Commissioning of the MAX 700MHz test stand

EuCARD² / MAX

CERN, March 21, 2014

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EuCARD² / MAX , CERN

MAX

MYRRHA Accelerator eXperiment

Research & development programme

SEVENTH FRAMEWORK PROGRAMME

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

INFN Istituto Nazionale di Fisica Nucleare

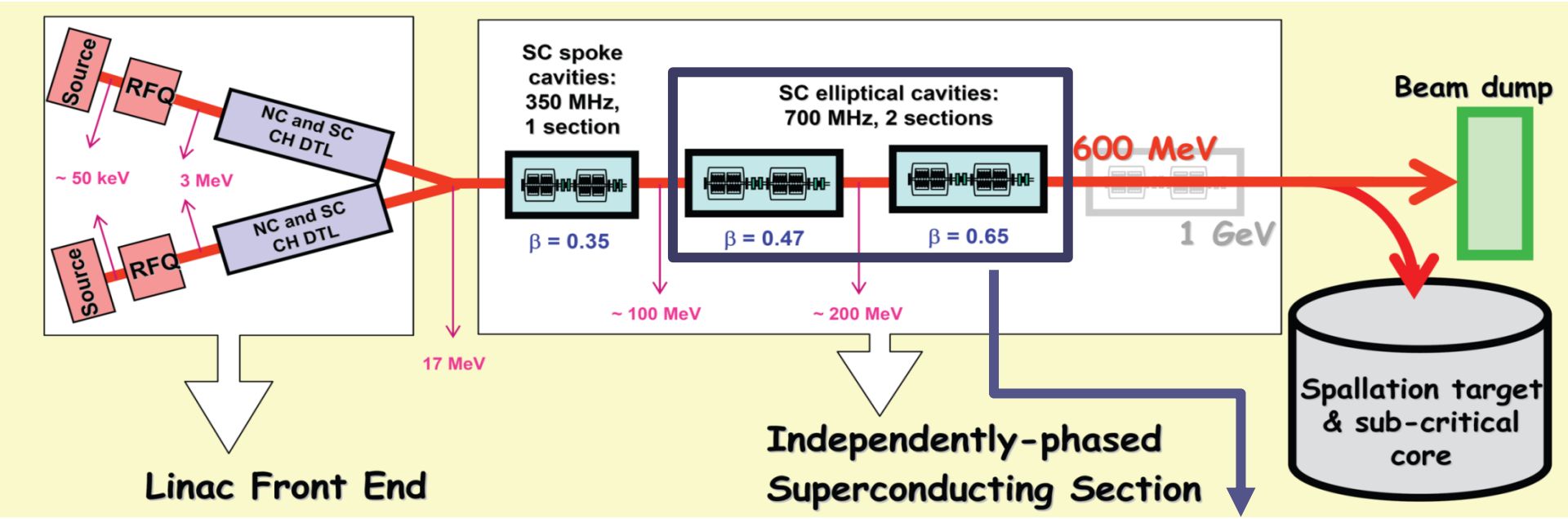
cnrs advancing the frontiers

Contents

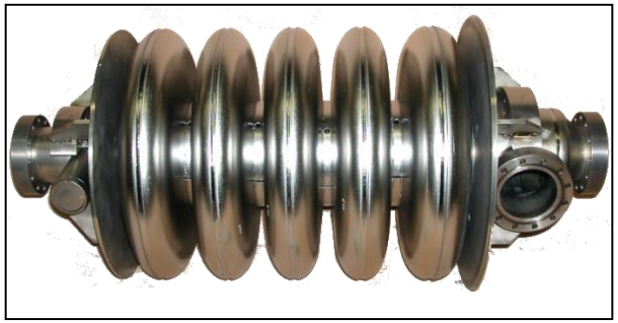
- 700 MHz test area.
- Power couplers.
- Cryogenic aspects.
- General qualification at higher power.
- Tuning System and microphonics.
- Conclusions.

Introduction

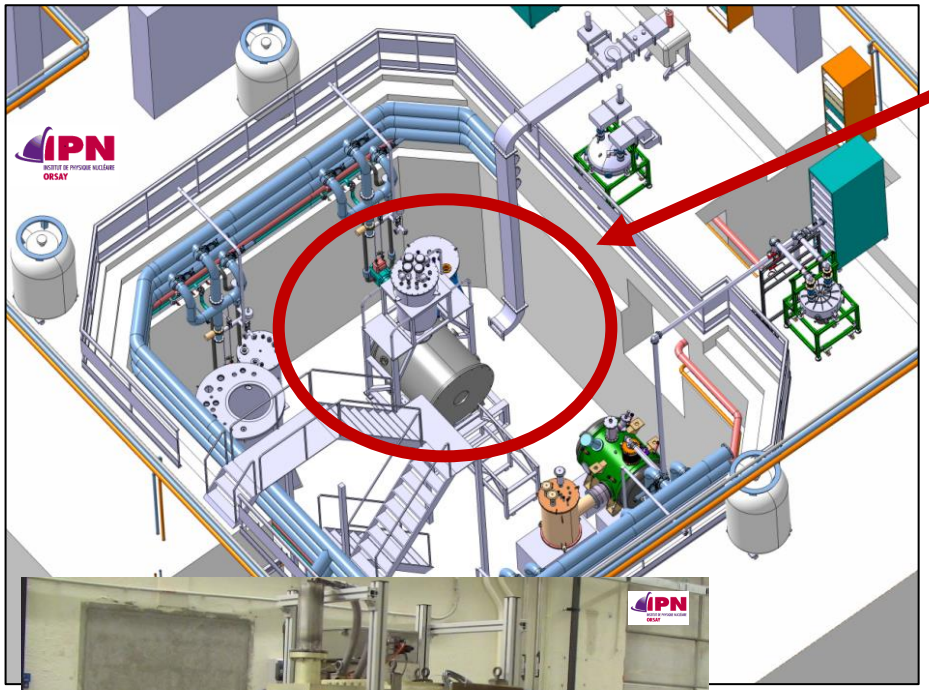
MYRRHA Accelerator Scheme



B_g = 0.47 section of the Linac
5 cell cavity
Freq = 704.4 MHz
Nominal accelerating voltage $E_{acc}(B_g)$ = 8.2 MV/m
Maximum E_{acc} for fault compensation = 10,7 MV/m



