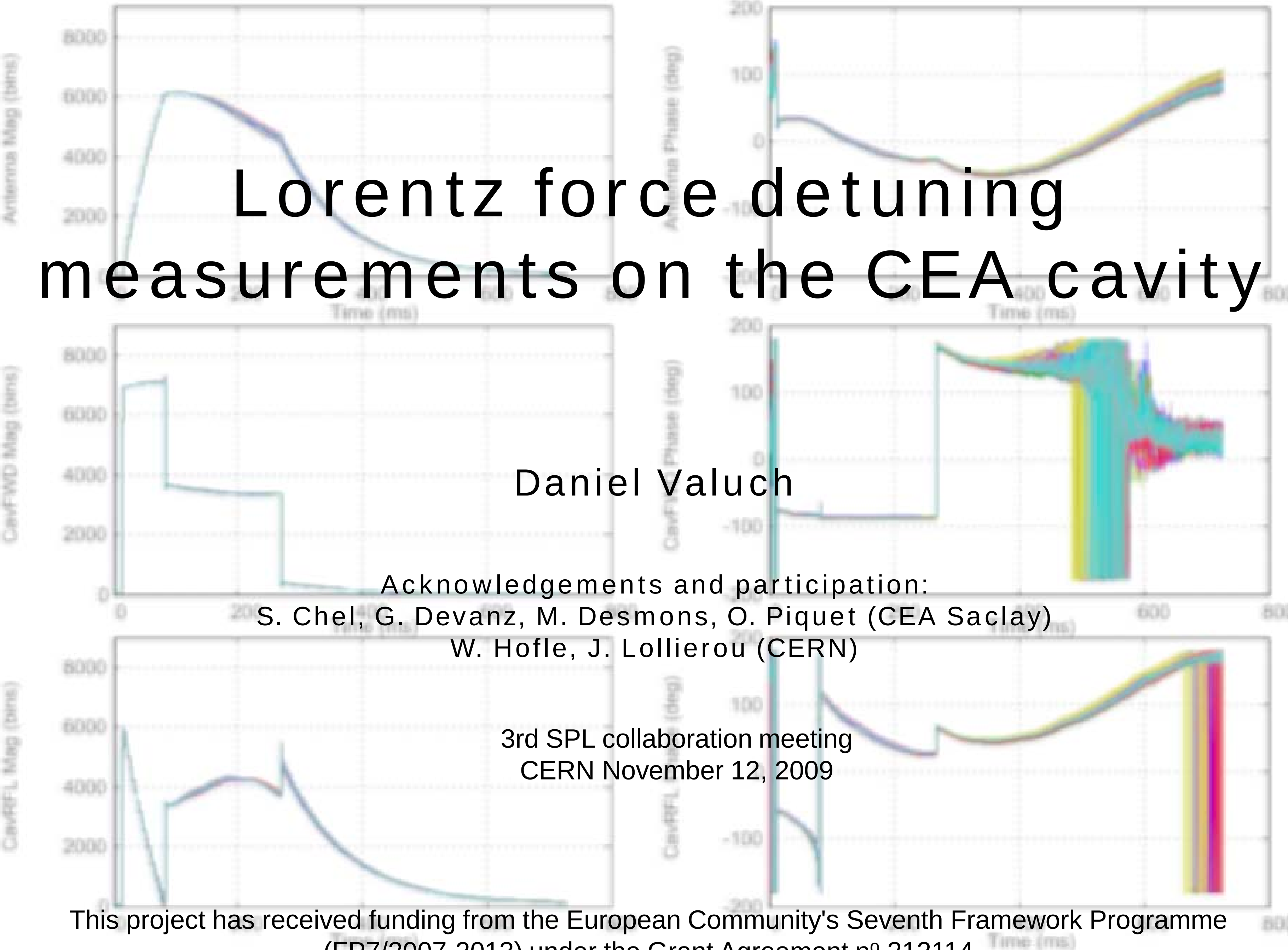

Lorentz force detuning measurements on the CEA cavity

Daniel Valuch

Acknowledgements and participation:
S. Chel, G. Devanz, M. Desmons, O. Piquet (CEA Saclay)
W. Hofle, J. Lollierou (CERN)

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Motivation

- To get realistic cavity parameters for simulation models (Lorentz Force detuning coefficients, mechanical resonant modes, microphonics etc.)

