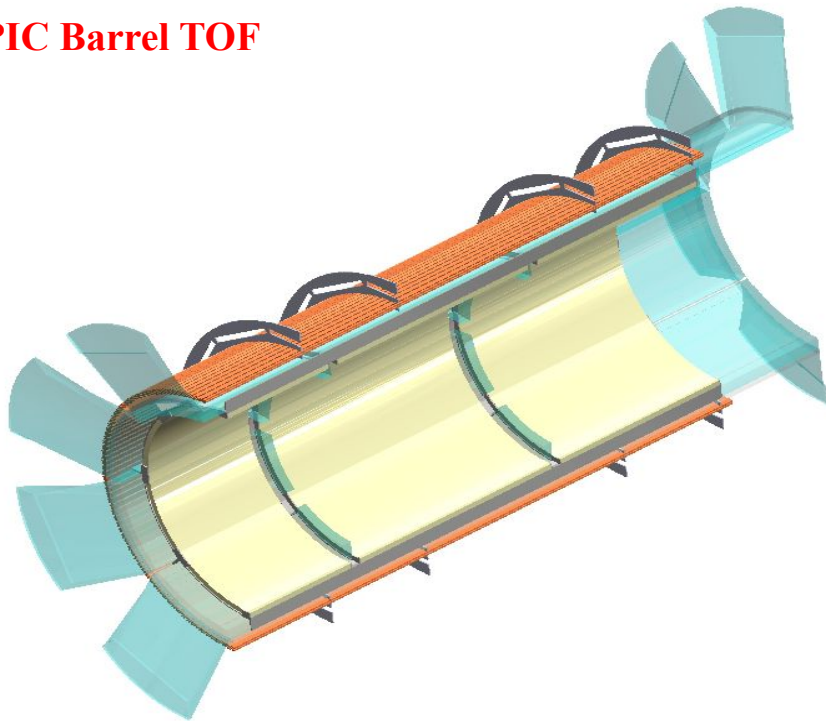# Barrel TOF Subsystem

Matthew Gignac, Satoshi Yano, Zhenyu Ye

We put our name on slides to indicate who assembled the slides (so mistakes are ours). It does not necessarily mean the person with the name on the slide will be in charge of the corresponding work package(s).

Institutions who are interested in the work packages please speak up.
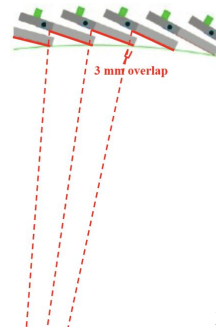
BTOF Detector

ePIC Barrel TOF

**STAR Intermediate Silicon Tracker**

ePIC BTOF follows cylindrical silicon tracker design (e.g. STAR IST)
- 144 tilted stave modules overlap in phi to fully cover the azimuthal 2π angle
- Each module is connected to 2 service hybrids (readout boards) from both ends
- Cooling tubes with liquid coolant at room temperature to take the heat generated by frontend ASIC

