

CERN Mock-up test results

LONG RUN

1. Setting up the Mock-up
2. LN2 tests
 - a) Overall conditions of the test
 - b) Stress test
 - c) Long stay test
3. LAr tests
 - a) Overall conditions of the test
 - b) Stress test and long stay test
 - c) Humidity tests
4. Conclusion

DarkSide20K Calibration
Meeting 17/07/2023

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Mock-up

INTRODUCTION

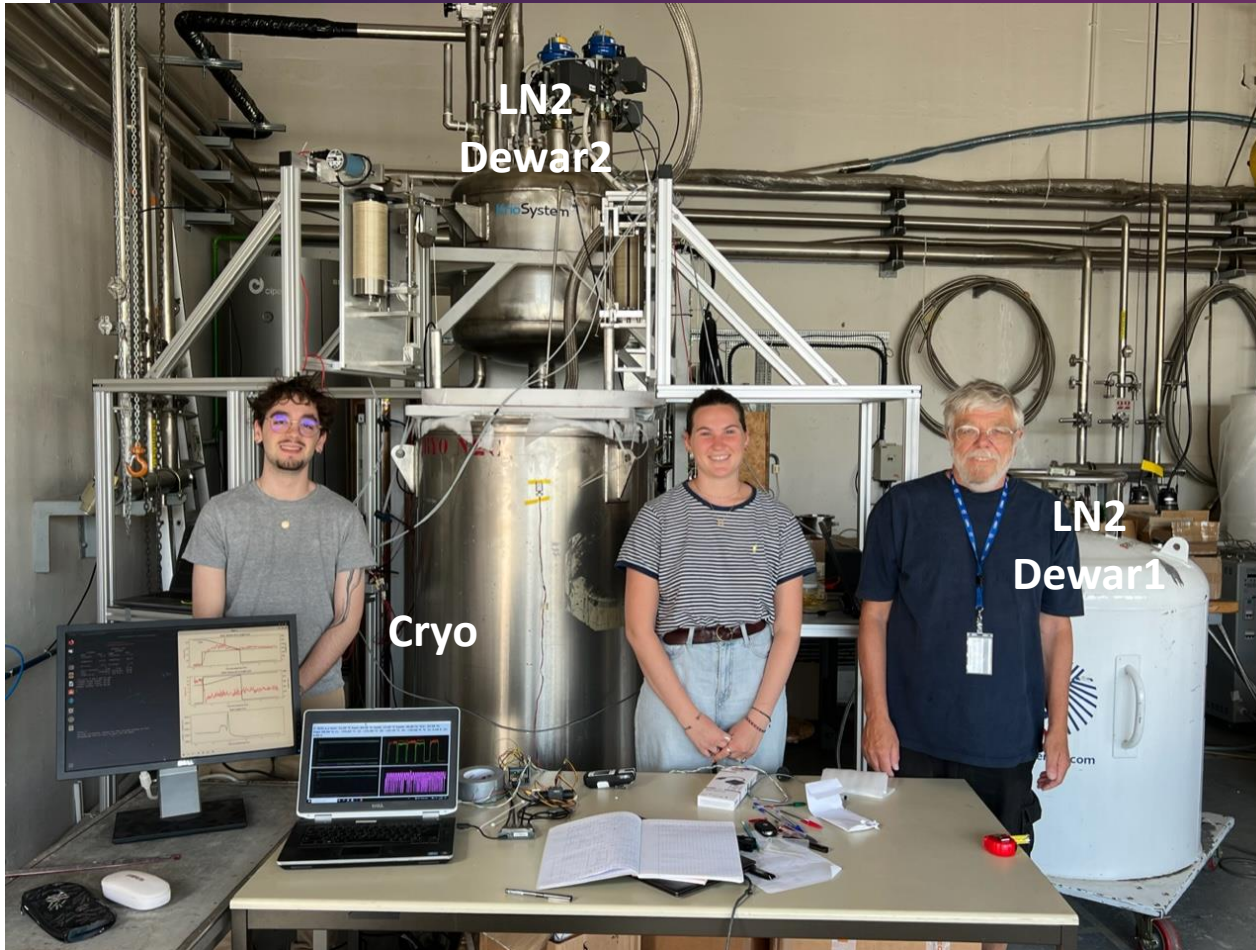
Determine robustness of calibration system at cold, and during a long period (LN2 then LAr).

| | MU_CShort | MU_CLong | MU_Warm |
|----------------------|---|--------------------------|----------------------------------|
| Purpose | Robustness against ice formation, source blocked, bend, pipe leak | | Behaviour in bends, DS20k Length |
| Temp. (K) | LN2 (77) | LN2 (77), LAr (88) | Room (290) |
| Location | CPPM | CERN | CPPM |
| Pipe lgth (m) | 4 | 2 | 15 (~DS-20k) |
| Nb bends | 2 | 1 | 15 (11, 7) |
| Runs | 09+11/22, 03/23 | 1 month @ June 23 | 03-04/23 |

Huge thanks to the CERN Cryolab for providing and running the Cryostat, the LN2 and the LAr

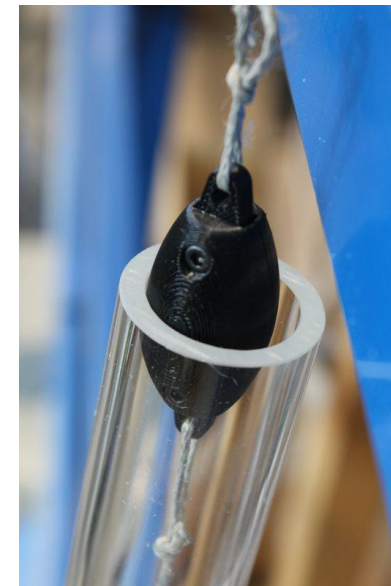
Mock-up

TEST'S SCHEDULE



Pseudo-source

- $L = 5.5\text{cm}$
- $\phi = 2.5\text{ cm}$
- $M = O(100)\text{ g}$



In CERN Cryolab, building 159

- 30/05-2/06 : Installation
- 5-9/06 : Settings
- 9-26/06 : LN2 tests
- 26/06-03/07 : Warming up Cryo to put LAr
- 03-17/07 : LAr tests

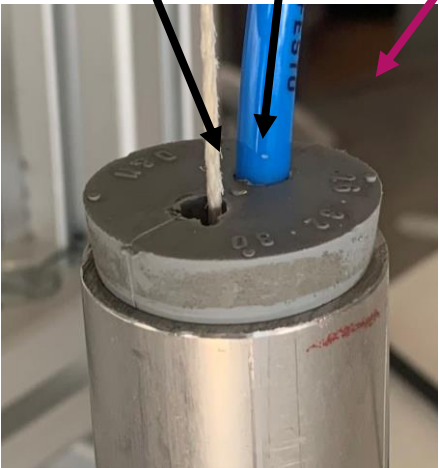
Mock-up

SETUP



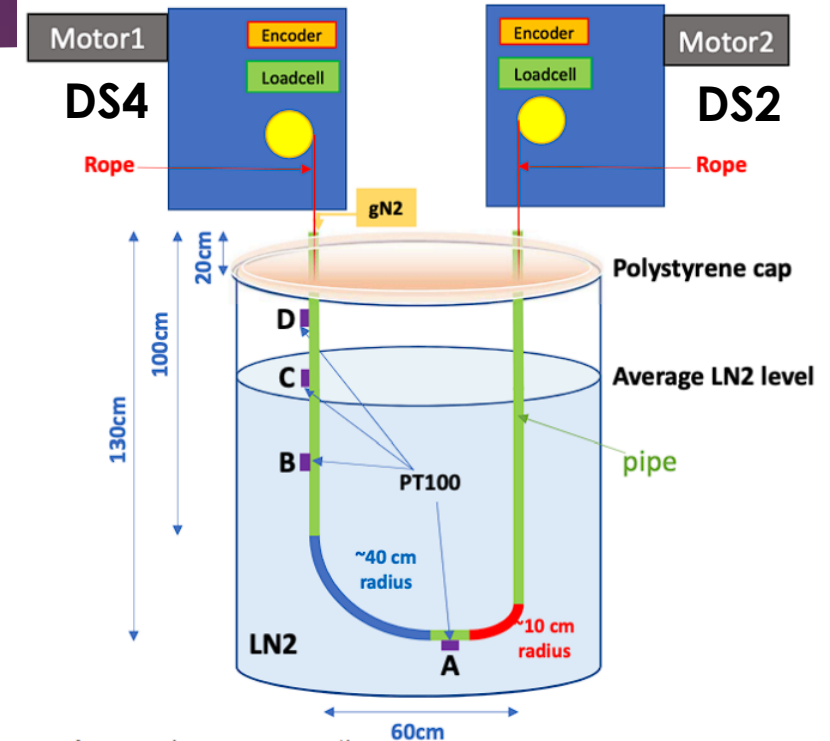
Rope

gN2 flush



The tube cap is **not fully hermetic** because of rope and gN2 flushing

The cryostat is **not fully adiabatic**
 → **Need constant refill with LN2**
 → **Only one fill for LAr**



- 4 PT100 probes (A, B, C, D)
- 1.3 meter of useful tube (from A to D)

Liquid Nitrogen tests

Mock-up

COMPARISON WITH CPPM MOCK-UP (FIRST 8 HOURS)

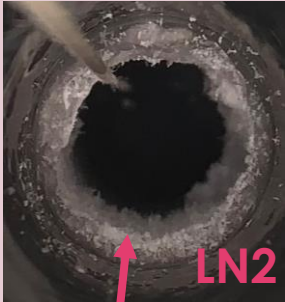
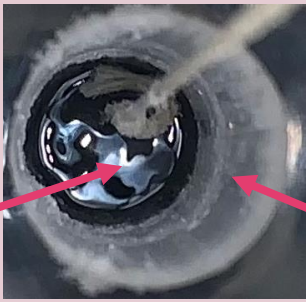


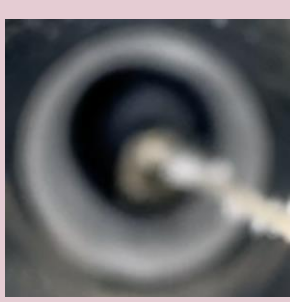

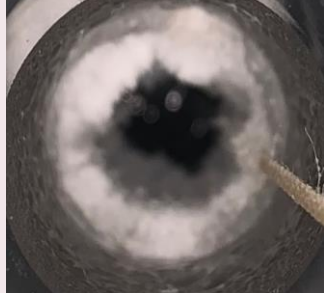
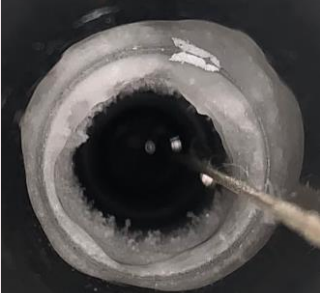
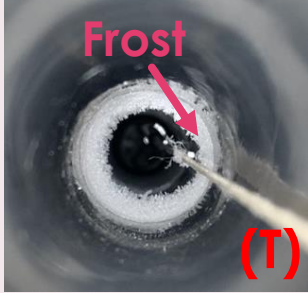

| RUN | Temperature of A, B, C, D | Tension | Conclusion |
|--|----------------------------------|--------------------------------------|---|
| CPPM short run, Poorly isolated cryostat (0.16 m³) | <p>Mock-up Run July 2021</p> | <p>Mock-up Run November 2022</p> | <ul style="list-style-type: none"> Left gN2 flushing at 60L/h $T_A \leq T_{LAr}$ for only 5h after filling <ul style="list-style-type: none"> Tension 12-40N |
| CERN long run, Vacuum isolated cryostat (0.4 m³) | <p>CERN Run 09 June 2023</p> | | <ul style="list-style-type: none"> Left gN2 flushing at 60L/h T_A, T_B, T_C always below T_{LAr} once filled <ul style="list-style-type: none"> Tension 5-25N |

