NuPECC LRP2010 Town Meeting
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The Large Hadron-electron Collider (LHeC)

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for the **LHeC Study Group**
http://cern.ch/lhec

Project:

- **LHeC@CERN** → ep/eA experiment using p/A from the LHC: E_p=7 TeV, E_A=(Z/A)E_p=2.75 TeV/nucleon for Pb.
- New e^+/e^- accelerator: E_{cm}~1-2 TeV/nucleon (E_e=50-150 GeV).

- Requirements:

* Luminosity~10^{33} $cm^{-2}s^{-1}$.

* Acceptance: 1-179 degrees (low-x ep/eA).

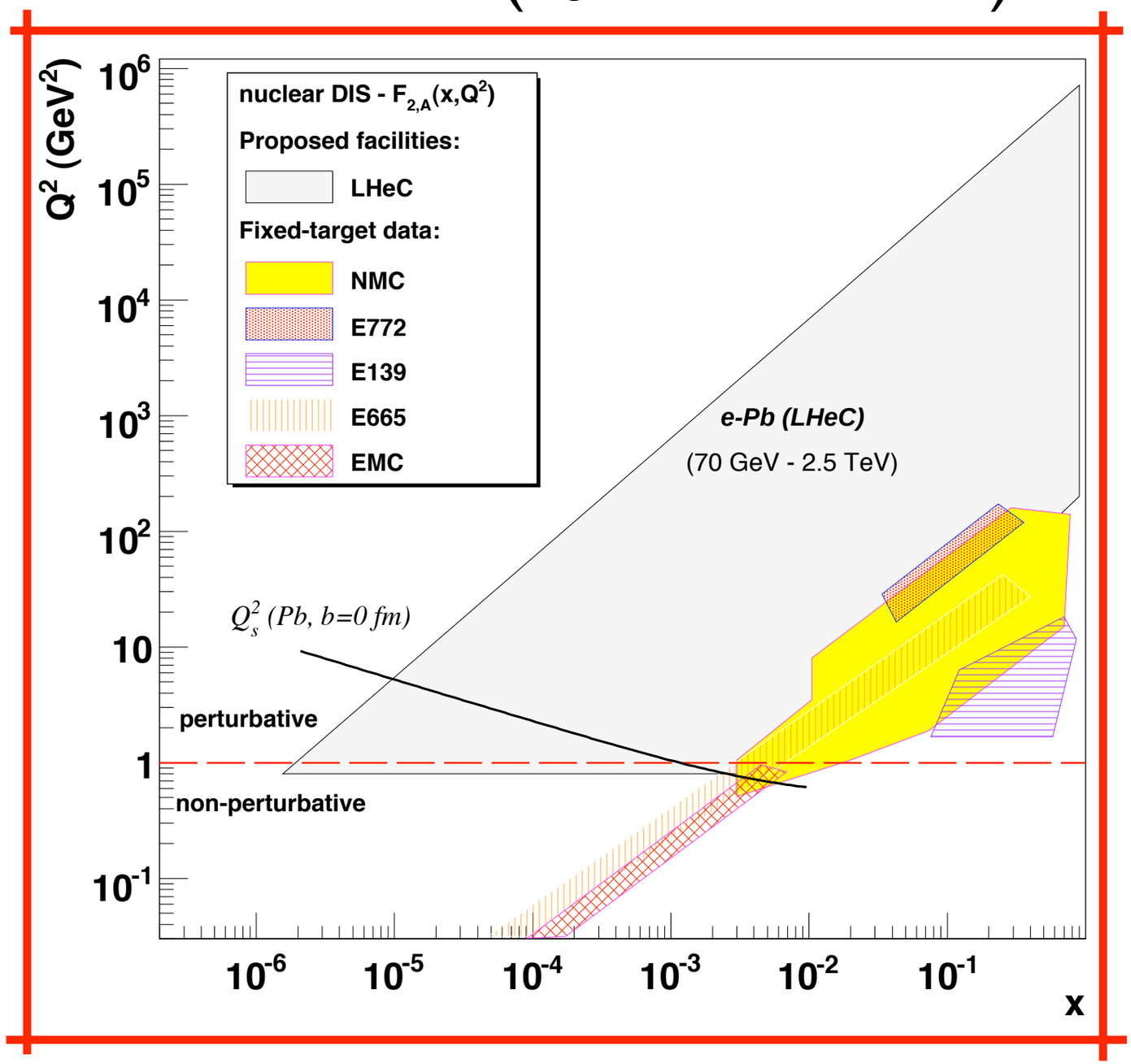
* Tracking to 1 mrad.

* EMCAL calibration to 0.1 %.

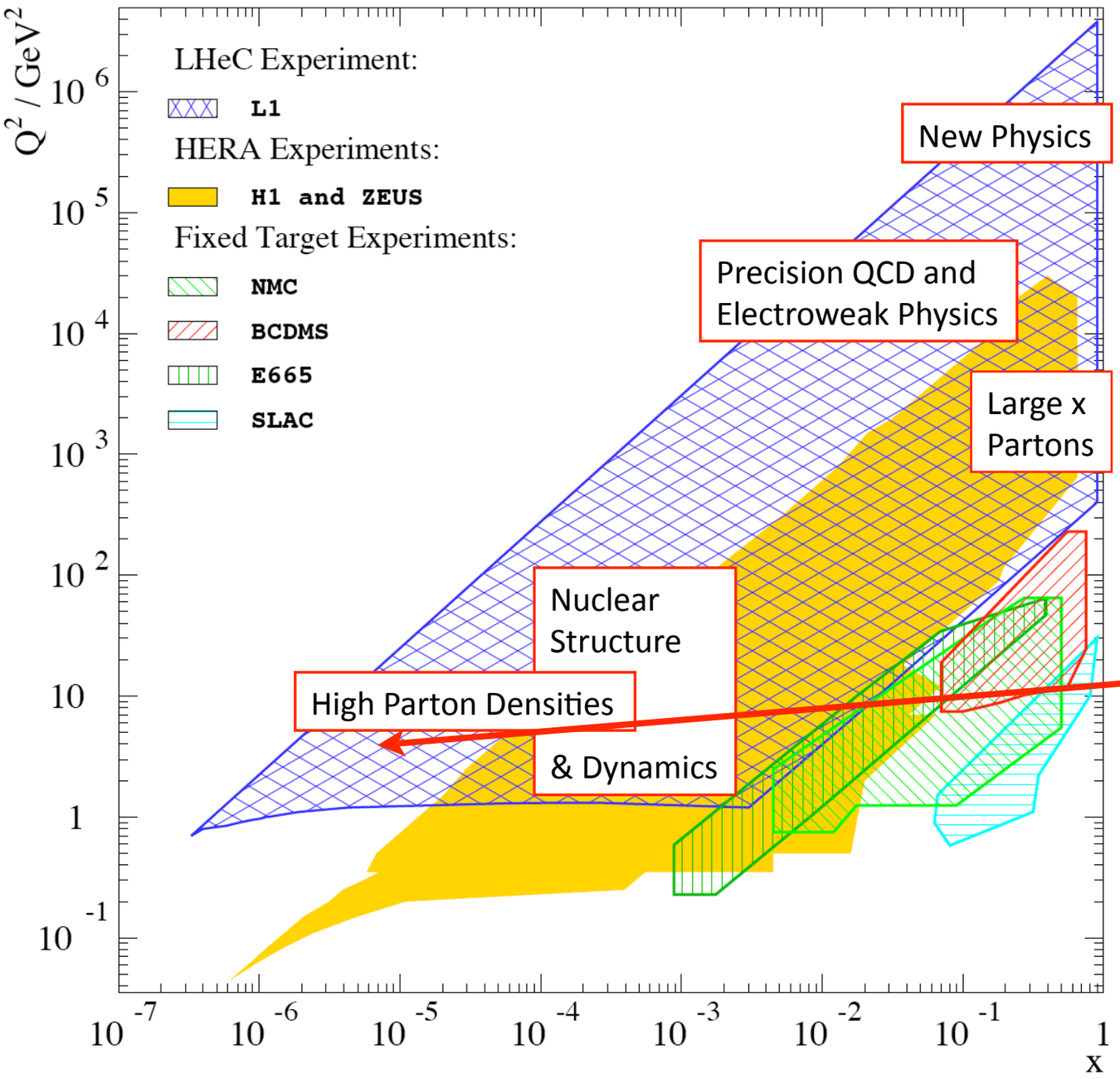
* HCAL calibration to 0.5 %.

* Luminosity determination to 1 %.

* Compatible with LHC operation.

