Microphonics experience in HIE-ISOLDE at CERN

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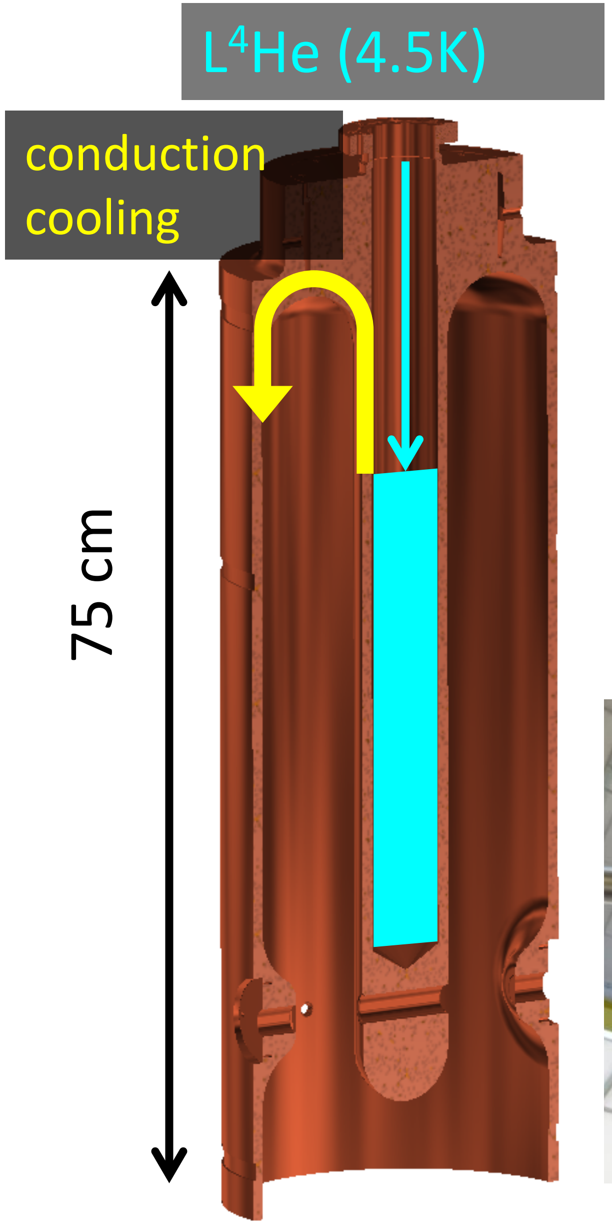
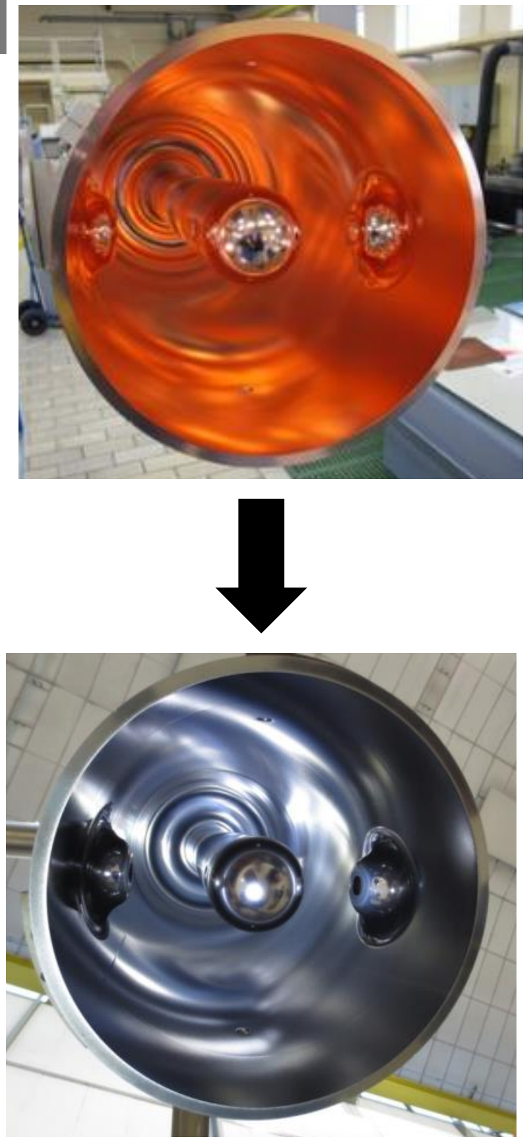
LLRF2018 topical Workshop on Microphonics @ NY

