Temperature & Pressure Evolution during Cool Down

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Outline

- Heat input & temperature evolution during cool down
- Temperature evolution in Insulation
- Temperatures and pressures in SGFT chimneys
- Pressures in insulation & tank during cool down

Heat input

Source	Heat input during cool down	Heat input during operation at 87 K
Membrane surface	$0.972\frac{W}{K} \times \Delta T$	200 W
Chimneys	$1.94\frac{W}{K} \times \Delta T$	400 W
Top-cap	$0.29\frac{W}{K} \times \Delta T$	60 W
Wires	$0.028\frac{W}{K} \times \Delta T$	5.8 W
Electronics	0 W	23 W
Pump	0 W	300 W
Warm gas pumped in	$7.1\frac{W}{K} \times \Delta T$	0 W
Evaporation of liquid	- 1344 W	0 W
Warming up of evaporated liquid	$4.28\frac{W}{K} \times (\Delta T - 206K)$	0 W
	14.95 W/K × ΔT – 2256 W	982 W

Temperature evolution during cool down

Assuming the internal energy of Argon in tank is proportional to its temperature, we get:

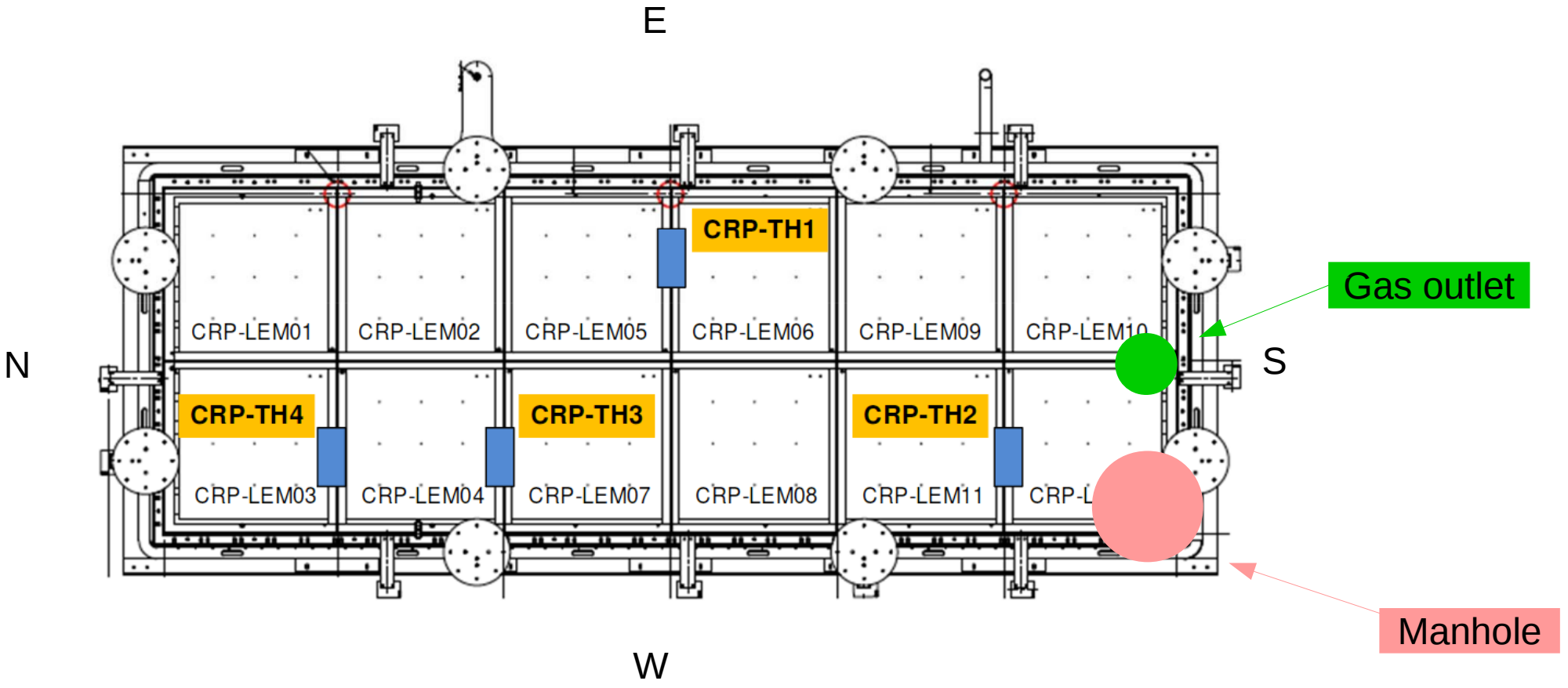
$$-\mathrm{C}\frac{\mathrm{d}\Delta\mathrm{T}}{\mathrm{dt}} = \quad 14.59\frac{\mathrm{W}}{\mathrm{K}} \times \Delta\mathrm{T} - 2256\,\mathrm{W}$$

With the following solution:

$$\Delta\mathrm{T}(\mathrm{t}) = \; 154.7\,\mathrm{K} \times \left(1 - \exp\left[-\frac{14.59\,\frac{\mathrm{W}}{\mathrm{K}} \times \mathrm{t}}{\mathrm{C}}\right]\right)$$

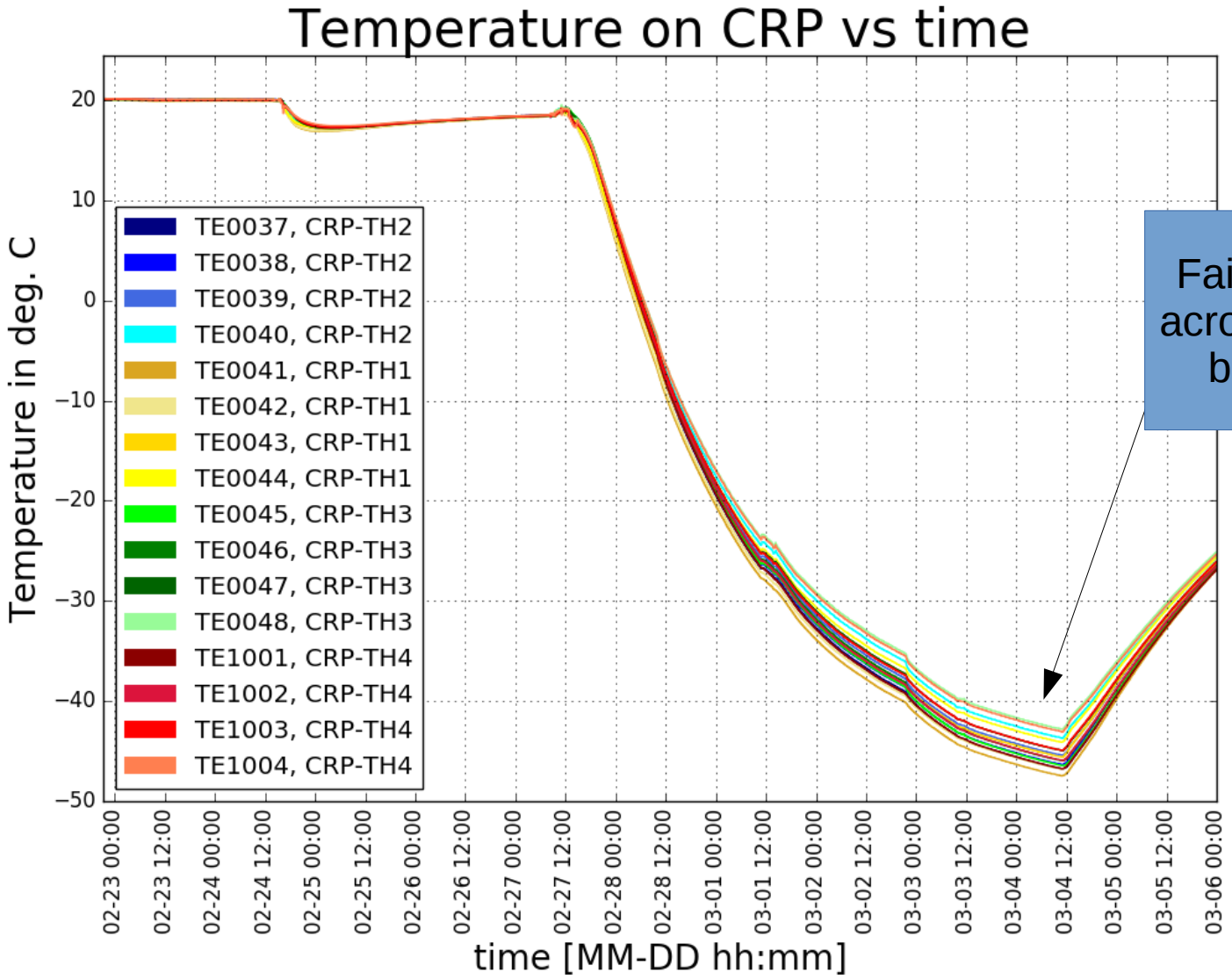
Thus **ΔT → 155 K** for **t → ∞** and $\mathbf{T_{tank}}$ **→ 138 K** ($\mathbf{T_{LAr}}$ **= 87 K**)

