EURISOL DS Project
Task 8: SC cavity development

Deliverable D7
Final report on spoke cryomodule test

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To assess that spoke cavities are capable to efficiently accelerate particles with the designed performances, one key test consists in a cold test of a superconducting spoke cavity fully equipped with all its ancillaries systems: Helium tank, power coupler, cold tuning system. Such a test allows addressing almost all potential difficulties in the operation of a superconducting cavity in a real accelerator. The mechanical, thermal, and RF behaviour of the full system is tested in a cavity configuration close to the final one in the accelerator.

The spoke cryomodule is composed of two main components (Fig. 1 & 2)

- The vacuum tank, which is hosting the cavity and its ancillaries, an helium dewar, the cryogenic piping and instrumentations.
- The “cold box”, external to the cryomodule, which provide the module with the cryogenic fluids (liquid, gas).
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The module was designed to be a laboratory test stand to test several spoke cavity types under several configurations. The main requirements were the following:

- The cryomodule was conceived to have dimensions long and wide enough to host a fully equipped spoke cavity, low or medium β.
- The temperature operation point is 4.2 K but both module and cold box have the possibility to operate using a depressed helium bath to perform cavity tests at lower temperature (typically 2K).
- The power coupler could be mounted with 2 different configurations: a vertical position (better for mechanical reasons), or with a 45° inclination with respect to the vertical position (potentially better for the spoke bar cooling by liquid helium)

