

New Storage Ring Air Temperature Monitoring System at Diamond Light Source

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DEELS'24

Outline

- Motivation
- Hardware Description
- Deployment Locations
- Initial Results
- Summary

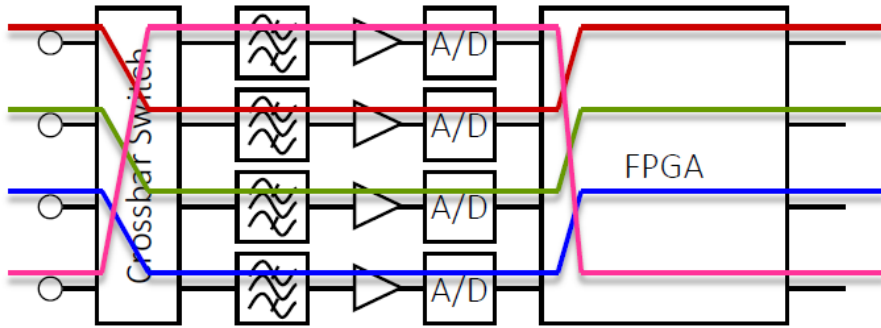


Motivation

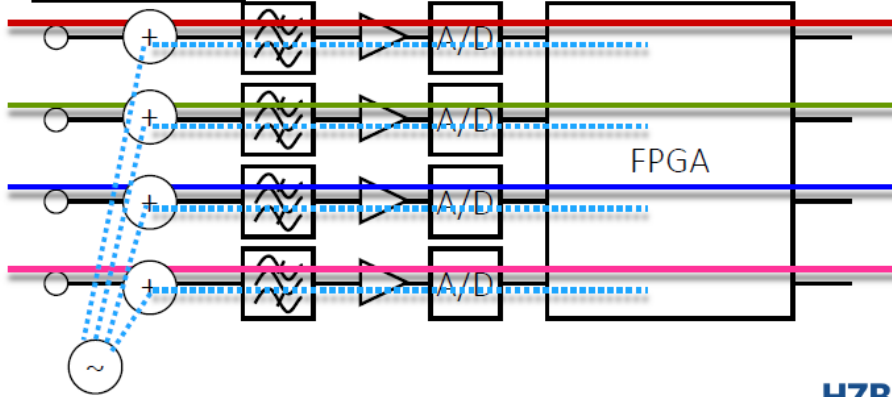
Compensation Schemes along “complete” rf signal processing chain to mitigate disturbances and drift require in-tunnel electronics

→ Environmental considerations

Switching

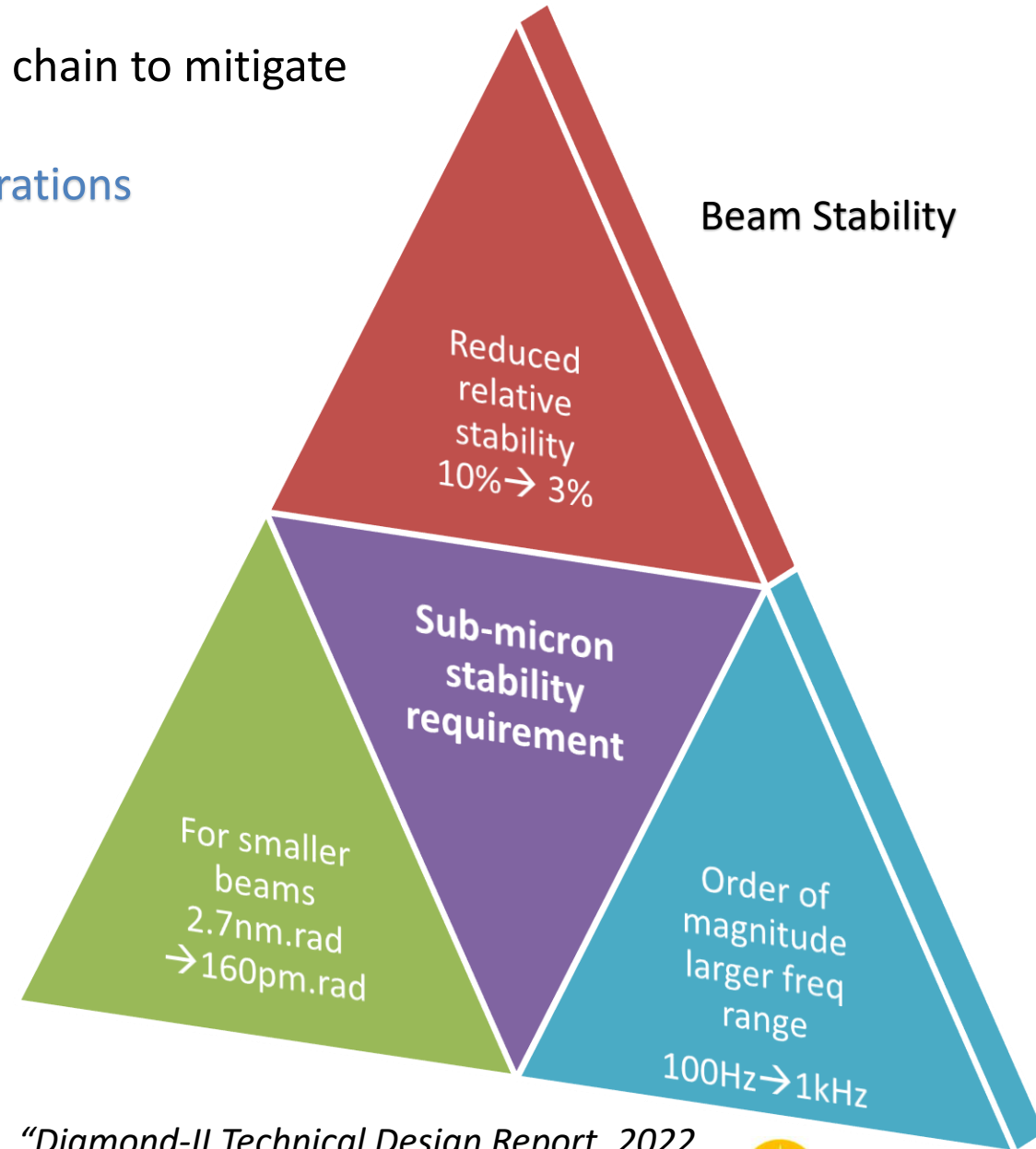


Pilot Tone



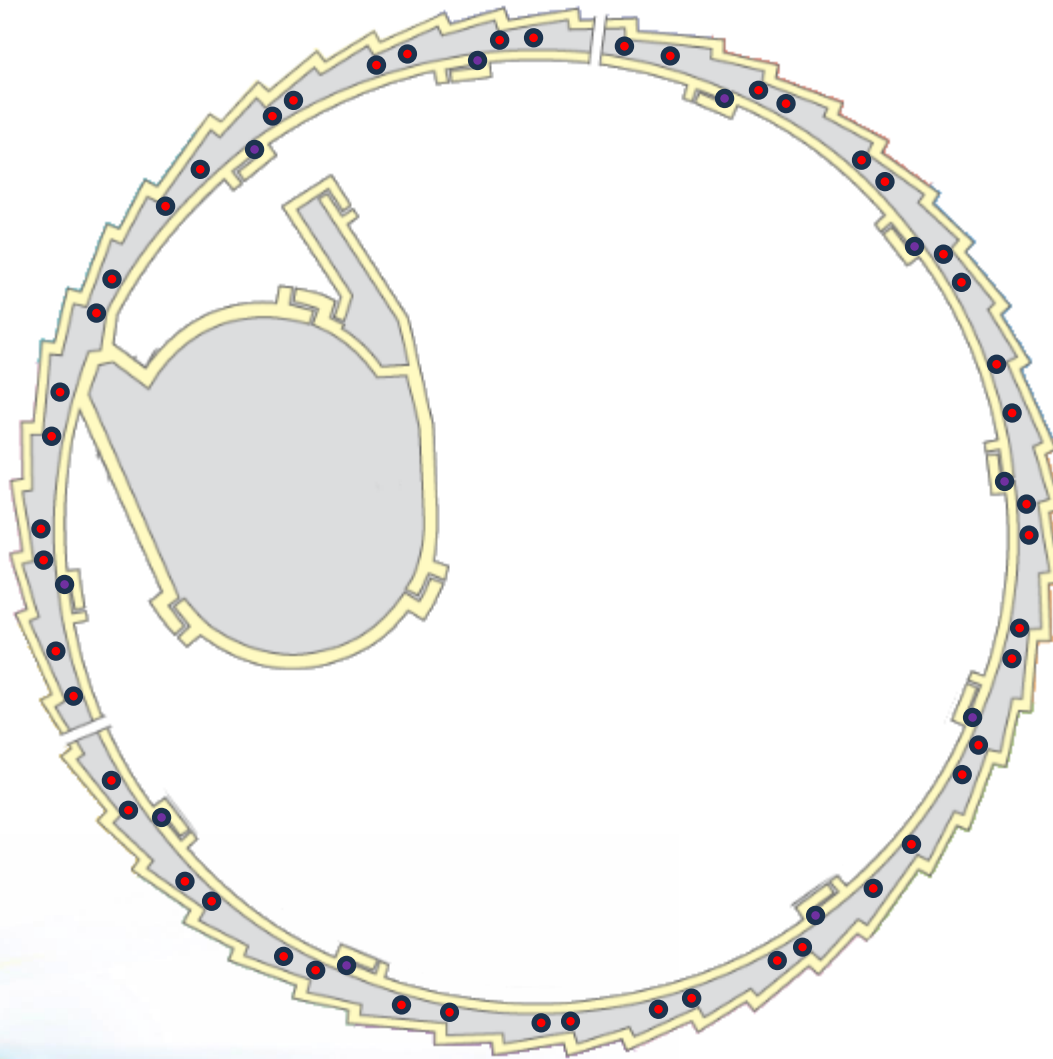
HZB BESSY II Light Source

Review of BPM Drift Compensation Schemes, G. Rehm, IBIC2022, Krakow



R.P. Walker et al., “Diamond-II Technical Design Report, 2022

Old Temperature Monitoring



1 sensor on Girder 1 (G1)

1 sensor on Girder 2 (G2)

usually 0.5 degree C resolution

..and not all of which work....!

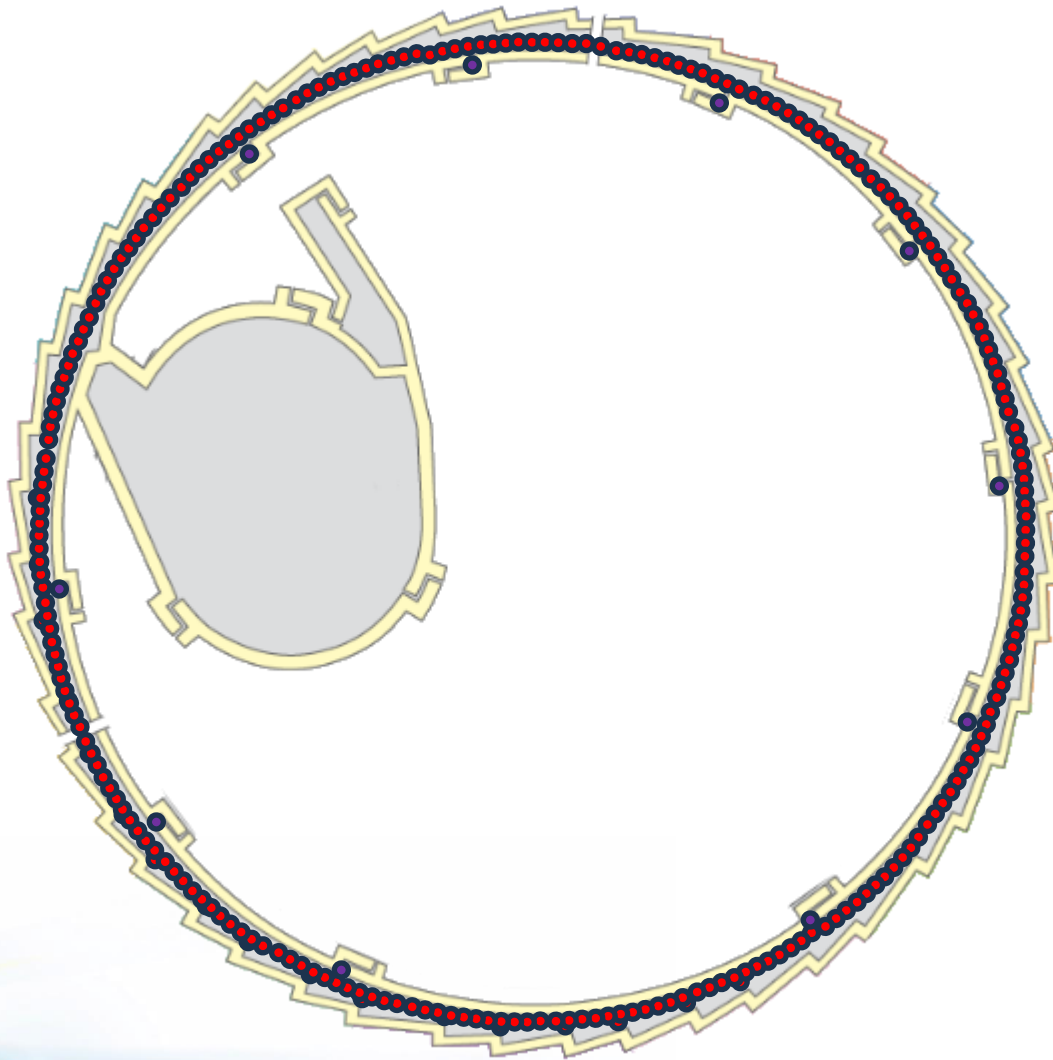
1 sensor in chicane

used for Air Handling Unit (AHU) feedback.

22 +/-0.5 °C

NB: No humidity control

New Temperature Monitoring



1 sensor every 2.1 m:

- 253 sensors total
- Consistent locations
- ± 0.01 °C relative resolution
- ± 0.1 °C absolute resolution

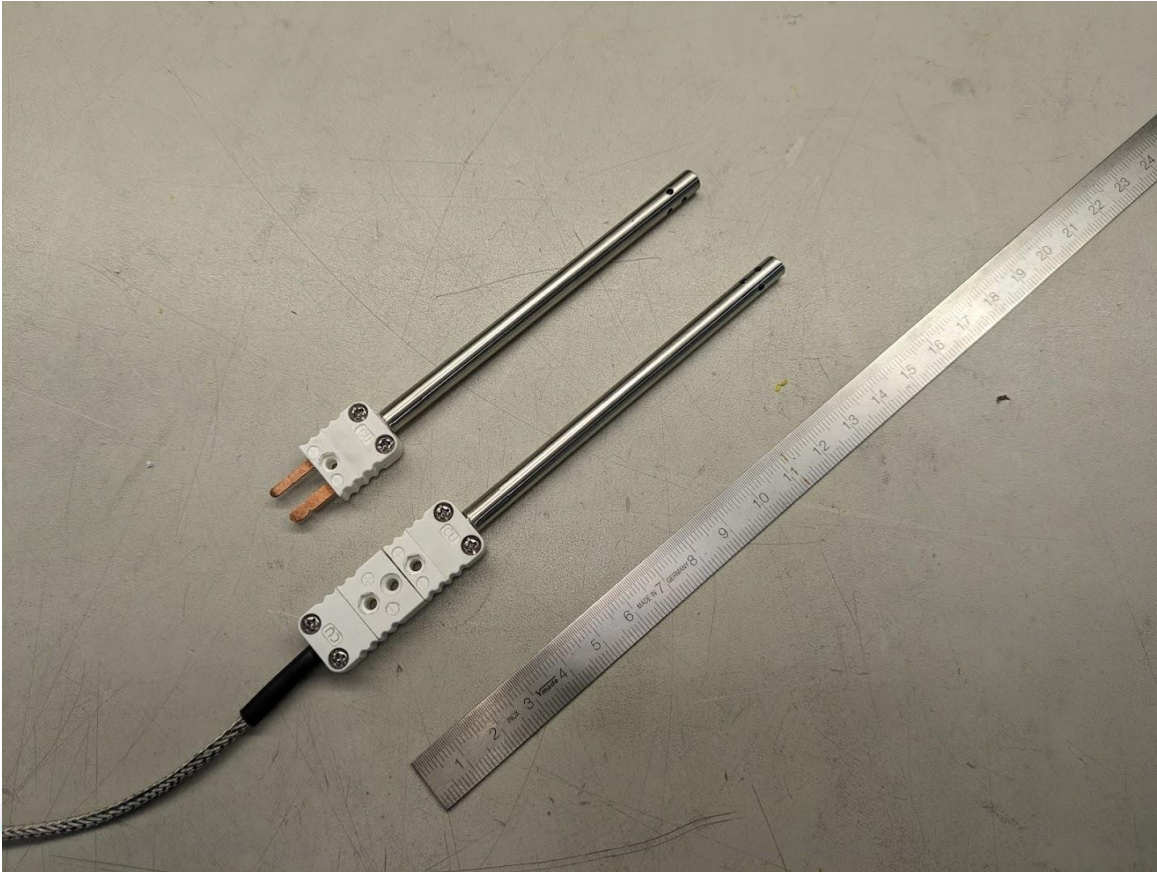
1 sensor in chicane

used for Air Handling Unit (AHU) feedback
 22 ± 0.5 °C

NB: No humidity control

Air Temperature Sensors

Specific PT1000 air temperature sensors from Testemp.

