SVT

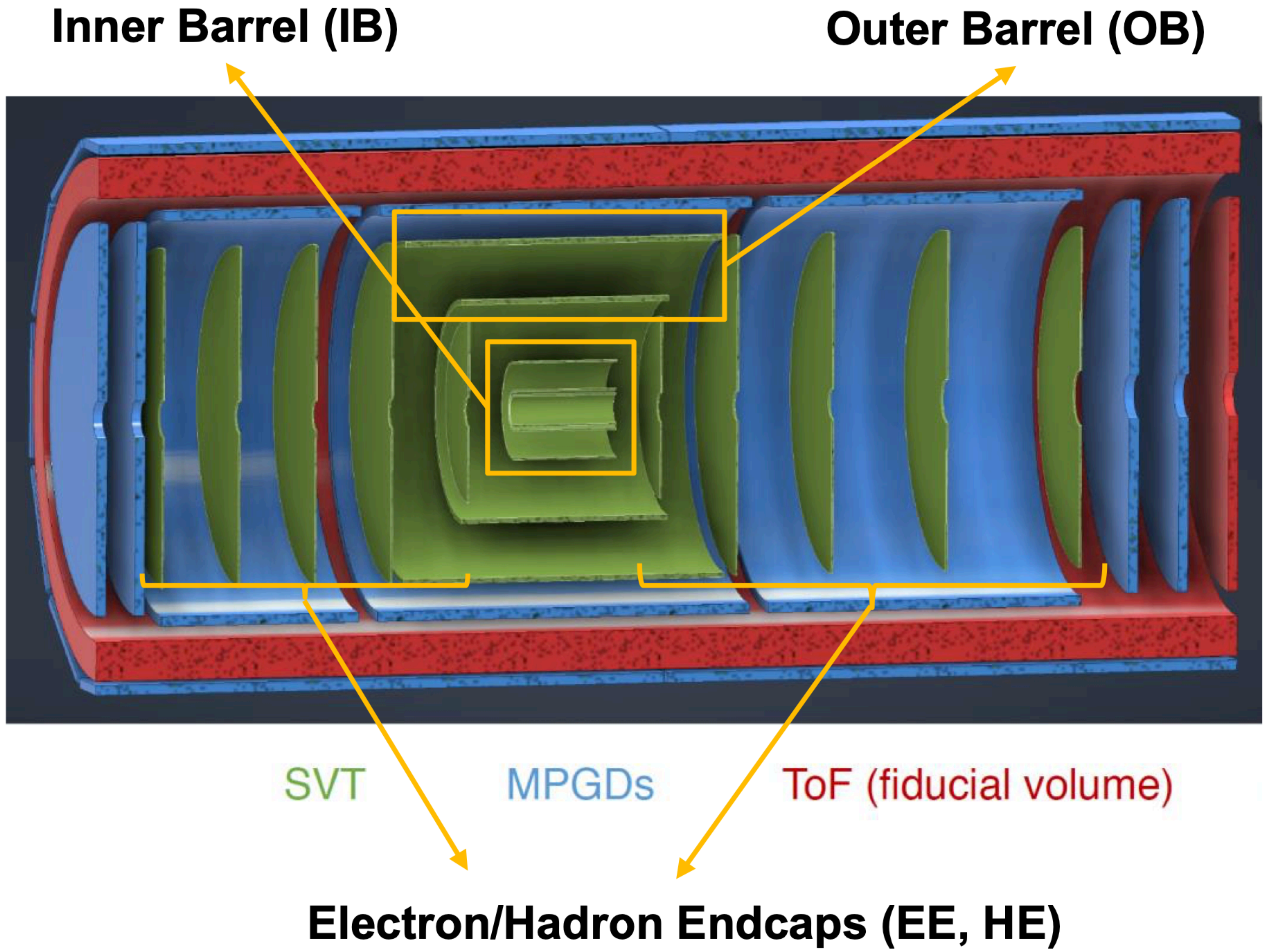
Physics-driven needs on tracking and vertexing for the EIC project detector ePIC are quite demanding. They drive the requirement of a well-integrated, large-acceptance, high-precision, low-mass tracking and vertexing subsystem: Silicon Vertex Tracker (SVT).

Tracking requirements from PWGs						
			Momentum res.	**Material budget**	**Minimum pT**	**Transverse pointing res.**
η						
-3.5 to -3.0	Central Detector	Backward Detector	$\sigma p/p \sim 0.1\% \times p \oplus 0.5\%$	~5% X0 or less (~MAPS + MPGD trackers)	100-150 MeV/c	
-3.0 to -2.5					100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 40 μm
-2.5 to -2.0			$\sigma p/p \sim 0.05\% \times p \oplus 0.5\%$		100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 20 μm
-2.0 to -1.5					100-150 MeV/c	
-1.5 to -1.0					100-150 MeV/c	
-1.0 to -0.5		Barrel	$\sigma p/p \sim 0.05\% \times p \oplus 0.5\%$		100-150 MeV/c	dca(xy) ~ 20/pT μm ⊕ 5 μm
-0.5 to 0						
0 to 0.5						
0.5 to 1.0						
1.0 to 1.5		Forward Detector	$\sigma p/p \sim 0.05\% \times p \oplus 1\%$		100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 20 μm
1.5 to 2.0					100-150 MeV/c	
2.0 to 2.5					100-150 MeV/c	
2.5 to 3.0			$\sigma p/p \sim 0.1\% \times p \oplus 2\%$		100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 40 μm
3.0 to 3.5					100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 60 μm

Yellow Report, Table 11.2

In turn, SVT requires high-granularity and low-power active elements — synergy with ITS3 sensor development

minimized material associated with mechanics, cooling, power, readout, slow control, etc.

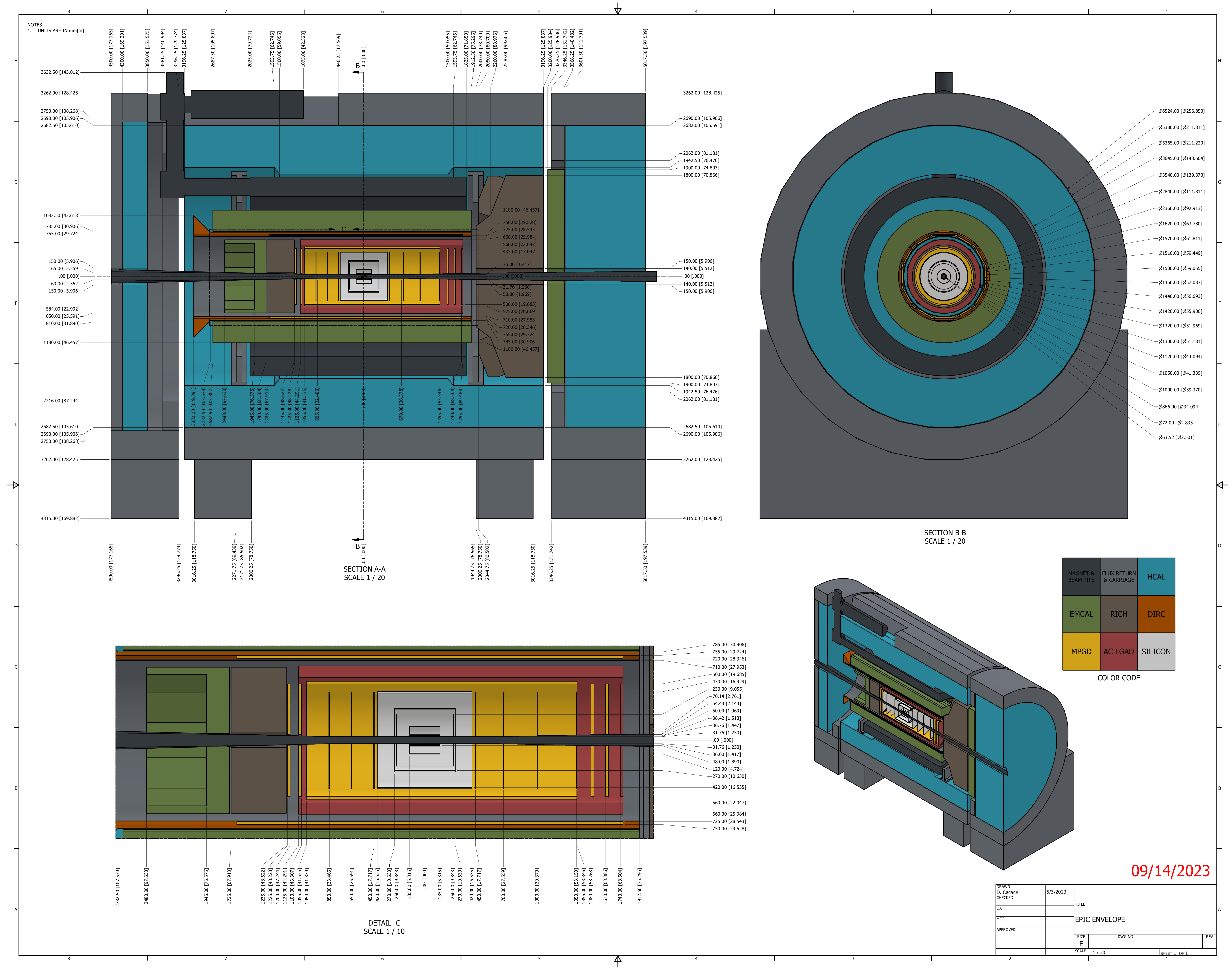


SVT Total (active) area **~ 8.5 m^2**

ePIC SVT target specifications	
Spatial resolution	~ 5 um
Power	< 40 mW/cm^2
Frame rate	≤ 2 μs
Material budget (per layer)	IB: **0.05%** X/X_0 OB: **0.25, 0.55%** X/X_0 EE/HE: **0.25%** X/X_0

Five barrel layers, normally referred to as L0—L4; L0,L1,L2 form the Inner Barrel (IB) and L3,L4 the Outer Barrel (OB)

Five disks on either side of the nominal interaction point, also numbered 0—4



SVT volume:

-1050 < z < 1350 mm

r ~ 430 mm

IB (L0—L2) wafer-scale sensor

i.e. length and radii derive from sensor dimensions

OB, EE, HE use EIC-LAS

OB — stave based

EE/HE — disks

Recent SVT workfest, c.f.

https://indico.bnl.gov/event/20473/sessions/6736/#all.detailed

has a wealth of information

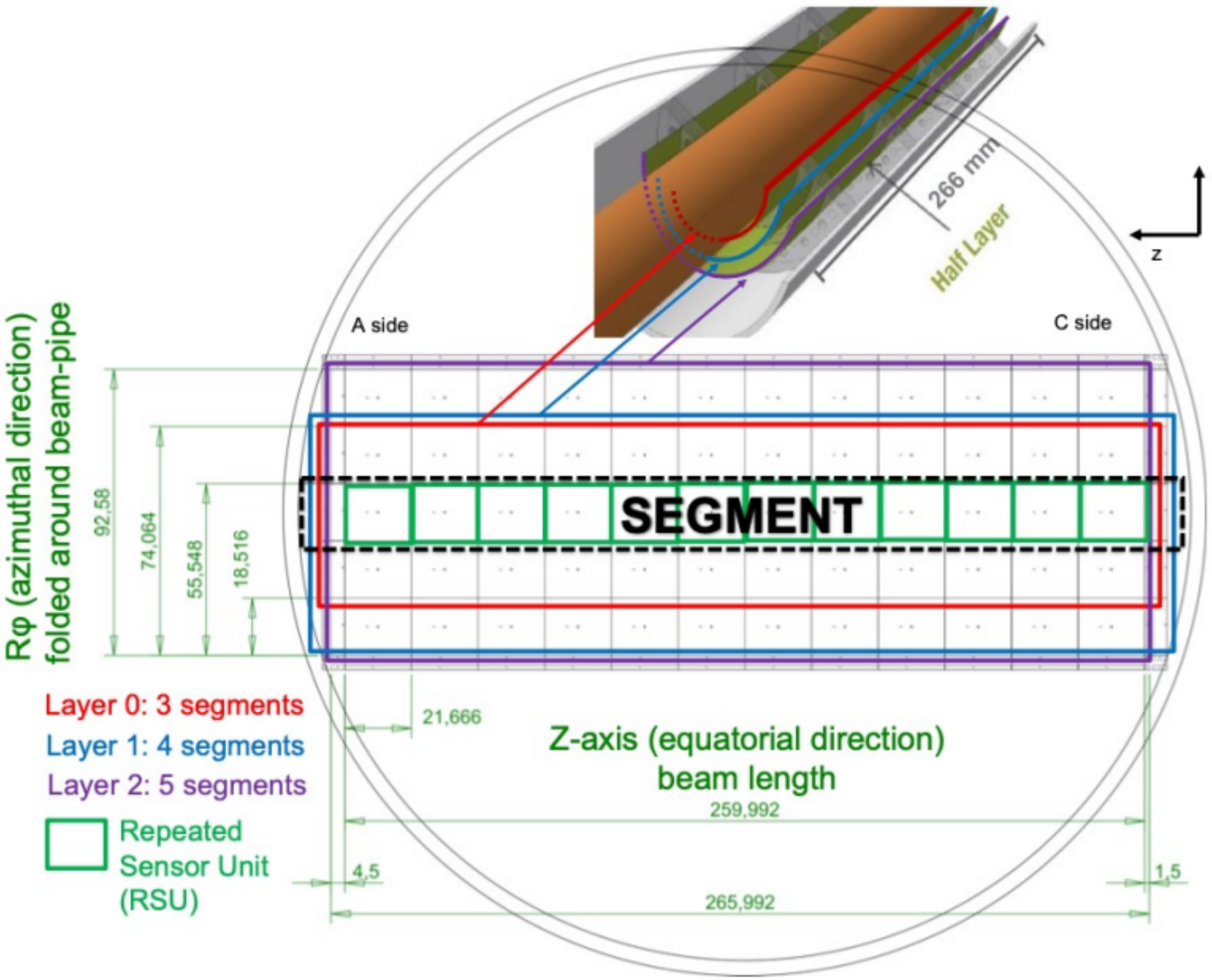
What follows is in part a summary/re-use and in part new/additional.

Sensor

Background - MOSAIX

ITS3 Chip development

- CERN currently developing a new chip for the ITS3 upgrade of ALICE – MOSAIX
- Will be “wafer scale” – full length, one reticle wide
- Idea is to thin and bend them around the beampipe. Dicing to different width will give the three required layers.

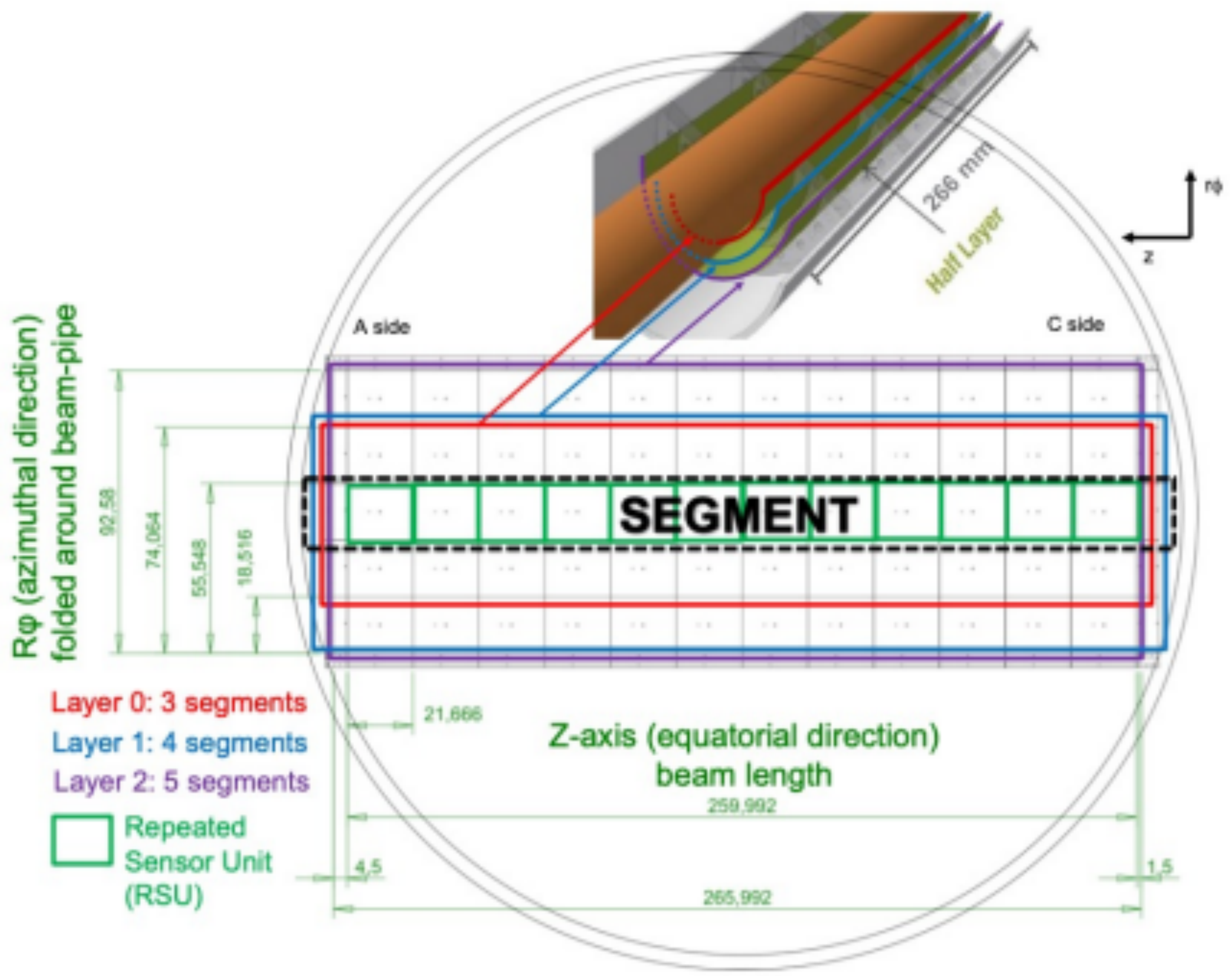


Science and Technology Facilities Council

Most recent data from the ITS3 plenary: https://indico.cern.ch/event/1341665/

Iain Sedgwick (RAL)

Background - MOSAIX



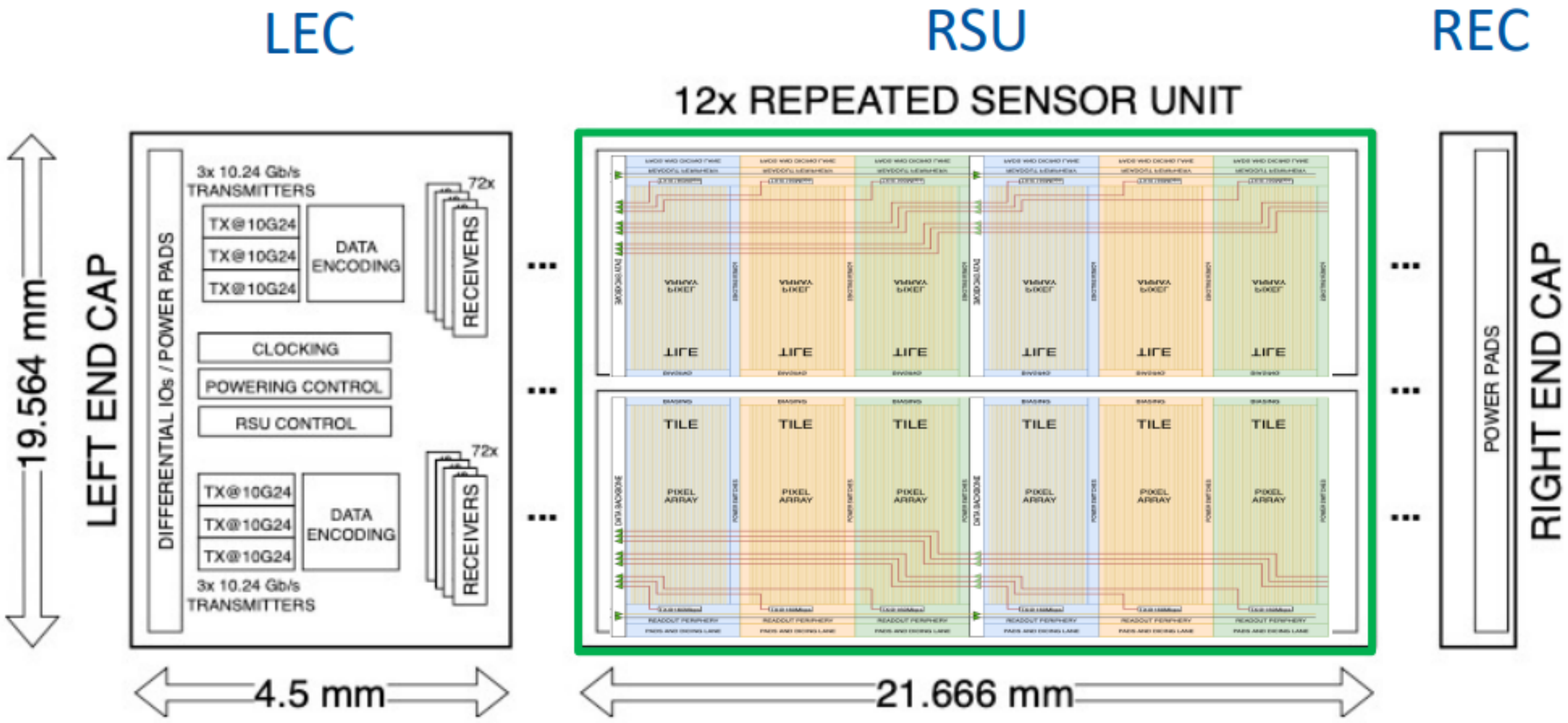
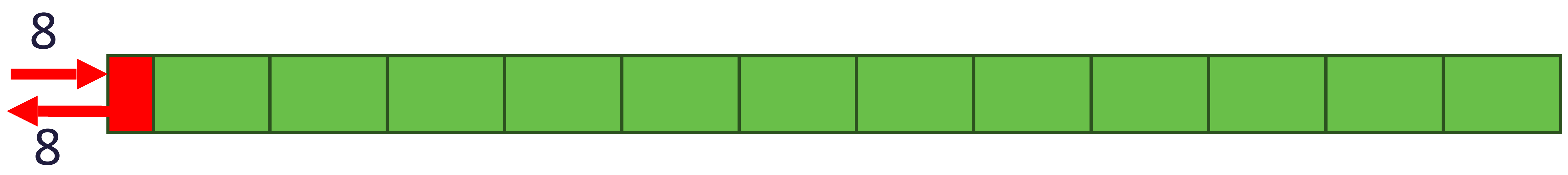
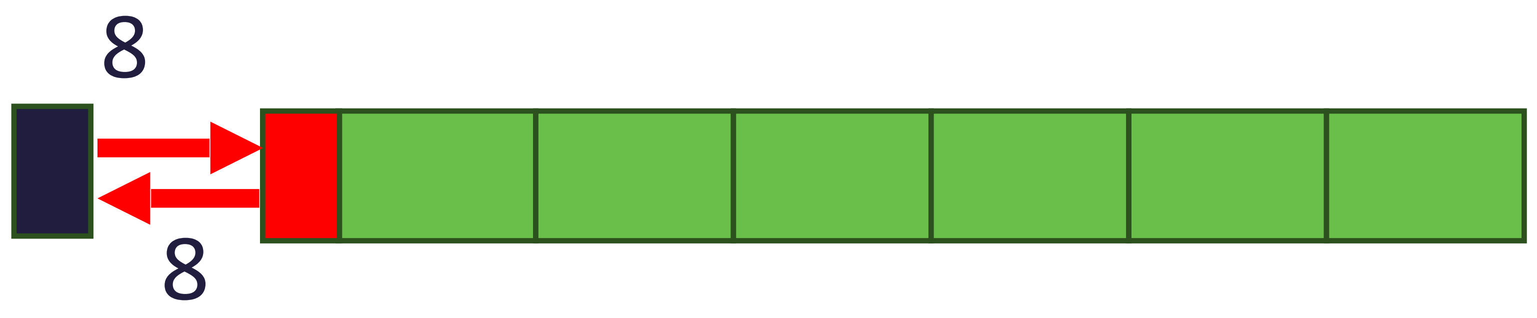


Figure 3.34: Block diagram of the sensor segment.

