Working group on Physics at High Parton Densities (ep and eA)

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- Main issues
- Observables
- Work so far and what needs to be done
- Schedule

Main physics goals

What we know:

- HERA demonstrated the strong growth of structure functions when x decreases.
- This proved non-trivial QCD dynamics in the high energy regime. Rising sea of small x partons.
- Relevant for many types of collisions: LHC, cosmic rays, ultrahigh energy neutrino interactions (smaller values of x possible).
- We can describe it via linear QCD evolution (in a limited regime).

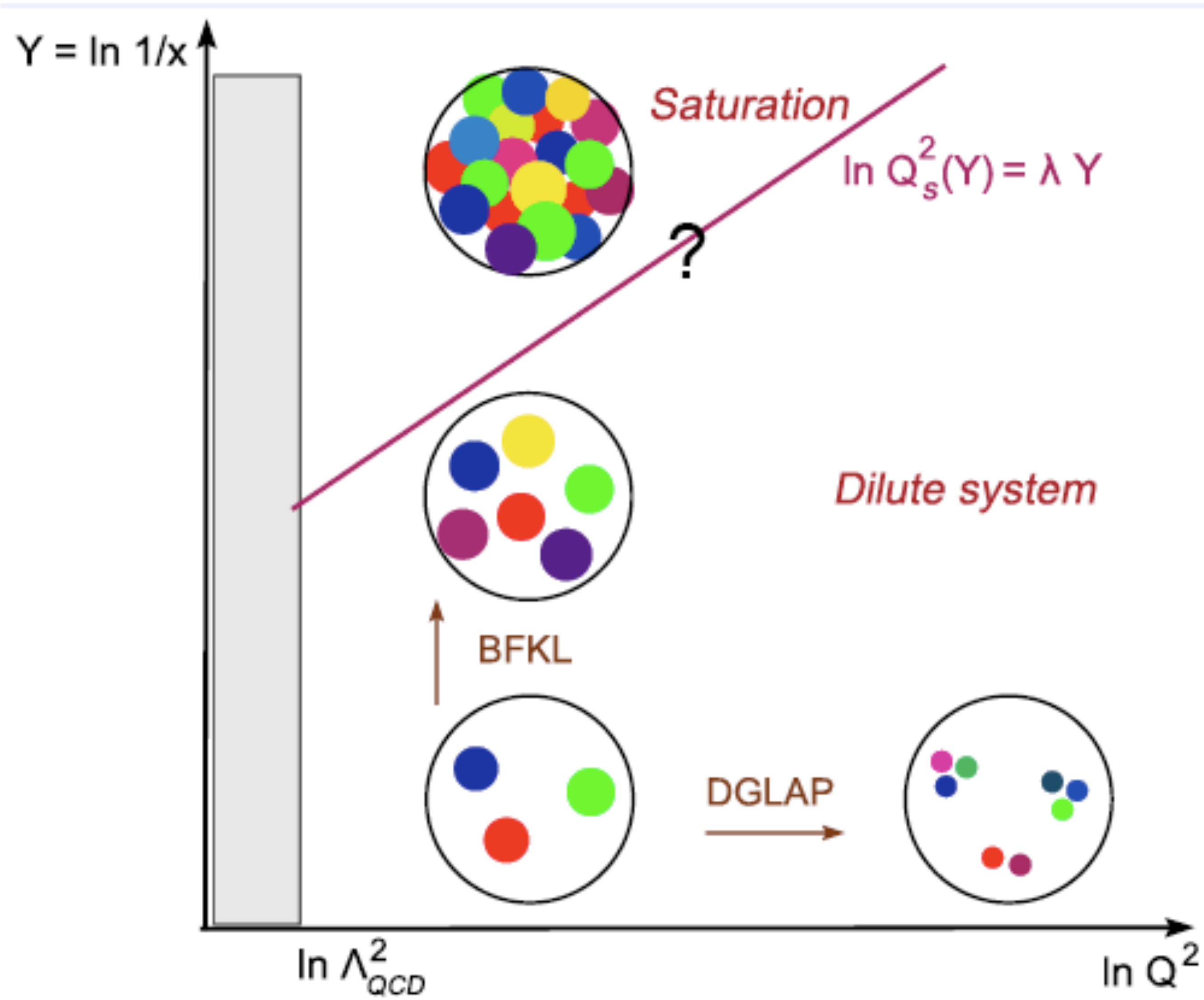
What we don't know:

- What happens when the parton density is very large? Amplified in nuclei.
- How the unitarity limit is approached in QCD?
- How do we see it in the data in an unambiguous way?
- How is it realized on a microscopic level?
- How do we modify the evolution equations?

Big question:

How the unitarity is realized in QCD ?

QCD Diagram



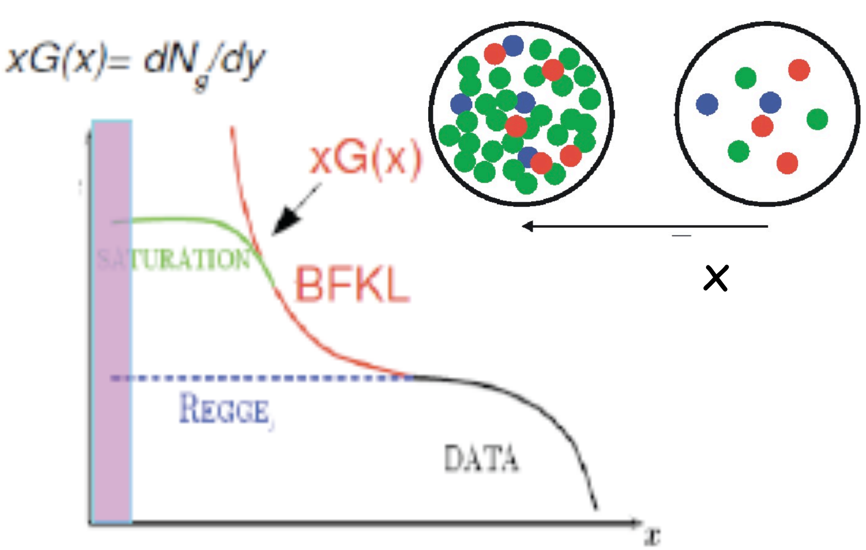
- What this diagram represents?
- Is parton saturation <u>the only</u> microscopic mechanism which leads to unitarity?
- Is there saturation scale?
- What is its value?
- What about the interplay with the nonperturbative region?
- The saturation at HERA: hints only at very low Q2.
- LHeC possibility of fixing Q2 and decreasing x.