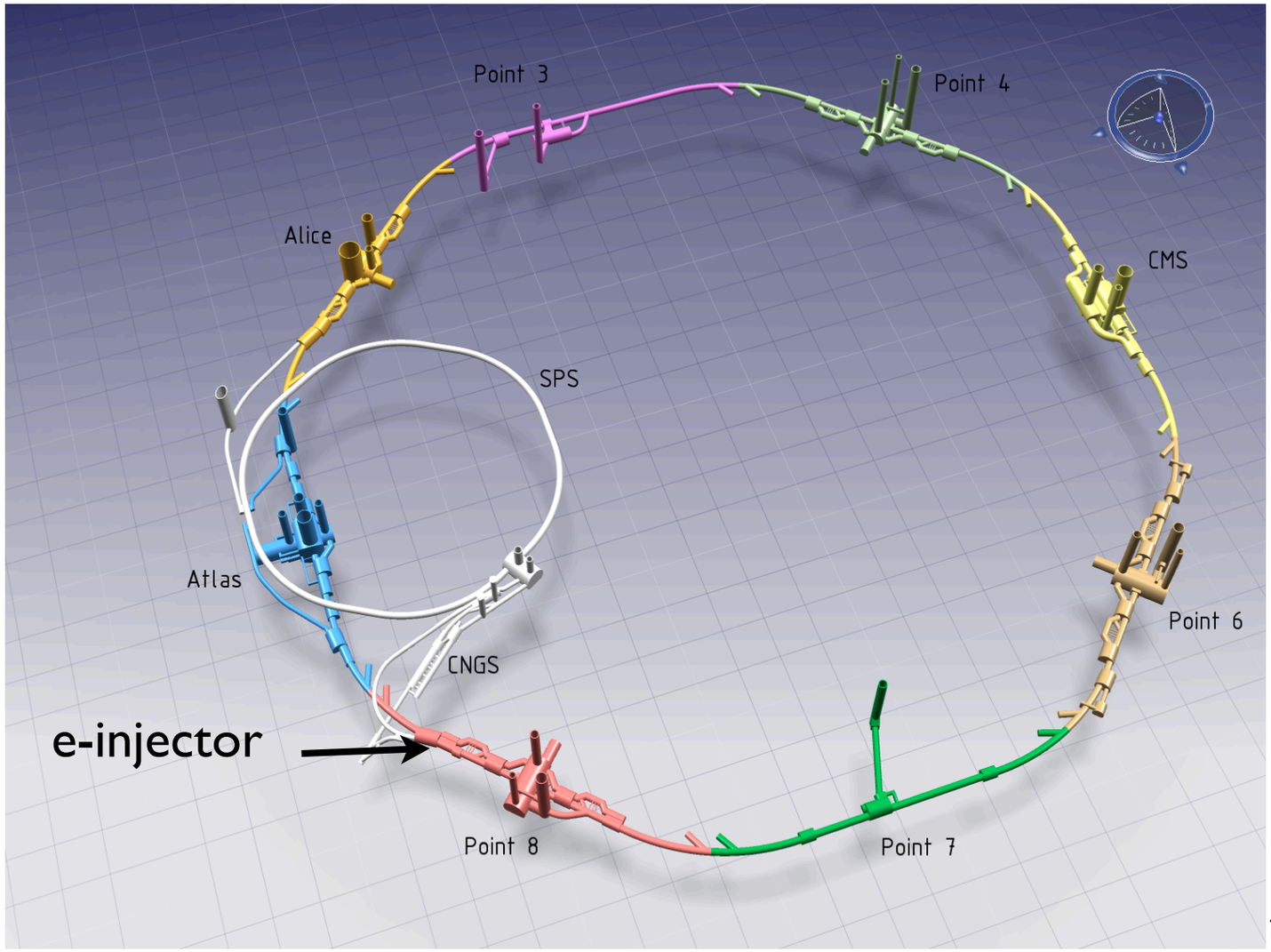


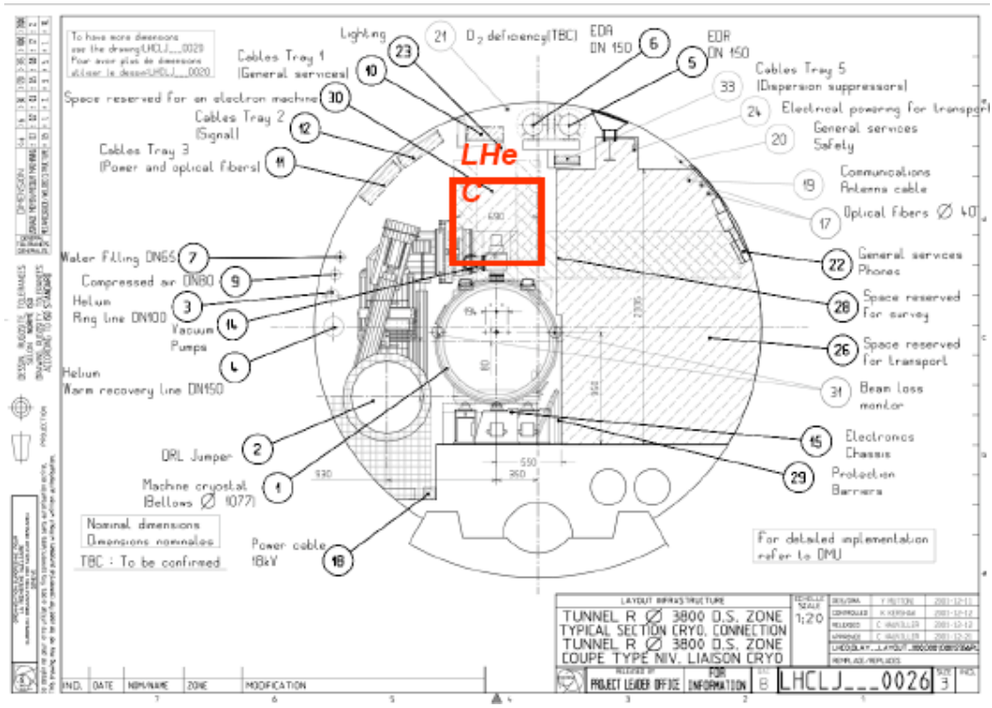
Physics goals:

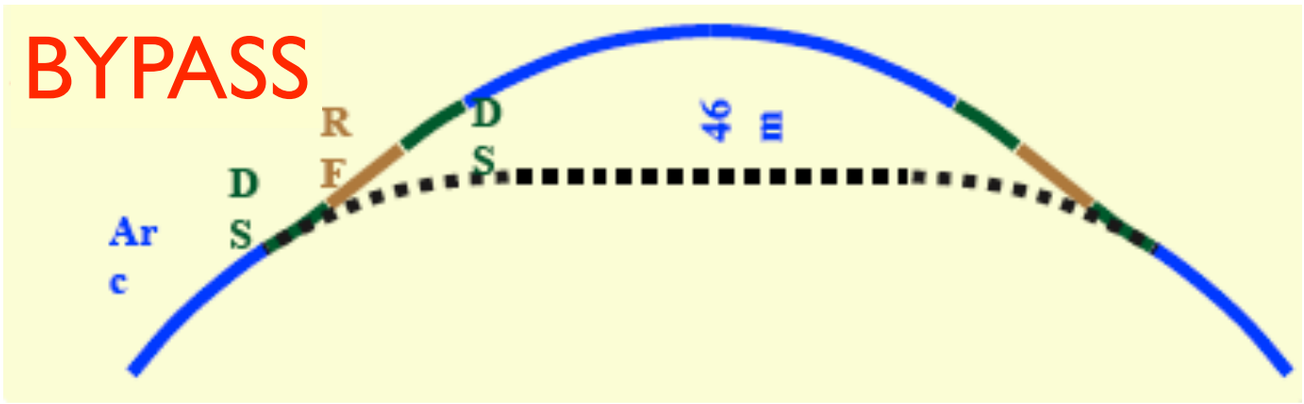


- Proton structure to a few 10^{-20} m: Q^2 lever arm.
- Precision QCD/EW physics.
- High-mass frontier (leptoquarks, excited fermions, contact interactions).
- Unambiguous access, in ep and eA, to a **qualitatively novel regime of matter predicted by QCD**.
- Substructure/parton dynamics inside nuclei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

The machine: Ring-Ring option



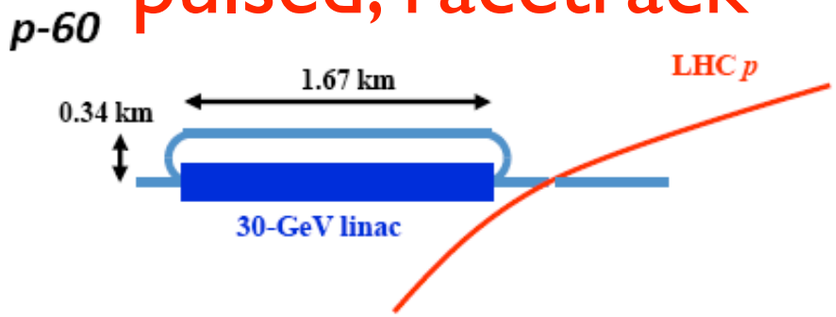




Standard Parameters	*Protons*	*Electrons*
	*Np=1.15*10^11*	*Ne=1.4*10^10*
	Ep=7 TeV	*Ee=60 GeV*
	nb=2808	*nb=2808*
	Ip=582mA	*Ie=111mA*
Optics	*β_{xp}=180cm*	*β_{xe}=12.7cm*
	β_{yp}=50cm	*β_{ye}=7.1cm*
	ε_{xp}=0.5nm rad	*ε_{xe}=7.6nm rad*
	ε_{yp}=0.5nm rad	*ε_{ye}=3.8nm rad*
Beam size	*σ_{xp}=30 μm*	*σ_{xe}=30μm*
	σ_{yp}=15.8 μm	*σ_{ye}=15.8μm*
Luminosity	*$1.3*10^{33}$ cm^{-2} s^{-1}*	

