SVT Cooling

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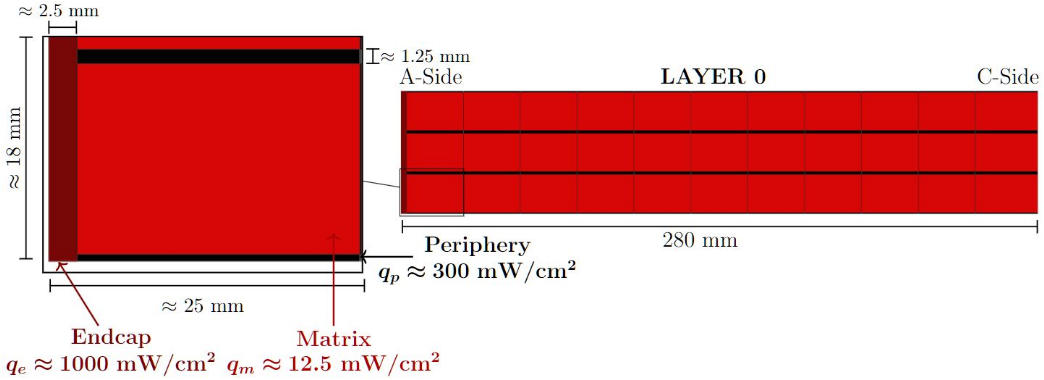
For the ePIC SVT DSC
ePIC TIC Meeting 9/11/23

SVT heat sources



Sensor (ITS3 wafer-scale, EIC LAS)

- Matrix → effective zone of particle detection → Lowest heat dissipation
- Endcap → control/configuration/signal/power → Highest heat dissipation
- Peripheries → Power transfer along stitching units → Intermediate heat dissipation
  - ***New information*** → still be worked into current/ongoing cooling tests

ePIC SVT DSC estimate: ~1 W per Endcap

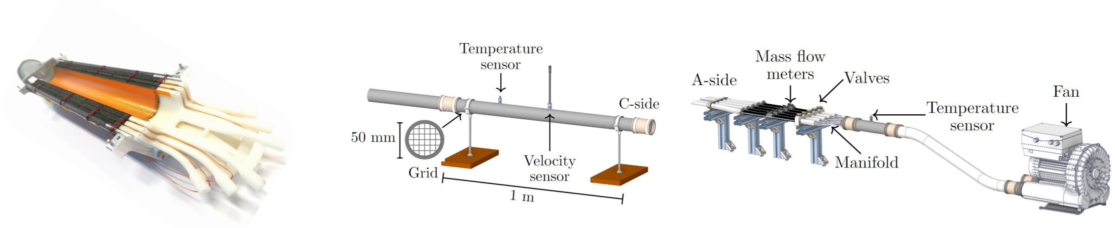
Total sensor power dissipation estimate: 4 kW

Next items to refine: power dissipation estimates

- Shunt-LDOs used in serial powering
- Off-sensor readout components near active area

Service estimates (work between SVT & project)

SVT IB air cooling



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

ALICE ITS3 cooling test setup

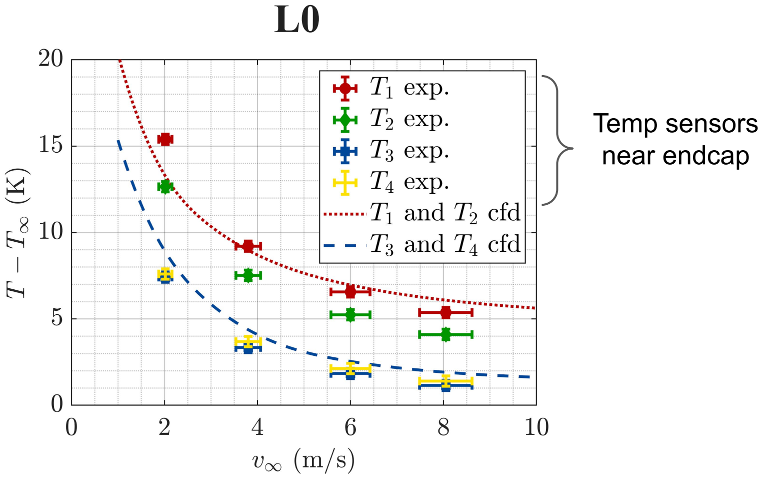
Starting point: Air cooling with carbon foam

Build off of work from ALICE ITS3

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

ePIC changes:

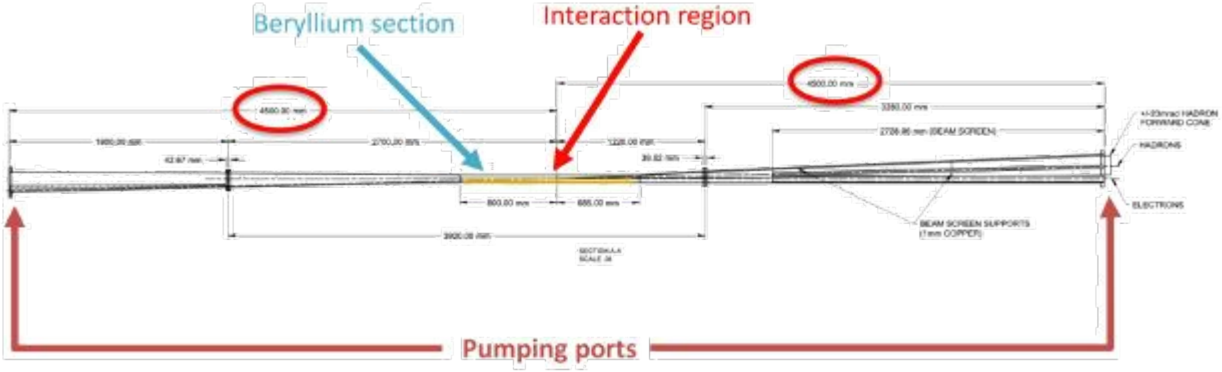
- Adapt to larger radii
- Adapt how air is routed in and out, i.e. suitable redesign of inlets and outlets.

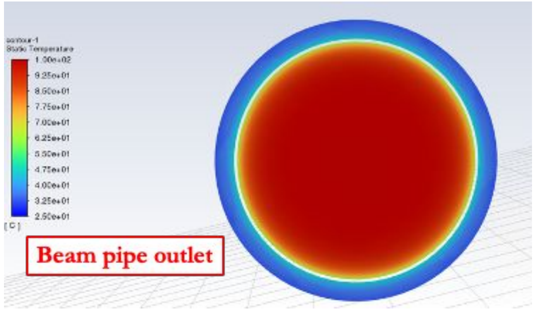


Measurements: endcap = 1 W/cm^2, matrix = 25 mW/cm^2

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

SVT IB air cooling: beam pipe bake-out





Previous ANSYS studies at JLab and LBNL: presentations on 6/6/22, 2/28/23

Bench setup at JLab verifies results

To be done and on the list: determine/refine temperature envelopes for materials (climate chamber), work with vacuum group for next steps

SVT presentations: 10/22/22, 2/28/23
eRD111

SVT R&D: internal air cooling

We have investigated two foam types: Reticulated Vitreous Carbon (RVC) and Chemical Vapor Deposition (CVD)

- RVC → insulating, lower X/X_0
- CVD → conducting, higher X/X_0

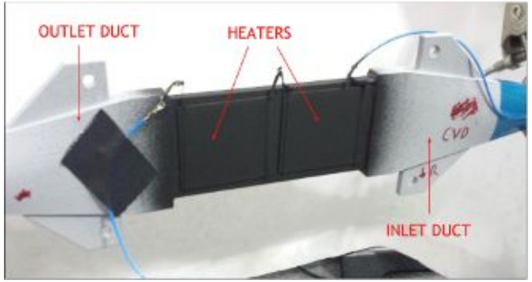
CVD maintains ΔT < 10° C for all tested power densities.

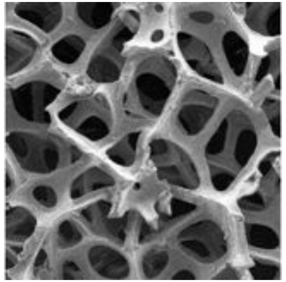
- RVC reasonable → will be tested with SVT specific heater

