DRD8 – WG2

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On behalf of the DRD8 preparation group

Forum on Tracking Detector Mechanics 2024

Purdue University, USA

Scope of WG 8.2

From Letter of Intent submitted in Feb 2024.

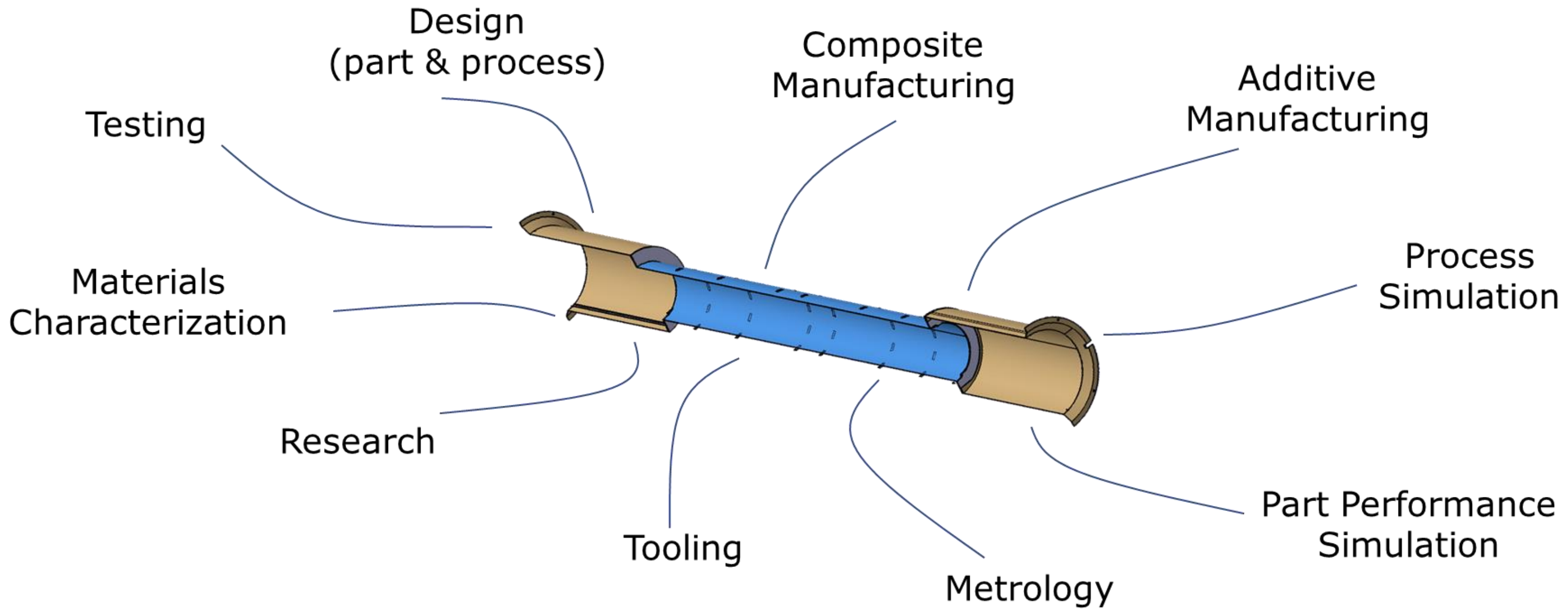
WG 8.2: Low Mass Mechanics and thermal management of Silicon sensors:

- A. Novel materials for structural and thermal management applications, including qualification for operation in harsh environments;
- B. Advanced manufacturing techniques, including additive manufacturing;
- C. Support structures with integrated cooling circuits, including silicon or ceramic substrates with embedded microchannels, composite substrates with embedded pipe-less networks and cold plates with thin-walled pipes;
- D. Modular, scalable designs for detectors with large surface areas;
- E. Vacuum-tight composite structures.

