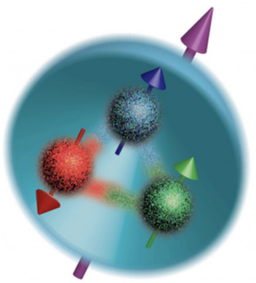
The ePIC Detector

John Lajoie

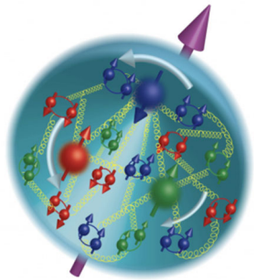
ePIC Collaboration

The EIC Physics Program

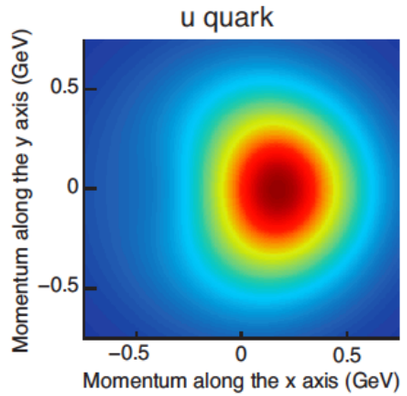
The Proton (1970s)

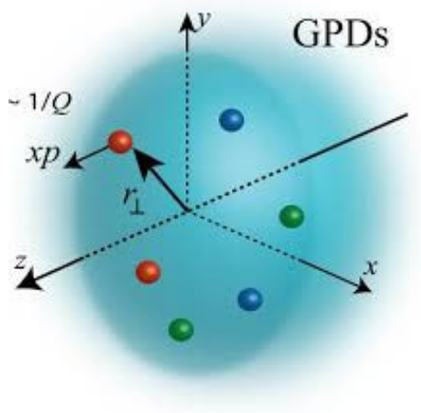


The Proton (2000s)

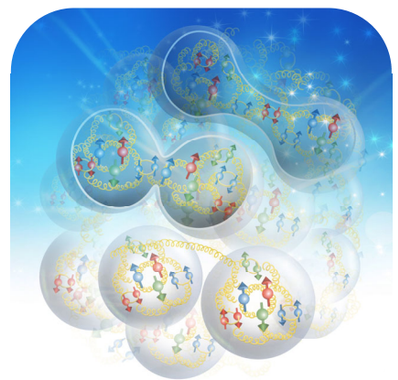


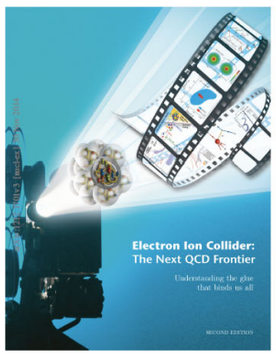
Multidimensional imaging of the structure of the proton



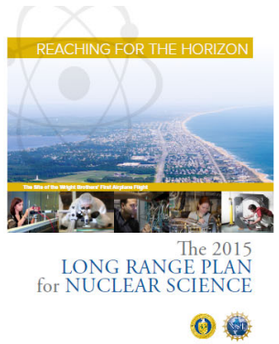


QCD dynamics that can affect the identity of nucleons in a nucleus

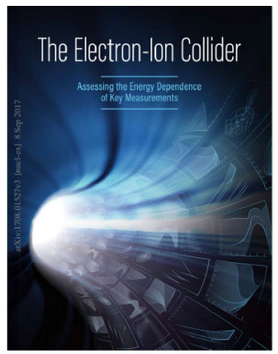




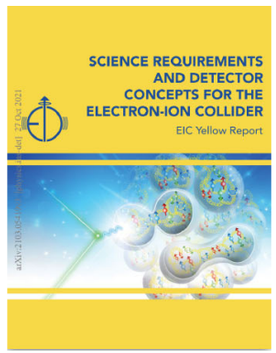
2012



2015



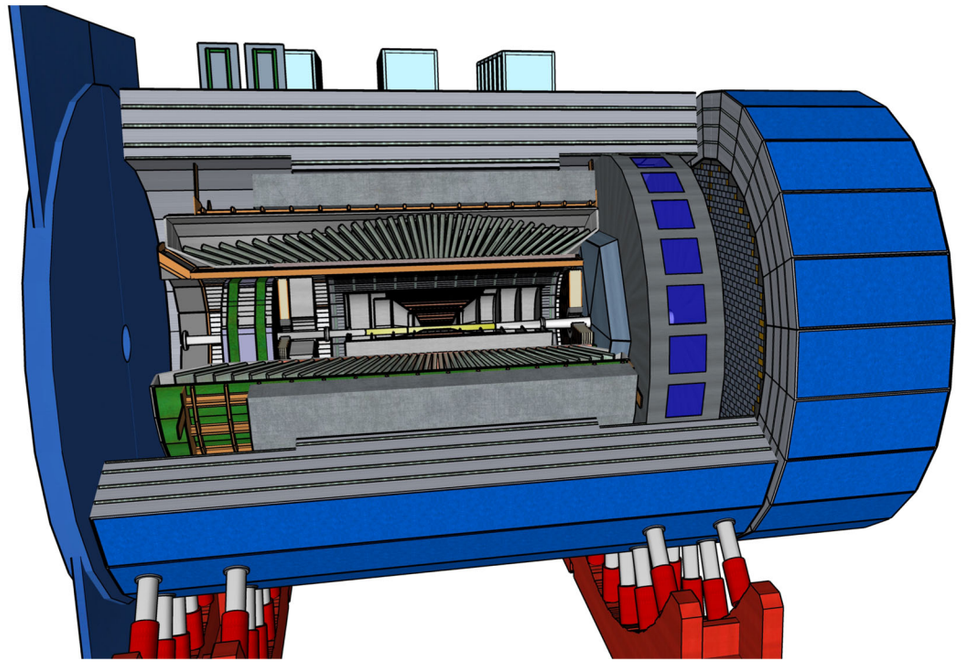
2017



2020

A Brief Timeline

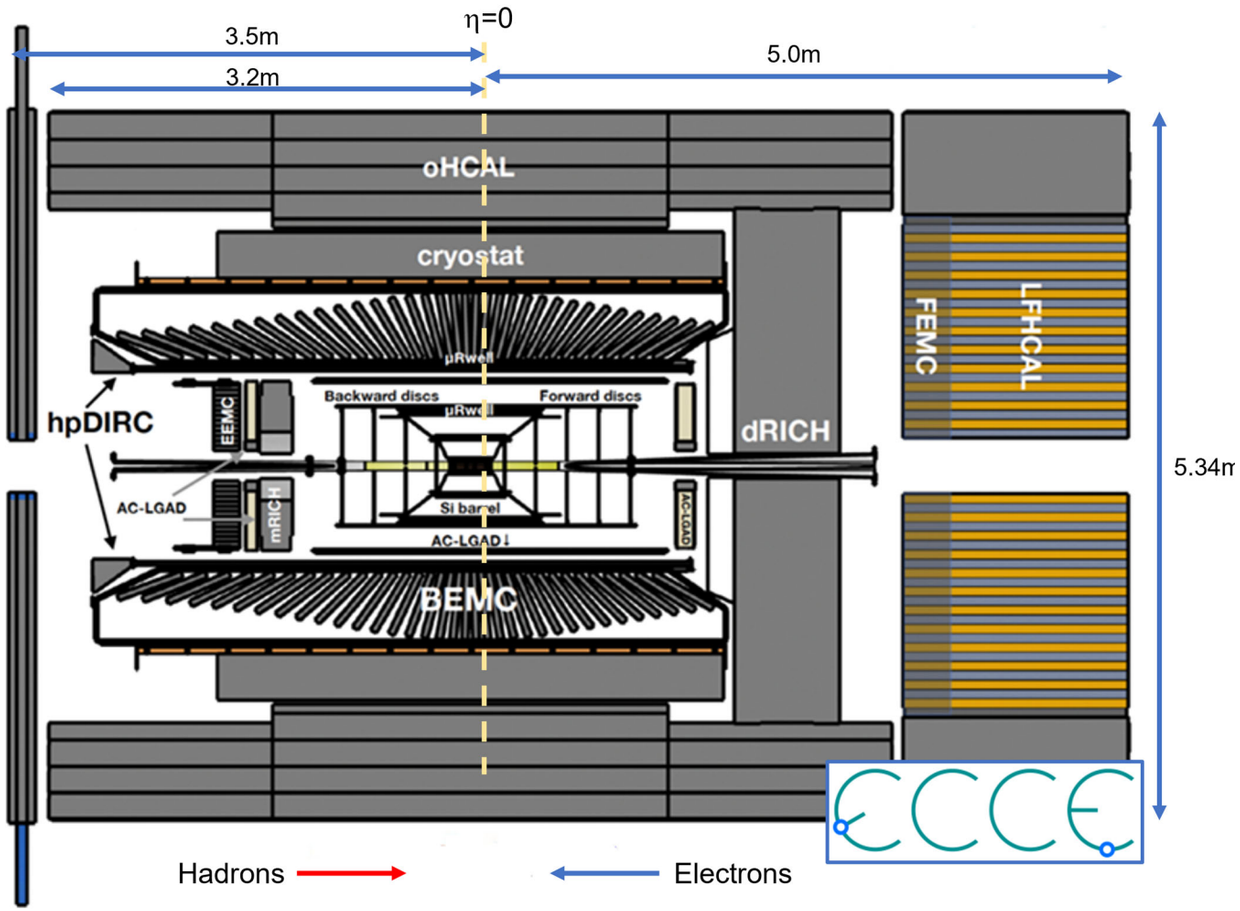
- EICUG Yellow Report (2020-21)
- Call for proposals issued jointly by BNL and JLab in March 2021
  - Proposals due Dec. 1, 2021
  - ATHENA, CORE and ECCE proposals submitted
- Public DPAP meetings Dec. 13-15, 2021
  - Presentations from proto-collaborations
  - Panel-assigned homework questions
- Second DPAP session Jan. 19-21, 2022
- DPAP closeout March 8th, 2022
  - Final report available March 21st, 2022
  - ECCE proposal chosen as basis for Detector-1 reference design
- Spring/Summer 2022 – ATHENA and ECCE form joint leadership team
  - Joint WG's formed and consolidation process undertaken
  - Coordination with EIC project on development of technical design
- Collaboration formation process started July, 2022
  - First IB Meeting July 18th
  - Charter writing committee formed and active – DE&I built in from start!
- First "Detector-1"/ePIC Collaboration meeting July 26-29, 2022

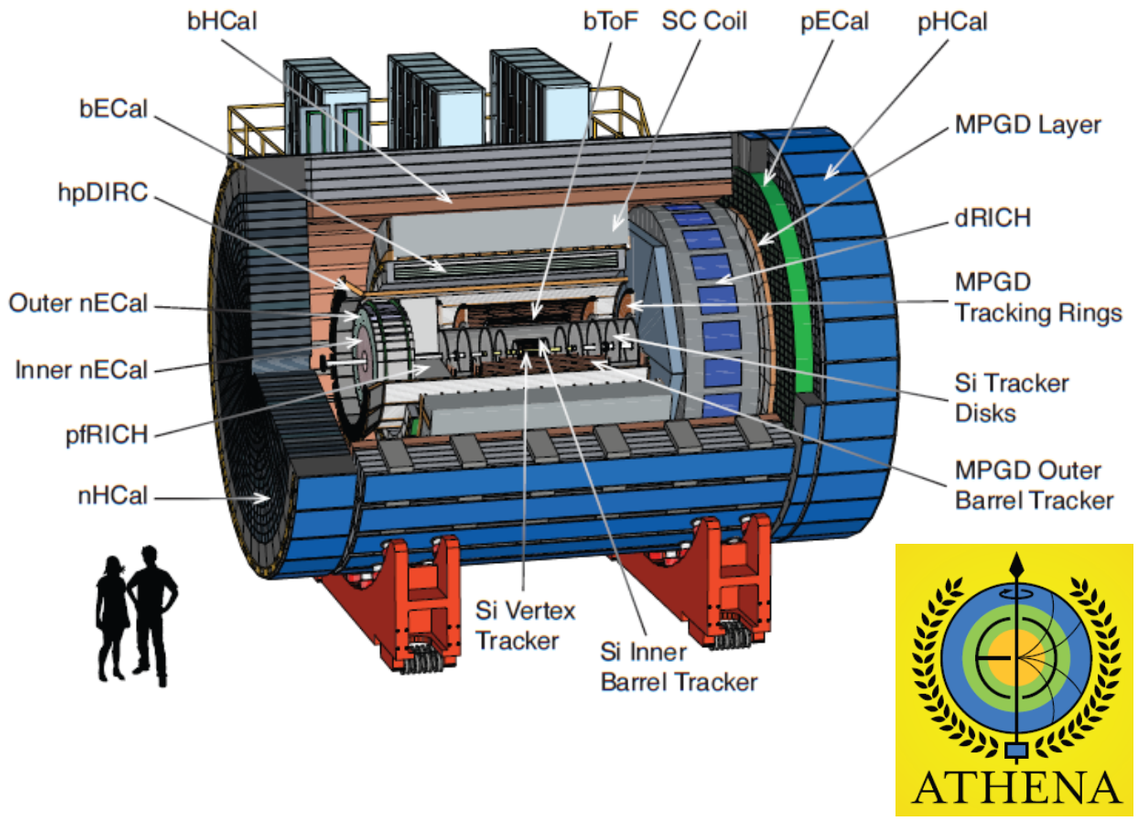


EIC Project Detector

- To be sited at IP6 (25mr crossing angle)
- Addresses EIC science program as outlined in the EIC white paper and NAS report
- Must be ready for Day-1 EIC operations
- Working towards pre-TDR and CD-2/3A

