

AC-LGAD Detectors for Spatial and Timing Measurements at the Electron-Ion Collider

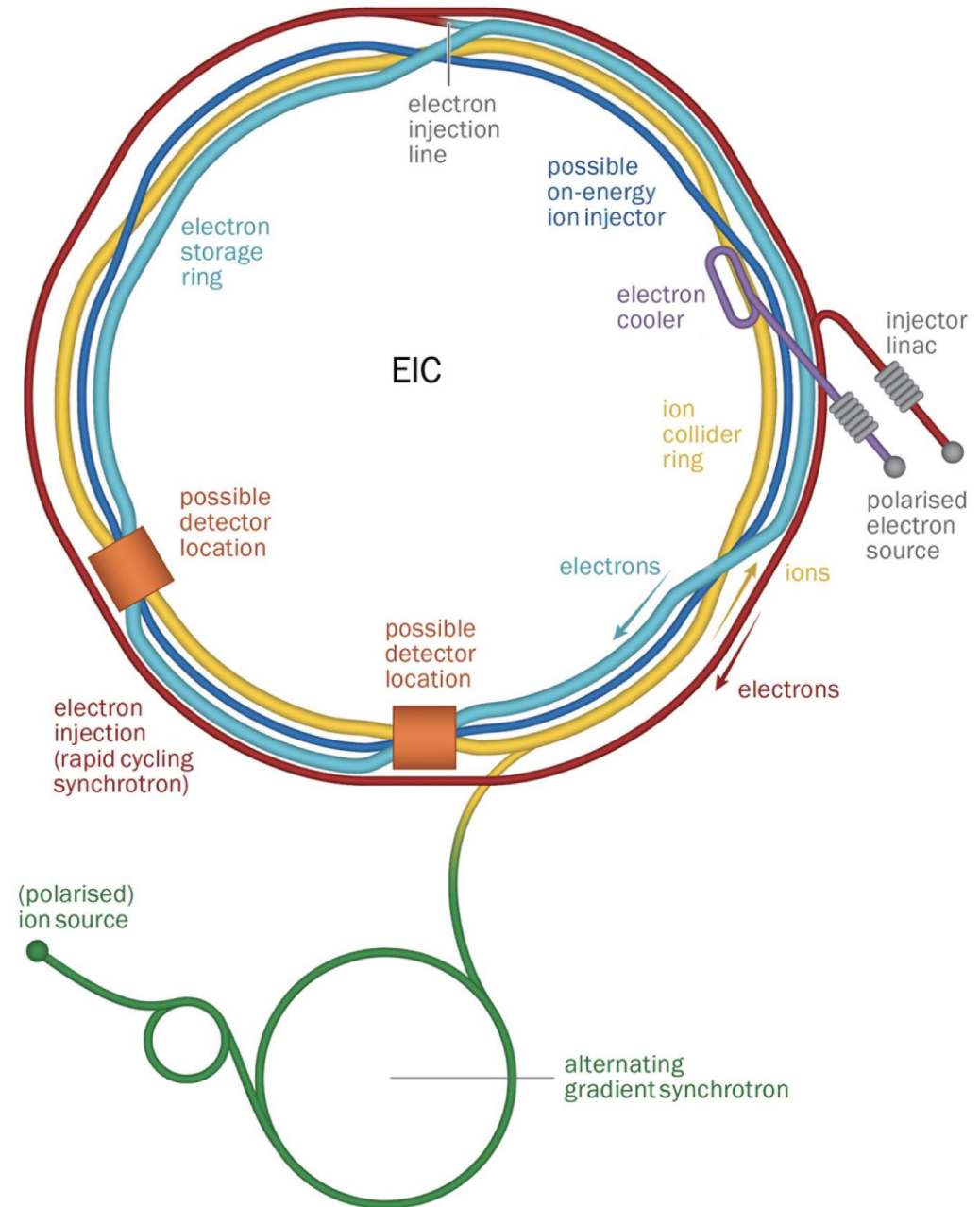
Oskar Hartbrich (ORNL)