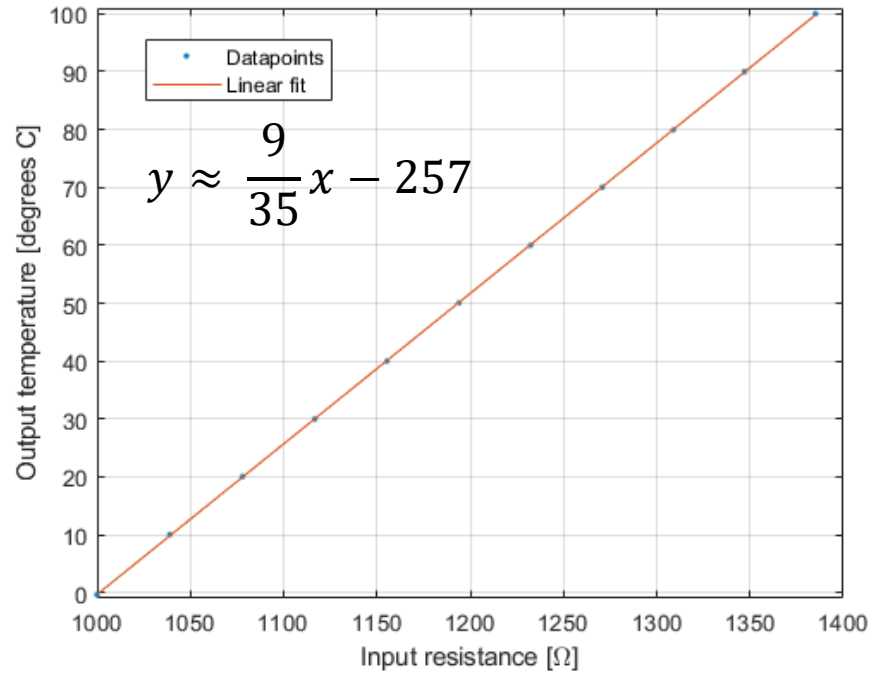


Beckhoff EL3208-0010 EtherCAT 16-bit readout electronics.

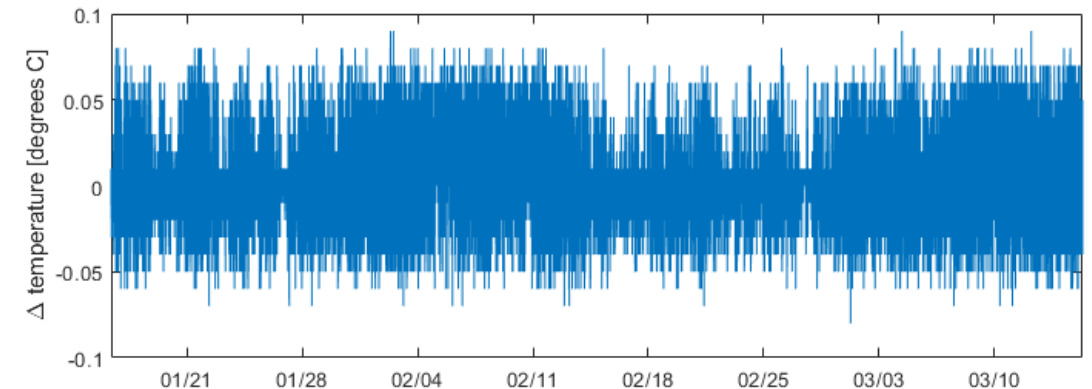
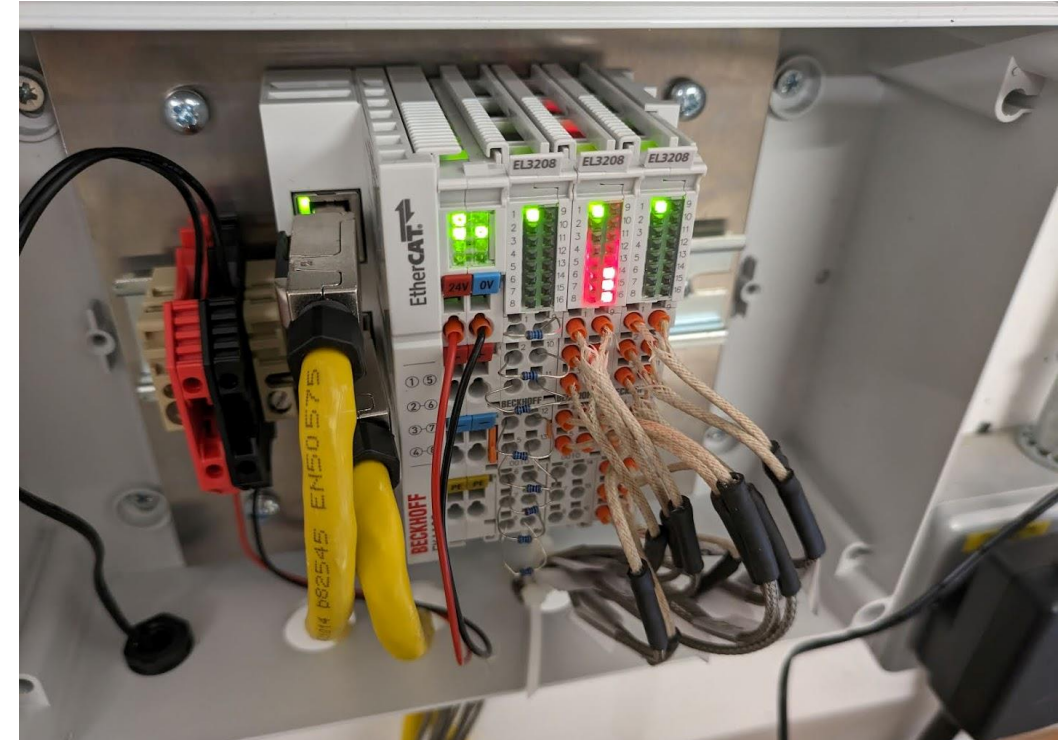


Sensor Characterisation

Linearity of Beckhoff ADCs over 0-100 degrees C using calibrated resistances

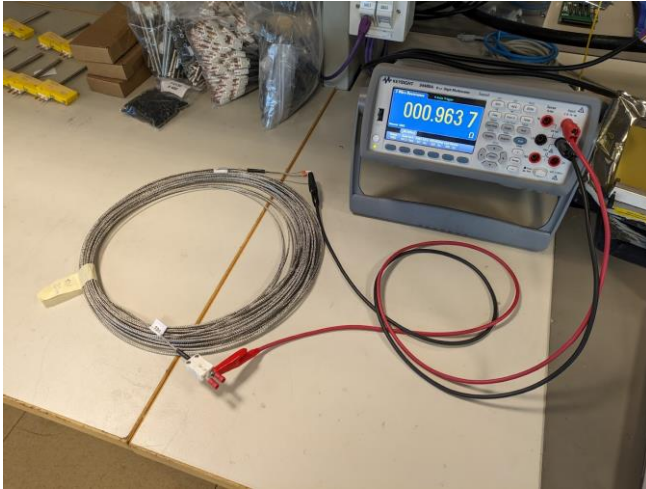


Stability over time (weeks) using thermally-stable 1000 Ohm resistors

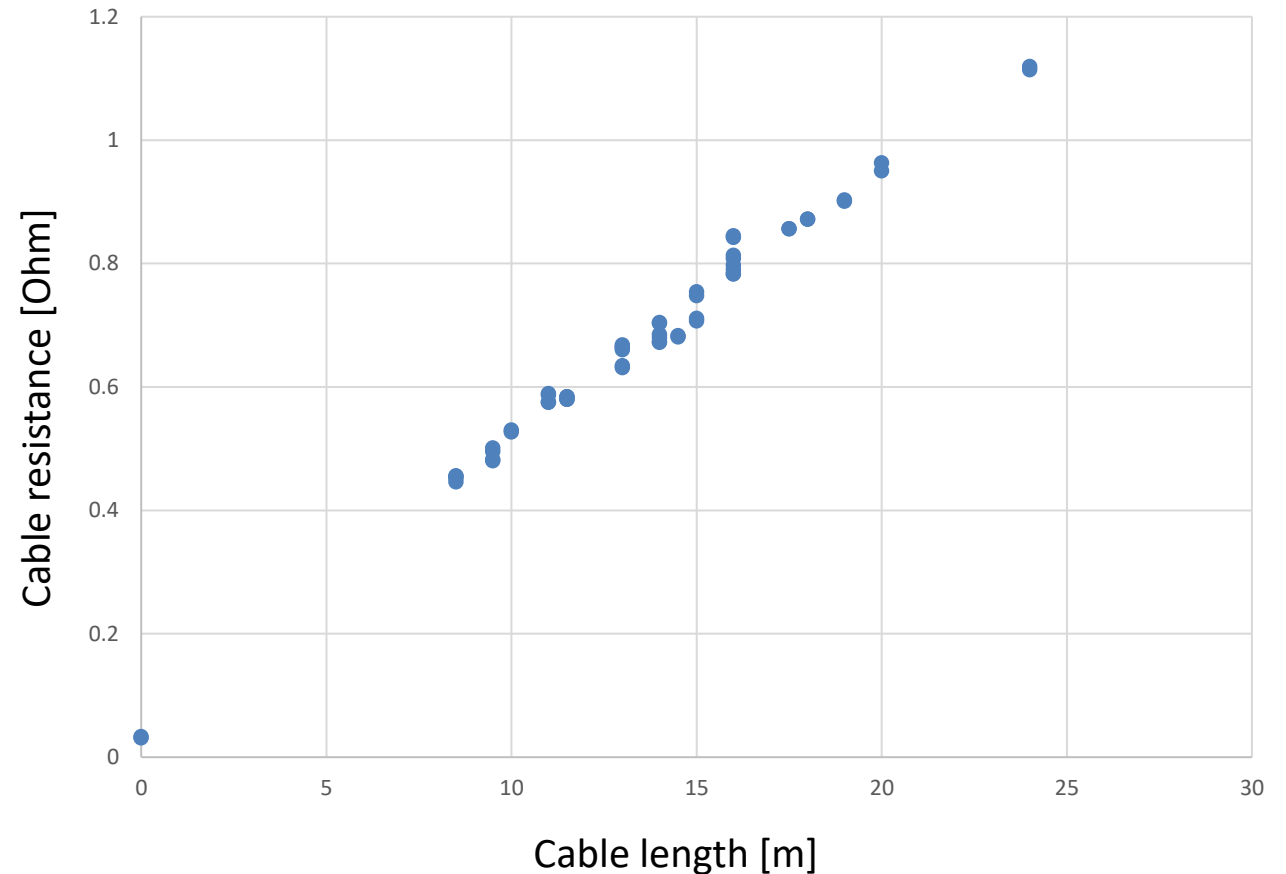


Cable Length Compensation

“DC” errors introduced by cable lengths between ADCs and sensors



Copper cable change in resistance due to change in temperature is negligible compared to PT1000:



Copper Cable

- 15m length has 0.7 Ohm resistance (measured)
- Coefficient of electrical conductivity w.r.t. temperature in copper is $4e-3$ [k^{-1}].
→ if the wire temperature changes by $1^\circ C$
→ the resistance of the wire changes by $4e-3 * 0.7 = 0.0028$ Ohm

PT1000

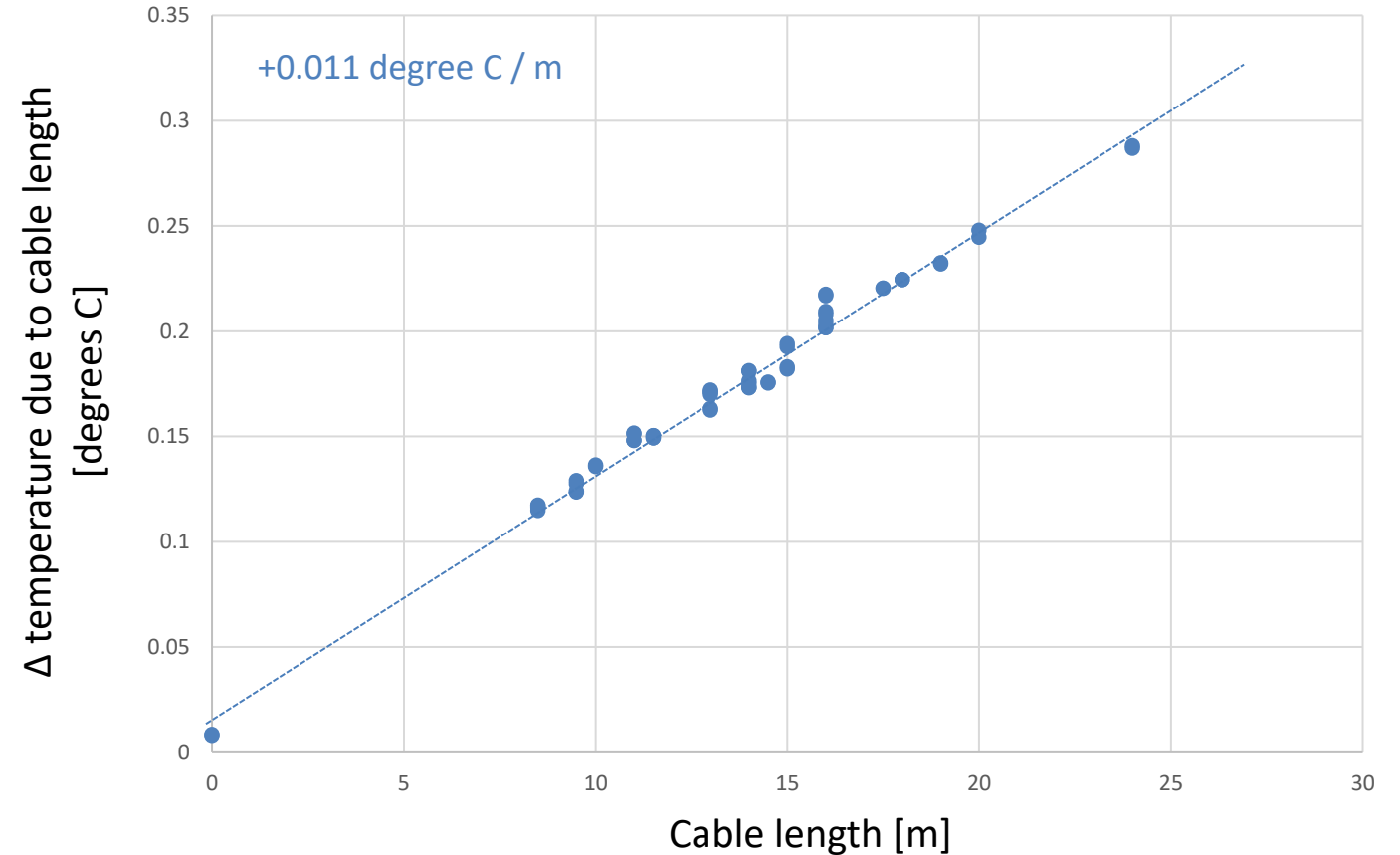
- $1^\circ C$ temperature change in PT1000
→ 3.9 Ohm resistance change at room temperature;

$$\frac{0.0028}{3.9} \times 100 \ll 1\%$$

Cable Length Compensation

“DC” errors introduced by cable lengths between ADCs and sensors

Sensor	Average cable length	
	St. Str.	Long str.
T01	19m	29m
T02	17m	25m
T03	13m	19m
T04	11m	16m
T05	9m	14m
T06	8m	13m
T07	11m	10m
T08	13m	11m
T09	14m	13m
T10	16m	15m
T11	18m	18m

