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.

SVT Cooling

Current estimate of power dissipation is thus higher than the initial estimate from November 2022 and amounts to ~ 6.5 – 8 kW

Starting point remains air-cooling internal to the mechanical structures, likely by bringing in pressurized air and complemented with liquid cooling,

Multiple temperatures and temperature-differentials in the system:

- operation of the EIC-LAS,
- thermal expansion of different materials and associated stresses,
- bake-out of the beam-pipe with the SVT installed (and off),

SVT will be operated at/near ambient temperature to within about 10^{o} C, to be further informed e.g. by climate-chamber tests,

Most of what follows is based on a presentation by Nikki Apadula during the recent SVT workfest at the January 2024 collaboration meeting, c.f. https://indico.bnl.gov/event/20473/sessions/6736#all

SVT Cooling – IB, ITS3

From EP R&D WP 1.2 General Reporting Meeting

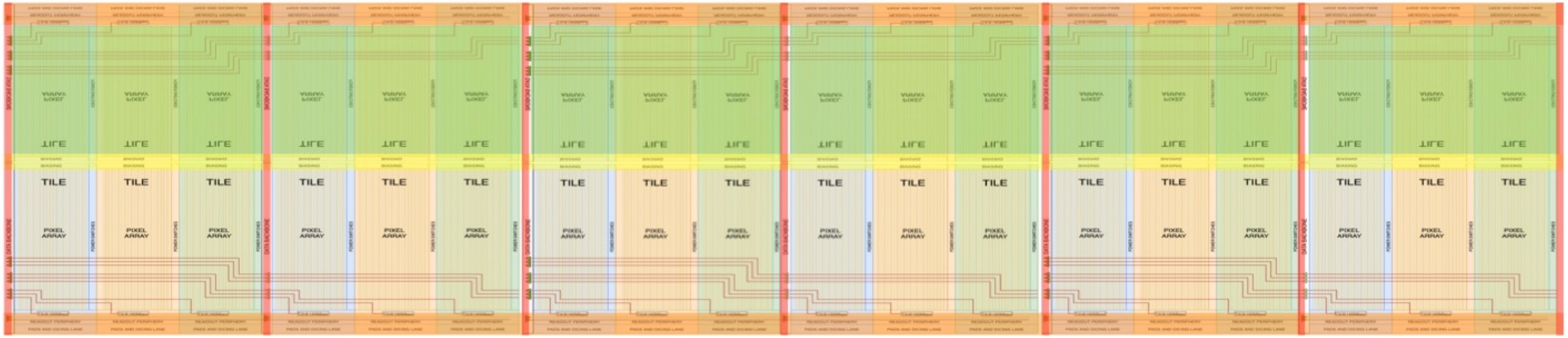
CERN

Power Density

	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

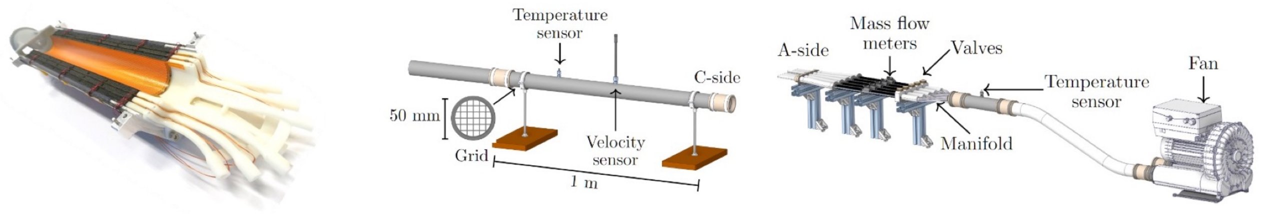
LEC (aka periphery) ~0.8 W/cm^2
Matrix (total) ~20-40 mW/cm^2

