Mechanical Structure for EPIC TOF

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About Us

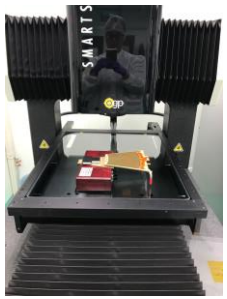
- US - Andreas Jung
  - Experienced in R&D for mechanical support structures, associate member of Purdue Composite Manufacturing & Simulation Center.
  - Working on the light-weight composite tracker support structures for CMS.

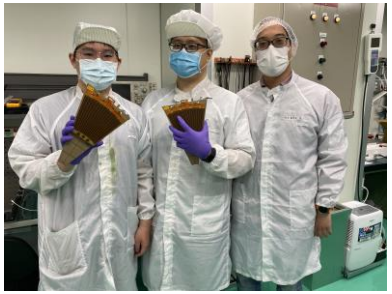
- Taiwan - Yi Yang & Po-Ju Lin
  - Experiences with the AMS-02 UTTPS radiator and lead the project of the mechanical structure of STAR FST

Resource from Taiwan

Taiwan Instrumentation and Detector Consortium (TIDC):

- https://tidc.phys.ntu.edu.tw/WordPress/
- Sophisticated machines for detector assembly
- One mechanical engineer available





NCKU:

- Strong mechanical engineering department
- Good relationship with Aerospace Industrial Development Corporation (expert on composite material)
- One electrical engineer available

AIDC

AS IoP:

- High precision machine shop
- One mechanical engineer available

STAR Forward Silicon Tracker

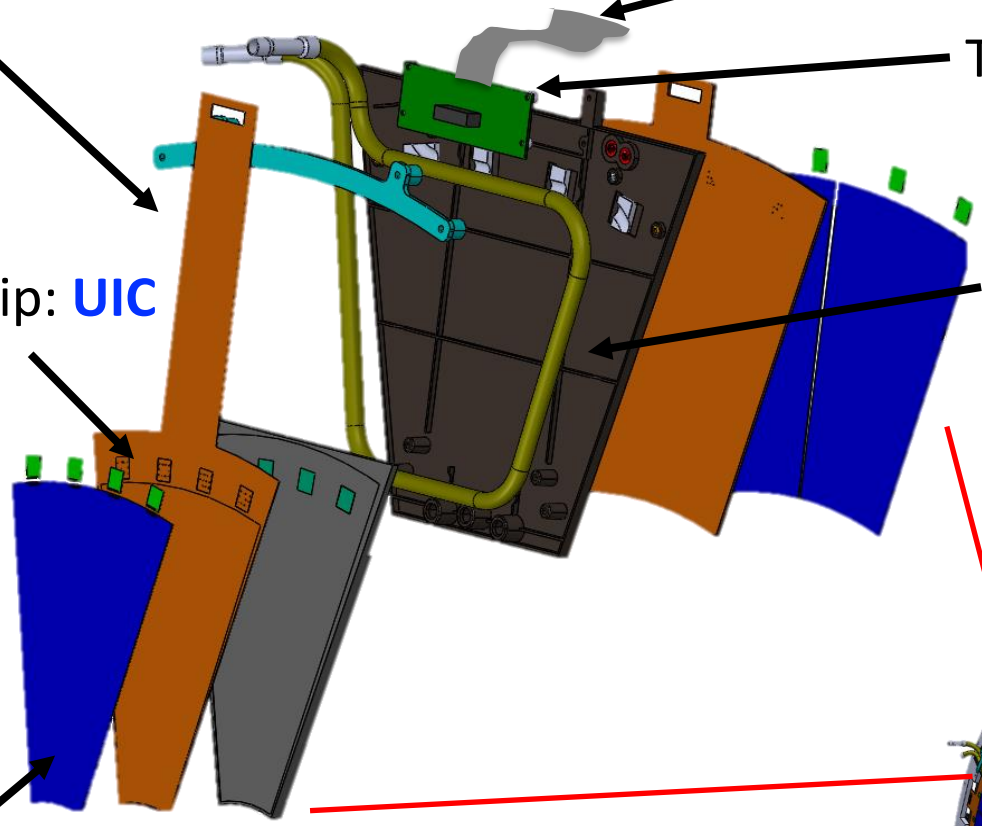
Flexible hybrid PCB: **SDU/IU**

Inner Signal Cable: **BNL/IU**

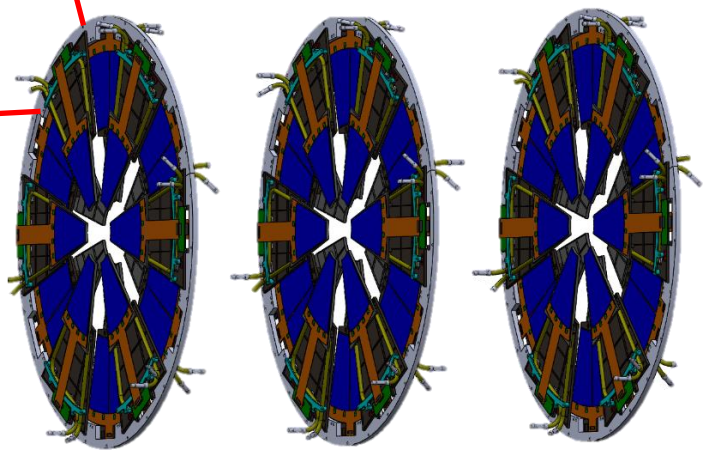
T-Board: **SDU/IU**

APV25 Chip: **UIC**

Mechanical Structure
(+ cooling pipe): **NCKU/AIDC**



Supporting Structure &
Integration: **BNL**



Silicon sensor: **UIC/BNL**

Cooling: **BNL/NCKU**

Simulation: **UIC/BNL/IISER/NCKU**

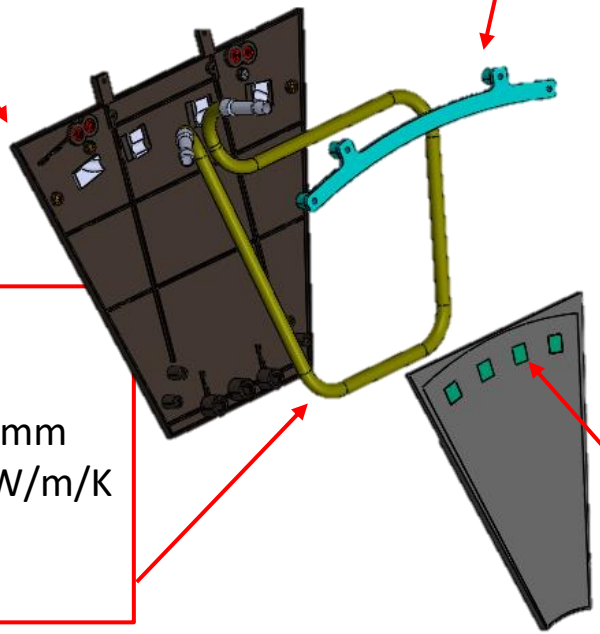
STAR Forward Silicon Tracker

Main structure:
- ❑ Material: PEEK
- ❑ Thermal Conductivity: 0.24 W/m/K
- ❑ ES&H: **Good**
- ❑ Rad.: **Good**

Tube fixture:
- ❑ Material: PEEK
- ❑ ES&H: **Good**
- ❑ Rad.: **Good**

Thermal grease:
- ❑ Material: Thermalrigh TF8 2G
- ❑ ES&H: **Good**
- ❑ Rad.: **Good**

Glue (inner MS+outer MS):
- ❑ Material: Loctite EA 9359.3 AERO
- ❑ ES&H: **Good**
- ❑ Rad.: **Good**



Tube:
- ❑ Material: Stainless 316
- ❑ Size: OD 6.35 mm, ID 5.54 mm
- ❑ Thermal Conductivity: 14 W/m/K
- ❑ ES&H: **Good**
- ❑ Rad.: **Good**

Glue (hybrid+MS):
- ❑ Material: Araldite 2011
- ❑ ES&H: **Good**
- ❑ Rad.: **Good**

Heat sink:
- ❑ Material: Al 6061
- ❑ Size: ~8.2 x 8.0 x 3 mm^2
- ❑ ES&H: **Good**
- ❑ Rad.: **Good**

