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BTOF in the ePIC detector

- BTOF is a main PID detector covering low-p_T at mid-rapidity

- High momentum particle momentum resolution is improved by BTOF

- Beam-induced background can be rejected by timing information

- Timing resolution of 35 ps and spatial resolution of 30 um is required
    - 3 sigma π/K separation up to ~1.2 GeV/c

- Strip AC-LGAD technology meets the requirements
    - To reduce total readout channels, strip AC-LGAD will be adopted (~12 m²)
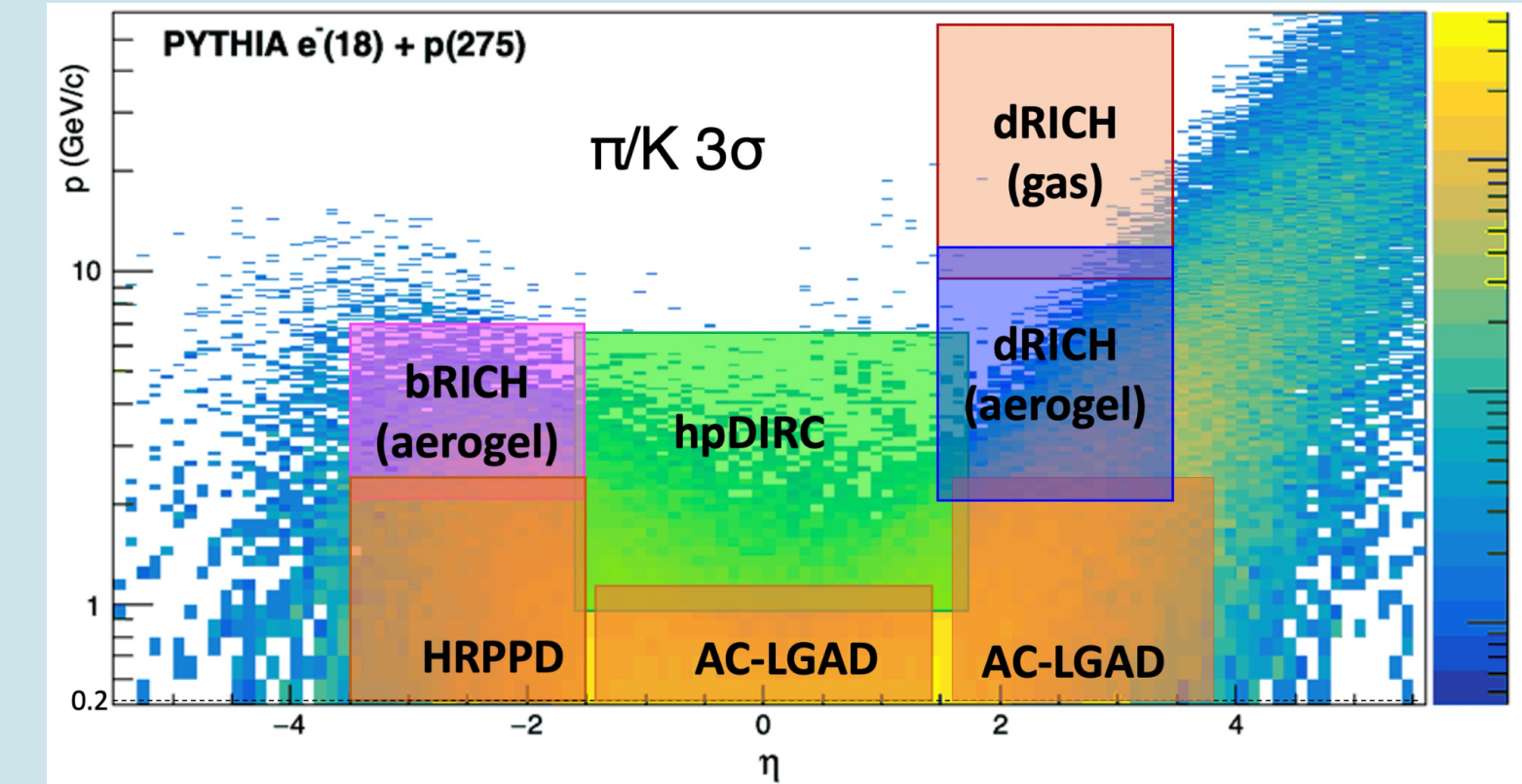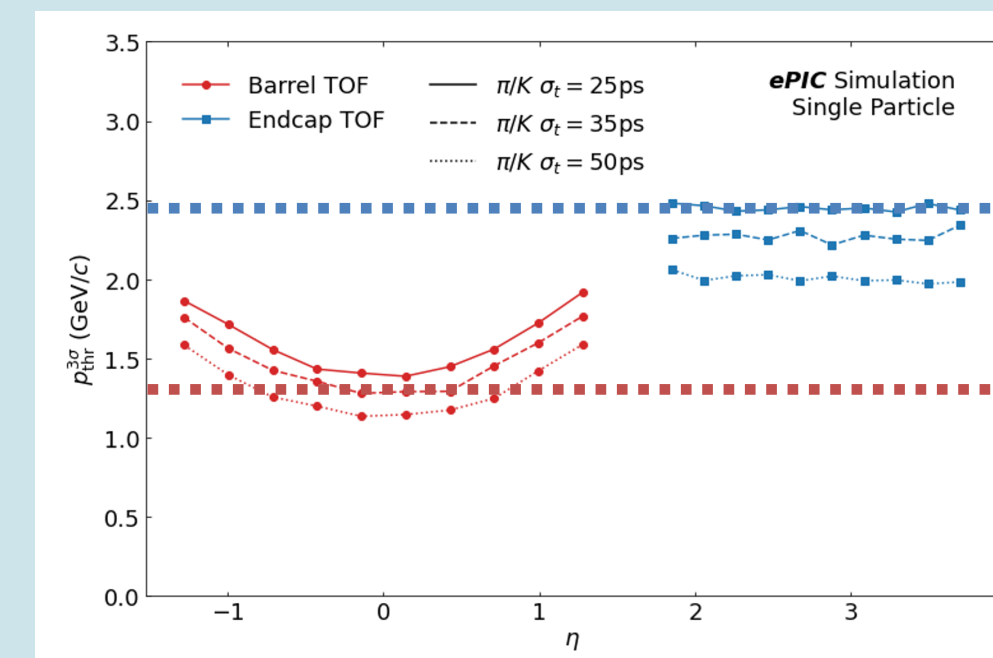
Tracking detectors in ePIC
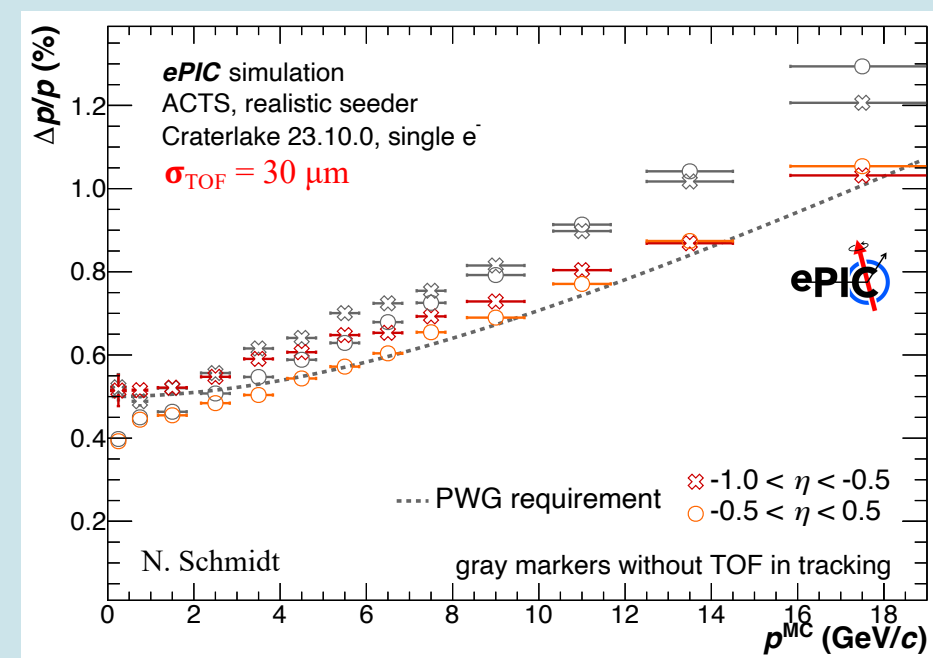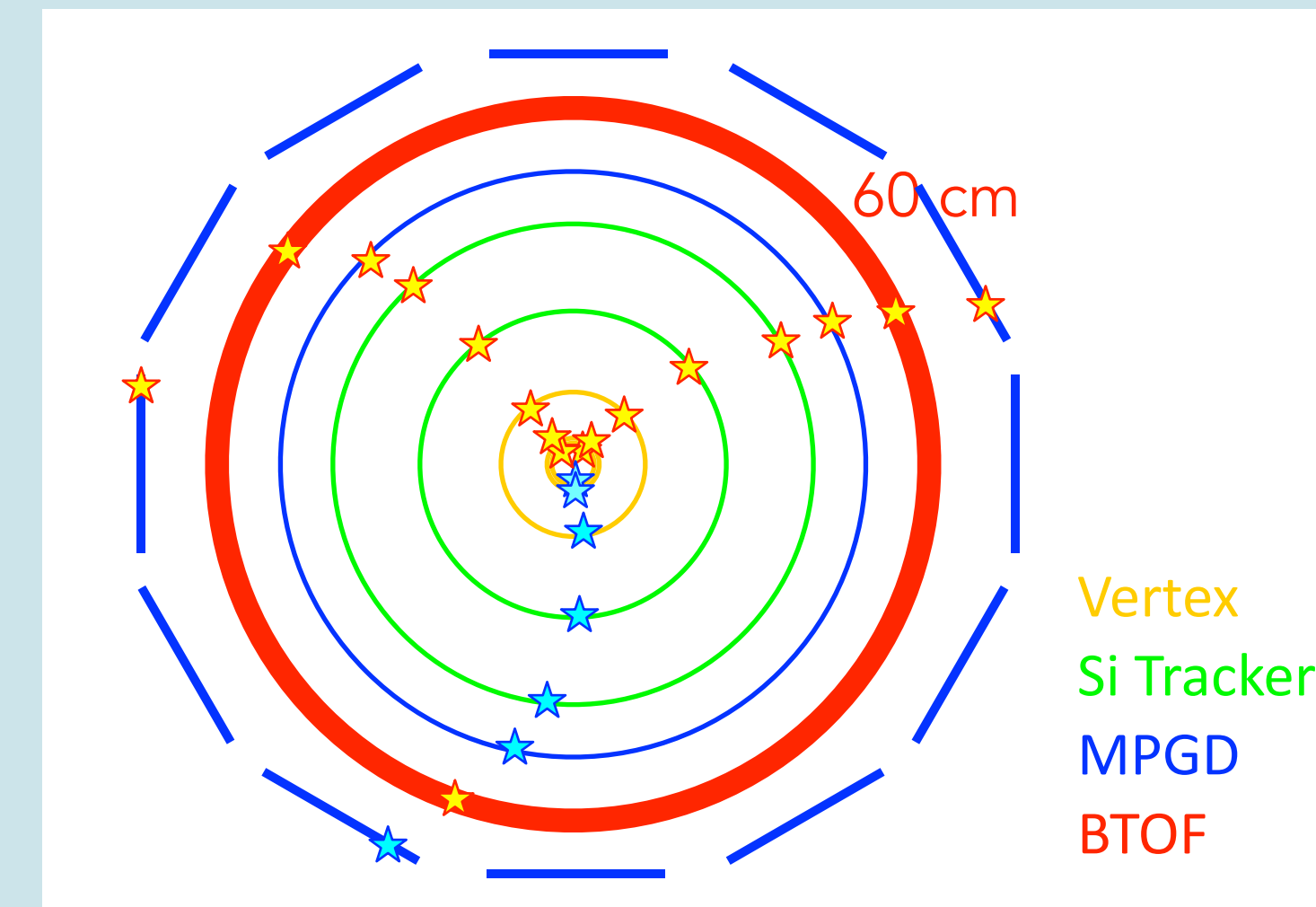