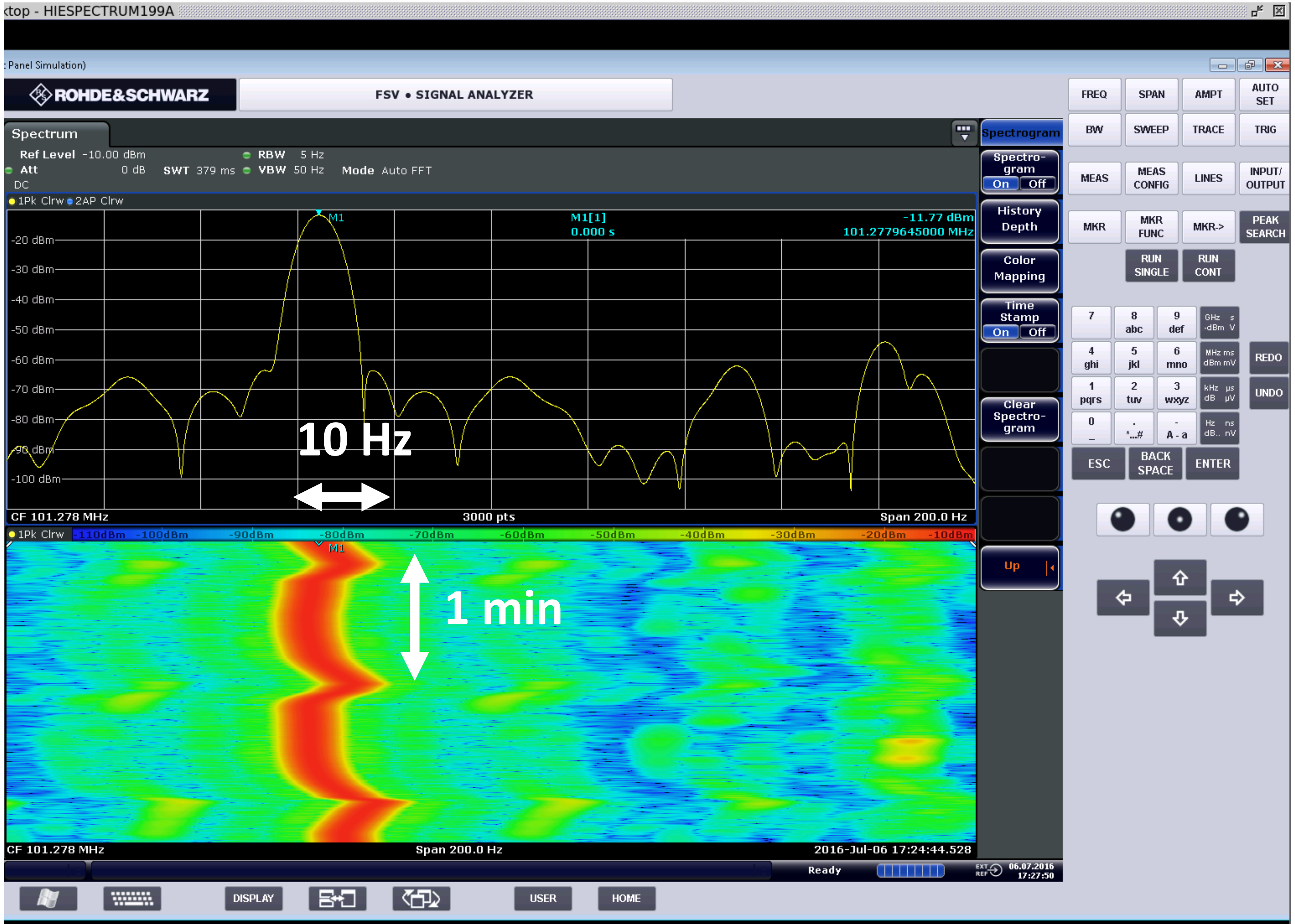
HIE-ISOLDE Cryomodule

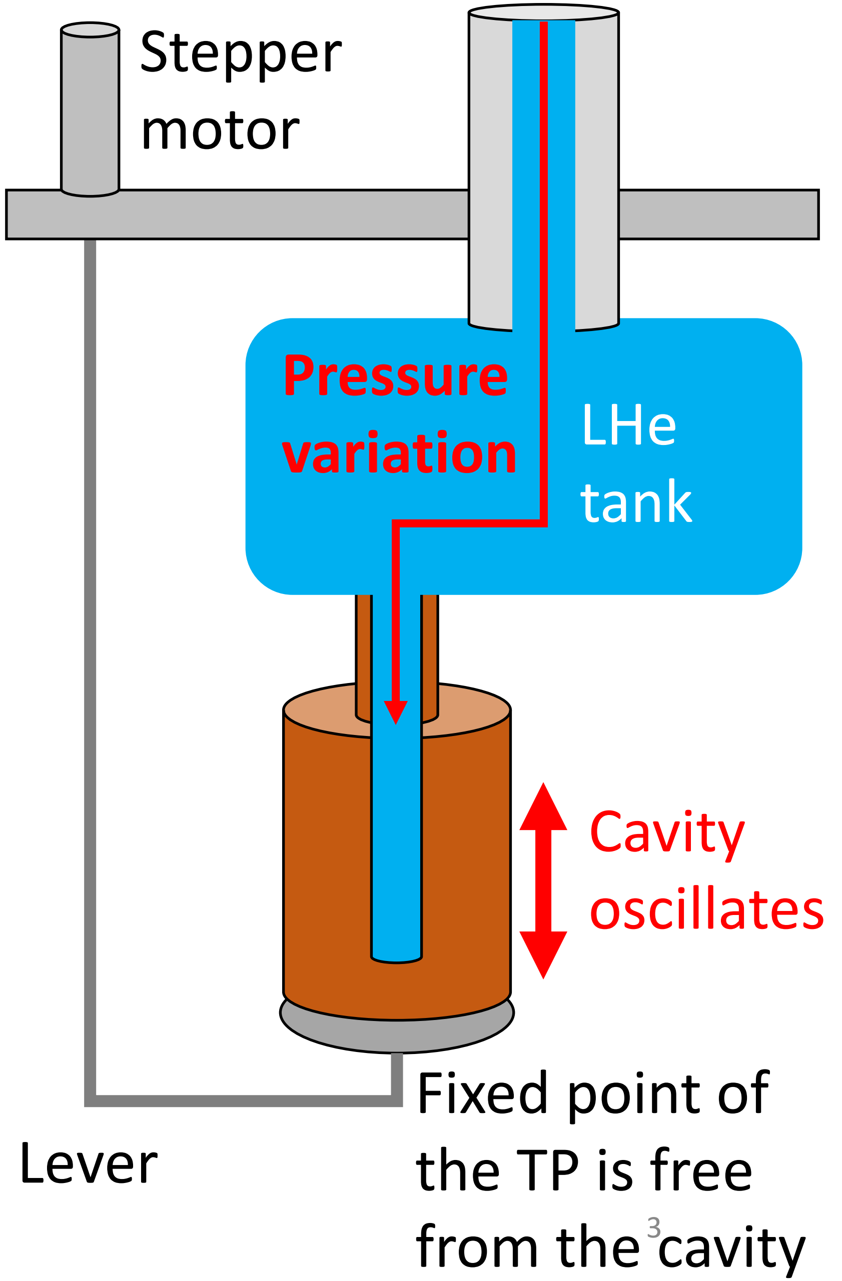




- 5 Quarter-wave resonators (QWR) in 1 CM
- Nb film sputtered on Cu substrate (**10 mm thick**)
  - Cf. bulk Nb cavities 3 mm thick
- Conduction cooling through Cu
- Common vacuum inside and outside the cavity
- Pressure sensitivity **0.01 Hz/mbar**
- Nb/Cu cavities can be robust against microphonics
- Thermal issue in coupler → Operation **BW 5-10 Hz**

Frequency perturbations (measured in SEL mode)

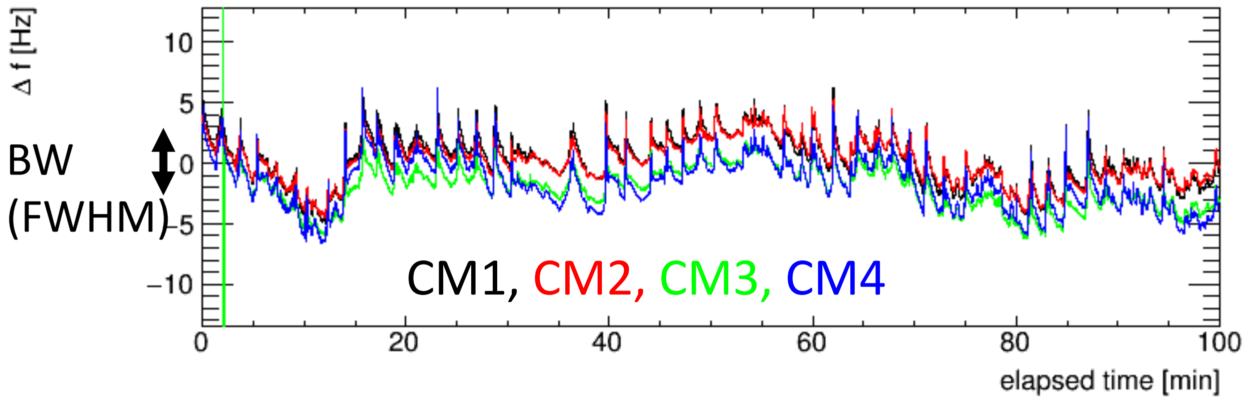




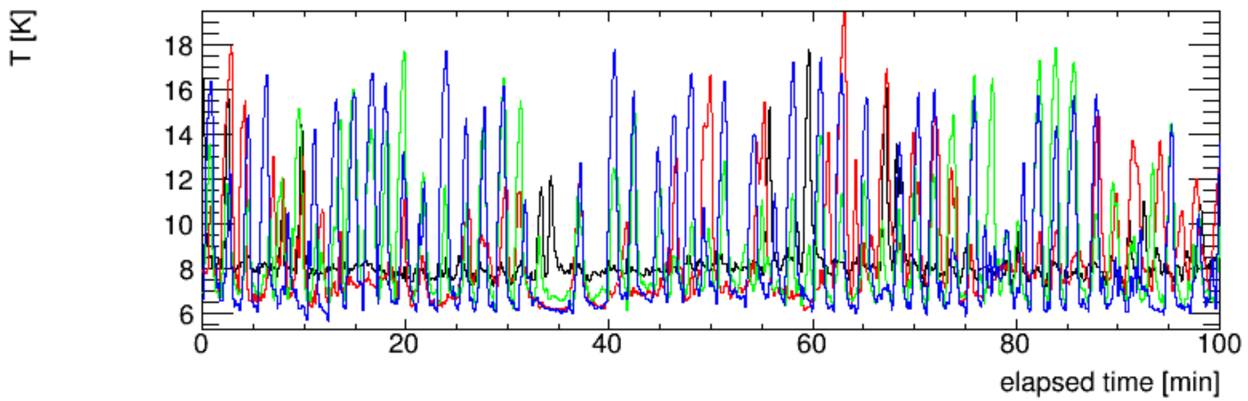
The frequency was sharply and periodically shifted!

