25th International Nuclear Physics Conference INPC2013
Firenze, June 4th 2013

Small-x Physics in eA at the LHeC: Understanding the Initial State of URHIC

Néstor Armesto
Departamento de Física de Partículas and IGFAE, Universidade de Santiago de Compostela
and
CERN, Physics Department, Theory Unit
nestor.armesto@usc.es
for the LHeC Study group, http://cern.ch/lhec

Contents:

1. Motivation.

2. eA at the LHeC and comparison to the LHC.

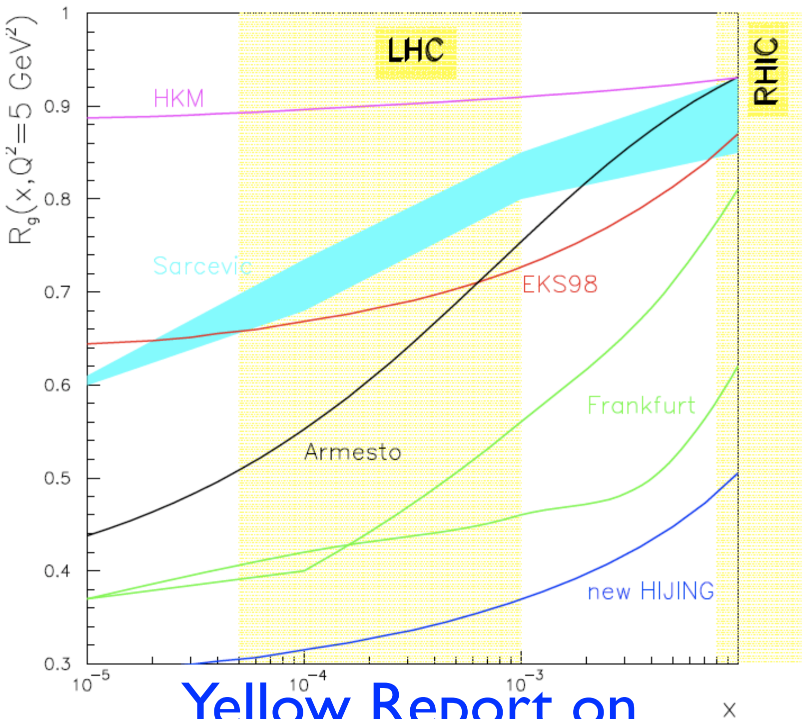
3. Physics case in eA:
   - Inclusive measurements and nuclear PDFs.
   - Diffraction.
   - Final states: dynamics of QCD radiation and hadronization.

4. Summary and outlook.

CDR, arXiv:1206.2913, J. Phys. G 39 (2012) 075001;
arXiv:1211.4831; arXiv:1211.5102;
LHeC talks at DIS2013 and LPCC 17-18.04.2013

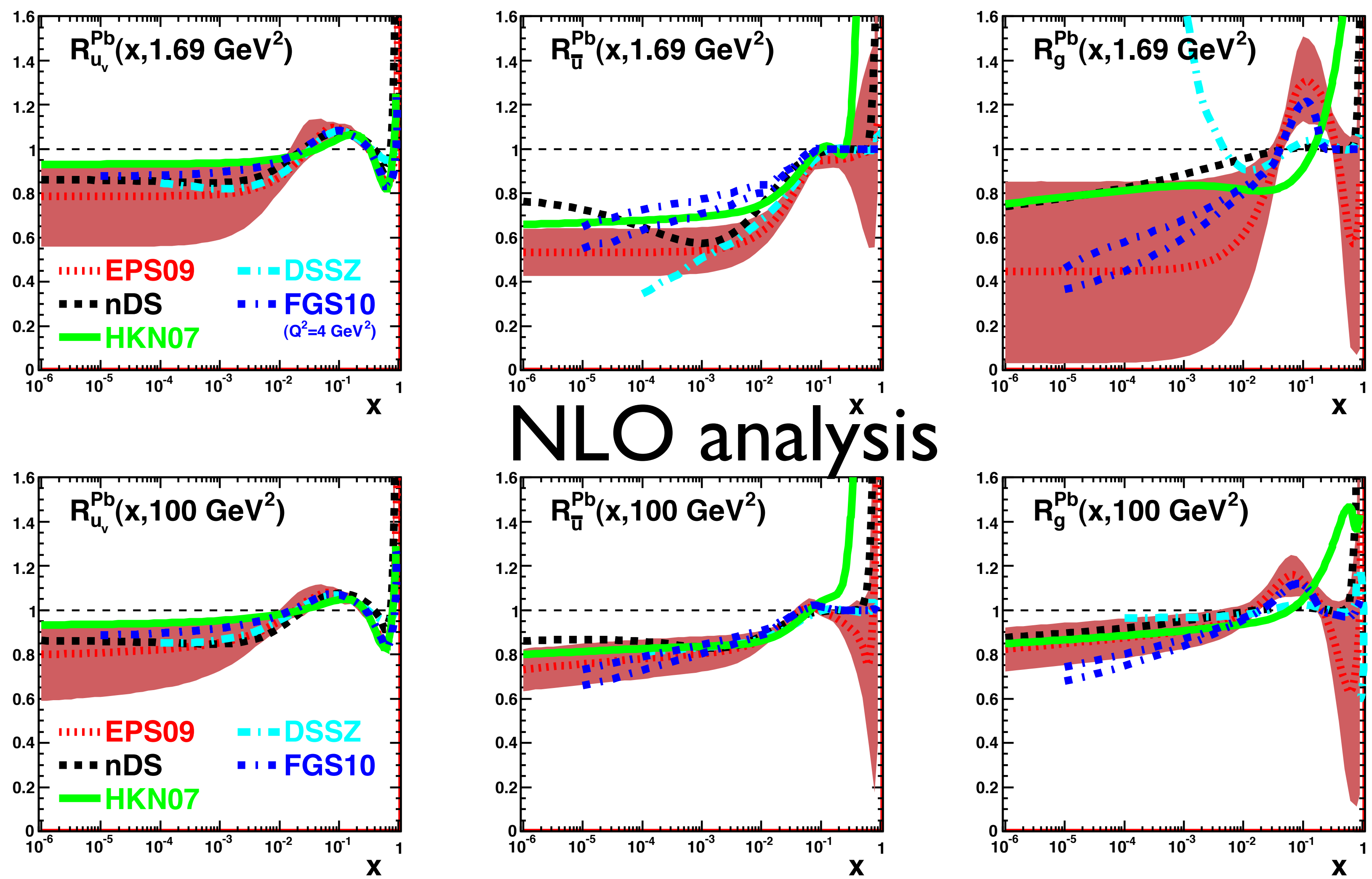
nPDFs: $R = \dfrac{f_{i/A}}{A f_{i/p}} \approx \dfrac{\text{measured}}{\text{expected if no nuclear effects}}$

- Lack of data ⇒ models give vastly different results for the nuclear glue at small scales and x: problem for benchmarking in HIC.



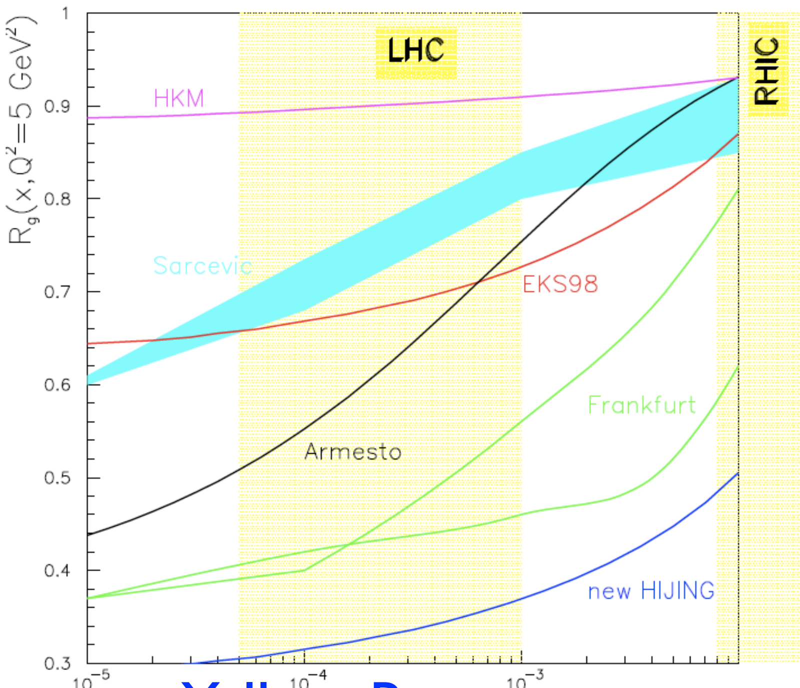
Yellow Report on Hard Probes, 2004

- Available DGLAP analysis at NLO show large uncertainties at small scales and x.



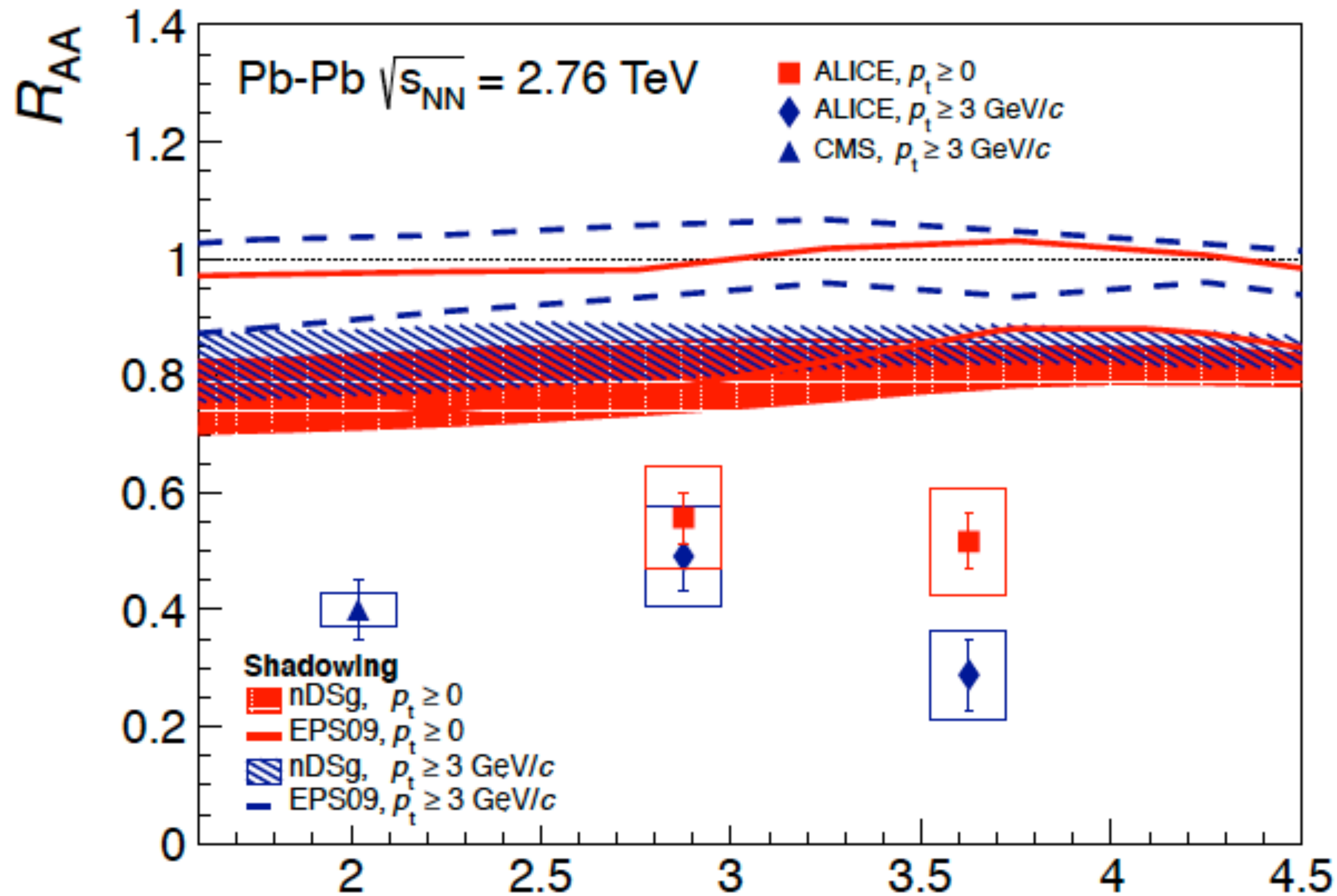
NLO analysis

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



Yellow Report on Hard Probes, 2004

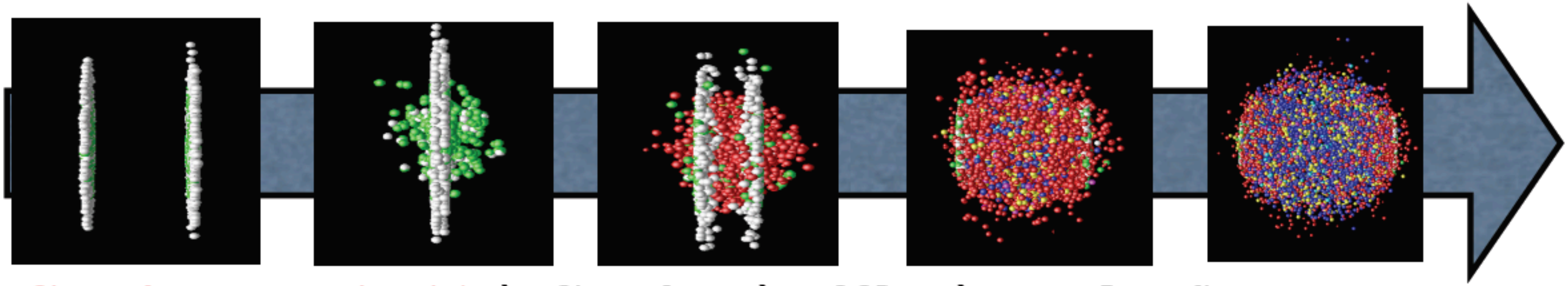
- Lack of data ⇒ models give vastly different results for the nuclear glue at small scales and x: problem for benchmarking in HIC.



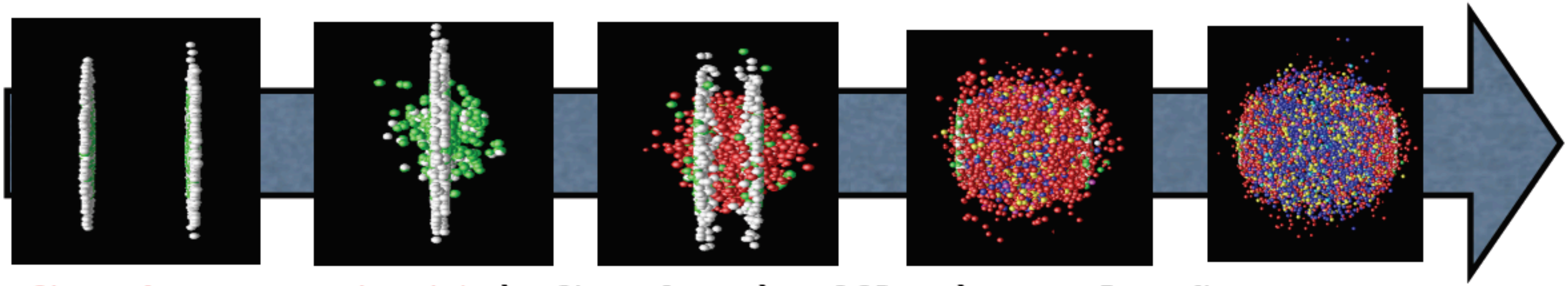
Inclusive J/ψ, 1202.1383

- Available DGLAP analysis at NLO show large uncertainties at small scales and x.

Relevance for the HI program:



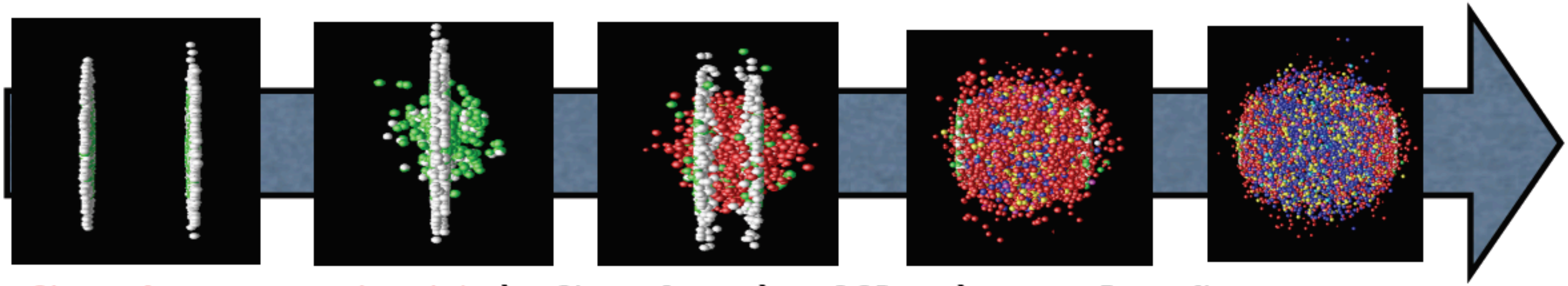
Relevance for the HI program:



Gluons from saturated nuclei → Glasma? → QGP → Reconfinement

- Nuclear wave function at small x: nuclear structure functions.

Relevance for the HI program:



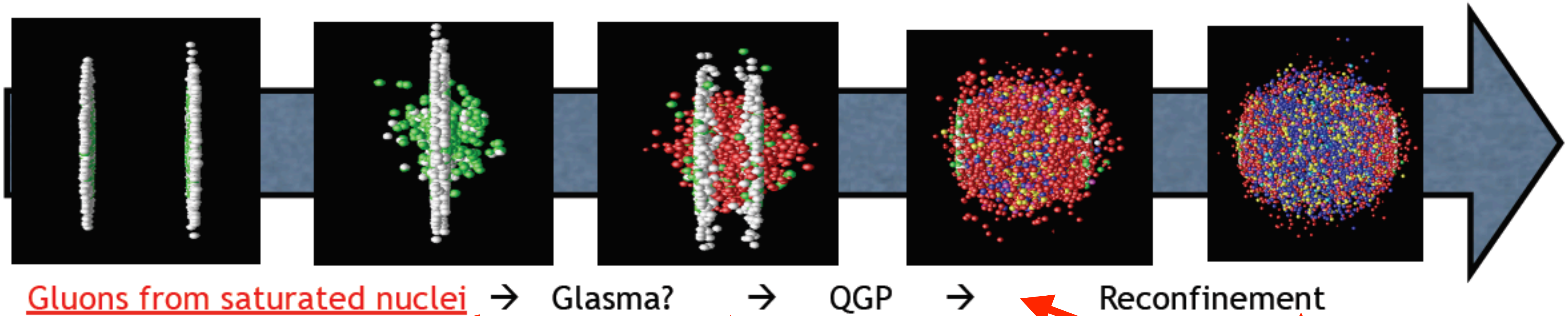
Gluons from saturated nuclei → Glasma? → QGP → Reconfinement

- Nuclear wave function at small x: nuclear structure functions.

- Particle production at the very beginning: which factorisation in eA?

- How does the system behave as ~ isotropised so fast?: initial conditions for plasma formation to be studied in eA.

Relevance for the HI program:



- Nuclear wave function at small x: nuclear structure functions.

- Particle production at the very beginning: which factorisation in eA?

- How does the system behave as ~ isotropised so fast?: initial conditions for plasma formation to be studied in eA.

- Probing the medium through energetic particles (jet quenching etc.): modification of QCD radiation and hadronization in the nuclear medium.

Contents:

1. Motivation.

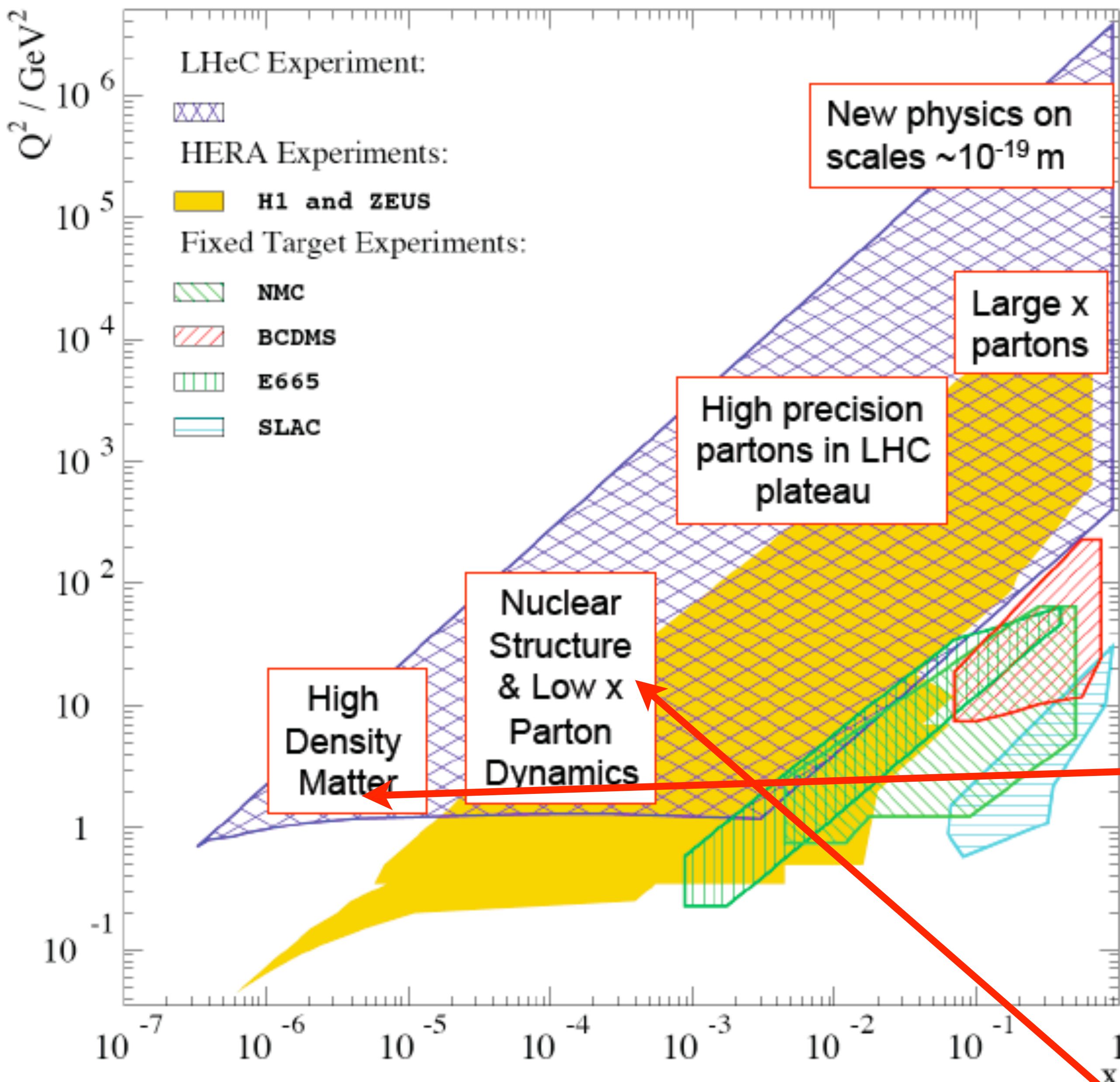
2. eA at the LHeC and comparison to the LHC.

3. Physics case in eA:
   - Inclusive measurements and nuclear PDFs.
   - Diffraction.
   - Final states: dynamics of QCD radiation and hadronization.

4. Summary and outlook.

CDR, arXiv:1206.2913, J. Phys. G 39 (2012) 075001;
arXiv:1211.4831; arXiv:1211.5102;
LHeC talks at DIS2013 and LPCC 17-18.04.2013

Physics goals:



- Proton structure to a few 10^{-20} m: Q^2 lever arm.
- Precision QCD/EW physics.
- Higgs physics.
- High-mass frontier (lq, excited fermions, contact interactions).
- Unambiguous access, in ep and eA, to a qualitatively novel regime of matter predicted by QCD.
- Substructure/parton dynamics inside nuclei with strong implications on QGP search.

Accelerator:

Design considerations:

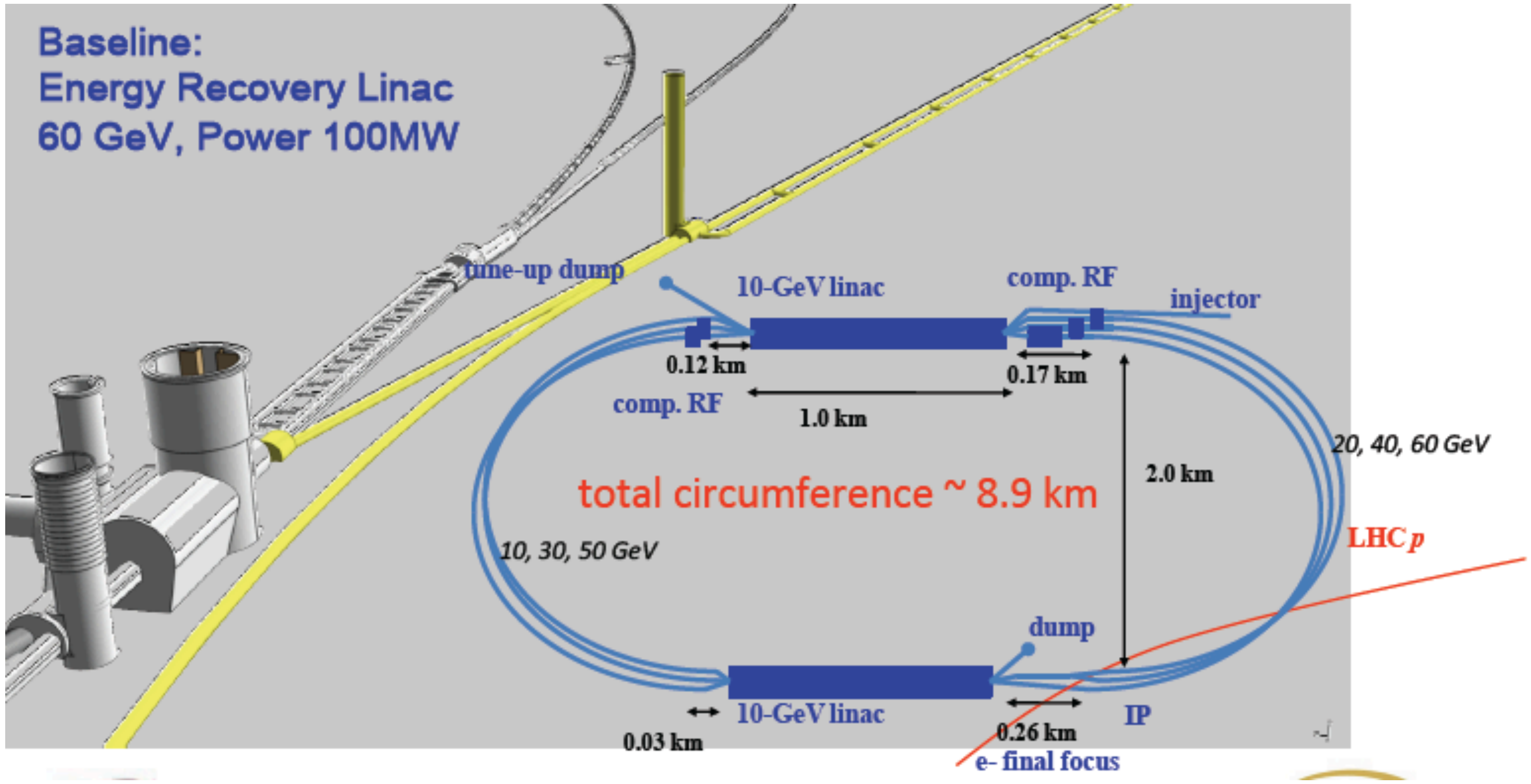
- $L \sim 10^{33}$ cm^{-2} s^{-1}.
- Power < 70 MW.
- Synchronous pp/ep.

E_e=60 GeV (benchmark).

e- IP beta funct. $\beta^*_{x,y}$ [m]	0.12	0.14
full crossing angle [mrad]	0	0
geometric reduction H_{hg}	0.91	0.94
repetition rate [Hz]	N/A	10
beam pulse length [ms]	N/A	5
ER efficiency	94%	N/A
average current [mA]	6.6	5.4
tot. wall plug power[MW]	100	100

CDR numbers for luminosity, to be considered now as lower bounds.

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



Luminosity per nucleon

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

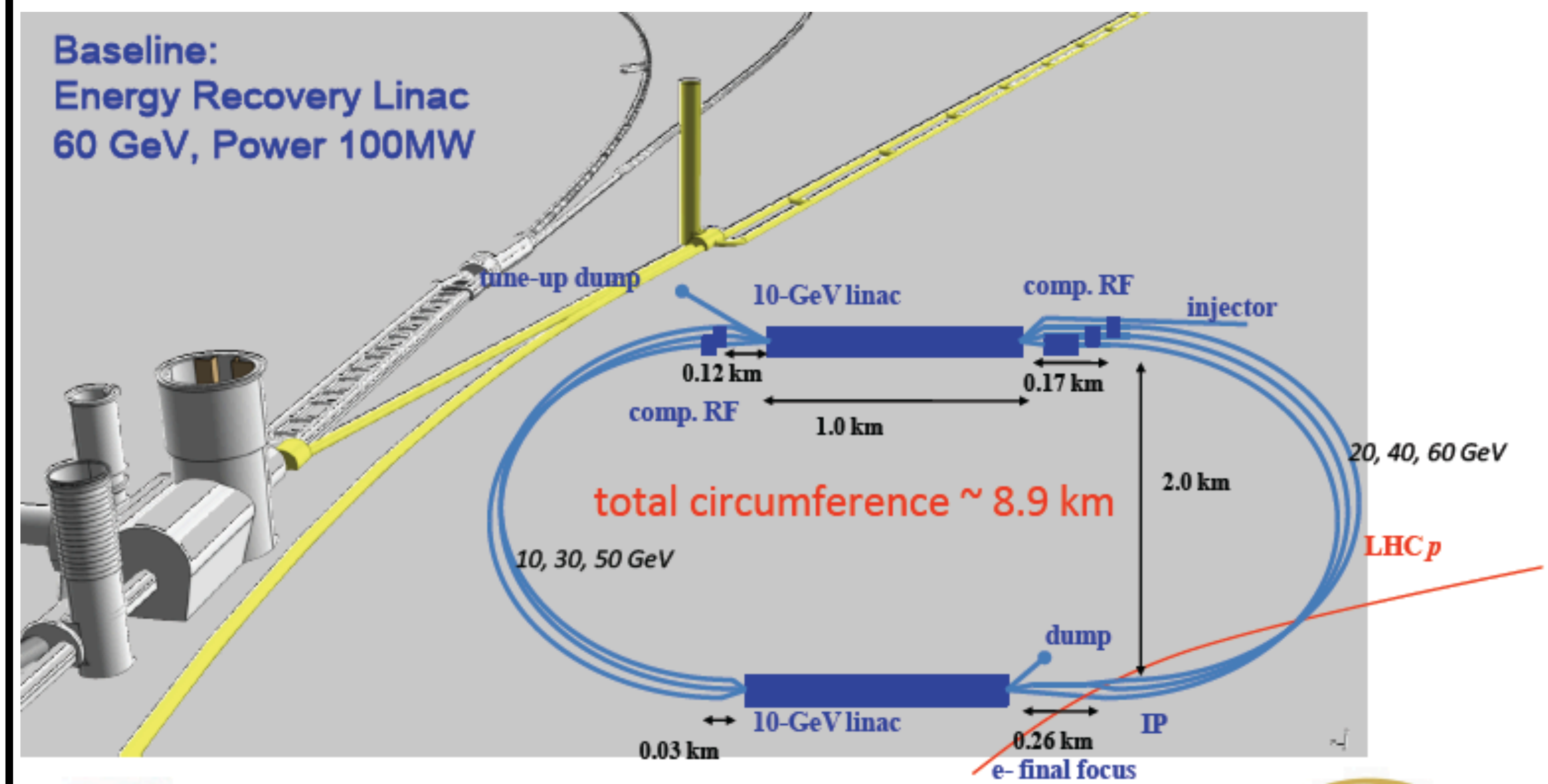
eD: $L_{eN}=AL_{eA} > \sim 3 \times 10^{31}$ cm^{-2}s^{-1}

Accelerator:

electron beam	LR ERL	LR
e- energy at IP[GeV]	60	140
luminosity [10^{32} cm^{-2}s^{-1}]	10	0.44
polarization [%]	90	90
bunch population [10^9]	2.0	1.6
e- bunch length [mm]	0.3	0.3
bunch interval [ns]	50	50
transv. emit. $\gamma\varepsilon_{x,y}$ [mm]	0.05	0.1
rms IP beam size $\sigma_{x,y}$ [μm]	7	7
e- IP beta funct. $\beta^*_{x,y}$ [m]	0.12	0.14
full crossing angle [mrad]	0	0
geometric reduction H_{hg}	0.91	0.94
repetition rate [Hz]	N/A	10
beam pulse length [ms]	N/A	5
ER efficiency	94%	N/A
average current [mA]	6.6	5.4
tot. wall plug power[MW]	100	100

CDR numbers for luminosity, to be considered now as lower bounds.

