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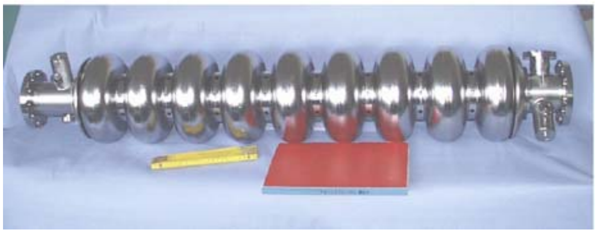

CARE activities on superconducting RF cavities at INFN Milano

A. Bosotti[a], P. Pierini[a], P. Michelato[a], C. Pagani[b], R. Paparella[a], N. Panzeri[a], L. Monaco[a], R. Paulon[a], M. Novati[a]
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Abstract

The SC RF group at INFN Milano-LASA is involved both in the TESLA/TTF collaboration and in the research and design activity on superconducting cavities for proton accelerators. Among these activities, some are supported by the European community within the CARE project. In the framework of the JRASRF collaboration we are developing a coaxial blade tuner for ILC (International Linear Collider) cavities, integrated with piezoelectric actuators for the compensation of the Lorenz force detuning and microphonics perturbation. Another activity, regarding the improved component design on SC technology, based on the information retrieving about the status of art on ancillaries and experience of various laboratories involved in SCRF, has started in our laboratory. Finally, in the framework of the HIPPI collaboration, we are testing two low beta superconducting cavities, built for the Italian TRASCO project, to verify the possibility to use them for pulsed operation. All these activities will be described here, together with the main results and the future perspectives.

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ABSTRACT

The SC RF group at INFN Milano-LASA is involved both in the TESLA/TTF collaboration and in the research and design activity on superconducting cavities for proton accelerators. Among these activities, some are supported by the European community within the CARE project. In the framework of the JRASRF collaboration we are developing a coaxial blade tuner for ILC (International Linear Collider) cavities, integrated with piezoelectric actuators for the compensation of the Lorenz force detuning and microphonics perturbation. Another activity, regarding the improved component design on SC technology, based on the information retrieving about the status of art on ancillaries and experience of various laboratories involved in SCRF, has started in our laboratory. Finally, in the framework of the HIPPI collaboration, we are testing two low beta superconducting cavities, built for the Italian TRASCO project, to verify the possibility to use them for pulsed operation. All these activities will be described here, together with the main results and the future perspectives.

Keywords: Superconducting RF cavities, piezoelectric actuator, coaxial blade tuner

1. INTRODUCTION

The start of the CARE (Coordinated Accelerator Research in Europe) project, sponsored by the European Community, has been a great help for the particle accelerator community. Above the obvious advantage of getting funding, another positive feature is the generation of a structured and integrated area of research and design, in which different European structures can collaborate and share knowledge on particle accelerator science advanced topics. In this framework the most advanced scientific and technological research activities in the field of particle accelerator, such as the ones that will be described in this paper, can found a fertile ground to grow and have success. We will start reporting the status of the coaxial blade tuner, a new way to perform tuning operation of superconducting RF structures. The description of our approach in the realization of low β superconducting RF cavities for proton accelerator will follow, together with the complete results of the first two tests in vertical cryostat. Last but not least, we will end with the status of the research activity, in our laboratory, in the field of the improved standard cavity fabrication.

2. BLADE TUNER FOR SUPERCONDUTING RF CAVITIES

As of today, no complete technological solution exists for a cold tuning system fulfilling the requirements envisaged for the International Linear Collider, based on the superconducting RF technology. The design of a coaxial tuner solution for superconducting structures was originally motivated from the need of a cold tuner for the TTF superstructures tests[1]. For this case the standard TTF tuner solution, with its longitudinal clearance, would have been incompatible with the foreseen increase in filling factor. The coaxial blade tuner[2,3], was then proposed both for the reduced cavity spacing foreseen by the TESLA TDR and for the superstructures. Prototypes were built and tested in the CHECHIA horizontal cryostat and on the TTF linac (Fig. 1) in 2002[1]. During both tests the blade tuner performed as expected in terms of stiffness, frequency sensitivity and tuning capability.

2.1. Evolution of tuner design

The prototype tuner[2] tested on the TTF linac provided the necessary slow tuning action, but did not provide the fast tuning action needed both for the high gradients (≥ 30 MV/m) in pulsed mode, at which the International Linear Collider will operate, and for the active compensation of microphonics in CW operation, for ERL and FEL applications. We therefore have made an improved design for the blade tuner, which provide both the slow structure tuning and the fast tuning capabilities, needed for Lorentz Force Detuning (LFD) and microphonics compensation, by means of the integration of active devices of the piezoelectric or magnetostrictive type.

Figure 1: One 2-cavity superstructure, equipped with blade tuners, during assembly in TTF.

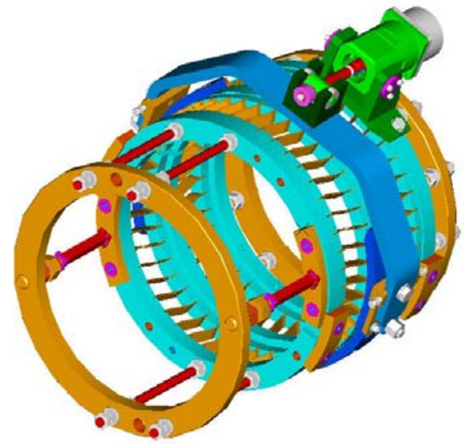


Figure 2: The piezo-assisted tuner.

