

# Update: Thermal Imaging

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ISU WEEKLY STAVE QA MEETING  
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# Since Last Time...

- ▶ Stave Reproducibility Tests
  - ▶ Took 5 sets of “identical” measurements
  - ▶ Took 4 sets of “changing air off waiting time” measurements
  - ▶ Took 3 sets of “waiting time after hitting temperature” measurements
  - ▶ Took 2 sets with different RPMs

# Variables- What We Control

- ▶ We can only control a few variables in the measurements
  - ▶ Time since reached set point (TSRSP)
  - ▶ Air off wait time
  - ▶ T set at chiller
  - ▶ Booster Pump RPM

# Variables-What we directly measure

- ▶ Thermocouples(measured every 1 sec in log)
  - ▶ T\_in: temperature of the fluid going into the stave
  - ▶ T\_out: temperature of the fluid going out of the stave
  - ▶ T\_box: temperature floating in the box above the cradle
  - ▶ T\_room: temperature floating above the table in the room
- ▶ Humidity Sensor(measured every 10 secs in log)
  - ▶ Humidity: measured by the sensor near the end of the stave
- ▶ Thermal Image
  - ▶ Image: average of 200 frames taken at 25 frames/sec
    - ▶ Then converted to profile along stave
    - ▶ Stave is never moved, so the frameanal.py always uses the same stave area

# Variables- Extracting data

- ▶ Using the log, the directly measured variables are found for the 60 seconds before and after the time the image is taken(using the file timestamp).
- ▶ The mean and standard deviation for each is found. The combined uncertainty includes the statistical uncertainty(fluctuations during the time) and the systematic uncertainty(precision of the measuring device)
- ▶ Slope of each variable is also found over the 2 minutes to find the current rate of change of the variable and its uncertainty.

# Final Chosen Variables

- ▶ T\_set: Chiller Set Temperature
- ▶ RPM: Booster pump RPMs
- ▶ TSRSP: Time since reached set point
- ▶ Air Wait: Time waited with air off before image was taken
- ▶ T\_in: Temperature of fluid into the stave
- ▶ T\_loss: Temperature of fluid lost through the stave
- ▶ T\_box: Temperature inside the containment
- ▶ T\_room: Temperature in the room
- ▶ Humidity: In containment

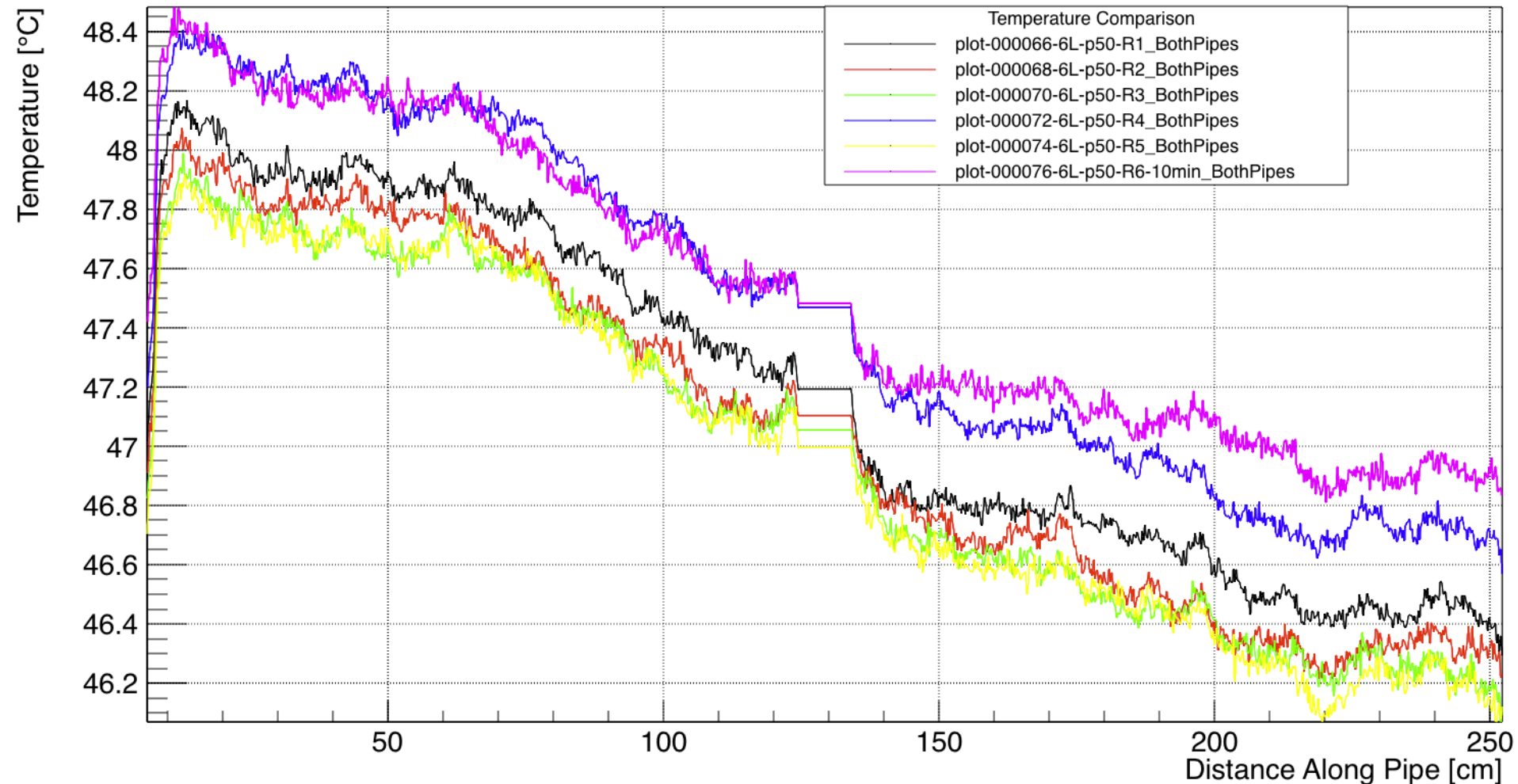
# Reproducibility- Constants (mostly)

- ▶ Five sets were taken with
  - ▶ T\_set = -55, 50 C
  - ▶ RPMs = 26.7, 21.4 rpm (corresponds to ~1l/min flow rate)
  - ▶ TSRSP = 0 min (hard to get precise, using log values +/- 1.4 min in actuality)
  - ▶ Air Wait = 10 min