ECCE and ATHENA

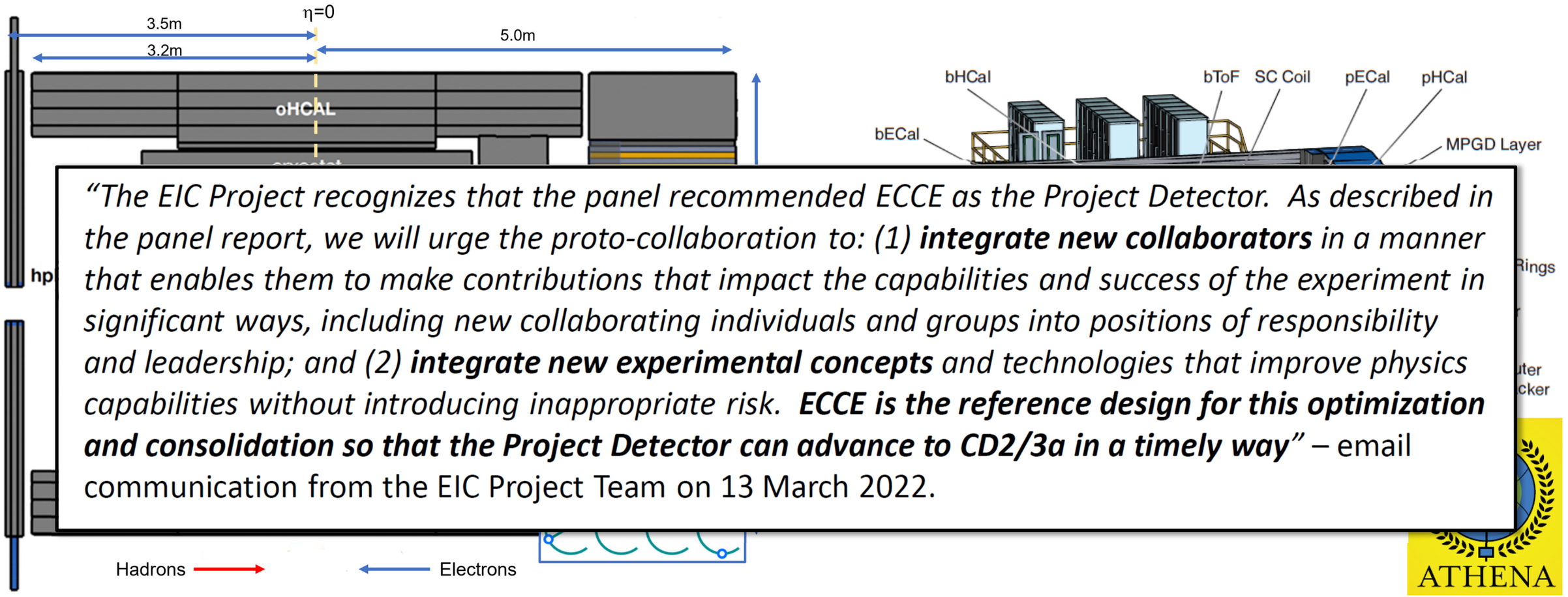




ATHENA

Key conceptual differences – bore size and magnetic field!

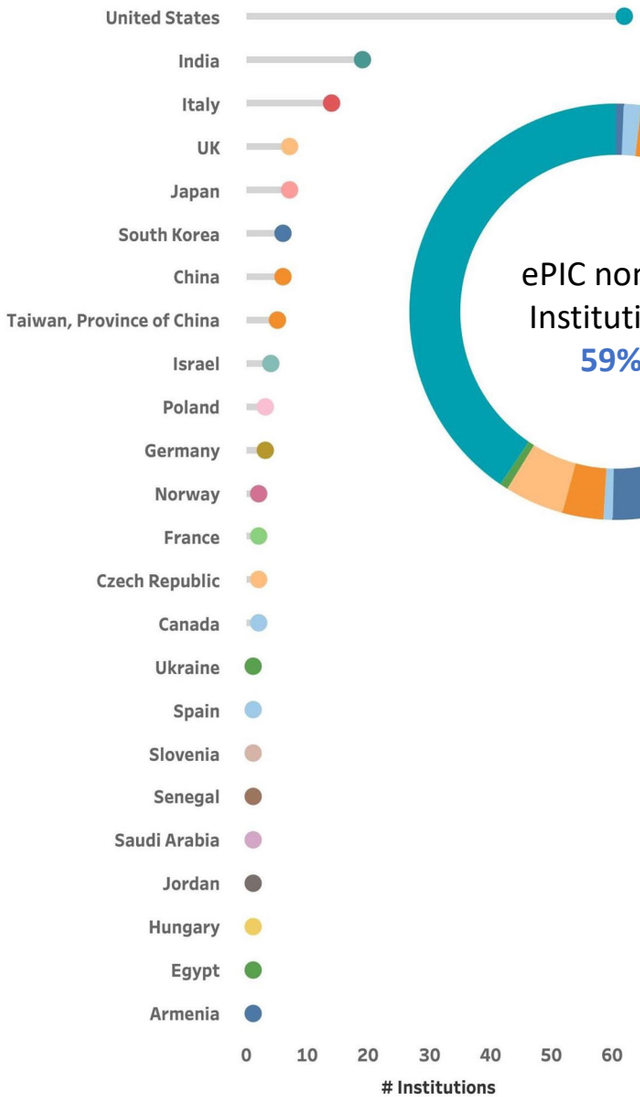
ECCE and ATHENA

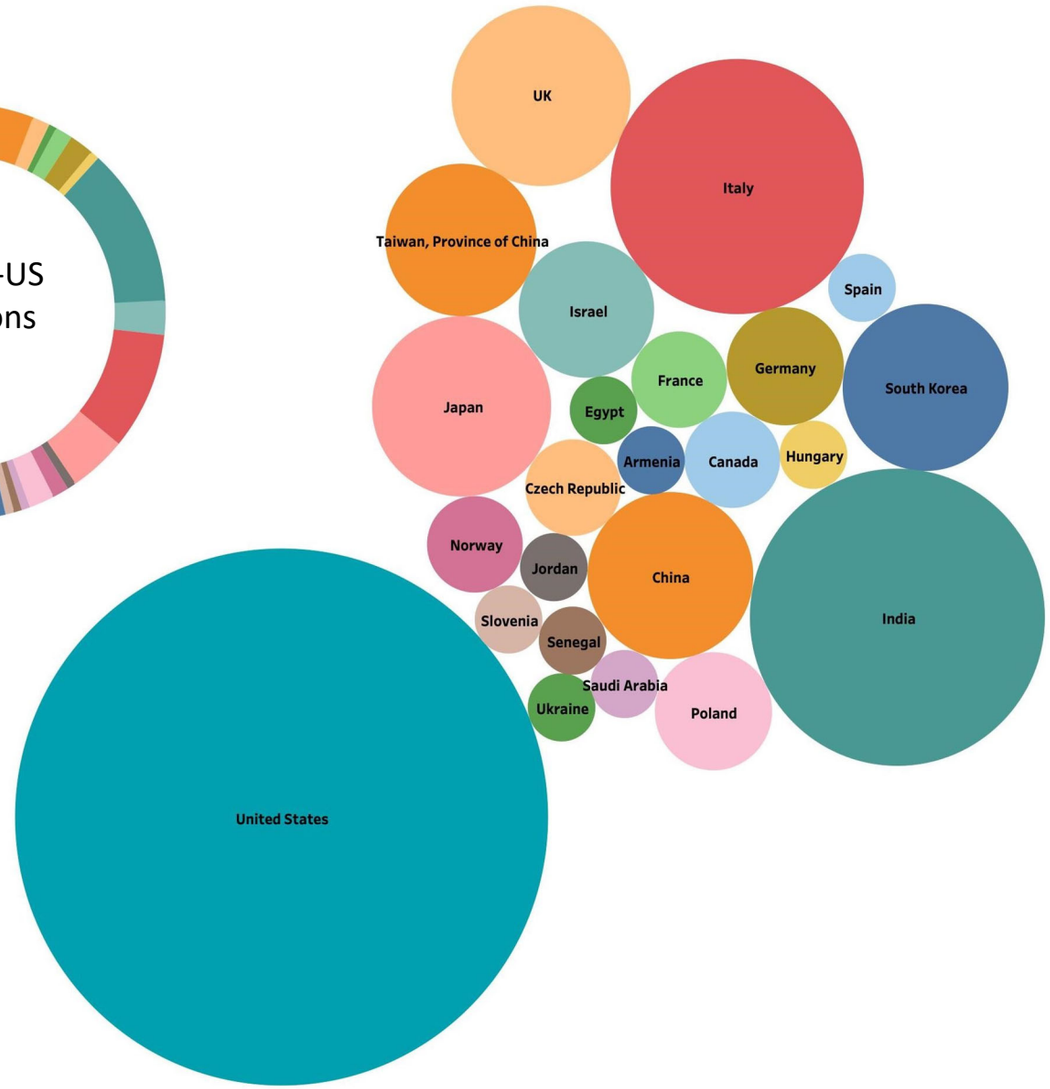


"The EIC Project recognizes that the panel recommended ECCE as the Project Detector. As described in the panel report, we will urge the proto-collaboration to: (1) ***integrate new collaborators*** *in a manner that enables them to make contributions that impact the capabilities and success of the experiment in significant ways, including new collaborating individuals and groups into positions of responsibility and leadership; and (2)* ***integrate new experimental concepts*** *and technologies that improve physics capabilities without introducing inappropriate risk.* ***ECCE is the reference design for this optimization and consolidation so that the Project Detector can advance to CD2/3a in a timely way"*** – email communication from the EIC Project Team on 13 March 2022.

Key conceptual differences – bore size and magnetic field!

The ePIC Collaboration



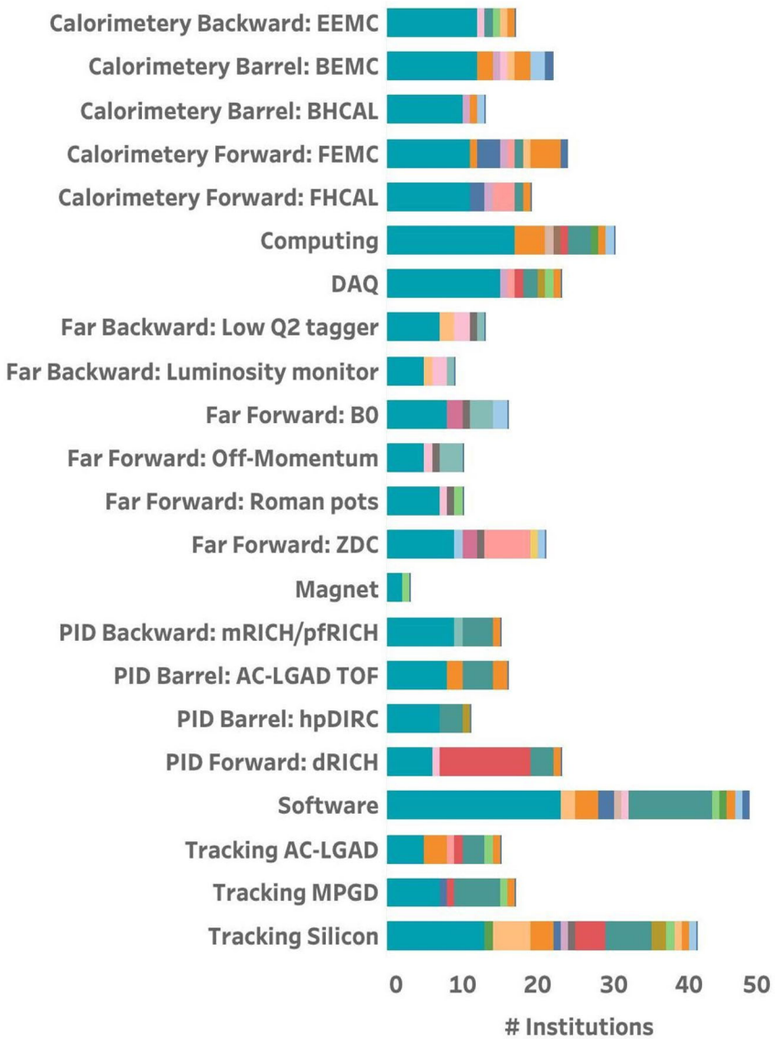


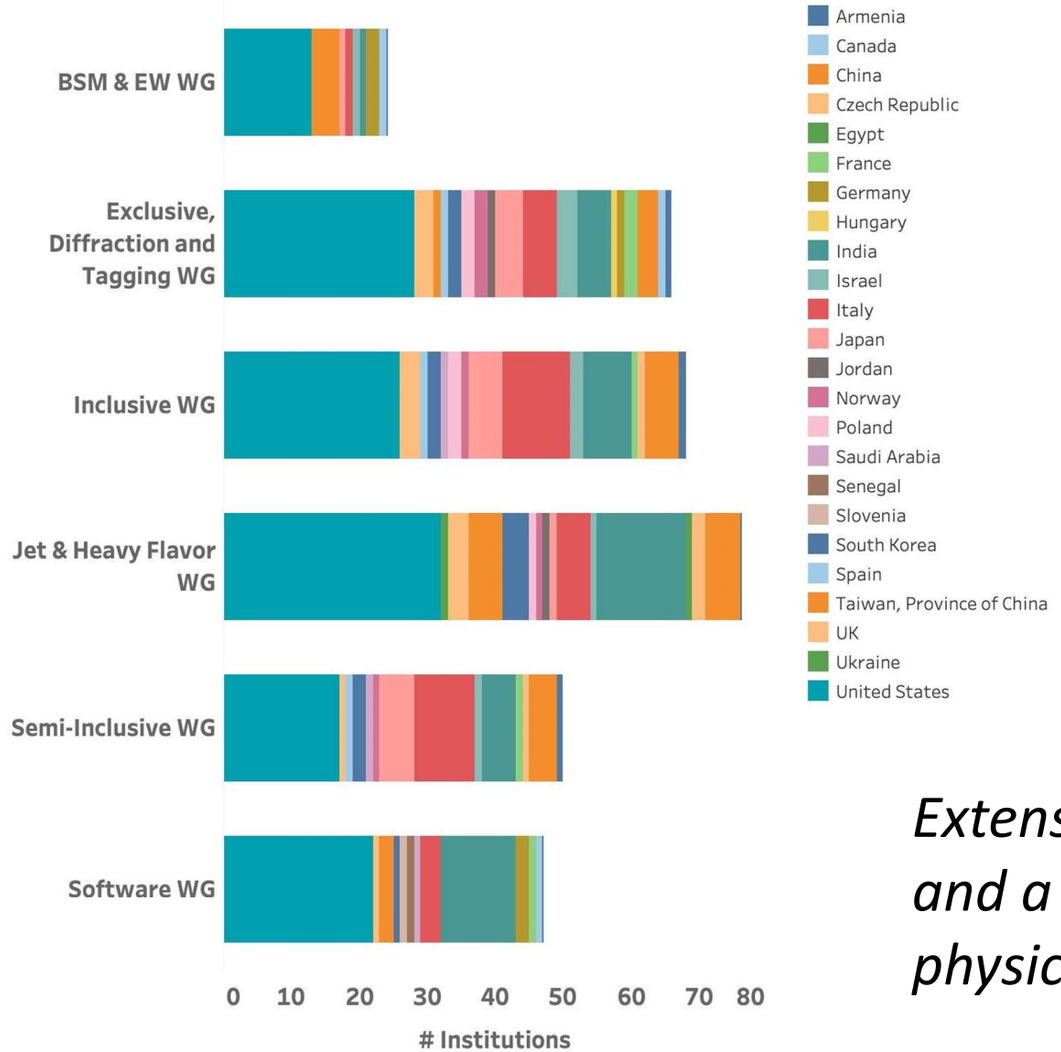
160+ institutions
24 countries

500+ participants

A truly global pursuit for a new experiment at the EIC!