2.1.1. Tuner design

The main tuner mechanism consists of a three-ring bending system connected by welded blades at an angle which transforms the azimuthal rotation (in opposite directions) of the two halves of the central ring into a variation of the distance between the end rings. The azimuthal rotation is provided by a leverage system connected to a stepping motor. The leverage system amplifies the torque of the stepping motor, contemporarily increasing the tuning sensitivity.
In the standard design[2] the two end rings are rigidly connected to the cavity He tank, which has been split in two halves joined by a bellow in order to allow the variation of the cavity length.
The bending system has been designed with a parametrical model, in terms of the blade length and inclination to define the structure kinematics and in terms of number and position of blades to provide the axial stiffness and tuning force compatibility.

2.1.2. Integration of the LFD compensation system

The parametrical model has been verified by means of finite element models, which provided more accurate information; such as stresses, deformations and stiffness not only in the axial but also in the transversal and torsional directions. These detailed informations have then been used for the integration of a fast tuning action based on piezoelectric actuators, which are subject to several requirements limiting the choice of possible design configurations.
First of all, the piezoelectric actuators (piezos) cannot be subject to tension forces, and bending and shear actions need to be carefully avoided. Moreover, in order to maximize their lifetime, a correct preload range needs to be guaranteed under all operating condition. In addition to that, the characteristic behavior of piezo operation at cryogenic temperatures, in terms of stroke and preload effects, is still a subject undergoing a systematic investigation, as explained below (cfr. par. 2.2).
From all the considerations expressed above, and using as guidelines the typical values of the TESLA type structures in terms of cavity elasticity and tuning requirements (i.e.: 500 kHz frequency range and 1500 μm axial movement for the slow tuning action, 1 kHz frequency range and 3 μm axial movement for the fast tuning action), we have integrated the piezoelectric elements in the tuner design, by inserting two elements between one of the end rings and the corresponding flange on the He vessel (Fig. 2). Under this configuration, the cavity elasticity is used to provide a controlled preload to the piezoelectric elements. Thus the cavity has to be tuned to operate in a stretched condition and the working points are

obviously chosen in order to avoid an inversion of the direction of the internal stress in the blades and piezos over the complete tuning ranges.
The current piezo capabilities assessed up to now[4] seem to satisfy the operating requirements. Furthermore, different piezos with different cross sections, or even magnetostrictive elements, can be accommodated in the prototype under construction with minimal variation. Thus the final choice of piezo actuators can be safely postponed after their complete characterization in terms of precise values of stroke and necessary preload conditions.

2.1.3. Characterization of the full system

The axial mechanical behavior of the full system (cavity + He tank + tuner) has been investigated parametrically by means of the spring model (Fig. 3). The stiffness of every part, for the TESLA cavity case, is reported in Table 1, together with the material types, the elastic properties (Young module) and the legend of symbols used. The stiffness values were either derived from FEM analysis or measured experimentally.

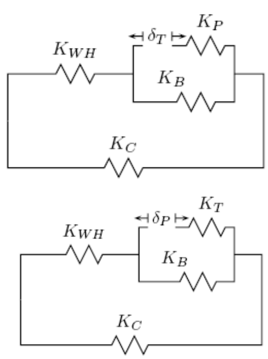


Figure 3: Equivalent spring models

Part	Material	Stiffness symbol	E (MPa)	K (N/µm)
He tank	Ti	K_H	119000	440
Tuner	Ti	K_T	119000	25
Cavity	Nb	K_C	105000	3.213
End disk	Nb	K_W	105000	27.1
Piezo	---	K_P	---	2 x 105
Tank bellow	Ti	K_B	119000	0.228

Table 1: Characteristics used in the spring model.

The forces and displacements of every part in the system corresponding to a tuner displacement (δ_T) of 1 mm (slow tuning action) or a piezo displacement (δ_p) of 1 µm (fast tuning action) have been evaluated and are reported in Table 2.
We note here that due to the low stiffness of the end disks, only 87 % of the displacement applied by the tuner is transferred to the cavity. For the fast tuning action a further contribution comes from the tuner stiffness, and 79 % of the displacement applied by the piezos is transferred to the cavity. In particular, to provide the designed fast tuning range, the piezo has to assure a maximum stroke of ~ 4 µm at 2 K. The use of stiffer end disks for the He tank connection would slightly reduce the requirements on tuner/piezo excursion.
It is also important to point out that the piezo preload is varying with the slow tuner action, therefore a suitable pre-tuning strategy needs to be assessed to ensure that during the slow tuning action the preload remains within valid operation limits. Furthermore, we have to ensure that the piezo preload has to be always lower than its load limit (the force above which the piezo risks to be damaged). For the prototype case of two piezos, with a cross section of 10 x 10 mm, the blocking force is 4 kN each, therefore if we assume a pre-load limit of 8 kN (obtained subtracting the 4 kN blocking force from the 12 kN load limit) a maximum slow tuning action of ~ 1600 kHz can be safely applied, which is at least a factor of four higher than the current warm-cold frequency reproducibility at the TTF. For sake of safety a lower preload value is preferable.
The experimental tests planned in the context of the CARE program to assess the thermal expansion of different piezo-ceramic materials together with the cold tests of the tuner prototypes (see below for details) will further reduce the overall uncertainty of the preload at the tuner working point. Moreover, the needed cold tuning action is expected to further reduce for the case of a big industrial cavity production, like the one needed by the XFEL or ILC cases.

