

## “RF Superconductivity in Genoa”

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on behalf of the Genoa Group

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### **Abstract**

The main activities of the Genoa Group are endowed by INFN under the “Special project on RF Superconductivity” grant.

The main goal of the project is the development of new techniques and new materials for Superconducting RF accelerators.

The research aims are mainly to give a contribution to the next generation of TeV linear collider either by reducing the production cost of the resonators or reducing the cryogenic plant's installation and running costs.

The Genoa Group works mainly to check the effectiveness of the Niobium based Nitrides for accelerator application.

As a side investigation the Group works, in collaboration with LAL Orsay, to understand the reasons for the limitations on the surface field. This investigation is performed by tacking advantage of the NEPAL installation in ORSAY.

The group is starting to work to the joint R&D project of INFN and ENEA aiming to check the feasibility of a high current superconducting proton accelerator as a driver of a neutron source.

### ***New production methods for High field accelerating cavities***

The Genoa Group is granted by INFN Under the “Special Project on RF Superconductivity”

The collaboration involves three INFN labs in Genoa, Legnaro and Naples

The main activities of our laboratory are the production of high quality SC RF cavities using bulk material, understanding of the field limitation and non ohmic losses in niobium and niobium based binary alloys (bulk or thin films )

The main fields of investigation are superconducting nitrides as NbN and  $(\text{Nb}_x\text{-Ti}_{1-x})\text{N}$  [2]

The aim is to asses they can be foreseen as a viable option to the niobium.

The high  $T_C$  of the nitrides (in the range 12-17.5 K) will allow to reach surface resistance in the 1-10 Nanohom at 4.2 K at 1.3GHz.

This value of surface resistance allows for operation at the Helium Normal Boiling Point with a substantial gain either in costs (plant and Operation) and System Reliability

Using He I refrigerators instead of superfluid Helium reduces the number of components needed for the Cryogenics and gives a higher MTBF (Mean Time Between Failure) allowing for a longer Beam time for the Users.

Production of Niobium Nitride cavity at Genoa is based on Thermal reactive diffusion in a Furnace

This method allows us to check the limit of the material without introducing limitations given by the film-substrate interaction and film growth already observed in Thin Film on copper substrate produced by reactive sputtering[3]. The results

of typical measurements on a 3 GHz Niobium Titanium nitride cavity are shown in figure 1 and Figure 2

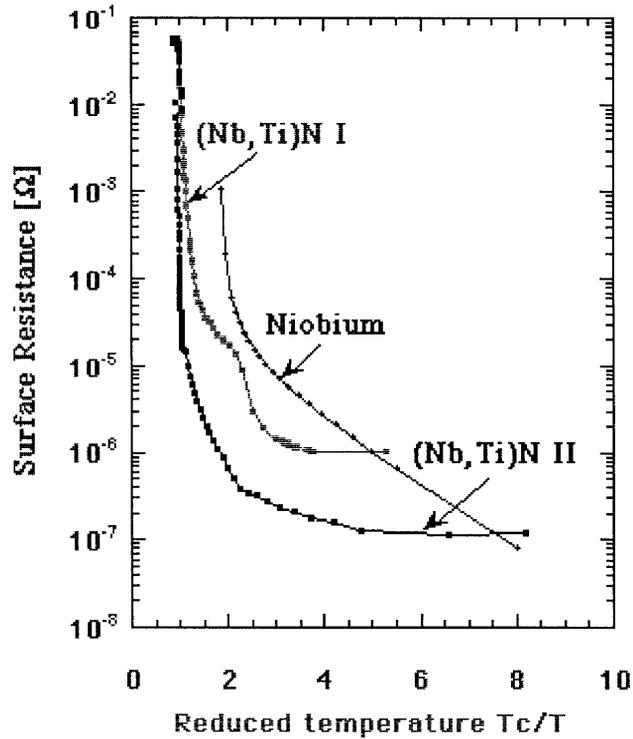


Fig 1; Comparison between the surface resistance of 3 GHz (Nb-Ti)N cavities and Theoretical BCS Surface resistance versus  $T_C/T$  of the Nitride. The Critical Temperature  $T_C$  of the Nitride was 17.1 K.

