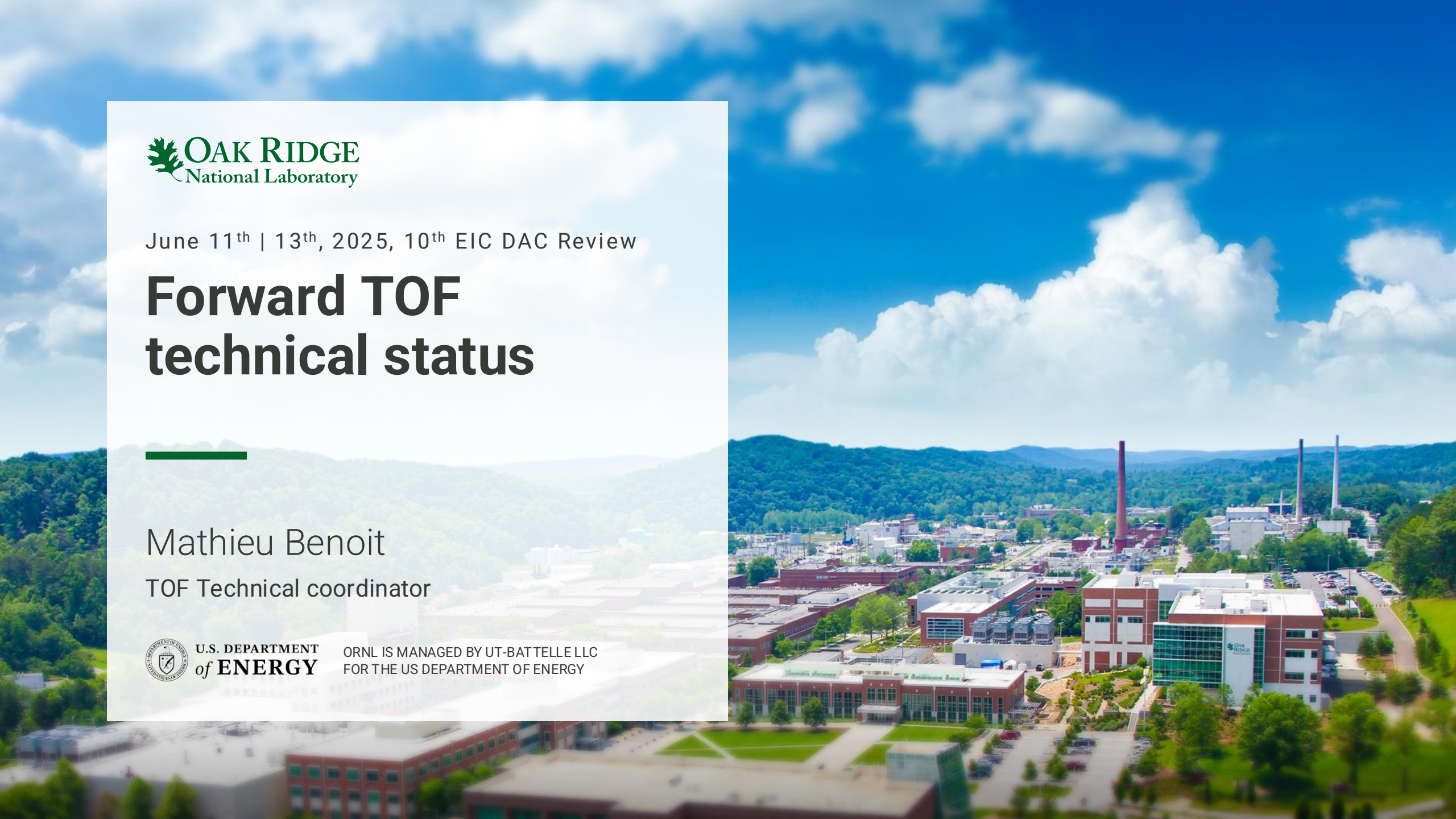


OAK RIDGE National Laboratory

June 11th | 13th, 2025, 10th EIC DAC Review

Forward TOF technical status

Mathieu Benoit

TOF Technical coordinator

U.S. DEPARTMENT of ENERGY

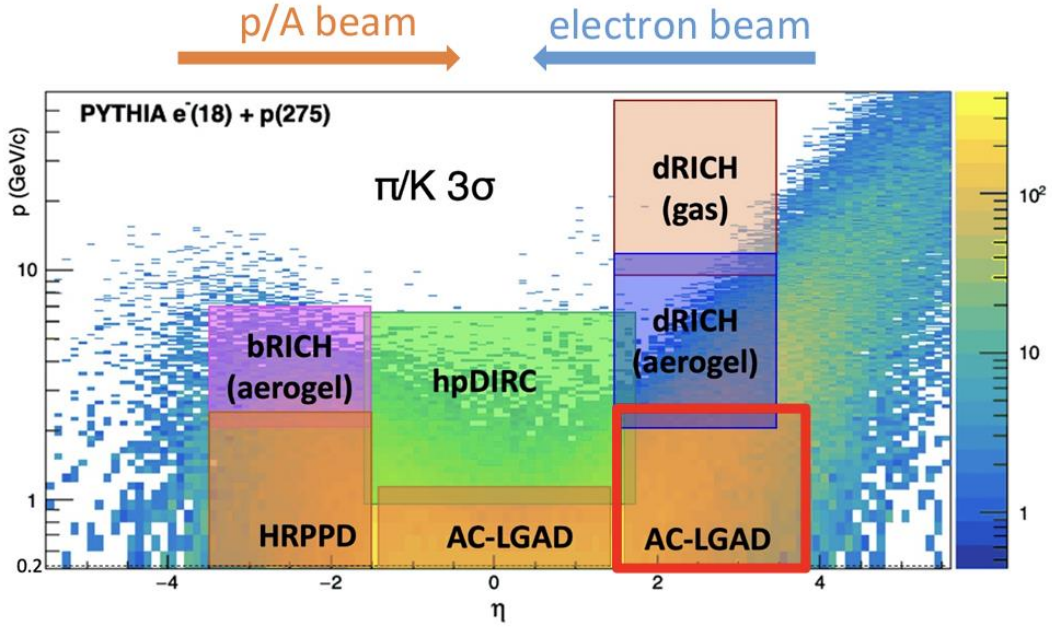
ORNL IS MANAGED BY UT-BATTELLE LLC
FOR THE US DEPARTMENT OF ENERGY

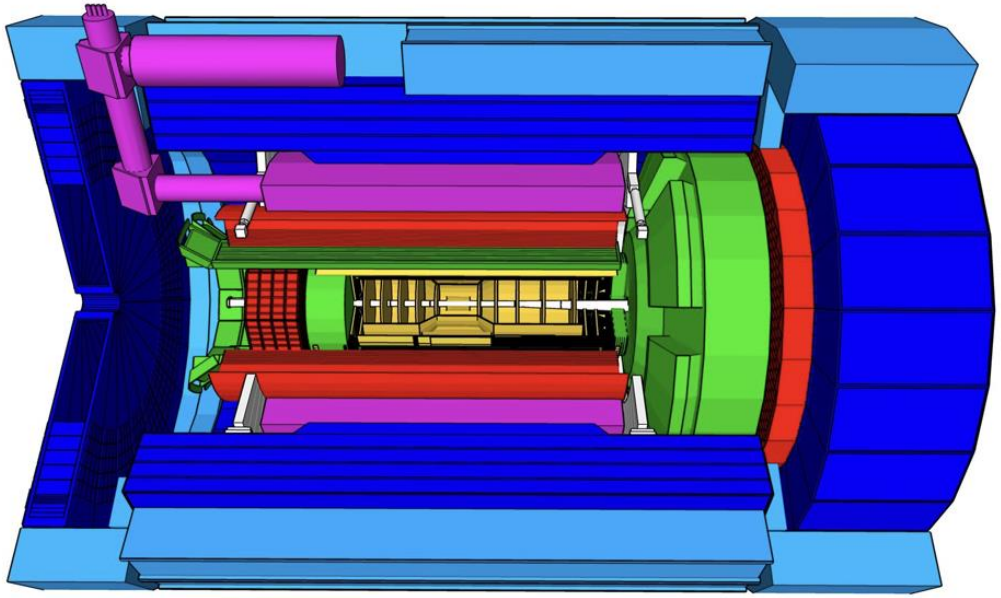
Charge Questions

- **Q1 :** Is the design of the ePIC detector and its sub-systems appropriate and progressing well?
- **Q2 :** Are the remaining work and technical, cost and schedule risks adequately understood? Are there opportunities?
- **Q3 :** Will the detector be technically ready for baselining by late 2025?
- **Q4 :** Are the detector integration and planning for installation and maintenance progressing well? Are there areas where further ideas should be pursued?
