# DESIGN OF A 1.3 GHZ SINGLE 9 CELL SC CAVITY TEST CRYOMODULE FOR ILC COLLABORATION AT IHEP *

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*Abstract*

In order to obtain the design, manufacture and operational experiences on the SRF cryomodule toward ILC, a test cryomodule for 1.3GHz single 9-cell SC cavity was designed by IHEP (Institute of High Energy Physics) and TIPC (Technical Institute of Physics and Chemistry) jointly. This cryomodule will be used as a 1.3GHz 9 cell SC cavity horizontal test facility. The cryogenic system for the cryomodule is designed and will be operated at 2.0K, with the saturated superfluid helium. The major requirements, design, simulation results of the cryomodule are reported in the paper. This key component of a superconducting accelerator test unit will be built in the near future at IHEP.

## INTRODUCTION

As an important part of the R&D activities for ILC in china, a collaboration group, between IHEP (Institute of High Energy Physics, Chinese Academy of Sciences) and TIPC (Technical Institute of Physics and Chemistry, Chinese Academy of Sciences) was set up in 2006, [1] the group's initial primary goal is to develop superconducting RF technologies and large cryogenic device technologies. Our test cryomodule was designed on the base of TTF3 cryomodule, but it is a small one, specially for IHEP-Low Loss 9-cell cavity as a horizontal test facility. The structure design, thermal and mechanical simulations, 3D modelling, Cryogenic flow diagram, manufacturing process study, cost estimation and etc were carried out for this cryomodule.

## CRYOMODULE STRUCTURE

Our design is based on the TTF3 cryomodule. Figure 1 shows a cross section view of the test cryomodule. Figure 2 shows the cryomodule's whole structure. The left one is the structure we designed before, now we adjust some detail, as shown in the right figure. The cryomodule includes cavity supporting structure, thermal shields, associated cryogenic piping, the insulating vacuum vessel, feedtroughs and etc. [2]

There are two fibreglass posts in the cryomodule connecting the vacuum vessel and the gas helium return pipe (GRP). One of them is fixed to the vacuum vessel, the other can move along the module to accommodate thermal shrinkage. The posts support all weight in the vacuum vessel, including the GRP, cavity, helium vessel, thermal shields and etc. 80K nitrogen cooled radiation shield and 5K helium cooled radiation shield are fixed to the post in sequence, providing the heat flow intercept at 5K and 80K. They surround the GRP and the helium vessel. The helium vessel is attached to the He GRP. There are totally seven cryogenic pipes in the cryomodule. The 80K nitrogen forward and return lines and the 5K helium forward and return lines directly cool the radiation shields and provide heat flow intercept for main coupler and cables. The 5K helium return pipe also cools the higher order mode (HOM) absorber. The 2K forward line transfers single phase helium to the helium reservoir tank, then connects the 2K two-phase supply line, which is connected with the He GRP at the end of the cryomodule. There is a warm up and cool down line connects the helium vessel bottom. It will be used during the cool down and warm up process, for reducing the temperature difference.

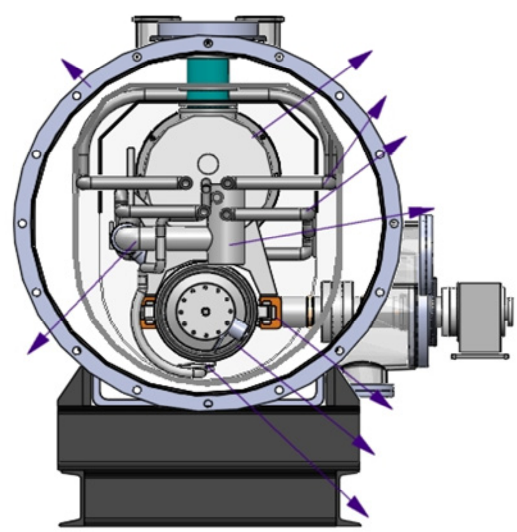

Figure 1: Cross section of the China test cryomodule for ILC.

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There is an invar rod attached to the He GRP, to avoid the longitudinally movement of the He GRP.

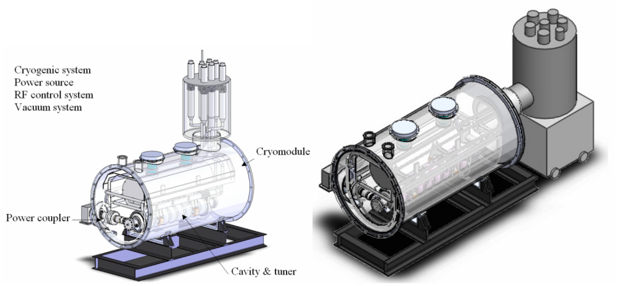


Figure 2: Old structure (left) and new structure (right) of the China test cryomodule for ILC.

