The ePIC Detector

Joerg Reinhold

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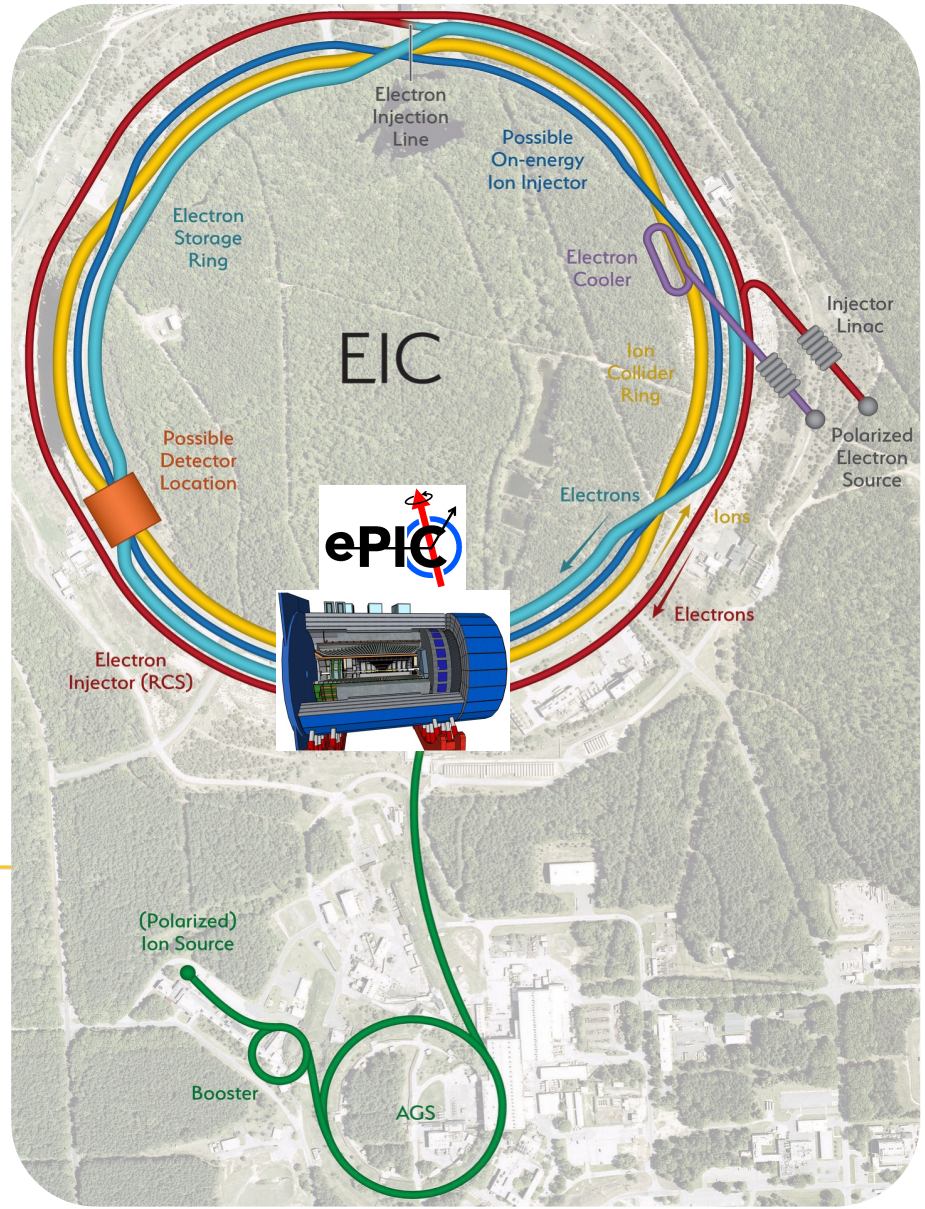
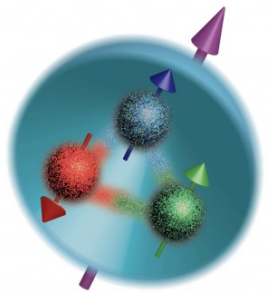
for the ePIC Collaboration



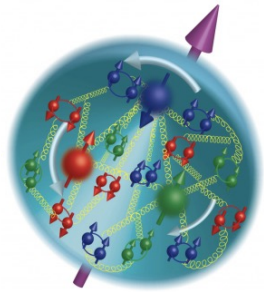
With thanks to John Lajoie

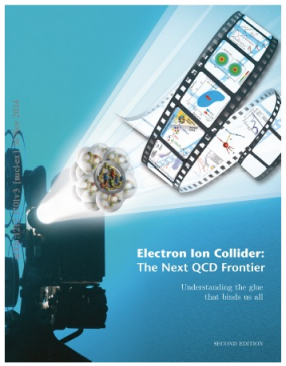
The EIC Physics Program

The Proton (1970s)

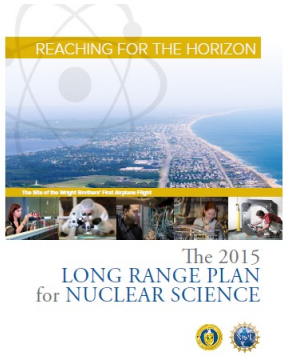


The Proton (2000s)

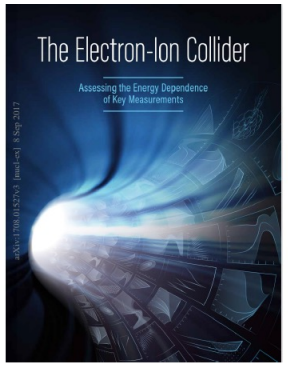




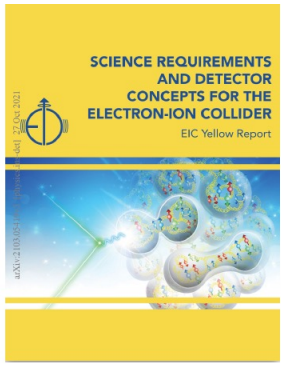
2012



2015

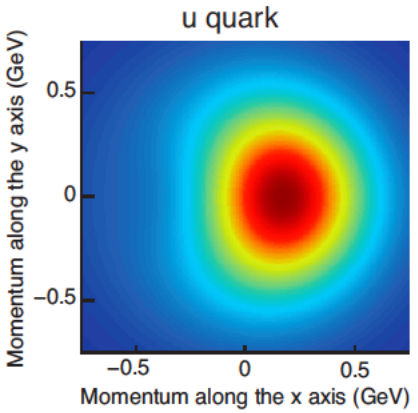


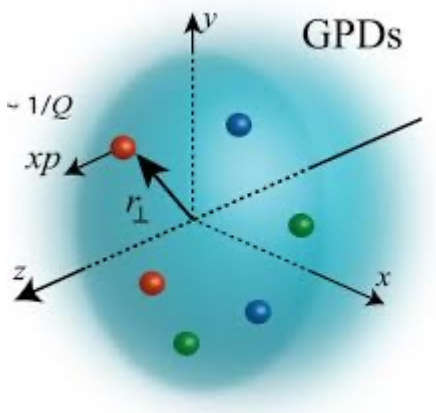
2017



2020

Multidimensional imaging of the structure of the proton





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

Requirements for an a EIC Detector

Radius/Distance from IP

Vertex detector → Identify primary and secondary vertices,
Low material budget: 0.05% X/X_0 per layer;
High spatial resolution: 10 um pitch CMOS Monolithic Active Pixel Sensor

Central tracker → Measure charged track momenta
MAPS – tracking layers in combination with micro pattern gas detectors
MPGD: µRWell or MicroMegas

electron and hadron endcap tracker → Measure charged track momenta
MAPS – disks in combination with micro pattern gas detectors

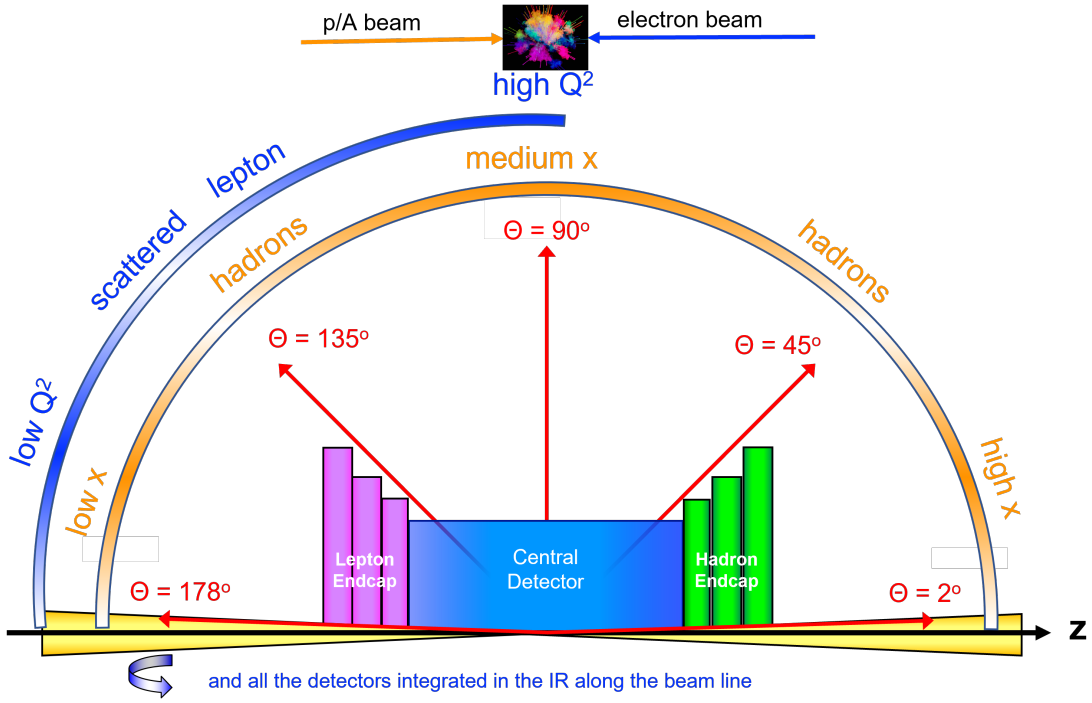
Particle Identification → pion, kaon, proton separation on track level
RICH detectors (modular and dual radiator RICH, DIRC) & Time-of-Flight
high resolution timing detectors (LAPPDs, LGAD) 10 – 30 ps
novel photon sensors: MCP-PMT / LAPPD

Electromagnetic calorimeter → Measure photons (E, angle), identify electrons
$PbWO_4$ Crystals (backward), W/SciFi Spacal (forward)
Barrel: Pb/SciFi+imaging part or new Scintillating glass

