OAK RIDGE National Laboratory

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

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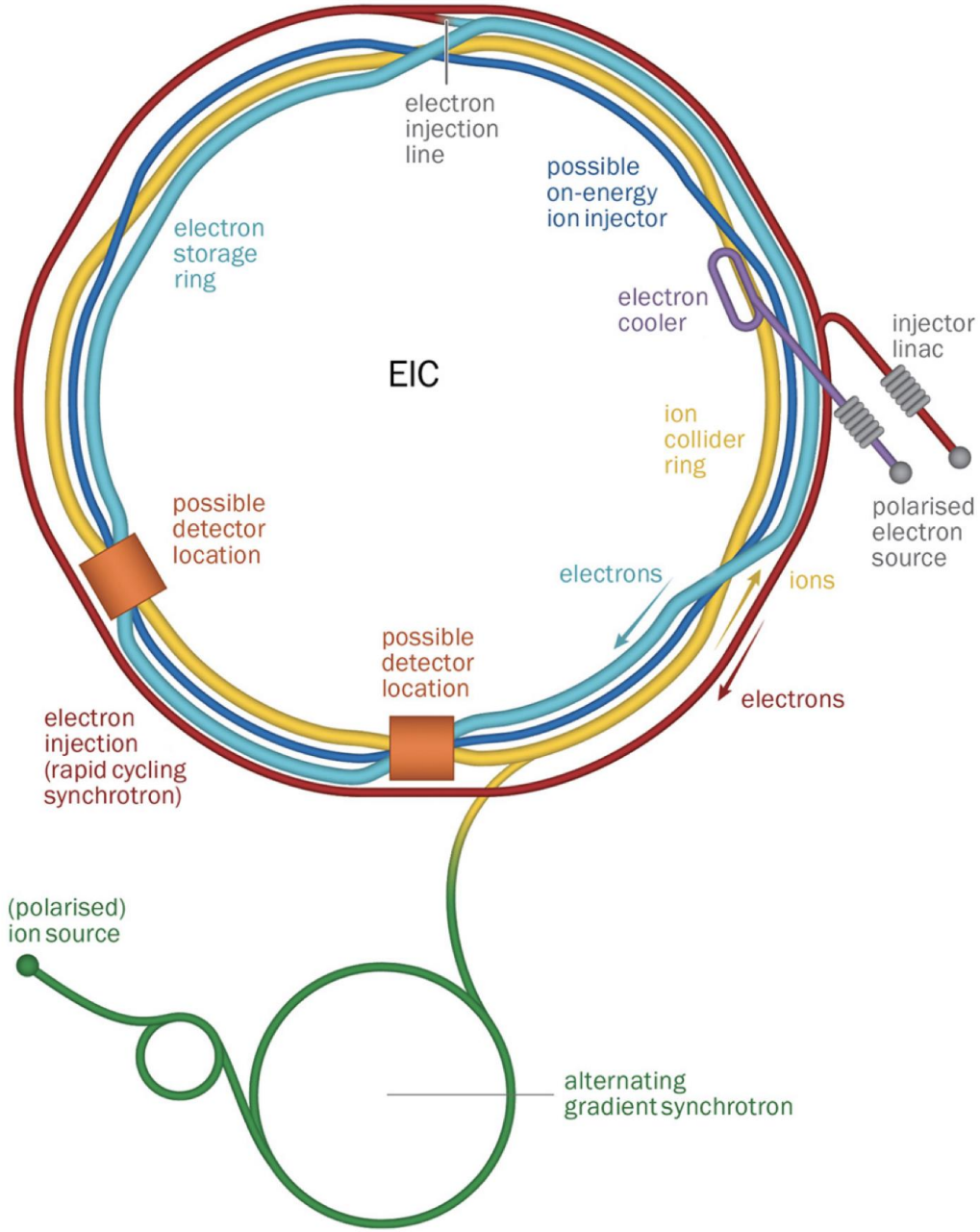
For the EIC AC-LGAD Consortium

