eA collisions at the LHeC and FCC

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for the LHeC study group: http://cern.ch/lhec

DIS 2014, Warsaw, 30th April 2014

#1 why eA collisions

nPDFs

- presently available constraining data is sparse
  - ↪ nPDFs as factorizable modification of nucleon PDFs

$$R = \frac{f_{i/A}}{A f_{i/p}} \approx \frac{\text{measured}}{\text{expected if no nuclear effects}}$$

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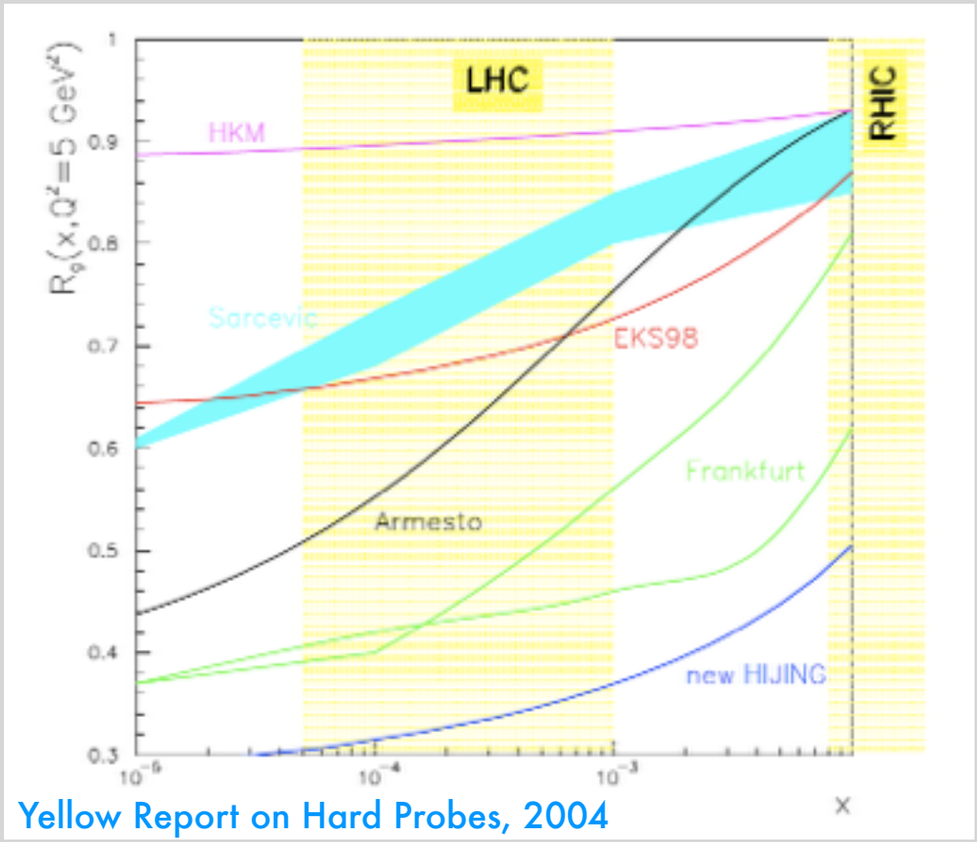

Yellow Report on Hard Probes, 2004

widely different model results for nuclear glue at small scales and x

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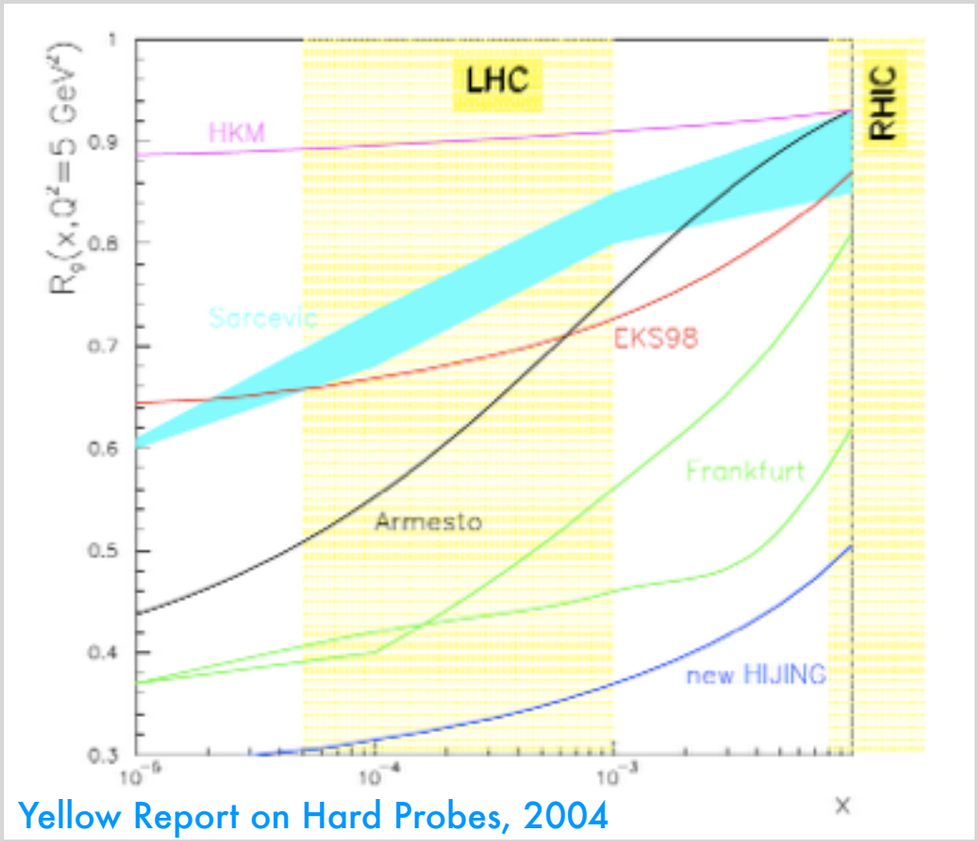

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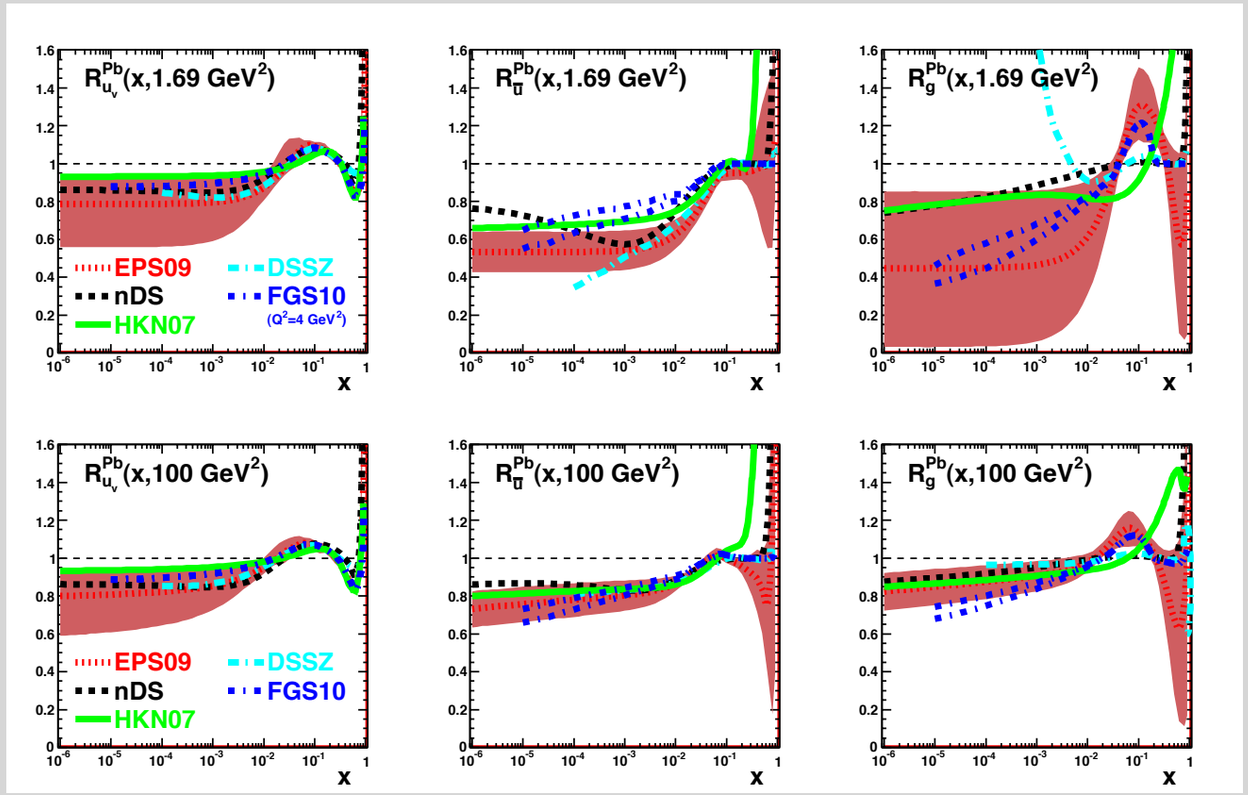

large uncertainties at small scales and x from NLO-DGLAP analyses

LHeC

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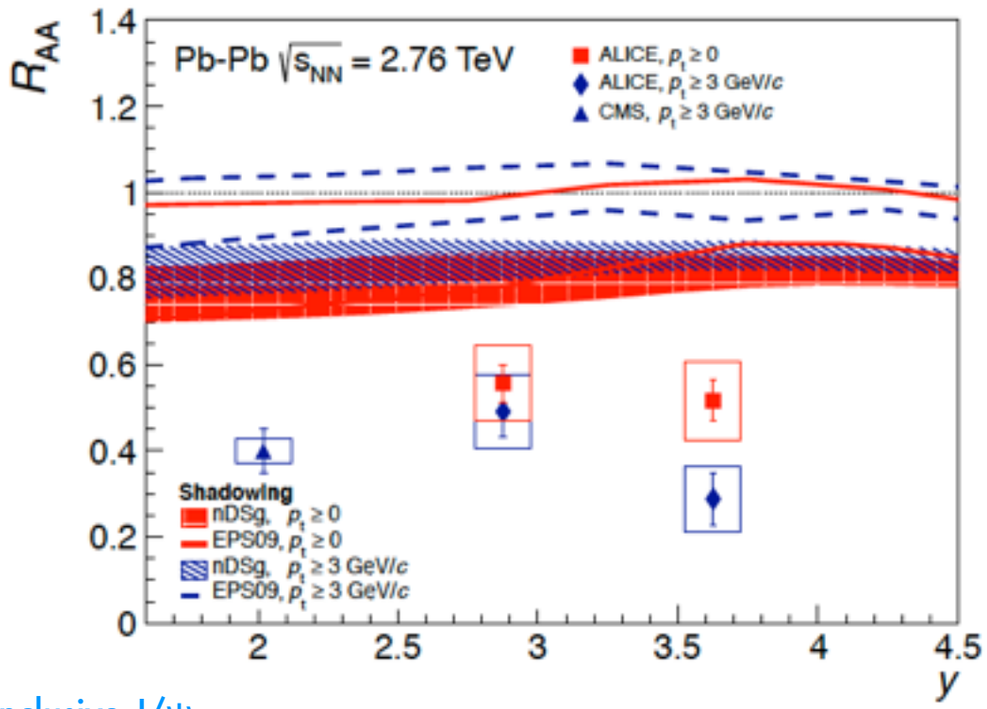

Inclusive J/ψ.

large benchmarking uncertainties in heavy ion collision studies

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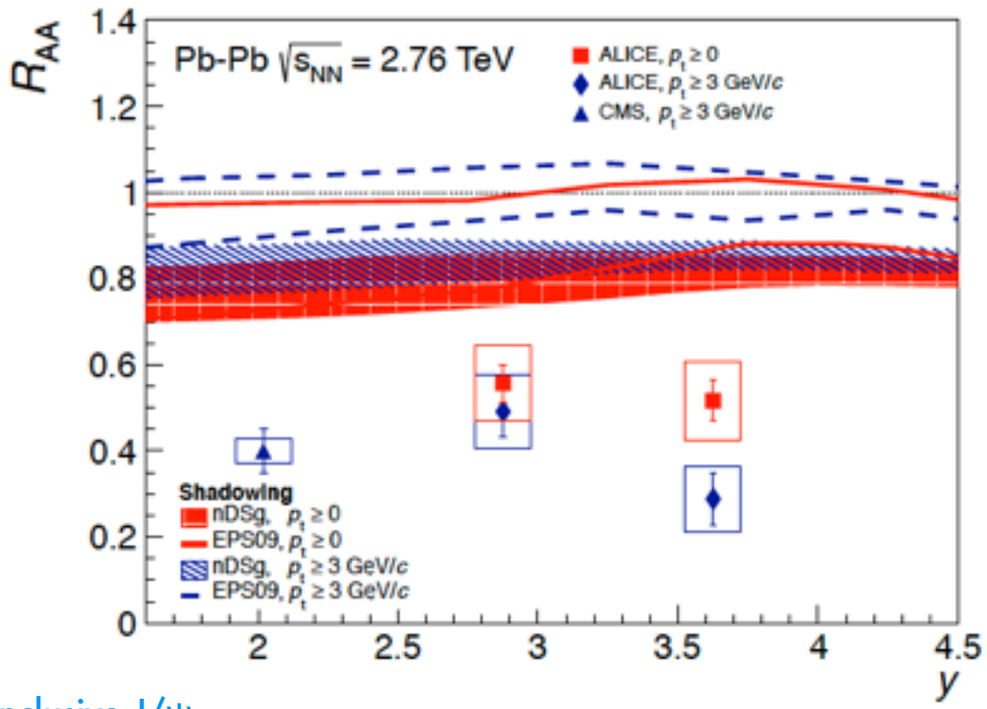

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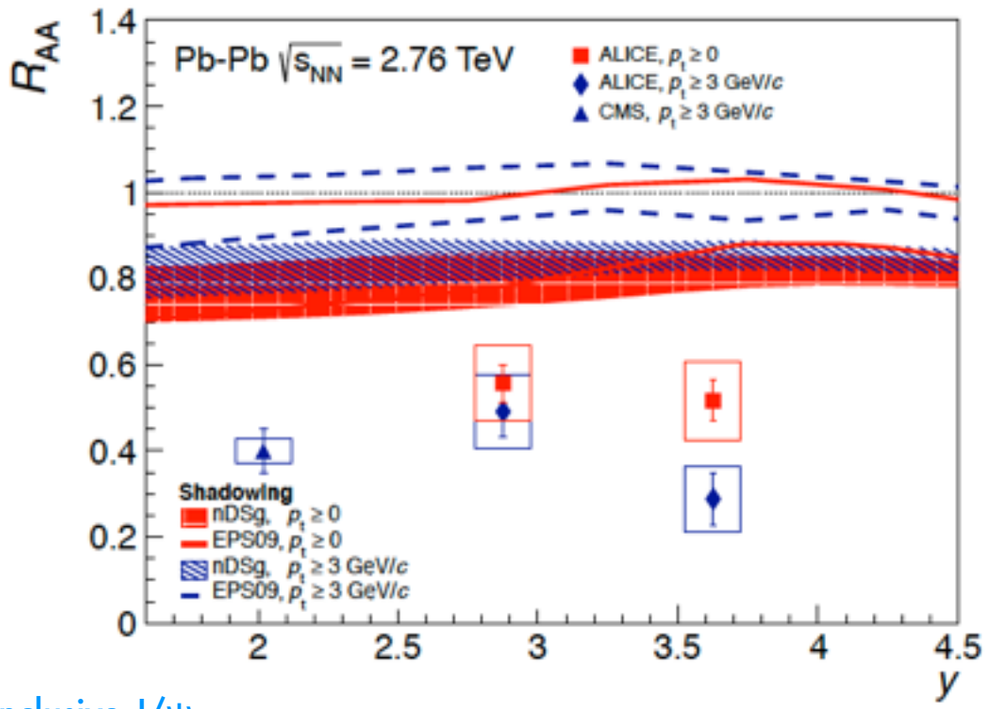


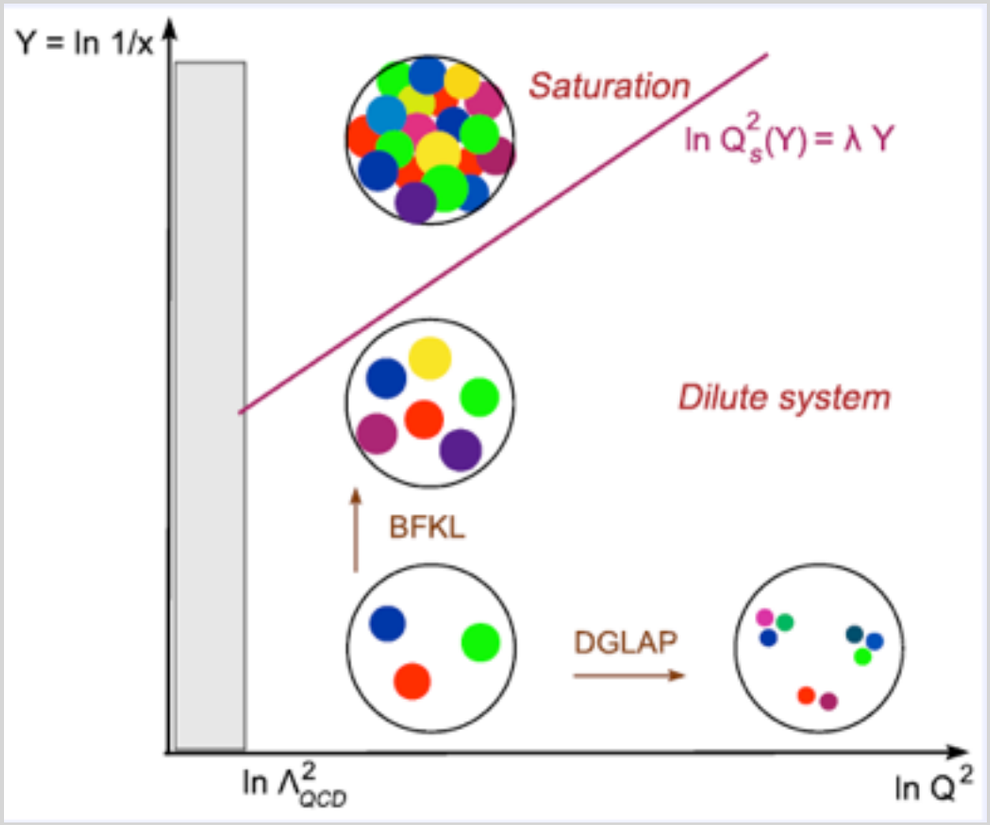
Inclusive J/ψ.

