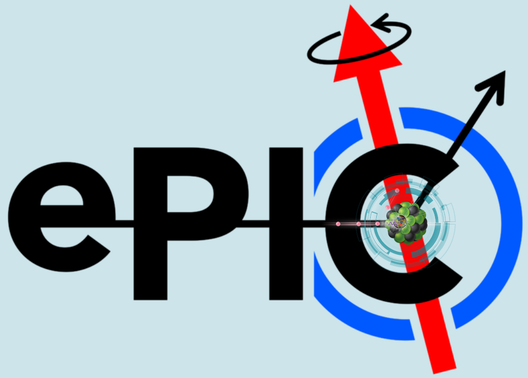


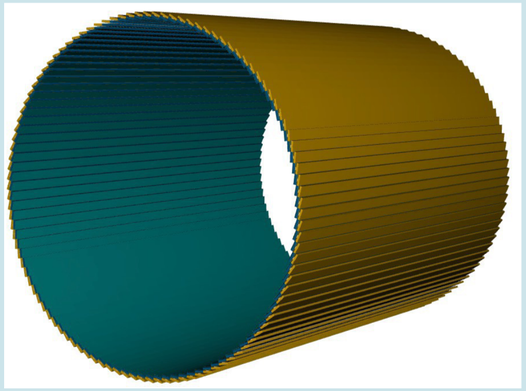
TOF

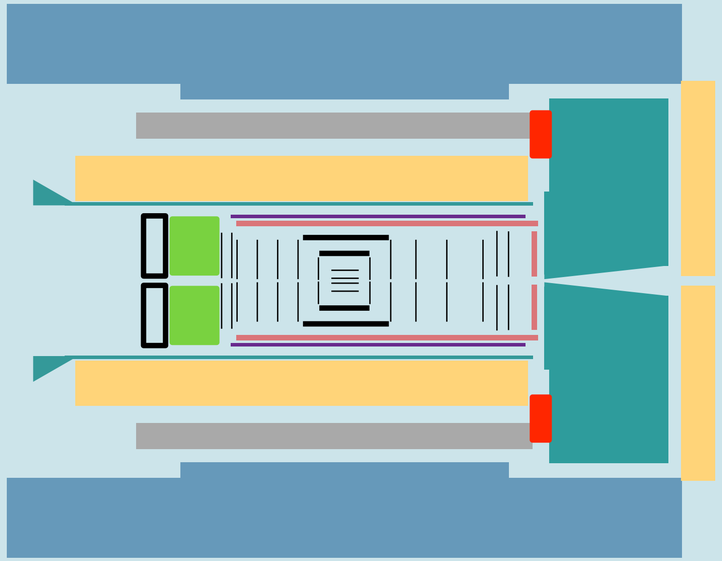
Satoshi Yano (Hiroshima University)

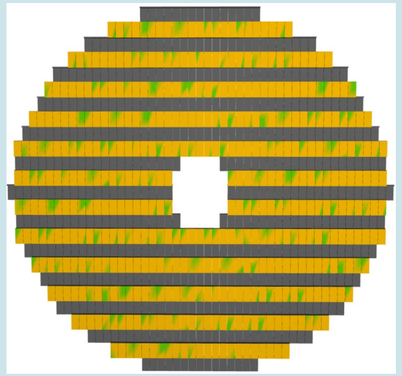
EIC-Asia monthly meeting

06/20/2024

Recap of BTOF and FTOF

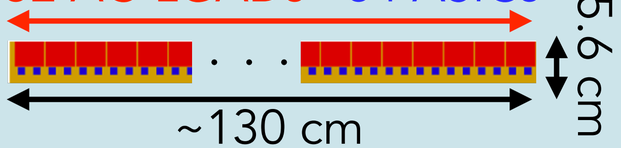


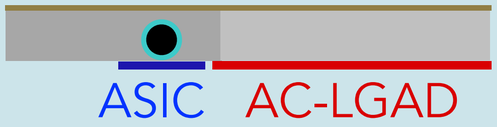




BTOF Module

32 AC-LGADs 64 ASICs

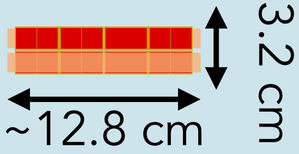


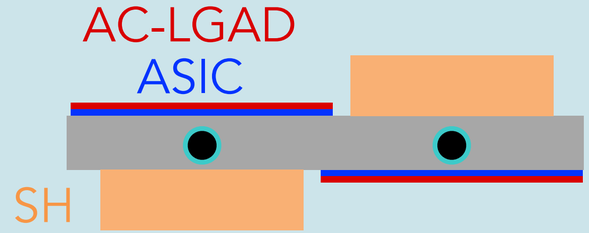


Required performance
Timing resolution ~ 30 ps
Spatial resolution ~ 30 μm

FTOF Module

16 AC-LGADs 16 ASICs





- Strip-type and pixel-type AC-LGAD are used for BTOF and FTOF, respectively
- FCFD and EICROC are used for strip-type and pixel-type AC-LGAD, respectively

New TOF DSC organization

- **New TOF organization members**
  - DSL: Zhangbu Xu (Kent State Univ.), Deputy DSL: Satoshi Yano (Hiroshima University)
  - DSTC
    - BTOF: Matthew Gignac (UC Santa Cruise)
    - FTOF: Mathieu Benoit (ORNL)
- **Work packages have been created**
  - Sensors: Simone Mazza (US Santa Cruise), Satoshi Yano (Hiroshima University)
  - Frontend Electronics: Wei Li (Rice Univ.)
  - Module integration and assembly: Mathieu Benoit (ORNL), Matthew Gignac (UC Santa Cruise)
  - System tests and validation: Takashi Hachiya (Nara Woman Univ.), (FF Liaison) Prithwish Tribedy (BNL)
  - Mechanical structure: Andy Jung (Purdue Univ.), Yi Yang (National Cheng-Kung Univ.)
  - DAQ & Clock distribution: Tonko Ljubicic (BNL)
  - Power system, Detector slow control, monitor and safety system: Frank Geurts (Rice Univ.)
  - Simulations, software & calibration: Kantaro Kawade (Shinshu Univ.), (deputy) Tommy Tsang (Kent State Univ.)

TOF DSC General Meeting
Wednesday 10:30 AM (BNL time)
You can find the indico here

TOF Japan Meeting
Monthly / Bi-weekly
You can find the indico here

Update since the last EIC Asia meeting

Simulation study

- The regular simulation package meeting has been started by Kentaro and Tommy
  - The latest indico can be found here

- The important tasks are:
  - Evaluation of machine-induced background effects on TOF performance (Shinshu University)
  - Evaluation of BTOF material budget on the other detectors (Hiroshima University)
  - Digitization and geometry of sensor in simulation (Stony Brook University, BNL, Kent University)
  - T0 determination performance by beam clock and HRPPD of phRICH (TBD)

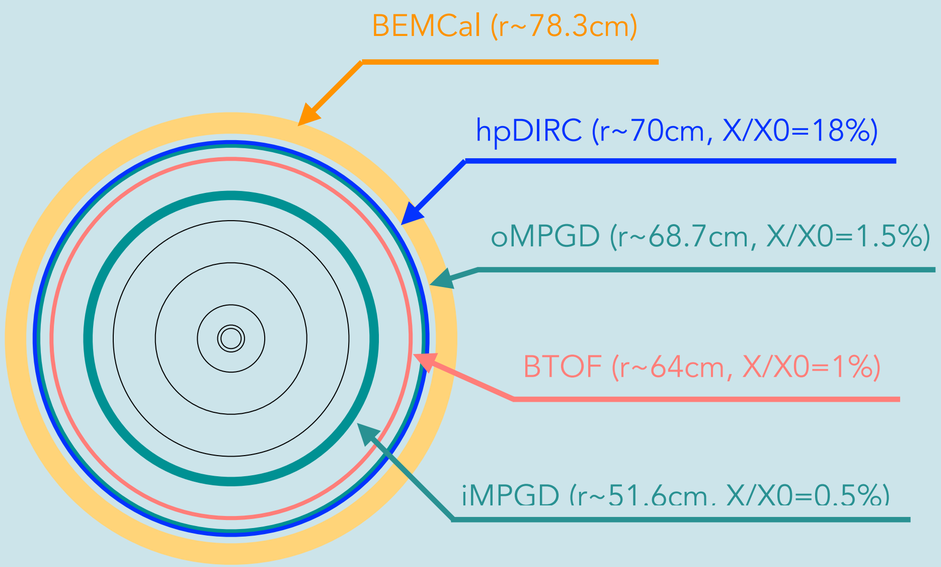
- Machine-induced background study is urgent and it should be included in pre-TDR
  - Shinshu University covers the topic

