Tuning system requirements

Can be corrected with room temperature tuning using plastic deformation:

- Fabrication tolerances
- Main cavity treatments :
  - 800℃ heat treatment against Q desease,
  - First heavy chemical treatment (150 to 200 μm)
- Field inbalance between cells

Has to be corrected with the cold tuner:

- The remaining error of the room temperature tuning
- The effect of the last chemical treatments
- The differential shrinkage of materials of the cavity, He vessel and tuner
- He Pressure, Lorentz detuning,

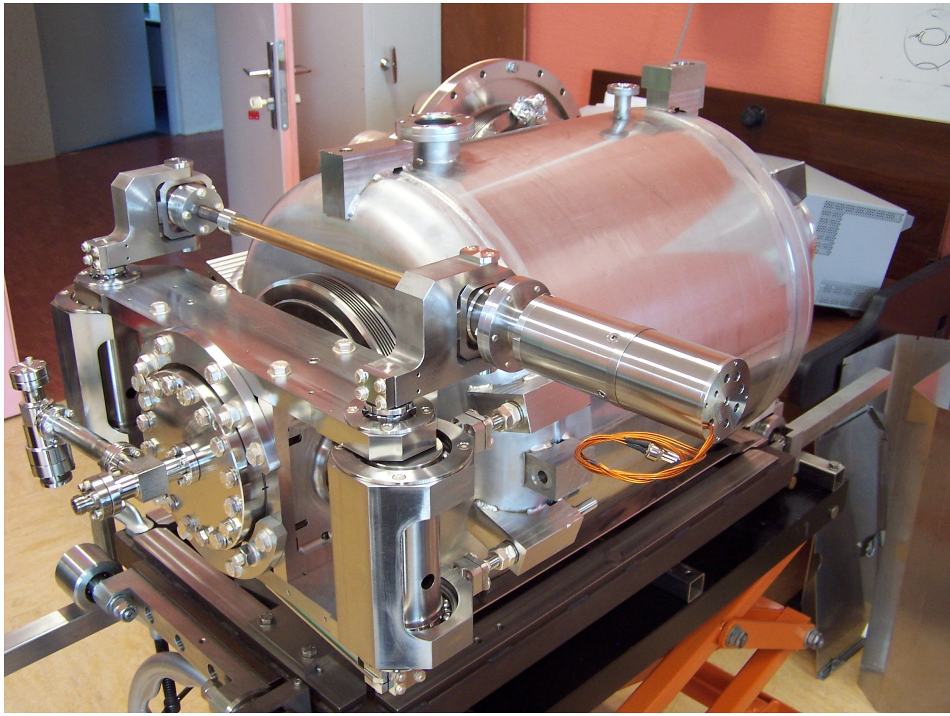
However:

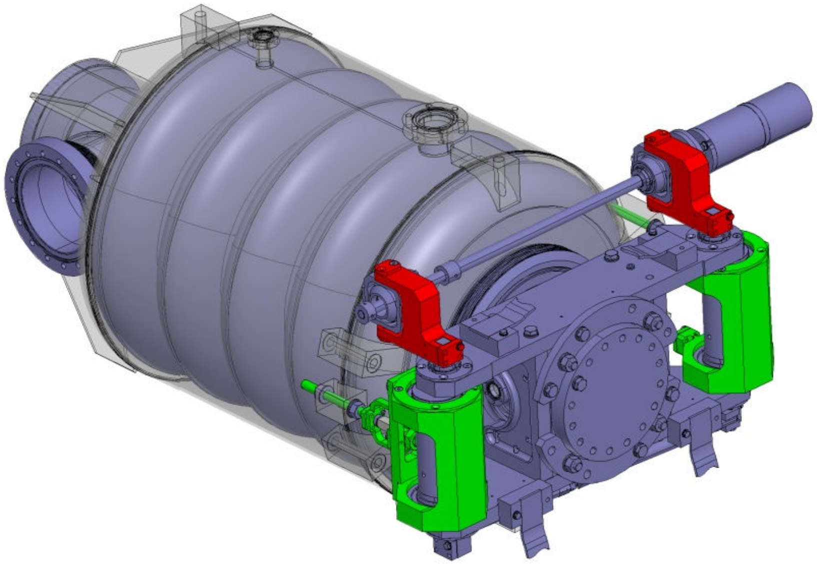
- Last points (diff. Shrinkage) can be taken into account for series cavities after the full test of the first prototype

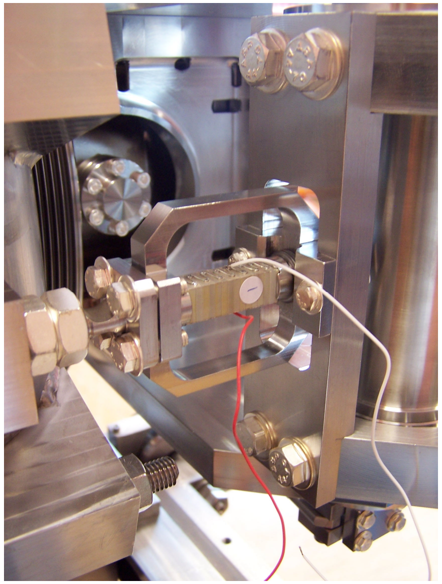
RANGE? (also operation/commissioning of the accelerator)

Saclay piezo tuner for 700MHz cavities

•Slow tuner with symmetric action
• Excentric/lever arm provenSaclay design
• Planetary gear box (3 stages)
• Single NOLIAC 30mm piezo actuator
• Stiffness measured on the tuner pneumatic jack = 35 kN/mm
• Initially developed for the beta=0.5 5-cell cavity



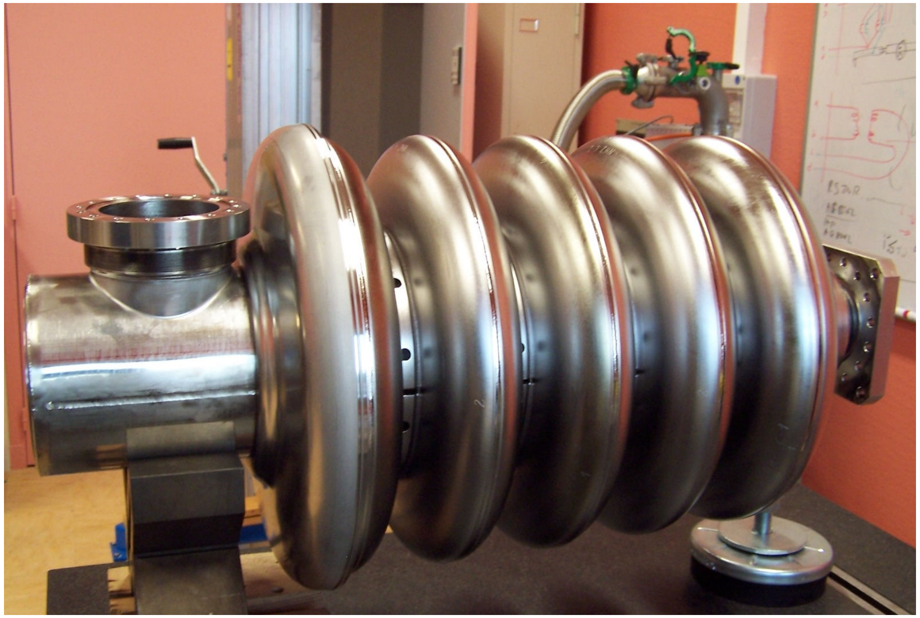




Beta 0.5 704 MHz 5-cell cavity

Cavity built in the CARE/HIPPI framework
Pulsed tests in vertical cryostat part of the CNI SLHC-PP of FP7