For the EIC AC-LGAD Consortium

ORNL is managed by UT-Battelle LLC for the US Department of Energy

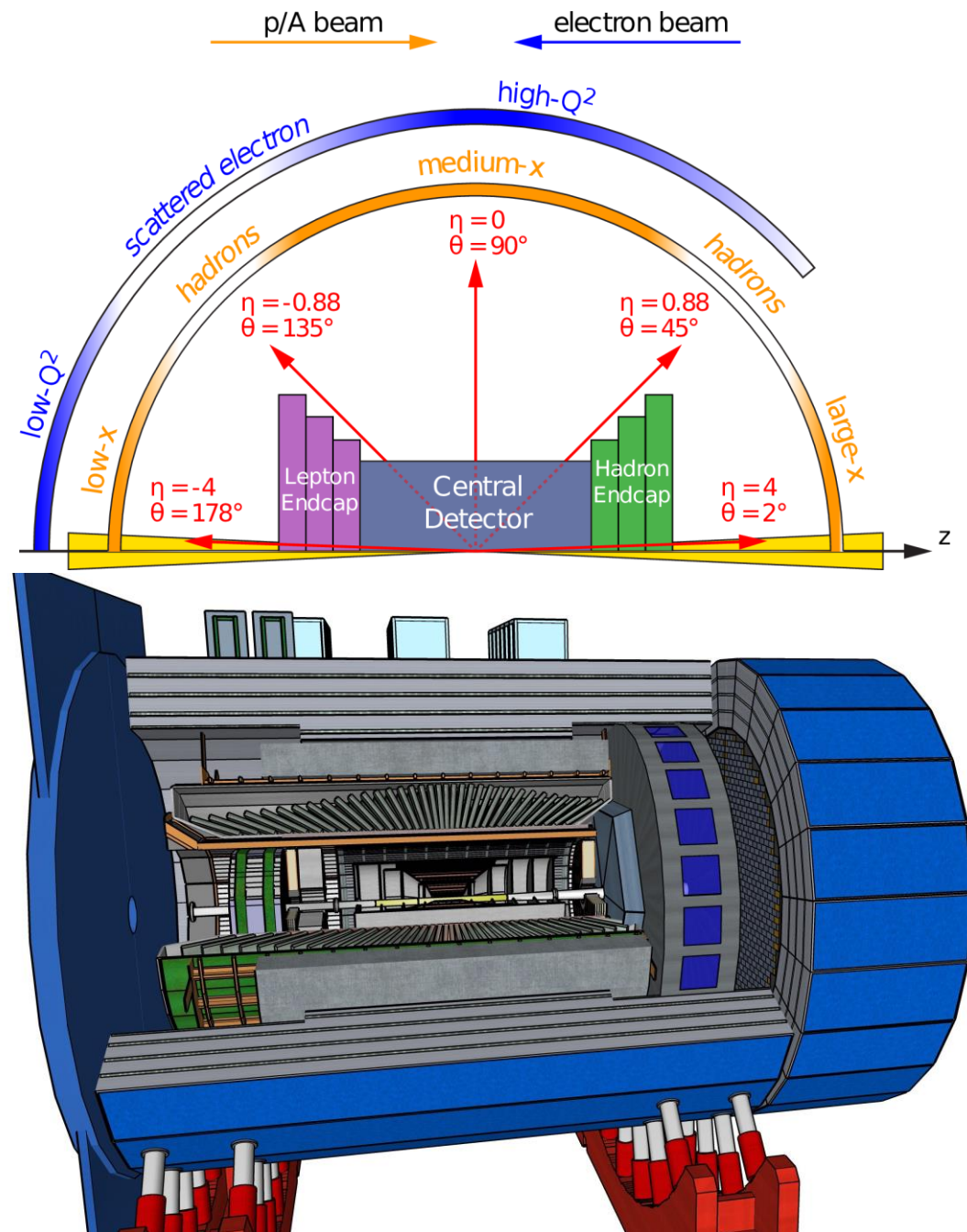
The Electron-Ion Collider

- Flagship Nuclear Physics Collider Experiment constructed at Brookhaven National Laboratory
 - Protons/nuclei 40-275 GeV ($Z/A \times E_p$)
 - Electrons up to 18 GeV
 - Up to 80% polarized beams
 - Luminosity up to $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ (100-1000x HERA)
- Two interaction regions
- First beams in early 2030s