By N. Schmidt
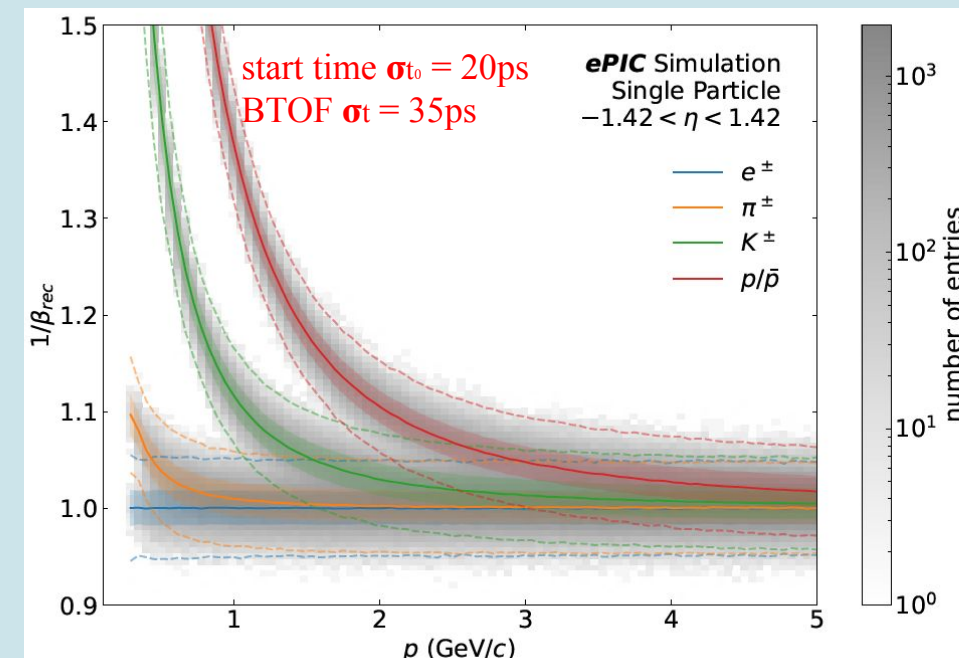
By O. Hartbrich

By O. Hartbrich

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Detector Layout

- BTOF is composed of 144 modules to make a cylindric

- 64 AC-LGAD strip sensors are attached to one module

  – ASIC place is under discussion (depending on the ASIC pixel geometry)

- Radius is 60 - 63 cm from the beam pipe covering -1.42<η<1.77
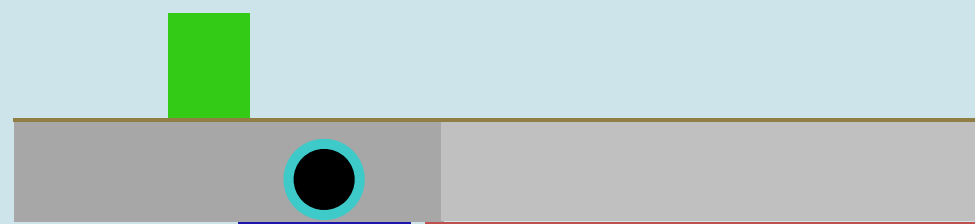
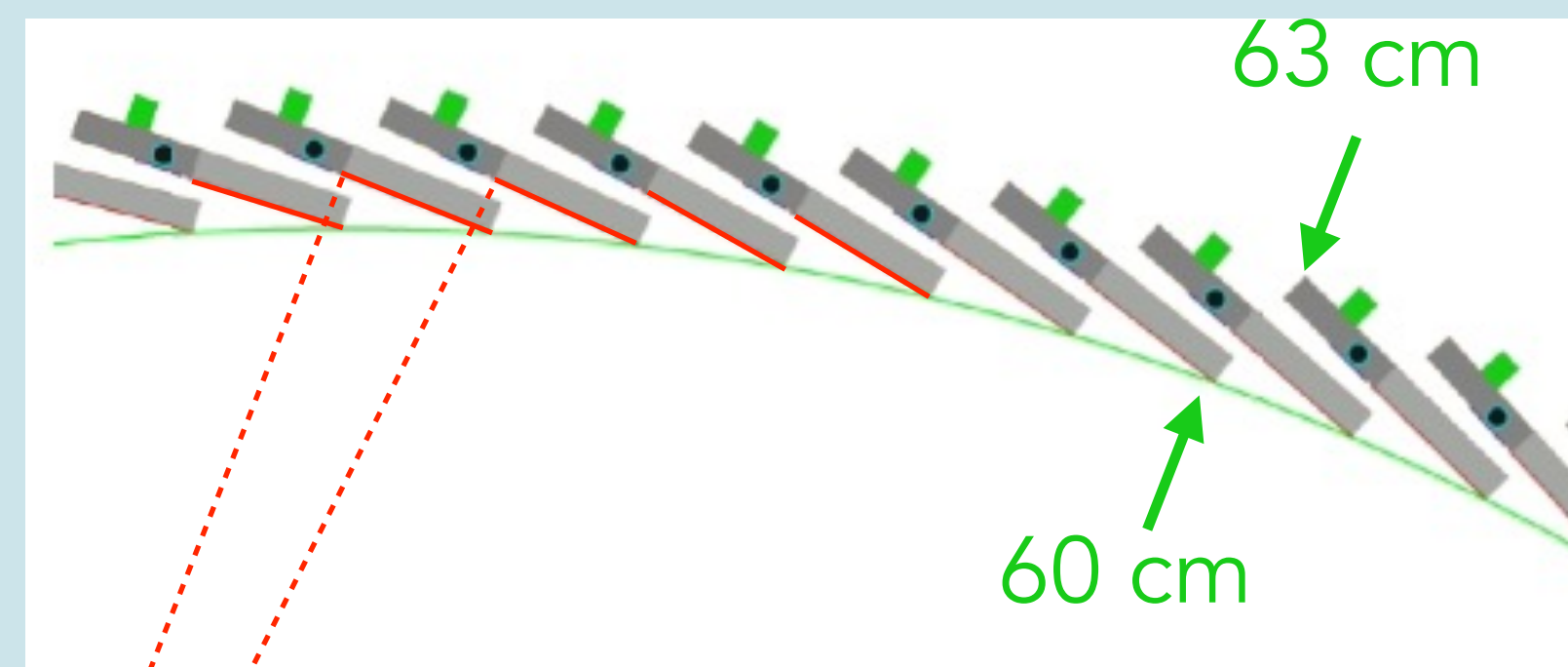- Total material budget in acceptance is ~0.01 X/X_0

