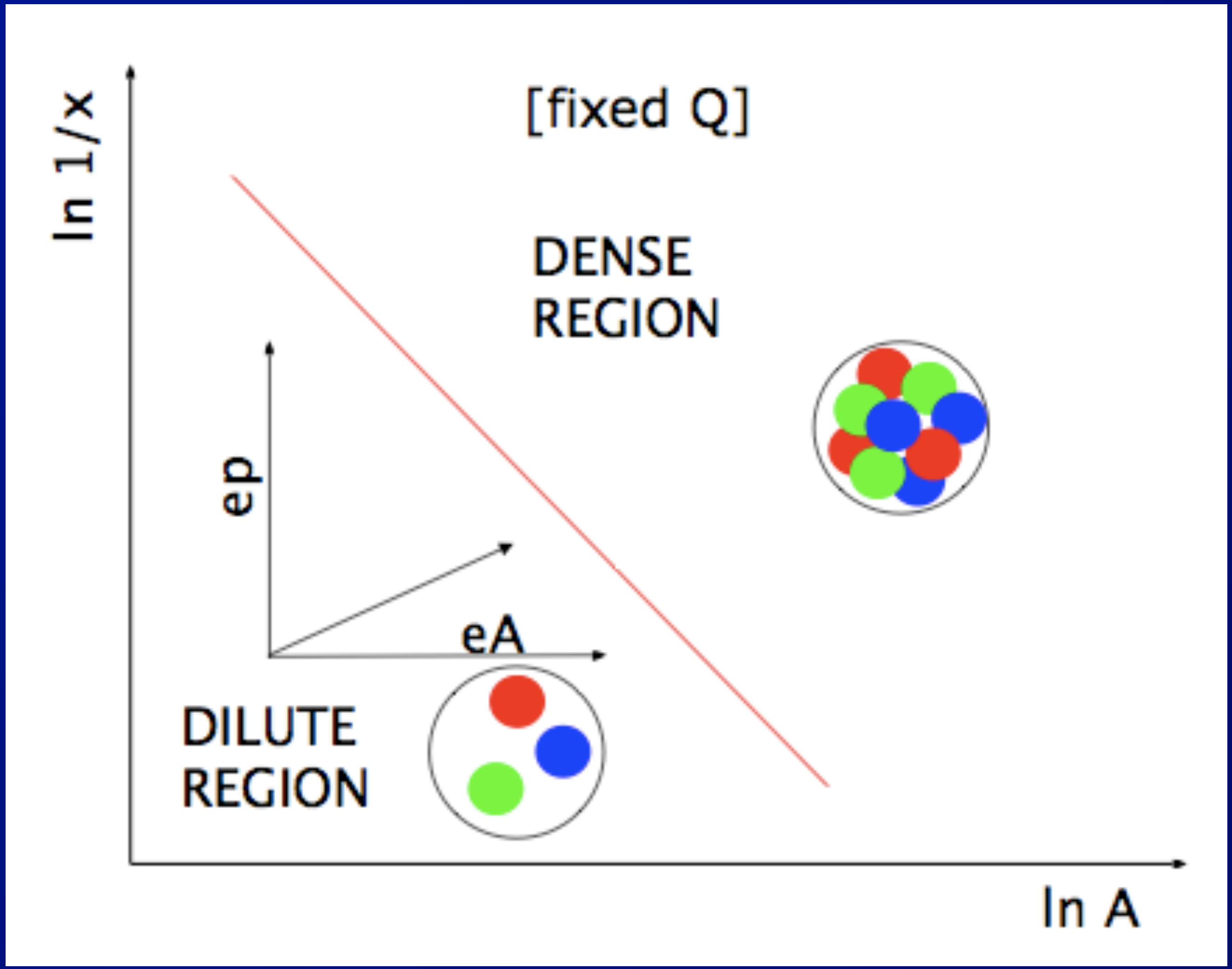


What happens when $|A| \to 1?$



High Parton Density (2)





- How to reach high parton density ?
  - Increase s ⇒ decrease x (evolution)

    ⇒Understanding of low-x evolution needed
  - Increase target thickness (p → A)

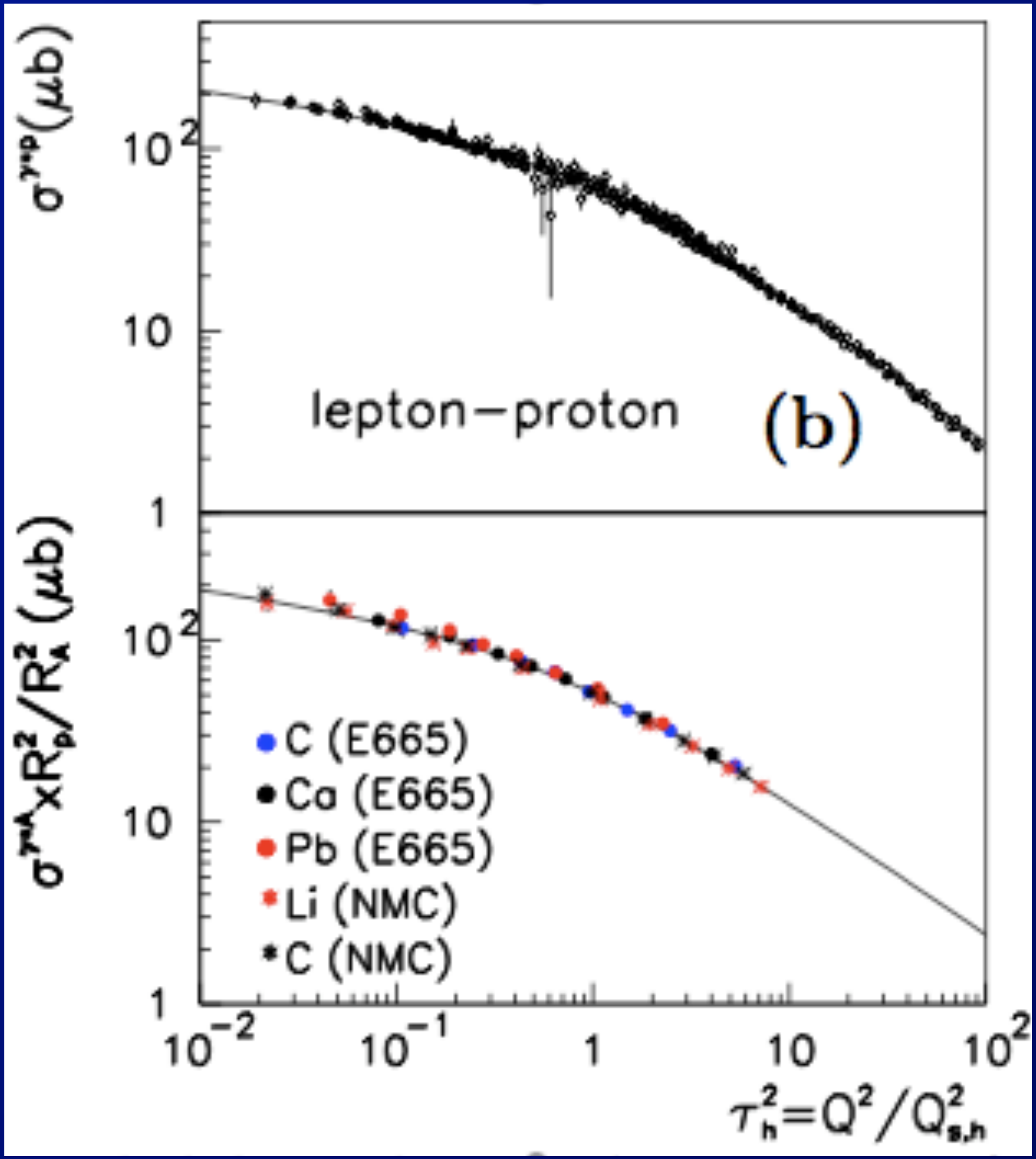
    ⇒Intuitively: most natural way to increase density