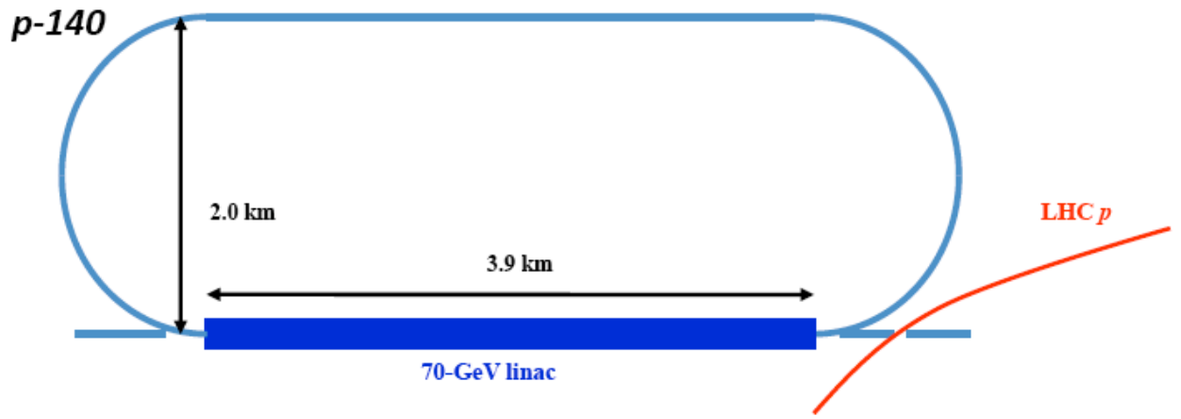
The machine: Linac-Ring option

pulsed, racetrack



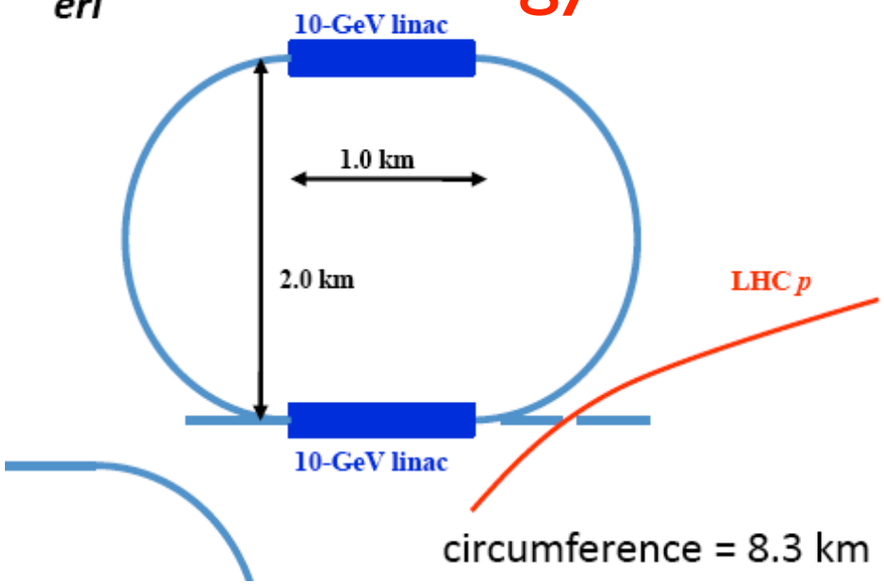
circumference = 4.4 km

highest energy racetrack



circumference = 14.1 km

CW energy recovery

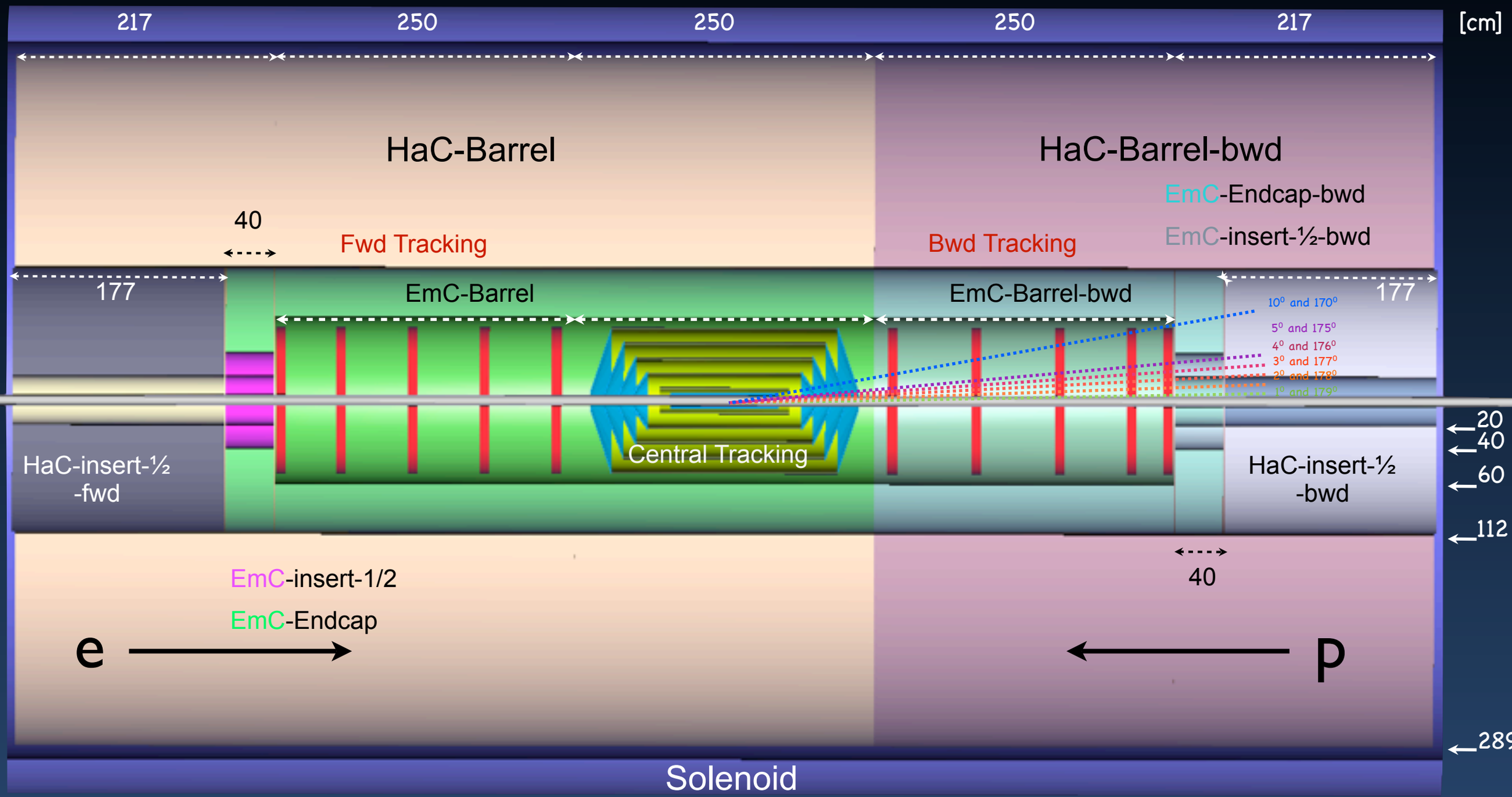


circumference = 8.3 km

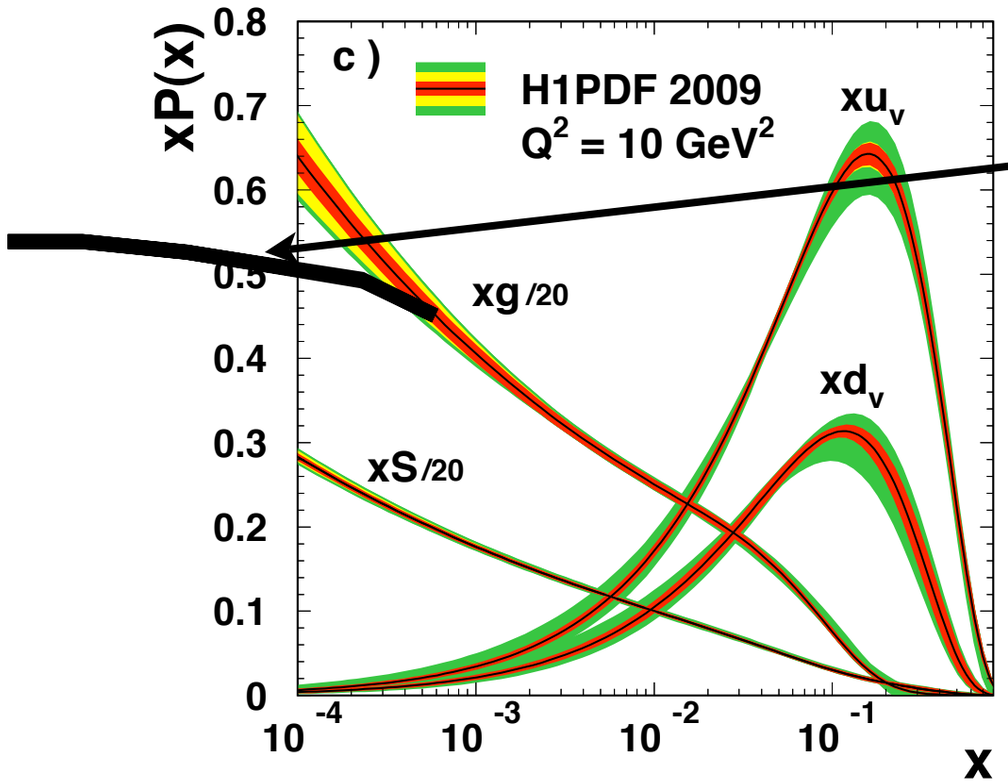
	p-60	erl	p-140
e^- energy at IP [GeV]	60	60	140
luminosity [10^{32} cm^{-2}s^{-1}]	1.1	10.1	0.4
polarization [%]	90	90	90
bunch population [10^9]	4.5	2.0	1.6
e^- bunch length [μm]	300	300	300
bunch interval [ns]	50	50	50
