



October 10th, 2025, CPAD'25 UPenn

The ePIC Detector

HEP Instrumentation Synergies

Oskar Hartbrich

ORNL



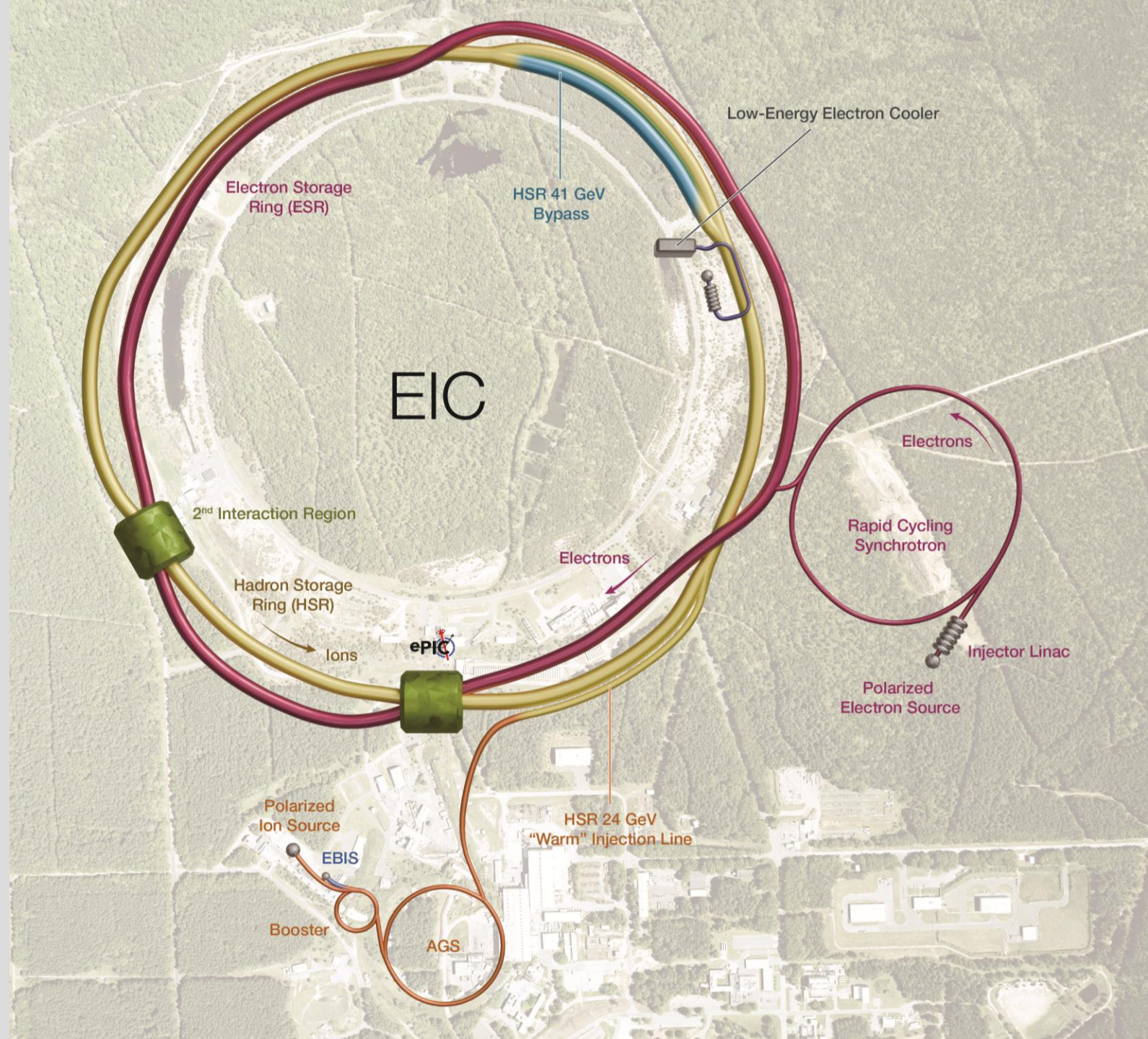
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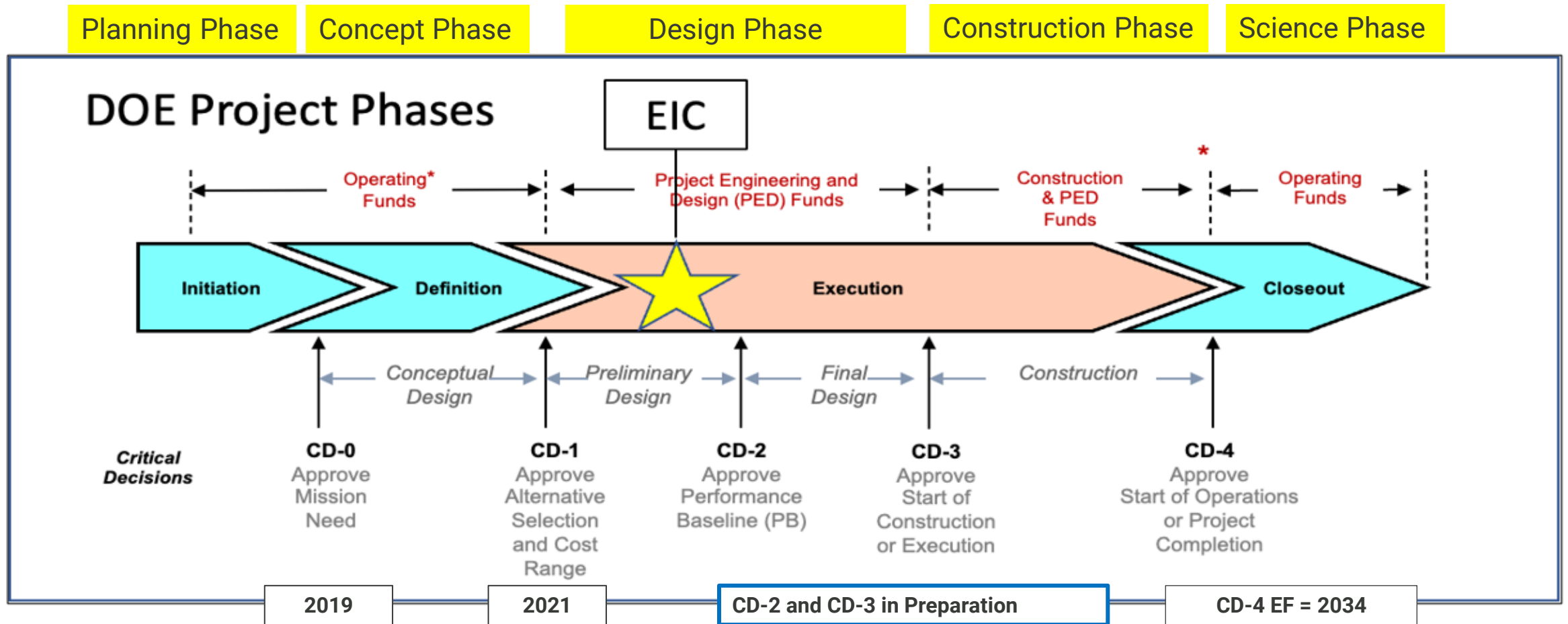