Iain Sedgwick (RAL)

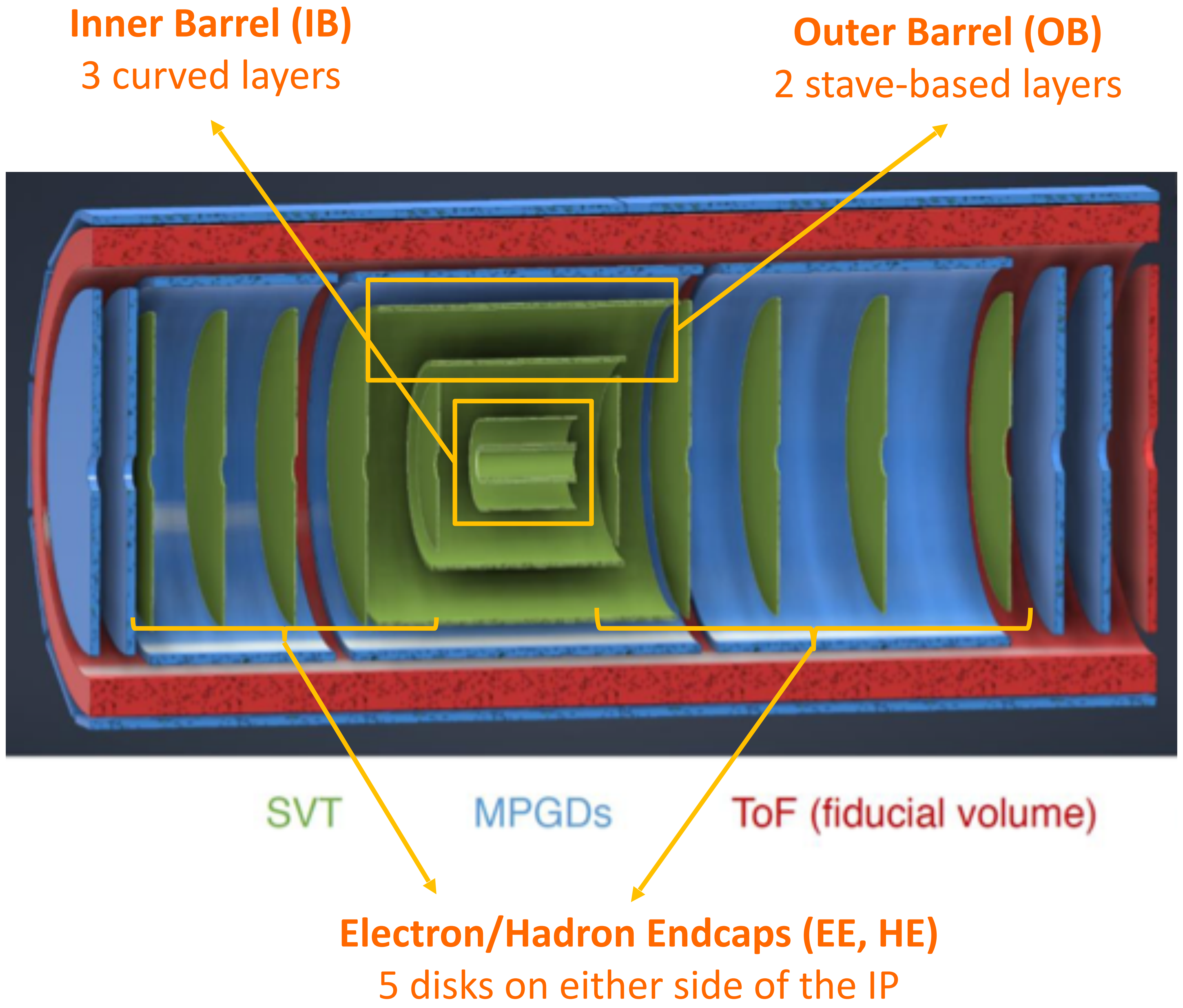
ITS3 to ePIC





Inner Barrel

- Use MOSAIX directly
- Requires supply agreement with CERN (in negotiation)
- Planning difficult since design in flux – need to account for this



Outer Barrel/Discs

- Improve Yield – reduce number of RSUs
- Need to reduce mass at system level
- Requires agreement for database access with CERN (in negotiation)

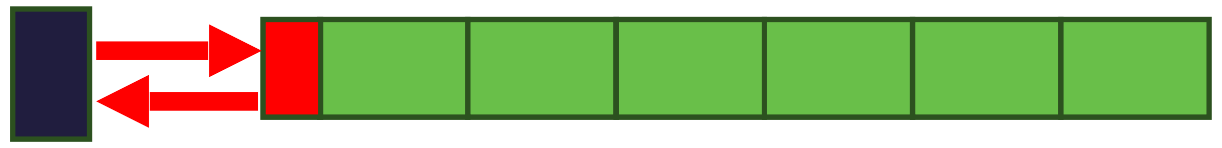
Develop an EIC-LAS plus support chip for staves and discs

Keep up to date with MOSAIC developments (TDR next major release)

Science and Technology Facilities Council

Iain Sedgwick (RAL)

MOSAIX to EIC-LAS



Inner Barrel

- 12 RSUs
- 8 data links
- 7 slow control links
- Direct powering

Outer Barrel

- Reduced number of RSUs
- Single data link
- Multiplex slow control
- Serial powering

12 RSUs → Reduced number of RSUs: Yield likely too low

8 data links → Single data link: Excess material for required data rate

7 slow control links → Multiplex slow control: Excess material when built into stave

Direct powering → Serial powering: Excess material when built into stave

Reduced number of RSUs, Single data link: Must be done on 65nm MOSAIX database

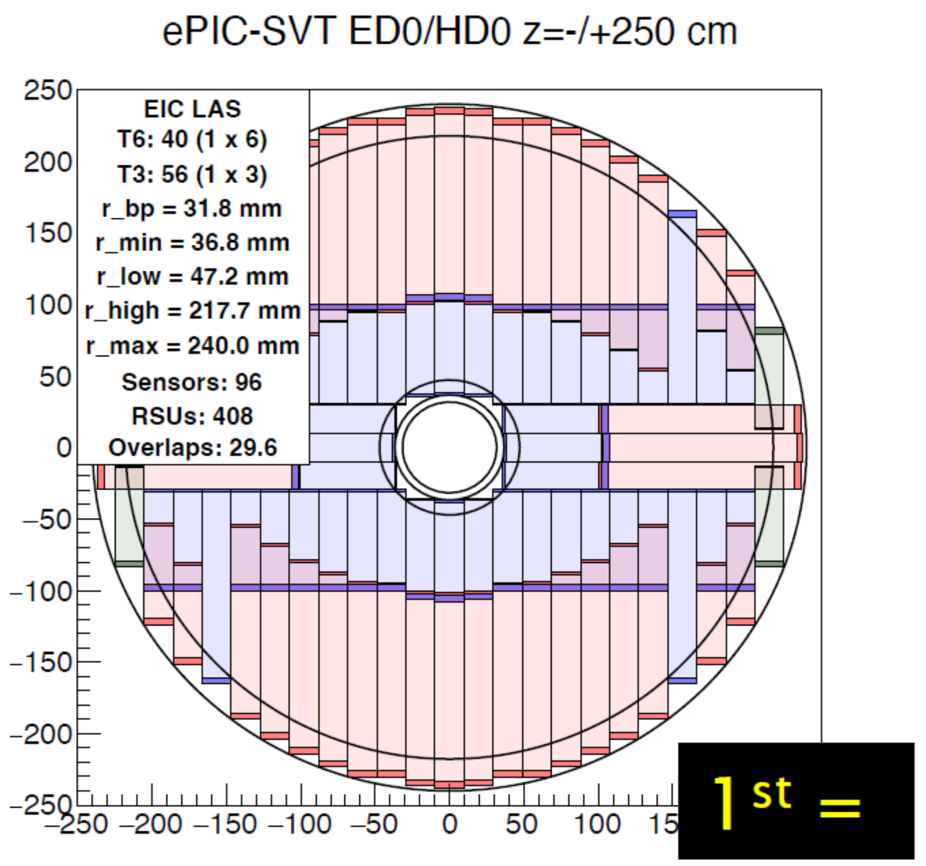
Multiplex slow control, Serial powering: Could be on support chip

Science and Technology Facilities Council

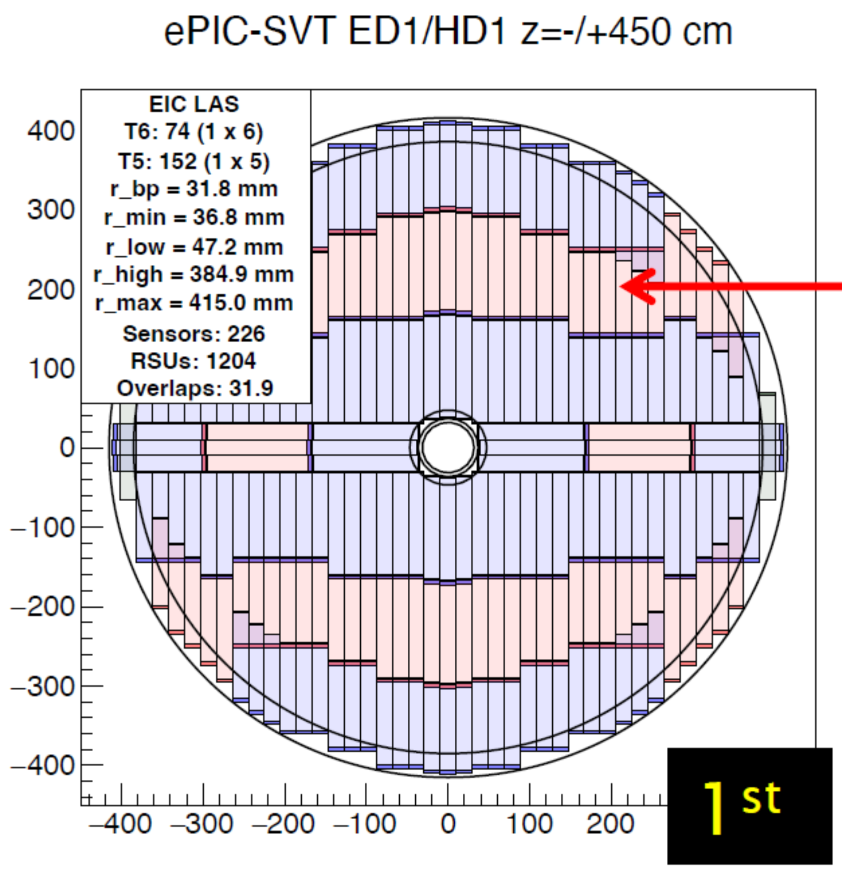
Staves and Disks

Peter Jones (Birmingham)

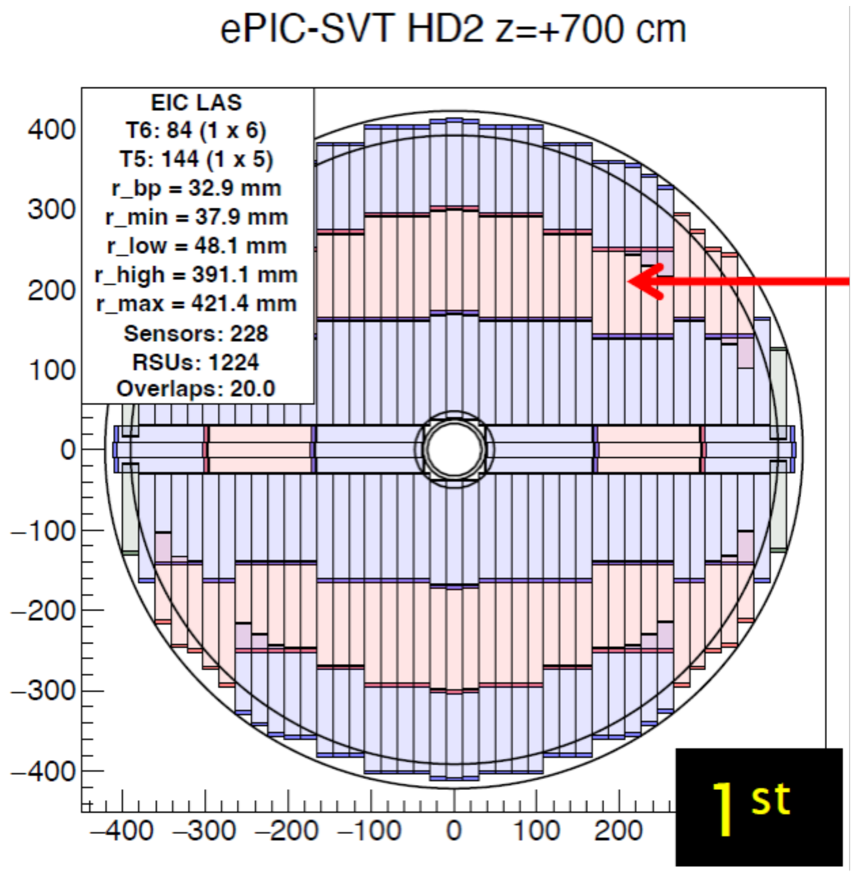
Many layout studies have been performed over the years — some examples below
Converged on use of an EIC-LAS with 5 and/or 6 RSUs



