XXIst International Workshop on Deep-Inelastic Scattering and Related Subjects
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Low-x Physics at the LHeC

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for the LHeC Study group, http://cern.ch/lhec

Contents:

1. Status and motivation.

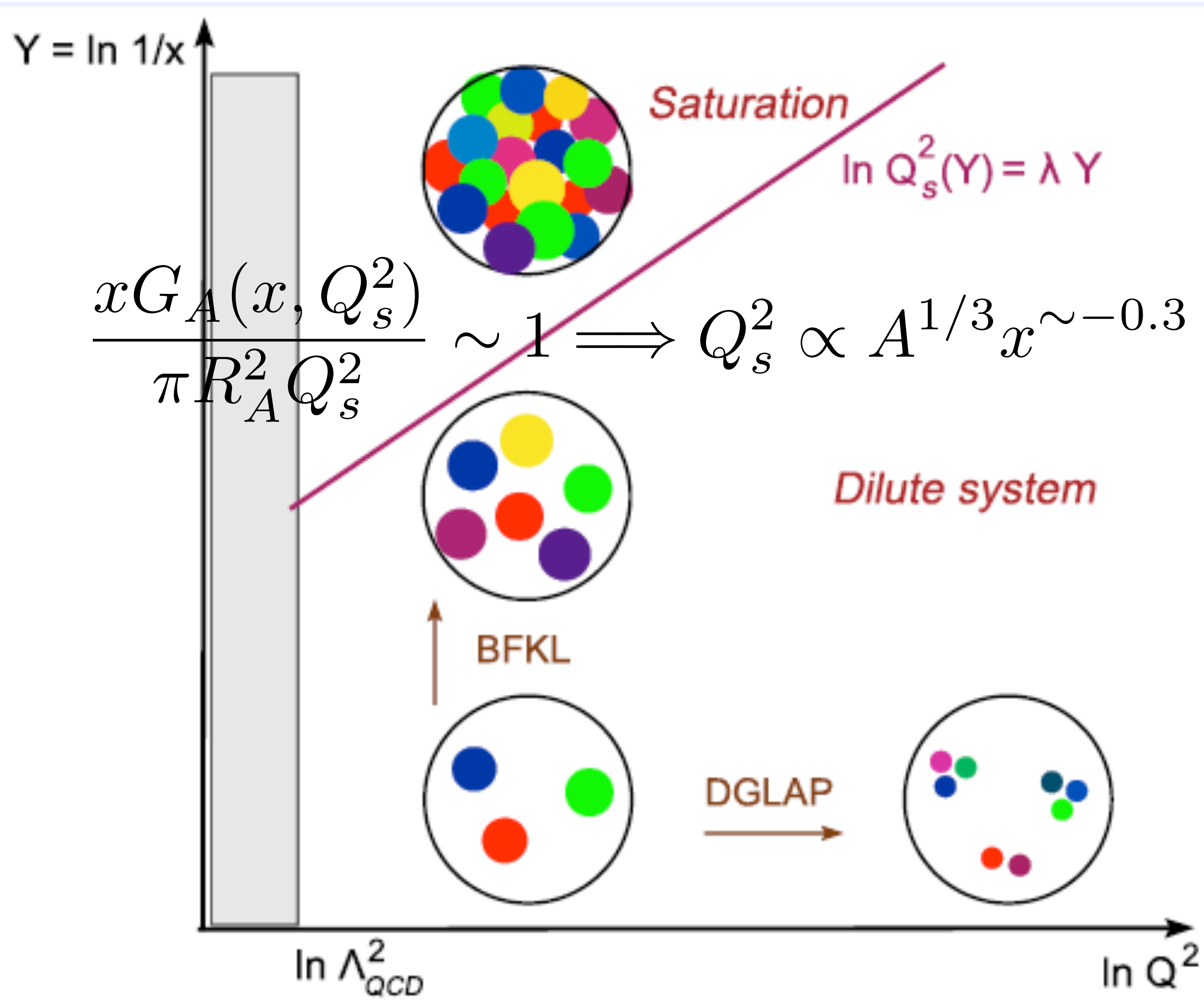
2. The Large Hadron Electron Collider.

3. Physics case at low x:
    - Inclusive measurements and small-x glue.
    - Inclusive diffraction.
    - Exclusive diffraction.
    - Final states: dynamics of QCD radiation and hadronization.

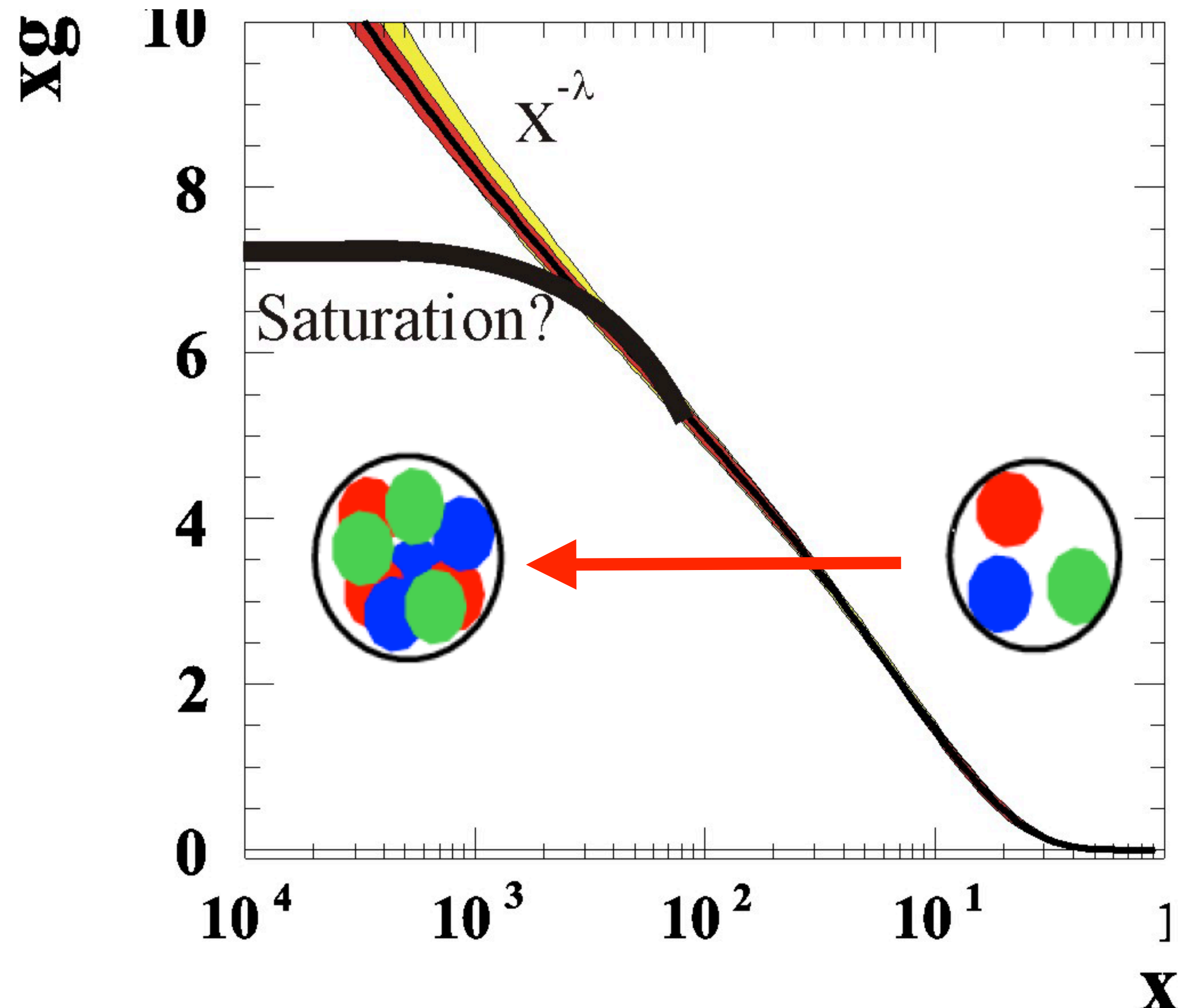
4. Summary.

CDR, arXiv:1206.2913, J. Phys. G 39 (2012) 075001;
arXiv:1211.4831; arXiv:1211.5102;
talks by Behnke, Erazmus and Radescu (plenaries); Bruening, Deshpande (WG6/7), Klein, Lamont, Machado, Mellado, Paukkunen (WG1/7) and South

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 ($gg \rightarrow g$, $\Delta[xg] \propto xg - k(xg)^2$).

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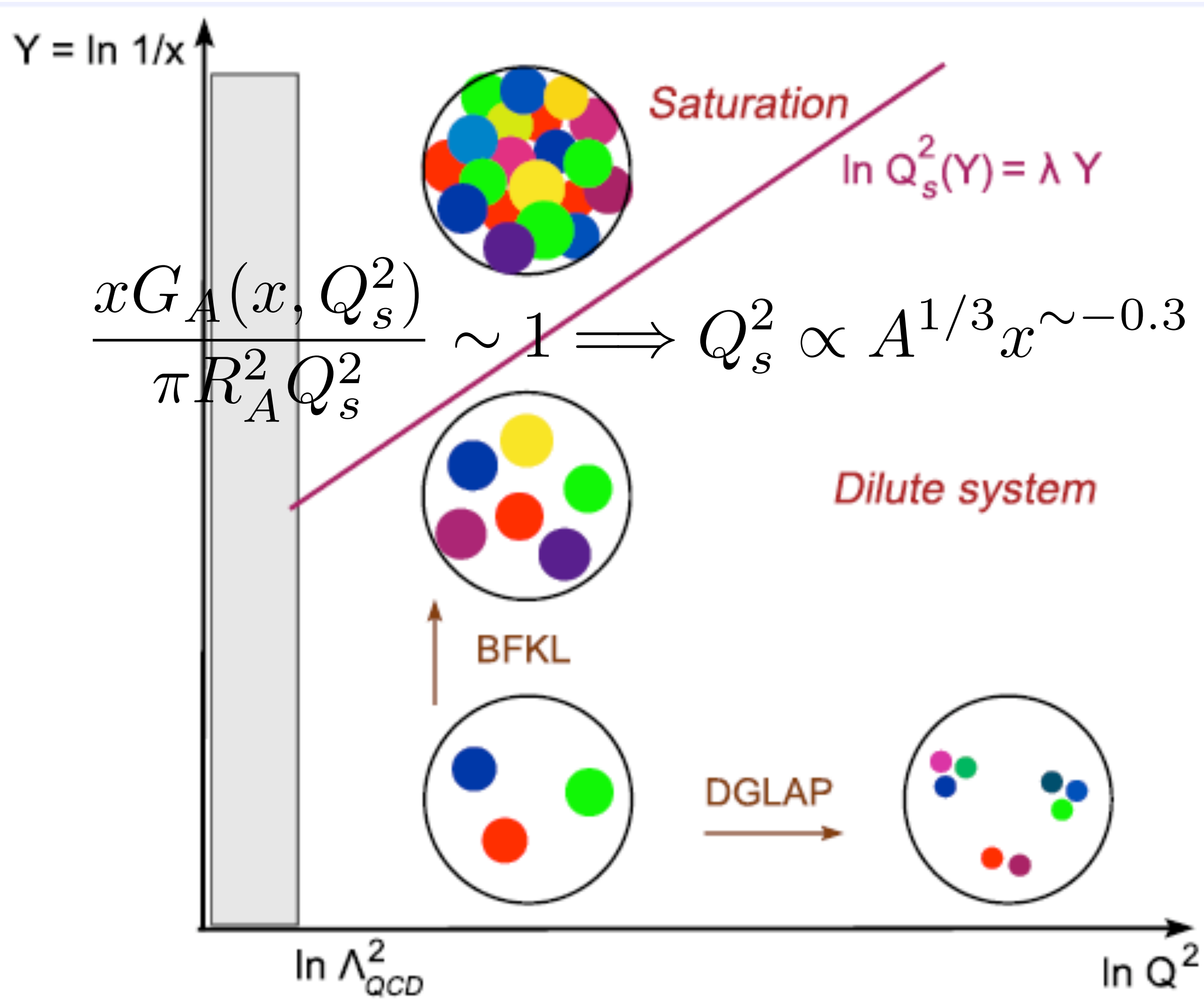

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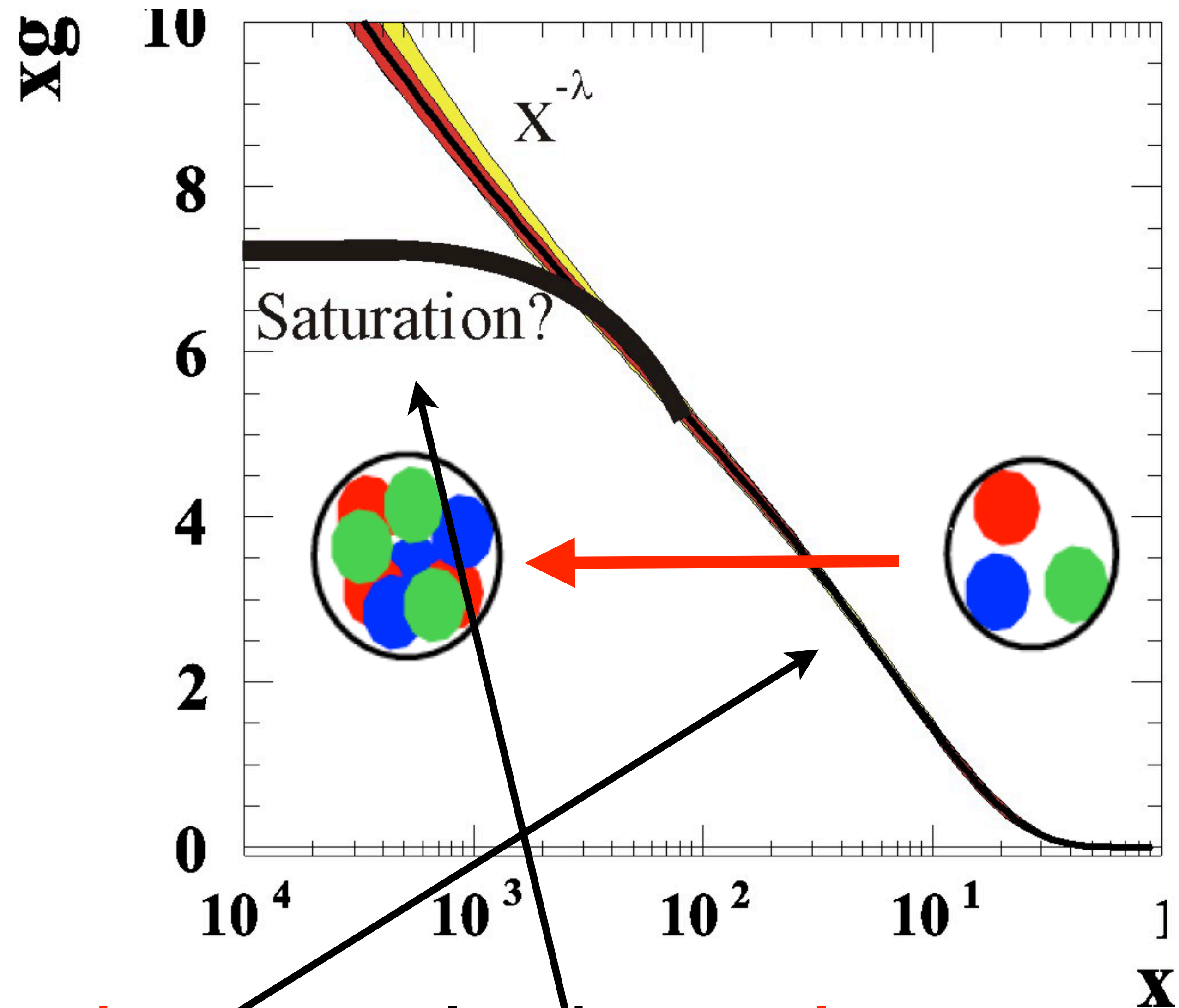

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Status of small-x physics:

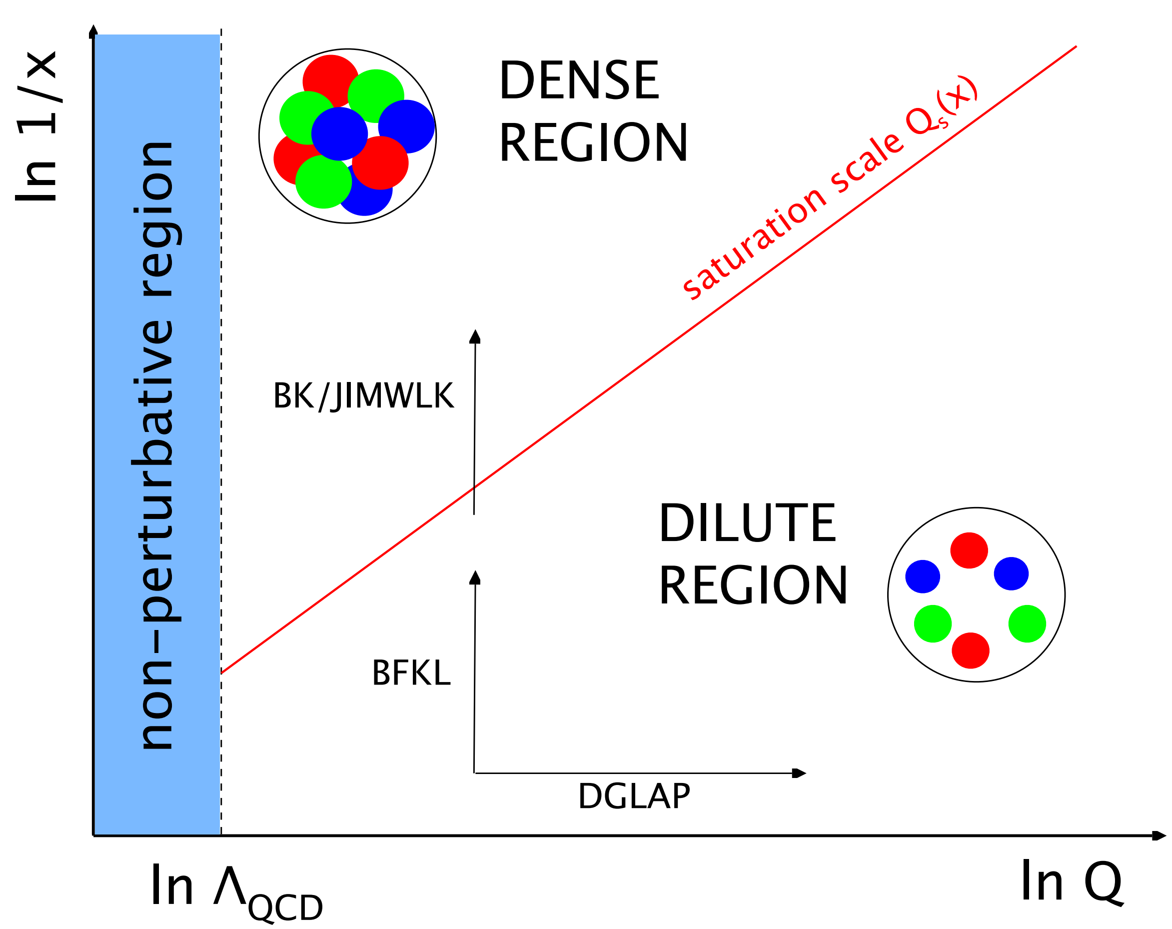
- Three pQCD-based alternatives to describe small-x ep and eA data (differences at moderate $Q^2 (> \Lambda^2_{QCD})$ and small x):

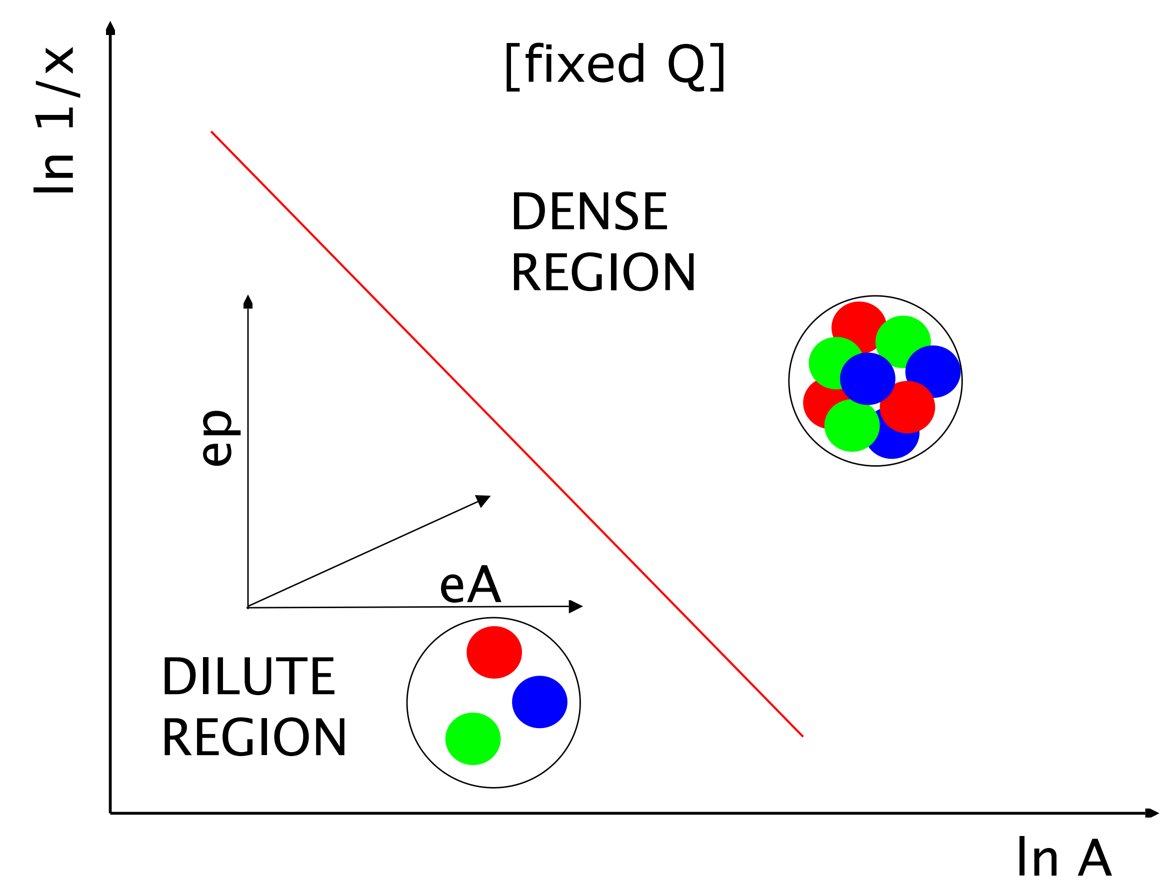
→ DGLAP evolution (fixed order perturbation theory).

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

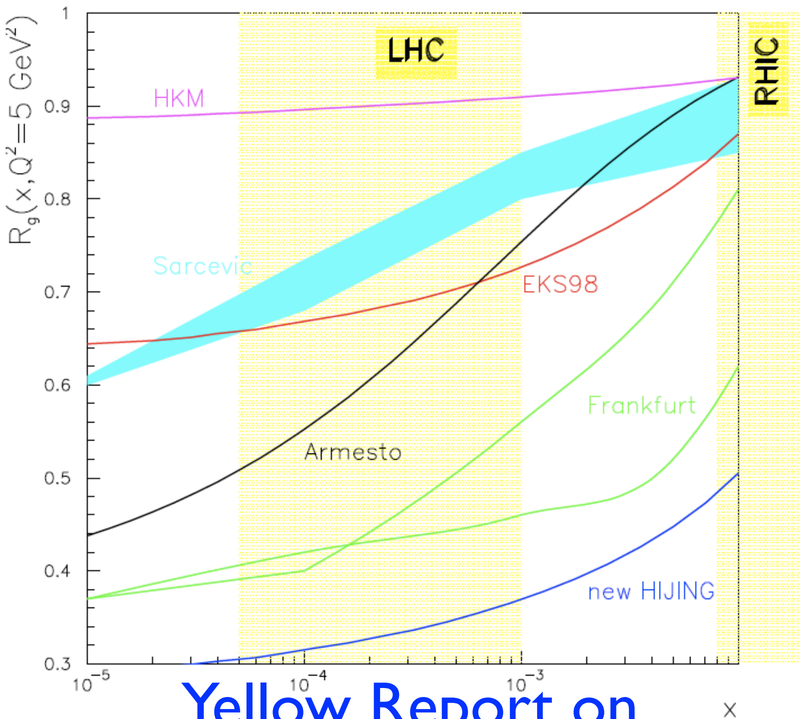
→ Saturation (CGC, dipole models).

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





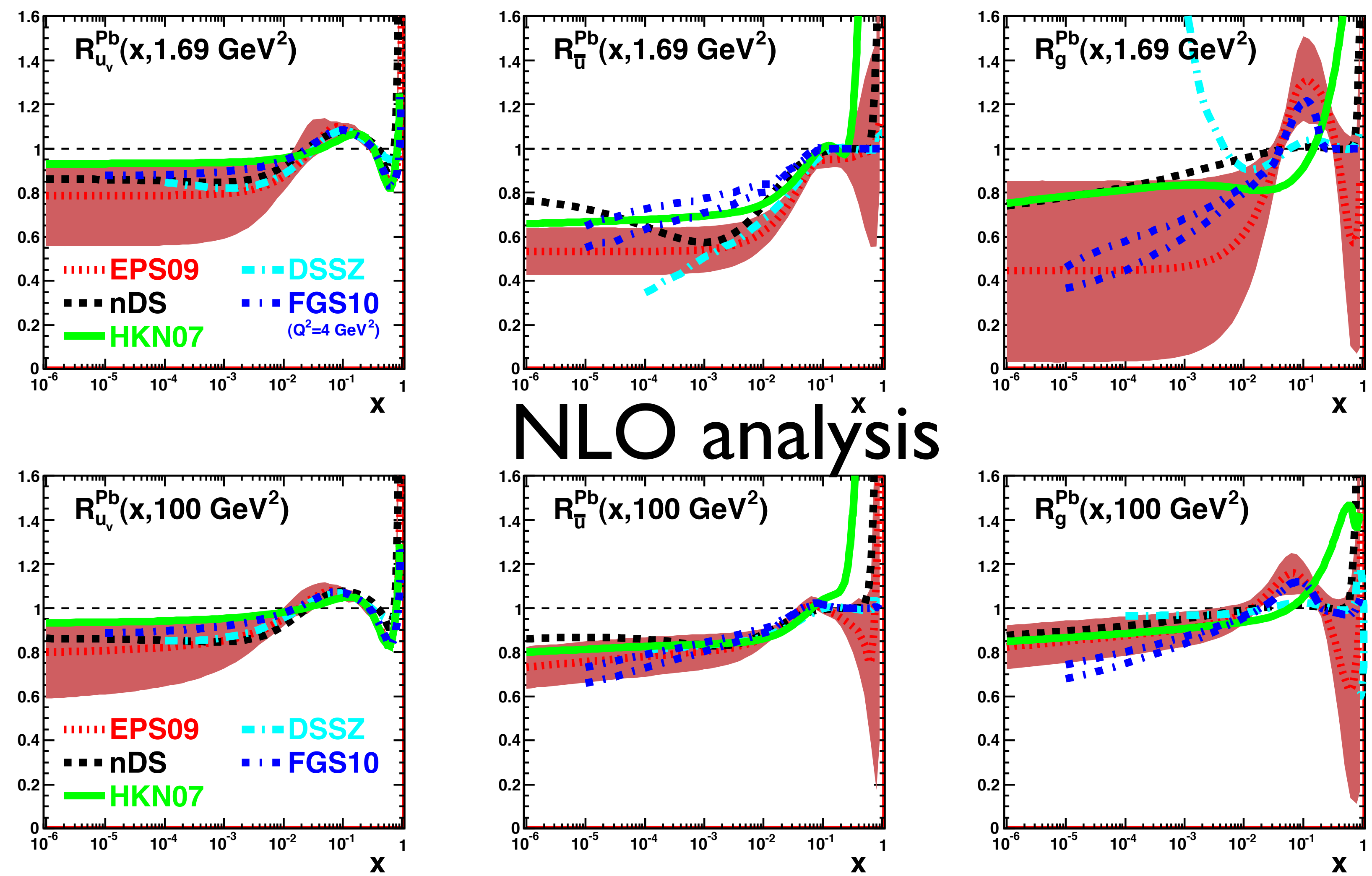
nPDFs: $R = \frac{f_{i/A}}{A f_{i/p}} \approx \frac{\text{measured}}{\text{expected if no nuclear effects}}$



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.

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



NLO analysis

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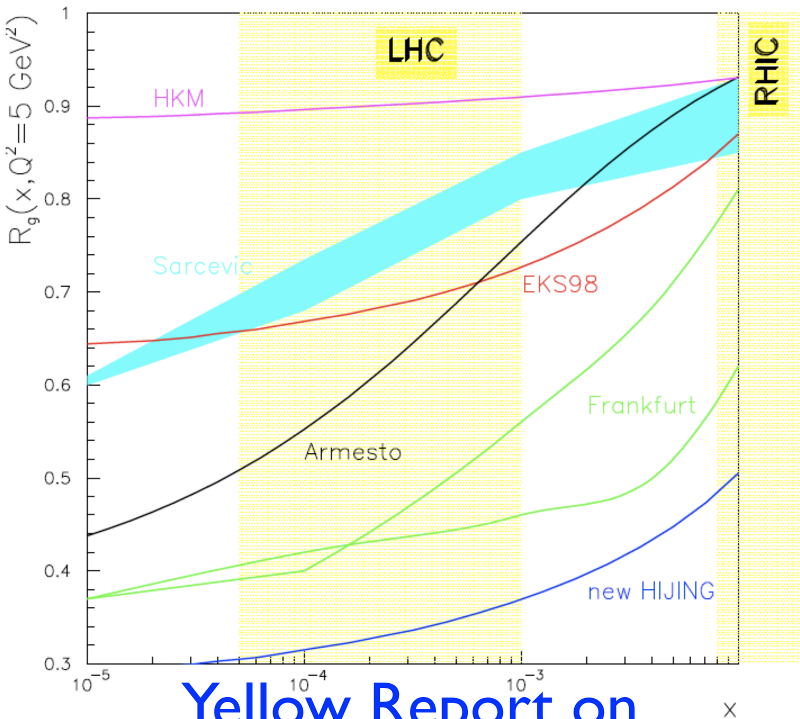

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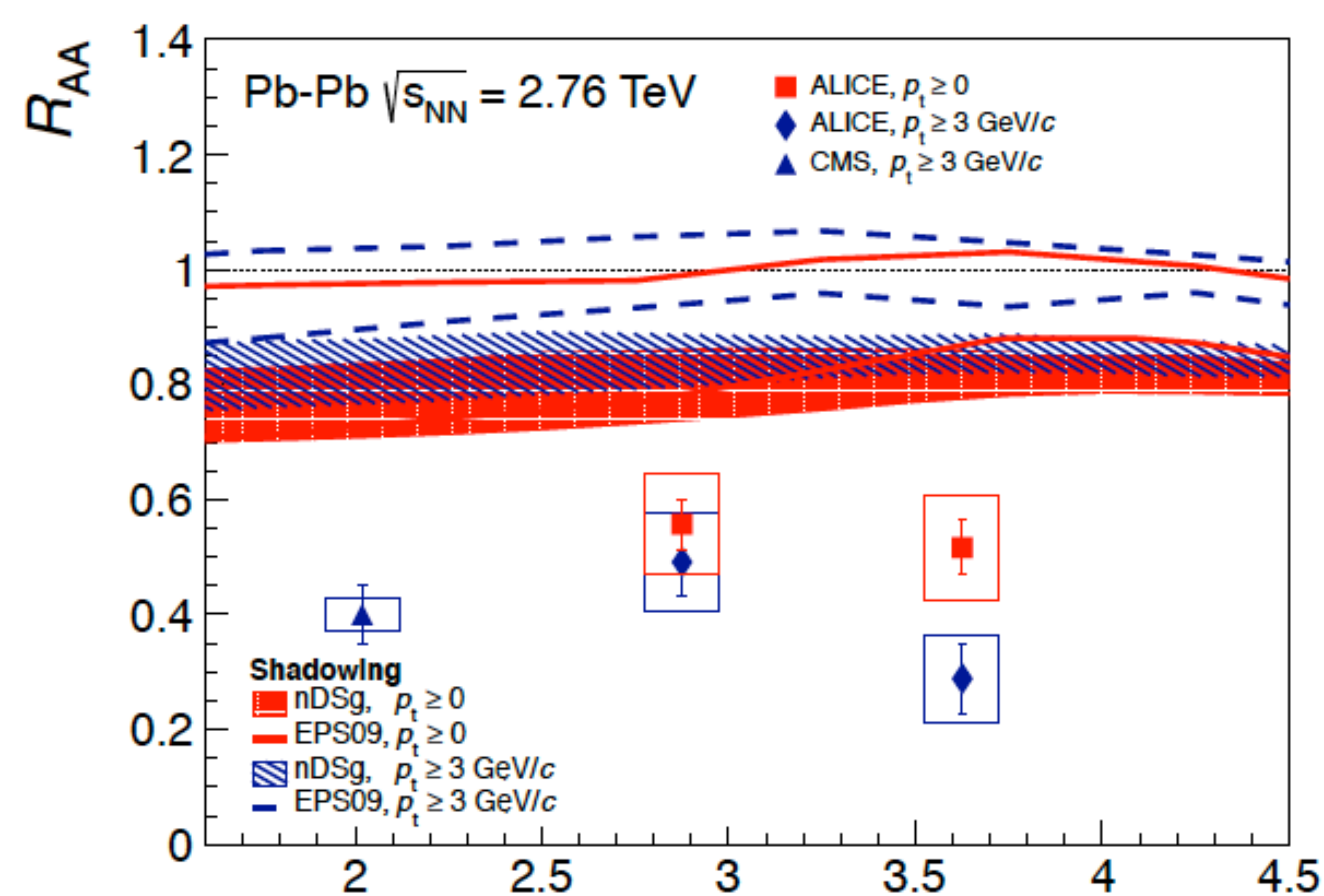
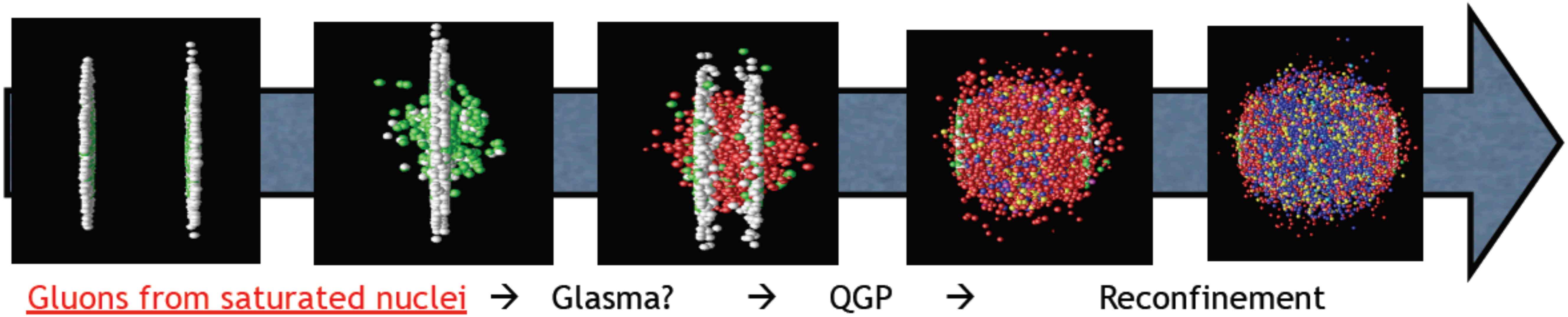


Inclusive J/ψ, 1202.1383

Relevance for the HI program:



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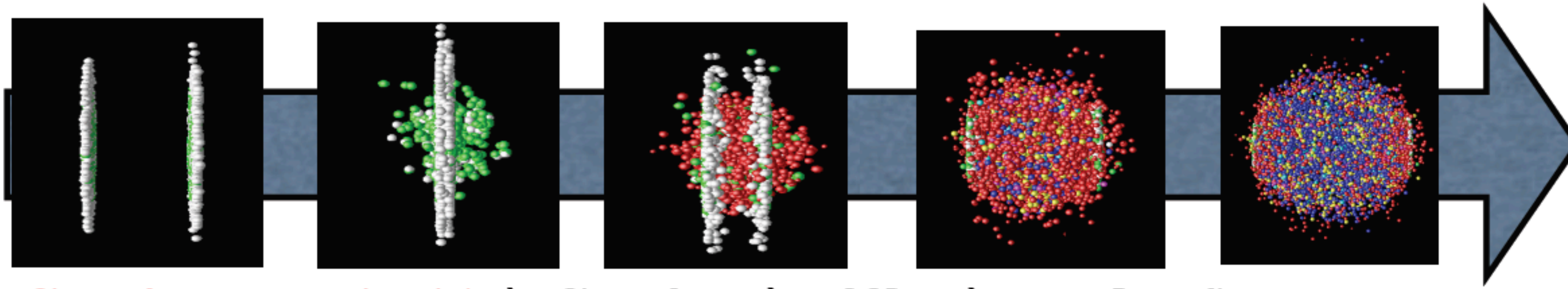
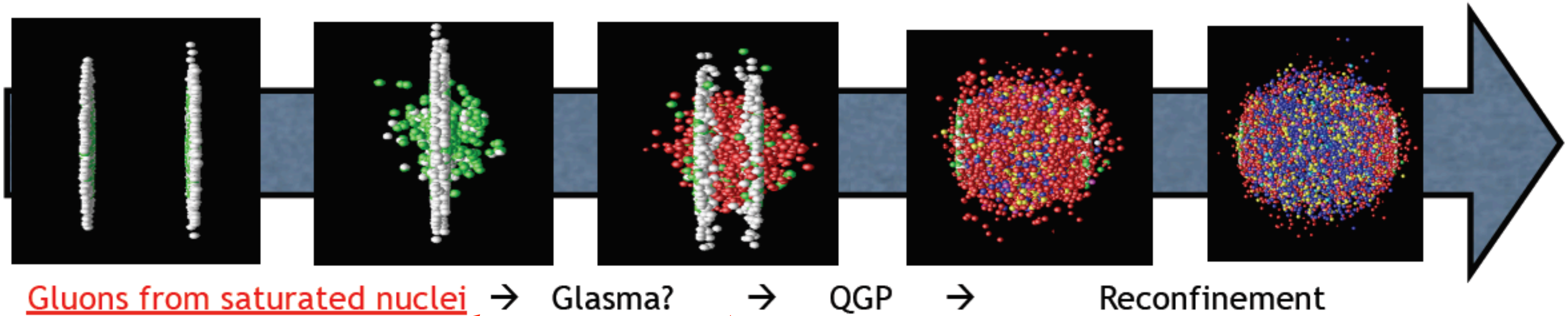


Gluons from saturated nuclei → Glasma? → QGP → Reconfinement

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

LHeC Relevance for the HI program:

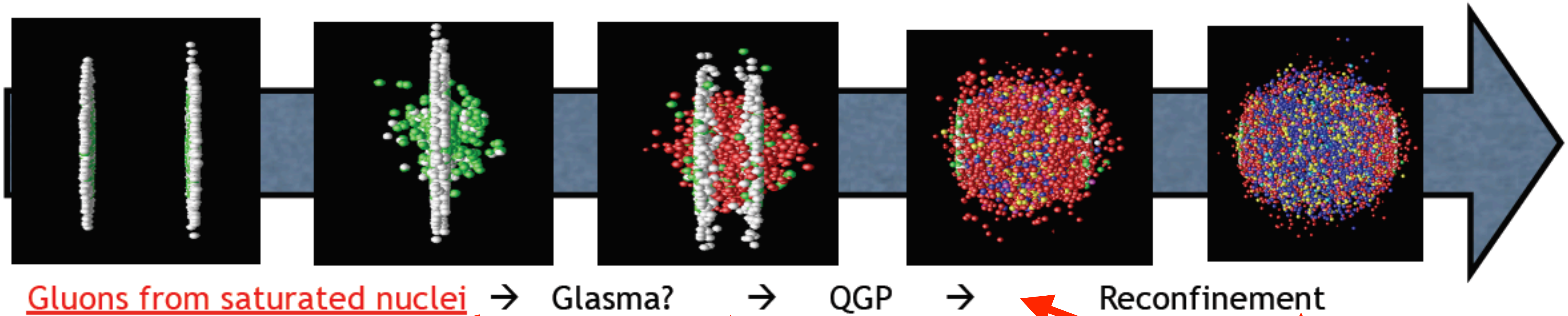


- Nuclear wave function at small x: nuclear structure functions.

- 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.

