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Temperature Analysis of Test Beam

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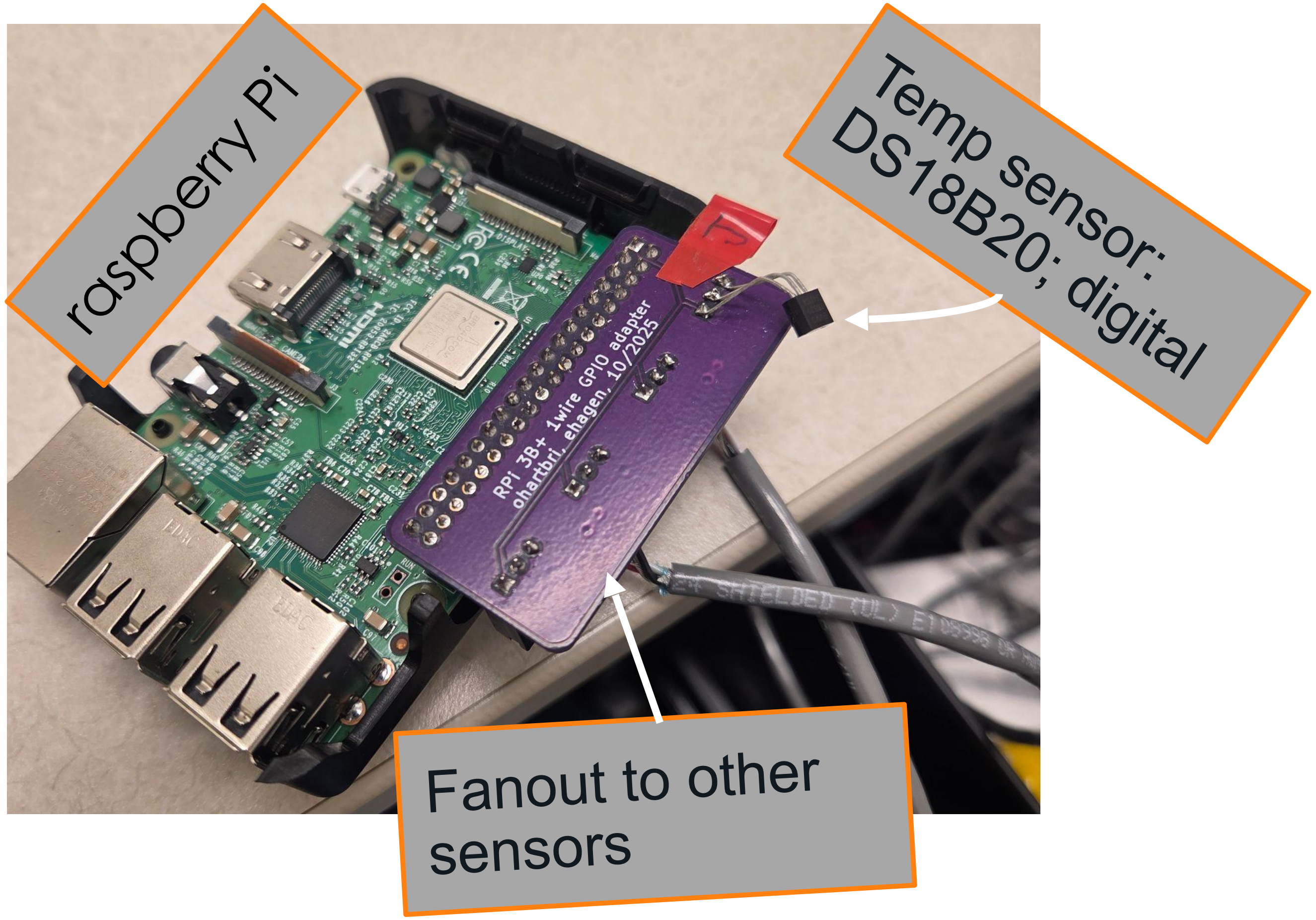
Motivation

- Measure/understand the temperature along the module during the Test Beam
    - some on steel, some in air, find temp correction to switch between the two

Overview

- How the sensors are set up
- What data is included
- How we interpret the data
- Secondary testing

Sensor Design



Test Beam Set up

Sensors:

- J was noise as it only picked up the heat from the Pi

- H, C, E were placed along the steel

- M was the ambient temperature of the room

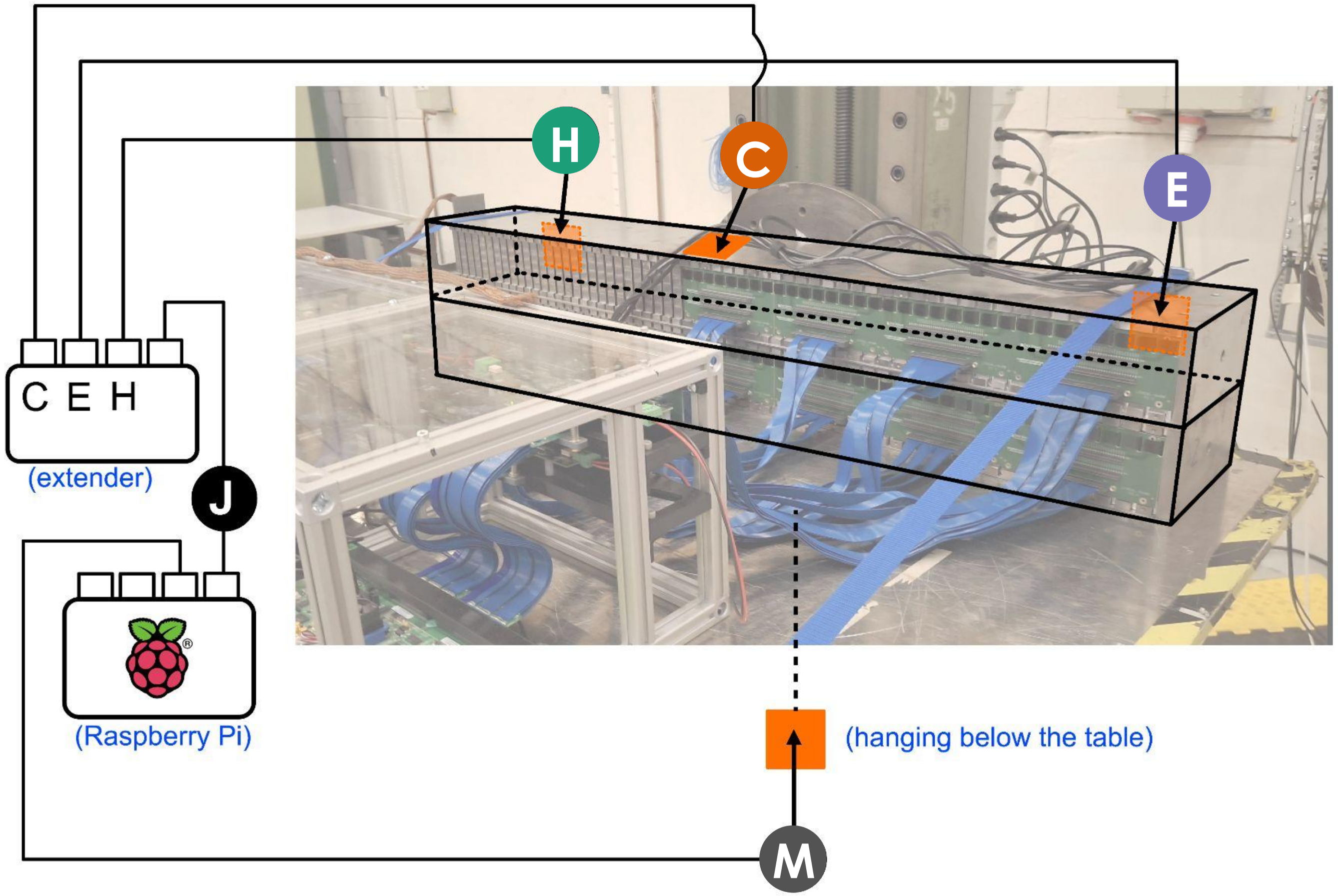
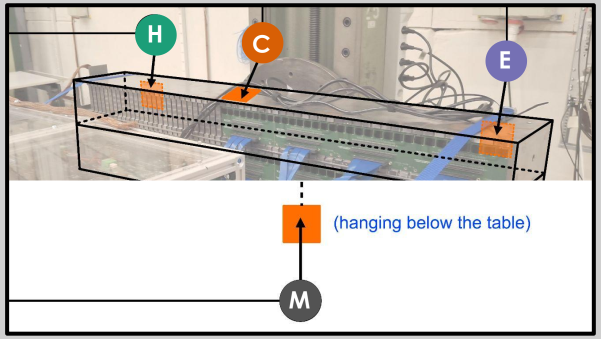
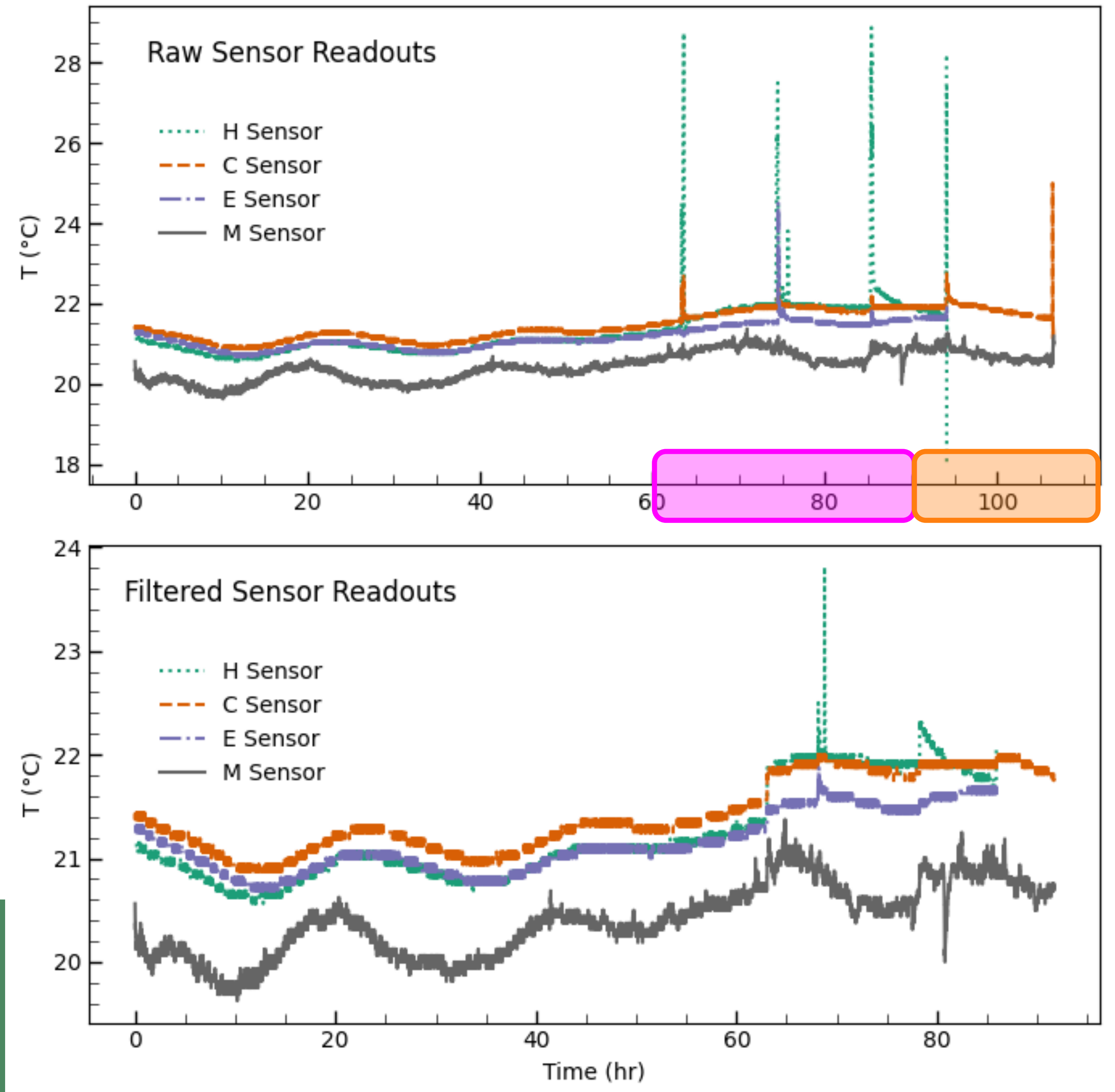


Image by Andi

Raw T.B. data

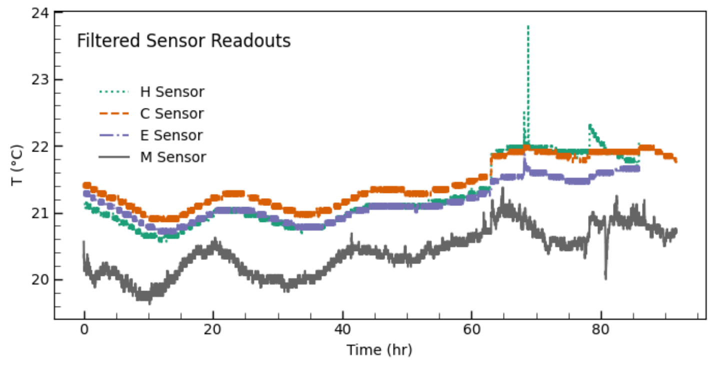
- Peaks due to interacting with the sensors
- Sensor readout fails in some areas
- Both areas not included in optimization

