Future electron-ion physics at CERN*

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* mostly stolen from N Armesto, Santiago de Compostela

GDR PH-QCD, Palaiseau, December 16th, 2014

Electrons at the LHC: a new beginning

A new committee is providing direction on the case for an electron–hadron collider, both at the LHC and at a Future Circular Collider complex.

From time to time, great experimental progress in particle physics suddenly reveals a crisis in theoretical physics. This happened in the early 1960s when a plethora of hadrons had been discovered, while strong-interaction theory dealt with analytical properties of the S matrix and a number of phenomenological models. At that time, Murray Gell-Mann, who had just introduced the notion of quarks, seconded by Georg Zweig, argued for focusing on "a higher-energy accelerator so that we can do more experiments over the next generation and really learn more about the basic structure of matter" (Gell-Mann 1967). The current situation is not so different.

At the LHC, the Standard Model is being subjected to a thorough confirmation, including the remarkable completion of its particle contents with the discovery of a Higgs boson. Important as these results are, however, there is still no indication of the existence of the long-predicted supersymmetric particles or of Kaluza–Klein

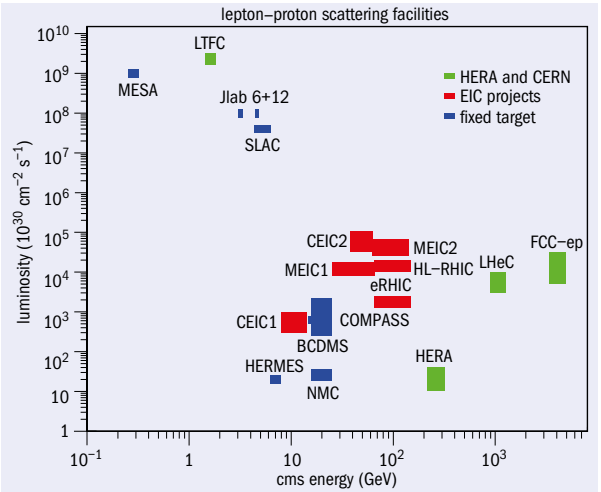


Fig. 1. Lepton–proton scattering projects – using fixed targets (blue), future medium-energy electron–ion collider projects (red), HERA and CERN's electron–proton concepts (green) – in terms of luminosity and centre-of-mass energy.

Cern Courrier June 2014

Current LHC schedule:

'New' (as of 2014) LHC schedule beyond LS1

Only EYETS (19 weeks) (no Linac4 connection during Run2)

LS2 starting in 2018 (July) 18 months + 3months BC (Beam Commissioning)