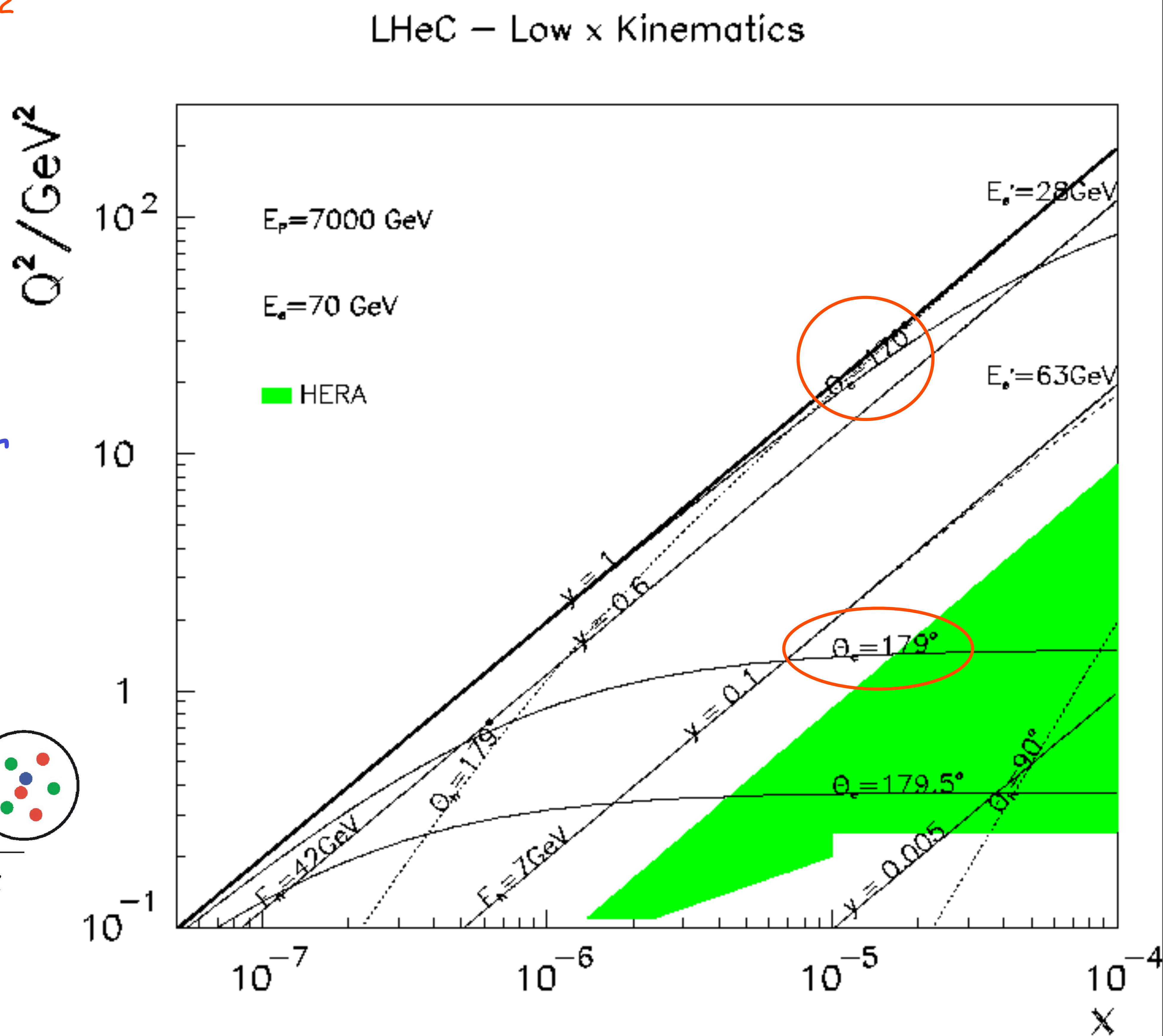
LHeC extended kinematic range gives opportunity to provide definite answers to the problem of unitarity.