- eA data from LHeC/FCC to cleanly:
  - test collinear factorization in nuclei
  - test factorizability of nuclear modifications
  - if all well, constrain nPDFs

large benchmarking uncertainties in heavy ion collision studies

observation of hallmarks of final-state collective behaviour in pA collisions [flow, ridges, …] potentially excludes pA data as benchmark for AA in part of kinematical plane

QCD non-linearities [saturation]



$$\frac{xG_A(x,Q_s^2)}{\pi R_A^2 Q_s^2} \sim 1 \Longrightarrow Q_s^2 \propto A^{1/3} x^{\sim -0.3}$$

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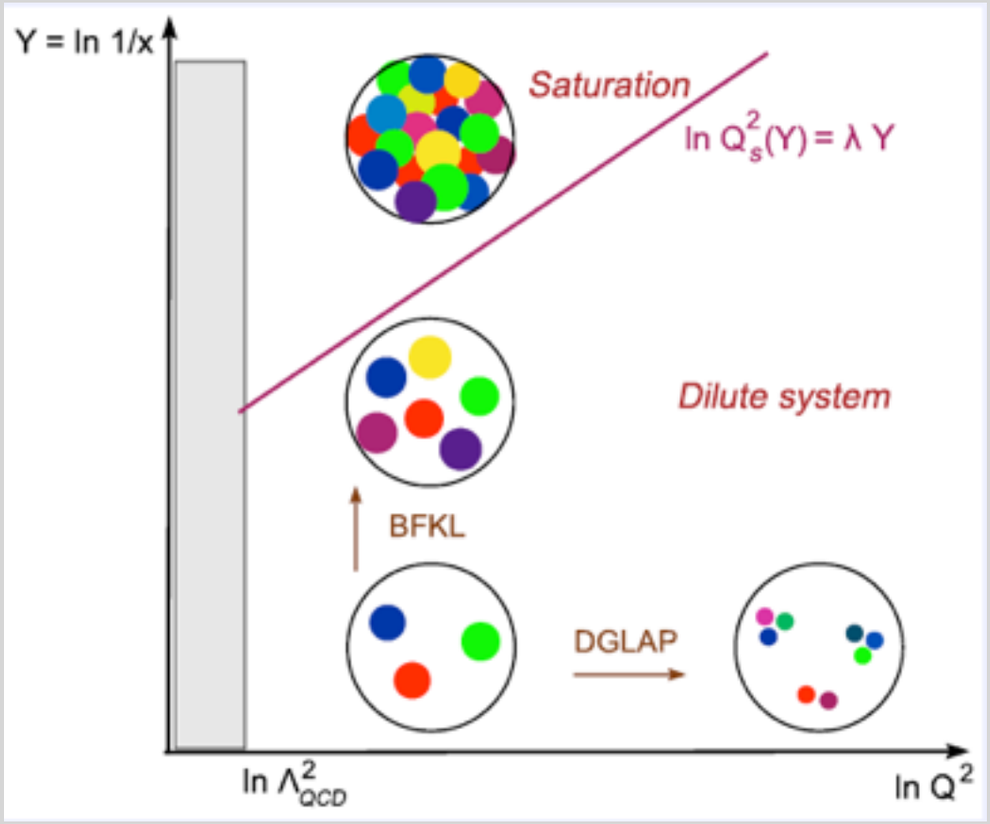

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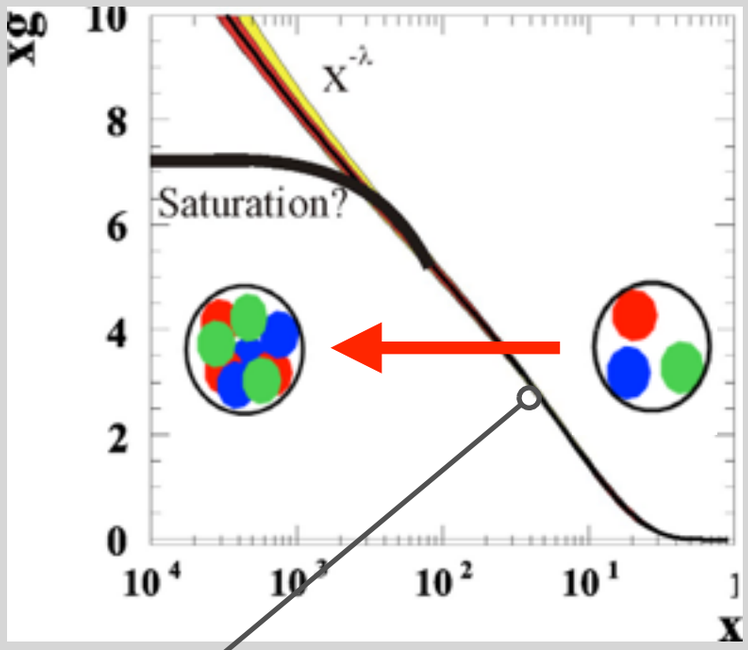

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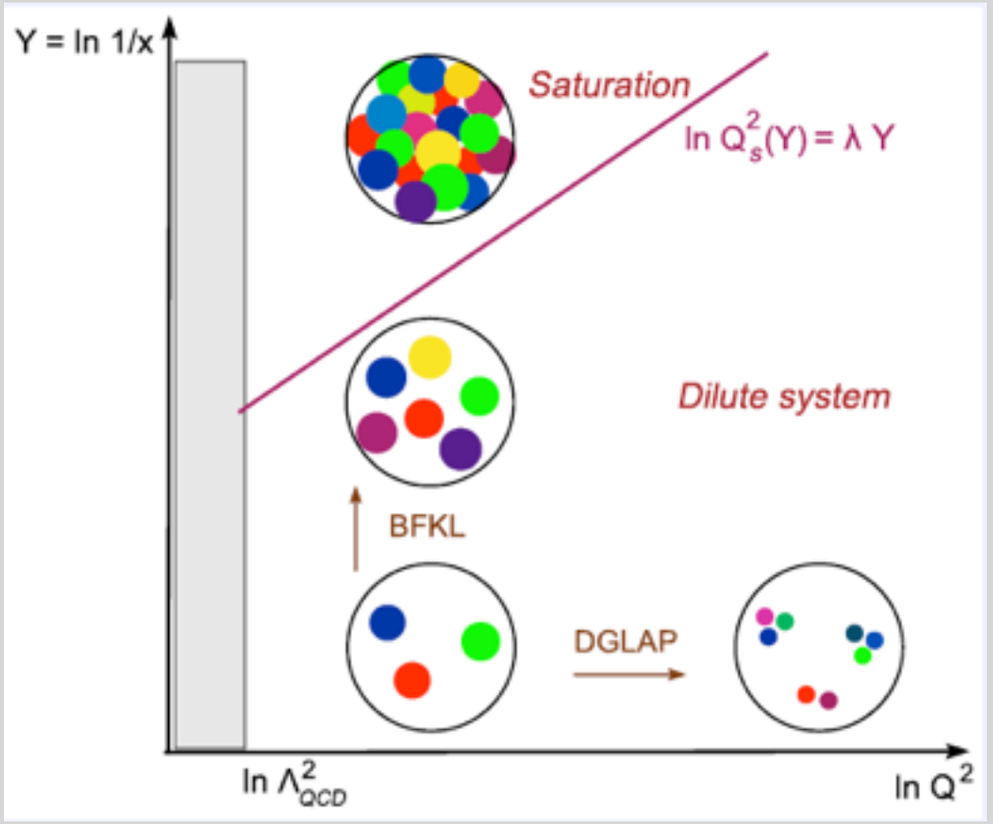

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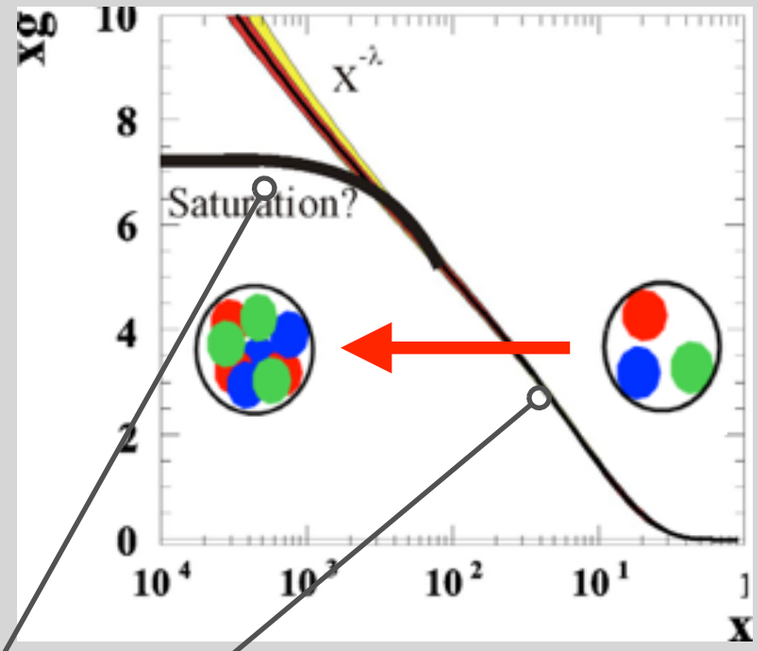
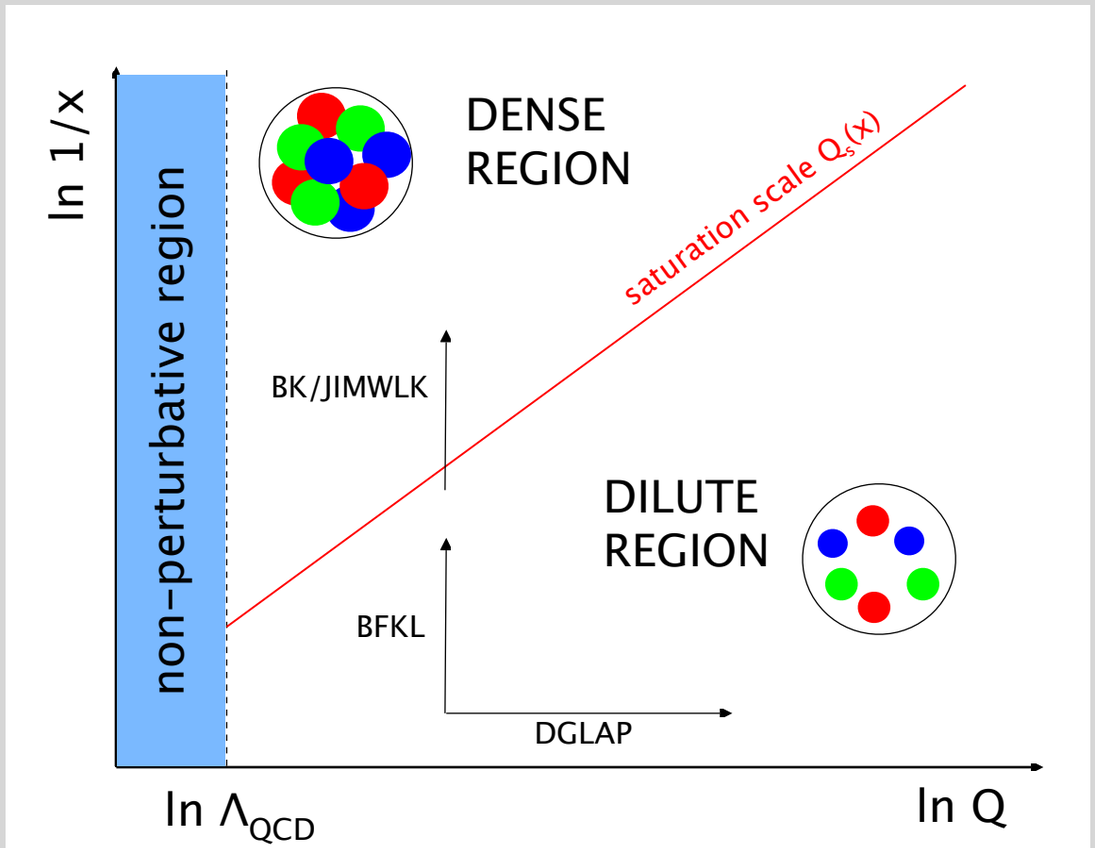
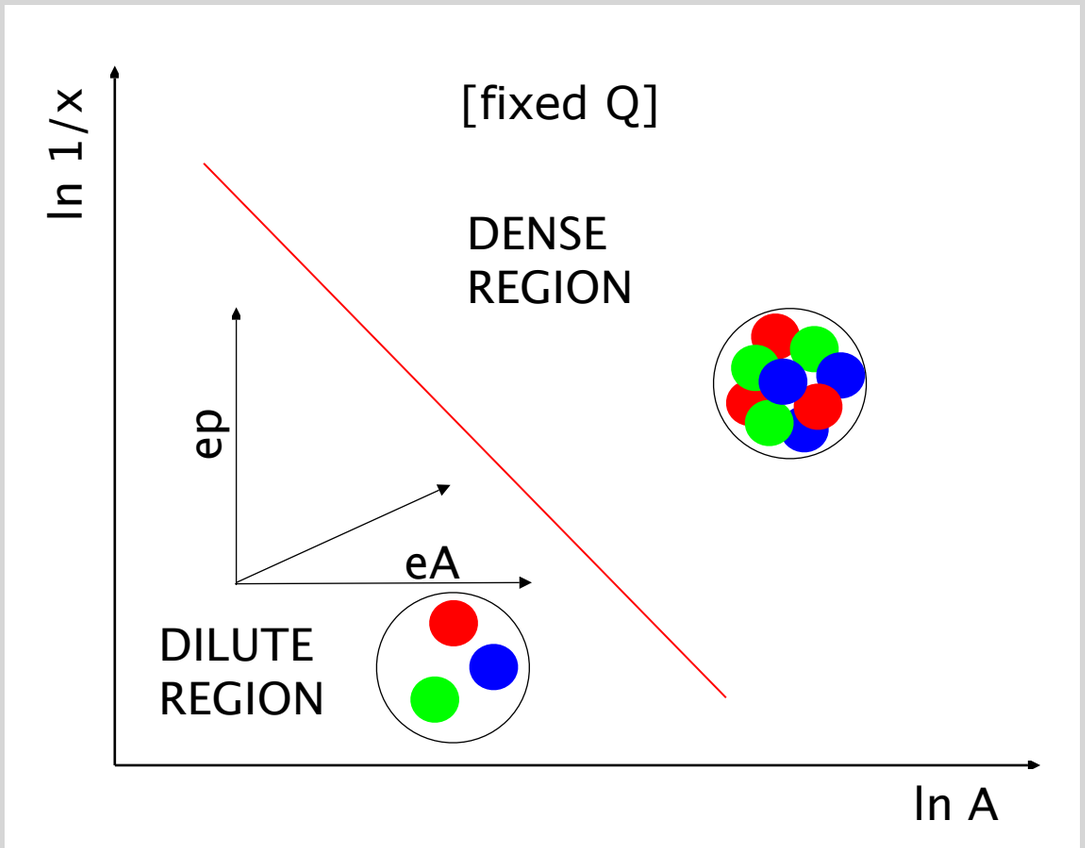