Cryogenic perturbation during RF commissioning 2018

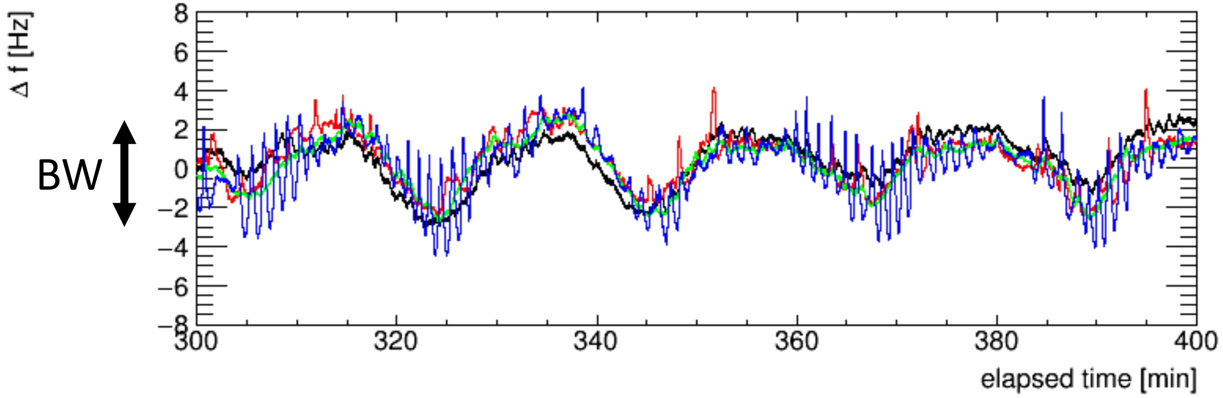
Initial perturbation > BW



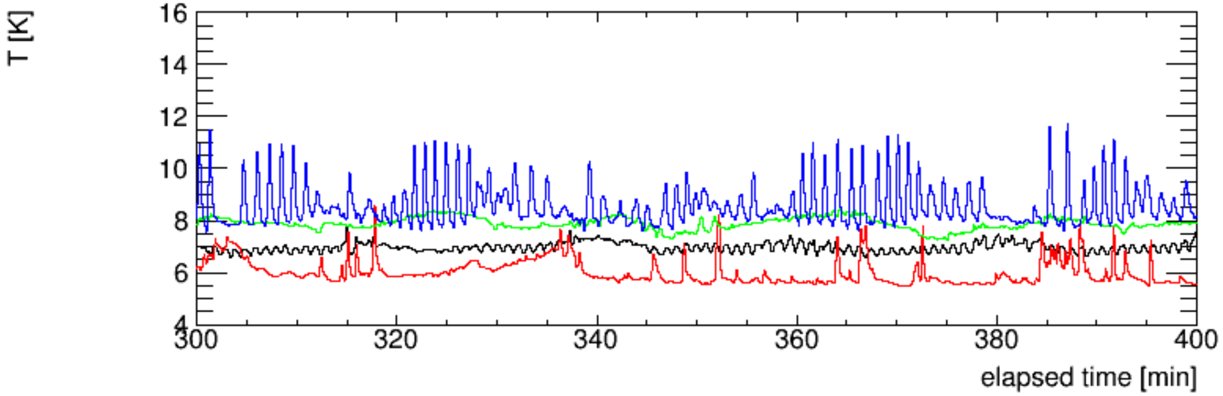
Return gas He temperature and pressure oscillate



Optimized cryogenic parameters



The fast oscillation was mitigated

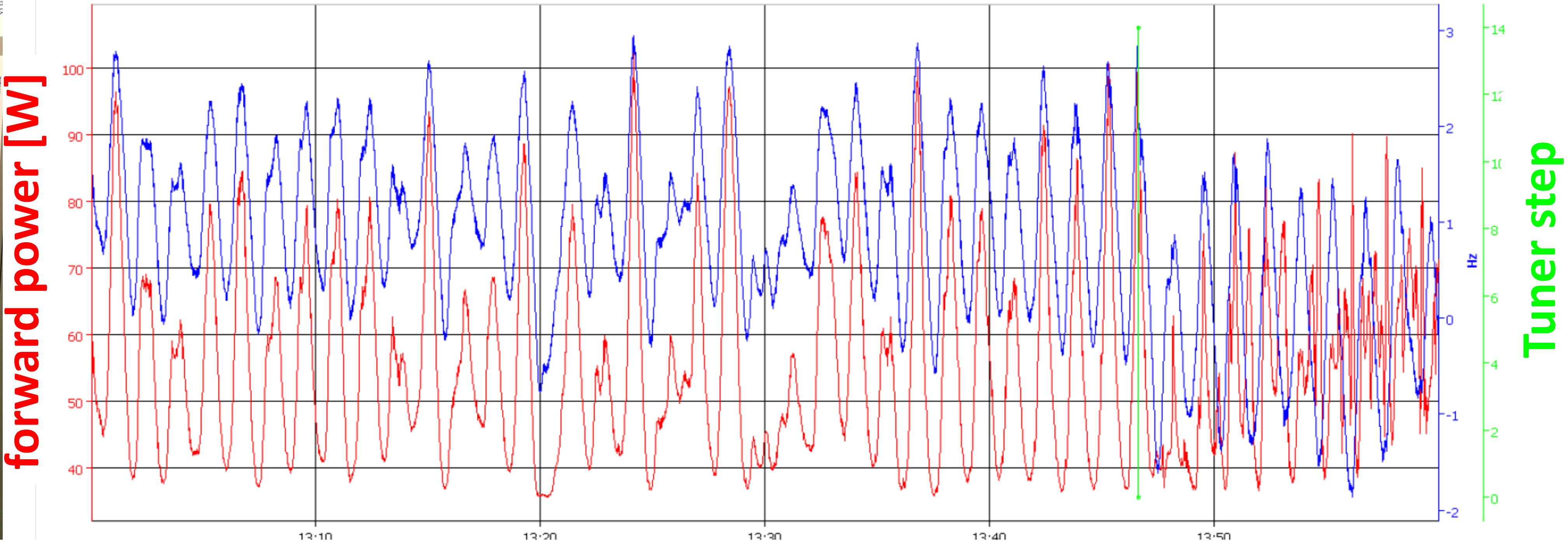


Optimize PID parameters and regulation target in cryogenic system → stabilize the system

Strategy from LLRF side

$$\Delta f = \frac{1}{2} BW \frac{|V_{fwd}|}{|V_{ant}|} \sin(\varphi_{ant} - \varphi_{fwd})$$