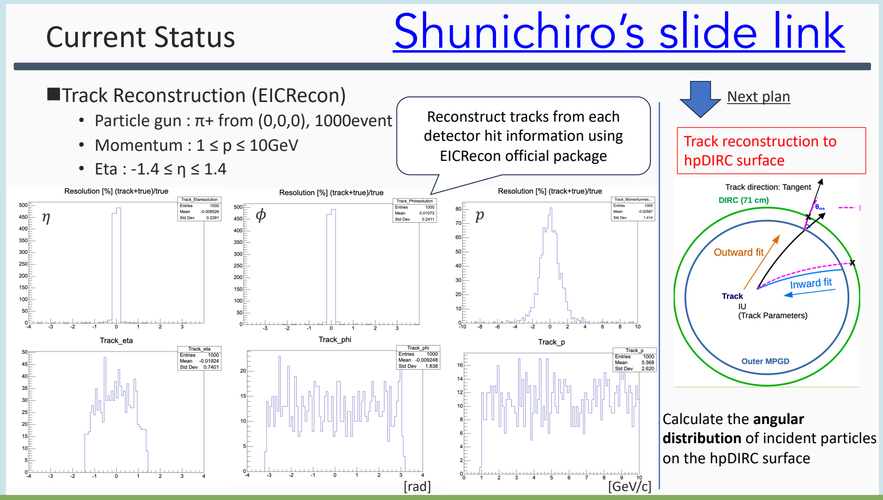
Material budget study (Hiroshima)

- **Shunichiro Muraoka** (M2 student) is working on the BTOF material effects on hpDIRC and BEMCal performance

- This study is significant for the stave structure design
  - oMPGD is placed just in front of hpDIRC in the latest design →Not big effects on angular determination resolution by the BTOF material
  - The material budget of hpDIRC in the active area is approximately 18% → Not big effects on the EMCal performance by the BTOF material

- The study will reveal if the very strict limit of 1% material budget imposed on BTOF is really necessary
  - This will open new options for the stave material selection and 1.3 m FPC design



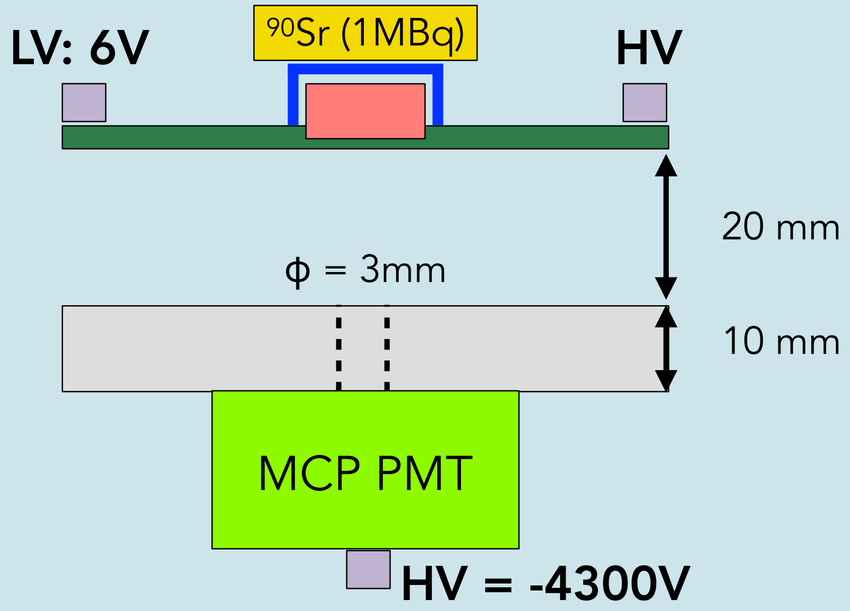


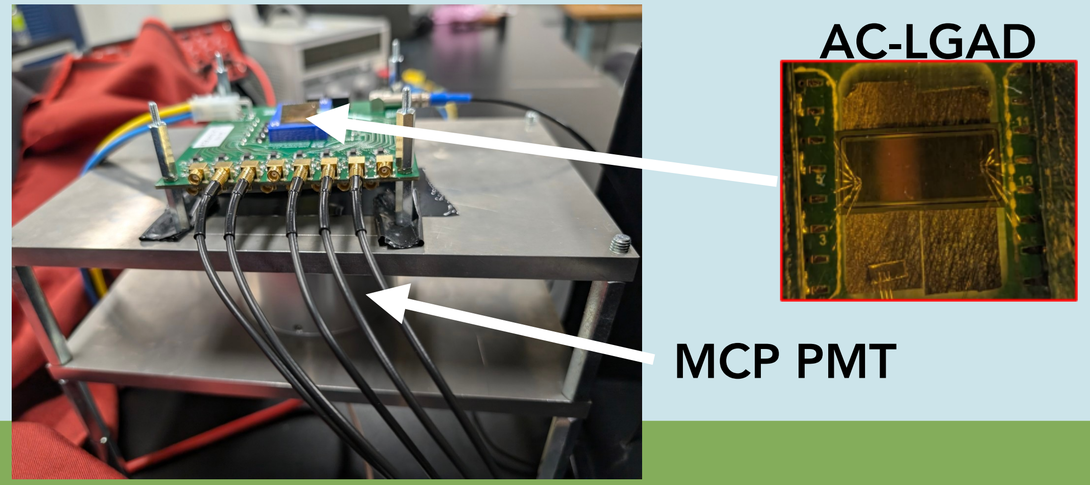
AC-LGAD sensor test (Hiroshima)

- **Kanato Matsutani** (M1 student) is working on the AC-LGAD sensor test
  - 0.4 x 10 mm^2 strips with 80 μm pitch (Sensor size: 5.48 x 11.15 mm^2 from KEK

- Tasks we consider as important are:
  - Temperature dependence of the performance
  - Gain stability of the full-size sensor

- The right setup has been established to test performances with the radiation source
  - MCP PMT is used for the trigger (σ ~ 10 ps)

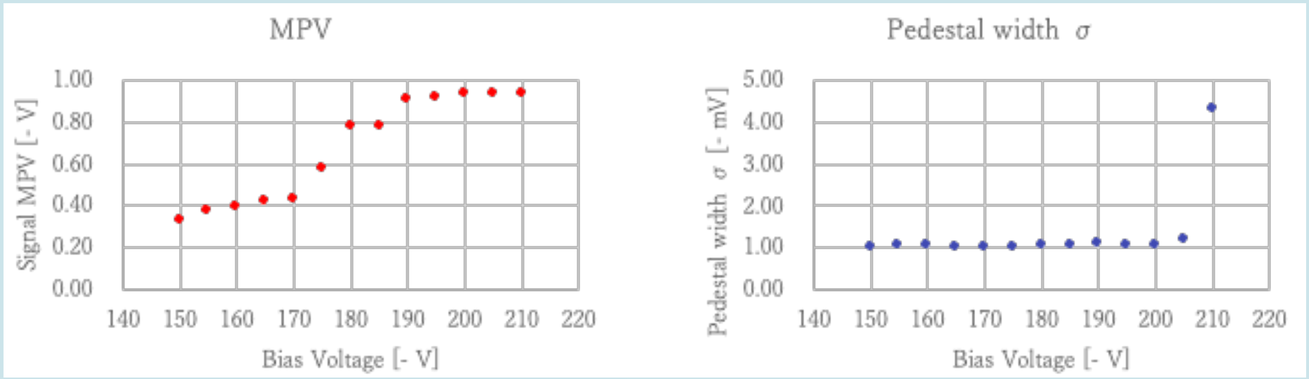


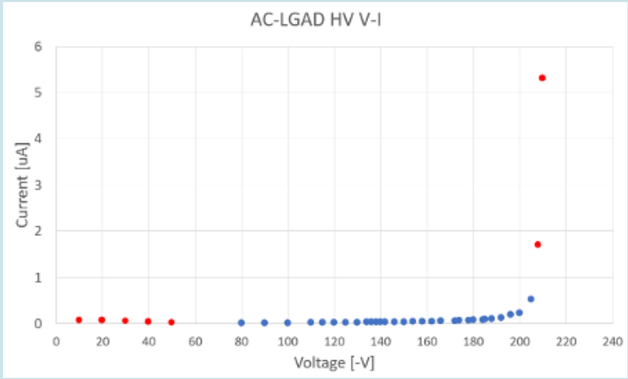


AC-LGAD sensor test (Hiroshima)