## THERMAL DESIGN AND SIMULATION

There are four temperature regions in the cryomodule, the vacuum vessel is at the room temperature. The shields' nominal temperatures are 80K and 5K. The cavity and helium vessel is operating at 2K. The multi-layer insulation is put at the outer surface of the shields and helium vessel to reduce the heat radiation. The input coupler and the posts are connected to the radiation shields. Most of the heat conducted from room temperature will be taken away by the shields. The 2K conduction heat load was optimized. The key design parameters are shown in Table 1: [3]

Table 1: Parameters of the Test Cryomodule System

| Parameter | Value | Units |
|---|---|---|
| Cavity in the module | One 9-cell | LL cavity |
| Pressure in LHe vessel | 3.3 | KPa |
| Temperature of the 2K system | 2.0-4.5 | K |
| Pressure in the 2K system | 3.13-122 | KPa |
| Heat load of 5k shiled | 2.55 | W |
| Heat load of 80K shiled | 12.5 | W |
| Static heat load | 15.64 | W |
| Dynamic heat load | 3.75 | W |
| Total heat load | 19.39 | W |

We simulated the test cryomodule with the FEM software ANSYS,[4] including the temperature distribution the thermal stress distribution and the deformation of the shields with varied mass flow of cooling gas, and the 2K system, the support posts and etc. As shown in Figure 3-6.

For the shield simulation, conduction and radiation heat loads were considered in the model, the steady state thermal load on the two shields after cool-down is 0.9W/m$^2$ for the 80K shield and 0.1W/m$^2$ for the 5K shield. [5] With the helium flow 0.16g/s, the maximum temperature of the 5K shield is 8.54K, and the 80K shield cooling with liquid nitrogen flow 0.24g/s, its temperature range is 80K to 89.18K.

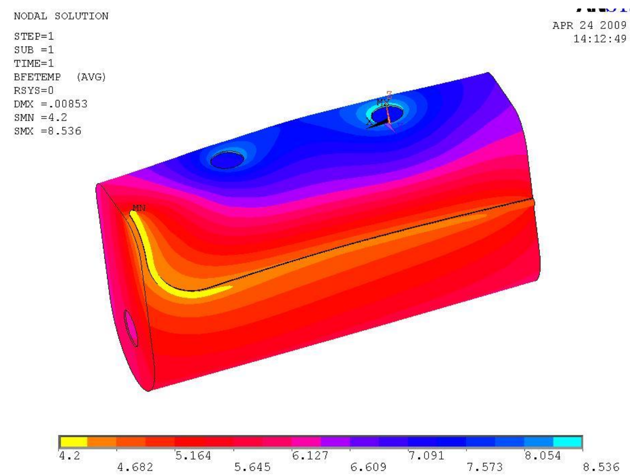


Figure 3: Temperature distribution of the 5K shield.

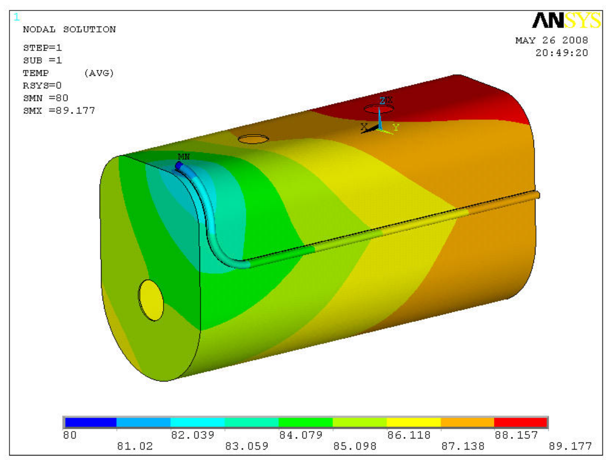


Figure 4: Temperature distribution of the 80K shield.

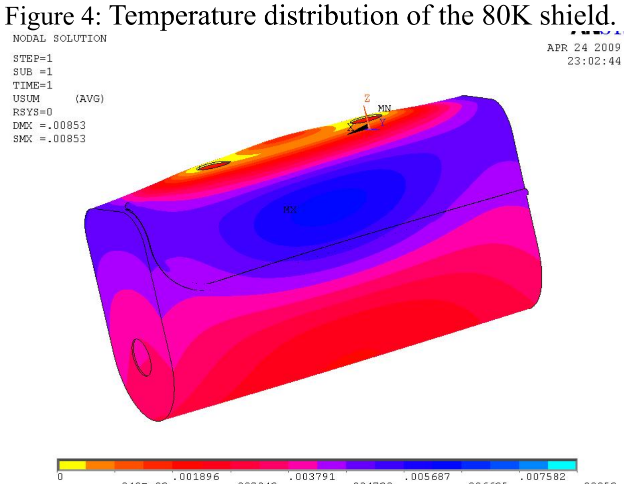


Figure 5: Displacement vector sum of the 5K shield.