Hadron calorimeter → Measure charged hadrons, neutrons and K_L^0
challenge achieve ~50%/√E + 10% for low E hadrons (<E> ~ 20 GeV)
Fe/Sc sandwich with longitudinal segmentation

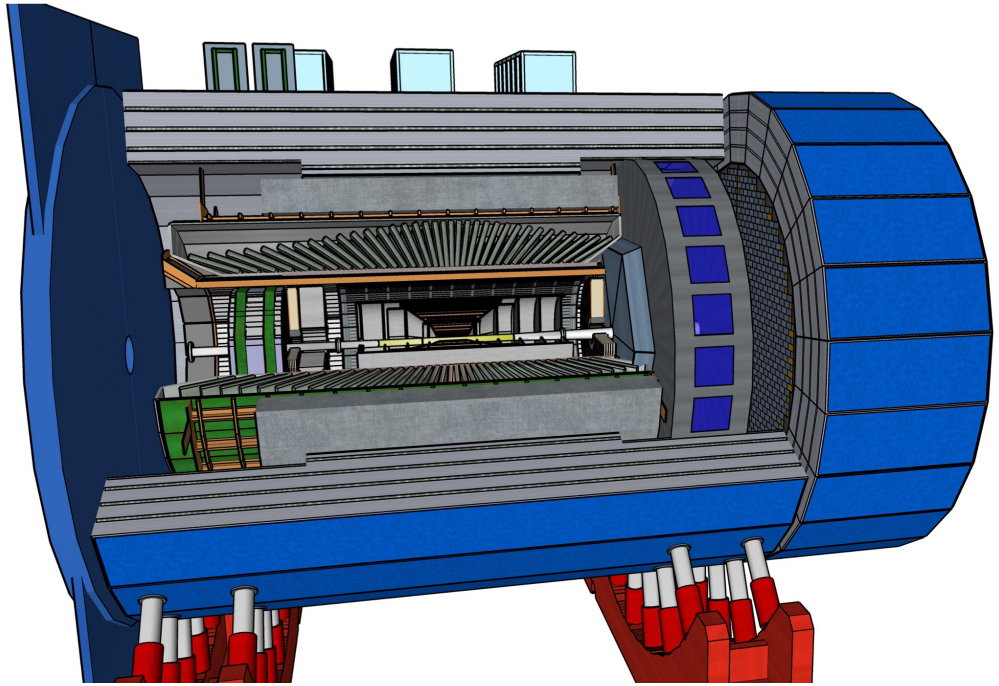
DAQ & Readout Electronics: trigger-less / streaming DAQ
Integrate AI into DAQ → cognizant Detector

Very forward and backward detectors → scattered particles under very small angles
Silicon tracking layers in lepton and hadron beam vacuum
Zero – degree high resolution electromagnetic and hadronic calorimeter



A Brief Timeline

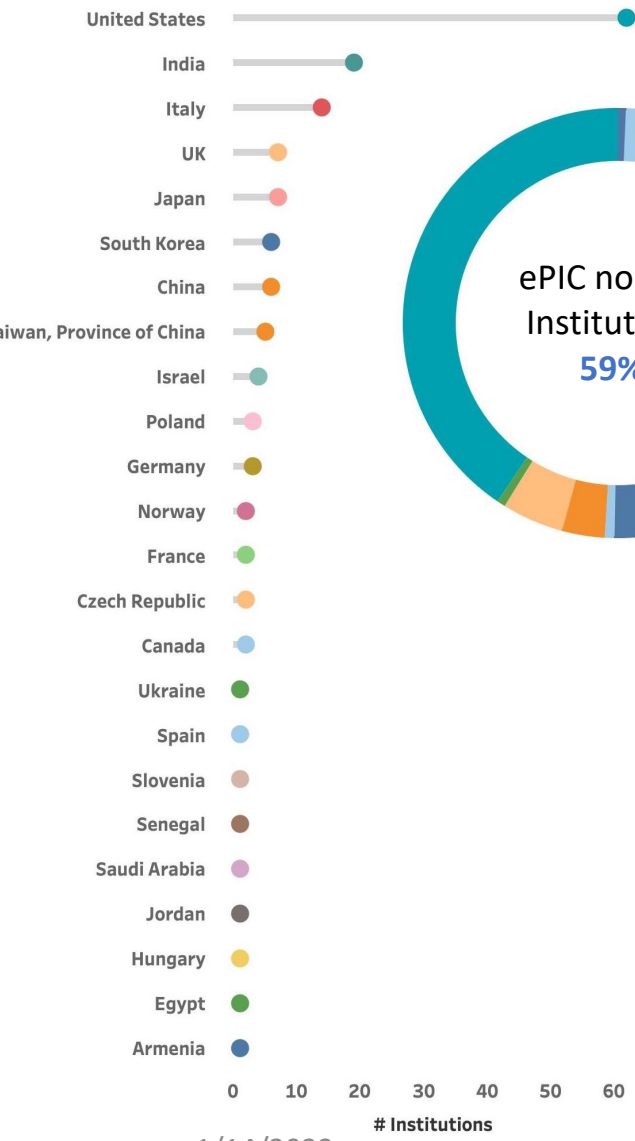
- EICUG Yellow Report (2020-21)
- Call for proposals issued jointly by BNL and JLab in March 2021
  - Proposals due Dec. 1, 2021
  - ATHENA, CORE and ECCE proposals submitted
- Public DPAP meetings Dec. 13-15, 2021
  - Presentations from proto-collaborations
  - Panel-assigned homework questions
- Second DPAP session Jan. 19-21, 2022
- DPAP closeout March 8th, 2022
  - Final report available March 21st, 2022
  - ECCE proposal chosen as basis for first EIC detector 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 ePIC Collaboration meeting July 26-29, 2022
- ePIC Charter approved Dec. 14th, 2022

