Mechanical Structure for EPIC TOF

6th June 2023

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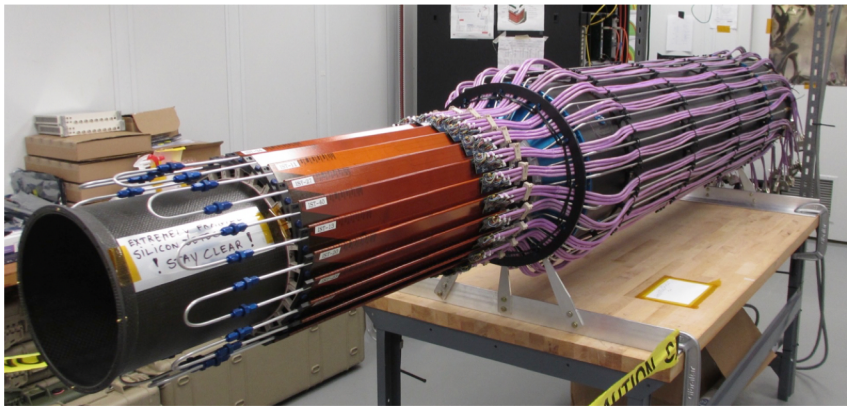
Po-Ju Lin Academia Sinica, Institute of Physics
Yi Yang National Cheng Kung University

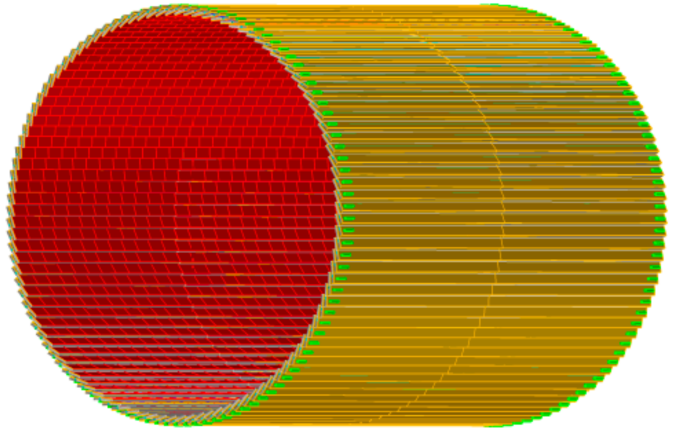
R&D FY23: Budget

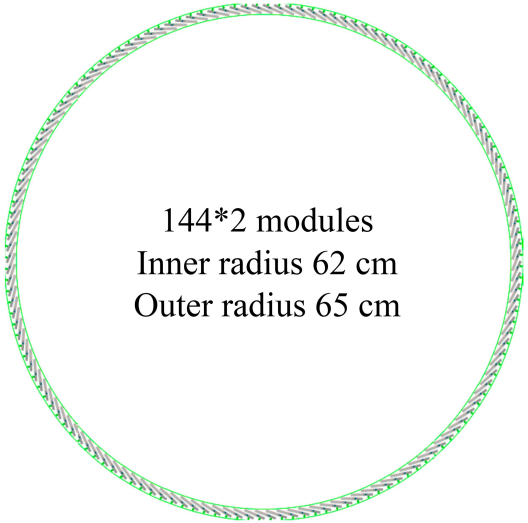
- **Budget**
  - 2022 – 2023: 30K (include material and cost of processing)
    - 2023 – 2024: 30K (include material and cost of processing)
    - 2024 – 2025: 30K (include material and cost of processing)
  - Purdue Deliverable: One 1.35m “plank” prototype until Sept 2023
    - Budget: 10% FTE engineer ~15k$ + low S&E $$
    - Materials: cost-effective by using non-final materials and usage of FEA
    - Lots of relevant experience to draw from and apply to benefit of EIC
- Goals:
  - Integrated cooling and mechanical support structures
  - Average material budget 1% X_0 or smaller
  - Cooling capable of dealing with multi-kW power dissipation
- Deliverables: 1-3 “stave” structures, i.e. no larger system aspects.
- Latest Updates:
  - Paperwork / SOW submitted
    - Purdue to BNL (late, on 31st March)
    - NCKU to JLAB (TBC)

