EURISOL DS Project
Task 8: SC cavity development

Deliverable D4
HW resonators study and fabrication (coupler & tuner) - Two HWR prototypes

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Half-Wave resonators (HWR) are particularly efficient in a beam velocity range of $0.06 < \beta < 0.4$ and a frequency between 150 MHz and 350 MHz. They can efficiently accelerate high power hadrons beams just after the RFQ, at the same frequency. HWR are the preferred technology for the EURISOL beam acceleration between the RFQ exit and ~60 MeV/u.

1. Half-wave resonators developments at 352 MHz

The first development was performed on HWR at 352 MHz, taking experience from previous development for the SPES project. The design of the two cavities at different beta (0.31 and 0.17) is shown in figure 1. Two different shapes for the inner conductor were used (flattened and cylindrical). They are characterized by a double-wall coaxial structure with an integrated helium vessel (Fig. 2). The beam port aperture is 30 mm, and they are equipped with a 1+5/8"port for a coaxial RF coupler. Two more 16 mm diameter ports are available for RF pick-up.

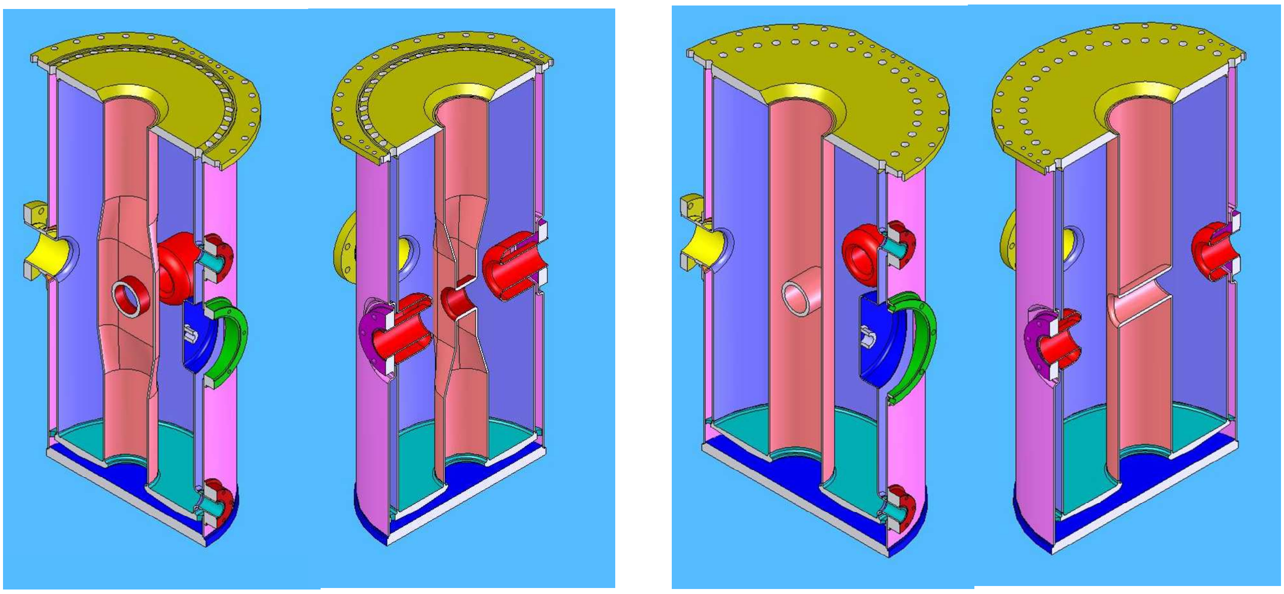

Fig. 1 : β 0.17 (left) and β 0.31 (right) 352 MHz HWR geometry

The outer niobium wall (helium jacket) is made of reactor-grade niobium. The β 0.17 cavity top and bottom plate is made of titanium and welded to the resonator, while for the β 0.31 prototype, these plates were made of stainless steel connected to the cavity by means of an indium seal. The pictures of the two fabricated cavities are shown in figure 2.

