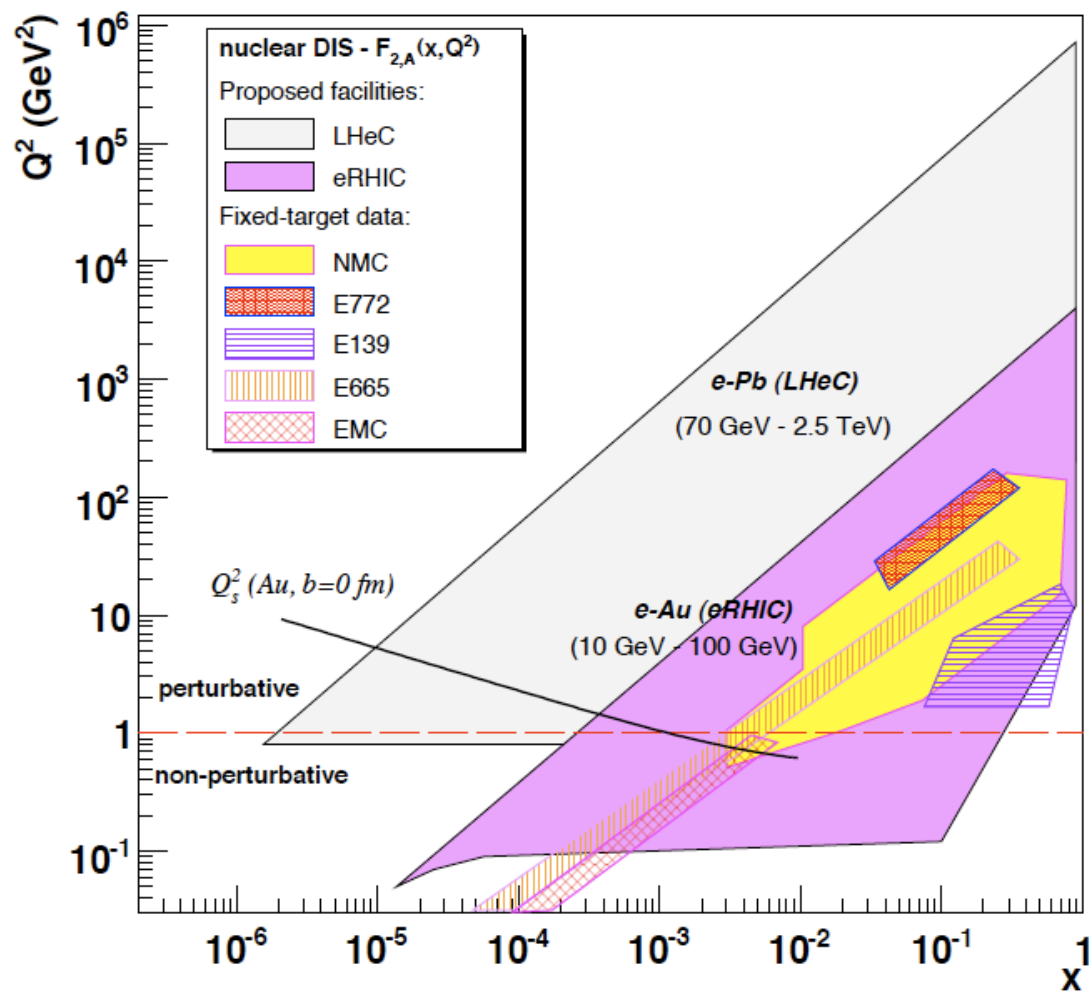


An Electron-Hadron Collider at the LHC www.lhec.org.uk

50..150 (e^\pm) GeV on 2.7 (Pb), 3.5 (D), 7(p) TeV



x: fractional parton momentum
 Q^2 : -four momentum transfer²

The LHeC may extend the kinematic range of eA by 4 orders of magnitude.