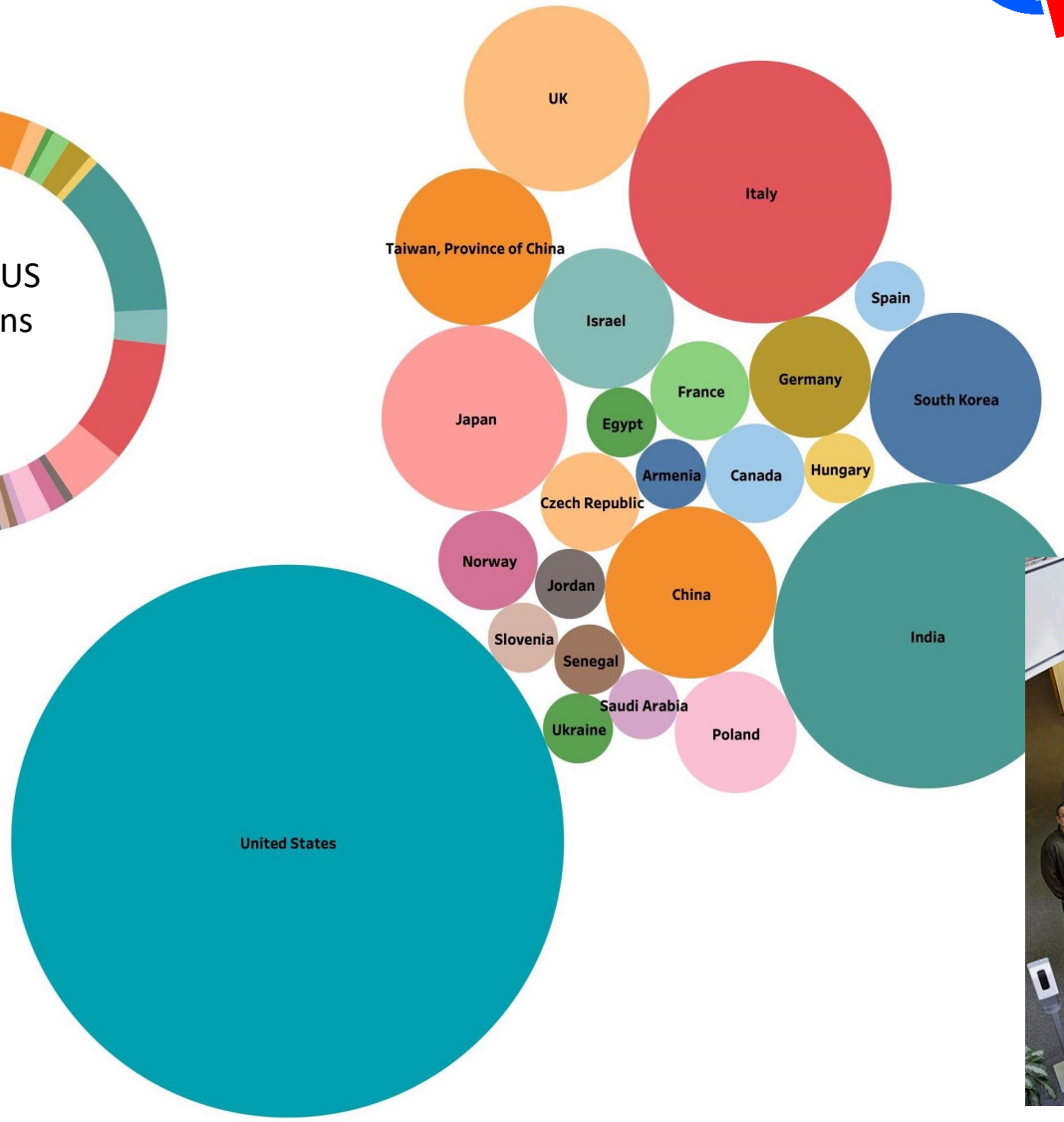


ePIC Detector

- 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

The ePIC Collaboration



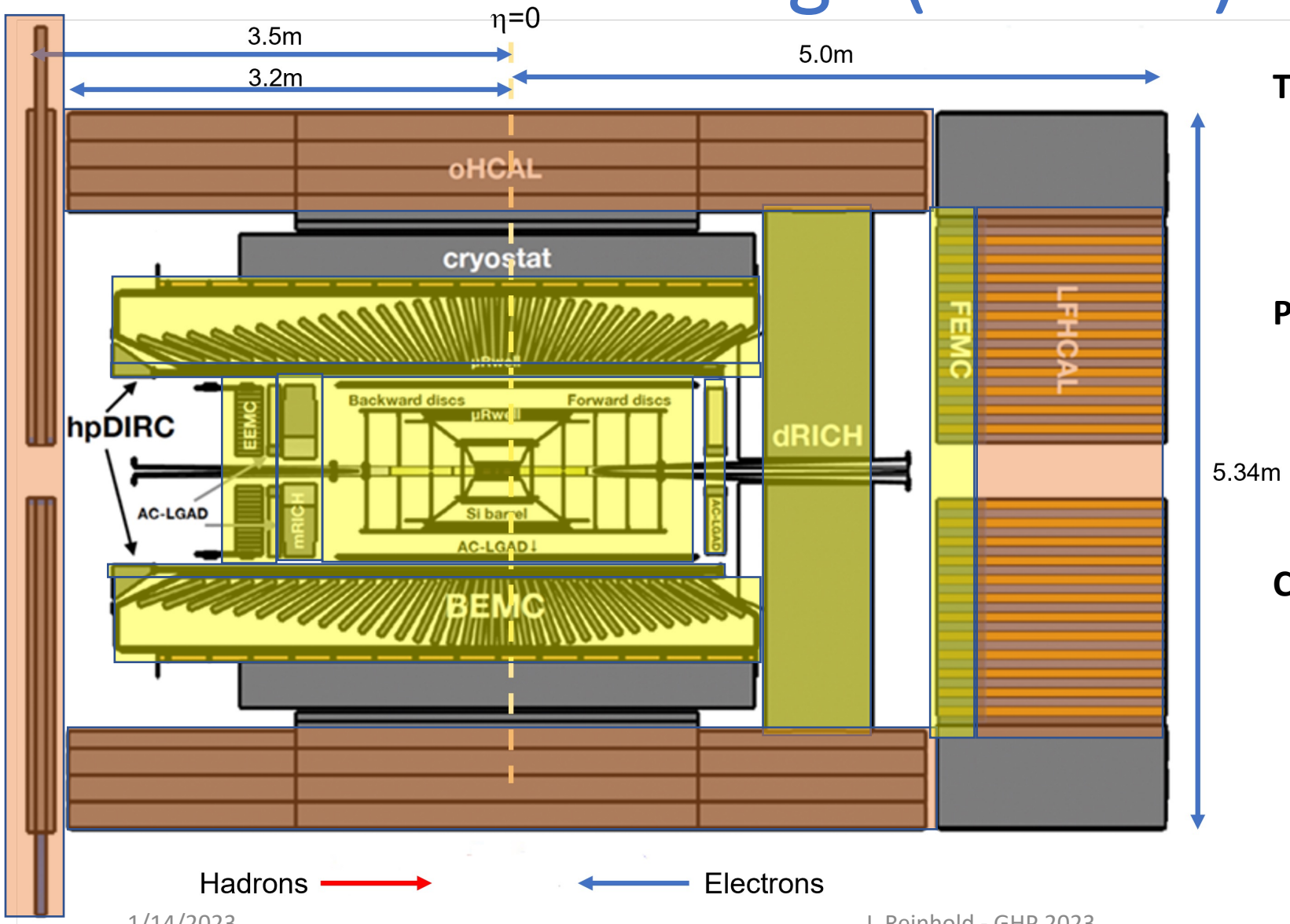


160+ institutions
24 countries

500+ participants

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

ePIC Detector Design (Current)



Tracking:

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

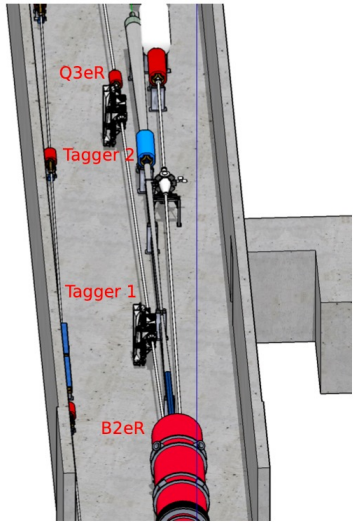
PID:

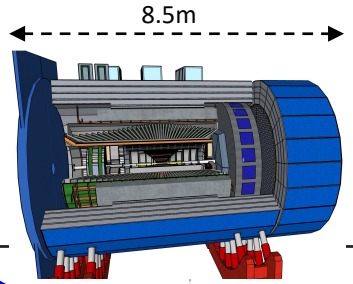
- hpDIRC
- mRICH/pfRICH
- dRICH
- AC-LGAD (~30ps TOF)

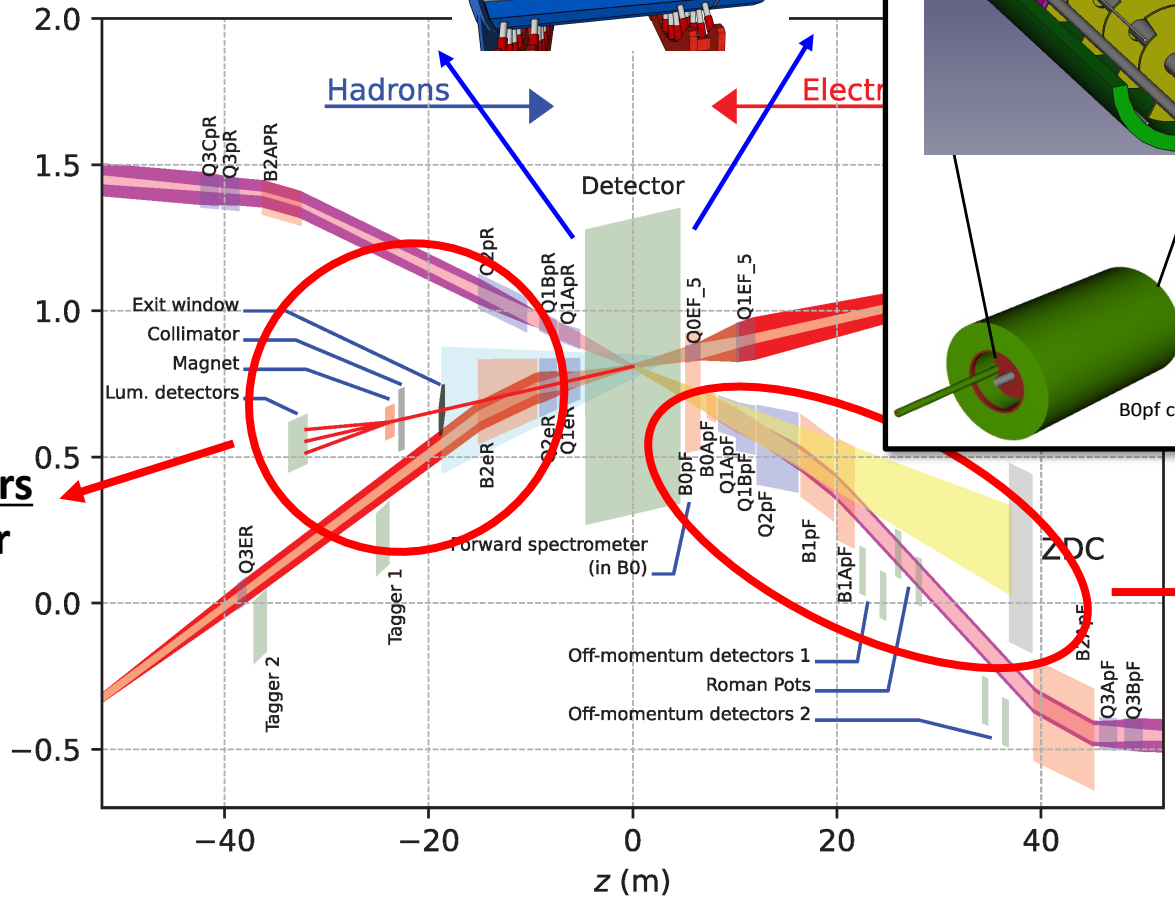
Calorimetry:

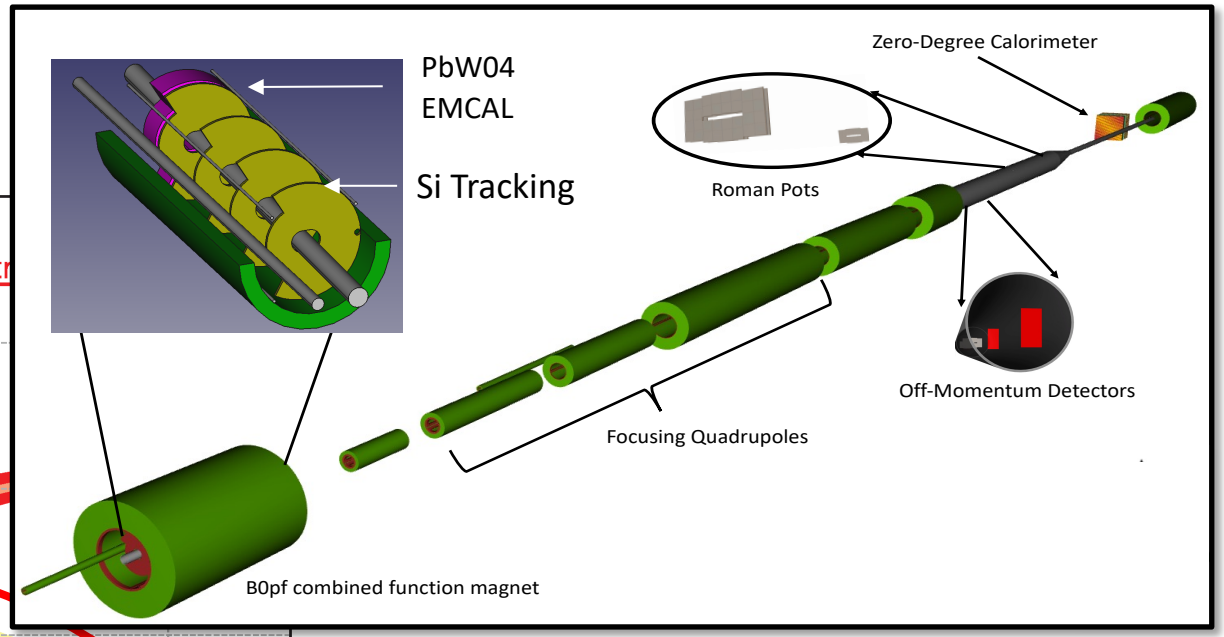
- SciGlass/Imaging Barrel EMCal
- PbWO4 EMCal in backward direction
- Finely segmented EMCal +HCal in forward direction
- Outer HCal (sPHENIX re-use)
- Backwards HCal (tail-catcher)