BTOF shape

Module top view

64 AC-LGADs

5.6 cm

~260 cm
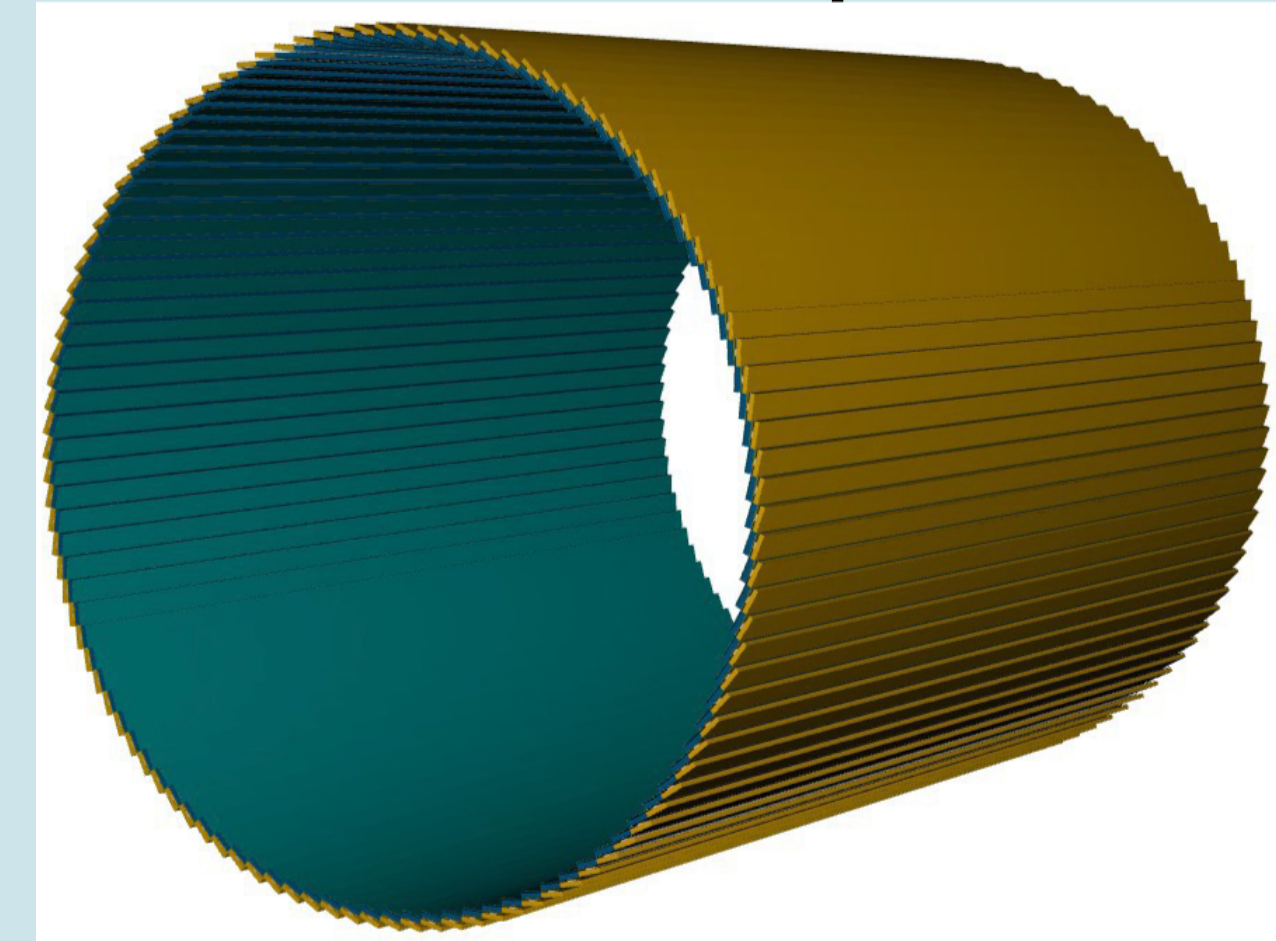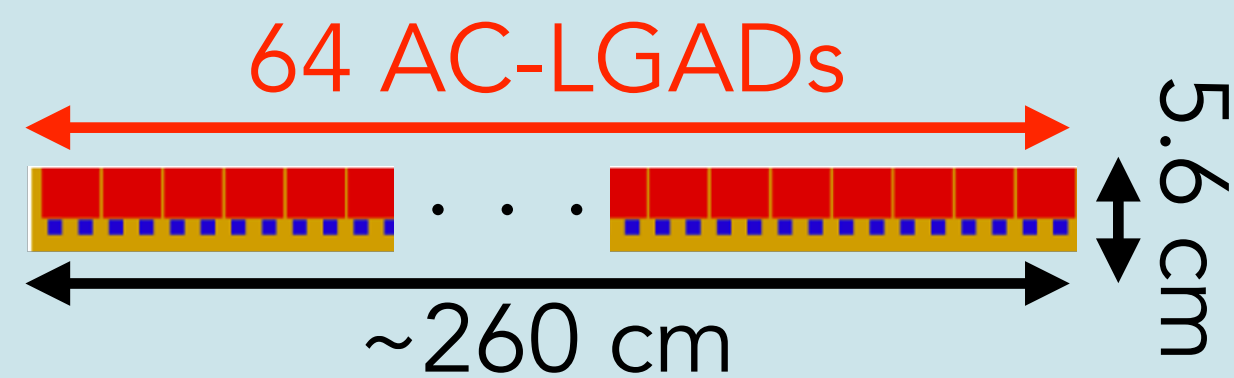
Module cross section