- **Q5 :** Will the detector be ready for start of construction by late 2026?

AC-LGADs TOF system for PID

Q1,Q2





Latest envelope (link)

Detector	r (cm)	z (cm)	Momentum range for 3σ π/K separation
Barrel TOF	62<r<69.5	-117.5<z<171.5	0.2 < p_T < ~1.2 GeV
Forward TOF	10.5<r<60	185<z<193cm	0.2 < p < ~2.3 GeV

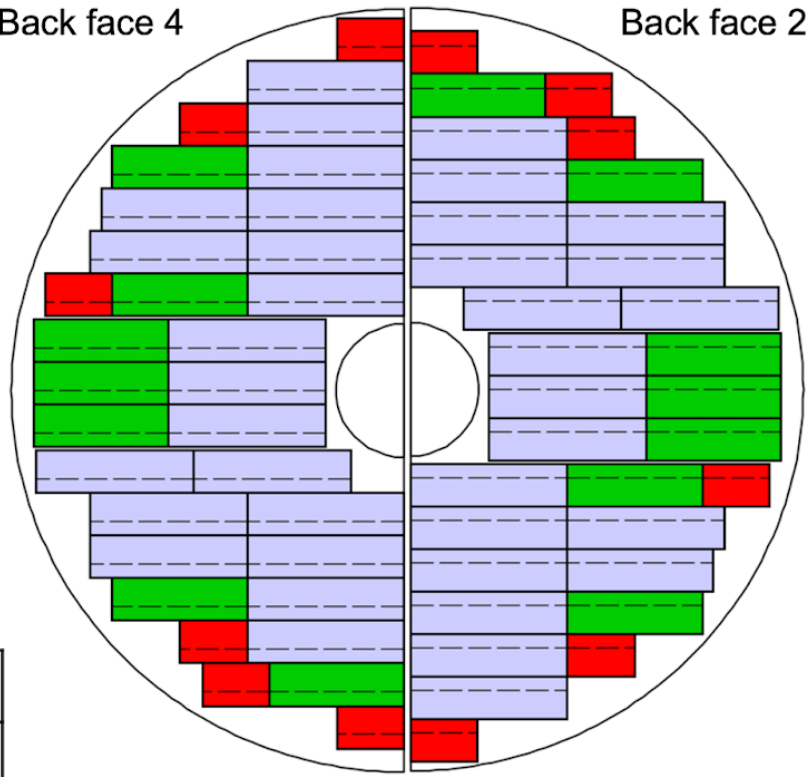
Total fTOF Area ~ 1m^2

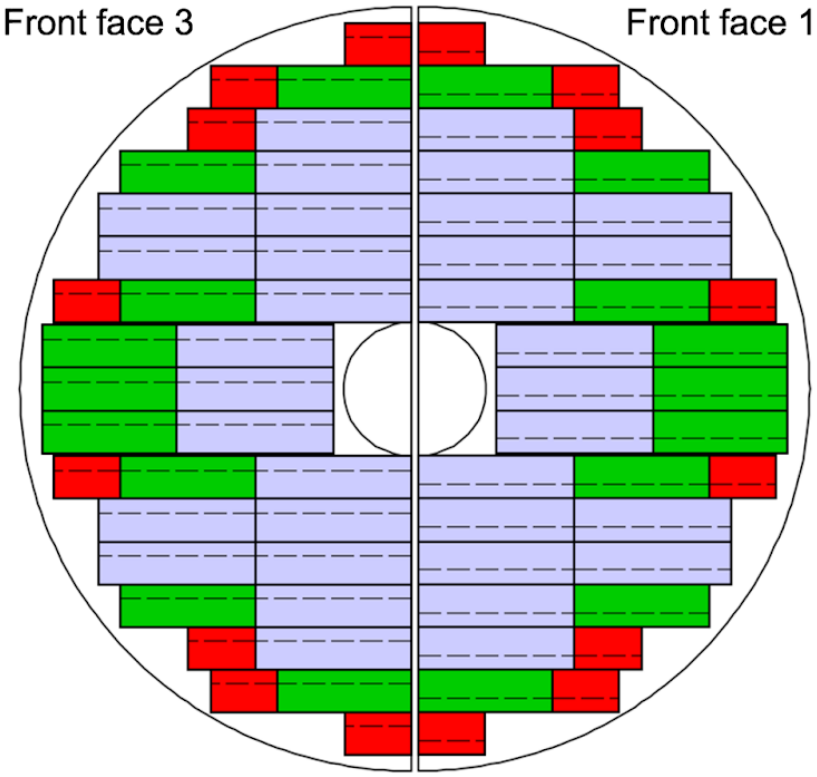
Forward TOF Detector Layout

Q1,Q2

To estimate the material budget, we consider the follow composition:
- Sensor: 300 microns (0.3%X0)
- ASICs: 400 microns (0.4%X0)
- RB and PB PCB board: 2 mm kapton (0.7%X0)
- Module PCB board: 0.6 mm kapton (0.2%X0)
- Aluminium nitride (AIN) base plate: 0.5mm (1.1%X0)
- Cooling and support: 5%X0 (Detailed design ongoing)