**Motorized Systems
work at CERN.**

Overall conditions of the test

ICE FORMATION MITIGATION

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| Date | 09/06 | 10/06 | 12/06 | 13/06 | 26/06 |
|------------------|--|--|--|--|--|
| Left Side (DS4) |  |  |  |  |  |
| Right Side (DS2) |  |  |  |  |  |

1- Ice formation on both sides (09/06)

→ Flush hot gN2 on left at 250L/h (4x nominal)
→ Left side ice turns into frost

2- LN2 inside (-50cm) tube prevent gN2 to reach right side

→ T pipe to flush left and right (250L/h)
→ Ice on right side turn into frost

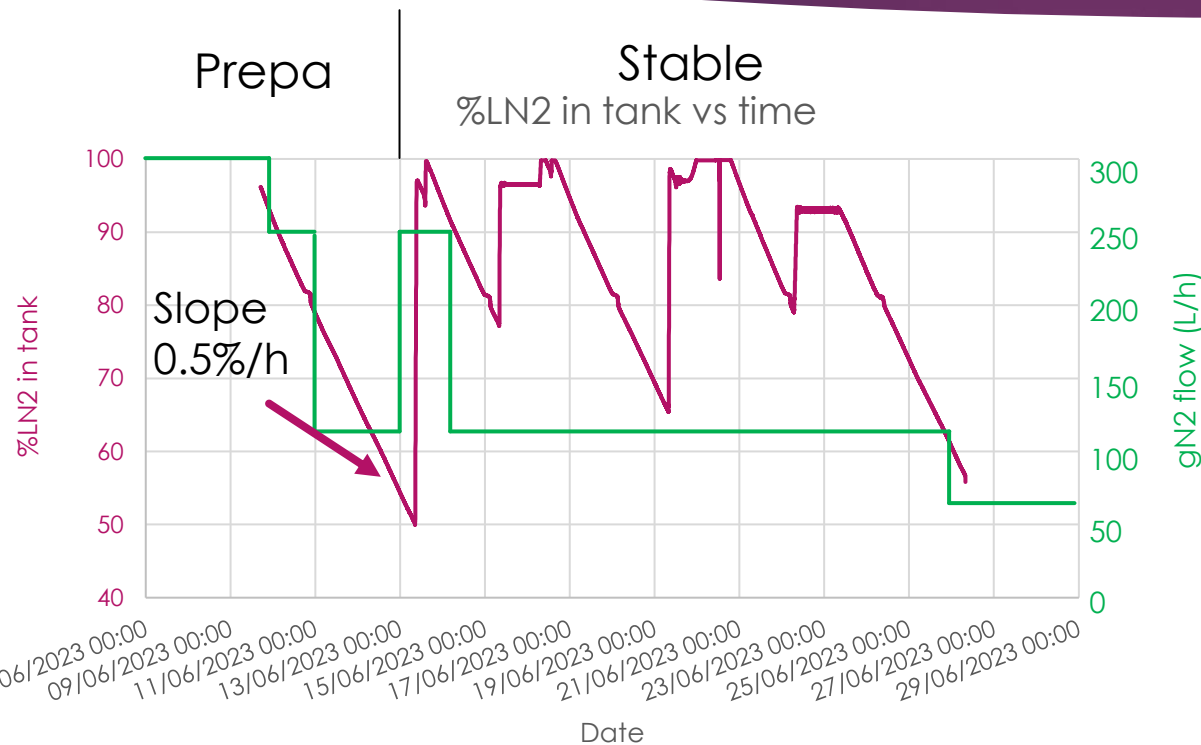
Pictures are cropped to be visible so do not pay attention on sizes, more on shapes.

The rope on the corner of tube to take the picture, in center usually

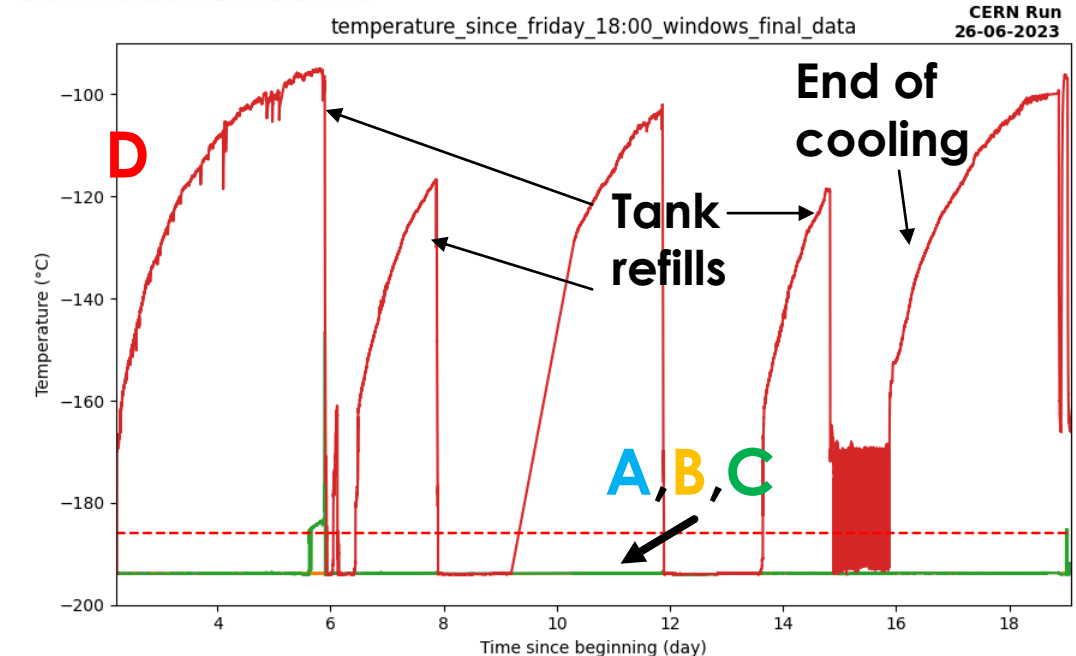
Ice turns into frost after 1 day of large gN2 flush on both sides → Stable conditions for test

Test conditions for LN2 (18 days)

TEMPERATURE OF PT100 AND TANK FILLING



Data file begins at: 2023-06-07 12:51:32
Data file finishes at: 2023-06-26 15:05:35



- **Filling process is automatic** (no auto-filling on the weekends and on Wednesday)
- Flushing at 120L/h (2x60 with T)

- T_A, T_B, T_C always below T_{LAr} for 18 days
- $T_D \in [-190, -100] \text{ } ^\circ\text{C}$

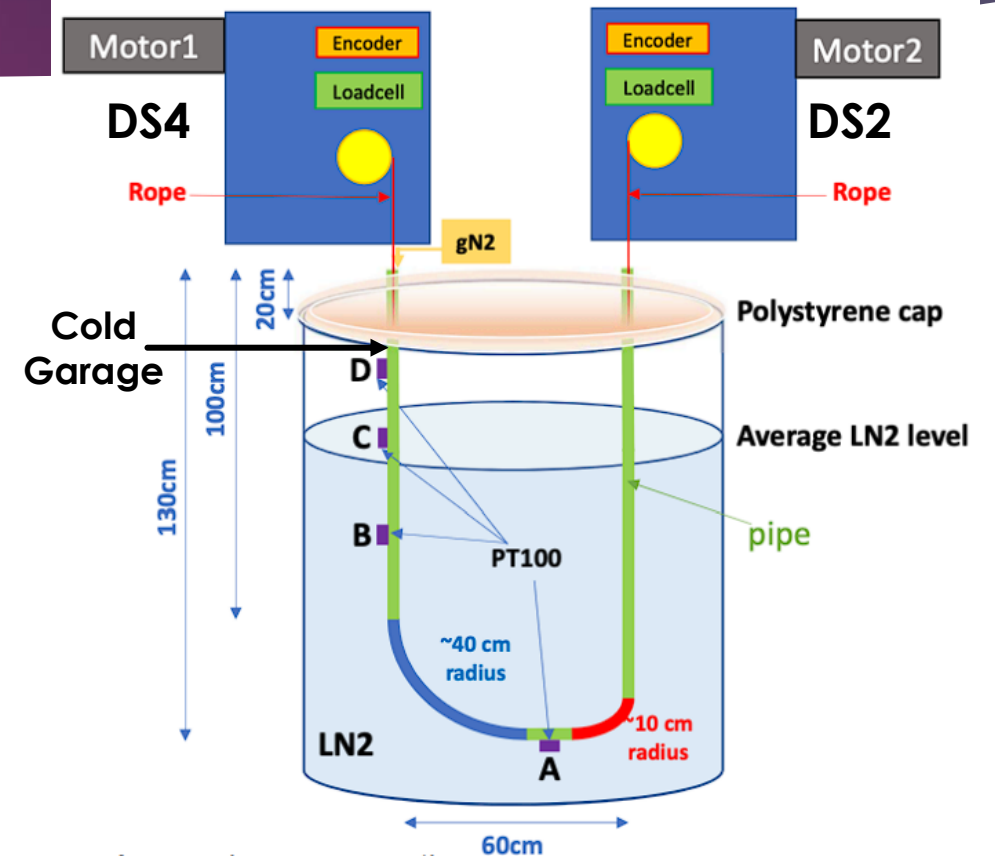
Stress test with LN2

PROGRAM

9

The goal is to check robustness of the Mock-up

- **Back and forth (b&f) from the cold garage to PT100 A** (2x 1,3m) with a ~1min stop at the edges (~1 cm/s)
- **35 b&f/day (~3h) for 8 days**
In DS20K, 8 sources so 4b&f and 20m tube
→ 280 b&f → **70x DS20k**
→ ~740m → **5x DS20k**