- The signal strength and noise level of AC-LGAD are checked by changing the bias voltage
  - The strength is saturated above ~ -190 V
  - The pedestal noise level increases above ~ -200 V

- V-I curve is also measured
  - Leak current increases above ~-185 V





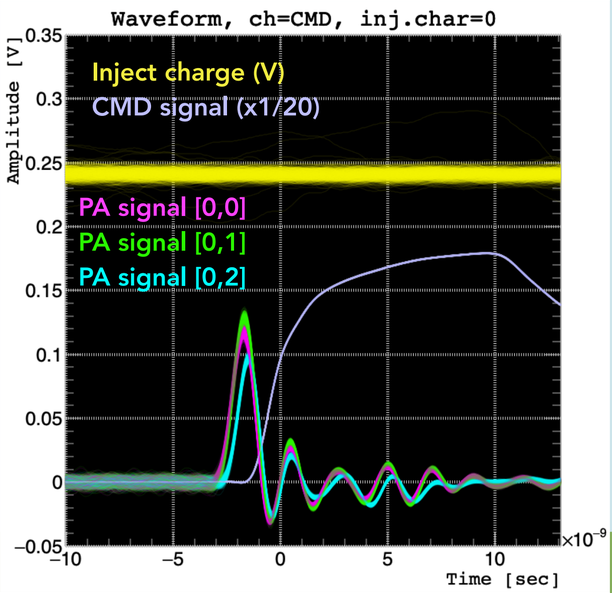
Room temperature 23°C
HV = -185V is set

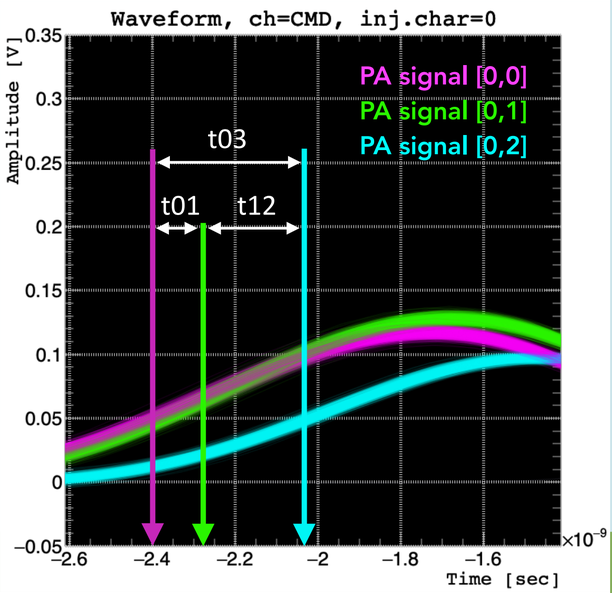
- After tuning the trigger threshold, the signal rate is ~60 Hz
- Charge sharing (synchronizing signals) has been observed
- The detailed study is ongoing and the results will be presented soon

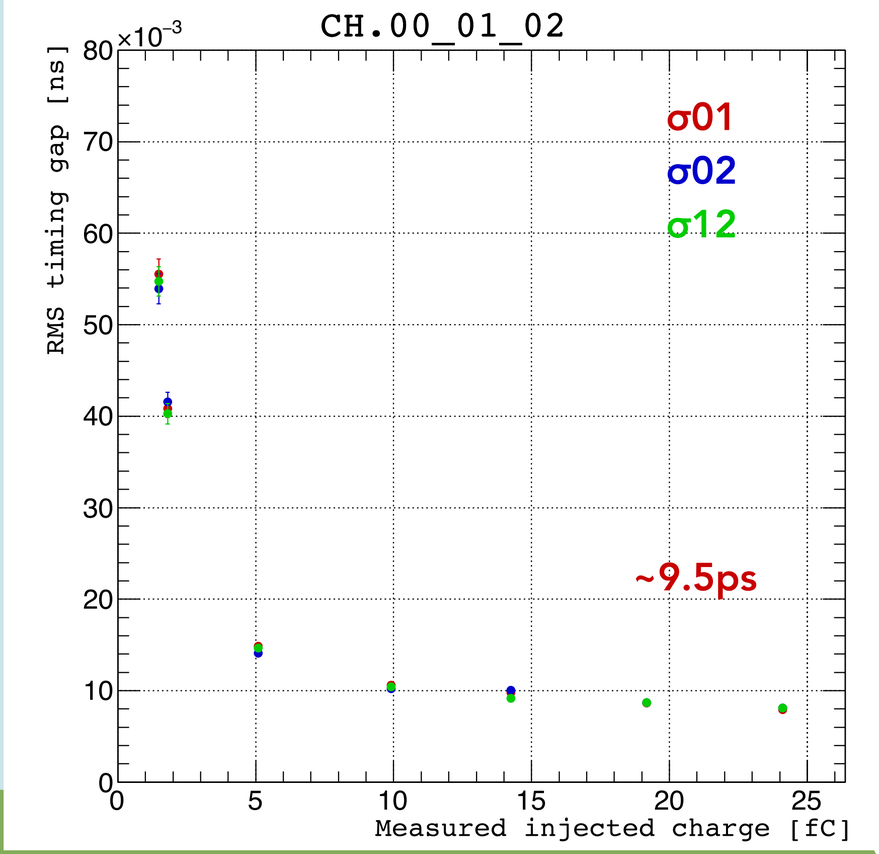
EICROC0 test (Hiroshima)

- EICROC0 characterization
  - Performance evaluation of analog block is being conducted

- The analog signal response with injected charges
  - Timing resolution has been calculated by signal timing differences