Relevance for the HI program:



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

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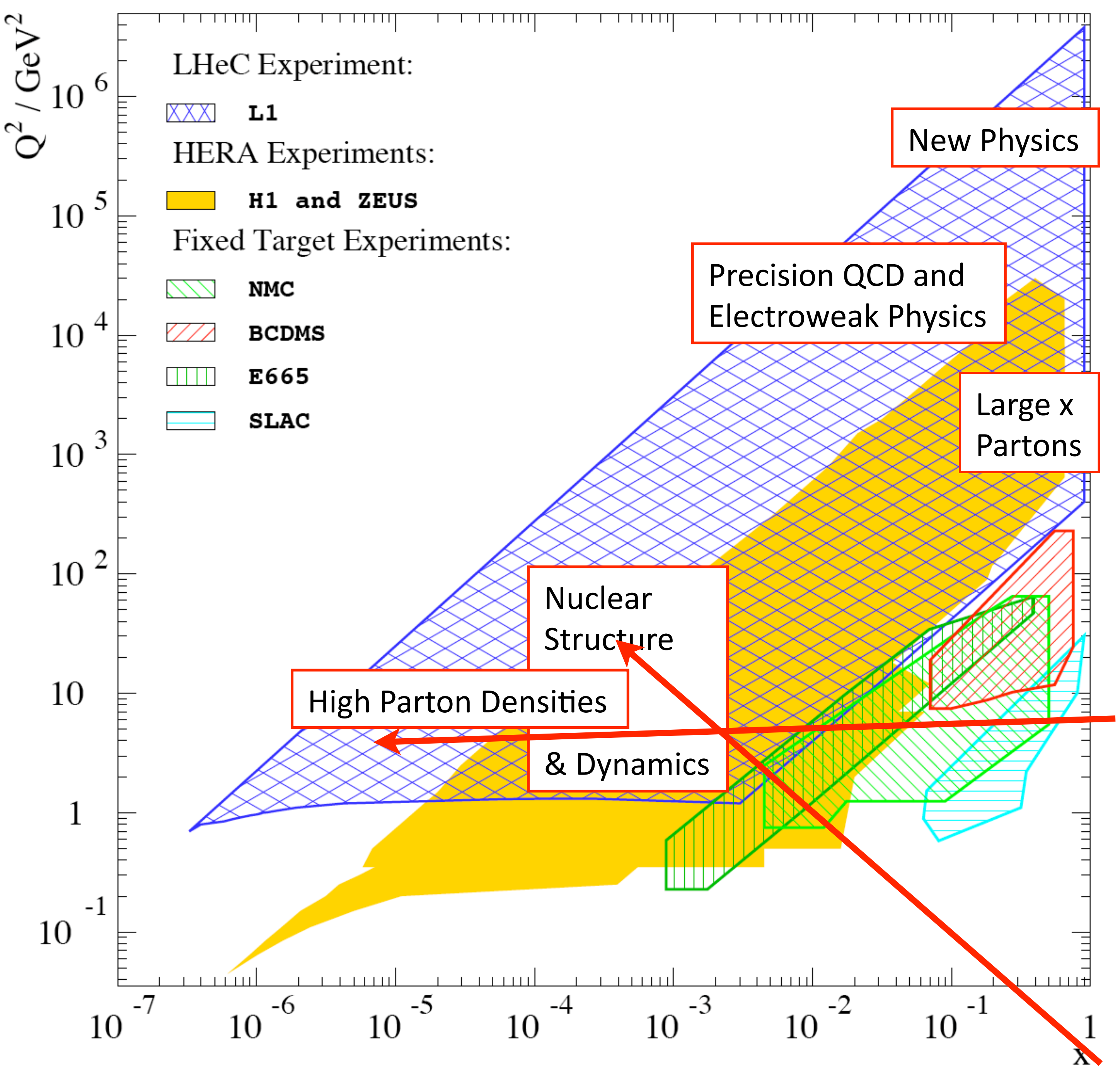
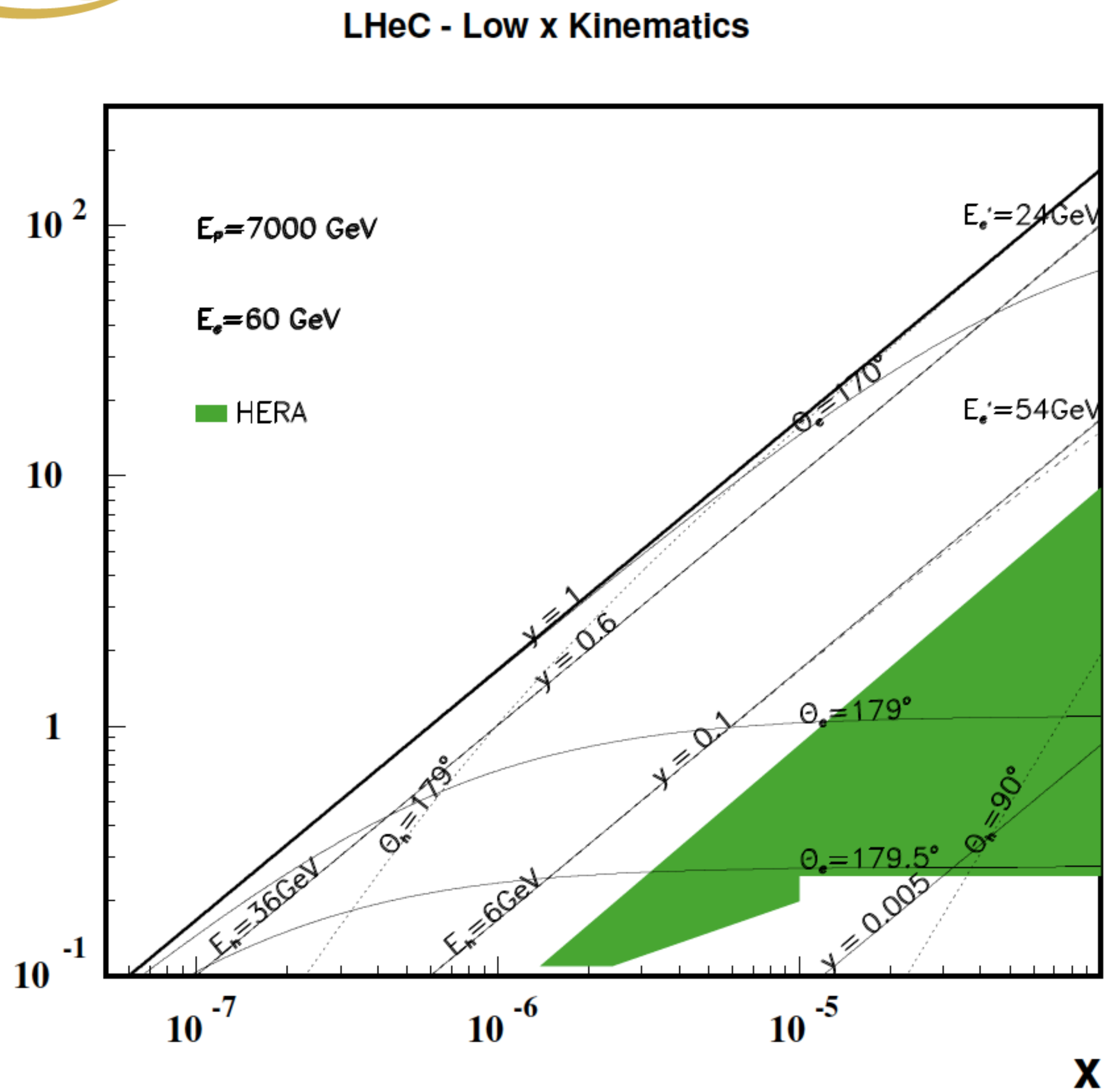
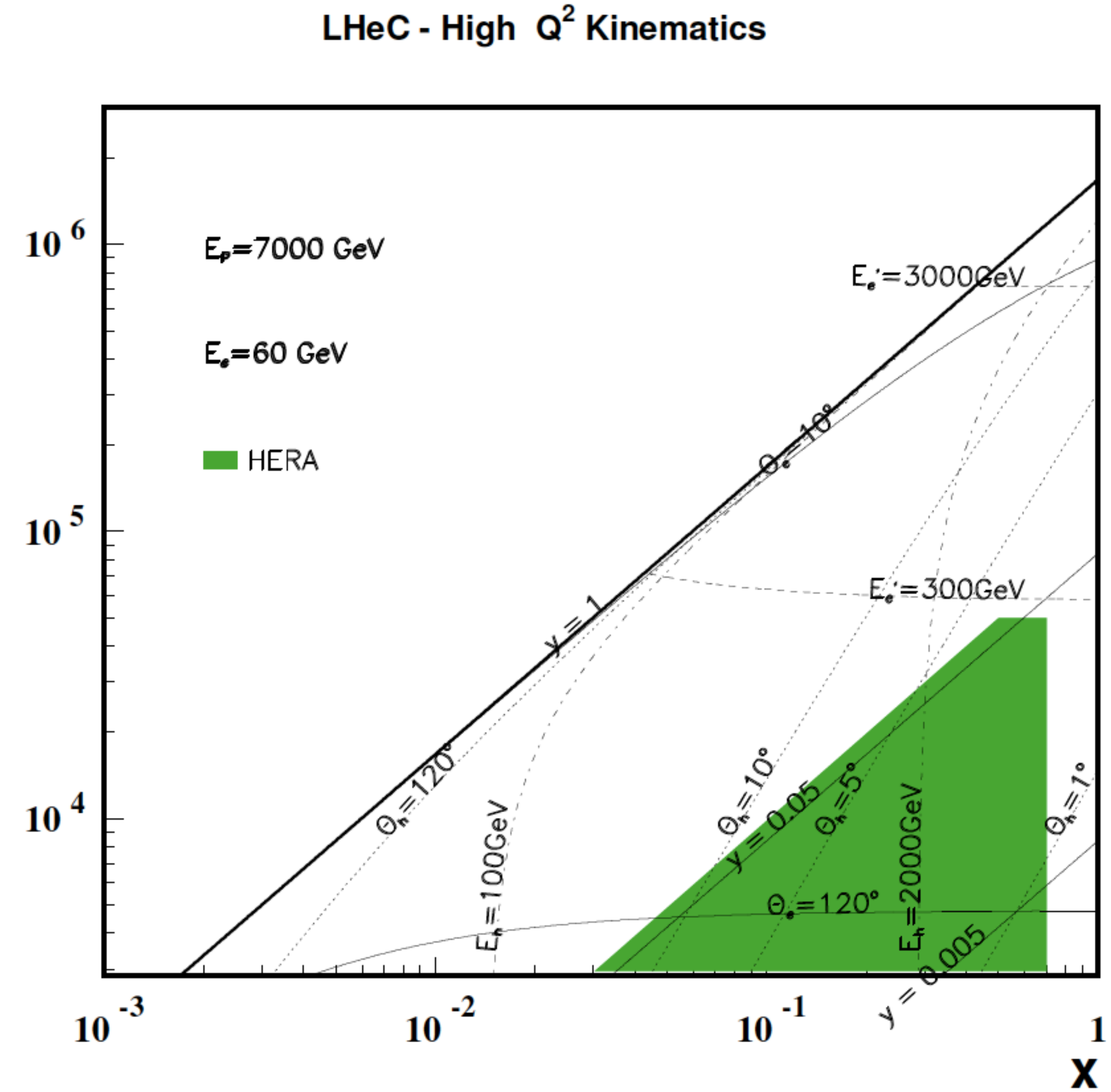
Physics goals:

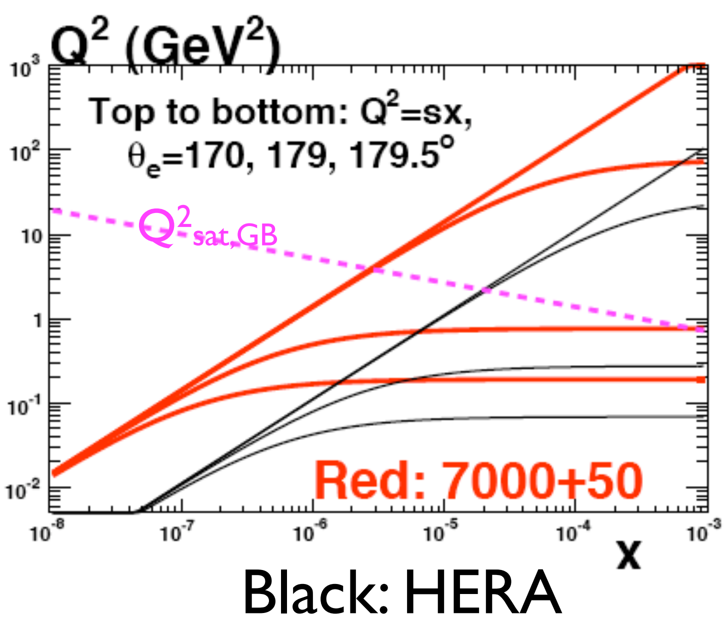


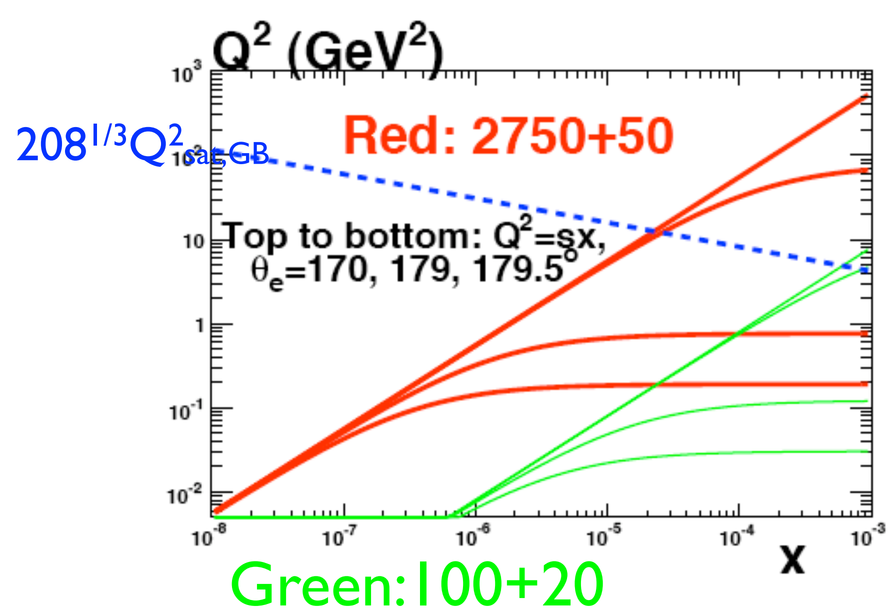
- Proton structure to a few 10^{-20} m: Q^2 lever arm.
- Precision QCD/EW physics.
- High-mass frontier (leptoquarks, excited fermions, contact interactions).
- Unambiguous access, in ep and eA, to a qualitatively novel regime of matter predicted by QCD.
- Substructure/parton dynamics inside nuclei with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

Kinematics:









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

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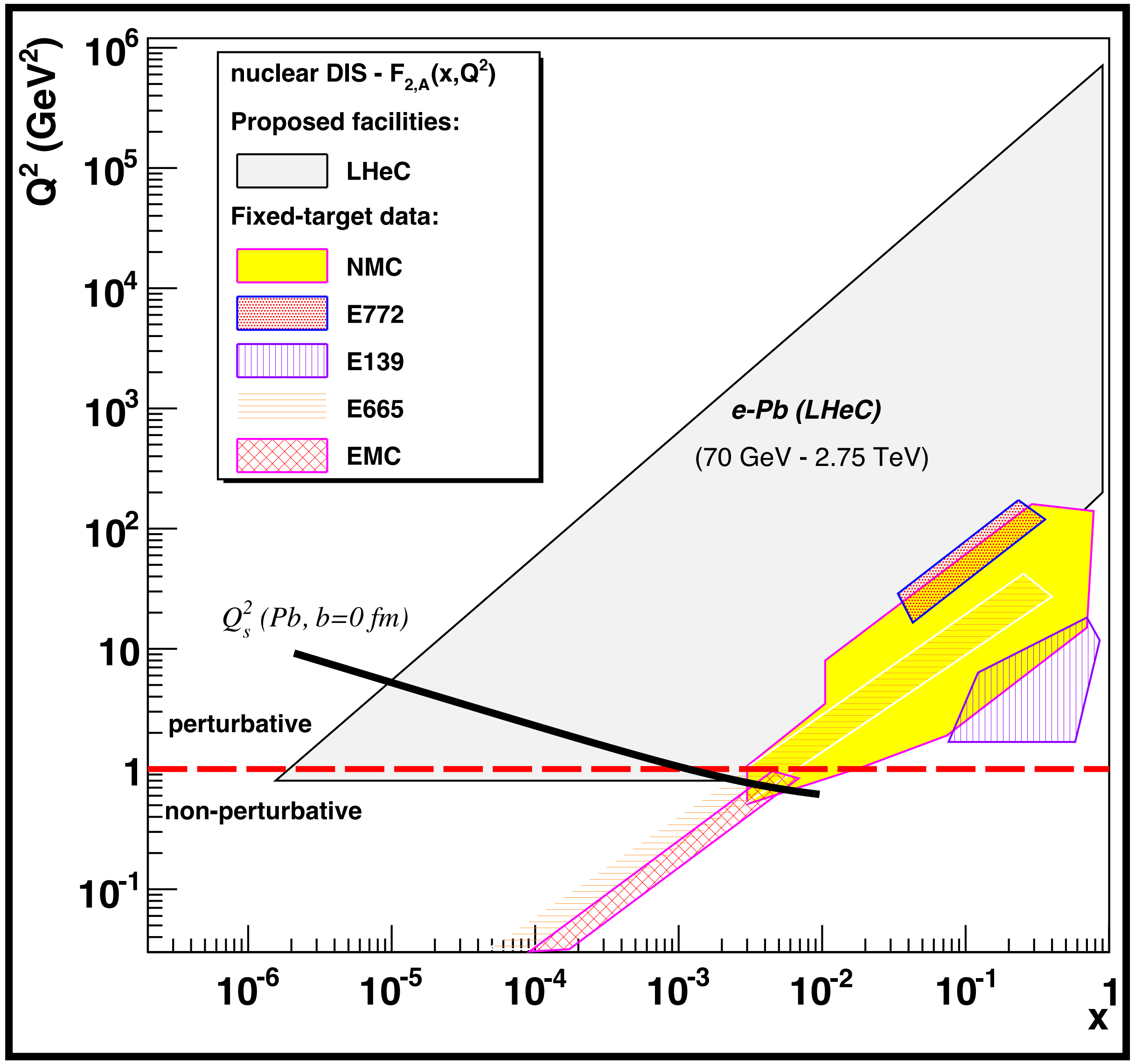
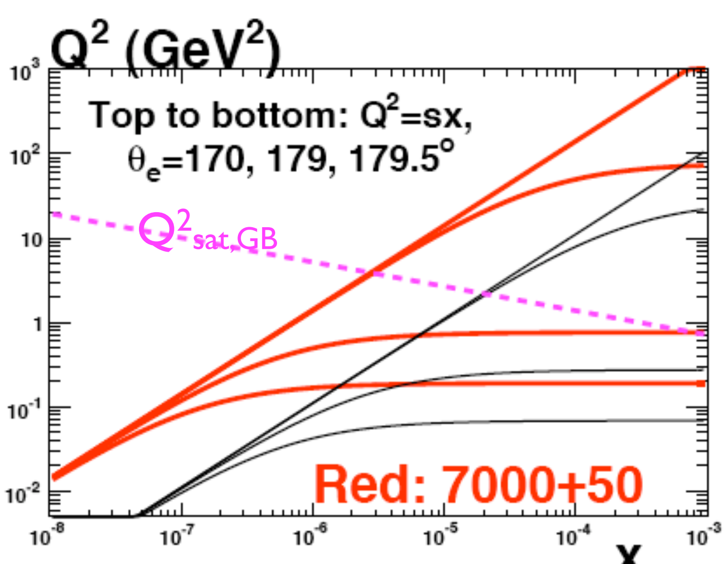
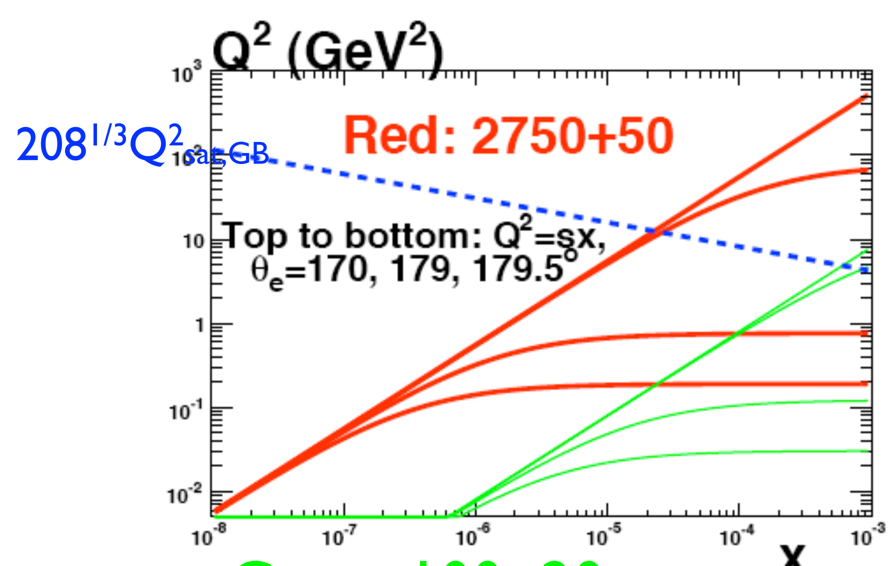




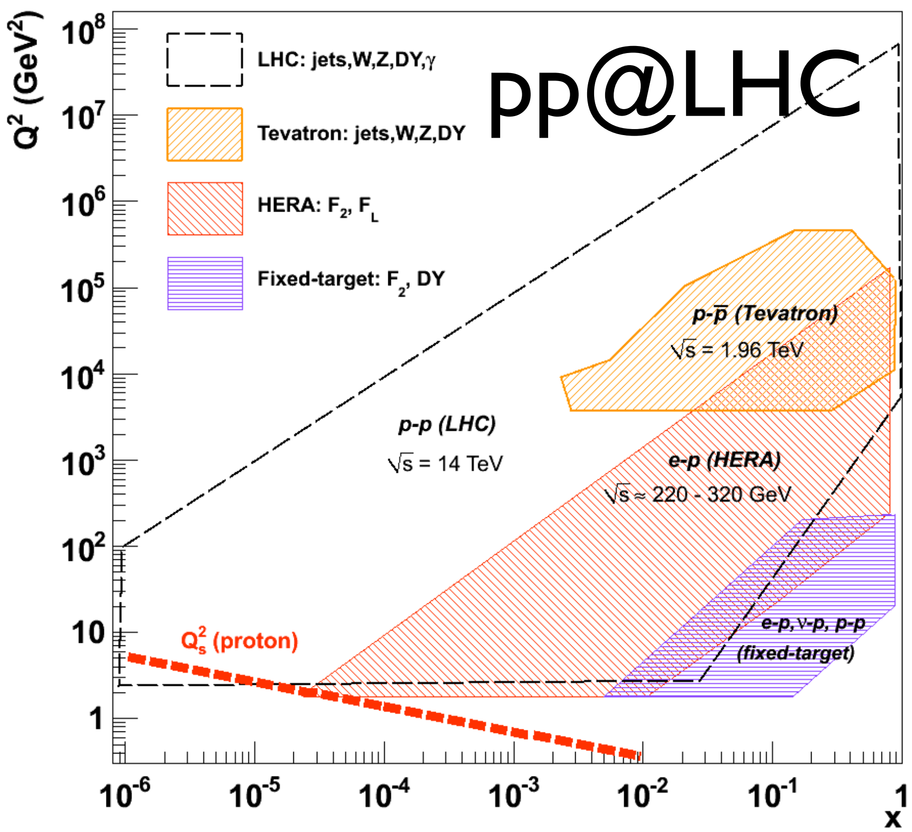
Black: HERA



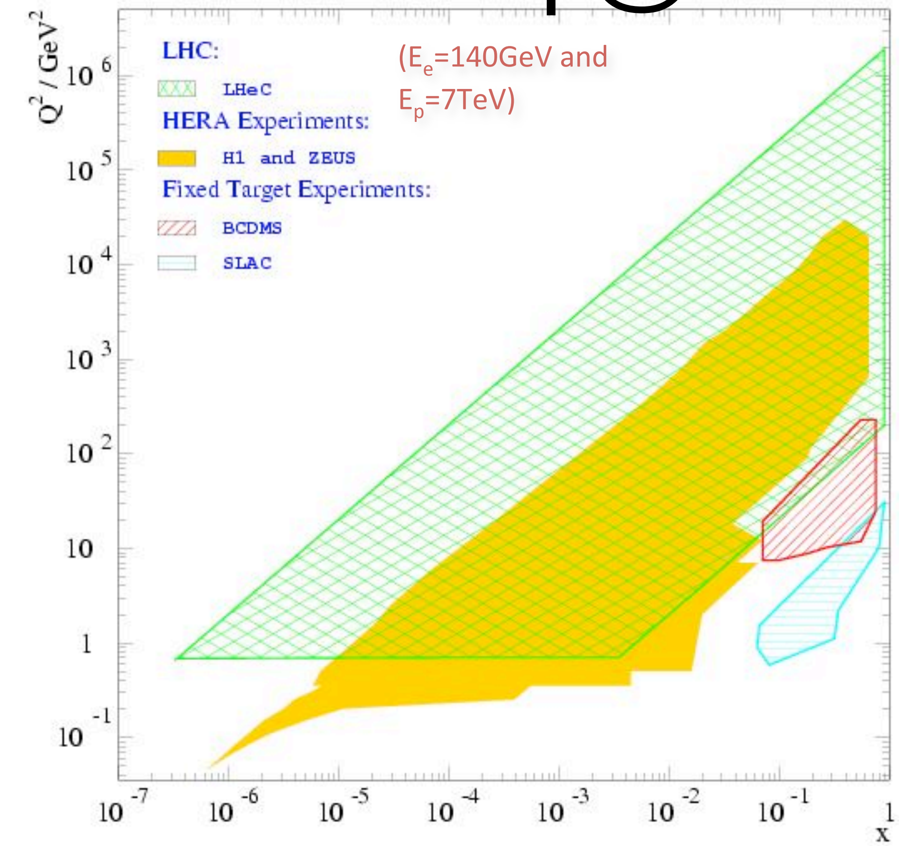
Green:100+20

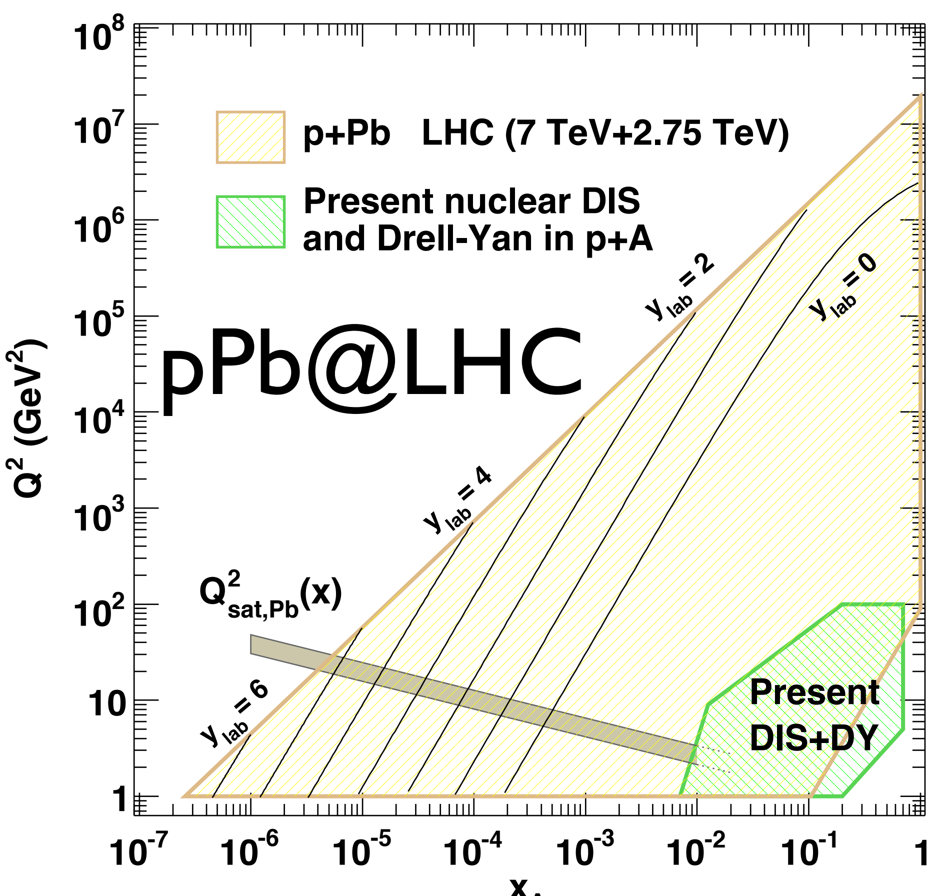
- Small-x demands 1 degree acceptance.
- Higher luminosity would benefit high-x and Q^2 studies.

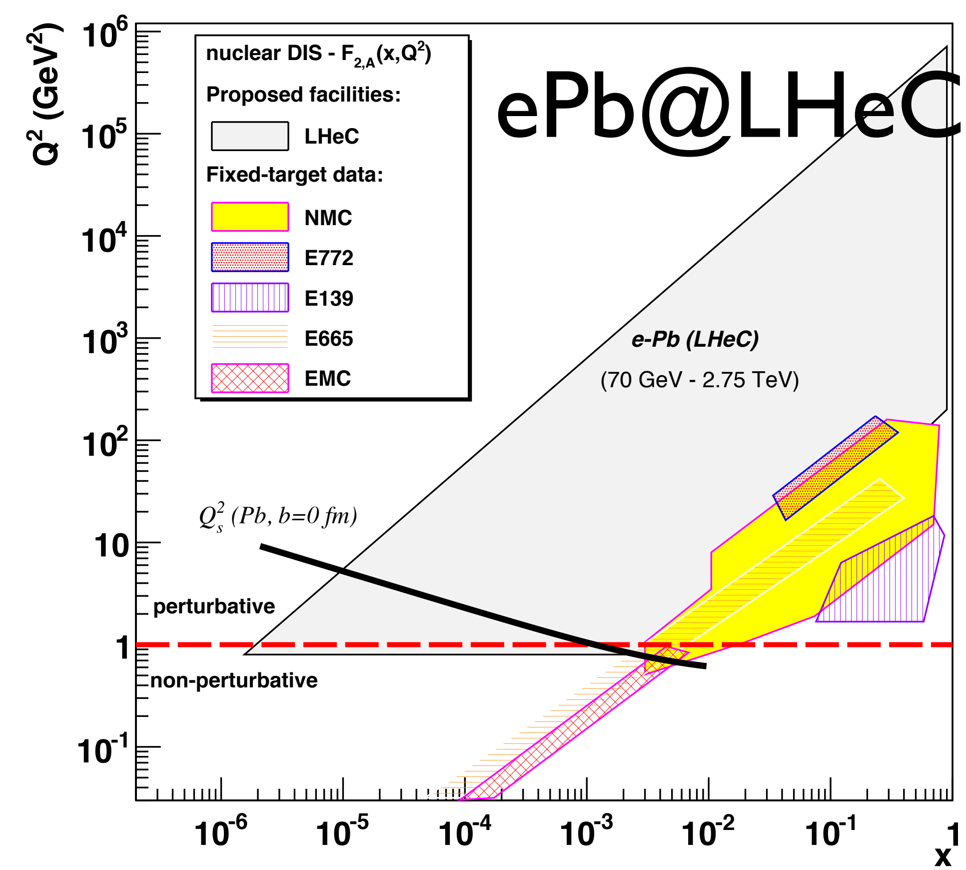
LHC vs. LHeC:



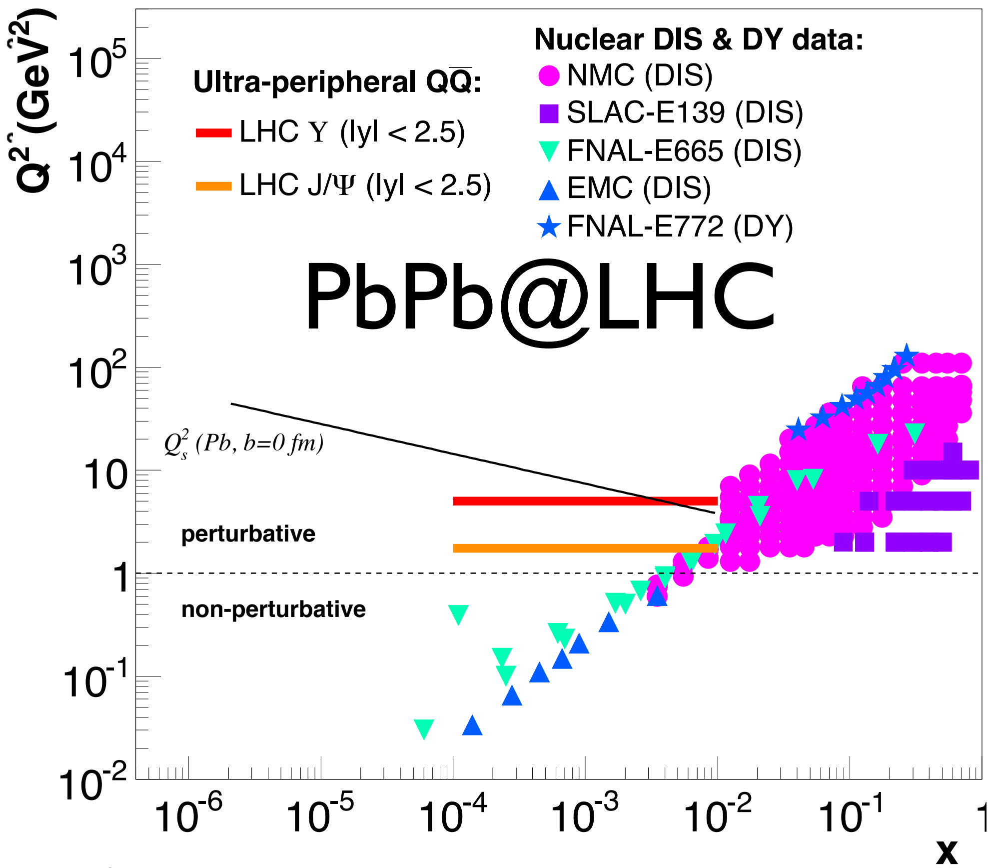
ep@LHeC

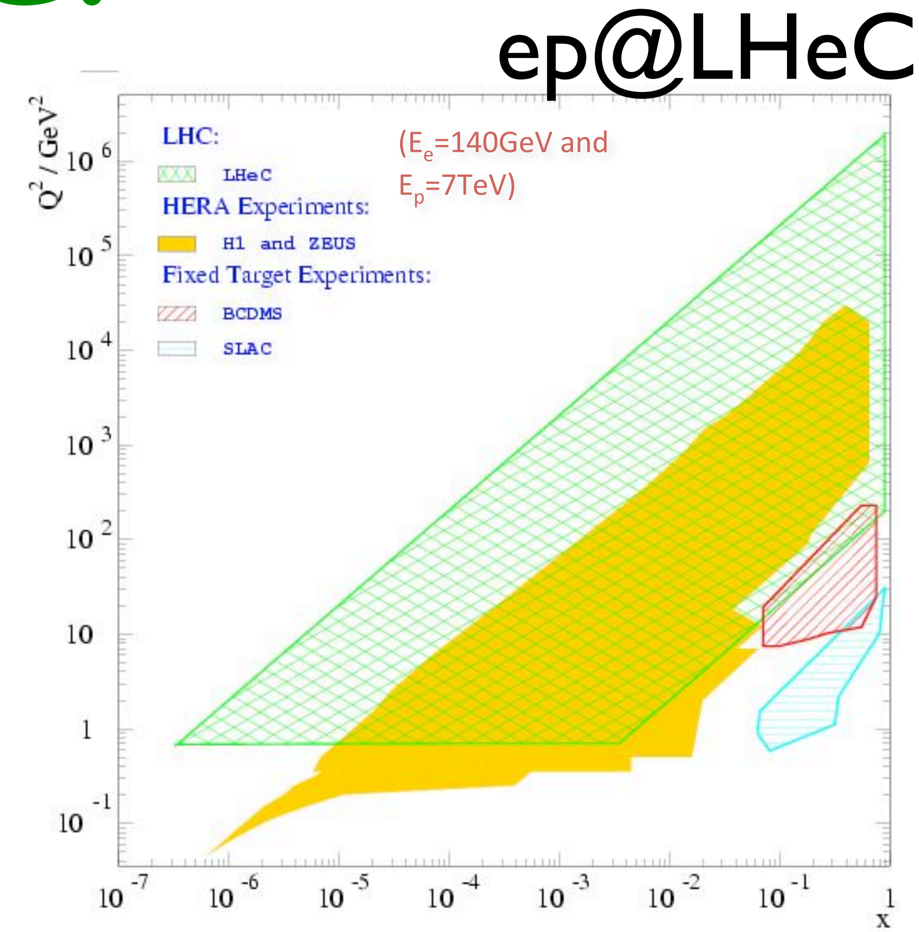


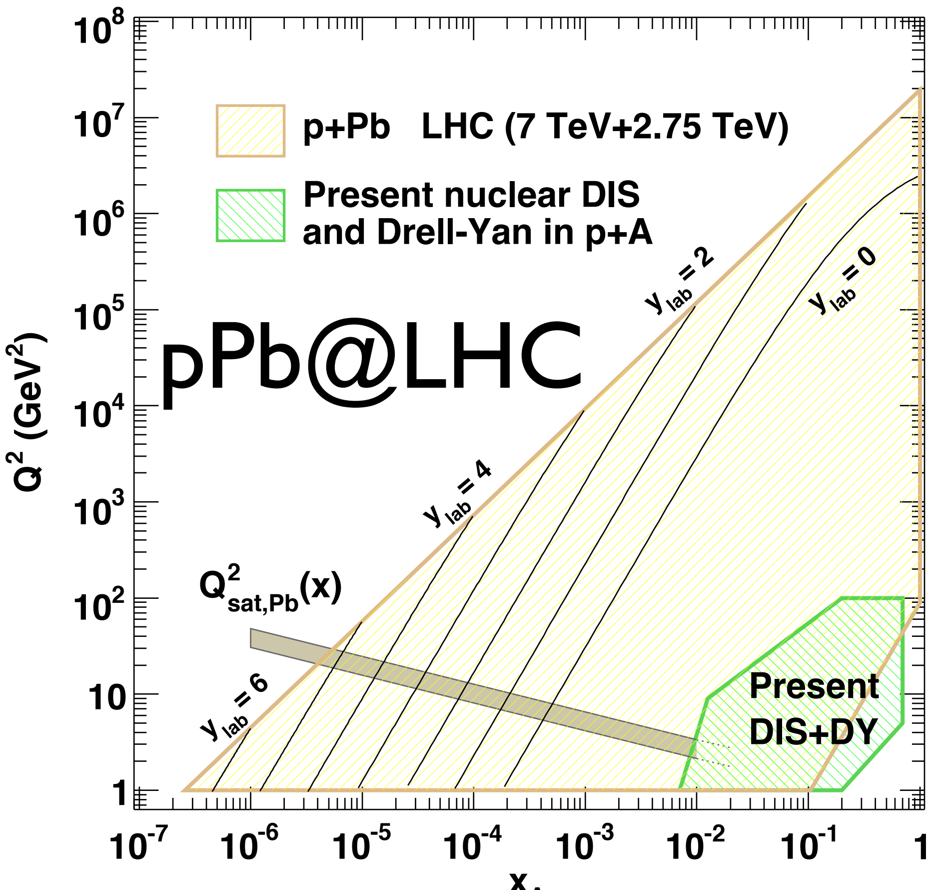


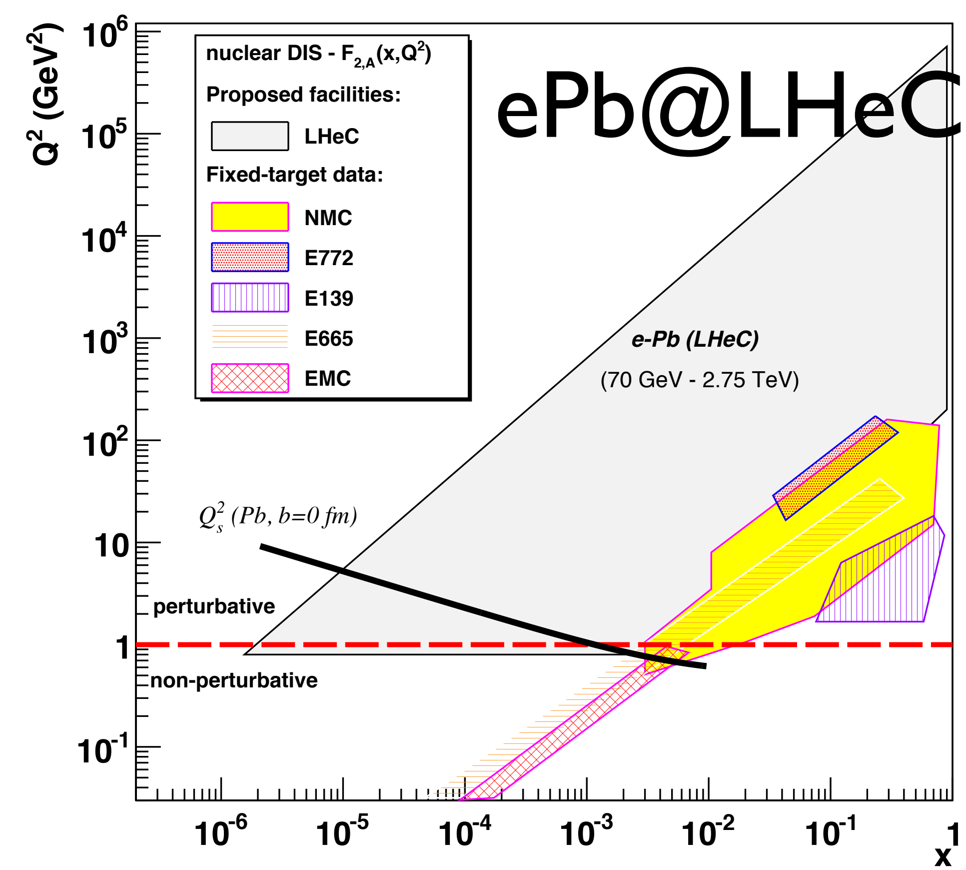


LHC vs. LHeC:

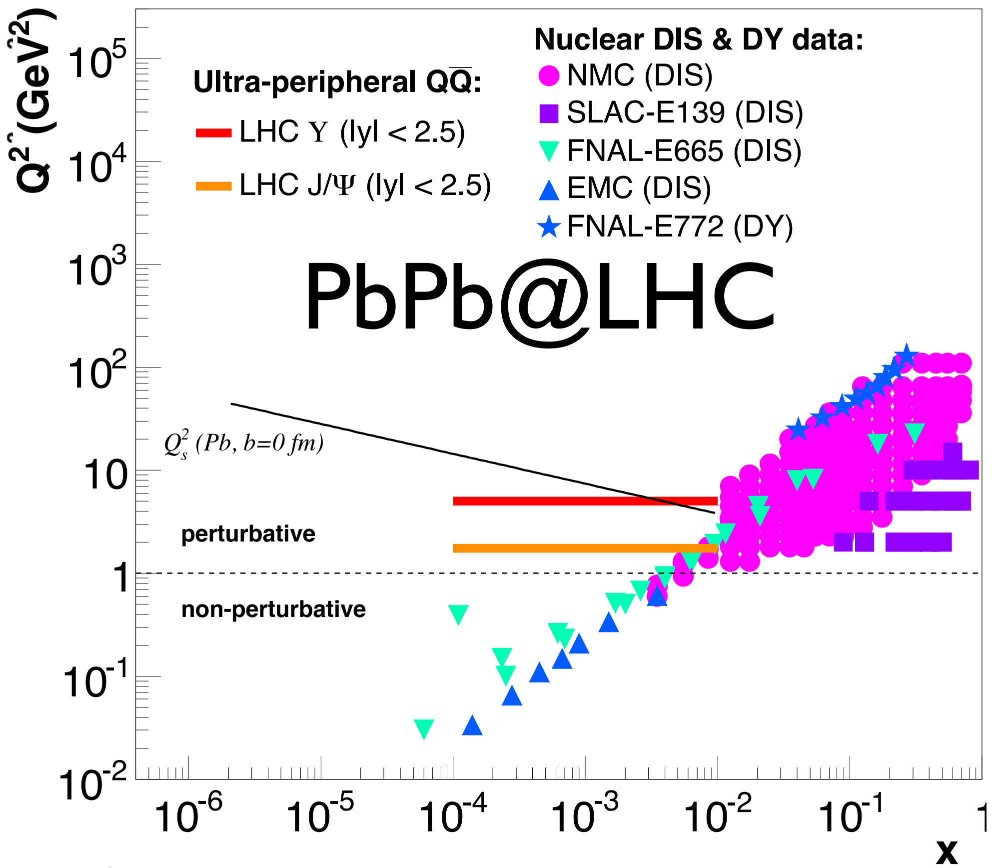

PbPb@LHC
Nuclear DIS & DY data:
NMC (DIS)
SLAC-E139 (DIS)
FNAL-E665 (DIS)
EMC (DIS)
FNAL-E772 (DY)
Ultra-peripheral QQ̄:
LHC Υ (|y| < 2.5)
LHC J/Ψ (|y| < 2.5)
Q_s^2 (Pb, b=0 fm)
perturbative
non-perturbative
Q^2 (GeV^2)
x

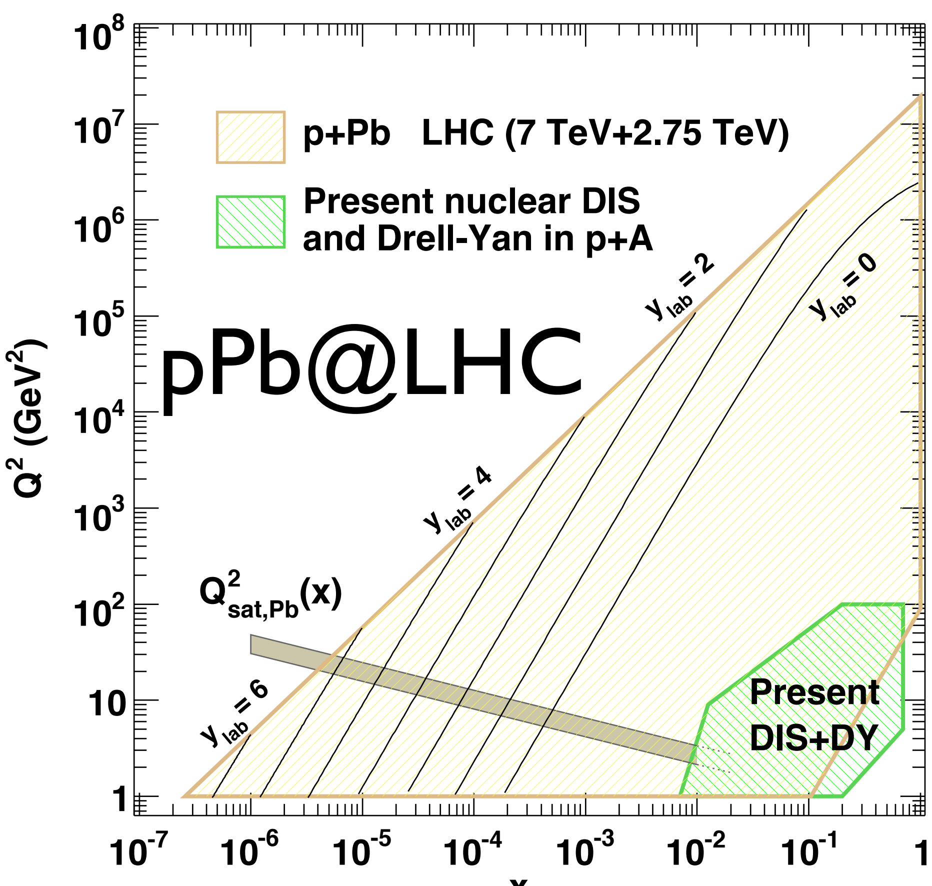

ep@LHeC
LHC:
LHeC
HERA Experiments:
H1 and ZEUS
Fixed Target Experiments:
BCDMS
SLAC
(E_e=140GeV and
E_p=7TeV)
Q^2 / GeV^2
x


pPb@LHC
p+Pb LHC (7 TeV+2.75 TeV)
Present nuclear DIS
and Drell-Yan in p+A
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


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

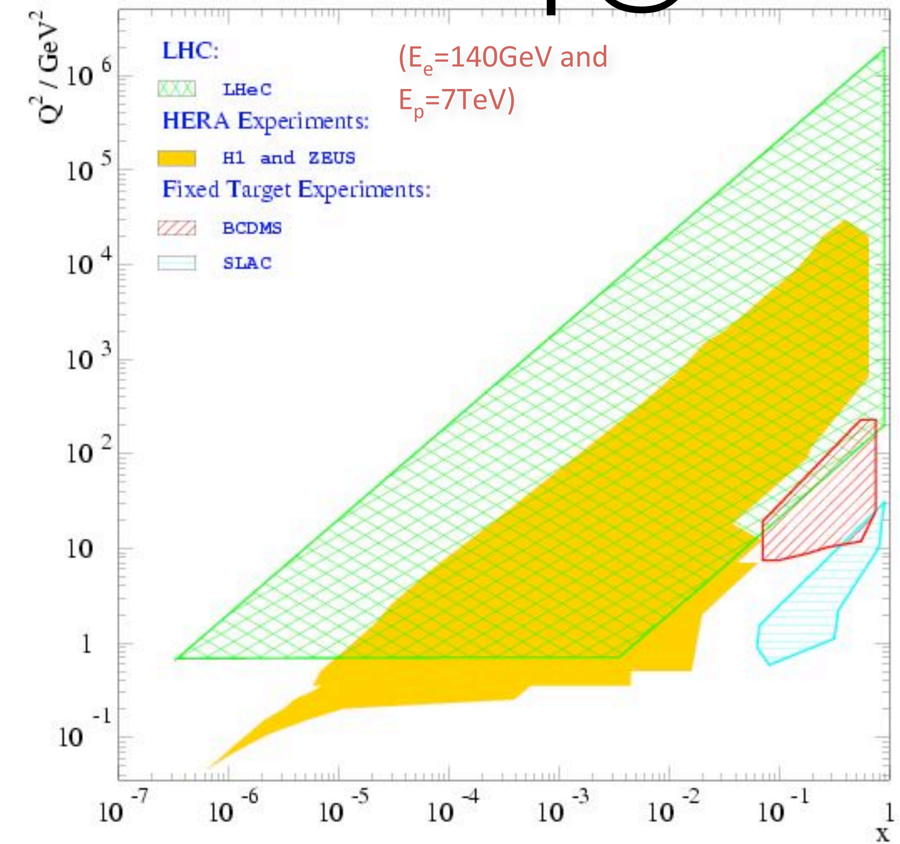
LHC vs. LHeC:

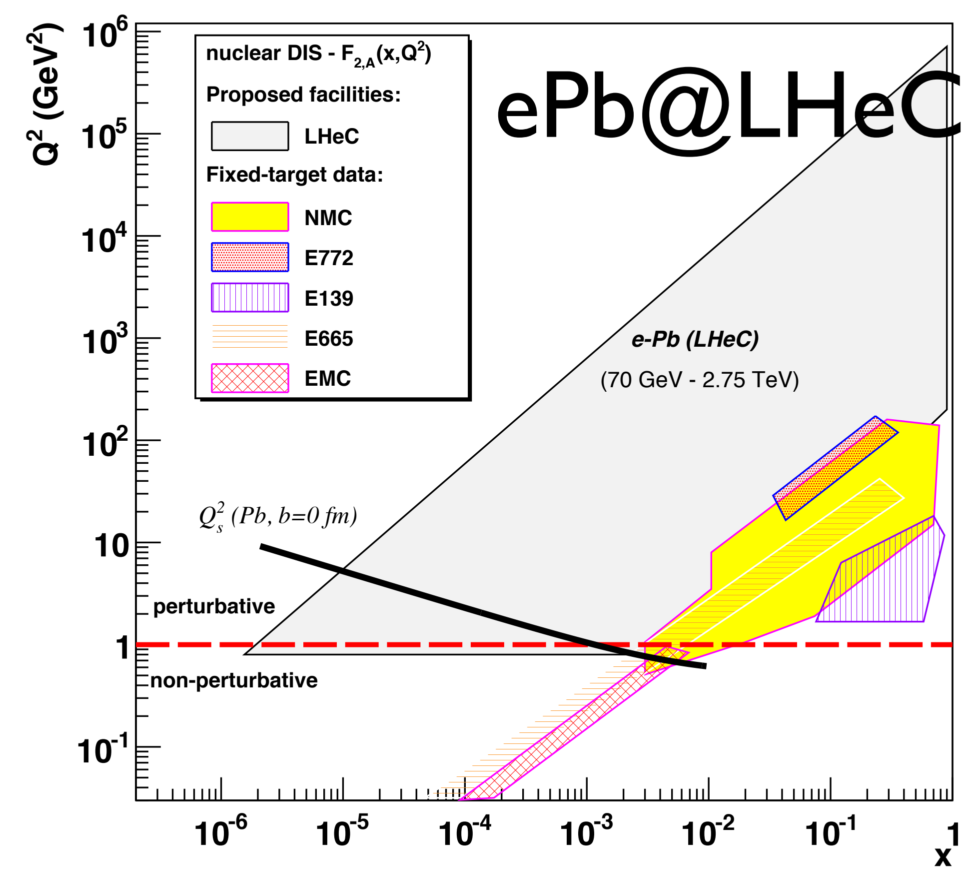




- The LHeC will explore a region overlapping with the LHC:
  - ➜ in a cleaner experimental setup;
  - ➜ on firmer theoretical grounds.