A. Novel Materials for Structural & Thermal Applications

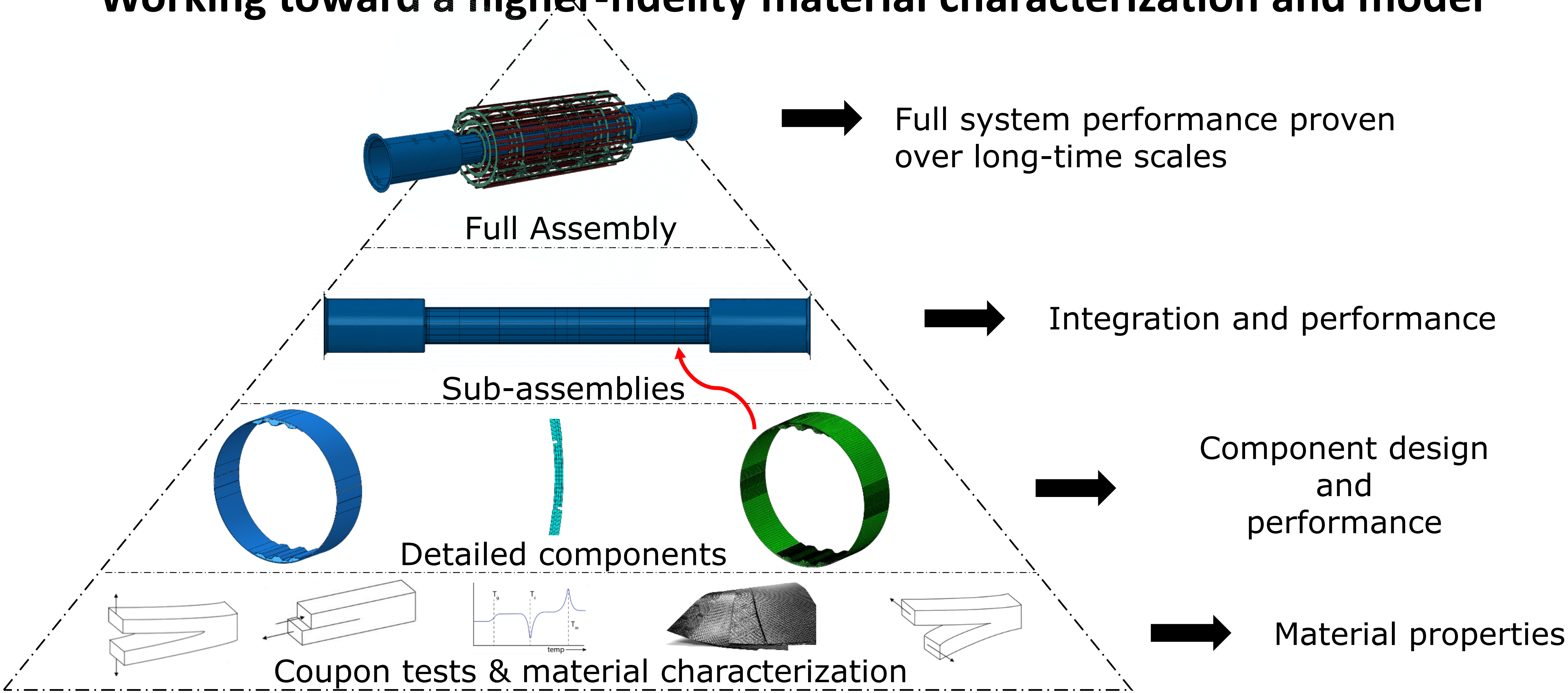
- Carbon-Carbon composites; co-molded multifunctional support structures
- Functionally graded carbon nanotubes for thermal applications and thermal pathways
- Doped ceramics for thermal pathways for dispersed cooling

- To go from conceptualization of novel material to full scale there are a multitude of steps needed to be implemented.



J. Hicks – FTDM 2021

Working toward a higher-fidelity material characterization and model



A. Material Characterization and Documentation

Radiation Resistance

Effect of radiation on –

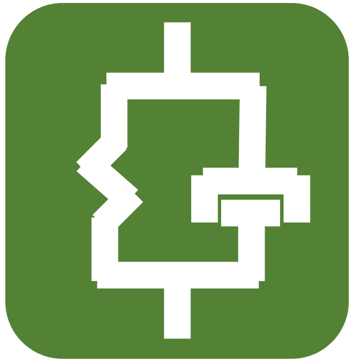
- Thermal Conductivity
- Elastic modulus
- Poisson's ratio
- Coefficient of thermal expansion (CTE)

Heat Transfer

- Thermal Conductivity
- Specific Heat
- Emissivity
- Performance at sub-zero temperatures

Thermo-mechanics

- Crystallization / Melting
- Coefficients of Thermal Expansion
- Bonding



Viscoelasticity

- Prony Series model

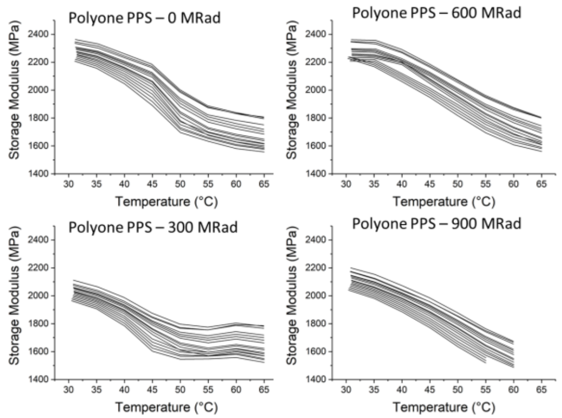
AND MANY MORE ….