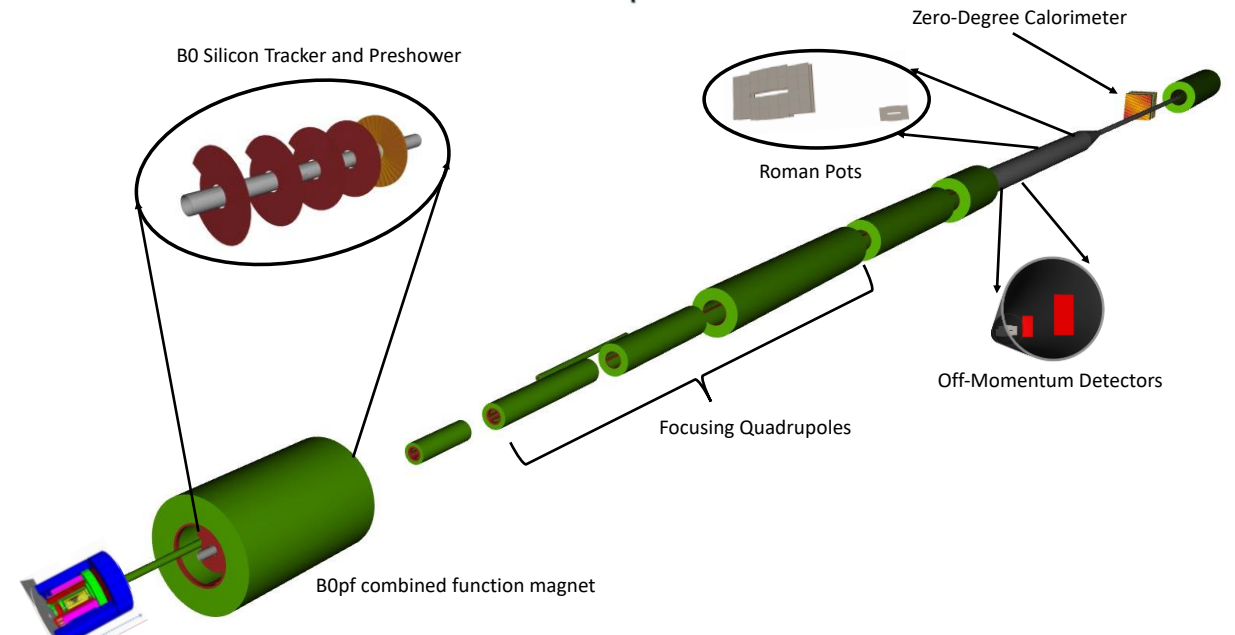
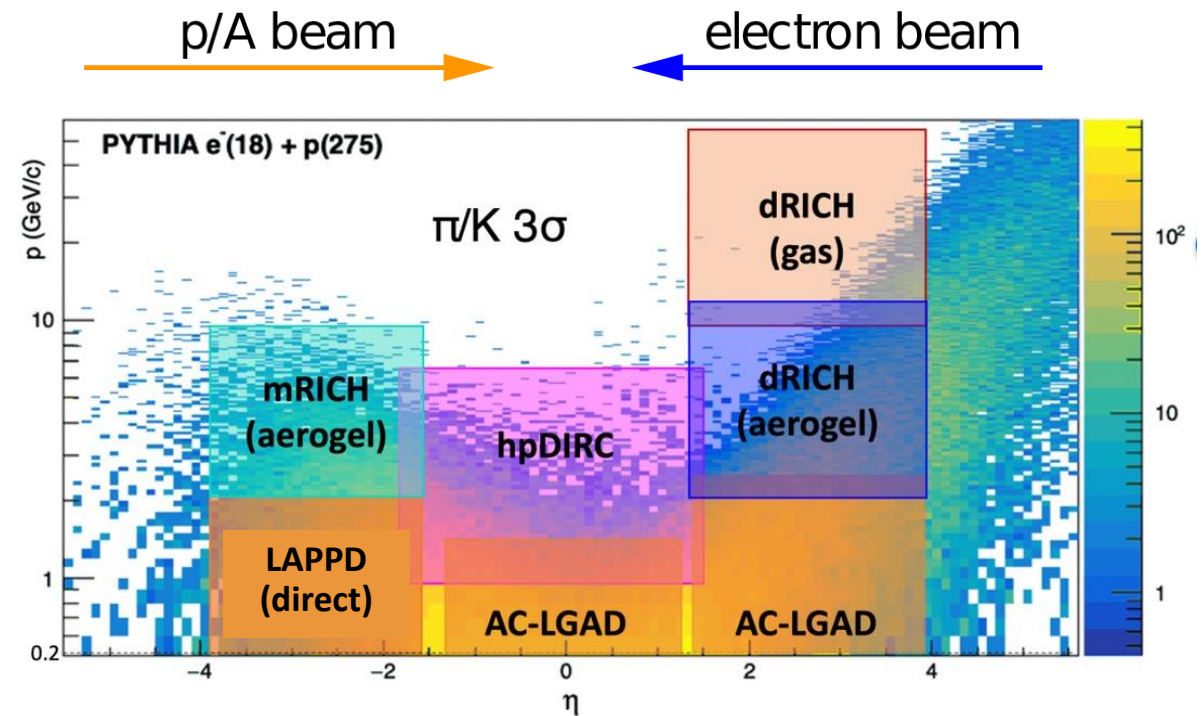
EPIC – The First Detector for EIC

- Full coverage detector see [[plenary talk by T. Ullrich](#)]
 - High precision tracking [[MPGD](#)]
 - Particle Identification [[dRICH](#)]
 - High granularity calorimeters [[1,2,3,4,5](#)]
 - Far forward/backward systems
- EPIC Collaboration formed July '22
 - Proponents of ATHENA/CORE/ECCE
 - Logo to be revealed soon!