ep@LHeC





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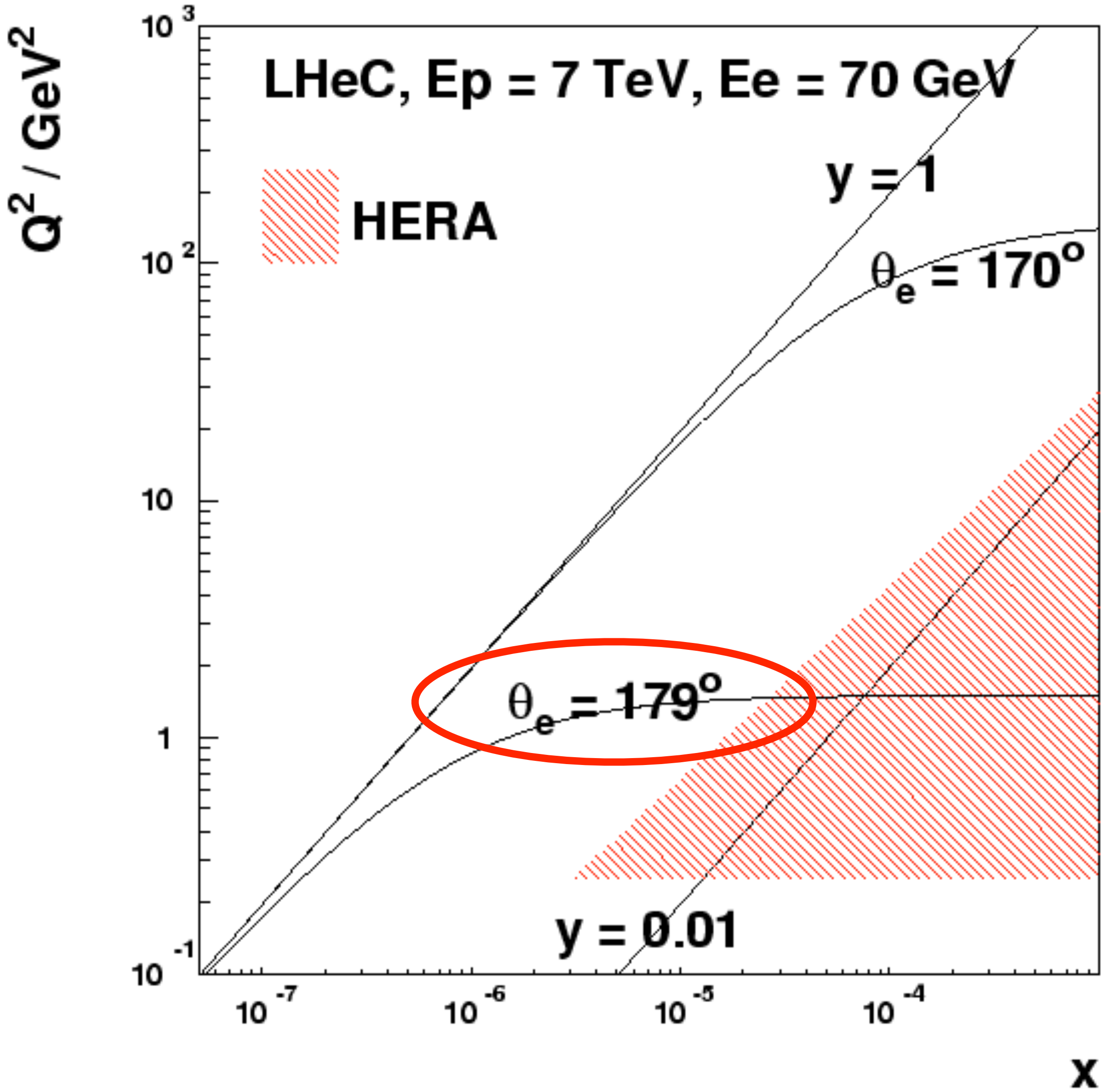
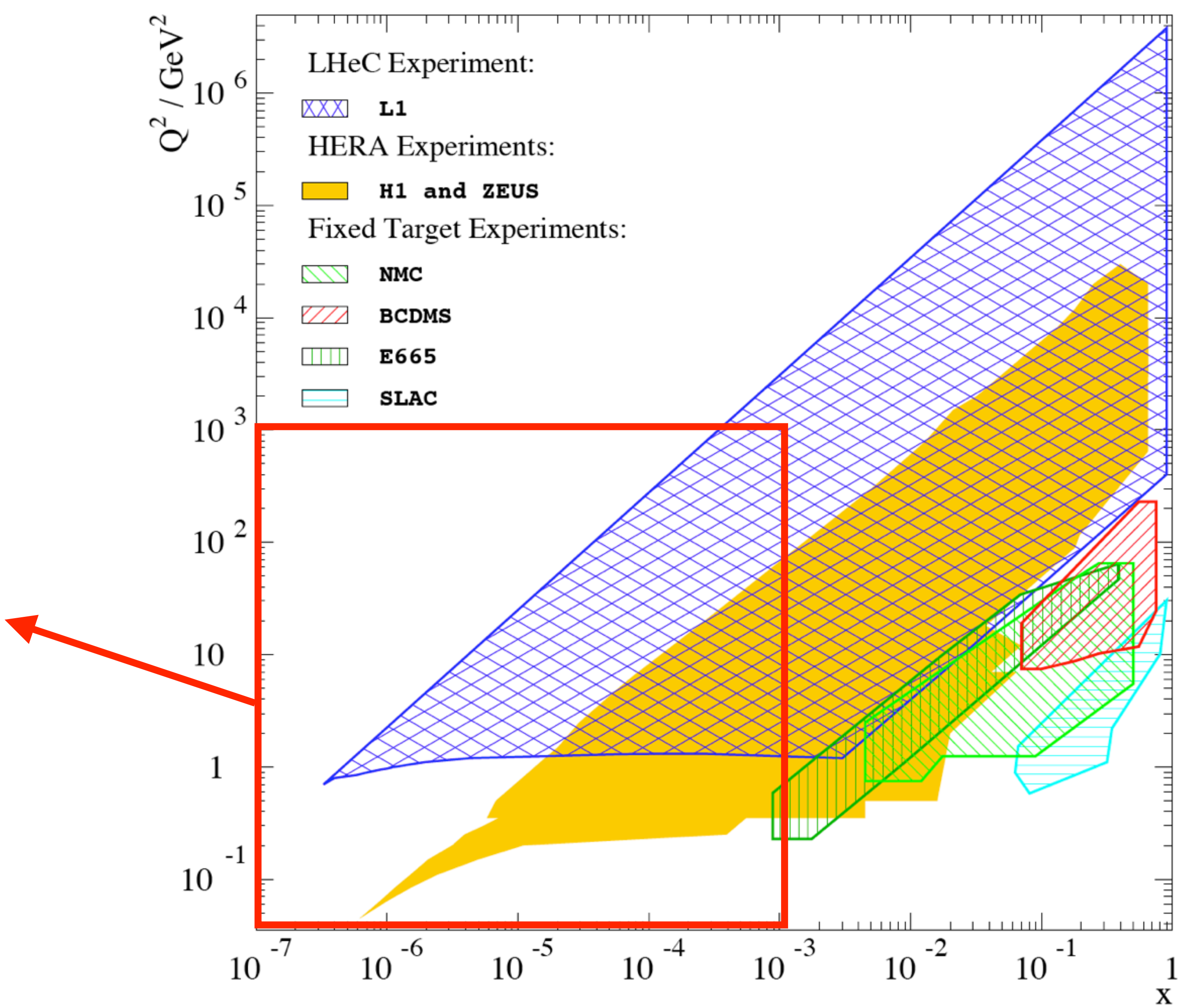
Proton PDFs at small x:

- Parton densities poorly known at small x and small to moderate Q^2: uncertainties in predictions.
- LHeC will substantially reduce the uncertainties in global fits: F_L and heavy flavour decomposition most useful.





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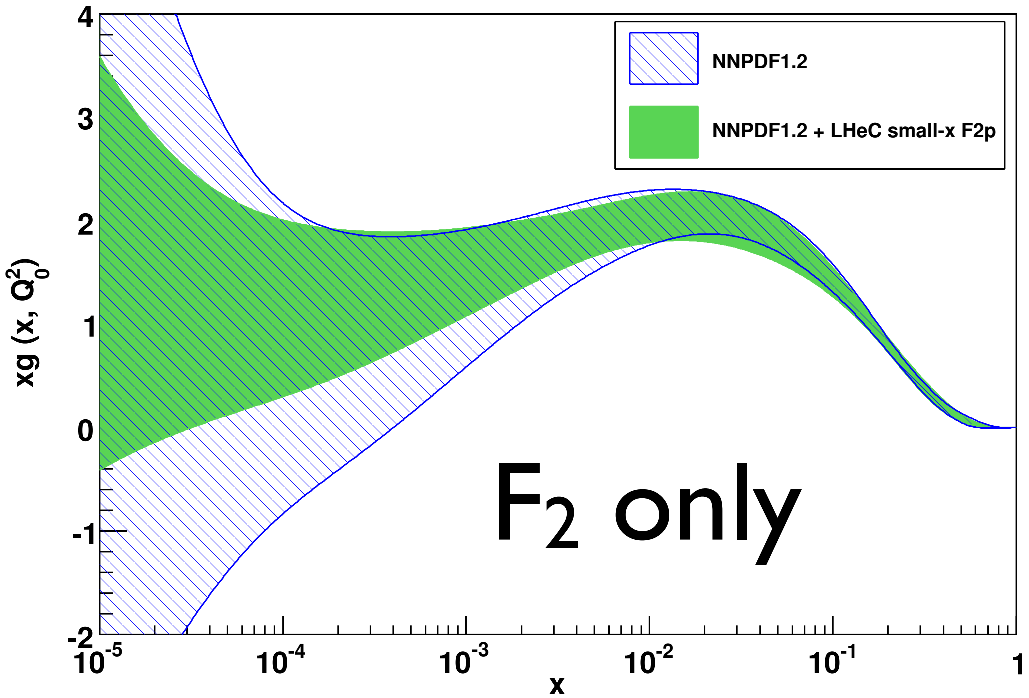
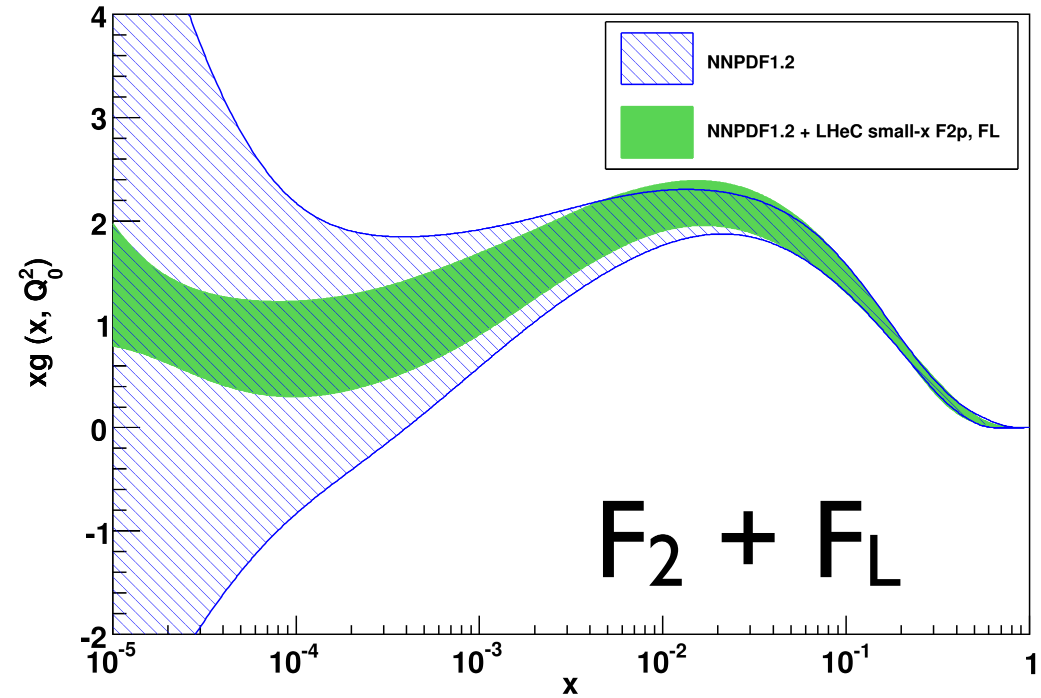
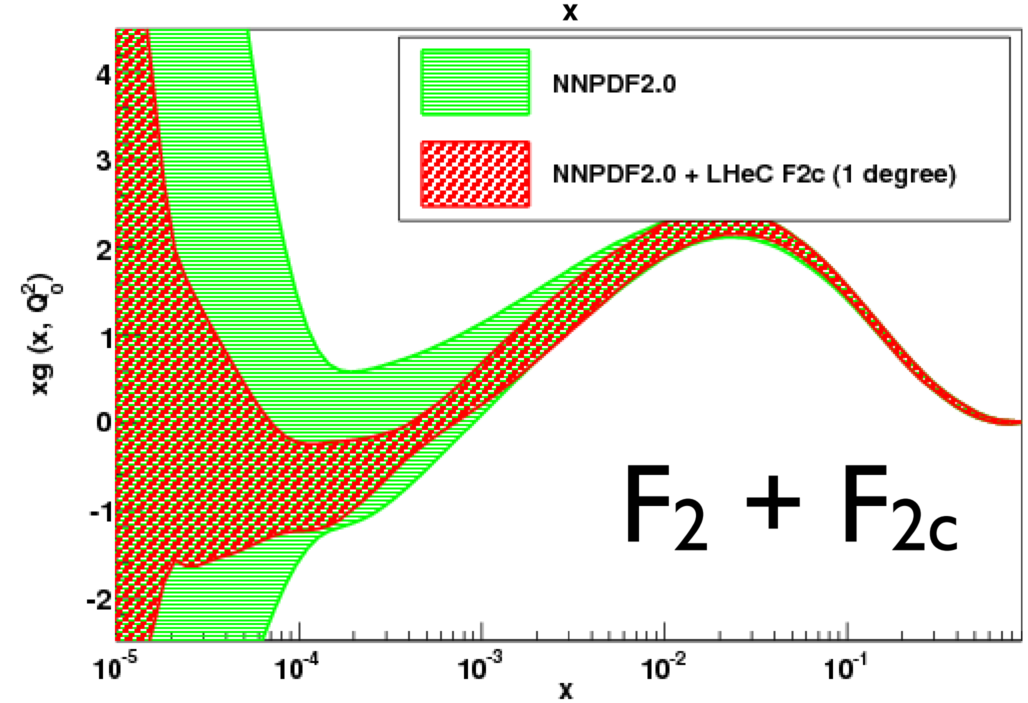
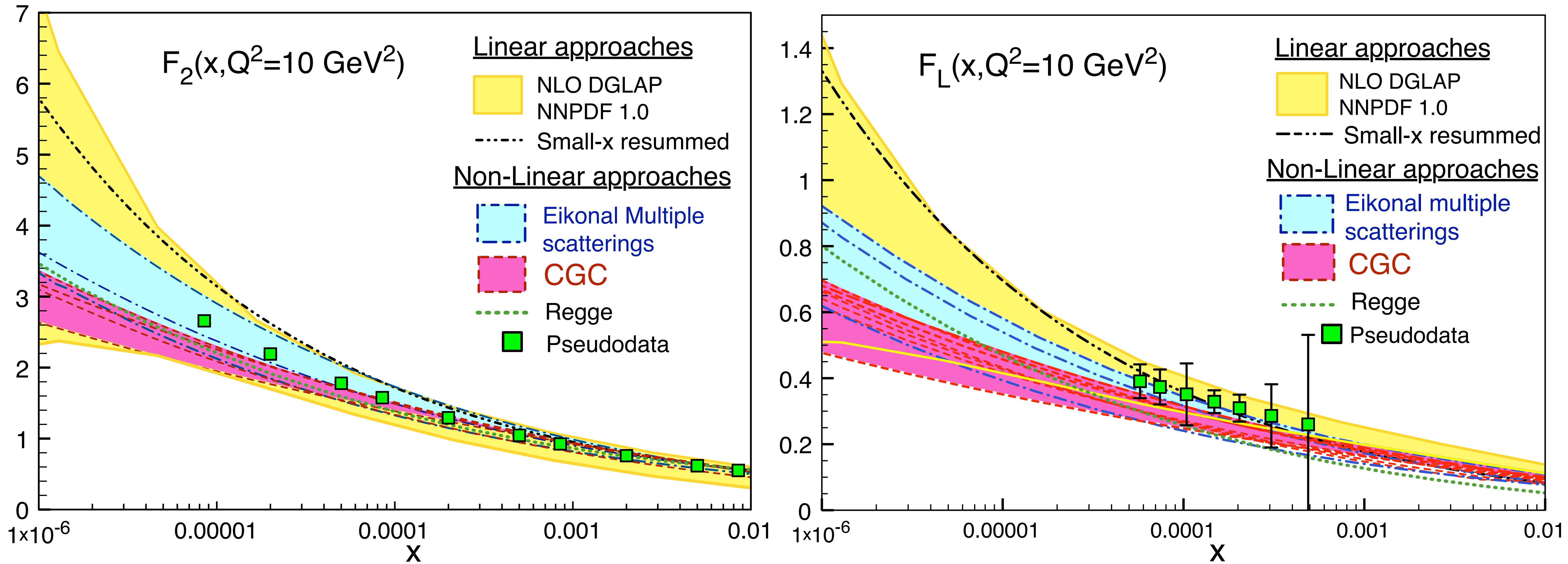




$Q_0^2=2$ GeV^2



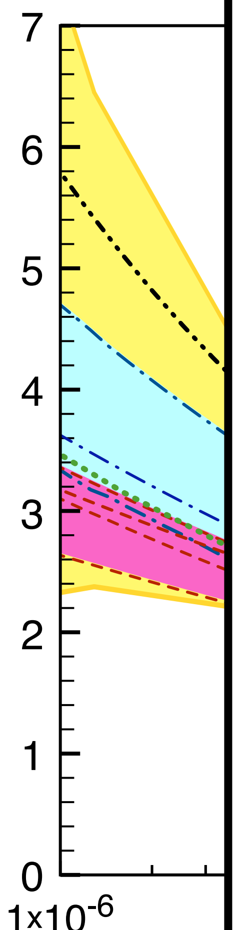
Effects beyond DGLAP?:

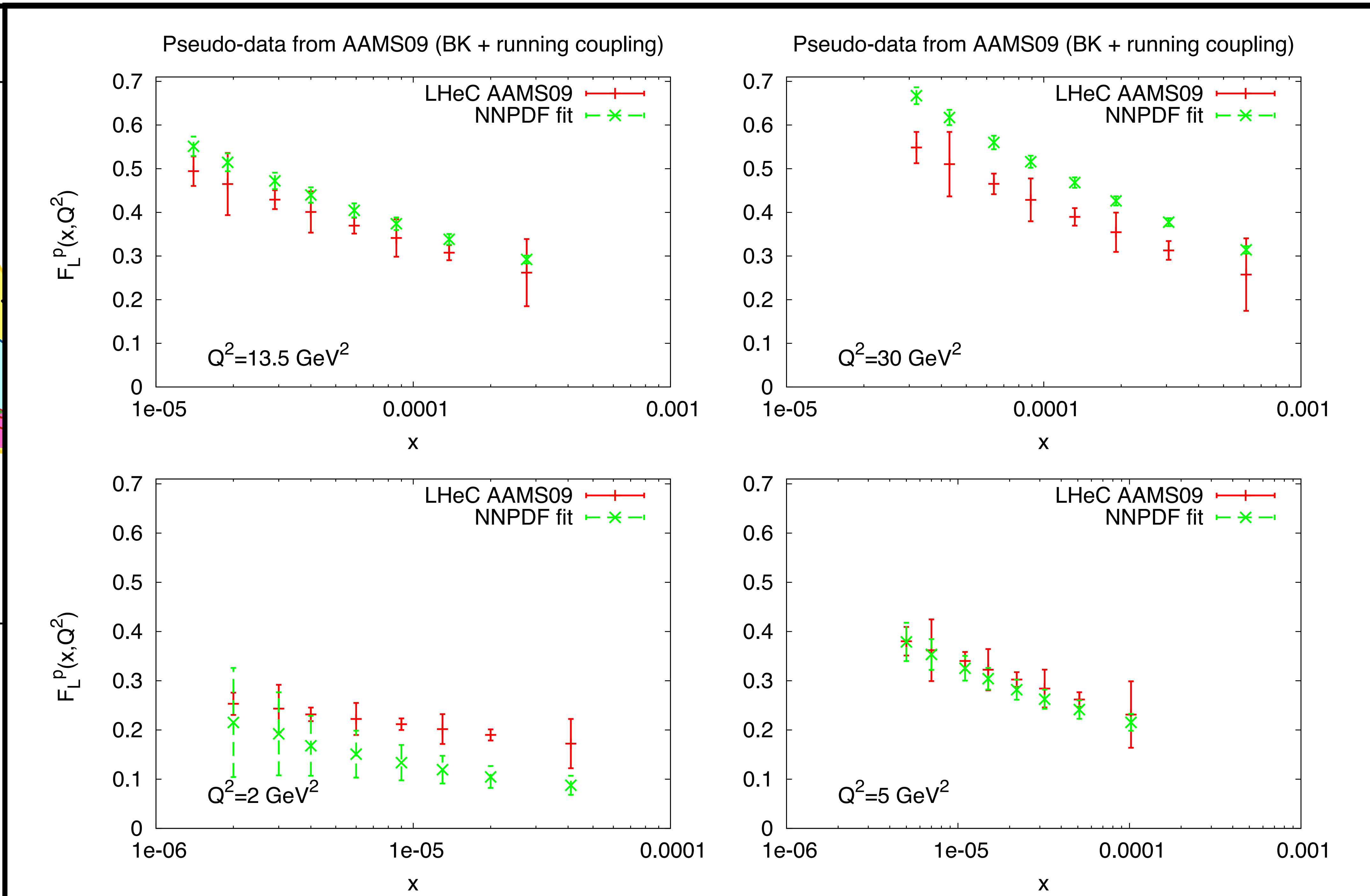


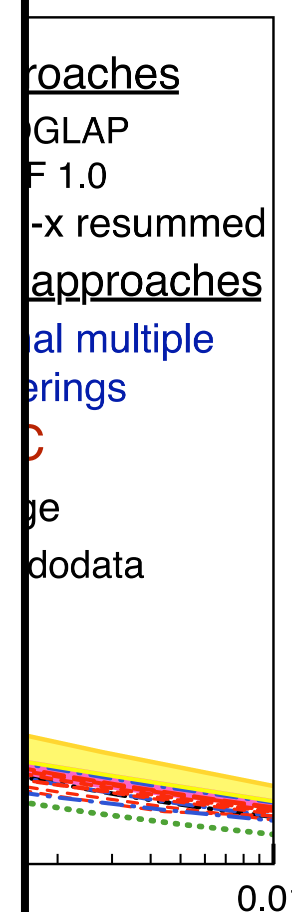
- LHeC F_2 and F_L data will have discriminatory power on models.

Effects beyond DGLAP?:

NLO DGLAP cannot simultaneously accommodate LHeC F_2 and F_L data if saturation effects included according to current models.

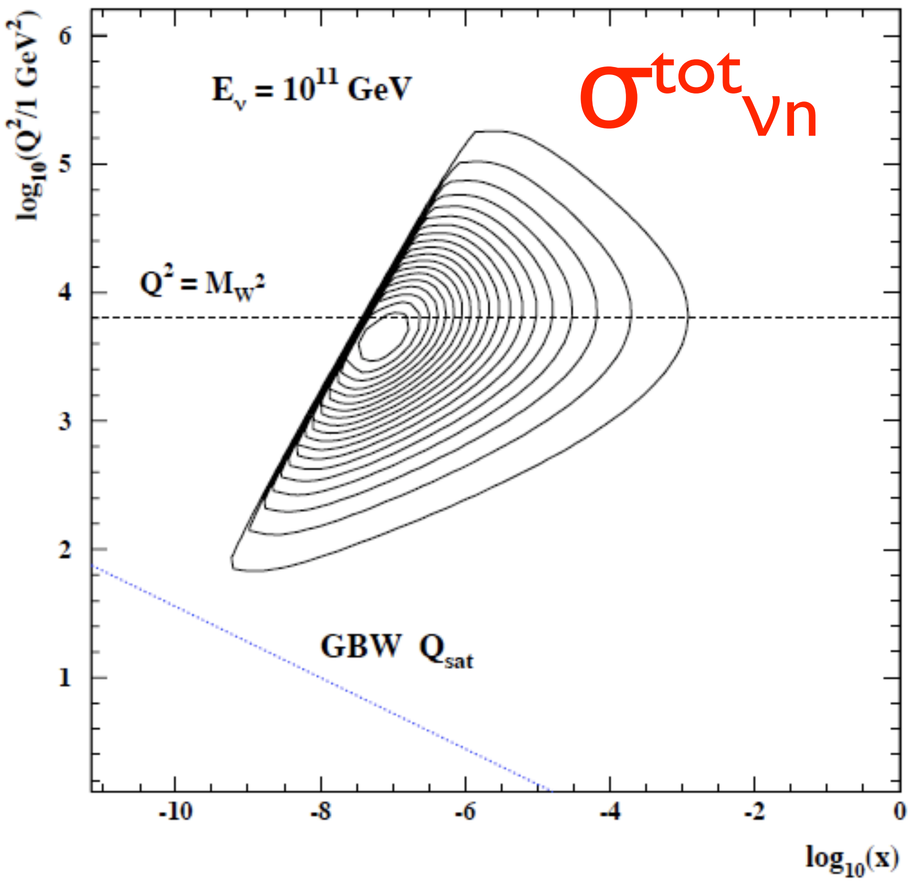






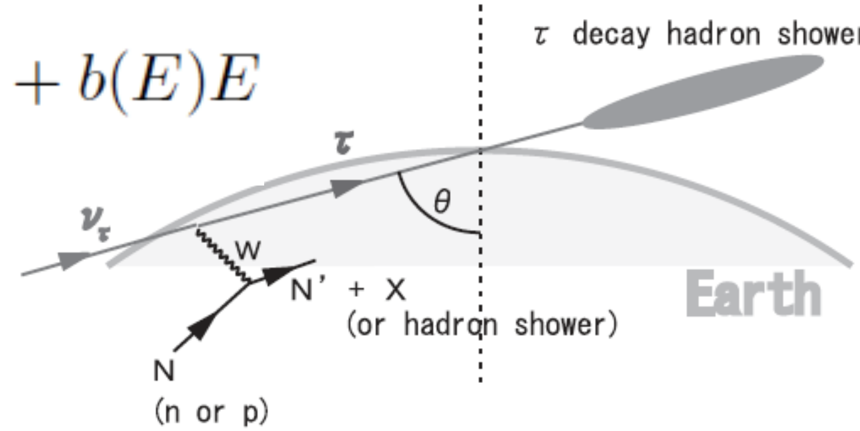
- LH... odels.

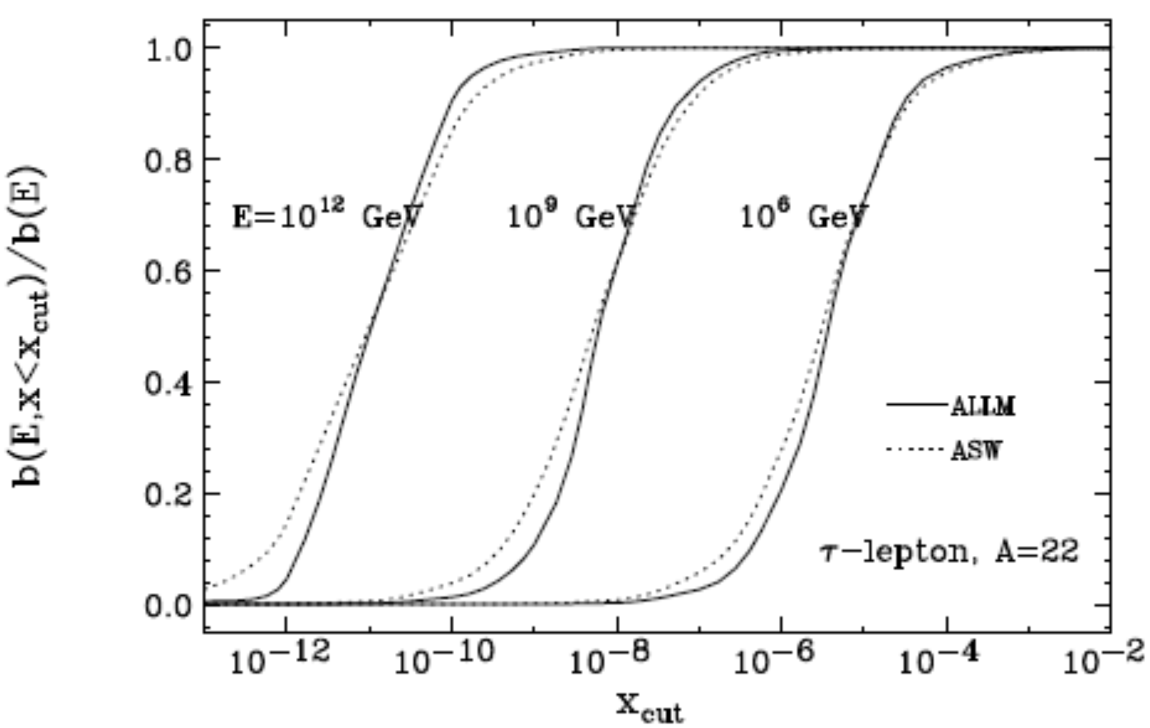
Implications for UHEν's:

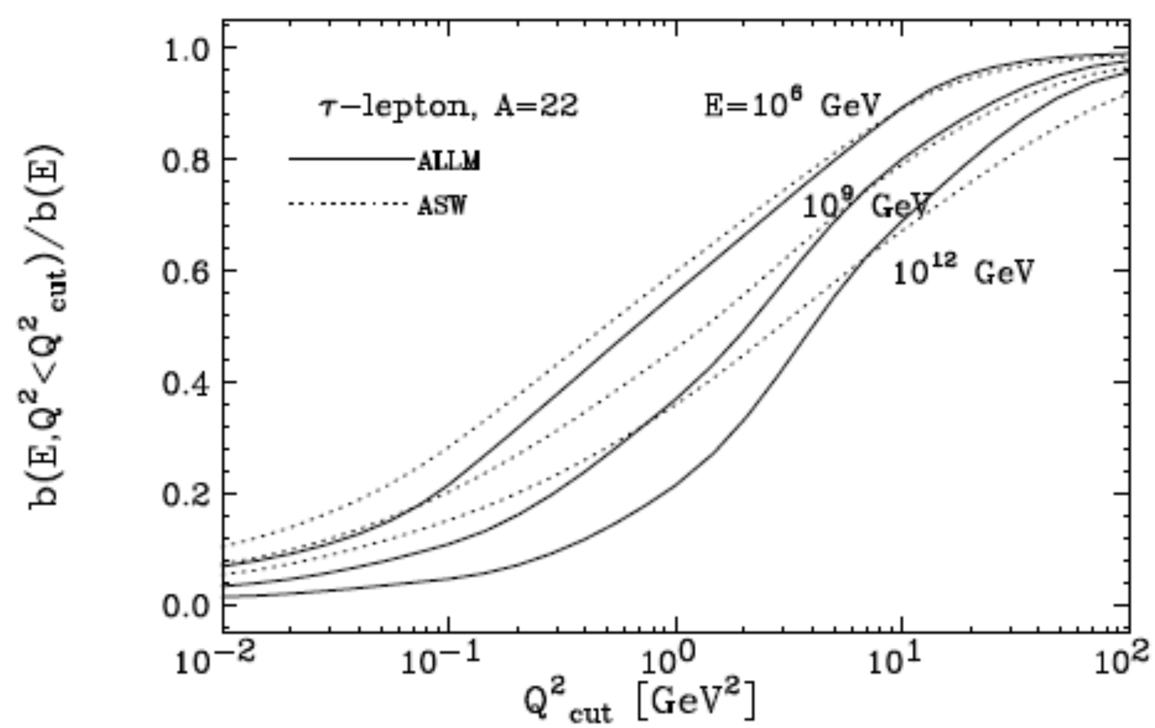


- ν-n/A cross section (τ energy loss) dominated by DIS structure functions / (n)pdfs at small-x and large (small) Q^2.
- Key ingredient for estimating fluxes.

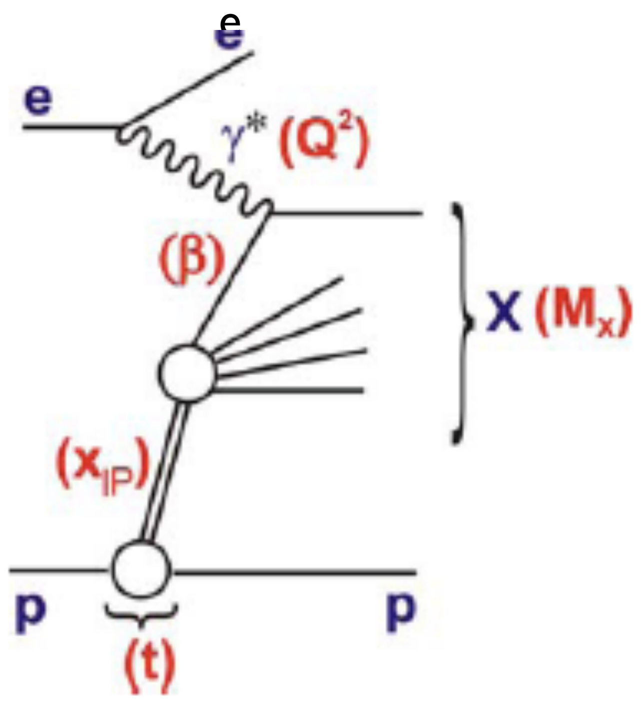
$$-\left\langle \frac{dE}{dX} \right\rangle = a(E) + b(E)E$$



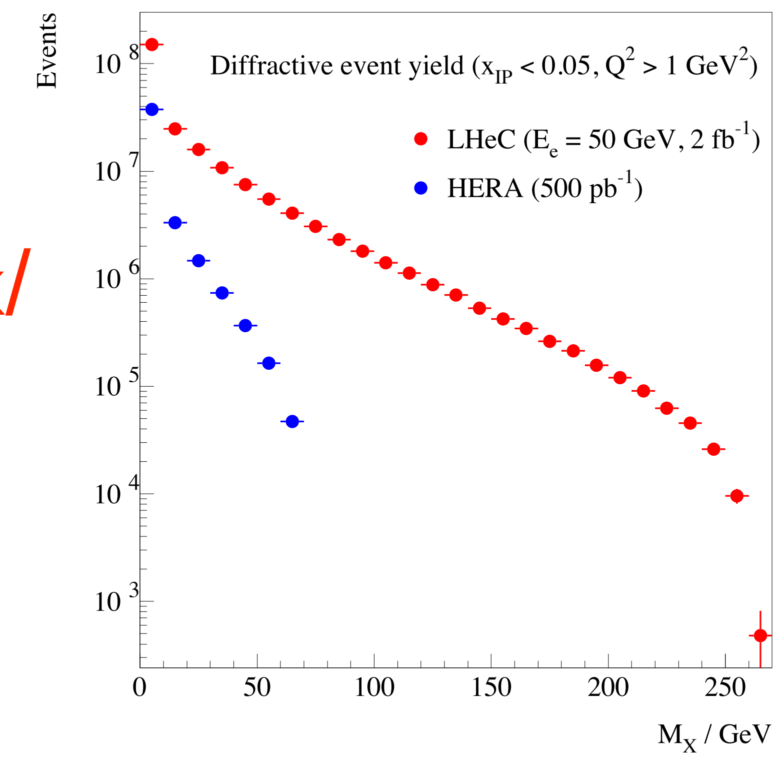




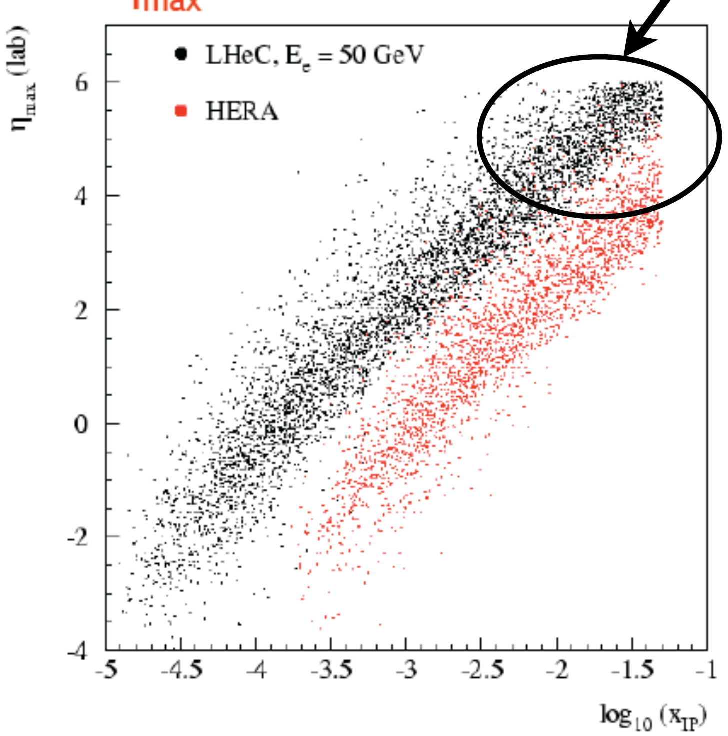
ep diffractive pseudodata:

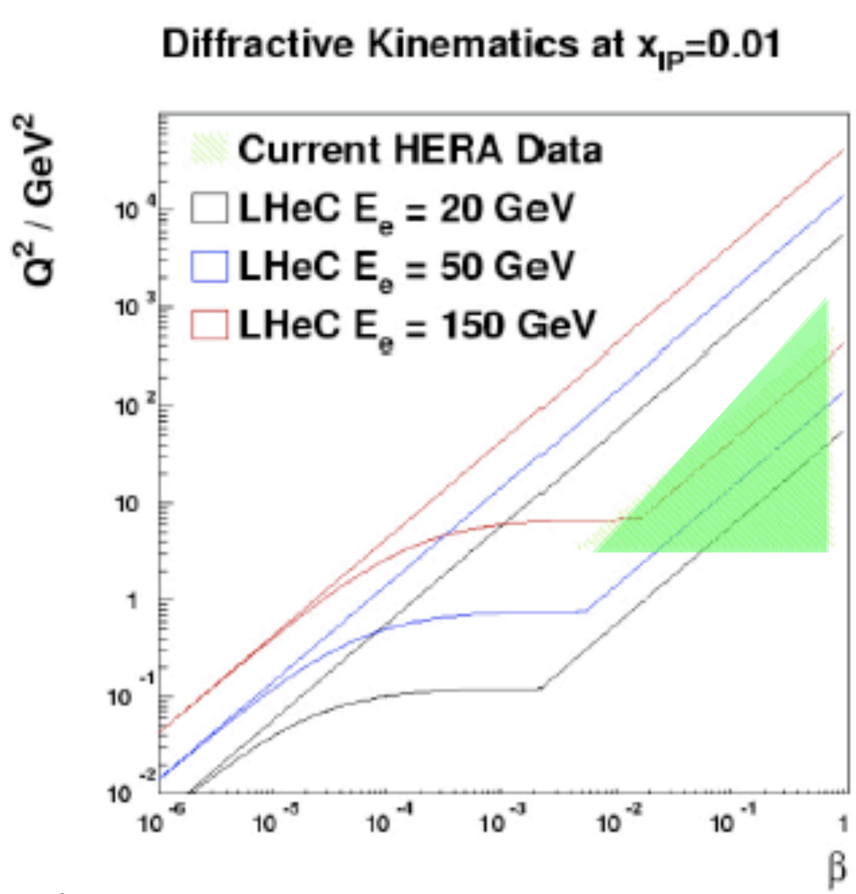


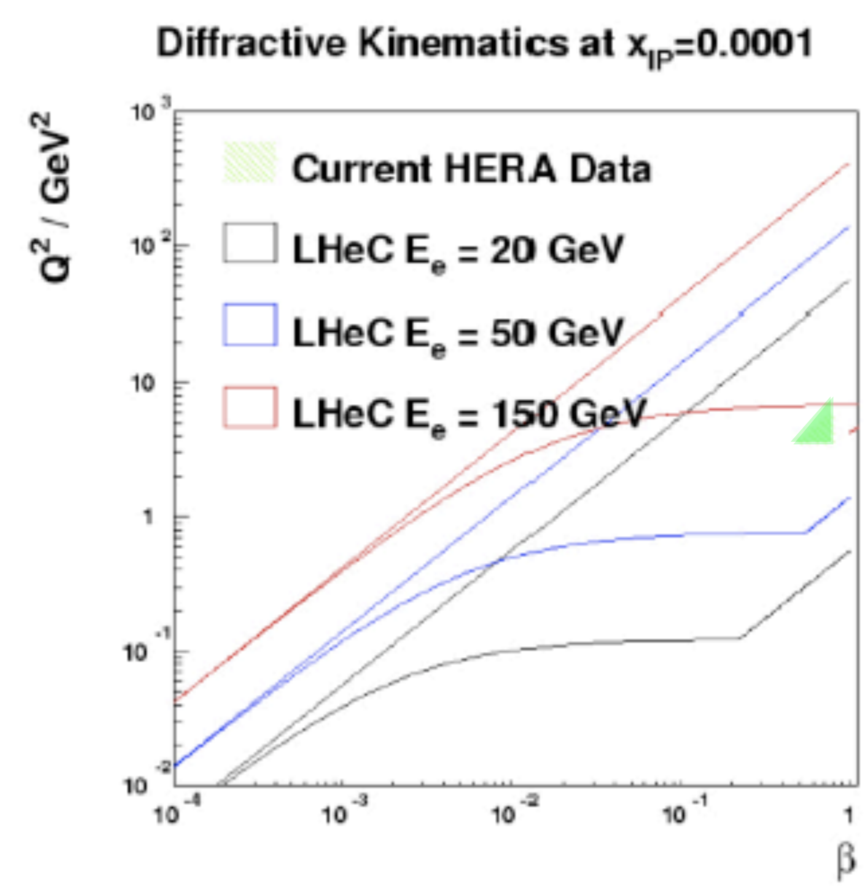
- Large increase in the M^2, $x_P=(M^2-t+Q^2)/(W^2+Q^2)$, $\beta=x/x_P$ region studied.
- Possibility to combine LRG and LPS.



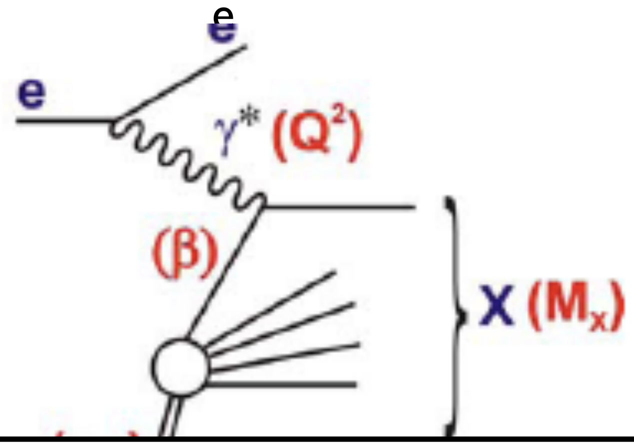
η_{max} from LRG selection ..



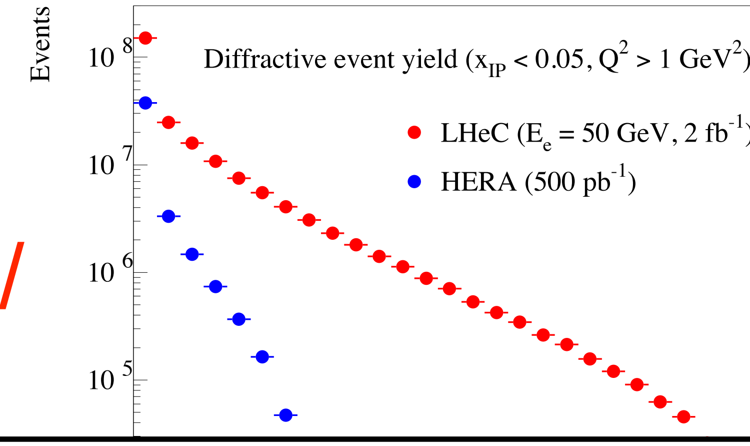




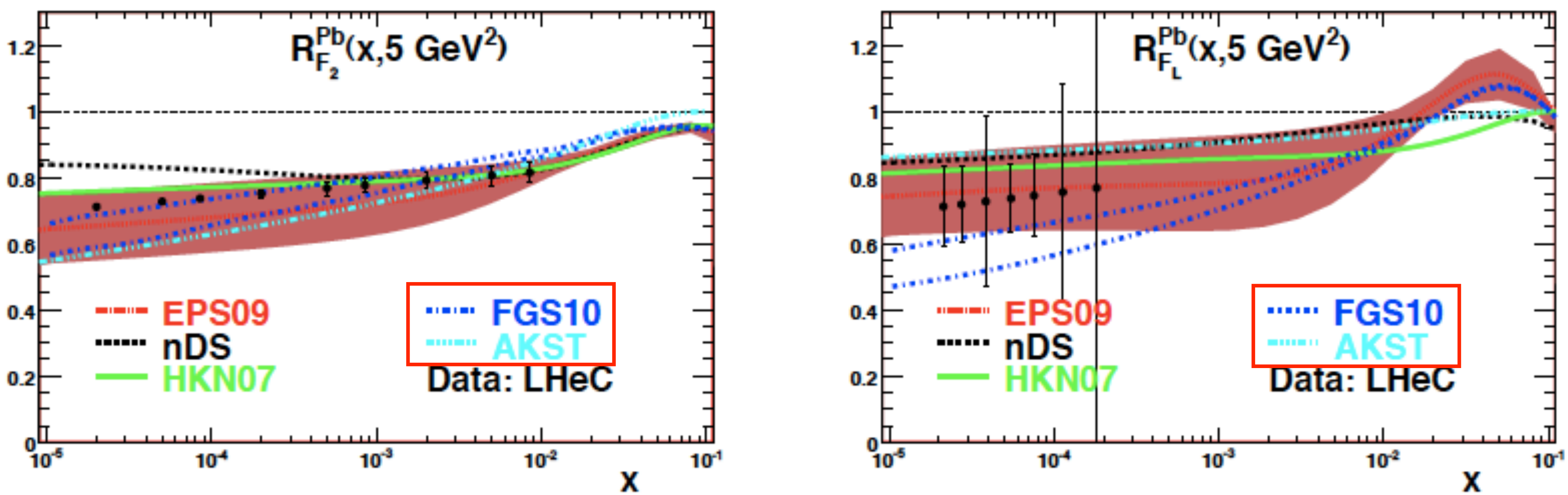
ep diffractive pseudodata:



- Large increase in the M^2, $x_P=(M^2-t+Q^2)/(W^2+Q^2)$, $\beta=x/x_P$ region studied.

