# A Detector(*) for the Large Hadron-electron Collider

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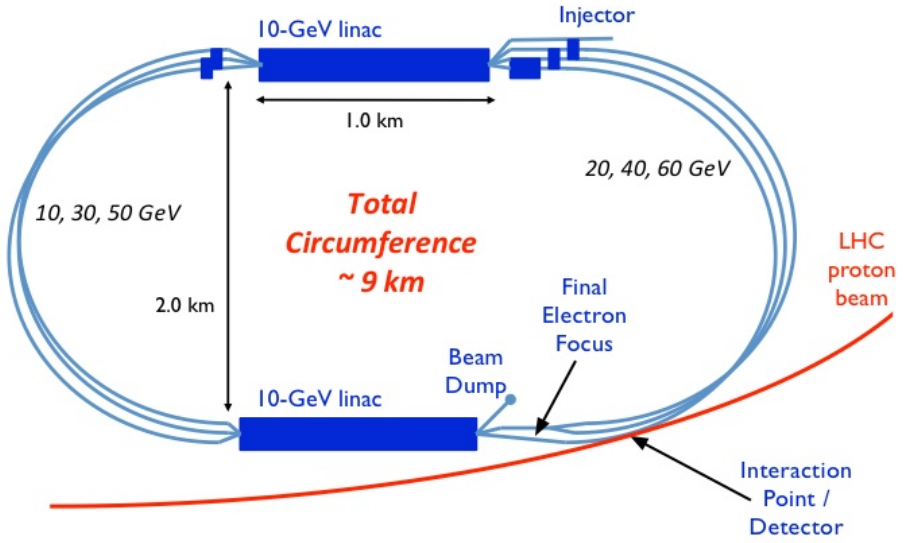
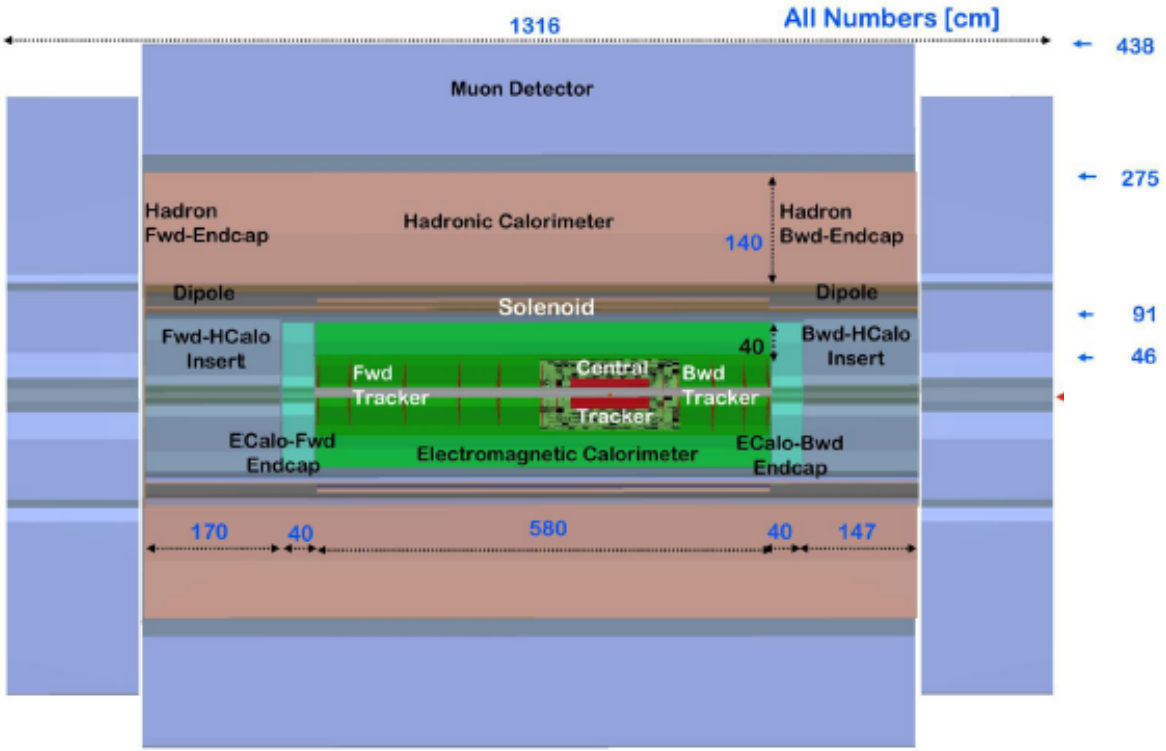
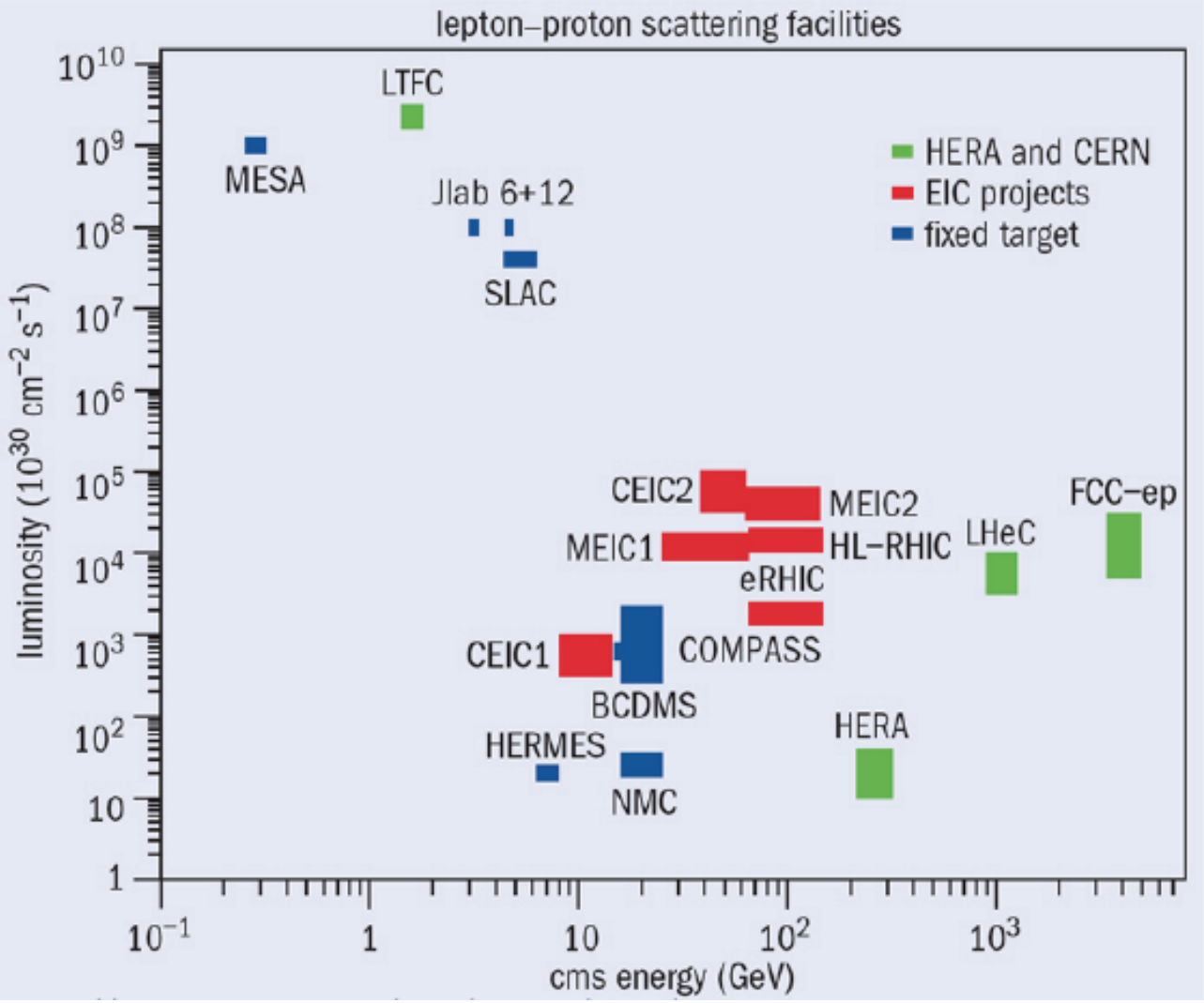



