The ep/eA study at the LHC and FCC – new impactful goals for the community

WG4

2023 | WS | 2024 | WS | 2025 | TWS | *input to ESPP*

proton and nuclear structure from EIC and HERA to LHeC and FCC-eh
novel QCD with high-energy DIS physics: what do we discover when breaking protons and nuclear matter in smaller pieces

general-purpose high-energy physics programme: precision physics and searches
enabling direct discoveries and measurements in EW, Higgs and top physics with high-energy DIS collisions

ep-physics empowering pp/pA/AA-physics (LHC and FCC)
improving the ATLAS, CMS, LHCb and ALICE discovery potential with results from a high-energy DIS physics programme

developing a general-purpose ep/eA detector for LHeC and FCC-eh
critical detector R&D (DRD collaborations), integrate in the FCC framework, one detector for joint ep/pp/eA/pA/AA physics

developing a sustainable LHeC and FCC-eh collider programme
design the interaction region, power and cost, coherent collider parameters & run plan, beam optimization, …

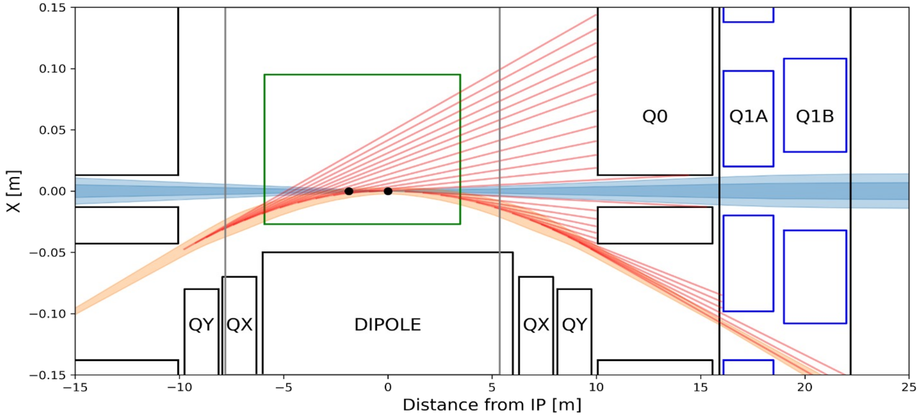
- typically 2-3 conveners per theme
- annual ep/eA workshops (**WS**)
- final thematic workshop with closing reports to inform the upcoming Strategy process with impactful information (**TWS**)
- inform the community with regular ep/eA Newsletters
- everybody is welcome to join

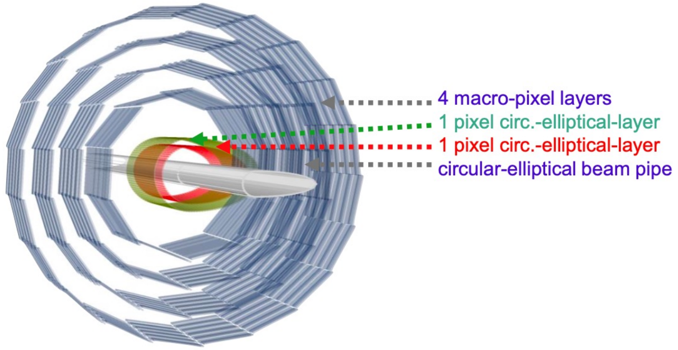
Coordination Panel: N. Armesto, M. Boonekamp, O. Brüning, D. Britzger, J. D'Hondt (spokesperson), M. D'Onofrio, C. Gwenlan, U. Klein, P. Newman, Y. Papaphilippou, C. Schwanenberger, Y. Yamazaki

Developing a general-purpose ep/eA detector – Some Challenges and Impact

Need to simultaneously optimise to

- Functionality as a GPD (Higgs, top, BSM …) → Collider Detector
- DIS-specific needs (Precision PDFs, low x QCD …) → Scattering Exp't





… A high-performance detector for next-generation highest energy, highest luminosity ep/eA collisions in a harsh synchrotron radiation environment

… A combined ep / eA (and perhaps pp / pA / AA) collider detector (for the first time ever)