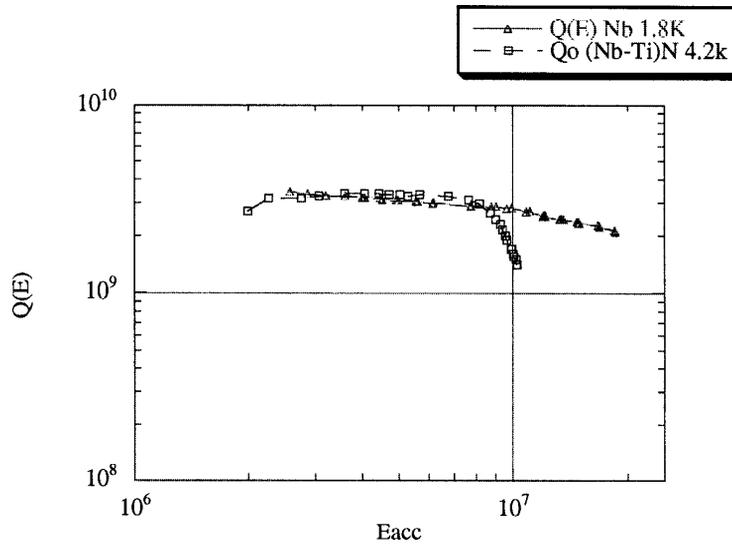


Fig 2, Comparison between Quality factor versus field of two 3 GHz cavities built in (Nb-Ti)N and niobium

### ***Electron Emission, discharges and limit field studies***

As a side to the development of alternative materials the Genoa Lab is active in investigating the effect of the surface treatments on the field emission and the limit field in accelerating cavities.

The investigation on the field limit and electron loading is performed through the collection and a careful correlation of a quite large statistical sample of RF measurements on omothetic accelerating cavities operating at 1.5 GHz-3GHz-4.5 GHz.

The aim of our measurement is to assess (possibly) frequency dependent effects like Multipactoring NREL

That investigation is supported through computer simulation of NREL and Multipacting in accelerating cavities

The result of the measurement and of the simulations confirms[4] the possibility of resonant discharges also in Spherical or elliptical cavities at quite high Fields.

The most dangerous MP level is found around a level of 22-28 MV/m for a cavity operating at 1.5 GHz. The resonant field is proportional to the operating frequency of the cavity.

A typical simulation for a 1.3 single cell cavity is reported on figure 3.

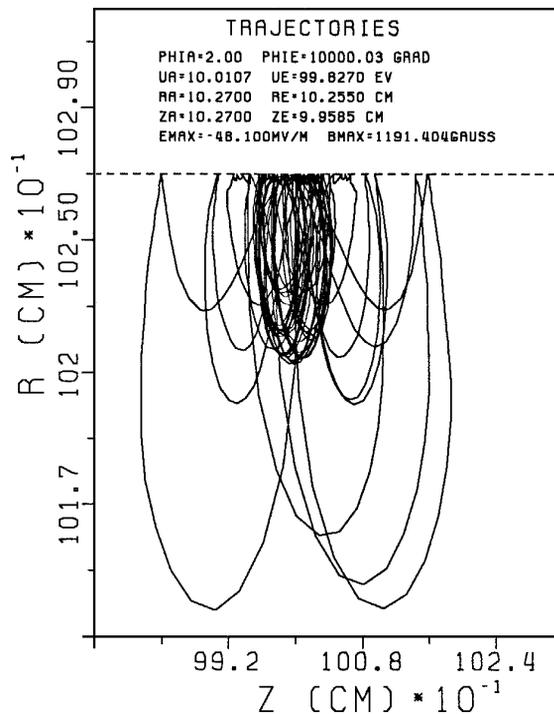


Fig 3; Two point Multipacting at the equator of a 1.3 GHz spherical cavity; the Accelerating field is 25 MV/m

The investigation about the effect of different surface treatments on the limiting fields is done by measuring 40 single cell and multicell cavities produced in the same way using same niobium (Wa Chang and Heraeus RRR 300 grade). The cavities were welded by two different companies to have independent parameters on the most critical operation of the cavity production.

The cavity are currently under test to extend the validity of the information on the limiting effects on the maximum obtainable field by using a quite large statistical sample

### ***Investigation of limit field by High power pulsed RF***

In collaboration with the LAL\_SERA Group in ORSAY the Genoa Lab is starting an investigation of the Maximum achievable Surface fields in Superconducting cavities.[5]

Theoretical speculations backed by some measurements on Indium and Tin showed that a Surface Magnetic Field higher than  $H_c$  should be reached and that the Ultimate limit field is The Superheating Thermodynamic Critical Field  $H_{sc}$  (240mT or 60 MV/m for the niobium).

