Update: Thermal Imaging

WILLIAM HEIDORN

IOWA STATE UNIVERSITY

ISU WEEKLY STAVE QA MEETING

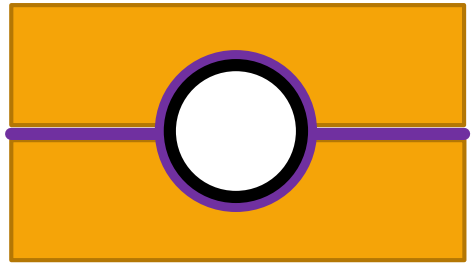
APRIL 4, 2018

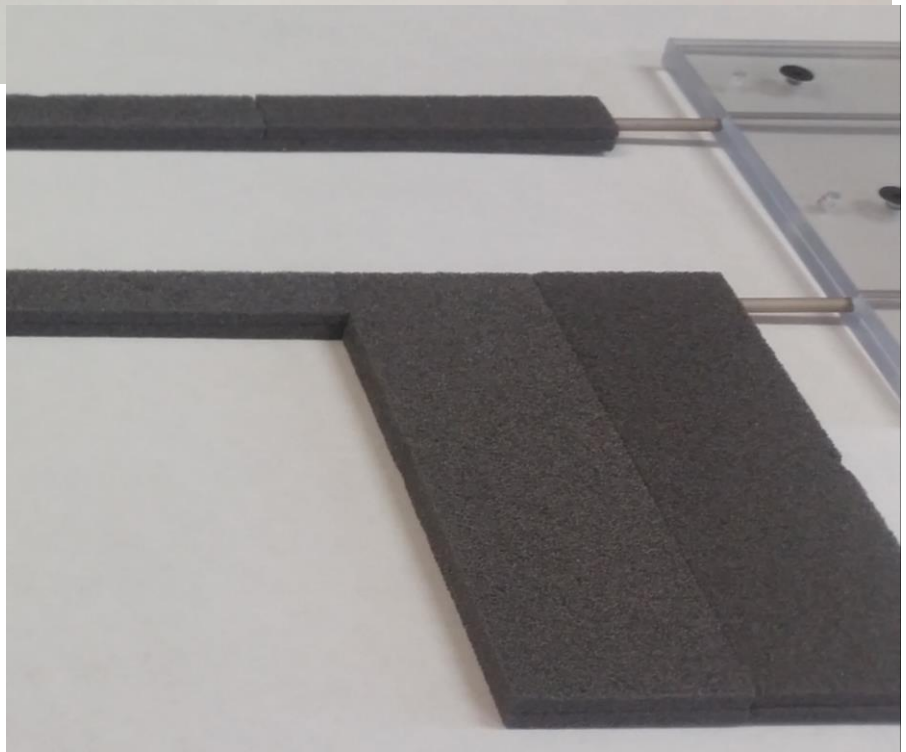
Since Last Week…

- The Pipe-Foam stave was thermally measured
  - 200 frames taken at 25 fps with the air off for at least 5 minutes to minimize air effects.
- Air Flow Effects
  - Stave 6 was measured with fluid at +50C, and -40C
  - Thermal videos were taken to see the changes made by the air on the cooling pipes
- Stave 6 was thermally measured for the first time…

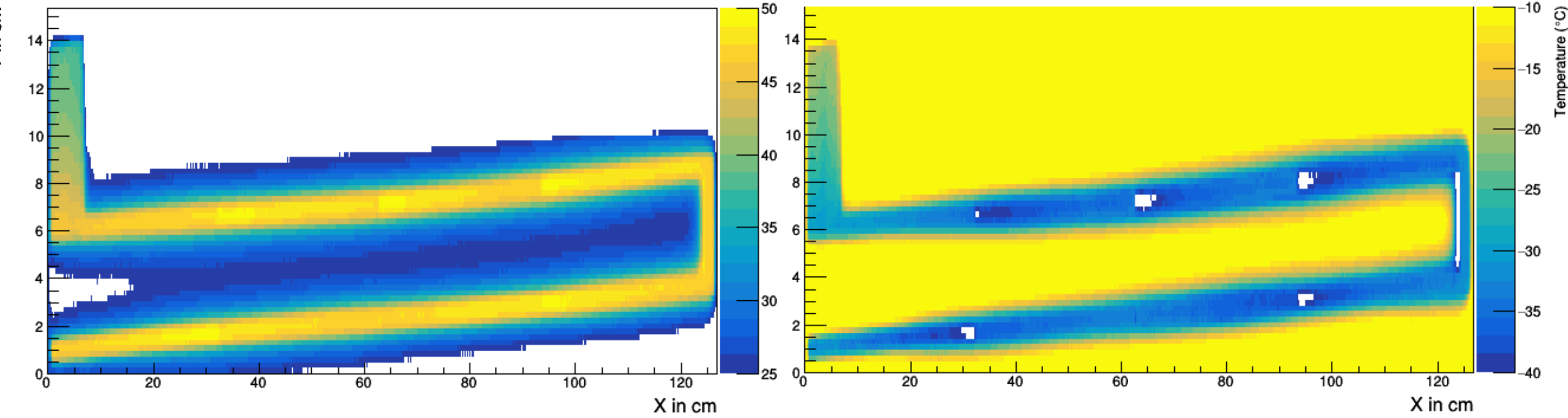
Pipe-Foam Images

- The pipe-foam stave is a titanium cooling pipe with the thermal foam put around it.
  - The thermal foam is purchased in 1'x1' squares and is machined into grooved halves that are glued on both sides of the pipe (like a sandwich)
- Different gluing techniques may have been used to assemble the structure
- Approximate emissivity 0.79