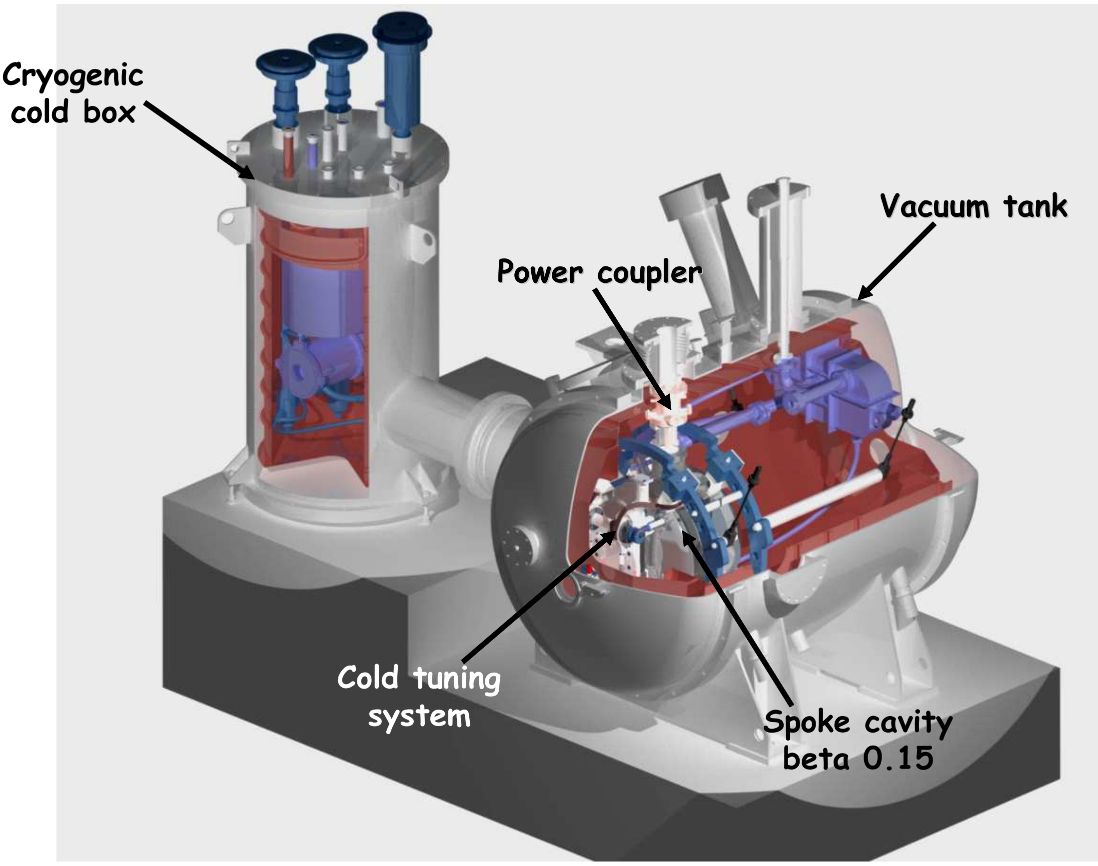

Figure 1: Sketch of the spoke test cryomodule and its associated cold box

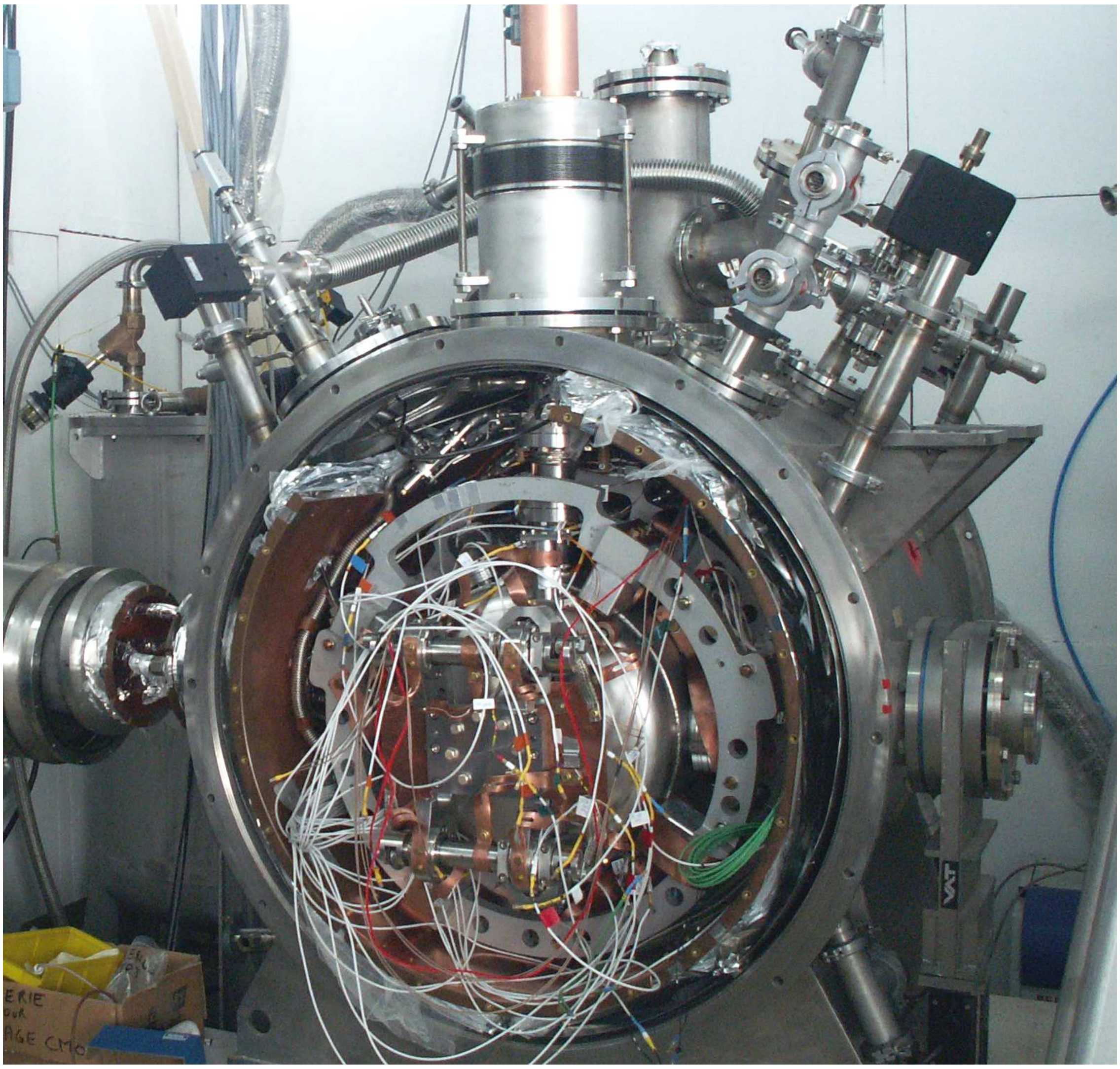

Figure 2: Picture of the spoke test cryomodule and its associated cold box

At IPN Orsay, the last preparation steps of this final test have been done in the Supratech infrastructures. In the class 10 clean room, the beta 0.15 spoke cavity was prepared before its assembly. The cavity has been removed from the cryomodule, underwent a high pressure water rinsing at 100 Bars with ultra-pure water (resistivity of 18.2 MΩ.cm-1). The power coupler, dismounted under the clean room laminar flow from the conditioning cavity has been mounted on the spoke cavity. The cavity/coupler assembly was pumped out and a final leak check was performed, in order to assess the vacuum tightness of the assembly. The module final assembly was then performed: the cavity/coupler assembly was inserted into the module vacuum tank. The coupler external coaxial conductor and the below was mounted. The cavity tuner and all the instrumentations were then installed (Fig. 3).

The complete assembly was then installed into the cryogenic test stand. The INFN/LNL 10 kW power amplifier was connected to the module by means of a coaxial standard rigid RF line, the cold box connected to the module cryo-fluids inputs and outputs. The 352 MHz low level digital RF controller developed by IPN Orsay and LPNHE laboratories was used to control the RF excitation of the cavity.

For this experiment, we have set the different parameters to simulate a coupler and cavity operation such as the cavity was set to accelerate a beam (i.e. operation with beam loading). The

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coupling factor of the antenna to the cavity was set to 1.10^6. In this configuration, but without beam, most of the incident RF power is reflected into the RF line, and the maximum achievable field in the cavity is about 1 MV/m. The main objective is to test all the RF line and the coupler up to the cavity flange at the nominal RF power.

