

Moveable Thermometer System in ProtoDUNE

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for the DUNE Collaboration

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Moveable Thermometer System in ProtoDUNE

- The Deep Underground Neutrino Experiment (DUNE) will employ the largest Liquid Argon Time-Projection Chamber (LArTPC), to date, as its far detector.

• Precision Temperature Measurements

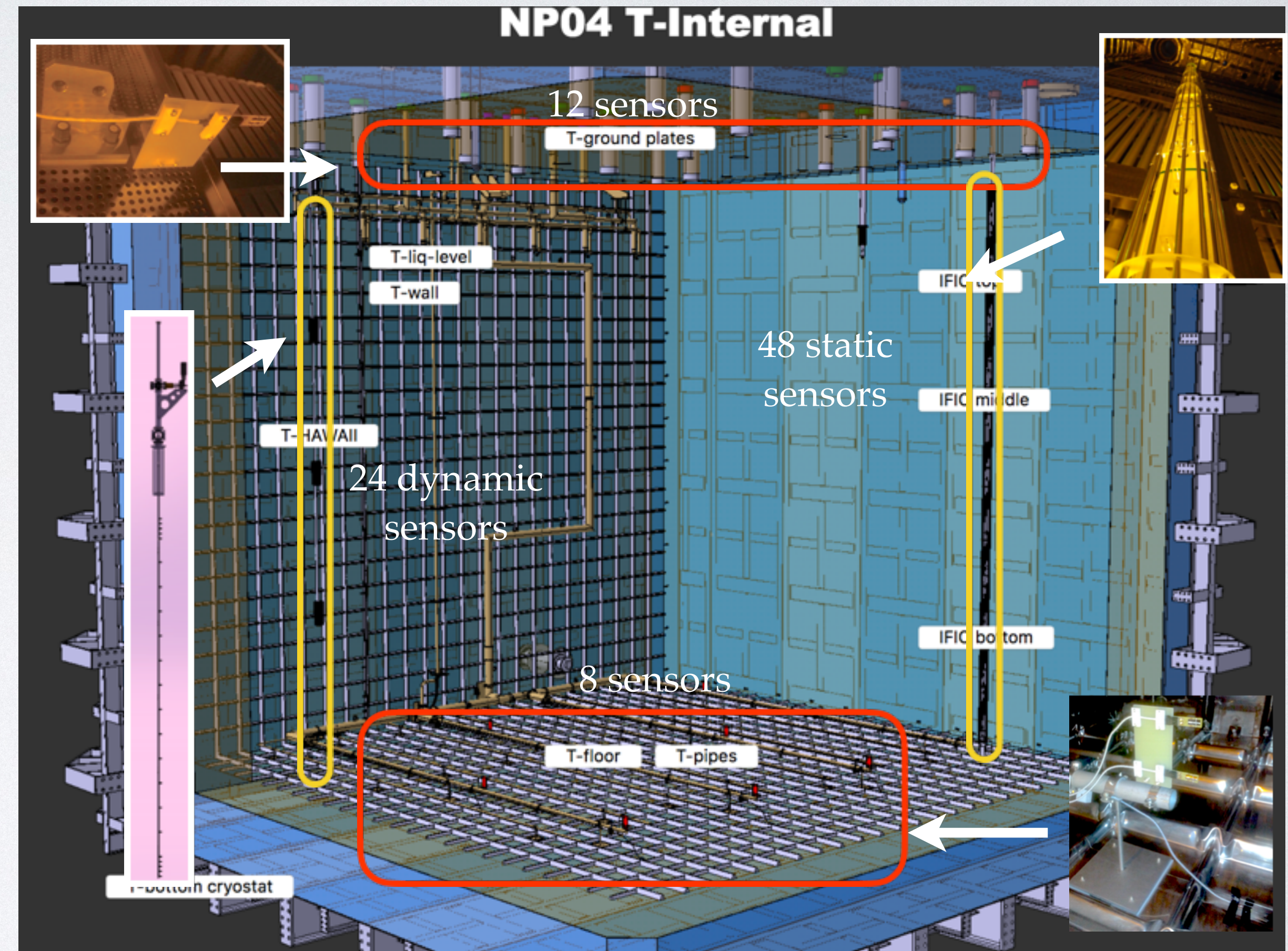
• Monitor detector during operations

• Constrain simulations & modelling.
• Understand electron-lifetime, drift velocity, ion flow

• Physics results

- Precise monitoring of the 17 kilo-ton (10 kilo-ton fiducial mass) liquid Argon temperature will be crucial to achieve the ultimate physics goals of the experiment.