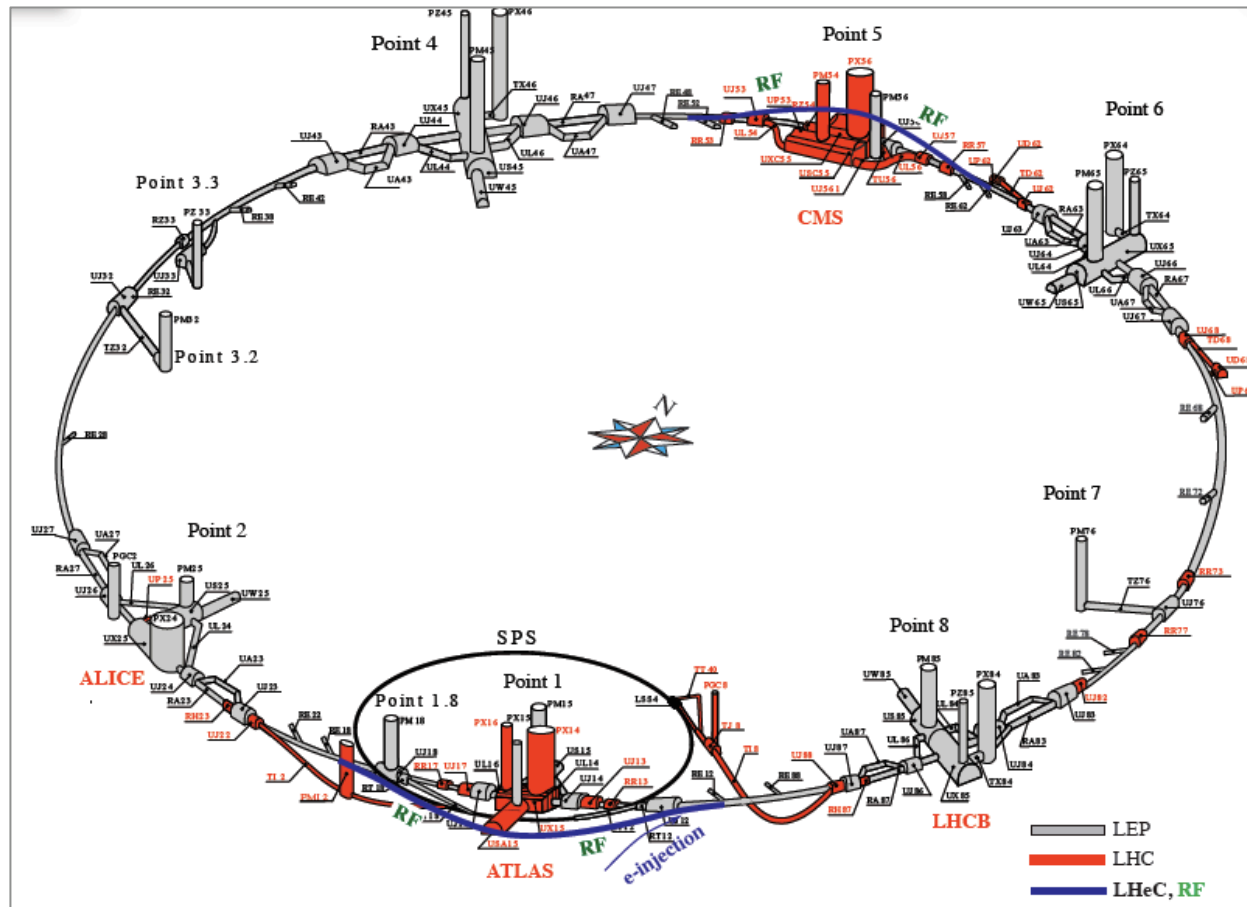
How? Why? When?

HERA missed eA,eD

Max Klein
 University of Liverpool
 LHeC Steering Group

NuPECC – F/Main 13/10/09

Ring-Ring ep/eA

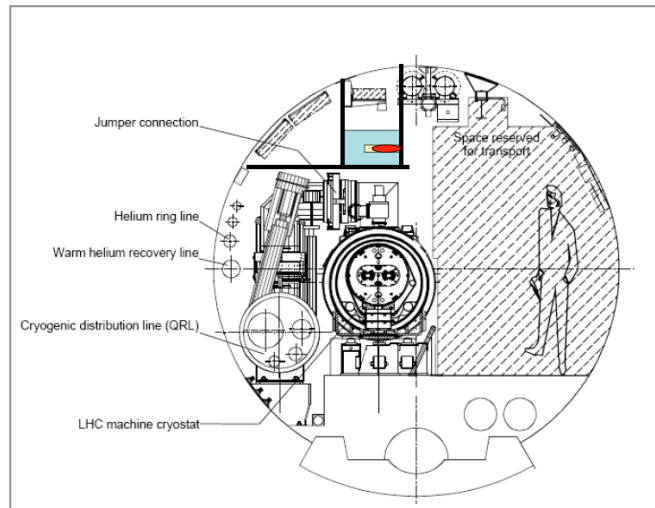


$$E_e = E_{inj} \dots 80 \text{ GeV. } L_{ep} \sim 10^{33} \text{ cm}^{-2} \text{ s}^{-1} \text{ (100 times HERA)}$$

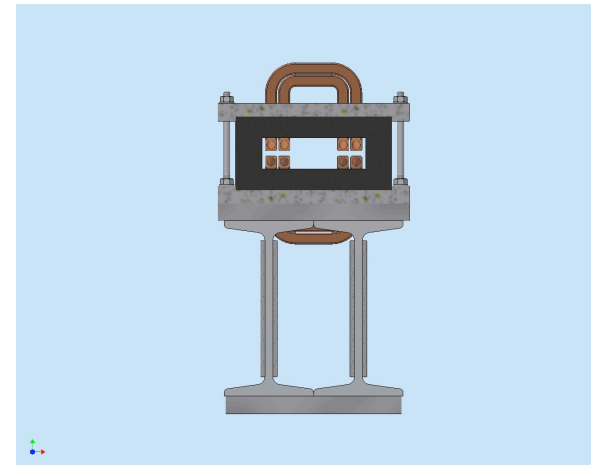
$1/x$ and $Q^2 \sim 10^{4(2)}$ times larger in eA (ep) than so far

Ring Challenges

Tunnel cross section

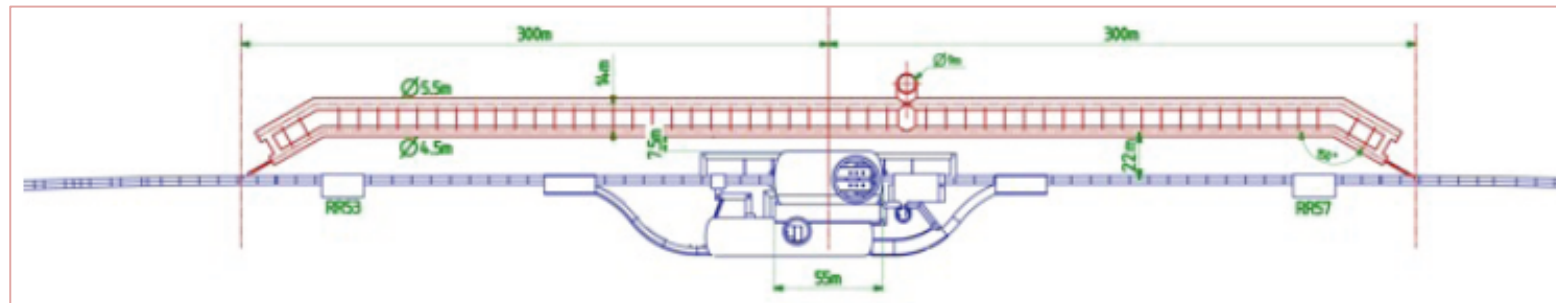


Dipole magnet design (BNP)