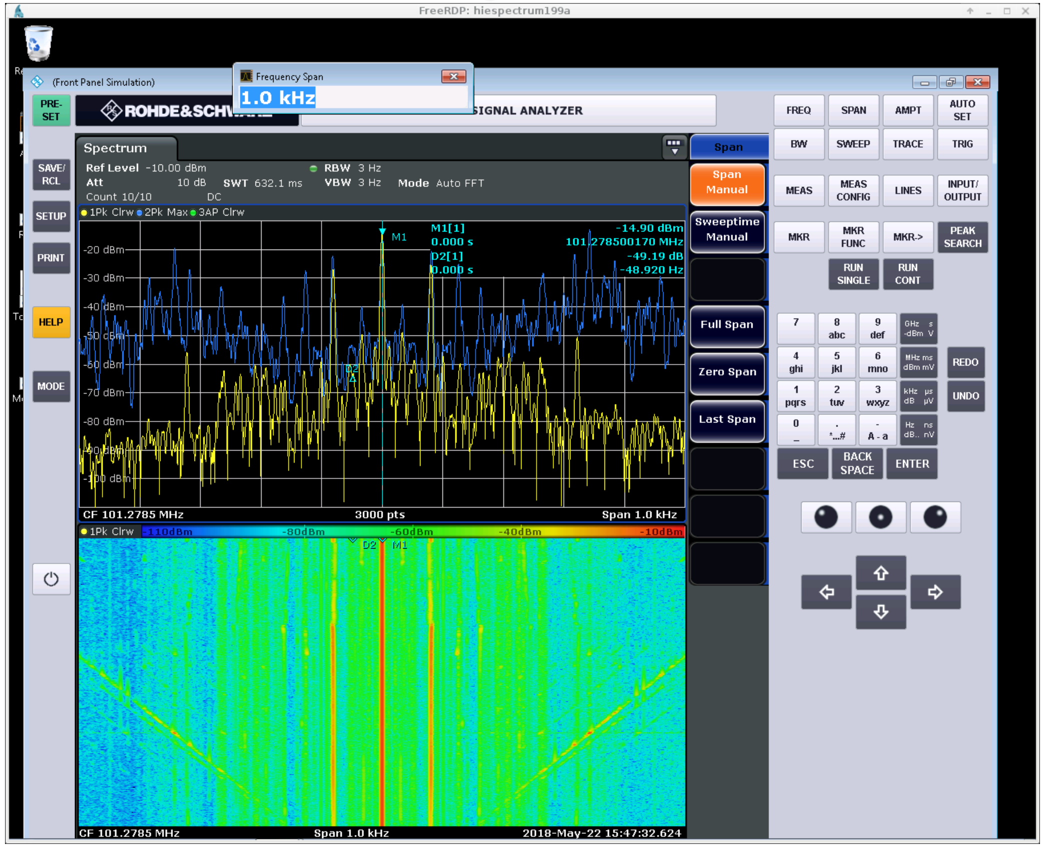
Δf [Hz]

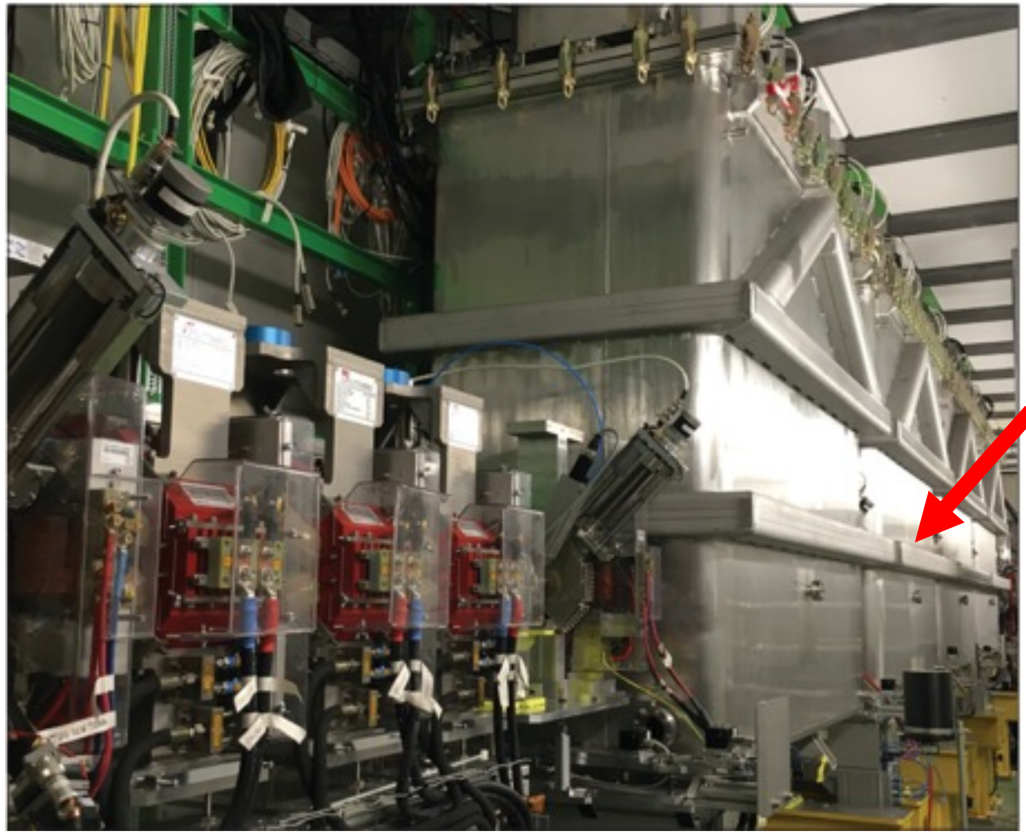


- No stepper-motor motion
- Compensated by forward power (RMS 100W, max 750W)
- Solid-state amplifiers (750W) can still handle the system

