A MEDIUM FIELD VARIABLE TEMPERATURE TEST MAGNET FOR FUSION AND HEP RESEARCH USING THE EXISTING HTS COILS

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We propose to design, build, and test a medium field (~5 T@4K), variable temperature (4K to 80K) dipole using HTS coils that are in hand and incorporate it into a flexible test facility for fusion and High Energy Physics (HEP). By leveraging existing HTS coils, the timeframe for this proposal is about two years and represents a unique opportunity to quickly bring unique testing capability online. This magnet will complement the other proposals for much higher field dipoles which will require much greater investments and longer time frames to implement. Even though this magnet will not provide the very high fields, the available field and variable temperature should still provide useful data and feedback to the development of the next generation fusion reactors. In addition to providing useful test data on the performance of HTS cables and coils, it will offer experimental validation of various models that can be extrapolated to higher fields. It will also provide added useful experience and planning background on using a future higher field facility. The proposed concept departs from the other designs by enabling the magnet coils to operate at the same variable temperature as the fusion cables or insert coils, thereby simplifying operation and reliability. Brookhaven National Laboratory (BNL) has a rich history of working with HTS coils and HTS magnet technology and is collaborating with the leaders in the promising fusion technology via a number of INFUSE and ARPA-E grants. We invite other laboratories and fusion industries to join us in this useful endeavor. Development of the details of the magnet design and the facility will incorporate feedback from them.

INNOVATION AND IMPACT

This proposal presents the development of a medium field all HTS magnet design leveraging existing HTS coils. The overall concept permits the use of the same HTS coils in both the conventional super-ferric dipole and in the common coil dipole geometry [1]. The common coil was initially developed for conductor dominated high energy collider dipoles. In the proposed design, however, the iron will contribute significantly to the field. The design differs in many ways from the other dipole magnets for the cable testing that are either built or are in the design stage. It offers many advantages such as: (a) a large reduction in magnet aperture since the test cable and magnet coil operate at the same temperature with no additional cryostat over cable needed; (b) an efficient and compact structure for testing fusion cables requiring large bend radii; (c) the ability to change the coil spacing either to attain higher field or higher aperture; and (d) a simple racetrack coil design, with a geometry that is inherently suitable for dealing with large Lorentz forces.

The proposed magnet can be built in a relatively short period (about two years from the receipt of funding) and with a highly competitive budget, as we will be leveraging the existing HTS racetrack coils, a major budget driver of such projects. Our plan is to use either (a) the twenty-four existing HTS coils (from the magnet in Fig. 1, middle) made with ~5 km of 4 mm wide tape from the R&D quadrupole [2] built for what was then called the Rare Isotope Accelerator (RIA) or (b) the eight existing HTS coils (in magnet in Fig. 1, left) made with 12 mm wide tape (~9 km 4 mm wide tape equivalent) for the R&D quadrupole [3] for the Facility for Rare Isotope Beams (FRIB). Both of these R&D magnets were built as a part of developing radiation-resistant high temperature magnet technology.

These coils and magnets have already been tested as a function of temperature (Fig. 1, right for RIA) providing a good estimate of expected field while mitigating the risks. A choice between the two (FRIB coils or RIA coils) will be made after a careful investigation of the two options.

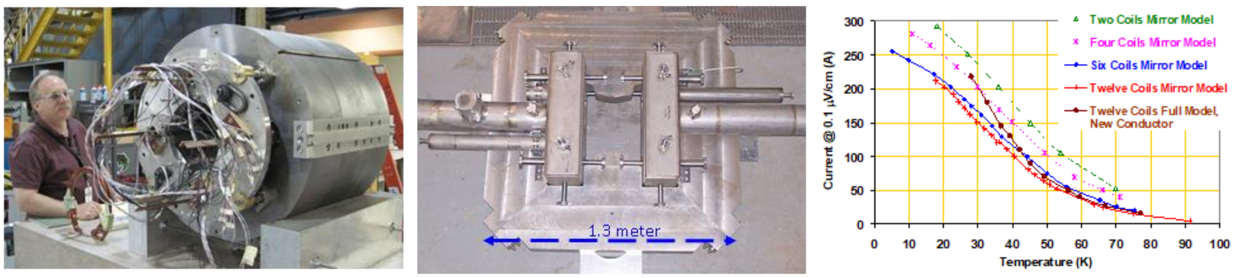

Fig. 1. Left: FRIB HTS R&D quadrupole [3], Middle: RIA HTS R&D quadrupole [2], Right: Performance of various RIA R&D quadrupole built with a number of HTS coils (as indicated) as a function of temperature [2].