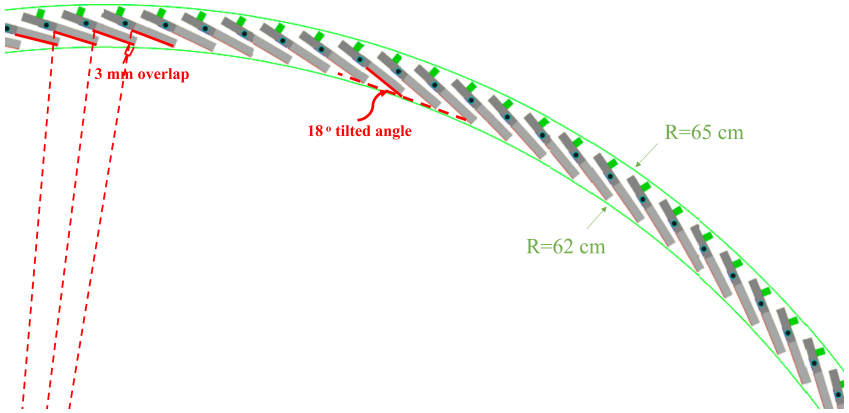
Barrel TOF

- Use the similar concept of STAR IST





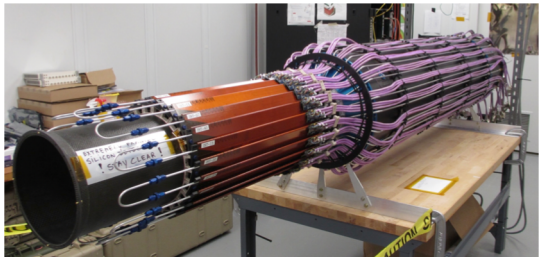


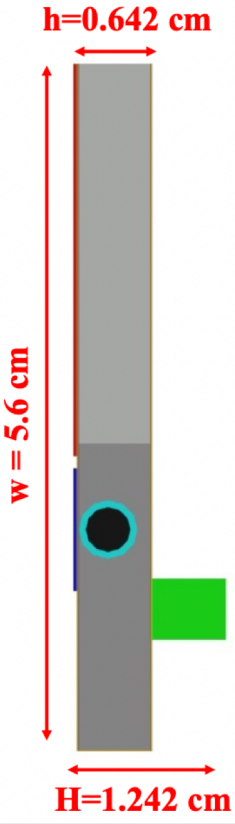


From Zhenyu's talk
https://indico.bnl.gov/event/16765/

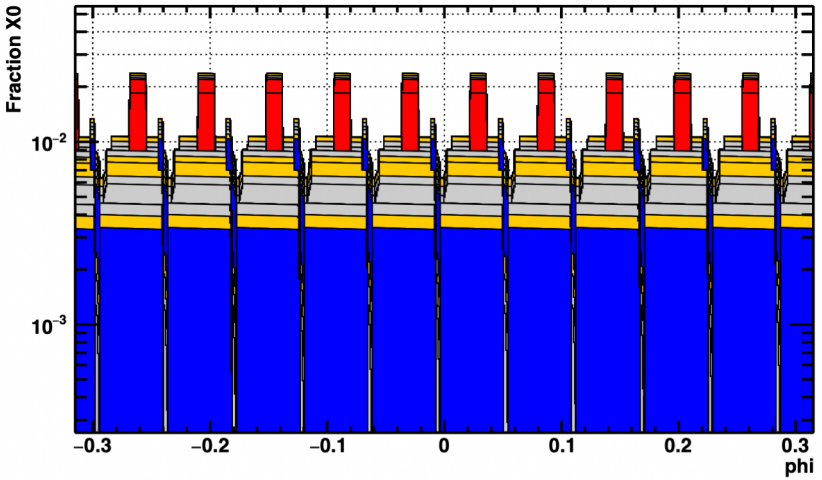
Barrel TOF

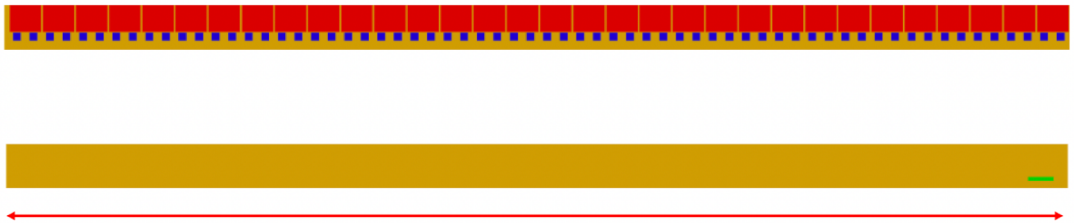
- In total 288 modules,
  - 9216 sensors, 18,432 ASICs, 2.4 M channels
  - ~70 kG, ~4 kW





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

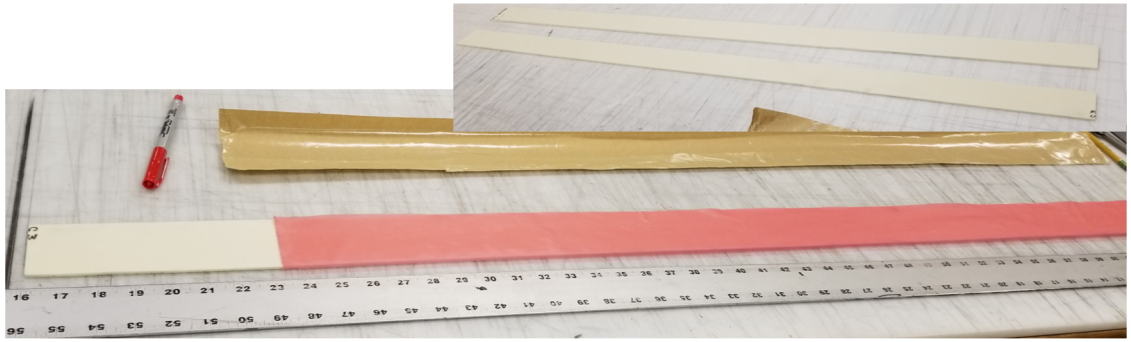




From Zhenyu's talk
https://indico.bnl.gov/event/16765/

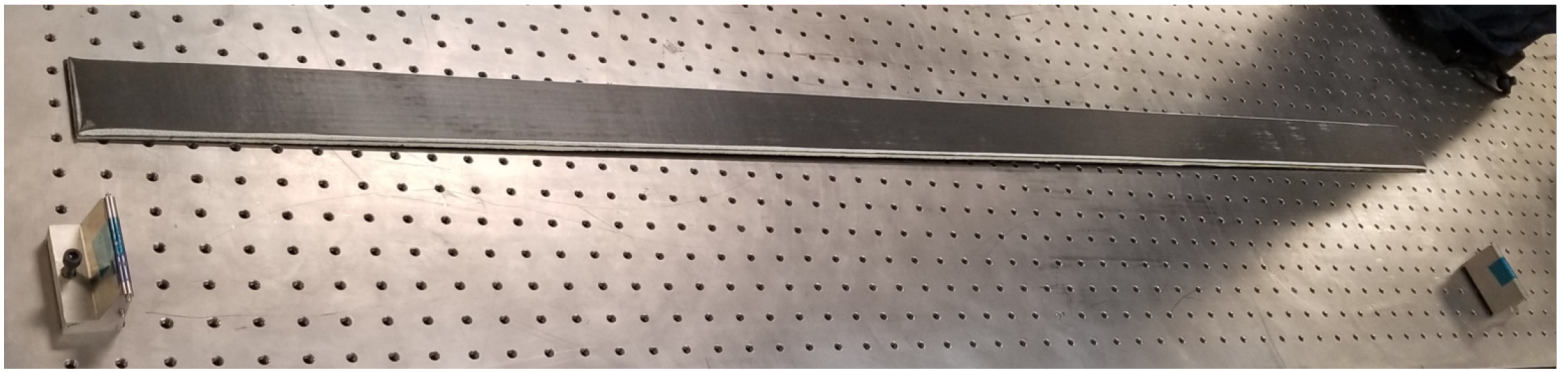
R&D progress FY23

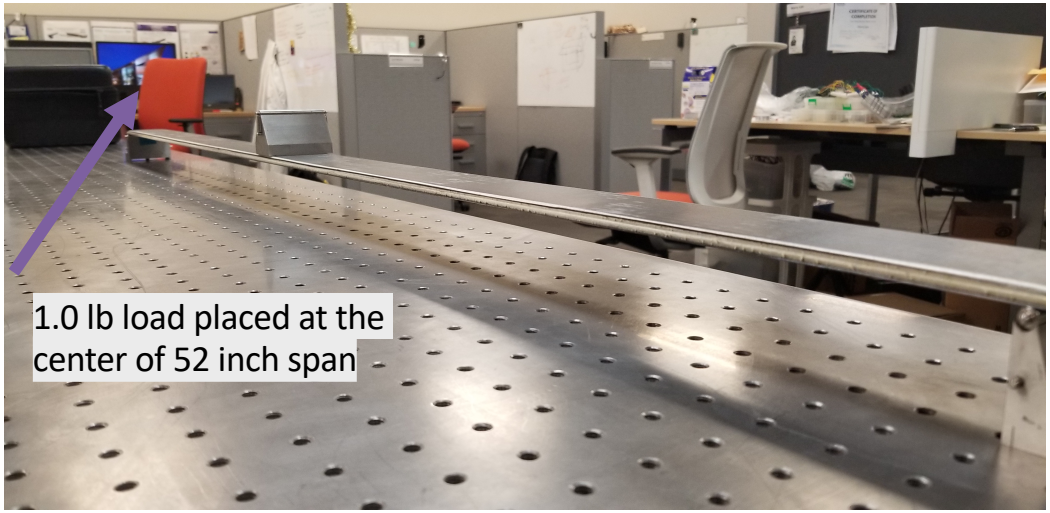
- **First limited activities started…**
- CAD model based on the STAR IST staves
- Dimensions as follows – total thickness is 6.9 mm (0.2 mm facesheet [0/90/0] + 3.25 mm foam + 3.25 mm foam + 0.2 mm facesheet [0/90/0])
- Foam material used – Airex 82.80
- Face sheet – Rockwest EHM32 / T700 – 250 F cure – UD prepreg – layup [0/90/0]