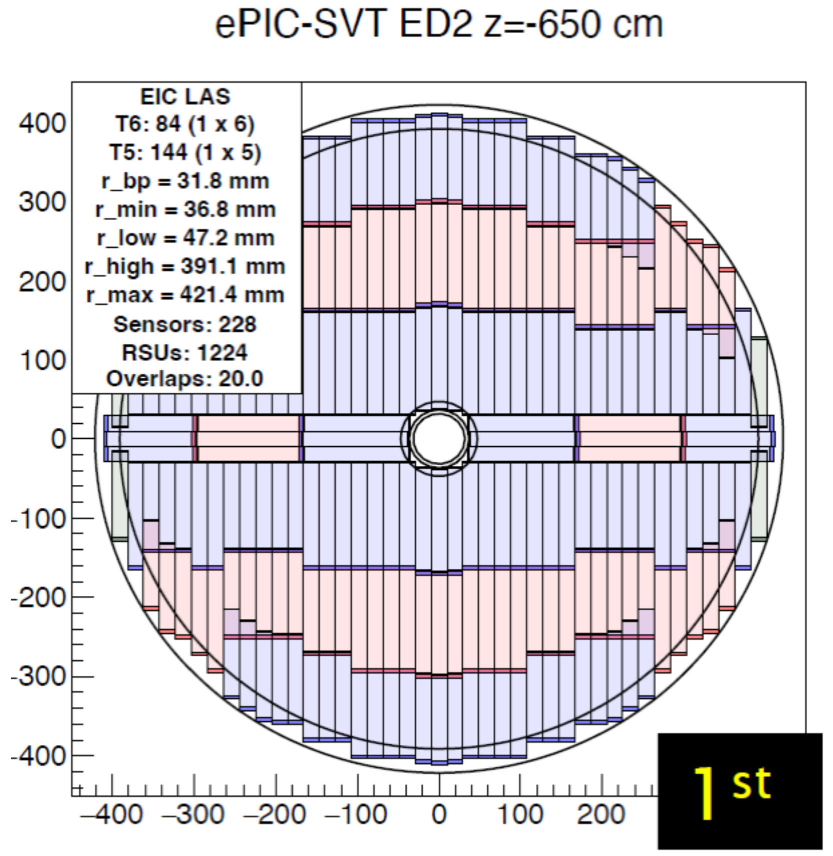
52 stave



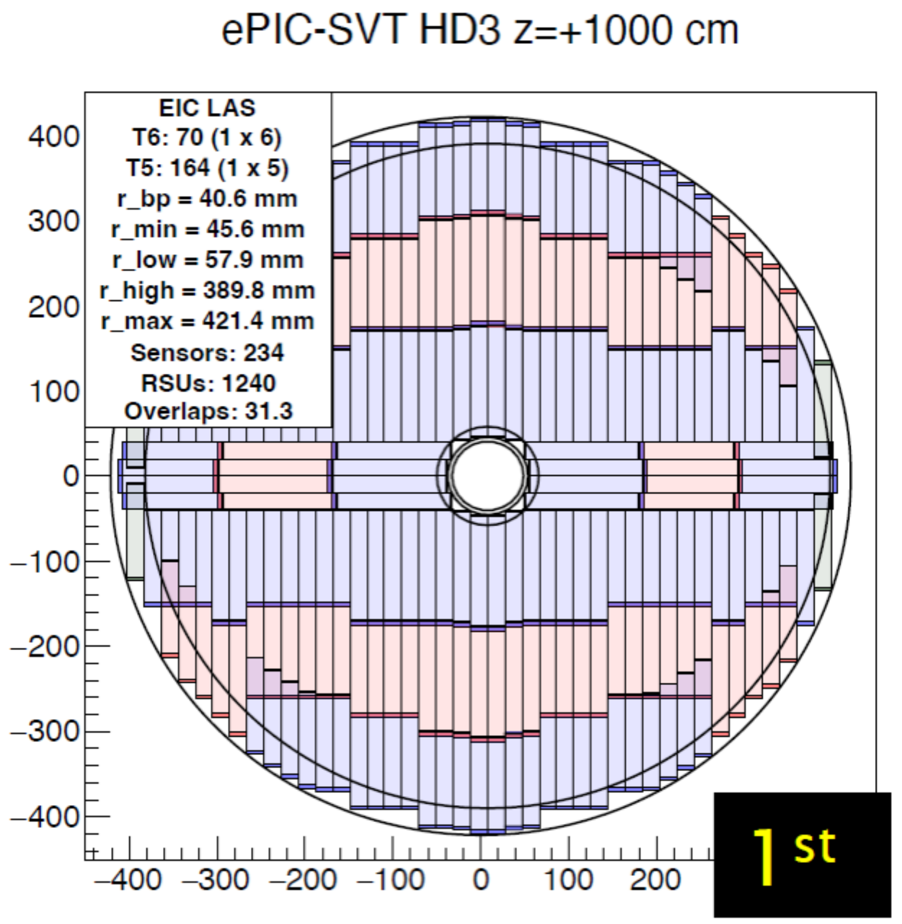
86 stave



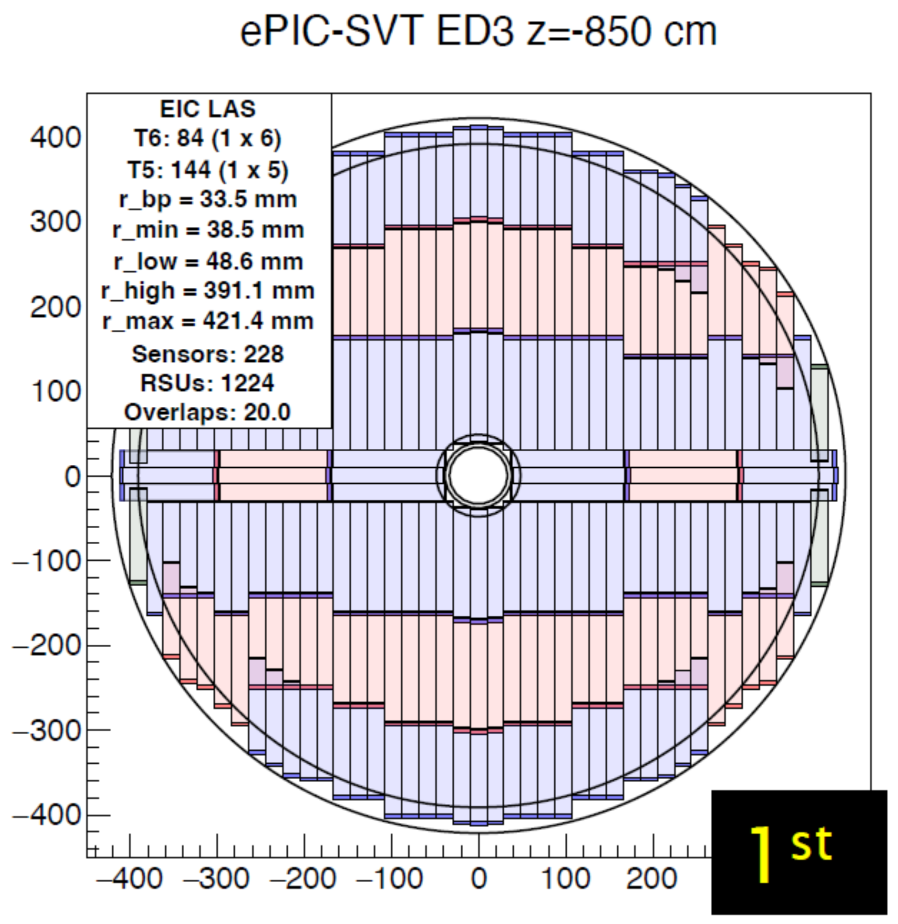
88 stave



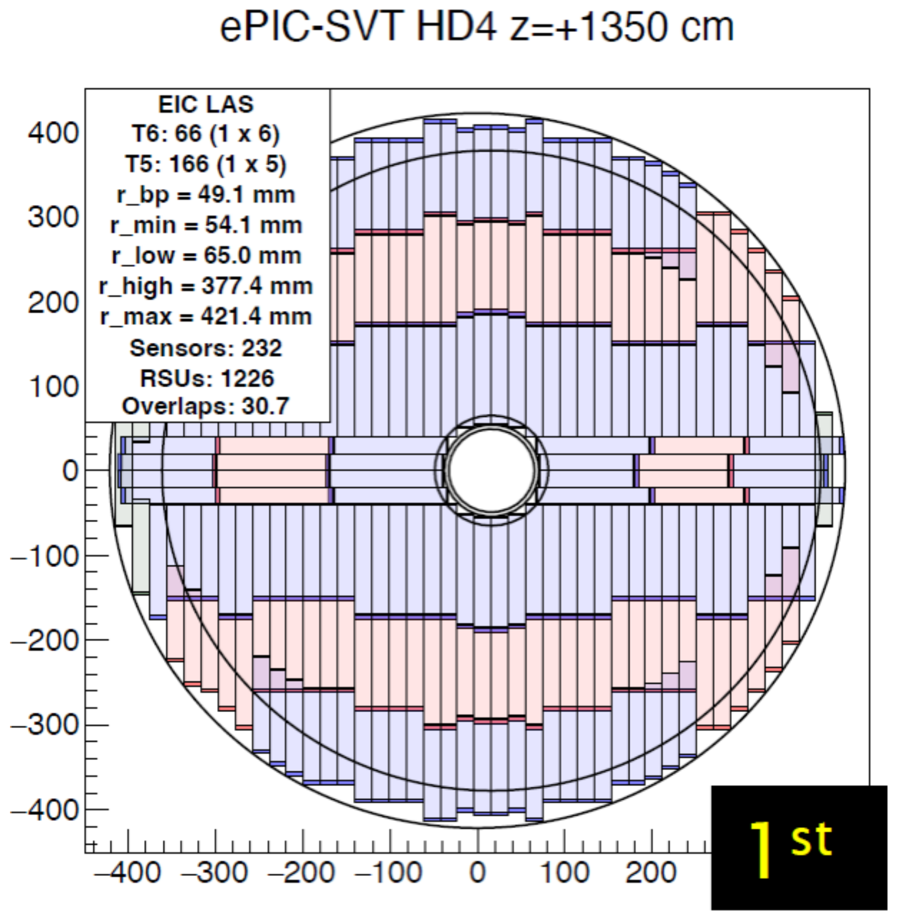
88 stave



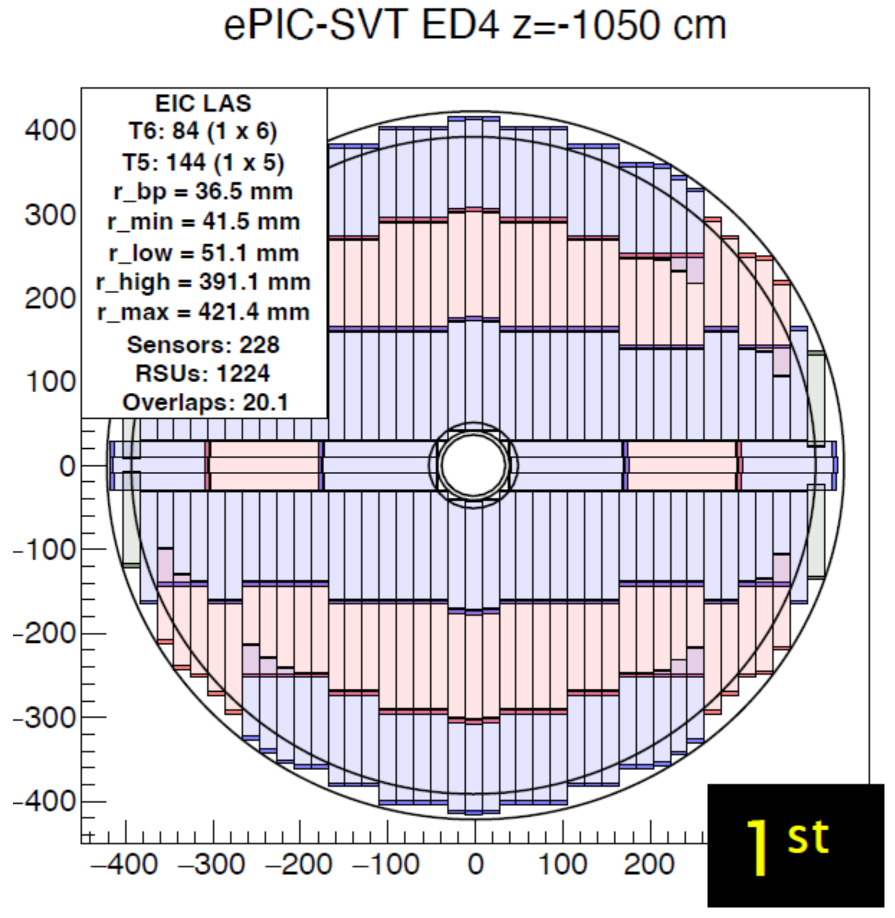
88 stave



88 stave



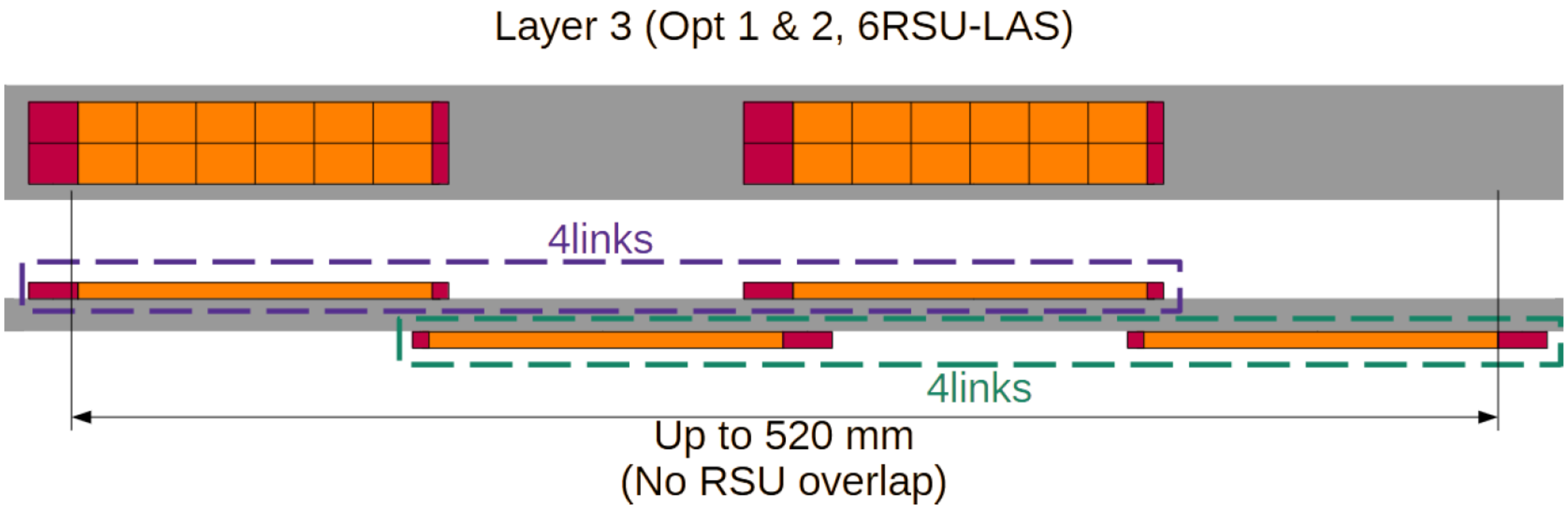
88 stave

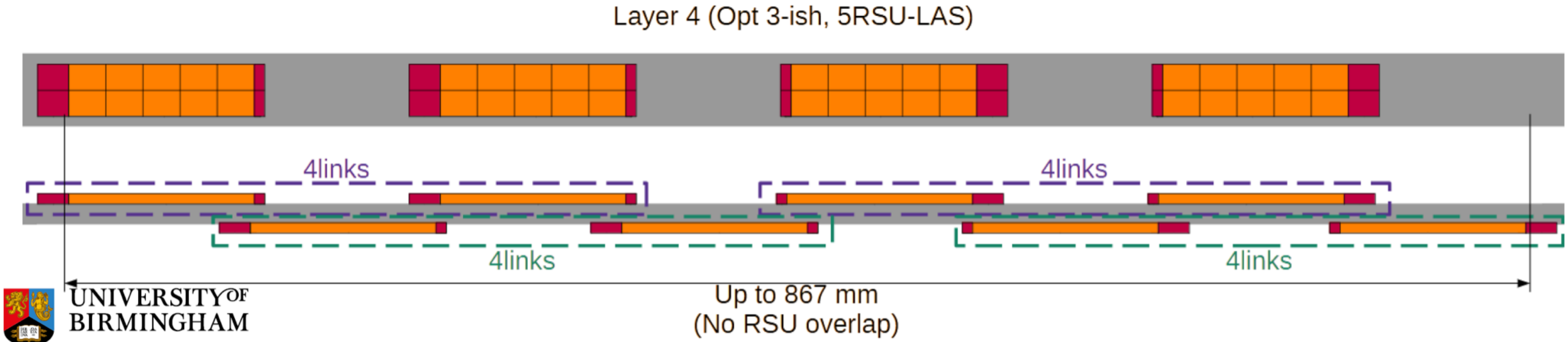


88 stave

James Glover (Birmingham)

Current stave-concept (option) for L3 and L4



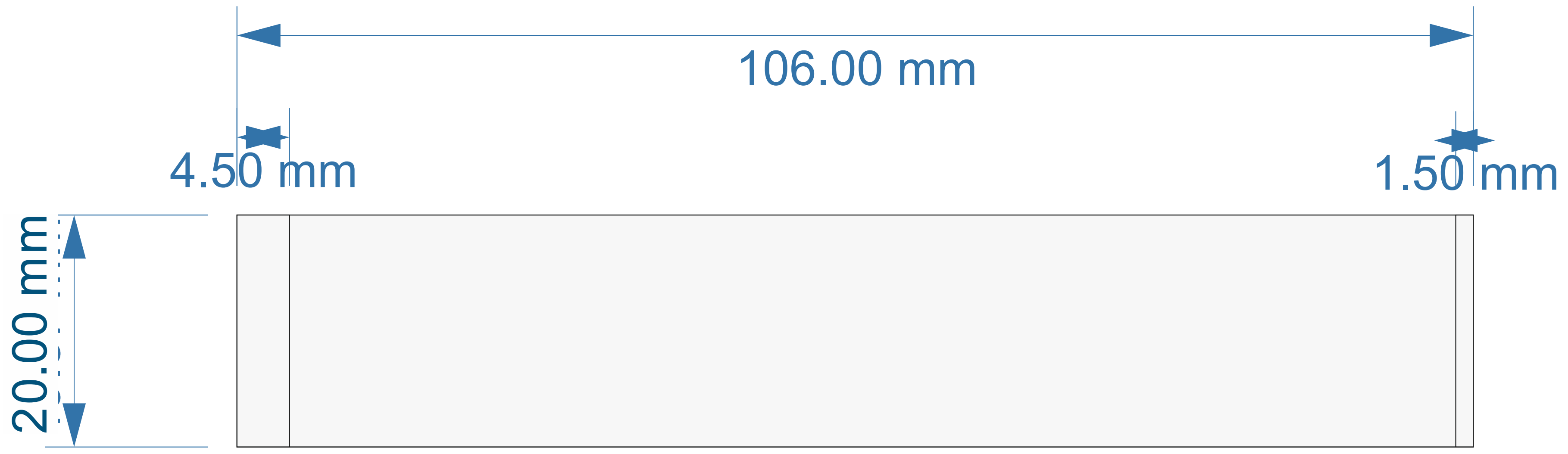


Georg Viehhauser (Oxford)

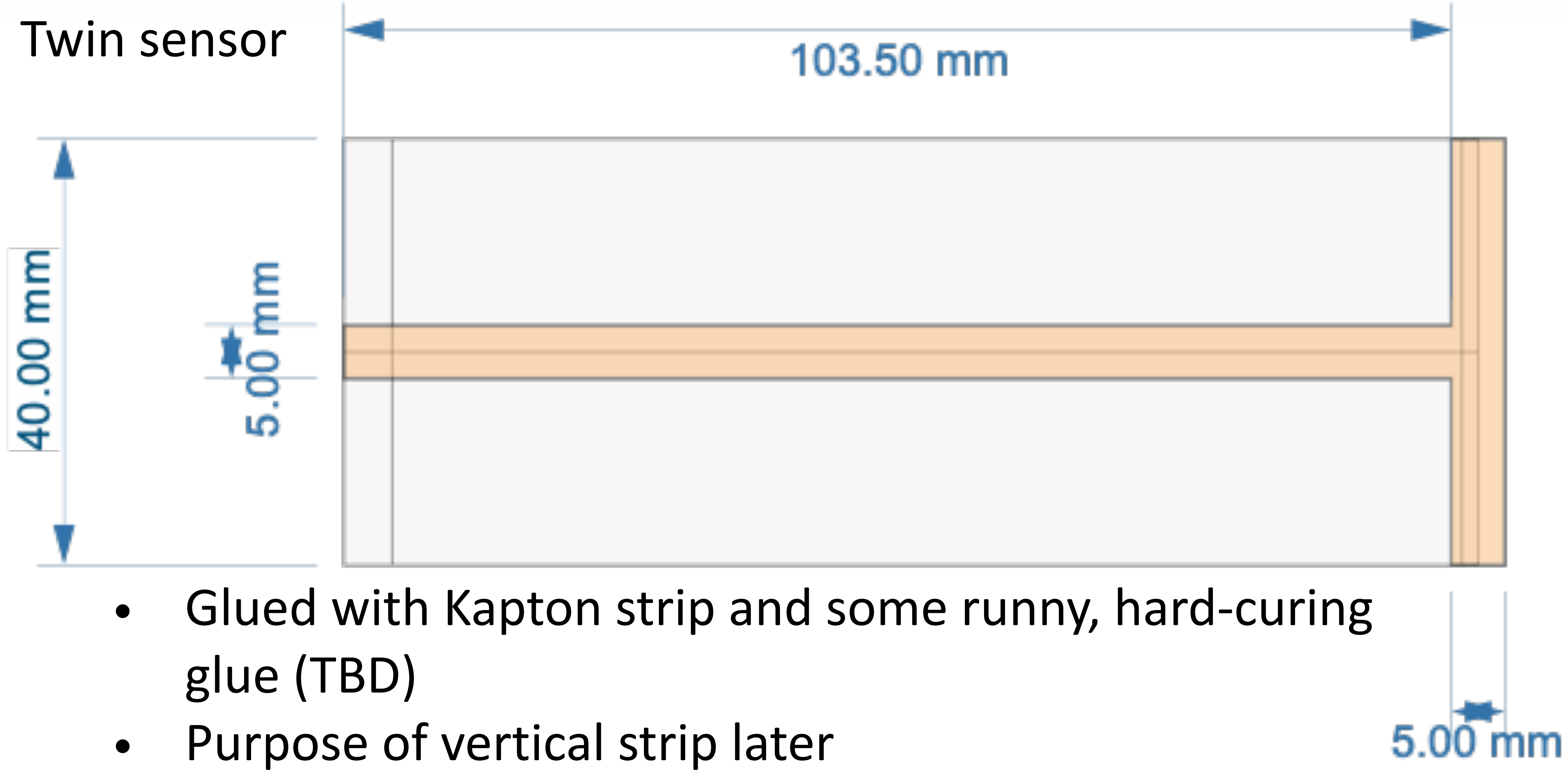
Concept

- Sensor assembly

Sensor geometry used (approximate 5RSUs)

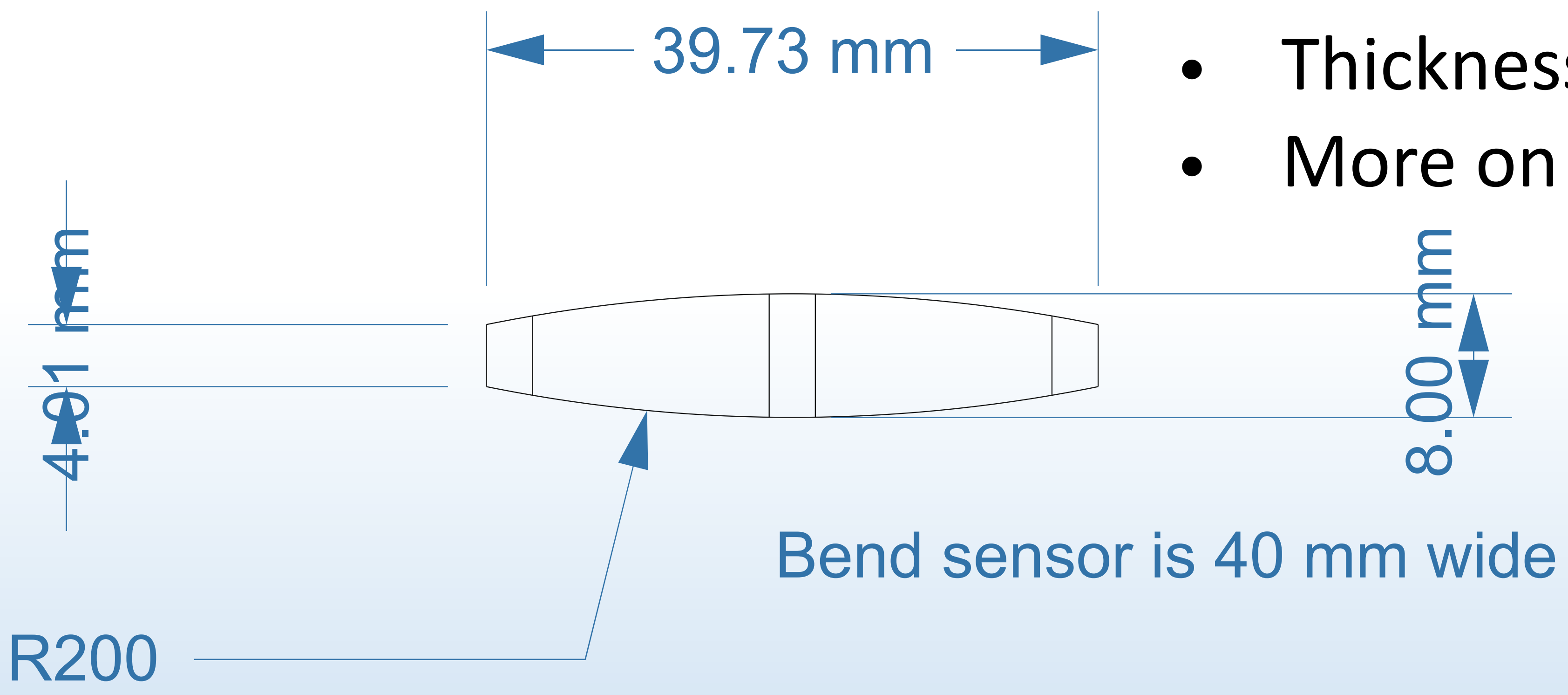


Twin sensor

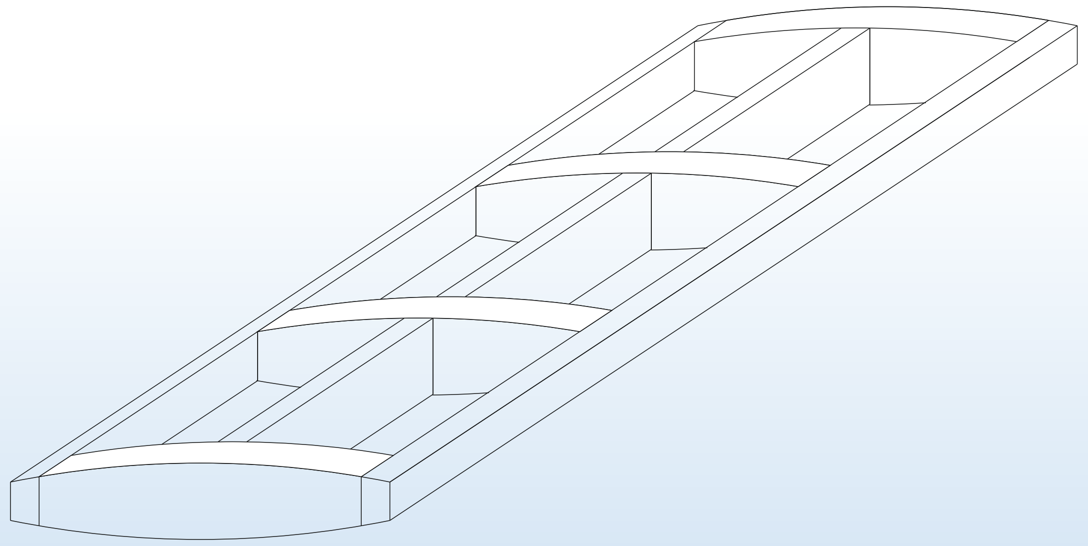


- Glued with Kapton strip and some runny, hard-curing glue (TBD)
- Purpose of vertical strip later

