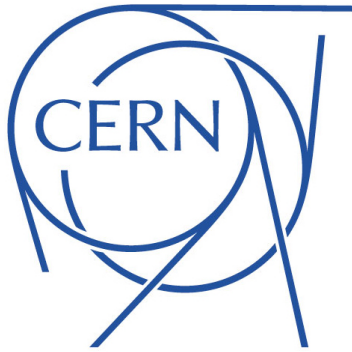




Magnetic field mapping for HIE-ISOLDE cavities

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September 11, 2015
CERN - Genève

1 ISOLDE and HIE-ISOLDE

The ISOLDE (Isotope Separator On Line DEvice) Radioactive Ion Beam is a facility at CERN and is dedicated to produce radioactive nuclei for researches in nuclear physics and in solid state physics, but also in biophysics. The radioactive nuclei are produced by collisions between high energy proton beam from the Proton Synchrotron Booster and a stationary target. Then several different devices are used to extract and separate nuclei according to their mass and immediately carry them in the experimental stations.

The HIE-ISOLDE (High Intensity and Energy ISOLDE) project is an upgrade of the existing facility with the aim of increasing the energy of the radioactive beam. The upgrade considers of a new LINAC, composed of five superconducting cavities per cryomodule.

1.1 HIE-ISOLDE cavities

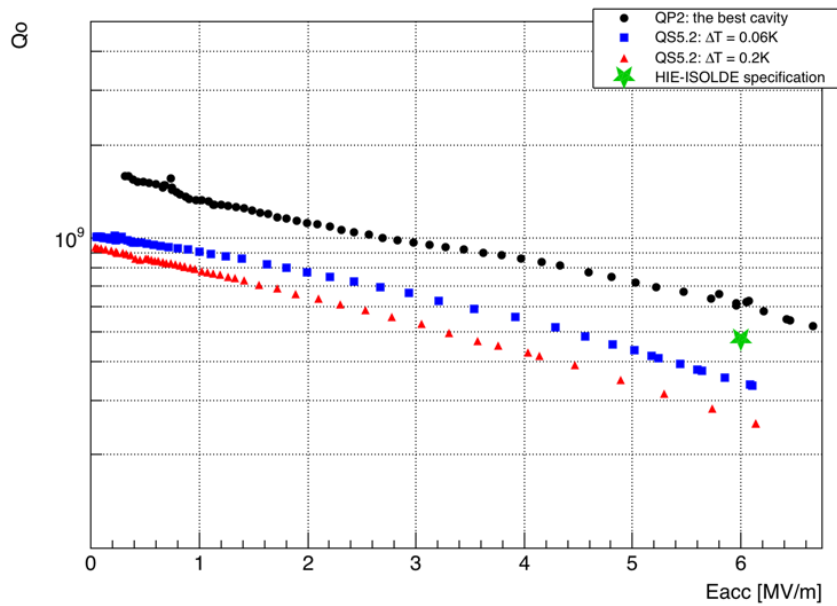
The HIE-ISOLDE cavities are made up of two different parts in copper: a cylinder and an antenna inside. They are welded together on the top of the cavity. The inner surface is coated by a niobium film with a sputtering process for low surface resistance. The thickness of the niobium film is a few micrometers.

The cavity is operated at 4 K, cooled by liquid helium, for niobium superconductivity ($T_c = 9.5$ K). The cavity is placed in ultra-high vacuum condition (1.0×10^{-8} mbar).

The cavities are operated at 101.28 MHz and the maximum dissipated power has to be 10 W at 6 MV/m.

1.2 Performances of cavities

In the following graph, the quality factor ($Q_0 = 30.8 \Omega / R_s$ where R_s is the surface resistance) versus the accelerating field (E_{acc}) is shown for two different cavities.

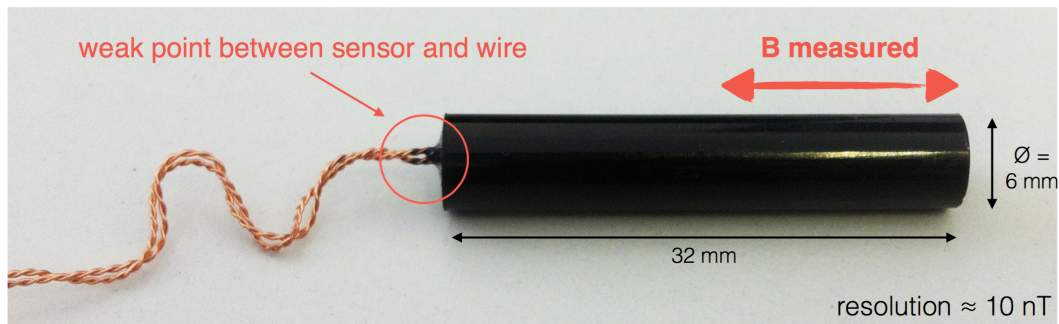


The measurements of the best cavity (QP2) in HIE-ISOLDE are in black dots. I measured the quality factor for the cavity QS5.2 and the performances of this cavity are below the HIE-ISOLDE specification.

