Air Cooling Studies for the EIC Silicon Tracker

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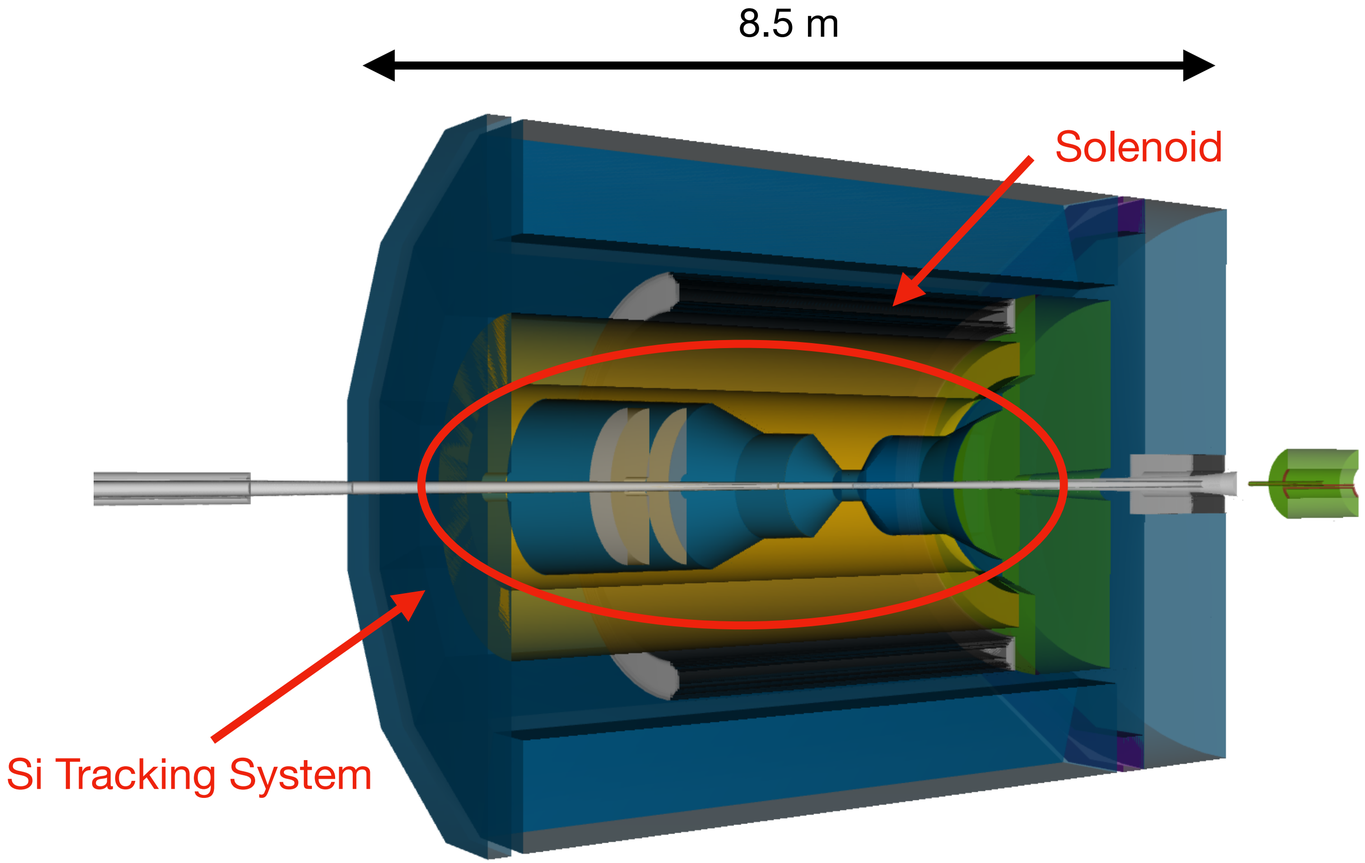
Tracking Requirements

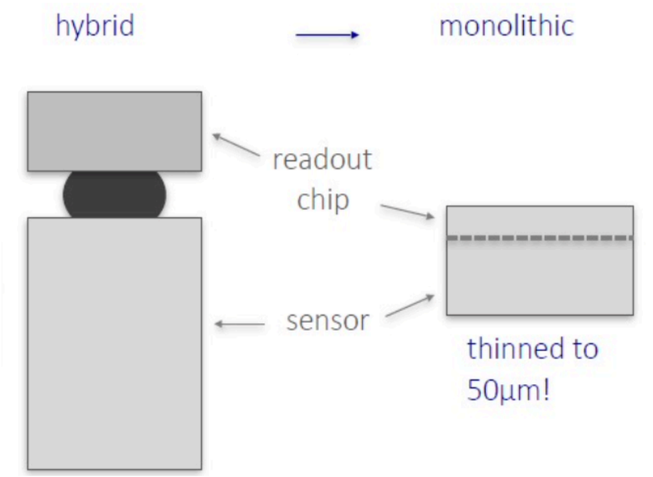
- Good momentum resolution
- Wide kinematic coverage
- Large acceptance
- High precision collision vertex determination
- **Low material budget with high granularity**

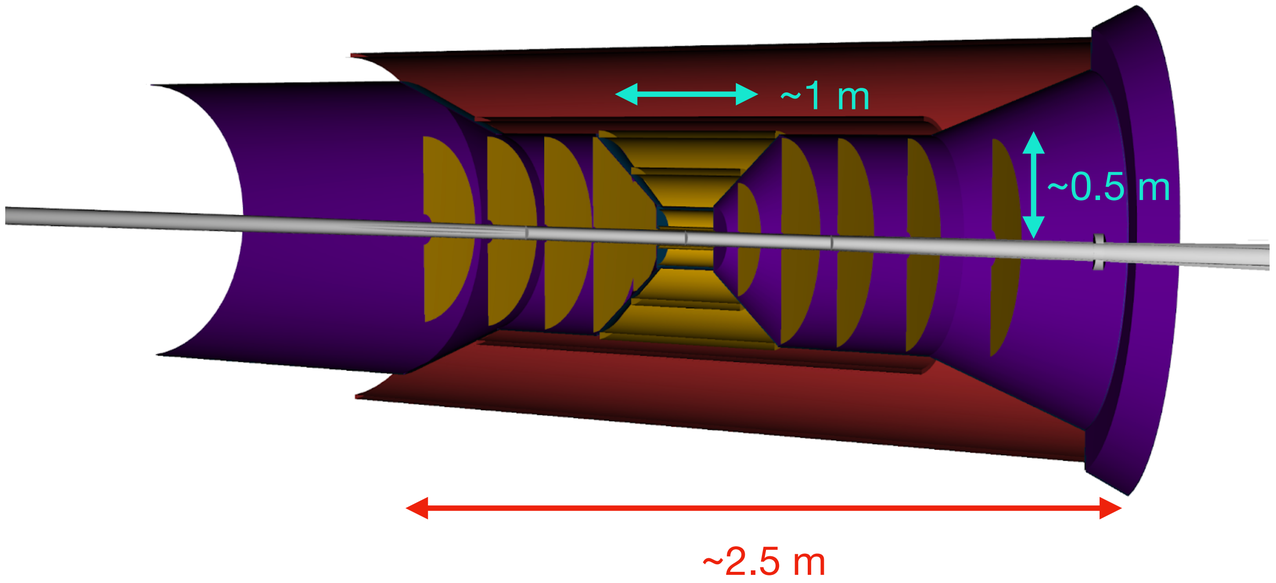


EPIC detector

Current Si Tracking Setup

- MAPS = Monolithic Active Pixel Sensors
  - Low material silicon wafers
- Barrel
  - 3 vertexing layers
  - 2 barrel layers
- Disks (forward & backward regions)
  - 5 on each side