- Core of stave is made of array of foam blocks



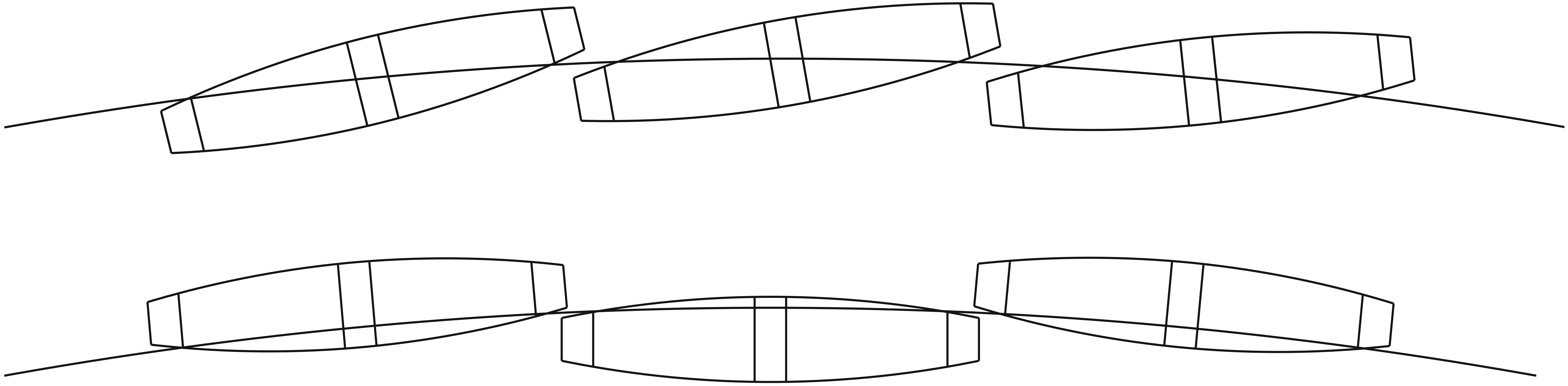
- Thickness and curvature arbitrary
- More on optimization later



- Crossribs are K9
- Central spar 3% RVC
  - Could be thinned to hourglass shape
  - Alternatively, carbon fibre I-beam
- Edges are 3% RVC
  - Alternatively, 3% Al, if we want to run the power bus through this
    - In that case the Al would be in shorter sections for serial powering

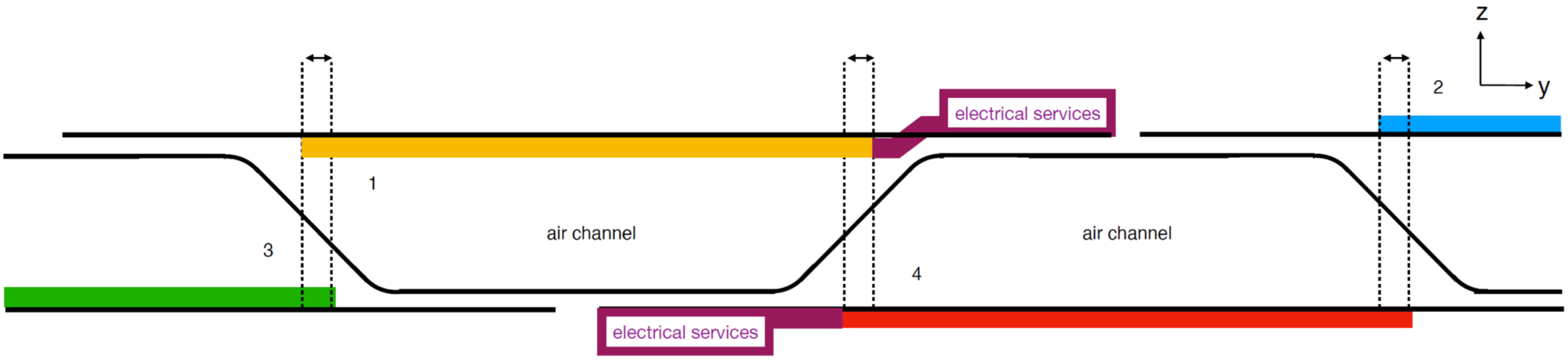
Georg Viehhauser (Oxford)

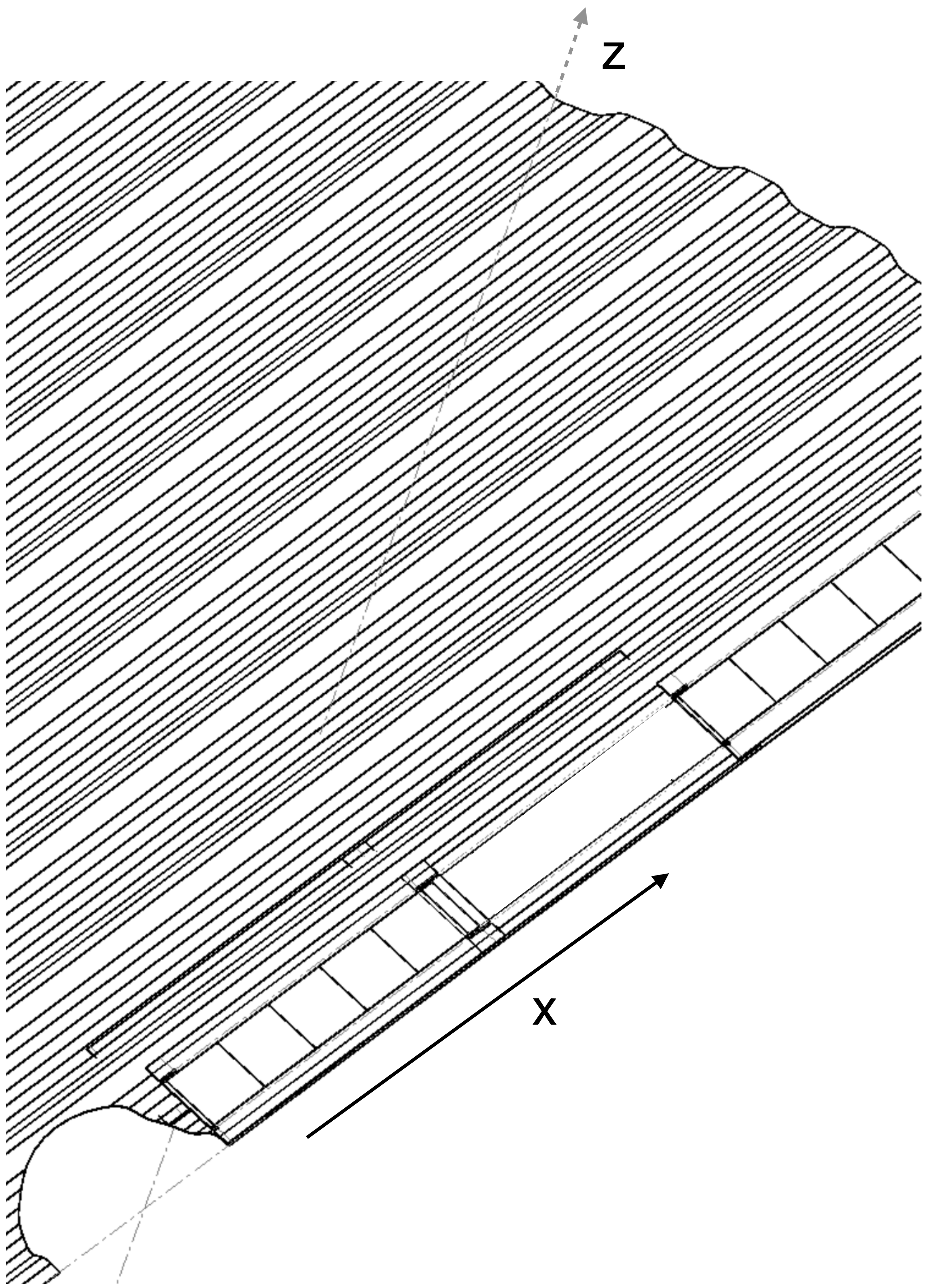
L4 cylinder

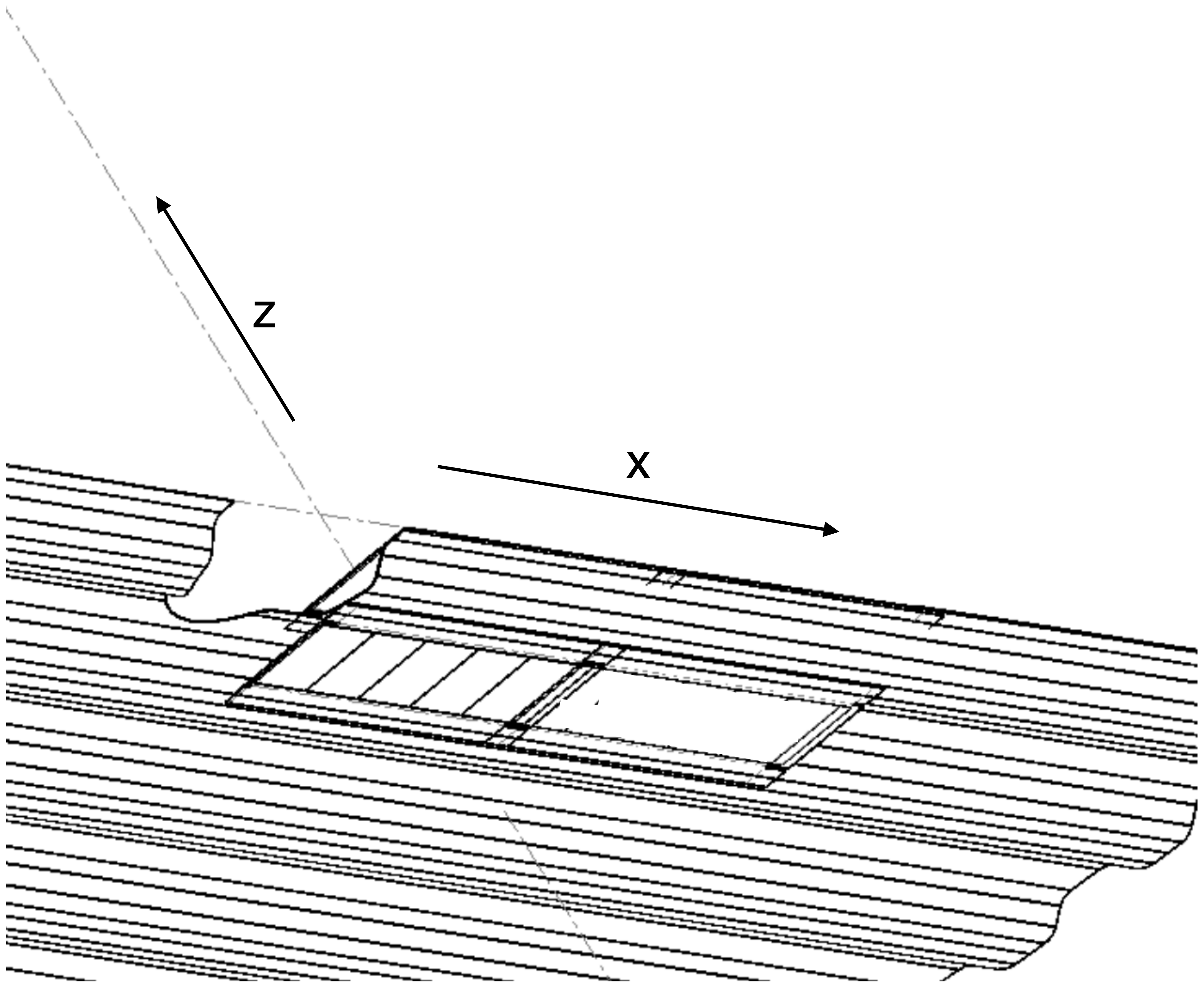


- Will investigate options for annular linking
- Might be beneficial to couple staves with some damping material (soft foam) to dampen air-flow induced vibrations

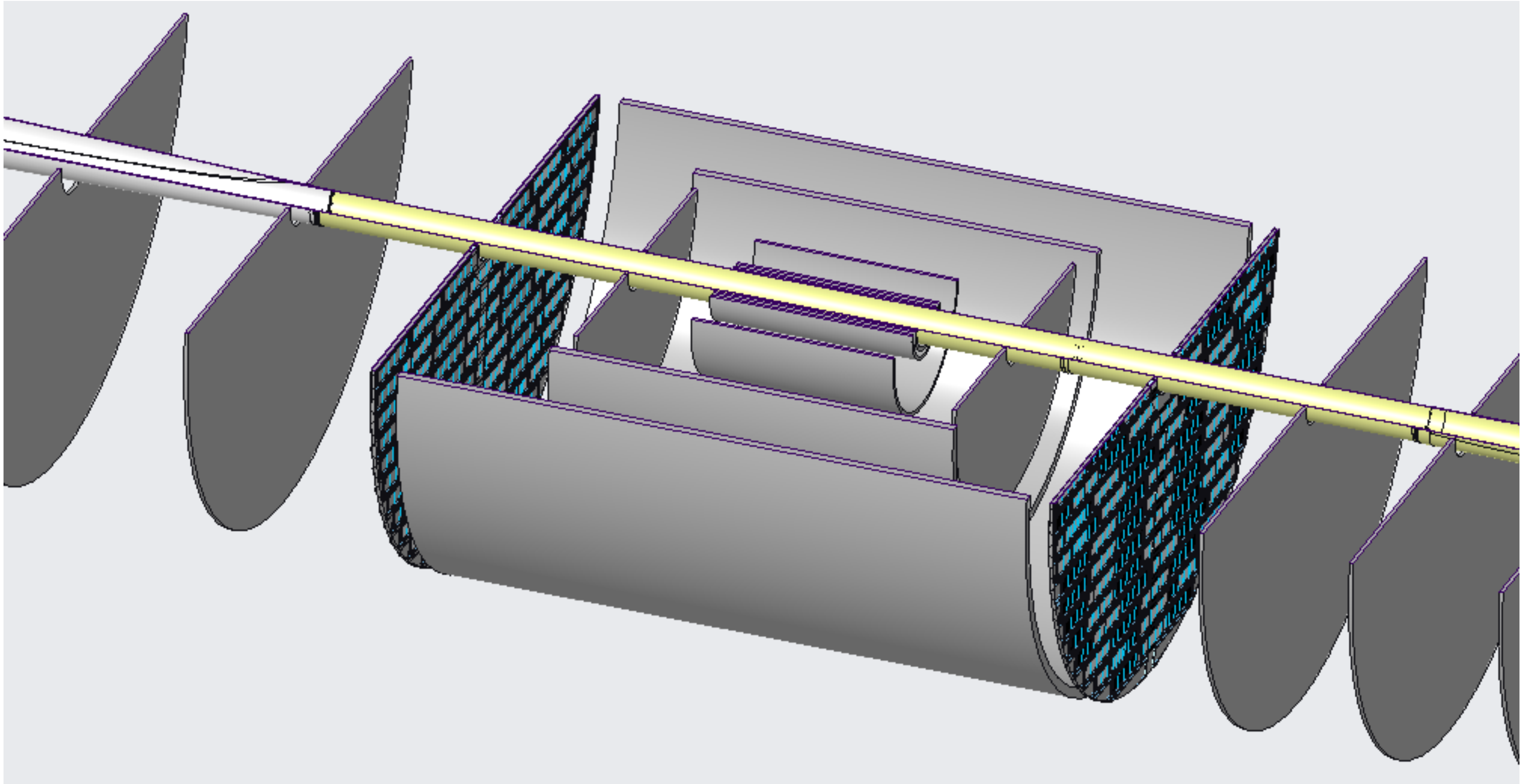
Current disk concept




z
x

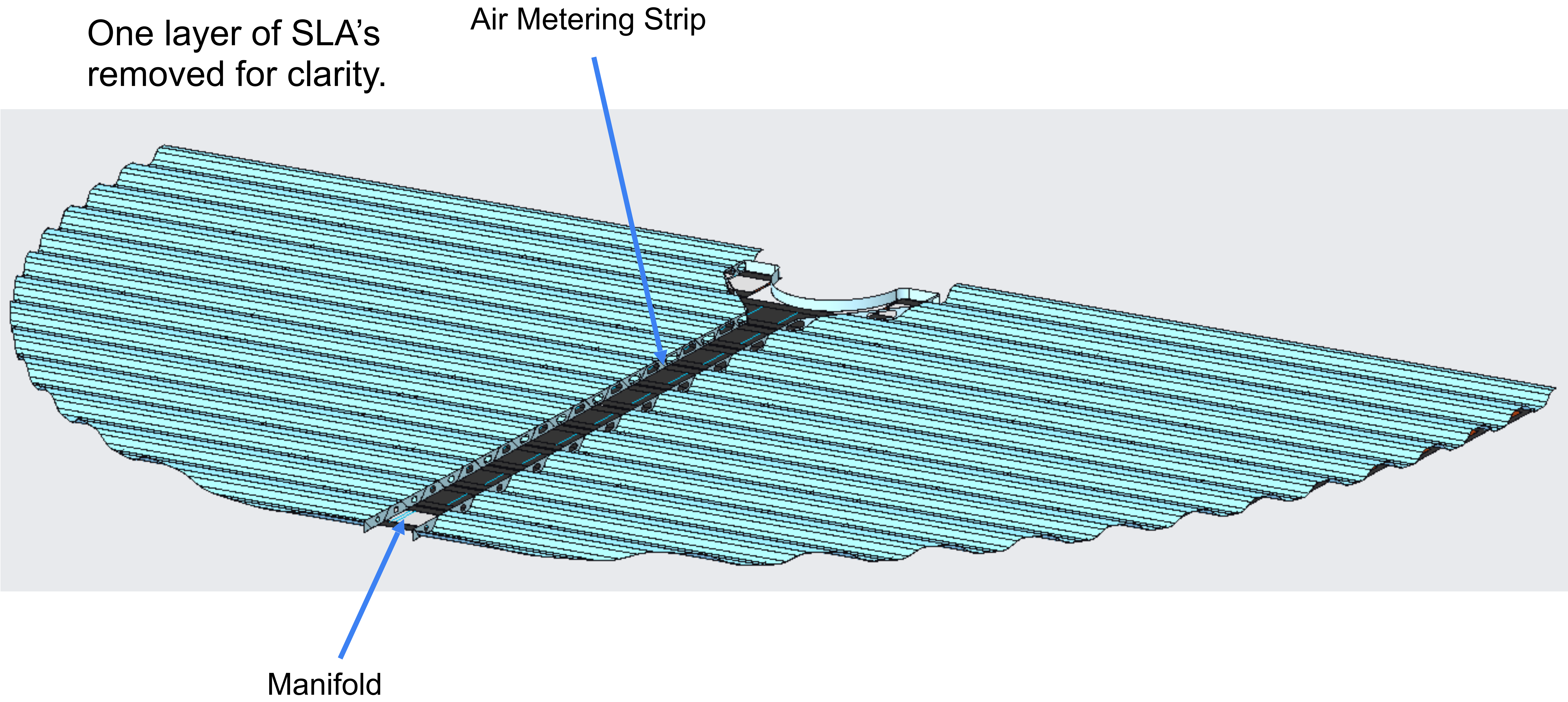

z
x

Jim Curtis (LBNL)

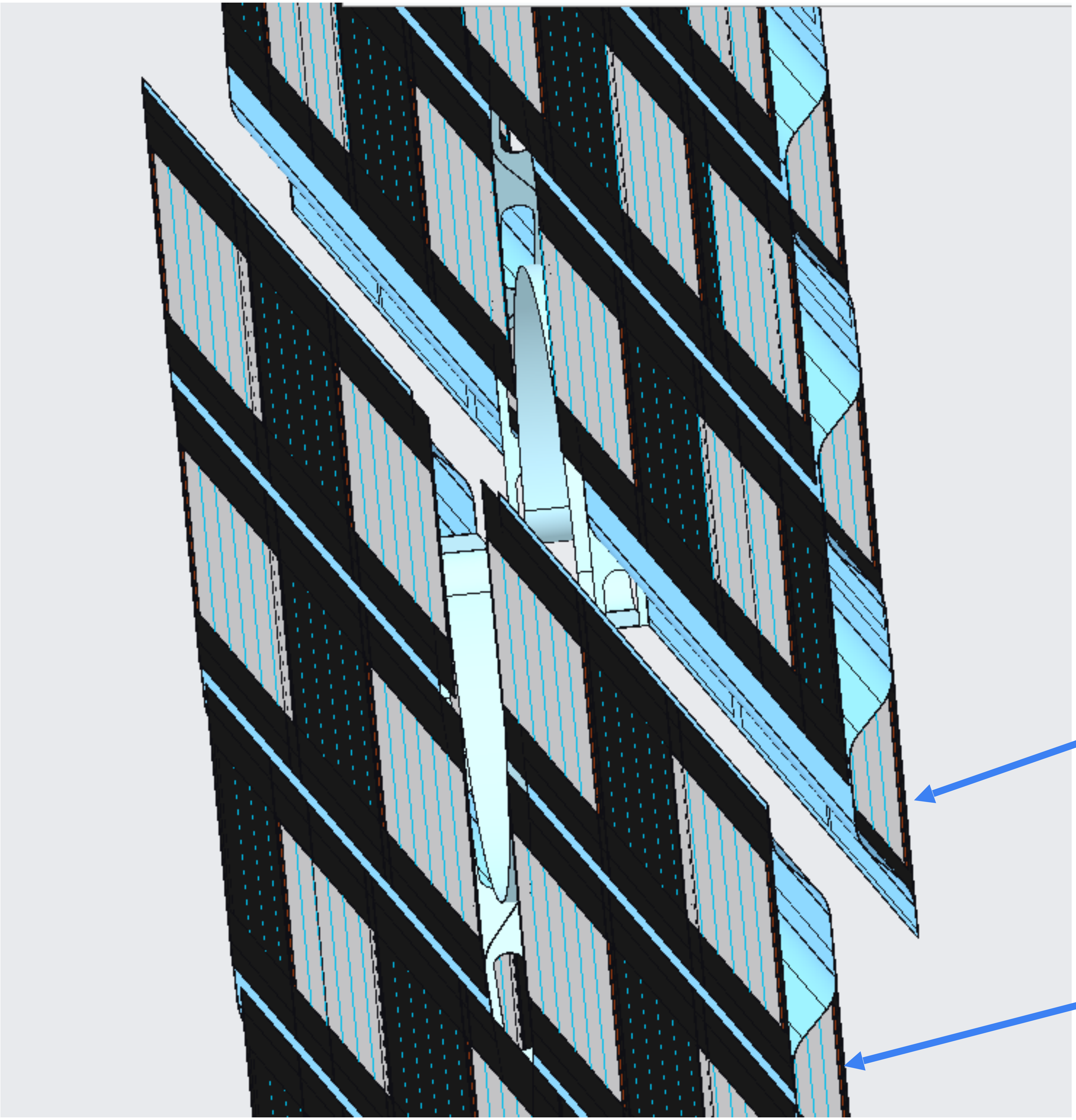


Jim Curtis (LBNL)

One layer of SLA's removed for clarity.