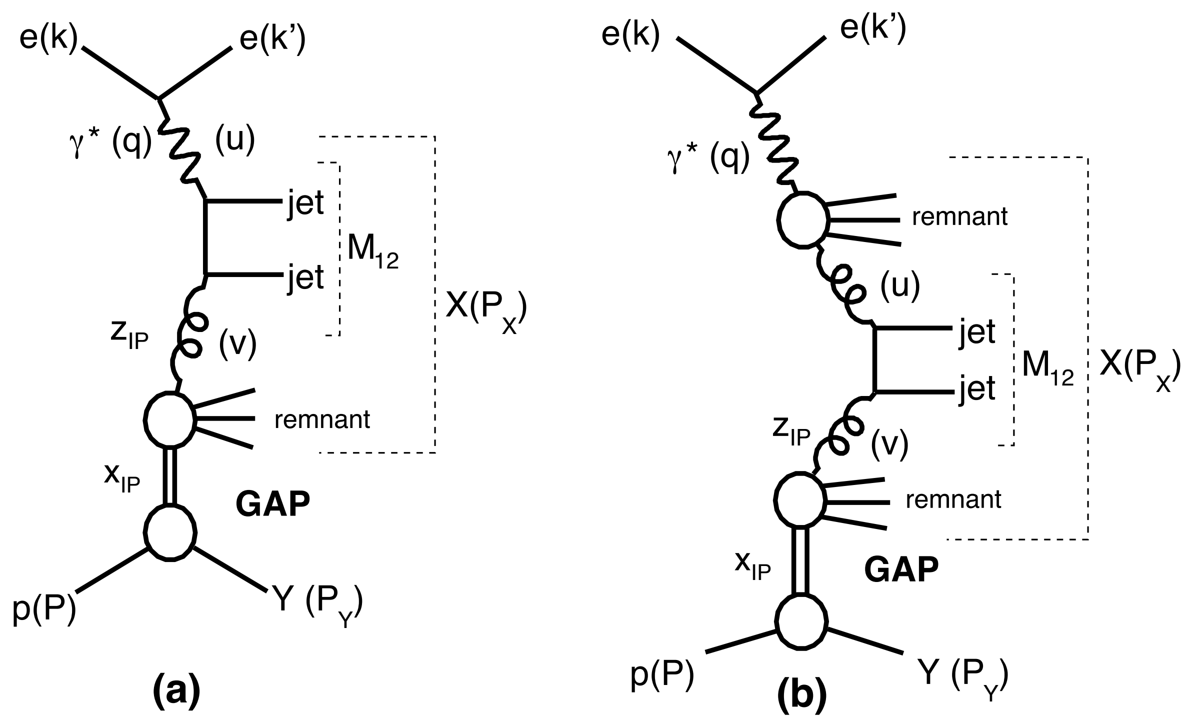


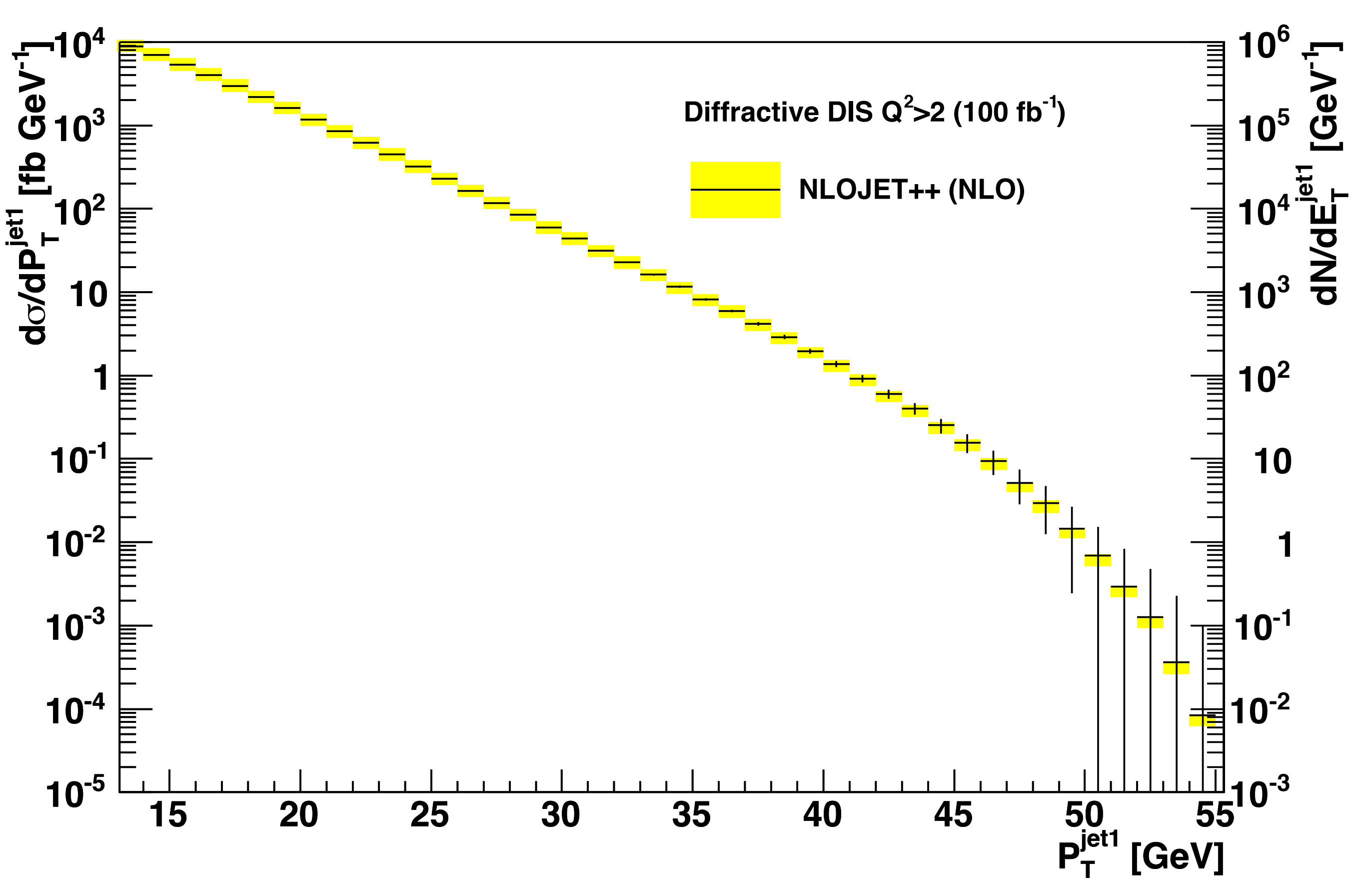
Note: diffraction in ep is linked to shadowing in eA (Gribov): FGS, Capella-Kaidalov et al,...



β β

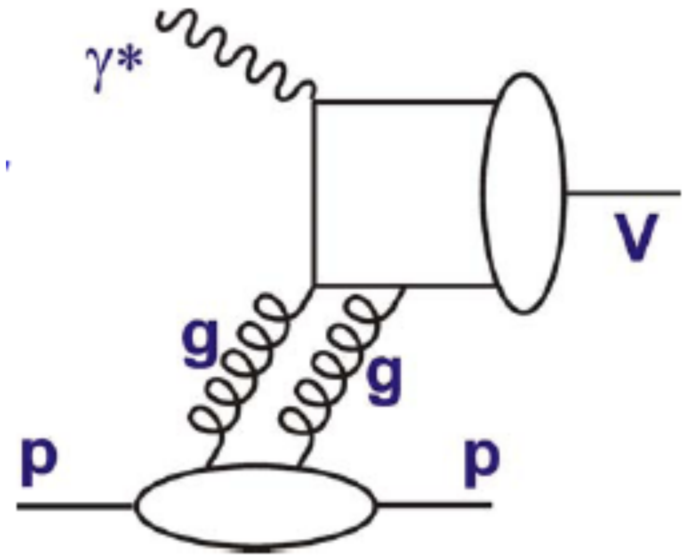
Diffractive dijets:

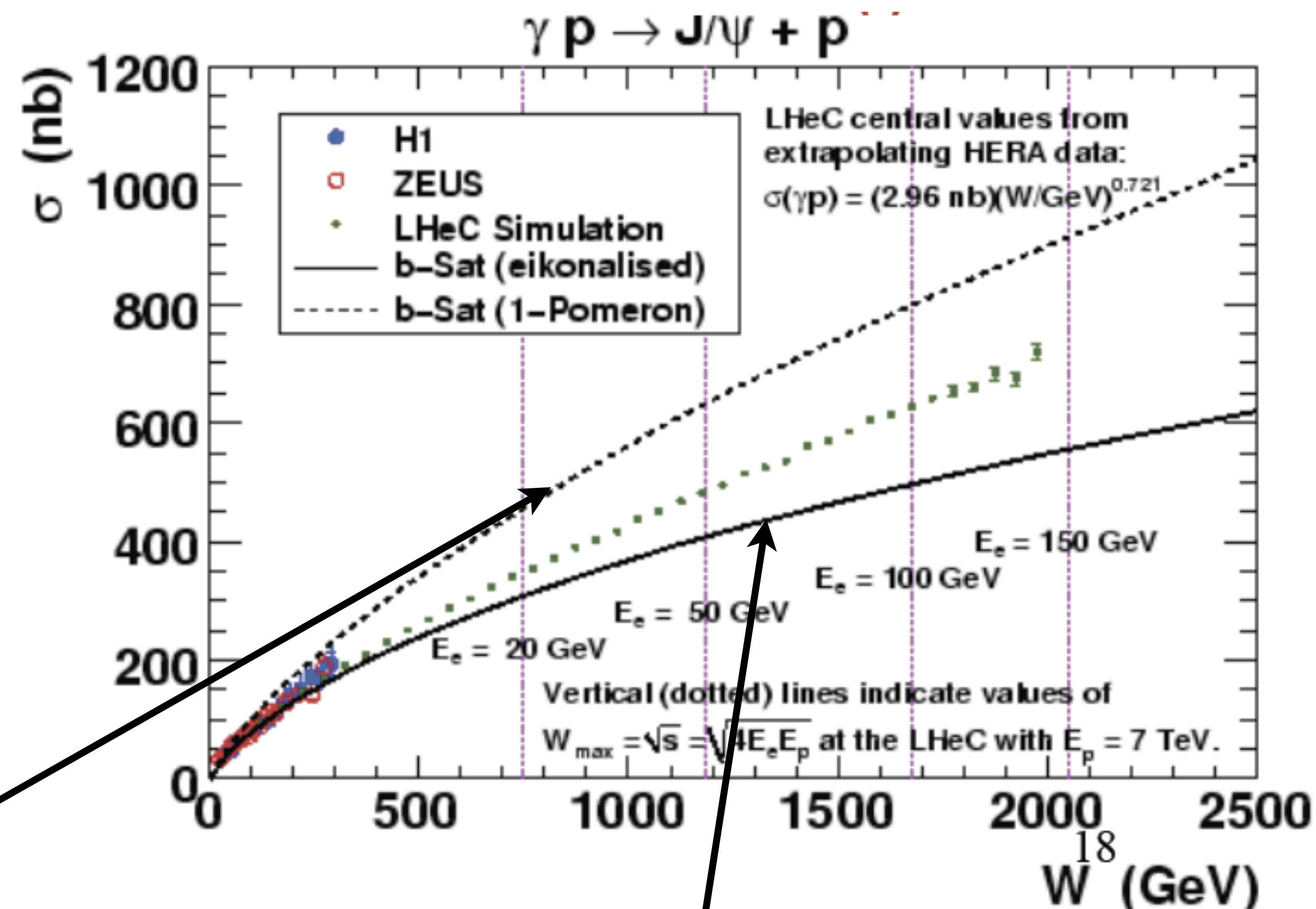




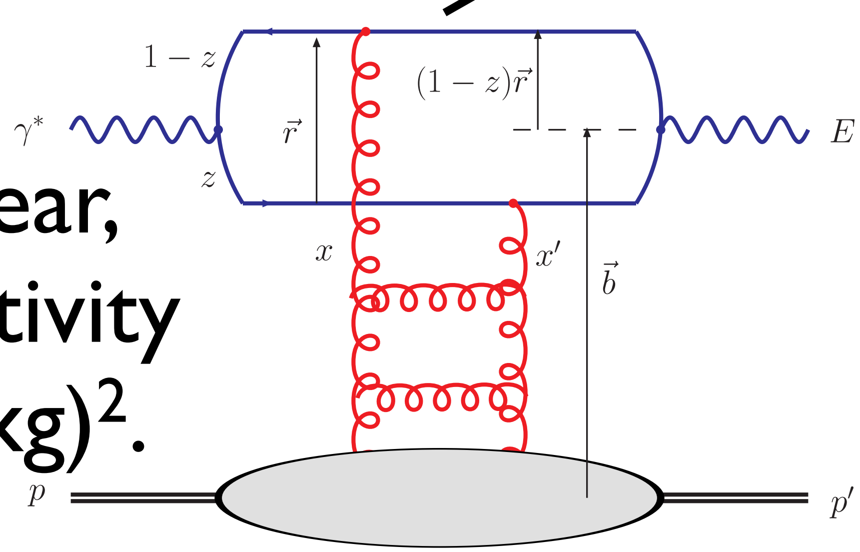
- Diffractive dijet and open heavy flavour production offer large possibilities for:
  - → Checking factorization in hard diffraction.
  - → Constraining DPDFs.
- Large yields up to large p_T^{jet}.
- Direct and resolved contributions: photon PDFs.

Elastic VM production in ep:

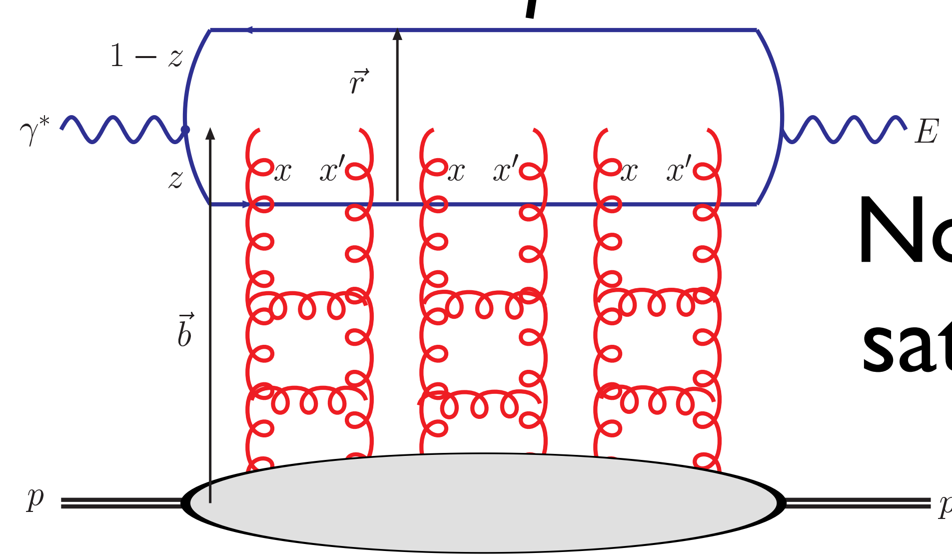




- Elastic J/ψ production appears as a candidate to signal saturation effects at work!!!

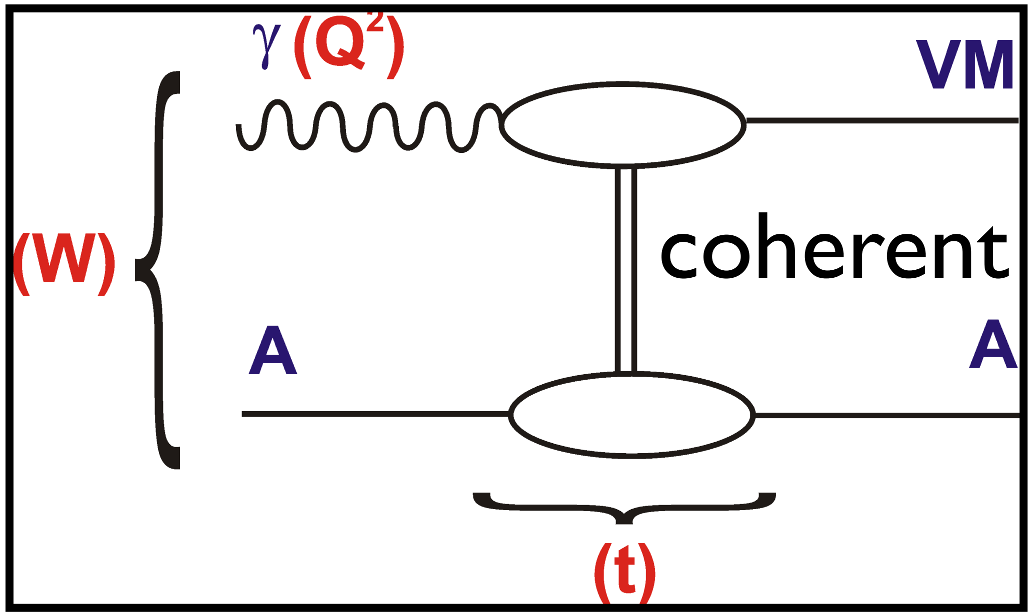


Linear, sensitivity to $(xg)^2$.



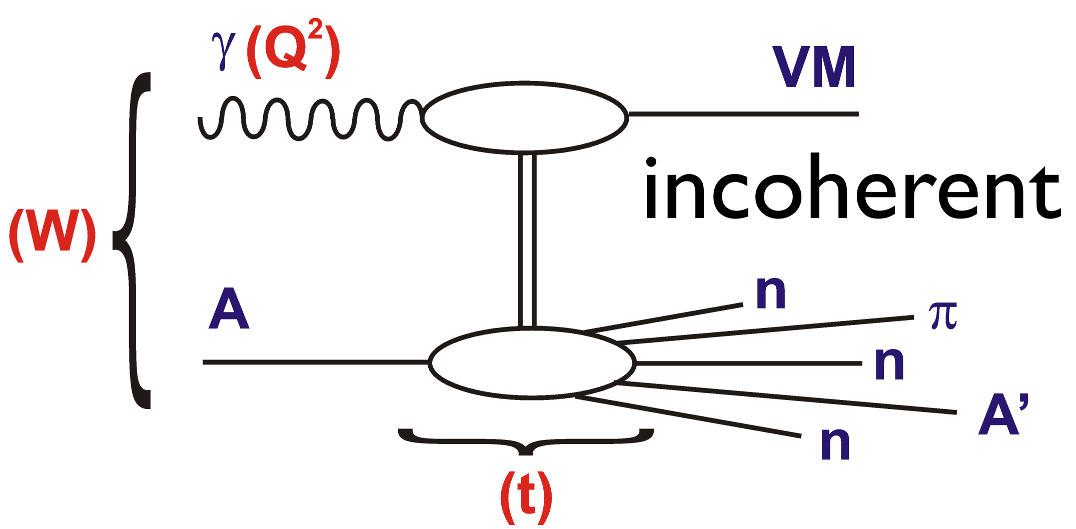
Non-linear, saturation.

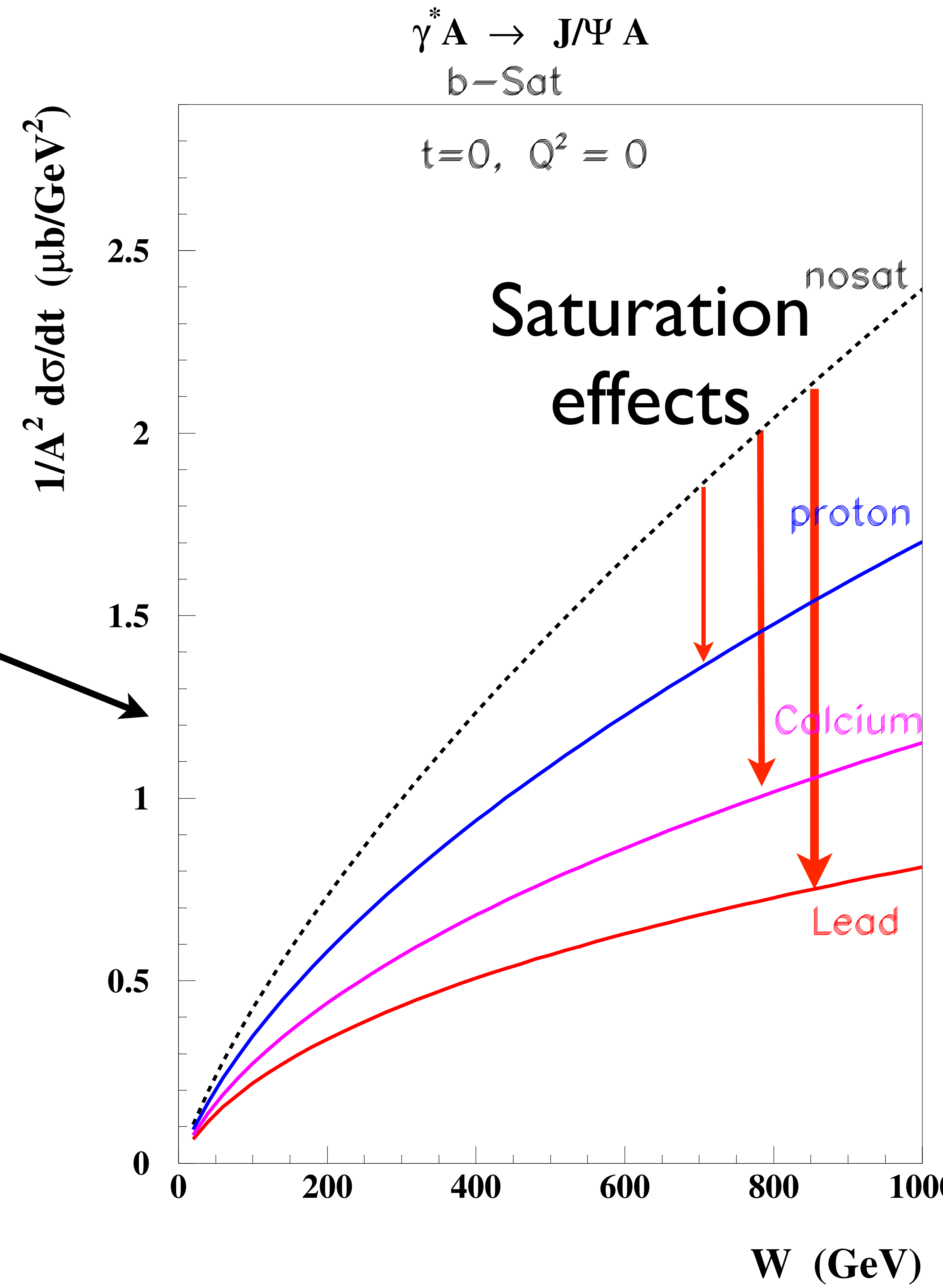
Elastic VM production in eA:



- For the coherent case, predictions available.

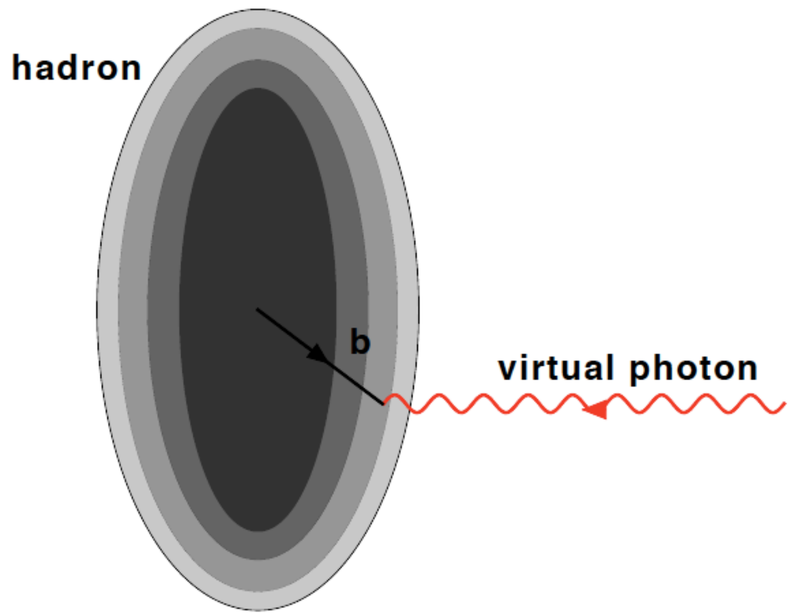
- Challenging experimental problem.

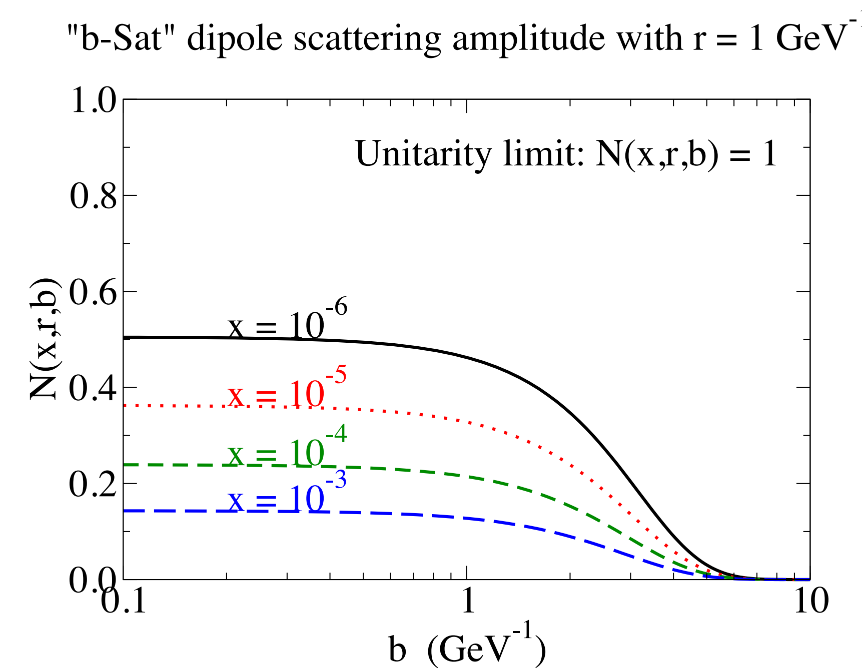


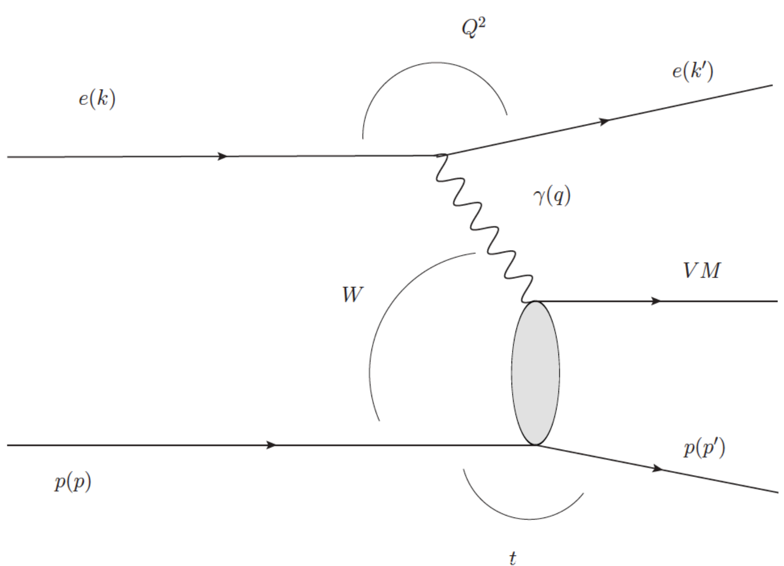


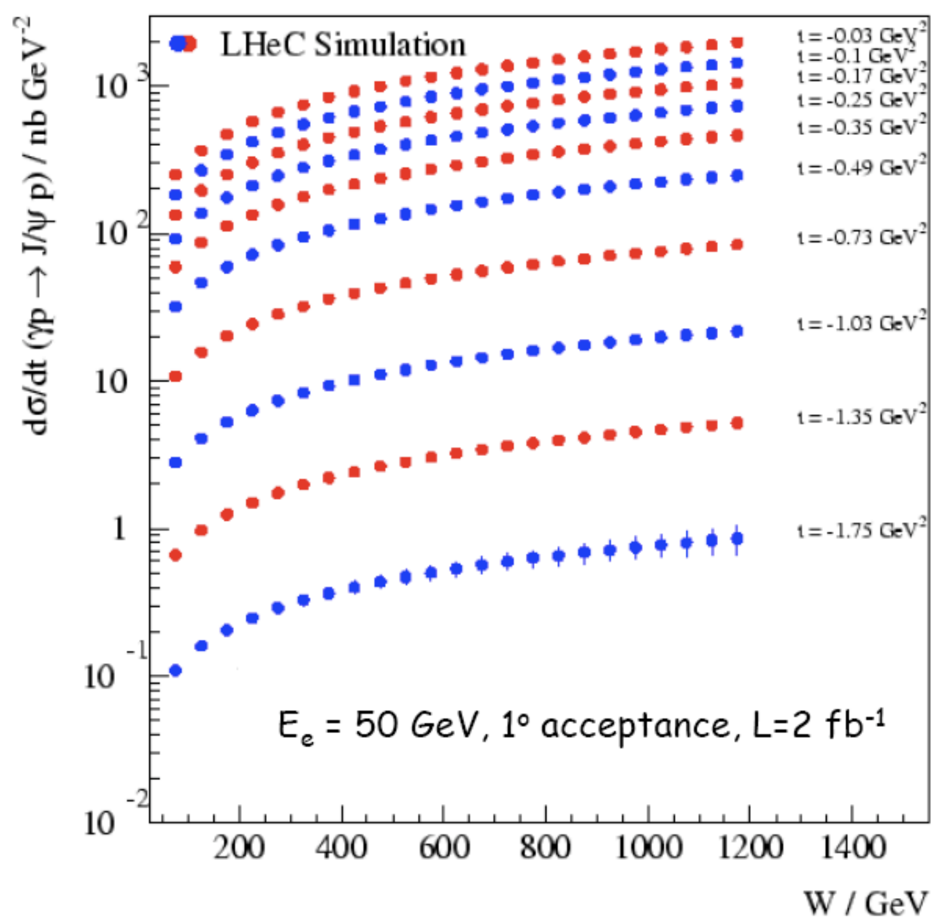
Transverse scan: elastic VM

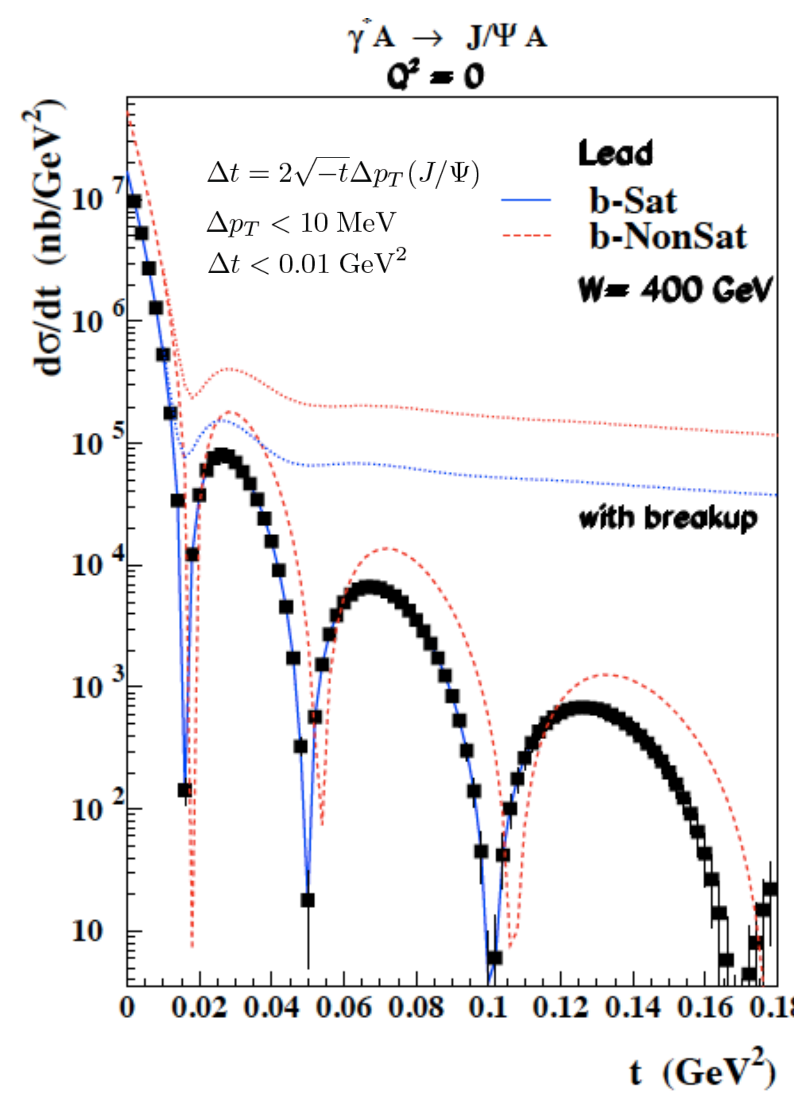
- t-differential measurements give a gluon tranverse mapping of the hadron/nucleus.





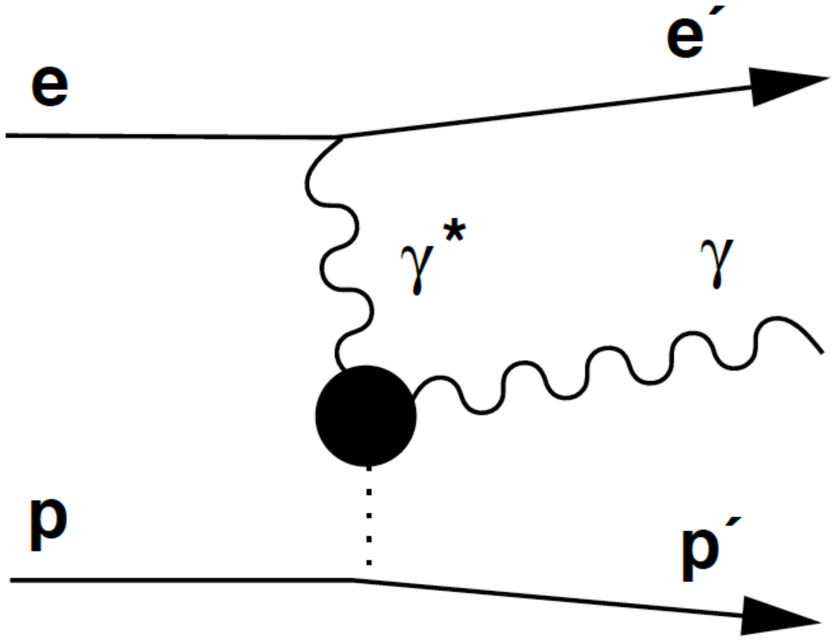




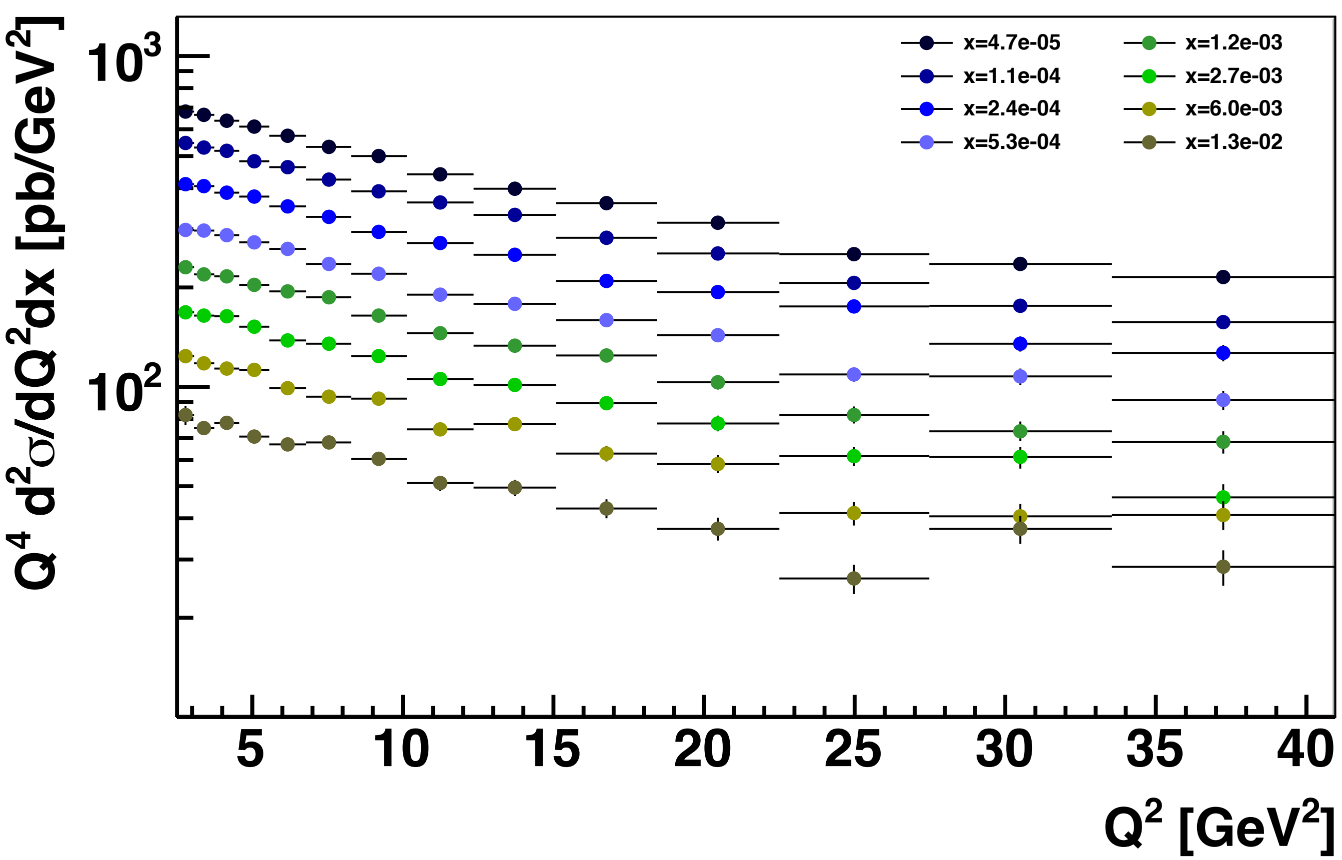


DVCS:

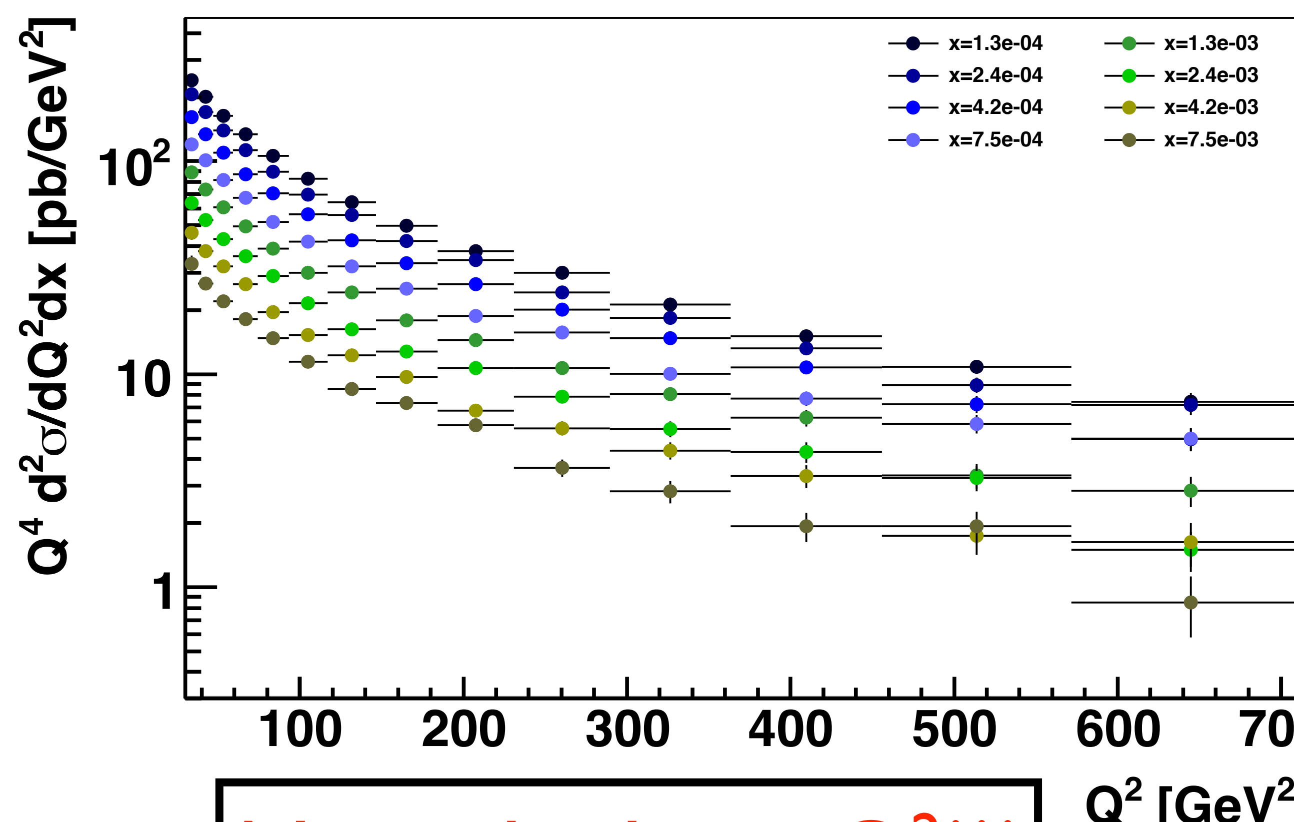
- Exclusive processes give information about GPDs, whose Fourier transform gives a tranverse scan of the hadron: DVCS sensitive to the singlet.
- Sensitive to dynamics e.g. non-linear effects.



DVCS, E_e=50 GeV, 1°,
$p_T^{\gamma,cut}$=2 GeV, 1 fb^{-1}

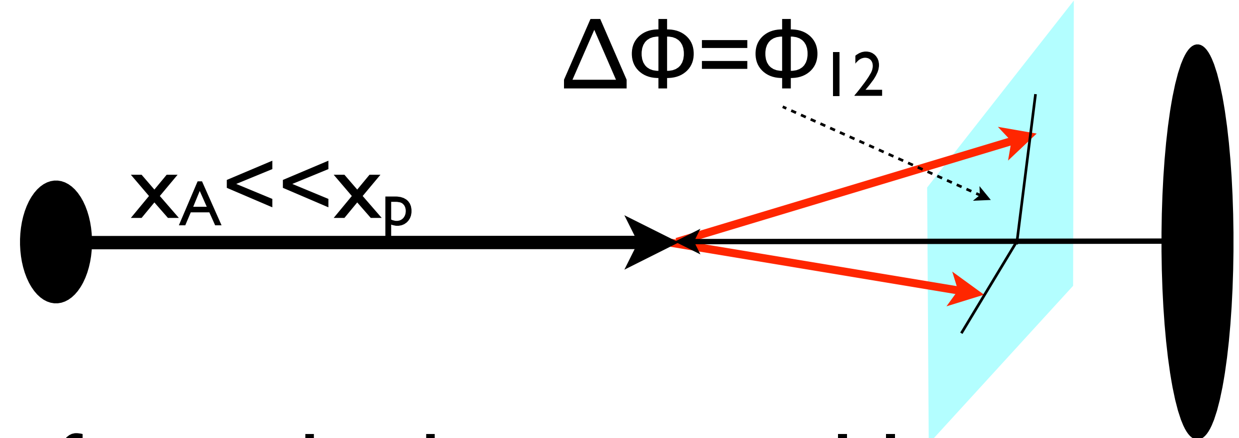


DVCS, E_e=50 GeV, 10°,
$p_T^{\gamma,cut}$=5 GeV, 100 fb^{-1}

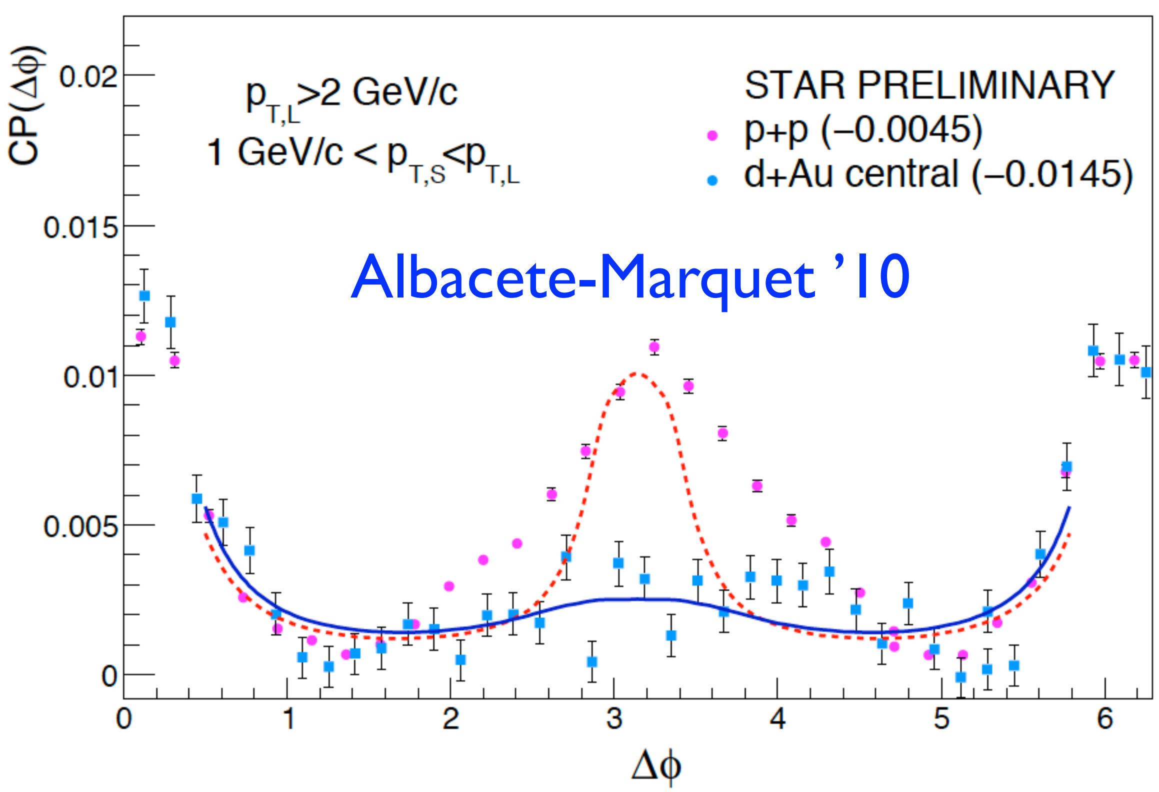


Note the huge Q^2!!!