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

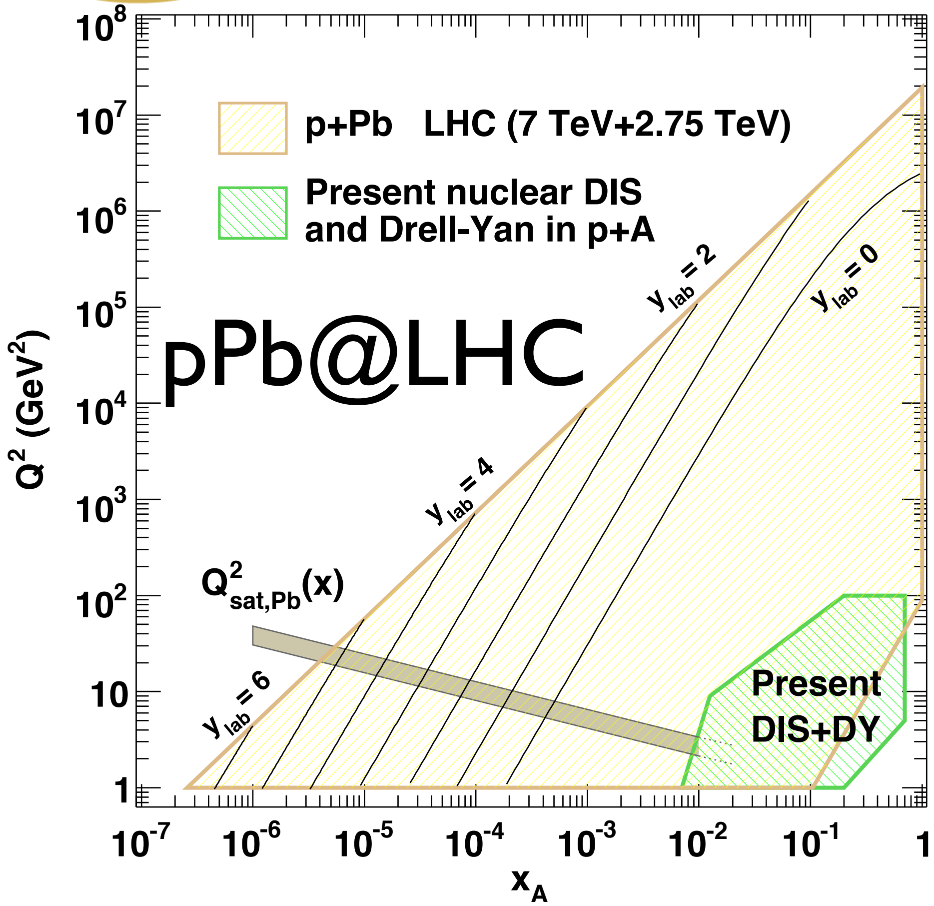


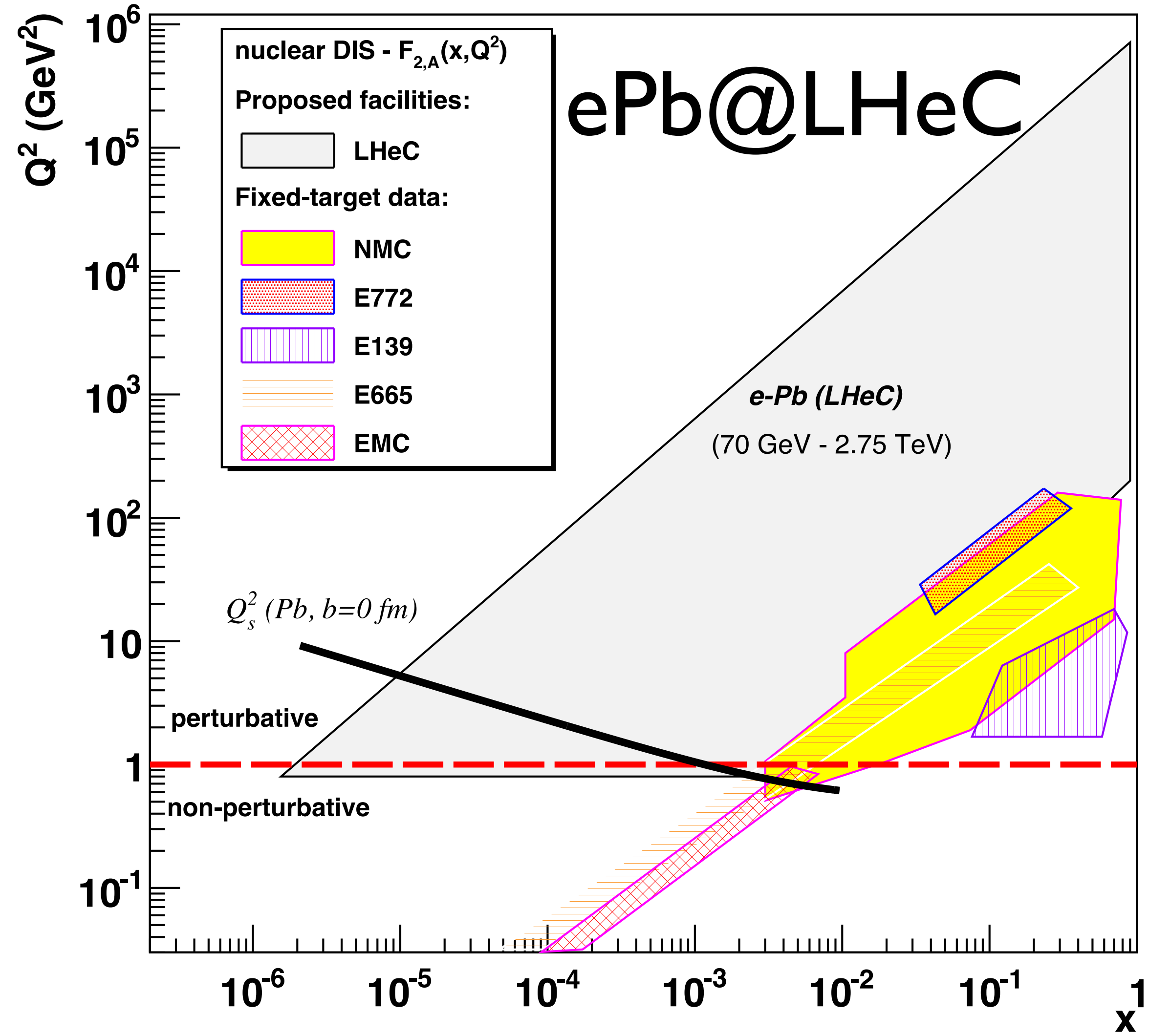
Luminosity per nucleon

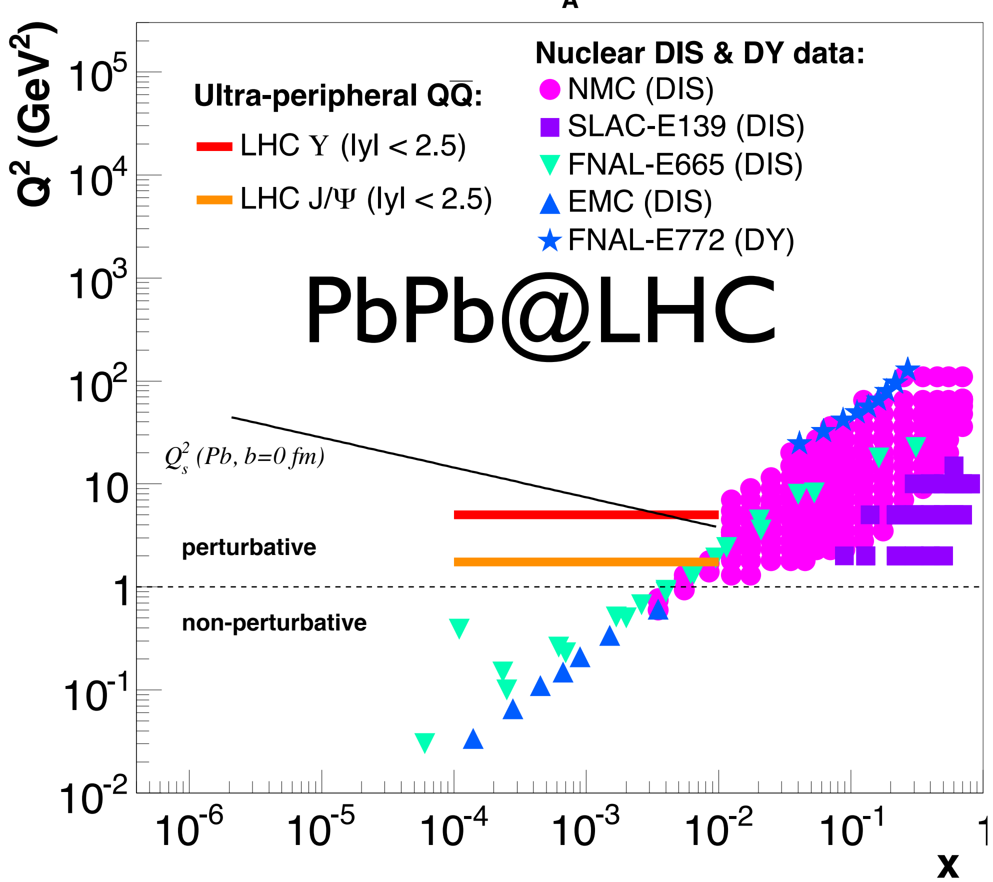
$$L_{eN} = \begin{cases} 9\times 10^{31}\ \mathrm{cm}^{-2}\mathrm{s}^{-1} & \text{(Nominal Pb)} \\ 1.6\times 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1} & \text{(Ultimate Pb)} \end{cases}$$

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

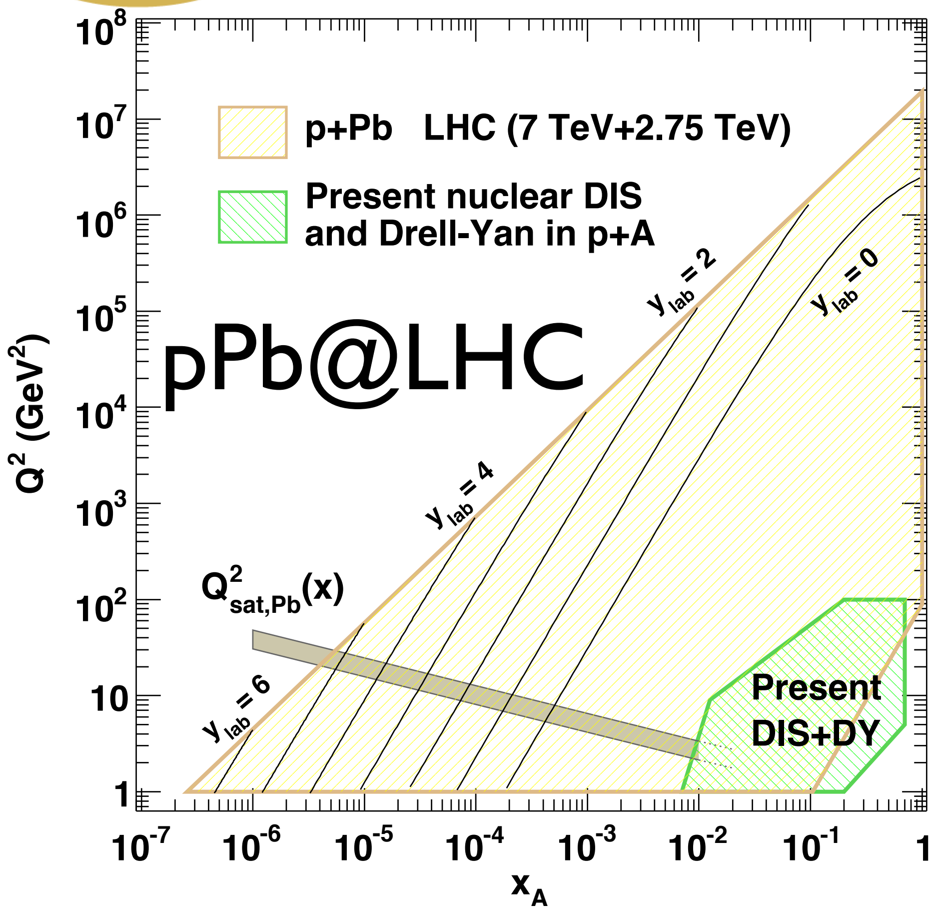
LHC vs. LHeC:

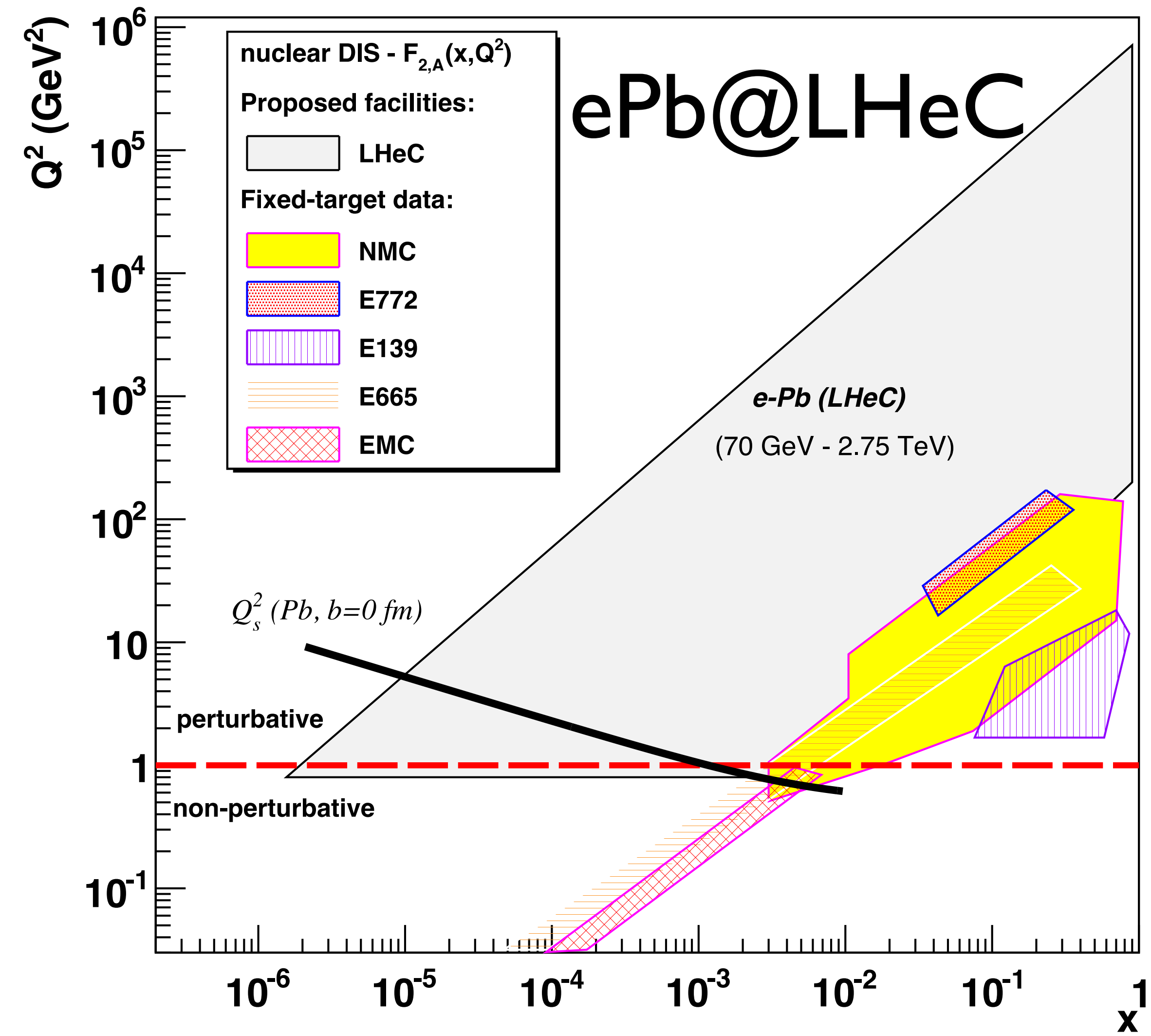

p+Pb LHC (7 TeV+2.75 TeV)
Present nuclear DIS and Drell-Yan in p+A
pPb@LHC
$y_{lab} = 2$
$y_{lab} = 0$
$y_{lab} = 4$
$y_{lab} = 6$
$Q^2_{sat,Pb}(x)$
Present DIS+DY
Q^2 (GeV^2)
x_A

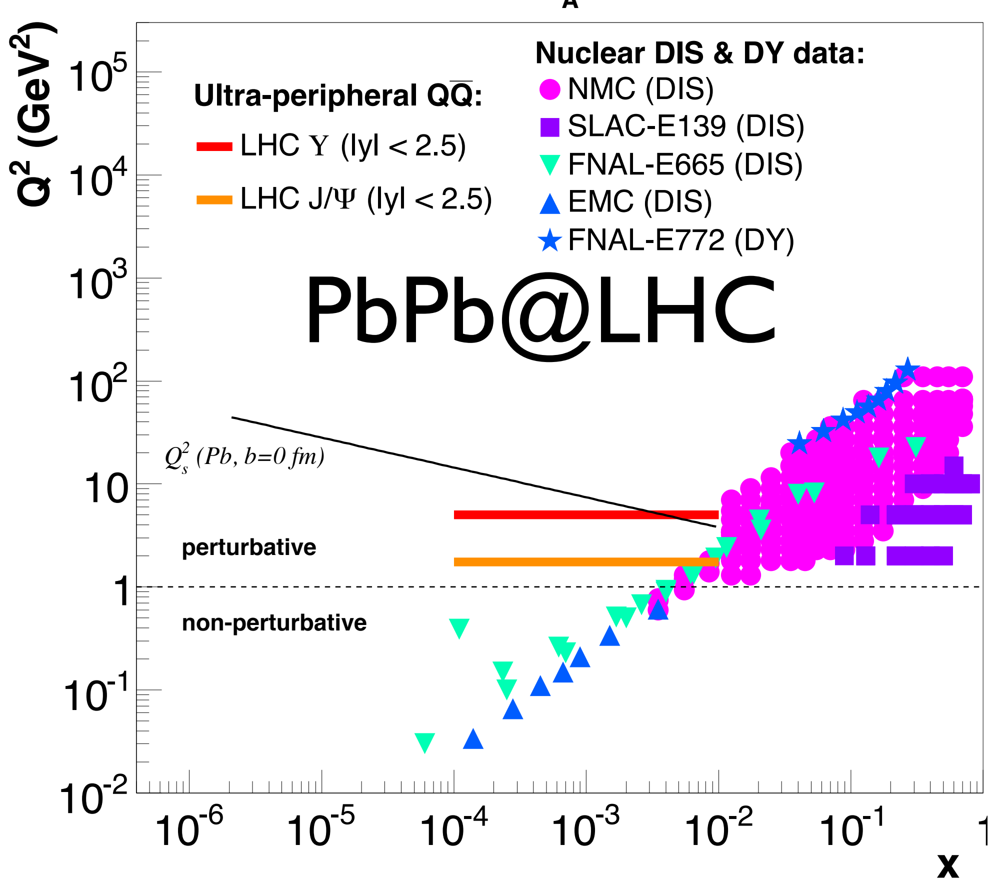

nuclear DIS - $F_{2,A}(x,Q^2)$
Proposed facilities:
LHeC
Fixed-target data:
NMC
E772
E139
E665
EMC
ePb@LHeC
e-Pb (LHeC)
(70 GeV - 2.75 TeV)
Q^2_s (Pb, b=0 fm)
perturbative
non-perturbative
Q^2 (GeV^2)
x


Ultra-peripheral $Q\overline{Q}$:
LHC Υ (|y| < 2.5)
LHC J/Ψ (|y| < 2.5)
Nuclear DIS & DY data:
NMC (DIS)
SLAC-E139 (DIS)
FNAL-E665 (DIS)
EMC (DIS)
FNAL-E772 (DY)
PbPb@LHC
Q^2_s (Pb, b=0 fm)
perturbative
non-perturbative
Q^2 (GeV^2)
x

LHC vs. LHeC:







- The LHeC will explore a region overlapping with the LHC:

➜ in a cleaner experimental setup;

➜ on firmer theoretical grounds.

Contents:

1. Motivation.

2. eA at the LHeC and comparison to the LHC.

3. Physics case in eA:
   - Inclusive measurements and nuclear PDFs.
   - Diffraction.
   - Final states: dynamics of QCD radiation and hadronization.

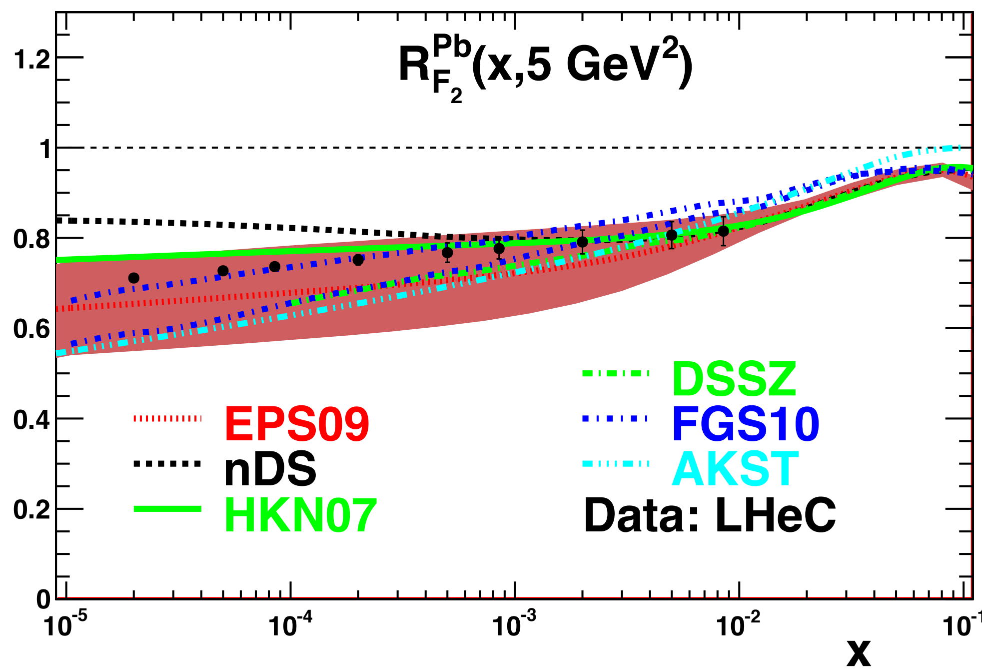
4. Summary and outlook.

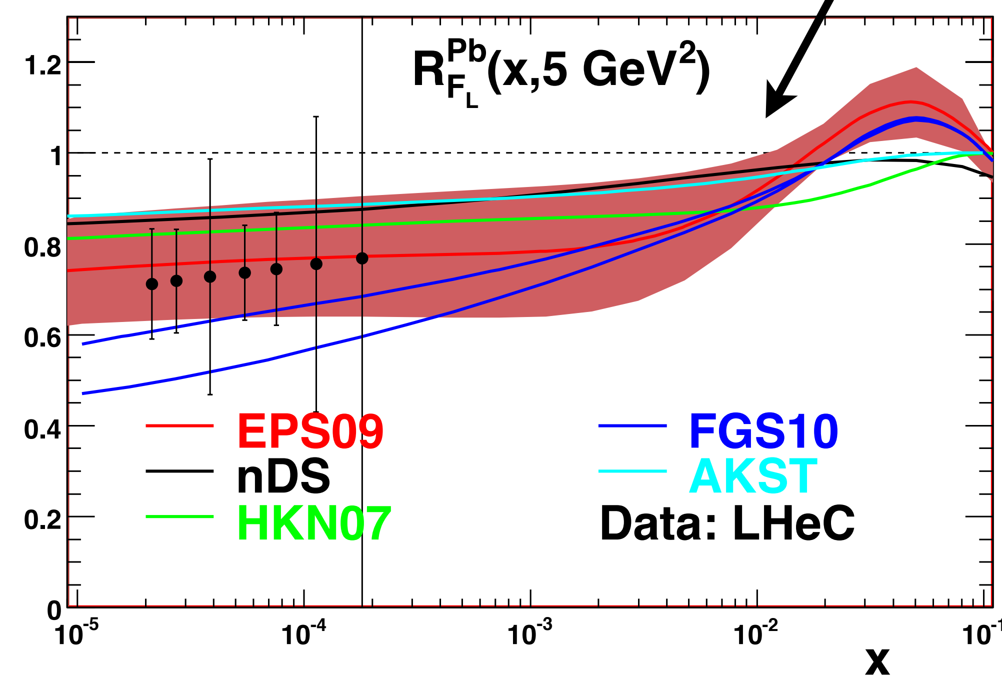
CDR, arXiv:1206.2913, J. Phys. G 39 (2012) 075001;
arXiv:1211.4831; arXiv:1211.5102;
LHeC talks at DIS2013 and LPCC 17-18.04.2013

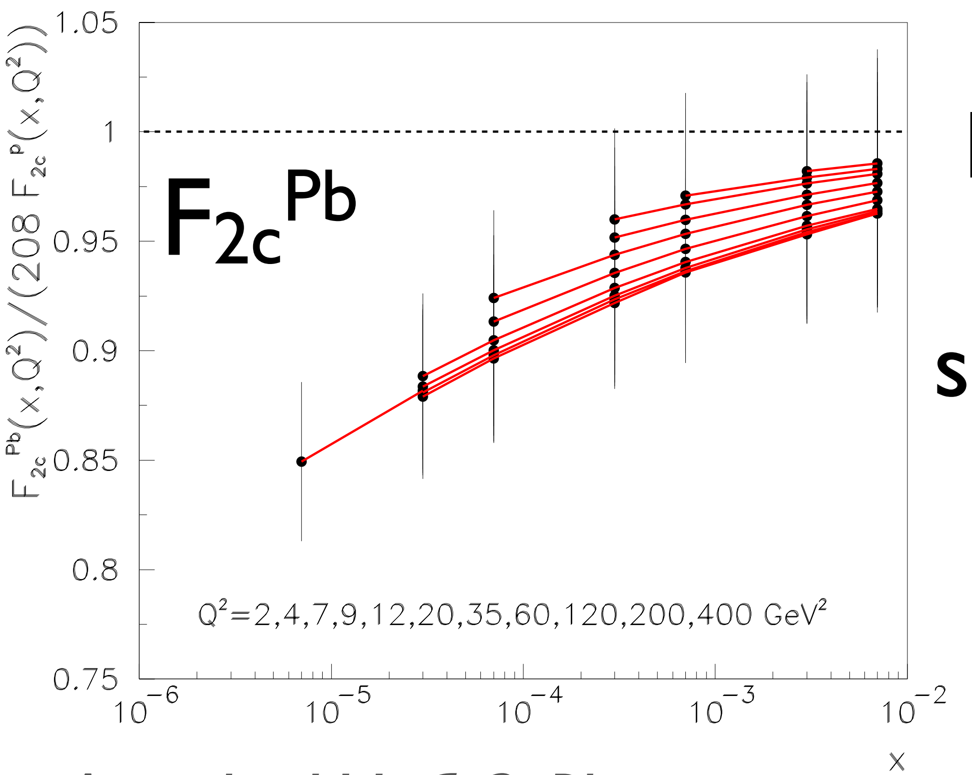
eA inclusive: comparison

- Good precision can be obtained for $F_{2(c,b)}$ and F_L at small x (Glauberized 3-5 flavor GBW model, NA '02).

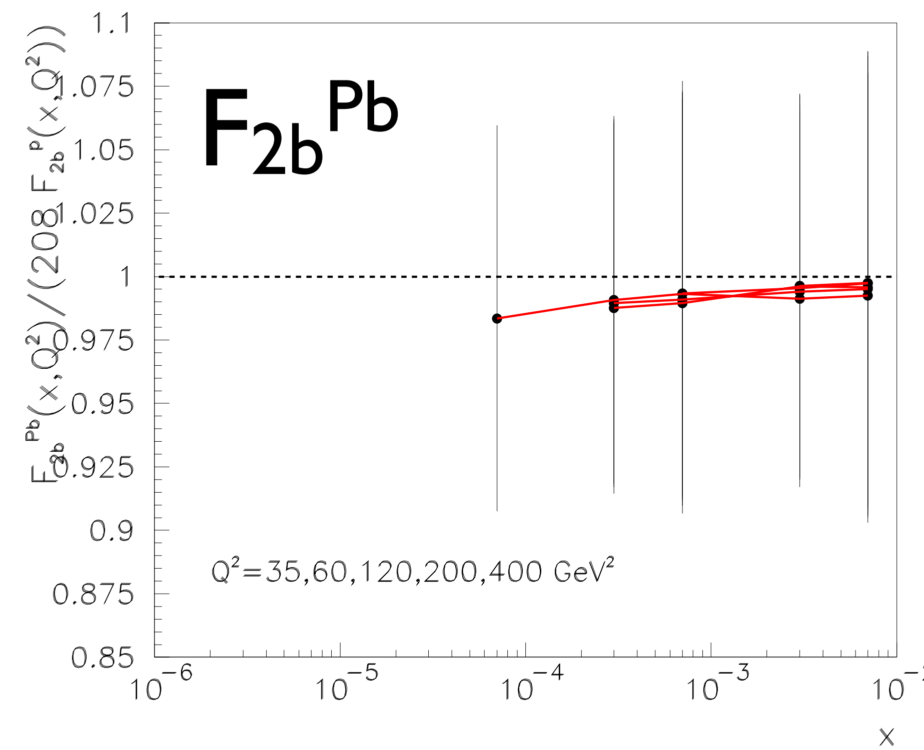
Not optimized!







Note the scale!!!



Nuclear PDFs at small x:

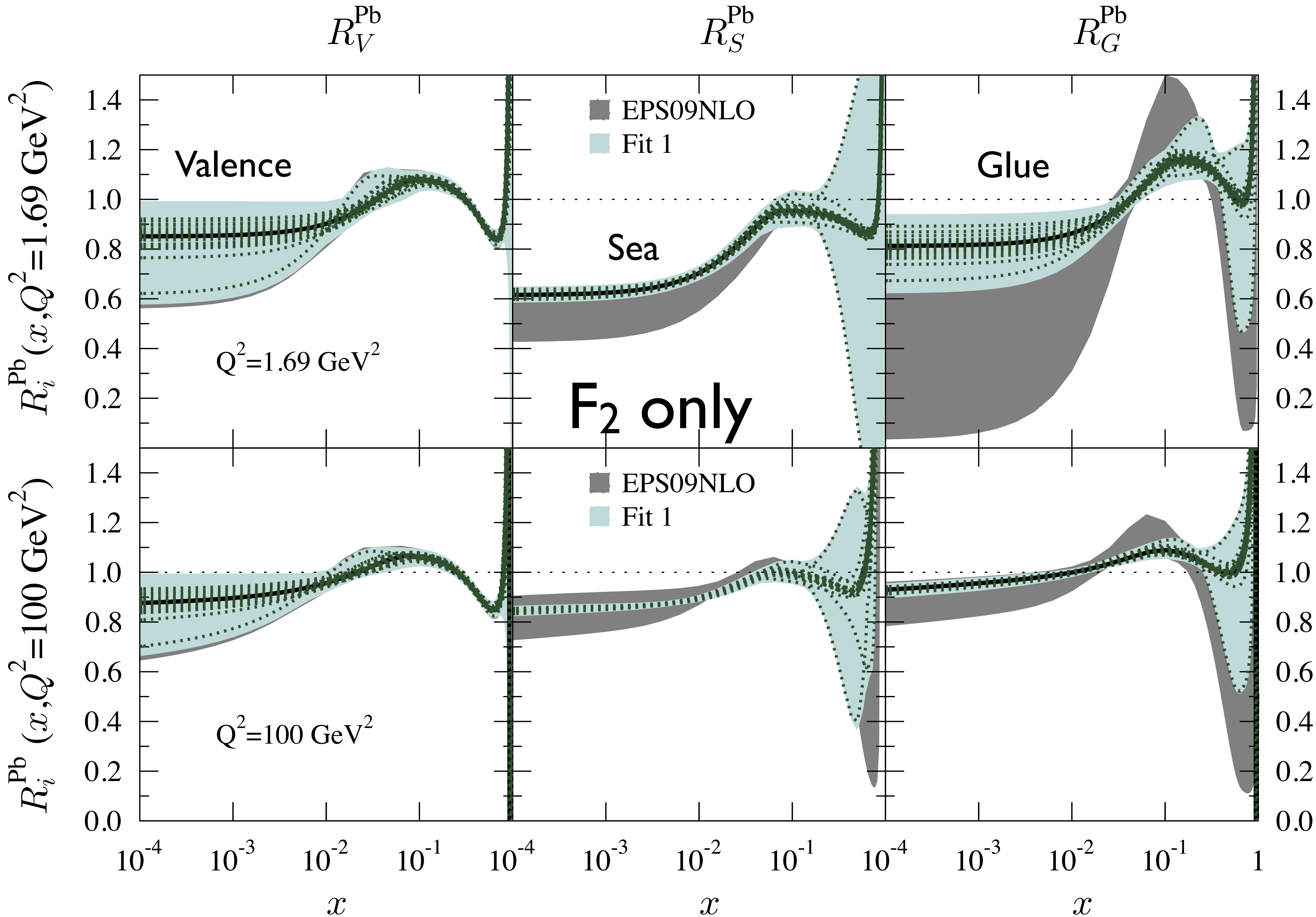
- F_2 data substantially reduce the uncertainties in DGLAP analysis;

inclusion of charm, beauty (new!); and F_L (new!) also give constraints.