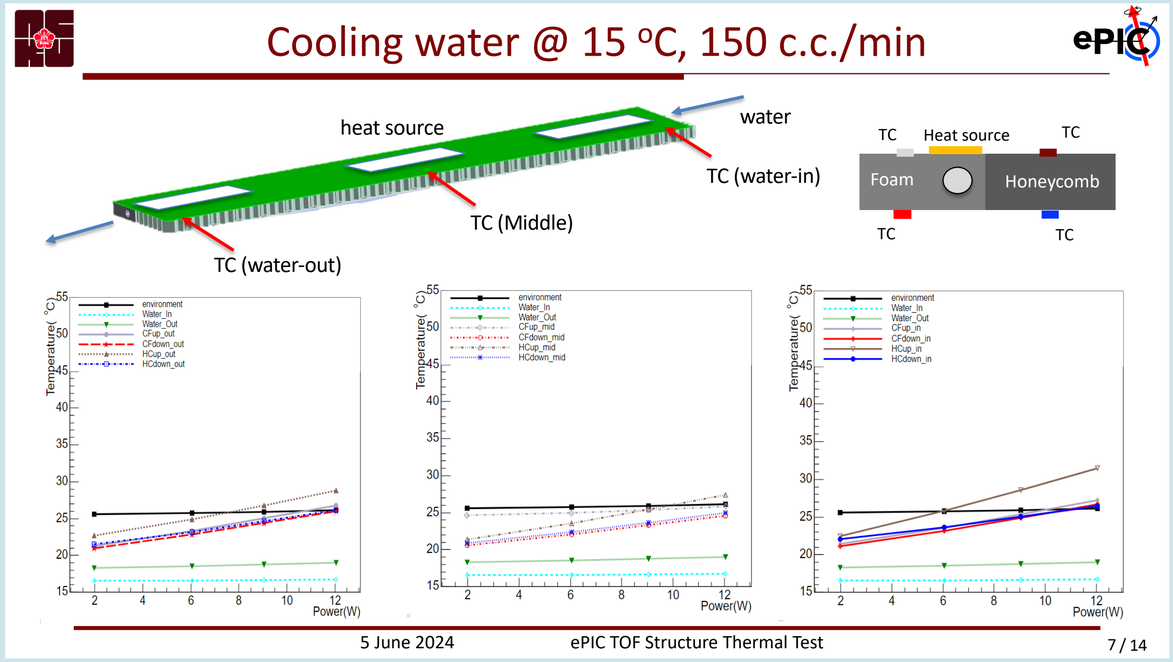


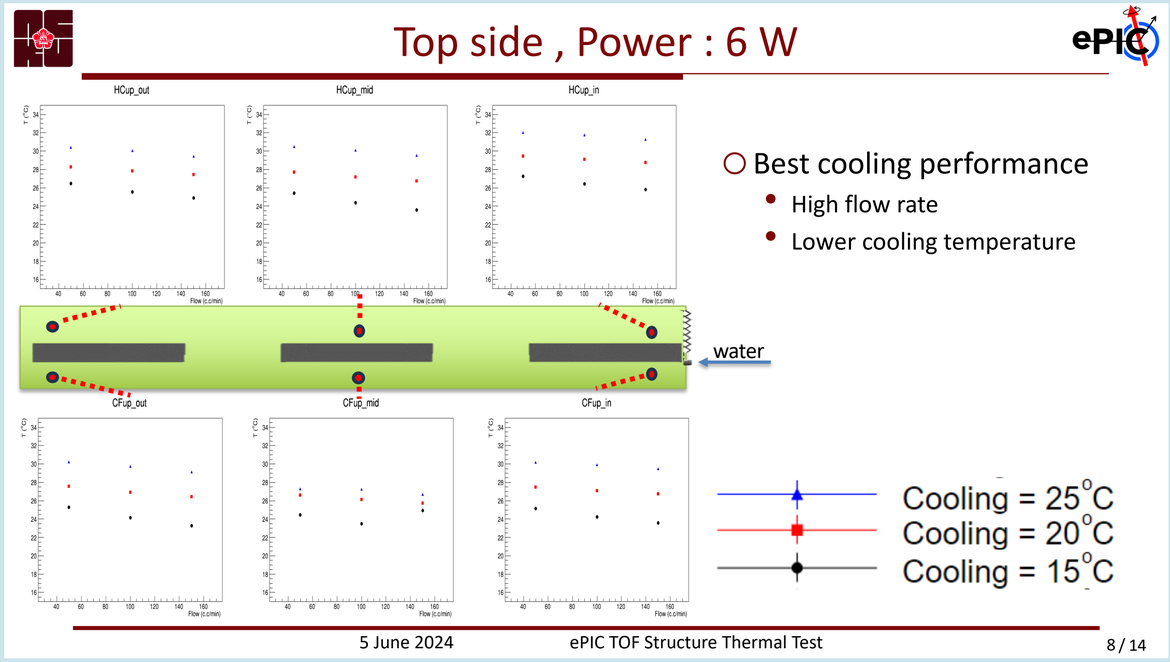




Structure thermal test (NCKU)

- **Yu-Tang Wang** is working on the cooling system for the BTOF stave
  - The latest presentation can be found here
- The relationship between cooling water temperature and flow rate is studied with a 30 cm long stave structure





The other news

- Zhenyu has stepped down from eRD112 (AC-LGAD R&D consortium) coordinator
  - Alex Jentsch (BNL) and Matthew Gignac (UC Santa Cruise) are selected as new coordinators instead of Zhenyu

- FY25 proposal of eRD112 is under preparation
  - Hiroshima University raised the hand to participate in eRD112 from FY25

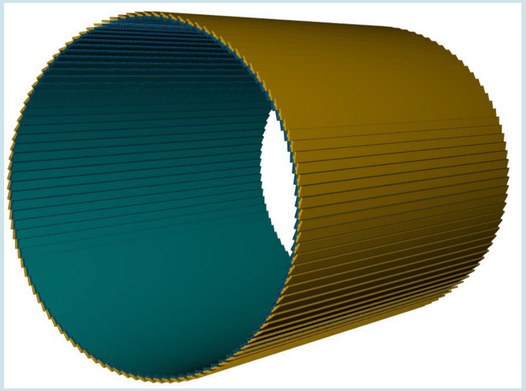
- T. Gunji presented the Japanese strategy for the ePIC project at RRB meeting (5/6~5/7)
  - A decision will be made around this December
  - $10M for 7 years for BTOF is requested from RIKEN to MEXT

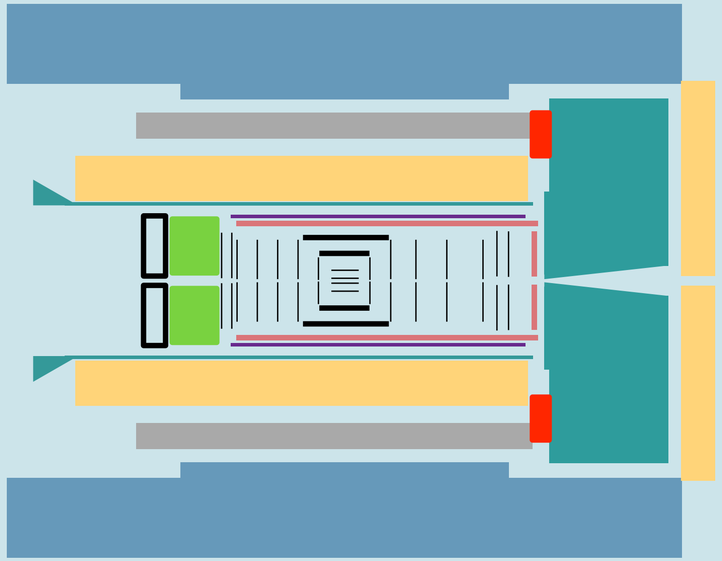
Summary

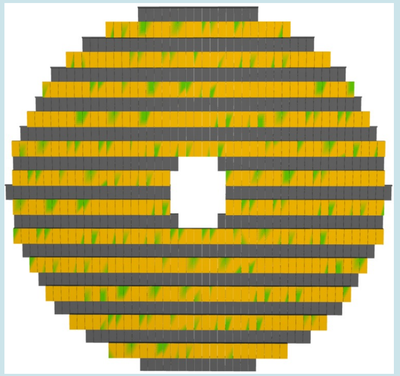
- The regular simulation meeting has been started and it will be held monthly
- Material budget effects on the other detector study have been started at Hiroshima University
- Study of the machine-induced background has been started at Shinshu University
- AC-LGAD sensor and ASIC R&D has been started at Hiroshima University
  - Hiroshima activity will be included in FY25 proposal
- Thermal test of stave structure is ongoing at NCKU