*PEEK has been used in collider experiments: e.g. STAR HFT

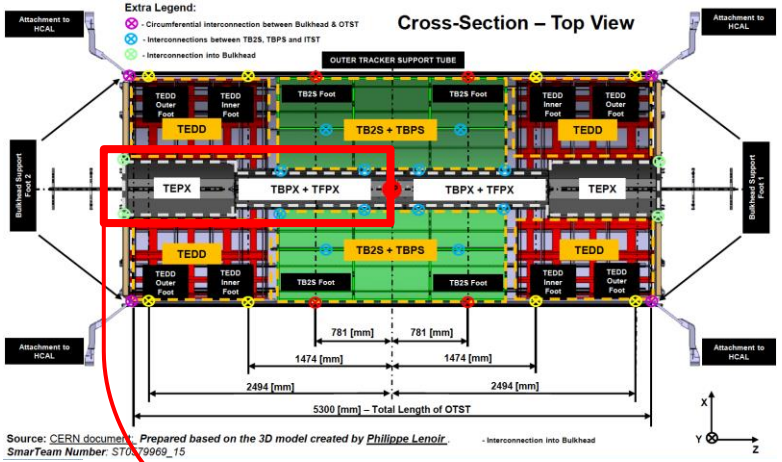
*Composite material for EPIC design → support from AIDC

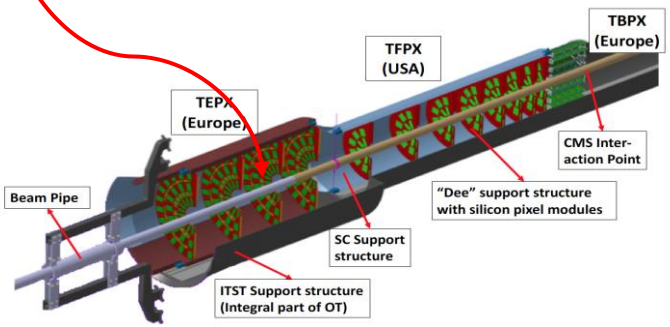
Resources from Purdue

- Composite Manufacturing & Simulation Center (CMSC) at Purdue, completed in summer 2016
  - Purdue Center of Excellence across disciplines: Aeronautics, Chemical Eng, Materials Eng, Aviation Tech, Computer graphics, **and Physics**
  - A. Jung – Associated member of CMSC
- Professional composite experience:
  - Seven full-time technical staff, five post-doctoral researchers, twenty grad's
  - 35,000 sq. ft. of office and laboratory space
    - 2 large pressurized ovens, 1 larger oven with vacuum hook-ups
    - Larger ovens accessible with industry partners

Resources from Purdue

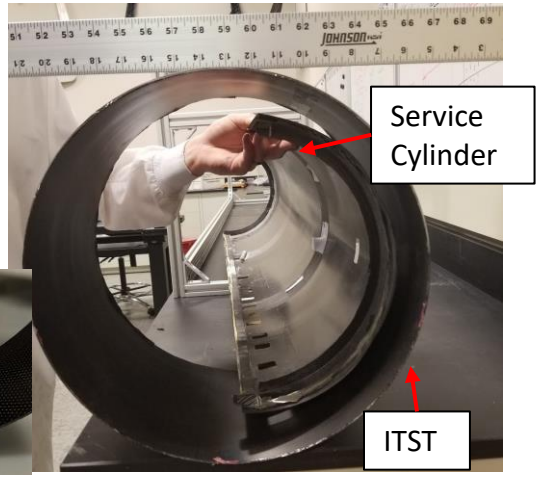
- CMS upgrade relies on Purdue for design & manufacturing of mechanical support structures
  - Service Cylinder housing the Inner Tracker (IT)
    - 4+2 half cylinder structures with a length of 2.9m and transition region between small & large radii
    - Barrel, Forward, and Extended Pixel Detectors
  - Components for Inner Tracker pixel
    - Sandwich structures to mount pixel modules (Dee's) for the forward pixel (US project)
    - CFRP structures for the barrel pixel (European led)
  - Inner Tracker Support Tube (ITST)
    - Supports the 4 IT Service Cylinders, separates Inner Tracker and Outer Tracker volumes
    - Longitudinal stiffness for the entire Outer Tracker
  - Components for Outer Tracker (OT) modules
    - CFRP stiffeners for the OT modules assembly
  - Barrel Timing Layer Tracker Support Tube
    - Support the entire IT + OT + Timing Layer of CMS

