Cooling Methods and Material Studies for a MAPS Based Silicon Vertex Tracker

BERKELEY LAB

Workforce Development & Education

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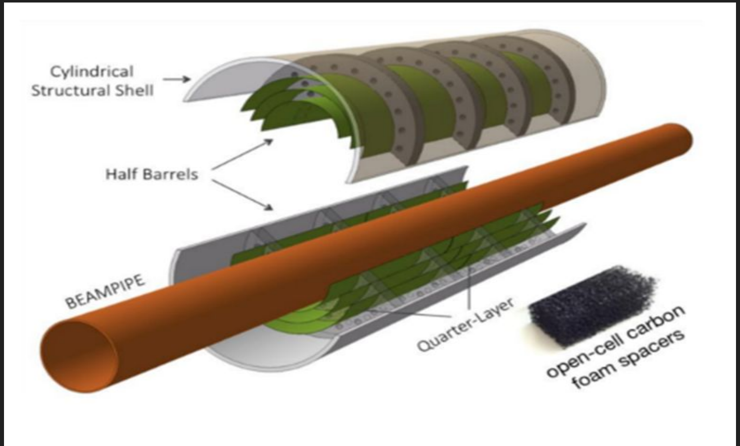
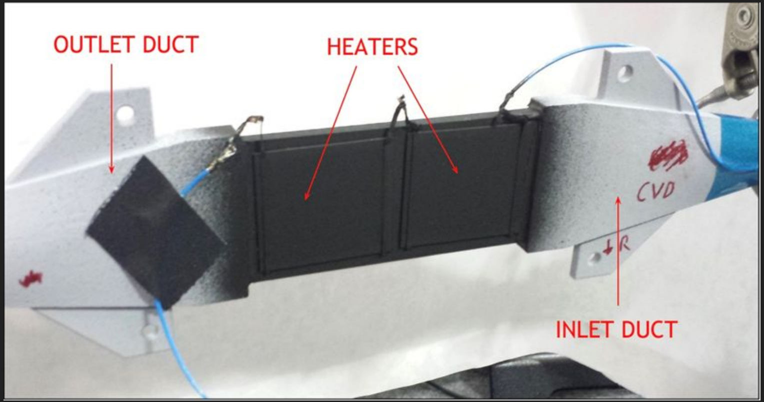
Research Questions

- Is air cooling a viable option for the staves and disks of the silicon vertex tracker?
- How can the temperature measurement accuracy be improved when testing each cooling option?

Background

- Recent studies show that a compact silicon detector within the ePIC design can provide similar or greater momentum resolution than recent hybrid material concepts.
- Efforts are directed towards minimizing material and maximizing performance.
- The “stave” is the foundational building block of the detector that consists of the silicon, power, readout, and support structure.
- Ceramic heaters serve as a material substitute for the silicon components during testing.
- The stave must have a form of cooling while in operation.





Materials

Reticulated Vitreous Carbon Foam (RVC) is an insulator that is synonymous to a low material budget.