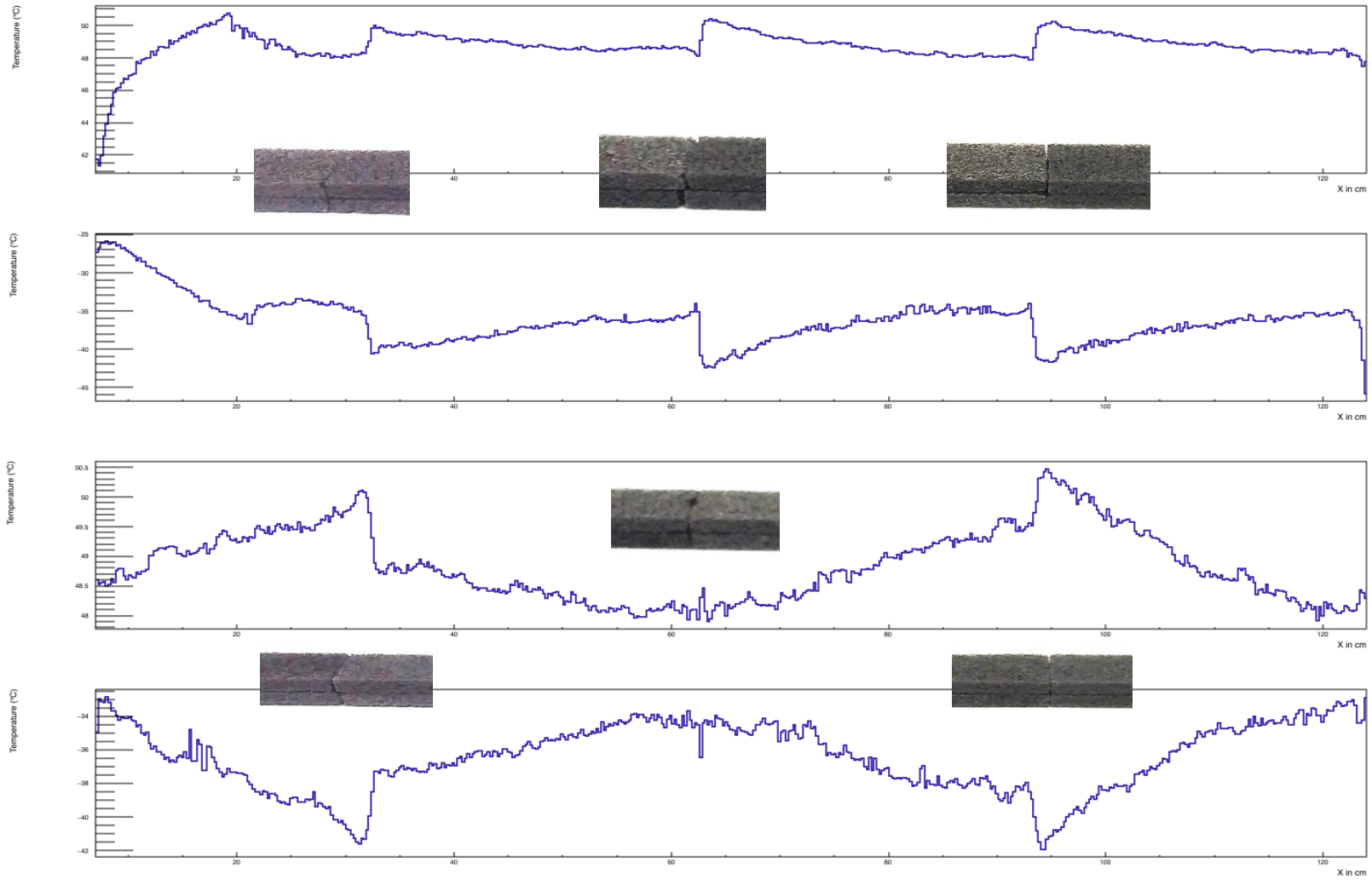


Pipe-Foam Stave J-Side

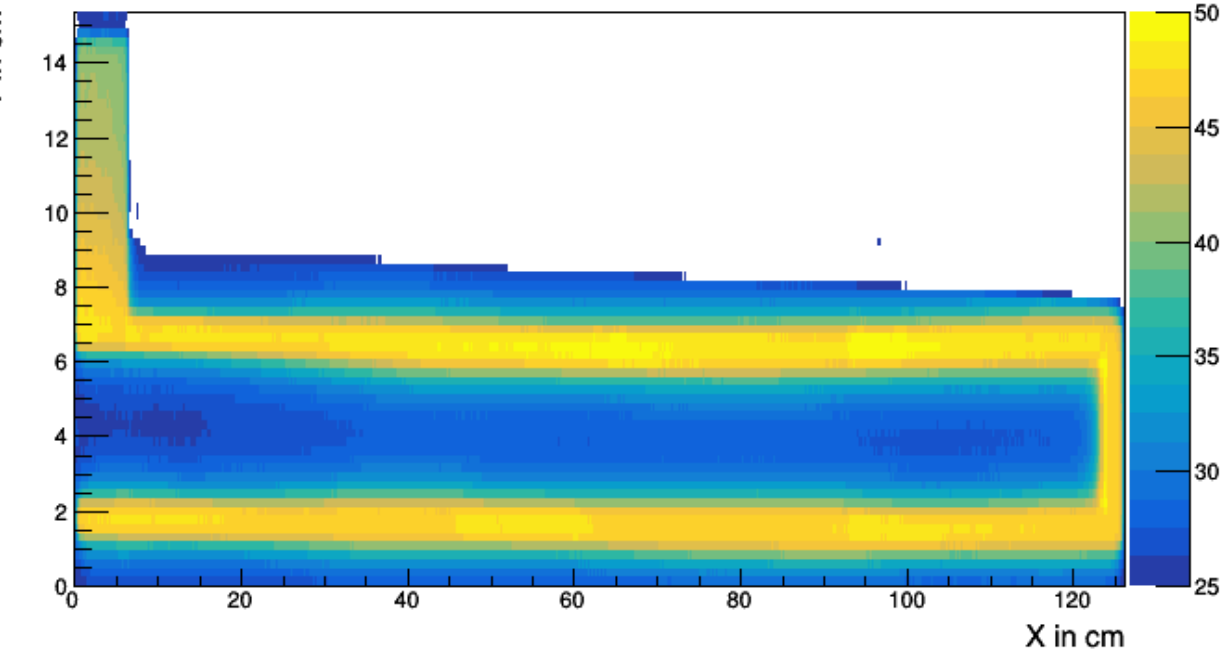


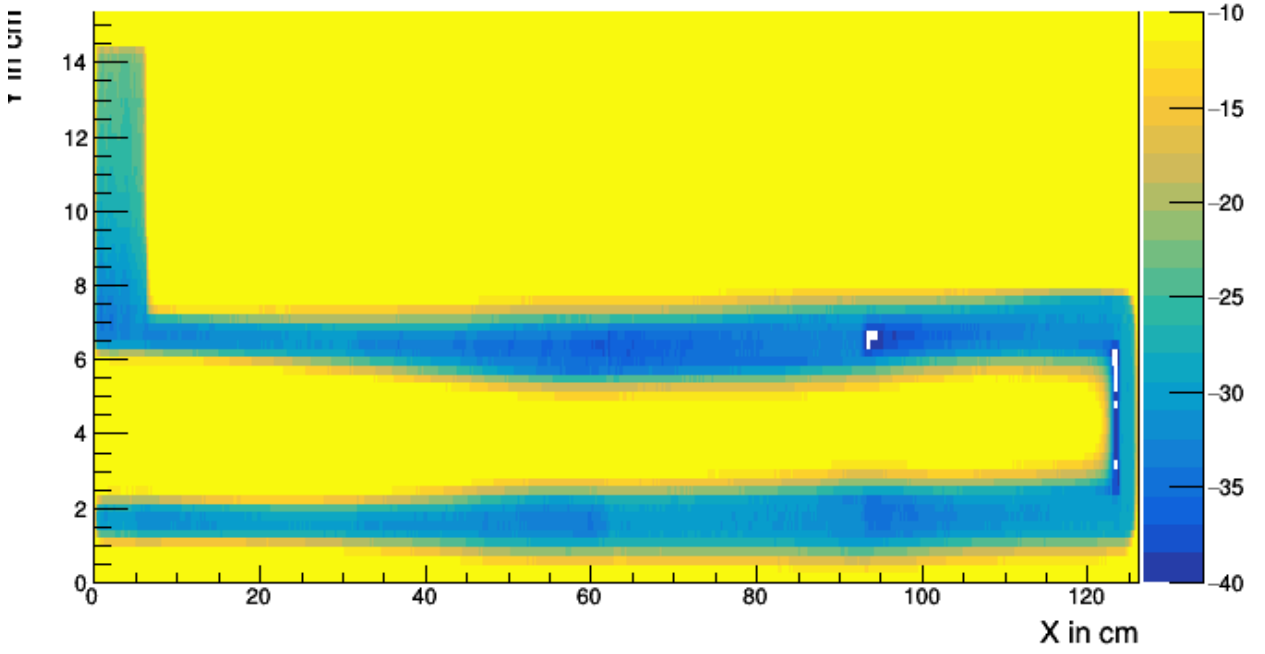
Pipe-Foam Stave J-Side (cont.)

- At each intersection between foam pieces a thermal jump can be seen.
- Comparing theses peaks to the foam, seems to indicate that the separation between plates may be due to breaks in the connection between chunks
- Smoothest transition is seen in well glued area

