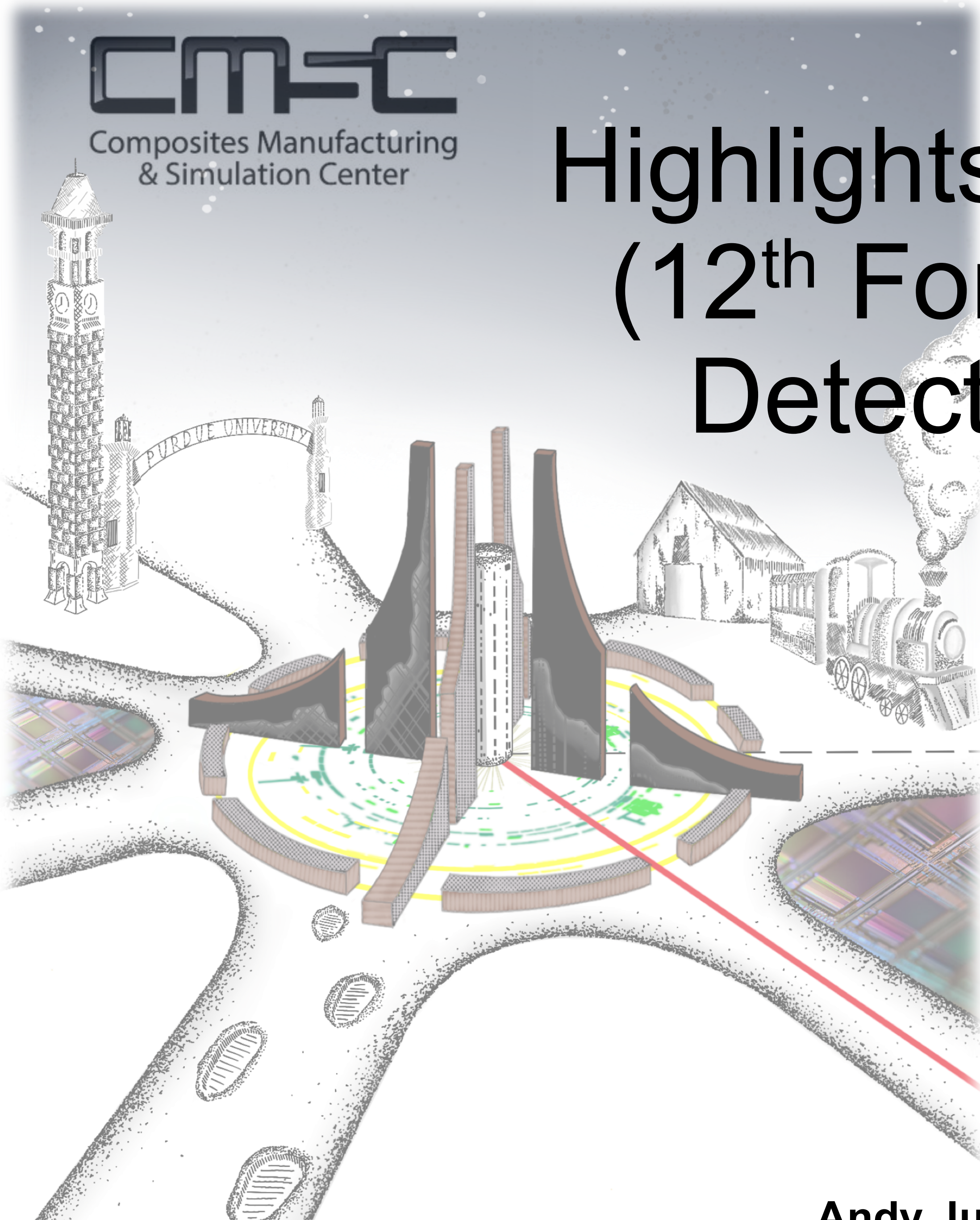


Highlights of the FTDM '24 (12th Forum on Tracking Detector Mechanics)

- Spirit of FTDM
- Satellite events
- Forum highlights…
  - No justice, check agenda

https://indico.cern.ch/event/1336746/timetable/#20240529.detailed

My own biased view

Andy Jung
EPIC TIC meeting

PURDUE
UNIVERSITY

June ~~10th~~ 17th, 2024

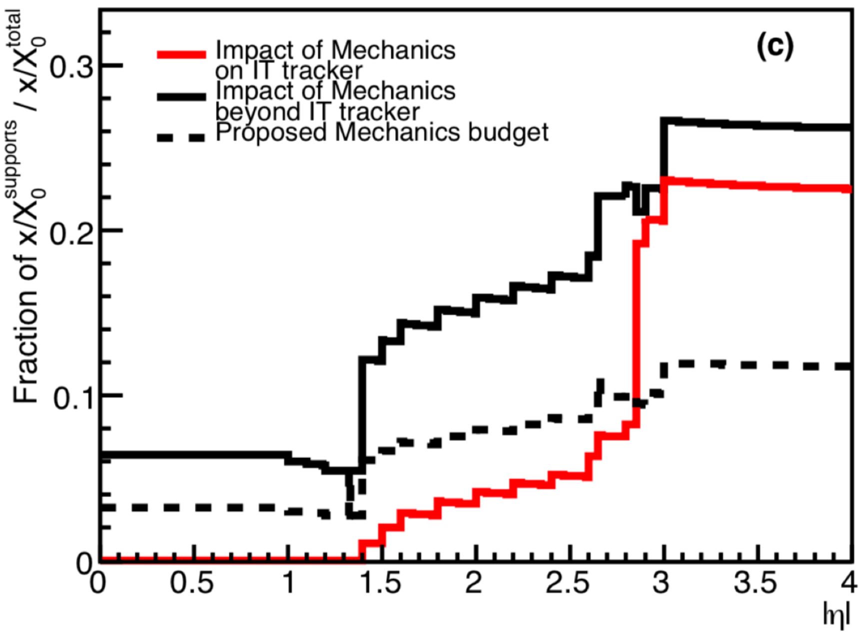
Material budgets & mechanics

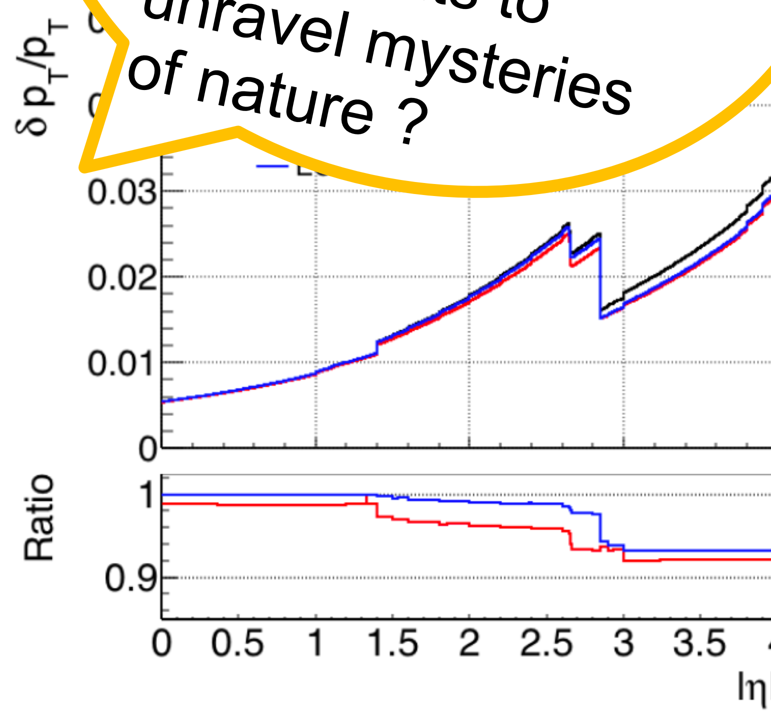
Substantial R&D on all fronts to make a FCC-hh dete

- Support & Cooling constrains Tracker performan
- Mechanics is significant fraction of the material
- **Lowest mass possible requires new approaches**

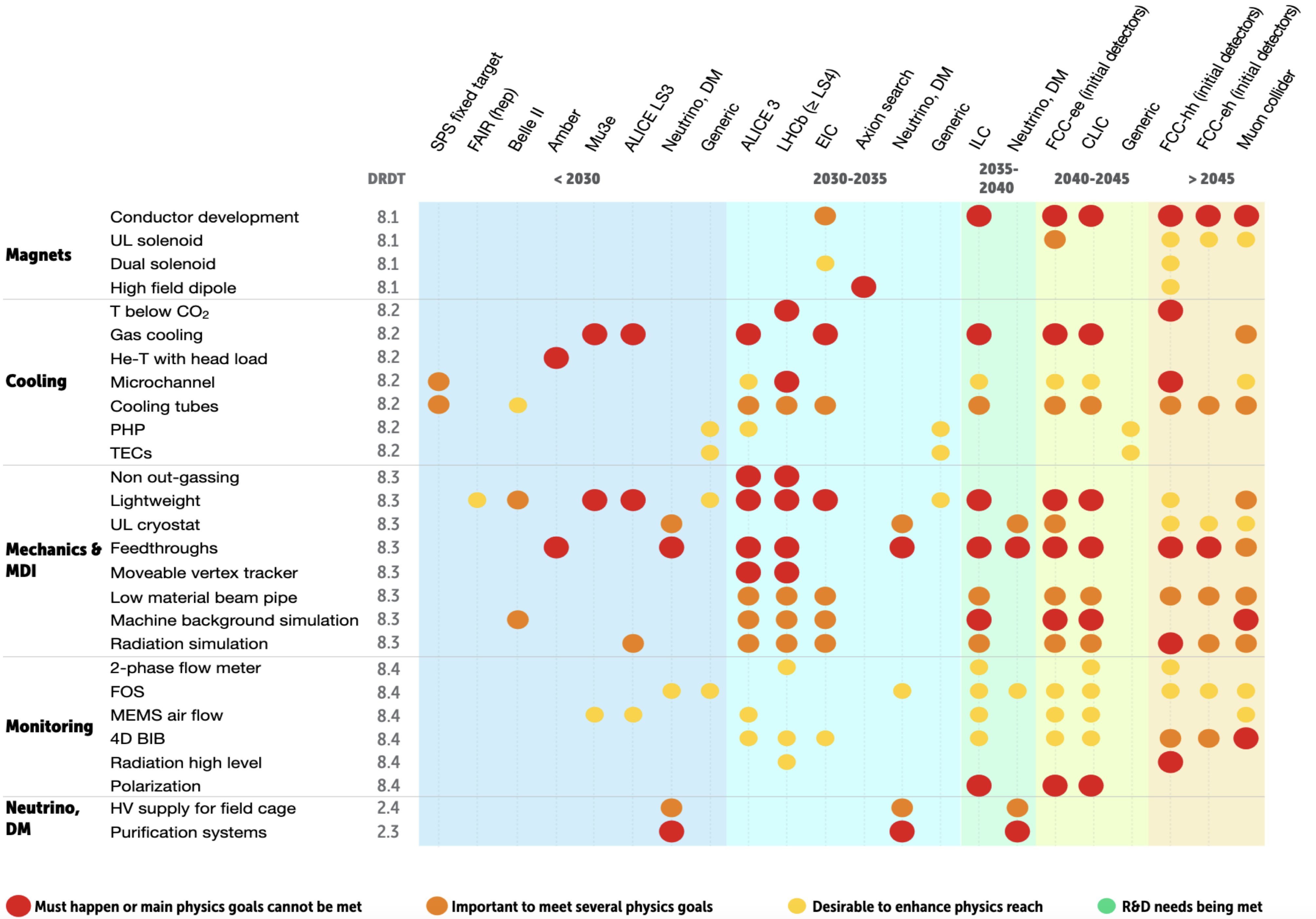
Are we harvesting all physics and performance out of great instruments to unravel mysteries of nature ?