transv. emit. $\gamma\epsilon_{x,y}$ [μm]	50	50	100
rms IP beam size [μm]	7	7	7
hourglass reduction $H_{\rm hg}$	0.91	0.91	0.94
crossing angle θ_c	0	0	0
repetition rate [Hz]	10	CW	10
bunches/pulse [10^5]	1	N/A	1
pulse current [mA]	16	10	6.6
beam pulse length [ms]	5	N/A	5
ER efficiency η	0	94%	0
total wall plug power [MW]	100	100	100

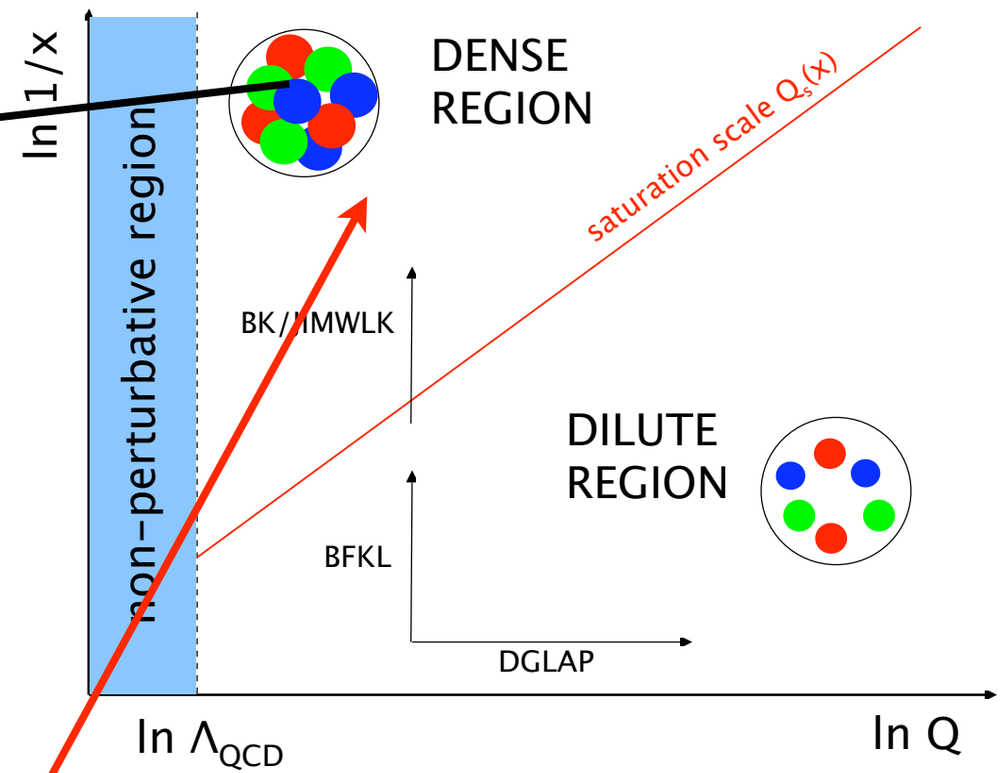
- For ions, RR/LR: Luminosity per nucleon ~ 1-2×10^{32}cm^{-2}s^{-1},~ ep for 179° acceptance (low-x setup).

Detector: low-x/eA setup

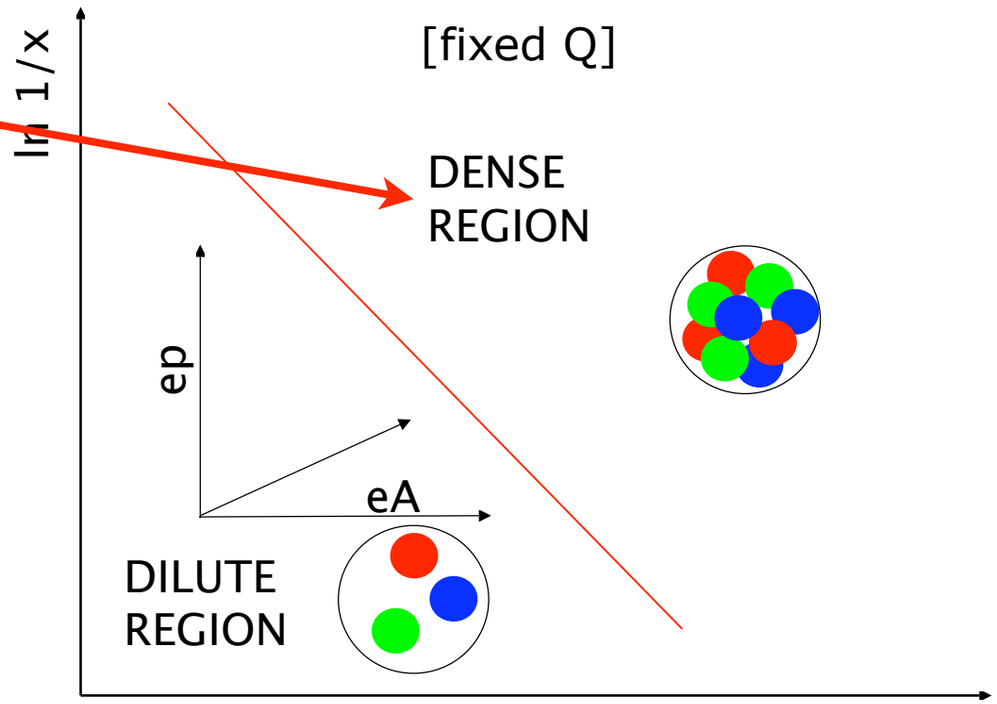


Small-x physics:



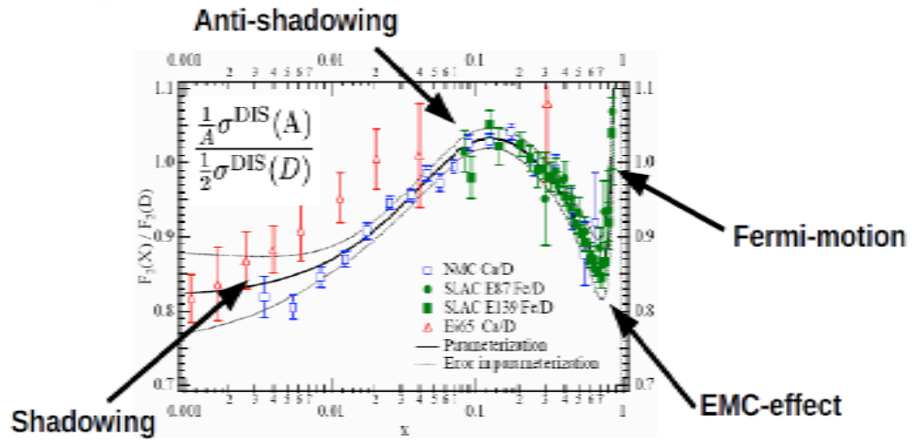


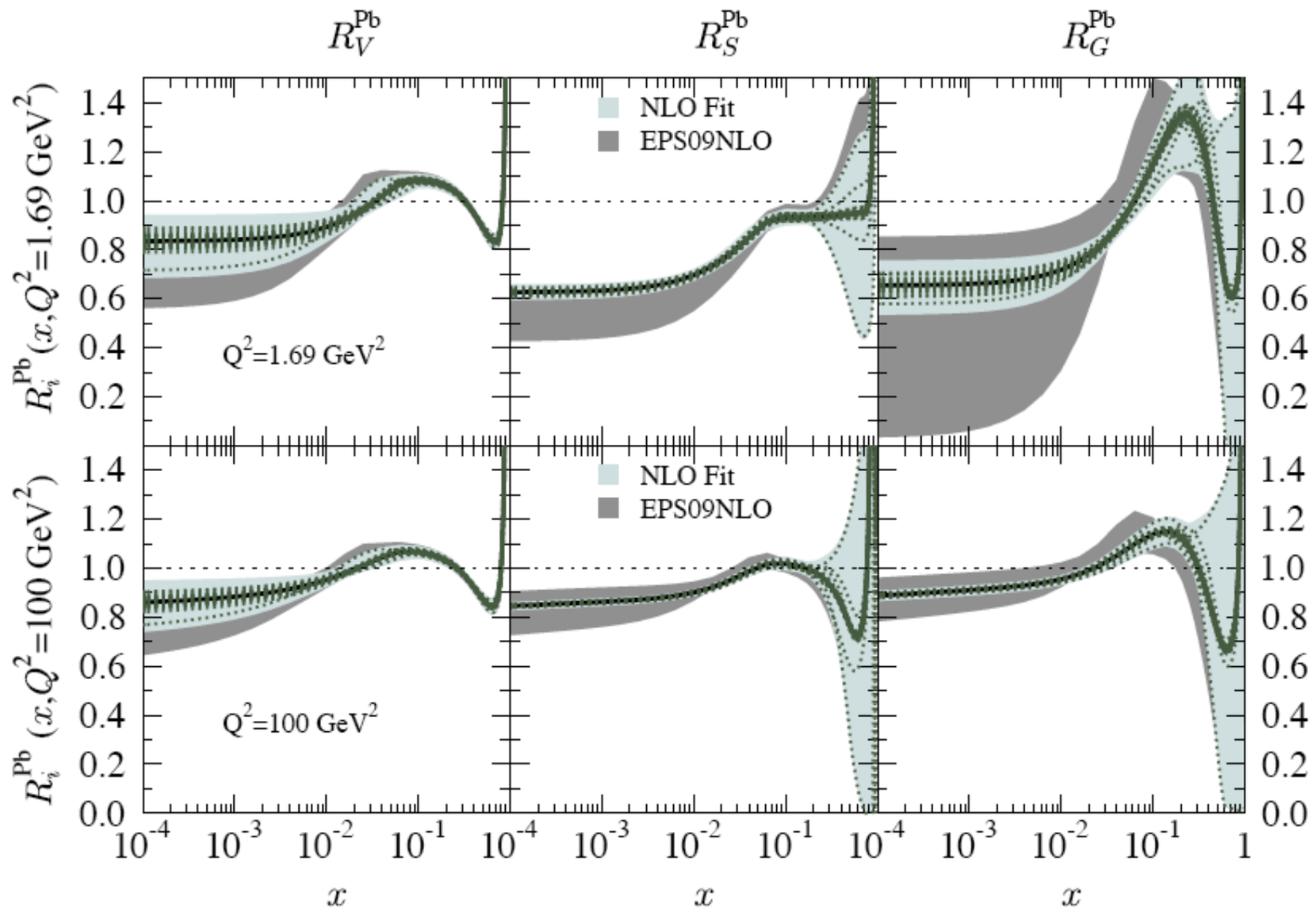
- **Novel regime of matter beyond the unitarity limit** at small x and/or high A: saturation of partonic densities.
- Two-pronged approach: ↓ x / ↑ A.
- Prediction: semiclassical QCD at weak coupling (CGC).



Nuclear parton densities (I):

$$R_f^A(x,Q^2) = \frac{f^A(x,Q^2)}{A \times f^p(x,Q^2)}$$

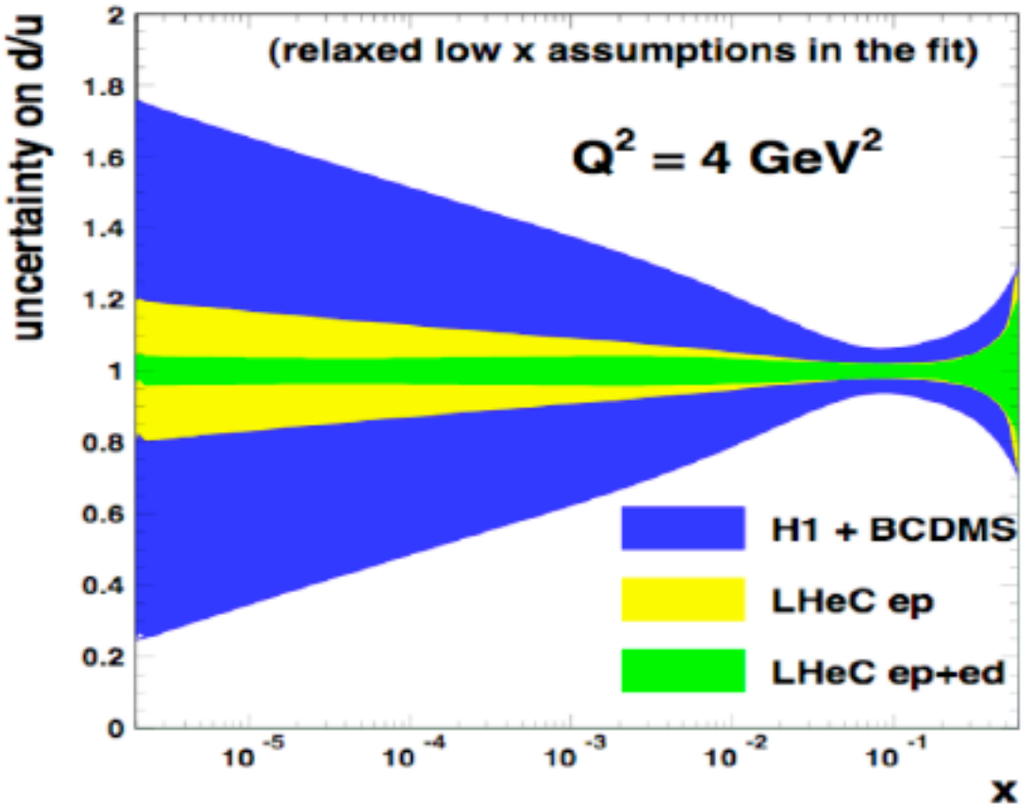


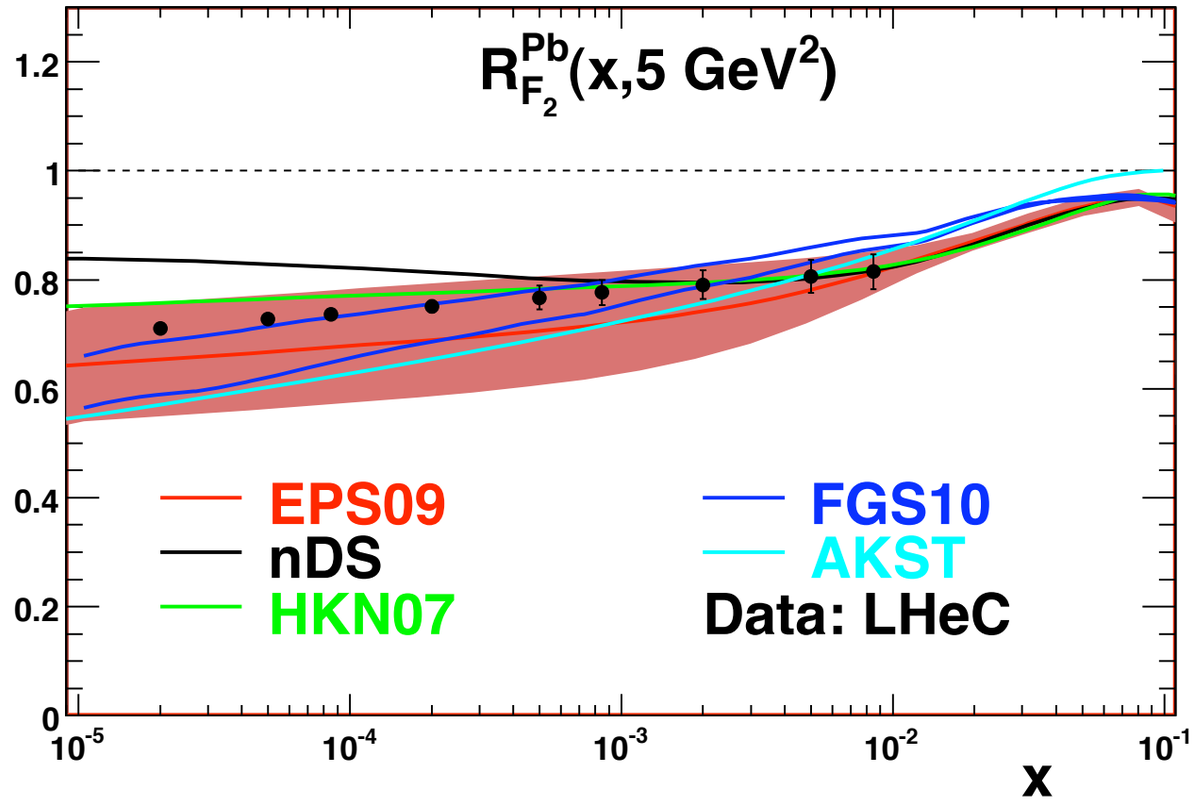


- Large uncertainties in parton densities at low x in nuclei (no existing data).
- LHeC data will substantially improve it.
- Impact on the characterization of the hot medium in UrHIC through hard probes (cold nuclear effects).