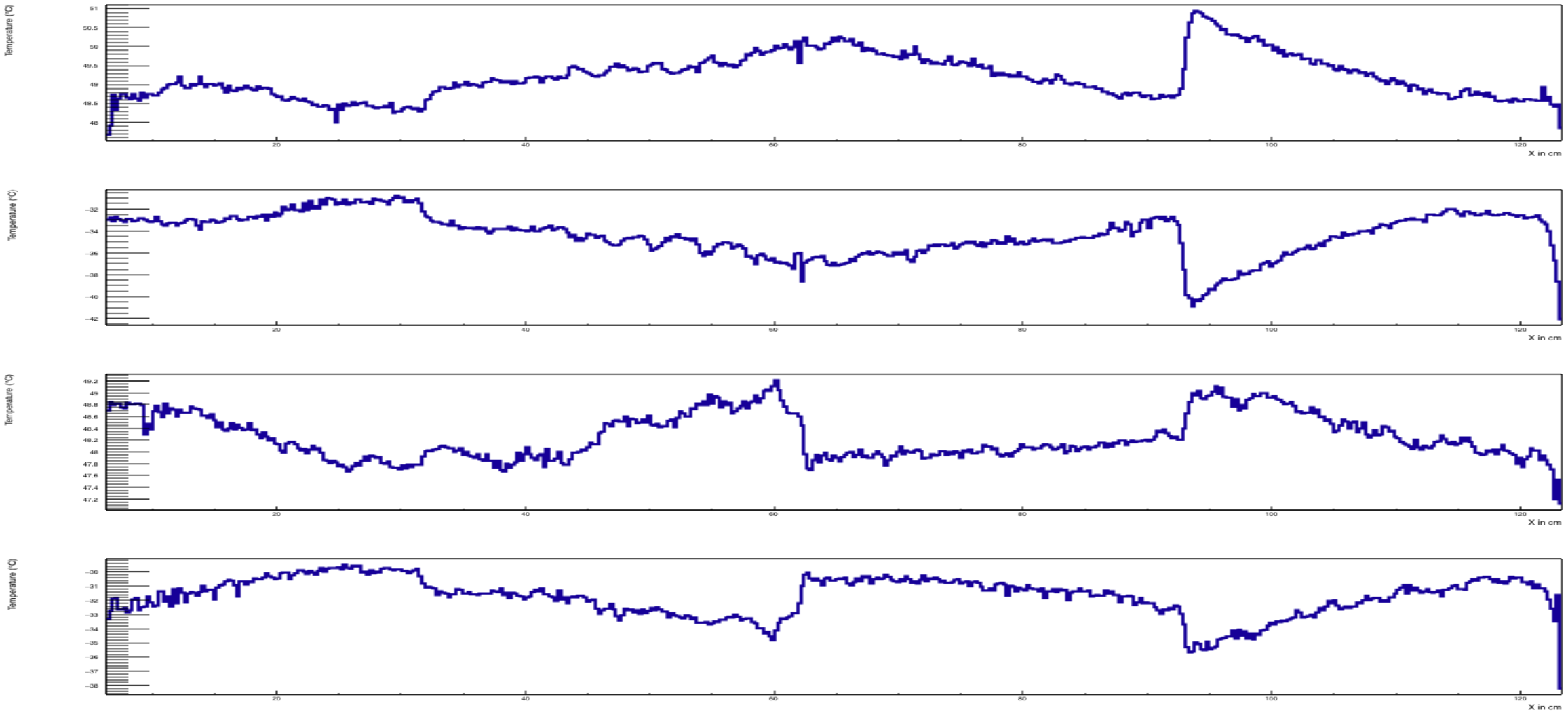


Pipe-Foam Stave L-Side



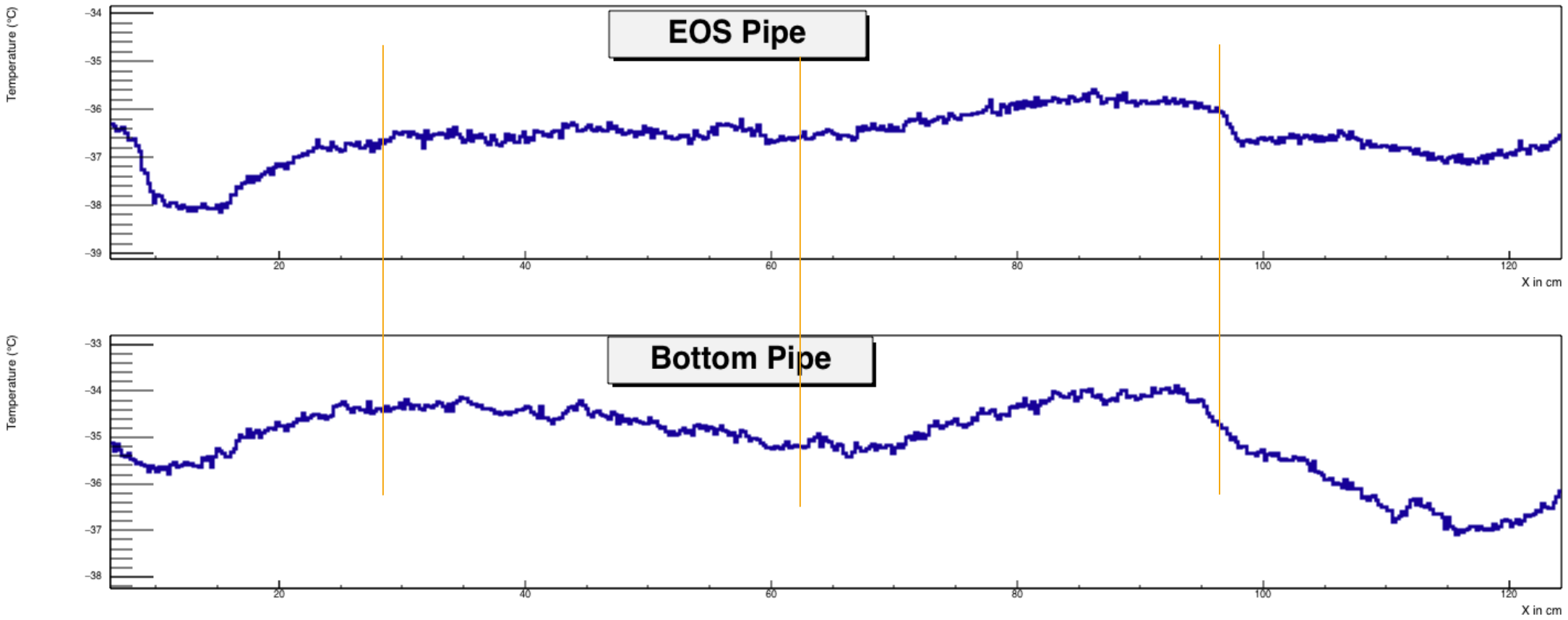


Pipe-Foam Stave L-Side

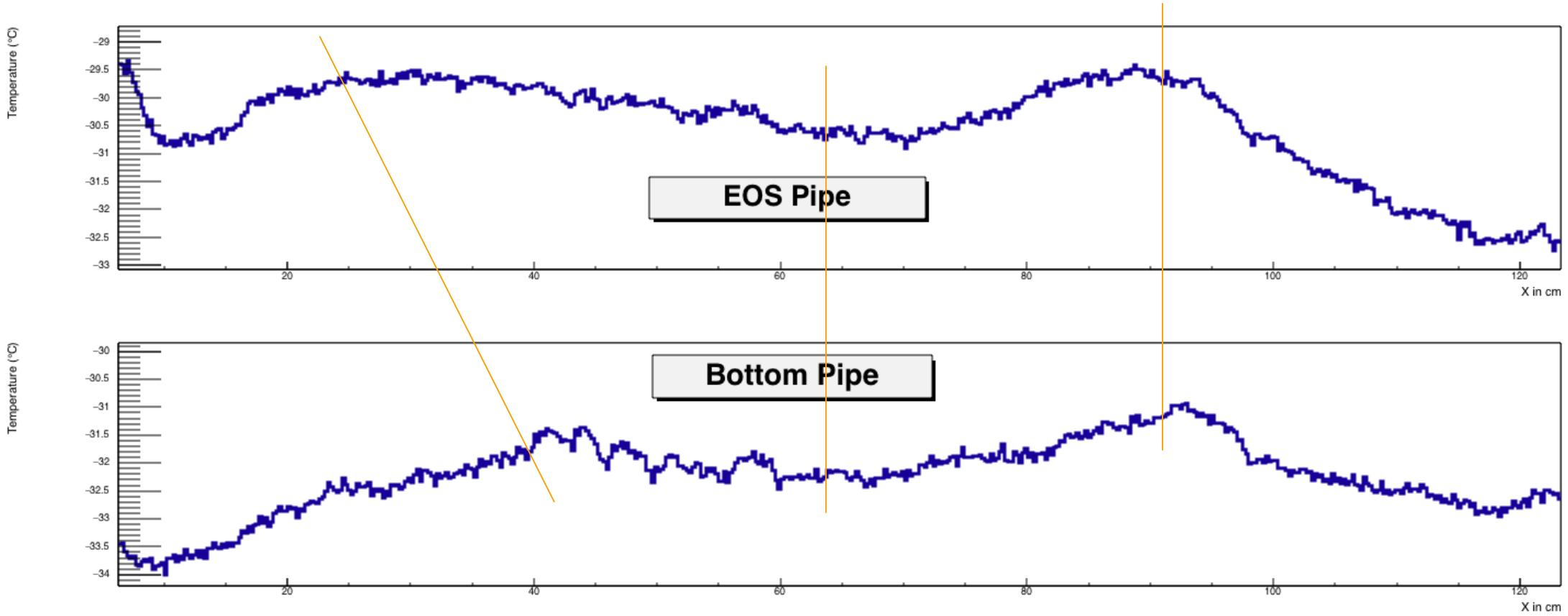


- Once you know about the pipe-foam structure, the basic structure of the cooling pipe profile begins to make a lot more sense…

Stave 5-JSide



Stave 5-LSide



Pipe-Foam Conclusions

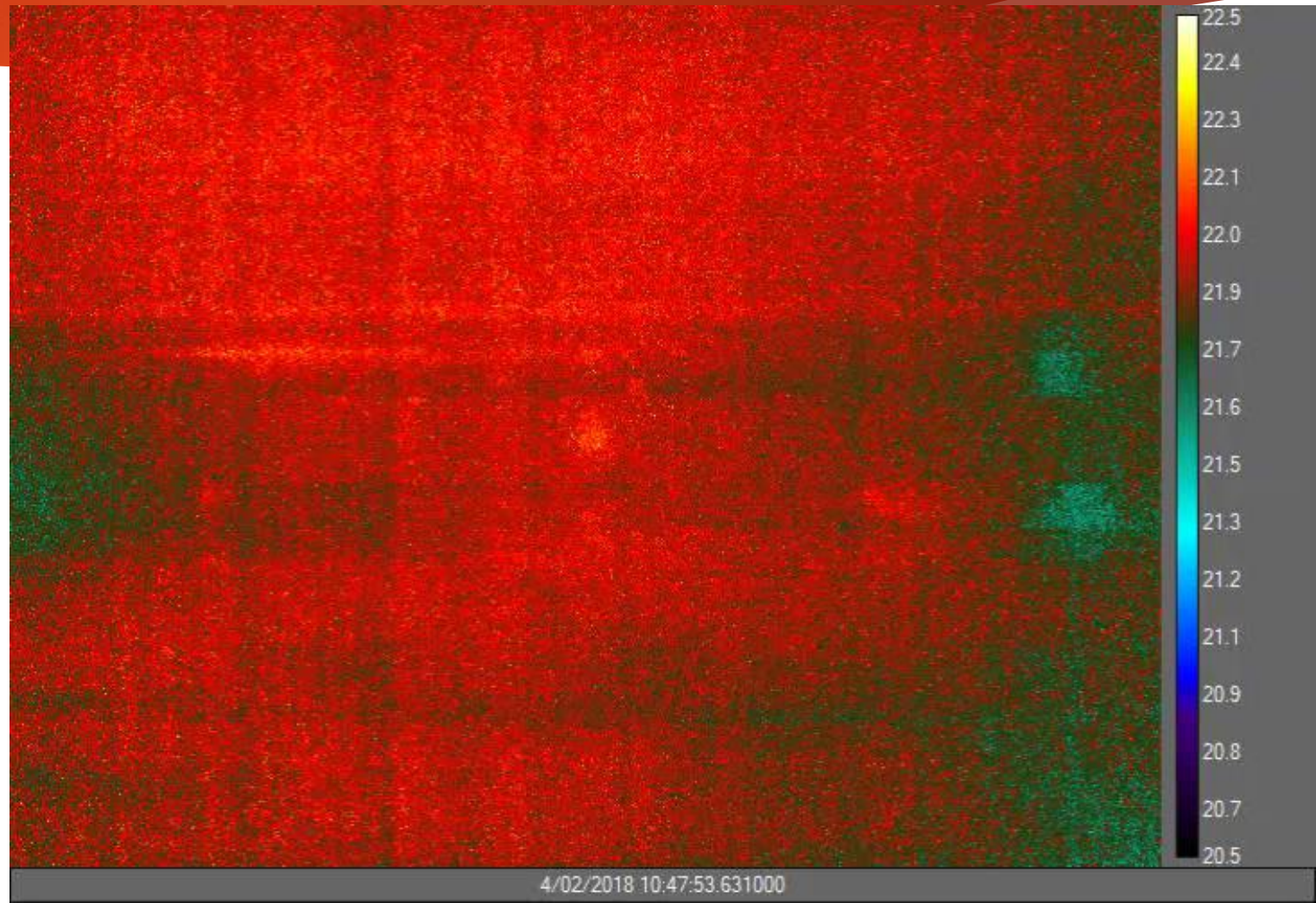
- Pipe-Foam thermal structure are the cause of background structures in stave thermal images
- Pipe-Foam thermal structure depends on pipe foam connection. If gaps exist between the foam pieces there are step functions that are generated in the thermal profile