- Compare the dynamic behaviour and tuning capabilities of the CEA and INFN β=0.5 cavities and tuners

- Study how to mitigate the Lorentz force detuning phenomenon in order to meet the required field stability constraints for various modes of operation on the sample cavities

Measurement procedure

- Tune state of the cavity **without beam** can be calculated out of the cavity forward and antenna signals*.

$$\Delta\omega = \frac{d\phi_{ANT}}{dt} - \omega_{12} \frac{V_{FWD}}{V_{ANT}} \sin\left(\phi_{FWD} - \phi_{ANT}\right)$$

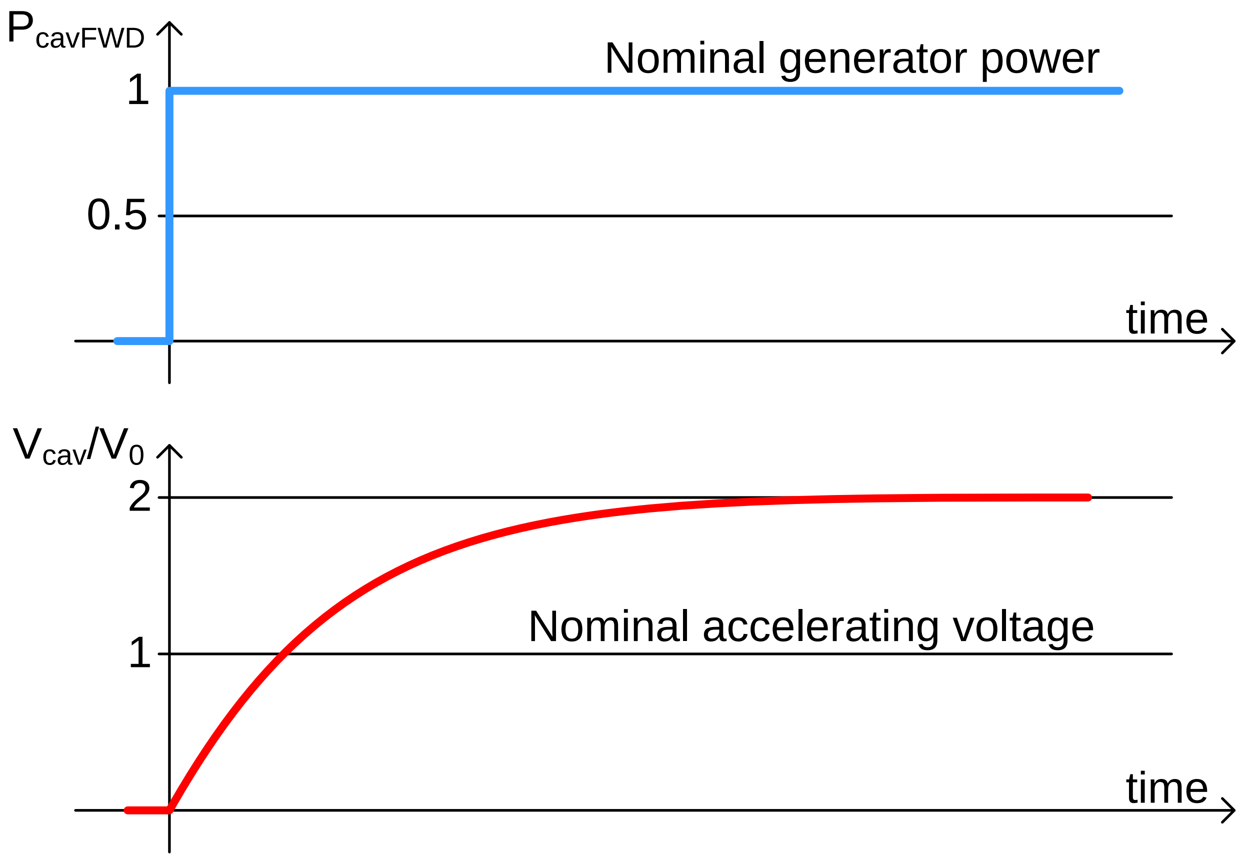
V_{ANT}, ϕ_{ANT} – cav. probe signal
V_{FWD}, ϕ_{FWD} – cav. forward signal
ω_{12} – cavity half bandwidth

- Tune state of the cavity **with beam** can be calculated from the cavity forward, cavity reflected and antenna signals. Math still to be finished.

- Good reference for pulsed operation: Thomas Schilcher, "Vector Sum Control of Pulsed Accelerating Fields in Lorentz Force Detuned Superconducting Cavities," Ph.D. Thesis, University of Hamburg, (1998).
- Limits of the equation with respect to the detuning rate of change must be checked.