2.1.4. Adaptation to the TTF CRY-3 design

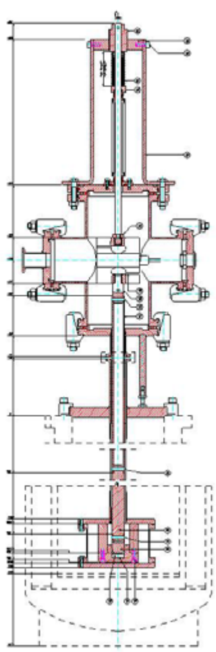
According to the design illustrated in the preceding sections, we have started the fabrication of two complete prototypes for the tuning system (including the leverage system, split He Tank and ancillary components). The system is designed to be fully compatible with the actual TTF cryomodule design (CRY-3), which is the base for the future developments needed for the industrial ILC and XFEL modules. Both tuner prototypes will be delivered in mid-2005, and we plan tests of the combined slow/fast tuning capabilities in CHECHIA. Their final installation in the high gradient TTF Module 6 is still open.

Load case: δ_T = 1 mm (slow tuning)			Load case δ_P = 1 µm (fast tuning)	
Part	Axial force (N)	Axial displ. (mm)	Axial force (N)	Axial displ. (µm)
He + disk	-2812.5	-0.110	-2.540	-0.100
Tuner	-3037.0	1.000	-2.743	-0.110
Cavity	2812.5	0.876	2.541	0.790
Piezo	-3037.0 / 2	-0.014	-2.743	1.000
He bellow	224.5	0.986	0.203	0.890

Table 2: Axial forces and displacements for a tuner elongation of 1 mm (slow tuning action), and for a piezo elongation of 1 µm (fast tuning action).

2.2 Characterization of piezoelectric ceramic at low temperature

An insert for vertical cryostat test has been realized (Fig. 4) to characterize piezoelectric ceramics in LHe environment. The piezoelectric element under test is hosted in a box under isolation vacuum. The box is immersed in liquid He in order to bring and keep the DUT at the temperature of 4.18 K. This value can be considered as a good approximation of the real operating temperature of the piezo (about 2 K, super fluid He condition), at least for what concerns electro-mechanical properties of the piezo itself.



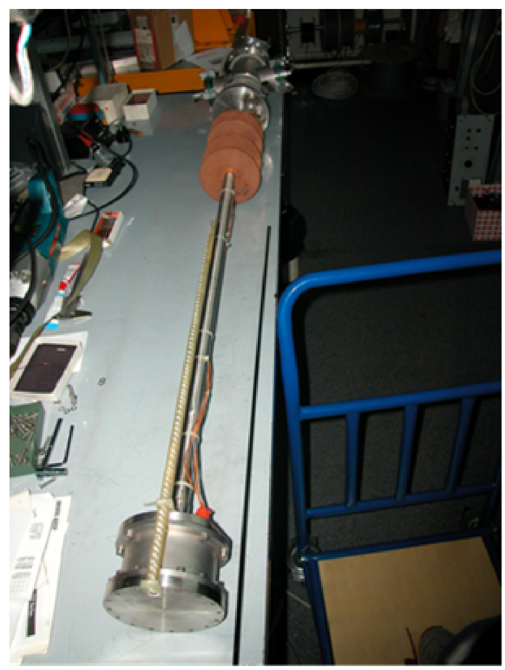


Figure 4: Vertical cryostat insert. Left: mechanical draw. Right: The insert assembled ready to be immersed in LHe.

The element to be tested is hosted in a properly shaped aluminum support (Fig. 5) to avoid any non-vertical force component on the ceramic element; the support element is then fixed inside the cold box (Fig. 6). The thermal contact between the DUT and the LHe bath is also provided by 4 copper strings that connect it to the bottom of the box. One of the main features of the insert is the possibility to exert a known force on the device under test, being it a piezoelectric ceramic or a force sensor. This is achieved via an external device, placed at the top of the insert, in which spring-washers are coupled to a screwed ring to generate the test force (up to 2.5 kN). This force is transferred, by a long steel & G10 rod, to the DUT. A calibrated load cell, working at room temperature, is in series and measures the generated force. The main purpose of this is the development of a method to measure the piezo pre-load in cryogenic environment. In active tuners system the proper preload force adjustment is mandatory[4] to guarantee the demanded lifetime of the active elements, and to check their working point to be sure to cover all the requested dynamic range.

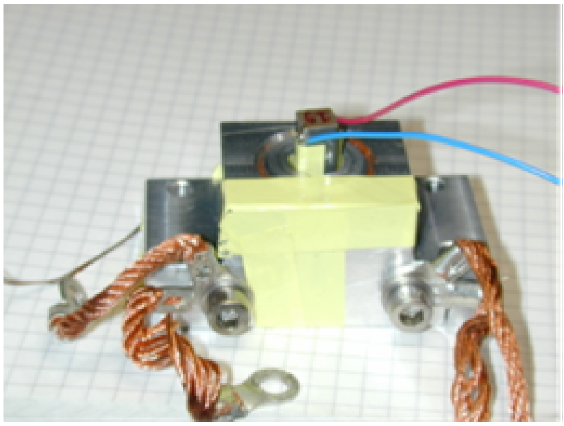


Figure 5: Support to host piezoceramic elements.

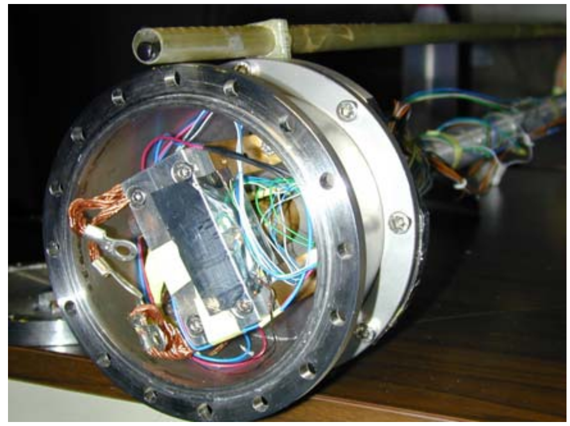


Figure 6: Cold box bottom view.