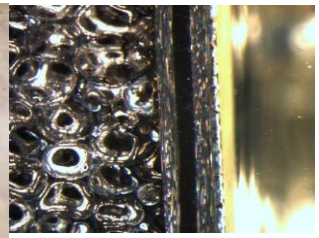


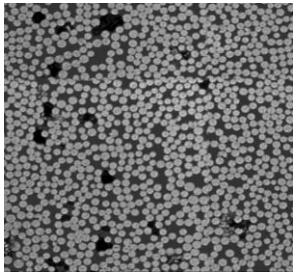


Resources from Purdue

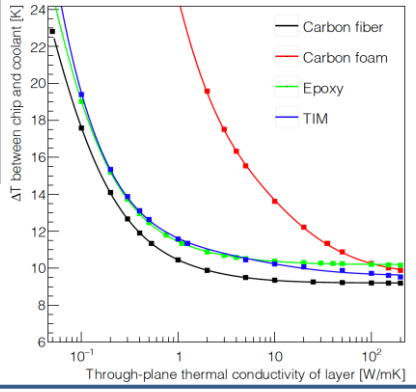
- Prototyping & Manufacturing related to ITST, SC, Dee's
  - Prototypes confronted with FEA predictions, multiple iterations
  - Prototyping and Development of additional structures for IT pixel
    - Cartridges, Portcard holders, all extensively studied for high thermal performance
    - Accompanied by irradiation campaigns: sample prep, characterization, etc.
    - Dedicated measurement of thermal conductivities
    - High thermally conductive materials for 3D printed parts

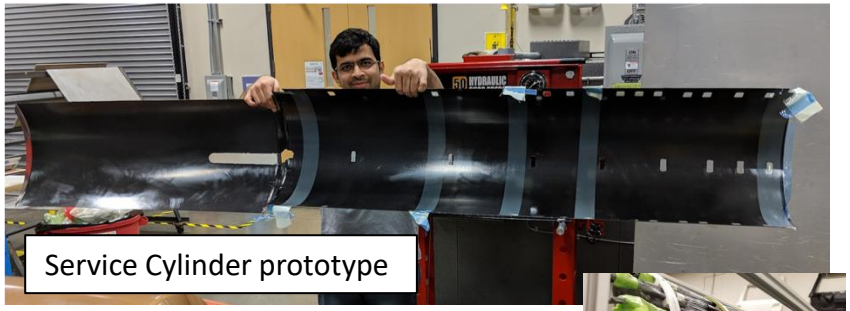


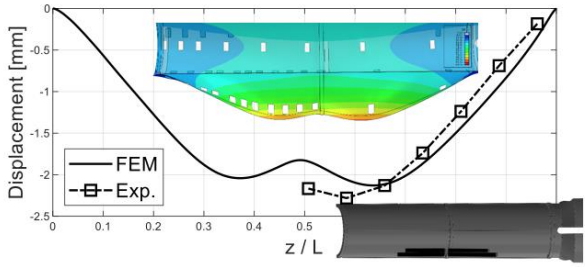




- Forward pixel dee prototype
- Co-cured samples
- Microscopies
- 3D printed mechanical supports
- Critical interfaces via FEA

