

## TESTS OF WIRE SUBLIMATIONS VERY CLOSE TO SPIRAL 2 SUPERCONDUCTING CAVITY

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### Abstract

The construction of the new Spiral 2 facility has started in Caen (France) at the National Heavy Ions Accelerator Center (GANIL). The SPIRAL 2 project is based on a multi-beam Superconducting Linac Driver delivering 5 mA deuterons up to 40 MeV and 1 mA heavy ions up to 14.5 MeV/u delivering different Radioactive Isotope Beams (RIB). The LINAC is composed of 2 cryomodule families. The low energy family (cryomodules A) is composed of 12 cryomodules housing a single superconducting cavity at  $\beta=0.07$ . The "high" energy family (cryomodules B) is composed of 7 cryomodules housing 2 cavities at  $\beta=0.12$ . In between cryomodules are located the focalisation quadrupoles and the diagnostic boxes. Their multiplication may lead to cavity pollution. Strong believes forbid the use of interceptives diagnostics around superconducting cavities. We simulated the use of wires for diagnostics in the linac, sublimating 14 wires of tungsten, niobium and carbon while operating the cavity B at full performances. The results describe in this paper looks promising.

### DESCRIPTION

The objective for SPIRAL2 is to produce light ions (deutons, protons) up to 5 mA and a large diversity of heavy ions with intensities up to 1mA, including noble gases like  $Ar^{12+}$  and metallic ions like Cr, Ni and Ca. The Injector, dedicated to protons, deuterons and ions of  $q/A=1/3$ , is mainly composed of two ECR ion sources with their associated LEBT lines, a warm RFQ and the MEBT line connected to the LINAC.

The LINAC is based on superconducting independently-phased resonators [1,2]. It is composed of 2 families of quarter-wave resonators (QWR) at 88 MHz, developed respectively by the CEA/DAPNIA and the IN2P3/IPNO teams: 12 resonators with  $\beta=0.07$  (1 cavity/cryomodule) [3], and 14 resonators at  $\beta=0.12$  (2 cavities/cryomodule) [4] (see Figure 1). The transverse focusing is ensured by means of room temperature quadrupole doublets located between each cryomodule. Additional dipolar coils are installed into the quadrupoles in order to compensate the steering effect of QWR cavities and eventually adjust the optimum beam position. These 20 "warm" sections (Figure 2), as opposed to the superconducting cavities, include also beam diagnostic boxes with different sensors types. The specifications require 20 Beam Monitors, 10 TOF and 6 phase length measurement devices and 20 vacuum pumping systems.

The multiplication of warm sections in such superconducting accelerator may lead to pollution problems and degradation of cavities performances.

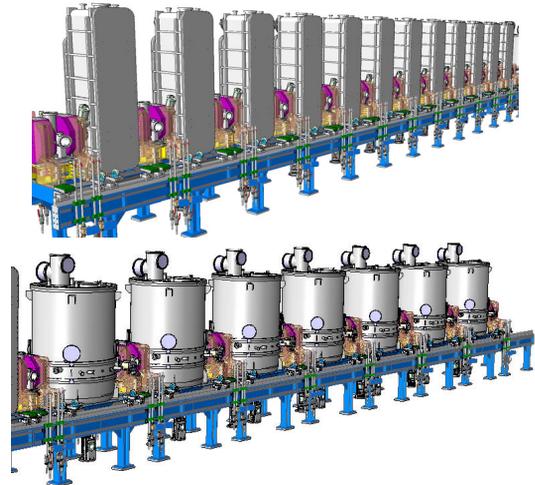


Figure 1: SPIRAL2 superconducting cryomodules (top:  $\beta=0.07$ , bottom:  $\beta=0.12$ ).

One of the main beam diagnostic devices is the Beam Monitor (BM) which will measure more than the classical position of the centroid of the beam in the beam pipe of the accelerator. It plays a role of prime importance for the accelerator tuning and control. These capacitive sensors BM are located in the LINAC between the LINAC's cryomodules and are mechanically integrated to the beam pipes into the quadrupole bore. The BMs give the classical beam positions, beam time of flight and possible phase information and current. Because of the non-cylindrical symmetry of the beam at this location, the signals return also information on quadratic moment related to the beam size. We expect CW operation as well as low duty factor pulsed mode operation. A  $\pm 0.1$ mm resolution is foreseen and this criterion must be strongly taken in account for the mechanics and the electronics.

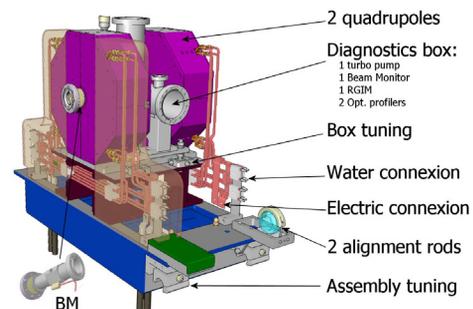


Figure 2 : Schematic of the "warm" section in between cryomodules.