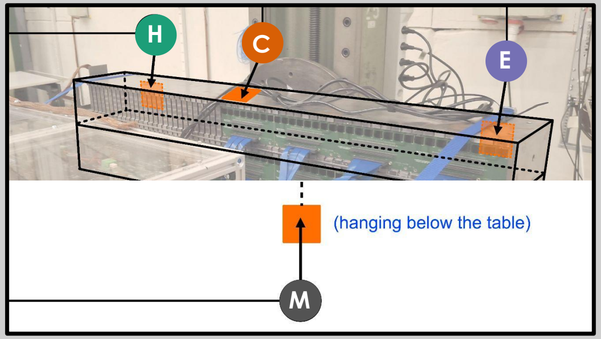


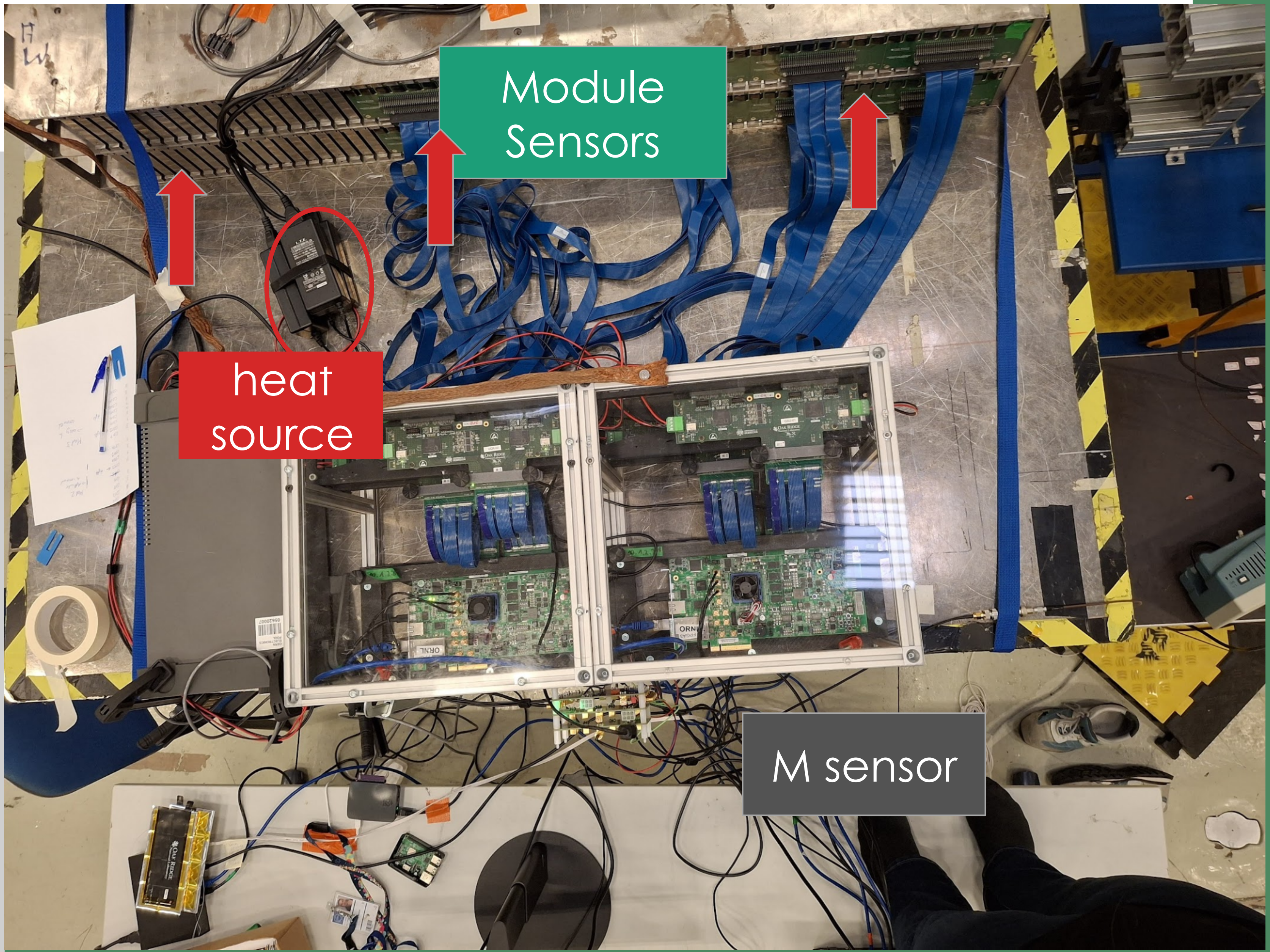


M's lower temp

- Current theory: M sensor isn't exposed to heat source



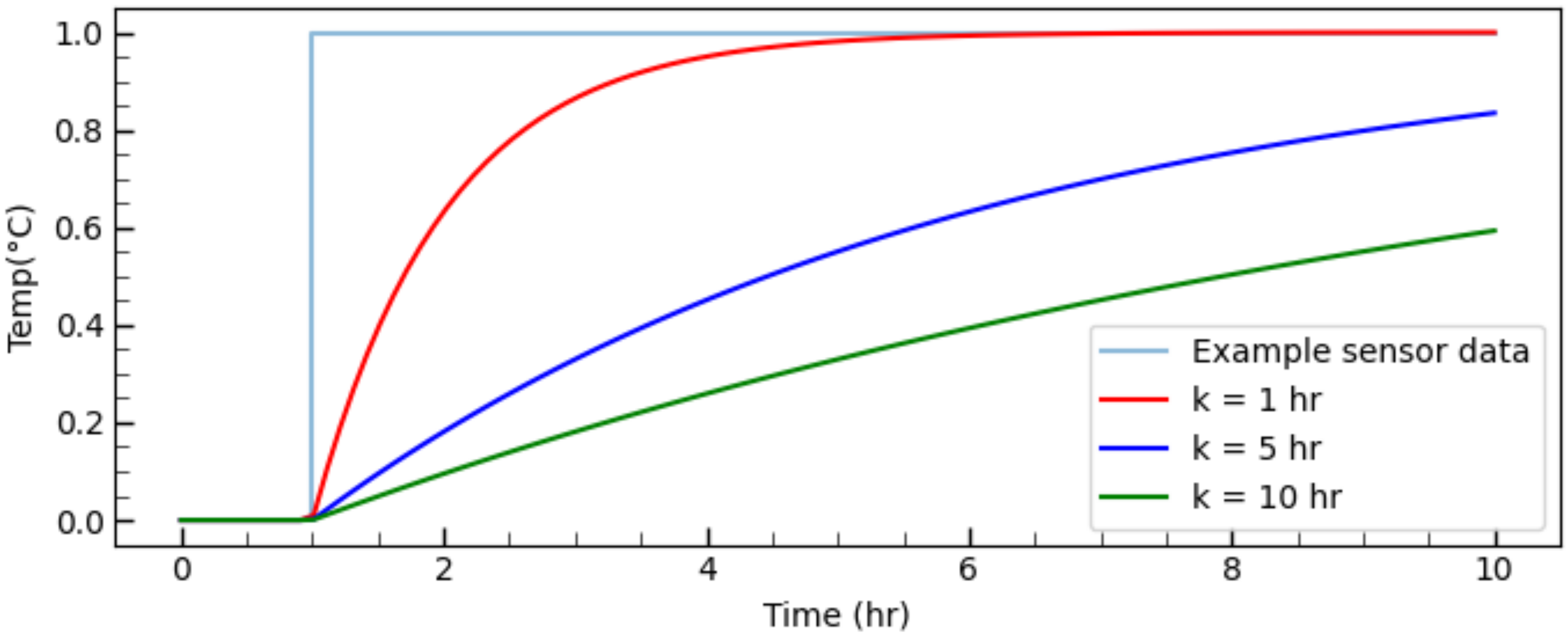




Air to Steel Temperature

Air temperature changes quicker than the steel of the module