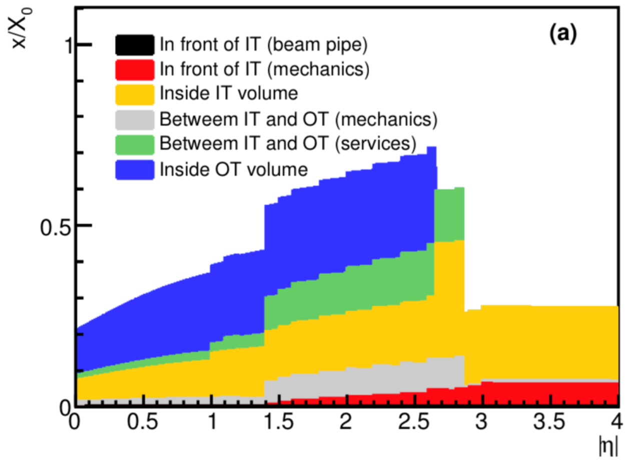
Detailed talk: FTDM 2022 - https://indico.cern.ch/event/853861/contributions/4841274/
CPAD workshop 2022 - https://indico.bnl.gov/event/17072/contributions/70707/

A. Novel Materials for Structural & Thermal Applications

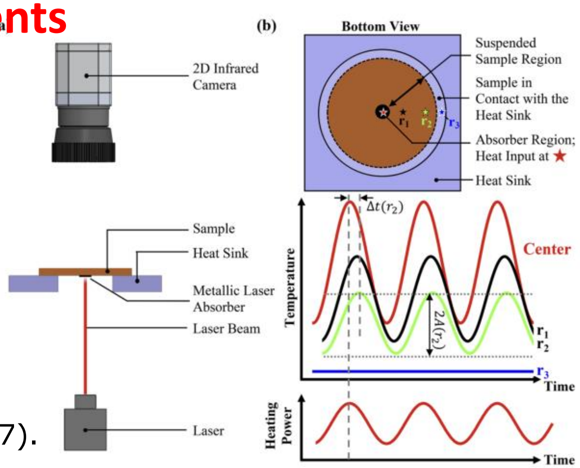
- High radiation environment – material qualification and radiation degradation testing needed

Pixel Layer dose (3.7cm)	HL-LHC $3ab^{-1}$	FCC $3ab^{-1}$	FCC $30ab^{-1}$	FCC (2.5cm) $30ab^{-1}$
$\times 10^{16}\ n_{eq}\ cm^{-2}$	1.5	3	30	70
Dose (MGy)	5	10	100	220



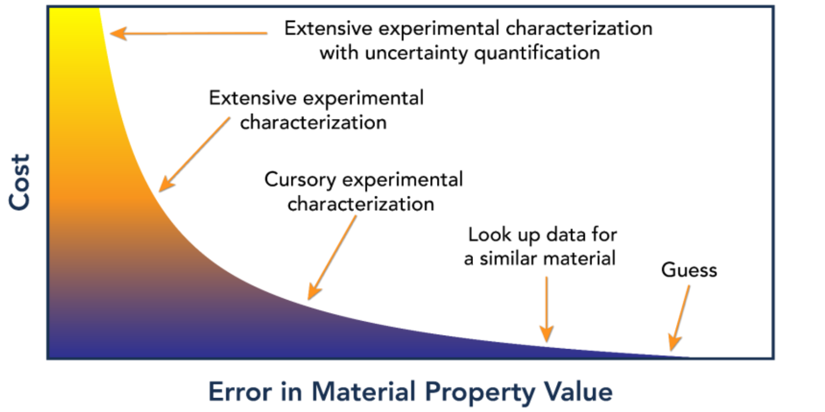


- HL-CMS upgrades has quantified cyanate ester CFRP for use up to 1.5GRad
- Joint effort between CERN + DESY + Purdue for revamped MaxRAD database
  - **Need inputs from other institutes and collaboration with current HEP experiments for central repository**



Gaitonde, et al. *Review of Scientific Instruments*, *94*(7). https://doi.org/10.1063/5.0149659