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

U.S. DEPARTMENT OF ENERGY

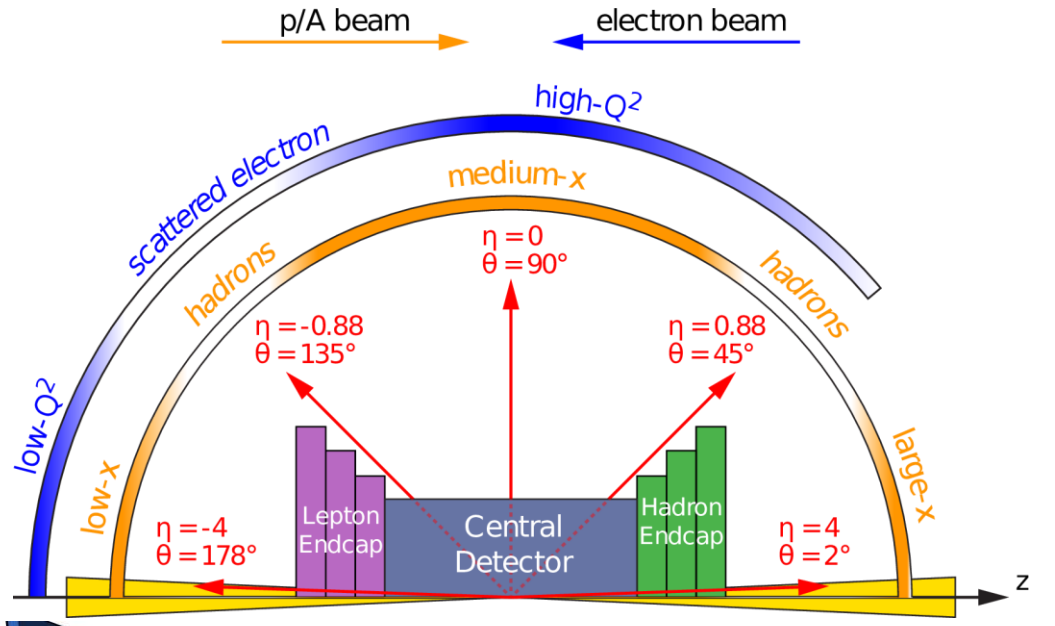
The Electron-Ion Collider

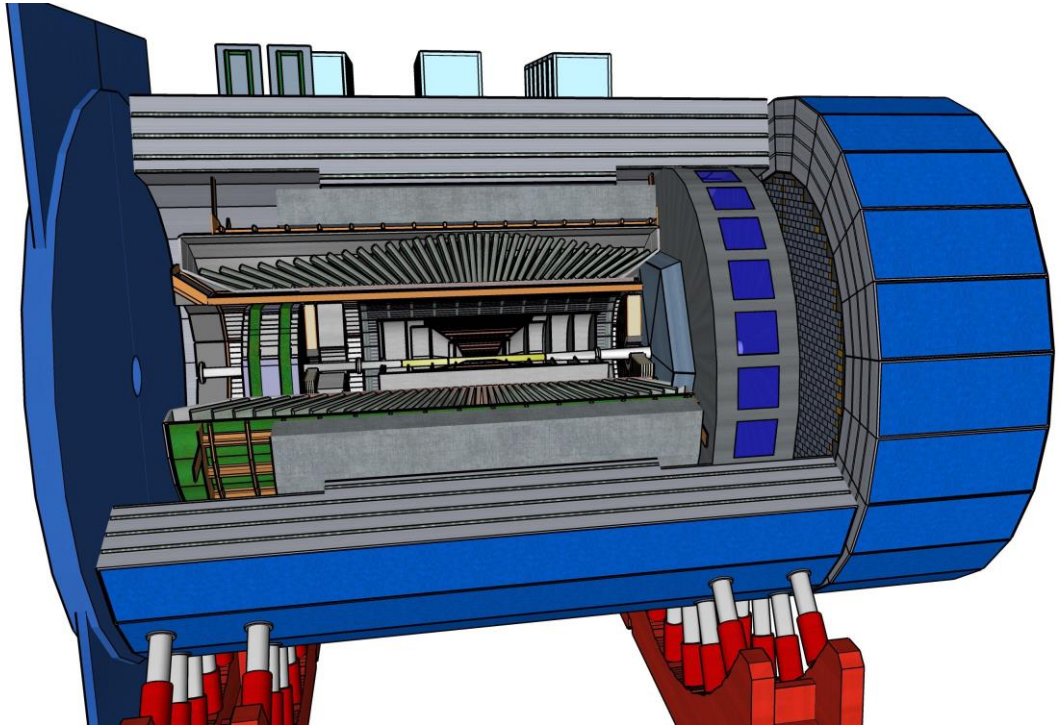
- Flagship Nuclear Physics Collider Experiment constructed at Brookhaven National Laboratory
  - Protons/nuclei 41-275 GeV/Z
  - Electrons up to 18 GeV
  - Up to 70% polarized beams
  - Luminosity up to 10^{34} $cm^{-2}s^{-1}$ (100-1000x HERA)
- Two interaction regions
- First beams in early 2030s



EPIC – The First Detector for EIC

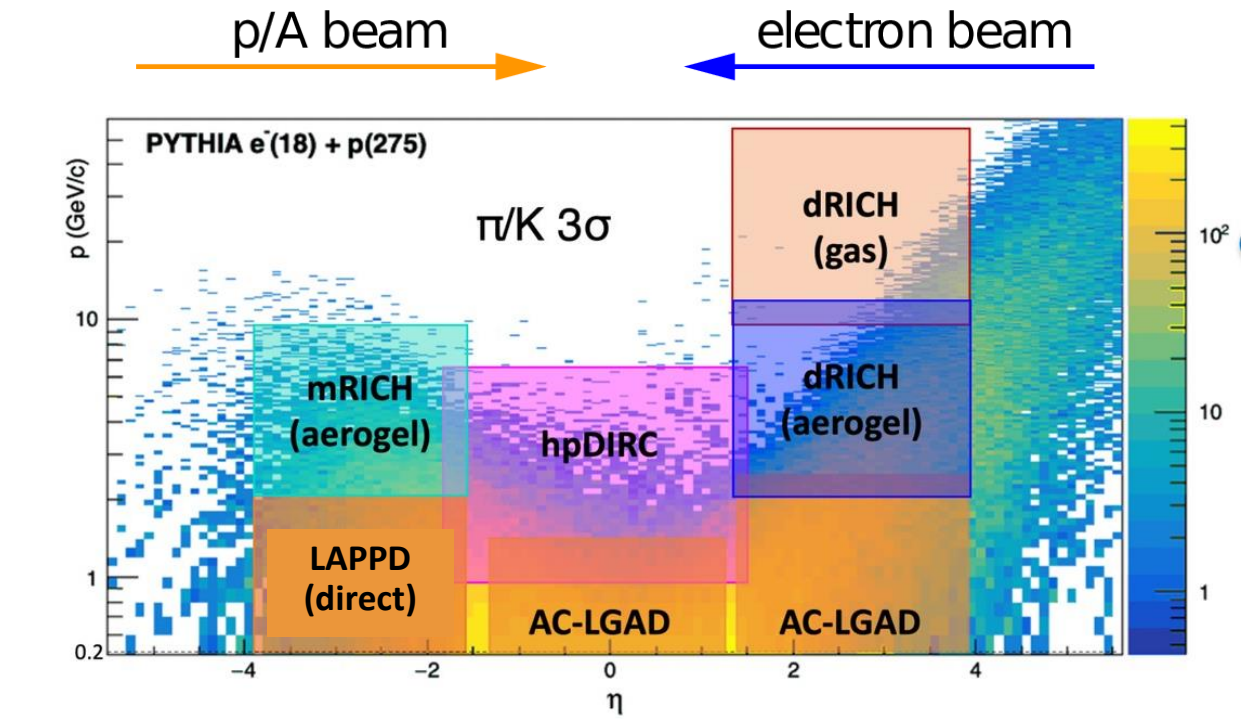
- Full coverage detector
  See [talk by T. Ullrich]
  - High precision tracking [MPGD]
  - Particle Identification [dRICH]
  - High granularity calorimeters [1,2,3,4]
  - Far forward/backward systems
- EPIC Collaboration formed July ’22
  - Proponents of ATHENA/CORE/ECCE
  - Logo to be revealed soon!