- Must adjust the M sensor to predict the overall temperature of the steel



$$T_{Steel}(t) = T_{Air} + \Delta T(1 - e^{\frac{-t-t_i}{k}})$$

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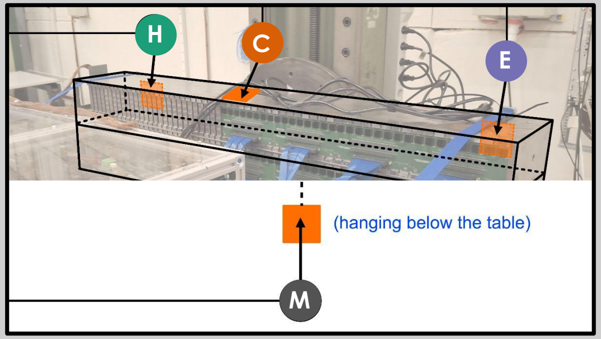
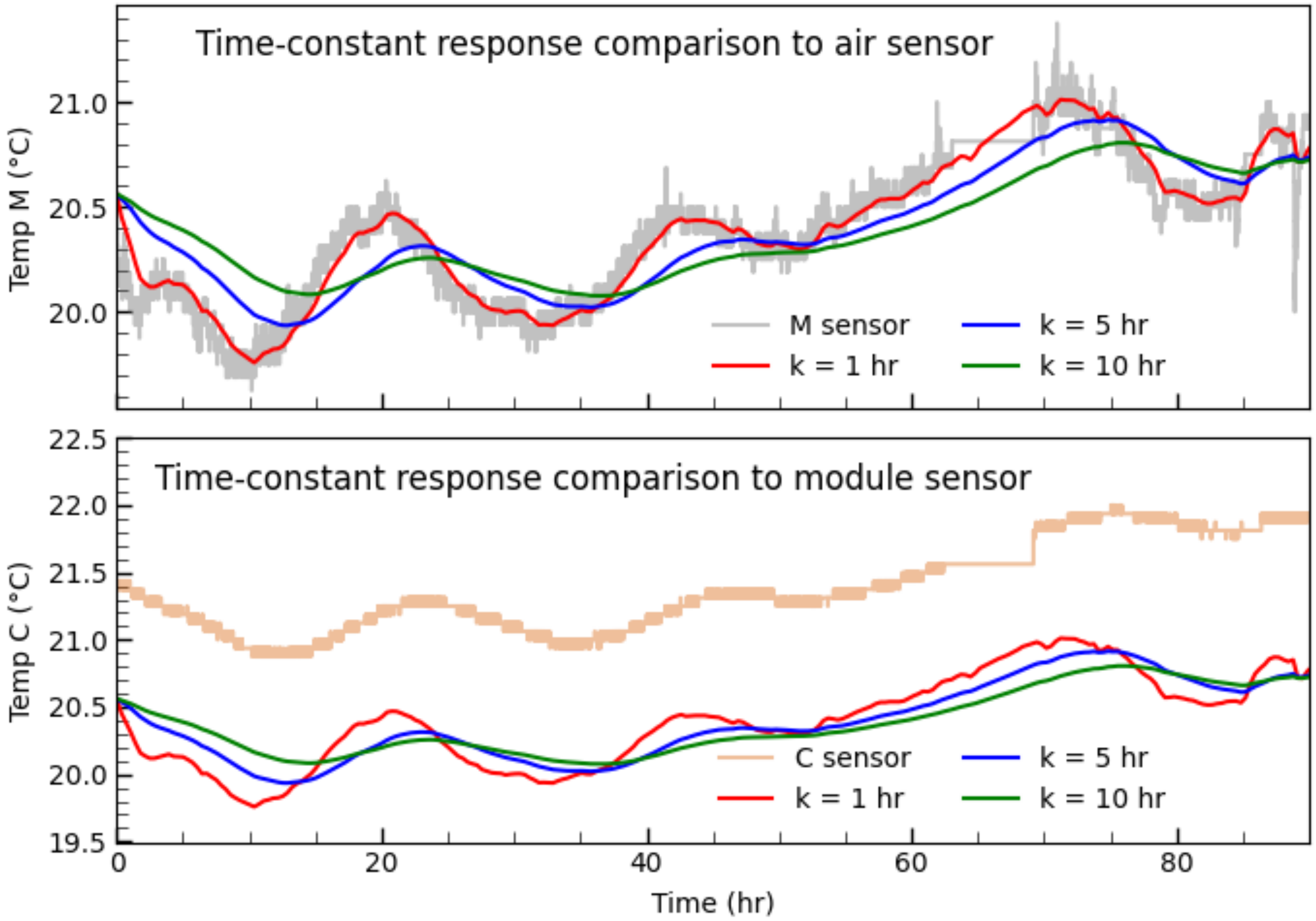
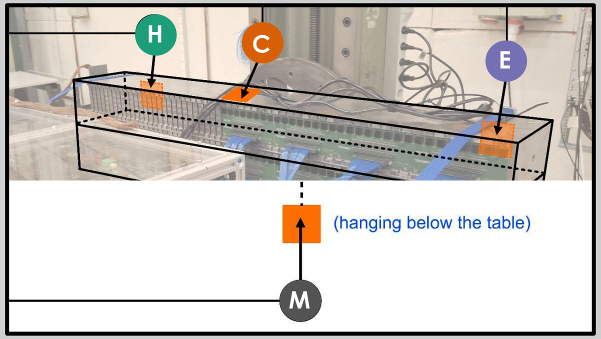


