



Initial CM operation performances on test and commissioning at ESS

TTC 2026

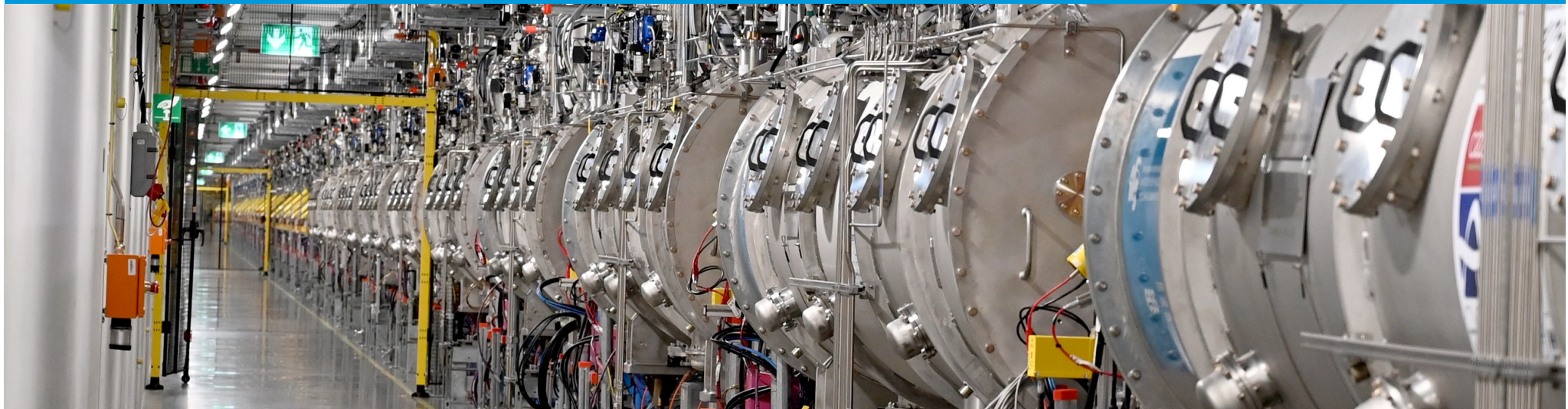
MAREK SKIBA ON BEHALF OF THE LINAC GROUP

2026-06-09

Table of Contents



1. ESS Overview and Timeline
2. LINAC Preparation for Commissioning
3. Challenges
4. Cryogenic Operation Experience

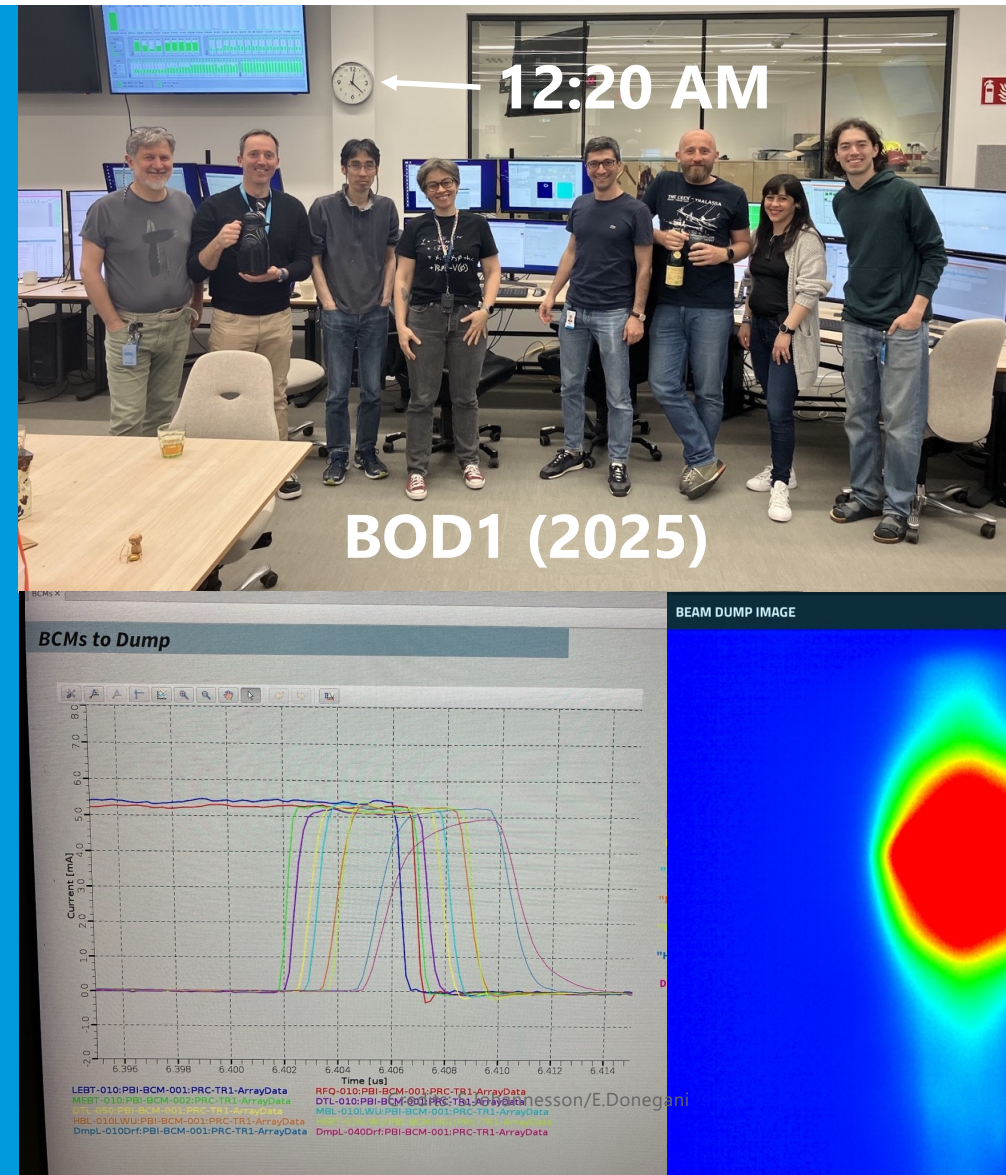


TTC 2026



2

LINAC Preparation for Commissioning (BOD2)



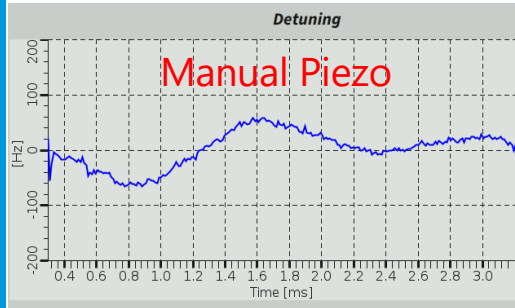
BOD1 (1Hz/1ms) vs BOD2 (14Hz/3.2ms)



LFD compensation algorithm developed by LLRF and ICS team

- Automated LFD compensation tested first in TS2
- Implemented to the LINAC for BOD2

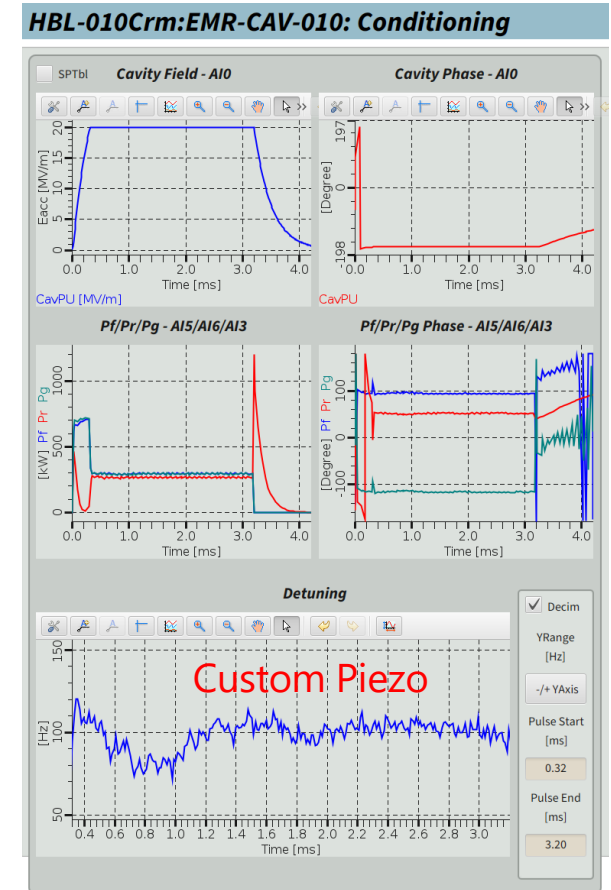
Piezo Voltage



Transfer function

More:
"Piezo compensation algorithm for SC cavities at ESS" (LLRF2025/62)