- linear [density independent] QCD evolution towards small x leads to large number of partons [gluons] :: $\Delta[xg] \propto xg$
- at high density [small x or large nuclei] non-linearities necessarily become important :: $gg \rightarrow g$, $\Delta[xg] \propto xg - k(xg)^2$

small-x physics in eA at the LHeC/FCC

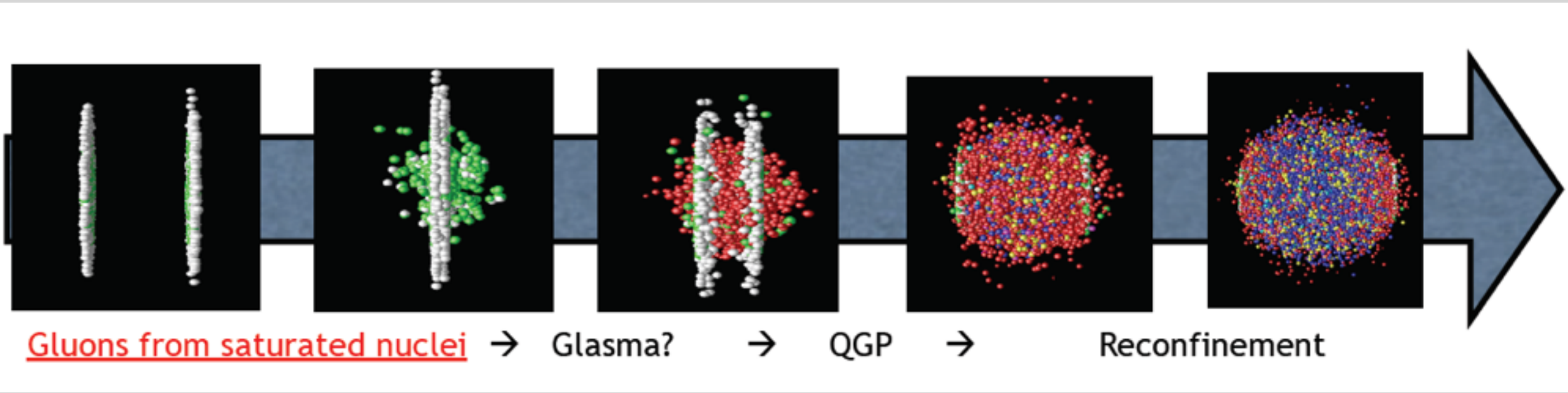
- two-pronged approach towards dense [non-linear] behaviour :: ↓ x / ↑ A
- distinguish different pQCD-based approaches
  - ↪ DGLAP [fixed order perturbation theory]
  - ↪ resummation schemes: BFKL, CCFM, ABF, CCSS
  - ↪ saturation [CGC, dipole models]





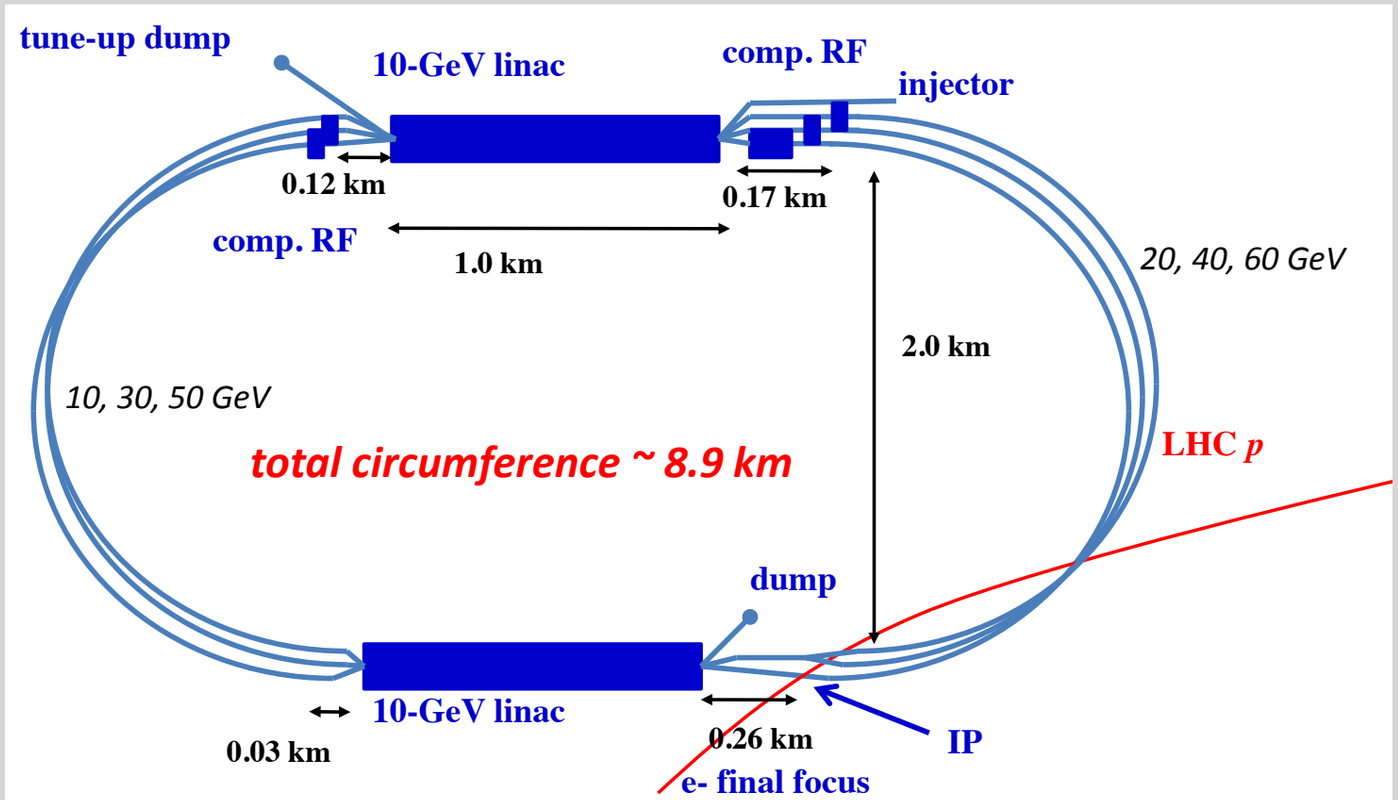
eA collisions and the HIC programme

- essential benchmark
  - ↪ initial conditions :: nuclear wavefunction at small-x [saturated glue]
    - seeds for rapid isotropization [?]
  - ↪ particle production at early times [which factorisation in eA]
  - ↪ jet quenching :: modification of QCD radiation pattern and hadronization in nuclear matter



#2 eA@LHeC/FCC

LHeC : linac-ring



$\sqrt{s} \simeq 0.8$ TeV/nucleon

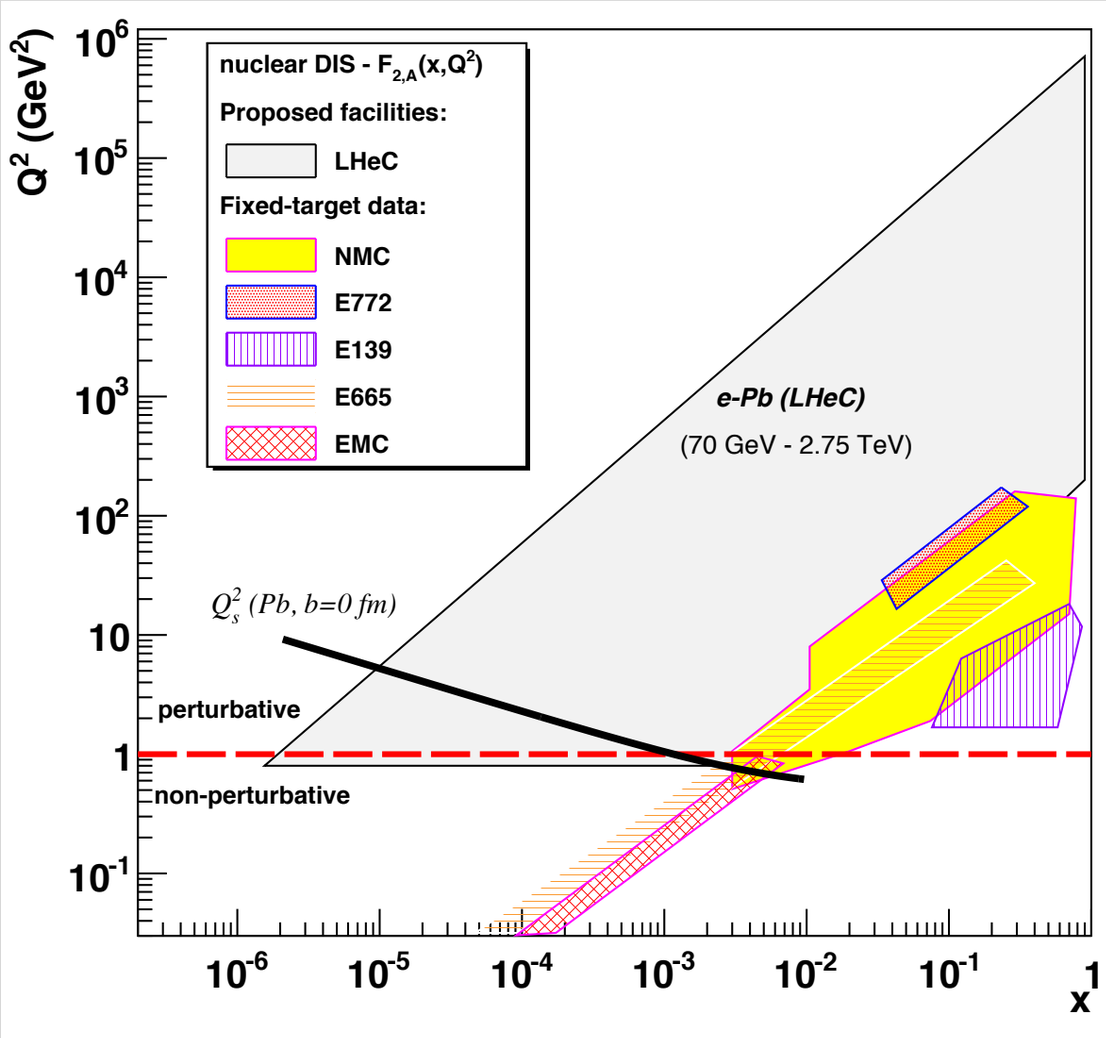
luminosities quoted in the CDR to be taken now as conservative lower bounds

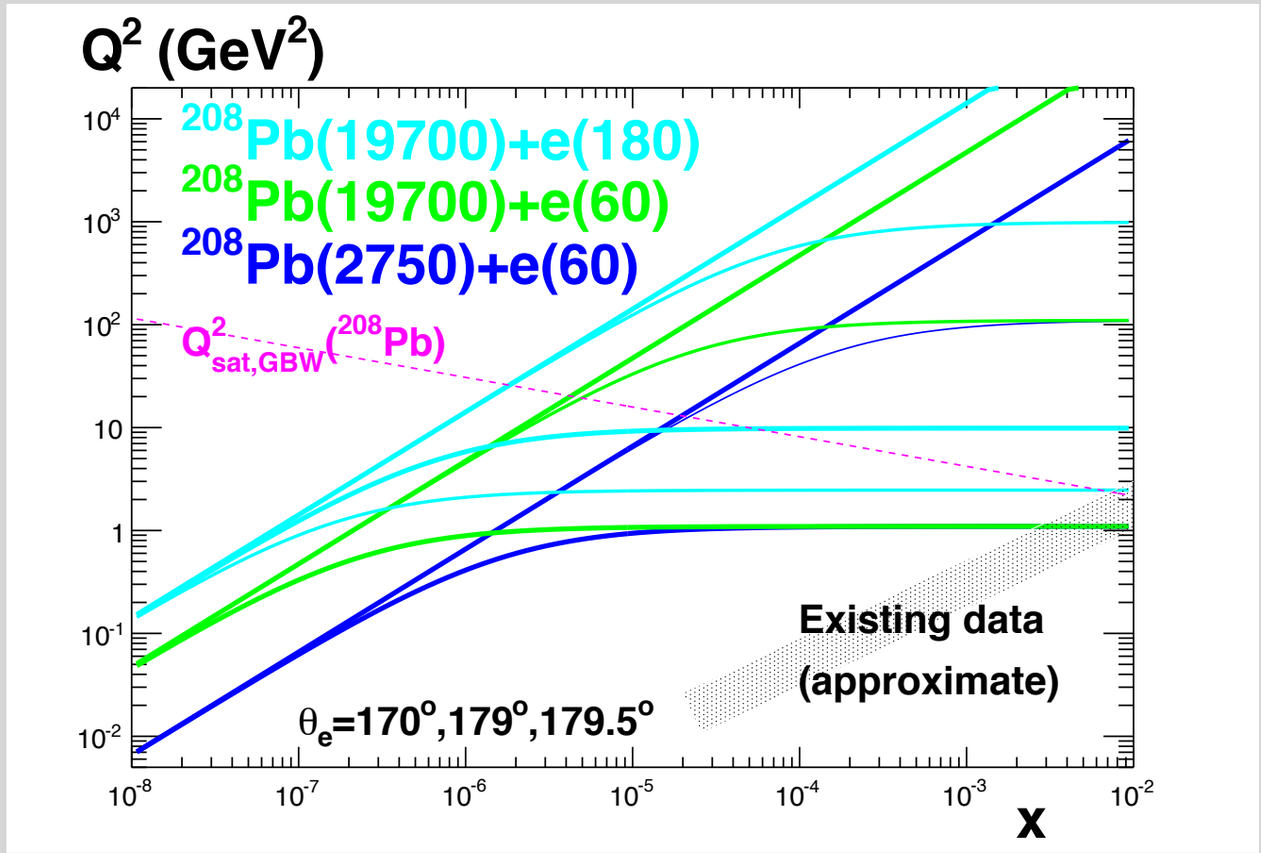
Luminosity per nucleon

$$L_{eN} = \begin{cases} 9 \times 10^{31}\ \mathrm{cm}^{-2}\mathrm{s}^{-1} & \text{(Nominal Pb)} \\ 1.6 \times 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1} & \text{(Ultimate Pb)} \end{cases}$$

eD: $L_{eN} = A L_{eA} > \sim 3 \times 10^{31}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

