The BESIII detector magnet

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BESIII (Beijing Spectrometer III) is a detector designed to run in the autumn 2007 at a 1×10^{33} $cm^{-2}s^{-1}$ luminosity @1.89 GeV at BEPCII (Beijing Electron-Positron Collider II) at IHEP Beijing. It has a 1 T superconducting solenoid magnet with the inner winding diameter of 2962 mm, winding length of 3532 mm and a 600 tonne flux return yoke. It will be assembled by the end of 2004 and tested in the middle of 2005. The indirectly cooled, pure aluminum stabilized single layer coil is internally wound with a 4 kA superconductor. The magnet design is described.

INTRODUCTION

BESIII detector magnet is one of the largest superconducting magnets in China. It generates 1.0 T magnetic field with a uniformity of 5% within the drift chamber. Rectangular aluminum stabilized NbTi/Cu superconductor, made by Hitachi Cable Ltd., is adopted to wind the one-layer coil inside a support cylinder. Furthermore, the winding is indirectly cooled by forced flow of two-phase helium. The main structure disign of BESIII magnet is shown in Figure 1. The important parameters of the magnet are listed in Table 1.

Table 1. The important parameters of BESIII magnet

Items	Value
Central field	1.0 T
Uniformity in the tracking region	5%
Operating current	3250 A
Inductance	2.1 H
Stored energy	9.5 MJ
Winding structure	single layer
Winding length	3532 mm
Winding mean radius	1490 mm
Total turns	905

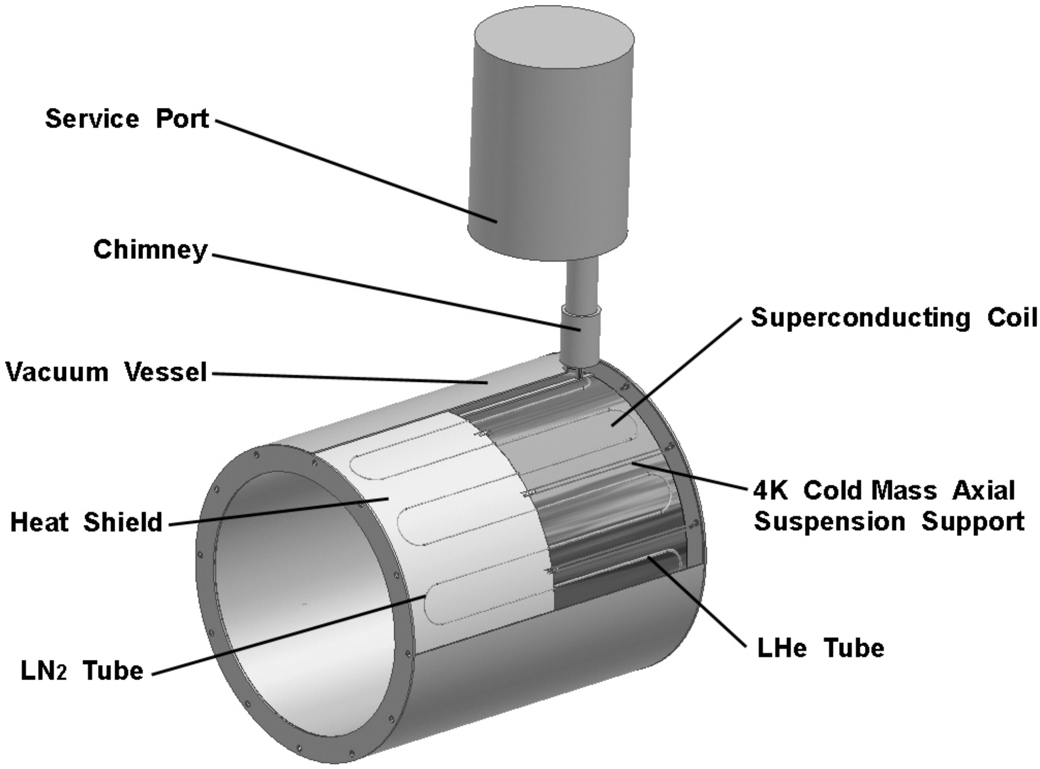

Figure 1. The design of BESIII magnet

CONDUCTOR

Total length of the superconductor is about 8500 m , it is composed of three long superconductors because of the limit of the manufacturing technique. The operating current is designed to be 3250 A and the critical current test of a short sample of the superconductor has been performed, whose result is about 7300 A at 4 T, so it has a large margin of safety. The NbTi/Cu superconducting cable is embedded in the center of the aluminum stabilizer. The coil temperature will be kept below 70 K after quench.

