Moveable Thermometer System in ProtoDUNE

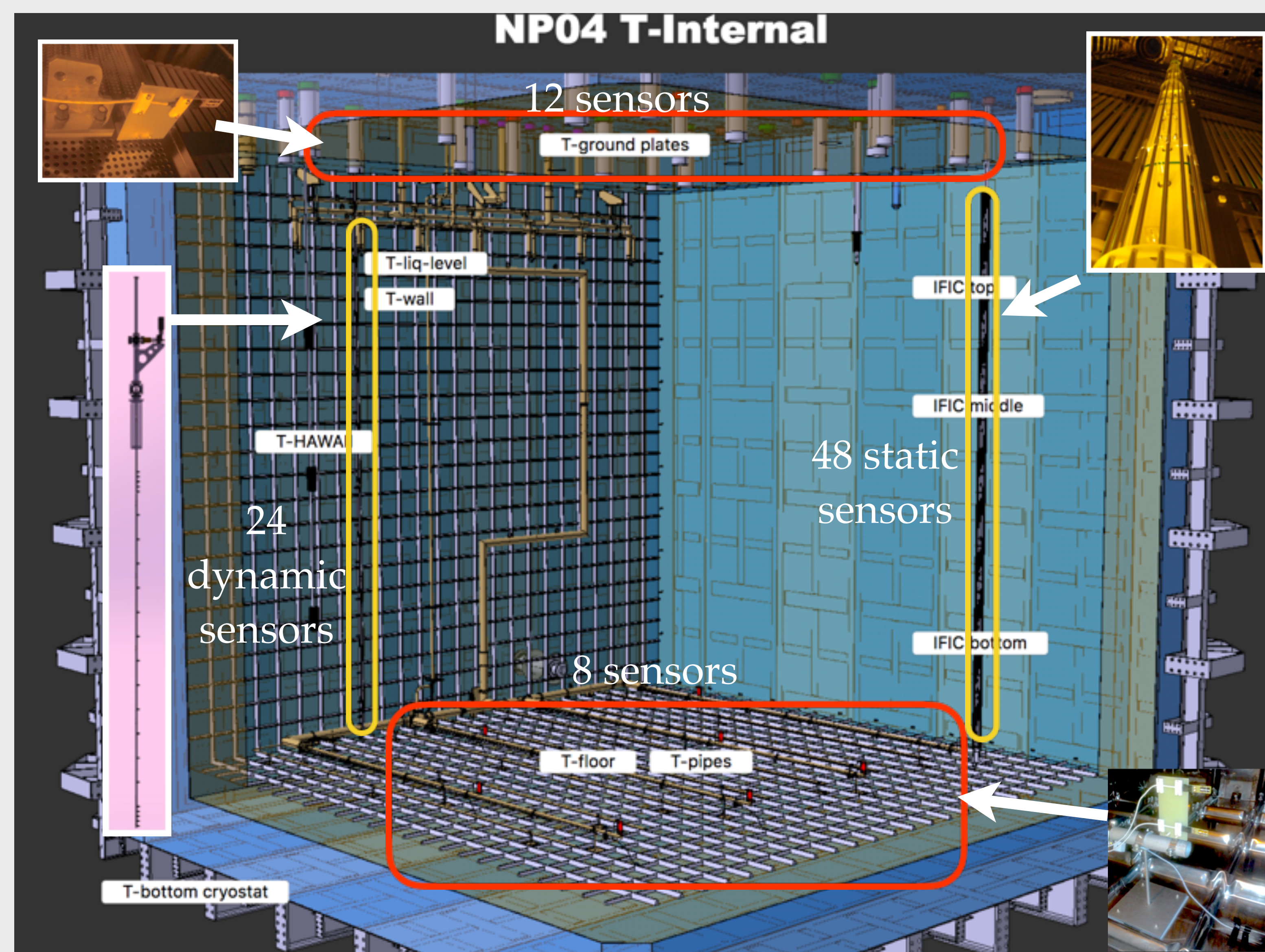