Nuclei: Geometric scaling

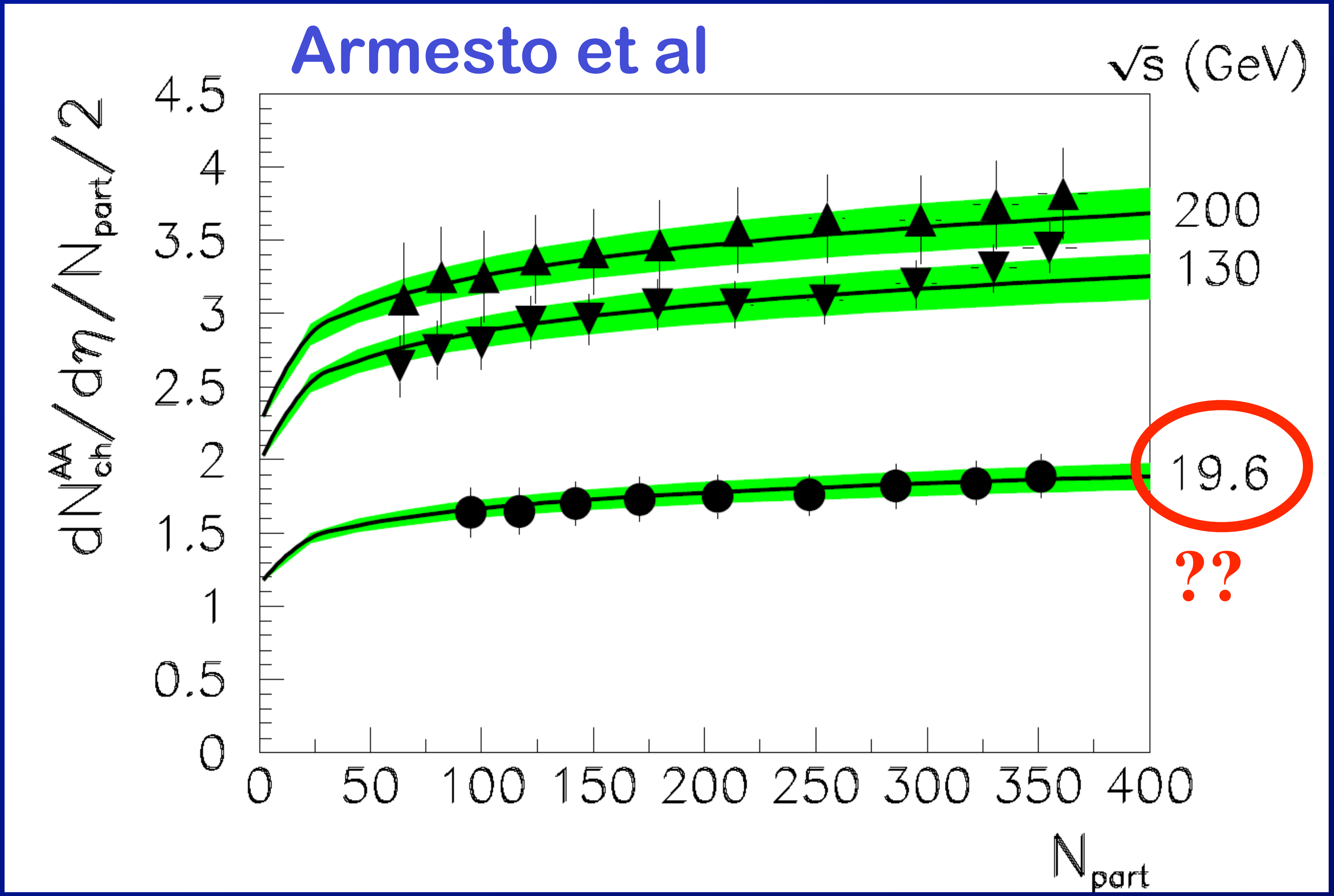
- **Armesto et al:**
  - nuclear geometric scaling
    - ⇒Extension of HERA saturation analysis to nuclear targets

$$Q_s^A = Q_s^p \left(A \frac{R_p}{R_A} \right)^{\lambda}$$

- **Good description of 5 different nuclear targets**
  - C^{12} - Pb^{208}



A+A Multiplicities from Saturation?!



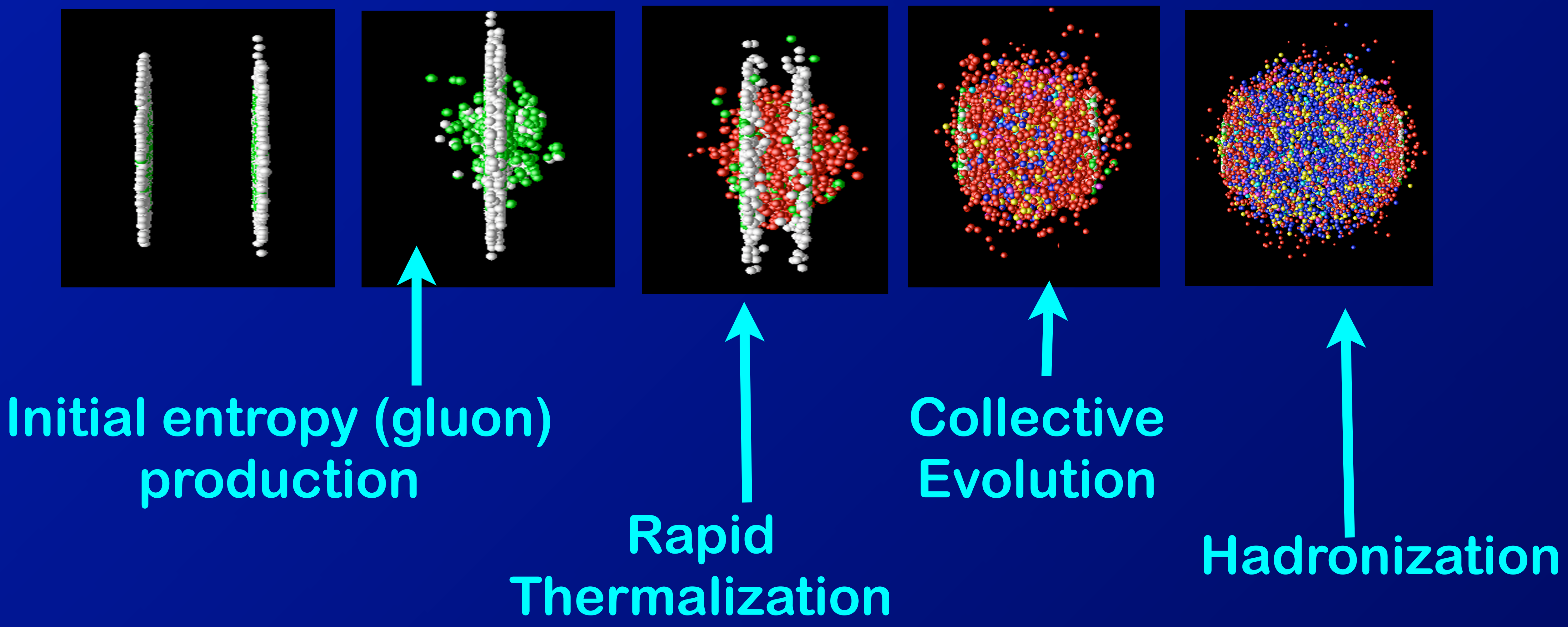
- Use nuclear saturation analysis

  +k_T factorization + Parton-hadron duality

  ⇒ A+A dN/dη vs centrality, √s

- Describes data (too?) well !