Far-Forward and Far-Backward Detectors









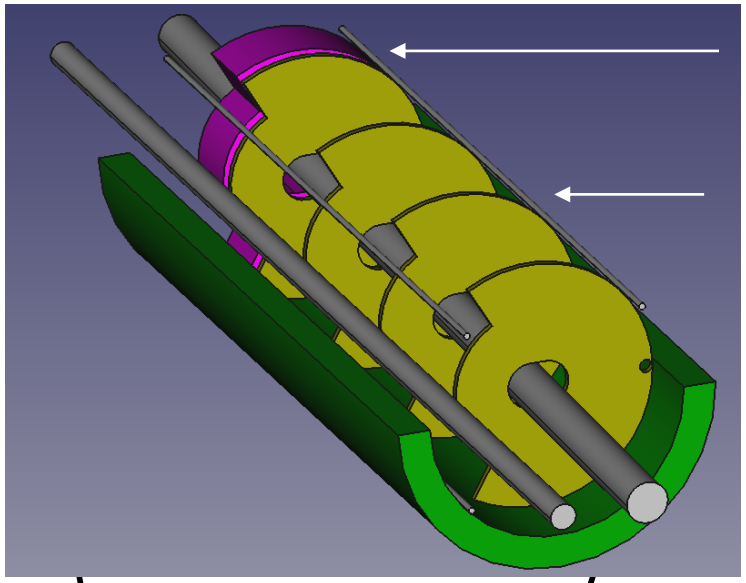
Far-Backward Detectors

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

Far-Forward Detectors

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

The Far-Forward Detectors



PbW04
EMCAL

Si Tracking

Zero-Degree Calorimeter

Roman Pots

B1apf

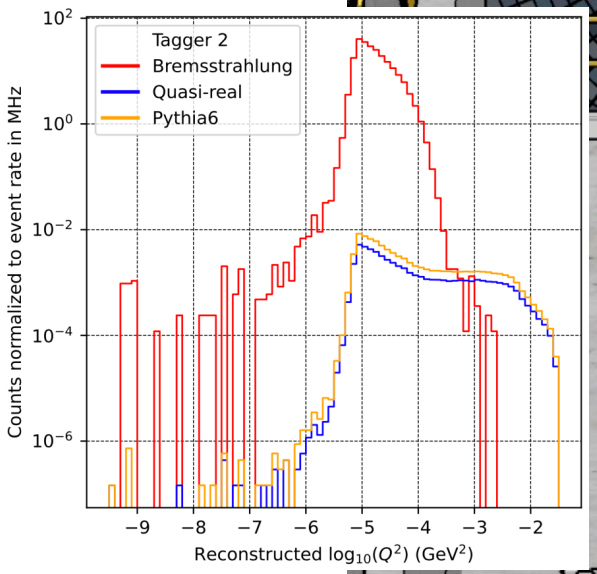
Off-Momentum Detectors

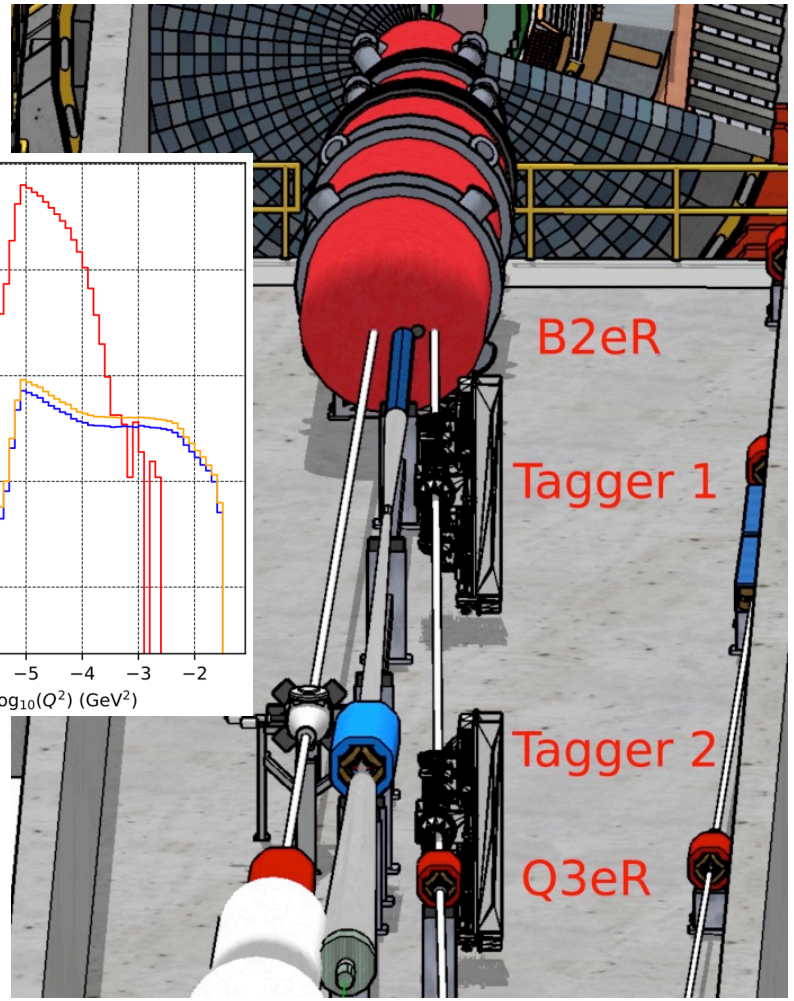
B0pf combined function magnet

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

Far Backwards Detectors

Low-Q^2 tagger



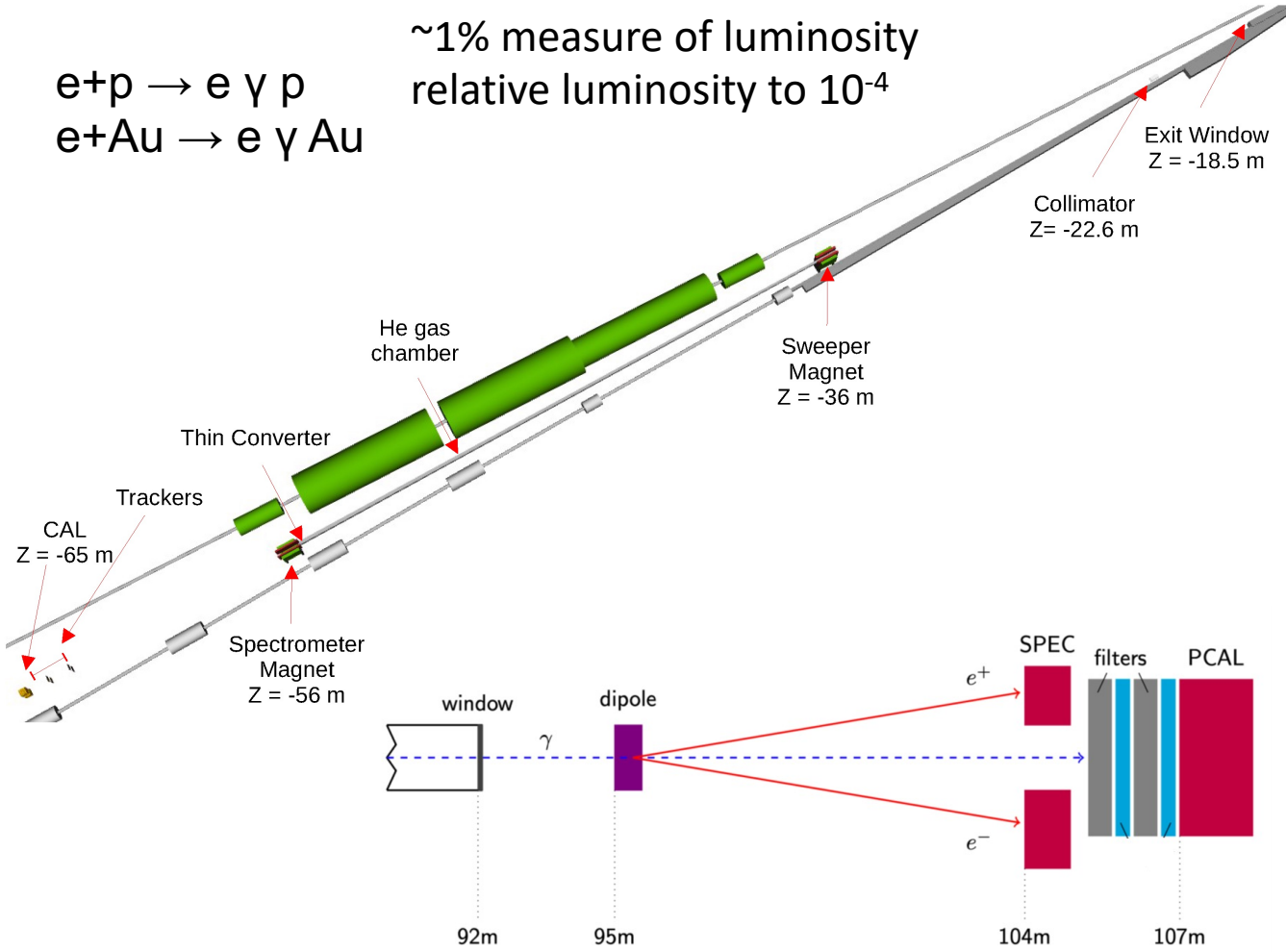


Clean photoproduction signal for $10^{-3} < Q^2 < 10^{-1}$

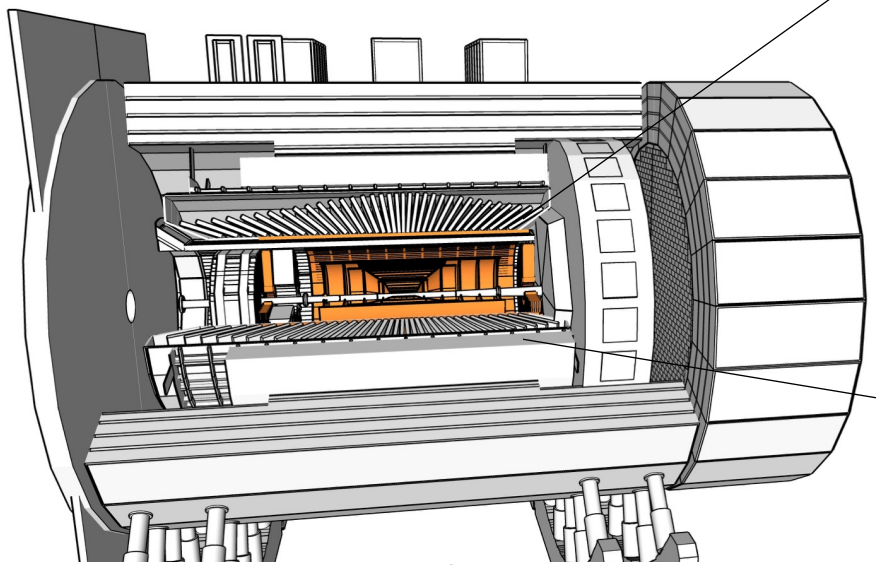