Faster microphonics observed in one cavity

78 Hz noise

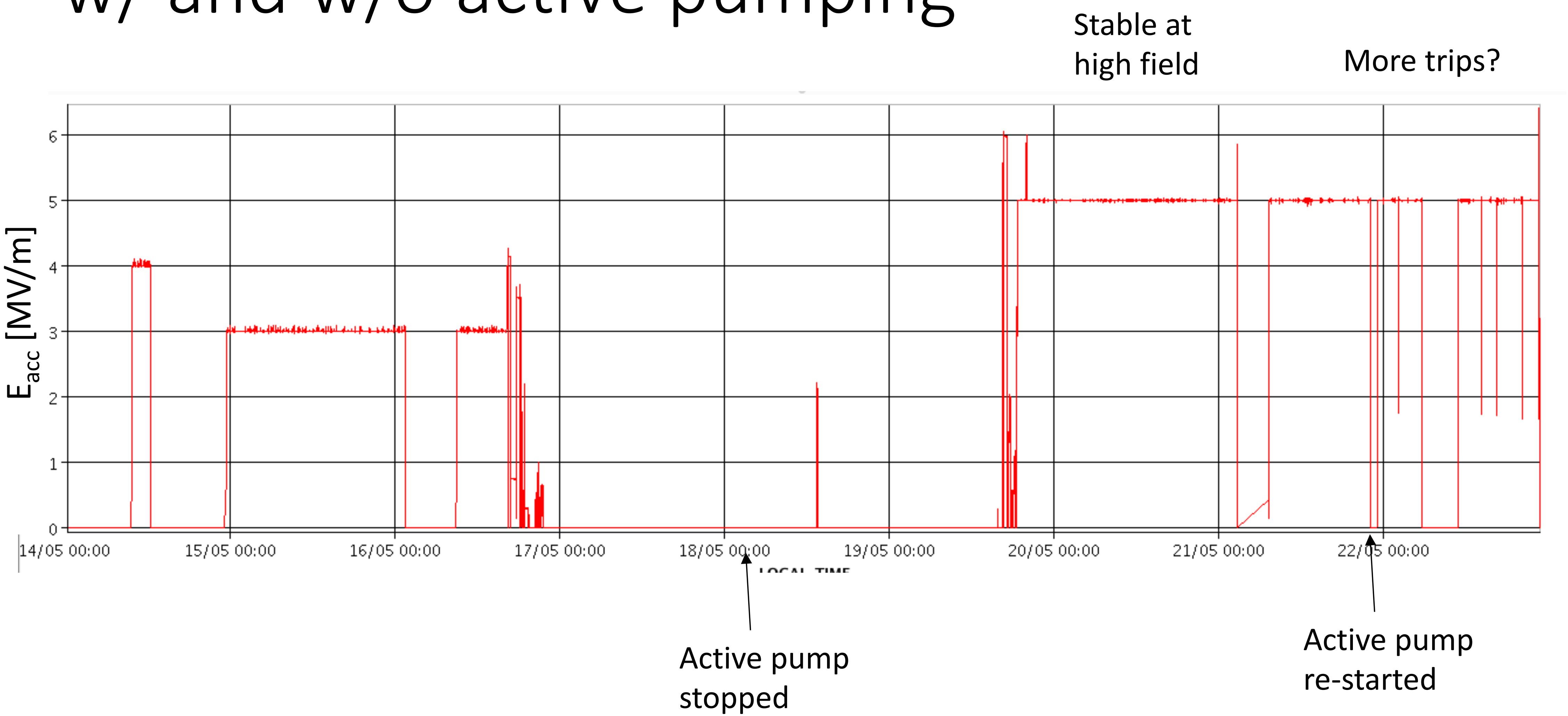




We felt obvious vibration on the vessel in this particular CM

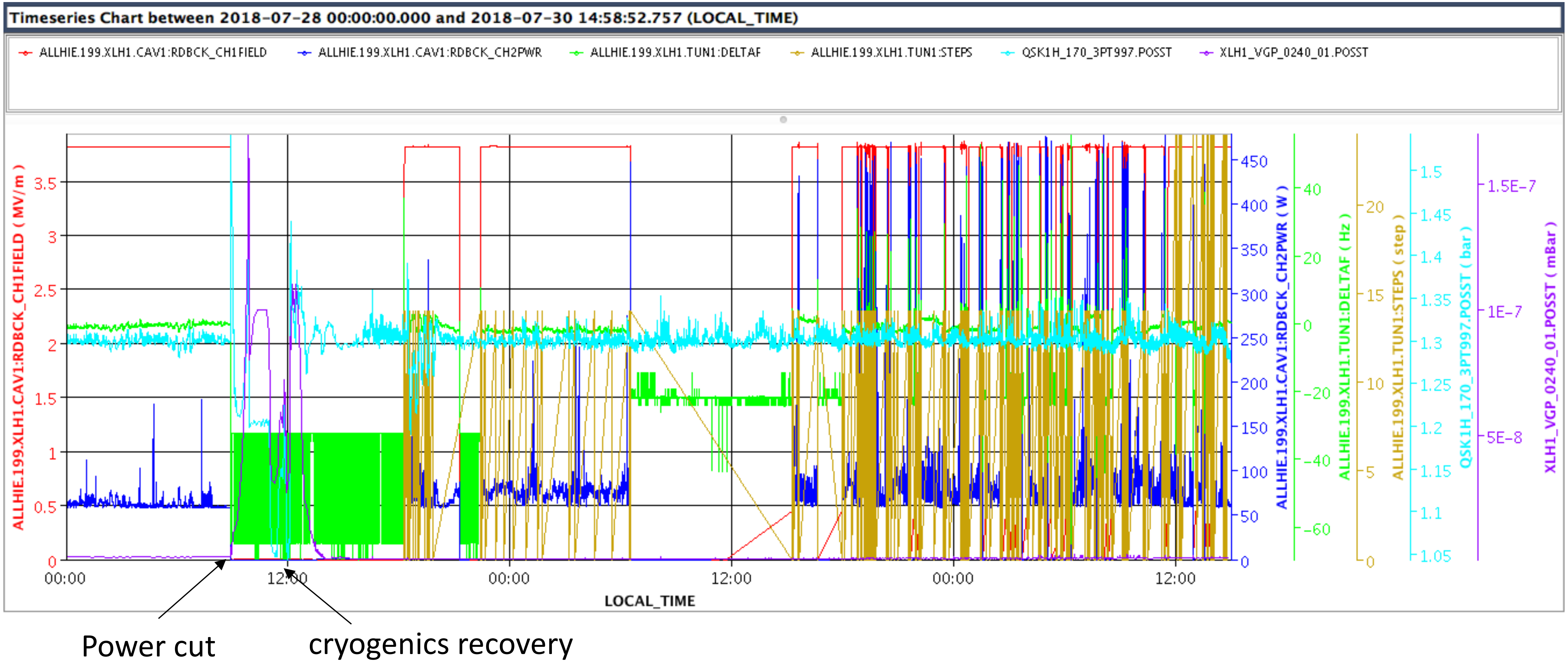
- The FB operation required much higher power than other cavities (400W >>RMS 40W)
- Demodulation of spectrum analyzer signal showed 78 Hz vibration in resonant frequency
- Tunnel access → obvious vibration was detected *by hand* in one cryomodule
- Stop active pumping → vibration and correspondingly frequency modulation stopped

w/ and w/o active pumping



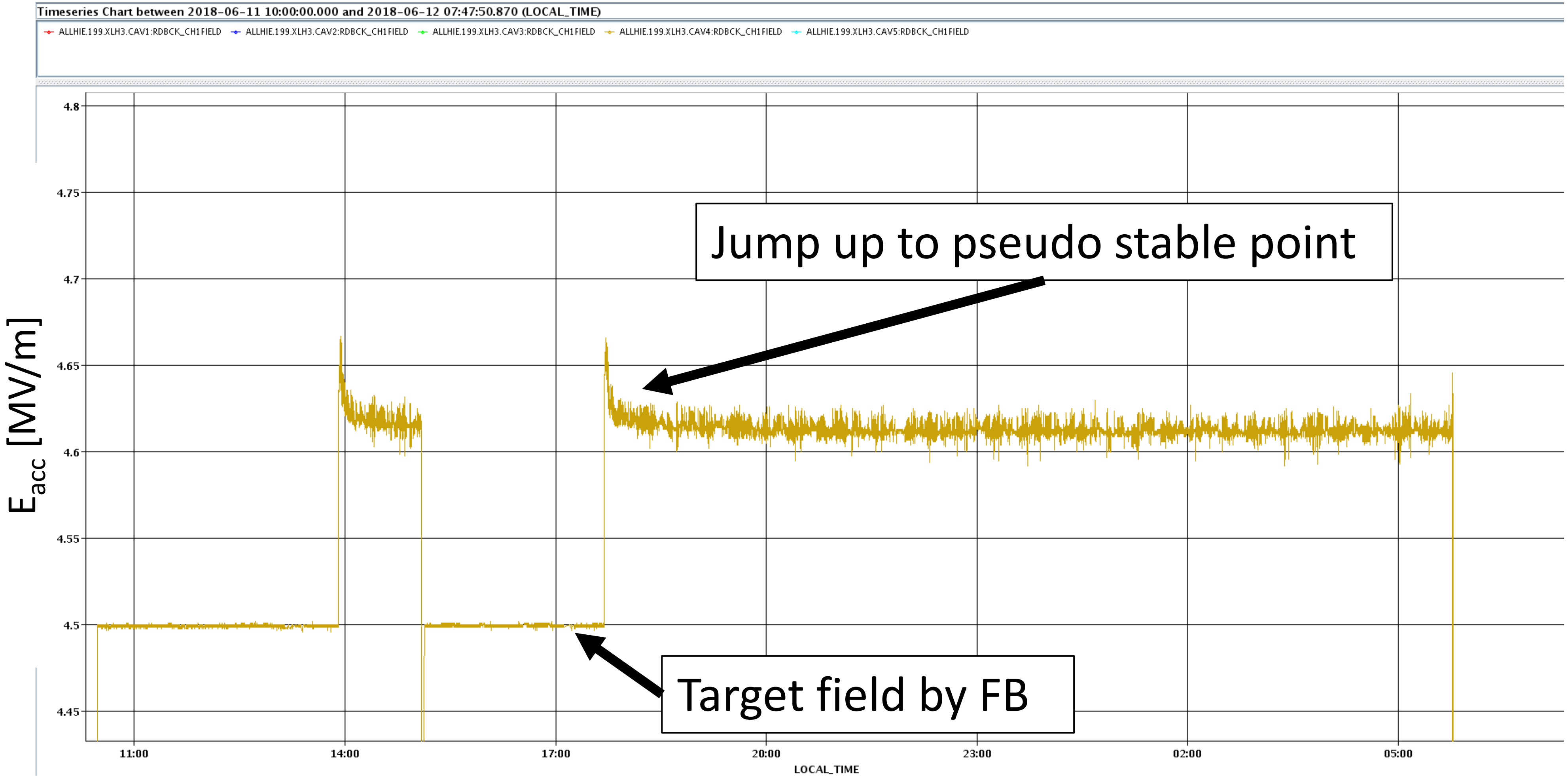
- Intuitively, more trips with active pumping but no enough time to do statistical testing during RF commissioning
- We decided to keep active pumping and limit the field level of this cavity (4MV/m < nominal 6MV/m)