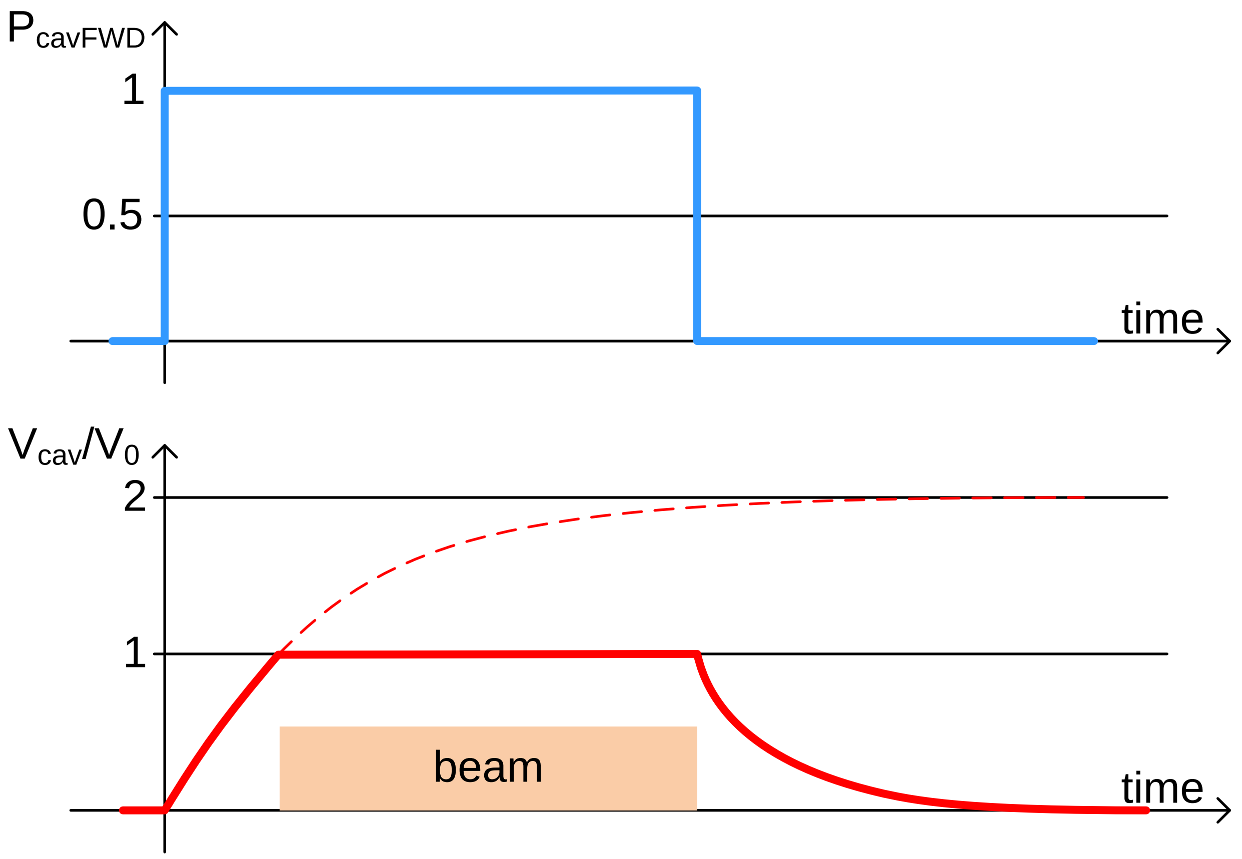
Typical waveforms

- General cavity filling transient with no beam



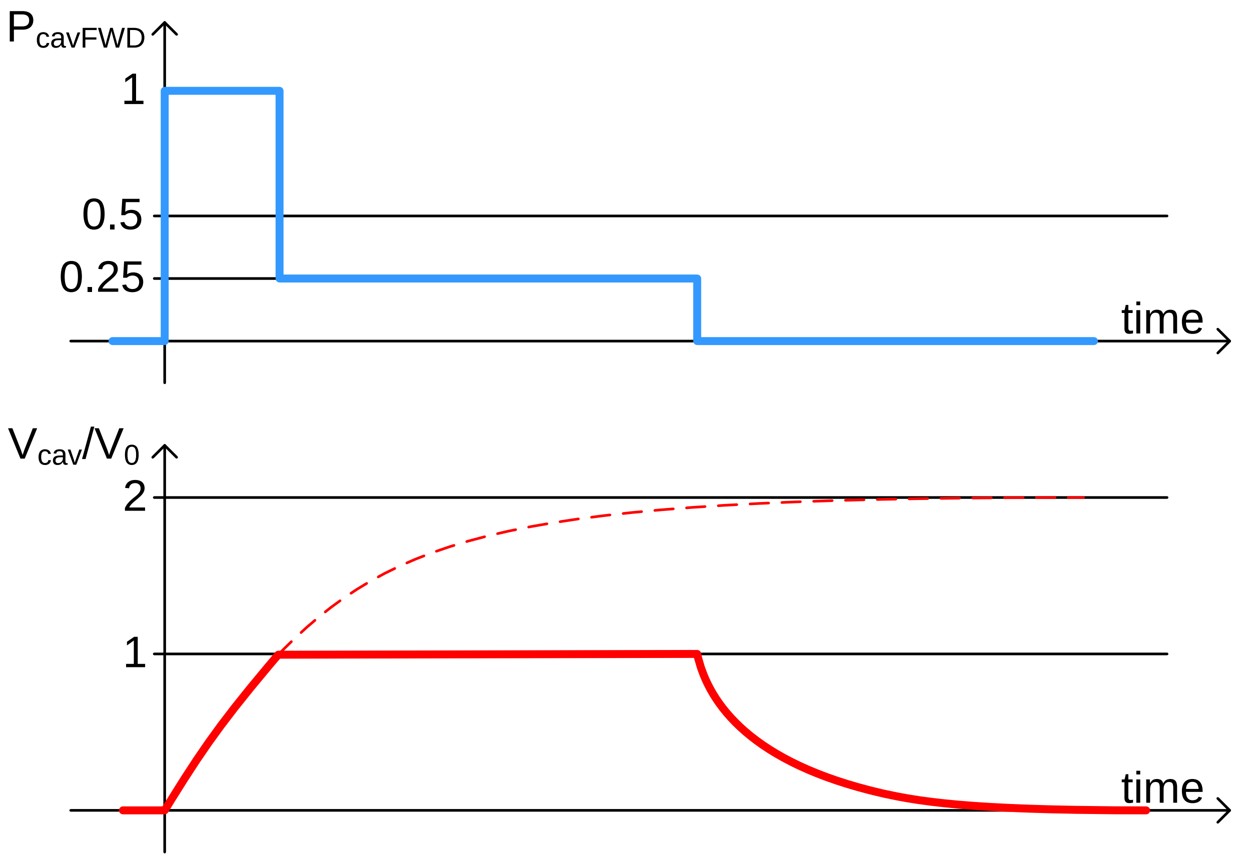
Typical waveforms

- Cavity filling transient with beam and optimal coupling



Typical waveforms

- Cavity filling transient with “simulated” beam



Measurement setup

- A set of LHC hardware was modified to get a stand-alone