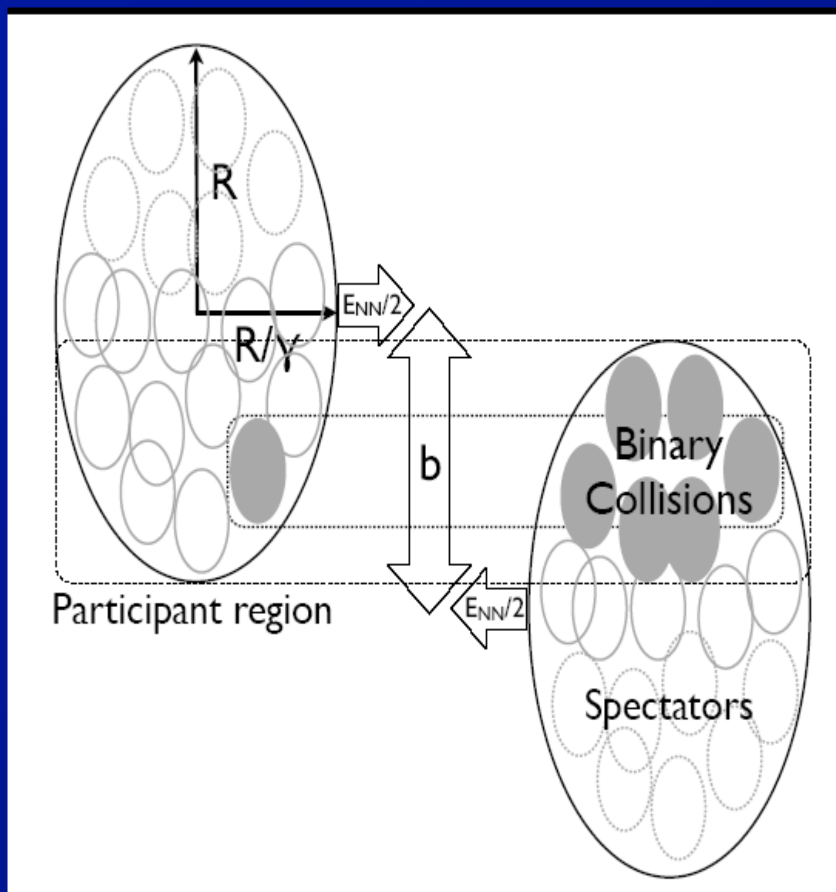
Pb+Pb (Canonical) Time History

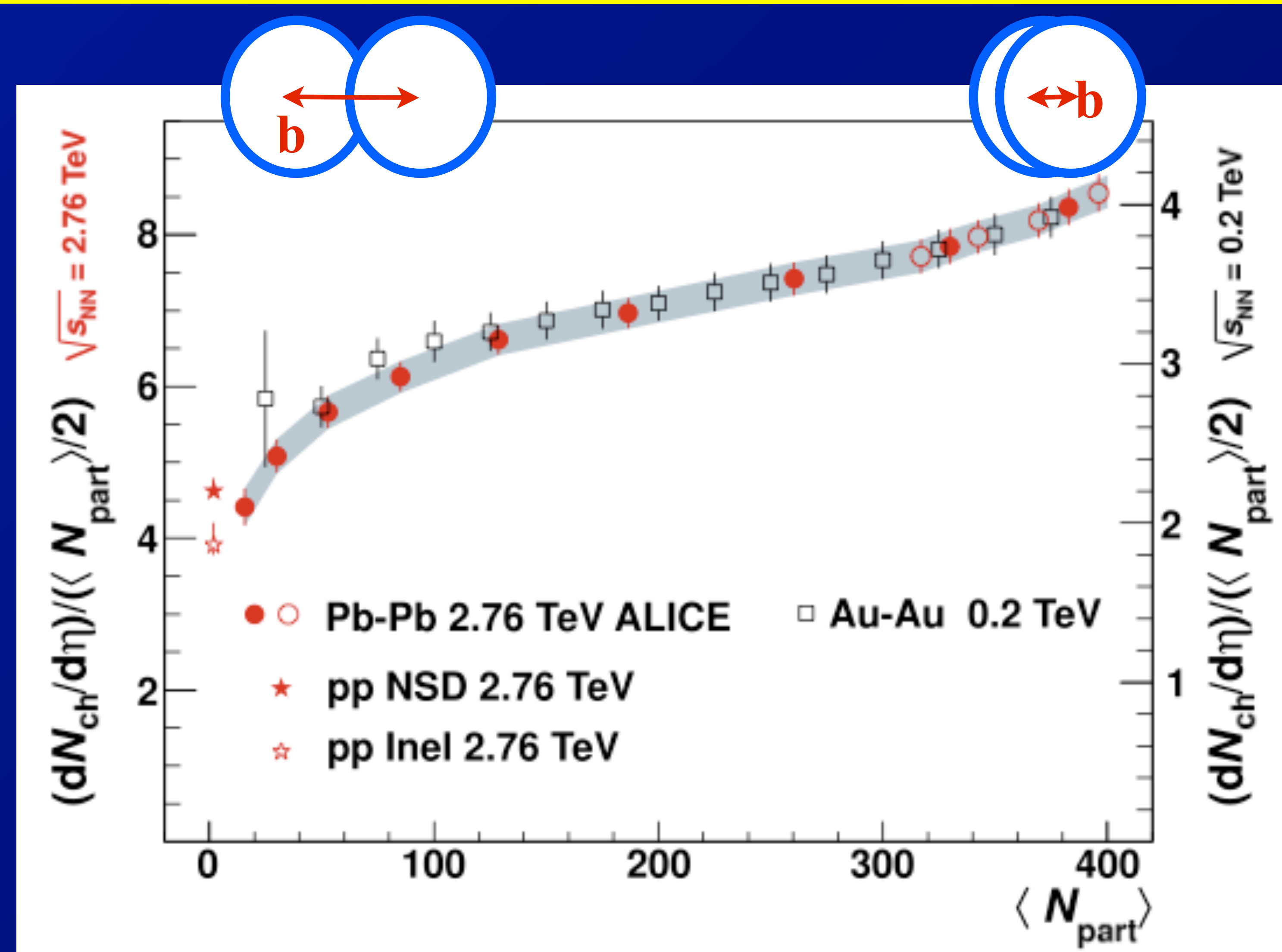


- **Understanding the initial conditions of A+A critical to understanding the later evolution.**
  - As will be shown below pQCD (inspired) + saturation models reasonably describe A+A multiplicities.
    - ⇒Ultimately, independent confirmation of assumptions/parameters with e+A essential