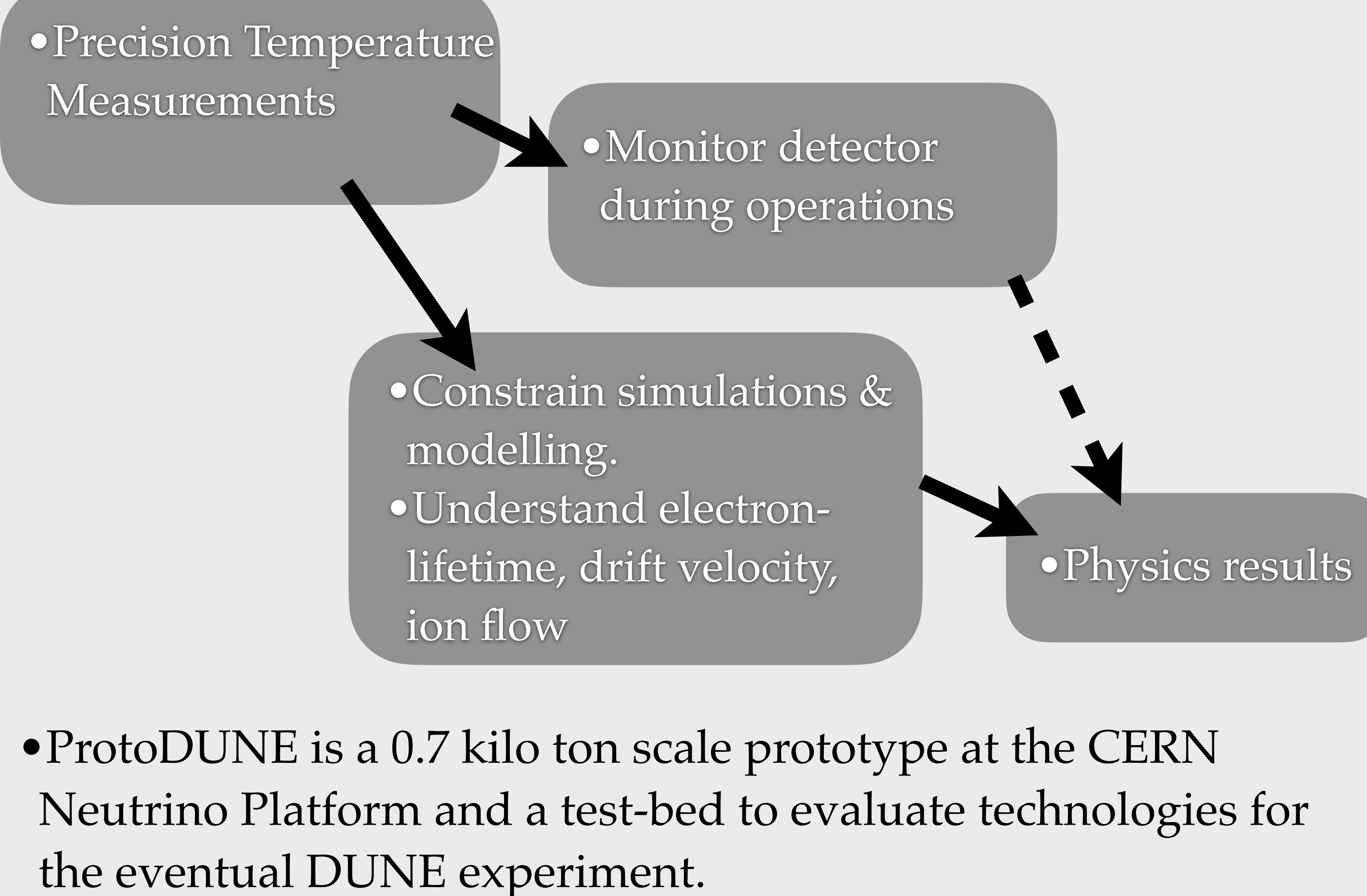Ranjan Dharmapalan for the DUNE Collaboration

