Design of a New Detector for ep/eA Collisions

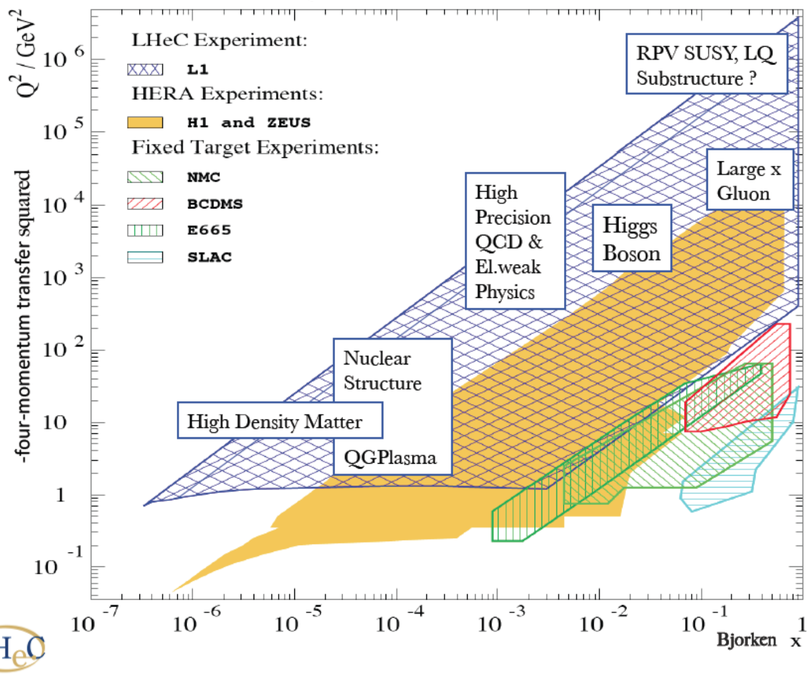
M. Klein (U. Liverpool and CERN), P. Kostka (U.Liverpool), A.Polini (INFN Bologna)
on behalf of the LHeC Collaboration

The Large Hadron electron Collider is a project for future ep and eA collisions from a new energy recovery linac of ~60 GeV energy and the LHC, and later the FCC. It needs a multi-purpose detector for pursuing a unique physics programme of deep inelastic scattering (DIS) with high precision over a hugely extended kinematic range wrt. HERA. This contribution summarises the current design concepts for a new detector of large polar angle coverage. For there is no pile-up and a more tolerant radiation environment, the LHeC detector may be based on currently available tracking and calorimeter technology, with special demands posed by the forward region. The experiment is designed for synchronous ep and pp operation and the interaction region therefore is for three beams, two of which are colliding. With a luminosity close to 10^{34} cm^{-2} s^{-1}, the LHeC, besides its genuine DIS program, also becomes a facility for precision Higgs physics and at the FCC-he a Higgs factory. The cms energy of the LHeC is ~1 TeV extended to ~4 TeV when a ~50 TeV proton beam becomes available for ep.

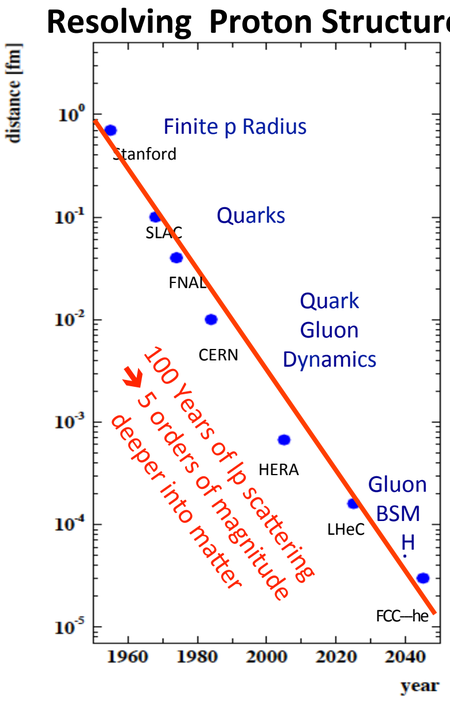
Physics Program

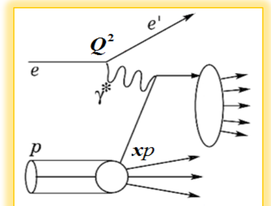
CDR, arXiv: 1211.4831 and 1211.5102 / http://lhec.web.cern.ch