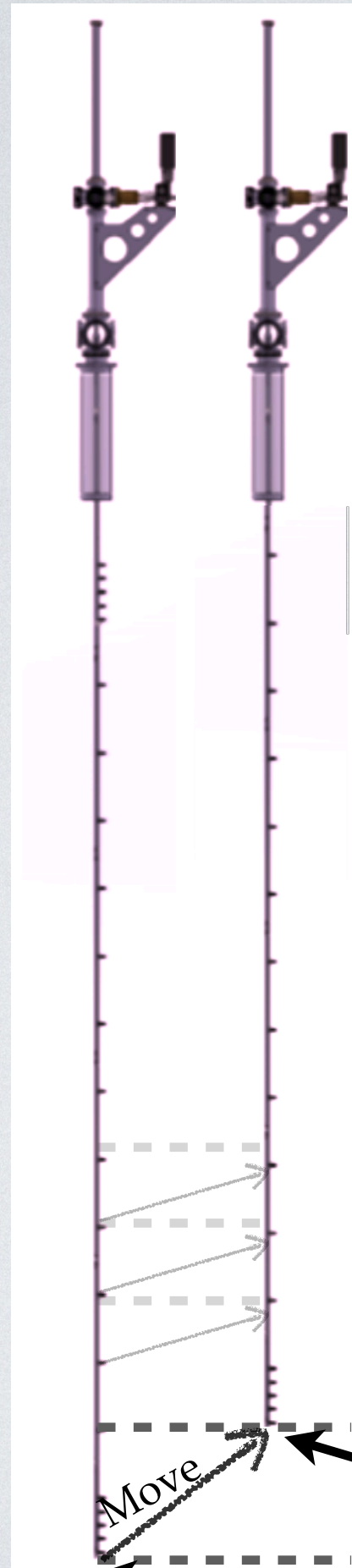
- ProtoDUNE is a 0.7 kilo ton scale prototype at the CERN Neutrino Platform and a test-bed to evaluate technologies for the eventual DUNE experiment.



Schematic showing various temperature sensors and their location in the ProtoDUNE cryostat. The dynamic temperature profiler is shown on the left.

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- The dynamic temperature profiler is a 7.5 meter moveable vertical array of 24 sensors, capable of measuring cryogenic temperatures with a precision of few milli kelvin.