EPS 2015
Vienna
24 July 2015

(*) Current Baseline Linac-Ring Version

# LHeC / FCC-he Context



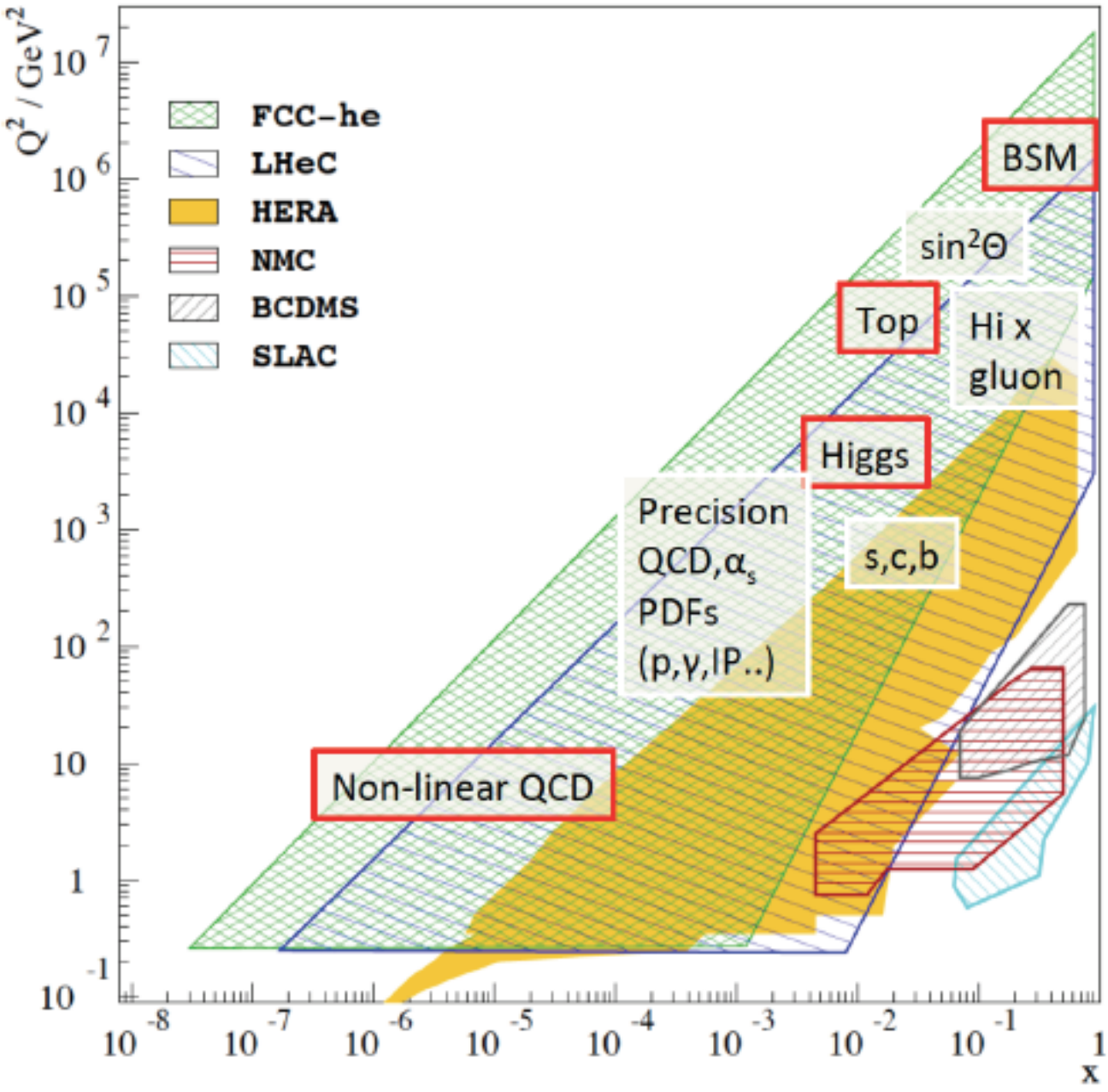

LHeC CDR, July 2012 [arXiv:1206.2913]

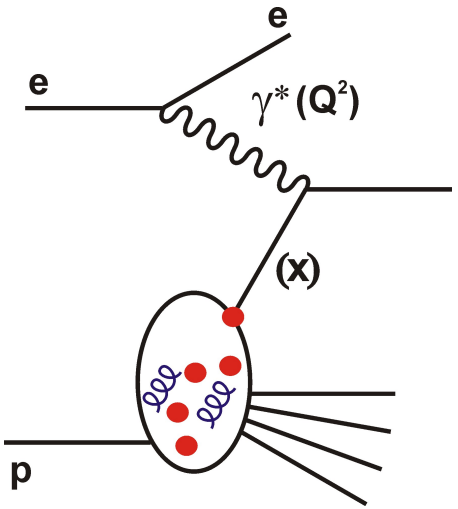
- **Lepton-hadron scattering at the TeV scale …**

**LHeC:** 60 GeV electrons x LHC protons & ions
→ $10^{34}$ cm$^{-2}$ s$^{-1}$
→ Simultaneous running with ATLAS / CMS sometime in HL-LHC period