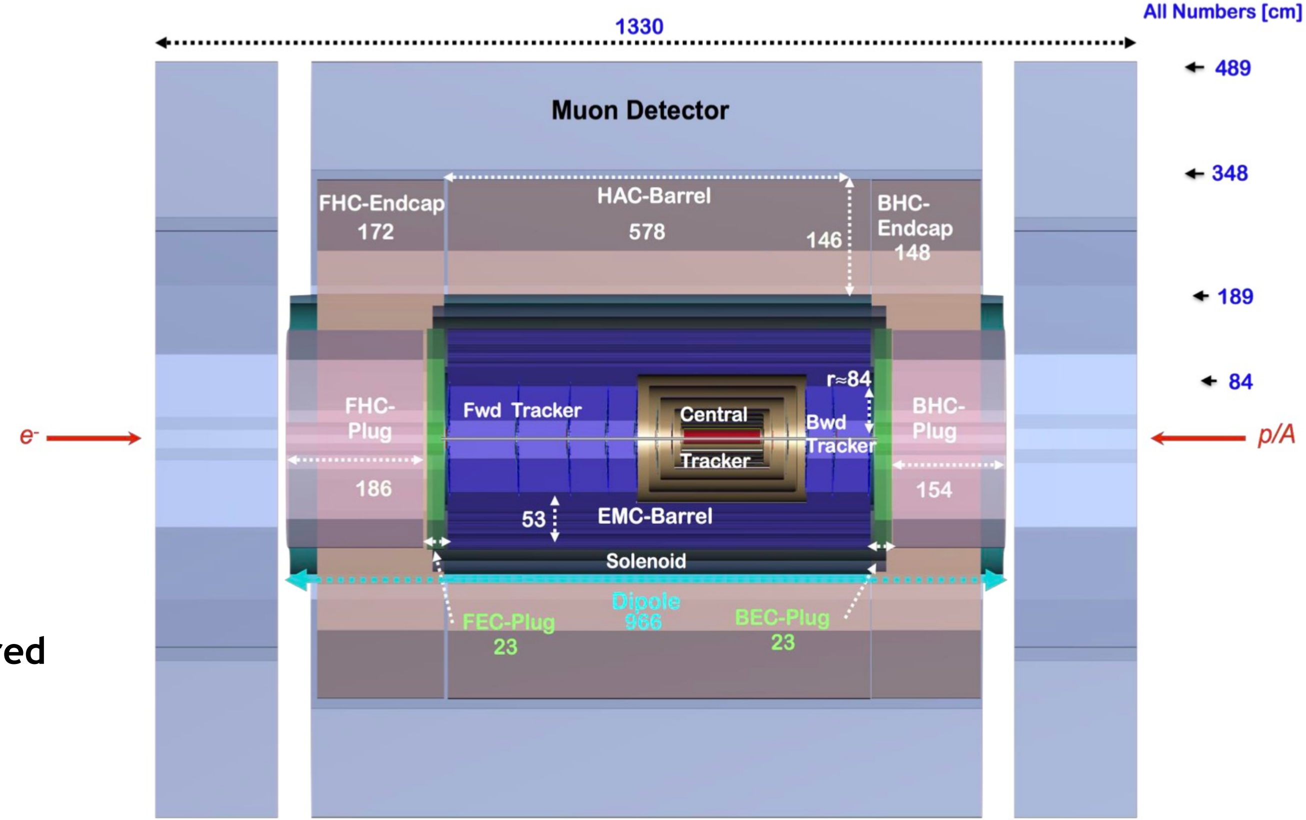
Detector design from Conceptual Design Report Update (2020)

Compact
- 13m x 9m
(c.f. CMS 21m x 15m,
ATLAS 45m x 25m)

Hermetic
- 1° tracking acceptance forward & backward.
- Beamline instrumentation incorporated from outset

Modular

Conditions are relatively 'easy'
→ Tiny fluences compared with HL-LHC
→ Pile-up ~ 0.1



A snapshot in time - not particularly well integrated or optimised. Many open questions

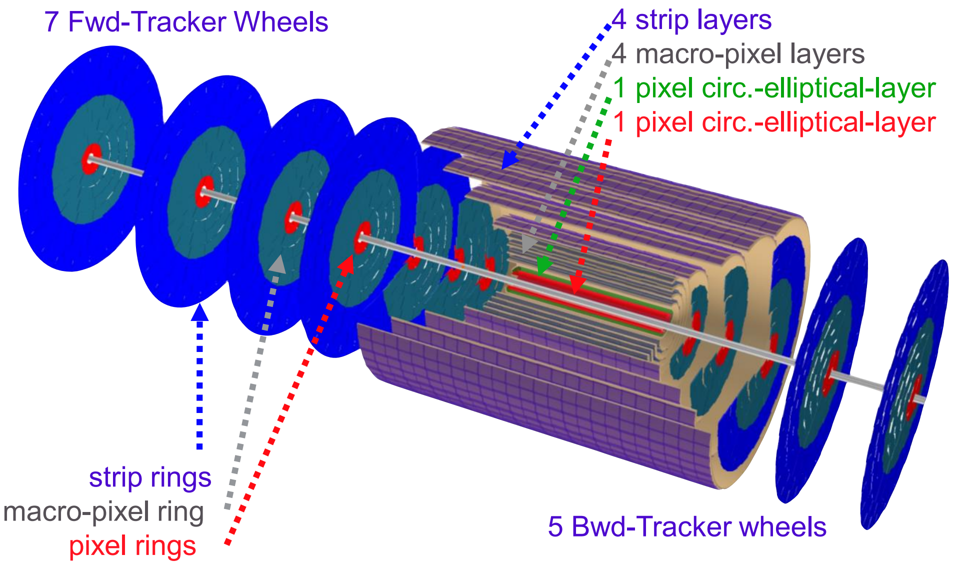
Detector design from Conceptual Design Report Update (2020) - Tracking