Frequency [MHz]	704.4
Epk/Eacc	3.36
Bpk/Eacc [mT/(MV/m)]	5.59
r/Q [Ω]	173
G [Ω]	161
Q_0 @ 2K Rs=8 nΩ	$2\ 10^{10}$
Optimal β	0.52
Geometrical β	0.47
Total length [mm]	832
Cavity stiffness [kN/mm]	2.25
Tuning sensitivity Δf/Δl [kHz/mm]	295
K_L @ k_{ext} = 30 kN/mm [Hz/(MV/m)²]	-3.9
Δf @ 12 MV/m, k_{ext} = 30kN/mm [Hz]	-560
K_L with fixed ends	-2.7
K_L with free ends	-20.3



cavity design parameters

Piezo tuner properties for the Saclay 700 MHz 5-cell cavities

- df/dl = 300 kHz/mm
- stiffness Kcav = 2.25 kN/mm
- stress per mm of tuning = 49 Mpa/mm

Differences for the SPL beta=1 cavity

- df/dl = 160 kHz/mm
- stiffness Kcav = 3.8 kN/mm
- stress per mm of tuning 35 Mpa/mm

In both cases, the tuning amplitude is limited by the cinematics of the tuner, not by the yield stress of Nb at 2K

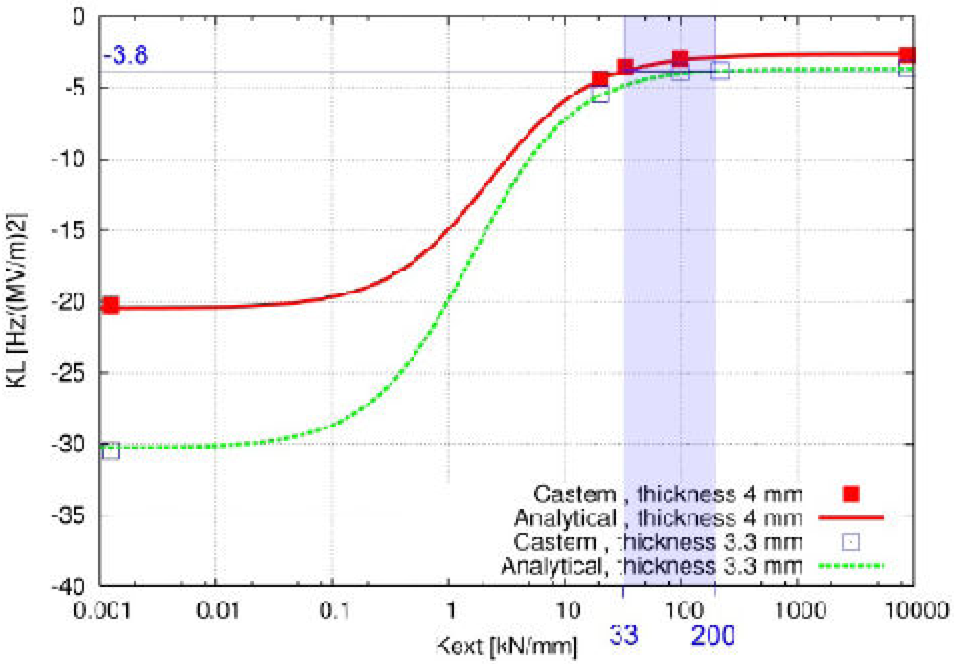
For the slow tuning and the fast tuning, these properties must be measured in the operating conditions, in our horizontal test cryostat Cryholab

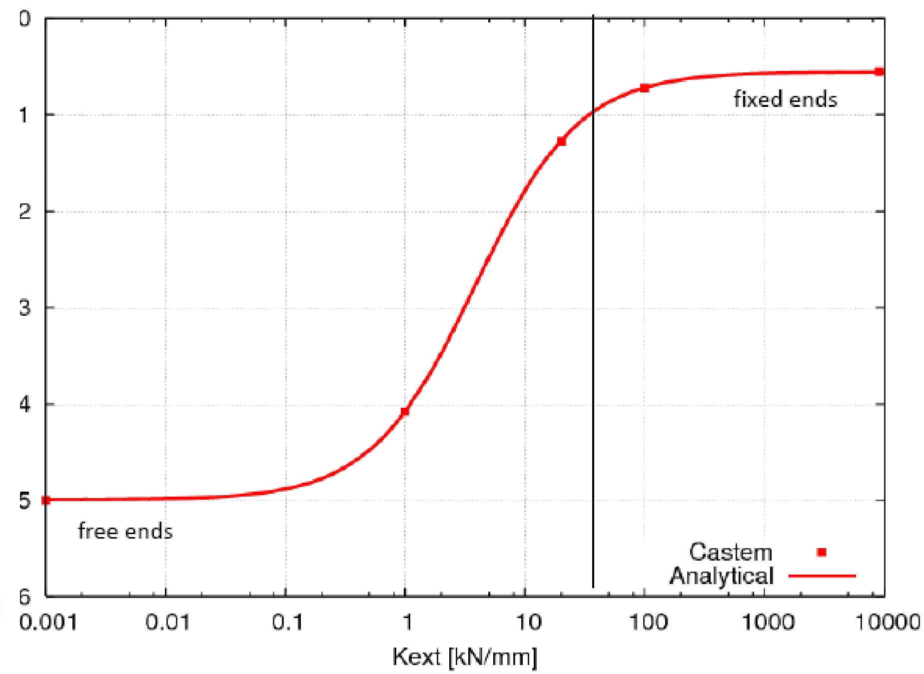
- linearity
- hysteresis
- amplitude

Piezo tuner stiffness requirements

Influence on Lorentz detuning

35 kN/mm





Beta=0.5 5-cell cavity

Beta=1 5-cell cavity

For 35 kN/mm :

KL = -3.8 Hz/(MV/m)² on beta=0.5 cavity
KL = -1 Hz/(MV/m)² on beta=1 cavity

Piezo support

Role : pre-load the piezo actuator at room temperature with a screw

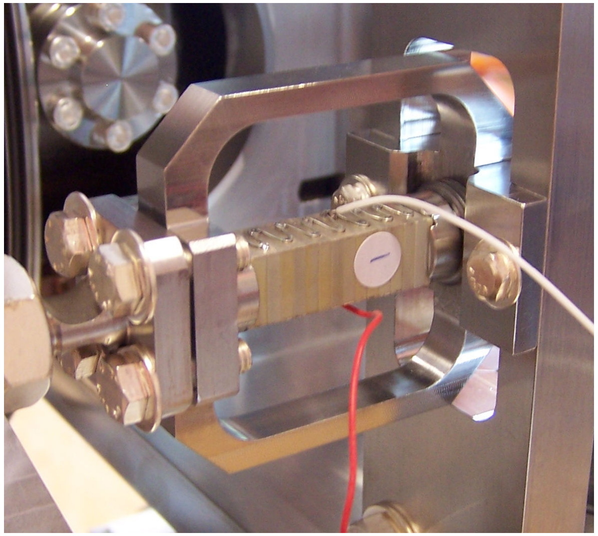
During cooldown, this preload is reduced (diff. shrinkage of materials)

The pre load also changes with cavity positive tuning (piezo is under compression)

Having a frame with a stiffness 10 times the cavity stiffness helps maintaining a consistant load state of the piezo