Nitrogen flow effects

- Dry nitrogen pumped into the enclosure can have an effect on the thermal image of the stave.
- Using stave 6 as the backdrop, multiple tests were done filming the nitrogen's effect to the box's thermal profile.
  - Volume of the box ~300 L
  - Flow rate into the box ~ 30L/min @ 10psi
  - Flow rate into the box ~ 20L/min @ 5psi

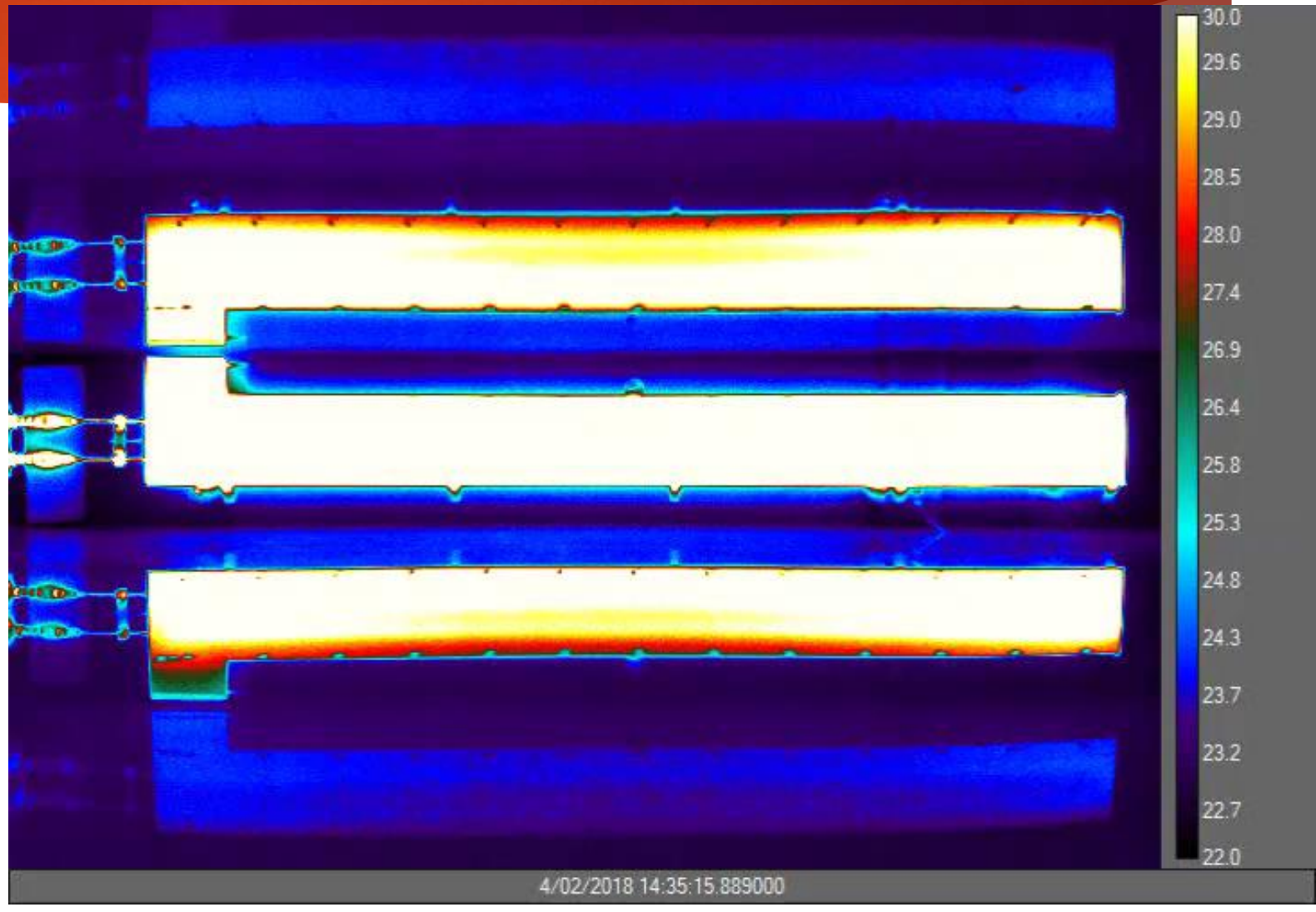
No fluid flow air effects

- While the room and box were at ambient temperature, the gas is then turned on at 10 psi and an image is taken every 15s.
- The air uniformly cools the box and stave a few degrees over 50 minutes of filming