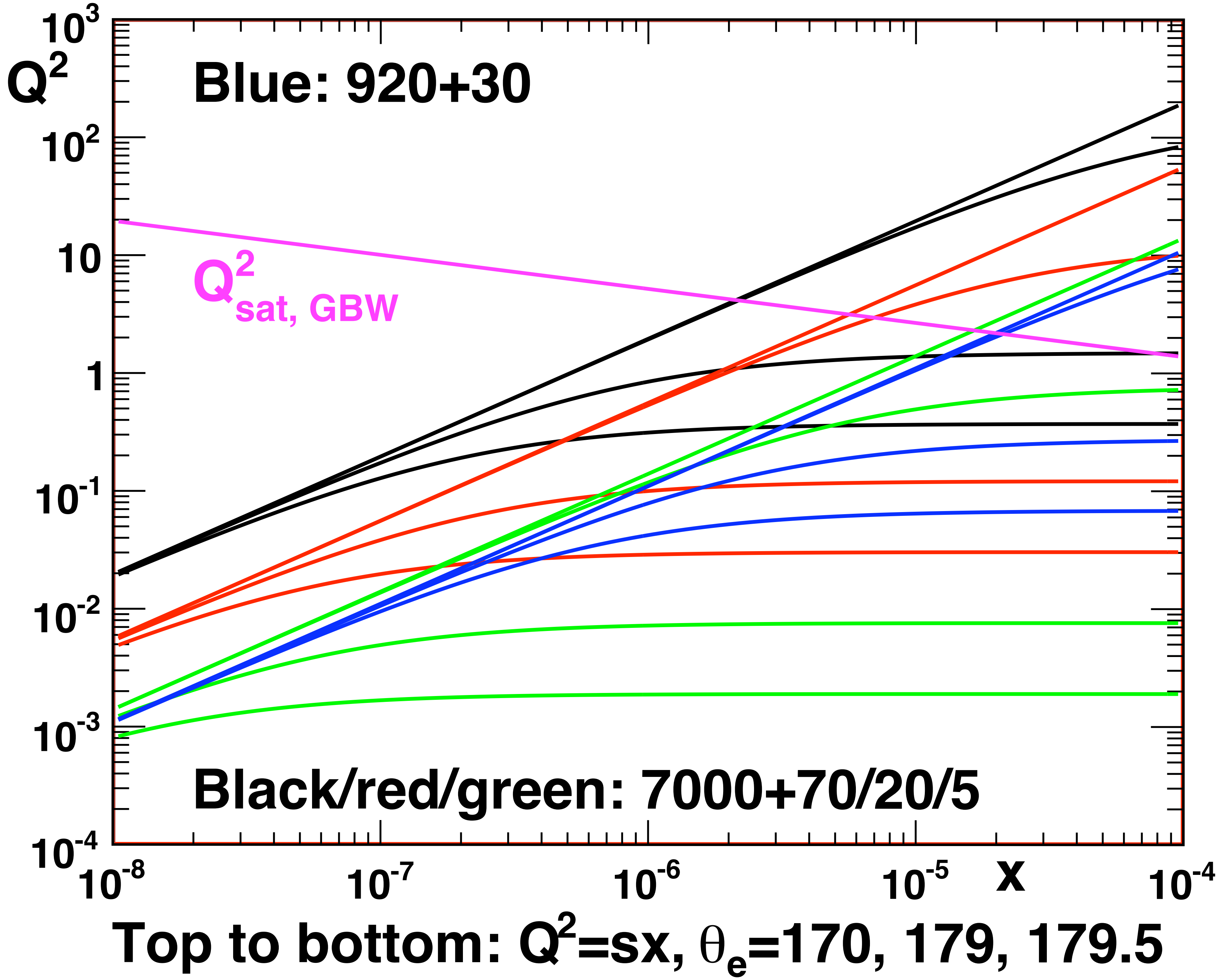
LHeC Kinematics for Low x Investigations

Access to $Q^2=1$ GeV^2 for all $x > 5 \times 10^{-7}$ IF we have acceptance to 179°

→ Without low β magnets ~ 1 fb^{-1} / yr … definitive low x facility (parton saturation ?…)







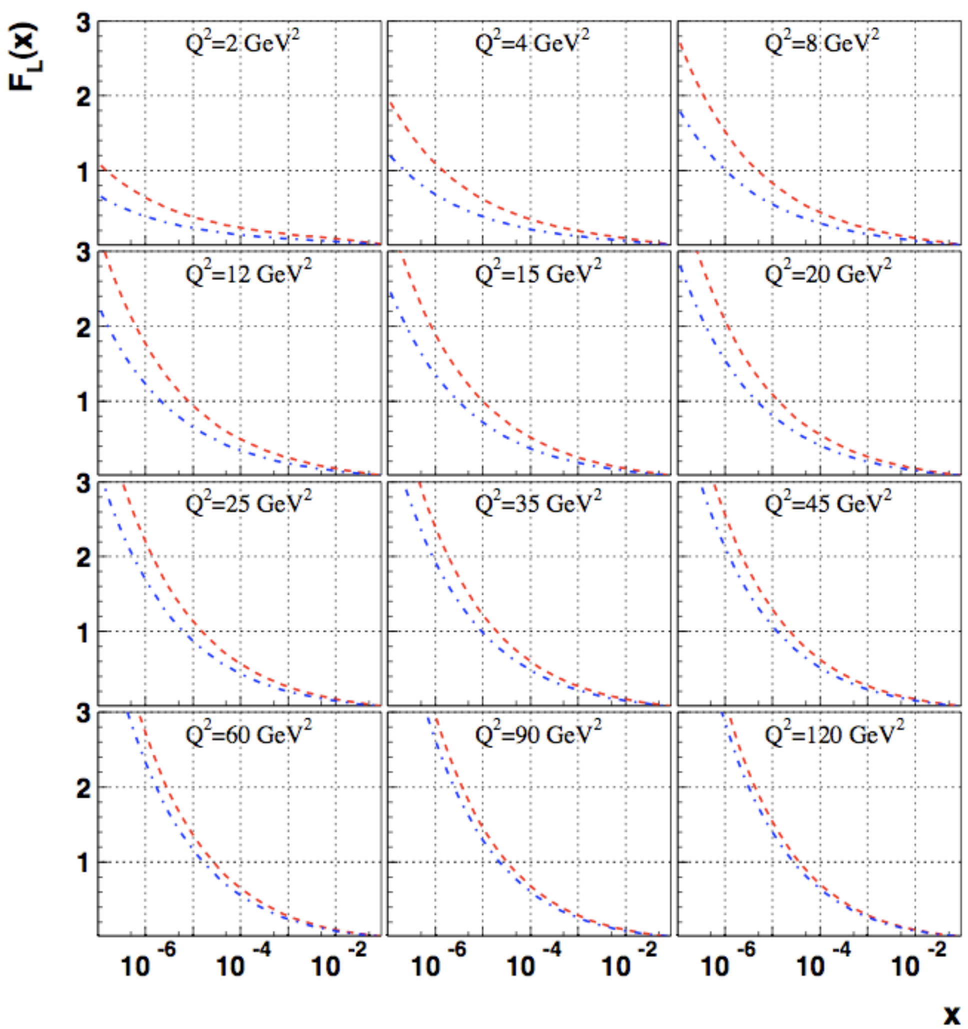
With 10 degree option nearly all of the interesting small x physics is killed...