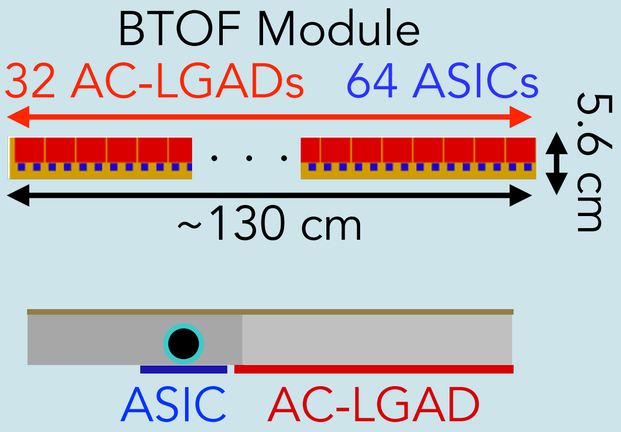
Backup

Recap of BTOF and FTOF

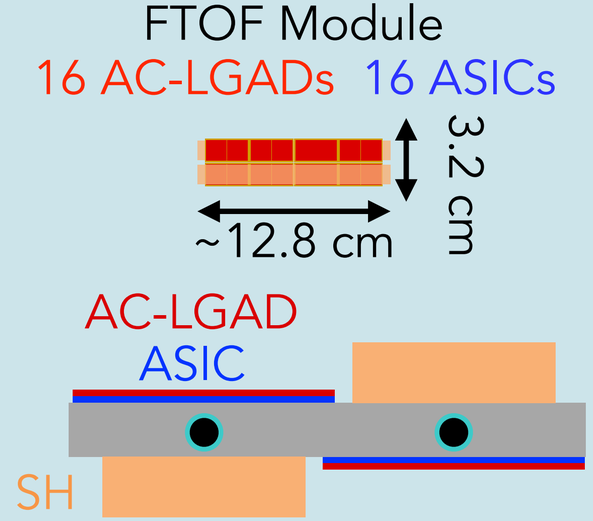








Required performance
Timing resolution ~ 30 ps
Spatial resolution ~ 30 μm

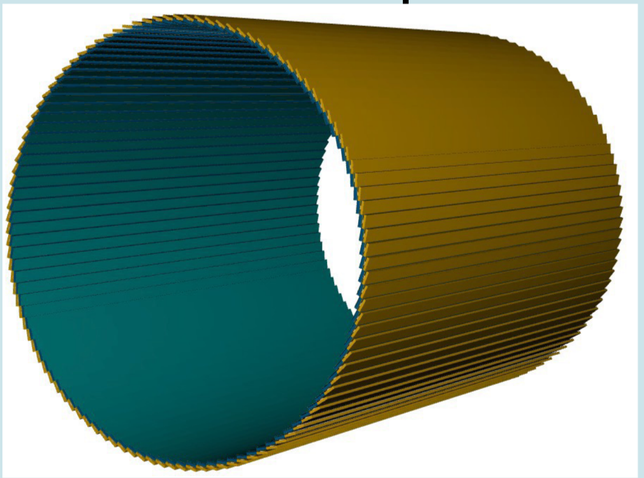


- Strip-type and pixel-type AC-LGAD are used for BTOF and FTOF, respectively
- FCFD and EICROC are used for strip-type and pixel-type AC-LGAD, respectively
- BTOF SH is placed in a different place from sensor+ASICs, but FTOF SH is placed in front of sensor+ASICs

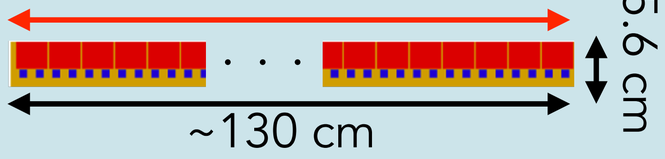
Detector Layout of BTOF

- 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 $-1.42<\eta<1.77$
- Total material budget in acceptance is ~0.01 X/X_0

BTOF shape



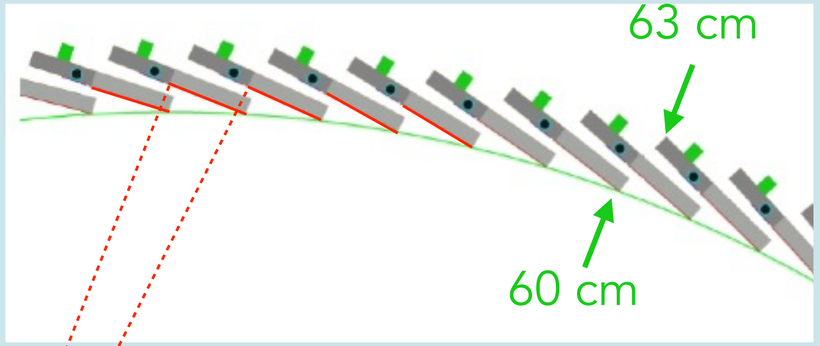
BTOF Module



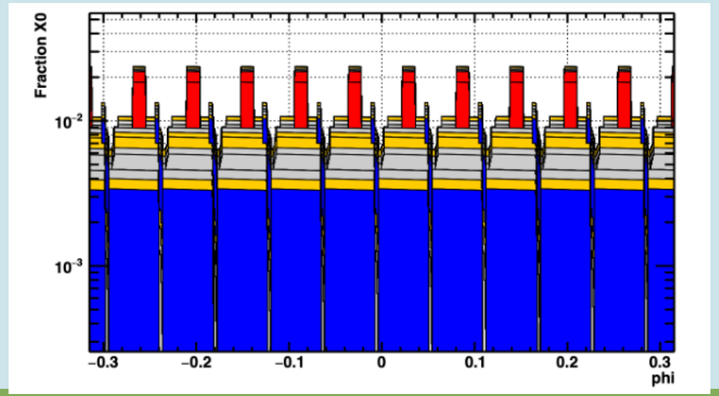
Module cross section

Cylindrical structure by modules

3 mm overlap in Φ



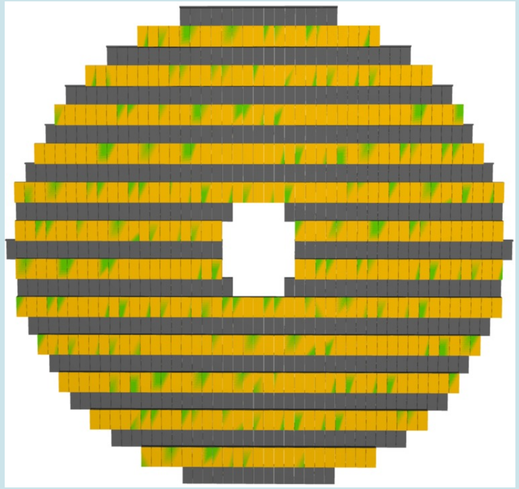
Material budget



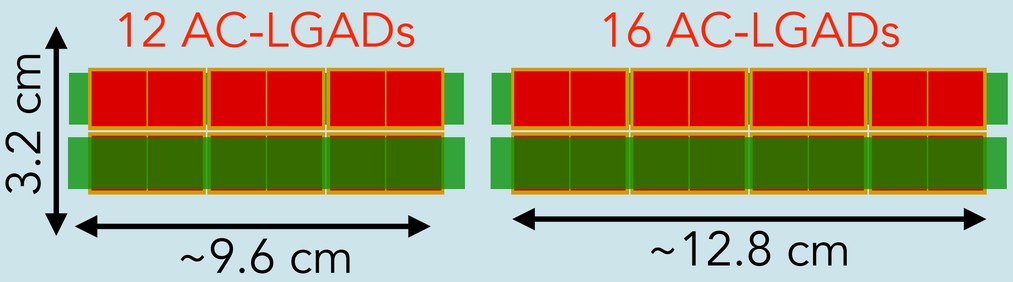
Detector Layout of FTOF

- FTOF is composed of 1816 modules to make a disk
- 12 or 16 AC-LGAD pixel sensors are attached to one module
- Radius is 8 - 60 cm from the beam pipe covering $1.86<\eta<3.85$
- Service hybrid, readout board + power board, is placed in front of sensors
- Total material budget in acceptance is ~0.025 X/X_0
- Service hybrid and cooling system design is important for FTOF