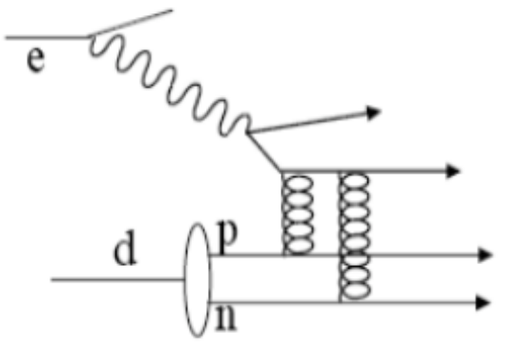
Nuclear parton densities (II):

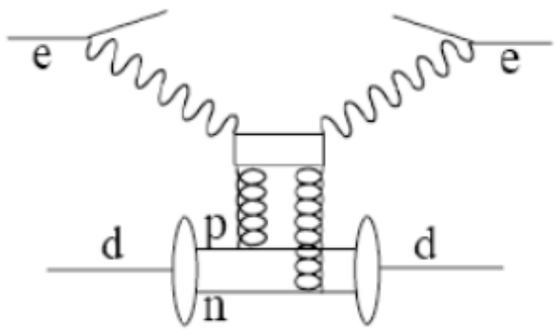
d/u at low x from deuterons





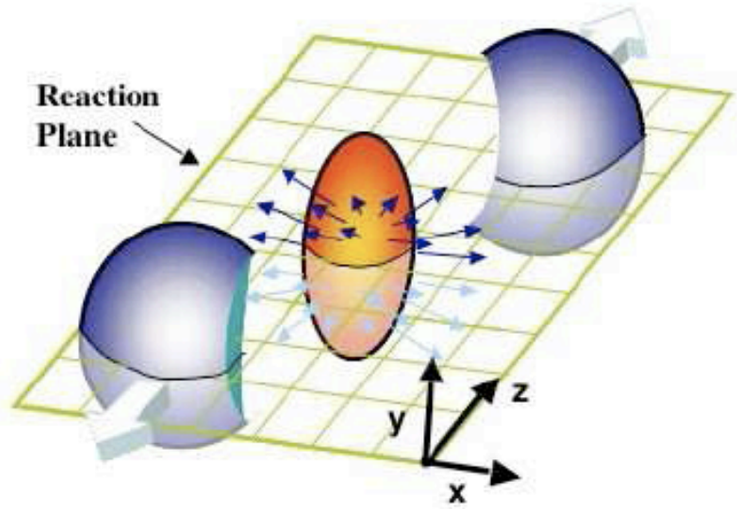
- ep/ed collisions at the LHeC would substantially improve our knowledge on the neutron pdf's.
- LHeC will test the relation between diffraction in ep and nuclear shadowing.

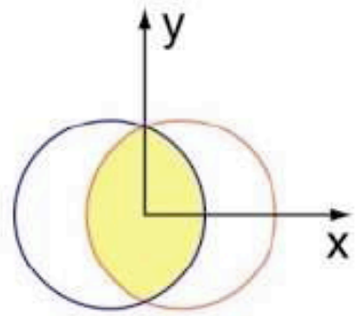


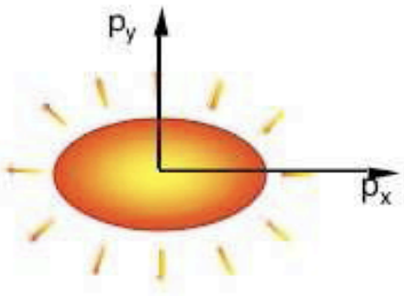


Initial conditions for UrHIC:

- Azimuthal anisotropy in UrHIC (RHIC) points to low viscosity/strong coupling of the produced medium.





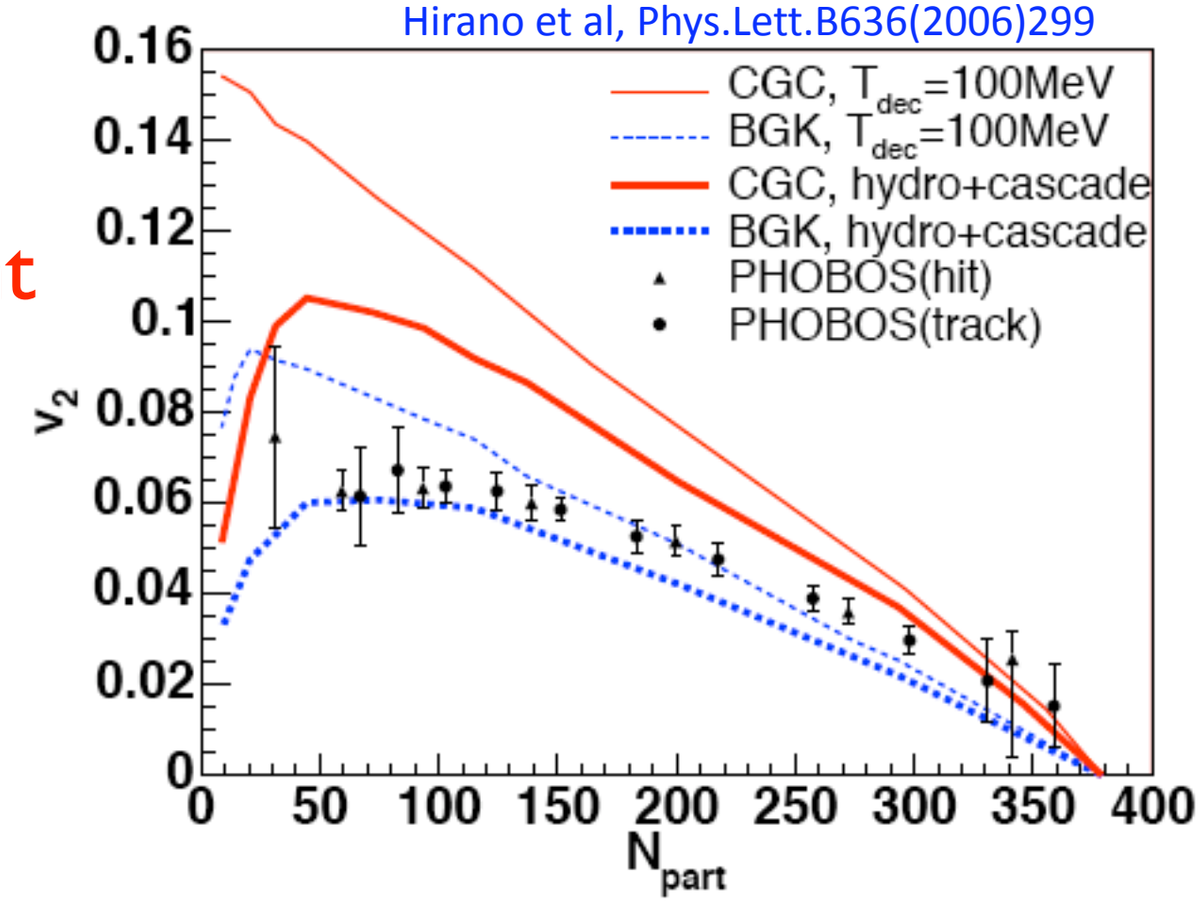


M.Tannenbaum, Rept.Prog.Phys 65 (2006) 2005

- Initial conditions crucial for the collective behavior.

- eA offers a clean environment to check the ideas about particle production giving the initial condition, and thermalization.