Figure3 and figure4 show the temperature distribution of the two shields. The simulation of the displacement shows the maximum displacement of the 5K shield is 8.53mm at the same simulation, the maximum deformation occurred at the centre of one side of the shield, which was attached to the cooling pipe.

The cavity, helium vessel and the GRP were simulated as a whole. In the simulation, the horizontal axial deformation of the GRP is 3.7mm, the fixed side is 1.1mm, and in the horizontal transverse direction, the maximum deformation is about 0.5mm. Figure6 shows the stress distribution at this part after cooling down to 2K. The maximum stress is located at the fixed post position.

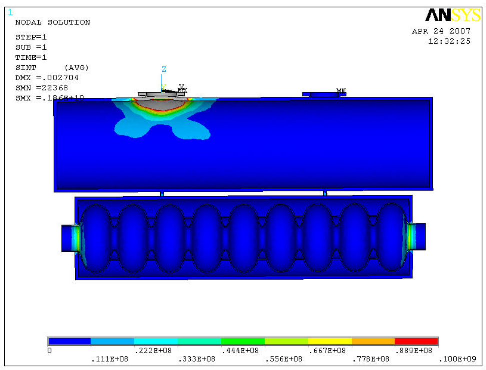


Figure 6: Stress distribution at 2K.

## CRYOGENIC SYSTEM

The operating temperature of a superconducting cavity is usually chosen so that the BCS resistance is reduced to an economically tolerable value, [6] so we choose superfluid helium providing the 2K bath cooling for the superconductivity RF cavity, and designed a small size 2K system for this cryomodule. Helium below 2K is turn to HeII, the thermal conductivity of HeII is extremely high, so the 2K heat load of the module is absorbed by superfluid helium flow rapidly without boiling.

Figure 7 shows the cryogenic flow diagram, There is a helium refrigeration system providing the 4.5K liquid helium; a liquid nitrogen tower providing the pre-cooling for the refrigeration and cooling for the 80K shield. During the steady state operation, we storage the liquid helium in a big helium dewar. The 5K forward line is connected to the dewar and lead to the 5K shield. It provides the cold capacity for the 5K shield and intercepts. The dewar also provide liquid helium for the 2K system. There is also an 80K helium gas line leading out of the refrigeration, with it we mix the cold gas and room temperature gas to obtain the gas temperature range from 80K to 300K, for cooling down the cavity and helium vessel in the cryomodule. After the precooling, we fill the helium vessel with 2K liquid helium. The 4.5K helium in the 2K system was cooled down to about 2.6K through the low temperature heat exchange, and flowing through a J-T valve, and then we obtain two phase helium. The return gas of the 2K system will be heated by a heater and sent to the clean helium storage. The 2K liquid helium flows to the module. There is a reservoir tank in the module, which is also a phase separator. A heater was attached in the tank. Adjusting the power of the heater, we can easily control the liquid level inside the tank which is the same with two phase supply line and the reservoir tank. [2][7]

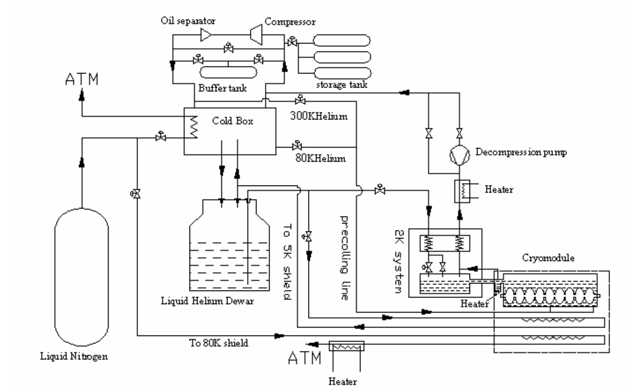


Figure 7: Cryogenic flow of the cryomodule.

## SUMMARY AND OUTLOOK

This paper presents the structure of the cryomodule, the thermal and mechanical simulation results and the cryogenic system. The detail design of this cryomodule and the 2-D drawing is now under way. We expect to have the first test cryomodule fabricated and tested with an IHEP-LL 9-cell cavity [8] next year. The cryogenic system will be done later.

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