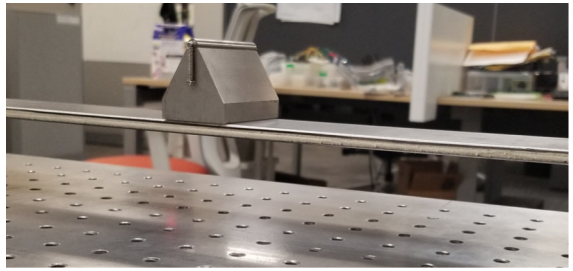


R&D progress FY23

- **Loading test w 1lb load in the center….**



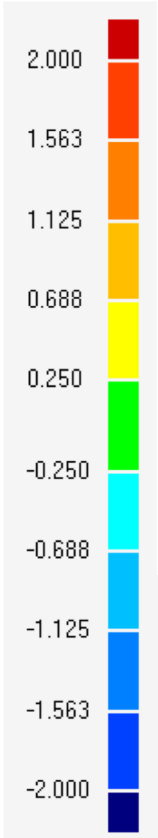




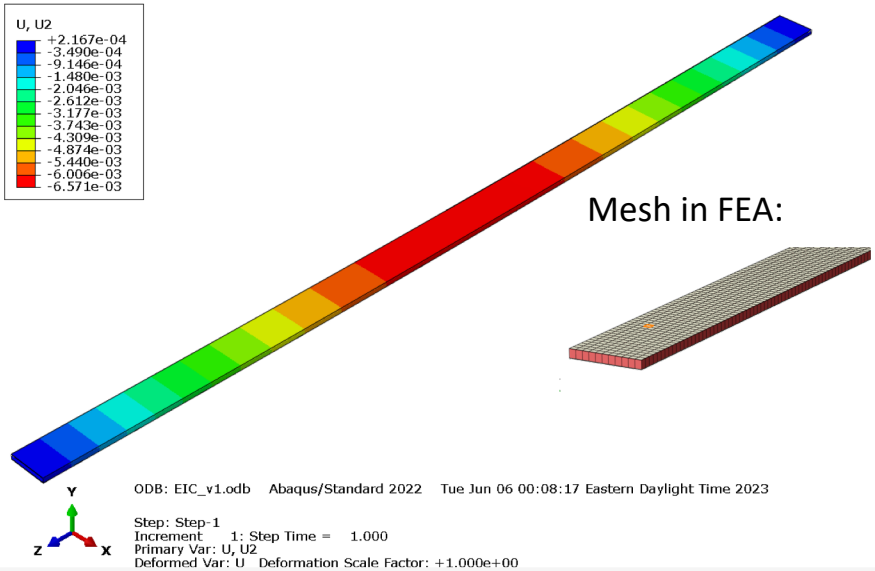
R&D progress FY23

FEA results…preliminary

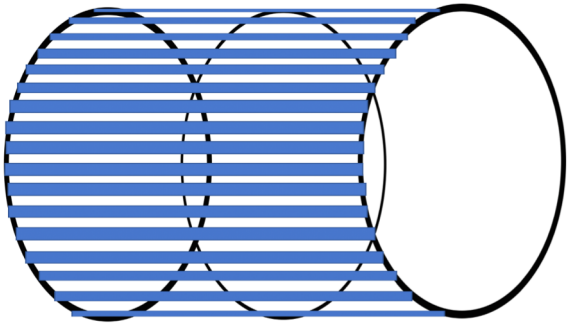
- FARO is at 6mm deflection, FEA at 2mm (longer worse, ~5cm)
  - Caveat: no pipe in it…not enough time.
- Calls for support structure which is to come – see here:

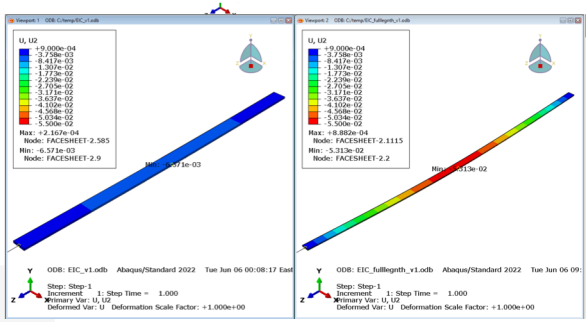


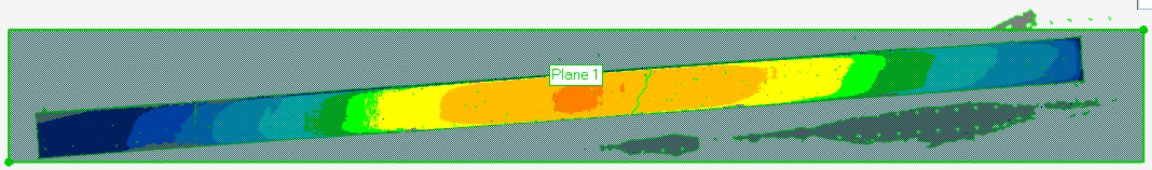
Unit: mm



Mesh in FEA:

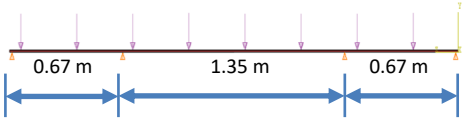






Top down view of the loaded stave.

- 5cm deflection full length stave
- w. supports down to 700mu



PED Request synergies

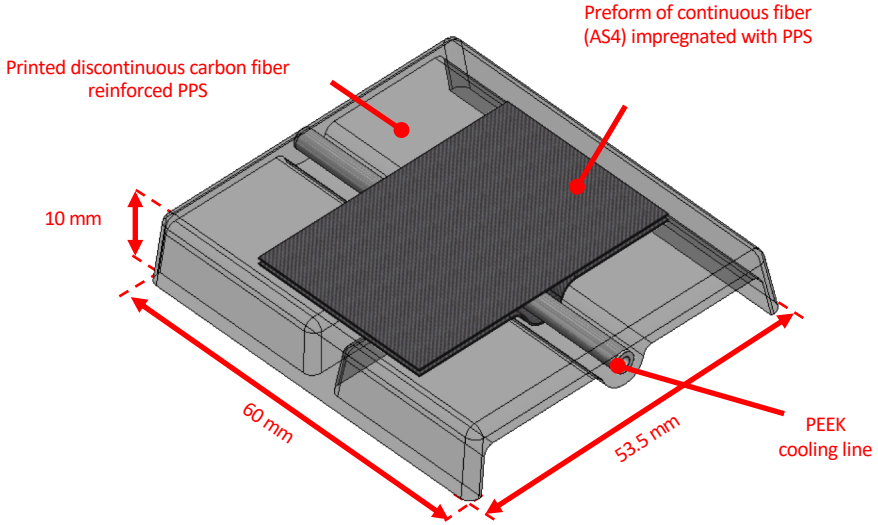
- PED request and TOF-LGAD mechanics team evolved since FY23 R&D
- Goals:
  - Includes a support structure for the barrel TOF-LGAD, see earlier slides
  - Look at a 1st concept for cooling performance (but relies on holistic detector wide concept)
  - Lots of synergies between R&D and PED…
  - MPGDs support relevant for barrel TOF-LGAD support, meet 8th June 2pm – thanks for setting this up. Needs to be discussed…