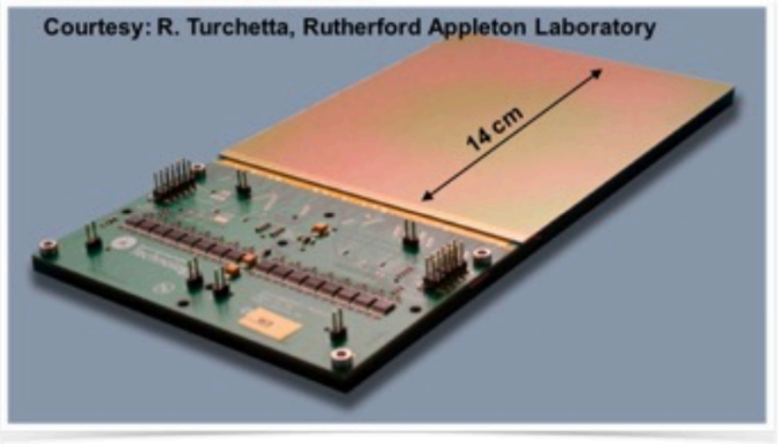


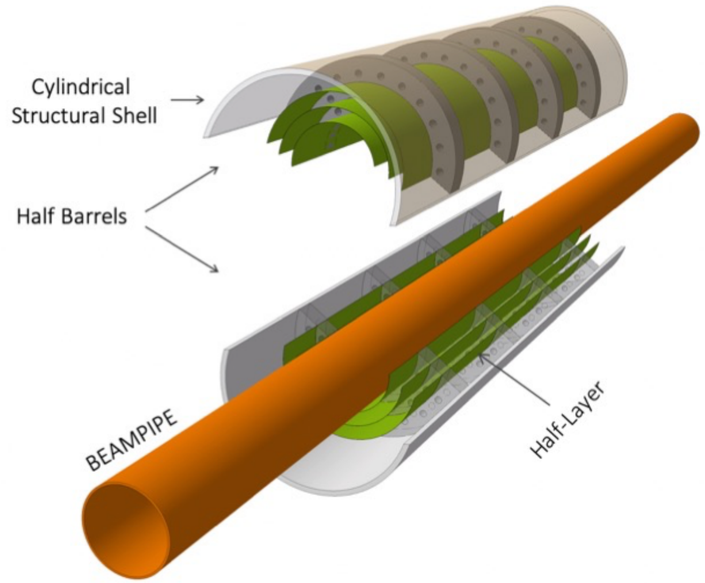


New Technology

- ALICE ITS2 used the ALPIDE chip
- New chip being developed for ITS3
  - Wafer scale (up to ~28 x 10 cm)
  - Ultra-thin (20-40 μm)
  - Curved
  - Fully stitched
- For the EIC…
  - Wafer-scale not suitable for staves & discs
  - Optimize for large area coverage and yield
    - ALICE ITS3 ~ 0.12 m^2 vs EIC silicon ~ 10 m^2

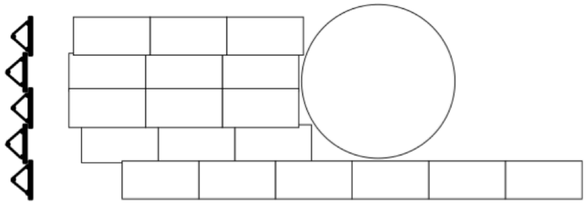
Wafer-scale sensor

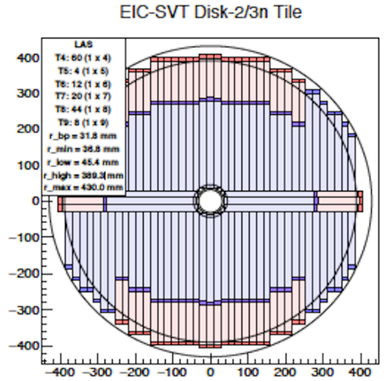


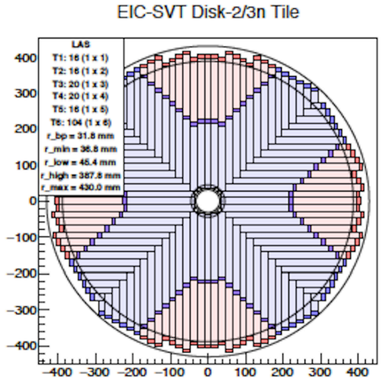


Layout of ITS3 Inner Barrel, ALICE Letter of Intent

Current R&D







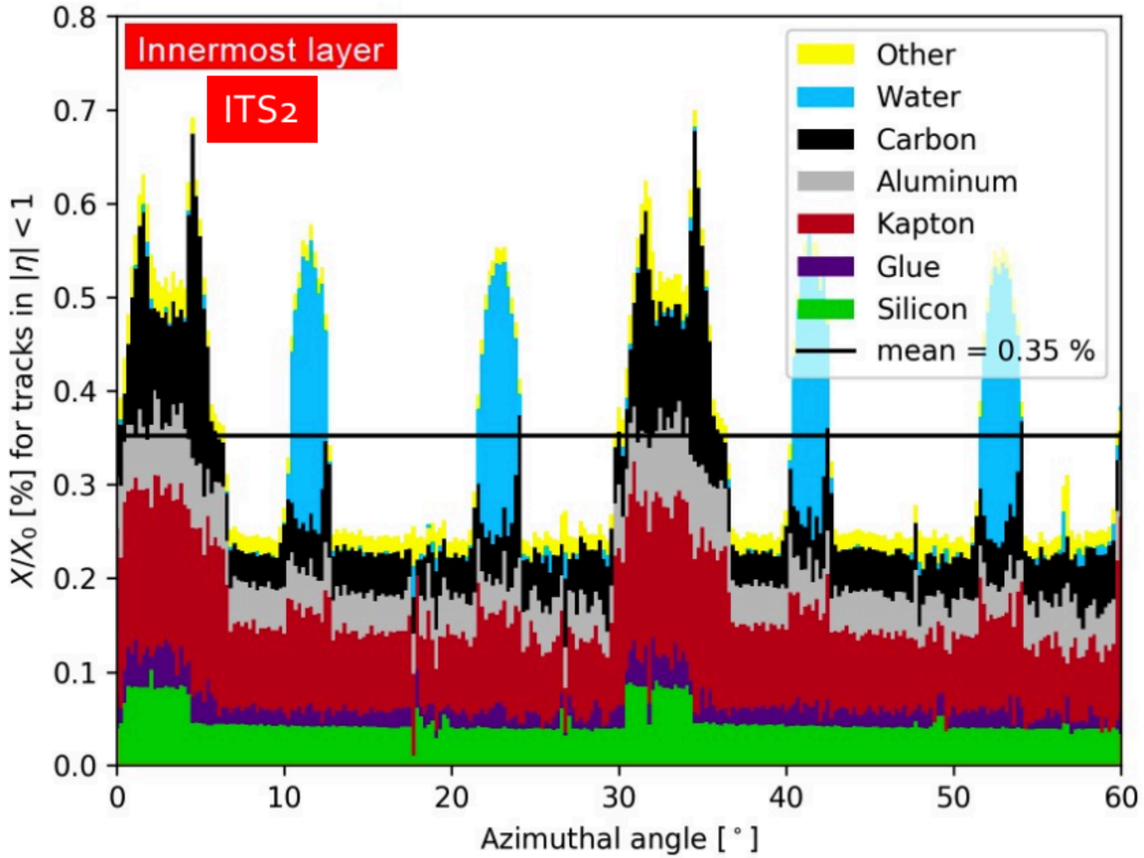
Work done by Peter Jones (UK Birmingham)

Project R&D at Berkeley (focused on Silicon tracker)

- Detector optimization
  - Geometry
  - Layout of staves and discs
- Mechanics, integration, and cooling
  - Is air cooling viable for staves/discs?