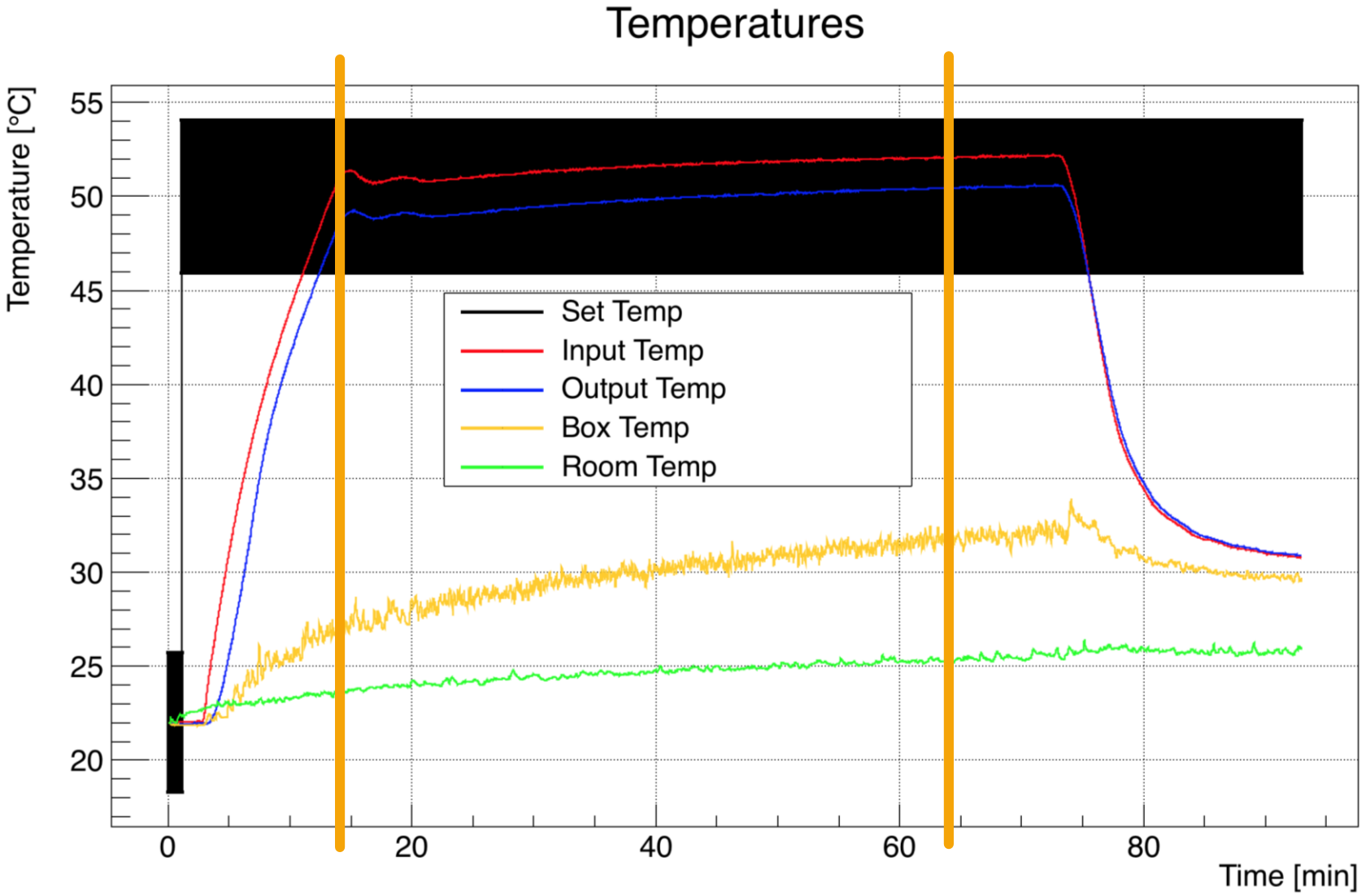
High temp effects

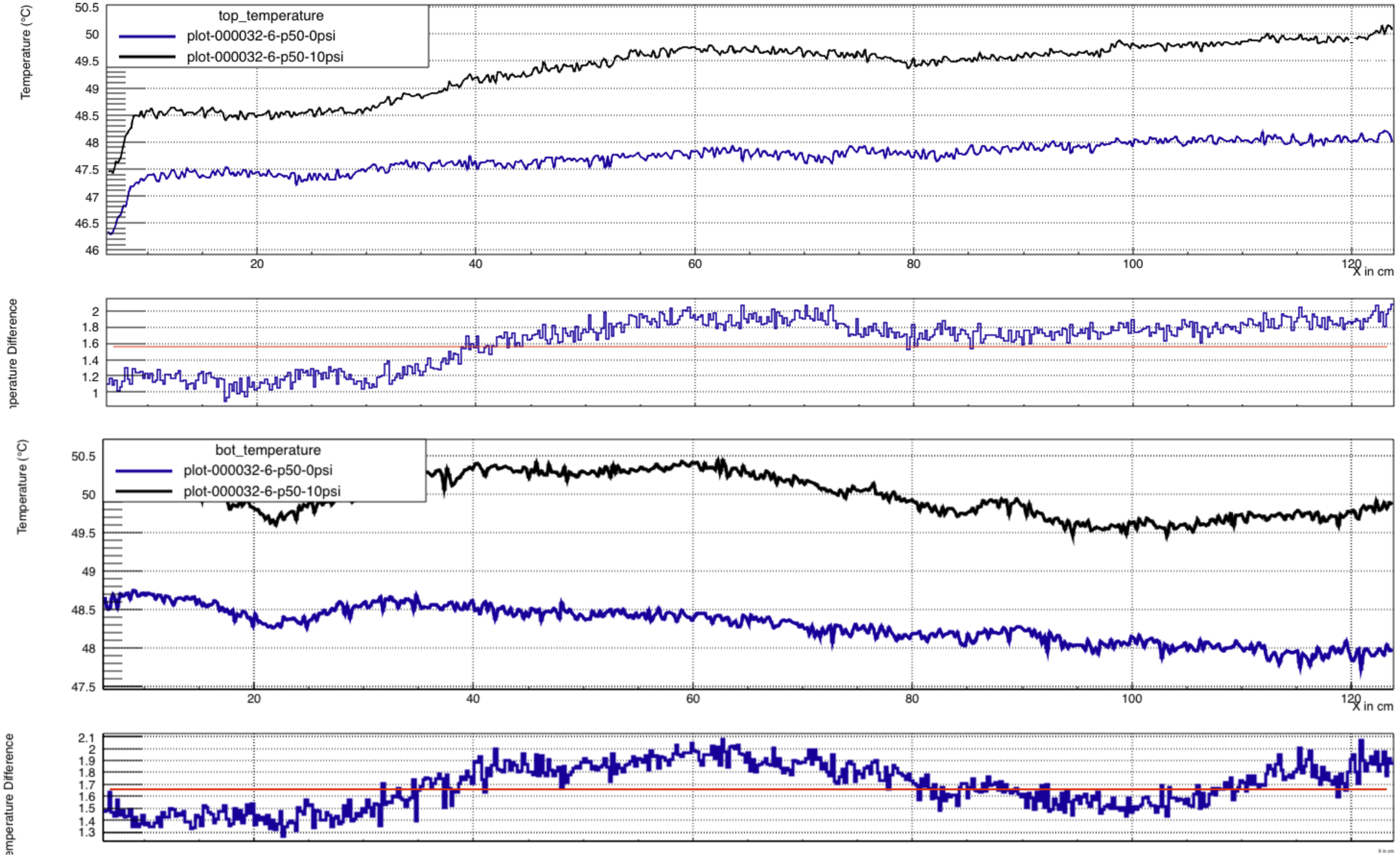
- +50C fluid is being pumped through the stave at around 1 l/min.
- The nitrogen has been off while the stave was going to +55C. The gas was then turned on at 10psi with the camera taking an image every 15 s
- When the airflow begins the box starts heating up. The box temp increases around 5 degrees over 50 mins



High temp effects cont.

- No obvious changes on thermocouple measurements
- No changes seen in box temperature measurement
- Yellow Line is when nitrogen is turned on and video was taken

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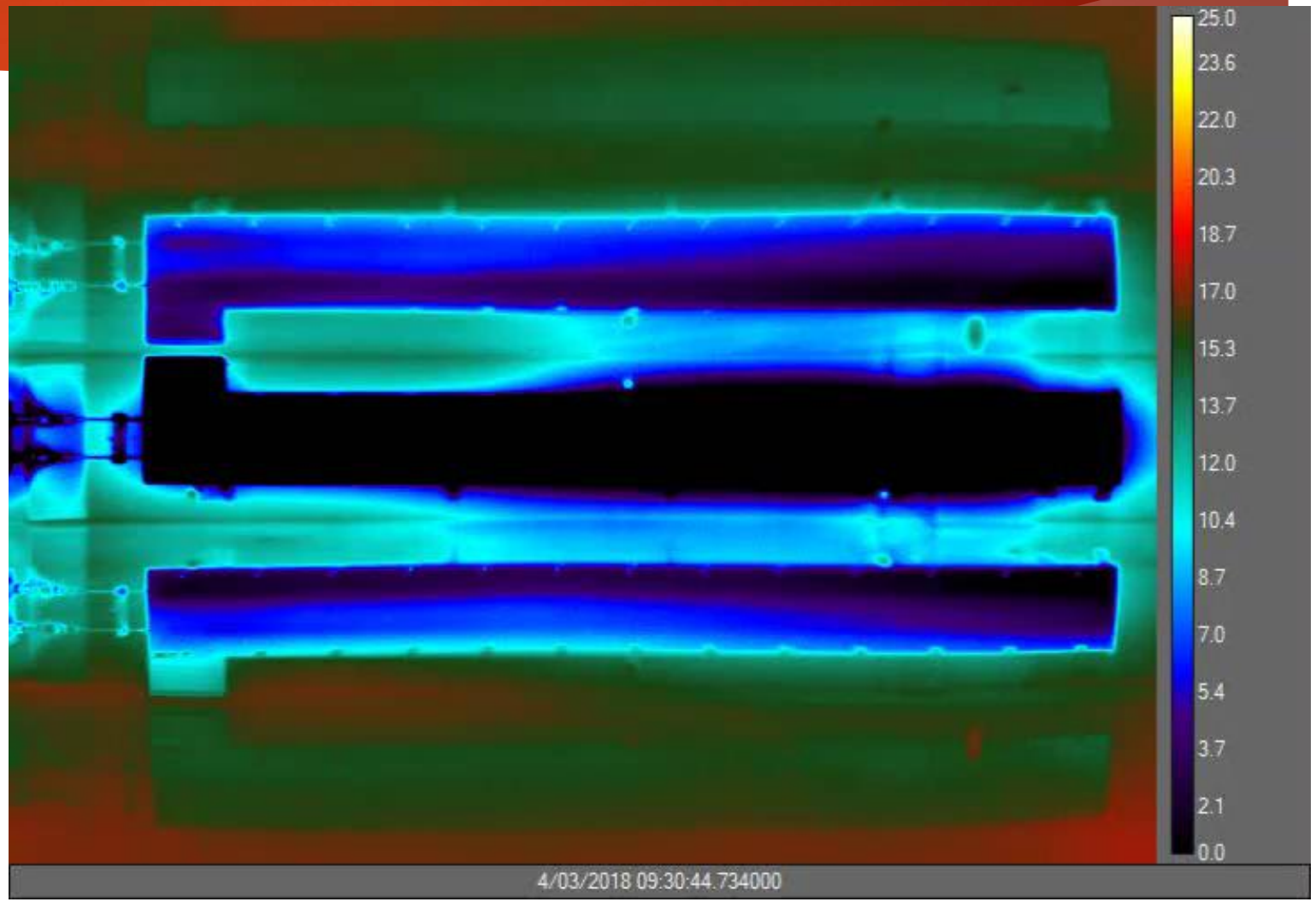
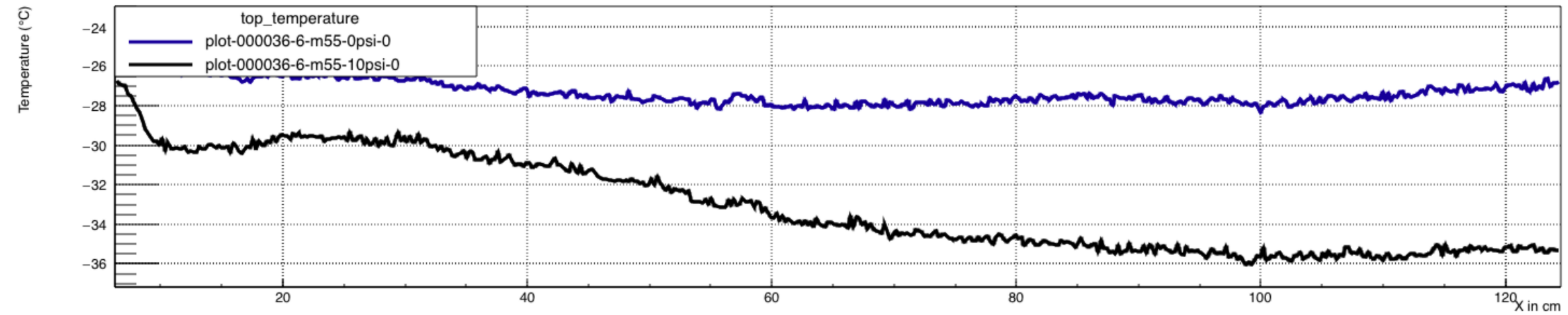
plot-000032-6-p50-0psi
plot-000032-6-p50-10psi
Temperature (°C)
X in cm
bot_temperature
plot-000032-6-p50-0psi
plot-000032-6-p50-10psi
Temperature (°C)
X in cm