The reference longitudinal diagnostics is the GANIL Residual Gas Ionization Monitor (RGIM) profiler [5] based on electron production resulting of the beam interaction with the residual gas (resolution 100 ps for a

10 mm beam, see Figure 3). They are equipped with micro-channel plate for amplification. This system does suffer of various difficulties like fixed errors, low response with a good vacuum, being fragile, but they are non interceptives.

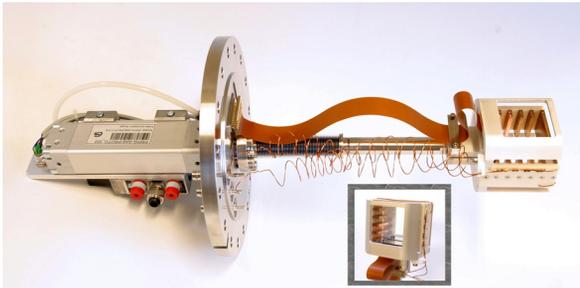


Figure 3 : RGIM diagnostic

Both the transverse and the longitudinal diagnostics will be difficult to build and tune and may suffer from low performances. Backup solution relies on interceptive wires used in pulse mode like S.E.M. Harp Profilers or wire scanners. This is not decided yet. We may be obliged to use them during the commissioning of the machine.

The use of interceptive diagnostics, located at about 70 cm from the superconducting cavities may result in serious malfunctions. Calculations showed that at these energies there are almost no sputtering from the beam on the wires. Nevertheless, from time to time the wires might be destroyed for various reasons: too long beam pulses, wrong beam focalisation, material fatigue etc... We fear quenches from such wires damages, permanent X-ray emission or overall degradation in cavities performances. The degradation of wires is not supposed to take place, and usually result from human errors. We count on none or low break frequency. It was decided to test the use of such wires during cavities operation at full power.

## TEST DESCRIPTION

The objectives of the test stand were multiples: analyse the influence of the wires close to a superconducting cavity, analyse the influence of the cryomodule (specially the X-rays emissions) on a RGIM device equipped with micro-channel plate, analyse the outgassing of the diagnostic box and its consequence on the cavities. Finally, a cohabitation test between the RGIM and an ionic pump was performed.

The cryomodule was assembled with two cavities, one with the power coupler and one with a  $\beta=1$  coupling. The diagnostics box was put at its normal location, but without the quadrupoles and the BM. The cavity vacuum was pumped either through the diagnostics box or through the other end of the cryomodule. On the diagnostic box, 2 types of pumps were successfully installed: a turbomolecular pump with a dry primary pump or an ionic pump. A residual gas analyser (RGA) was installed on the diagnostics box, as well as a gas dosing valve for various gas injections. Schematics are given Figure 4.

For the wire sublimation tests, two sets of 7 wires were successfully inserted in the diagnostic box, in front of the

cavities aperture. The distance between the sublimated wires and the center of the cavity was 70 cm, the distance being only 51 cm from the first superconducting surface. Each set included two 30  $\mu\text{m}$  carbon wires, two 30  $\mu\text{m}$  niobium wires, one 70  $\mu\text{m}$  tungsten wire and two 150  $\mu\text{m}$  tungsten wires. The wires were successfully sublimated with a controlled current power supply, while the cavity was working at full power (6.5 MV/m, about 1 kW RF power injected, 0.15 W transmitted). Every cavity parameters were recorded, as well as temperatures, helium consumption and un-calibrated X-rays emissions. The vacuum pressure was also recorded and images taken with a CCD camera (Figure 5).

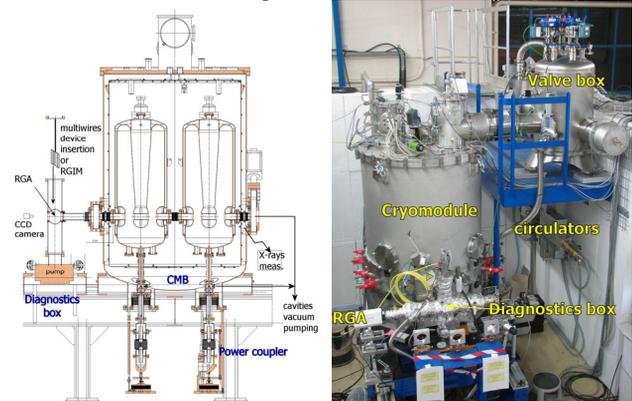


Figure 4 : Drawing and image of the setup.

## SUBLIMATION RESULTS

The multipactor barriers being easily passed with the power coupler, it was chosen to make the tests in front of the cavity with the power coupler.

As soon as a wire is warm to white, the X emission and the cavities vacuum increased slightly. The level of X-rays reached 1 to 5 mSv/h at 20 cm from the beam axis exit, and the pressure about  $2 \cdot 10^{-6}$  hPa. A strong outgassing occurs when it breaks.

