Thermal Simulations for the Scintillating Bubble Chamber Experiment

Ezri Wyman

SNOLAB User Meeting 2024

Outline

Motivation — Convection management for SBC

COMSOL — Choosing a strategy

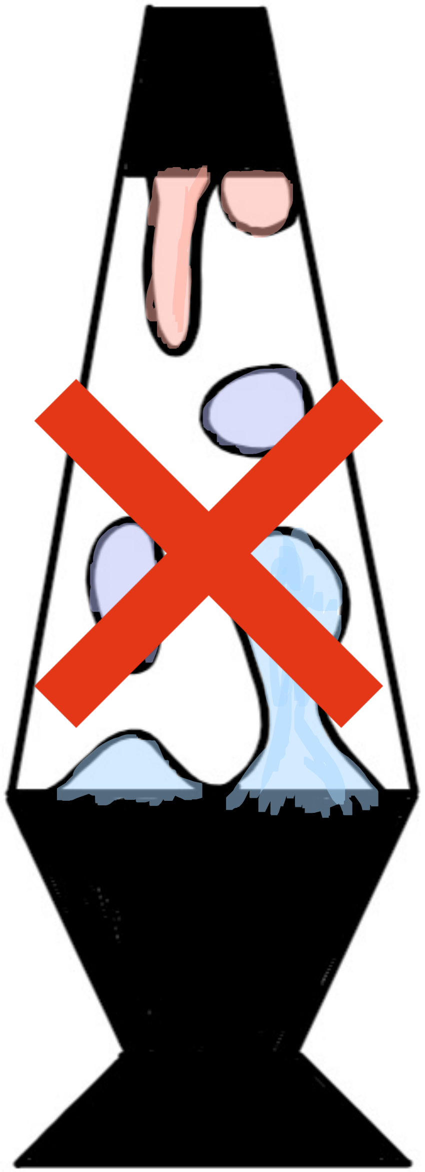
Digital SBC — Defining geometry and materials

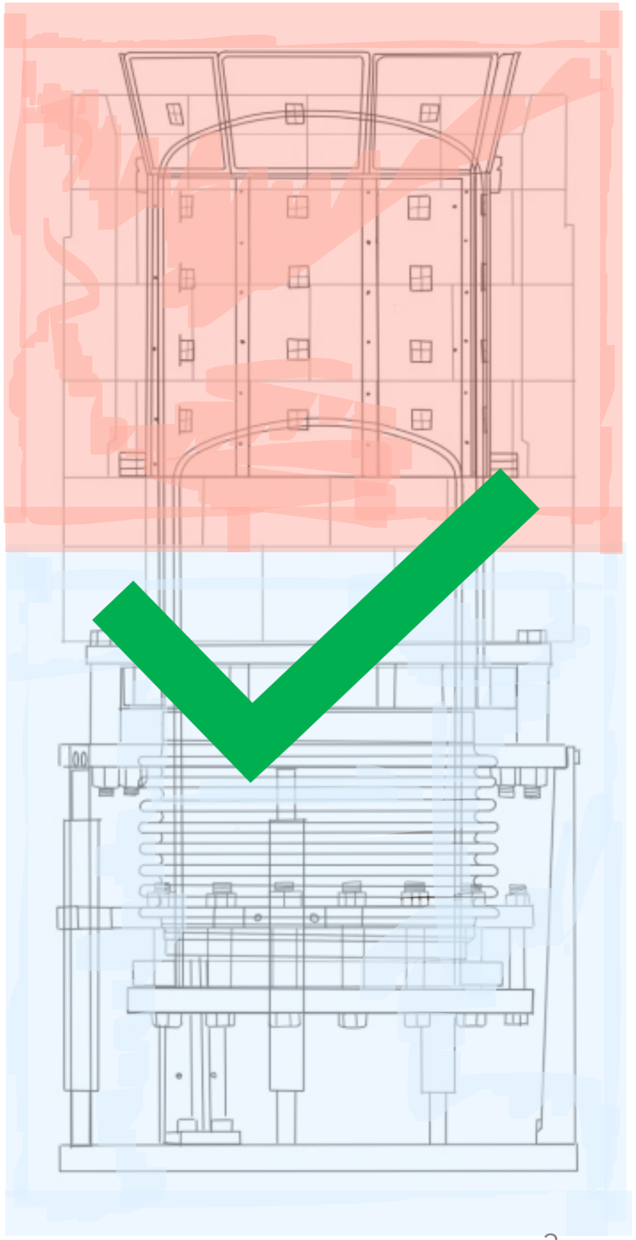
Result — Simulation output and comparison to Fermilab engineering run data

Next Steps — Iterating on this approach!