Temperature evolution during cool down



16 temperature sensors
in 4 groups of 4 each

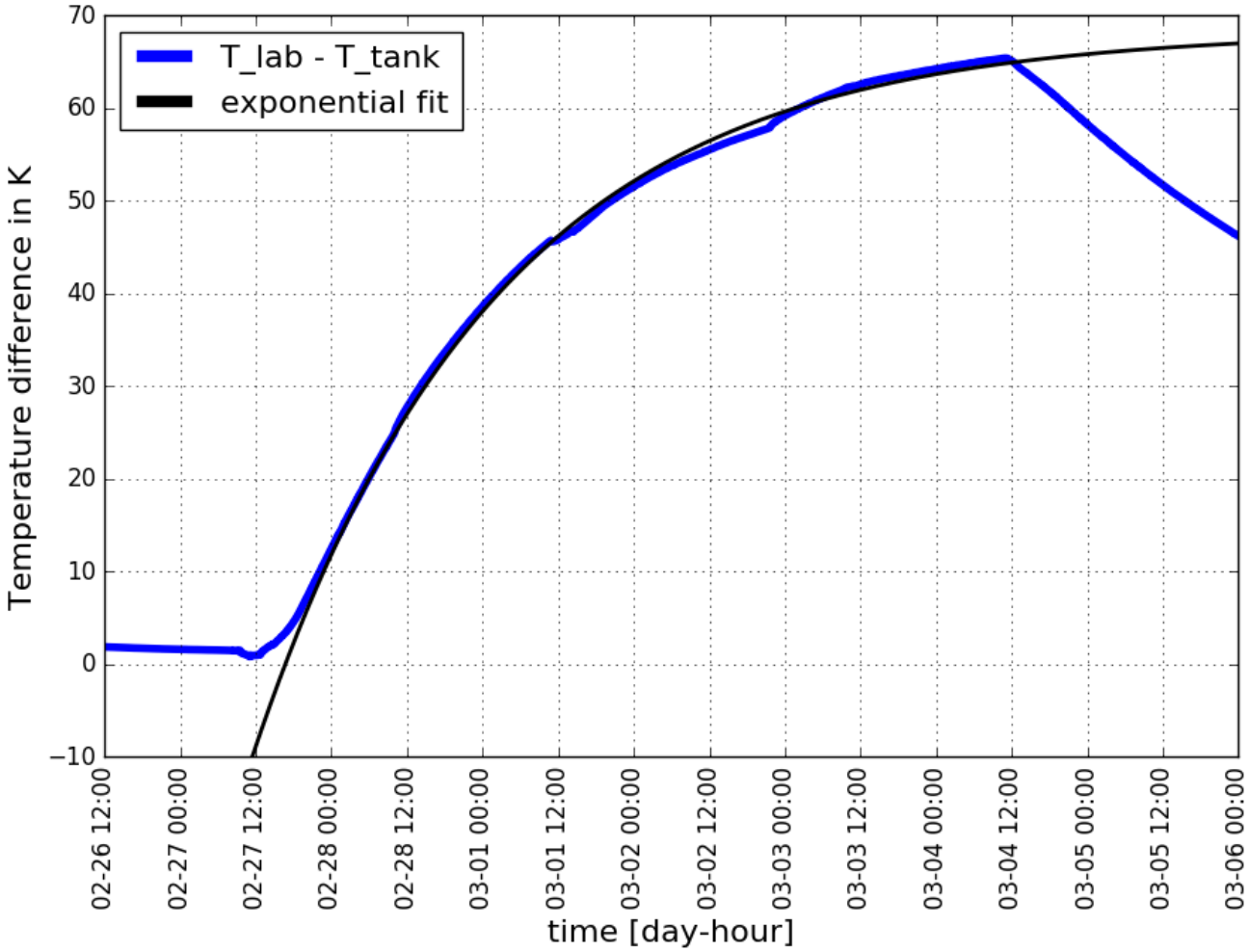
Temperature evolution during cool down



Fairly uniform temperature across CRP with differences between sensors < 5 K

Temperature evolution during cool down

Exponential fit of $\Delta T = T_{lab} - T_{tank}$ during cool down



Equation from heat input considerations:

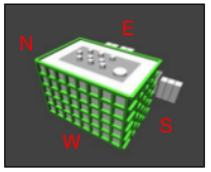
$$-\mathrm{C}\frac{\mathrm{d}\Delta\mathrm{T}}{\mathrm{dt}} = 14.59\frac{\mathrm{W}}{\mathrm{K}} \times \Delta\mathrm{T} - 2256\,\mathrm{W}$$

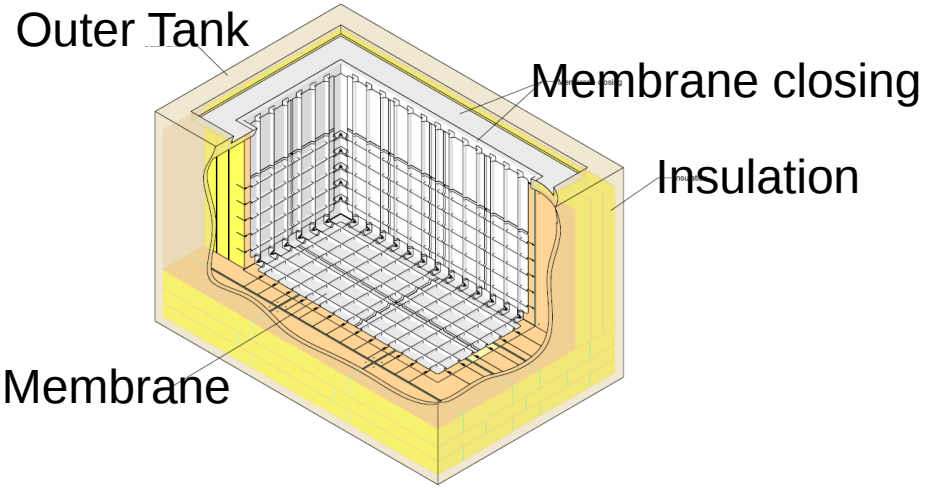
to be compared with parameters from exp. fit:

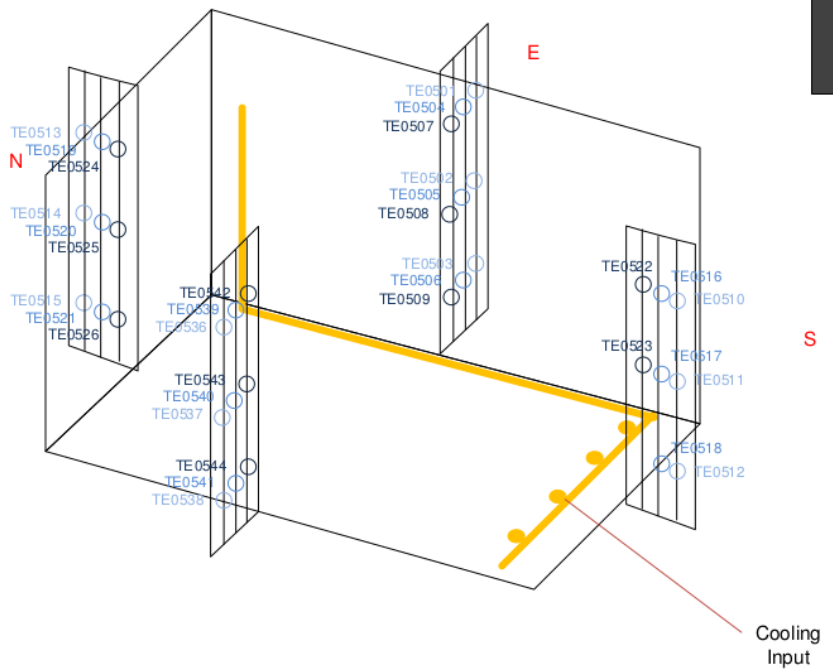
17.8 W/K 1216 W

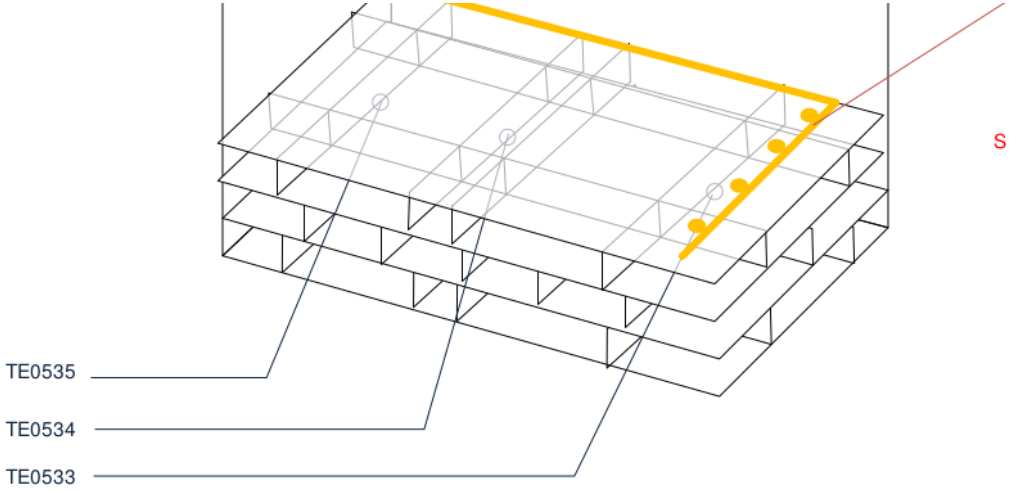
Temperature sensors in Insulation

- 44 sensors total
- arranged in 3 layers on all 4 sides and bottom

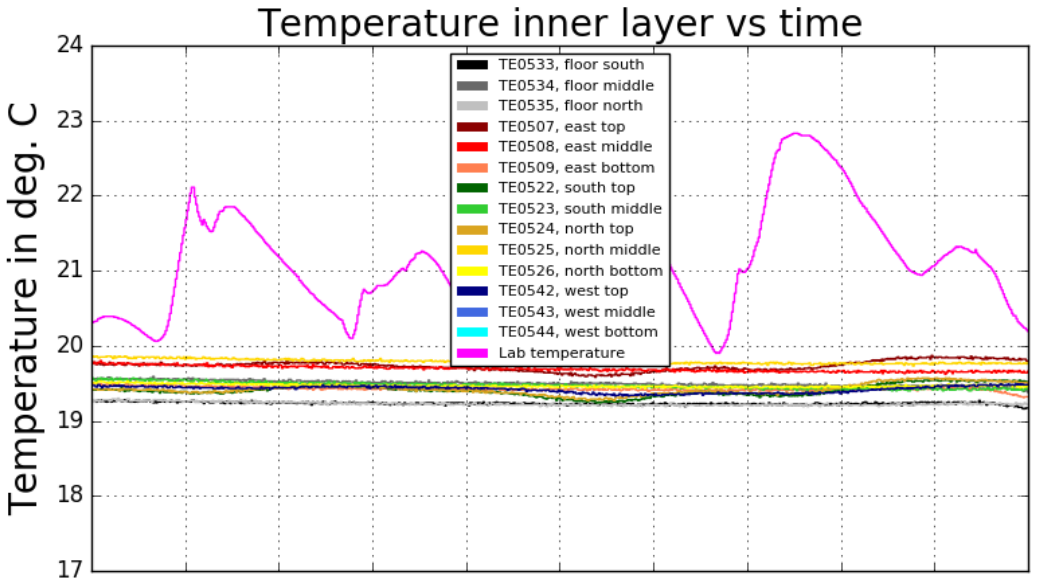


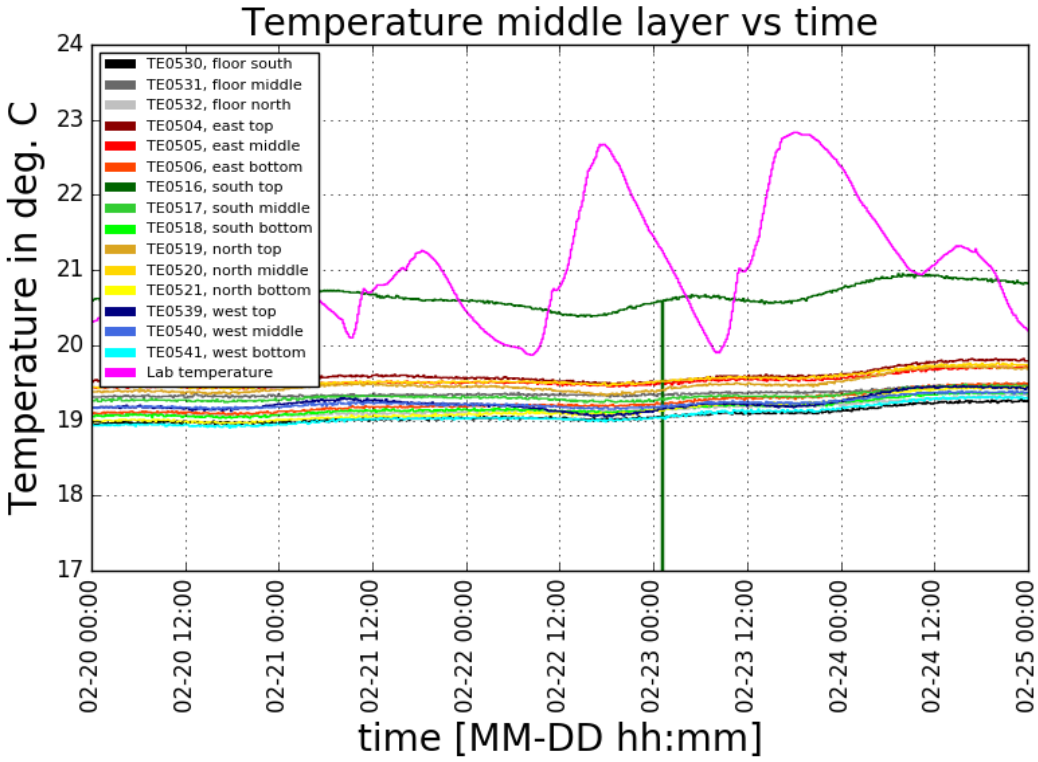


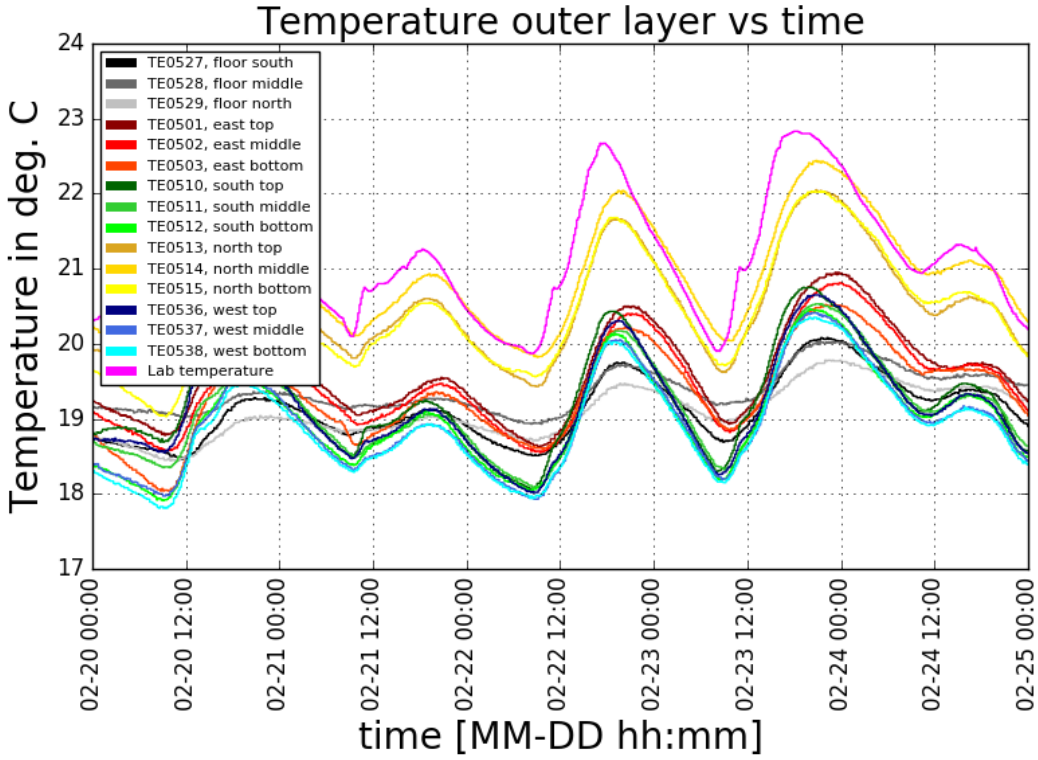




Insulation temperature before cool down







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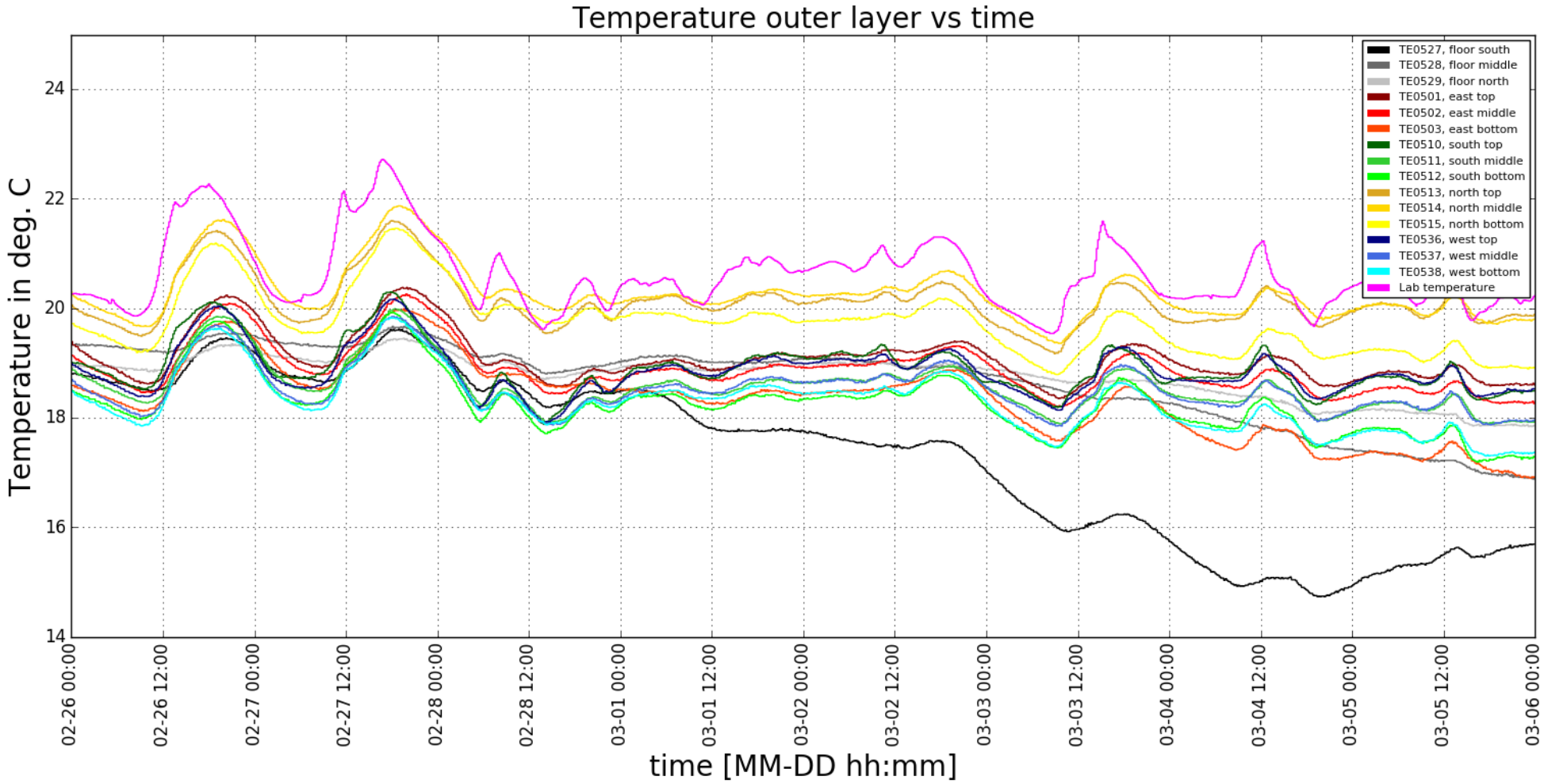
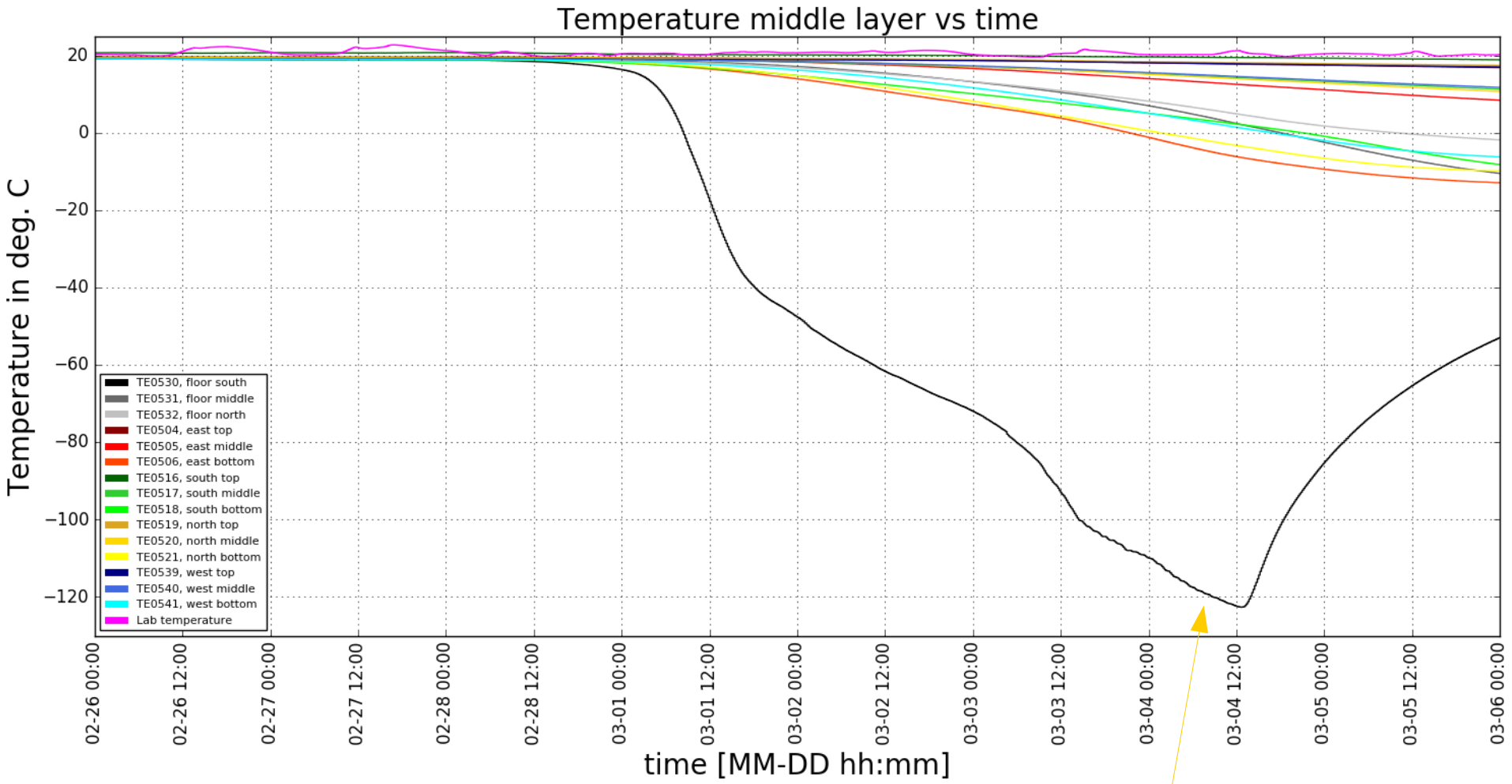
Insulation temperature during cool down