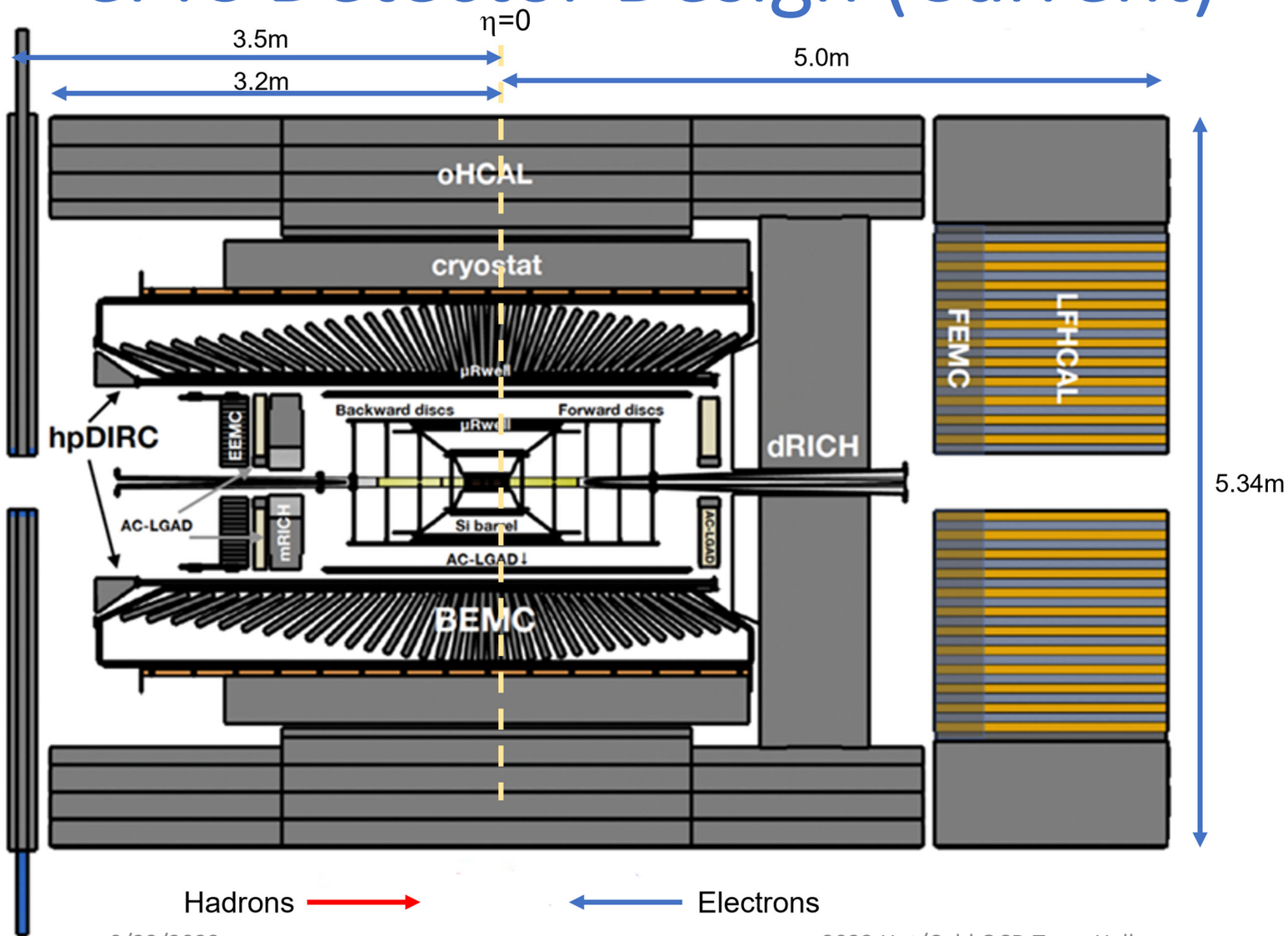
The ePIC Collaboration



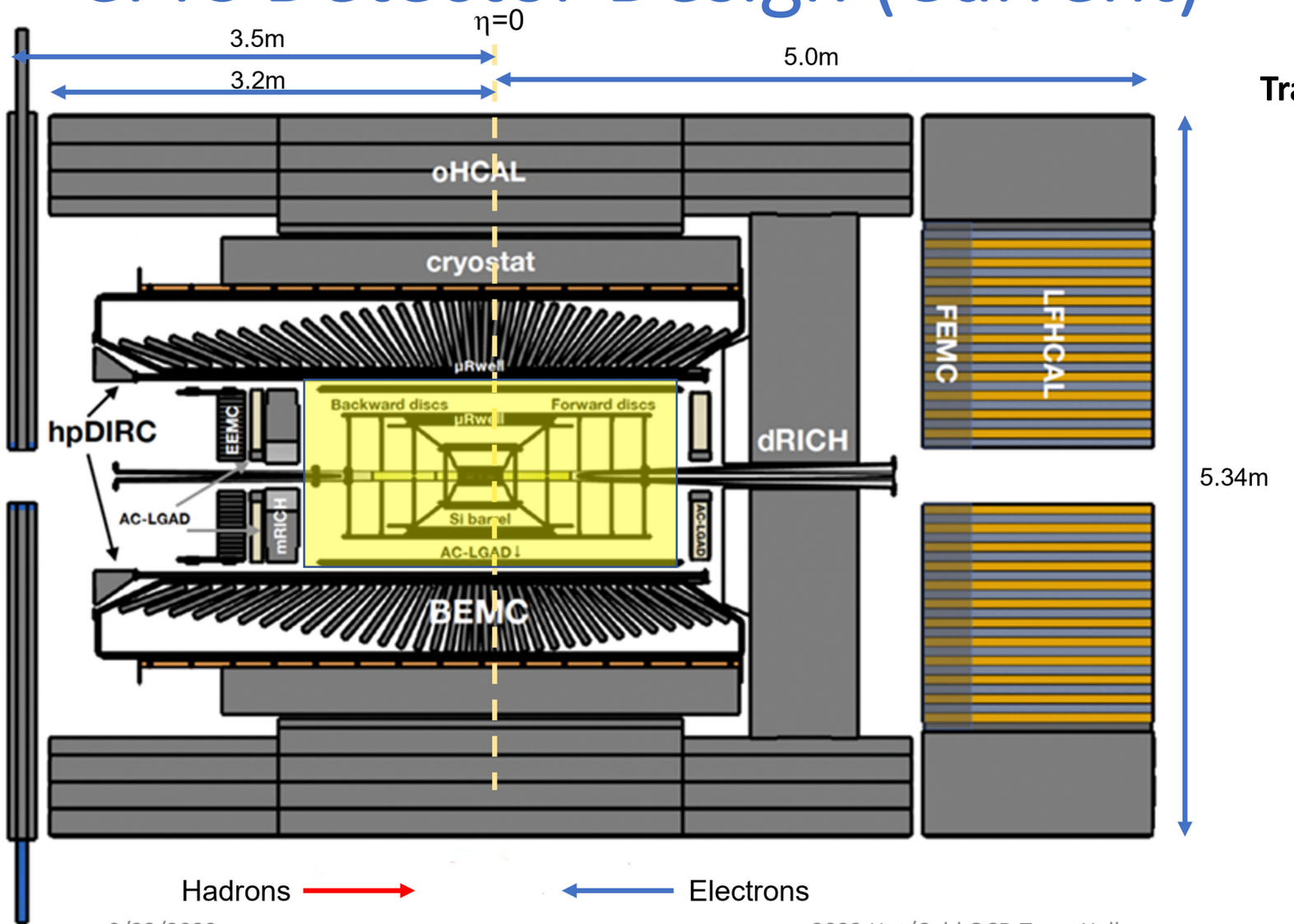


Extensive expertise and a wide array of physics interests.

ePIC Detector Design (Current)



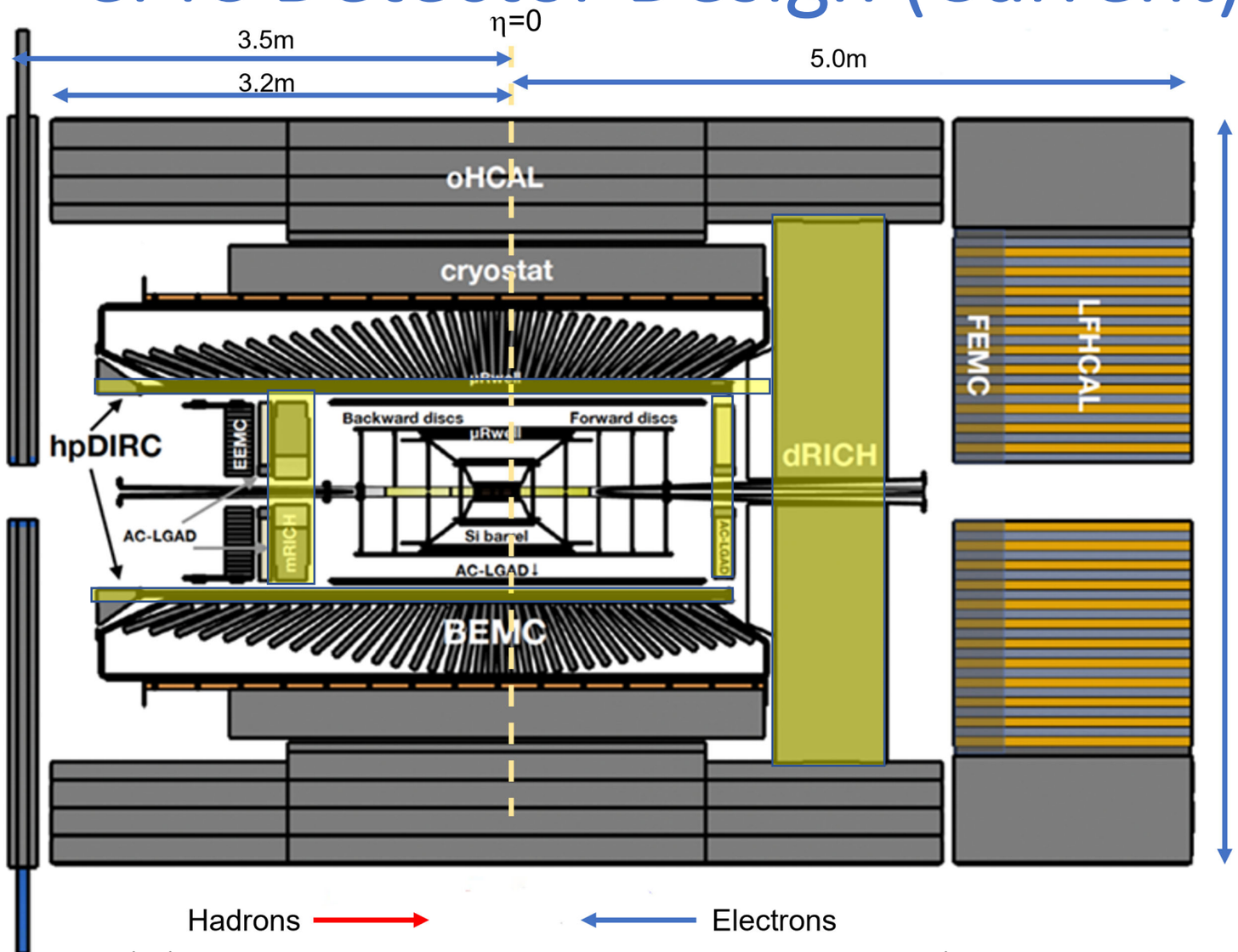
ePIC Detector Design (Current)



Tracking:

- New 1.7T solenoid
- Si MAPS Tracker
- MPGDs (μRWELL/μMegas)

ePIC Detector Design (Current)



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PID:

- hpDIRC
- mRICH/pfRICH
- dRICH
- AC-LGAD (~30ps TOF)