test setup to measure and characterize superconducting cavity detuning

- The system measures **Cavity Forward**, **Cavity Reflected**, **Cavity Antenna** and **Klystron Forward** signals in amplitude and phase (phase with respect to the fixed reference)

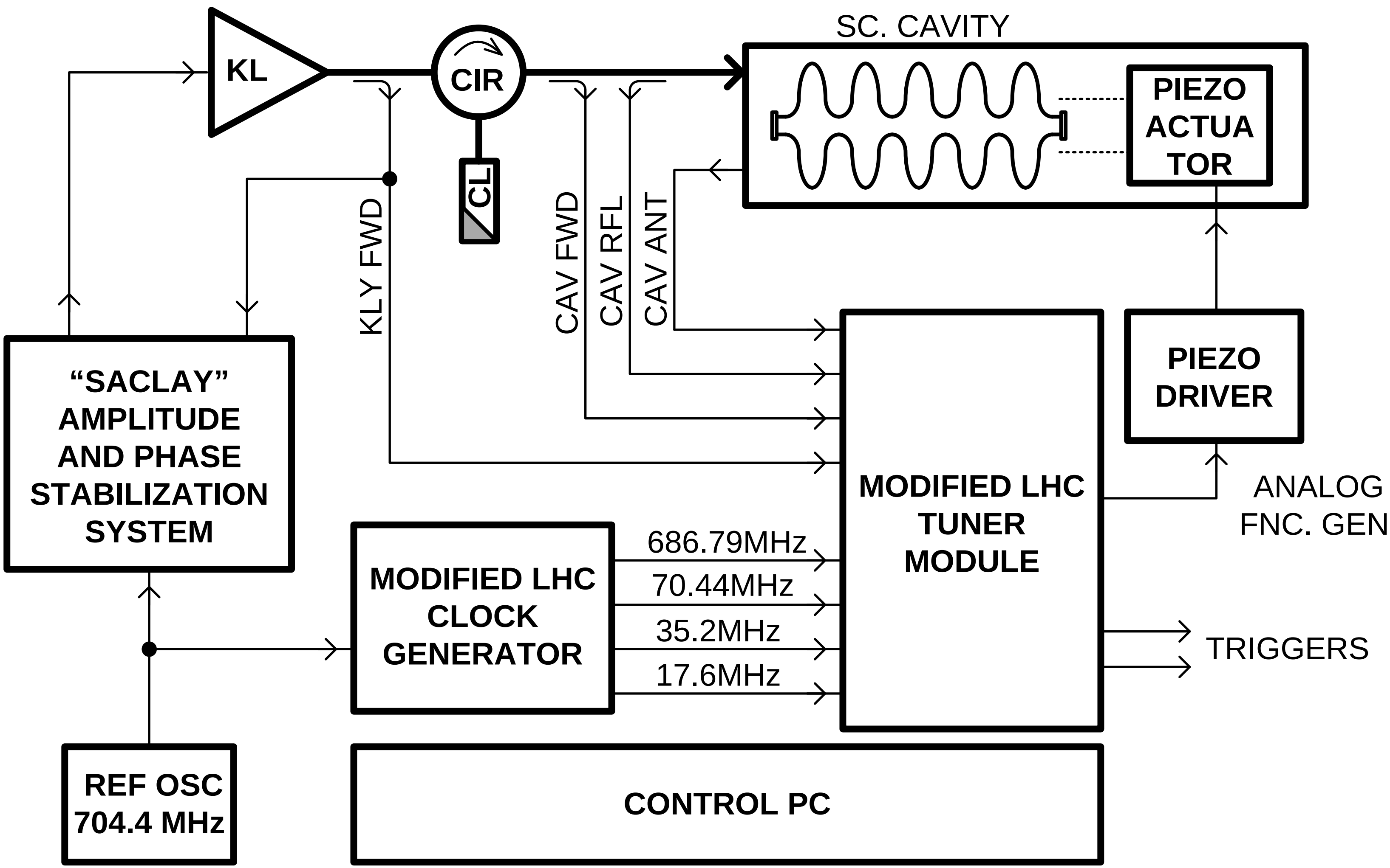
- Data are acquired at a rate up to 35 Msps with a record length of up to 128k points