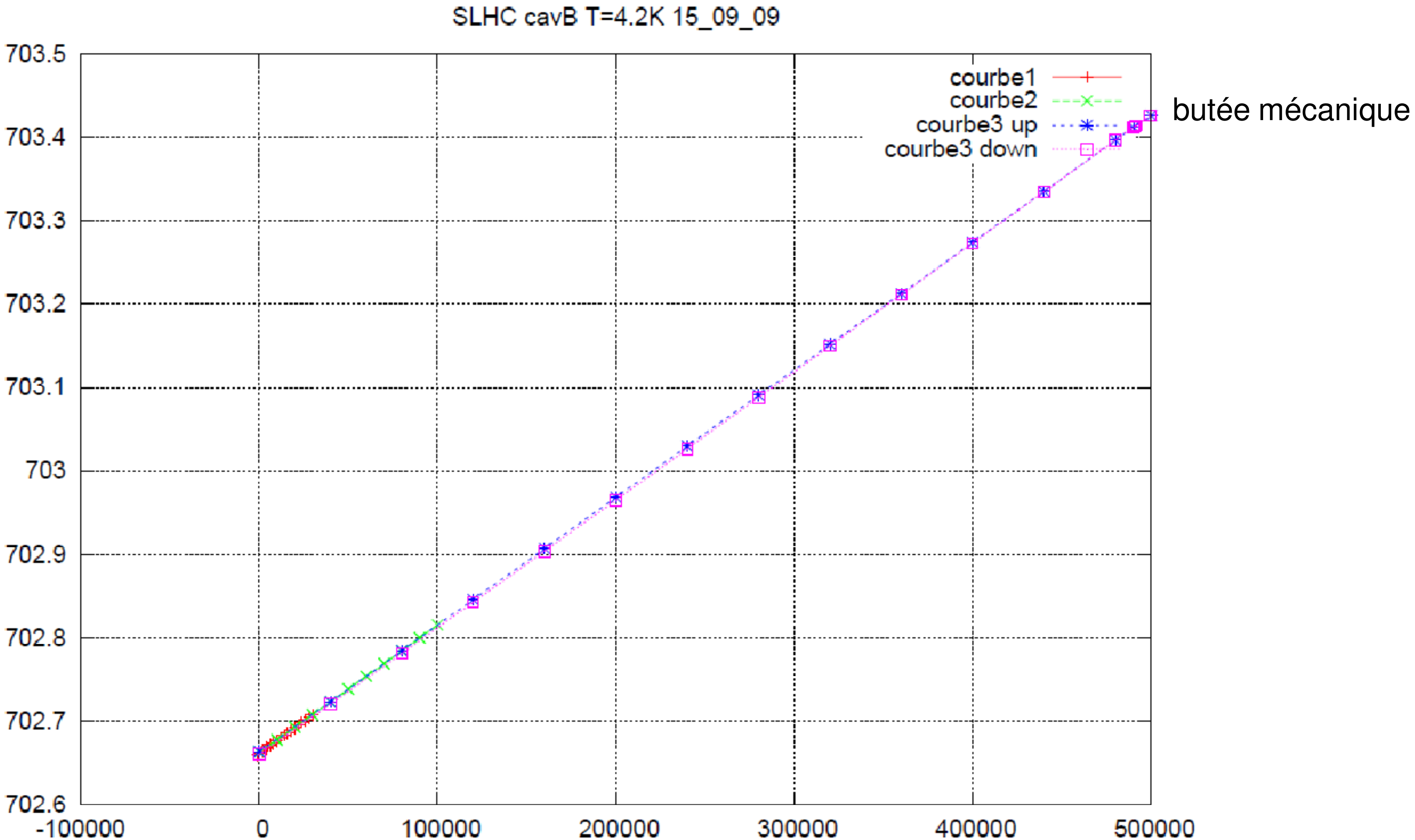
Computed stiffness 22 kN/mm, for the beta 0.5 cavity

This stiffness should be increased for the SPL cavity

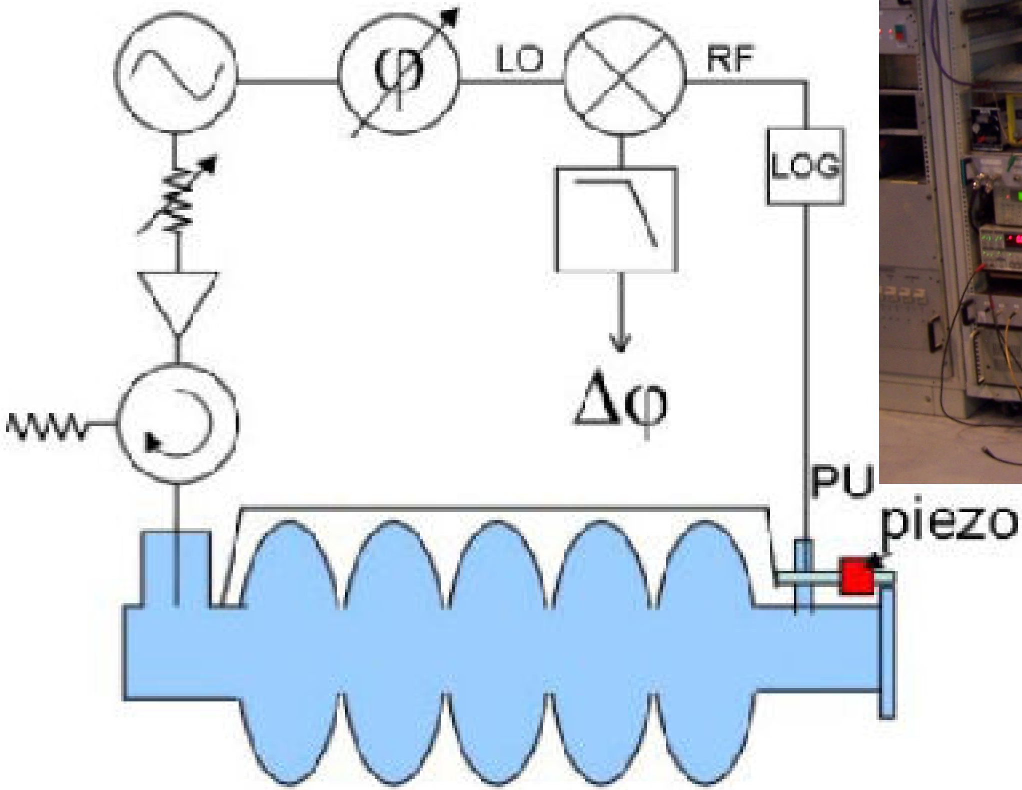


Beta 0.5 cavity tuning

- 4.5 K, amplitude = +760kHz corresponding to 2.5 mm -> would be +400 kHz on SPL beta=1 cavity
- Mechanical hysteresis measurements will be done at 2 K