EIC Scope

- High Luminosity:
 $L = 10^{33} - 10^{34} \text{ cm}^{-2}\text{sec}^{-1}$,
 $10 - 100 \text{ fb}^{-1}/\text{year}$
- Highly Polarized Beams: 70%
- Large Center of Mass Energy Range: $E_{\text{cm}} = 29 - 140 \text{ GeV}$
 - e: 5 – 18 GeV
 - p: 41 GeV, 100-275 GeV
- Large Ion Species Range: p – U
- Large Detector Acceptance and Good Background Conditions



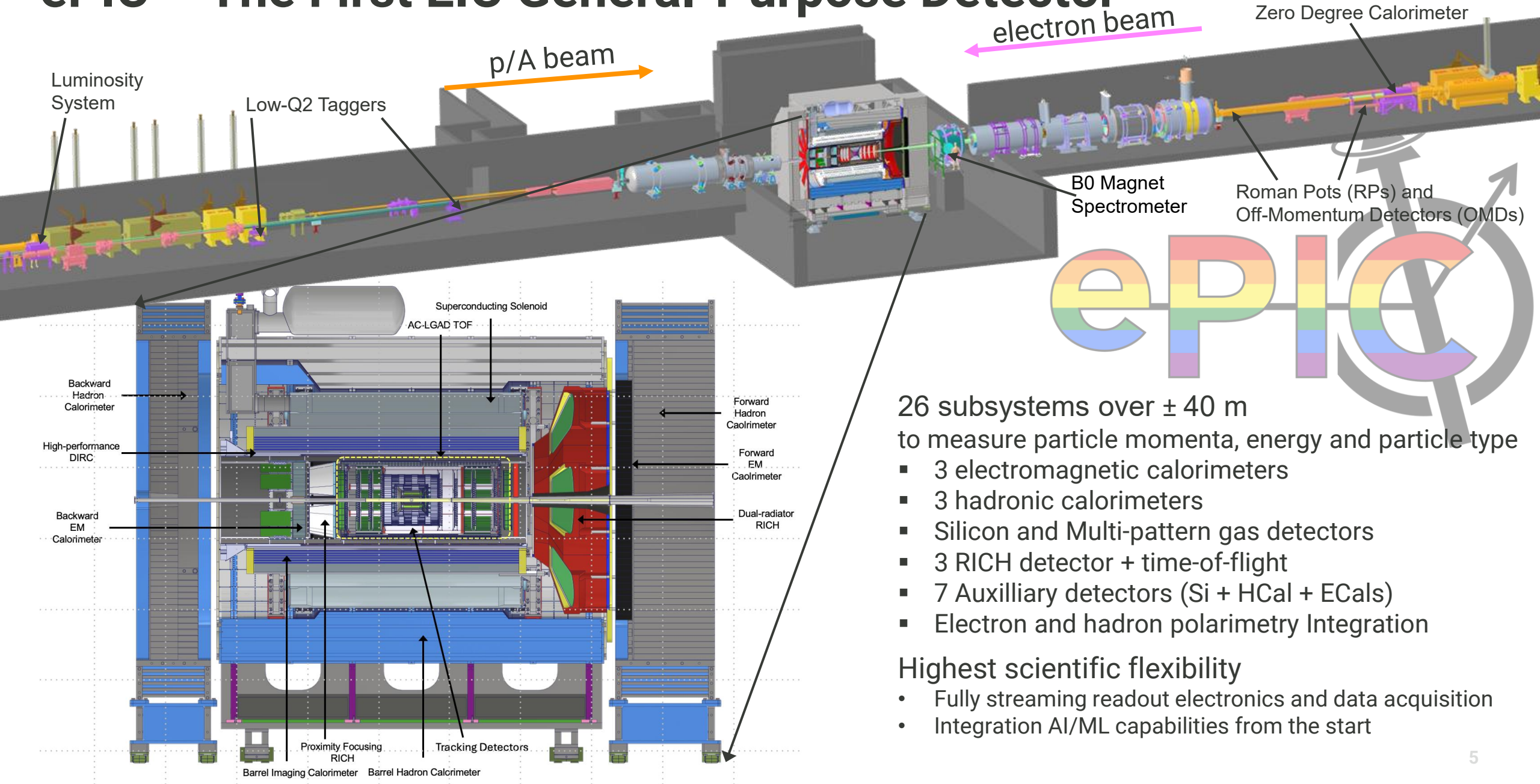
EIC Project-Critical Decisions and Plans



- CD-3A, Long-Lead Procurement, approved March 2024. Excellent use of IRA funding.
- CD-3B, Long-Lead Procurement, authorization anticipated Fall 2025 (ESAAB).
- CD-2, Project Performance Baseline, requires a more certain annual funding profile.

* FY25 and FY26 funding impact CD-2 and CD-3 milestone dates.

ePIC – The First EIC General-Purpose Detector



26 subsystems over ± 40 m
to measure particle momenta, energy and particle type

- 3 electromagnetic calorimeters
- 3 hadronic calorimeters
- Silicon and Multi-pattern gas detectors
- 3 RICH detector + time-of-flight
- 7 Auxilliary detectors (Si + HCal + ECals)
- Electron and hadron polarimetry Integration

Highest scientific flexibility

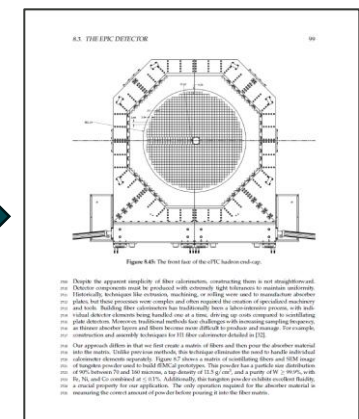
- Fully streaming readout electronics and data acquisition
- Integration AI/ML capabilities from the start

Progress since CD-1

BNL and TJNAF Jointly Leading Efforts Towards Experimental Program		
2021	Call for Collaboration Proposals for Detectors https://www.bnl.gov/eic/CFC.php	March 2021
	BNL/TJNAF Proposal Evaluation Committee	Spring 2021
	Collaboration Proposals for Detectors Submitted	December 2021
2022	Decision on Project Detector – baseline “ECCE”	March 2022
	Process to consolidate ECCE & ATHENA to the EIC Project Detector	Spring 2022
	ePIC Collaboration Formed – 160 institutions	July 2022
2023	ePIC Charter ratified & elected Leadership Team	February 2023
	1 st Resource Review Board Meeting	April 2023
	ePIC (Central) Detector remaining technology choices made	April 2023
2024	ePIC Detector technical baselined	February 2024
	Introduction of early physics planning to ePIC Collaboration	July 2024
	Started drafting Preliminary Technical Design Report	July 2024
2025	Passed 60% Cost-Weighted Design Maturity	April 2025
	Detector R&D Completed (projected)	September 2025
	Preliminary Technical Design Report completed (projected)	December 2025

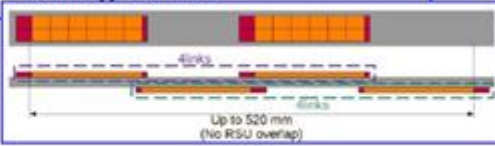


[see T. Ullrich's talk at CPAD'22](#)

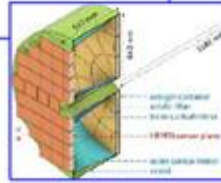


ePIC – New Technologies

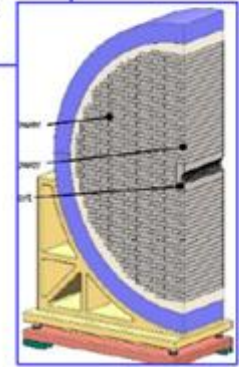
EIC Large Area Sensor (LAS), modification of ITS3 sensor with 5 or 6 RSU forming staves as the basic building elements for the Outer Barrel and the Tracking Disks



