DESIGN OF THE MEBT REBUNCHERS FOR THE SPIRAL2 DRIVER

M. Di Giacomo, JF Leyge, M. Michel, P. Toussaint, GANIL, Caen, France

Abstract

The SPIRAL2 project uses room temperature RFQ and rebunchers and a superconducting linac to accelerate high intensity beams of protons, deuterons and heavier ions. All cavities work at 88 MHz, the beta after the RFQ is 0.04 and 3 rebunchers are located in the MEBT line, which accepts ions with A/q up to 6. The paper describes the RF design and the technological solutions proposed for an original 3-gap cavity, characterised by very large beam holes (60mm) and providing up to 120 kV of effective voltage.

INTRODUCTION

The SPIRAL2 [1] driver presents a quite long medium energy beam transport line (Figure 1) to insert a second beam line from a future RFQ for heavier ions: q/a=1/6, a single bunch selector and the corresponding beam dump. The line is seven and a half meters long and is equipped with three rebunchers to keep the beam longitudinal phase dimension.

Room requirements for all the devices are very tight and the cavities have to be compact on the beam axis direction. Moreover, the beam transverse section can be quite large in the line, then the beam aperture in the cavity drift tubes is much longer than the tube length and the gap electric fields interact with each other. The Transit Time Factor (TTF) is consequently quite low and voltages higher than usual have to be applied on the electrodes to obtain the required effective voltage.

REBUNCHER REQUIREMENTS

The first and the last cavities will work at an effective voltage of 120 kV with the heaviest ions while the second one will work at 60 kV CW only. For the RFQ initial commissioning, only the first cavity will be installed before the diagnostic test bench and pulsed voltages up to 190 kV will be used for emittance measurements.

The line beta is 0.04 which is a reasonable figure with respect to the injector working frequency of 88,0525 MHz.

RF DESIGN

To keep the longitudinal length of the cavity as small as possible and to handle reasonable values of RF power and electric field, a 3-gap structure has been chosen. The double quarter wave resonator of Figure 2 has been preferred to the more usual split ring, to have right stems with more homogeneous loss, easier cooling opportunities and better alignment guarantees. The central part of the tank has a square section to host the beam ports and the tuner (trimmer) while the rest of the tank is cylindrical. The stems are conical to progressively increase the diameter from the drift tube end (where it couldn't be bigger) to the short circuit. The drift tubes are spaced in order to obtain the required beta value and to limit the maximum electric field.

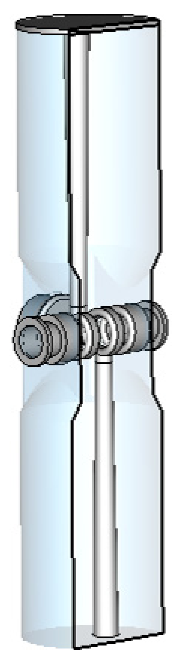
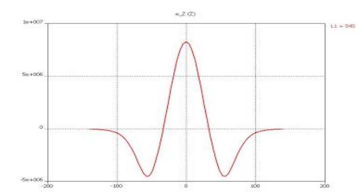
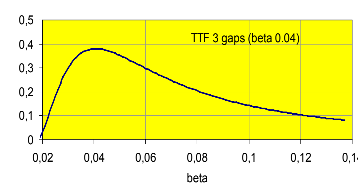
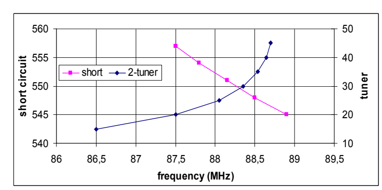


Figure 2: The RF structure.



Electric field on the beam axis (@1 joule of stored energy)





Tuner and shorting plate responses

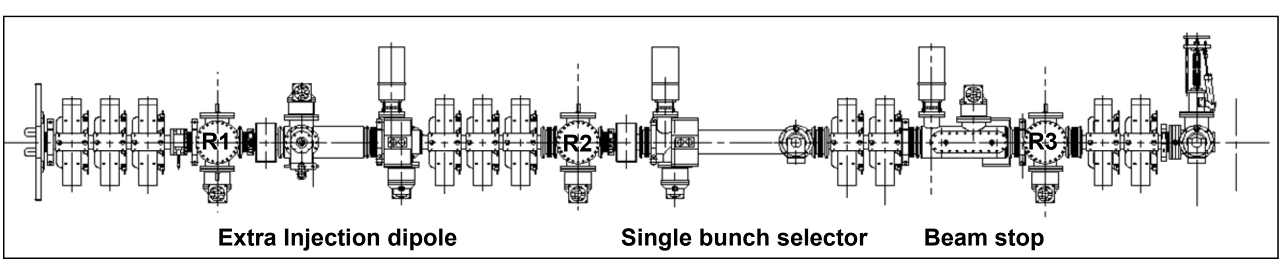


Figure 1: The medium energy beam transport line.