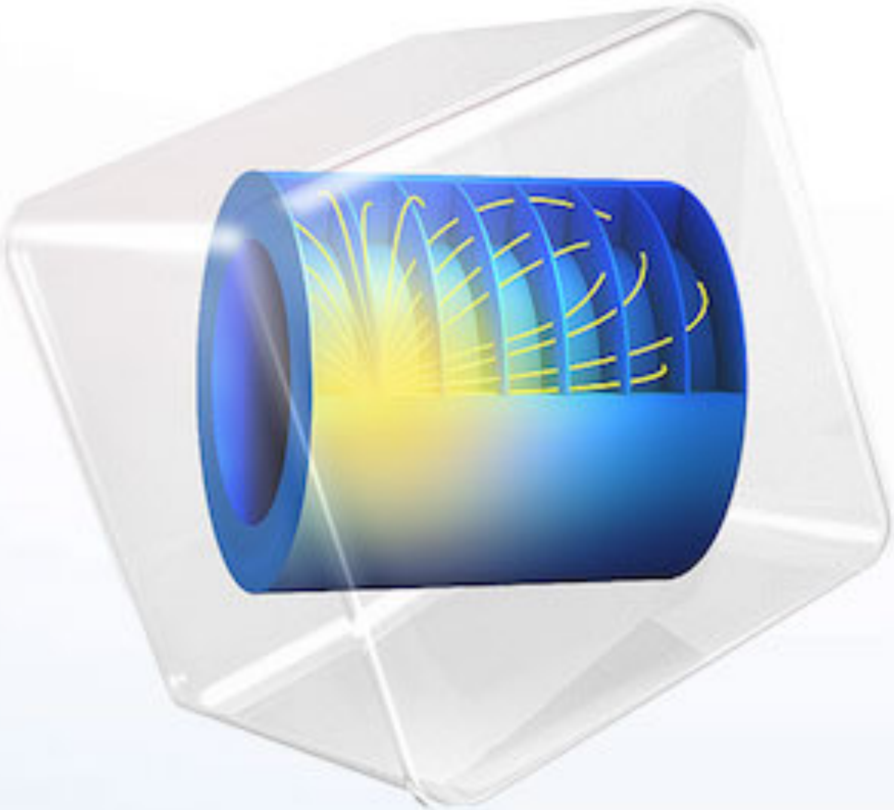
Motivation

- SBC's science needs require two distinct temperatures
  - Superheated region (~130 K):
    - On top
    - Bubbles can form
  - "Cold" region (~90K):
    - On the bottom
    - Bubbles cannot form
    - Impurities can settle out
    - Rougher materials can be used