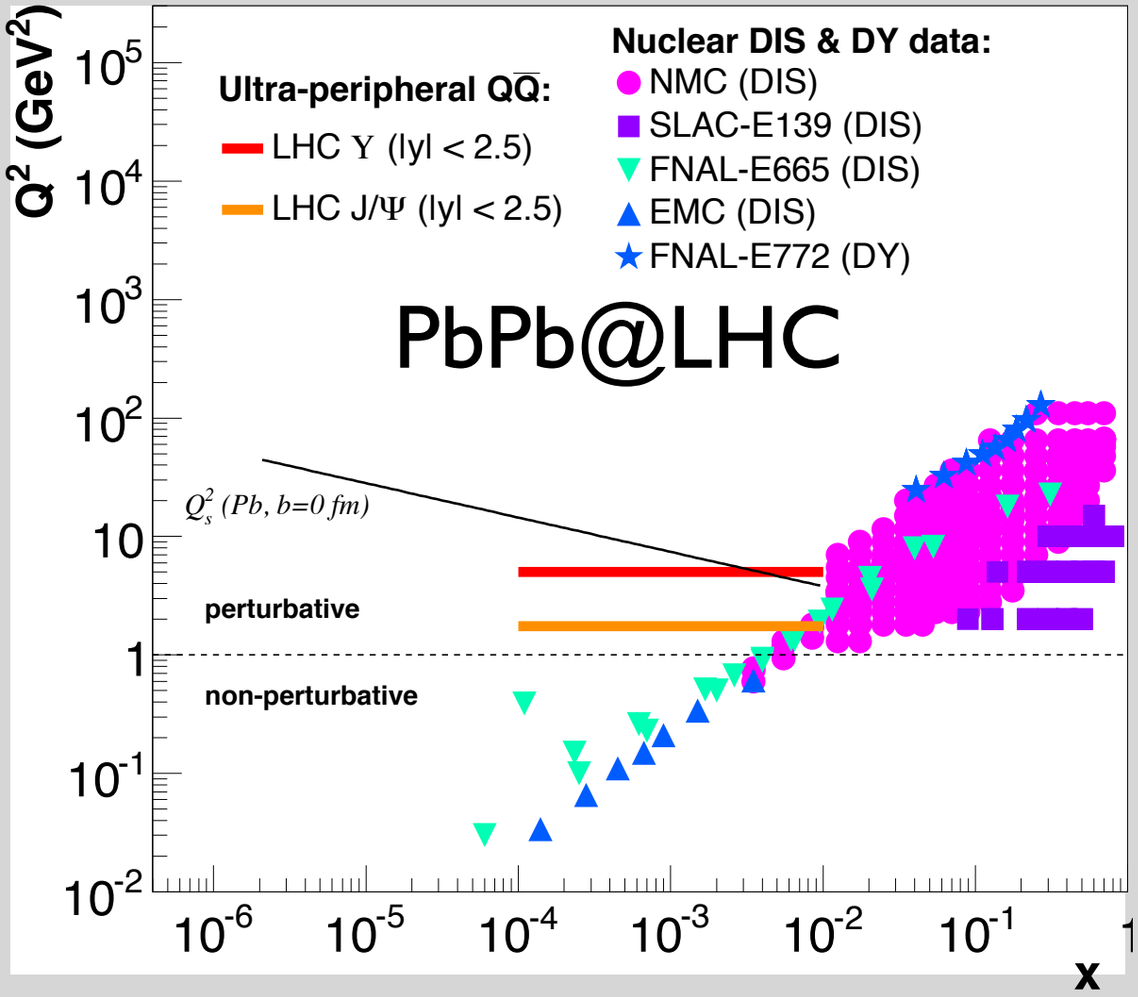
eA@LHeC/FCC : kinematics

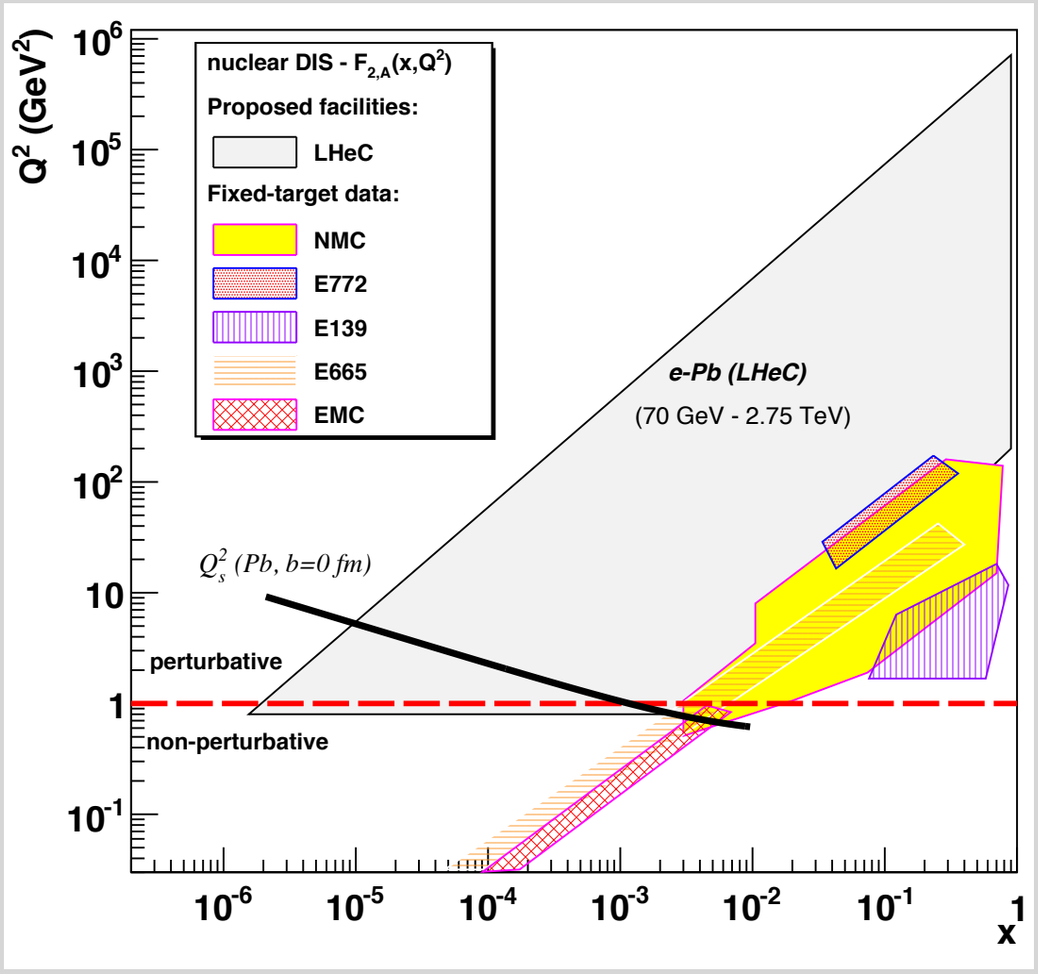




- enormous improvement in kinematical coverage wrt existing data
- small-x physics requires 1 degree acceptance for 60 GeV electron
  - higher electron energy compromises studies [unfeasible acceptance]

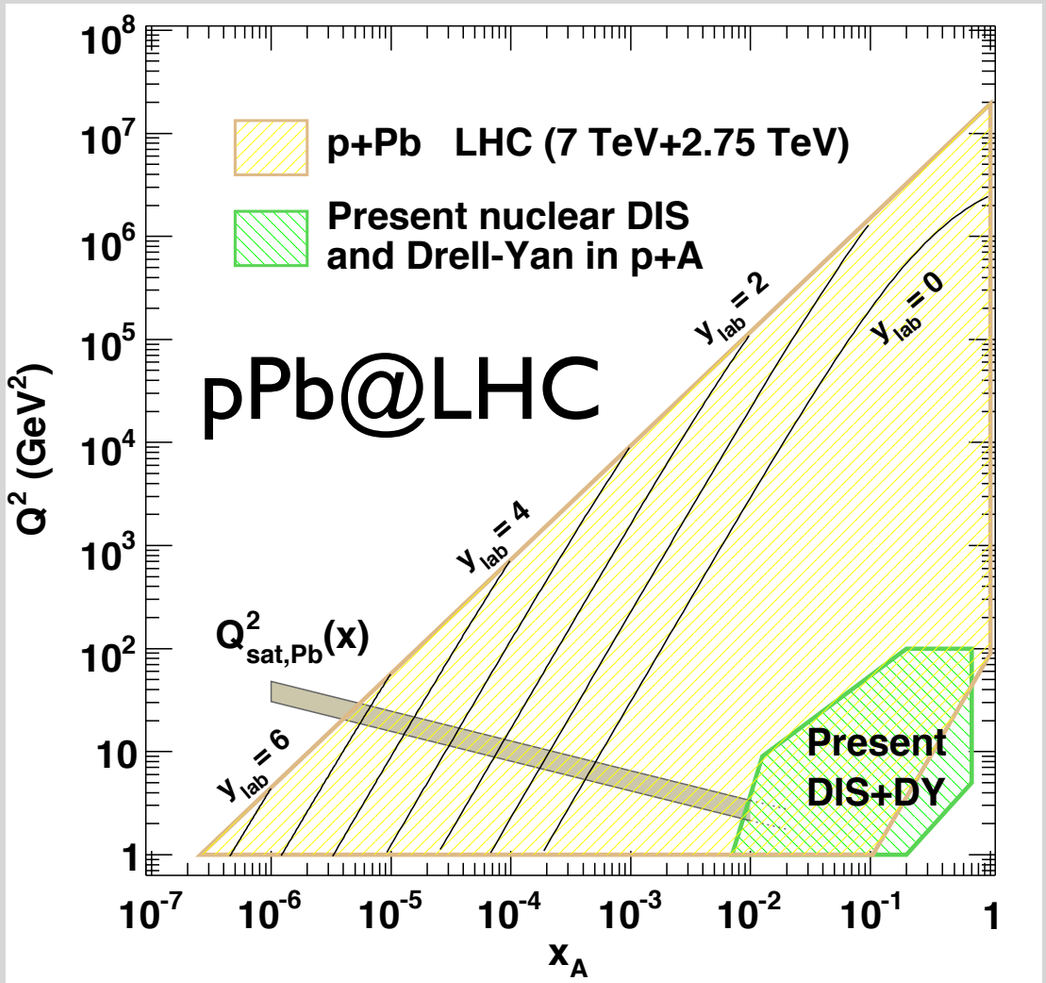
LHeC for the LHC

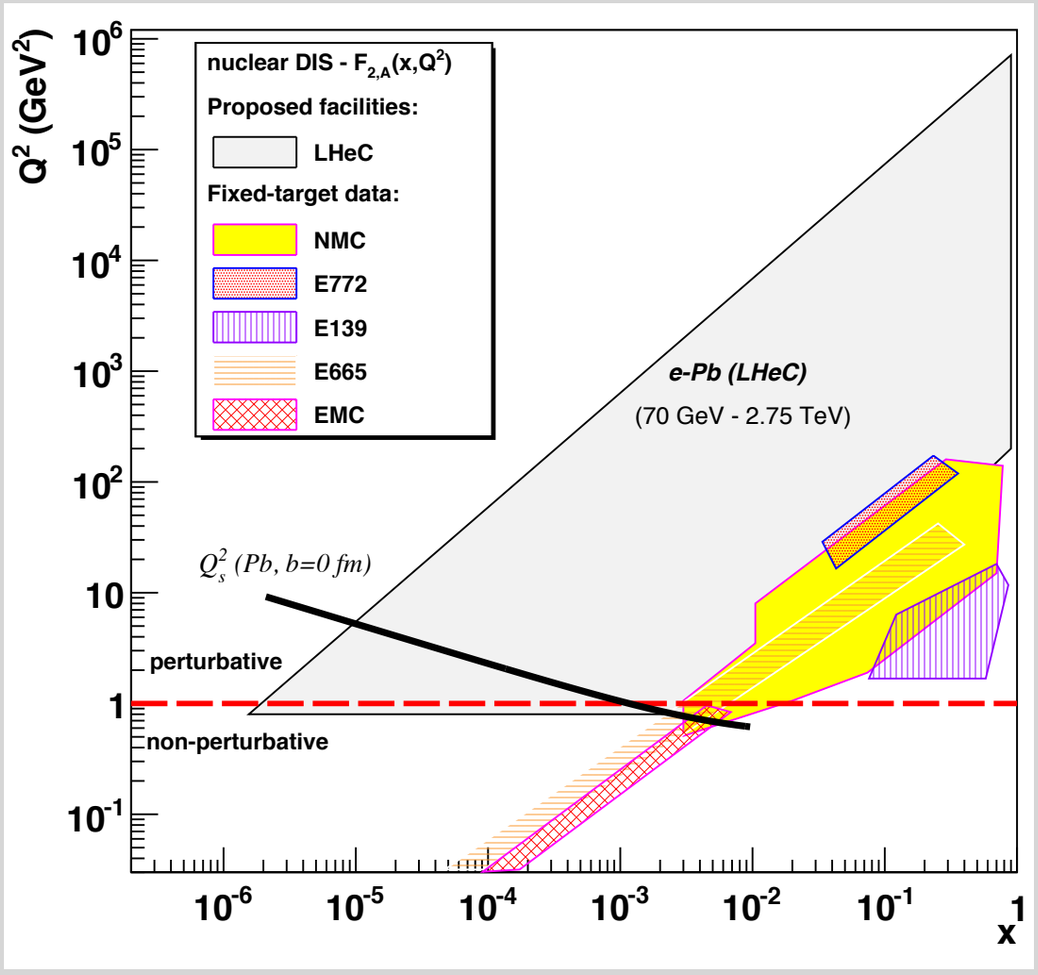




- the LHeC will explore an overlapping region with the LHC AA programme in a cleaner experimental setup and on much firmer theoretical grounds

LHeC for the LHC



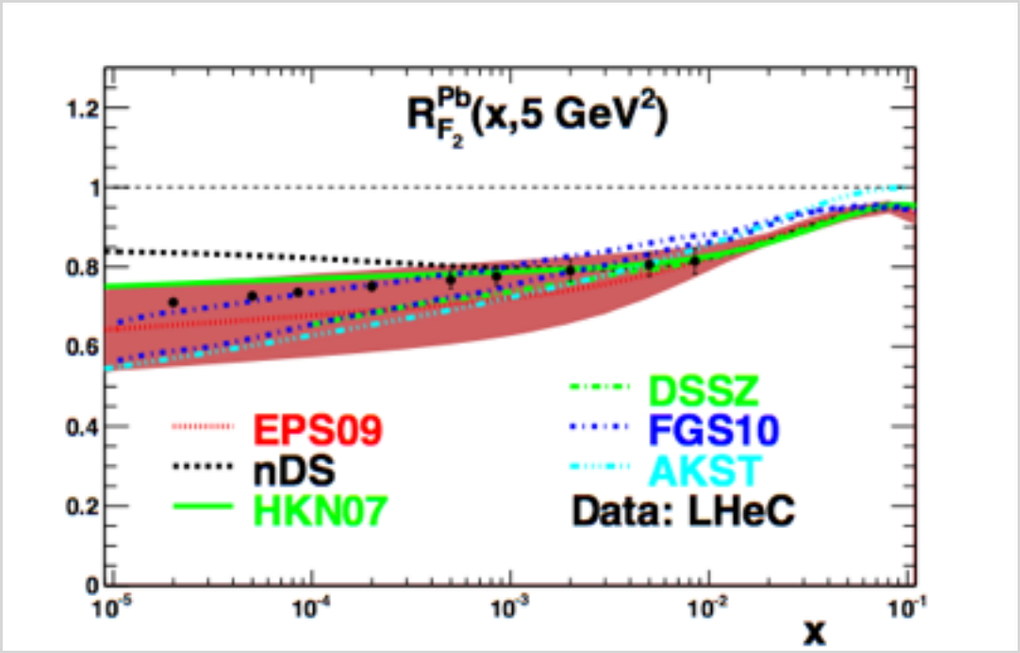


- the LHeC will also explore an overlapping region with the LHC AA programme in a cleaner experimental setup and on much firmer theoretical grounds

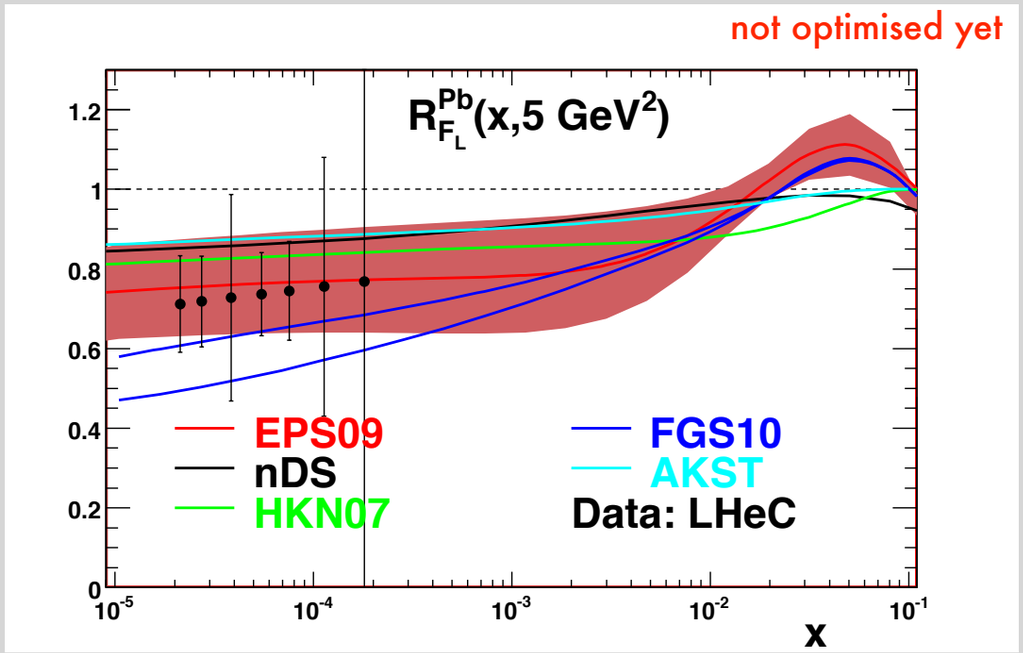
- also for pA :: benchmarking the ‘benchmark’