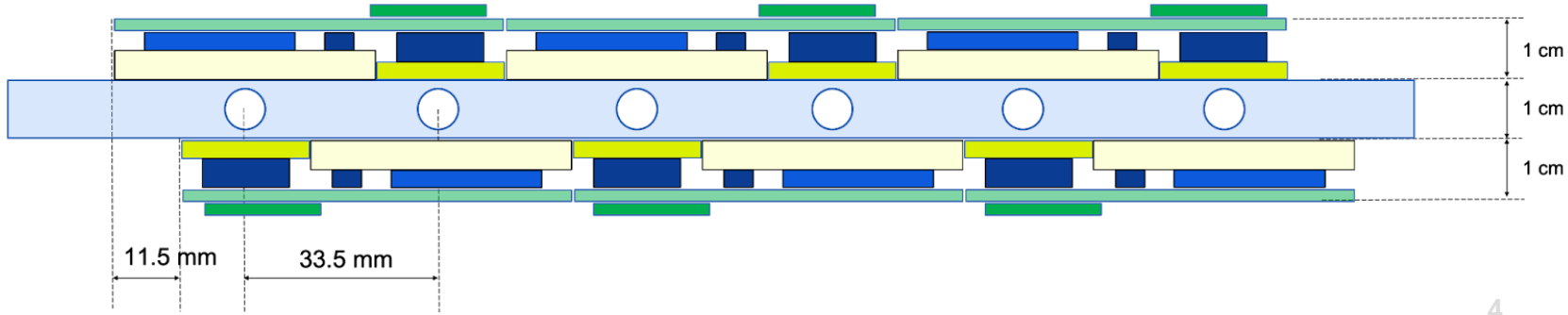
Total material budget is currently estimated to be: 7.7% X0





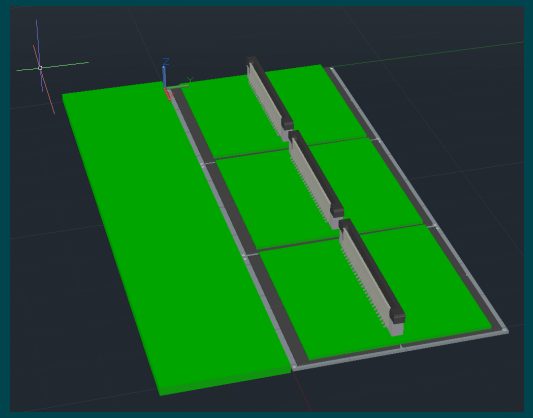
Type	FACE 1 & 3	FACE 2 & 4	Total
3 module SH	8	6	28
6 module SH	9	8	34
7 module SH	17	18	70
Modules	197	192	**778**
Sensors	788	768	**3112**

Number of Service Hybrids (SH) and modules of the detector.