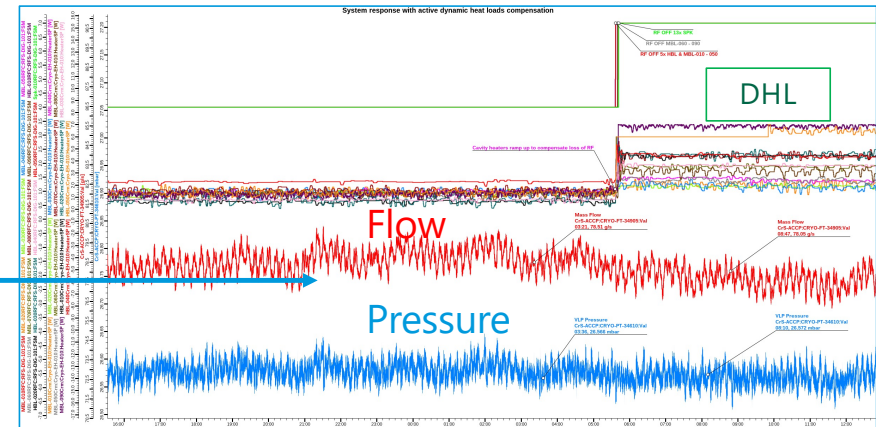
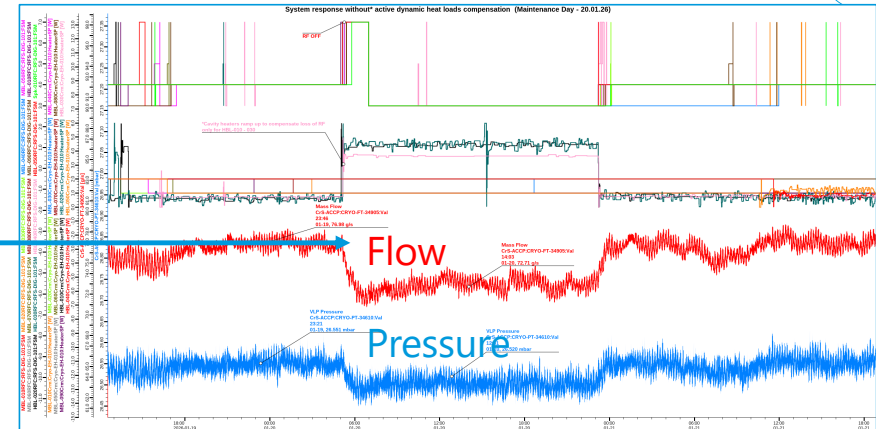
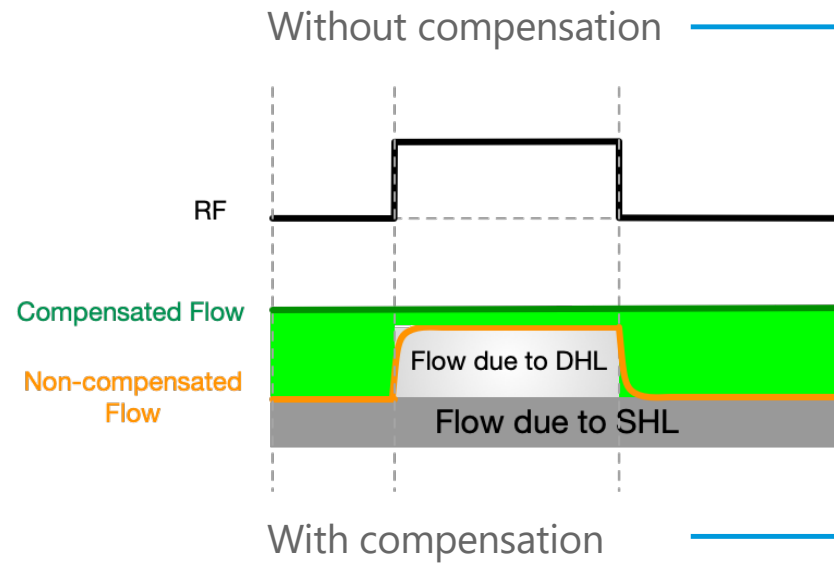
2026-06-09 ESS CM COMMISSIONING



BOD1 (1Hz/1ms) vs BOD2 (14Hz/3.2ms)

Handling Dynamic Heat Loads

Prevention of surge/choke flow for CCs (Trip)



Readiness for Beam (BOD2)



Nominal RF Pulse:

- 14Hz
- 3.2ms

Workflow:

- warm coupler conditioning
- cool down
- cold coupler conditioning
- calibration
- cavity conditioning

ESS LINAC Cavities Supervision

Linac Group Ver. 2.0 2025/06/13 Go to the Water Skids

NCL	Spk	MBL	HBL
Spk-010-C1	Normal	RF-PASS	RF-ON
Spk-010-C2	Normal	RF-PASS	RF-ON
Spk-020-C1	Normal	RF-PASS	RF-ON
Spk-020-C2	Normal	RF-PASS	RF-ON
Spk-030-C1	Normal	RF-PASS	RF-ON
Spk-030-C2	Normal	RF-PASS	RF-ON
Spk-040-C1	Normal	RF-PASS	RF-ON
Spk-040-C2	Normal	RF-PASS	RF-ON
Spk-050-C1	Normal	RF-PASS	RF-ON
Spk-050-C2	Normal	RF-PASS	RF-ON
Spk-060-C1	Normal	RF-PASS	RF-ON
Spk-060-C2	Normal	RF-PASS	RF-ON
Spk-070-C1	Normal	RF-PASS	RF-ON
Spk-070-C2	Normal	RF-PASS	RF-ON
Spk-080-C1	Normal	RF-PASS	RF-ON
Spk-080-C2	Normal	RF-PASS	RF-ON
Spk-090-C1	Normal	RF-PASS	RF-ON
Spk-090-C2	Normal	RF-PASS	RF-ON
Spk-100-C1	Normal	RF-PASS	RF-ON
Spk-100-C2	Normal	RF-PASS	RF-ON
Spk-110-C1	Normal	RF-PASS	RF-ON
Spk-110-C2	Normal	RF-PASS	RF-ON
Spk-120-C1	Normal	RF-PASS	RF-ON
Spk-120-C2	Normal	RF-PASS	RF-ON
Spk-130-C1	Normal	RF-PASS	RF-ON
Spk-130-C2	Normal	RF-PASS	RF-ON

ESS LINAC Cavities Supervision

Linac Group Ver. 2.0 2025/06/13 Go to the Water Skids

NCL	Spk	MBL	HBL
MBL-010-C1	Normal	RF-PASS	RF-ON
MBL-010-C2	Normal	RF-PASS	RF-ON
MBL-020-C1	Normal	RF-PASS	RF-ON
MBL-020-C2	Normal	RF-PASS	RF-ON
MBL-030-C1	Normal	RF-PASS	RF-ON
MBL-030-C2	Normal	RF-PASS	RF-ON
MBL-040-C1	Normal	RF-PASS	RF-ON
MBL-040-C2	Normal	RF-PASS	RF-ON
MBL-050-C1	Normal	RF-PASS	RF-ON
MBL-050-C2	Normal	RF-PASS	RF-ON
MBL-060-C1	Normal	RF-PASS	RF-ON
MBL-060-C2	Normal	RF-PASS	RF-ON
MBL-070-C1	Normal	RF-PASS	RF-ON
MBL-070-C2	Normal	RF-PASS	RF-ON
MBL-080-C1	Normal	RF-PASS	RF-ON
MBL-080-C2	Normal	RF-PASS	RF-ON
MBL-090-C1	Normal	RF-PASS	RF-ON
MBL-090-C2	Normal	RF-PASS	RF-ON
MBL-100-C1	Normal	RF-PASS	RF-ON
MBL-100-C2	Normal	RF-PASS	RF-ON
MBL-110-C1	Normal	RF-PASS	RF-ON
MBL-110-C2	Normal	RF-PASS	RF-ON
MBL-120-C1	Normal	RF-PASS	RF-ON
MBL-120-C2	Normal	RF-PASS	RF-ON
MBL-130-C1	Normal	RF-PASS	RF-ON
MBL-130-C2	Normal	RF-PASS	RF-ON

ESS LINAC Cavities Supervision

Linac Group Ver. 2.0 2025/06/13 Go to the Water Skids

NCL	Spk	MBL	HBL
HBL-010-C1	Normal	RF-PASS	RF-ON
HBL-010-C2	Normal	RF-PASS	RF-ON
HBL-020-C1	Normal	RF-PASS	RF-ON
HBL-020-C2	Normal	RF-PASS	RF-ON
HBL-030-C1	Normal	RF-PASS	RF-ON
HBL-030-C2	Normal	RF-PASS	RF-ON
HBL-040-C1	Normal	RF-PASS	RF-ON
HBL-040-C2	Normal	RF-PASS	RF-ON
HBL-050-C1	Normal	RF-PASS	RF-ON
HBL-050-C2	Normal	RF-PASS	RF-ON
HBL-060-C1	Normal	RF-PASS	RF-ON
HBL-060-C2	Normal	RF-PASS	RF-ON
HBL-070-C1	Normal	RF-PASS	RF-ON
HBL-070-C2	Normal	RF-PASS	RF-ON
HBL-080-C1	Normal	RF-PASS	RF-ON
HBL-080-C2	Normal	RF-PASS	RF-ON
HBL-090-C1	Normal	RF-PASS	RF-ON
HBL-090-C2	Normal	RF-PASS	RF-ON
HBL-100-C1	Normal	RF-PASS	RF-ON
HBL-100-C2	Normal	RF-PASS	RF-ON
HBL-110-C1	Normal	RF-PASS	RF-ON
HBL-110-C2	Normal	RF-PASS	RF-ON
HBL-120-C1	Normal	RF-PASS	RF-ON
HBL-120-C2	Normal	RF-PASS	RF-ON
HBL-130-C1	Normal	RF-PASS	RF-ON
HBL-130-C2	Normal	RF-PASS	RF-ON