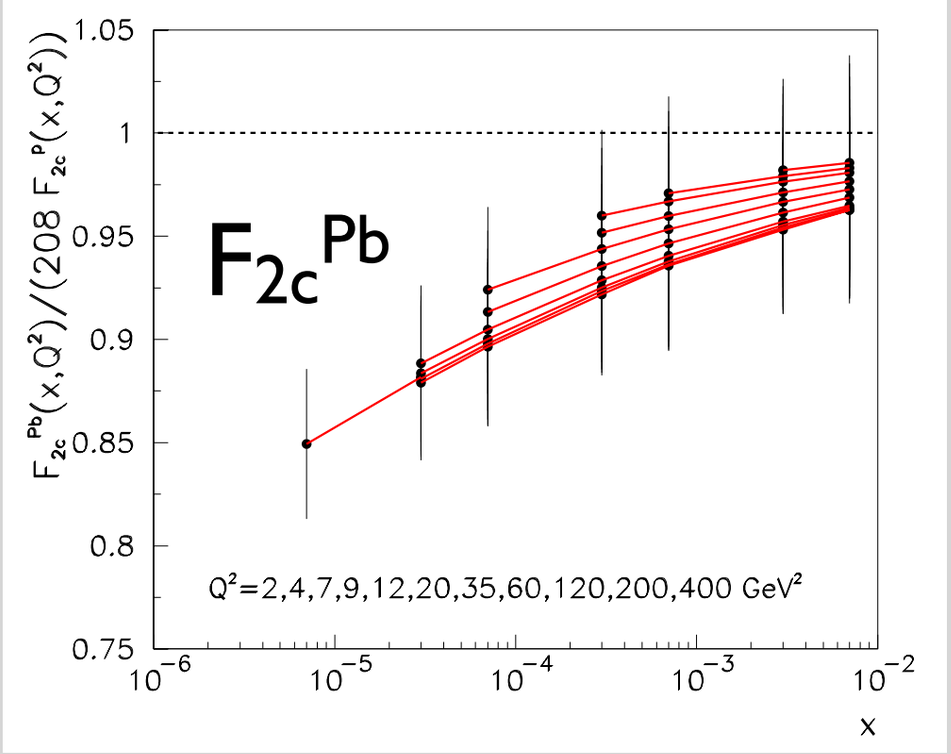
#3 physics opportunities in eA

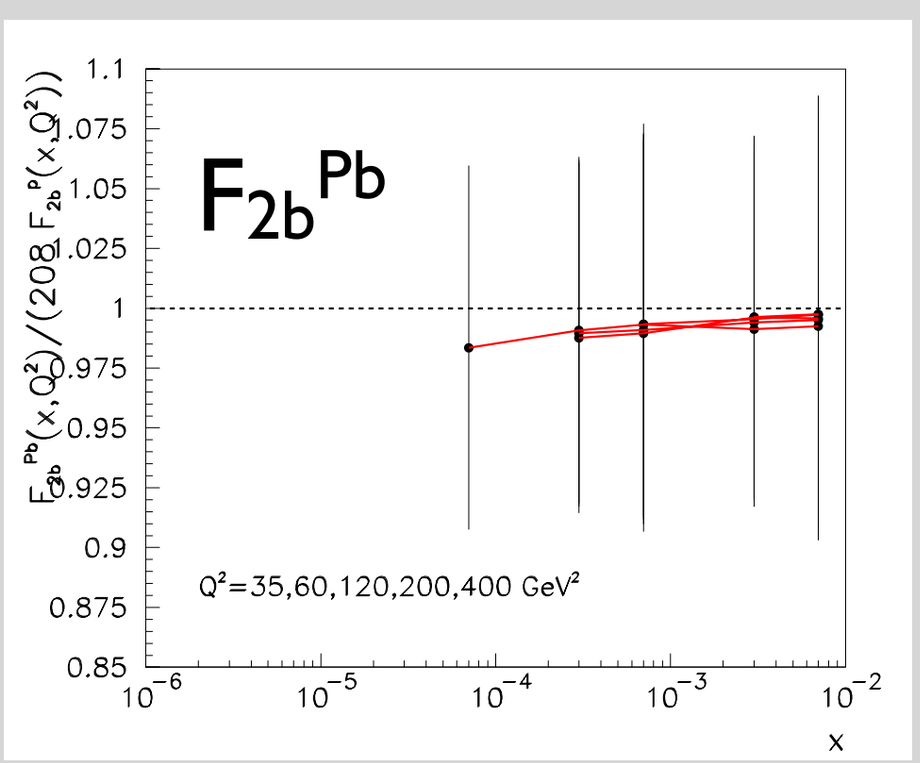
inclusive measurements: F_2, F_L, F_{2c}, F_{2b}



not optimised yet







based on Glaubarized [3-5 flavours] GBW saturation model [Armesro 2002]

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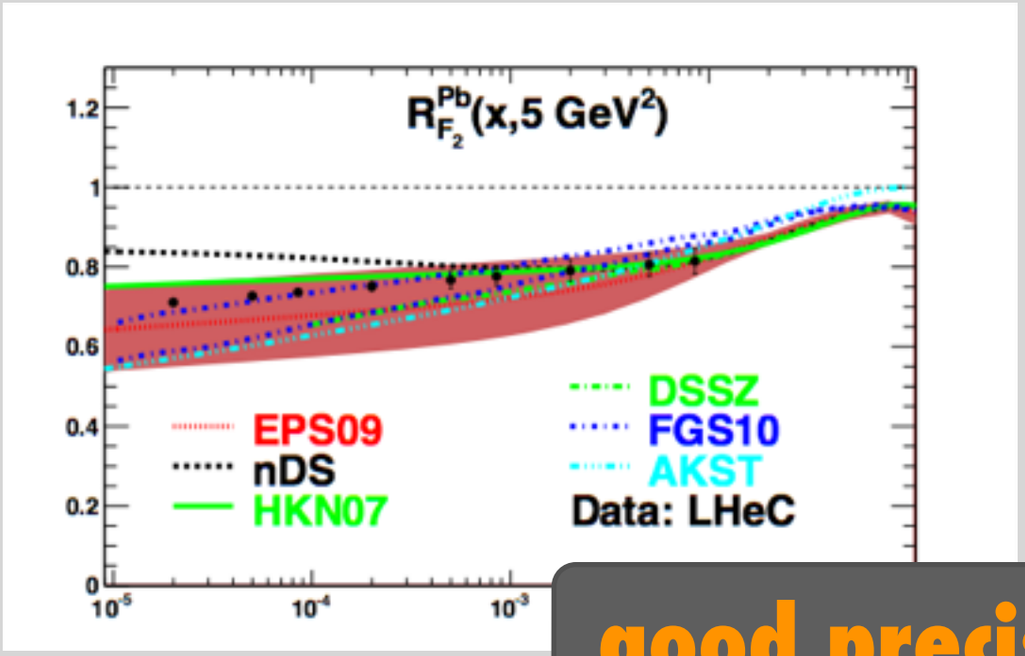

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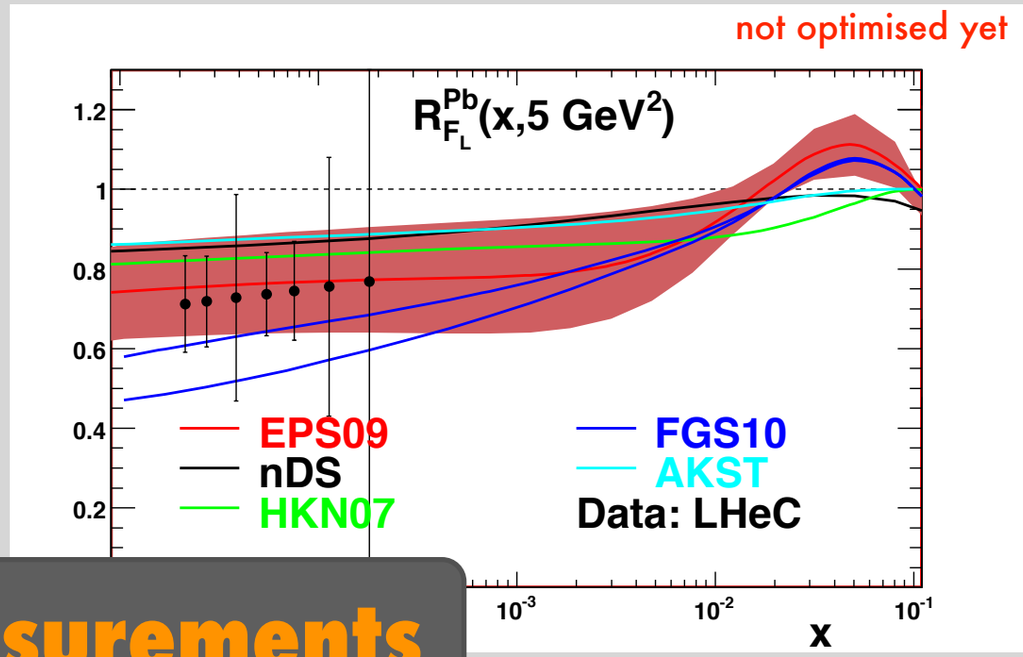
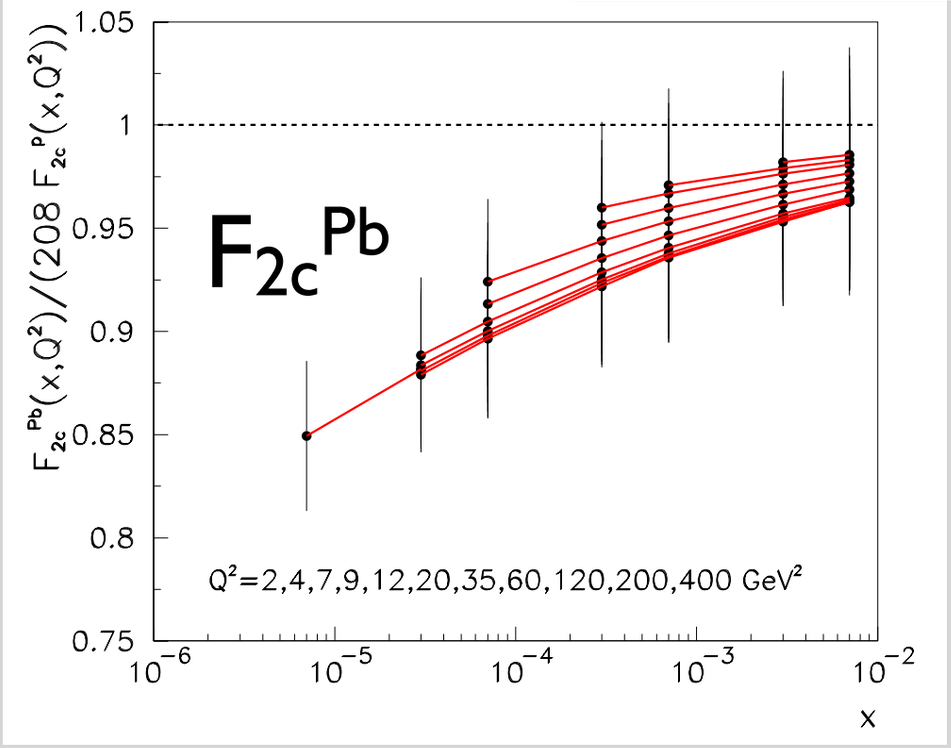
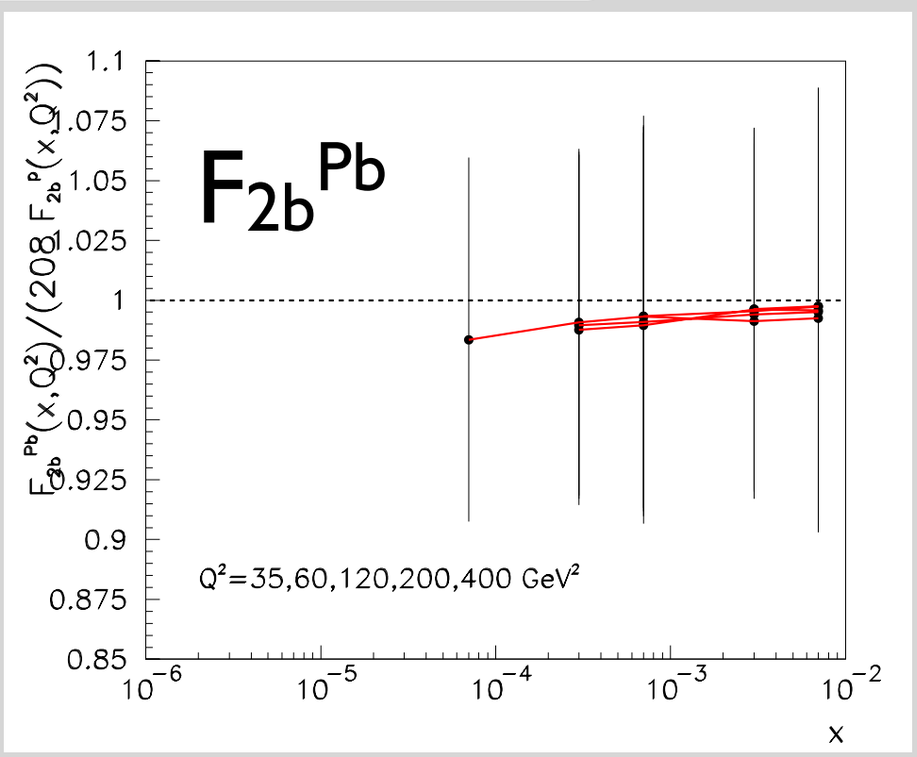


good precision measurements





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uncertainties in DGLAP analyses

Paukkunen, LHeC workshop Jan 2014

Effects in nPDFs, LHeC

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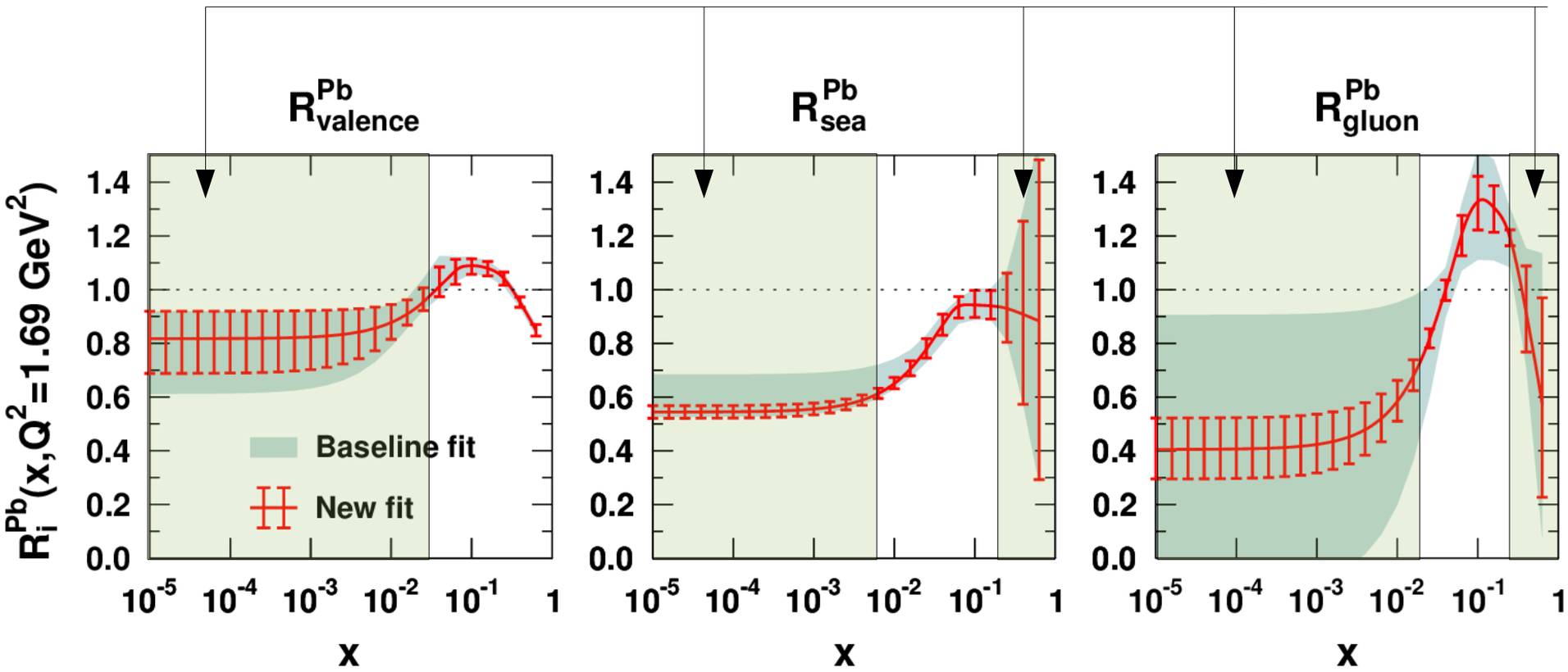