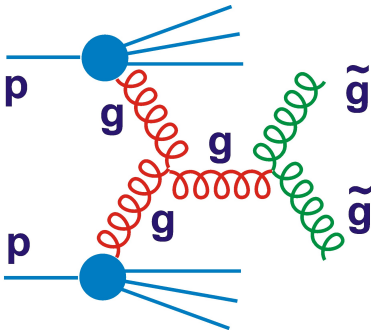
**FCC-he:** 60 GeV electrons x 50 TeV protons from FCC

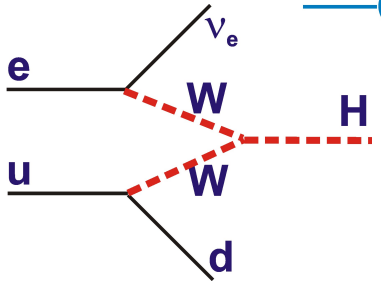
# Physics Overview



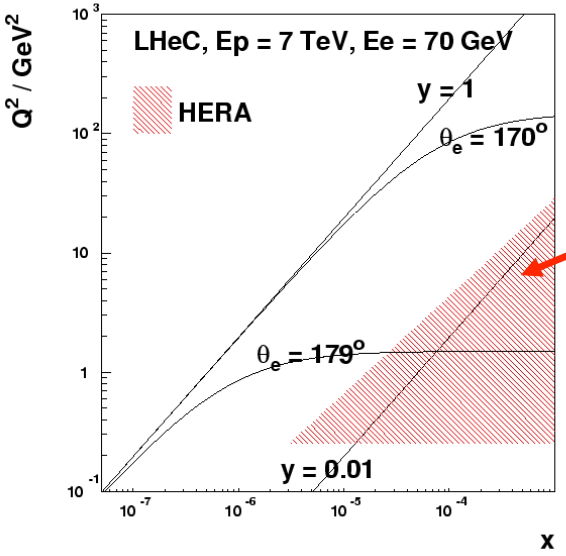

Diverse physics goals require precision throughout wide accessible kinematic region.

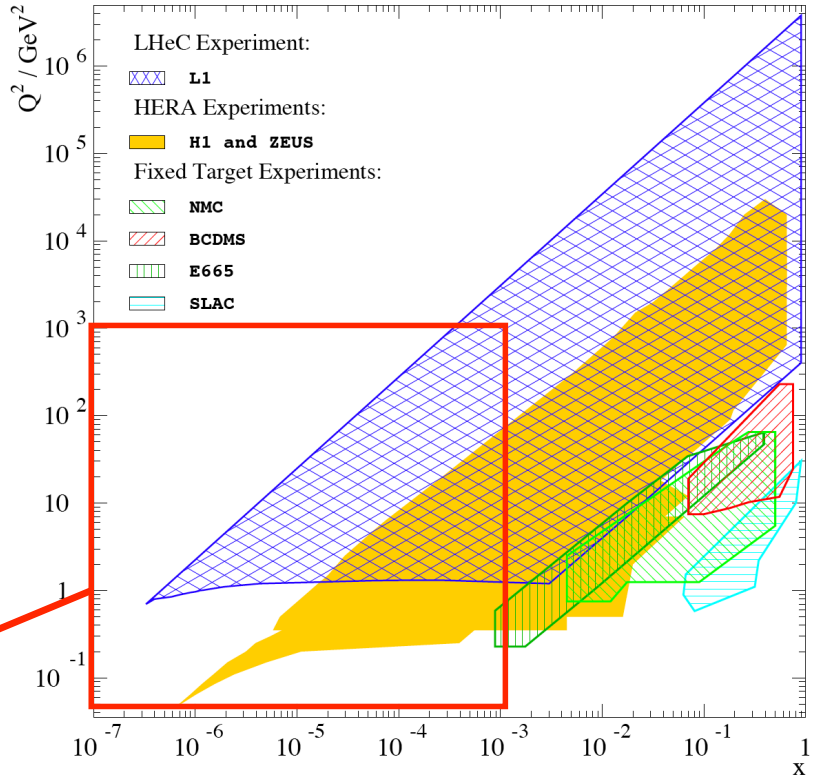


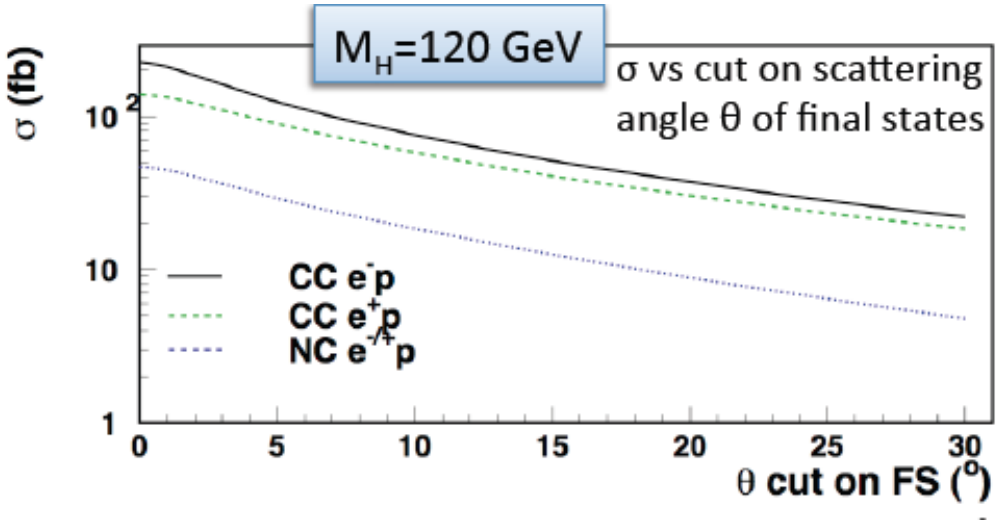



# LHeC Kinematic Detector Requirements

Access to $Q^2$=1 GeV$^2$ for all x > 5.10$^{-7}$ acceptance for electrons scattered through as little as 1$^o$