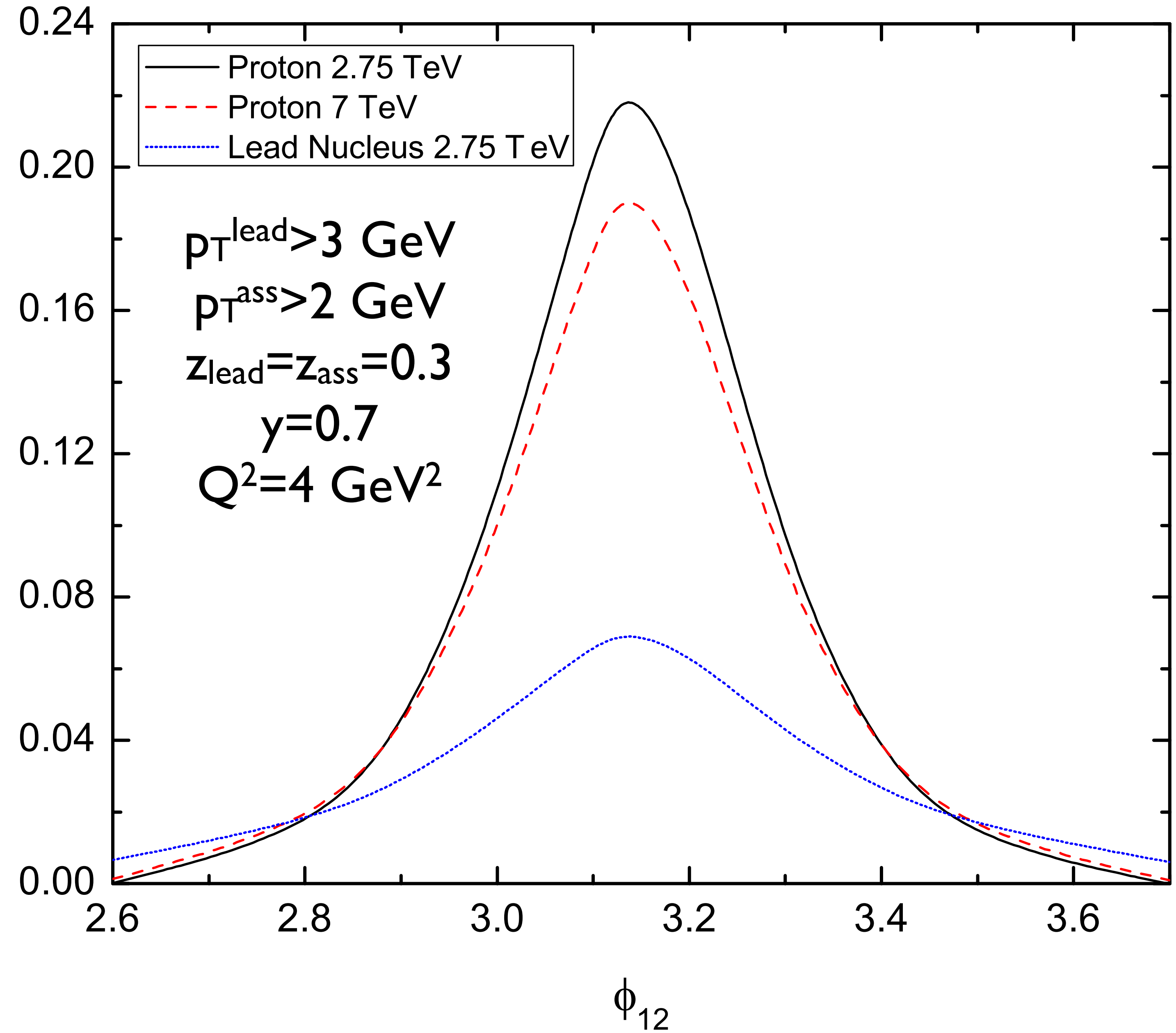
Dihadron azimuthal decorrelation:



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



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



Dijet azimuthal decorrelation:

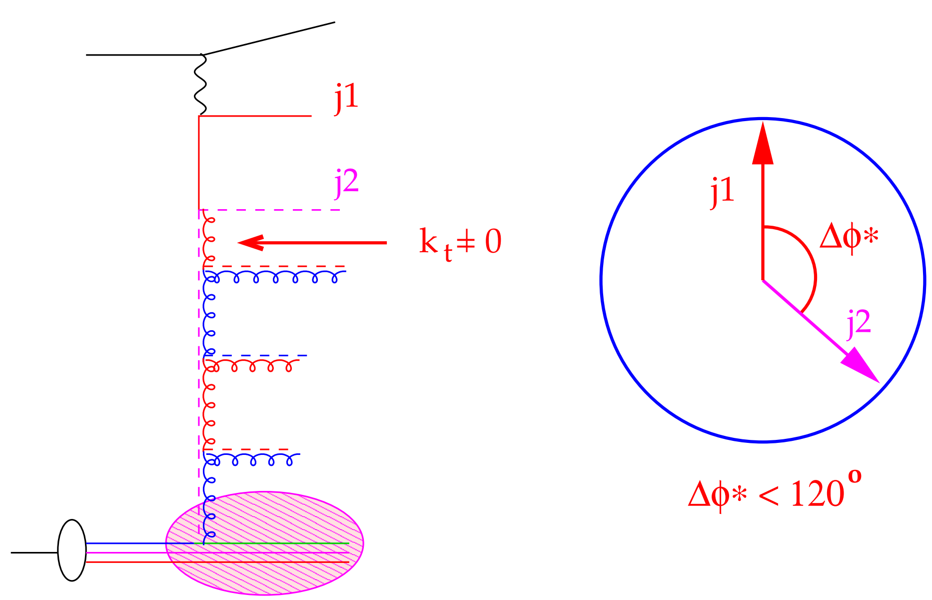
- Studying dijet azimuthal decorrelation or forward jets ($p_T \sim Q$) would allow to understand the mechanism of radiation:

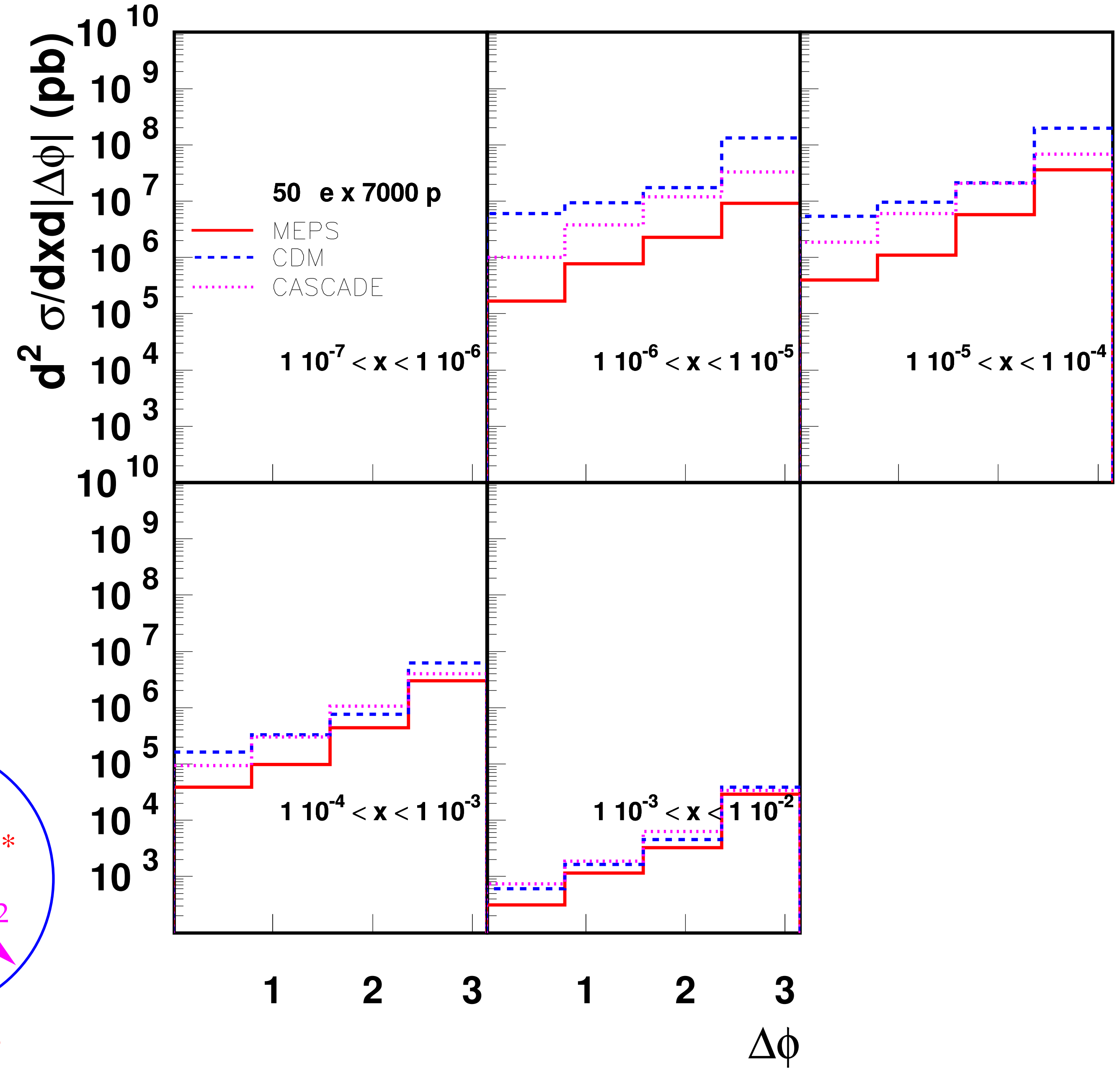
→ k_T-ordered: DGLAP.

→ k_T-disordered: BFKL.

→ Saturation?

- Further imposing a rapidity gap (diffractive jets) would be most interesting: perturbatively controllable observable.





Forward jets:

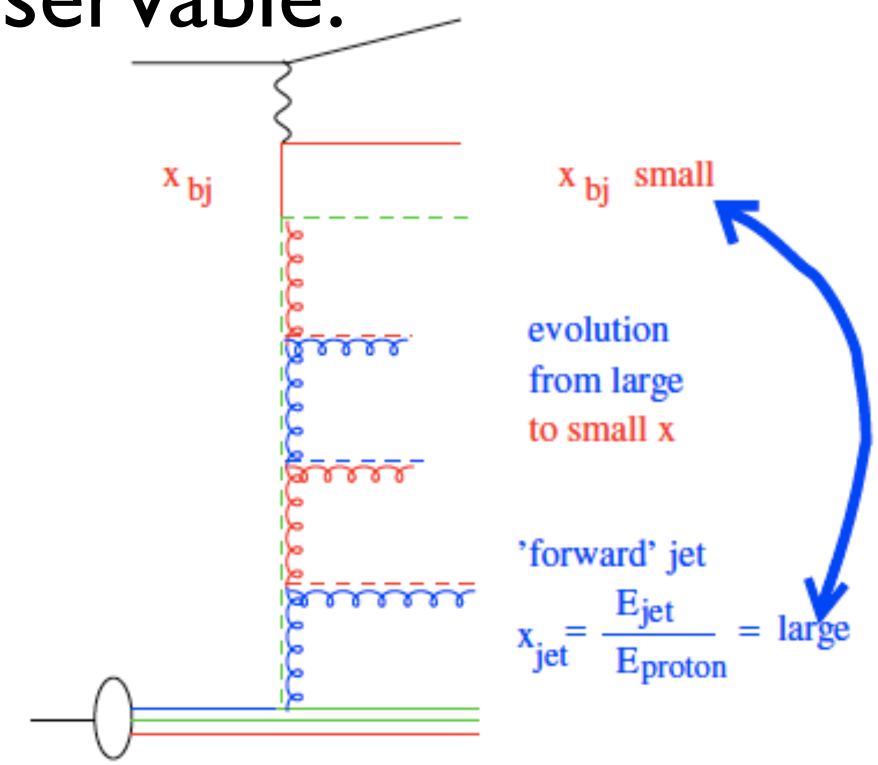
- Studying dijet azimuthal decorrelation or forward jets ($p_T \sim Q$) would allow to understand the mechanism of radiation:

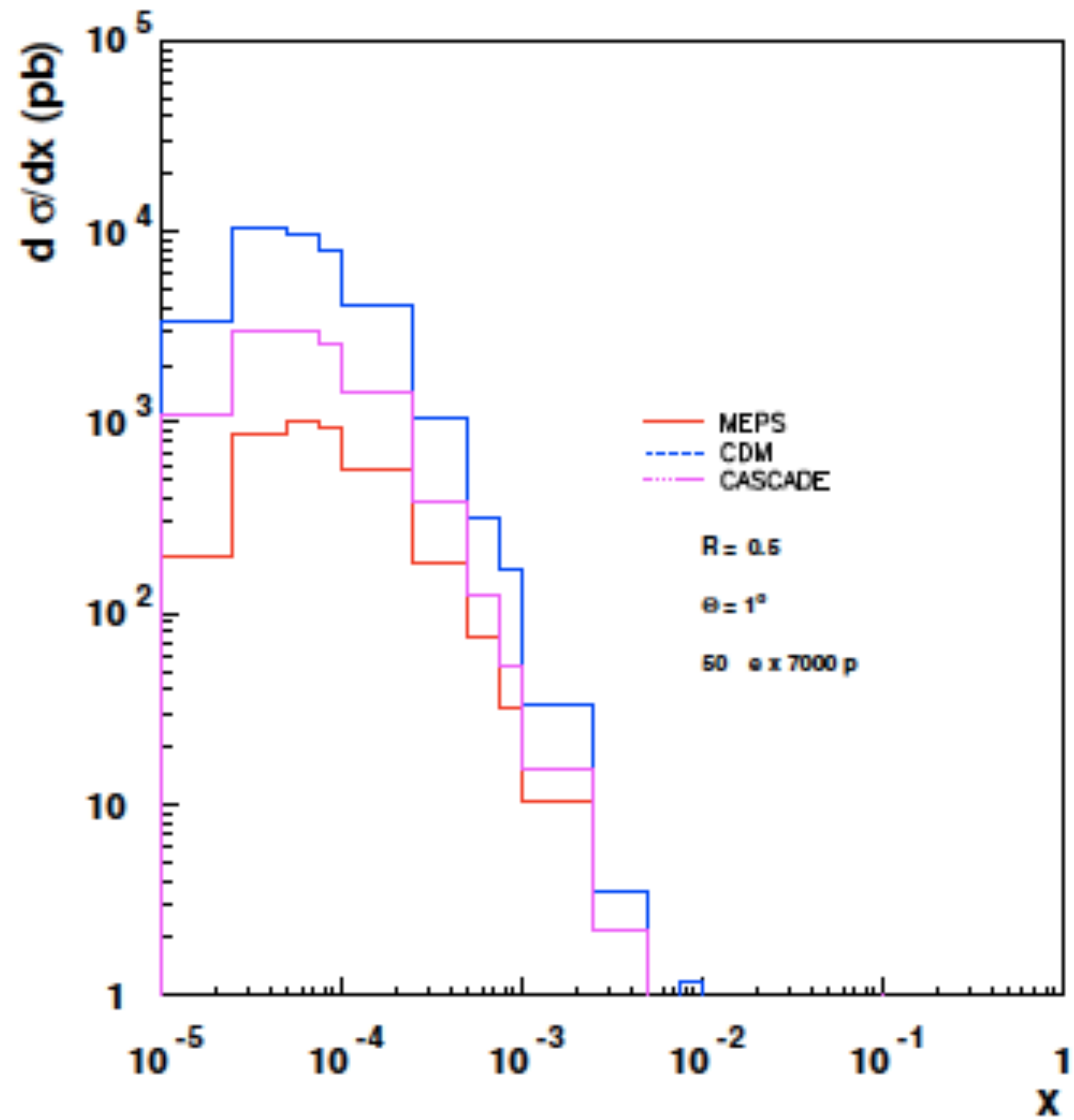
→ k_T-ordered: DGLAP.

→ k_T-disordered: BFKL.

→ Saturation?

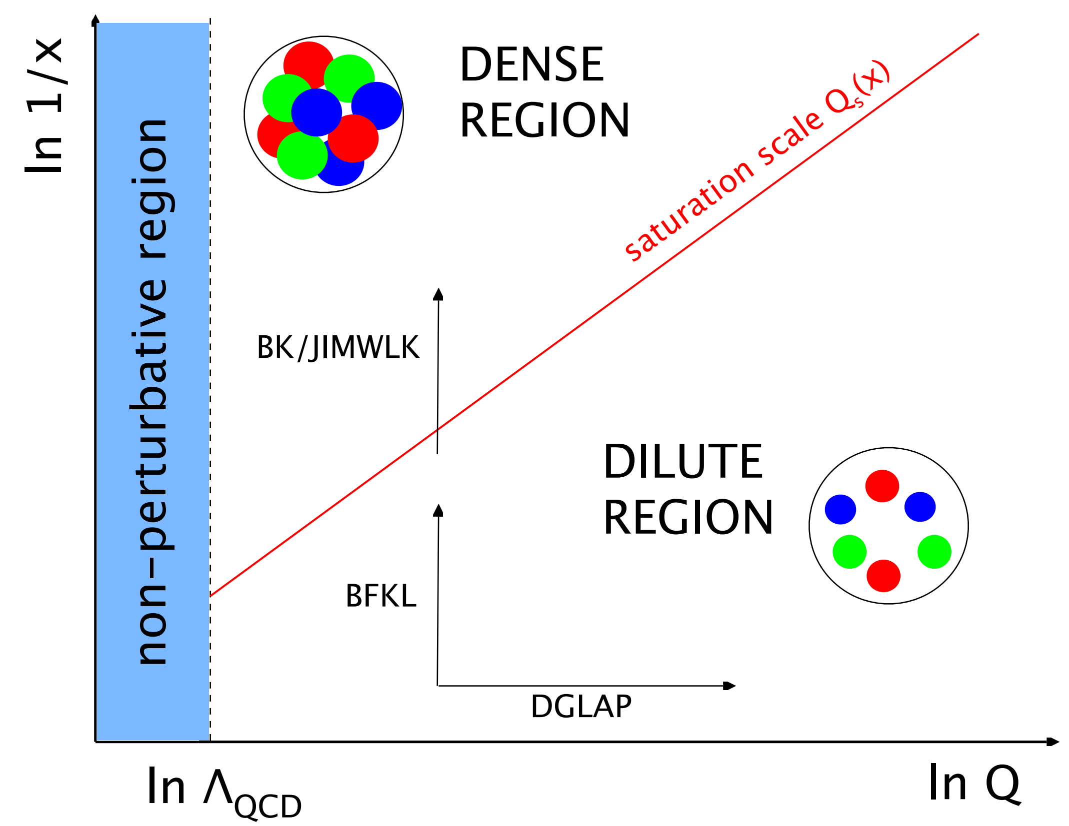
- Further imposing a rapidity gap (diffractive jets) would be most interesting: perturbatively controllable observable.

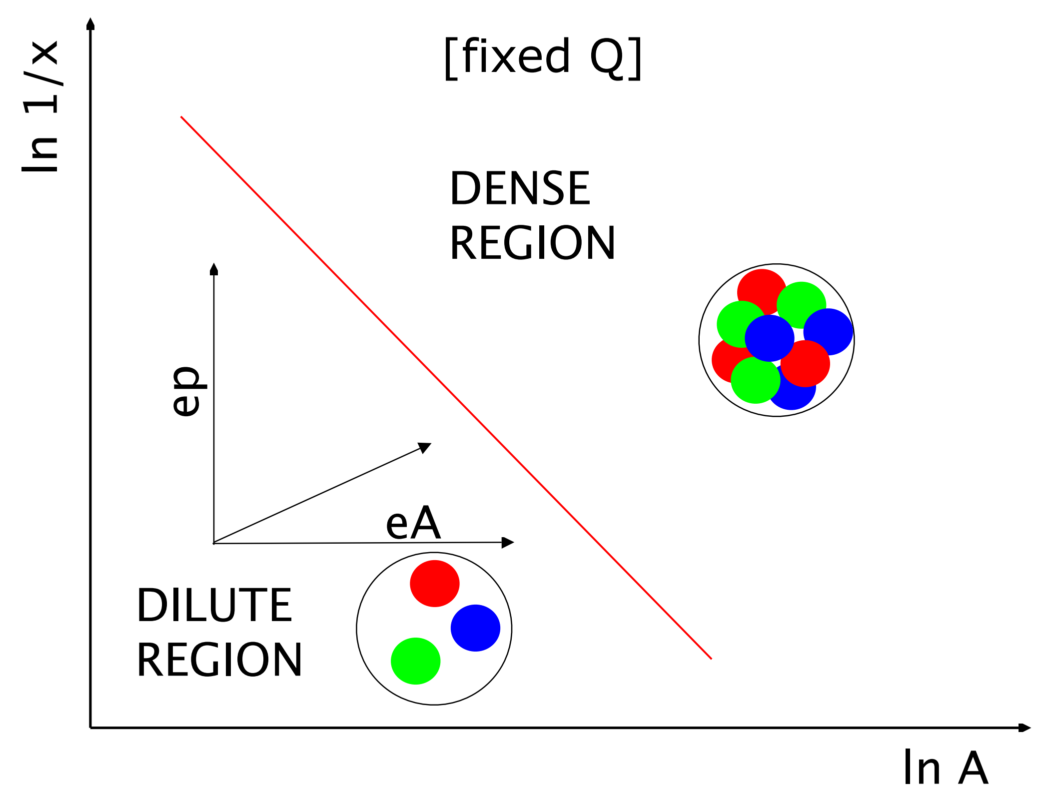




Summary:

- ***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!!!**





Future plans:

• **Next: follow CERN mandate and go towards a TDR.** This requires a further elaboration of the physics case:

➜ diffraction: studies on DPDFs and nDPDFs.

➜ GPDs: complementarity of exclusive VM production and DVCS, also in the nuclear case.

➜ complementarity with the LHC, both ep/pp and eA/pA.

➜ ...

Any collaboration is more than welcome!!!

Future plans:

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J.L.Abelleira Fernandez[16,23], C.Adolphsen[57], A.N.Akay[03], H.Aksakal[39], J.L.Albacete[52], S.Alekhin[17,54], P.Allport[24], V.Andreev[34], R.B.Appleby[14,30], E.Arikan[39], N.Armesto[53,a], G.Azuelos[33,64], M.Bai[37], D.Barber[14,17,24], J.Bartels[18], O.Behnke[17], J.Behr[17], A.S.Belyaev[15,56], I.Ben-Zvi[37], N.Bernard[25], S.Bertolucci[16], S.Bettoni[16], S.Biswal[41], J.Blümlein[17], H.Böttcher[17], A.Bogacz[36], C.Bracco[16], G.Brandt[44], H.Braun[65], S.Brodsky[57,b], O.Brüning[16], E.Bulyak[12], A.Buniatyan[17], H.Burkhardt[16], I.T.Cakir[02], O.Cakir[01], R.Calaga[16], V.Cetinkaya[01], E.Ciapala[16], R.Ciftci[01], A.K.Ciftci[01], B.A.Cole[38], J.C.Collins[48], O.Dadoun[42], J.Dainton[24], A.De.Roeck[16], D.d'Enterria[16], A.Dudarev[16], A.Eide[60], R.Enberg[63], E.Eroglu[62], K.J.Eskola[21], L.Favart[08], M.Fitterer[16], S.Forte[32], A.Gaddi[16], P.Gambino[59], H.García Morales[16], T.Gehrmann[69], P.Gladkikh[12], C.Glasman[28], R.Godbole[35], B.Goddard[16], T.Greenshaw[24], A.Guffanti[13], V.Guzey[19,36], C.Gwenlan[44], T.Han[50], Y.Hao[37], F.Haug[16], W.Herr[16], A.Hervé[27], B.J.Holzer[16], M.Ishitsuka[58], M.Jacquet[42], B.Jeanneret[16], J.M.Jimenez[16], J.M.Jowett[16], H.Jung[17], H.Karadeniz[02], D.Kayran[37], A.Kilic[62], K.Kimura[58], M.Klein[24], U.Klein[24], T.Kluge[24], F.Kocak[62], M.Korostelev[24], A.Kosmicki[16], P.Kostka[17], H.Kowalski[17], G.Kramer[18], D.Kuchler[16], M.Kuze[58], T.Lappi[21,c], P.Laycock[24], E.Levichev[40], S.Levonian[17], V.N.Litvinenko[37], A.Lombardi[16], J.Maeda[58], C.Marquet[16], B.Mellado[27], K.H.Mess[16], A.Milanese[16], S.Moch[17], I.I.Morozov[40], Y.Muttoni[16], S.Myers[16], S.Nandi[55], Z.Nergiz[39], P.R.Newman[06], T.Omori[61], J.Osborne[16], E.Paoloni[49], Y.Papaphilippou[16], C.Pascaud[42], H.Paukkunen[53], E.Perez[16], T.Pieloni[23], E.Pilicer[62], B.Pire[45], R.Placakyte[17], A.Polini[07], V.Ptitsyn[37], Y.Pupkov[40], V.Radescu[17], S.Raychaudhuri[35], L.Rinolfi[16], R.Rohini[35], J.Rojo[16,31], S.Russenschuck[16], M.Sahin[03], C.A.Salgado[53,a], K.Sampei[58], R.Sassot[09], E.Sauvan[04], U.Schneekloth[17], T.Schörner-Sadenius[17], D.Schulte[16], A.Senol[22], A.Seryi[44], P.Sievers[16], A.N.Skrinsky[40], W.Smith[27], H.Spiesberger[29], A.M.Stasto[48,d], M.Strikman[48], M.Sullivan[57], S.Sultansoy[03,e], Y.P.Sun[57], B.Surrow[11], L.Szymanowski[66,f], P.Taels[05], I.Tapan[62], T.Tasci[22], E.Tassi[10], H.Ten.Kate[16], J.Terron[28], H.Thiesen[16], L.Thompson[14,30], K.Tokushuku[61], R.Tomás García[16], D.Tommasini[16], D.Trbojevic[37], N.Tsoupas[37], J.Tuckmantel[16], S.Turkoz[01], T.N.Trinh[47], K.Tywoniuk[26], G.Unel[20], J.Urakawa[61], P.VanMechelen[05], A.Variola[52], R.Veness[16], A.Vivoli[16], P.Vobly[40], J.Wagner[66], R.Wallny[68], S.Wallon[43,46,f], G.Watt[16], C.Weiss[36], U.A.Wiedemann[16], U.Wienands[57], F.Willeke[37], B.-W.Xiao[48], V.Yakimenko[37], A.F.Zarnecki[67], Z.Zhang[42], F.Zimmermann[16], R.Zlebcik[51], F.Zomer[42]

Future plans:

• **Ne**
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→ GP
DVCS

→ cor

→ ...

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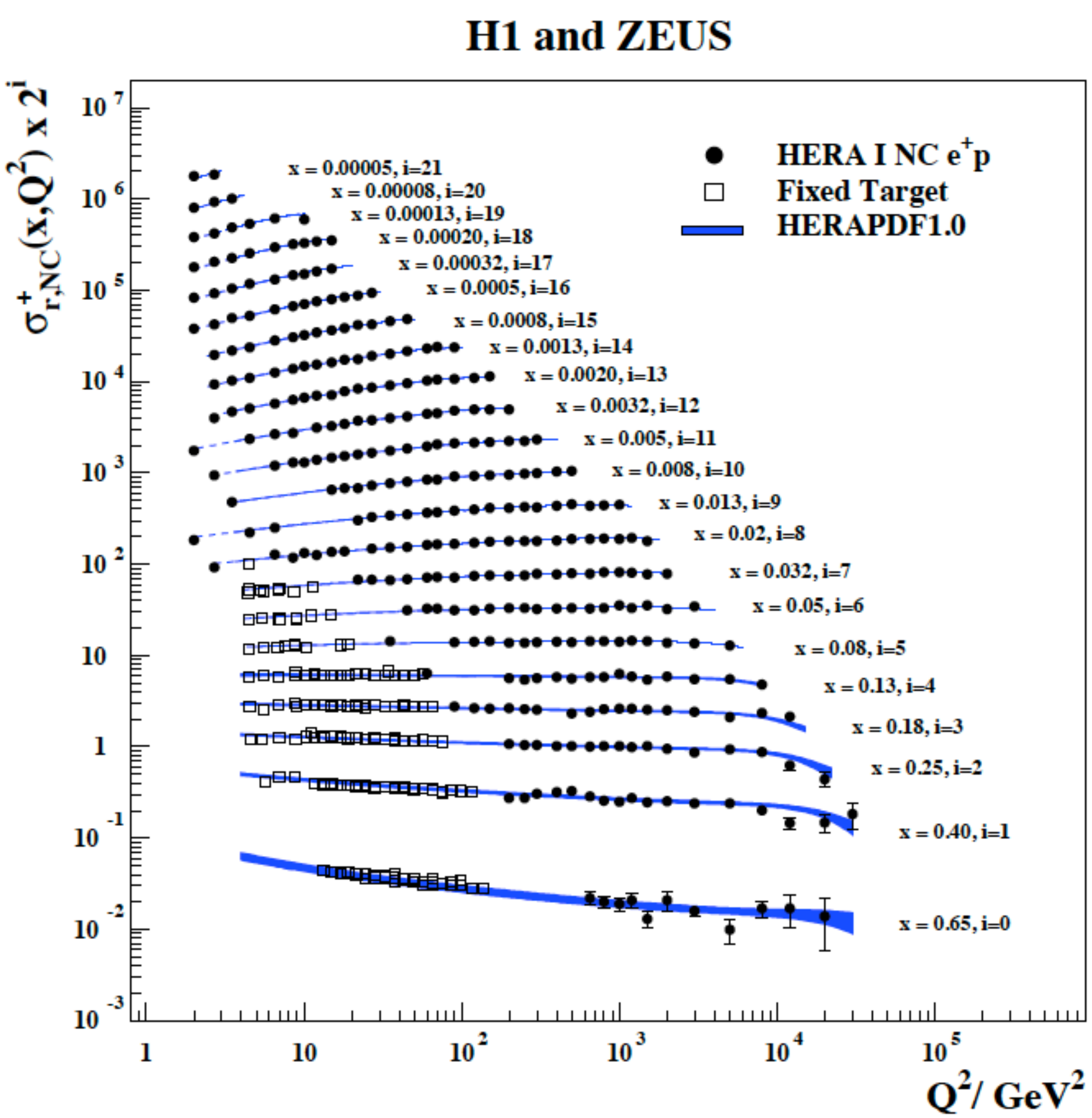
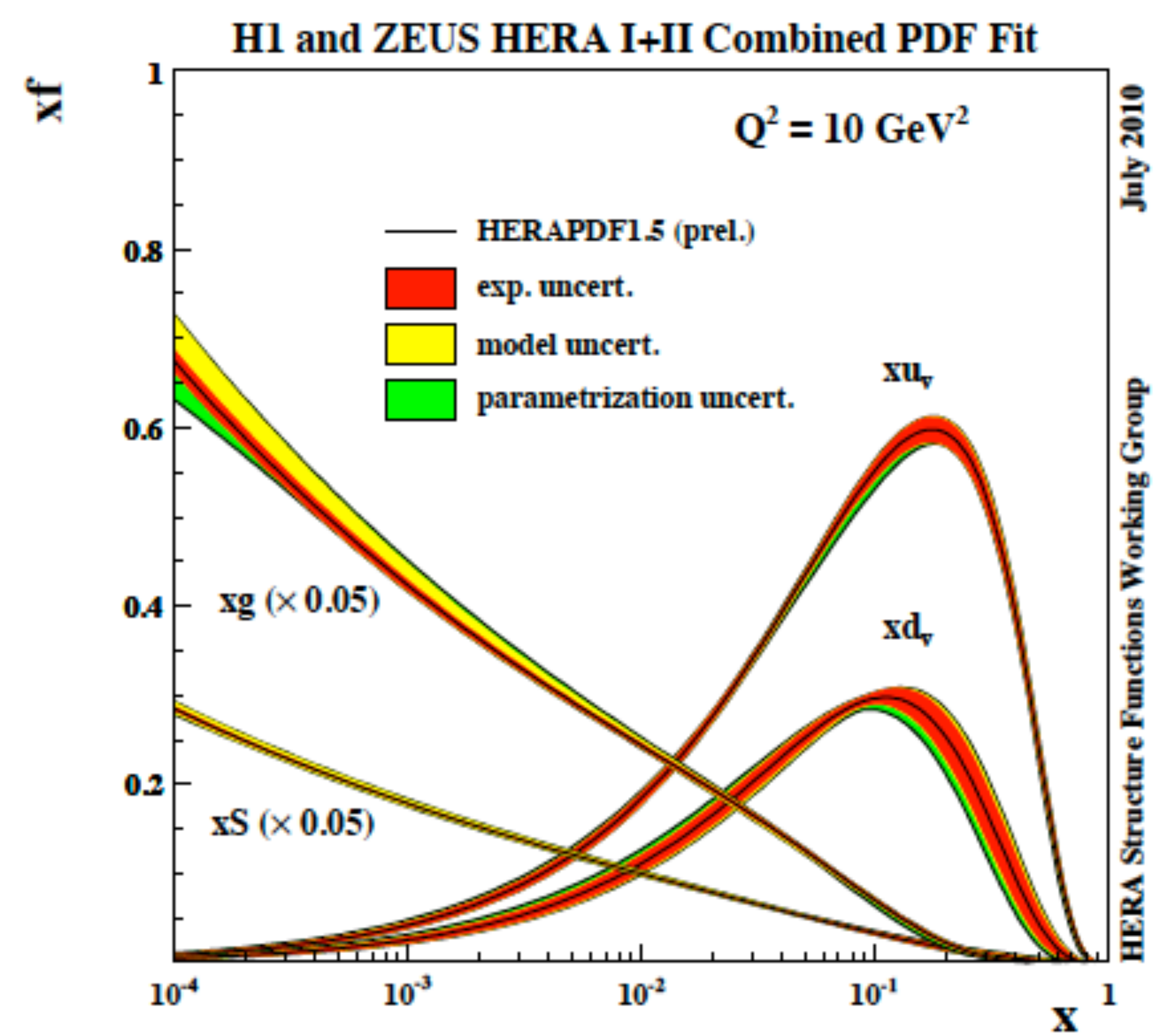
Thanks for your attention!

Backup:

Legacy from HERA:

- Structure functions in an extended x-Q^2 range, xg $\propto 1/x^{\lambda}$, $\lambda>0$.
- Large fraction of diffraction $\sigma_{diff}/\sigma_{tot}\sim 10\%$.
- But: no eA/eD, kinematical reach at small x, luminosity at high x / for searches (odderon,...), flavour decomposition, TMDs,...





Legacy from HERA:

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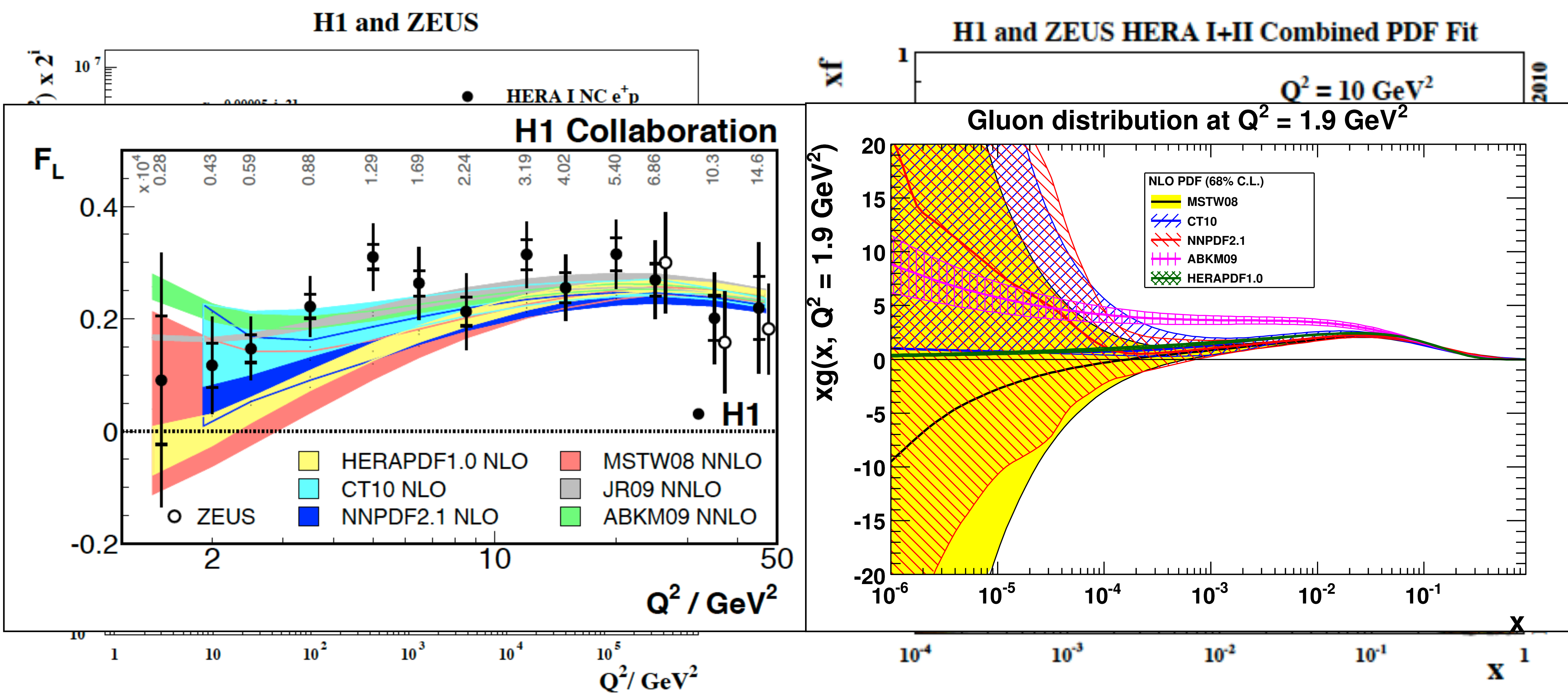
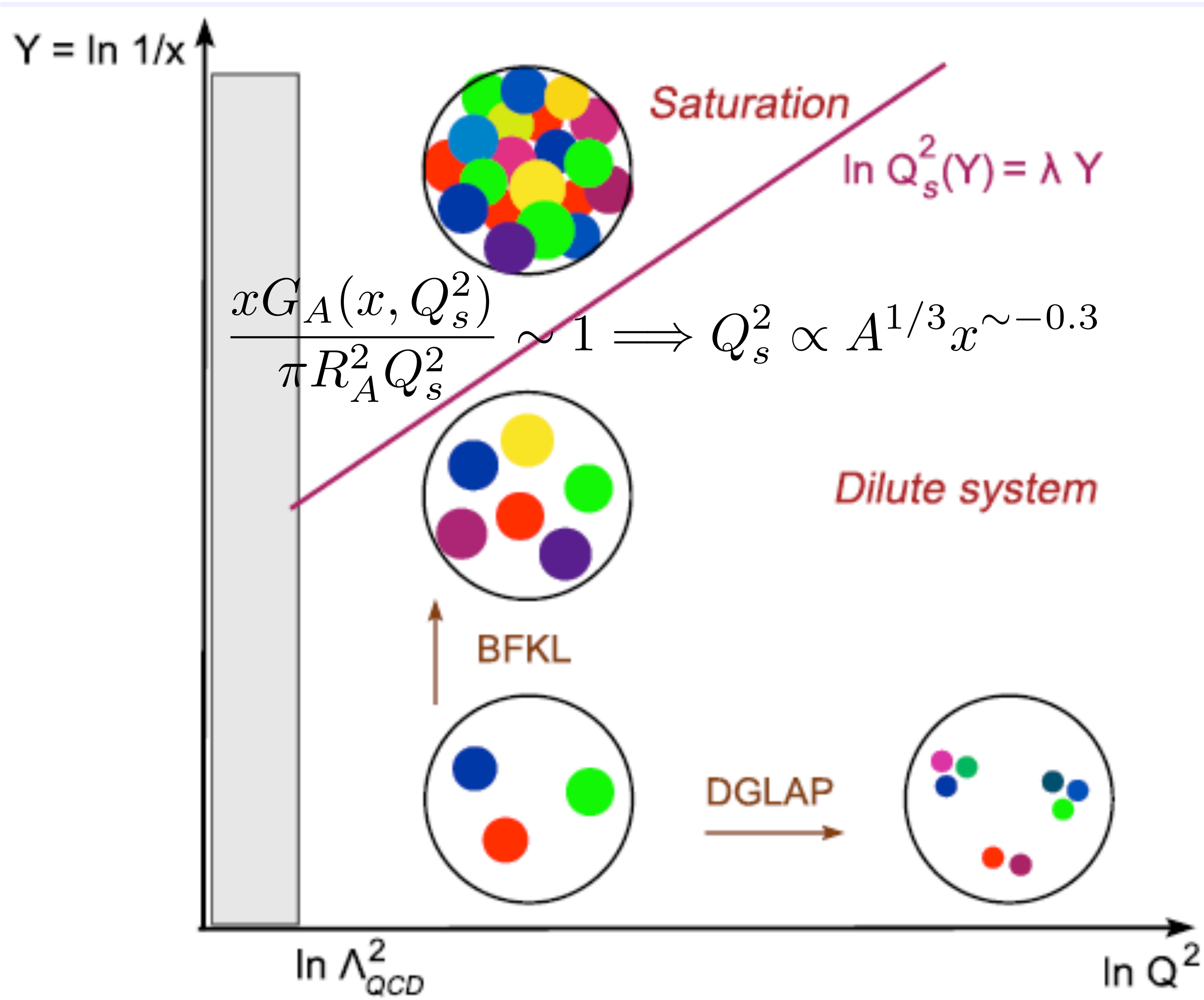


The ‘QCD phase’ diagram:

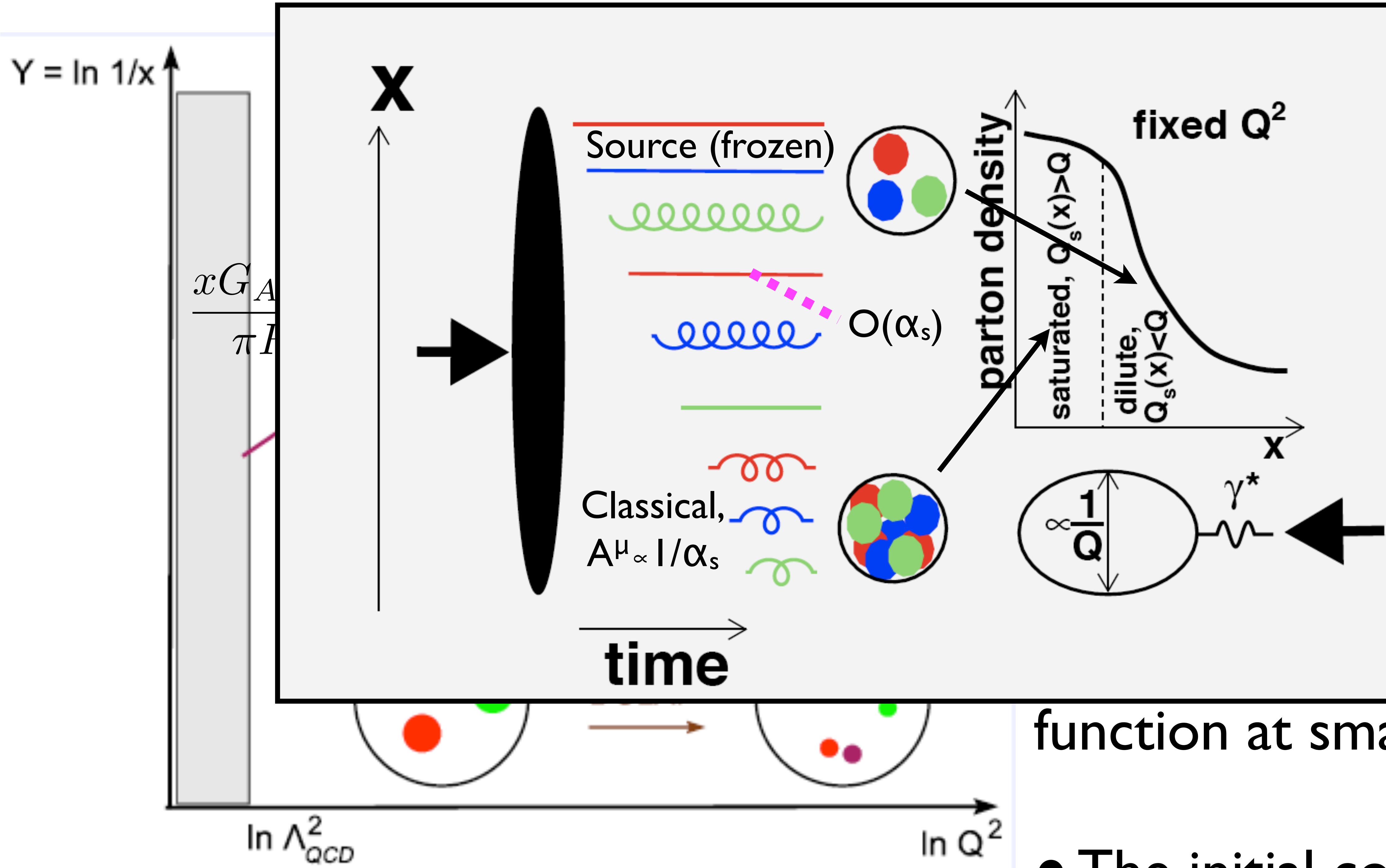


Origin in the early 80’s: GLR, Mueller et al, McLerran-Venugopalan.

Our aims: understanding

- The implications of unitarity in a QFT.
- The behaviour of QCD at large energies.
- The hadron wave function at small x.
- The initial conditions for the creation of a dense medium in heavy-ion collisions.