BTOF Detector Module

h=0.642 cm

w = 5.6 cm

H=1.242 cm
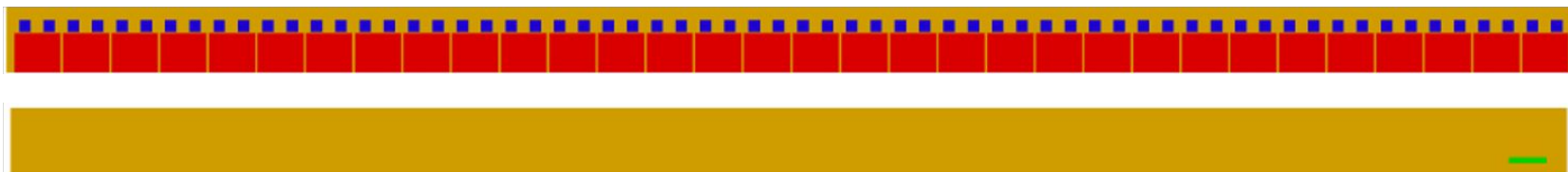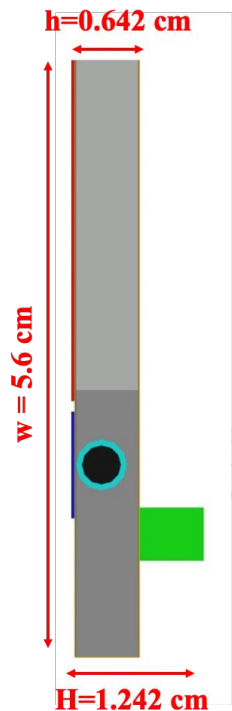
- **64 AC-LGAD strip sensors**, each $3.2*4$ cm^2 read out by **2 ASICs**
- **Low mass flexible Kapton PCB** distributes power and I/O signals from connector
- **Liquid coolant** in **Al tube** embedded in CF light-weight structure for heat removal
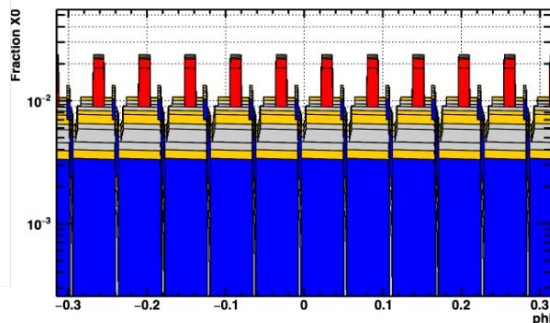
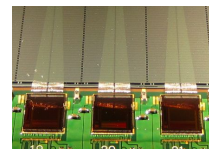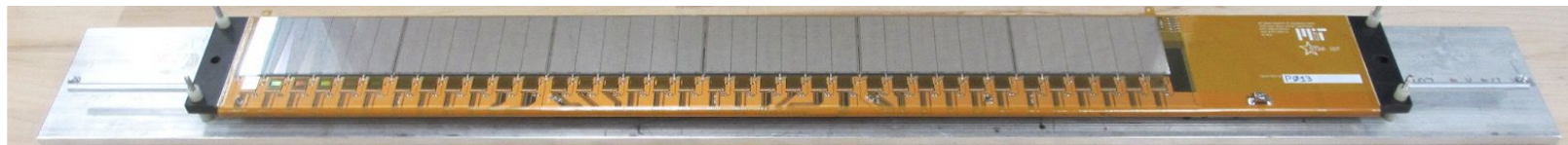144 modules, each with 2 readout boards with 2 LV+HV cables, 2 DAQ fiber, and 1 cooling line
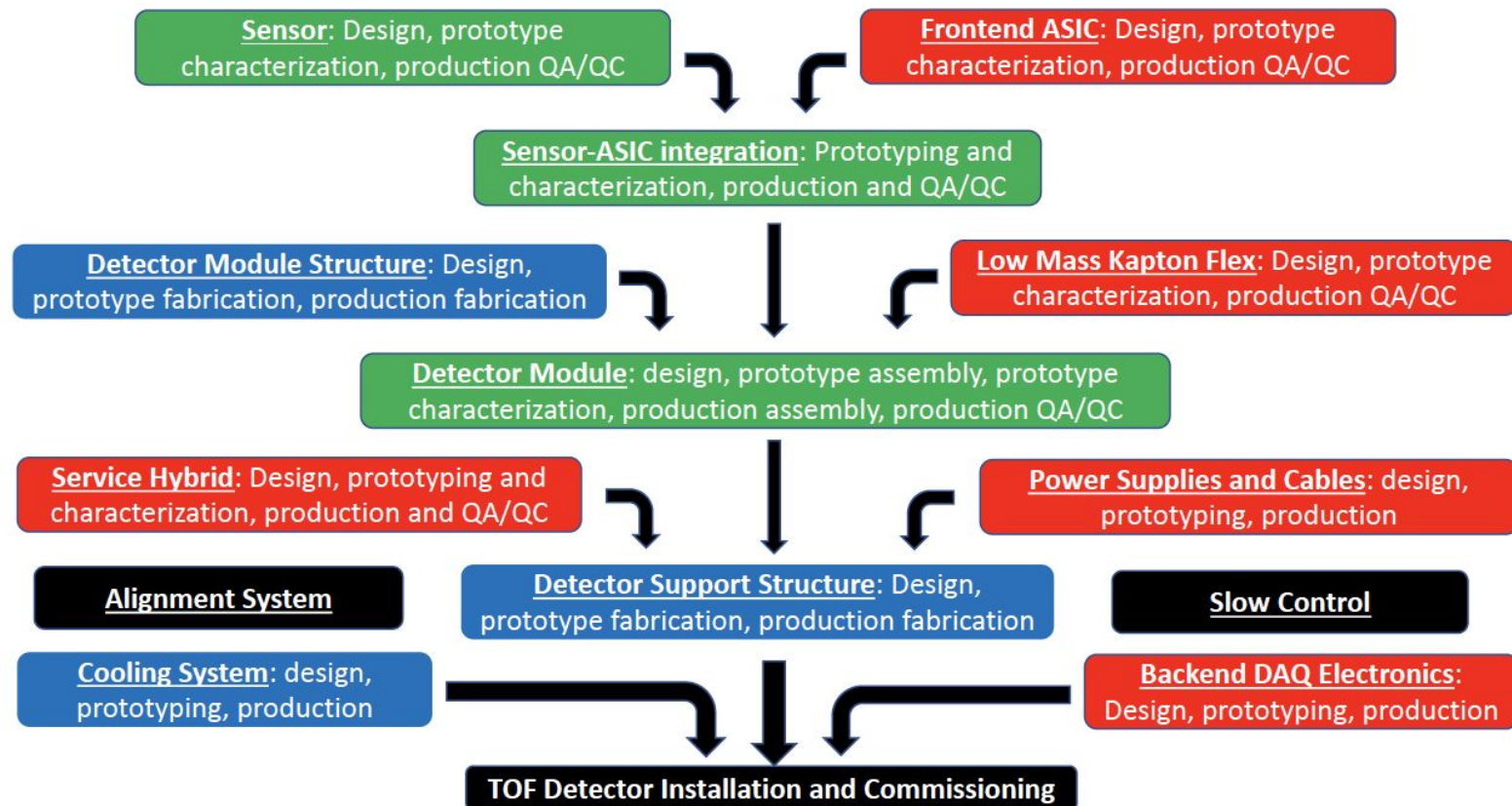
Power consumption: ~4 kW (2.4kW for ASIC, 1 kW for DC-DC, 0.6kW for sensors+cable)