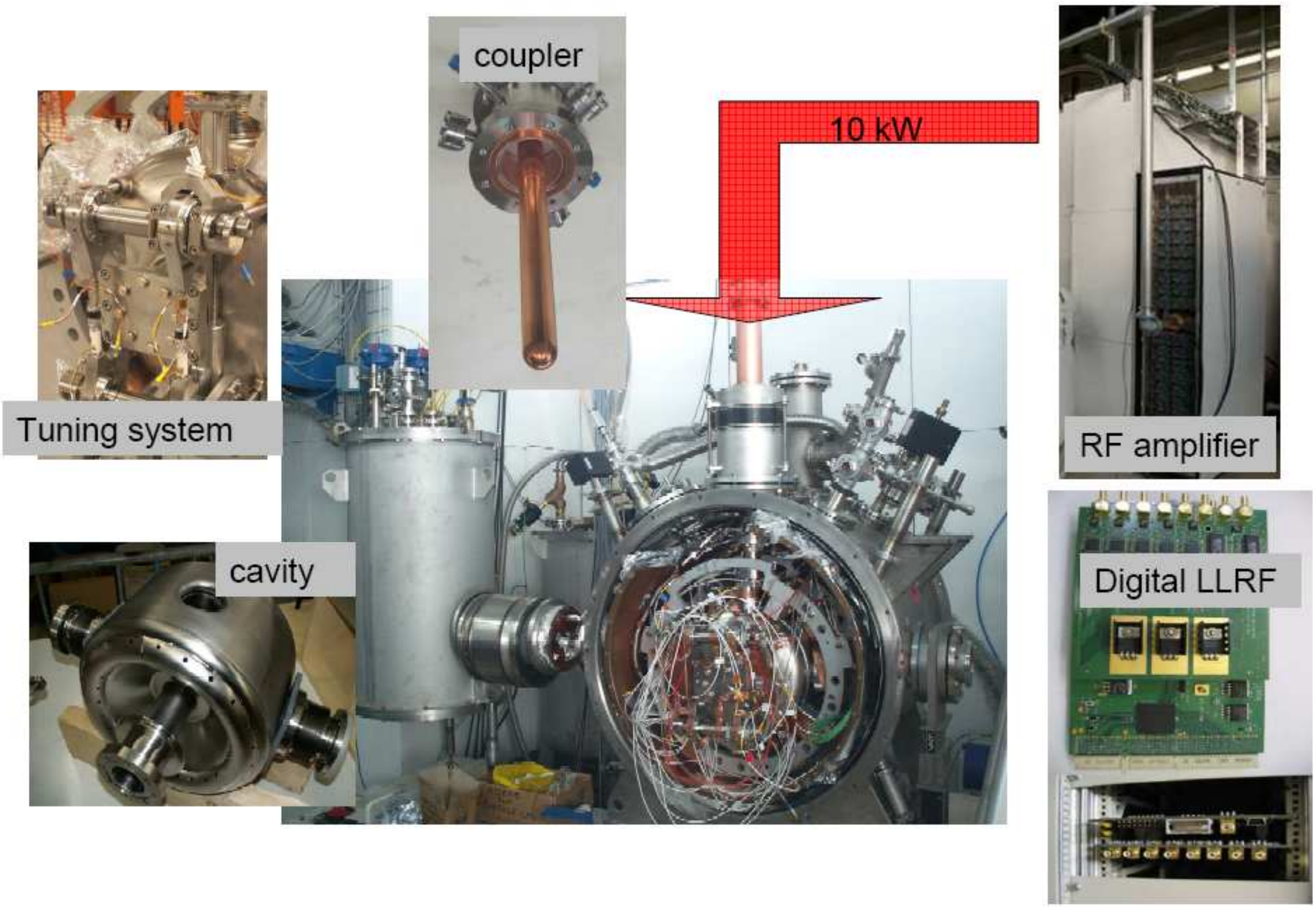

Figure 3: Spoke cryomodule and its auxiliaries ready for test at 4.2 K

The main results of this final experiment are the following:

- The cryogenic operation of the cryomodule was successful: modifications performed afer a first cryogenic test allow to efficiently cool the entire systems, including the cold tuning system (CTS), without having important temperature differences between the cavity and the CTS for instance.
- The coupler was easily conditioned in-situ in less than 2 hours: 5.5 kW or RF power was transported thru all the RF line, thru the ceramic window up to the cavity flange in a detuned mode (out of the cavity resonance). The heating of the ceramic window was not an issue.
- The estimated Qo (a precise measurement is impossible with a high RF coupling) showed that the magnetic shielding was efficient and that the power coupler has no influence on the cavity dissipation at low accelerating fields.
- The CTS operation was successful: the system operated perfectly, without any mechanical problem and only a minor hysteresis. A frequency regulation was performed, and a +/- 10 Hz regulation was obtained over several hours (Fig. 4 and 5).

- A cryogenic test at 2K was also performed, just to check to overall capability of the whole system to operate with a depressed helium bath. This configuration might be an alternative to a 4 K operation because increased performances could be obtained on the spoke resonators, at a rather low price because the in the EURISOL driver linac layout, the next accelerating section is operating at 2K (elliptical cavities).