Observables

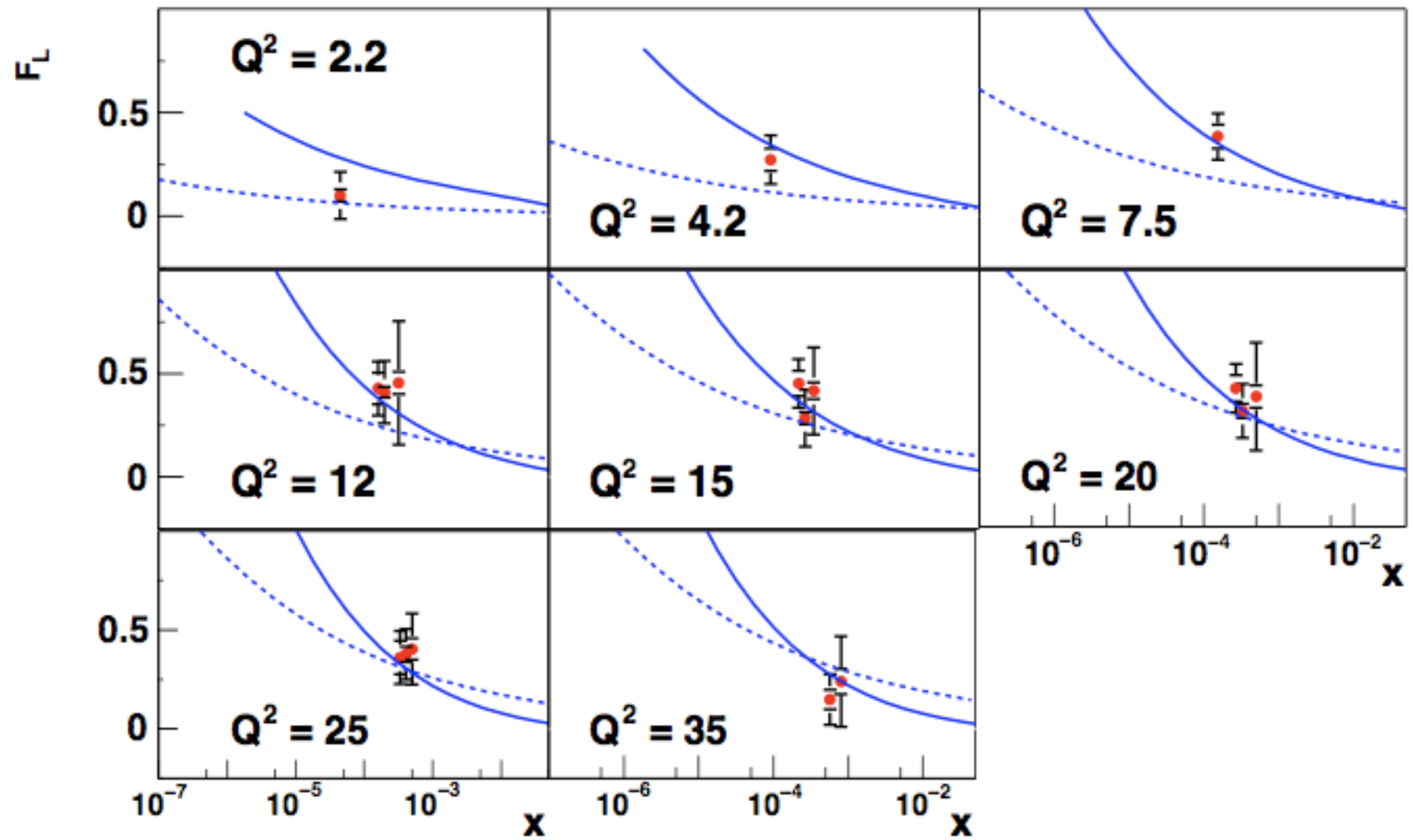
- Unitarity and saturation:
  - Inclusive observables: F2, FL at low x and both high and low Q. F2 is not enough, need FL to constrain glue at small x. Simulated data are available based on 70/7000 and 1 degree scenario. Two groups are doing fits to 'saturated' data. Shown in Divonne.
  - Diffraction: Can diffractive measurements provide unambiguous indication of approach to the unitarity limit? Can we use diffractive/inelastic cross-section ratios to evaluate degree of blackness? Simulated F2D data exist. Shown in Divonne.
  - Vector meson production. Elastic photoproduction: energy dependence. Elastic electroproduction of vector mesons. Measurement of the t (momentum transfer) dependence provides information about the impact parameter and hence the profile of the S-matrix. This should be the best way to quantify saturation. Need lots more work here. (Kowalski, Motyka ?, Watt; Strikman, Rogers ?, Stasto). Also simulated data for DVCS exist.