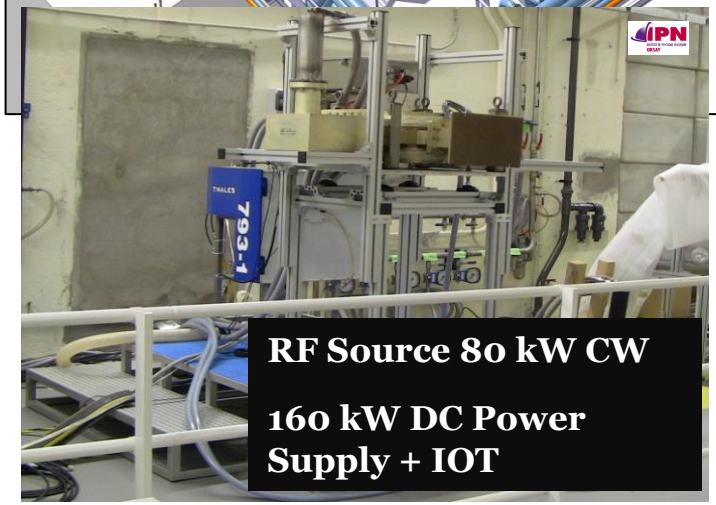
700 MHz area



700 MHz Cryomodule

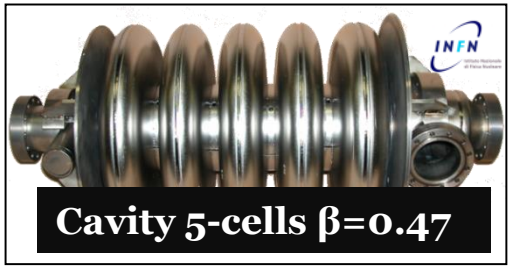
- Cavity & tuning system
- Power Coupler
- RF source 80 kW CW
- Cryogenic Valves Box