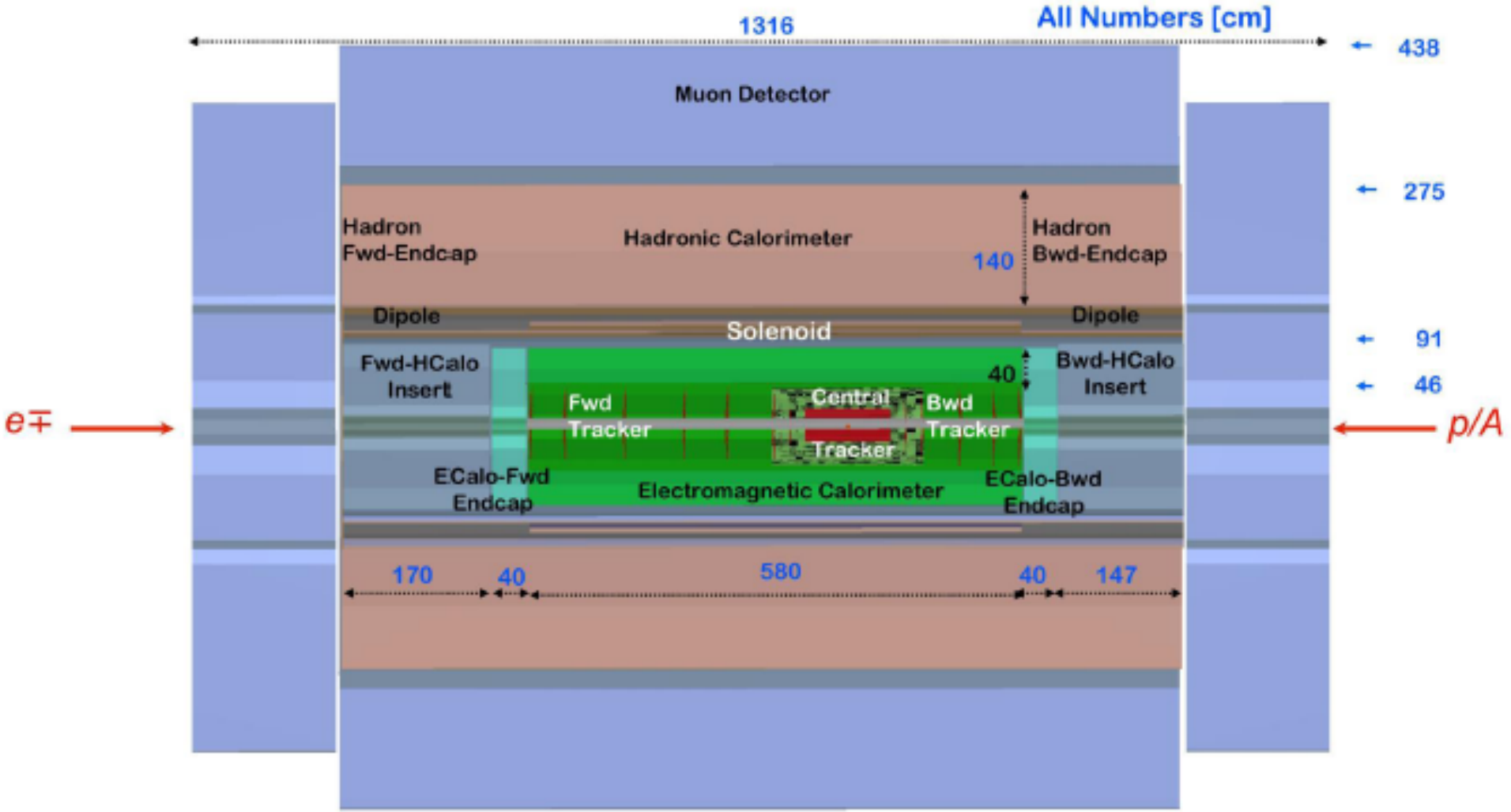


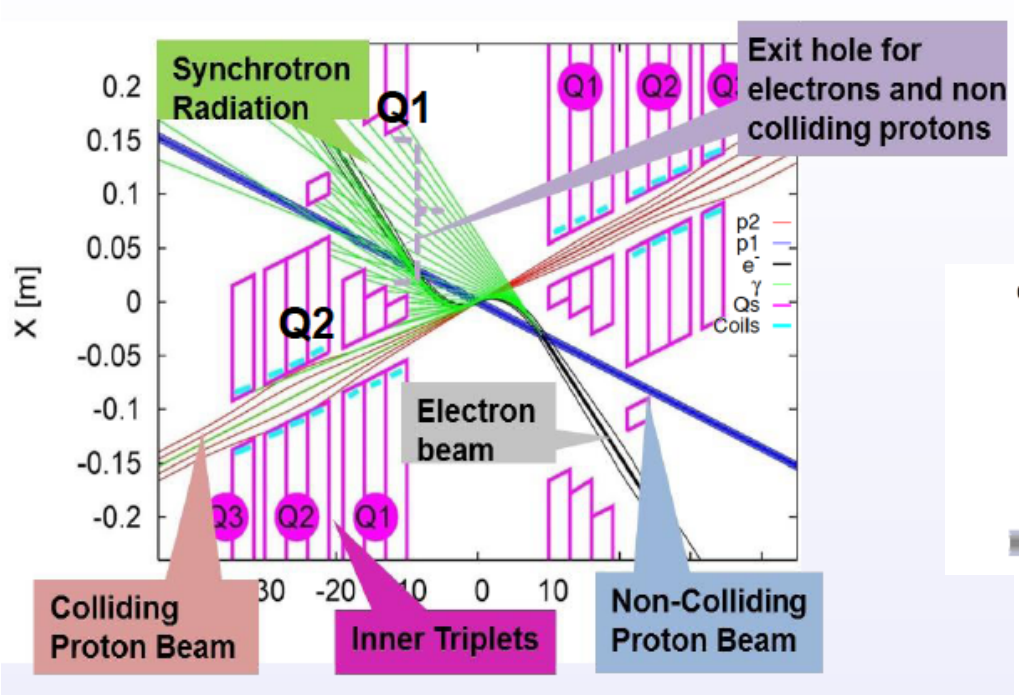

Also need 1$^o$ acceptance in outgoing proton direction to maximise acceptance for Higgs, sensitivity to high x signatures, and contain hadrons for kinematic reconstruction

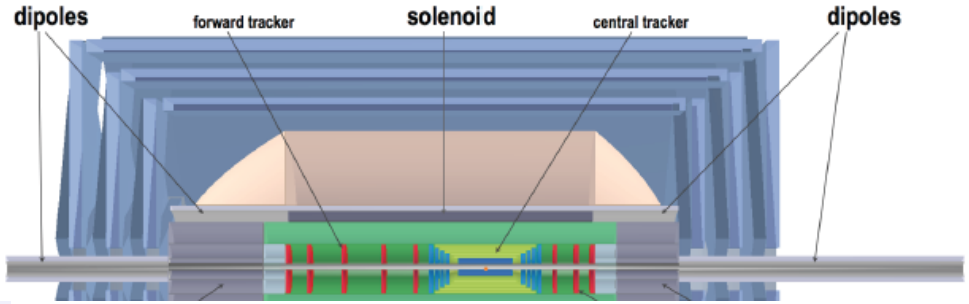
# Detector Design Overview



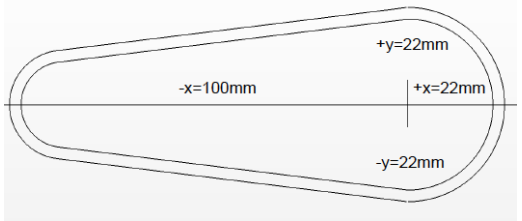

- Present size 13m x 9m (c.f. CMS 21m x 15m, ATLAS 45m x 25m)
- Forward / backward asymmetry reflecting beam energies
- Demanding tracking → high fraction of pixels, wide acceptance