To determine this parameter an absolute force sensor able to work at cryogenic temperatures is needed. The possibilities to do this are either using a cryogenic force sensor (i.e. a load cell) or looking to the variation of selected piezo parameters for different loads (i.e. one of the piezo resonances). For what concerns the use of load cells, we first tried some commercial load buttons that could fit in the piezo support. Unfortunately these devices are not designed to work at 4 K, and though linear and affordable at room temperature,they failed in LHe environment, giving unacceptable lack of stability, uniformity and repeatability in the response. The main problems were the plastic deformations of the glue and the choice of the strain gauges. As a consequence a custom load cell has been realized under our specifications by an Italian firm, CELMI srl (Buccinasco – MI) and tested in order to verify the performances of cryogenic devoted sensitive elements (strain gauges and glue). The tests made in LHe on the prototype have been successful and proved that this load cell can work in cryogenic environment with good sensitivity and repeatability (Fig. 7).

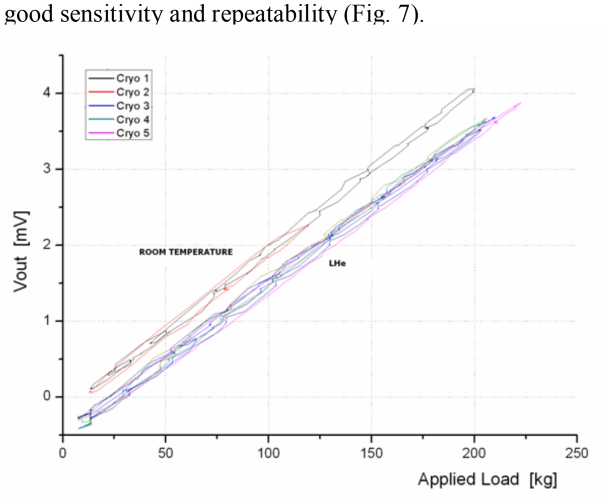


Figure 7: Cryogenic load cell and its transfer characteristics.

The other method is to track the change of one of the many piezo resonance frequencies for varying applied forces. This is due mainly to the change of the ceramic mechanical length. To do this, the piezo element is connected to form a resistance divider (Fig. 8). A calibrated resistor is used, in the range 50–10000 Ω. A FFT signal analyzer is used to acquire the *Vpiezo/Vsupply* transfer function, the divider ratio value, as a function of the frequency, showing the piezoceramic resonant frequencies drift towards higher frequencies as the pre-load force increases (Fig. 9). An alternative possible calibration method could be the measure of its static capacitance under load conditions.

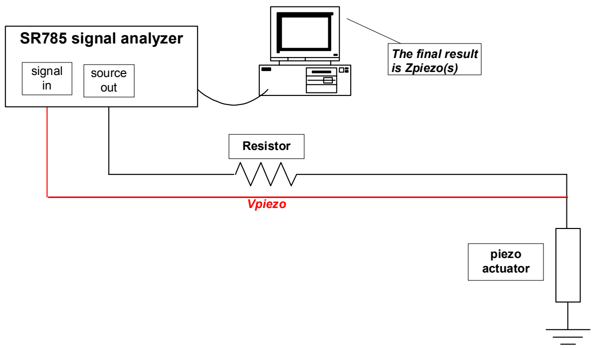


Figure 8: Test setup to measure piezo resonance frequency

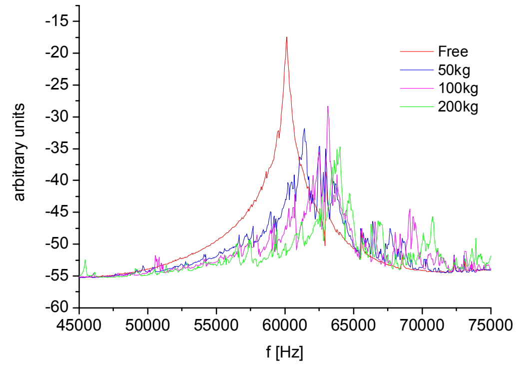


Figure 9: Noliac SCMAS/S1/A/10/30/6000 resonance frequency shift with increasing applied force.

The insert was also used for piezo life time test. The purpose of this test is to investigate the behavior of piezoelectric ceramics under working conditions equivalent to 10 years of operation as actuators in active frequency tuner for ILC superconducting cavities.. To do this a Physik Instrumente PI P-888.90 PIC255 piezoelectric ceramic has been cooled down in LN_2 and has been excited uninterruptedly for a month up to its limits, sustaining about 1.5 10^9 cycles of switching, up to nearly the maximum stroke, a good estimate of ten years as actuator for ILC cavities.

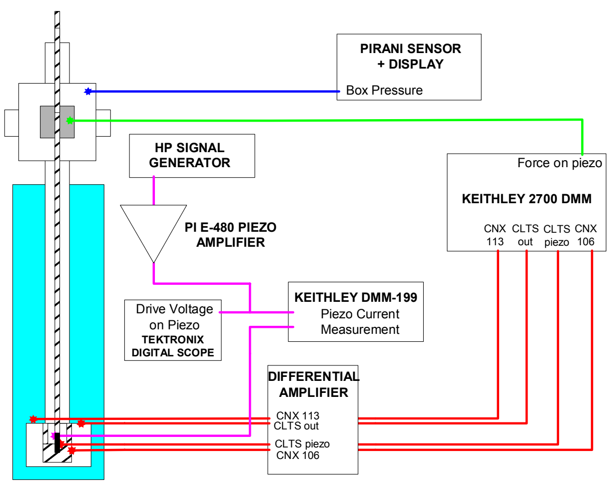


Figure 10: Piezo long time test set up.