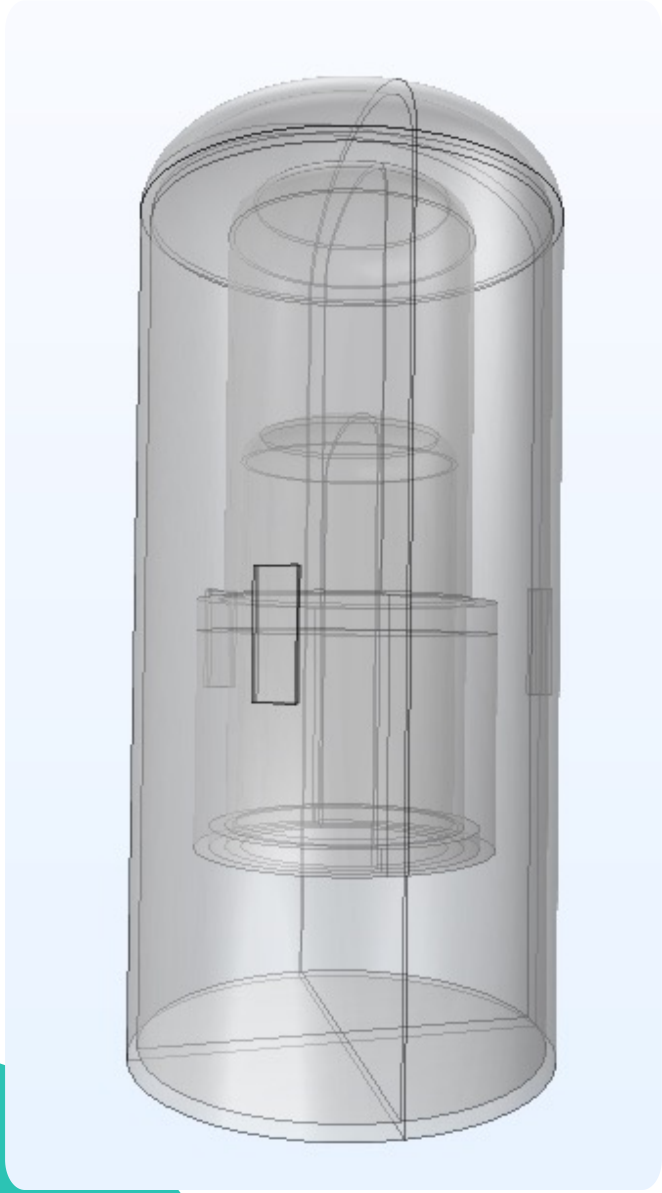


COMSOL MULTIPHYSICS®



- “Lego” for physics simulations
- Widely used
- Qualitative and quantitative results

(And we had access to a license)

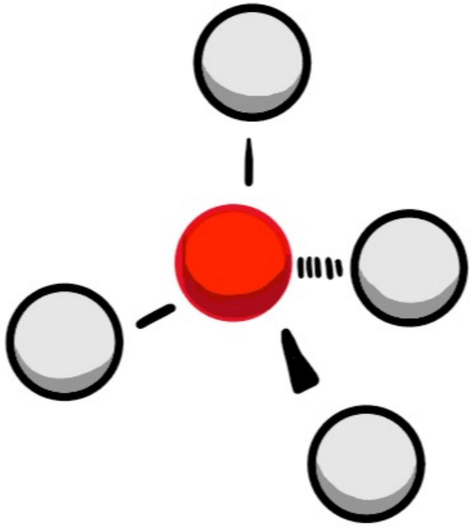


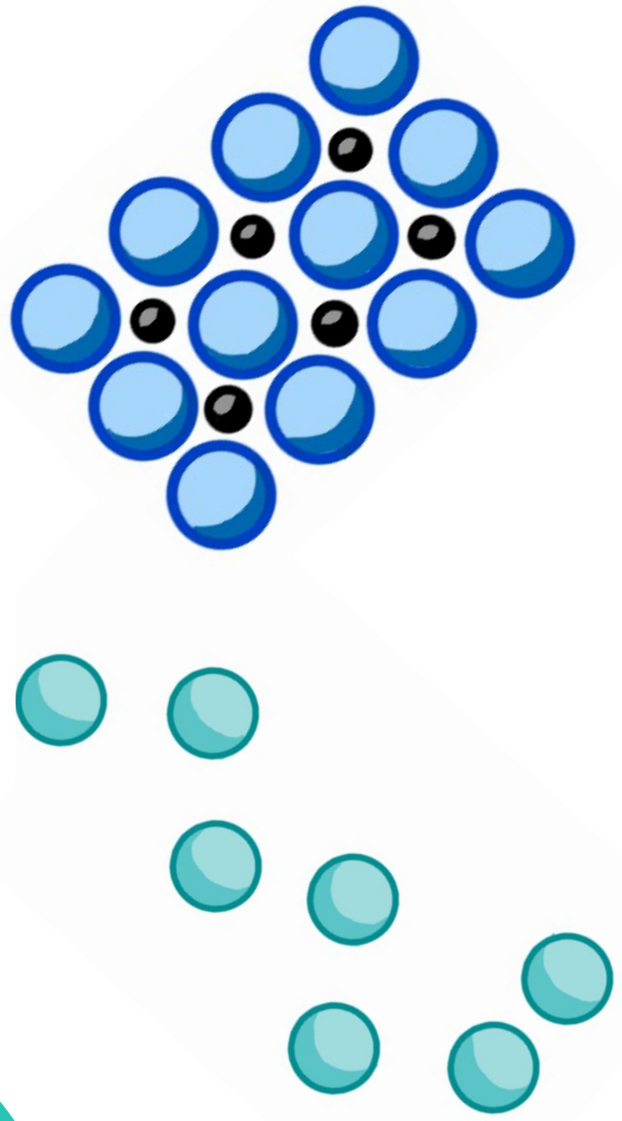
Building a Digital Detector

- Geometry and materials need to be defined
- Different levels of detail characterize different sim iterations
- Dimensions come from engineering drawings and the SOLIDWORKS model

