Corrugated carbon composite disc design for the ePIC SVT

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Forum on Tracking Detector Mechanics

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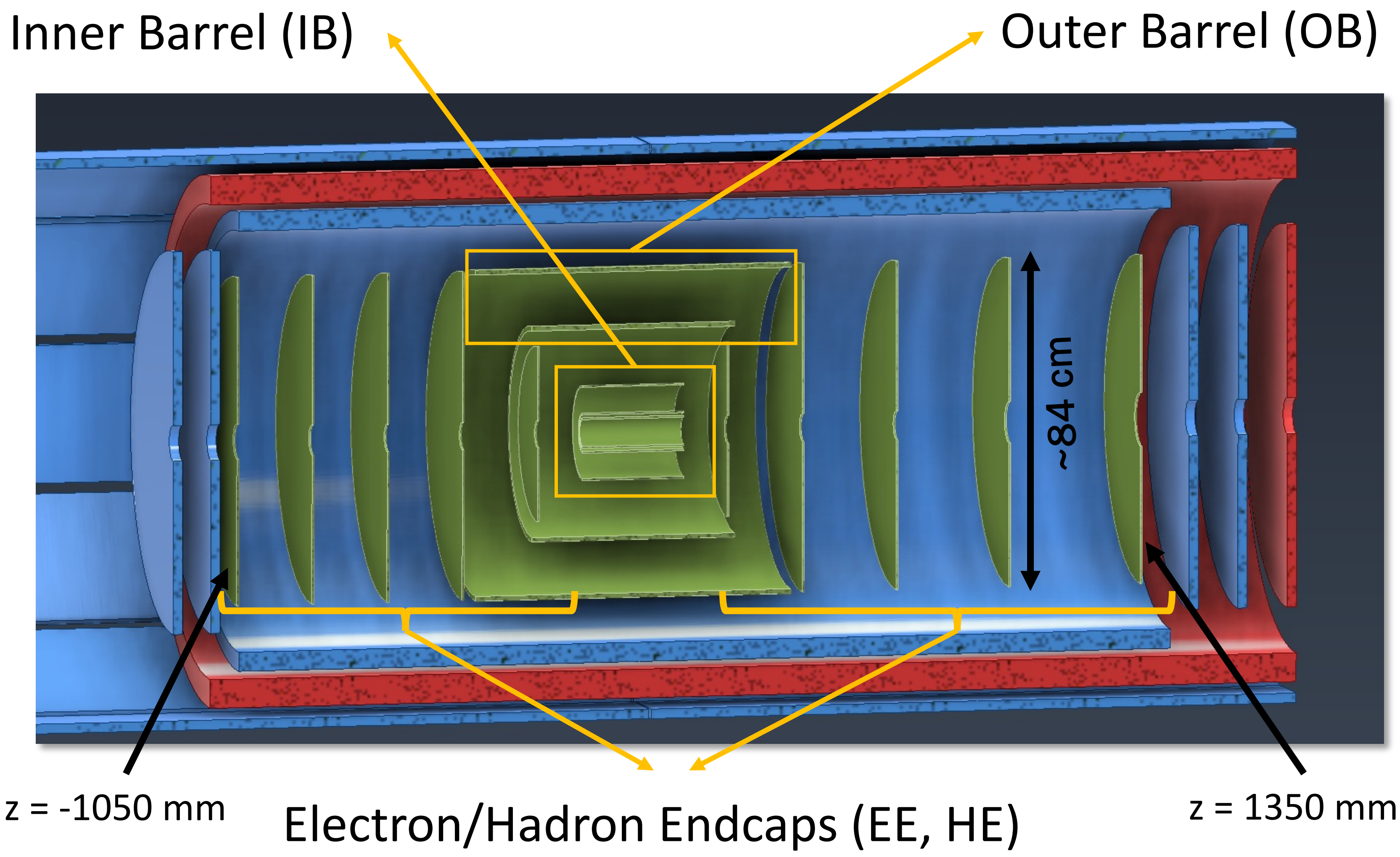
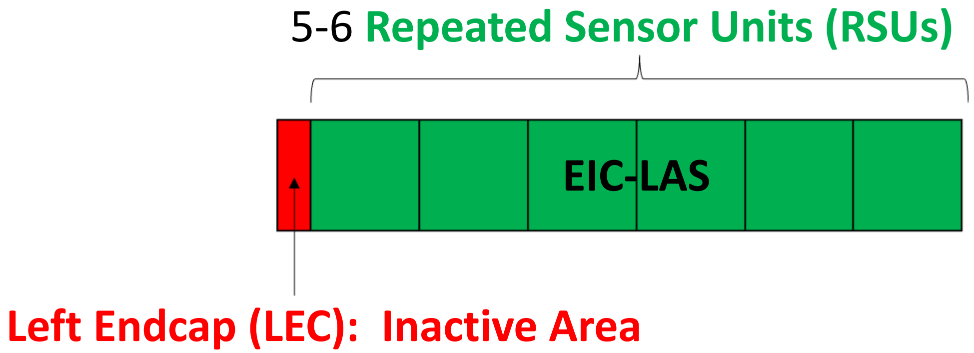
Silicon Vertex Tracker (SVT) Overview



Target Specifications

- IB
  - L0 - L2: 0.05% X/X_0
- OB
  - L3: 0.25% X/X_0
  - L4: 0.55% X/X_0
- Endcaps
  - ED0-4: 0.25% X/X_0
  - HD0-4: 0.25% X/X_0

Towards a disc design



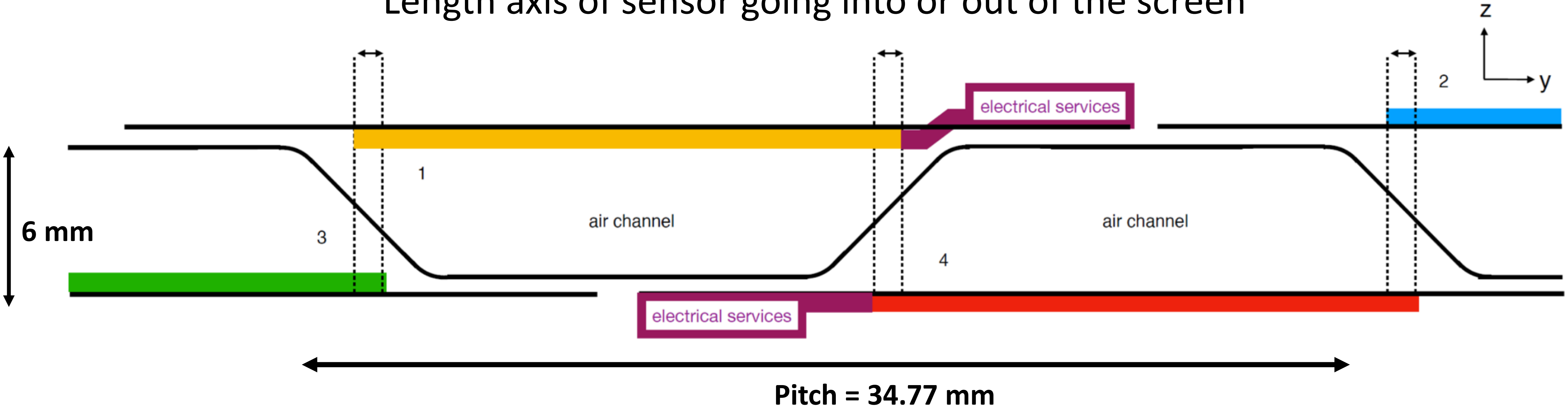
- Double-sided design
  - Overlap to account for inactive areas on sensor (EIC-LAS)
- Needs to be assembled in halves
- Material budget is a concern
  - Want strength without added mass
- Minimal number of module types to simplify production/construction
- Sensor layout varies disc-to-disc
  - Beam pipe separates & widens → Disc inner radius grows with |z|

Region	Disk	z [mm]	inner radius [mm]	outer radius [mm]	X/X0
EE	ED0	-250	36.76	240	0.24 %
	ED1	-450	36.76	415	0.24 %
	ED2	-650	36.76	421.4	0.24 %
	ED3	-850	40	421.4	0.24 %
	ED4	-1050	46.35	421.4	0.24 %

Region	Disk	z [mm]	inner radius [mm]	outer radius [mm]	X/X0
HE	HD0	250	36.76	240	0.24 %
	HD1	450	36.76	415	0.24 %
	HD2	700	38.46	421.4	0.24 %
	HD3	1000	53.43	421.4	0.24 %
	HD4	1350	70.14	421.4	0.24 %

Corrugated core

Length axis of sensor going into or out of the screen

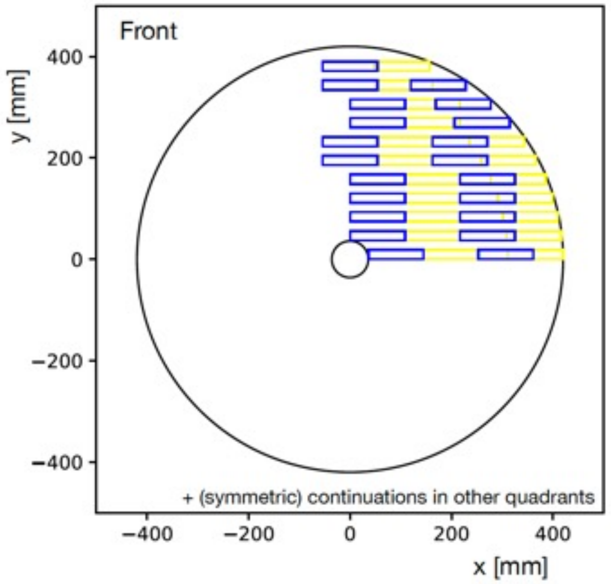


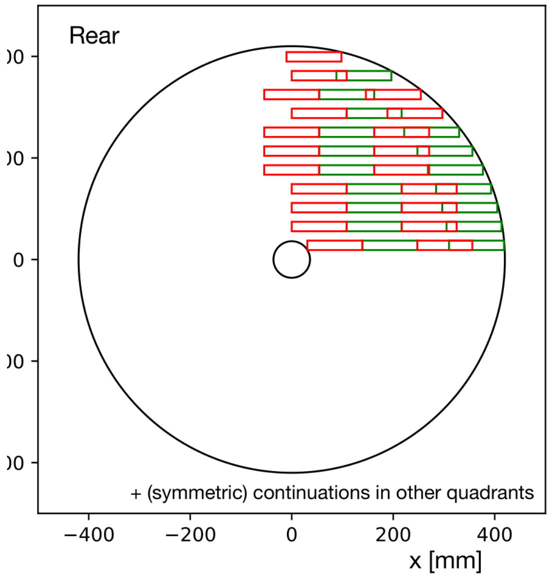
Overlap along the length axis by alternation

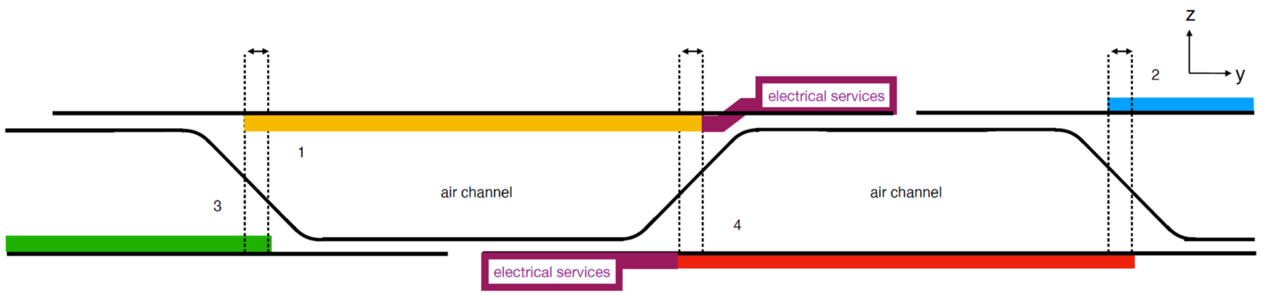
Corrugation pitch and height determine overlap along the short axis → Optimization ongoing

Corrugated disc design

- Face sheet constructed out of modules
- Two module types:
  - **Belly up** (sensor facing outward from corrugation)
  - **Belly down** (sensor facing inward to corrugation)

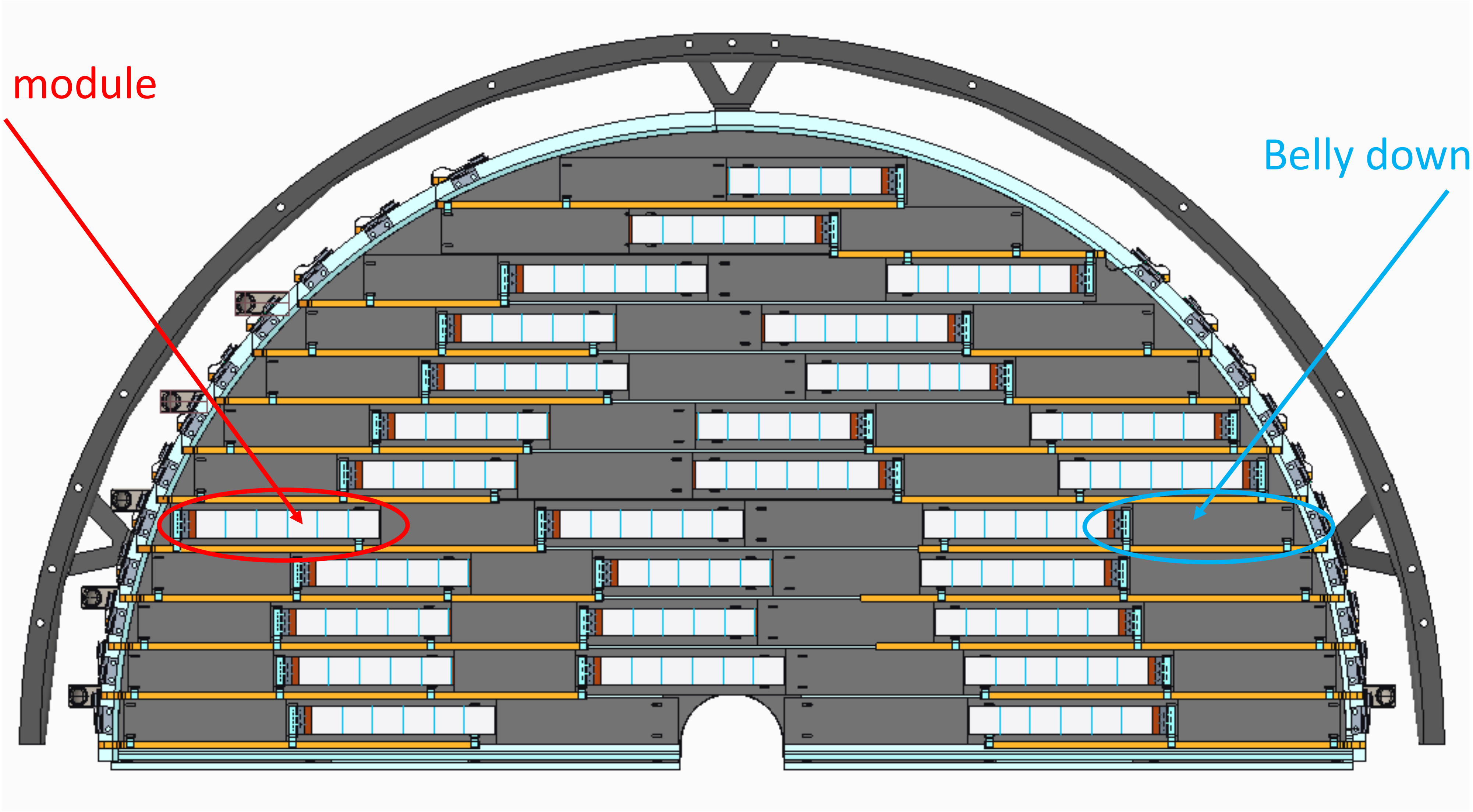






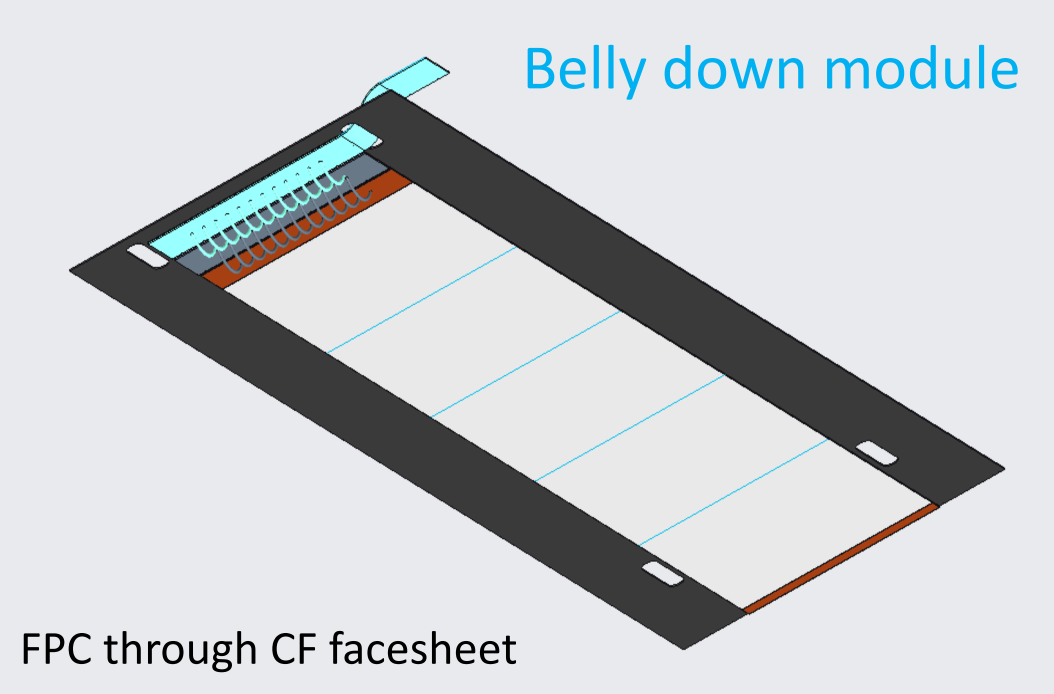
Sensor layout

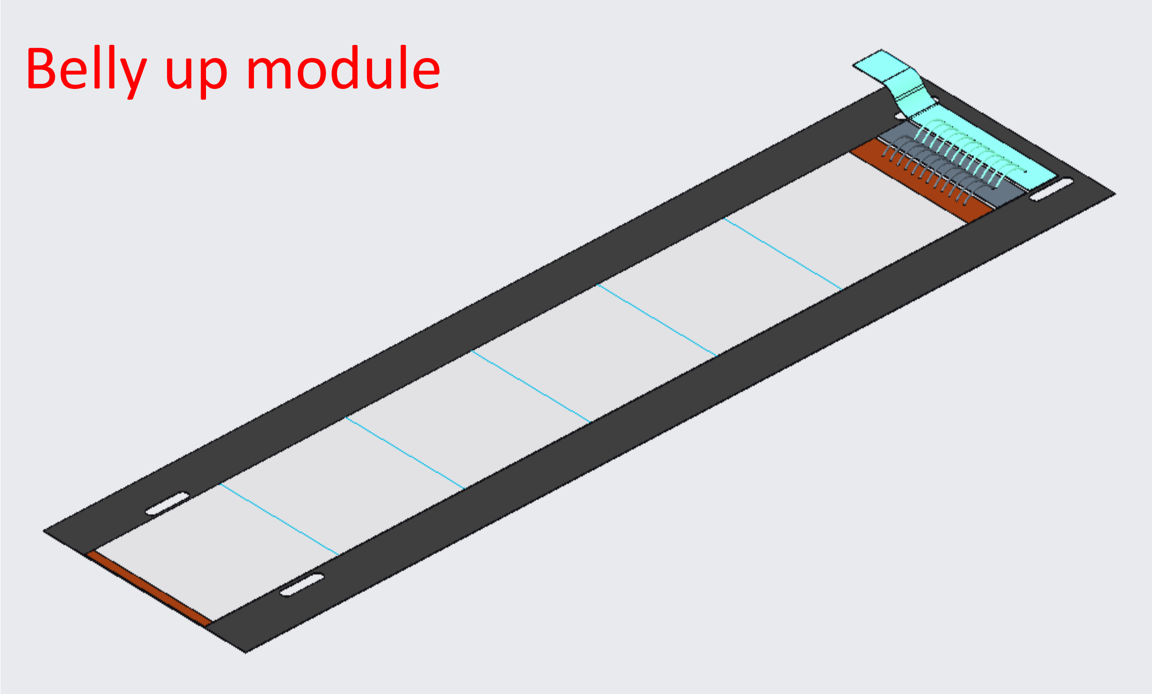
"Front" face of disc (facing in towards interaction region)



Modules

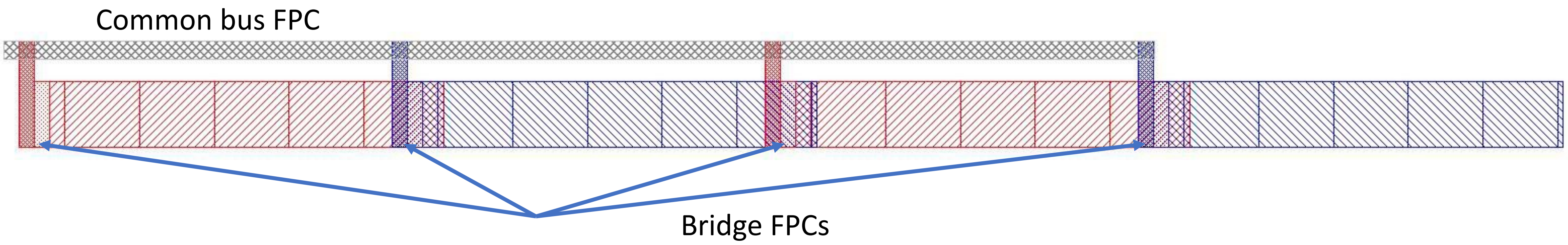
- One sensor glued to a carbon fiber sheet & bonded to an Ancillary ASIC (AncASIC) and Flexible Printed Circuit (FPC)



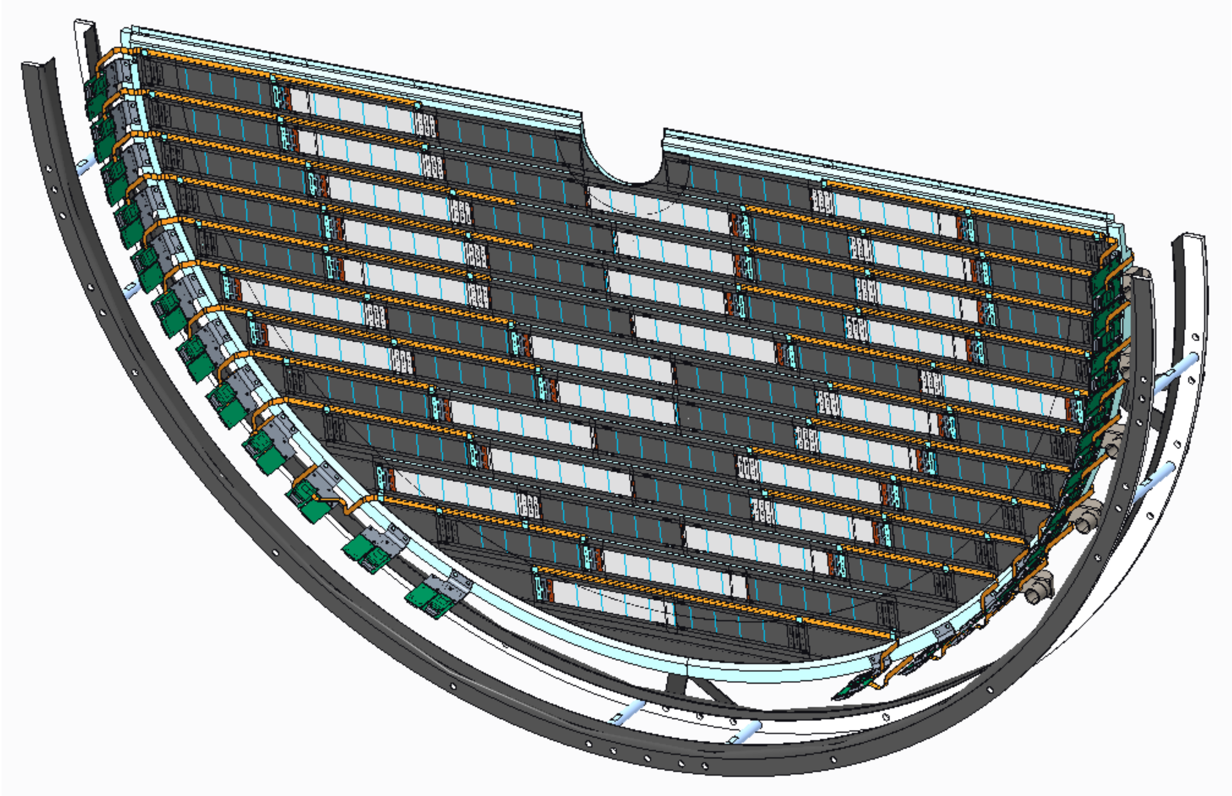


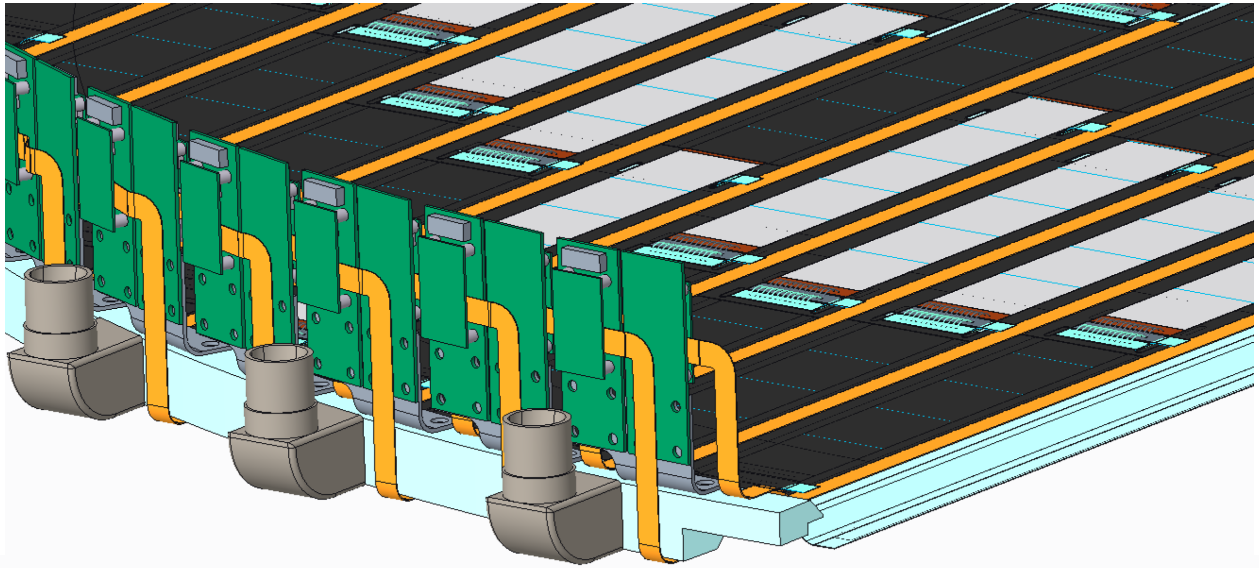
Module grouping

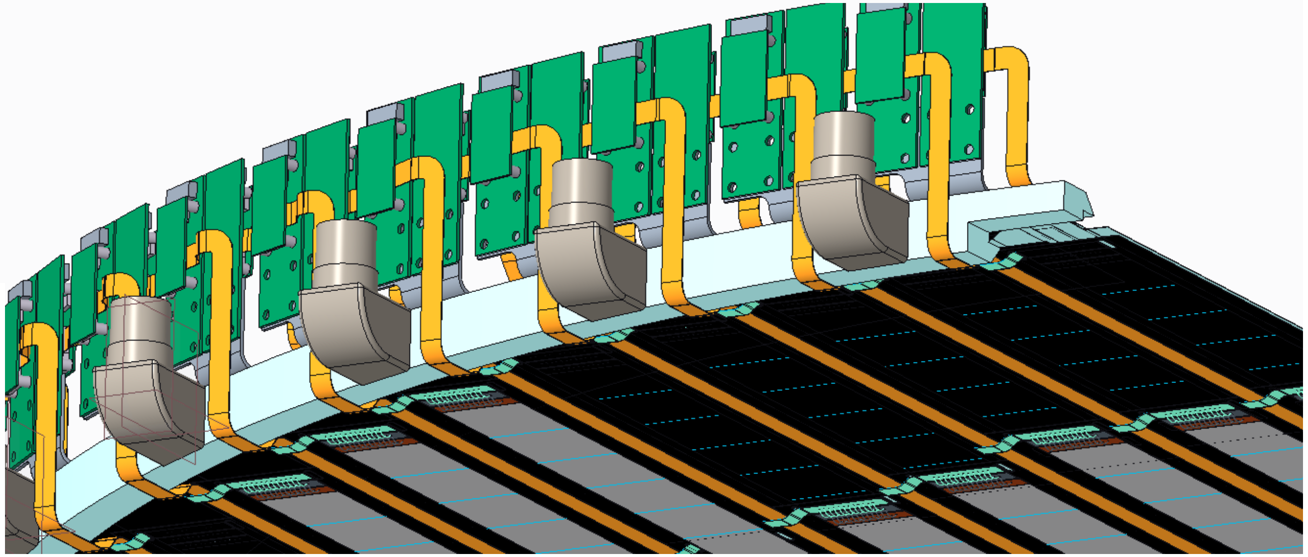
- Up to four EIC-LAS grouped together
- Reduces services with serial powering and multiplexed slow control
- EIC-LAS bonded to AncASIC and FPC bridge
- Up to four FPC bridges connect to common bus FPC
- Common bus FPC connects to Readout Board up to 40 cm away



Readout boards

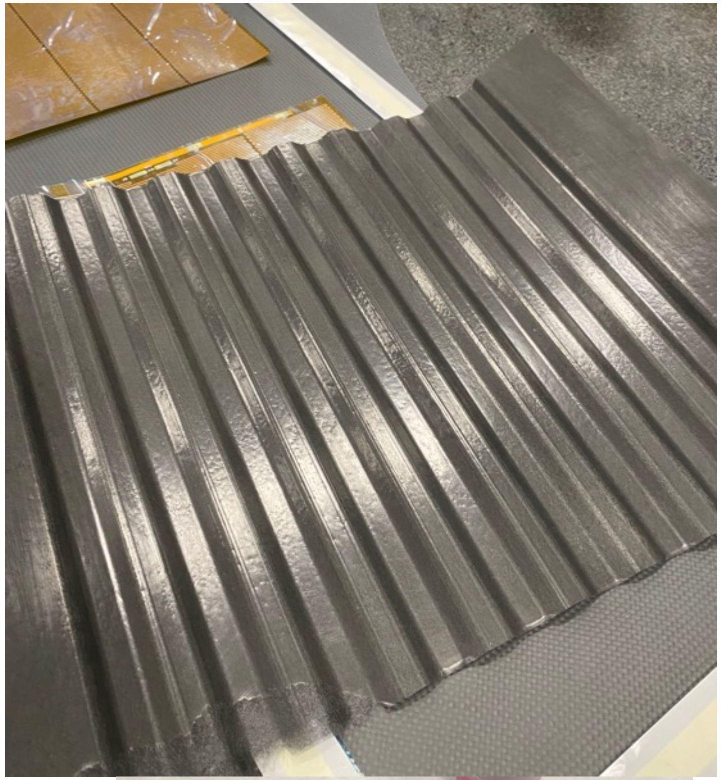


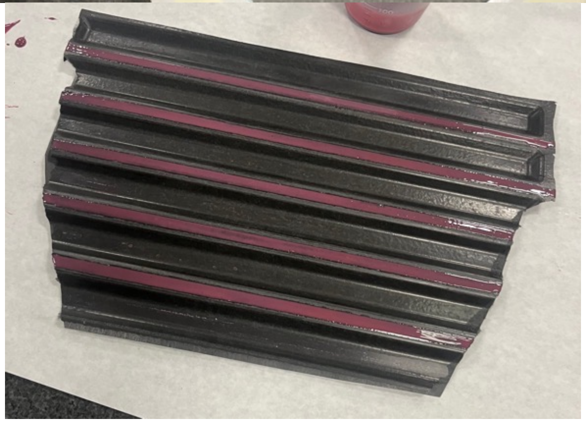




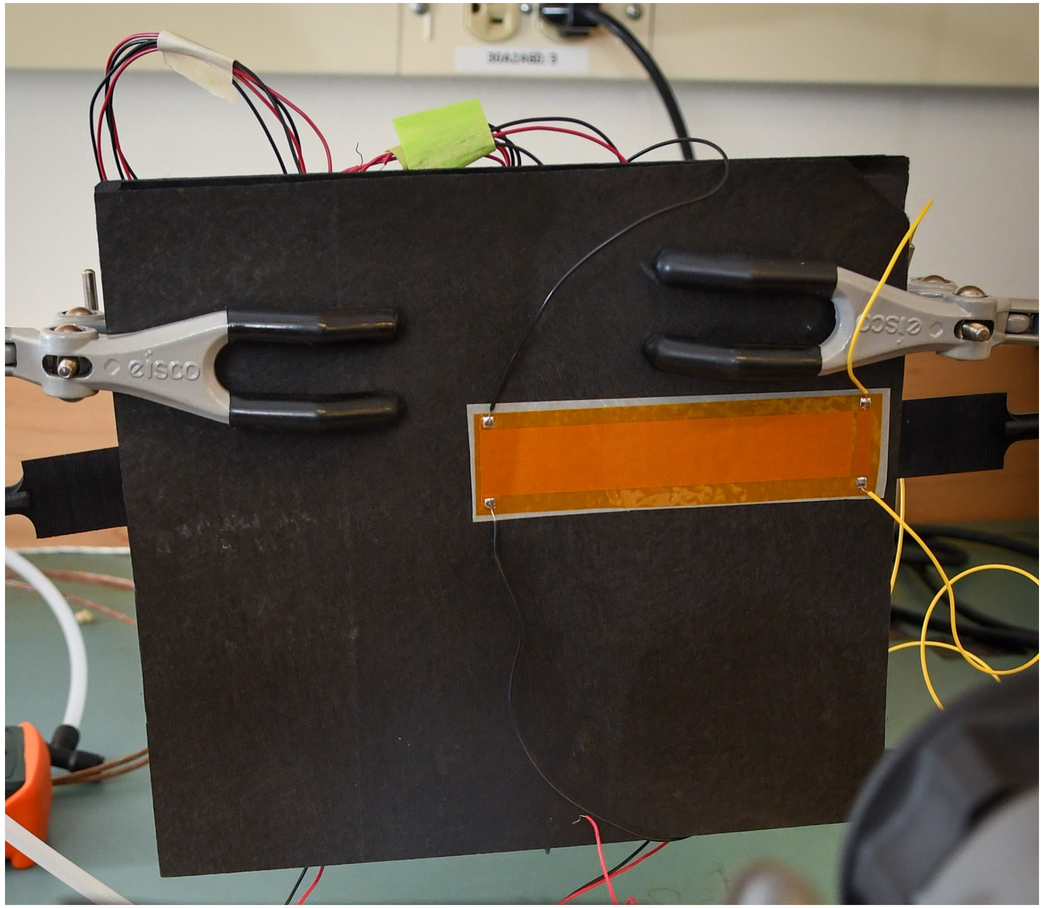
First prototype test piece

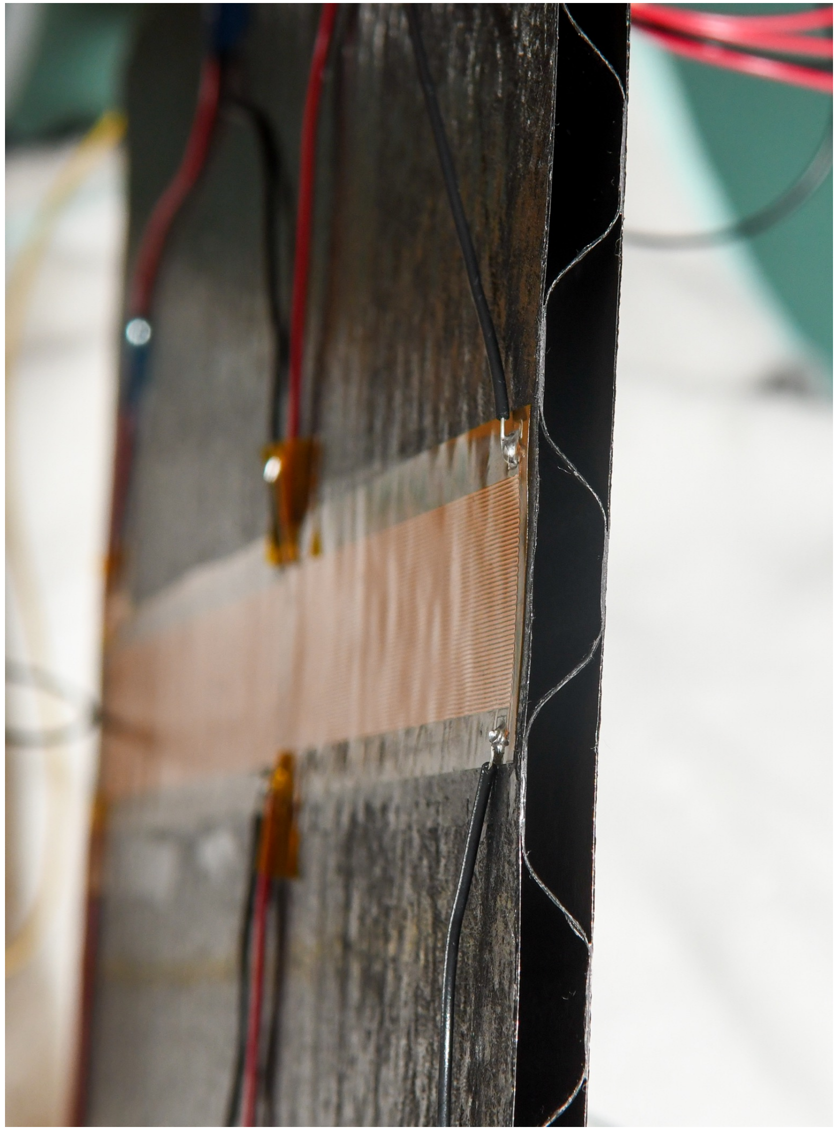
- 2 layers 34 gsm veil & 5 layers 10 gsm resin
- Face sheet glued with 9309 adhesive in 5 mm strips
- Final size of prototype test piece = 22.4 cm x 20.2 cm
- Final weight of prototype test piece = 22.5 g
- Density = 497 gsm → ~0.12% X/X_0



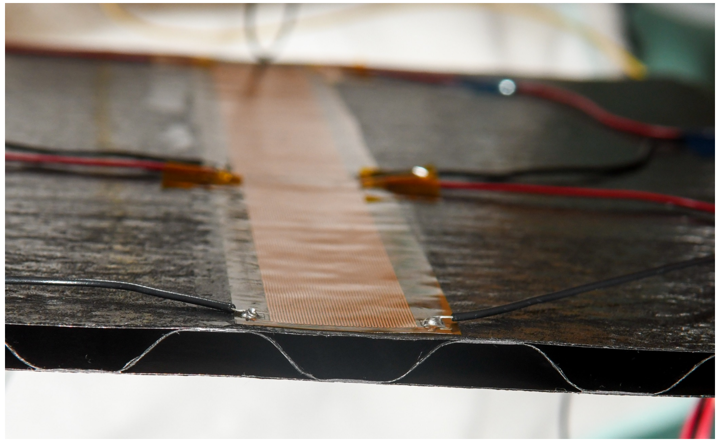


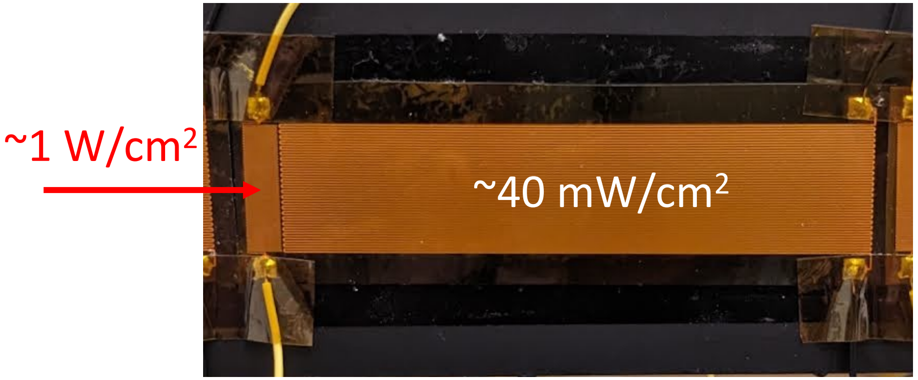
First prototype test piece





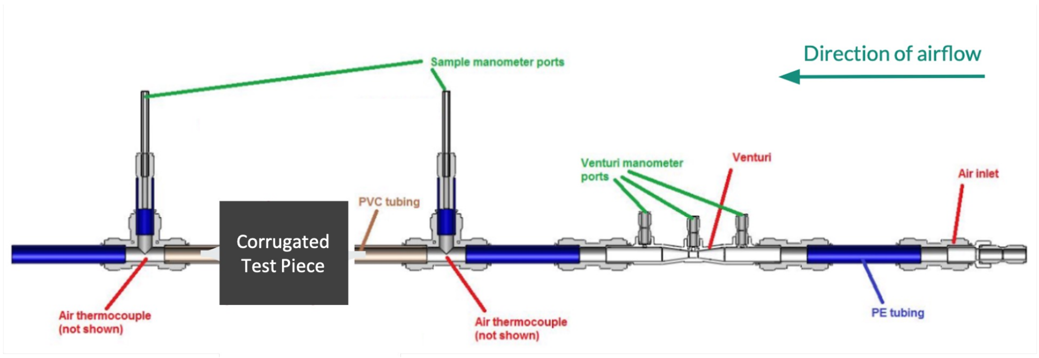
Air cooling



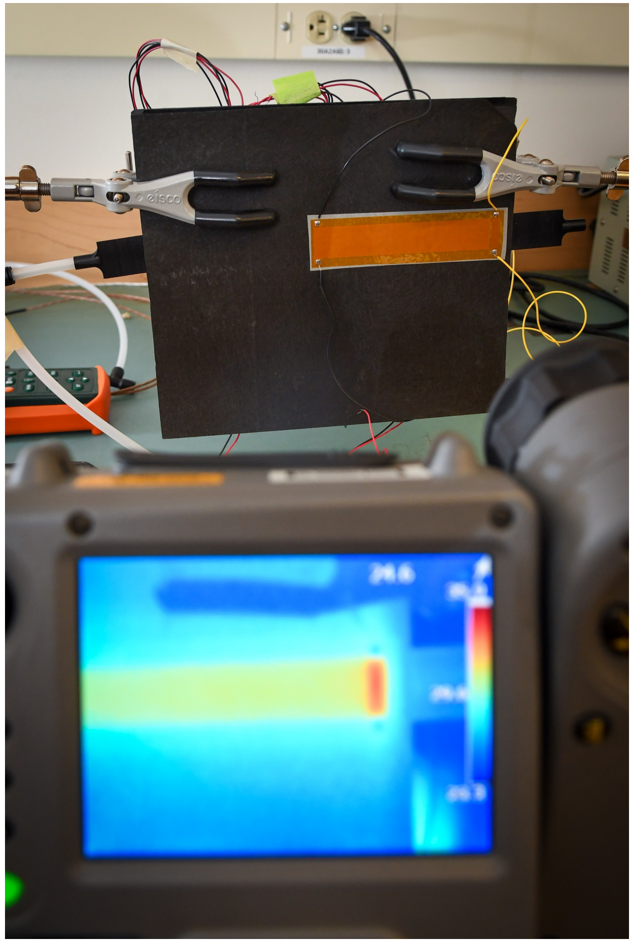


- Corrugated design provides channels for forced air convection
- Thermal prototype → use corrugated test piece
- Heaters with separate zones to mimic sensor power dissipation
  - Left Endcap (LEC): ~1 W/cm^2
  - Matrix/RSUs: ~40 mW/cm^2
- Heaters attached with 3M 467MP double-sided tape, 60 μm thick (used for STAR HFT)

Thermal tests



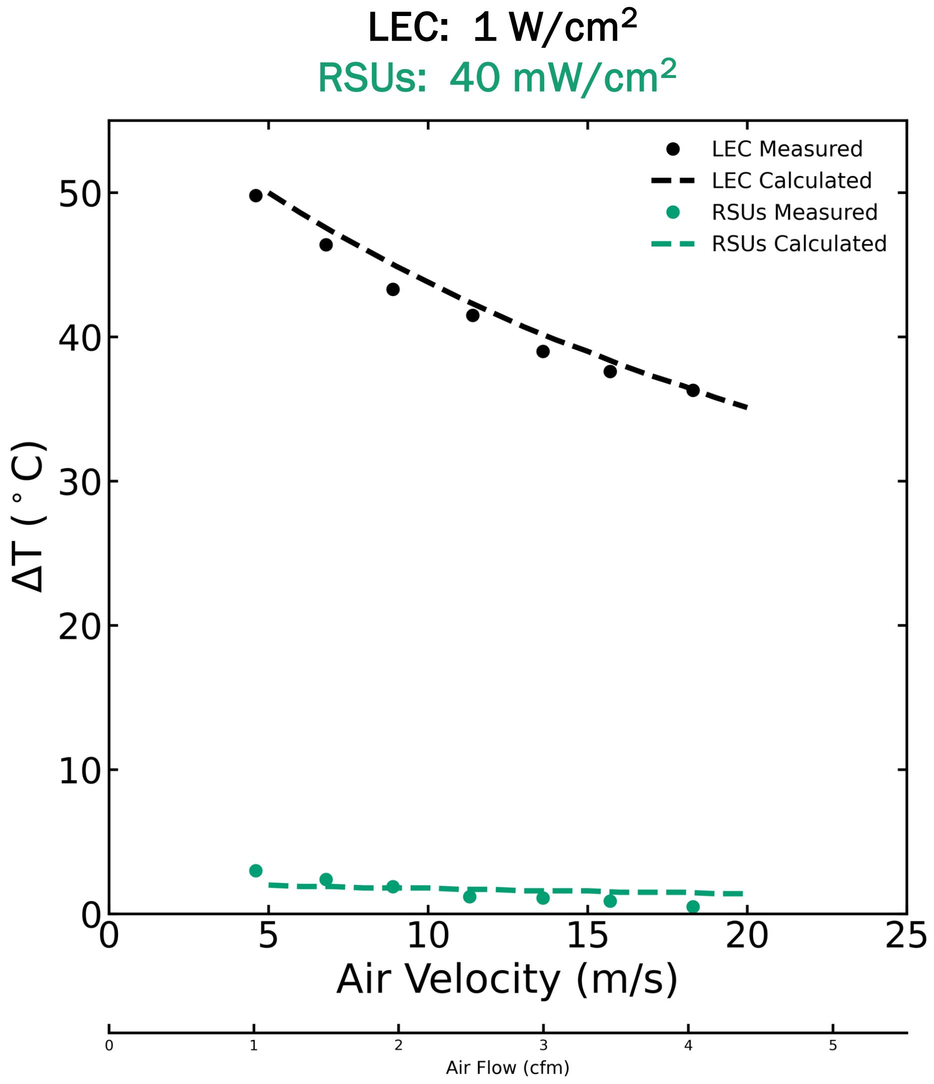
- End goal is operation of sensor at/near ***room temperature***
- Temperatures measured with thermal camera
- $\Delta T = T_{\text{Heater}} - T_{\text{Inlet Air}}$
- **"Reasonable"** ΔT is one that achieves room temperature operation with sensible air inlet temperature
    - $\Delta T < 10°C$ is used often as a "standard", but is not a requirement



Thermal tests

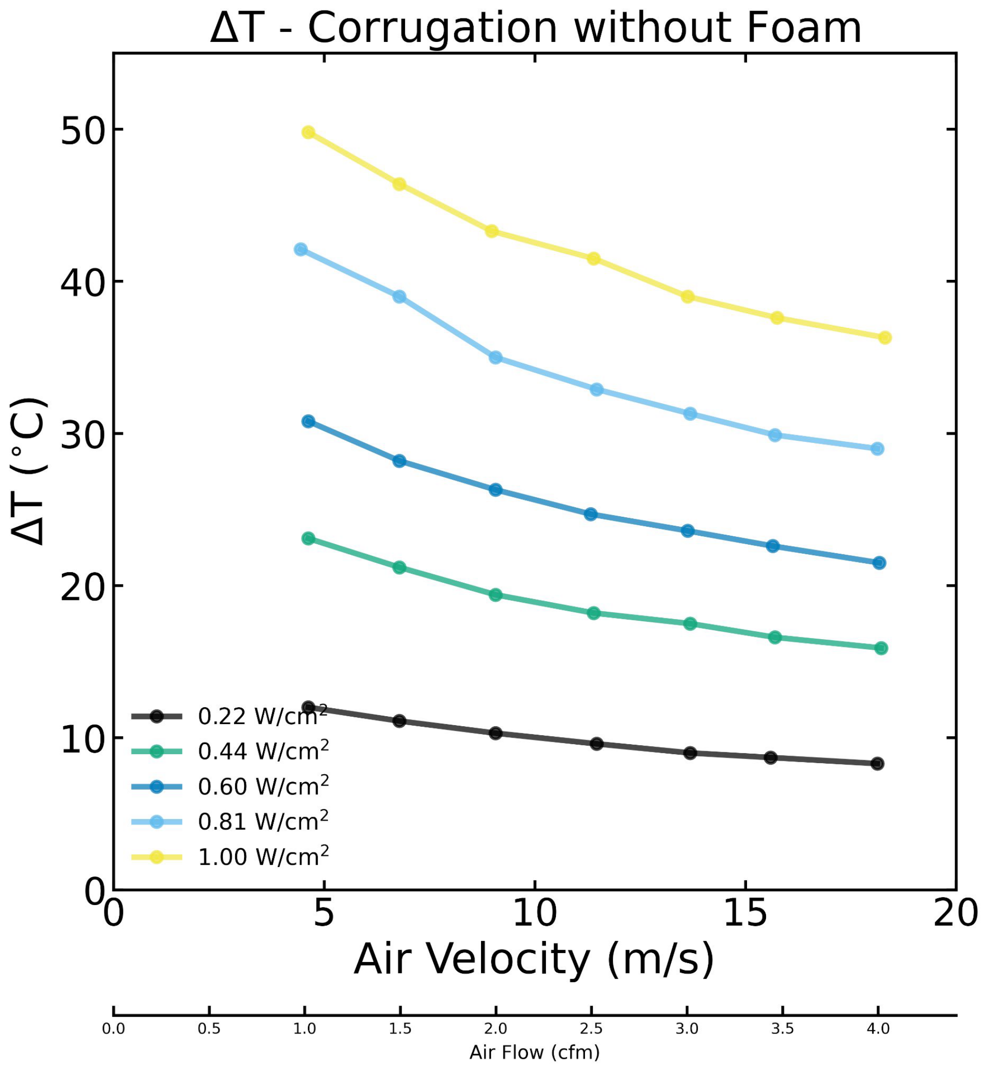
- $\Delta T = T_{Heater} - T_{Inlet\ Air}$
- Air cooling sufficient for **RSUs**
- **LEC** trending in the right direction

- Add carbon foam to mitigate high power density regions?
- Sensor designers believe the LEC power can be reduced



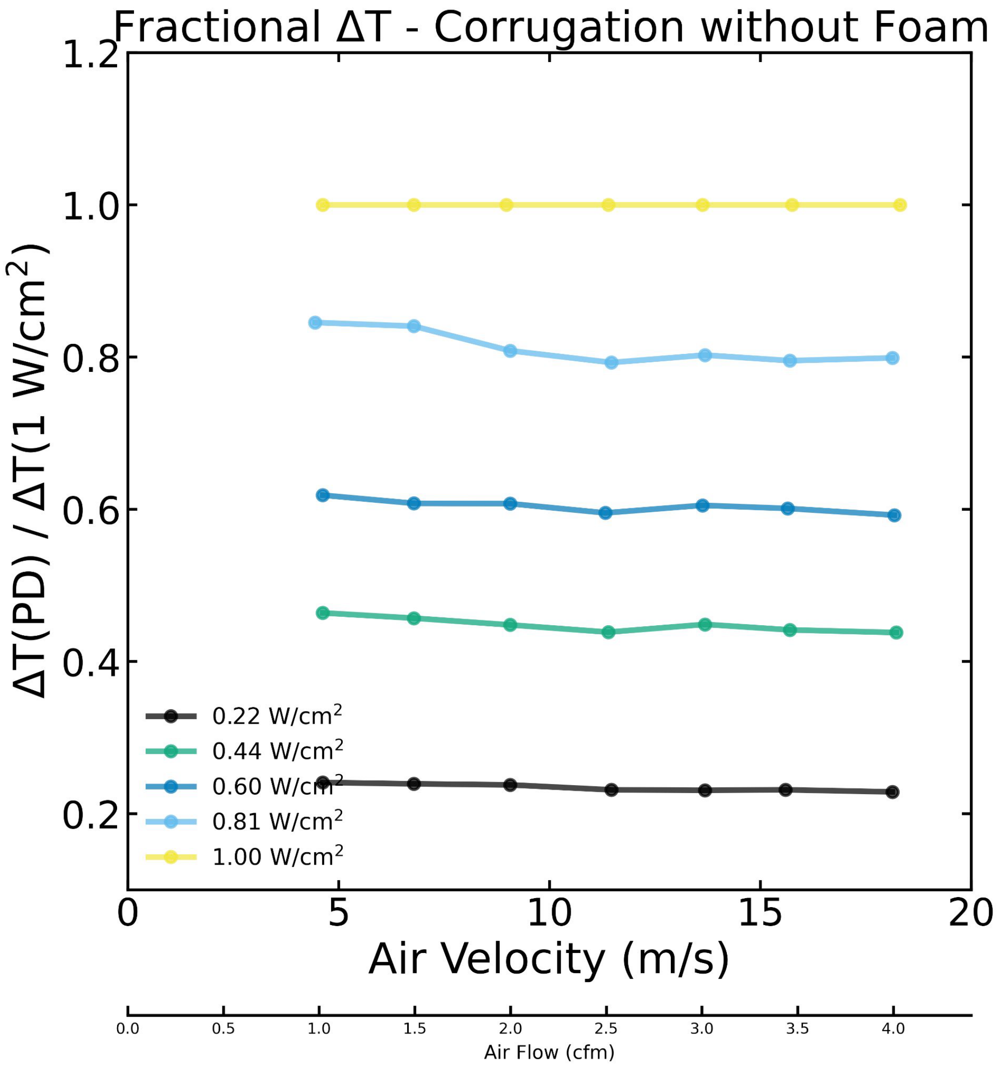
Thermal tests

- Studied a range of LEC power densities
- **ΔT reasonable for power < 0.6 W/cm²**



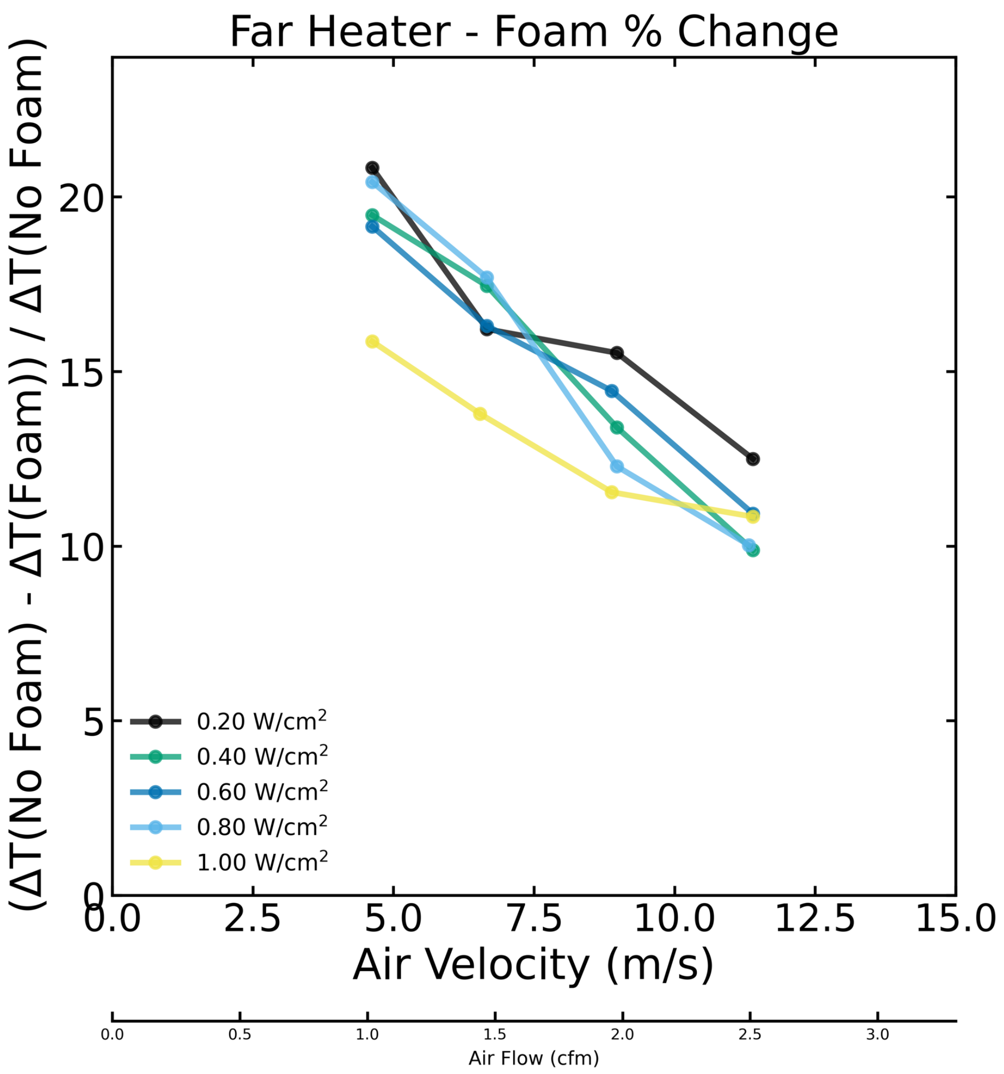
Thermal tests

- Studied a range of LEC power densities
- ΔT reasonable for power < 0.6 W/cm²
- **ΔT scales with power density**



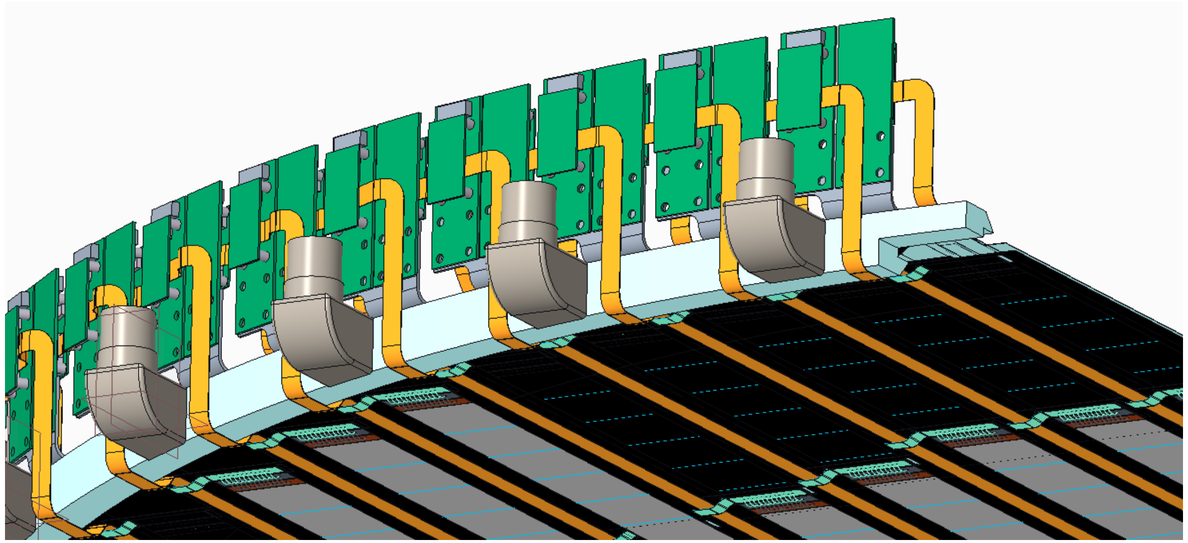
Thermal tests

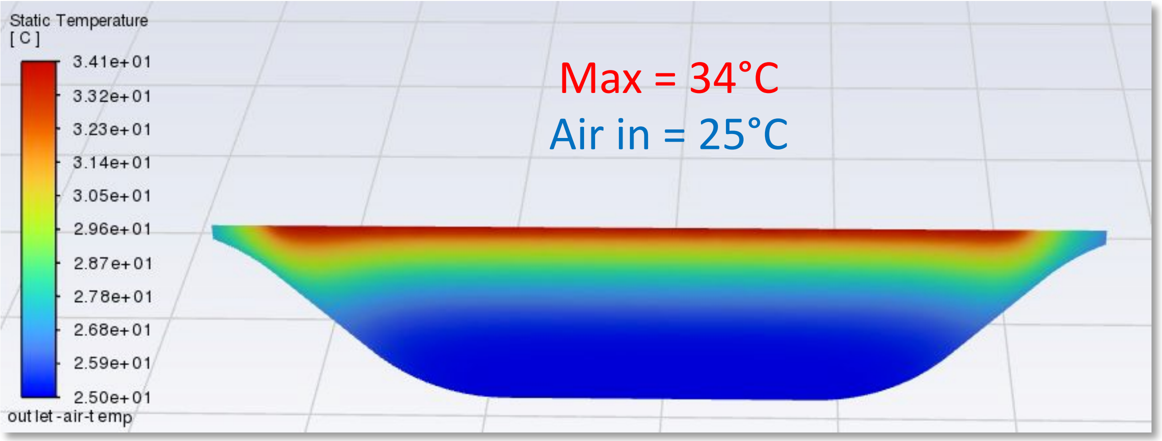
- Studied a range of LEC power densities
- ΔT reasonable for power < 0.6 W/cm^2
- ΔT scales with power density
- **Carbon foam** under LEC provides **10-20% reduction in ΔT**
  - Caveat: this is insulating foam. Will be measured with thermally conductive foam



Air cooling

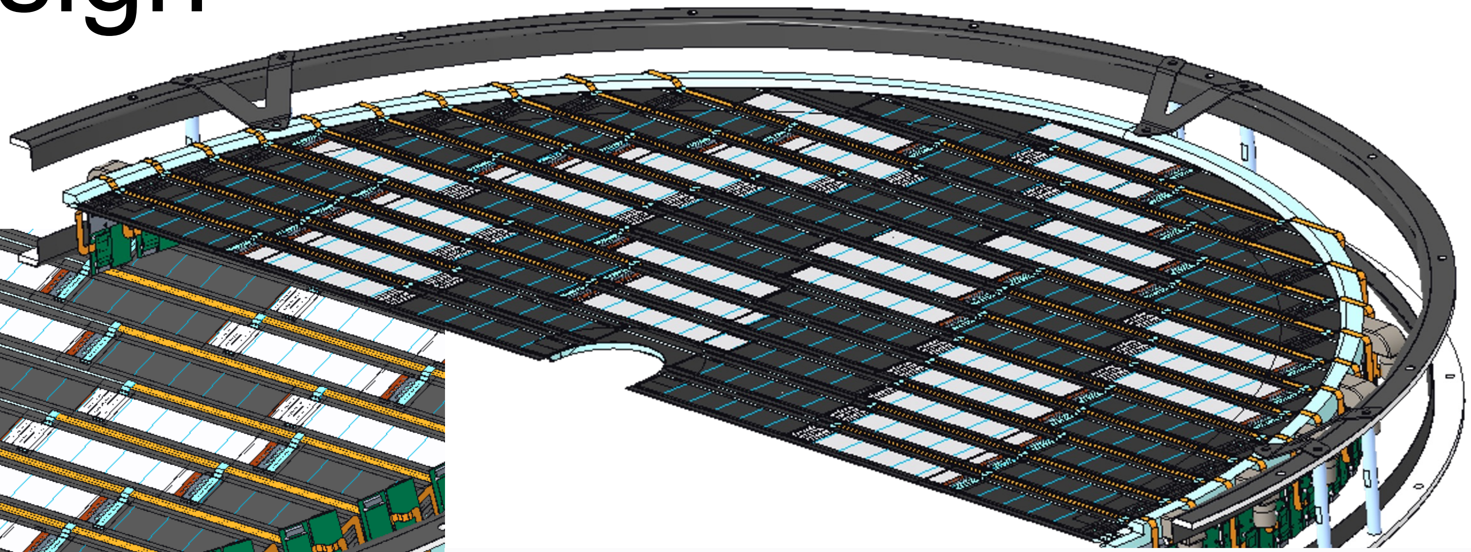
Static Temperature of Cooling Channel
Outlet at a Velocity of 10 m/s

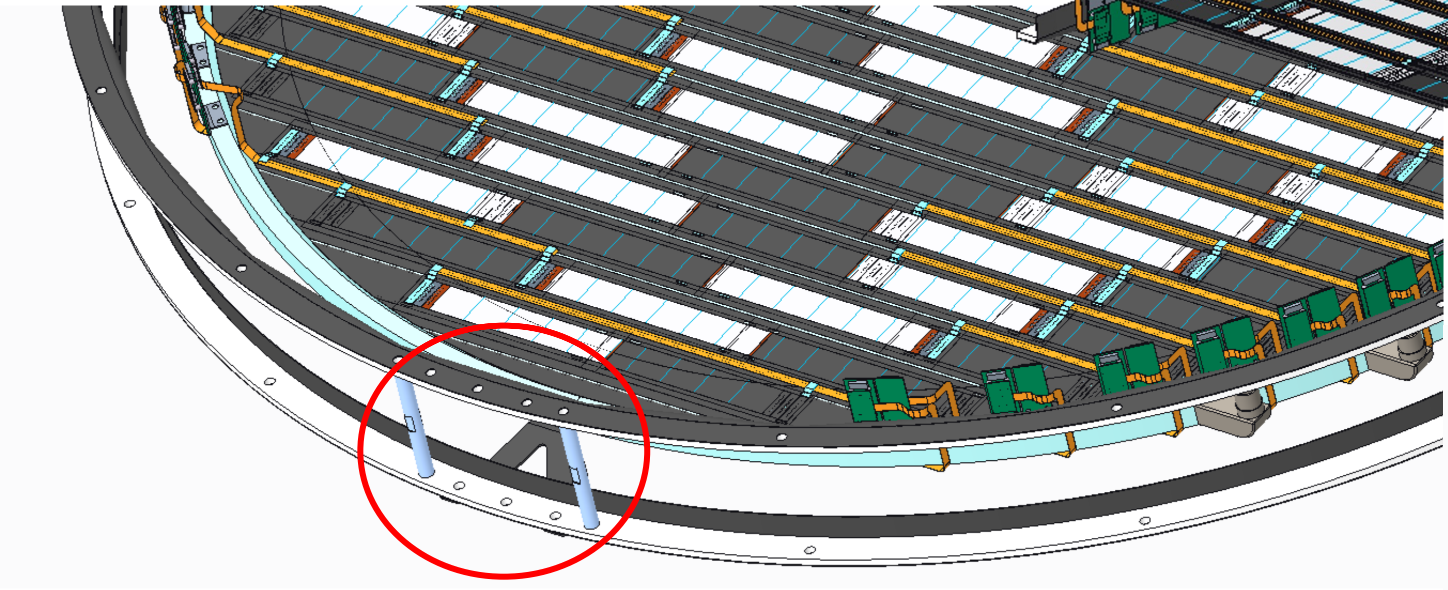


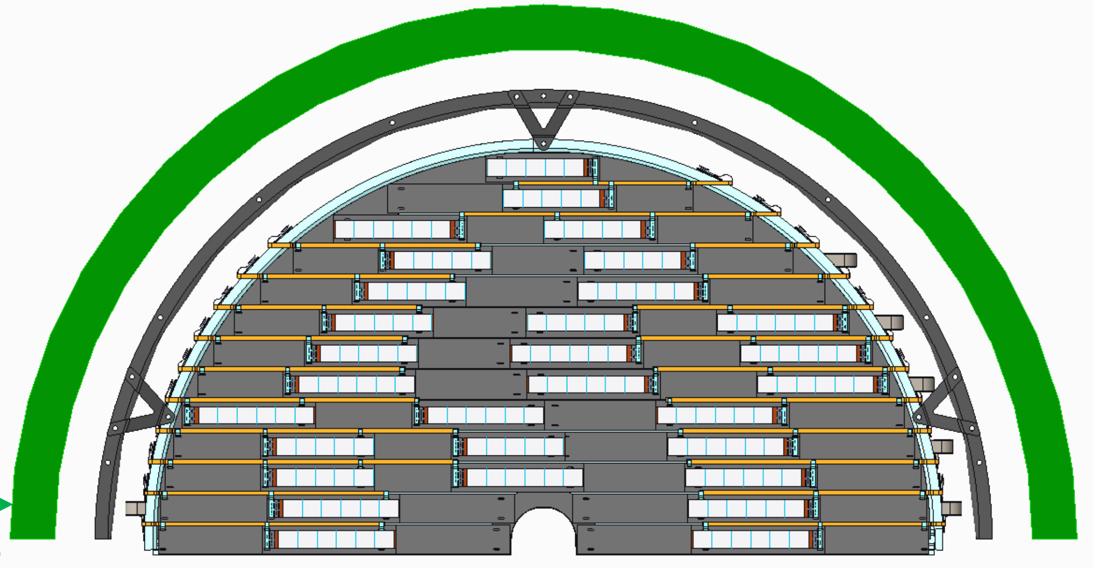


- Volumetric static temperature of air minimal
  - Air can be used in multiple channels → reduces total air volume

Towards a final design



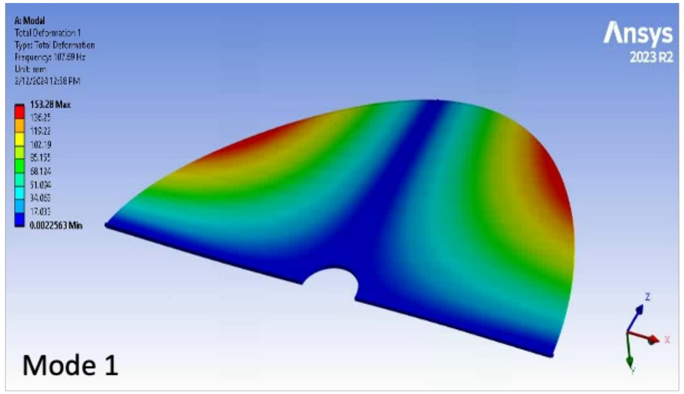


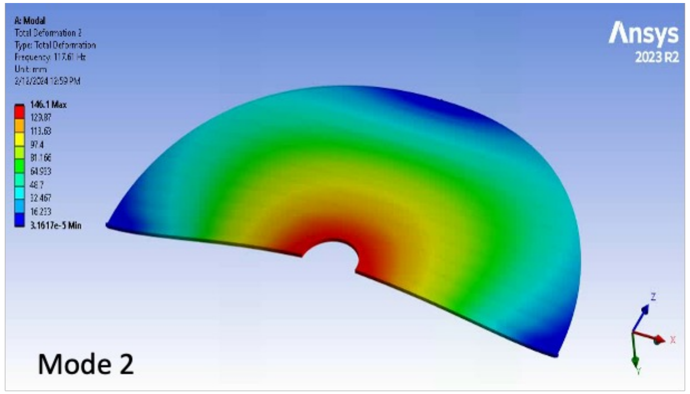


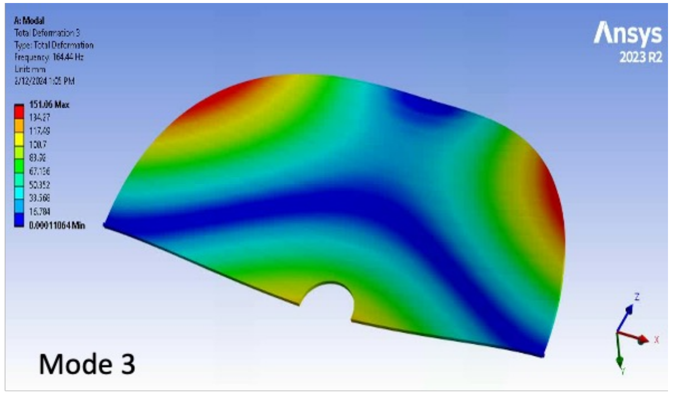
Three connection points per half-disc
Outer rails allow for resting points for the discs

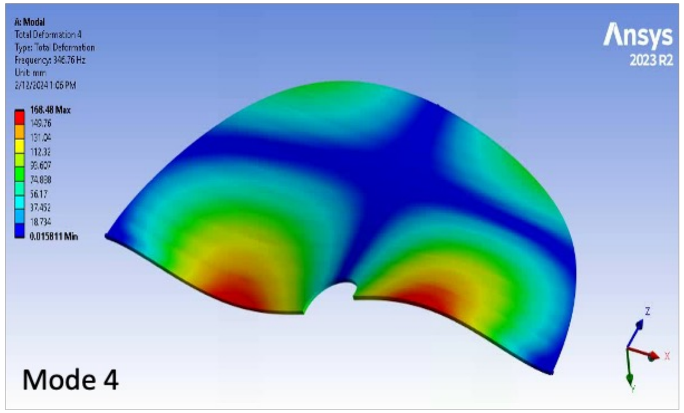
Outer gas detector

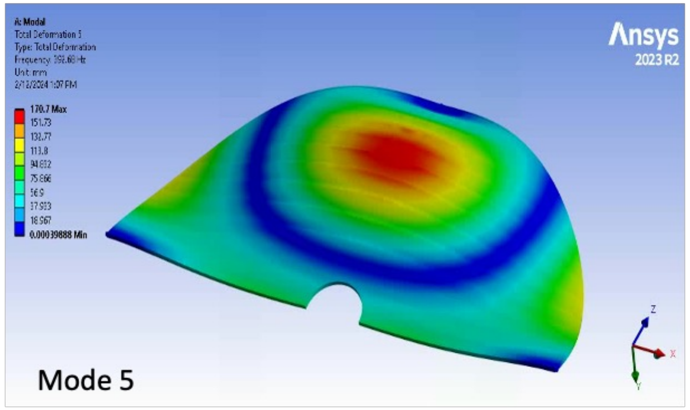
Natural frequency

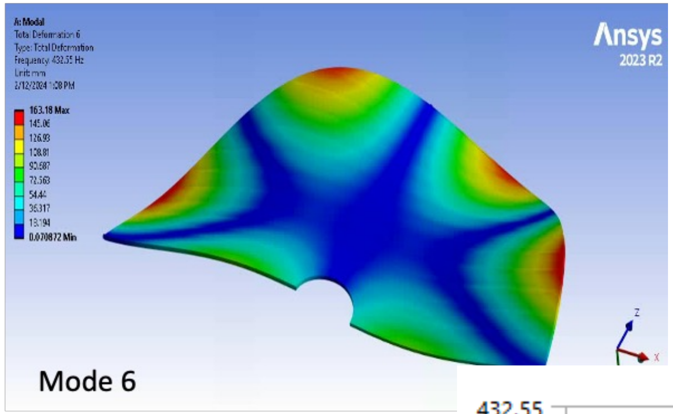




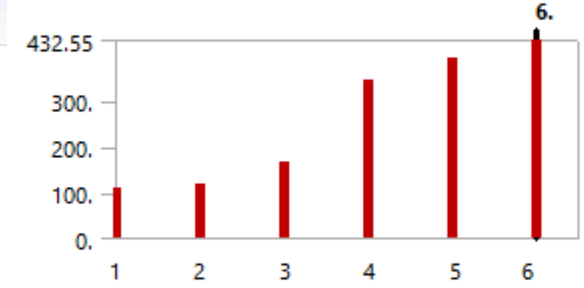








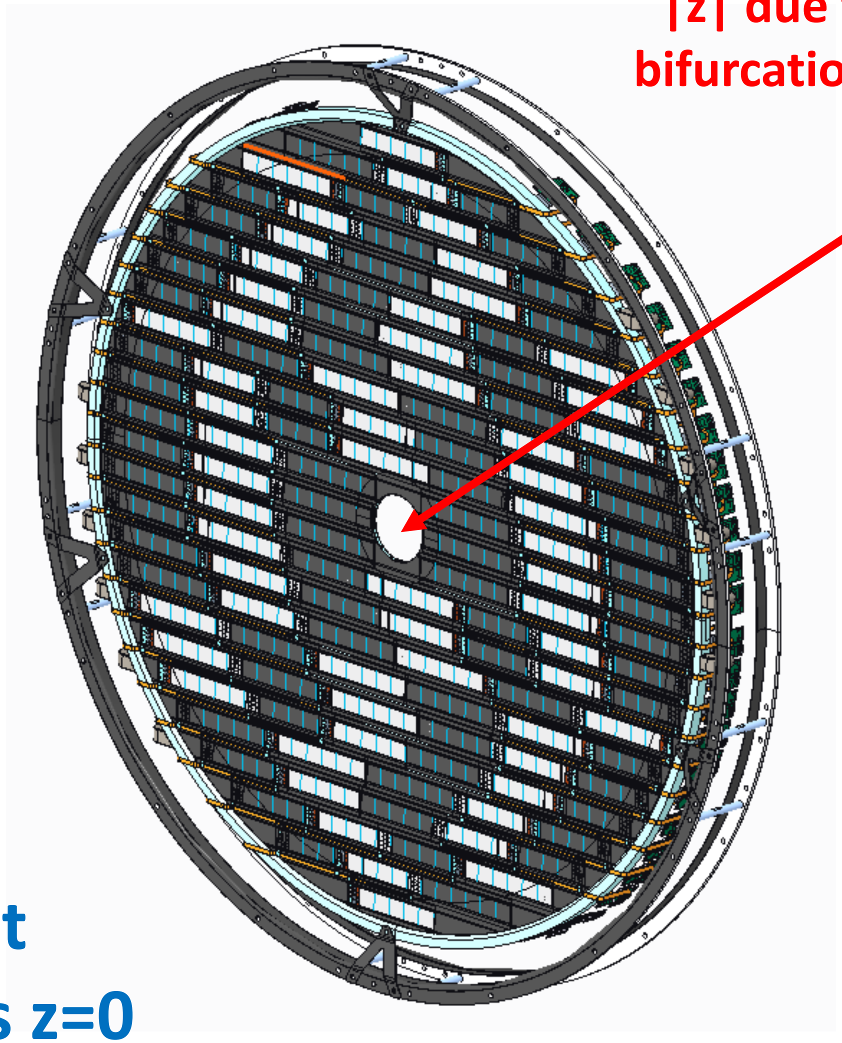
Mode	Frequency [Hz
1.	107.69
2.	117.61
3.	164.44
4.	346.76
5.	392.68
6.	432.55



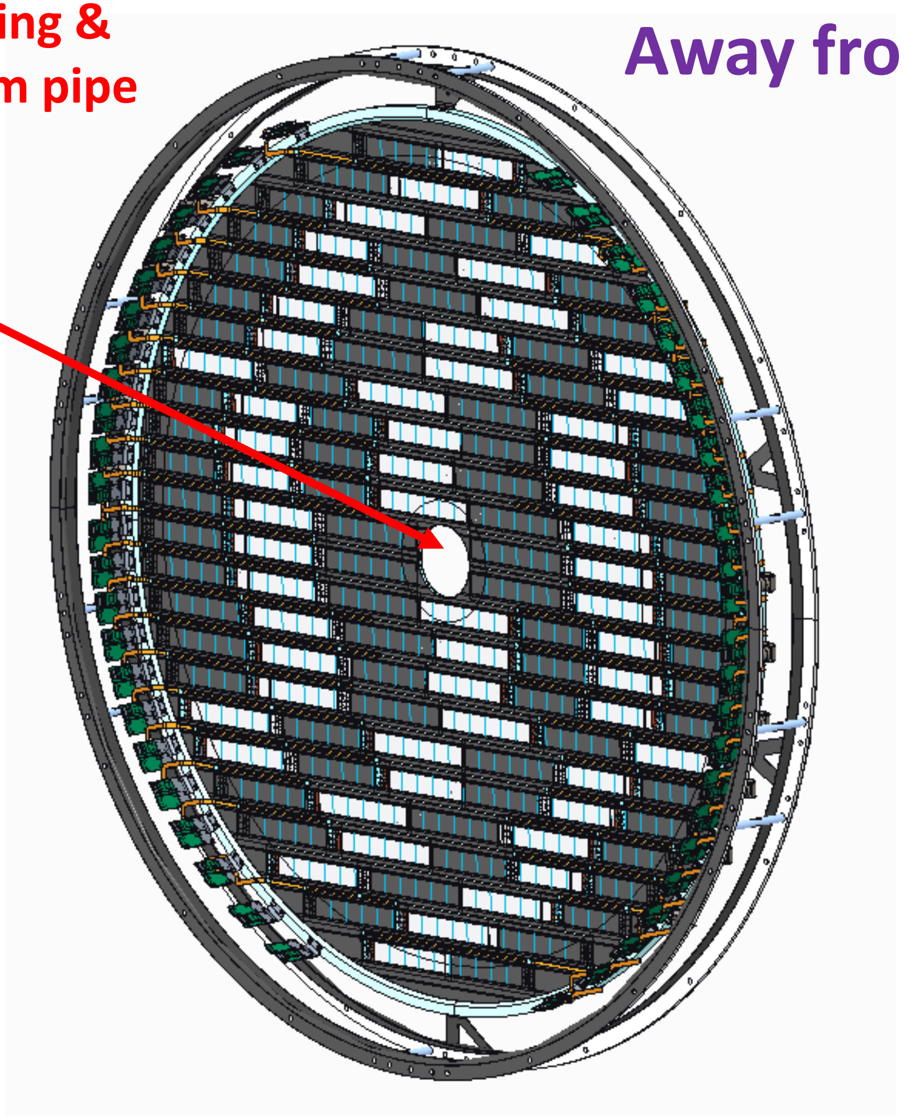
Corrugated Disc of 6 mm Height – Rev 2 (Mesh size = 2 mm)

Full discs

Inner Radii will grow with |z| due to the widening & bifurcation of the beam pipe

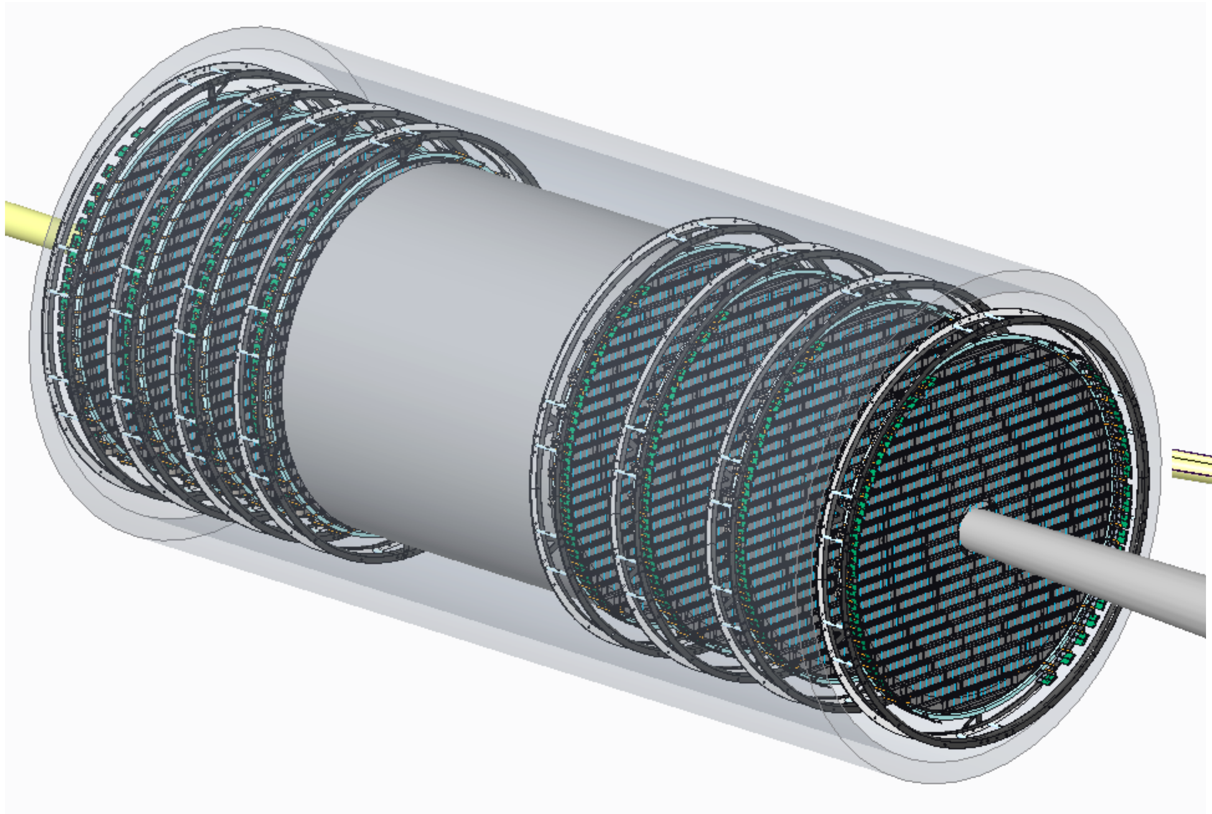


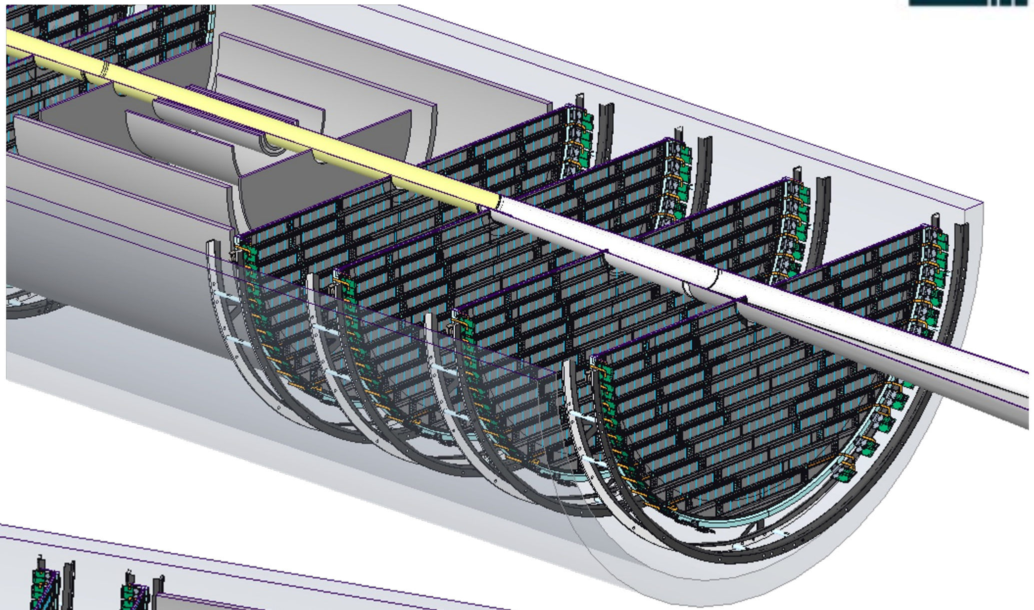
Front
Towards z=0

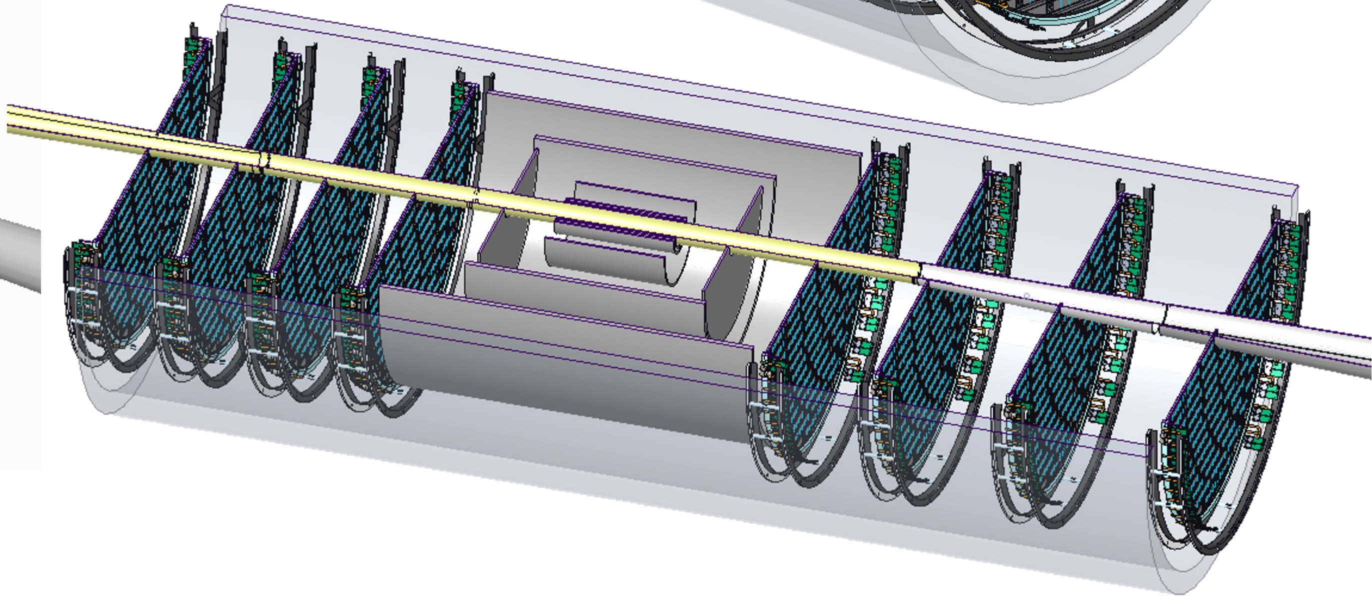


Back
Away from z=0

Within the ePIC SVT design







Top-down symmetry favors a horizontal segmentation of the discs

Summary

- EIC tracking requirements pose challenges for a low mass, high acceptance tracker
- Developed a double-sided disc design with a corrugated carbon fiber core
  - Sensors in 4 planes (front/back, belly up/down)
  - Provides channel for forced air convection
- First prototype piece made and tested with thermal mock ups of the sensor
- Prototypes with new layups currently being made for thermal and mechanical tests
- Pre-production/construction begins in 2026