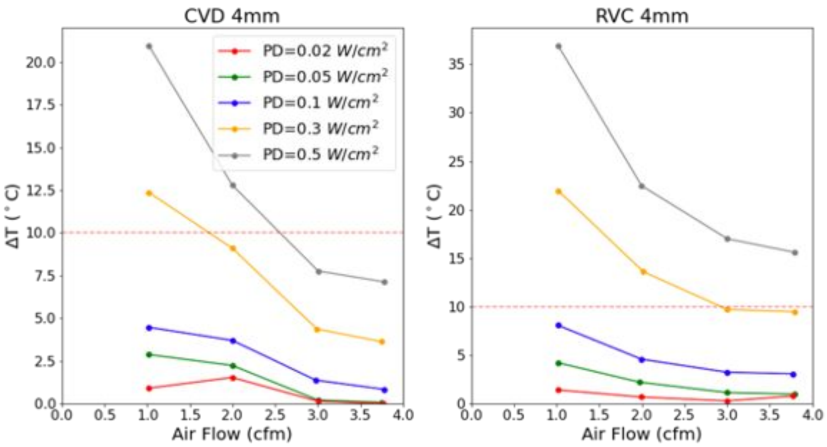
Internal air cooling is viable

- Dependent on mechanical structure → needs further testing/modeling

In progress → SVT specific heater prototypes







Aiming for ΔT < 10° C

Further cooling tests & calculations

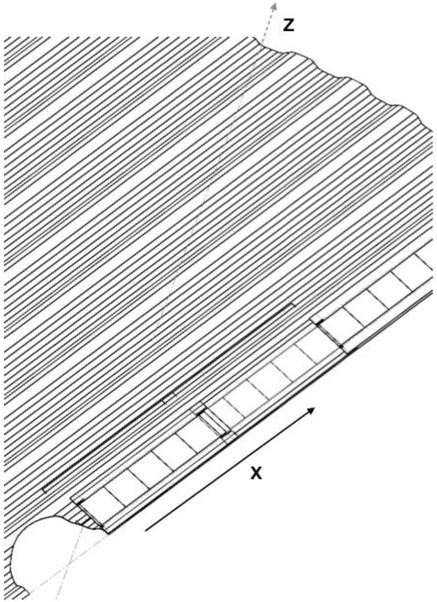
Initial calculations done for air and water cooling on discs

- Air is feasible through corrugated channels
- Water provides significantly more cooling power and can be routed near endcaps/peripheries
    - Estimated from ITS2 values

Calculations to be verified with bench tests to develop an adequate cooling model

SVT-specific mockups currently being developed for testing

- Corrugated carbon fiber
- Verify cfm needs
- As power numbers get updated → is air enough?
- Water routing specifics – related with tiling specifics



Summary/To do

SVT: Air cooling → lowest X/X_0 (before “exotics” like ^4He)

- Base assumption for IB, being further explored for OB/EE/HE

Internal air cooling shown to be feasible

- Testing with SVT specific prototypes in progress

Initial cooling calculations done for SVT discs

- Air a possibility → will be verified through testing
- Explore options to route water cooling as necessary

Operational environment

- Early to define in very specific terms, but current estimate and goal is room temperature and constant power dissipation

SVT cooling is a work in progress

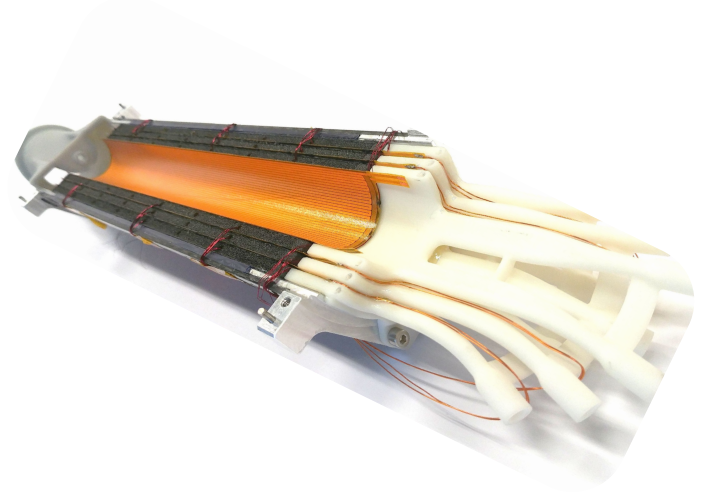
- Current estimate ~4 kW for the sensors in the IB, OB, EE, and HE
- A lot has been done and a lot remains to be done