Fraction of mechanics vs entire Detector material





- Can improve b-ID efficiencies by ~2% per b-jet and high b-jet multiplicity ~10%
- Significant improvement by novel approach, b-ID relevant for top & Higgs physics



110th Plenary ECFA Meeting
https://indico.cern.ch/event/1172215/

The "forum" spirit…

- 50-50 split or higher for engineers vs physicists
- 3 days including a poster session and R&D sessions
- Long talks and ample time for discussion
- Discuss what went wrong not just what was a success
- ~~Duplicated effort~~ and learn from other, community building

- 12th edition of FTDM: ~60 registered participants
    - https://indico.cern.ch/event/1336746/
- Industry session by 2 vendors relevant to Mechanics
- This years edition included 2 satellite events on CMS and EPIC with lots of time for detailed discussions
    - CMS: half day, internal, turned out to be almost a full day
    - EPIC: full day

The “forum” spirit…

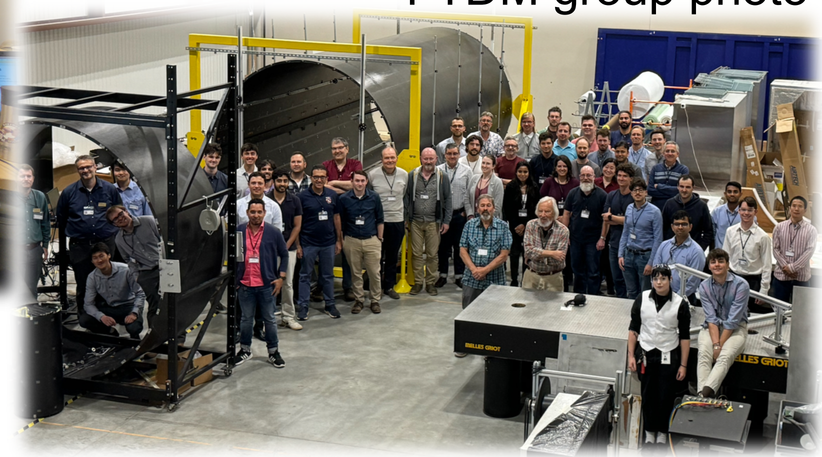
Some of the sessions – here EPIC SVT talk

Many helpers behind the scenes

EPIC satellite
May 28th

CMS satellite

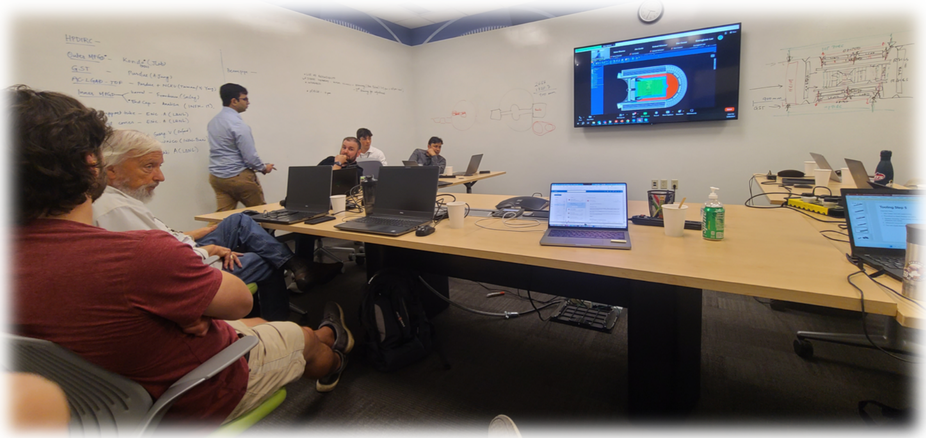
FTDM group photo



EPIC mechanics satellite

- Started at 10am
- Session on SVT local and global mechanics
- Transition to global aspects, aka global support tube, GST
- TOF mechanics as it relates to GST and MPGD supports
- Folded with discussion on services & space
- pfRICH vessel discussions

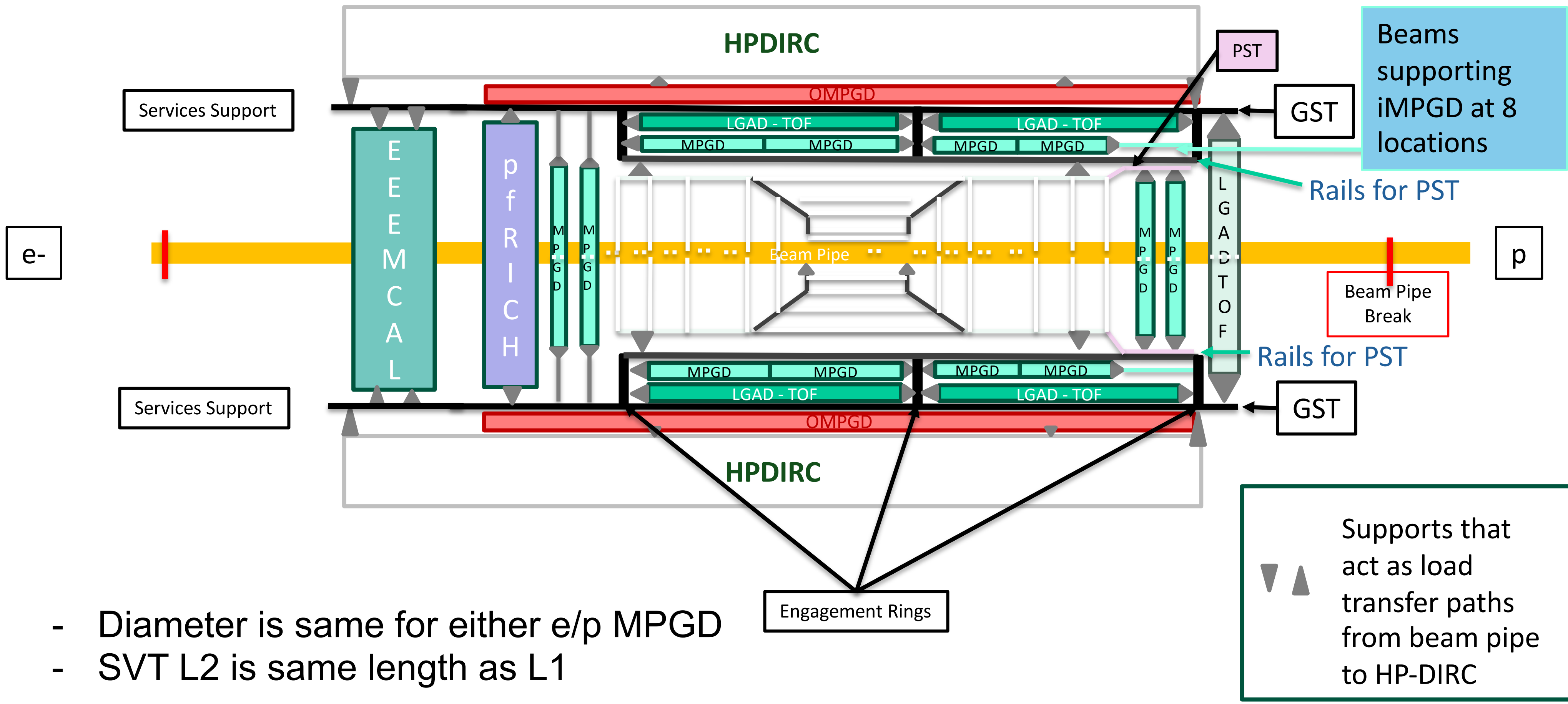
EPIC satellite May 28th



Outcomes of EPIC satellite

ePIC Detector Support Hierarchy Y-Z View – Option 1

FIRST DRAFT – NOT TO SCALE

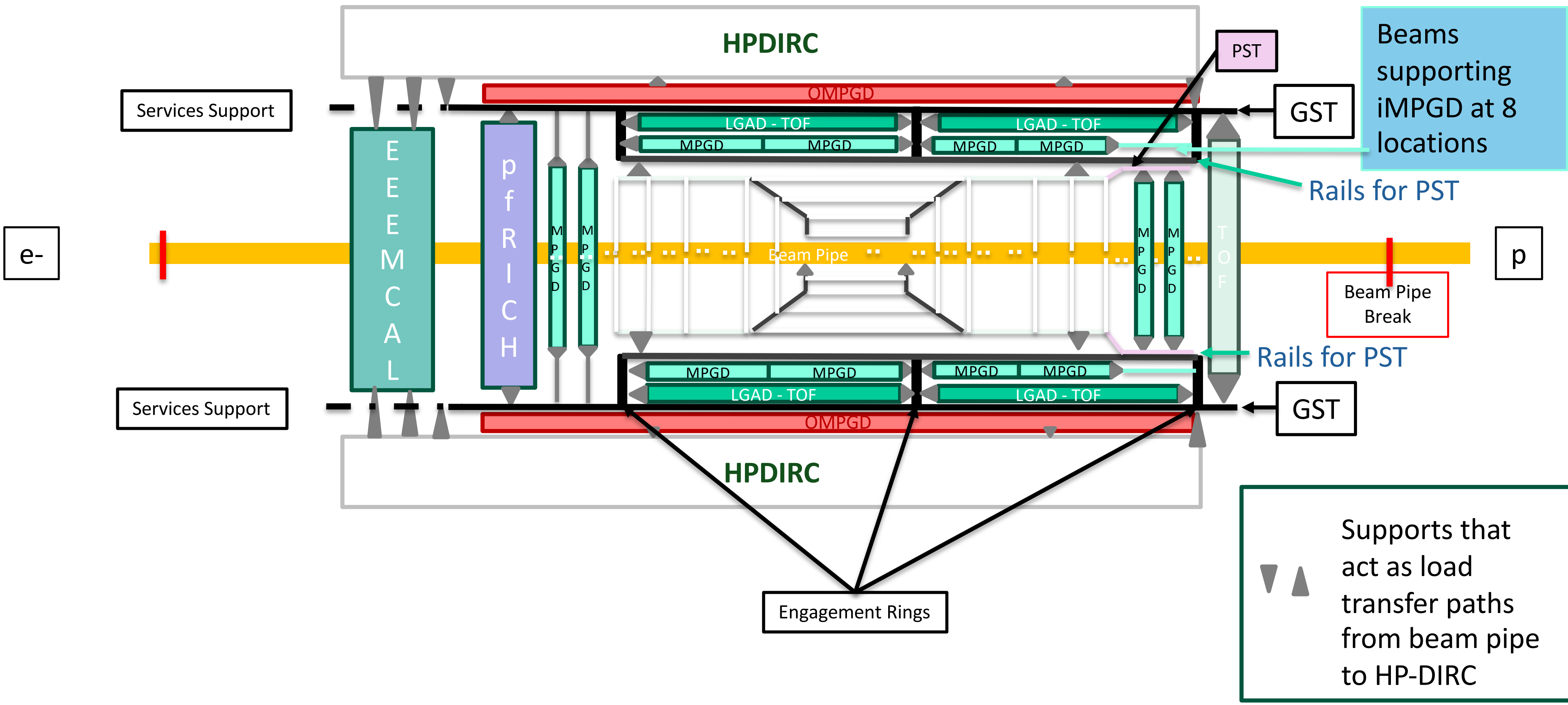


- Diameter is same for either e/p MPGD
- SVT L2 is same length as L1

Outcomes of EPIC satellite

ePIC Detector Support Hierarchy Y-Z View – Option 2

FIRST DRAFT – NOT TO SCALE



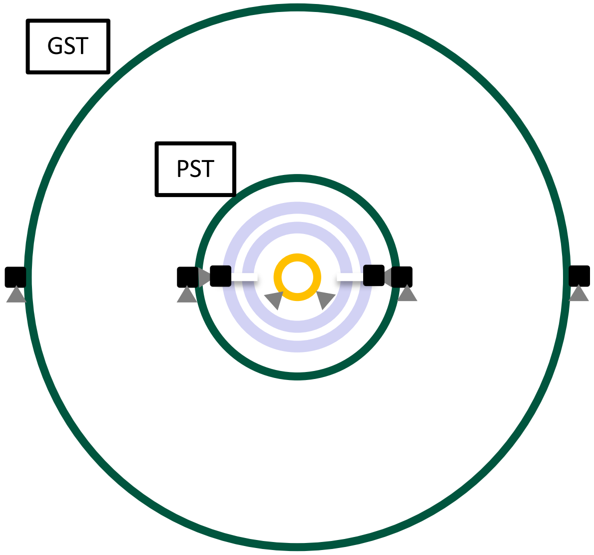
ePIC Detector Support Hierarchy r-Φ View

- Support hierarchy being finalized
  - Naming convention for the “tubes”
  - First iteration in previous slides
- List of Responsibility + contacts for engineering questions
- Determine envelopes
  - Long process, includes services & R/O cards
- pfRICH meeting – satellite of a satellite ;)
- Integration & Assembly questions:
  - - Cleanroom specs & Crane supports

FIRST DRAFT – NOT TO SCALE

Key:
Beam Pipe
SVT
Composite Support Tube

▲ Support
■ Rail



WORK IN PROGRESS

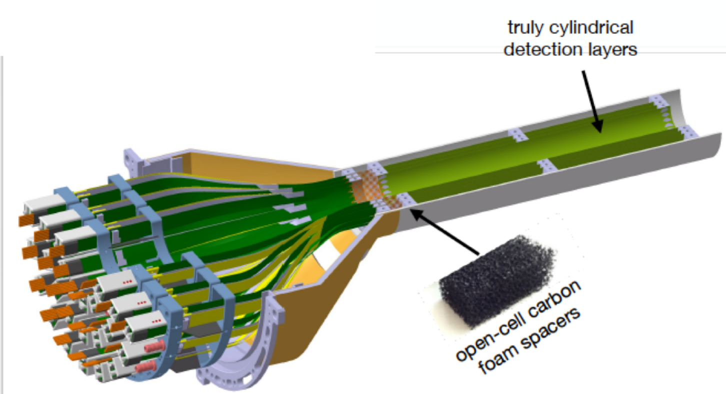
1. R-phi view for support hierarchy
2. Detailed write up of support hierarchy

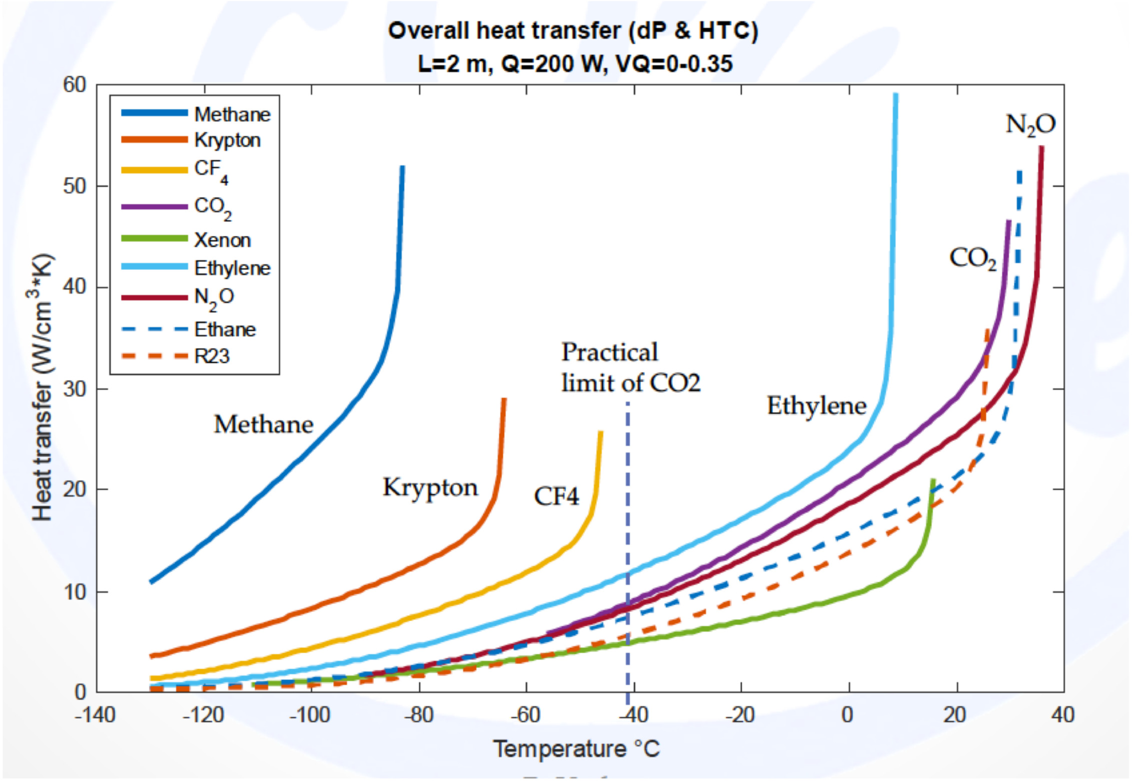
Coming up in a few days

Cooling & support structures

- Reached the limit for cold CO2 technology
- Further improvement if power densities require it:
  - Super-critical krypton cooling (around -60C)

- …but air cooling the “weapon of choice” as long as power densities are low enough
- Little to no support mass needed, example ALICE ITS3
- Can we dream ? 1st layer of vertex detector into beam pipe
- Beam current shield vs. beam pipe mass





Mechanics and cooling for **ALICE future vertex detectors**

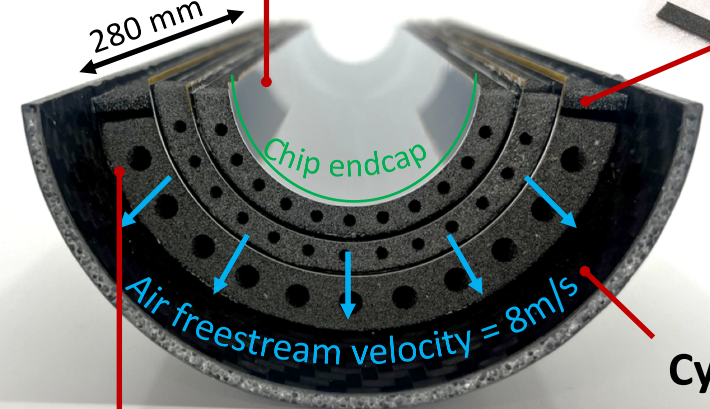
Massimo Angeletti

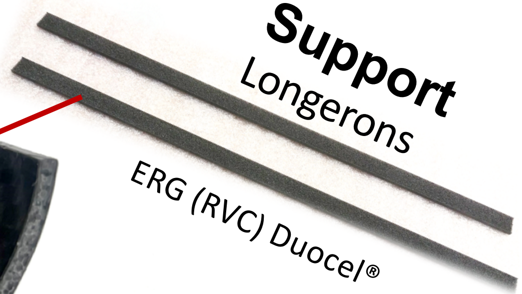
On behalf of:

- CERN EP R&D WP4: mechanics
- ALICE ITS3 WP5: mechanics and cooling

LS3 ITS3: Design

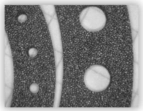
The limited dissipated power allows for the use of **air cooling** at ambient temperature
The material budget requirement call for a unpalpable support structure, i.e. **carbon foam**





Cylindrical support structure: carbon sandwich

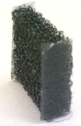
Support & **cooling**



Allcomp K9

Standard Density

Support



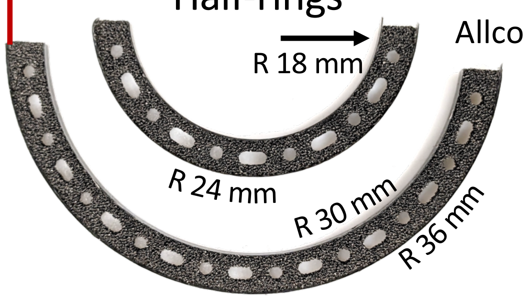
ERG Carbon RVC

@Duocel

$\rho = 0.045$ kg/dm^3

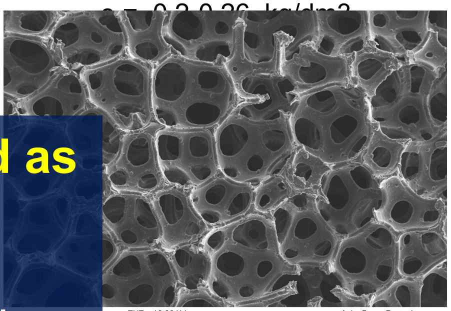
Support & **cooling**

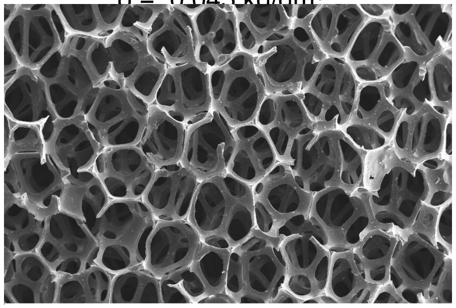
Half-rings



Carbon foam used as radiator

Higher thermal conductivity but higher density





Conceptual Design for the ePIC SVT Outer Barrel Staves

Adam Huddart - Rutherford Appleton Laboratory

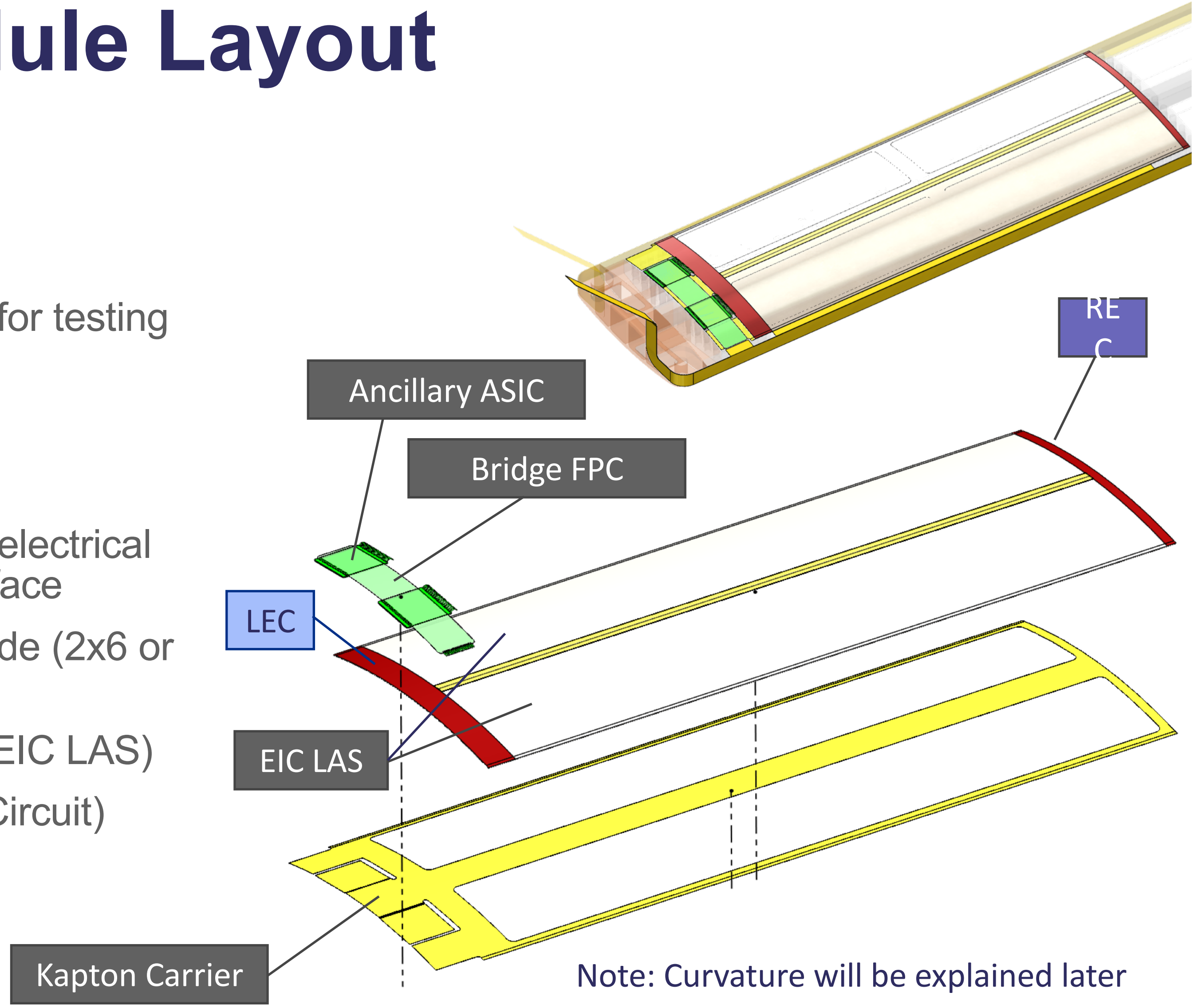
Georg Viehhauser, James Julian Glover, Laura Gonella, Marcello Borri, Qing Yang

EIC-LAS Module Layout

EIS-LAS are built into a module for testing and wire bonding

Modules are comprised of:

- Kapton carrier – serves as an electrical insulation layer & bonding surface
- 2 EIC-LAS mounted side by side (2x6 or 2x5 RSU)
- Ancillary ASIC (one ASIC per EIC LAS)
- Bridge FPC (Flexible Printed Circuit)



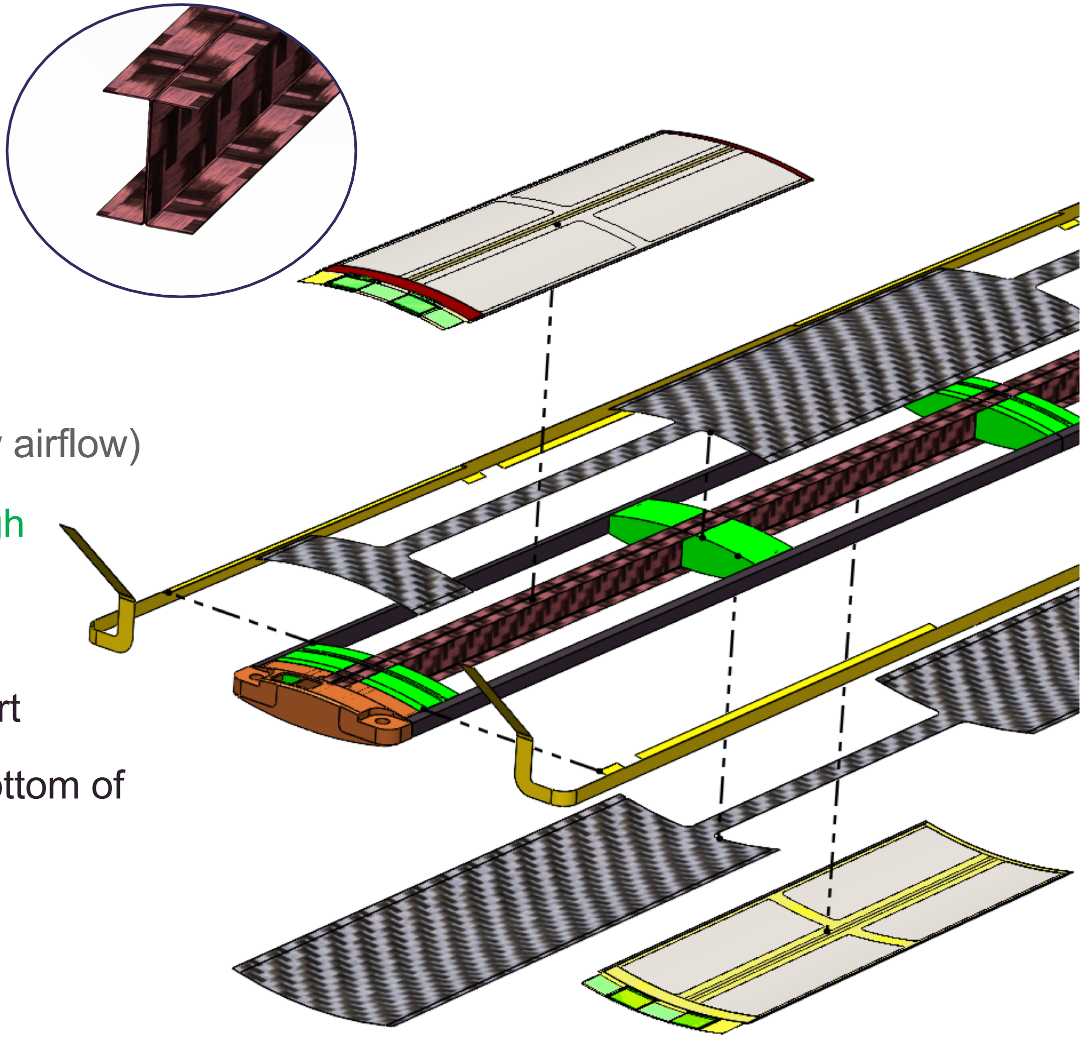
Note: Curvature will be explained later

Science and Technology Facilities Council

Adam Huddart - Rutherford Appleton Laboratory

Stave Structure

- Combination of carbon foams and carbon composite laminates
  - Central carbon fibre I-beam divides left and right air channels (shown in red)
  - 2 Densities of carbon foam (high porosity → allow airflow)
    - K9 used as a heatsink, in contact with the high power regions (ASIC & LEC) to aid heat dissipation
    - 3% RVC foam longerons for structural support
  - 0.1mm thick 2ply carbon fibre skins on top and bottom of the structure
- FPCs run along the longerons (shown in yellow)



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Investigating Cracks in ATLAS ITk Strips

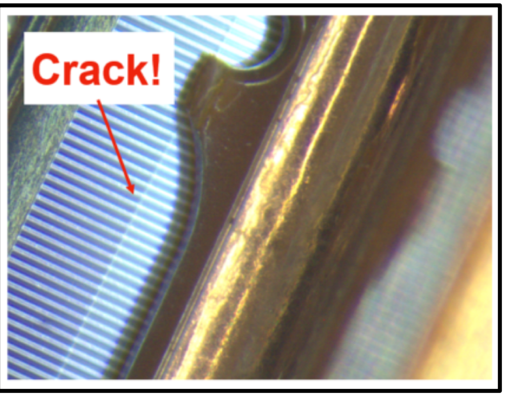
G. Vallone[1], H. Abidi[2], E. Anderssen[1]
[1]LBNL, [2]BNL

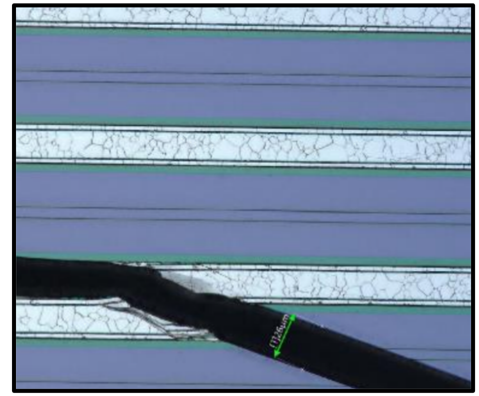
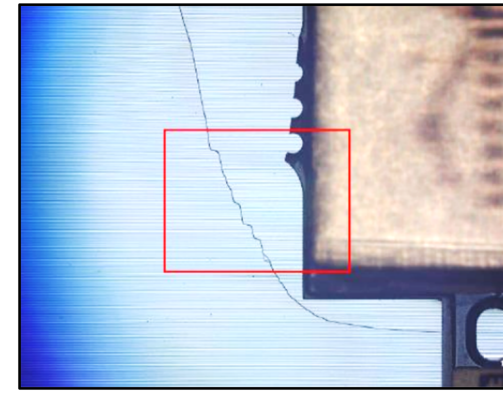
From a collective effort of the ITk HV Task Force

Forum on Tracking Detector Mechanics
Purdue University, 30 May 2024

Science and Technology Facilities Council

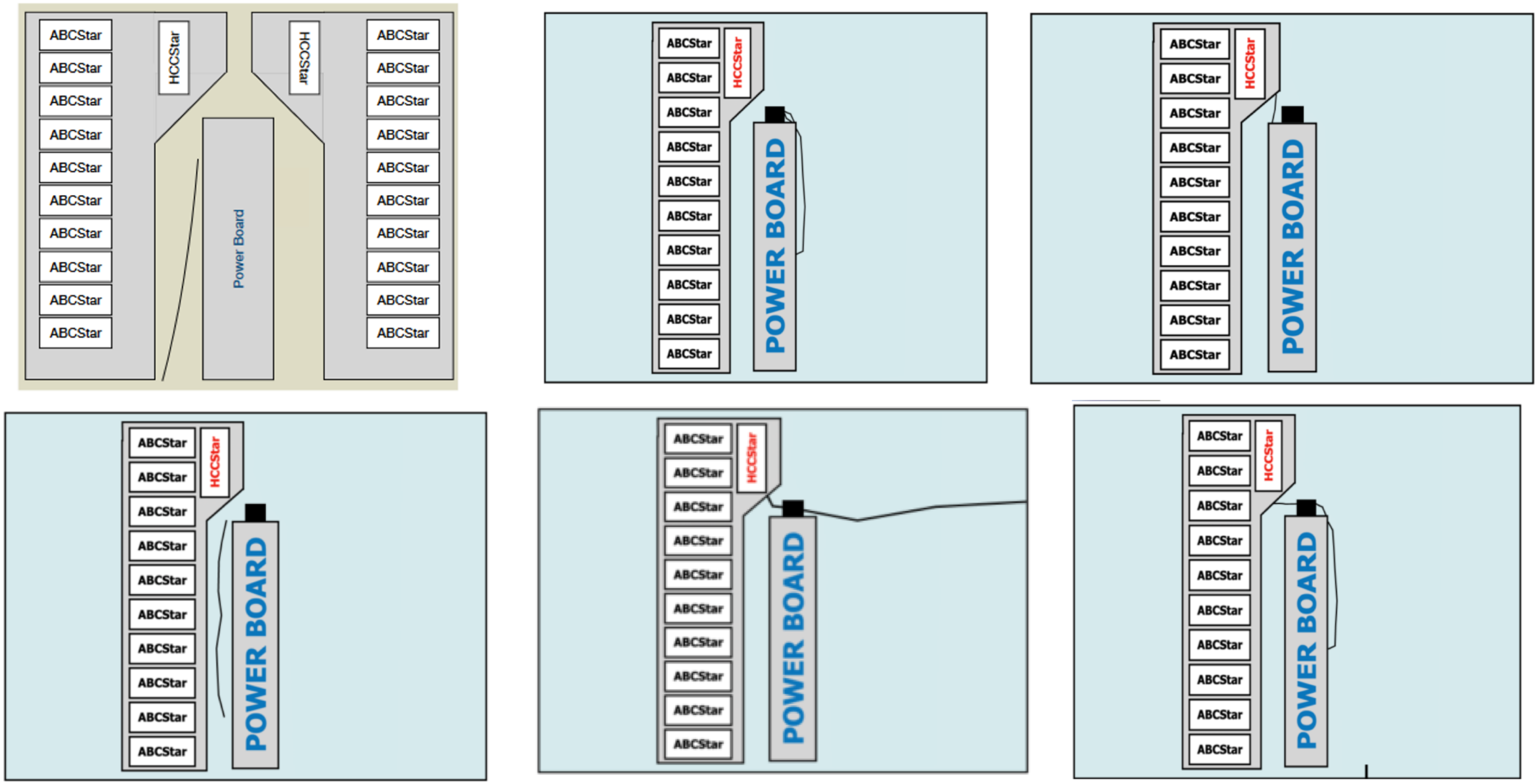
Introduction



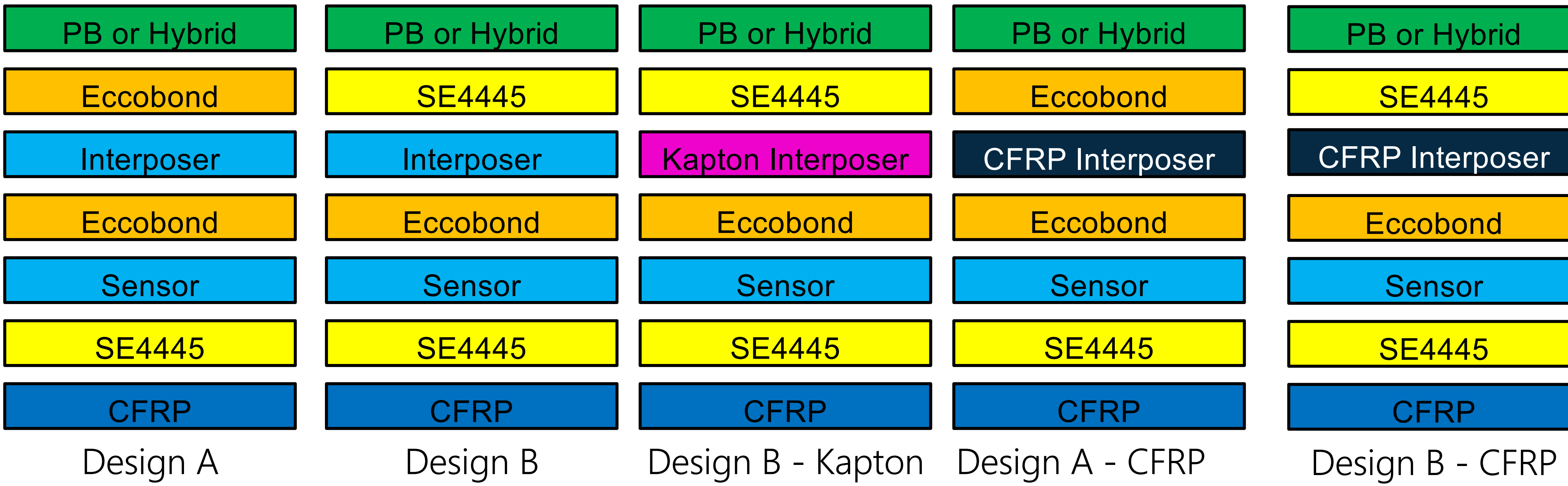
- Some sensors failed high voltage testing (early breakdown)
- After visual inspection, **mechanical failures** were detected across sensors during thermal cycling
  - Failed areas look like a ‘**crack**’
- As part of a task force effort, we have developed numerical simulations and performed mechanical tests to better understand:
  - **Why/when** it fails
  - How the design can be **improved** to avoid further failures

Crack Locations



- Cracks seem to appear at some point during **thermal cycling/powering** at -40 C, only on some modules
- Not clear why, when, and where they start

The Interposer Solution



- We proposed to add an additional component to the stack, the ‘**interposer**’
  - Added between the **sensor** and the **flexes** in an attempt to reduce stresses
  - Multiple **strategies** proposed
  - Two main ‘families’:
    - Design A: **stiff** interposer and glue
    - Design B: **soft** interposer and glue

Conclusion

- **Simulations** suggest that **high stresses** are introduced in the silicon by differential thermal contraction effects
  - The model was **validated** against **displacements** measured on real modules
  - The predicted **stresses** are very **close** to **failure** stresses from literature and measurements on relevant samples
  - The failure locations are consistent with the computed peak stress areas
- Multiple **mitigation** strategies were studied
  - The '**soft interposer**' solution can reduce the stresses by 95%

Future work

- Improve accuracy of the **failure envelope** with additional bending tests
- Work in progress to **assemble** a full stave with **interposer** modules
- We would like to further **validate** the **simulations**, and improve our understanding of the failure mechanism
  - Silicon strain gauges are a promising solution, testing in progress

DRD7: Cooling plates

On behalf of the DRD7.4c collaborators

DRD7.4: EXTREME ENVIRONMENT AND LONGEVITY

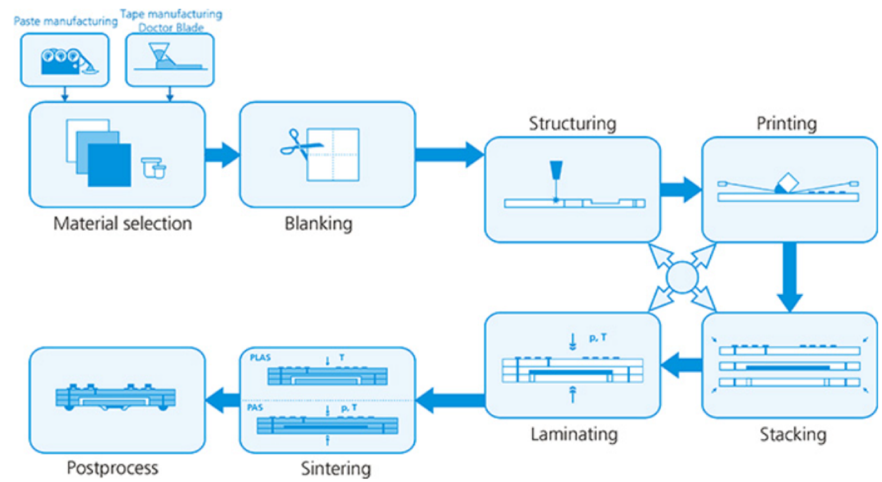
IMPLEMENTING DRD7:
AN R&D COLLABORATION ON ELECTRONICS AND ON-DETECTOR PROCESSING

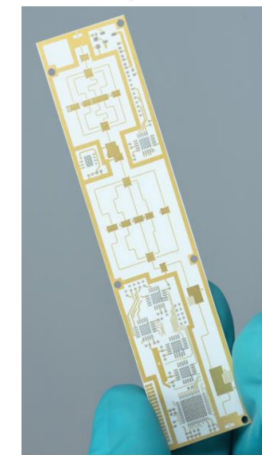
Oscar Augusto de Aguiar Francisco (The University of Manchester)
oscar.augusto@cern.ch

05/30/2024

Ceramics

- Manufacturing at IKTS Fraunhofer (Germany)
- Different base materials: YSZ, Al_2O_3, … including **SiC** and **AIN**
- Manufacturing based on several layers
- **<u>Why?</u>**
  - Robustness, reliability, stability in ultra-high-vacuum
  - Possible to embed conductive layers in between ceramics layers and metalize the surface
    - Potential to integrate electronics or high conductivity elements
  - Mechanically robust and compatible with high ultra vacuum





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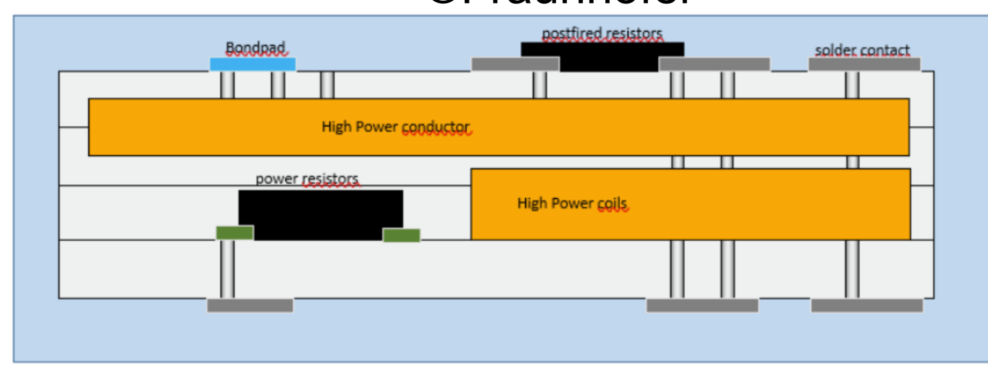
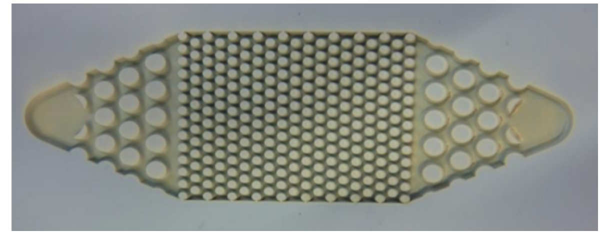


Ceramics

- Experience with fluidic applications
- First prototype based on the early VELO Upgrade I CERN design
  - Initial channel with $70\mu m$ width (restrictions)
  - Channels height $100\mu m$
  - Overall dimensions: $40 \times 60 mm^2$
  - Based on LTCC
    - $Al_2O_3/Glass \sim 1:1$
    - Al_2O_3 HTCC is $\sim 96\%$
  - Possible to move to SiC or AlN
- Encouraging results from FEA studies
  - Geometry based on the VELO Upgrade I design (5 mm overhang)
  - For $2 W/cm^2$, $\Delta T \sim 9°C$ (coolant heat transfer coefficient not considered)



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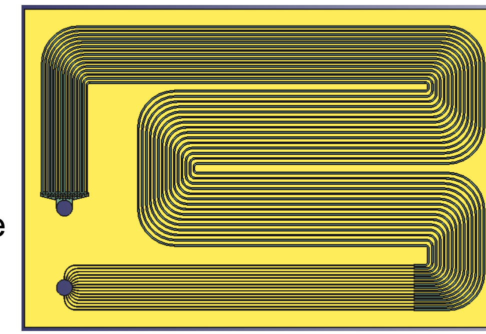
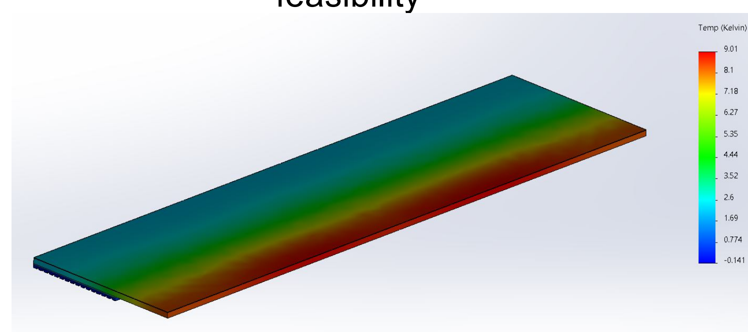
MANCHESTER 1824
The University of Manchester



SNAKEI based design to optimize printing parameters/test feasibility



Simplified FEA focusing on the 5 mm overhang. Substrate in alumina and heat conduction on one side of the cooling plate and Stycast (100um).

Oscar Augusto de Aguiar Francisco
(The University of Manchester)

Ceramics: Goal and status

- Goal:
  - ✓Manufacture first samples (IKTS)
    - ✓Miniaturized version (2x smaller in-plane)
    - ✓Expected 35um and 100um width restrictions and main channels respectively!
  - Second round being prepared
  - Validate initial prototypes to high pressure, leak tightness and cooling performance
  - Benchmark: LHCb VELO Upgrade 2 requirements (High pressure 186 bar, leak tight (vacuum operation) and excellent thermal performance
- Very encouraging first manufacturing results!!!

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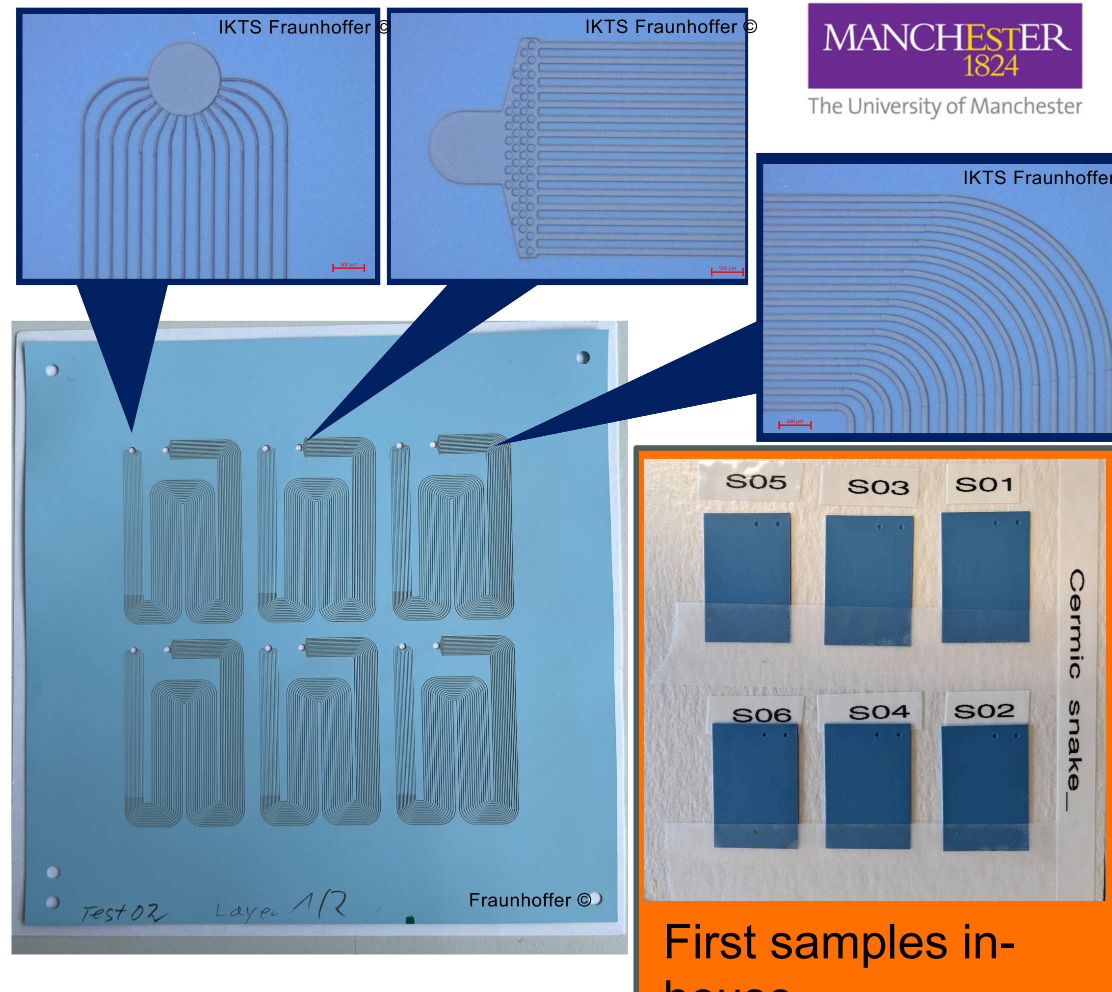


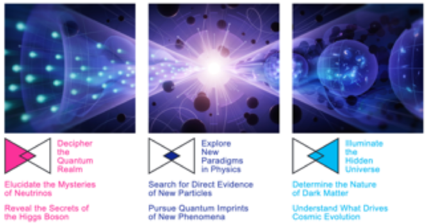
First samples in-house
(eagerly waiting to be tested)

R&D Collaboration 10

aka RDC10:

Status & plans

Eric Anderssen & Andy Jung



P5 outcome

Current priorities: HL-LHC, the first phase of DUNE and PIP-II, the Rubin Observatory to carry out the Legacy Survey of Space and Time (LSST)

Future priorities on experiments

- CMB-S4, which looks back at the earliest moments of the universe,
- Re-envisioned second phase of DUNE with an early implementation of an enhanced
- Offshore Higgs factory, realized in collaboration with international partners, …
- Ultimate Generation 3 (G3) dark matter direct detection experiment…
- IceCube-Gen2 for the study of neutrino properties …

…**This includes an aggressive R&D program that**, while technologically challenging, could yield revolutionary accelerator designs that chart a realistic path to a 10 TeV parton center-of-momentum (pCM) collider. In particular, the muon collider option builds on Fermilab strengths …

- Colliders are long term project that need strong investment into R&D now, which was recognized
- Smaller scale experiments provide opportunities for "Mechanics R&D"

https://www.usparticlephysics.org/2023-p5-report/

CPAD & RDC's - What is it & How to engage

- Coordinated Panel for Advanced Detectors / CPAD
  - Structure to form community on "Blue Sky" high risk R&D
  - Funded by DOE, some "bias" to High Energy Physics (Strong desire to enhance)
  - CPAD web page: https://cpad-dpf.org/?page_id=1549
- RDC10 webpage in development
  - Volunteers needed
  - https://cpad-dpf.org/?page_id=1727
- How to subscribe to any RDC10:

- To SUBSCRIBE to a mailing list called MYLIST:
- Send an e-mail message to listserv@fnal.gov
- Leave the subject line blank
- Type "SUBSCRIBE MYLIST FIRSTNAME LASTNAME" (without the quotation marks, and using the string before the @ in the mailing list's name as MYLIST- as well as your own name) in the body of the e-mail message

For example "SUBSCRIBE CPAD_RDC1 ALICE SMITH"

RDC#	TOPIC	COORDINATORS	MAILING LIST
1	Noble Element Detectors	Jonathan Asaadi, Carmen Carmona	cpad_rdc1@fnal.gov
2	Photodetectors	Shiva Abbaszadeh, Flavio Cavanna	cpad_rdc2@fnal.gov
3	Solid State Tracking	Anthony Affolder, Sally Seidel	cpad_rdc3@fnal.gov
4	Readout and ASICs	Angelo Dragone, Mitch Newcomer	cpad_rdc4@fnal.gov
5	Trigger and DAQ	Zeynep Demiragli, Jinlong Zhang	cpad_rdc5@fnal.gov
6	Gaseous Detectors	Prakhar Garg, Sven Vahsen	cpad_rdc6@fnal.gov
7	Low-Background Detectors	Daniel Baxter, Guillermo Fernandez-Moroni, Noah Kurinsky	cpad_rdc7@fnal.gov
8	Quantum and Superconducting Sensors	Rakshya Khatiwada, Aritoki Suzuki	cpad_rdc8@fnal.gov
9	Calorimetry	Marina Artuso, Minfang Yeh	cpad_rdc9@fnal.gov
10	Detector Mechanics	Eric Anderssen, Andreas Jung	cpad_rdc10@fnal.gov
11	Fast Timing	Gabriele Giacomini, Matt Wetstein	cpad_rdc11@fnal.gov

Outlook

- Community building to fully establish a R&D collaboration for Mechanics, Services and Cooling
  - Join the CPAD RDC10 email lists! See earlier slides
  - Realistically: bi-annual meetings
    - One in overlap or simply the Forum itself
    - One more in Fall but ahead of the yearly CPAD community meeting (November-ish)
  - Community (US centric) survey in preparation of the RDC10 Fall meeting

- CPAD white paper process in anticipation of next DOE BlueSky FOA
  - P5 plan implementation has a promise to increase R&D funds in coming years

- P5 has released the priorities early December and a town hall at Fermilab on 11th December
  - https://indico.fnal.gov/event/61641/
  - Link to Report: https://www.usparticlephysics.org/2023-p5-report/

DRD8: R&D on Mechanics & Cooling of Future Vertex and Tracking Systems

May 31, 2024

Burkhard Schmidt for the DRD8 Steering Committee

(C. Gargiulo, A. Jung, A. Mussgiller, P. Petagna, B. Schmidt, G. Viehhauser)

Demonstrators

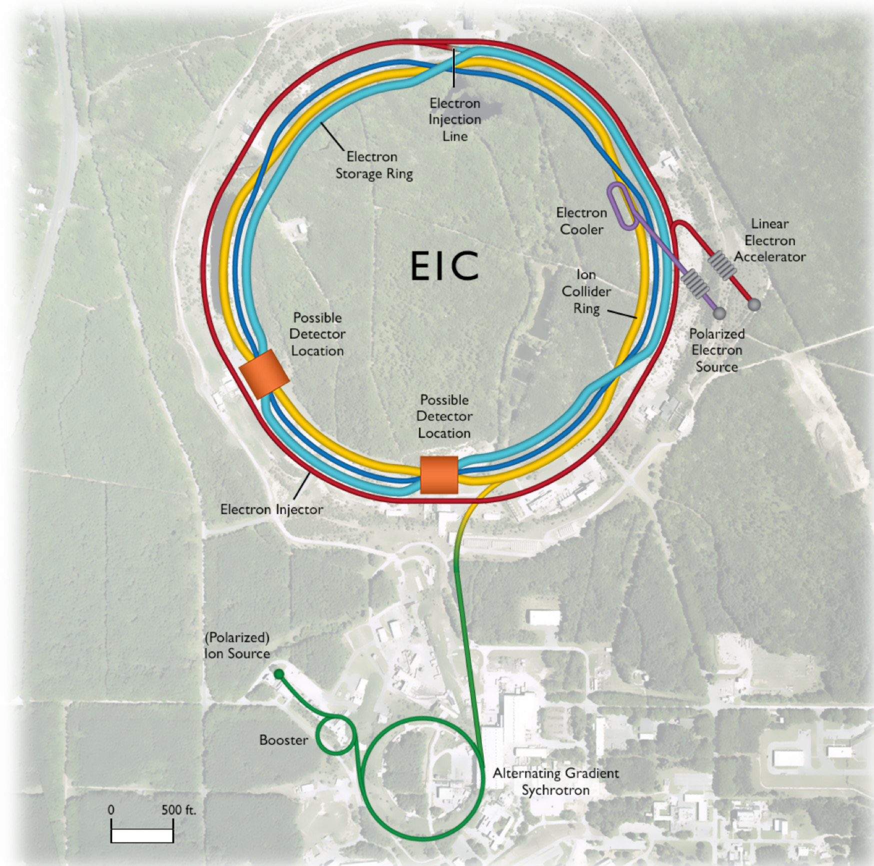
The LoI mentions also **targeted and collaborative R&D work** which includes (besides mechanics and cooling) sensors, front-end electronics, and electrical and readout services, for two application frameworks

1. **Low intensity (LI):** In this framework the mechanics and cooling will support sensors and electronics that have been designed for low power densities. The number and cross-section of electrical services will be small. Radiation damage levels will be low, and thus there will be no need to operate these systems cold (< 15 °C). Where possible, gas cooling will be an appealing solution. Radiation hardness levels of materials will be moderate.
2. **High intensity (HI):** Detector systems within this framework will have to cope with large fluxes of signal and background particles. The high channel density and complexity of the front-end electronics will result in high power densities, which will need to be supplied by advanced powering systems. For the removal of the dissipated power further developments of evaporative cooling systems will be needed. Significant radiation damage will require cold (< -35 °C) operation to keep leakage currents under control. Materials will need to be qualified for the high radiation environment.

- **We should discuss about this topic further after the presentations of the WGs**

R&D: Many avenues possible

- Low mass detectors
- Low mass structures
- Dual use structures
- Active sensing …



https://www.usparticlephysics.org/2023-p5-report/

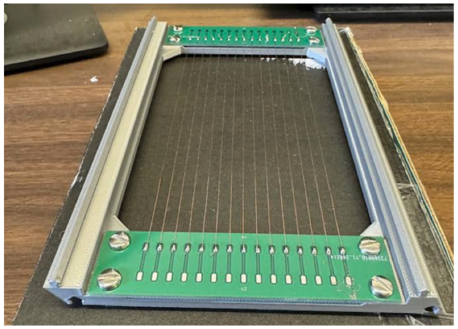
…caveat: EPIC/EIC is not R&D but going into production but it adopts a lot Of low mass tech that's highly applicable to FCC and others

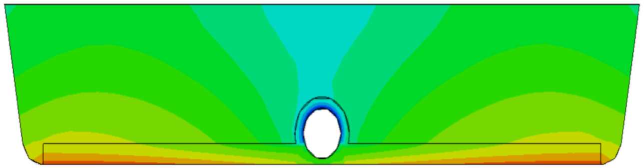
Summary

• https://indico.cern.ch/event/1336746/

Detector mechanics can play a significant role in a detector's performance, improvements require:

- In-depth study of total mass folded w thermal performance
- Novel ways to reduce the total mass





Detector Mechanics R&D https://www.usparticlephysics.org/2023-p5-report/

- **P5 HEP planning recognized R&D as critical!**
- Need to make the case now for future developments
- Long time-scales, many are crossing areas
- Realize strongest proposals but needs additional funds

Backup

This research is supported by:

NSF

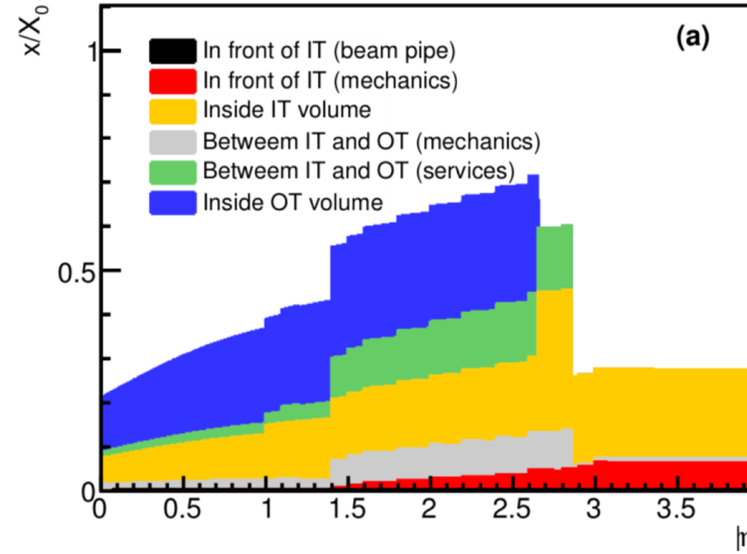
U.S. DEPARTMENT OF ENERGY
Office of Science

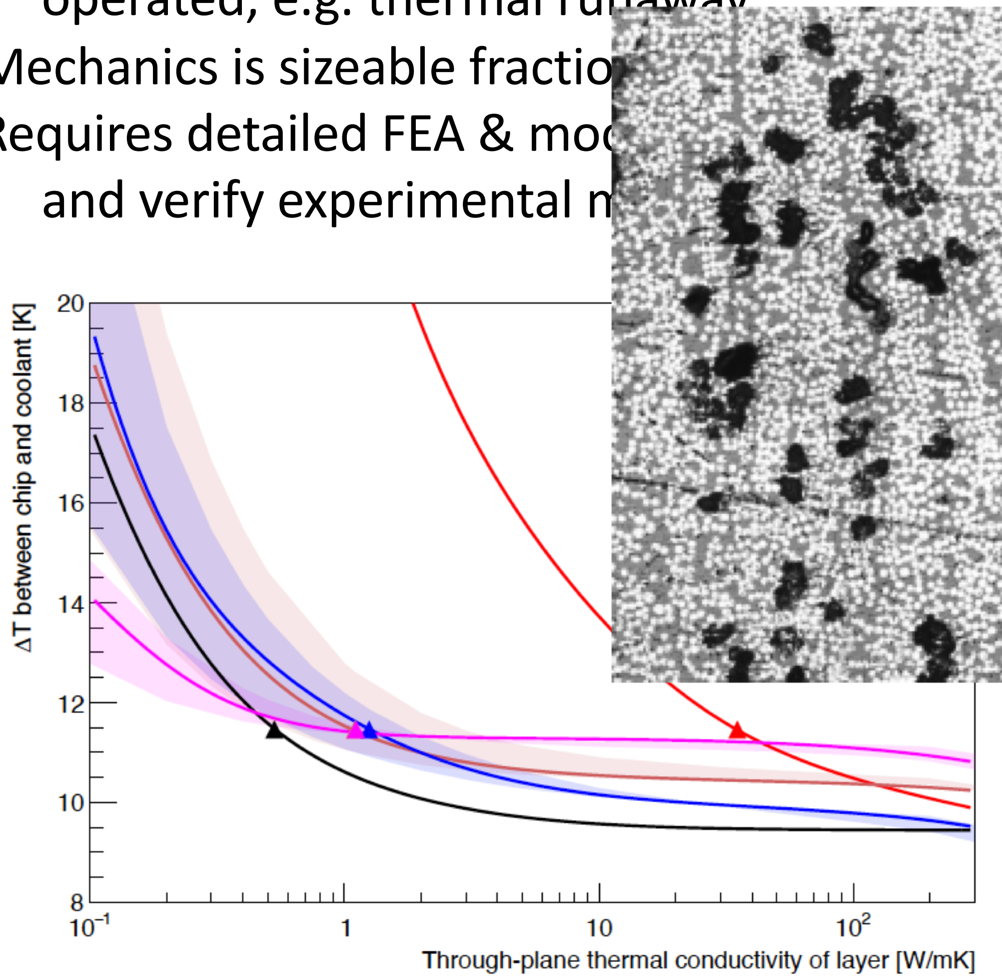
PURDUE RESEARCH FOUNDATION

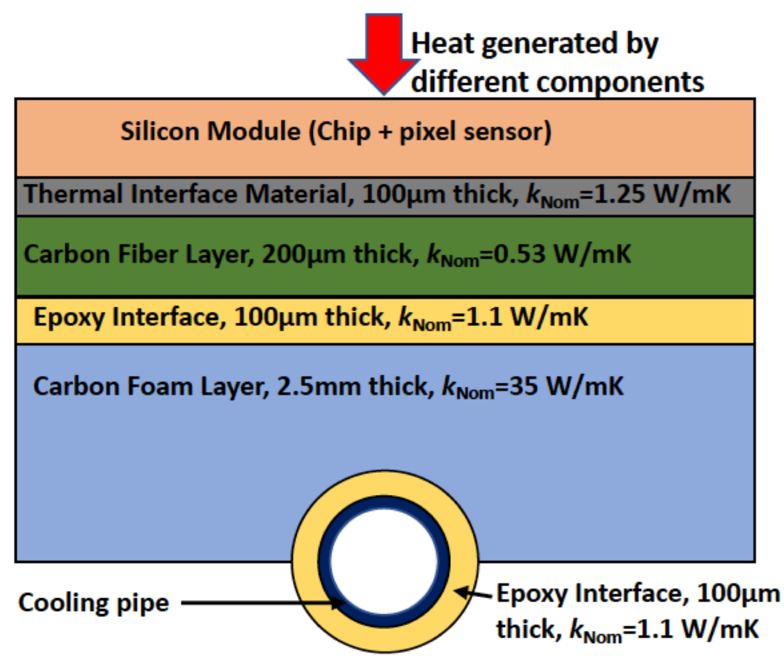
Impact of tracker mechanics…

Tracker of the HL-LHC is a very significant fraction of the total CMS upgrade budget

- Support & Cooling is the constrain in which Tracker is operated, e.g. thermal runaway
- Mechanics is sizeable fractio… budget
- Requires detailed FEA & mod… and and verify experimental m…



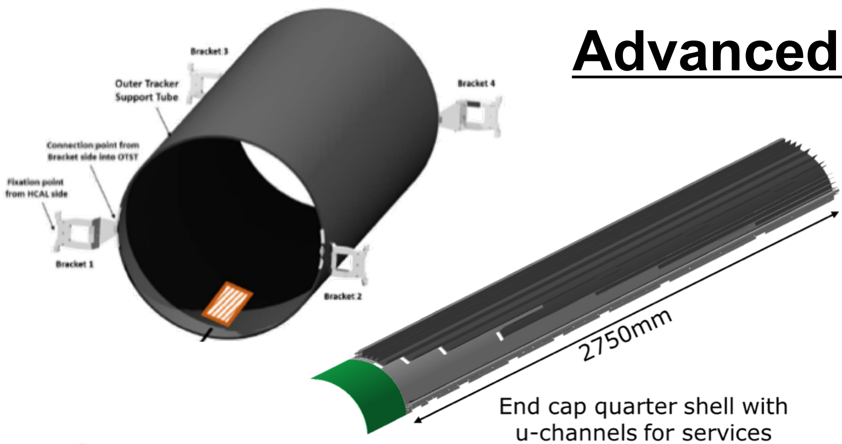


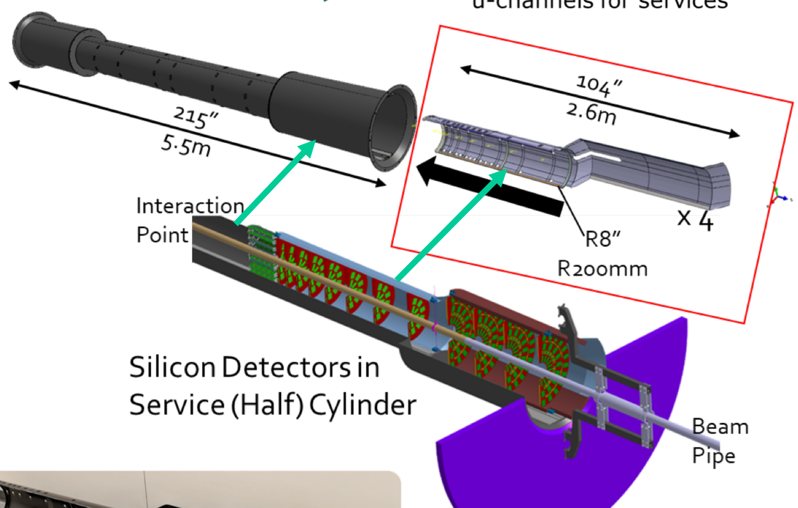


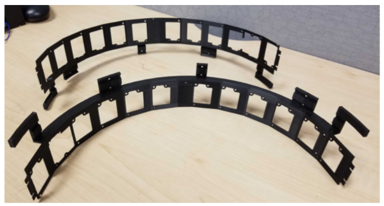
What's possible today…(biased view/selection)

Composites Manufacturing & Simulation Center

Advanced Mechanics & Composites activities at Purdue







Large Support Structures – light-weight but rigid

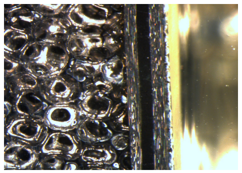
1. BTL Tracker Support Tube (CMS)
2. Inner Tracker Support Tube (CMS)
3. Inner Tracker Service Cylinder (CMS)
4. End Cap Quarter-Shells (ATLAS)

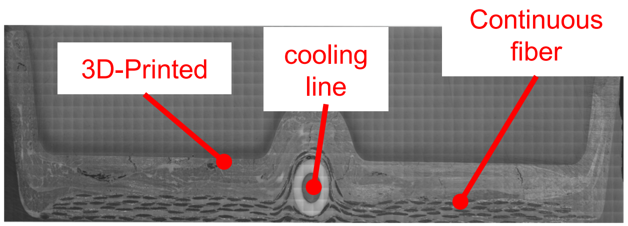
Small Structures – extremely flat and thin

1. Pixel Dees Support Structure (CMS)
2. High-TC flat sheets for silicon modules (CMS)

Irradiation campaigns:

- In collaboration with US TFPX institutes (Cornell, Rice, others)





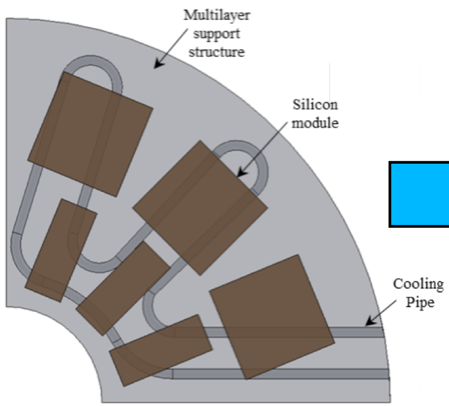
Future Mechanics and R&D:

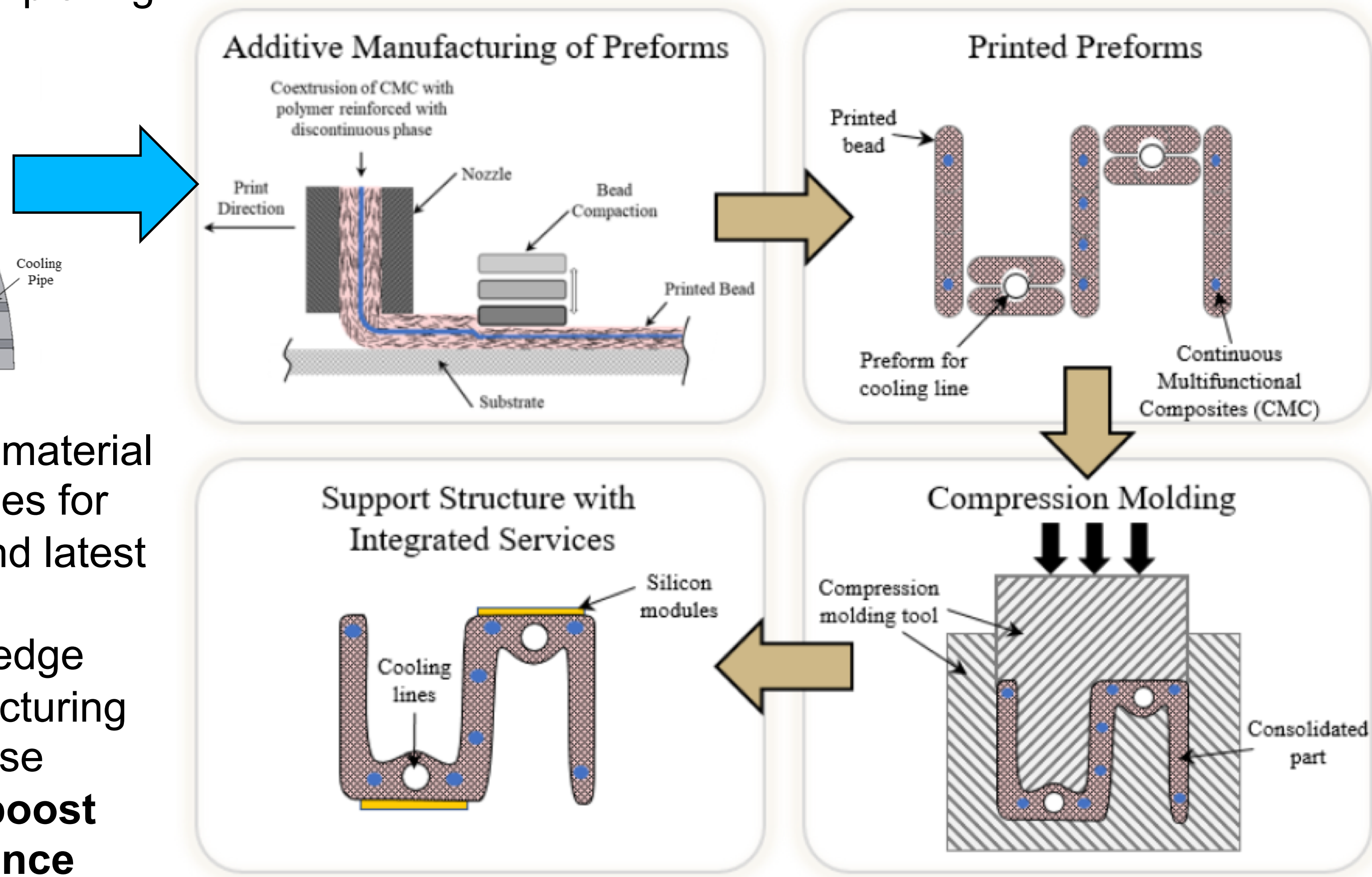
1. "BlueSky Mechanics" for detectors at future Colliders (FCC, muon, LC, etc.) https://arxiv.org/abs/2203.14347
2. "CalVision" project for mechanics of dual readout calorimetry https://arxiv.org/abs/2203.04312

Going into the future of mechanics

Identified by DOE BRN effort & CPAD

- Scaling of low-mass detector system towards irreducible support structures with integrated services. Includes: integrated services, power management, cooling, data flow, and multiplexing.



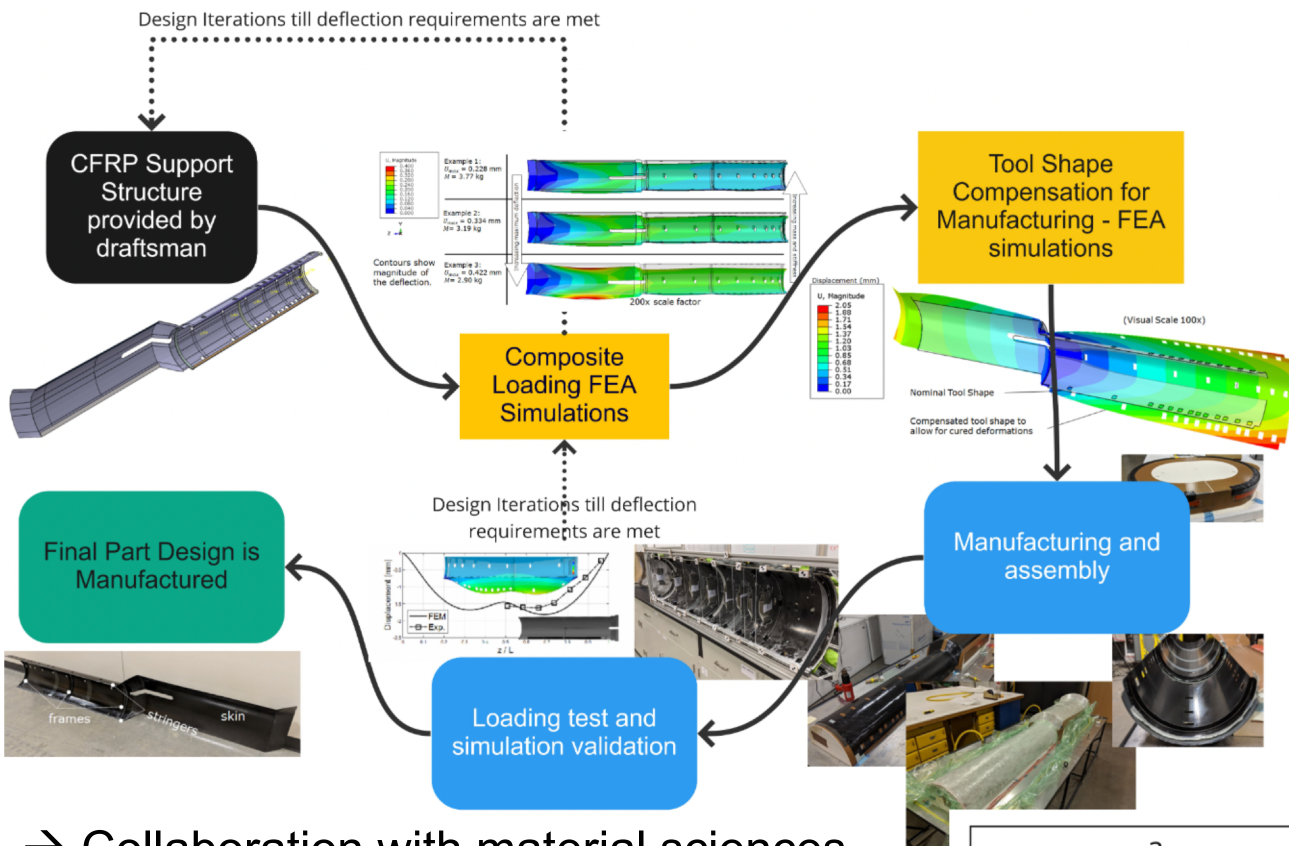


→ Collaboration with material sciences, companies for novel materials, and latest techniques.
→ Example: Cutting-edge composite manufacturing techniques, in-house
→ **Reduce mass & boost thermal performance**

Going into the future of mechanics

Composites Manufacturing & Simulation Center

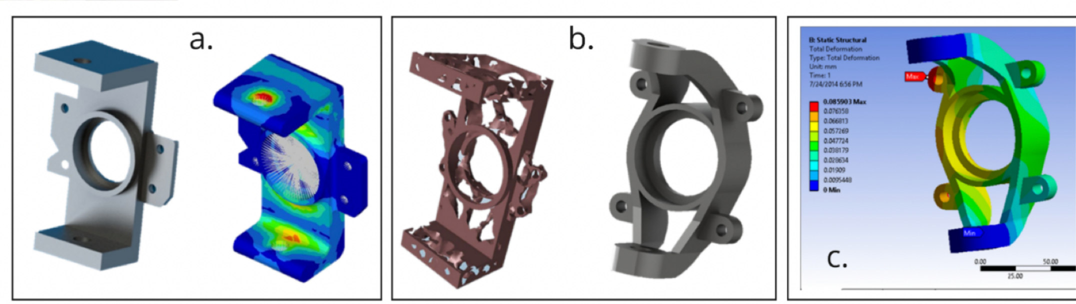
→ Scalable mechanics structures: multi-functional & mass optimized
→ Ease integration, applies also to calorimetry, TOF, etc.



Full cycle of Process & Performance simulation:

→ FEA, prototypes, iterative process.
→ Consistent approach to better controlled manufacturing process, eases assembly.
→ Especially true the larger the structures become, integration is a “challenge”

→ Collaboration with material sciences, companies for novel materials, and latest techniques.
→ Example: ML for optimization with HEP inputs, **excites future generation**



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Pixel support structures

- 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