Luminosity Spectrometer

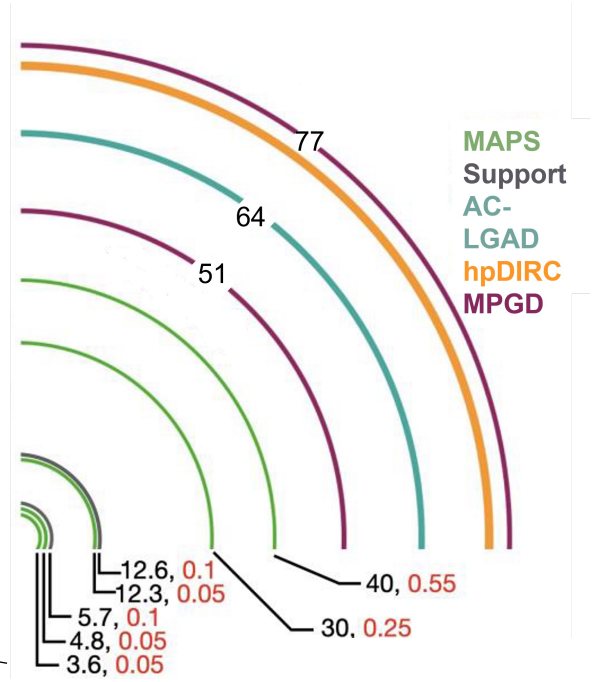
e+p ⟶ e γ p
e+Au ⟶ e γ Au

~1% measure of luminosity relative luminosity to 10^{-4}



Tracking



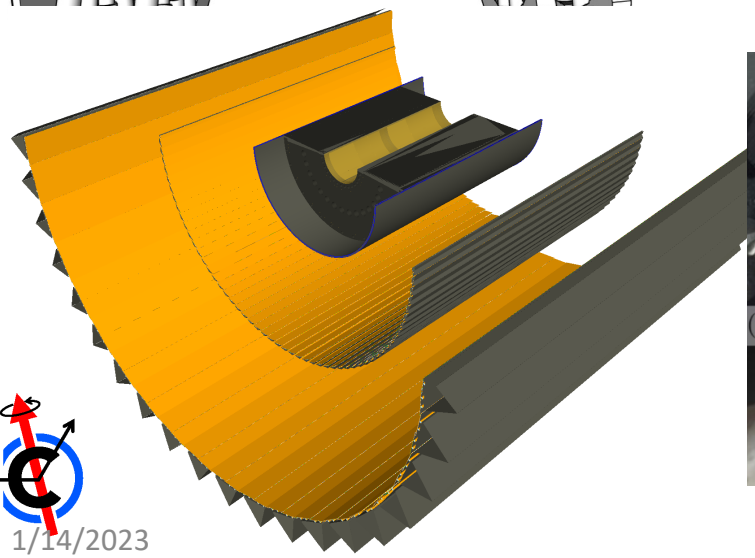


Si Tracker based on ALICE ITS3 65nm MAPS sensors.

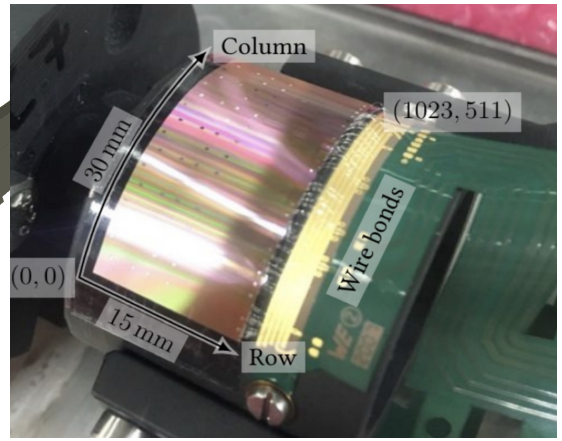
Five layers in barrel, supplemented by MPGDs for pattern recognition.

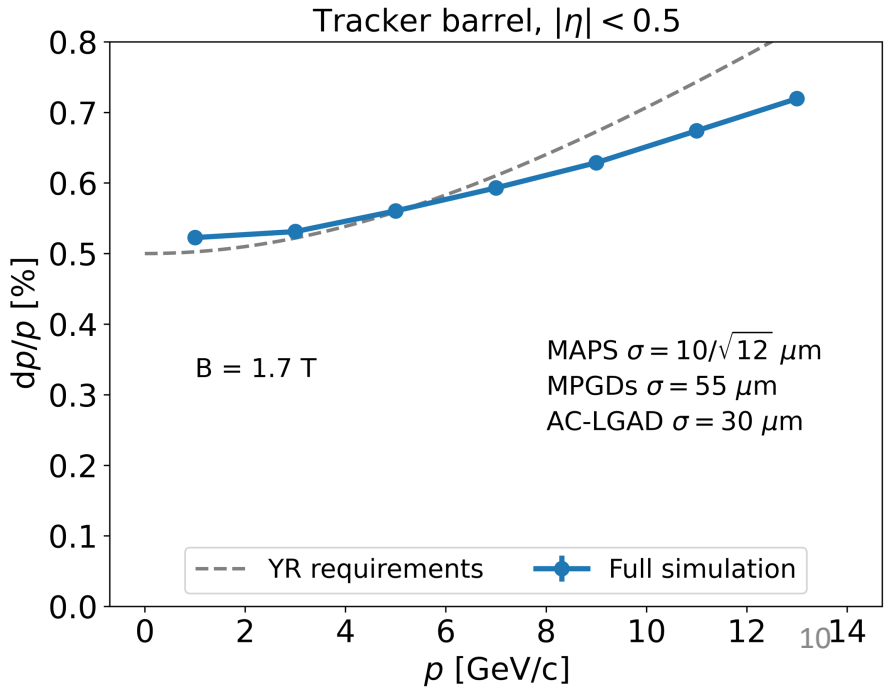
Five discs in forward/backward directions (+MPGD in forward)

Meets EICUG Yellow Report design requirements.

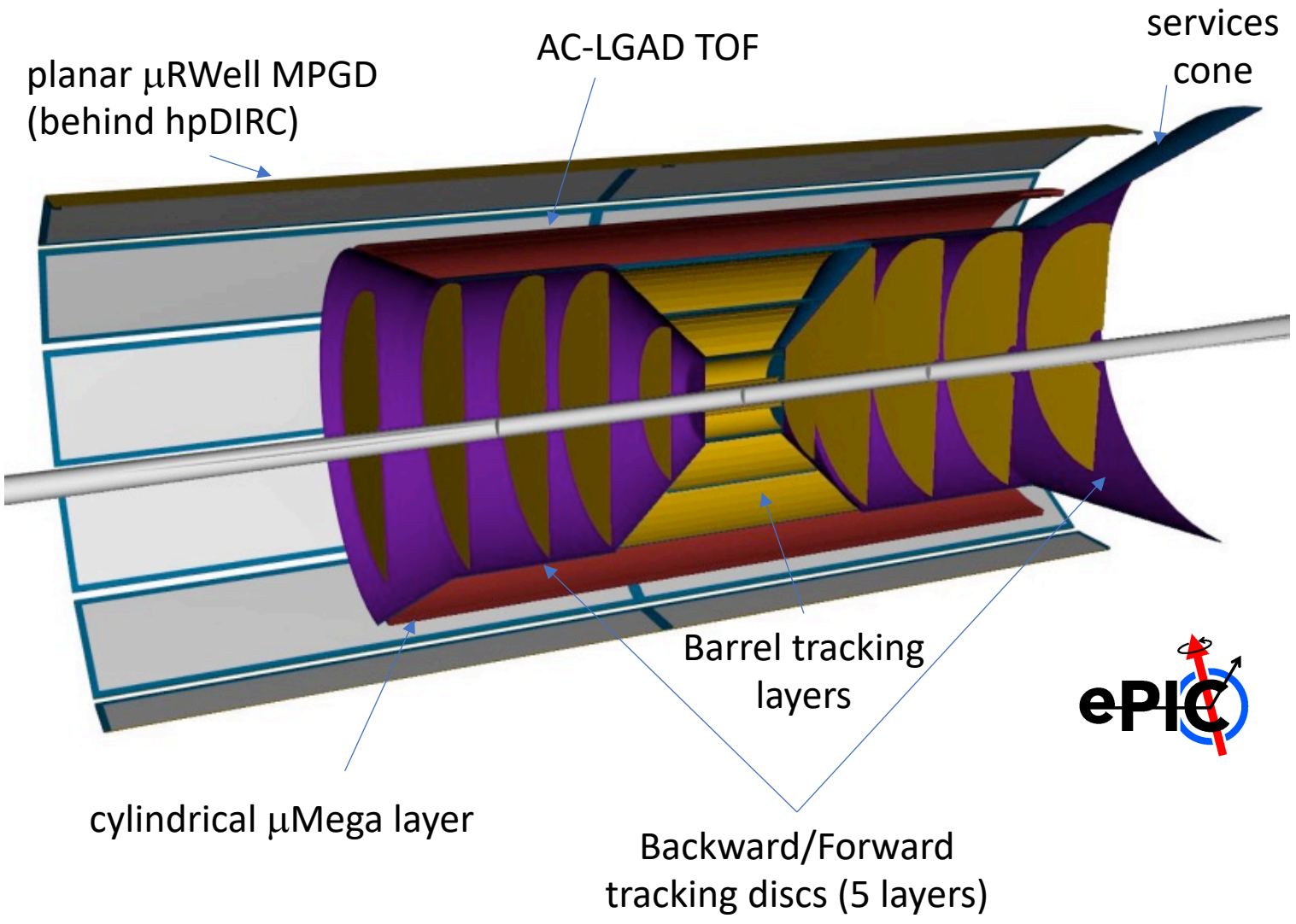


First "µITS3" assembly at CERN





Tracking



Inner two vertex layers optimized for beam pipe bakeout and ITS3 sensor size.