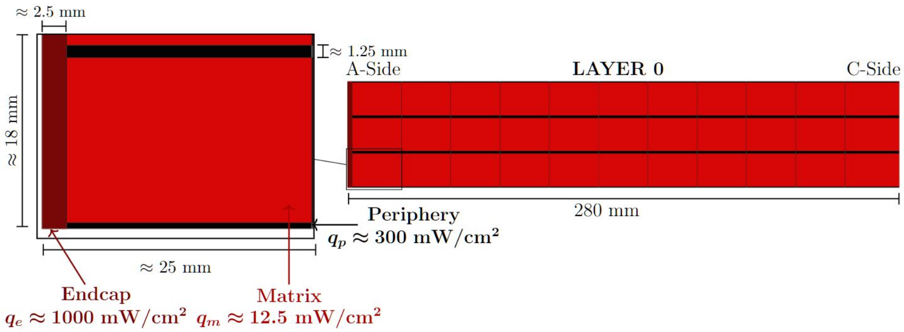
Under consideration for cooling is a global solution that could be applicable for the SVT, MPGD, and the TOF. Though the SVT does not need to be cooled to a low temperature (~25C operating), nor has a large power density, the material budget of the cooling solution is extremely important. Solutions applicable for the MPGD and TOF will likely be usable to keep the SVT cool, but will need to be carefully studied for the effect on the material budget.

Backups

DESIGN → LAYOUT

- LS3 → Three innermost layers of the ITS2 replaced (Inner Barrel)
- ALICE ITS3 Inner Barrel → Silicon layers of 40 µm of thickness → Bent into cylindrical shape





Power dissipation in the silicon layers of the ALICE ITS3

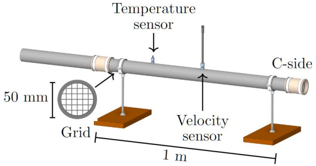
- Monolithic Pixel Sensors → Stitching of smaller units of ≈ 18 × 24 mm
- **Matrix → Effective zone of particle detection → Lowest heat dissipation**
- **Endcap → Electrical interconnections → Highest heat dissipation**
- **Peripheries → Power transfer along the stitching units → Intermediate heat dissipation**
- Beam pipe → Heat dissipation depending on particle collisions → $q_{bp} \in [0,100]$ mW/cm²

THERMAL ANALYSIS → METHODOLOGY

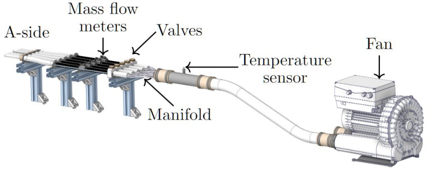
- Thermal performance of the ITS3 cooling system

EXPERIMENTS

(a) Prototype

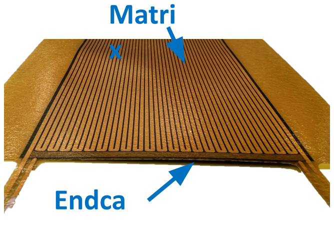


(b) Inlet of the wind tunnel

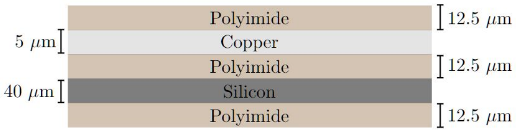


(c) Outlet of the wind tunnel

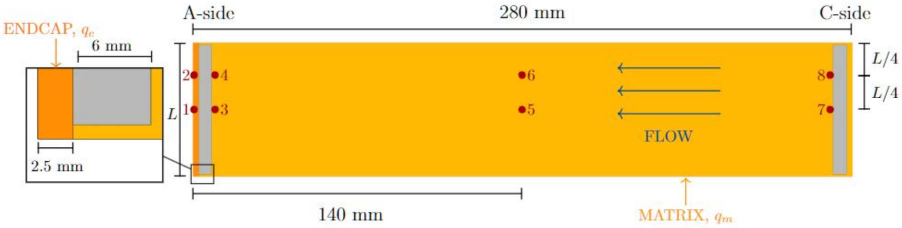
- Wind tunnel with velocity sensor, mass flow meters, and temperature sensors
- Prototype built with the design previously mentioned → Scan verification
- Power dissipation of the silicon layers → Integrated heaters with two zones and 8 temperature sensors



(a) Si layer + heaters (CERN EP-DT-DD MPT service)



(b) Layout (total thickness 160 μm)