HV Bias

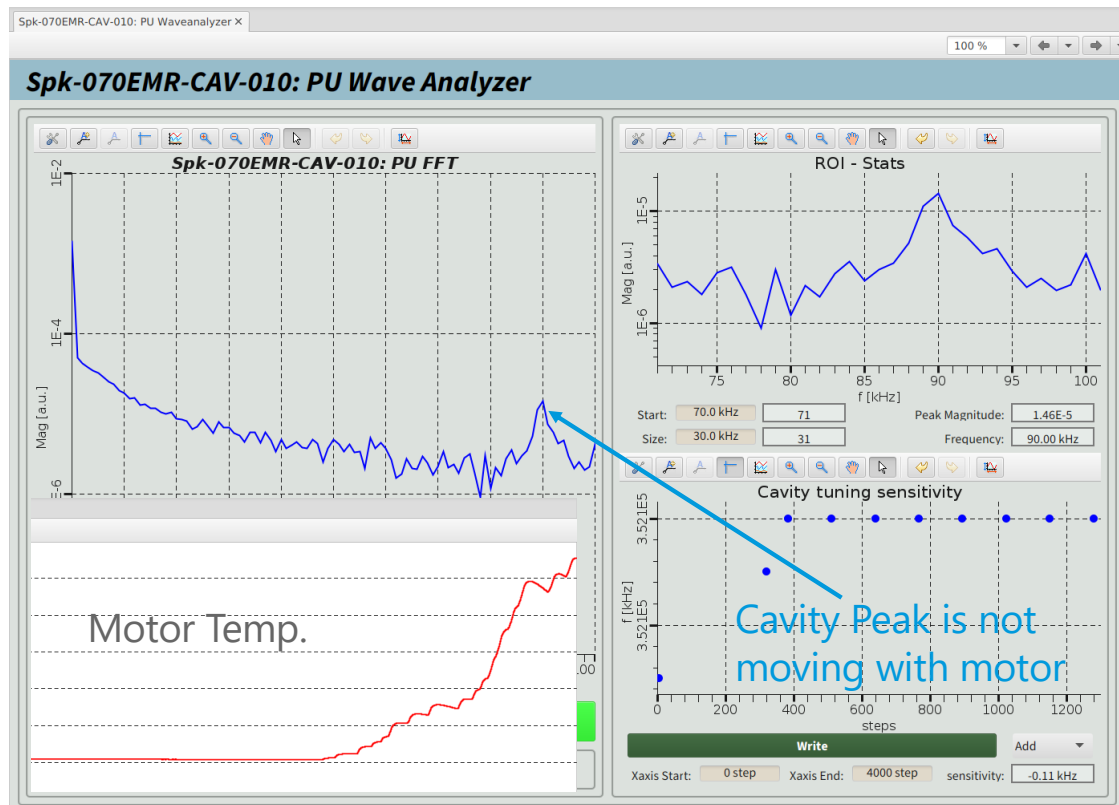
3

Challenges

Spoke motor failure



SPK-070-1 tuner dead

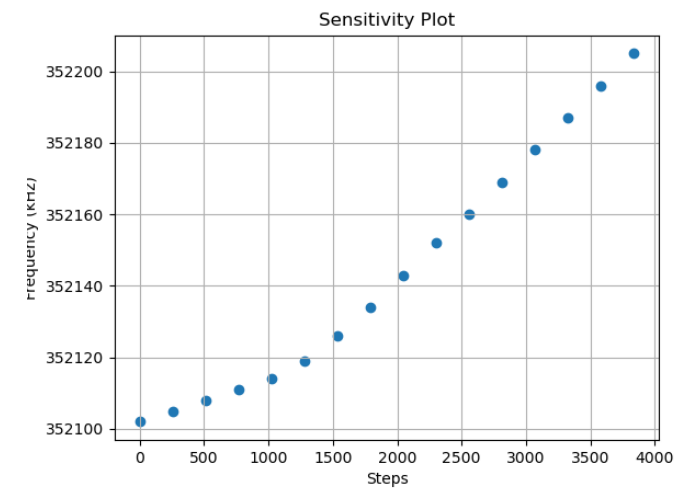


2026-06-09 ESS CM COMMISSIONING

SPK-100-2 tuner half dead ?

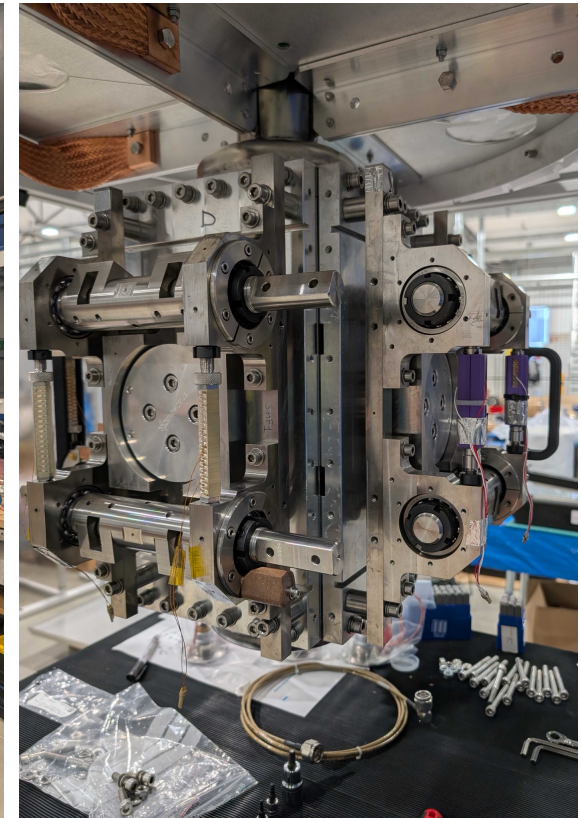
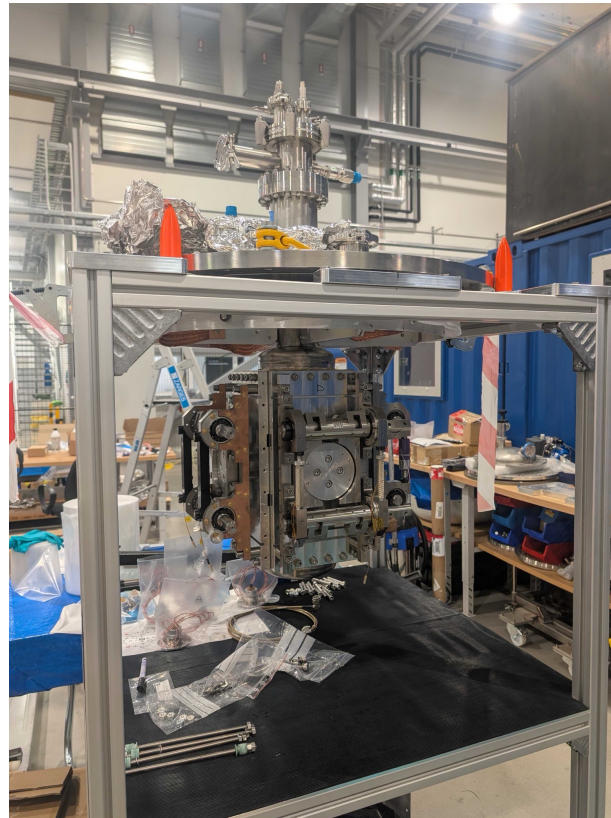
Fine tuning after cryo trip:

- at nominal motor drive current tuner was not moving
- increased from 600mA to 900mA helped



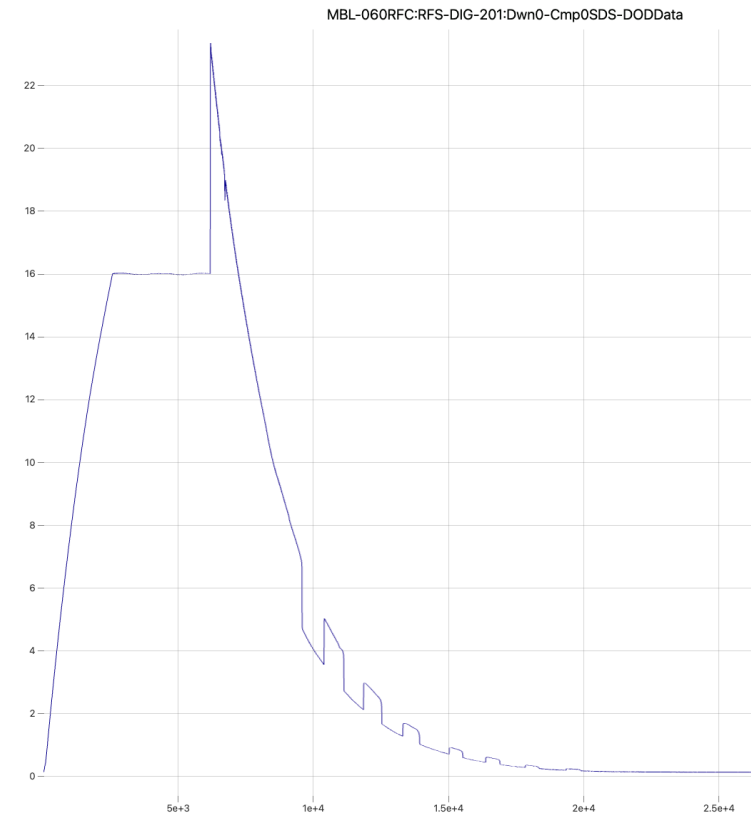
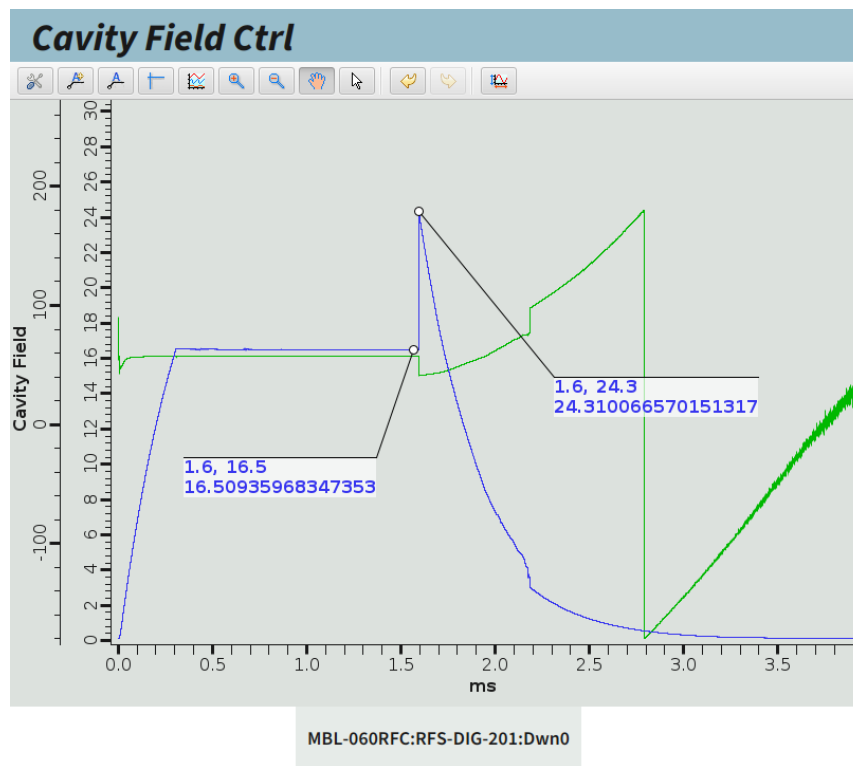
Spoke CTS Test Stand