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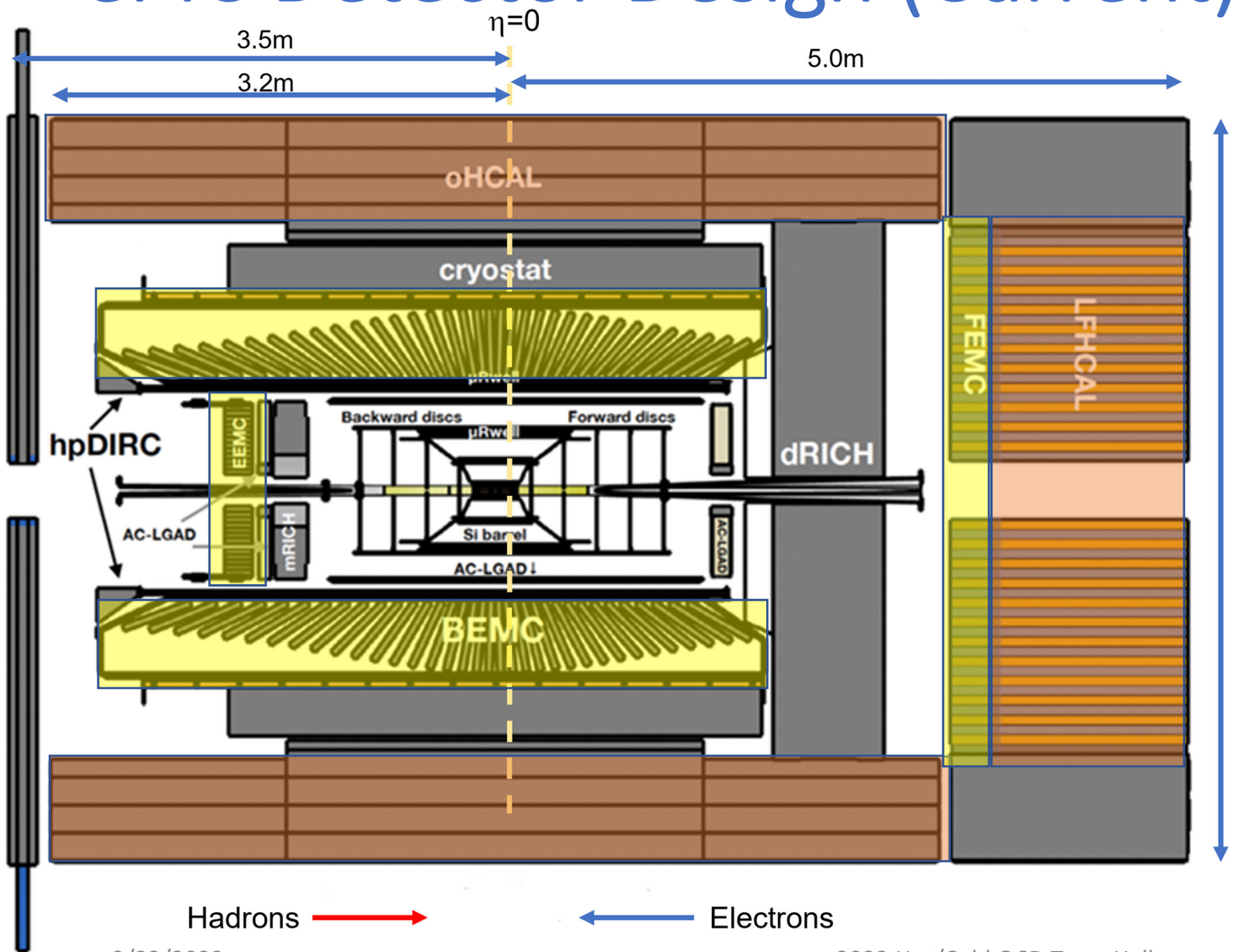

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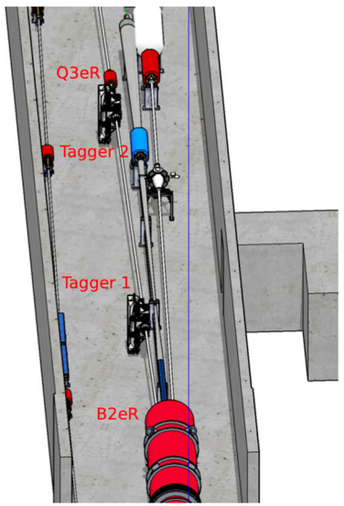
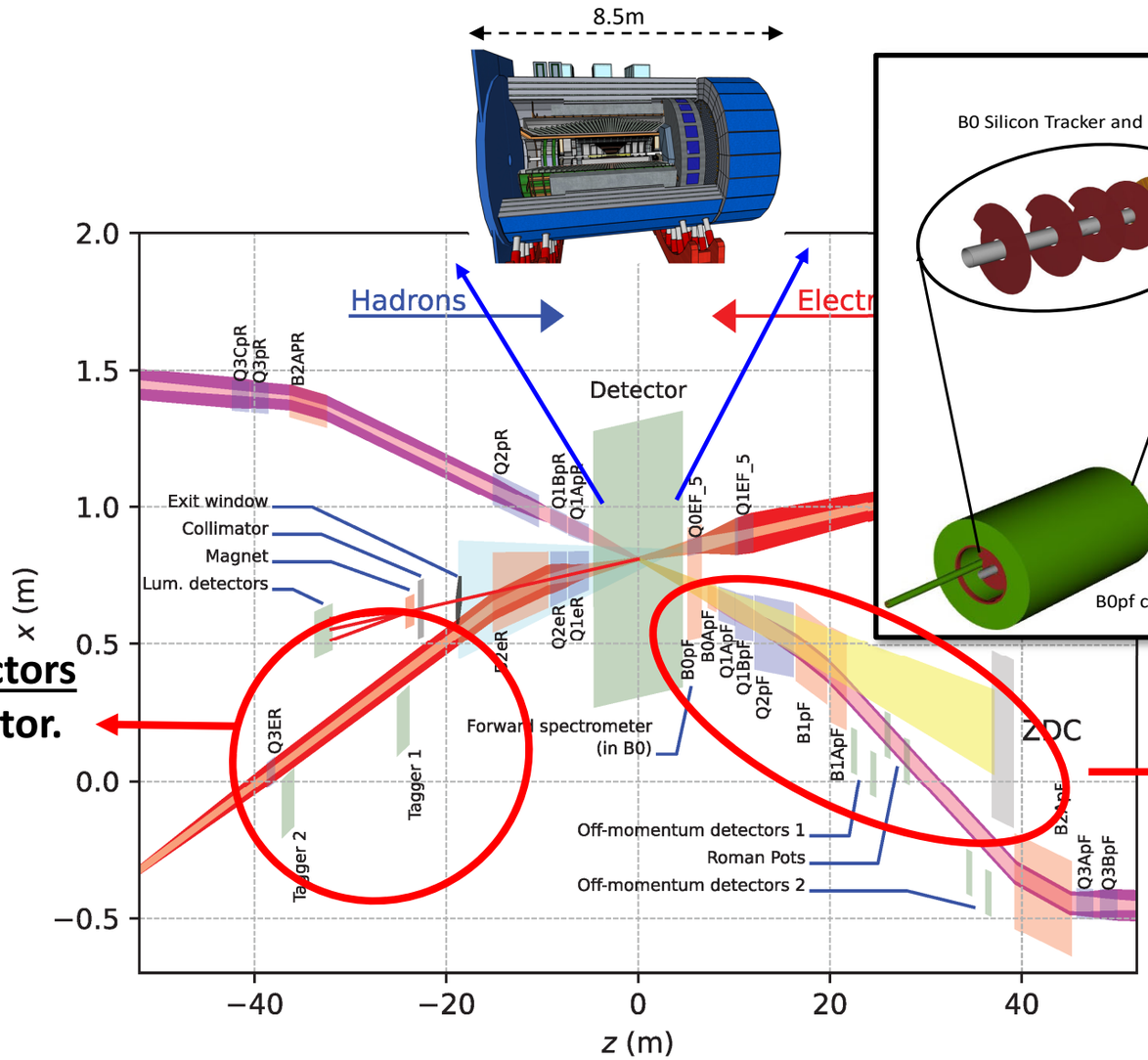
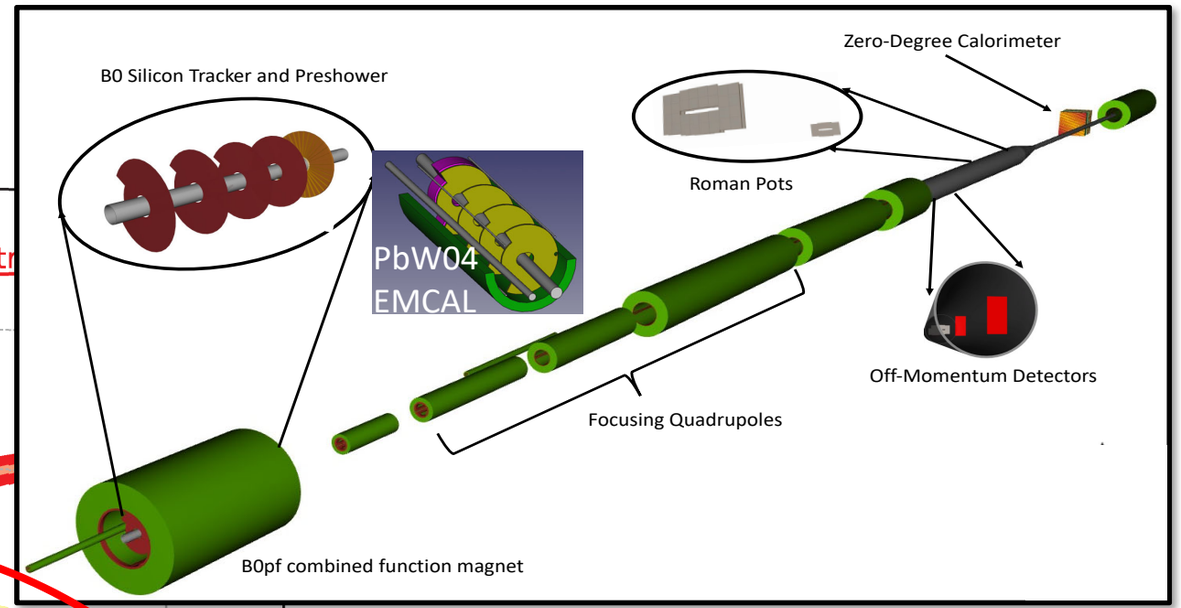
Calorimetry:

- SciGlass/Imaging Barrel EMCal
- PbWO4 EMCal in backward direction
- Finely segmented EMCal +HCal in forward direction
- Outer HCal (sPHENIX re-use)

Far-Forward and Far-Backward Detectors







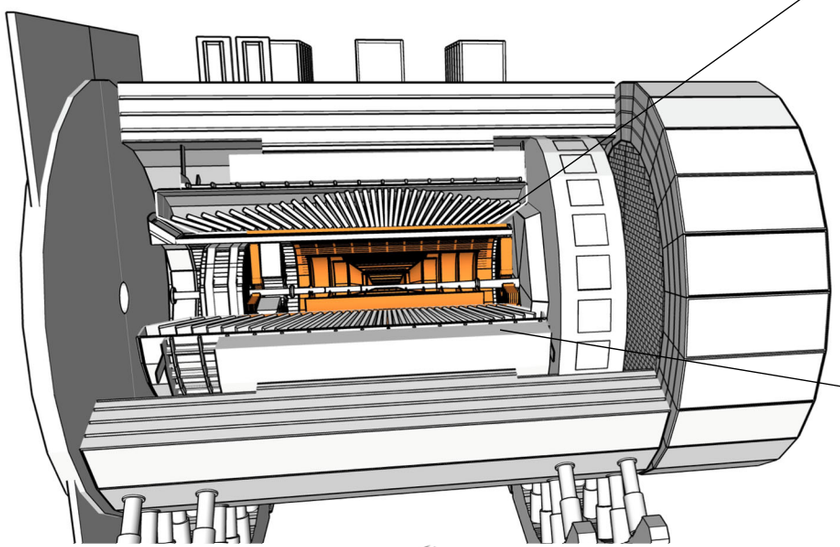
Far-Backward Detectors

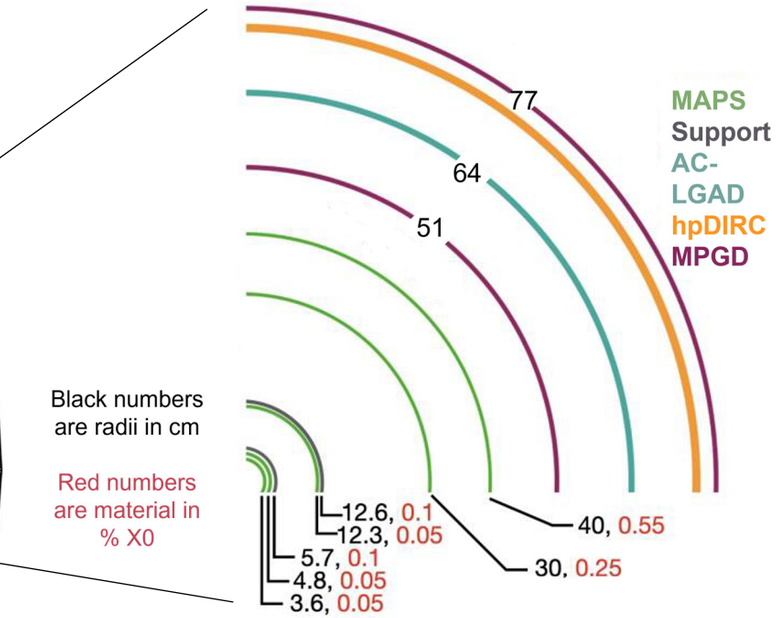
- **Luminosity monitor.**
- **Low-Q^2 Tagging Detectors**

Far-Forward Detectors

- **B0 Tracking and Photon Detection**
- **Roman Pots and Off-Momentum Detectors.**
- **Zero-Degree Calorimeter.**

Tracking



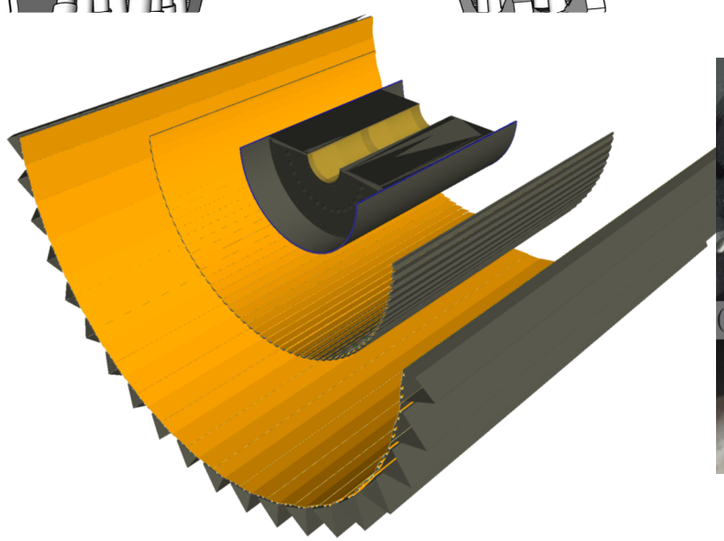


Si Tracker based on ALICE ITS3 65nm MAPS sensors.