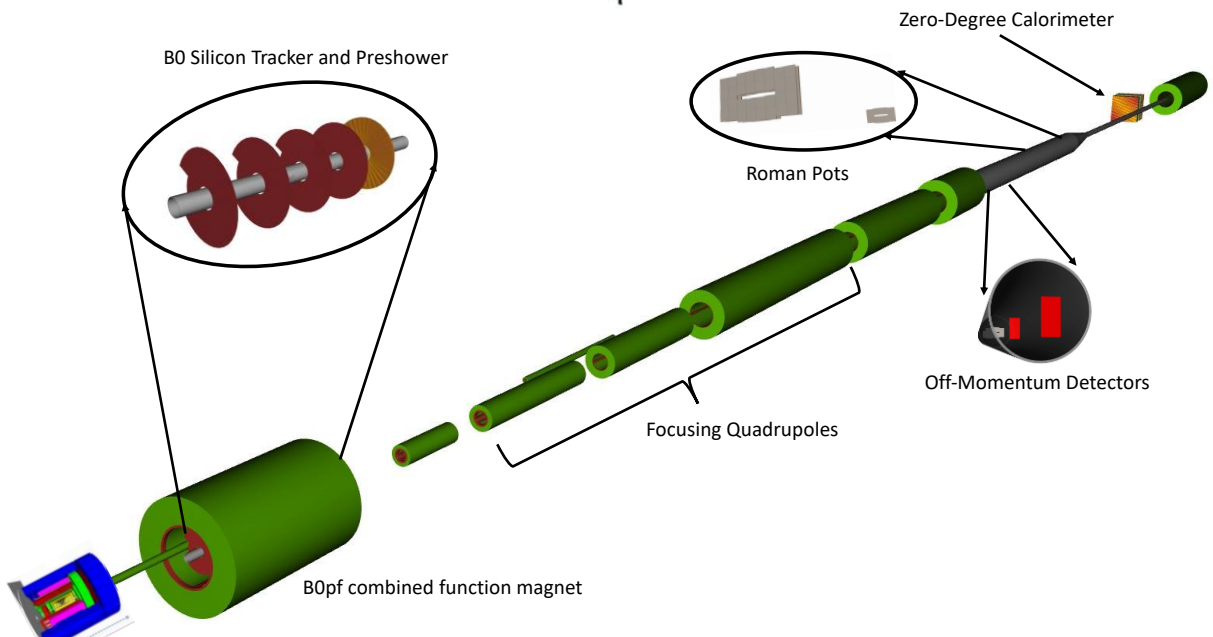




AC-LGADs in EPIC

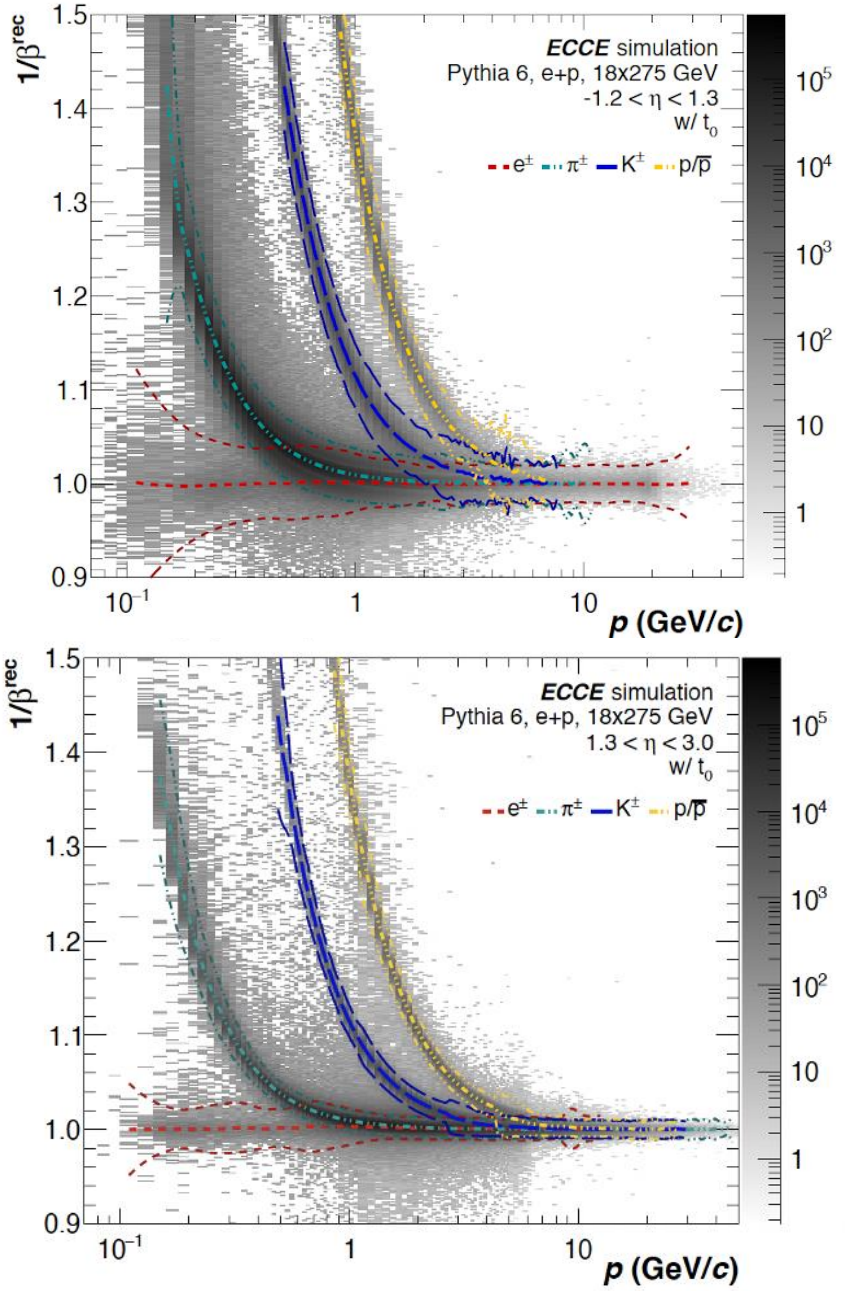
- AC-LGADs: true 4D tracking
  - <30ps MIP sensor timing achieved
  - Adjacent electrodes share signal, improving resolution
  - No dead area between electrodes
  - Several talks at this workshop: [1,2,3,Plenary]
- Several EPIC systems based on AC-LGAD
  - Time-of-flight PID
  - Far forward
  - >10m^2 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