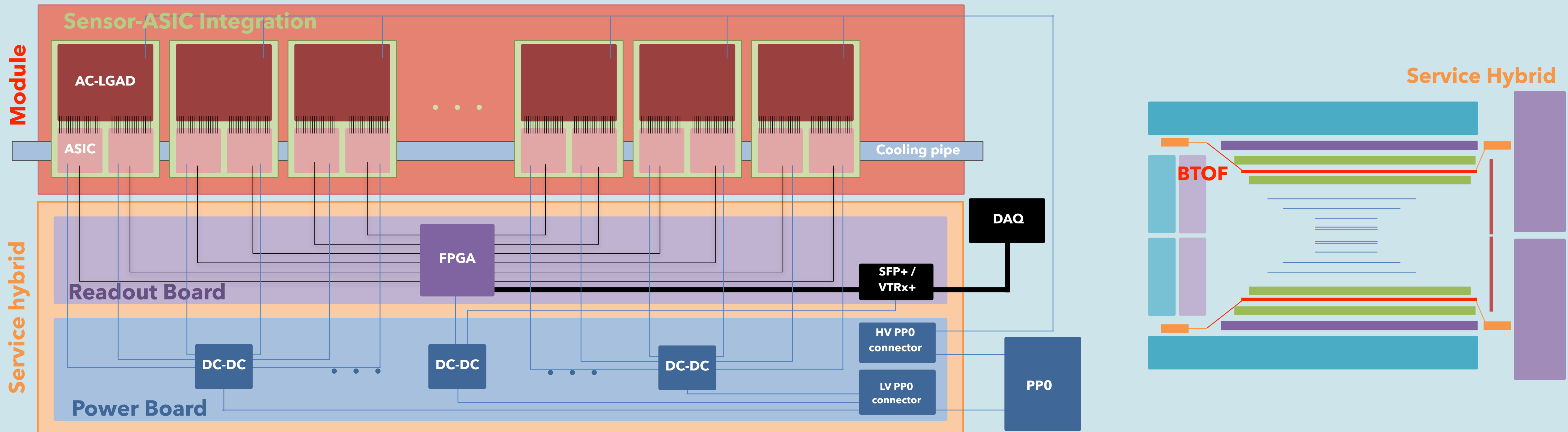**Cylindrical structure by modules**

3 mm overlap in Φ

63 cm

60 cm

Material budget
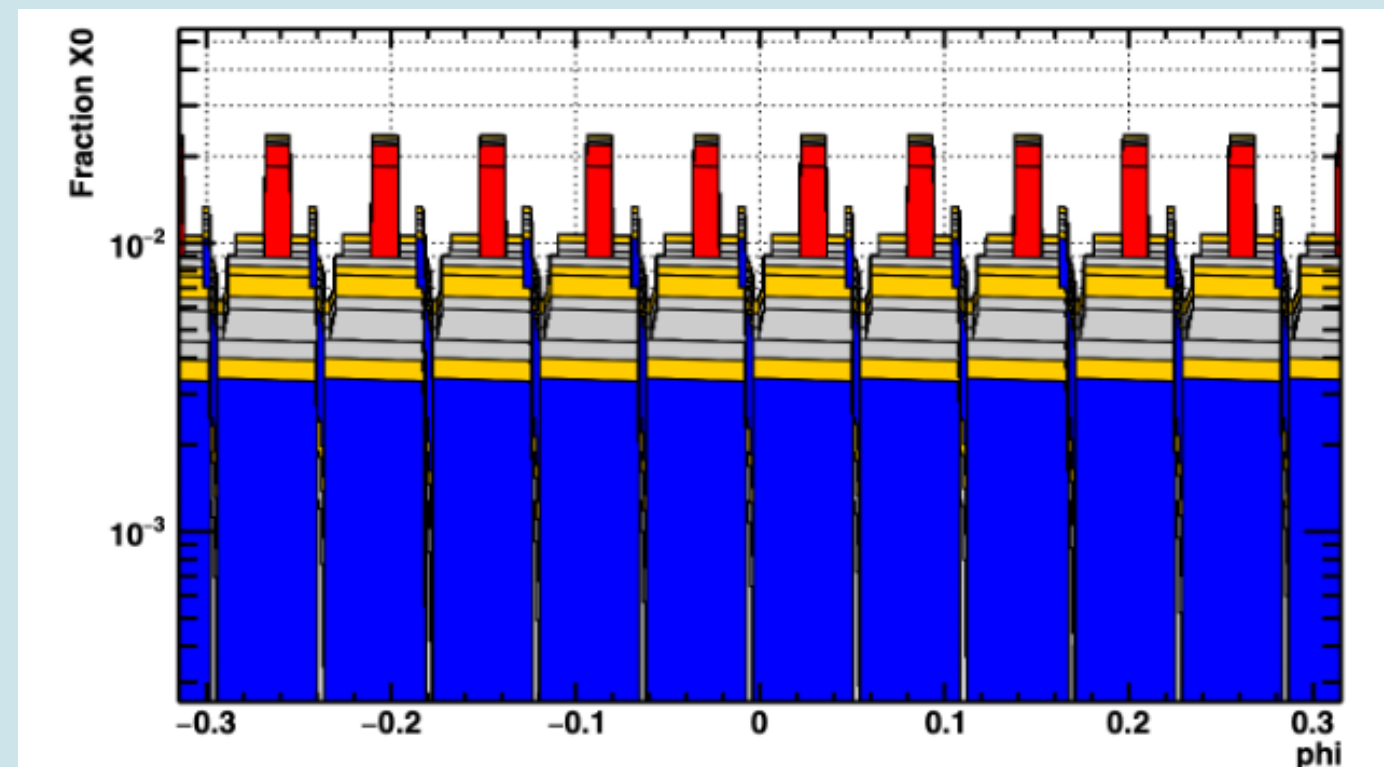
BTOF system structure

- Sensor signal is readout by 2 ASICs
- ASICs which is the main heat source are cooled by a water pipe embedded inside the module
  - Beam pipe geometry depends on the position of the ASIC
- Data I/O and power supply are controlled by the Service-hybrid
- The service-hybrid is placed outside of the acceptance

- AC-L[...]ents
- Strip-type sensor, 3.2 x 4 cm^2 sensor size with 0.05 x 1 cm^2 metals, is used in BTOF
  - The readout metal geometry in a sensor is 64 x 4 and 256 channels each
- Due to charge sharing between multiple readout electrodes, 30μm spatial resolution can be achieved in φ direction