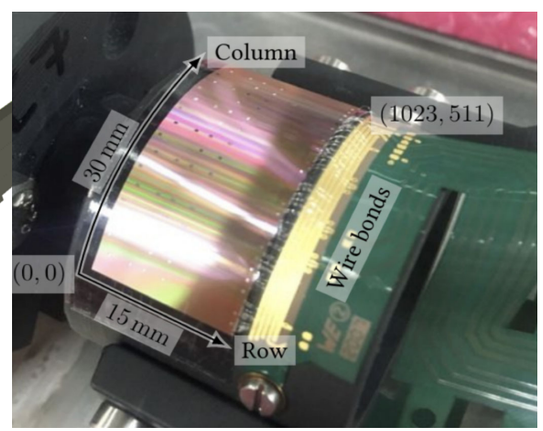
Five layers in barrel, supplemented by MPGDs for pattern recognition.

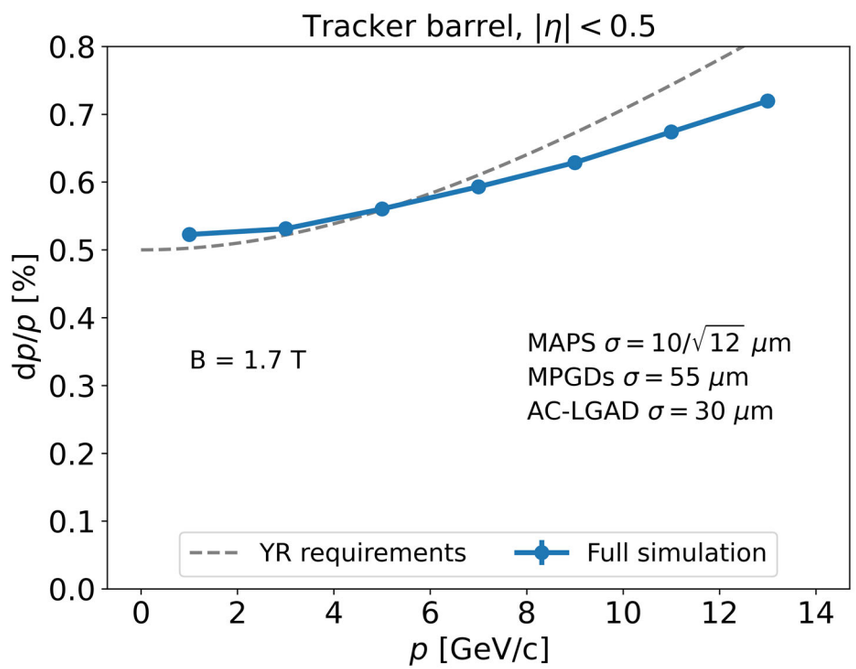
Five discs in forward/backward directions (+MPGD in forward)

Meets EICUG Yellow Report design requirements.



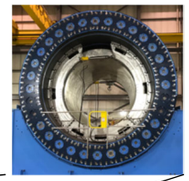
First "µITS3" assembly at CERN



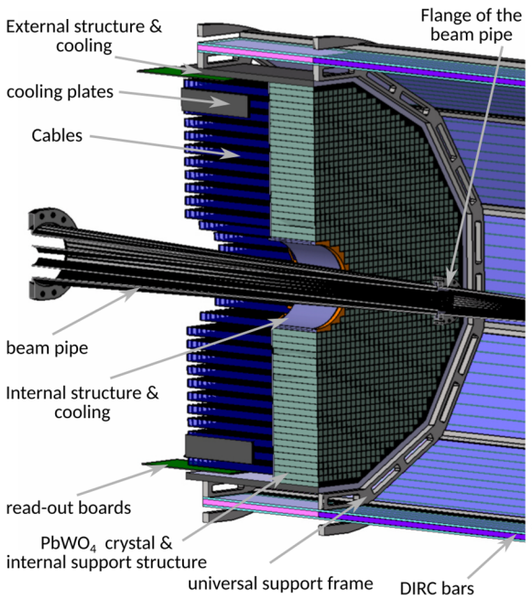


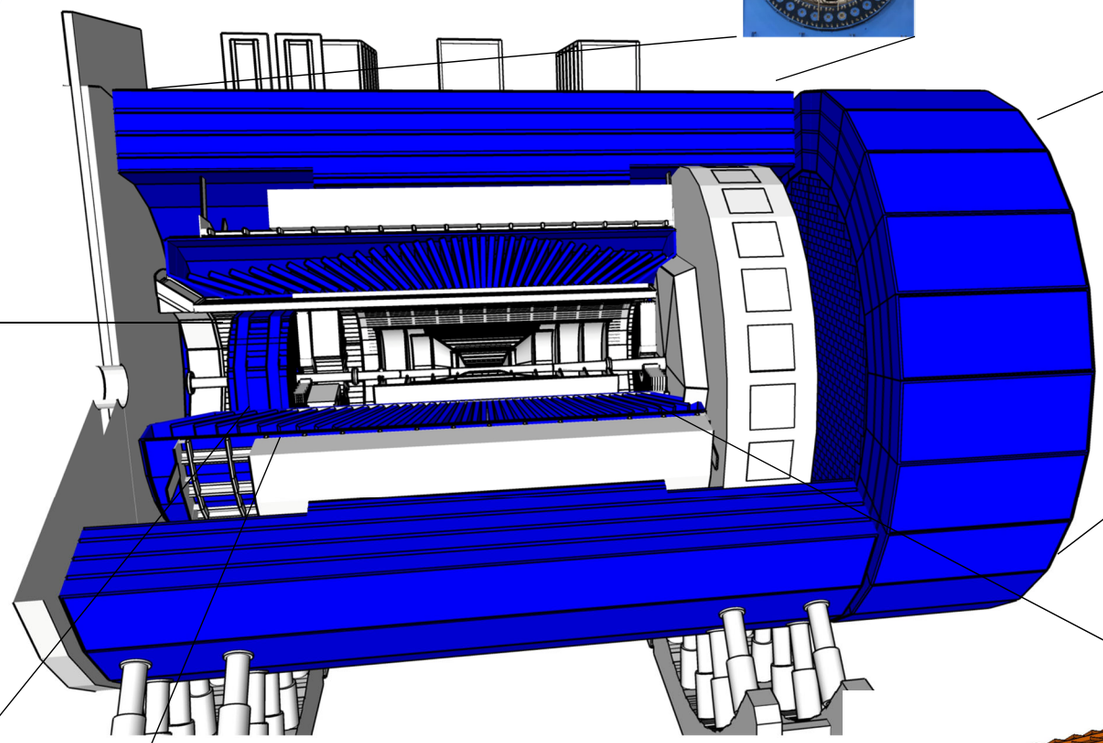
Calorimetry

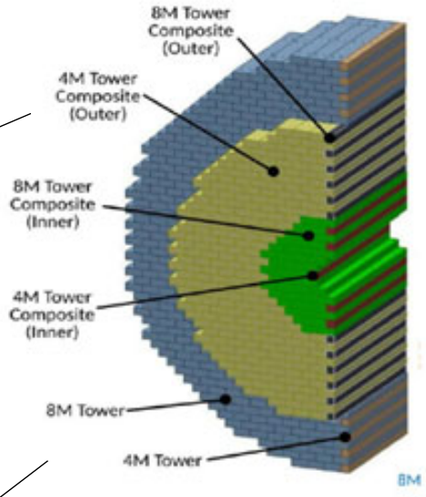
Barrel HCAL
(sPHENIX re-use)



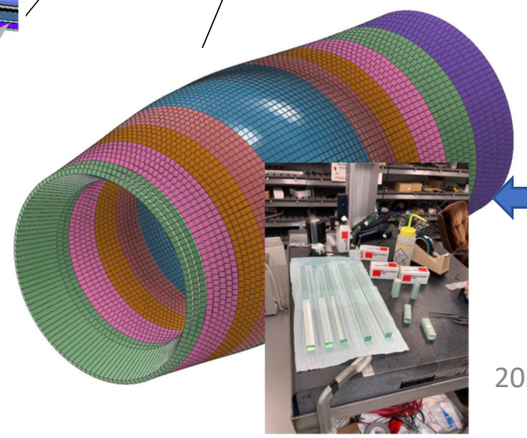
Backwards EMCal
PbW04 crystals



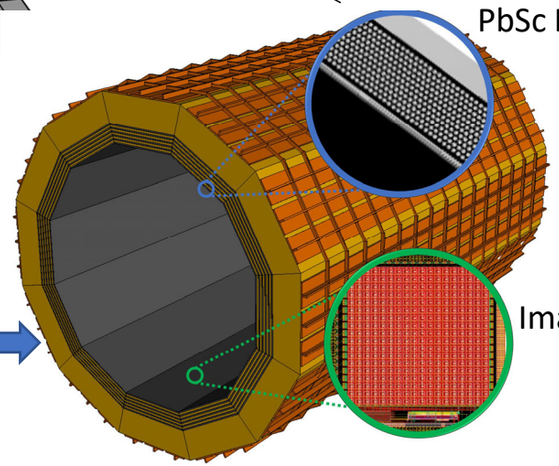




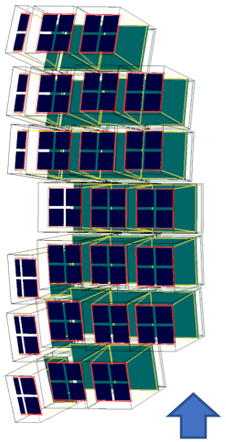
High granularity shashlik W/SciFi EMCal
Longitudinally separated HCAL with high-η insert



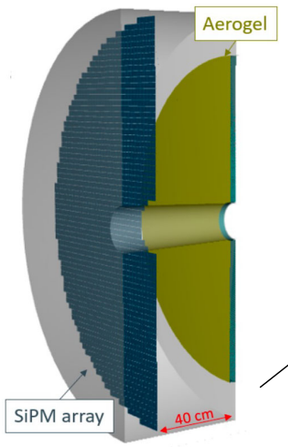
Complementary options for BECAL: SciGlass or Imaging Calorimeter



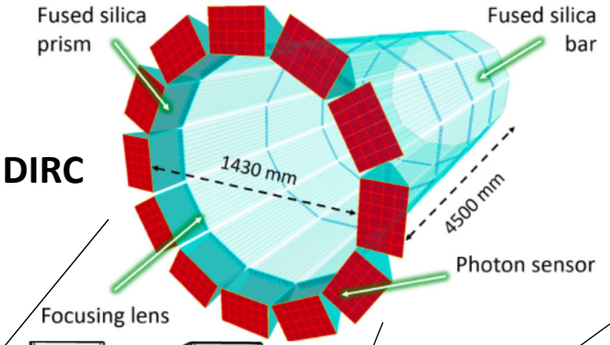
Particle ID

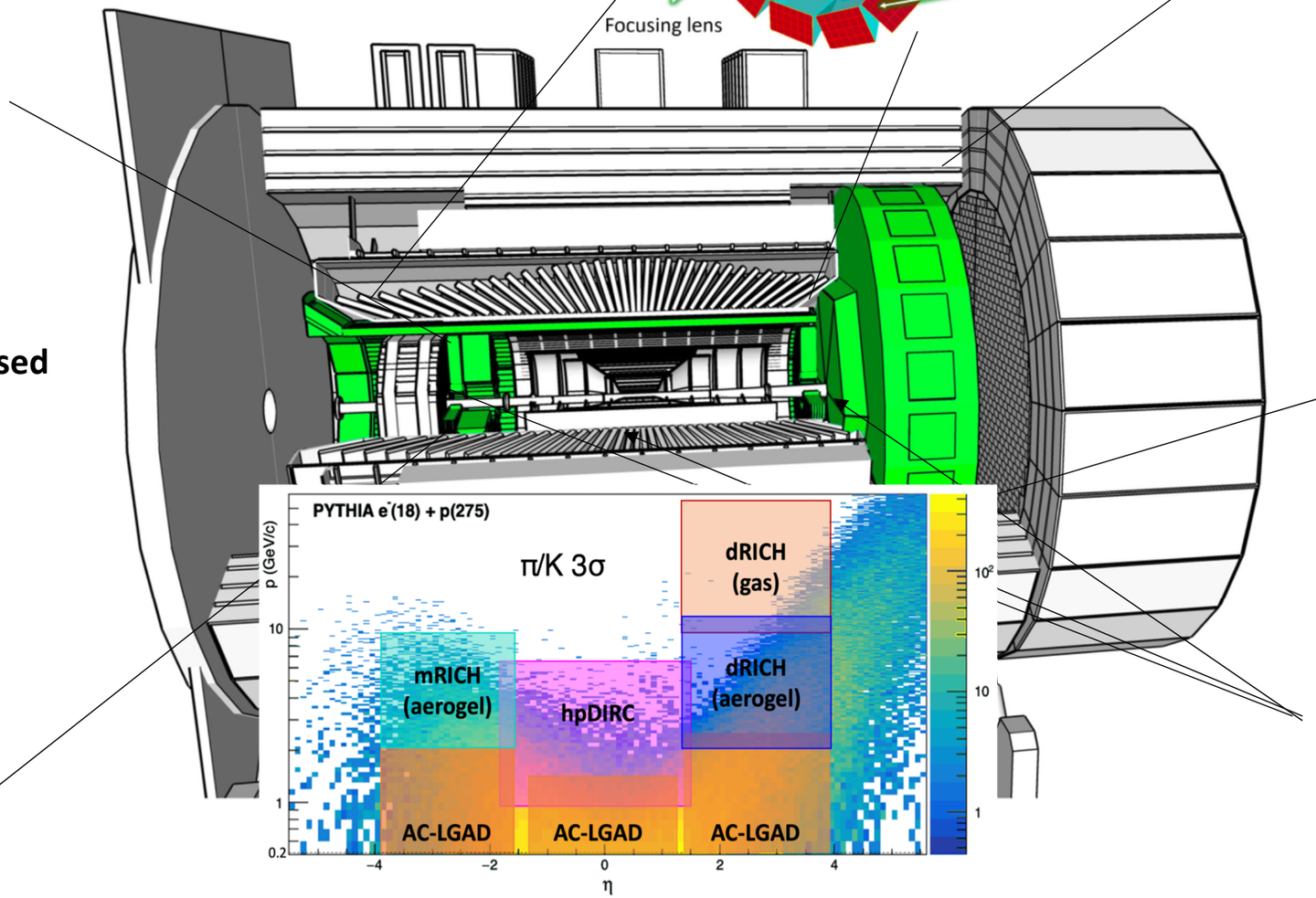


Modular (mRICH)
or Proximity Focused (pfRICH)