LHC Particle Multiplicity

A+A Geometry

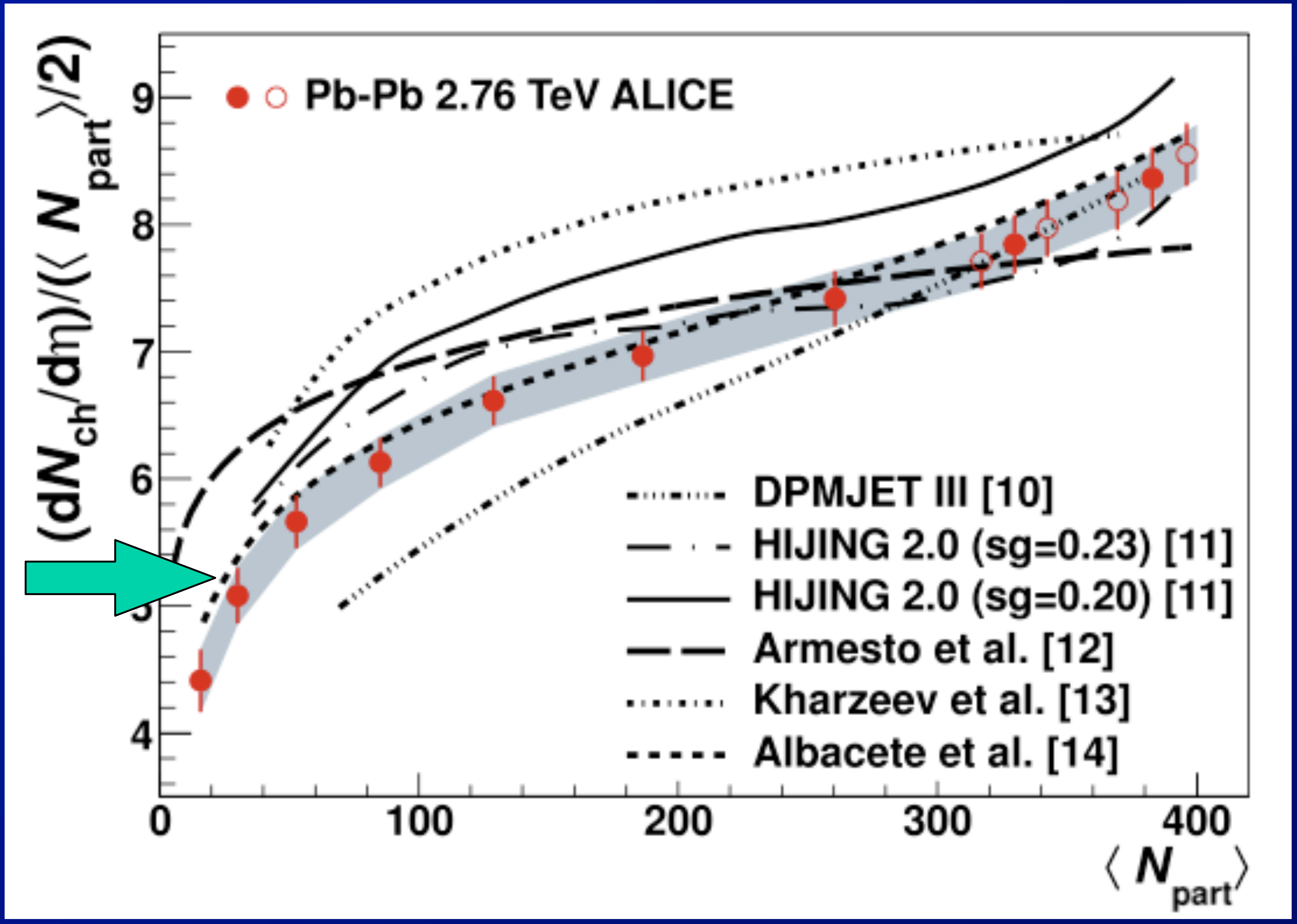




- **Experimentally:**
  - A+A multiplicity at RHIC and the LHC primarily determined by initial-state geometry

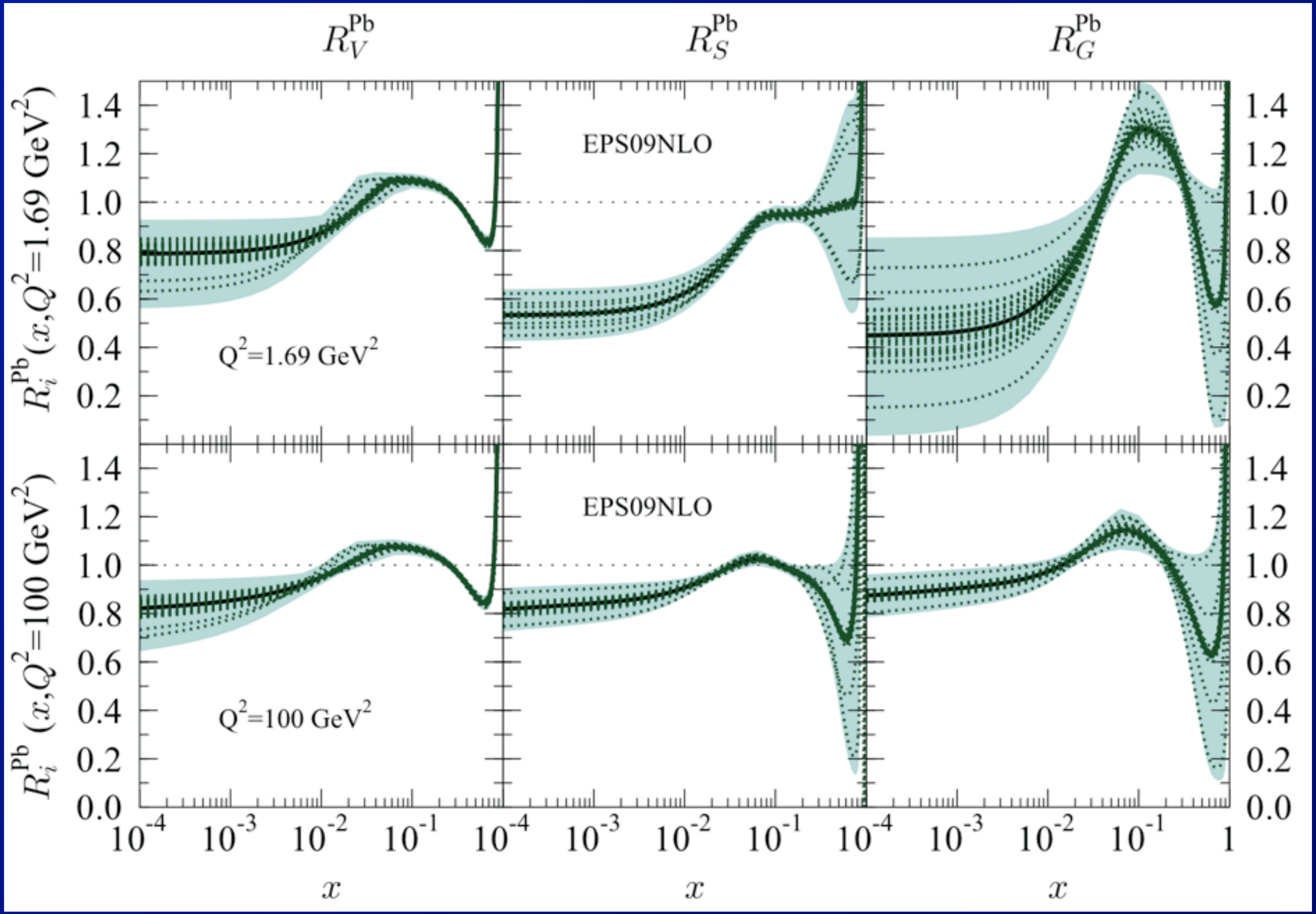
    ⇒# colliding nucleon pairs
  - Though see ArXiv:1103.1259v1.

A+A Multiplicity and Saturation



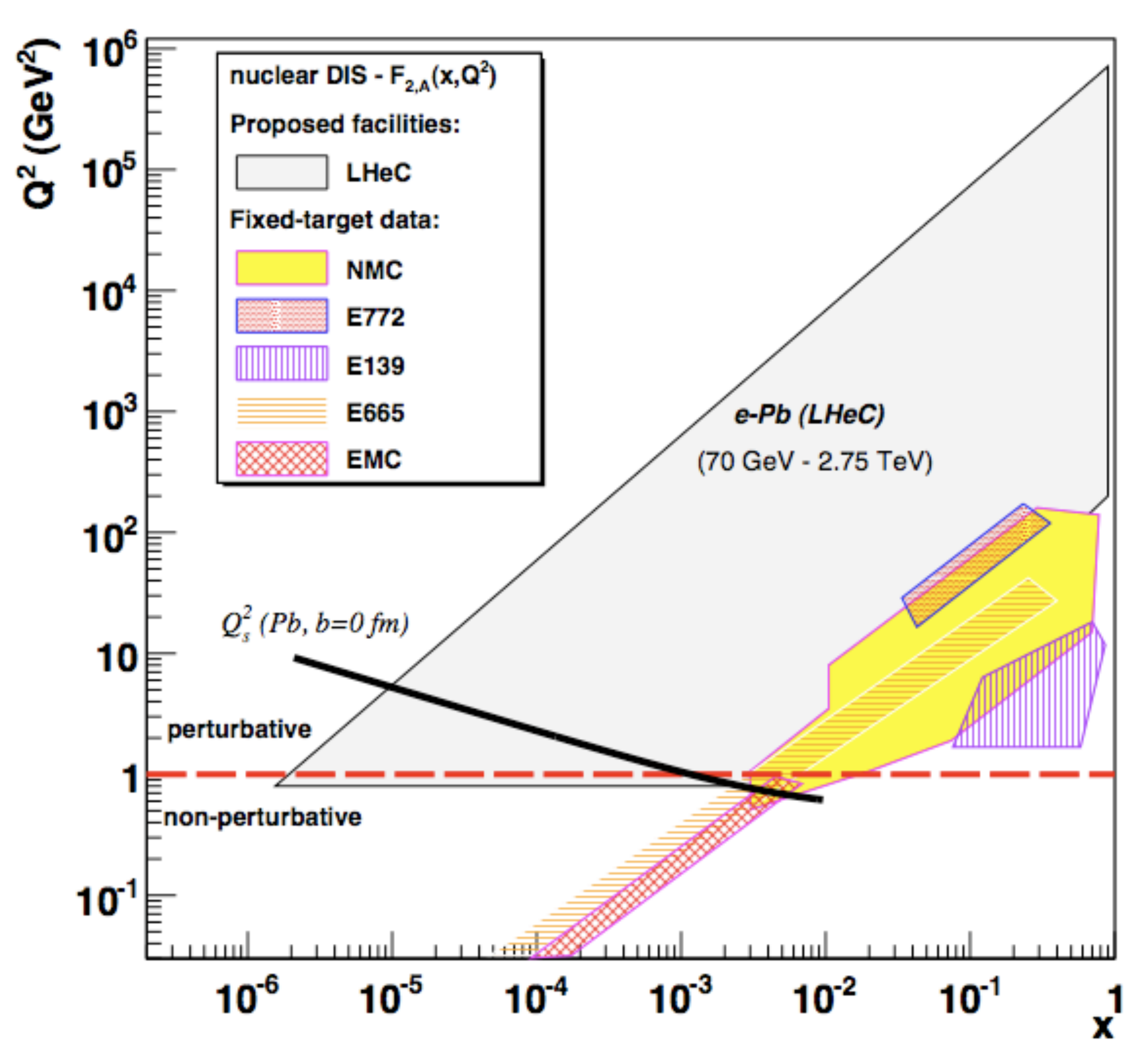
- Saturation calculation of Albacete et al provided the best prediction of Pb+Pb dN/dη
  - But, the predictions varied widely.
    - ⇒Need independent constraint