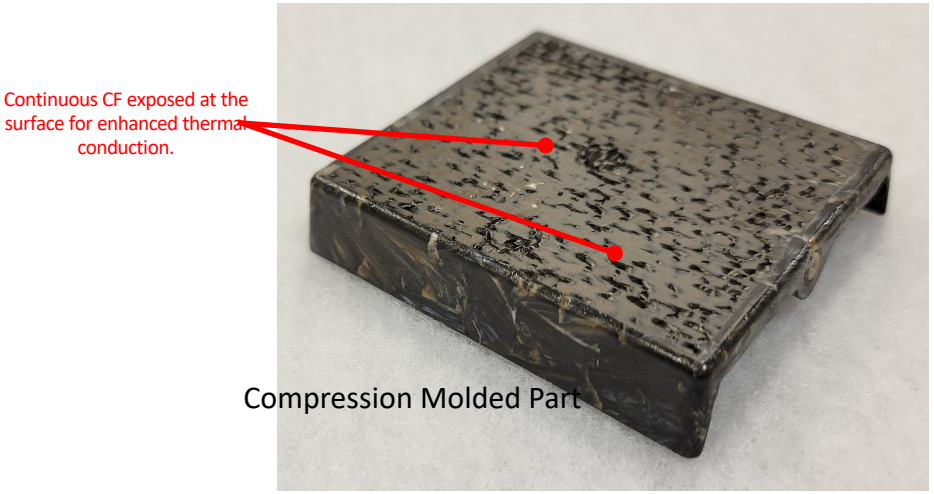
Resource	FTE (%)	Budget (k$)
Manufacturing Design of pre-production		
Mechanical Engineer + Technician, Purdue	50	150
UG students, Purdue	20	0 (in-kind)
Postdoc, NCKU	20	0 (in-kind)
G/UG students, NCKU	20	0 (in-kind)
Materials and Supplies (stave supports, endcap discs, etc.)	-	35
Integration aspects / Services		
Mechanical Engineer, Purdue	20	40
Total	-	225

Table 1: Purdue/NCKU budget request on engineering design for barrel TOF in FY23. All entries in thousands of dollars.