The cavity was simulated with Microwave Studio. Tables 1 and 2 recall geometrical dimensions and RF parameters.

Table 1: RF Cavity Simulated Geometry

Parameter	**mm**
Beam diameter	60
Ring external diameter	90
Electrode ring length	32
Gap distances	13, 30, 13
Trimmer diameter	130
Trimmer stroke	15 to 45
Stem diameters	32, 40
Cavity central section sides	180x180
Cavity central section height	2*152
Cavity inner diameter	260
Cavity height	2*545
Flange to flange distance	280 mm

Table 2: Results of Simulation with Microwave Studio [2]

Electrode voltage (@120 kVeff)	79 kV
TTF	0,38
Q	7600
Rs (effective voltage^2/ power)	3680
Power loss (@120 kV)	4 kW
Max E field (pulsed)	11 MV/m
Max H field (pulsed)	17,4 A/m

Tuner

Two capacitive panels are located on the side of the drift tubes. This solution has been preferred to an inductive plug on the short circuit area, where the stroke would have been longer and the sliding RF contacts more sophisticated due to the high magnetic field. Both panels are used to set the resonant frequency, in such a way that their position is symmetrical at 4 kW power level, but only one is motorised to be driven by the fine tuning loop. Their diameter has been designed in order to require a stroke of few centimetres. In this way, as shown in Figure 3, it has been possible to use flexible belts screw on both sides to transfer RF currents and heath.

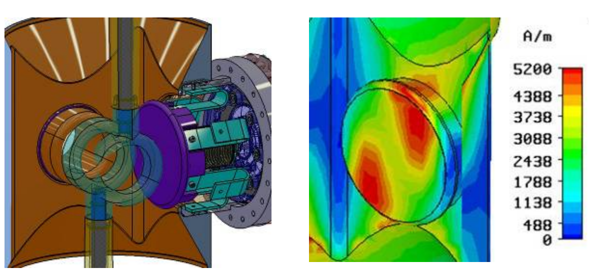


Figure 3: a) The tuner with flexible belts for RF and thermal contact; b) the current distribution.

RF Loss on each plate at maximum voltage depends on the position but is of the order of few tenth of watt. The maximum current density in the belts is around 12 A/cm.

Coupler

A power loop situated on the bottom end of the tank matches the cavity to the 50 ohm transmission line from the amplifier. The presence of the coupler slightly changes the field symmetry but simulations have shown that field asymmetries introduced by the presence of the coupler and by a misalignment up to ±0.75 mm of the drift tubes don't perturb the beam dynamics.

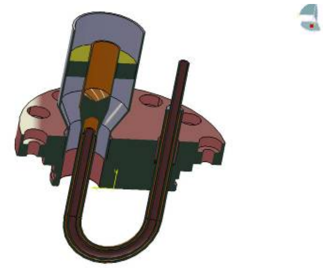


Figure 4: The coupling loop.

THERMAL AND MECHANICAL STUDIES

External tanks made of thick copper or of copper plated stainless steel sheet have been studied. Use of steel was excluded in order to keep the possibility of plating the cavity again in case of problems after the first process. A minimum thickness of 5 mm was required for radiation protection. Thermal calculations were made with a margin factor of 1.5 applied to the loss distribution. In the case of the copper plated tank, special attention was paid to put the cooling channels along the warmest areas, while no special care was taken for the copper one. The temperature maps with input water at 26°C.are shown in Figure 5.

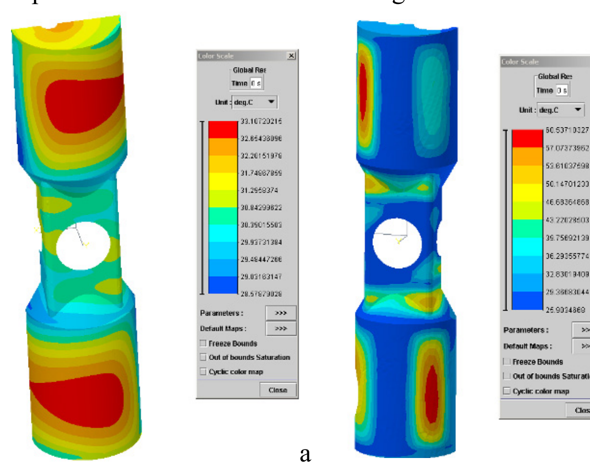


Figure 5: Temp. maps: a, solid copper, b: plated.

The copper structure stays very cold and maximum temperature difference is only of few degrees. The plated cavity warms up more but the hottest spots stay below 60 degrees. Displacements along the 3 axes of the points where the stems are connected stay below 0.1 mm.