- Unitarity and saturation:
    - <u>Inclusive observables</u>: Fits to F2, predictions for FL based on Balitsky-Kovchegov + NLO, dipole fits with DGLAP evolution (Armesto et al.). FL from BFKL+DGLAP improved model supplemented with higher twists (Golec-Biernat, Stasto)

Preliminary(non saturated kt BFKL +DGLAP simple resummed)
Golec-Biernat and Stasto



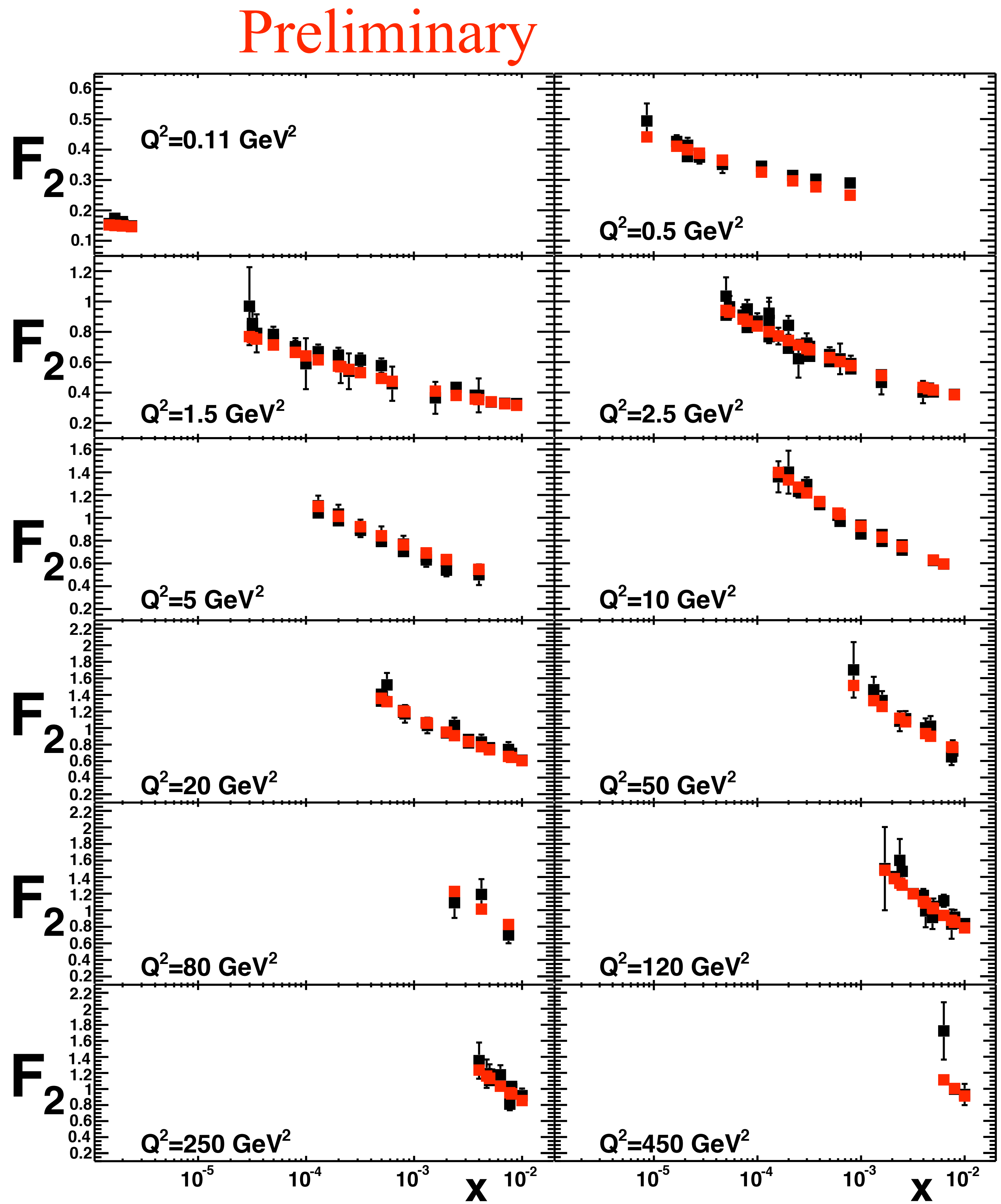
Preliminary
Armesto et al (dipole fit)



New work since Divonne

What we want to explore in LHeC range

Armesto et al
Gluon density from NLO Balitsky-Kovchegov equation.
Compared with HERA data.
Step beyond the simple dipole models.



Also available:

Diffraction: Dipole fits improved with DGLAP (for example Golec-Biernat, Kowalski). Dipole-like unitary fit with Regge phenomenology and DGLAP evolution(Armesto,Kaidalov,Salgado, Tyvoniuk)