Nuclear PDFs



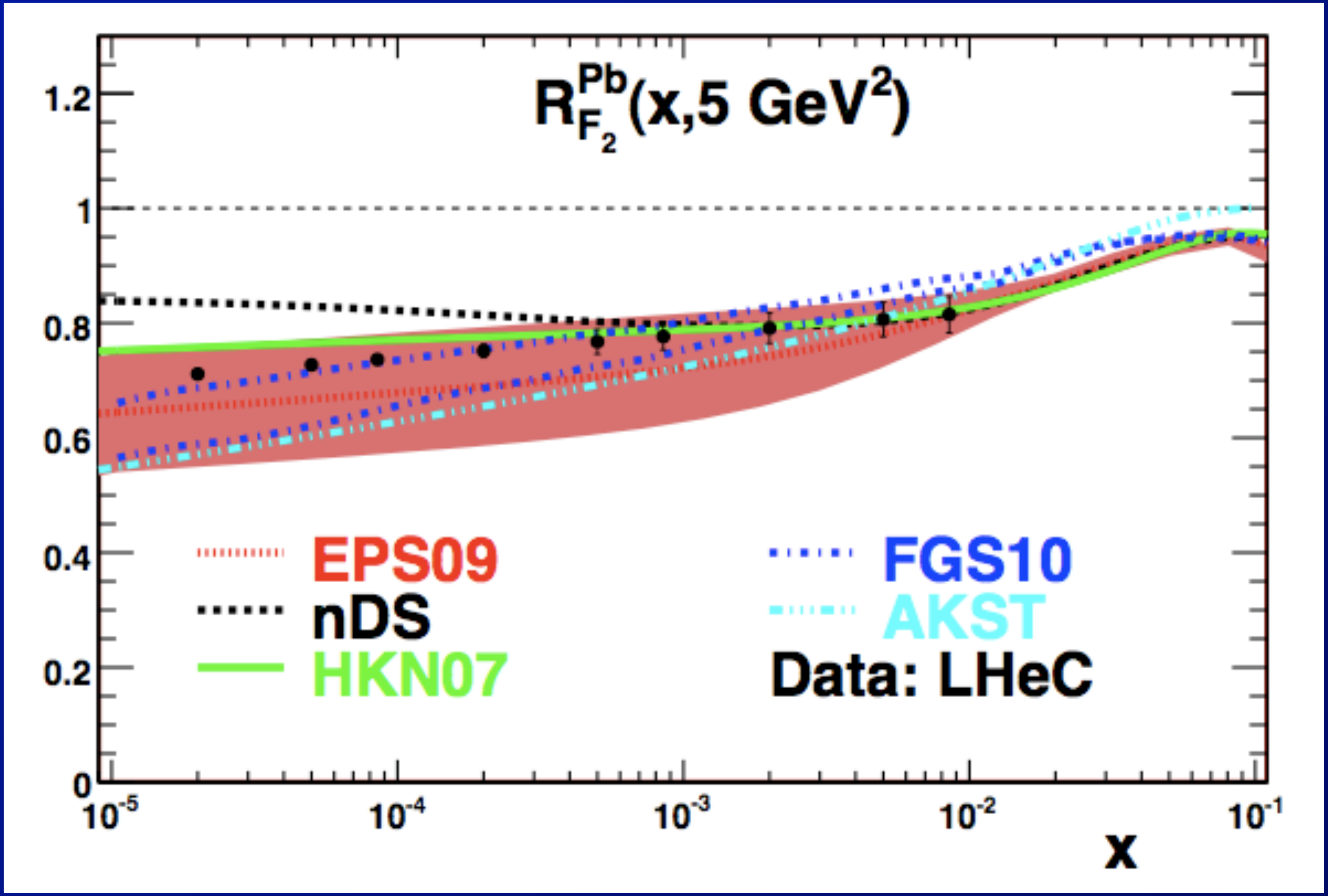
- Gluon distribution in nucleus very poorly known for $x < 2 \times 10^{-2}$

LHeC e+A Kinematic Coverage



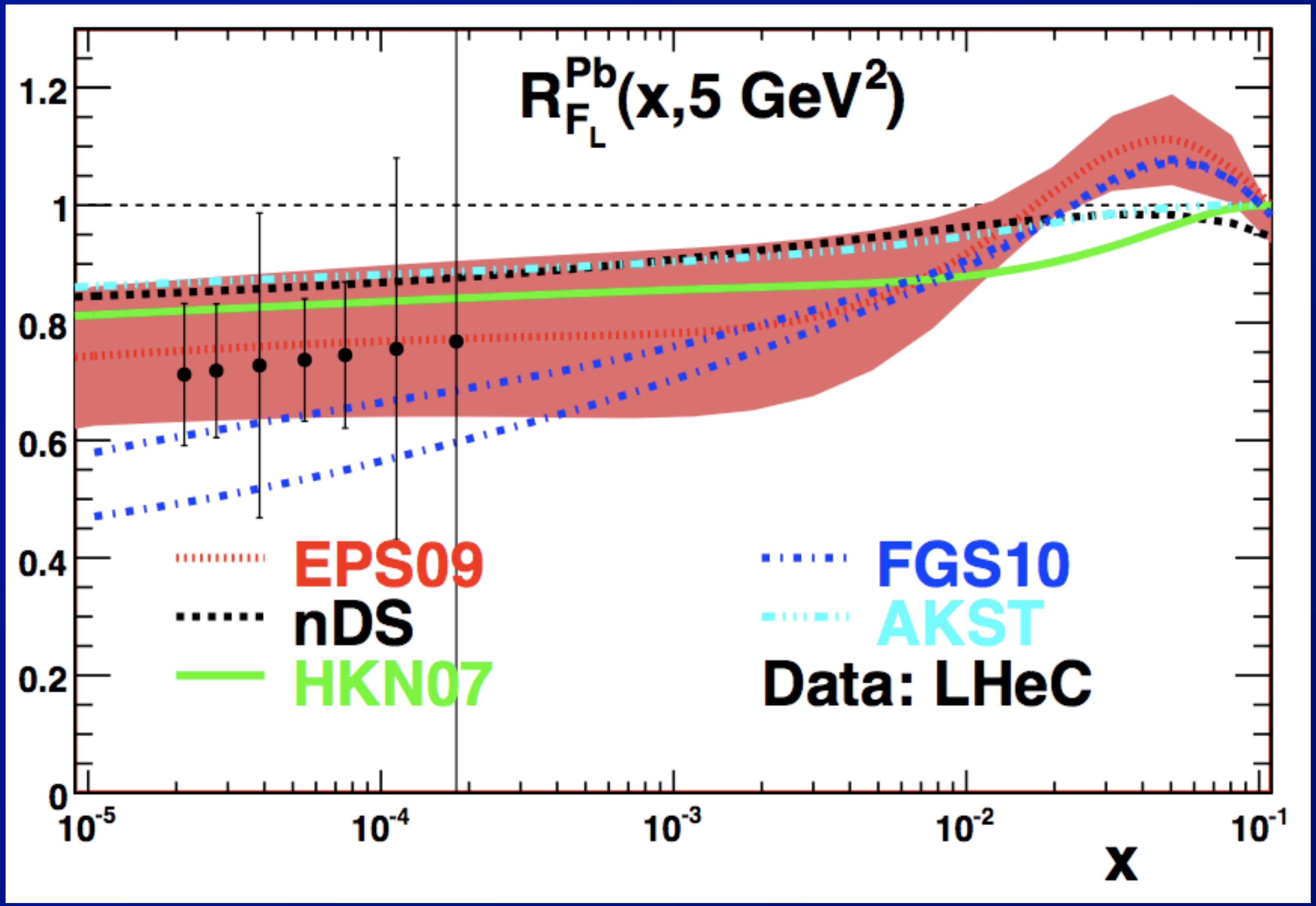
- The LHeC will dramatically expand $x - Q^2$ coverage of nuclear DIS measurements.
- Access to saturation scales $Q_s^2 \sim 5\ \mathrm{GeV}^2$
  - at b = 0.