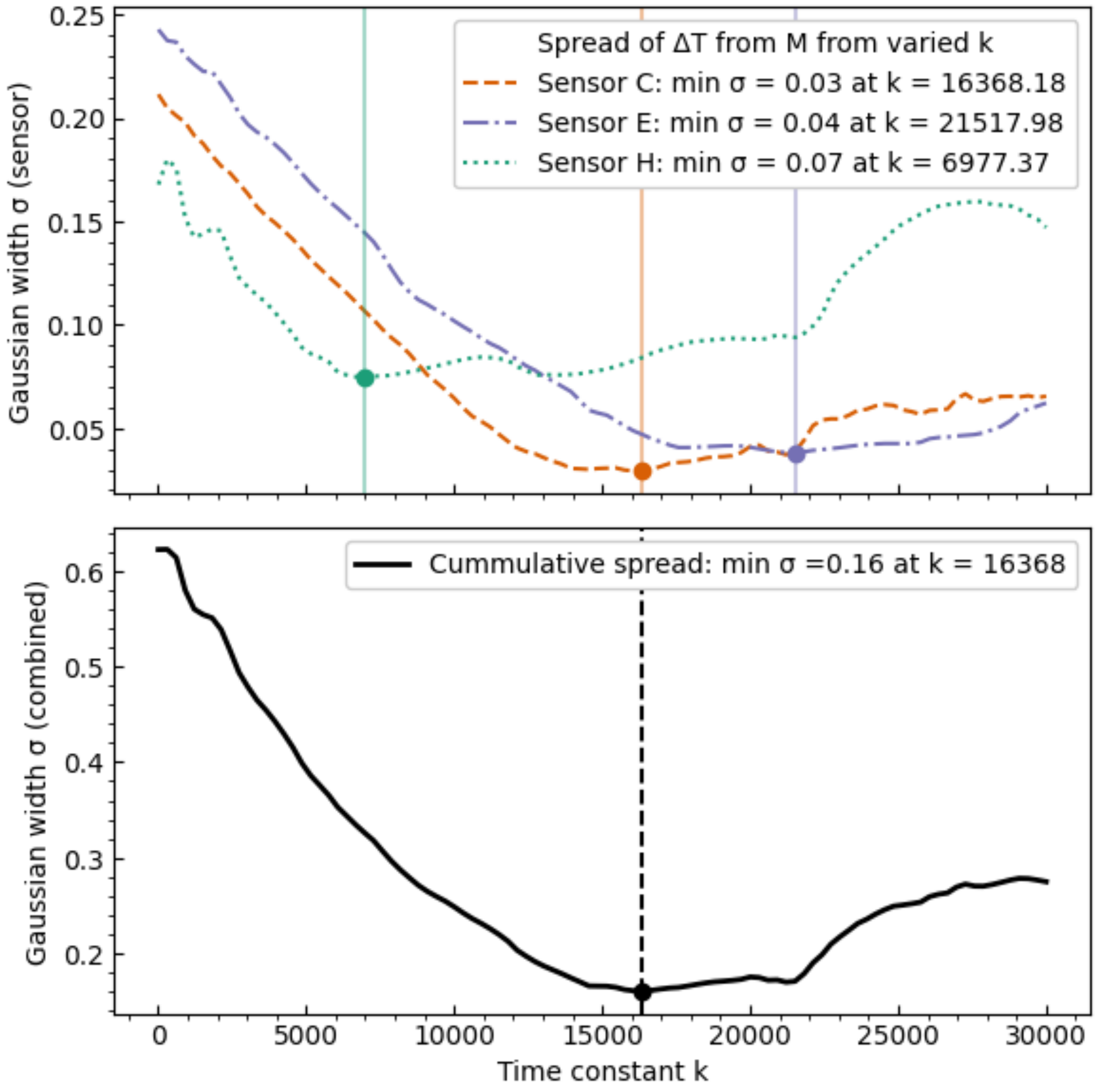


Deriving Optimal Time Constant

We want to find a time constant that best fits with our sensors that were on the steel