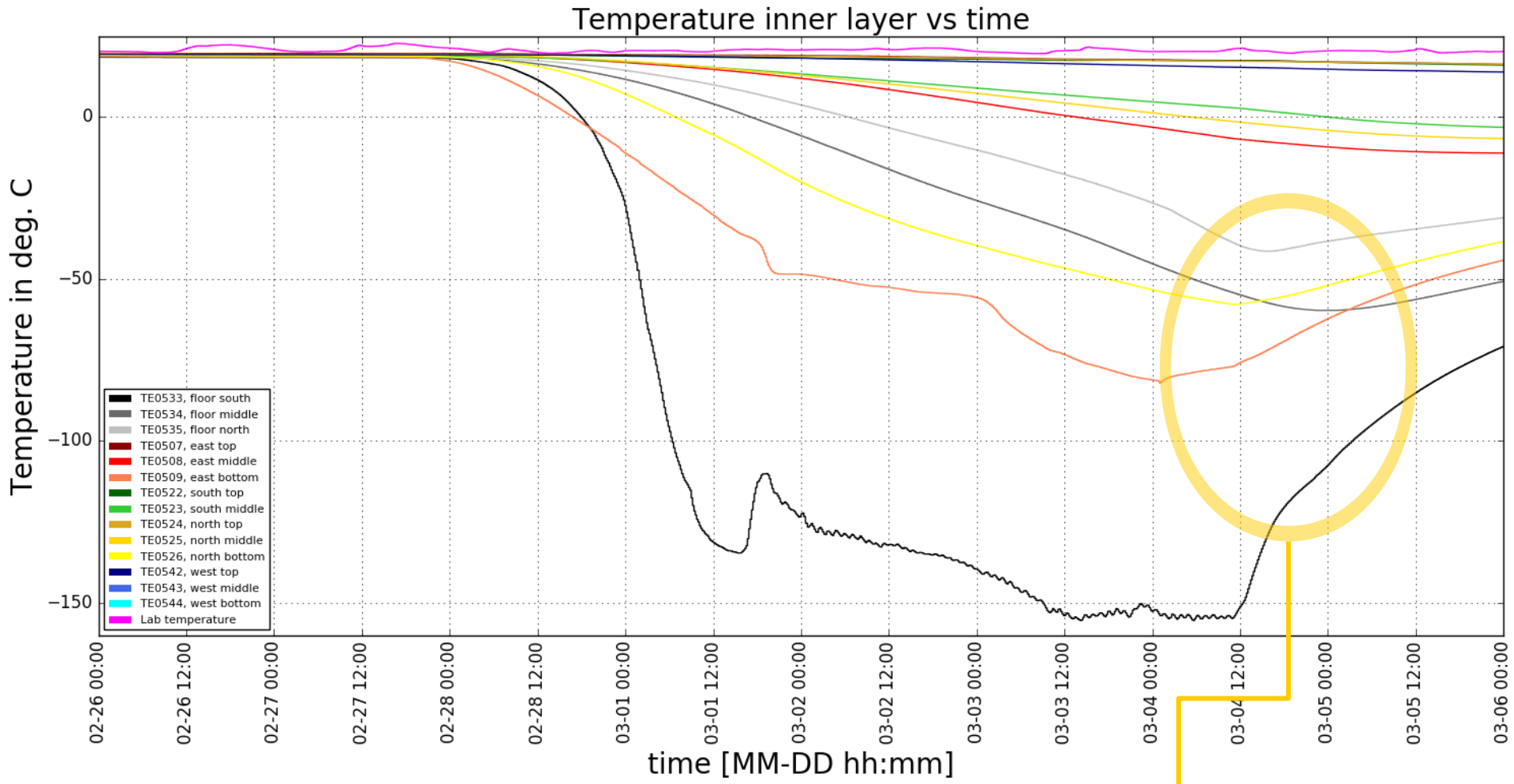


Insulation temperature during cool down



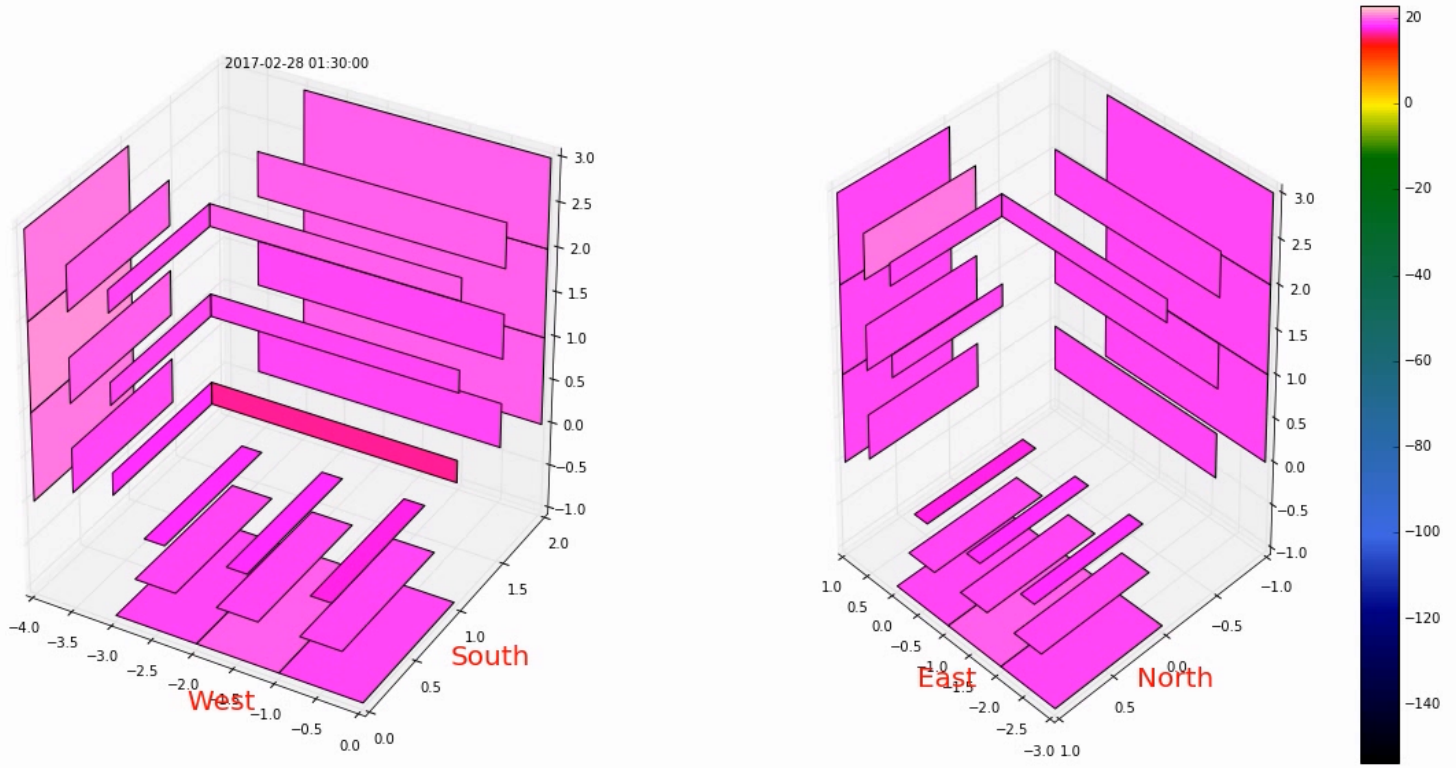
Floor sensor

Insulation temperature during cool down

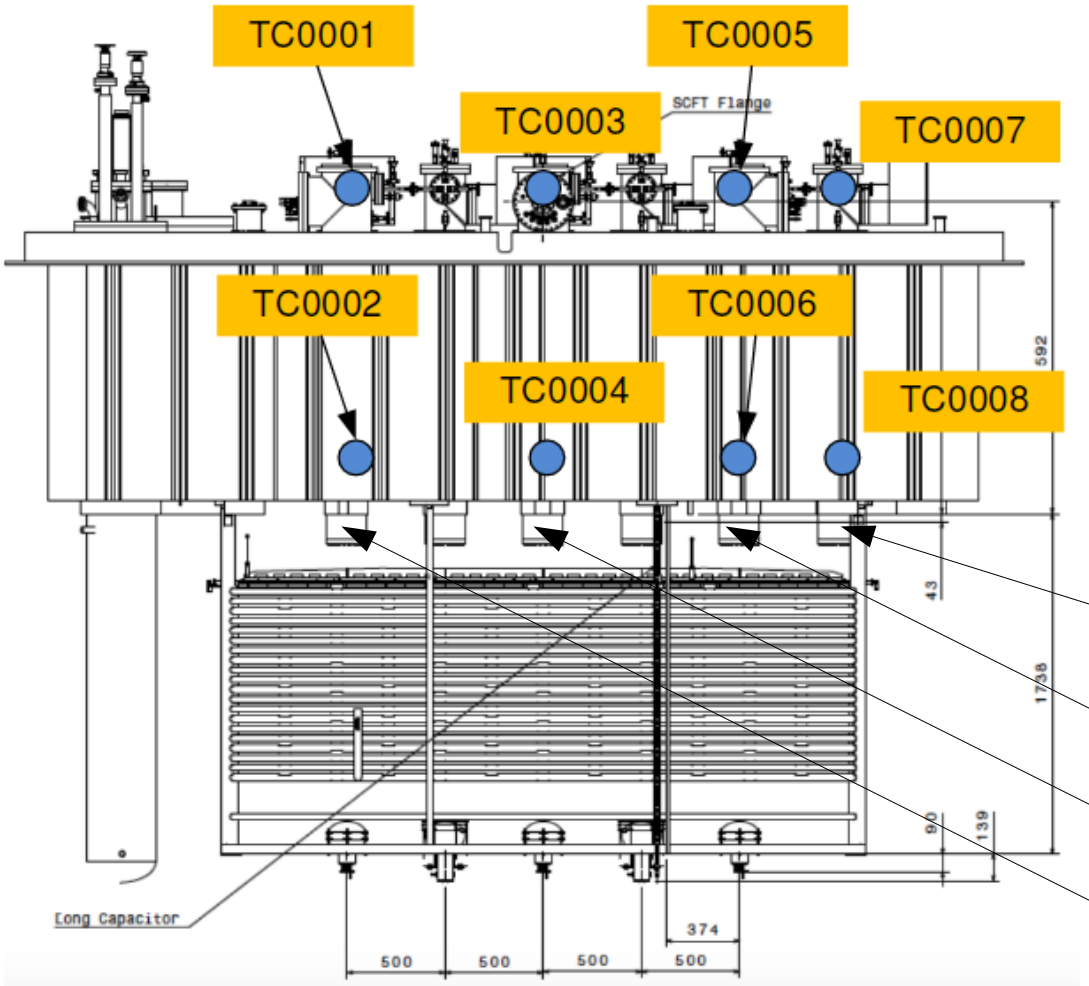


Bottom and floor sensors

Insulation temperature evolution during cool down

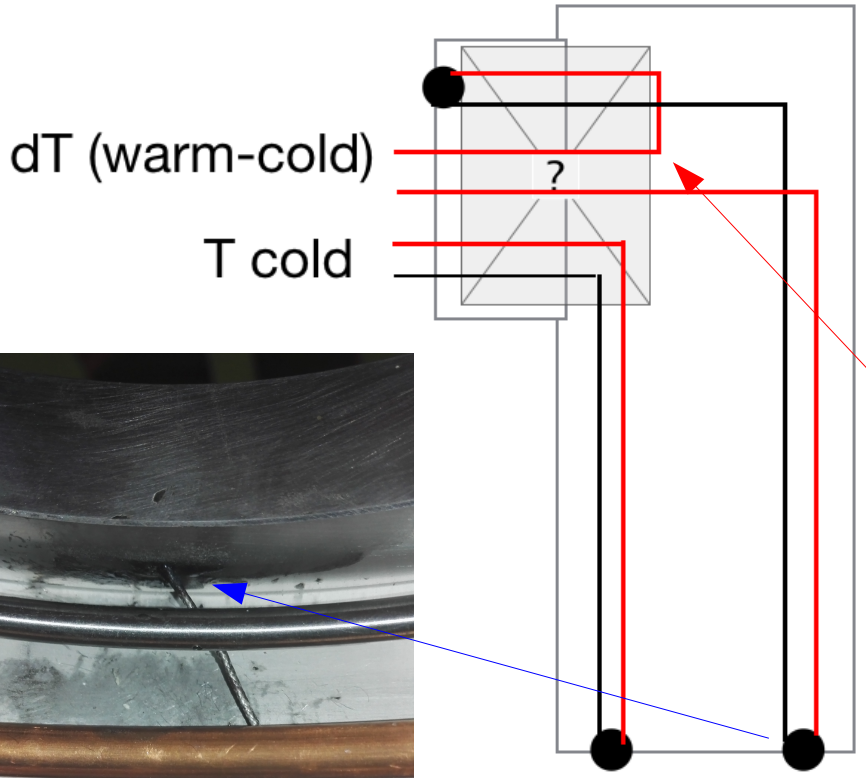


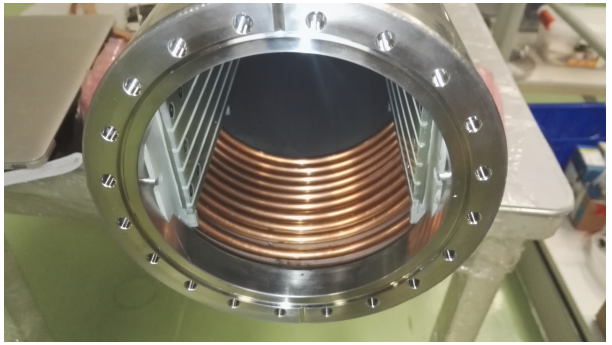
Temperature sensors in SGFTs



- 2 thermocouple sensors in all SGFT chimneys
- one on top, one on bottom