# Reproducibility-Hot

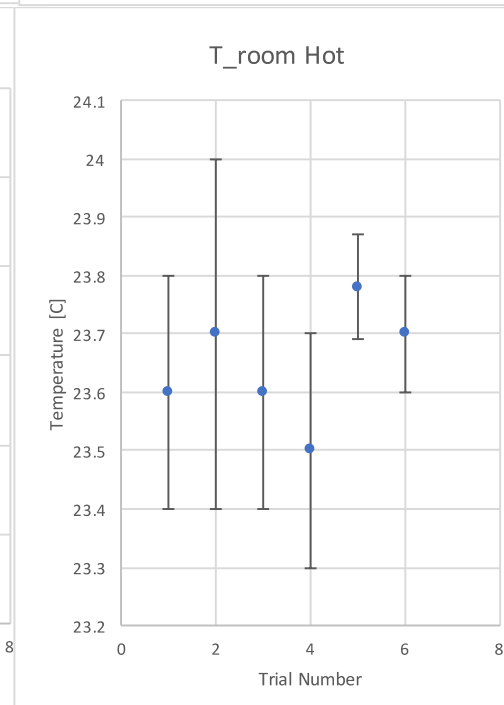
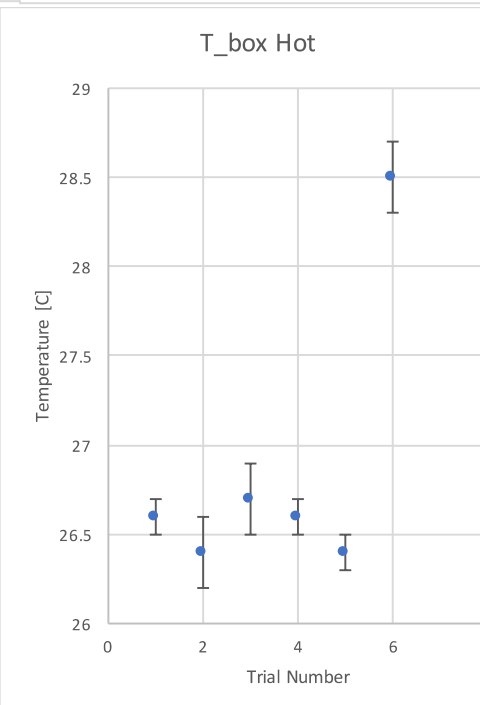
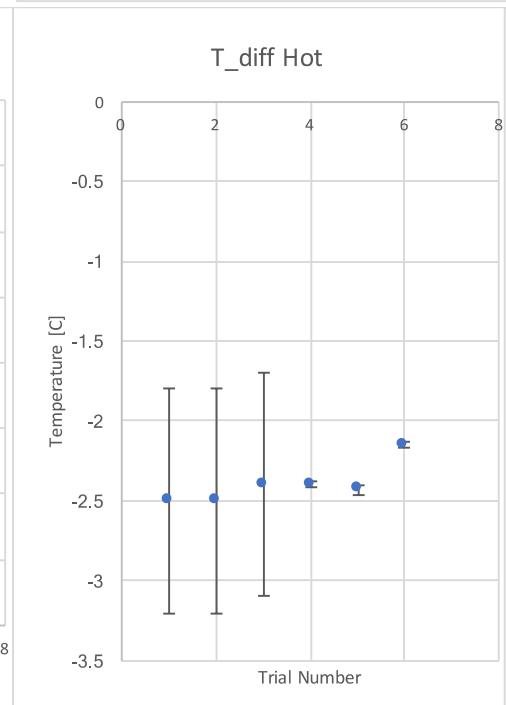
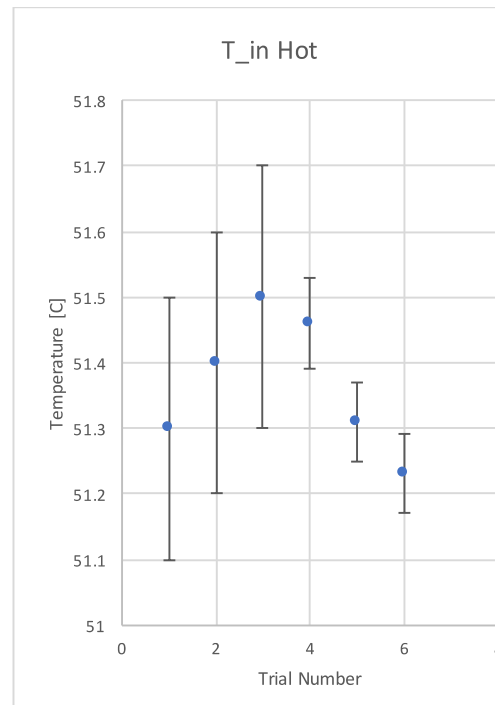
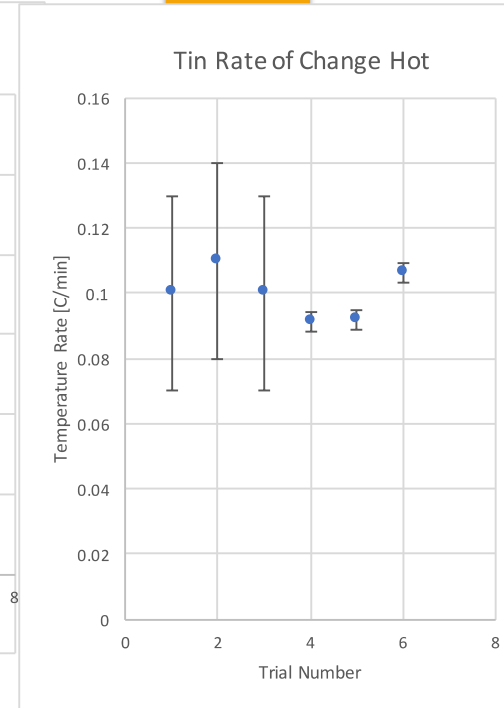
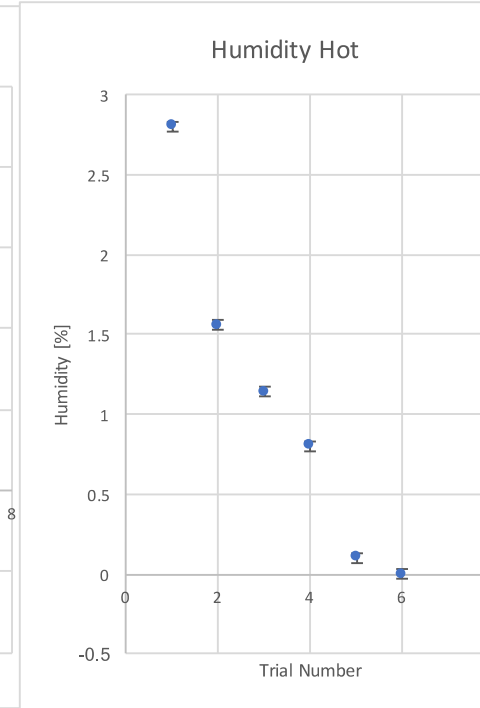
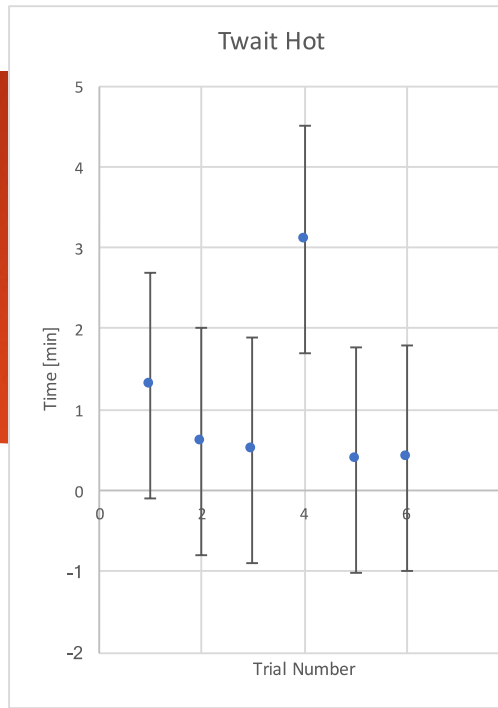
- ▶ R2, R3, R5 best bunch
- ▶ Spread of around 0.5-0.8 C
  - ▶ Okay Reproducibility