4 cols

64 rows

HPK_W2_3_2_50T_1P0_500P_50M_E240, 180V
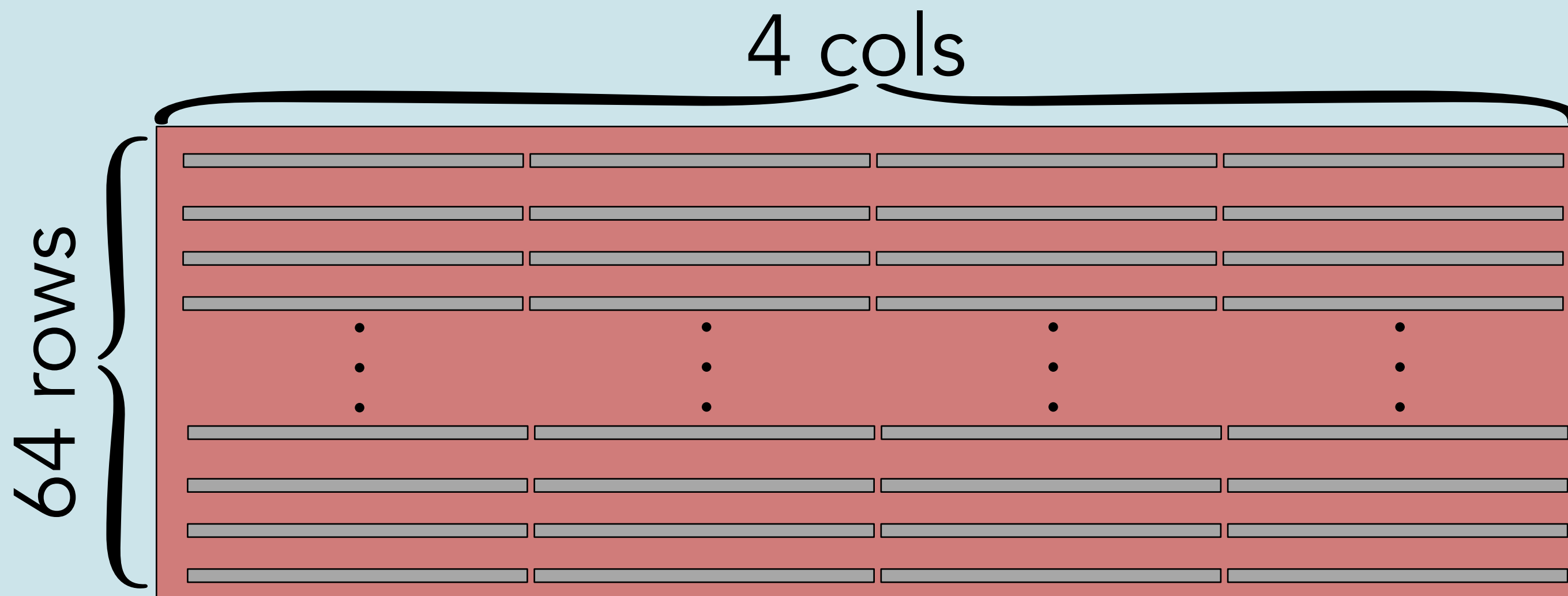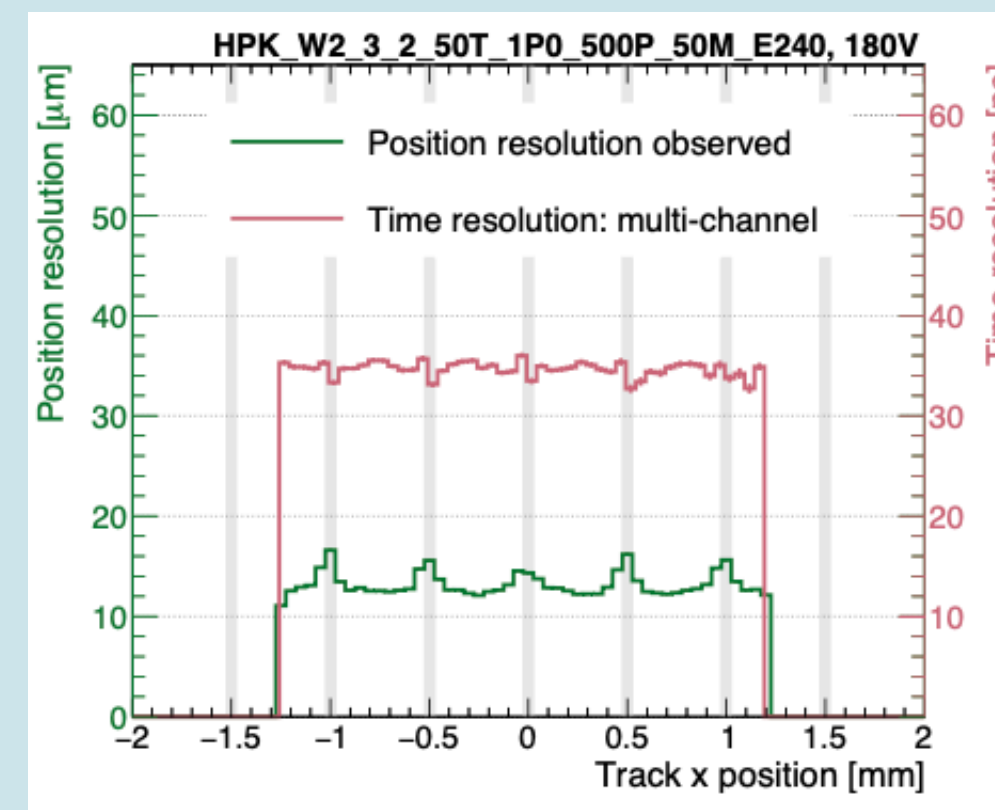
- Total information
  - **9216 sensors**
  - **11.8 m^2**
 - **2.4 M readout channels**

The latest sensor performance details will be reported at the next session (link)

BTOF ASIC

ASIC

- Not only high-time resolution TDC but also ADC must be measured
- Due to the large capacitance and readout geometry characteristics caused by the strip type, care must be taken when selecting an ASIC

- EICROC (16x16) is one of the common ASICs used in ePIC
  - Design focuses on pixel AC-LGAD readout (tuned for low capacitance)
  - 10-bit TDC and 8-bit ADC is now available (EICROC0)
  - Modification is necessary to read higher capacitance sensor (strip AC-LGAD)

- FCFD is a new ASIC to use strip AC-LGAD readout
  - FCFD can read higher capacitance AC-LGAD sensor
  - Multiple-channel analog is available for FCFDv1