Stress test with LN2

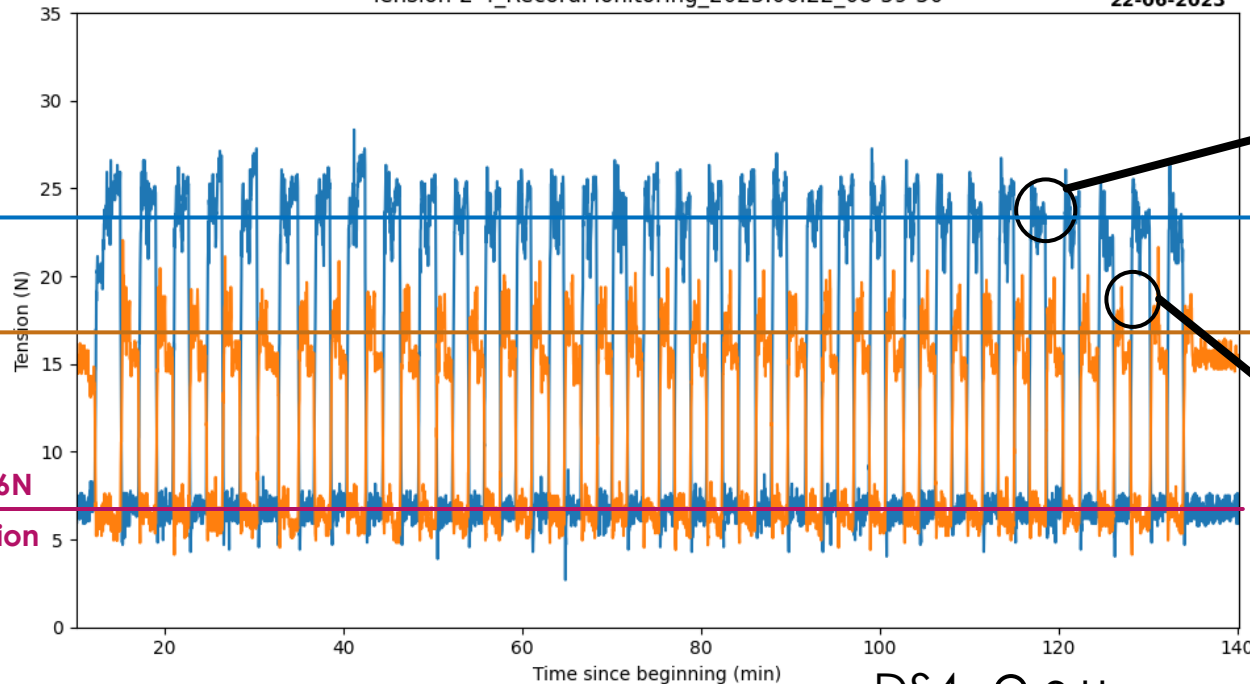
TYPICAL RUN

10

Data file begins at: 2023-06-22 08:55:28
Data file finishes at: 2023-06-22 16:16:06

Tension-2-4_RecordMonitoring_2023.06.22_08-59-50

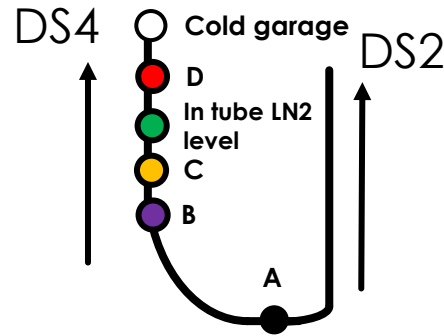
CERN Run
22-06-2023



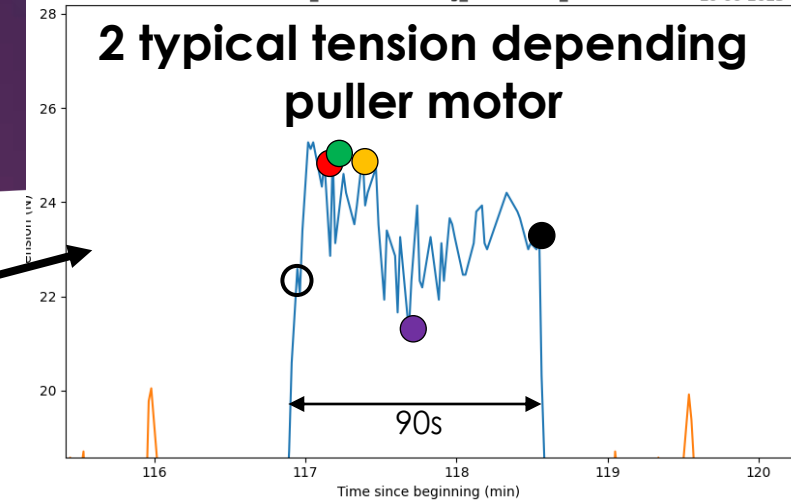
Following motor's tension

- DS2 tension around 24N, no visible impact of tube geometry
- DS4 tension lower, and reflects the tube geometry

28/06/2023



2 typical tension depending puller motor

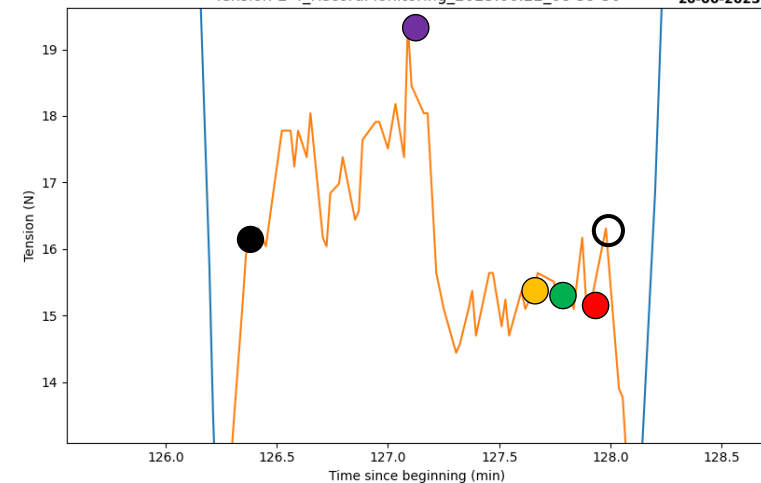


Typical tension for DS2

Data file begins at: 2023-06-22 08:55:28
Data file finishes at: 2023-06-22 16:47:14

Tension-2-4_RecordMonitoring_2023.06.22_08-59-50

CERN Run
26-06-2023



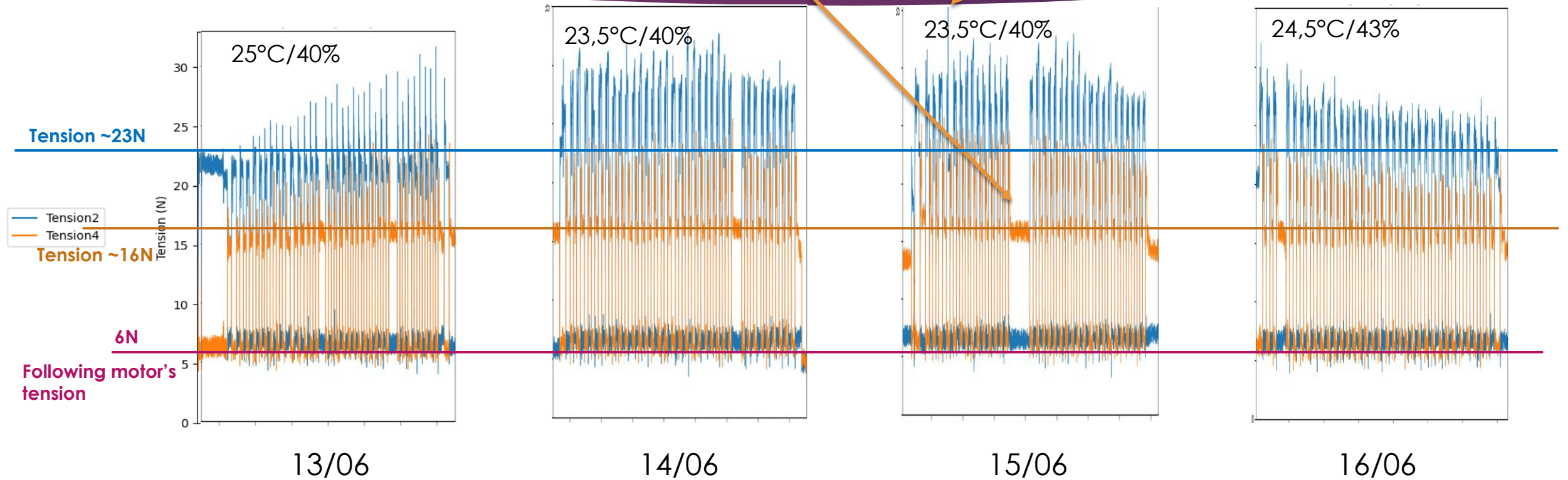
Typical tension for DS4

Stress test with LN2

RESULTS (FIRST WEEK)

10min break during the test

40N spike

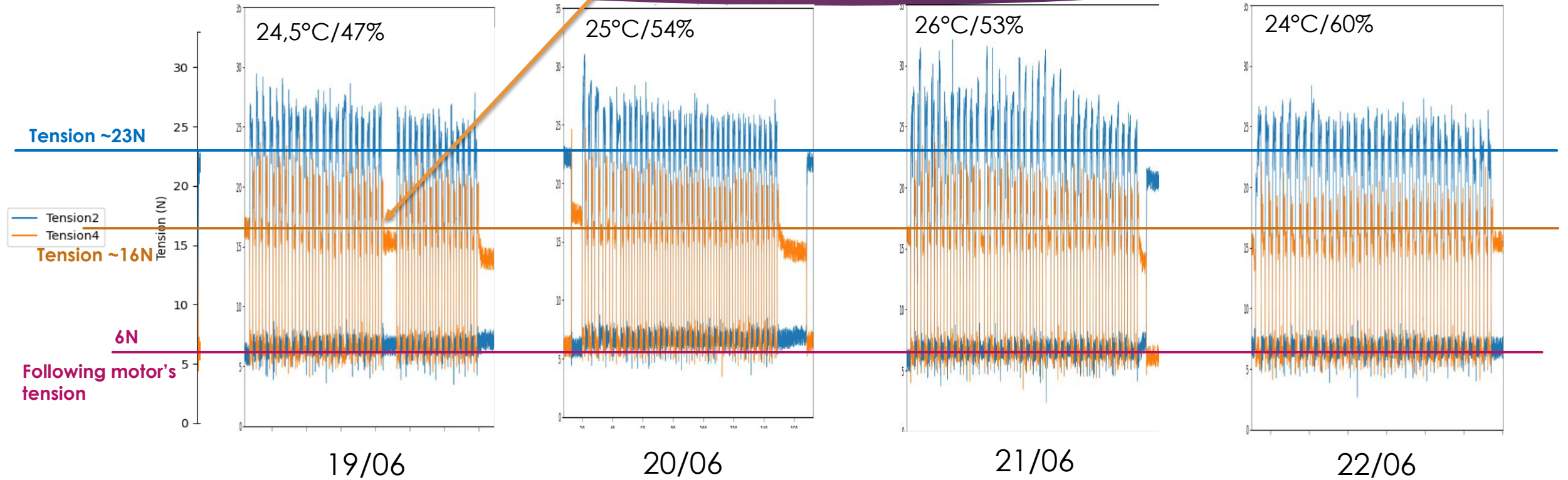


DS2 tension : two days at 25-30N at worst

Stress test with LN2

RESULTS (SECOND WEEK)

