# MAGNETIC SHIELD FOR THE 1.3GHZ CRYOMODULE AT IHEP

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*Abstract*

A 1.3GHz Superconducting RF (SRF) accelerating unit is being studied at IHEP. In order to achieve the design performance including both accelerating gradient and quality factor, the SRF cavity must be cooled with ambient magnetic field well shielded to the level of several mG [1, 2]. In this paper, permeability of several kinds of materials for magnetic shielding made in China is systematically studied in cooperation with China Iron & Steel Research Institute Group (CISRI) and reported for the first time. By using proper material, numerical calculation for the magnetic shielding design was done via the program of Opera-3D, and then magnetic shield was fabricated by CISRI. This paper will show those studies above and the magnetic shielding effect at room temperature. Comparisons between simulation result and real effect will also be discussed in the paper, as well as the preliminary analysis for the magnetic field leaking of this design.

## INTRODUCTION

1.3 GHz Superconducting RF (SRF) technologies have been chosen by the International Linear Collider (ILC). As a member in ILC collaboration frame, a program called 1.3GHZ SRF accelerating unit was carried on at IHEP. The program includes two 1.3GHz 9-cell cavities which are a low-loss large grain cavity and a tesla-like fine grain cavity respectively, and a cryomodule for one

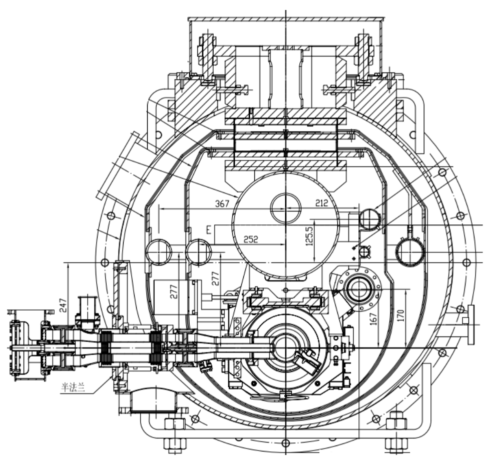

Figure 1: Schematic view of the cryomodule cross-section at IHEP.

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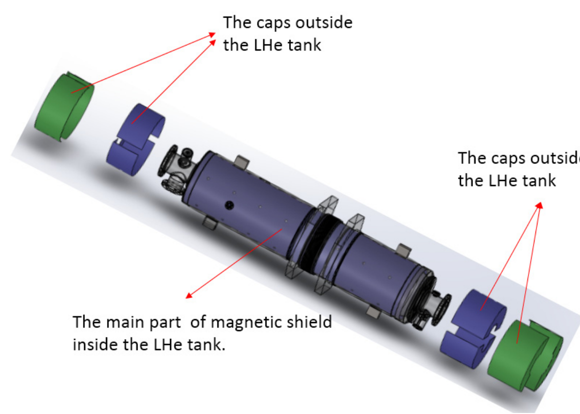


Figure 2: Schematic diagram of the magnetic structure

of them, expecting the low-loss cavity at present. Since the ambient Earth's magnetic field is one of factor effecting the performance of SRF cavities when they are cooling down from room temperature to 2K, the magnetic shielding should be considered as one of important components for the cryomodule. A cross-sectional view of the cryomodule is shown as figure 1. As we can see, it includes several parts. We expect the magnet shield as close as the cavity to avoid the interference of those components. It requires that the magnetic shield can also be able to work in the low temperature even to 2K. However, at present to the domestic material in China,

Figure 3: The photo of the permeability measurement experiment at LHe temperature.

