SVT

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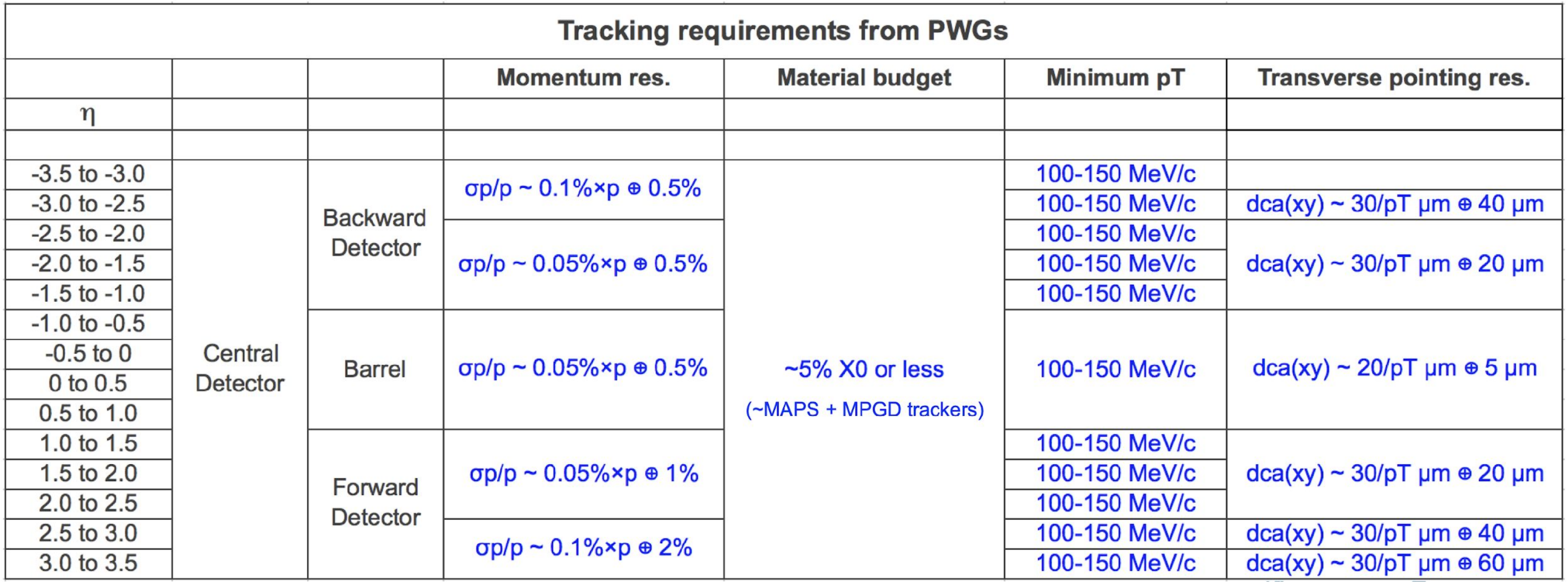
ePIC TIC Mtg.
February 26, 2024

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).



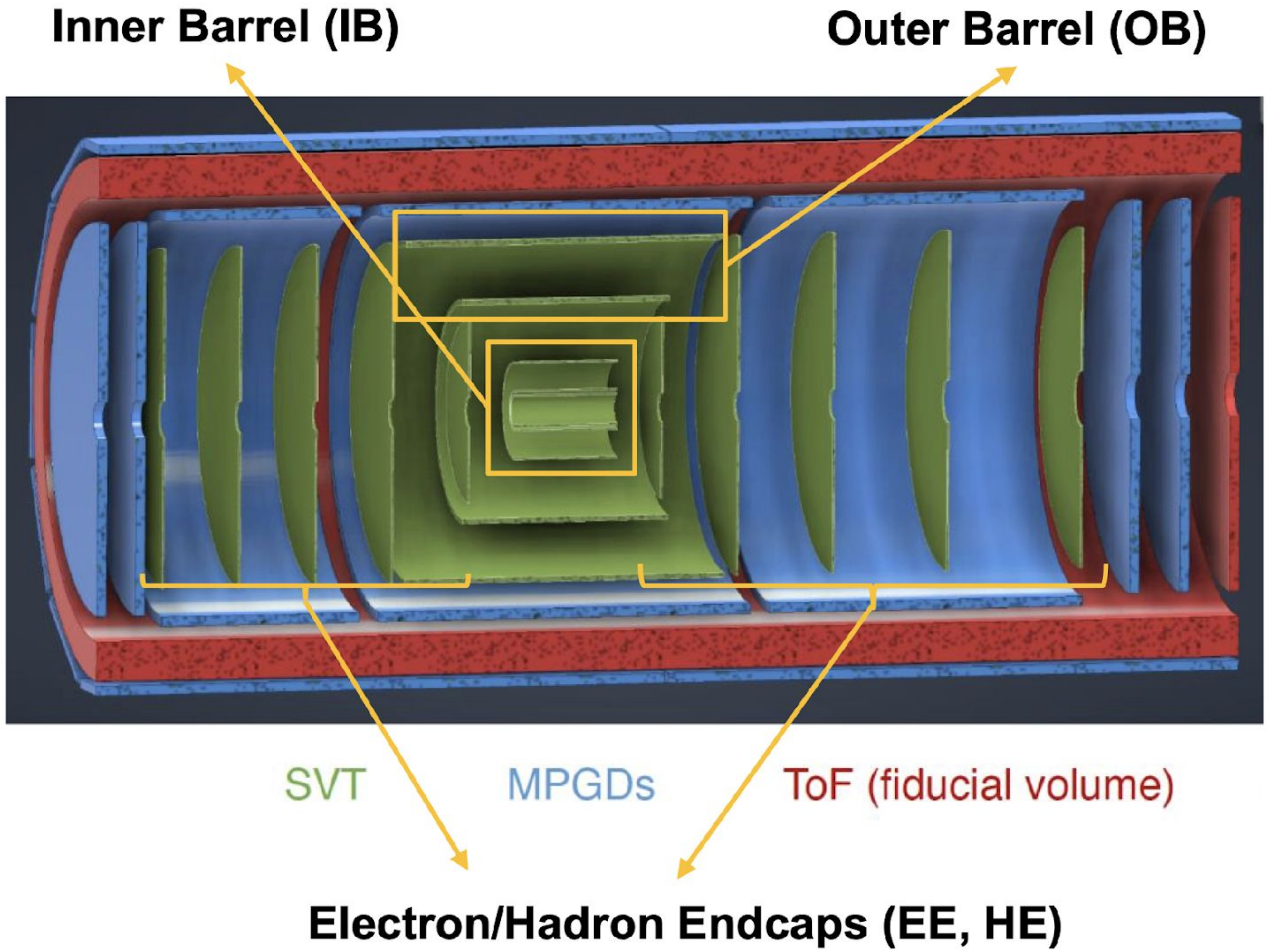
Tracking requirements from PWGs

			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.

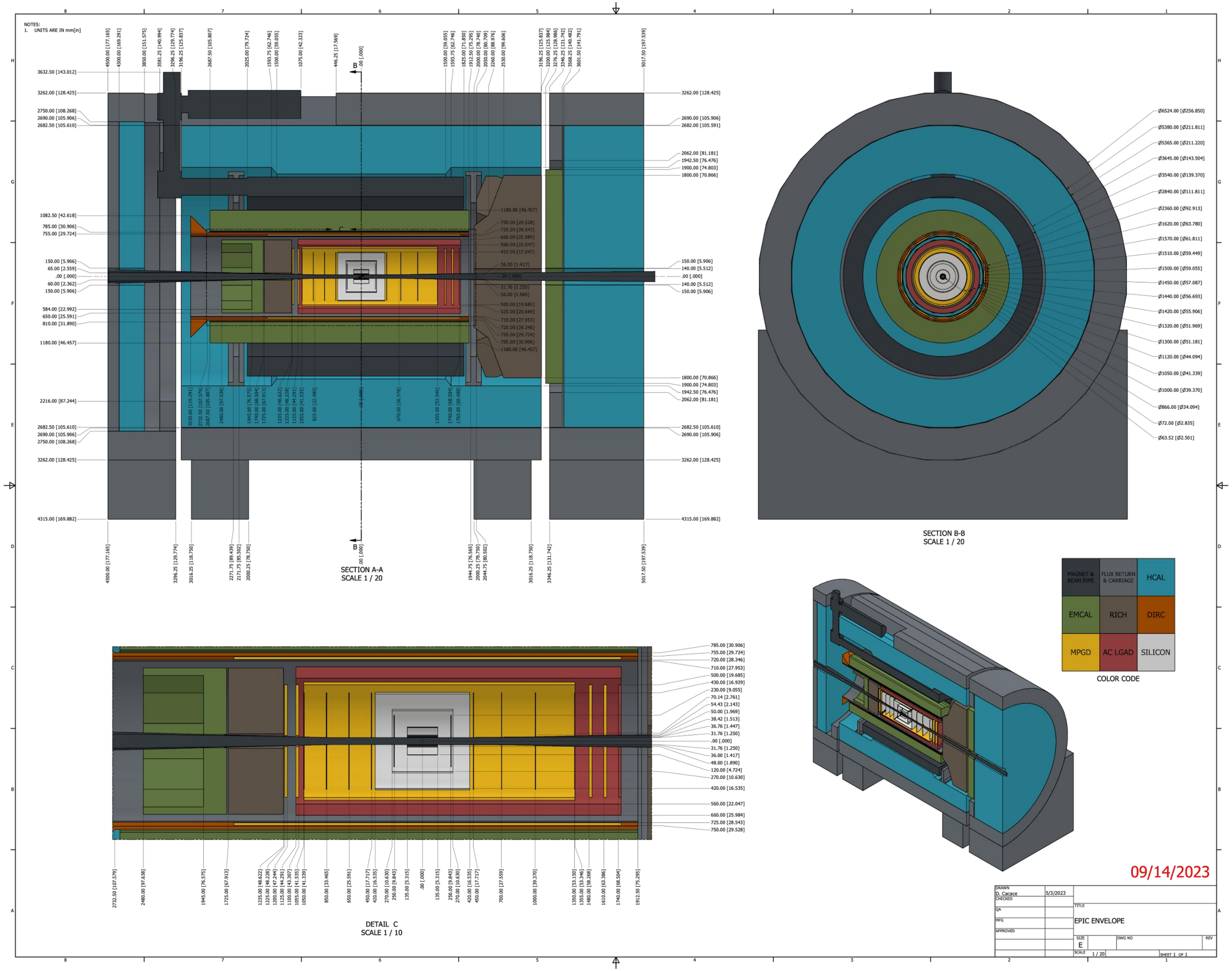


SVT Total (active) area **~ 8.5 m^2**

ePIC SVT target specifications	
Spatial resolution	~ 5 um
Power	< 40 mW/cm^2
Frame rate	$\leq 2\ \mu s$
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



09/14/2023

SVT volume

$-1050 < z < 1350$ mm

$r \sim 430$ mm

IB (L0—L2)

ITS3 wafer-scale sensor

i.e. length and radii derive from sensor dimensions

OB (L3, L4), EE (ED0-4), HE (HD0-4)

EIC-LAS sensor

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

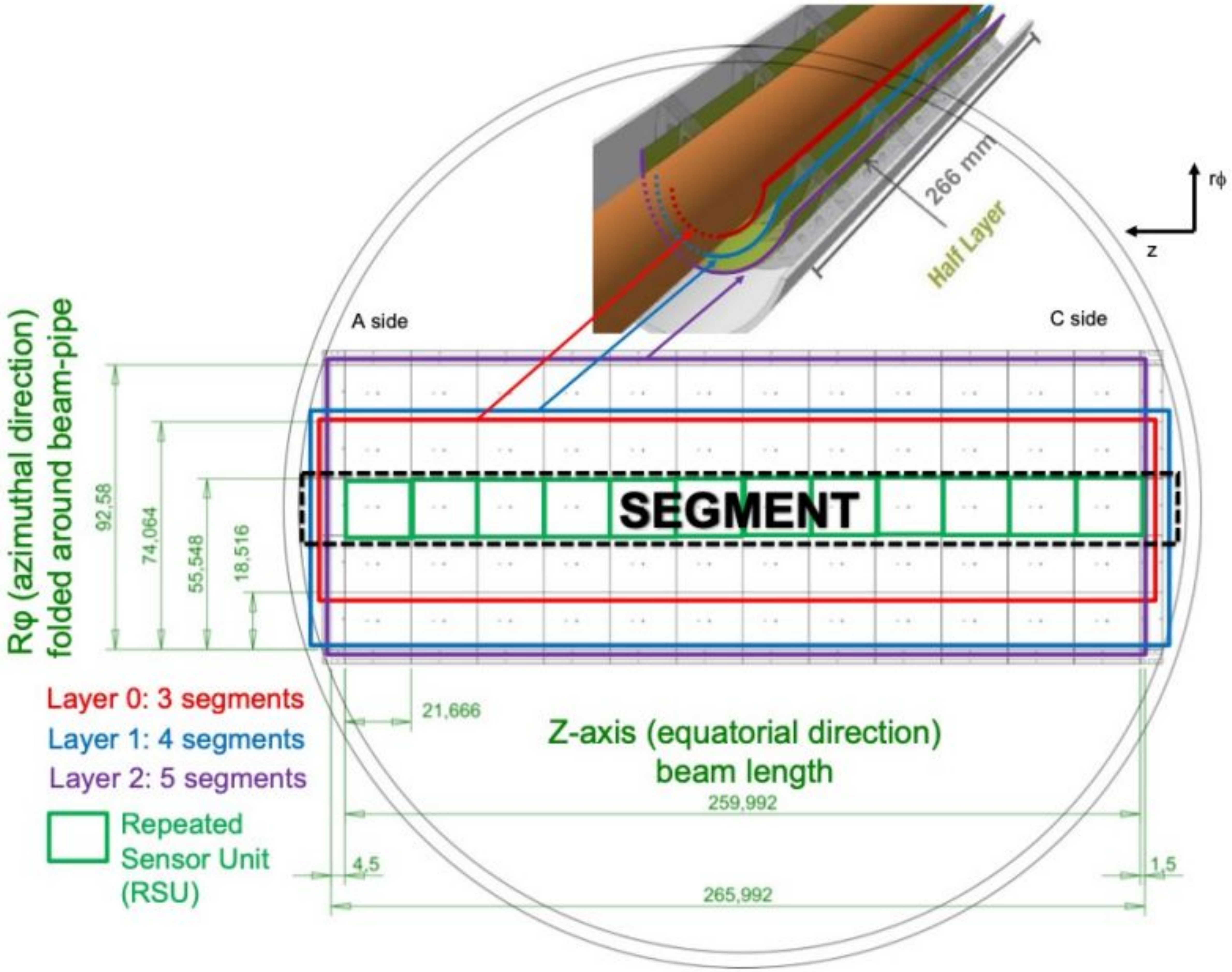
What follows is in part a summary/re-use and in part new/additional.

Sensor and Ancillary IC

Background - MOSAIX

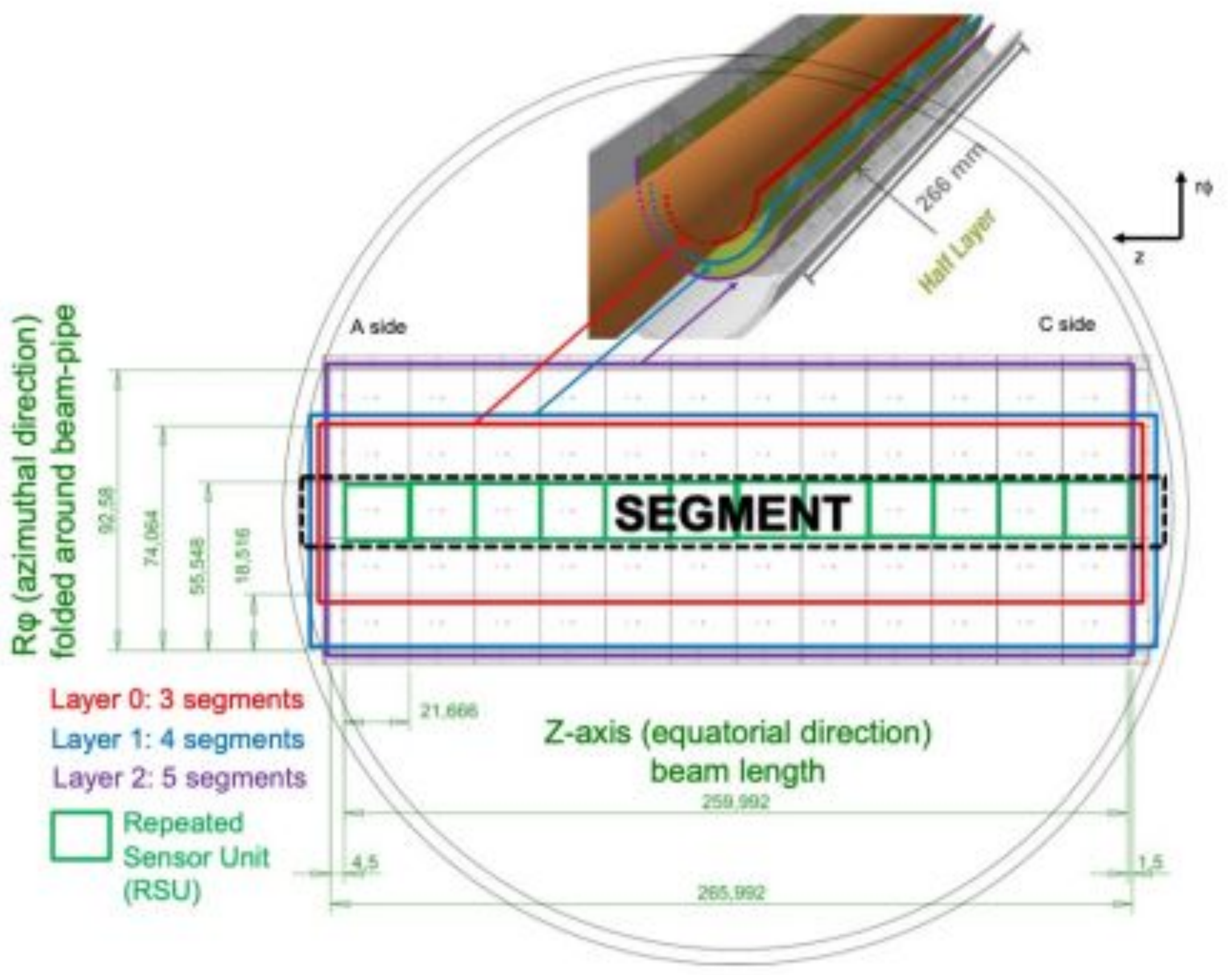
ITS3 Chip development

- CERN currently developing a new chip for the ITS3 upgrade of ALICE – MOSAIX
- **This sensor will be used for the SVT IB (L0, L1, L2)**
- It will be “wafer scale” – full length, one reticle wide
- Idea is to thin and bend them around the beam pipe. Dicing to different width will give the three required layers.



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

Background - MOSAIX



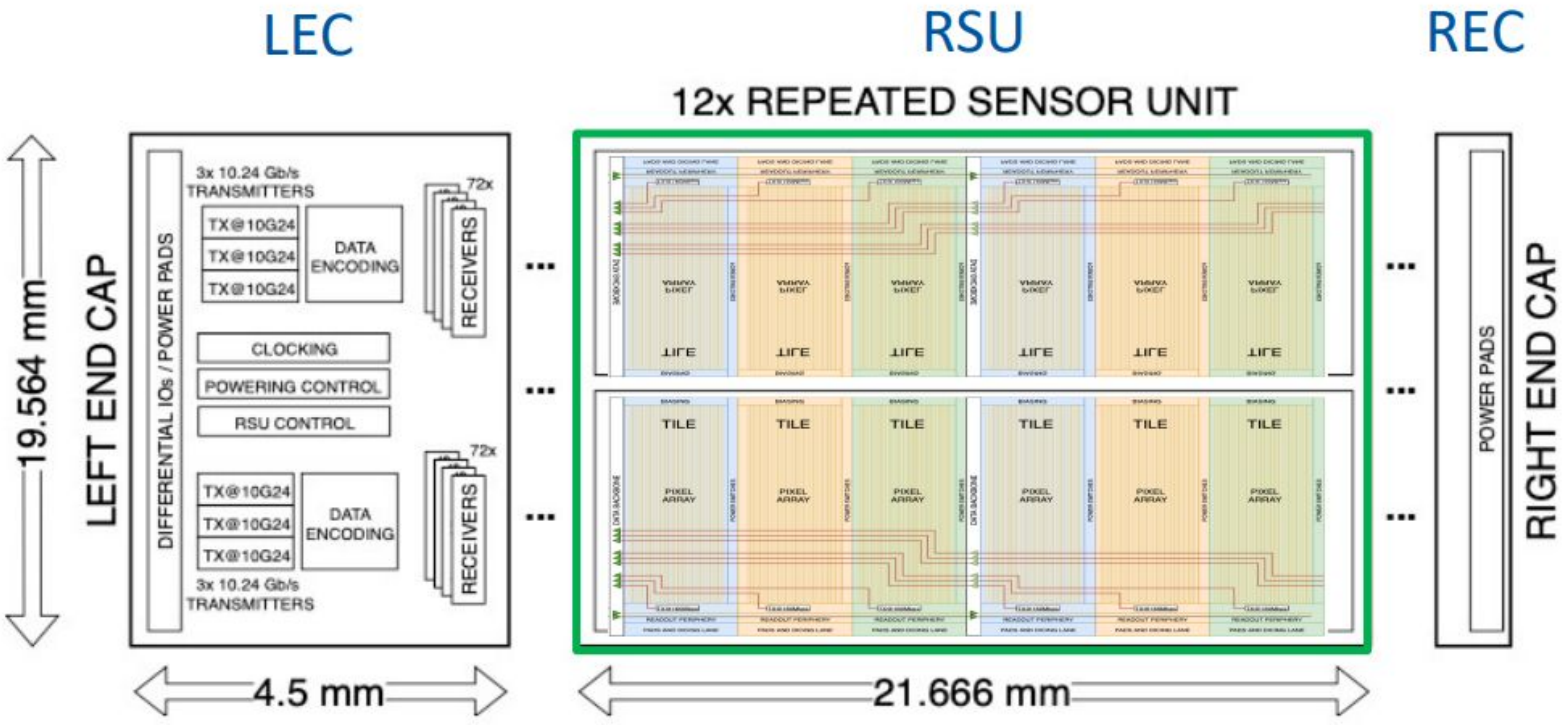
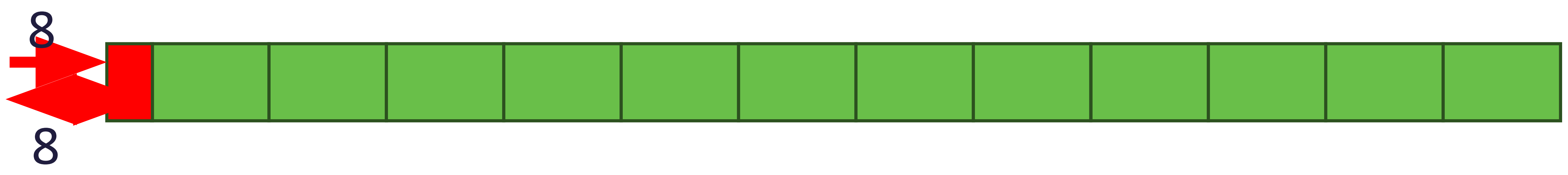
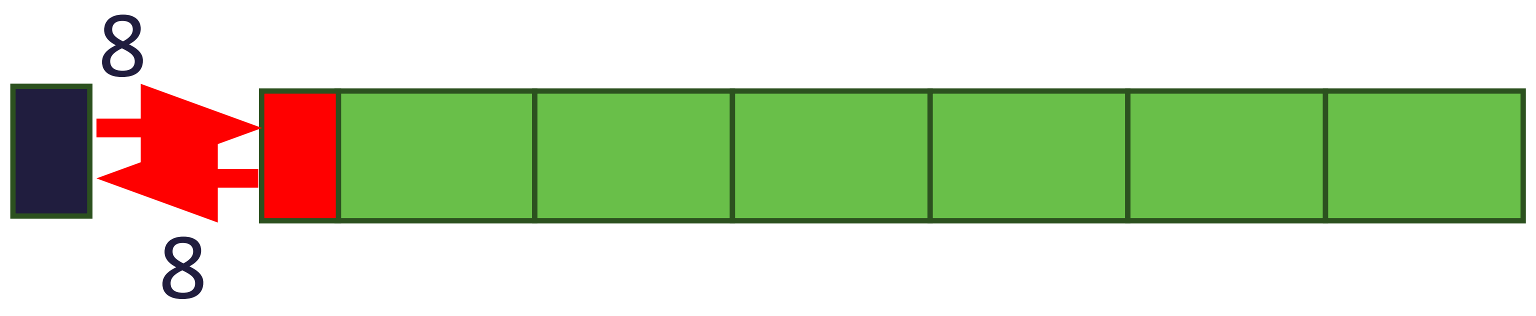


Figure 3.34: Block diagram of the sensor segment.

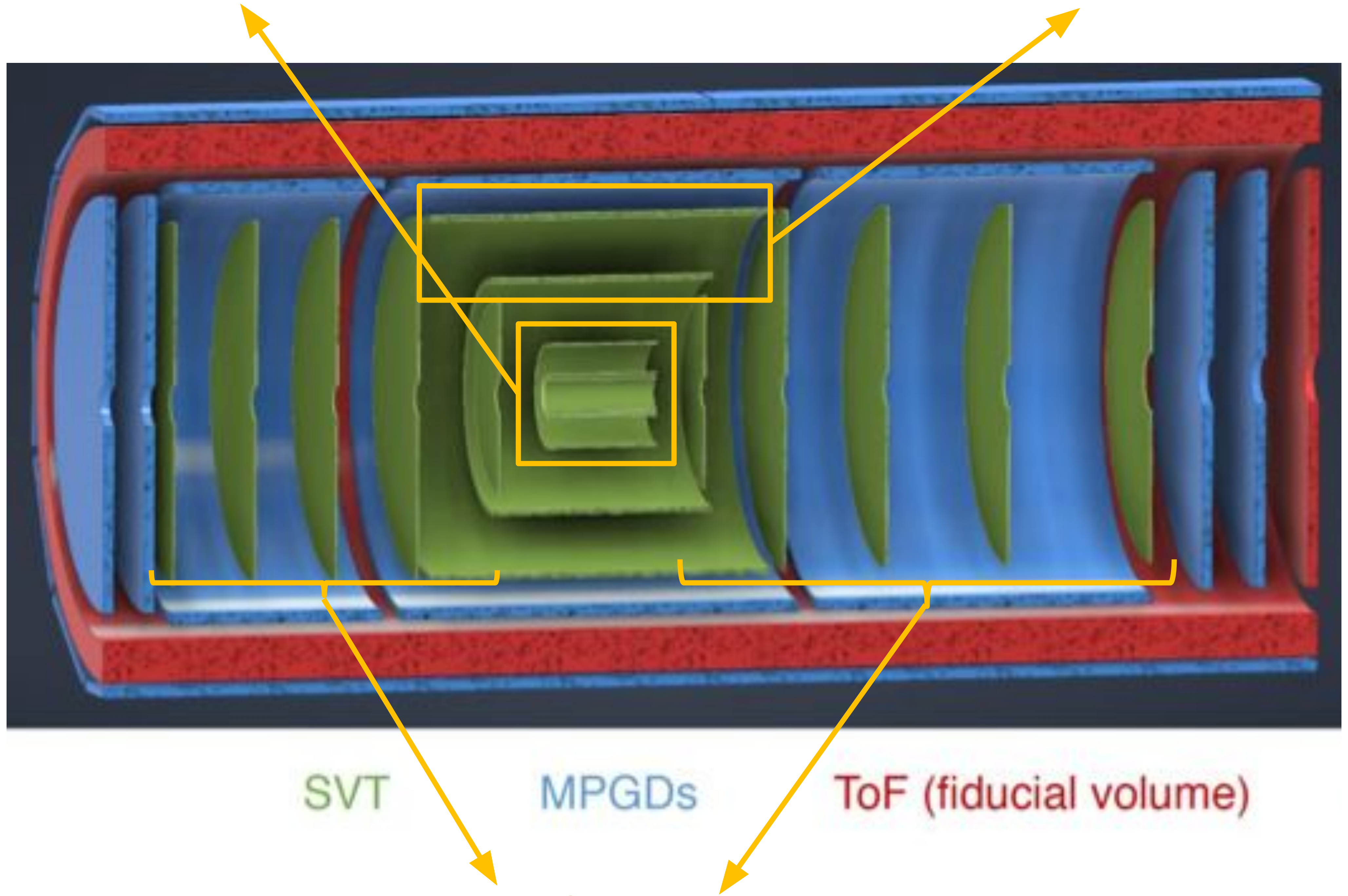
ITS3 to ePIC





Inner Barrel

- Use MOSAIX directly
- Requires supply agreement with CERN (in negotiation)
- Design still progressing



Outer Barrel (OB)
2 stave-based layers

Electron/Hadron Endcaps (EE, HE)
5 disks on either side of the IP

Outer Barrel/Discs

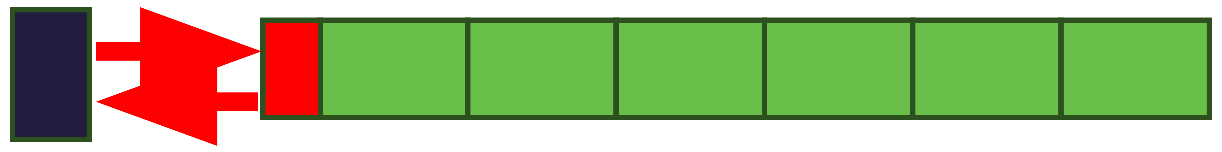
- Improve Yield – reduce number of RSUs
- Need to reduce mass at system level
- Requires agreement for database access with CERN (in negotiation)

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

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

Iain Sedgwick (RAL)

MOSAIX to EIC-LAS



Inner Barrel		**Outer Barrel**
12 RSUs	Yield likely too low	Reduced number of RSUs
8 data links	Excess material for required data rate	Single data link
7 slow control links	Excess material when built into stave	Multiplex slow control
Direct powering	Excess material when built into stave	Serial powering

Must be done on 65nm MOSAIX database

Could be on ancillary chip

Science and Technology Facilities Council

Sensor and Ancillary IC — Summary

Good progress on the formal sensor agreement between EIC/BNL and ALICE/CERN:

- Two sensor designers affiliated with ePIC institutions are embedded in the ITS3 team,
- Complemented with teams of experienced designers in the UK and the US,
- Ongoing discussion e.g. on number of wafers from ER2 and beyond,
- However, the agreement is not yet signed and we have no access yet to the sensor design database.

Ancillary IC is a justified path while we are waiting for signatures / design database. It has three main functions:

- Power to the four domains of the ITS3 MOSAIX and EIC-Large-Area-Sensor (SLDO regulators),
- Provide sensor bias voltage (Negative Voltage Generator),
- Multiplexing (and transcoding) of slow-control to reduce services (Slow Control),
- Coordination via bi-weekly ePIC-specific designers meetings; ad-hoc meetings as needed,

Characterization efforts:

- Ongoing, now also including ER1 and new-ish elements (e.g. higher-temperatures using a climate chamber),
- Irradiation and characterization of ancillary IC in the planning stages.

EIC-LAS — Power, Readout and Slow-Control

- The OB and disks will use the EIC-LAS sensor

- The EIC-LAS is one segment of 1x5 or 1x6 RSUs plus LEC for power and data
  - There is probably also going to be a REC to terminate the design; no power or data connection

- The EIC-LAS will have one data link

- The EIC-LAS works with an auxiliary chip that will provide
  - Current to voltage conversion for the serial powering scheme – SLDO
  - Negative voltage generation to bias the sensor – NVG
  - Slow control interface – Slow Ctrl

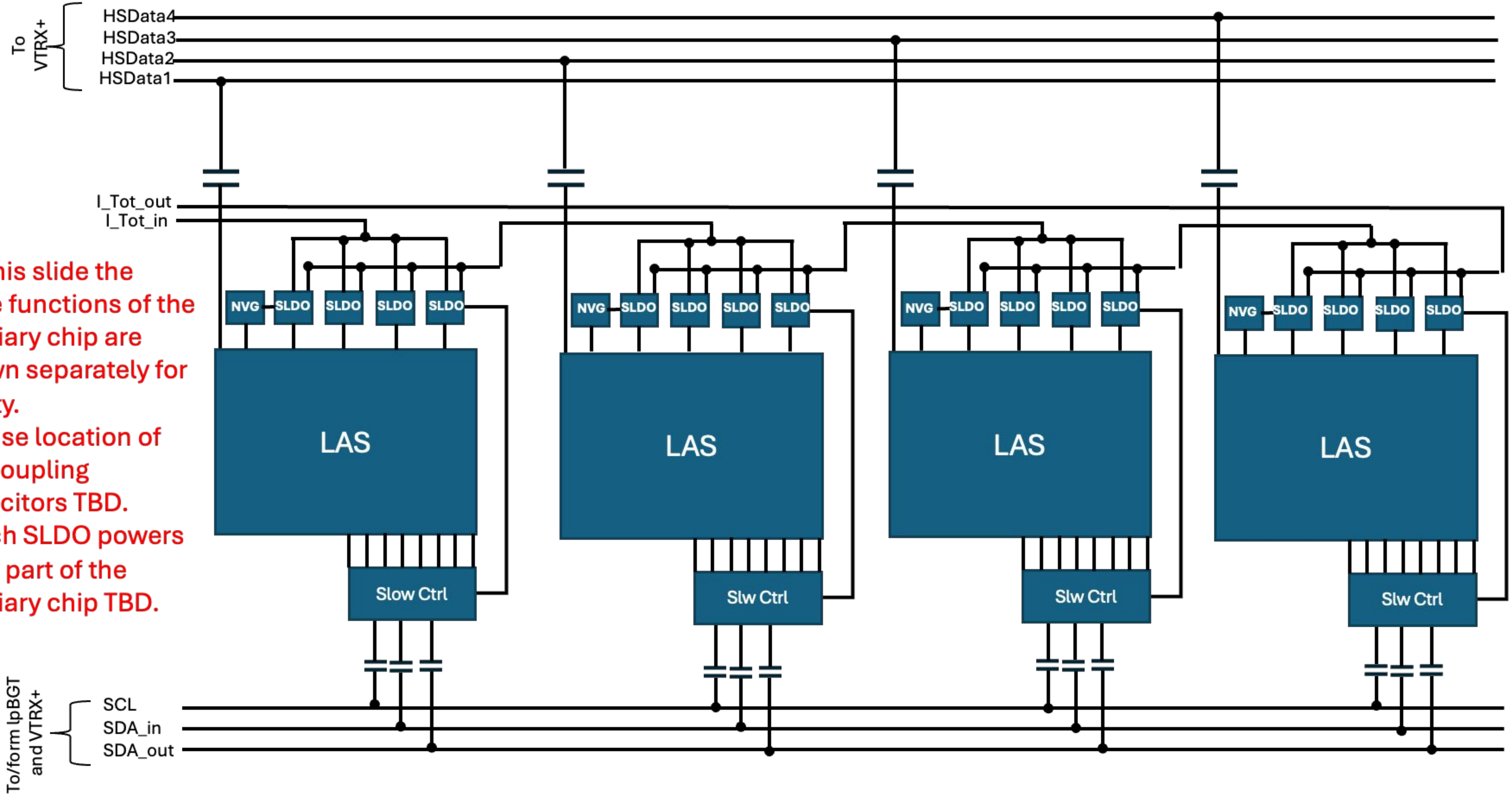
- **In the current OB and disks design concepts, groups of up to 4 EIC-LAS sensors will be one powering, data, slow control unit**

- An FPC will route power, data and slow control between sensors and auxiliary chips on the staves/disks and the readout and control boards

Note: more on this at the SVT meeting next week

EIC-LAS connections on FPC along stave/disk

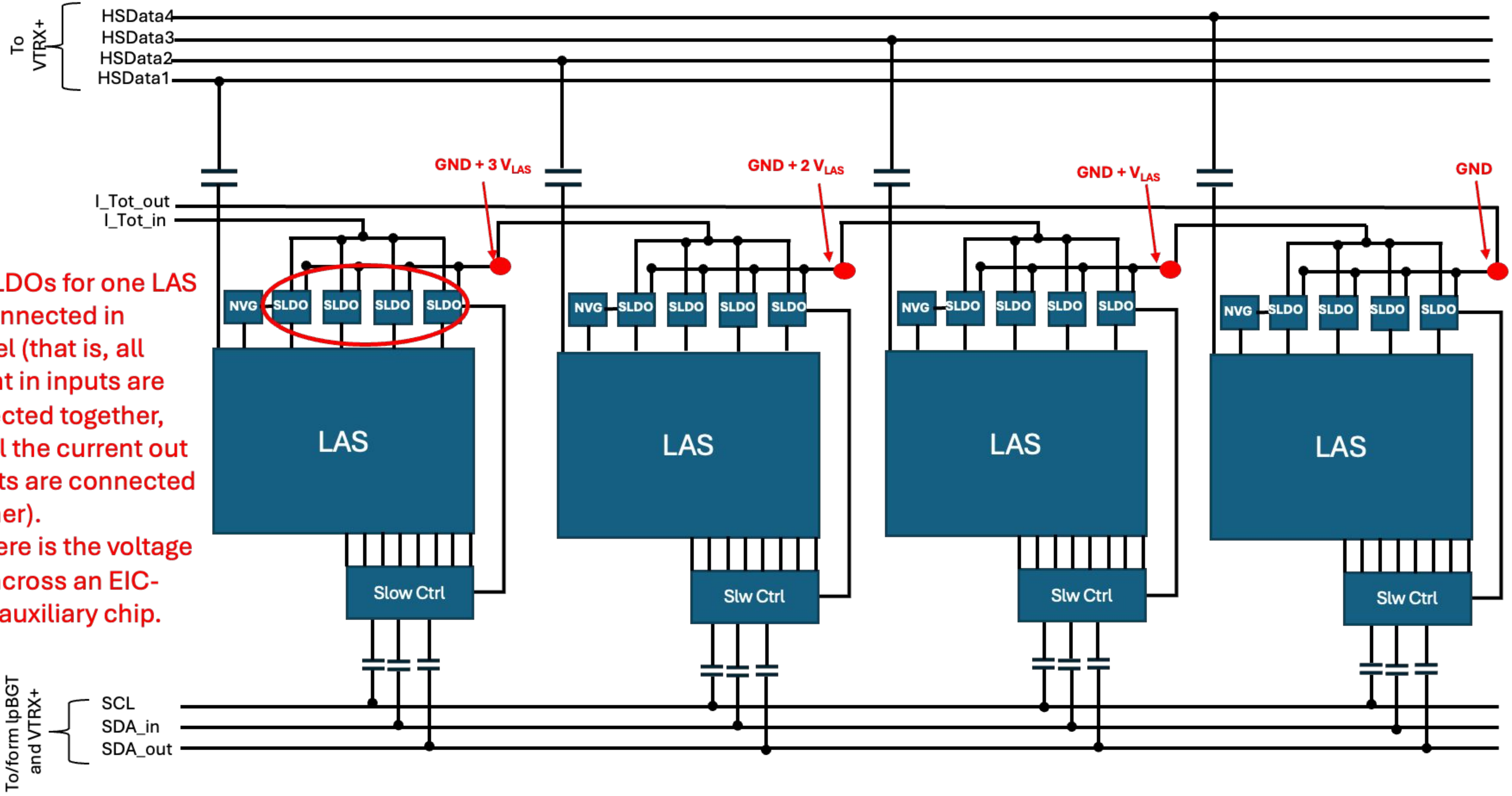
Schematic drawing by
Marcello Borri (STFC)



- On this slide the three functions of the auxiliary chip are shown separately for clarity.
- Precise location of AC-coupling capacitors TBD.
- Which SLDO powers what part of the auxiliary chip TBD.

EIC-LAS connections on FPC along stave/disk

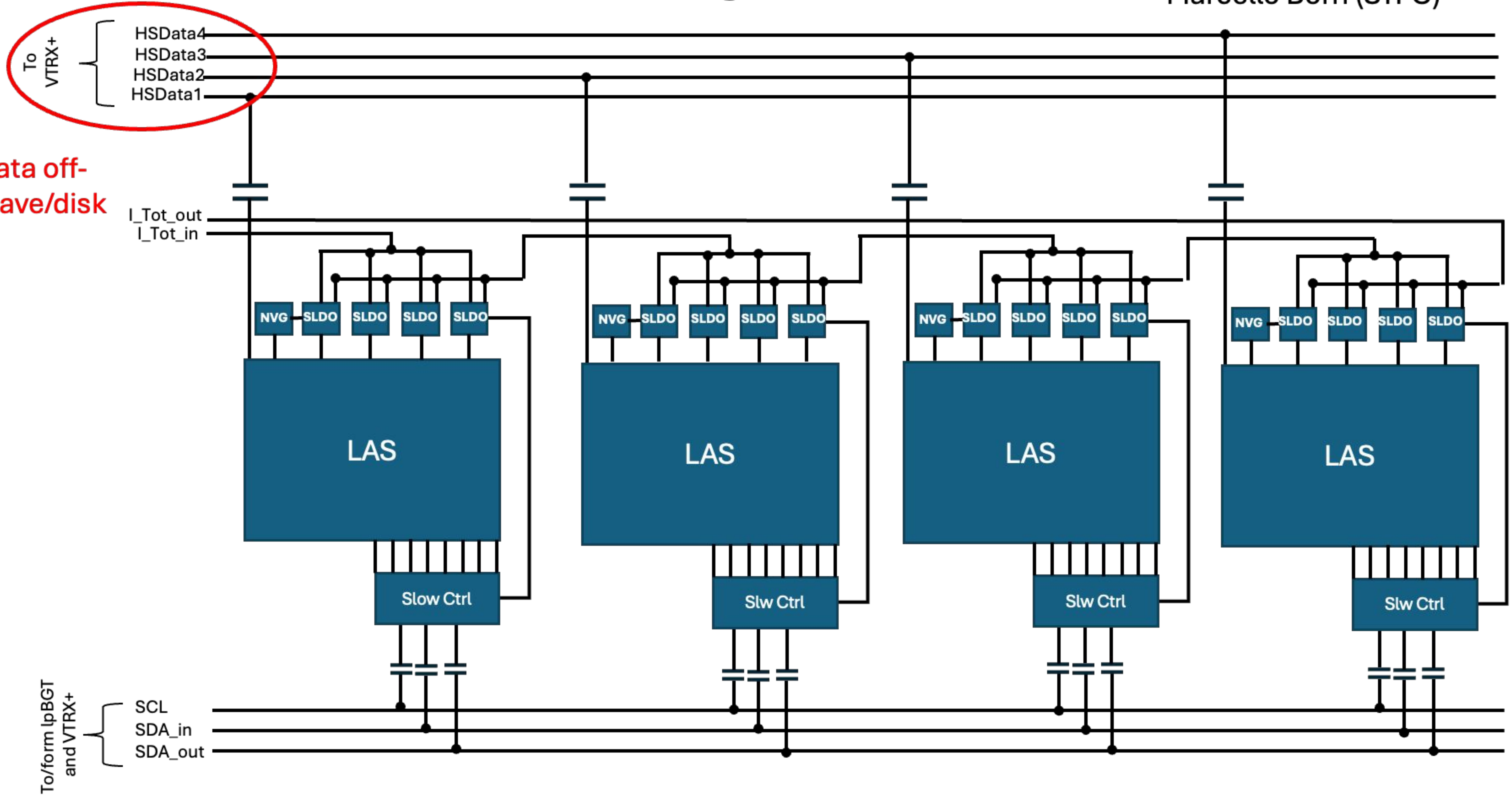
Schematic drawing by
Marcello Borri (STFC)



- The SLDOs for one LAS are connected in parallel (that is, all current in inputs are connected together, and all the current out outputs are connected together).
- V_{LAS} here is the voltage drop across an EIC-LAS + auxiliary chip.

EIC-LAS connections on FPC along stave/disk

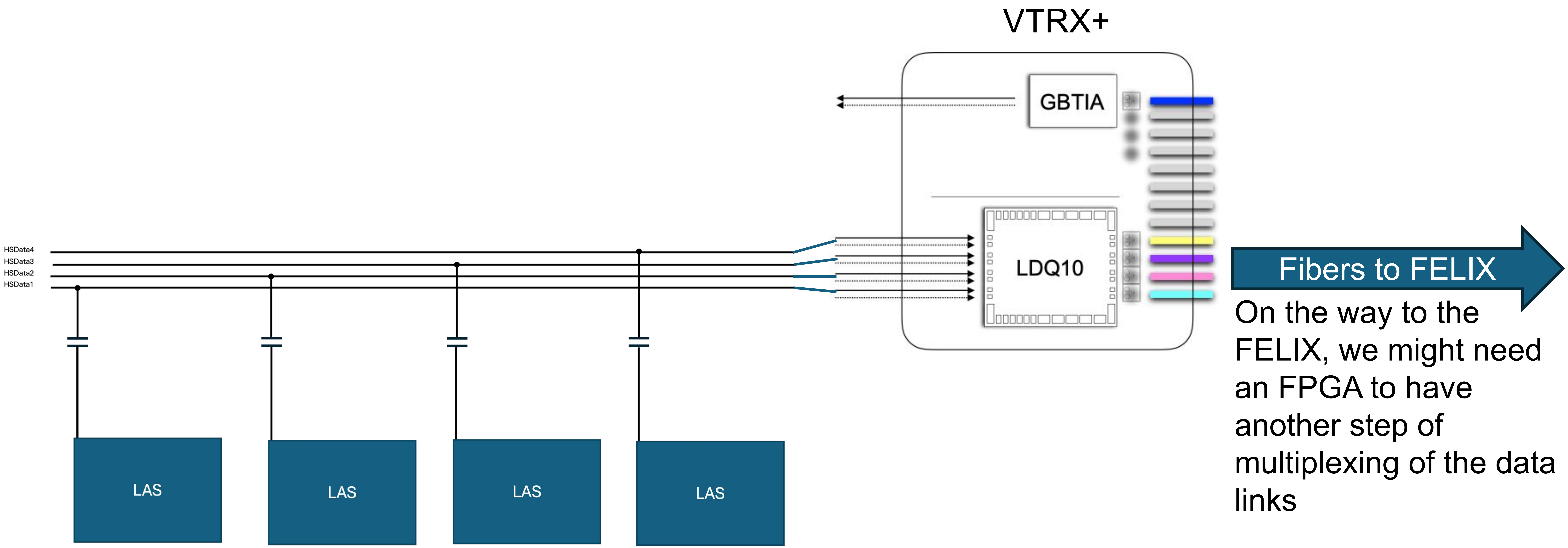
Schematic drawing by
Marcello Borri (STFC)



Data off-stave/disk

Data from stave/disk to control room

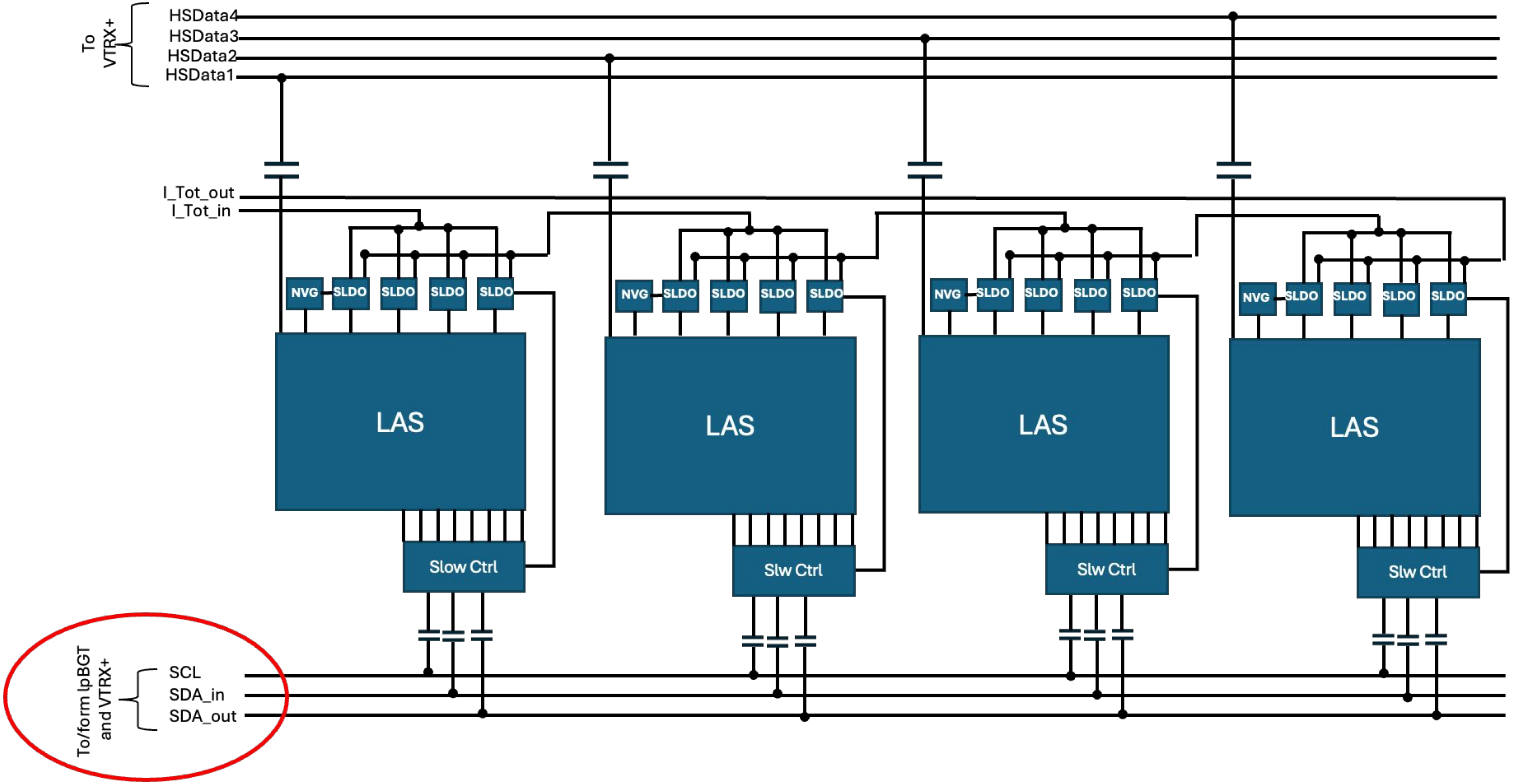
Up to 4 EIC LAS to 1 VTRX+ to 4 fibers
# of EIC-LAS = # data fibers



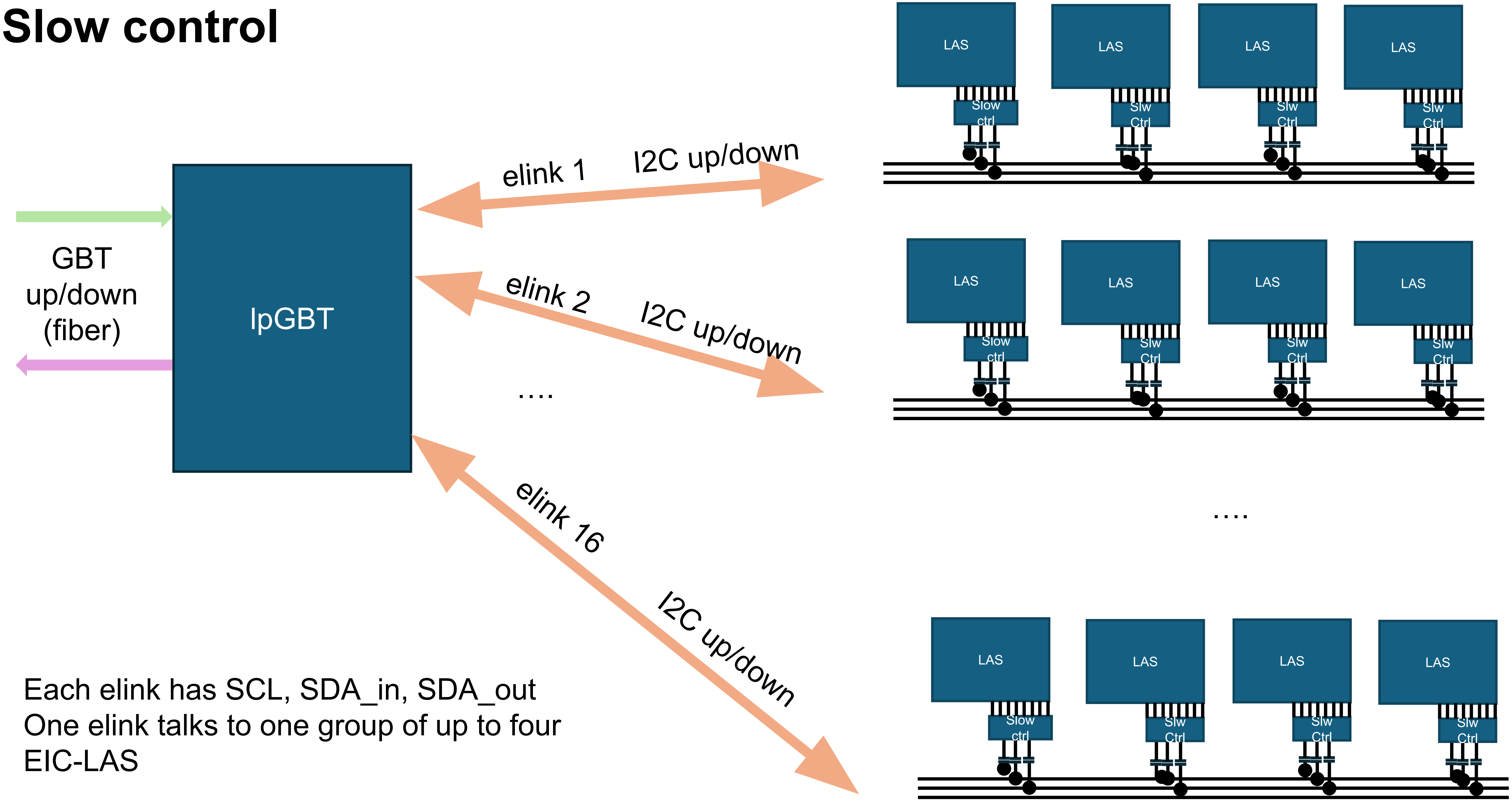
On the way to the FELIX, we might need an FPGA to have another step of multiplexing of the data links

EIC-LAS connections on FPC along stave/disk

Schematic drawing by
Marcello Borri (STFC)



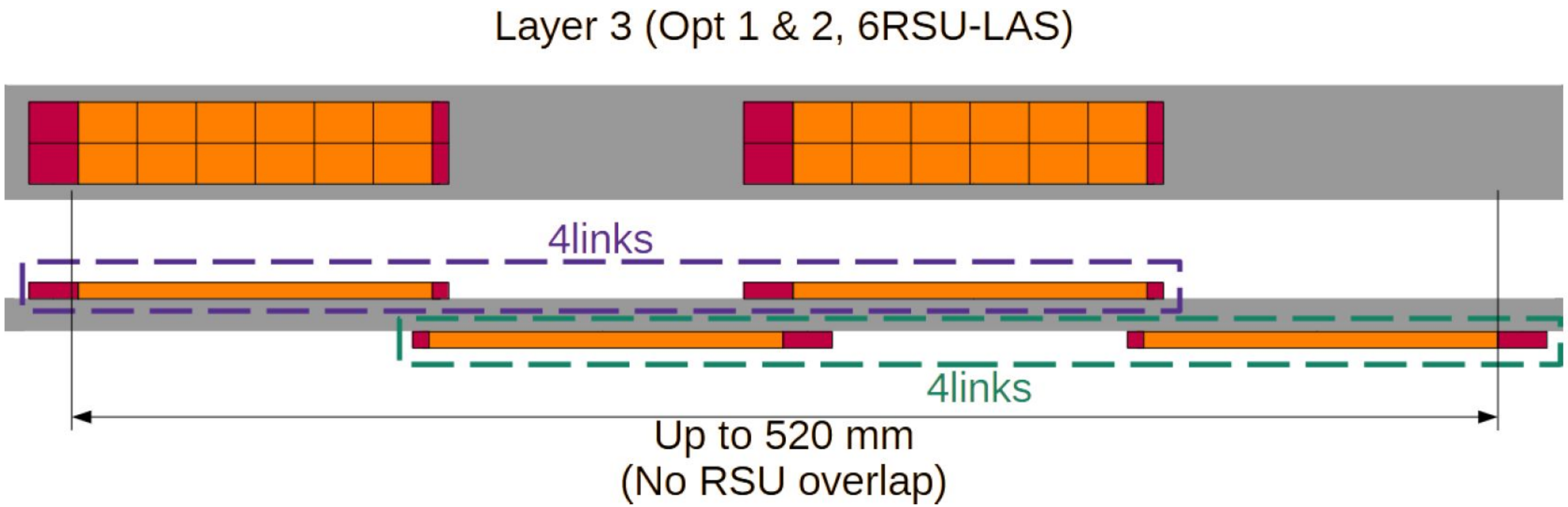
Slow control

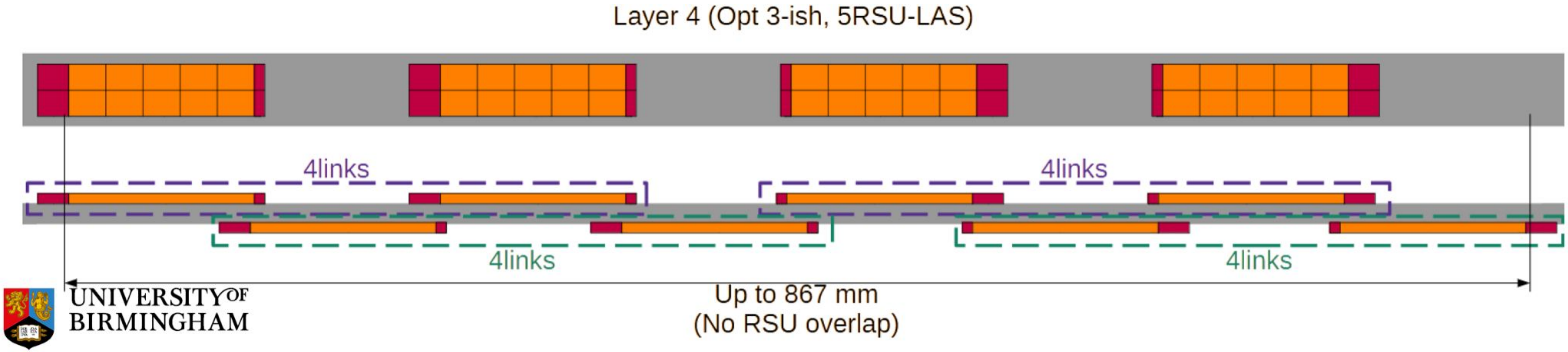


Each elink has SCL, SDA_in, SDA_out
One elink talks to one group of up to four EIC-LAS

Staves and Disks

Current stave-concept (option) for Outer Barrel, i.e. L3 and L4





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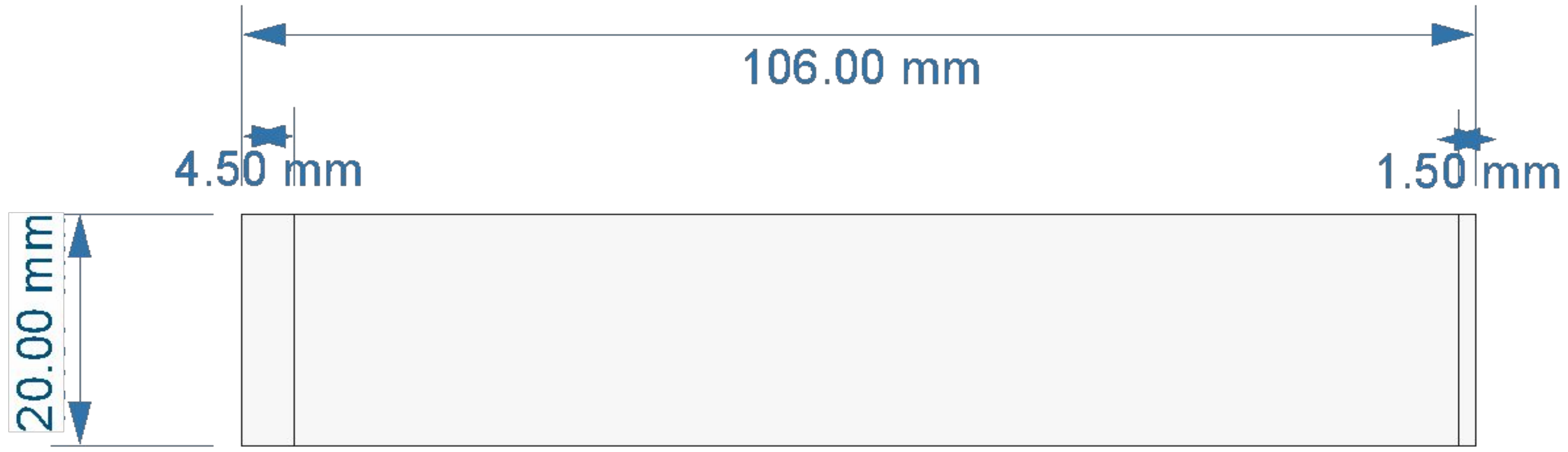
OB structure: general idea

- Follow the ITS3 concept
  - Bent sensor supports itself
  - Only reinforced around perimeter
    - LEC has highest power density and foam there is good thermal conductor (K9)
    - Foam on edges (longerons) and REC are structural (3% foam)
  - Over most of the area silicon is in direct contact with air flow
- Try to make each element fulfil more than one functions (active, mechanical, thermal, electrical, gas flow, etc.)

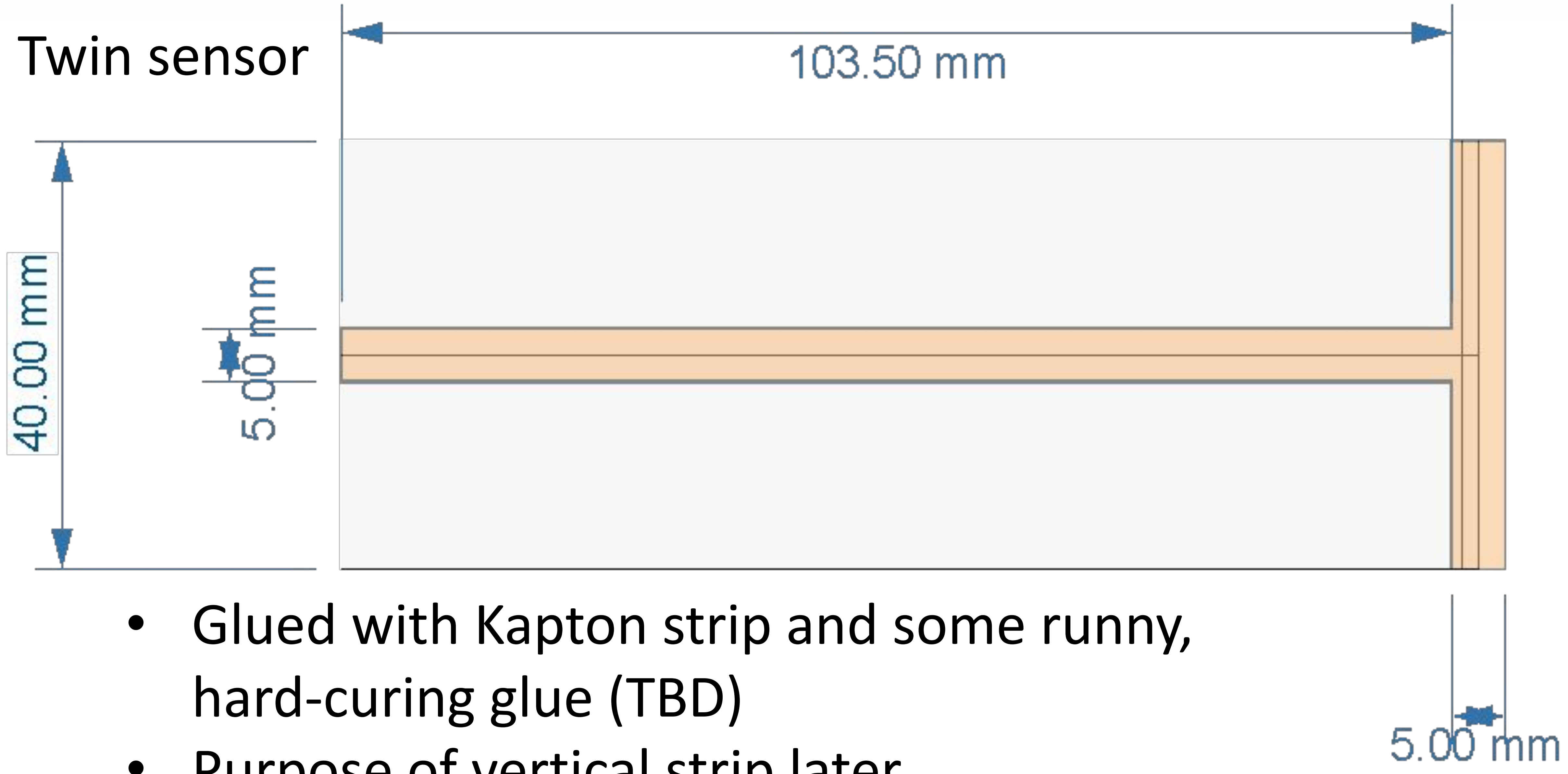
Concept

- Sensor assembly

Sensor geometry used (approximate 5RSUs)

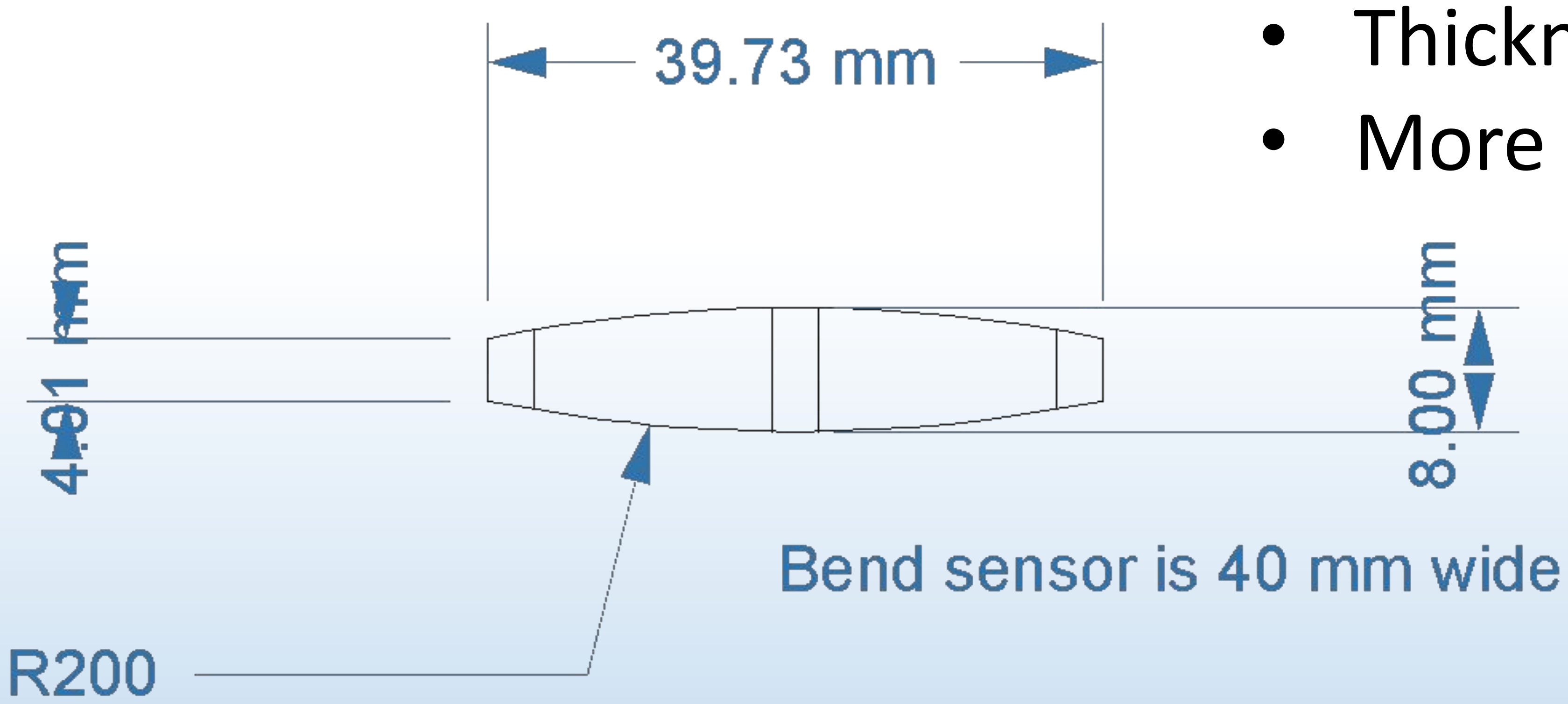


Twin sensor

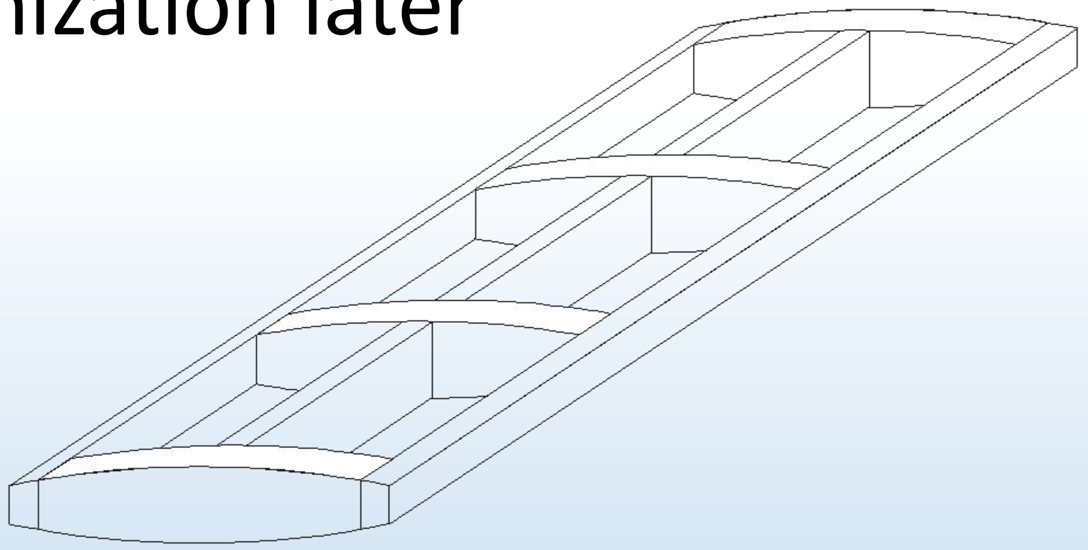


- Glued with Kapton strip and some runny, hard-curing glue (TBD)
- Purpose of vertical strip later

- Core of stave is made of array of foam blocks
  - Thickness and curvature arbitrary
  - More on optimization later

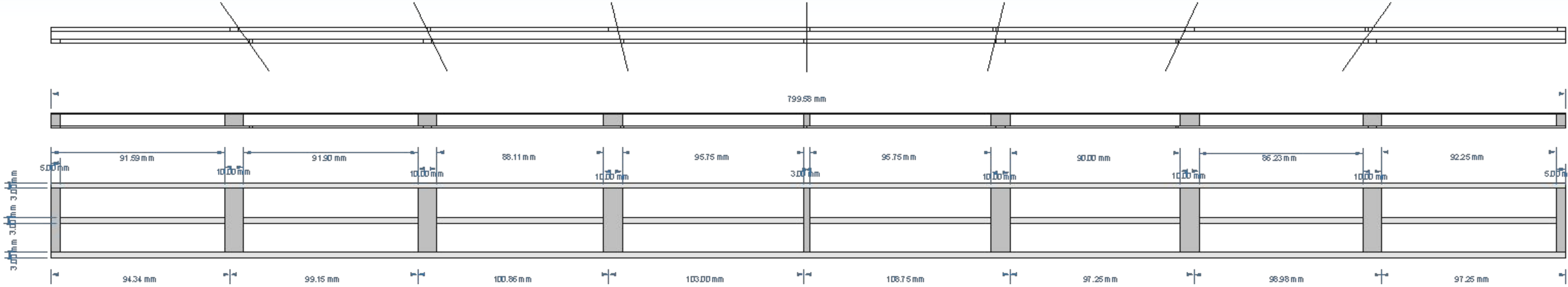


Bend sensor is 40 mm wide



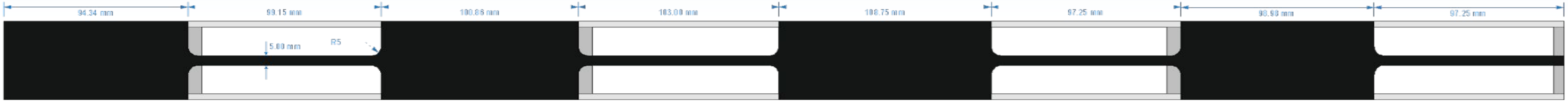
- Crossribs are K9
- Central spar 3% RVC
  - Could be thinned to hourglass shape
  - Alternatively, carbon fibre I-beam
- Edges are 3% RVC
  - Alternatively, 3% Al, if we want to run the power bus through this
    - In that case the Al would be in shorter sections for serial powering

L4 stave foam skeleton

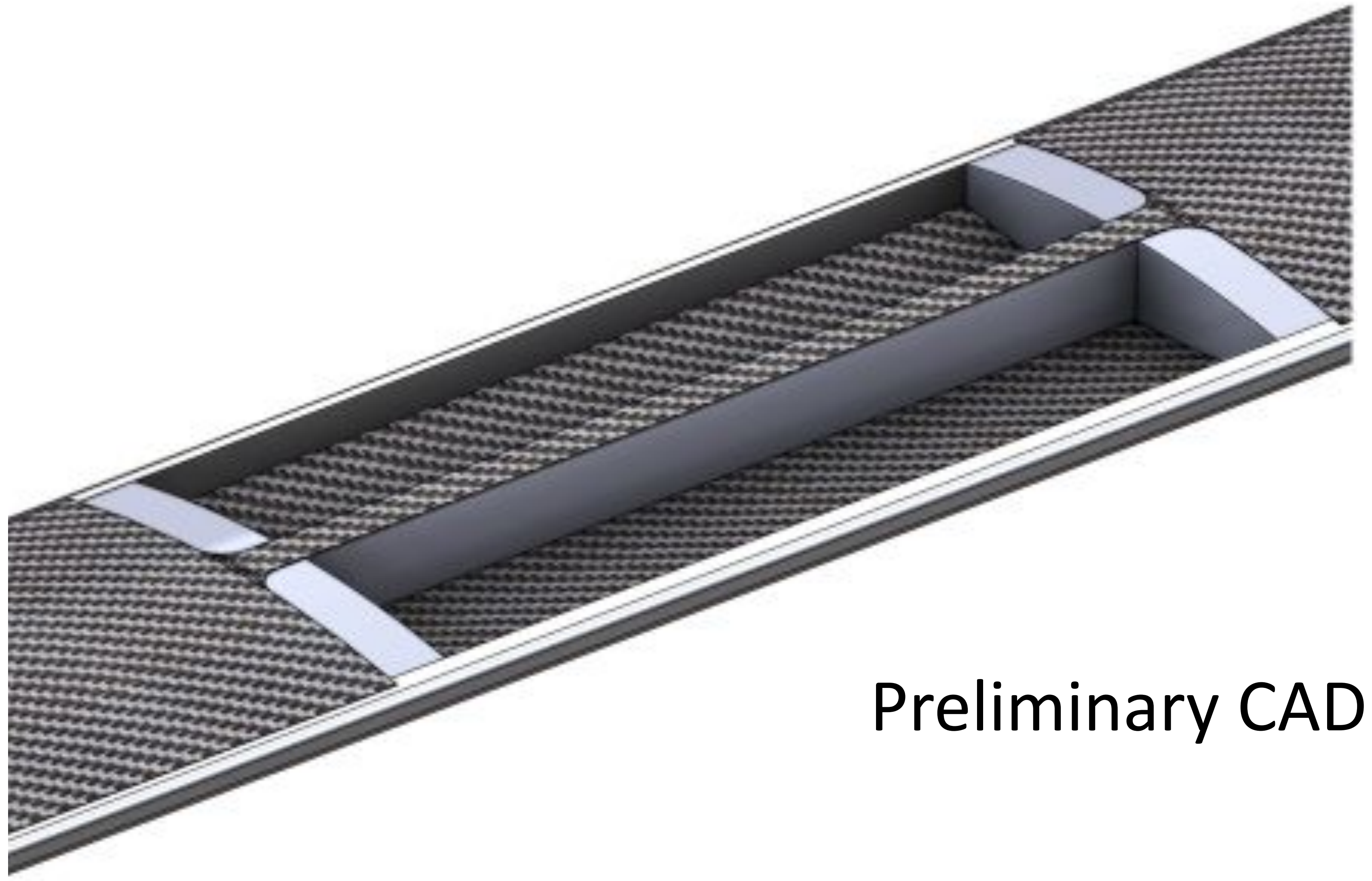


- Sensors alternating on both sides, allow for
  - Overlaps
  - Space for connections (interposers)
- LEC areas (+ ancillary chips) are backed by K9 foam ribs
  - These would also mechanically support bond areas
- Central spar will support joint between twin sensors and maintain curvature of sensors
- Edge blocks a through-going for structure, to possibly contain liquid cooling pipe, or possibly power bus

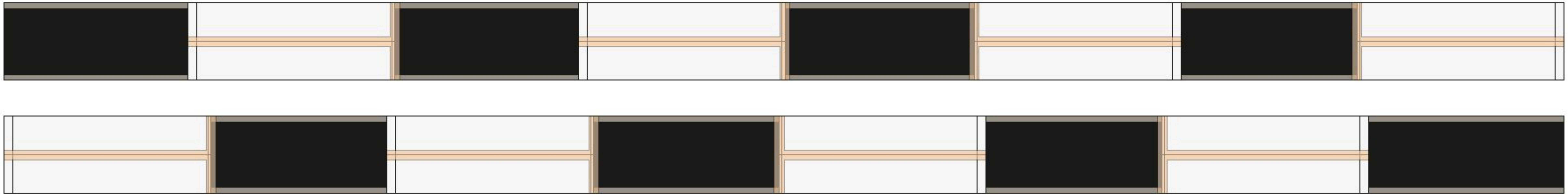
L4 stave CF covers and mounting



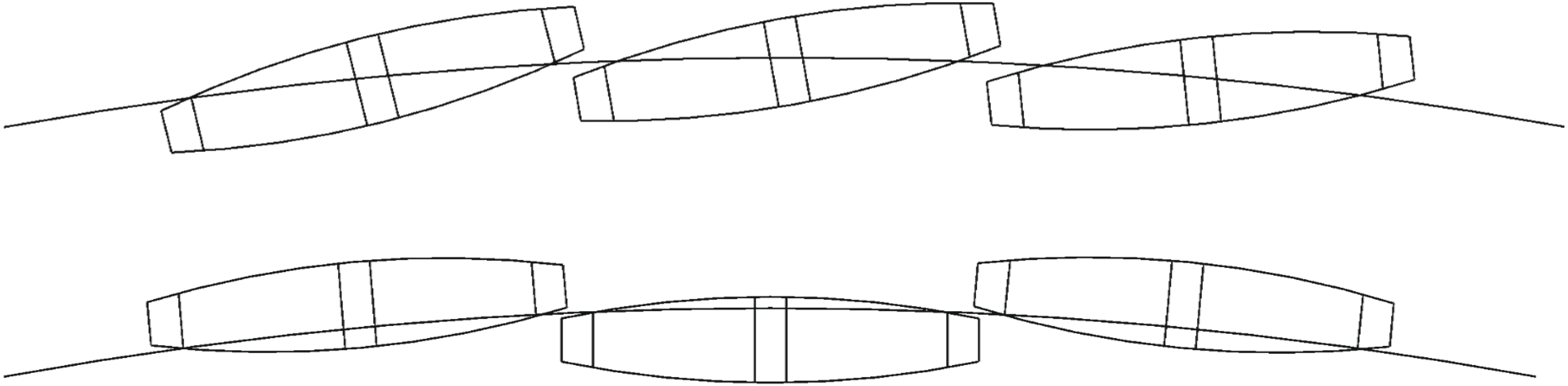
- Surface between sensors covered with CF skin
  - Probably beneficial to have central, through-going strip
- Sensors are placed over empty gaps



Preliminary CAD model

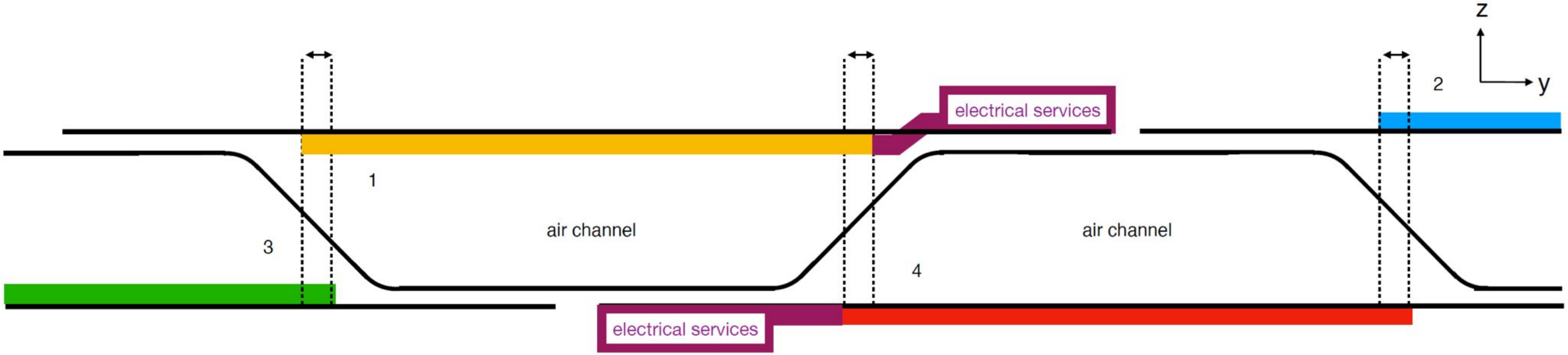


L4 cylinder

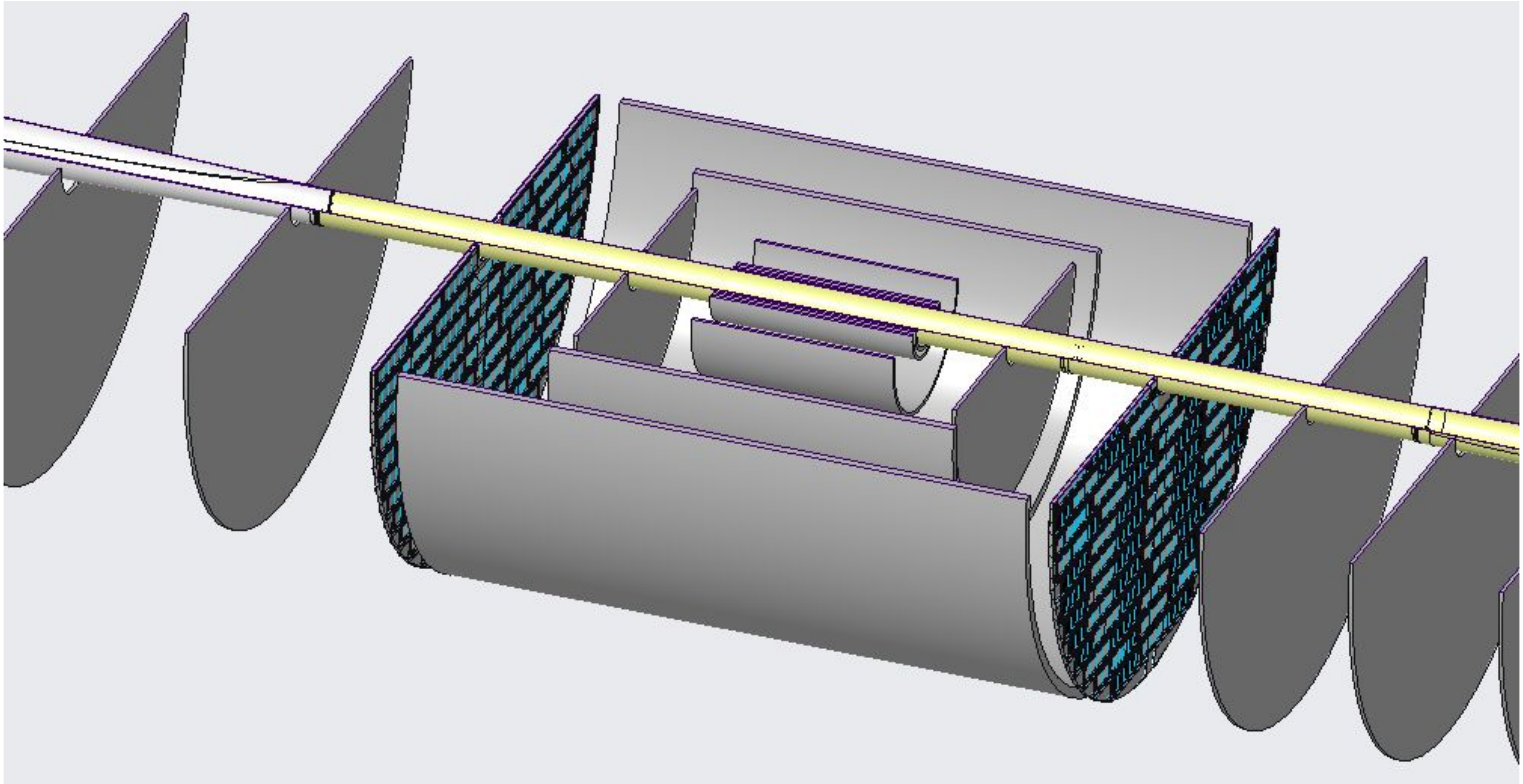


- Will investigate options for annular linking
- Might be beneficial to couple staves with some damping material (soft foam) to dampen air-flow induced vibrations

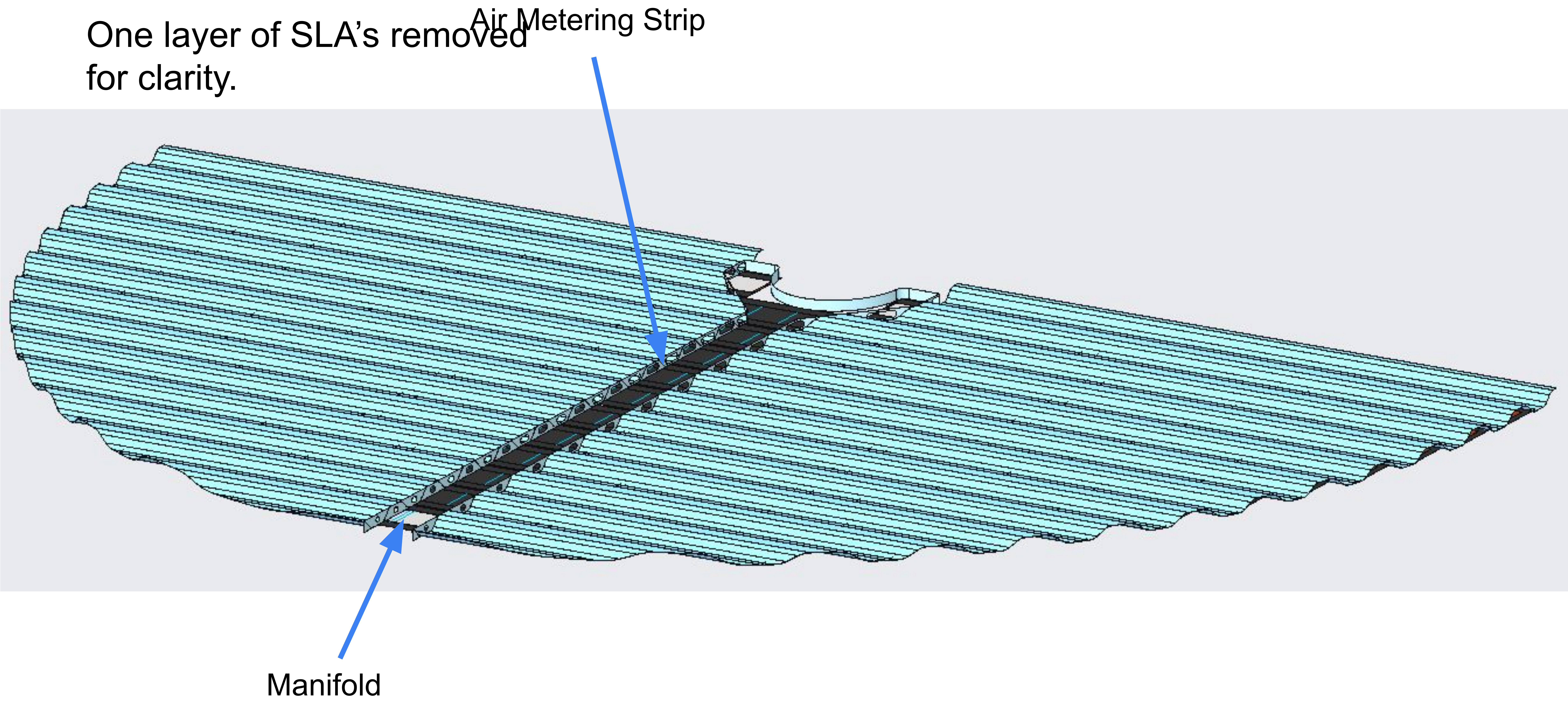
Current disk concept

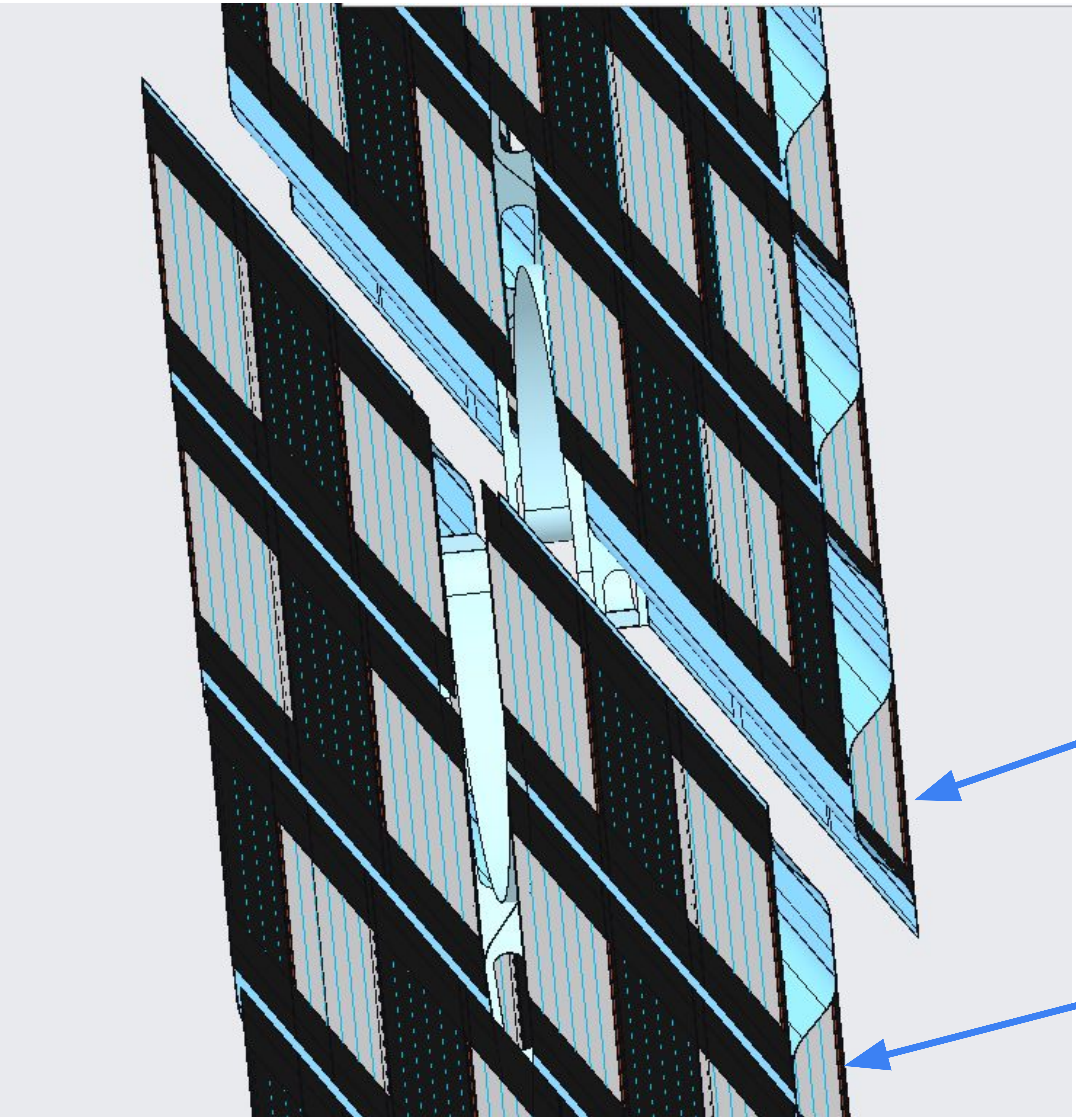


Jim Curtis (LBNL)



One layer of SLA's removed for clarity.





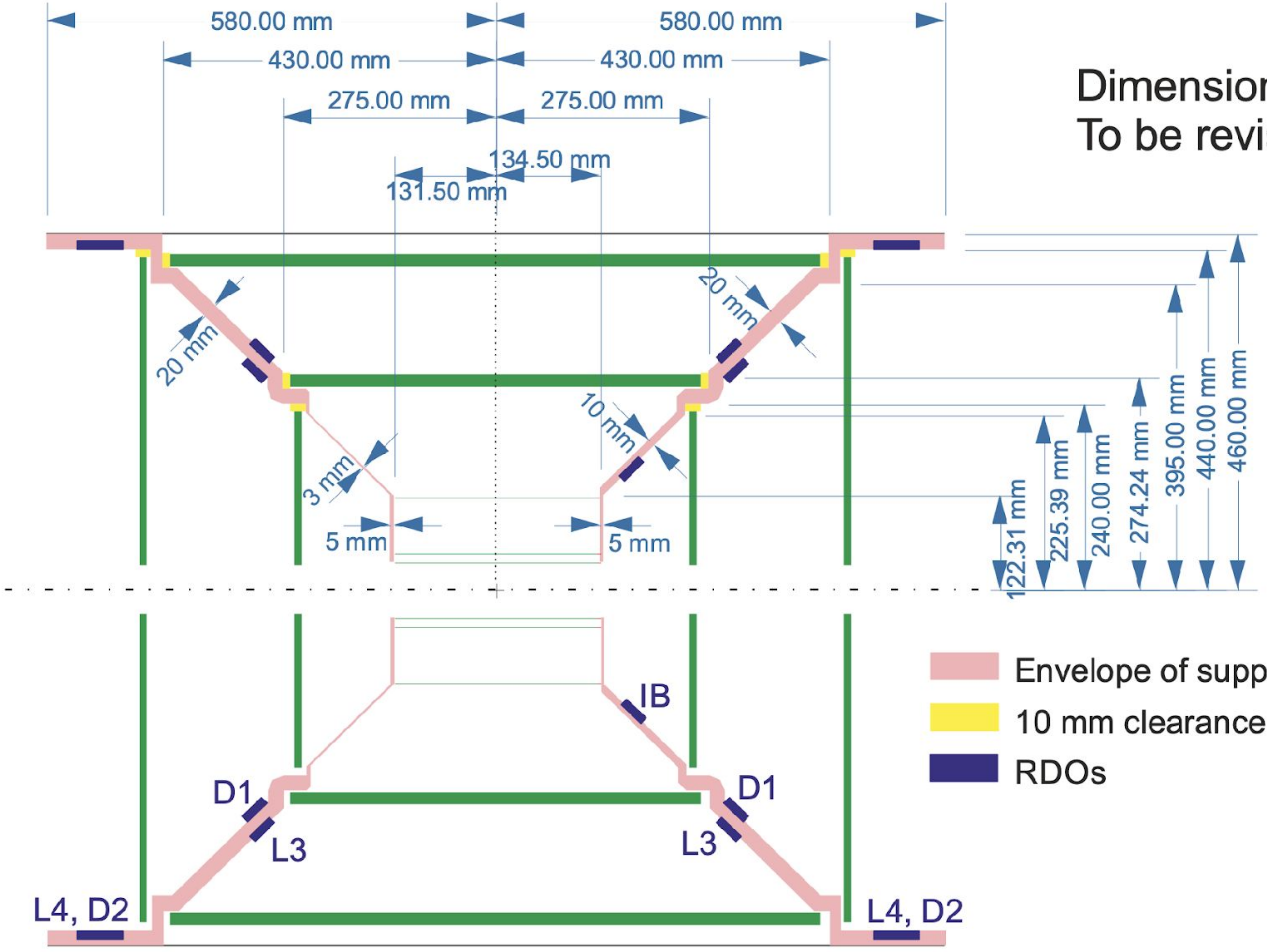
Discs are shown with a 10mm offset for clarity.

Upper Half-Disc

Lower Half-Disc

Inner Barrel

Inner Barrel — Context



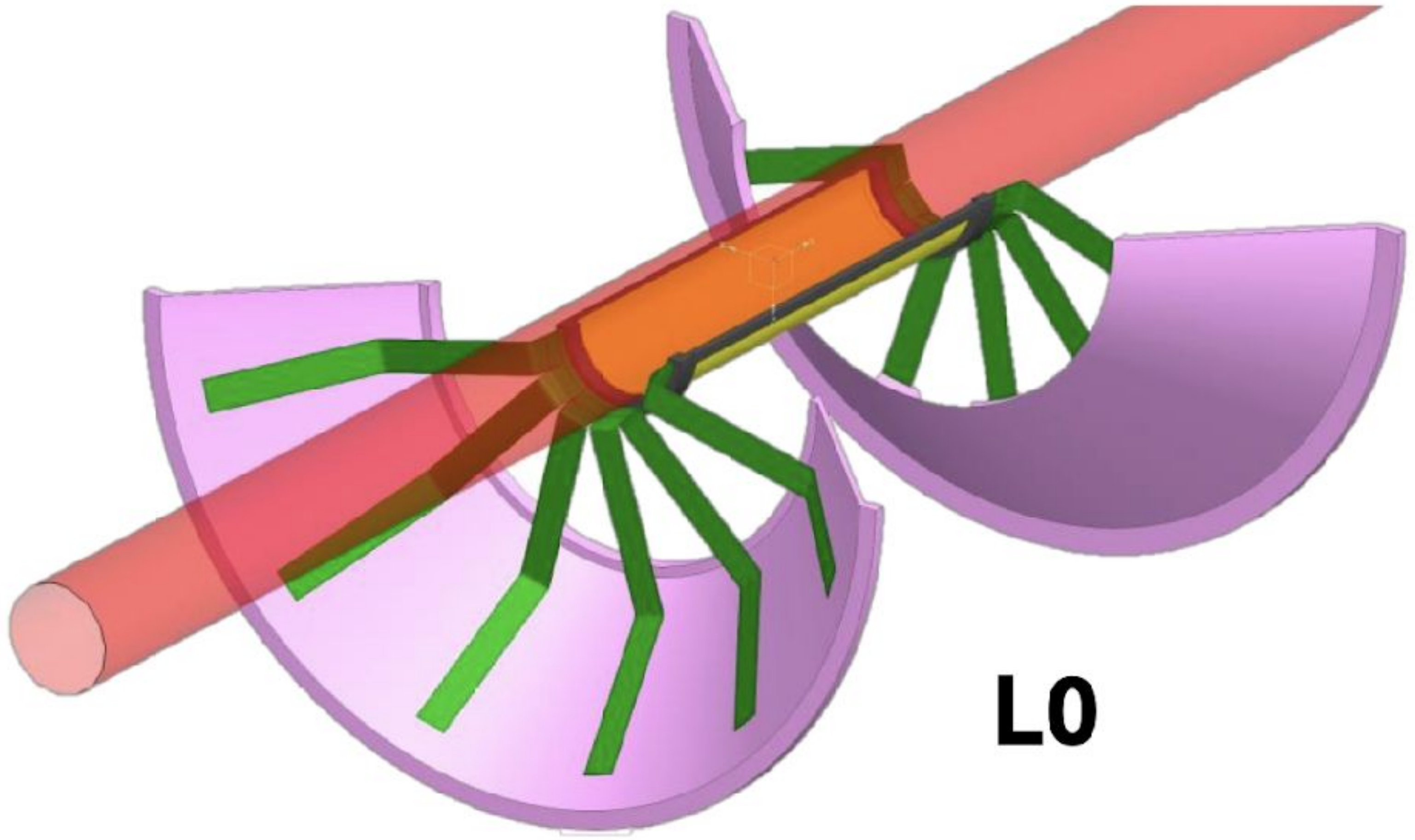
Dimensions indicative only!
To be revised after proper design

🟥 Envelope of support cones and services (electrical, optical and air)

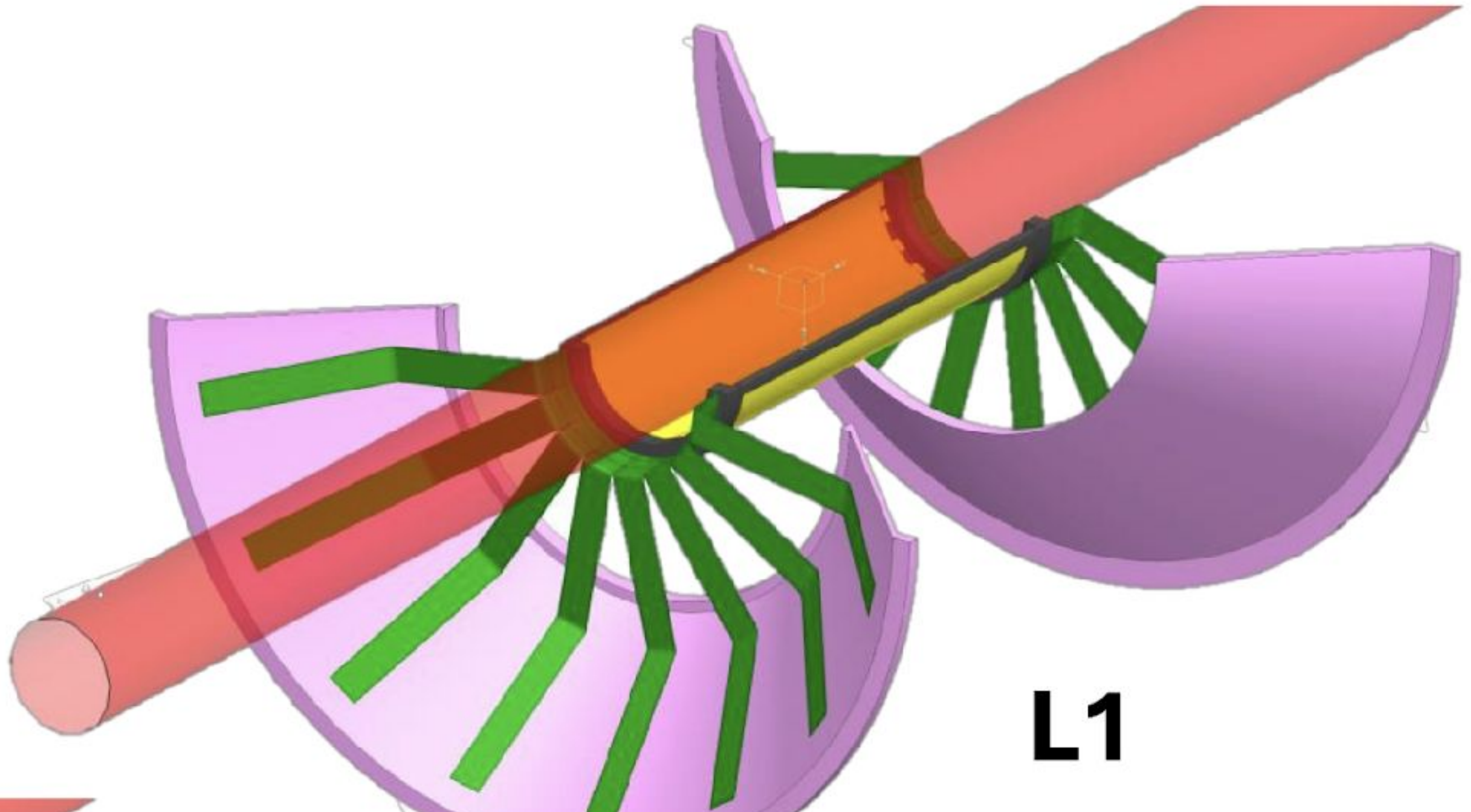
🟨 10 mm clearance at end of local supports

🟦 RDOs

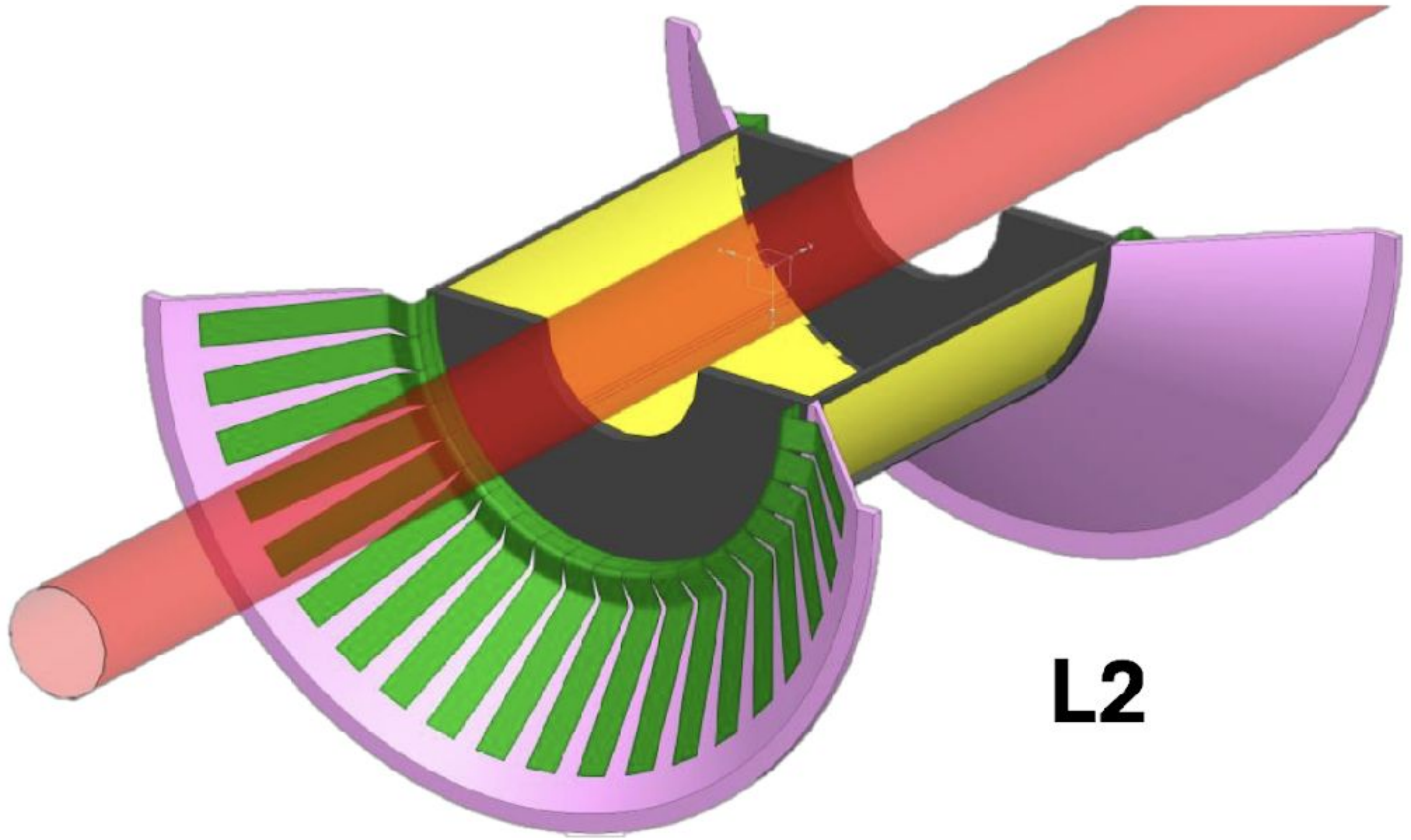
Inner Barrel — Initial CAD concept separated by Layer



L0



L1



L2

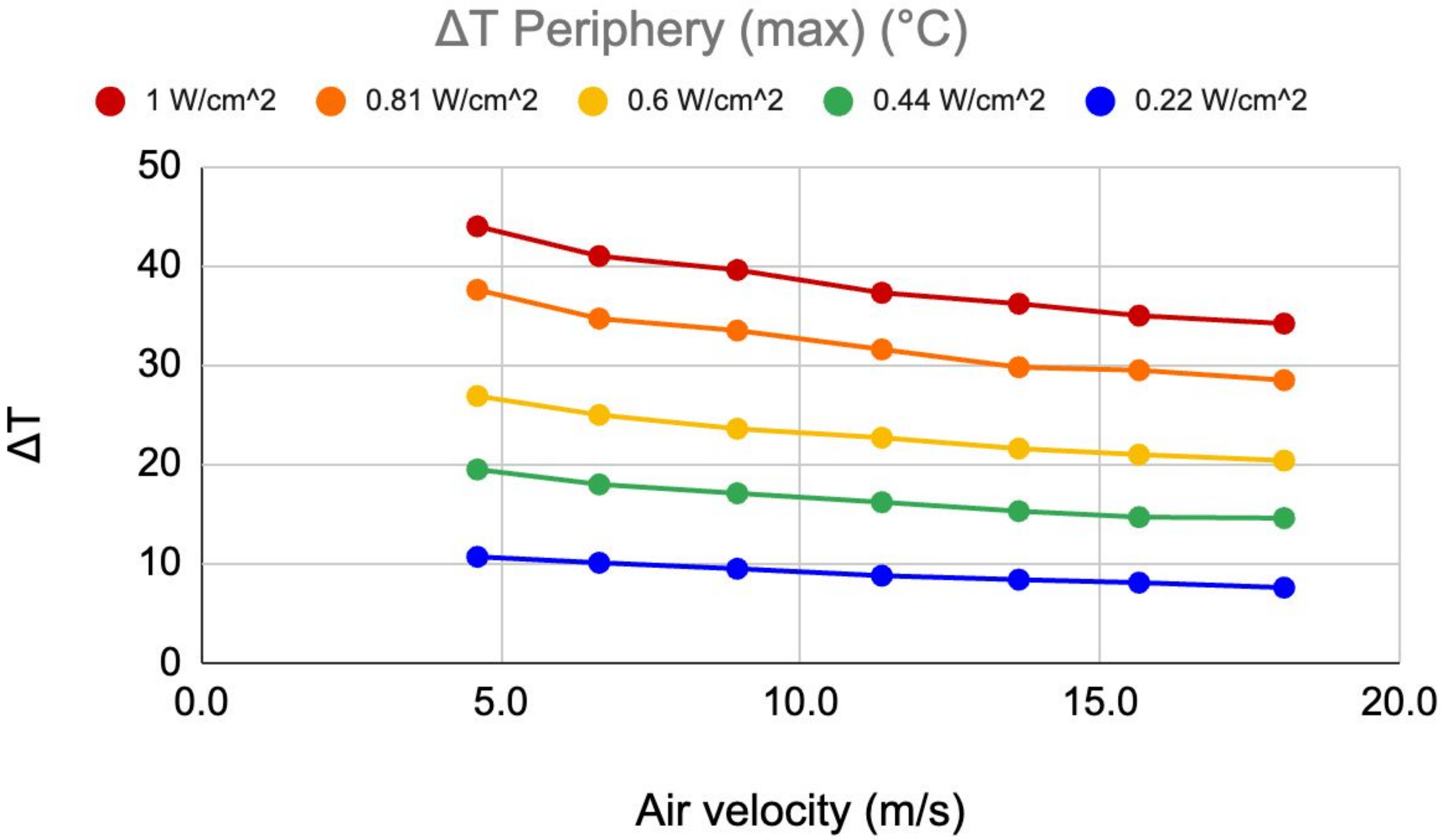
Cooling

Presented at TIC meeting on 5 February

A few updates here on work since then

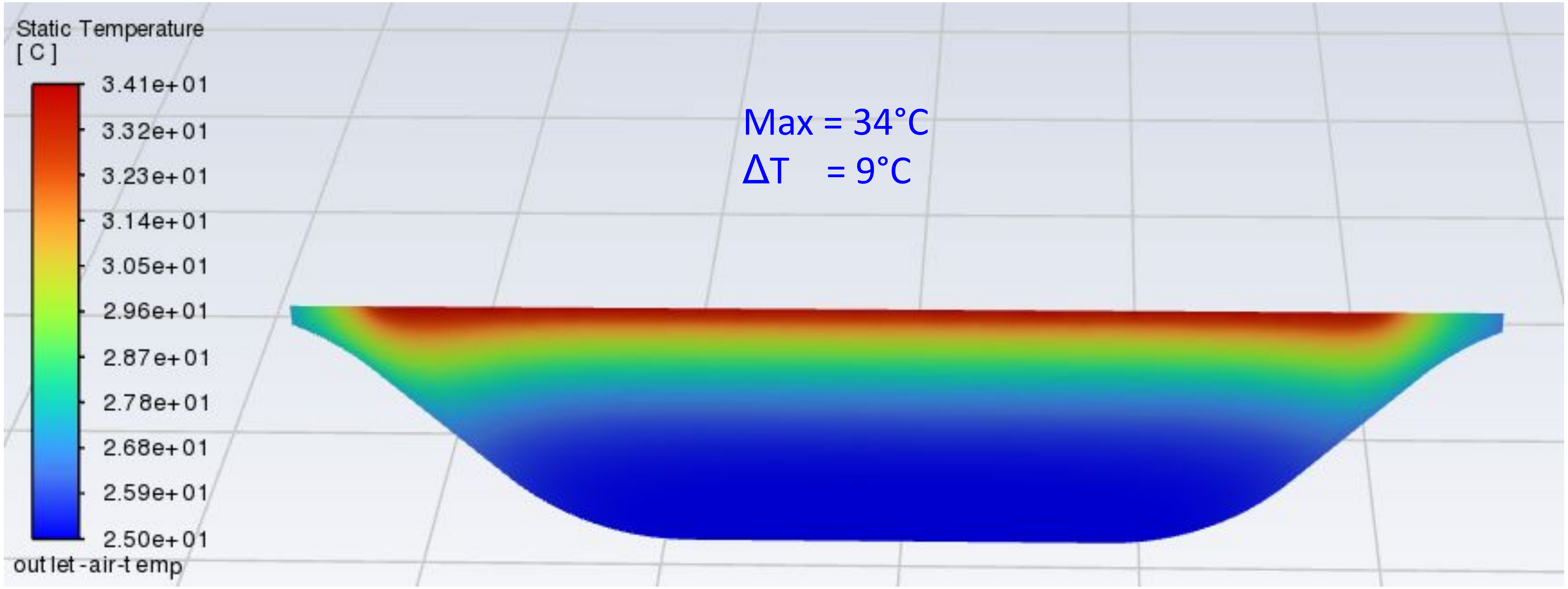
Nicole Apadula (LBNL)

No foam



Ongoing efforts to better estimate LEC power dissipation for EIC-LAS,
Ongoing efforts to improve dissipation with foam (or fins) to effectively increase surface area,
Baseline cooling option remains a hybrid, with the dominant part done by air.

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

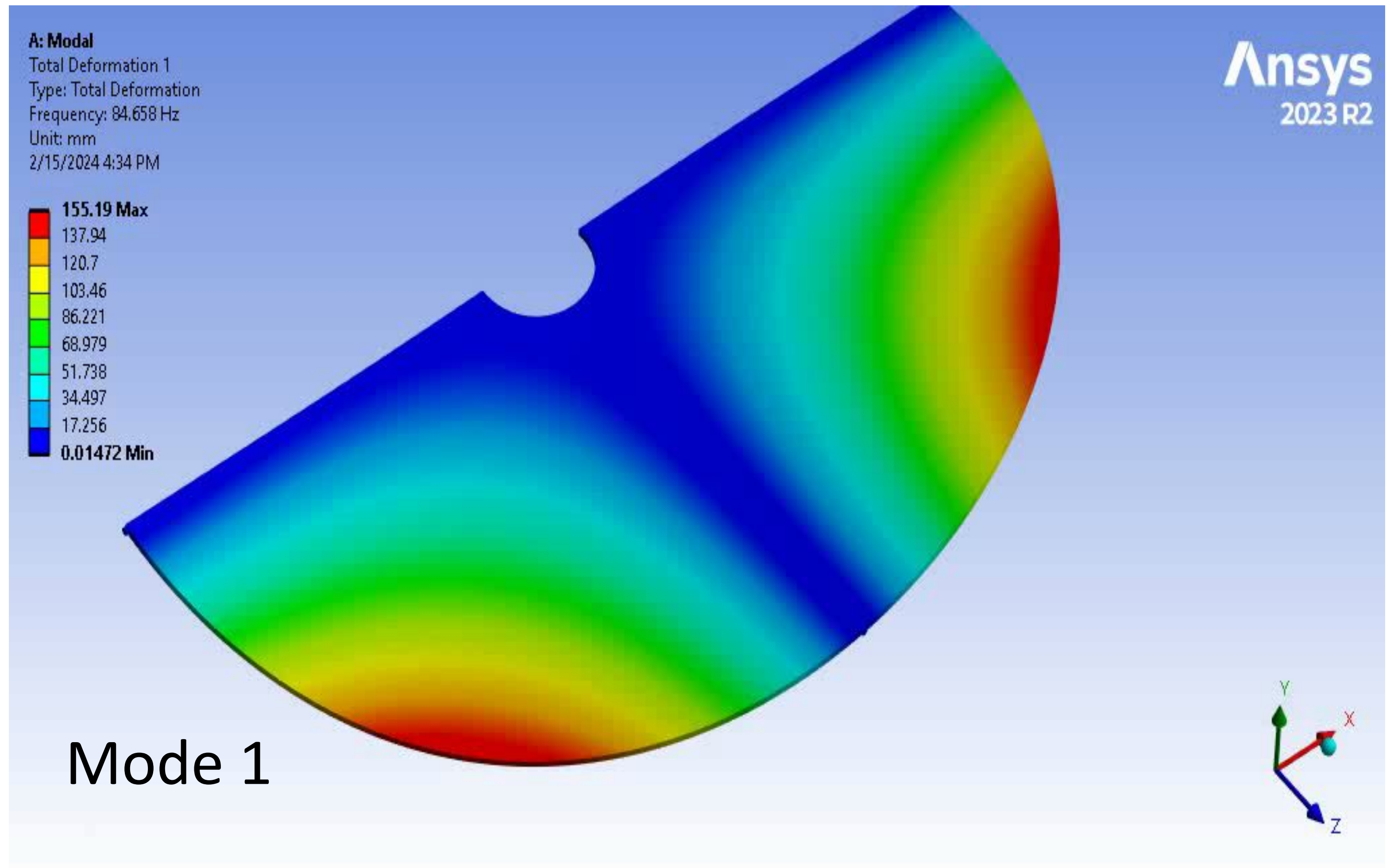


Max = 34°C
ΔT = 9°C

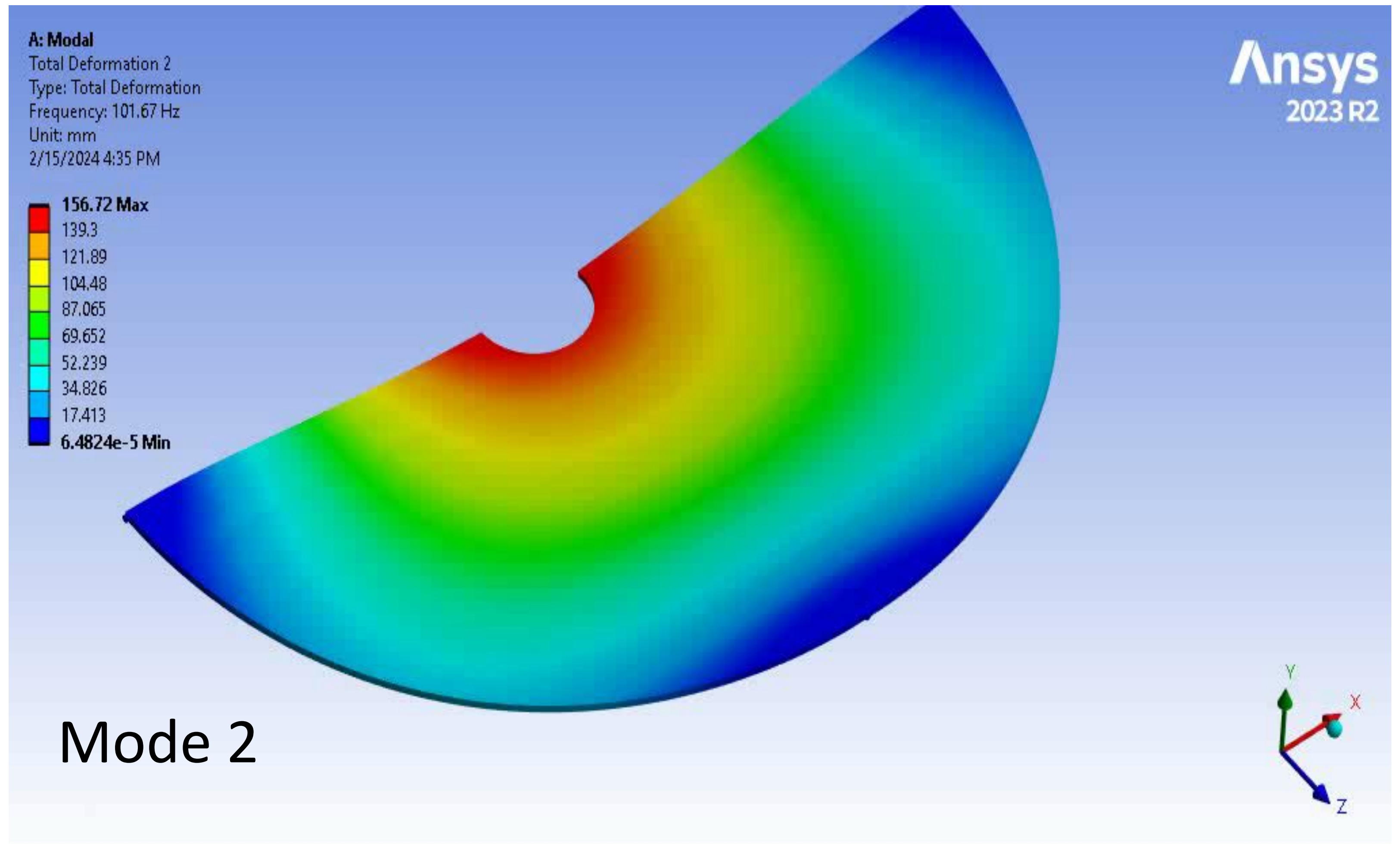
Overall air volume needed by the cooling concept is neither "small" nor "out there",
O(10^2 kWh) as reported before— consider e.g. option of a thinner disk (improves acceptance, reduces flow).

Mera Horne (LBNL)

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


A: Modal
Total Deformation 1
Type: Total Deformation
Frequency: 84.658 Hz
Unit: mm
2/15/2024 4:34 PM

Mode 1


A: Modal
Total Deformation 2
Type: Total Deformation
Frequency: 101.67 Hz
Unit: mm
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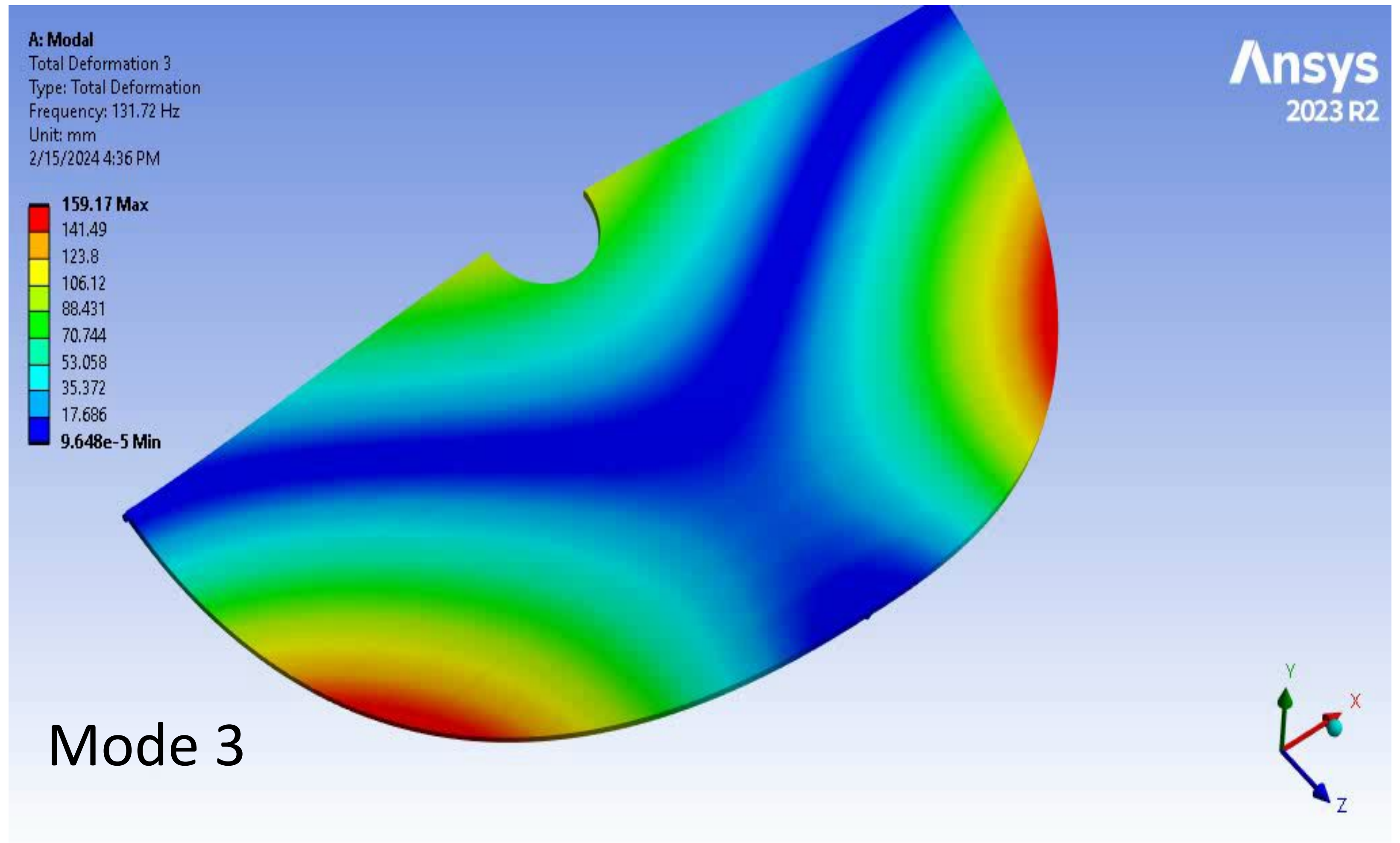
Mode 2


A: Modal
Total Deformation 3
Type: Total Deformation
Frequency: 131.72 Hz
Unit: mm
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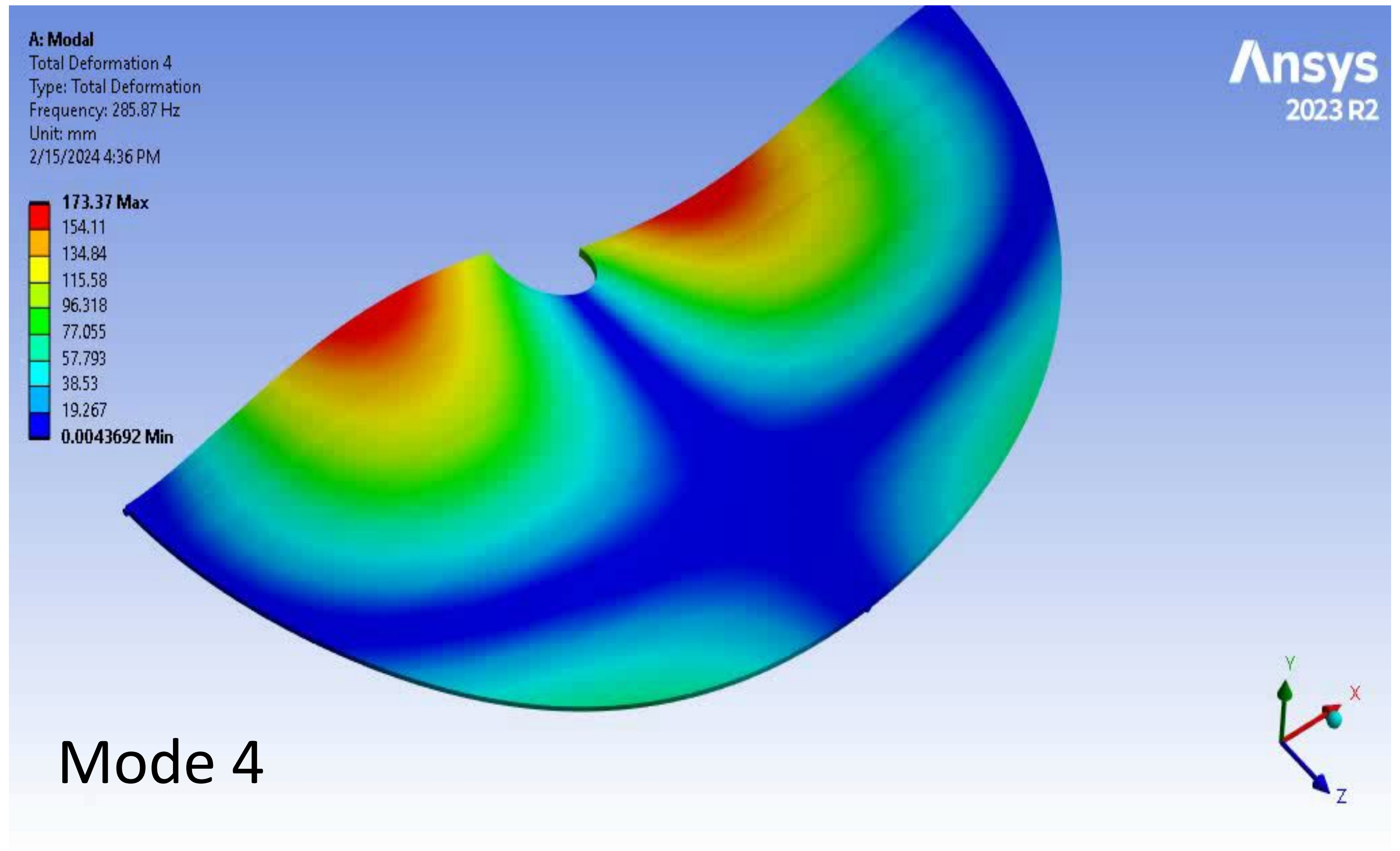
Mode 3


A: Modal
Total Deformation 4
Type: Total Deformation
Frequency: 285.87 Hz
Unit: mm
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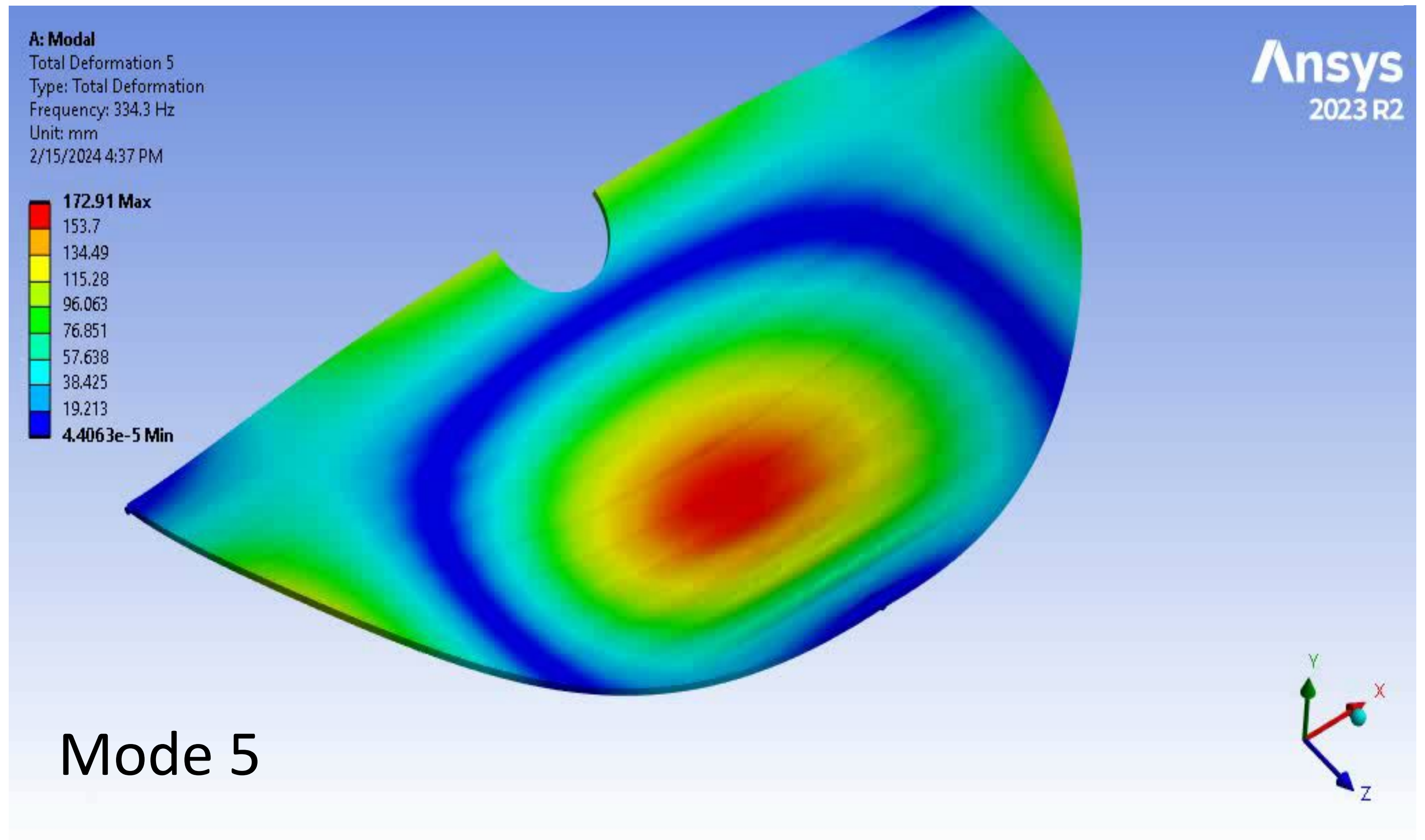
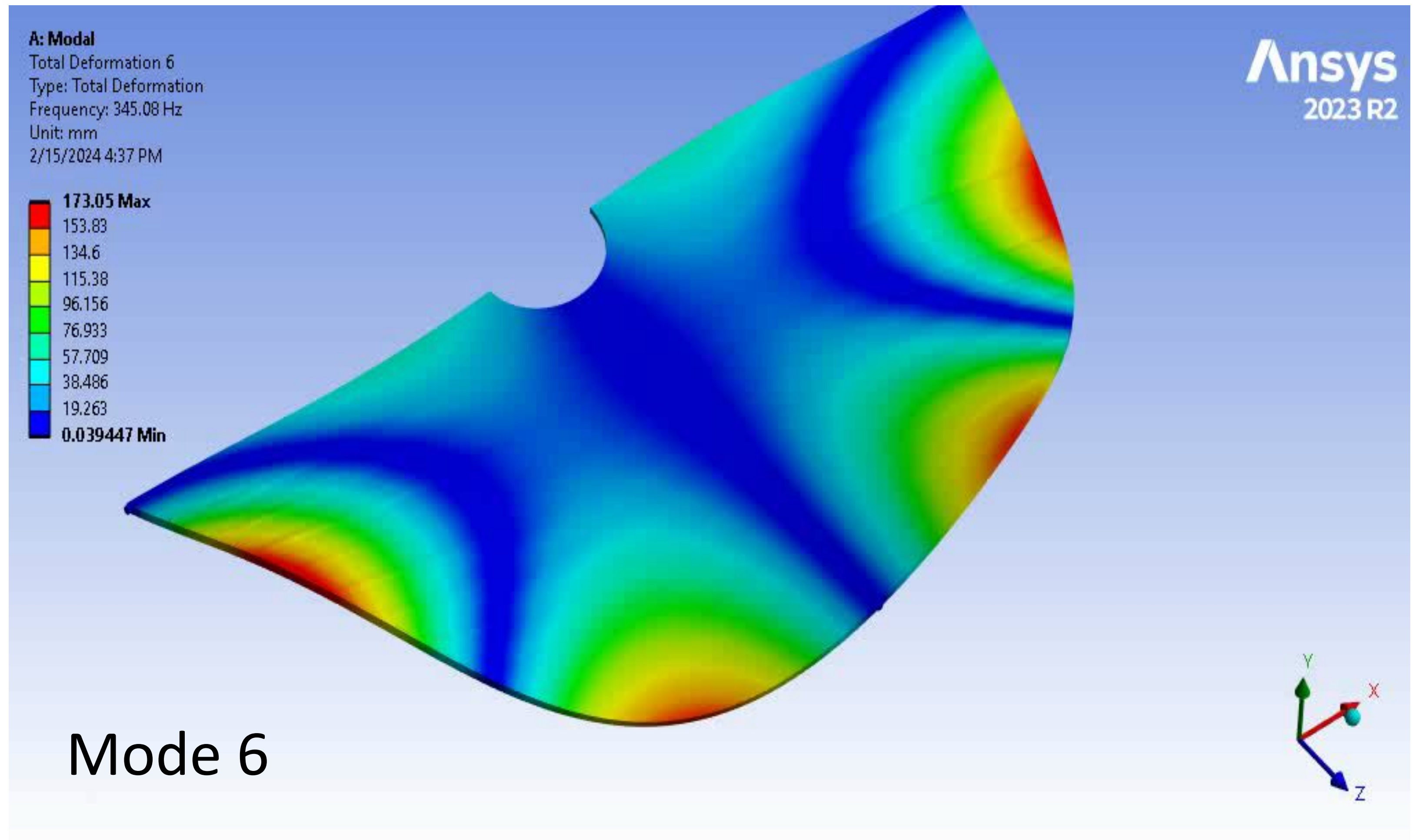
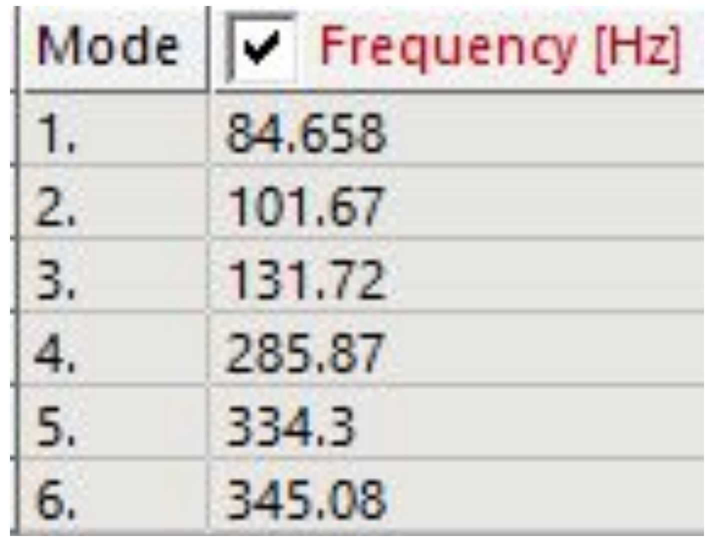
Mode 4


A: Modal
Total Deformation 5
Type: Total Deformation
Frequency: 334.3 Hz
Unit: mm
2/15/2024 4:37 PM

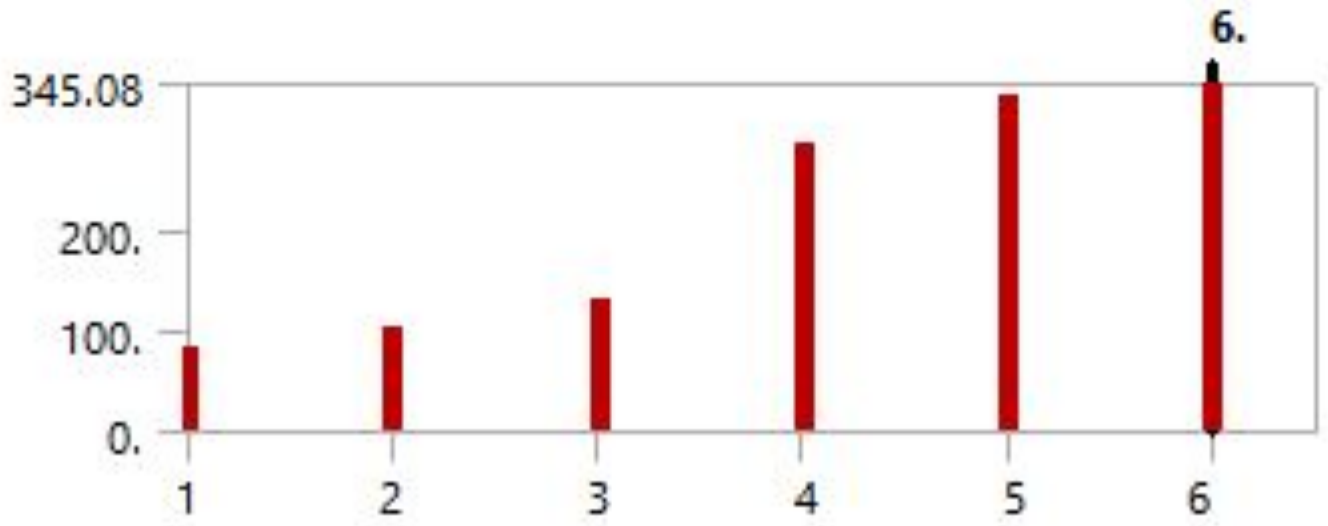
Mode 5


A: Modal
Total Deformation 6
Type: Total Deformation
Frequency: 345.08 Hz
Unit: mm
2/15/2024 4:37 PM

Mode 6



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



Recent SVT workfest, c.f.

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

has a wealth of information.

We feel it was invaluable, in and by itself, as well as for the next steps; we will certainly organize a next, extended, in-person meeting (although likely before / separate from the Lehigh meeting),

Many of the next steps have been or are being set; sensor, ancillary IC, cooling, IB, etc.

Lots of work remains but a lot of progress in the last six months.