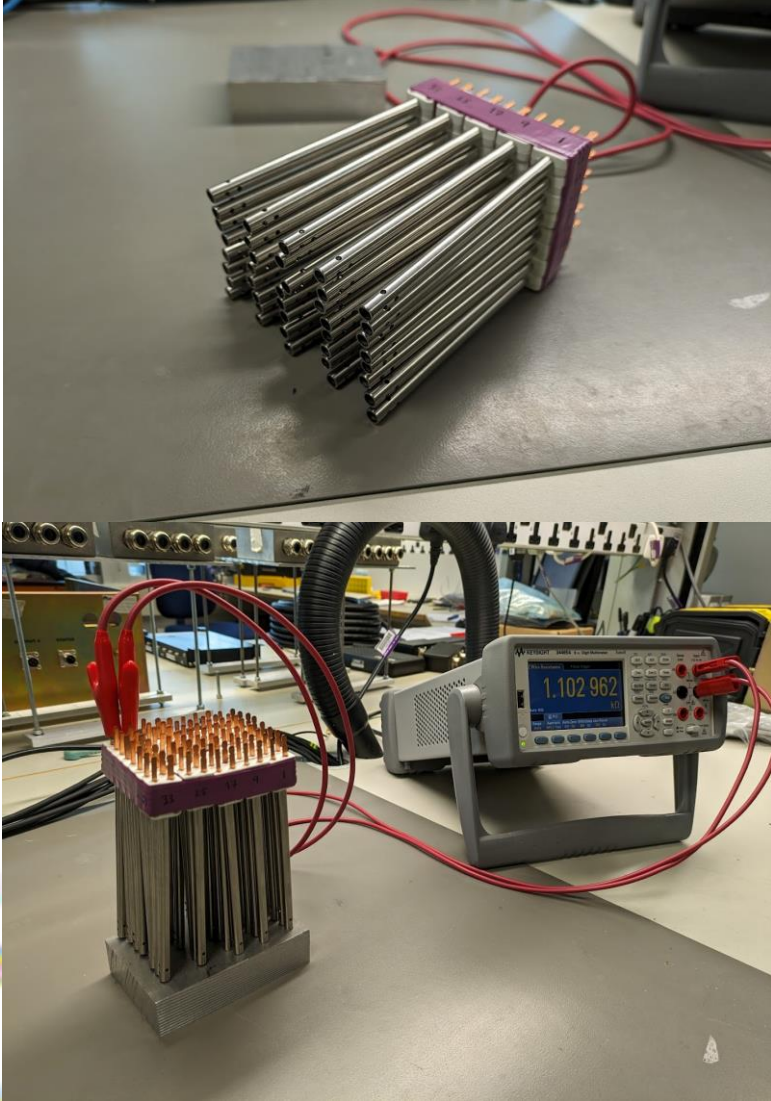


15m of cable will increase total resistance by **0.7 Ω**
corresponding to measured temperature offset of **0.18 deg. C**

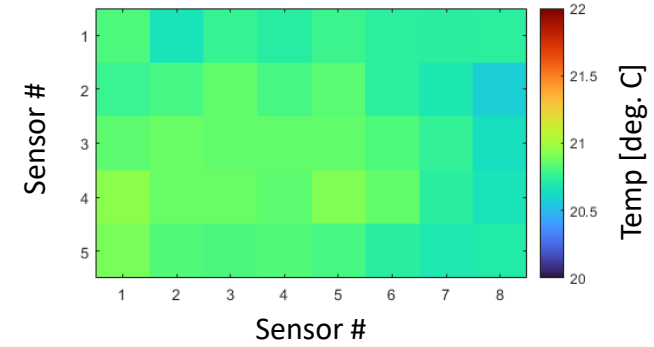
→ Therefore cable offsets are included in the reported measured temp calculation

Sensor Comparison

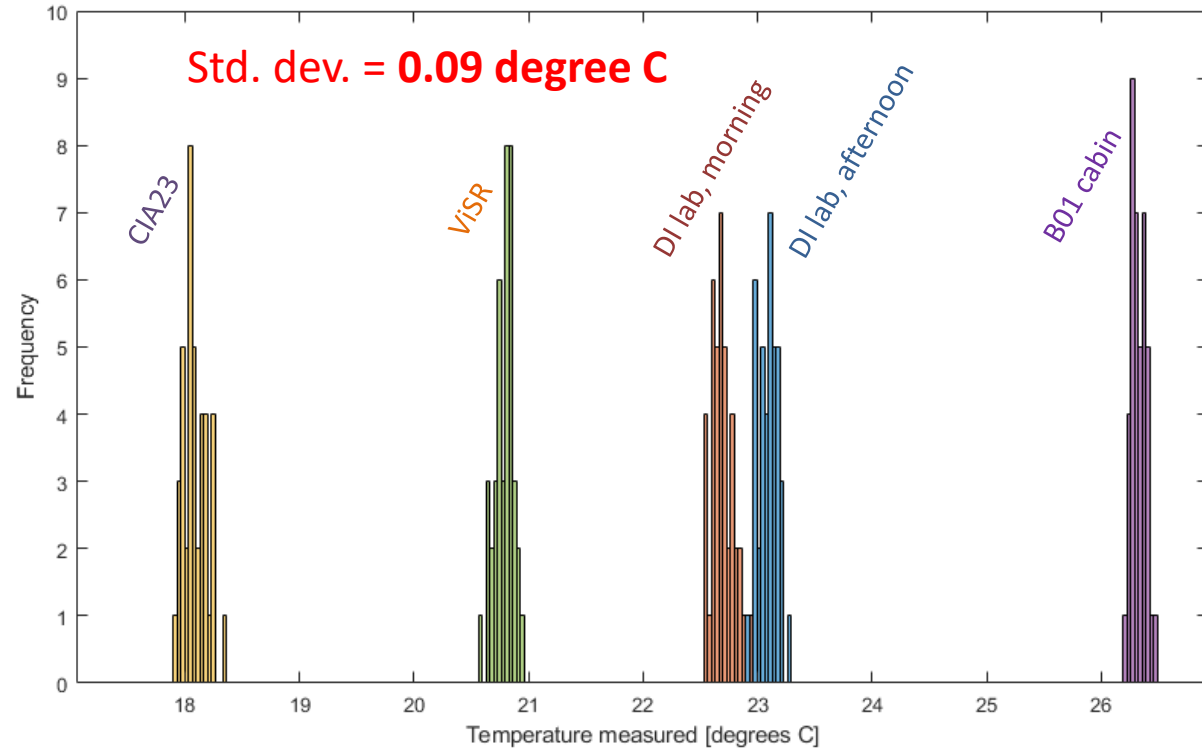
“Hedgehog” of 40 sensors used to verify spread of individual sensor offsets



Typical spread of measured temperatures:



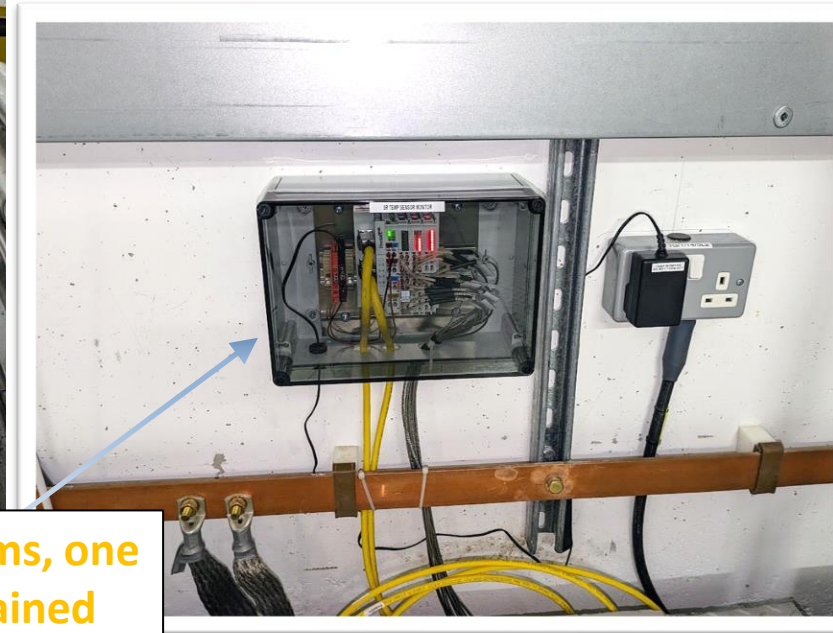
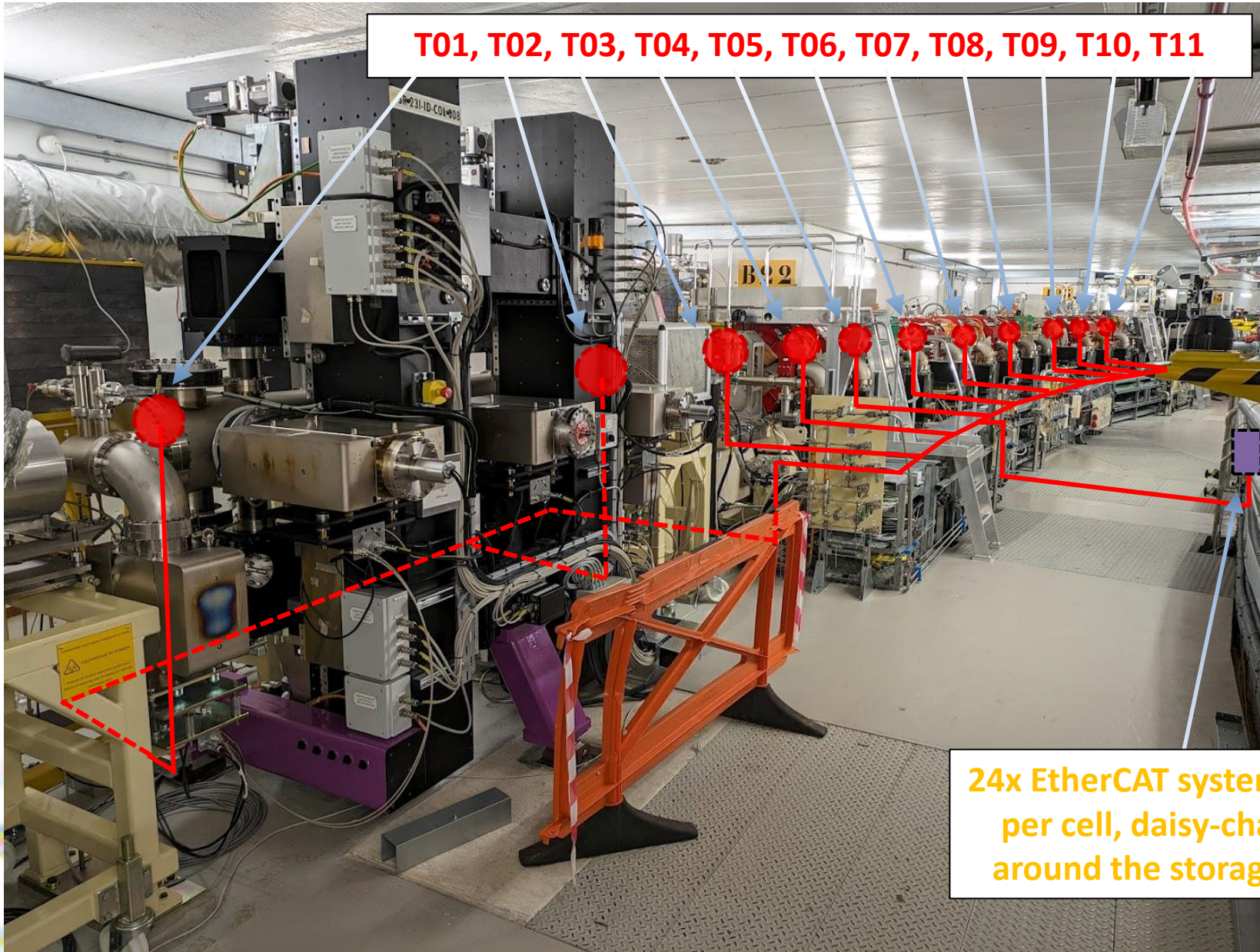
Measured in a few different places with different temperatures:



Sensor Deployment

T01, T02, T03, T04, T05, T06, T07, T08, T09, T10, T11

11 sensors per cell
(except DDBA which has 10)



24x EtherCAT systems, one per cell, daisy-chained around the storage ring

Cable Length Considerations

T01, T02, T03, T04, T05, T06, T07, T08, T09, T10, T11



24x EtherCAT systems, one per cell, daisy-chained around the storage ring

Cable lengths make small but measurable difference, so they're recorded.