Characterization Cost vs. Accuracy

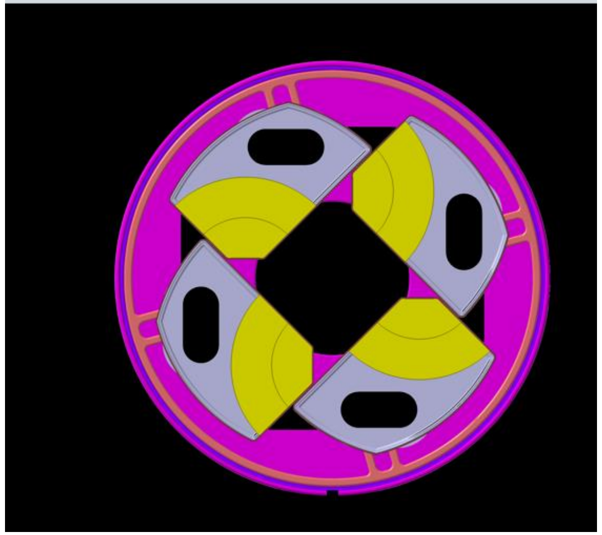


Irreducible mass structures – ALICE ITS3

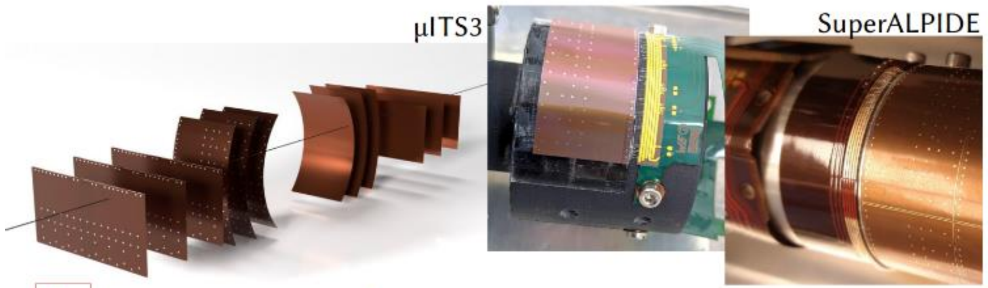
https://indico.cern.ch/event/1395929/timetable/?view=standard

First layer at few mm from IP

Vertex in primary vacuum- IRIS



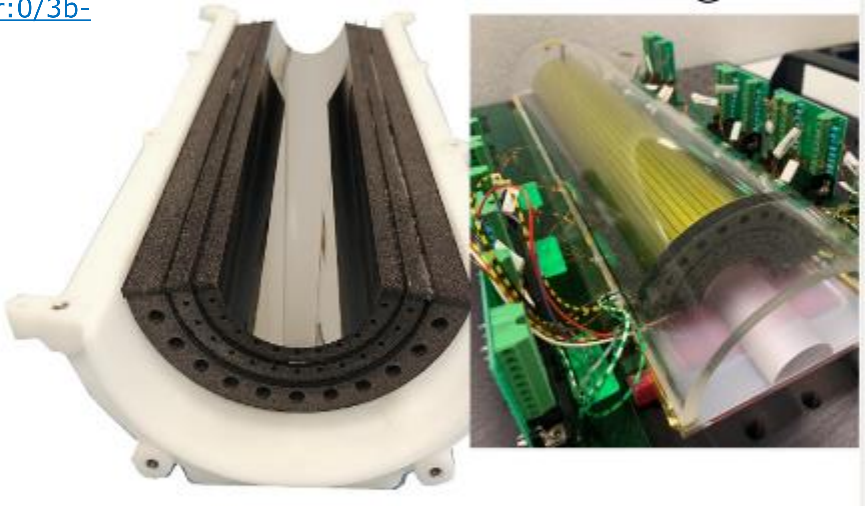
- C. Gargiulo and team
- Applications to ALICE ITS3 for Run 4
- ePIC SVT inner barrel for EIC at BNL



A.
- Beam tests of *bent* ALPIDE chips (*arXiv:2105.13000*)
- Beam tests with μITS3
- Construction of SuperALPIDE, ongoing

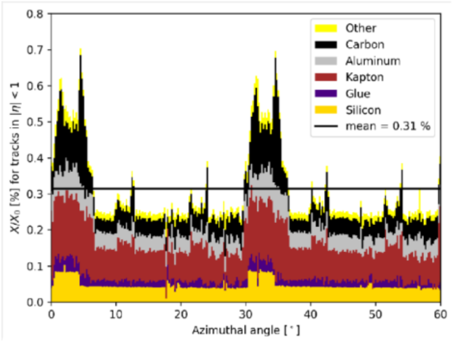
(i.e. ITS2 chip 50-μm thick, 180-nm technology)