Power coupler

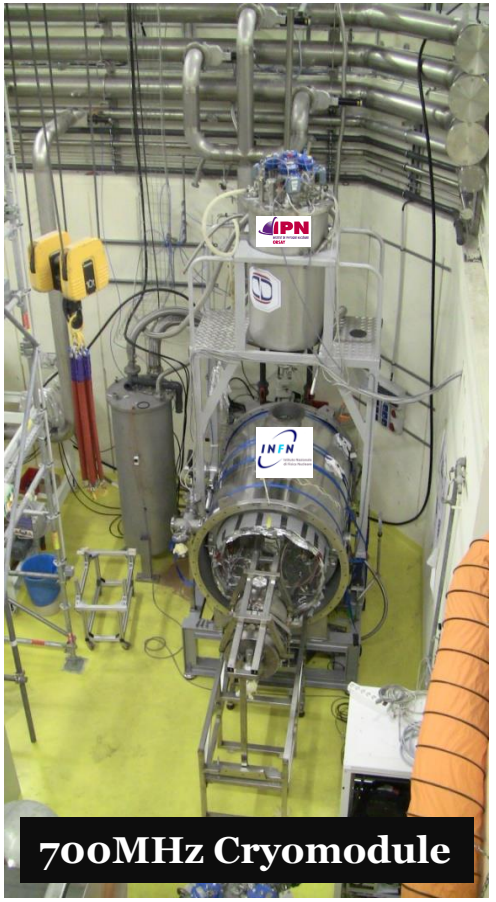


RF Source 80 kW CW

160 kW DC Power Supply + IOT



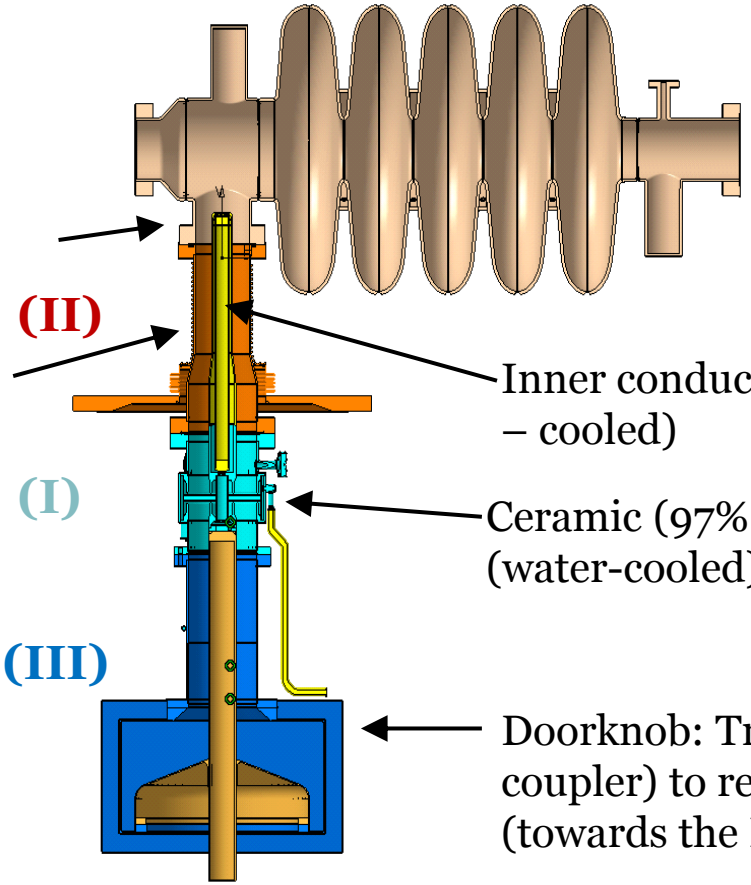
Cavity 5-cells β=0.47



700MHz Cryomodule

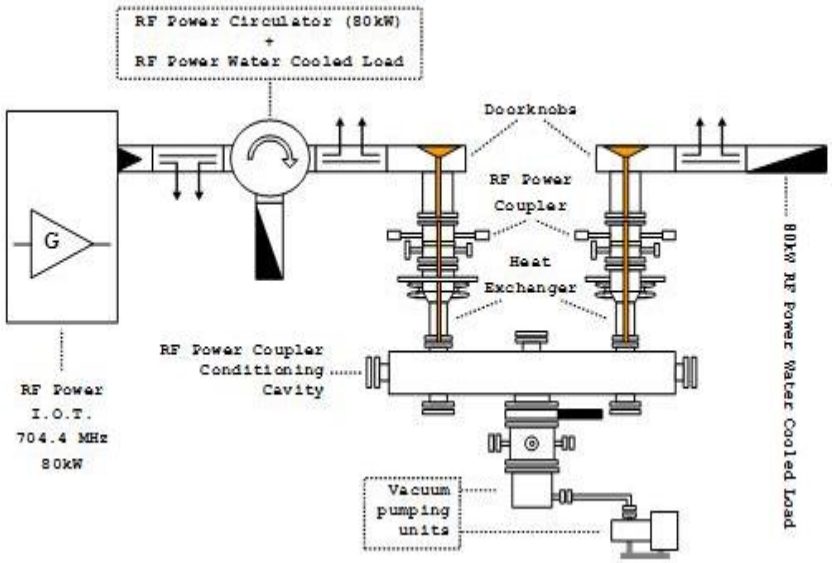
Power couplers

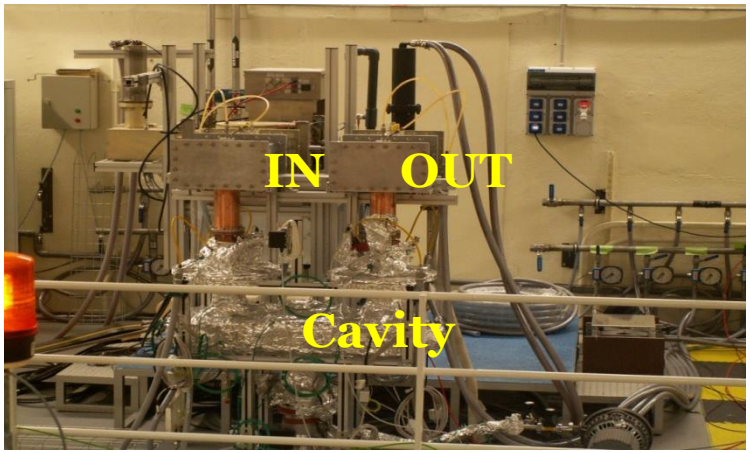
❑ Power coupler main view



Power Couplers conditioning setup

❑ Power coupler conditioning : Experimental setup

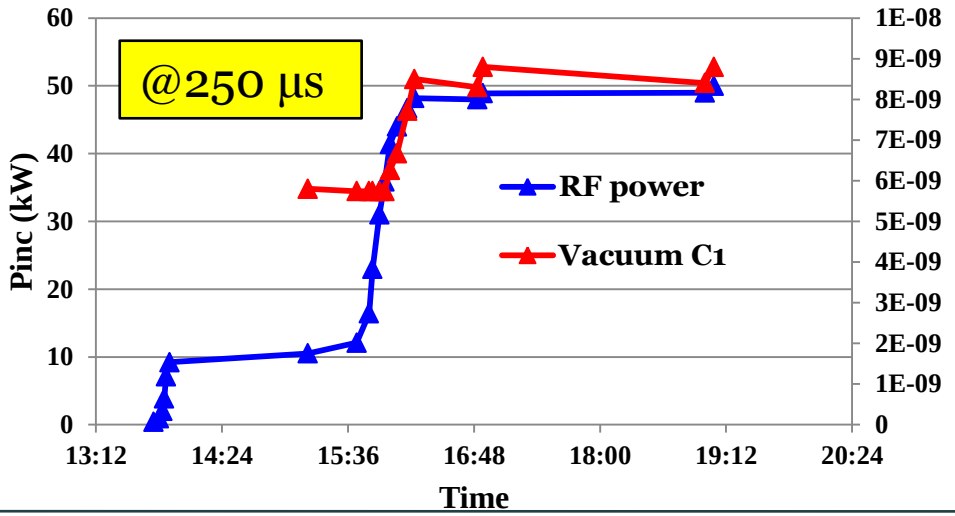




➢ Conditioning strategy

• Raising gradually the power from a few kWs up to maximum power starting from a pulse width of 100 µs up to CW.

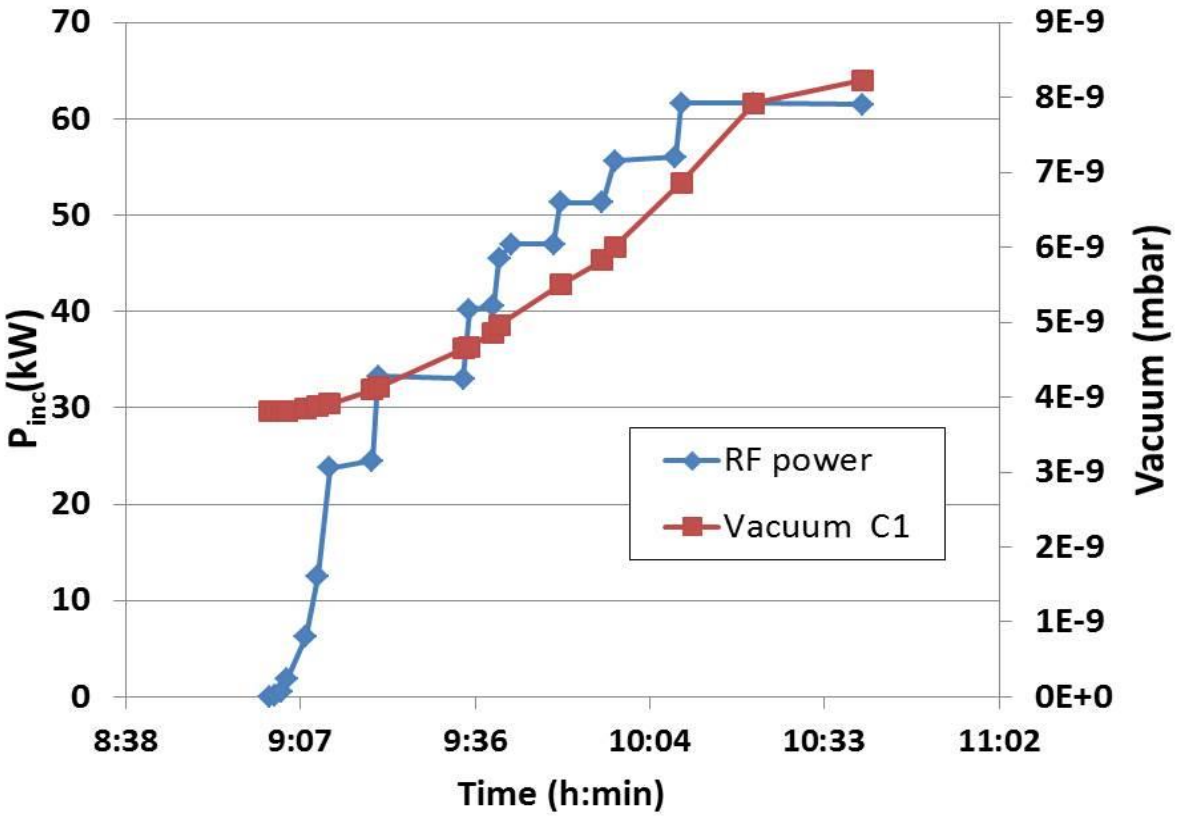
• The enabling of RF is based on hardware interlocks. Threshold are defined on multipacting current and vacuum level.



Results

- **The couplers were conditioned until 62 kW in CW mode.**
  - 10 days RF conditioning

C. Joly & J. Lesrel



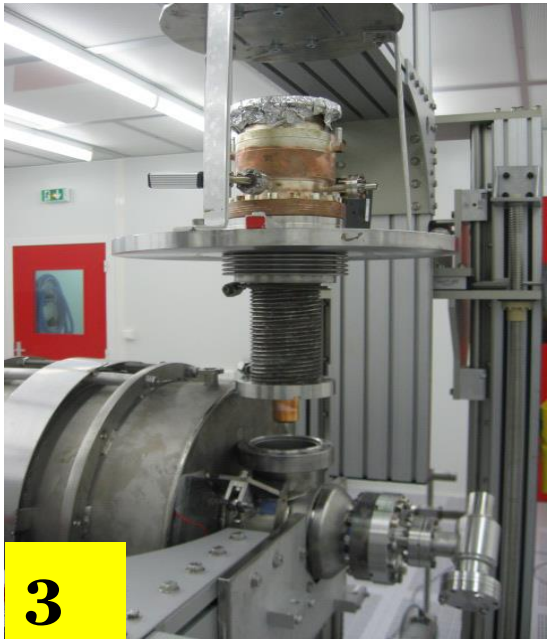
Cavity and coupler assembly

❑ Assembly procedure.