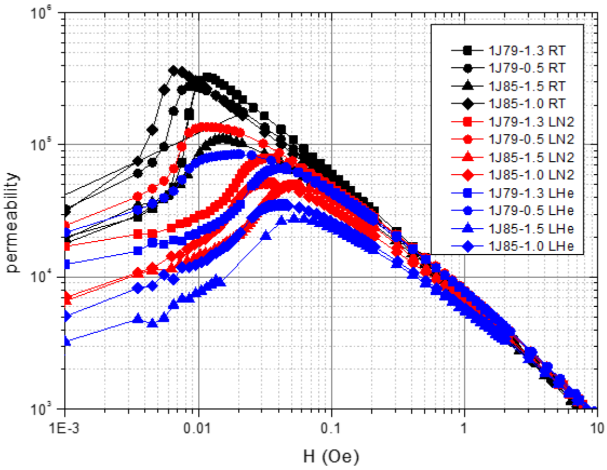


Figure 4: Permeability characteristics of different material at room temperature (RT), liquid nitrogen temperature (LN2), and liquid helium temperature (LHe), respectively.

there is no systemic data in the low temperature. So the performance of the materials which the Chinese company can provide also need to test. This work is completed in cooperation between IHEP and China Iron & Steel Research Institute Group.

## STRUCTURE OF MAGNETIC SHIELD

To SRF accelerators, structures for magnetic shield can be mainly classified to the types of inside and outside liquid helium (LHe) tank [3]. The type of outside magnetic shield is earlier developed by DESY and FNAL although there are not exactly the same. Then he inside magnetic shields are developed by KEK. Comparing with outside shields, the inside magnetic has several benefits such as good shielding effect with small number of connections of holes, simple structure for fabrication and so on [3]. So, we would like to choose inside LHe tank structure as our design scheme. However, due to the mechanical reason, in the LHe tank, we don't have enough space near the two end groups of the cavity for the two caps of magnetic shield. So, the two caps finally were designed outside the LHe tank. A schematic diagram of the design is shown as figure 2. There are two layers of caps in each side of the cavity to avoid the magnetic field leaking in the connection area.

## PERMEABILITY MEASUREMENT

Permeability is the most important performance for the magnetic shielding. However, there is no systemic data on this characterise at low temperature for the magnetic shielding material which are provided by Chinese company. So the measurement of permeability was first carried out as a necessary data to estimate whether those material can be used in our project for magnetic shielding.

Fig. 3 is the photo of the experiment for the permeability measurement at LHe temperature. A permeability measurement device of model MATS-2010SD was used in the experiment. Several ring samples were specially made for this study. Then copper wires with insulated layer outside are twined the ring samples. After fixing the sample on a wood supporter, they are inserted to the LHe Dewar for the test.

In the experiments, four kinds of material belong to two categories have been measured at room temperature, liquid nitrogen temperature, and liquid helium temperature, respectively. The results can been seen in the fig. 4. As we can see, for all the tested material, their permeability are various in the different ambient magnetic fields. Since the main effect of magnetic shied is to reduce the effect of the ambient earths' magnetic field, the permeability in the region around 0.1Oe is what we need pay more attention to. The permeability of all t material will be decrease when temperature becomes lower. However, as shown, the material of 1J79 shows that there is no obvious different between LN2 temperature and LHe temperature, especially at the region that the ambient magnetic fields is around 0.1Oe Taking account of the mechanism performance, the material 1J79-1.3 has been chosen as a candidate for the fabrication of our magnetic shield.

## SIMULATION RESULTS

In order to ensure the material that we chose above could be able to work for magnetic shield, besides the characteristic of permeability measurement, the further simulations are also needed to estimate the reduction of shielding effect by using the data of permeability.

The simulation was done by the code of Opera-3D which is a powerful analysis package usually used for the calculation of low frequency or static magnetic fields [4]. Since the earths' magnetic fields is along nearly in the south-north direction, the effect of the magnetic shielding will be also different in the different direction. In this study, we chose two directions for the calculation, which

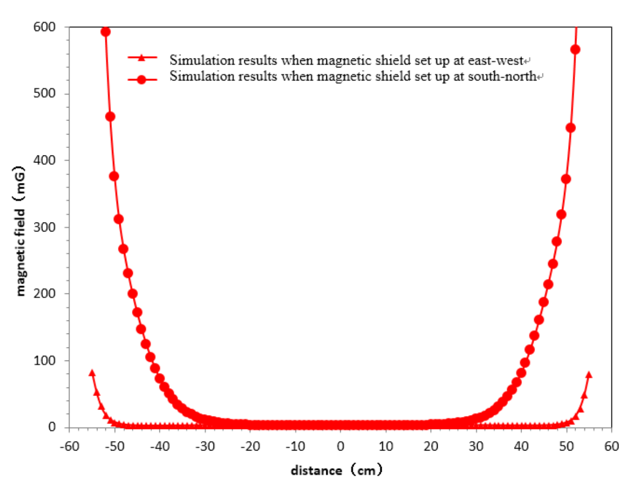


Figure 5: Simulation results when the magnetic shied setup at east-west direction and south-north direction at 4.2K