10min break during the test



The tension is stable

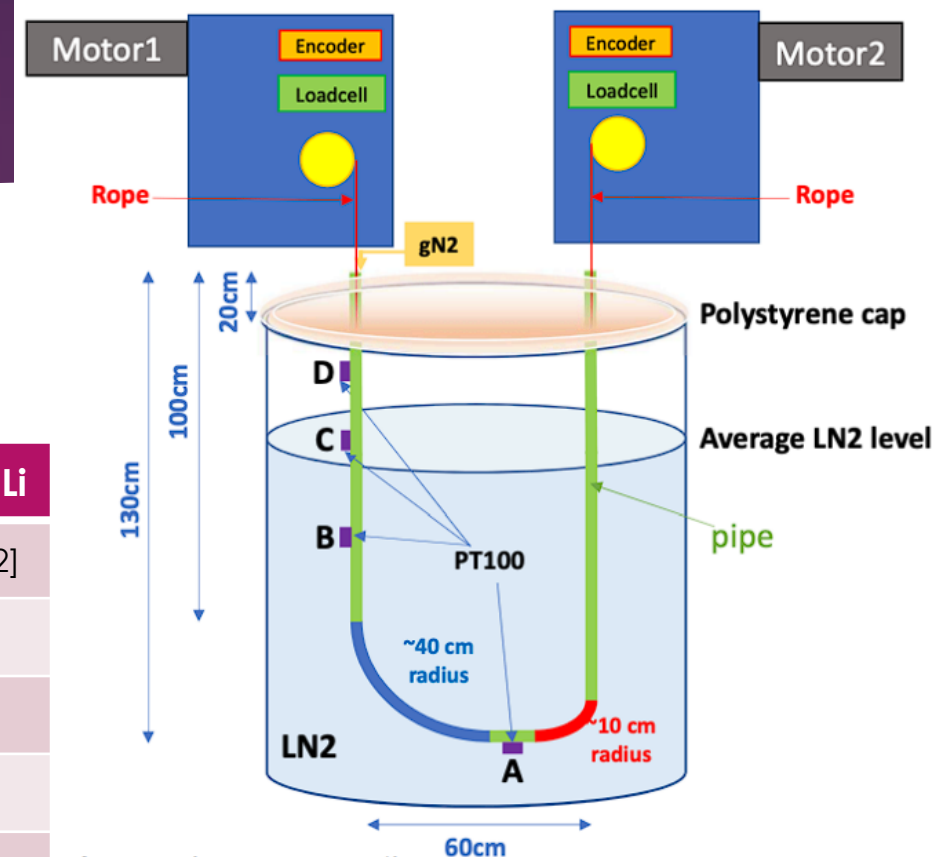
Long stay test with LN2

PROGRAM FOR THE TEST

The goal is to check **how the motors react when the source is left for a long time** at a PT100 step.

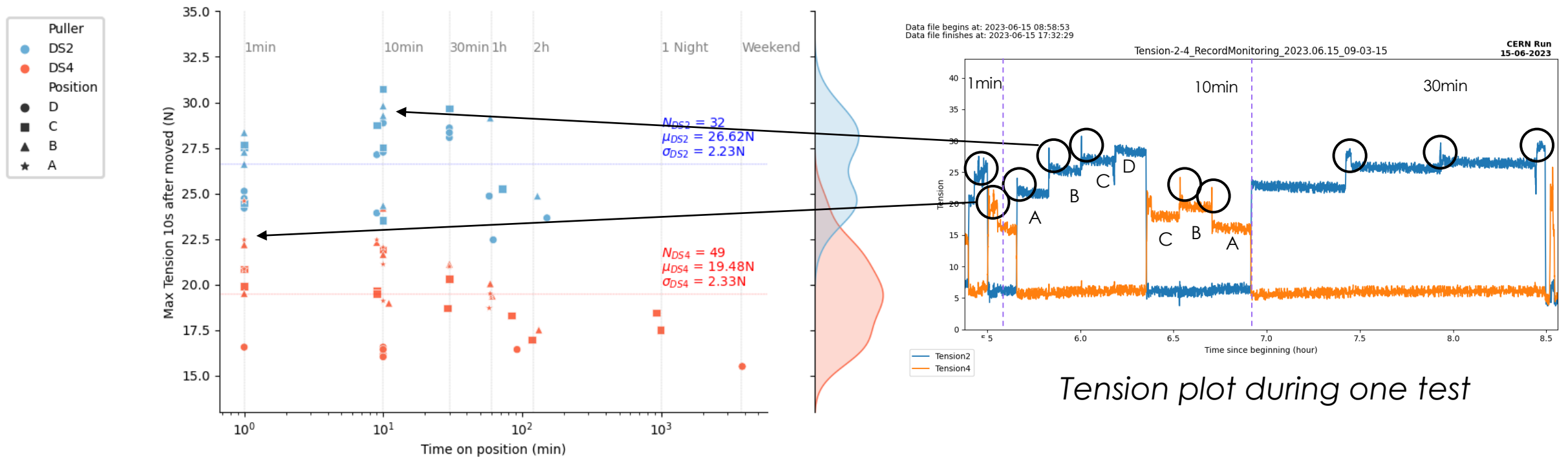
We left the source at different spots for different periods of time (1min, 10min, 30min, 1h, 2h, a night, a weekend)

| Source | ^{57}Co | ^{133}Ba | ^{22}Na | ^{137}Cs | ^{60}Co | AmBe | AmC | AmLi |
|-----------------------------|------------------|-------------------|------------------|-------------------|------------------|-----------|--------|--------|
| Energy (keV) | 122 | 356 | 511 | 662 | 1173 | [0.2, 12] | [2, 7] | [0, 2] |
| Activity (side) (kBq) | 18 | 1,9 | 0,36 | 2,2 | 0,36 | 0,14 | 0,15 | - |
| Activity (bottom) (kBq) | 100 | 5 | 0,67 | 4,6 | 0,6 | 0,18 | 0,18 | - |
| Duration of calibration (h) | 3,84 | 18,72 | 23,52 | 36 | 74,4 | 200 | 200 | - |
| Time on each spot | 12' | 1h50' | 2h20 | 3h45' | 8h | 22h | 22h | - |



Long stay test with LN2

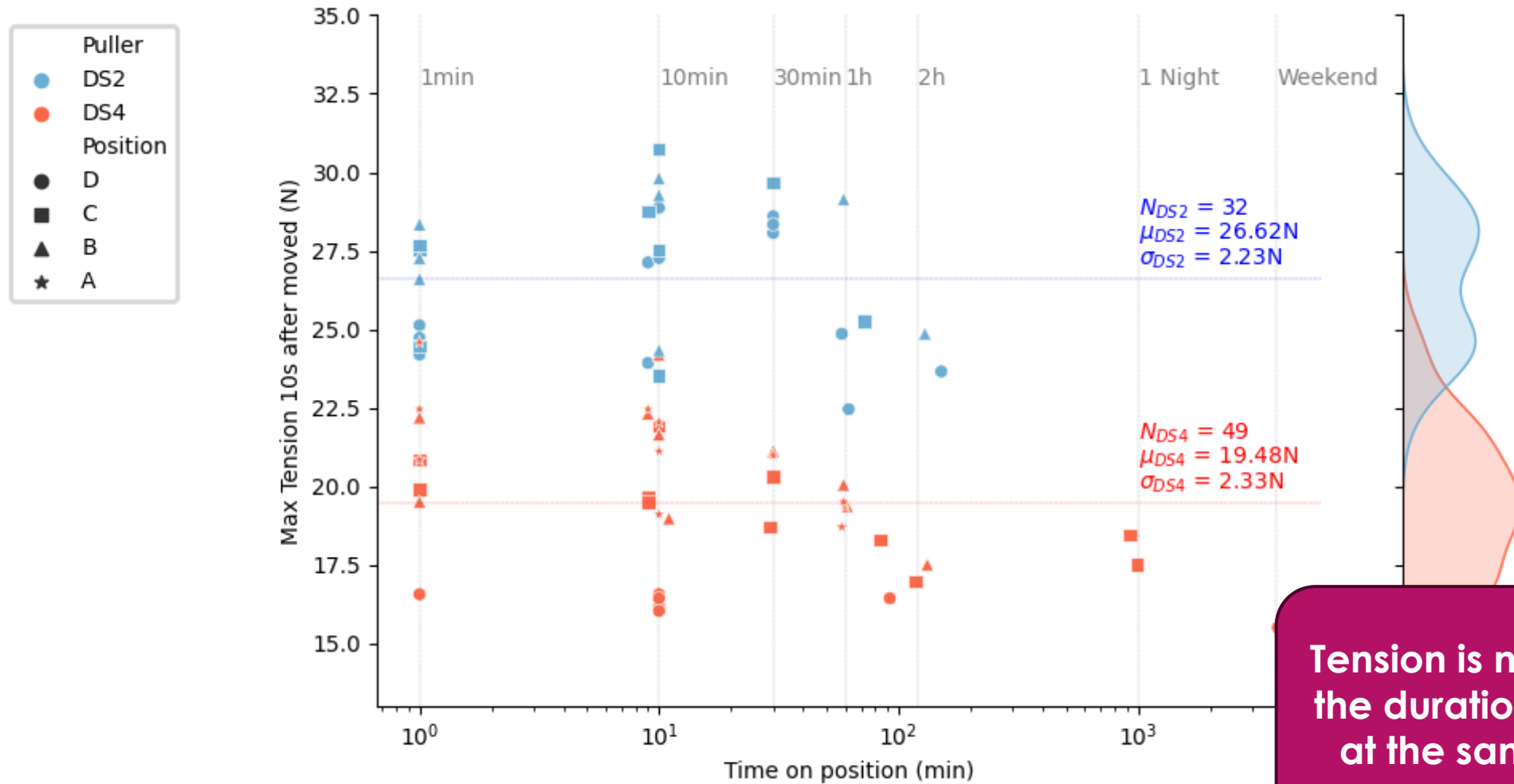
TENSION AFTER STOP



When the source is moved from its staying position, extract maximal tension 10s after the start of the move

