SPS DQW Module: MDs 2023 & Outlook

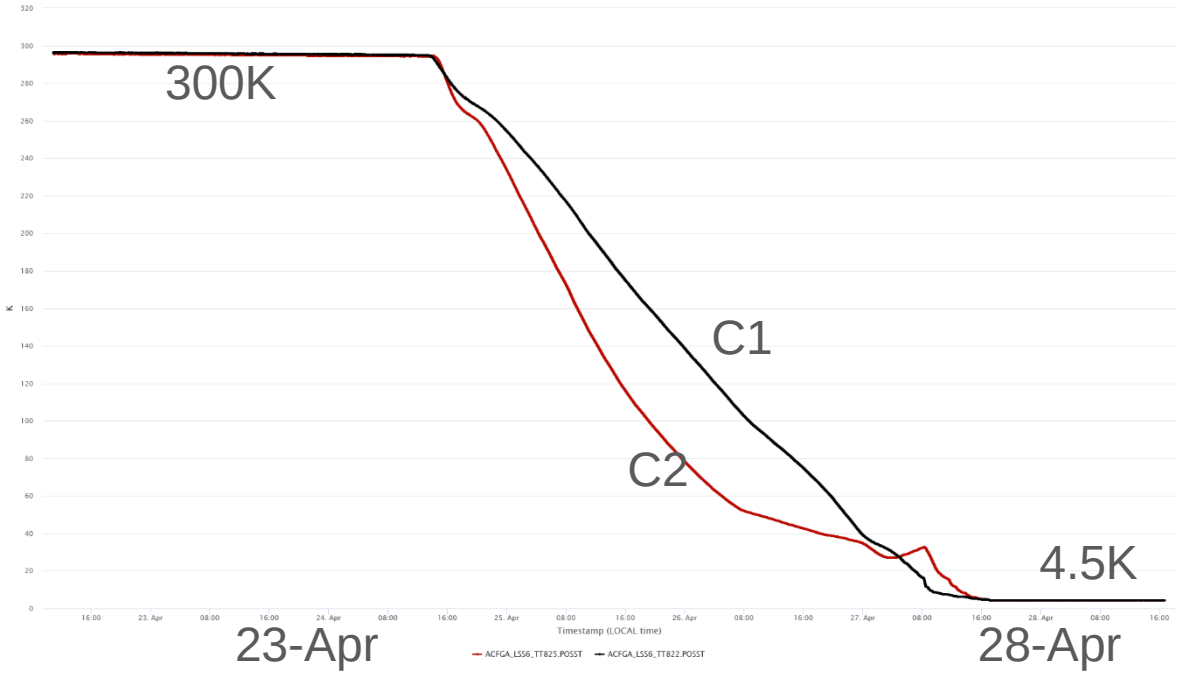
HL-LHC WP4/WP2/WP13
CERN

Big thanks: WP9, WP12, SPS operations and many others

28 September 2023

DQW-SPS MDs, 2023 Experience

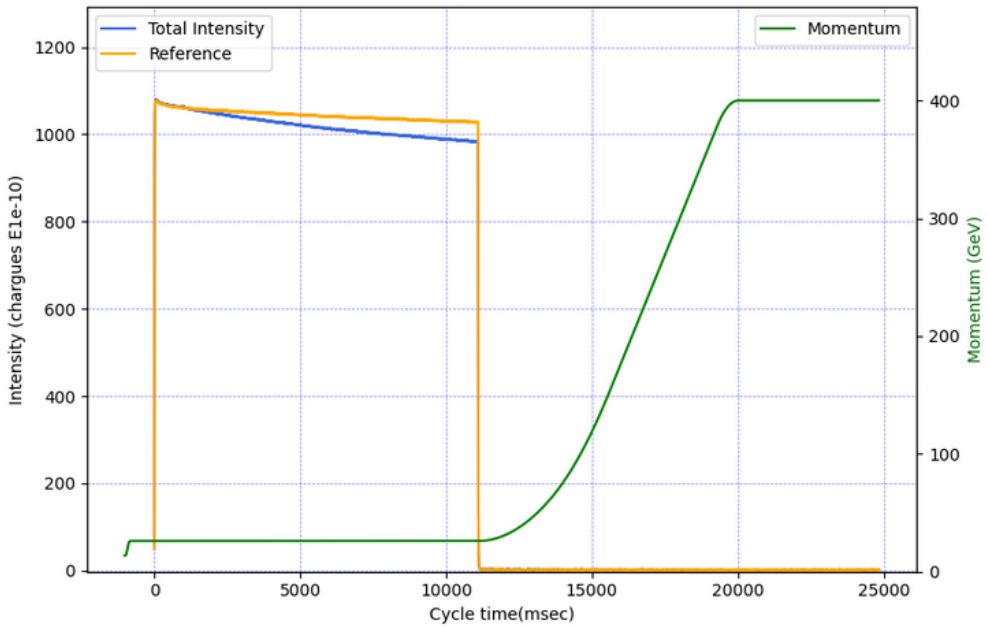
- 4 MDs performed in 2023 (May 2 – Jul 27)
  - MD 1-2: high intensity setup & instability studies
  - MD 3-4: CC amplitude noise & emittance growth
  - MD 5: RF-ON sequence with high intensity (72b & 8b4e)



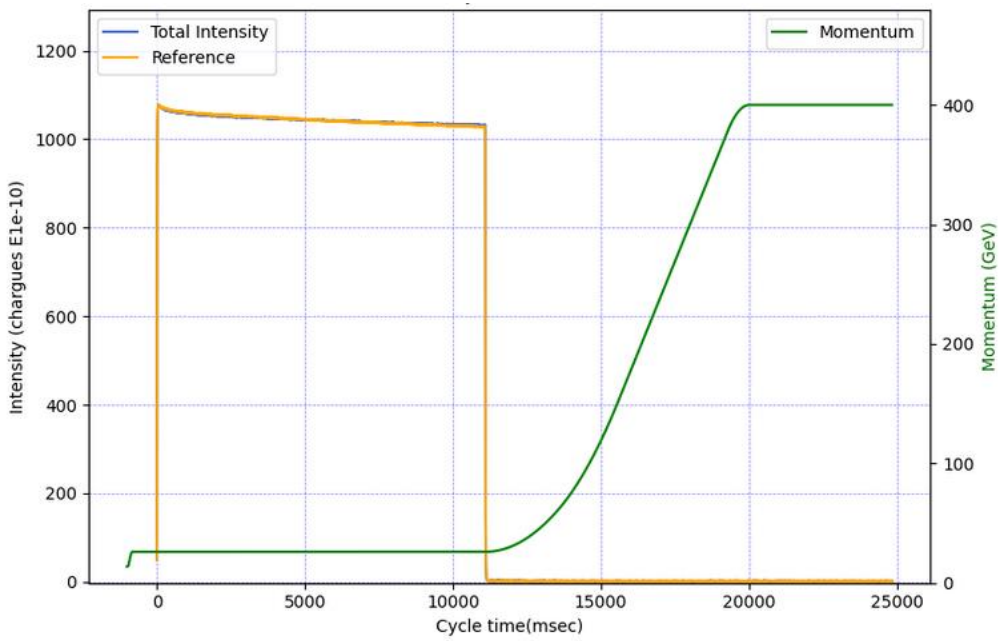
MD 1: Slow losses with high intensity

- When cavities are **counter-phased** with the same voltage, the effect of the slow losses are fully suppressed, indicating an aperture restriction with crabbed beam

