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HIGH FIELD SUPERCONDUCTING MAGNET PROGRAM FOR ACCELERATORS IN CHINA*

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Abstract

High field magnet technology is the key to the success of the high energy accelerators in future. China is pursuing critical technologies R&D for future circular colliders like the Super Proton Proton Collider (SPPC). SPPC will need thousands of high field (12-20 T) superconducting magnets in around 20 years. A long term R&D roadmap of the advanced superconducting materials and high field magnets has been made, aiming to push the technology frontier to the desired level, and a strong domestic collaboration is established, which brings together expertise of Chinese superconductivity community from fields of physics, materials, technology and application. The goal is to address prominent scientific and technological issues and challenges for high field applications of advanced superconducting materials. In the past years model magnets with hybrid coils (NbTi, Nb_3Sn and iron-based superconductors) have been developed and tested. An overview of the high field magnet program, R&D status and the future plans will be presented.

CONCEPTUAL DESIGN STUDY OF THE MAGNET FOR SPPC

A conceptual design study of 12-T 2-in-1 dipole magnets is ongoing with the Iron-based superconducting (IBS) technology, to fulfill the requirements and need of a proposed large-scale superconducting accelerator: Super Proton Proton Collider (SPPC), which aims to discover the new physics beyond the standard model with a 100-km circumference tunnel and 75 TeV center-of-mass energy [1]. The design study is carried out with an expected J_e level of IBS in 10 years, i.e., about 10 times higher than the present level. Besides the significant improvement of J_e, we are also expecting that the IBS superconductor would have much better mechanical performance comparing with present high field conductors like Nb_3Sn, ReBCO and Bi-2212, and the much lower cost than them.

The aperture diameter of the magnets is 45 mm. The main field is 12 T in the two apertures per magnet with 10^{-4} field uniformity. The common-coil configuration is adopted for the coil layout because of its simple structure and easy to fabricate. Two types of coil ends are considered and compared for the field quality and structure optimization: soft-way bending and hard-way bending. For the hard-way bending the coil is wound with flared ends and in such way the needed superconductors is minimized. The cross sections of the two design options are shown in Fig. 1. The detailed information is presented in [2].

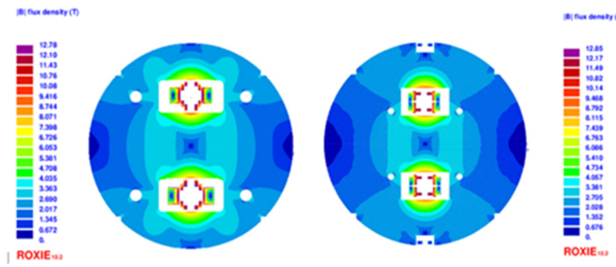

Figure 1: Cross sections of the two design options for 12-T IBS SPPC dipole.

PROGRESS OF HIGH FIELD DIPOLE MAGNET R&D

R&D of high field model dipole magnets is ongoing at the Institute of High Energy Physics. As the first step, a 12-T subscale common-coil dipole magnet named LPF1 (Let the Proton Fly) with two apertures and graded coil configuration was designed, fabricated, and tested. With 4 NbTi racetrack coils outside and 2 Nb_3Sn racetrack coils inside, this hybrid dipole magnet can provide a 12-T main field in two apertures operating at 6100 A. The safety margin is 17% @ 4.2K for the designed current and field. To reduce the field enhancement at the ends of the coils, the coils were designed with different lengths. All of the six coils were wound with superconducting Rutherford cables and impregnated. Coils were pre-stressed during assembly at room temperature with water-pressurized bladders in vertical and horizontal directions. Two end plates and four aluminum tension rods were adopted for pre-loading in axial direction. A 0.1 Ohm dump resistor was used for the quench protection during the test of LPF1. LPF1 was tested at 4.2 K and a field plateau had been shown around 10.2 T after the 13th quench, as shown in Fig. 2. The parameters of the design, the process of the fabrication and the test performance of LPF1 are presented in [3].