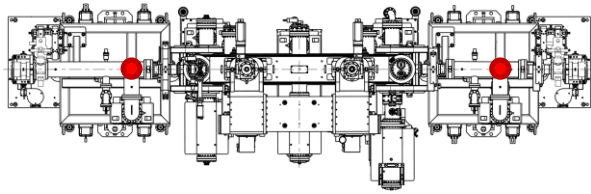
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	St. Str.	Long str.
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T04	11m	16m
T05	9m	14m
T06	8m	13m
T07	11m	10m
T08	13m	11m
T09	14m	13m
T10	16m	15m
T11	18m	18m

Standardised Locations

SR Temperature sensor layout per cell:

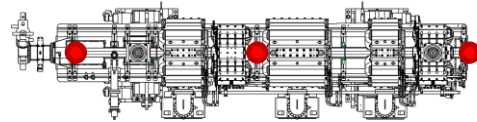
11 sensors girder sensors repeated around the SR, T01 – T11

Top view



T01

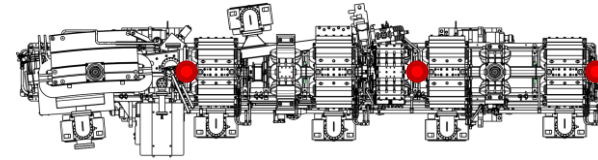
T02



T03

T04

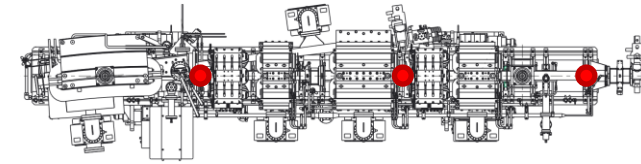
T05



T06

T07

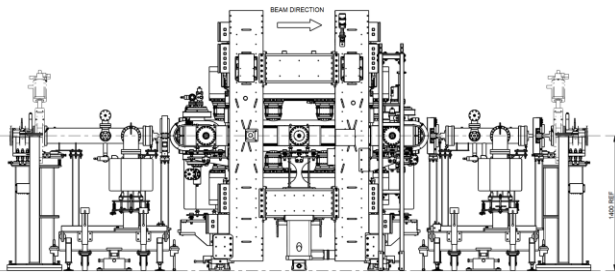
T08



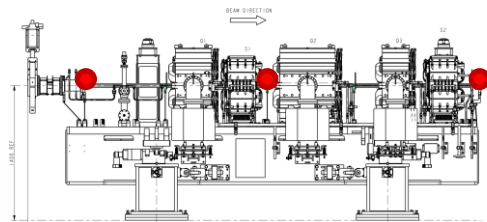
T09

T10

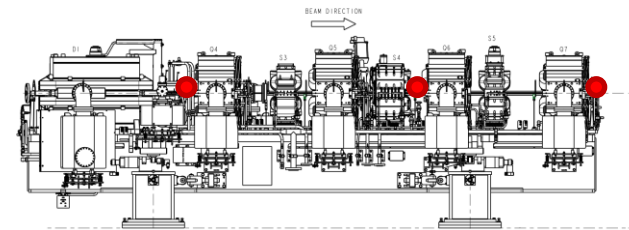
T11



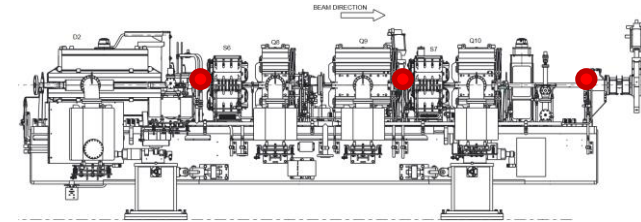
Straight



Girder 1



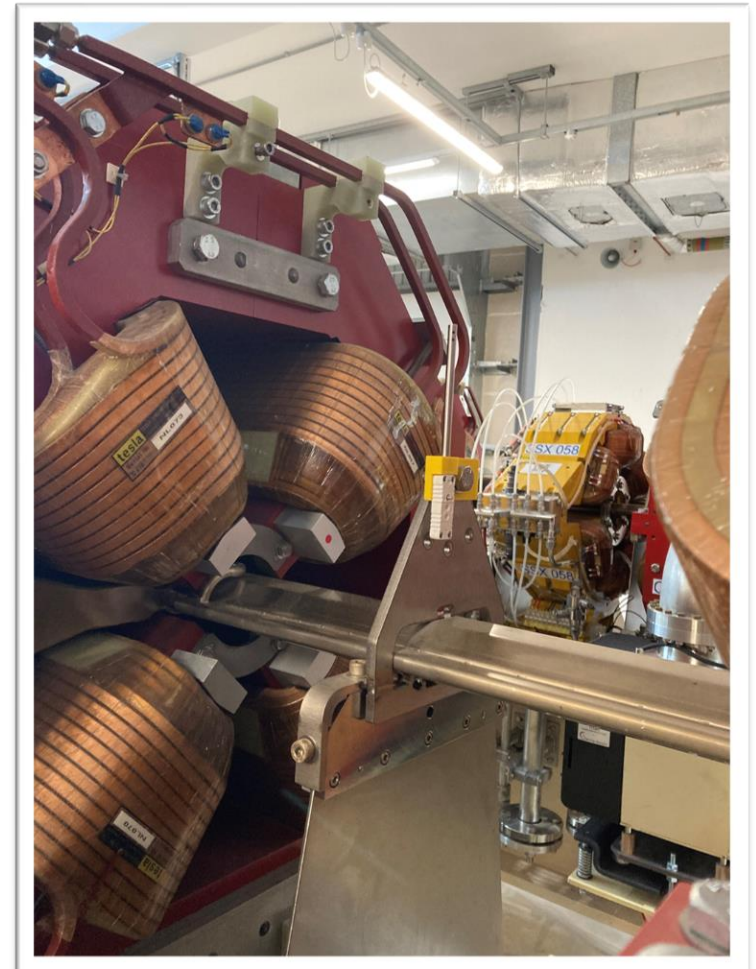
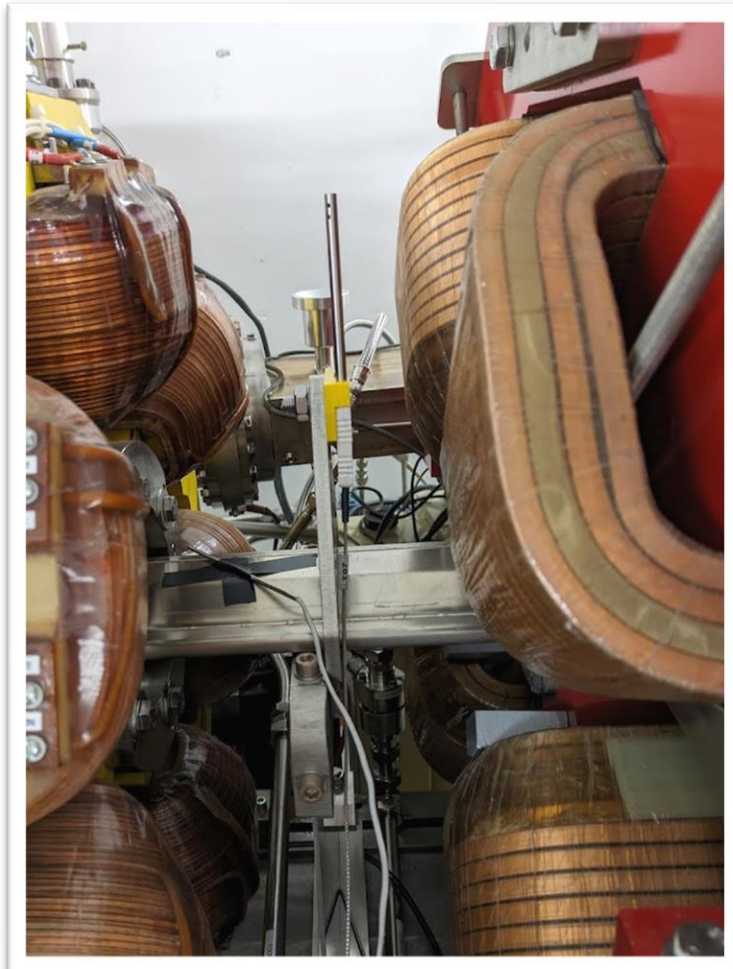
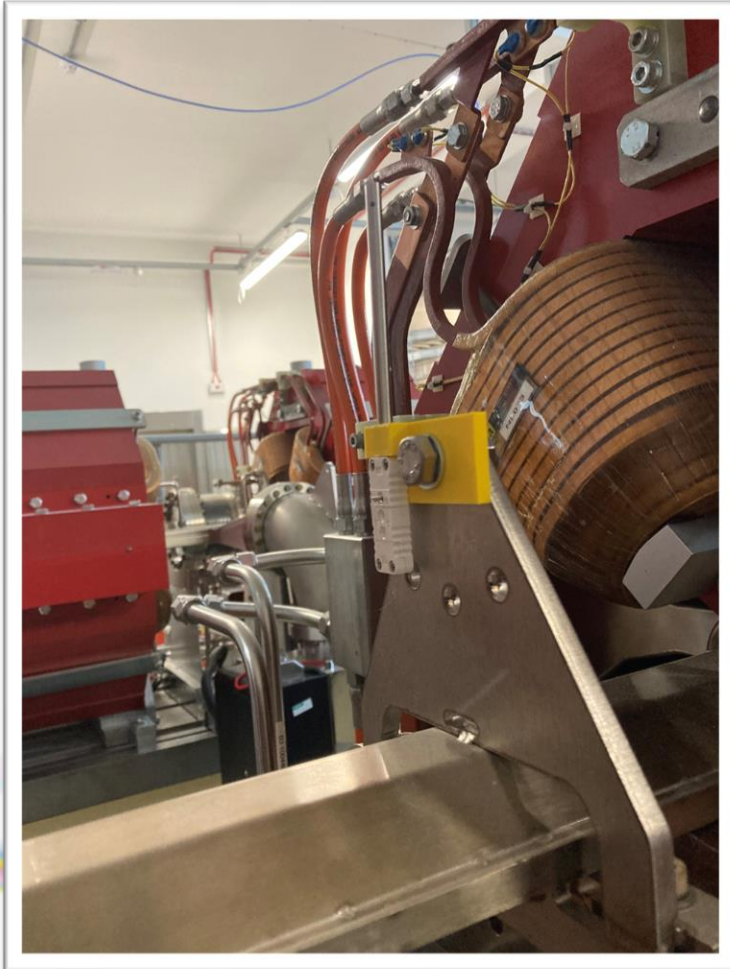
Girder 2



Girder 3

Mounting

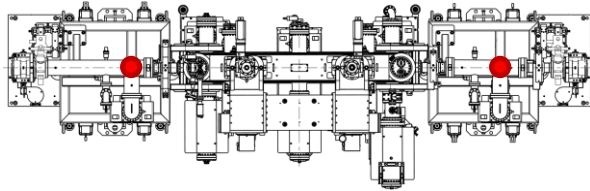
Sensors mounted to vacuum string lifting eyes, located at regular intervals along girder.