Thermocouples in SGFT chimneys





- 4 SGFT chimneys with 3 TCs each
- Designed to measure absolute temperature on bottom and differential temperature between top/bottom
- However, we measure an absolute temperature on both
- Live wire of bottom or top TC grounded
  → measure T instead of ΔT

1 live wire grounded

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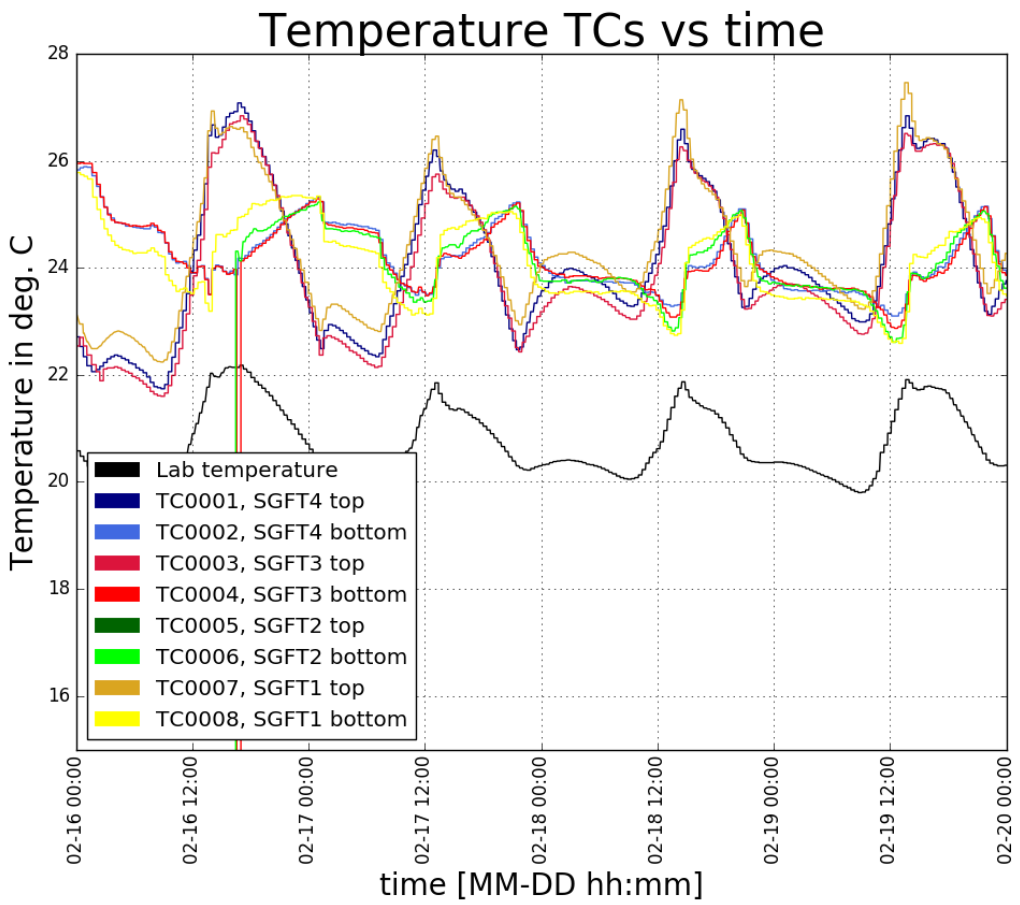
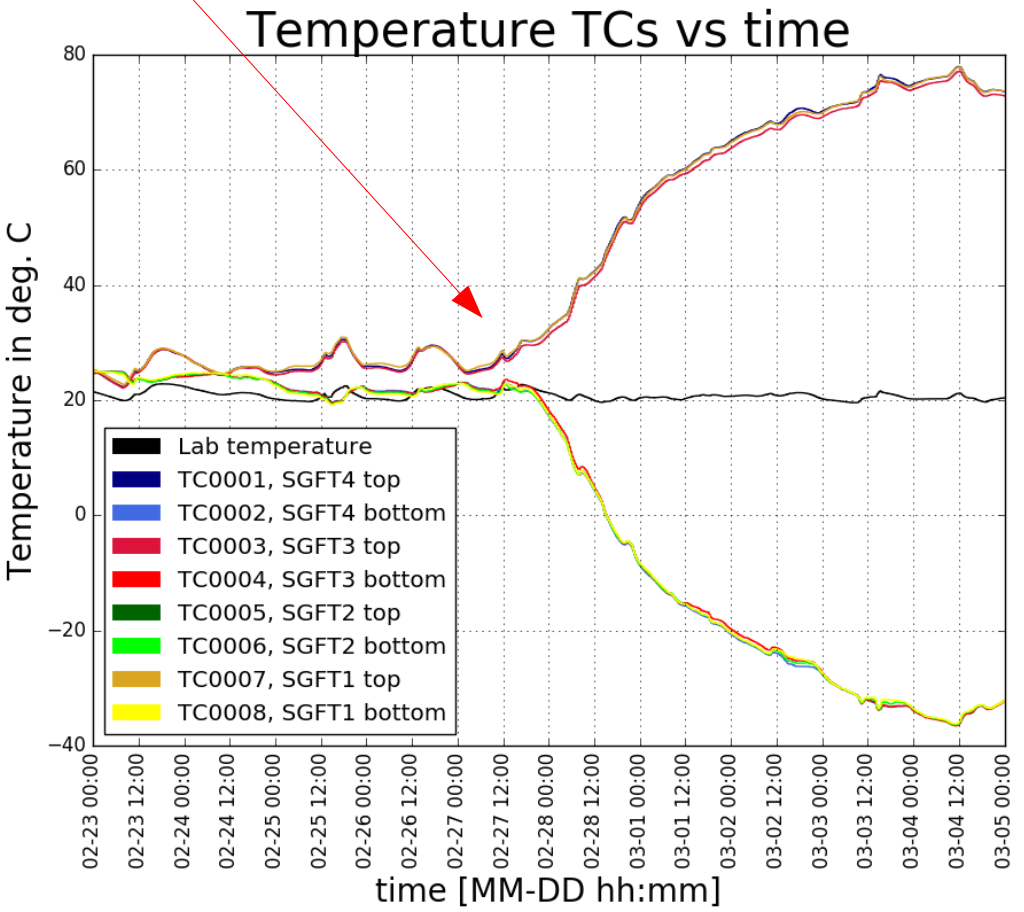
Thermocouples in SGFT chimneys