Jim Curtis (LBNL)



Discs are shown with a 10mm offset for clarity.

Upper Half-Disc

Lower Half-Disc

Cooling

SVT Cooling

Initial service estimates based on:

- Approximately 4,000 EIC Large Area Sensors (EIC-LAS),
- Power dissipation dominated by endcap (periphery), then thought to consume ~1 W
- Air cooling or a hybrid with liquid cooling – R&D
- Writeup of November 2022 may be found at this sharepoint link

Estimates have evolved since the initial writeup:

- Sensor count remains approximately 4,000 EIC-LAS,
- Power dissipation in the pixel matrix has increased and is estimated to contribute 0.6 – 1 W per EIC-LAS
- Power dissipation in the periphery is under investigation and may be reduced through a reduction of the number of data lines – this relies crucially on the sensor agreement and subsequent modification of the design of the sensor periphery,
- Serial powering reduces the electrical service load and requires an ancillary IC with its own power dissipation; this dissipation is under investigation / to be determined,
- The readout chain with LpGBT and VTRx+ is thought to be a smaller contributor,

SVT cooling is a (still ongoing) R&D item with implications on X/X_0 and hence tracking performance.

February 5 TIC meeting: https://indico.bnl.gov/event/21650/

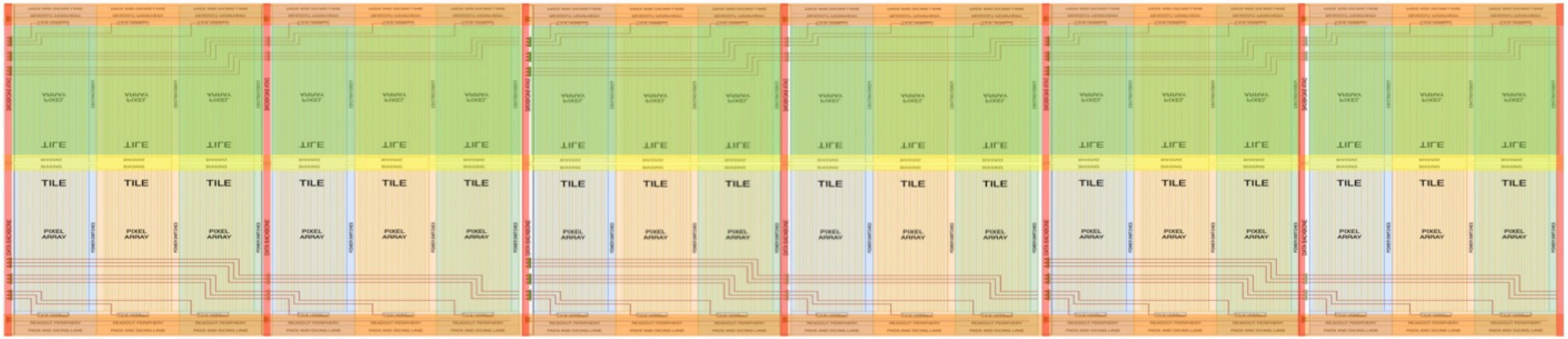
Power Density

From EP R&D WP 1.2 General Reporting Meeting

	Power density [mW cm^{-2}] Expected 25 °C	Max 25 °C	Max 45 °C
Left End Cap (LEC)		791	
Active area (RSU)	28	44	[illegible]
Pixel matrix	15	32	51
Biasing	168	168	168
Readout peripheries	432	457	496
Data backbone	719	719	719

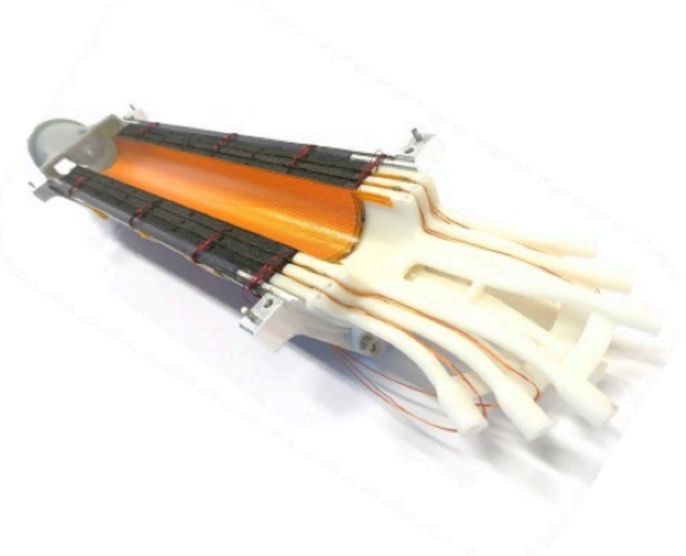
Table 3.10: Estimates of average power dissipation per unit area over the main blocks composing the sensor.

LEC (aka periphery) ~0.8 W/cm^2
Matrix (total) ~20-40 mW/cm^2

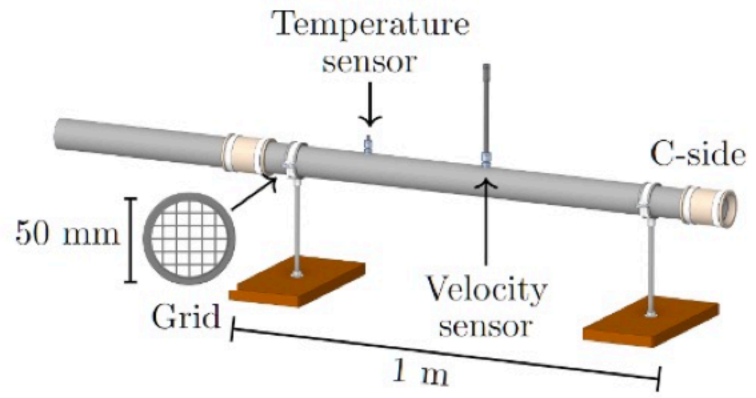


Note: EIC-LAS LEC is expected to dissipate less power — reduction under study.

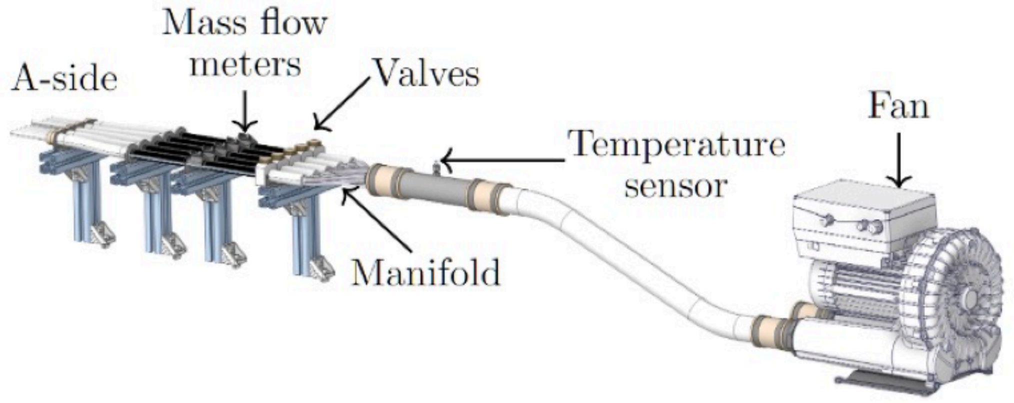
SVT IB air cooling



(a) Prototype



(b) Inlet of the wind tunnel



(c) Outlet of the wind tunnel

ALICE ITS3 cooling test setup

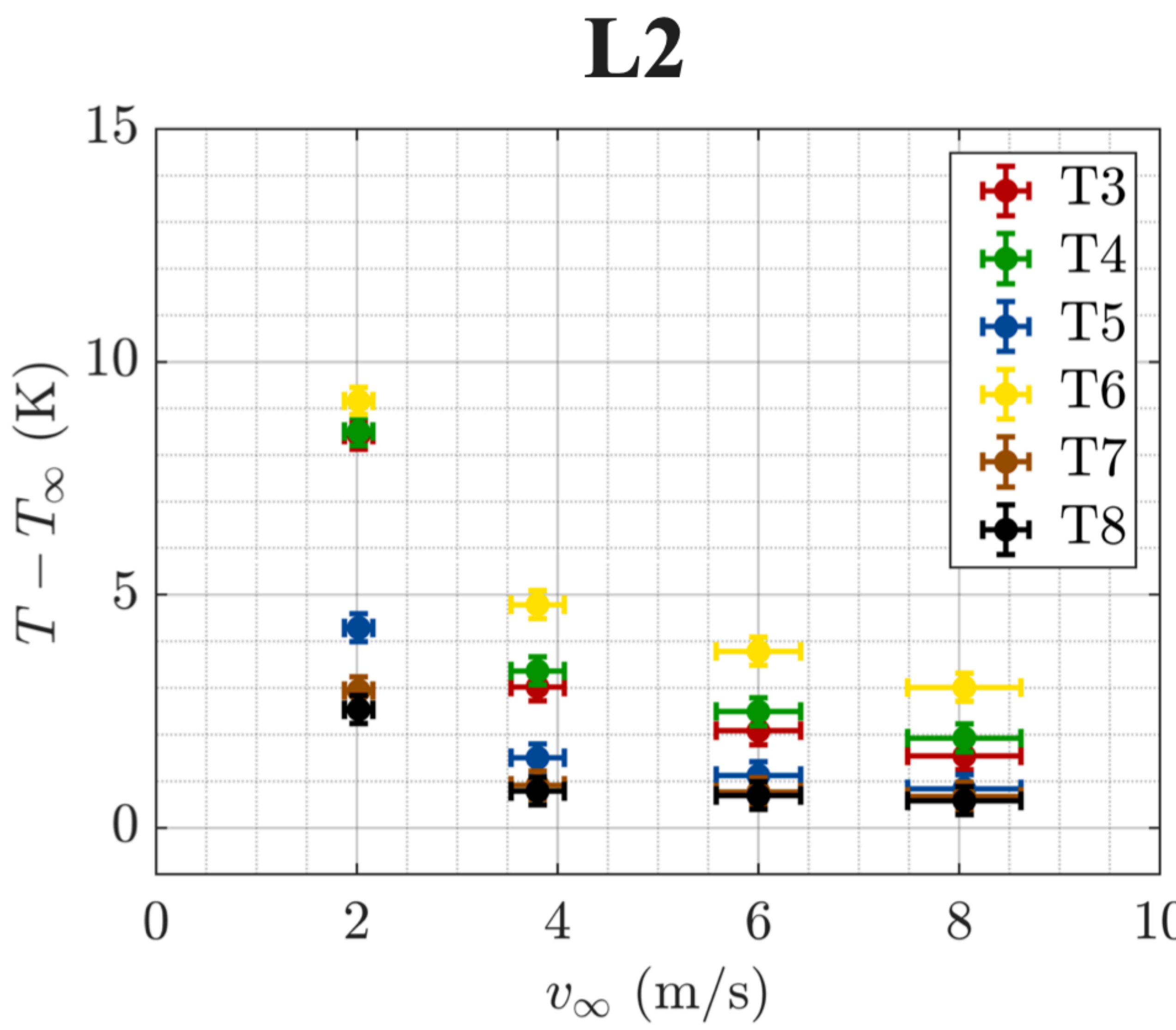
Starting point: Air cooling with carbon foam

Build off of work from ALICE ITS3

ALICE ITS3 has shown that air cooling is sufficient to keep ΔT < 10° C

ePIC changes:

- Adapt to larger radii
- Adapt how air is routed in and out, i.e. suitable redesign of inlets and outlets.



Temp sensors near endcap

Measurements: endcap = 1 W/cm², matrix = 50 mW/cm²

ALICE ITS3 presentation at Forum on Tracking Detector Mechanics 2023

SVT Cooling – OB, disks

Air-cooling internal to the mechanical structures offers advantages, e.g. in routing of air,

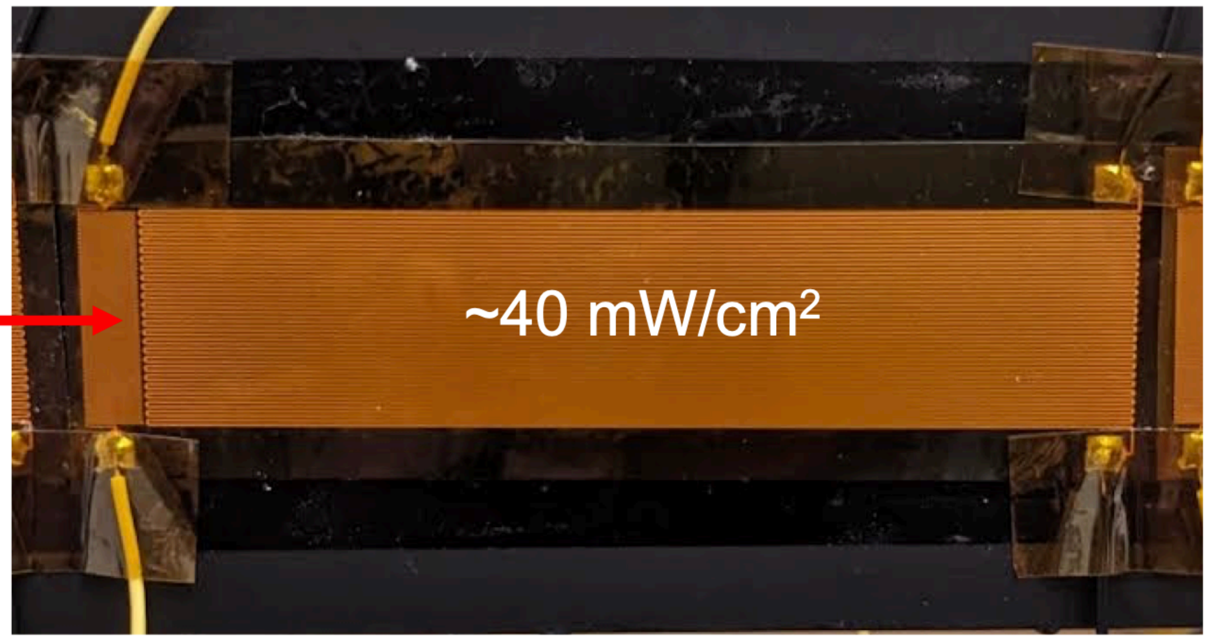
Builds on prior LBNL LDRD with carbon composite structures and RVC or CVD (heat conducting) foam,

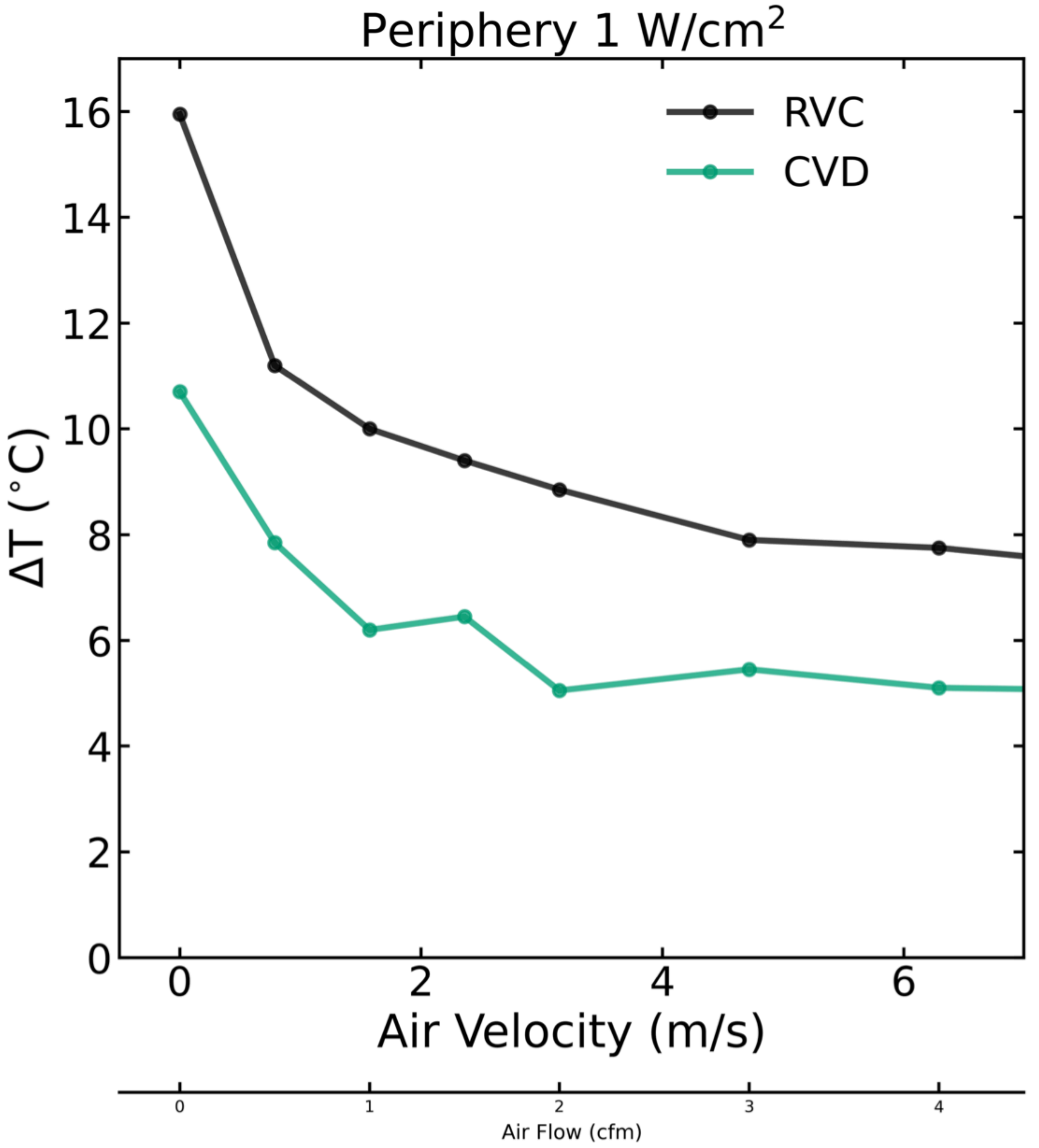
Started from existing structures and heat-loads, inherited from prior LDRD,

Heat loads were changed to become SVT specific while SVT-specific, lower mass, mechanical structures were being developed.

Concept demonstrated on the right with existing mechanical structures; 10^{o} C in reach – structure is too ”massive” though.

~1 W/cm²





*Air velocity calculated at duct

SVT Cooling – disks

Corrugated prototype test pieces

Each piece → 2 layers 34 gsm veil + 5 layers resin

Face sheets glued with 9309 adhesive in 5 mm strips

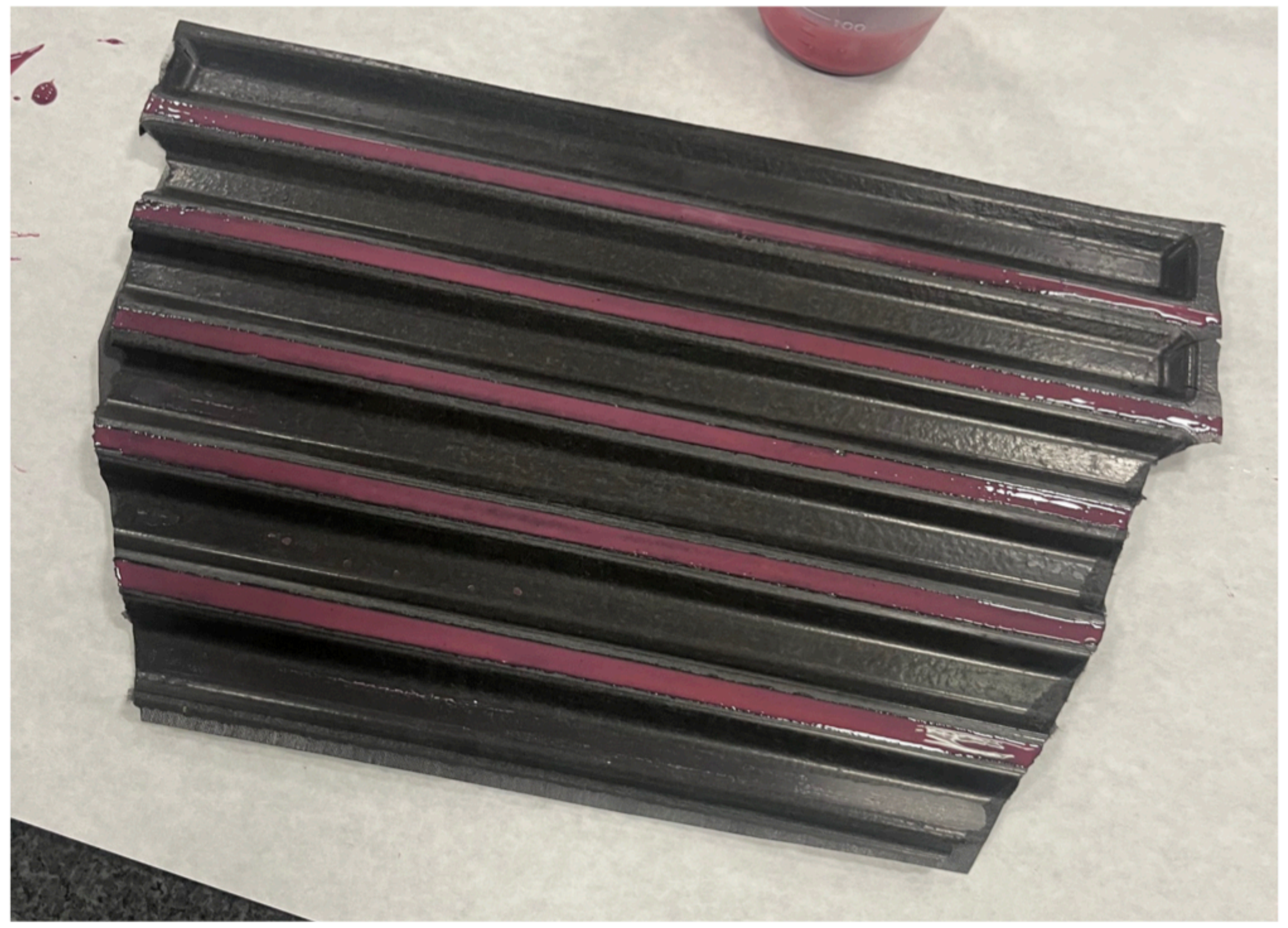
Final size of prototype test piece = 22.4 cm x 20.2 cm