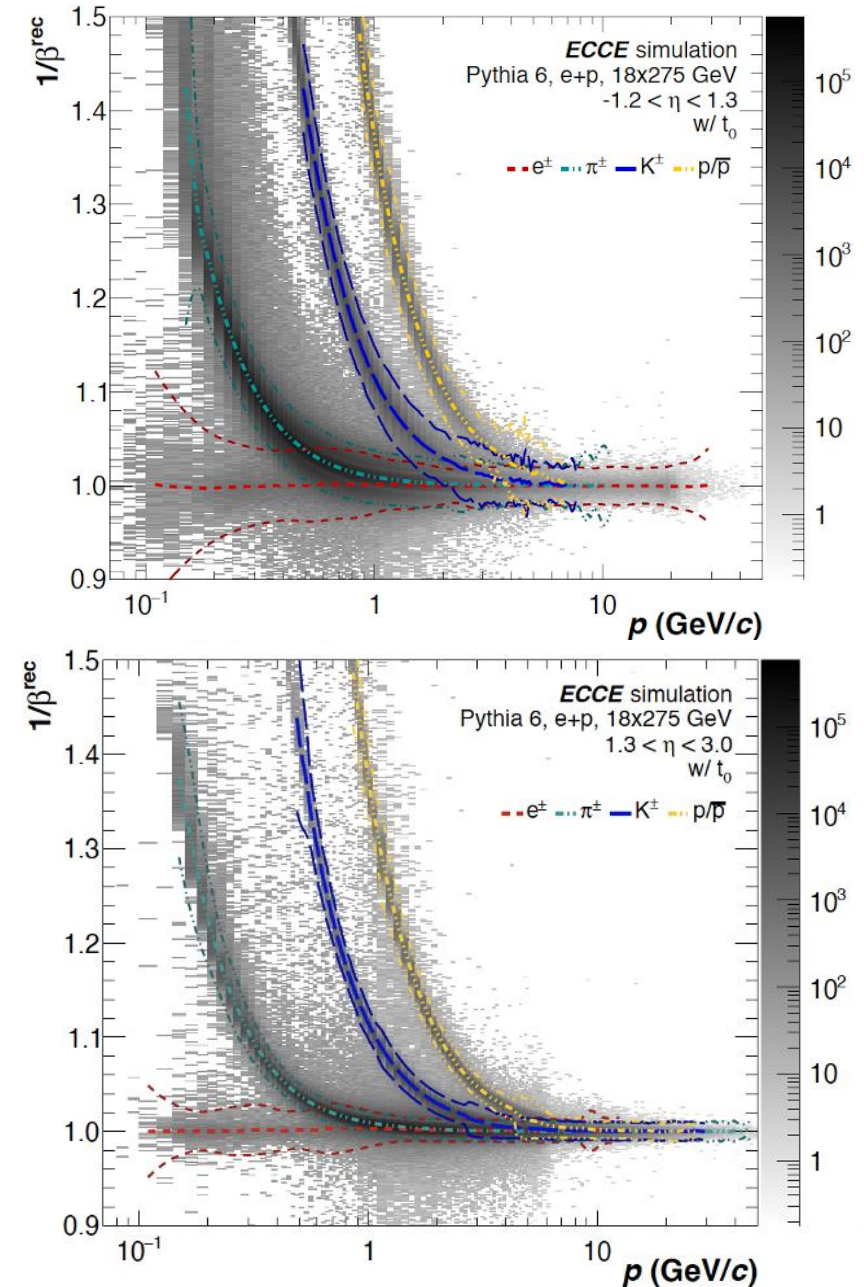
AC-LGADs in EPIC

- AC-LGADs: true 4D tracking
 - <30ps MIP sensor timing achieved
 - Adjacent electrodes share signal, improving resolution
 - No dead area between electrodes
 - Several talks at this workshop: [[1](#),[2](#),[3](#),[Plenary](#)]
- Several EPIC systems based on AC-LGAD
 - Time-of-flight PID
 - Far forward
 - >10m² total active area
- EIC AC-LGAD Consortium
 - ~12 institutes involved
 - Joint R&D for all systems
 - Paving the way into the future...



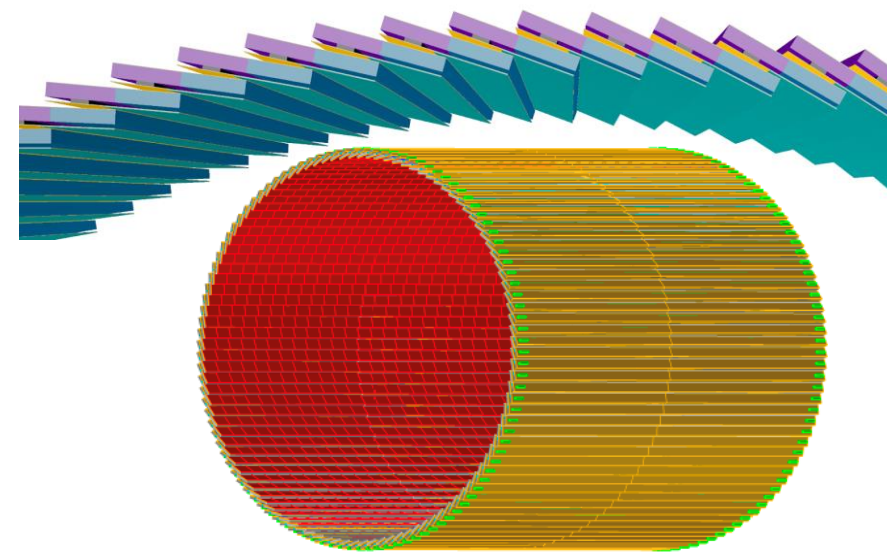
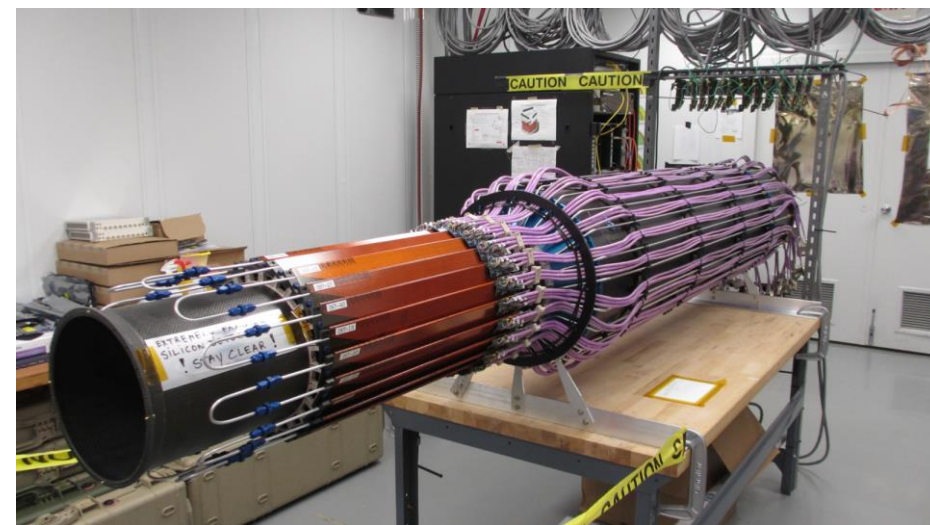
AC-LGAD TOF in EPIC