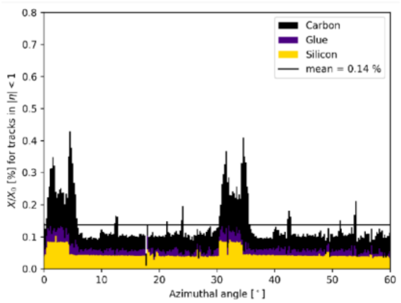
B. Mechanical integration, cooling test

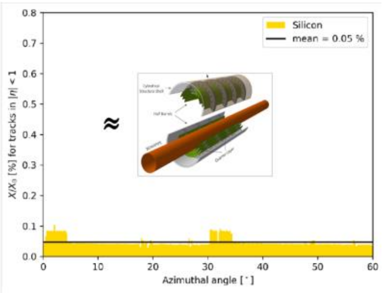


Antonin MAIRE – IPHC Strasbourg

https://atrium.in2p3.fr/nuxeo/nxfile/default/2e09b700-59a9-4a30-87bf-82d27005f37a/blobholder:0/3b-Pres-ALICE-ITS3-Maire.pdf

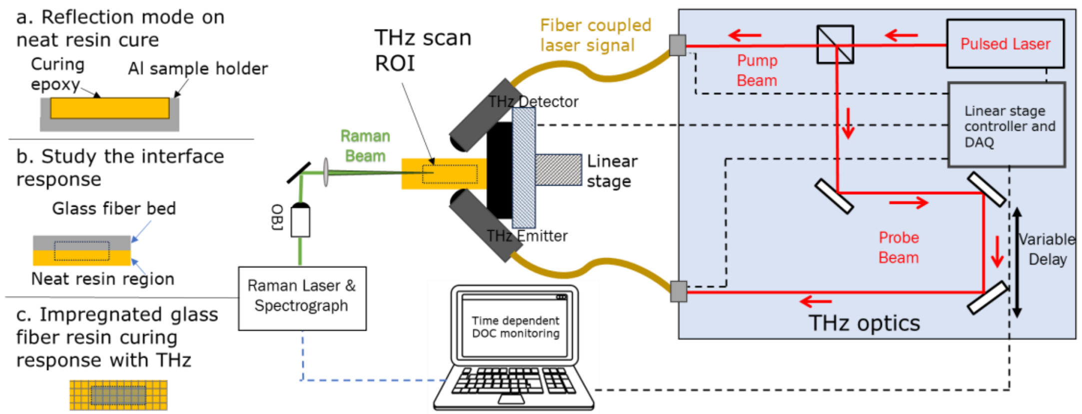


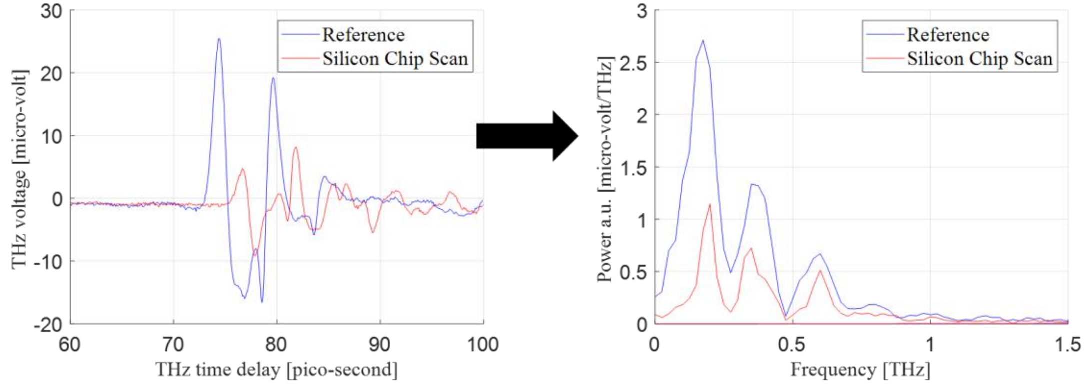




A. Material/manufacturing QC and NDE techniques

- With push to go to irreducible mass detectors for HEP – stringent quality control and part inspection needed to give back the “additional factor of safety” currently designed into support structures
- In-situ non-contact non-destructive evaluation of parts.
  - Terahertz Time Domain Spectroscopy for sub-surface voids, defects and stress/strain mapping in polymer composites.
  - XRD for metal inclusions – currently used
  - Part manufacturing QC with thermography (K9-Lockheed carbon foam)
  - Ultrasonic and acoustic testing for structural components.