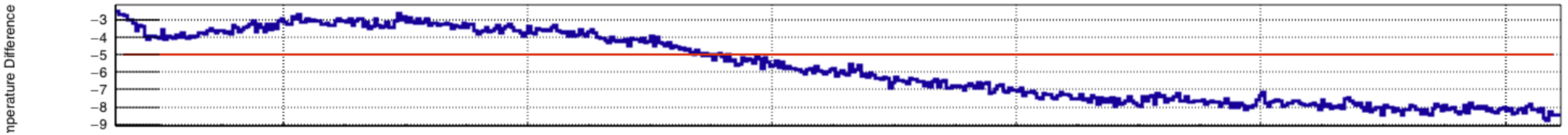
Low temp effects (shutting off air)

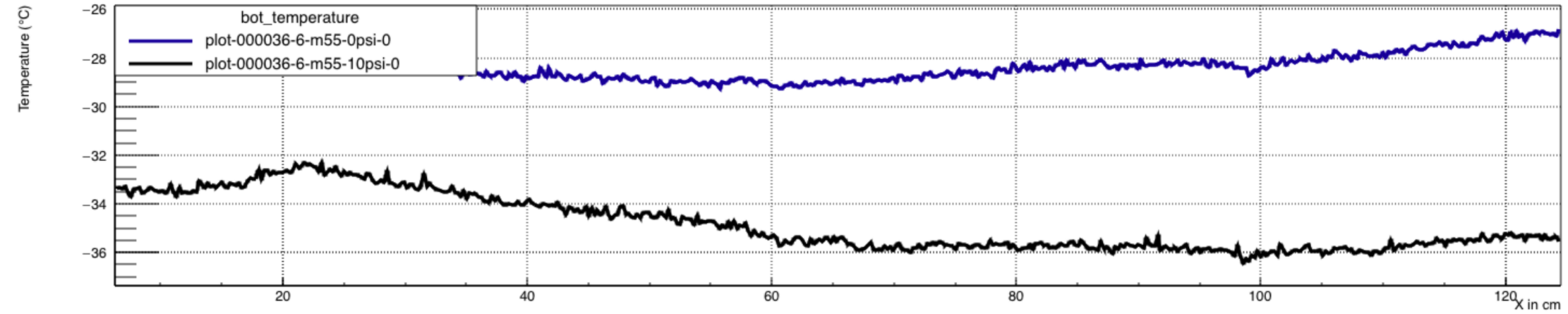
- -36 C fluid is being pumped into the stave at a rate near 1l/min
- The nitrogen has been on while the chiller struggled to get the stave to this temperature… (Had some interesting chiller ctrl problems causing a few restarts)
  - Mainly due to the logging process freezing up
- An image is taken of the enclosure every 10 seconds for 33 mins. The box warms up during this time

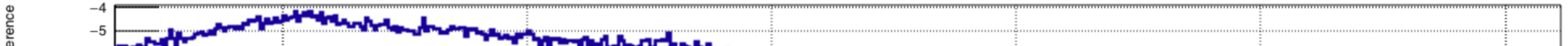
NEXT SLIDE: Temperature difference between beginning and end frame




top_temperature
plot-000036-6-m55-0psi-0
plot-000036-6-m55-10psi-0
Temperature (°C)
−24
−26
−28
−30
−32
−34
−36
20
40
60
80
100
120
X in cm


nperature Difference
−3
−4
−5
−6
−7
−8
−9

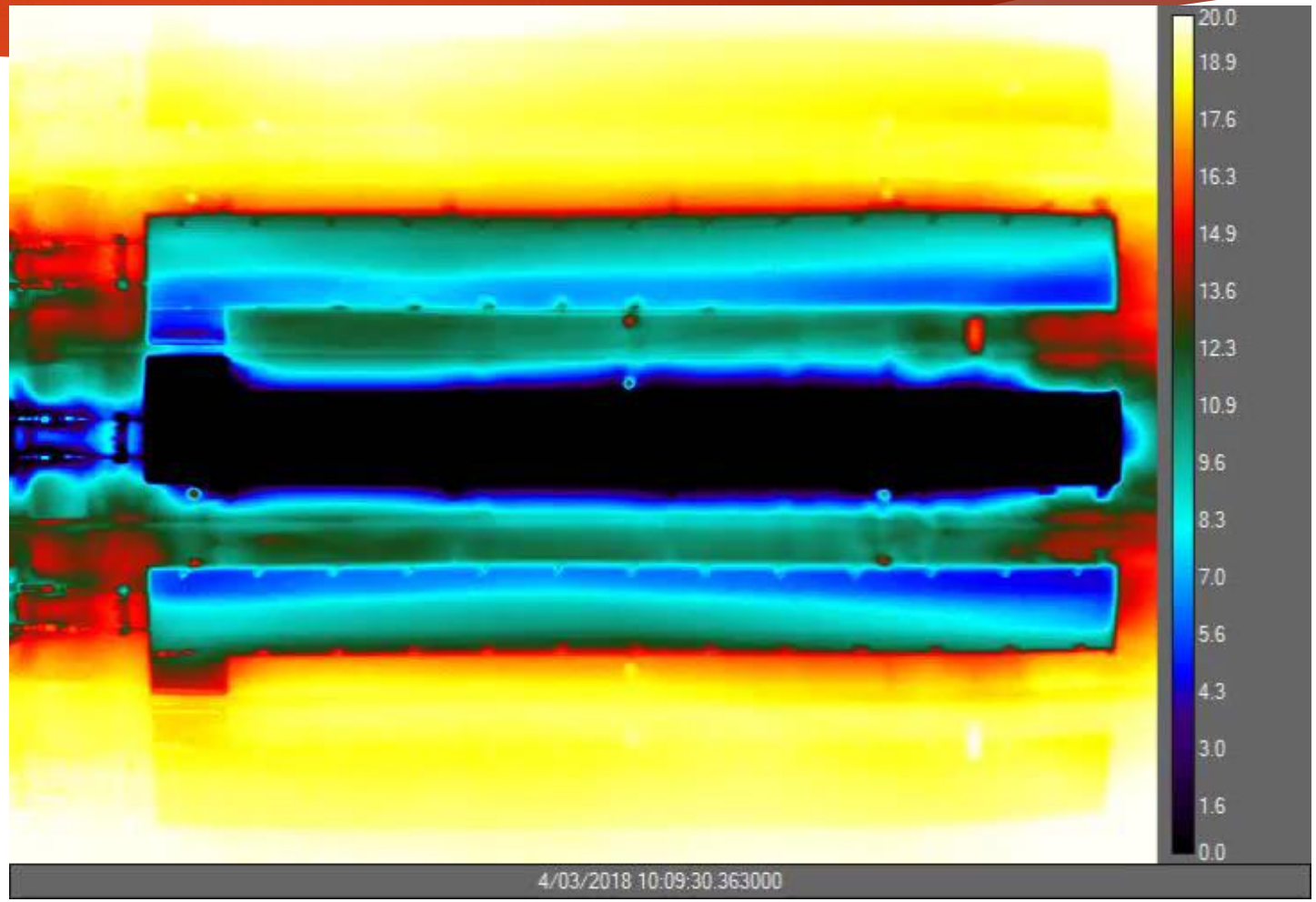

bot_temperature
plot-000036-6-m55-0psi-0
plot-000036-6-m55-10psi-0
Temperature (°C)
−26
−28
−30
−32
−34
−36
20
40
60
80
100
120
X in cm