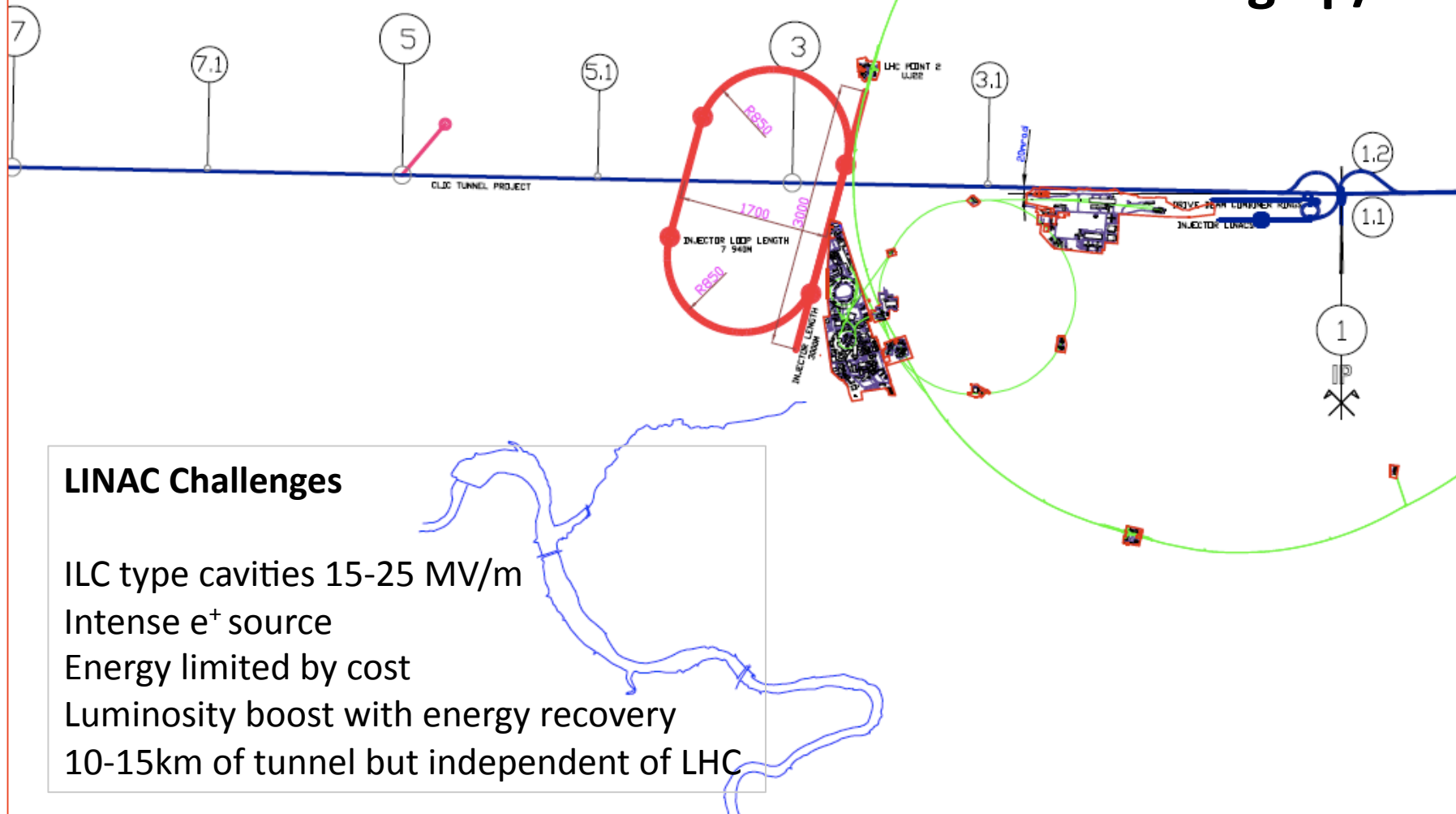
O-shaped magnet with ferrite core

Sketch of bypass tunnel around CMS (double tunnel, 1 shaft, houses rf)



$$L = \frac{N_p \gamma}{4\pi e \epsilon_{pn} \beta^*} \cdot \frac{P}{E_e} = 5 \cdot 10^{32} \cdot \frac{P / MW}{E_e / GeV} cm^{-2} s^{-1}$$