Other R&D efforts

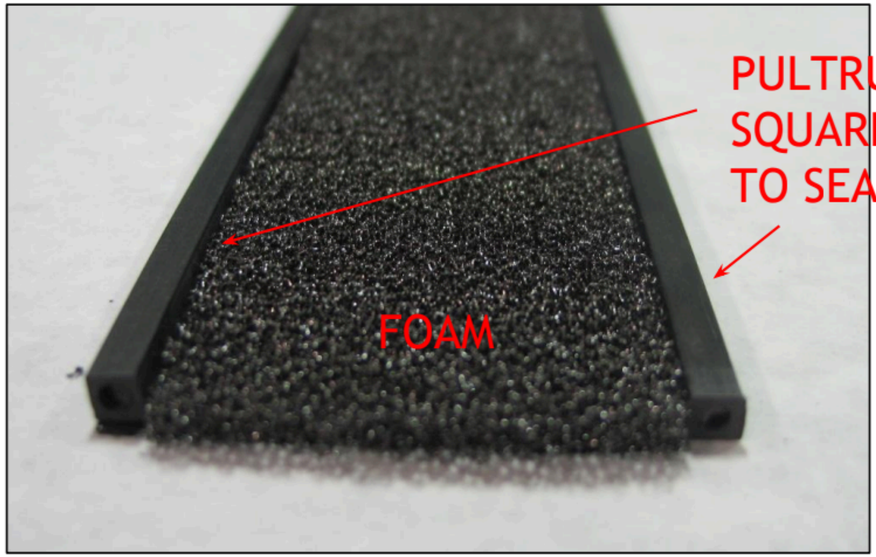
- Services reduction
- Forming modules from stitched sensors

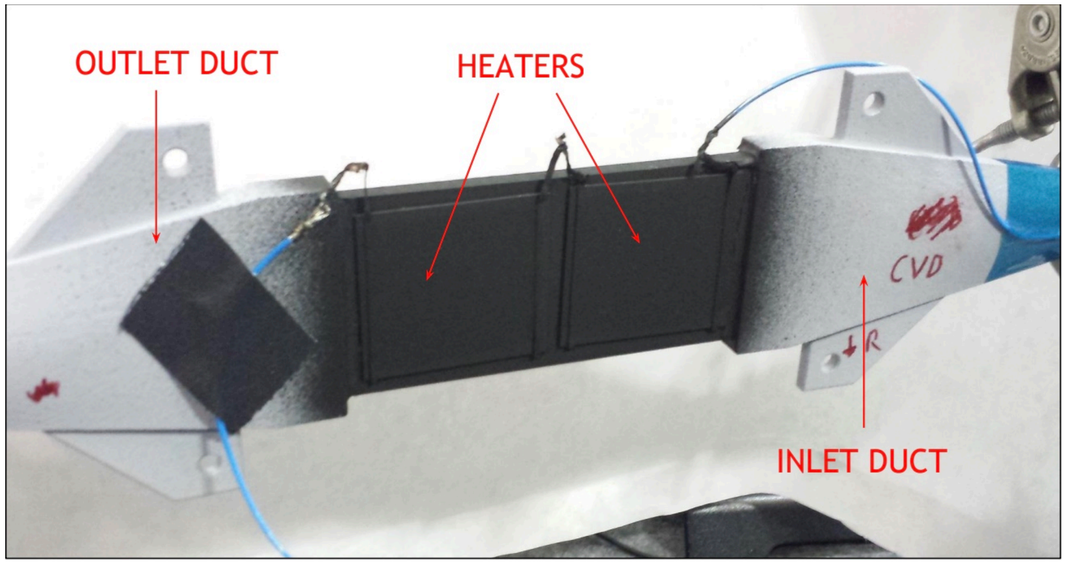


Air Cooling

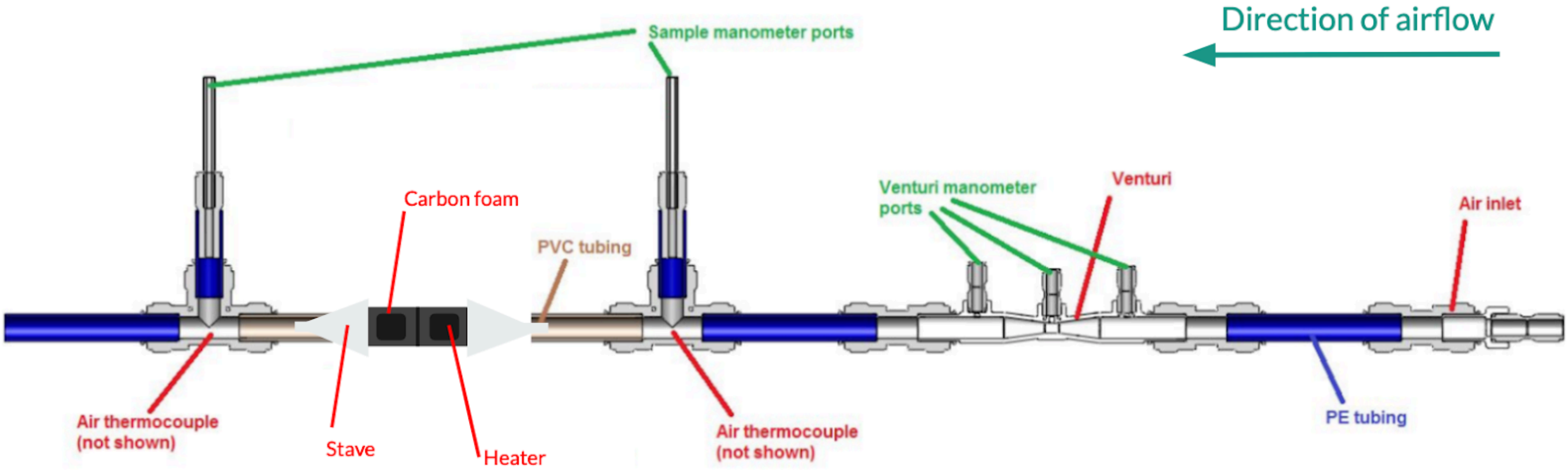
Tracking requirements for EIC are very strict and heavily influenced by material budget.

- Is internal air cooling a viable option?
  - Is air effective enough?
  - Is our design stable enough to withstand air being blown at it?
- Goal: Optimize the temperature and pressure
- Variables we can adjust:
  - Power consumption
  - Foam types
  - Foam thicknesses