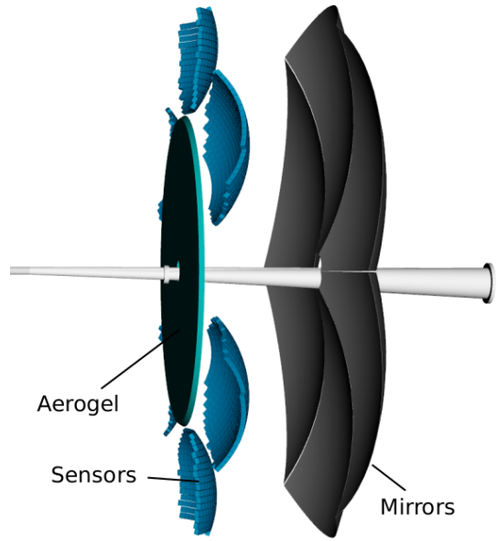


High-Performance DIRC

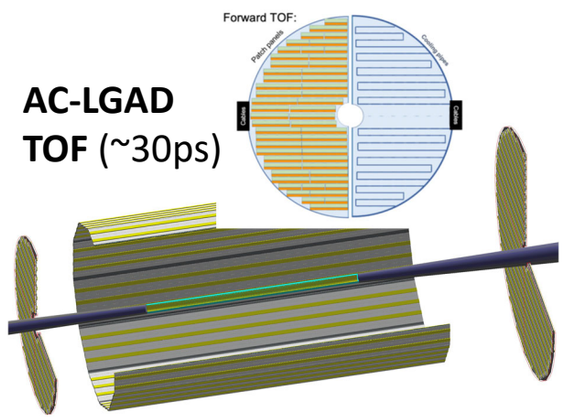




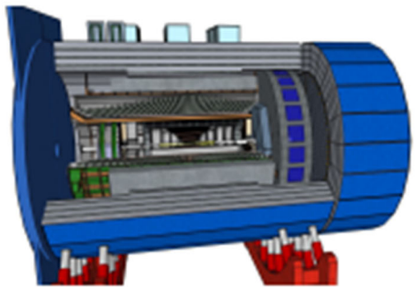
Dual-Radiator RICH (dRICH)

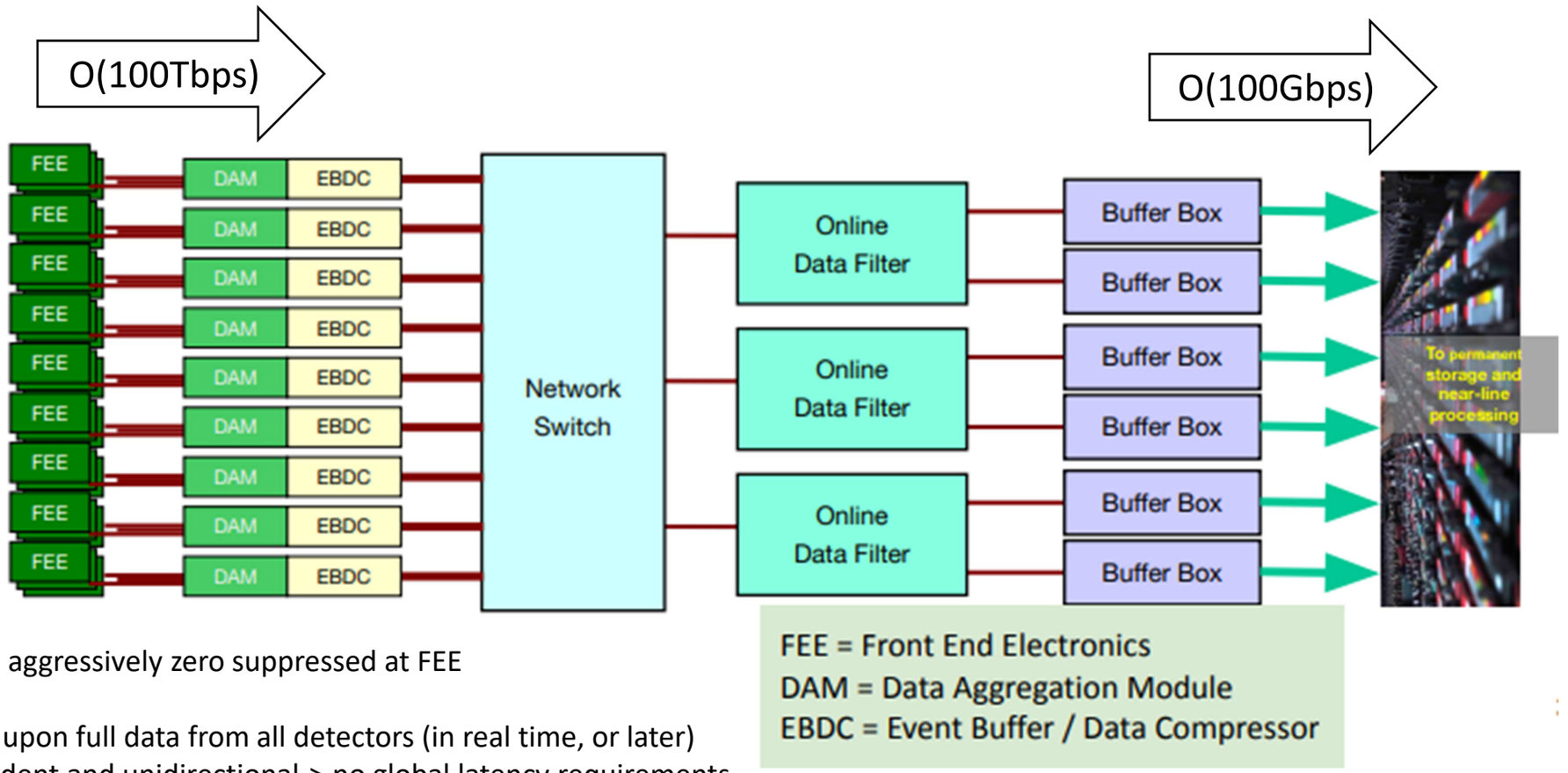


AC-LGAD TOF (~30ps)



ePIC Streaming DAQ

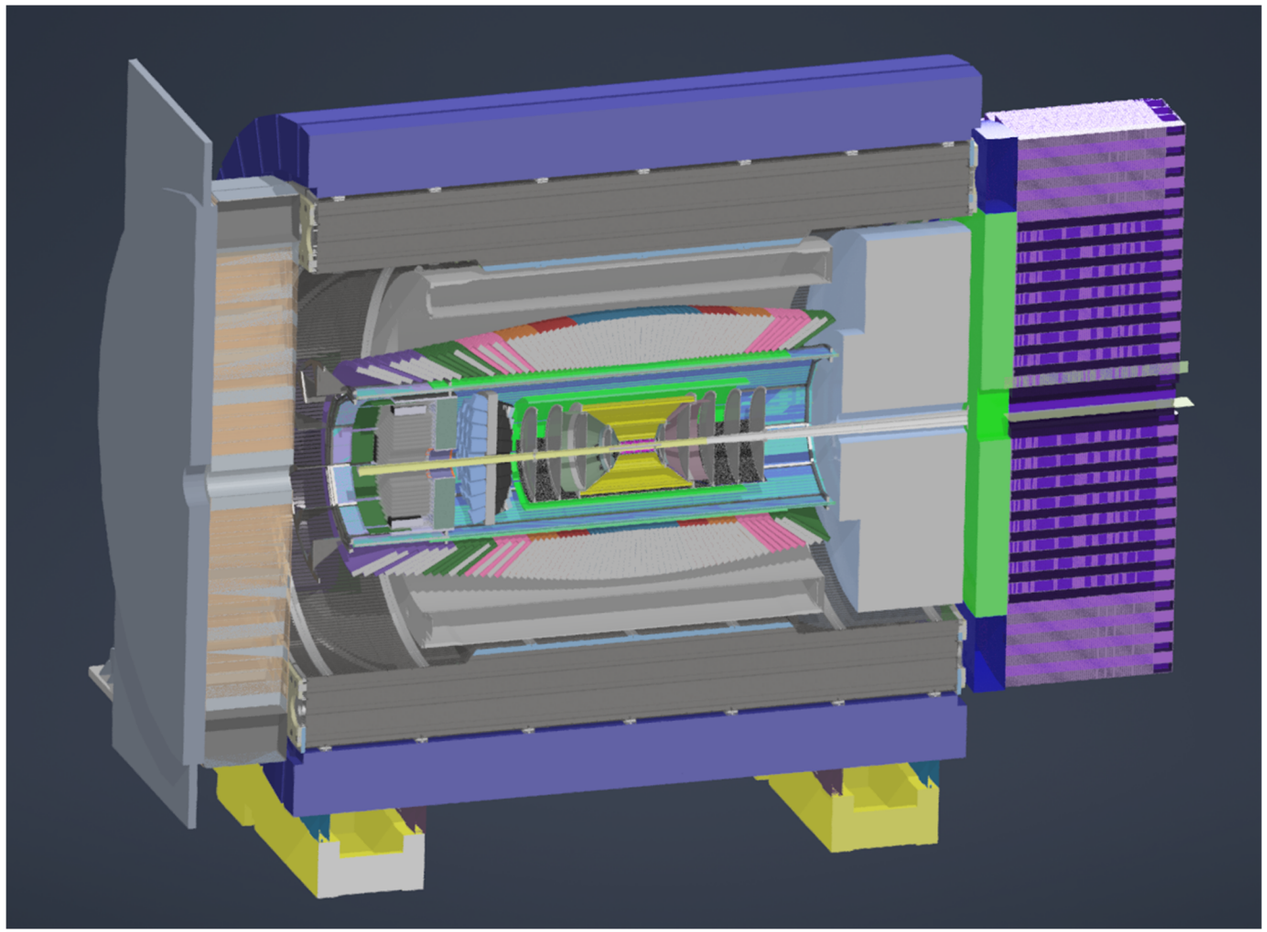




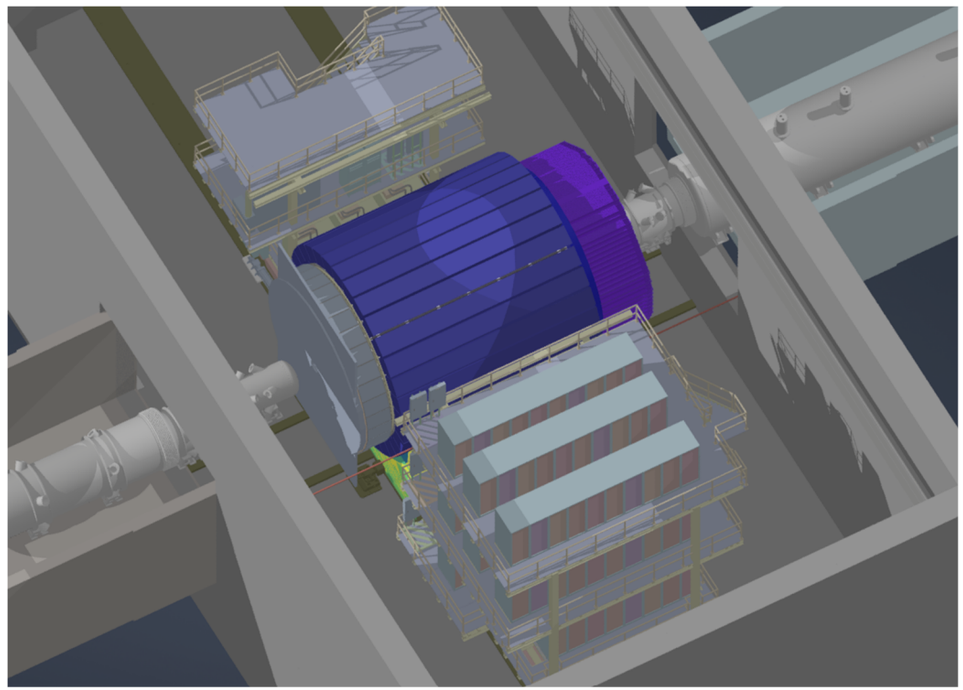
- No External trigger
- All collision data digitized but aggressively zero suppressed at FEE
- Low / zero deadtime
- Event selection can be based upon full data from all detectors (in real time, or later)
- Collision data flow is independent and unidirectional-> no global latency requirements
- Avoiding hardware trigger avoids complex custom hardware and firmware
- The “Front End Processing”, programmable hardware between the FEEs and the DAQ computers, is deemphasized relative to the yellow report, but should not be precluded.
- Data volume is reduced as much as possible at each stage

Stored data volumes ~O(100Pb) per run

Engineering Design



Full CAD design of ePIC ongoing to facilitate *realistic* detector integration.



What does ePIC need in the LRP to be successful?