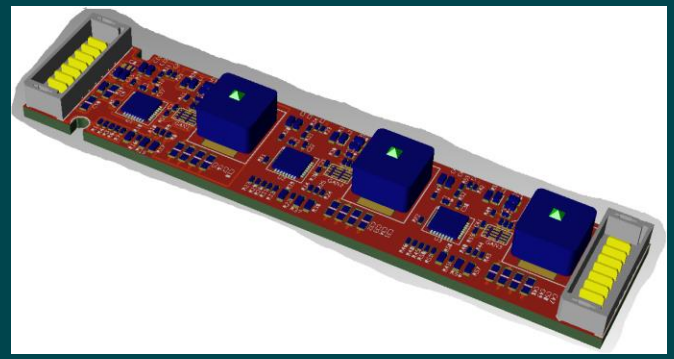


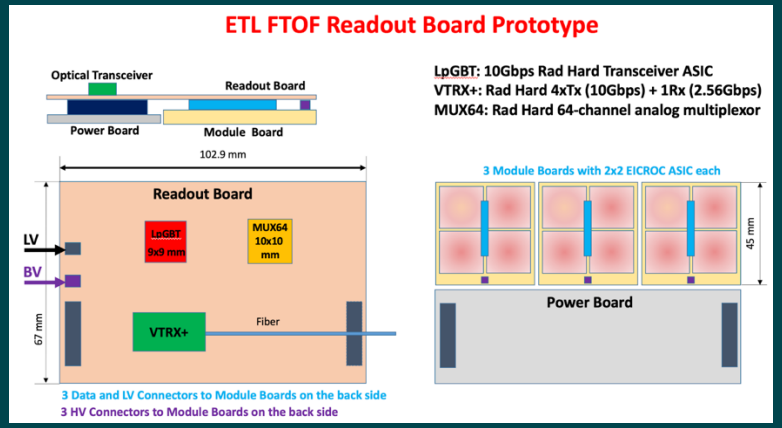
EIC fTOF Building Blocks

Modules

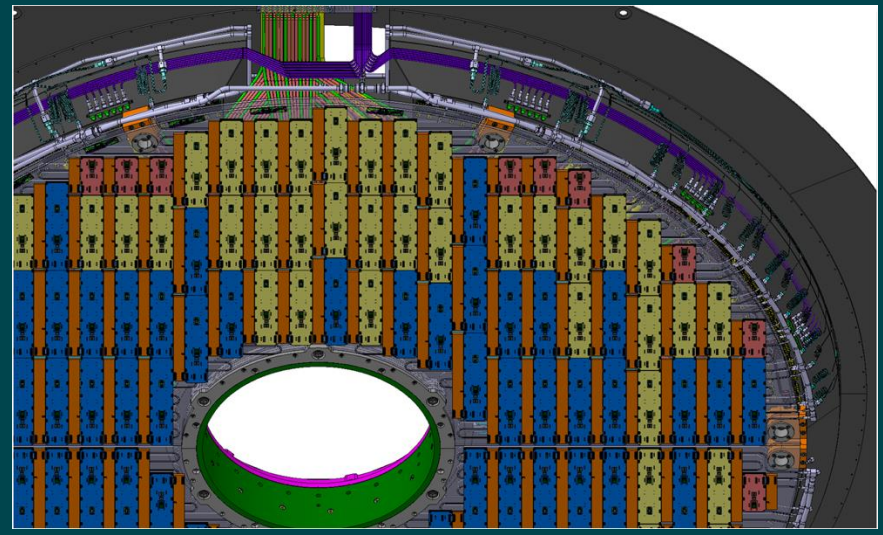


Service hybrids





Cooling and mechanical support

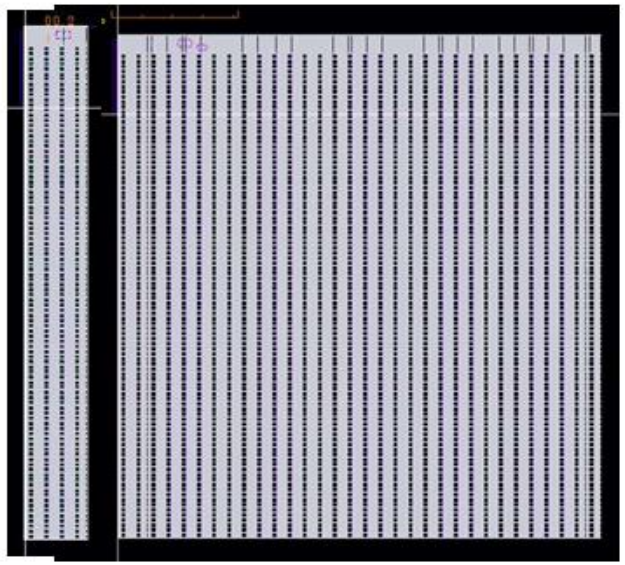


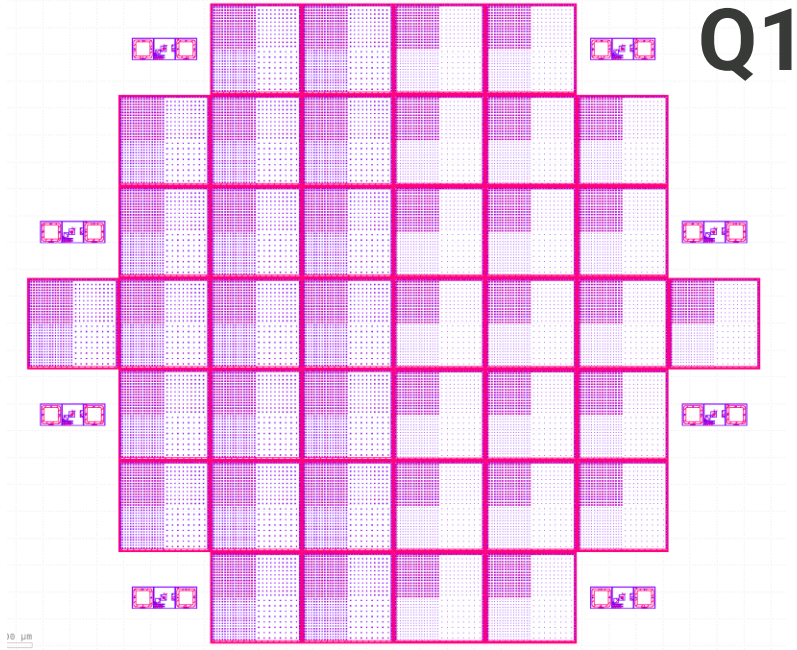
EIC fTOF modules

The EICROC will be the readout for the fTOF

- EICROC1A(4x32)/1B(32x32) currently in design for submission this summer
- EICROC0/A/B design completed (Frontend optimisation)

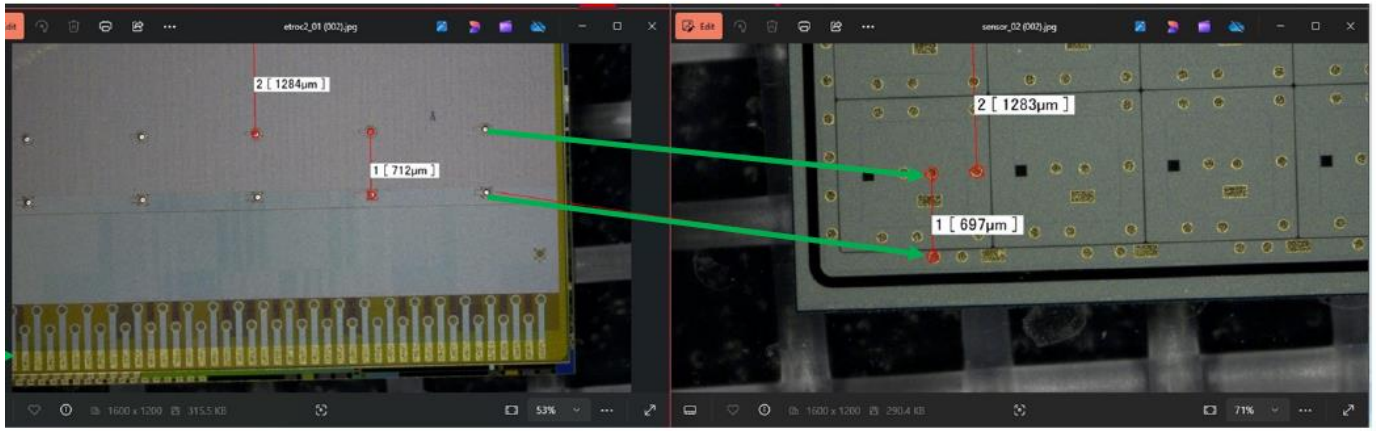
EICROC2 should be the final design for fTOF and far-forward, planned for tapeout in ~Q3 2026





Q1,Q2

HPK Sensor production for pixel ongoing, first trials with EICROC1 when available (Q4 2025)



ETROC2.01

HPK sensor with dummy pads

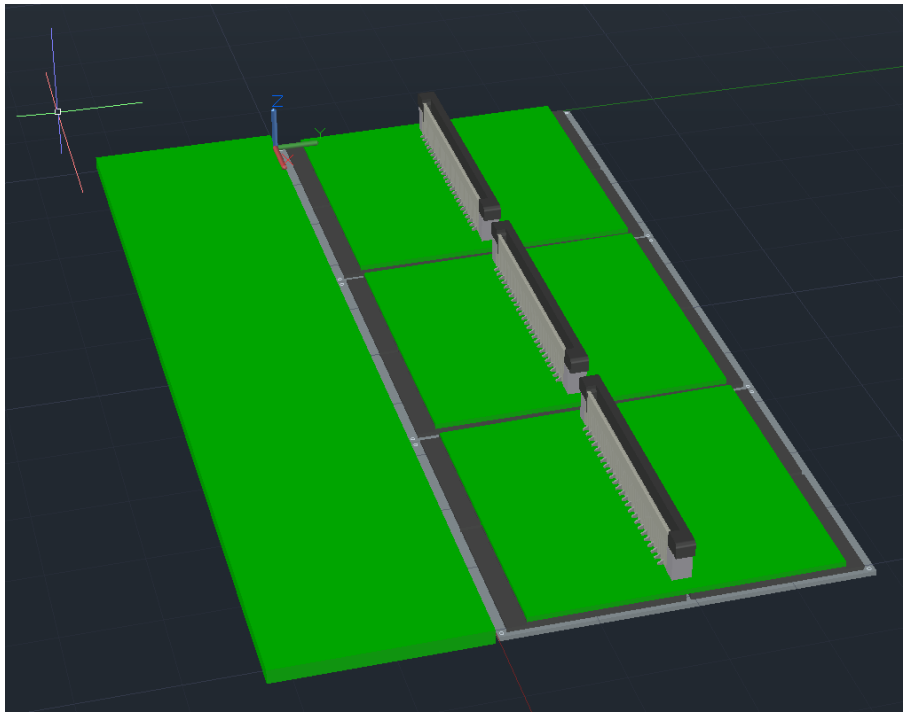
We are following closely **CMS ETL efforts** in developing their bump-bonding process. **ORNL actively involved in developing flip-chip process.**