Preparation ongoing



MBL-060 S2 mystery

Unphysical jumps to higher field

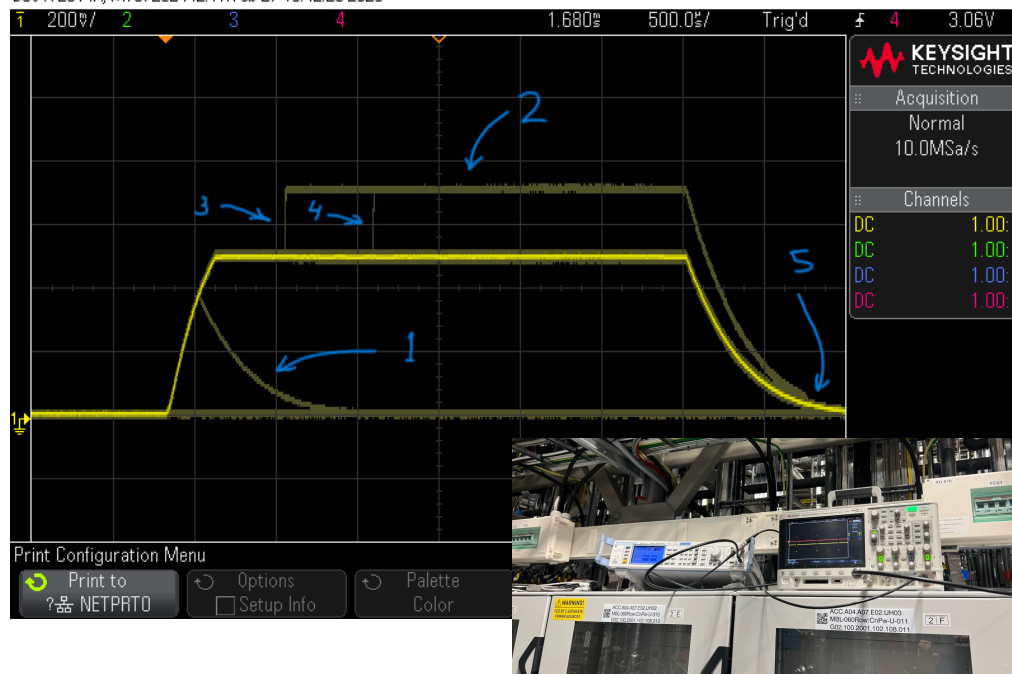


MBL-060 S2 mystery

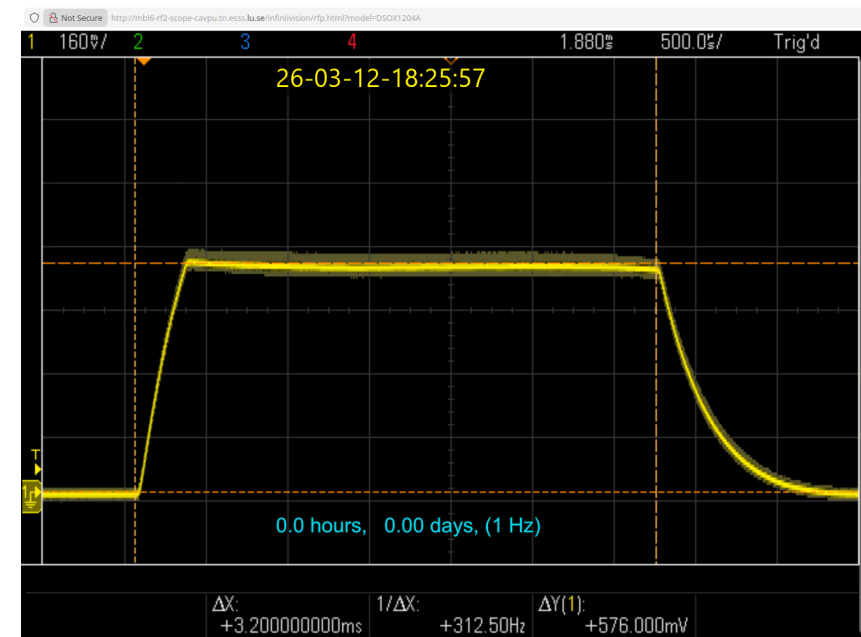


- Cavity PU connected to Oscilloscope
- LLRF fed by Signal Generator
- Long pulse and Piezo ON (custom)

DSO-X 2014A, MY57232442: Fri Feb 27 15:42:29 2026



- Cavity PU connected to Oscilloscope
- Nominal field and RF pulse
- Piezo ON (predefined = manual)