## Cooling Pipe Temp



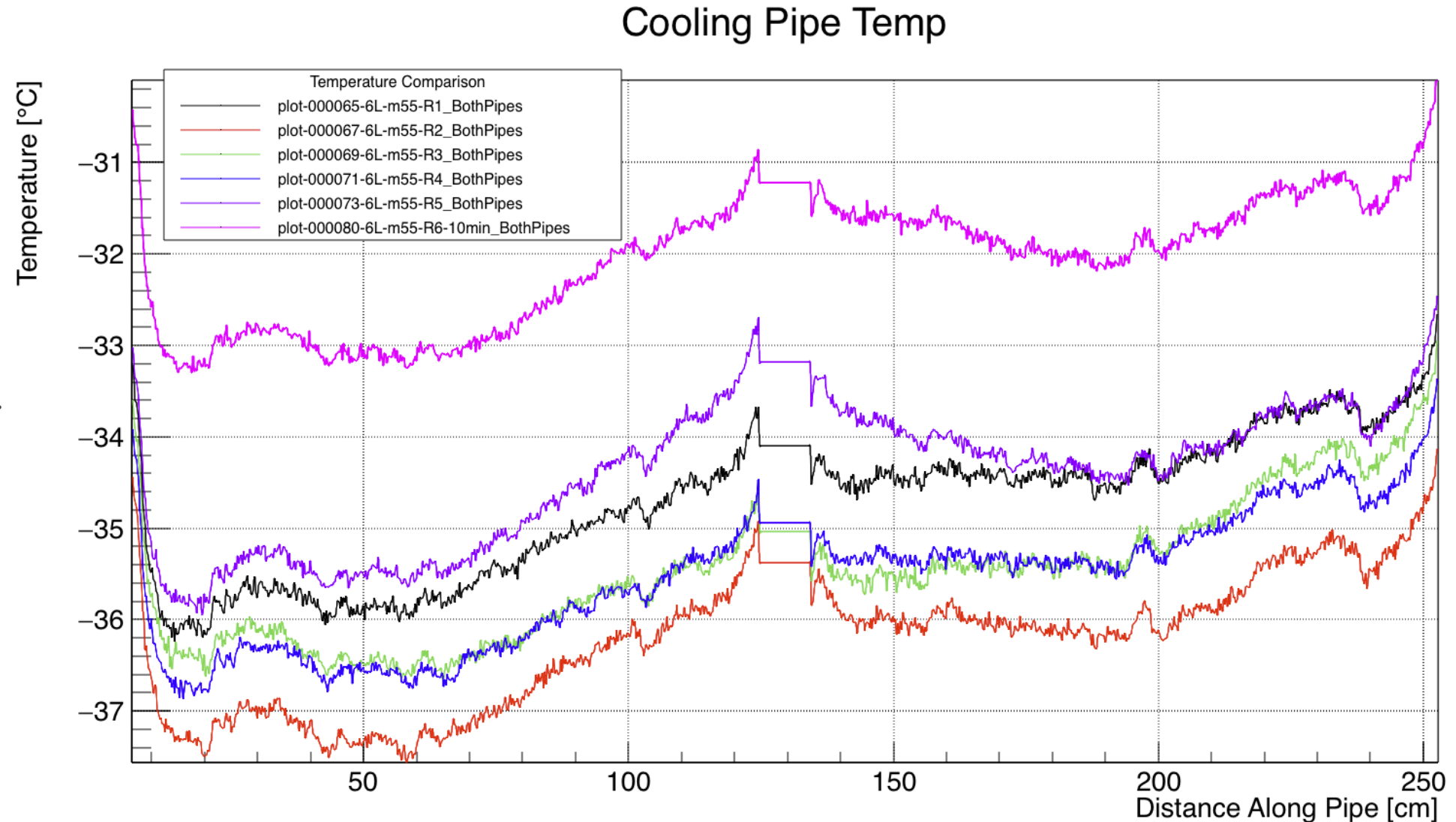


# Reproducibility- Hot: Other Differences

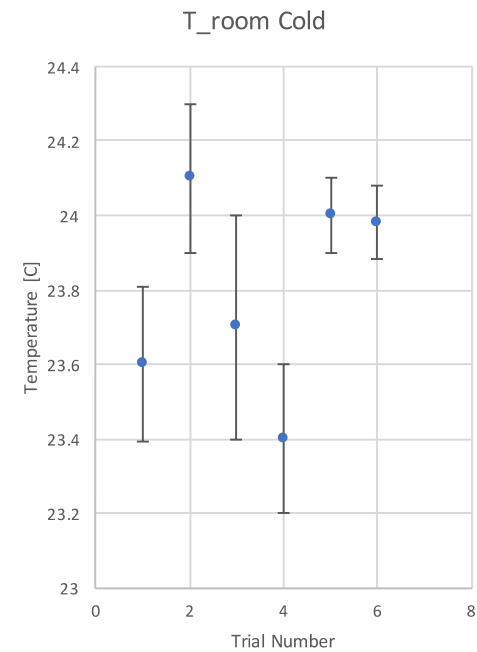
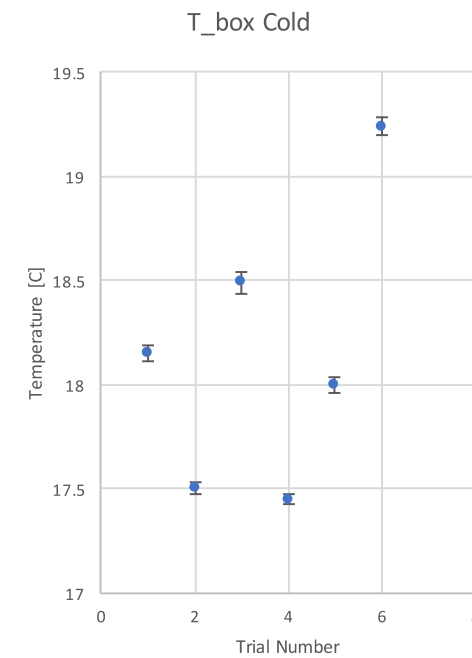
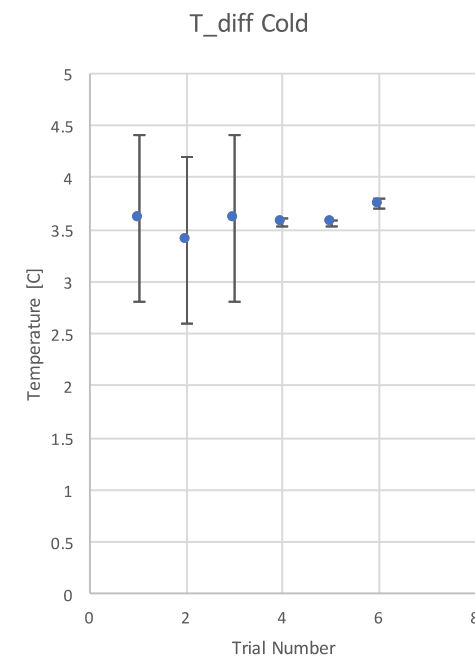
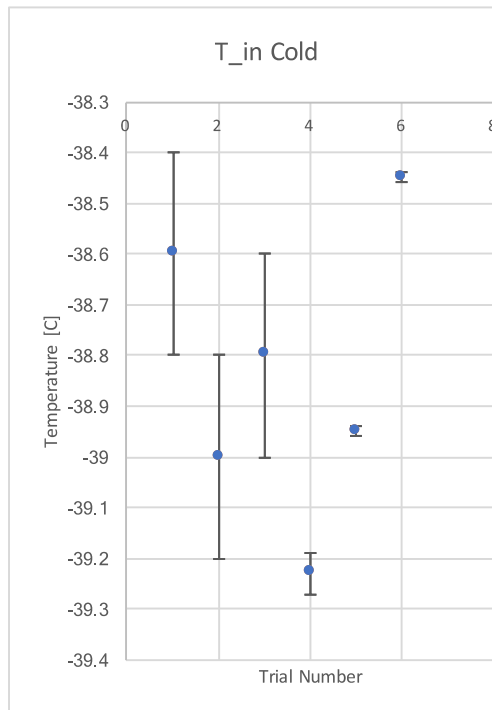