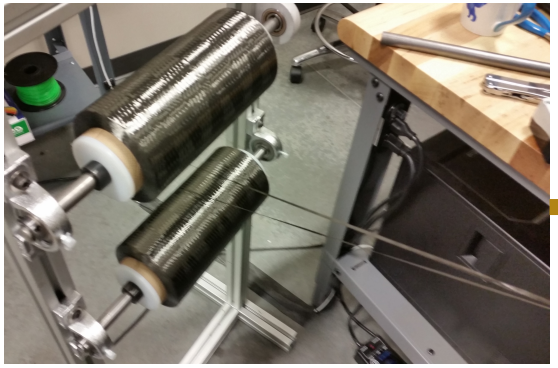
BlueSky R&D at Purdue

- Could be applicable to EIC – recent progress…

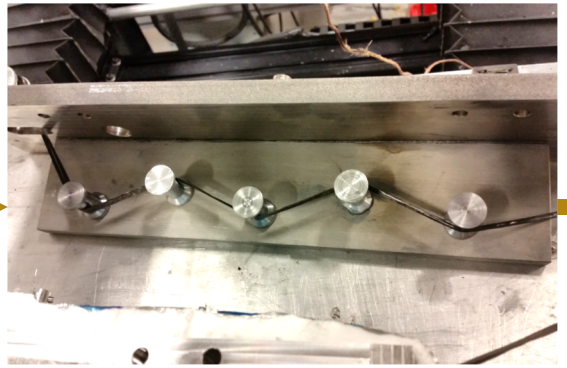




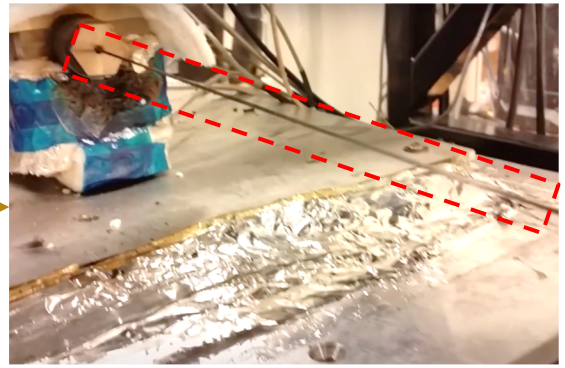
Compression Molded Part



Spools of Carbon Fiber



Interior of Impregnation Chamber

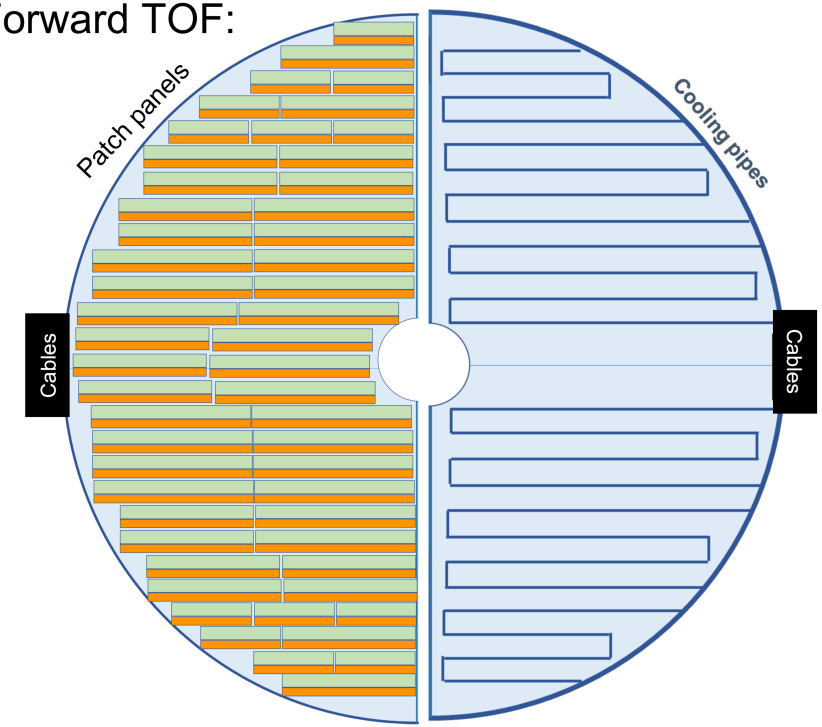


Carbon Fiber Impregnated with PPS

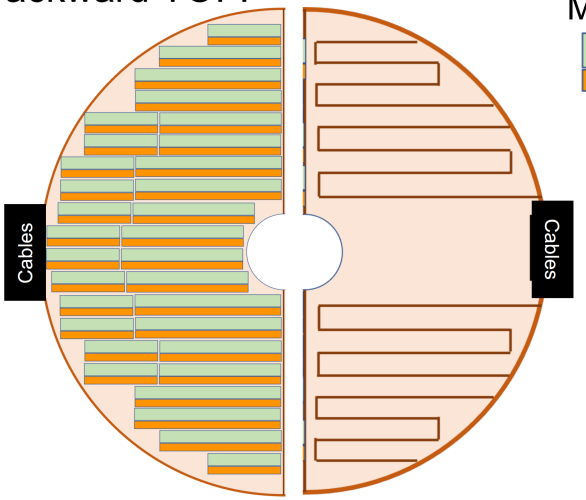
Endcap TOF

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

Forward TOF:



Backward TOF:



- "Clam shells" or DEEs
  - Convenient for installation/maintaenance
  - 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)

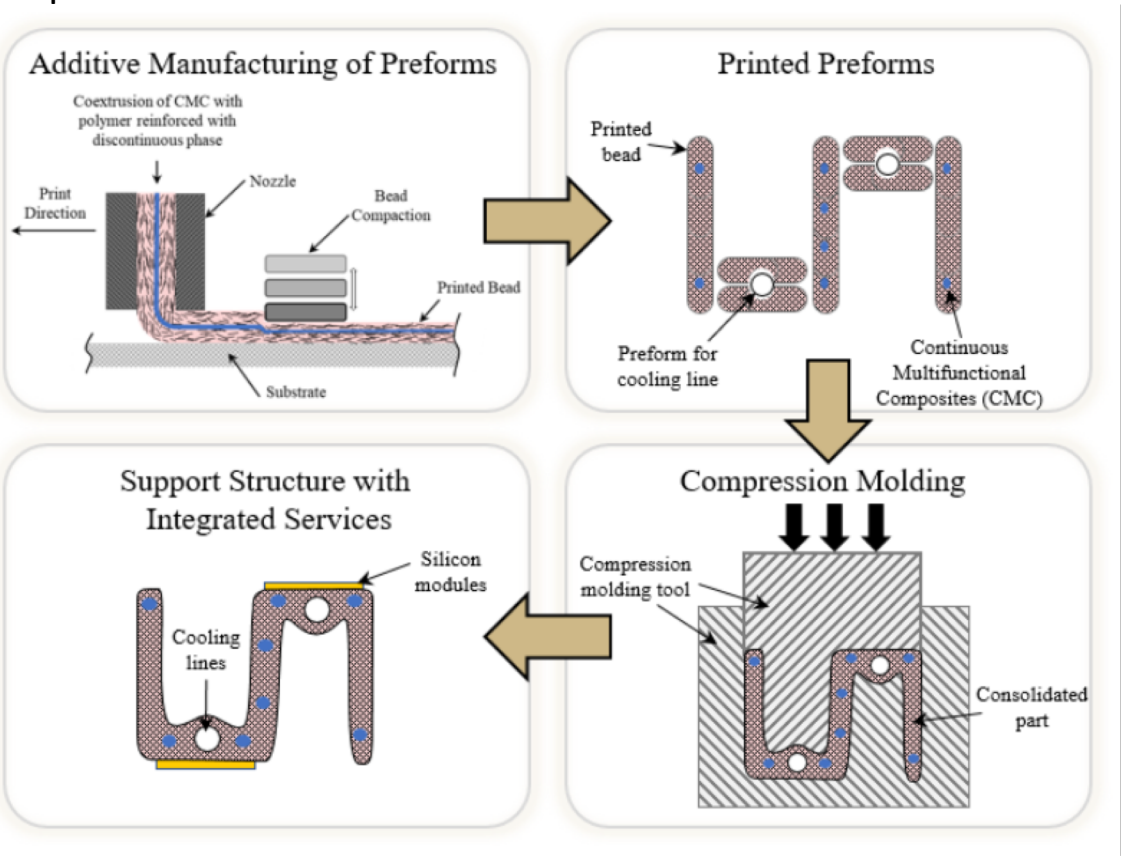
R&D FY24: Budget

- **Theme: RD request to push for endcap solution, whole system support + staves folded into PED request**
- **Budget**
  - 2022 – 2023: 30K (include material and cost of processing)
    - 2023 – 2024: 30K (include material and cost of processing)
    - 2024 – 2025: 30K (include material and cost of processing)
  - Purdue Deliverable: 1-3 “wedge” prototype until Sept 2024
    - Budget: 10% FTE engineer ~15k$ + low S&E $$
    - Materials: cost-effective by using non-final materials and usage of FEA
    - Lots of relevant experience to draw from and apply to benefit of EIC
- Goals:
  - Develop and push a light-weight solution for endcap compatible with needs of subsequent detectors
- Deliverables: 1-3 “wedge” structures, incl. solution for connections

Backups

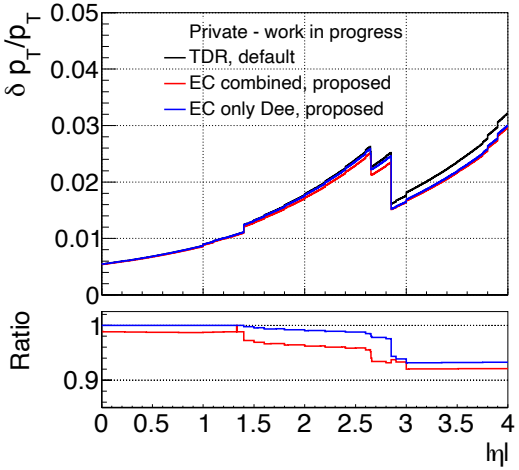
R&D for irreducible sturctres…

- Identified by DOE BRN effort
  - Scaling of low-mass detector system towards irreducible support structures with integrated services. Includes: integrated services, power management, cooling, data flow, and multiplexing.
  - Purdue proposed to DOE:

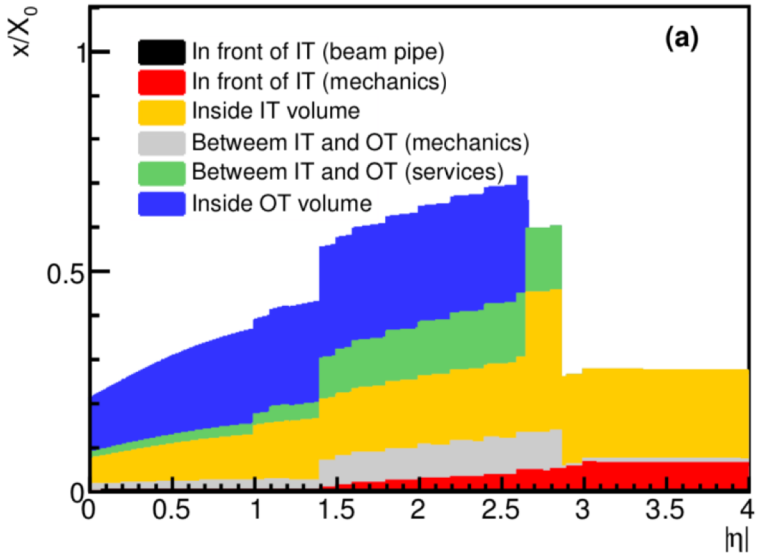


BlueSky R&D at Purdue

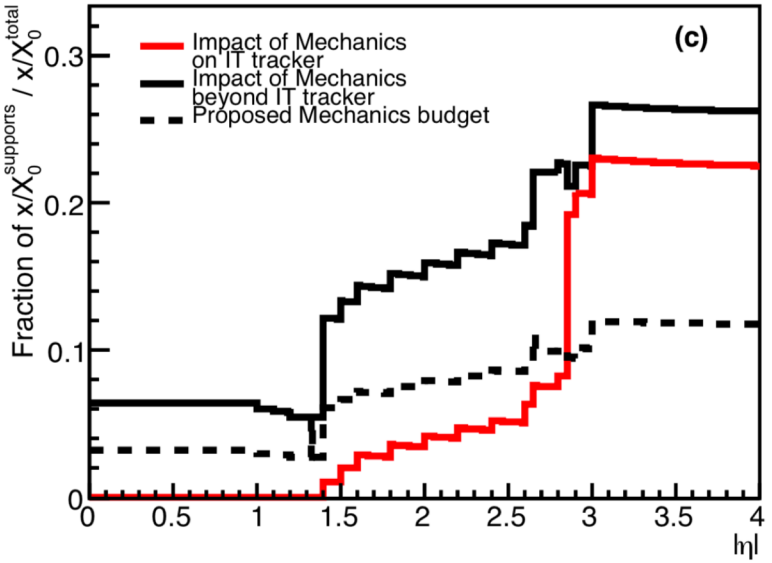
- Radiation length plot more specific to EIC (hope to get that one done till 6th)
- These techniques more easy benefit endcap detectors whereas gains are limited in barrel region
- This seems like a good fit to the needs of TOF



Example from CMS….



Aggressive design…



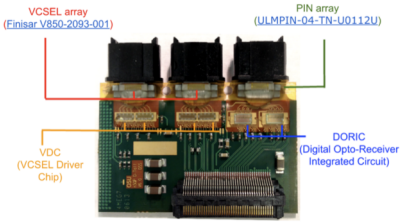
About Andreas Jung

Purdue University

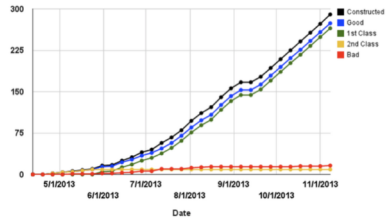
- Andreas Jung, previous experience
  - CMS IT mechanics convener (2017-2020)
    - Leading the Barrel, Forward and Extended Pixel projects
  - Mechanics leadership in CMS
    - Technical lead for the CMS BTST project, Contact for procuring all high thermal conductive CF needs in CMS and leading the related R&D at Purdue
    - Coordinating tracker mechanics projects (ITST, SC, OT, BTST) at Purdue.
  - Associated member of the Composite Manufacturing & Simulation Center at Purdue University
  - DOE Blue Sky R&D grant for irreducible tracker support structures for detectors at future colliders (FCC, ILC, muon, etc.)
  - Operation & Optimization of track trigger at H1 (HERA), and operation of silicon tracker at D0 (Tevatron)

About Yi Yang

- **2012 – 2014 (@OSU)**: Project manager for the Opto-board for inner detector

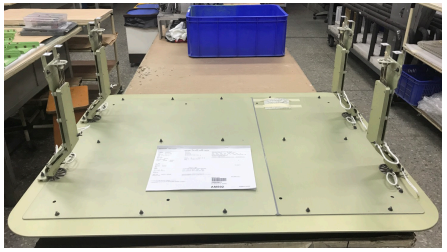


Photograph of an opto-board

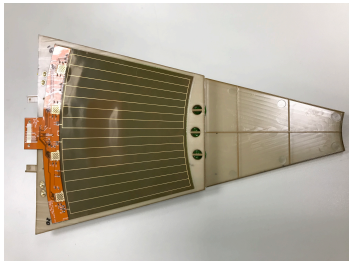


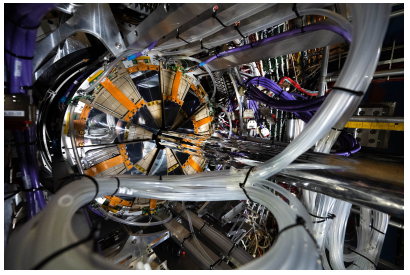
Opto-board production status

- **2015 – 2018 (@NCKU):** Project leader for the AMS-02 UTTPS radiator



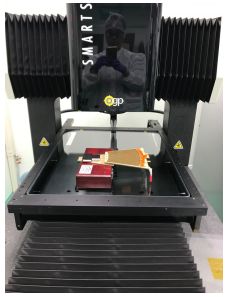
- **2018 – 2021 (@NCKU):** Deputy manager for the STAR FST, project leader for the mechanical structure for FST

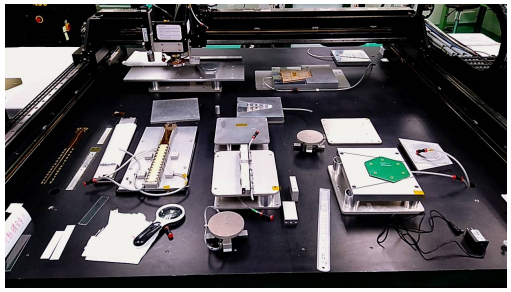


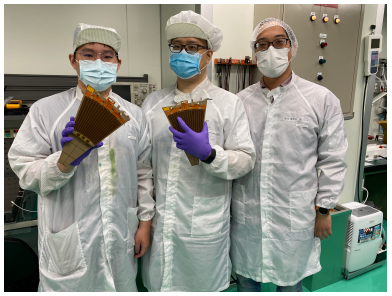


Resource from Taiwan

- **Taiwan Instrumentation and Detector Consortium (TIDC):**
  - https://tidc.phys.ntu.edu.tw/WordPress/
  - Sophisticated machines for detector assembly







- **NCKU:**
  - Strong mechanical engineering department
  - Good relationship with Aerospace Industrial Development Corporation (expert on composite material)