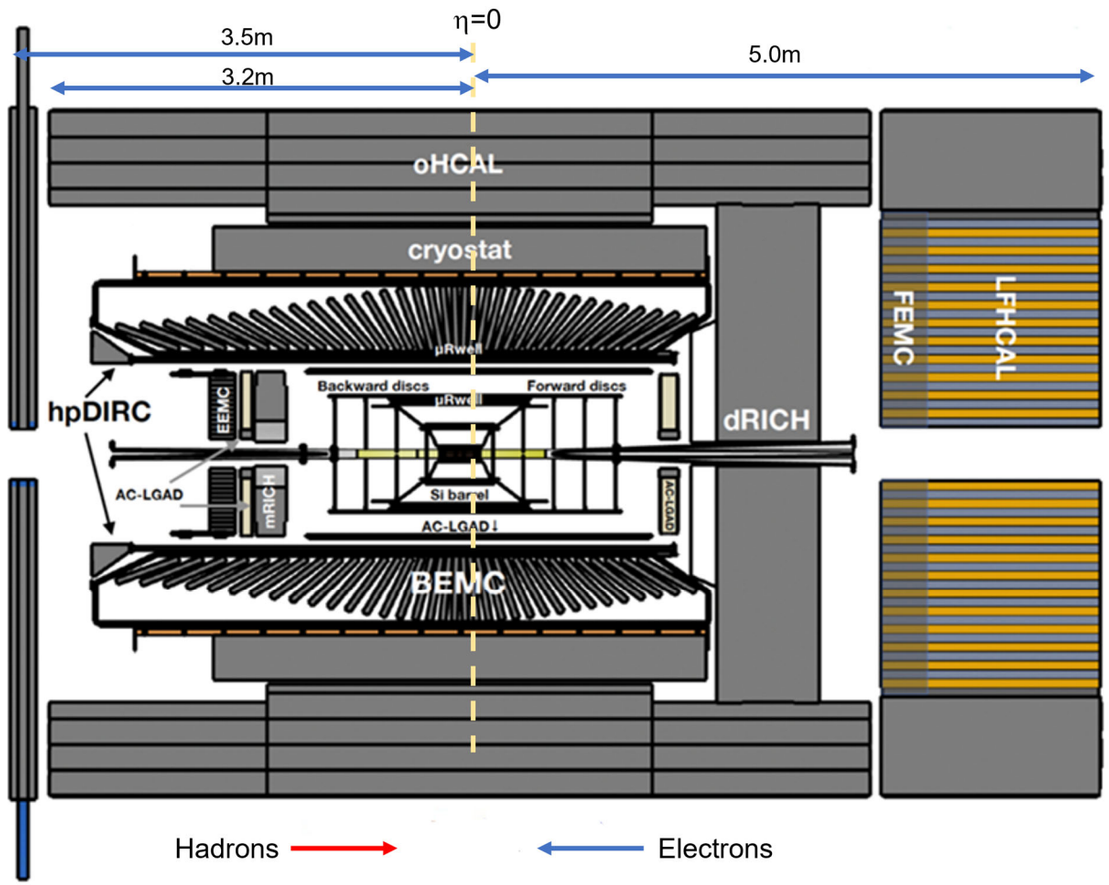
- The EIC as the top priority for new construction
  - ePIC is part of the EIC project
- Continued support for high-performance computing and software development in NP
  - Open, standard software environment capable of processing simulation and real data at all stages of ePIC
  - Support for laboratory computing infrastructure to enable streaming DAQ and AI integrated workflows
- Support for NP Theory
  - Critical to continuing to evolve the EIC science program
- Support for the EIC workforce
  - The EIC is a great opportunity to build a more diverse and international workforce in US Nuclear Physics
  - Need support for the EIC workforce through the DOE and NSF for operating budgets as groups transition from RHIC/Jlab/LHC

Conclusions

- The ePIC Collaboration has kicked-off:
  - Ongoing WG meetings focused on consolidation and developing ePIC technical design for CD-2/3A
    - Forum to focus community and R&D consortium expertise
  - Collaboration formed, expect charter and elections soon
  - Next collaboration meeting at JLab, Jan. 9-11th
- The ePIC Detector is maturing into a detailed technical design
  - EIC detectors are an enormous undertaking that will require participation and expertise from both the RHIC and JLab communities, as well as key international contributions!
- Key requirements for ePIC to be successful:
  - EIC construction, HP computing, Theory, Workforce

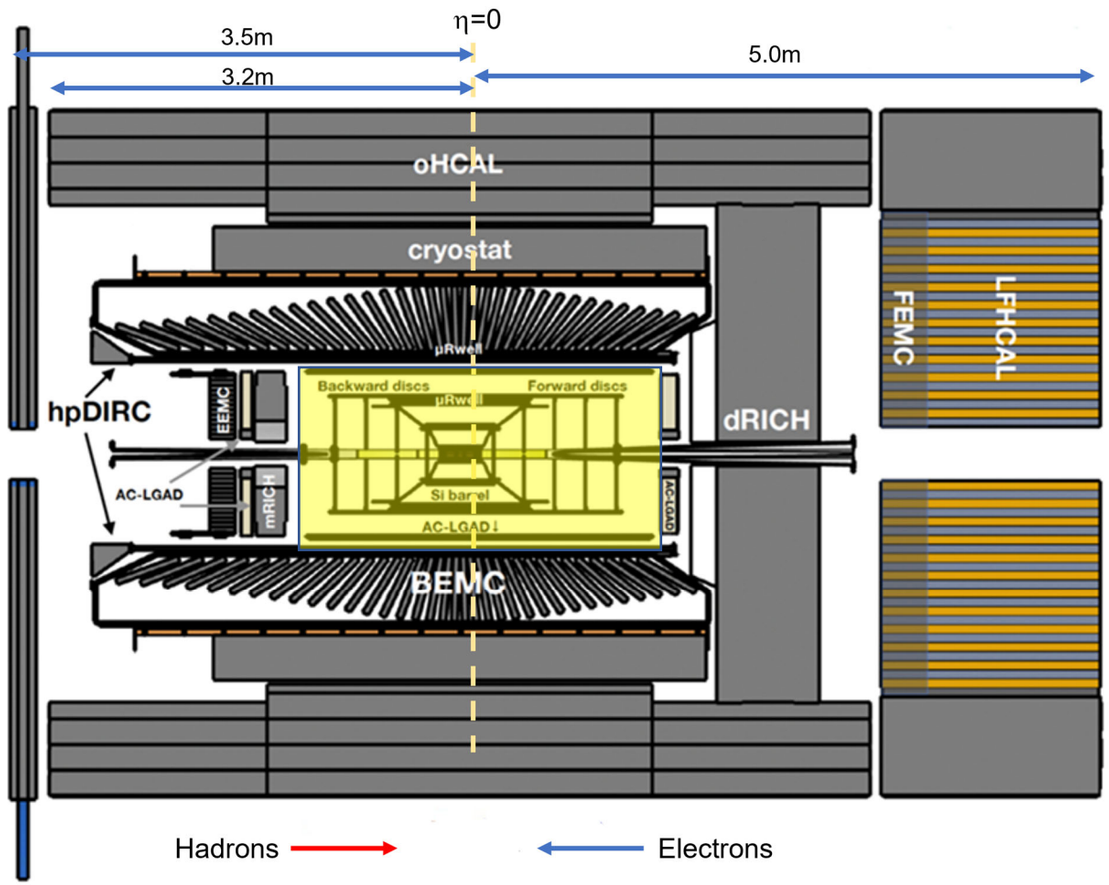

BACK UP

Work Underway on ePIC Design



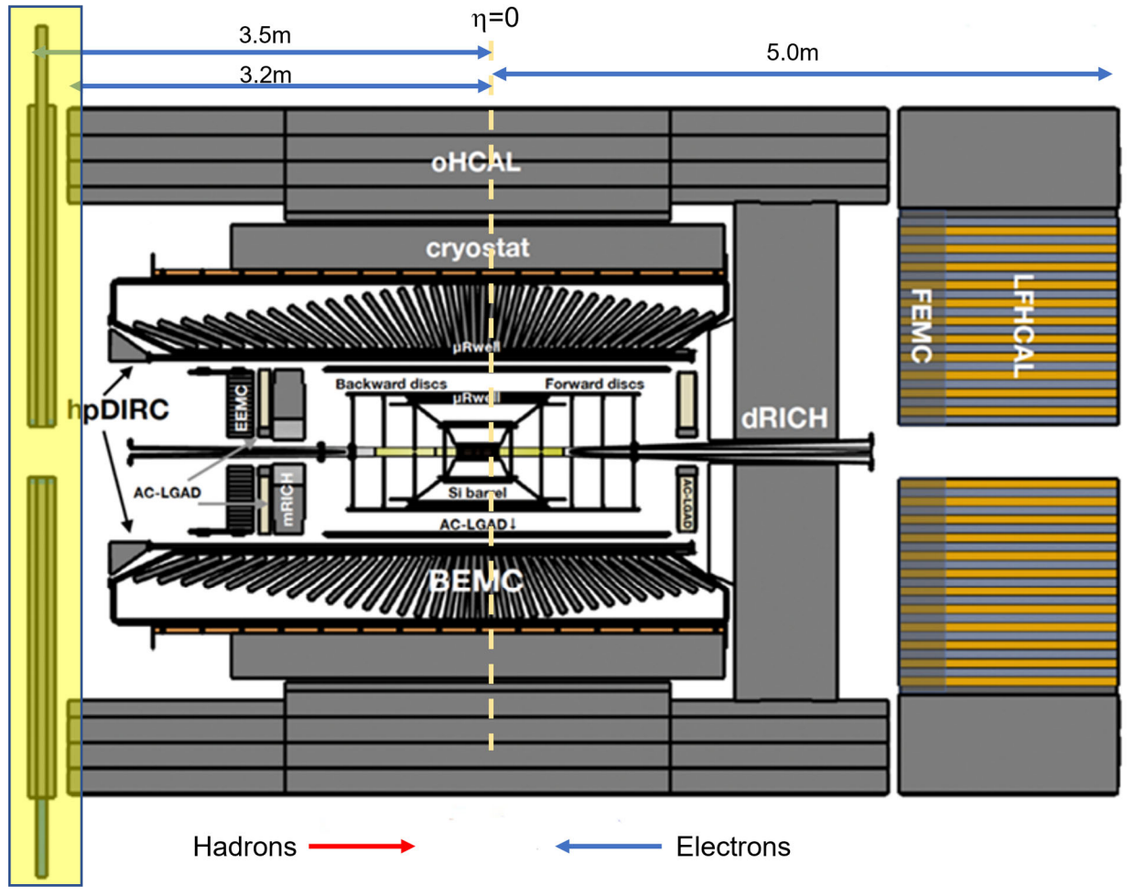
Work Underway on ePIC Design

- Optimization of barrel tracking
  - Achieving a realistic, low-mass design with good performance
    - Efficiency/seeding studies w/backgrounds
    - MPGD configuration



Work Underway on ePIC Design

- Optimization of barrel tracking
  - Achieving a realistic, low-mass design with good performance
    - Efficiency/seeding studies w/backgrounds
    - MPGD configuration
- Reference design did not include a backwards HCAL
  - Steel will need to be present
  - Is there a strong physics justification?



Work Underway on ePIC Design

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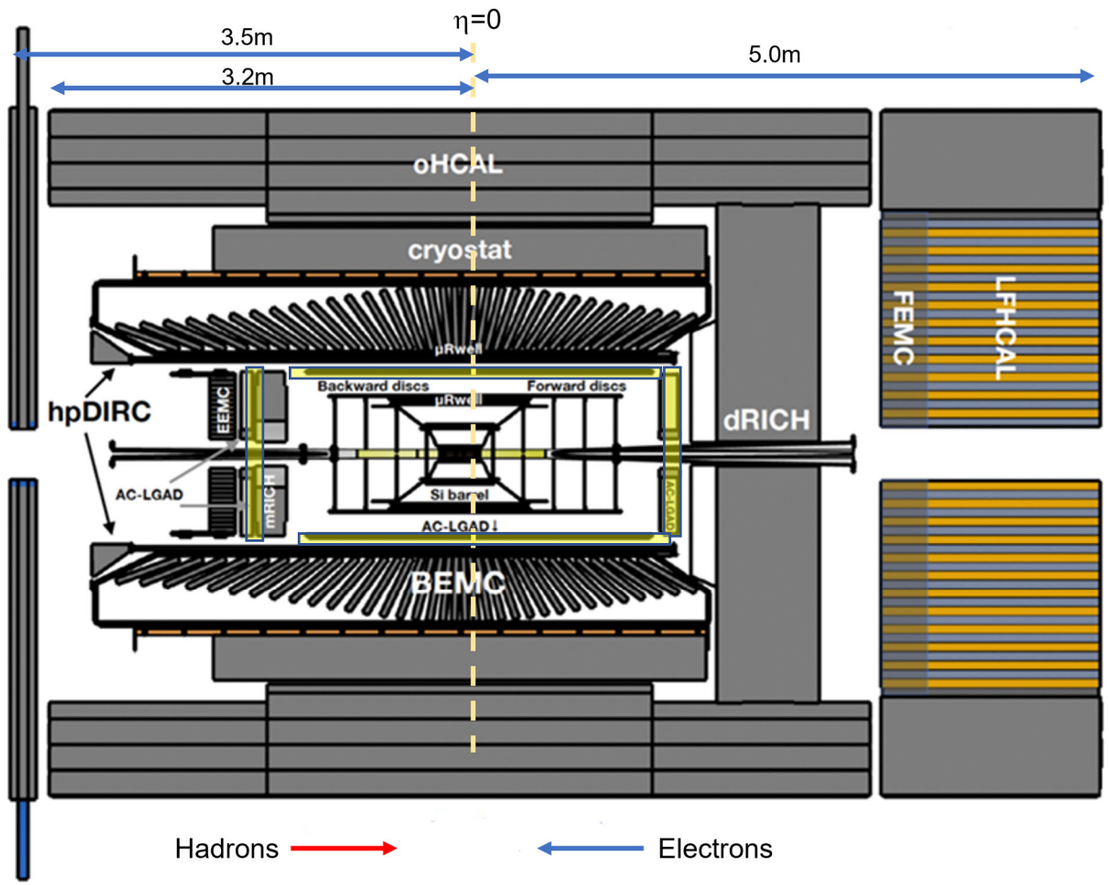
  - Achieving a realistic, low-mass design with good performance
    - Efficiency/seeding studies w/backgrounds
    - MPGD configuration
- Reference design did not include a backwards HCAL
  - Steel will need to be present
  - Is there a strong physics justification?
- AC-LGADs are a new, unproven technology
  - Balance risk with R&D, alternatives