R. Martret, A. Stephen & L. Renard

BCP: Buffered chemical Polishing

- PNF: Phosphoric Nitric Fluorhydric acid
- PNF acid : forced circulation in 2 directions of the cavity.
- HPR



- A layer thickness of 27µm was removed on 35 min.
- The frequency of the cavity increases with 110 kHz.

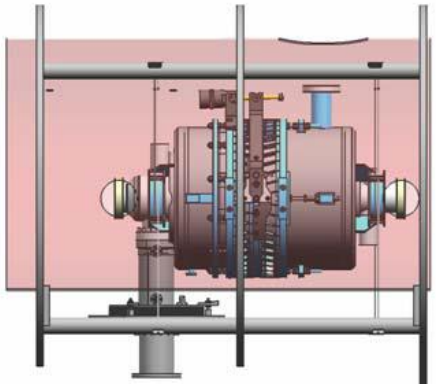
The cavity and cold coupler part were connected successfully in the clean room

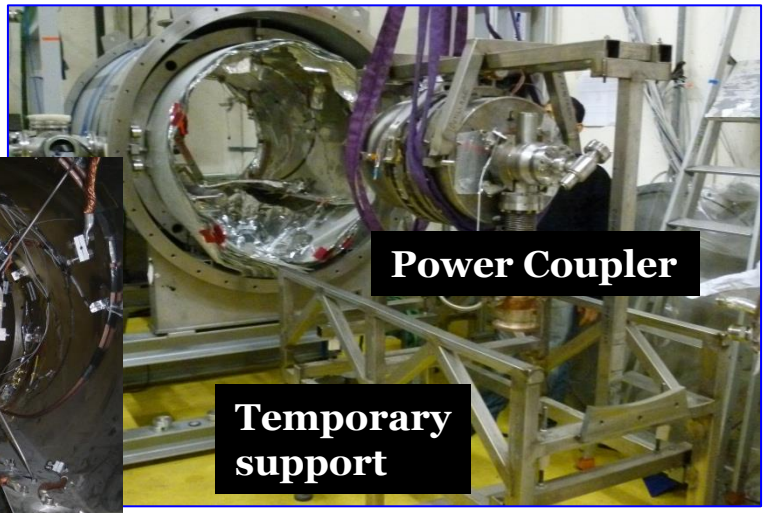
Cryomodule assembly procedure

D. Grolet & T. Pépin-donat

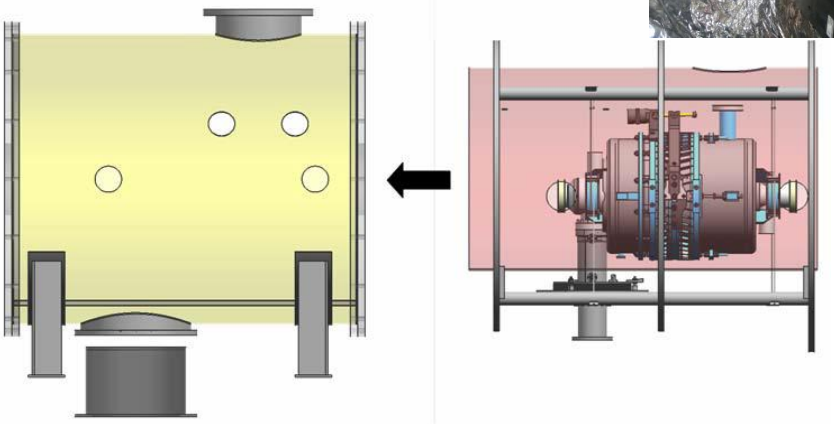
- **The main steps of the power coupler and cavity insertion into the vessel.**

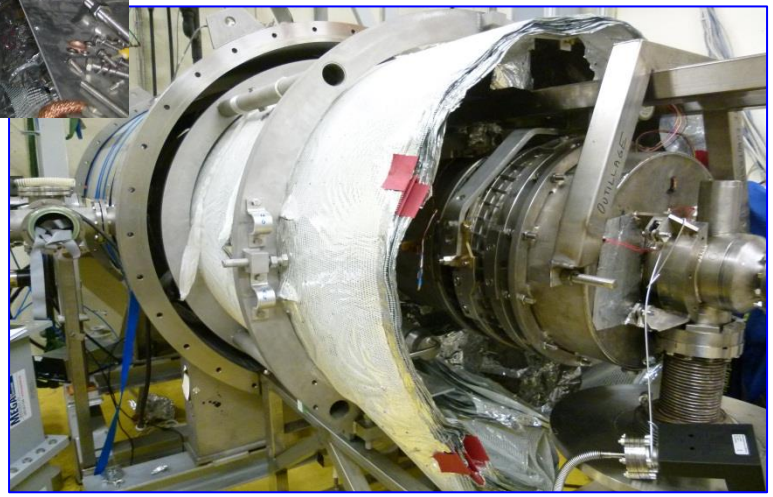
1 – Pre-assembly of the cold mass on the spaceframe