- **AS IoP:**
  - High precision machine shop

- **Three mechanical engineers from AS, NCKU and TIDC**

STAR Forward Silicon Tracker

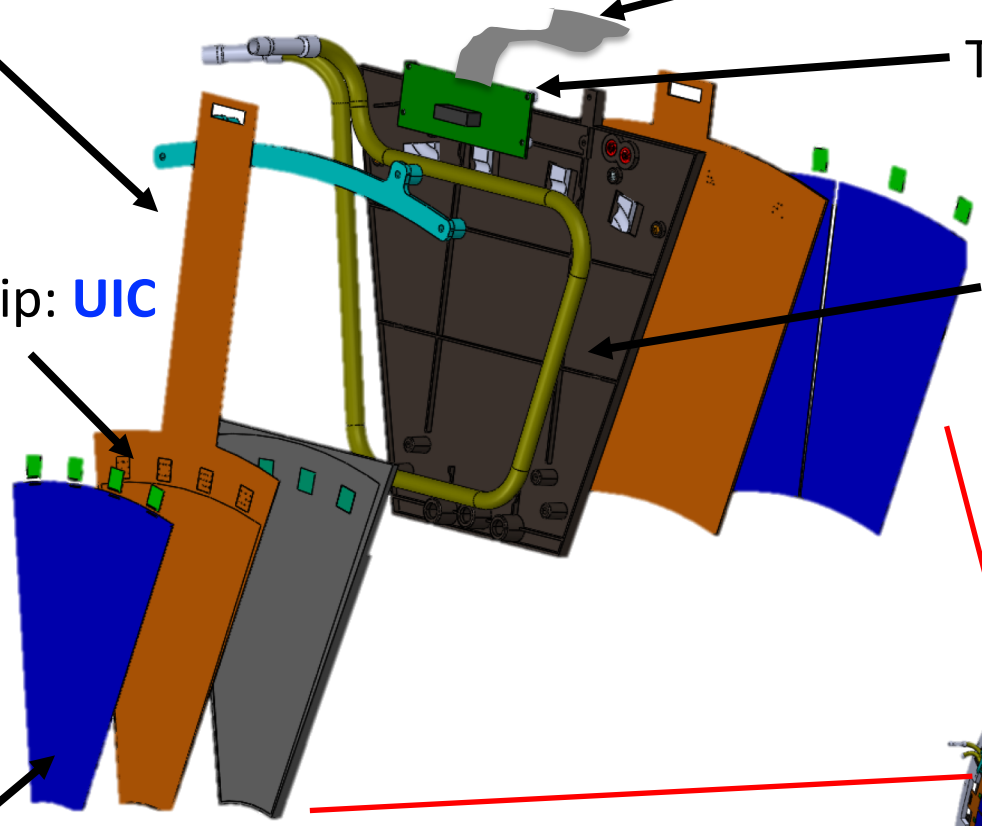
Flexible hybrid PCB: **SDU/IU**

Inner Signal Cable: **BNL/IU**

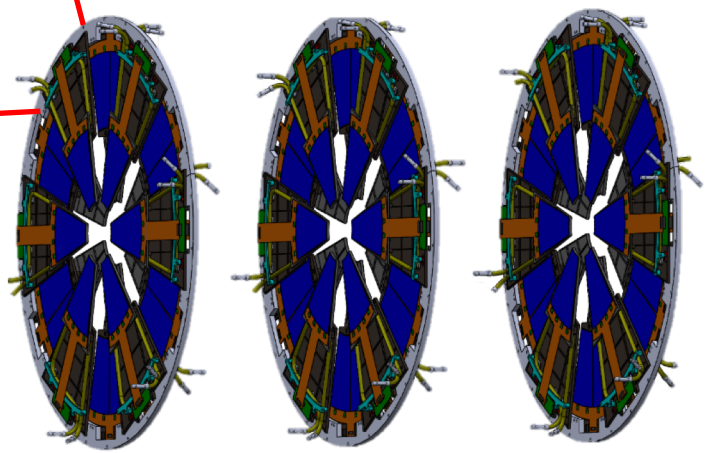
T-Board: **SDU/IU**

APV25 Chip: **UIC**

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



Supporting Structure &
Integration: **BNL**



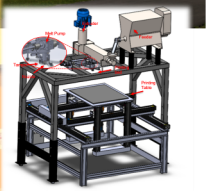
Silicon sensor: **UIC/BNL**

Cooling: **BNL/NCKU**

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

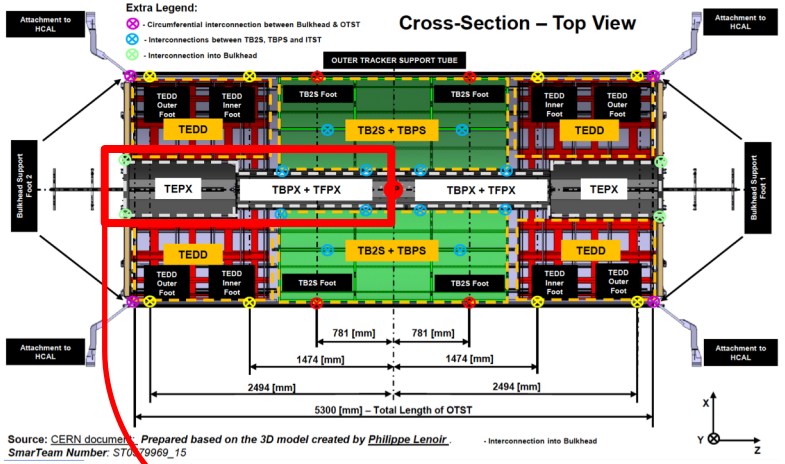
Resources from Purdue

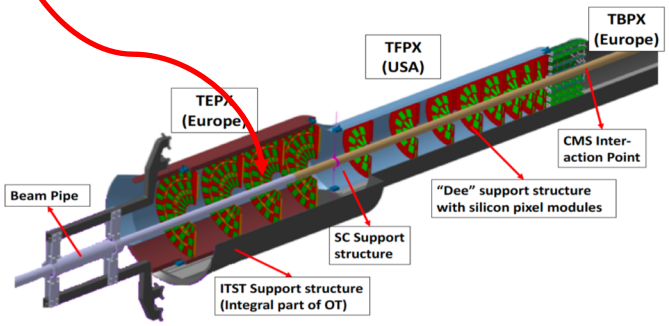
- Composite Manufacturing & Simulation Center (CMSC) at Purdue, completed in summer 2016
  - Purdue Center of Excellence across disciplines: Aeronautics, Chemical Eng, Materials Eng, Aviation Tech, Computer graphics, **and Physics**
  - A. Jung – Associated member of CMSC
- Professional composite experience:
  - 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