- Target: 25ps detector resolution
- <20ps event t_0 determination
 - Machine clock + X-t correlation
 - Scattered e⁻ timing, fitted hadron timing
- Serves as additional tracking layer
 - Barrel: 0.5mm x 10mm strips
 - Hadron endcap: 0.5mm x 0.5mm pixels



EPIC Barrel TOF

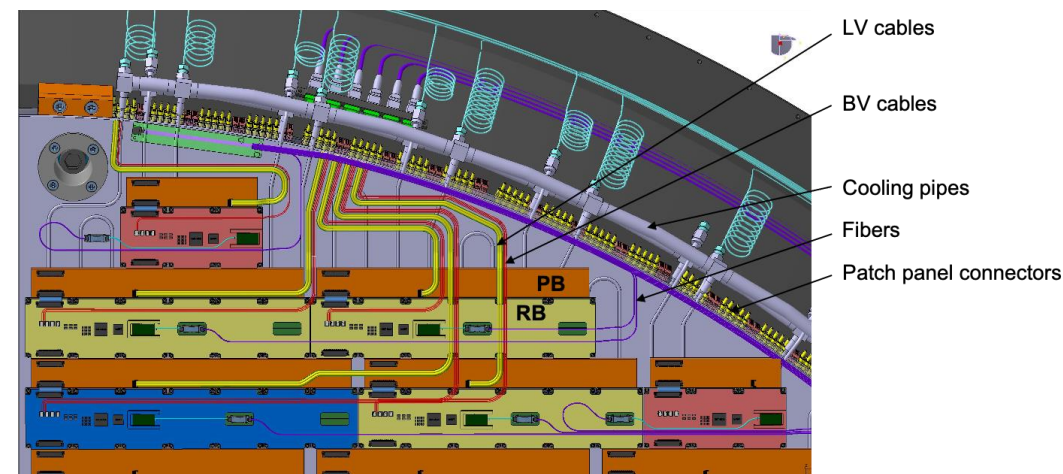
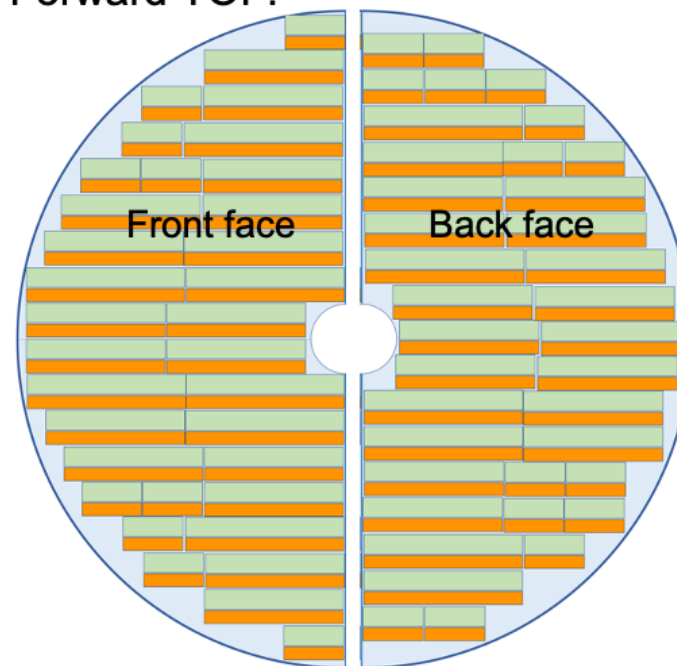
- Based on STAR IST mechanics
 - Carbon foam, Kapton flex PCB
 - Expect $\sim 1\%$ X/X_0 material
- Long staves: 2.40m span
- Large area: 10m^2 sensors
- $\sim 4\text{kW}$ total power dissipation
- Requires fabrication tests and demonstrators



EPIC Endcap TOF

- Based on CMS-ETL design
 - Double-sided clamshell
- 1.3m diameter (1.5 m²)
 - <10cm total thickness
 - Expect ~8% X/X_0 material
- Significant power dissipation
 - 13kW at 0.5 x 0.5mm² segmentation, scaling with pixel size/density
 - Operation at room temperature

Forward TOF:



EPIC Far Forward Tracking

B0 Silicon Tracker and Preshower

B0 tracking:

- Far forward tracking in magnetic field.
- High spatial resolution (~10 μ m) required!
- Integrated timing layer for background rejection