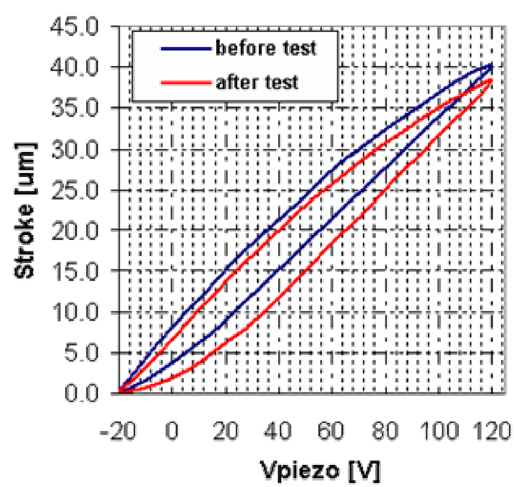


Figure 11: Hysteresis comparison before and after the test.

This piezo is a good representative of the kind of ceramic to be used in active tuners at cryogenic temperatures. So even if this model will not be the final choice, the device to be used will not be substantially different from it for what concerns the major characteristics of the ceramic (in the coaxial tuner will be probably used a different actuator, with higher stroke and blocking force, but with ceramic properties close to the PI item). The piezo was preloaded with 1.2 kN load and pulsed up to 100 V to set operating conditions close to the real ones, with except of the working temperature. In the real environment, considering that the tuner is installed under the 4K shield, the actuator temperature should be lying in a range from 2 to 4 K. Because performing the lifetime test means a long period of cool down in vertical cryostat, using LHe as coolant would be very expensive. So, considering that the mechanical stresses for a ceramic are quite the same at 4K and at 77K, we have chosen to perform the lifetime test in LN_2 bath. Moreover, due to the liquid nitrogen higher thermal capacity, less refilling were needed, simplifying the test procedure. During the test the piezo temperature and current were constantly monitored (Fig. 10).

The life time test was successful. The main parameters, such as electrical capacitance, resonance frequency, the hysteresis figure (Fig. 11) and the maximum stroke were measured before and after the test, in order to detect any variation after the equivalent of ten years of stresses. After about one month of operation in LN_2 environment under extreme conditions, and after more than 1.5×10^9 oscillations driven between (nominal) operating voltage limits, the PI P 888.90 piezo is still working with almost the same characteristics.

3. DESIGN, PRODUCTION AND TESTS OF THE β = 0.5 SC CAVITIES

As part of the TRASCO program, multicell superconducting cavities of the elliptical type have been designed, in collaboration with CEA and IN2P3 for the design of an ADS system based on a superconducting linac[5,6]. In the past years four single cell β=0.5 cavities have been fabricated by the Italian company Zanon and tested in collaboration with TJNAF and Saclay. After the successful tests[7] of the single cells the fabrication of two complete 5 cell structures was launched. Both cavities were tested at TJNAF and Saclay and reached a maximum gradient a factor of two higher than the design value[11,12]. As part of the HIPPI[10] program, INFN made available one of the existing TRASCO cavities for the experimental test of pulsed operation at relevant power in a horizontal cryomodule at the foreseen RF facility under development at Saclay. These tests are planned at the end of the program.

3.1. Cavity fabrication

High RRR (>250) niobium sheets of 4 mm thickness have been used for the cavity fabrication. The parts were formed and electron beam welded at Zanon. The half cells were deep drawn using two set of dies for the equator and iris regions. Two half cells of the internal shape have been welded at the iris to form the dumb bells, and a ring was welded at 70 mm distance from the beam axis, in order to decrease the sensibility to Lorentz forces and increase the cavity stiffness. The dumb bells were then trimmed in length to adjust the frequency. The end tubes (with diameter 130 mm at the power coupler side and 80 mm at the other side) were then formed, equipped with coupler, pickup, HOM ports and flanges on the beam axis and welded to the end cells. Two titanium disks have been welded through NbTi transitions at the cavity beam tubes to provide support for a Ti helium tank, which will be equipped in the future. The dumb bells and the end sections were then mounted in a dedicated fixture for the final equatorial welds. NbTi flanges derived from the DESY and SNS types, using $AlMg_3$ gaskets, have then been used for all the ports. Finally, the pickup and power coupler flanges have been added in the last electron beam welding stage. The resulting cavity is shown in Figure 12.

During the stages described above, the half cells and dumb bells frequencies have been measured in order to determine the spread due to fabrication (< 1 MHz) and the required amount of trimming for frequency adjustment.

Figure 12: The Z502 cavity.

3.2. 5 cell RF tests

The main cavity parameters[5] are summarized in Table 3

Parameter	Value
Design Frequency	704.4 MHz
Geometrical β	0.47
Iris radius	40 mm
Cell to cell coupling	1.34 %
R/Q	180 Ohm
G	160 Ohm
E_{peak}/E_{acc}	3.57
B_{peak}/E_{acc}	5.88 mT/(MV/m)
Stiffening ring radial position	70 mm
Lorentz Force Coefficient (est.)	-7 Hz/(MV/m)^2

Table 3: Main 5 cell Cavity Parameters

Figure 13: The cavity supports at TJNAF (left) and at Saclay (right).