Linac-Ring ep/eA



LINAC Challenges

- ILC type cavities 15-25 MV/m
- Intense e⁺ source
- Energy limited by cost
- Luminosity boost with energy recovery
- 10-15km of tunnel but independent of LHC



e-A Collisions

- Present nominal Pb beam for LHC

- Same beam size as protons, fewer bunches

- $k_b = 592$ bunches of $N_b = 7 \times 10^7$ $^{208}\text{Pb}^{82+}$ nuclei

- Assume lepton injectors can create matching train of e^-

- $k_b = 592$ bunches of $N_b = 1.4 \times 10^{10}$ e^-

- Lepton-nucleus or lepton-nucleon luminosity in ring-ring option at 70 GeV

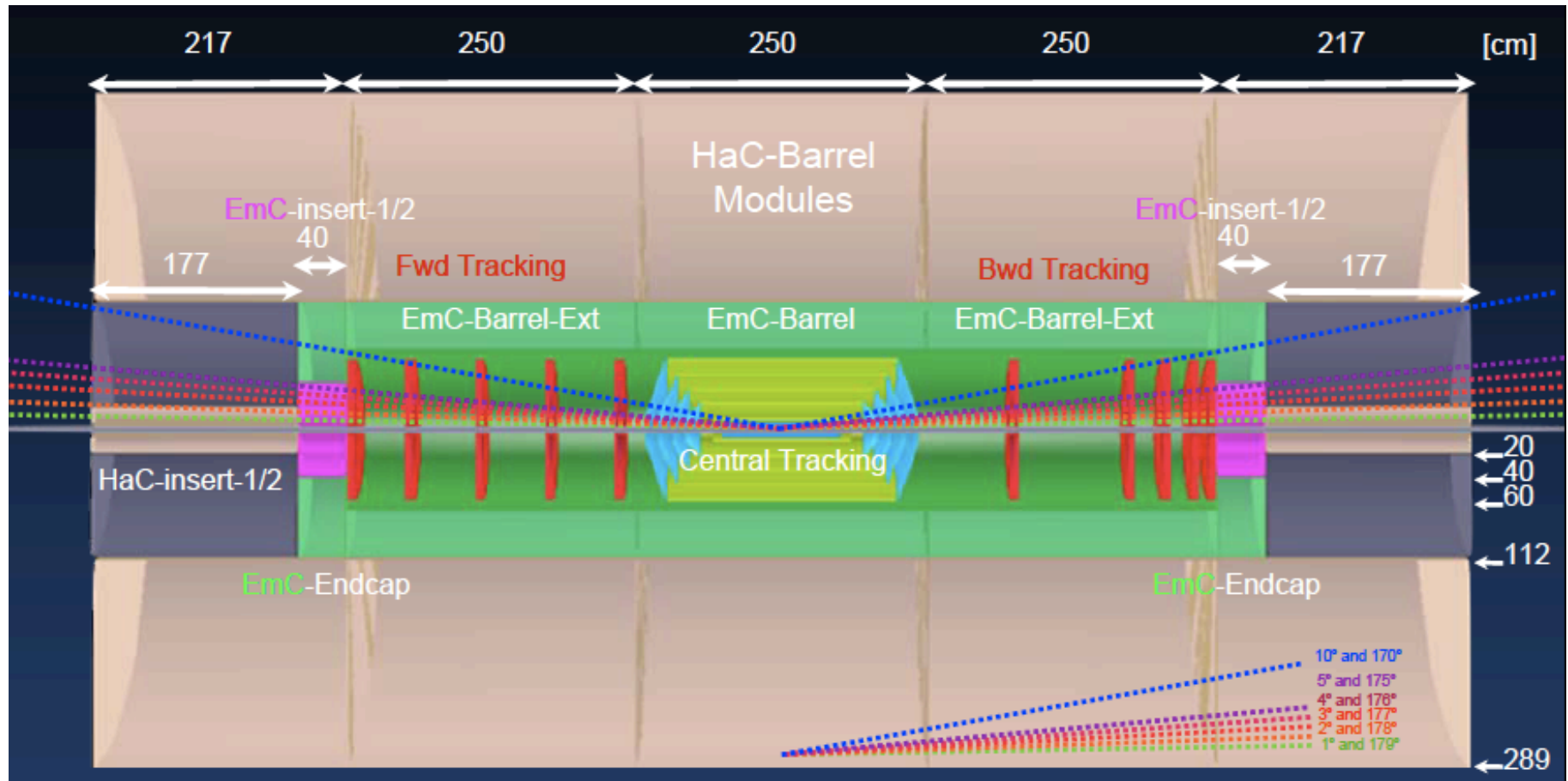
- $L = 1.09 \times 10^{29} \text{ cm}^{-2}\text{s}^{-1} \Leftrightarrow L_{\text{en}} = 2.2 \times 10^{31} \text{ cm}^{-2}\text{s}^{-1}$

- gives 11 MW radiated power

eA collisions may be realised at the LHC building on AA,pA: Pb-Pb (in 2010)

Need to maintain ion injector and possibly extend to Ca and Deuterons

Detector under Design



New detector: high precision, large acceptance, LHC/ILC/HERA related, fwd. p,n,d, ..

LHeC Detector: version for low x Physics

Muon chambers

(fwd,bwd,central)

Coil (r=3m I=8.5m, 2T)

[Return Fe not drawn,

2 coils w/o return Fe studied]

Central Detector

Hadronic Calo (Fe/LAr)

El.magn. Calo (Pb,Sc)

GOSSIP (fwd+central)

[Gas on Slimmed Si Pixels]

[0.6m radius for 0.05% * pt in 2T field]

Pixels

Elliptic beam pipe (~3cm)

Fwd Spectrometer

(down to 1°)

Tracker

Calice (W/Si)