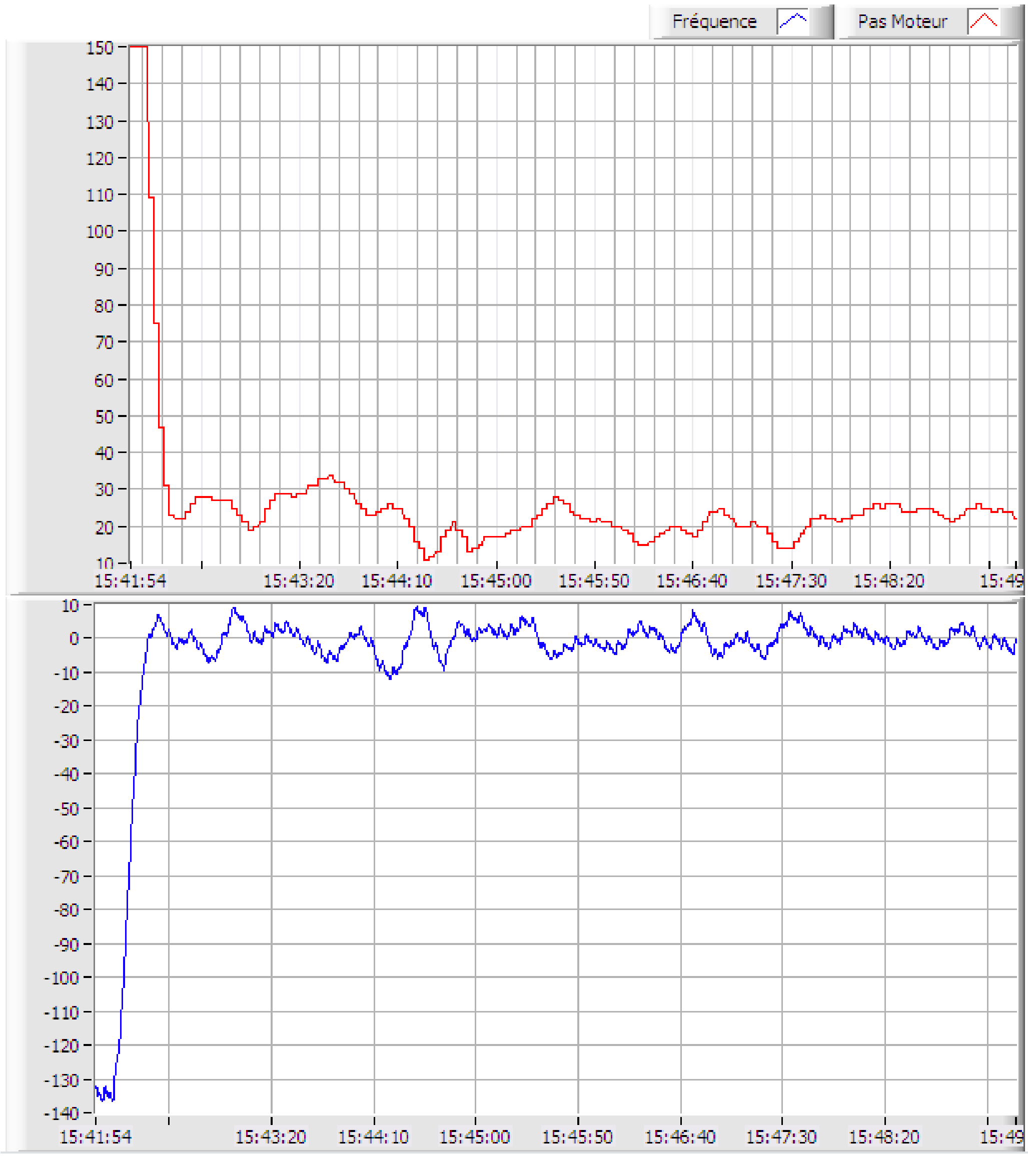

Fig. 4: experimental curves showing the frequency regulation obtained with the spoke CTS during the cryomodule test at 4.2 K. Top curve is the motor displacement (step motor number) as a function of time and bottom curve is the obtained frequency error in Hz with the same horizontal time scale (here only a few minutes).

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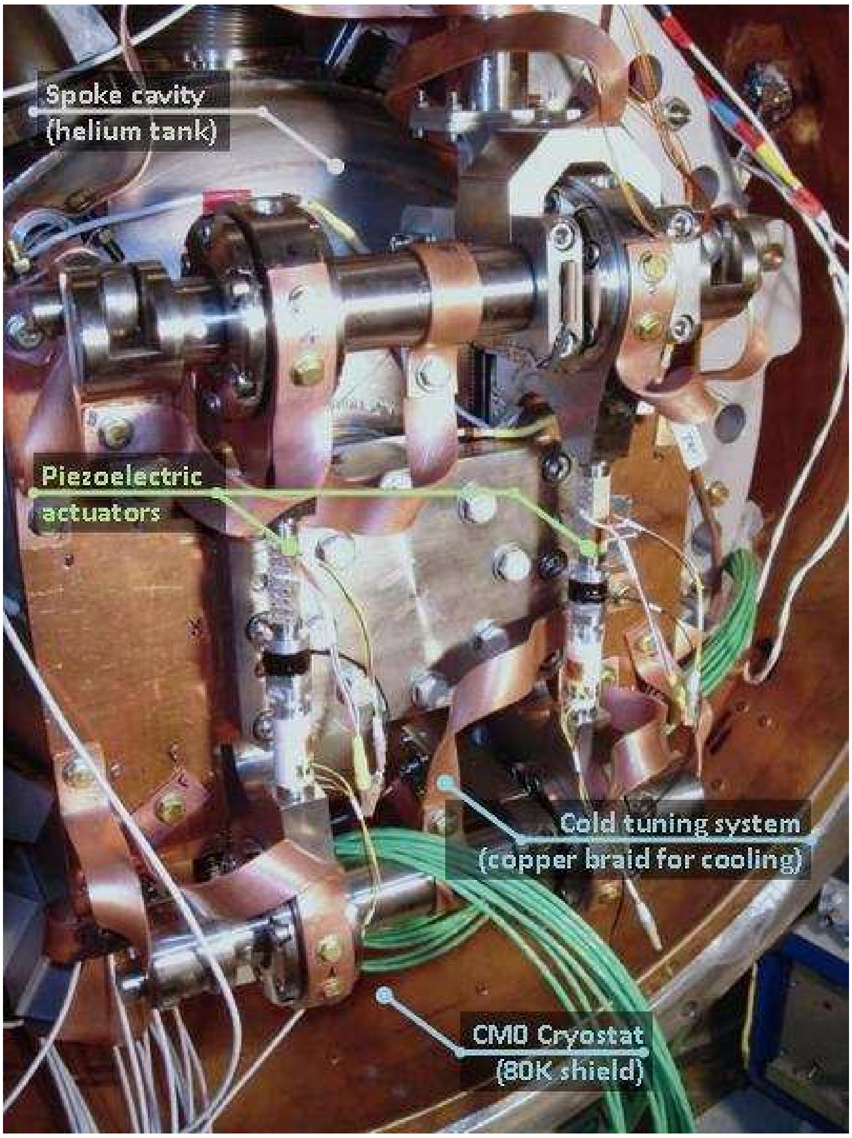