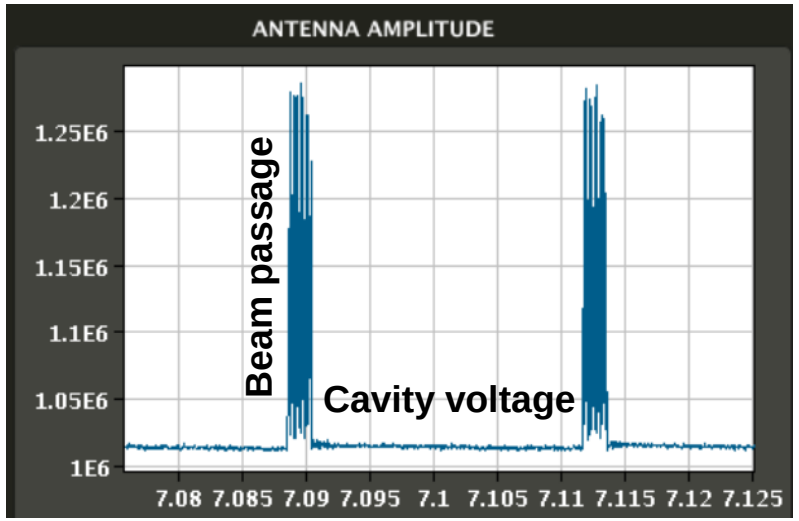
C1 & C2 at 1 MV, Arbitrary phase

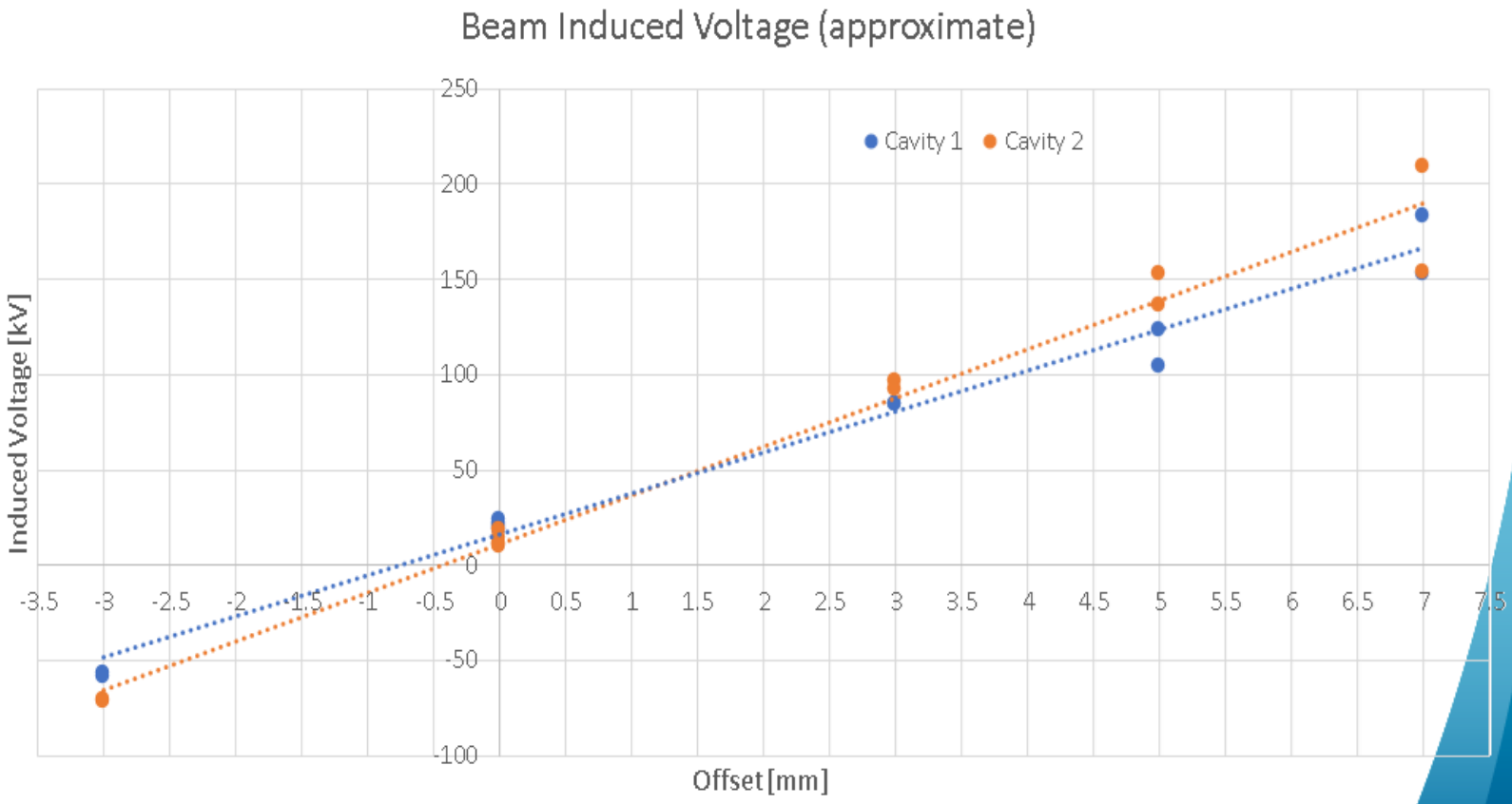


C1 & C2 at 1 MV, Counter-phased



MD1: Orbit Scan in Cavities & Centering

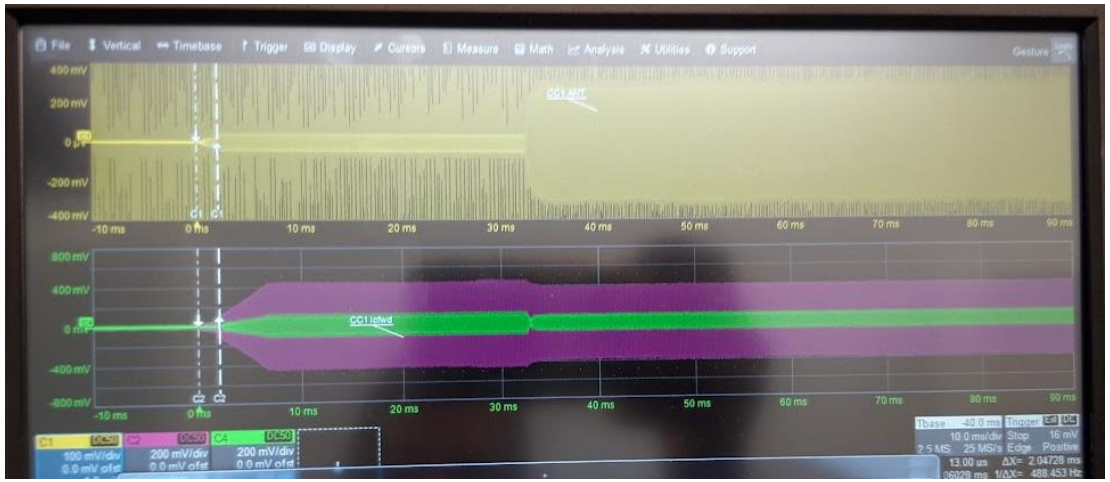




MD 1: RF sequence with 72b, 1.1e11 p/b

- Standard sequence is have RF-ON with beam circulation. But voltage ramp doesn't follow RF power ramp. Mitigation found with RF-ON before beam in SPS.
- Suspect some multipacting and/or ecloud like effect