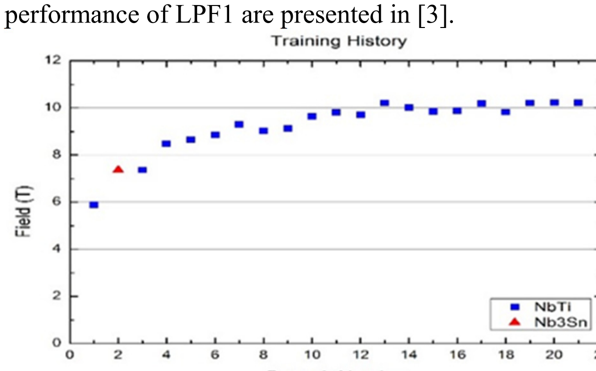

Figure 2: The LPF1 model dipole magnet reached 10.2 T at 4.2 K in two apertures.

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R&D AND TEST OF THE IBS COILS

A series of ϕ35 mm IBS (Iron Based Superconductor) coils including single pancake (SPC) and double pancakes (DPC) were designed and winded with the 7-filamentary Ba122 (Ba1-xKxFe2As2) tape which was produced by the Institute of Electrical Engineering, Chinese Academy of Sciences (IEE-CAS). The tests of the IBS coils were firstly carried out at 4.2 K and 10 T background field. The highest quench current of the coils at 10 T is 68.4 A, which is about 79% of the quench current at self-field and about 90% of the critical current of the short sample. Then two SPCs were selected and tested at 4.2 K at 24 T. The highest quench current of the coils at 24 T is 25.6 A, which is about 39% of the quench current at self-field, as shown in Fig. 3. The detailed information is presented in [4]. These results suggest that the iron-based superconductors are very promising for high-field magnet applications.

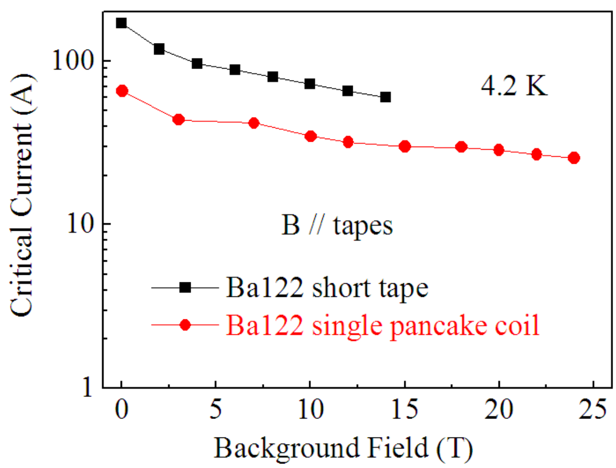

Figure 3: Magnetic field dependence of transport critical current at 4.2 K for IBS tape and SPC.

PROGRESS OF THE CCT MAGNETS FOR HL-LHC

The HL-LHC is the luminosity upgrade project for the Large Hadron Collider. By replacing the final focusing quadrupole magnets and separation dipole magnets at the ATLAS and CMS interaction regions, the peak and integrated luminosity of the LHC will be significantly increased. In order to control the crossing angle of the particle beam and to correct the closed orbit, HL-LHC needs a new type of orbit correction magnets. The magnets need to provide mutually perpendicular dipole field in two apertures. The integral field strength is 5 T·m. The aperture diameter is 105 mm. The central magnetic field is less than 3 T to reduce the magnetic cross-talk between the two apertures. The length of the magnet is approximately 2.2 m. the Canted Cos-theta (CCT) configuration is adopted for the coil fabrication. It will be the first series of CCT superconducting magnets be used in operating particle accelerators. In September 2018, IHEP and CERN signed formal collaboration agreement for the development of the HL-LHC CCT magnets, as shown in Fig. 4. IHEP will develop 8 series of formal magnets and 4 series of spare magnets for the HL-LHC project by the end of 2021. Two 0.5 m model coils have been fabricated and tested in 2018. Performance of the two coils is significantly higher than the design specifications. The 2.2 m full length prototype magnet is under development and will be completed and tested by August 2019.

Figure 4: MoU formally signed between IHEP and CERN for the collaboration on HL-LHC CCT magnets in Sep. 2018.

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