Long stay test with LN2

TENSION AFTER STOP



Tension is not related to the duration of the stay at the same position

Liquid Argon tests

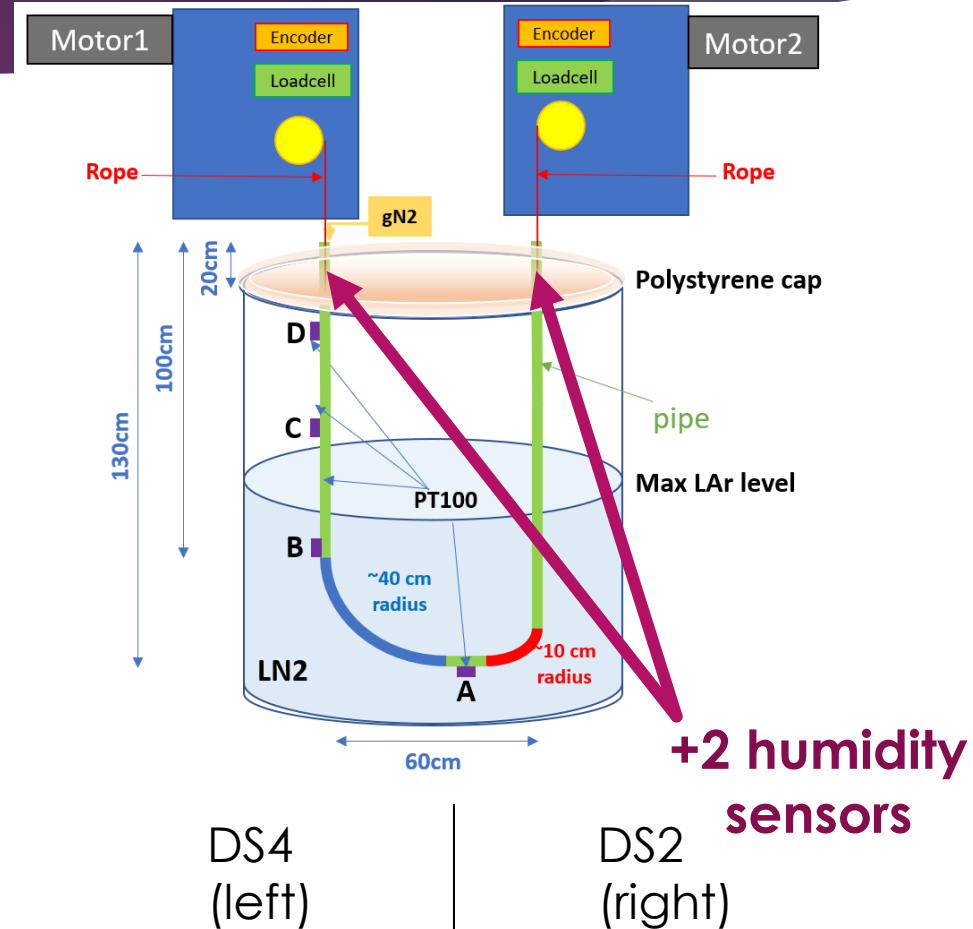
Mock-up – LAr

SETUP

Rope
gN2 flush



+2 humidity
sensors 10cm
below



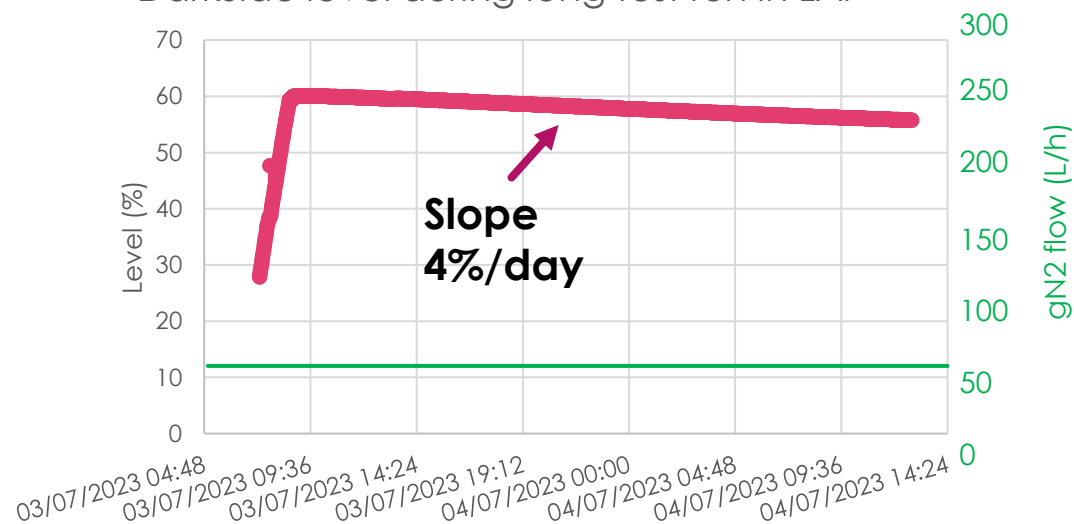
Test conditions for LAr (17 days)

TEMPERATURE OF PT100 AND TANK FILLING

Prepa

Stable

DarkSide level during long test run in LAr



- **Only one fill of LAr in tank**
- Flushing at 60L/h (no LN2 in tube → no T)

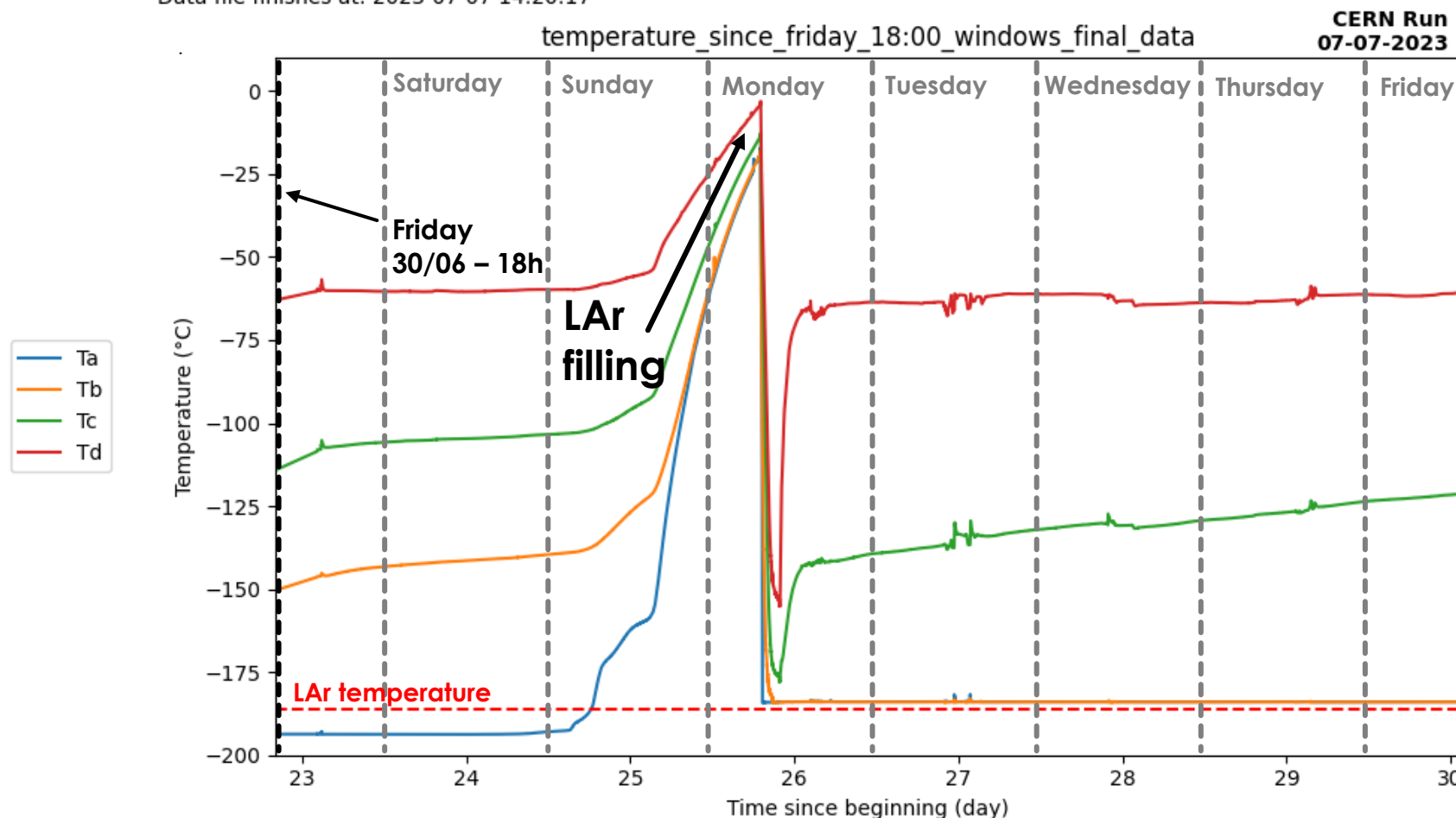
- T_A, T_B always at T_{LAr} for ?? days
- $T_D, T_C \in [-186, -30] ^\circ C$

Tank filling with LAr

- Monday 26/06 :
Start the heating process.
Small heater placed in the tank.
- Thursday 29/06 :
Heating process accelerated : larger heater inside the tank, lid of the tank removed
- Friday 30/06 :
End of the active heating process, letting tank heat with ambient temperature.
- Monday 03/07 :
Filling of the cuve with LAr

28/06/2023







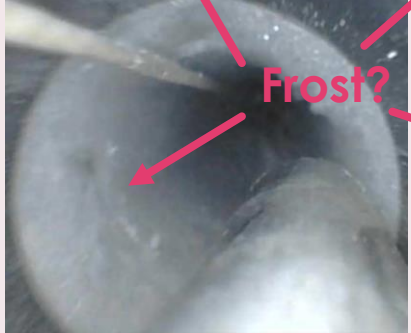

Data file begins at: 2023-06-07 12:51:32
Data file finishes at: 2023-07-07 14:20:17



Overall conditions of the test

ICE FORMATION MITIGATION

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| Date | Monday 03/07 | Tuesday 04/07 | Wednesday 05/07 | Friday 07/07 |
|------------------|--|---|--|--|
| Left Side (DS4) |  |  |  |  |
| Right Side (DS2) |  |  |  |  |

1- Some Ice formation on both side

→ **Want more to check how ice can be mitigated**

2- Breathing into tube

→ Increase humidity to 100%

→ Ice formation increased

→ **Need to check if it is ice or frost**

Pictures are cropped to be visible so do not pay attention on sizes, more on shapes.

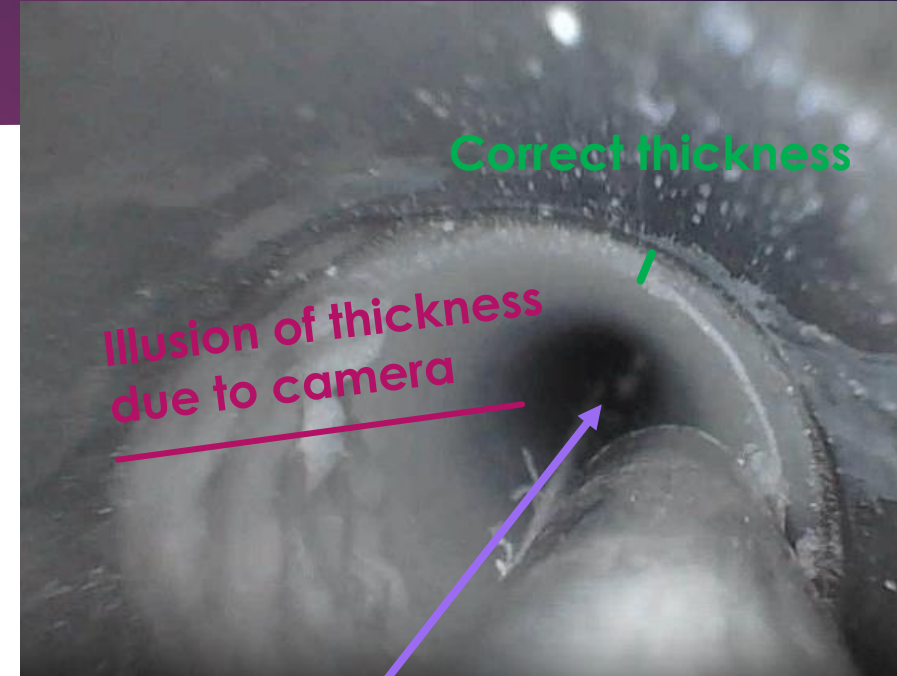
The rope on the corner of tube to take the picture, in center usually

Ice formation increased, need to check what type and if it changes tension

Ice/Frost identification (on DS2)