Impact of power cut (July 28th)



- The cryogenic plant stopped by (short) power cut and took 6 hours to restart sending LHe
- A sensitive cavity was affected by the cryogenic instability for a couple of days
- We skipped the cavity for the physics run during that week

Rare events



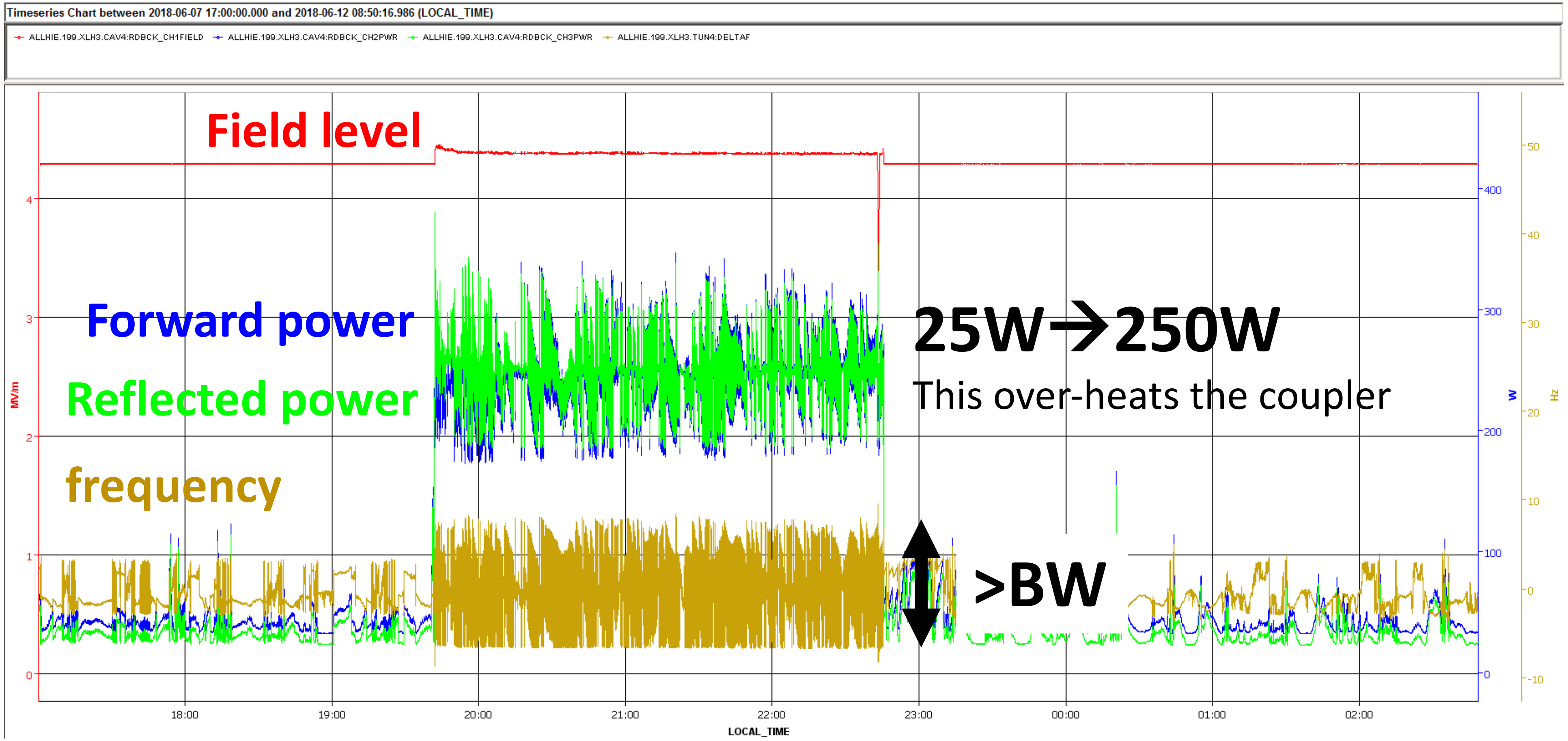
<u>Observed twice during 2018 summer</u>

19th cavity on June 12th : lasted 1 week and disappeared

9th cavity on September 6th : lasted 1 week and disappeared

We did not change any parameters!

Rare events



- Apparently, FB algorithm found strange "operation point" where the tuner loop cannot fix the resonance
- No field emission in the cavity, cryogenics is stable, …
- The LLRF card was replaced → no impact
- We suspect field-induced vibration of probably the tuning plate → dedicated test in vertical cryostat is planned

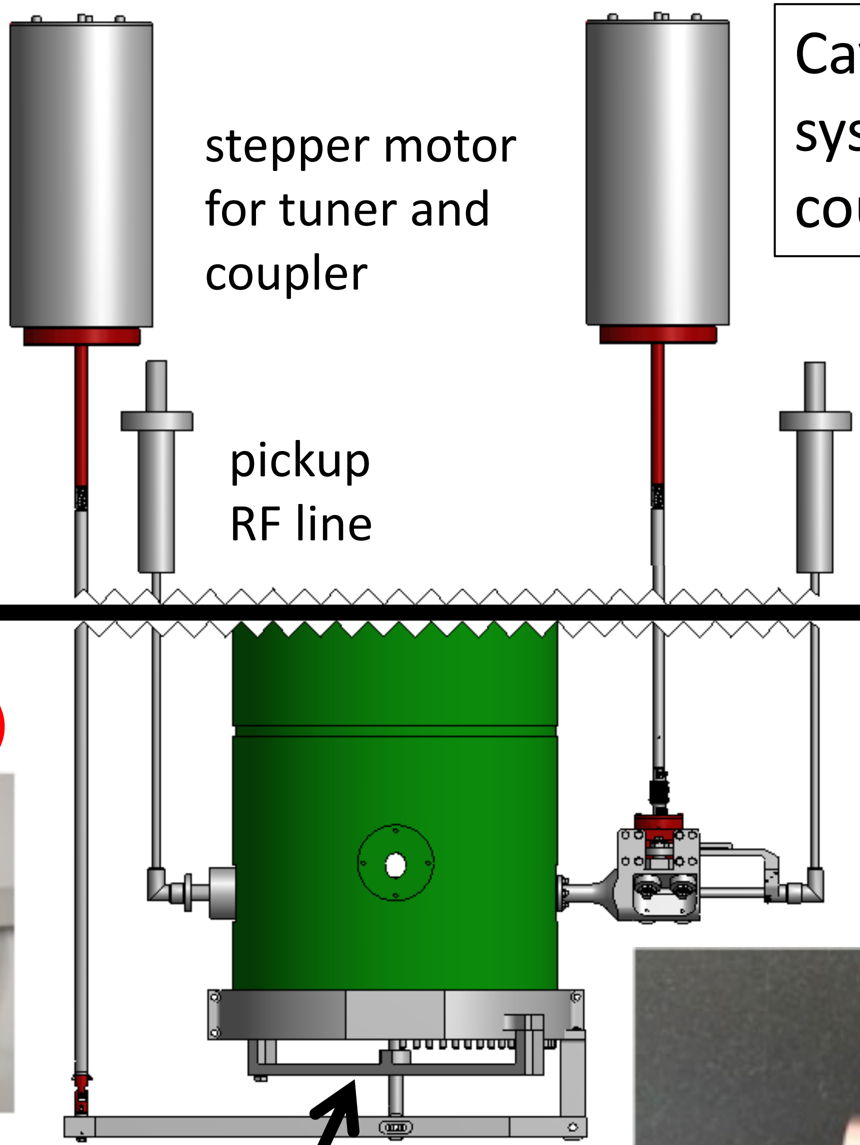
Summary

- The thick Cu wall is very insensitive to pressure variation but the thin tuning plate is an issue when operation BW is extremely low
  - Thicker TP is recommended for the future project (better understanding of pre-tuning)
- HIE-ISOLDE cryomodules suffer from three different "vibrations"
  - Slow but significant (>BW) mechanical detuning per 1-2min
  - Fast microphonics probably due to active pumping
  - Maybe very rare field-induced vibration when certain condition is fulfilled
- LLRF system compensate the oscillation by the margin of 750W solid-state amplifier, and is operational if cryogenic system is quiet enough
- Sometimes we face rare events which cannot be just solved by LLRF and we pragmatically either limit the field level or skip the cavity
  - The users during very precious beam time never wait us!