# Interaction Region & Magnets

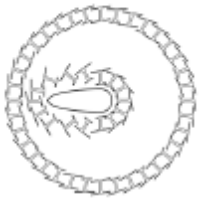



- Dual dipole magnets (0.15 – 0.3 T) throughout detector region (|z| < 14m) bend electrons into head-on collisions



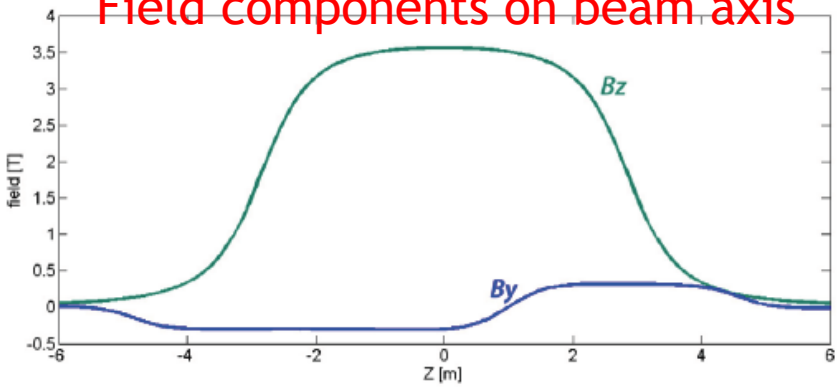




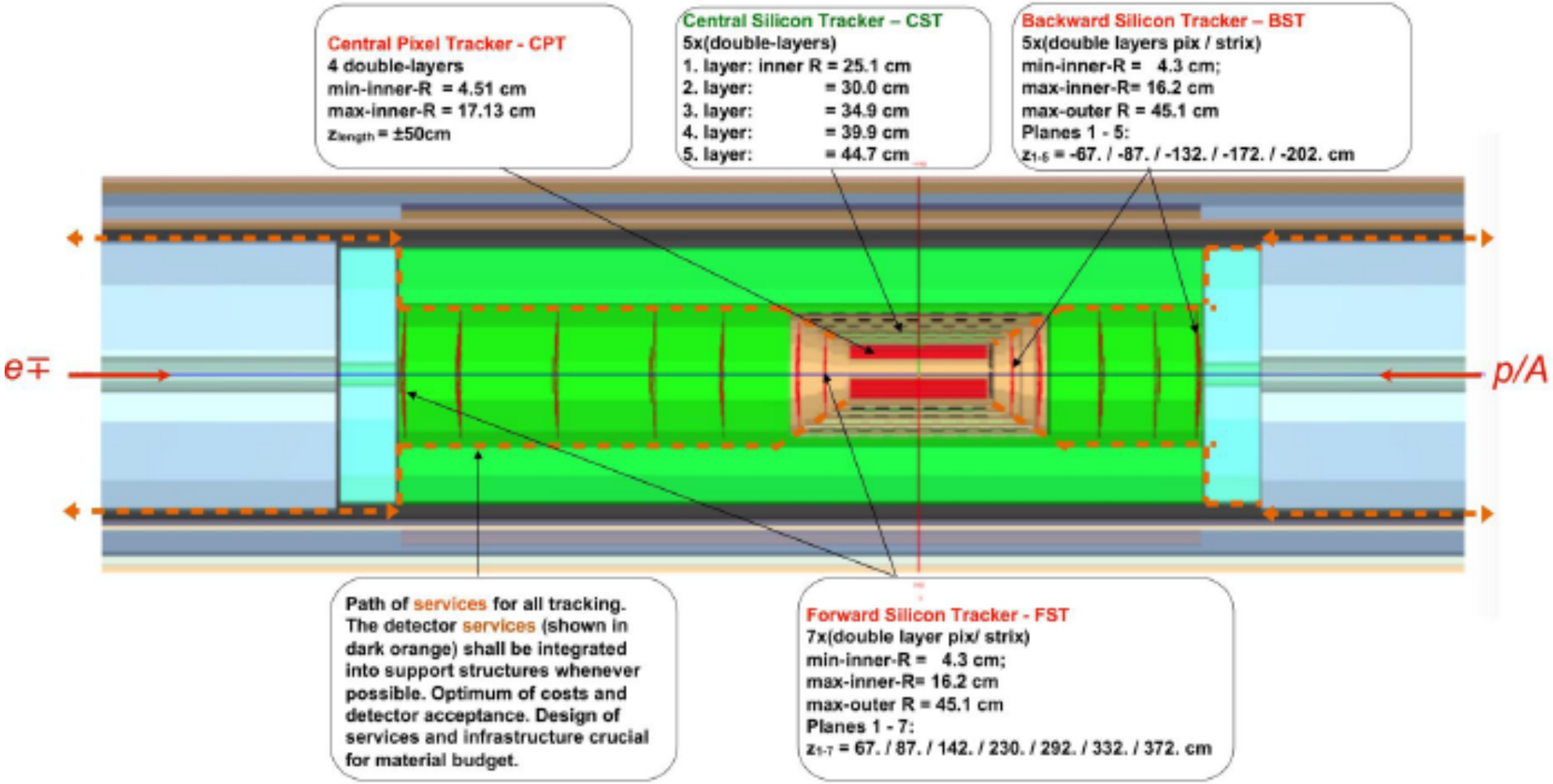
- Eliptical beampipe (6m x 3mm Be) accommodates synchrotron fan

- 3.5 T Superconducting NbTi/Cu Solenoid in 4.6K liquid helium cryo.