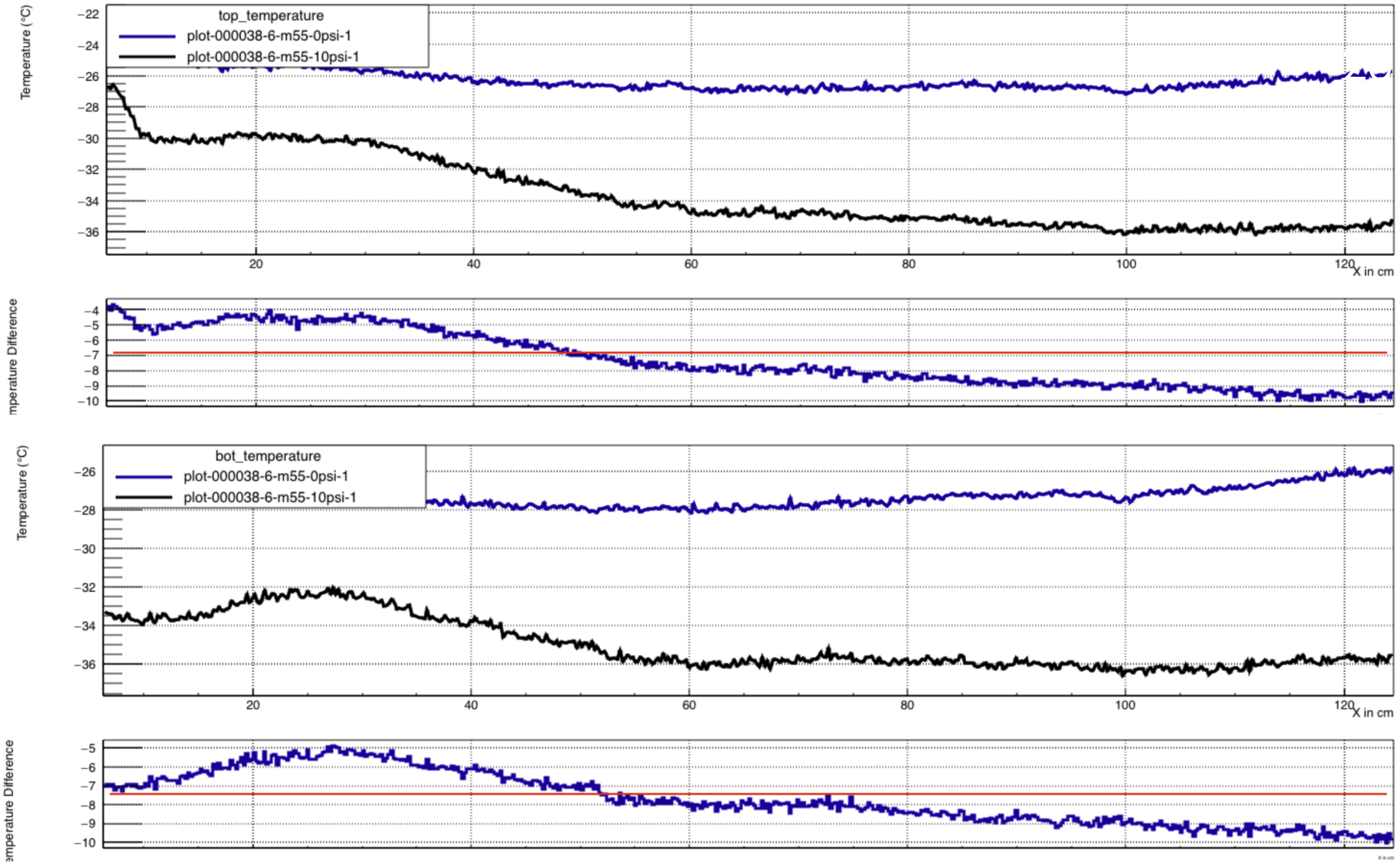

erence
−4
−5

Low temp effects (turning off air)

- After the 33 min without air the air is turned back on and a picture is taken every 10 seconds for another 33 min
- The temperature of the box slowly begins to cool down over the time.

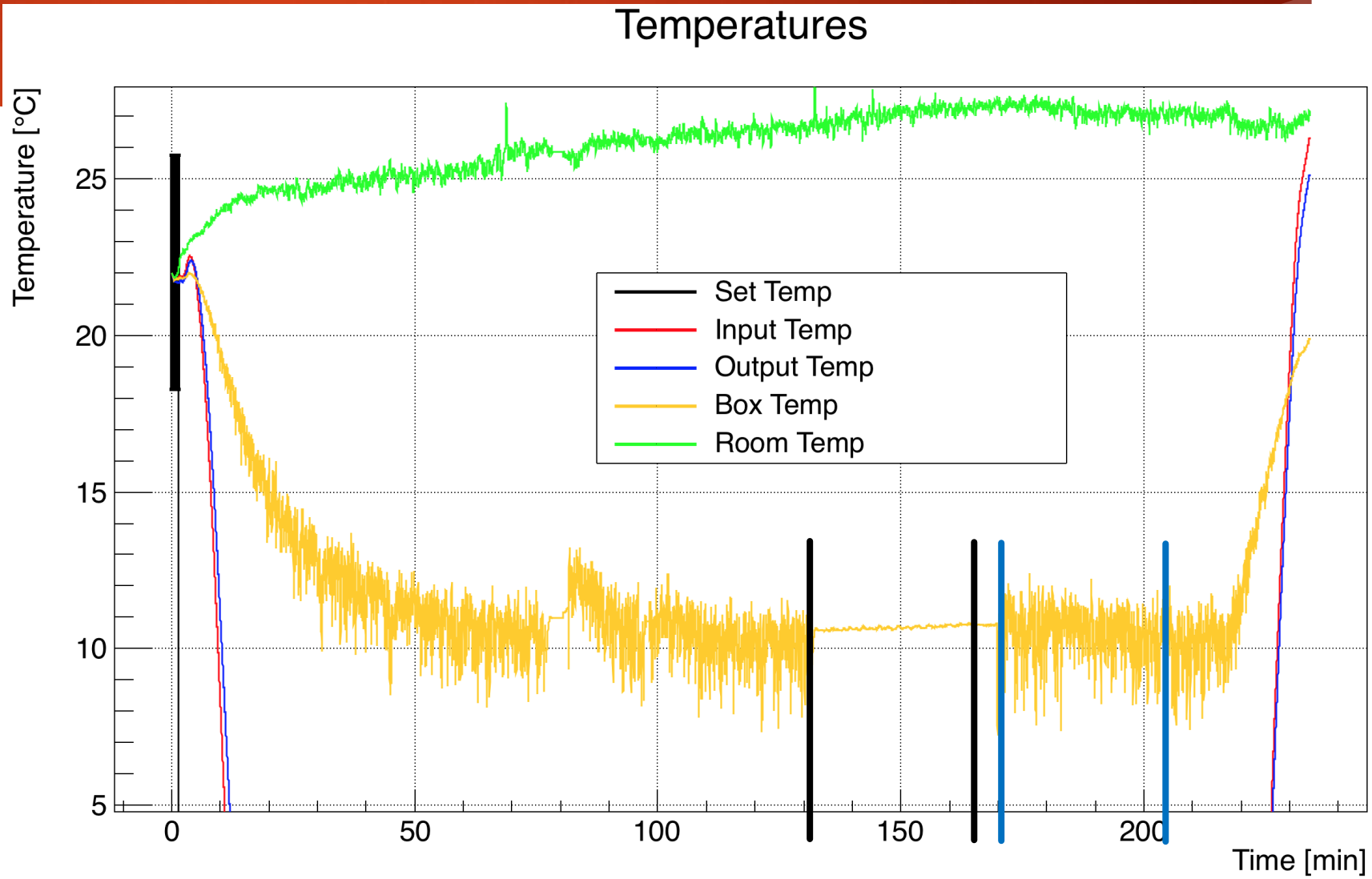
NEXT SLIDE: Temp diff between beginning and end frames




top_temperature
plot-000038-6-m55-0psi-1
plot-000038-6-m55-10psi-1
Temperature (°C)
X in cm
mperature Difference
bot_temperature
plot-000038-6-m55-0psi-1
plot-000038-6-m55-10psi-1
Temperature (°C)
X in cm
emperature Difference

Low temp effects cont.

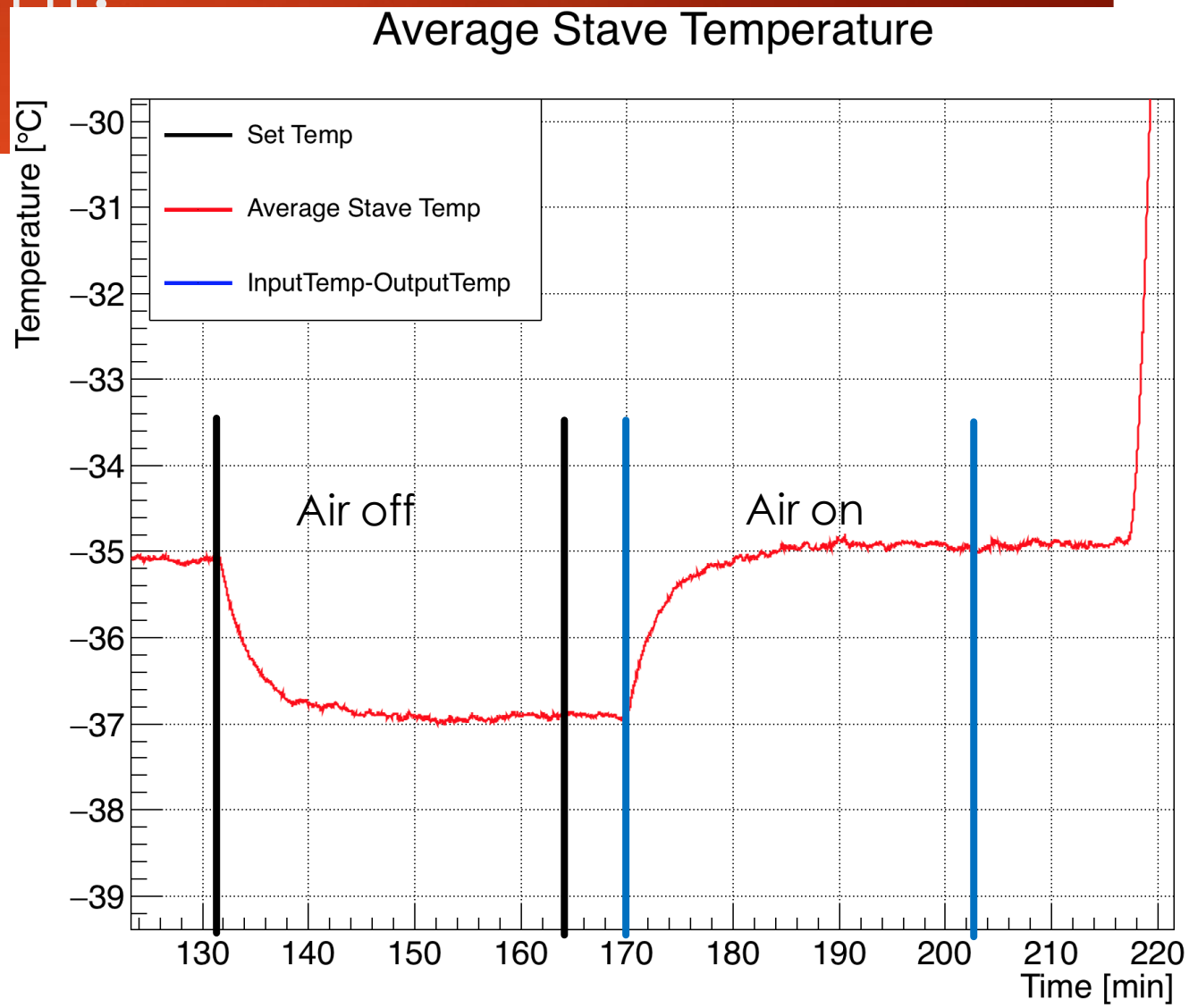
- Shutting off air is black portion
- Turning on air is blue portion