Characterizing Materials

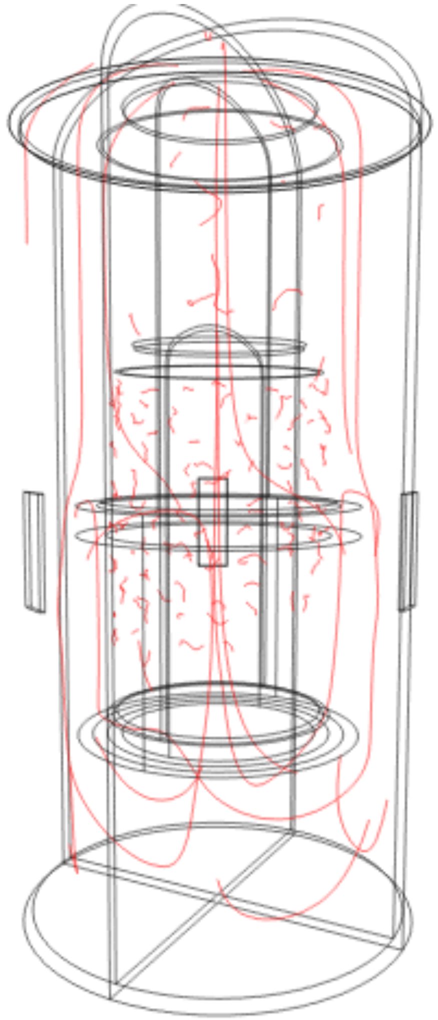
- Some materials (steel and synthetic quartz) are pre-defined in COMSOL
- Others (CF_4 and liquid argon) needed to be partially or entirely user defined
- Best available option: fitting existing experimental data
- There's more interesting work to be done here!





Qualitative Results

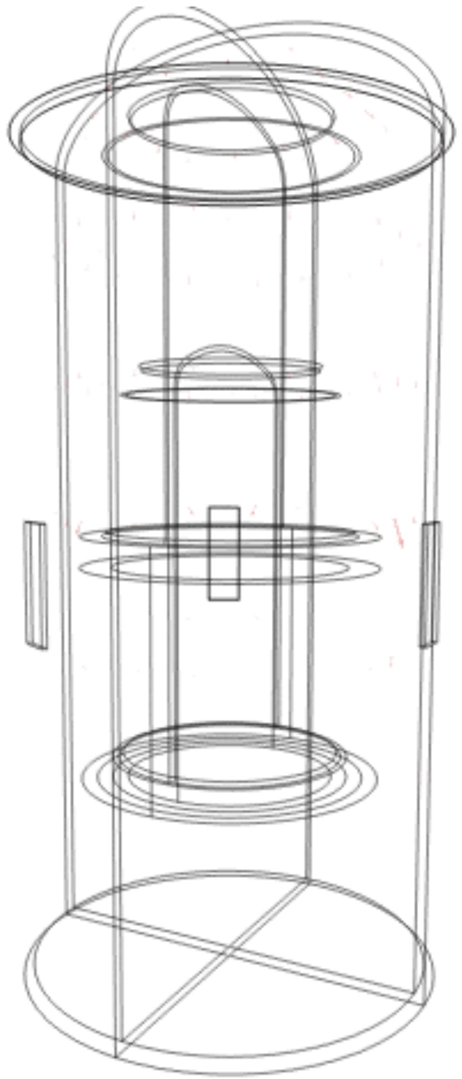
Velocity Streamline Plot



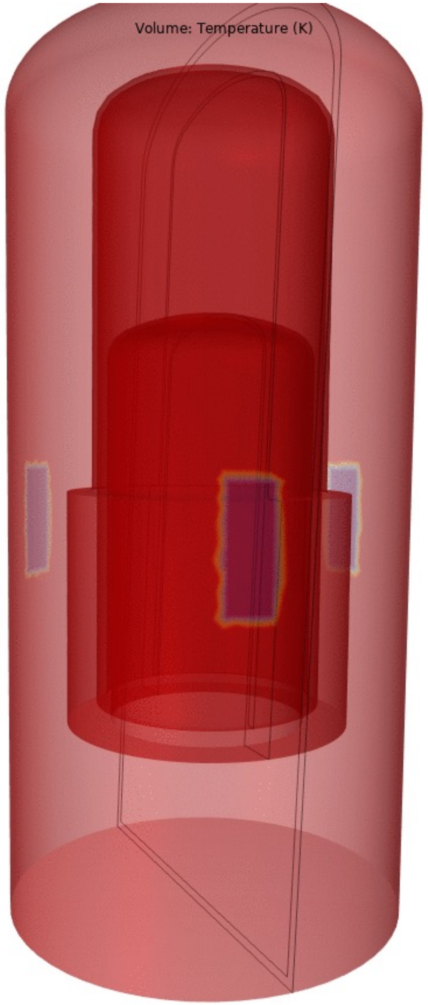
- Shows continuous flow pathways
- Visual indication of convection loops