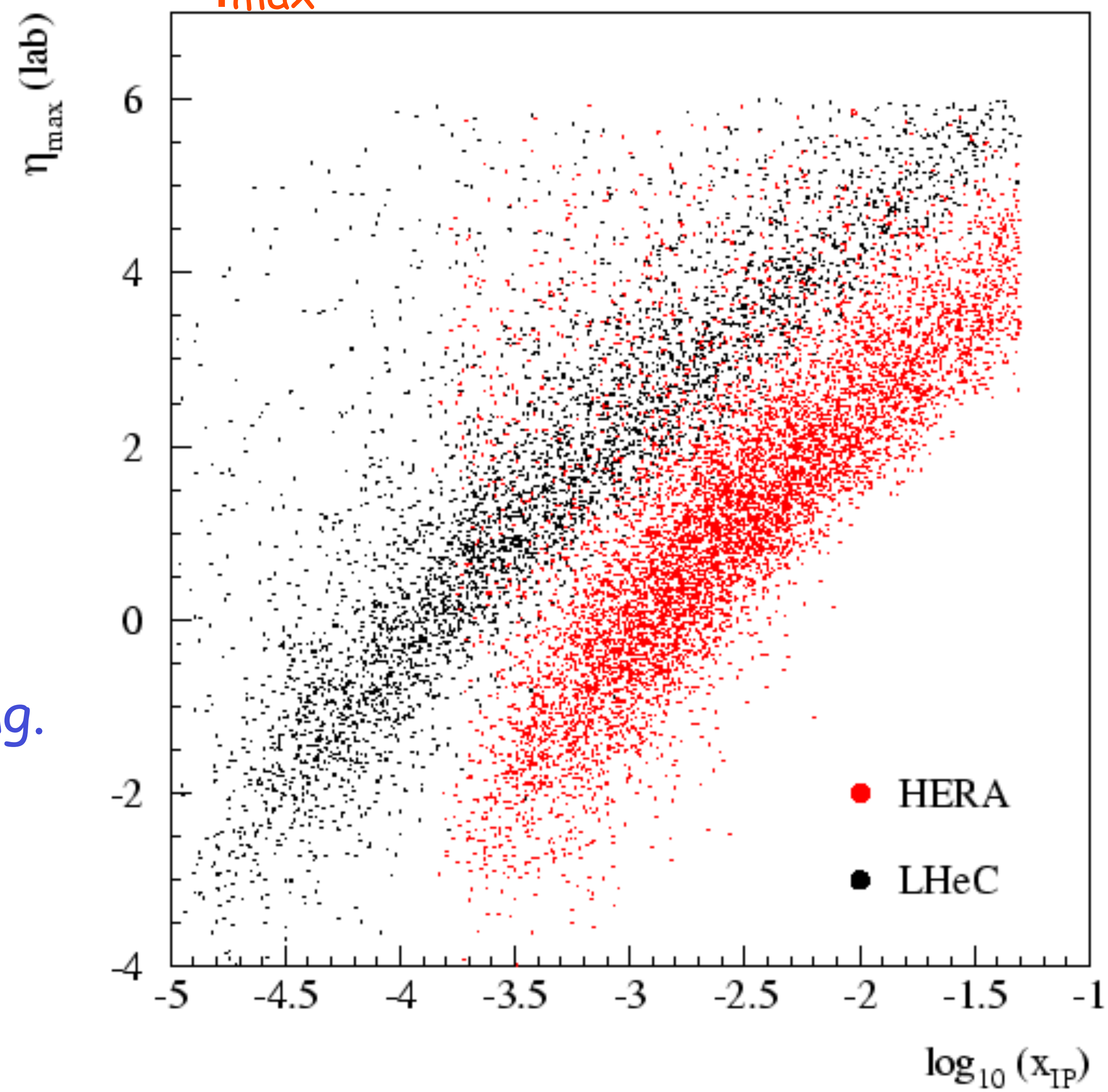
Forward and Diffractive Detectors

- Very forward tracking / calorimetry with good resolution …
- Proton and neutron spectrometers …

η_{max} from LRG selection …

- Reaching $x_{IP} = 1 - E_p'/E_p = 0.01$ in diffraction with rapidity gap method requires η_{max} cut around 5 …forward instrumentation essential!

- Roman pots, FNC should clearly be an integral part. Diffraction will need proton tagging.