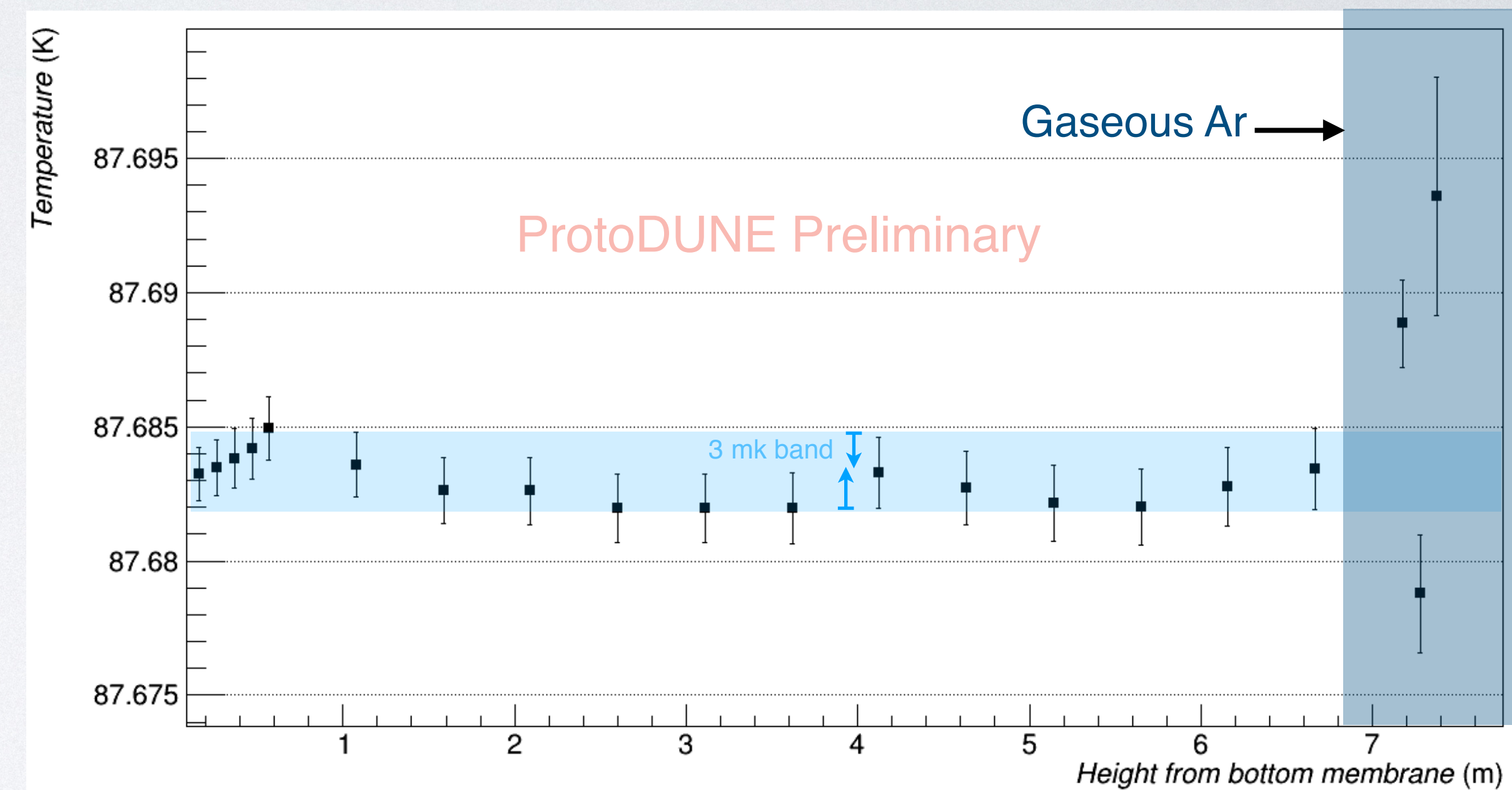
- In the schematic on left:

$$\text{Offset}_{(\text{Sensor6})} = T_{(\text{Sensor6})} - T_{(\text{Sensor1 @ location of Sensor6})}$$
- Mechanical constraints limit the number of moves and some locations are probed by multiple sensors.
- Given a certain number of moves, sensors, and temperatures we can extrapolate using a χ^2 minimization technique:

$$\chi^2 = (S_1 - T_1) + (S_2 - \text{offset}_2 - T_1) + (S_1 - T_2) \\ \dots + (S_n - \text{offset}_n - T_{(n-1)}) \dots$$