Improvements in Nuclear PDFs (1)



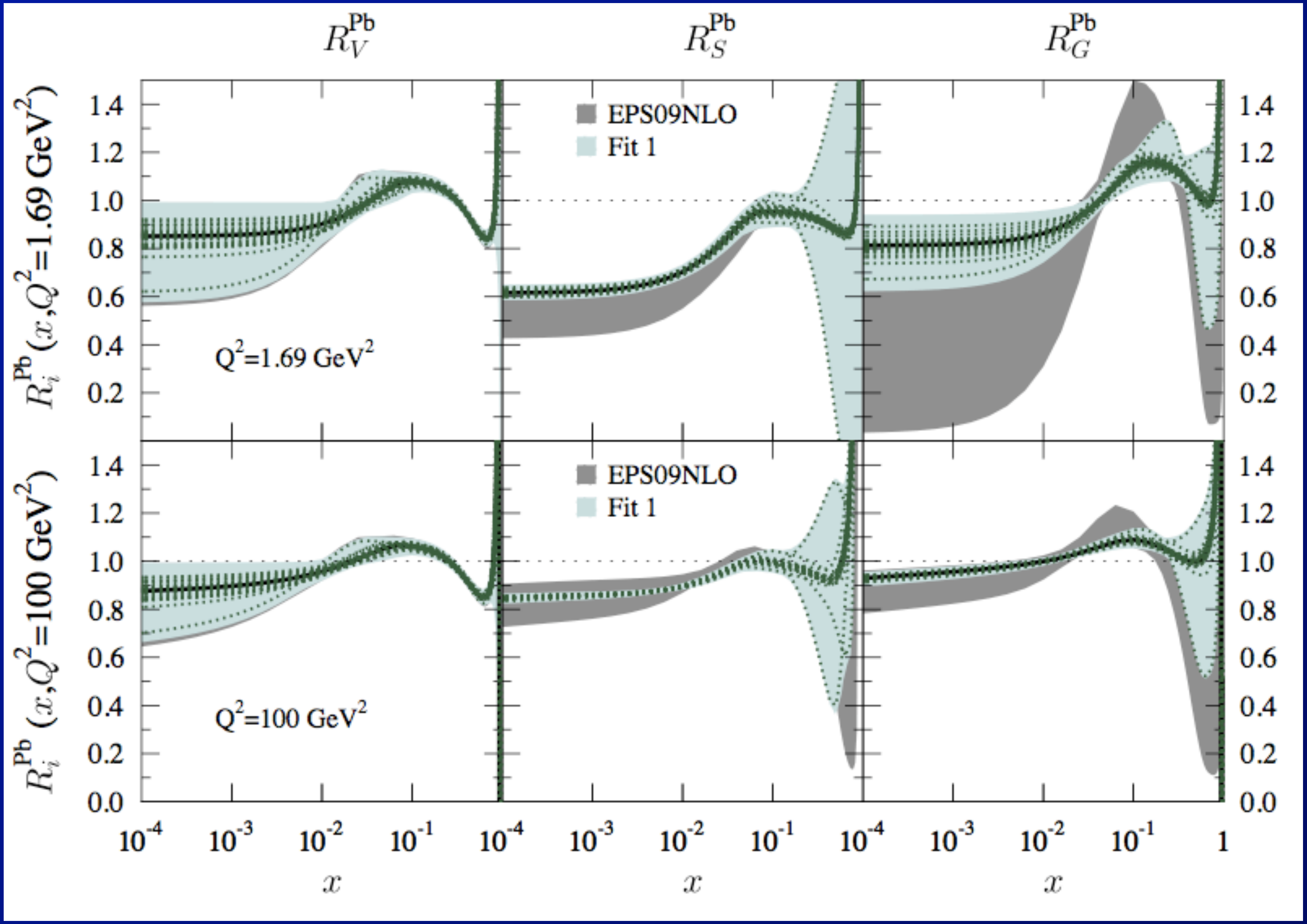
- Comparison of LHeC pseudo-data with error bars to current nuclear F_2 fits/parameterizations
  - LHeC data will significantly reduce uncertainties

Improvements in Nuclear PDFs (2)



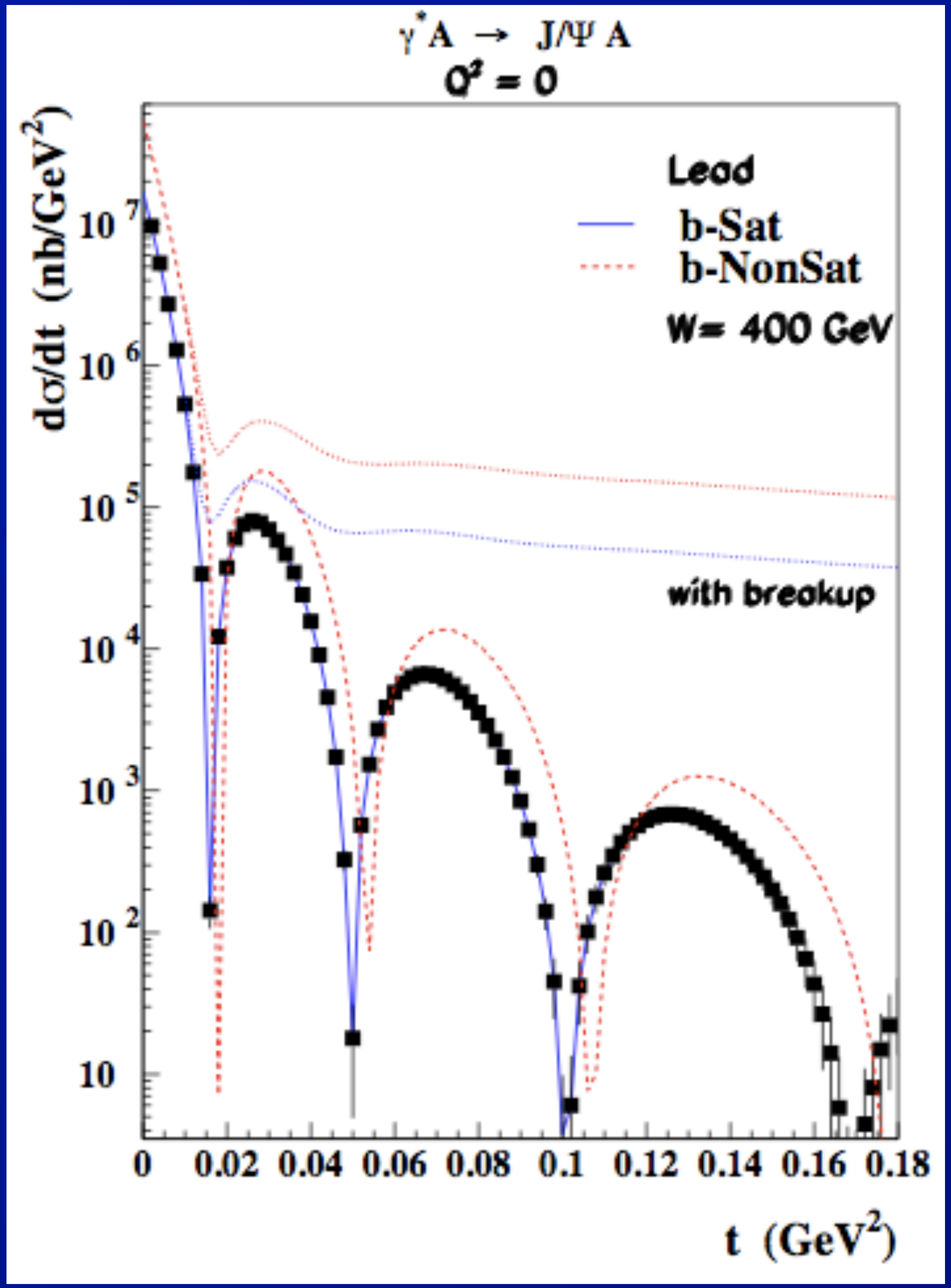
- Currently we have no nuclear F_L data.
- Based on current guesses at e-A availability @ LHeC, F_L will have sizable errors
  - But will still provide valuable constraint on PDFs