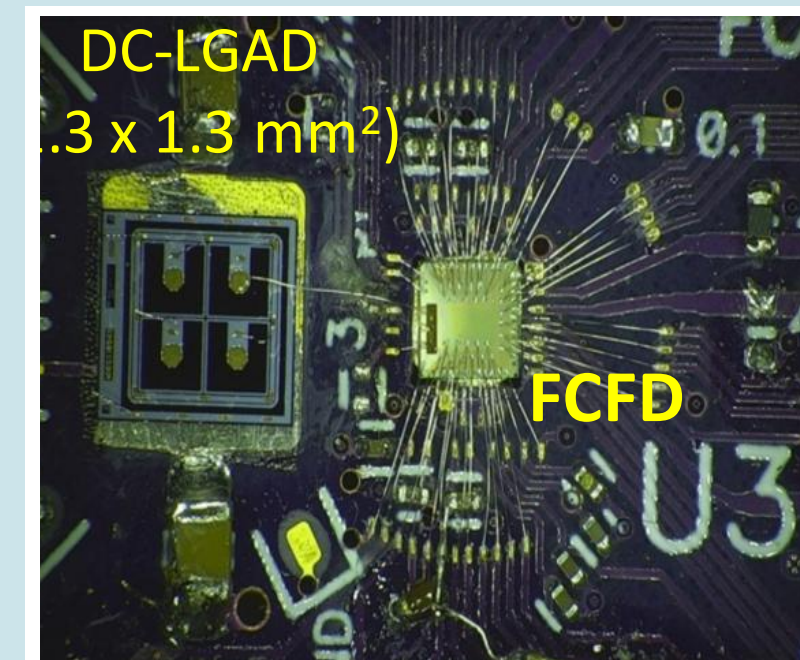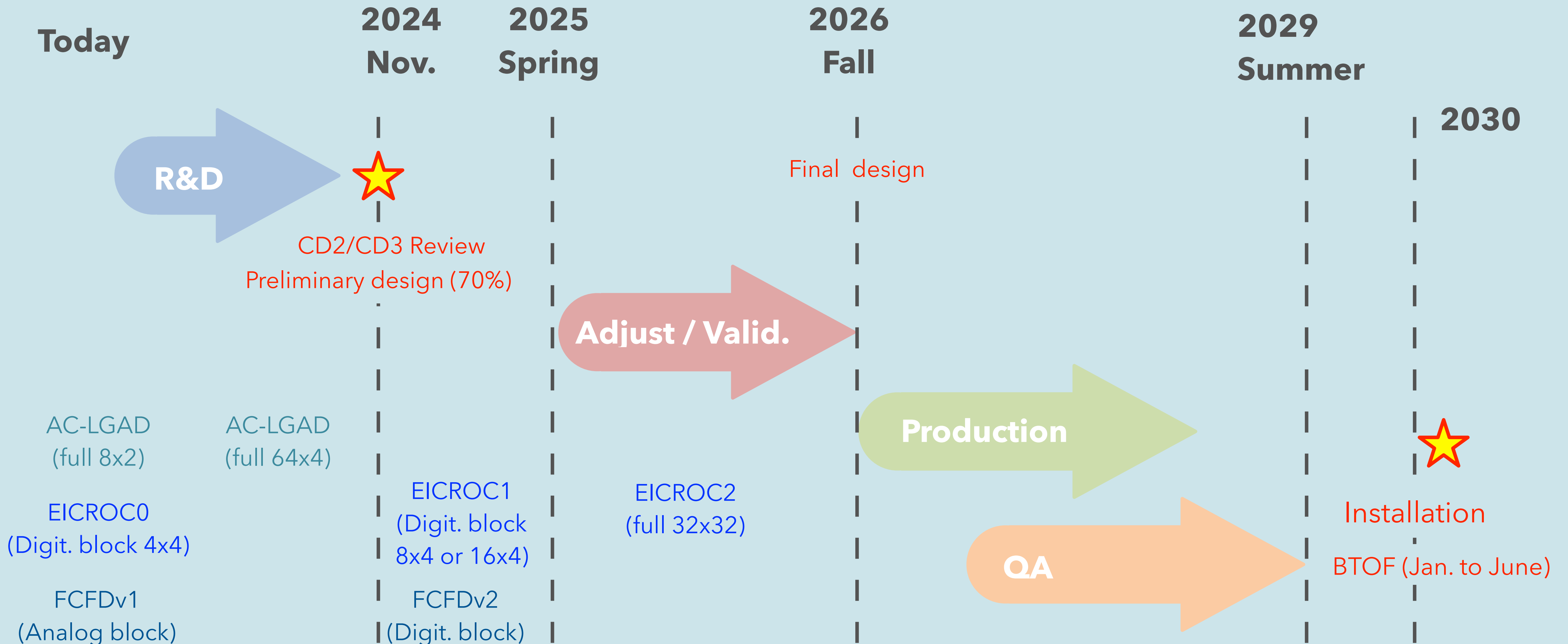- A variety of third-party ASICs continue to be explored as back-up solutions
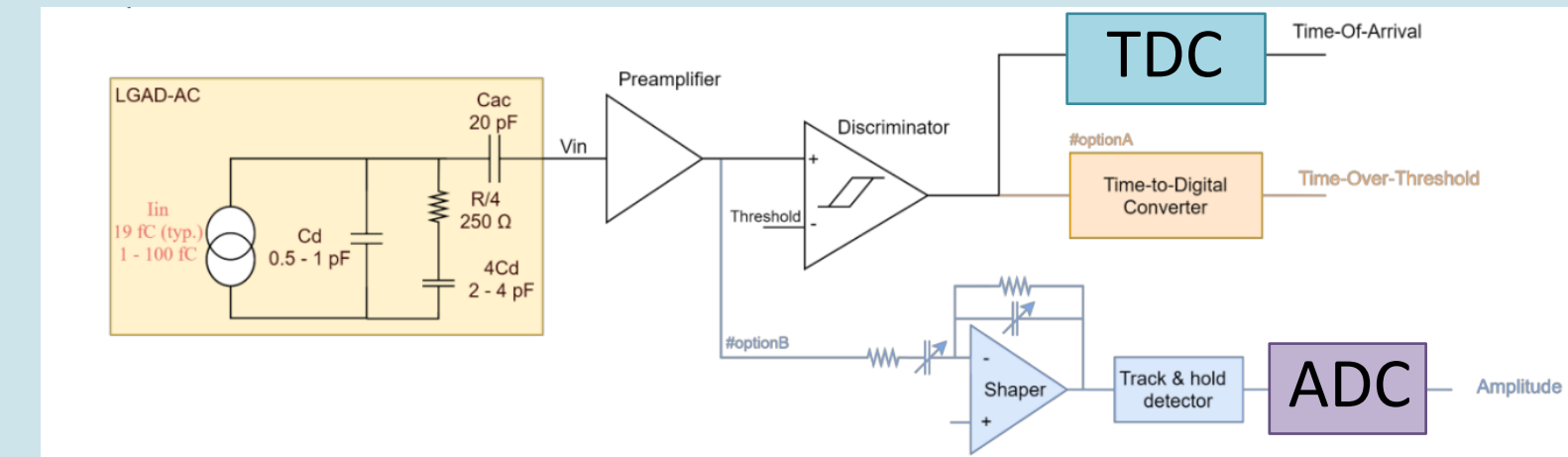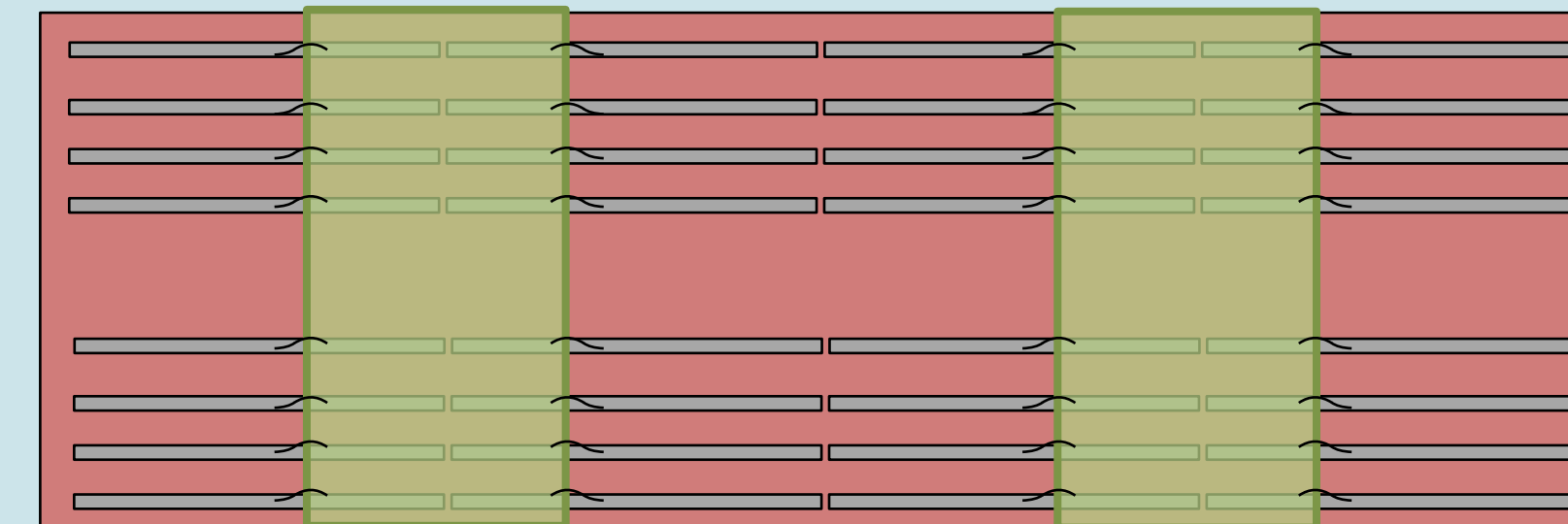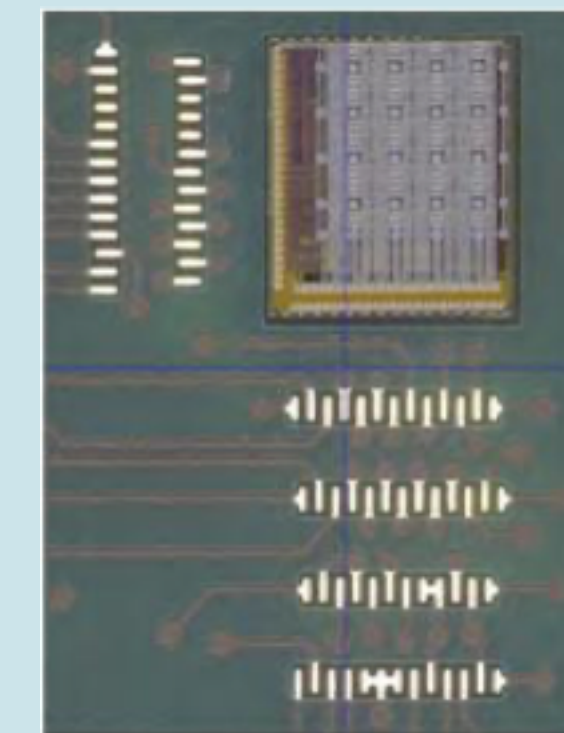
EICROC0   FCFDv0