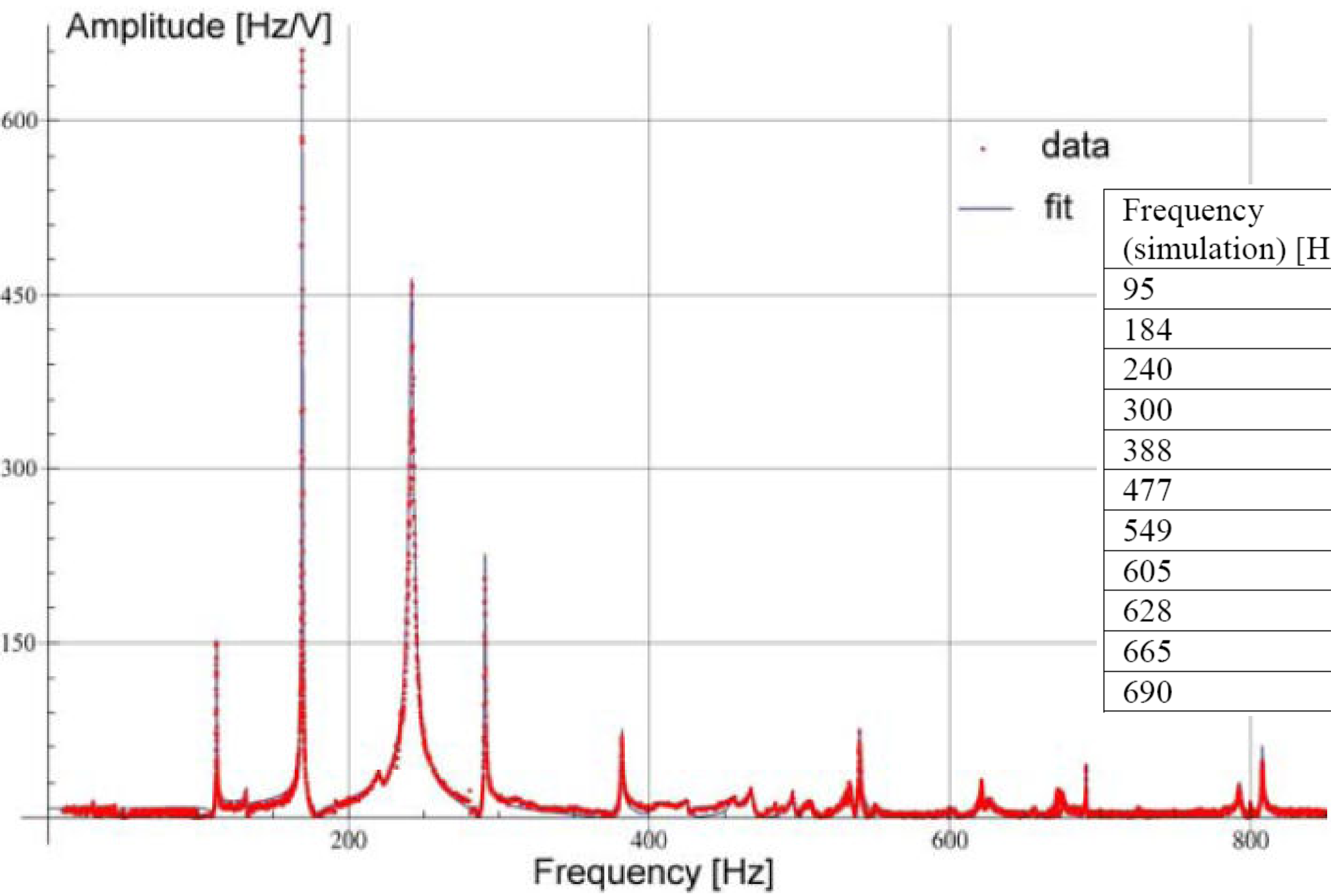


Transfer function measurements



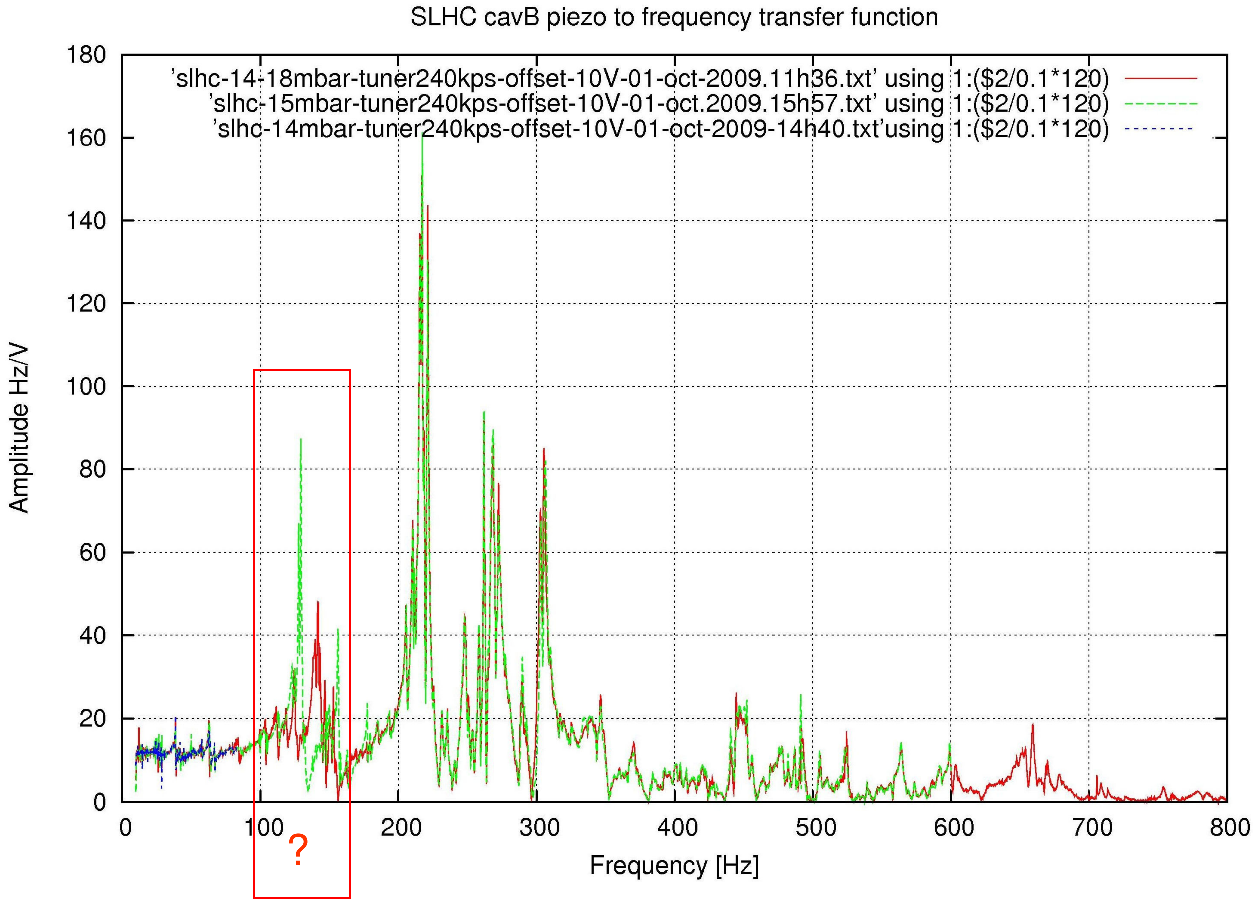
Dynamical behavior

Measurement of 'bare' cavity longitudinal mechanical modes



Frequency (simulation) [Hz]	Frequency (meas.) [Hz]	Q_m (meas.)
95	112	400
184	169	500
240	242	90
300	291	500
388	382	300
477	468	195
549	540	500
605	601	100
628	621	350
665	672	300
690	691	1000