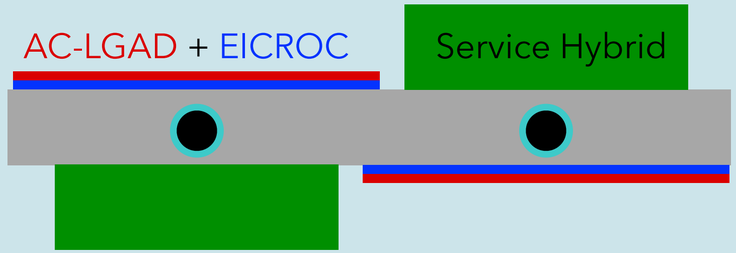
BTOF shape

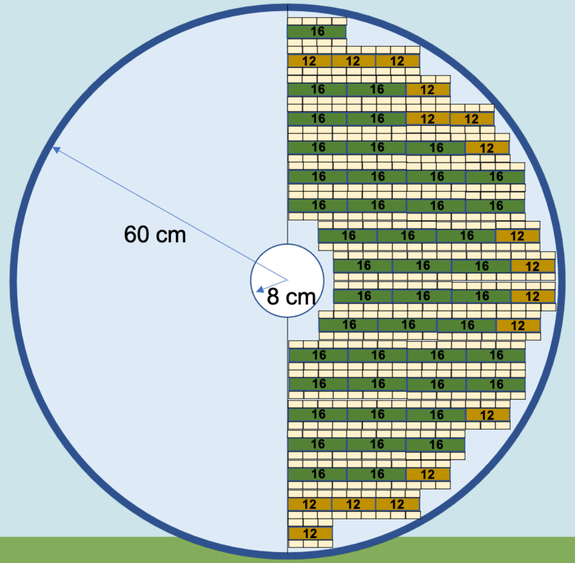


Module top view



Module cross section



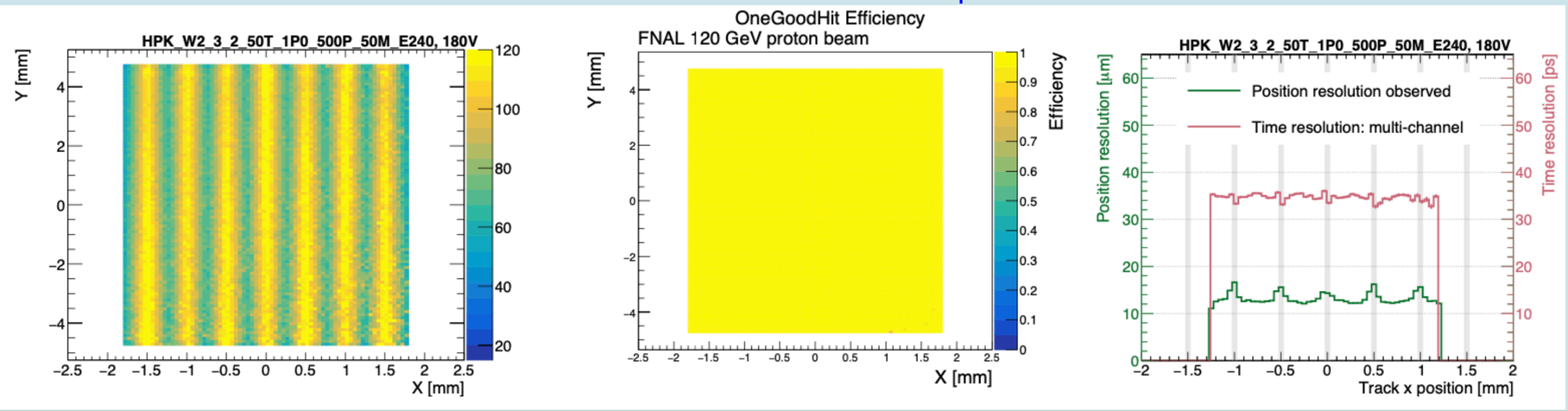


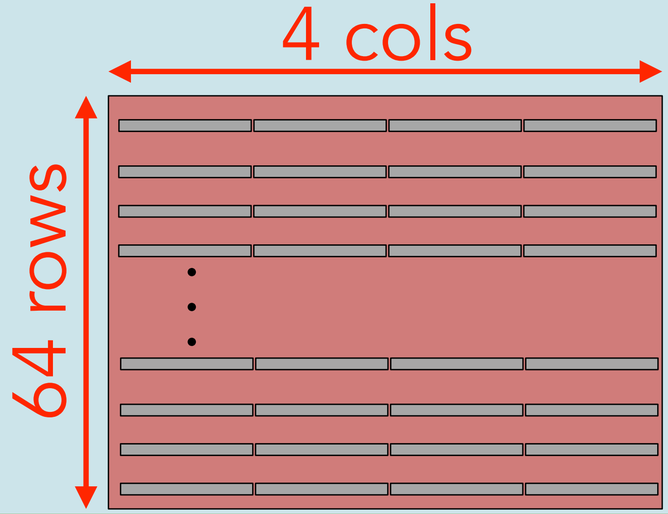
BTOF AC-LGAD sensor

- AC-LGAD technology meets the strict spatial and time resolution requirements
- 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
- 2 ASICs are attached for each with wire bonding

- Total information
  - **9216 sensors**
  - **10 m^2**
  - **2.4 M readout channels**

[eRD112 FY24 Proposal]



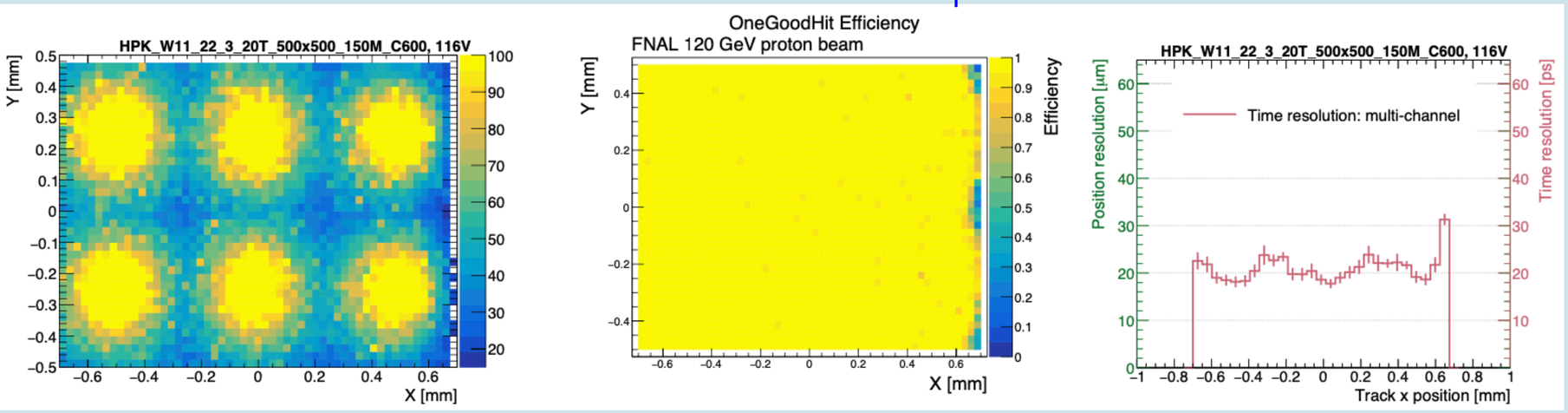


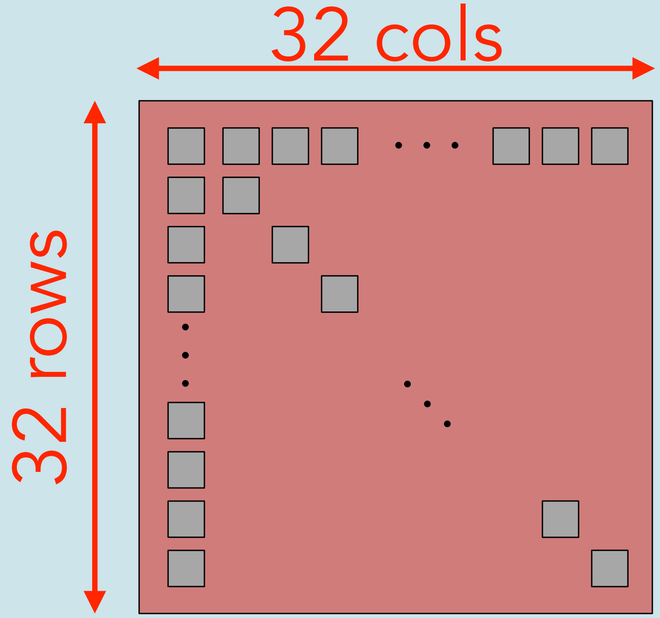
FTOF AC-LGAD sensor

- Pixel-type AC-LGAD sensor, 1.6 x 1.6 cm^2 sensor size with 500 x 500 μm^2 pitch, is used in FTOF
  - The readout metal geometry in a sensor is 32 x 32 and 1024 channels each
- One ASIC (2D 32x32) is attached to the one sensor
- Bump bonding is planned for soldering to ASIC