- A drastic reduction in the small-x gluon and sea quark uncertainties
- More freedom in the fit function should be allowed – the baseline uncertainty probably underestimated
- Addition of charged-current data should give a handle on the flavor dependence, which is currently (practically) unconstrained

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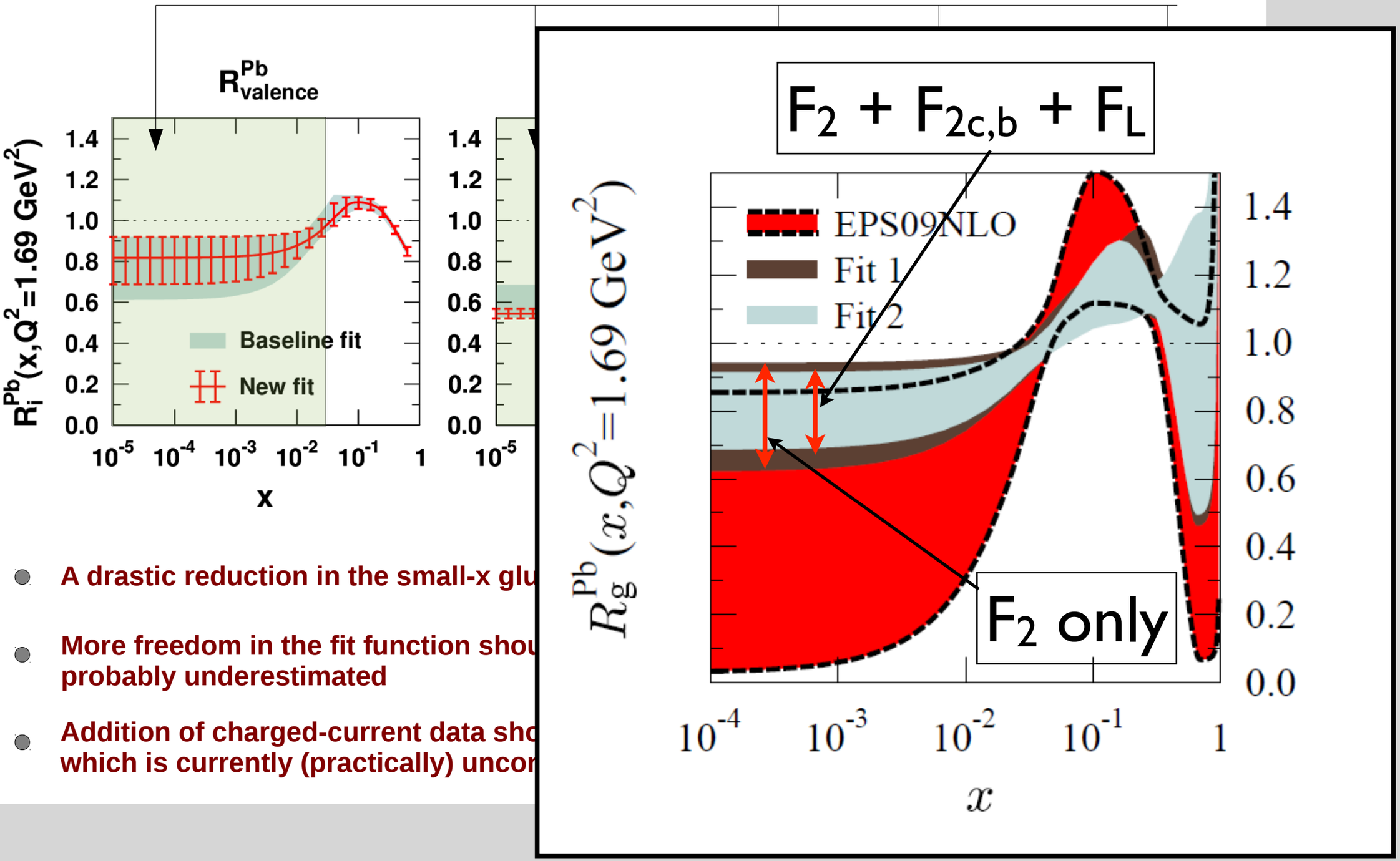

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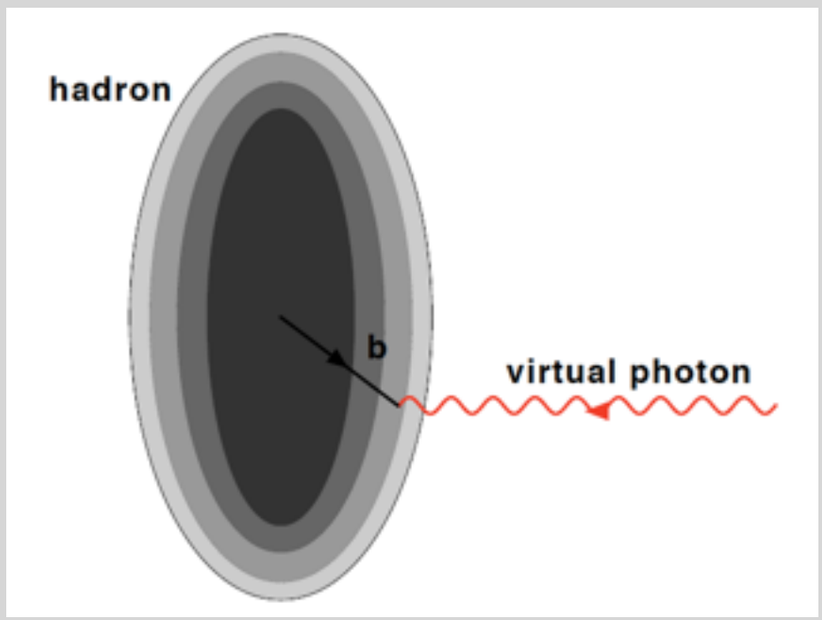
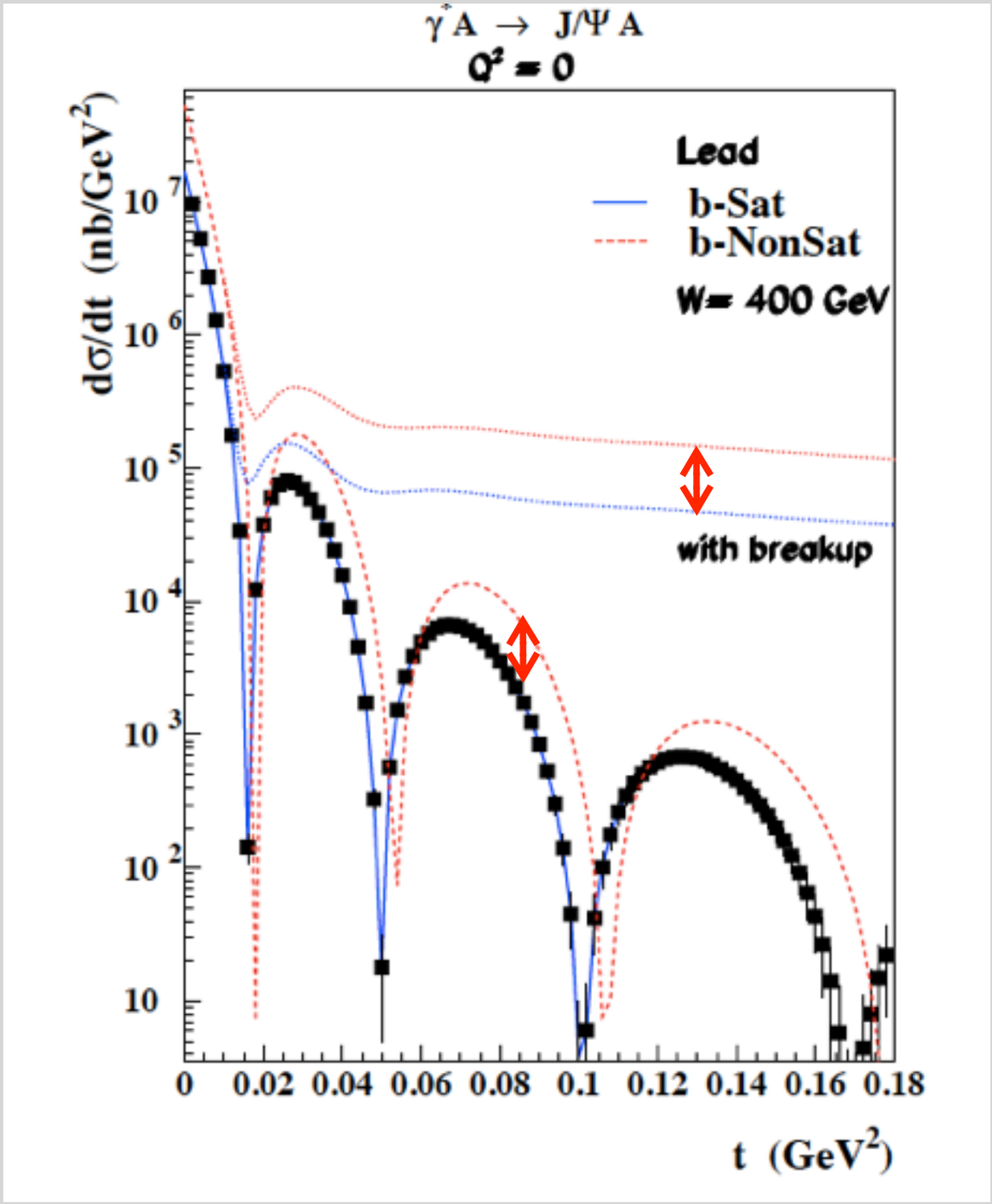
transverse scan: elastic VM

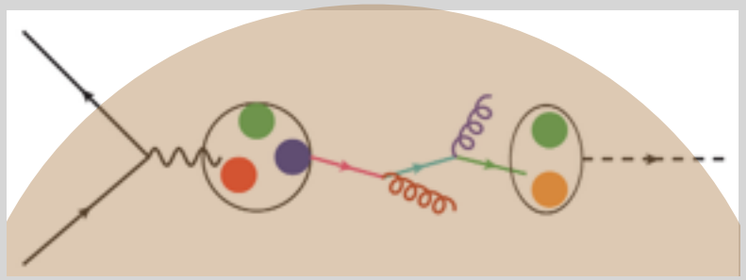
- t-differential measurements map transverse glue mapping of hadron/ nucleus
- large lever-arm in t with good precision
- sizeable saturation effects expected





partonic evolution and hadronization in matter

- benchmark for jet quenching studies in AA



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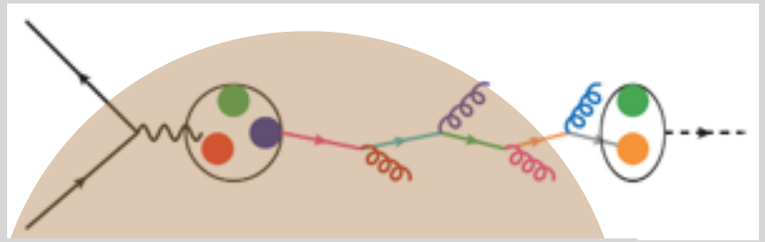
  (pre-)hadronic absorption :: formation times



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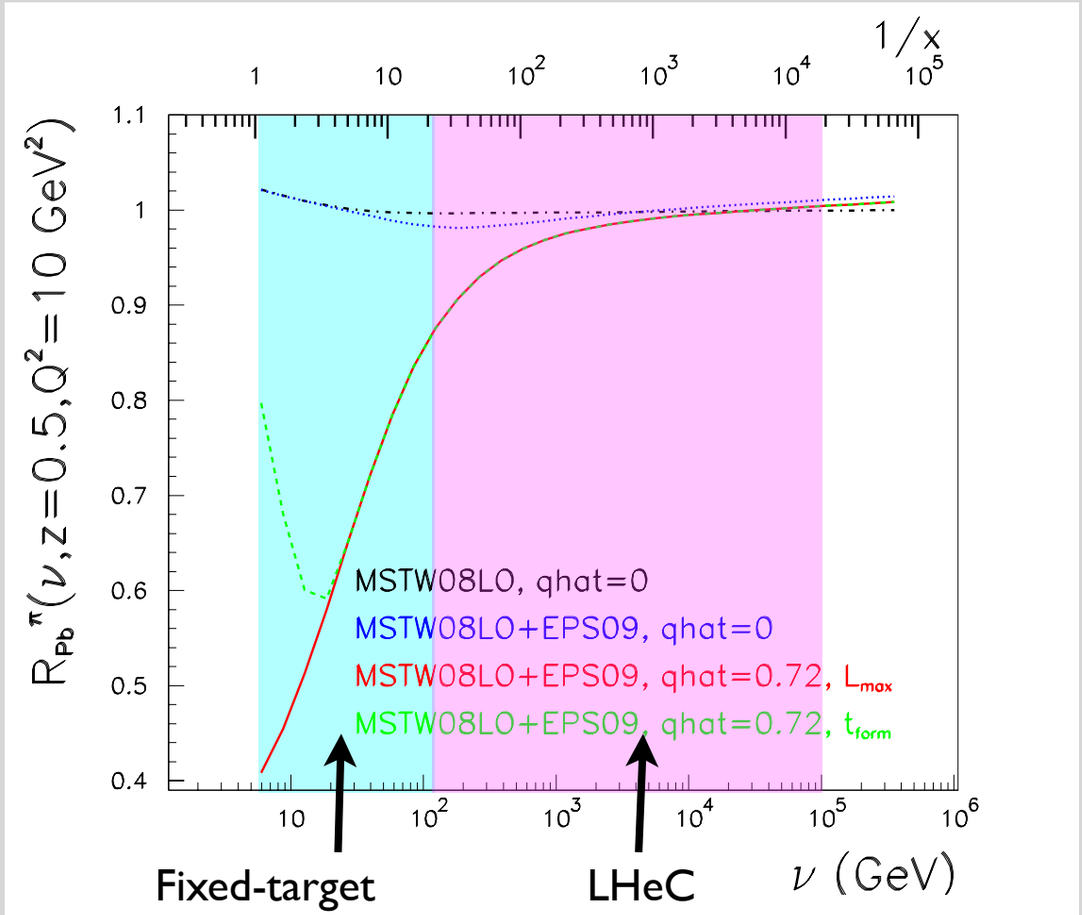

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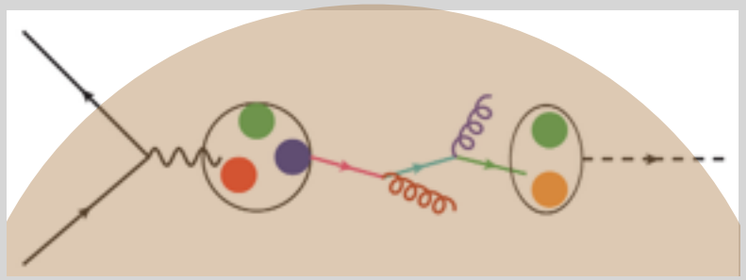