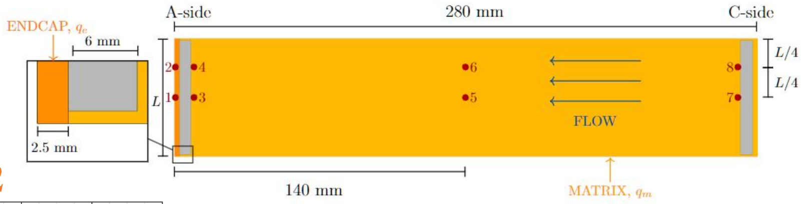
(c) Position of the temperature sensors

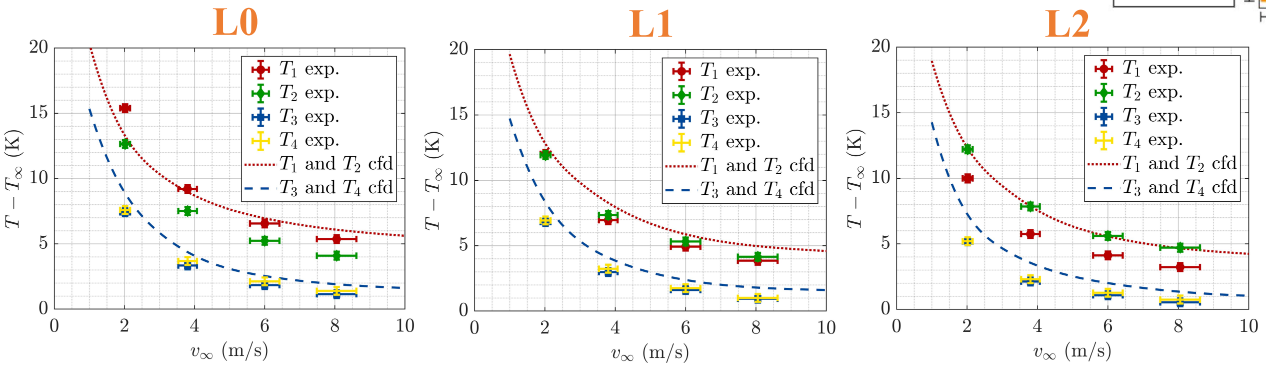
Integrated heaters

CFD SIMULATIONS → Geometry of the prototype, parameters obtained from material characterization

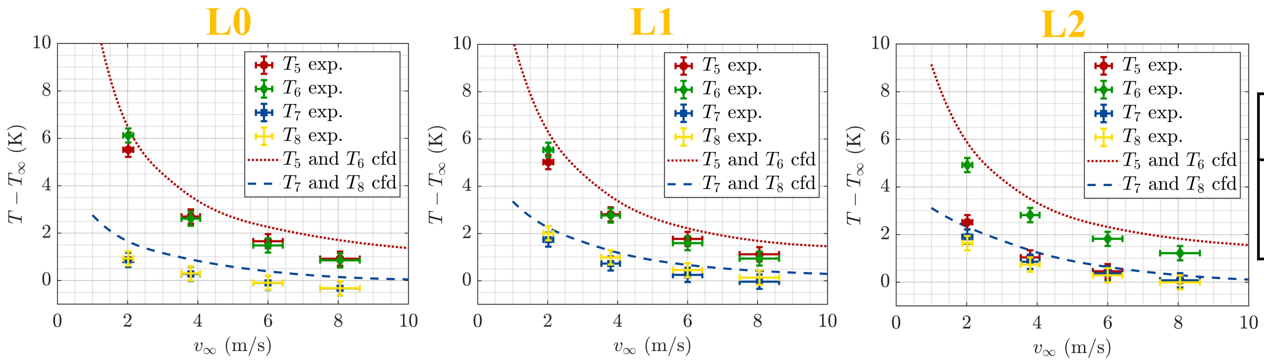
THERMAL ANALYSIS → RESULTS

- Two zones of different power dissipation: endcap and matrix
- $q_m = 25\ \mathrm{mW/cm^2}$, $q_e = 1000\ \mathrm{mW/cm^2}$
- Same freestream velocity v_∞ in all layers, $T_\infty \approx 20\ °\mathrm{C}$





Temperature variation in the **ENDCAP** obtained from experiments and CFD simulations



Temperature variation in the **MATRIX** obtained from experiments and CFD simulations

- Accurate CFD prediction
- Thermal resistance (glue) → Differences between the sensors
- L0 → Highest ΔT

- Similar conclusions as in the endcap
- Thermal resistances + non-constant $T_\infty \rightarrow \Delta T < 0$

REQUIREMENT	ENDCAP	MATRIX
ΔT < 10 K	ΔT < 6 K ✓	ΔT < 2 K ✓