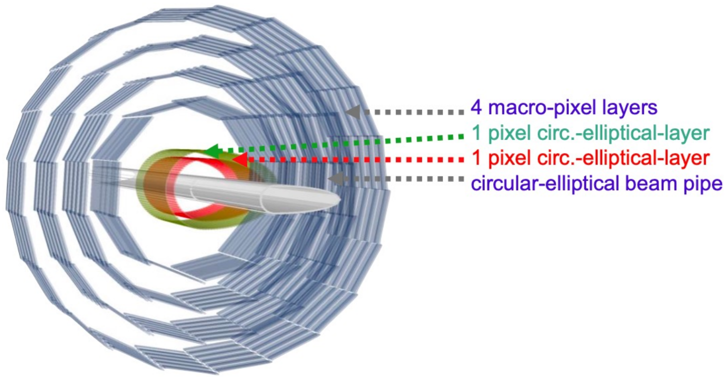
- All silicon tracker

- HV-CMOS MAPS technology is low material (0.1mm) and cost-effective

- Bent / stitched wafers for inner layers (as ALICE and ePIC)

- Semi-elliptical inner layers





Pitch (μm)	$r\phi$	z
pixel	25	50
macro pixel	100	400
strip	100	10-50mm

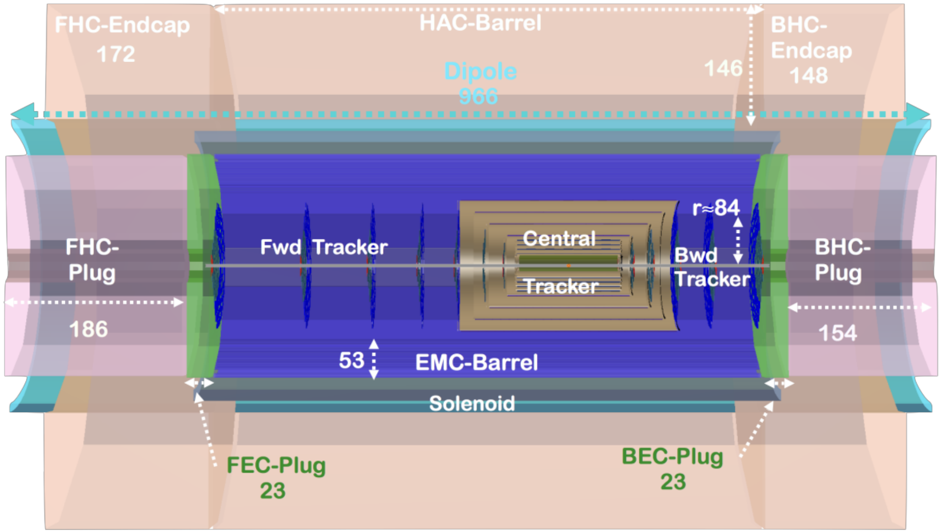
Detector design from Conceptual Design Report Update (2020) - Calorimeters

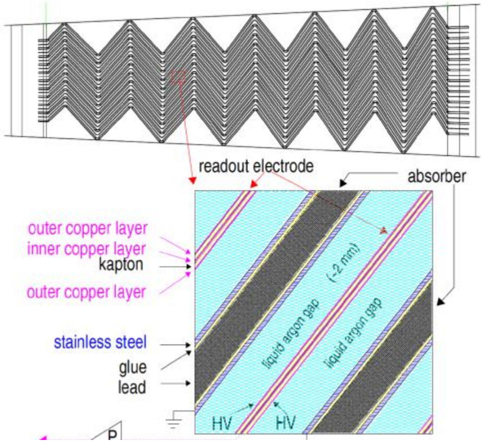
- ‘Accordion’ geometry LAr EM Barrel ($|\eta|<2.8$), inside solenoid / dipole