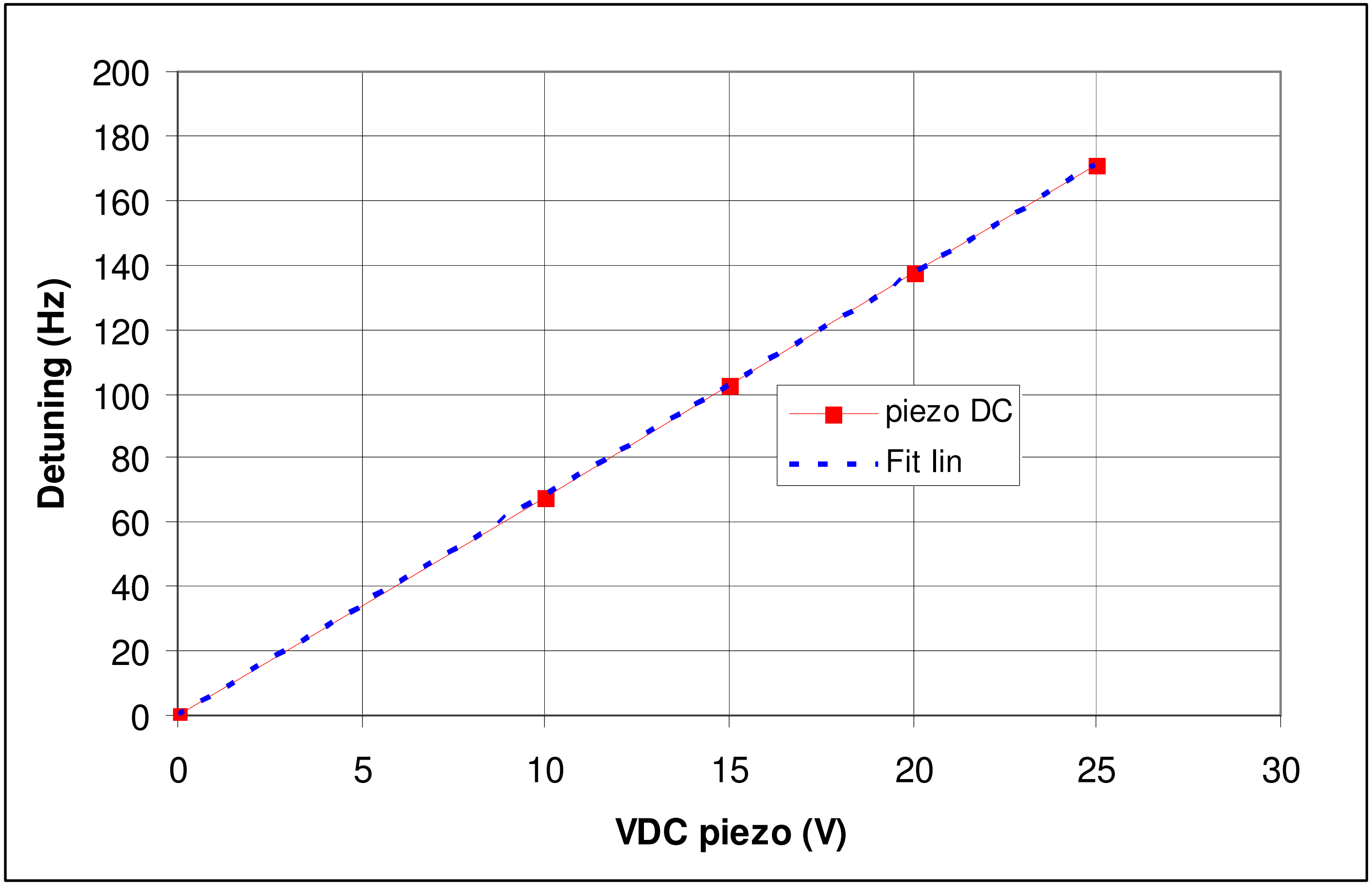
Transfer function measurements



Phase demodulation measurements at 1.8K in Cryholab
TF piezo drive voltage -> cavity detuning can be used to identify the mecanical modes of the system, especially modes generating most detuning (220 Hz)
Reproductible measurements except in the 100-160 Hz range (why?)

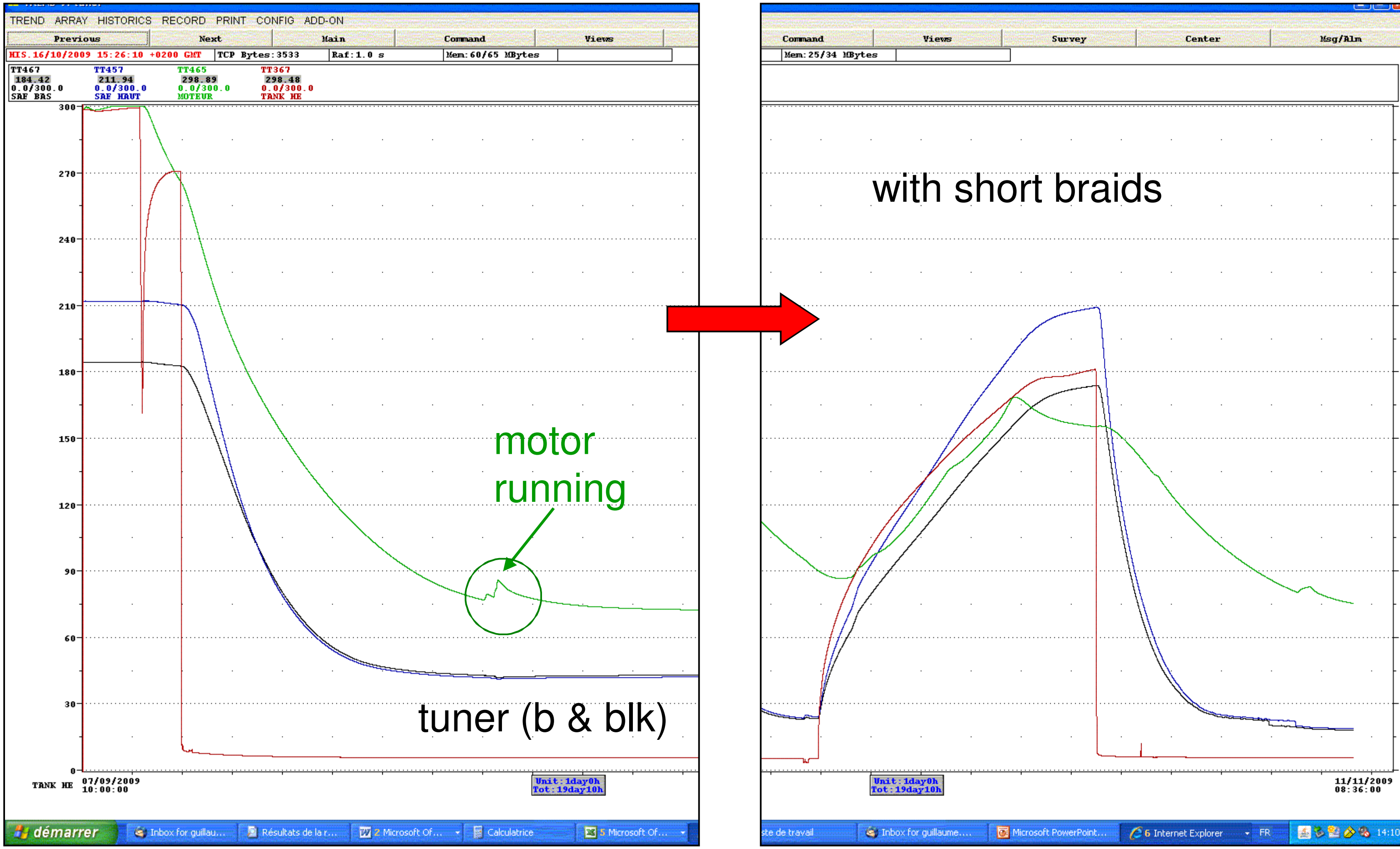
Fcav=703 MHz, far from tuner neutral point

Piezo detuning (DC)



measured at 1.8 K (main tuner parts at 20 K)
piezo 44V for 1 µm elongation of the cavity (~2 µm for the piezo actuator)
Maximum detuning measured at 150V DC = +1 kHz

Thermal behavior



•Added short braids connected to the He tank: reduced cooling time from 5 to 2.5 days after LHe injection

•The motor is not cooled directly in these tests

Interface/process requirements

Saclay tuner can be fully assembled before installation on a ***single, closed*** cavity :
Square flange
But : Extra requirement for a cavity string assembly in the clean room:

A leak test has to be performed in the clean room on the cavity string before it exits the c.r.