The calculated RF parameters are given in the table of figure 3.

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Fig. 2 : Pictures of the two 352 MHz HWR prototypes

β_0	0.17	0.31	
U/E_a^2	0.067	0.086	$J/(MV/m)^2$
B_p/E_a	12	10.4	$mT/(MV/m)$
E_p/E_a	5.8	3.9	
R_{sh}/Q_0	1230	1180	Ω/m
$R_s \times Q_0$	55	66	Ω
Tuning df/dh	~70	~107	*kHz/mm*
Active length L	180	224	*mm*
Maximum Length L_{re}	232	286	*mm*
Aperture a	30	30	*mm*
Design E_a	5	6	*MV/m*

Fig. 3 : Main RF parameters of the two 352 MHz HWR prototypes

Both prototypes have been tested at 4.2 K at Legnaro in vertical cryostat (Fig. 4).

The results are shown in Fig. 5 and Fig. 6. Very good results were obtained with a maximum accelerating field of 6.8 MV/m for the low beta one, and 7.9 MV/m for the high beta. One has to mention that these good performances were obtained despite the lack of a standard cavity preparation (no high pressure rinsing).

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Fig. 4 : Half-wave resonator mounted on the cryostat insert just before the cold test

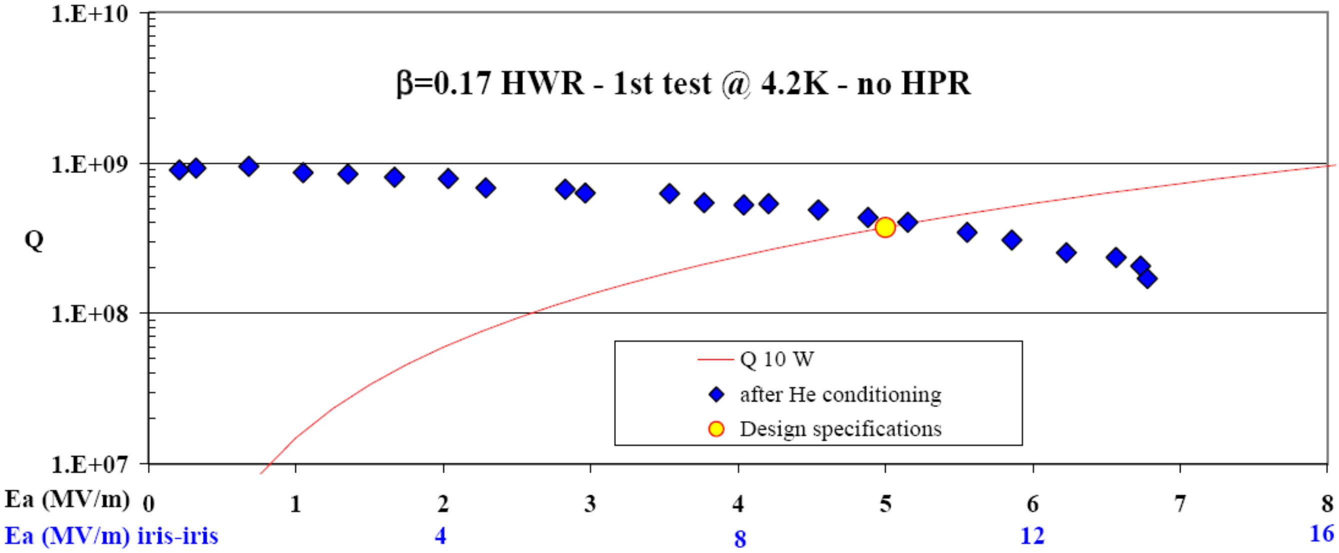

Fig. 5 : Test results at 4.2 K of the β 0.17 HWR

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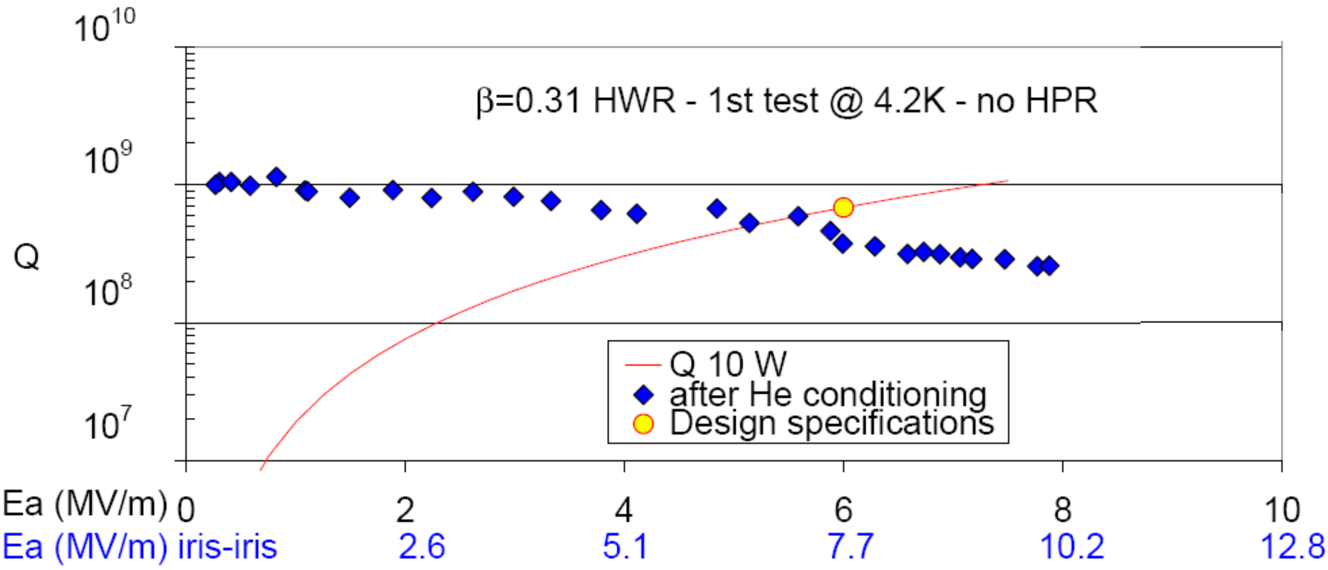

Fig. 6 : Test results at 4.2 K of the β 0.31 HWR

2. Half-wave resonators developments at 176 MHz

The previous HWR design at 352 MHz was adapted at 176 MHz to take into account the evolution of the EURISOL driver reference layout. Two different beta (β 0.09 and β 0.16) were also studied and optimized (see Fig. 7). The RF parameters are given in the table of fig. 8