LHeC x-Q² DIS Kinematic Plane



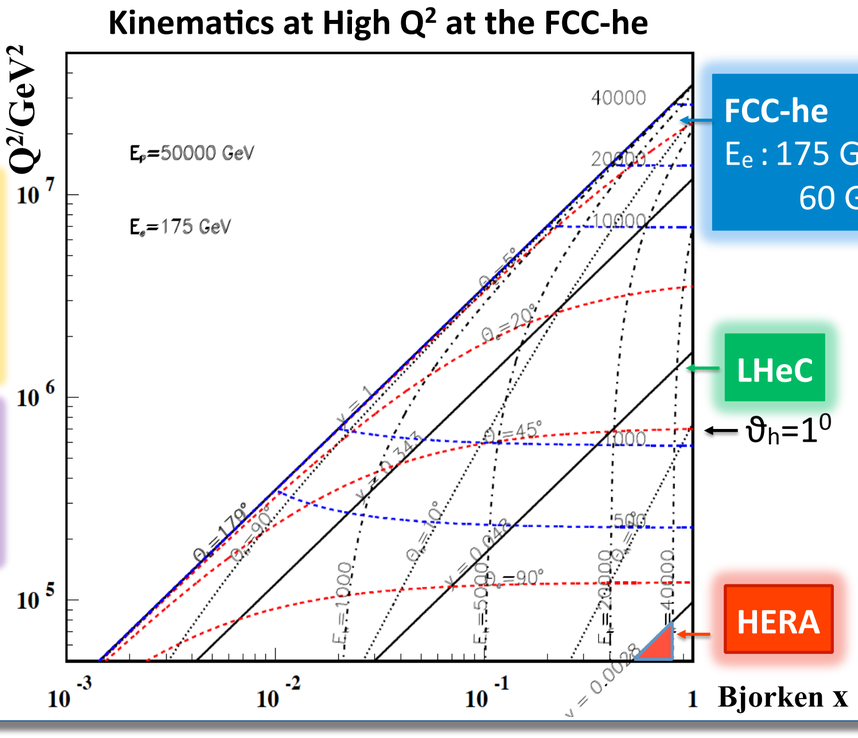
Resolving Proton Structure





HERA-LHeC-FCC-eh: finest microscopes with resolution increasing as $1/\sqrt{Q^2}$

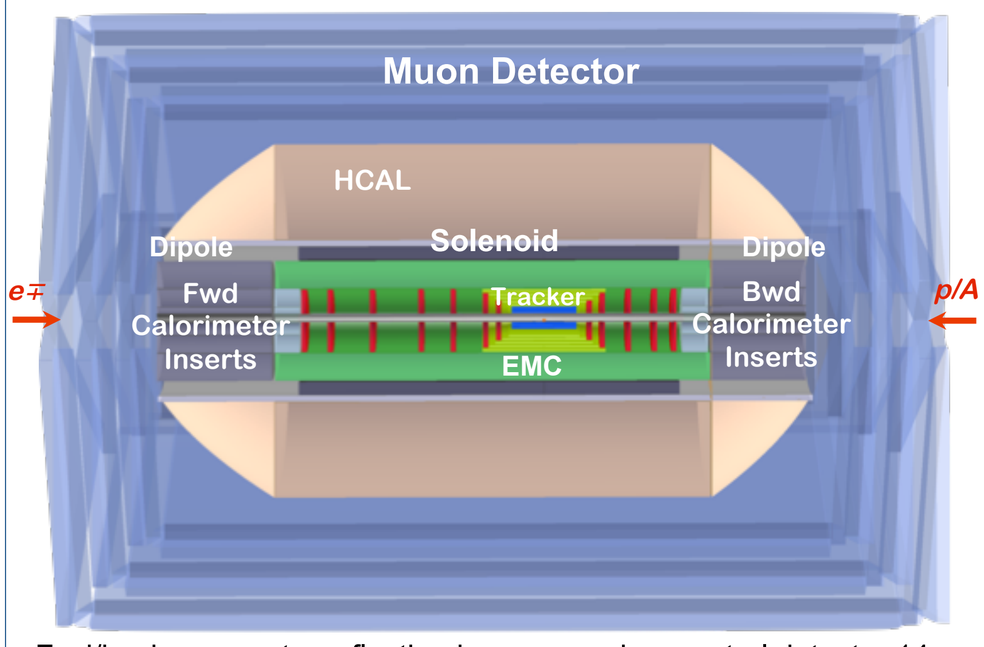
Kinematics at High Q² at the FCC-he



FCC-he
E_e : 175 GeV
60 GeV

LHeC - Detector Layout

- The **LHeC** Experiment (**Energy Recovery Linac+LHC**) is designed to run **simultaneously** with the **LHC**, requiring a **three beam IR** and compatible optics configuration
- Head-on collisions: synchrotron radiation fan from e± beam**, dipoles around the beam-pipe (±9m)** for avoiding a finite crossing angle to obtain maximum luminosity