Introduction

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

- Precise monitoring of the The 17 kilo-ton (10 kilo-ton fiducial mass) liquid Argon temperature will be crucial to achieve the ultimate physics goals of the experiment.
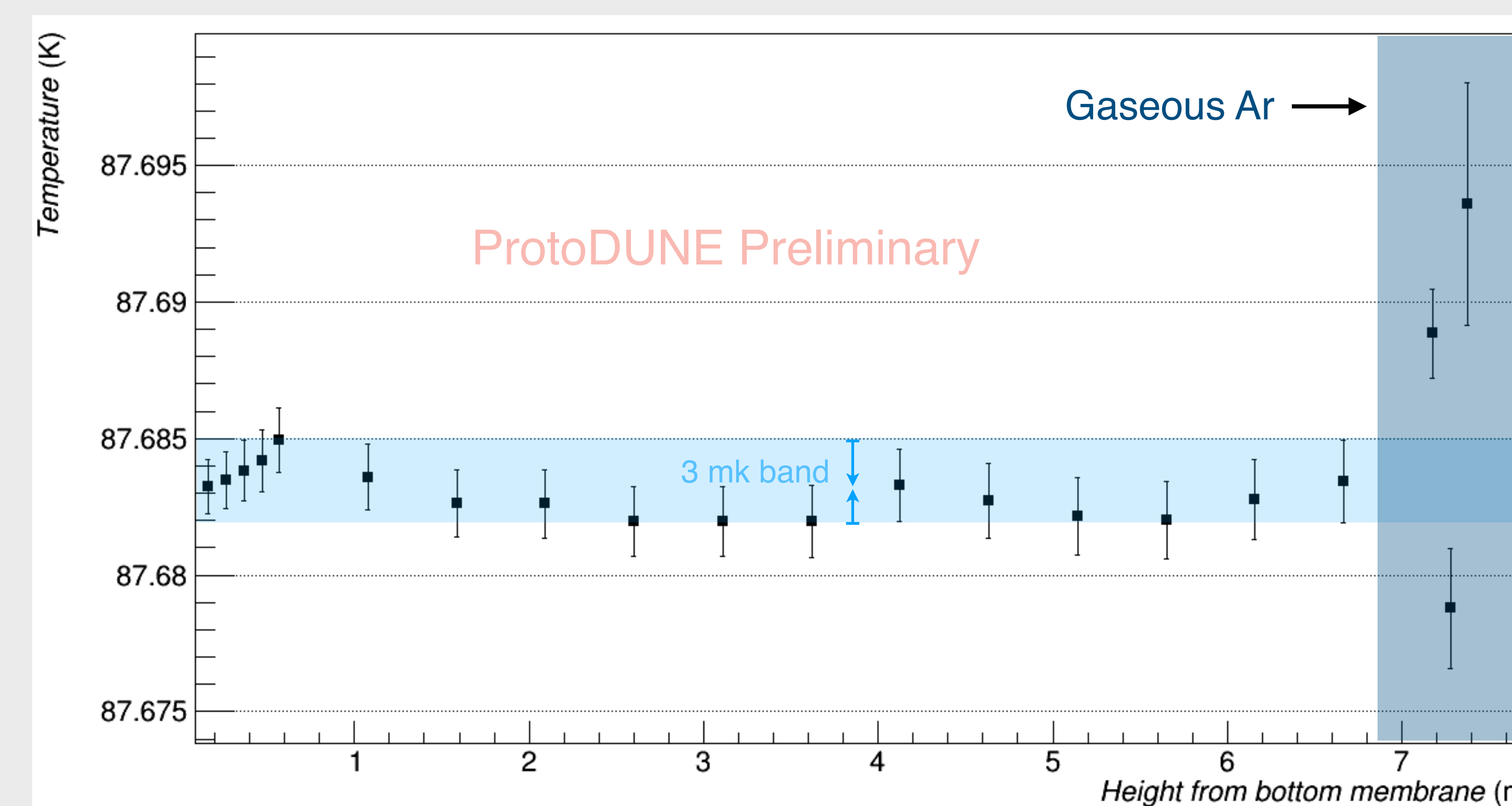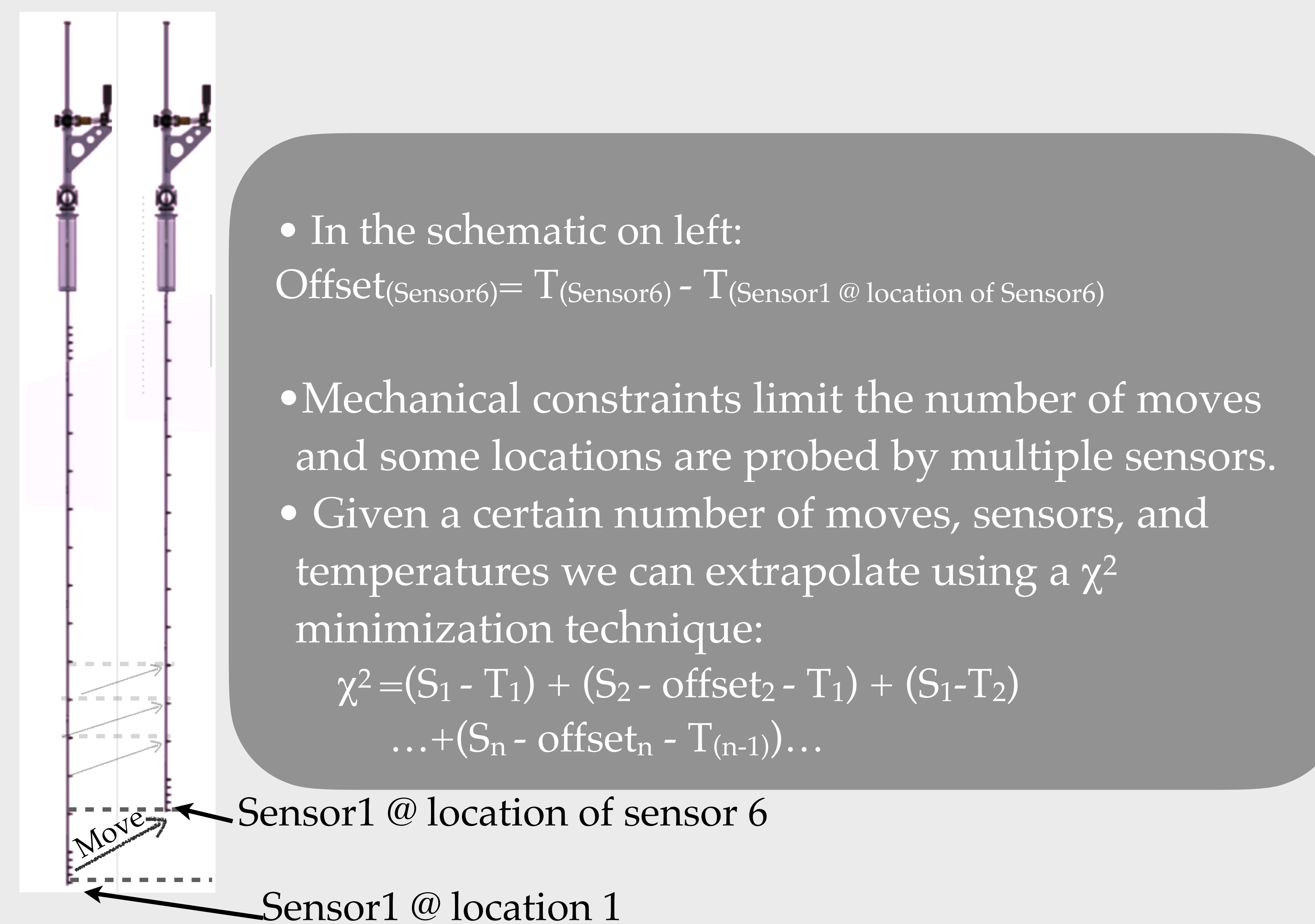
- Precision Temperature Measurements
- Monitor detector during operations
- Constrain simulations & modelling.
- Understand electron-lifetime, drift velocity, ion flow
- Physics results