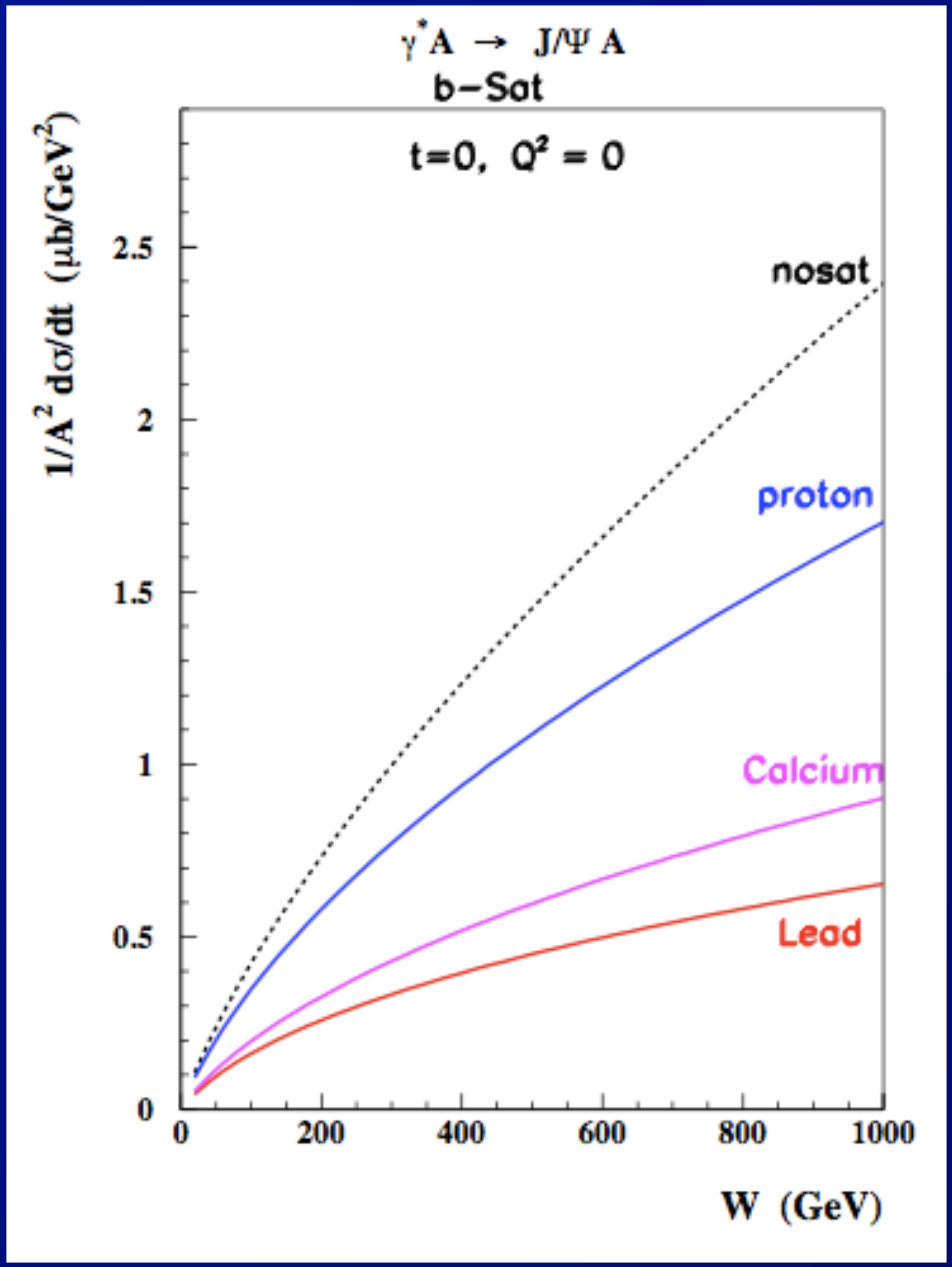
Improvements in Nuclear PDFs (3)



- **EPS study of impact of LHeC measurements on uncertainties in nuclear PDF (ratios)**

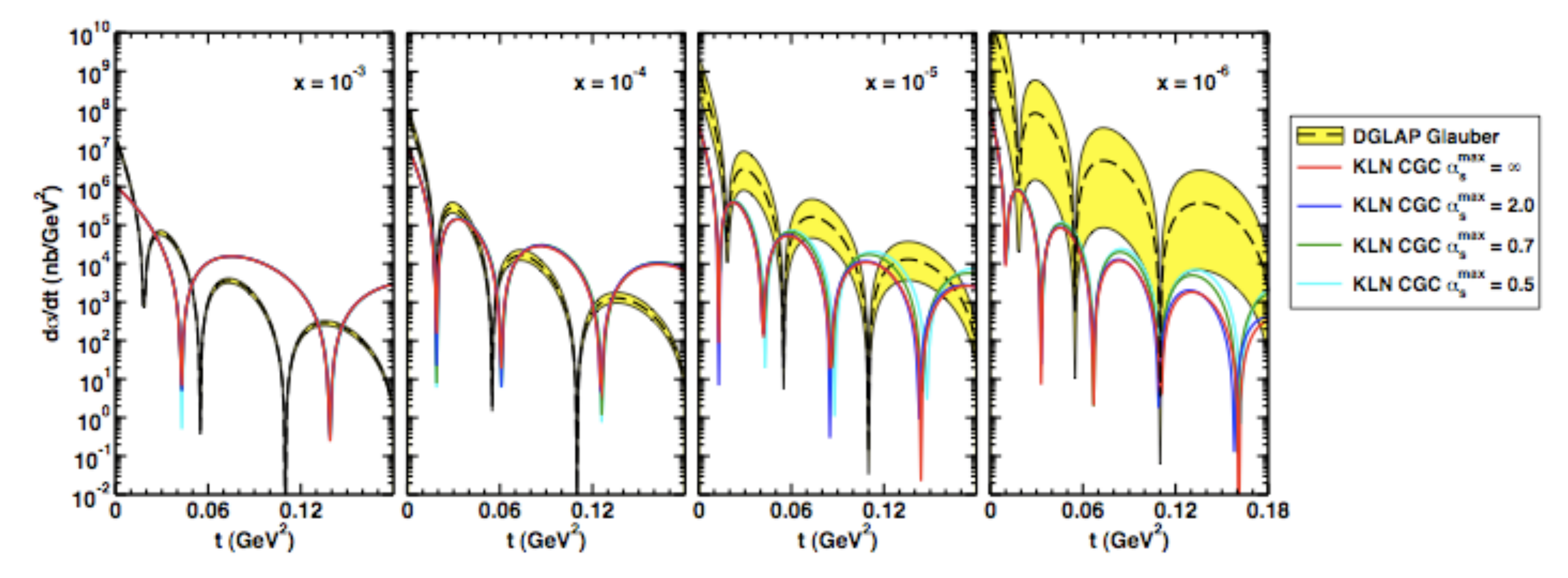
Exclusive VM Photoproduction





- *t* and *W* dependence of nuclear J/ψ photo-production
  - t dependence sensitive to detection of break-up
  - W dependence sensitive to saturation