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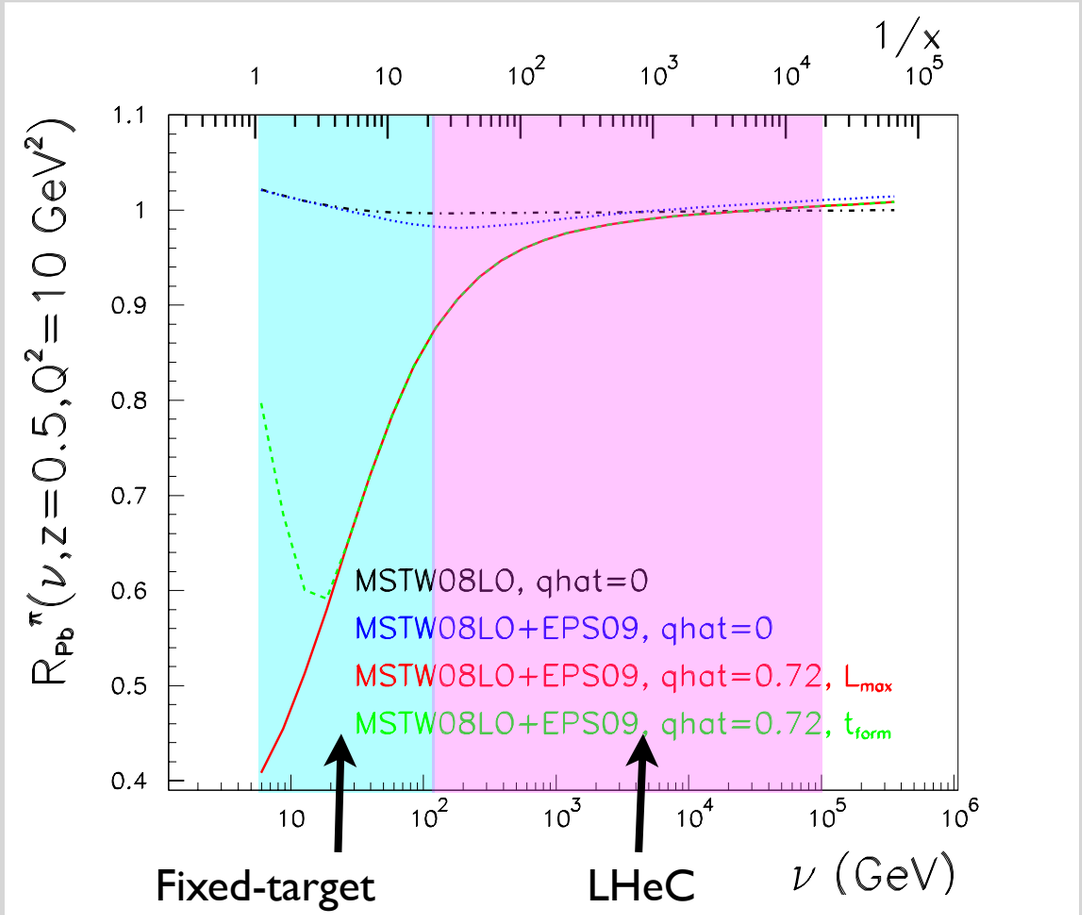
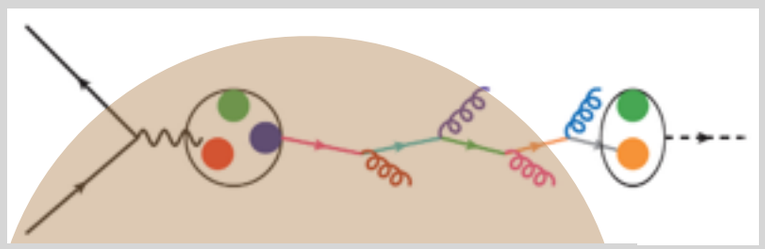




jets plentiful in eA ::
much needed benchmarking for AA and pA

outlook

- *clear mandate from CERN and NuPECC to further enhance physics case for a TDR circa 2015*

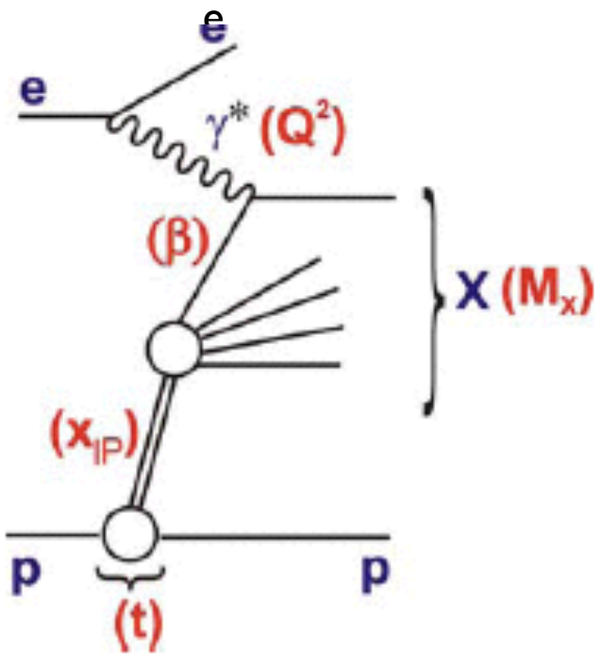
- *clear need [from the heavy ion side] for an eA programme*

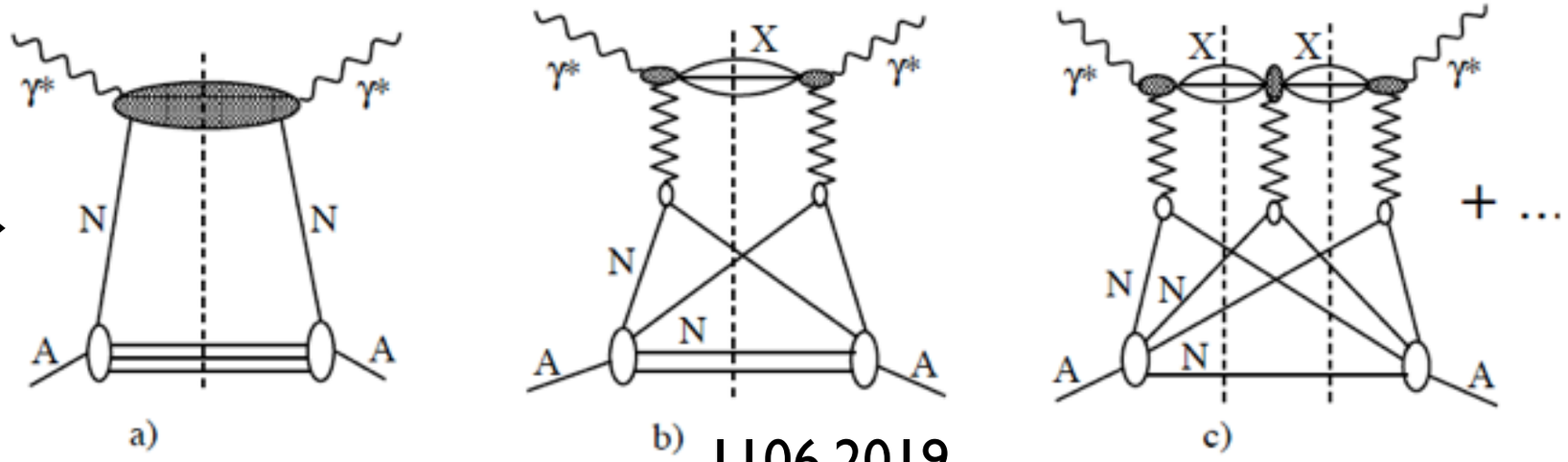
- *a very long to do list:*
  - *refine/optimize DGLAP fits to pseudo-data*
  - *MC generators*
  - *nuclear GPDs, ...*
  - *jet studies: reconstruction, ...*

Further information: many talks in this conference;
CDR [1206.2913, JPhys G39(2012)075001];
1211.4831; 1211.5102

backups

Diffraction in ep and shadowing:





1106.2019

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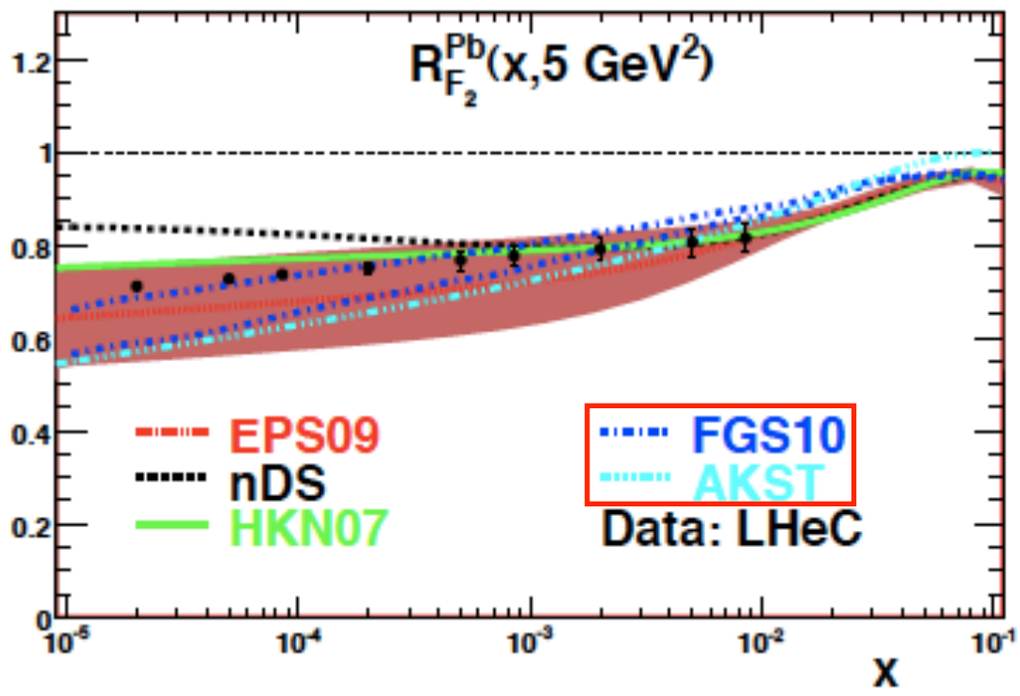

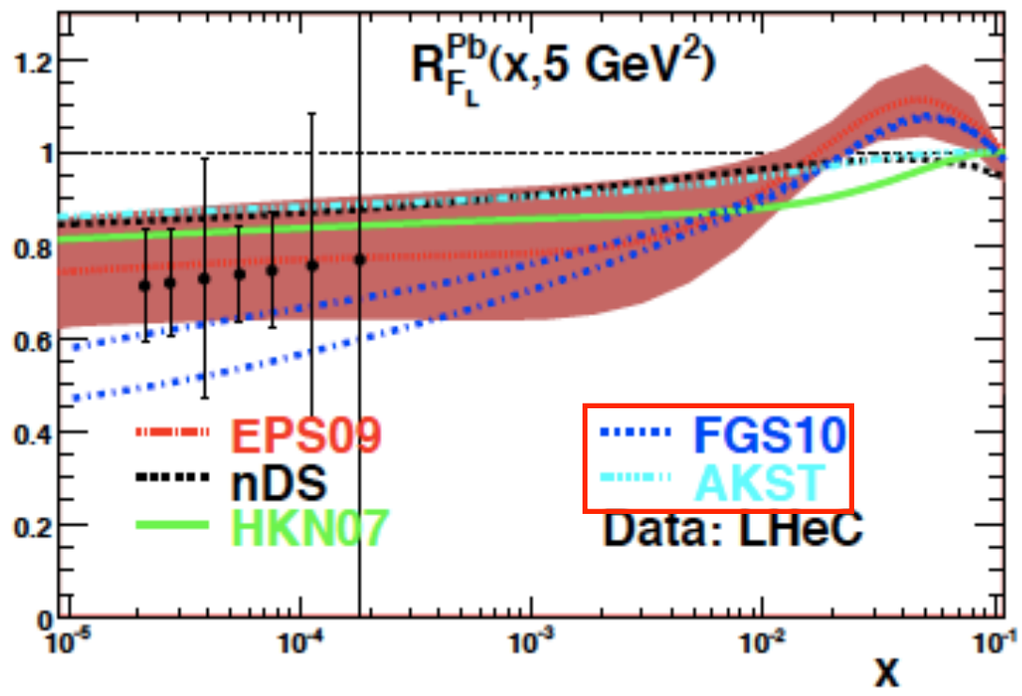

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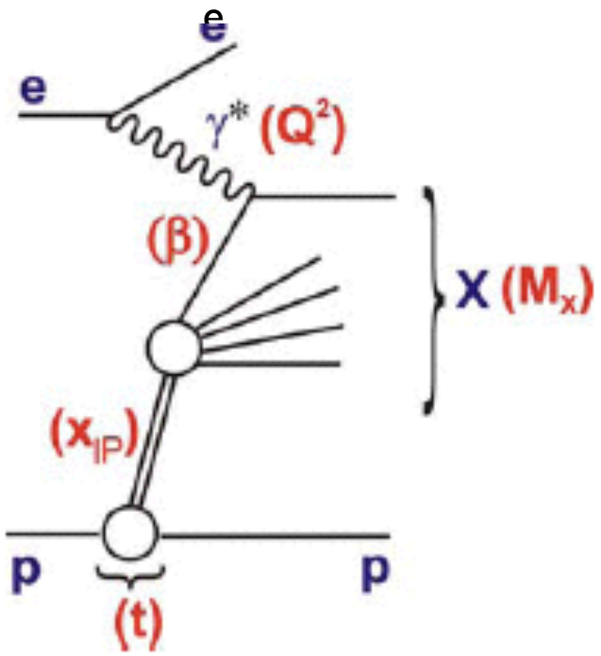