Third layer dual-purpose (vertex + sagitta)

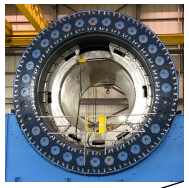
Cylindrical μMega/TOF provide pattern recognition redundancy

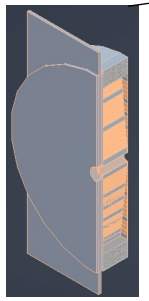
μRWell behind hpDIRC provides ring seed direction, space point for pattern recognition

BARREL	r [mm]	l [mm]	X/X0 %
Si vertex layer 0	36	270	0.05
Si vertex layer 1	48	270	0.05
Si layer 2	**120**	270	**0.05**
Si sagitta layer 3	**270**	540	**0.25**
Si sagitta layer 4	**420**	840	0.55
Cyl.Micromegas layer	550	2300	0.5
AC-LGAD layer	640	2400	1.0
μRWELL behind DIRC	**730**	3420	~1.0%

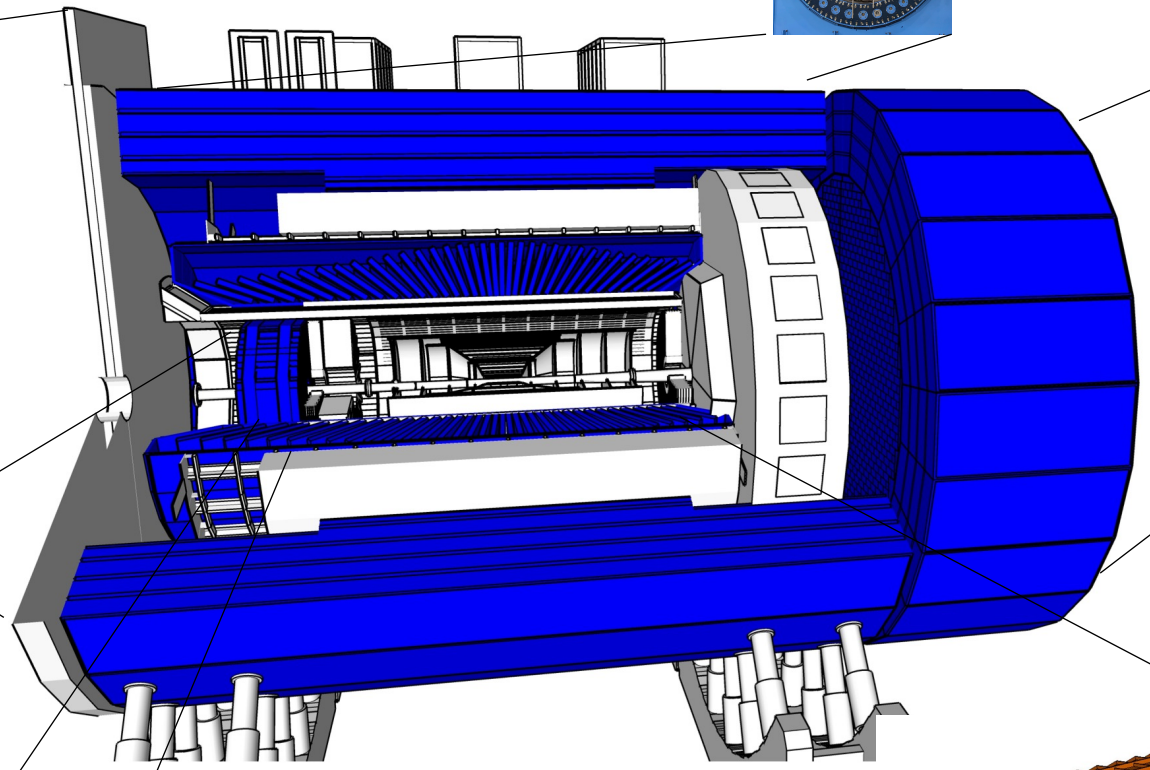
Calorimetry

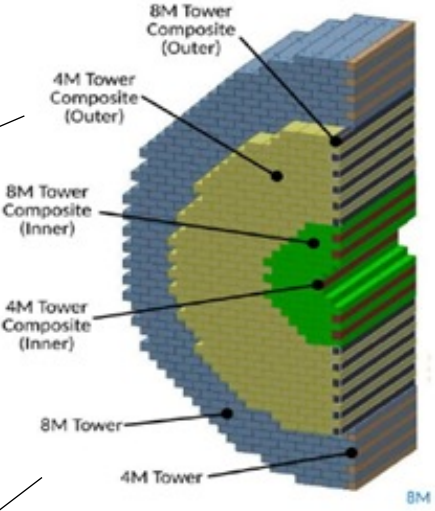
Barrel HCAL (sPHENIX re-use)



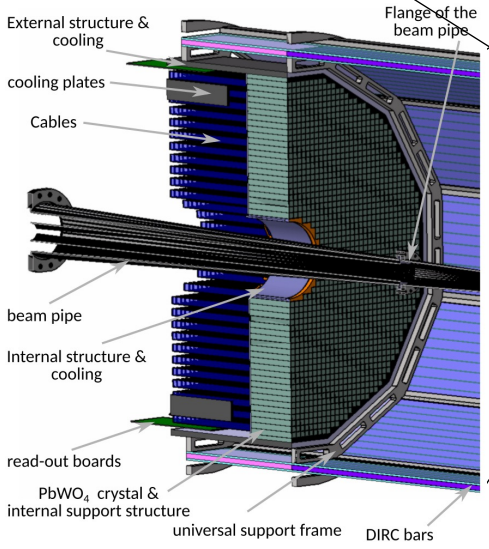


Backwards HCal Steel/Sc Sandwich tail catcher

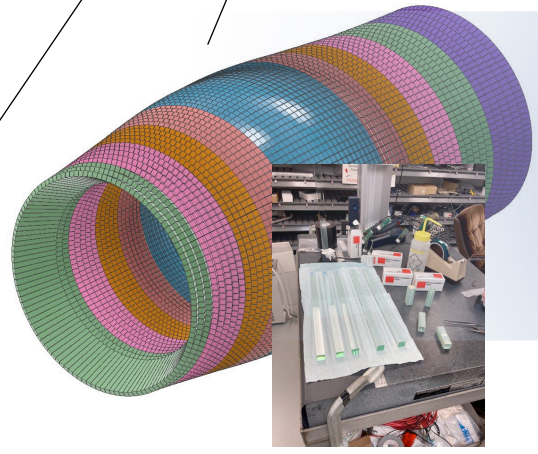




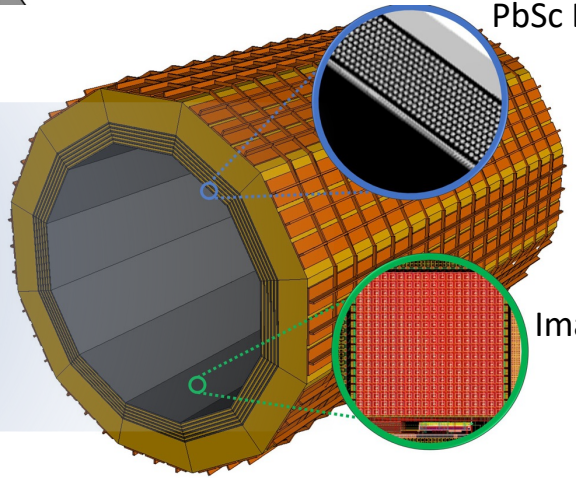
High granularity W/SciFi EMCal
Longitudinally separated HCAL with high-η insert



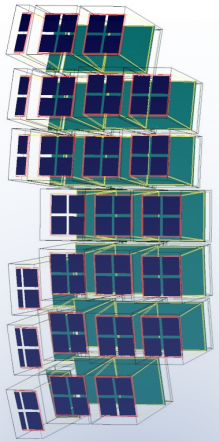
Backwards EMCal PbW04 crystals



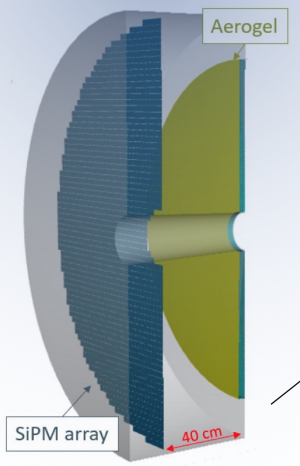
Complementary options for BECAL: SciGlass or Imaging Calorimeter



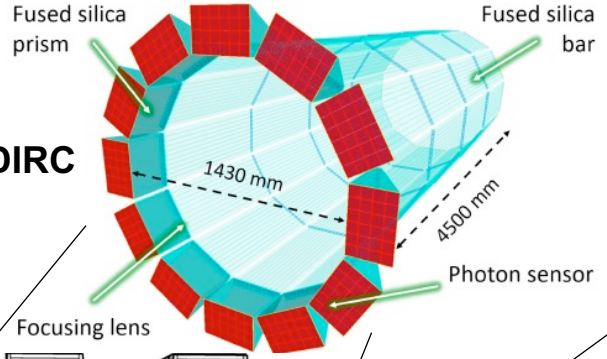
Particle ID

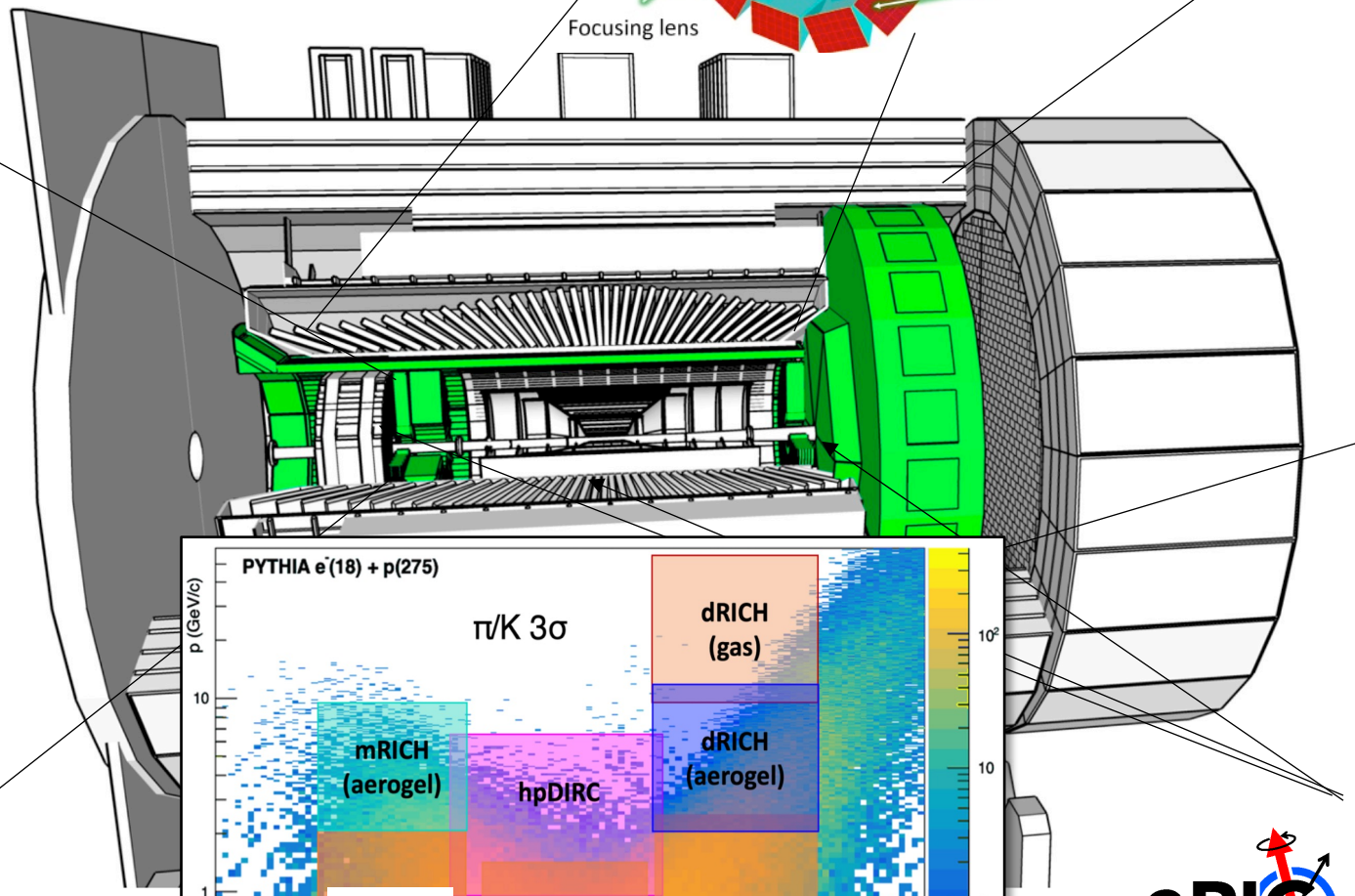


Modular (mRICH) or Proximity Focused (pfRICH)