- Total information
  - **3632 sensors**
  - **1.4 m^2**
  - **3.6 M readout channels**

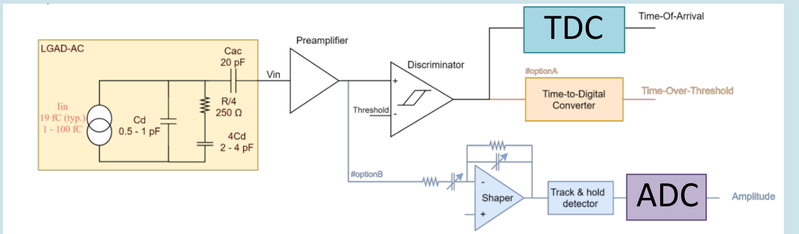
[eRD112 FY24 Proposal]





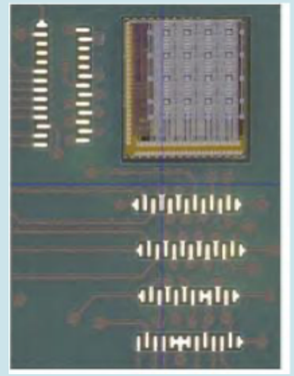
TOF ASIC

- Not only high-time resolution TDC (TOA) 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

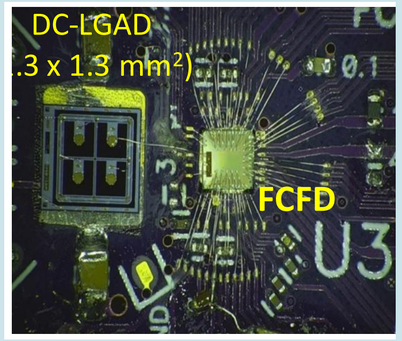


- EICROC (32x32) is one of the common ASICs used in ePIC
  - Design focuses on pixel AC-LGAD readout (tuned for low capacitance)
  - 10-bit TDC and 8-bit ADC is now available (EICROC0)
  - Modification is necessary to read higher capacitance sensor (strip AC-LGAD)

EICROC0



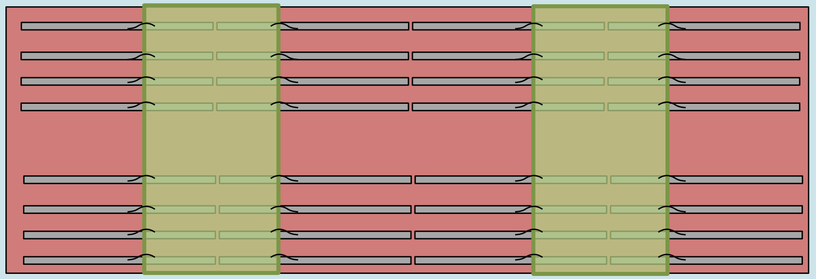
FCFDv0



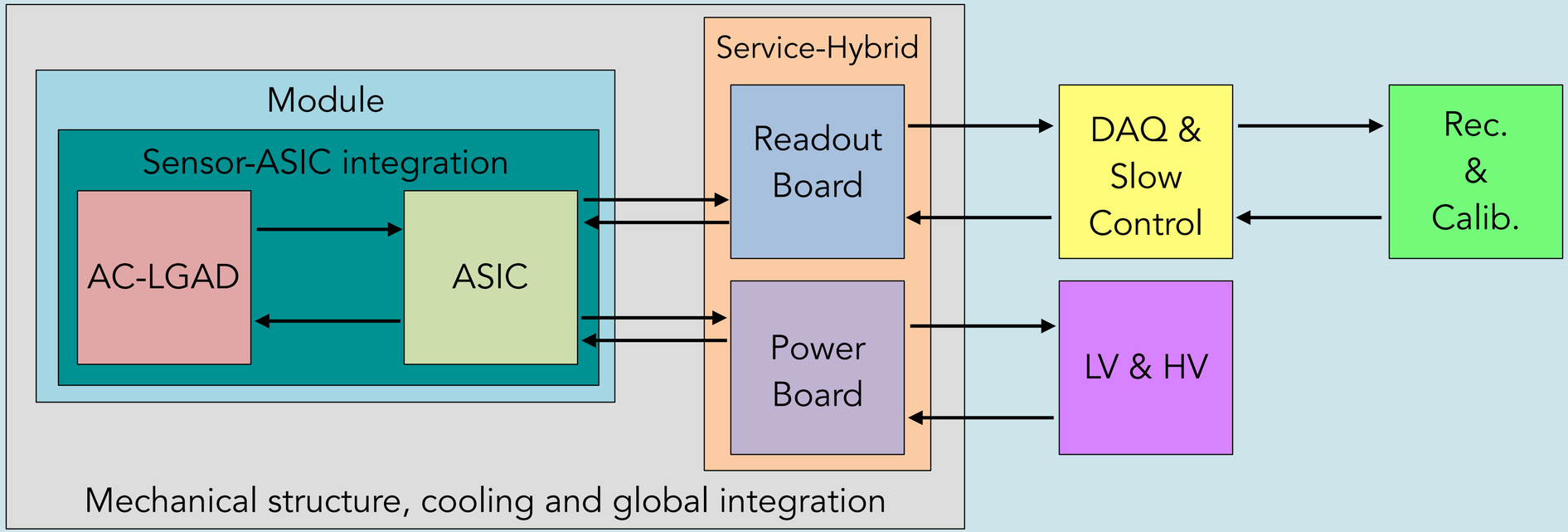
- FCFD is a new ASIC to use strip AC-LGAD readout
  - FCFD can read higher capacitance AC-LGAD sensor
  - Multiple-channel analog is available for FCFDv1

- The possibility of HGCROC has begun to be discussed
  - It can measure ADC, TOA, and TOT
  - We have to investigate the possibility of the chip as soon as possible and make collaboration with the experts