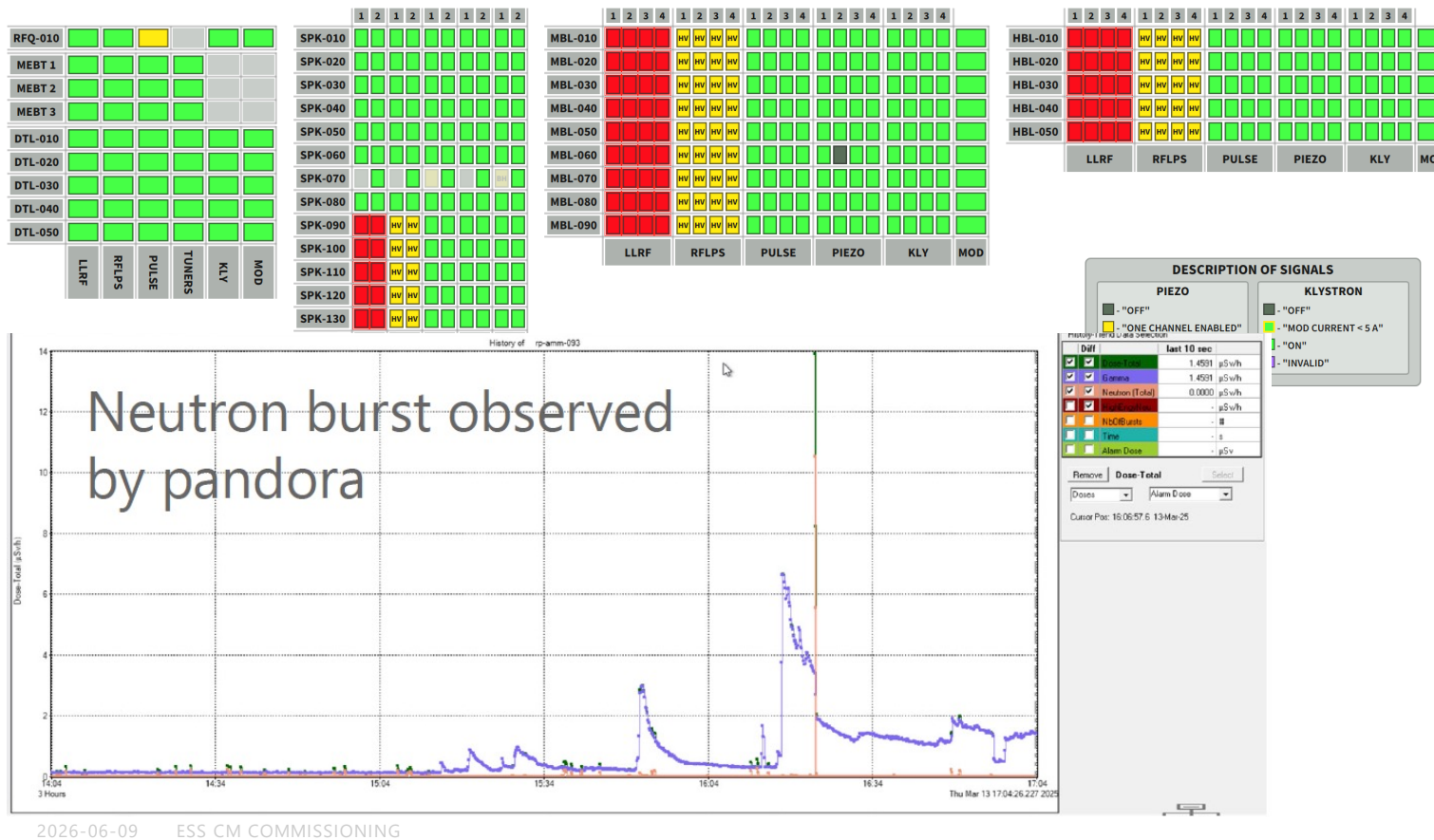


Collective arcs

Operating in FE regime



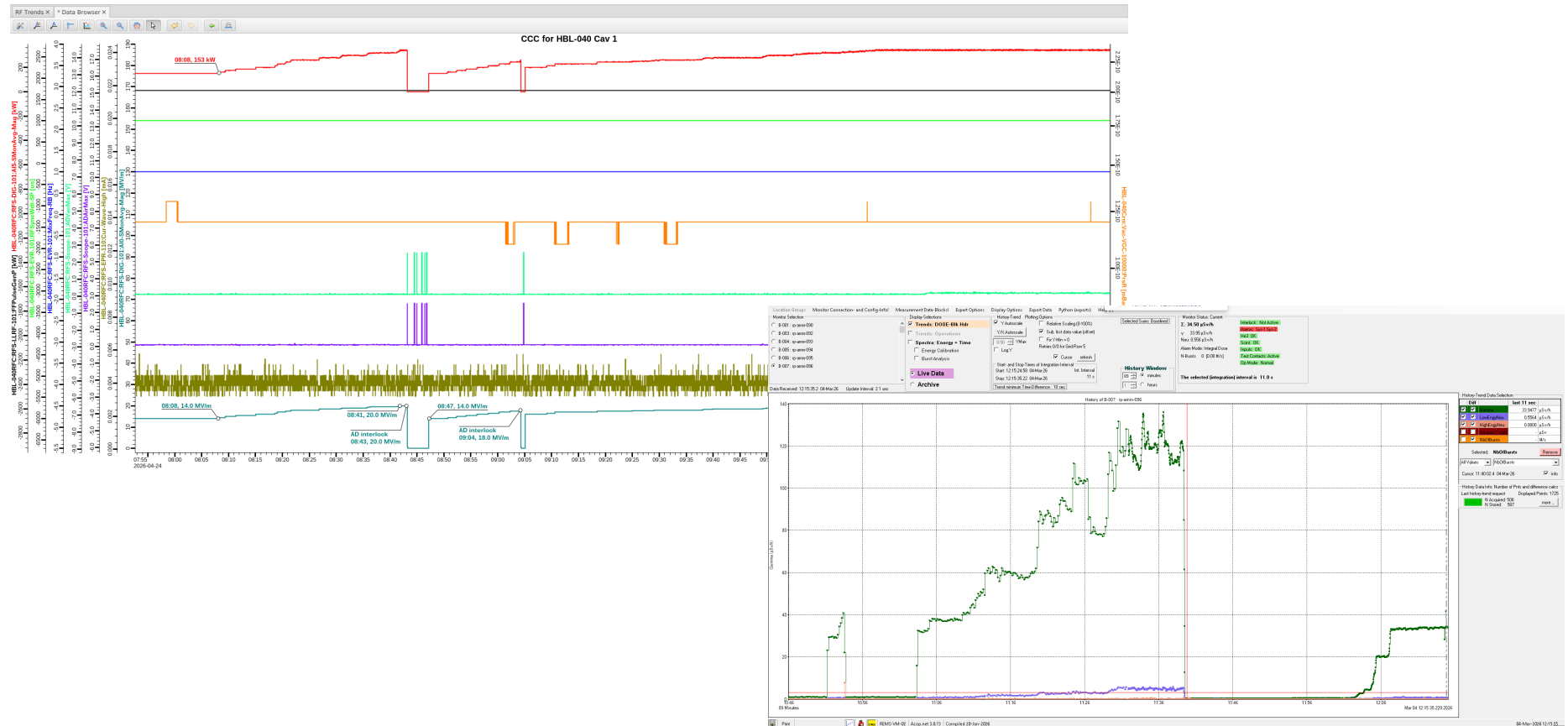
More 10/06:
FE experience
by C.Maiano



2026-06-09 ESS CM COMMISSIONING

Performance degradation

HBL-020 C1 ,HBL-030 C3 C4, HBL-040 C1



2026-06-09 ESS CM COMMISSIONING

4

Cryo Experience



Commissioning of Accelerator Cryogenic Timeline



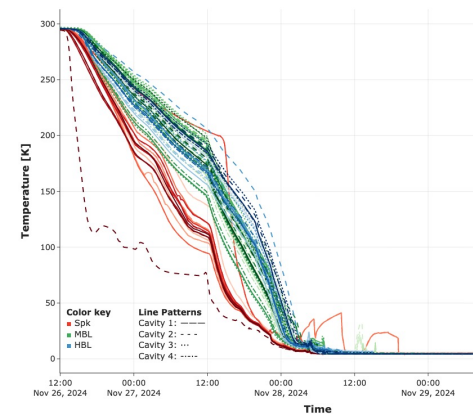
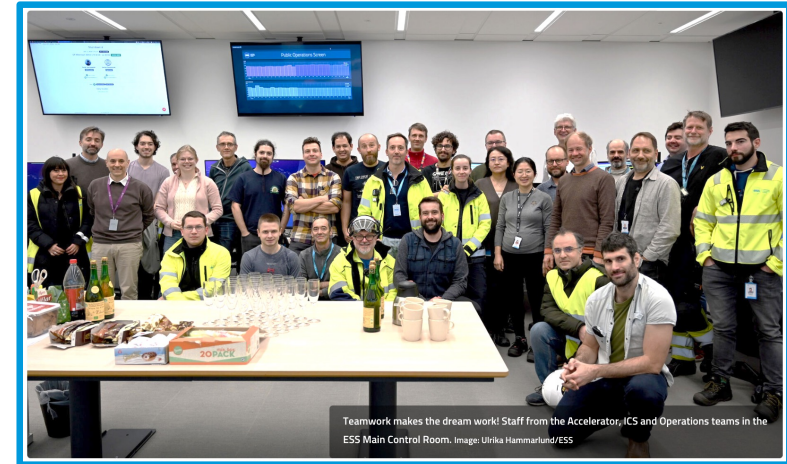
1st Cooldown of the ACCP and CDS: Dec-2022 (8K)
- identification of some issues (high HL, TAO, valves tightness)

2nd Cooldown of the ACCP and CDS: Jun-2023 (2K)
+ 2 cryomodules (Spokes **SPK-110** and Elliptical **MBL-020**).

1st Cooldown of the LINAC: Nov-2024 (2K) BOD1
+ 27 cryomodules (up to **HBL-050**).

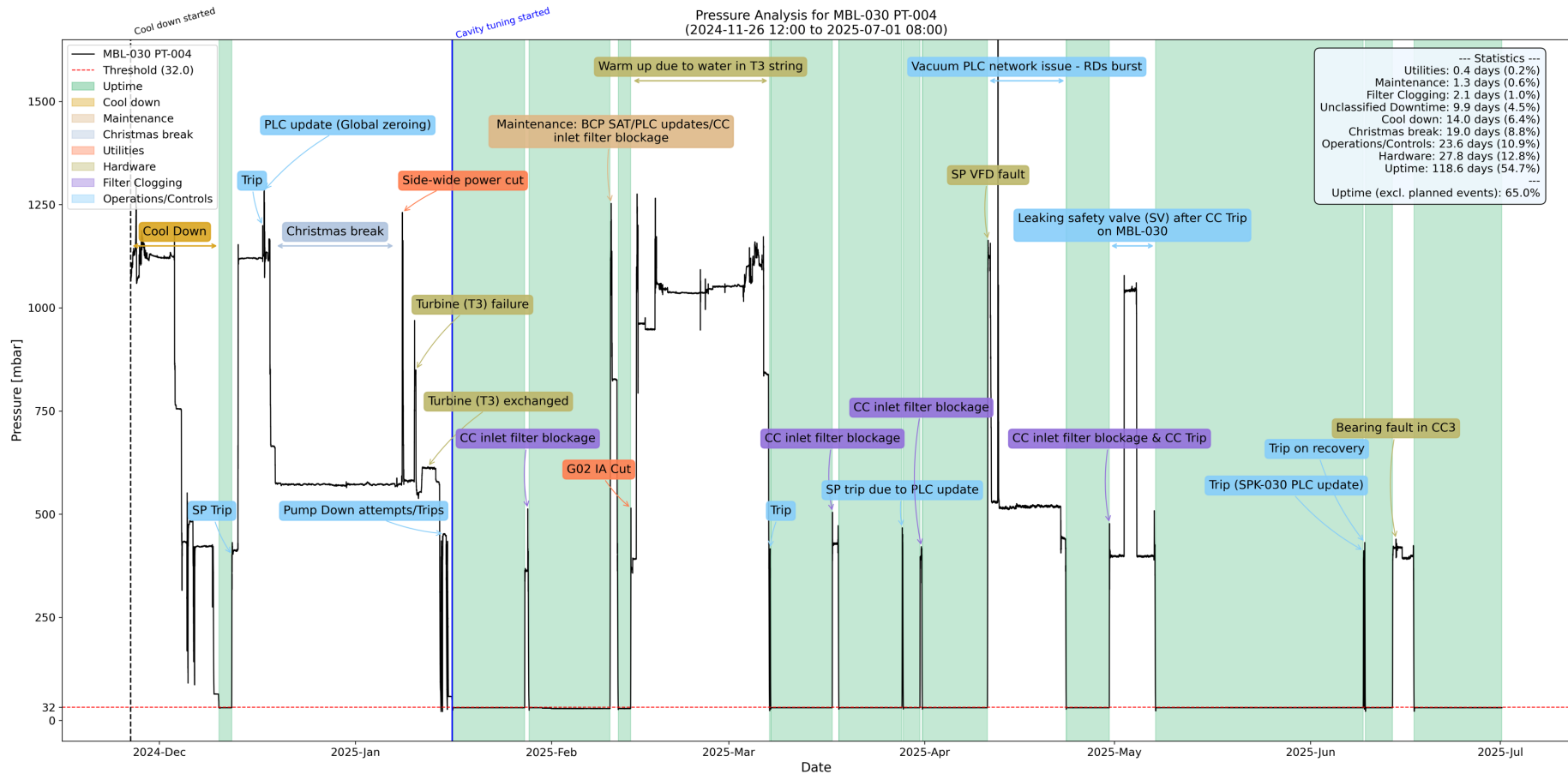
2nd Cooldown of the LINAC: Feb-2025 (2K) BOD1
(unplanned)
+ 27 cryomodules (up to **HBL-050**).

3rd Cooldown of the LINAC: Nov-2025 (2K) BOD2
+ 33 cryomodules (up to **HBL-110**).