RF-ON after beam circulating

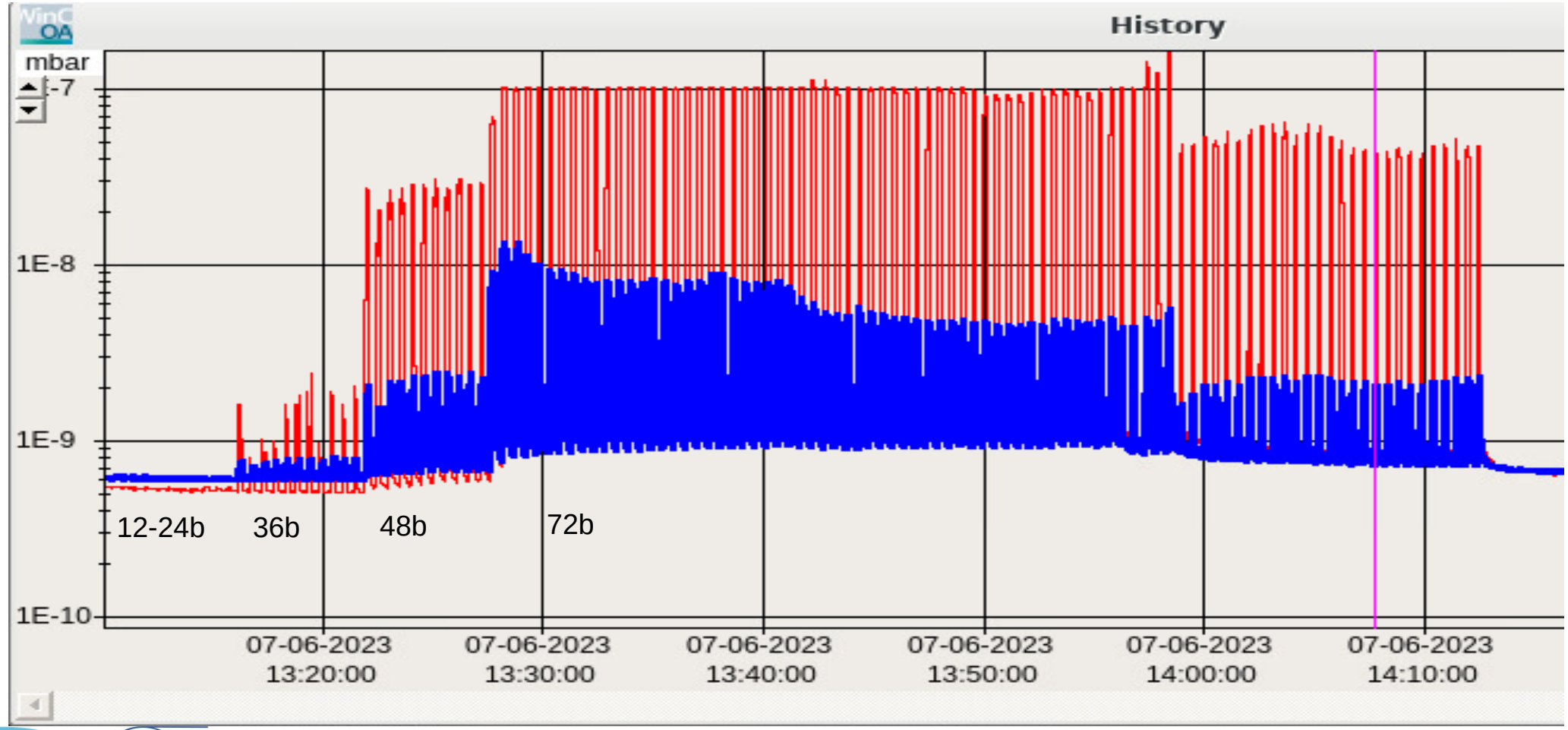


RF-ON before beam circulating

Plot missing
but the effect is not important

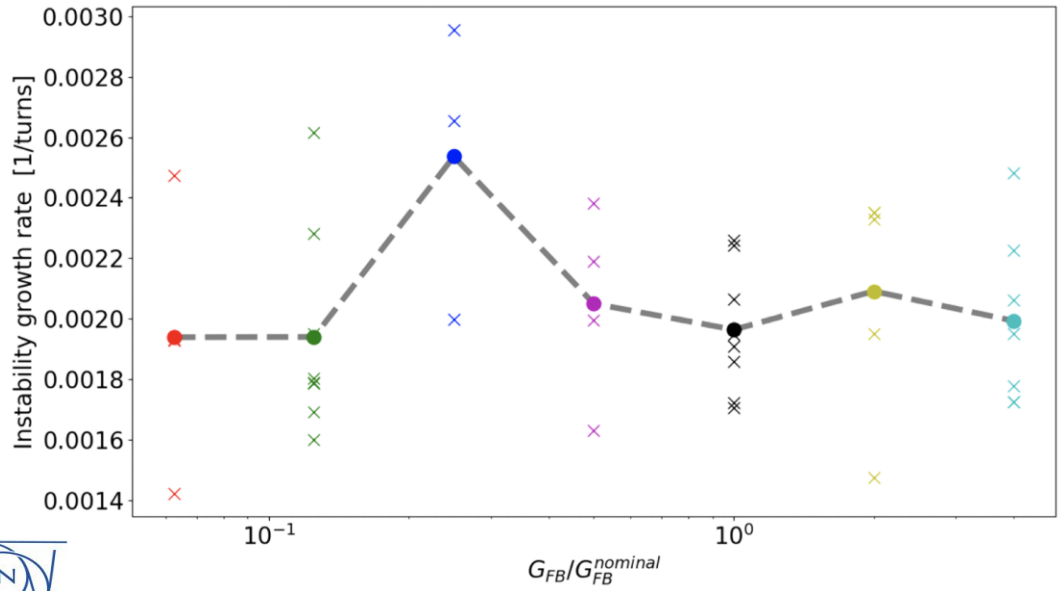
MD 2: Beam Vacuum with trains

- Vacuum activity left/right of CM seen starting 48b and higher

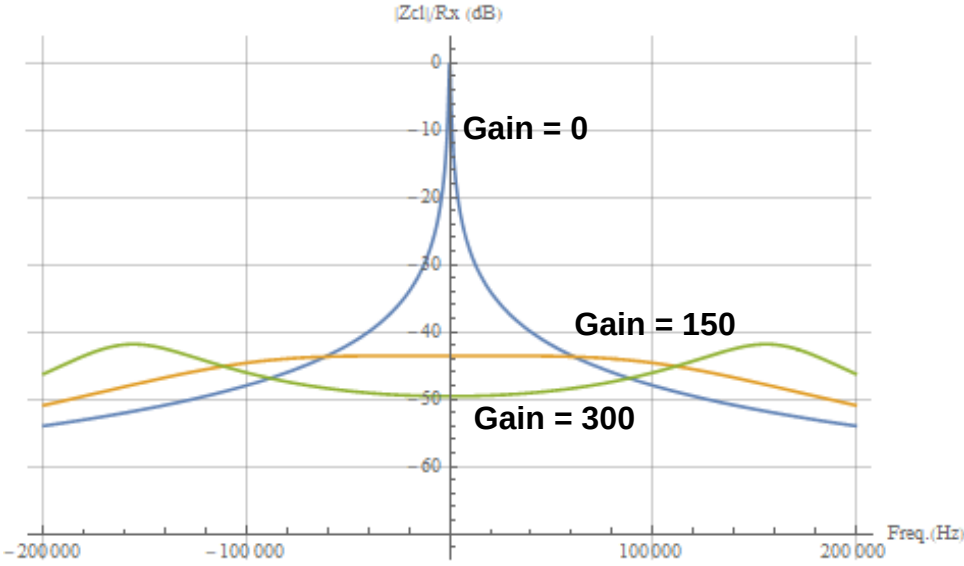


MD 2: Instability study with FB gain

- Direct RF feedback gain was scanned from the nominal value down to 1/100th and up to x4 higher
- Effect on beam stability doesn't scale as expected and not conclusive (see L. Giacomel)