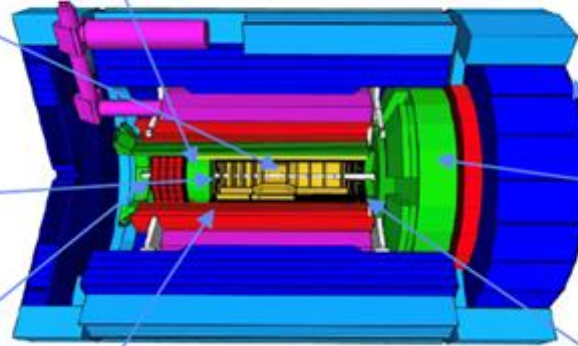
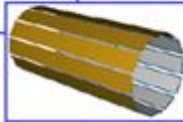
HRPPDs for Cherenkov imaging and Time-of-Flight for *pfRICH*



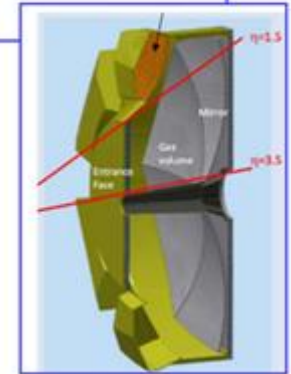
first-time full-size CALICE-like calorimeter in collider experiment in the forward HCal



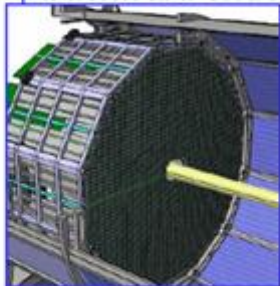
planar double amplification (GEM & μ RWELL) modules & 2D-strip readout for the MPGD outer trackers and disks



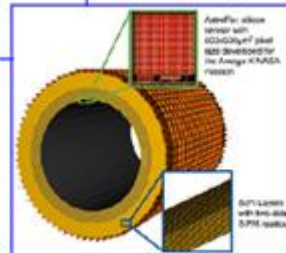
First use of SiPMs as Photosensors in a RICH for the dRICH



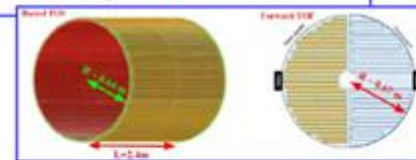
SiPM as Photosensors in crystal calorimetry for backward endcap ECal



Use of ASTROPIX in Calorimetry for the imaging barrel ECal



First time use of AC-LGAD in a collider detector for barrel and forward endcap ToF

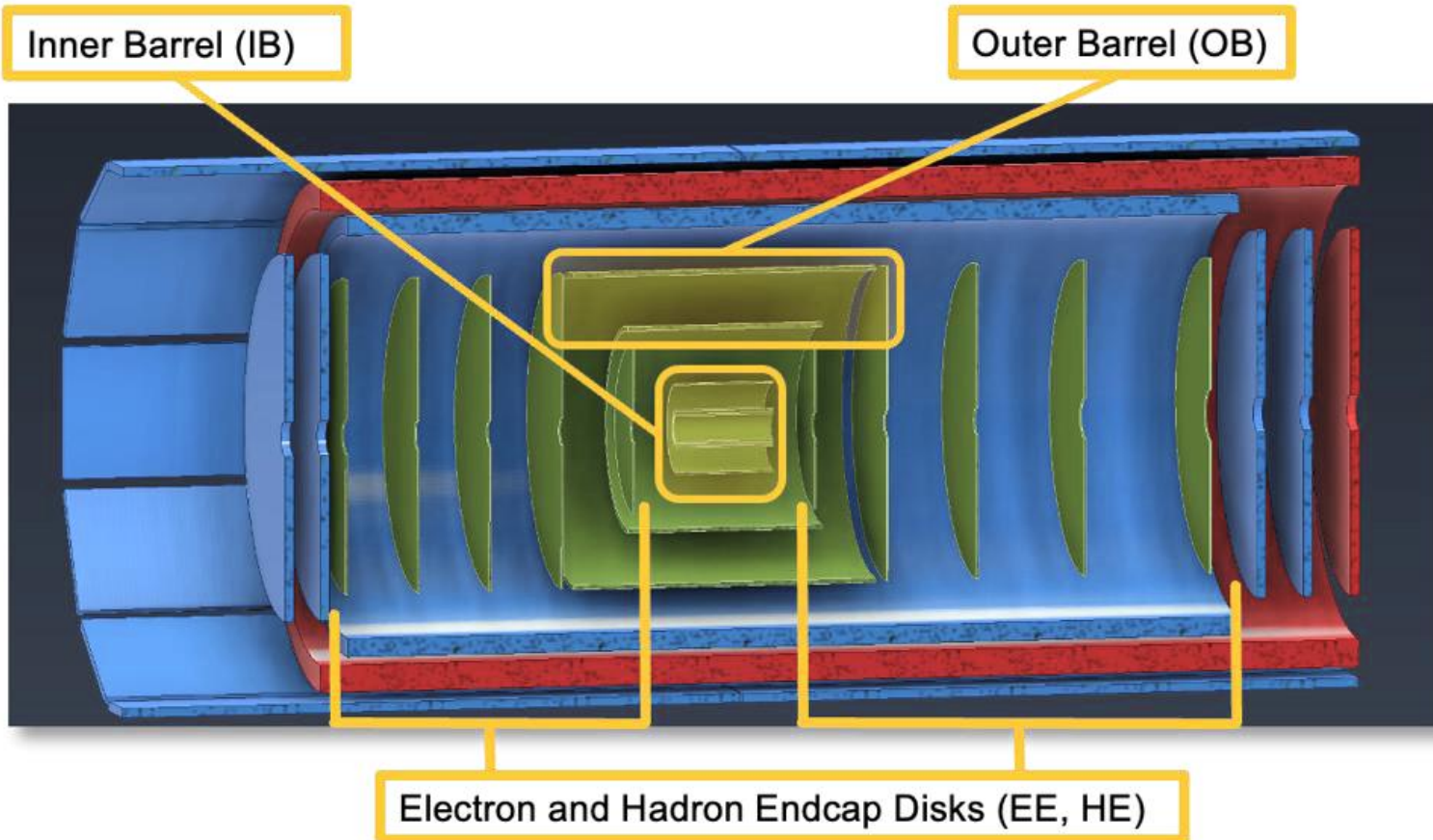


ePIC SVT

Large Area MAPS Tracking

ePIC Silicon Vertex Tracker (SVT)

- Large acceptance, high precision tracking system
- 8.5m² total active area



Target Specifications:

- ~5 μ m spatial resolution
- ~40mW/cm² power
- <2 μ s frame rate
- Material budget per layer:
 - IB: 0.05% X/X₀
 - OB: 0.25%, 0.55% X/X₀
 - EE/HE: 0.25% X/X₀