Nuclear PDFs at small x:

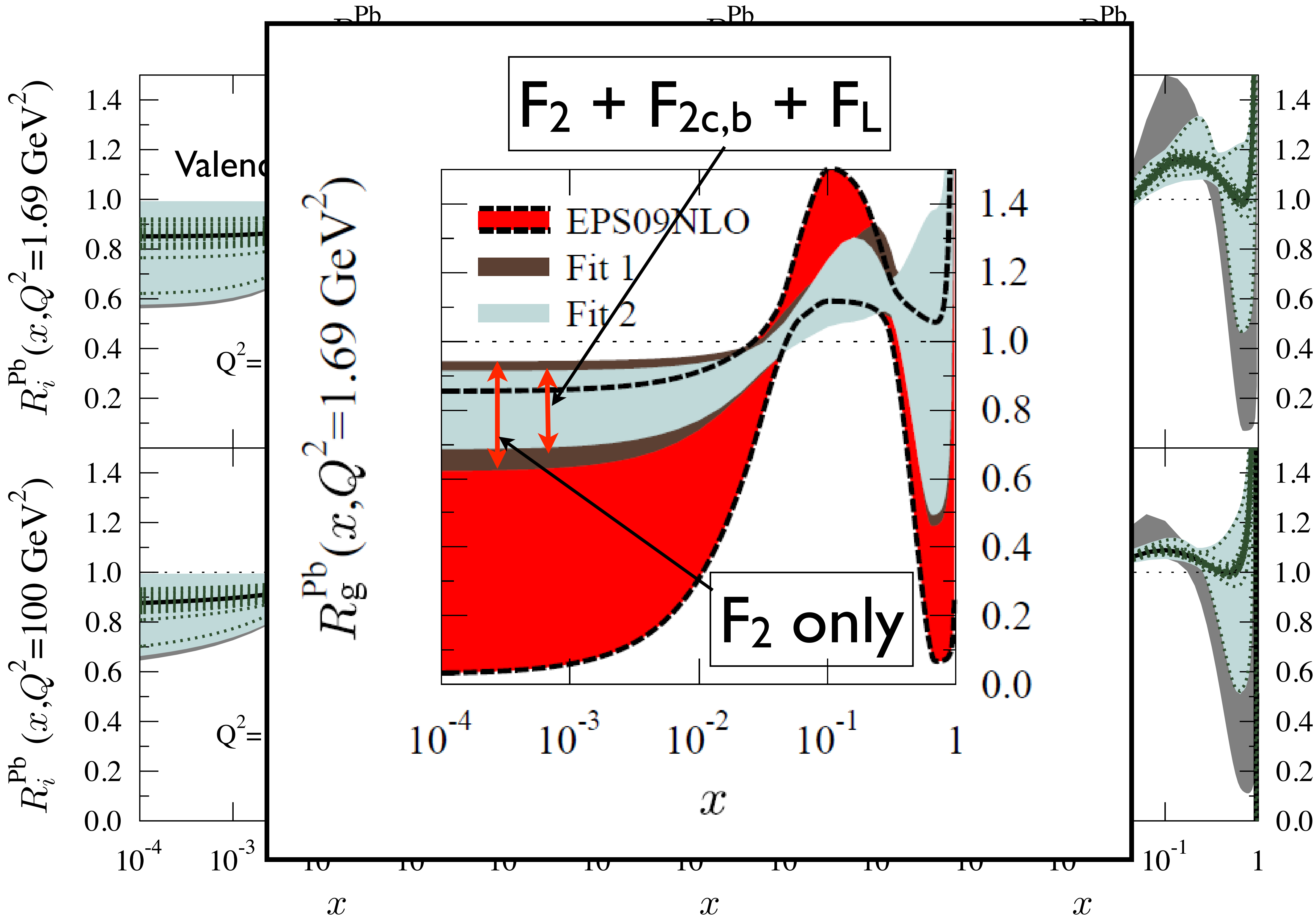
- F_2 data substantially reduce the uncertainties in DGLAP analysis;

inclusion of charm, beauty (new!); and F_L (new!) also give constraints.

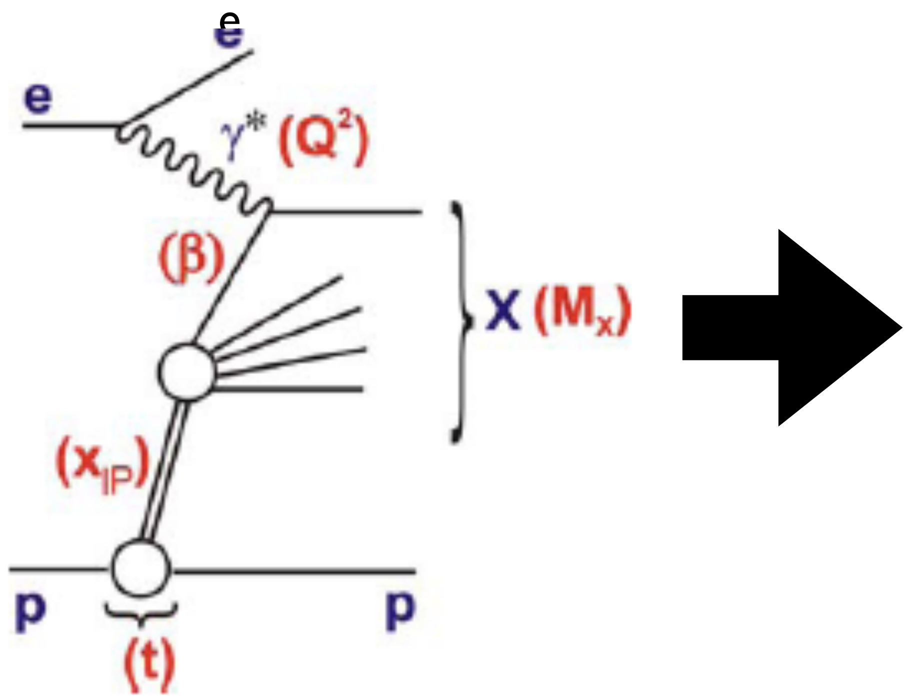


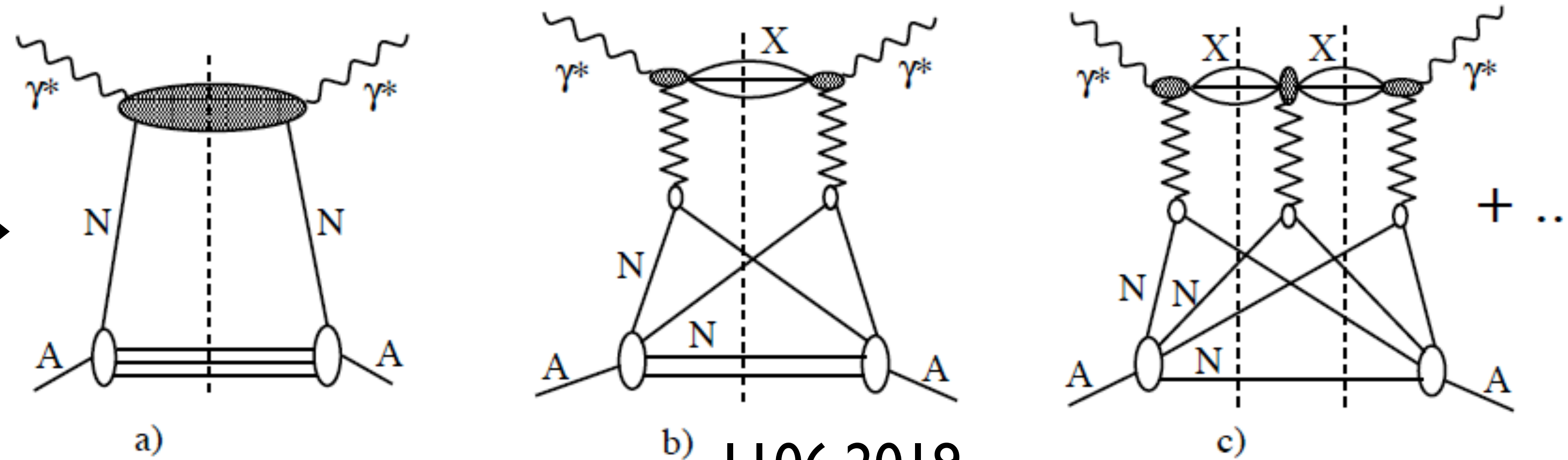
Nuclear PDFs at small x:

- F_2 data substantially reduce the uncertainties in DGLAP analysis; inclusion of charm, beauty (new!); and F_L (new!) also give constraints.



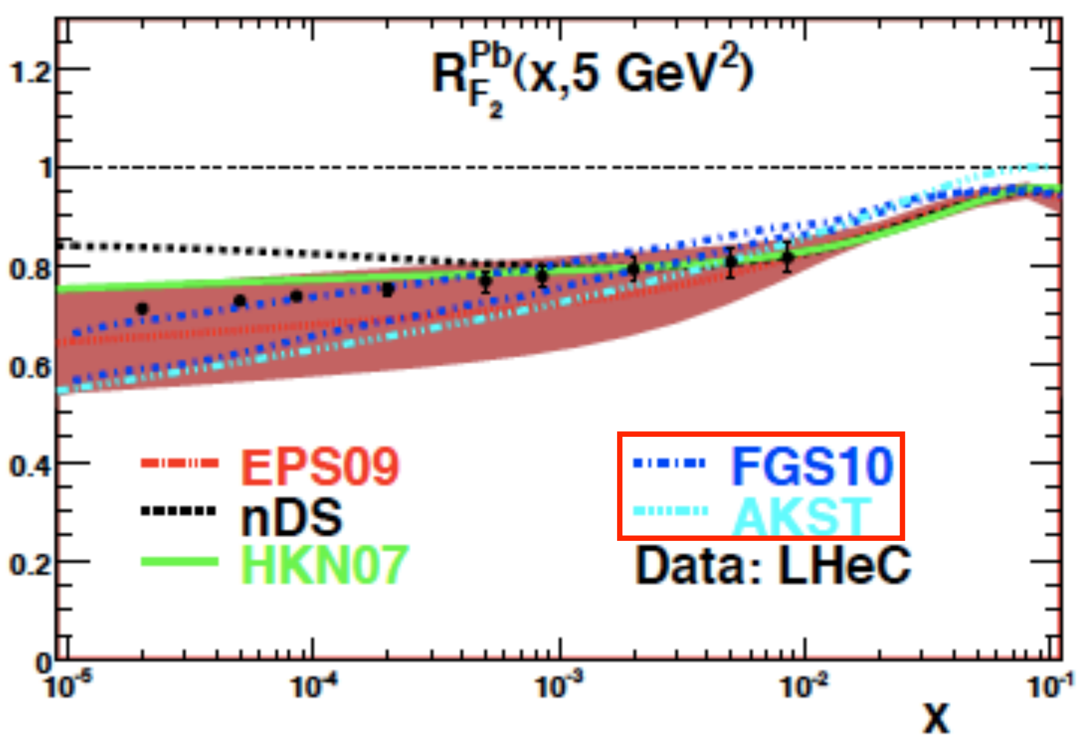
Diffraction in ep and shadowing:

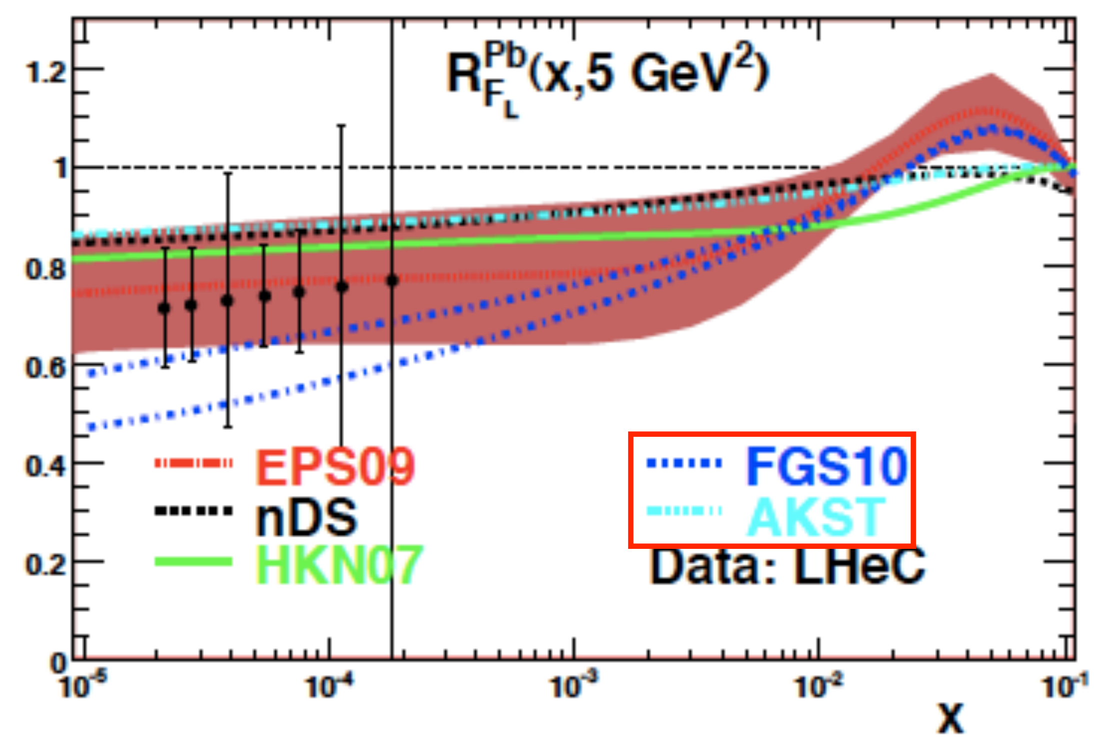




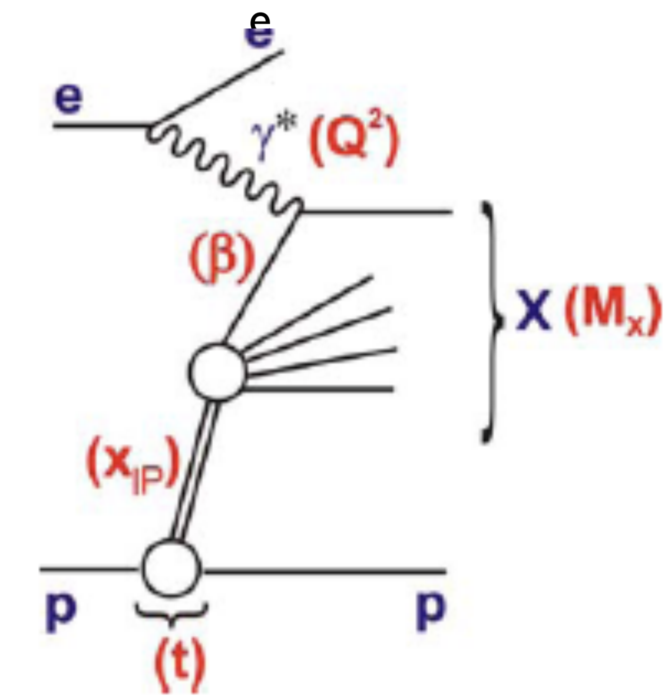
1106.2019

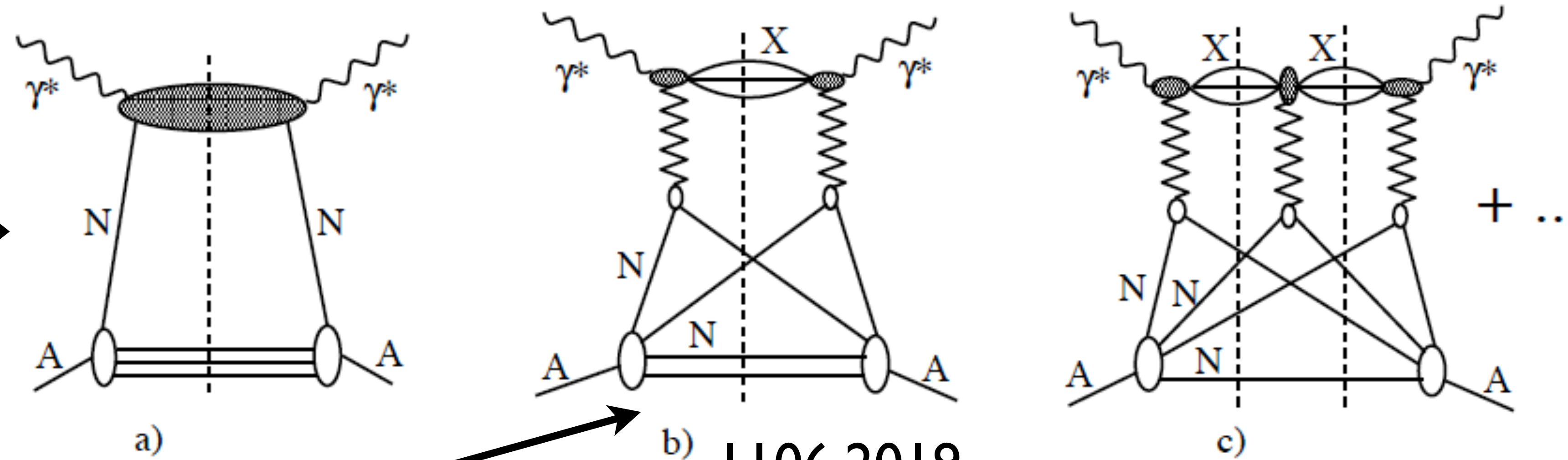
- Diffraction is linked to nuclear shadowing through basic QFT (Gribov): eD to test and set the 'benchmark' for new effects.





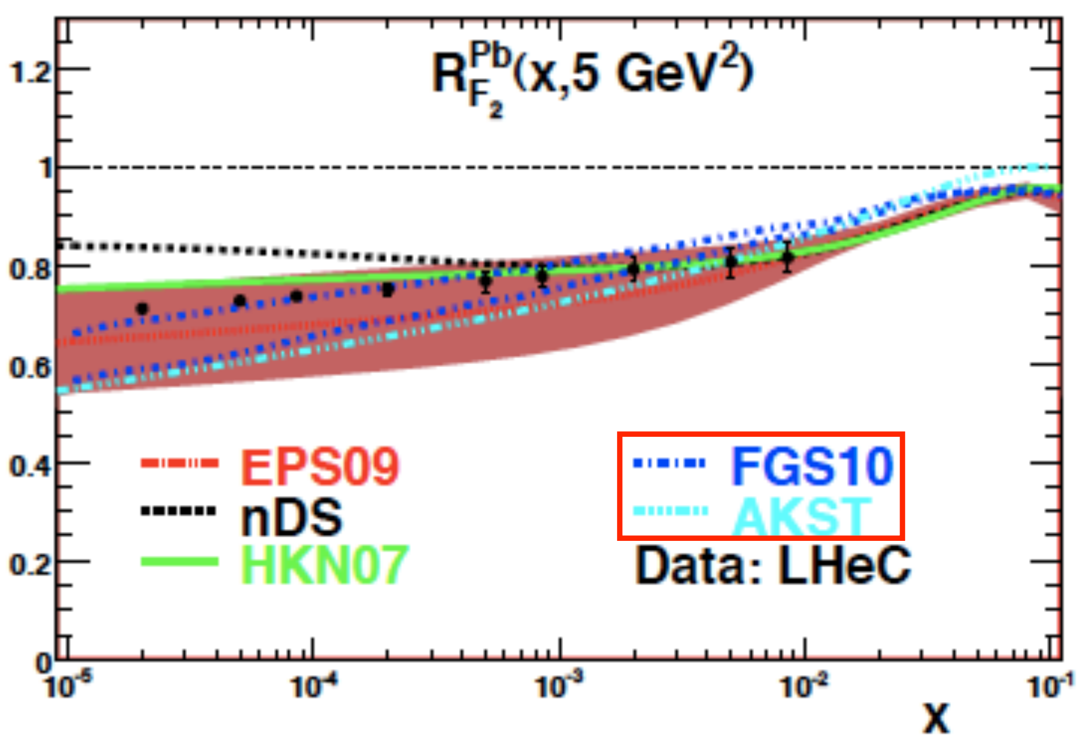
Diffraction in ep and shadowing:

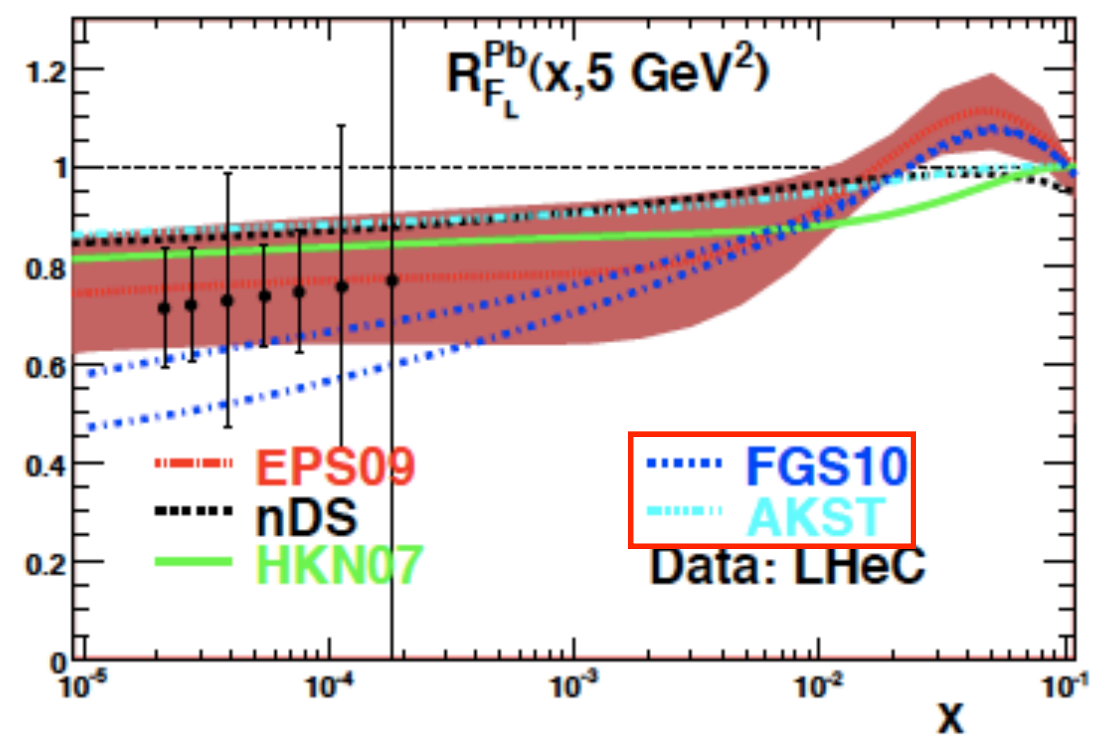




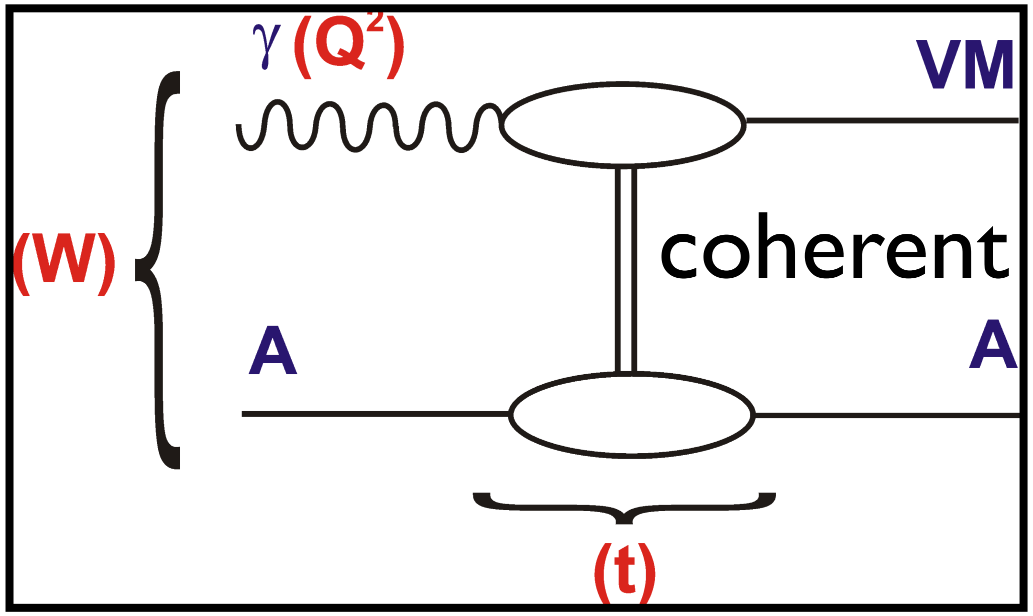
1106.2019

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



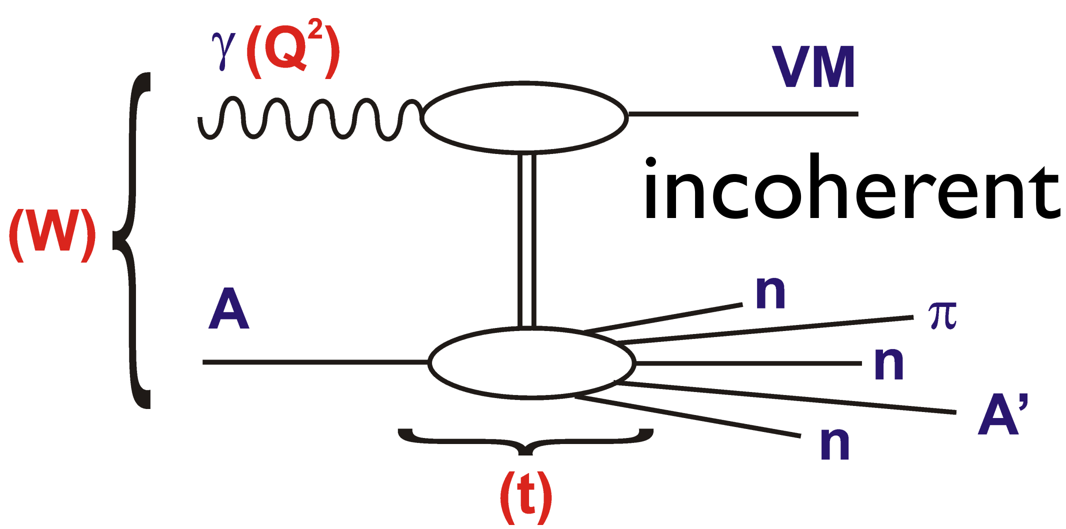


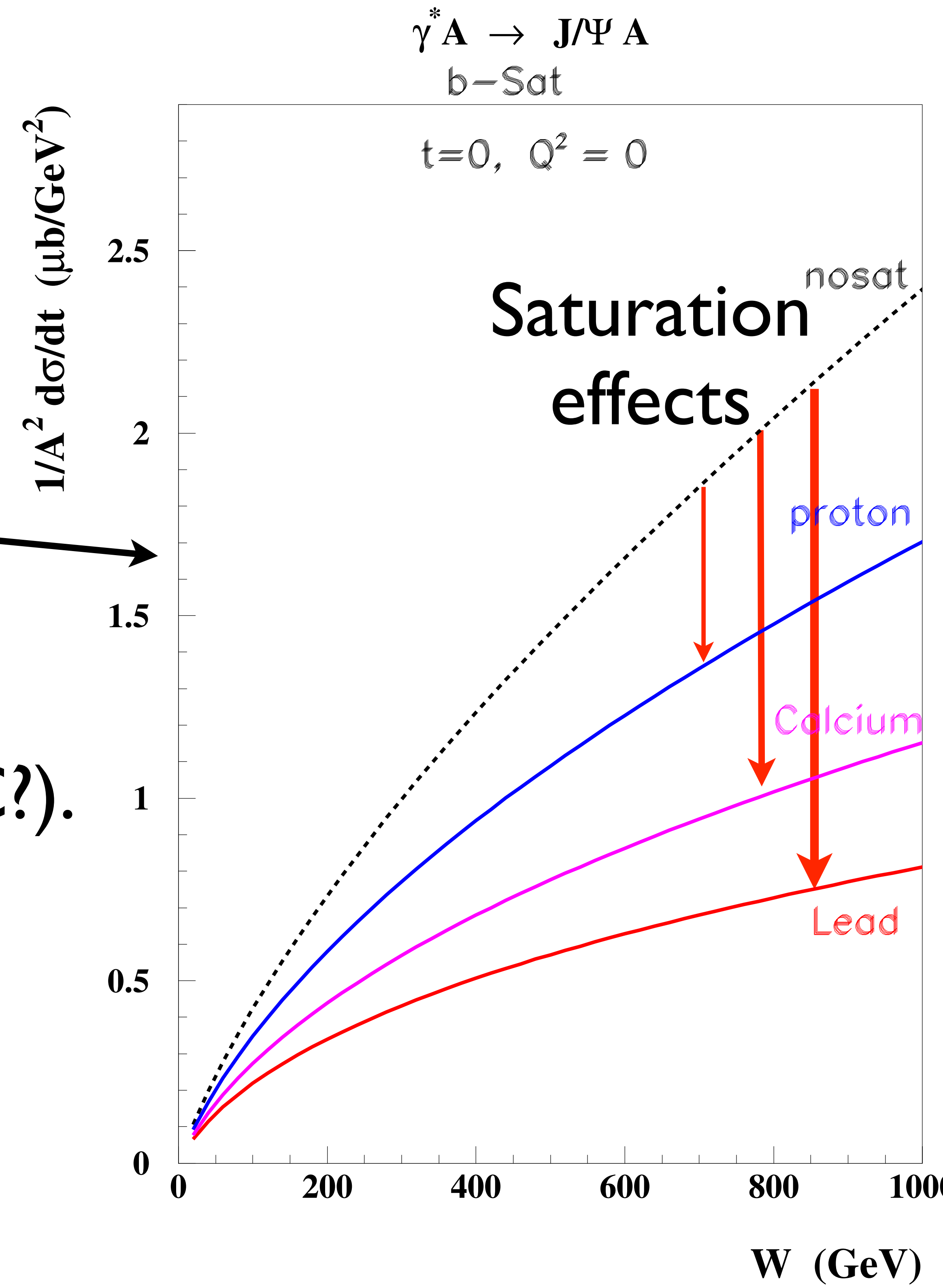
Elastic VM production in eA:



- For the coherent case, predictions available.

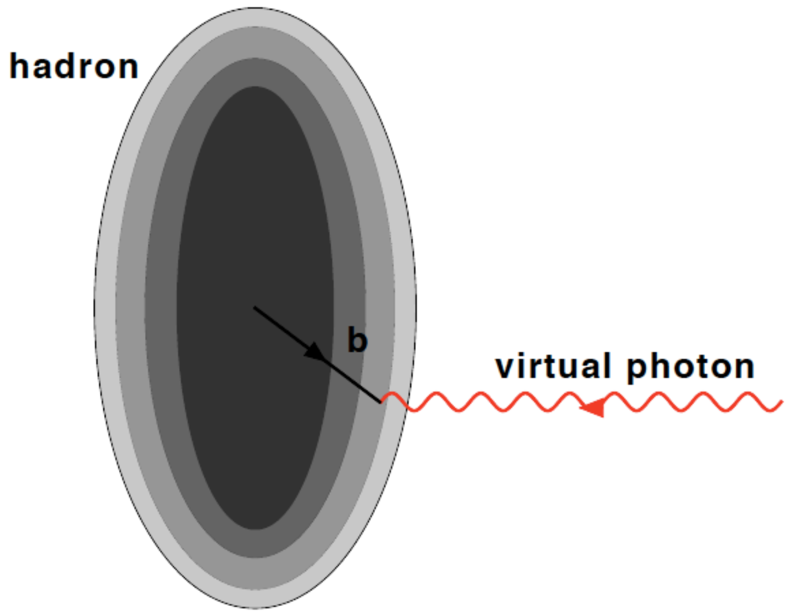
- Challenging experimental problem (neutron tagging in ZDC?).

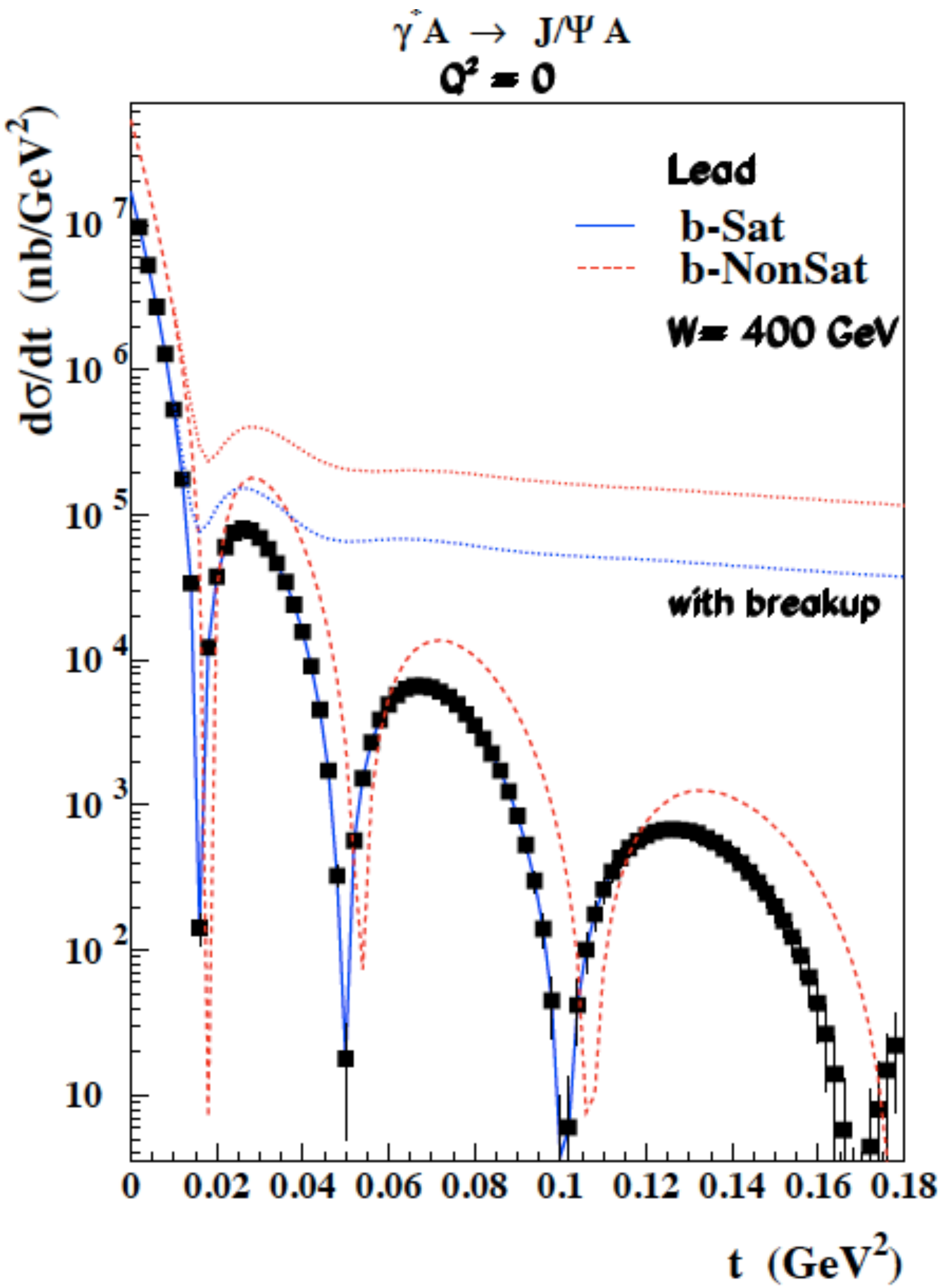




Transverse scan: elastic VM

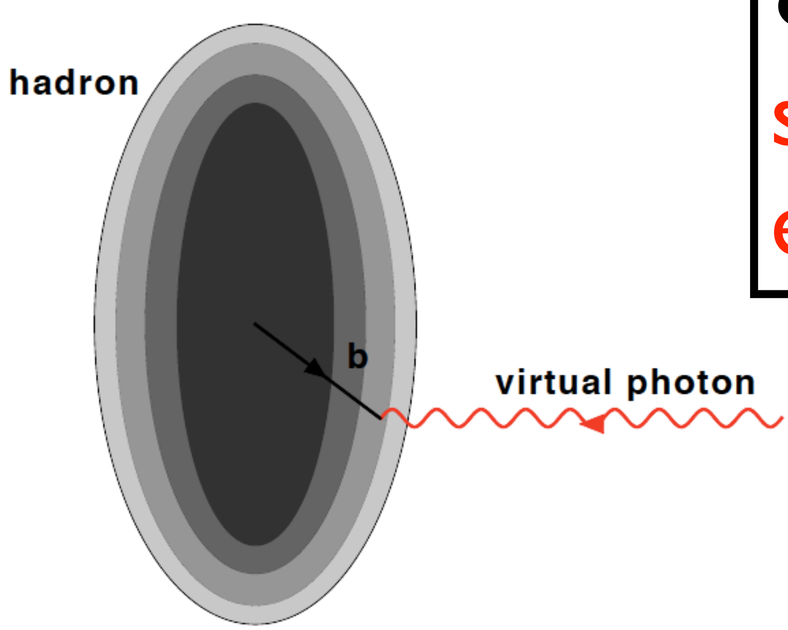
- t-differential measurements give a gluon tranverse mapping of the hadron/nucleus.