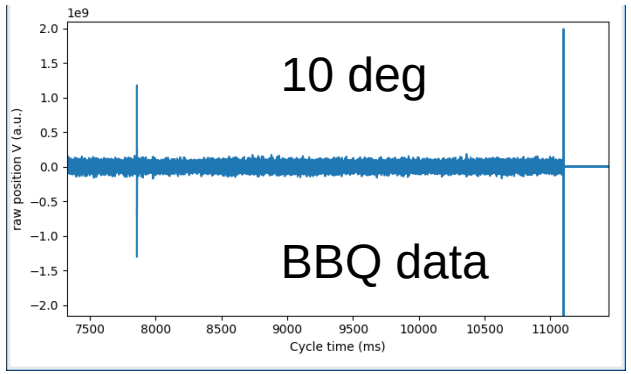


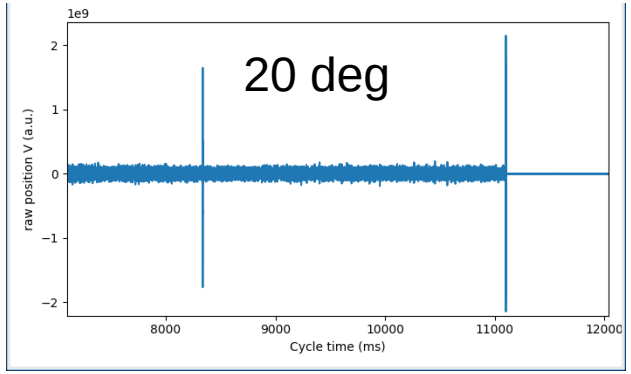
Direct RF feedback to reduce the impedance at the fundamental mode ($\sim 1\ \mathrm{G\Omega/m}$)

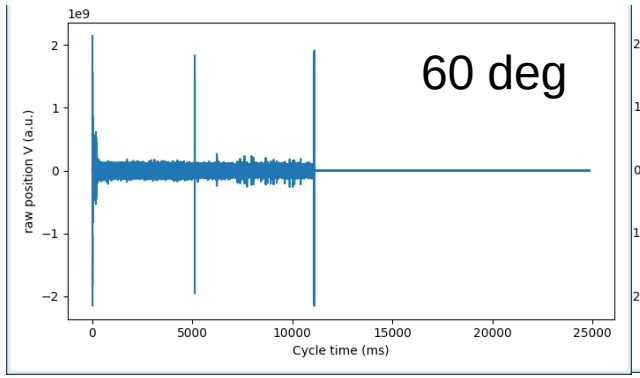


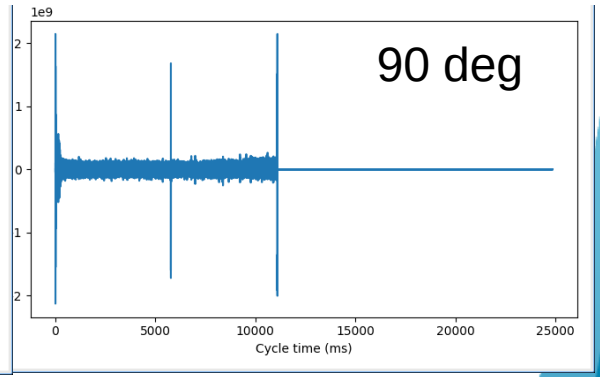
MD 2: Machine Protection

- Abrupt phase changes were made on-demand but with RF feedback off to avoid tripping the amplifiers (C1 & C2 counter-phased)
- Slow losses at the level when cavities are not counter-phased was observed when phase change > 60 deg
- Analysis underway with MP (see previous talk)