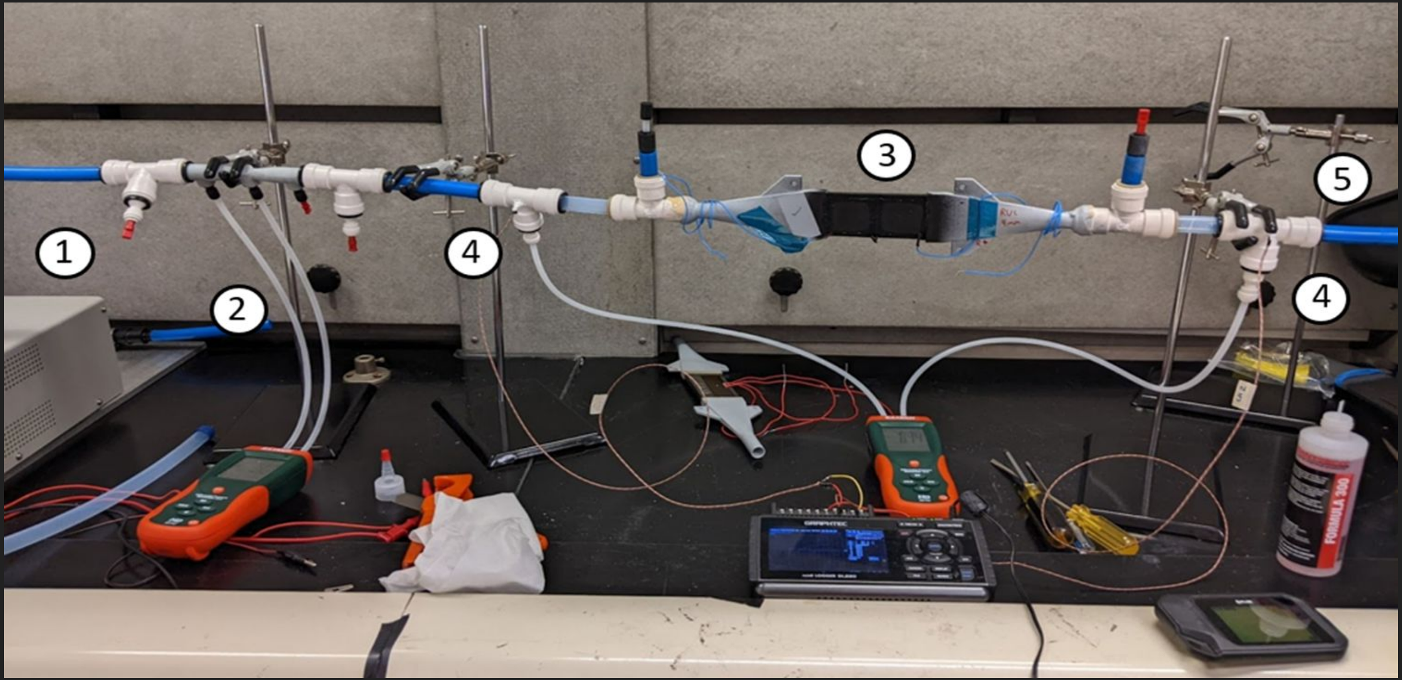
Graphitized Carbon Foam (CVD) is a conductor that provides high thermal performance resiliency.

Challenge:

- Adhere to a compact material budget that decreases the likelihood of particle scattering, which leads to inefficient resolution for particle tracking.
- Search for areas susceptible to overheating.
- Determine which material will maximize thermal performance at a reasonable temperature differential while minimizing material.
- ΔT is the difference between the “heater off” (dark temperature) and “heater on with air flowing (recorded)
- ΔT must be kept to a minimum in order to present effective thermal performance.

Target: A standard of ≥ Δ10 °C and capability to handle ~ 1 Bar

Setup Under the Fume Hood



Near Side →Far Side

Methods for Heating and Cooling

Heating

- Fixed airflow (cfm) with an increasing power density (W/cm^2)

Cooling

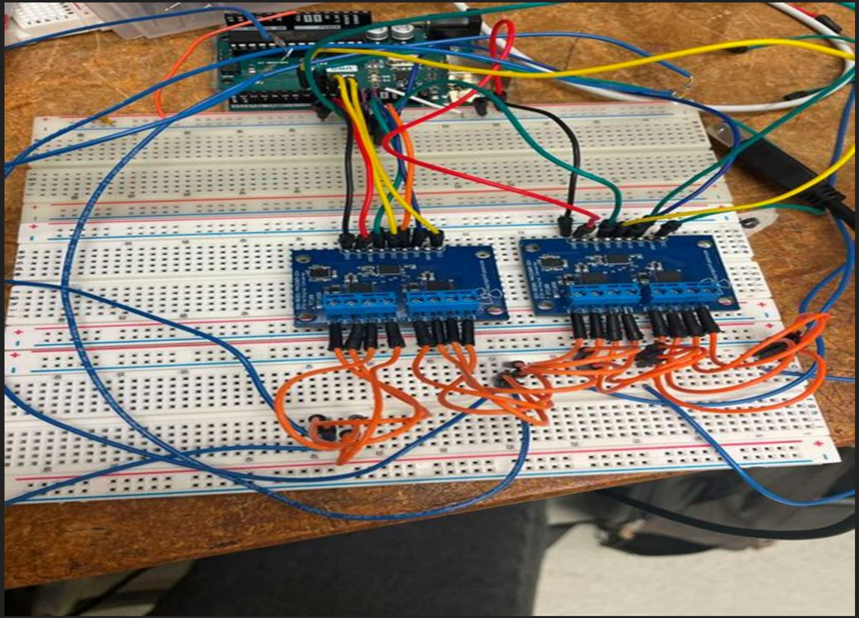
- Fixed power density (W/cm^2) with an increasing airflow (cfm)

When adjusting these parameters in the set up, a ΔT value derived between the initial dark temperature and final recorded temperature can be determined.