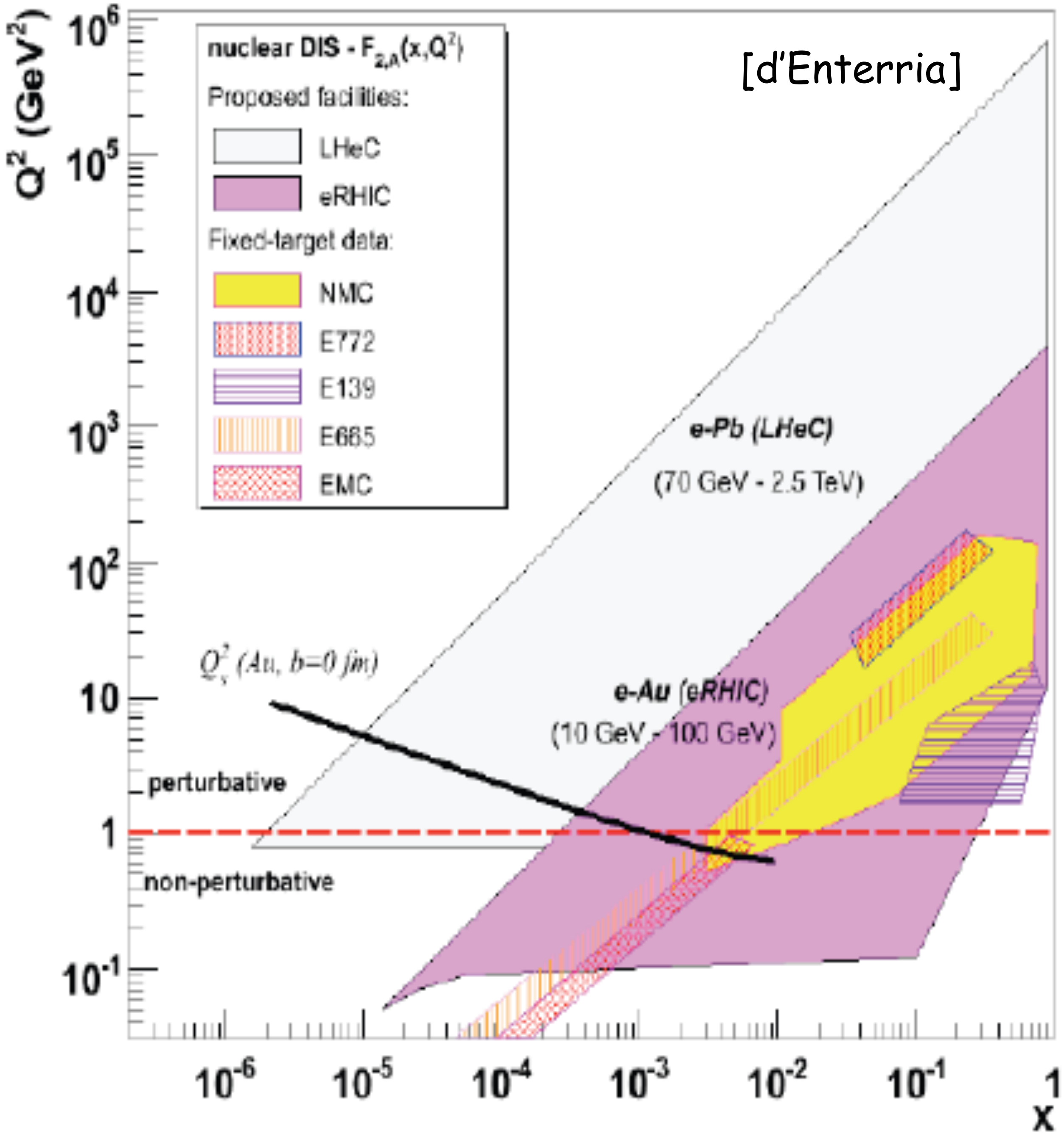


eA

With AA at LHC, LHeC

- Very limited x and Q^2 range so far (unknown for x <~ 10^{-2}, gluon very poorly constrained)

- LHeC extends kinematic range
- by 3-4 orders of magnitude



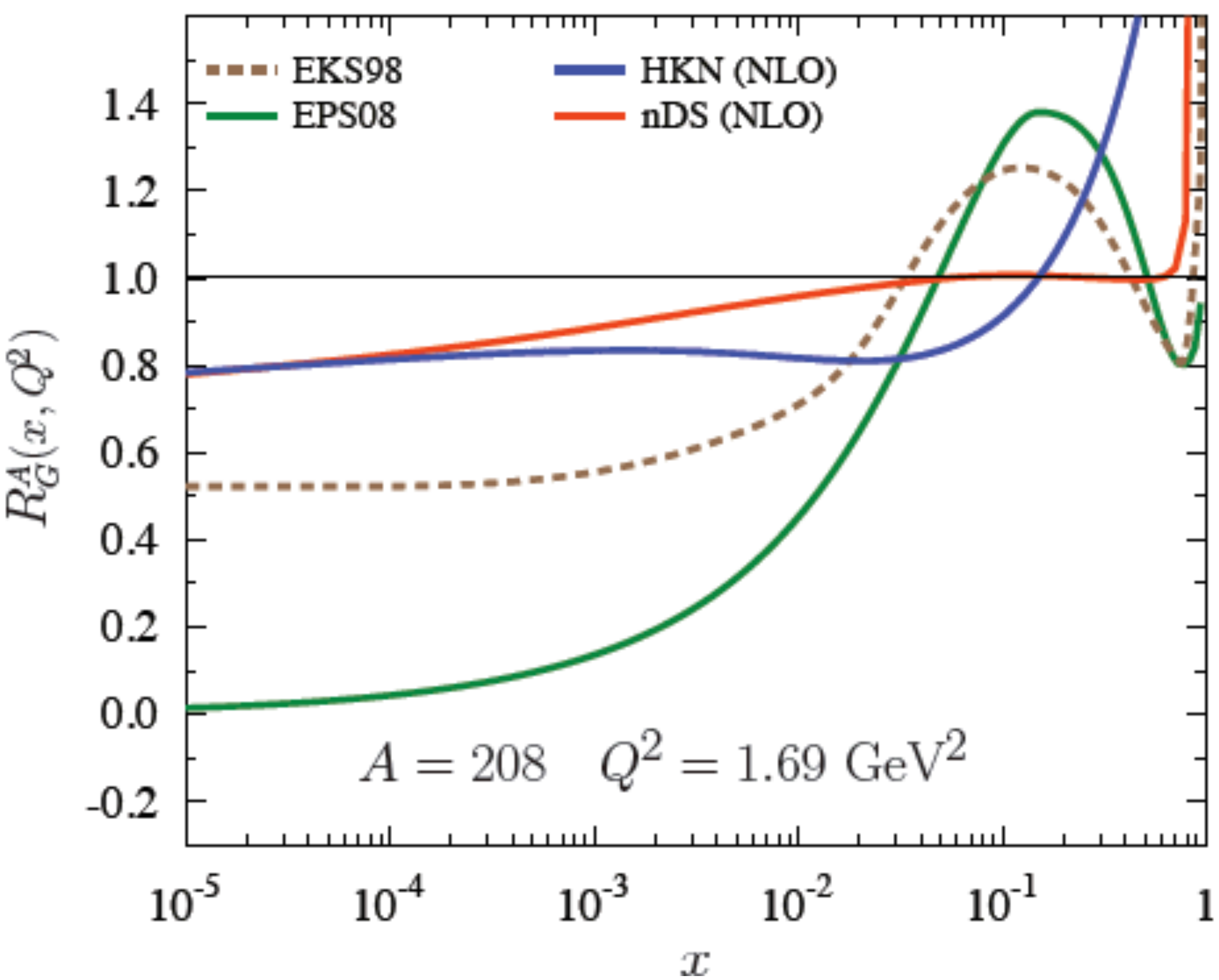
… opportunity to extract and understand nuclear parton densities in detail …

→ ~$A^{1/3}$ enhanced gluon density → additional sat^n sensitivity
→ initial state in AA quark-gluon plasma studies @ LHC / RHIC
→ relations between diffraction and shadowing
→ Neutron structure & singlet PDF evolution from deuterons