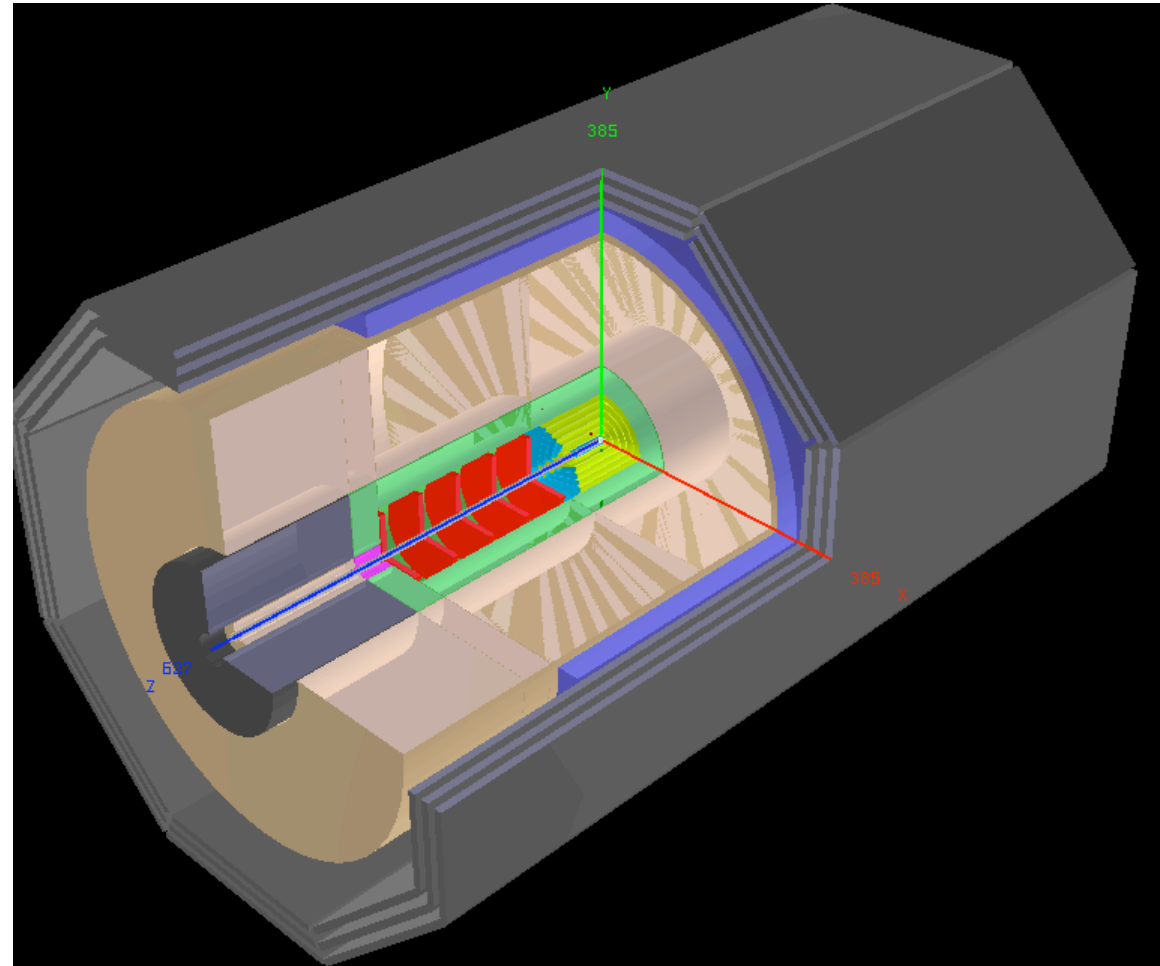
FwdHadrCalo

Bwd Spectrometer

(down to 179°)

Tracker

Spacal (elm, hadr)



Extensions in fwd direction (tag p,n,d) and backwards (e, γ)

Project Status

2007: (r)ECFA and CERN invite for CDR

2008: Reports to NuPECC (9/08), ICFA (10/08) and ECFA (11/08)

2009: 2nd workshop on the LHeC under auspices of CERN, ECFA, NuPECC

2010: Conceptual Design Report (CDR)

[machine, interaction region, detector, physics: BSM, QCD+elweak, HPD]

Further consideration depends on CDR and LHC

Project may be realised within 10 years and thus fit to the 2nd phase of LHC

www.lhec.org.uk

Physics Programme of the LHeC

Unfolding completely the partonic structure of the proton (neutron and photon) and search for sub-substructure down to scales ten times below HERA's limit

Sensitive exploration of new symmetries and the grand unification of particle interactions with electroweak and strong interaction measurements of unprecedented precision