Standardised Locations

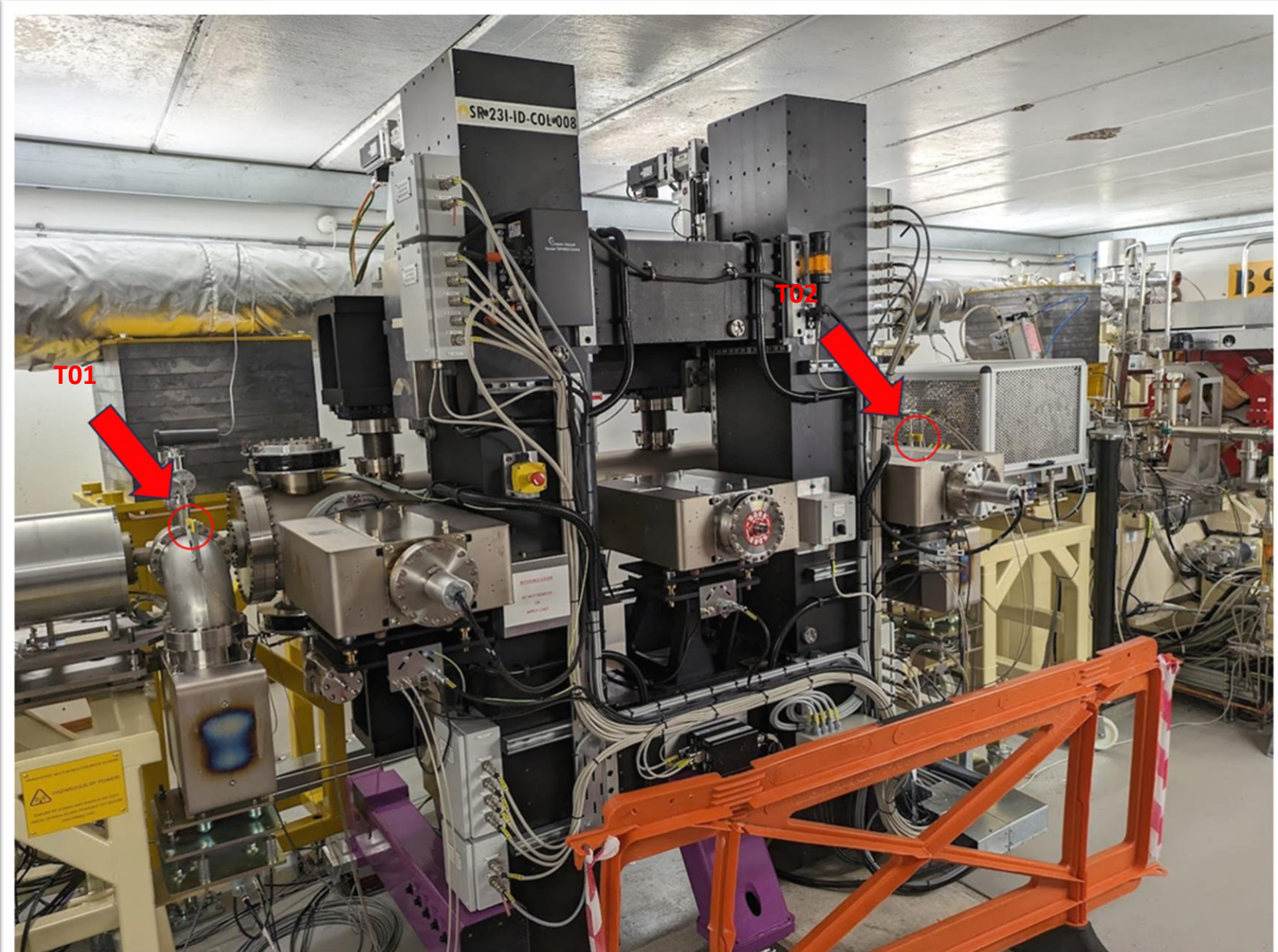
Straight

Top view



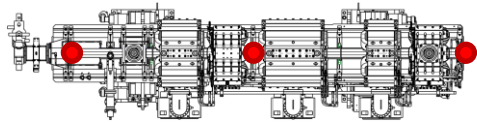
T01

T02



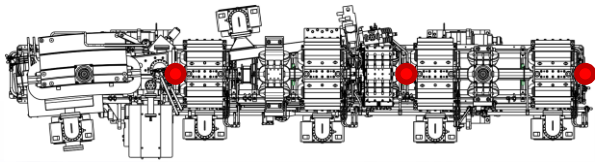
Standardised Locations

Girder 1

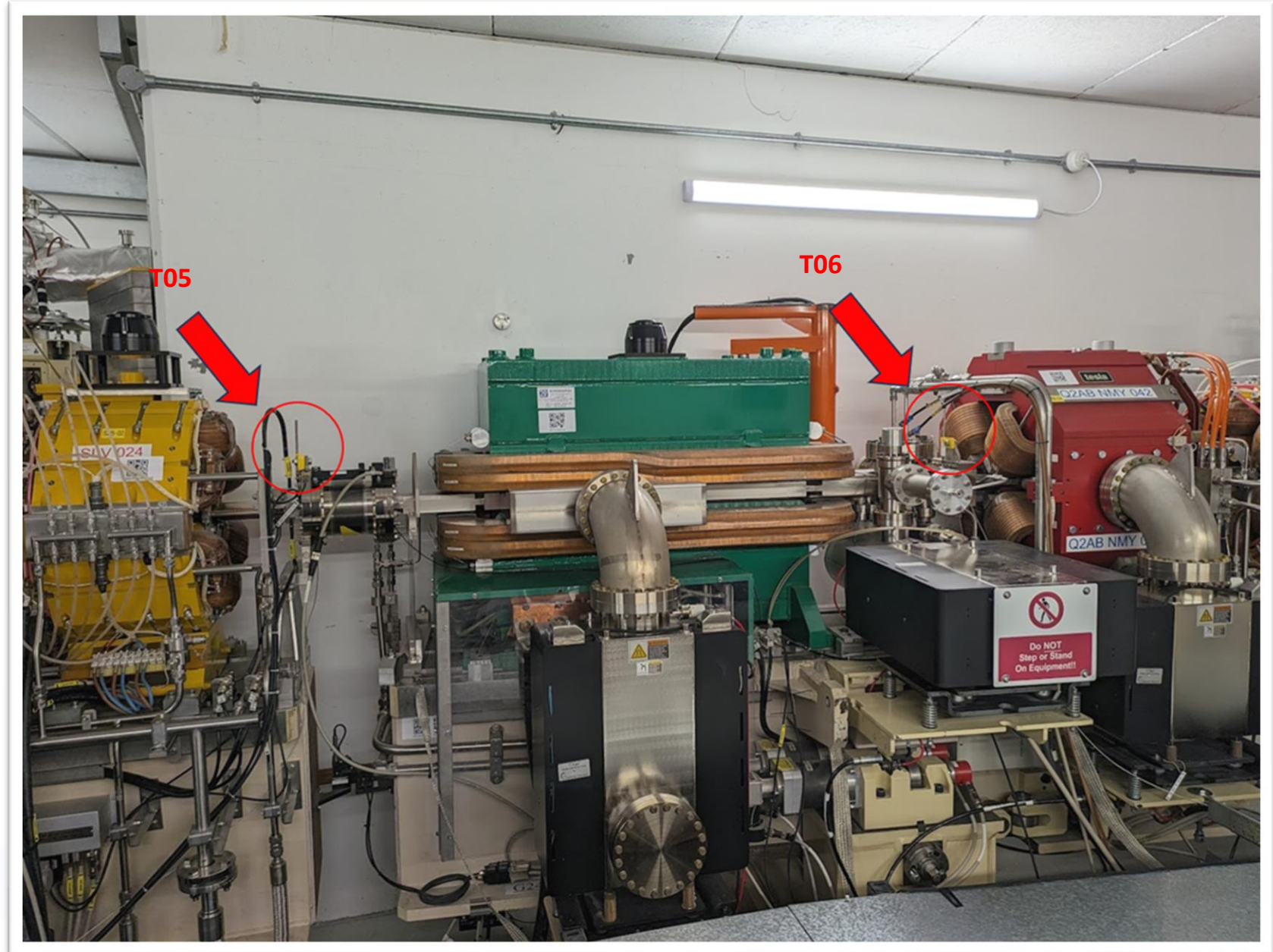


T03 T04 T05

Girder 2

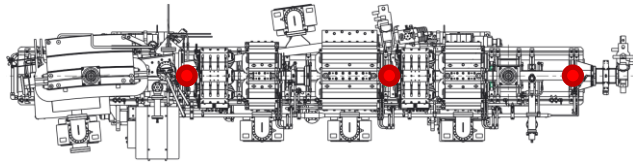


T06 T07 T08



Standardised Locations

Girder 3



T09

T10

T11



Archiver

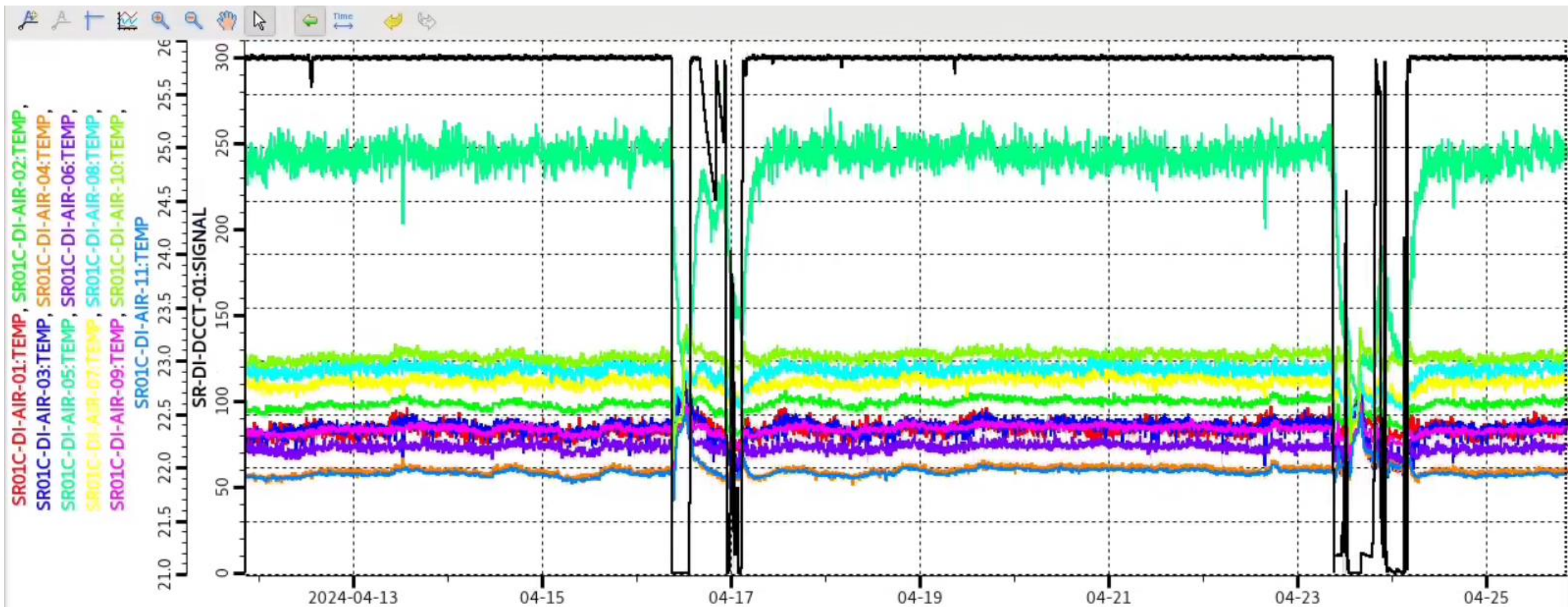
Cell 01	SR01C-DI-AIR-01:TEMP	← First sensor in cell at start of injection kickers
	SR01C-DI-AIR-02:TEMP	
	...	
	SR01C-DI-AIR-10:TEMP	
	SR01C-DI-AIR-11:TEMP	← Last sensor in cell at end of girder 3
Cell 02	SR02C-DI-AIR-01:TEMP	} DDBA straight slightly different, only has 10 sensors
	SR02C-DI-AIR-02:TEMP	
	...	
	SR02C-DI-AIR-09:TEMP	
	SR02C-DI-AIR-10:TEMP	
Cell 03	SR03C-DI-AIR-01:TEMP	← First sensor in cell upstream of ID
	SR03C-DI-AIR-02:TEMP	
	...	
	SR03C-DI-AIR-10:TEMP	
	SR03C-DI-AIR-11:TEMP	← Last sensor in cell at end of girder 3
Cell 04	SR04C-DI-AIR-01:TEMP	
	SR04C-DI-AIR-02:TEMP	
	...	
	etc	

Confluence – Internal use only

<https://confluence.diamond.ac.uk/x/KAu5D>

Or search “SR air temperature sensors”.

Archiver

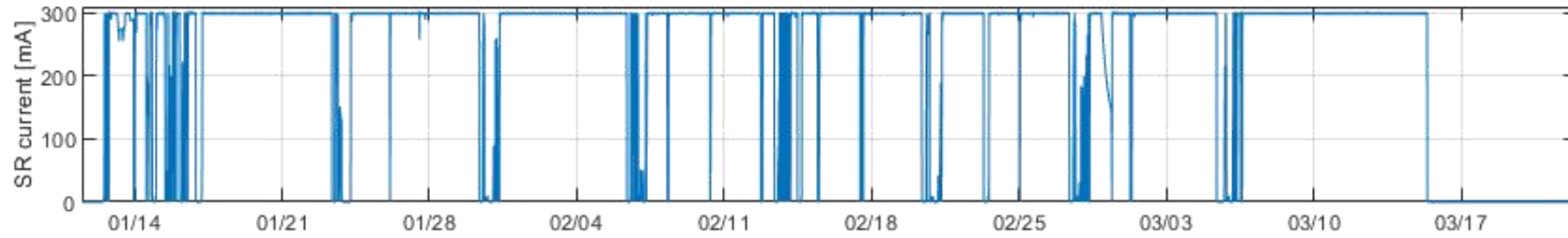


Confluence –Internal use only

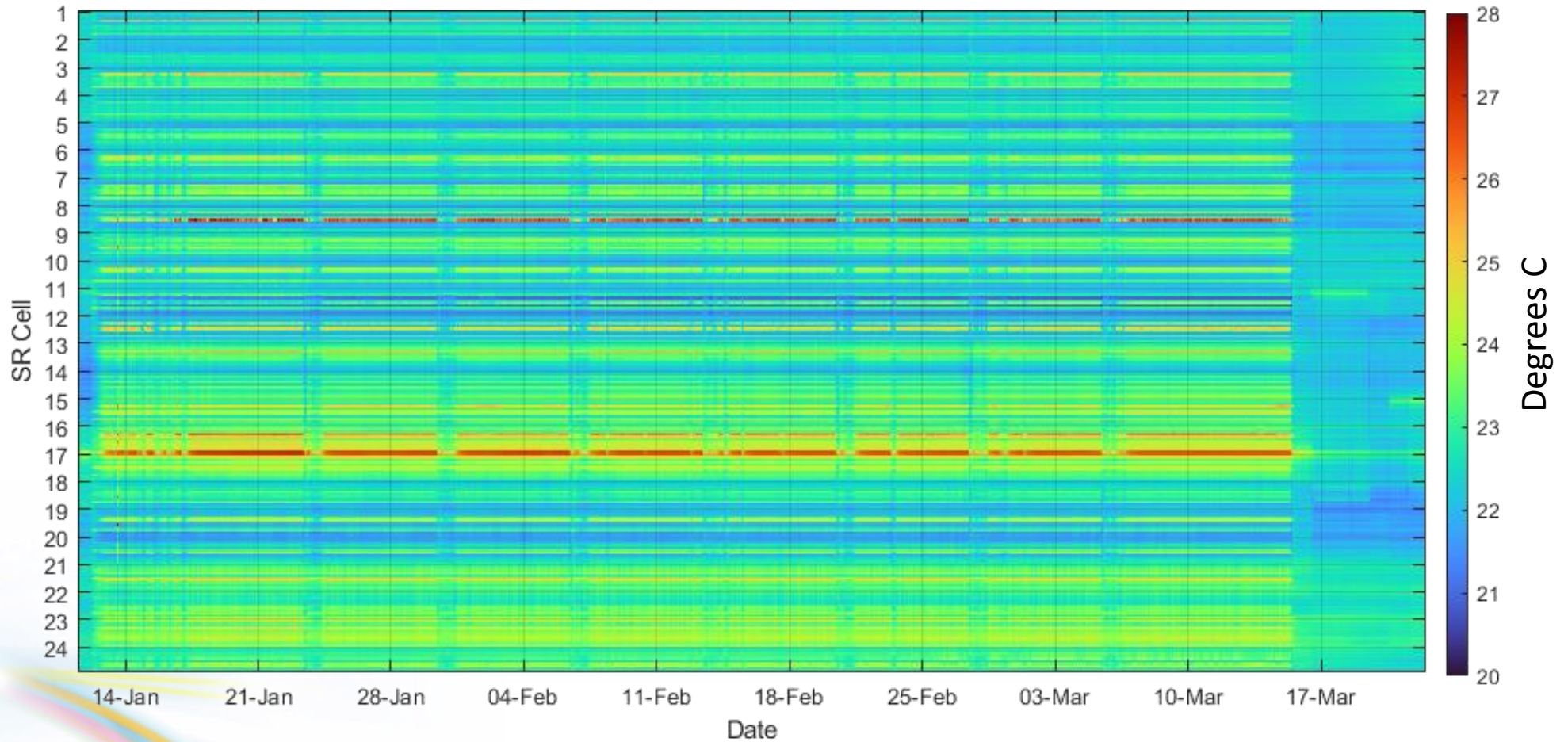
<https://confluence.diamond.ac.uk/x/KAu5D>

Or search “SR air temperature sensors”.