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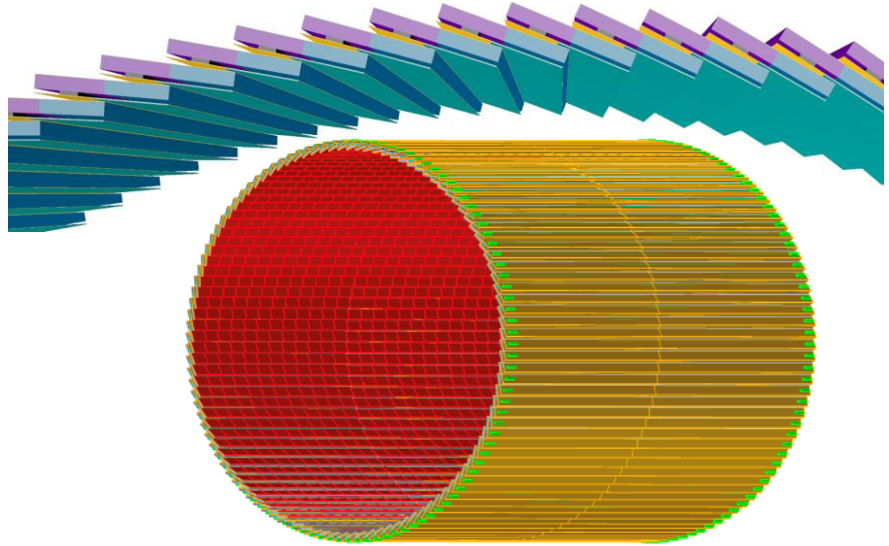
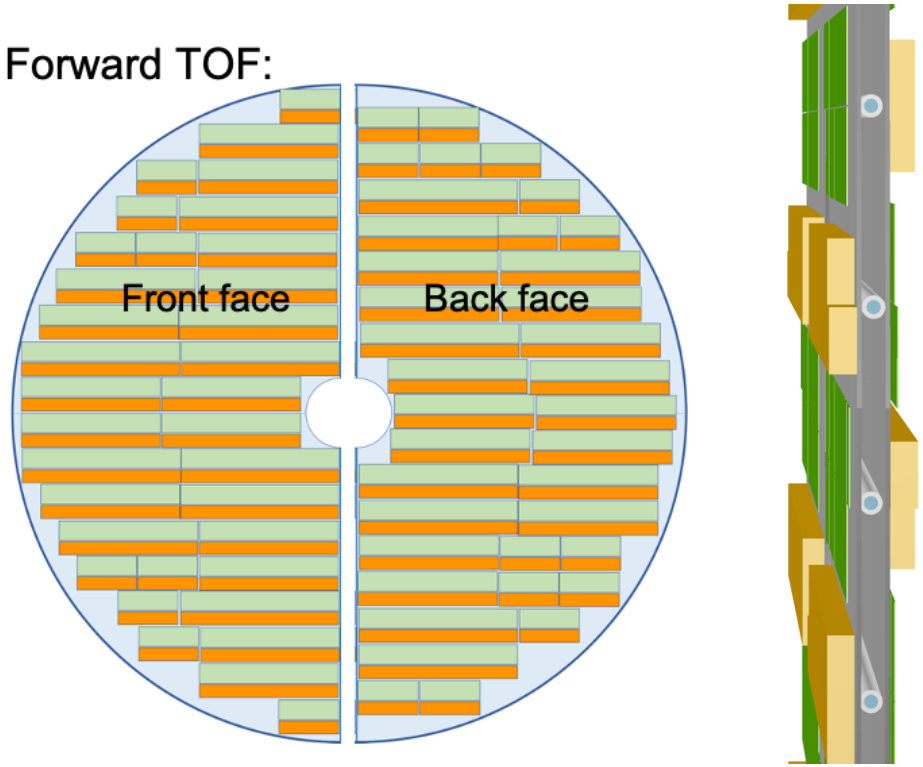
EPIC Barrel TOF