Soft frost removed with
the stick



Frost pieces coming off

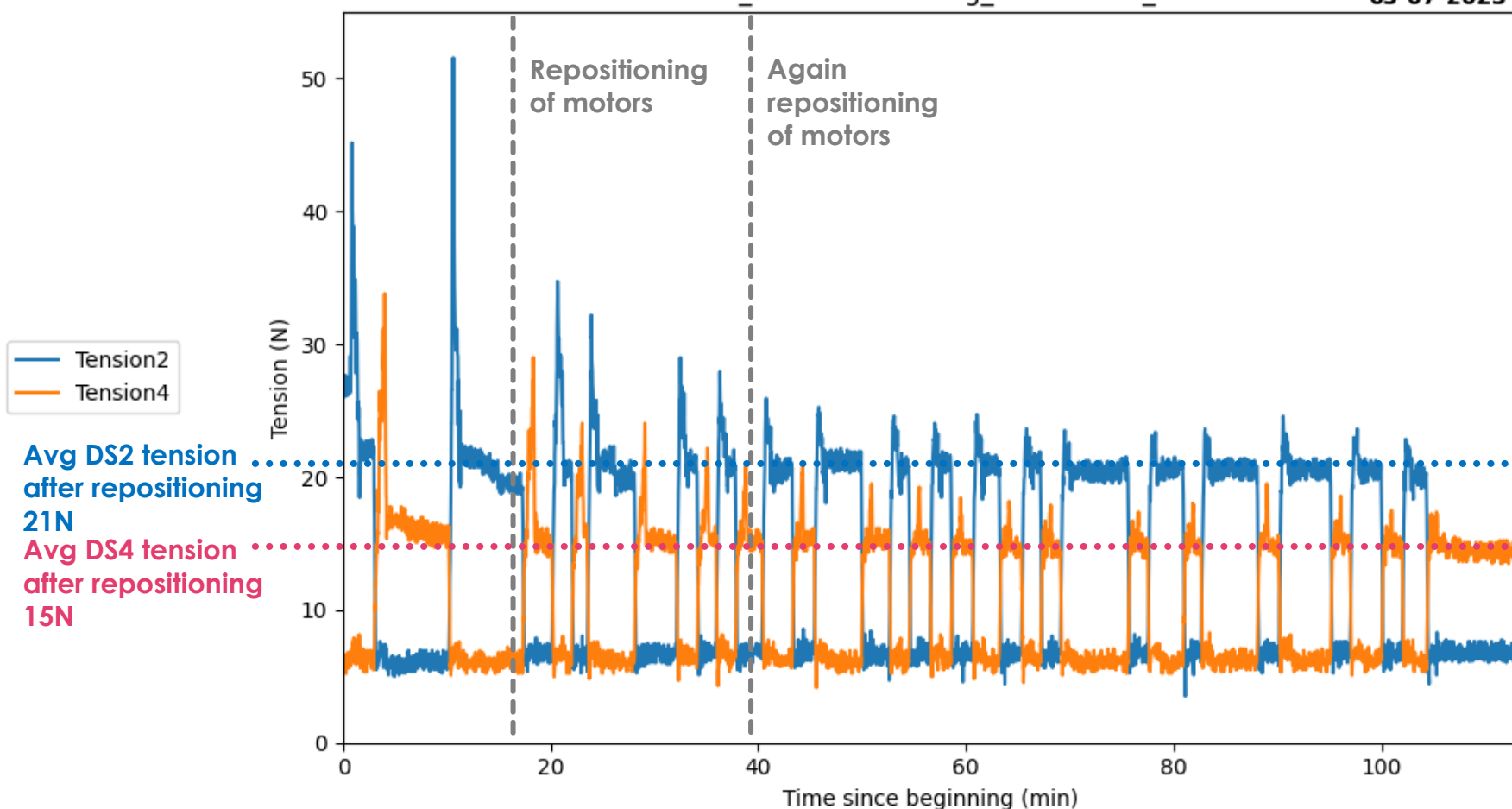
**The top part is frost (~1mm thick)
Same on DS4**

Tension during stress test

Data file begins at: 2023-07-03 15:07:18
Data file finishes at: 2023-07-03 17:05:24

CERN Run
03-07-2023

Tension-2-4_RecordMonitoring_2023.07.03_15-11-39



- At beginning, tension very high
→ Reposition of the motors to be in straightly in front of the cap centers
→ Once again after adding humidity sensors
- Tension value about same value as LN2 testing

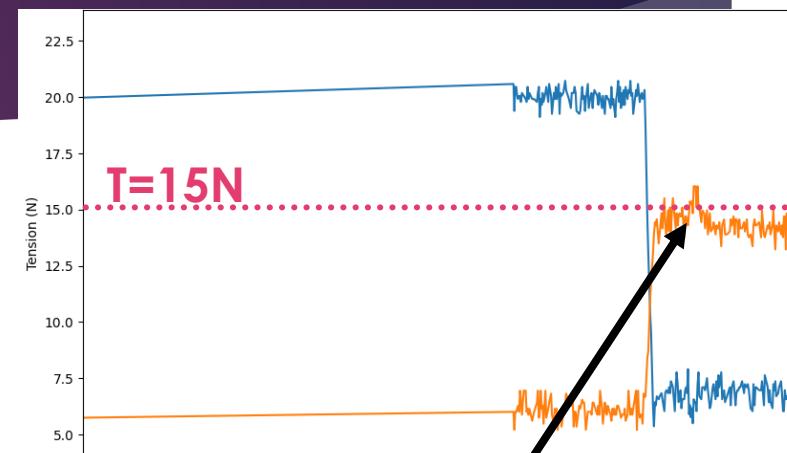
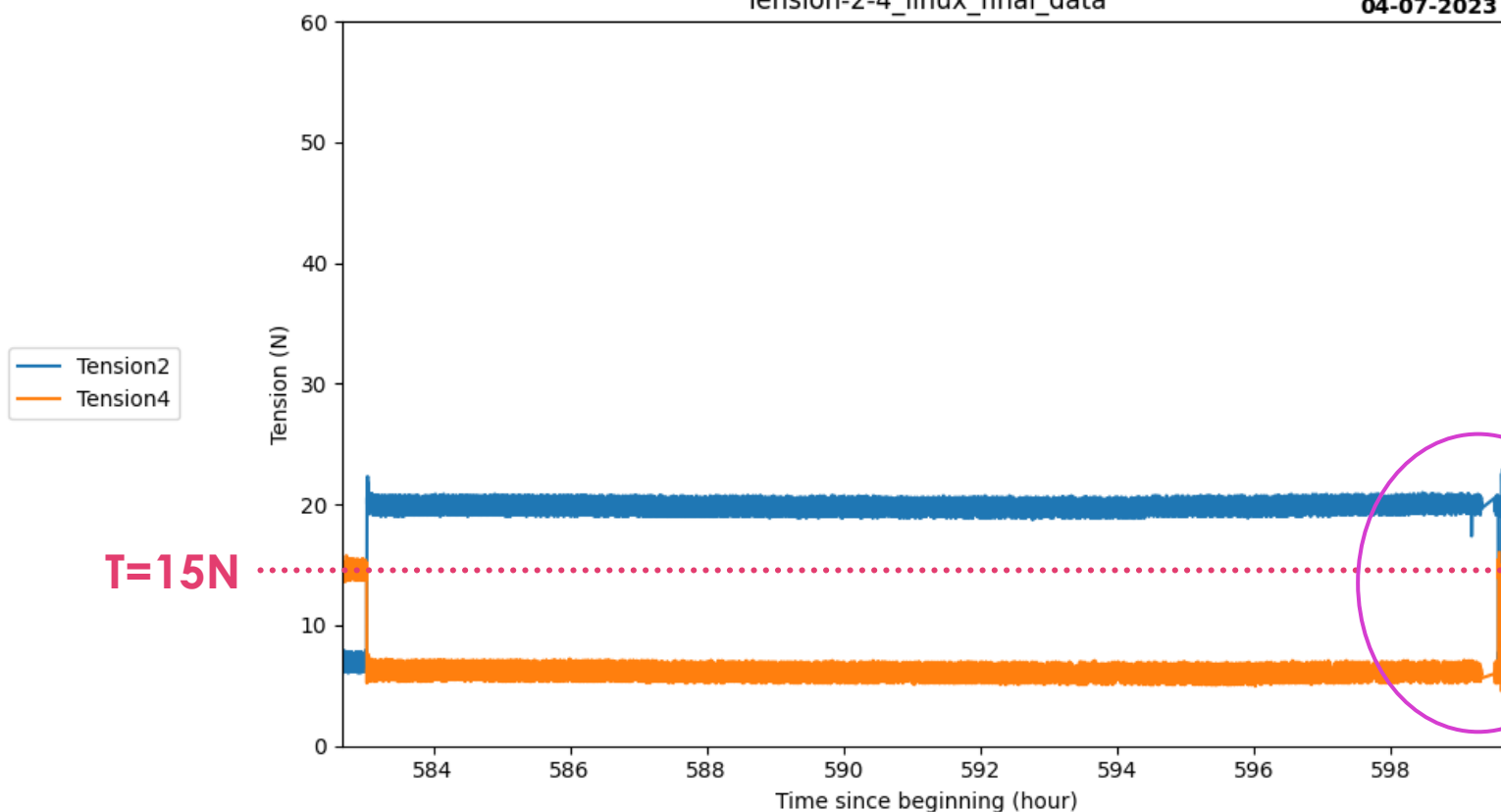
→ Tension value stable and comparable to LN2

Long stay test (one night)

Data file begins at: 2023-06-09 11:00:24
Data file finishes at: 2023-07-04 14:53:32