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



SVT Cooling – IB, ITS3

SVT IB air cooling



(a) Prototype **(b)** Inlet of the wind tunnel **(c)** Outlet of the wind tunnel

ALICE ITS3 cooling test setup

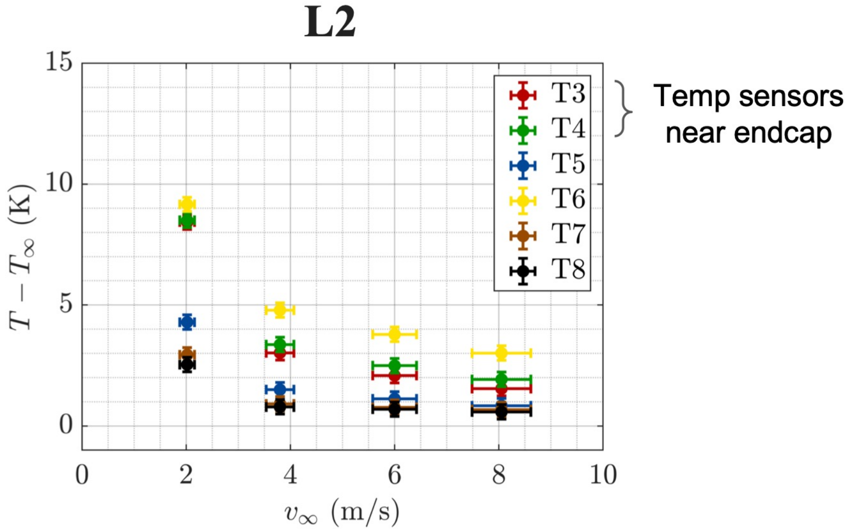
Starting point: Air cooling with carbon foam

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.



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

[ALICE ITS3 presentation at Forum on Tracking Detector Mechanics 2023]

SVT Cooling – OB, disks

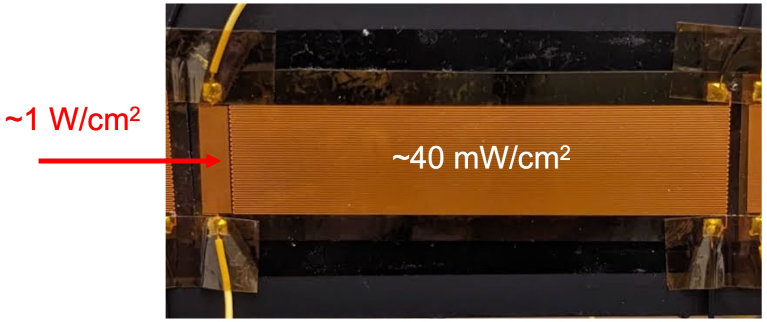
Air-cooling internal to the mechanical structures offers advantages, e.g. in routing of air,

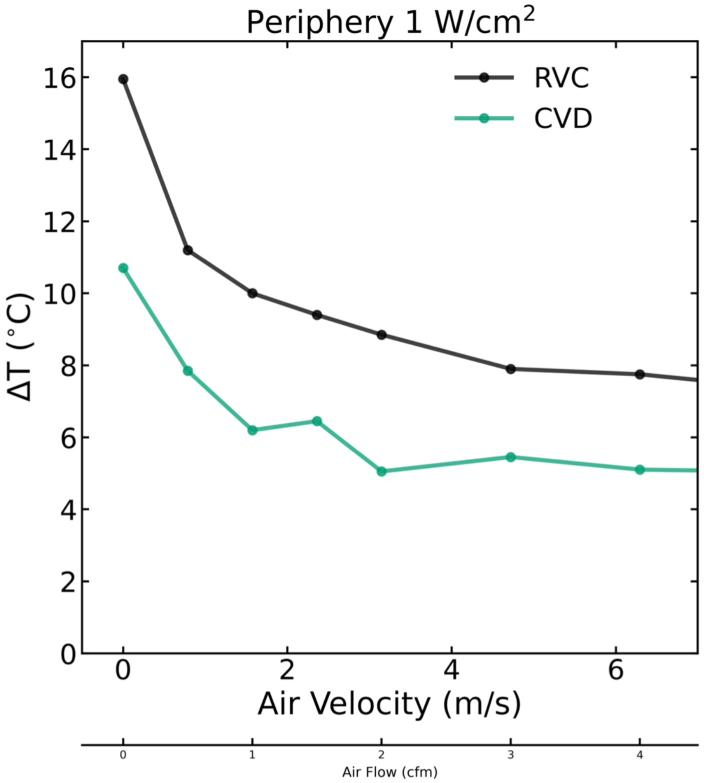
Builds on prior LBNL LDRD with carbon composite structures and RVC or CVD (heat conducting) foam,

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° C in reach – structure is too ”massive” though.