- NOTE* Threshold for overheating limited to 0.5 W/cm^2

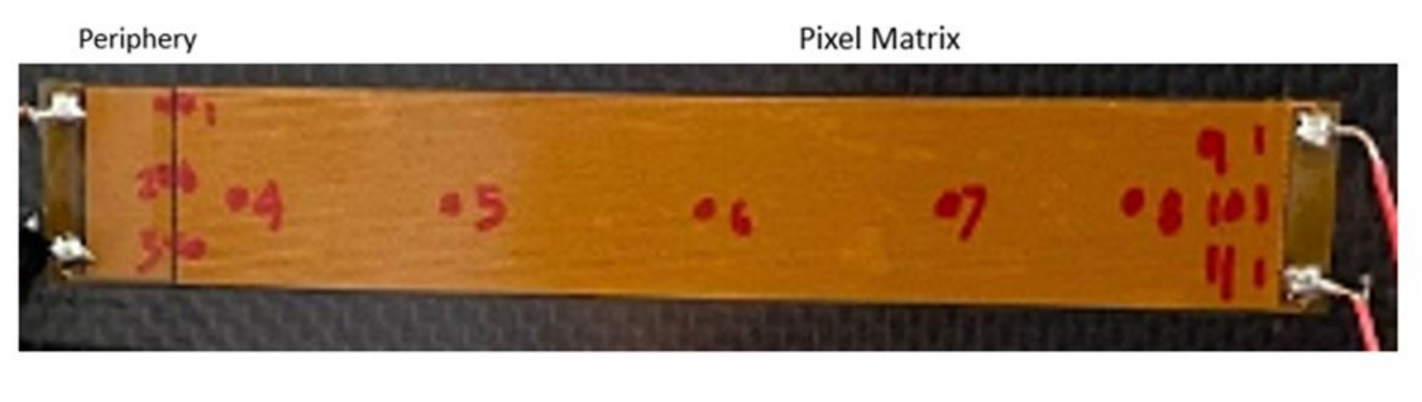
Methods for Temperature Measurement

FLIR Thermal Camera



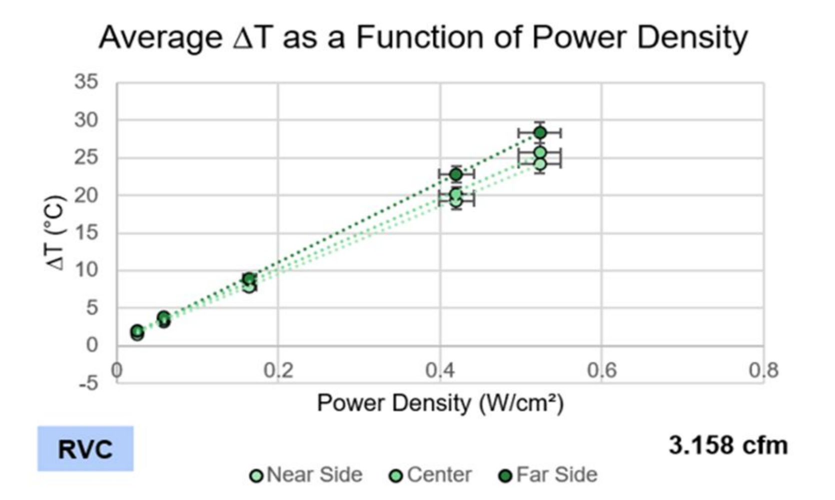
Arduino RTD PT100 Circuit Design
(Resistance Temperature Detector)