Hirano et al, Phys.Lett.B636(2006)299

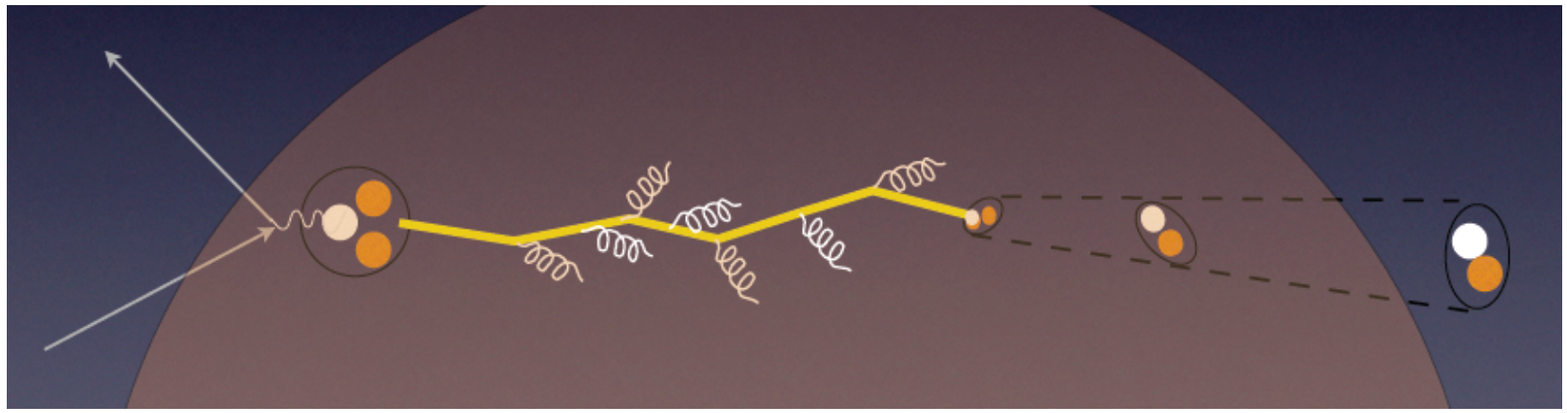


Final state exploration:

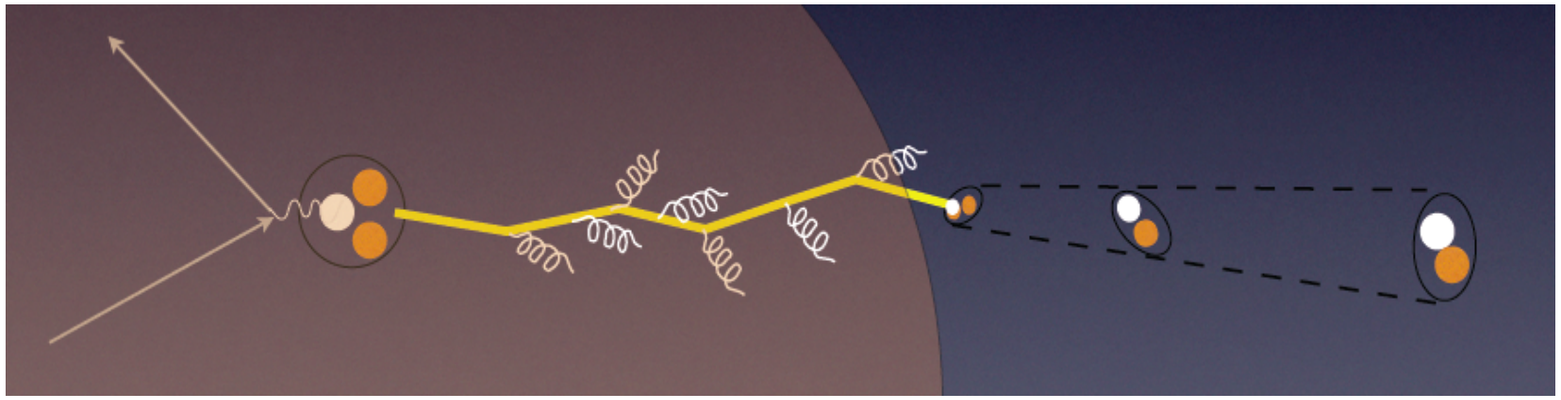
- LHeC (ν_{max}~10^5 GeV) will study the dynamics of hadronization

(partonic/hadronic eloss) by introducing a length of colored material to modify its pattern (length/nuclear size, chemical composition).

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



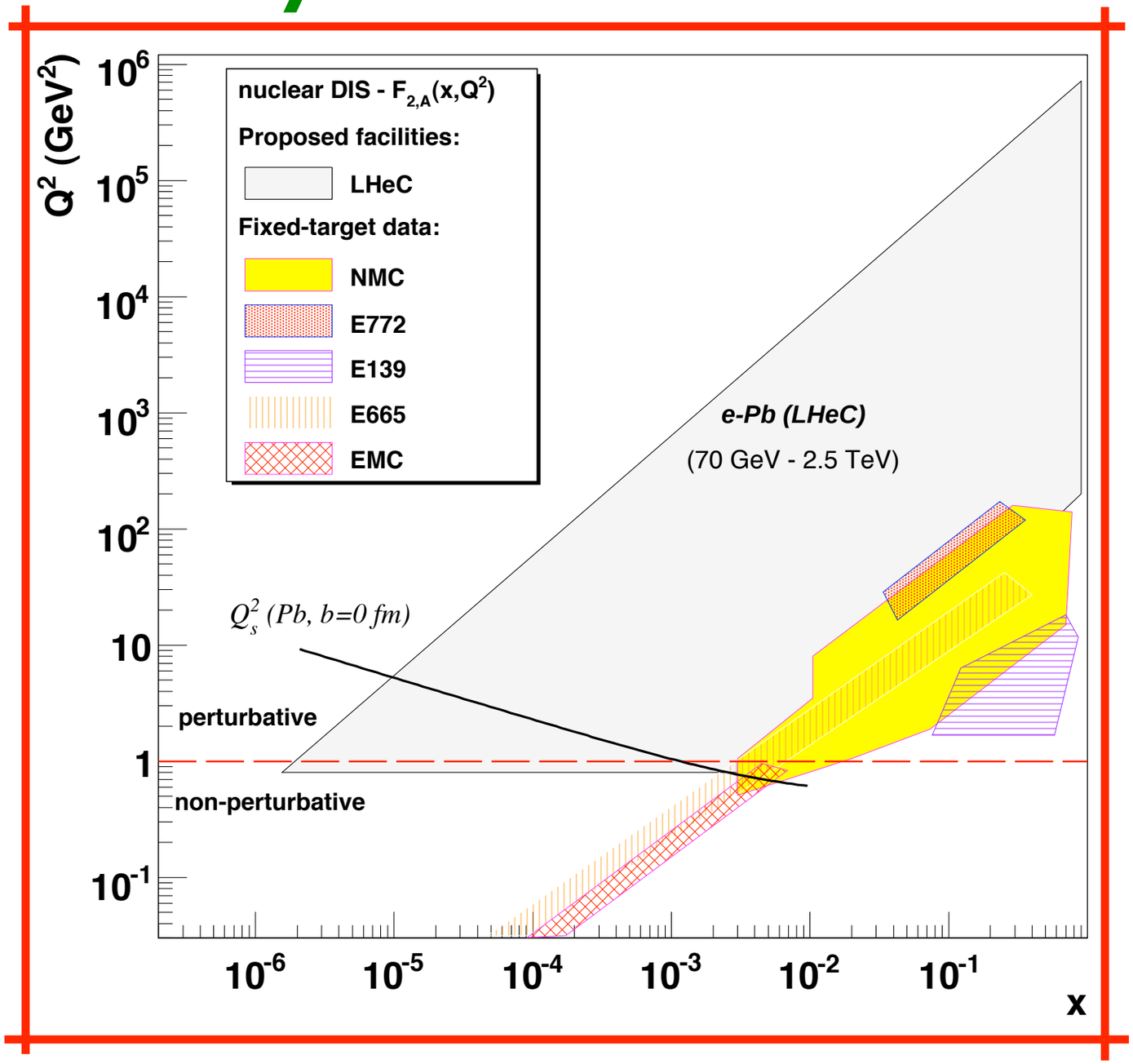
- High energy: partonic evolution altered in the nuclear medium, partonic energy loss.



Summary:

- LHeC: new facility at CERN for ep/eA collisions at E_{cm}~1-2 TeV under design.

- For nuclei, it will explore a new realm in their partonic structure.



- LHeC physics has strong implications on UrHIC (thus complementary to pA@LHC).

- LHeC could be built in 10 years, depending on the LHC schedules and on us.

http://cern.ch/lhec

Plans for the CDR:

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

Steps to go in 2010

1. Finalise physics and technical studies
2. DIS10 Firenze [April] and IPACC Japan [May]
3. Draft CDR September 2010
4. Divonne 28.10.-30.10. Final Workshop
5. November 2010: Final report to ECFA
6. Submit CDR to CERN, ECFA, NuPECC

Many thanks to Max Klein, Brian Cole, Paul Newman, Anna Stasto, Urs Wiedemann, Peter Kotska, David d'Enterria, Kari Eskola, Hannu Paukkunen, Carlos Salgado, Mark Strikman, Konrad Tywoniuk and all other collaborators in the preparation of the CDR!!!