- Scan k values to find optimal value

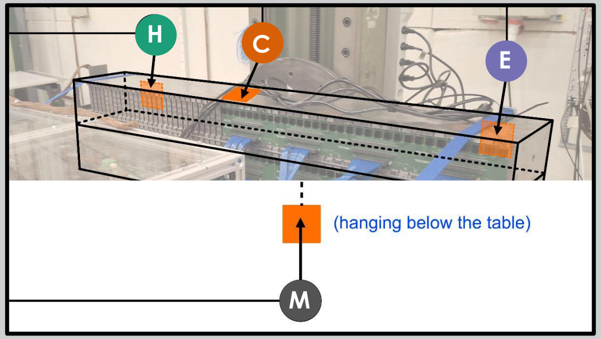


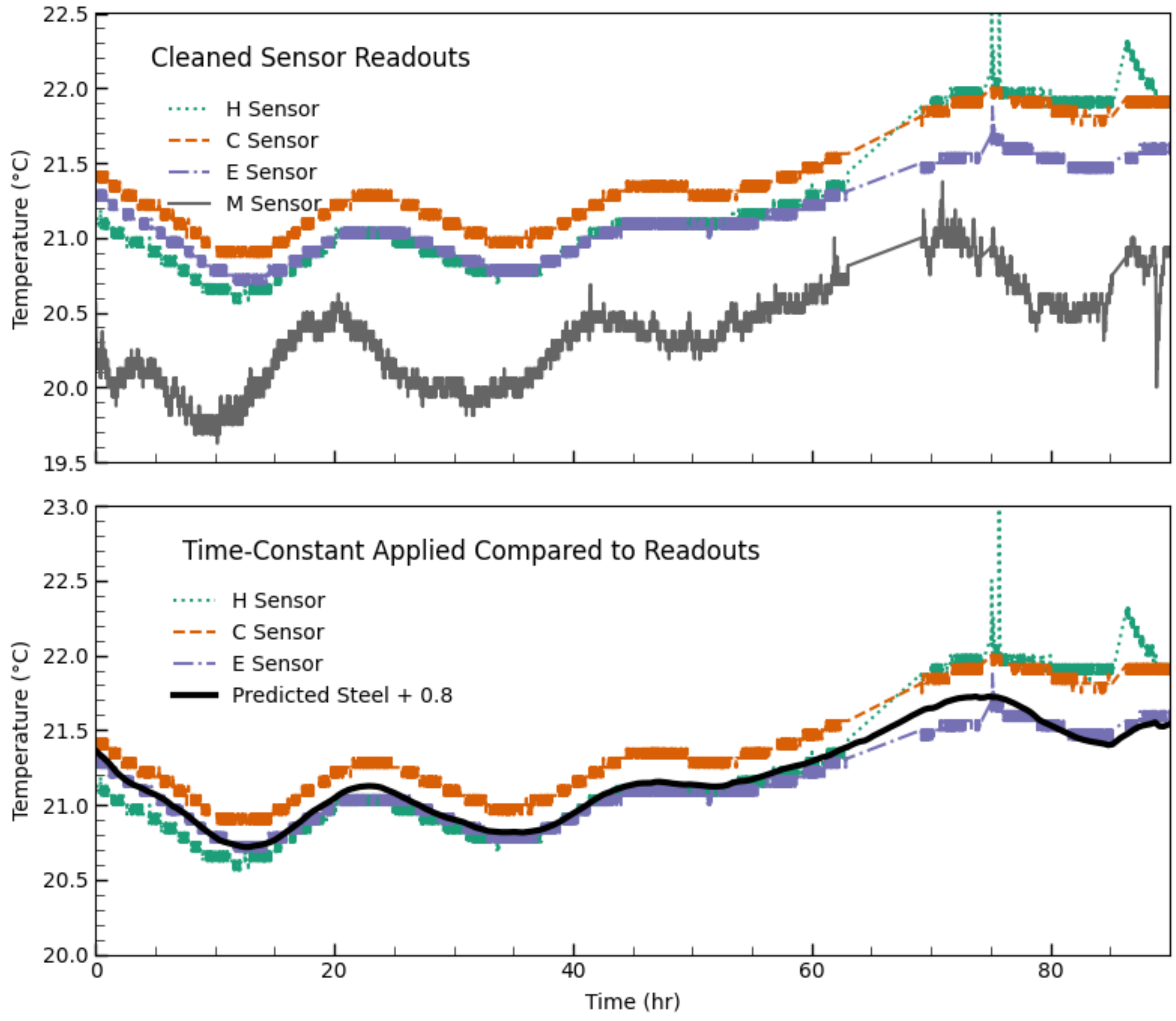


Best time constant ≅ 16370s ≅ 4.5 hr

Visualizing effects of optimization

- Predicted steel matches the sensors on the module when a small offset is applied





Theoretical Comparison

- Experimental value: 4.5 hr
- Consistent with theory:

$$\tau = \frac{C_{\text{th}}}{hA}$$

$$C_{\text{th}} \approx 6.1 \times 10^4 \text{ J/K}, \quad A = 0.568 \text{ m}^2, \quad h = 7 \text{ W m}^{-2} \text{K}^{-1}$$

$$\tau \approx 1.5 \times 10^4 \text{ s} \approx 4.3 \text{ hours}$$

- Geometry: $0.20 \times 0.10 \times 1.32 \text{ m}^3$
- Effective density: $\rho_{\text{eff}} = 5000 \text{ kg/m}^3$
- Natural convection (horizontal): $h \approx 7 \text{ W/m}^2\text{K}$
- Resulting thermal time constant: $\tau \approx 4.3$ h

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Questions left

- How precise are these sensors over long periods of time?
- Does the placement of these sensors impact their readout values?

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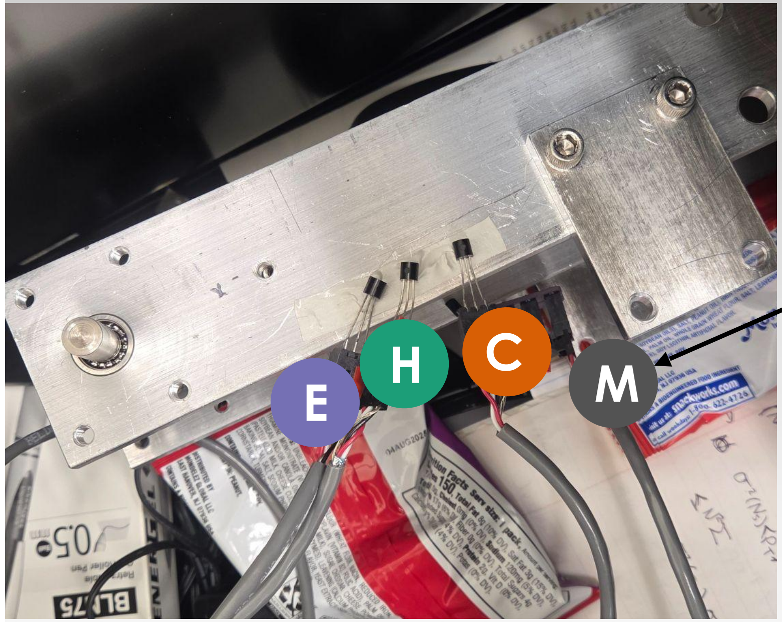
Uncertainty Set-ups