Unfortunately the first set of 7 wires was not very useful as a mix was observed between the wires. Also, some wires did short-circuit the others. Nevertheless the 7 sublimations did not induce any noticeable effect on the cryomodule performances, and the outgassing was of no noticeable effect on the set up.

The second set was used more carefully. We started with the 2 carbon wires, then the 3 tungsten ones and finally the 2 niobium wires. The 2 first sublimations did induce a quench in the cavity. The X-ray level went up by 50%, and stayed there, meaning that a carbon emitter was "glued" on the superconducting surface.



Figure 5: CCD camera views of a tungsten wire before sublimation (on the left) and during its breaking (right).

All the other wires induced a 2 to 20 times pressure increase for a short period (cf. Figure 6). None of the other cavity parameters evolved. We observed difference between the Nb wires and the W wires only on the pressure increase. It is most probably due to the wire diameter difference. The Nb wires were also extremely difficult to put in place, being easily broken. As they did not improve anything during the test, they will not be used for the drawback profiler solution.

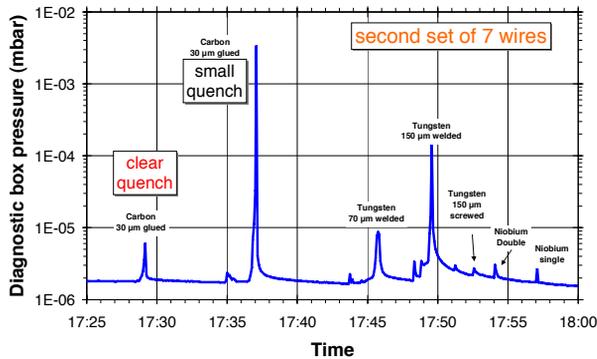


Figure 6: Outgassing during wire sublimation.

### RGIM RESULTS

The tests with the RGIM were made first with the ionic pump off, as well as the Residual Gas Analyser, in order to minimise the background noise. The superconducting cavities did not generate noise on the micro-channel plate of the RGIM, as soon as the multipactor barrier was over. The X-ray level dropped to about 30 mSv/h at the nominal cavity working point. Nevertheless this is not enough to validate the device, since the returning beam profile can also be modified by the electrostatic field of the cavity.

The ionic pump generates a lot of parasitic signals, making it incompatible with its use in a real machine. At a pressure level of  $10^{-8}$  hPa, as it is expected in the machine, it should be kept acceptable, but it is a challenge.

### GAS POLLUTION RESULTS

The warm section will be backed at 150°C, and the expected outgassing will consist mostly of hydrogen. The multiplication of warm section compare to other linac design may result in more vacuum leak and hydrogen gas pollution than normally acceptable. The hydrogen at  $10^{-8}$  hPa and 4.5K is not pumped. Hydrogen is pumped for a partial pressure of  $1.3 \cdot 10^{-6}$  hPa for cavities at 4.4 K.

The pollution test consisted in injecting either hydrogen or filtrated room air for about an hour in the 2 cavities. The cavity performances were then tested, once the vacuum was good enough for RF injection. The injected gas quantity was equivalent to one year of continuous pollution. The pressure was about  $2 \cdot 10^{-6}$  hPa with the hydrogen and  $4 \cdot 10^{-8}$  hPa with the air.

The effect of the pollution was not evident. Just after injection the  $Q_0$  was slightly degraded. After a week end at about 80k, the performances were up again (Figure 7).

The resulting curves could also be in the errors bars.

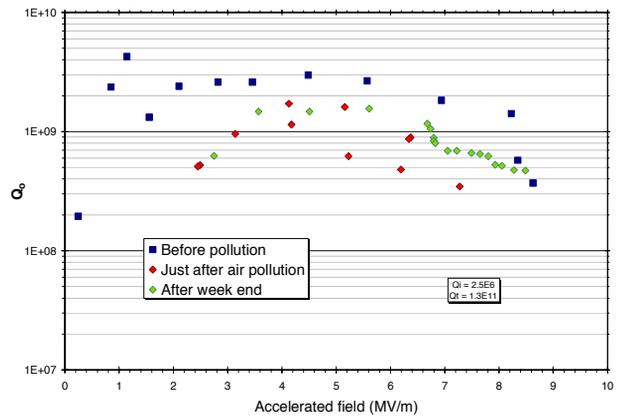


Figure 7: Cavity performance before and after pollution.

### CONCLUSION

First tests of the wire sublimation were very encouraging. If we clearly suffer from 2 carbon wires sublimations, 12 sublimations of tungsten and Nb wires did not induce any noticeable change in the cryomodule parameters. We need more statistics, but the use of wires for beam parameter measurements close to the cryomodules might be contemplate as a drawback solution if the other diagnostics do not provide the expected performances. It is foreseen to make such tests close to the first cryomodule family ( $\beta=0.07$ ) in order to complete the statistics.

### ACKNOWLEDGEMENTS

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