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Figure 6: The photo of magnetic shield and the test process at room temperature.

are vertical to the earths' magnetic field (nearly east-west direction) and along the earths' magnetic field (nearly south-north direction) for the magnetic shield placing. The simulation results 2K are shown as in fig. 5.

As analysis above, in the two different placing directions, the shielding effect has obvious difference especially at two ends. This is because that a hole in each side of the two ends has to be remain for the assembly of the beam tube of the SRF cavity. So, if the magnetic shield assembly along with the same direction of earths' magnetic field, the shielding effect will be worst, and conversely that will be best. However, in the range of a SRF 9-cell cavity, the average of magnetic fields after shielding are about 4.9mG and 65mG at 4.2K for east-west and south-north placing, respectively. Since the machine will be assembled in east-west direction, we think the design structure and the material of 1J79-1.3 are suitable for this work.

## EXPERIMENT RESULATS

After fabrication by the China Iron &Steel Research Institute Group, the effect of magnetic shield was test at room temperature. The photo of magnetic shield and the test process at room temperature are shown in fig.6. In the test, a magnetic flux meter of CH-33 is used, which can measure all three components of the magnetic field in the same time. The probe of the magnetic flux meter is assembled on a plastic bar to ensure that there is no extra magnetic field impacting the results.

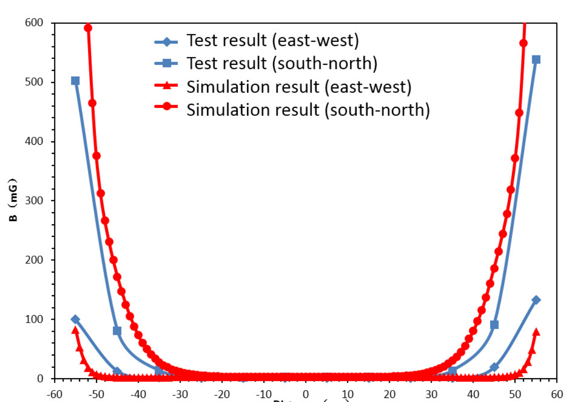


Figure 7: Test results and the simulation results of magnetic shield at room temperature

The ambient magnetic field of test surroundings is first measured which is about 491mG. Then, from one side to the other, the magnetic field is measured in every 10cm. The test results are shown in fig. 7 with blue marks and lines. To corresponding to the simulation results, we also measured the results with the magnetic shield in the east-west and south-north directions. The two series of red marks and lines are the simulation results corresponding to the magnetic field along and vertical to the magnetic shield axis.

We can see that the test results are between the two simulation results. It is not hard to understand since the simulation results are the worst and best shielding effects, respectively. So, the real shielding effects will be reasonably between the two limitations. After integration, the average magnetic fields after shielding are about 5mG and 23mG at room temperature in east-west and south-north direction, respectively. According to the permeability of the material talked above, the final shielding effect at low temperature should be a little worth than this value. However, we think the remained magnetic field after shielding should not greater than 10mG since the permeability doesn't become 1 time smaller. The further study is under study to make sure this problem further.

## SUMMERY

The permeability of several kinds of materials for magnetic shielding at low temperature made in China is systematically studied for the first time. According to those data above, numerical calculations via the code of Opera-3D are carried out for the material choice and structure design for the magnetic shield of IHEP 1.3GHZ SRF accelerating unit. After those performance analysis, the magnetic shield has been made by CISRI. The experimental result shows that the magnetic field after shielding at room temperature can be lower than 5mG. The study will be carried on to ensure it can be also meet the requirement at low temperatures, such as at 4.2K.

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