- Data are then off-line analyzed using high level tools such as LabView or Matlab

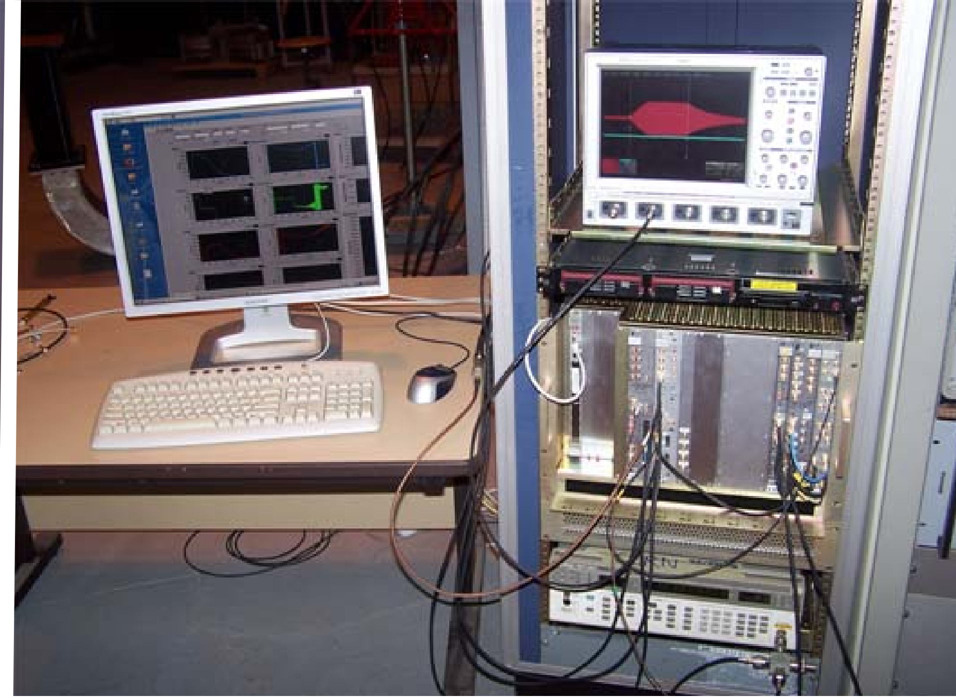
Measurement setup

- Four input RF channels
- Nominal input power 0 dBm
- RF Frequency 704.4 MHz (but input itself is wideband)
- LO frequency 39/40*RF
- Observation memory: 128k data points for each channel
- Max. observation rate 35.22 Msps
- Decimation in powers of two
  - 0 (full rate), resolution 28.4 ns/point, record length 3.7 ms
  - 2 (half rate, offset compensation), resolution 56.8 ns/point, rec. length 7.4 ms
  - Down to 32768, resolution 0.93 ms/point, record length 122 s
- External/internal triggers (observation start, observation freeze)
- Large FPGA available on the board. Presently used only as a simple vector receiver, a function generator to drive the piezo or “on-the-fly” detuning calculation can be implemented