If the cavity can not withstand the vacuum load (vacuum inside, atm pressure outside), then 3 scenarii possible :

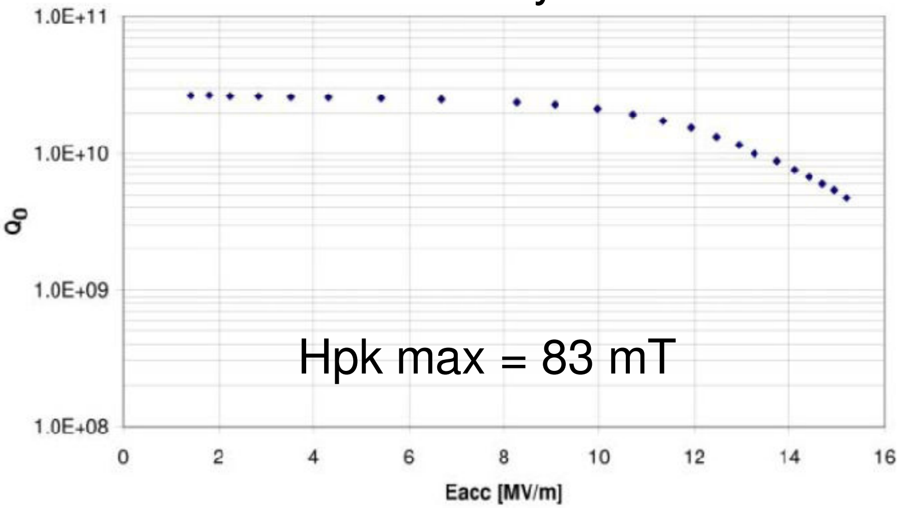
1. The cavity length is held constant during pumping using an easy to clean brace,etc. Then the cavity string is vented, then leaves the clean room, tuner is assembled outside
2. The cavity length is held constant during pumping using an easy to clean brace,etc. Then the cavity string leaves the clean room under vacuum, tuner is assembled outside, brace removed -> the brace must not interfere with the tuner
3. The tuner is partly assembled in the clean room before the leak test (time consuming, contamination likely to occur from bearings, heavy parts…)

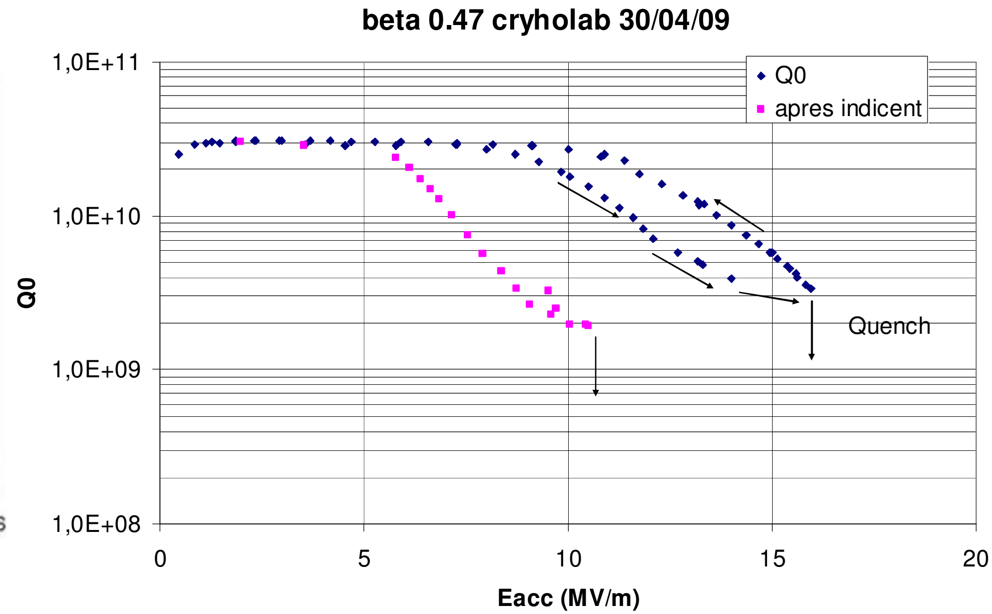
Solution 2 is prefered, the same brace can be used during cavity transport, chem. treatment, … (ttf 9cell cavity technique)

This bracing scheme has to be included in the cavity/He vessel/Tuner integration study