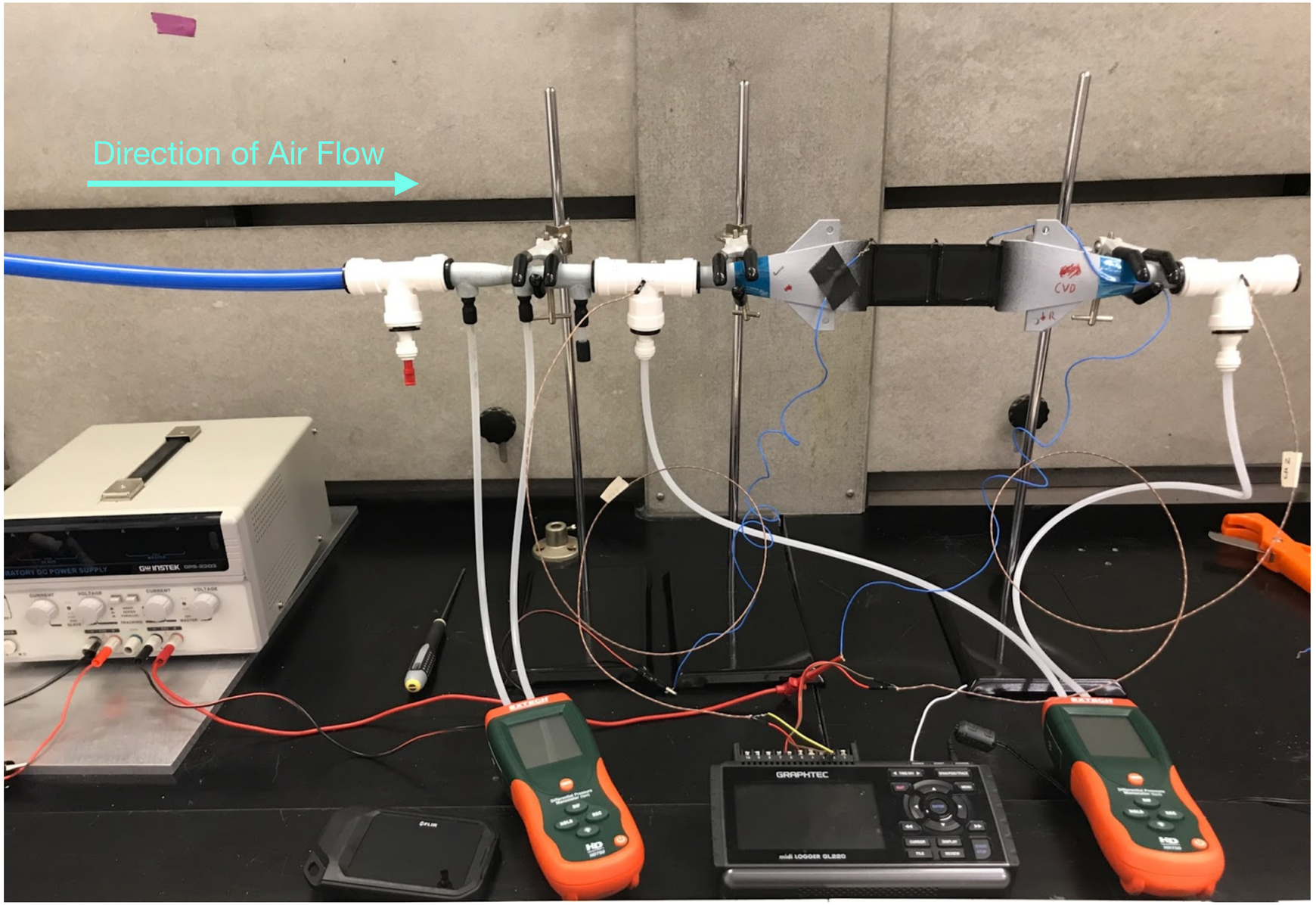




Setup (Schematic)