First Results – Run 1 2024 : Absolute Temp

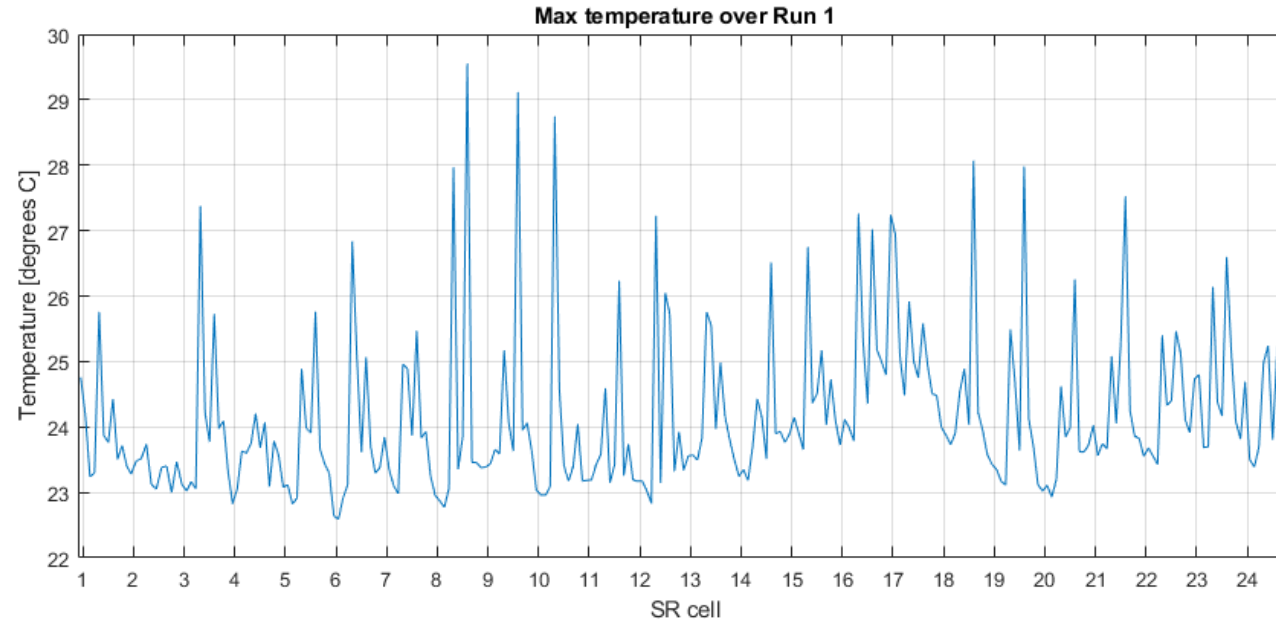


Absolute temperatures

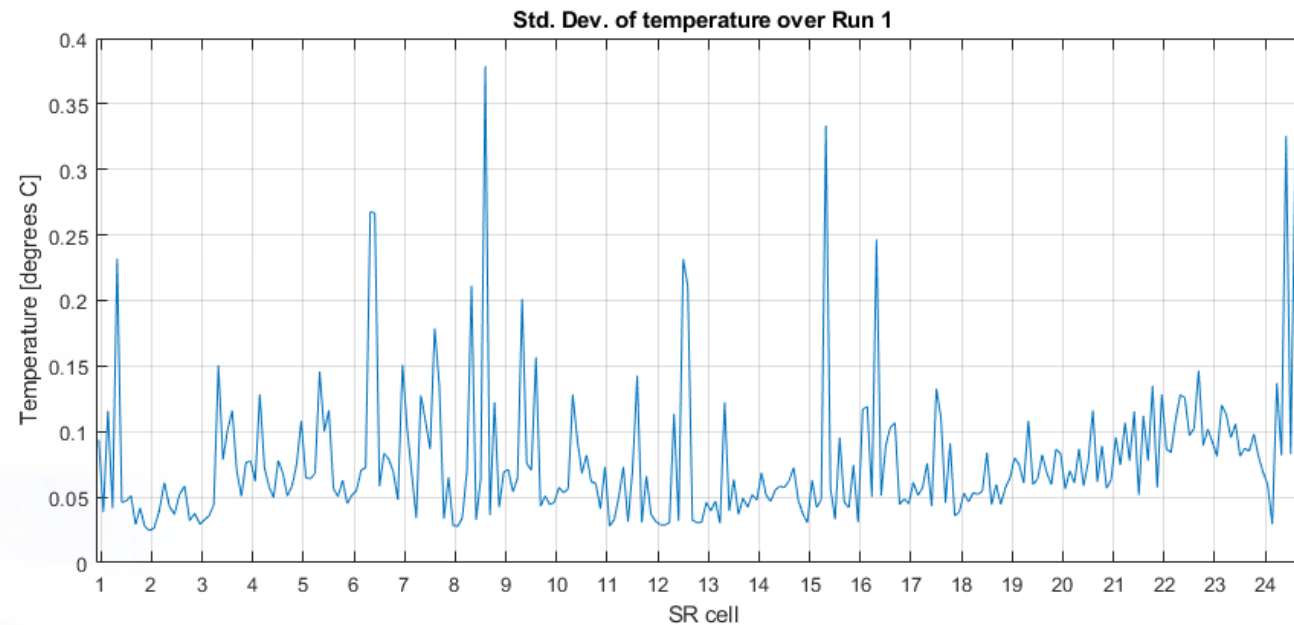


First Results – Run 1 2024 : Absolute Temp

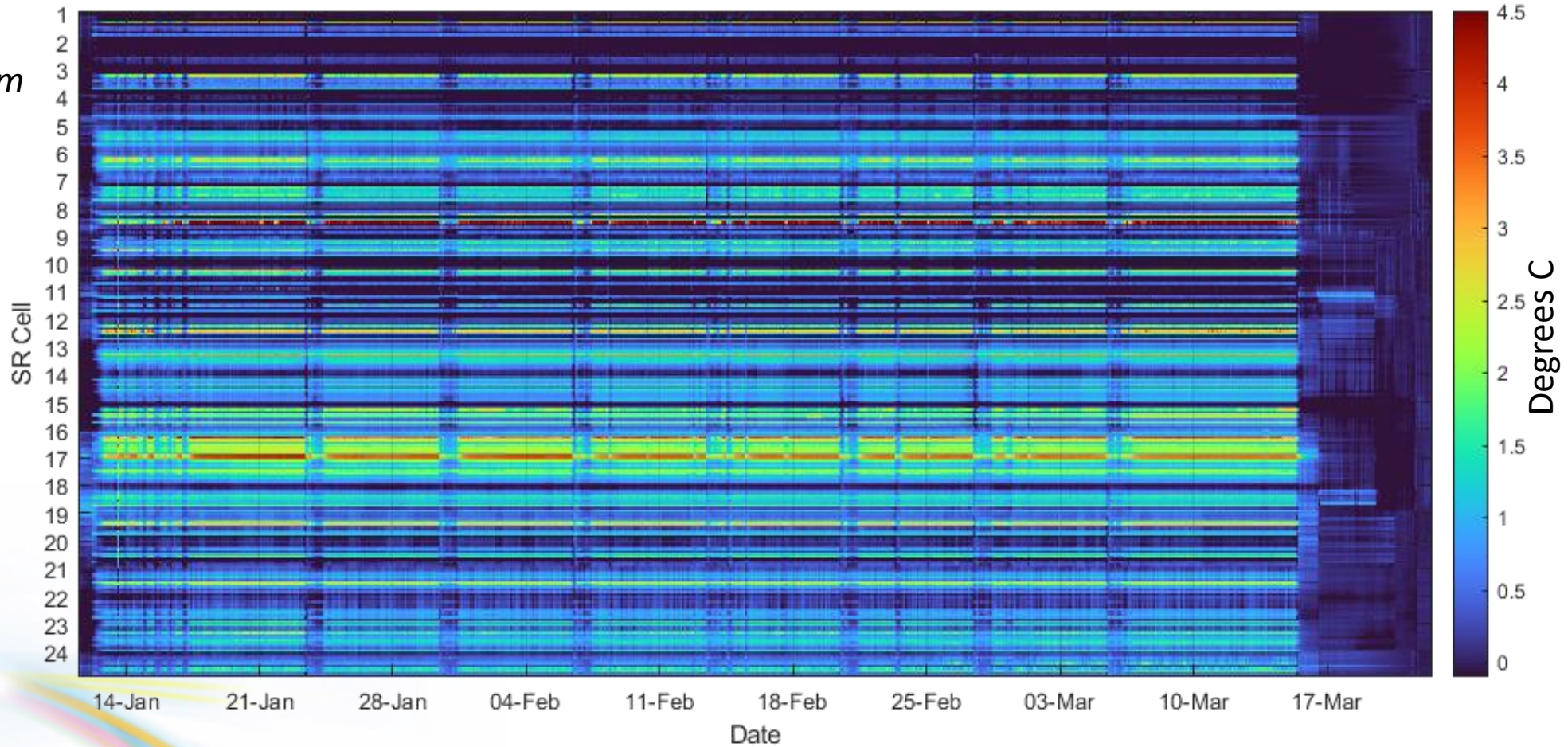
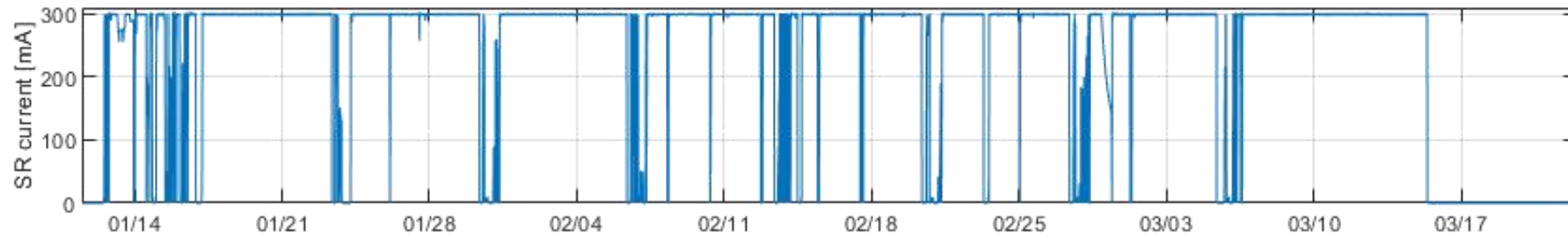
Over the whole of run 1,
maximum temperature seen:



Over a week of continuous
300mA, the **std. dev.** of
temperature variations seen:



First Results – Run 1 2024 : Δ “Cold” Machine



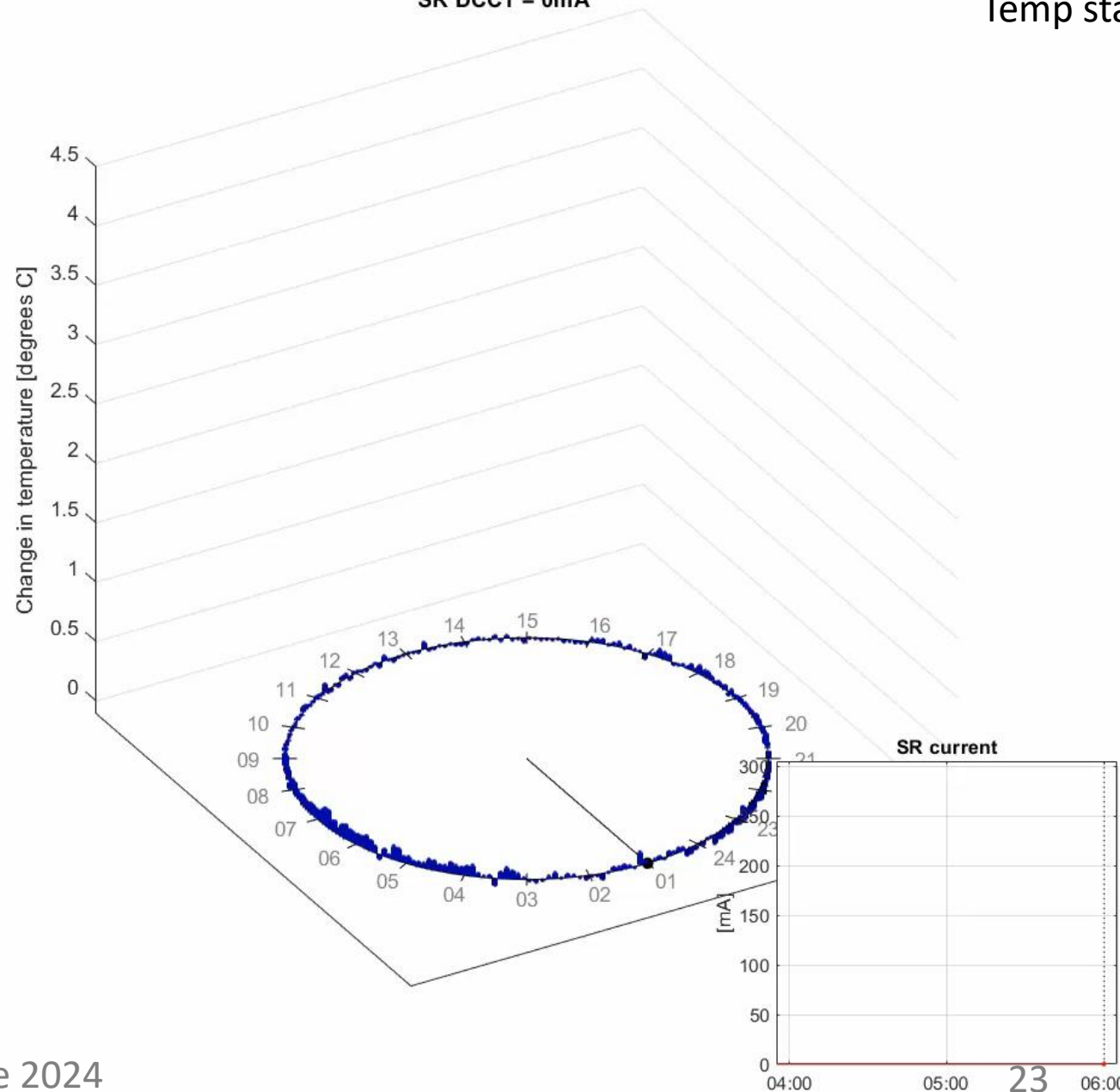
Increase in temperatures from “cold” machine

First Results – Run 1 2024 : Stabilisation

Cell	Description
1	Injection
2	DDBA
3	ID + BM Beamlines
⋮	
12	Wiggler
13	ID + BM Beamlines
14	
15	RF NCC Wiggler
16	RF NCC
17	RF SC
18	RF NCC
19	ID + BM Beamlines
⋮	
24	

24-Jan-2024 06:00
SR DCCT = 0mA

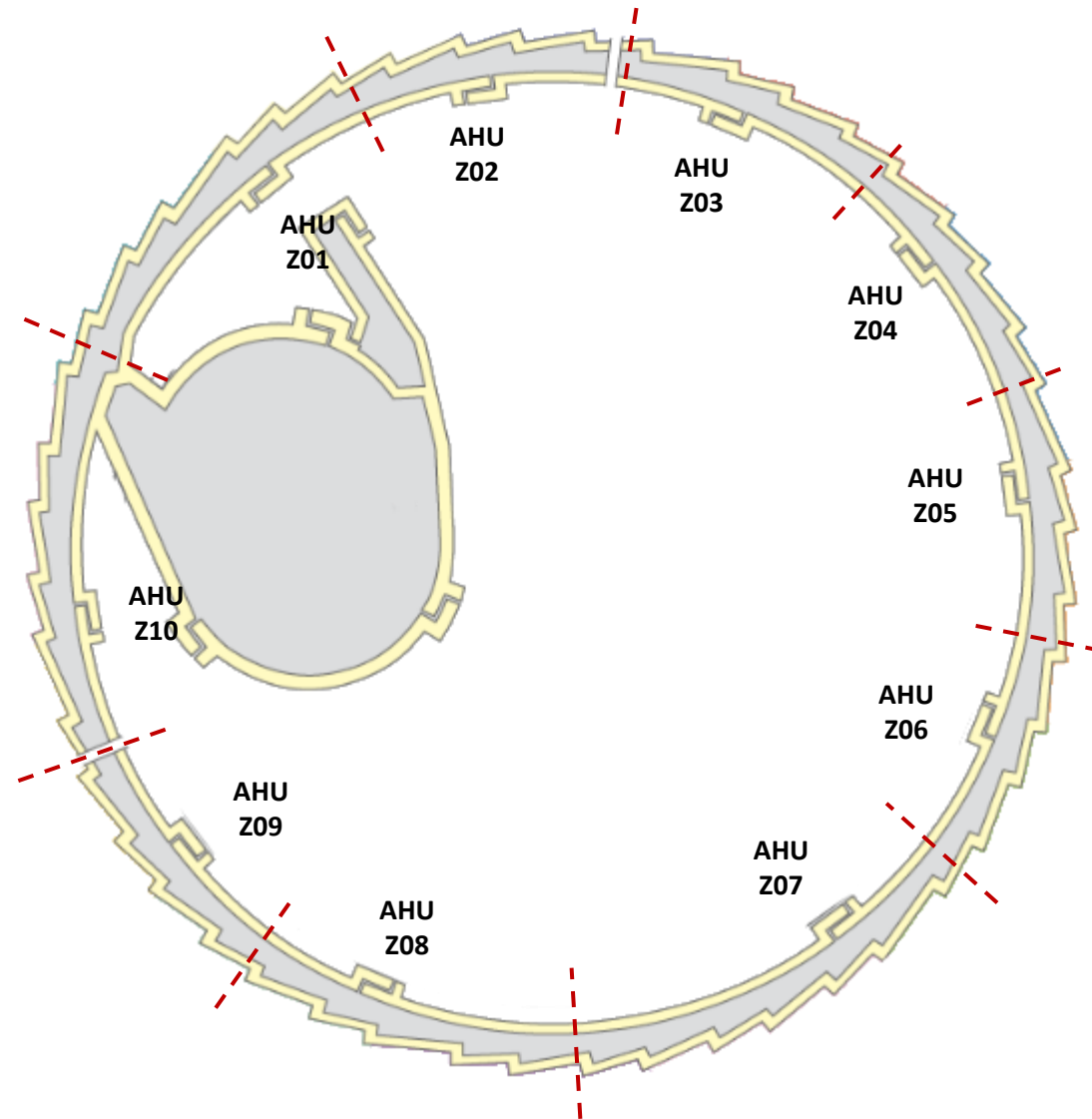
Temp stabilisation: 2-3hr



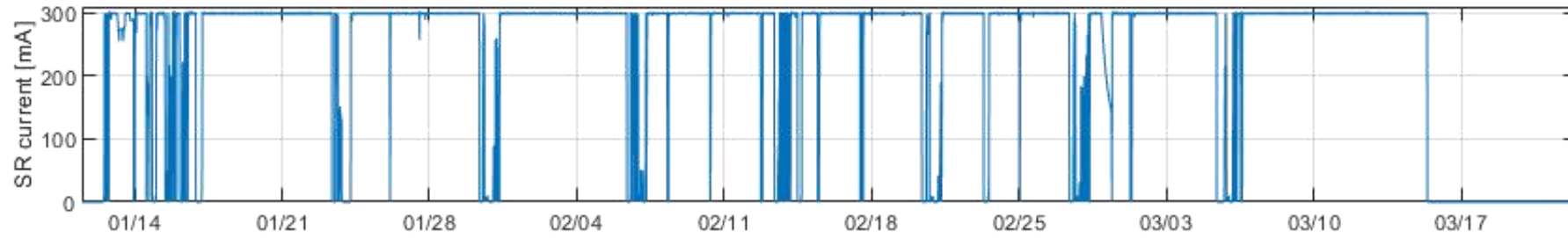
NCC = Normal Conducting Cavity
SC = Superconducting Cavity
DDBA = Double Double Bend Achromat lattice