LS3 LHC: starting in 2023 => 30 months + 3 BC

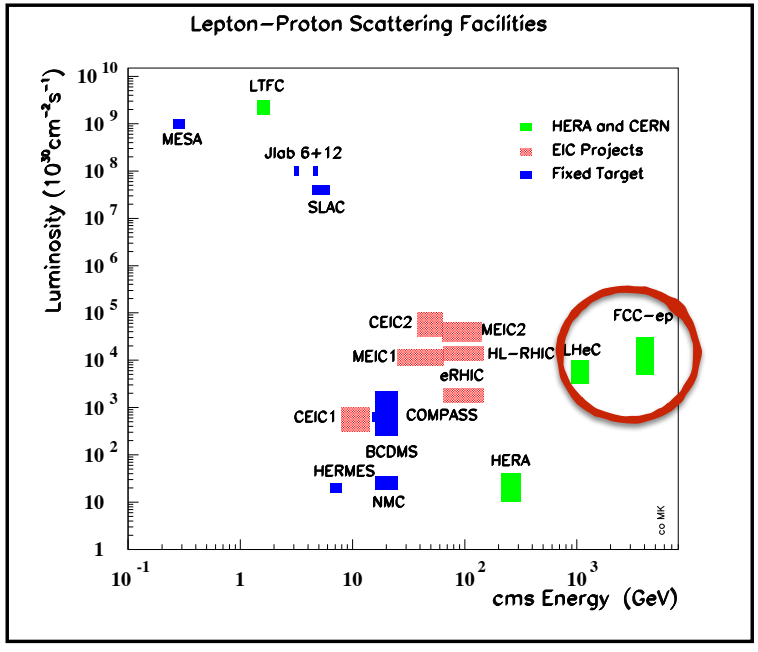
injectors: in 2024 => 13 months + 3 BC

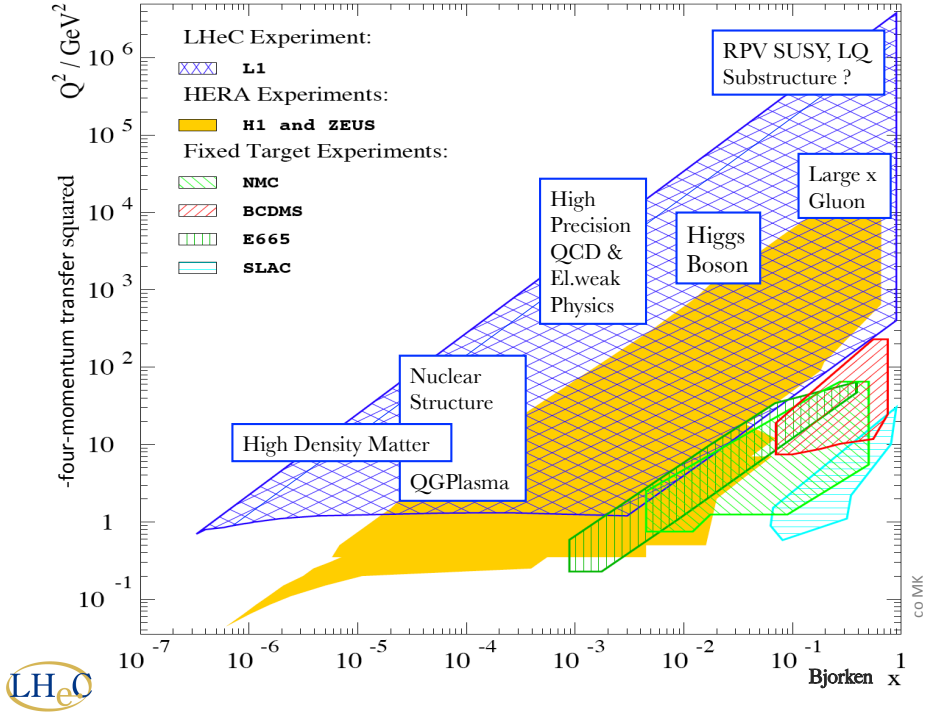
Here we are

LHC schedule approved by CERN management and LHC experiments spokespersons and technical coordinators
Monday 2nd December 2013

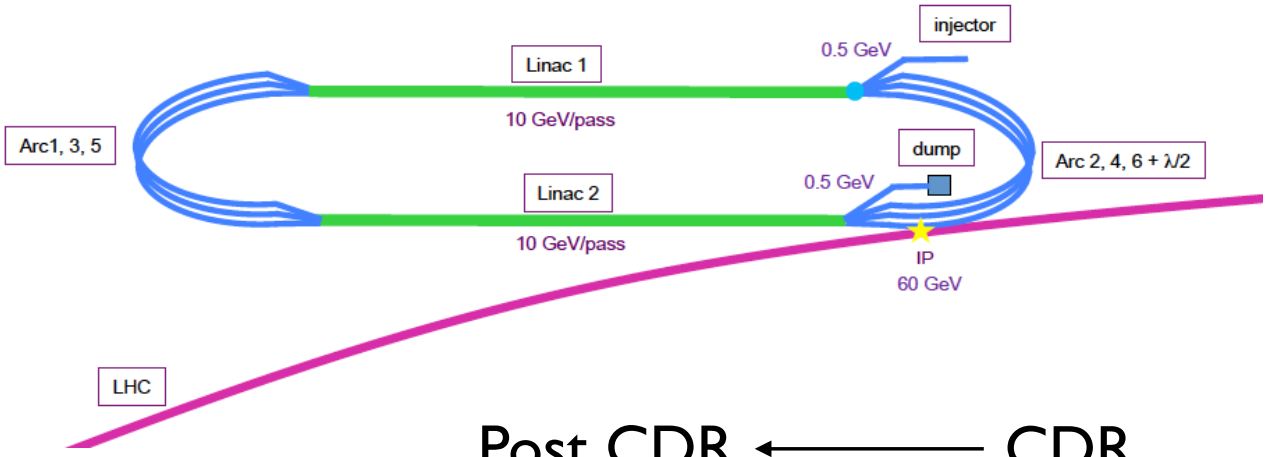
LHeC/FCC-he:

- **LHeC, FCC-he** → ep/eA experiment using p/A from the LHC/FCC: E_p=7/50 TeV, $E_A=(Z/A)E_p$=2.76/19.7 TeV/nucleon for Pb.
- New e^+/e^- accelerator: E_{cm}~several TeV/nucleon (E_e=50-175 GeV).
- **Compatible with synchronous LHC/HL-LHC/FCC operation.**
- Large physics case beyond our interests: precision QCD and EW, small x, eA, Higgs, BSM.





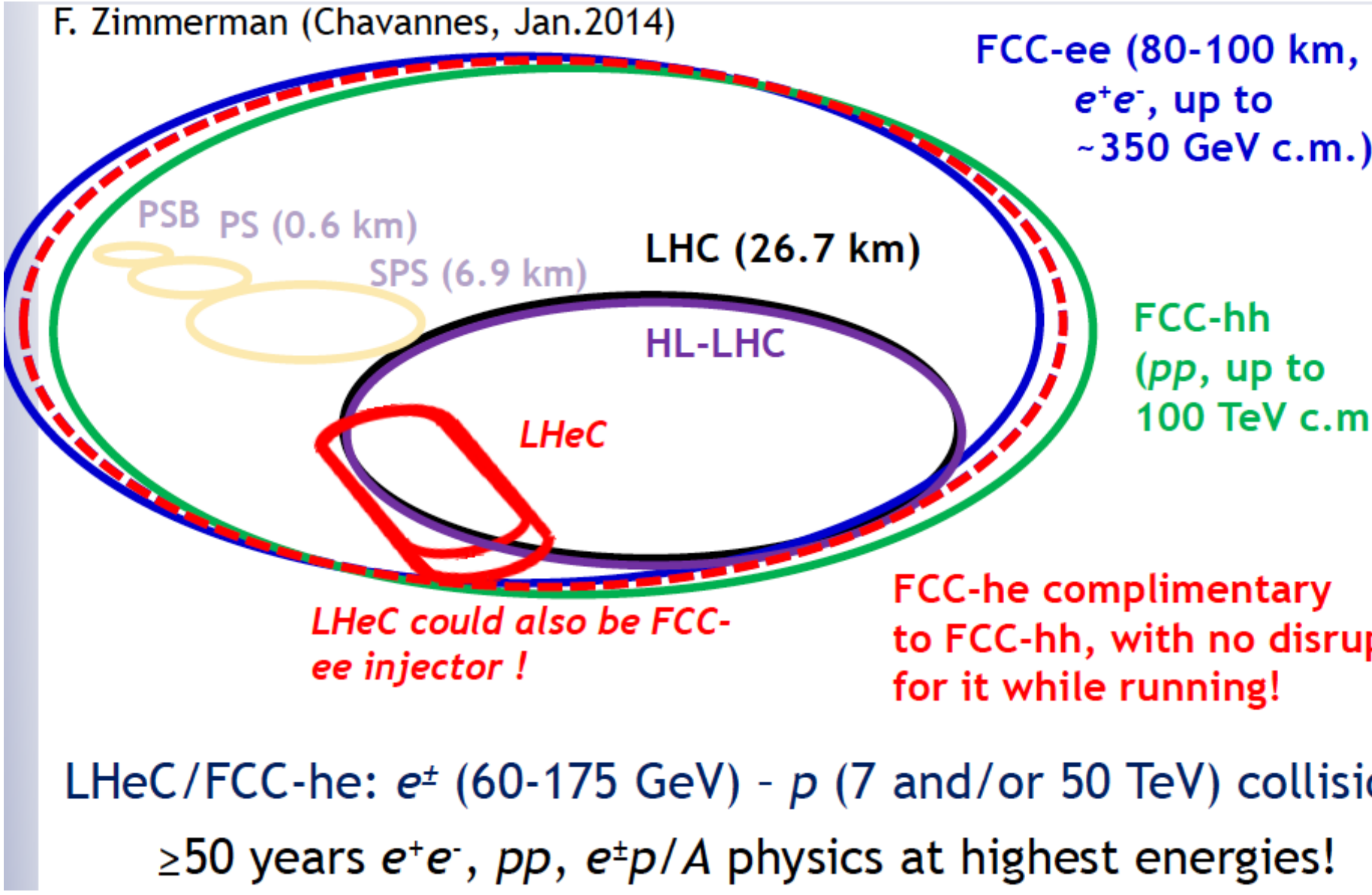
LHeC: Linac-Ring option



Post CDR ← CDR

10^{34} cm^{-2} s^{-1} Luminosity reach	PROTONS	ELECTRONS	PROTONS	ELECTRONS
Beam Energy [GeV]	7000	60	7000	60
Luminosity [10^{33}cm^{-2}s^{-1}]	16	16	1	1