3.2.1. Z501 procedures at TJNAF

The cavity has been sent to TJNAF after fabrication, where it was tuned for a field flatness of 7% at the room temperature frequency of 699.268 MHz. The cavity has then undergone an initial degreasing, a BCP 1:1:2 (HF, HNO_3, H_2PO_4) etching to remove 150 μm, and a thorough rinsing. Then, the cavity was heat treated at 600°C in vacuum for 10h, standard SNS procedure, to desorb hydrogen generated during the chemical treatment and absorbed in the bulk material. A field flatness of 5.5 % at 698.856 MHz was reached in a second tuning stage. A final chemistry with a 100 μm removal was then followed by rinsing and two stages of High Pressure Rinsing. The cavity was then left to dry overnight in the class-10 clean room before the installation of the input antenna in the main coupler port and a second antenna in the pick-up port. One of the main beam pipe ports was used to connect to the vacuum pump, and the other was closed by a stainless steel blank flange. The cavity flanges were closed with the SNS $AlMg_3$ gaskets, derived from TESLA cavities. The cavity was then suspended on the vertical insert (Fig. 13 left), supported at the He-vessel end dishes by a titanium cage. The cavity was evacuated and sealed, no pumping was provided during the RF tests.

3.2.2. Z502 procedures at Saclay

The Z502 cavity has been tuned to 5% field flatness at 700.195 MHz in LASA before sending it to Saclay. Here a total of 120 μm has been removed in two BCP stages from the cavity inner surface, leading to a final frequency (room temperature, in air) of 699.83 MHz. The chemistry was followed by a thorough high pressure rinsing, then the cavity was left to dry overnight in the clean room before the assembly of the antennas at the main coupler and RF pick-up positions. The cavity beam flanges have been closed with indium joints, while the AlMg3 gaskets were used to seal the main coupler and pickup ports. Finally, the structure has been equipped with a stainless steel frame in order to provide sufficient stiffness (Fig. 13 right). Pumping was provided through one of the beam ports. The cavity has not been heat treated for hydrogen desorption, so a rapid cooldown procedure has been followed, to avoid the 100 K, "Q disease", effect. A small leak developed after the superfluid transition was reached, and it was necessary to pump the cavity with a turbomolecular pump during the RF tests in order to maintain good vacuum conditions ($< 10^{-6}$ mbar).

3.2.3. Results of the RF tests

The surface resistance as a function of the inverse of the temperature during the cooldown is plotted in Figure 14 for the two measurements. The experimental data have been fitted with the BCS theory (using Halbritter's code[8]) in order to obtain an estimation of the residual resistance. A value of ~ 5.5 nΩ in the TJNAF tests and 7.0 nΩ for the Saclay measurements has been obtained, typical of the high RRR niobium material used.

During both tests two multipacting barriers have been observed. The first one appeared at low field values (ranging from 1.5 to 3 MV/m) and was easily overcome. In the second barrier (ranging from 6 to 8 MV/m) there were signs of strong electron emission, that lead to continuous cavity quenches when the cavity approached the barrier level, due to the induced local heating. This multipacting level was anyhow processed with approximately half an hour of RF processing on the fundamental and in the other modes of the band. After this procedure, no further signs of multipacting were observed during further testing.

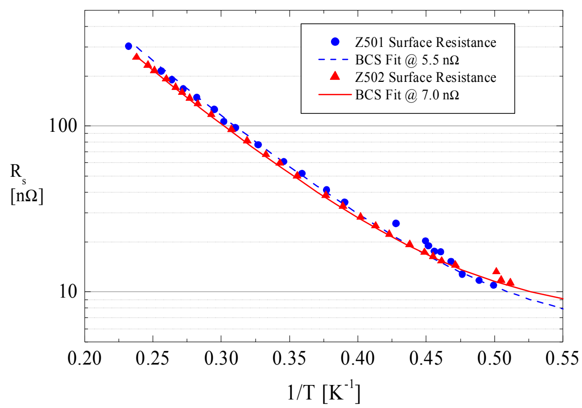


Figure 14: R_s values from RF measurements.

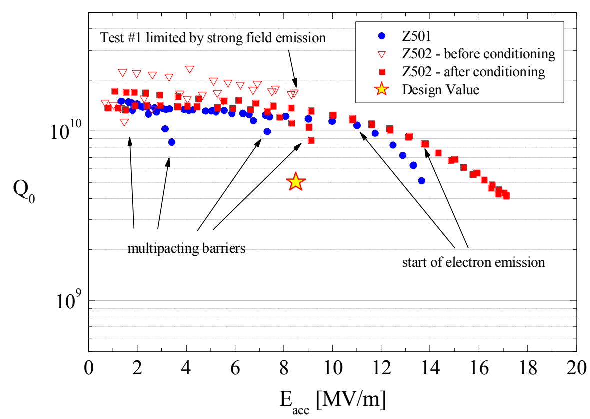


Figure 15: Q_0 vs E_{acc} curve for the two cavities.

The curve of the cavity quality factor, Q_0, as a function of the accelerating field is shown in Figure 15 for the two tests of Z501 (TJNAF) and Z502 (Saclay). Both cavities outperformed the design accelerating field value of 8.5 MV/m.
In the TJNAF Z501 tests the two multipacting barriers were encountered at 2.8 and 6.8 MV/m. The first one was processed quickly, while the second took 20 minutes of RF processing in the 4/5 π more. The cavity was limited by field emission at higher fields (starting from 11 MV/m) and reached an accelerating gradient of 13.7 MV/m with a quality factor, Q_0, of 5 10^9.