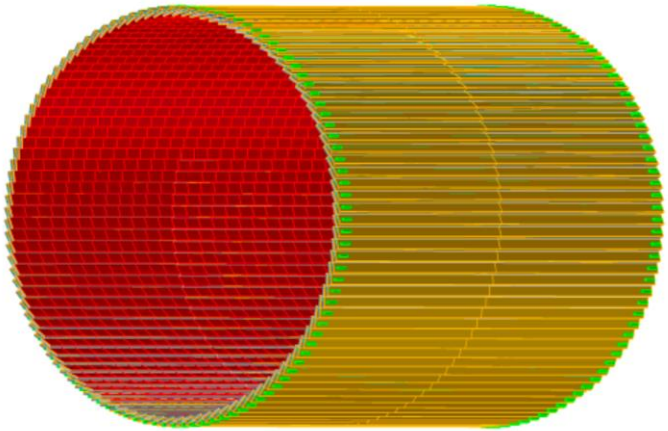


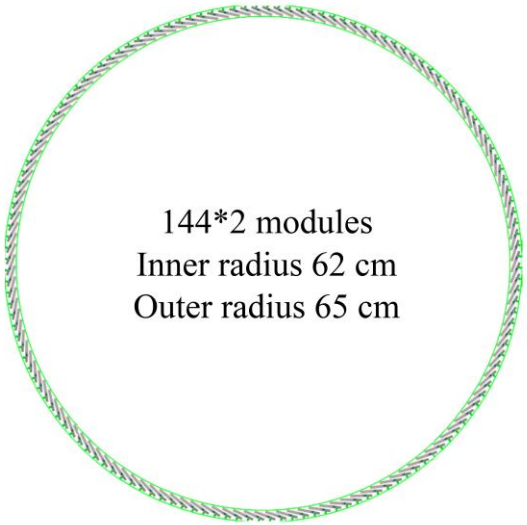


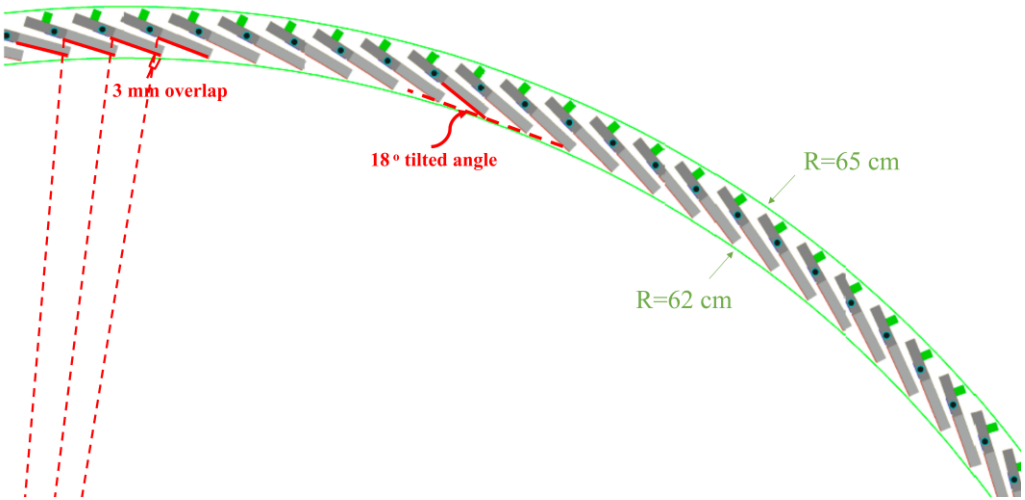


Barrel TOF

- For v0 design of Barrel TOF, pixels of 0.5x10 mm^2 strips proposed.
- Single layer of strip AC-LGAD sensors
  - 62<R<65 cm, 2.7m long, ~11 m^2 area
- Strip metal electrodes, with 500 μm pitch in $r\phi$ and 1 cm* in z



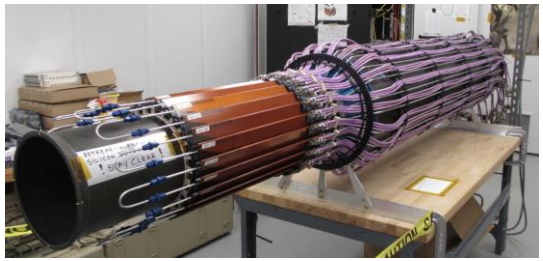




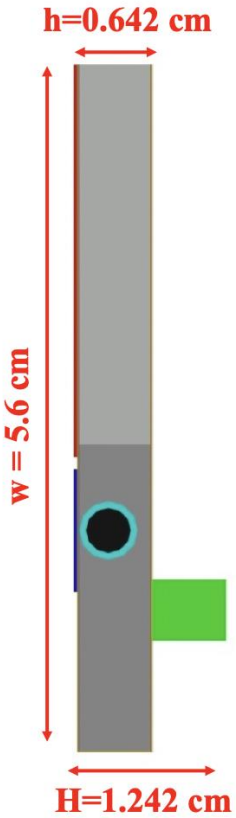
From Zhenyu's talk
https://indico.bnl.gov/event/16765/