ASIC

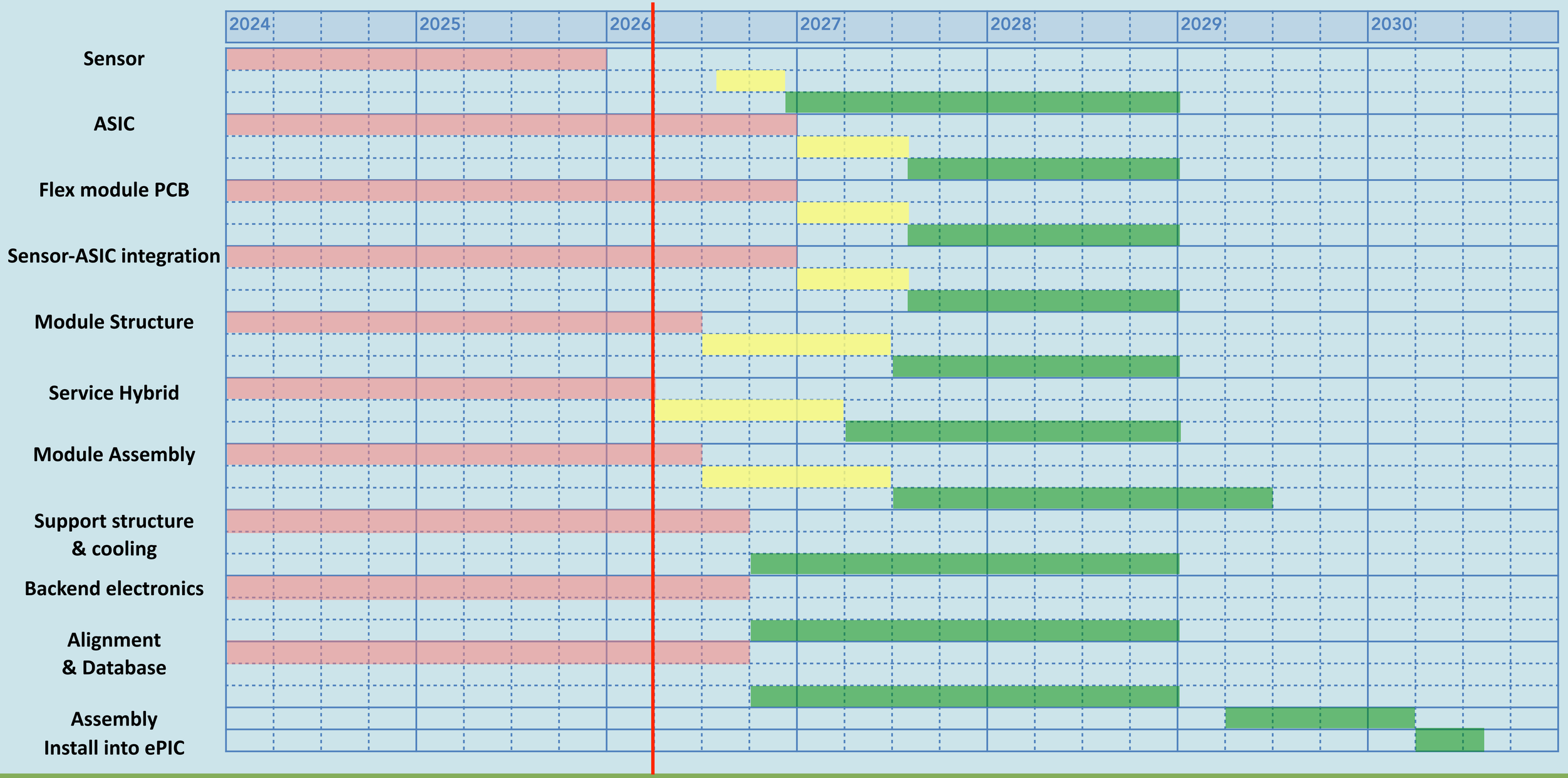


TOF structure

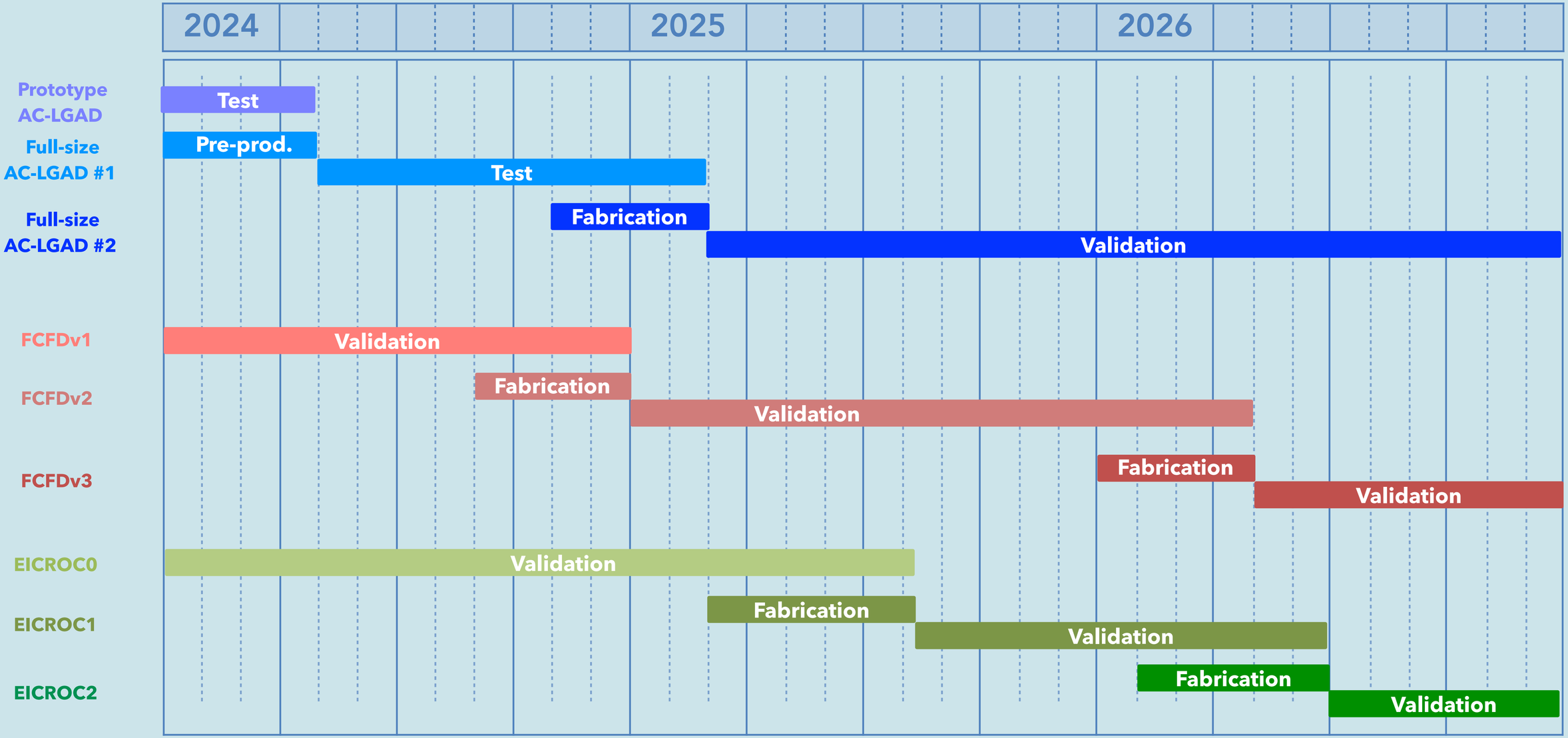


- **Barrel-TOF (BTOF)**
  - Strip-type AC-LGAD
  - ASIC (FCFD)
  - Sensor-ASIC integration
  - Module
  - Service-Hybrid
  - Mechanical structure
  - Global integration
- **Forward-TOF (FTOF)**
  - Pixel-type AC-LGAD
  - ASIC (EICROC)
  - Sensor-ASIC integration
  - Module
  - Service-Hybrid
  - Mechanical structure
  - Global integration
- **Common system**
  - DAQ
  - Cooling
  - Software (Rec. & Calib.)
  - HV & LV
  - Slow control

New clean room (100m²) @ HU



Schedule of sensor and ASIC



Power budget of TOF

- BTOF power consumption is larger than the FTOF due to the size difference
- Sensors+ASICs and SH of FTOF are placed on the same board, so the cooling power is designed for the sum of the consumption
- SH of BTOF is located in a different place than sensors + ASICs

BTOF

	Power
Sensors	4kW
FCFD	9.4kW
DC-DC	3.3kW
FPGA	1kW
Total	17.7kW

SH = 4.3kW

FTOF

	Power
Sensors	0.3kW
EICROC	3.6kW
DC-DC	2.5kW
FPGA	1kW
Total	7.4kW

Institutes in TOF tasks (official)

- 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)
- IJCLab, OMEGA, CEA-Saclay (FR)

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
  - IJCLab/OMEGA/CEA-Saclay
- **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**
  - ORNL
  - Nara Woman University
- **Service Hybrid**
  - Rice University
- **Backend electronics**
  - BNL