Before cool down

top/bottom anti-correlated

During cool down





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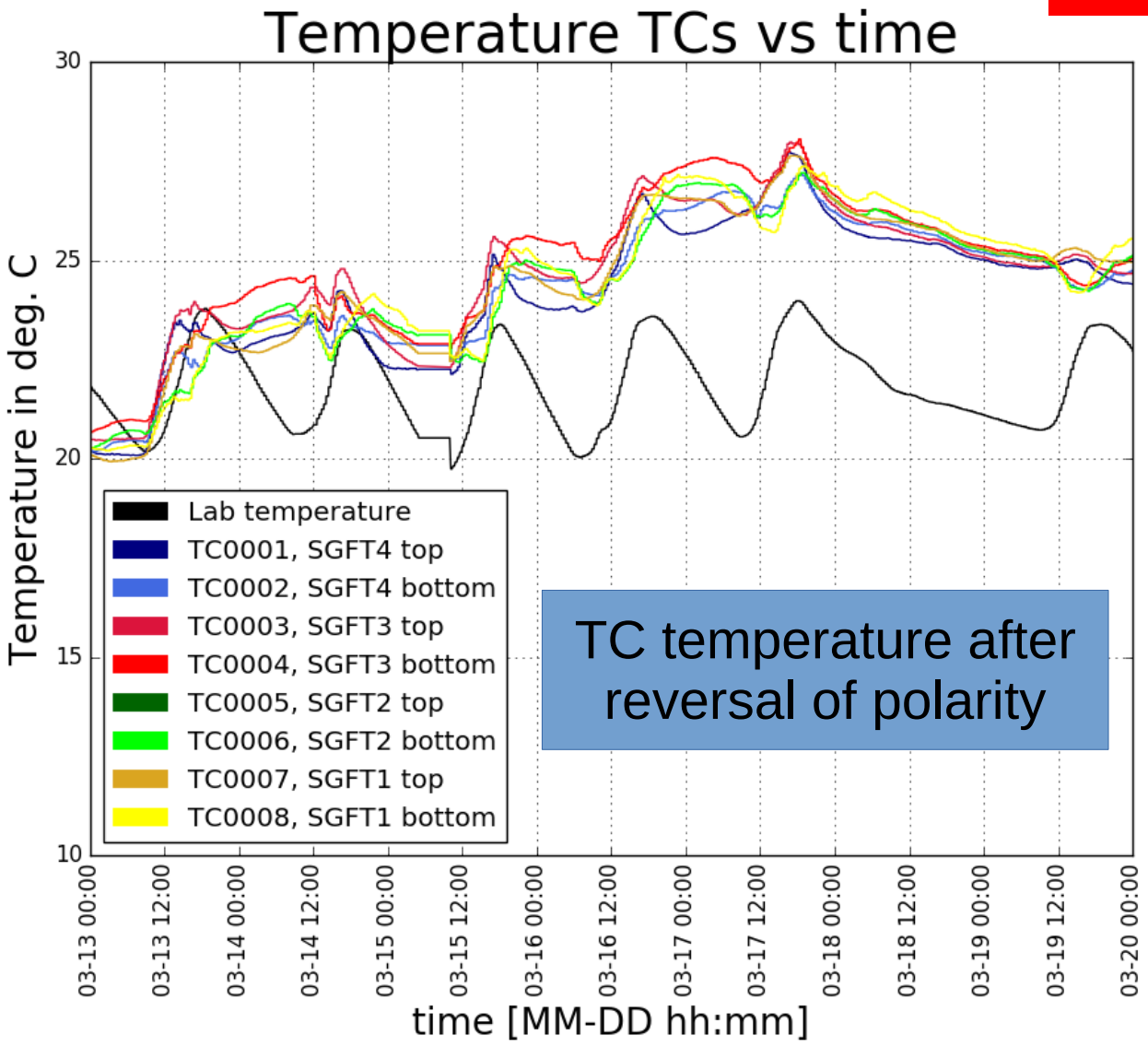
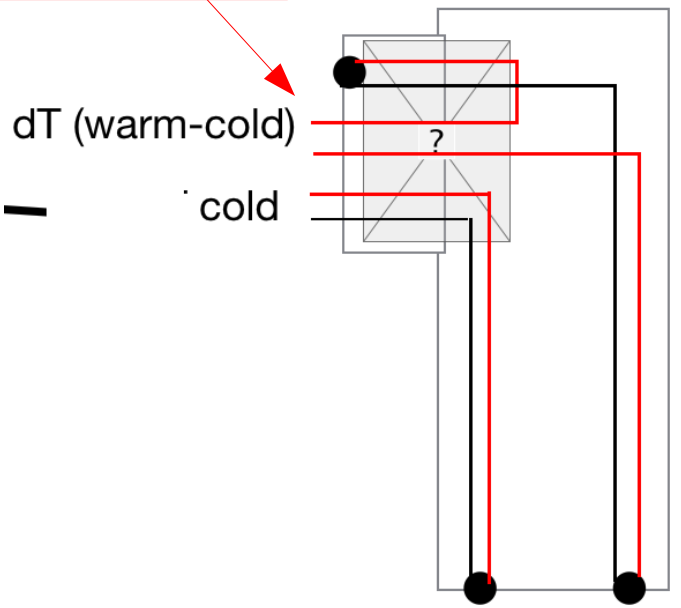
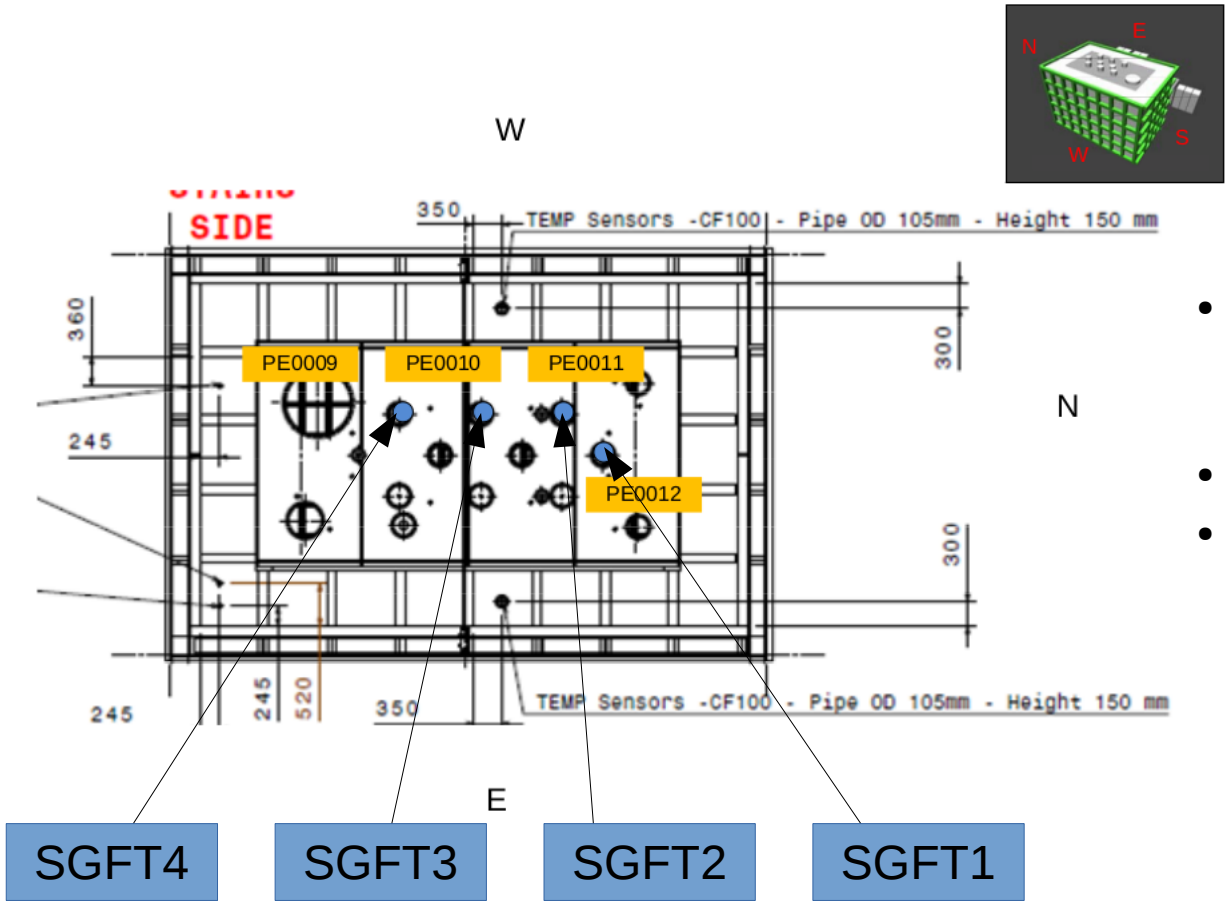
Thermocouples in SGFT chimneys



Polarity switched

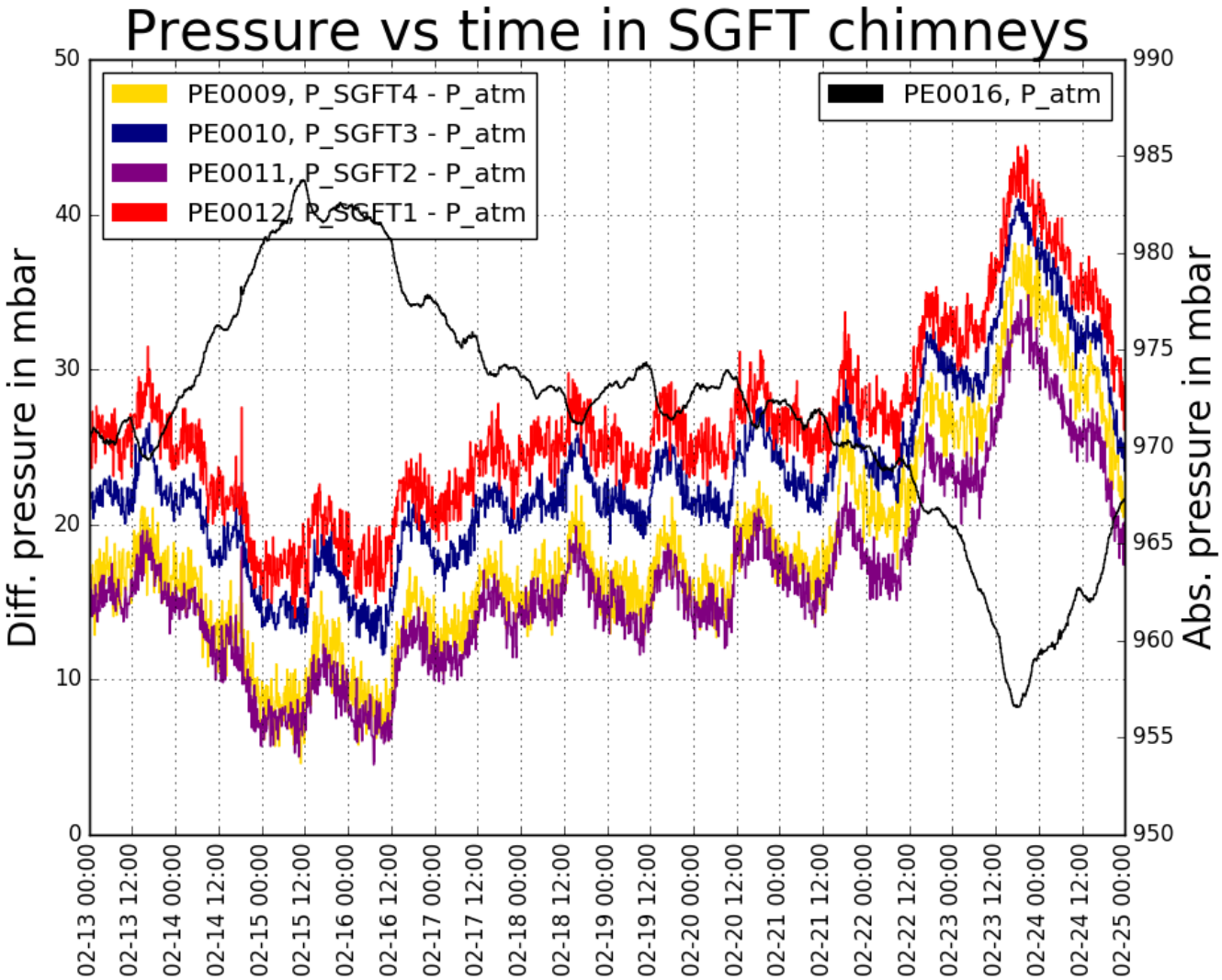


Differential pressures SGFT chimneys



- SGFT chimneys have gas volume isolated from tank & atmosphere
- filled with N_2
- relative pressure sensor to atmosphere in each chimney