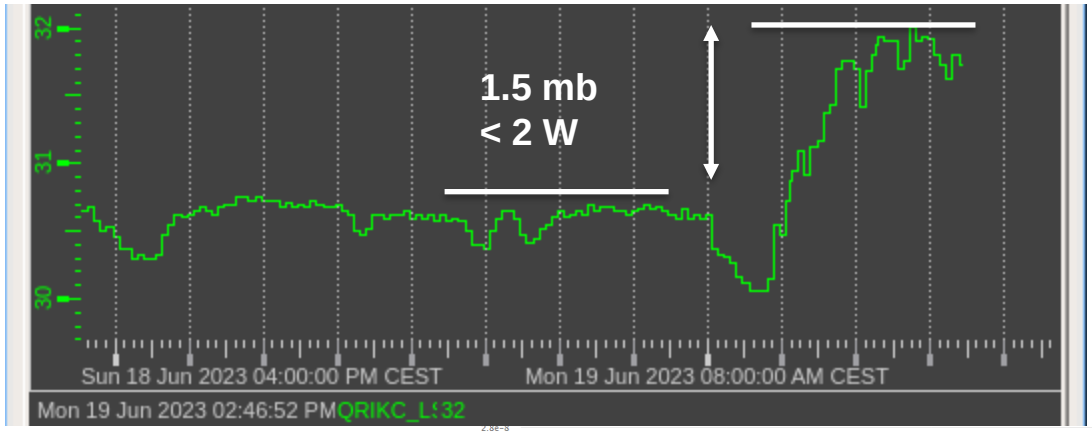


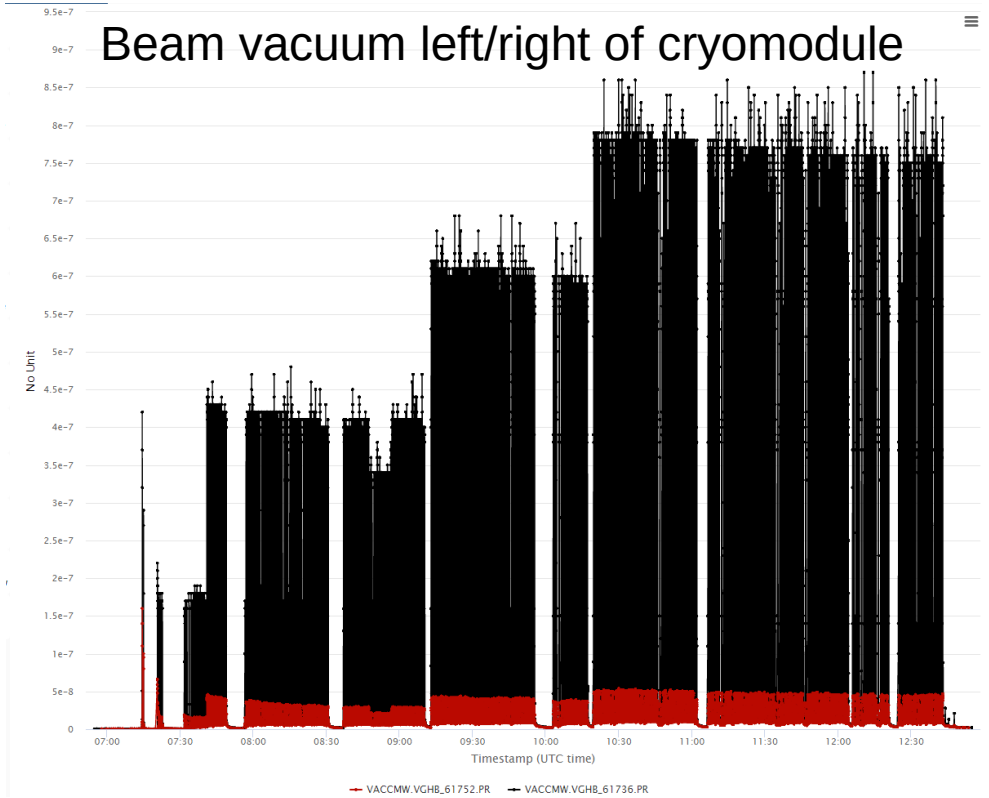


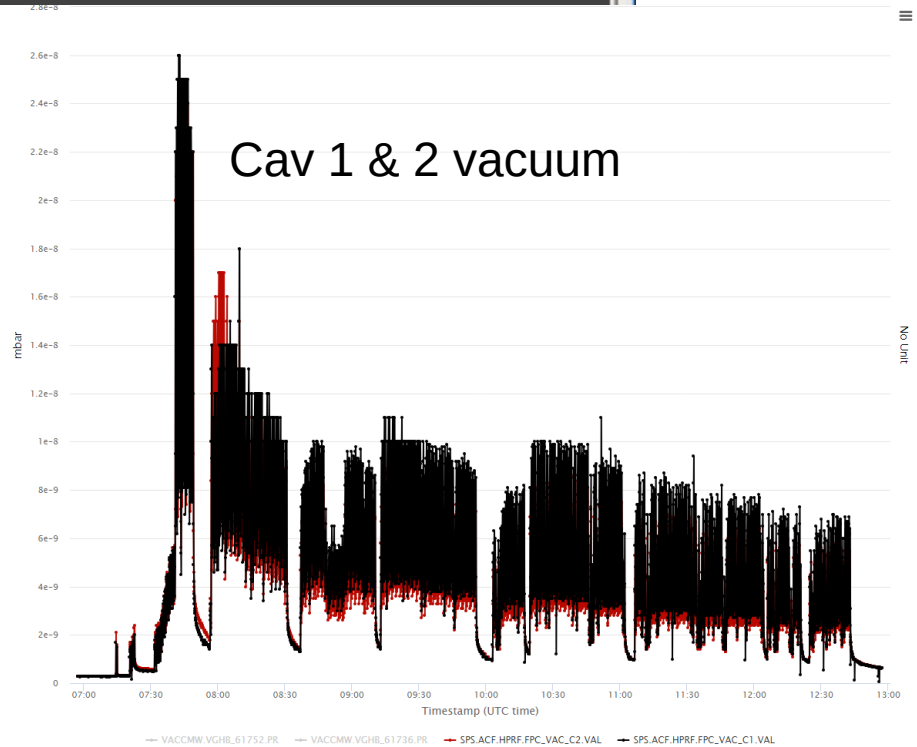




Heat load during COLDEX MD

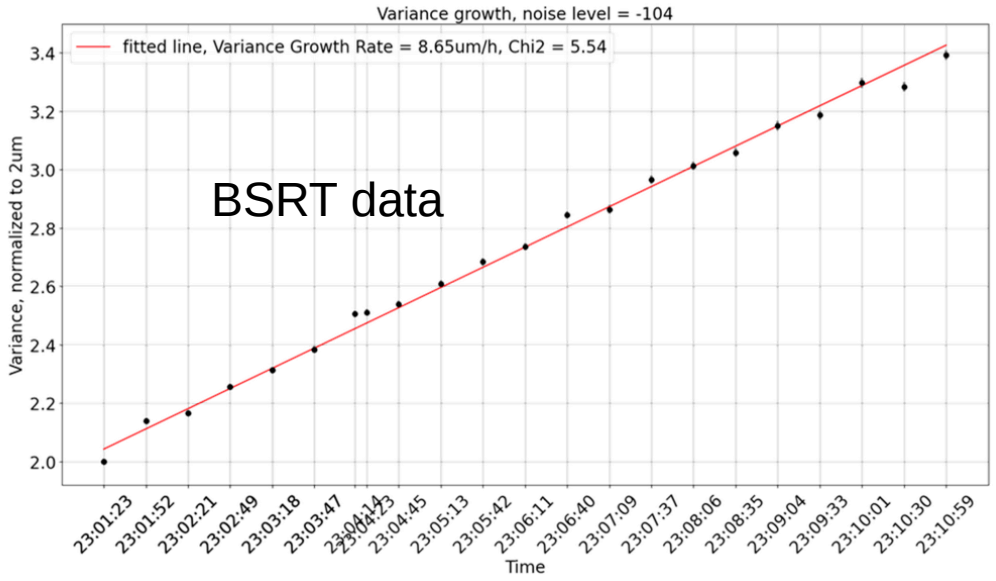


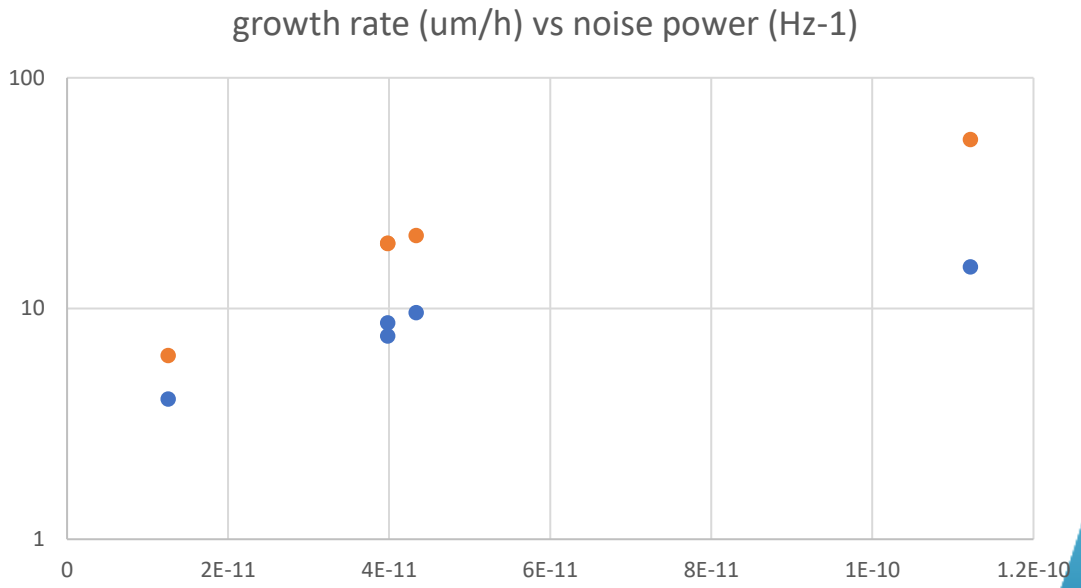




MD 3 & 4: Emittance growth

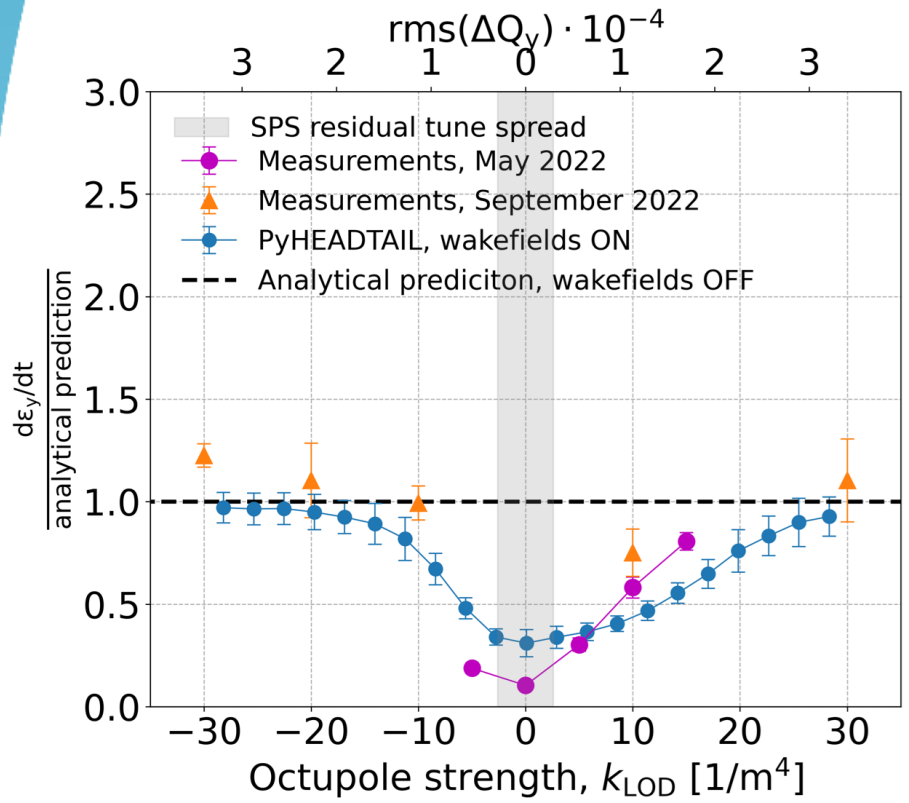