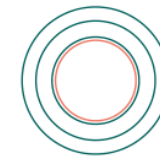
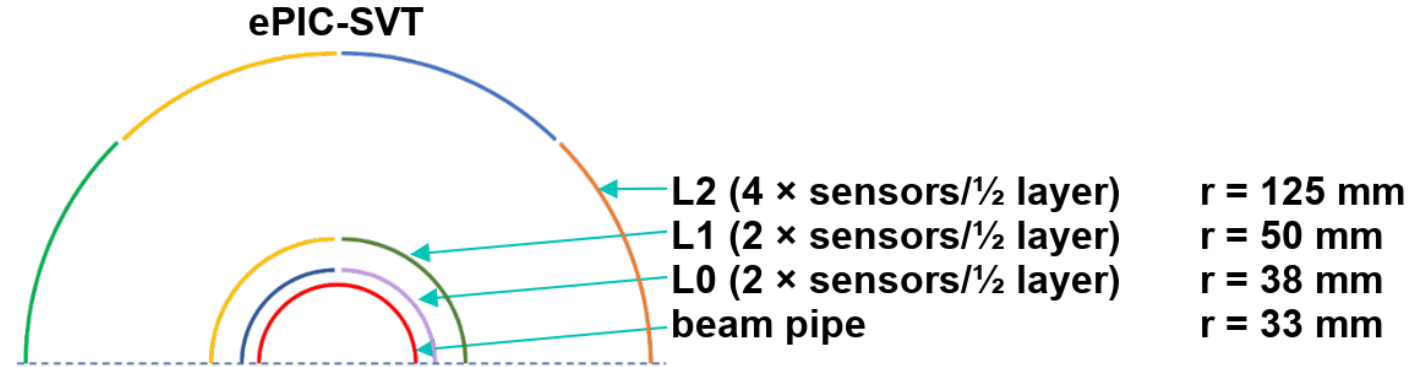
ePIC Inner Barrel (IB) Tracking

- ALICE ITS3 project fulfills all requirements:

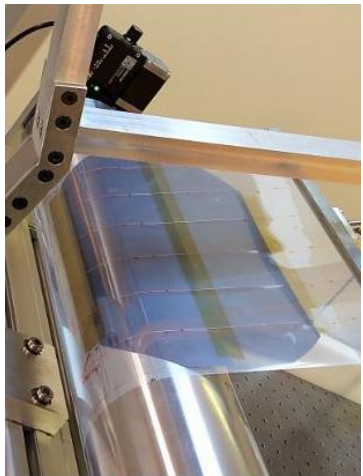
- Thin, bent, wafer scale silicon sensors
- Minimal mechanical support, air cooling, no services in active area
- Strong cooperation with ITS3 developers

- Some operational constraints within ePIC:

- L0, L1: Large beam pipe diameter, 5mm clearance for bake-out
- L2: large radius vertexing/sagitta layer without increase in material
- Requires multi-wafer bending



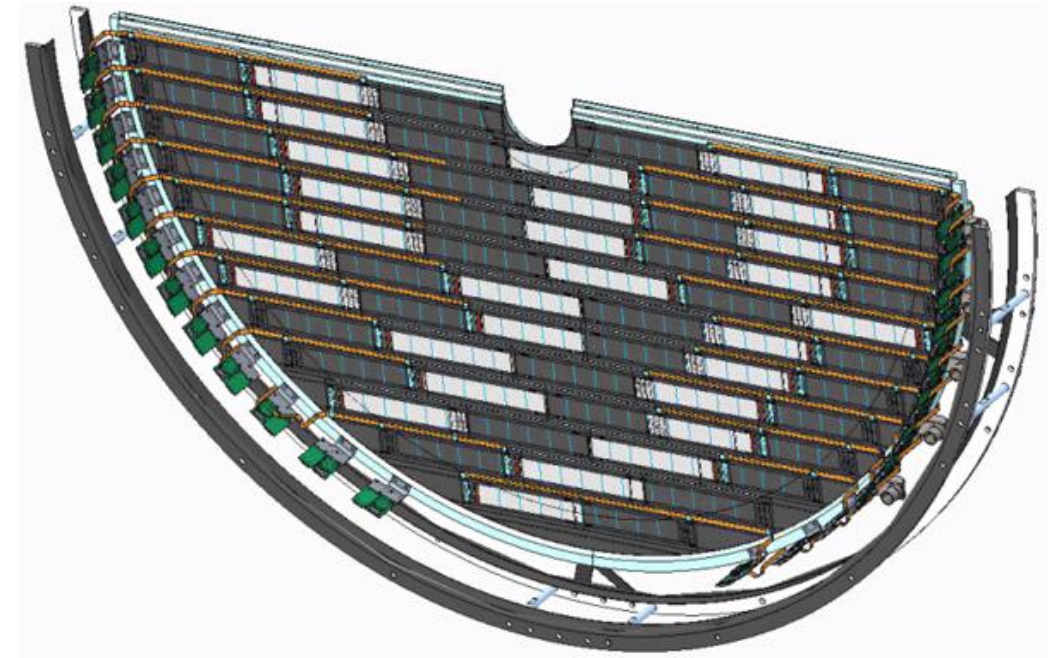
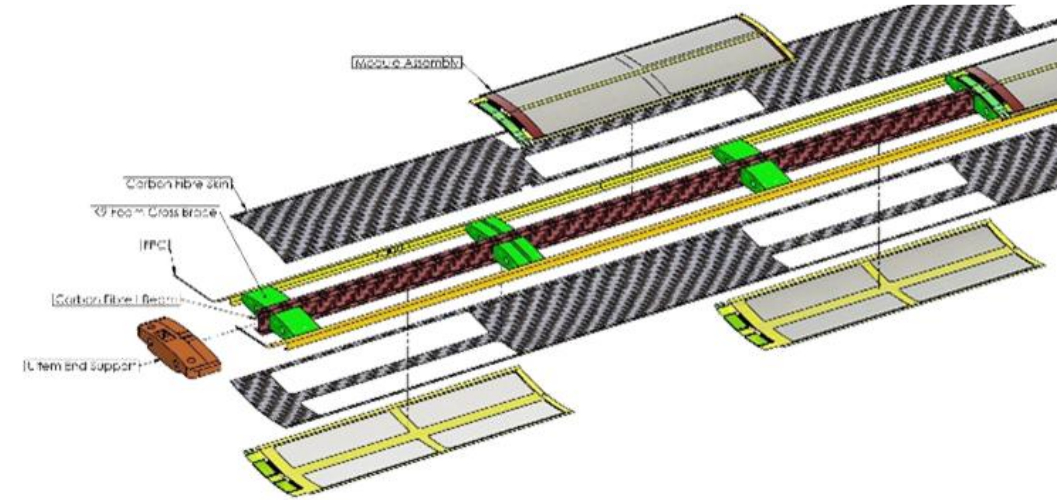
Compared to ALICE-ITS3 (to scale)
radii: 18, 24, 30 mm
(beam pipe: 16.5 mm)
ONE sensor/ $\frac{1}{2}$ layer



IB	MOSAIX /sensor	W (mm)	L (mm)
L0	3	58.7	266
L1	4	78.3	266
L2	5	97.8	266

ePIC Outer Barrel and Endcap Disks

- Hit rates in outer regions much smaller than LHC rates
- Modified ITS3 sensor: EIC-LAS
 - Based on same stitched Repeating Sensor Unit (RSU)
 - Same architecture, modified periphery
 - Reduced data rate, reduced number of readout links
 - Smaller sensors for higher yield
- No bending in OB, simplified mechanics
- Minimal material budget with lightweight mechanical supports
 - Integrated cooling, electrical interfaces