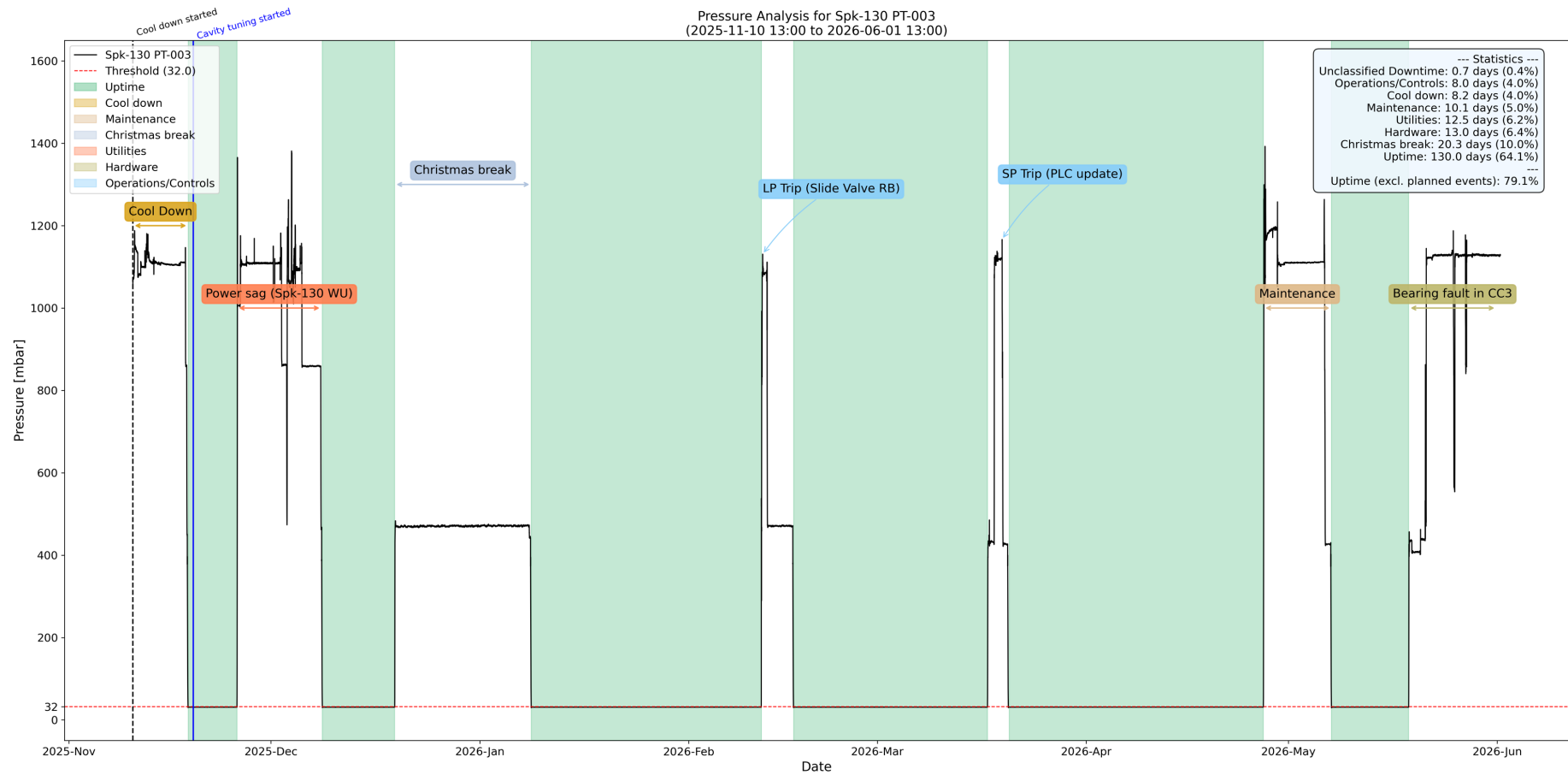
Cryo 2K uptime BOD 1

21 trips
2K for 65%



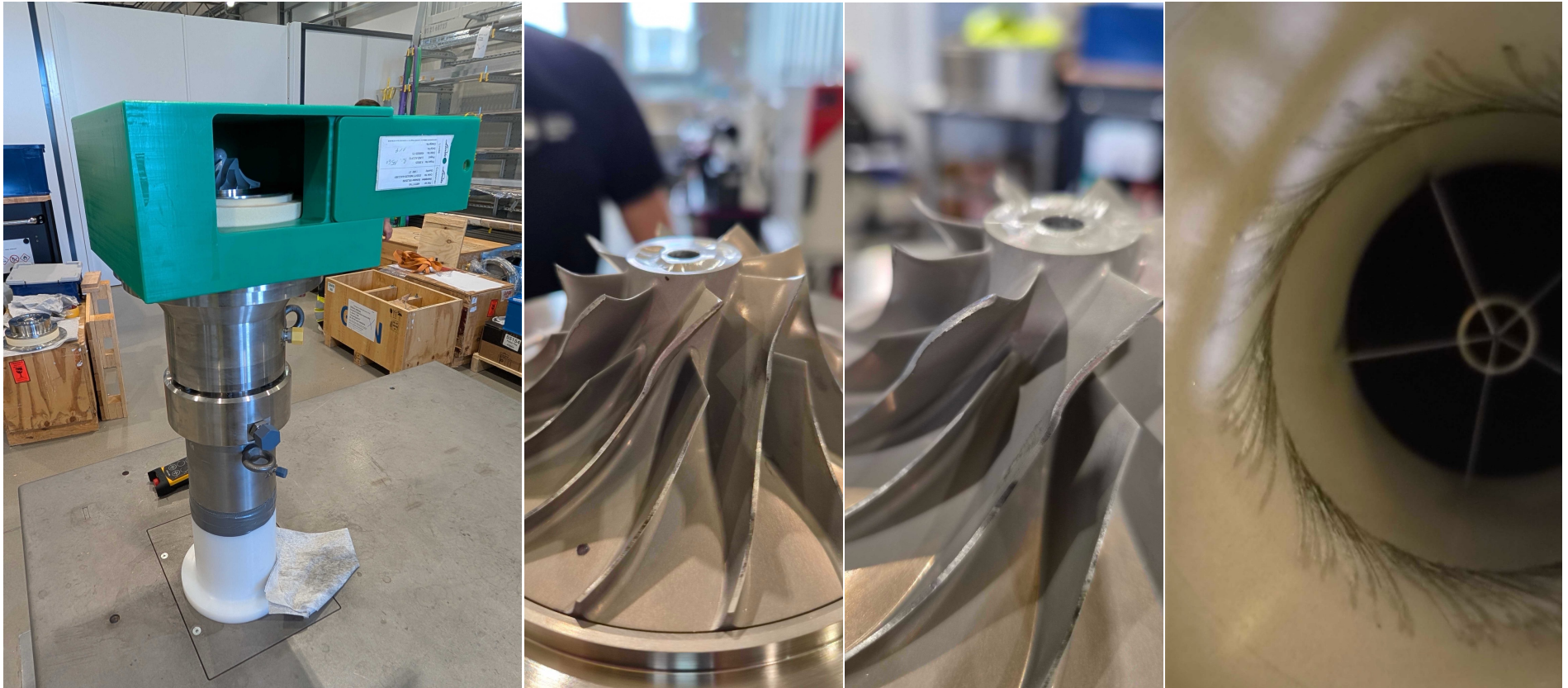
Cryo 2K uptime BOD 2

4 trips
2K for 79%



Cold Compressor bearing failure

CC3 damaged after 3000 hours



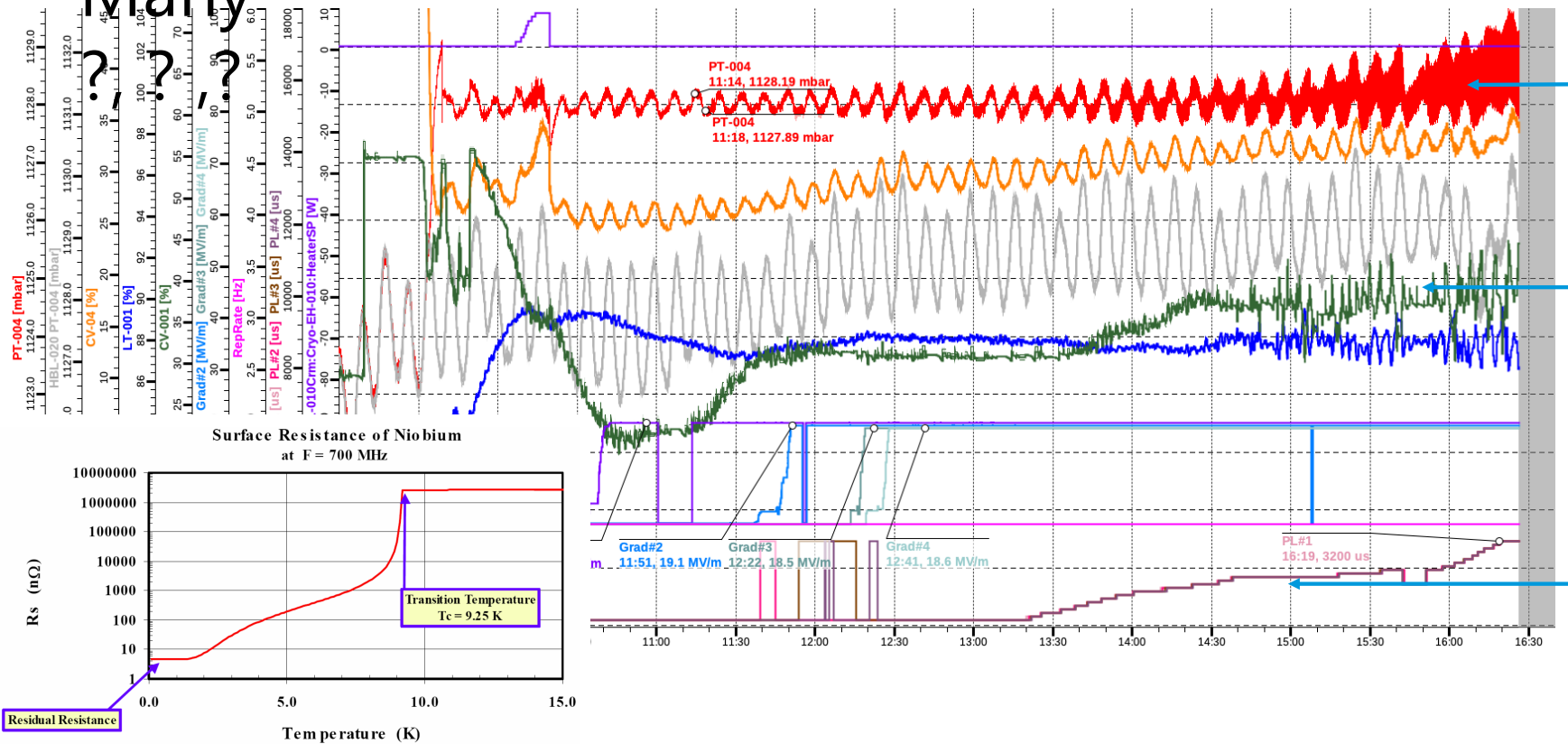
No Cryo – No Cry ?

4K Operations: HBL-010, 4 cavities, 1 Hz, gradually increased pulse length



Many

???



Pressure oscillations

Helium boiling

Pulse Length



Questions?