- 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.

NP04 T-Internal

12 sensors
48 static sensors
24 dynamic sensors
8 sensors

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

Dynamic Temperature Profiler

- 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.
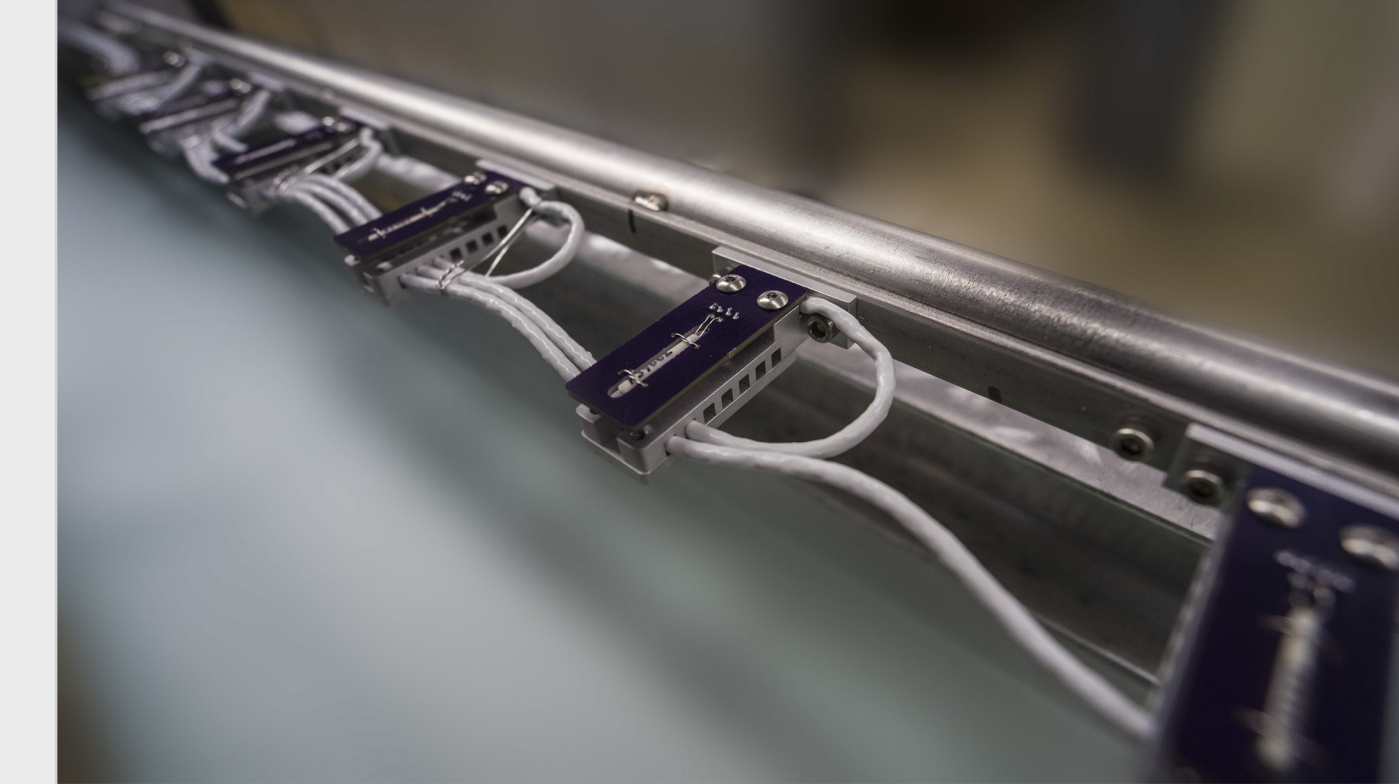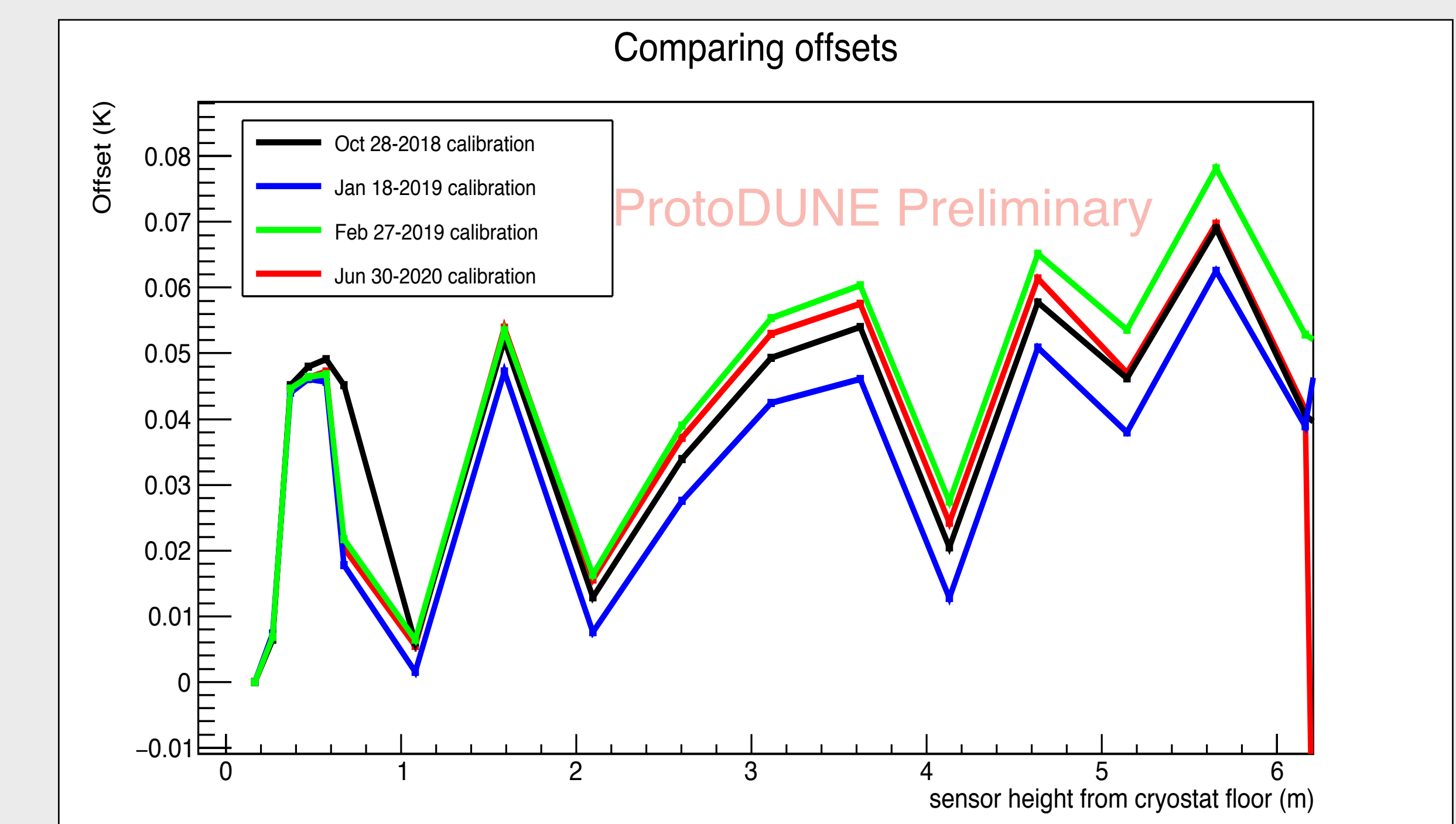
- The ability to move the dynamic profiler, allows for cross-calibration of the sensors.