The latest ASIC performance details will be reported at the next session (link)

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BTOF schedule and cost estimation

Today

2024 Nov.

2025 Spring

2026 Fall

2029 Summer

2030

R&D

CD2/CD3 Review
Preliminary design (70%)

Final design

Adjust / Valid.

Production

AC-LGAD
(full 8x2)

AC-LGAD
(full 64x4)

EICROC0
(Digit. block 4x4)

EICROC1
(Digit. block
8x4 or 16x4)

EICROC2
(full 32x32)

QA

Installation

BTOF (Jan. to June)

FCFDv1
(Analog block)

FCFDv2
(Digit. block)

Total cost: $11M + α (Sensors: $5M   ASIC: $5M   Module: $1)

Institutes in BTOF tasks

- Brookhaven National Laboratory (USA)
- Fermi National Accelerator Laboratory (USA)
- Rice University (USA)
- Oak Ridge National Laboratory (USA)
- Ohio State University (USA)
- Purdue University (USA)
- University of California Santa Cruz (USA)
- University of Illinois at Chicago (USA)
- Hiroshima University (JP)
- RIKEN (JP)
- Shinshu University (JP)
- Nara Woman University (JP)
- National Chen-Kung University (TW)
- National Taiwan University (TW)

Tasks in BTOF

- **AC-LGAD sensor**
  - BNL
  - ORNL
  - Univ. of California, Santa Cruz
  - Univ. of Illinois, Chicago
  - Hiroshima University
  - Shinshu University

- **Frontend ASIC**
  - Fermilab
  - Rice University
  - ORNL
  - Hiroshima University
  - National Taiwan University

- **Sensor-ASIC integration**
  - BNL
  - ORNL
  - Univ. of California, Santa Cruz
  - Univ. of Illinois, Chicago
  - National Taiwan University

- **Module structure**
  - Purdue University
  - National Cheng-Kung University

- **Module assembly**
  - BNL
  - ORNL
  - Ohio State University
  - Univ. of California, Santa Cruz
  - Hiroshima University
  - RIKEN
  - Nara Woman University
  - National Taiwan University

- **Flex PCB**
- **Service Hybrid**
- **Backend electronics**

Summary

- BTOF is the main detector for low-p_T particle identification at mid-rapidity
- High-p_T particle momentum resolution can be improved by the BTOF

- Strip AC-LGAD technology is adopted
- The cylindrical structure is built by modules and 9216 sensors with 2.4M channels in total

- Because of the large capacitance, EICROC would not be usable without modification.
- FCFD is being developed primarily for use in strip AC-LGAD
- To mitigate the risk, both developments of modified-EICROC and FCFD would be urgent

- Schedule and cost are being finalized, the cost is expected to be above $11M to construct