Beta 0.5 704 MHz 5-cell cavity performance

Test in vertical cryostat 1.8 K

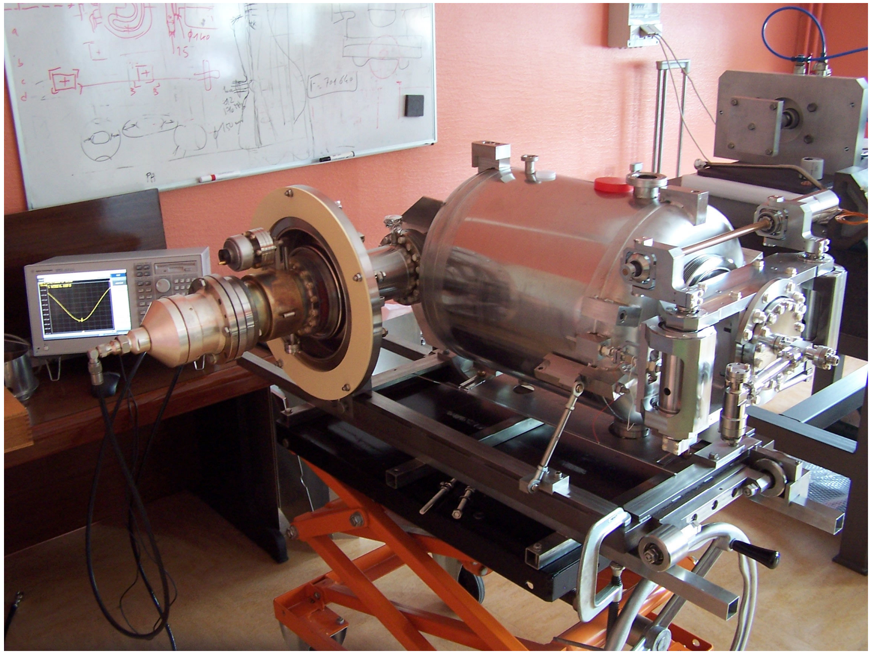


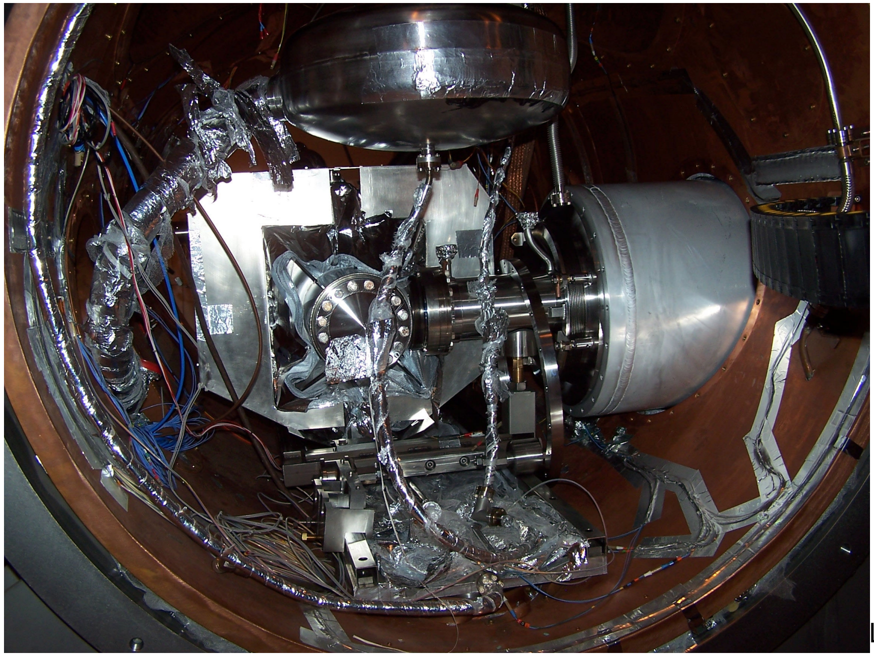


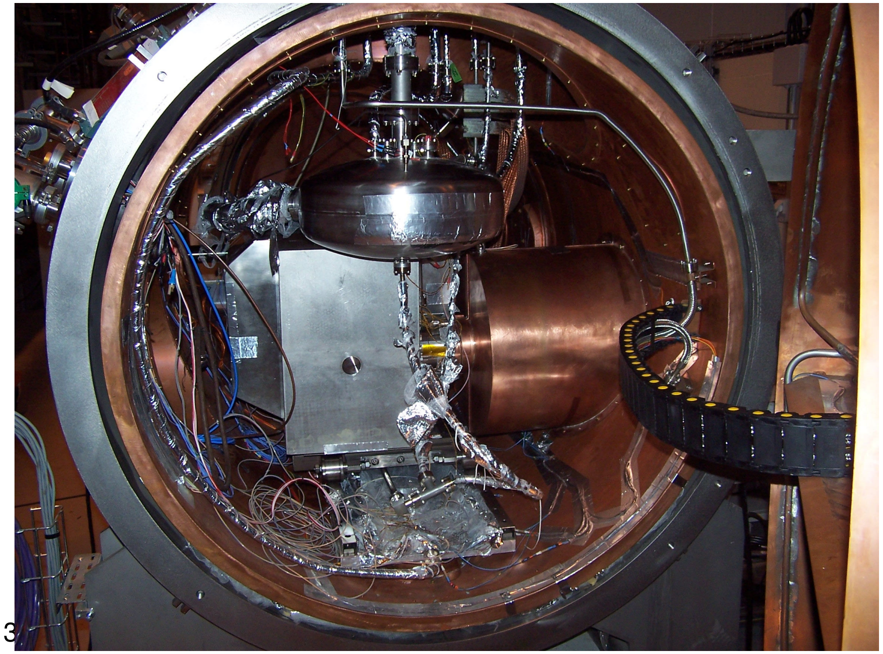
Test in horizontal cryostat 1.8 K with magnetic shield

- Field emission above 10 MV/m field, high levels of radiation
- Wide mulltipactor barrier at 8-10 MV/m also produced lots of radiation
- This MP barrier is identified with MUPAC code simulated barrier at 8.1 MV/m, 2 points, at equator
- In cryholab, best results equivalent to vert. Cryostat after FE was processed
- FE was resumed on 4/5pi mode, even worse!
- Cavity was reprocessed with a light BCP, and standard HPWR

Configuration for pulsed RF in Cryholab

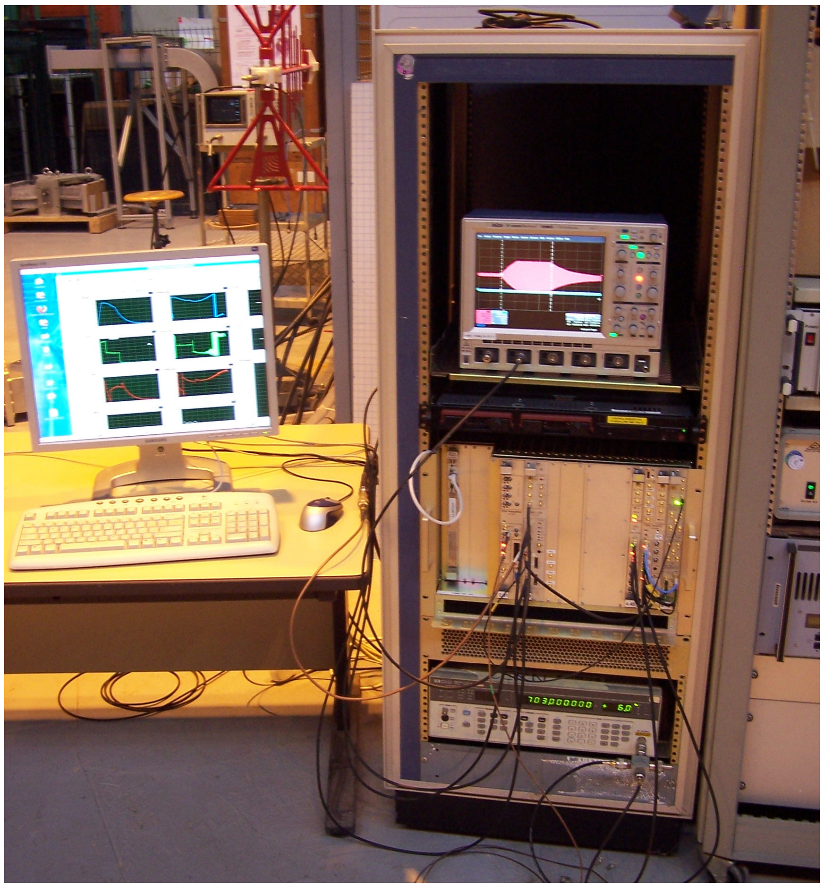


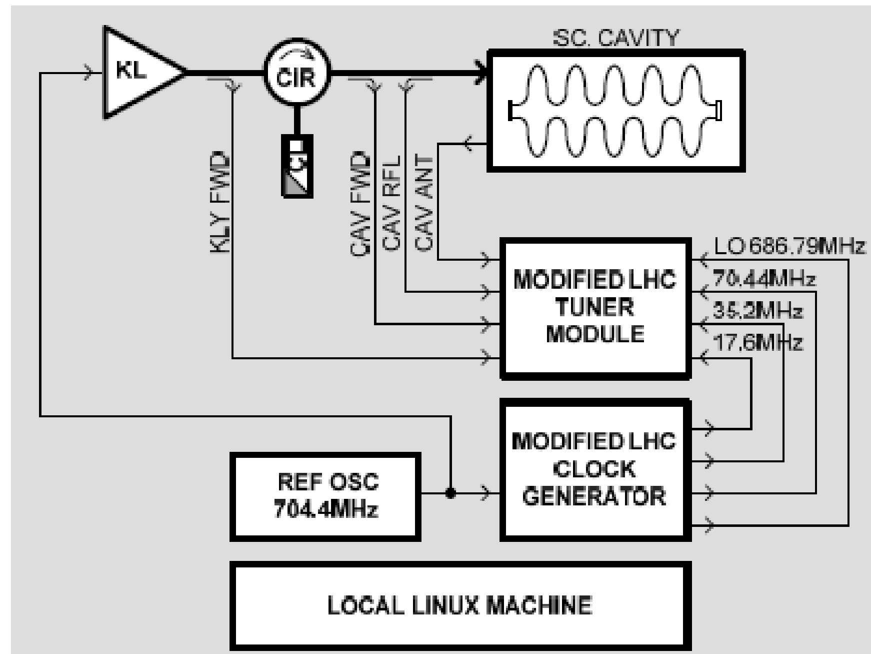




Pulsed RF

- Feedforward compensation of the klystron P-P/4 phase jump
- Coupler conditioning in full reflection at Fdrive=703 MHz, Fcav=702.662 MHz, T=4.5 K
- Installation of the CERN 4 channels I/Q measurement crate
- No field emission
- Cavity reached Eacc max = 16 MV/m at 1.8K, no quench observed yet, FE not observed yet