- Emittance growth with amplitude noise using BSRT. Absolute calibration of the BSRT w.r.t wire scanners still missing ?
- Reduction of growth rate with/without octupoles is 40% with amplitude noise, although no reduction was expected (to be compared to 400% with phase noise)





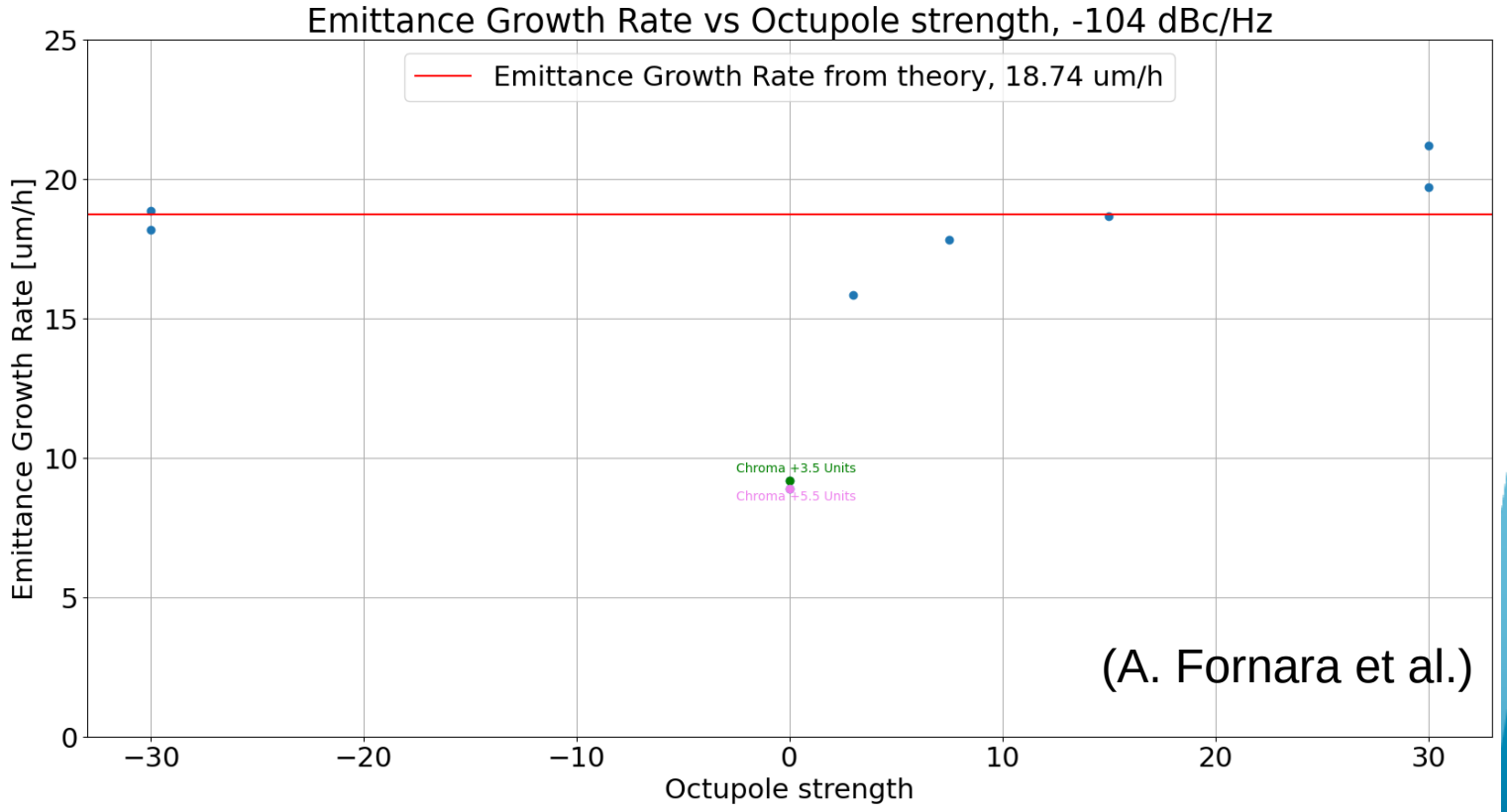
Emittance Growth (Phase & Amplitude Noise)