Fig. 5: Spoke CTS with its piezo actuators.

A test was also performed with the piezo actuators. They were used to regulate the cavity resonant frequency over a small range. The results are shown in figure 6: we succeeded in the frequency regulation with a sensitivity of about 100 Hz / µm.

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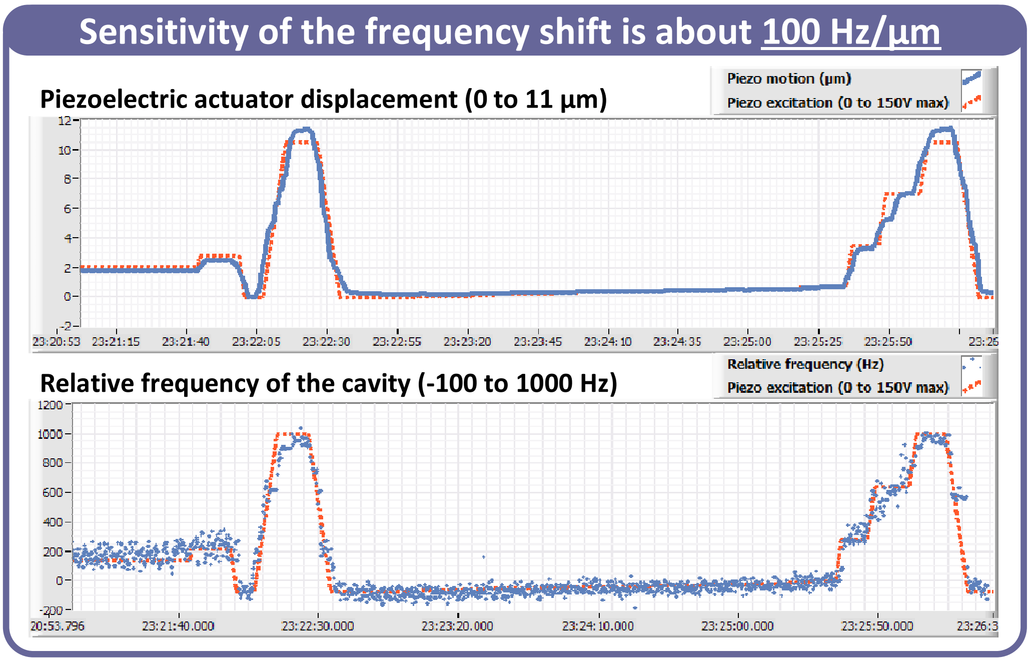

Fig. 6: Cavity resonant frequency control using the piezo actuators during the experiment at 4.2 K inside the cryomodule

This final experiment on a spoke cavity fully equipped with its helium tank, power coupler and cold tuning system showed the efficiency of the full accelerating system design (cavity, tuner, power coupler). This experiment is an important and decisive step towards the final proof that spoke cavities are an efficient solution to accelerate intense protons beams.

An experiment was envisaged within the EURISOL-DS program to use the low current beam of the IPN Orsay tandem accelerator to “feed” the spoke cryomodule, and then to test a spoke cavity with beam for the first time. Unfortunately, due to the important development of the ALTO facility at the tandem, not enough time and space frame were found to develop this complex experiment.

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