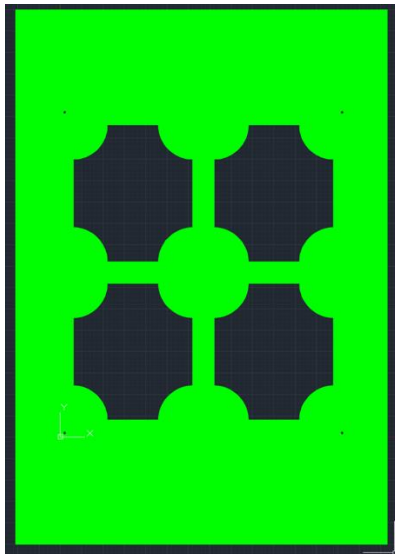
Module Assembly Q1,Q2

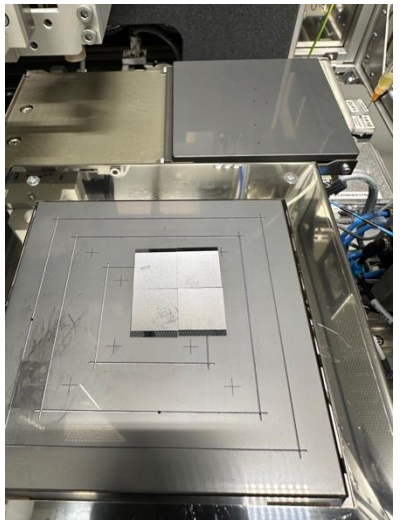
- **Prototype 0 (Show and tell) Summer 2025**
  - We are assembling mechanical prototypes of assemblies at ORNL (1.6x1.6cm Sensor, 1.6x1.8cm ASIC)
  - Rather quick to make , can make enough of a few modules
  - Purchased AlN plates (0.3,0.5mm) that we will laser dice to hold assemblies
  - Mounted with dummy PB&RB

- **Prototype 1 (Thermo-mecanical) Q4 2025**
  - We plan on doing lithography in-house to make ASIC and Sensor heaters that can be WB to flex/PCB
  - Assemble following prototype 0 geometry for thermal testing on stave etc .

- **Prototype 2 (Functional EICROC1 + Dummy LGAD) Q2-3 2026**
  - Demonstrate power distribution, readout (even if not final scheme)
  - Can be used for more realistic thermal testing





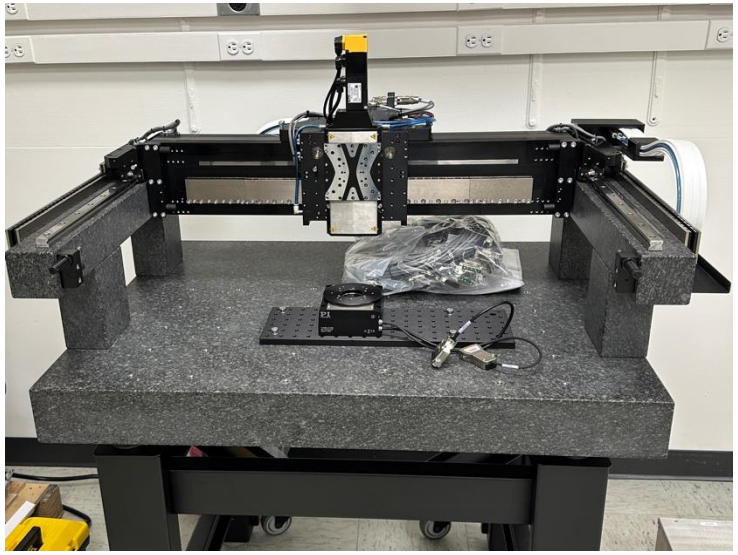


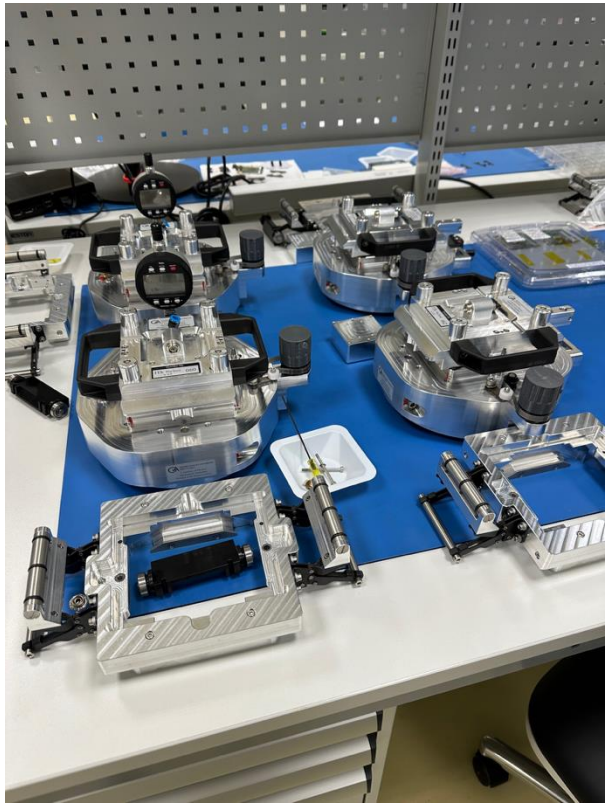
Module Assembly plans

Q2

We are investigating two module assembly path:

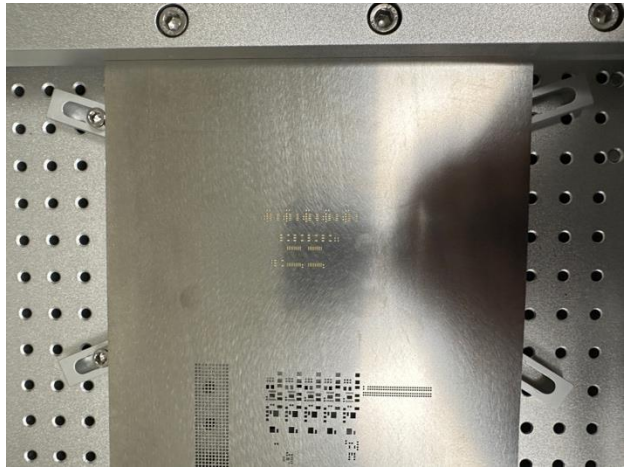
- **Jig-based assembly**
  - More labor intensive
  - Lower cost of entry
- **Robotic Gantry-based assembly**
  - Less labor intensive and faster
  - Higher cost of entry (gantry available with some collaborators)