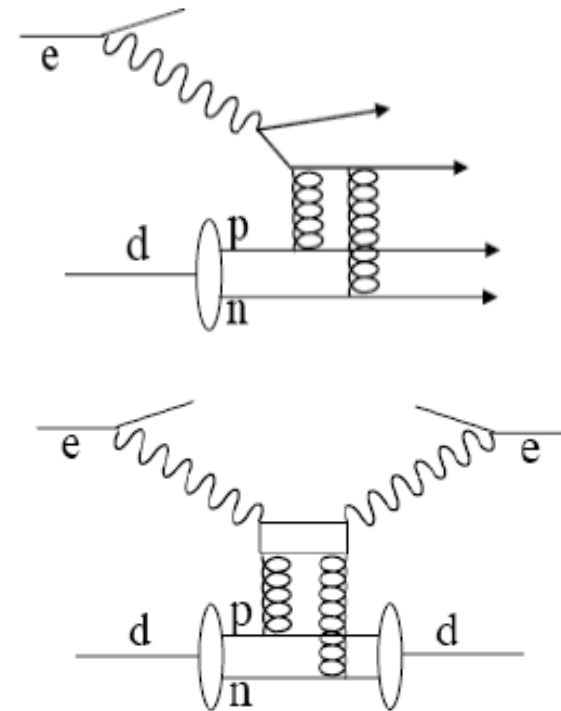
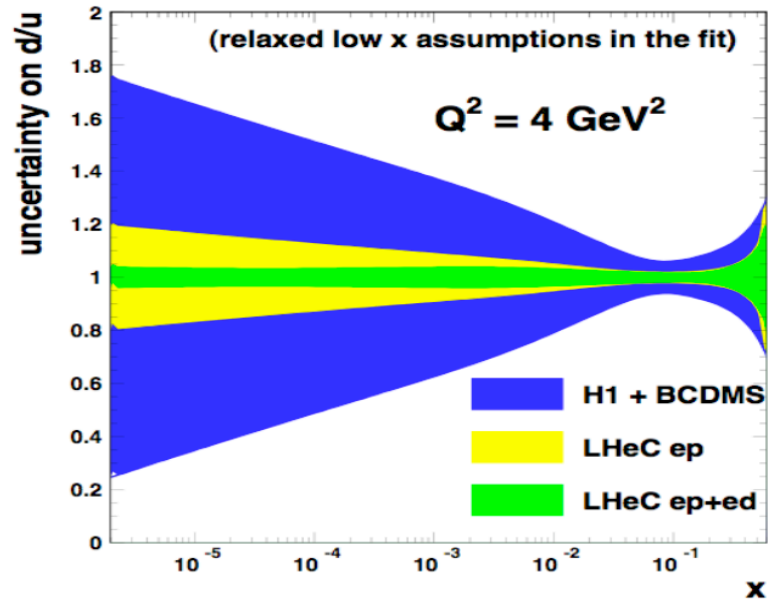
Search for and exploration of new Tera scale physics, in particular for singly produced new states (LQ, RPV SUSY, excited fermions), complementary to the LHC pp program

Exploration of high density matter (low x physics beyond the expected unitarity limit for the growth of the gluon density)

Unfolding the substructure and parton dynamics inside nuclei and study of quark-gluon plasma matter, by an extension of the kinematic range of lepton-nucleus scattering by 4 orders of magnitude

Neutron Structure

d/u at low x from deuterons

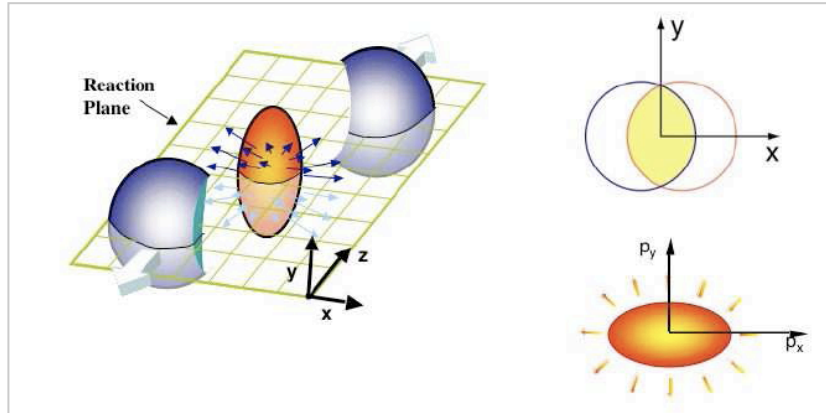


Neutron structure unknown in HERA range and below. Crucial to resolve parton structure and to predict scattering on nucleon rather than proton targets

In eA at the collider, test Gribovs relation between shadowing and diffraction, control nuclear effects at low Bjorken x to high accuracy

Quark Gluon Plasma

Landau 1953. **RHIC**: QGP strongly coupled plasma with liquid behaviour instead of weakly interacting gas of partons



Related to cold atoms and to superstring theory AdS/CFT

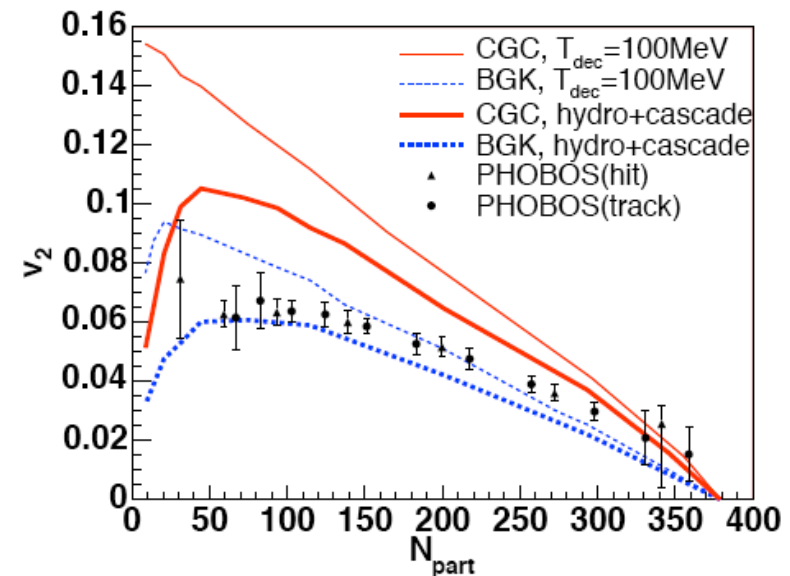
Collective flow in non-central collisions anisotropic

Anisotropy proportional to $1/\text{viscosity}$ of fireball, dominantly elliptic (" v_2 " coefficient)