Field components on beam axis



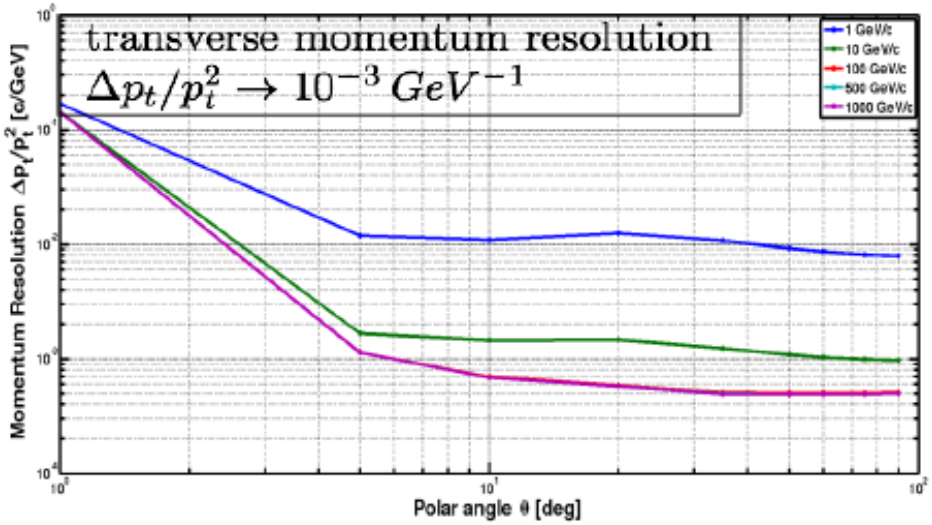
# Tracking Region

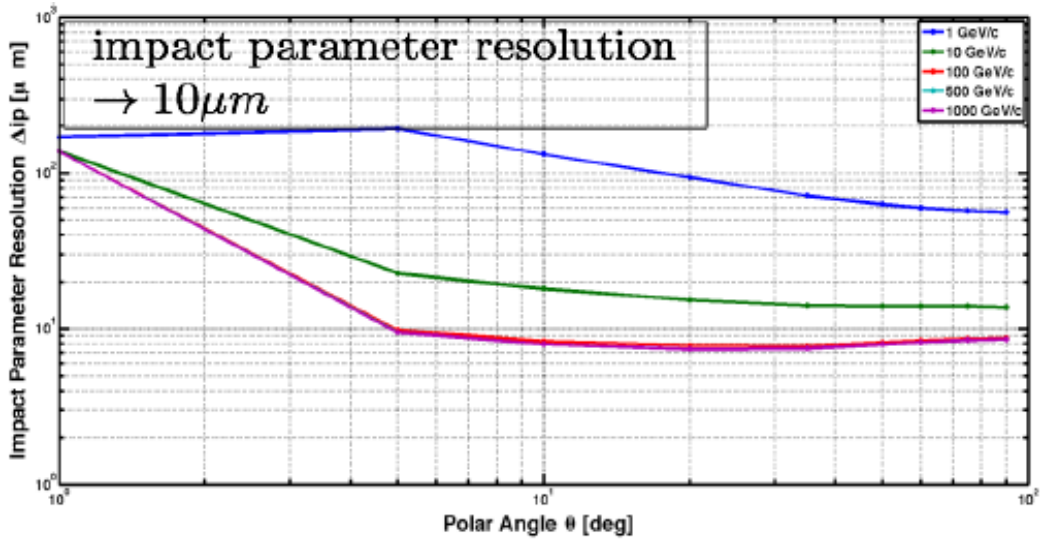



- Long tracking region → 1° electron hits 2 tracker planes
- Forward direction most demanding (dense, high energy jets)
- Pixels (CPT) + Strips; several technologies under discussion

# Tracking Simulation

Performance evaluated from basic layout (LicToy 2.0 program)



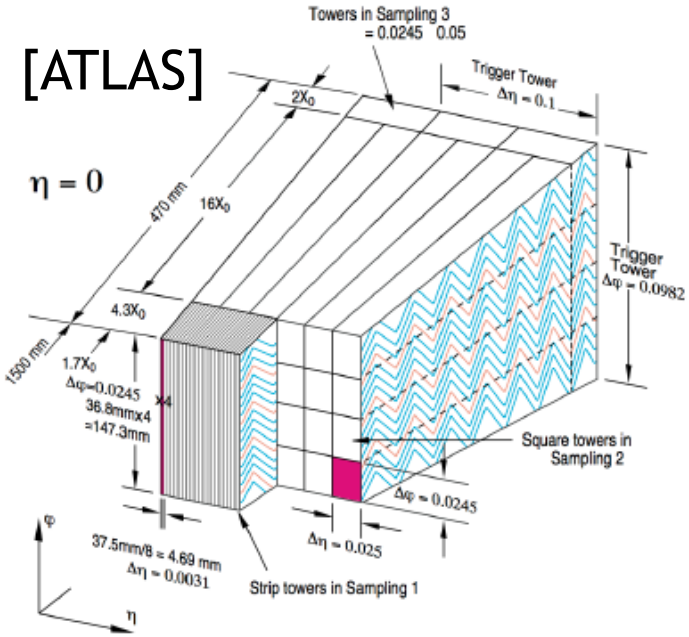

- Central tracks:
  - Excellent track resolution: $\Delta p_t/p^2_t \rightarrow 6.10^{-4}$ GeV$^{-1}$
  - Excellent impact parameter resolution: → 10μm

- Forward / Backward tracks:
  - Resolution degrades for θ <~ 5°
  - At 1°, bending field component = 0.36 T (similar to dipole)