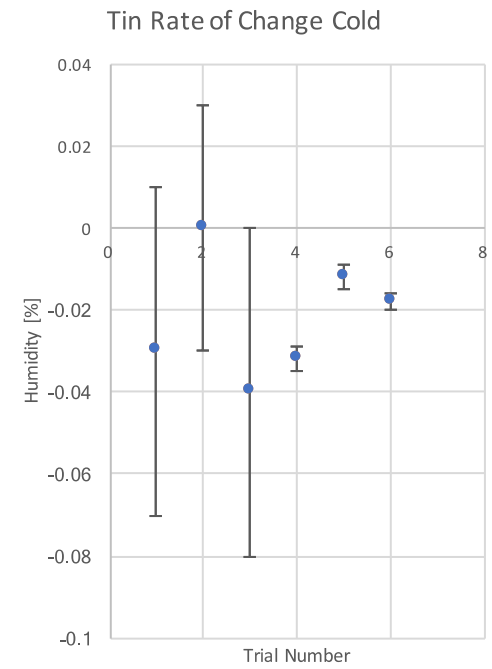
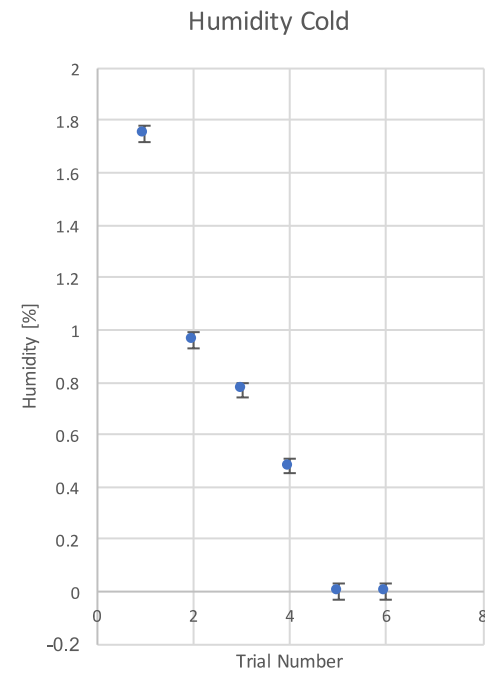
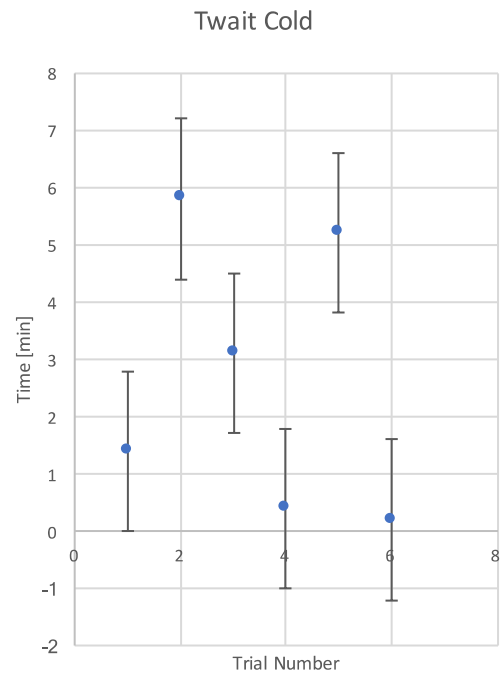


# Reproducibility-Cold

- ▶ R3, R4 most similar
- ▶ Spread of around 4 C!
- ▶ Reproducibility at -40 C is hard...