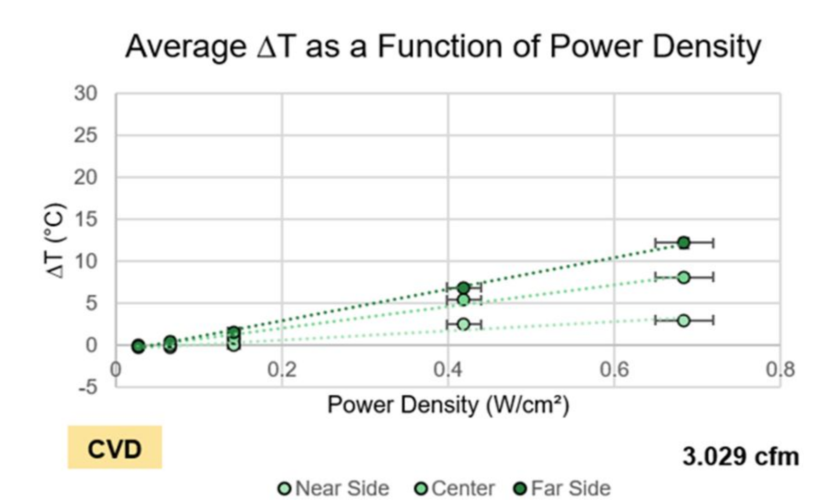
Periphery and Pixel Matrix



The periphery side generates heat much faster than the pixel matrix and should be the primary target for air cooling.