- In the schematic on left:

$$\text{Offset}_{(Sensor6)} = T_{(Sensor6)} - T_{(Sensor1 @ location of Sensor6)}$$

- 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

ProtoDUNE Preliminary

Gaseous Ar

3 mk band

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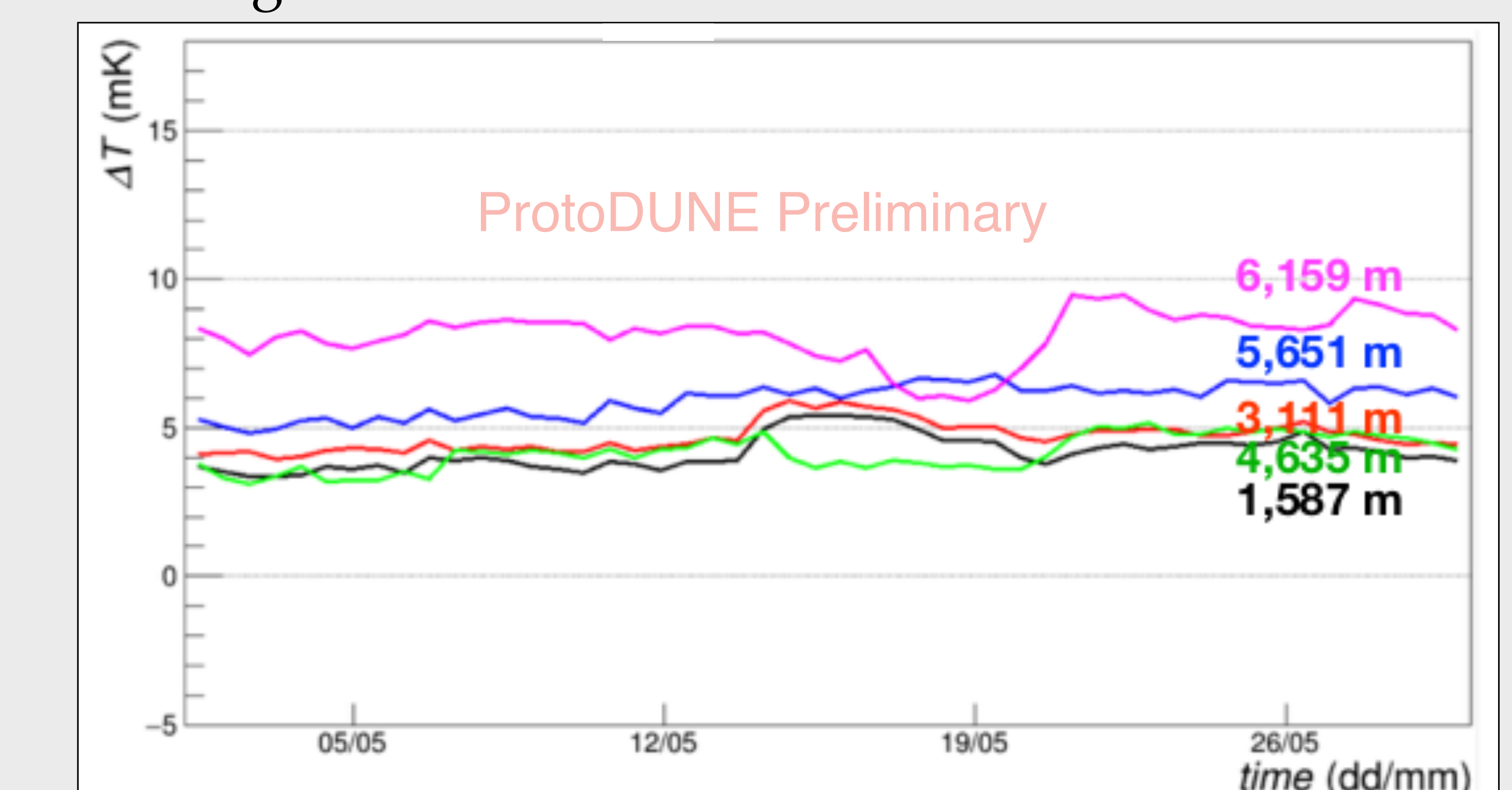
Operation at ProtoDUNE

- The sensor offsets are consistent over the four calibration campaigns. The differences are due to local variations during movement and small compared to the overall offset.

Comparing offsets

Oct 28-2018 calibration
Jan 18-2019 calibration
Feb 27-2019 calibration
Jun 30-2020 calibration

ProtoDUNE Preliminary

- 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.