*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

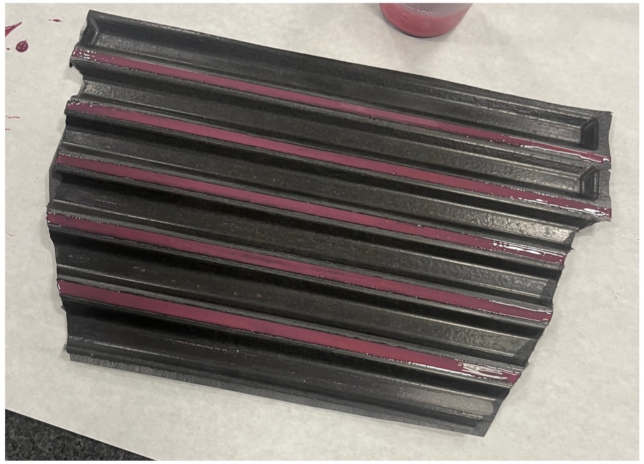
Final size of prototype test piece = 22.4 cm x 20.2 cm

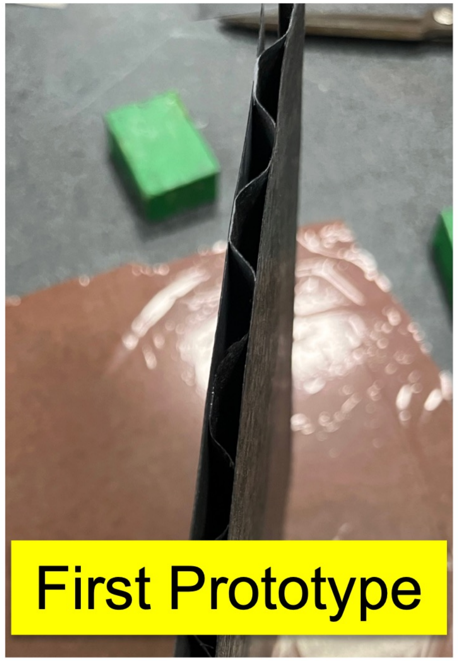
Final weight of prototype test piece = 22.5 g

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)





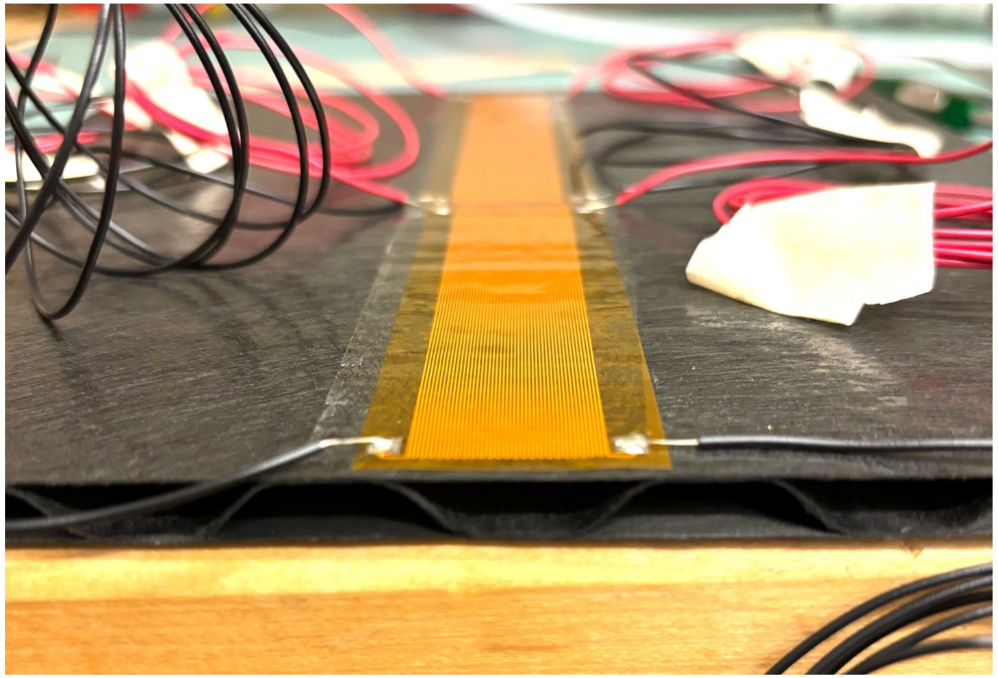
SVT Cooling – disks

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)