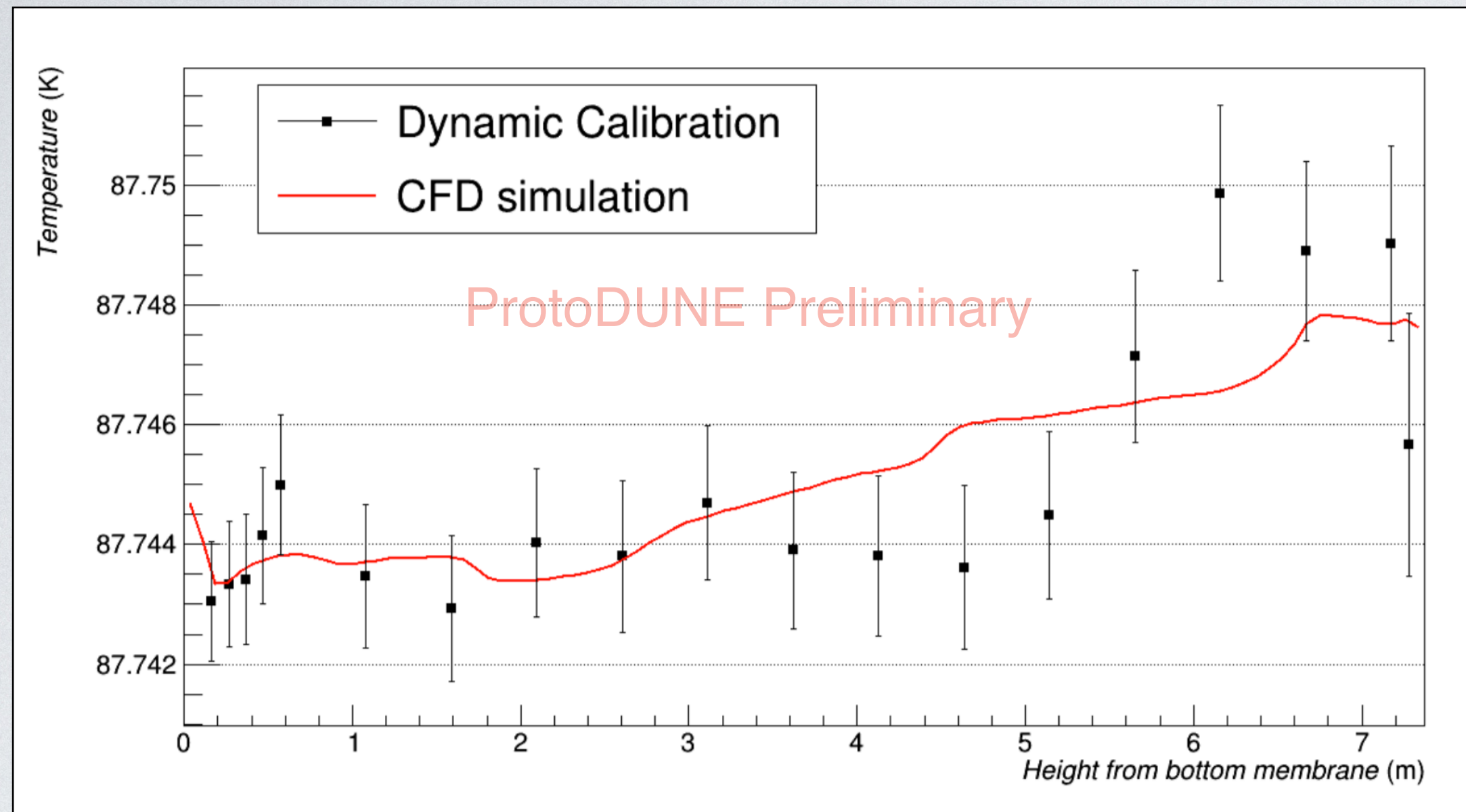
Sensor1 @ location of sensor 6

Sensor1 @ location 1

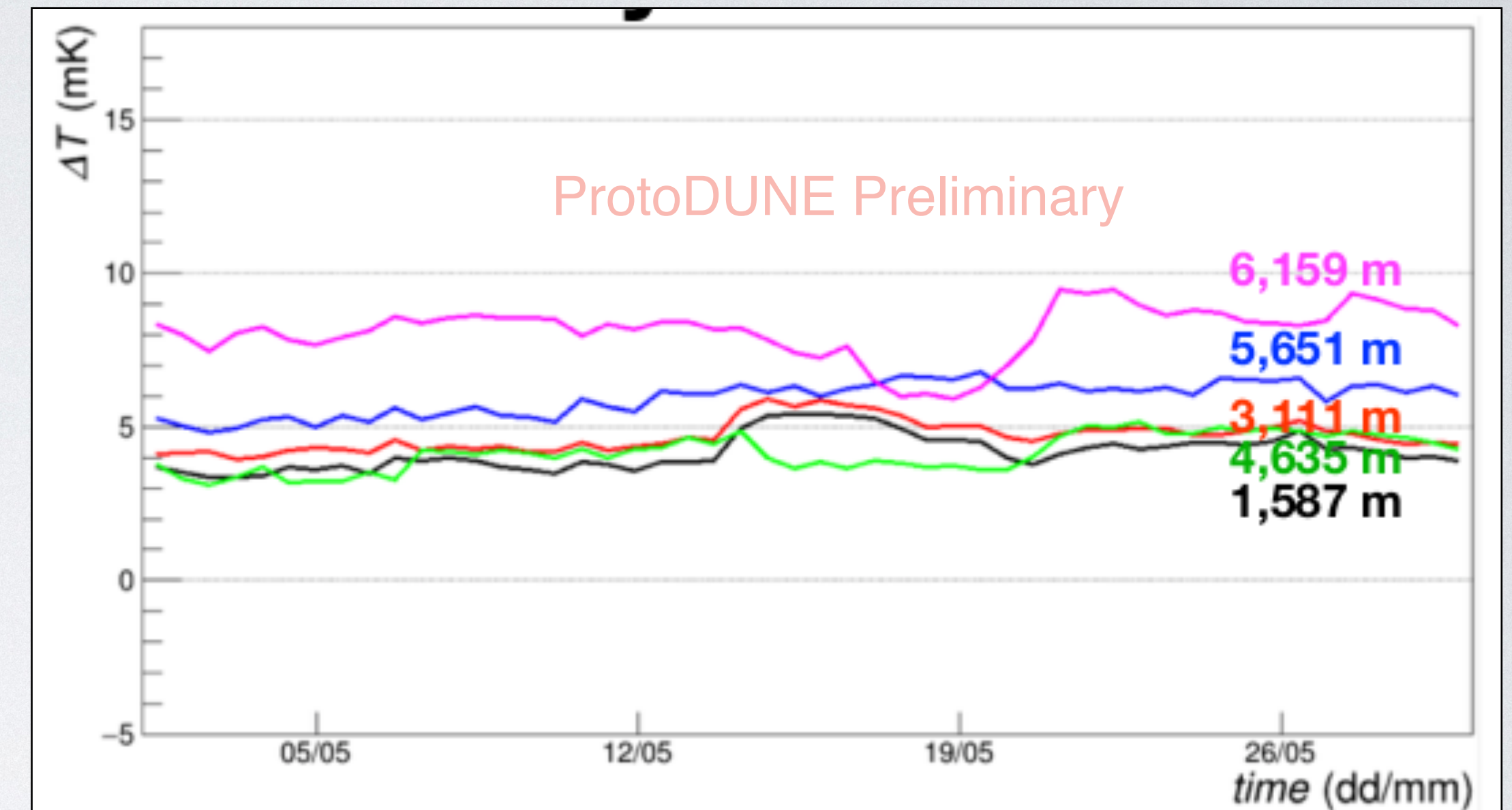


- Including the offsets corrects for residual parasitic resistance and electromagnetic noise and yields a relative accuracy of 2-3mK.

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- The ability to move the sensors vertically is utilized to cross-calibrate the static sensors. The sensor values are then used to validate Computational Fluid Dynamic (CFD) models of liquid Argon in the detector.



- Stability of the dynamic temperature profiler over two months is shown below. Here ΔT is the difference between the bottom-most sensor and the sensor at the heights shown.

Conclusions:

- The dynamic temperature profiler was continuously operating in ProtoDUNE since fall 2018. The system has been stable and exhibited no fatigue in cryogenic operation.
- The system has an outstanding accuracy of around 2 to 3 mK.