Dynamic Calibration
CFD simulation

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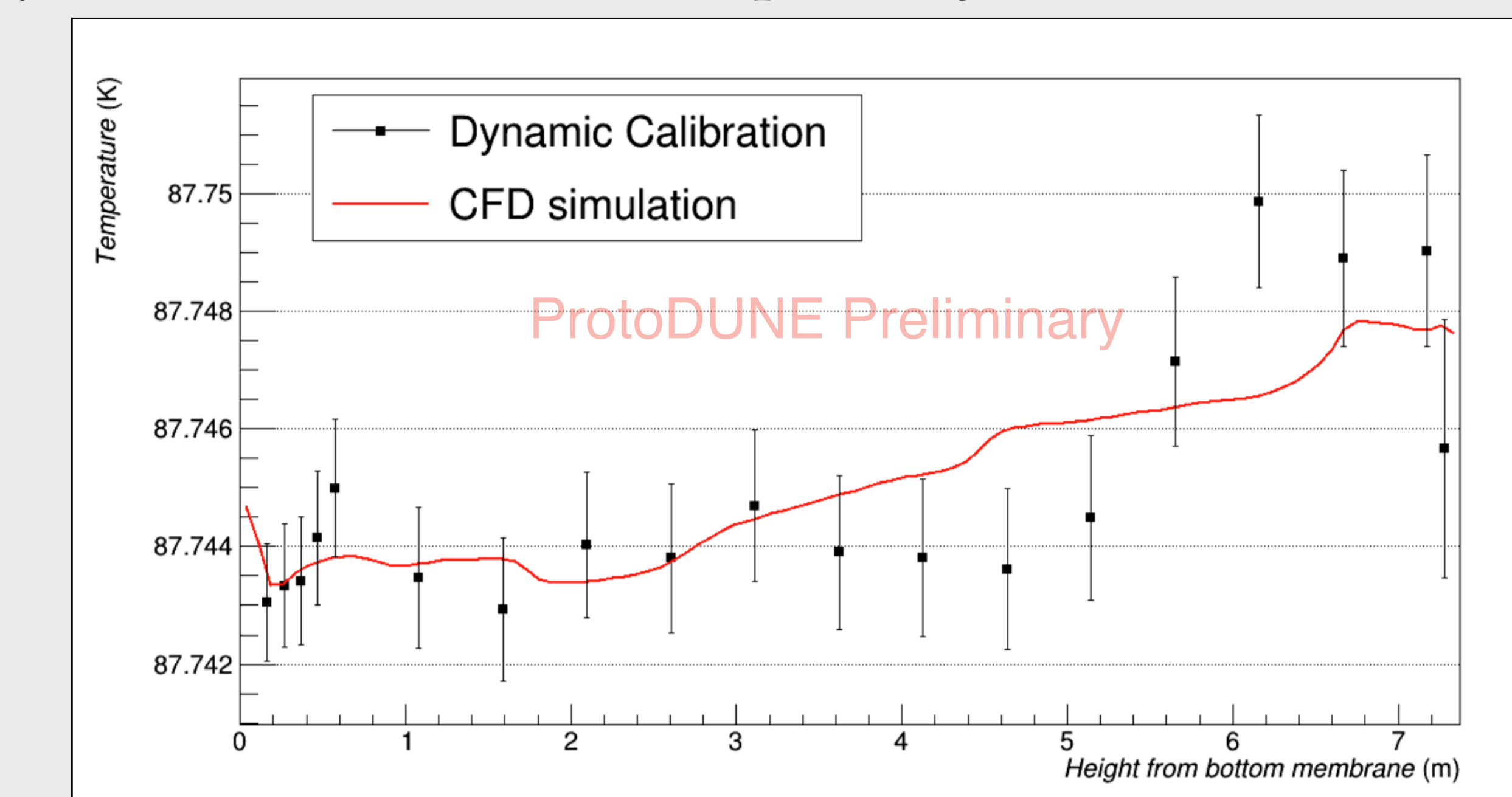
- Stability of the dynamic temperature profiler over two months is shown below. Here ΔT is the difference between the bottom-most sensor and the sensor at the heights shown.

ProtoDUNE Preliminary

6,159 m
5,651 m
3,111 m
4,635 m
1,587 m

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.