Module production : 778 + 10% spare = 856 modules

- 2h per modules (Jig), 20 Modules a week -> 43-week production (for 1 site)
- Jig method could speed this up by factor 2-4x



Service Hybrids

Q1,Q2

Power Board (PB):

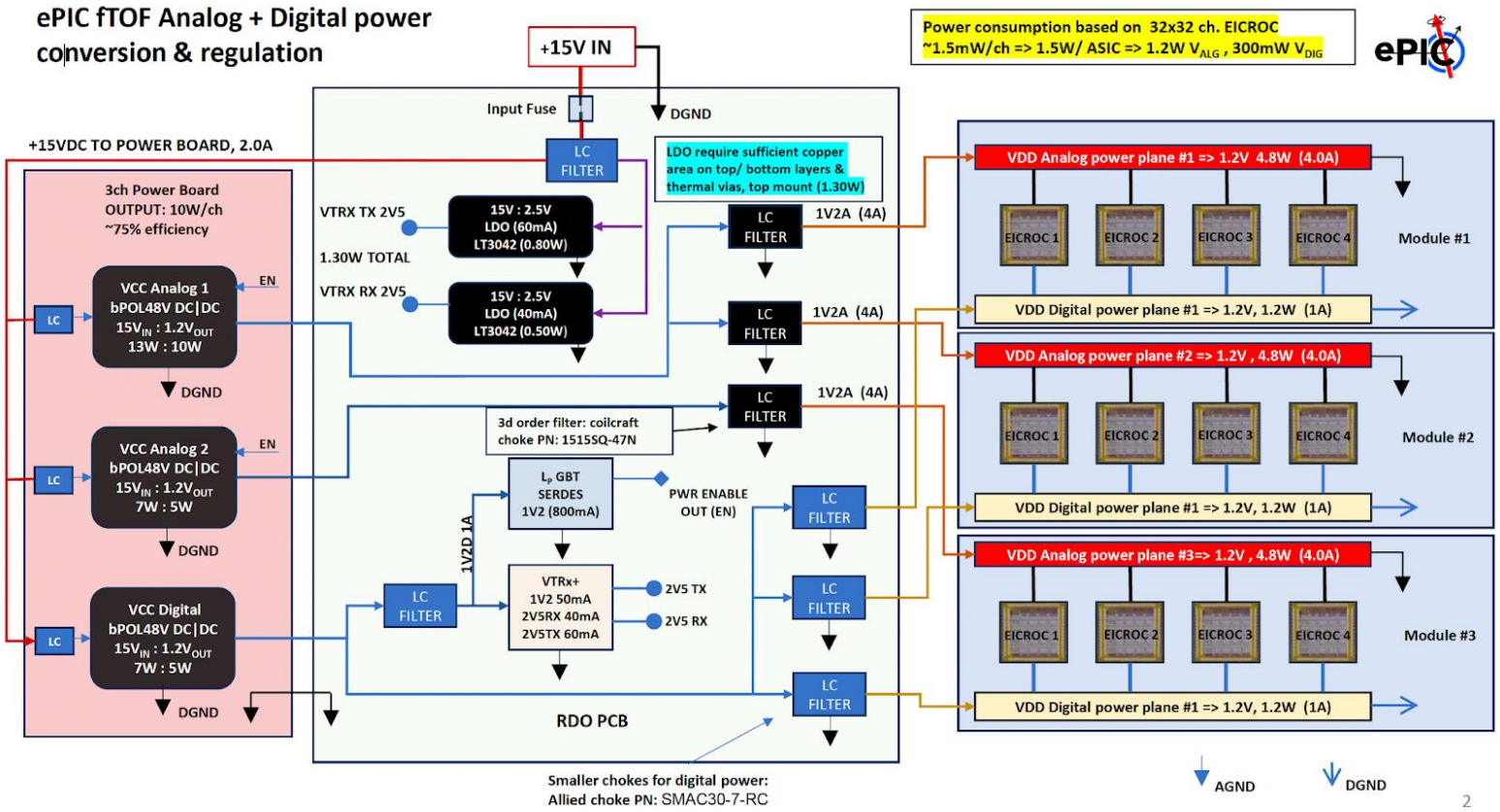
Each PB consists of **three CERN bPOL48V DC-DC converters** to provide the necessary voltages for powering the RB and EICROC chips. The PB connects to the RB through board-to-board connectors.

- First prototype in production
- First test to be carried with dummy loads

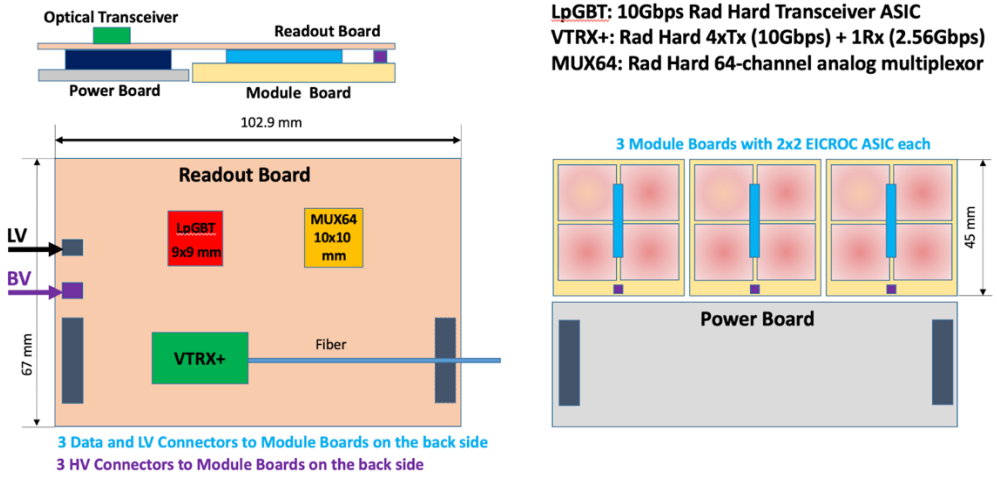
Readout Board (RB):
Each RB includes:

- **lpGBT** for high-speed data transmission.
- **VTRx+** optical transceiver.
- **MUX64 multiplexer** for monitoring