- Plastic-scintillator HCAL for e/h separation

- Finely segmented plugs (W, Pb, Cu) for compact showering, with Si sensors

- 25-50 X_0 and ~10λ throughout



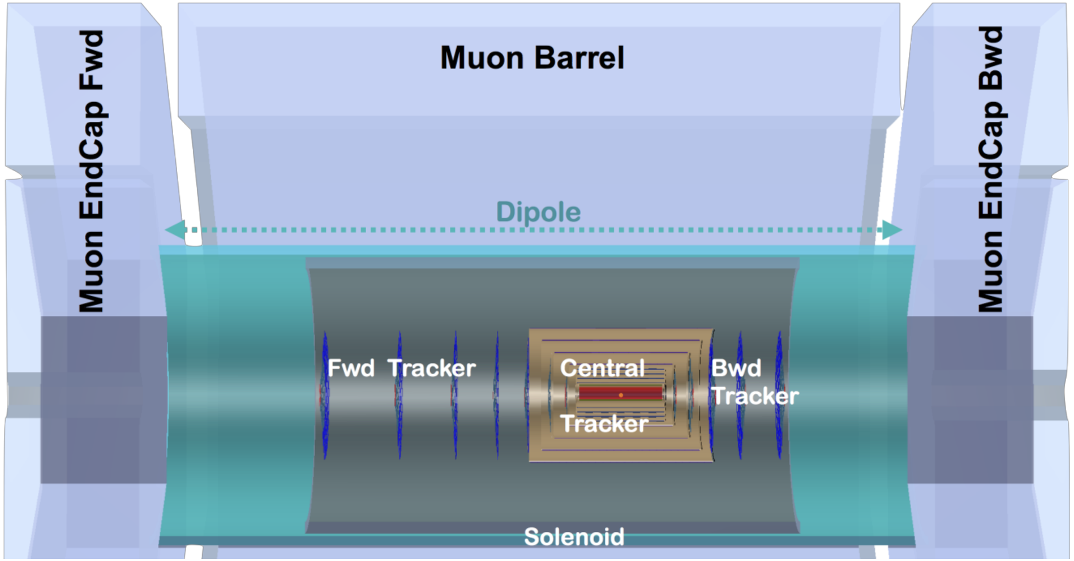


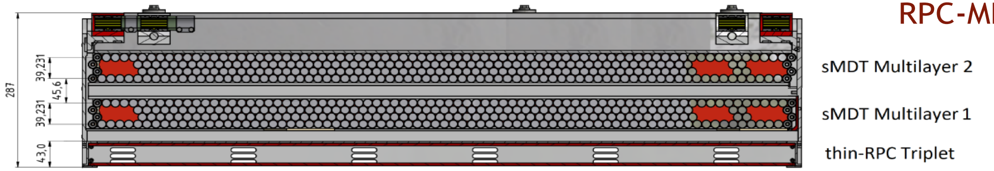
Baseline configuration		η coverage	angular coverage
EM barrel + small η endcap	LAr	$-2.3 < \eta < 2.8$	$6.6° - 168.9°$
Had barrel+Ecap	Sci-Fe	(~ behind EM barrel)	
EM+Had very forward	Si-W	$2.8 < \eta < 5.5$	$0.48° -$
EM+Had very backward	Si-Pb	$-2.3 < \eta < -4.8$	$-179.1°$

Detector design from Conceptual Design Report Update (2020) - Muons

No dedicated outer magnetic field in current design
→ Momentum measurement in central tracker.
→ Outer muon detectors for tagging / triggering

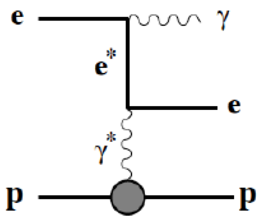
Borrowing HL-LHC technologies
→ Multiple layers of thin RPCs (1mm gas gap) for fast response
→ Small (1.5cm diameter) MDTs for spatial precision