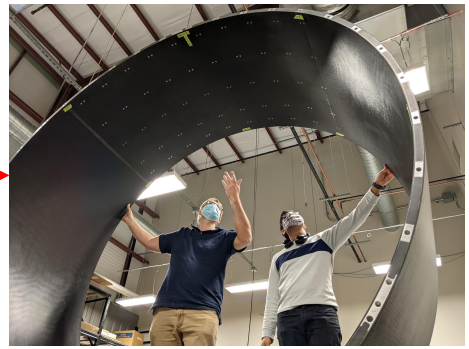


Resources from Purdue

- 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

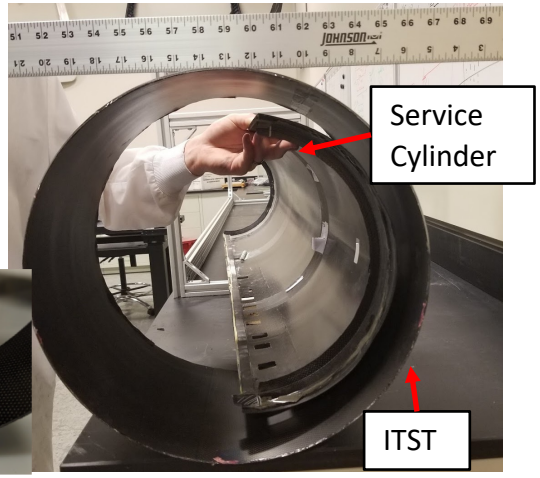


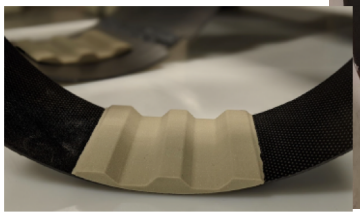


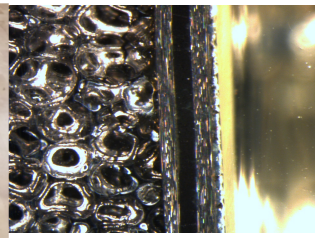


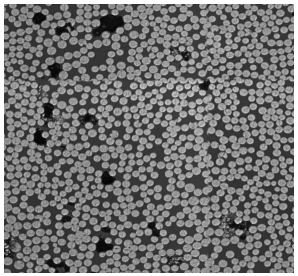
Resources from Purdue

- 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

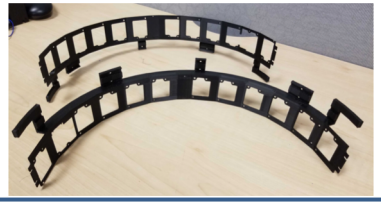


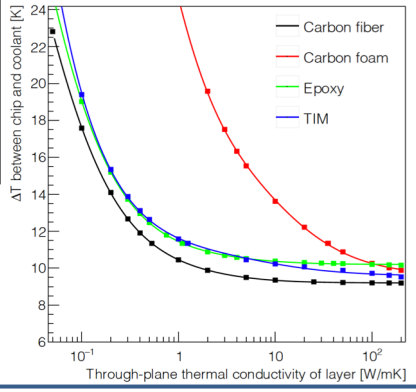


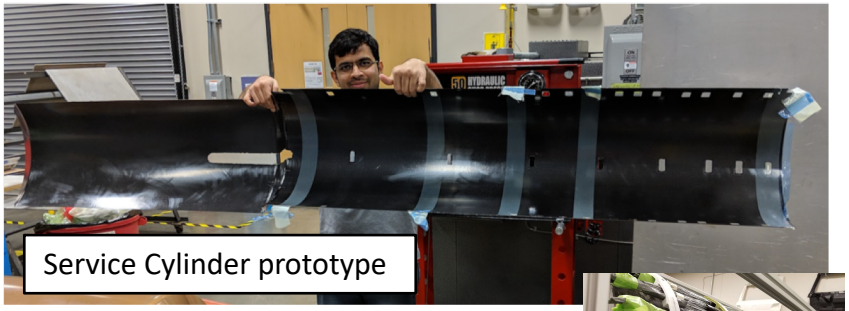


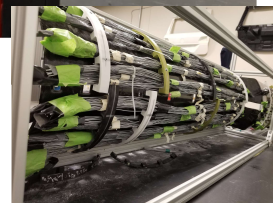


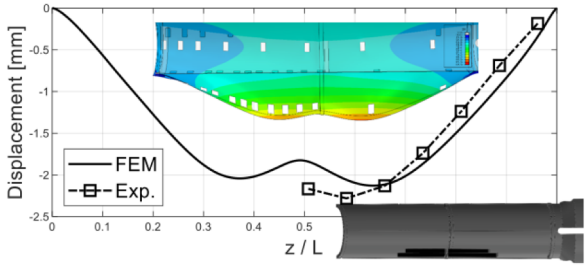
- Forward pixel dee prototype
- Co-cured samples
- Microscopies
- 3D printed mechanical supports
- Critical interfaces via FEA









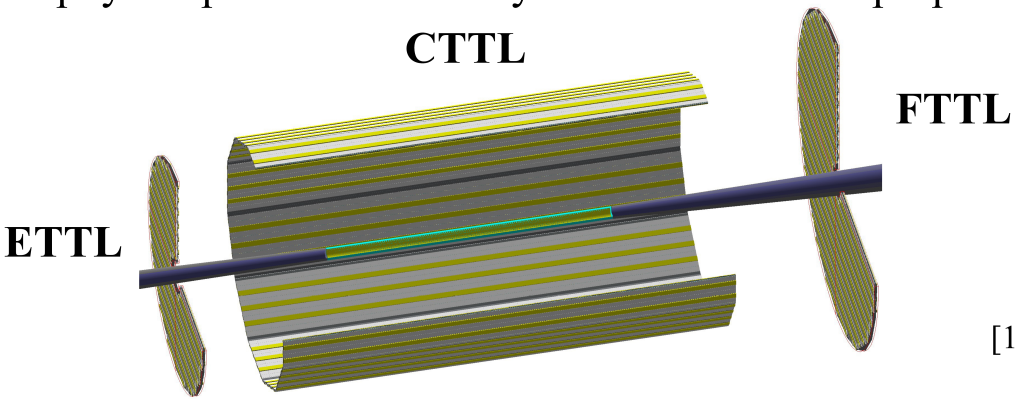


Backups

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

AC-LGAD Layer for TOF PID + Tracking

- The goal is to conceive a reference layout and technical design (v0) as inputs to GD/I group to advance the detector integration (service routing etc.)
- However, there are still on-going studies to investigate the optimal channel granularity based on physics performance so by no means this is a proposal for final design.



For v0 design, we propose:

- **Barrel: 0.5x10 mm² strips**
- **Endcap: 0.5x0.5 mm² pixels (same as RPs) [1]**

[1] Wei Li, TOF-PID WG Meeting Aug 29, 2022

	acceptance	Z (m)	Radius (m)	Area (m²)	Channel size (mm²)	# of Channels
ETTL	$-3.7<\eta<-1.74$	-1.61 to -1.71	0.12 to 0.63	1.20	0.5*0.5	4.8M
CTTL	$\|\eta\|<1.4$	-1.2 to 1.5	0.625 to 0.655	10.9	0.5*10	2.4M
FTTL	$1.5<\eta<3.5$	1.555 to 1.705	0.12 to 0.85	2.22	0.5*0.5	8.8M