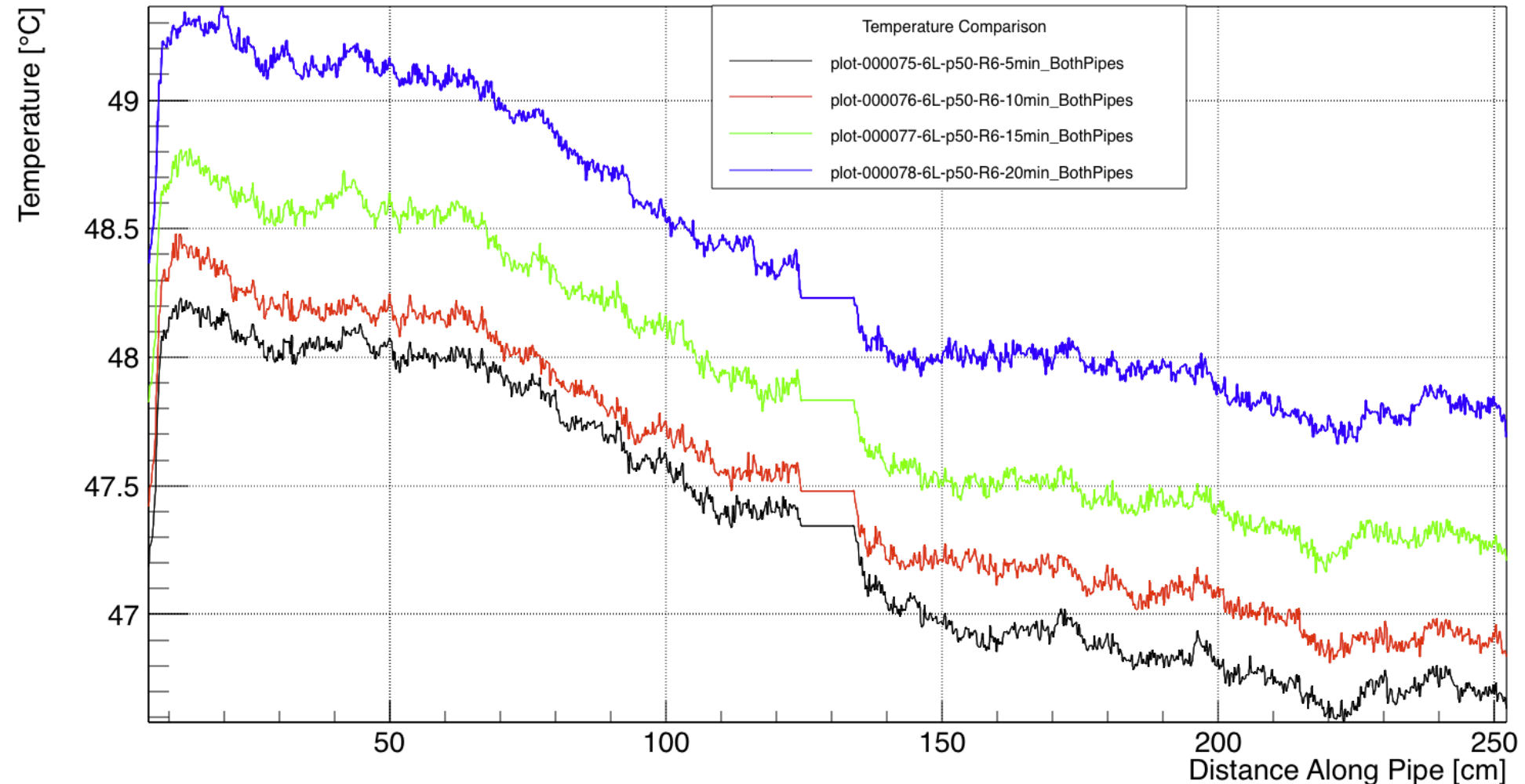
# Reproducibility- Cold: Other Differences