Back Up Slide 1

Cavity Parameters



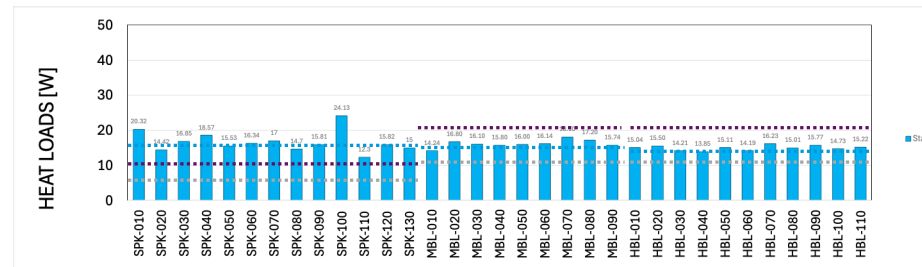
Requirement	Spoke	medium- β	high- β
Frequency / MHz	352.21	704.42	704.42
Optimum β	0.5		
Geometric β		0.67	0.86
$E_{acc} / \text{MV m}^{-1}$	9.0	16.7	19.9
$E_{pk} / \text{MV m}^{-1}$	39	45	45
$B_{pk}/E_{Acc} / \text{mT}/(\text{MV}/\text{m})$	6.80	4.79	4.3
E_{pk}/E_{Acc}	4.28	2.36	2.2
Iris diameter / mm	56	94	120
RF peak power / kW	335	1100	1100
G / Ω	130	196.63	241
maximum R/Q / Ω	425	394	477
$Q_{ext} / 10^5$	1.75-2.85	7.5	7.6
$\min Q_0(E_{acc}) / 10^9$	1.5	5	5

Back Up Slide 2

Heat load distribution: Measured Heat Loads



Static



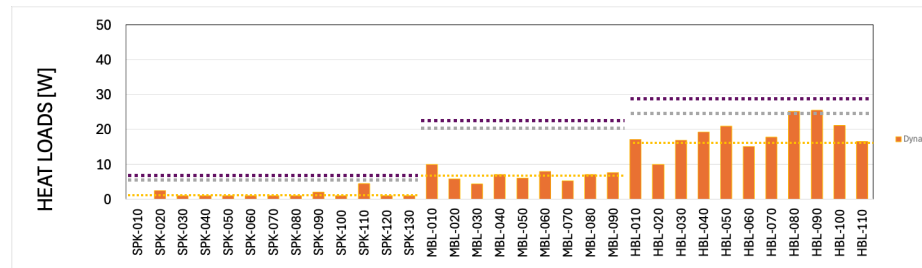
Avg/CM

Spk: 16.7 W
Mbl: 16.2 W
Hbl: 15.0 W

Totals

tot: 528 W

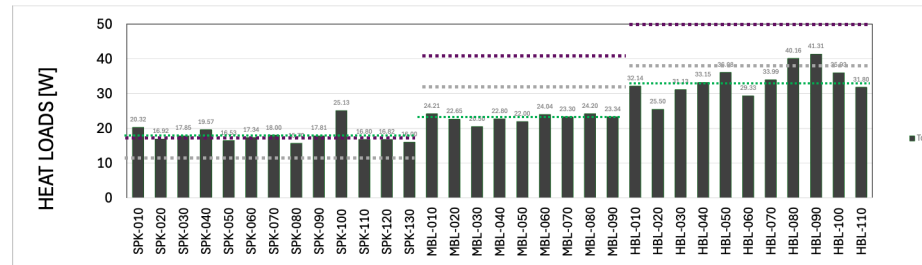
Dynamic



Spk: 1.4 W
Mbl: 6.8 W
Hbl: 18.7 W

tot: 285 W

Total

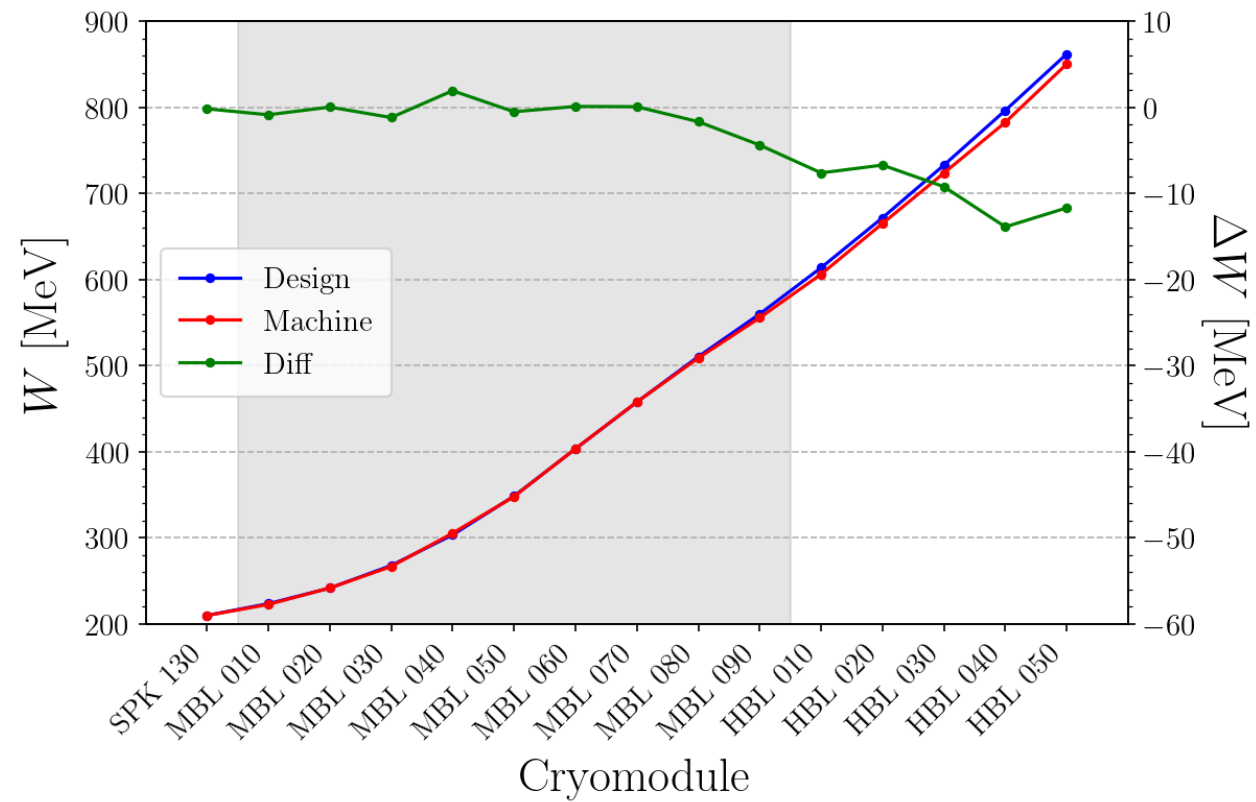


Spk: 18.1 W
Mbl: 23.0 W
Hbl: 33.7 W

tot: 812 W

Back Up Slide 3

LINAC Phase Scans Results



Back Up Slide 4

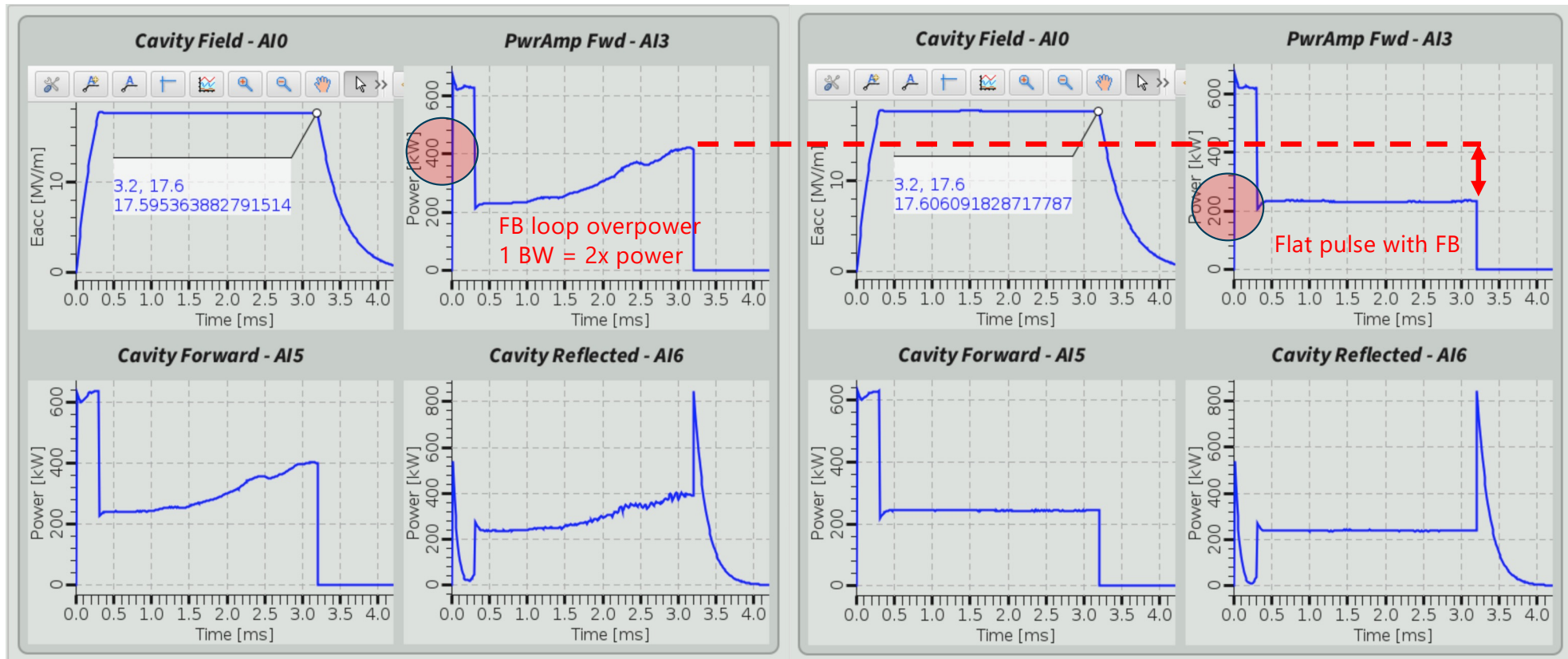
Piezo operations (manual)

Piezo OFF

Cavity detuning at high field (LFD) requires > 50% extra power at pulse end!