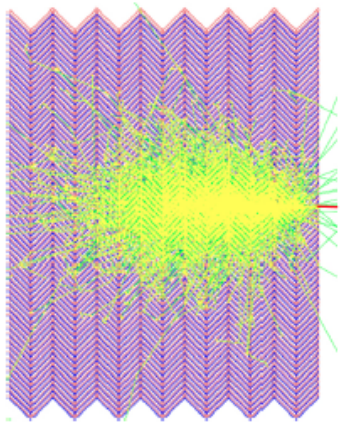
# Barrel EM Calorimeter

Liquid Argon Barrel EM Calorimeter
inside coil

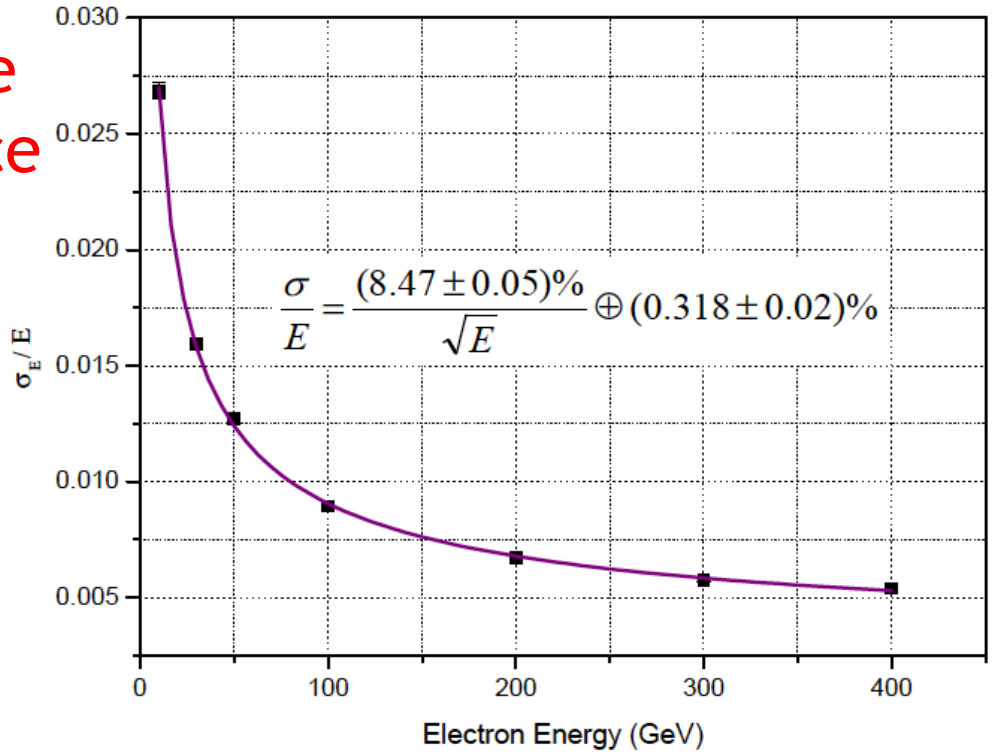
- $-2.3 < \eta < 2.8$
- Possibly accordion geometry
- 2.2mm lead + 3.8mm LAr layers
- Total depth ~ 20 $X_0$



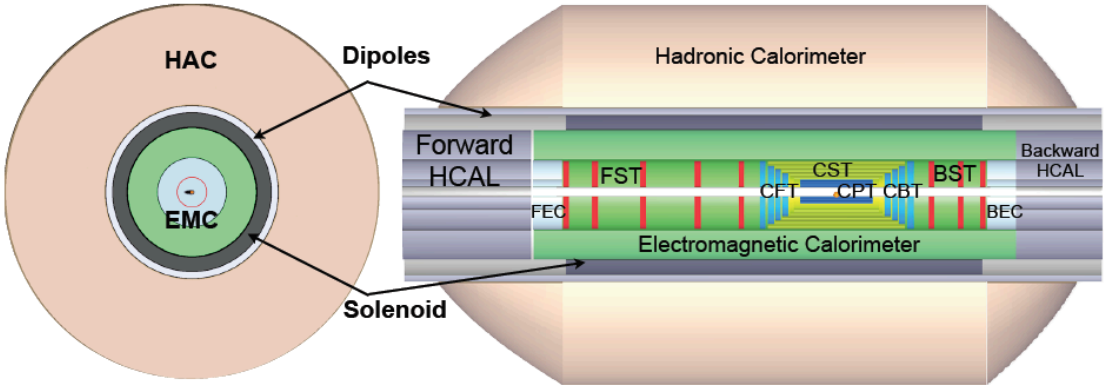

- Geant4 simulation of response to electrons at normal incidence [cf ATLAS: 10%/√E + 0.35%]



[20 GeV electron]



# Calorimeters Overview

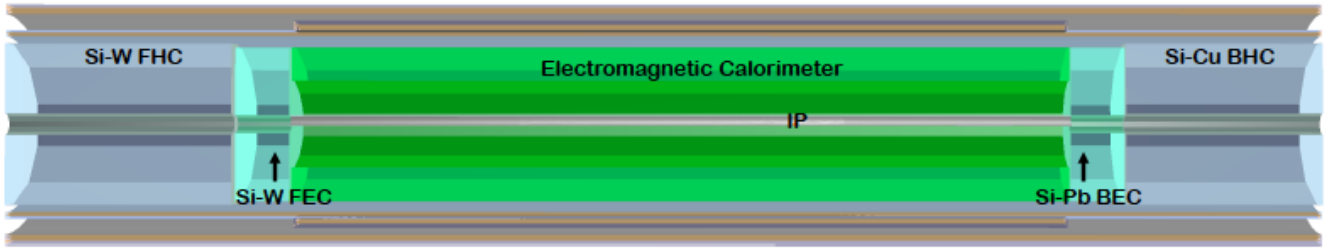



Current design based on (experience with) ATLAS (and H1), re-using existing technologies

- Barrel HAD calorimeter, outside coil
  → 4mm Steel + 3mm Scintilating Tile
  → 7-9 $\lambda$, $\sigma_E/E \sim 30\%/\sqrt{E} + 9\%$ [~ ATLAS]

- Forward end-cap silicon + tungsten, to cope with highest energies & multiplicities, radiation tolerant EM → $30X_0$, Had→$9\lambda$

- Backward end-cap
Pb+Si for EM ($25X_0$)
Cu+Si for HAD ($7\lambda$)

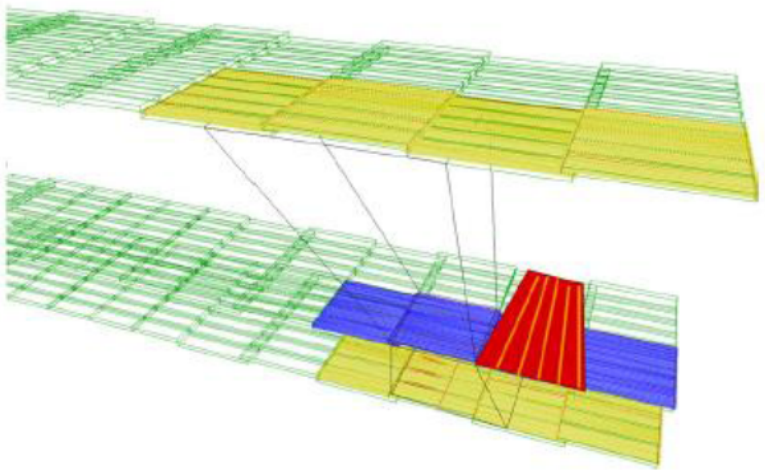


# Muon System

Baseline: Provides tagging, but not momentum measurement
: Angular coverage → 1° vital eg for e.g. elastic J/Ψ
: Technologies used in LHC GPDs and their upgrades
(more than) adequate

- 2 or 3 Superlayers

- Drift tubes / Cathode strip chambers → precision
- Resistive plate / Thin Gap chambers → trigger + 2nd coord]