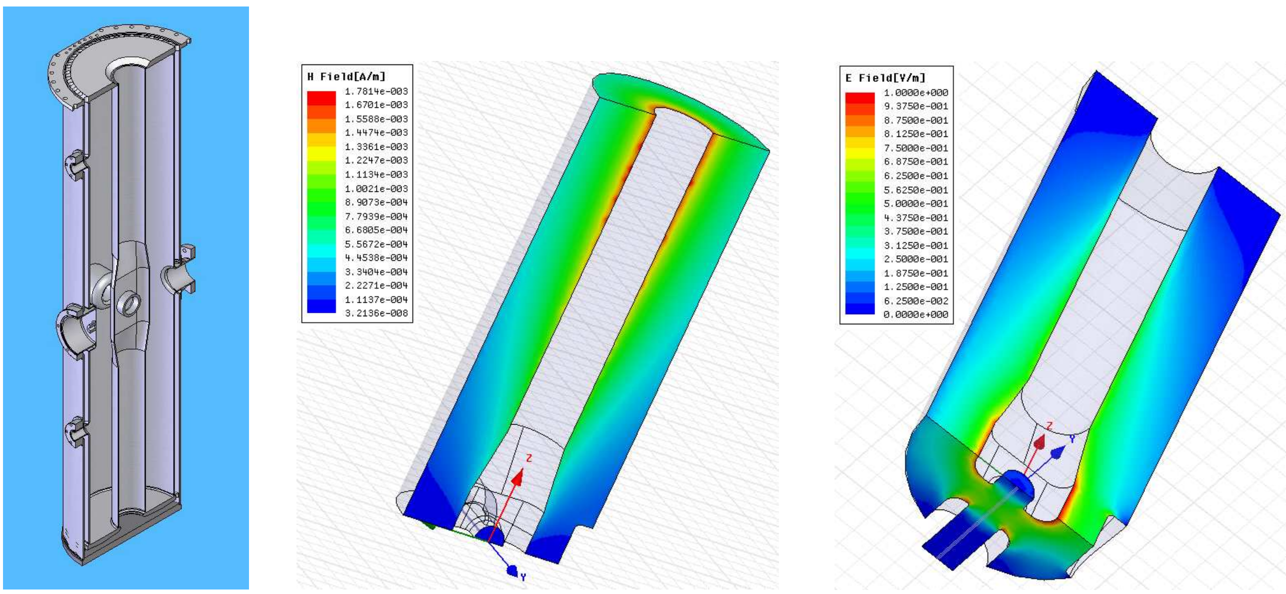

Fig. 7: 176 MHz, β 0.09 HWR (left) and RF field distribution (middle: magnetic; right: electric).

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Resonator type	HWR1	HWR2	*units*
β	0.085	0.155	
U/E_a^2	0.134	0.173	$J/(MV/m)^2$
B_p/E_a	12.4	11.7	$mT/(MV/m)$
E_p/E_a	5.8	4.2	
R'_{sh}/Q_0 $(E_a^2 L/(Q_0P))$	1215	1181	Ω/m
$R_s \times Q_0$	31.9	38.2	Ω
Active length L	180	224	*mm*
Maximum Length L_{re}	232	286	*mm*
Aperture diameter a	30	30	*mm*
Design E_a	5	6	*MV/m*
He Pressure detuning	1	3.7	*Hz/mbar*
Lorentz force detuning	-3.6	-1	$Hz/(MV/m)^2$

Fig. 8 : Main RF parameters of the two 176 MHz HWR.

3. Cold Tuning System (CTS) for Half-Wave Resonators

A Cold Tuning System (CTS) is a mandatory ancillary system for a resonant accelerating structure in order to be able to tune a cavity inside the module. The high efficiency (quality factor) of a superconducting cavity leads to a quite narrow frequency bandwidth, putting strong requirements on the CTS in terms of resolution and adjusting frequency range.

For the HWR, the proposed solution for the CTS is the following (see fig. 9 & 10): a 1.25 mm thick niobium membrane is closing a port located on the cavity at the opposite side of the power coupler port. A mechanical system composed of a stepping motor, a screw-nut system and a L-shaped lever can push or pull on the niobium membrane, deforming it and changing the inner cavity volume thus resulting in a cavity frequency change.