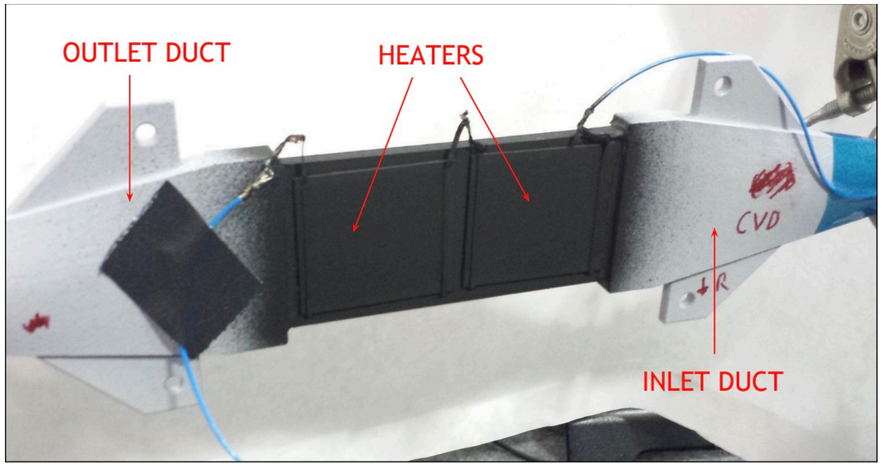


Setup


Direction of Air Flow
GW INSTEK GPS-2303
GRAPHTEC
midi LOGGER GL220
CVD

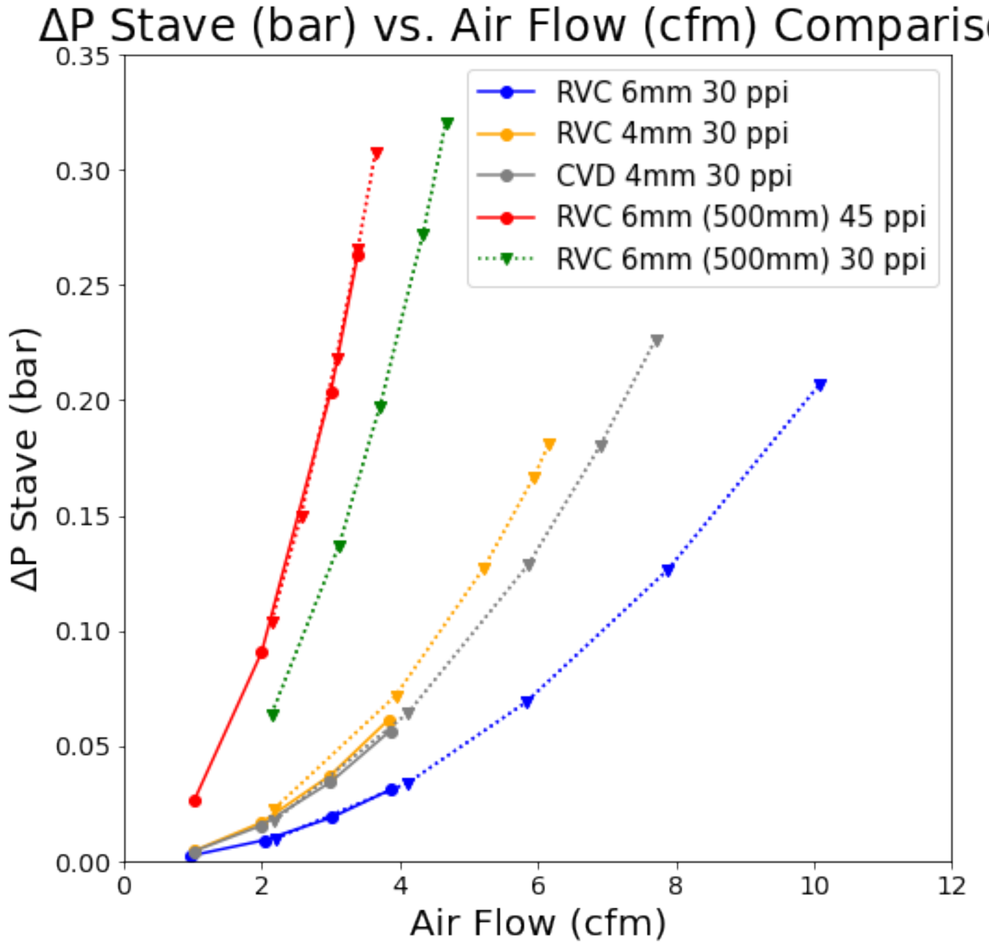
Types of Carbon Foam Staves

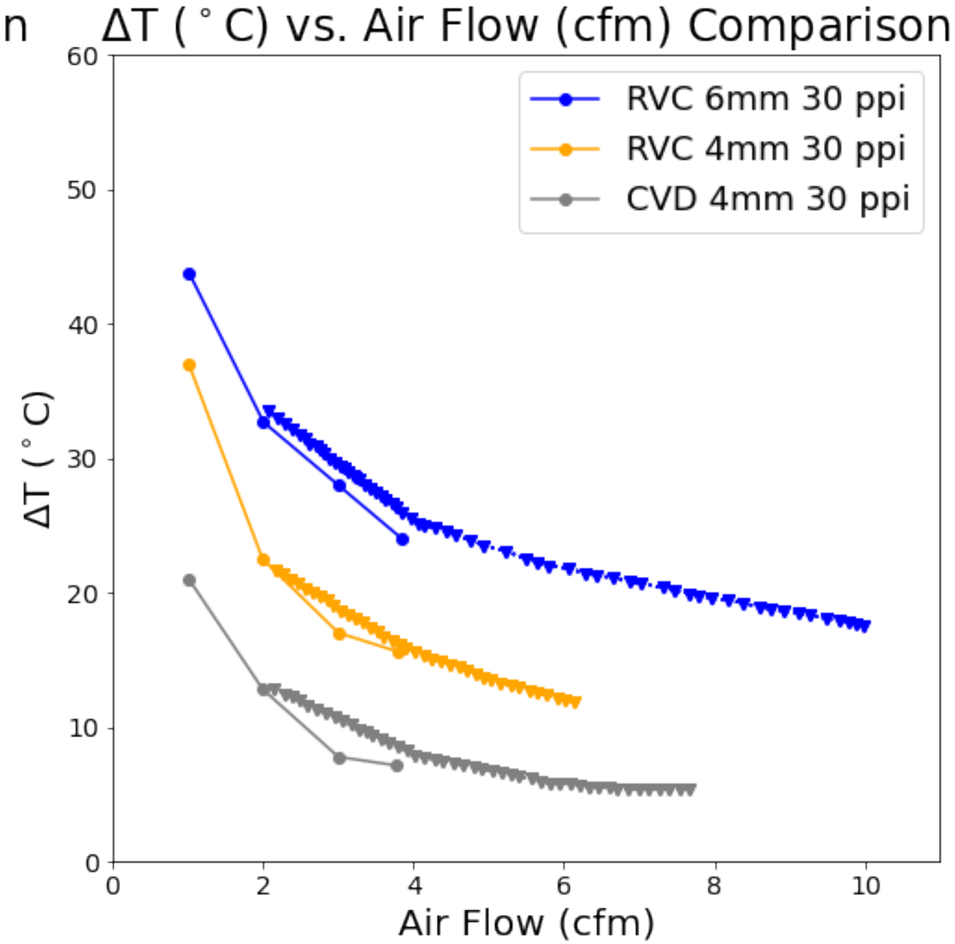
- Chemical Vapor Deposition (CVD)
  - Insulator, precursor to RVC
- Reticulated Vitreous Carbon (RVC)
  - Conductor, due to graphite coating



Type	Length (mm)	# of Si Heaters	Foam ppi	Thickness (mm)	Width (mm)
CVD	100	2	30	4	40
RVC	100	2	30	4	40
RVC	100	2	30	6	40
RVC	~500	8	45	6	40

LDRD Comparison of Different Length Staves





= Our data

= LDRD data

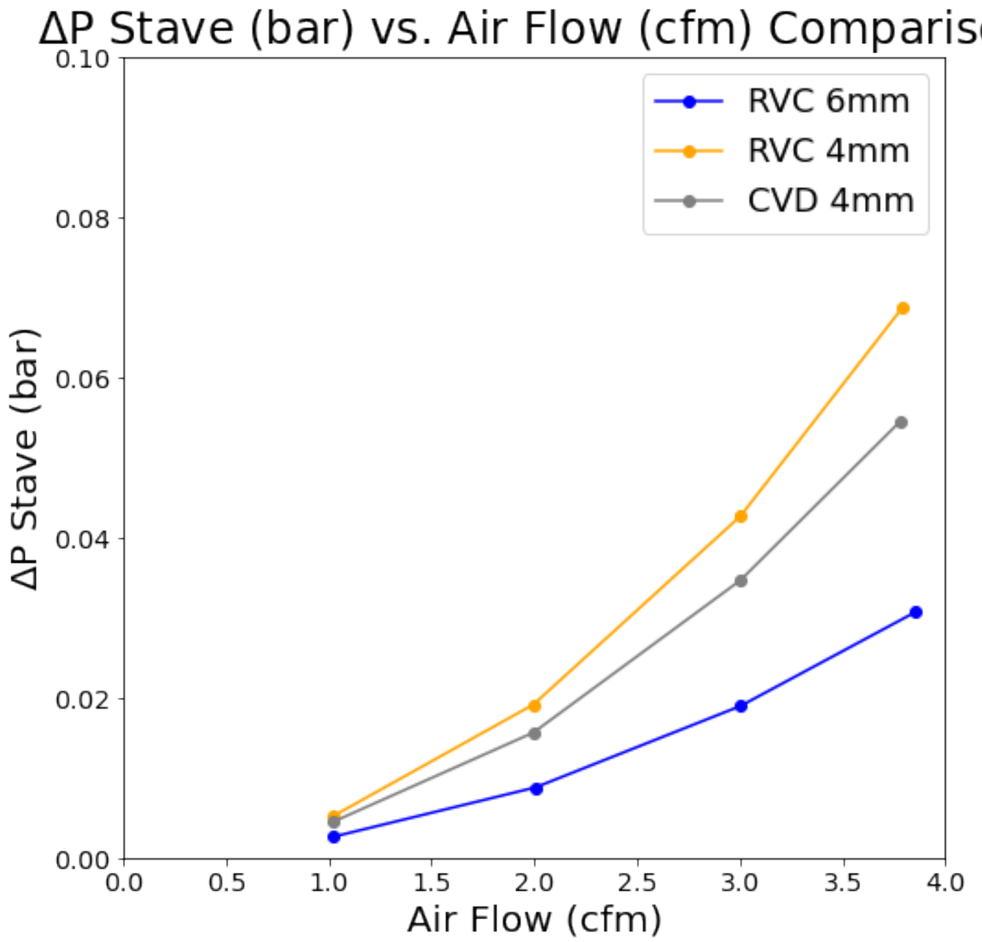
Power Density
= 0.5 W/cm^2

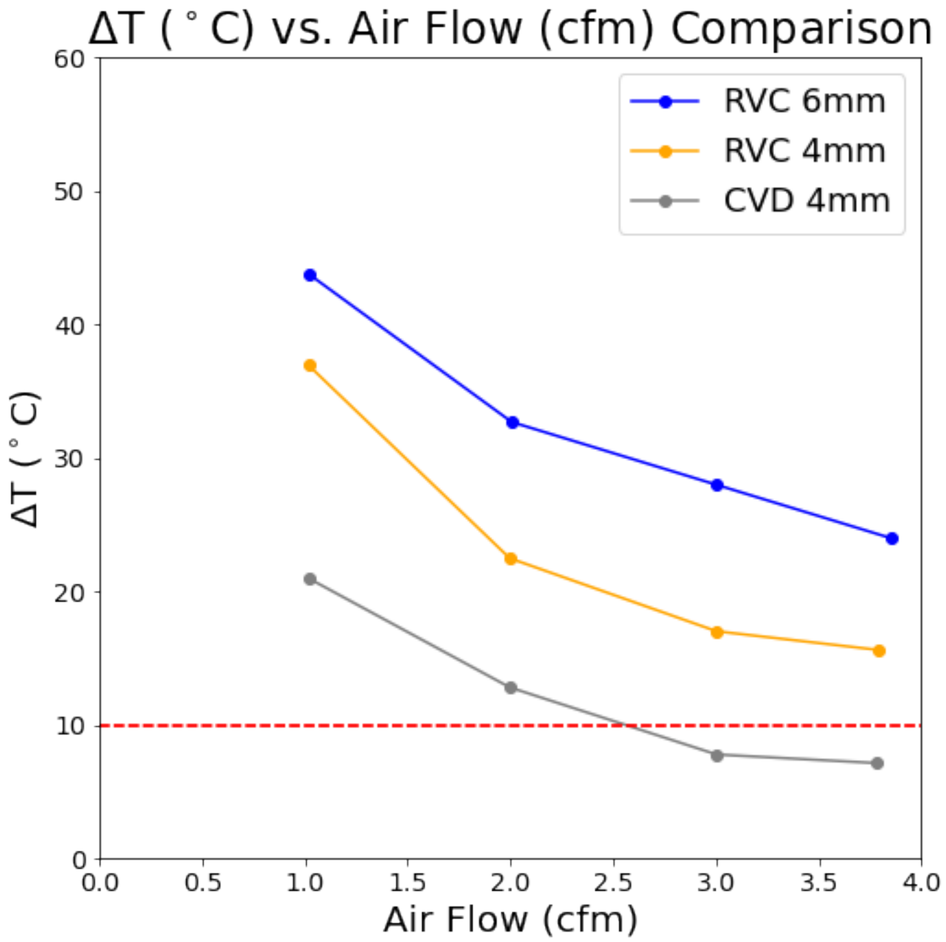
The temperature and pressure measurements line up pretty well with the LDRD measurements.