- Design completed; PED request ongoing for production of first demonstrator



ETL FTOF Readout Board Prototype



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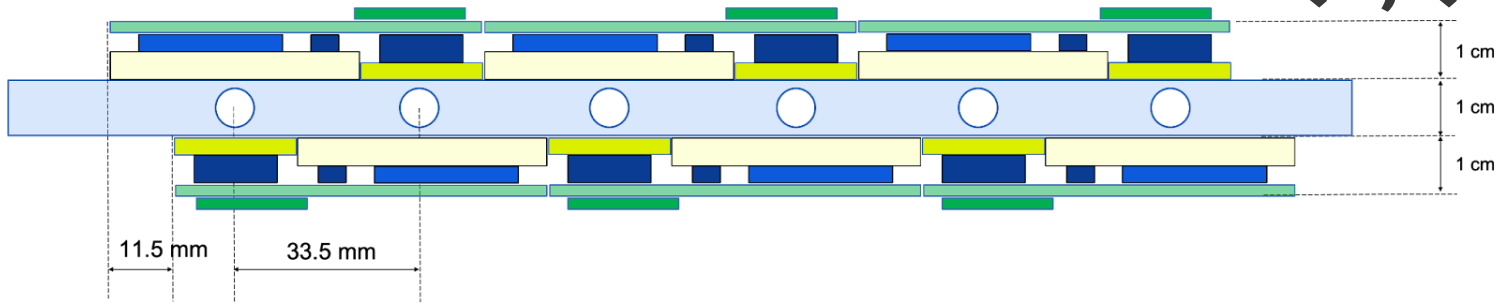
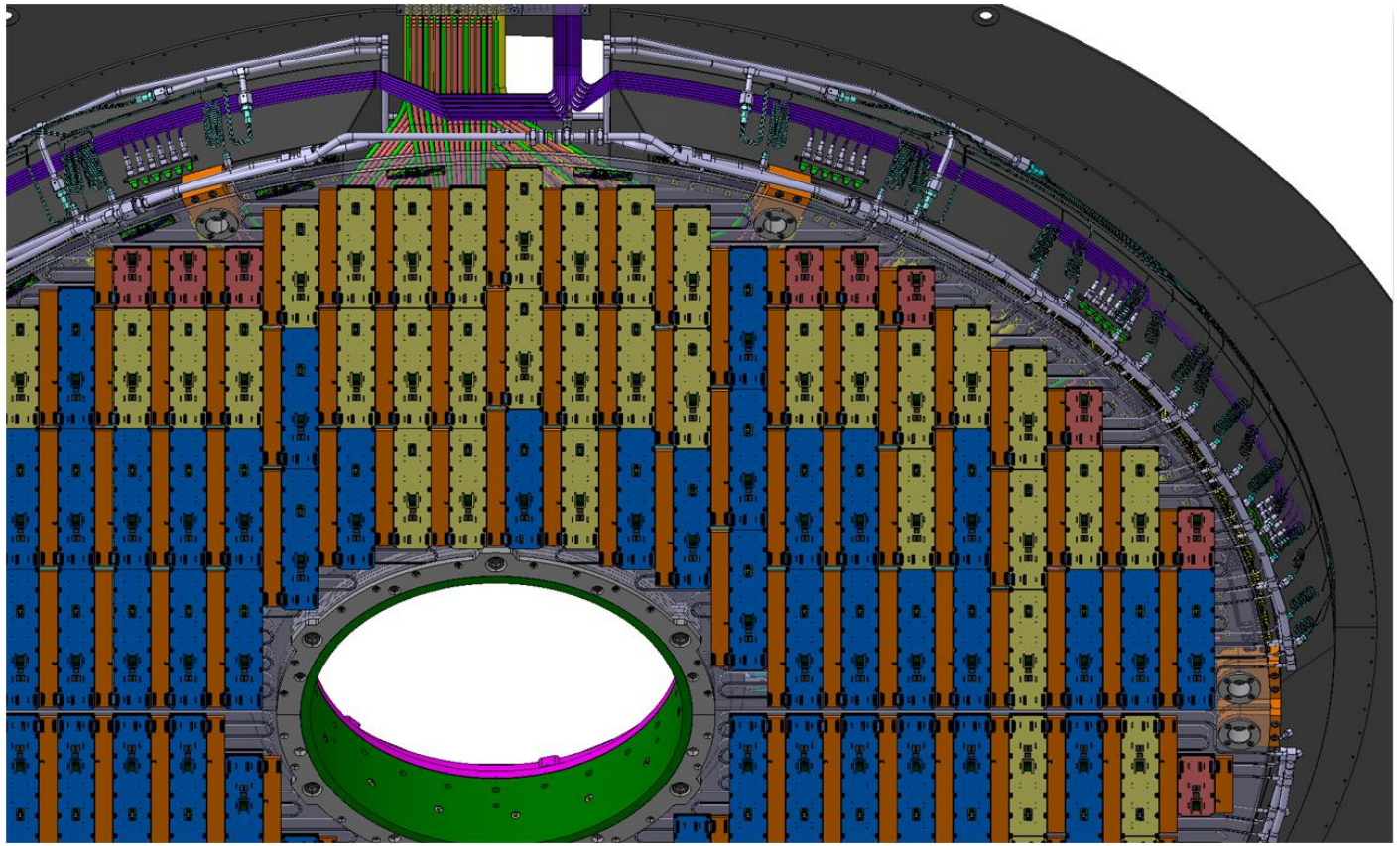
Mechanical integration and cooling

Q1,Q2



The mechanical supports for the fTOF will follow closely the CMS ETL design (ongoing). A double-sided disk base structure (Carbon) will support cooling tubes

- SH + modules to be mechanically mounted on disk with thermal coupling and interconnected.
- Service cabling from SH is routed to the outer radius for fanout to Patch Panel at the rim of the structure
- **Detailed design ongoing (Purdue)**



Readout architecture

The connection the to readout board optical links will be done using ATLAS Phase-II FELIX Card

- 4 DAM (FELIX-155) boards will each service a quarter of the disk's sensors (left/right, front/back)
- 4 DAQ PCs needed for readout