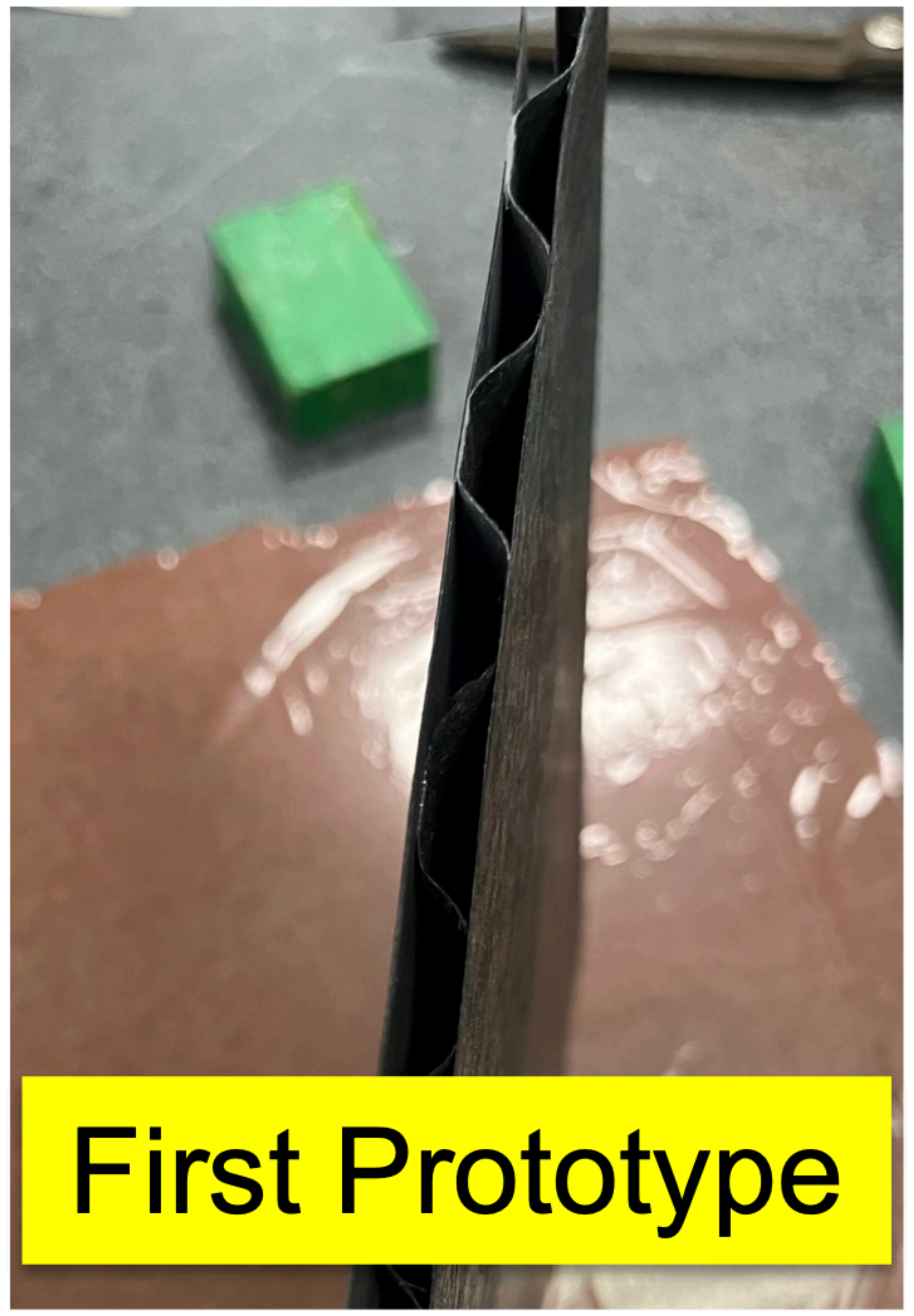
Final weight of prototype test piece = 22.5 g

Density = 497 gsm → ~ 0.12% X/X0

Silicon ~0.05% X/X0, adhesive 0.01-0.02% X/X0

(Recall, SVT target of X/X_0 ~ 0.25% per disk)





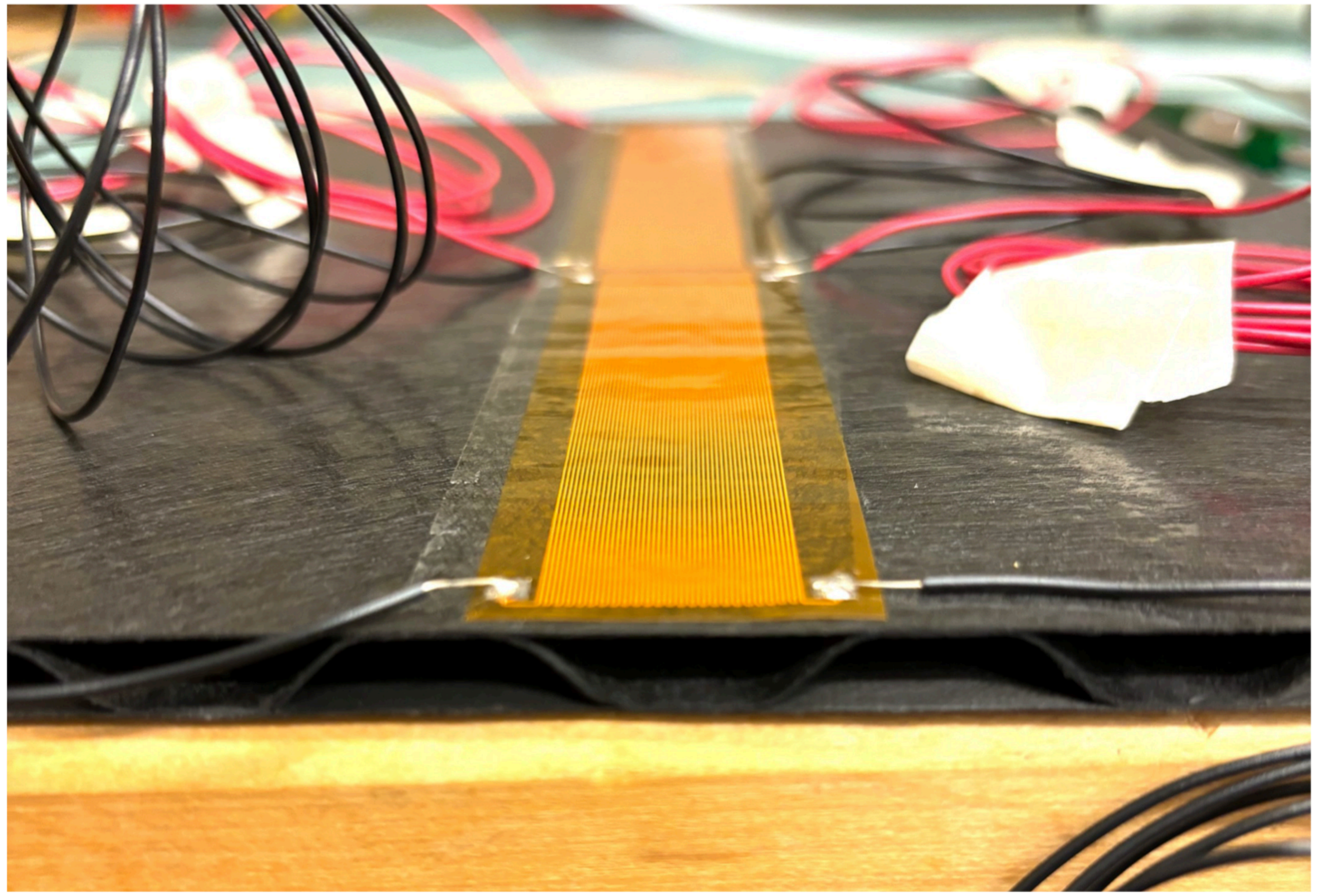
SVT Cooling – disks

Corrugated carbon fiber thermal tests

Two heaters with separate power zones for LEC (~1W/cm^2) & matrix (~40 mW/cm^2)

Using 3M 467MP double-sided tape, 60μm thick (used to glue silicon for STAR HFT PXL)

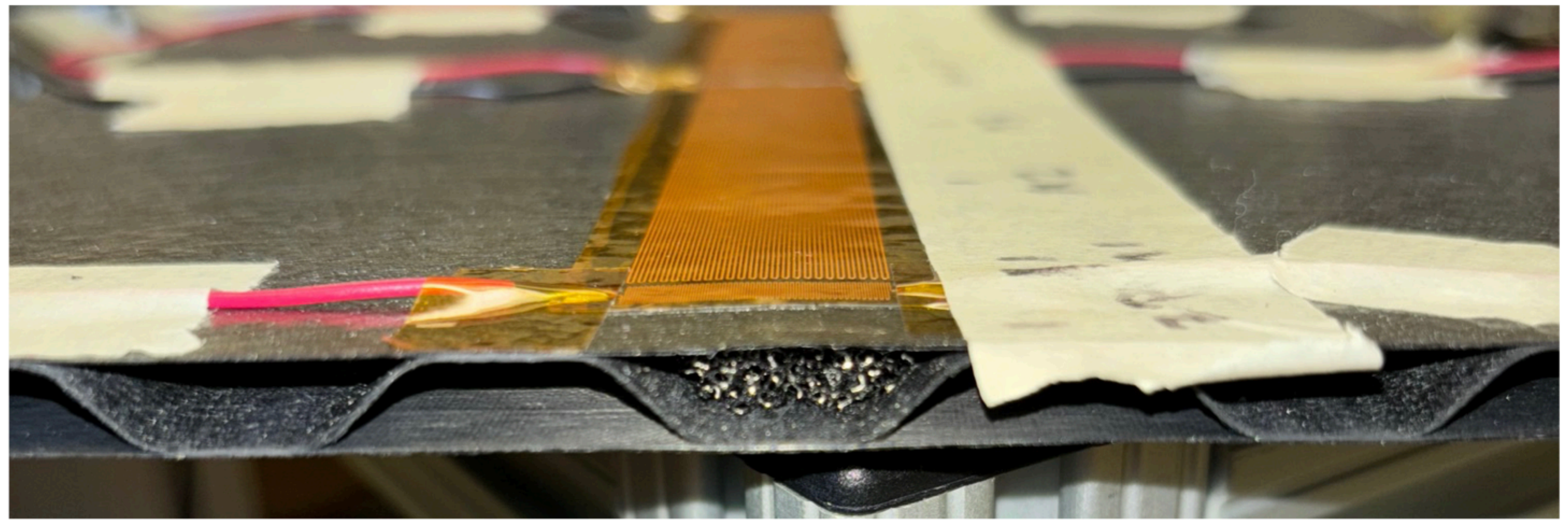
- First step: Put a tube in corrugated channel and blow air through

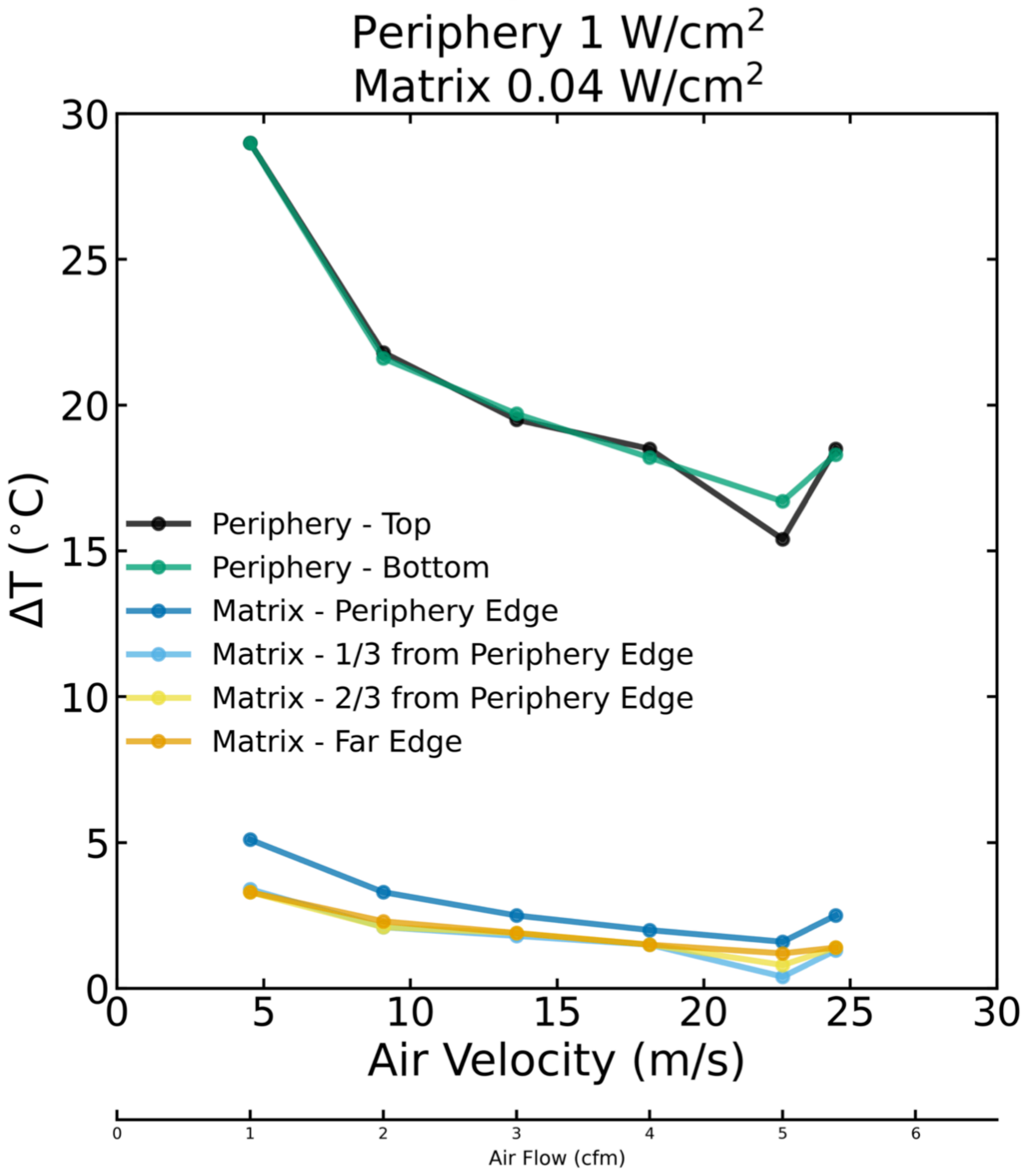


SVT Cooling – disks

Results: air flow through corrugation

- No issues cooling the matrix
- LEC (Periphery) trending in the right direction
- Next steps:
  - Add foam under the LEC
  - Improve thermal conductivity
  - Better air control

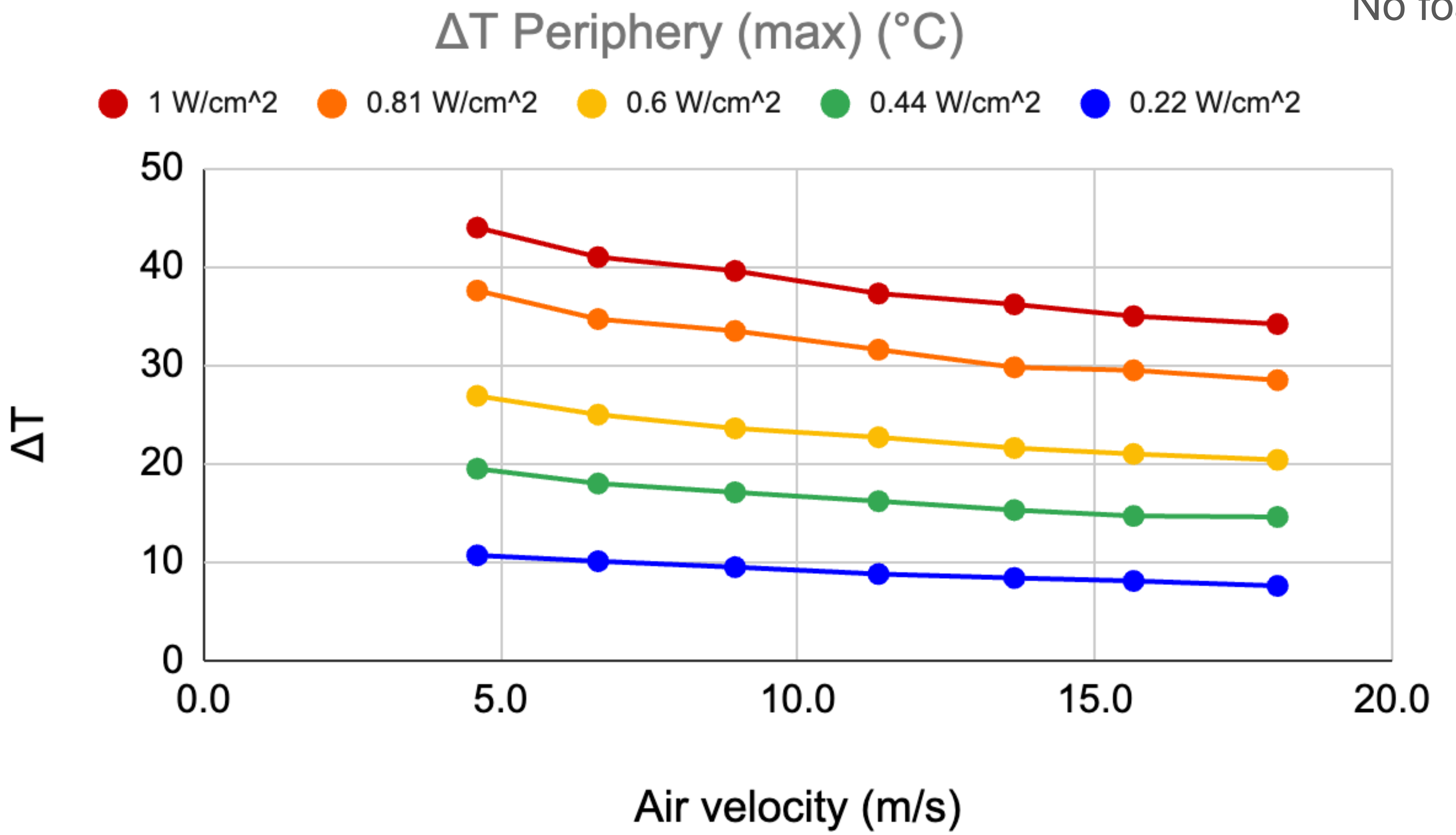




Uptick at highest velocity possibly due to thermocouple breakage

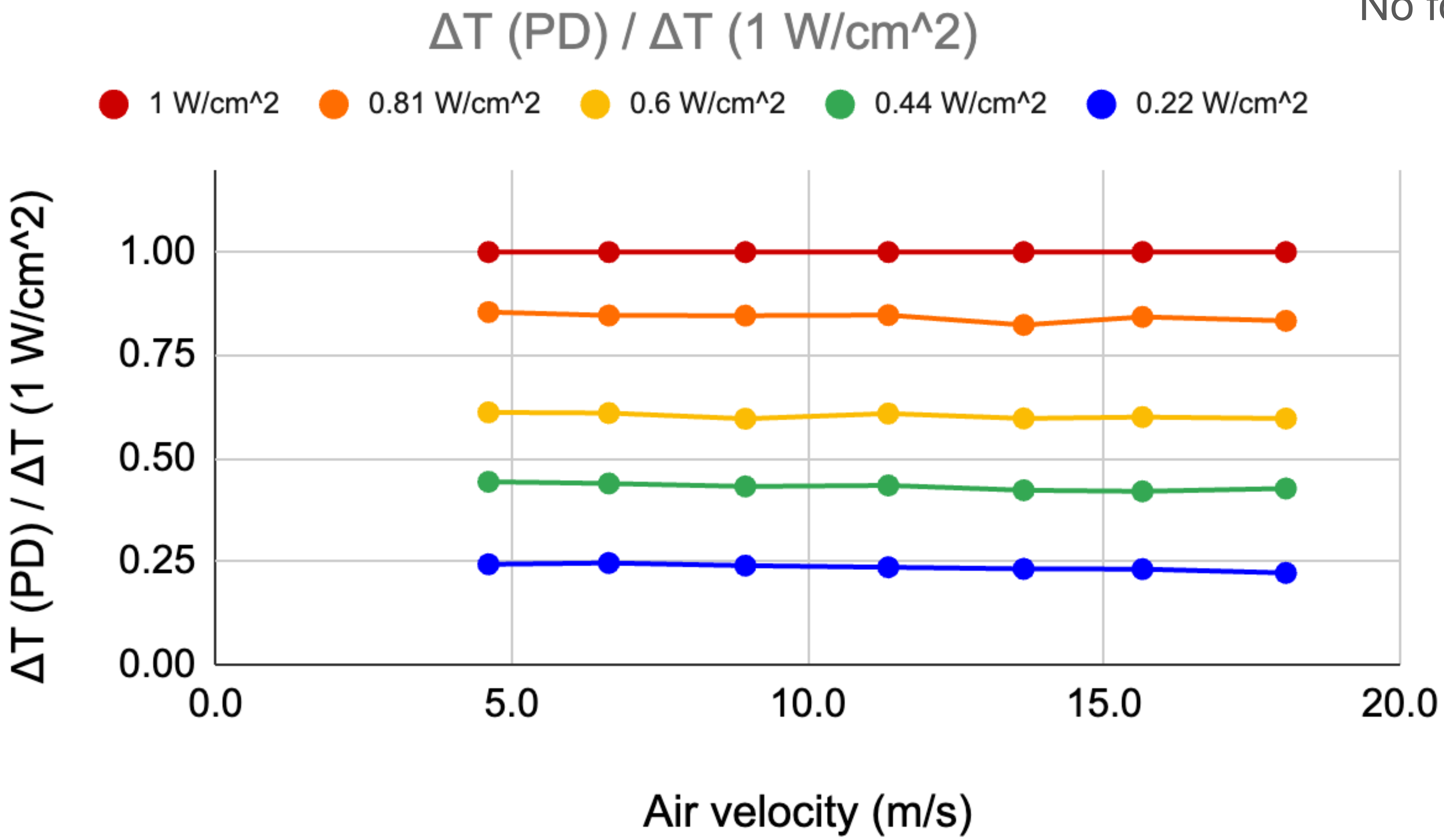
Nicole Apadula (LBNL)