Zero-Degree Calorimeter

Roman Pots

Off-Momentum Detectors

Focusing Quadrupoles

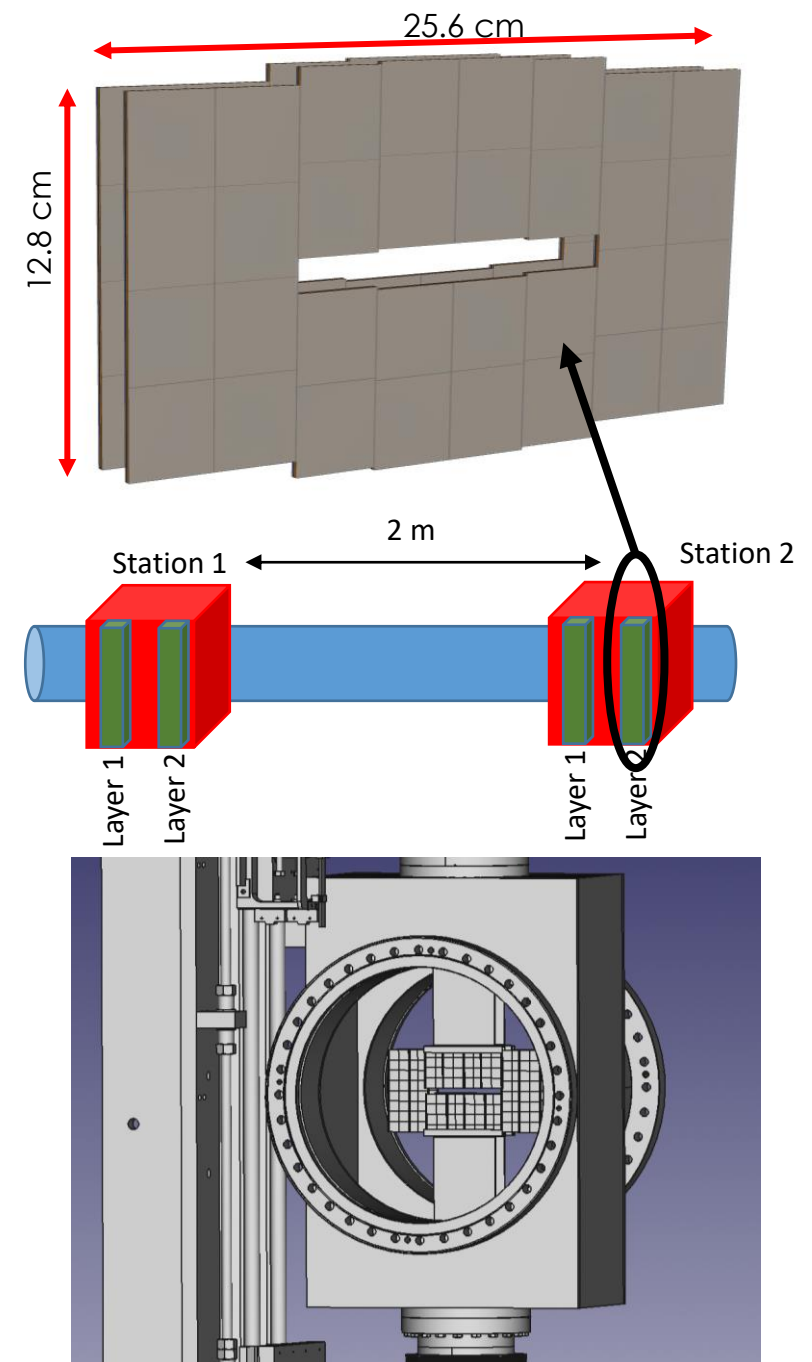
B0pf combined function magnet

RP/OMD Tracking

- Less stringent spatial resolution requirements.
 - Sensitive to misalignment.
- Sensors inside beam vacuum

EPIC Roman Pots

- Two Roman Pot stations
 - ~25m from IP, ~2m between stations
- At least two layers of AC-LGAD tracking per station
 - 25ps timing, 0.5mm x 0.5mm pixels
- Sensor modules placed directly in machine vacuum
 - Linear actuation of sensors based on beam conditions
 - High precision, repeatability for alignment
- Low mass cooling system in vacuum
 - ~500W total, silicon micro-channels?