Barrel TOF

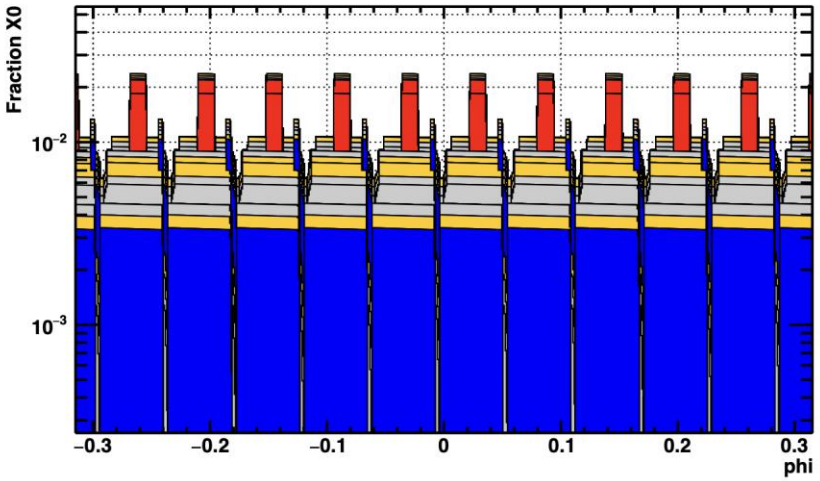
- Use the similar concept of STAR IST
- Rather long support (1.35m) with minimal deflection
  - R&D with carbon fiber composite materials

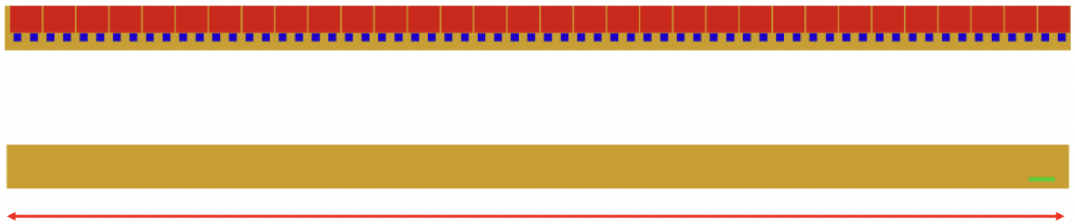


- In total 288 modules,
  - 9216 sensors, 18,432 ASICs, 2.4 M channels
  - ~70 kG, ~4 kW



- AC-LGAD sensor
- Frontend ASICs
- Carbon foam+
  Carbon honeycomb+
  CF skins
- Al cooling tube
- Liquid coolant
- Kapton PCB
- Connector





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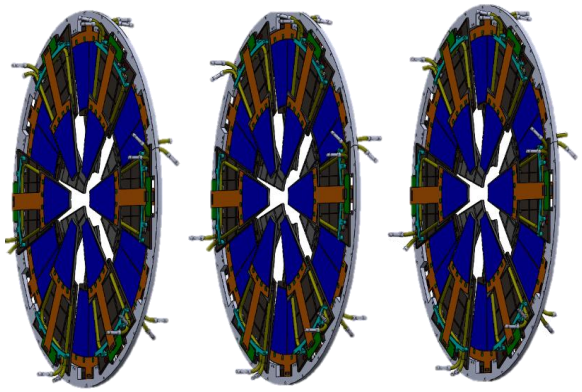
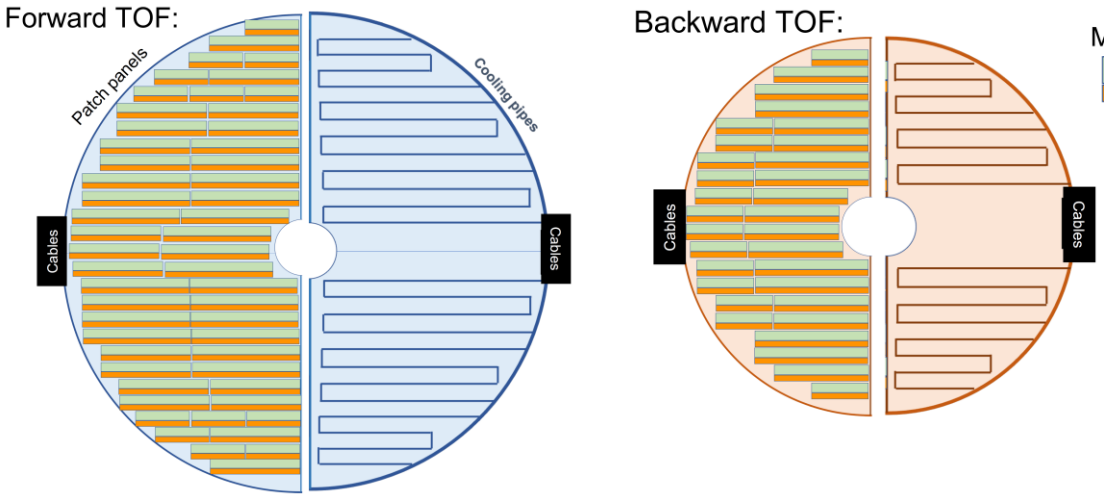
Endcap TOF