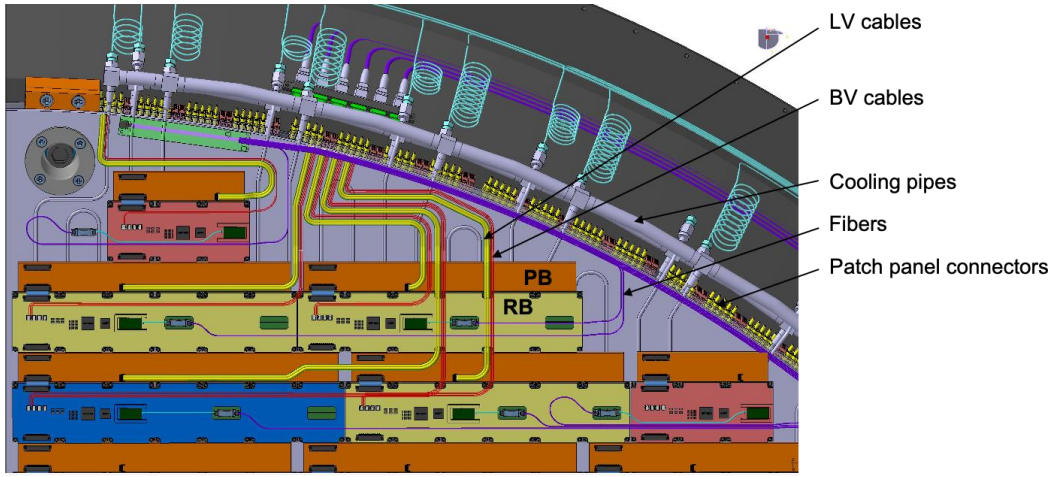
- Based on STAR IST mechanics
  - Carbon foam, Kapton flex PCB
  - Expect ~1% X/X_0 material
- Long staves: 2.40m span
- Large area: $10m^2$ sensors
- ~4kW total power dissipation
- Requires fabrication tests and demonstrators



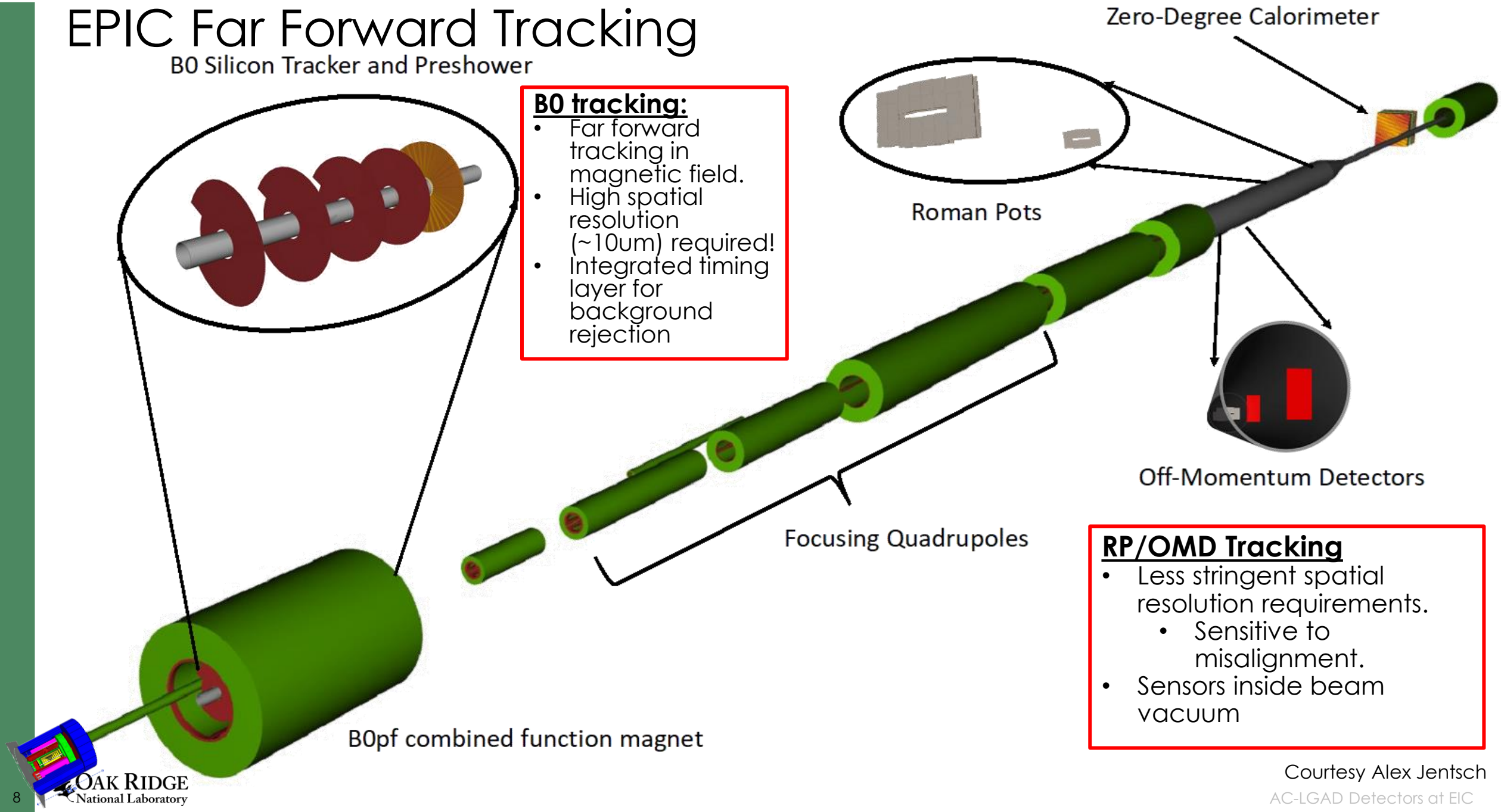
EPIC Endcap TOF

- Based on CMS-ETL design
  - Double-sided clamshell
- 1.3m diameter (1.5 m^2)
  - <10cm total thickness
  - Expect ~8% X/X_0 material
- Significant power dissipation
  - 13kW at 0.5 x 0.5mm^2 segmentation, scaling with pixel size/density
  - Operation at room temperature