A magnetic model of a possible design using the RIA HTS coils is shown in Fig. 2, right. It is expected to produce ~5 T at 20 K based on the measured coil performance. The general approach will remain the same as that which has been used in making the common coil dipole DCC017 [4] shown in Fig. 2, left, and turning it into a productive test facility for the fusion and HEP community. We will examine a bolted structure, as shown in Fig. 2 (middle), which will allow an easier variation in field to aperture ratio as is possible in a common coil geometry.

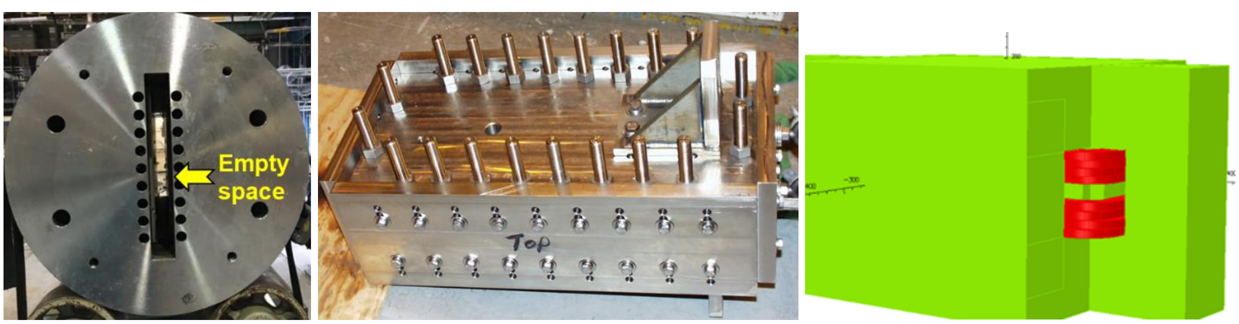

Fig. 2. Left: Structure used in the BNL common coil dipole [4] allowing direct insertion of U-shape bent cable as in Fig. 1, Middle: Bolted structure used at BNL in R&D common coil dipole for assembling HTS cable and HTS coils together , Right: Model of the Proof-of-Principle dipole using RIA HTS coils that is expected to produce ~5 T at 20 K based on the measured coil performances shown in Fig. 2.

The proposed work will continue the development of our advanced quench protection system - a critical technology for HTS magnets. Demonstration of a reliable quench protection of HTS magnets remains a major challenge. The development of the quench protection system and use of it in protecting this dipole will follow the advanced quench protection system approach that BNL has implemented to protect previous HTS coils [5].

REFERENCES

1. R.C. Gupta, A Common Coil Design for High Field 2-in-1 Accelerator Magnets, Presented at the 1997 Particle Accelerator Conference in Vancouver, Canada (1997).
2. R. Gupta, et al., "Design, Construction and Test Results of a Warm Iron HTS Quadrupole for the Facility for Rare Isotope Beams," IEEE Trans. on Appl. Superconductivity 18(2):236 - 239 (2008).
3. R. Gupta, et al., "HTS Quadrupole for FRIB - Design, Construction and Test Results", 2014 Applied Superconductivity Conference, Charlotte, NC, August 2014.
4. R. Gupta, et al., "React & Wind Nb_3Sn Common Coil Dipole", 2006 Applied Superconductivity Conference, Seattle, USA, August 2006.
5. P.N. Joshi, et al., "Novel Quench Detection System for HTS Coils," Proceedings of 2011 Particle Accelerator Conference, New York, NY, USA, pp. 1136-1138, March 28 – April 1, 2011.