Total weight: ~70 kG

STAR IST

Workflow

BTOF Work Packages

- Sensor and sensor-ASIC integration
  - Sensor
  - Sensor-ASIC integration
- Front-end Electronics
  - ASIC
  - Flex module PCB
  - Service hybrid
- Detector Module
  - Module mechanical structure
  - Module assembly

Sensor (Matthew)

- Sensor **prototyping efforts** (January 2024 - March 2025):
  - Studies during early prototyping periods needed to define scope of sensor QA/QC, i.e.
    - Visual inspection & metrology
    - IV/CV, and possible laser measurements to check gain uniformity?
  - Frame design for handling individual sensors, with functionality to allow QA/QC
  - Procurement of test bench equipment
  - Software design for test benches
  - Shipment & packaging to module assembly sites
  - Ideally, would like to gain experience with multiple vendors ~now
  - Explore double metal layer as possible sensor/ASIC integration?
- **Sensor deliveries**:
  - Pre-production (April 2025 - September 2026) → 10%
  - Production (October 2026 - December 2028) → 90%
- **Interested institutes**: BNL, UC Santa Cruz, UIC, …

Frontend ASIC (Zhenyu)

Frontend ASIC:

Channel: 64 x 2

Input charge: 4-40 fC (?)

Input capacitance: ~10 pF (?)

Jitter: < 10 ps @ 20 fC

Clock: ~98.5 MHz

Power consumption: 1-2 mW/channel

Output: TDC (10 bit) + ADC (8 bit)

Readout scheme: streaming readout

Tasks:

- Now - ~03/2025: (design and) characterize prototype ASICs - develop test hard/firm/software, Q_{inj}/beam/TID/SEU
- 04/2025 - 09/2026: pre-production ASIC Q_{inj}/beam/TID/SEU tests; develop QA/QC setup, procedure and criteria
- 10/2026 - 12/2028: production QA/QC, sort and distribute ASICs to sensor-ASIC integration sites

Institutions:

- Design: IJCLab/Omega (EICROCx), FNAL (FCFD)
- BNL, Hiroshima Univ, UIC, …
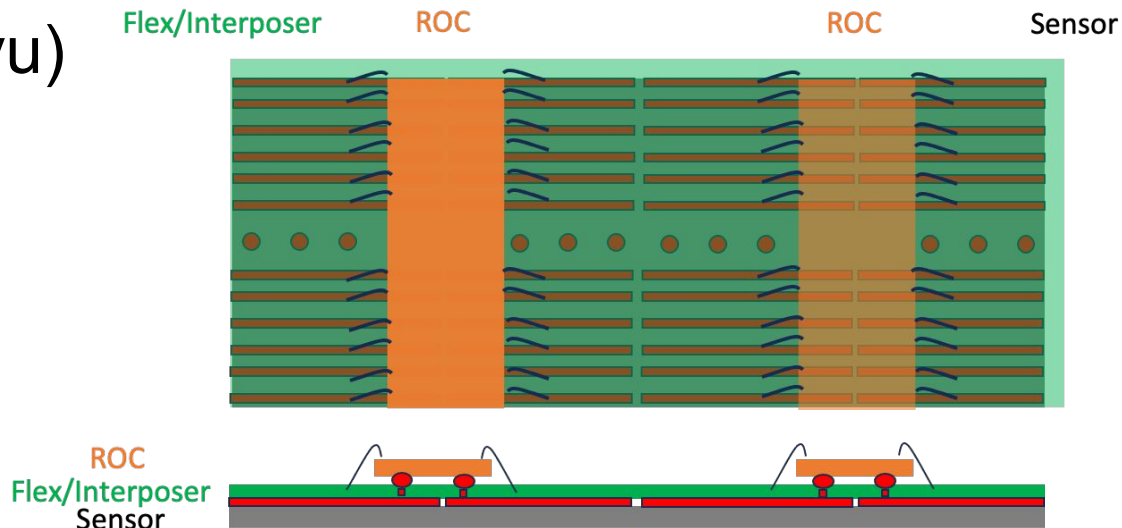
Flex Module PCB, ASIC-Sensor Integration (Zhenyu)

Flex Module PCB: Route LV/HV to ASIC and Sensor, and digital I/O to ASIC

Tasks:

- Now-03/2025: design and characterize prototype flexs
- 04/2025-09/2026: pre-production flex characterization
- 10/2026-12/2028: production flex QA/QC

Institutions: ORNL, …

Sensor-ASIC Integration: Wire-bond or bump-bond ASIC-Sensor with good electrical/mechanical/thermal connections

Tasks:

- Now-03/2025: prototype sensor-ASIC integration (interposer between sensor/ASIC if no double metal layer?)
- 04/2025-09/2026: integrate pre-production sensors and ASICs
- 10/2026-12/2028: integrate production sensors and ASICs
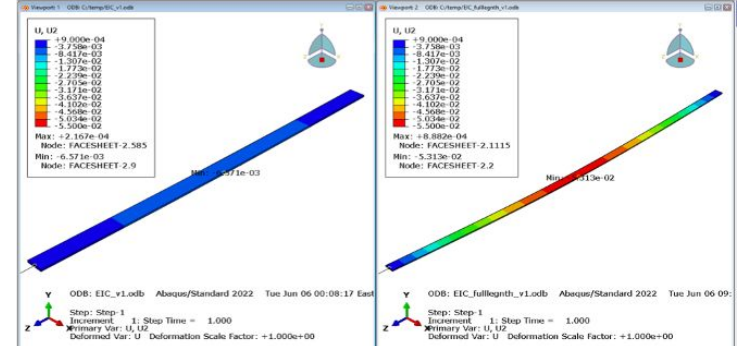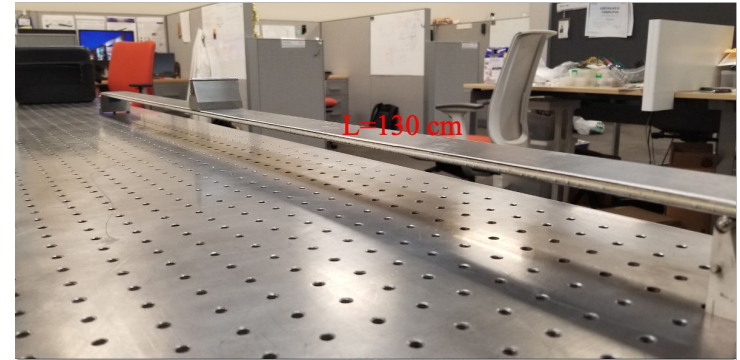
Institutions: UCSC, ORNL, UIC (interposer), …

BTOF Module Mechanical Structure (Zhenyu)

Module mechanical structure: lightweight mechanical and cooling structure for BTOF modules

Tasks:

- Now - 2025: design and characterize prototypes
- 2026: pre-production
- 2027: production

Institutions: Purdue, NCKU, …

Detector Module Assembly (Matthew)

- Module prototyping strongly dependent on timelines of all earlier components
- Early efforts likely can only focus on mechanical modules (<Sept 2024)
  - Patterned glass ASICs chips, mechanical sensors, etc …
  - Useful to develop assembly techniques, tooling, etc …
  - Can be used as first step towards defining procedural QA/QC documents
  - Feedback into component design
- First demonstrate 'short modules' with a single sensor and ASICs (<March 2025)
  - Requires short flexes (with decisions on sensor & ASIC interconnect), support structures, etc…
  - Critically needed for development & commissioning of electrical test stands
- Full-sized modules need to be demonstrated shortly thereafter (<Sept 2026)
  - Pre-production consisting of ~15-20 full-sized modules (~5% of production)
- **Interested institutes**: UC Santa Cruz, BNL, …