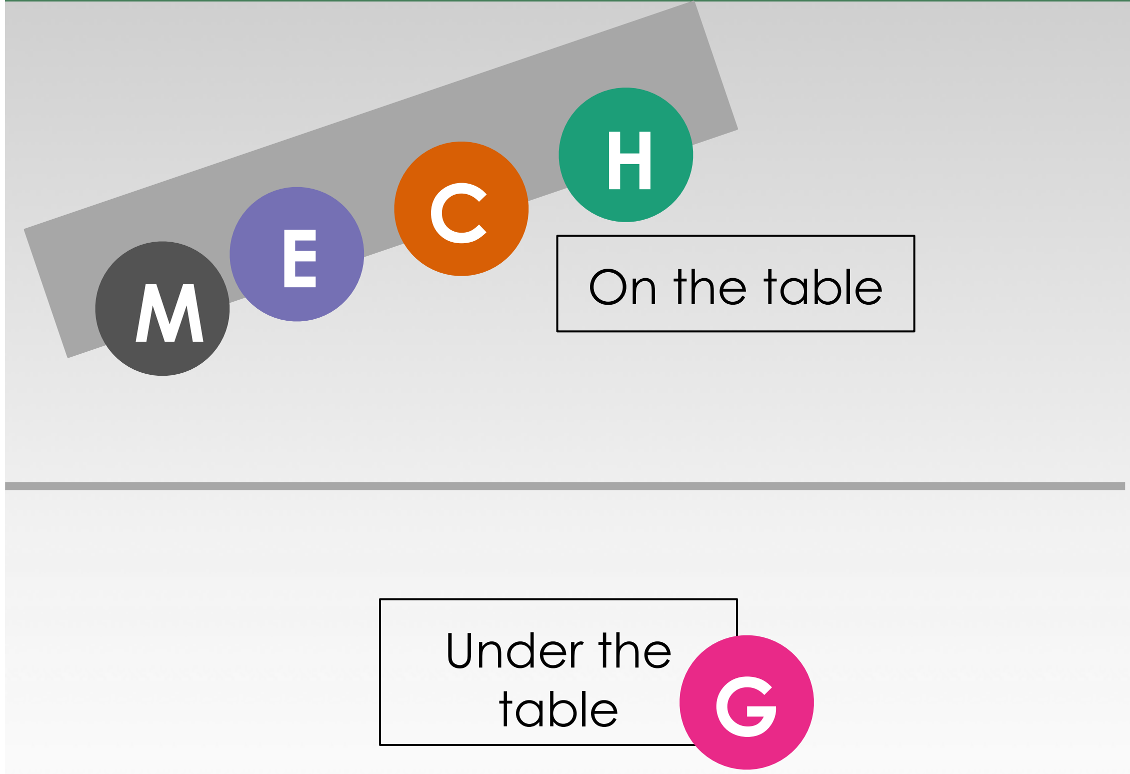
Standard Deviation



Was originally with others, must've fallen during the week

Run over a week

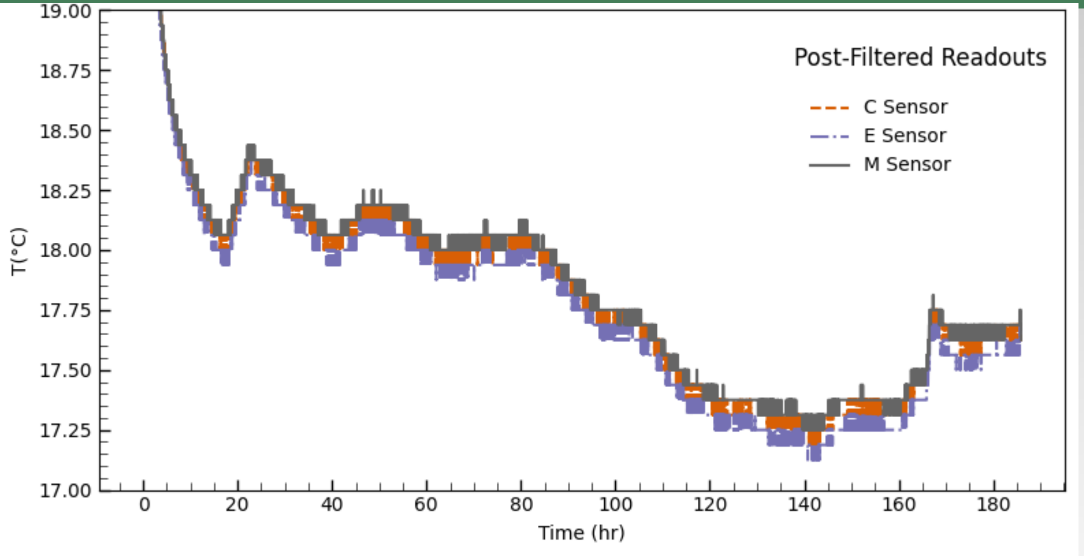
Placement - Dependence

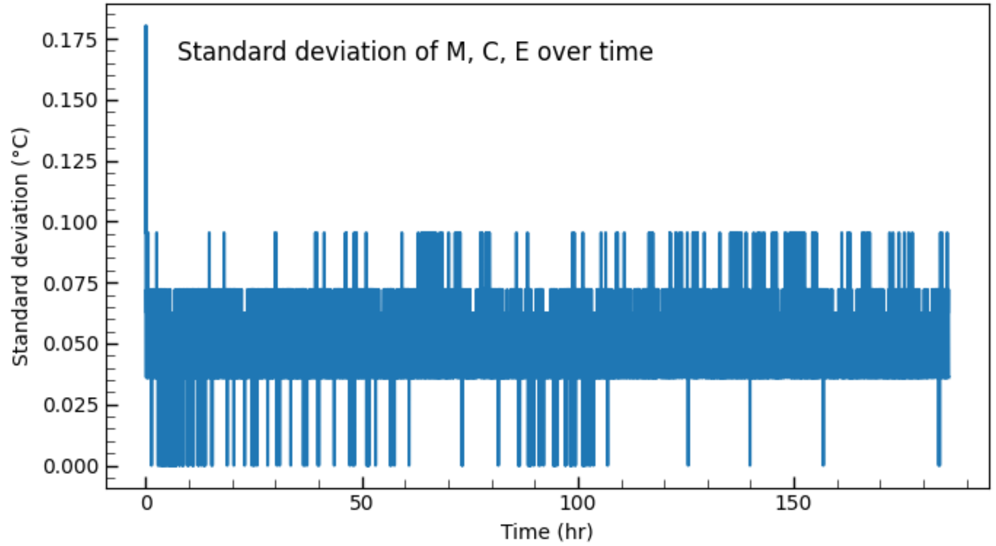


Run over a weekend

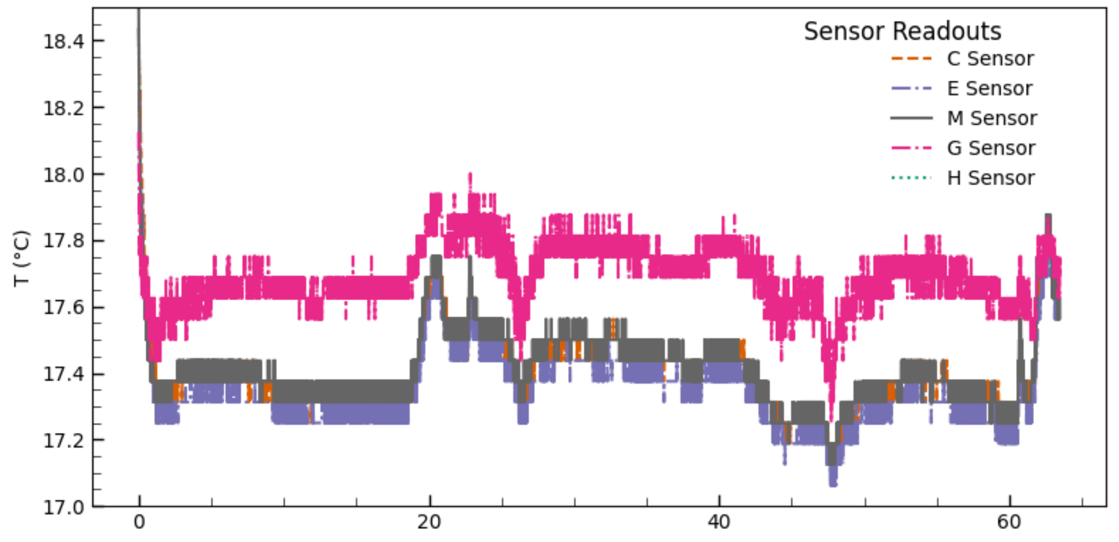
Uncertainty Data

Standard Deviation





Placement- dependence



- Why is G reading higher despite being placed lower?
  - Could it be due to which spot on fanout board it is placed in?

Summary

- We can switch between air temperature and steel’s
  - Though the SiPMs will likely be different than both of these
  - Could be used to fill gaps in data if sensor fails
- Sensors are precise