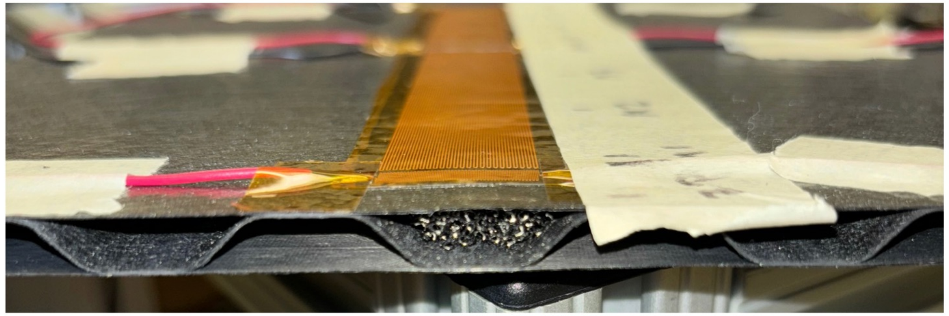
- First step: Put a tube in corrugated channel and blow air through

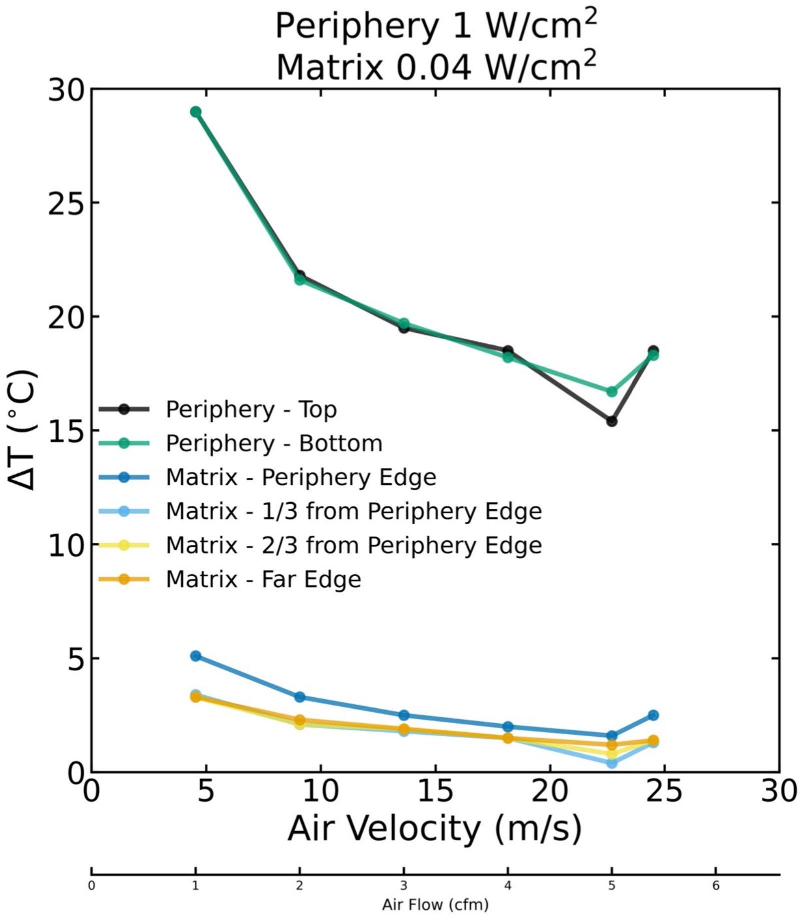


SVT Cooling – disks

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

SVT Cooling – Closing Comments

SVT power dissipation estimate has increased since November 2022 in view of ITS3 sensor development and needs associated e.g. with serial powering, slow control, and readout,

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

Routing of air within structures clear (enough), but some effort remains needed e.g. between structures to manage overall flow,

“Pinch points” in services external to the SVT envelope may impose constraints or at least use of pressurized air – constraints should surprise no-one; explicit envelopes by subsystem in these areas may be beneficial,

Current thought is to release air into the experiment for it to make its way out through gaps etc; may be beneficial to develop specs e.g. on heat loads between subsystems.