Service Hybrid (Satoshi)

- Service hybrid = power board (PB) + readout board (RB)
- The PB provides power to the readout ASIC, FPGA, and SFP+/VTRx+
- The RB manages control and monitoring signals, provides clock signals to the readout ASIC, and transfers data from the FPGA to the DAQ via the SFP+/VTRx+
- The service hybrid will be placed outside of the TOF acceptance, so (so far) the material budget has not big impact on measurements at the central barrel

CMS ETL TDR
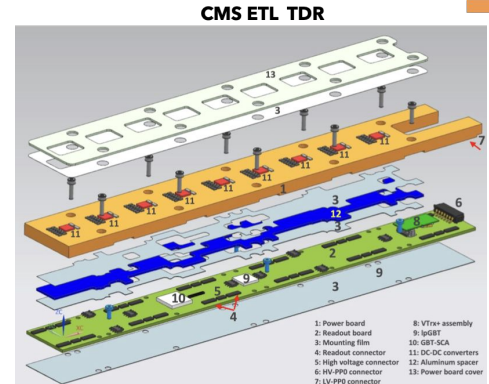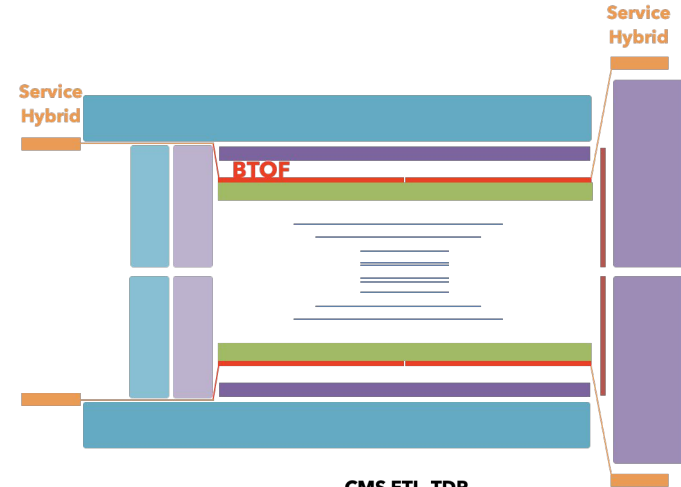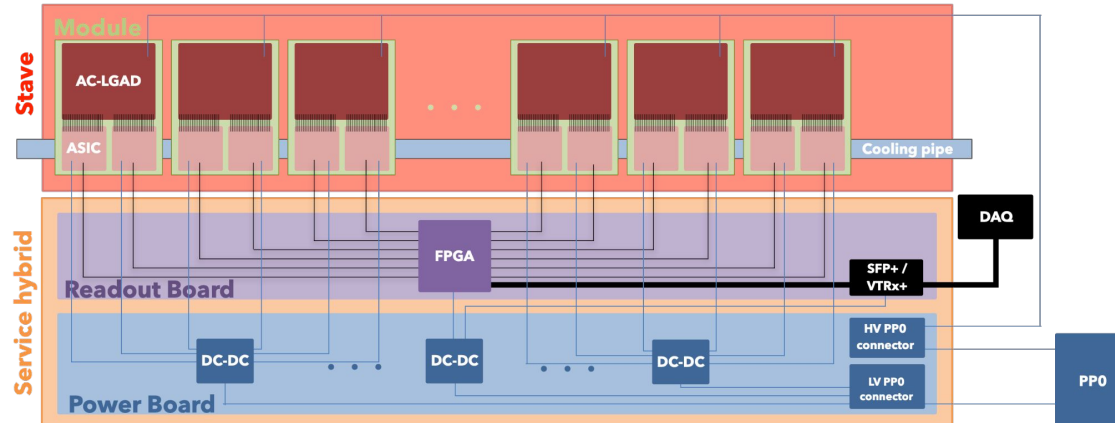
Service Hybrid (Satoshi)

Service hybrid: readout board and power board

- The strong cooperation between several components, e.g. the readout ASIC, DAQ, and the TOF common system, etc is mandatory
- The prototyping depends on the other components development

Tasks:

- Now - 2025: design and characterize prototypes (readout board and power board)
- 2026: pre-production
- 2027: production

Institutions: BNL, Rice, UIC, …