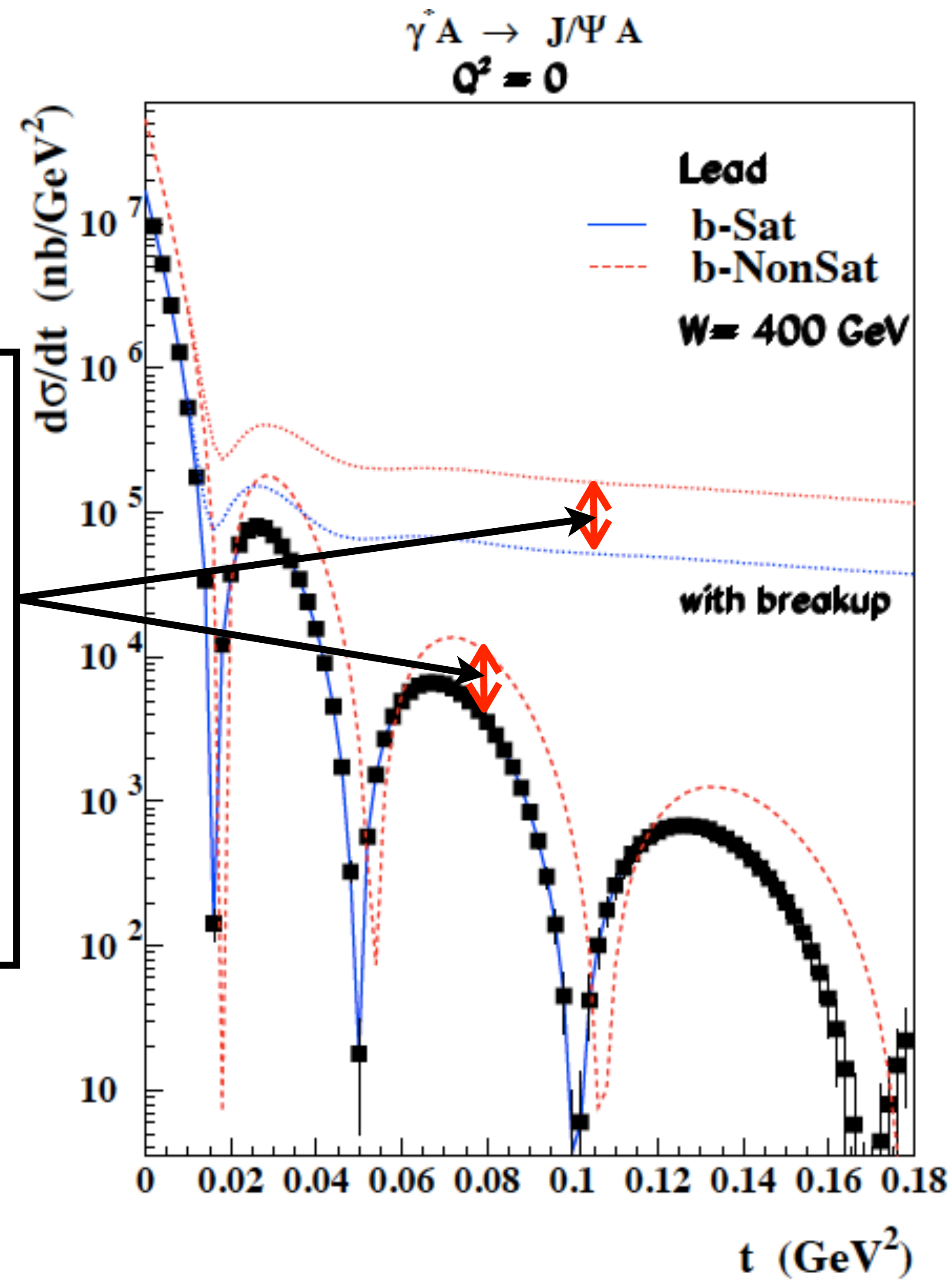


Transverse scan: elastic VM

- t-differential measurements give a gluon tranverse mapping of the hadron/nucleus.

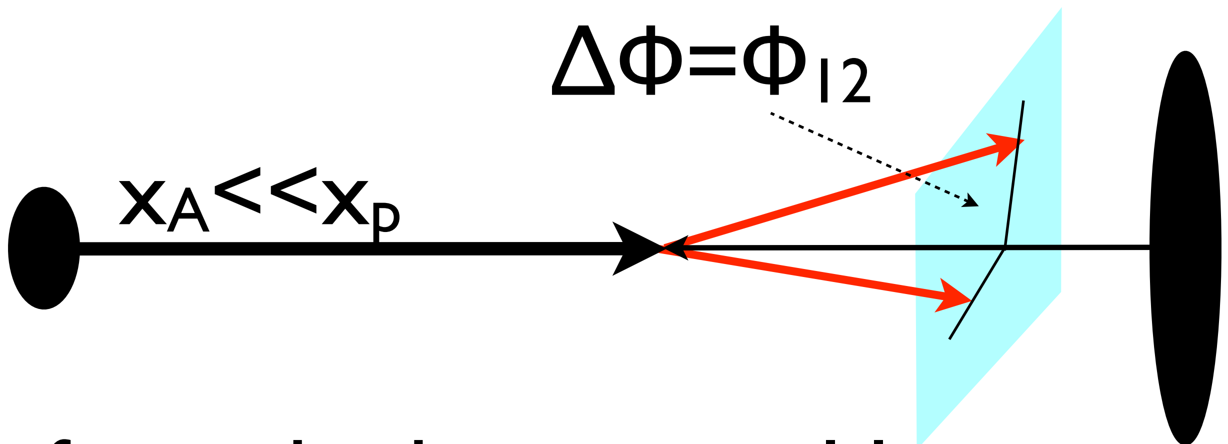


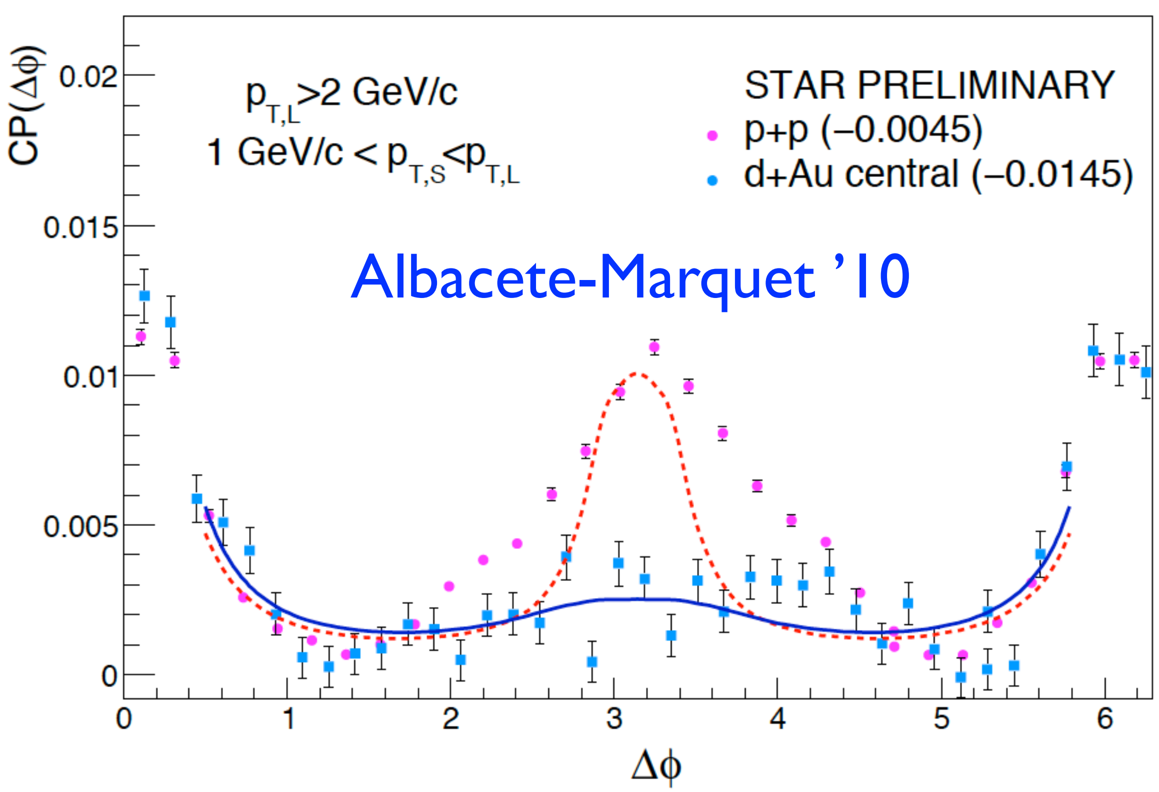
- Large extent in t with good precision.
- Sizable saturation effects expected.



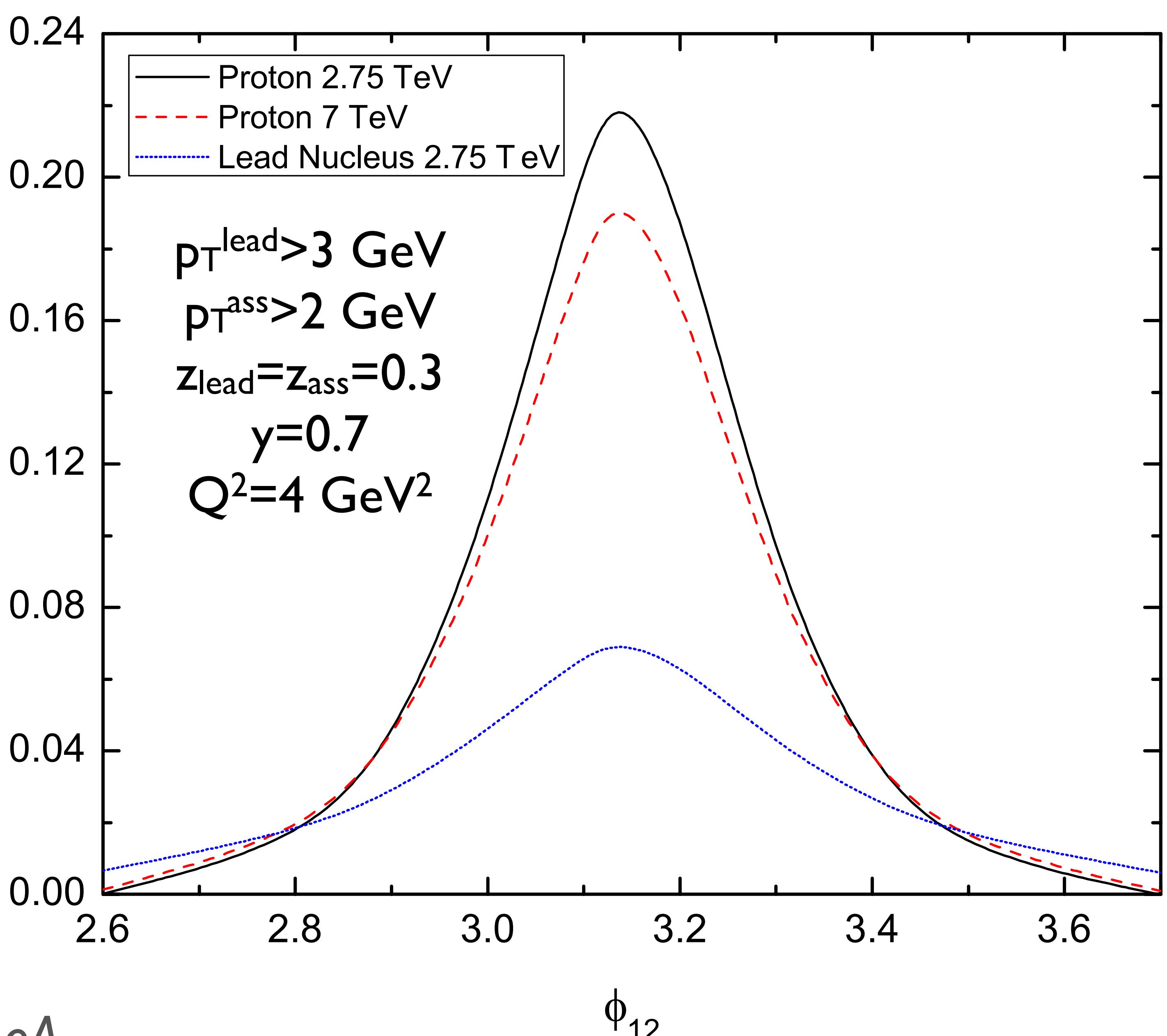
Dihadron azimuthal decorrelation:

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





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

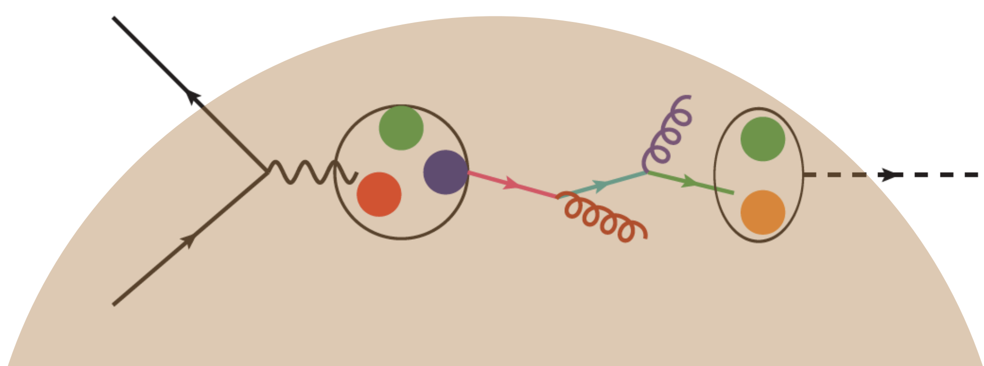


Radiation and hadronization:

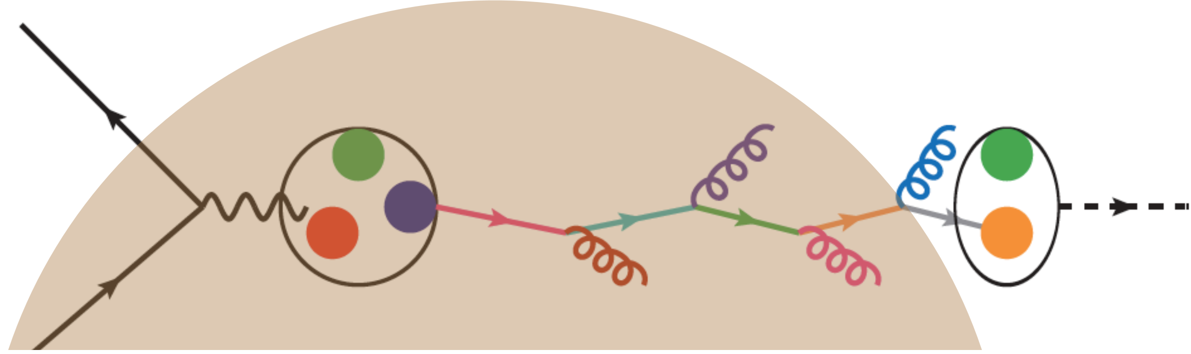
- LHeC: dynamics of QCD radiation and hadronization.
- Most relevant for particle production off nuclei and for QGP analysis in HIC.

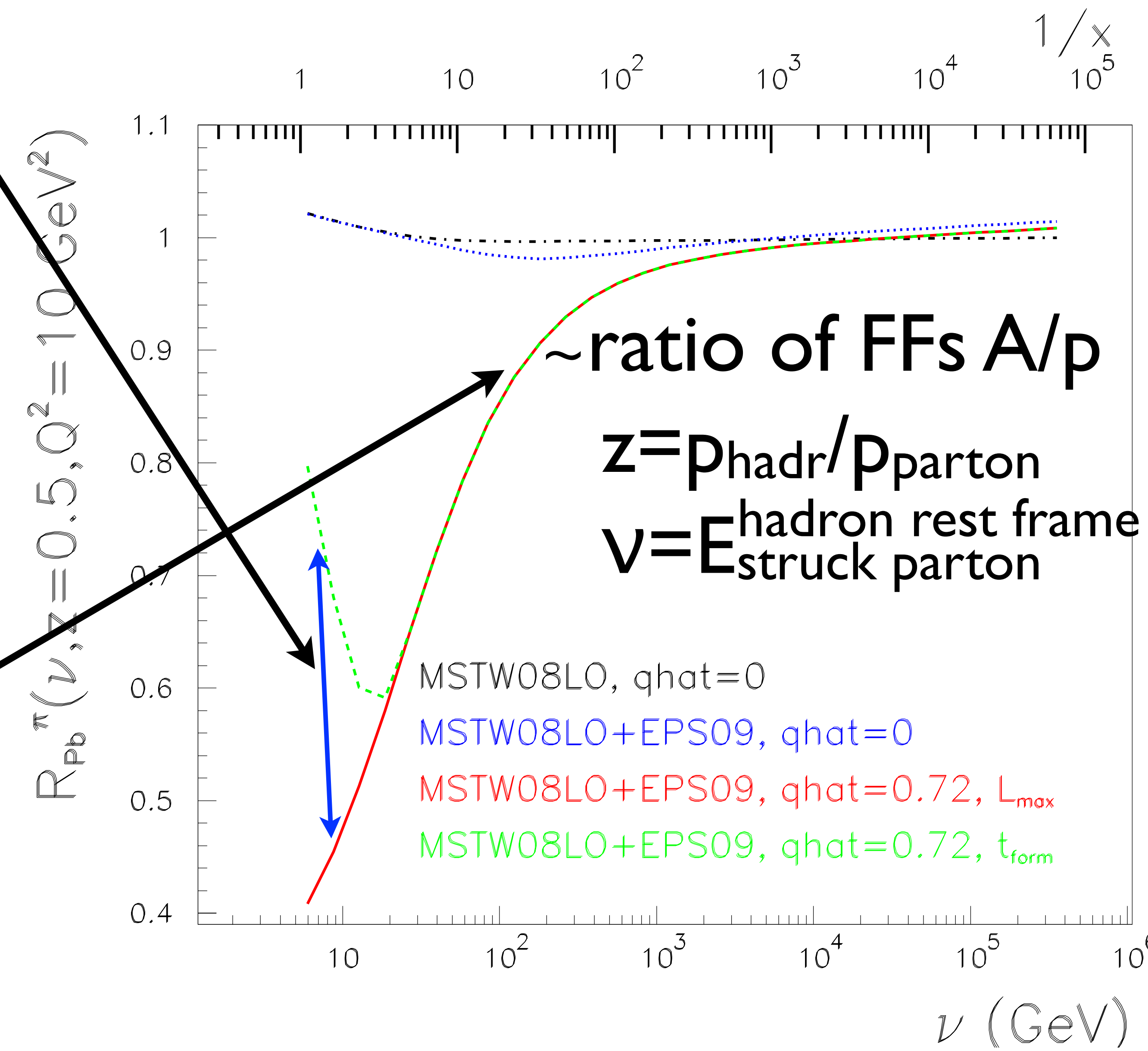
$$R_A^h(z,\nu) = \frac{1}{N_A^e}\frac{\mathrm{d}N_A^h(z,\nu)}{\mathrm{d}\nu\,\mathrm{d}z} \Big/ \frac{1}{N_D^e}\frac{\mathrm{d}N_D^h(z,\nu)}{\mathrm{d}\nu\,\mathrm{d}z}$$

- Low energy: hadronization inside → formation time, (pre-)hadronic absorption,...



- High energy: partonic evolution altered in the nuclear medium.





~ratio of FFs A/p

$z=p_{hadr}/p_{parton}$

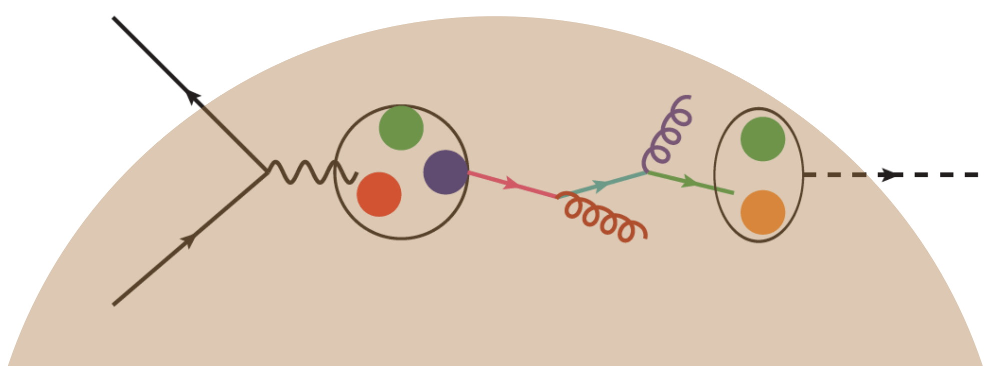
$\nu=E^{\text{hadron rest frame}}_{\text{struck parton}}$

Radiation and hadronization:

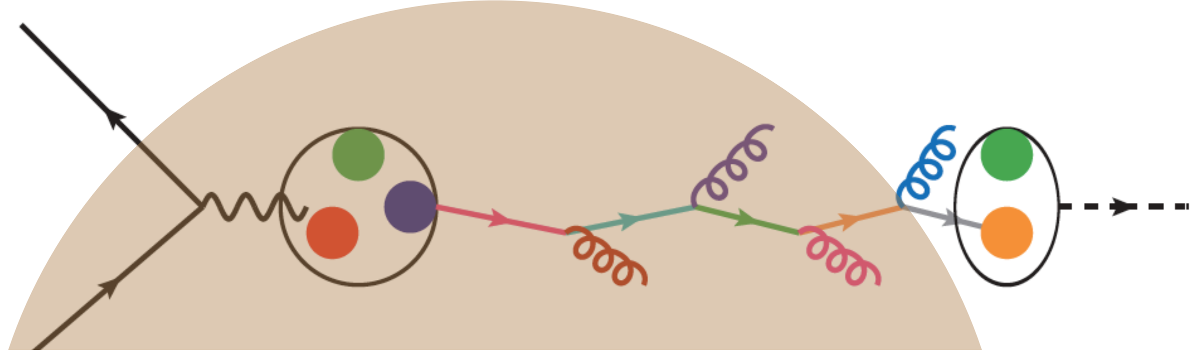
- LHeC: dynamics of QCD radiation and hadronization.
- Most relevant for particle production off nuclei and for QGP analysis in HIC.

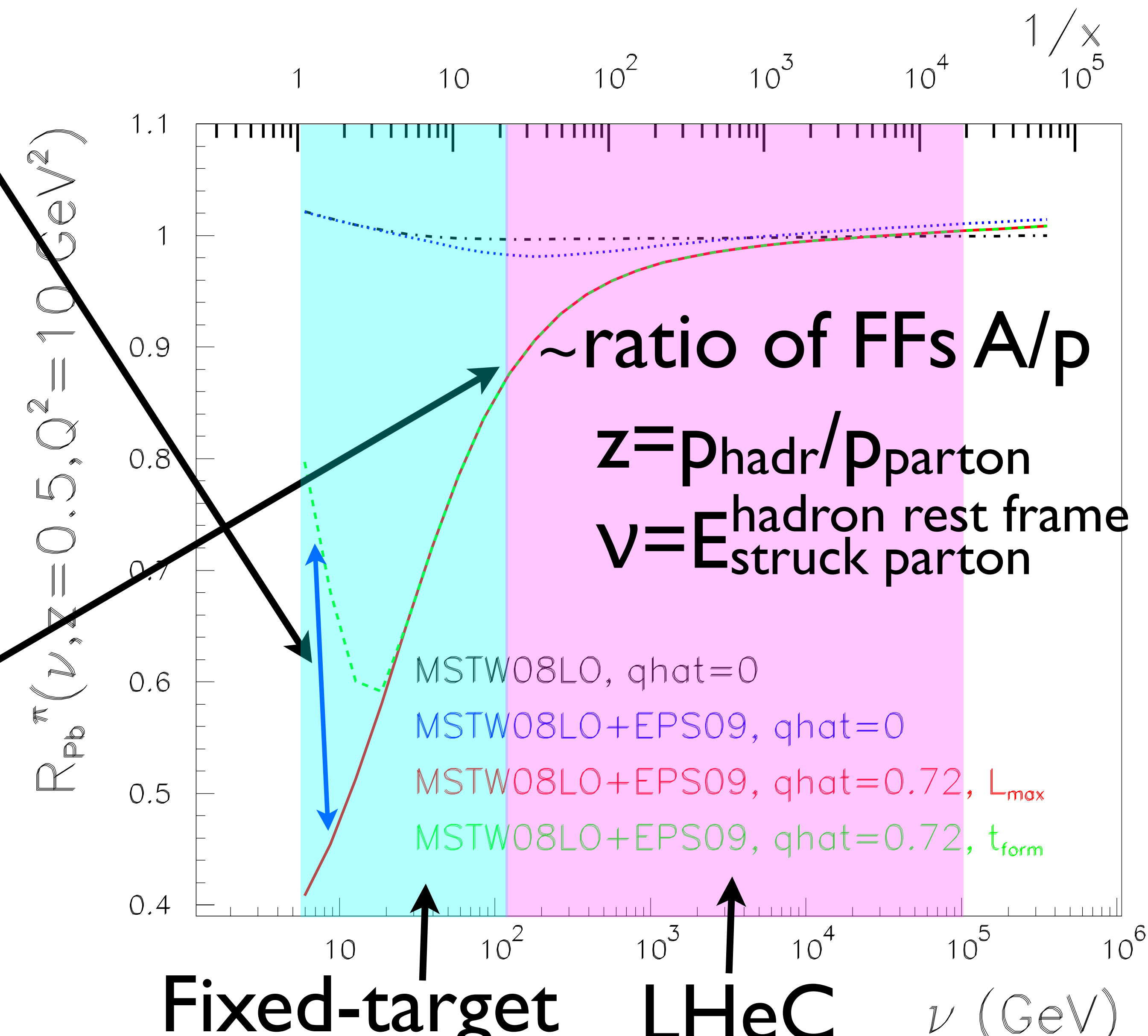
$$R_A^h(z,\nu) = \frac{1}{N_A^e}\frac{dN_A^h(z,\nu)}{d\nu\, dz} \Big/ \frac{1}{N_D^e}\frac{dN_D^h(z,\nu)}{d\nu\, dz}$$

- Low energy: hadronization inside → formation time, (pre-)hadronic absorption,...



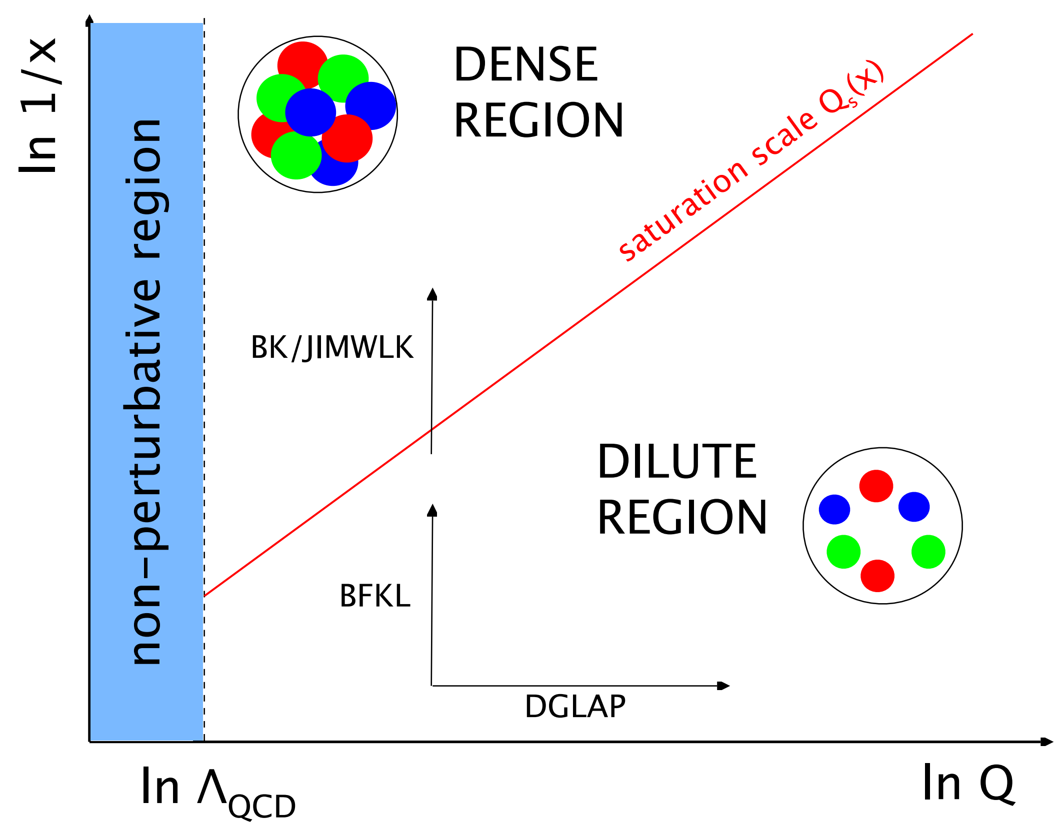
- High energy: partonic evolution altered in the nuclear medium.

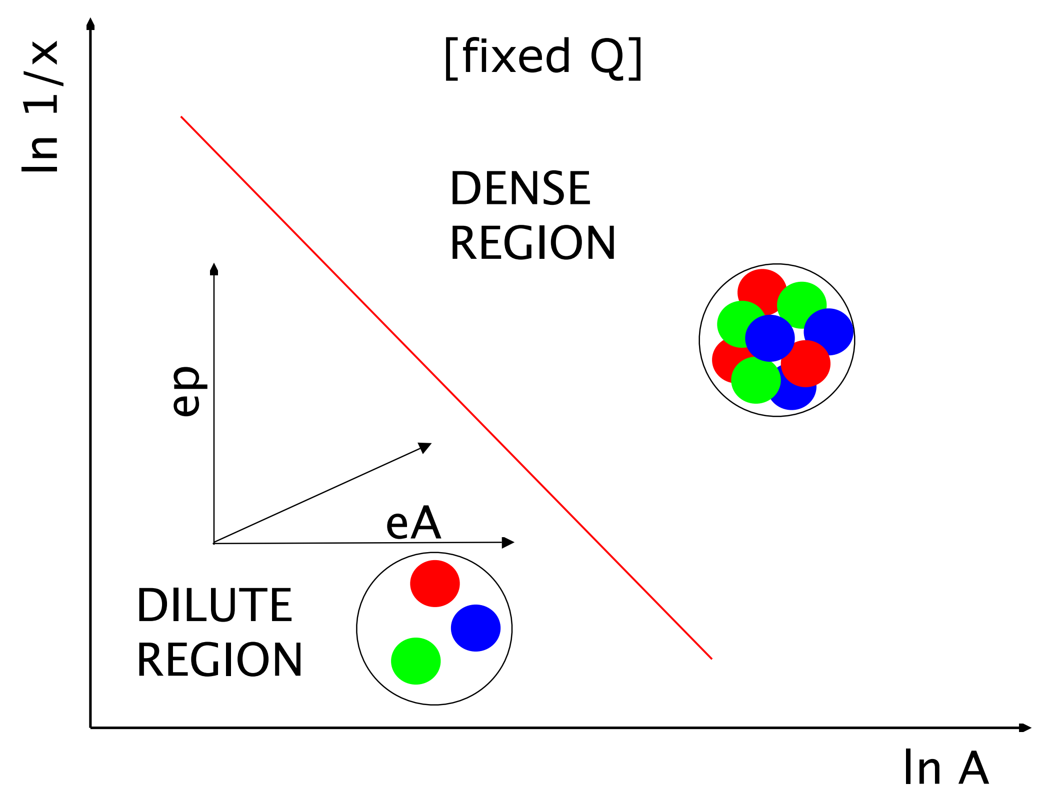




Summary:

- ***At an LHeC@CERN***:
  - ➜ High-precision tests of collinear factorization(s) and determination of PDFs.
  - ➜ Unprecedented access to small x in p and A.
  - ➜ Novel sensitivity to physics beyond standard pQCD.
  - ➜ Stringent tests of QCD radiation and hadronization.
  - ➜ Transverse scan of the hadron/nucleus at small x.
  - ➜ ... with implications on our understanding of QGP.
- **The LHeC will answer the question of saturation/ non-linear dynamics. For that, ep AND eA essential!!!**





Outlook:

• With CERN and NuPECC mandate to further motivate the physics case and produce a TDR around 2015, several items have to be done/improved:

➜ Refine DGLAP fits with flavour decomposition (include neutrino data, relax assumptions) and optimized F_L scenarios, and LHC data.

➜ Monte Carlo generators!!!

➜ Studies on diffraction: separation of coherent from incoherent, ndPDFs, dijets,...

➜ Large x, EW bosons.

➜ Nuclear GPDs: nuclear DVCS etc.

➜ eD.

➜ Jet reconstruction, angular decorrelation...

➜ ...