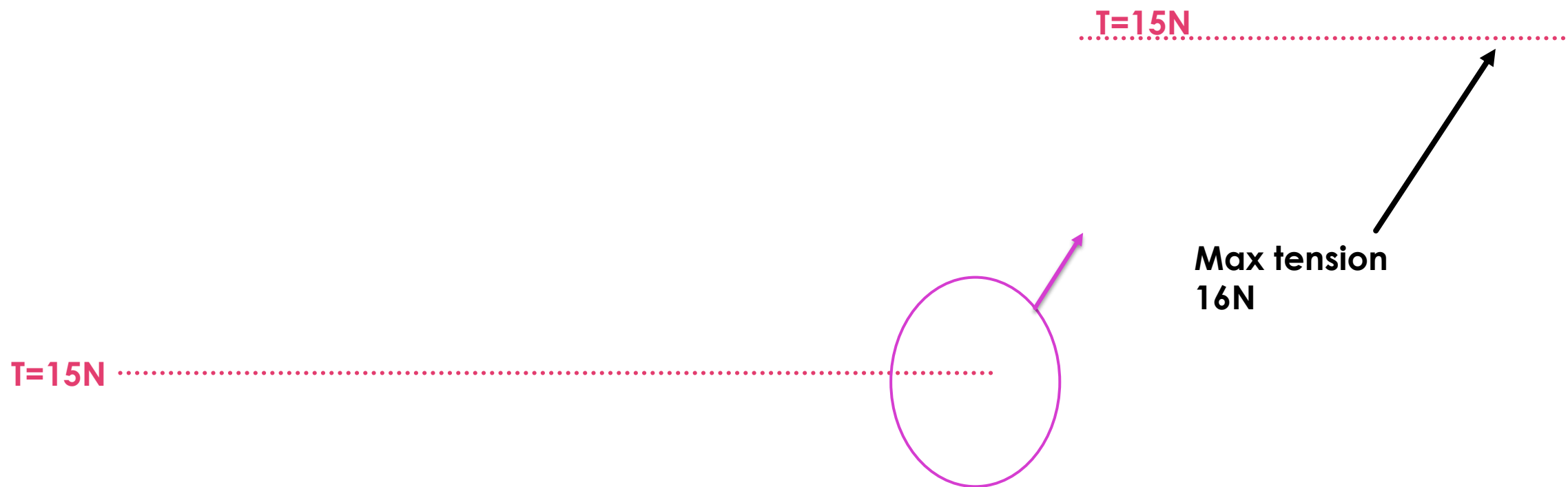
Tension-2-4_linux_final_data

CERN Run
04-07-2023

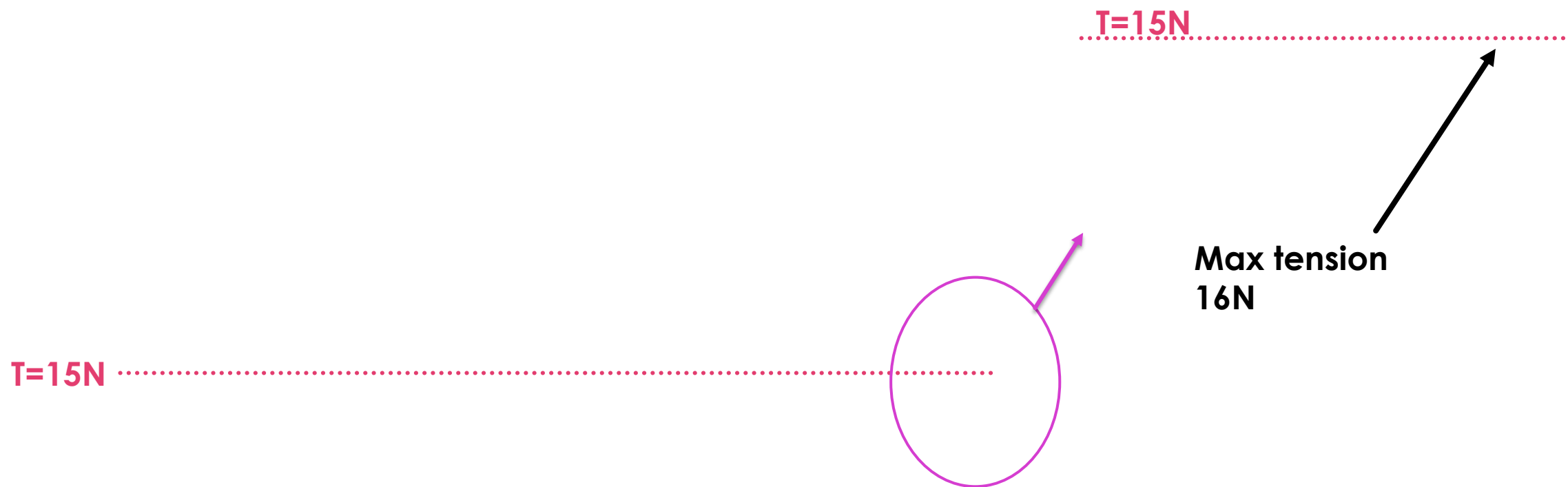


Max tension
16N

Long stay test (5 days)

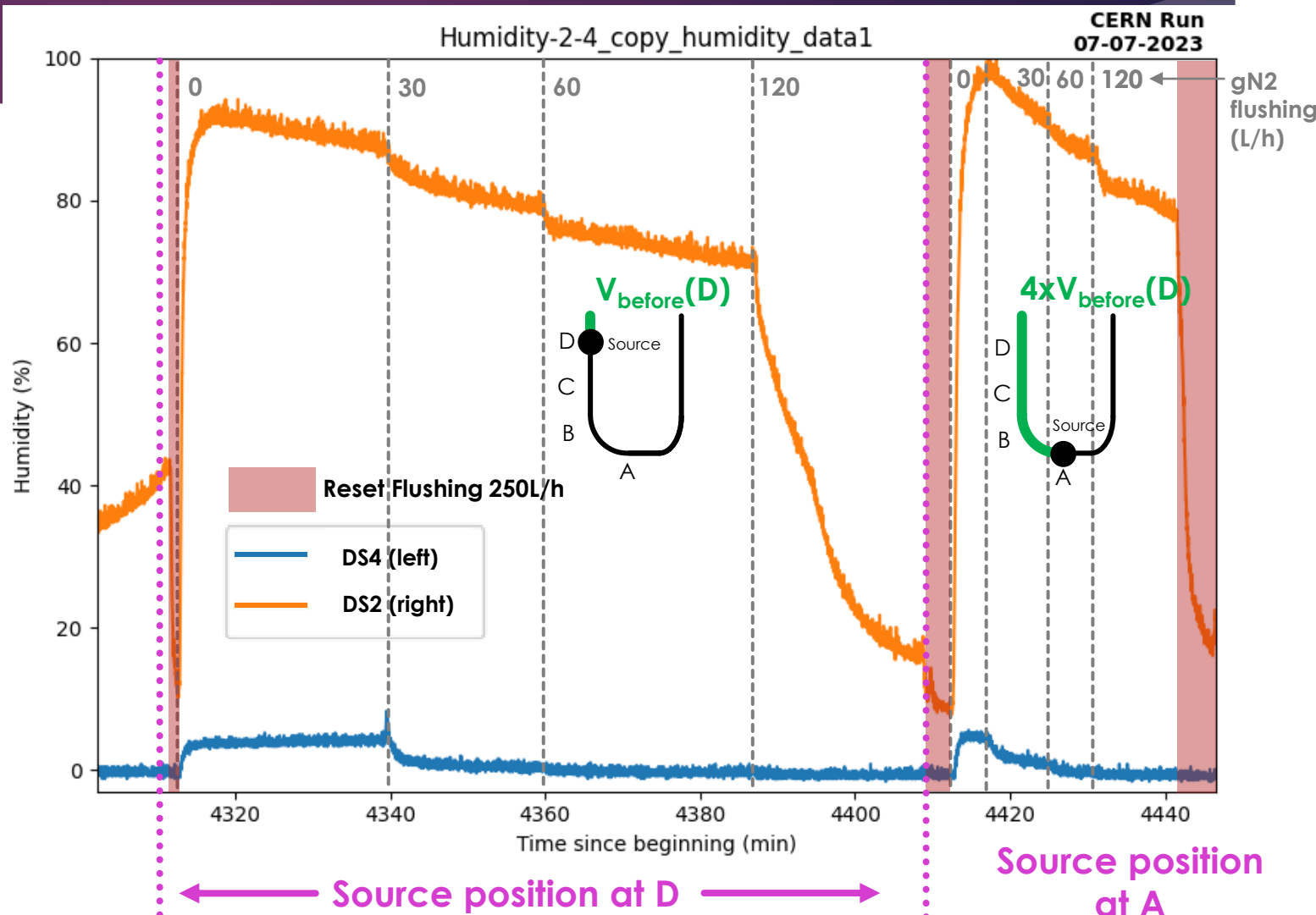


Long stay test (6 days)



Humidity test 1/3 – Without moving source

- Vary gn2 flushing F and measure humidity when source at two positions : top-left (D), bottom (A)
 - Determine F which remove humidity “instantly” ($\leq 5\text{min}$) $\rightarrow F_{\text{threshold}}$
 - Source Top-left : V_{before} small
 $\rightarrow 60 < F_{\text{threshold}} < 120 \text{ L/h}$
 \rightarrow **Measure : $F_{\text{threshold}} = 100 \text{ L/h}$**
 - Source Bottom: V_{before} larger
 $\rightarrow 120 < F_{\text{threshold}} < 250 \text{ L/h}$
 \rightarrow **Measure : $F_{\text{threshold}} = 150 \text{ L/h}$**
- \rightarrow Assuming same scaling, $F_{\text{threshold}}$ for DS20k with source at bottom might be around 300L/h

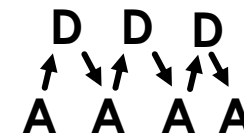
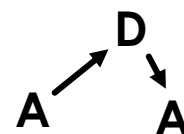
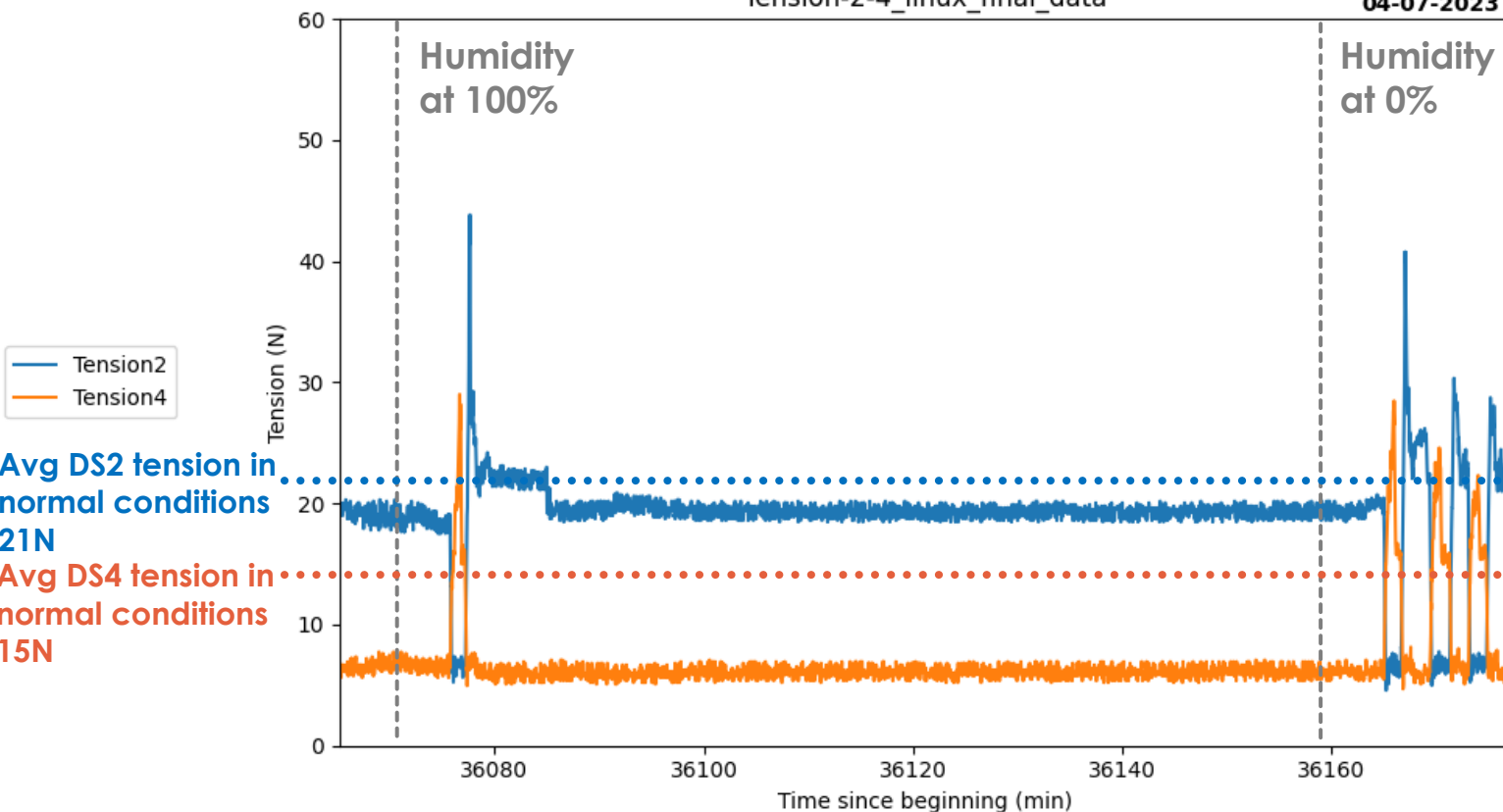