2 – Rolling into vessel



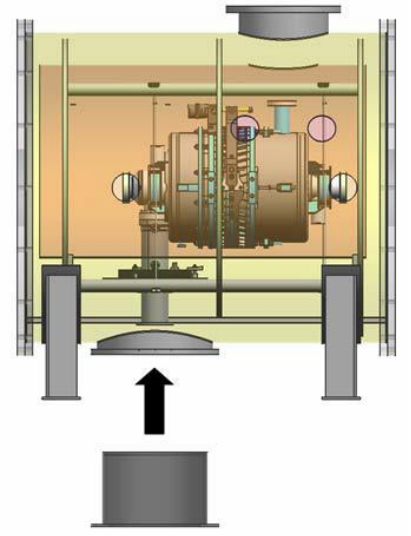


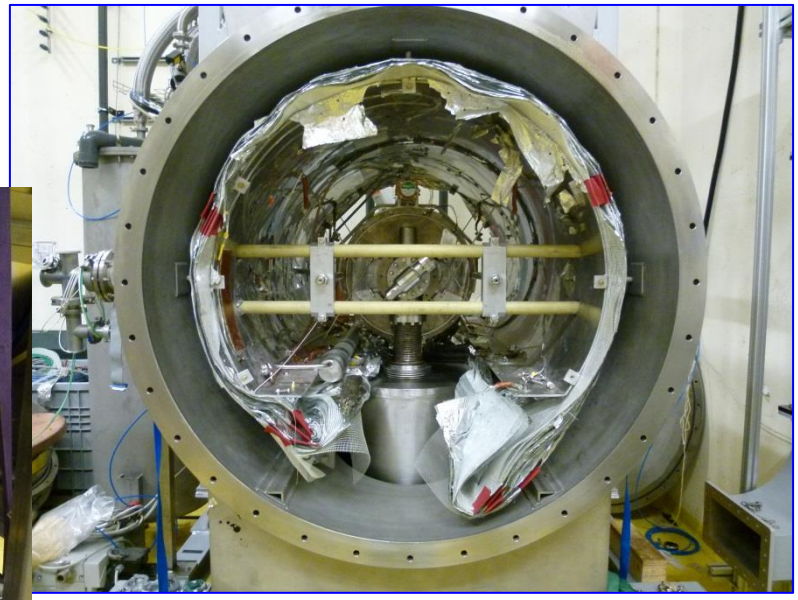
Cryomodule assembly procedure

- **The main steps of the power coupler and cavity insertion into the vessel.**

3 – Vacuum enclosure

D. Grolet & T. Pépin-donat





The cavity – coupler insertion successfully achieved

Cryogenic performance

❑ Qualification of the Cryo-operation at 4K, 2K + Supercritical loop at 5K.

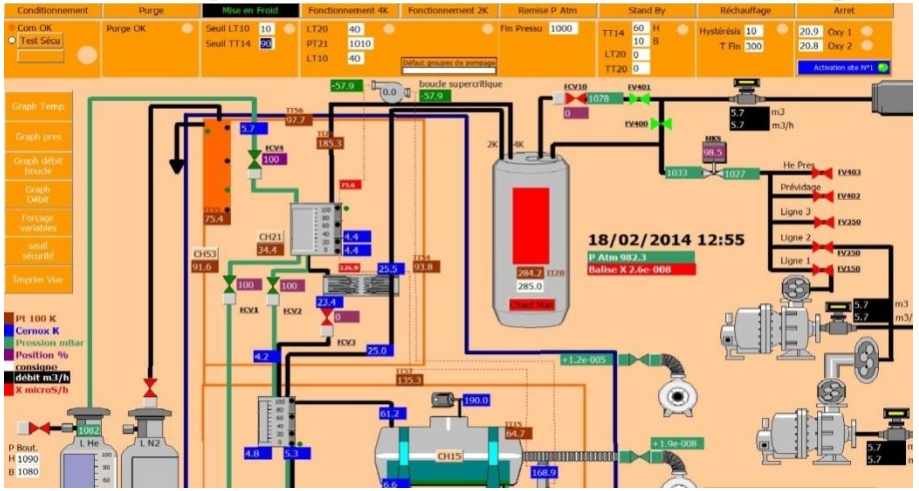
Cryogenic control system :

- Valves control
- Collect data (vacuum, temperature, levels)
- Manage safety aspects (Vacuum loss, Quench, etc…)

Labview supervision programme :

- Display the measured data
- Manage the cool down procedure

H. Saugnac, F. Chatelet, M. Pierens & J. Chapoul



■ The module and the cryogenic installation were fully qualified .

■ Measured performances in agreement with expectations : at 2 K one can operate the module until ~35 W heat load on the cavity + ~ 7 W static losses (i.e. ~ 41 W Losses).

❑ Static losses at 2K

Module	Design	measured
Valve Box	**2,0 W**	**2 W**
Cryostat	**4 W**	**5 W** With coupler Loop
Coupler : With Cooling Loop	**< 1 W**	**~1 W**

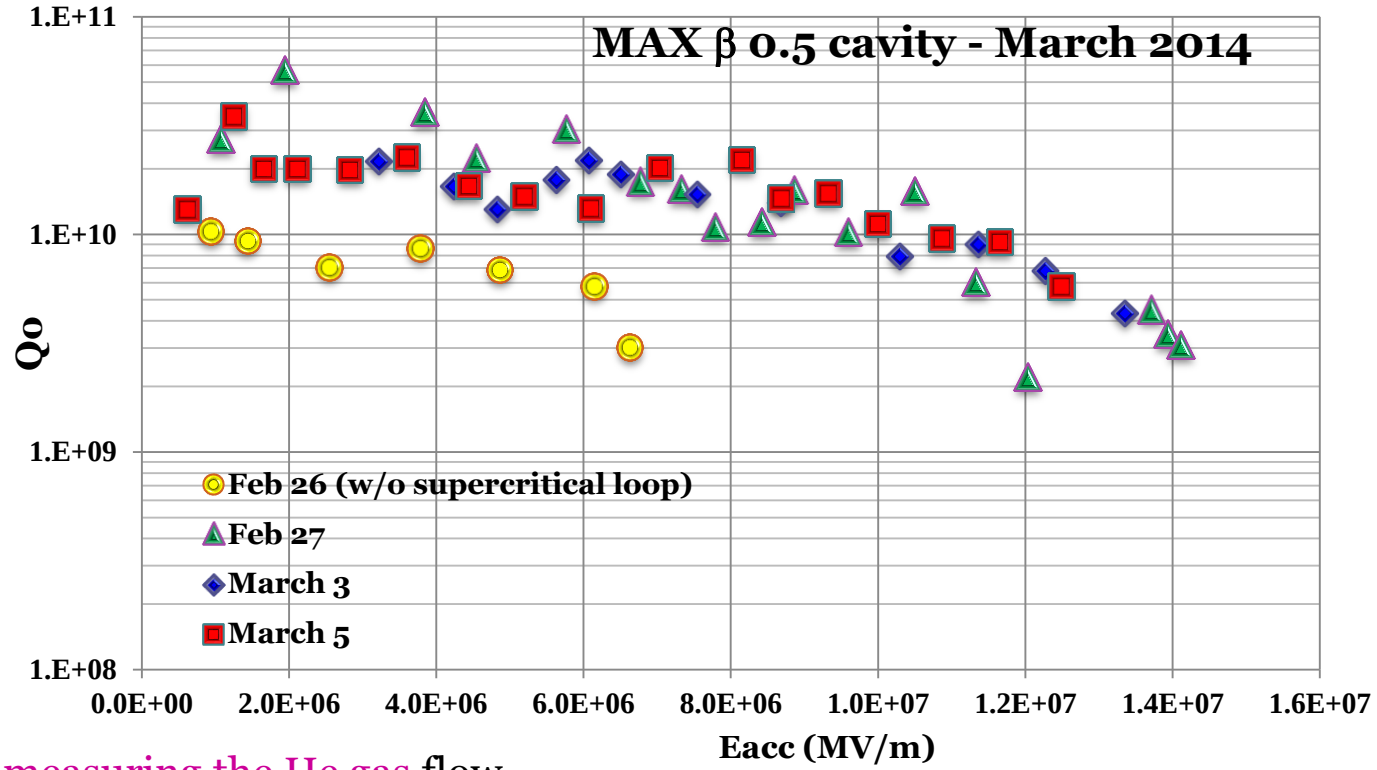
General qualification at high power

❑ **Q₀ measurements obtained in over-coupling configuration.**

C. Joly & J. Lesrel

Estimated coupling:

- Qi = 2,6 .10^{+7}
- Qt = 1,54 .10^{11}



➤ Evaluating the Qo by measuring the He gas flow.