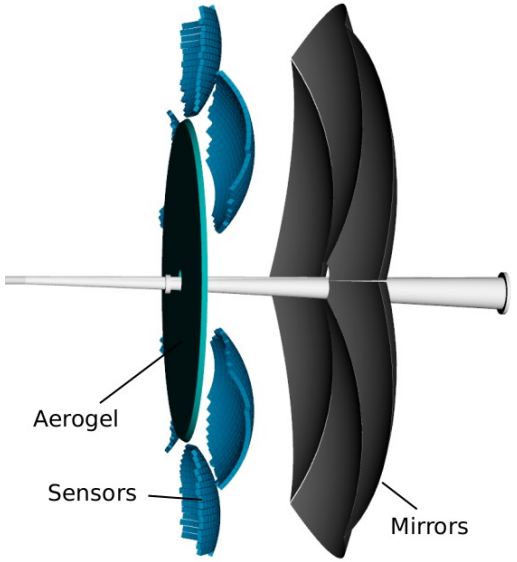


High-Performance DIRC

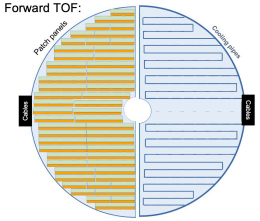


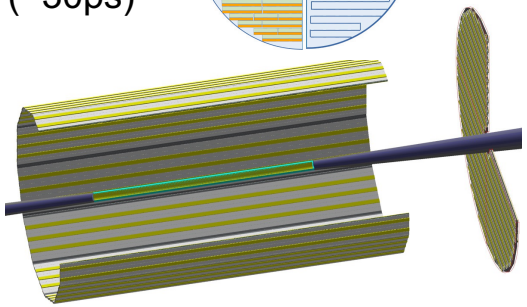


Dual-Radiator RICH (dRICH)

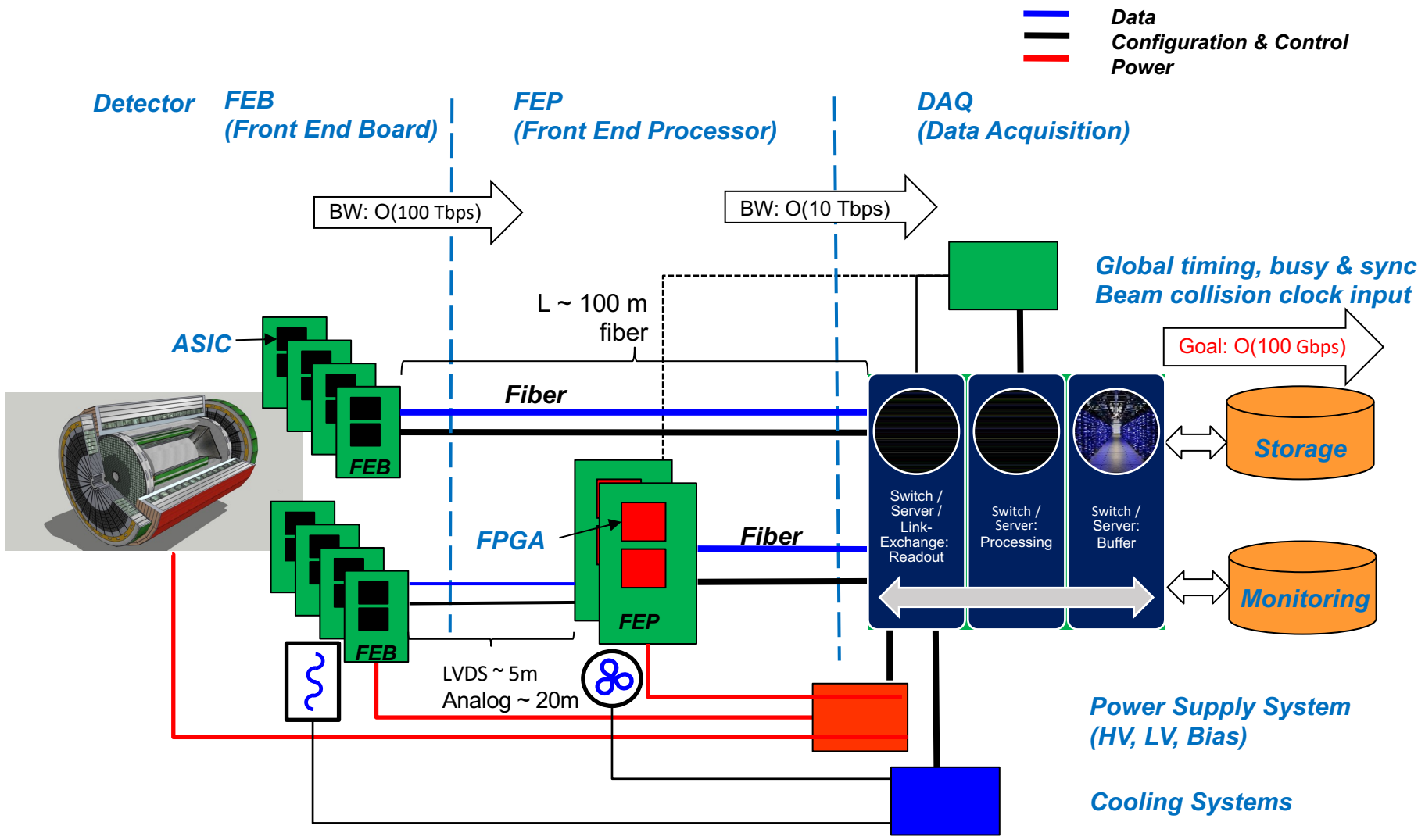


AC-LGAD TOF (~30ps)





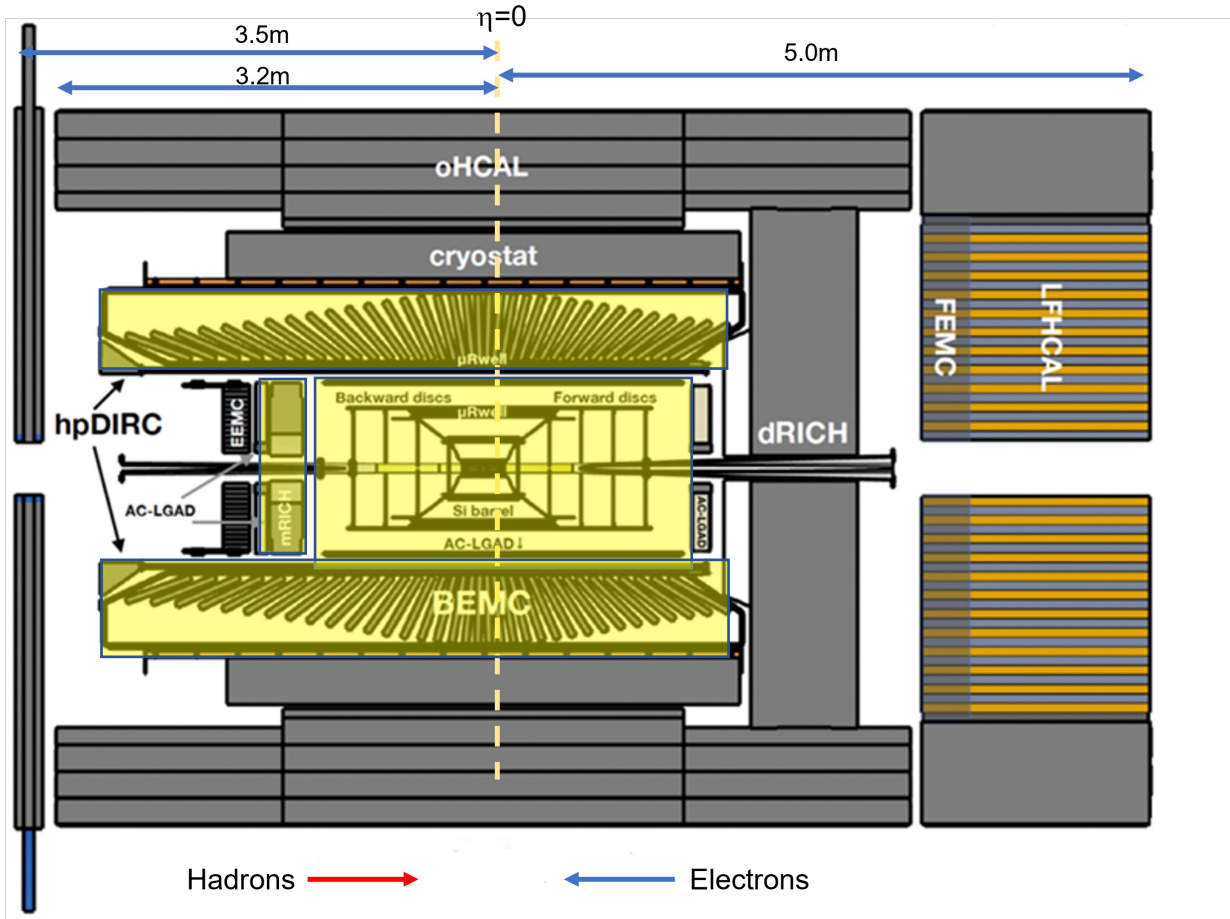
ePIC Streaming DAQ



- No External trigger
- All collision data digitized but aggressively zero suppressed at FEB
- 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
- Data volume is reduced as much as possible at each stage