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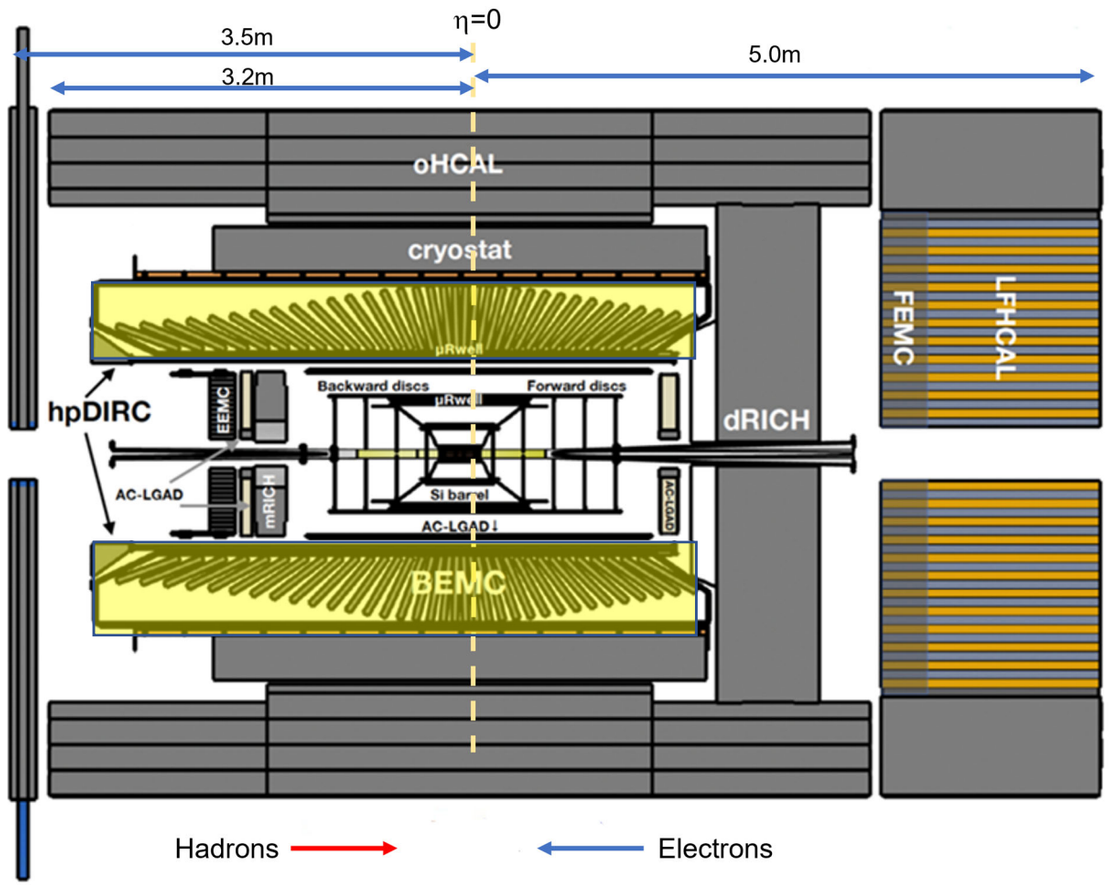

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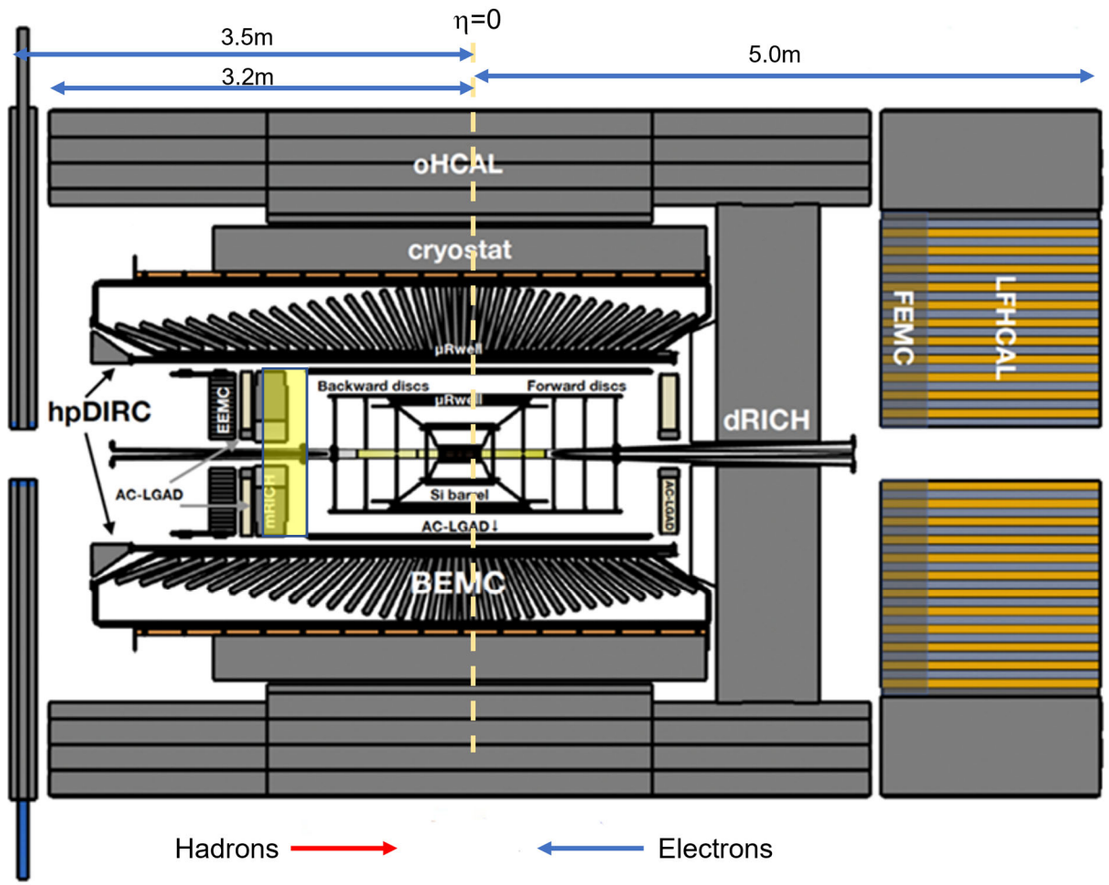

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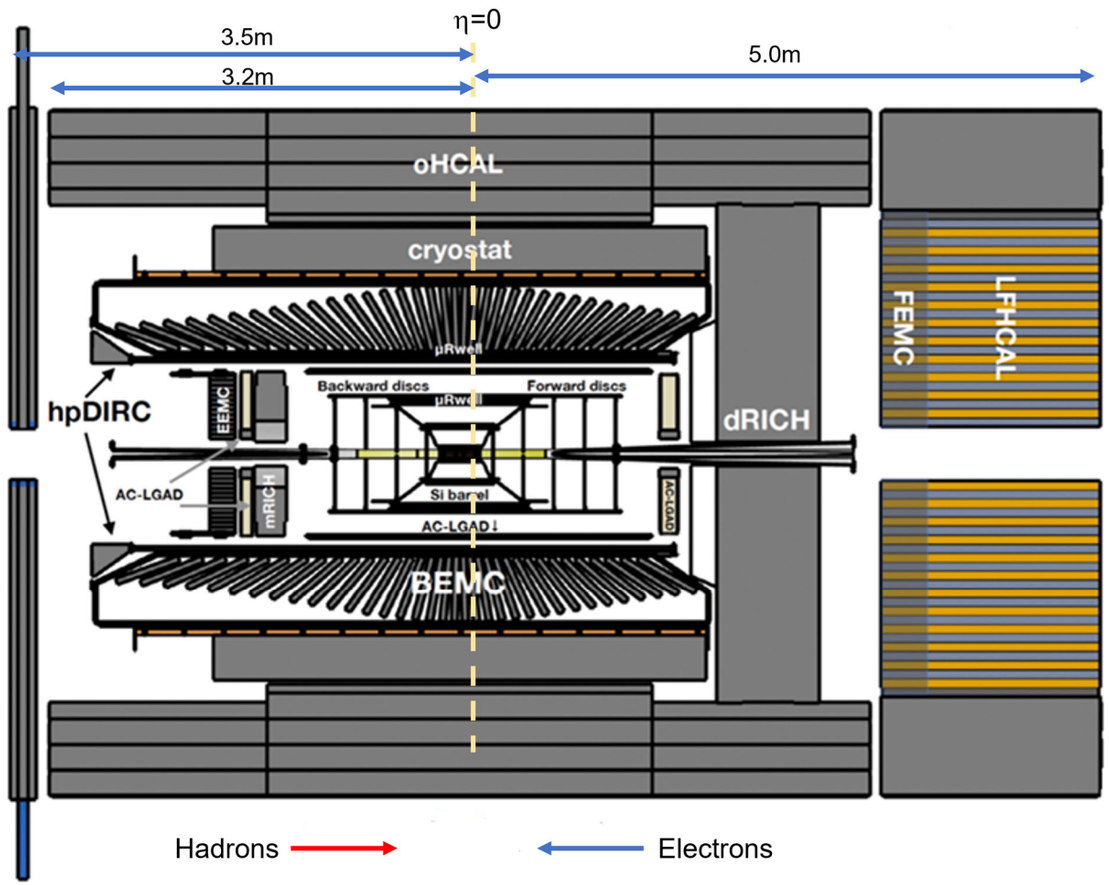
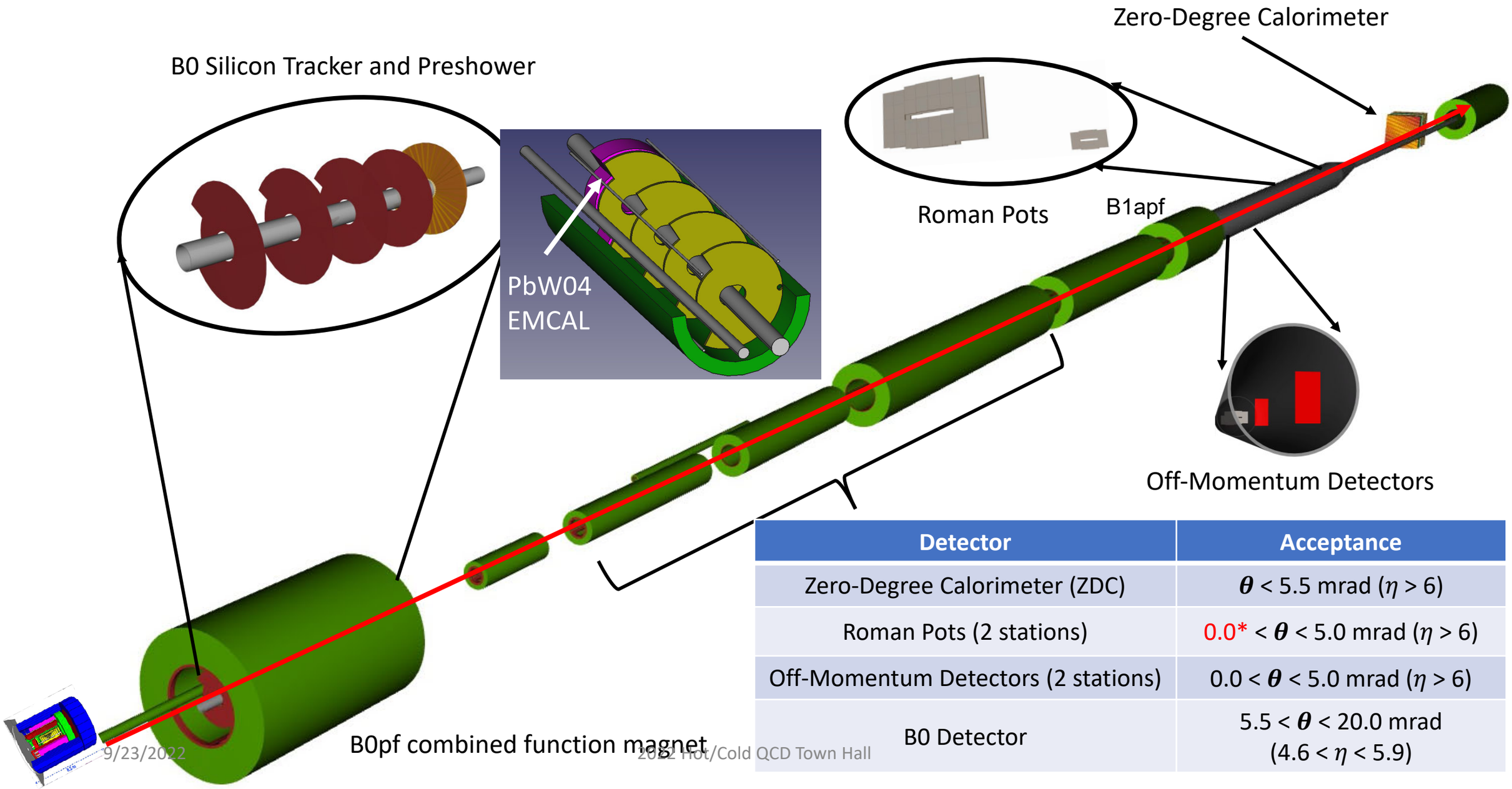


Process is driven by physics performance!

Iterative process between ePIC Collaboration and EIC Project

The Far-Forward Detectors



Detector	Acceptance
Zero-Degree Calorimeter (ZDC)	θ < 5.5 mrad (η > 6)
Roman Pots (2 stations)	0.0* < θ < 5.0 mrad (η > 6)
Off-Momentum Detectors (2 stations)	0.0 < θ < 5.0 mrad (η > 6)
B0 Detector	5.5 < θ < 20.0 mrad (4.6 < η < 5.9)

EICUG Draft Recommendation

Recommendation: We recommend expeditious completion of the EIC as the highest priority for facility construction

The EIC is a powerful and versatile new accelerator facility, capable of colliding high-energy beams ranging from heavy ions to polarized light ions and protons with high-energy polarized electron beams. In the 2015 Long Range Plan the EIC was put forward as the highest priority for new facility construction and the expeditious completion remains a top priority for the nuclear physics community. The EIC, accompanied by a general-purpose large-acceptance detector, ePIC, will be a discovery machine that addresses fundamental questions such as the origin of mass and spin of the proton as well as probing dense gluon systems in nuclei. It will allow for the exploration of new landscapes in QCD, permitting the "tomography", or high-resolution multidimensional mapping of the quark and gluon components inside of nucleons and nuclei. Realizing the EIC will keep the U.S. on the frontiers of nuclear physics and accelerator science and technology.

EICUG Draft Initiative

Initiative: We recommend targeted efforts to enable the timely realization of a second, complementary detector at the Electron-Ion Collider

The EIC is a transformative accelerator that will enable studies of nuclear matter with unprecedented precision. The EIC encapsulates a broad physics program with experimental signatures ranging from exclusive production of single particles in ep scattering to very high multiplicity final states in eA collisions. High statistical precision matched with a similar or better level of systematic precision is vital for the EIC and this can only be achieved with carefully optimized instrumentation. A natural and efficient way to reduce systematic errors is to equip the EIC with two complementary detectors. Two detectors will expand the scientific opportunities, draw a more complete picture of the science, and mitigate the inherent risks that come with exploring uncharted territory by providing independent confirmation of discovery measurements. The second detector effort will rely heavily on the use of generic detector R&D funds and accelerator design effort to integrate the detector into the interaction region. The design and construction of such a complementary detector and interaction region are interwoven and must be synchronized with the current EIC project and developed in the context of a broad and engaged international EIC community.