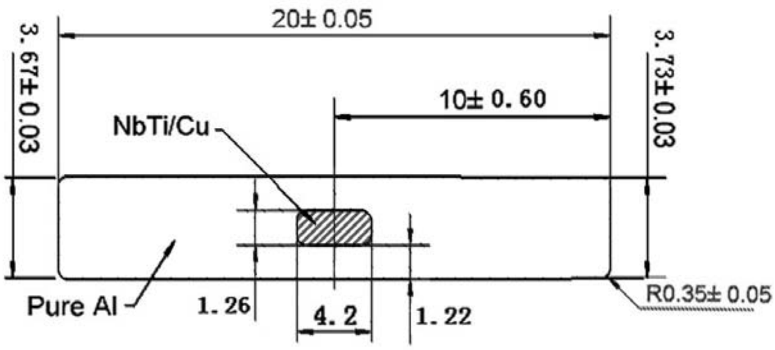

Figure 2. The cross section of the conductor(in mm)

COIL SUPPORT SYSTEM

The loads to be supported are the self weight of the cold mass and the magnetic forces due to the decentring and misalignment of the coil with respect to the return yoke, the contraction of the coil during cooling must also be taken into account. The 4.5 K cold mass is about 3900 kg. There are 12 radial supports at each end and the total radial load is 10,065 kg. The capacity of each radial support is rated at 2516 kg with a safety factor. There are 12 axial supports in each direction to support 53291 kg. Each axial support is rated at 4540 kg with a safety factor. The race-track shape GFRP (Glass Fiber Reinforced Plastic) supports are adopted in order to decrease the heat leak through the supports.

Table 2. The main characters of the conductor

	Items	Value
SC cable	Total length	8.5 km
	SC core wire material	NbTi/Cu
	Aluminum stabilizer material	Al purity 99.998%
	RRR of copper in core wire	70
	RRR of Aluminum in cable	500
	Interface shearing stress between core wire and aluminum	20 MPa
	Cross section area ratio	NbTi/Cu/Al~1:0.9:28
SC core wire	No of strands	12
	Strand diameter	0.7 mm
	Pitch of twisted wire	50 mm
	Critical current	6800 A @ 4 T, 4.2 K
Single strand	Filament diameter	15~20 μm
	Pitch of twisted filaments	20 mm

WINDING

An inner winding machine is under construction. The superconductor will be wound onto the inner surface of the support cylinder. Before the winding, the helium cooling tubes will be welded onto the outer surface of the support cylinder, and the ground plane insulation will be mounted on the inner surface of the support cylinder.

One layer of 0.075 mm thick UG (Upilex-Glassfiber) film is designed for turn-to-turn insulation of the conductor with 100% coverage. The 0.025 mm thick upilex layer has dielectric strength of 7.4 kV at 25℃. Taking into consideration the reality that the dielectric strength of polyimide is higher at cryogenic temperature than that at the room temperature, it is estimated that the mentioned UG turn-to-turn insulation design will fully satisfy the required insulation strength above 100 V. Two layers of GUG (Glassfiber-Upilex-Glassfiber) are employed as ground plane insulation., with 0.07 mm epoxy resin and non flatness, the total thickness of the ground plane insulation is 0.4 mm. The GUG sheets will be attached onto the inner surface of the support cylinder warmed to 80℃. The conductor joints will be made with TIG (Tungsten Inert Gases) welding technique, and the joint resistance is designed to be less than $1*10^{-9}$ Ω at room temperature. Some pure aluminum strips will be mounted onto the inner surface of the coil along the axial direction, it will serve as a quench propagator.

CRYOSTAT

Thermal shield cooled by liquid nitrogen is designed to reduce the radiation heat load to the 4.5 K cold mass. According to the estimation on the heat loads and using a margin factor of 1.5， the mass flow rates of nitrogen and helium have been determined, which is 1.89 g/s and 10 g/s respectively. There are 50 layers of super insulation between the heat shield and the vacuum vessel, and 15 layers between the heat shield and the coil.

SUMMARY

The BESIII magnet will be fabricated and assembled in Beijing by the end of 2004 and will be tested in the middle of 2005. The NbTi/Cu superconductor has been delivered and the critical current test of a short sample of the superconductor has been performed. An inner winding machine is under construction.

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REFERENCES

1. Yamamoto, A. et al., A thin superconducting solenoid wound with the internal winding method for colliding beam experiments, Journal de Physics – C1 (1984) 337-340
2. Yamamoto, A. et al., Performance of the TOPAZ Thin Superconducting Solenoid Wound with Internal Winding Methods, Japanese Journal of Applied Physics (1986)
3. Lucio Rossi, Superconducting magnets for accelerators and detectors, Cryogenics (2003) 43 281-301
4. Goldacker, W. et al., Development of superconducting and cryogenic technology in the ITP of Research Center Karlsruhe, Cryogenics (2002) 42 735-770
5. Paola Miele, et al., The superconducting magnet system for the ATLAS detector at CERN, Fusion Engineering and Design (2001) 58-59 195-203
6. Herve, A. et al., CMS-The Magnet Project Technical Design Report, CERN/LHCC 97-10, (1997)
7. Wilson M., Superconducting Magnets, Oxford University Press, Oxford, UK (1983) 200-232