Results

ΔP and ΔT vs Q for different 100 mm staves

CVD stave achieves the desired temperature and pressure differences





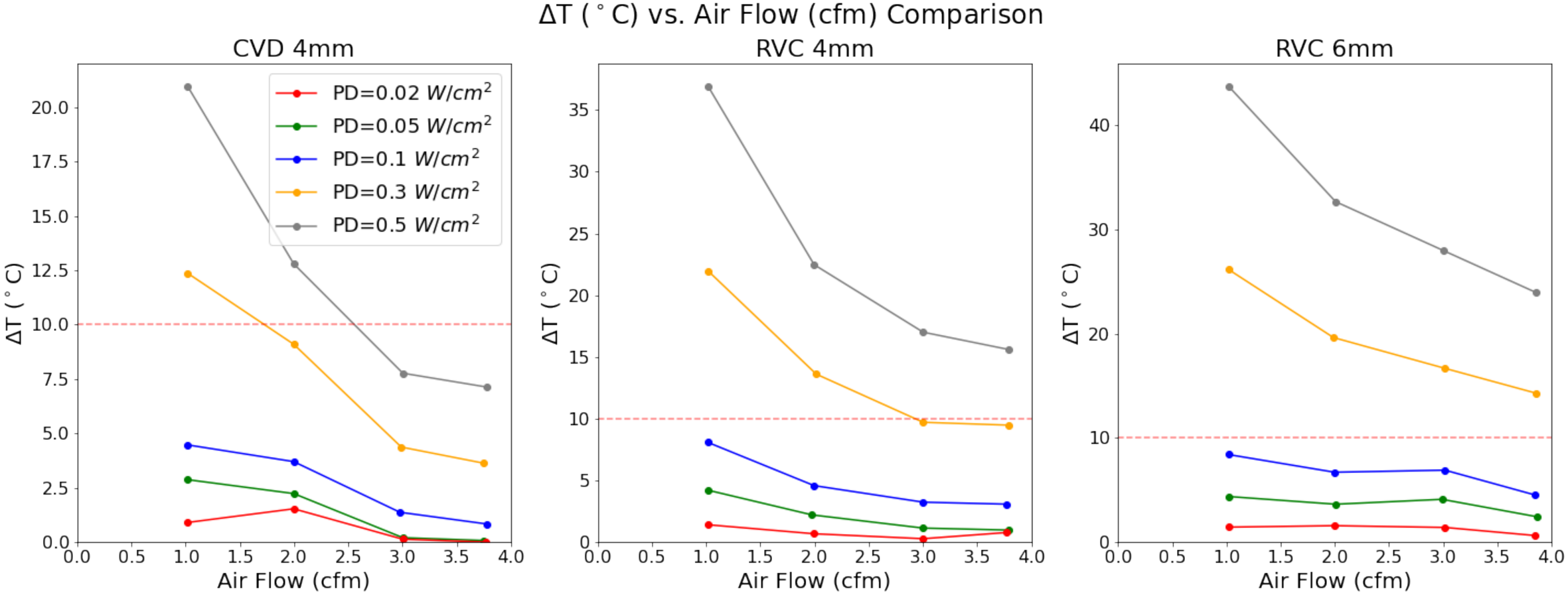
Power Density = 0.5 W/cm²

- ΔT < 10 ˚C
- ΔP < 1 bar for a 1 m long stave

Results

ΔT vs Q for different power densities in each stave

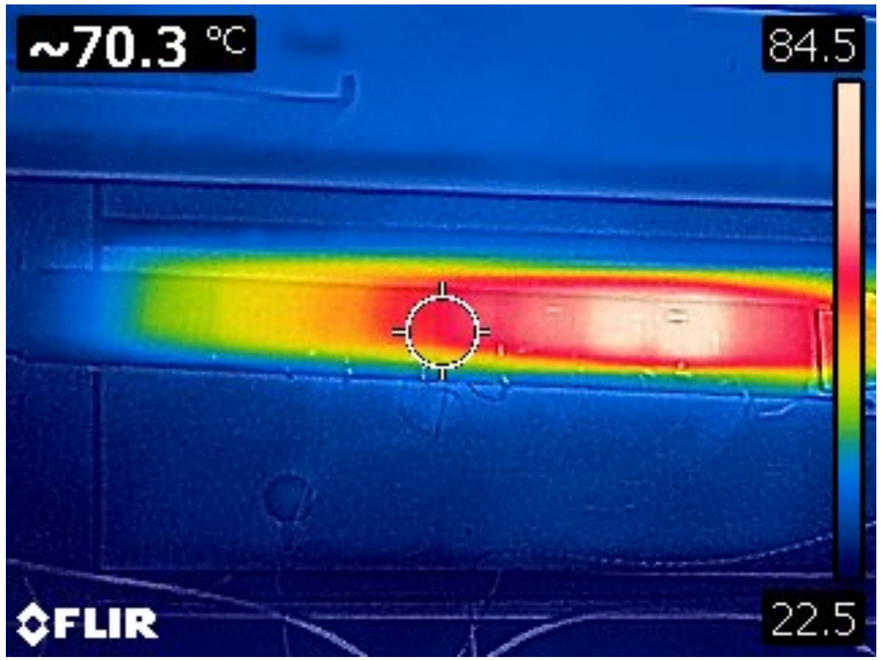
CVD stave achieves the desired ΔT for all power densities, RVC stave does not



Pixel matrix ≤ 0.02 W/cm², periphery ≥ 0.5 W/cm²

Recent Work

- Adjustments were made to the setup
  - Different temperature probes
  - Replaced hoses
  - Worked on increasing air speed
- Made heat measurements along the 0.5 m stave
  - Measured ΔT at air speeds of 2 - 3.4 cfm and power densities of 0.02 - 0.50 W/cm^2
  - Learned to predict ΔT based on the volumetric flow value and the z-distance
- Ordered a new fan
- Looked into other heater options
- Results in Mathias' talk!