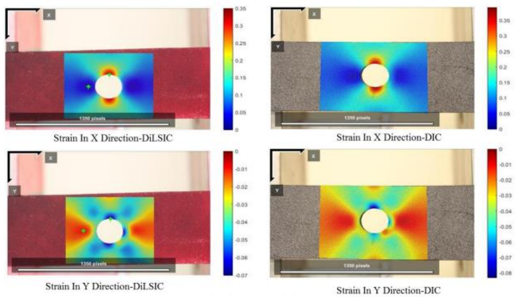
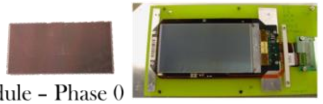


Figure 10: Strain concentration contour- DIC (left) and DiLSIC (right) results comparison

https://arxiv.org/pdf/2001.03840

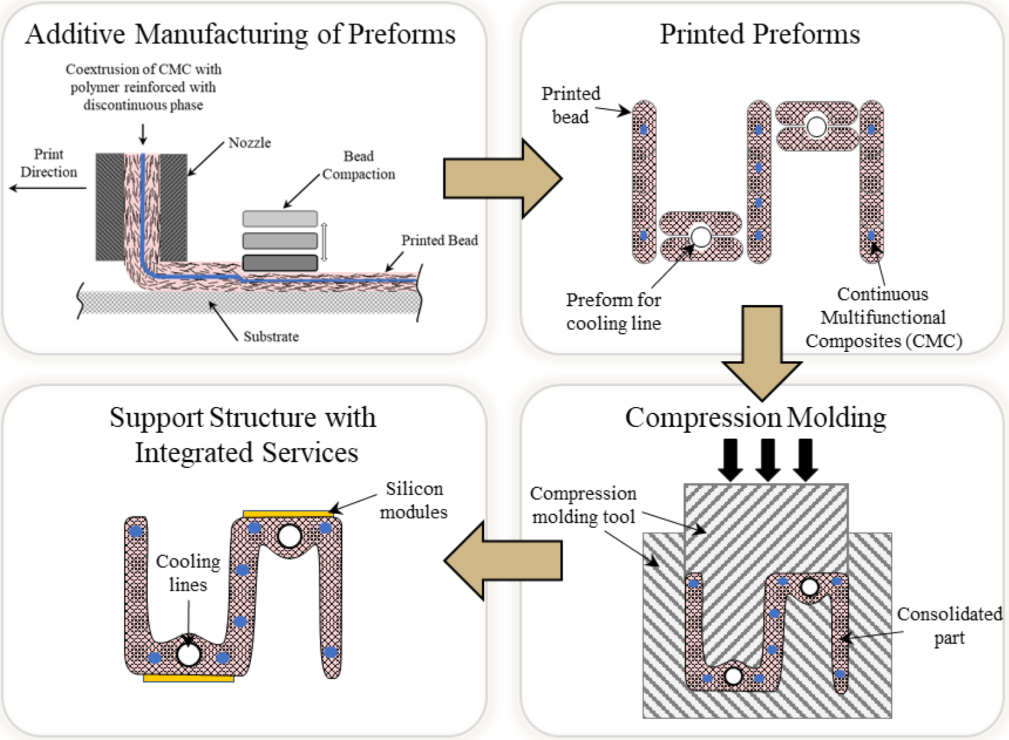


CMS IT module – Phase 0

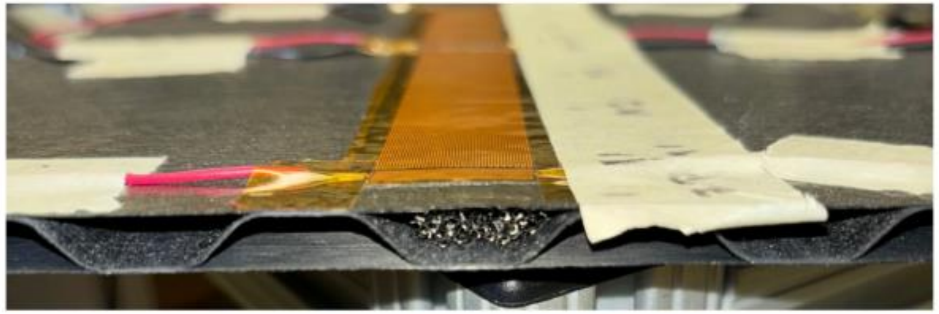
Development of THz-TDS at Purdue Univ. for subsurface NDE of polymers

B. Advanced Manufacturing Techniques

- Co-molding and injection overmolding with embedded sensors and electronics.
- Additive manufacturing for both metal and polymers; most of the current state of the art prints rely on getting CF-PEEK parts printed for integration.