QGP most perfect liquid – smallest shear viscosity/entropy

Conclusions depend on initial fireball eccentricity

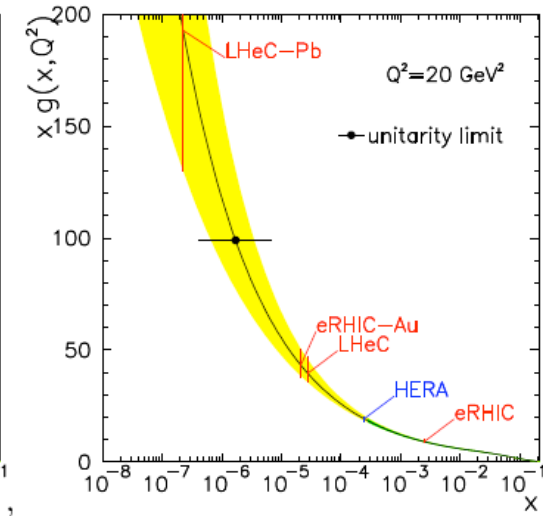
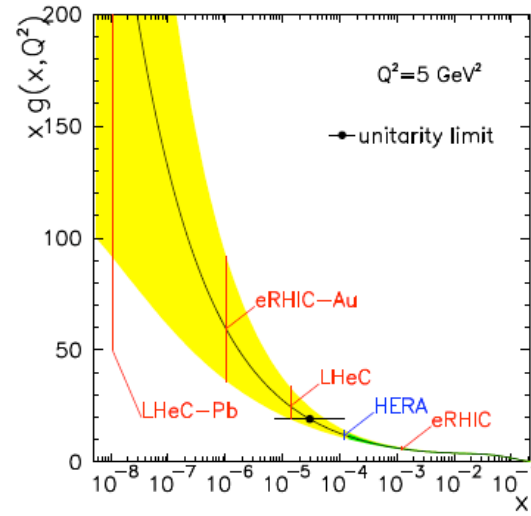
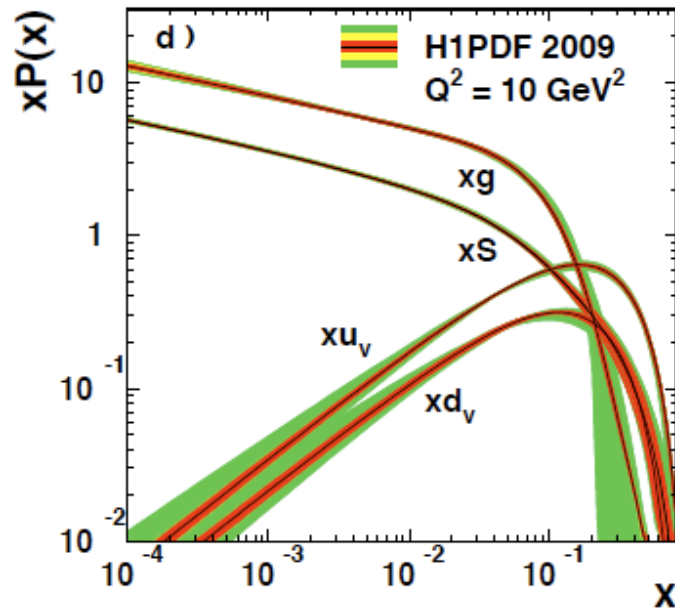
eA to measure the initial conditions of QGP.



Colour Glass Condensate

Perturbatively calculable via non-linear evolution equations

HERA: Quark and Gluon Density rise towards low Bjorken x
Gluon dominance in DIS region



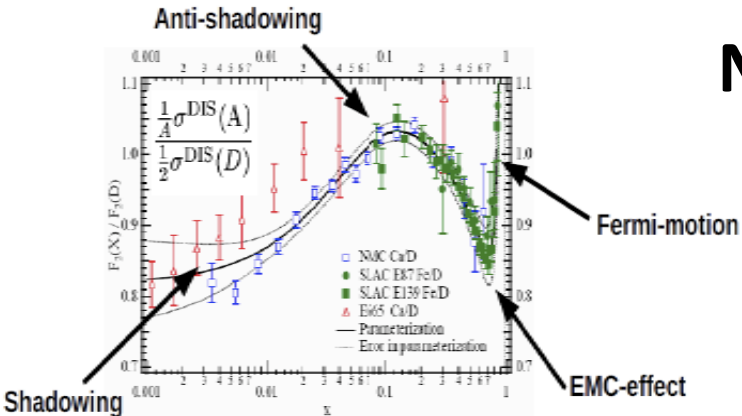
Expect saturation of rise at $Q_s^2 \approx xg \alpha_s \approx c x^{-\lambda} A^{1/3}$

Qualitative change of scattering behaviour:

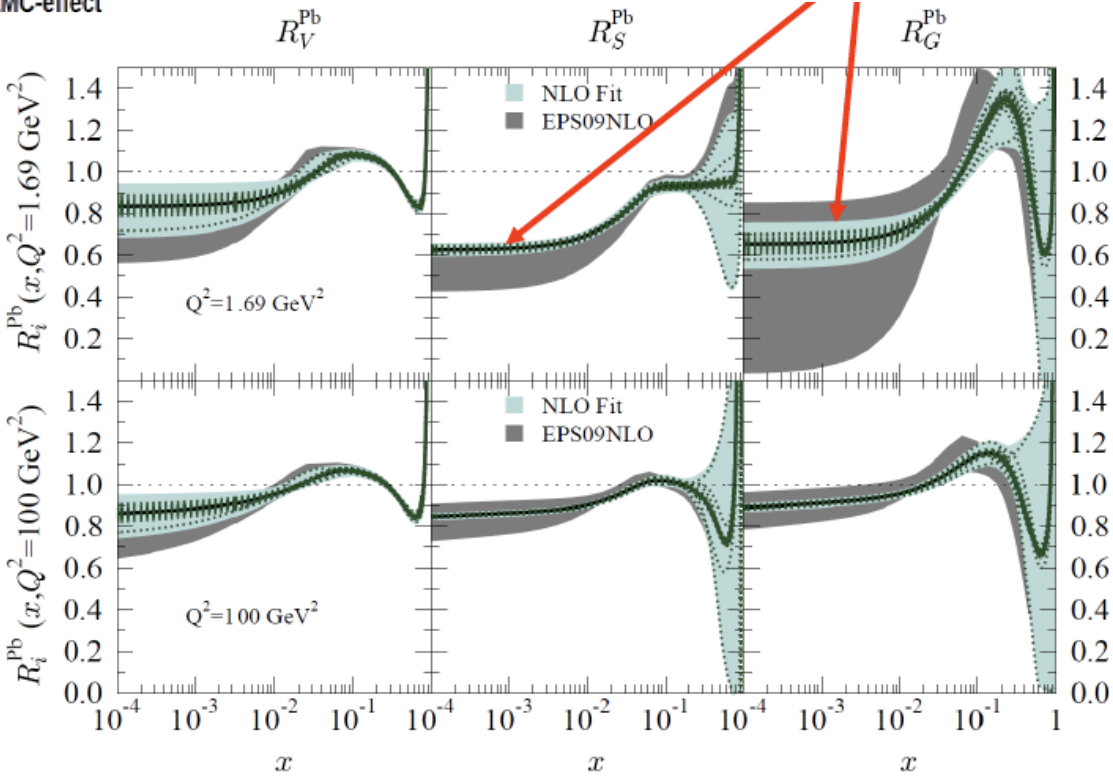
- Saturation of cross sections amplified with $A^{1/3}$
- Rise of diffraction to 50% of cross section
- more may be added here

Systematic evaluation of QGC both with ep and eA and small α_s

Nuclear Parton Distributions



Quantitative improvement, but based on DIS DATA for the 1st time



Shadowing ← diffraction

Fermi motion ← p tagging

p, D, Ca, Pb

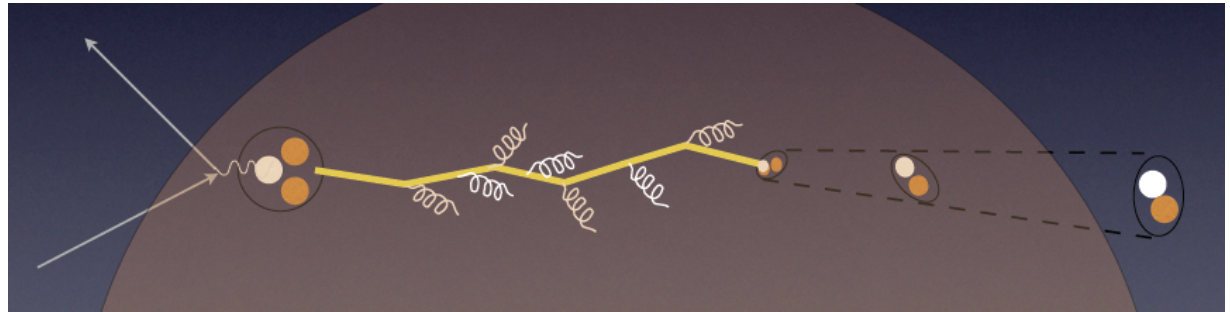
LHeC will have immense impact on the partonic structure of nuclei

→ the basis for understanding partonic matter at high densities, complementary to AA at the LHC

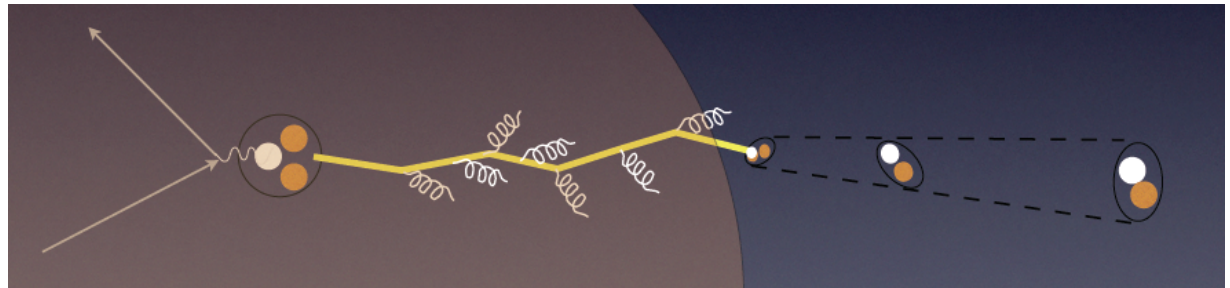
In-medium Hadronisation

The study of particle production in eA (fragmentation functions and hadrochemistry) allows the study of the space-time picture of hadronization.

Low energy (ν): need of hadronization inside.
Parton propagation: p_t broadening
Hadron formation: attenuation



High energy (ν): partonic evolution altered in the nuclear medium.



LHeC : study the transition from small to high energies, testing the energy loss mechanism: crucial for understanding of the medium produced in HIC characterised by jet quenching studies.

Summary

Some points

Choose a detector picture

Perhaps add saturation in ep? It yet is mentioned

References to be added for plots

Deeply Virtual Compton Scattering

Better not