Unfortunately the performances of the cavities are not always above the specification: this means that the superconducting film might have some troubles because even very small (a few $\text{n}\Omega$) difference in R_s can impact the Q_0 . Some phenomena could degrade the performances of the cavity. The trapped magnetic field, several surface defects (pinholes, cracks, oxides and other impurities), some unknown problems in the interface between the copper bulk and the niobium film or even the thermoelectric currents could increase the surface resistance of superconducting film. A magnetic field mapping (B-mapping) is proposed in order to analyze the surface of cavities and understand the reason of these bad performances. Moreover the B-mapping could give important information for improving the cavities.

2 Magnetic field mapping

Three fluxgate sensors are available for our measurement. The resolution of sensor is 10 nT.



As shown in the photo above, the sensor is extremely fragile and it is not easy to hold the sensor in a chosen direction. Moreover it is important to protect the weak point between the sensor and the wire.

My task has been to design the supports for each sensor in the three directions of space.

2.1 Material for supports: PEEK

There are few possible materials for the supports because of following three reasons:

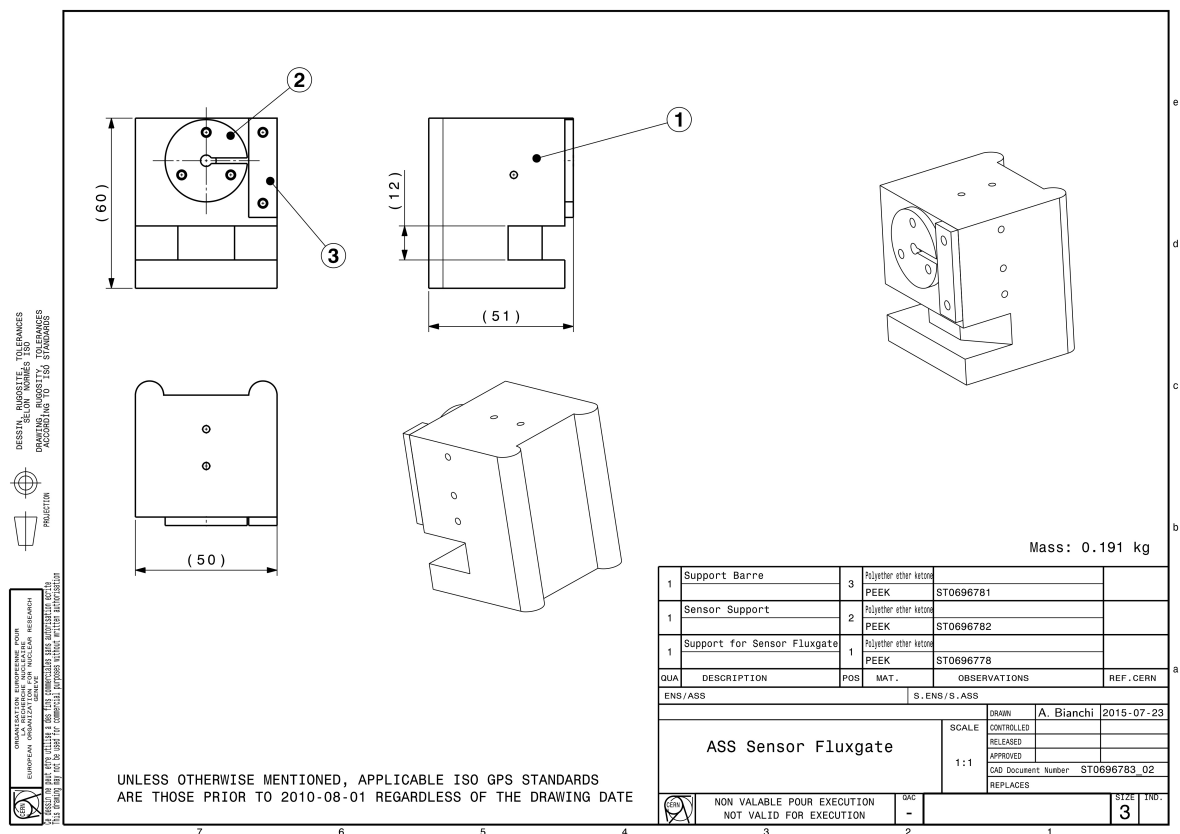
1. the material of the support should have a low outgassing because there is the ultra-high vacuum outside the cavity;
2. the material should have a low shrinkage from room temperature to the temperature of cavity (4 K) in order to prevent some damages at the sensor;
3. it is not possible to use a metal for the support because it interferes with the measurements of magnetic field. For precise measurements the minimum distance between the sensor and every type of metal is 10 mm.