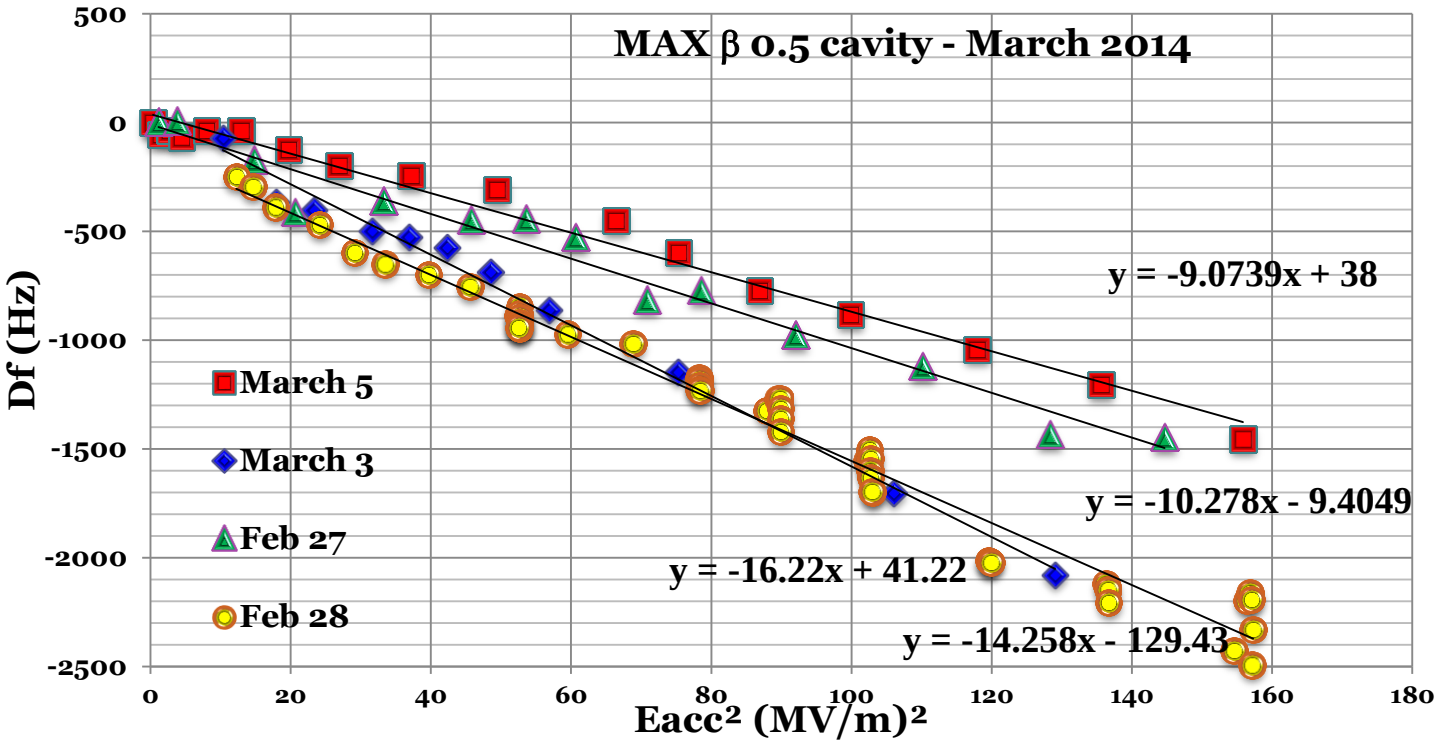
➤ Multipacting at 5,5 MV/m and 7 MV/m but easily processed,

➤ Quench value at 14MV/m (confirm the previous result in Vertical Cryostat).

➤ Still above MYRRHA requirements

RF Measurements @ 2K

❑ Lorentz factor detuning coefficient KL & pressure sensitivity.



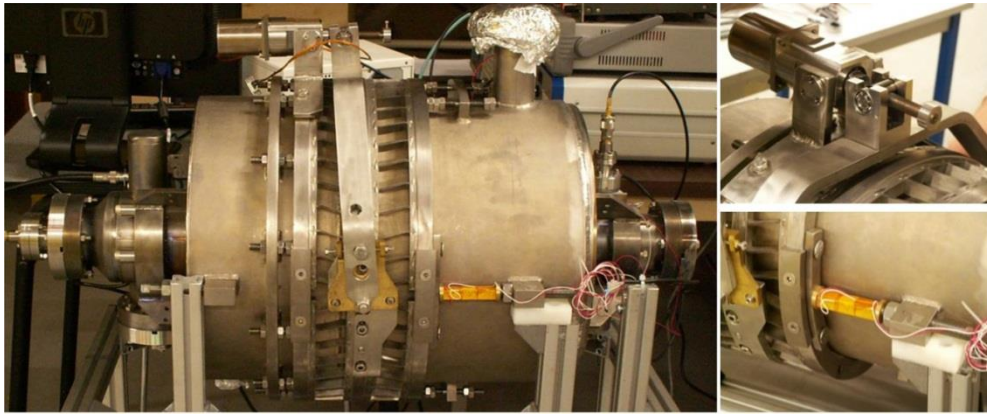
➢ The RF measurements yielded a $9 < K_L < 16$ Hz / $(MV/m)^2$.

❑ Pressure sensitivity.

The frequency sensitivity according to the tank pressure is 359 Hz / mbar.