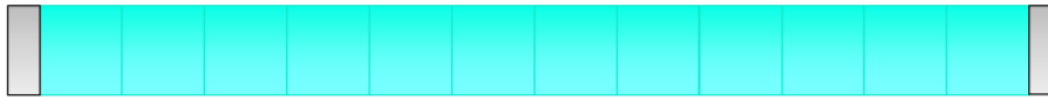


ITS3 Sensors and EIC Modifications

MOSAIX

- Used in IB layers L0-2
- Identical sensor as ITS3

MOSAIX segment



- 12 RSUs
 - 8 data links
 - 7 slow control links
 - Direct powering
- Improved yield
- Lower material budget
- Lower material budget
- Lower material budget

EIC-LAS

- Used in OB layers L3-4 and endcap disks
- Modified version of MOSAIX, specifically for EIC

EIC-LAS and ancillary chip

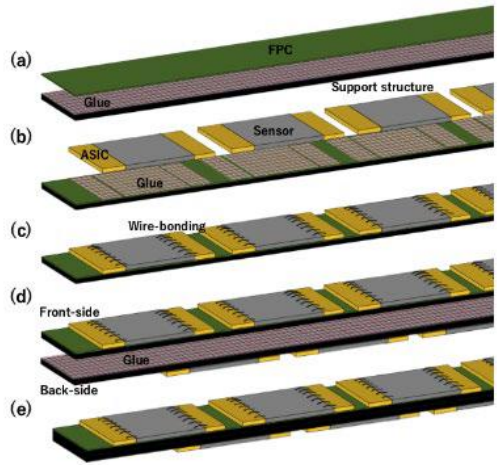
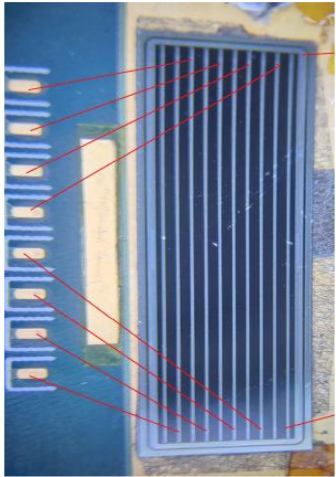


- 5 or 6 RSUs
 - Single data link
 - Multiplexed slow controls
 - Serial powering
- EIC-LAS
- Ancillary ASIC

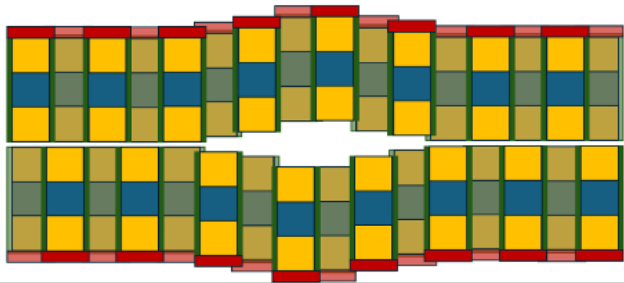
Fast Timing with AC-LGADs

AC-LGADs in ePIC

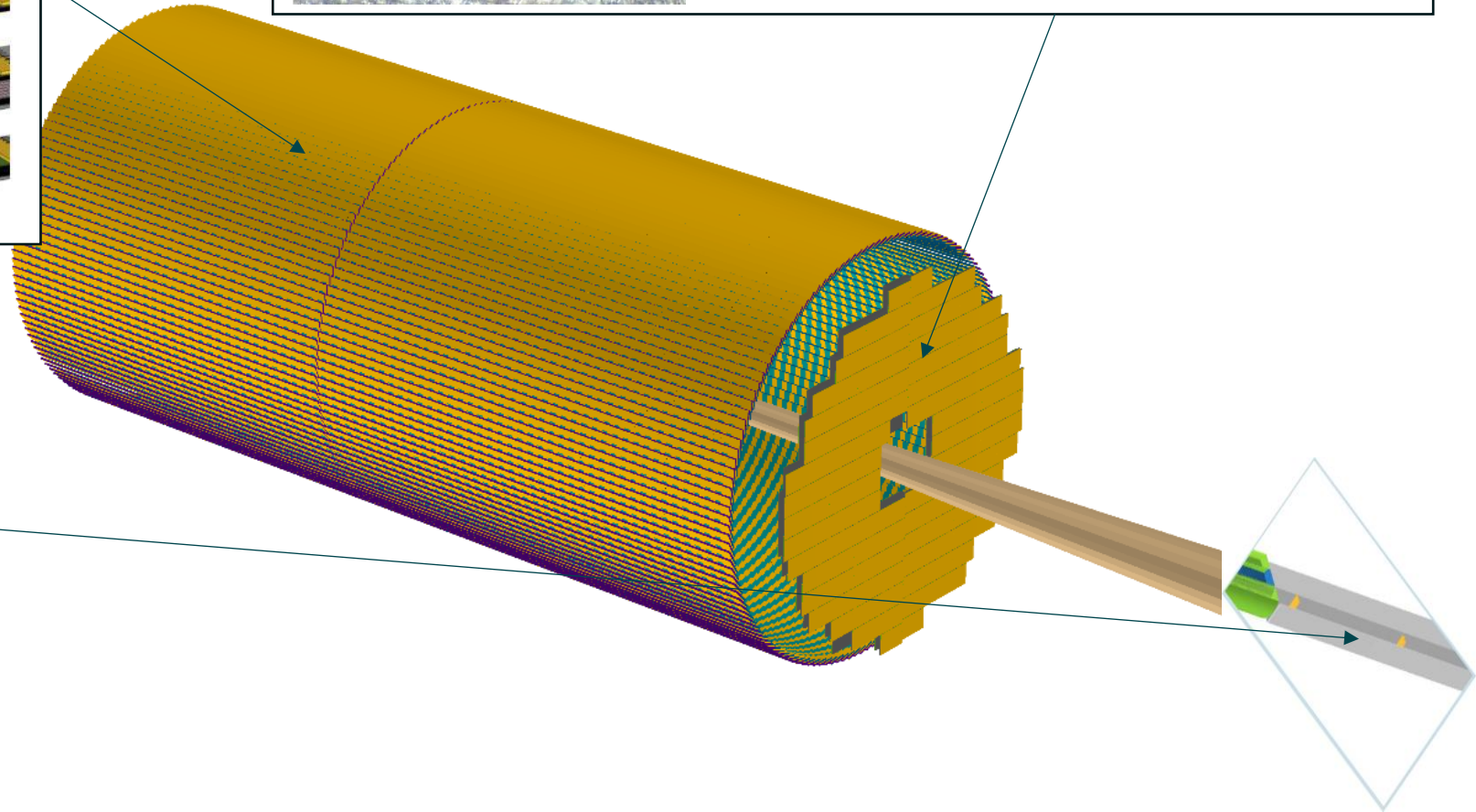
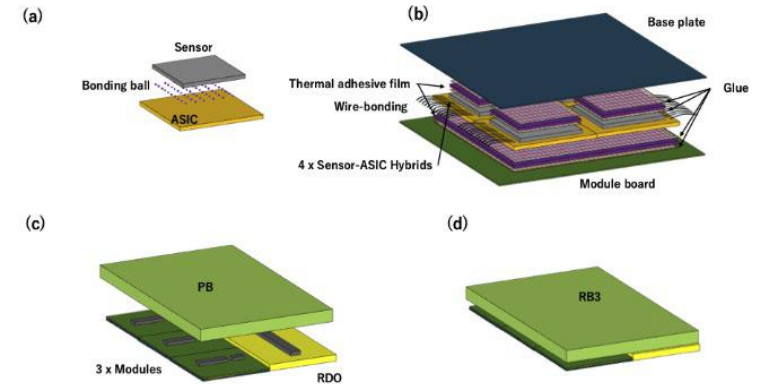
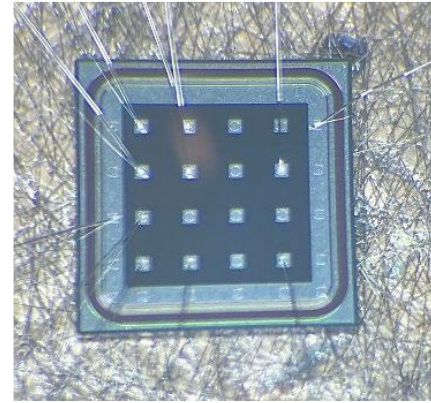
Barrel TOF: strips, FCFD readout