Air Handling Units

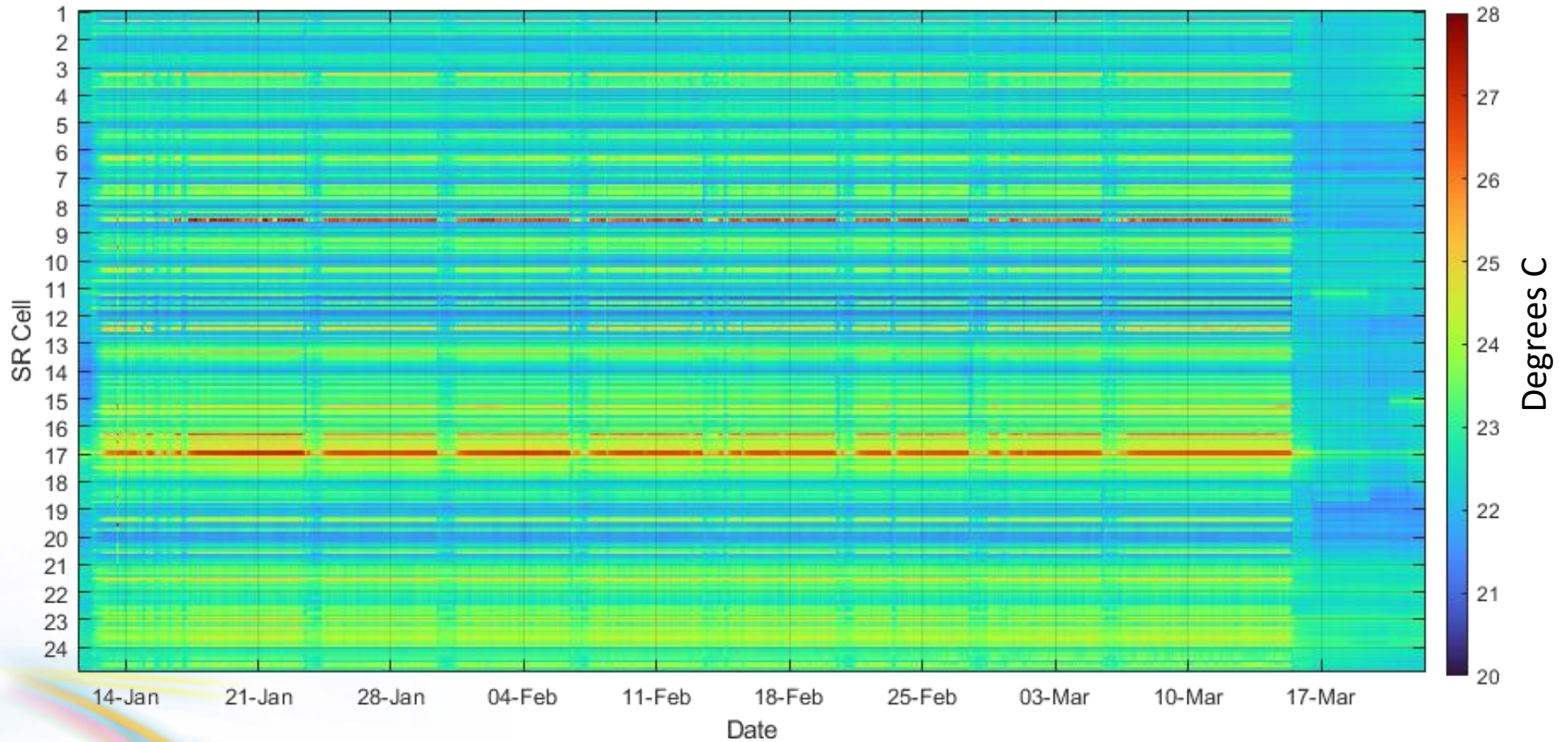
Storage ring has 10 AHU zones.
...they don't all behave equally!



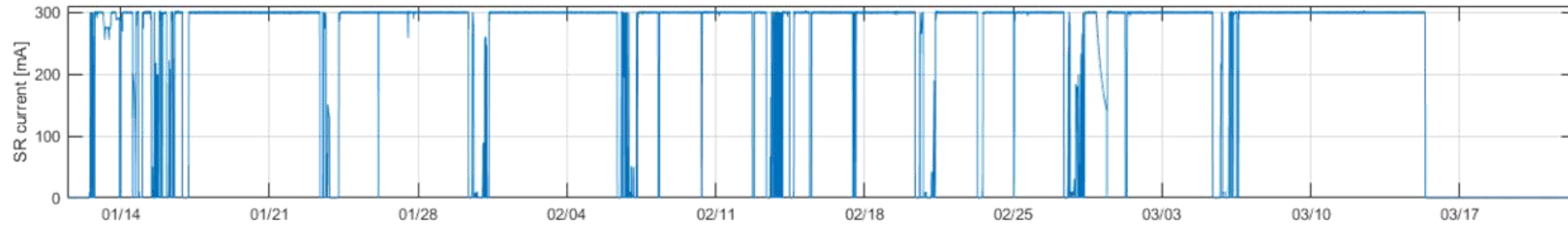
First Results – Run 1 2024 : Absolute Temp



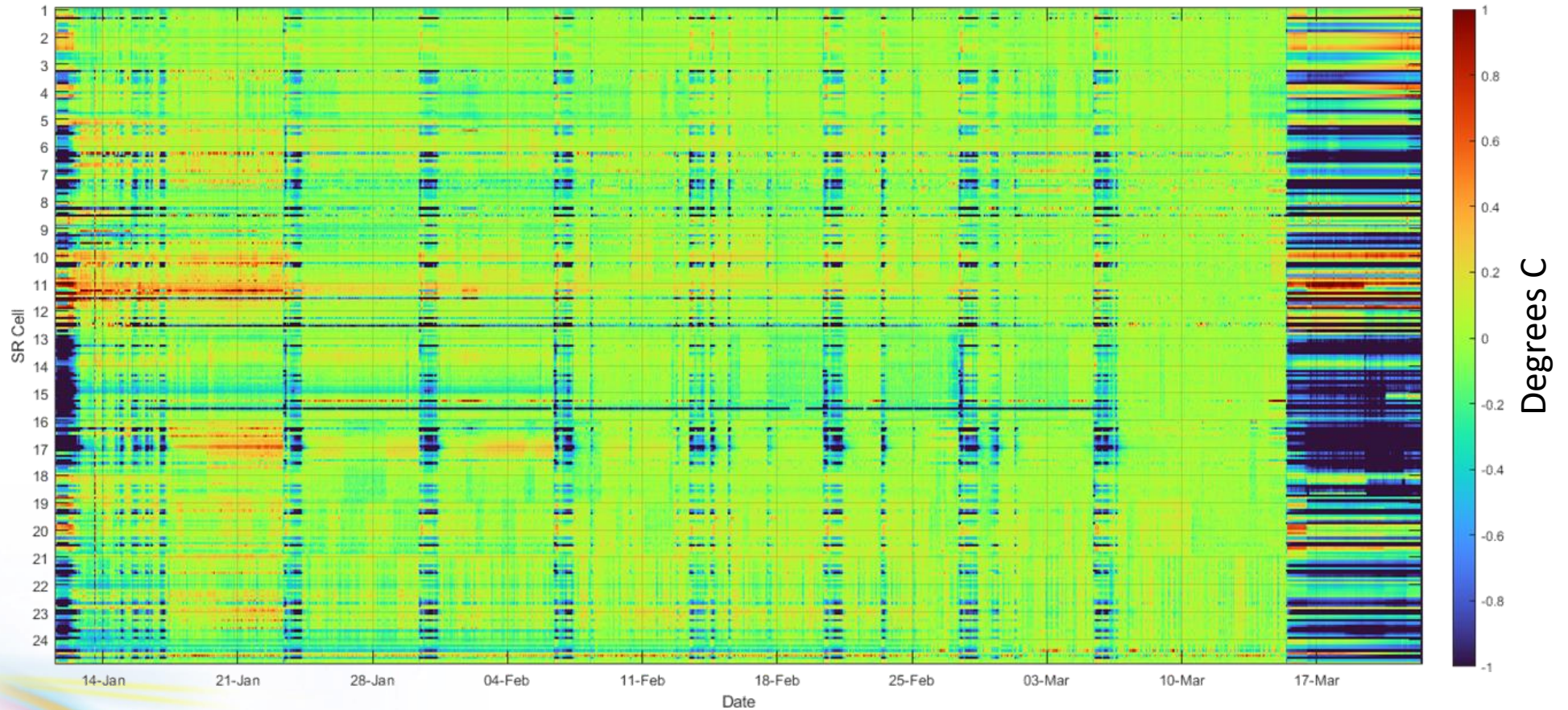
Absolute temperatures



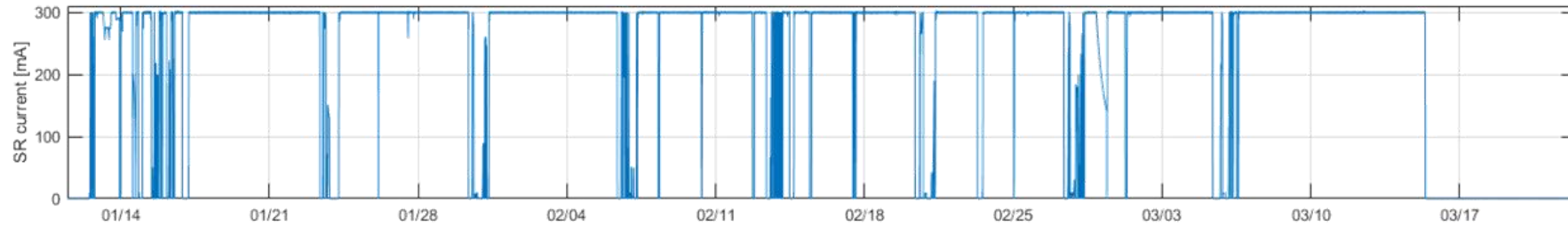
First Results – Run 1 2024 : Relative Temp



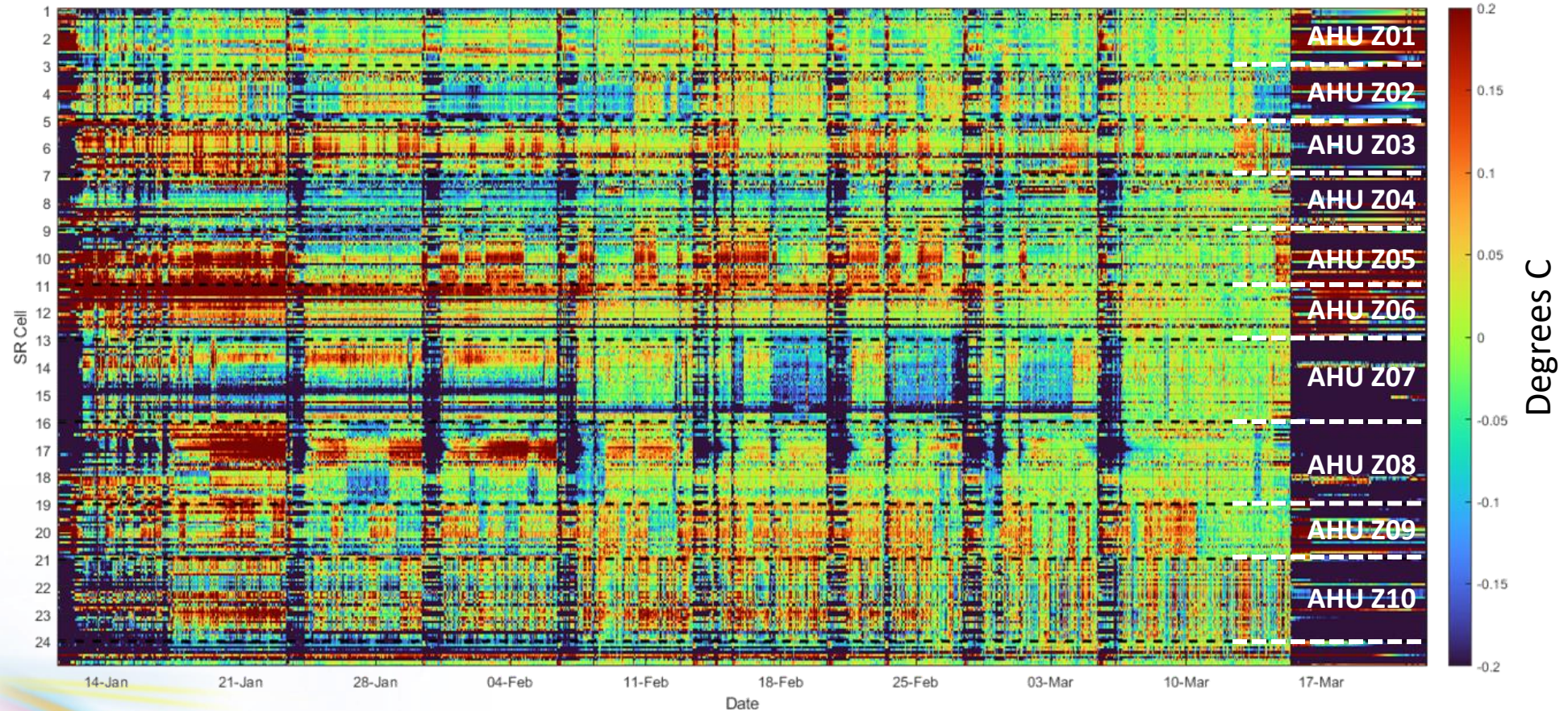
Relative temperatures



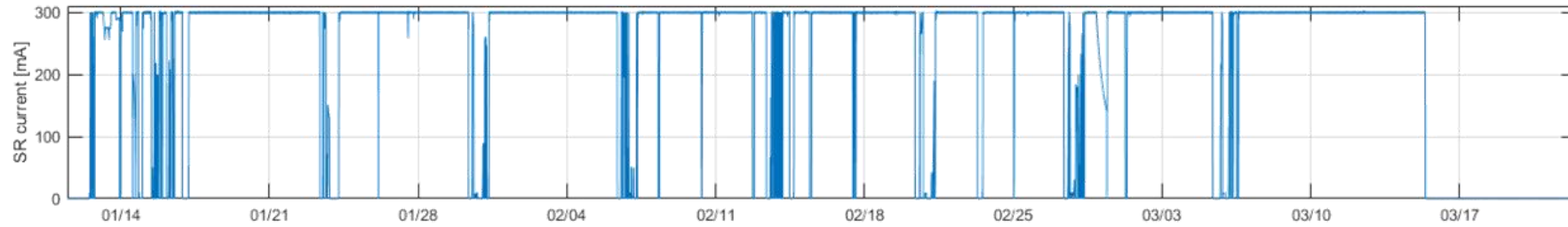
First Results – Run 1 2024 : Relative Temp