# Changing Air Off Time Length Hot

## Cooling Pipe Temp

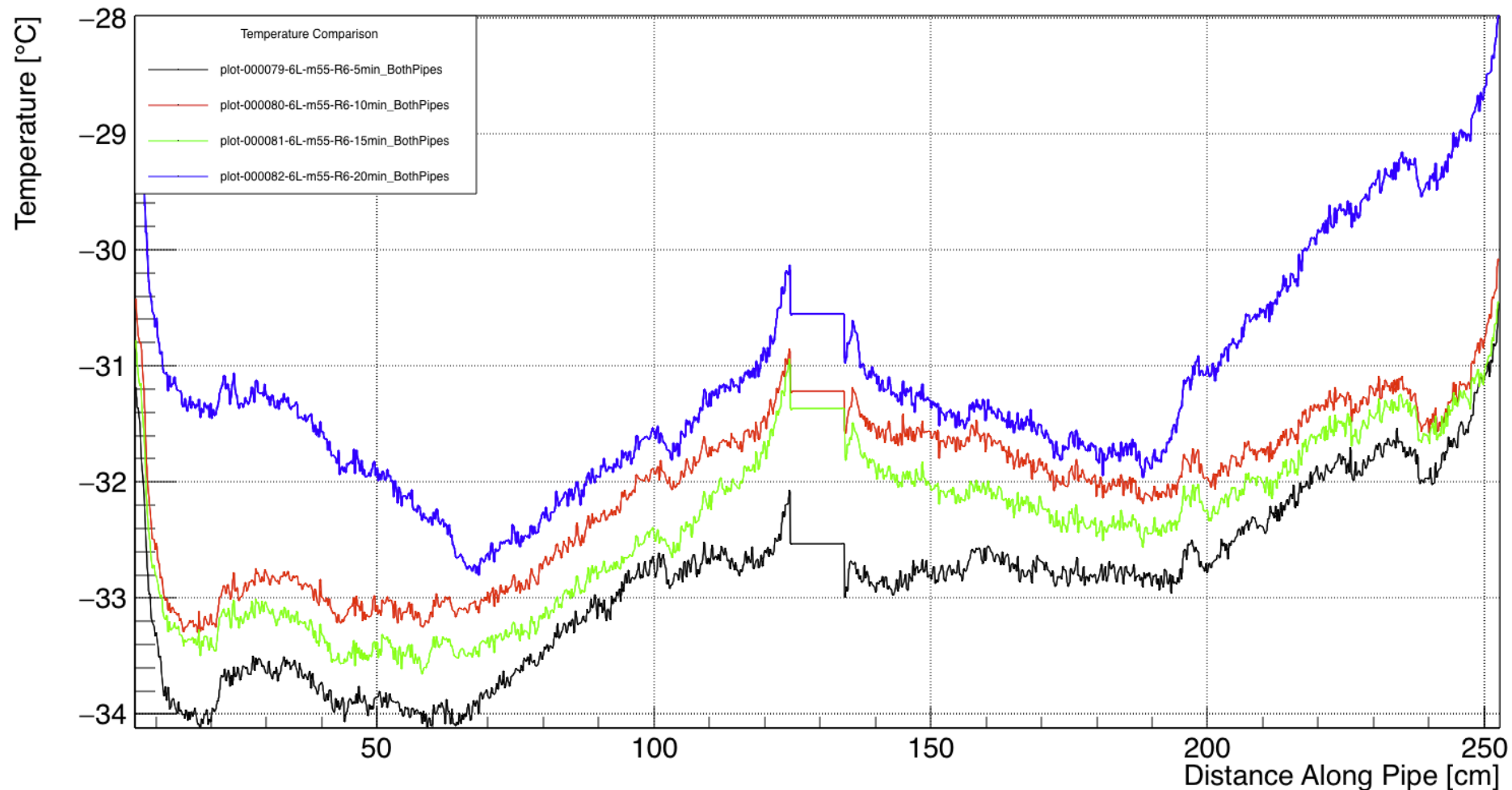
- ▶ Changing the amount of time with the air off increases the thermal profile



# Changing Air Off Time Length Cold

- ▶ Shape of the profile changes with more time without air...
- ▶ Not a simple change like was seen with hot fluid