2022 (phase noise)



(N. Triantafyllou, thesis)

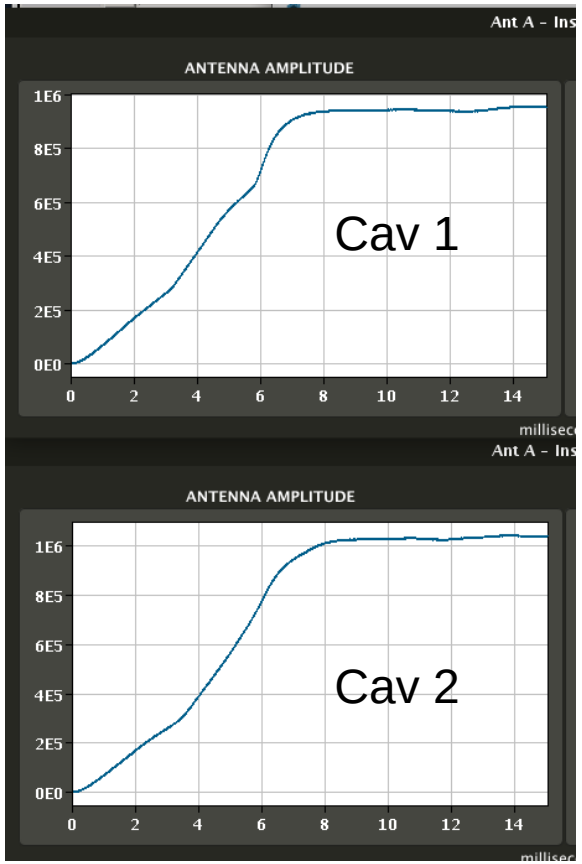
2023 (amp noise)

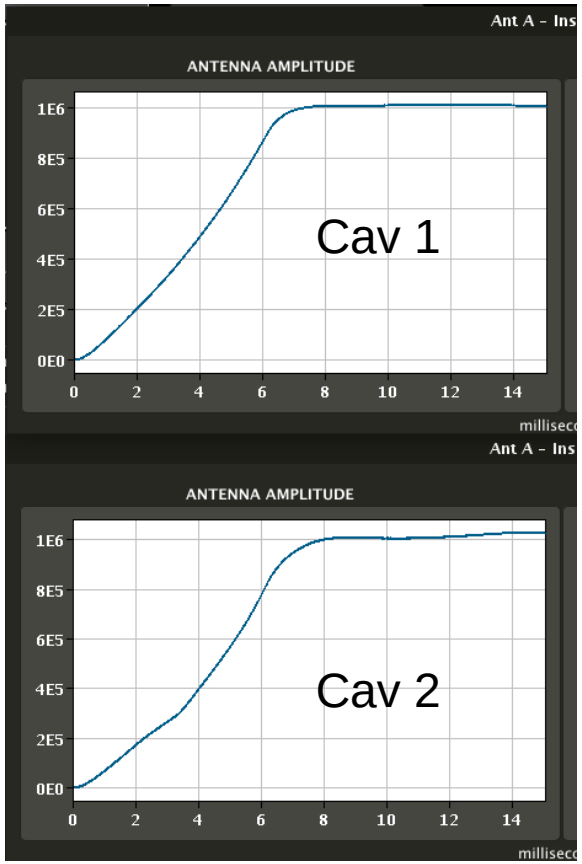


MD 3 & 4: Voltage Ramp on C1 & C2

- Problems detected on C1 amplifier triggered a replacement of the tube. Since, the ramp on C1 is smooth w/o kinks. Retuning on C2 to adjust the voltage/power ramp for 2024