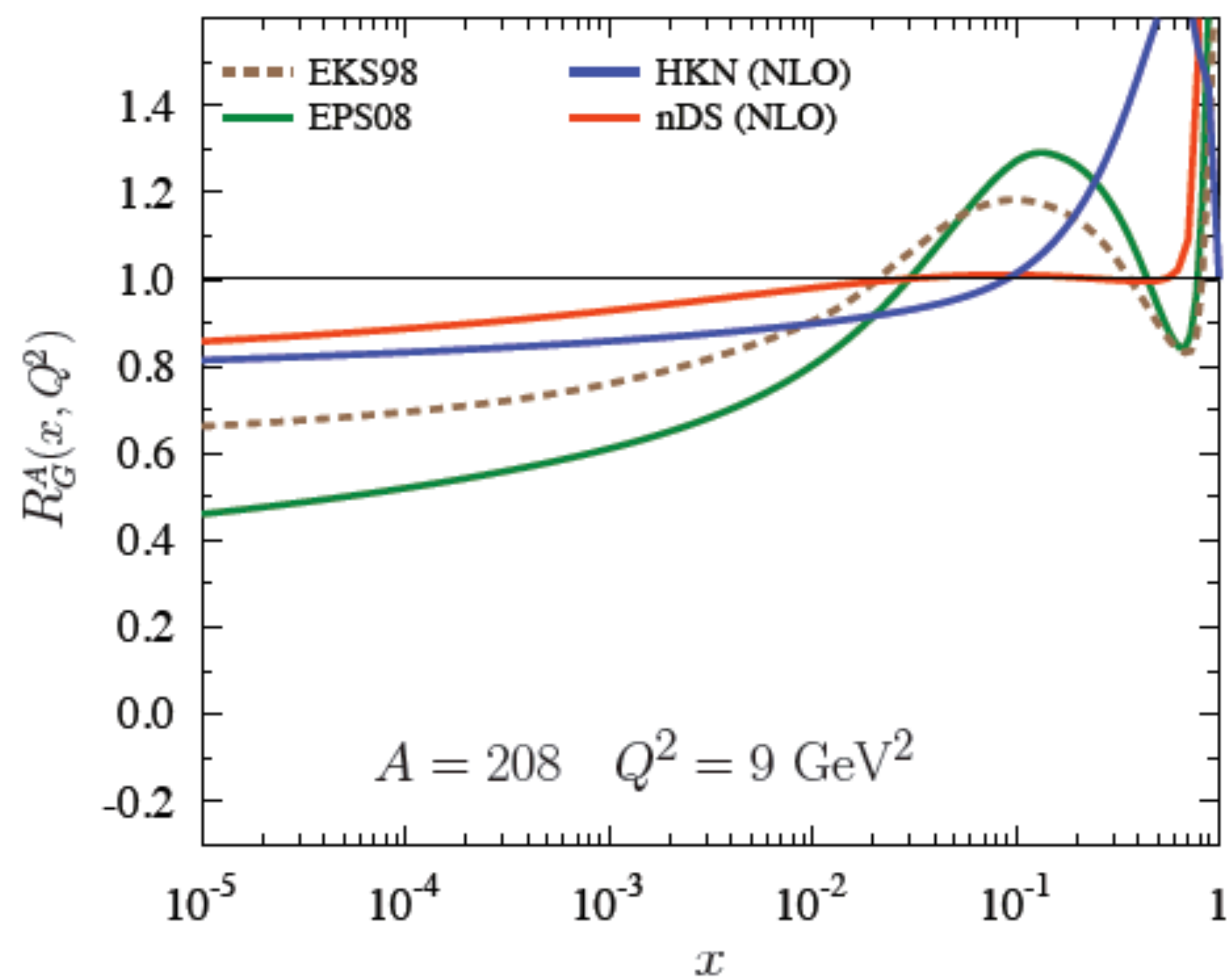
Lots more work needed. Preliminary calculations of the ratios of gluon densities from N.Armesto et al. Huge difference between models at low x

Preliminary

Ratios for gluons and Pb nuclei



Ratios for gluons and Pb nuclei



More basic work for eA: Monte Carlo simulations needed.

Other interesting topics

- QCD evolution and resummation at small x. We have now a theoretical consensus among different groups that the small x resummation is crucial and we have procedures how to perform it. Matching different expansions and gaining information about the all order QCD evolution. DGLAP/BFKL (LO+NLO) and possibly CCFM. For this one needs both sea and glue constrained (FL!). Hints from resummation: better direction in the evolution, respecting constraints from kinematics, combination of x and kt? Altarelli et al, Ciafaloni et al, Thorne and White

- Transverse momentum dependence of the parton densities. Unintegrated parton distributions. Both from Monte Carlo as well as possibility of extraction from the resummed approaches. Forward jet production. Azimuthal jet decorrelations as an indication of the transverse momentum dependence. Jung, Kutak; Stasto...

- Transition to the photoproduction region. What is the rate of increase of the photoproduction cross section as compared to electroproduction and what it tells us about the unitary limit? Total cross section measurement.

- Jet correlations: do we have hot spots in the proton? How are multiple scatterings correlated (need impact parameter description)? J. Bartels at Divonne.

- Leading neutron production. Absorptive correction. F2_pion. Relation to cosmic rays.

- Fragmentation functions: what is the space-time evolution of the off-shell parton. Constraining the proton fragmentation for z>0.5. Lots more work needed.

Schedule

- In addition to DIS in Madrid and autumn meetings:
- 'High density' working group meeting in February 16-20th at CERN. Goal: have a first draft of the physics motivation.
- Regular EVO meetings of conveners 3-4 weeks with reports on progress. Having topical discussions and inviting contributing people to join them.
- Basic contacts: mailing list. Invite all people who contributed at Divonne (and others too).
- Web page is set up, one can add simulated data there. Possibly extending to Wikipage...