EPIC Far Forward Tracking



B0 tracking:

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

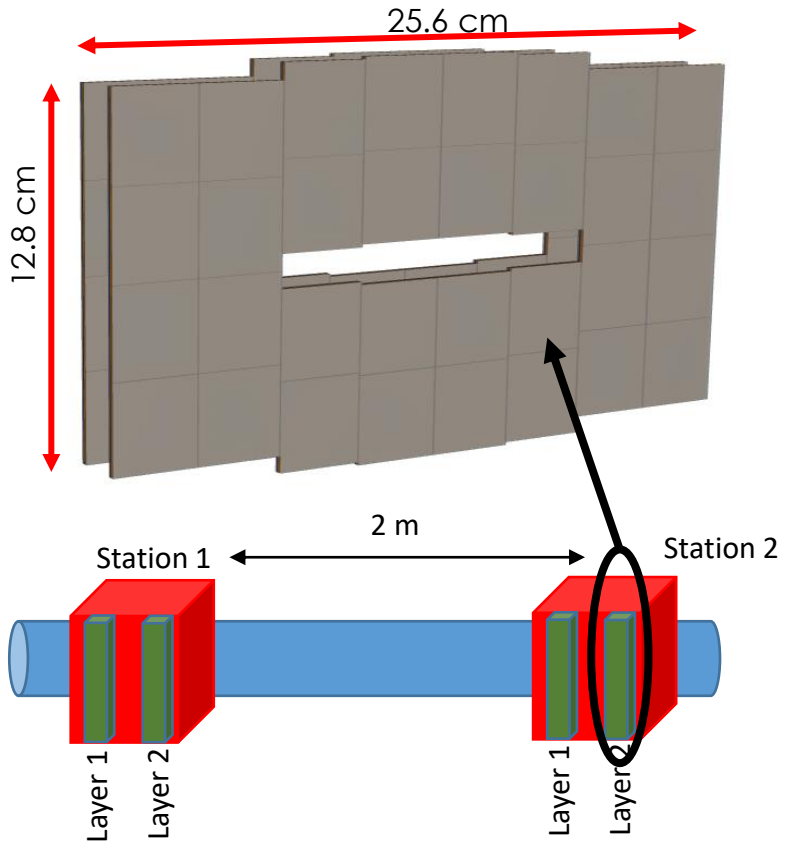
RP/OMD Tracking

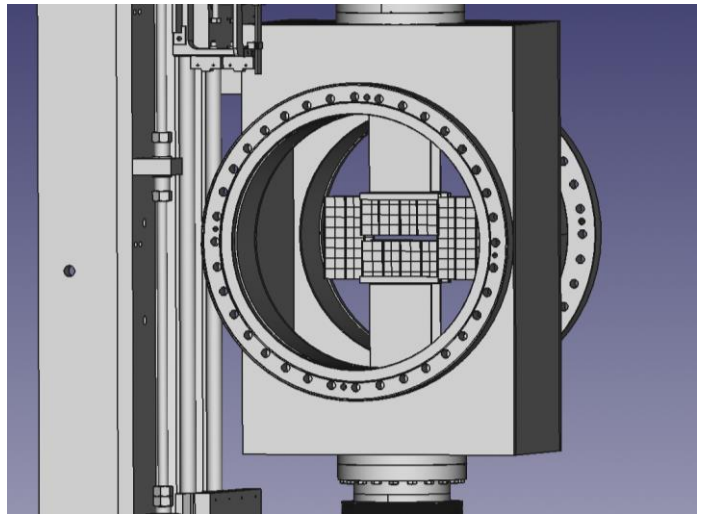
- Less stringent spatial resolution requirements.
  - Sensitive to misalignment.
- Sensors inside beam vacuum

Courtesy Alex Jentsch

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?