Working Group Convenors

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Uwe Schneeekloth (DESY),
Pierre van Mechelen (Antwerpen)

Detector Design
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Rainer Wallny (UCLA),
Alessandro Polini (Bologna)

New Physics at Large Scales
George Azuelos (Montreal)
Emmanuelle Perez (CERN),
Georg Weiglein (Hamburg)

Precision QCD and Electroweak
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Paolo Gambino (Torino),
Thomas Gehrmann (Zuerich)
Claire Gwenlan (Oxford)

Physics at High Parton Densities
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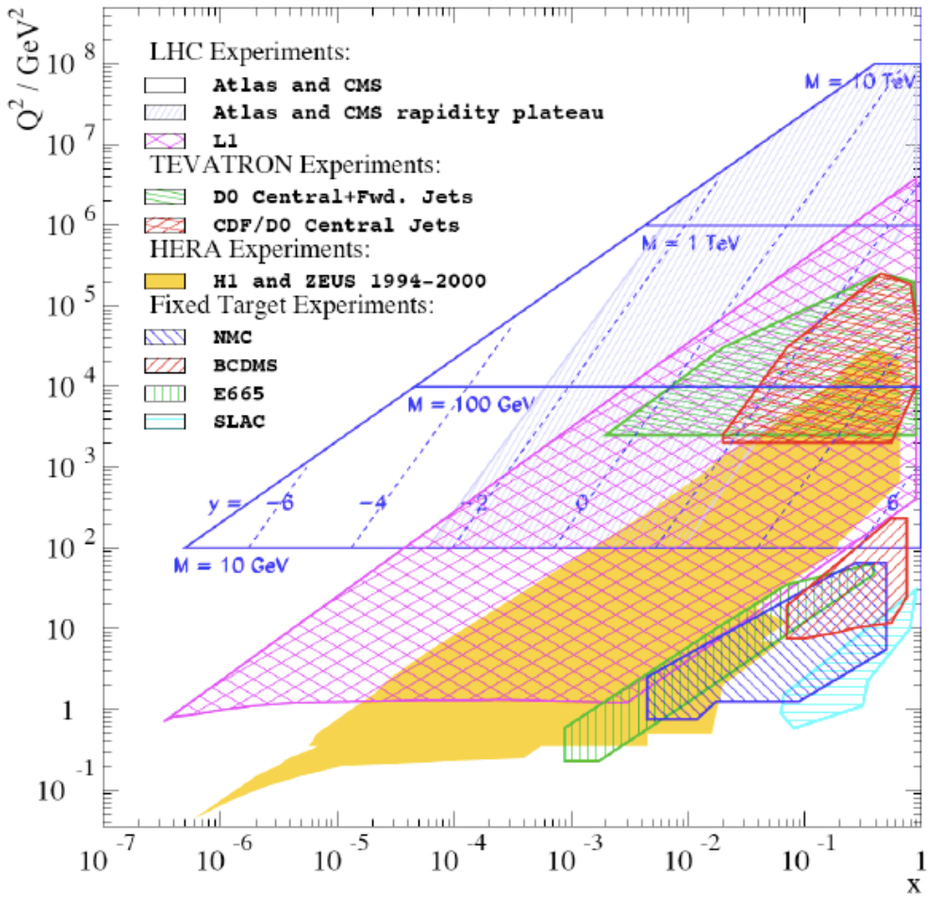
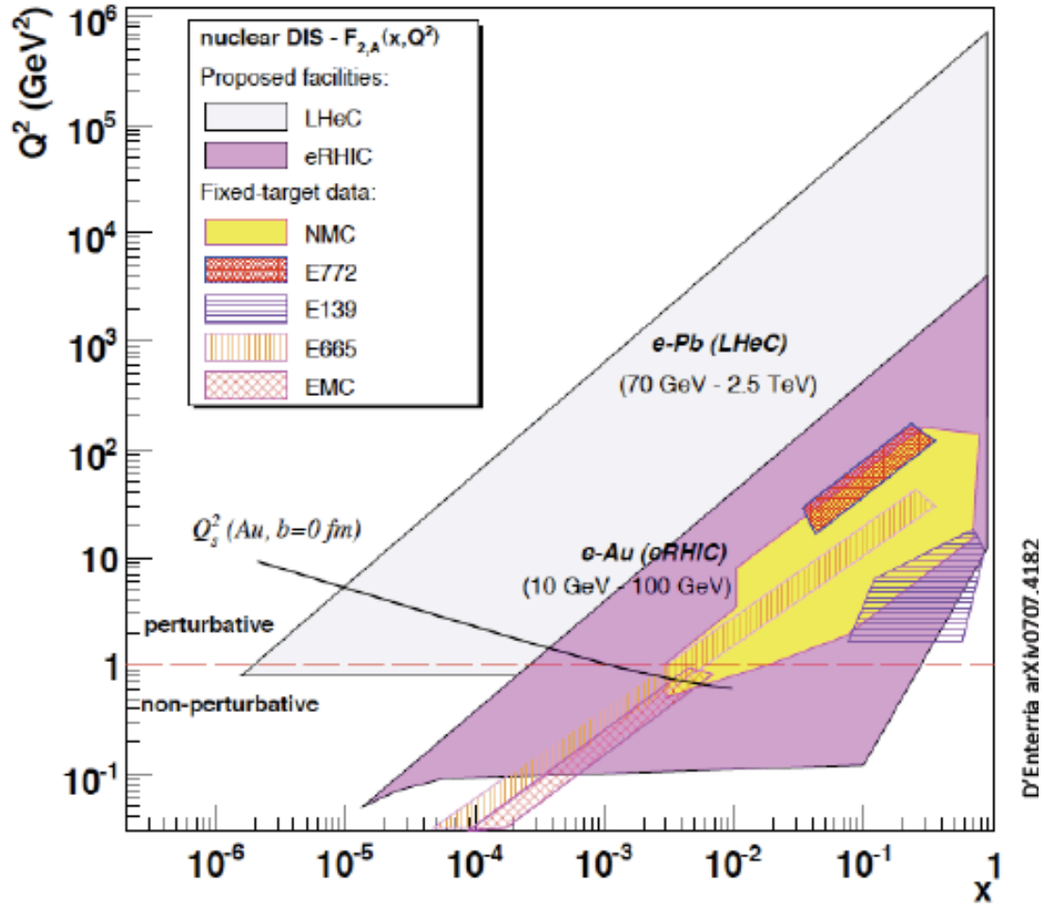
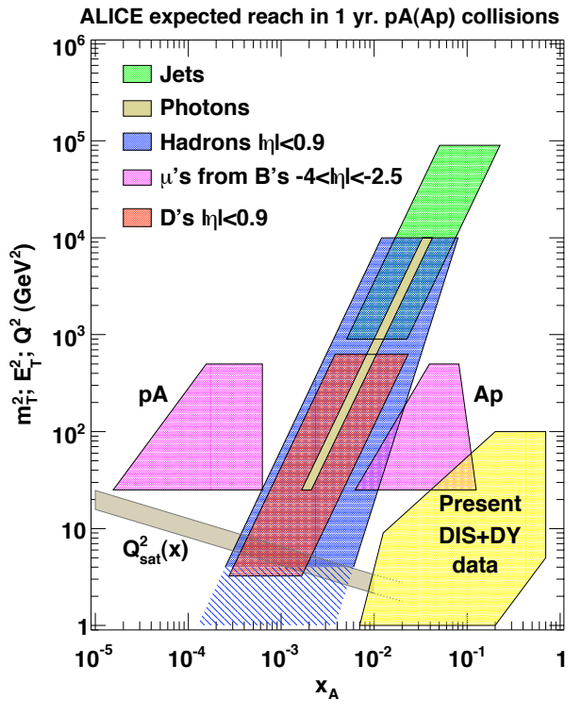
Brian Cole (Columbia),
Paul Newman (Birmingham),
Anna Stasto (PennState)

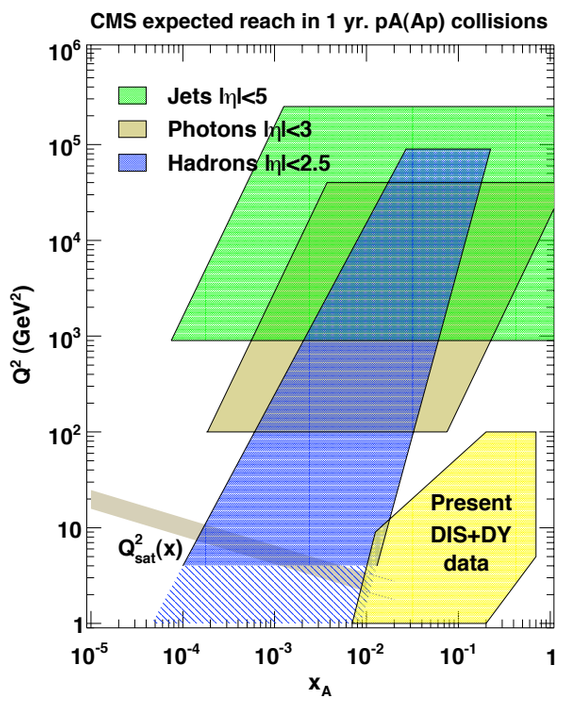
Backup: kinematics





- ep: access to the perturbative region below x ~ a few 10^{-5}.
- eA: new realm.
- pA@LHC will cover larger x, Q^2.





Backup: eA collisions

- Ions are part of the LHC program: Pb, maybe Ar, Ca, O,...
- RR/LR: Luminosity per nucleon ~ 1-2×10^{32}cm^{-2}s^{-1}.

- Roughly the same luminosity per nucleon than in ep for a 1-179 degree acceptance (low-x/eA setup).