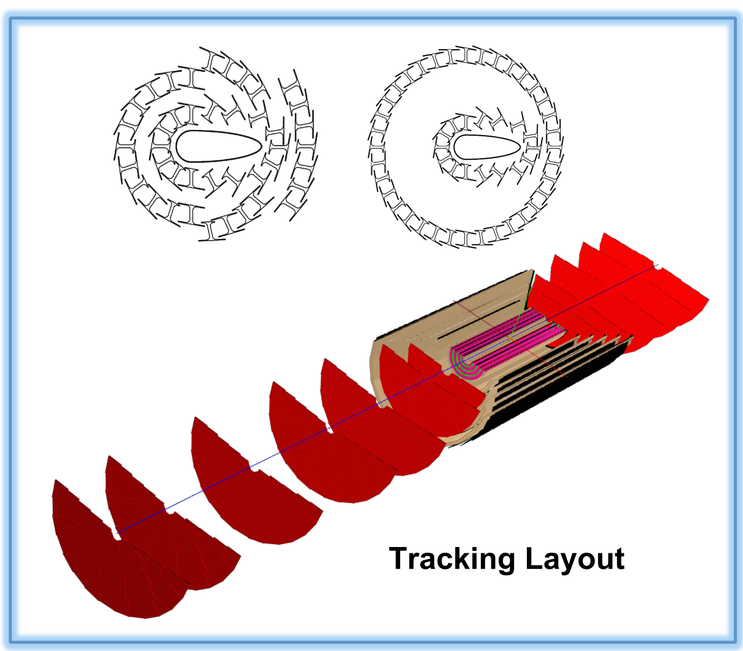


- Fwd/bwd asymmetry reflecting beam energies; central detector 14m x 9m

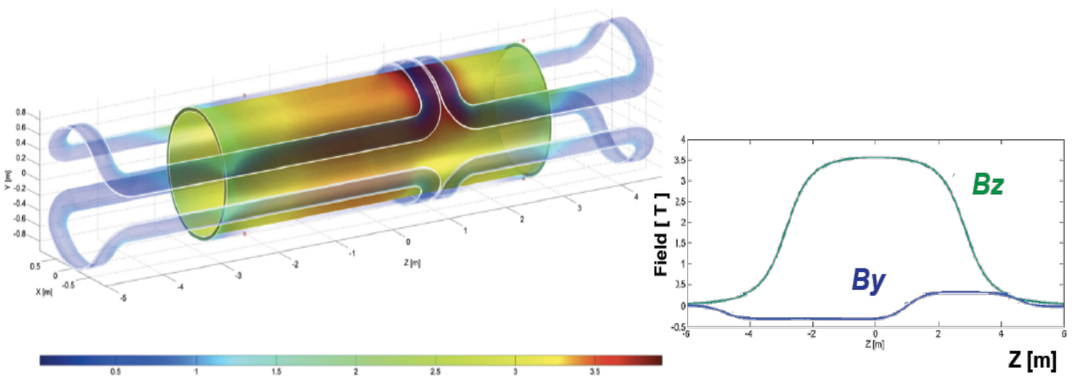
Beampipe:
- CDR: 6m length, Beryllium 2.5-3mm thickness
- Inner dimensions: circular(x)=2.2cm, elliptical(-x)=10cm & (y)=2.2cm
- composites also investigated

Silicon Track Detector Layout:
- Very compact design, contained within the EMC
- Large coverage in the proton direction: dense forward jet production (down to 1° in θ)
- Services and Infrastructure demand careful design as the main contributors to the Material Budget

Calorimetry:
- Hermetic EMC and HAC calorimetry surrounding the silicon tracking with appropriate thicknesses (X_0 and λ_i)
- Technology baseline in the Conceptual Design (CDR):
  - EMC: Liquid Argon Technology
  - HAC: Barrel Scintillator Tiles/Iron
- Fwd-Bwd Inserts (Silicon/Tungsten-Silicon/Copper)



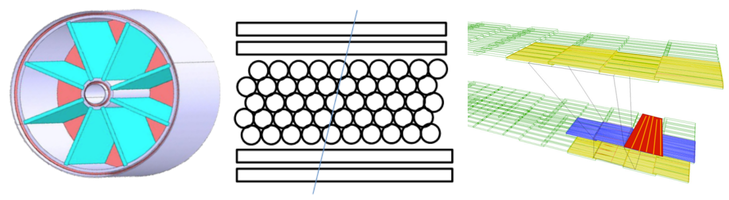
Magnet System



A superconducting coil between the barrel EMC and HCAL provides a field of 3.5 T. The solenoid and dipoles (~0.3T, required for steering of the electron beam) are placed within the same cold vacuum vessel.