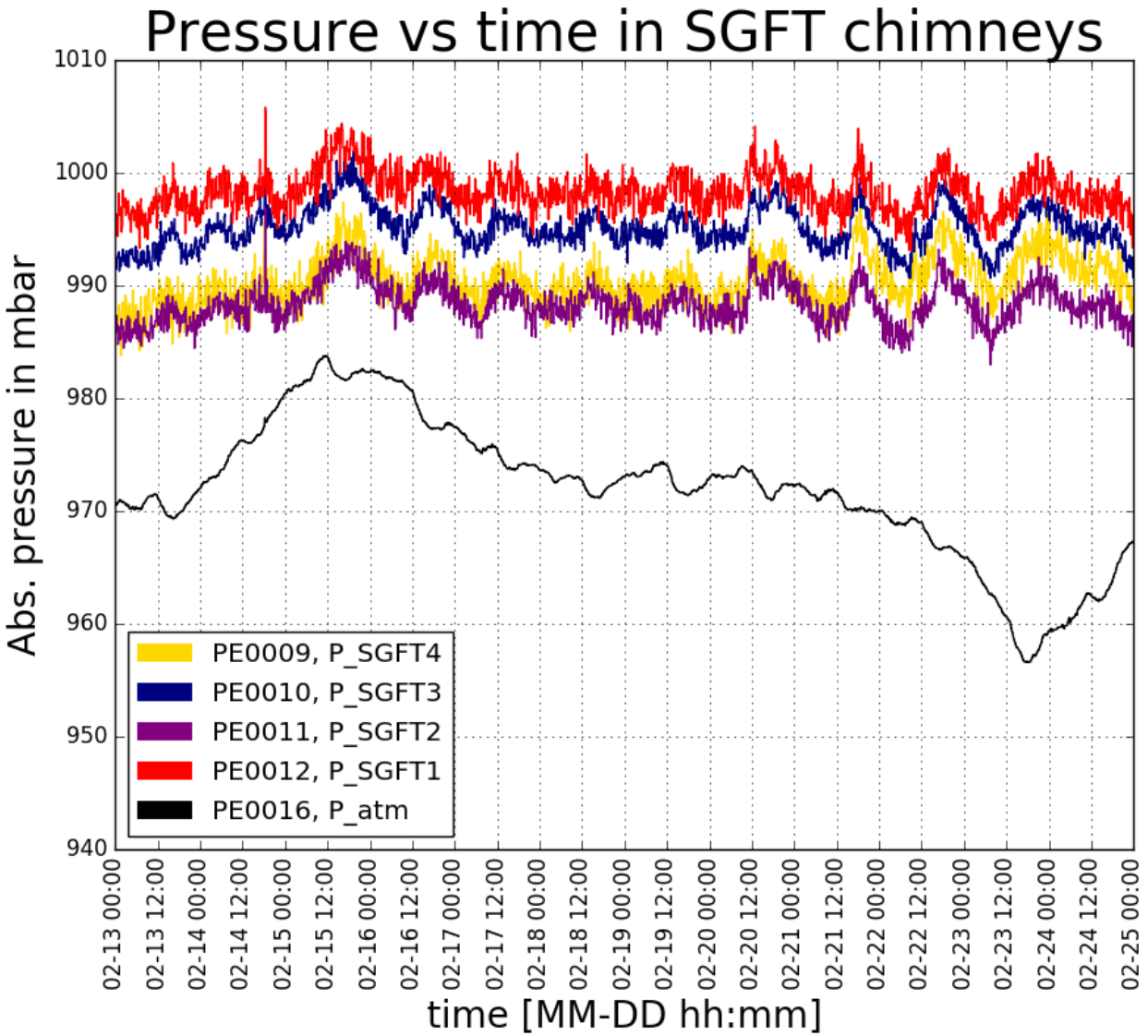
Differential pressures SGFT chimneys



Differential pressure before cool down

- SGFTs were filled with N2 at a slight overpressure wrt. atm
- Differential pressure anti-correlated with atm

Absolute pressures SGFT chimneys



Absolute pressure before cool down

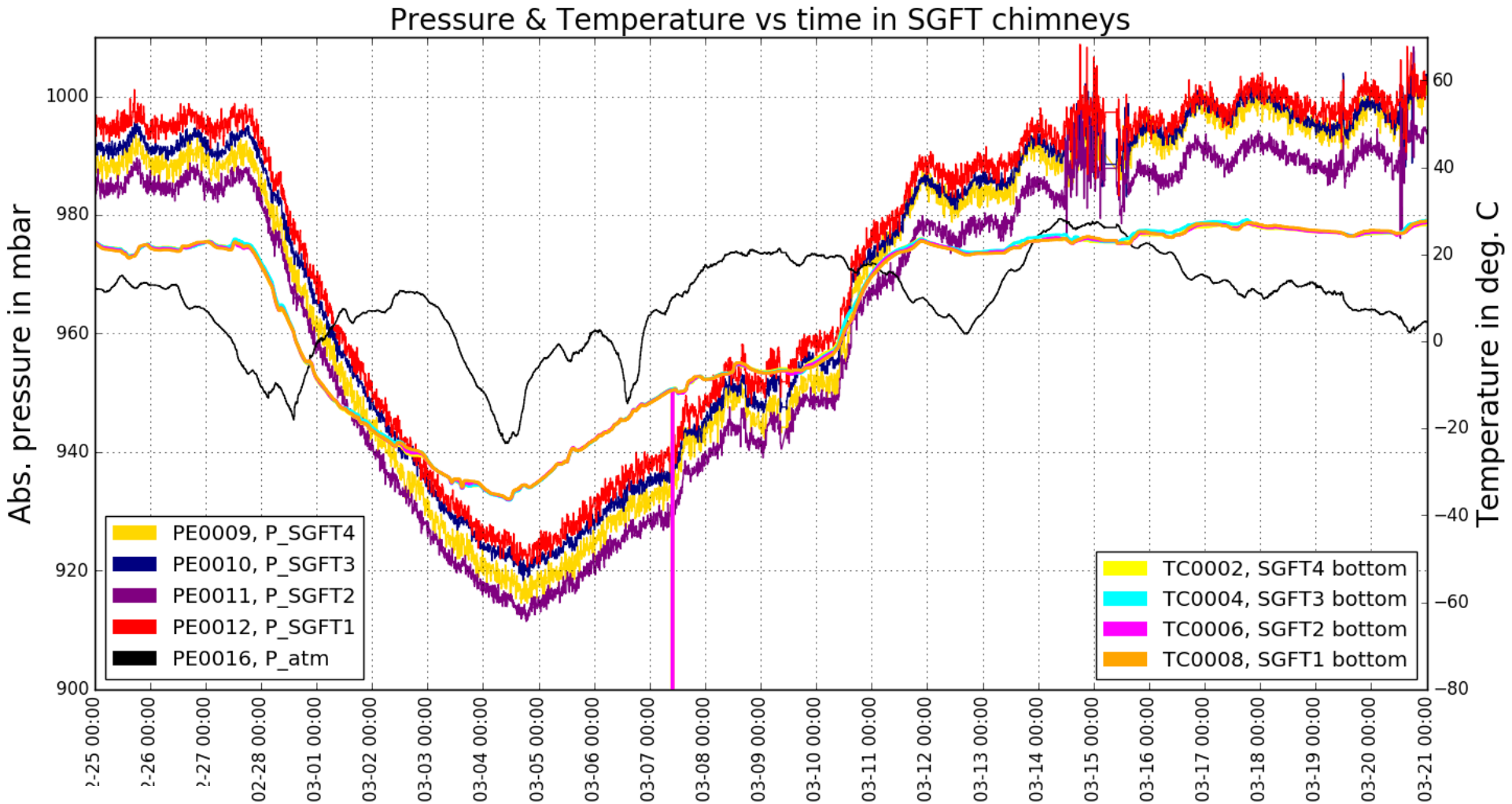
Stays roughly constant & above atmospheric pressure → No leaks in chimneys