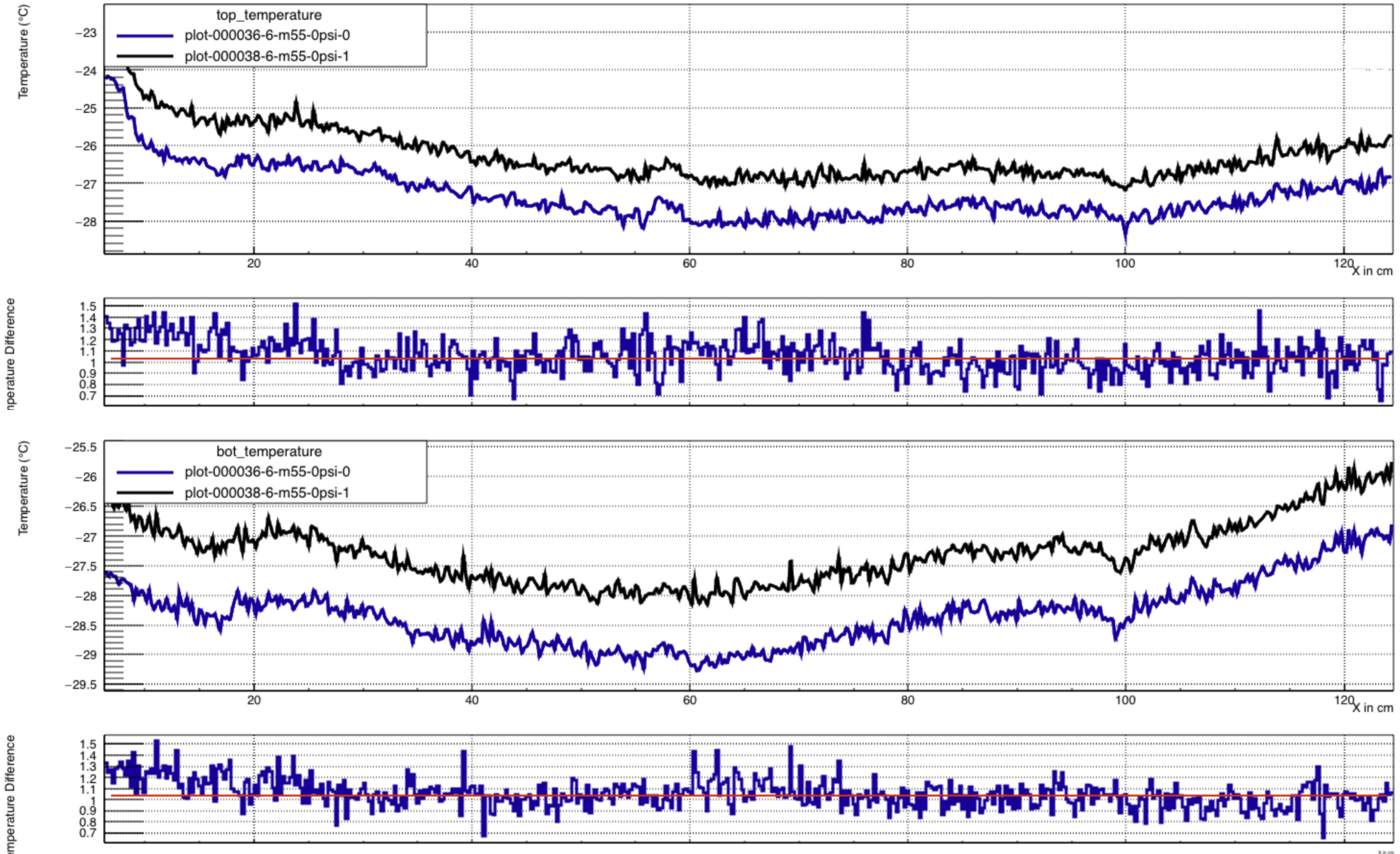


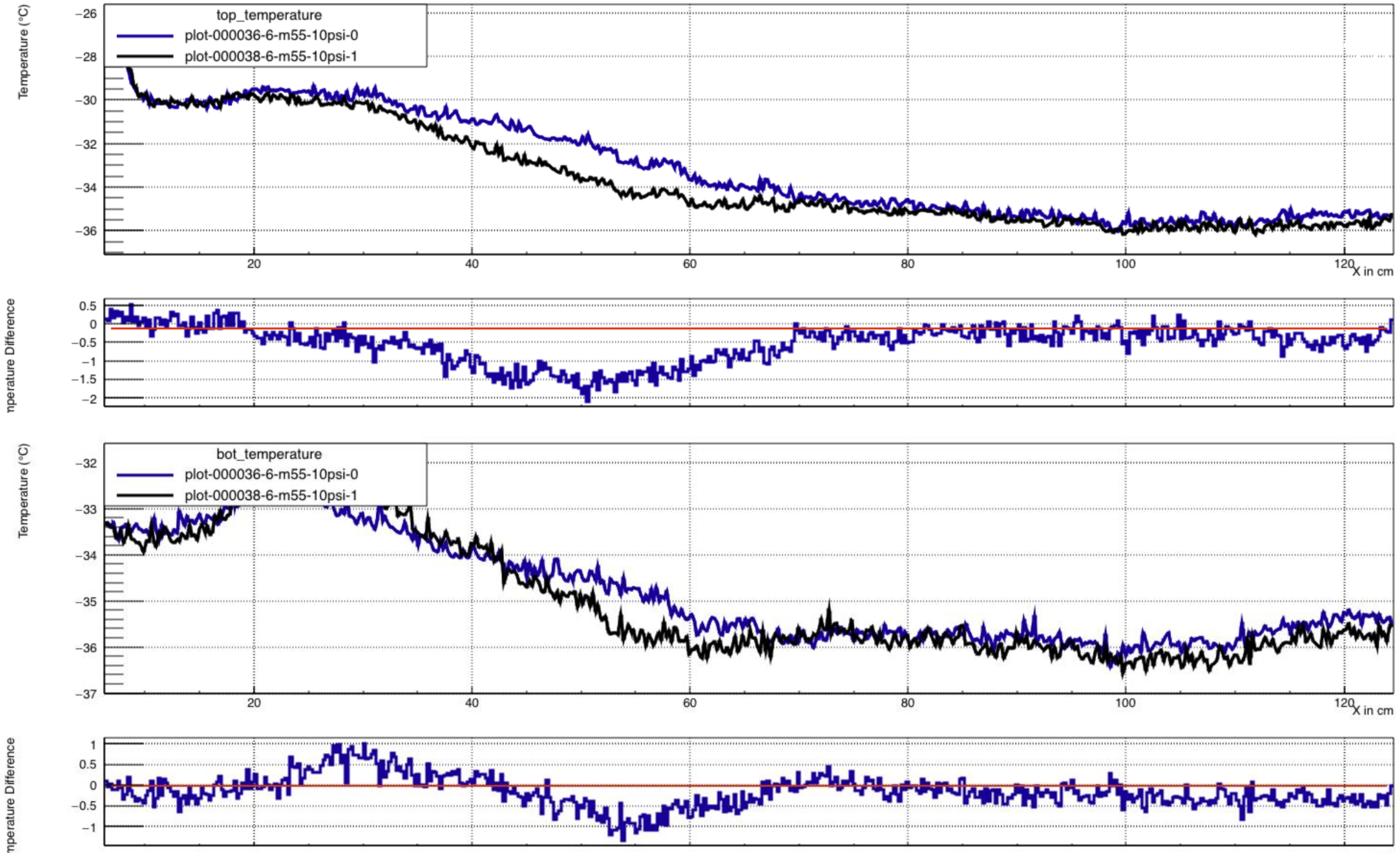
Low temp effects cont.

- With the air off the average temperature of the stave inlet and outlet gets lower
- It takes about 10 min to reach thermal equilibrium with the nitrogen

NEXT SLIDES: Comparison between both equilibrium plots




top_temperature
plot-000036-6-m55-0psi-0
plot-000038-6-m55-0psi-1
Temperature (°C)
−23
−24
−25
−26
−27
−28
20
40
60
80
100
120
X in cm
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
bot_temperature
plot-000036-6-m55-0psi-0
plot-000038-6-m55-0psi-1
Temperature (°C)
−25.5
−26
−26.5
−27
−27.5
−28
−28.5
−29
−29.5
20
40
60
80
100
120
X in cm
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7


top_temperature
plot-000036-6-m55-10psi-0
plot-000038-6-m55-10psi-1
Temperature (°C)
X in cm
bot_temperature
plot-000036-6-m55-10psi-0
plot-000038-6-m55-10psi-1
Temperature (°C)
X in cm

Airflow conclusion

- The airflow has distinct effects on the environment of the enclosure.
  - Changes the equilibrium temperature of the stave
  - Changes the shape of the stave thermal profile
- It takes around 10 min for the system to come to equilibrium after changing the airflow rate

Backup Slides

- no