backup

Tuner and coupler

Cavity and motor system is mechanically coupled to the insert



stepper motor for tuner and coupler

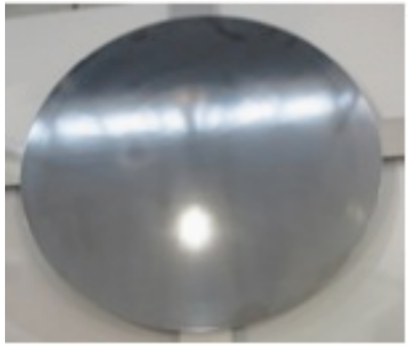
pickup RF line

fundamental coupler RF line

3m

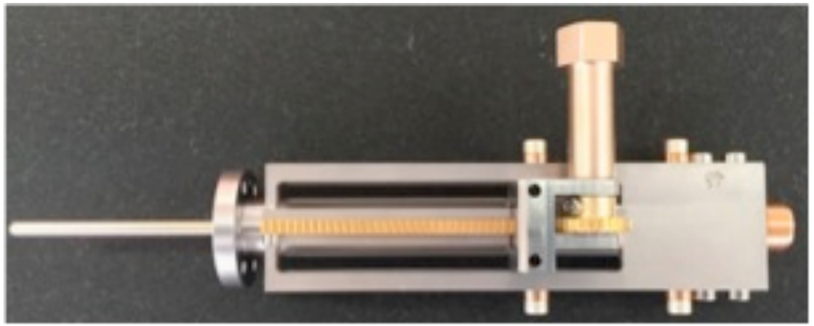
Outside the cryostat (300K air)

inside the cryostat (4.5K, beam vacuum)



Thin Nb coated Cu plate (**0.3 mm**)
tuning range 40 kHz

Mobile coaxial coupler



Tuner and coupler

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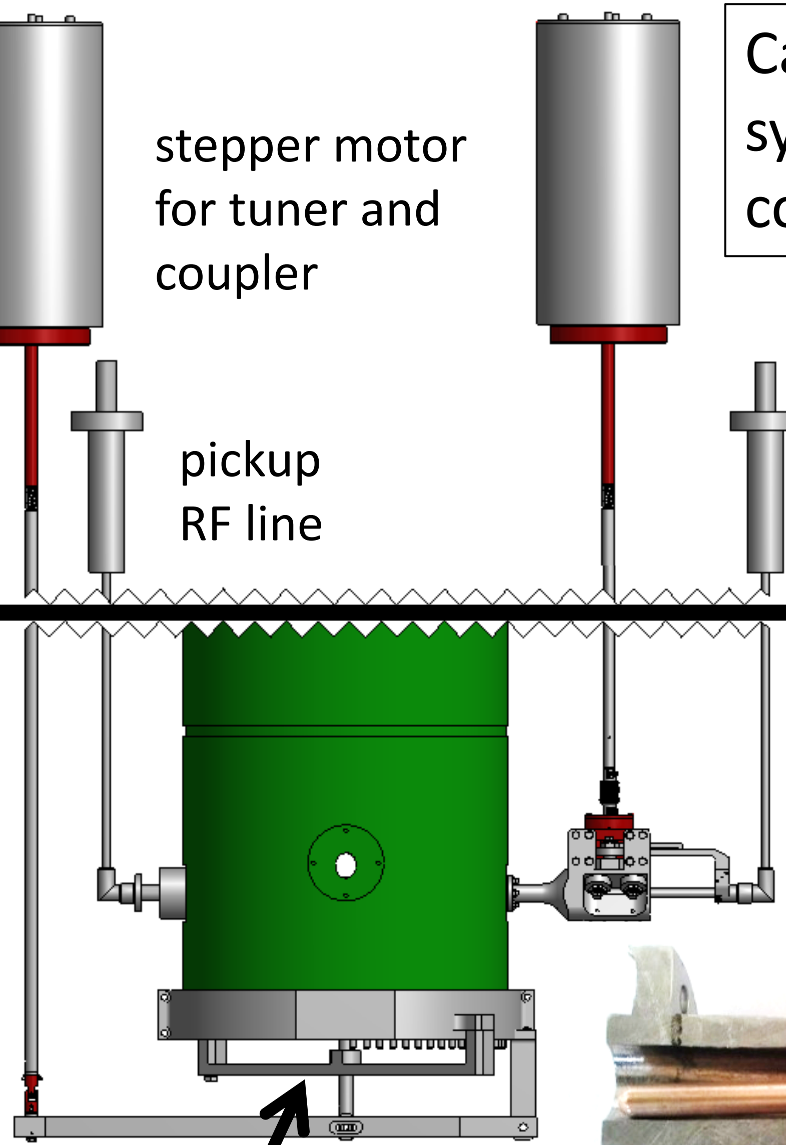
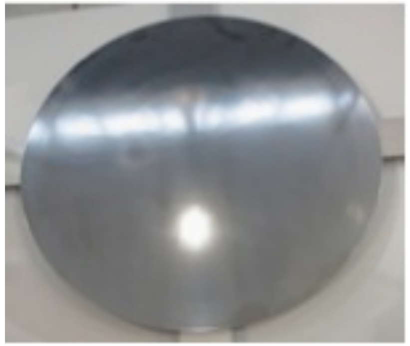
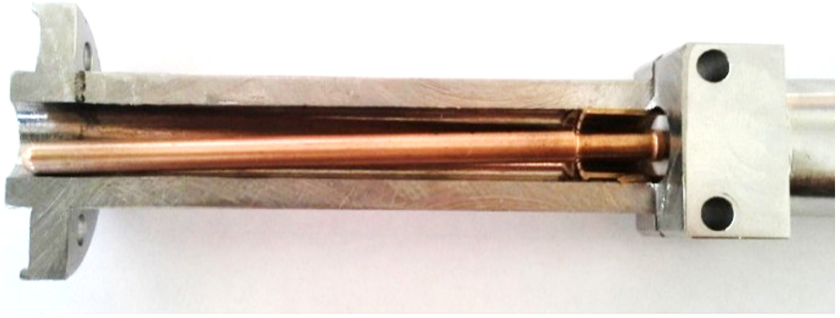