Future Improvements

- Air
  - Faster air flow
  - Cooling the air
- Setup
  - EIC specific structures
    - Vertexing layers: Wind tunnel with EIC layout
    - Outer layers and discs: More sizably realistic structures
  - More material budget friendly design
  - New types of foams
  - Using a combination of air + liquid

Power Densities: ≥ 0.5 W/cm^2 ≤ 0.02 W/cm^2

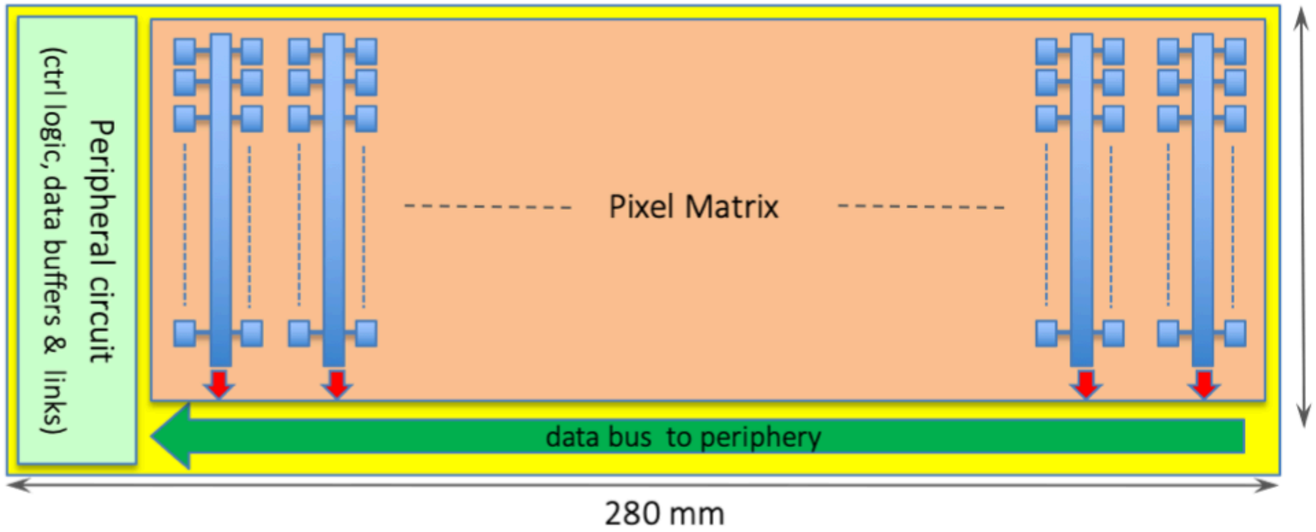
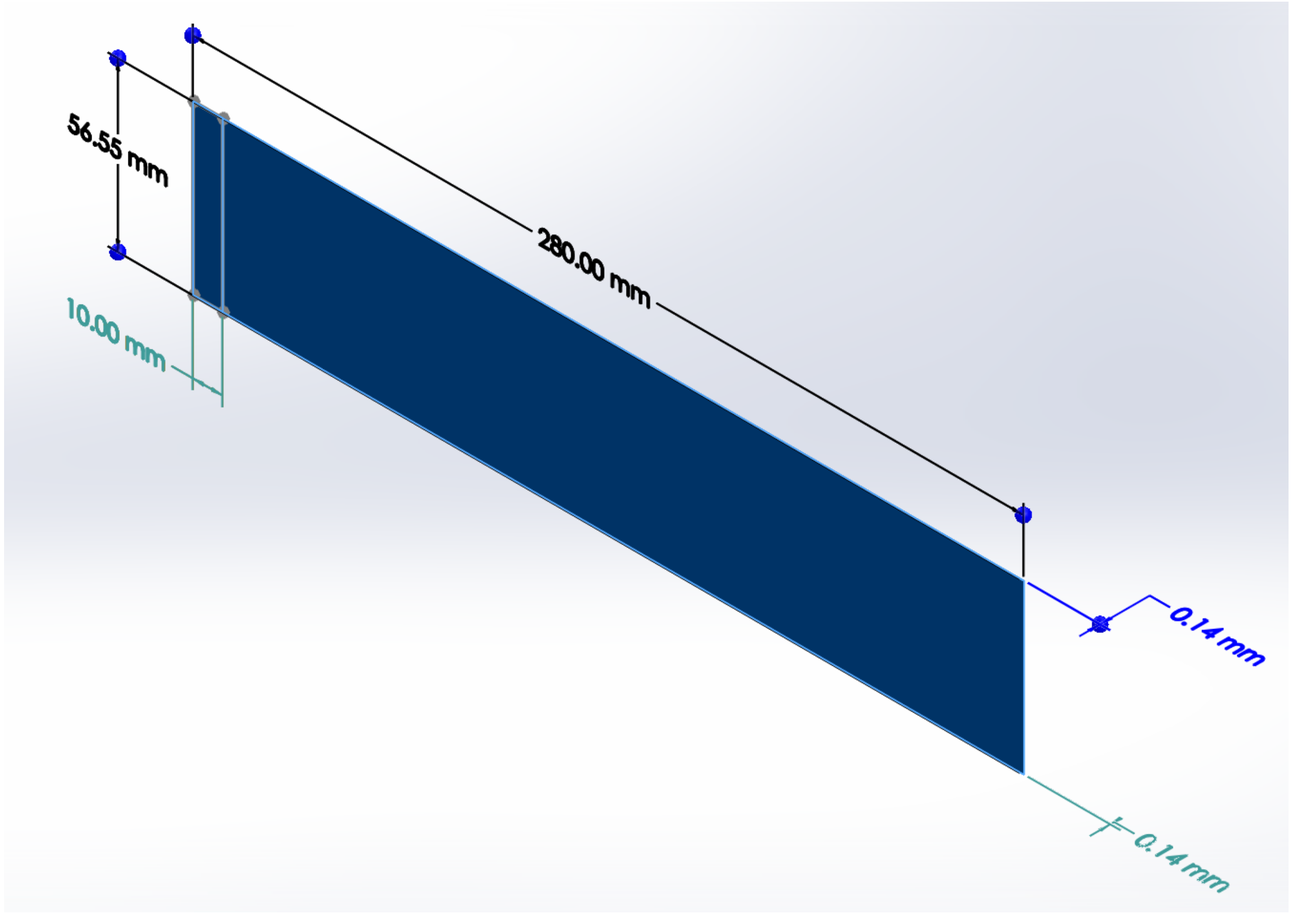


Diagram of ITS3 Stitched Sensor, ALICE ITS3 LoI

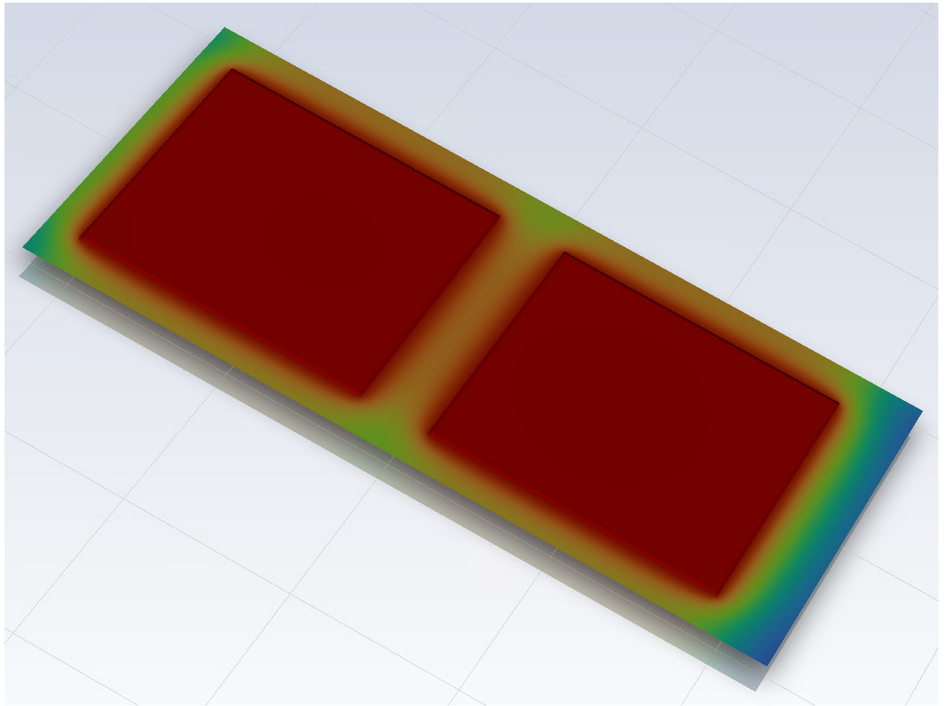
Heaters

- Want a more realistic heater
- Design
  - Pixel matrix is 3 x 9 reticles
    - Each reticle is (1.885 x 3) cm
  - Periphery is (1 x 5.655) cm
- Power density requirements
  - Pixel matrix: 0.01 W/cm^2
  - Periphery: 1 W/cm^2
- Currently in contact with 2-3 companies
- Will put onto stave with foam