→ Cooperation with EIC in some of these items desirable.

Any collaboration is more than welcome!!!

Outlook:

- With CERN and NuPECC mandate to further motivate the physics case and produce a TDR around 2015, several items have to be done/improved:

➜ Refine DGLAP fits with flavour decomposition (include neutrino data, relax assumptions) and optimized F_L scenarios, and LHC data.

➜ Monte Carlo generators!!!

➜ Studies on diffraction: separation of coherent from incoherent, ndPDFs, dijets,...

➜ Large x, EW bosons.

➜ Nuclear GPDs: nuclear DVCS etc.

➜ eD.

➜ Jet reconstruction, angular decorrelation...

➜ ...

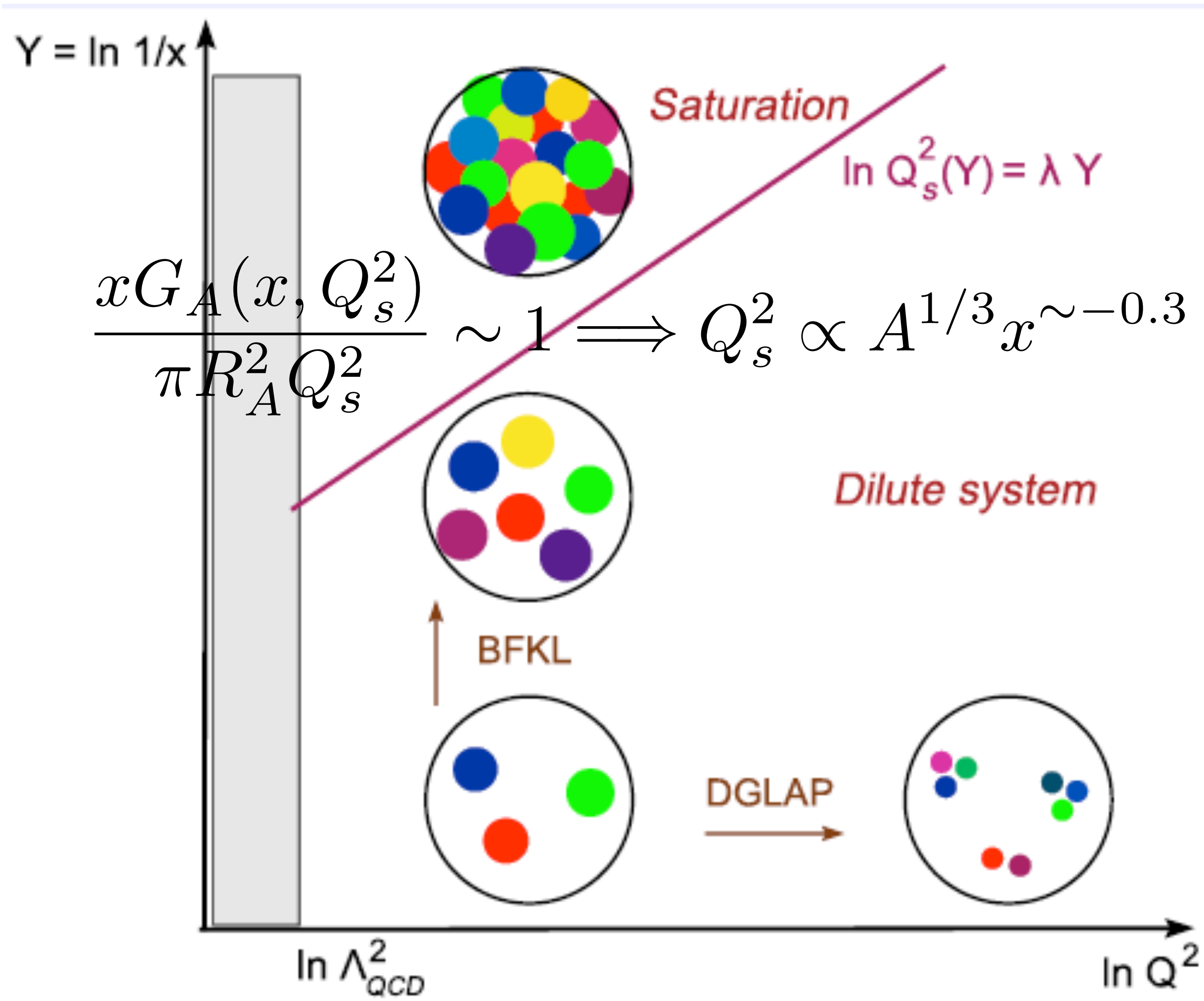
Thanks for your attention!

→ Cooperation with EIC in some of these items desirable.

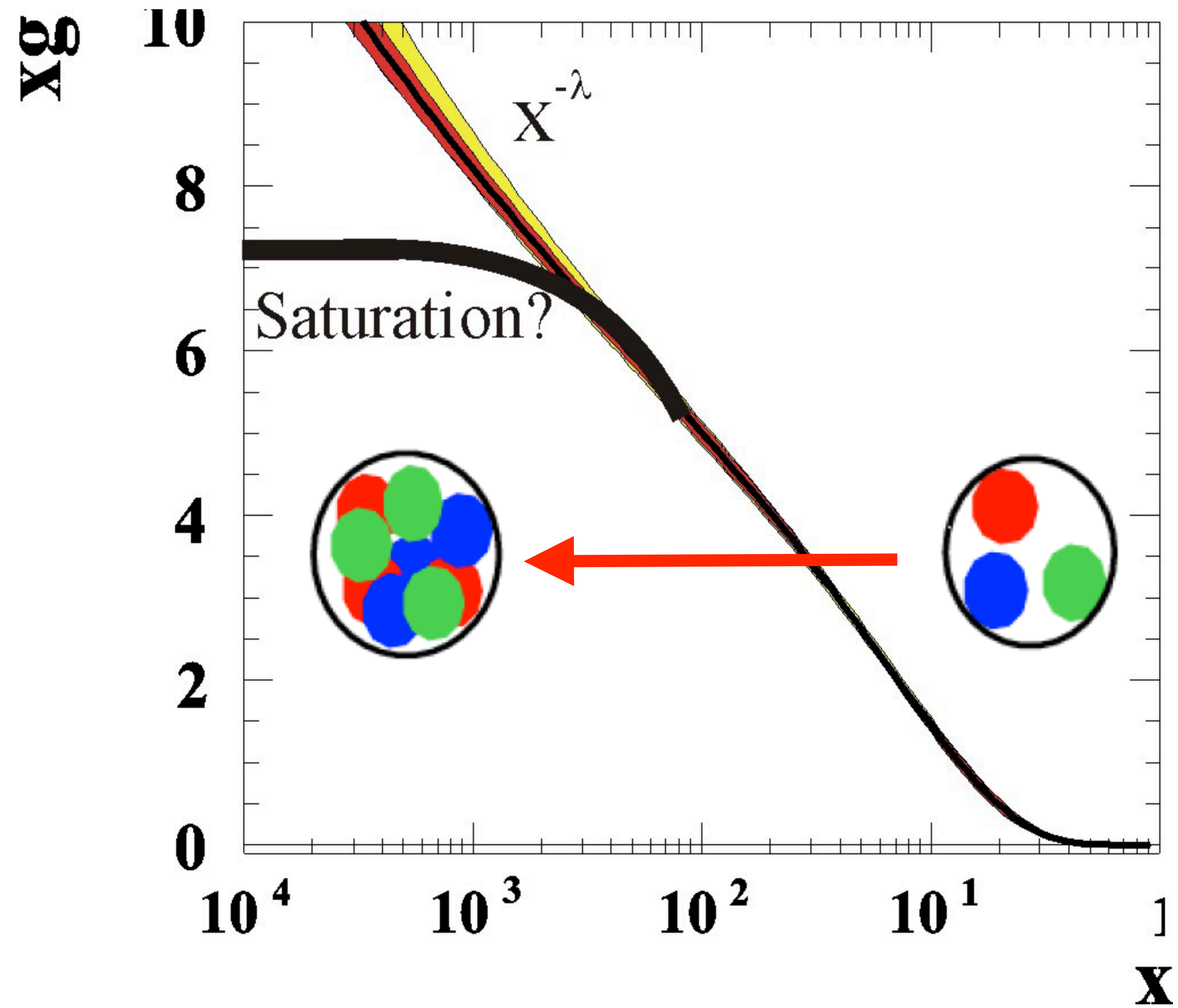
Any collaboration is more than welcome!!!

Backup:

Small x and saturation:

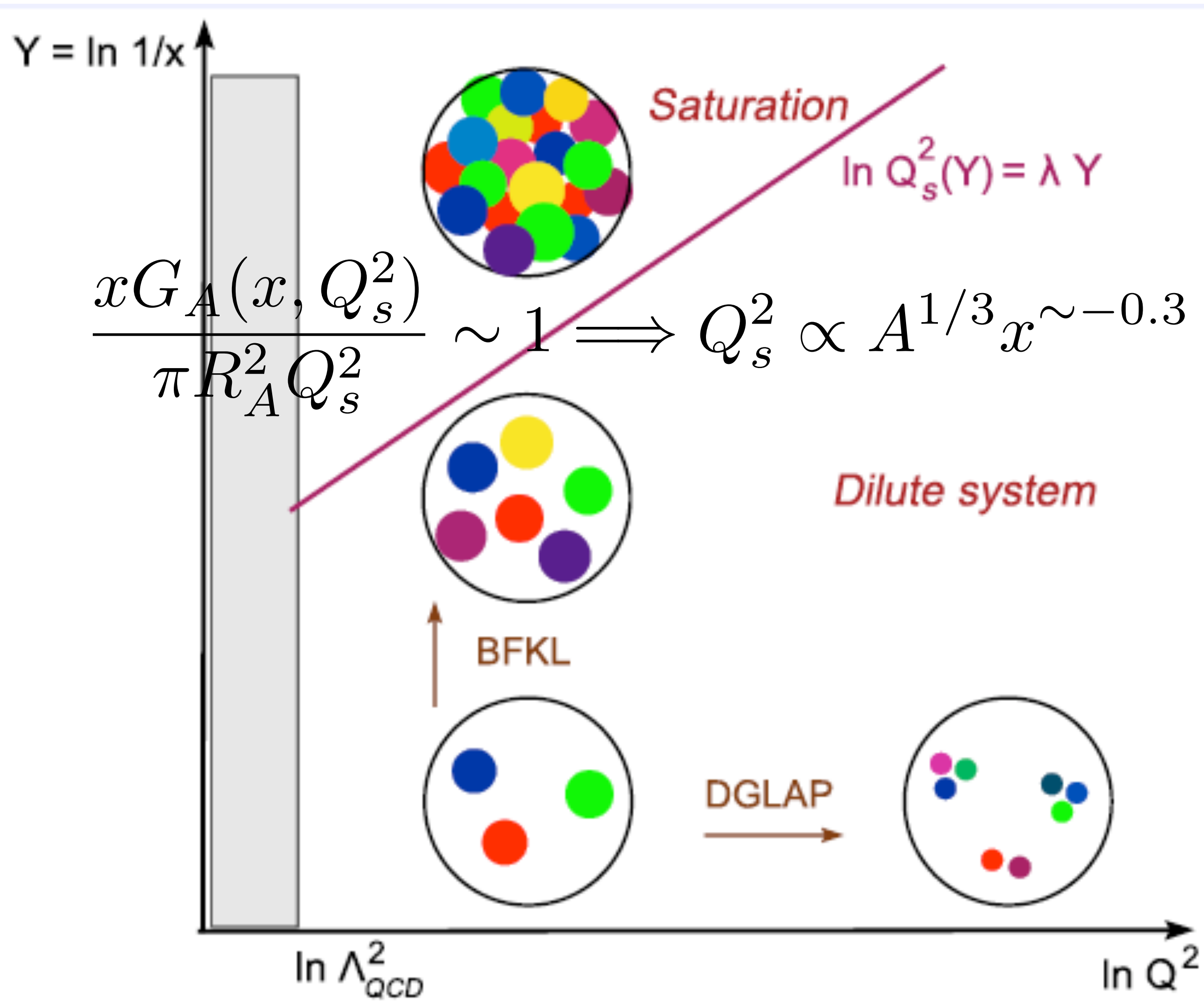


$$\frac{xG_A(x,Q_s^2)}{\pi R_A^2 Q_s^2} \sim 1 \Longrightarrow Q_s^2 \propto A^{1/3} x^{\sim -0.3}$$

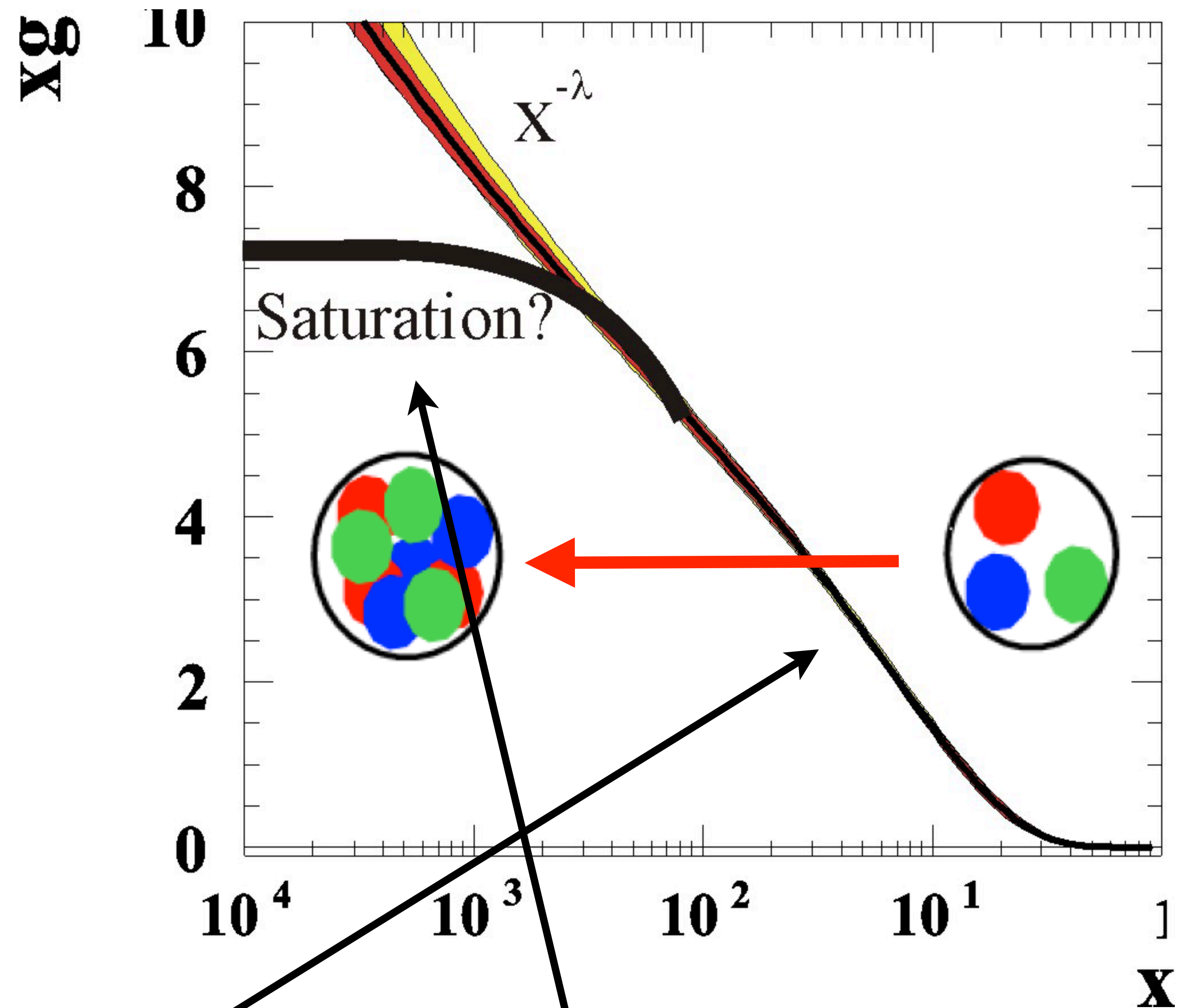


- QCD radiation of partons when x decreases leads to a large number of partons (gluons), provided each parton evolves independently (linearly, $\Delta[xg] \propto xg$).
- This independent evolution breaks at high densities (<u>small x or high mass number A</u>): non-linear effects ($gg \rightarrow g$, $\Delta[xg] \propto xg - k(xg)^2$).

Small x and saturation:



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



- QCD radiation of partons when x decreases leads to a large number of partons (gluons), provided each parton evolves independently (linearly, Δ[xg] ∝ xg).
- This independent evolution breaks at high densities (<u>small x or high mass number A</u>): non-linear effects (gg→g, Δ[xg] ∝ xg - k(xg)^2).

Status of small-x physics:

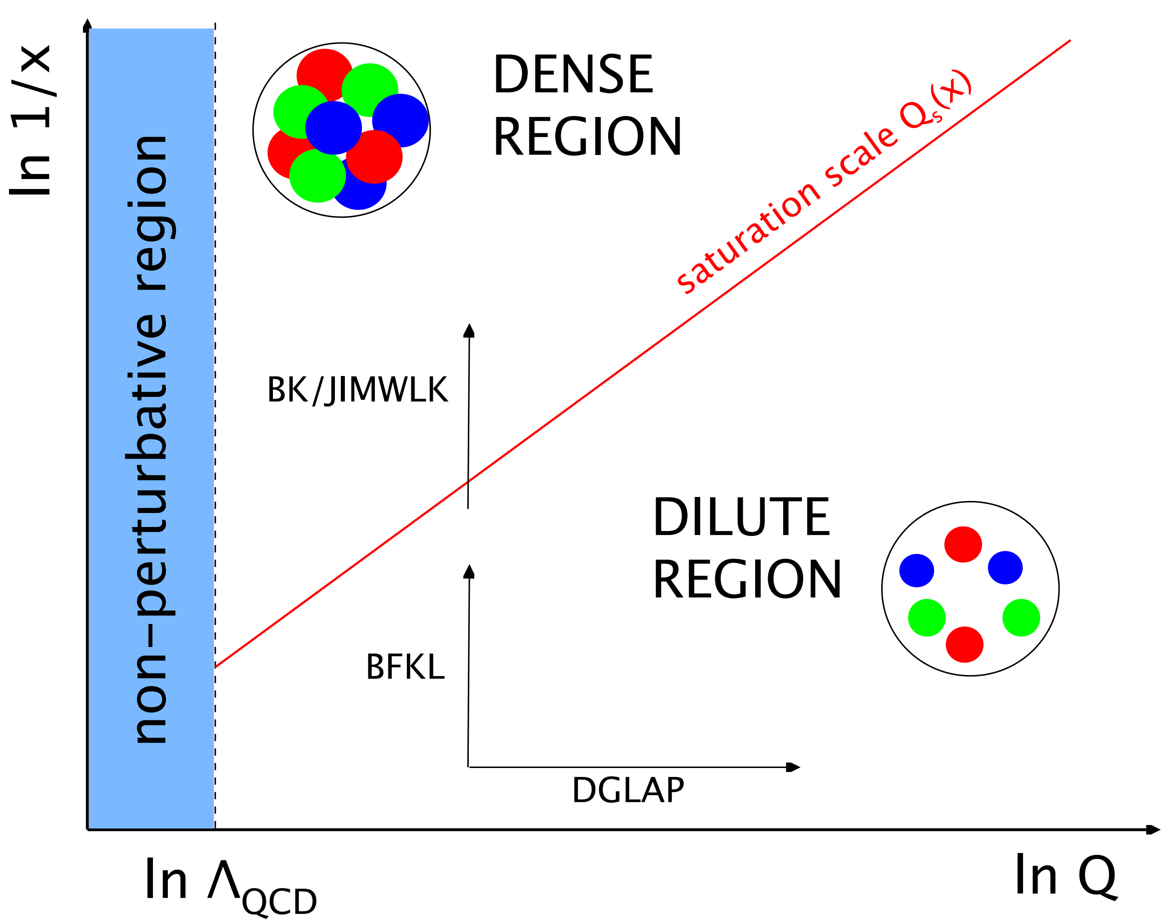
- Three pQCD-based alternatives to describe small-x ep and eA data (differences at moderate $Q^2(>\Lambda^2_{QCD})$ and small x):

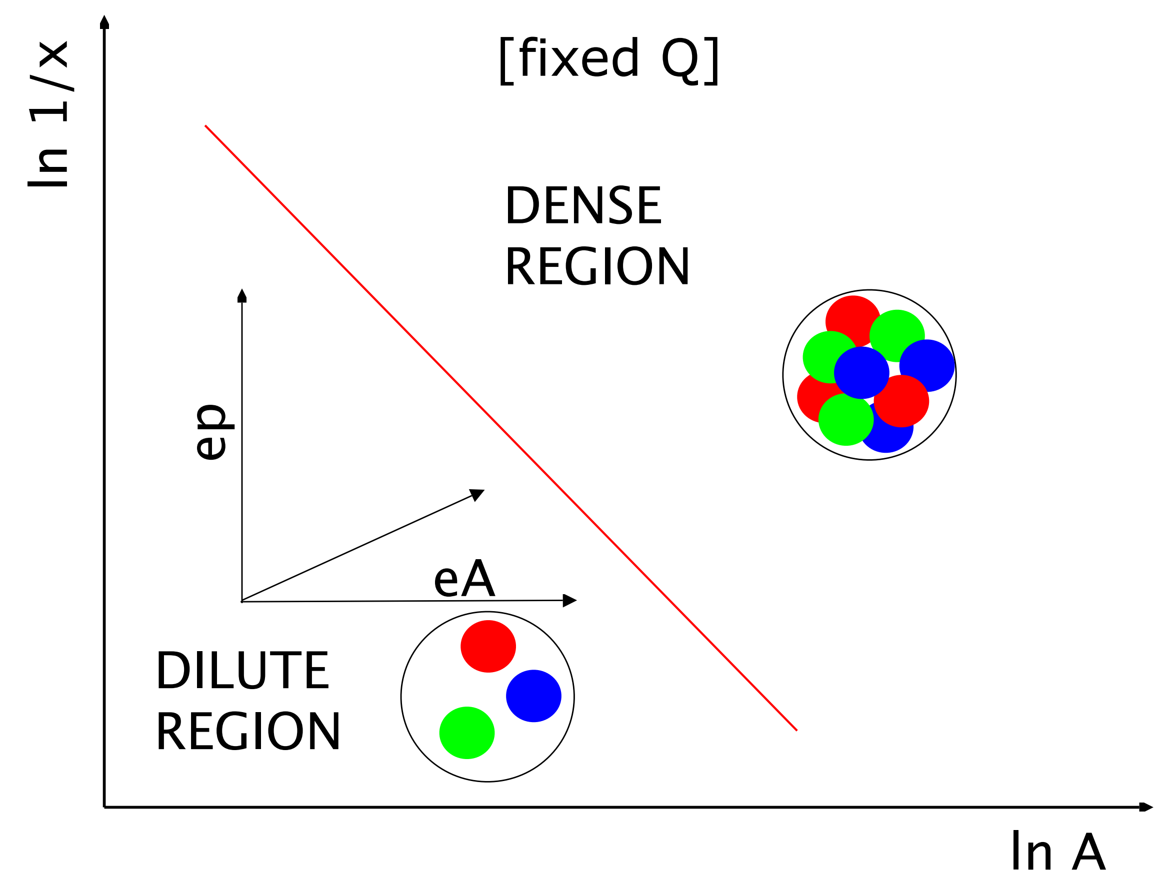
→ DGLAP evolution (fixed order perturbation theory).

→ Resummation schemes: BFKL, CCFM, ABF, CCSS.

→ Saturation (CGC, dipole models).

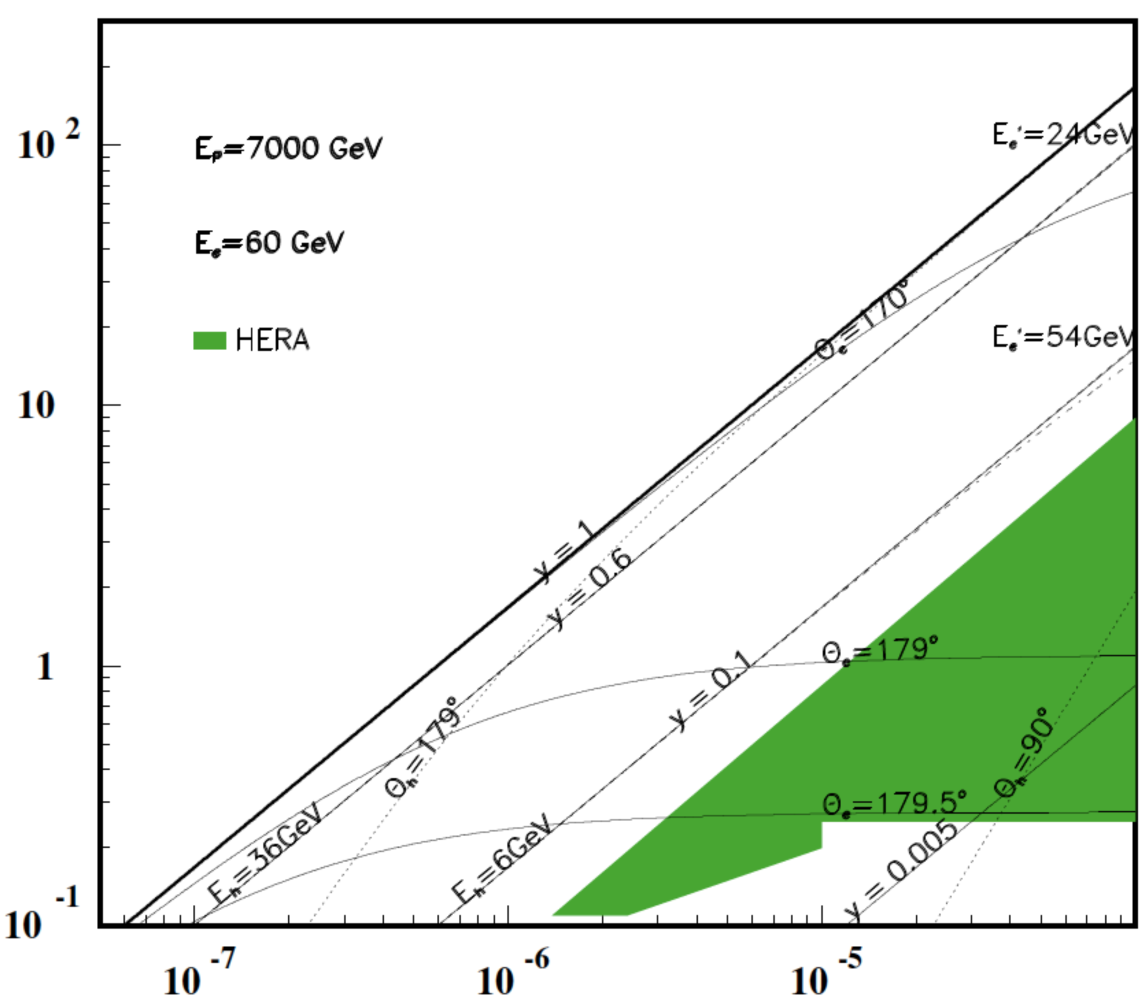
- **Non-linear effects** (unitarity constraints) are density effects: where? ⇒ **two-pronged approach at the LHeC**: ↓ x / ↑ A.



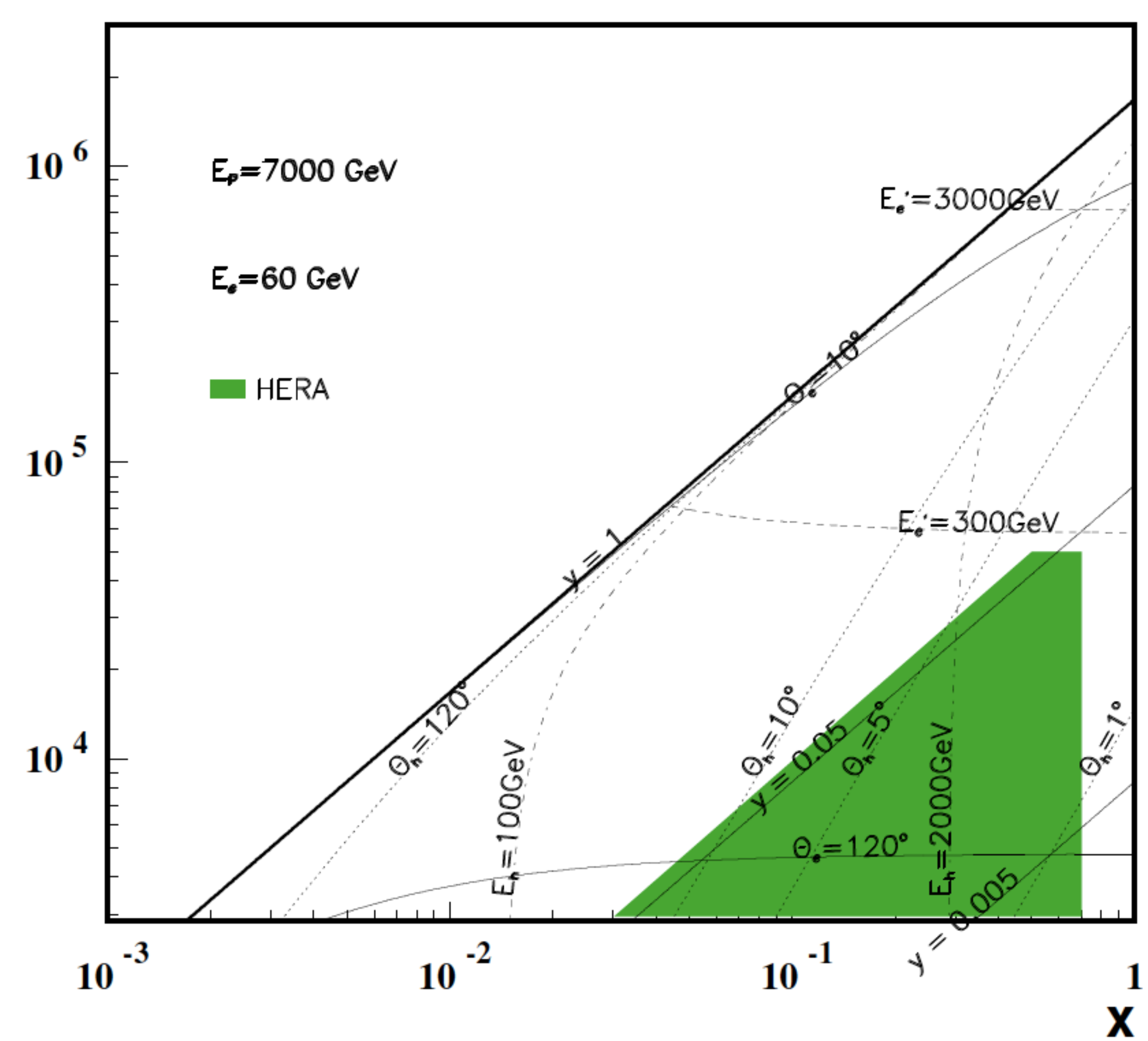


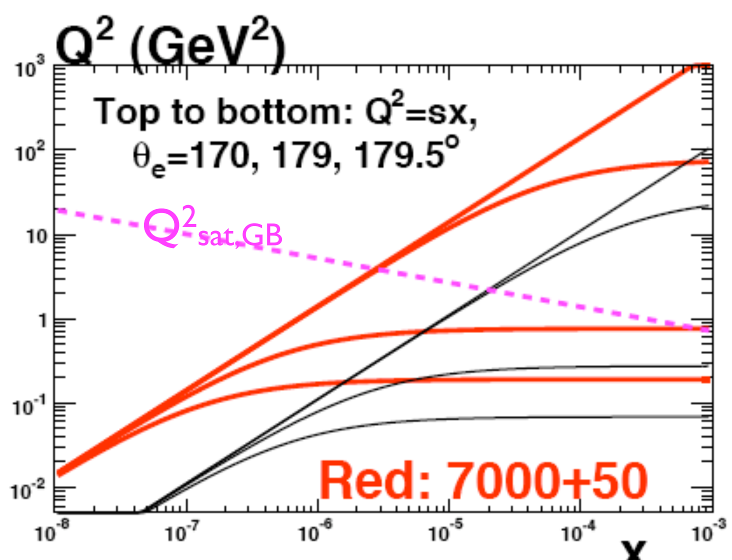
Kinematics:

LHeC - Low x Kinematics

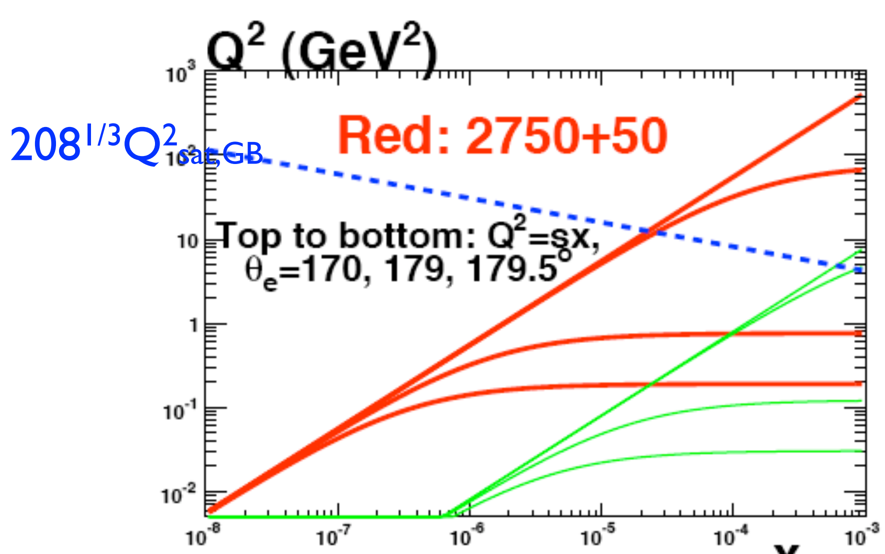


LHeC - High Q^2 Kinematics





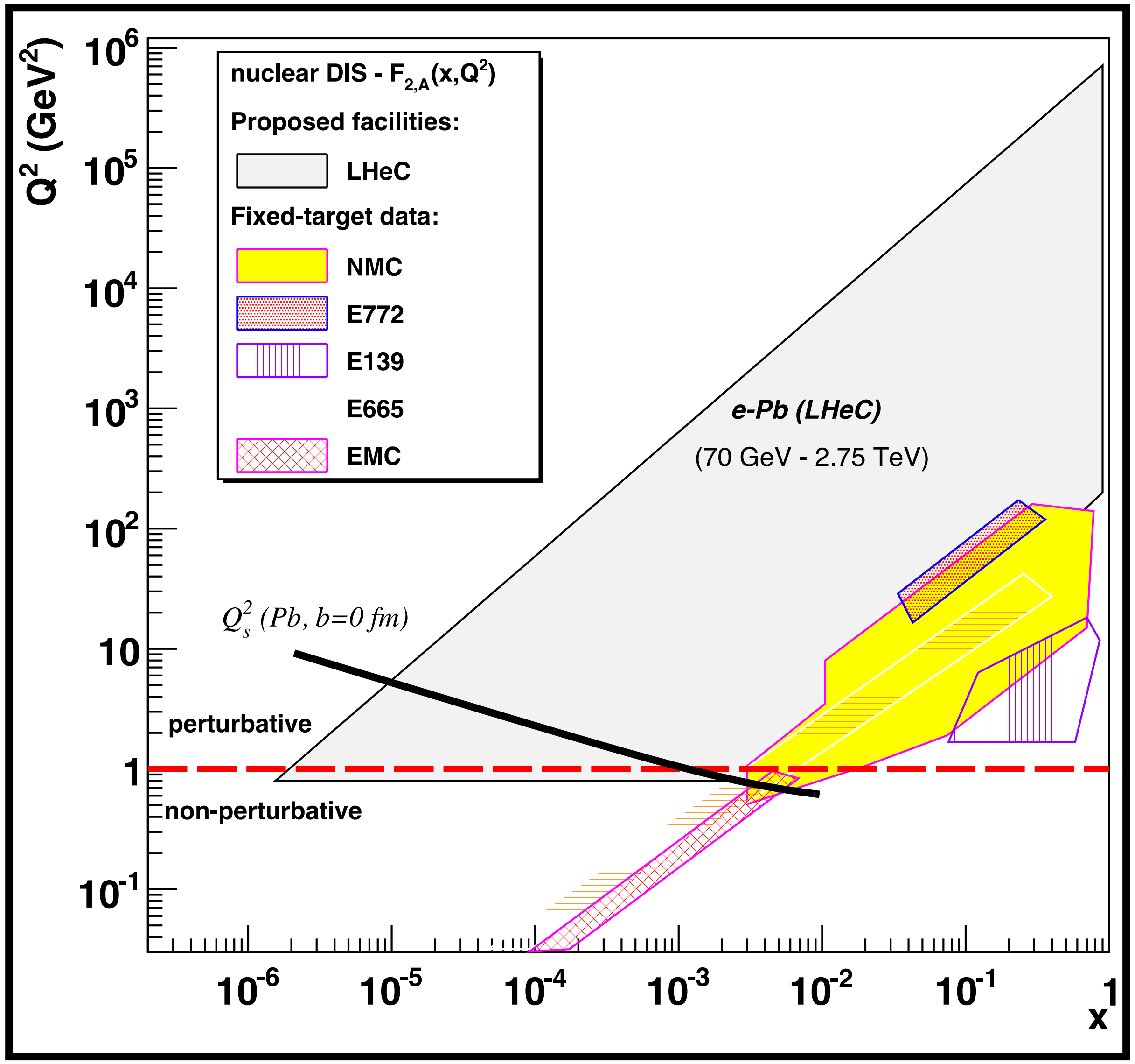
Black: HERA

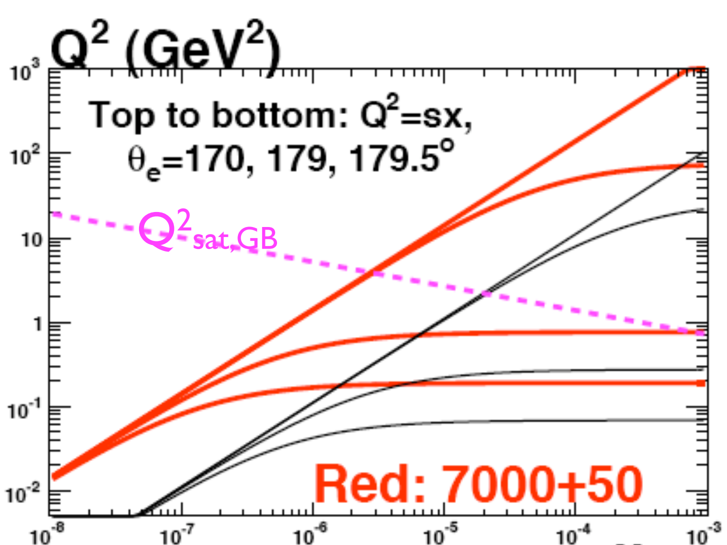


Green:100+20

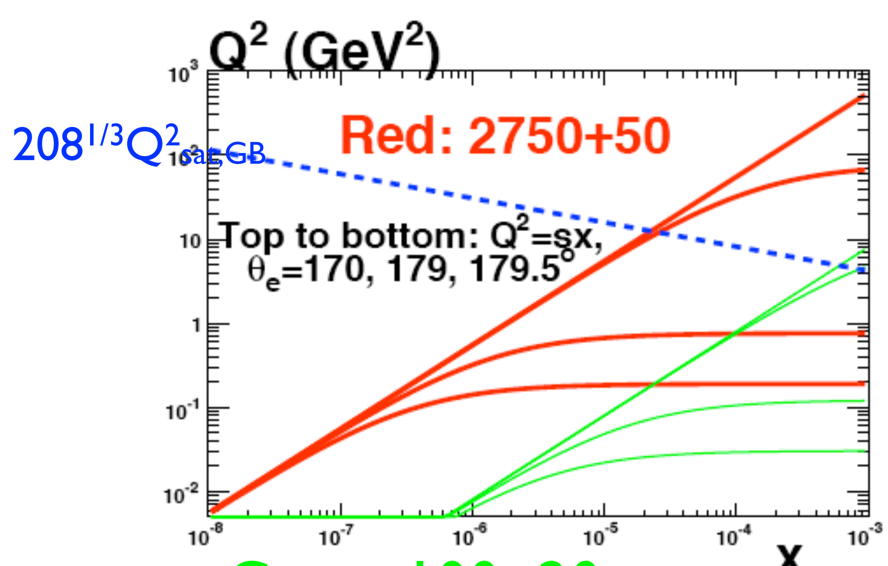
- Small-x demands 1 degree acceptance.
- Higher luminosity would benefit high-x and Q^2 studies.

Kinematics:





Black: HERA



Green:100+20

- Small-x demands 1 degree acceptance.
- Higher luminosity would benefit high-x and Q^2 studies.

LHC studies:

- **PbPb**:

➜ EW bosons.
➜ VMs in UPCs.
➜ Ridge.
➜ ...

- **pPb**:

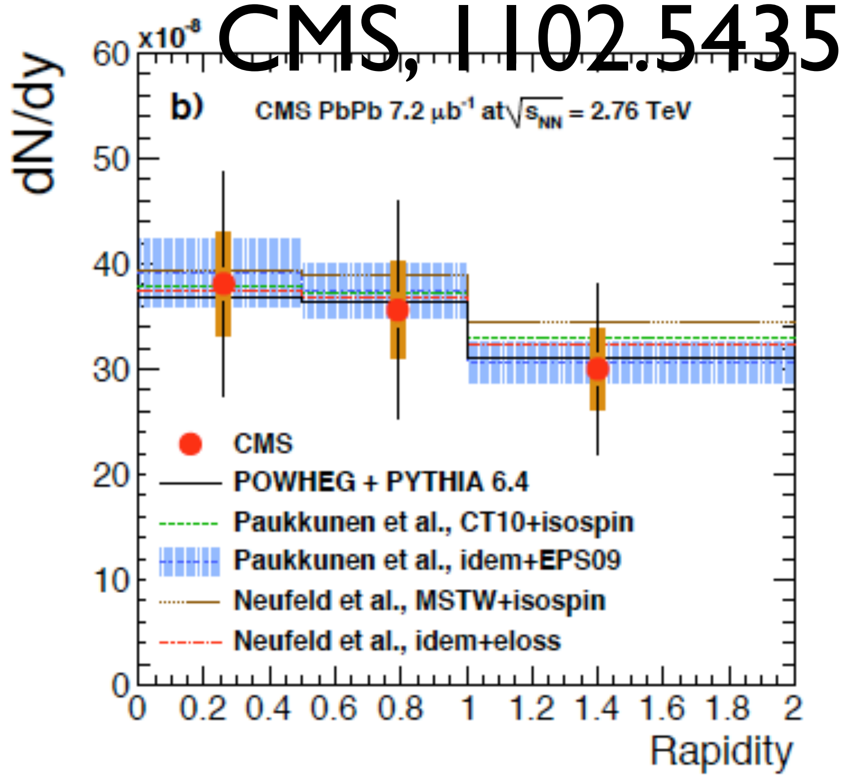
➜ Charged particles.
➜ Ridge.
➜ Flow.
➜ Back-to-back correlations, central-forward and forward-forward?
➜ EW bosons, DY?
➜ VMs, HF?
➜ UPCs?
➜ Jets and interjet activity?
➜ ...

LHC studies:

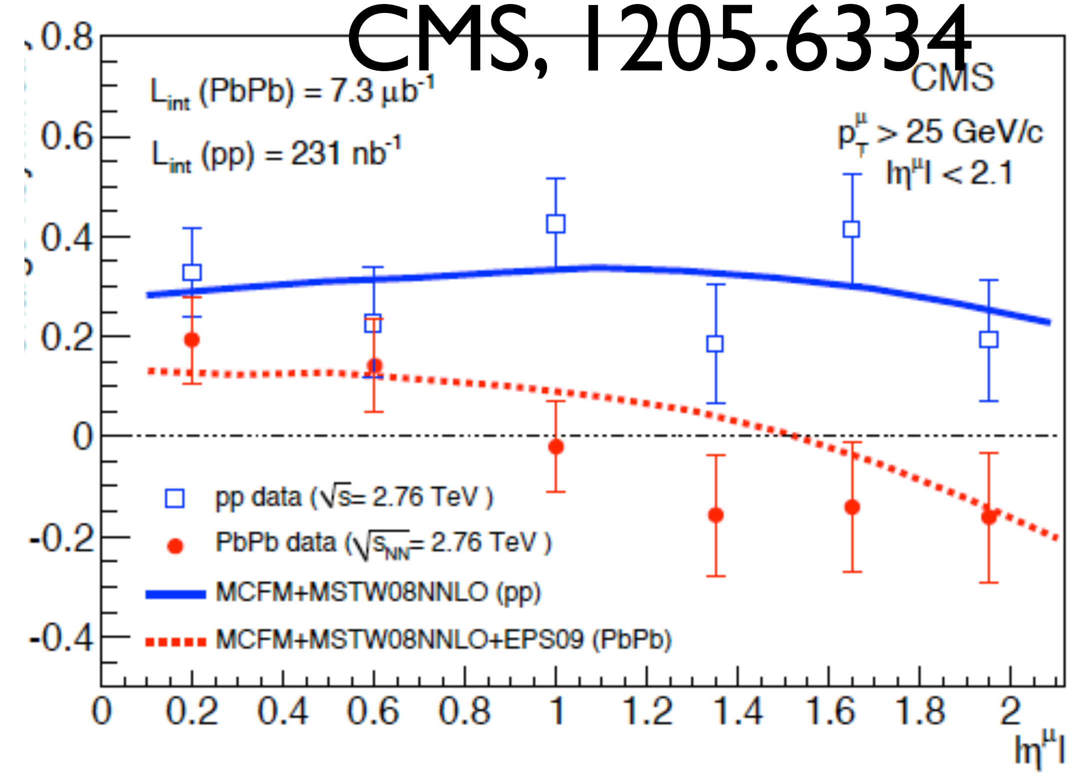
- **PbPb**:
  ➜ EW bosons.
  ➜ VMs in UPCs.
  ➜ Ridge.
  ➜ ...

- **pPb**:
  ➜ Charged particles.
  ➜ Ridge.
  ➜ Flow.
  ➜ Back-to-back correlations, central-forward and forward-forward?
  ➜ EW bosons, DY?
  ➜ VMs, HF?
  ➜ UPCs?
  ➜ Jets and interjet activity?
  ➜ ...

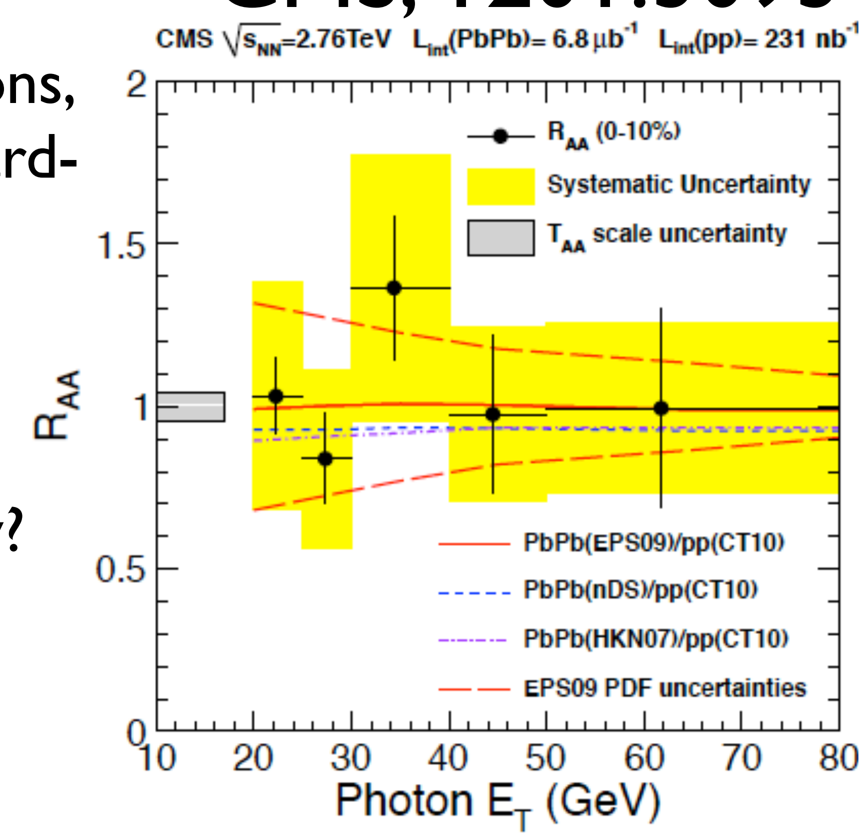
CMS, 1102.5435



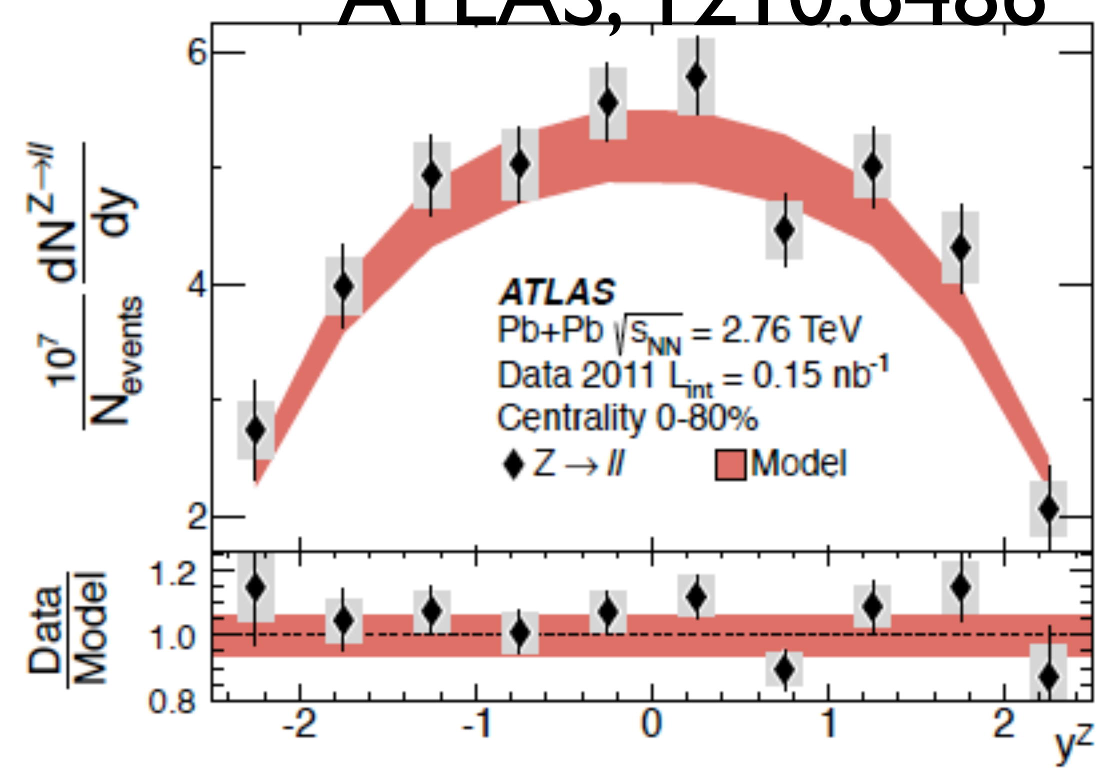
CMS, 1205.6334



CMS, 1201.3093



ATLAS, 1210.6486



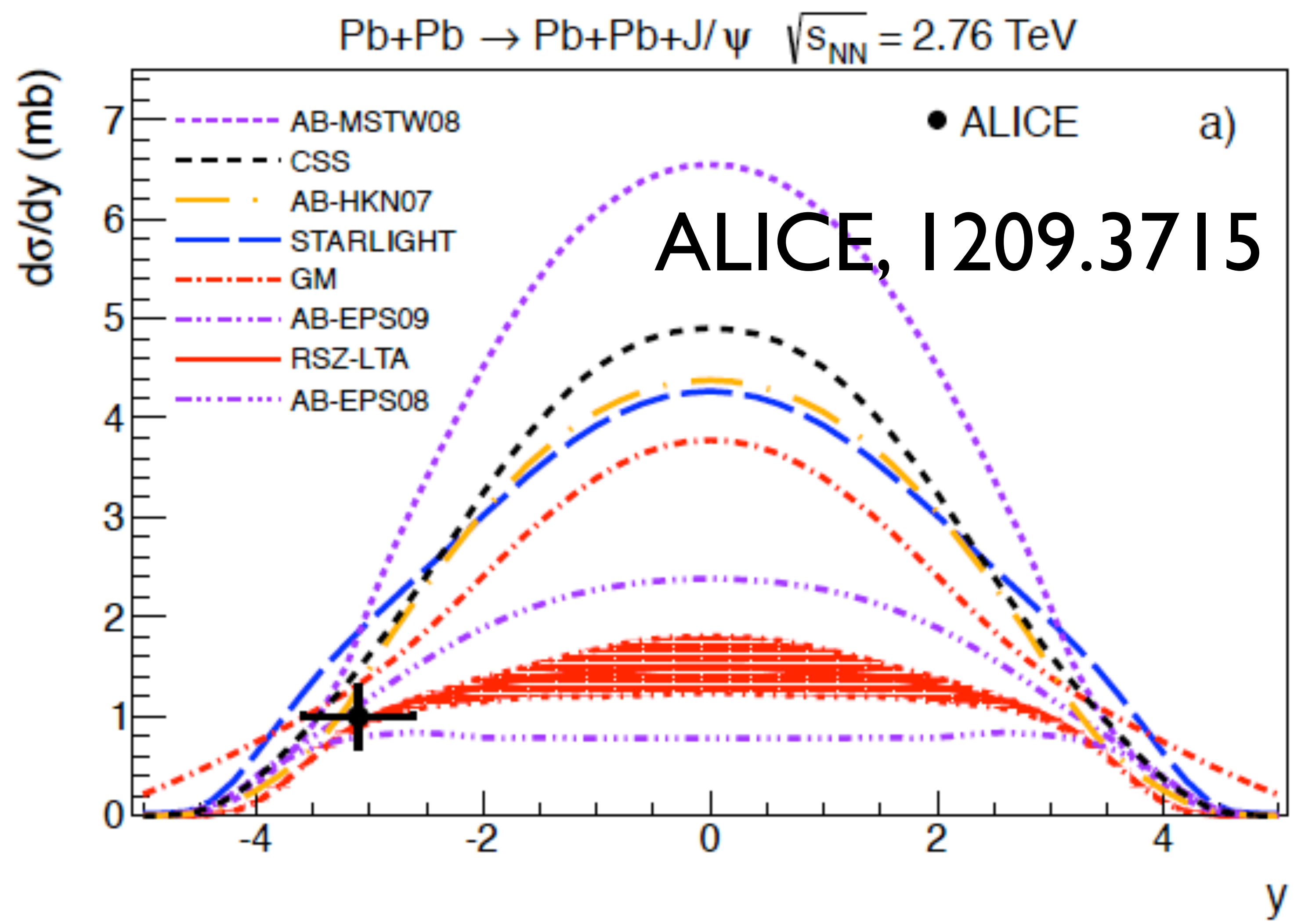
LHC studies:

- PbPb:

➜ EW bosons.
➜ VMs in UPCs.
➜ Ridge.
➜ ...

- pPb:

➜ Charged particles.
➜ Ridge.
➜ Flow.
➜ Back-to-back correlations, central-forward and forward-forward?
➜ EW bosons, DY?
➜ VMs, HF?
➜ UPCs?
➜ Jets and interjet activity?
➜ ...

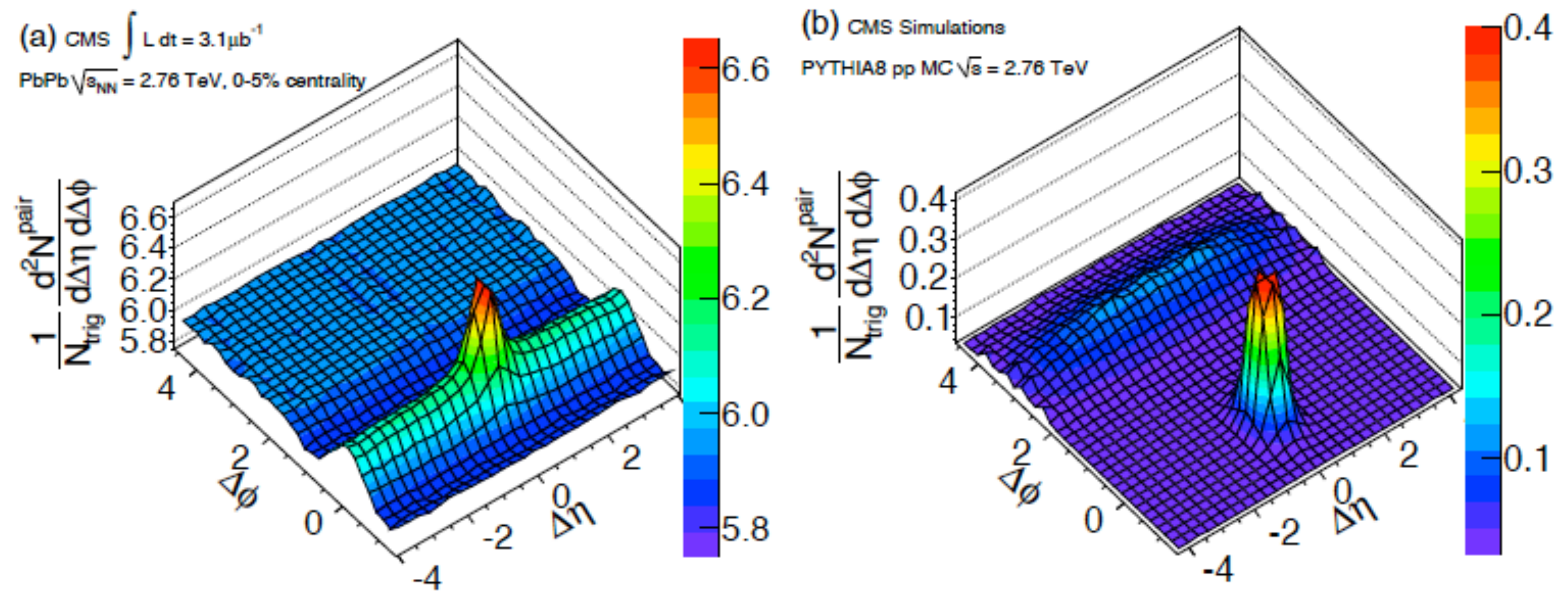


LHC studies:

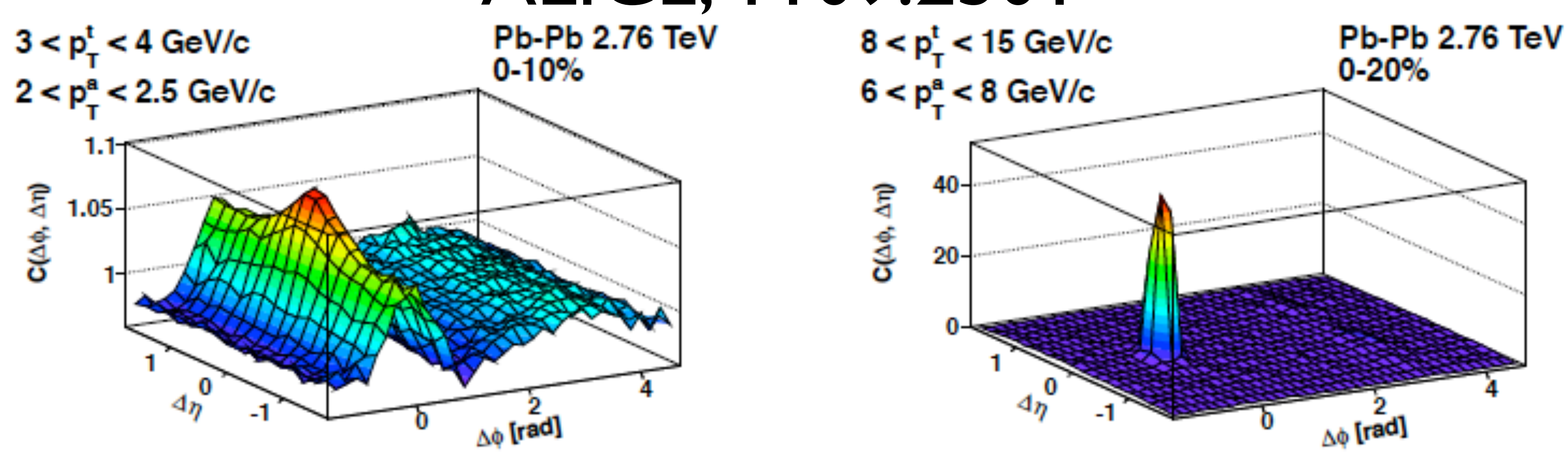
- PbPb:
  - ➜ EW bosons.
  - ➜ VMs in UPCs.
  - ➜ Ridge.
  - ➜ ...

- pPb:
  - ➜ Charged particles.
  - ➜ Ridge.
  - ➜ Flow.
  - ➜ Back-to-back correlations, central-forward and forward-forward?
  - ➜ EW bosons, DY?
  - ➜ VMs, HF?
  - ➜ UPCs?
  - ➜ Jets and interjet activity?
  - ➜ ...

CMS, 1105.2438



ALICE, 1109.2501



LHC studies:

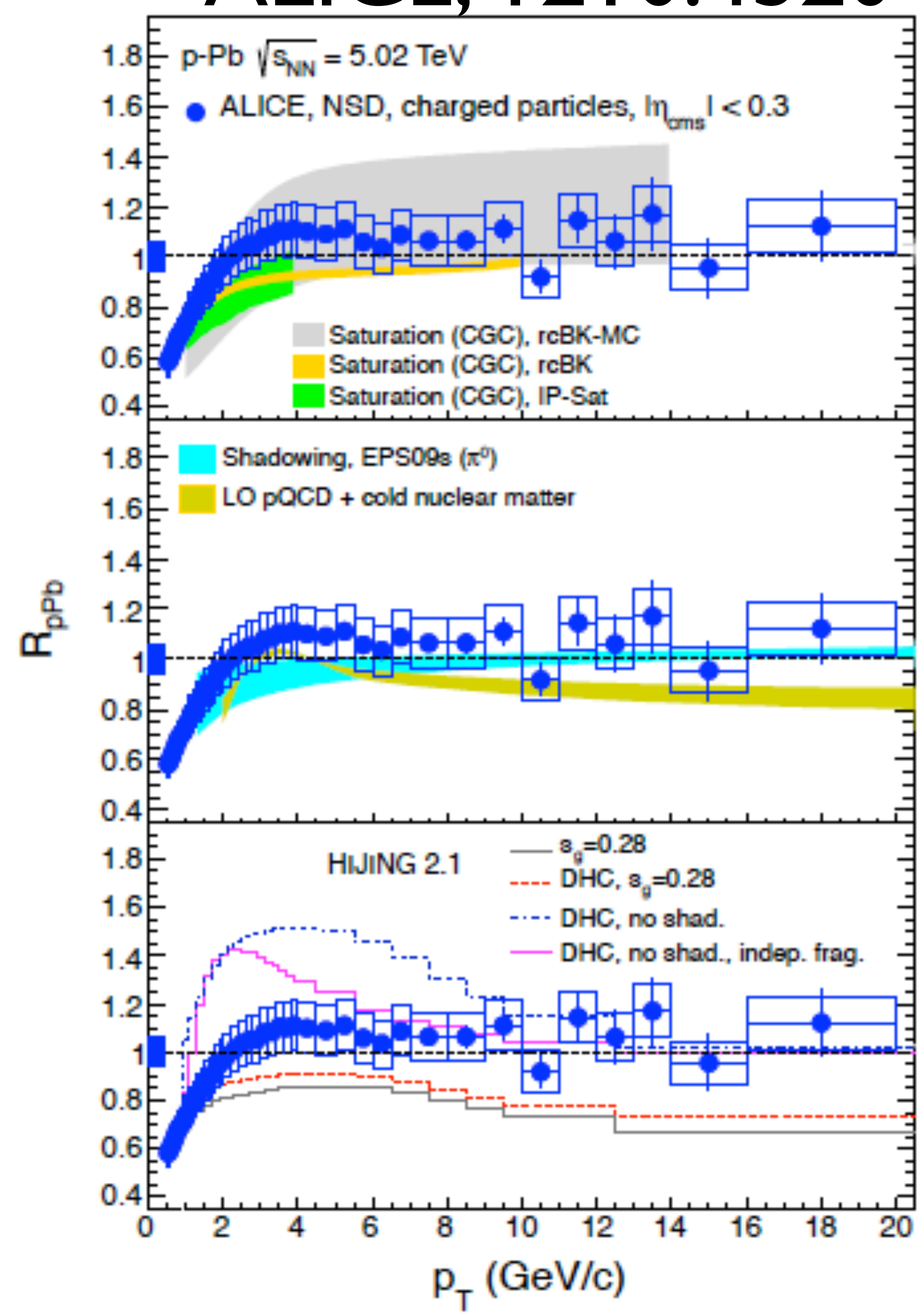
- PbPb:

➜ EW bosons.
➜ VMs in UPCs.
➜ Ridge.
➜ ...

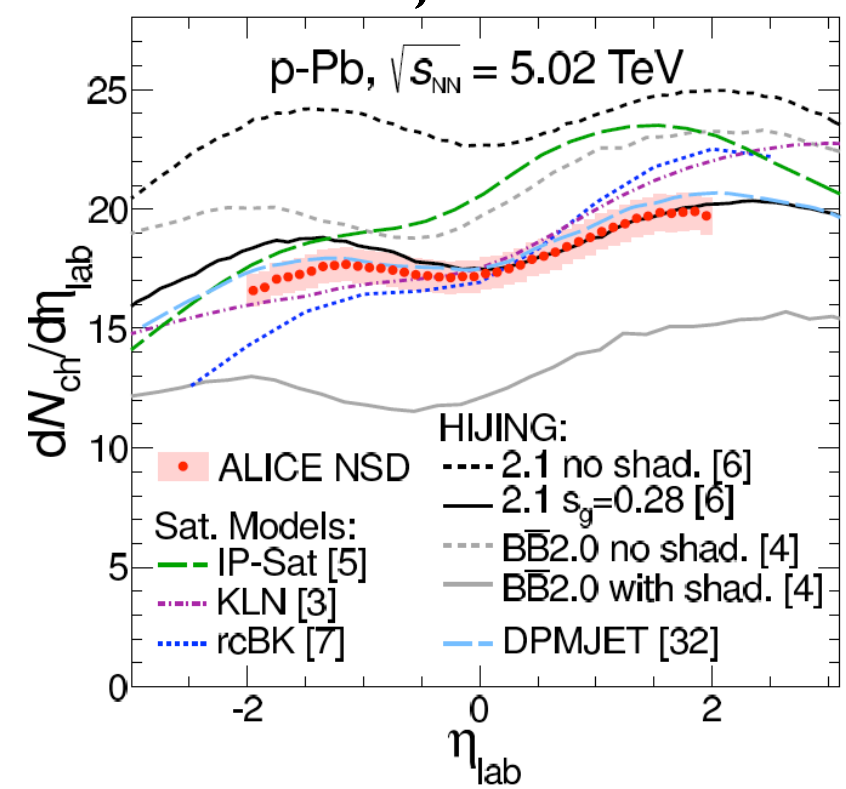
- pPb:

➜ <u>Charged particles</u>.
➜ Ridge.
➜ Flow.
➜ Back-to-back correlations, central-forward and forward-forward?
➜ EW bosons, DY?
➜ VMs, HF?
➜ UPCs?
➜ Jets and interjet activity?
➜ ...