Muons

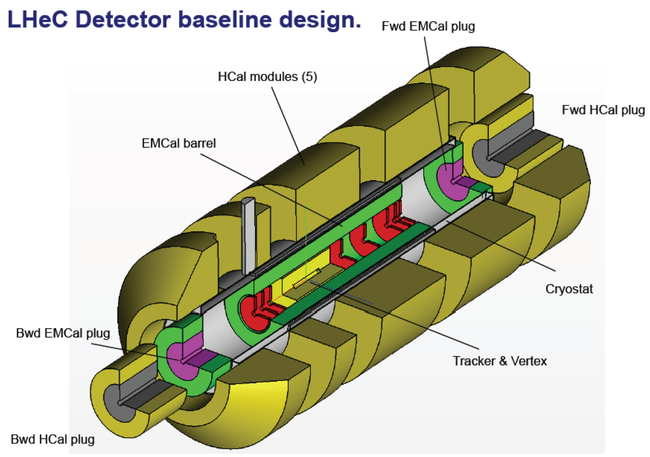
Muon system with 2-3 super-layers surrounding the central detector. Baseline: muon tagging, no independent momentum measurement and use of technologies as at LHC (and elsewhere).
Extensions possible: Independent momentum measurement: → larger solenoid or dual coil system with all of calorimeter within inner coil; in forward region: toroid (air core design)



Conclusions

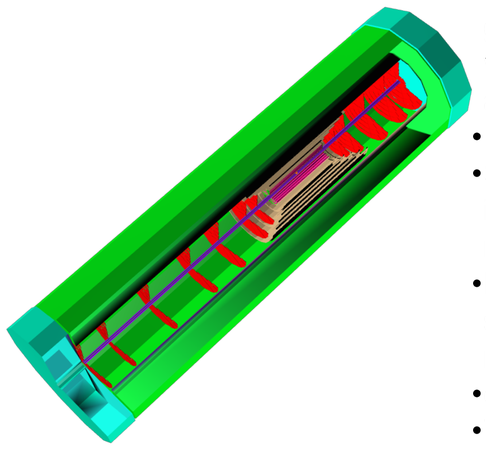
A high resolution, large acceptance detector is being designed for precision DIS physics in a kinematic range extending over six orders of magnitude in Q^2 and 1/x. With no pile-up and much less radiation compared to pp operation, the LHeC detector can be based on existing technology. Current work focusses on the software description of the design to support more refined studies as on the Higgs or top physics. This design may be scaled to the FCC-he kinematics, roughly by extending the forward dimensions by a factor of ln(50/7) ~2 while keeping the backward region as it is determined by the electron beam energy. The rare H→μμ decay is an example of new processes, accessible at the FCC-he, leading to new detector considerations such as on the muon momentum measurement.

On–site Installation



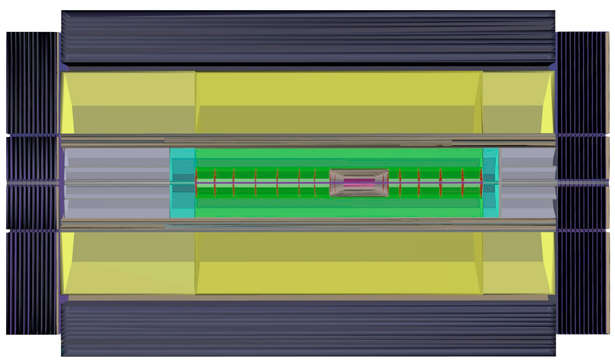
Installation study: Modularity and pre-mounting on the surface to be compliant with LHC shutdown durations.

Detector Description - DD4hep



http://aidasoft.web.cern.ch/DD4hep

- Full detector description; geometry, materials, visualisation, readout, alignment, calibration etc.
- Full experiment life cycle
- Single source of detector information, simulation, reconstruction, analysis
- **LHeC** and **FCC-he** same software; but different geometry, materials etc.
- **$e^{\mp}p/e^{\mp}A$ simulation**
- The LHeC/FCC-he detectors are being described using **DD4hep**



DD4hep sketch of the FCC-he detector design
Central detector dimensions: ~ 21m x 12m