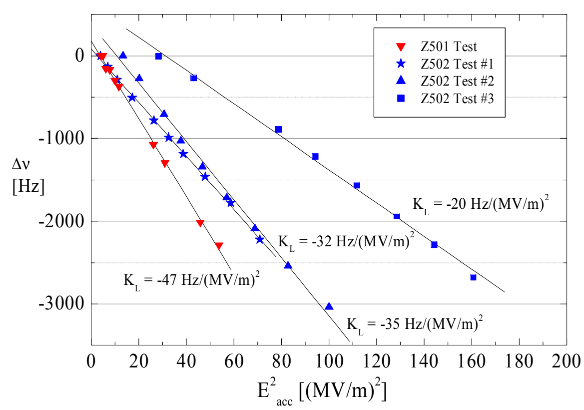


Figure 16: Lorentz force coefficient estimations from RF measurements.

In the tests at TJNAF the Z501 cavity showed a higher than expected frequency sensitivity to the accelerating field. A static Lorentz force coefficient of nearly 47 Hz/(MV/m)^2, close to the case of "free" boundary conditions, was determined from the RF tests, indicating that the cavity was weakly constrained in length during the tests (Fig. 16). Further tests with a stiffer cavity length constraint are going to be made at TJNAF.
The two barriers encountered during the Z502 Saclay tests were at approximately 1.5 and 8 MV/m. Like in the TJNAF test the former barrier was processed quickly, while the second needed more than 30 minutes of RF processing in the

2/5 π and 4/5 π modes of the cavity band. During the conditioning process the cavity quenched continuously when approaching the barrier level, due to the local thermal heating induced by the strong electron emission hitting the surface. After the conditioning, the barriers were not experienced in successive tests.
Also in this case the Z502 cavity was limited by field emission (starting at 13 MV/m), and reached the value of 17.1 MV/m with a Q_0 of $4\ 10^9$.
A static Lorentz force coefficient in the range from 20 to 35 $Hz/(MV/m)^2$ has been determined from the Saclay RF measurements (Fig. 16). Three data sets were taken from the Z502 cavity and a single data set for Z501. The data at low and high fields has not been used for the K_L estimation, due to the limited accuracy in the measurement frequency at low fields and the electron emission occurring at high fields. The spread in the resulting K_L value seems compatible with the support frames used in the experimental setup, based on 3 or 4 thin rods that provide some mechanical constraint on the cavity length. The estimation of 7 $Hz/(MV/m)^2$ is indeed based on a mechanical model for a constrained (fixed length) internal cell geometry[5] and rises up to nearly 90 $Hz/(MV/m)^2$ for the case of an unconstrained cell length. Therefore, the detailed interpretation of the experimental data requires a more detailed analysis of the full cell geometry coupled electromagnetic/mechanical calculations and further dedicated tests.

3.3. Considerations after the first RF tests and future perspectives

Both the TRASCO cavities outreached the nominal specifications with a considerable operational margin. The corresponding peak electric and magnetic fields reached in the TJNAF tests are 49 MV/m and 81 mT, yielding compatible performances with the ones achieved by the multicell SNS cavities. The tests at Saclay reached peak electric and magnetic fields of 61 MV/m and 100 mT, respectively, with performances similar to the standard TTF cavities production. In both tests the cavity performance was limited by field emission at high fields, and considering the peak electric field on the surface, the performance limits were compatible with a BCP treated TESLA cavity shape in the 25-30 MV/m range. This limitation suggests the possibility to treat the cavity with further BCP and longer HPR procedures in order to possibly suppress electron emitters and reach the thermal quench limit at even higher fields.
In the context of the HIPPI subproject of the CARE program[10], our group is going to equip the two low beta 700 MHz elliptical cavities, for high power pulsed measurements in CRYHOLAB at CEA/Saclay, to verify the feasibility of LFD compensation of these structures. The test of these structures under pulsed operation is particularly significant for the feasibility studies of superconducting high power proton drivers.
On the basis of the design procedures described in the preceding sections, a scaling of the coaxial tuner, and its adaptation to the TRASCO cavity case, has been performed, and the layout is shown in Fig. 17. The construction of the tuner prototypes for the HIPPI program is foreseen in late 2006, thus the final detailed engineering of the tuner will be finalized after the end of the tests that will be performed at DESY on the TESLA type tuner.

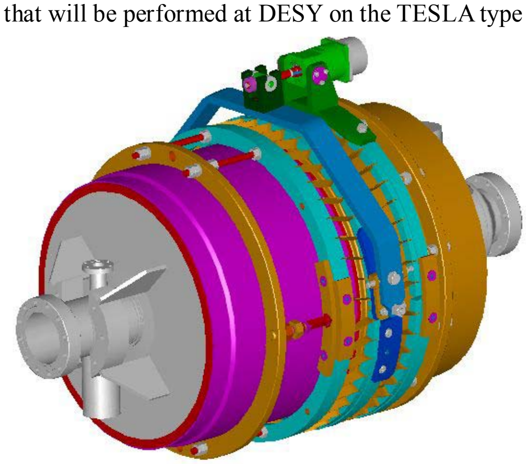
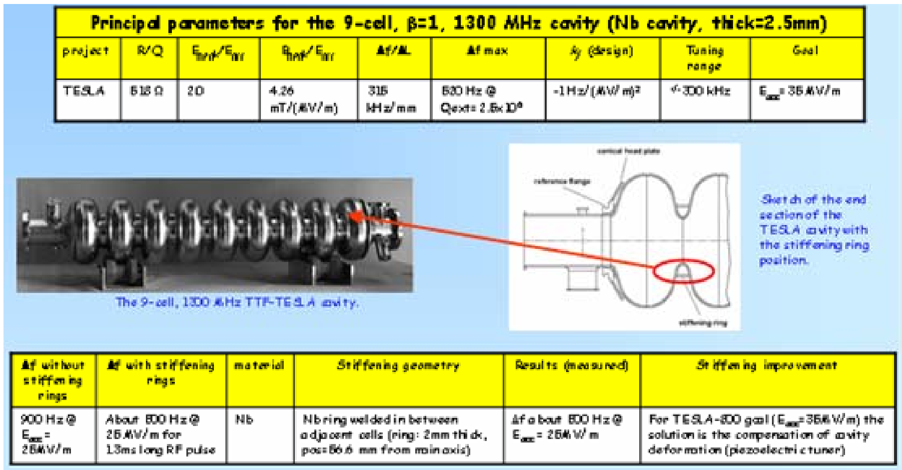