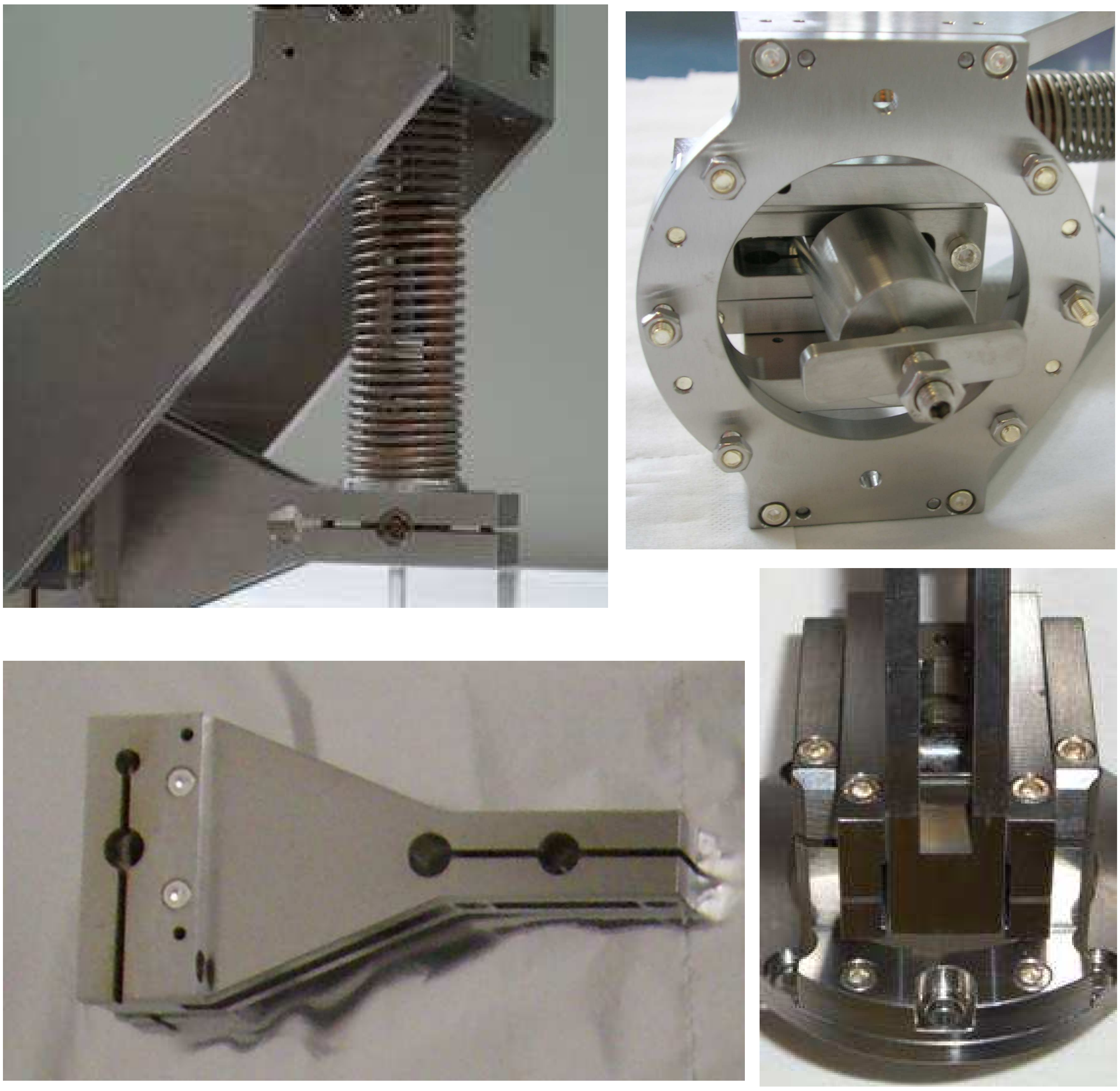

Fig. 9 : Pictures off HWR cold tuning systems parts.

The CTS for half wave resonator has been successfully tested at cold temperature in a vertical cryostat. The system could provide a 100 kHz tuning range, with a 10 nm mechanical resolution giving about1 Hz of frequency resolution.

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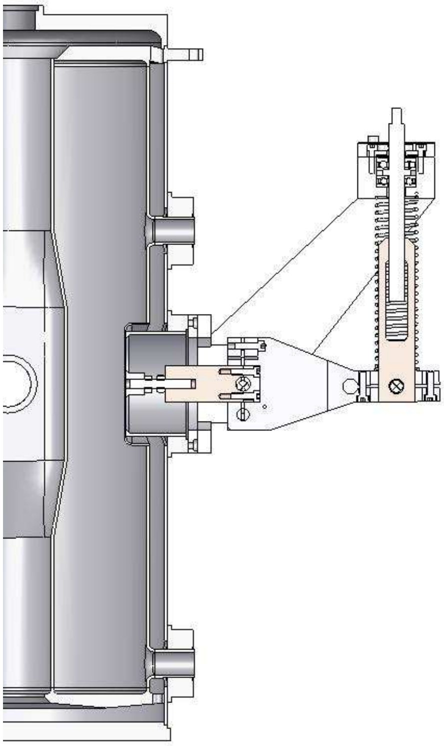 

Fig. 10 : Sketch and picture on the cold tuning system mounted on the HWR.