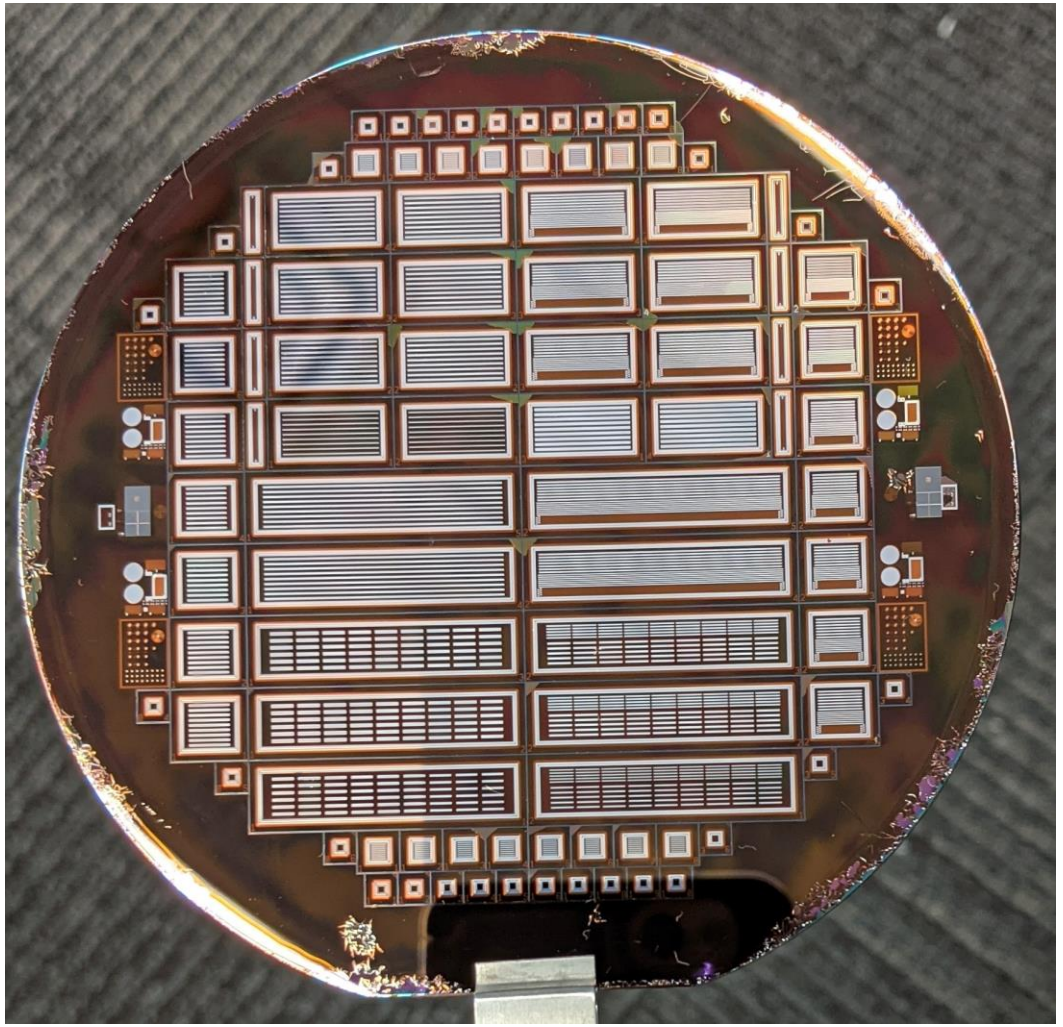


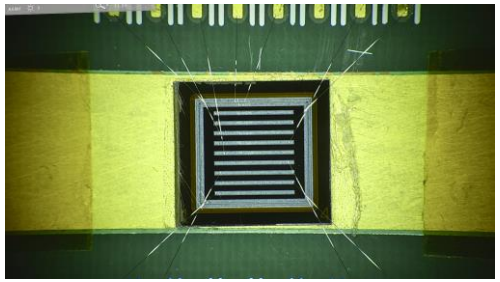


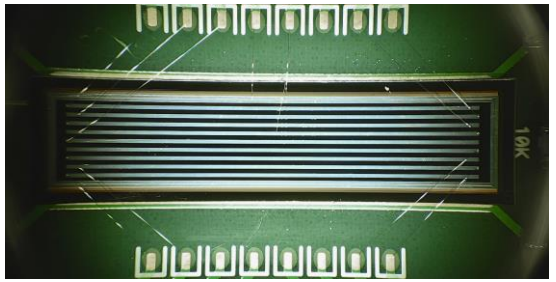
AC-LGAD Sensor R&D

- 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

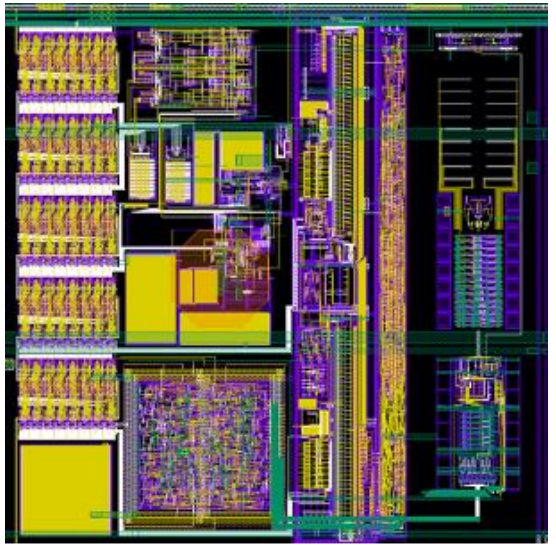


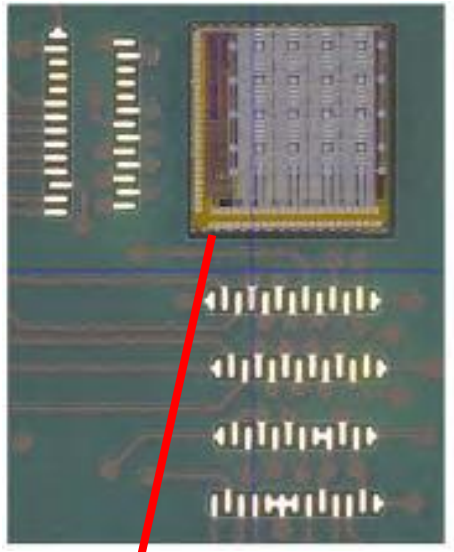


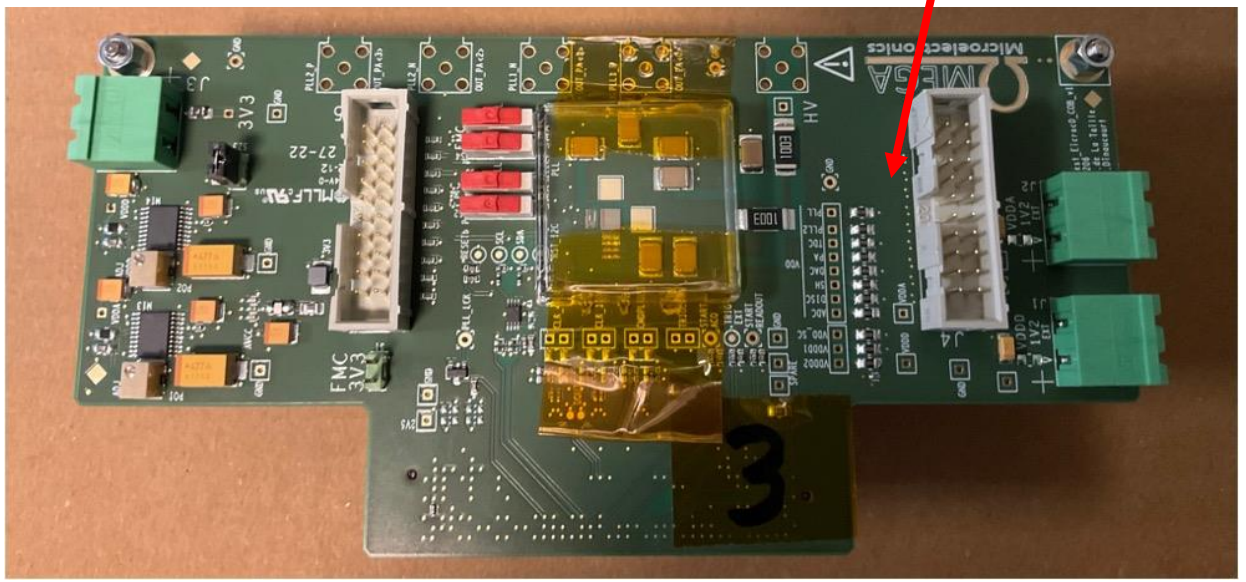


Frontend ASIC & Readout Electronics

- 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