Components	Total
DAM (FELIX-155) Cards	4
DAQ PCs	4

Table: Number of DAQ DAM cards and PCs

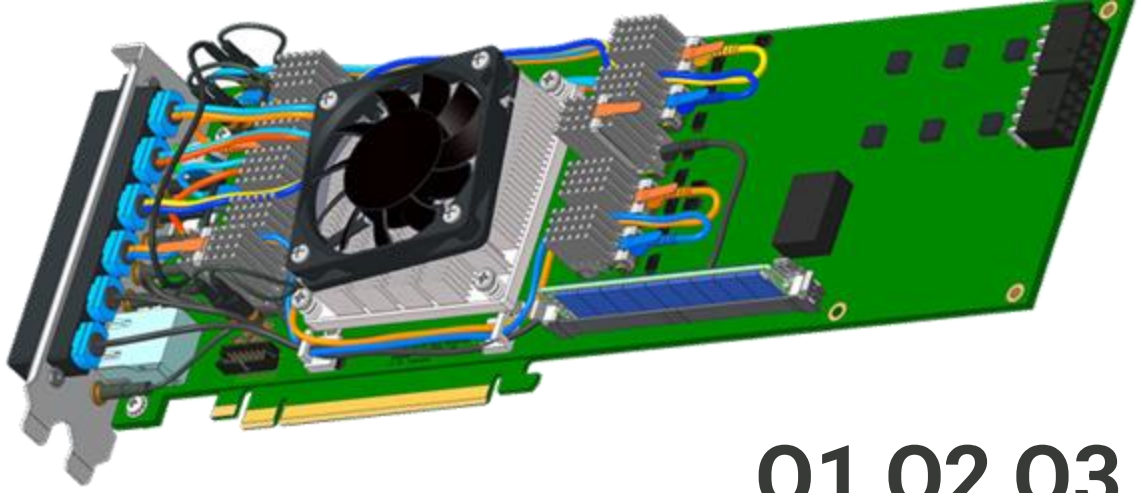
Power supplies to be completed later

Components	Total
HV cables	132
LV cables	132
Data fiber-pair cables	132

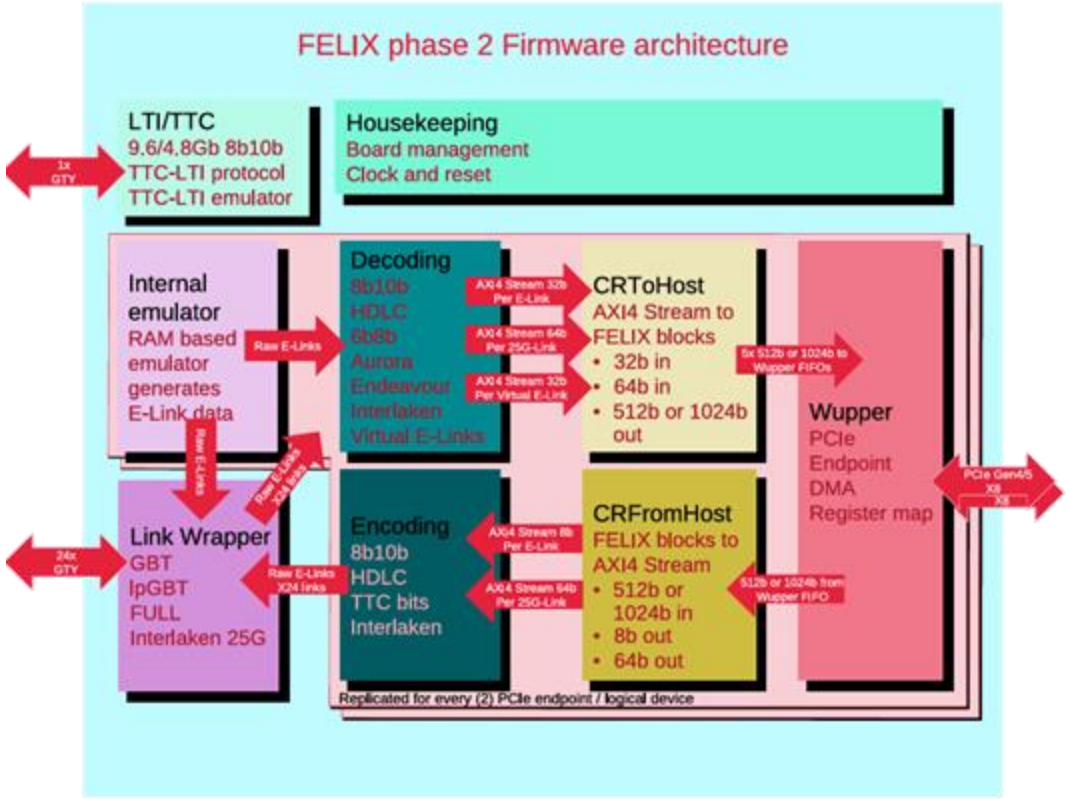
Table: Number of cables

FLX-155

AMD Versal Premium VP1552
PCIe Gen 5 x 16 (480Gb/s)
48 Bidirectional optical links (25Gb/s)
1 Firefly for Timing Trigger & Control (TTC)
1 Firefly for 100Gb Ethernet



Q1,Q2,Q3



Schedule and baselining

Q4,Q5

Modules

- A series of 3 demonstrators planned for module assembly. The demonstrator will allow to baseline module concept and assembly procedure
  - Show-and-tell **(summer 25)**
  - Thermo-mechanical **(Q4 25)**
  - Functional **(Q2-3 2026)**
- EICROC1A/B submission waiting for final EICROC1B design, we expect availability Q4 25. EICROC2 is baseline.
- Sensor production with HPK ongoing to validate EICROC0B performance , next production aimed at final design baseline.

Service Hybrids and readout

- Power board demonstrator **in production**
  - Will allow to measure power consumption and heat dissipation
- Readout board demonstrator **designed, waiting for PED fund for production**
  - Will allow to test interface to FELIX, clock distribution etc.
- EICROC2 digital interface specification **will be required for the final design** of the boards.
- FLX-155 board identified for readout

Mechanical Integration

- The module concept defines the granularity for integration to mechanical support
- Design ramping up for disk support , **first model expected Q4 2025**
- Assembly and integration kinematics to be established along the design of the support and **refined in 2026.**

Charge Questions

- **Q1 :** Is the design of the ePIC detector and its sub-systems appropriate and progressing well?
    - **Yes, the design of its subsystem are progressing well, wit the main bottlenecks being availability of ASIC, Sensors and the progress of the mechanical design. First full-size ASIC allowing module activities with electrical samples planned by end of 25. Mechanical support design efforts ramping up, shared with barrel TOF. Prototypes for Service hybrid are well under way.**
- **Q2 :** Are the remaining work and technical, cost and schedule risks adequately understood? Are there opportunities?
    - **Remaining work is well understood. Module demonstrator 0,1 and 2 will follow availability of components and demonstrate assembly procedures and determine how production will be carried (jig/robotic). Thermomechanical version will allow to settle sensor and ASIC placement in the module. Our main schedule risks are related to availability of ASIC and sensors. Cost risks are related to current geopolitical situation. We are pursuing possible opportunities for cost reduction (robotic assembly, low cost bump-bonding)**
- **Q3 :** Will the detector be technically ready for baselining by late 2025?
    - **The detector baseline is well established, and we hope to close the few open questions by end of FY25 (ASIC, sensor cooling in module, mechanical interface details), provided no geometry or other fundamental changes are imposed from the leadership.**
- **Q4 :** Are the detector integration and planning for installation and maintenance progressing well? Are there areas where further ideas should be pursued?
    - **We have a plan for a set of demonstrator modules and SH that will lead us to higher level integration steps. It is crucial that ASIC, Sensor production and mechanical design progress on schedule.**
- **Q5 :** Will the detector be ready for start of construction by late 2026?
    - **Provided the final EICROC2 ASIC is available in Q4 2026, as well as sensors, we can plan for the start of the bump-bonding campaign for the modules in Q1 2027. and the start of the qualification of module assembly sites. SH hybrid should be mature and ready for production by Q4 2026. Provided the ramp-up for mechanical integration for fTOF continue, we should be able to have a final design by Q1 2027 for production.**