The ‘QCD phase’ diagram:



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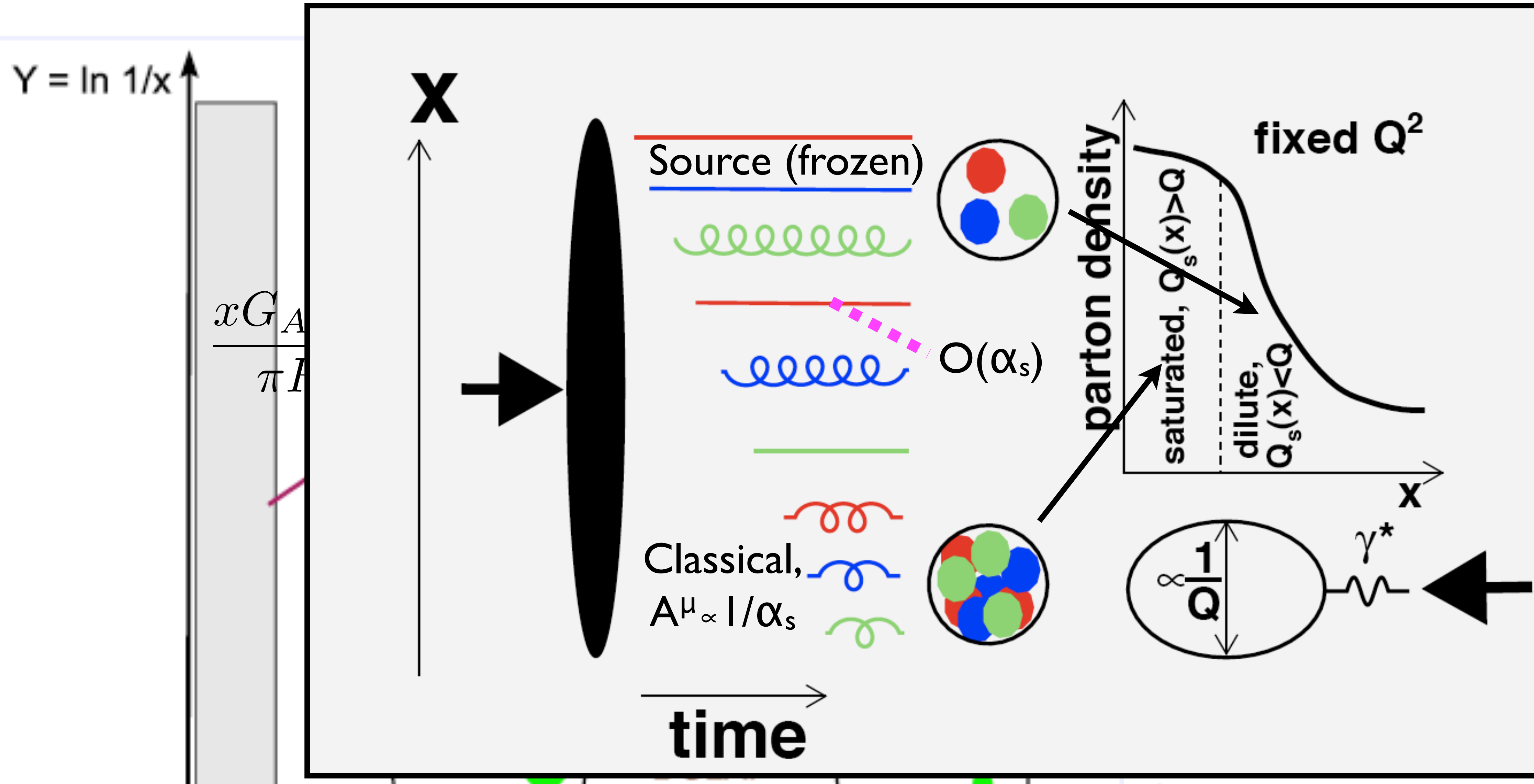
function at small x.

- The initial conditions for the creation of a dense medium in heavy-ion collisions.

Origin in the early 80’s: GLR, Mueller et al, McLerran-Venugopalan.

The ‘QCD phase’ diagram:



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Questions:

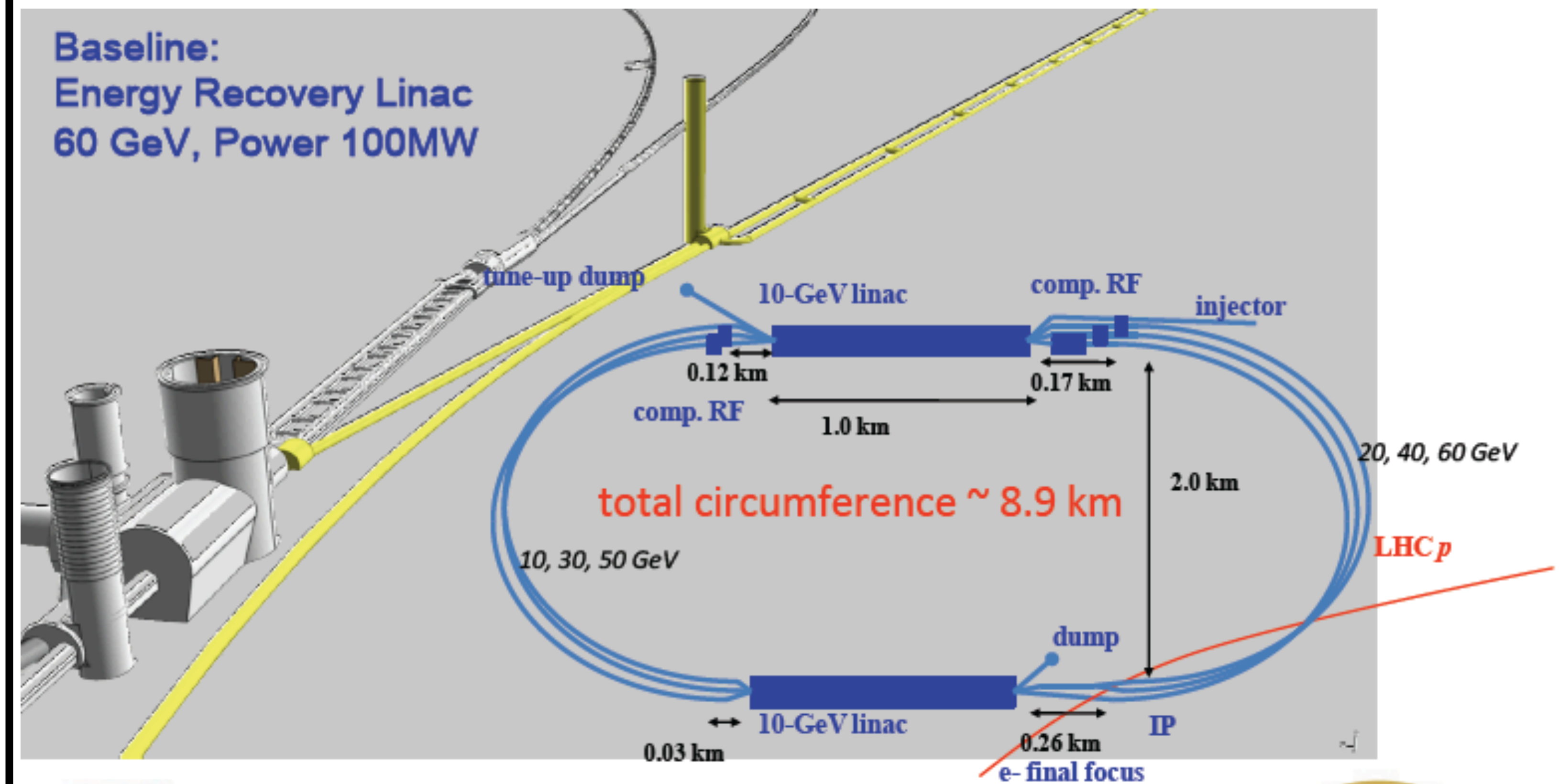
- Theory: can the dense regime be described using pQCD techniques? Or non-perturbative - Regge, AdS/QCD,...? Which factorisation is at work?
- Experiment: where do present/future experimental data lie?

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

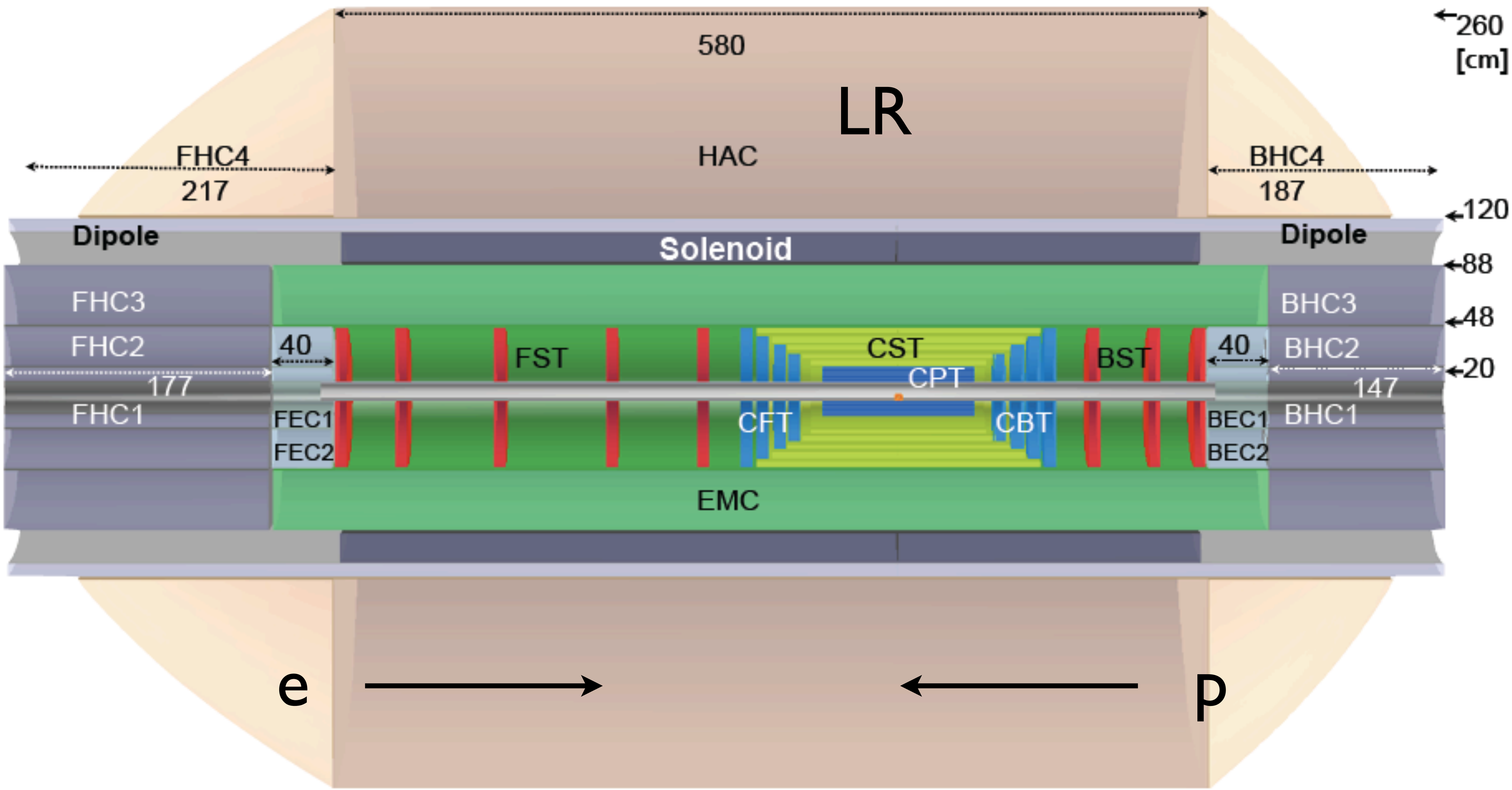


Luminosity per nucleon

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

eD: $L_{eN}=AL_{eA} \gtrsim 3\times10^{31}\ cm^{-2}s^{-1}$

The detector: low-x/eA setup



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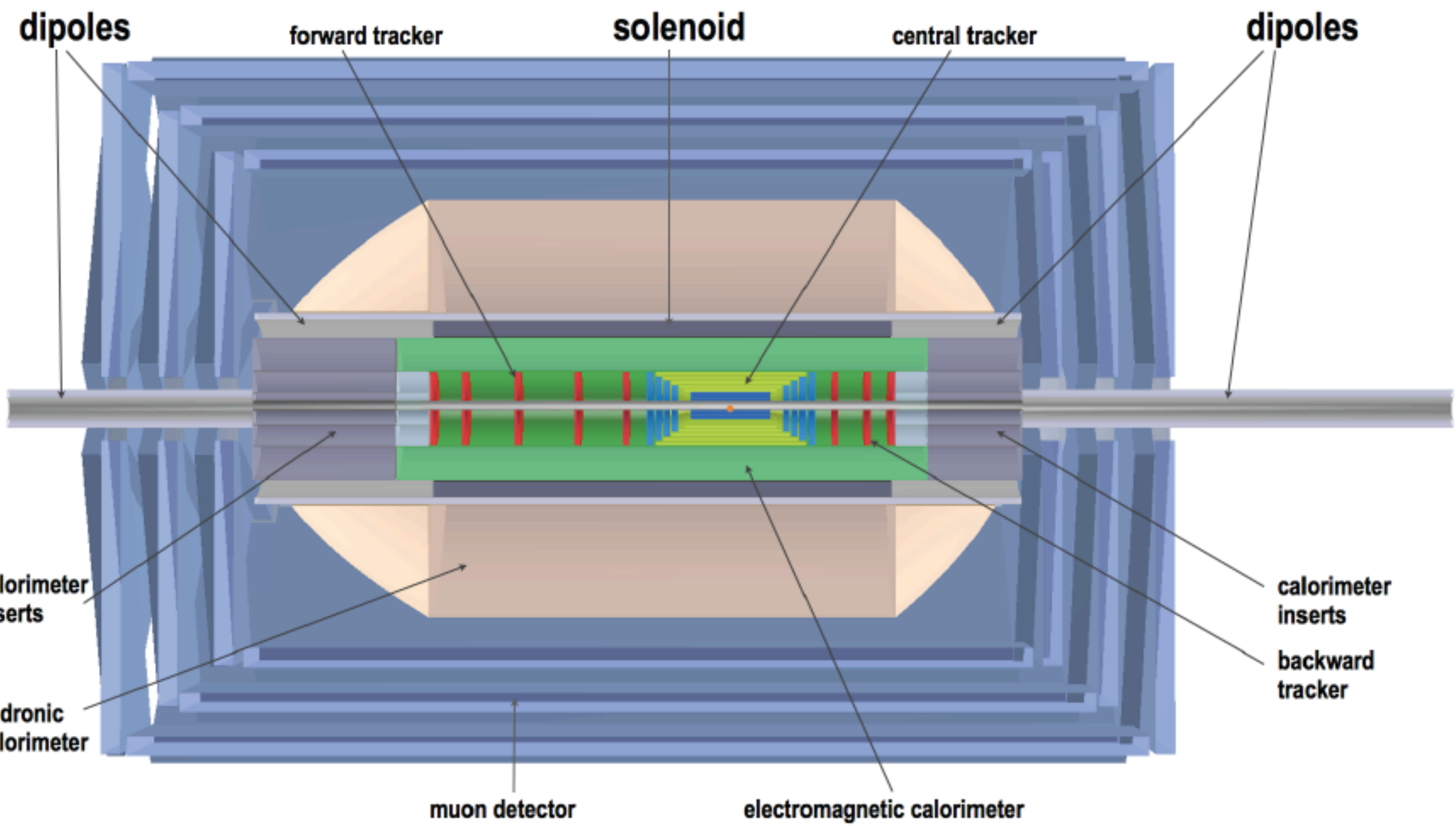

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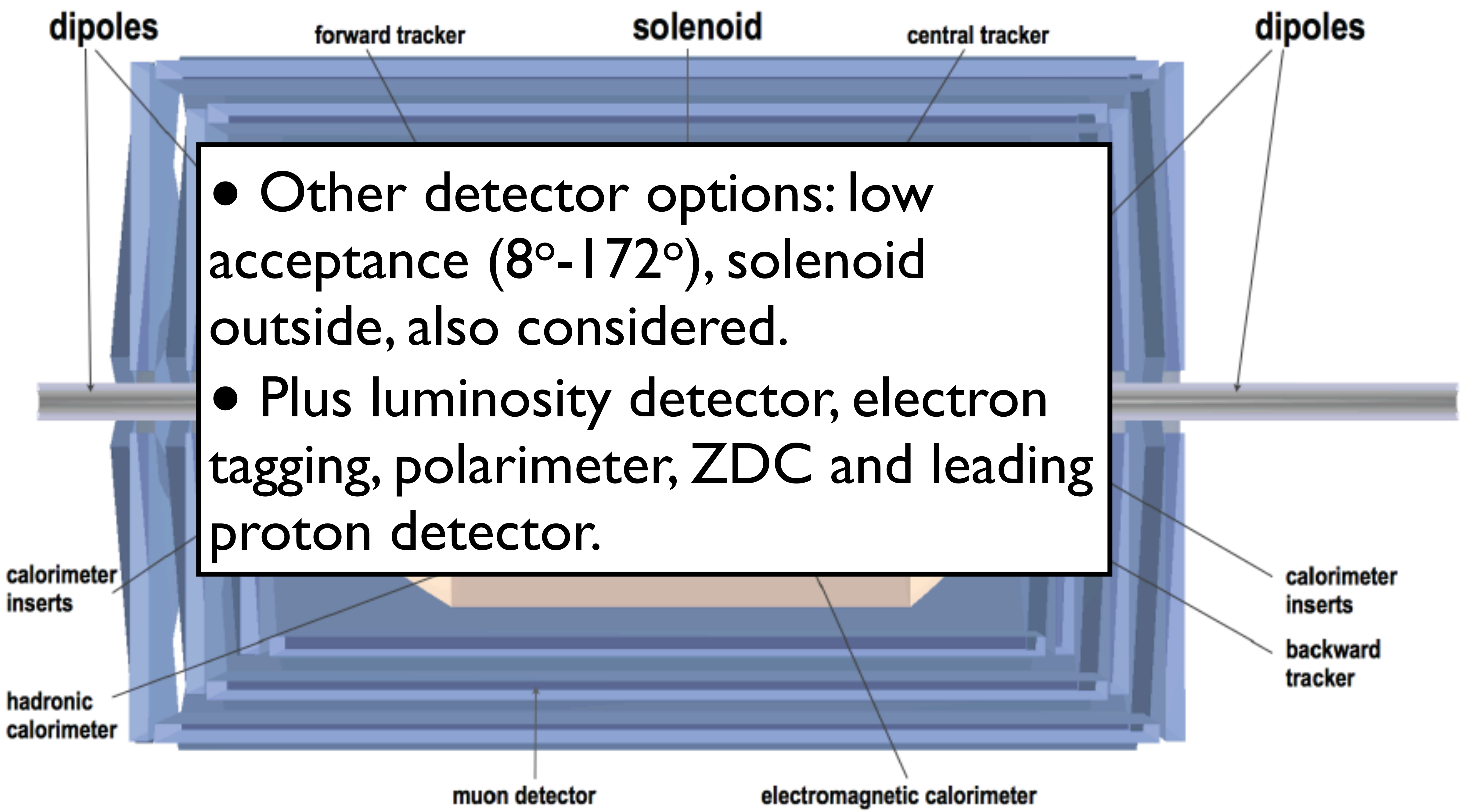


- Other detector options: low acceptance (8°-172°), solenoid outside, also considered.
- Plus luminosity detector, electron tagging, polarimeter, ZDC and leading proton detector.

LHeC scenarios:

For F_2

config.	E(e)	E(N)	N	$\int L(e^+)$	$\int L(e^-)$	|Pol|	$L/10^{32}$	P/MW	years	type
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^{-4}	10^{-4}	0.4	10^{-3}	30	1	ePb
H	50	1	p	--	1	--	25	30	1	lowEp
I	50	3.5	Ca	$5 \cdot 10^{-4}$		?	$5 \cdot 10^{-3}$	?	?	eCa

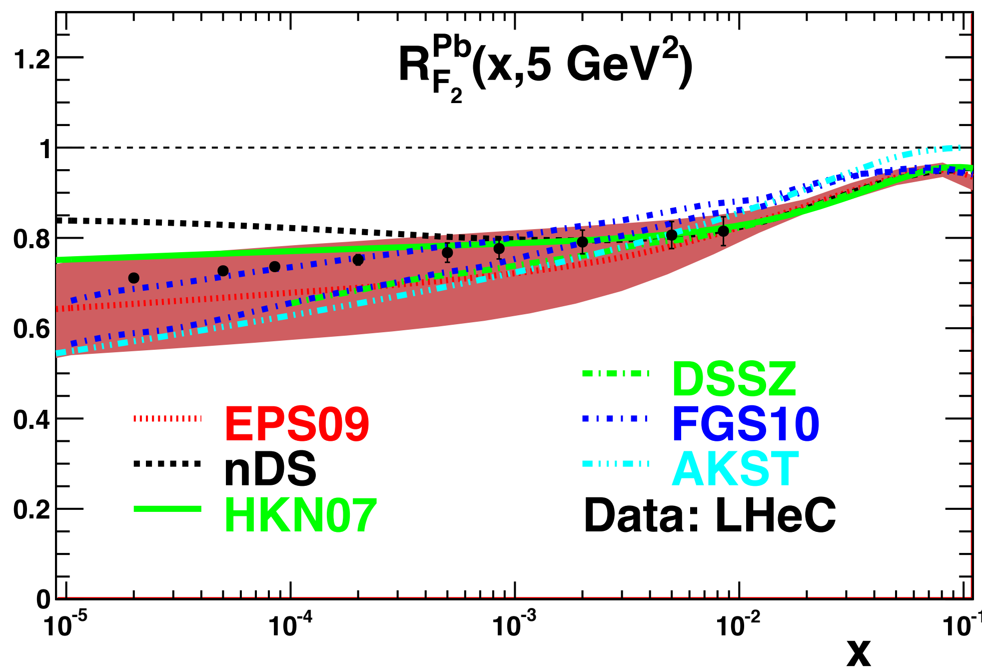
- For F_L: 10, 25, 50 + 2750 (7000); $Q^2 \leq sx$; Lumi=5,10,100 pb^{-1} respectively; charm and beauty: same efficiencies in ep and eA.

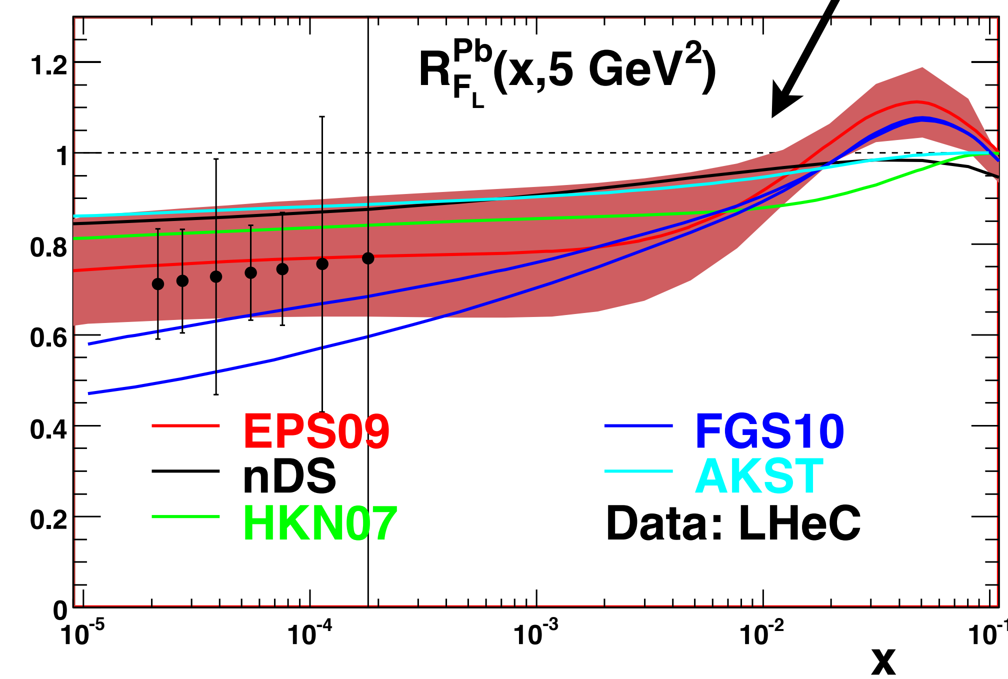
eA inclusive: comparison

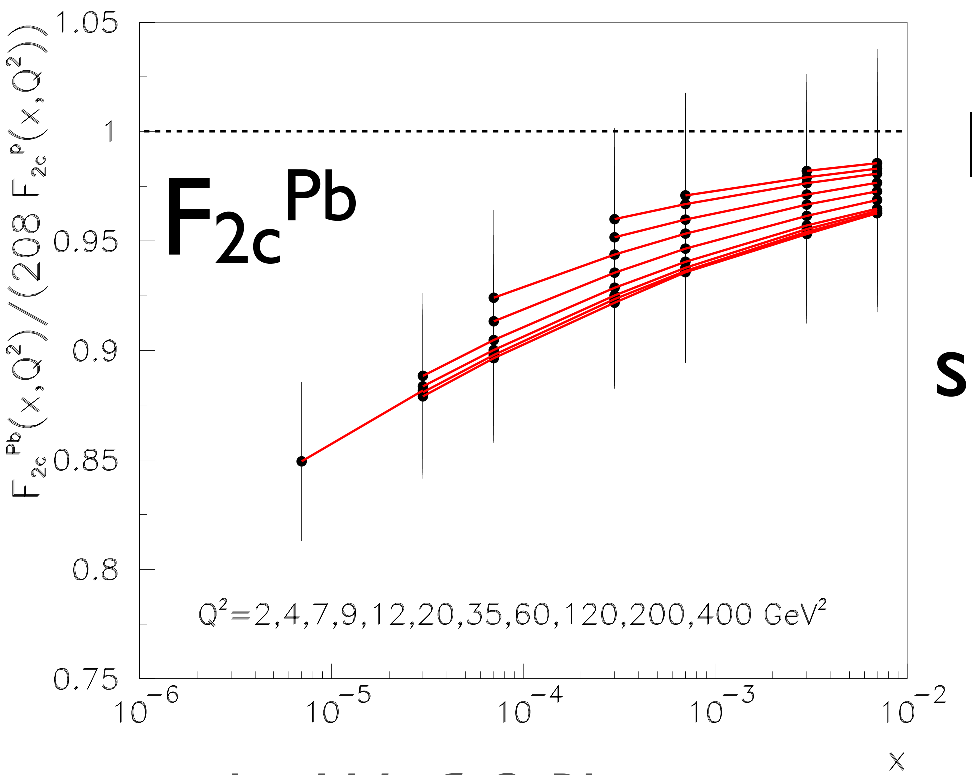
- Good precision can be obtained for $F_{2(c,b)}$ and F_L at small x

(Glauberized 3-5 flavor GBW model, NA '02).

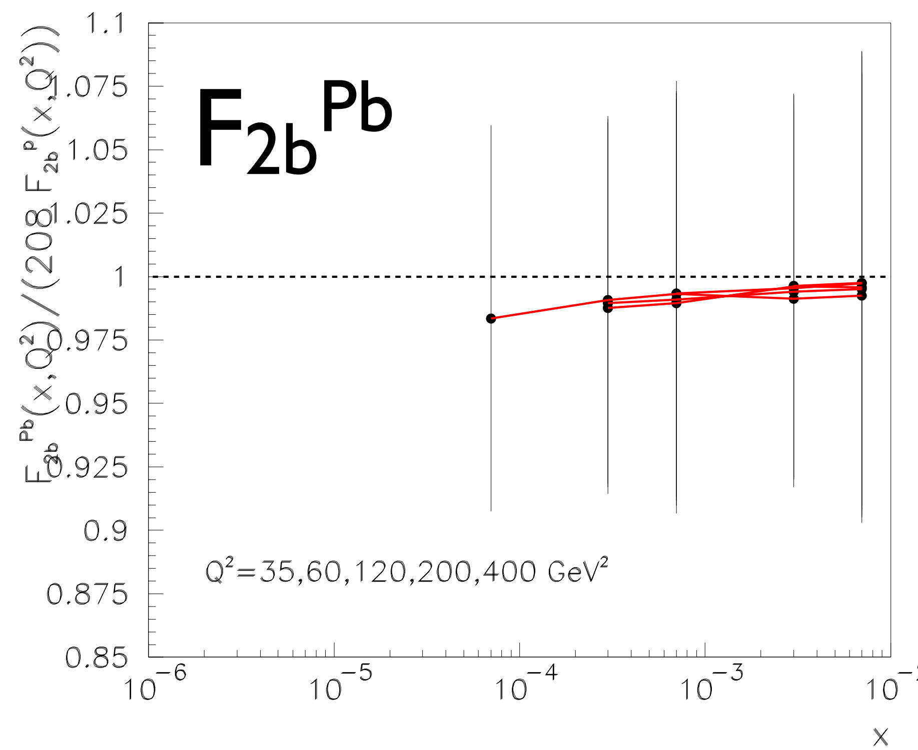
Not optimized!







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:

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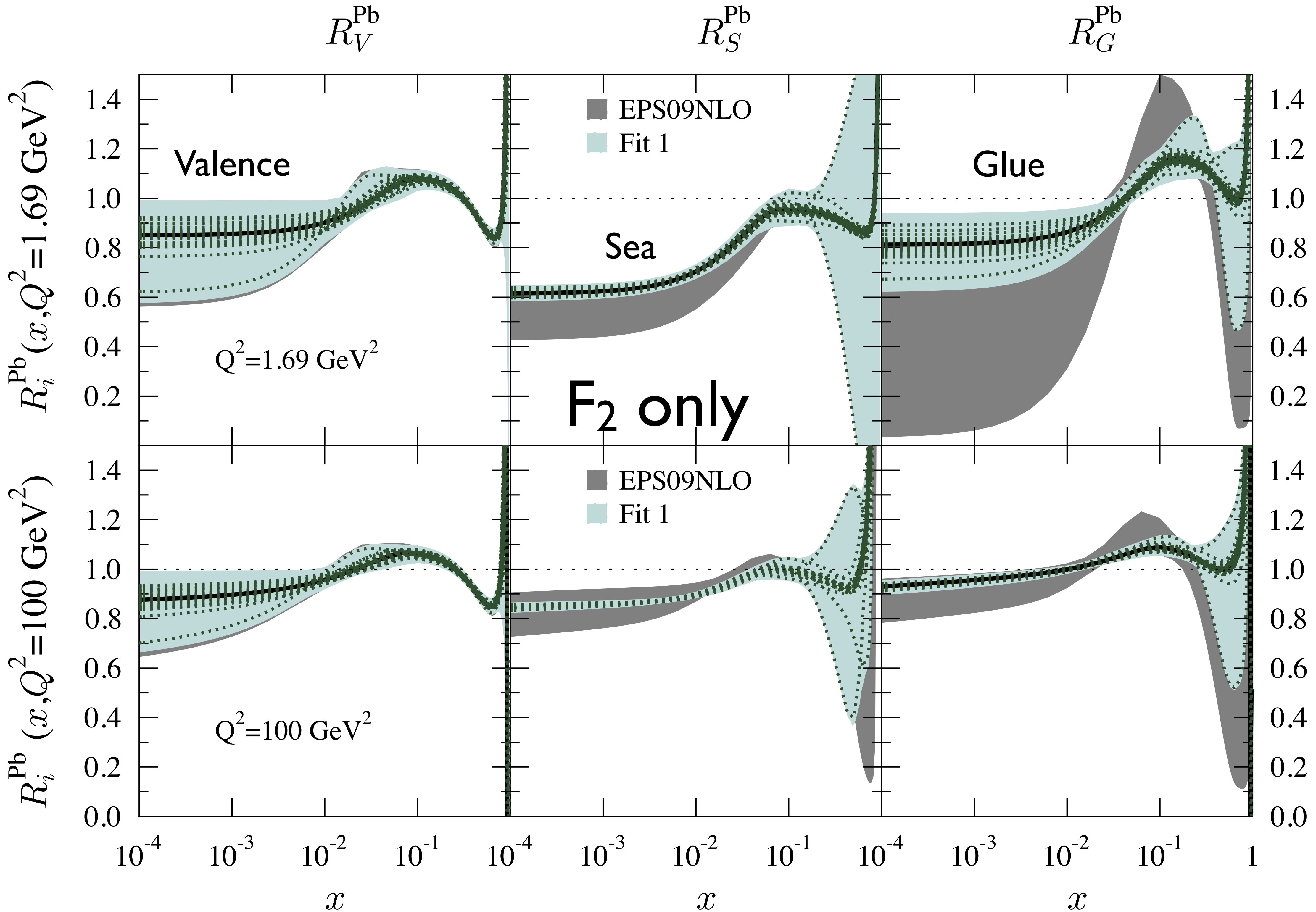

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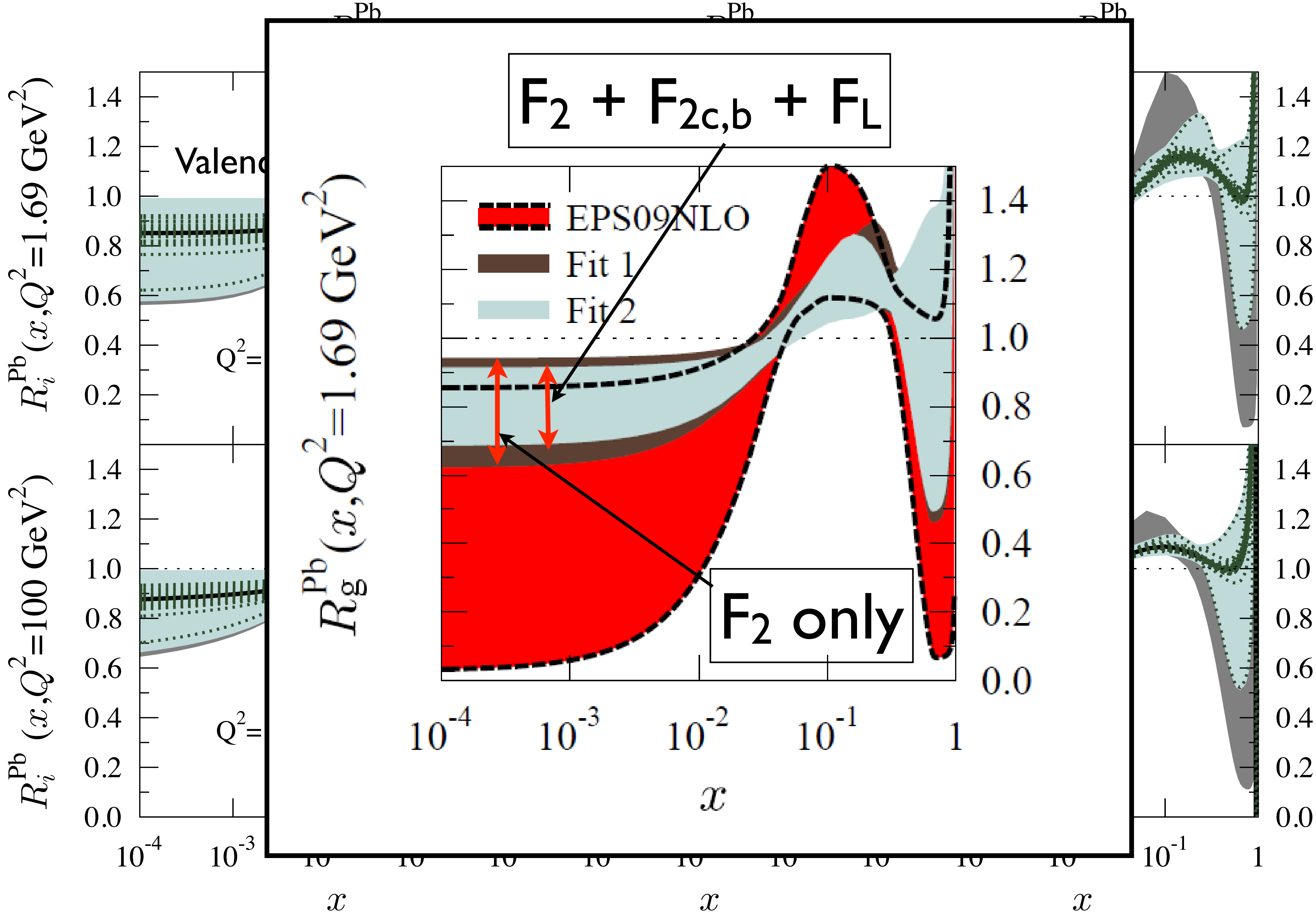

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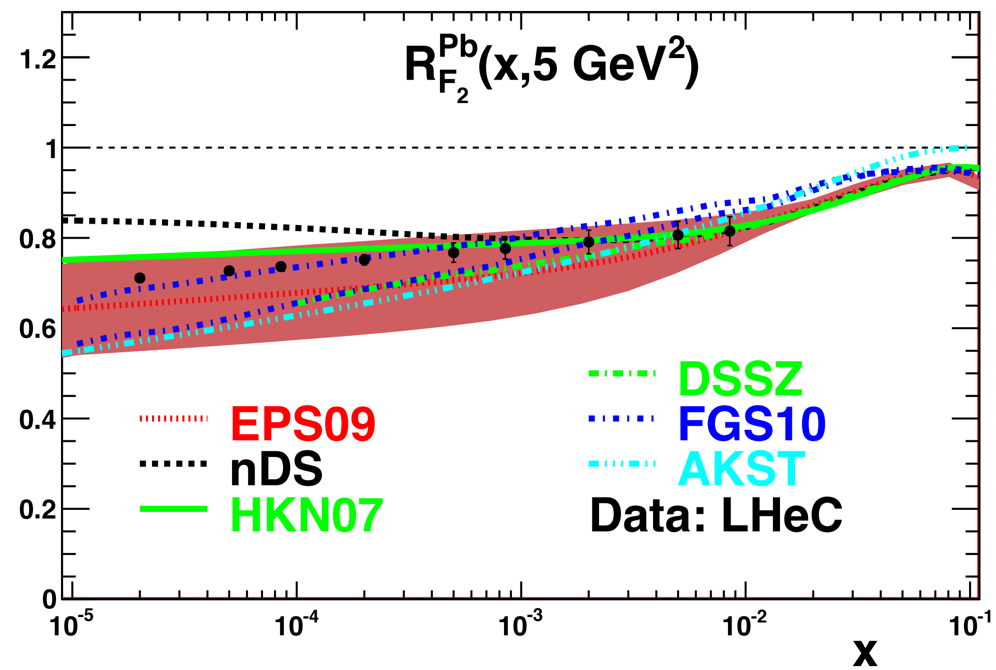
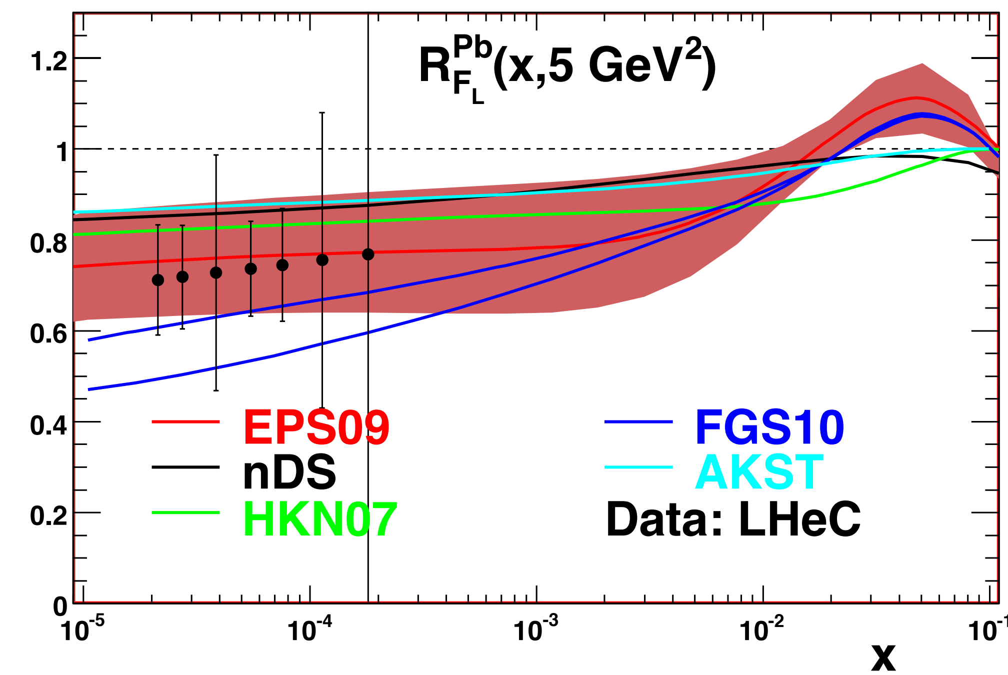
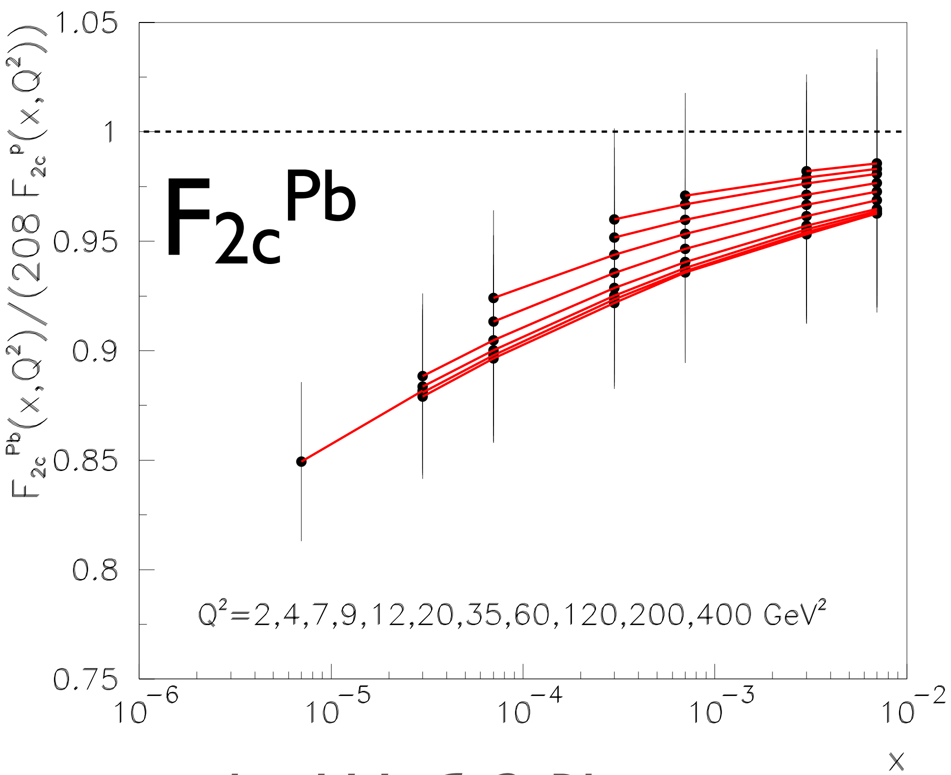
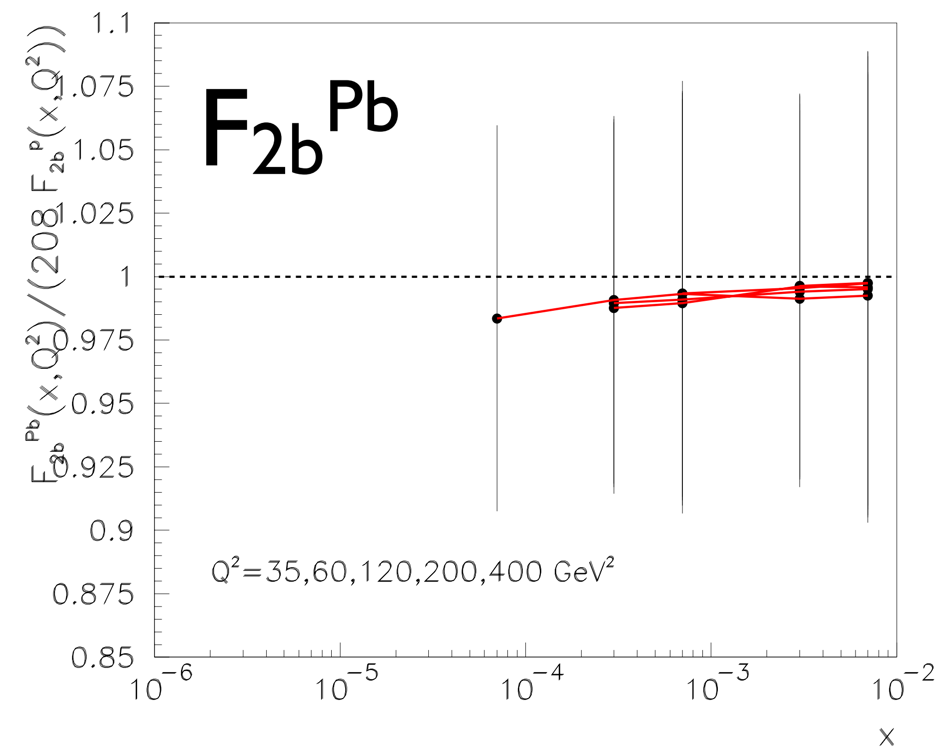








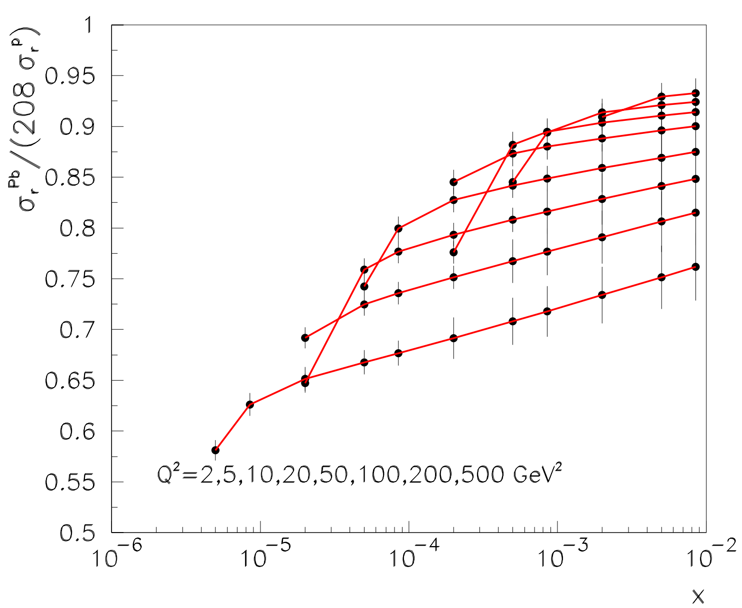
Note: F_L in eA

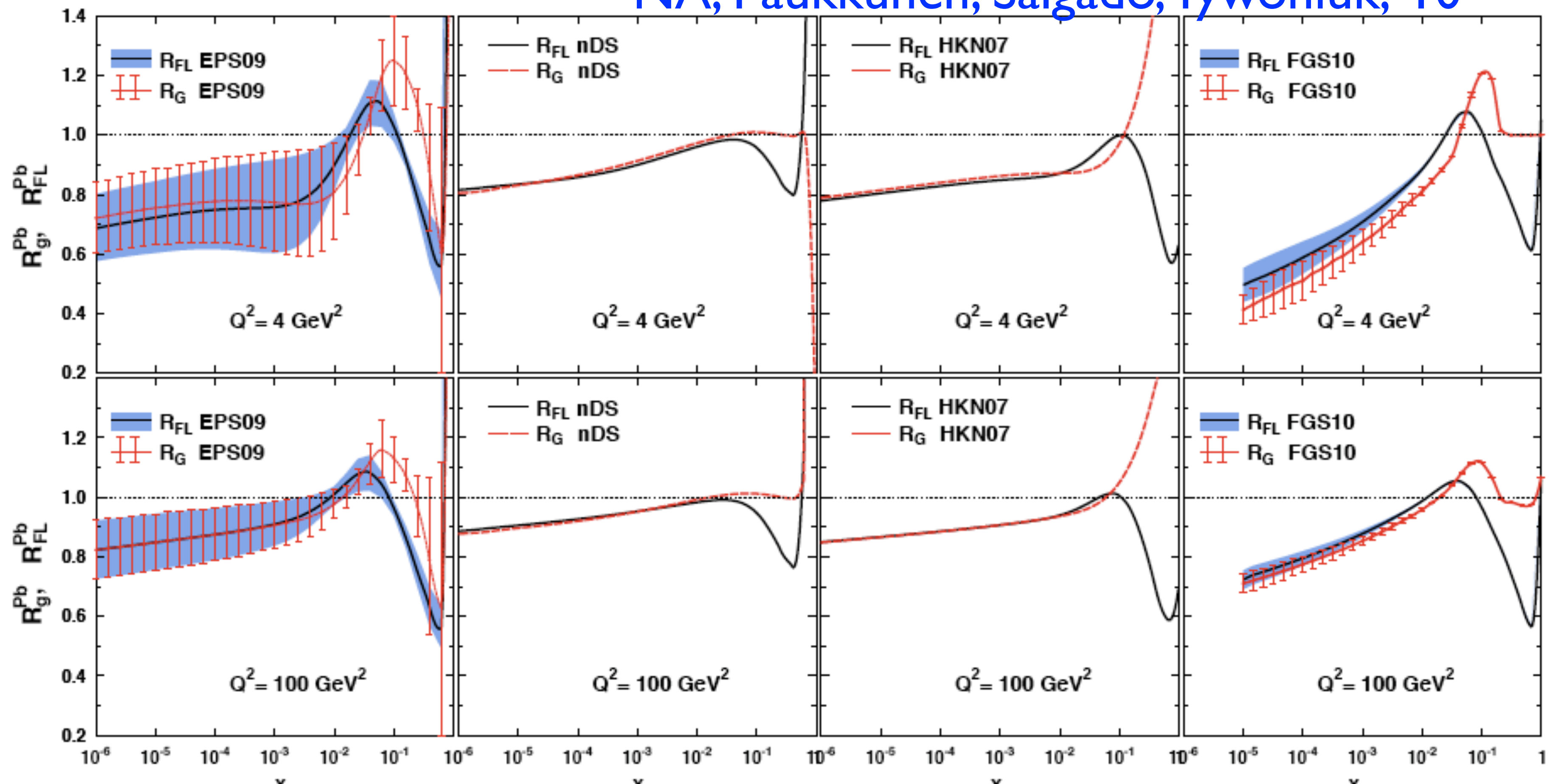
$$\sigma_r^{NC} = \frac{Q^4 x}{2\pi\alpha^2 Y_+}\frac{d^2\sigma^{NC}}{dxdQ^2} = F_2\left[1-\frac{y^2}{Y_+}\frac{F_L}{F_2}\right], \qquad Y_+ = 1+(1-y)^2$$

- 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.) ⇒

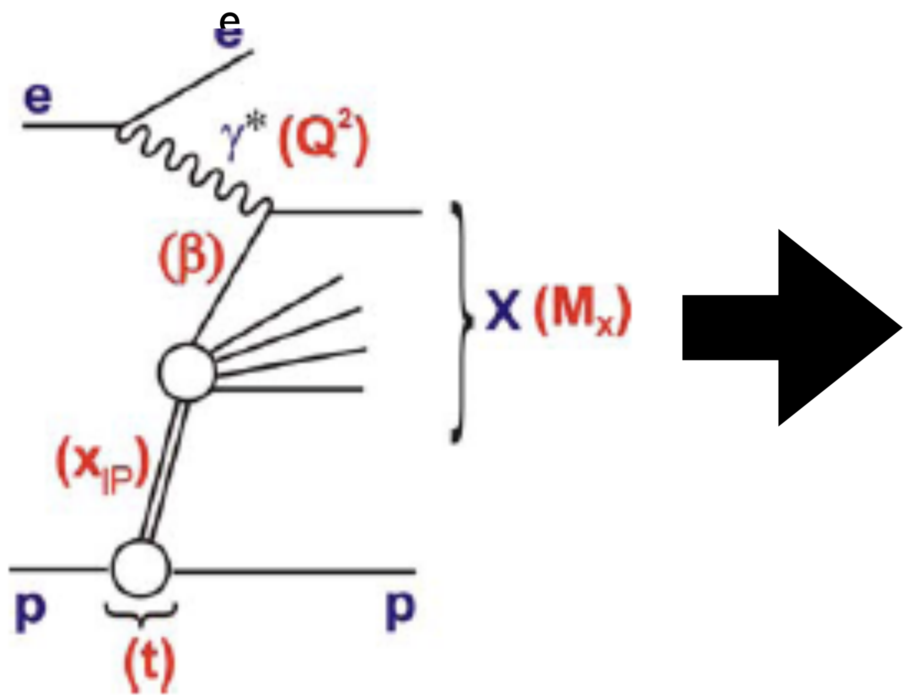
measure F_L or use the reduced cross section (but then ratios at two energies...).