No foam

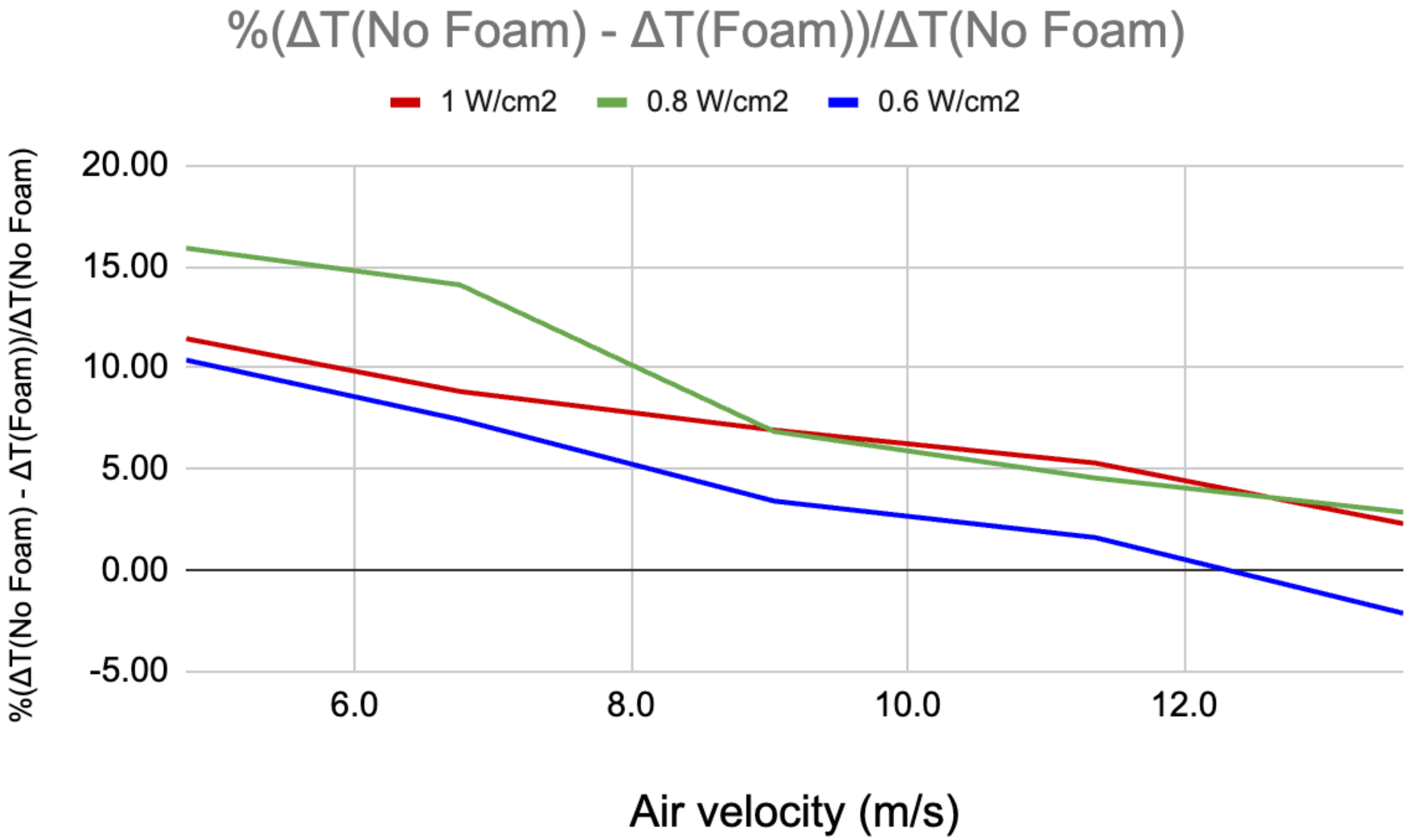


Nicole Apadula (LBNL)

No foam



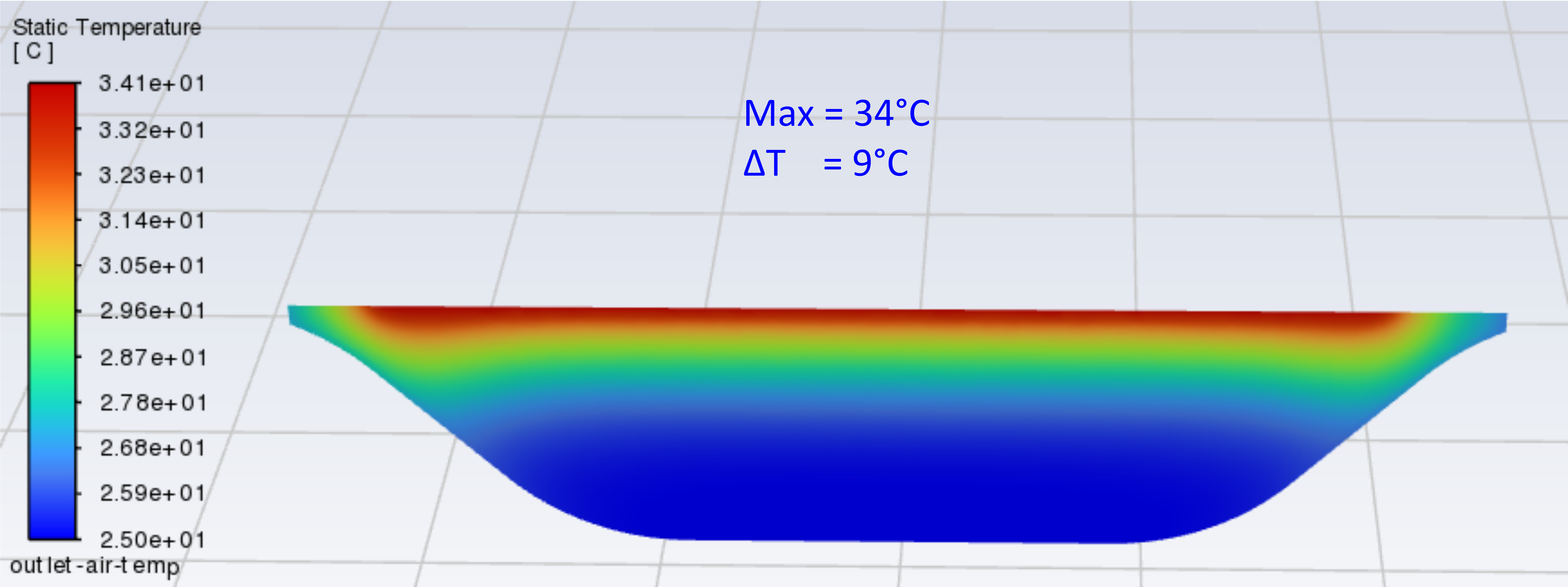
Nicole Apadula (LBNL)



Note: not all foam is created equal — here, foam is simply RVC; alternative being considered

Mera Horne (LBNL)

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



Cooling:

- One way to look at e.g. a large disk is simply as an 80 cm by 4 mm cross section,
- Airflow up to 10 m/s then points to 0.032 m^3/s or 68 cfm air flow,
- The total airflow in an endcap is ~ 4.5 times larger (4 large disks, one small disk),
- This corresponds to 0.144 m^3/s or **305 cfm**
- Add 50% if the disk-thickness will be 6 mm,
- Multiply by 2 if air is guided in from the center of the disk and sent out at the edges,
- The total for an endcap is then 0.432 m^3/s or **915 cfm**

This is, of course, consistent with the values Nikki put forward at the SVT workfest at ANL.

The difference between ~300 and ~1,000 cfm is, of course, not negligible.

"Shop air"

- Common problem "everywhere"
- Source here is from a "Topring" catalogue
- Indicates the need for a 32 – 50 mm diameter tube into the experiment with 6 – 7 atmospheres

In practice, more likely:

- 6 — 8 of such tubes for the two endcaps, the inner and outer barrel, and the segmentation in top and bottom halves,
- Or fewer, if one groups.

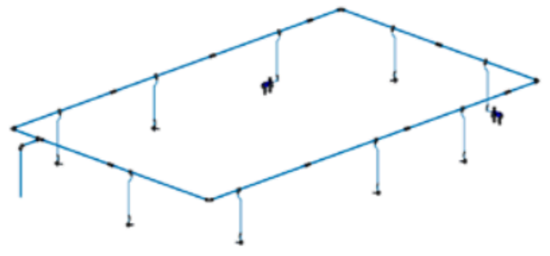
Distribution and regulation needs engineering input/design.

Minimum diameter pipe sizing for a closed loop network

TOTAL LENGTH OF THE NETWORK (FEET)

TOTAL FLOW REQUIRED

SCFM \ FEET	200	300	400	500	600	800	1000	1200	1400	1600	1800	2000	2500	3000	4000	6000	8000
5	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
10	16	16	16	16	16	16	16	16	16	16	16	16	16	16	20	20	20
15	16	16	16	16	16	16	16	16	16	20	20	20	20	20	20	25	25
20	16	16	16	16	16	16	16	20	20	20	20	20	20	20	25	25	25
30	16	16	16	16	20	20	20	20	20	20	25	25	25	25	25	32	32
40	16	16	20	20	20	20	20	25	25	25	25	25	25	25	32	32	32
60	20	20	20	25	25	25	25	25	25	32	32	32	32	32	32	40	40
80	20	20	25	25	25	25	32	32	32	32	32	32	32	32	40	40	40
100	25	25	25	32	32	32	32	32	32	32	32	32	40	40	40	40	50
125	25	25	32	32	32	32	32	32	32	40	40	40	40	40	40	50	50
150	25	32	32	32	32	32	40	40	40	40	40	40	40	50	50	50	63
200	32	32	32	40	40	40	40	40	40	40	50	50	50	50	50	63	63
300	32	40	40	40	40	40	50	50	50	50	50	50	50	63	63	63	80
400	40	40	40	50	50	50	50	50	50	63	63	63	63	63	63	80	80
500	40	50	50	50	50	50	63	63	63	63	63	63	63	80	80	80	80
750	50	50	50	63	63	63	63	63	80	80	80	80	80	80	80	100	100
1000	50	63	63	63	63	63	80	80	80	80	80	80	80	100	100	100	100
1500	63	63	63	80	80	80	80	80	100	100	100	100	100	100			
2000	63	80	80	80	80	100	100	100	100	100	100	100					
2500	80	80	80	100	100	100	100	100	100								
3000	80	80	100	100	100	100	100										
4000	100	100	100	100	100												
5000	100	100	100														
6000	100																

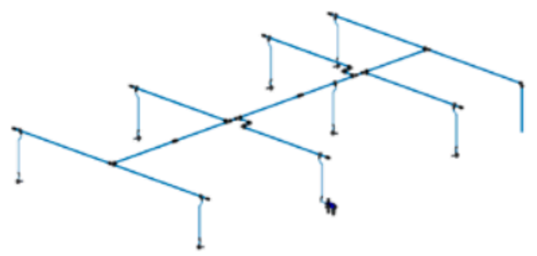


Minimum diameter pipe sizing for a linear network (dead end)

TOTAL LENGTH OF THE NETWORK (FEET)

TOTAL FLOW REQUIRED

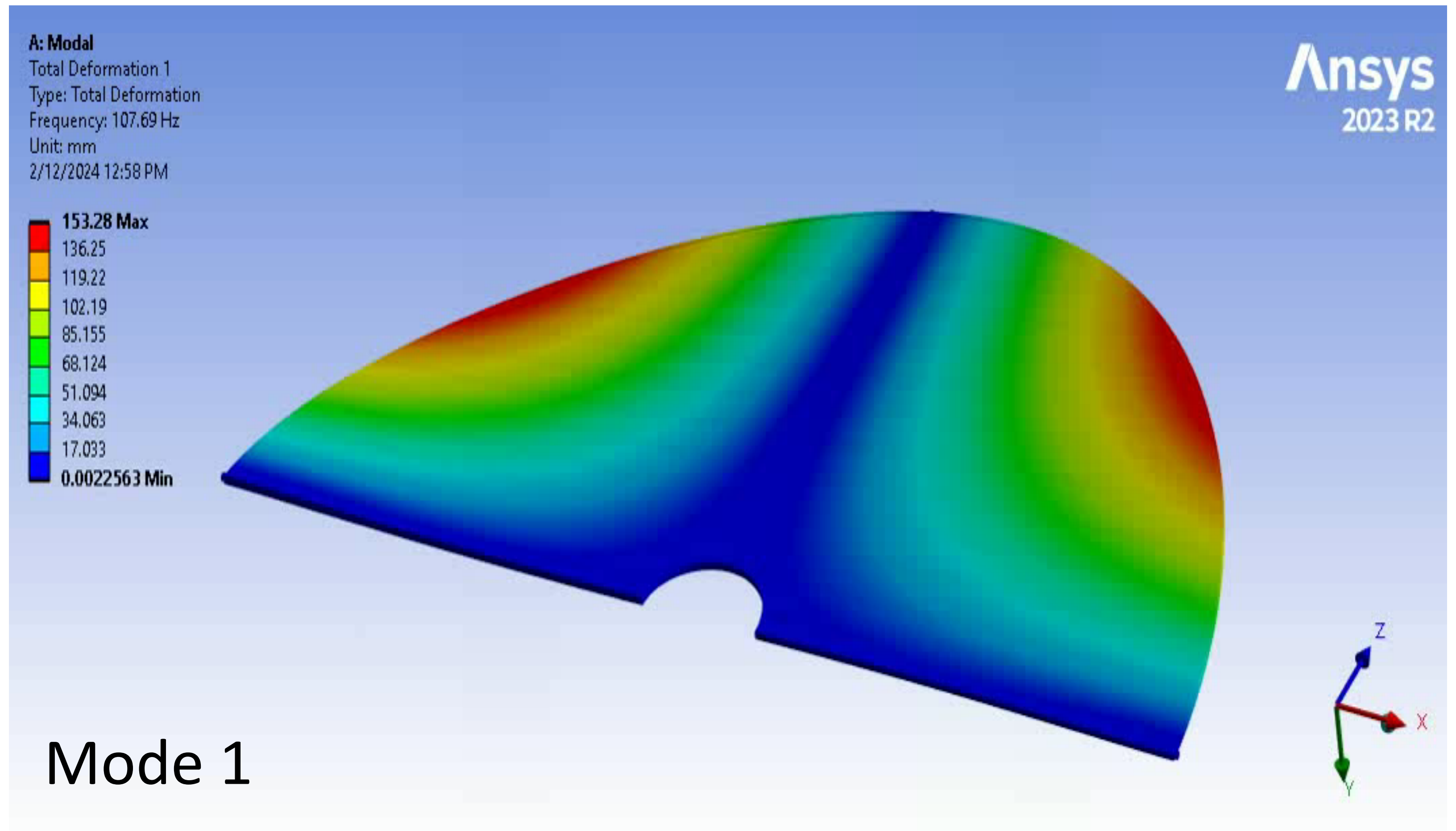
SCFM \ FEET	25	50	100	200	300	400	500	600	700	800	900	1000	1250	1500	2000	3000	4000
5	16	16	16	16	16	16	16	16	16	16	16	16	16	16	20	20	20
10	16	16	16	16	16	16	16	20	20	20	20	20	20	20	25	25	25
15	16	16	16	16	20	20	20	20	20	20	25	25	25	25	25	32	32
20	16	16	16	20	20	20	20	25	25	25	25	25	25	25	32	32	32
30	16	16	20	20	25	25	25	25	25	32	32	32	32	32	32	40	40
40	16	20	20	25	25	25	32	32	32	32	32	32	32	32	40	40	40
60	20	20	25	25	32	32	32	32	32	40	40	40	40	40	40	50	50
80	20	25	25	32	32	32	40	40	40	40	40	40	40	50	50	50	63
100	20	25	25	32	32	40	40	40	40	40	50	50	50	50	50	63	63
125	25	25	32	32	40	40	40	40	50	50	50	50	50	50	63	63	63
150	25	32	32	40	40	40	50	50	50	50	50	50	50	63	63	63	63
200	32	32	40	40	50	50	50	50	50	63	63	63	63	63	63	80	80
300	32	40	40	50	50	63	63	63	63	63	63	63	80	80	80	80	100
400	40	40	50	50	63	63	63	63	80	80	80	80	80	80	80	100	100
500	40	50	50	63	63	63	80	80	80	80	80	80	80	100	100	100	100
750	50	50	63	63	80	80	80	80	100	100	100	100	100	100	100		
1000	50	63	63	80	80	100	100	100	100	100	100	100					
1500	63	80	80	100	100	100	100										
2000	63	80	80	100													
2500	80	80	100	100													
3000	80	100	100														

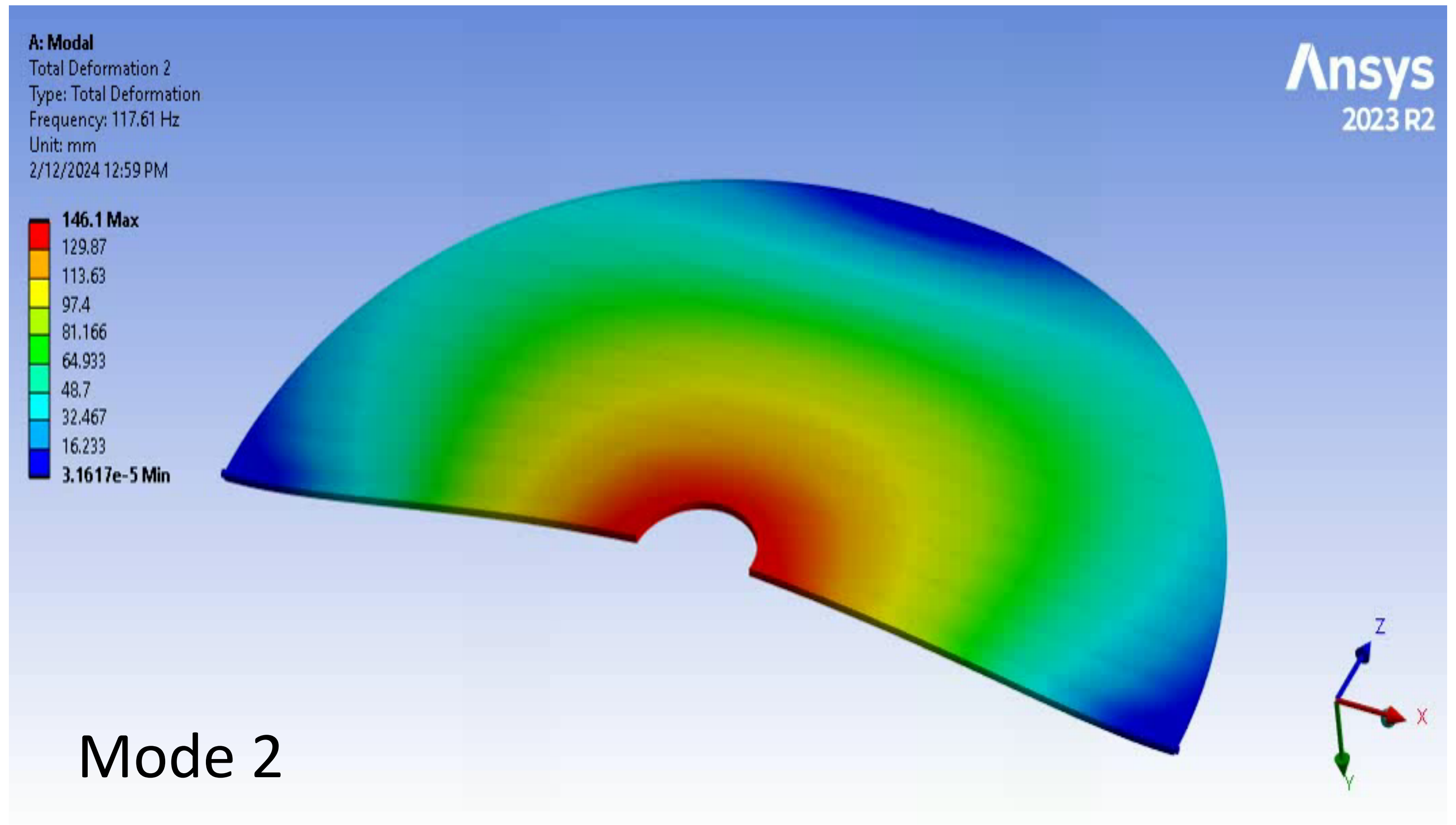


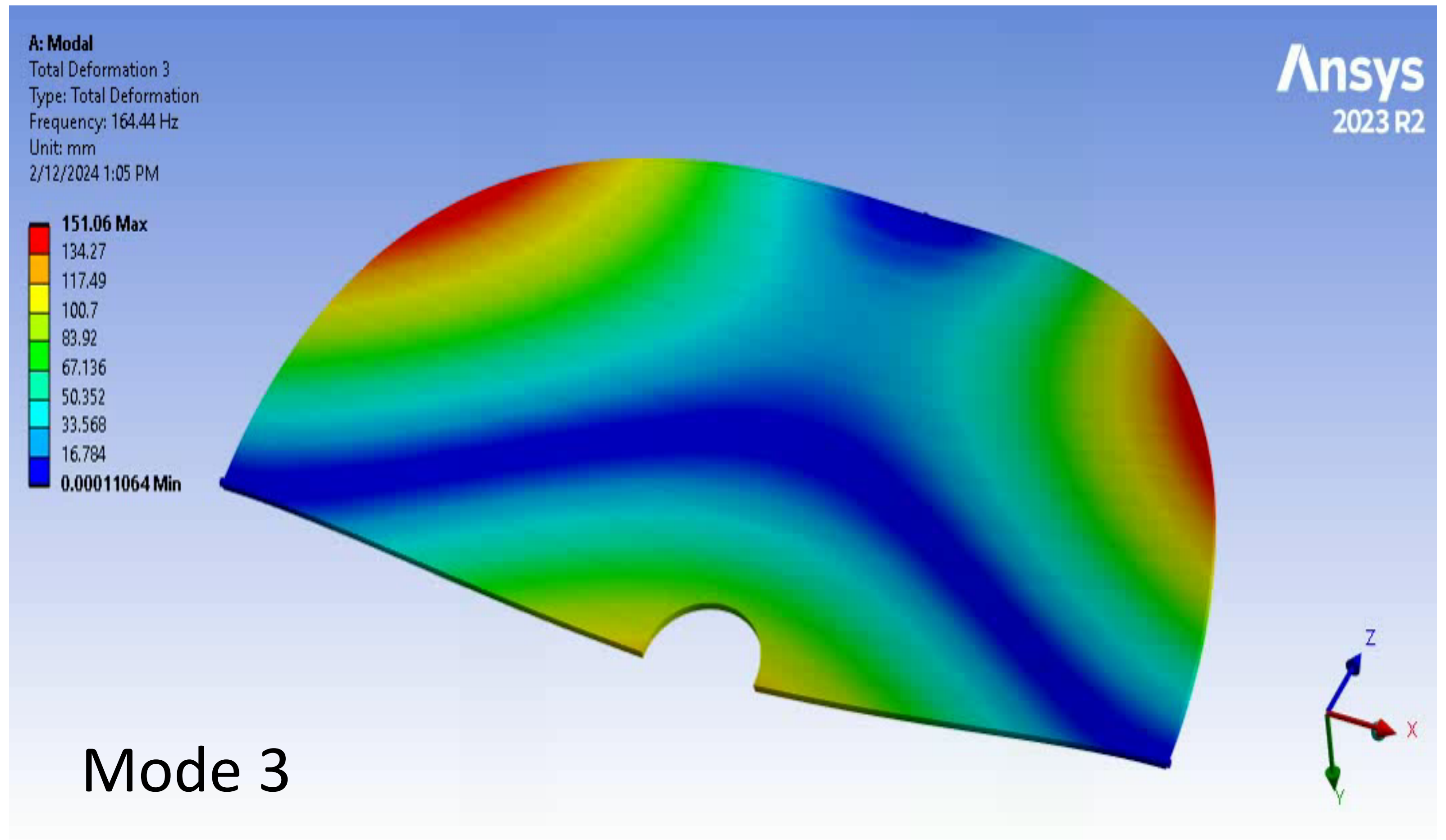
Note: Diameters are based on the CAGI Handbook's recommendations for pressure drop less than 3 psi, with the following conditions: pressure 100 psig at 20 degrees C, main loop including 2 valves and 4 elbows

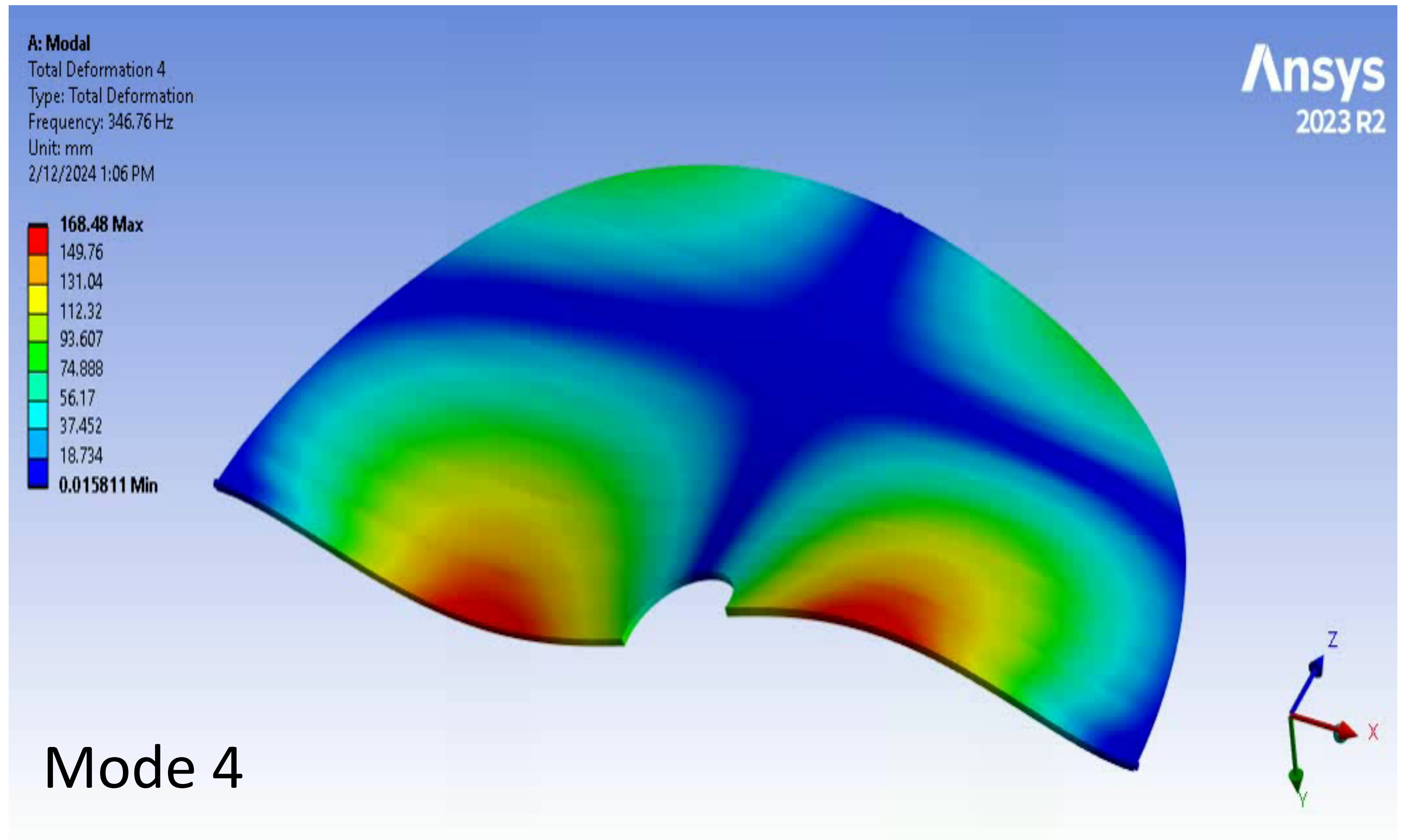
Corrugated Disc of 6 mm Height – Rev 2 (Mesh size = 2 mm)

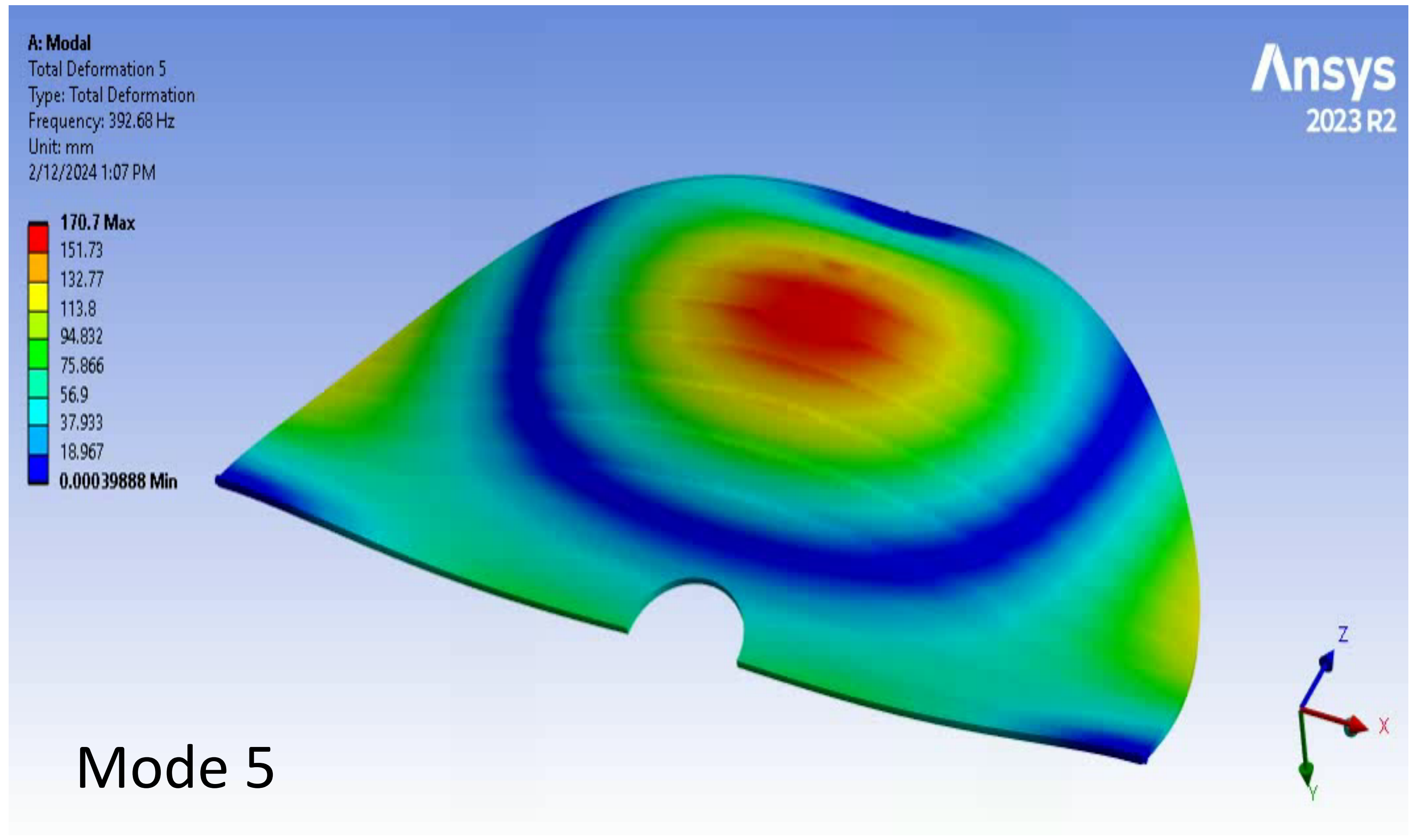
Mera Horne (LBNL)

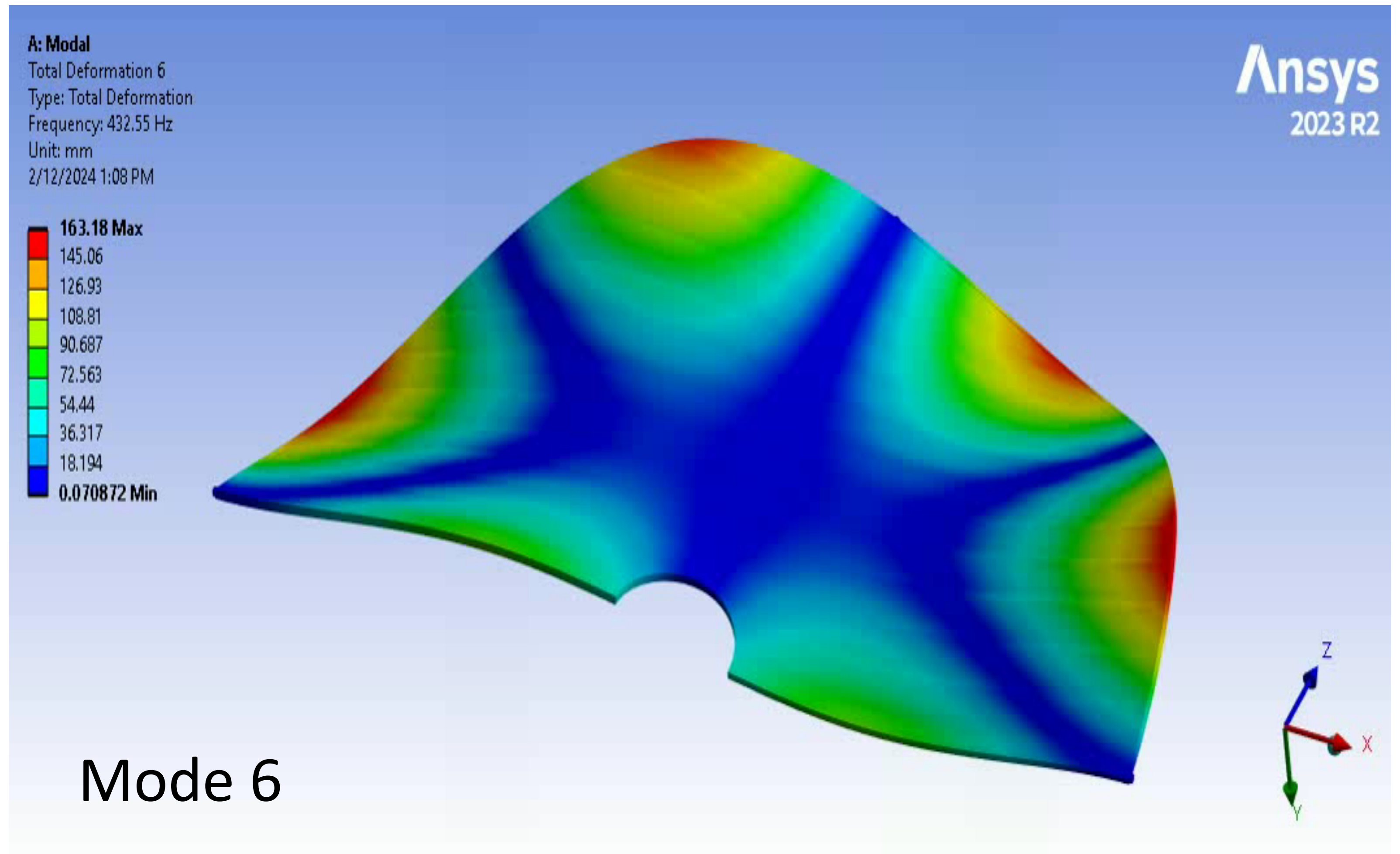




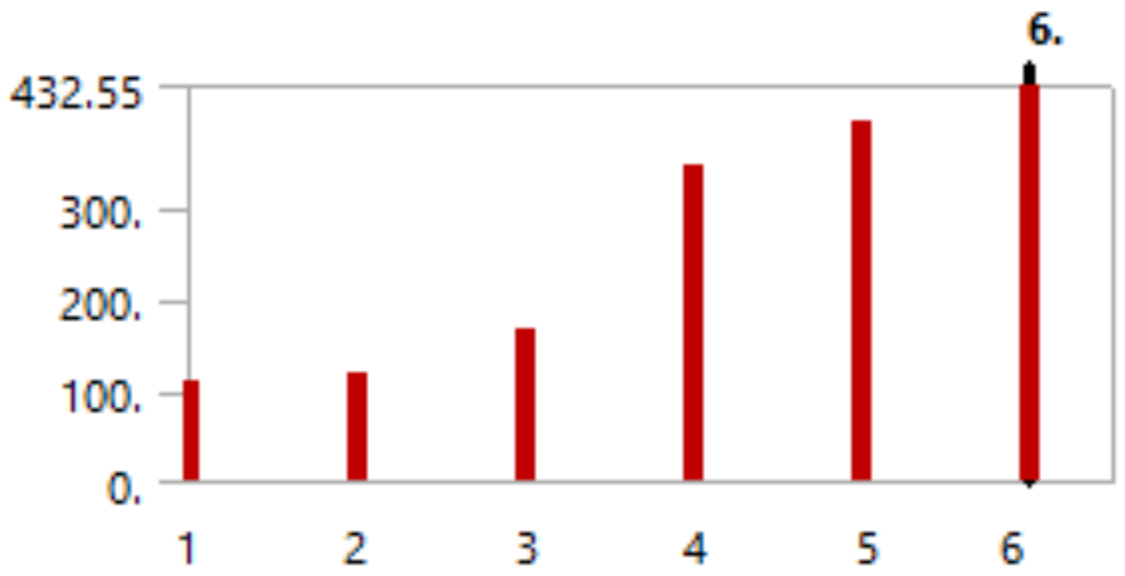






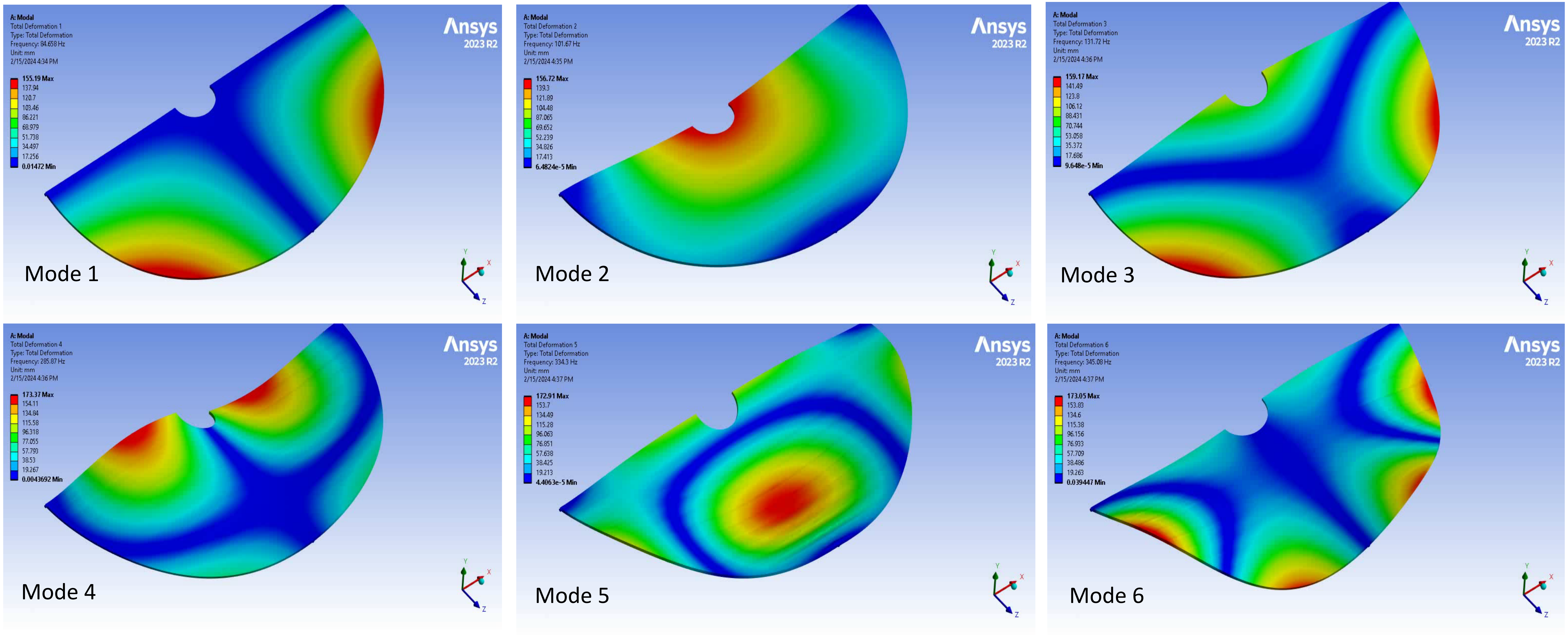


Mode	☑ Frequency [Hz
1.	107.69
2.	117.61
3.	164.44
4.	346.76
5.	392.68
6.	432.55

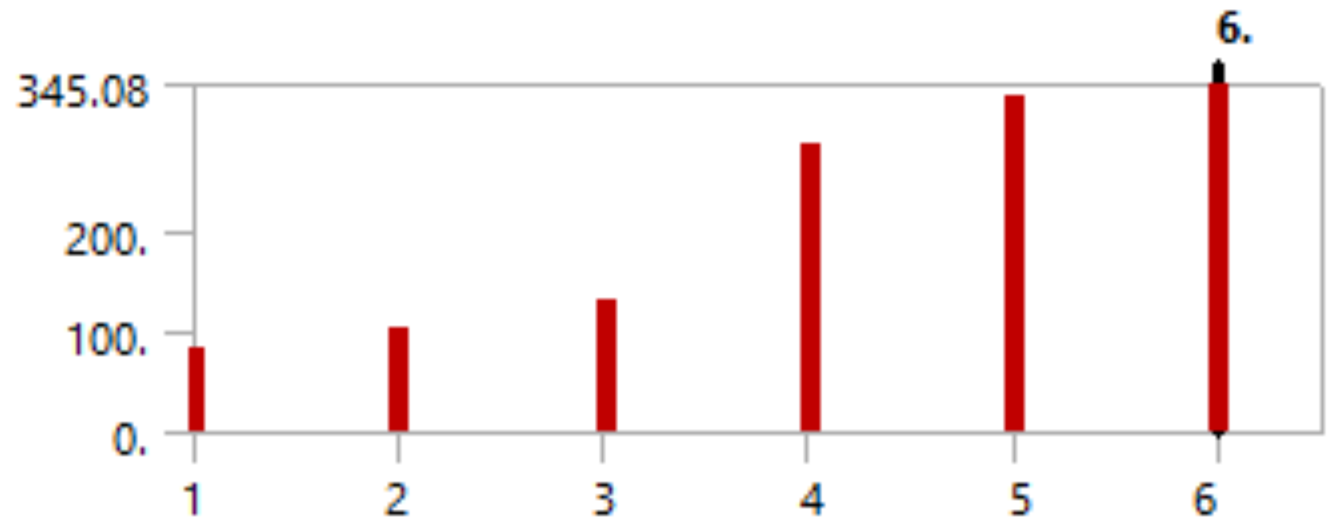


Corrugated Disc of 4 mm Height – Rev 1 (Mesh size = 2 mm)

Mera Horne (LBNL)



Mode	Frequency [Hz]
1.	84.658
2.	101.67
3.	131.72
4.	285.87
5.	334.3
6.	345.08



Many SVT aspects not covered here,

Bi-weekly SVT general meeting today at noon is “on topic”

- Elke Aschenauer will discuss integration and installation constraints
- Andy Jung and Georg Viehhauser will address envelopes, mounting hierarchy
- Domenico Elia may update on IB CAD effort at INFN

Logistics:

https://indico.bnl.gov/event/22343
https://cern.zoom.us/j/61734290399?pwd=bUkzYy94U0xaWnFkWmdTSjI4YkNIZz09
Meeting ID: 617 3429 0399
Passcode: 601003

Thanks Rahul for agreeing to mesh the schedules!