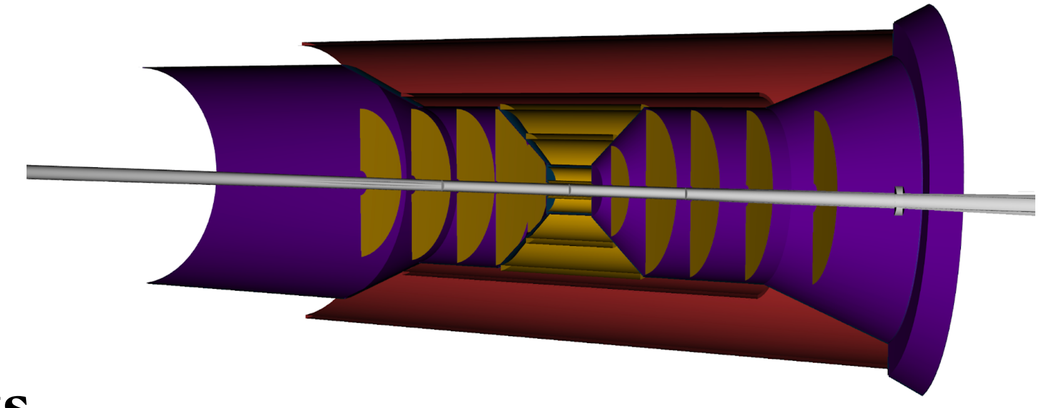


Simulation

- Work performed by Emma Yeats
- Ansys fluid simulations
  - Modeling the transient and steady state silicon temperature
    - Study effects of air cooling on the entire tracker
    - Based on in-lab setup
    - Will be applied to current design for the EIC Silicon Tracker (both disks and barrel)
  - Temperature simulations of the beampipe bakeout
    - Incoming cooling air for silicon
    - Hot gas to heat beryllium beampipe
    - Check that temperature gets past 100 °C for proper bakeout



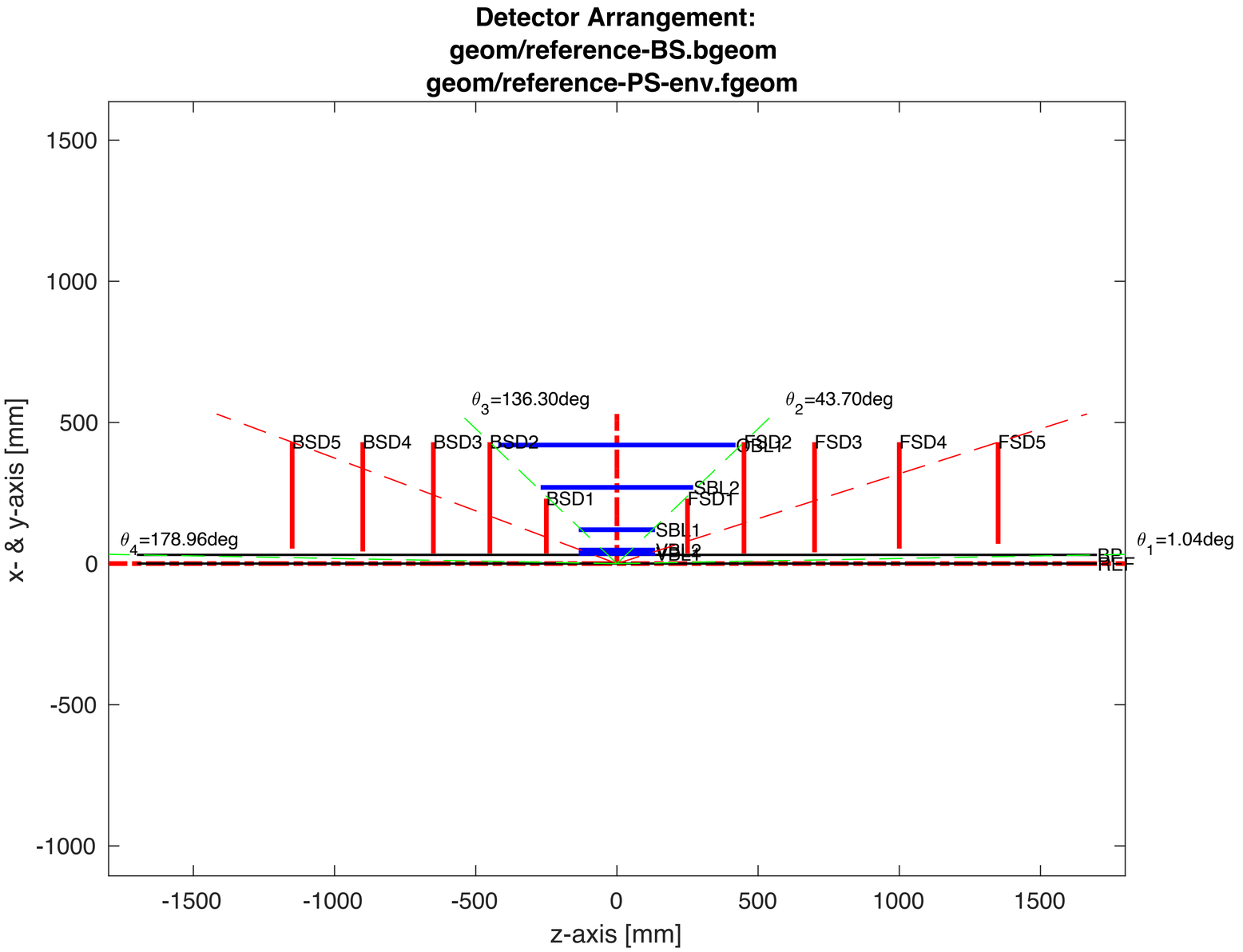
Summary



- EIC has **strict tracking resolution requirements**
- Tracking resolution performs better with less material budget
- Several efforts being made to **improve the material budget**, including designing a new MAPS chip and testing alternative ways of cooling the system
- Current testing is being done using heaters and carbon foam
- Simultaneously doing simulation work to see how well the setup will hold under higher pressures
- With additional testing and improvements to the setup, we can create a more material budget friendly way of cooling the EIC silicon detector!

Thank you!

Backup


Detector Arrangement:
geom/reference-BS.bgeom
geom/reference-PS-env.fgeom
x- & y-axis [mm]
z-axis [mm]
1500
1000
500
0
-500
-1000
-1500
-1000
-500
0
500
1000
1500
θ_3=136.30deg
θ_2=43.70deg
θ_4=178.96deg
θ_1=1.04deg
BSD5
BSD4
BSD3
BSD2
BSD1
FSD2
FSD3
FSD4
FSD5
FSD1
SBL2
SBL1
VBL2
VBL1
BP
REF