ALICE, 1210.4520



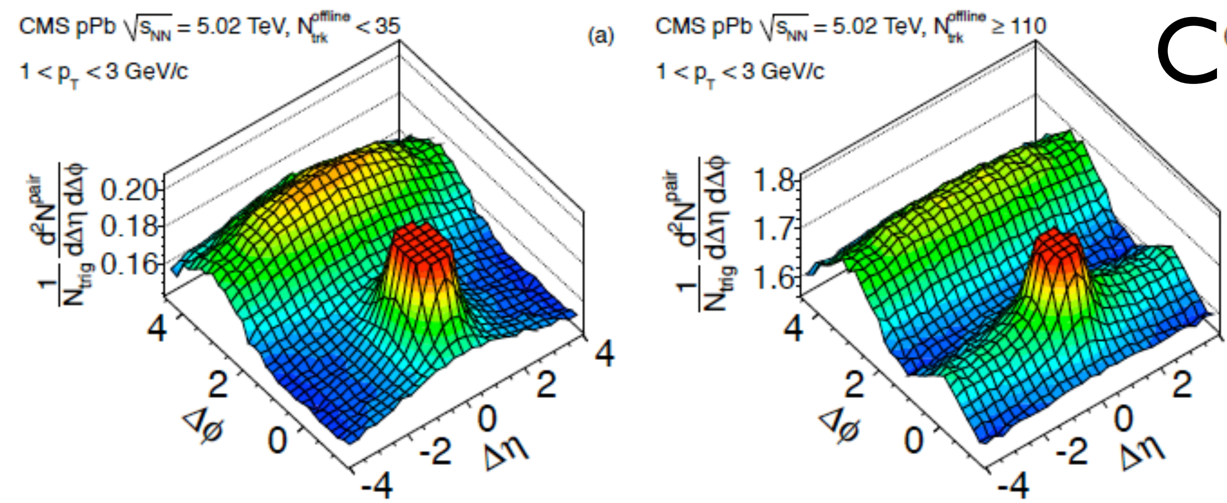
ALICE, 1210.3615



LHC studies:

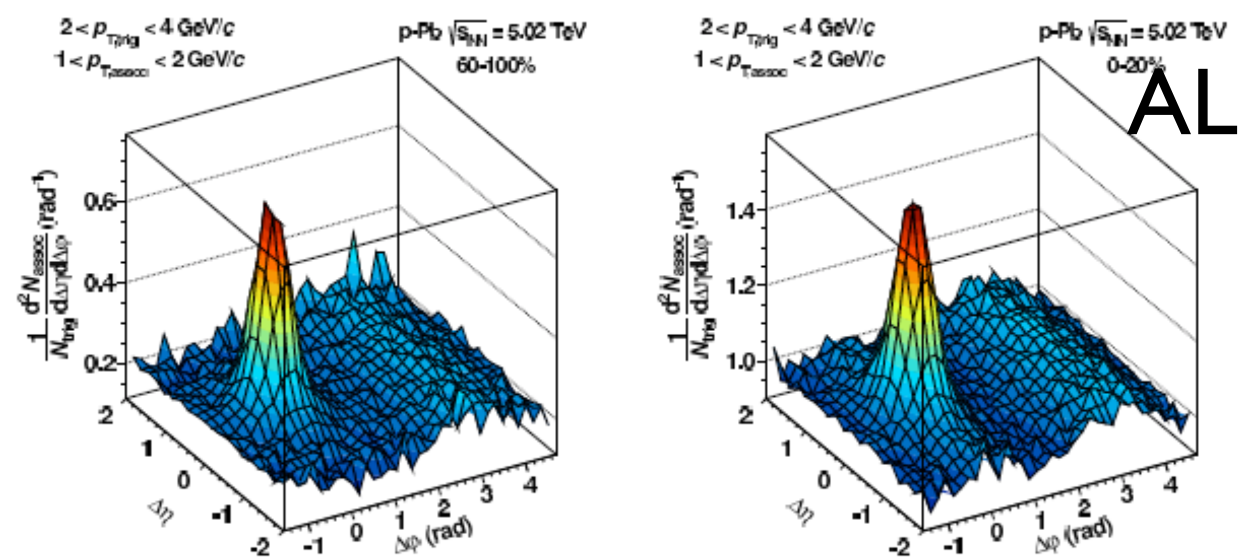
- **PbPb**:
  - ➜ EW bosons.
  - ➜ VMs in UPCs.
  - ➜ Ridge.
  - ➜ ...

CMS, 1210.5482

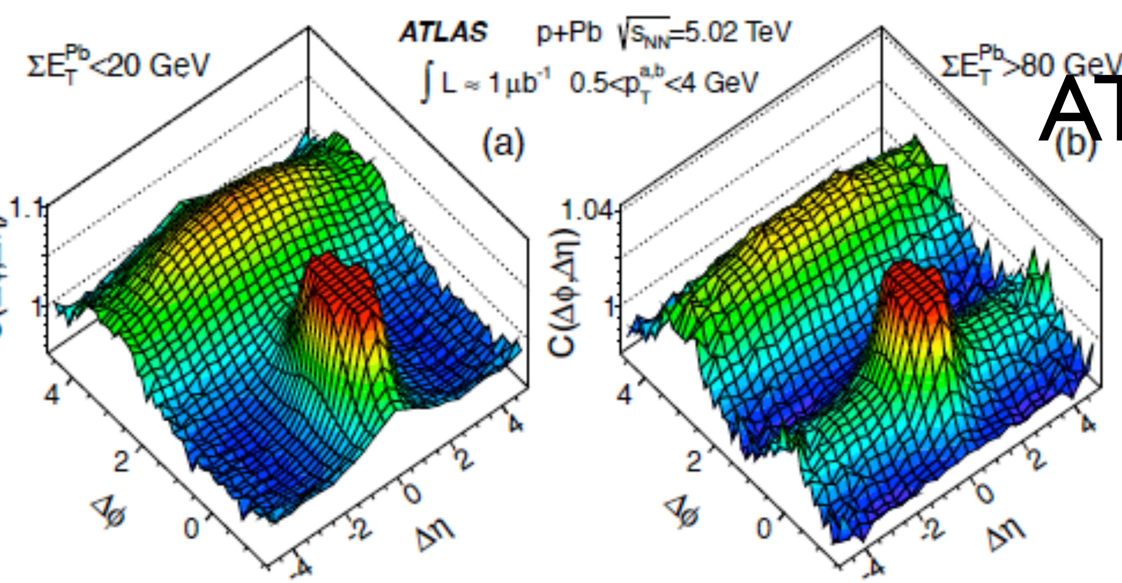


- **pPb**:
  - ➜ Charged particles.
  - ➜ Ridge.
  - ➜ Flow.
  - ➜ Back-to-back correlations, central-forward and forward-forward?
  - ➜ EW bosons, DY?
  - ➜ VMs, HF?
  - ➜ UPCs?
  - ➜ Jets and interjet activity?
  - ➜ ...

ALICE, 1212.2001



ATLAS, 1212.5198

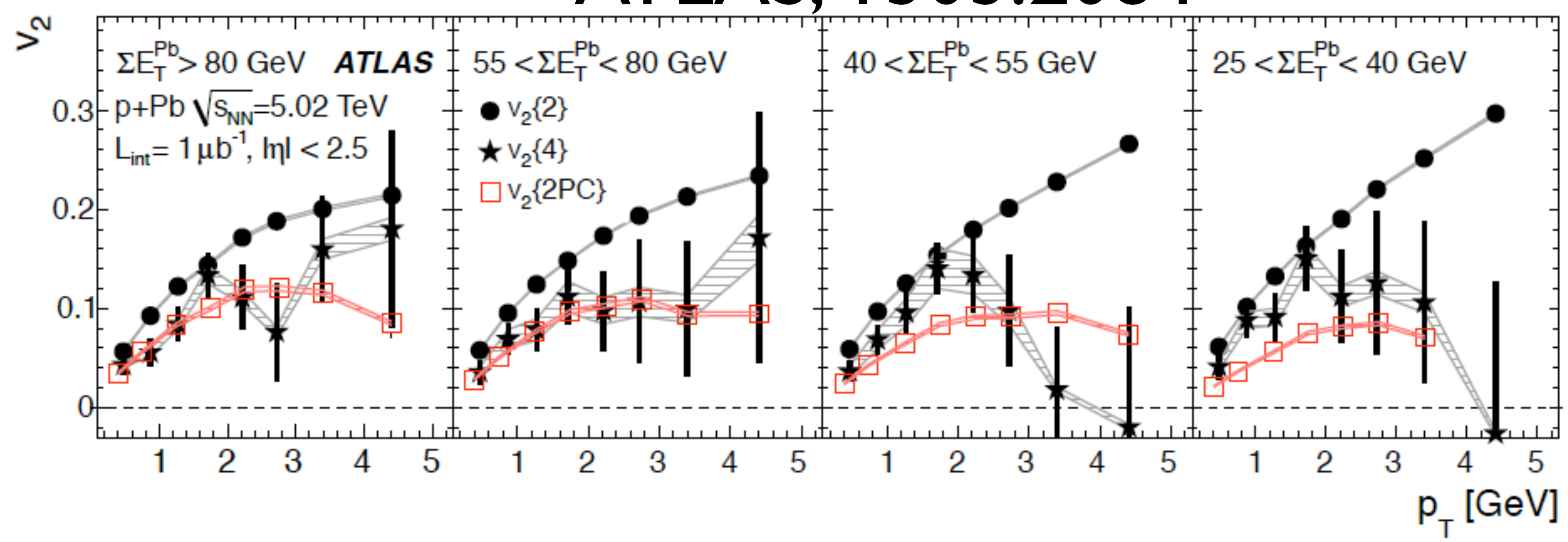


LHC studies:

- **PbPb**:
  - ➜ EW bosons.
  - ➜ VMs in UPCs.
  - ➜ Ridge.
  - ➜ ...

- **pPb**:
  - ➜ Charged particles.
  - ➜ Ridge.
  - ➜ Flow.
  - ➜ Back-to-back correlations, central-forward and forward-forward?
  - ➜ EW bosons, DY?
  - ➜ VMs, HF?
  - ➜ UPCs?
  - ➜ Jets and interjet activity?
  - ➜ ...

ATLAS, 1303.2084



LHC studies:

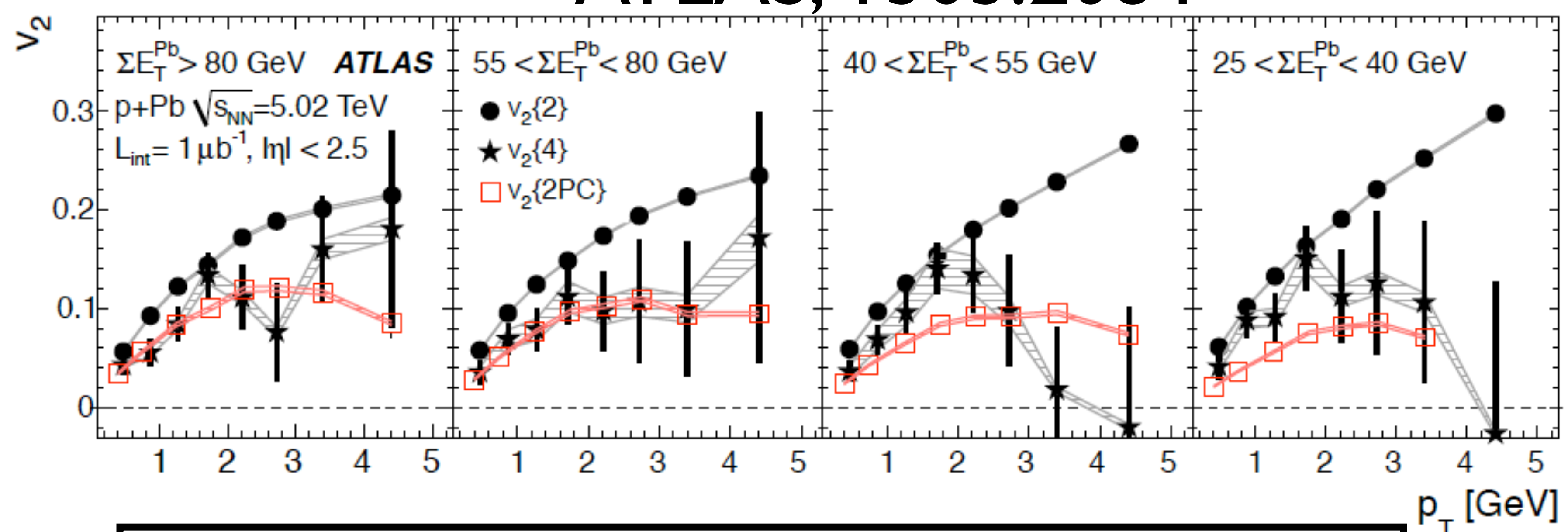
- PbPb:

➜ EW bosons.
➜ VMs in UPCs.
➜ Ridge.
➜ ...

- pPb:

➜ Charged particles.
➜ Ridge.
➜ <u>Flow</u>.
➜ Back-to-back correlations, central-forward and forward-forward?
➜ EW bosons, DY?
➜ VMs, HF?
➜ UPCs?
➜ Jets and interjet activity?
➜ ...

ATLAS, 1303.2084



- The existence of collective effects in pPb is somewhat unexpected.
- Are they really final state? Do they exist also in eA?

LHeC scenarios:

config.	E(e)	E(N)	N	∫L(e⁺)	∫L(e⁻)	|Pol|	$L/10^{32}$	P/MW	years	type
				For F_2						
A	20	7	p	1	1	-	1	10	1	SPL
B	50	7	p	50	50	0.4	25	30	2	RR hiQ^2
C	50	7	p	1	1	0.4	1	30	1	RR lo x
D	100	7	p	5	10	0.9	2.5	40	2	LR
E	150	7	p	3	6	0.9	1.8	40	2	LR
F	50	3.5	D	1	1	--	0.5	30	1	eD
G	50	2.7	Pb	10^{-3}	10^{-3}	0.4	10^{-3}	30	1	ePb
H	50	1	p	--	1	--	25	30	1	lowEp
I	50	3.5	Ca	$5\cdot10^{-3}$		?	$5\cdot10^{-3}$	?	?	eCa

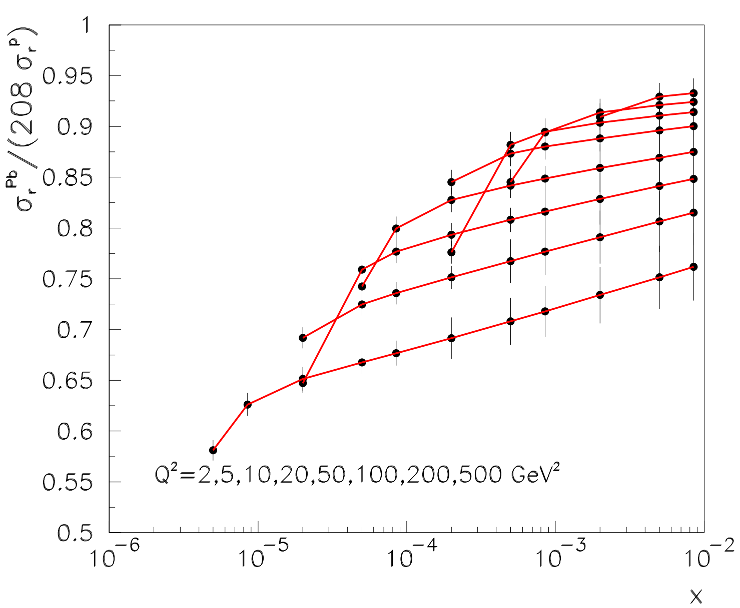
- For F_L: 10, 25, 50 + 2750 (7000); $Q^2 \leq sx$; Lumi=5,10,100 pb^{-1} respectively; charm and beauty: same efficiencies in ep and eA.

Note: F_L in eA

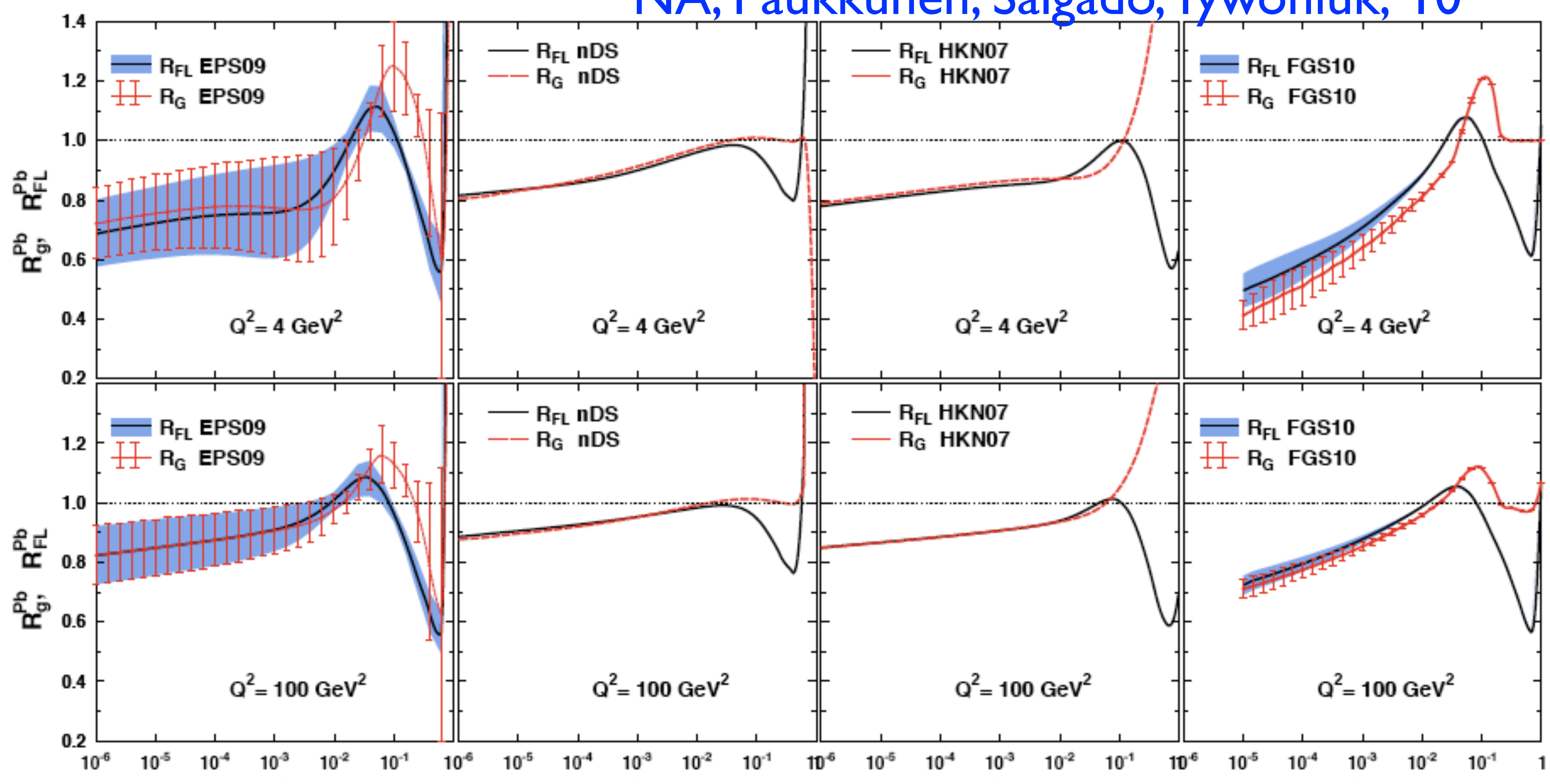
$$\sigma_r^{NC} = \frac{Q^4 x}{2\pi\alpha^2 Y_+} \frac{d^2\sigma^{NC}}{dx dQ^2} = F_2 \left[1 - \frac{y^2}{Y_+} \frac{F_L}{F_2} \right], \qquad Y_+ = 1 + (1-y)^2$$

- F_L traces the nuclear effects on the glue (Cazarotto et al '08).
- Uncertainties in the extraction of F_2 due to the unknown nuclear effects on F_L of order 5 % (larger than expected stat.+syst.) ⇒

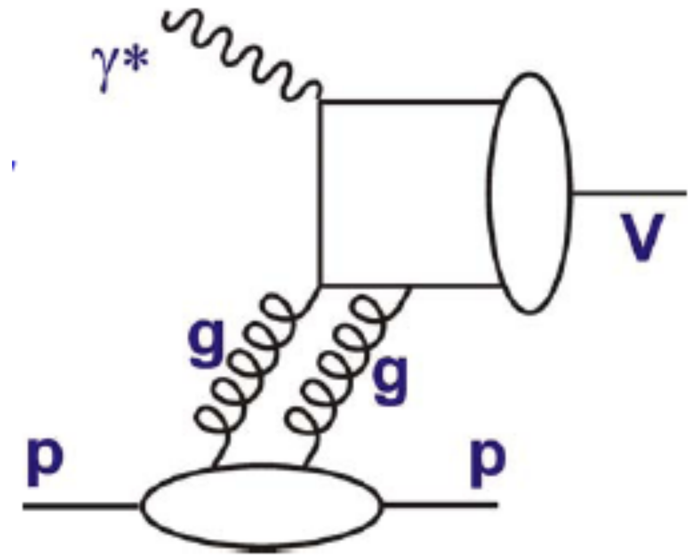
measure F_L or use the reduced cross section (but then ratios at two energies...).



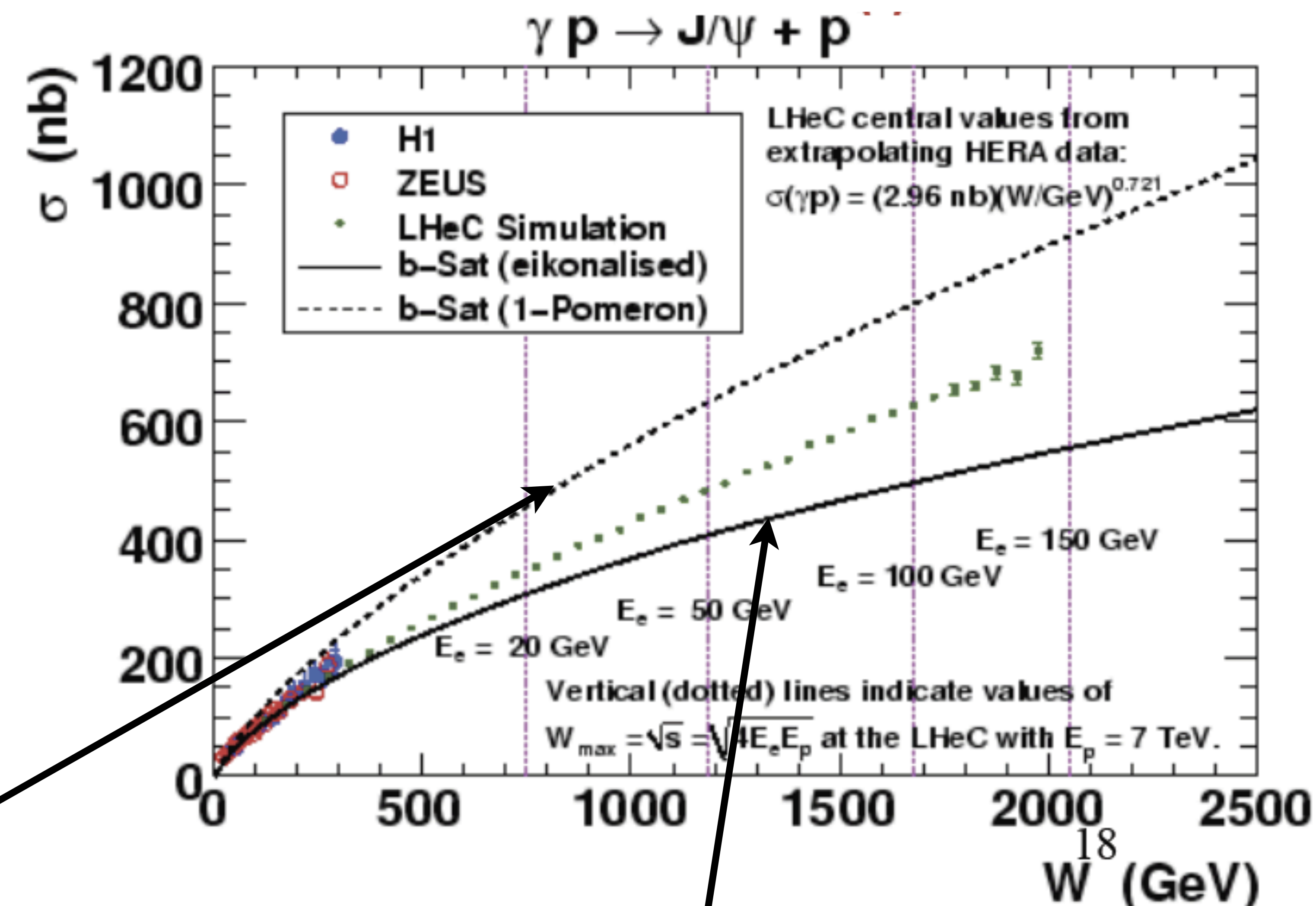
NA, Paukkunen, Salgado, Tywoniuk, '10

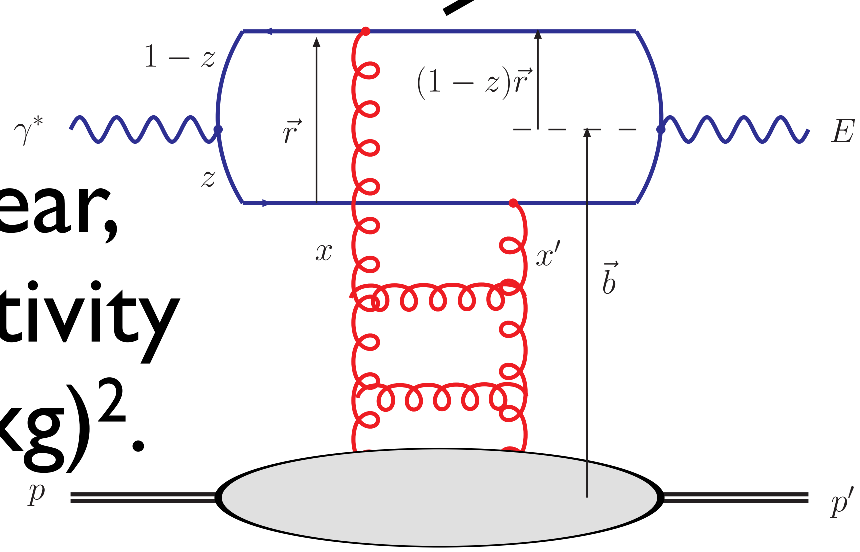


Elastic VM production in ep:

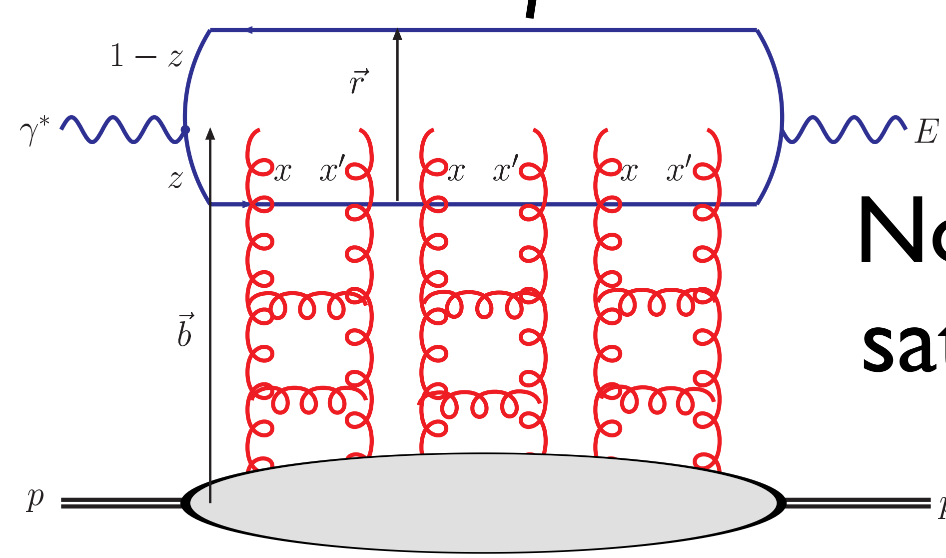


- Elastic J/ψ production appears as a candidate to signal saturation effects at work!!!



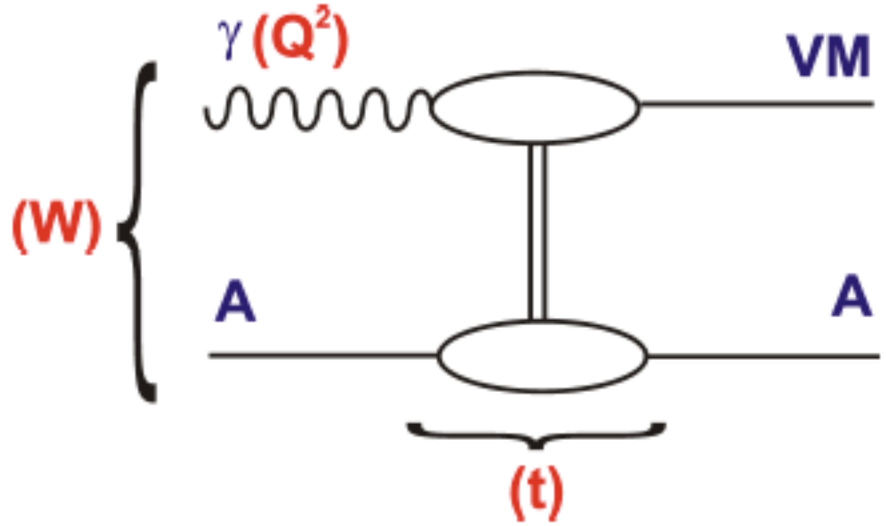


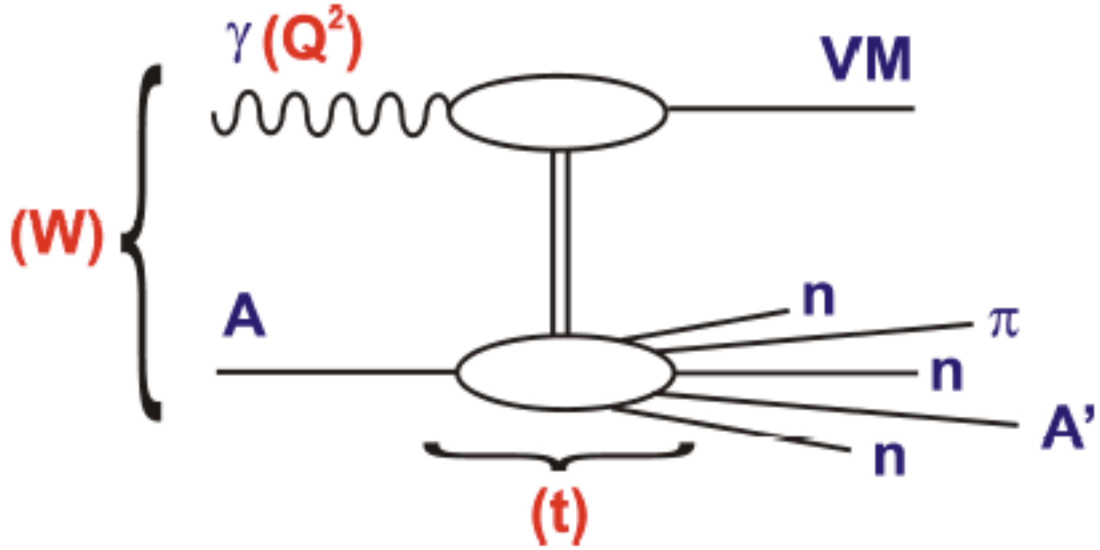
Linear, sensitivity to $(xg)^2$.



Non-linear, saturation.