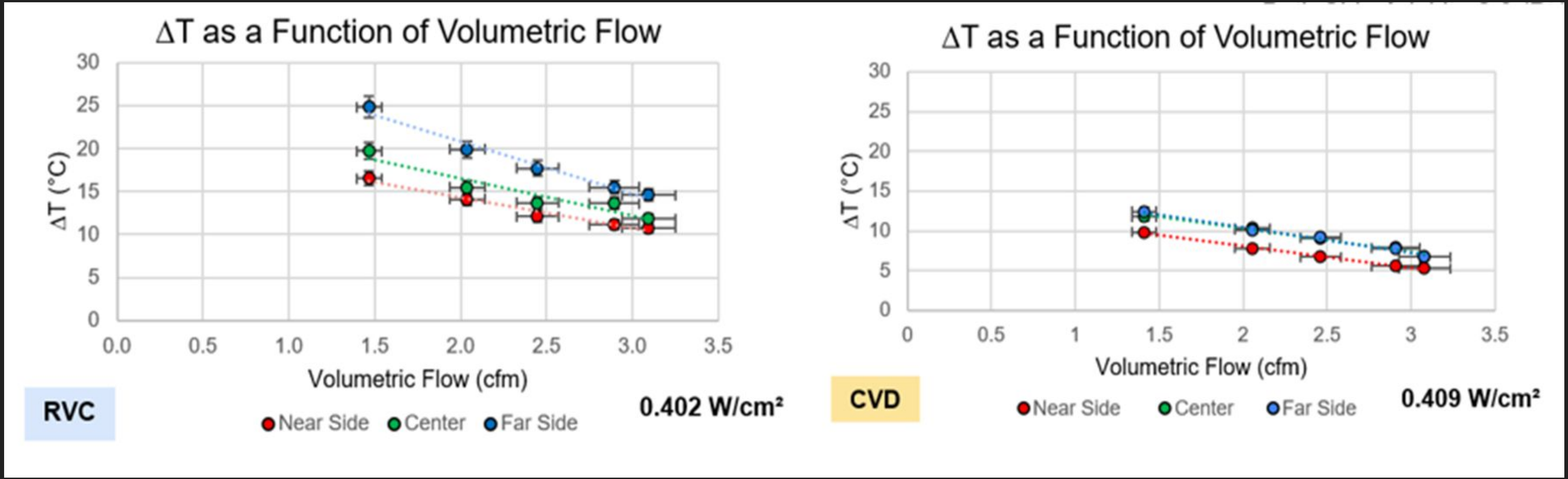
Results for Heating





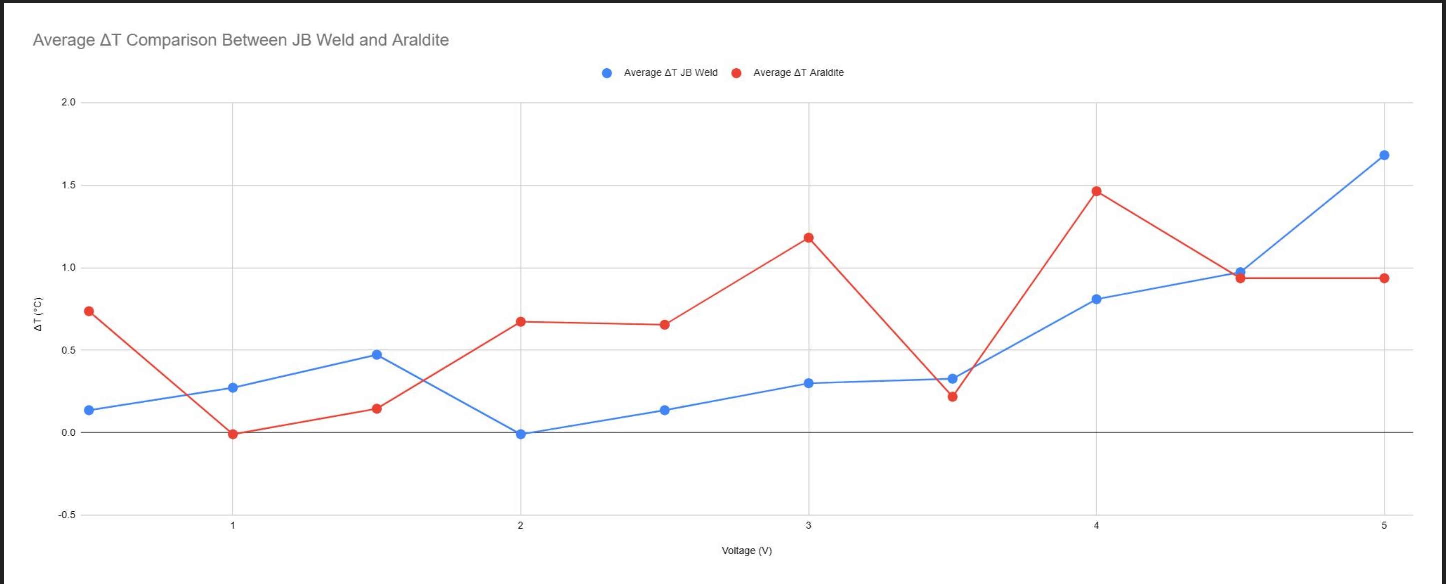
- Fixed max airflow provided with increasing power density
- Presumably, air becomes hotter as it travels further along the stave towards the far side.
- RVC Near Side ΔT ~ 5.7°C (overall ΔT ~ 23.2°C)
- CVD Near Side ΔT ~ 3.2°C (overall ΔT ~ 12.2°C)

Results for Cooling



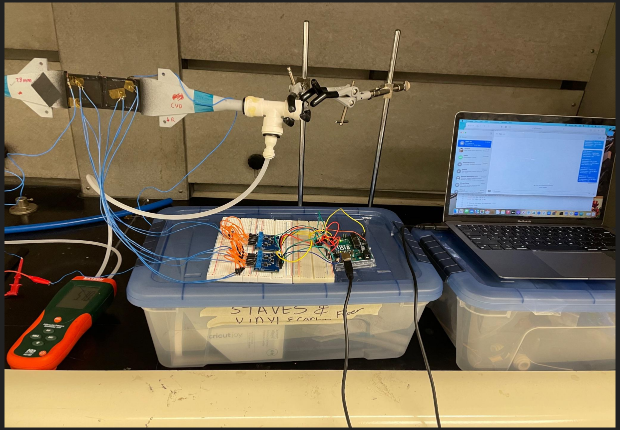
- Fixed max power density with increasing airflow
- Air cooling is effective towards the far side direction as cfm increases
- RVC Near Side ΔT ~ 5.7°C (overall ΔT ~ 10.2°C)
- CVD Near Side ΔT ~ 4.5°C (overall ΔT ~ 6.2°C)

Heat Resistant Glues for the Test Setup



- Araldite performed similar to JB Weld and remained within its respective temperature threshold.
- Further experimentation will be done on BondaTherm in the near future. Preferably with the PT100.

Conclusion



- We expect the ΔT to increase rapidly on the far side because the airflow gets hotter due to the power density as it travels further away from the near side.
  - Cooling is most effective on the near side.
- Periphery section of the sensor should be oriented towards the near side for maximum cooling efficiency.
- Pixel Matrix does not generate as much heat compared to the periphery and should be placed on the far side.

VERDICT

- CVD performs better than RVC thermally given similar parameters.
  - ΔT kept relatively under Δ10°C throughout testing.
- Temperatures recorded with the FLIR thermal camera are considered sufficient for analysis.

Future Projection and Final Remarks

- PT100 sensor should be the primary tool for recording temperature values rather than the FLIR.
  - 12 channel configuration optimizes PT100 analysis.
- A supplementary cooling fan or vacuum pump can be implemented into future cooling approaches for new maximum airflow values.
  - Goal: Exceed ~3.15-3.2 cfm