Velocity Arrow Plot

- Length of each arrow indicates magnitude
- The tail of each arrow sits at the point for which the velocity is indicated

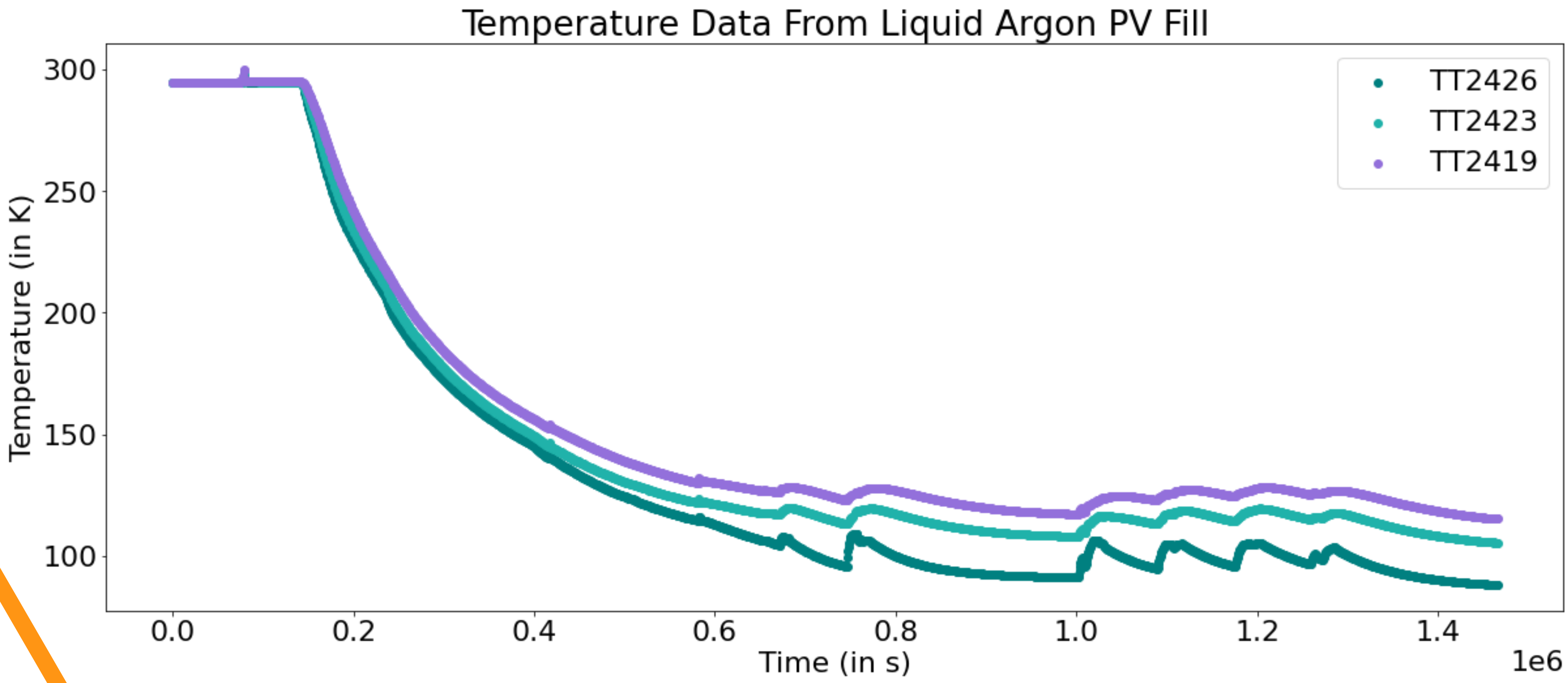


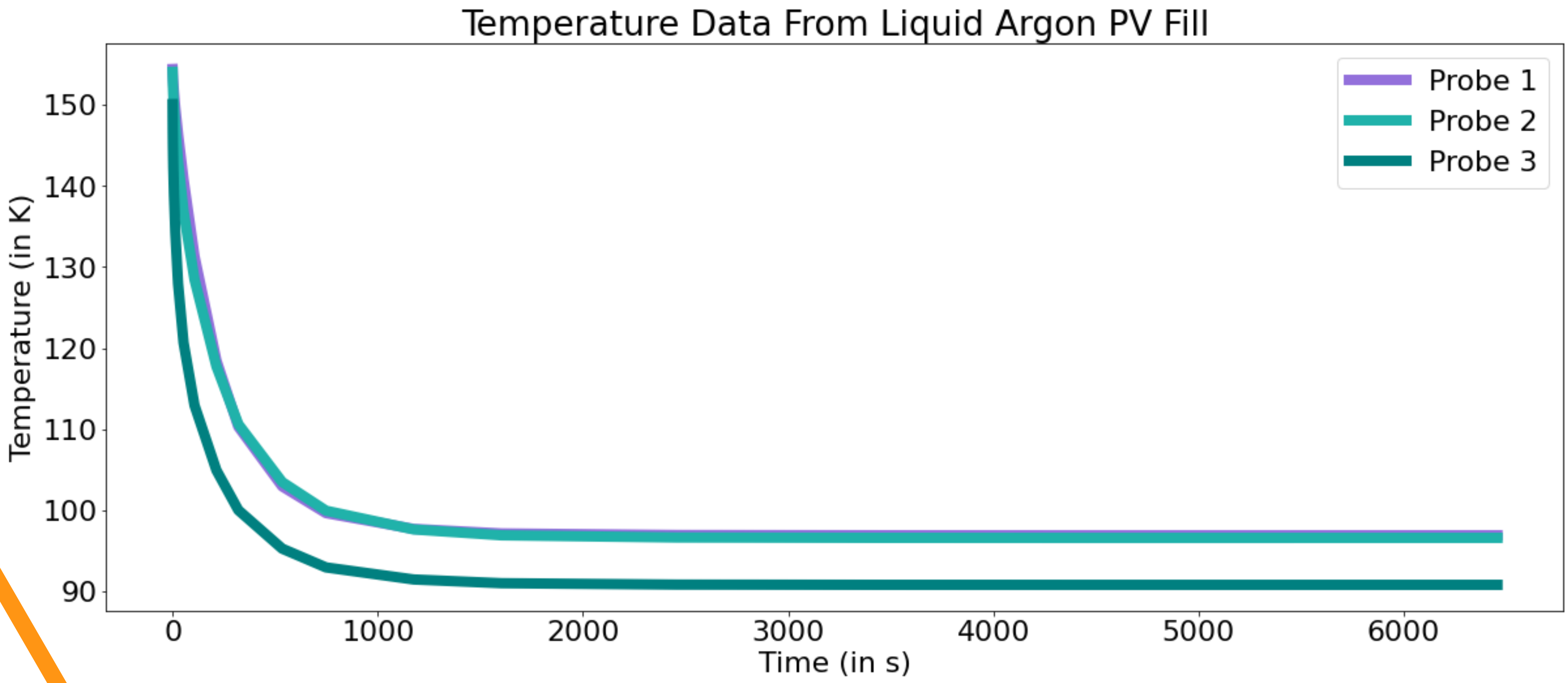
Temperature Plot



- Preliminary but promising!

Quantitative Results


Temperature Data From Liquid Argon PV Fill
Temperature (in K)
300
250
200
150
100
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Time (in s)
1e6
TT2426
TT2423
TT2419


Temperature Data From Liquid Argon PV Fill
Probe 1
Probe 2
Probe 3
Temperature (in K)
150
140
130
120
110
100
90
0
1000
2000
3000
4000
5000
6000
Time (in s)

Looking at the Temperature Data

Good news:

- Both exponential
- Clear which sensors were where
- Built infrastructure for this kind of comparison

Learning Opportunities:

- VERY different timescales
- Need to implement thermal coupling interference
- t0 needs adjustment
- Bonus good news: some of this will go away automatically in later iterations

Next Steps

- Implementing more of the detector assembly in sim
- Comparing to later engineering runs (and eventually with detector data)
- Iterative improvement!

Questions?