Off-Momentum Roman Pots: pixels, EICROC readout

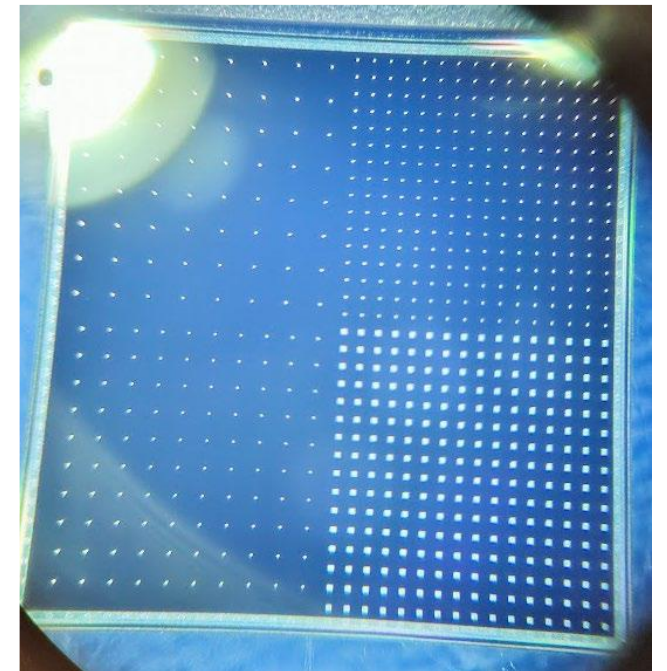
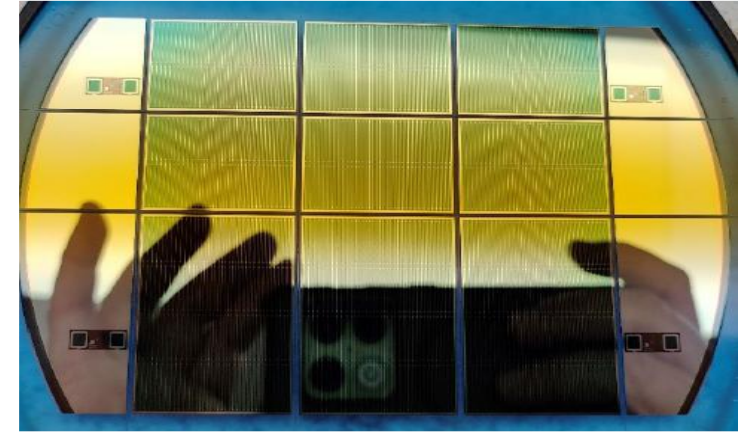


Forward TOF: pixels, EICROC readout



AC-LGADs in ePIC

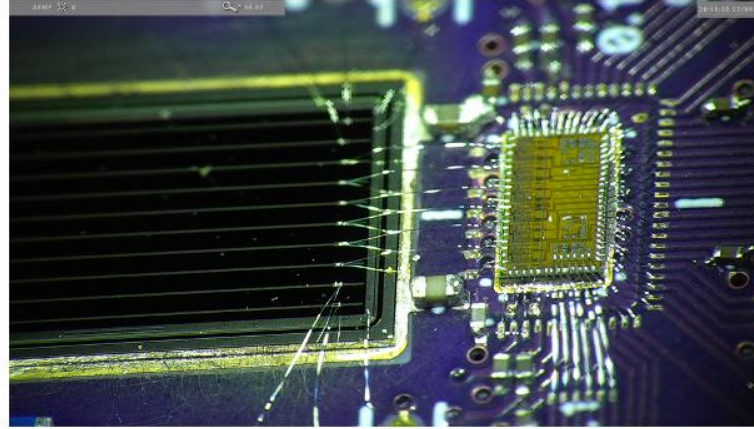
- $\sim 10\text{m}^2$ of AC-LGAD sensor area required for ePIC detector
 - First large scale application of AC-LGADs
- Required significant R&D efforts to finalize sensor designs
 - Strip and pixel types, see [S. Mazza's talk earlier this week](#)
- Full size HPK productions of strip and pixel sensors available
 - up to $3.2 \times 4.2\text{cm}$, largest AC-LGAD ever
 - Various metallization geometries
- New productions from FBK and HPK will be ready soon
- ePIC sensors are near finalized for production
 - As always, many new ideas came out of this



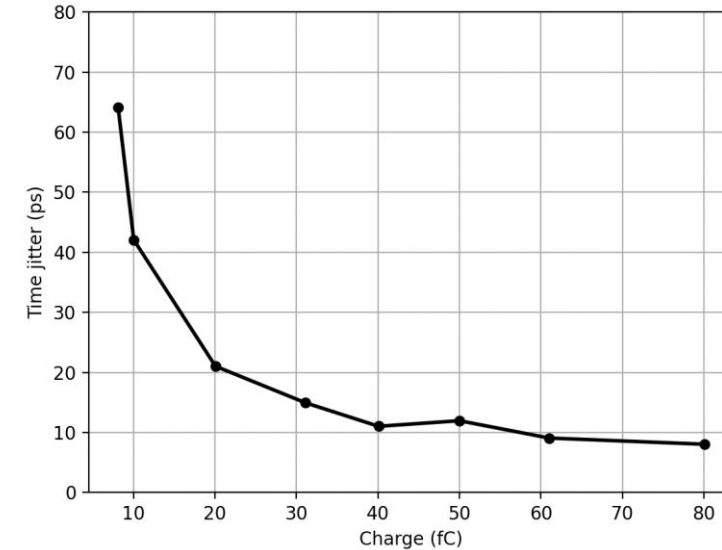
Readout ASICs for AC-LGADs in ePIC

FNAL FCFD (65nm) for Strip-type:

- Detector capacitance target: $<15\text{pF}$
- Dynamic range: $5 \sim 40 \text{ fC}$
- Power consumption: $2\sim4 \text{ mW/ch}$
- $64 \times 2 = 128 \text{ ch}$
- Timing jitter (analog): $10 \sim 20 \text{ ps}$

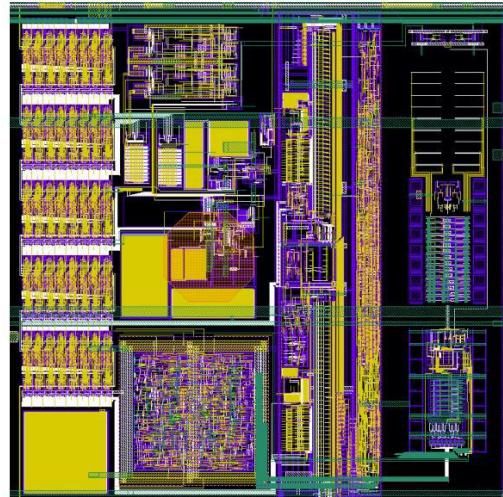


FNAL Preliminary



OMEGA EICROC for Pixel-type:

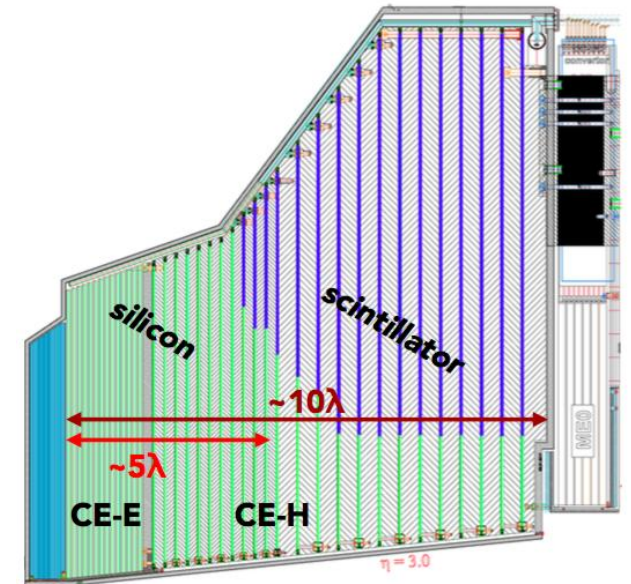
- Detector capacitance target: $1\sim5 \text{ pF}$
- Dynamic range: $1\sim50 \text{ fC}$
- Power consumption: $<2 \text{ mW/ch}$
- $32 \times 32 = 1024 \text{ ch}$
- Timing jitter (analog): $10 \sim 20 \text{ ps}$



High Granularity Calorimetry

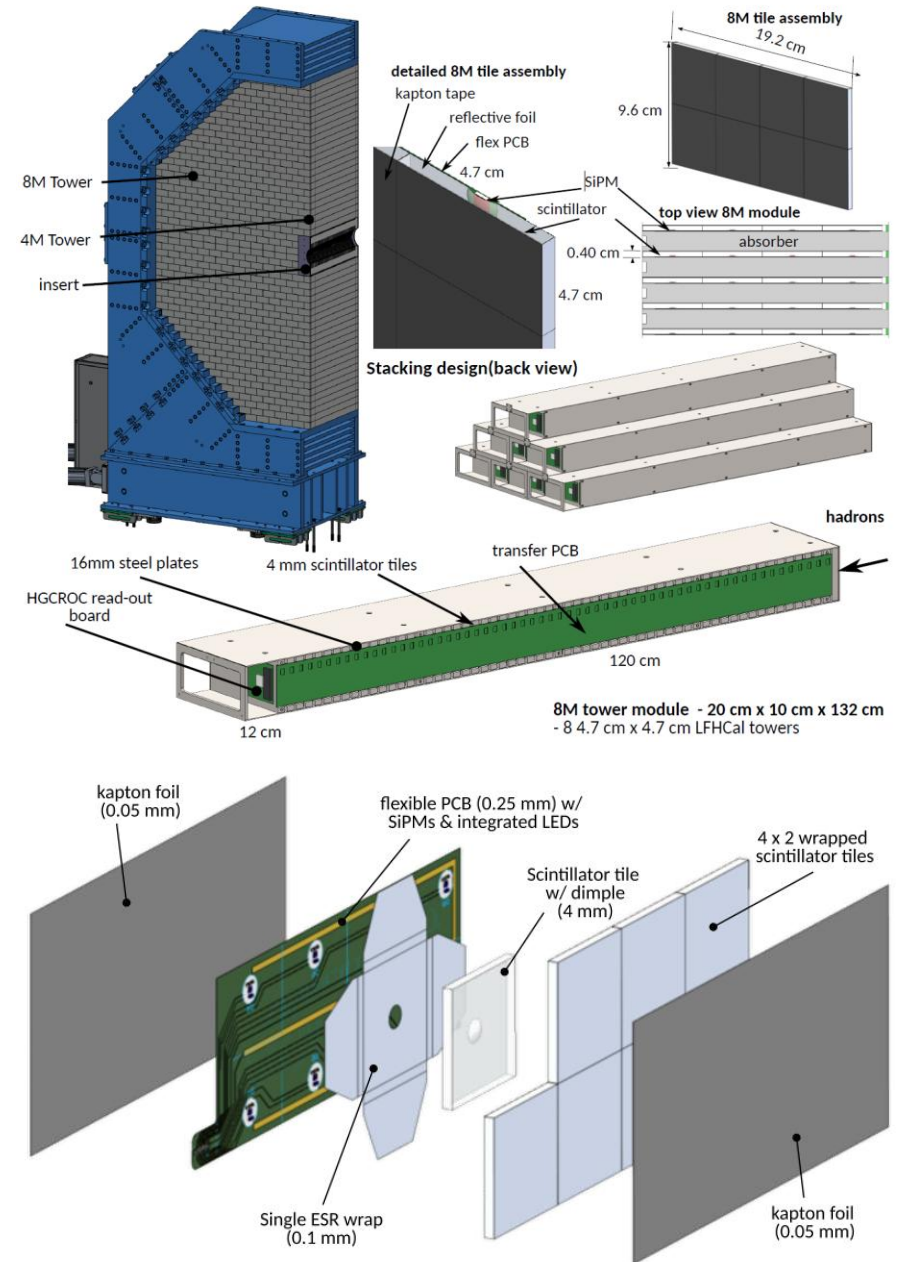
SiPM-on-Tile Calorimeters in ePIC

- CALICE collaboration (AHCAL, ScECAL) have pioneered the direct coupling of SiPMs to plastic scintillator tiles since 2005
 - Enables cost effective construction of very high granularity hadron calorimeters for particle flow reconstruction
- Application in HEP: CMS HGCAL
- ePIC calorimeters are high granularity
- Several HCALs are SiPM-on-tile based:
 - Forward and backward HCALs
 - Zero Degree Calorimeter



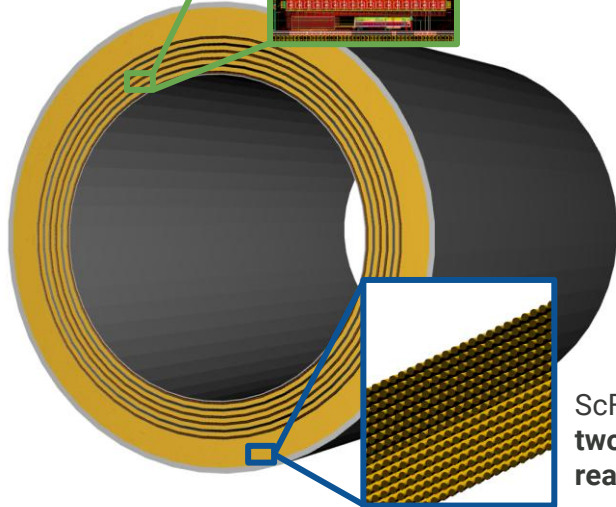
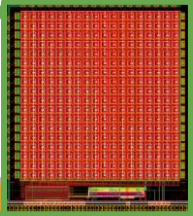
LFHCAL + Insert