Normalized emittance $\gamma\varepsilon_{x,y}$ [μm]	2.5	20	3.75	50
Beta Funtion $\beta^*_{x,y}$ [m]	0.05	0.10	0.1	0.12
rms Beam size $\sigma^*_{x,y}$ [μm]	4	4	7	7
rms Beam divergence $\sigma'^*_{x,y}$ [μrad]	80	40	70	58
Beam Current [mA]	1112	25	430 (860)	6.6
Bunch Spacing [ns]	25	25	25 (50)	25 (50)
Bunch Population	$2.2*10^{11}$	$4*10^{9}$	$1.7*10^{11}$	$(1*10^{9})$ $2*10^{9}$
Bunch charge [nC]	35	0.64	27	(0.16) 0.32

The LHeC - FCC complex

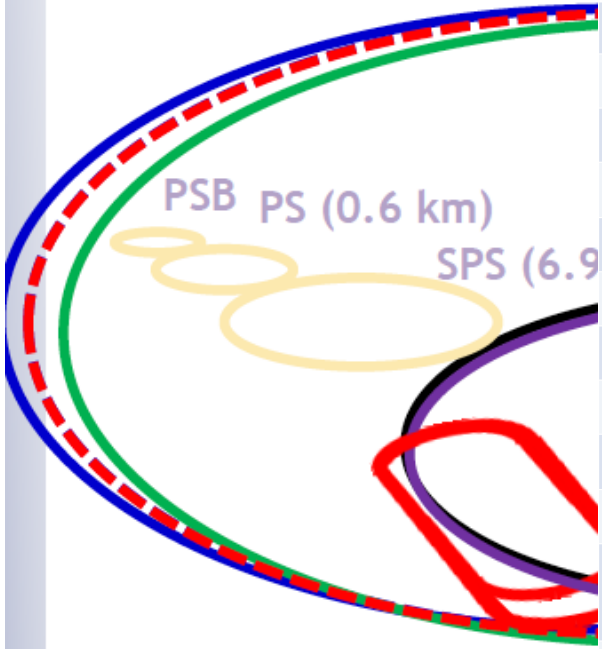


LHeC/FCC-he: $e^{\pm}$ (60-175 GeV) - p (7 and/or 50 TeV) collisi

≥50 years e^+e^-, pp, $e^{\pm}p/A$ physics at highest energies!