Jun 2023, MD



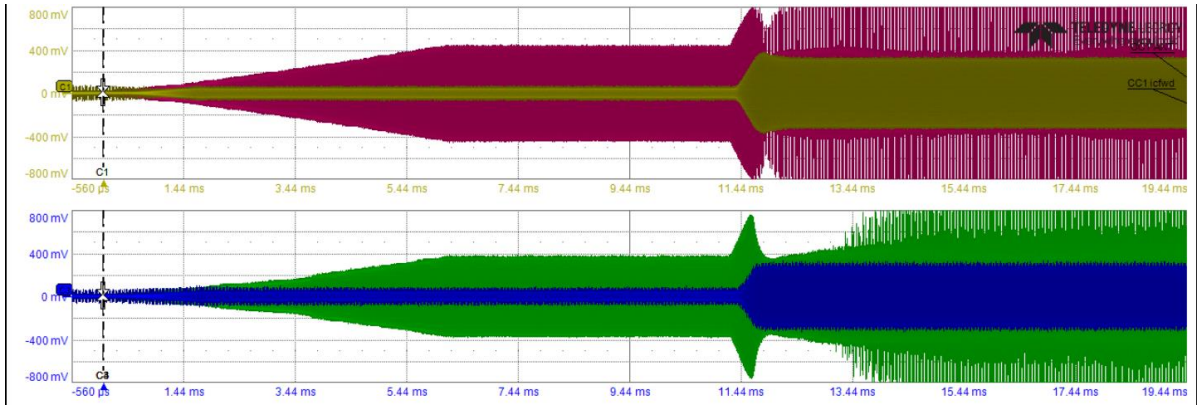


Jul 2023, MD

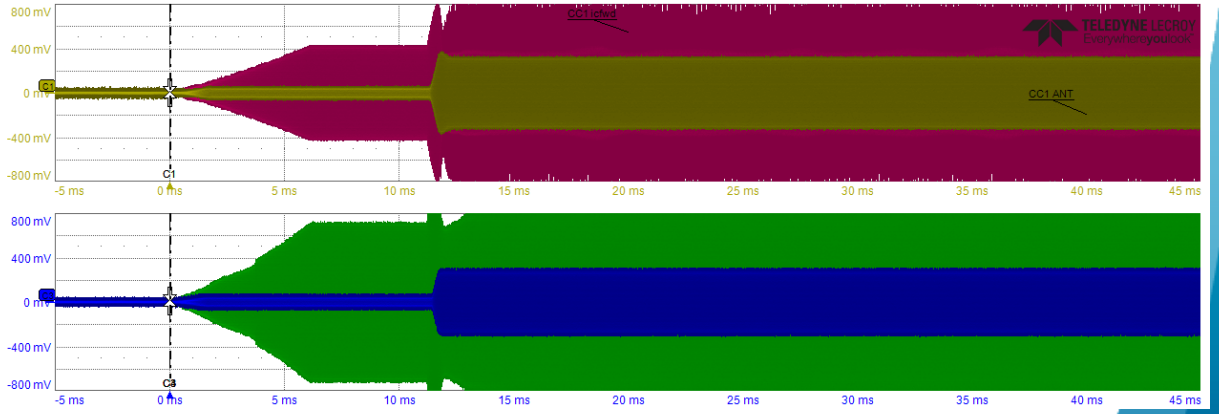
MD 5: RF-ON with 8b4e vs. 72b

- The drive sent to amplifier (red/green) ramps in 7 ms
- The cavity voltage (beige/blue) “saturates” at few hundreds kV. The RF fdbk is closed at +12 ms resulting in an abrupt increase in drive (TX power) and the voltage then “jumps” to the demanded 1 MV (The Frev spikes in TX drive after fdbk closure result from amplification of beam signal picked up by antenna).
- The effect varies from shot-to-shot and suspected due to “multipacting” like effects. Not conclusive if 8b4e is better

8b4e

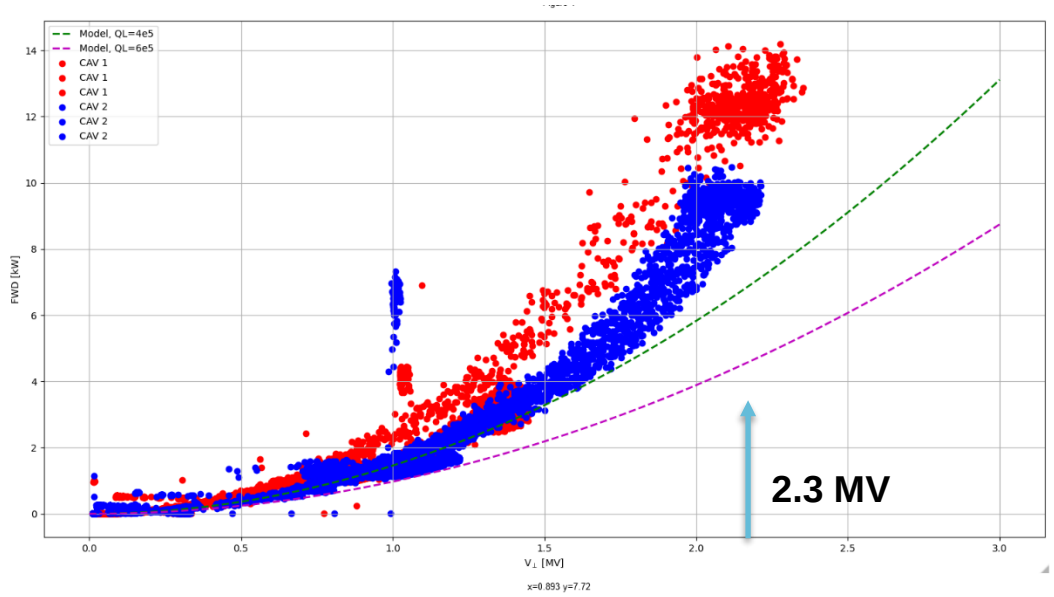


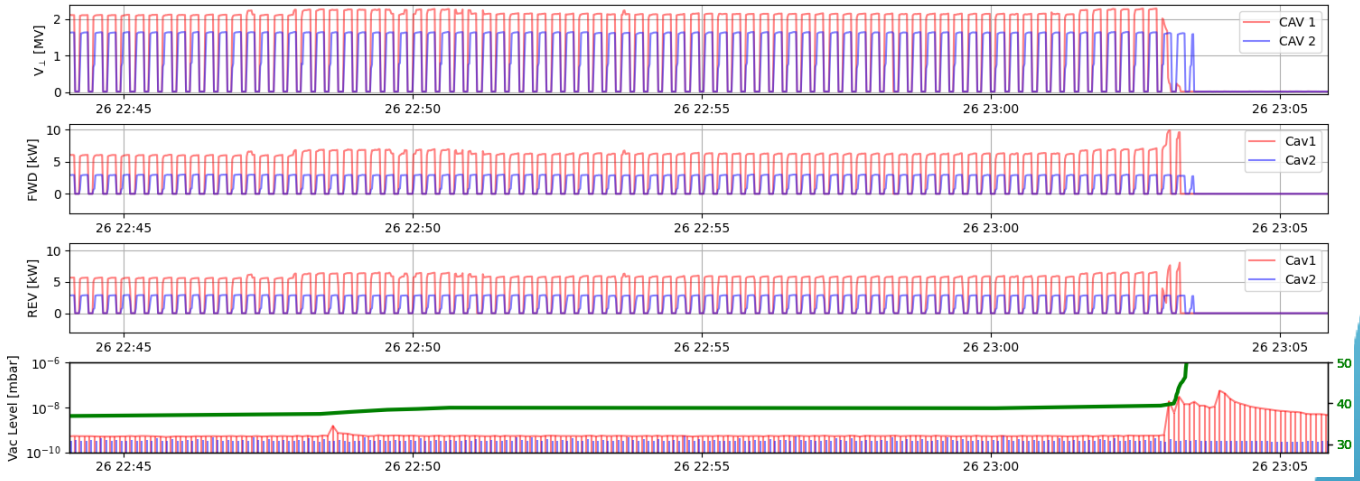
72b



Pushing the Voltage with RF Conditioning

- Performed RF conditioning with PLL on both cavities, settings not perfected yet for PLL to follow the cavity tune
- At end-Jul we could pulse the cavities above 2 MV for an extended period, so promising improvement from 2022





Some comments

- Total of 4 MDs performed (high intensity batches at injection & emittance growth with amplitude noise)
  - Slow beam losses with high intensity batches was due to aperture vetical restrictions, solved by counter-phasing the cavities
  - Observed perturbations on the RF sequence due to the presence of the beam. Mitigation by injection after RF-ON
  - Data acquired for fast phase changes in open-loop for benchmarking

- Many important tests to be done with RFD module to probe the impedance effects with high intensity beams and operational aspects