- ePIC forward hadronic calorimeter: LFHCAL
 - based on plastic scintillator tiles injection molded at FNAL
 - ~1M 47x47mm² tiles wrapped in reflective foil
 - Passive signal routing, no buried readout electronics
 - Assembled from >1000 e-beam welded steel absorber modules
 - See [P. Garg's talk earlier this week](#)
- LFHCAL features high granularity insert close to beam pipe
 - Accessible between runs to replace SiPMs if needed
 - [First SiPM-on-Tile calorimeter operated in collider experiment!](#)

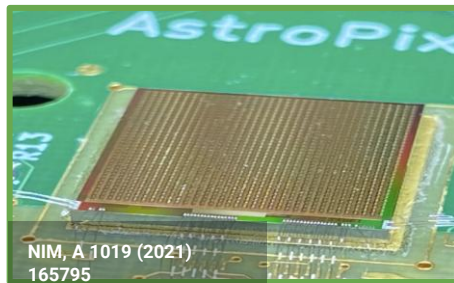


Barrel Imaging Calorimeter (BIC)

AstroPix: silicon sensor with $500 \times 500 \mu\text{m}^2$ pixel size

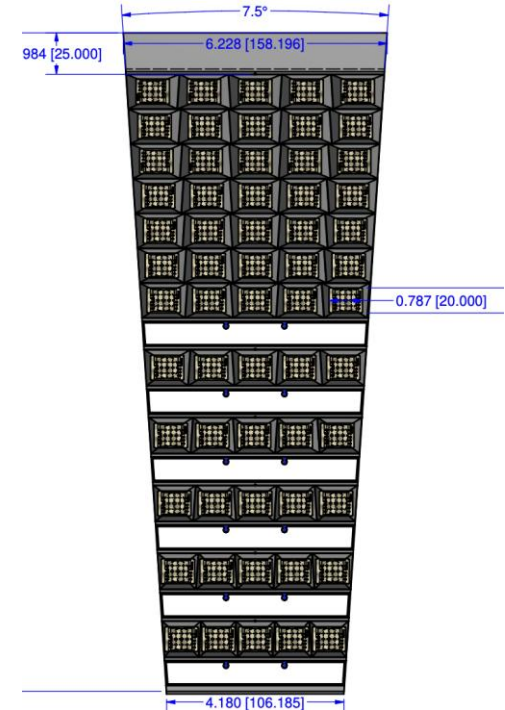


ScFi Layers with two-sided SiPM readout



Start from mature layered Pb/ScFi technology with side-readout (same as the GlueX calorimeter) for **state-of-the-art sampling calorimeter** performance

Insert layers of monolithic AstroPix silicon sensors (ultra-low-power, developed for NASA at ANL) to capture a **3D image of the shower**

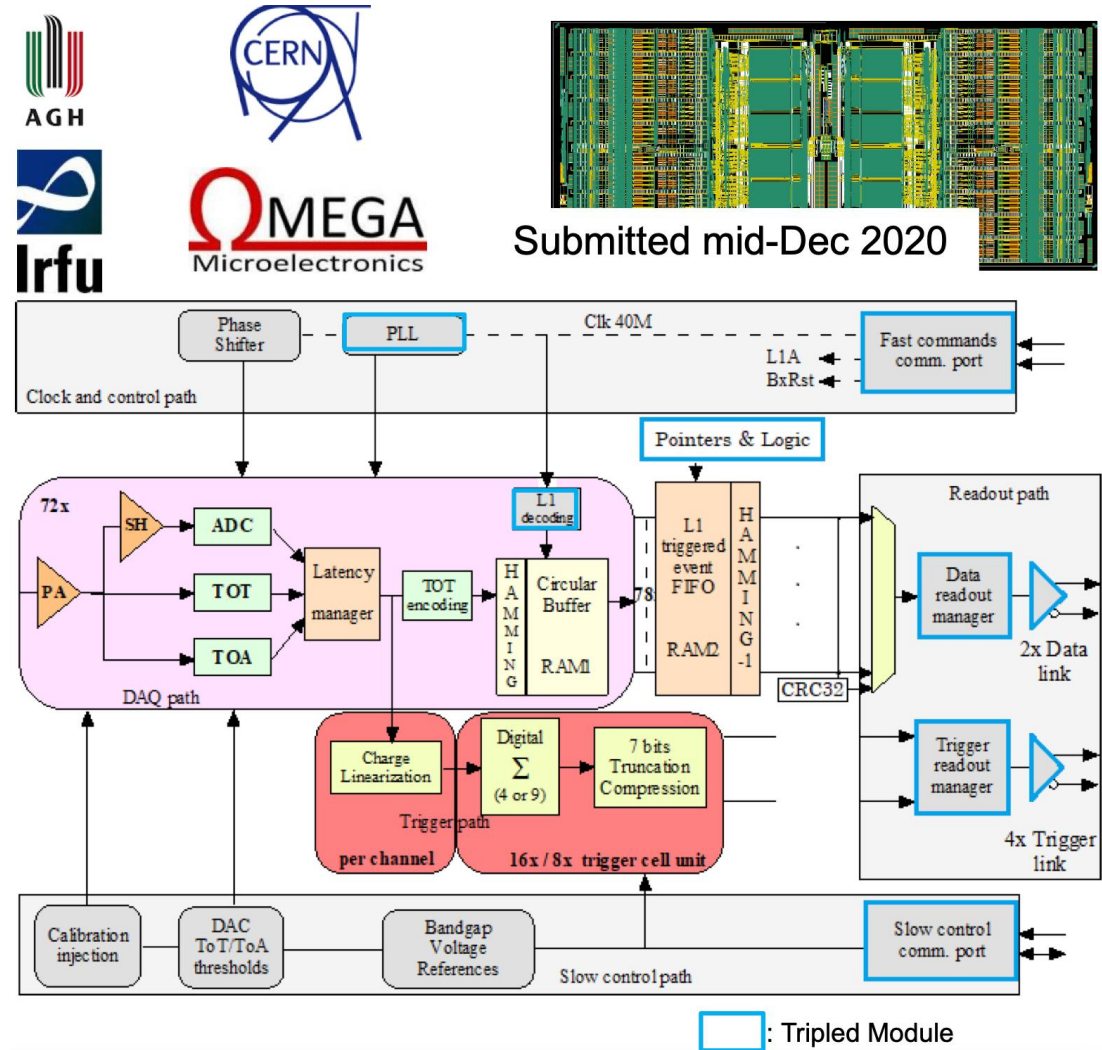


ePIC Simulations: Barrel ECal Geometry Rendering

Combination of SciFi and Si tracking layers yields unprecedented shower position resolution ~ 0.1 deg.

SiPM Readout in ePIC: HGCROC/CALOROC

- HGCROC development led by OMEGA for CMS HGCAL
 - 72 channels, low power, rad. hard SiPM readout
- Planned for use in (almost) all ePIC calorimeters
 - ePIC is 100% streaming readout, need self-trigger
- CALOROC: EIC-specific version of HGCROC
 - Self triggered, only 32ch for flexibility
 - Optional dual-ADC instead of ADC/TOT
 - Submitted, expect wafers soon



Conclusion

- ePIC will be possible thanks to the strong ties and collaboration between NP and HEP instrumentation
- ePIC Collaboration has >1000 members
 - Always happy to welcome new contributors, we are building some very cool detectors!
- EIC Funding Opportunity just released, deadline October 23rd (I believe!)
 - Generic R&D proposals for EIC, future detectors, ePIC upgrades...
 - Contact Michelle Shinn for details: Michelle.Shinn@science.doe.gov