Measurement setup




Crate Management
TUNER LOOP
VTU
Clock Generator
2.91

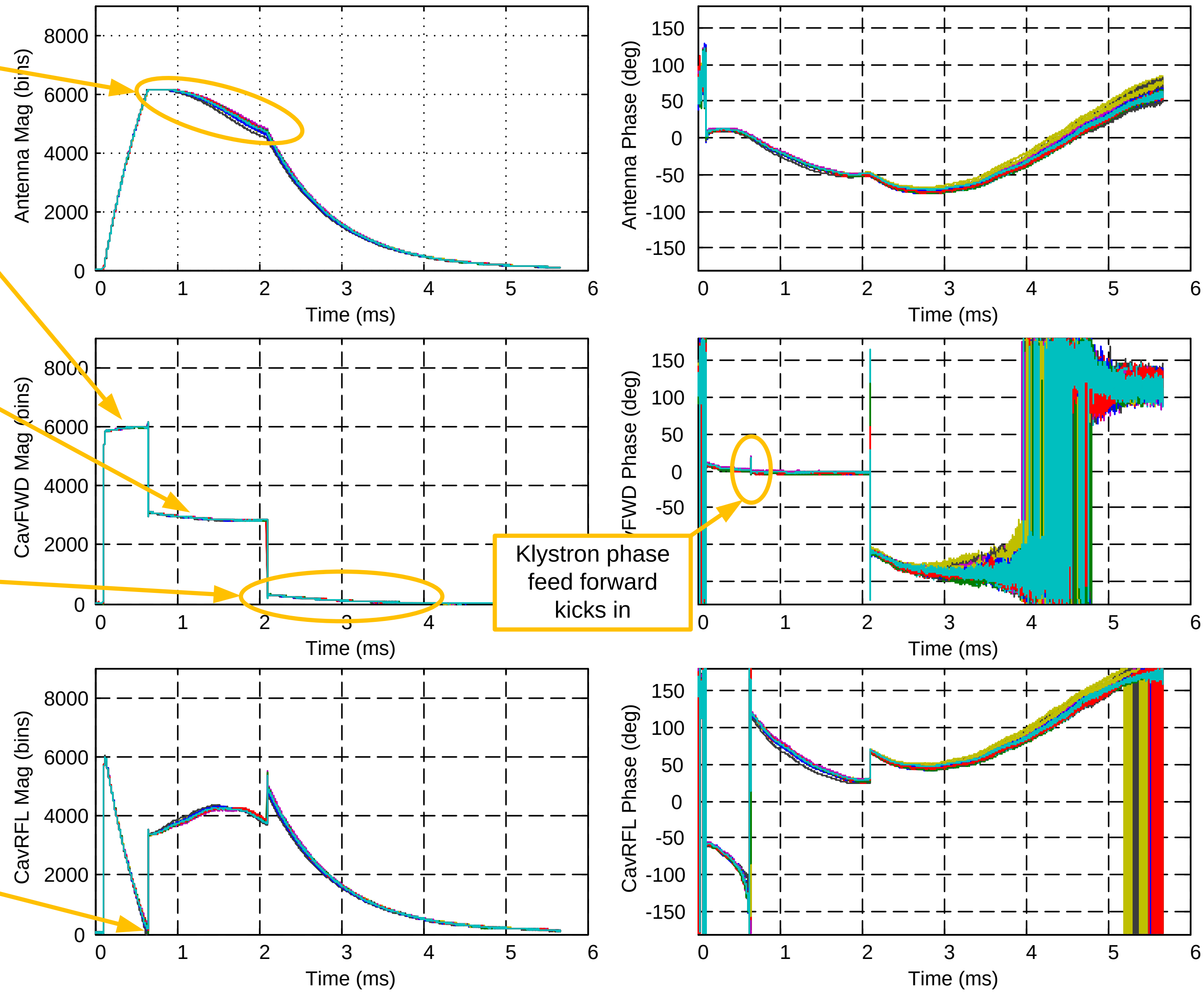


Preliminary results

- The measurement setup was successfully integrated in the high power test stand at CEA Saclay (CryHoLab) (so far only in a "passive" mode)
- We started to acquire data while the cavity and coupler was being conditioned and later during two days with cold cavity, and worked on a calibration procedure; coupler directivity and circulator matching needs to be taken into account and be studied
- We were able to calculate realistic detuning data with the available signals