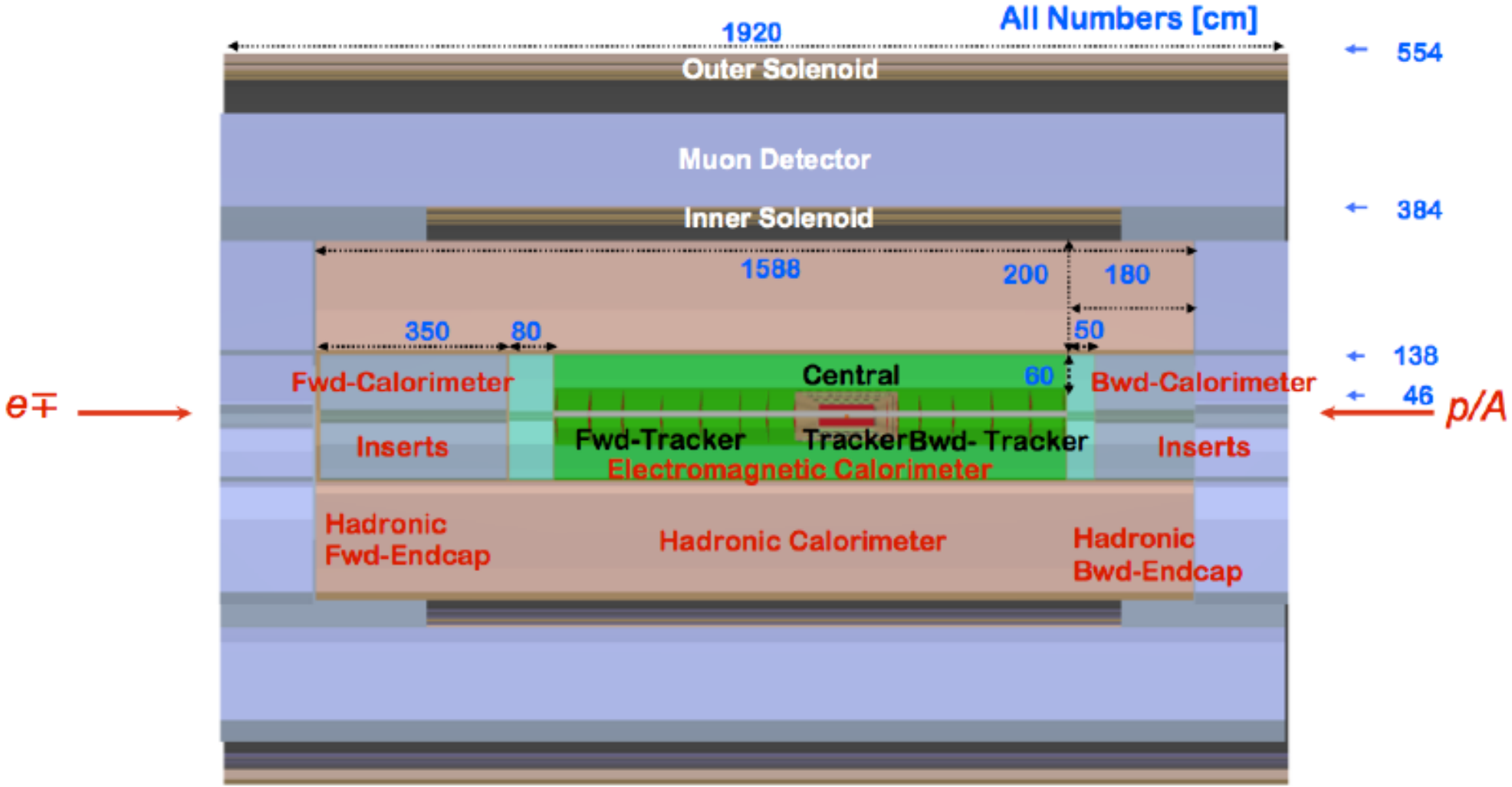


# Beamline Instrumentation


- Forward proton & neutron tagging

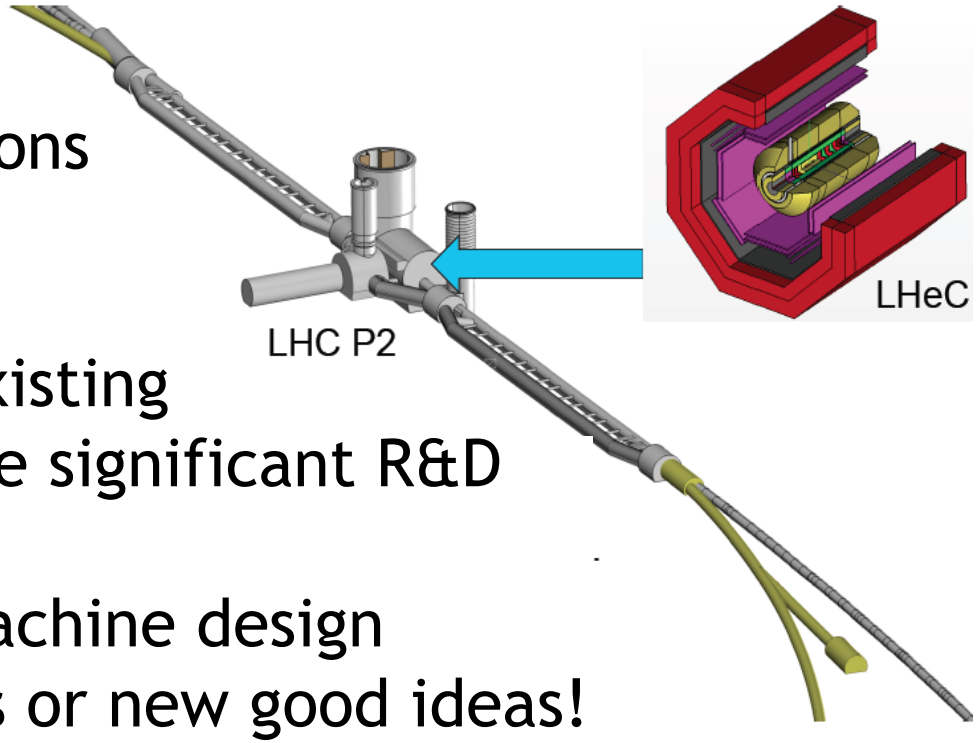
-Backward electron tagging & luminosity monitoring (ep→epγ)

# First Thoughts on FCC-he Detector




- Shower depths: dimension x ln(50/7)~2 fwd, ~1.3 bwd, central
- How to ensure head-on-collisions? [p Crab cavities? Dipoles?]
- Higgs physics → improved muon detectors, b tagging …

# Summary




- Possible LHeC detector solutions evaluated in some detail

- Ideas shown here based on existing technologies and do not require significant R&D

- May change in response to machine design development, physics demands or new good ideas!

- Full detector simulation under development using DD4HEP tool-kit → towards a Technical Design Report

• More, at LHeC web …

**lhec.web.cern.ch**

and …


- LHeC Study Group (CDR), J Phys G39 (2012) 075001
- Klein & Schopper, CERN Courier, June 2014
- Newman & Stasto, Nature Phys 9 (2013) 448
- Bruening & Klein, Mod Phys Lett A28 (2013) 1130011