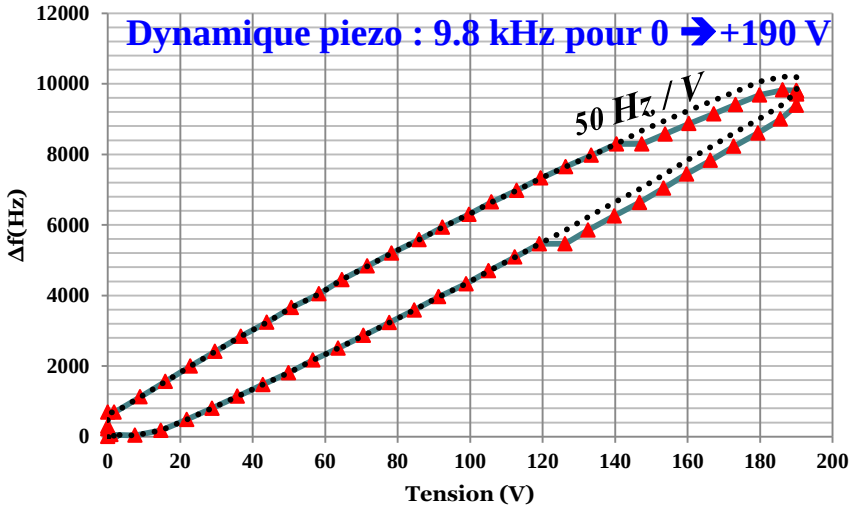
Cold tuning system

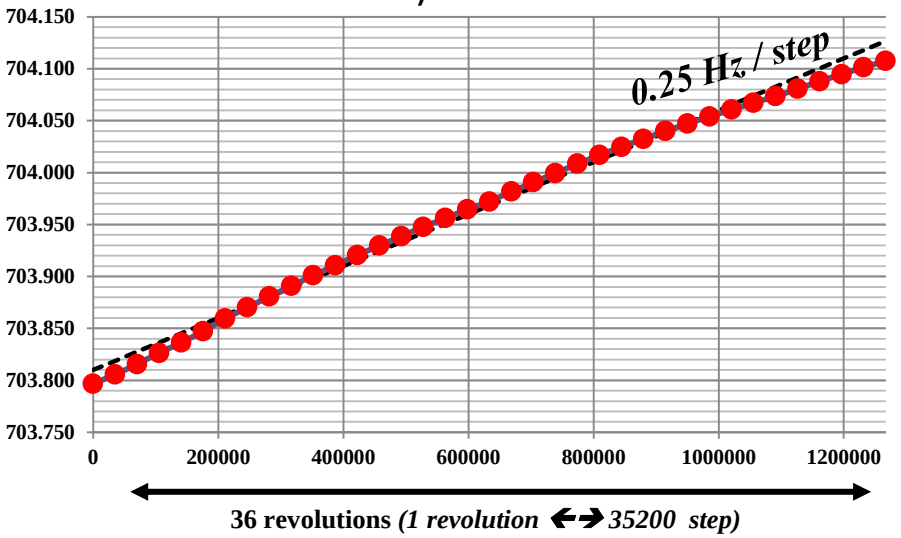
❑ Tests of the CST motor and piezo (sensitivity, range, hysteresis…)



N. Gandolfo & R. Paparella

- Motor:
  - Sensitivity (~ 0,25Hz/step).
  - Range (~ 311kHz).
- Piezoelectric actuators :
  - Sensitivity (50 Hz / V)
  - Range 9.8khz
  - Fast detuning capability (100 band within 3 sec)

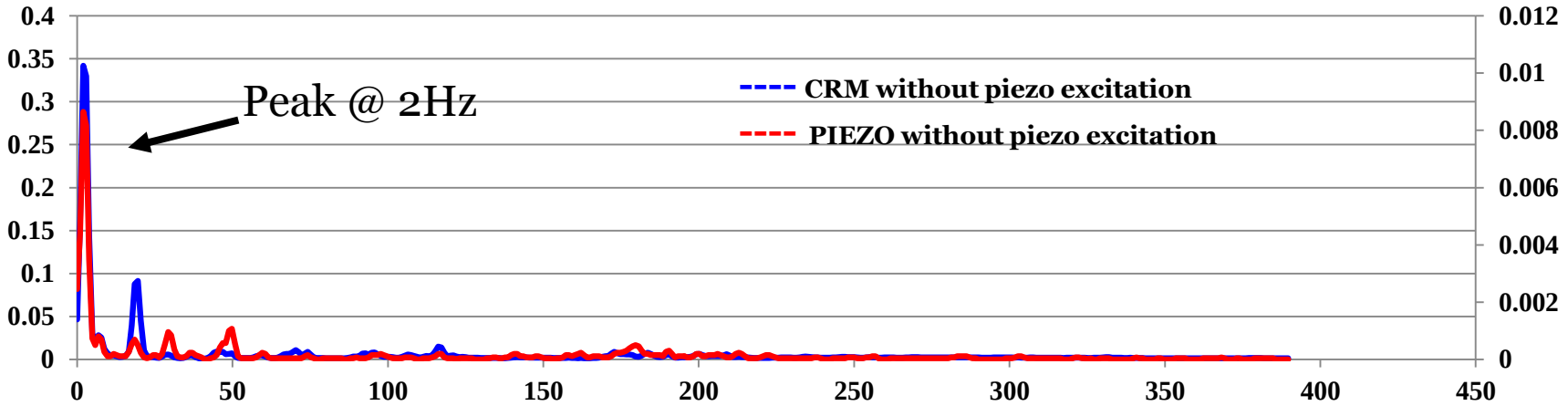


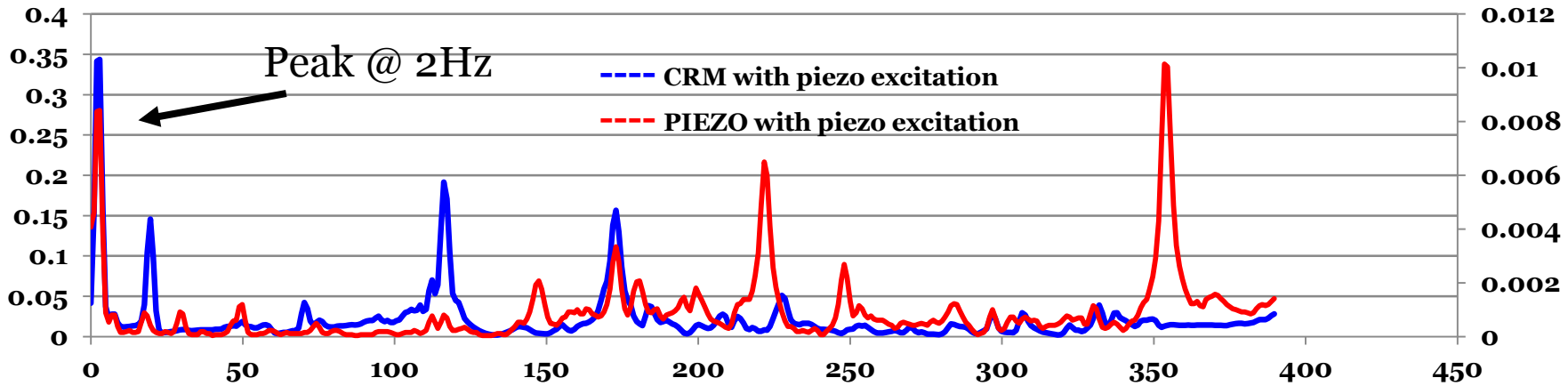


Microphonics

❑ Microphonics spectrum measurement.