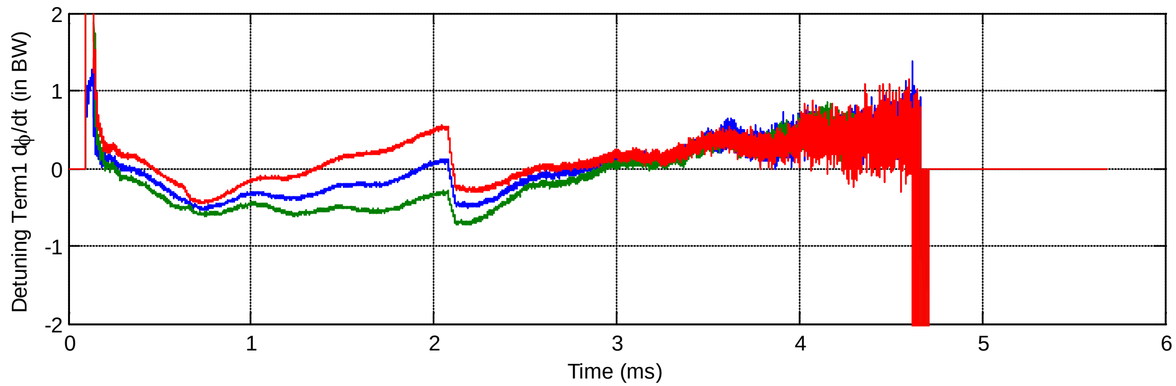
Preliminary results

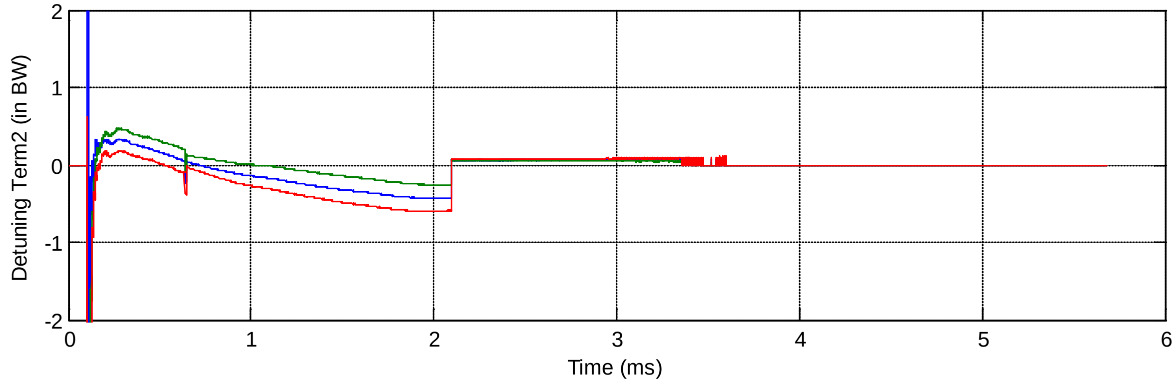
- Acquired c… a typical li… pulse
- The beam was simulated by lowering the forward po… nominal
- A set c… measurements showing pulse reproducibility

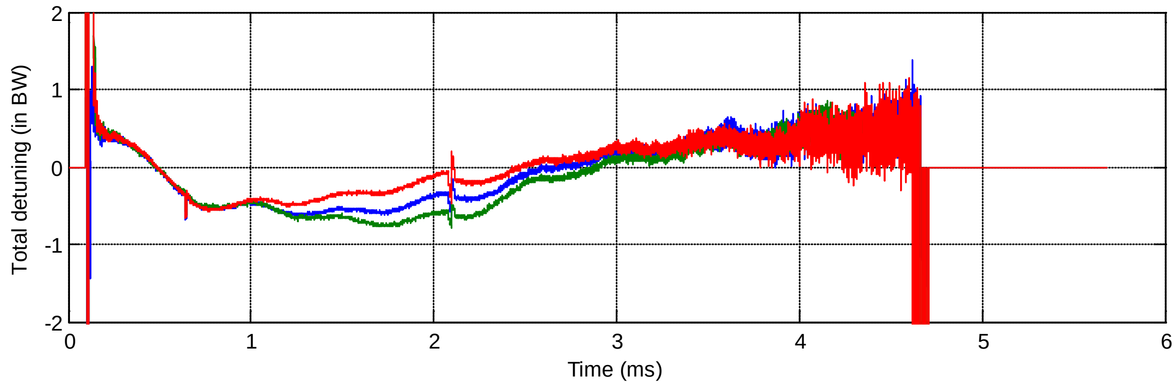


Preliminary results

- Calculated cavity detuning during the setting up process
- The cavity was deliberately detuned by known amount to verify the calibration and calculations