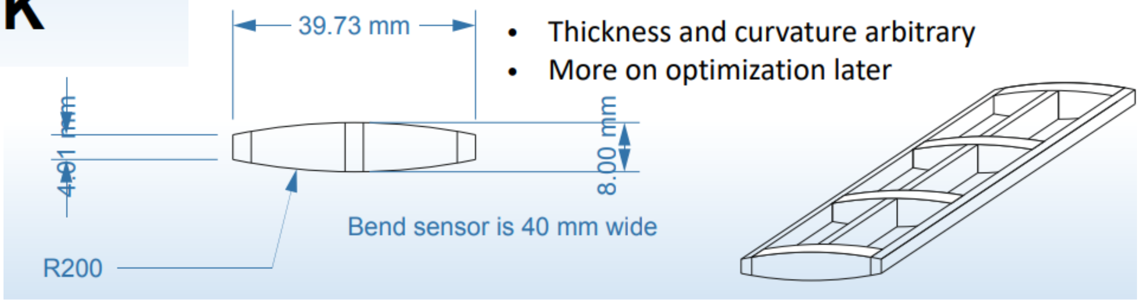
Slides from Nikki Apadula & Eric Andersson (LBNL)



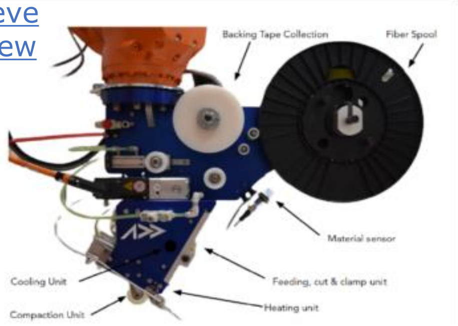
Georg Viehhauser (Oxford)

ePIC UK

Core of stave is made of array of foam blocks



https://indico.bnl.gov/event/20473/timetable/?view=standard



AFP-XS tool elements

FANUC R2000ic/210F

FANUC R30iB controller

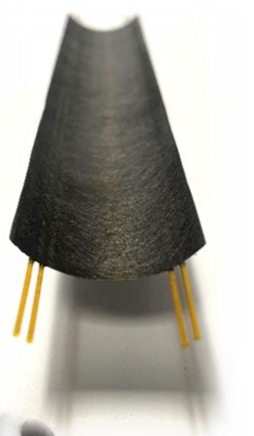
Automated Fiber and Tape Placement

C. Support Structure with integrated cooling

HIGH OVERLAP with WG3 – See talk by Bart

- Structure and material interaction with the cooling needs fulfilled by WG3 is important to integrate and conceptualize manufacturing of such components at beyond prototypes to full systems which can be tested for robustness.

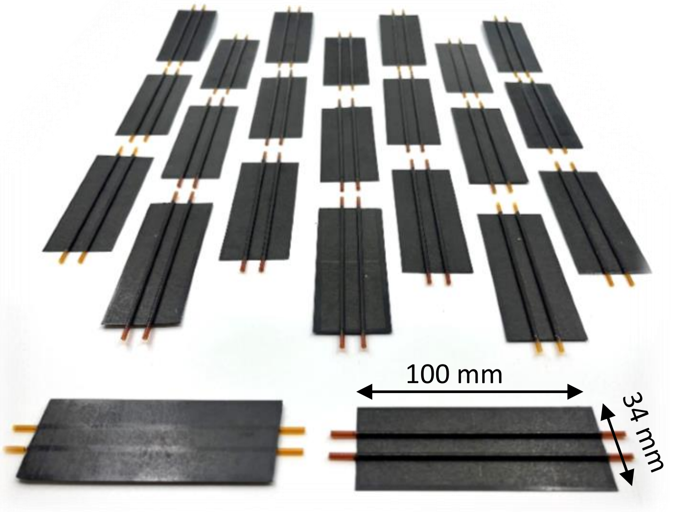
[Link to original talk by C. Gargiulo]



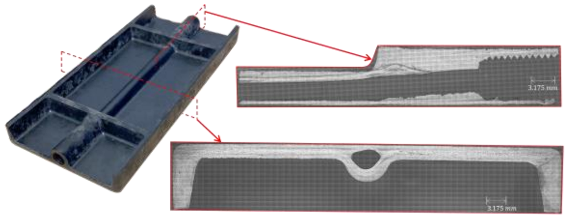
(D. Hellenschmidt)

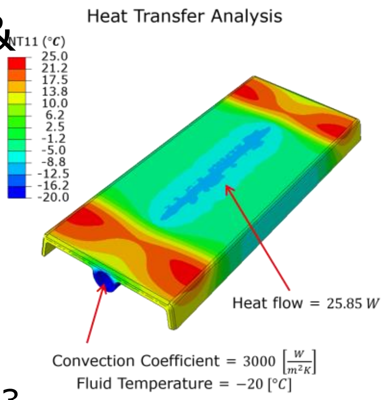
EP-DT Composite Lab
(M. Dias)