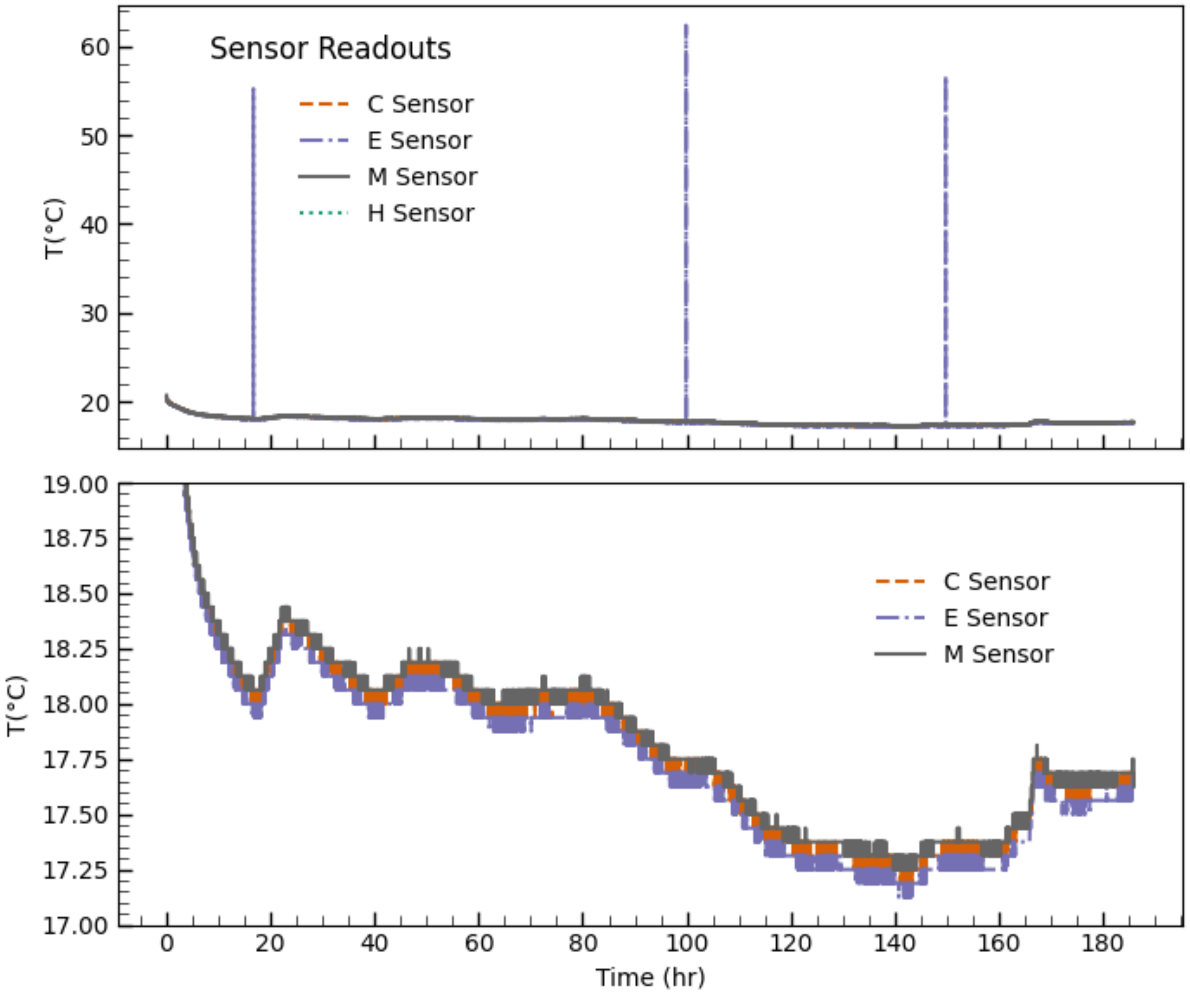
Questions still yet to be answered:

- How accurate are the sensors to the actual temperature?
- Does the location on the fan out board impact the sensor readout?
- How do we account for the heat source near the modules?

Backups

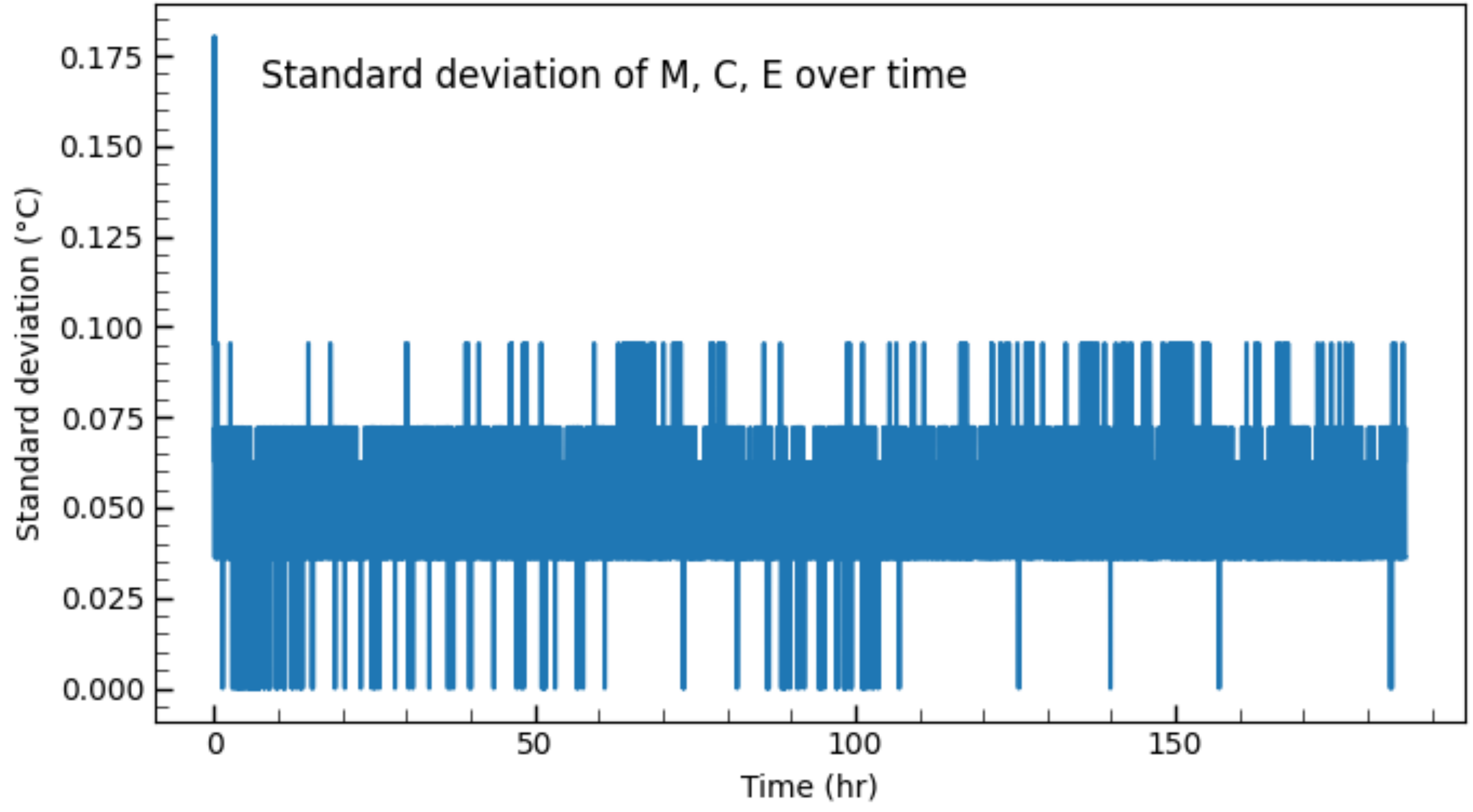
Uncertainty Filtering

- Sharp peaks in E sensor, use median filtering to correct it
- H sensor doesn't read out, so we exclude that and J in analysis



Standard Deviation

- Between sensor M, C, E across time
- Pretty small, shows consistency



$$\sigma(t) = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(x_i(t) - \bar{x}(t)\right)^2}$$