- For v0 design of Endcap TOF, pixels of 0.5x0.5 mm^2 proposed.
- Option 1, design concept similar to STAR FST
- Option 2, design concept similar to CMS, as bought up by Wei Li in the TOF-PID WG meeting on Aug. 29





From the talk of Wei Li
https://indico.bnl.gov/event/16742/

- "Clam shells" or DEEs
  - Convenient for installation/maintenance
  - Each is patched by TOF modules (one or more types) on both faces

Power Budget

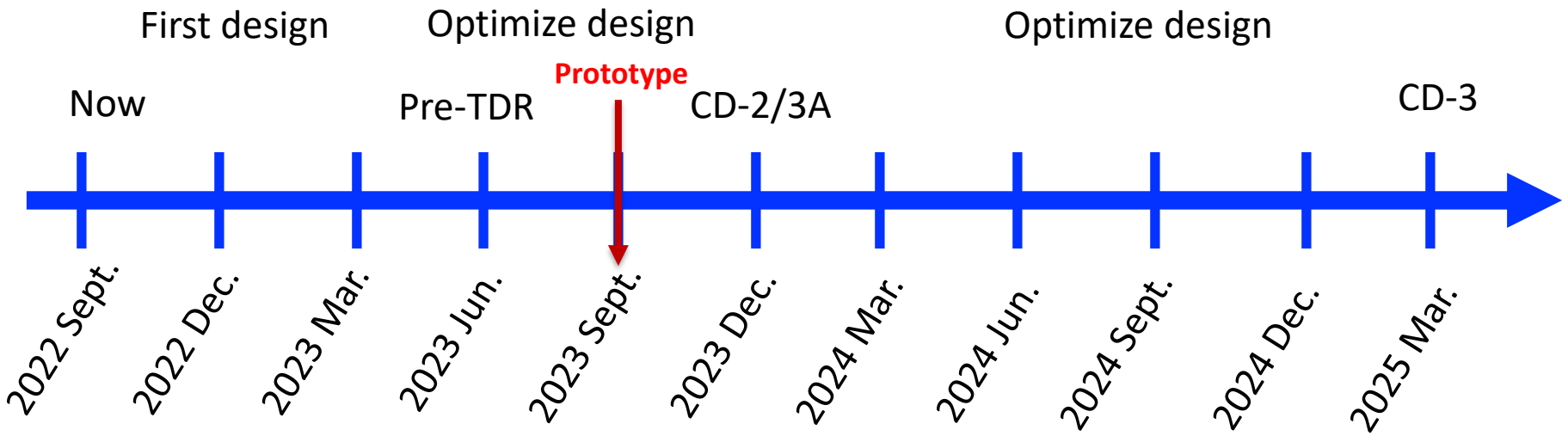
	Forward	Backward
Sensors	0.6kW	0.35kW
EPTROC	8.5kW (17kW)	4.8kW (9.6kW)
DC-DC	3.5kW	2kW
lpGBT, VTRx+, SCA	0.5kW	0.3kW
Power cables	0.5kW	0.3kW
Total	13.6kW (22.1kW)	7.75 (12.55kW)

Budget and Schedule

Budget

- 2022 – 2023: **30K**
  - One prototype 1.35m “plank” prototype by Sep. 2023.
  - Purdue: 10% FTE engineer ~15k$ + low S&E $ = 20k (Materials: cost-effective by using non-final materials and usage of FEA)
  - Taiwan: Material & processing fee 10k
- 2023 – 2024: **30K** (include material and cost of processing) → very rough estimation

Schedule



Summary

- Integrated cooling and mechanical support structures - with carbon fiber composite materials
- Optimization for the thermal performance while keeping the radiation length low.
- Goal:
  - Average material budget 1% X_0 or smaller
  - Cooling capable of dealing with power of budget of multi-kW
  - Deflection tolerance on the scale of one to few millimeters for a part of about 5m long

Backups