Thin Nb coated Cu plate (0.3 mm)
tuning range 40 kHz

Mobile coaxial coupler



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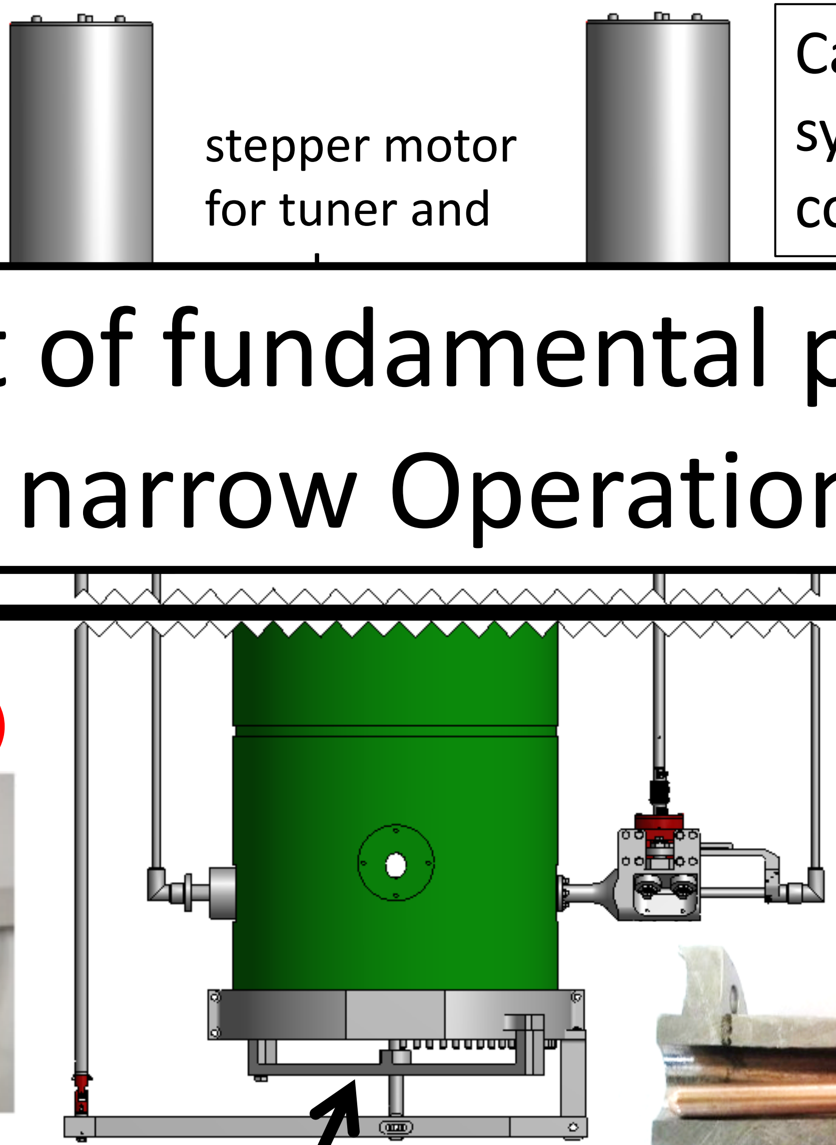
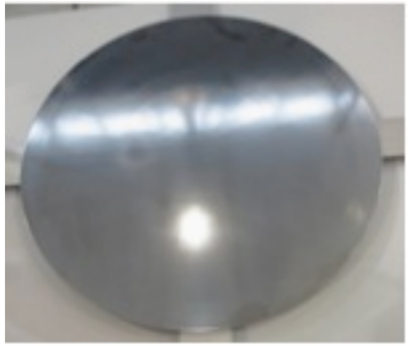


Thermal fault of fundamental power coupler
→ Extremely narrow Operation BW 5-10 Hz

inside the cryostat
(4.5K, beam vacuum)



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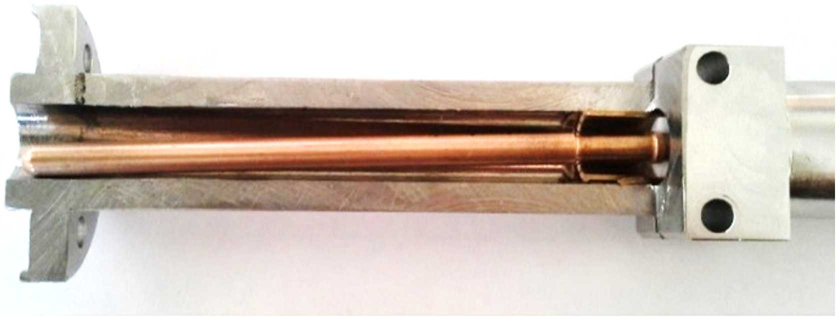
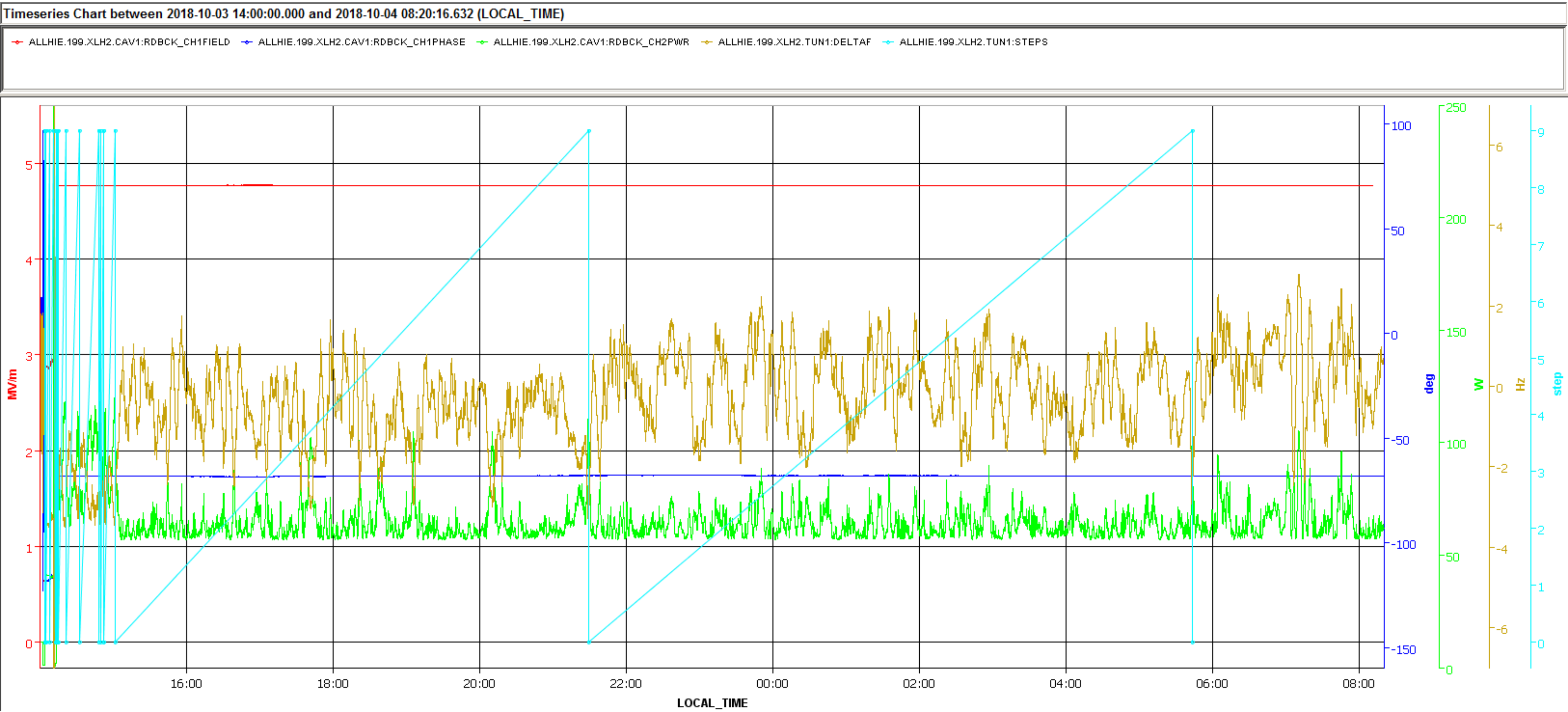


Stable condition



Lesson learned

- Microphonics issues are linked to all the aspects of the project
  - Nb/Cu is potentially insensitive to vibration thanks to its thicker wall
  - Frequency pre-tuning was not precise → wide tuning range required (40kHz) → very thin TP → sensitive to vibration
  - Poor cooling of the coupler did not allow wide BW (>30Hz) operation → extremely narrow BW (5Hz)
  - Common vacuum → stepper motor far away and no fast tuner like piezo next to the TP → only slow mechanical tuning no possible active damping
  - Cryogenics perturbation
  - Vibration propagated from the active pumping unit
- LLRF algorithms can compensate the issues but there are certain limitations
- Pragmatic decision is sometimes necessary once physics campaign starts