Work Underway on ePIC Design

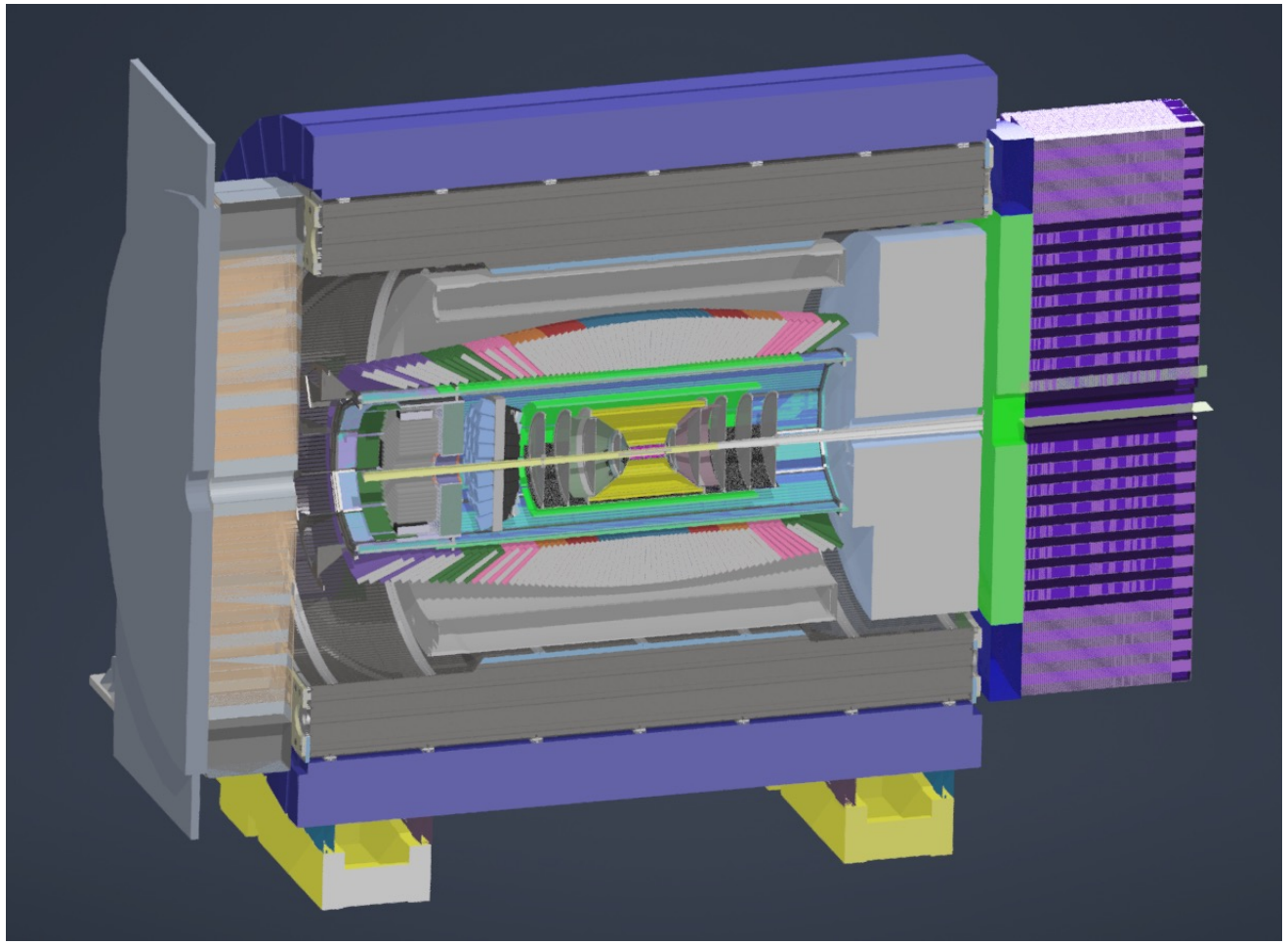
- Tracking optimization
  - Achieve a realistic, low-mass design with good performance
    - Efficiency/seeding studies w/backgrounds
    - MPGD configuration
    - Integrate support and services
- Alternative technologies for barrel EMCal
- PID in backwards region (competing implementations)



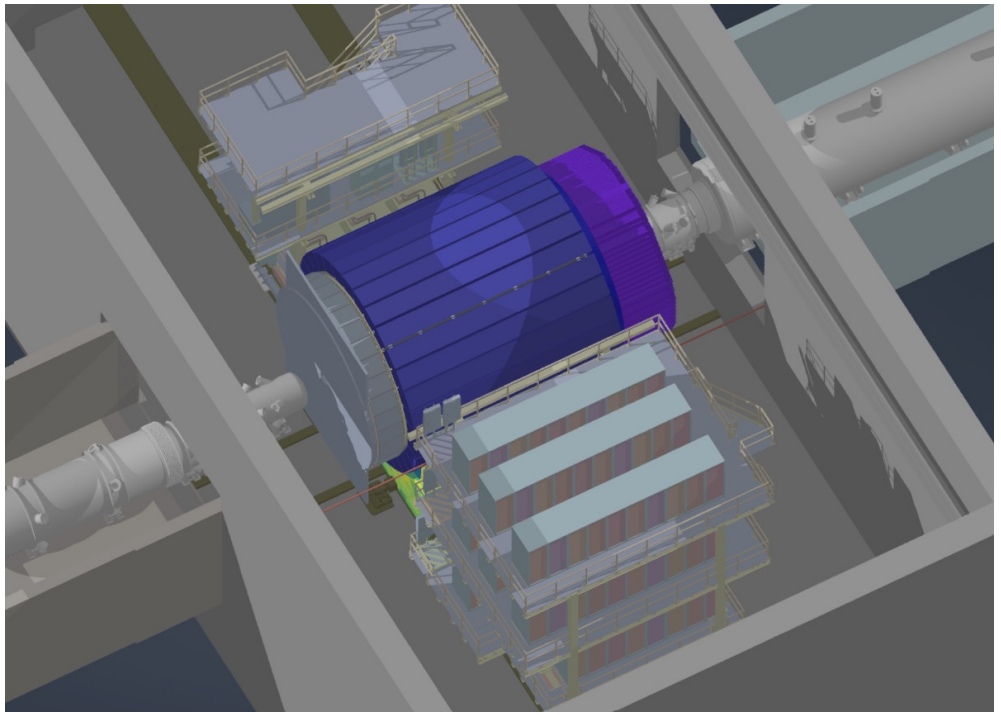
Process is driven by physics performance!

Iterative process between ePIC Collaboration and EIC Project

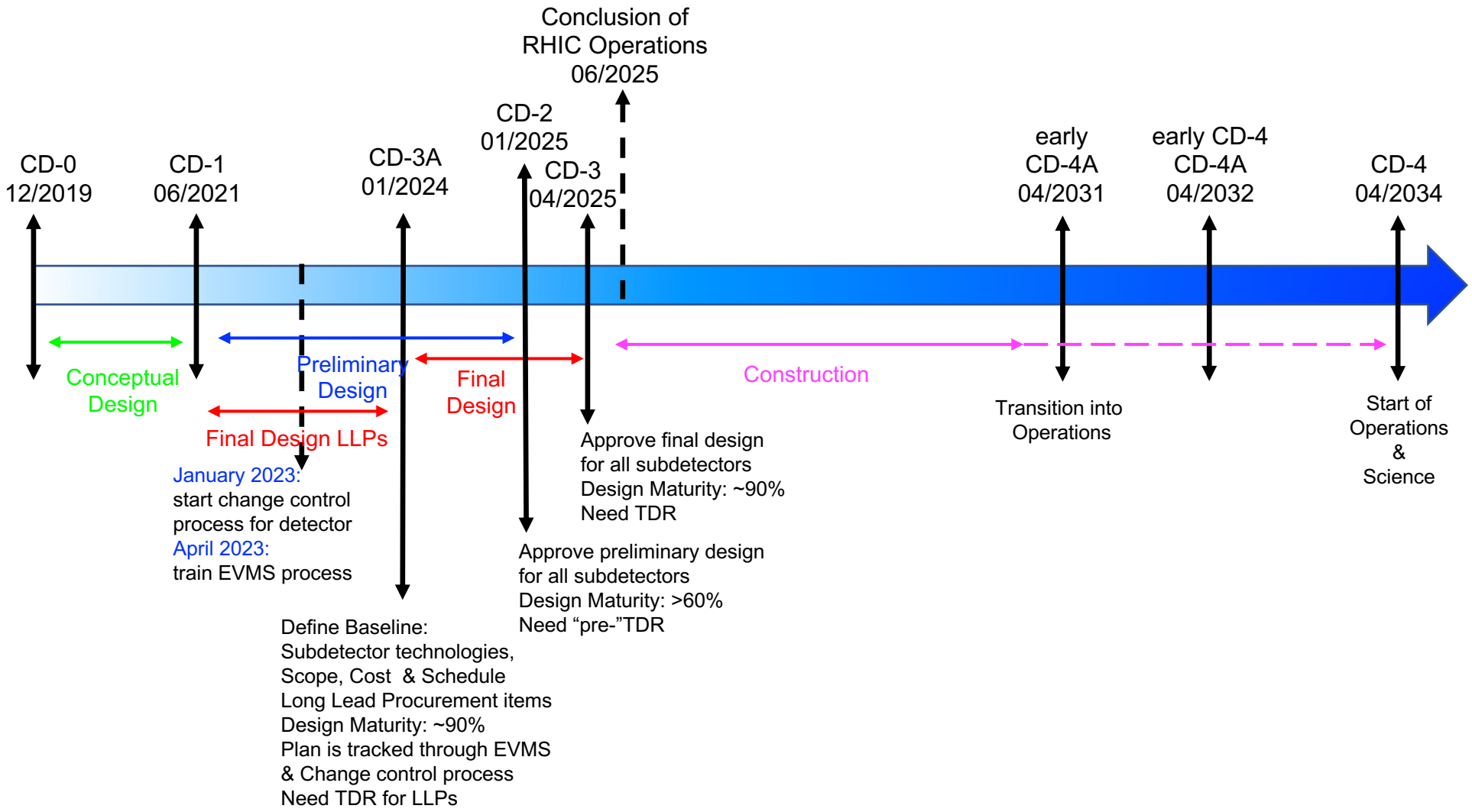
Engineering Design



Full CAD design of ePIC ongoing to facilitate *realistic* detector integration, including cabling and services.



EIC Project Schedule



Conclusions

- The ePIC Collaboration has kicked-off:
  - Charter approved Dec. 14, 2022
    - Leadership elections underway
  - Second collaboration meeting Jan. 9-11, 2023
    - https://indico.bnl.gov/event/17621/
  - Ongoing WG meetings focused on developing the ePIC technical design for CD-2/3A
    - Forum to focus community and R&D consortium expertise
  - Strong support and participation from EIC community
- 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
  - International participation is key!
  - Progress towards DOE milestones CD-3A/CD-2/CD-3 in 2023