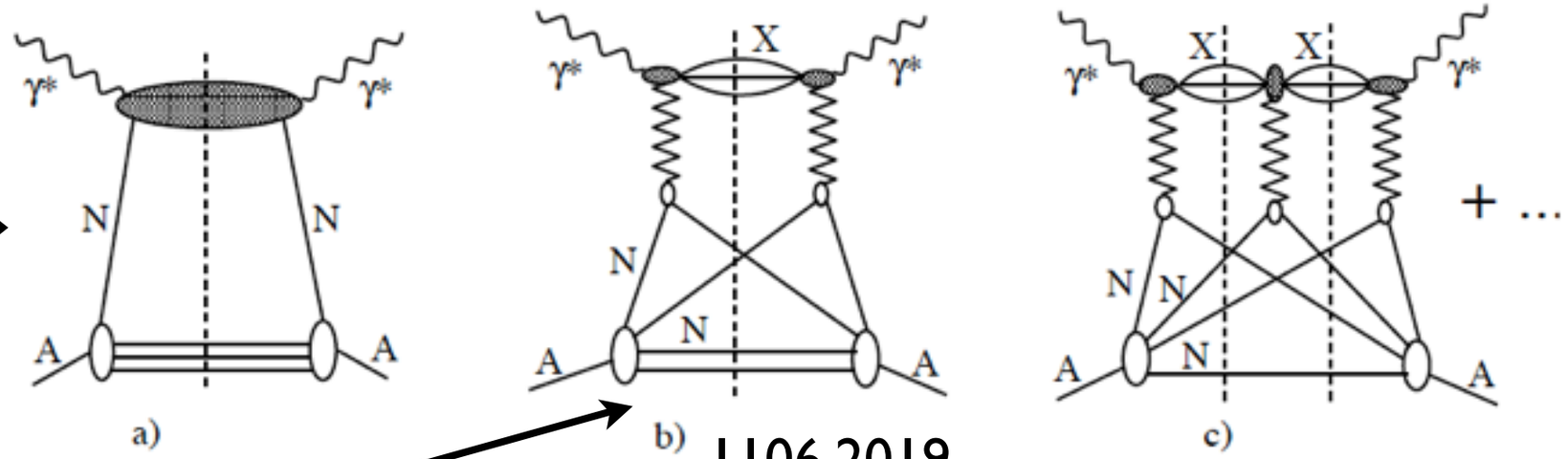

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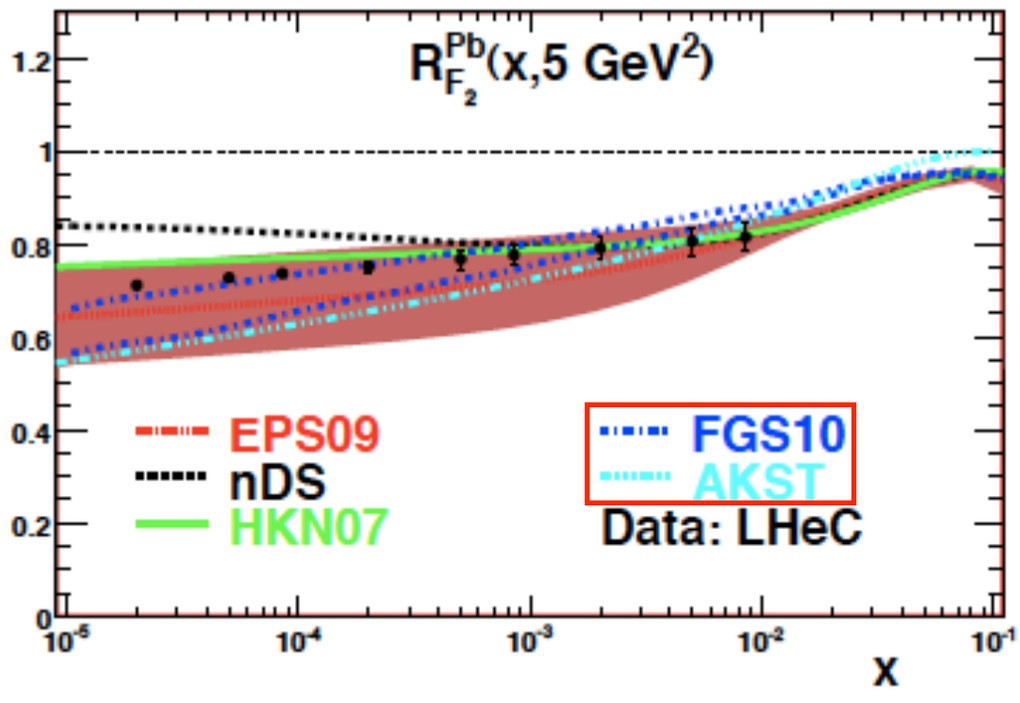
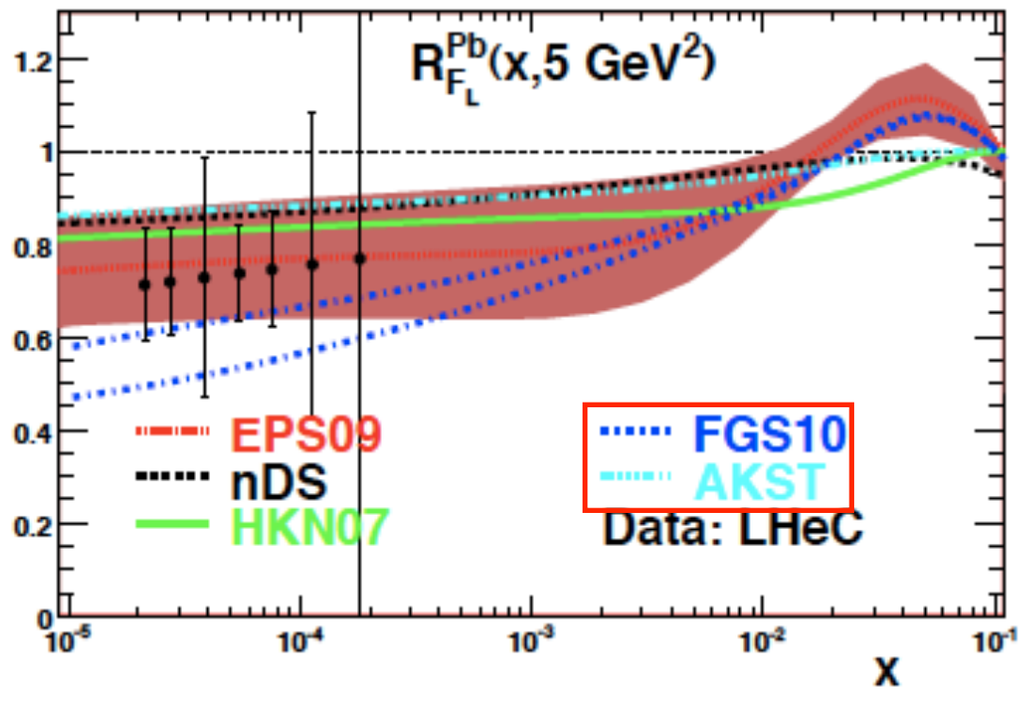
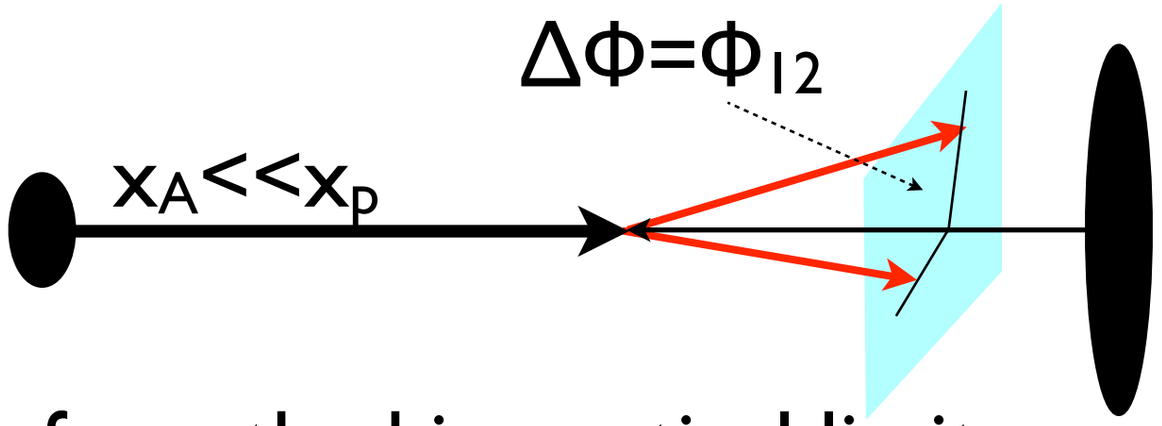
- Diffraction is linked to nuclear shadowing through basic QFT (Gribov): eD to test and set the 'benchmark' for new effects.

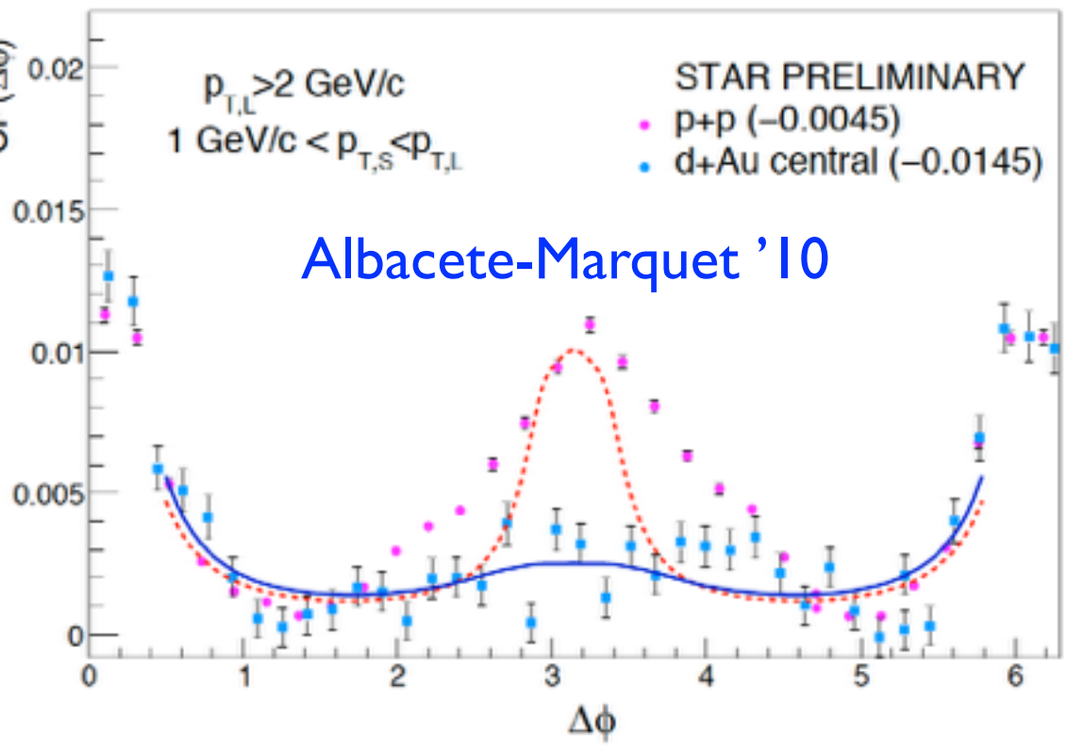




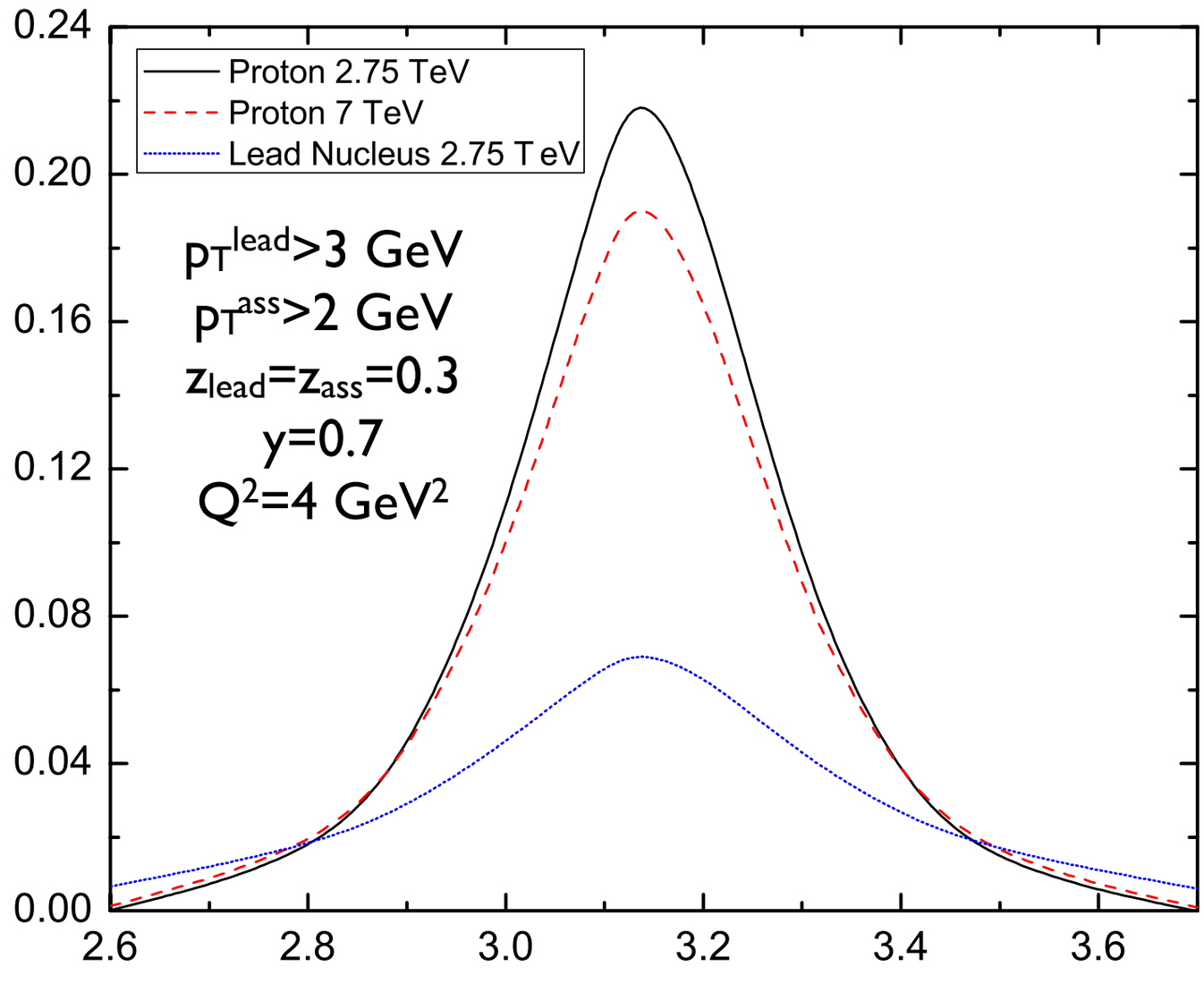
Dihadron azimuthal decorrelation:

- Dihadron azimuthal decorrelation: currently discussed at RHIC as suggestive of saturation.
- At the LHeC it could be studied far from the kinematical limits.

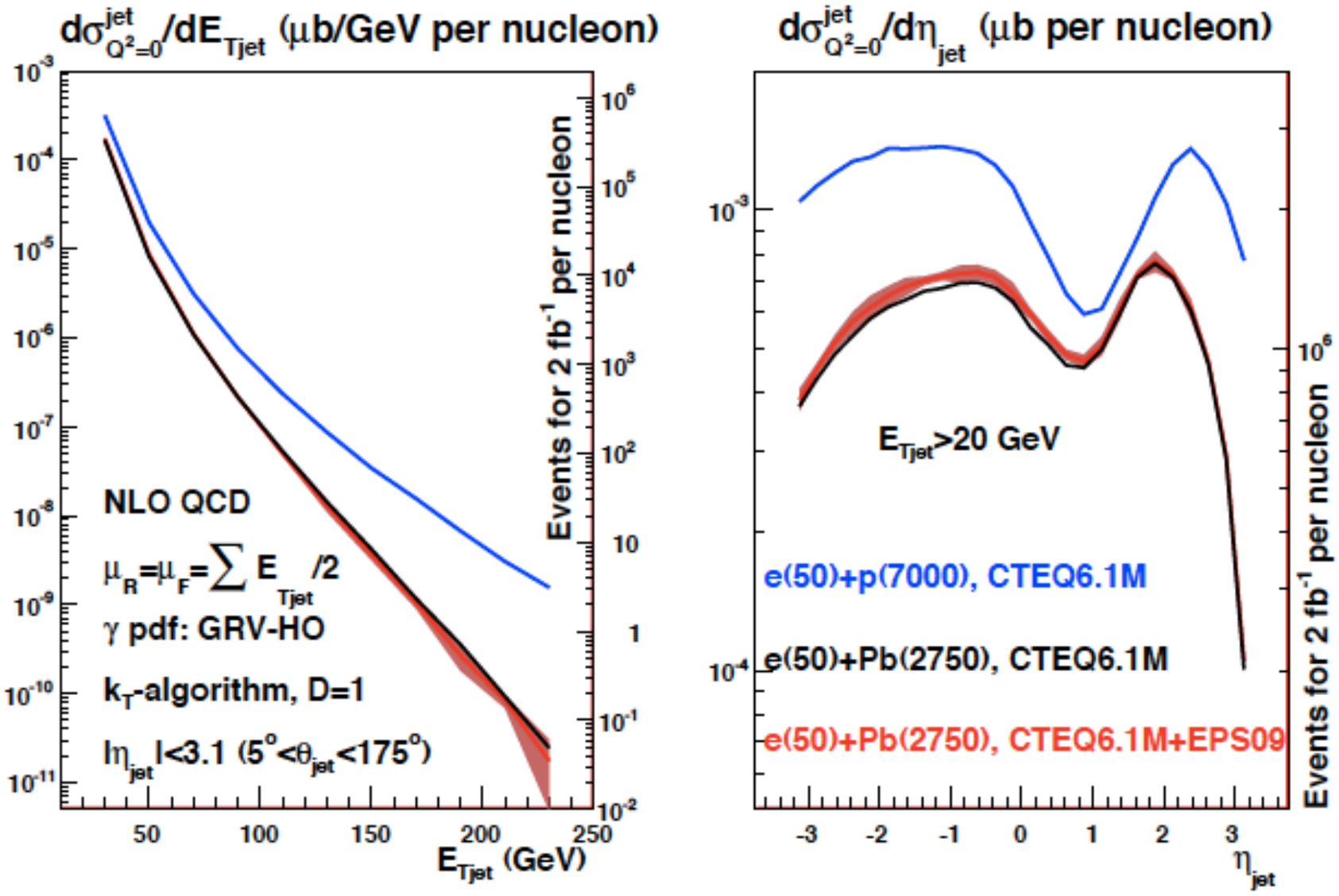




$$C(\phi_{12}) = \frac{1}{\frac{d\sigma(\gamma^* N \to h_1 X)}{dz_{h1}}} \frac{d\sigma^{\gamma^* N \to h_1 h_2 + X}}{dz_{h1} dz_{h2} d\phi_{12}}$$



Jets:



- Jets: large E_T even in eA.
- Useful for studies of parton dynamics in nuclei (hard probes), and for photon structure.
- Background subtraction, detailed reconstruction pending.