The FCC parameters

F. Zimmerman (Chavannes,



collider parameters	FCC ERL	FCC-ee ring		protons
species	e^- (e^+?)	$e^\pm$	$e^\pm$	p
beam energy [GeV]	60	60	120	50000
bunches / beam	-	10600	1360	10600
bunch intensity [10^{11}]	0.05	0.94	0.46	1.0
beam current [mA]	25.6	480	30	500
rms bunch length [cm]	0.02	0.15	0.12	8
rms emittance [nm]	0.17	1.9 (x)	0.94 (x)	0.04 [0.02 y]
$\beta_{x,y}$*[mm]	94	8, 4	17, 8.5	400 [200 y]
$\sigma_{x,y}$* [μm]	4.0	4.0, 2.0		equal
beam-b. parameter ξ	(D=2)	0.13	0.13	0.022 (0.0002)
hourglass reduction	0.92 (H_D=1.35)	~0.21	~0.39	
CM energy [TeV]	3.5	3.5	4.9	
luminosity[10^{34}cm^{-2}s^{-1}]	1.0	6.2	0.7	

F.Zimmermann ICHEP14, June

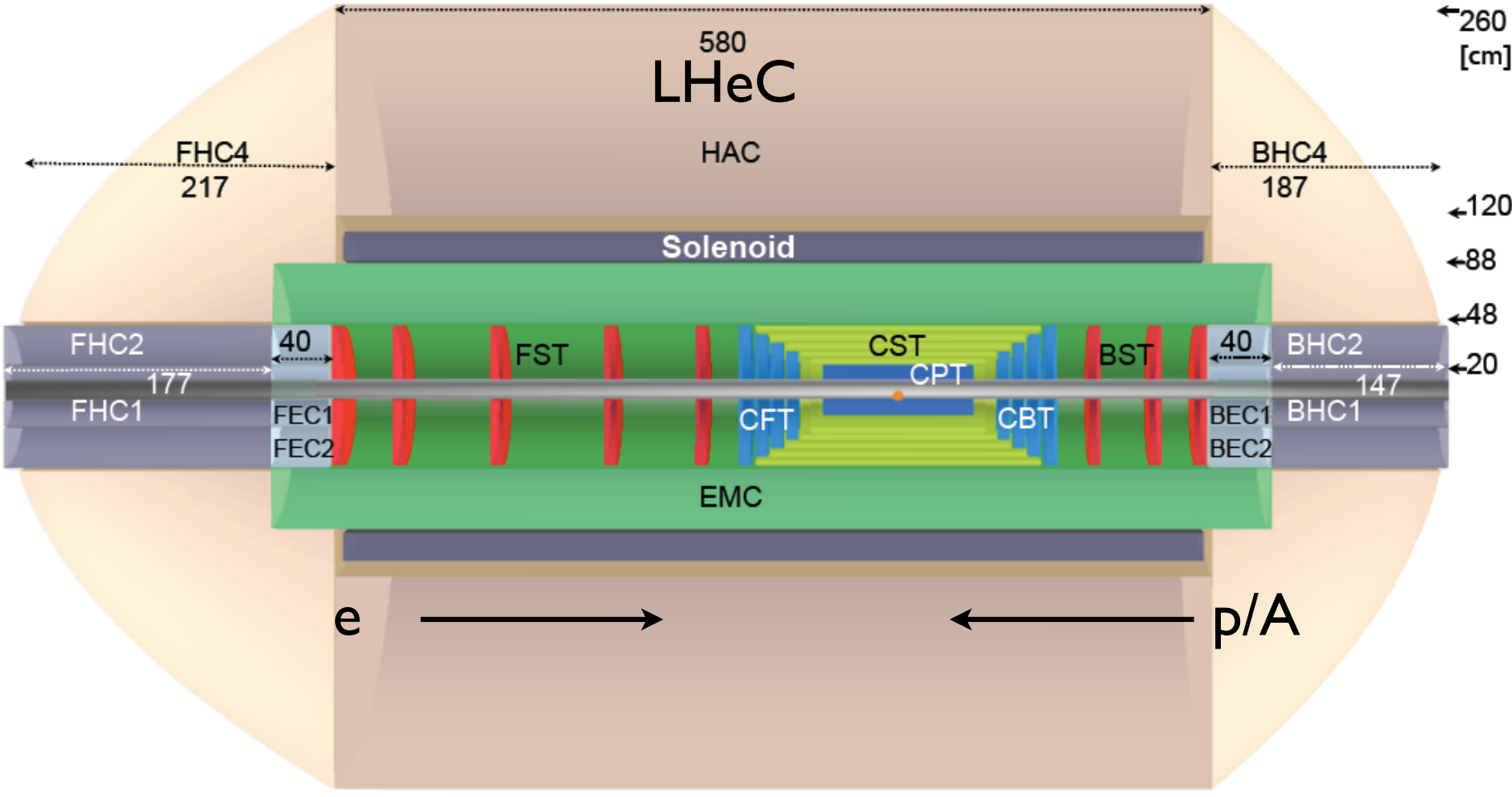
PRELIMINARY
L is 1000*HERA

LHeC could
ee injector

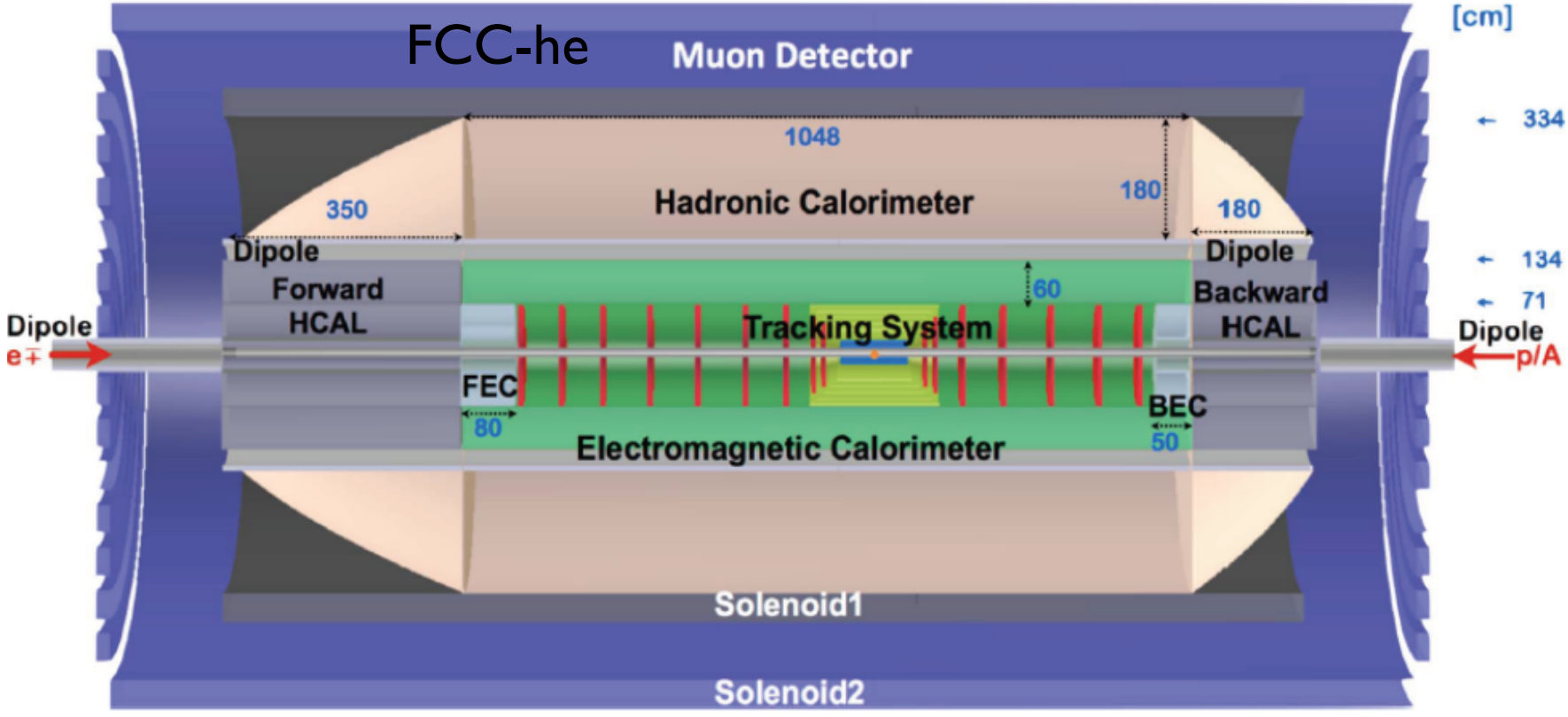
LHeC/FCC-he: $e^\pm$ (60-175 GeV) - p (7 and/or 50 TeV) collisions

$\geq$50 years e^+e^-, pp, $e^\pm p/A$ physics at highest energies!