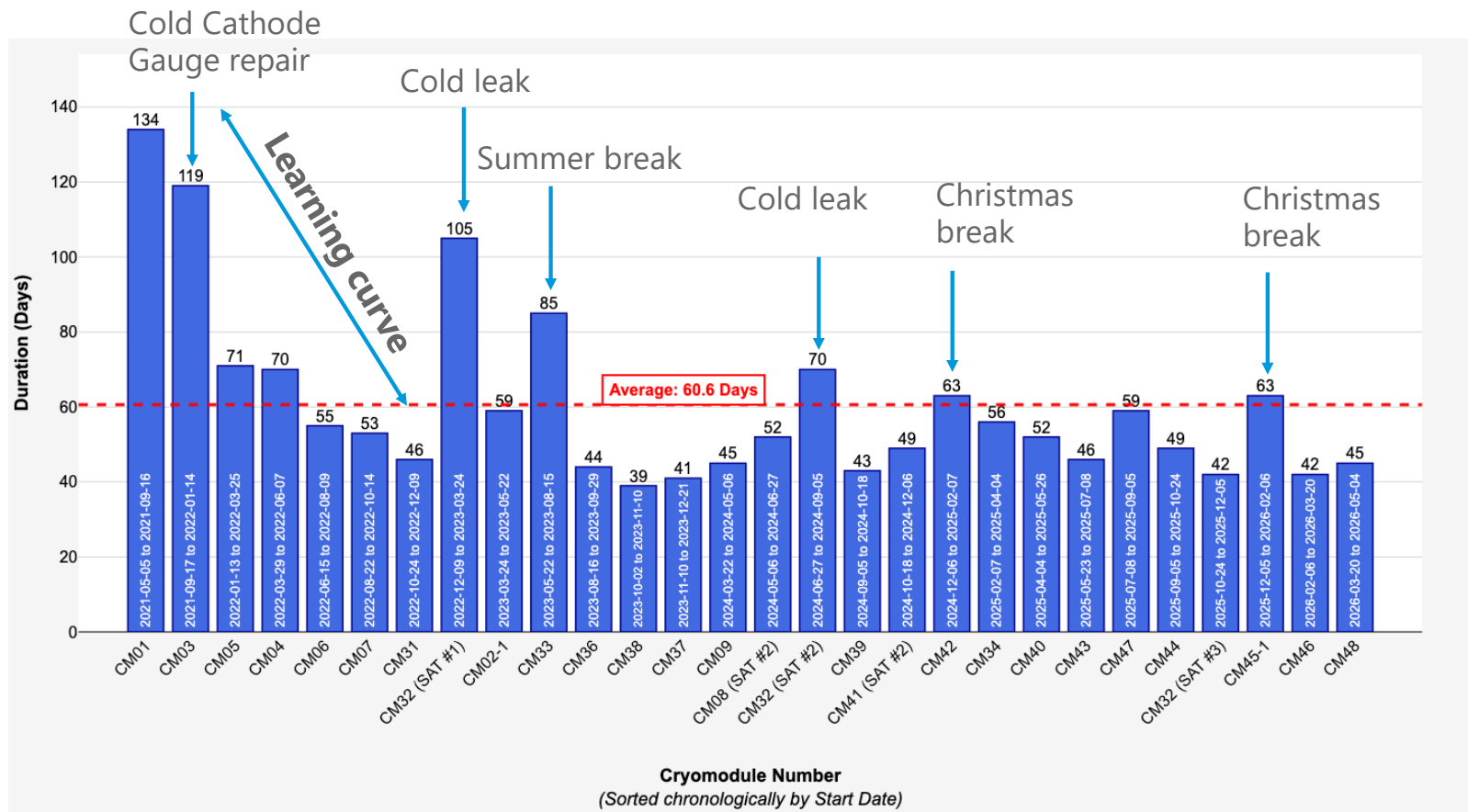


Piezo ON



Back Up Slide 5

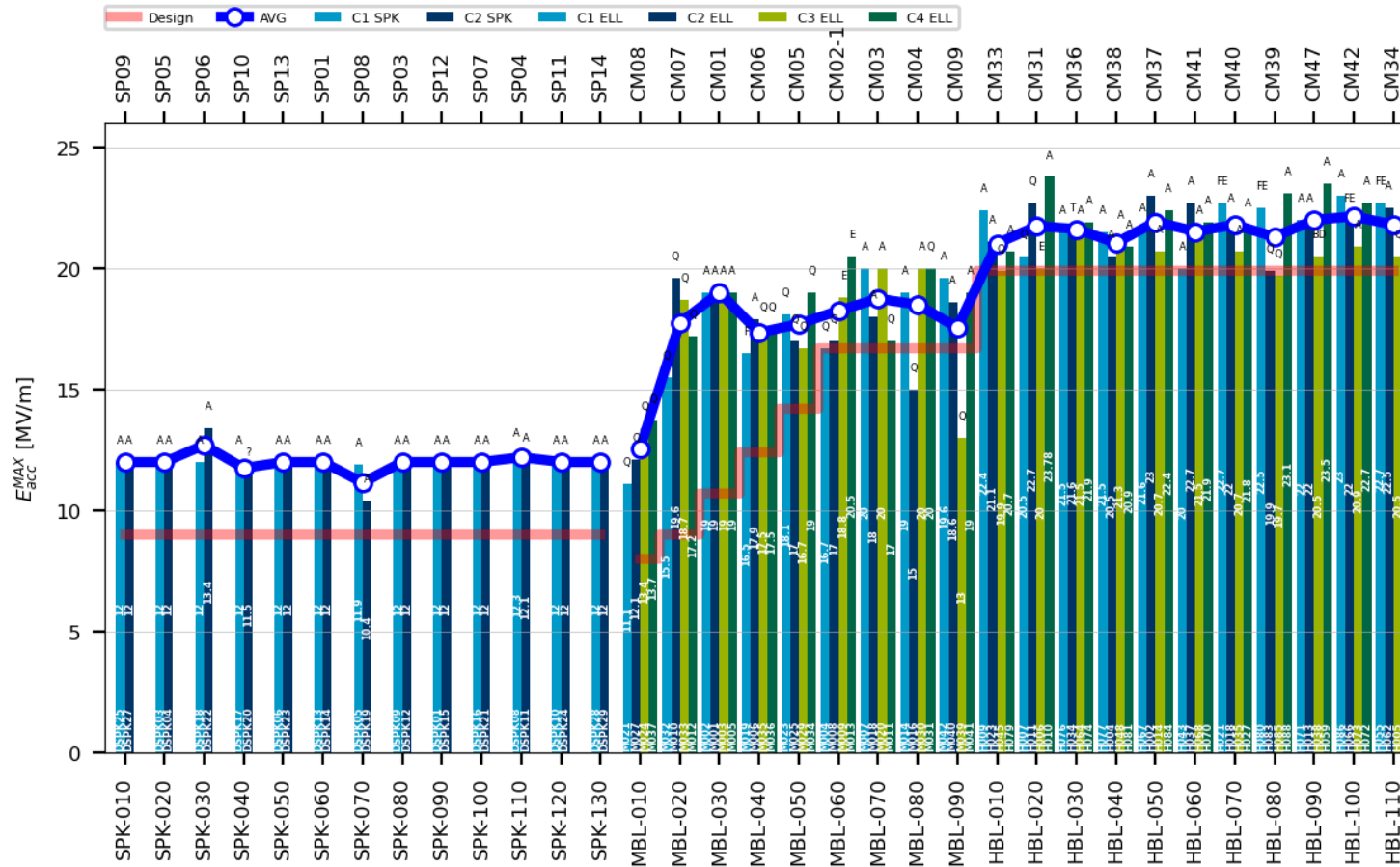
TS2 SAT: Total Time Spent in the Bunker



Back Up Slide 6



Linac Design



Back Up Slide 8

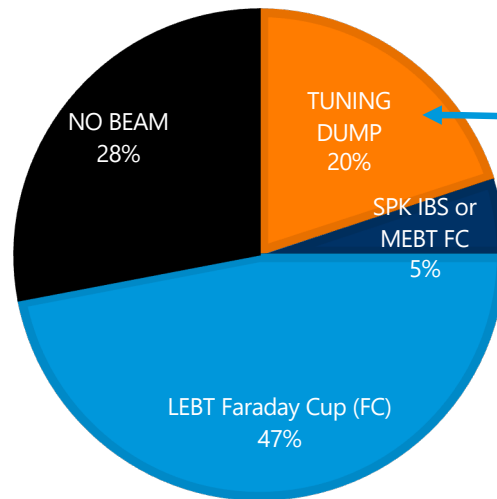
Differences and time usage



BOD1

Beam: 6mA, 5us
RF pulse: 1ms, 1Hz
No piezo

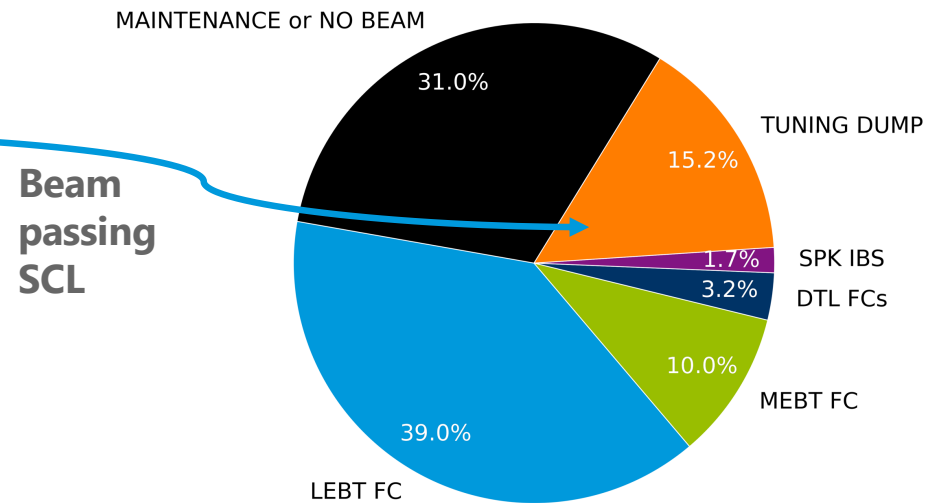
BOD 1 commissioning 2025



BOD2

Beam: >6mA, >5us
RF pulse: 3.2ms 14Hz
With Piezo

BOD2 commissioning (from 27-January-2026 to 22-May-2026)



Courtesy: S.Johannesson/E.Donegani