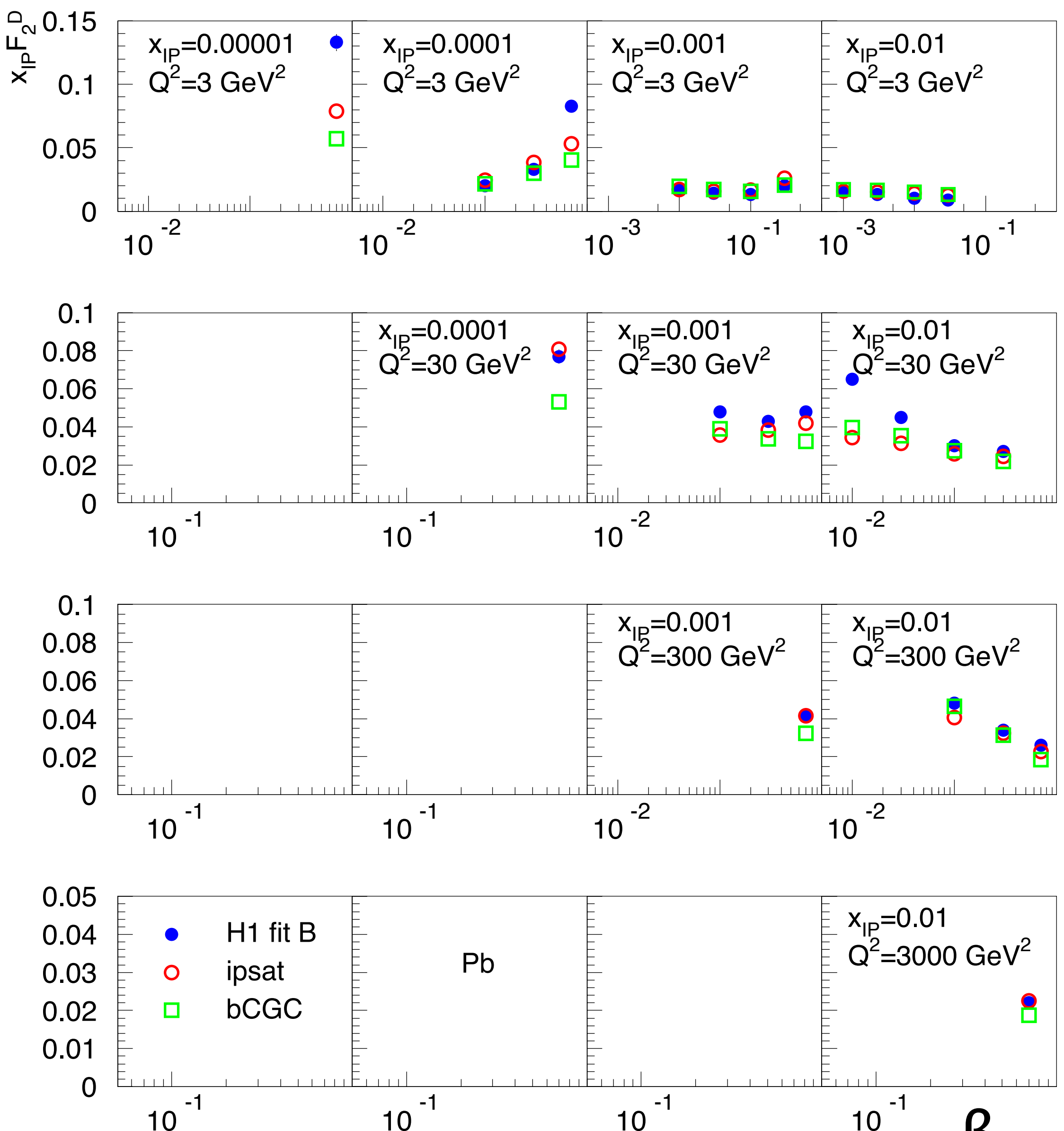
Diffractive DIS on nuclear targets:





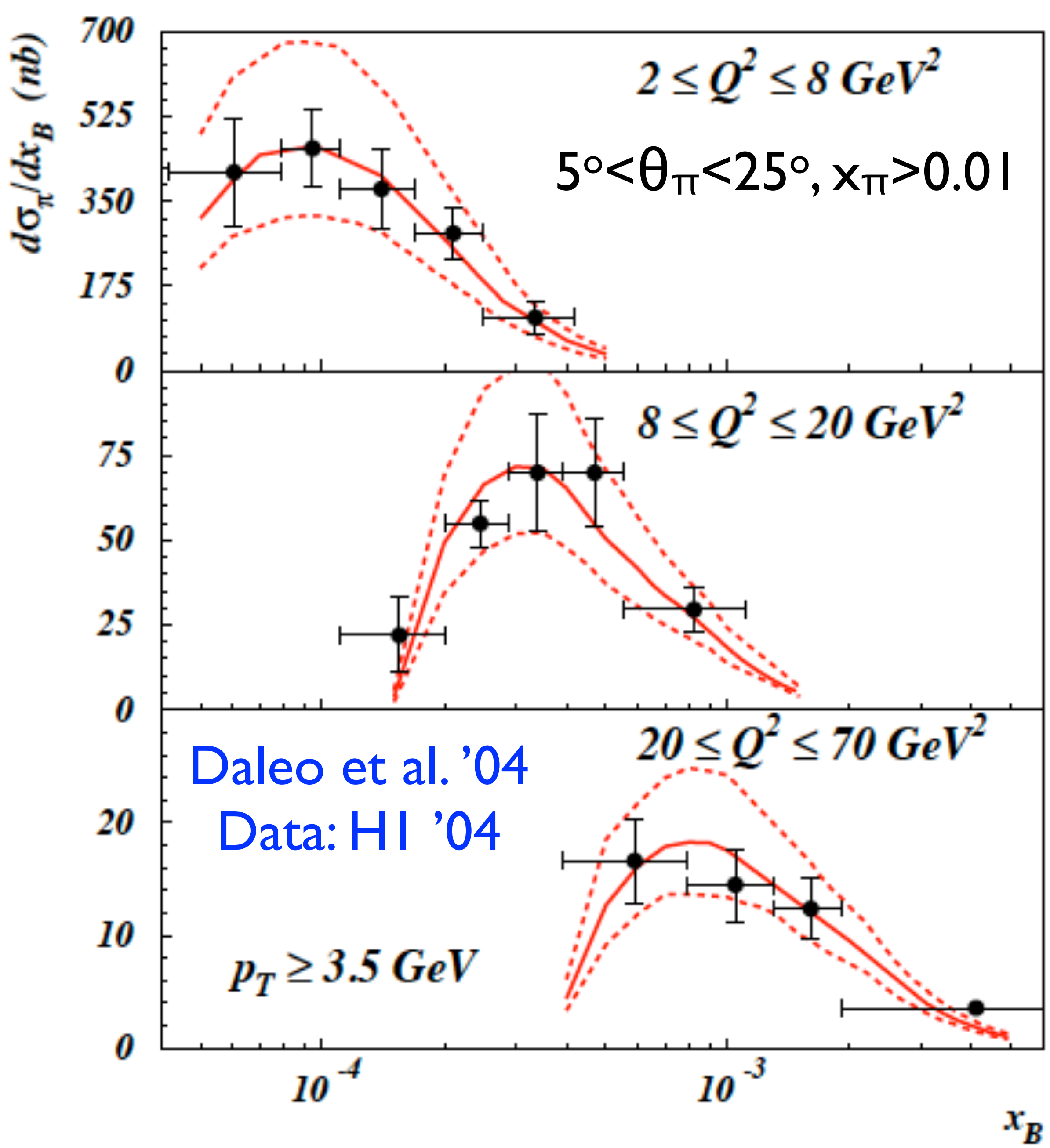
- Challenging experimental problem, requires Monte Carlo simulation with detailed understanding of the nuclear break-up.

- For the coherent case, predictions available.

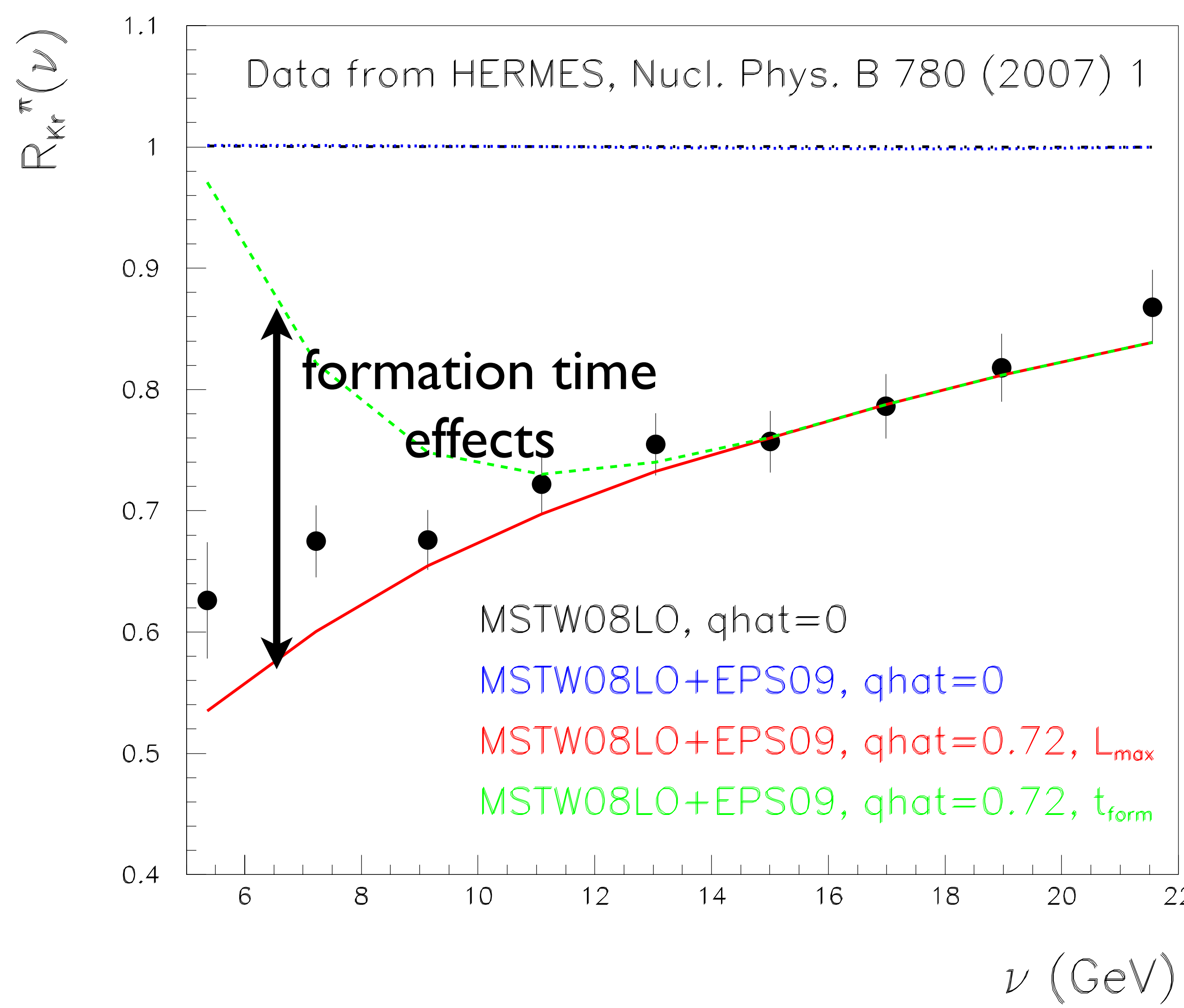


Radiation and hadronization:

- Large (NLO) yields at small-x (H1 cuts, 3 times higher if relaxed).
- Nuclear effects in hadronization at small ν (LO plus QW, Arleo '03).

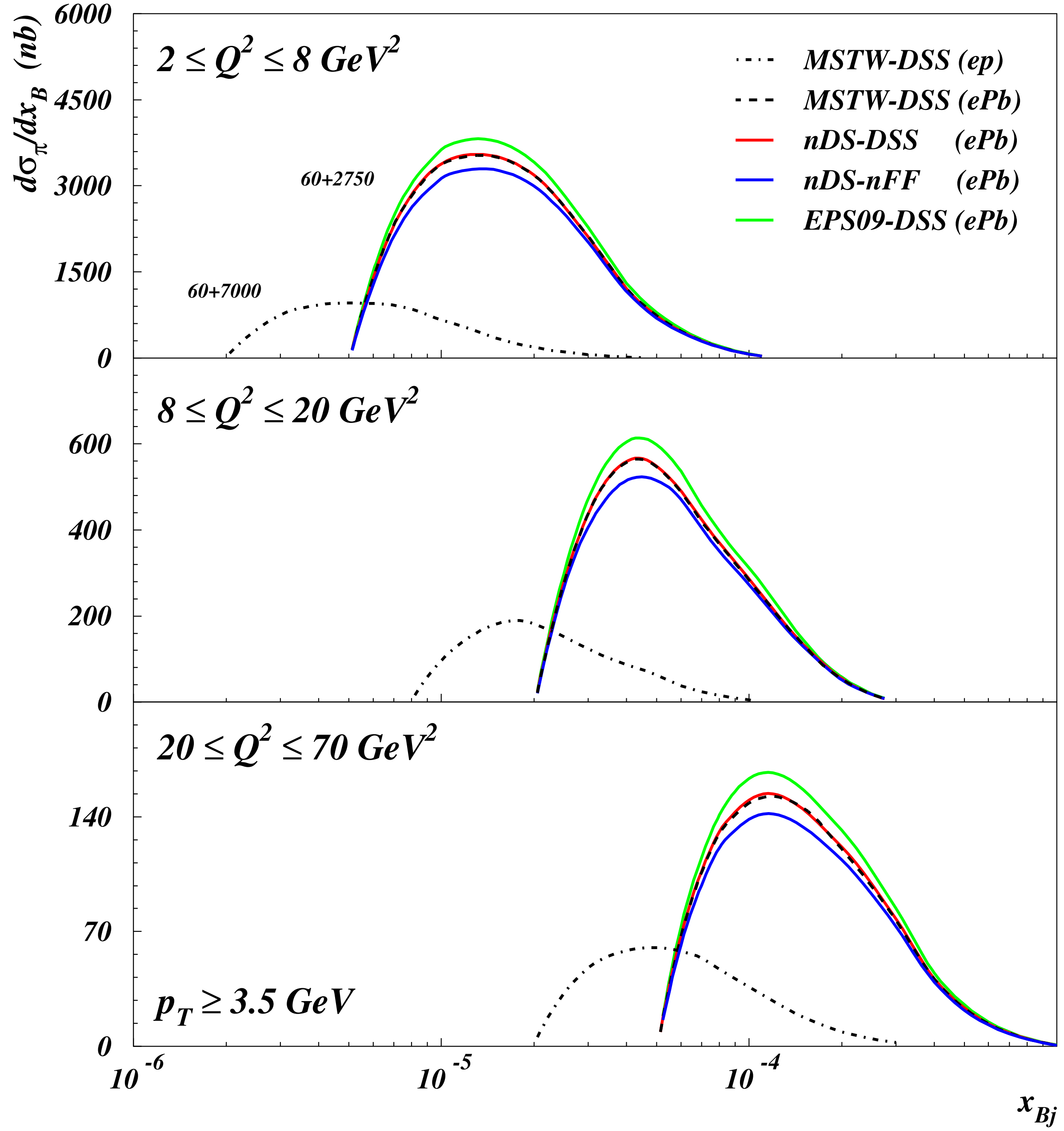


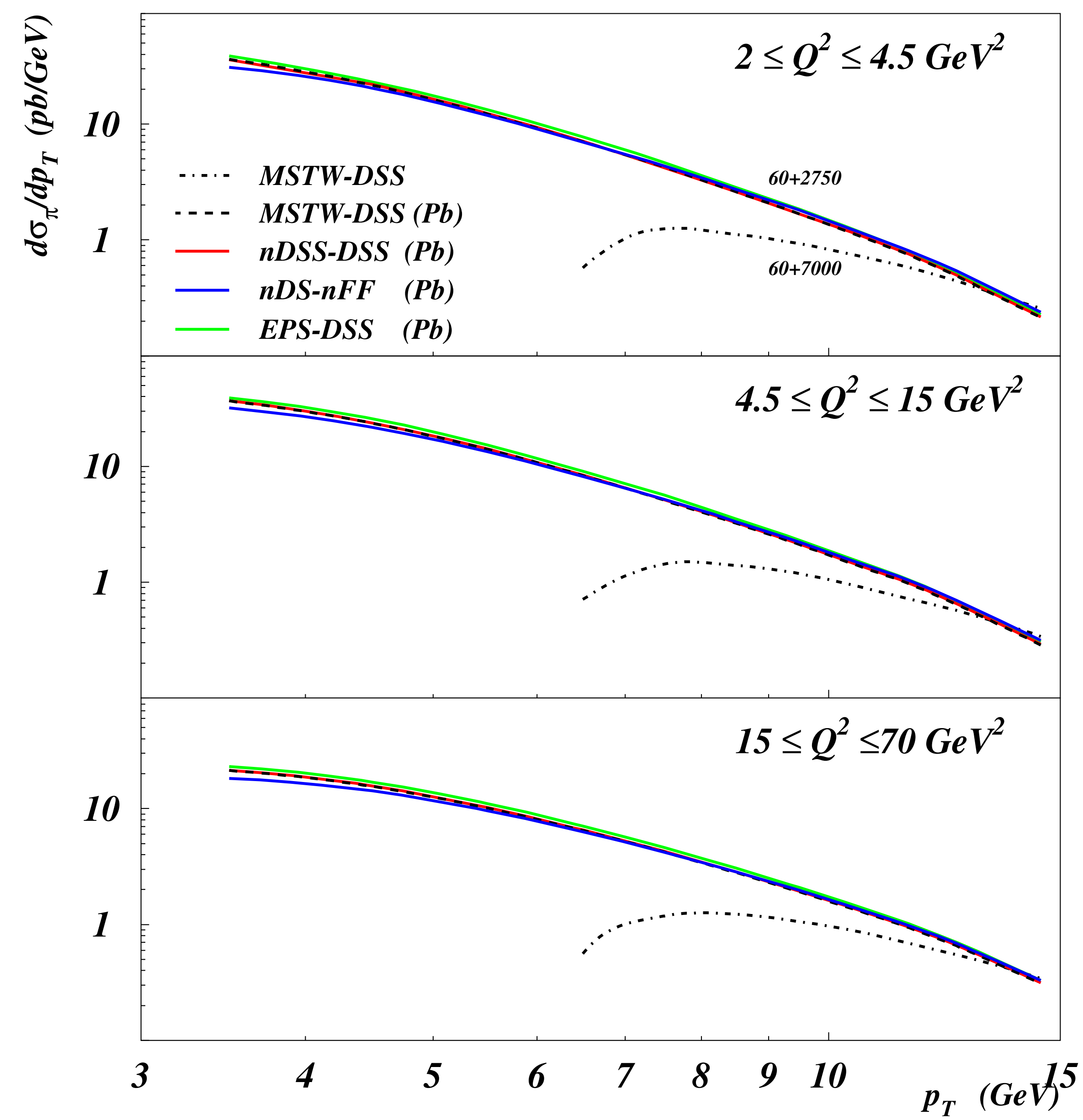
$$R_A^h(z,\nu) = \frac{1}{N_A^e}\frac{dN_A^h(z,\nu)}{d\nu\, dz} \Bigg/ \frac{1}{N_D^e}\frac{dN_D^h(z,\nu)}{d\nu\, dz}$$



Radiation and hadronization:

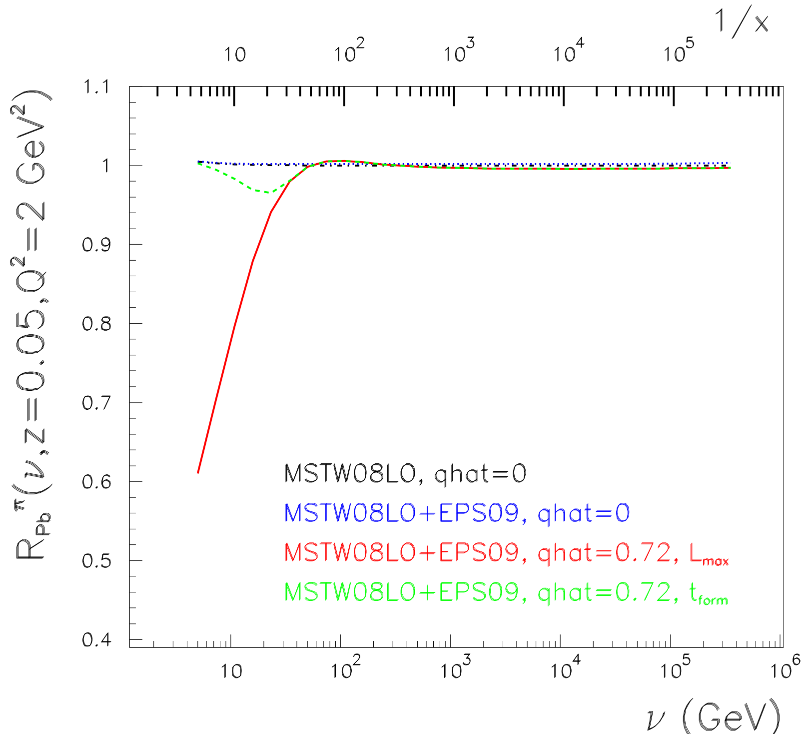
- Large (NLO) yields at small-x (H1 cuts, 3 times higher if relaxed).
- Nuclear effects in hadronization at small ν (LO plus QW, Arleo '03).

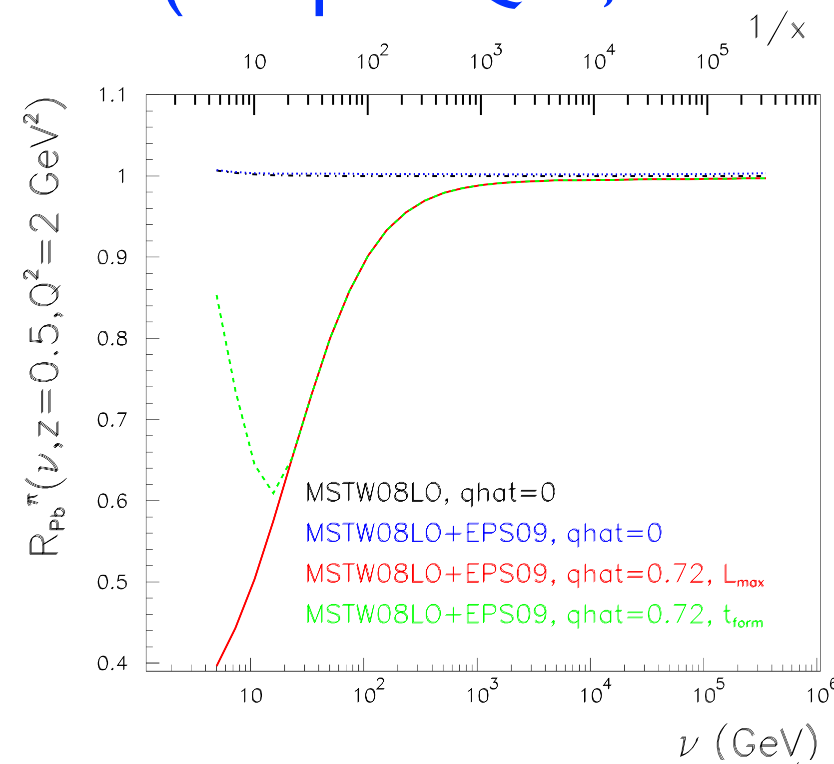




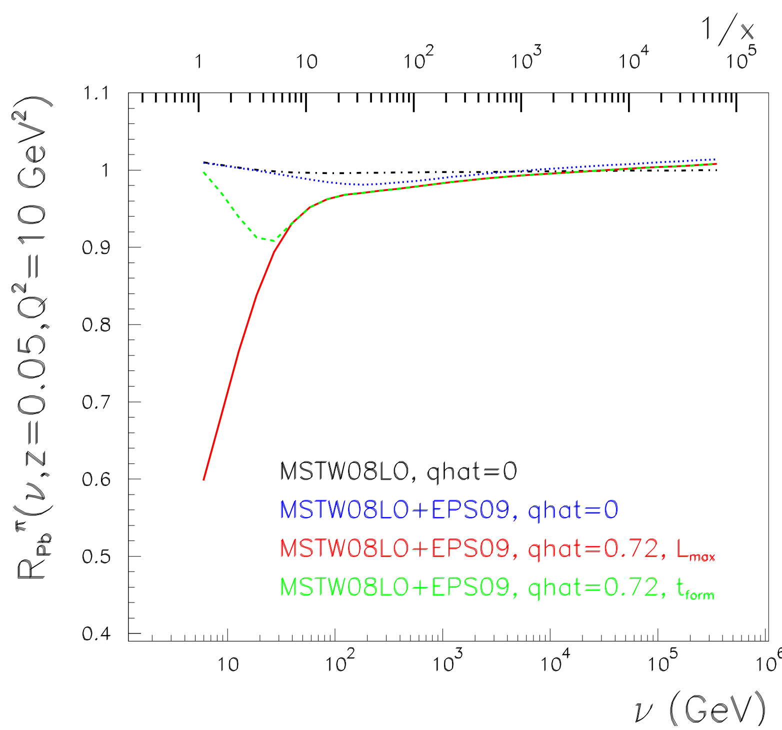
Radiation and hadronization:

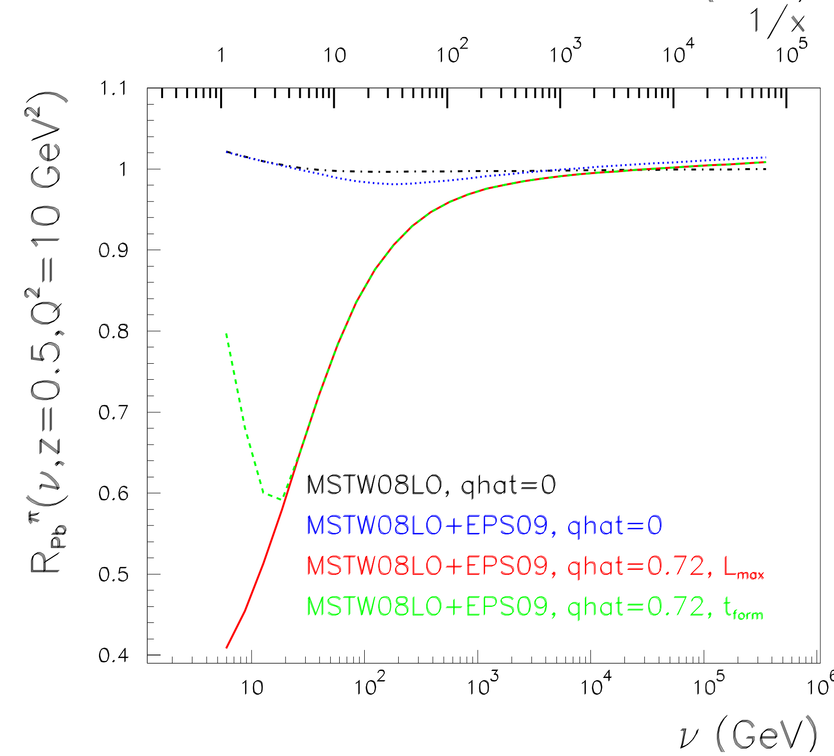
- Large (NLO) yields at small-x (H1 cuts, 3 times higher if relaxed).
- Nuclear effects in hadronization at small ν (LO plus QW, Arleo '03).



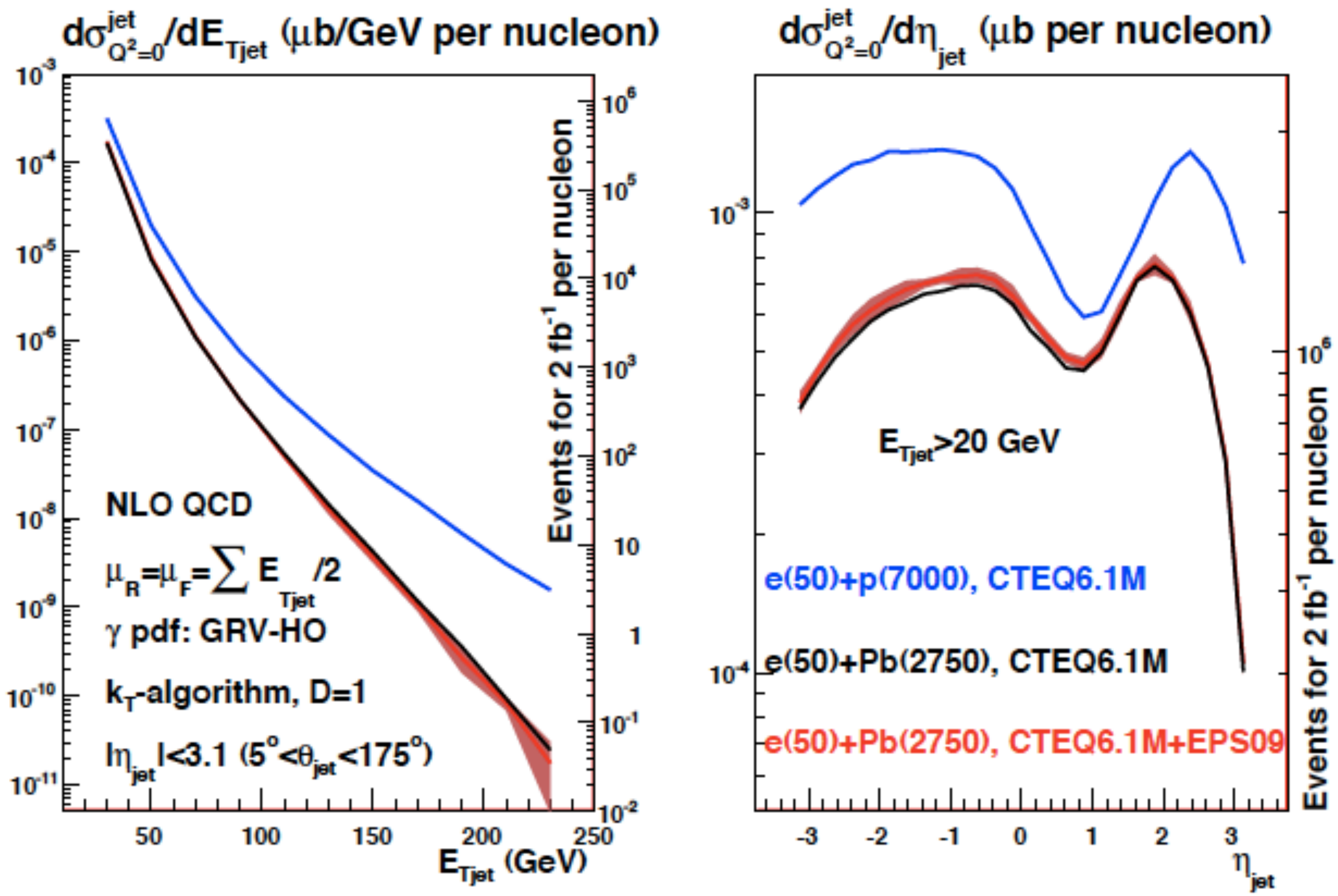


$$R_A^h(z,\nu) = \frac{1}{N_A^e}\frac{dN_A^h(z,\nu)}{d\nu\, dz} \Big/ \frac{1}{N_D^e}\frac{dN_D^h(z,\nu)}{d\nu\, dz}$$





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.

Outlook:

- With CERN and NuPECC mandate to further motivate the physics case and produce a TDR around 2015, several items have to be done/improved:

➜ Refine DGLAP fits with flavour decomposition (include neutrino data, relax assumptions) and optimized F_L scenarios, and LHC data.
➜ Monte Carlo generators!!!
➜ Studies on diffraction: separation of coherent from incoherent, ndPDFs, dijets,...
➜ Large x, EW bosons.
➜ Nuclear GPDs: nuclear DVCS etc.
➜ eD.
➜ Jet reconstruction, angular decorrelation...
➜ ...

→ Cooperation with EIC in some of these items desirable.

Outlook:

- With CERN and NuPECC mar
physics case and produce a TDR
be done/improved:

➜ Refine DGLAP fits with flavo
data, relax assumptions) and opti
➜ Monte Carlo generators!!!
➜ Studies on diffraction: separat
ndPDFs, dijets,...
➜ Large x, EW bosons.
➜ Nuclear GPDs: nuclear DVCS
➜ eD.
➜ Jet reconstruction, angular de
➜ ...

→ Cooperation with EIC in som

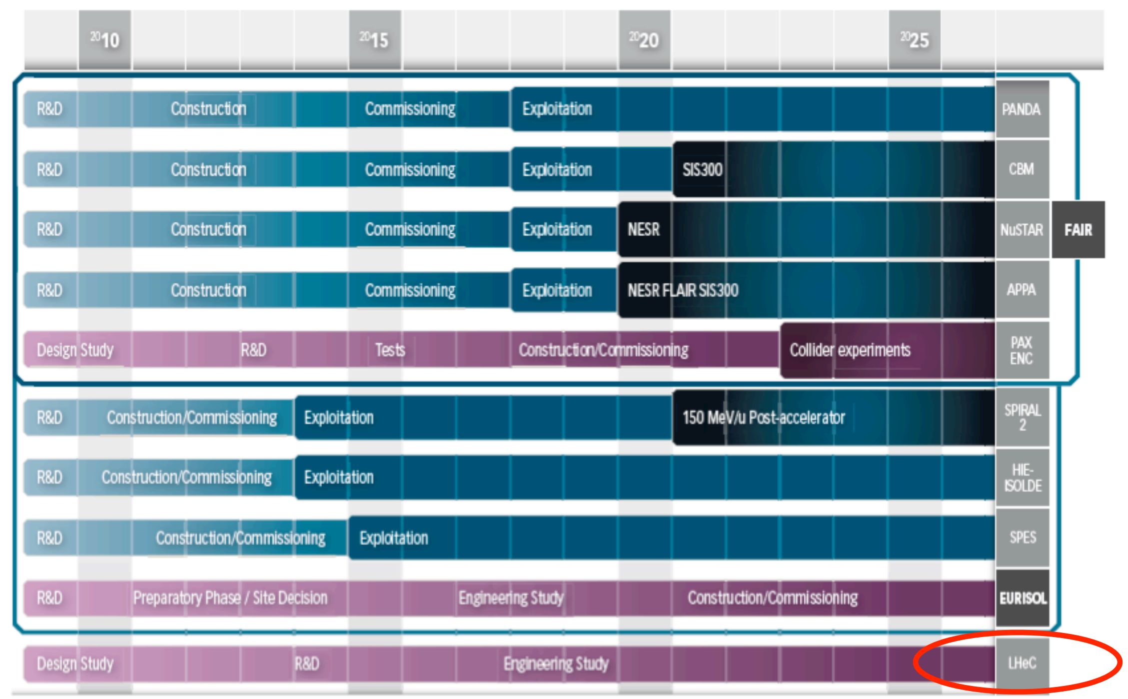
2. Recommendations and Roadmap

NuPECC LRP

EURISOL in future updates of the ESFRI list, based on the successful EURISOL Design Study in FP6.
- The Technical Design Study for intense radioactive ion beams at ISOL@MYRRHA.
- The Technical Design Study for a polarised proton-antiproton, PAX, and an electron-nucleon/ion collider, ENC, at FAIR.
- The Technical Design Study for a high-energy electron-proton/ion collider, LHeC, at CERN.
- The inclusion of Nuclear Physics programmes at the multi-purpose facilities ELI and ESS.

2.2 Facilities Roadmap

We present below the roadmap for building new large-scale Nuclear Physics research infrastructures in Europe. The time span ranges until the middle of the next decade. Facilities whose first phases have already been approved are coloured in blue, future upgrades thereof in dark blue. The ISOL facilities SPIRAL 2, HIE-ISOLDE and SPES are designated to lead to EURISOL. PAX and the ENC at FAIR, EURISOL and the LHeC at CERN are still in the design or R&D phase. They are coloured in purple.



Roadmap for New Large Scale Facilities.

20 | Perspectives of Nuclear Physics in Europe – NuPECC Long Range Plan 2010

Outlook:

- With CERN and NuPECC mandate to further motivate the physics case and produce a TDR around 2015, several items have to be done/improved:

➜ Refine DGLAP fits with flavour decomposition (include neutrino data, relax assumptions) and optimized F_L scenarios, and LHC data.
➜ Monte Carlo generators!!!
➜ Studies on diffraction: separation of coherent from incoherent, ndPDFs, dijets,...
➜ Large x, EW bosons.
➜ Nuclear GPDs: nuclear DVCS etc.
➜ eD.
➜ Jet reconstruction, angular decorrelation...
➜ ...

→ Cooperation with EIC in some of these items desirable.

Outlook:

- With CERN and NuPECC mandate to further motivate the physics case and produce a TDR around 2015, several items have to be done/improved:

➜ Refine DGLAP fits with flavour decomposition (include neutrino data, relax assumptions) and optimized F_L scenarios, and LHC data.
➜ Monte Carlo generators!!!
➜ Studies on diffraction: separation of coherent from incoherent, ndPDFs, dijets,...
➜ Large x, EW bosons.
➜ Nuclear GPDs: nuclear DVCS etc.
➜ eD.
➜ Jet reconstruction, angular decorrelation...
➜ ...

Thanks for your attention!

→ Cooperation with EIC in some of these items desirable.