N. Gandolfo





The microphonic's peak at 2 Hz has been identified as excitation from supercritical loop

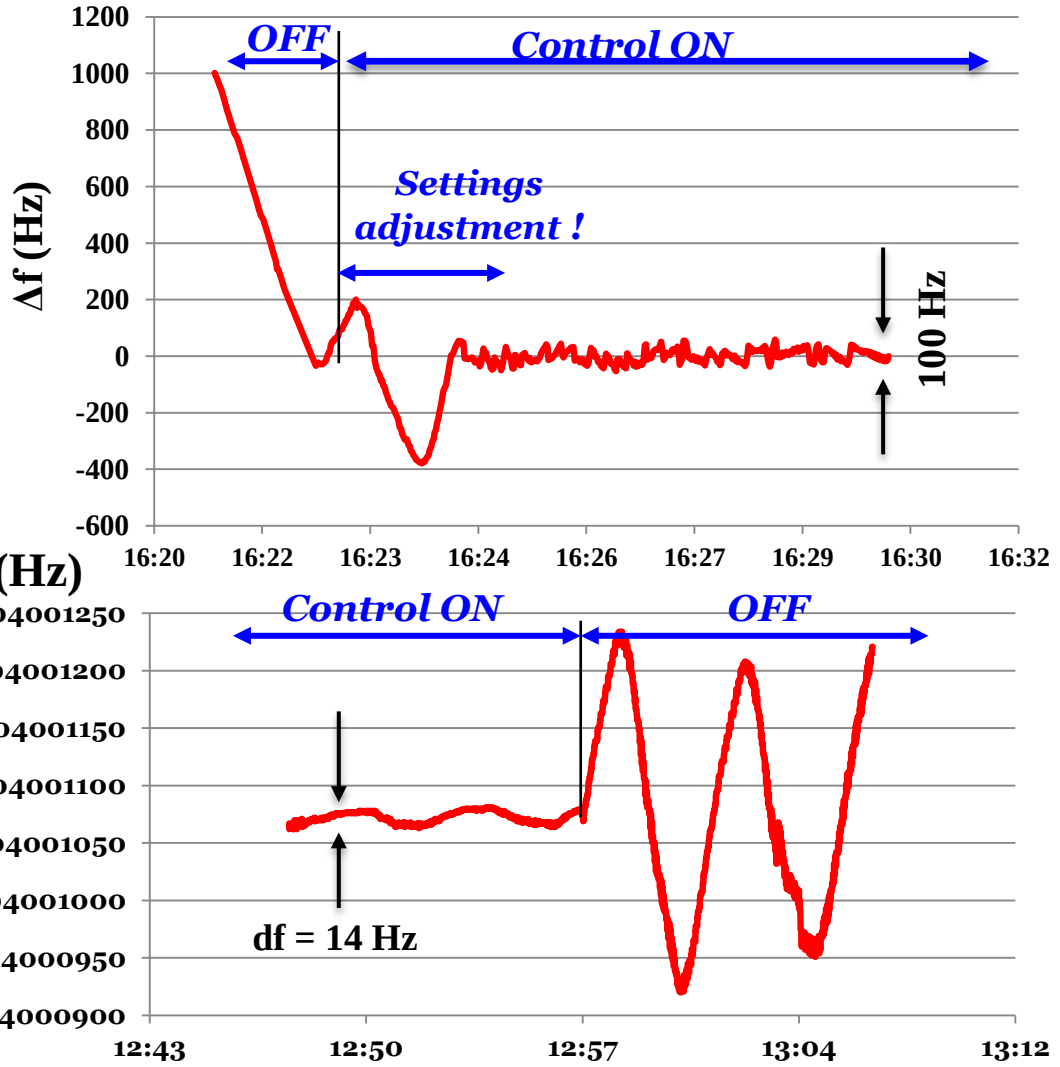
CTS: Control test

N. Gandolfo

❑ Motor control algorithm

- Si f > fo + 50 Hz :
  ➡ Moteur execute -N pas
- Si f < fo - 50 Hz :
  ➡ Moteur execute +N pas

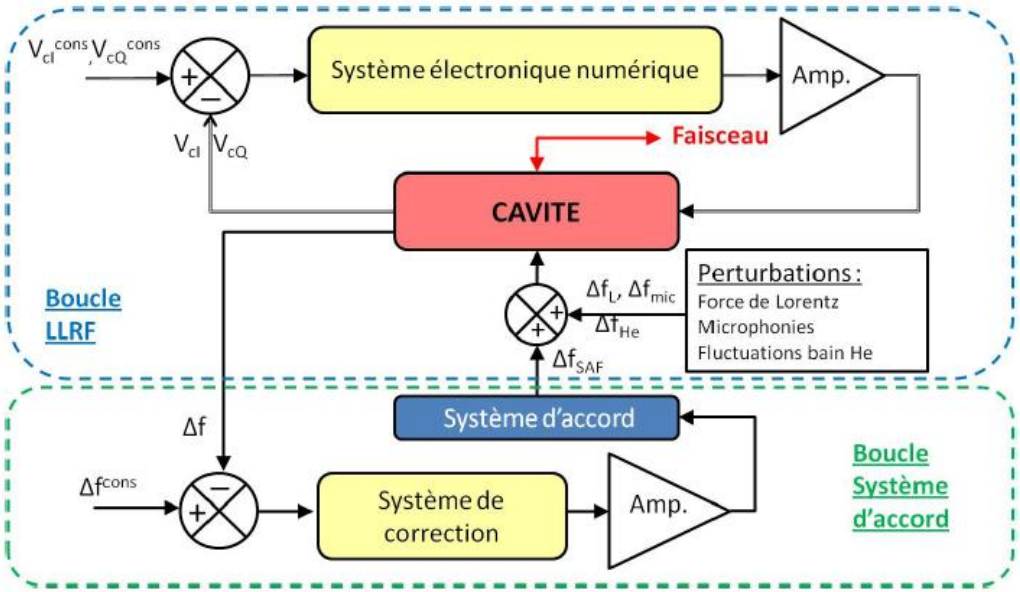
❑ Piezo control : PI correction



Perspectives: Qualification of coupled control systems

Required elements

- Cavity + coupler + CTS
- Cryomodule
- IOT
- Digital LLRF loop
- Piezo digital control board



Main objectives

- E_{acc} and phase regulation with DLLRF loop.
- Optimization of the CTS control loop (comparison PID/ ADEX Control) (**See the talk of Isaias**).
- Qualification with coupled control CTS+ DLLRF during fast set points change (fault compensation scenario)

Conclusion & Roadmap

- Successful Commissiong of the Cryomodule at high power and at 2K.
- The Cavity reaches 14 MV/m as foreseen.
- The Cavity is very soft mechanically as expected.
- Microphonics and CTS measurements.
- Goal June 2014: reliability-oriented experiment with Digital LLRF + Cold tuning system + ADEX smart control to validate the fast fault recovery procedure.

I Would like to Thank you very much for your attention