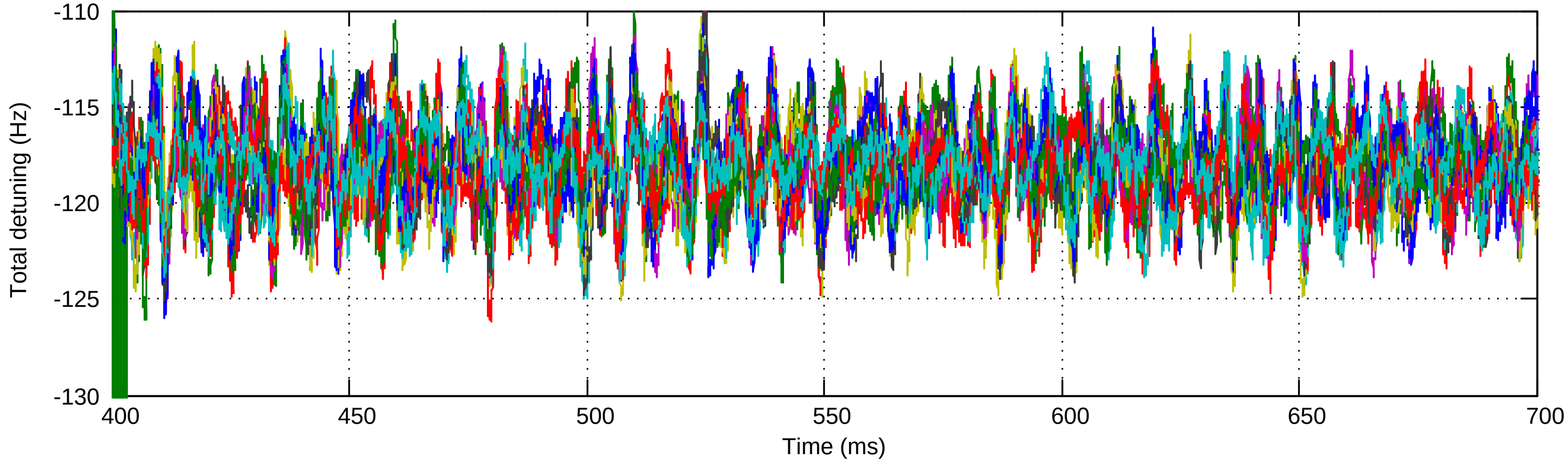


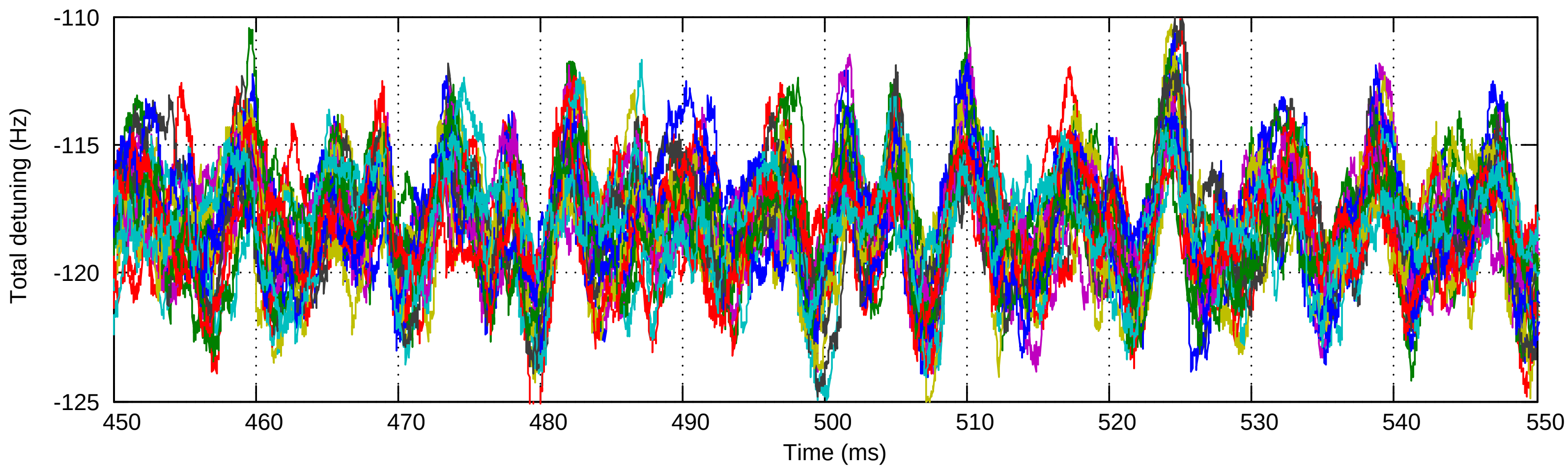




Preliminary results

- Low power measurement with cavity excited by the piezo element





Conclusions and following actions

- The measurement setup was successfully integrated in the high power test stand at CEA Saclay (CryHoLab)

- The concept proved to be viable

- During the two days with cold cavity we were able to do few preliminary measurements to check the measurement setup

- The device was so far used only in a “passive” mode

Conclusions and following actions

- Proper calibration of signal paths using a low power RF amplifier (500W - 1kW) (no LF detuning)
- Obtain accurate cavity parameters for simulations and for measurements (f_c, Q_{ext})
- Introduce a correction for coupler directivity (+circulator) into the signal processing

Conclusions and following actions

- Low power measurements:
  - Characterize cavity microphonics
  - Excitation by piezo to measure mechanical resonant modes of the cavity (f_{mech} and Q_{mech})
  - Excitation by piezo to get realistic model parameters for the compensation system (delay, tuning range etc.)
  - Find optimal piezo drive pulse shape (amplitude, delay, function, observe and mitigate resonant build-up of detuning from pulse-to-pulse)
  - Find optimal control algorithm to drive the piezo tuner

Conclusions and following actions

- High power measurements:
  - Measure and quantify dynamics of the cavity in a pulsed environment
  - Measure the mechanical mode damping times (2 Hz vs. 50 Hz operation)
  - Measure the klystron and cavity behaviour with full length, full power RF pulses
  - Quantify reproducibility of the klystron pulses
  - Quantify reproducibility of the cavity field pulses (feed-back vs. feed-forward compensation, how fast etc.)

Conclusions and following actions

- Switch the piezo tuner from a simple passive excitation mode to a feed back and/or feed forward control
  - Find proper pulse shape
  - Find and implement proper control algorithm

- Measure the cavity field quality and reproducibility with the compensation systems

- Repeat measurements with the INFN cavity when available