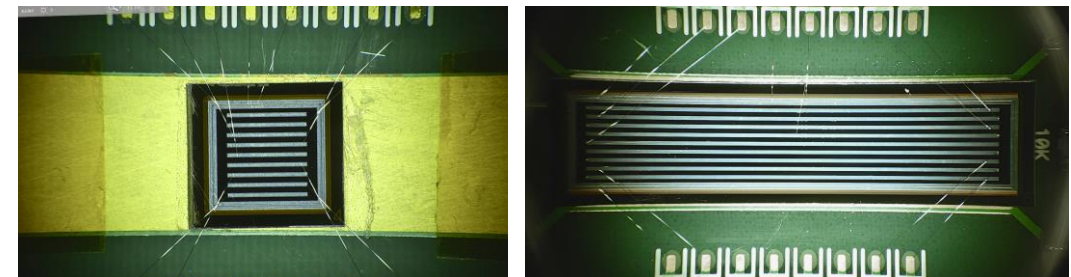
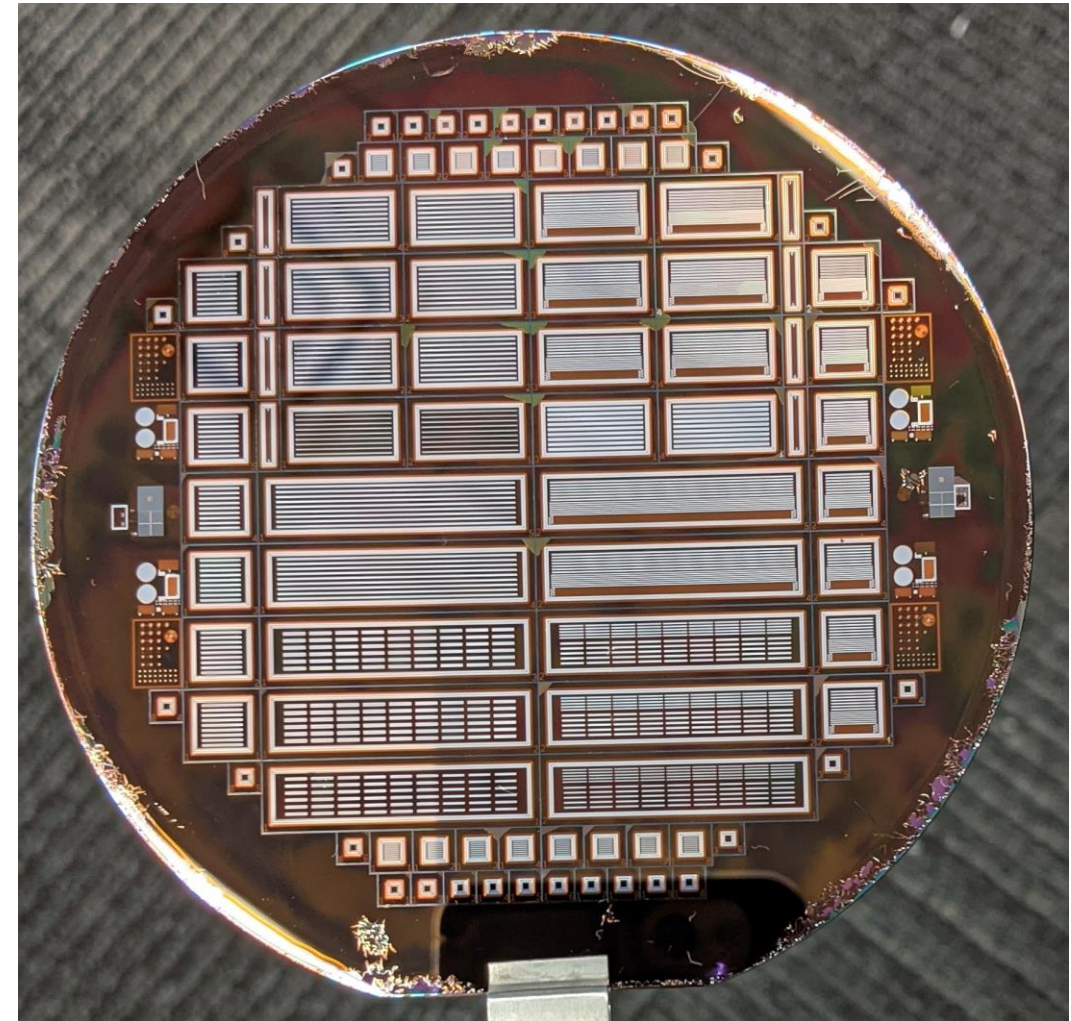


AC-LGAD Detectors at EIC

AC-LGAD Sensor R&D

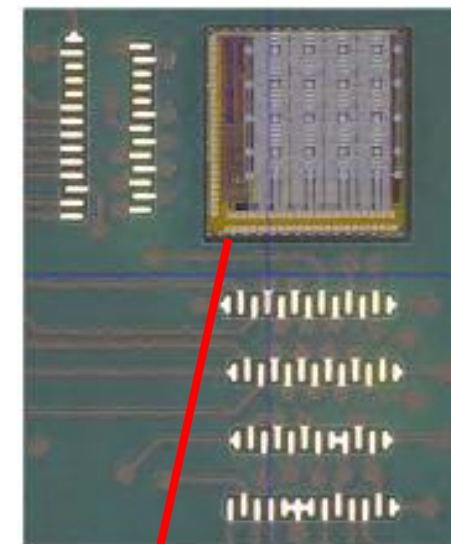
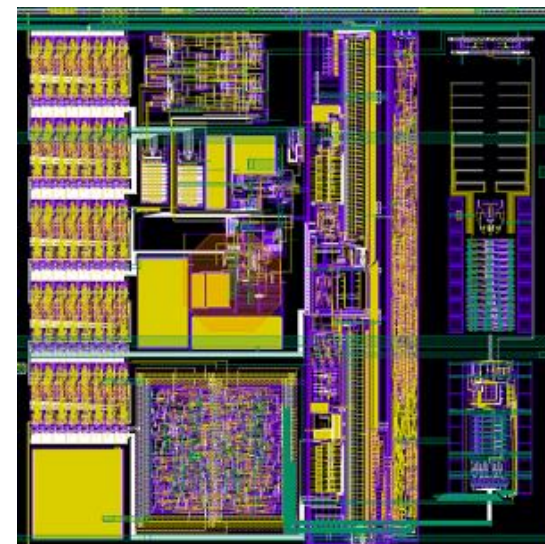
- Custom AC-LGADs from BNL
 - Various geometries: pixels, strips, zigzags!
 - 0.5mm x 0.5mm pixels: 30ps, 25um
 - 10mm x 0.5mm strips: 35ps, 37um
- Next prototype production underway
 - Thinner Si, doping, electrode geometries...
- More details: [[1](#),[2](#),[3](#),[Plenary](#)]