4. Power couplers for Half-Wave Resonators

The 352 MHz half wave resonator and spoke cavities could use the same power coupler design. The only difference is due to the different power coupler port aperture between the HWR and spoke. The complete description of the power coupler design is not given in this report, as it has been presented in the deliverable n°3.

To check that the spoke coupler could be adapted to the half-wave, calculations of the mechanical transition between the two diameters have been performed. The results are given in the figure 11. The results show that the coupler could be easily adapted to the HWR, with only a small degradation of the S11 parameter.

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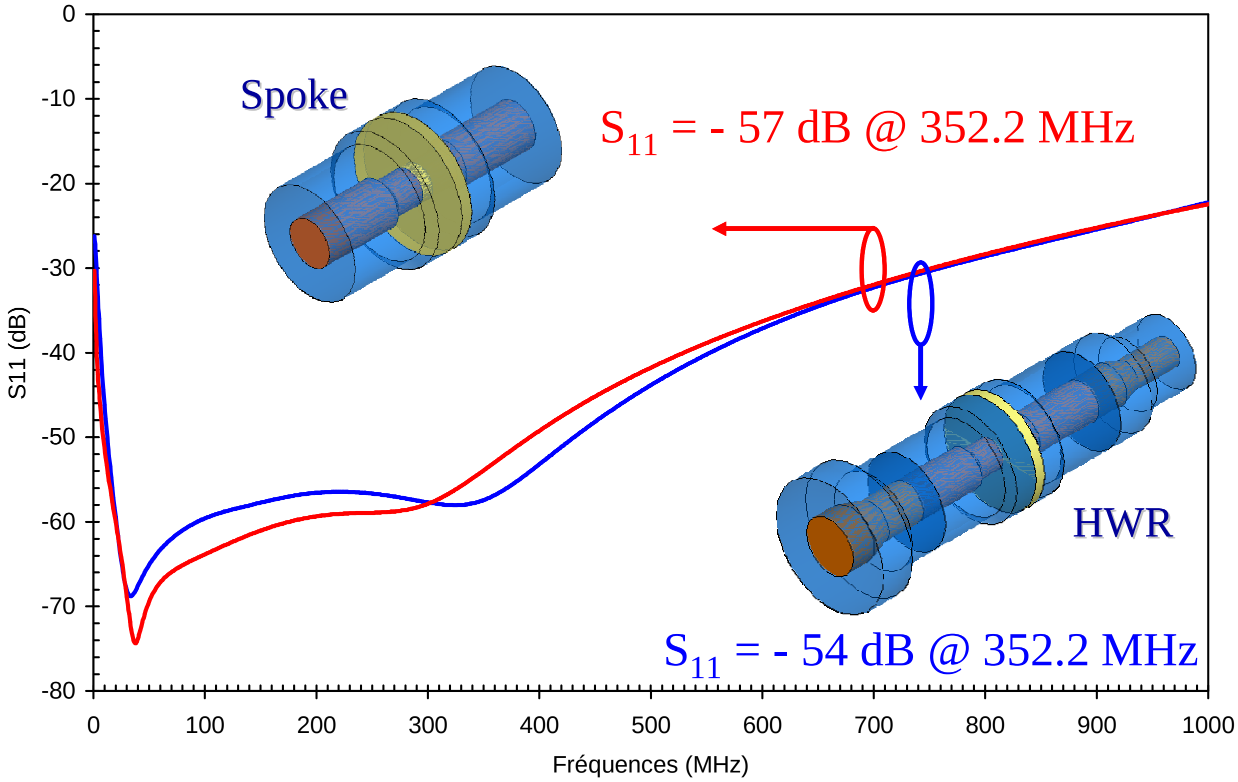

Fig. 11 : S11 comparison of the original coupler design for the spoke cavities with its adaptation to the half-wave resonators.

Fig. 11 : Picture of the power coupler prototypes at 352 MHz

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