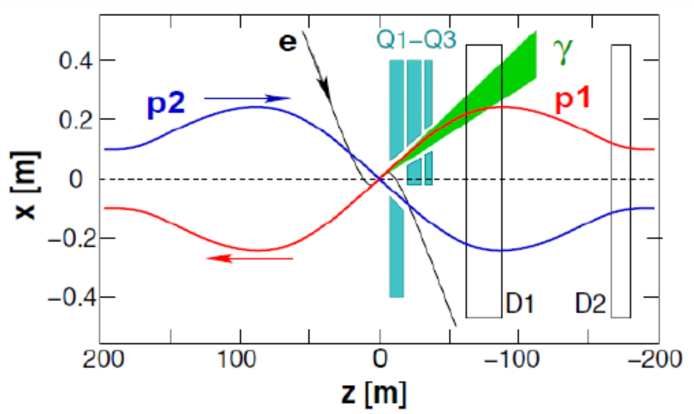




ATLAS Phase-I RPC-MDT assembly

Detector design from Conceptual Design Report Update (2020) - Beamline





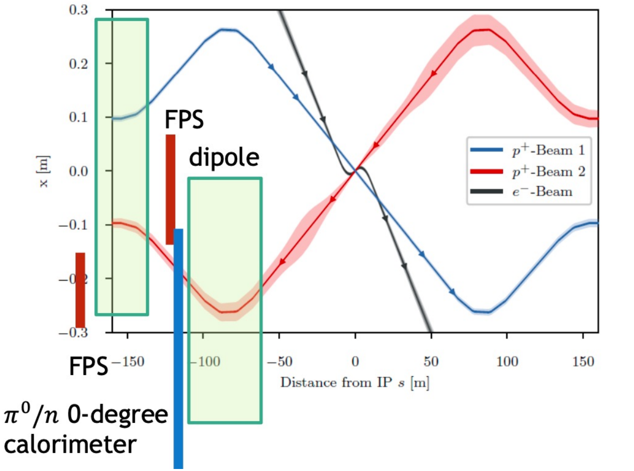
Outgoing electron direction

→ photoproduction e-taggers 14-62m
→ photon detector at around 120m for lumi measurement via Bethe-Heitler

Outgoing proton direction

→ Roman pot-based FPS around 200m (as per ATLAS/CMS)
→ Also (for higher ξ) around 120m
→ Possibility of covering lower x from FP420 design

→ Si-W Zero Degree Calorimeter around 110m
(could have highly segmented design like ALICE FoCAL)



Developing a general-purpose ep/eA detector – Future tasks

Tasks include both consolidation of existing design and 'from scratch' addition of new aspects / capabilities

- **Optimising the technology and layout of detectors near beamline**
  - Inner tracker technology and layout to understand fluences and place sensors very close to the beam line
  - Development of Forward / Backward instrumentation fully integrated with the Interaction Region design
- **Adding Particle ID capabilities (Cerenkov, TOF)**
  - Investigation of possible addition of Cerenkov-based detectors or AC-LGAD timing layers
  - Exploring the instrumentation needed to connect with SIDIS studies at EIC and physics in AA
- **Developing a Trigger / DAQ scheme**
  - Understanding the physics and background rates
  - Obtaining a (triggered or streaming) concept for data acquisition
- **Review aspects of the detector 'inherited' from ATLAS?**
  - Are calorimeter and muon designs really ideal for use in ep / eA? → Optimisation or complete redesign?
- **LHeC versus FCC-eh**
  - Implications of higher energies … 'same again only bigger', or can we be smarter?
- **A joint detector eh and hh detector?**
  - What are technical challenges in simultaneously serving the needs of e-h and h-h studies
  - What are the opportunities from a joint detector for cross-calibration and systematics reduction

Developing a general-purpose ep/eA detector – Methodology & Connections

- Overall design and simulation code development for detailed investigations of detector response

- Detailed synchrotron radiation simulations

- Particle ID studies

    Physics simulations to understand target momentum range for LHeC and FCC-eh

    Investigating 'space' compromises with respect to other detector components

    Investigation (and possibly R&D) on candidate technologies

→ Connecting to ongoing DRD R&D collaborations in moving towards basic technology decision-points:

    Radiation tolerant tracking and beam-line instrumentation

    Calorimetry, Muon, DAQ options …

→ Connecting to EIC community to share knowledge, particularly on beam-line instrumentation and PID

→ Connecting to LHC hh community: explore minimal changes for an hh detector to also perform for eh

Developing a general-purpose ep/eA detector – Organisation and Practical aspects

WG convenors: Paul Newman (Birmingham, p.r.newman@bham.ac.uk)
: Yuji Yamazaki (Kobe, yamazaki@phys.sci.kobe-u.ac.jp)

Please do get in touch with ideas / suggestions / interest to take on tasks

Self-subscribe to the WG mailing list: ep-eA-WG4-structure@cern.ch.

Anyone with a CERN account or a light account can register to this email list (as well as sign out). Subscribe/unsubscribe to the list via: https://e-groups.cern.ch/ (use the search option, and search for "ep-eA-WG" in all e-groups).

WG indico page: https://indico.cern.ch/category/17308/.

Meeting schedule to be confirmed soon

Towards a transformed and transformational design for the next European Strategy exercise and beyond