Strip Length	Strip Width	Timing	Position (eff.)
5 mm	200 um	30 ± 1 ps	37 ± 1 um
10 mm	100 um	35 ± 1 ps	37 ± 1 um
10 mm	200 um	32 ± 1 ps	55 ± 1 um
10 mm	300 um	36 ± 1 ps	60 ± 1 um
25 mm	200 um	51 ± 1 ps	117 ± 1 um



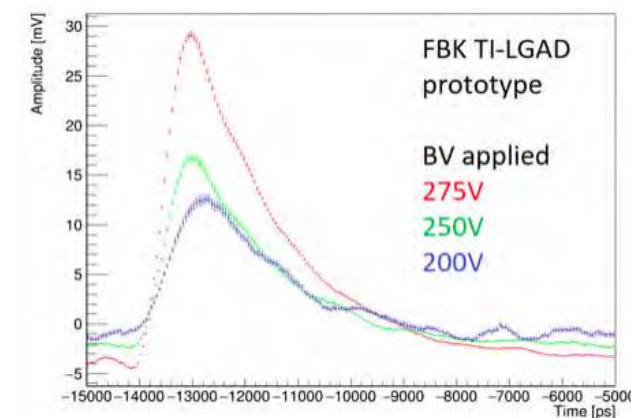
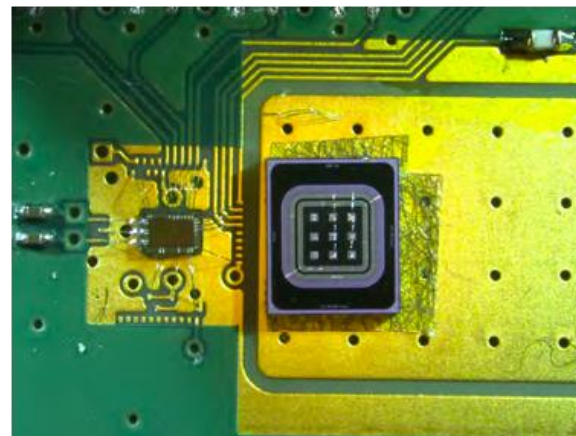
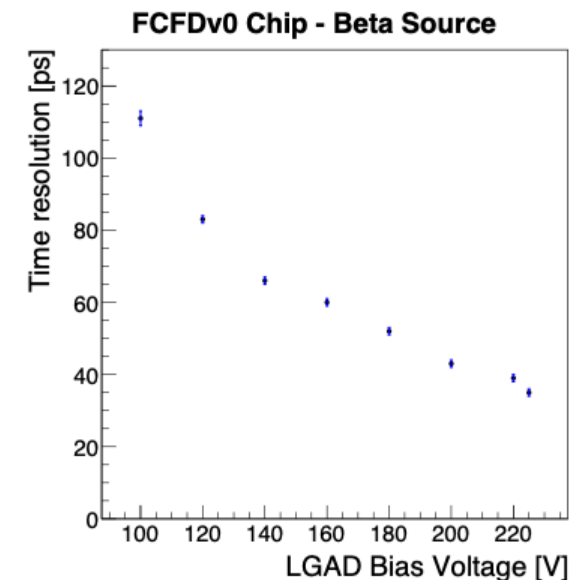
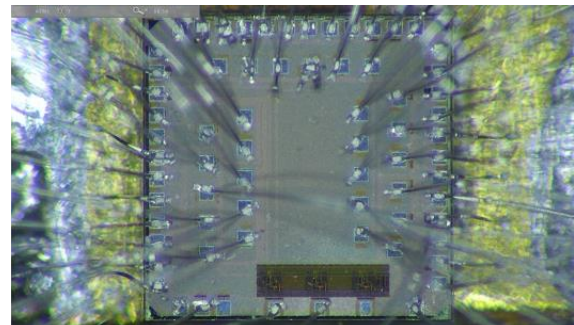
Frontend ASIC & Readout Electronics

- OMEGA EICROC:
 - Designed for Roman Pot reqs.
 - Based on ATLAS ALTIROC, CMS HGCROC
- EICROC0:
 - 4x4 channels, 0.5mm x 0.5mm pitch
 - 30ps TDC/TOA
 - 8bit ADC
 - Received in July '22, tests in progress
 - Target 1mW/ch



Frontend ASIC & Readout Electronics

- Fermilab FCFDv0: →
 - ON-chip constant fraction discrimination
- INFN Torino FAST:
 - Discriminator + TDC
- [\[Nalu Scientific\]](#) HPSoC: →
 - 8-10GSa/s digitizer, DSP
- Anadyne ASROC:
 - Si-Ge BiCMOS technology



Summary

- EPIC at EIC plans for $>10 \text{ m}^2$ of AC-LGADs
 - Far forward tracking, barrel and endcap time-of-flight systems
 - Largest AC-LGAD based detector project
- Activities bundled in international EIC AC-LGAD Consortium
 - BNL, UIC, LANL, ORNL, UCSC, Rice, FNAL, Purdue, OSU, NCKU, IJCLab, CEA Paris-Saclay, OMEGA
 - Sensors, ASICs, readout electronics, integration, mechanics, simulation, ...
- The future is fast timing!
 - At this workshop:
 - 11 contributions containing “[LGAD](#)”
 - 7 contributions containing “[LAPPD](#)”
 - 27 contributions containing “[timing](#)”