The LHeC detector



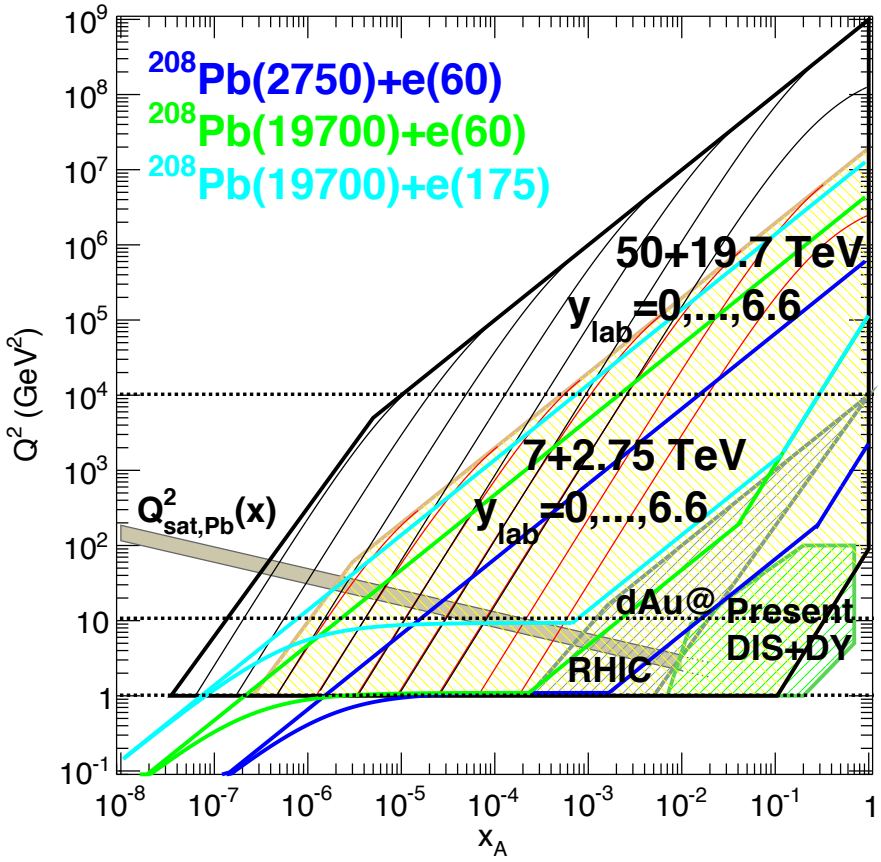
The FCC - he detector



Crab cavities for p instead of dipole magnet for e bend to ensure head on collisions
1000 H → μμ may call for better muon momentum measurement
H→ HH → 4b (and large/low x) call for large acceptance and optimum hadr. E resolution
Detector for FCC scales by about ln(50/7) ~2 in fwd, and ~1.3 in bwd direction

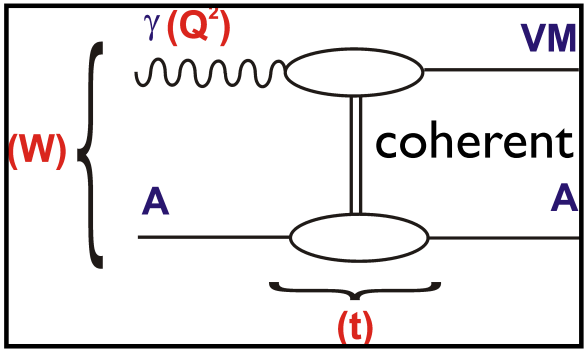
Kinematics:

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

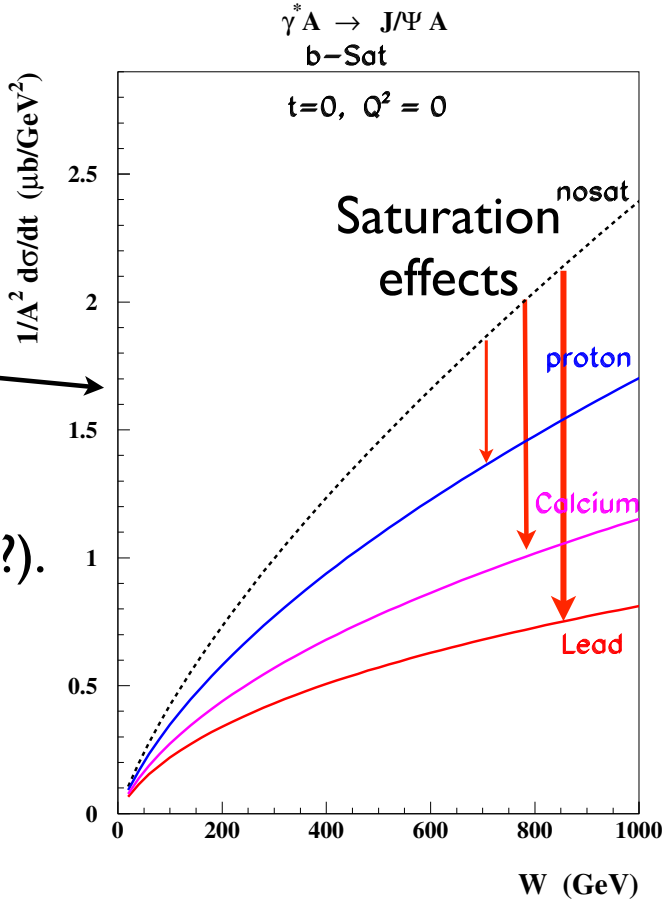


A physics case example

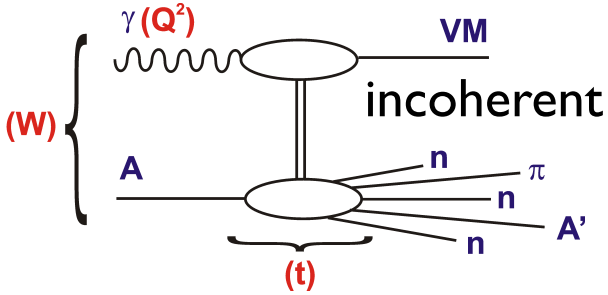
Elastic VM production in eA:



- For the coherent case, predictions available.



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



Conclusions

- **LHeC, FCC-he:** eA colliders in the TeV cms regime providing
  - ➜ Clean access to a large perturbative domain at small x: saturation?
  - ➜ Determination of nPDFs for nuclear colliders, with the possibility of releasing many of the current assumptions.
  - ➜ Studies of QCD radiation and hadronisation inside the nuclear medium.
  - ➜ Transverse scan of hadrons and nuclei: nGPDs.
  - ➜ Diffraction.
  - ➜ … with implications on our understanding of pA and AA collisions.

- **LHeC, FCC-he** (cern.ch/lhec)**:**
  - ➜ TDR for the next European Strategy for Particle Physics in 2017/2018.
  - ➜ Organisation: new IAC, new Coordination Group, several working groups, in the Study Group.
  - ➜ Updated physics summary to be produced for next June.
  - ➜ ERL Test Facility in CERN mid term plan since last June: LoI for end 2015.
  - ➜ Small-x/eA coordinators: NA, Paul Newman, Anna Stasto.
  - ➜ Regular workshops: 01/14, **24-26/06/15 Chavannes-de-Bogis**.

- **FCC week 2015**: Washington D.C., 23-27/03/2015, hh, ee, he.

Visit the web pages: everybody is more than welcome to join!!!