Despite those arguments the maximum Surface magnetic field in accelerating niobium cavities is in the range of 100 mT (25 MV/m) a factor two lower than the Critical Thermodynamic Field.

To asses the limit field for niobium and niobium base superconductors we plan to use the method developed by Campisi and Farkas in SLAC in the early eighties[6]

Using The Nepal Test Facility at LAL , a vintage '83 high power test set Courtesy of CEBAF and brand new Niobium cavities made in INFN GENOA, pulsed measurements of the maximum achievable fields can be obtained.

The pulsed method will allows us to reconstruct the magnetic field versus temperature curve giving us the answer about the ultimate recheable field.

### ***Material Analysis***

The facilities built in the Genoa Lab for the development of the Niobium based superconductors allows for a complete characterisation of the electrical and magnetic properties of the superconductor composites.

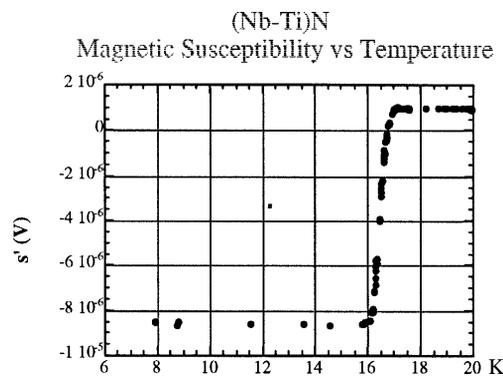


Fig.4 AC Magnetic susceptibility of Niobium Titanium Nitride showing only a clean 17.1 Tc phase on the sample surface

The measurement of the AC Magnetic susceptibility , as shown on figure 4 allow for the determination of the different phases on the surface of the samples and the Critical Fields  $H_{c1}$  and  $H_{c2}$ .

The investigation of the Surface contamination and the surface chemistry of niobium and niobium composites give valuable information about the mechanism of the field emission and  $Q_0$  changes with the field.

For this reason an ESCA, Auger Analysis system is used for the determination the surface of niobium and Niobium based Superconductors.

The possibility of measurement of the electrical Work Function of the Material and the correlation with the chemical composition of the surface gives us the capability of understanding the effect of the contamination on the Field emission.

This facility is open to all the people of the SRF Community needing a close investigation of the effect of surface treatments on the surface composition

### ***The INFN\_ENEA PROTON LINAC Project***

Together with the LNL, LNS and Milan INFN laboratories Genoa works on the Joint INFN-ENEA project for the development of a High current proton linac.

This project is aimed to develop the design of an intense Neutron spallation source for the transmutation of Nuclear waste.

This Project is jointly supported by INFN And ENEA in collaboration with The Italian industries.

The activity of The Genoa Lab is focused to the design , the construction and tests of the prototypes of the Superconducting cavities for the high energy Linac.

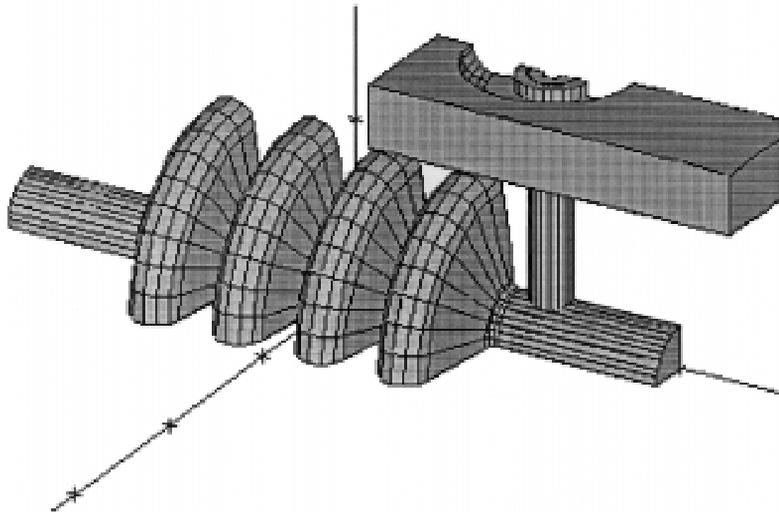


Fig 5; Design of the prototype cavity equipped with the main coupler

The Groups works mainly on the design and test of the cavity and the characterisation of the niobium surfaces.

A great deal of effort is spent also in designing the RF couplers either to check the efficiency of the coupler design and eventually the field distortion induced by the coupling.

A typical cavity for the Proton linac module equipped with the main coupler is shown on figure 5

## References

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