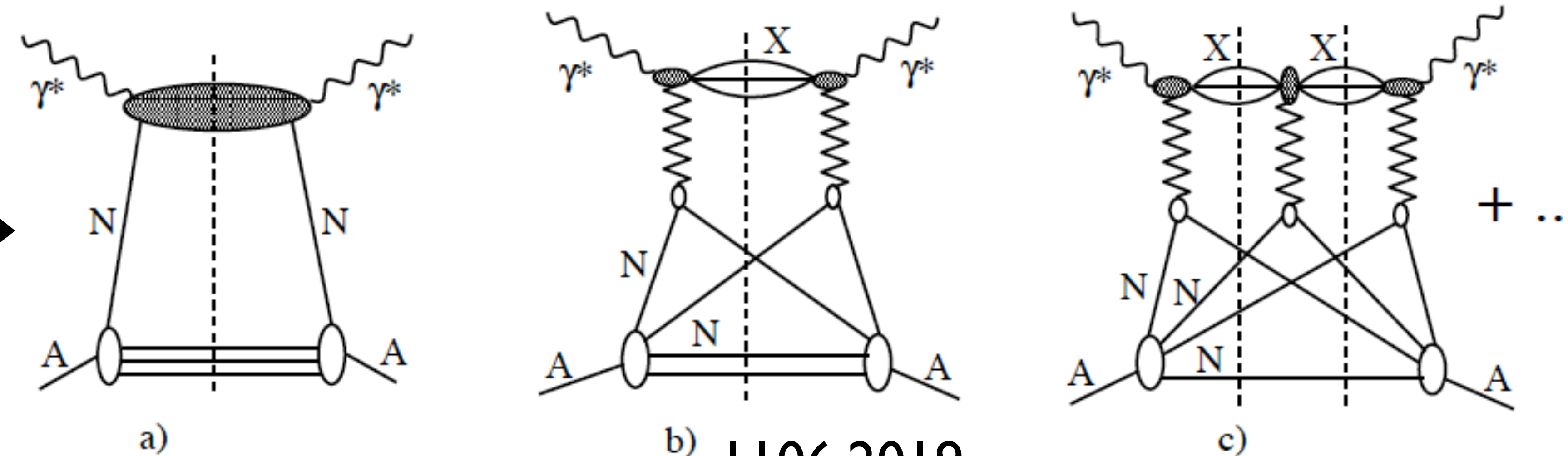
NA, Paukkunen, Salgado, Tywoniuk, '10





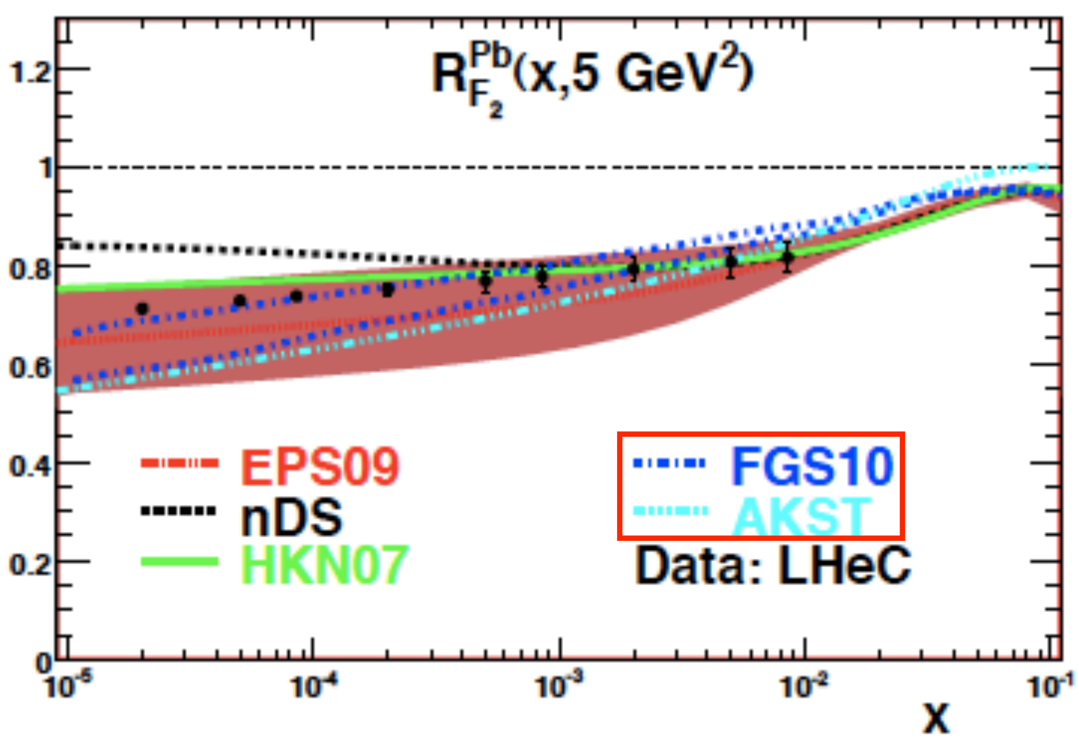
Diffraction in ep and shadowing:

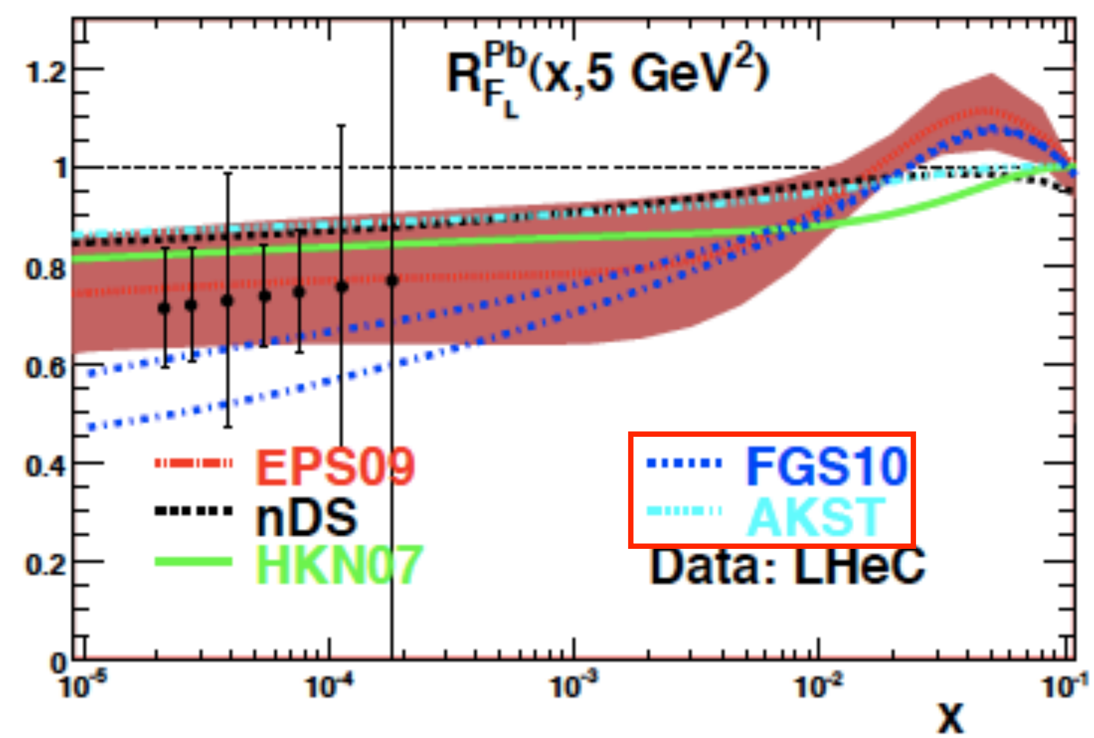




1106.2019

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





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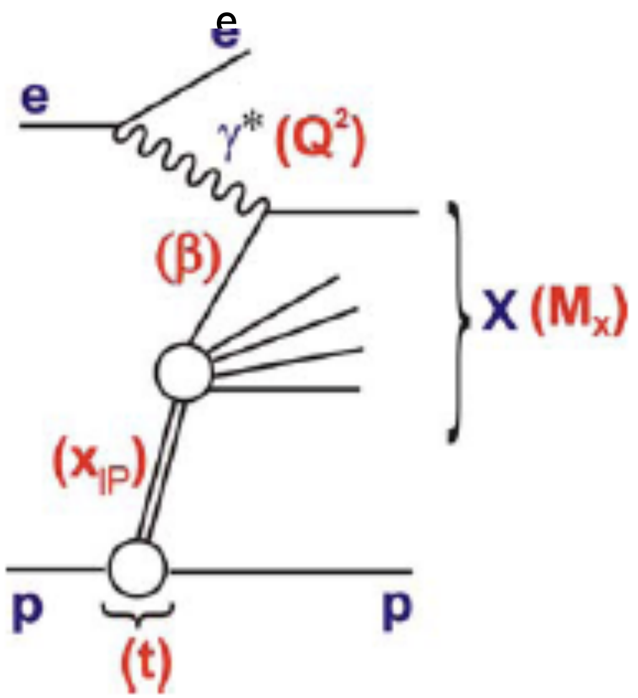

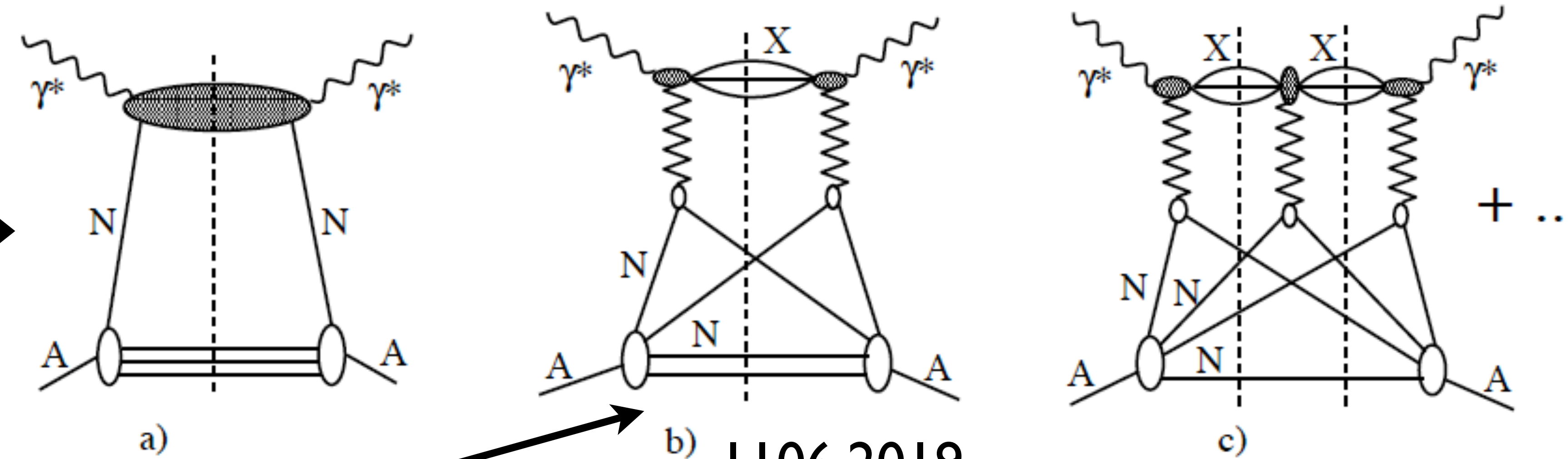

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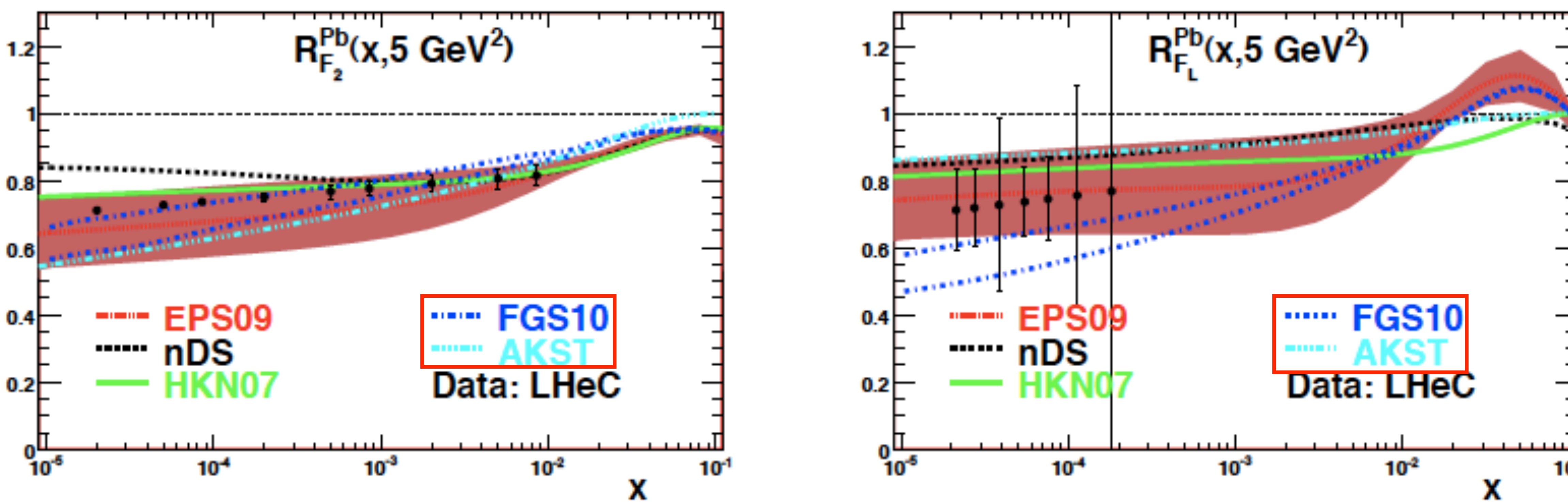
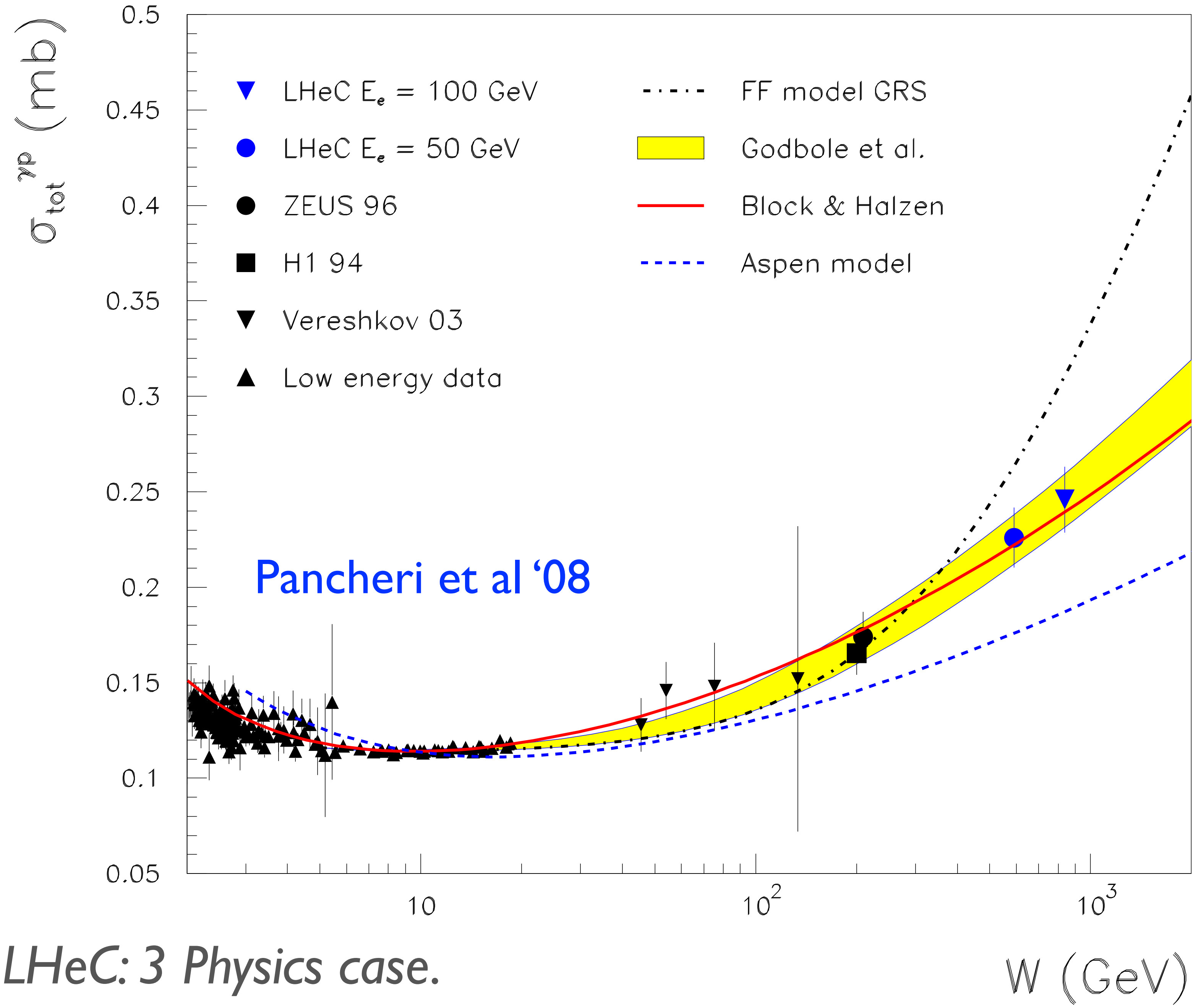


Photoproduction cross section:

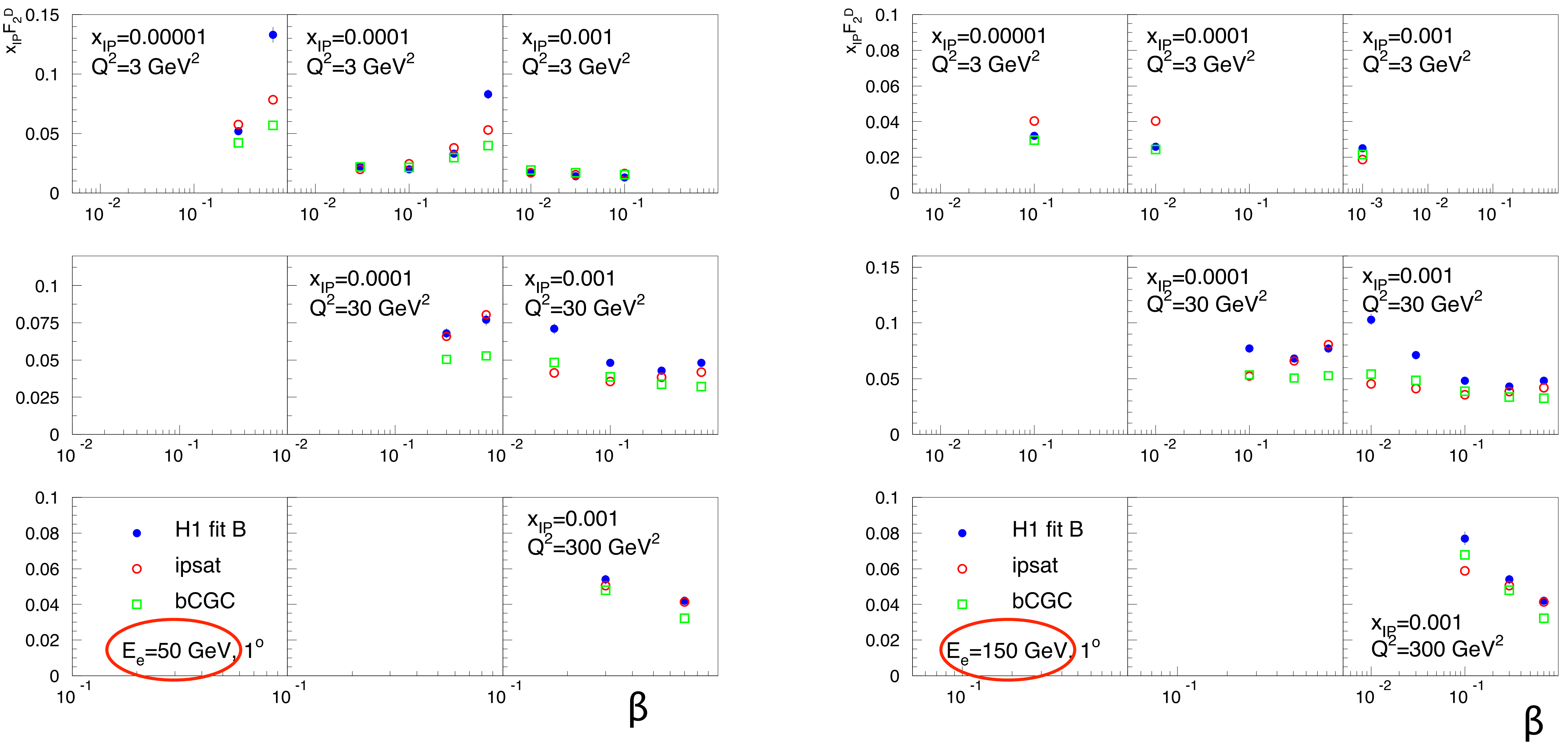
- Small angle electron detector 62 m far from the interaction point: $Q^2<0.01$ GeV, $y\sim0.3 \Rightarrow W\sim0.5\sqrt{s}$.

- Substantial enlarging of the lever arm in W.

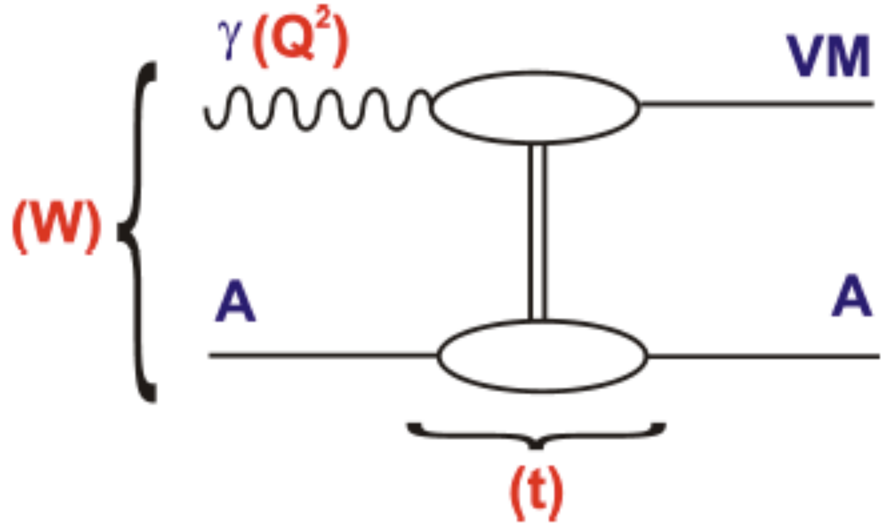


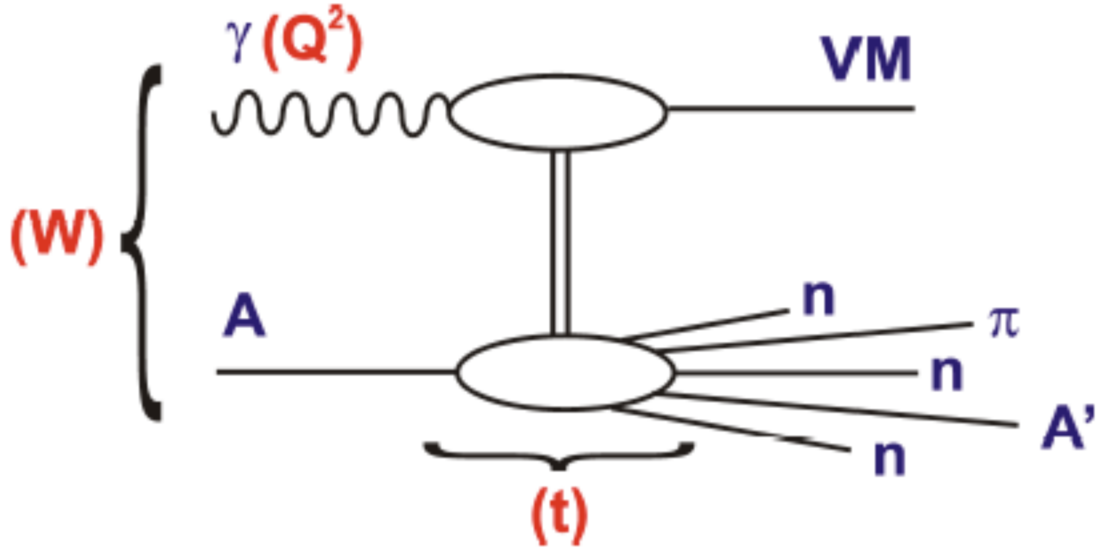
Diffraction and non-linear dynamics:

- Dipole models show differences with linear-based extrapolations (HERA-based dpdf's) and among each other: possibility to check saturation and its realization.



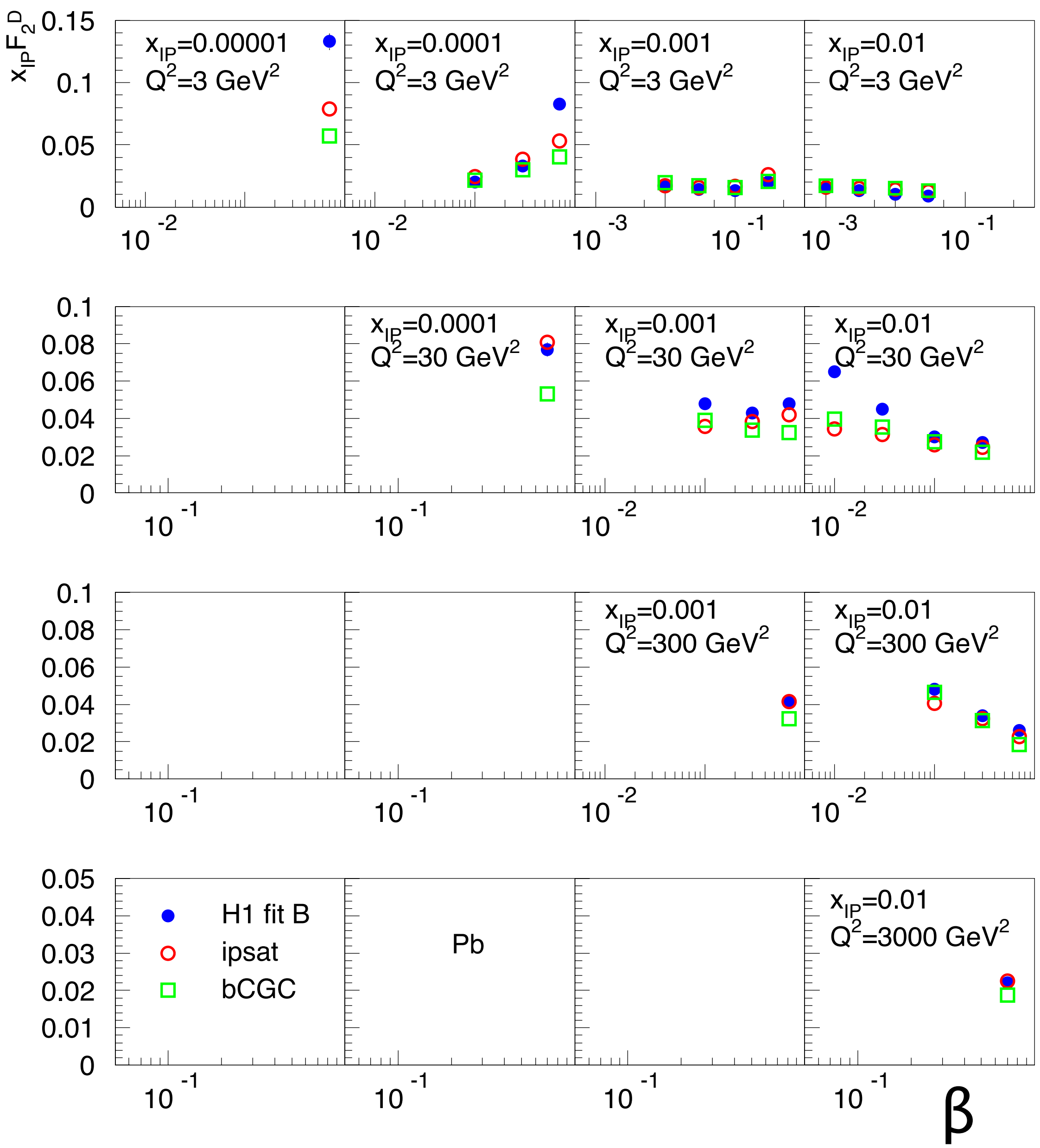
Diffractive DIS on nuclear targets:





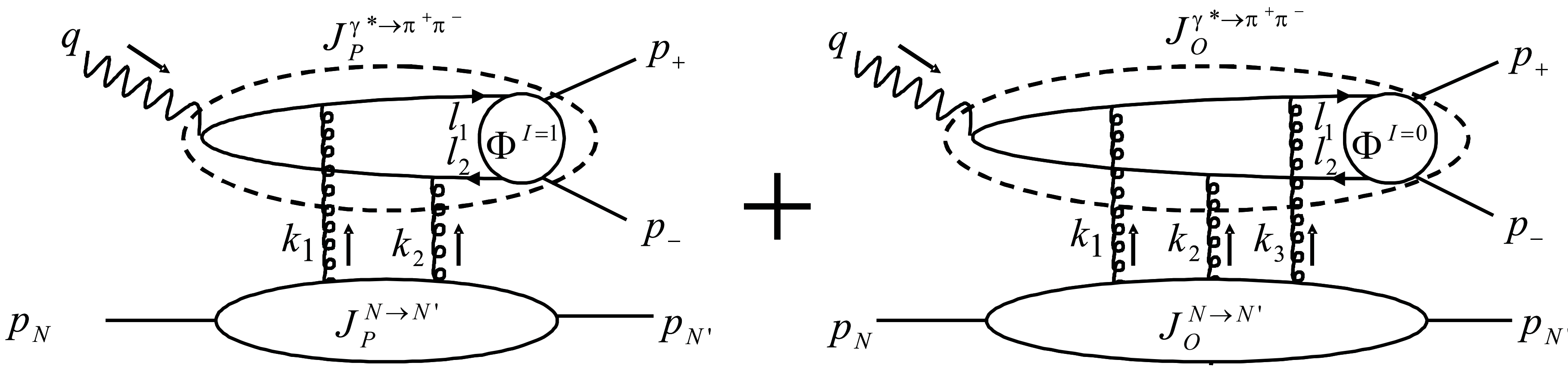
- Challenging experimental problem, requires Monte Carlo simulation with detailed understanding of the nuclear break-up.

- For the coherent case, predictions available.



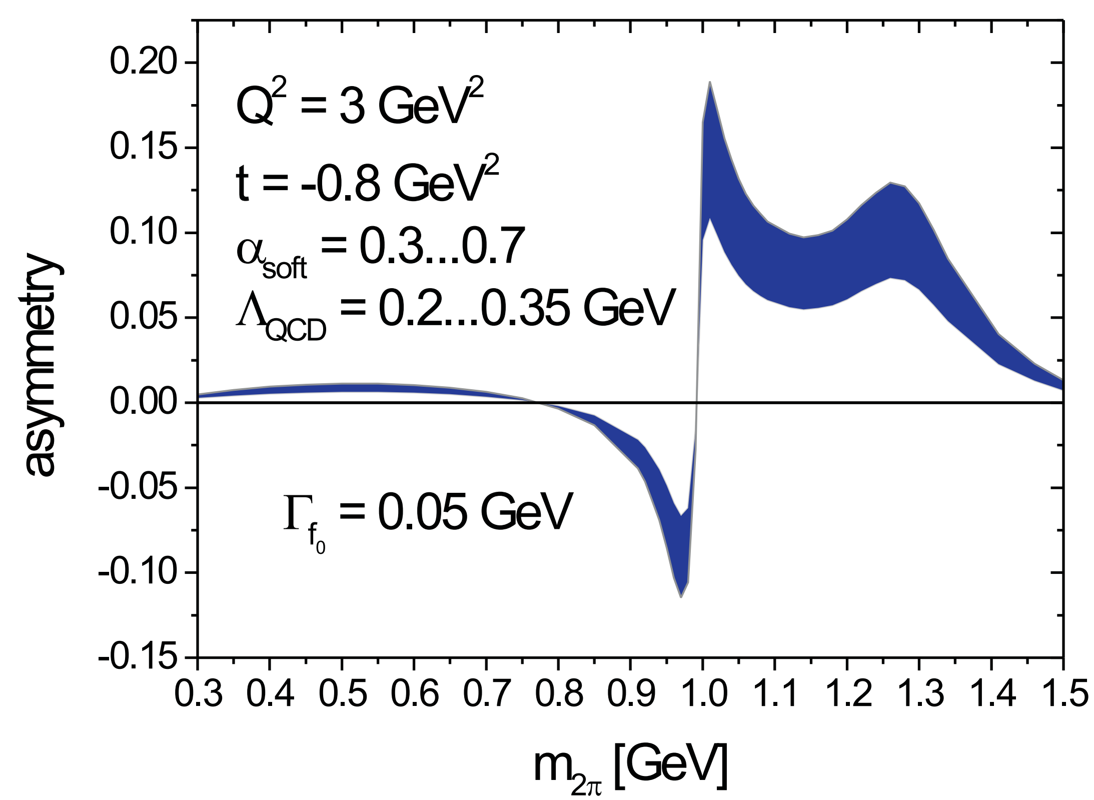
Odderon:

- Odderon (C-odd exchange contributing to particle-antiparticle difference in cross section) seached in $\gamma^{(*)}p \to Cp$, where $C = \pi^0, \eta, \eta', \eta_c \ldots$ or through O-P interferences.



$$A(Q^2,t,m_{2\pi}^2) = \frac{\int \cos\theta \, d\sigma(W^2,Q^2,t,m_{2\pi}^2,\theta)}{\int d\sigma(W^2,Q^2,t,m_{2\pi}^2,\theta)} = \frac{\int_{-1}^{1} \cos\theta \, d\cos\theta \, 2 \, \mathrm{Re}\left[\mathcal{M}_P^{\gamma_L^*}(\mathcal{M}_O^{\gamma_L^*})^*\right]}{\int_{-1}^{1} d\cos\theta \left[|\mathcal{M}_P^{\gamma_L^*}|^2 + |\mathcal{M}_O^{\gamma_L^*}|^2\right]}$$

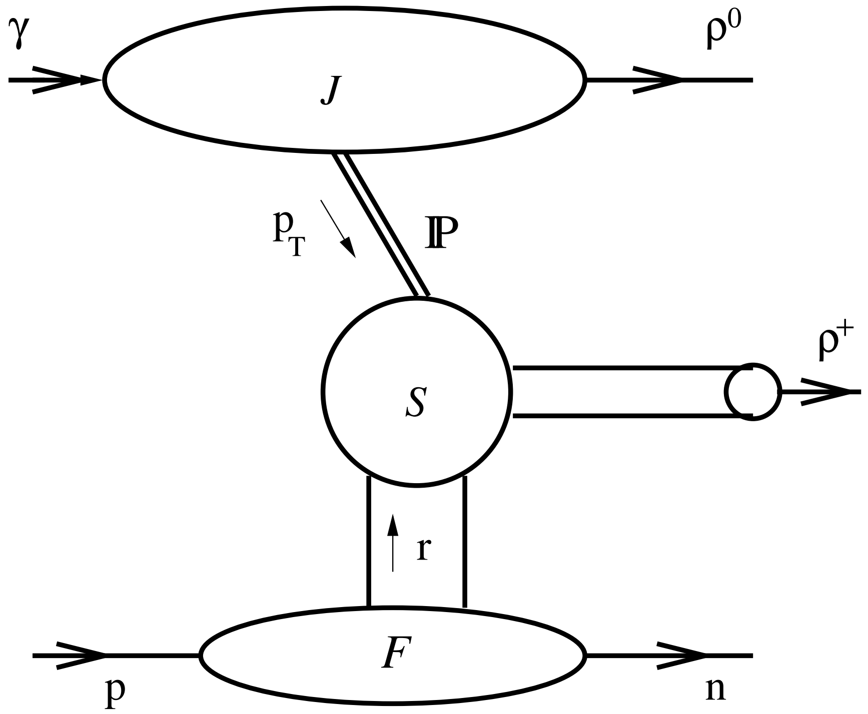
- Sizable charge asymmetry, yields and reconstruction pending.



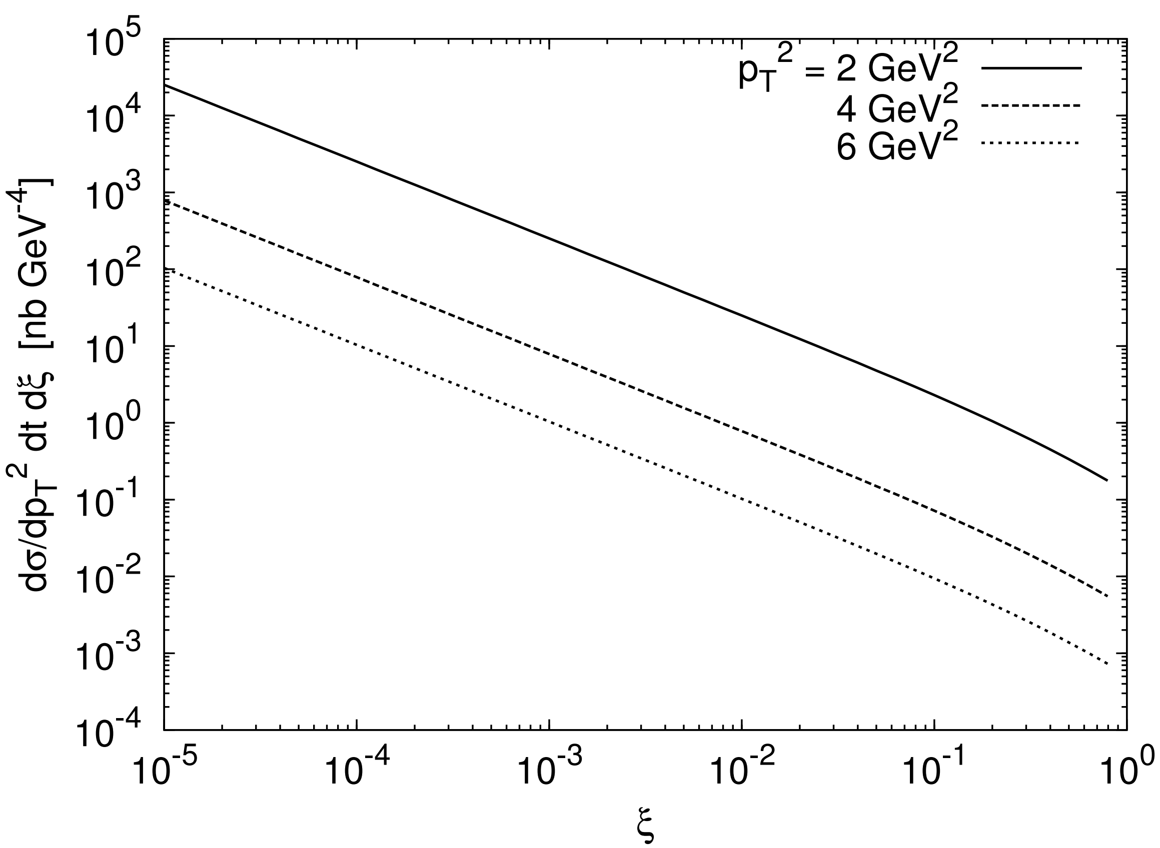
Transversity GPDs:

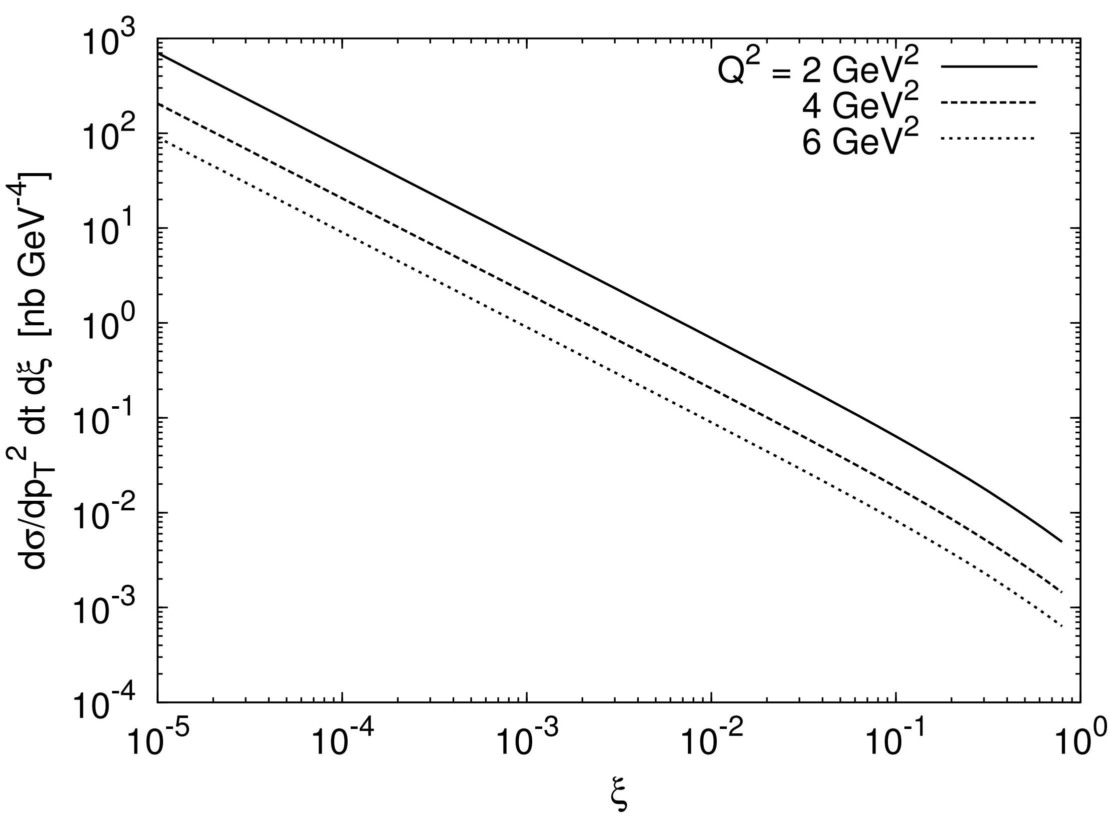
- Chiral-odd transversity GPDs are largely unknown.