Absolute pressures SGFT chimneys

Absolute pressure during cool down and warm up

Strongly correlated with Temperaure

Pressure drops below atmosphere



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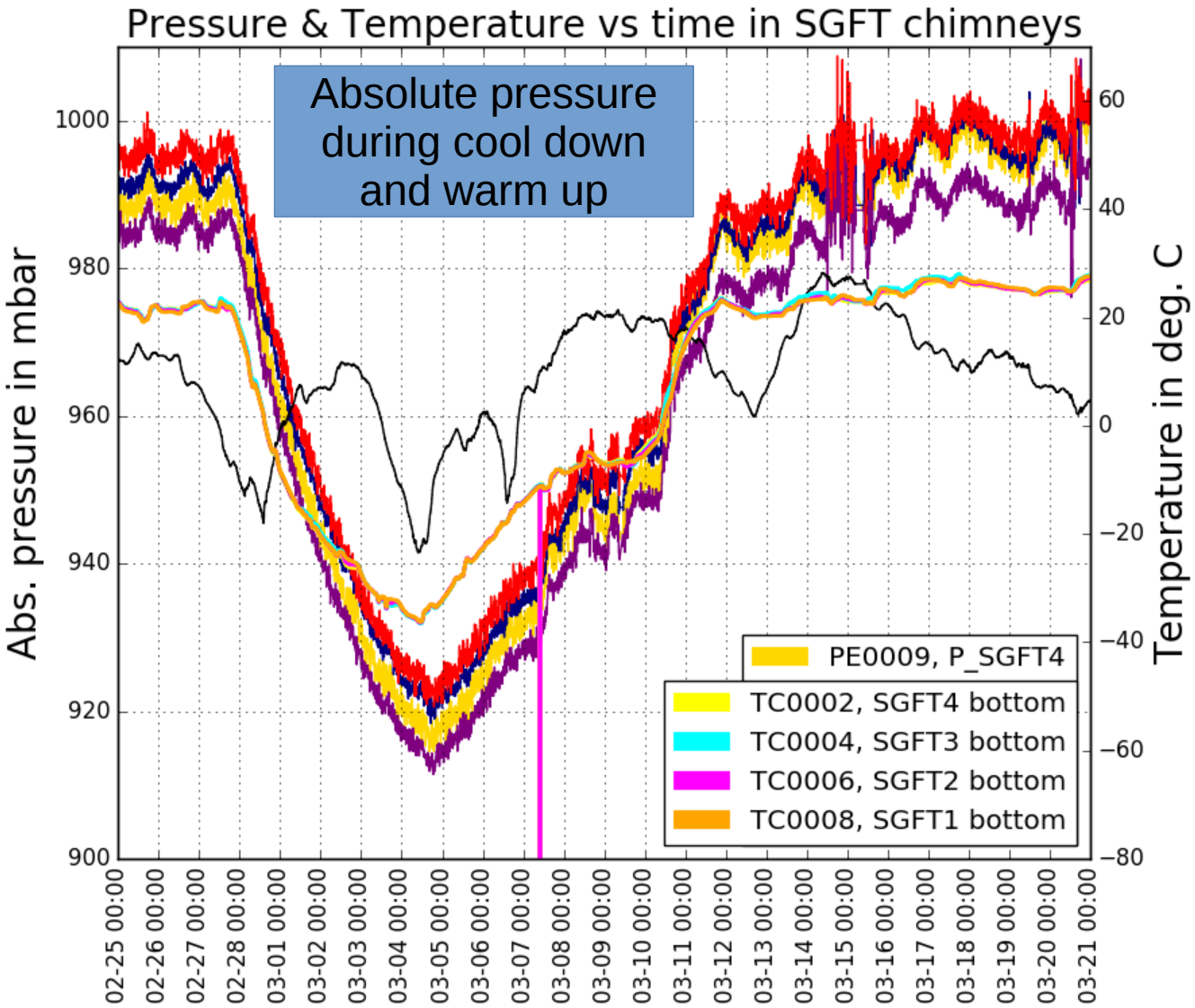
Absolute pressures SGFT chimneys

Strongly correlated with Temperaure

Pressure drops below atmosphere



- Pressure in chimneys needs to be regulated during cool down
- 4 SGFTs for 3x1x1
- automated system for 6x6x6 required

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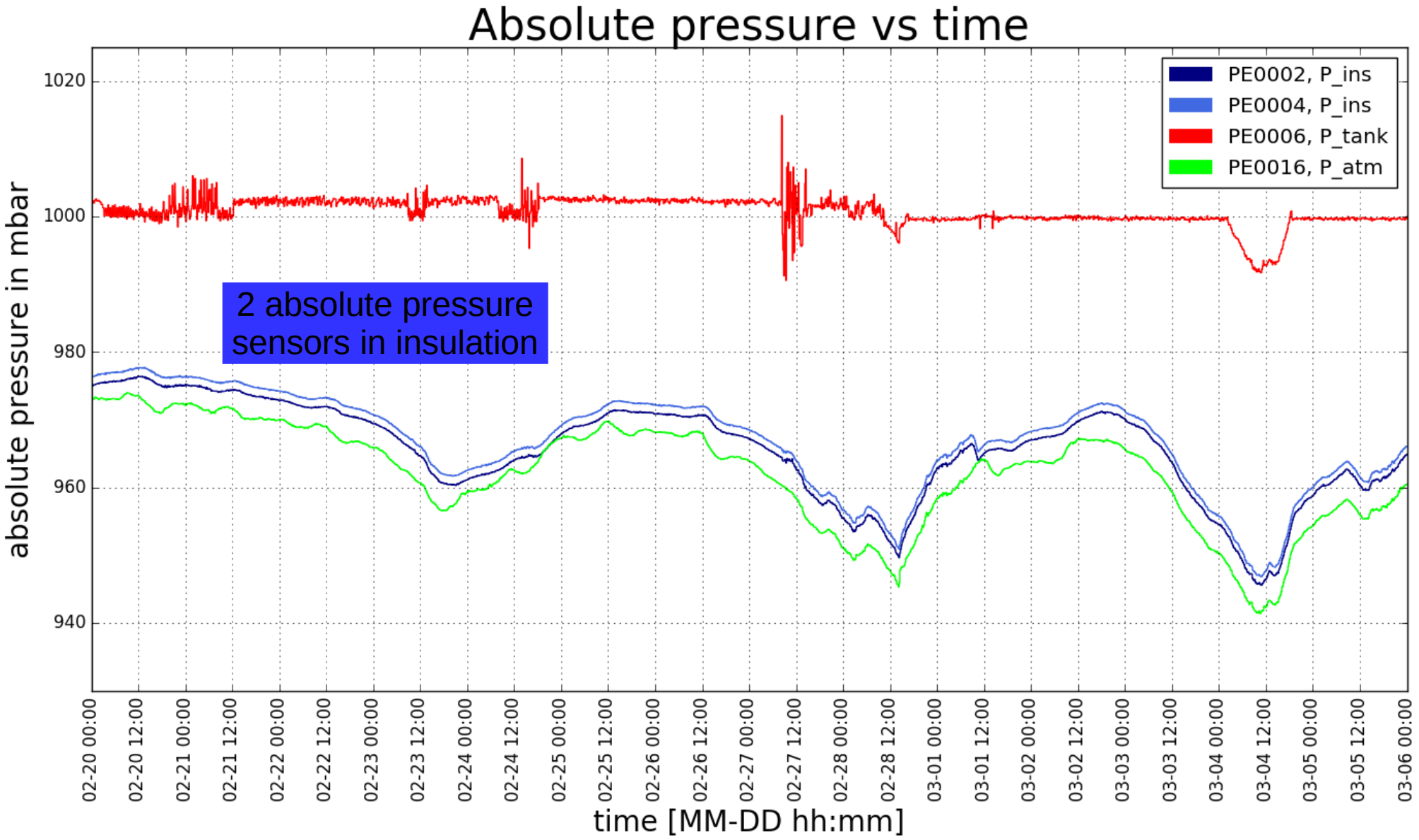
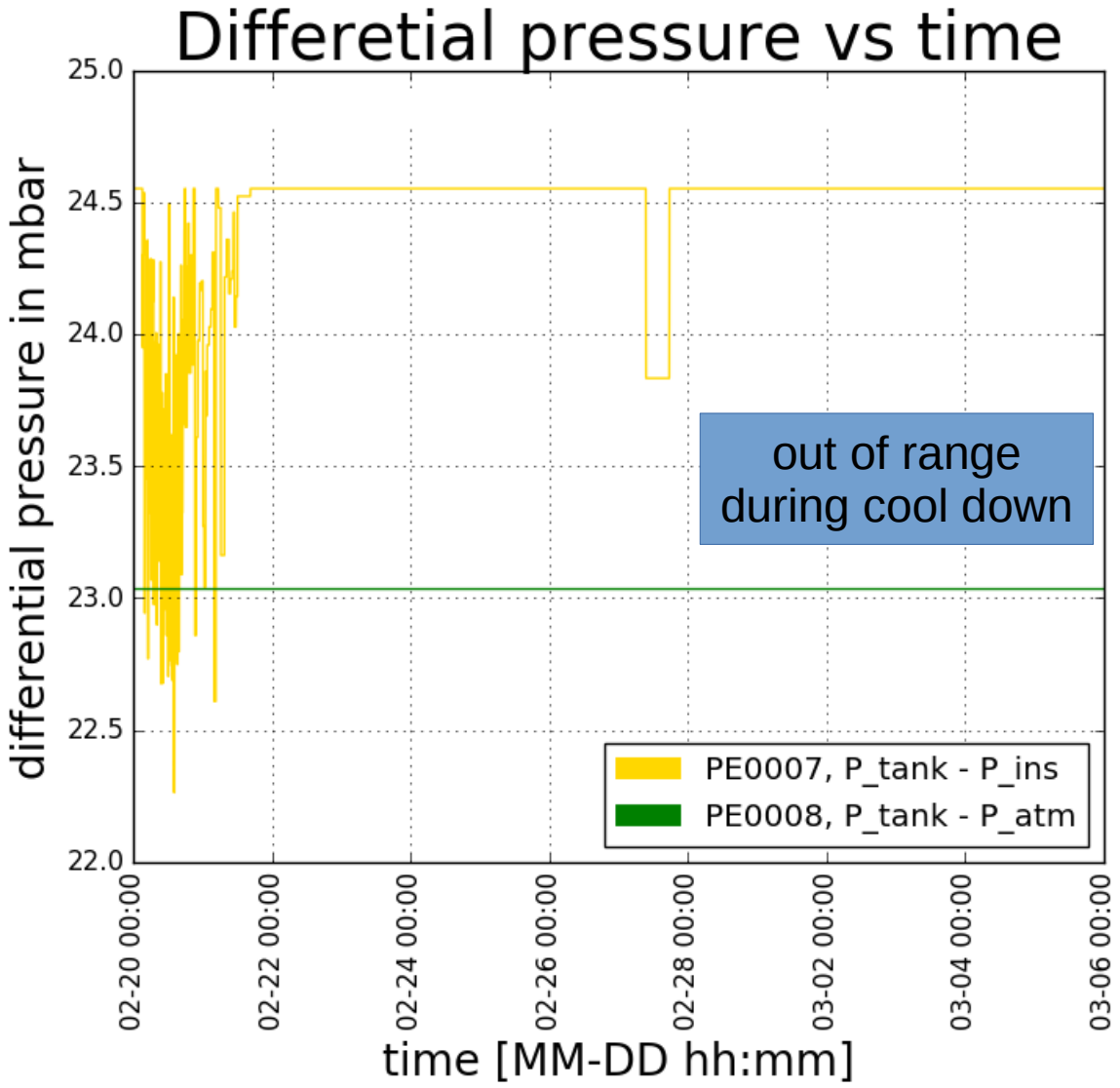
Absolute pressures in Tank/Insulation & atm



Differential pressures Tank/IS, Tank/atm



- 1 relative pressure sensor: $P_{tank} - P_{atm}$
- 1 differential pressure sensor: $P_{tank} - P_{IS}$
- range of old sensors: -20 +20 mbar
- new sensors have been installed
- range of new sensors: -50 +50 mbar

New sensors installed with ranges of -50 +50 mbar

Conclusion

- Temperature evolution during cool down is described by an exponential function
- Insulation temperatures need to be checked continuously during cool down
- Care has to be taken when installing thermocouples in chimneys
- Pressures in chimneys need to be adjusted during cool down
- Ranges of pressure sensors need to be checked before installation