Mechanically, the tank is built of three parts, welded before being copper plated. The central section is machined from a solid block for more precision, while the cylindrical parts are made of formed sheets. All other elements of the cavity are made of solid copper.

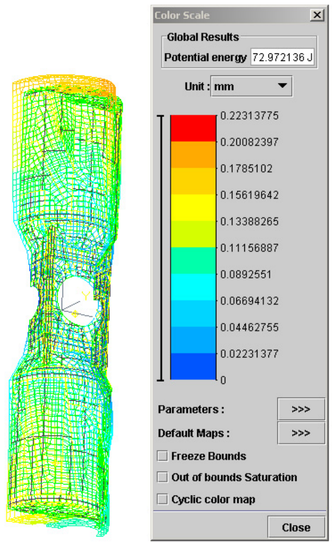


Figure 6: Deformations of the steel structure.

For the beam ports, the drift tubes and the trimmers; this is to avoid deterioration of the RF surface in case of sparks, while for the stems and short circuit plates this is to improve cooling and limit deformations. Figure 7 shows mechanical assembly of all elements.

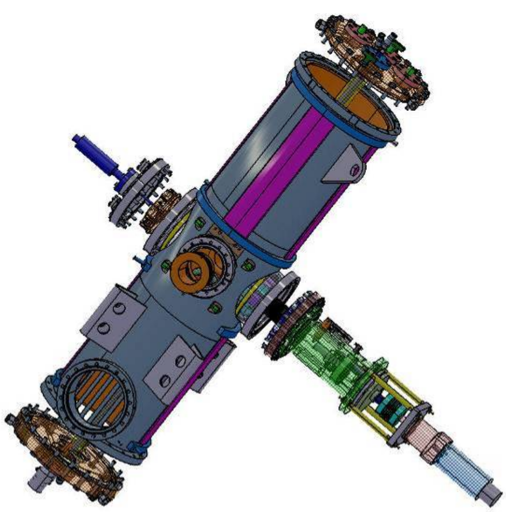


Figure 7: Cavity assembling.

The drift tubes and beam ports are cooled by thermal conduction through the stems or the tank. The stems are cooled by a continuous layer of water flowing inside the stem (Figure 8). Total displacements of the whole structure induce a misalignment of the electrode axis of only few tenths of mm. The tuner sensitivity around the nominal distance of 25mm gives good margins to lower the resonant frequency but not to increase it. Then the shorting plate is designed with an over-thickness to be adjusted after frequency measurements.

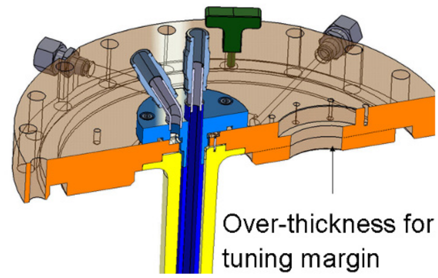


Figure 8: Stem cooling circuit and tuning margins.

HIGHER FREQUENCY APPLICATION

In the framework of the collaboration between the projects, the application of the SPIRAL2 design to the Saraf linac has been studied. Saraf works at 176 MHz, beta 0.056, but the beam diameter is 100 mm and only 100 kV are required. The geometry on Figure 9 fits the requirements, with a total length on the line around 200 mm and losses of the order of 3 kW.

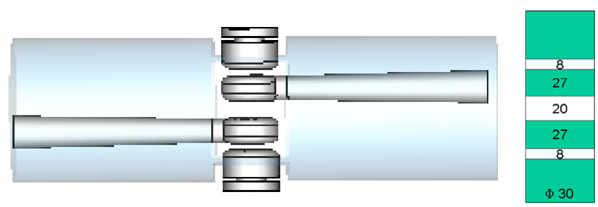


Figure 9: 176 MHz, beta 0.056 cavity and electrode geometry.

CONCLUSION

An original RF structure has been designed to fit the SP2 requirement for the MEBT rebunchers. The proposed cavity grants high gradient, compactness along the beam axis, tight alignment tolerances. The cavity design is completed and a call for tender in progress.

ACKNOWLEDGEMENTS

Many people have been involved in this work but we would particularly mention D. Uriot for beam dynamics simulations, G. Le Dem for field maps macros, M. Malabaila and T. Dettinger for their explanations about the copper plating process and M. Vretenar, H Vormann and their teams at CERN and GSI for their help and comments on the overall design.

REFERENCES

[1] T. Junquera et al., Status of the construction of the SPIRAL2 accelerator at GANIL, Proc. Linac 08.
[2] MWS, Computer Simulation Technology, Darmstadt, Germany.