Humidity test 2/3 – Moving source at A

Data file begins at: 2023-06-09 11:00:24
Data file finishes at: 2023-07-04 14:53:32

Tension-2-4_linux_final_data

CERN Run
04-07-2023



- Pseudo-source in position A
- Blow in tube from both sides to increase humidity at maximum and remove gN2 = **Extreme nonrealistic scenario**
- After 5min, both humidity are at 100%
- A → D → A : **+23N/+15N** wrt normal
- After 15min, put back the top caps and gN2 at 120L/h
- After 1h30, both humidities at 0%
- A → D → A : **+20N/+15N** wrt normal but back to normal after 3 times

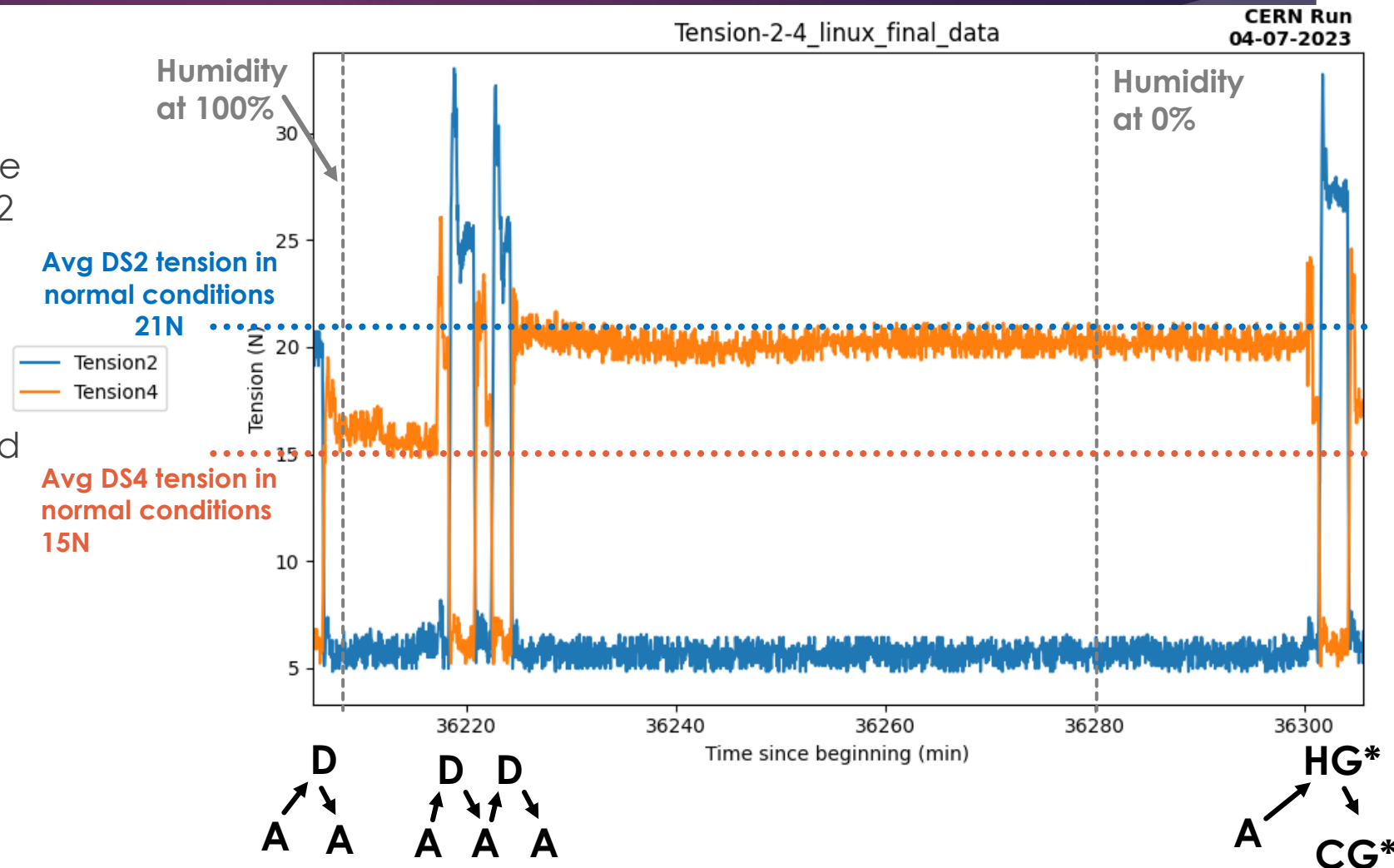
Humidity test 2/3 – Moving source at B

- Pseudo-source in position B
- Blow in tube from both sides to increase humidity at maximum and remove gN2
= **Extreme nonrealistic scenario**
- After 5min, both humidity are at 100%
- A → D → A : **+12N/+11N** wrt normal
- After 15min, put back the top caps and gN2 at 120L/h
- After 1h30, both humidities at 0%
- A → HG* → CG* : **+12N/+9N** wrt normal

*HG : Hot Garage

*CG : Cold Garage

28/06/2023



Humidity test 3/3 – After night

CERN Run
05-07-2023

Tension-2-4_linux_final_data

- Pseudo-source in position Cold garage for 1 night

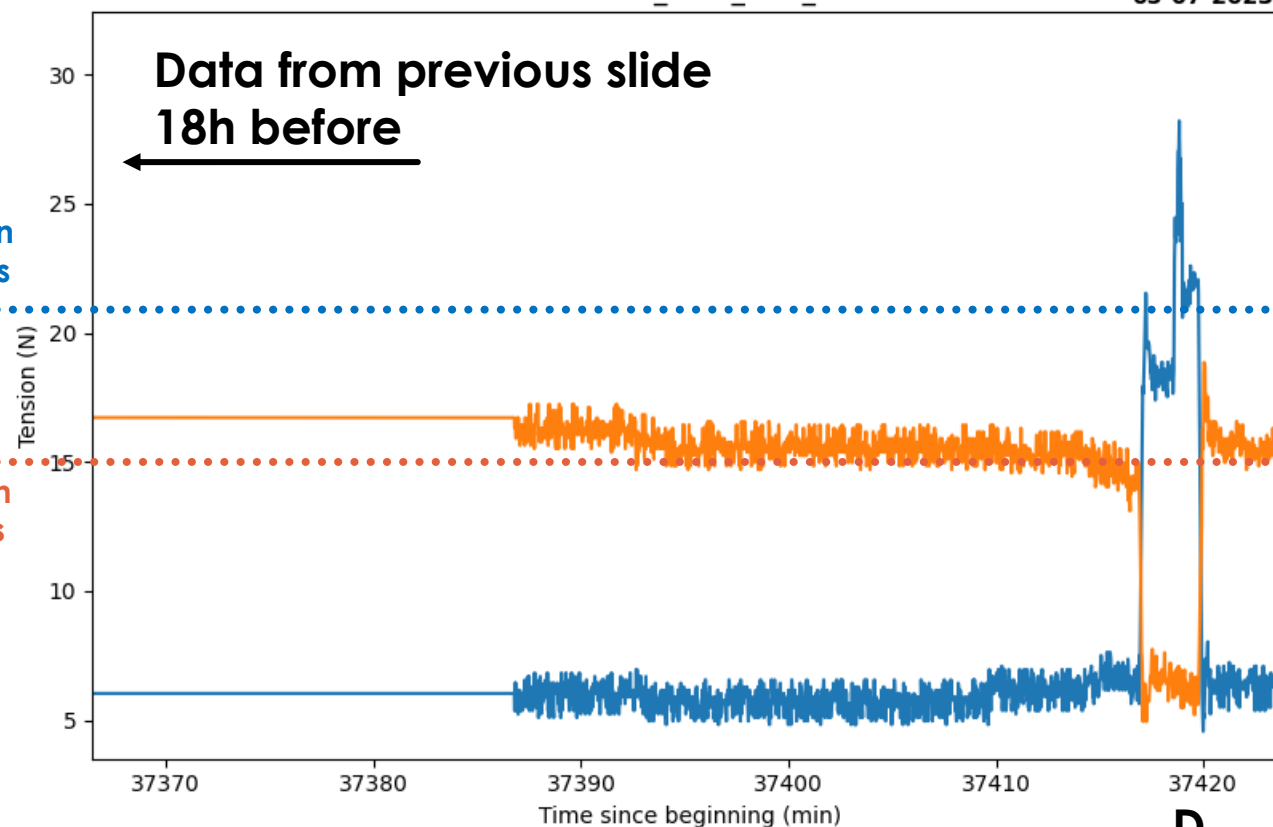
→ CG* → D → A : +8N/+5N wrt normal

→ With long-time flushing, maximum tension due to ice formation decreases

Avg DS2 tension in normal conditions
21N

Avg DS4 tension in normal conditions
15N

— Tension2
— Tension4



CG* → D → A

*HG : Hot Garage

*CG : Cold Garage

Conclusion

LN2 MOCK-UP TEST

- **Run at CERN for one month (1,3m of useful tube)**
 - ✓ Liquid in the tube 50cm from top with LN2 → T pipe
 - ✓ Ice formation mitigated using gN2 → Frost
 - ✓ Average tension 15-30N during stress test
 - ✓ No big impact on tension when stopping for different periods

Robust behavior of calib system at LN2 and LAr temperature for 2 weeks each

| Liquid in tank | LN2 | LAr |
|---------------------------------|--------------------|------------|
| Speed of the source (cm/s) | 1 | 1 |
| Position Accuracy (cm) | ±1 | ±1 |
| Tension (N) | 15-30 | 15-30 |
| Ice formation (block) | Mitigated with gN2 | On purpose |
| Total Length for one source (m) | 740 | >100 |
| Total nb of back&forth / pipe | 280 | >40 |

| | DS-20k | MU_CS | MU_CL | MU_W |
|------------------------------------|----------------------------|-------------|----------------|-----------------|
| | General | | | |
| Goals | NA | Cold behav. | Robust at cold | bends scale 1:1 |
| Availability | 10/24 | 09/22 | 05/23 | 02/23 |
| Runs | >02/26 | 2022-23 | 2023 | 2023 |
| | Conditions | | | |
| Temperature (K) | 88 | 77 | 77 | 88 |
| Usage time / run (days) | 30 | 0.3 | 18 | 5 |
| Location | LNGS | CPPM | CERN | CPPM |
| | Mechanics | | | |
| Pipe Total length (m) | 20 | ~ 4 | ~ 2 | ~15 |
| Pipe thickness (mm) | 1.5 | 1.65 | 1.5 | 1.5 |
| Pipe internal Diameter (mm) | 30 | 30 | 33 | 30 |
| Pipe Material | SS | Ti, SS | SS | Plastic |
| Nb of Bends / pipe ($\phi=30$ cm) | 14, 15 | 2 | 1 | 15 |
| Source length (cm) | TBD | 3 | 5 | 5 |
| Source diameter (cm) | TBD | 1 | 2.5 | 2.5 |
| | Requirements / Performance | | | |
| Speed of the source (cm/s) | > 1 | 3 | — | 2 |
| Position Accuracy (cm) | ±1 | ±1 | — | ±1 |
| Tension (N) | < 150 | 25-40 | — | 60-90 |
| Ice formation (block) | No | No | — | NA |
| Total Length for one source (m) | 100 | > 100 | — | > 100 |
| Total nb of back&forth / pipe | 10 | 44 | — | >6 |