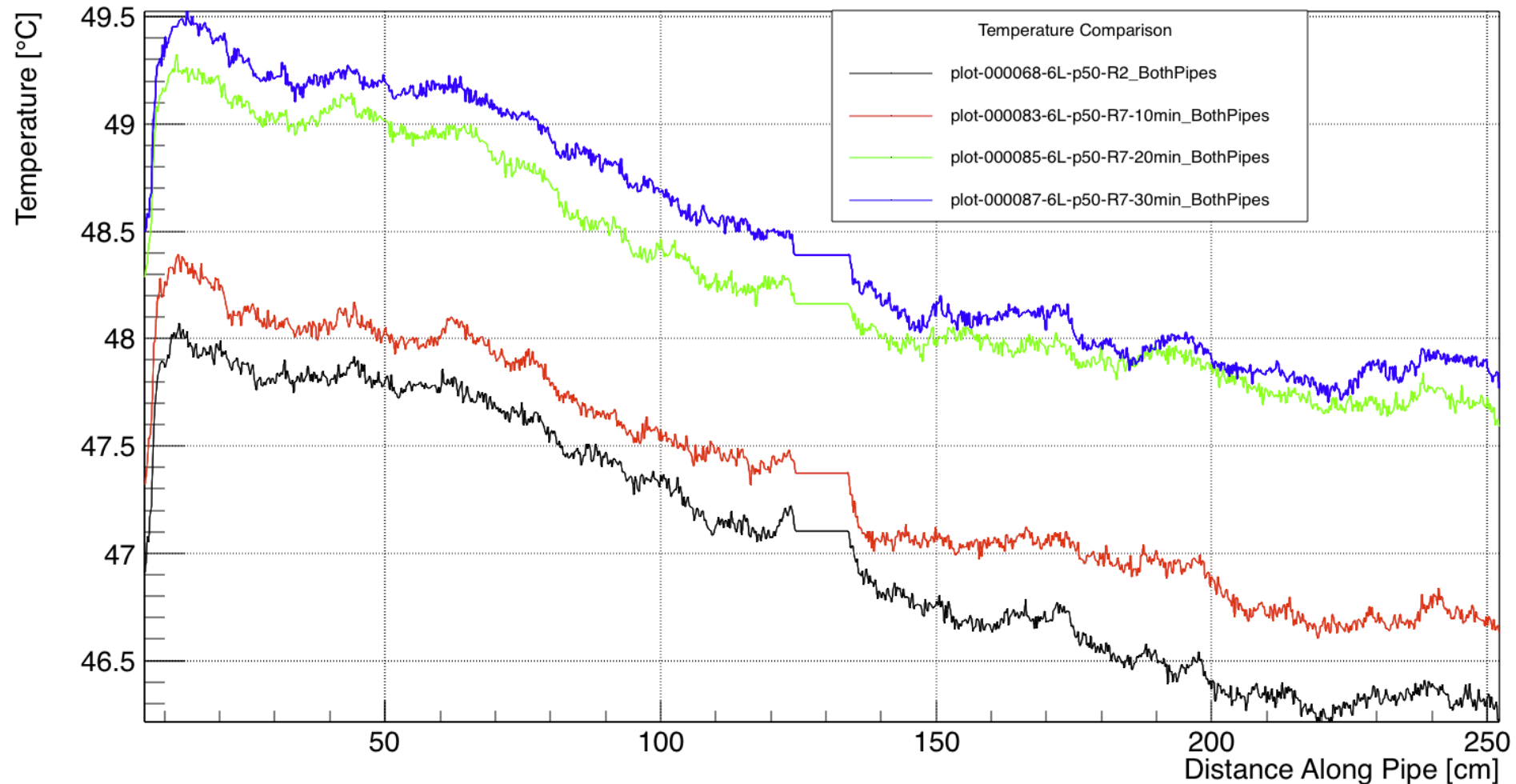
## Cooling Pipe Temp



# Changing Wait Time Hot

- ▶ Longer wait time gives a higher temperature profile

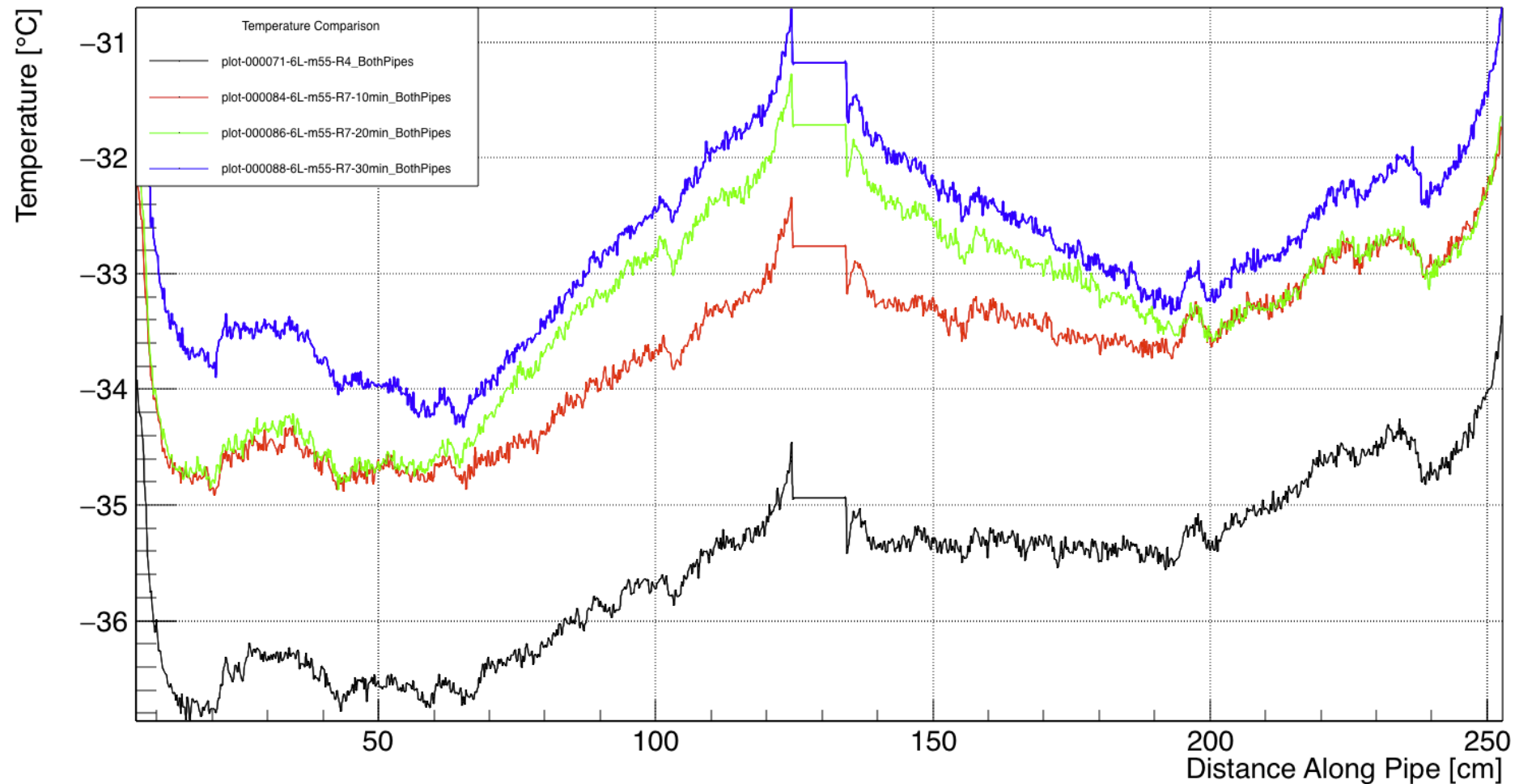
## Cooling Pipe Temp



# Changing Wait Time Cold

- ▶ Longer wait time changes the profile's shape and pushes it closer to ambient

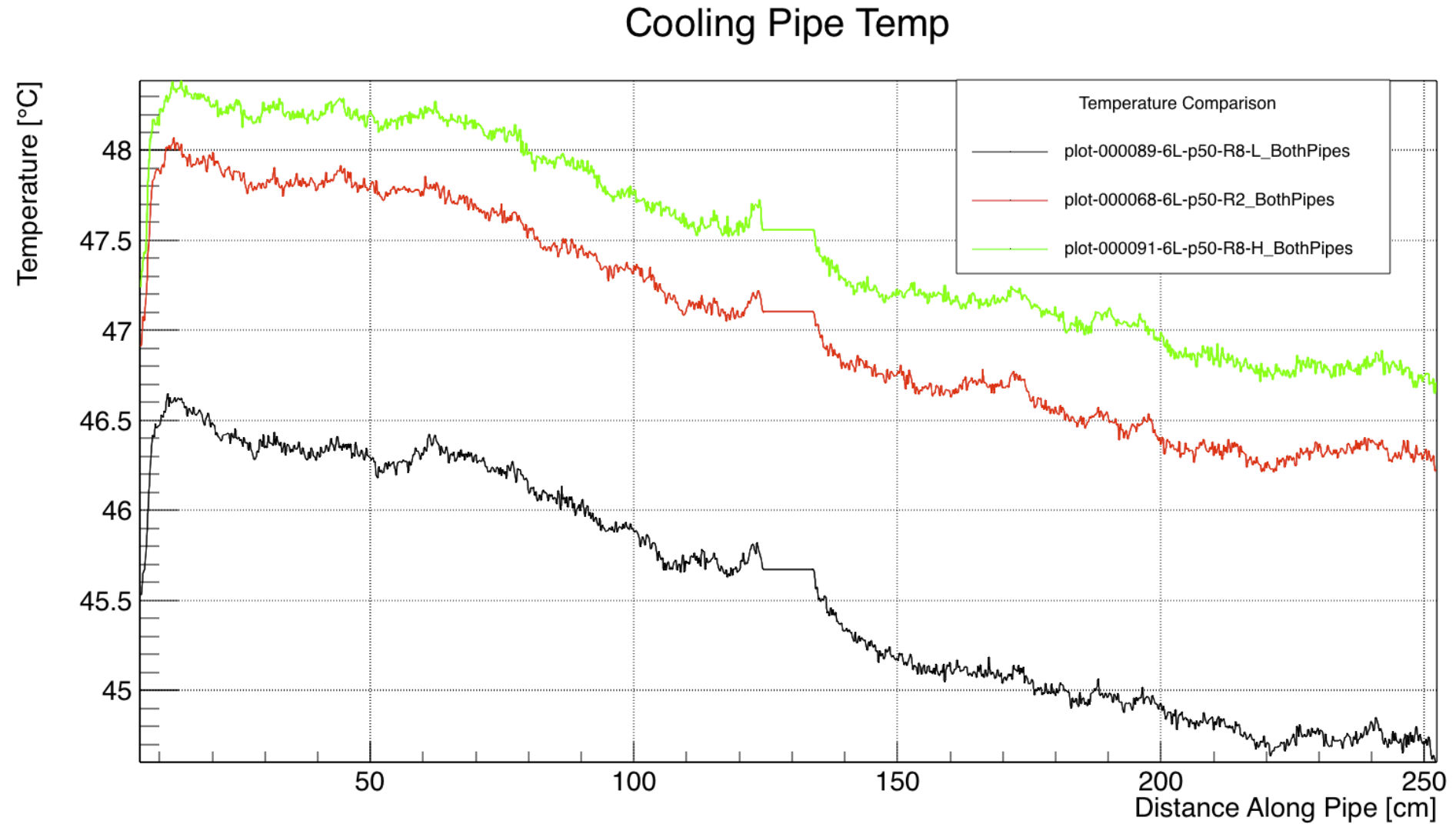
## Cooling Pipe Temp



# Changing RPMs Hot

▶ All three lines have different fluid flow rates.

- ▶ Black: 0.9 l/min
- ▶ Red: 1 l/min
- ▶ Green: 1.1 l/min

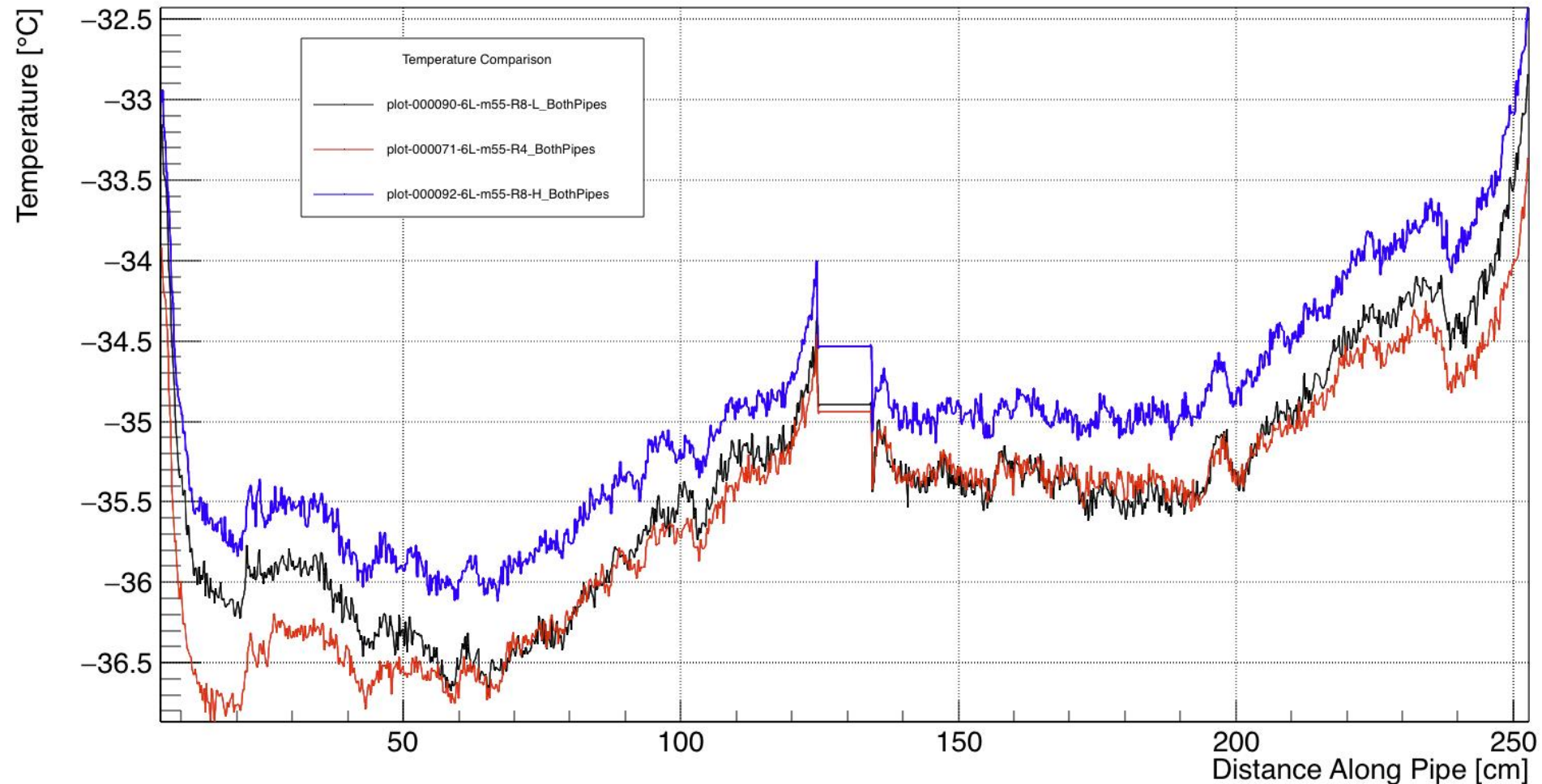




# Changing RPMs Cold

- ▶ All three lines have different fluid flow rates
  - ▶ Black: 0.9 l/min
  - ▶ Red: 1 l/min
  - ▶ Blue: 1.1 l/min

## Cooling Pipe Temp



# Conclusions

- ▶ More work to be done extracting information from the thermocouples...
- ▶ So far...
  - ▶ Precise reproduction for hot(cold) temperatures fell within 0.5-0.8 (~4) C
  - ▶ High temperature
    - ▶ Longer wait times correspond to higher temperatures
    - ▶ Higher RPMs correspond to greater energy transfer
  - ▶ Cold temperature
    - ▶ Longer wait times correspond to weird shapes...
    - ▶ Differing RPMs don't seem to change the spectrum?
  - ▶ More Questions than answers so far...

# Backup Slides