- They can be accessed through double exclusive production:



$$ep(p_2) \to e'\gamma^{(*)}_{L/T}(q)\ \ p(p_2) \to e'\rho^0_{L,T}(q_\rho)\ \ \rho_T(p_\rho)\ N'(p_{2'})$$





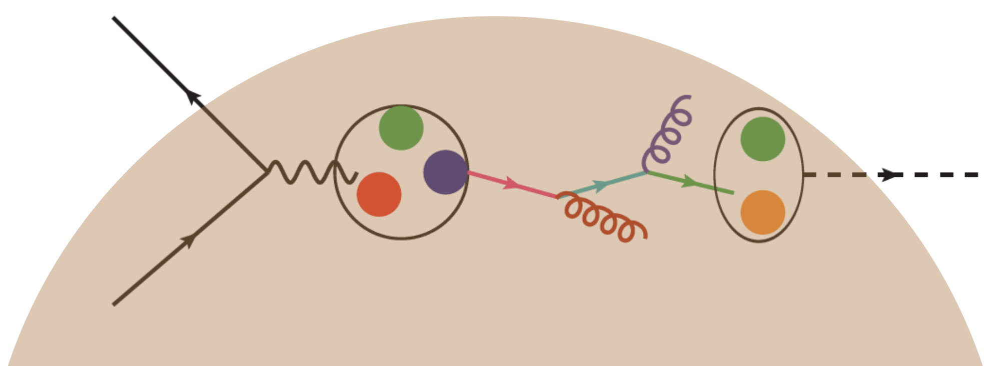
$$\xi \approx x_B/(2 - x_B)$$

Radiation and hadronization:

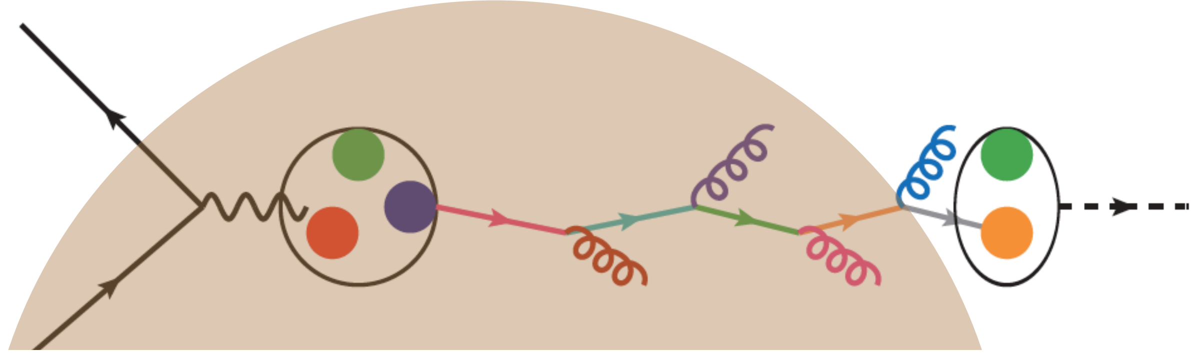
- LHeC: dynamics of QCD radiation and hadronization.
- Most relevant for particle production off nuclei and for QGP analysis in HIC.

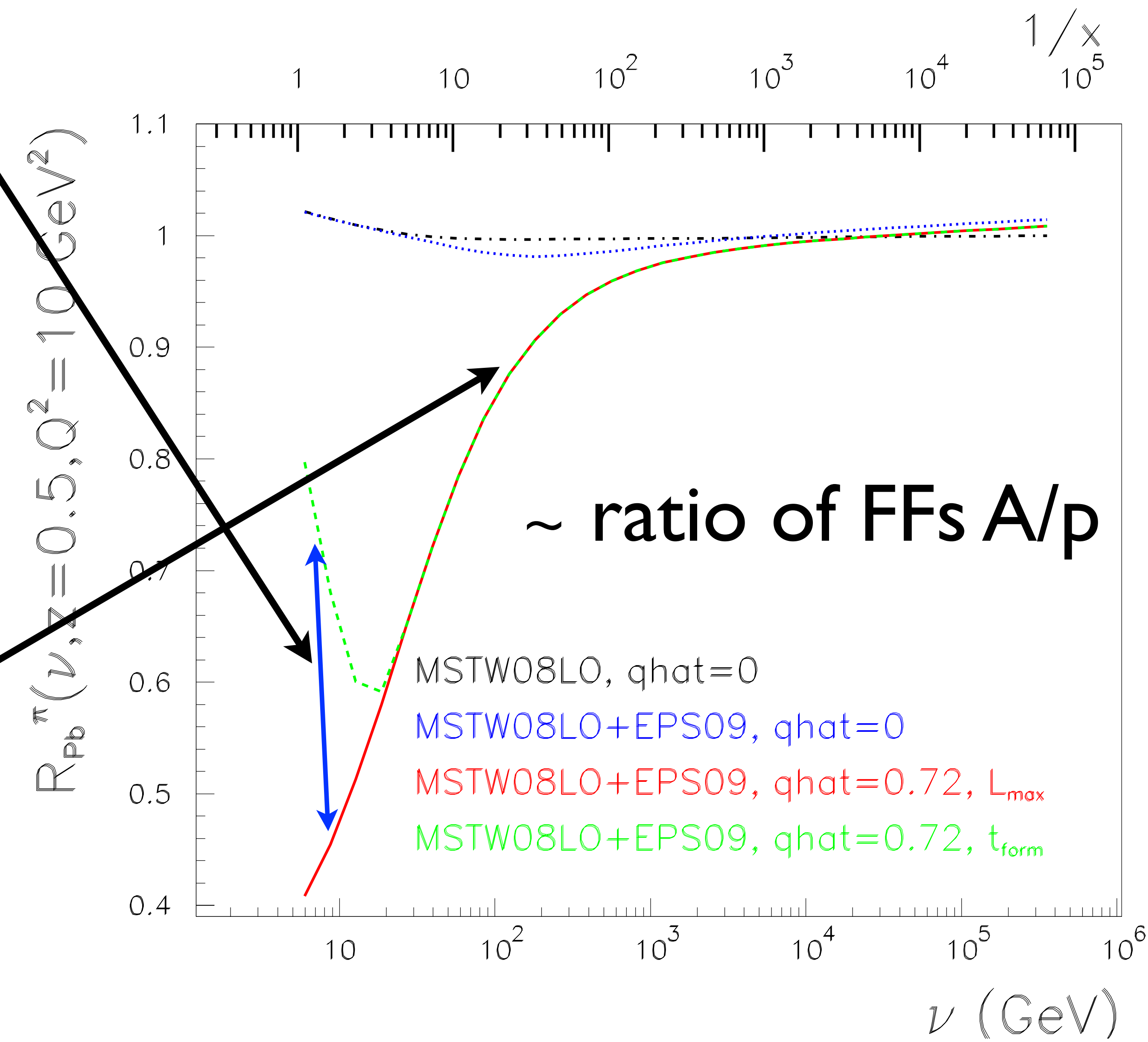
$$R_A^h(z,\nu) = \frac{1}{N_A^e}\frac{dN_A^h(z,\nu)}{d\nu\, dz} \Big/ \frac{1}{N_D^e}\frac{dN_D^h(z,\nu)}{d\nu\, dz}$$

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



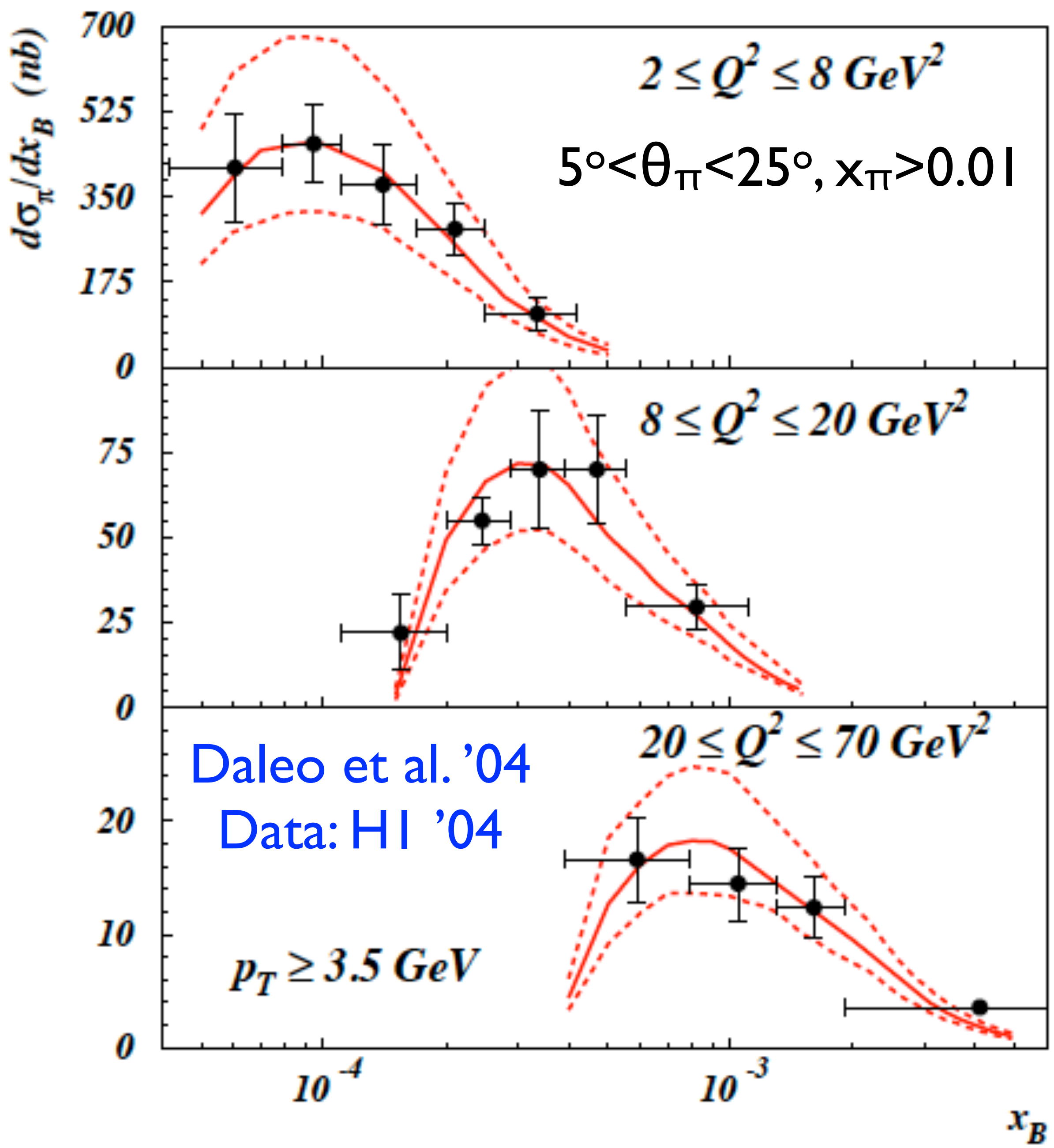
- High energy: partonic evolution altered in the nuclear medium.





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).



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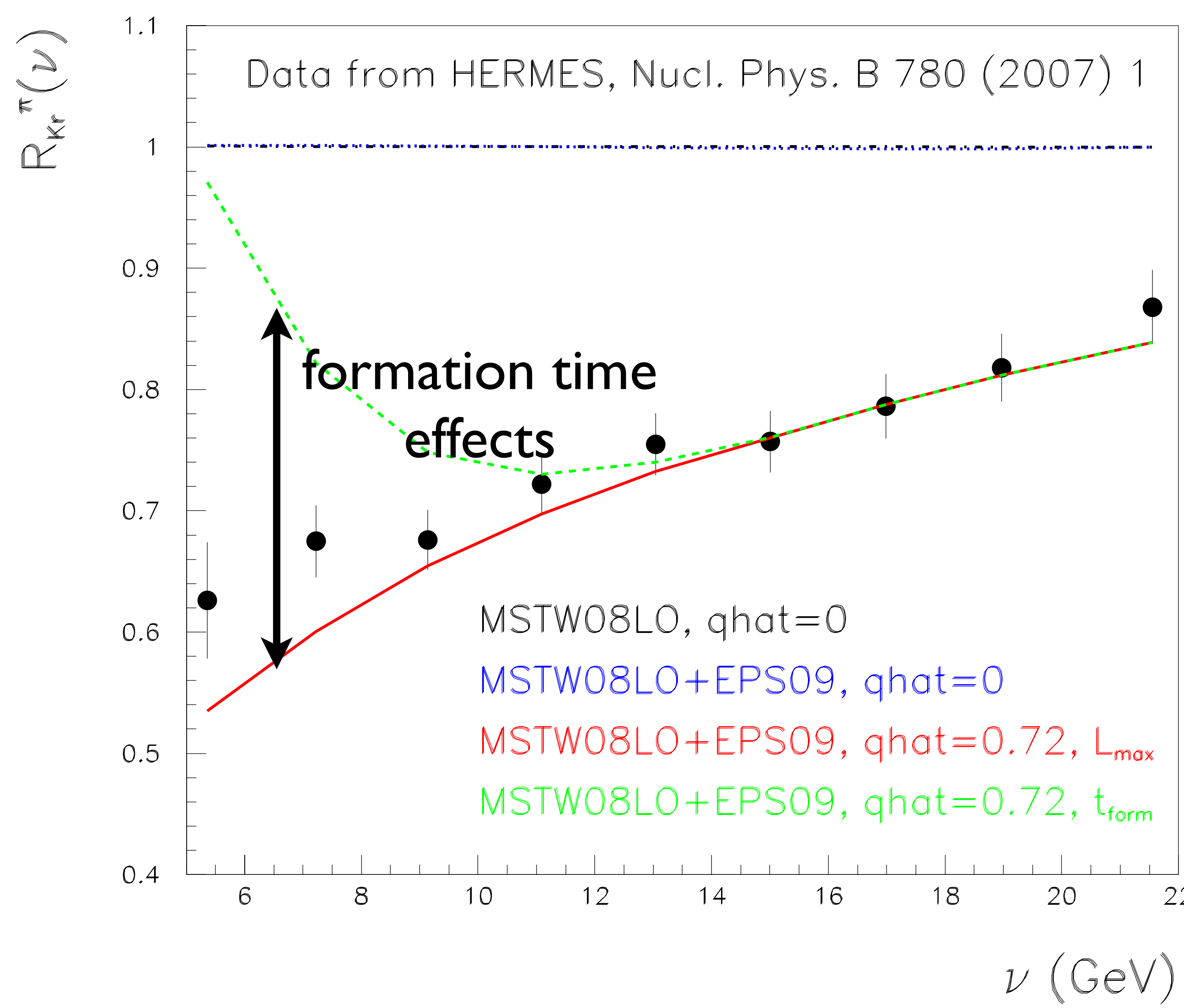

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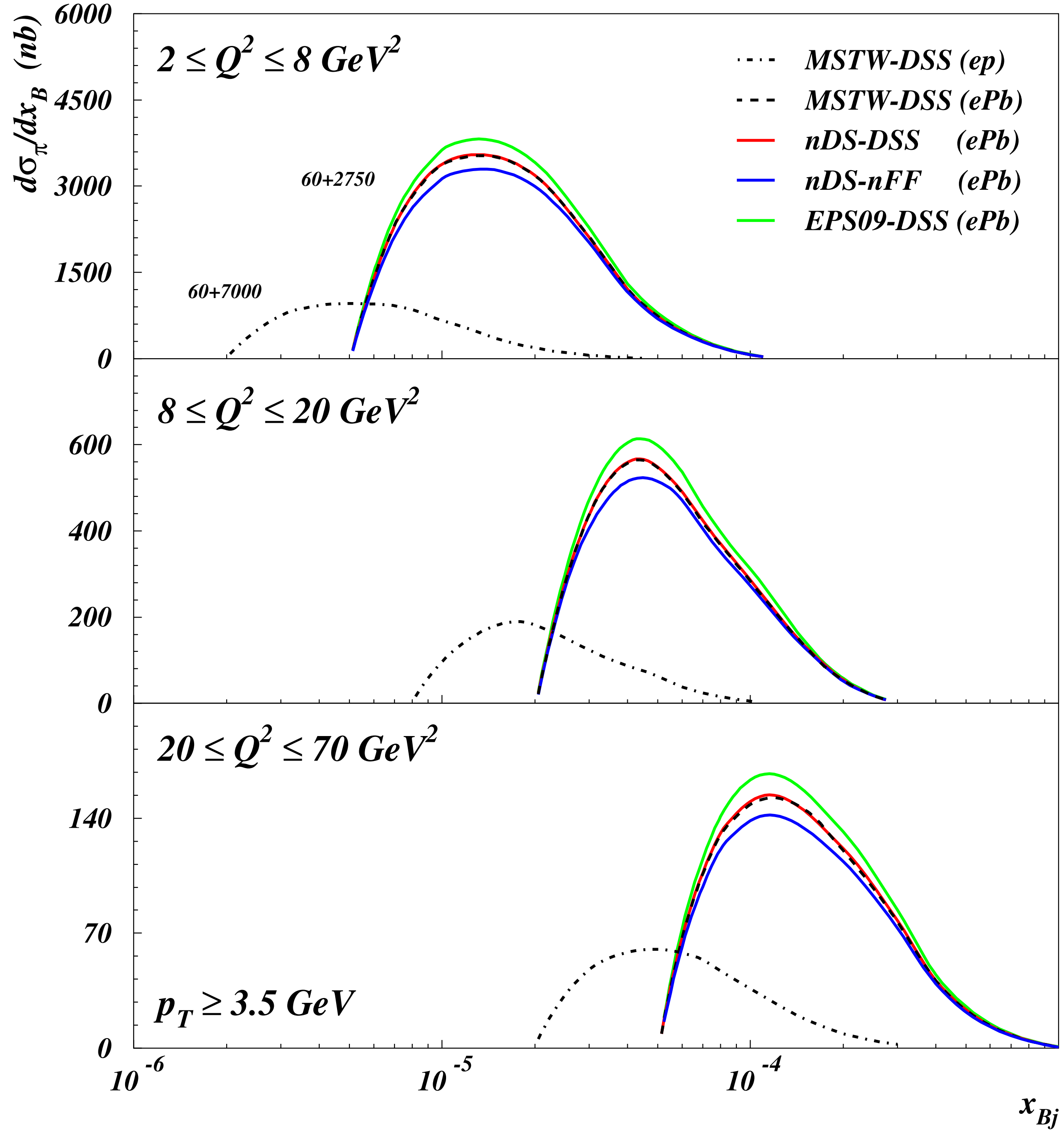

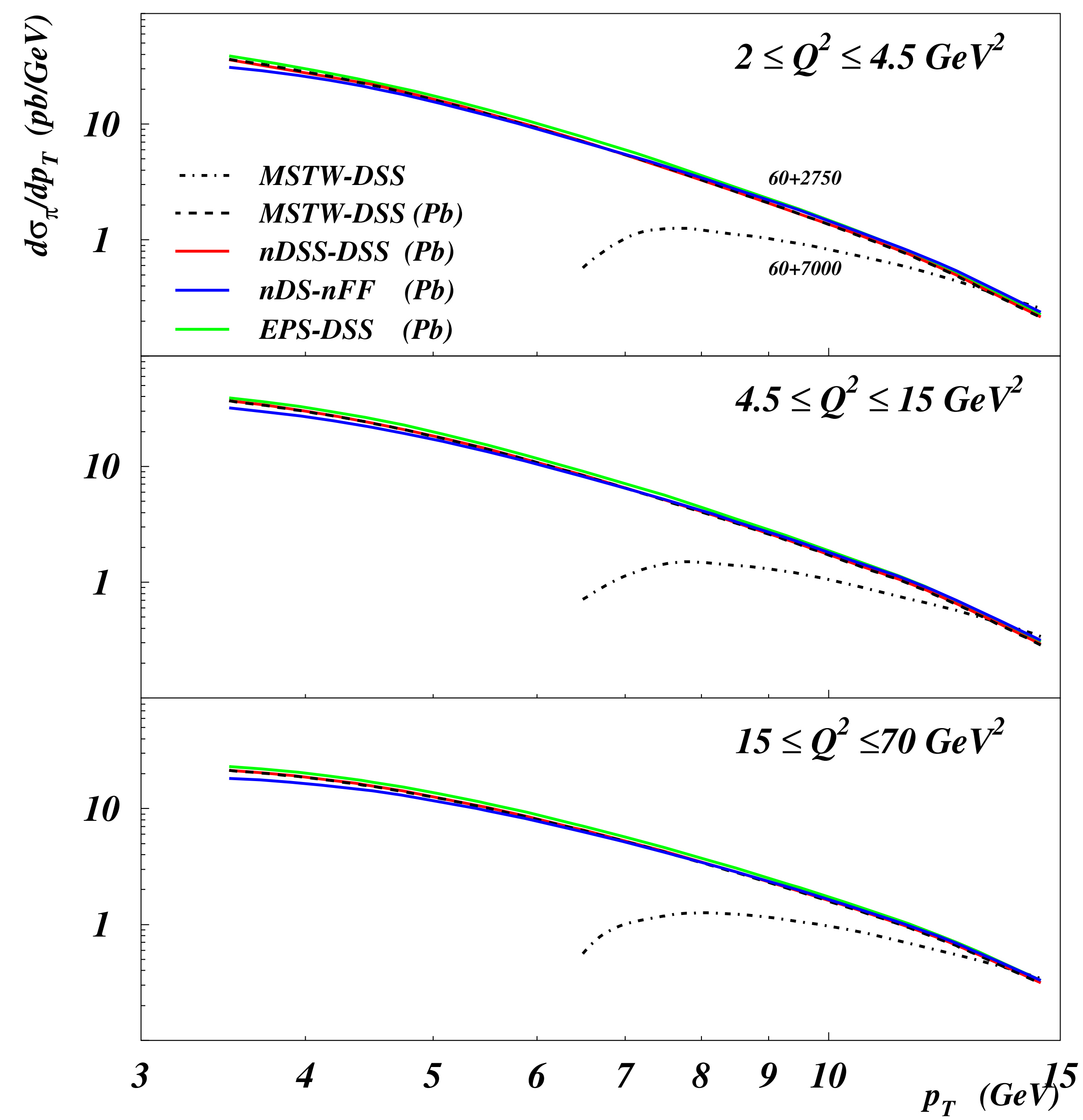

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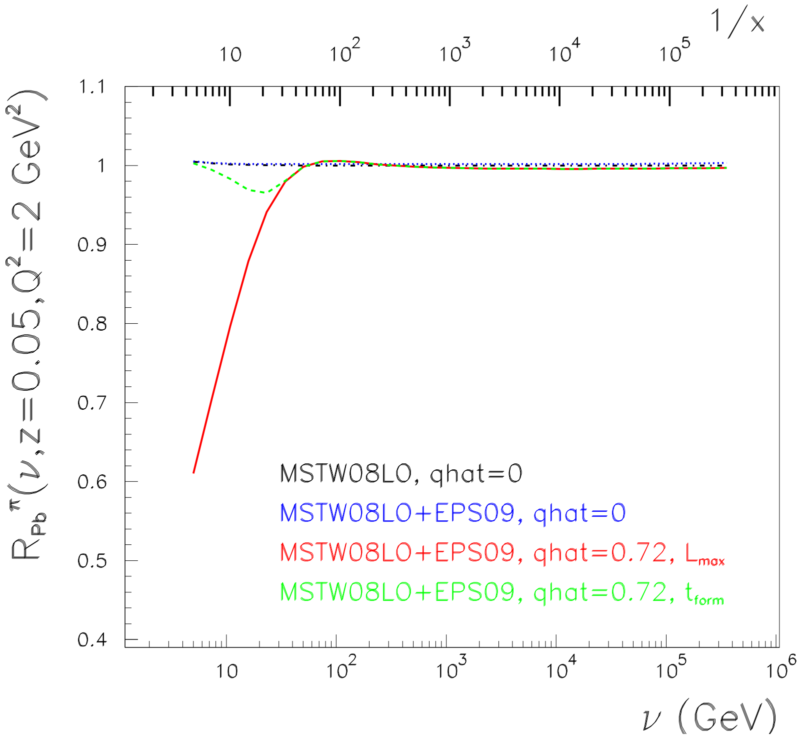
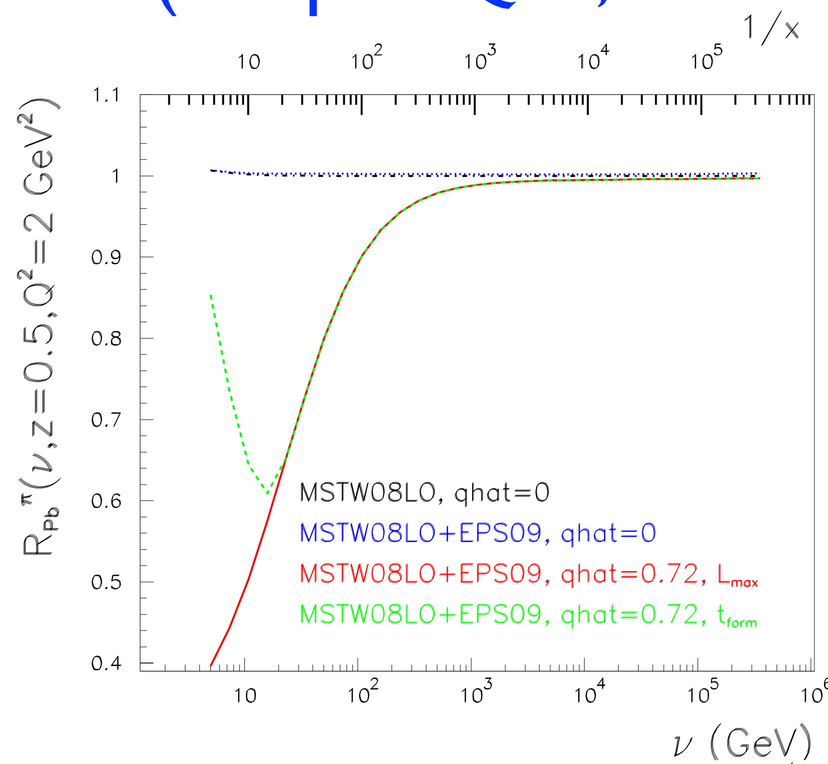
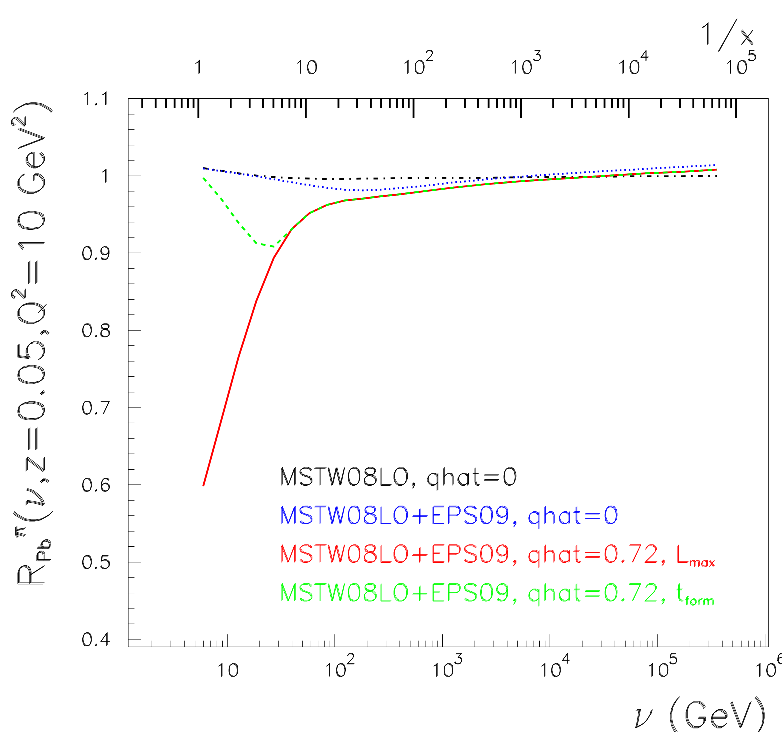
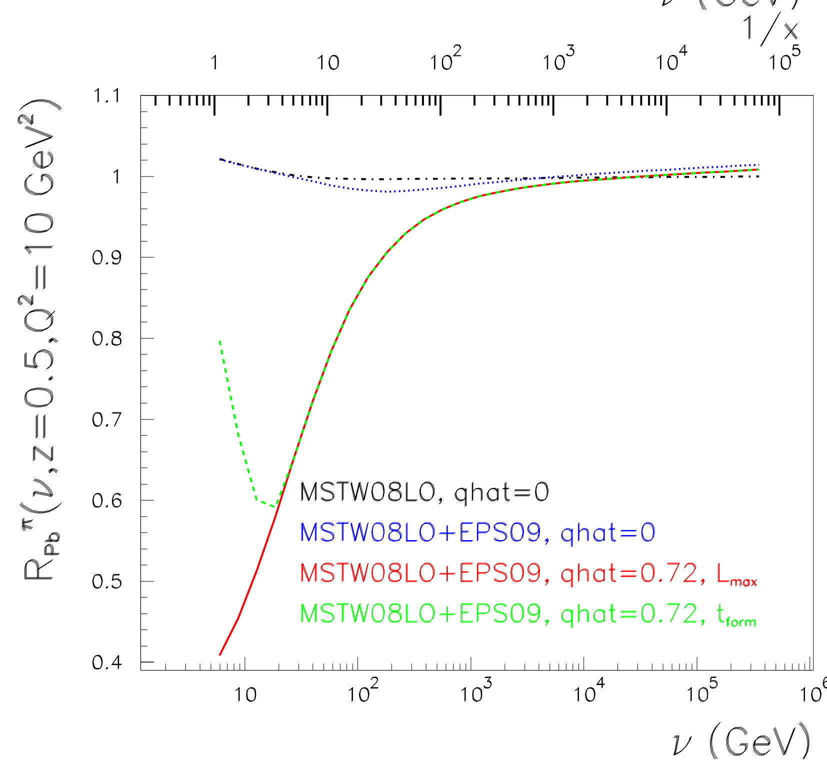


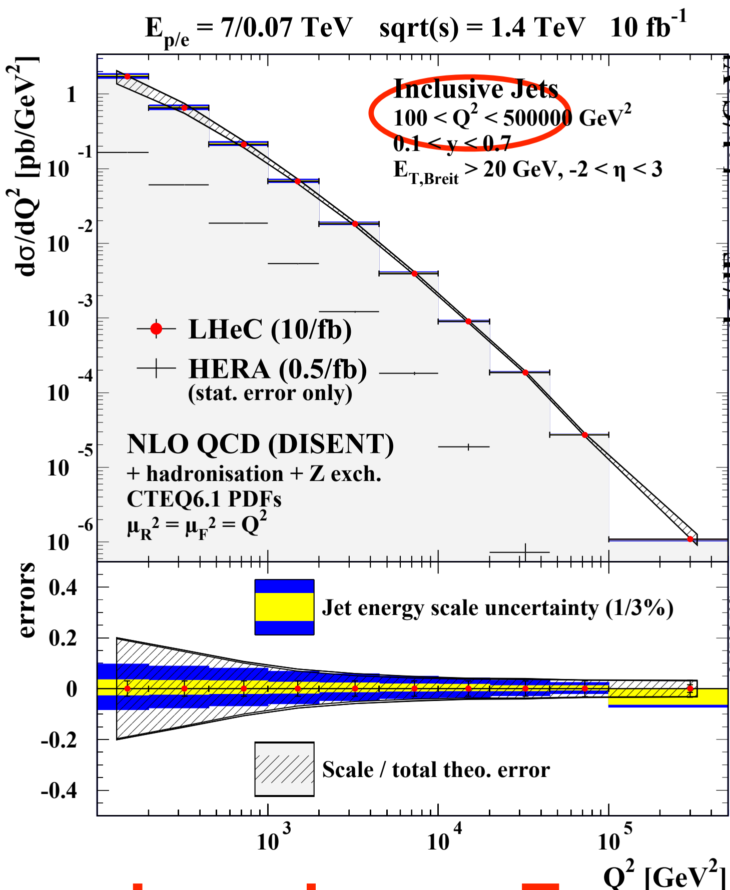


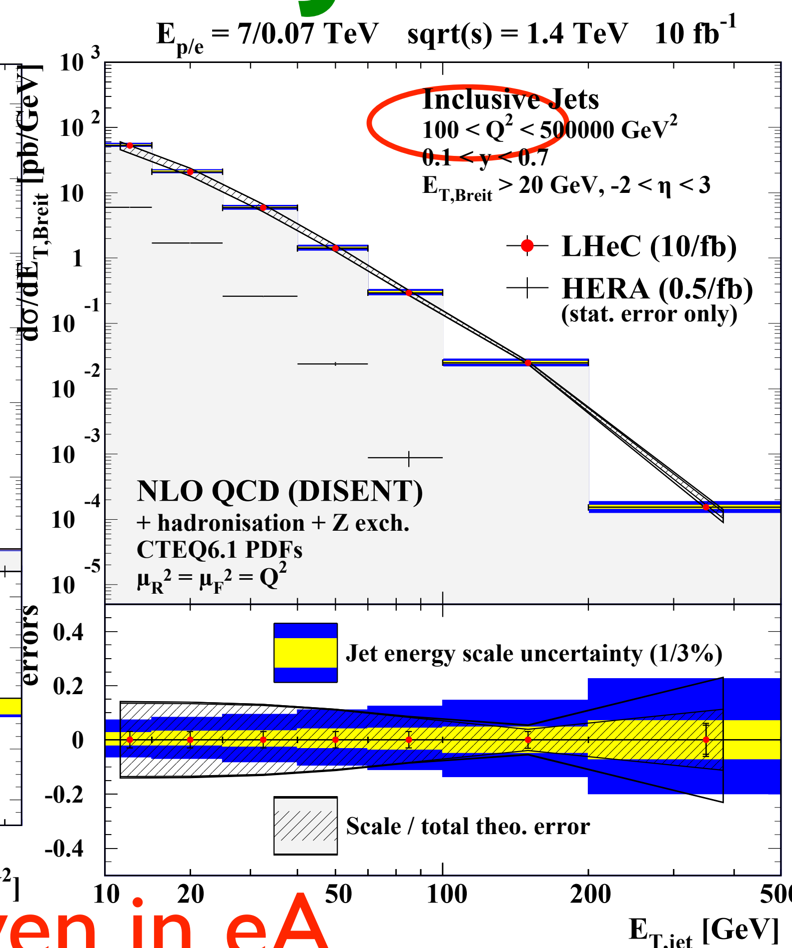
$$R_A^h(z,\nu) = \frac{1}{N_A^e}\frac{dN_A^h(z,\nu)}{d\nu\,dz} \Bigg/ \frac{1}{N_D^e}\frac{dN_D^h(z,\nu)}{d\nu\,dz}$$

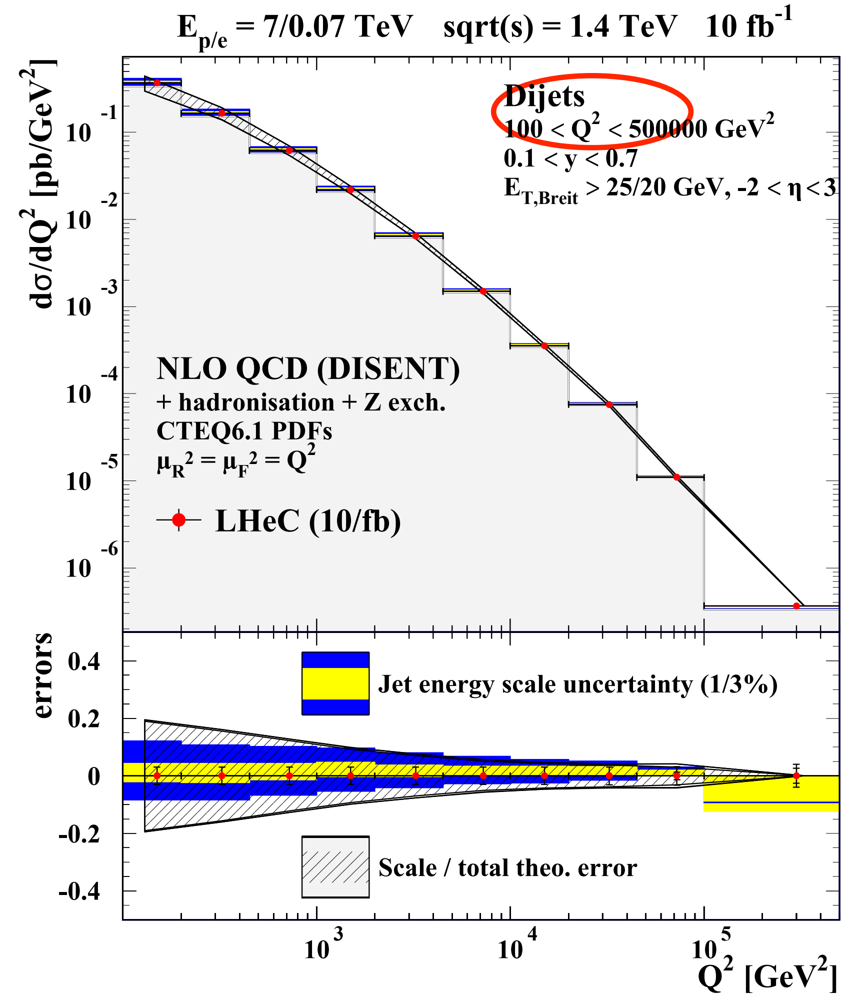




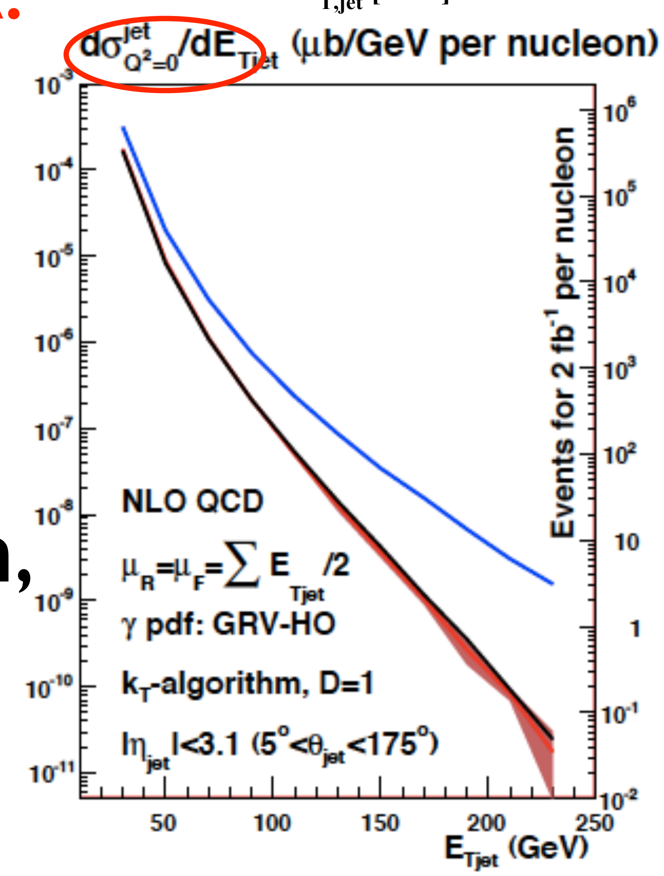
Jets:

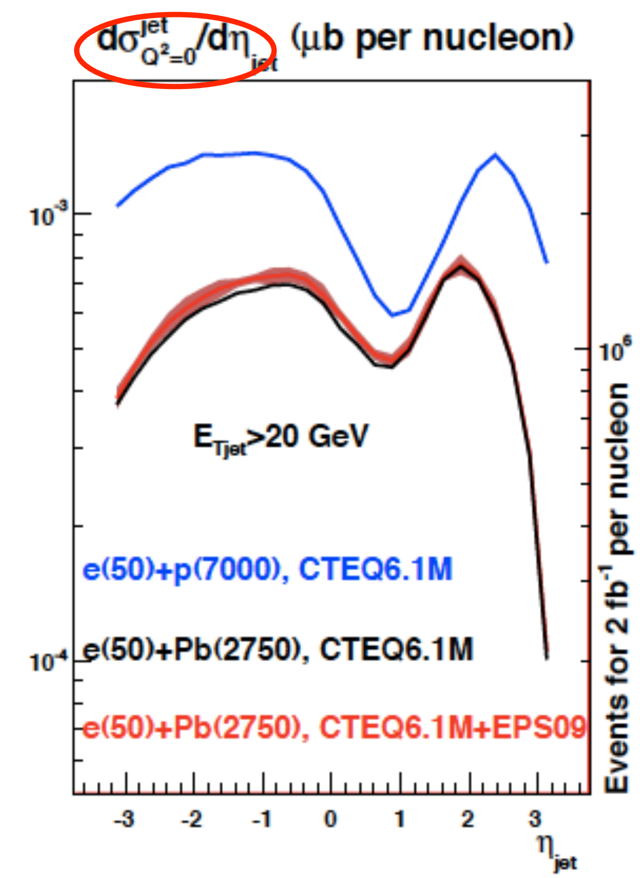






- Jets: large E_T even in eA.
- Useful for studies of parton dynamics in nuclei (hard probes), and for photon structure.
- Background subtraction, detailed reconstruction pending.





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2007: Invitation by SPC to ECFA and by (r)ECFA to work out a design concept

2008: First CERN-ECFA Workshop in Divonne (1.-3.9.08)

The LHeC Study Group
http://cern.ch/lhec

Report

2009: 2nd CERN-ECFA-NuPECC Workshop at Divonne (1.-3.9.09)

2010: Report to CERN SPC (June)
3rd CERN-ECFA-NuPECC Workshop at Chavannes-de-Bogis (12.-13.11.10)
NuPECC puts LHeC to its Longe Range Plan for Nuclear Physics (12/10)

2011: Draft CDR (530 pages on Physics, Detector and Accelerator) (5.8.11)
being refereed and updated

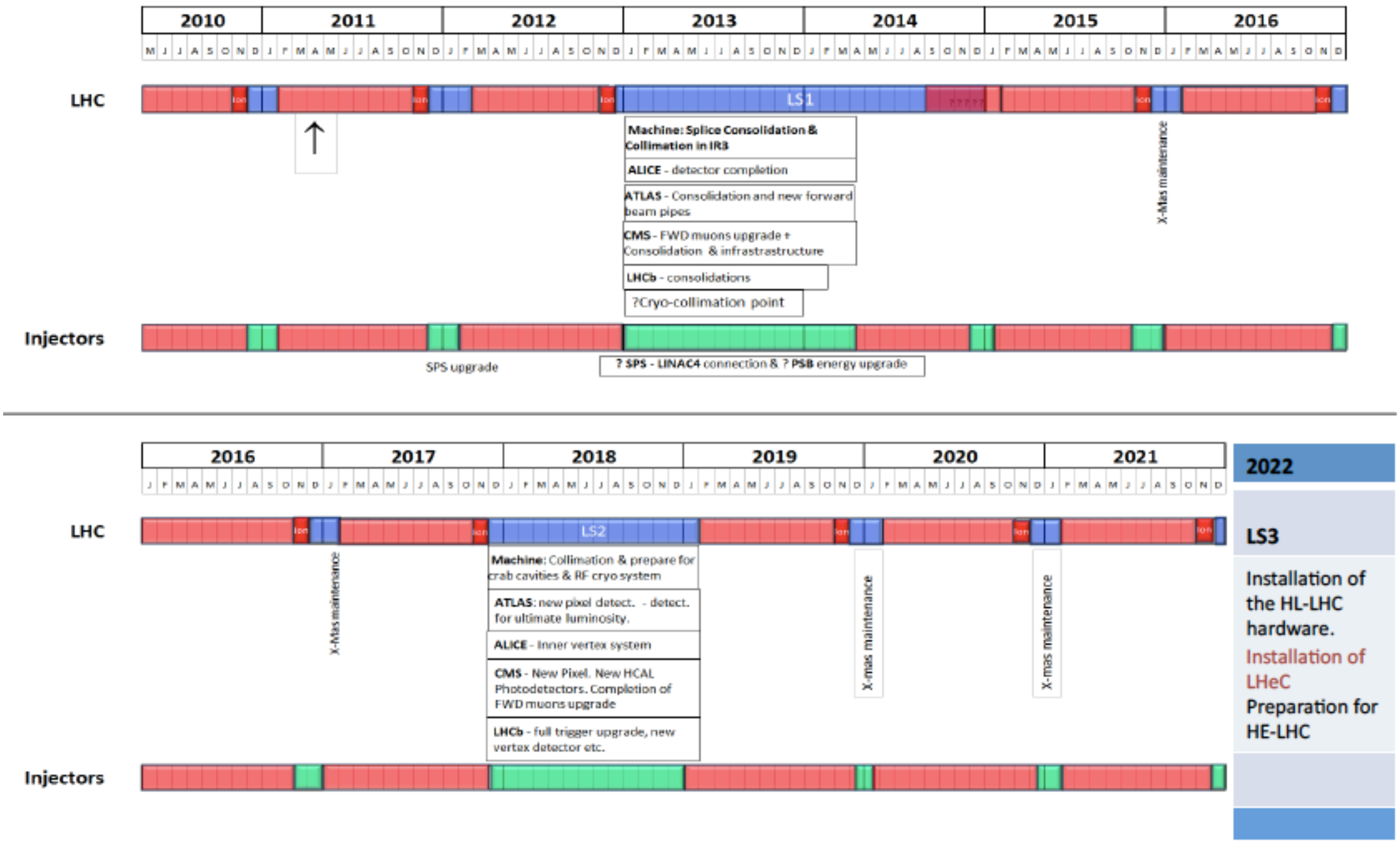
2012: Publication of CDR – European Strategy
New workshop June 14-15 2012

Goal: TDR by 2015
Perspective: Operation after LS3 (synchronous with pp/pA/AA)

Tentative timeline:

New rough draft 10 year plan

Not yet approved!



July 26, 2011 S. Myers, HEP2011, Grenoble 42

Tentative timeline:

New rough draft 10 year plan

Not yet approved!

2010	2011	2012	2013	2014	2015	2016

→ LHC death by radiation damage estimated by 2030-2035.

→ LHeC should work for ~ 10 years.

→ No disturbance to LHC operation: built on surface, installation during LS3.

⇒

Injectors

July 26, 2011 S. Myers, HEP2011, Grenoble 42

Tentative timeline: