ToF: Power Budget Estimation and Cooling Design Strategy

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ePIC Collaboration meeting, BNL
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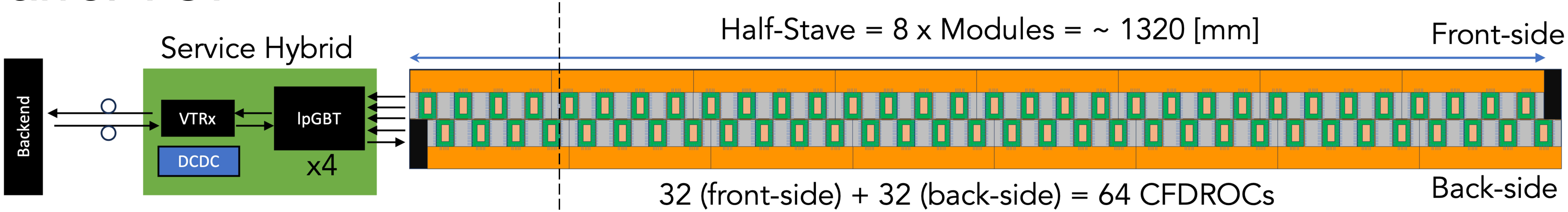
Electron-Ion Collider

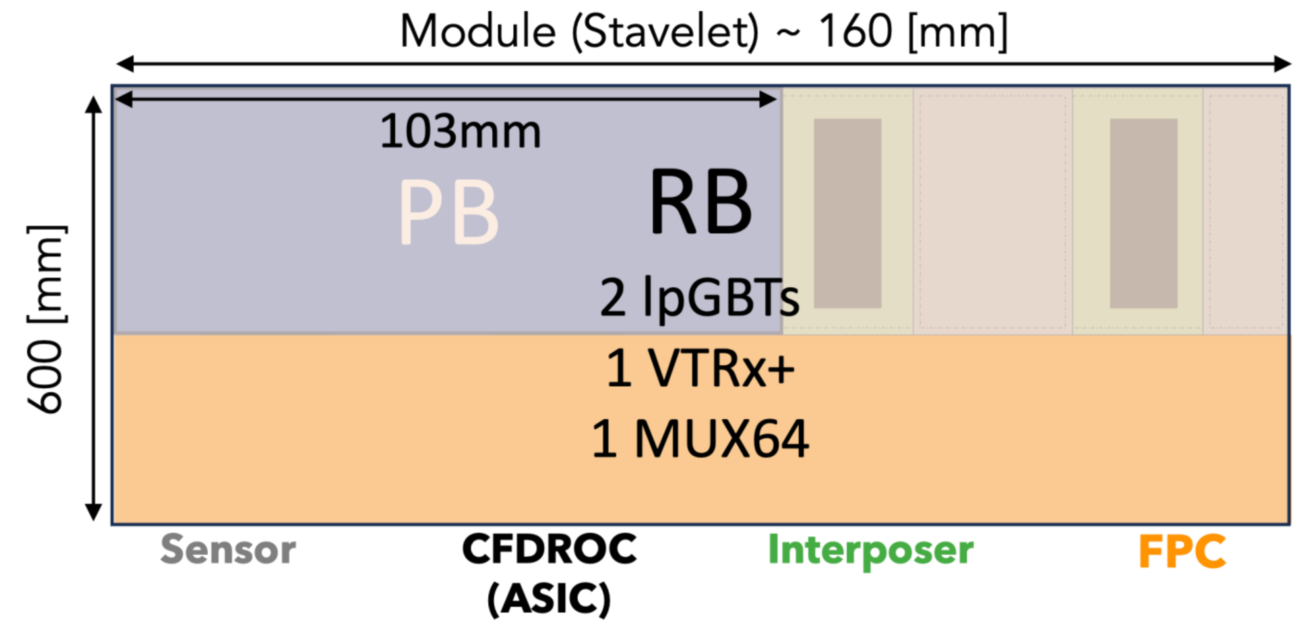
Inner detector structure and TOF – Oct 2025

A. Jung

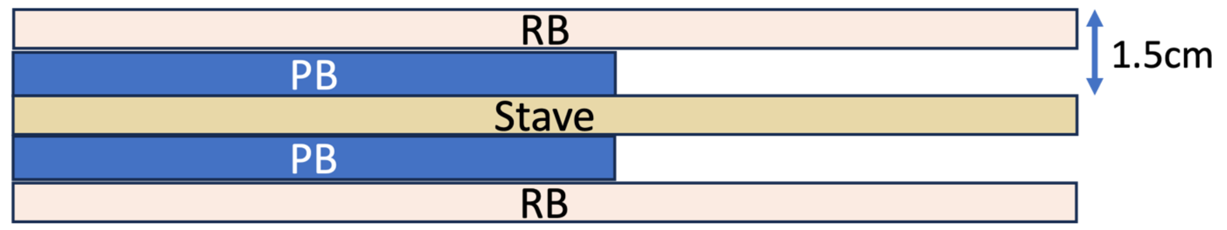
Barrel TOF

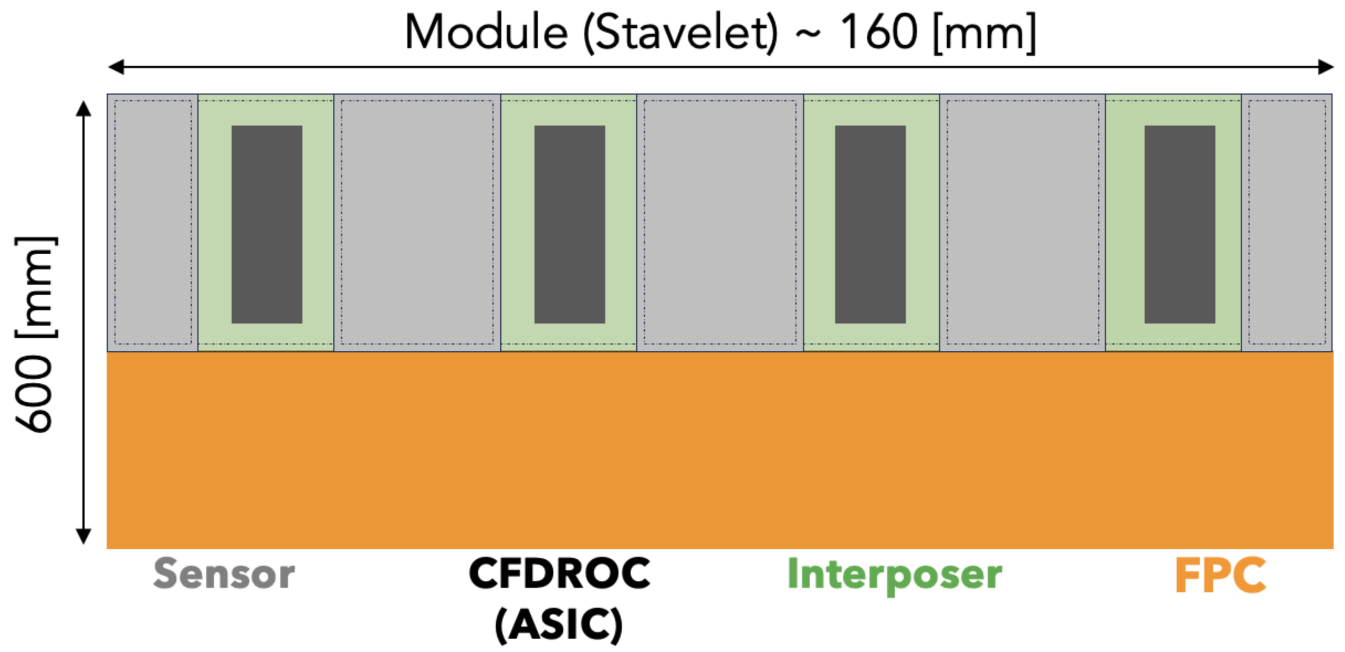


Higher heat density at the end due to PB



Stacked view:





X/X_0 < 3% (including support structure)

ASIC (FCFD) specs **(TBD)**:
- # of channels: 128
- Power: 4mW/ch, **~0.5W/ASIC**

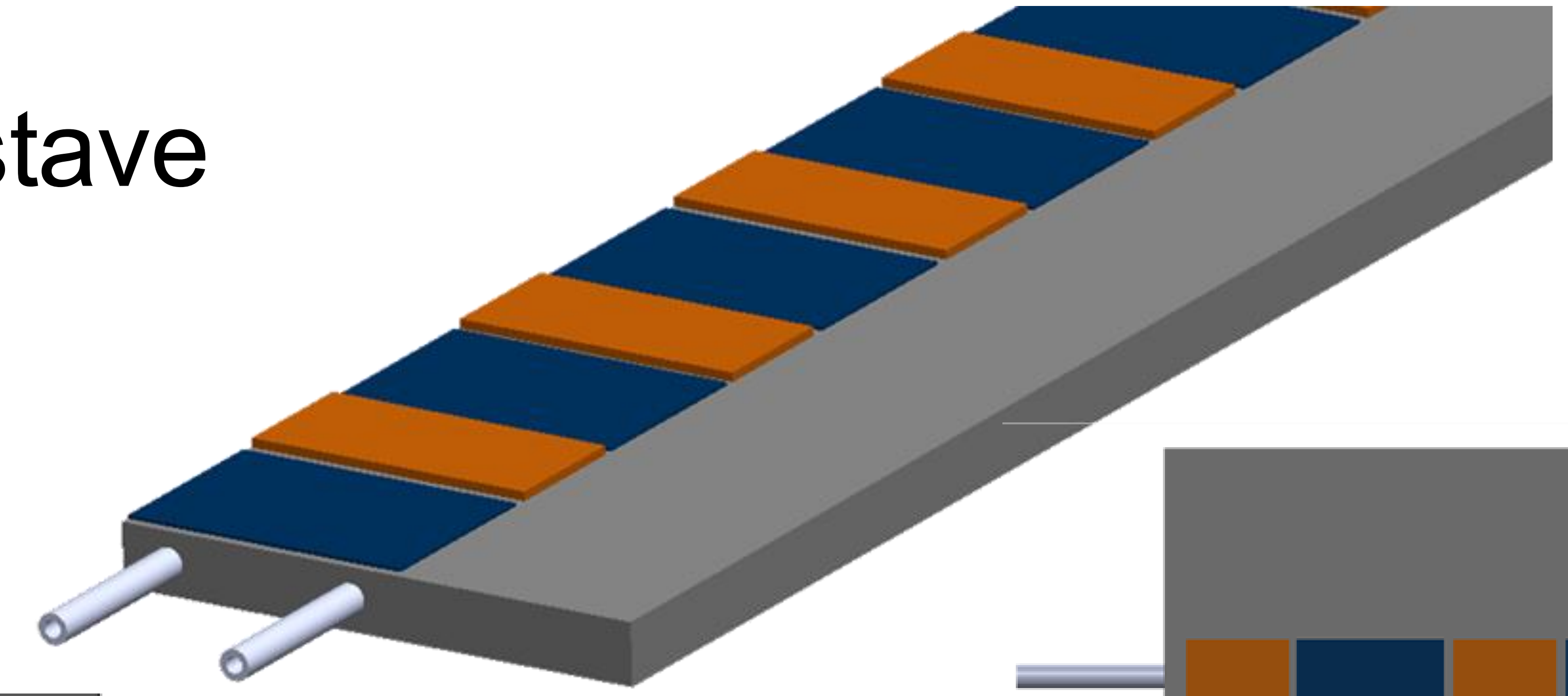
PB heat dissipation:
- 32*25% = **8W/half-stave**

(75% bPOL48V efficiency)
- **Entire BTOF: 8*288=2304W**

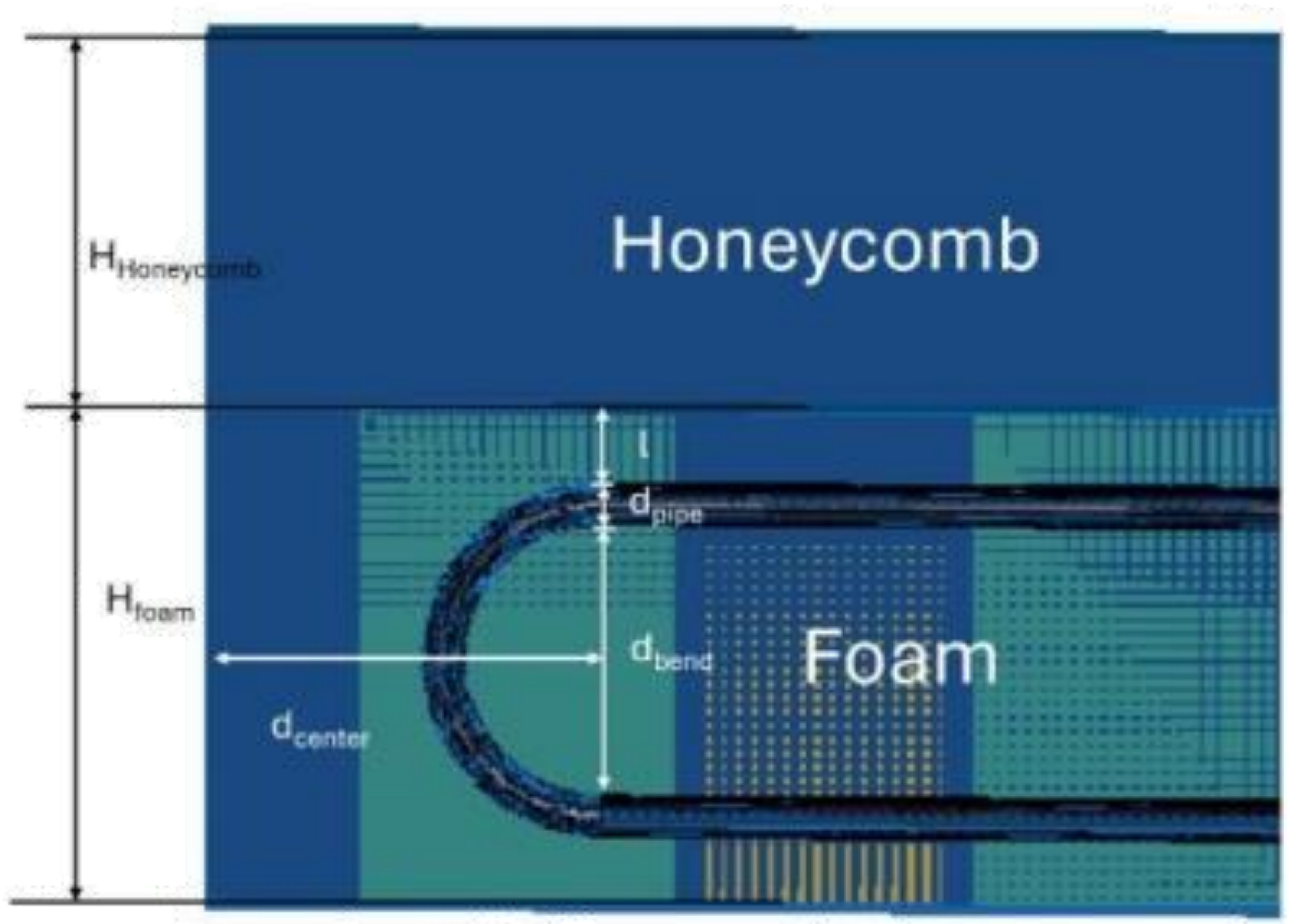
Total power consumption of ASICs:
- A stavelet: 0.5*8 = **4W**
- A full half-stave: 4*8 = **32W**
- **Entire BTOF: 32*288 = 9216W**

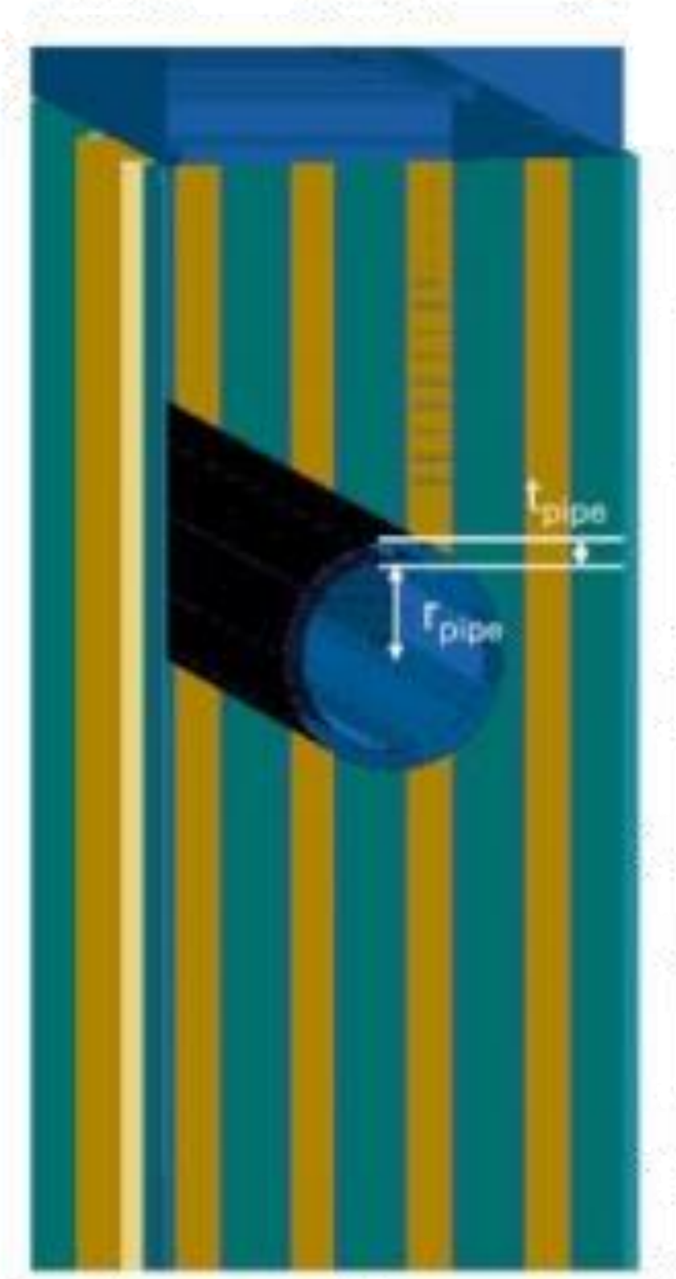
Barrel TOF cooling structure

Modules on both faces of the stave
w/ carbon fiber structure



Part Name	Thermal Conductivity (W/mK)	Thickness (μm)
ROC and ASIC (Kapton properties)	0.97	400 and 300
Silicon Module	148	200
Carbon Face Sheet	Kxx - 180 Kyy - 150 Kzz – 0.70-2.01(Shown in graph)	200
Carbon Foam	25	6420
Loctite Epoxy	1.28	120
Stainless Steel Pipe	16	716





Dimensions

Rpipe - 0.876300 mm

Length - 1978.9 mm

Tpipe - 0.7112 mm

Dcenter - 30 mm

Dpipe – 3.175 mm

Dbend – 24.83 mm

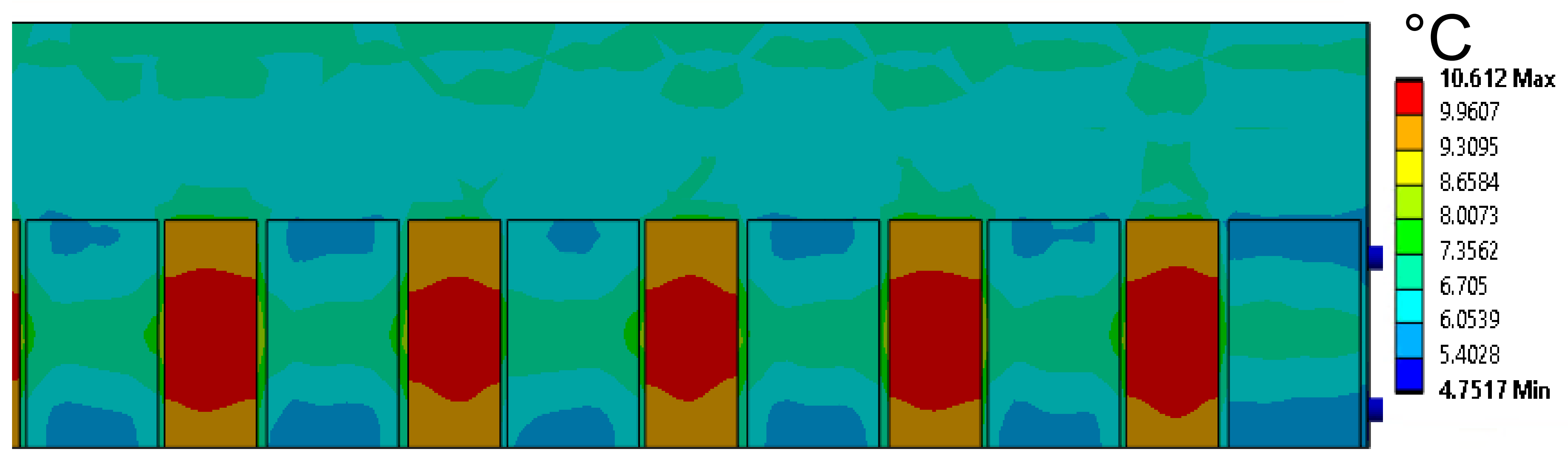
L – 4.58 mm (see below)

Inner Volume - 4773.96 mm^2

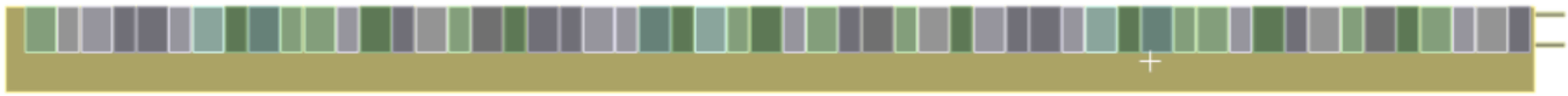
Barrel TOF heat transfer FEA

- Heat Flux
  - 1.024 W/Module converted to heat flux on top surface
  - ROC Modules - 1.09 W
  - ASIC Modules- 3.14 W
- Pipe Cooling: **Glycol**
  - **-5 C** -> h = 895.58 W/m^2
  - **+5 C** -> h = 915.48 W/m^2
- Ambient Air Cooling: h = 5 W/m^2 at **T = 22 C**

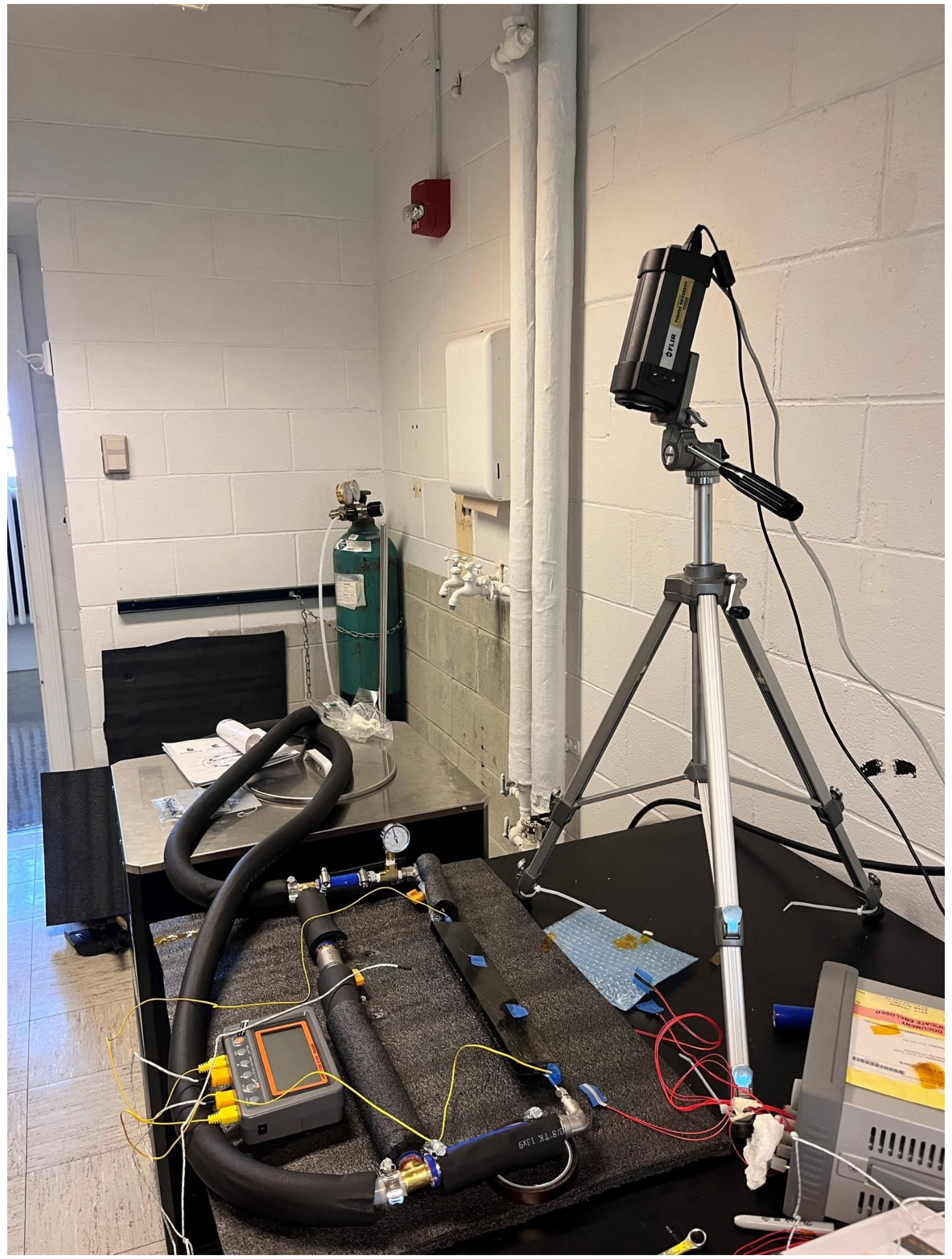
Simulation



Working Fluid	ASIC End	ASIC Middle	ASIC Front	Silicon End	Silicon Middle	Silicon Front
-5 C Glycol	-0.001	-0.018	0.101	-3.297	-3.464	-3.500
+5 C Glycol	9.919	9.904	10.020	6.576	6.462	6.426
Average temperature for each sensor/ASIC along the length of half stave in °C						

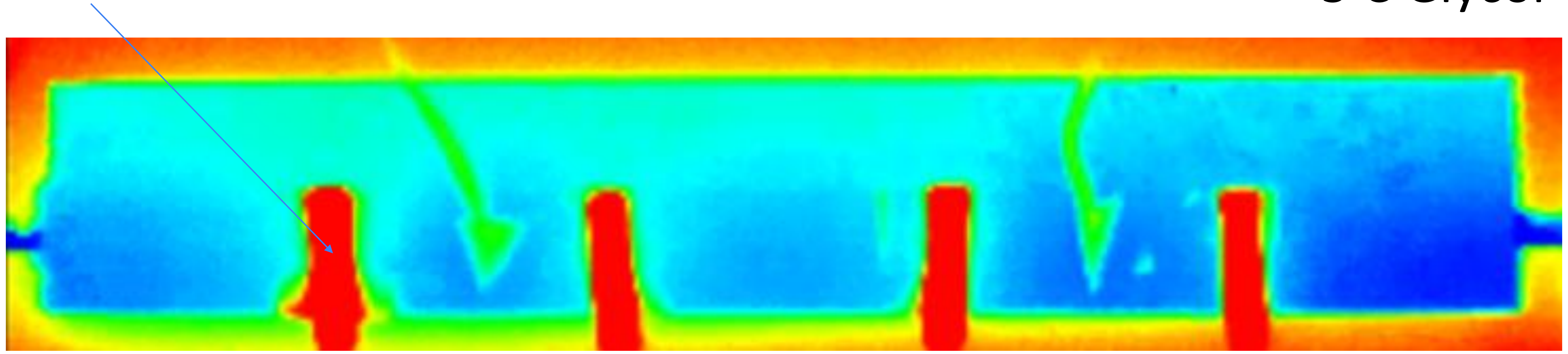


Barrel TOF heat transfer studies – experimental results

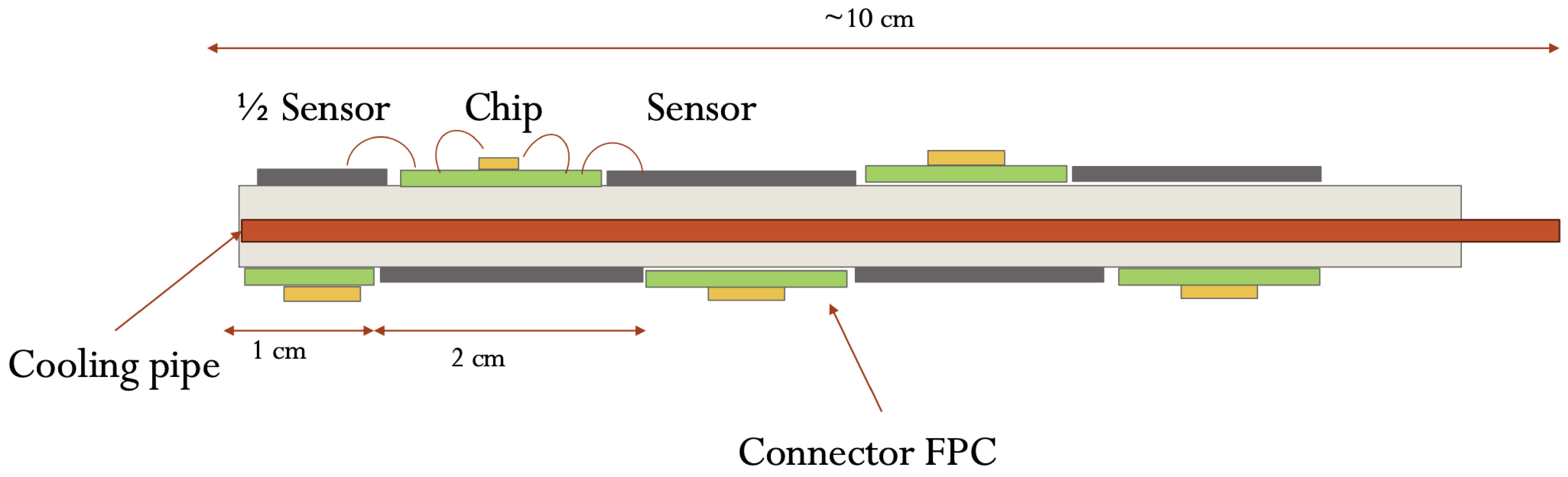


ASIC

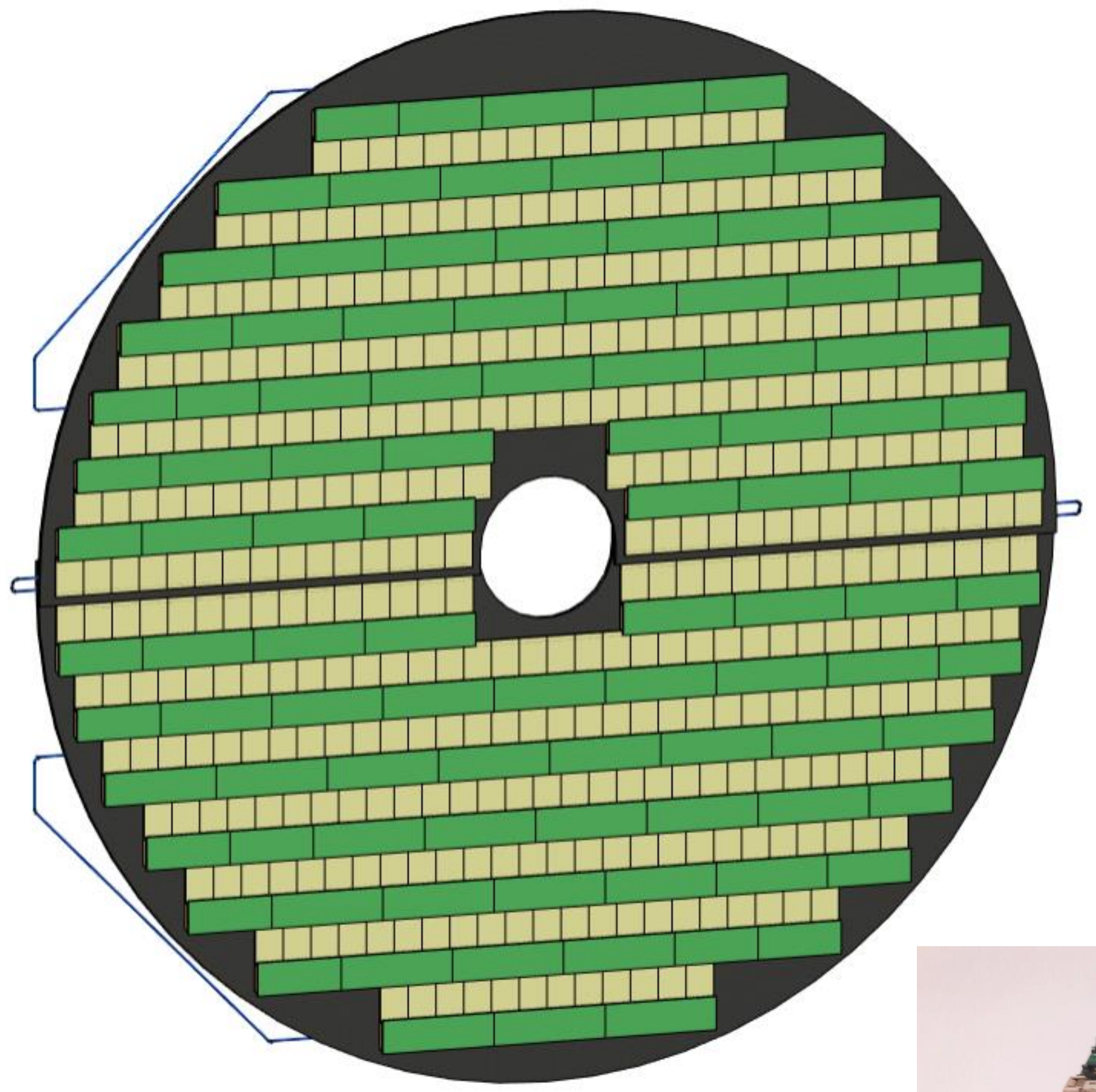
+5 C Glycol

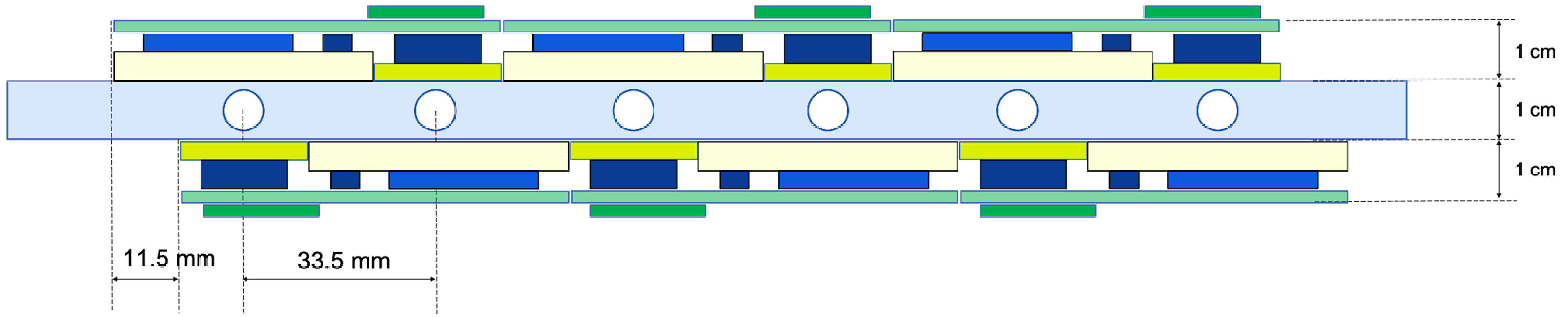


Next step: stavelet demonstrator



Forward TOF

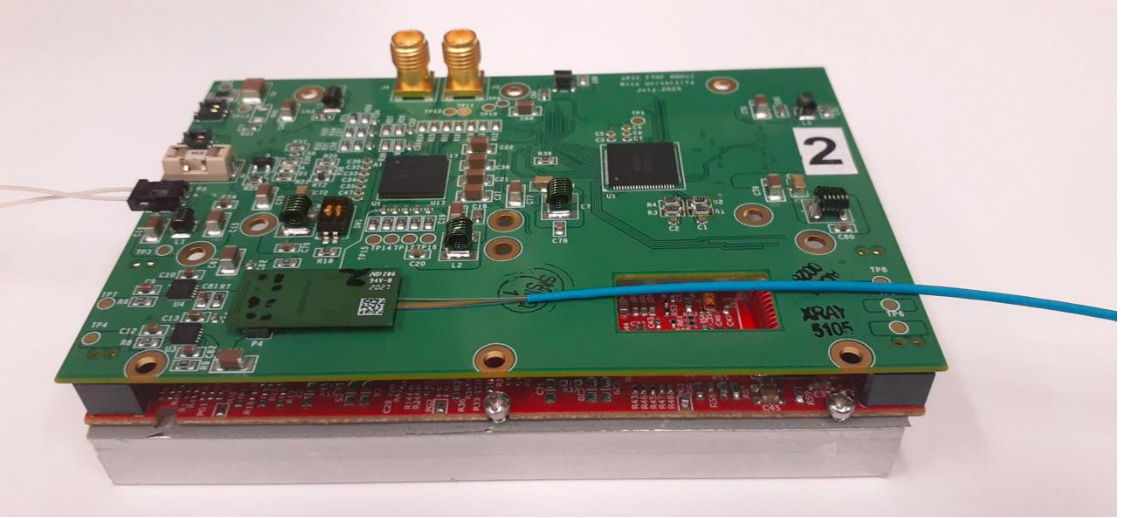


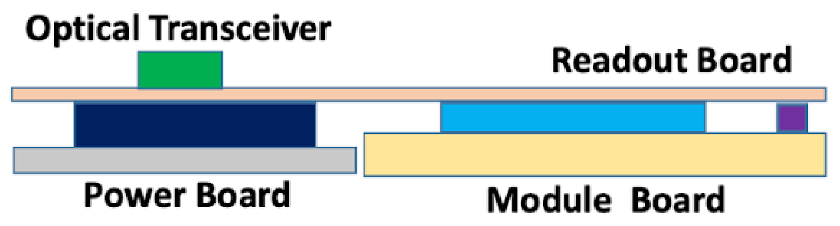


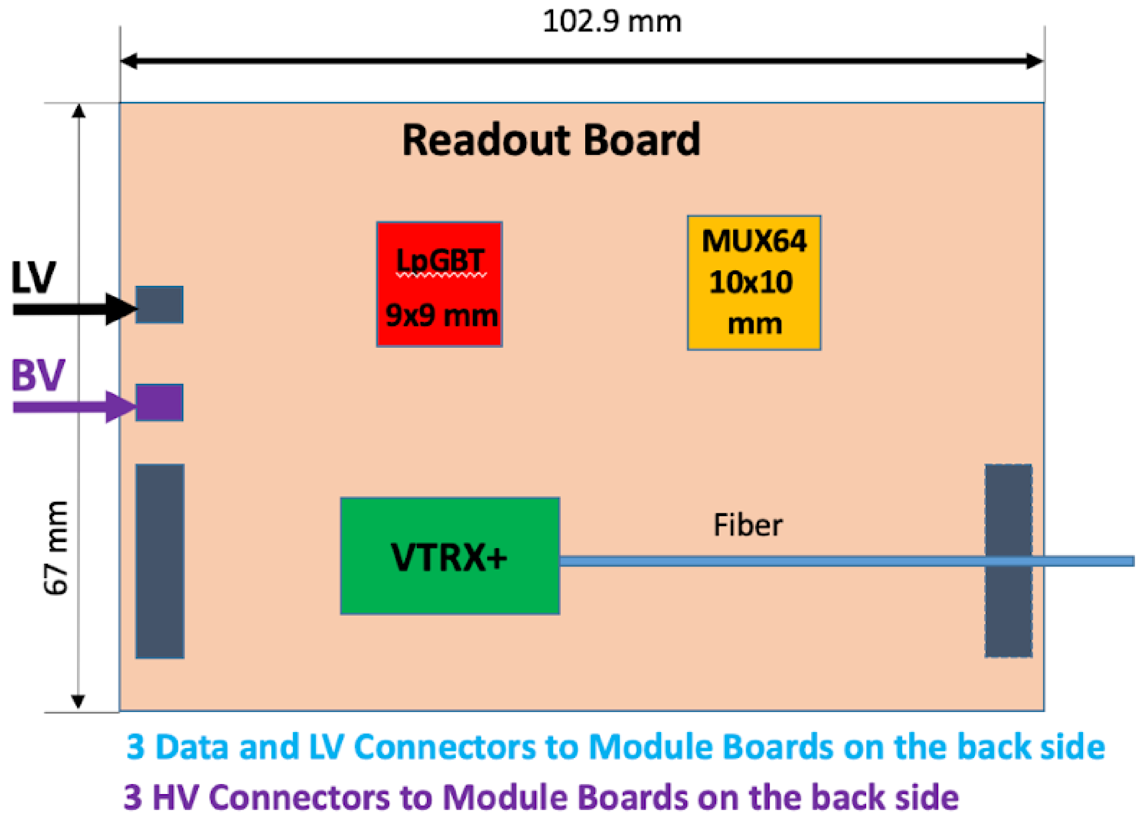
Aim to reduce to ~1W

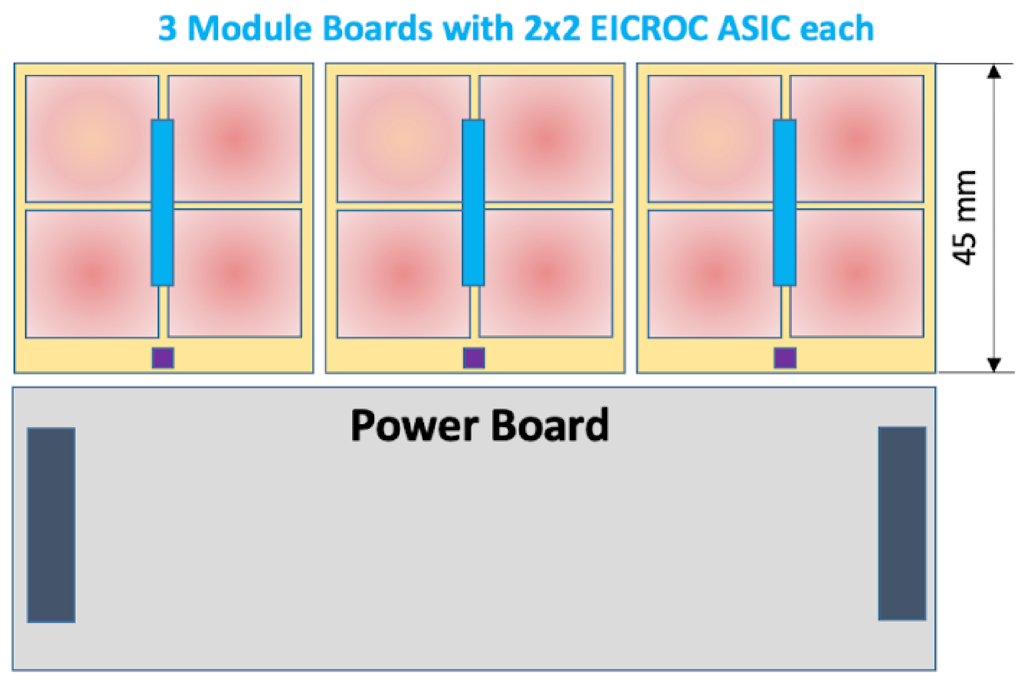
Type	Quantity	Unit power consumption (W)	Total power consumption (W)
ASICs	3112	1.5	**4668**
Sensors	3112	0.002	**6.2**
PB3	28	7	196
PB6	34	13	442
PB7	70	15	1050
RB3	28	2.3	64.4
RB6	34	2.3	78.2
RB7	70	2.3	161
Service hybrids (RB+PB) total			**1991.6**
Grand total			**6666**

Service hybrids





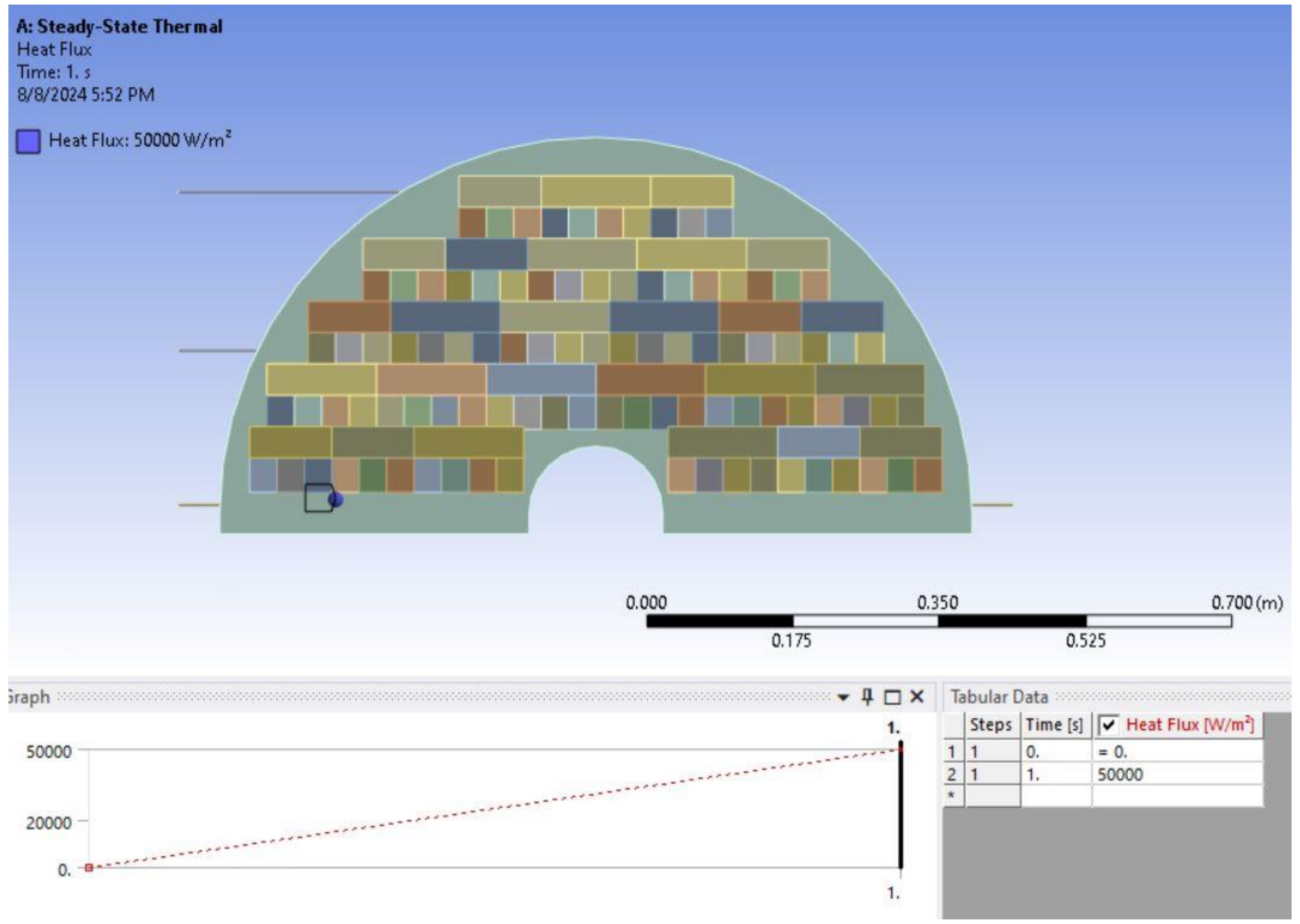




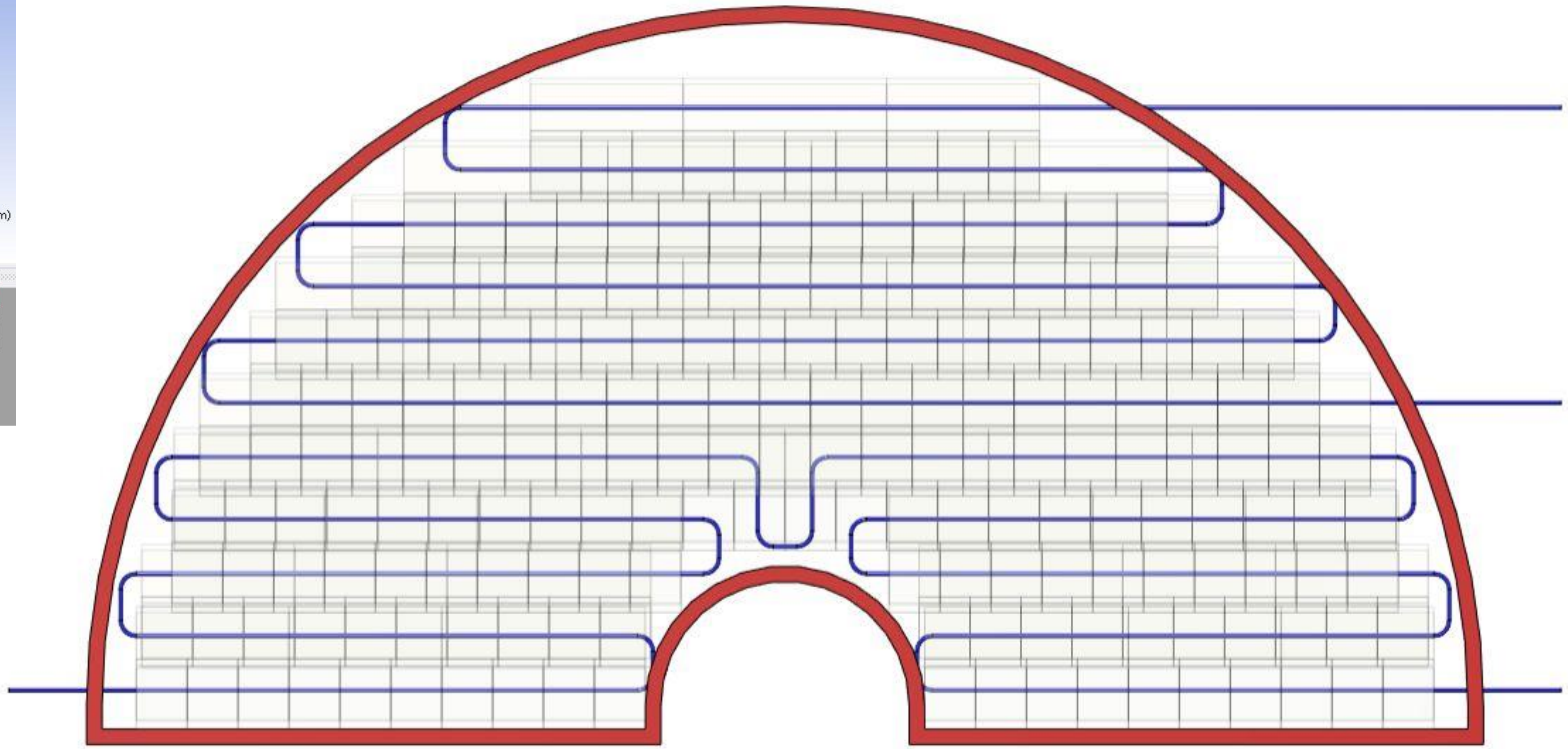
Forward TOF heat transfer FEA

- 1.4 W/cm^2 on ASIC surface
- 5 C pipe cooling – water/glycol 70/30
- 22 C ambient air with 5 W/m^2 Film Coefficient
- 30 C impinging air from R500-R600 with 10 W/m^2 Film Coefficient

Forward TOF heat transfer FEA



Pipe – rerouting and repeat on FEA



Updated results to come next, followed by the first prototype

Summary

Total power consumption reasonably understood but w/ uncertainties

- BTOF: ~11.5kW
- FTOF: ~6.7kW

w/ local “hot spots” of ASICs

First BTOF and FTOF heat transfer FEA completed to study temperature distributions along the staves/disks.

First experimental heat transfer studies done for BTOF -> BTOF stavelet prototype next

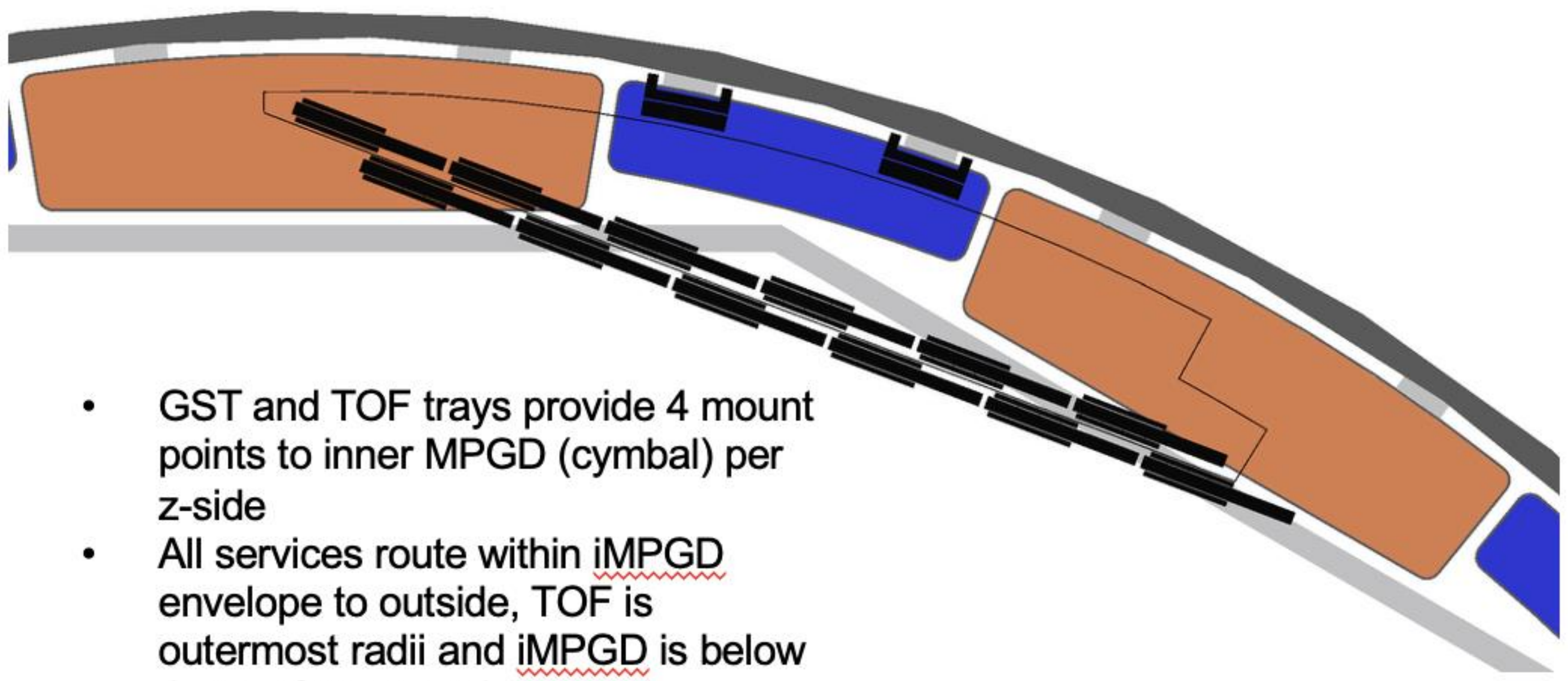
Finalizing the preliminary studies of FTOF FEA and then moving onto the first prototype

Backups

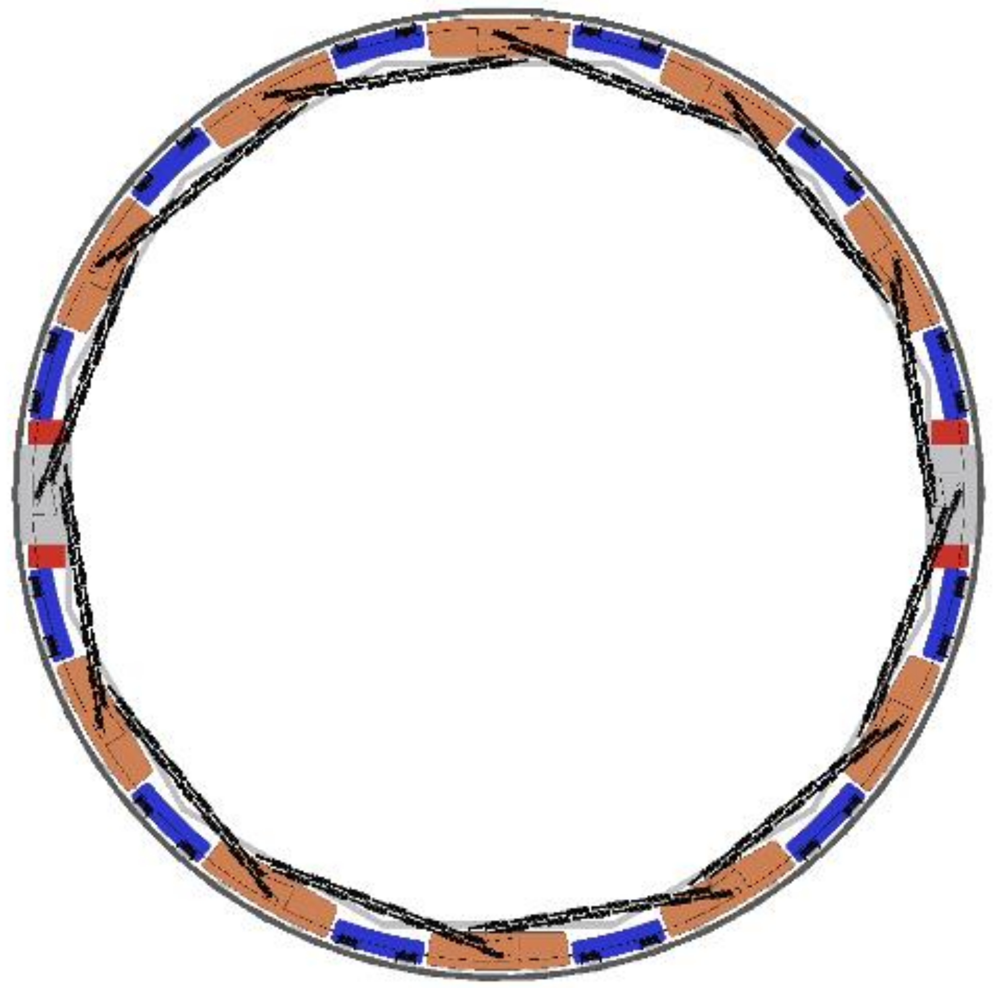
Barrel TOF & inner MPGD supports

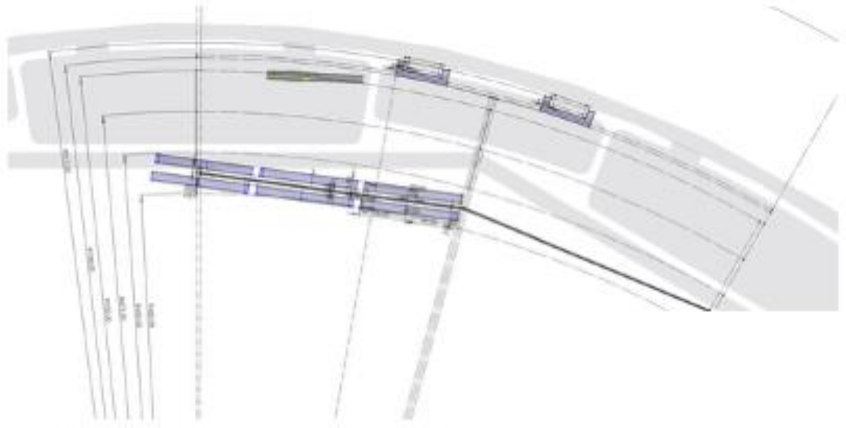
Charge 1, 4, 6

- Tray mounts via top rails to GST
  - Thin line "tracks" a TOF tray, open space inside is for services of TOF
  - Designed for 2mm overlap
- Other solidly filled areas are "reserved" for service of SVT+oMPGD and TOF+iMPGD

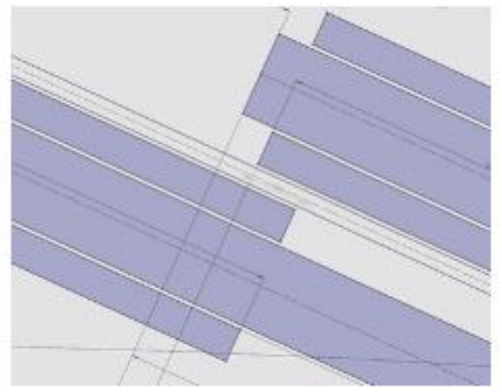


- GST and TOF trays provide 4 mount points to inner MPGD (cymbal) per z-side
- All services route within iMPGD envelope to outside, TOF is outermost radii and iMPGD is below that as far as services go





2mm overlap



Updated drawing for support of inner MPGD:
Example from CMS "trays"