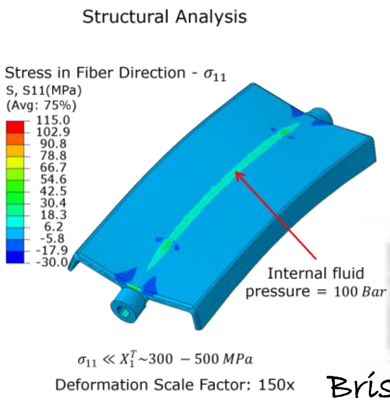
Bristol Composites Institute



Slides from E. Barocio & Pedro Soto (Purdue)







Detailed talk: CPAD workshop 2023 - https://indico.slac.stanford.edu/event/8288/contributions/7895/

D. Modular, scalable designs for large detectors

- Biggest push –

Standardized Interfaces:

Standardization of mechanical and electronic interfaces between modules is crucial. It ensures compatibility across different components and simplifies the integration process, and common cooling and service systems.

Symbiotic relationship between detector groups can focus on perfecting a certain part of the mechanics and structures while benefitting from standardized interfaces to reduce part count and costs.

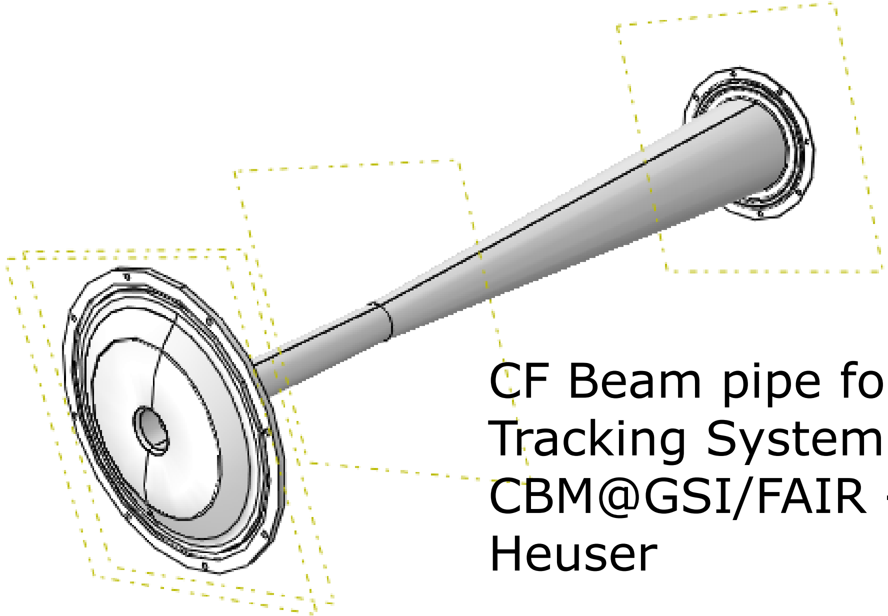
- This has been implemented successfully in electronics and sensor modules --- RD53A (CERN); HRPPD (ePIC)

- Same concept maybe implemented for mechanics and supports.

E. Vacuum tight composite structures

- Viable replacement for Beryllium beam pipe
- Cryostat and Beam Pipe demonstrators by CERN EP R&D WG4
- CF beam pipe for STS – CBM experiment @GSI/FAIR
- Possible application for EIC project @ Brookhaven National Labs, USA

C. Gargiulo, S. Molina



CF Beam pipe for Silicon Tracking System – CBM@GSI/FAIR - Johann Heuser

Link to original talk

https://indico.cern.ch/event/1395929/contributions/5867741/

Summary

1. Community efforts for material characterization
    i. Availability of radiation/beam time across labs around the world
    ii. Unified reporting and database – MaxRAD v2
2. Non-destructive QC and evaluation technique development as a design requirement instead of an after thought in all structural components
3. For new manufacturing methods/materials – long validation experiment plans
4. Integrated multifunctional irreducible mass structures – collaboration with WG3
    i. Set up clear boundaries between WG2 and WG3

<u>Timelines and other details in DRD8 – WG3 slides. Link -</u>

https://indico.cern.ch/event/1336746/contributions/5923177/

Current institutes that have presented interest in DRD8 – WG2 :

Country/Institute
France
CPPM Marseille
LPNHE Paris
Germany
DESY
GSI Darmstadt
Italy
INFN Pisa
INFN Perugia
Spain
CNM Barcelona
IFIC Valencia
Switzerland
CERN
Univ. of Geneva
United Kingdom
UKRI-STFC RAL
University of Bristol
Bristol Comp. Inst.
Nat. Comp. Centre
Univ. of Manchester
Univ. of Oxford
Univ. of Liverpool
USA
Purdue University
Fermilab
LBNL and SLAC