Figure 17: The preliminary layout of the scaled coaxial tuner for the 700 MHz 0.5 beta TRASCO cavity

4. IMPROVED STANDARD CAVITY FABRICATION

Improved Standard Cavity Fabrication (ISCF) aims at improving the present cavity fabrication technology. It is based on the operating experience with superconducting cavities in the test linac TTF. There is an obvious need to modify at

least partially the cavity design and the preparation procedures to improve the performance and reliability of the SRF accelerating system.
The information retrieving about the status of the art on ancillaries and experience of various laboratories involved in SCRF is an important tool to highlight different designs and technological solutions. Information about principal ancillaries like He vessel, flanges, stiffening, etc., have been collected and organized in a database for systematic studies. As an example, in Fig. 18 is shown the database informations for TESLA relative to stiffening and fast tuner.



Principal parameters for the 9-cell, β=1, 1300 MHz cavity (Nb cavity, thick=2.5mm)								
project	R/Q	E_{peak}/E_{acc}	B_{peak}/E_{acc}	Δf/ΔL	Δf max	K_L (design)	Tuning range	Goal
TESLA	518 Ω	2.0	4.26 mT/(MV/m)	315 kHz/mm	520 Hz @ Qext= 2.5x10^6	-1 Hz/(MV/m)^2	+/-300 kHz	E_{acc}= 35 MV/m

Δf without stiffening rings	Δf with stiffening rings	material	Stiffening geometry	Results (measured)	Stiffening improvement
900 Hz @ E_{acc} = 25MV/m	About 500 Hz @ 25 MV/m for 1.3ms long RF pulse	Nb	Nb ring welded in between adjacent cells (ring: 2mm thick, pos=56.6 mm from main axis)	Δf about 500 Hz @ E_{acc} = 25MV/m	For TESLA-800 goal (E_{acc}=35MV/m) the solution is the compensation of cavity deformation (piezoelectric tuner)

Figure 18: TESLA cavity stiffening and fast tuner data retrieving.

Different design of cold flanges has been compared and a preliminary analysis of the sealing behavior is on going applying Finite Element Analysis (FEA) code.
TTF cavity cold flange behavior, calculated using FEA code, during tightening at room temperature is shown (Fig. 19 and 20). The graph in Fig. 19 shows the Al seal: compression as a function of the displacement, while Fig. 20 is the FEA analysis of the plastic deformation of the seal at the end of the tightening of the flange.

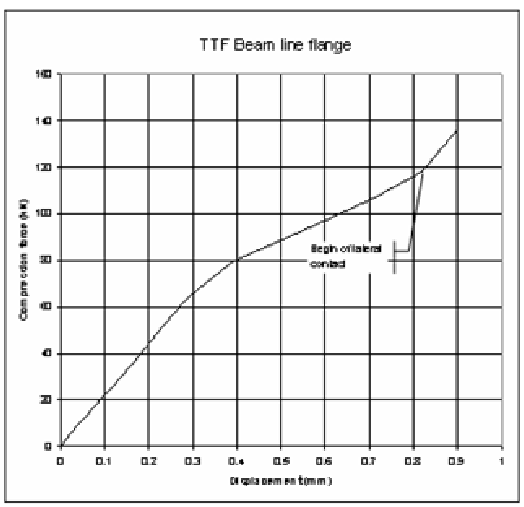


Figure 19: Calculated compression vs. displacement curve for the TTF cavity flange.

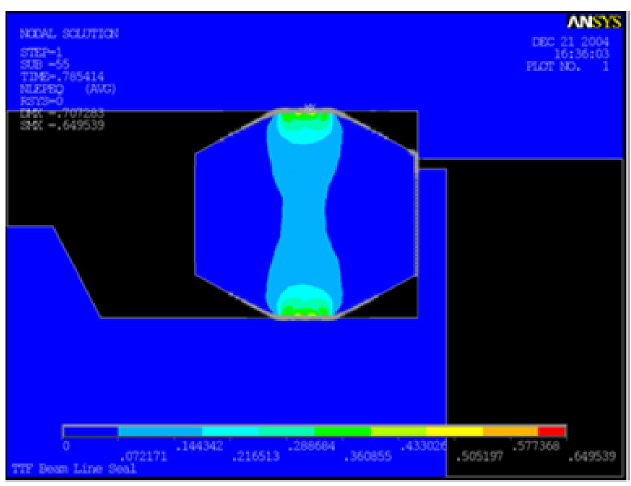


Figure 20: Plastic deformation of the Al seal at the end of the tightening of the flange: displacement is 0.7 mm.

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