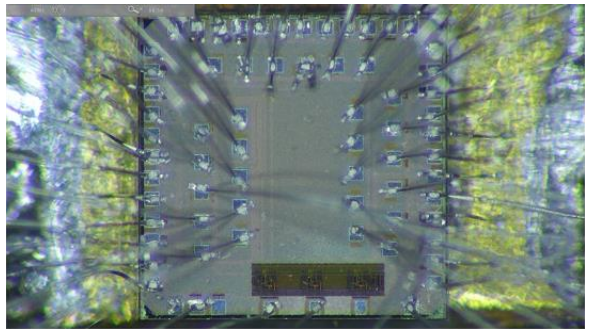


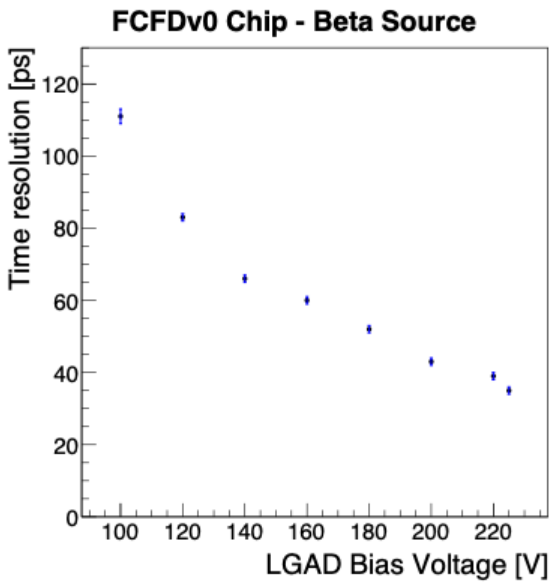


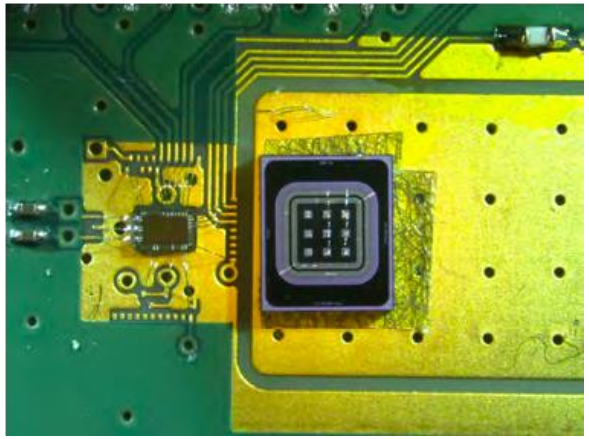


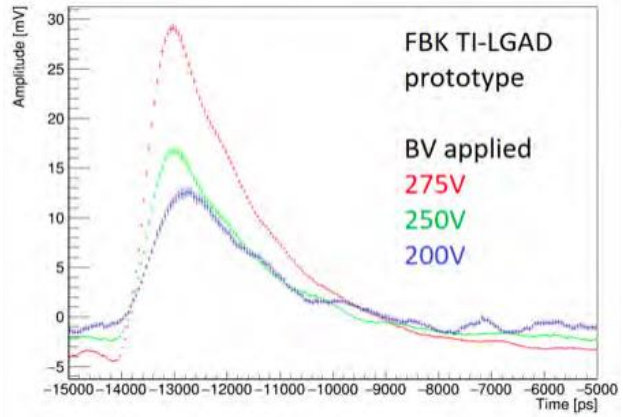
Frontend ASIC & Readout Electronics

- 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 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 working group eRD112
  - 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"