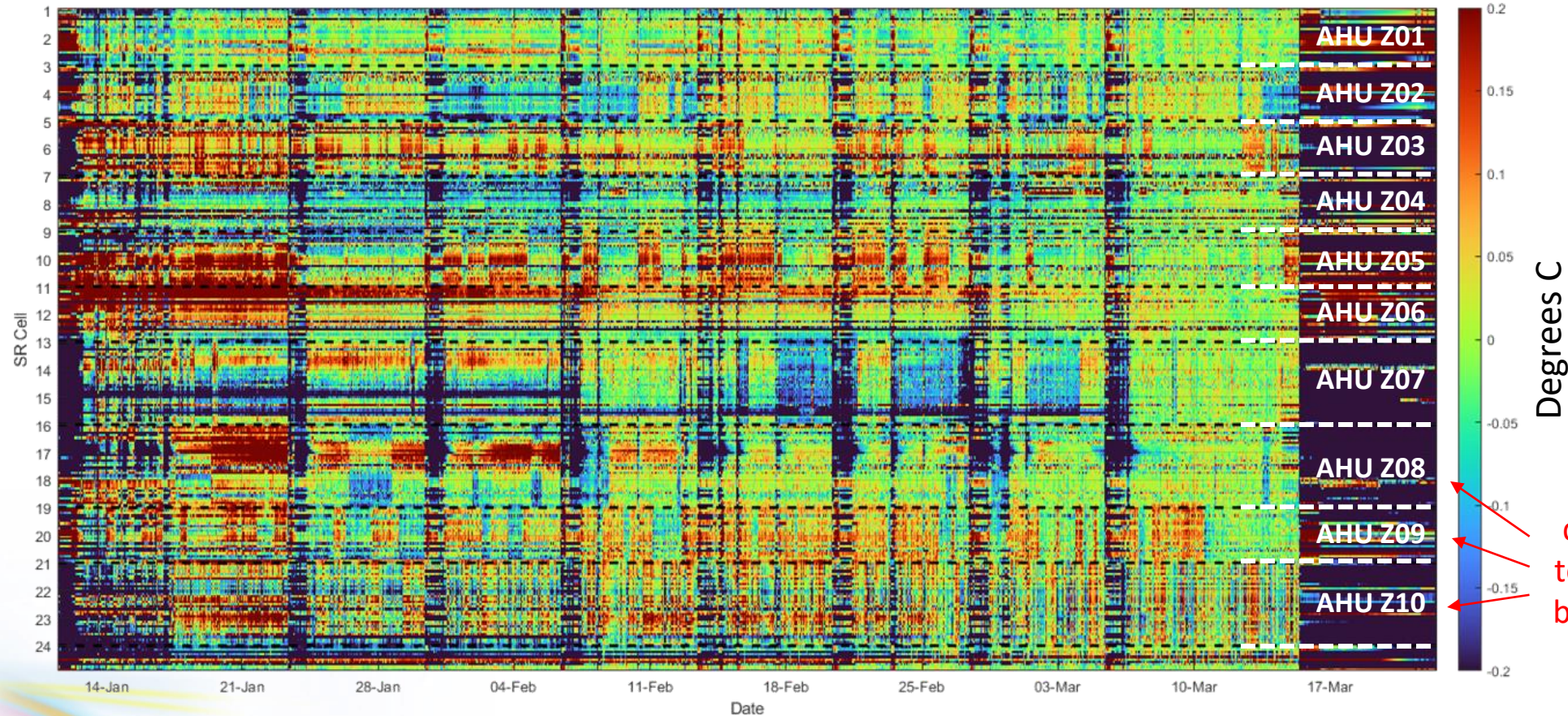
Relative temperatures



First Results – Run 1 2024 : Relative Temp



Relative temperatures

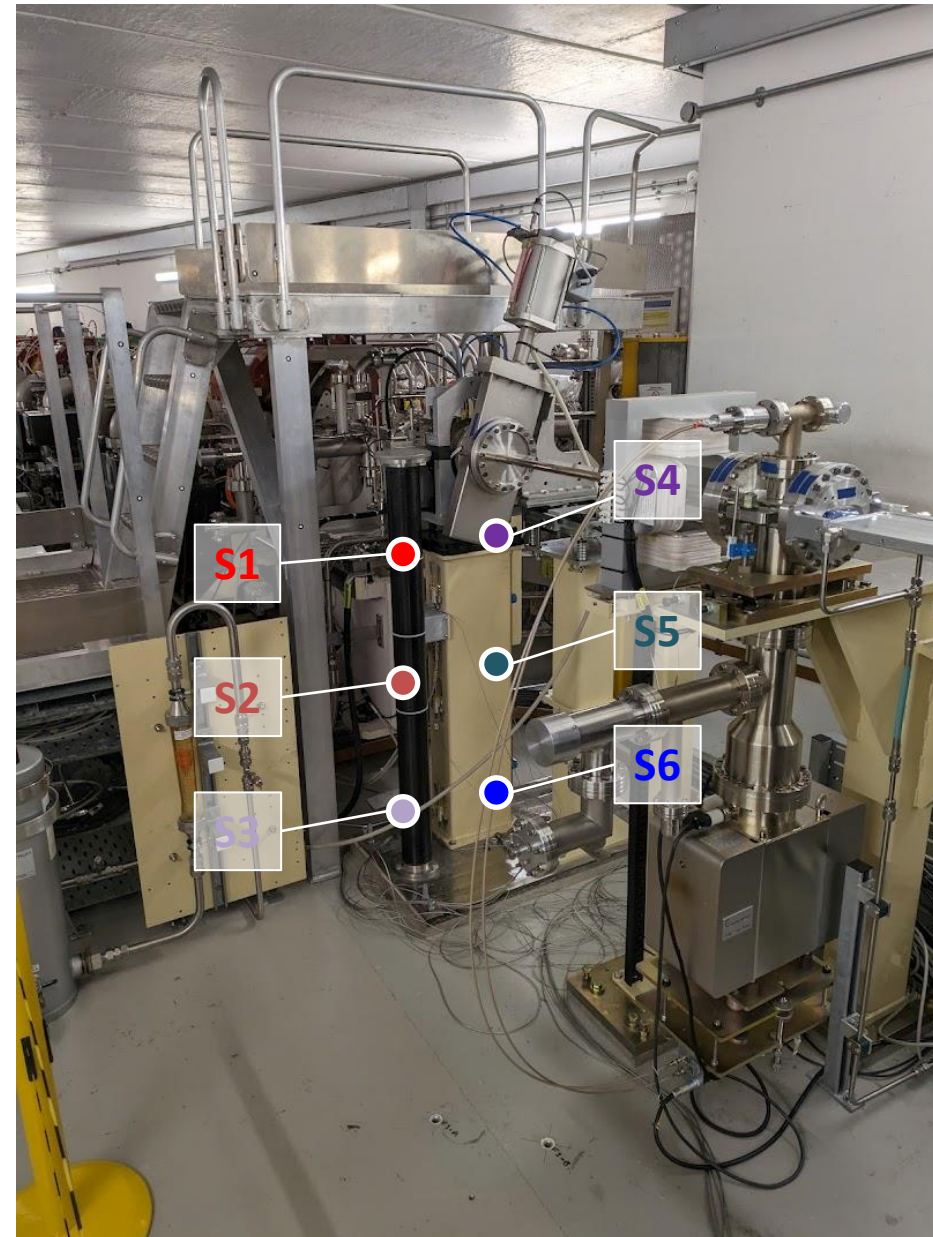


Why such difference in temp stability between AHU zones?

Primary BPM Support

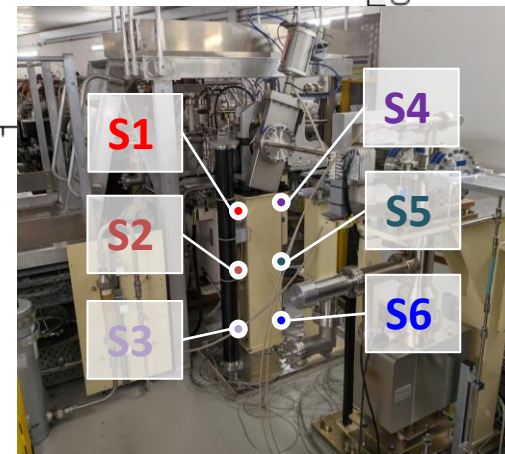
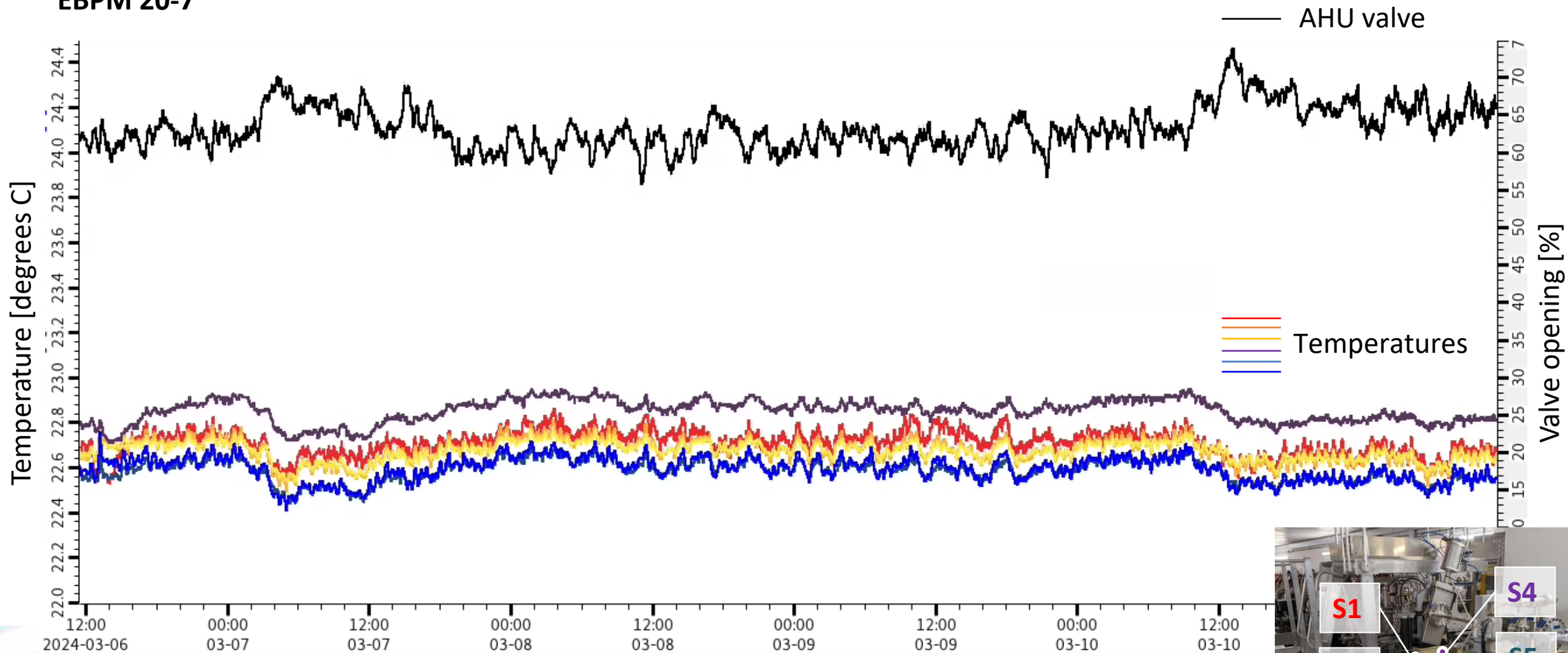
There is additional capacity to add more sensors.

Installed 12 more sensors in straight 21 at the very end of last run, 6 on each primary electron BPM column.



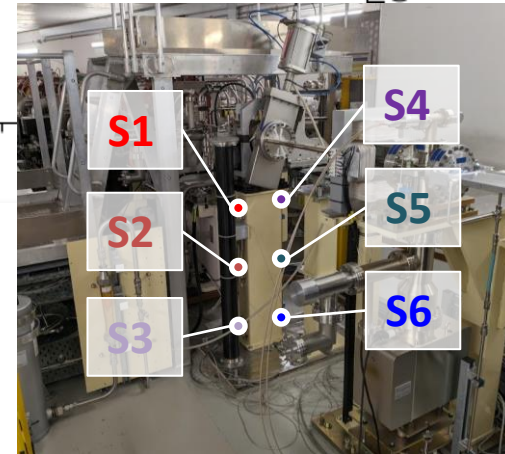
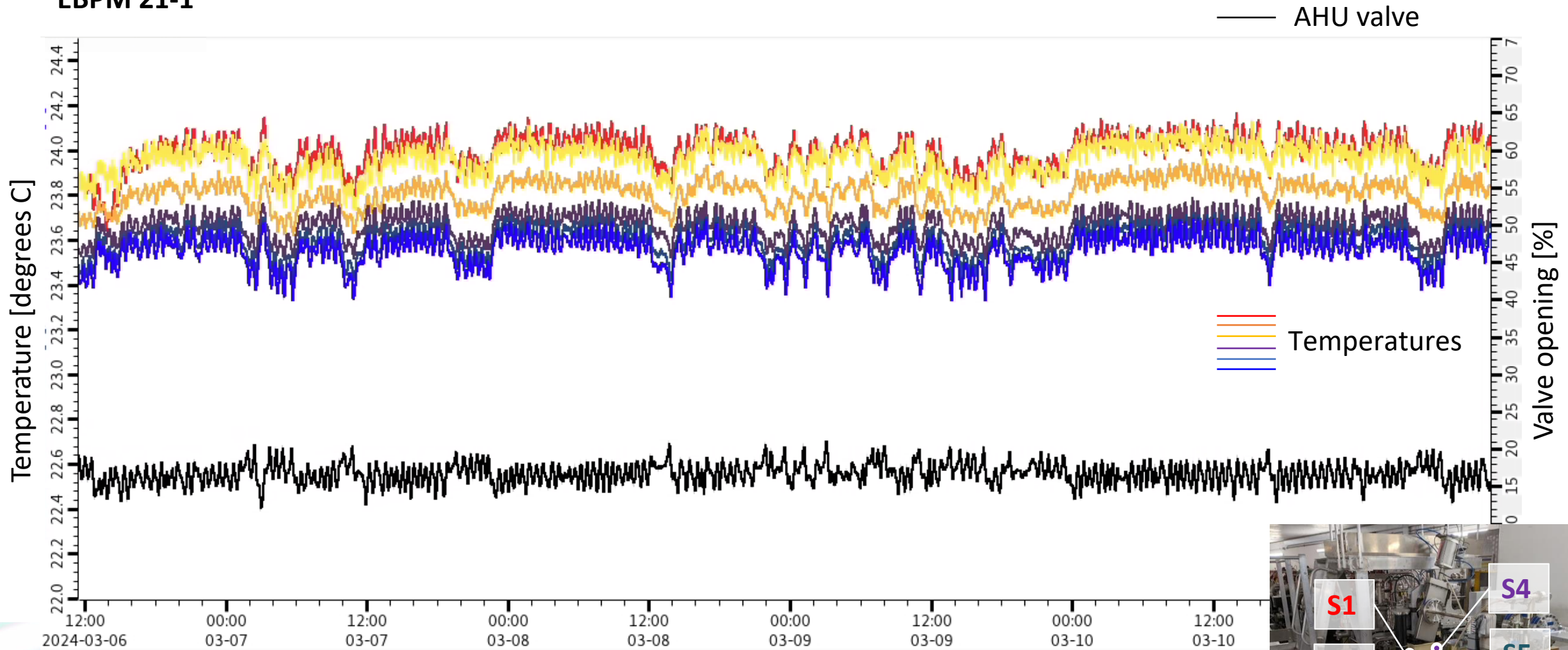
AHU near Primary BPM

EBPM 20-7



AHU near Primary BPM

EBPM 21-1



Summary

Air temperatures vary:

- Over time
- With beam current
- Cell-to-cell

Although there is an air handling feedback system for tunnel temperature stabilisation the sensors used are located metres away from the machine in the tunnel chicanes.

→ Air temperatures vary in close proximity to the machine where electronics and diagnostics are located

New air temp monitoring system has been installed and incorporated into our archivers. It will be recycled for Diamond-II.

Results are aiding the development of in-house BPMs, and provide further justification for Invar primary BPM supports.

Discussions underway on whether the AHU feedback can be improved.

Thank you for your attention!

Acknowledgements:

Chris Bloomer (who led much of this work and these slides!)

Graham Cook

Paul Hamadyk

Shoaib Khaja

Ken Jones