I compared three materials: MACOR is a ceramic material, instead VESPEL and PEEK are two different plastics. I used the total mass loss (TML) to evaluate the outgassing of the materials. This parameter is the difference of mass directly before and after a standard vacuum test (*ASTM-E595*). For the evaluation of shrinkage I used the values of linear thermal coefficient from room temperature to the temperature of liquid helium (4 K).

I selected the thermoplastic PEEK as material of the supports, because the total mass loss of PEEK is almost equal to the outgassing of copper: 0.2% more or less for the two materials. The shrinkage of PEEK is 1% from room temperature to 4 K: this value is three times greater than the shrinkage of copper, which is still acceptable with a correct design of the support in order to avoid the damages at the sensor.

2.2 Design of supports

After the selection of the proper material, I designed the shape of the three supports. Each support is composed of three parts in PEEK and also the screws are in PEEK in order to avoid some problems of shrinkage. Here the assembly of the support for one direction is shown.

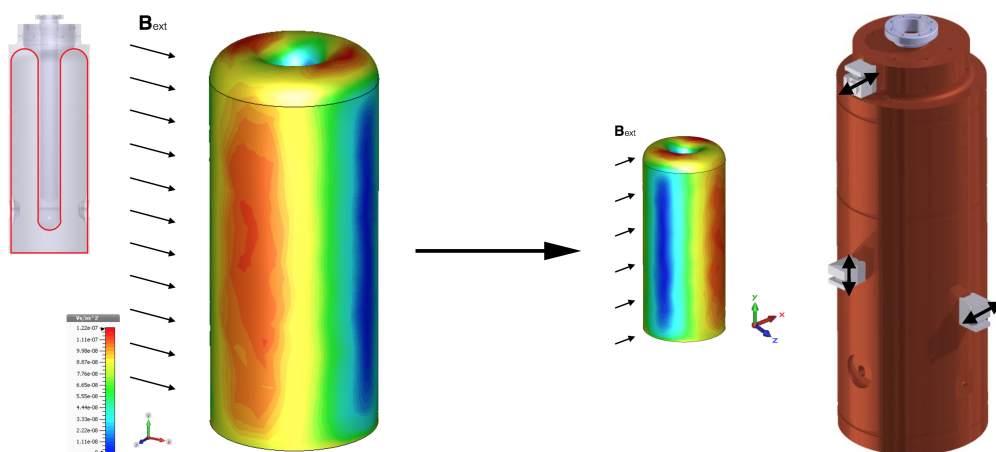


I drew the supports with the software *CATIA*. The *component 1* is the main part of the support; the fluxgate sensor is placed in the middle hole. In the following drawing, the main part of the support for the normal direction is shown. The function of lateral holes is the evacuation of gas when the pressure goes down in the cryostat. The *component 2*

[illegible]

3 Simulation of external magnetic field

I simulated the behavior of external magnetic field around the cavity in order to find the best configuration of sensors for the first measurements. In *CST Suite Studio* the external magnetic field is assumed perfectly horizontal. This is a good hypothesis because there are two big coils in the cryostat in order to compensate two out of three components of external field. The results of the simulation show that the external field, affected by Meissner effect, has two maxima: one maximum is on the side of the cavity and the second one is on the top, close to the welding.



My proposal for the first measurements is shown on the right side of the figure. One sensor is placed along the vertical direction to check if two out of three components of external field are correctly compensated with the two coils of the cryostat. The sensor, placed on the cylindrical part, can measure the extent of Meissner effect on the side of the cavity. The last sensor is placed on the top of the cavity in order to measure the extent of Meissner effect in the other maximum, according to simulation, and also could give some partial information about the welding.

The supports, which I designed, are only appropriate to measure the magnetic field in three fixed places of the cavity. In the future a mobile support could be useful to get a total B-mapping, in order to measure the magnetic field in a lot of places of the cavity; but this is a difficult mechanical challenge for several reasons. First of all, the available space around the cavity is not a lot. Moreover it is necessary to avoid the twisting of the wires of sensors. Finally the magnetic field of the motors for the mobile support could interfere with the measurements of magnetic field. At the moment they are open questions.

4 Acknowledgements

I thank Robin Betemps, Maria Jose Garcia Borge, Walter Venturini Delsolaro, François Morel, Pei Zhang, Sarah Aull, Mathieu Therasse and Philippe Frichot. Moreover I want to thank Akira Miyazaki with profound gratitude.