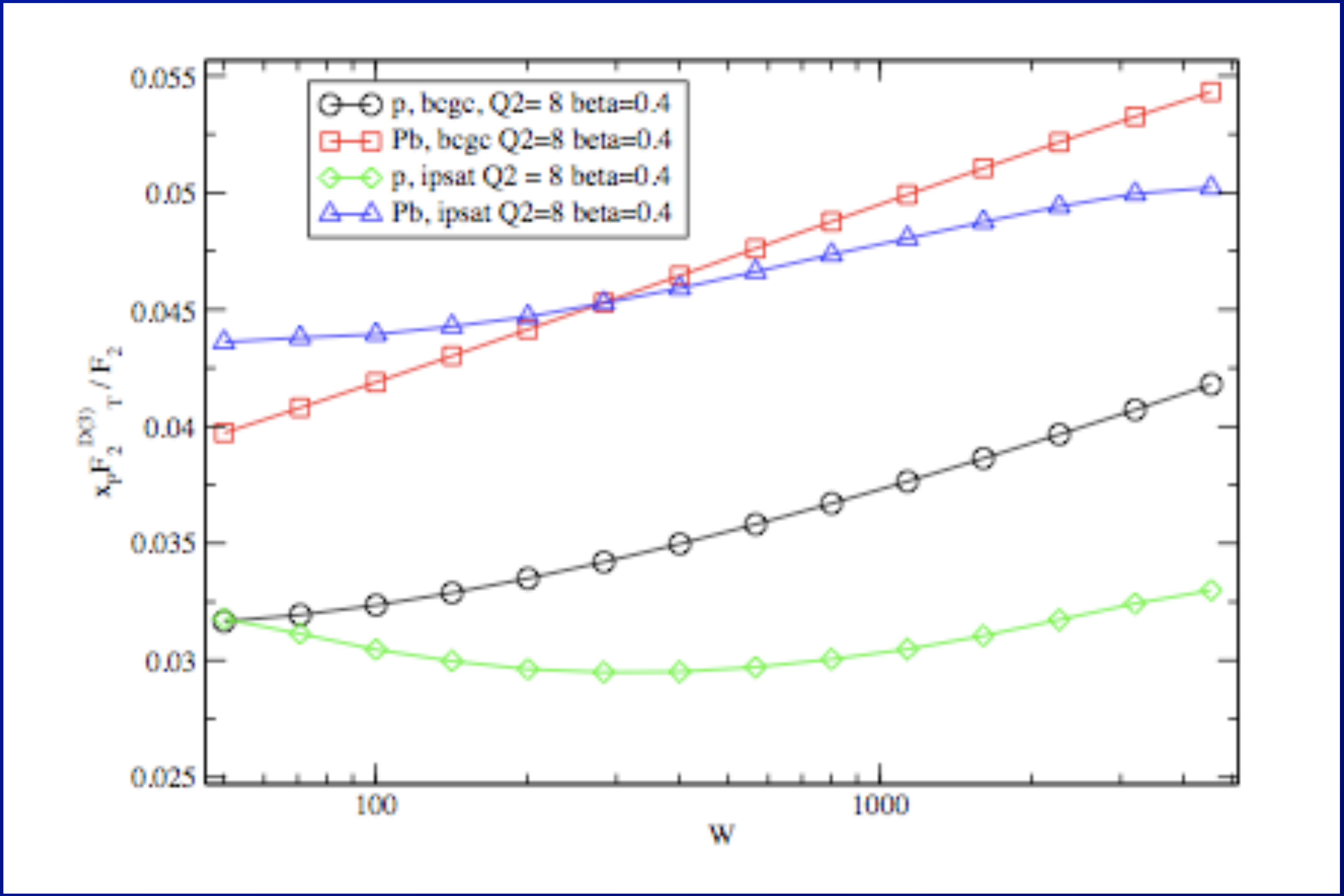
Exclusive VM Photoproduction (2)



- Study by W. Horowitz of J/ψ photo-production
- Comparing
  - DGLAP + nuclear geometry
  - CGC saturation

    ⇒ Sensitive to saturation effects.

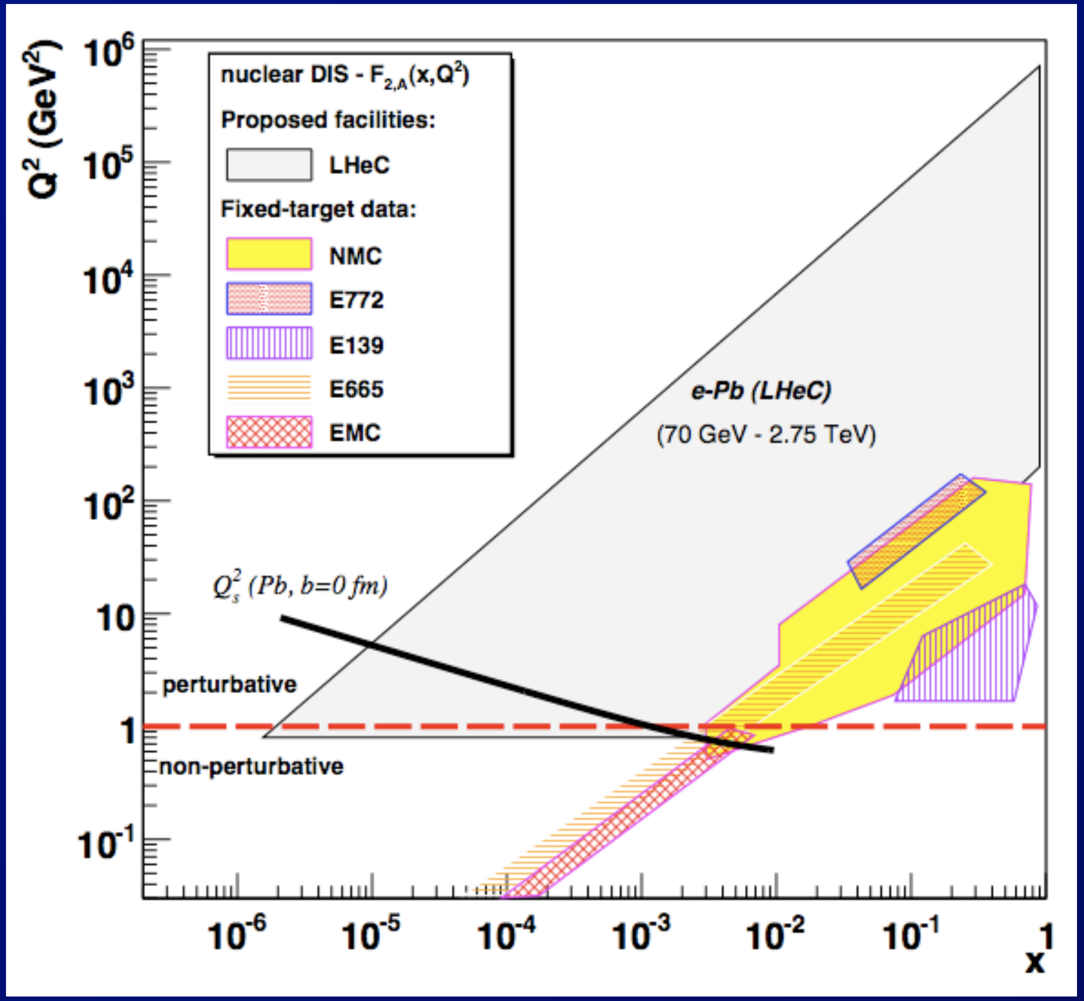
Inclusive Diffraction



- **Diffractive to inclusive structure function ratio**
  - CGC vs IPsat, p vs Pb
    - ⇒Saturation effects visible in increased diffraction

Summary

- e+A measurements are critical for the reasons set out at the beginning (+ others of course)
  - QCD at high parton density.
  - Nucleus+Nucleus initial conditions
  - Nuclear parton distributions



- LHeC has the kinematic reach to contribute to all of these.
  - With coverage down to $x \sim 10^{-6}$
- Work well along to study e-A performance
  - ⇒ Included in HPD chapter of LHeC CDR.