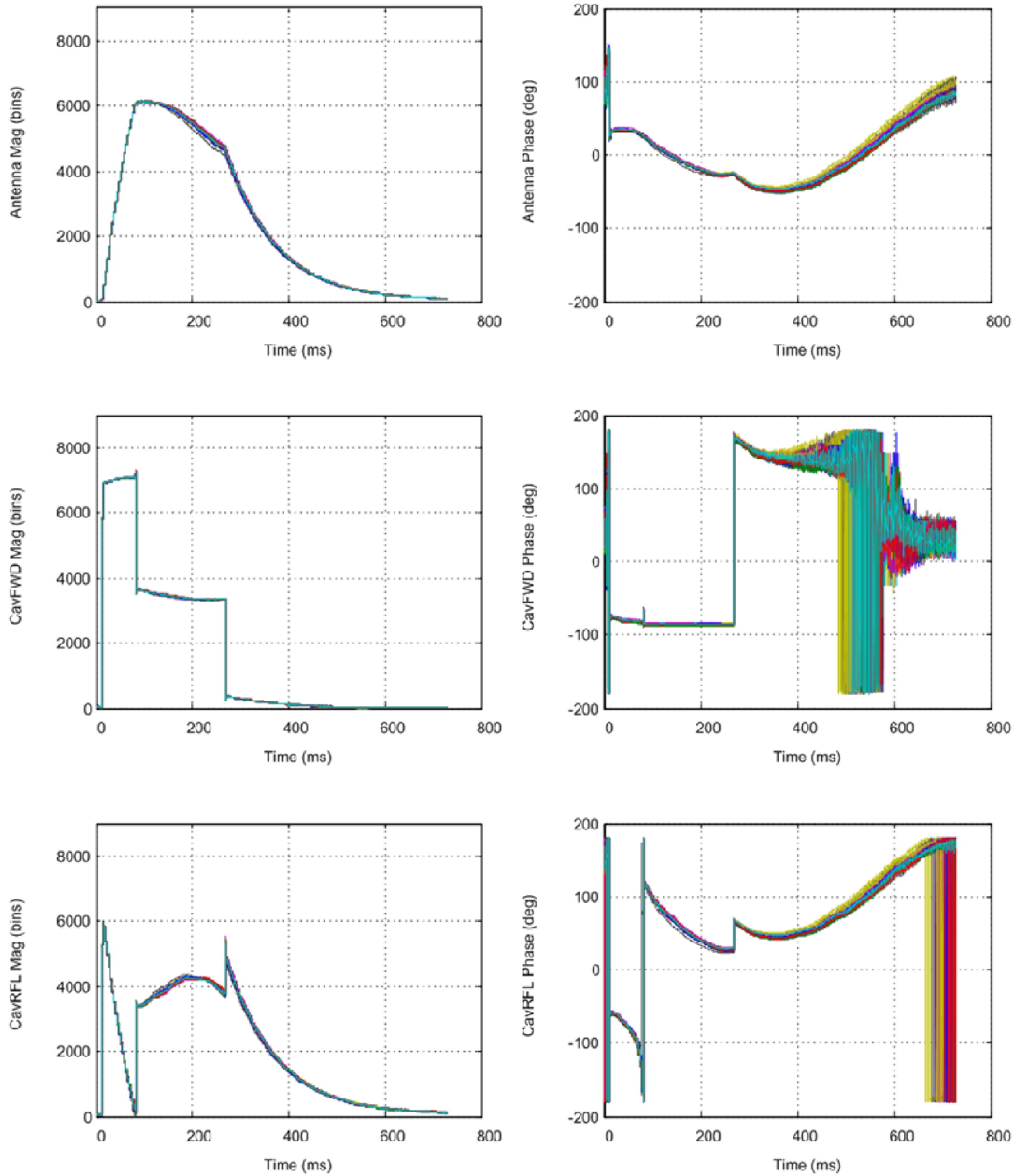




Irfu cea saclay

Pulsed RF

- Uncompensated Lorentz detuning during pulse
- Klystron phase jump compensated during 4P/P transition to simulate flat top
- Slope on the forward voltage due to limited directivity of the WG directional couplers
- 25 pulses acquisition to check reproducibility



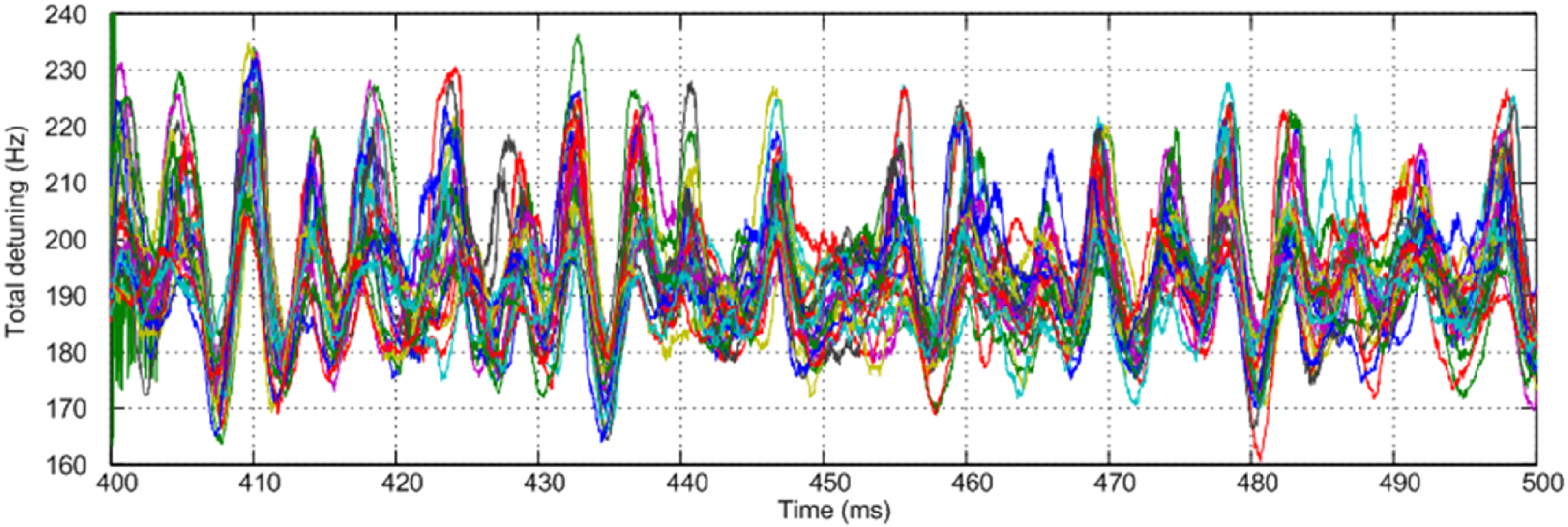
cavity pickup

forward

reflected

Piezo pulses with CW RF

Piezo induced detuning



Conclusion

- Piezo tuner is working as expected
- Caracterization of the cavity is going on
- Lorentz Force Detuning compensation not yet tested, will be done with the fixed and modified HPVS, with long pulses 2ms, 50 Hz
- Preliminary compensation tests with 2 ms, 5 Hz are foreseen in the upcoming weeks
- The CERN crate is working now as an fast IQ acquisition system, will be used as the piezo controler, and ultimately a adaptive feed-forward for LFD compensation could be implemented.