NB_3SN BLOCK-COIL DIPOLE FOR HIGH-FIELD SUBSTITUTION IN THE LHC LATTICE*

Eddie Holik, Al McInturff, Peter McIntyre#, and Akhdiyor Sattarov
Texas A&M University, College Station, TX 77843 USA

Abstract

A design is being developed to prototype for a dipole for this purpose: a block-coil dipole with 13 T short-sample field, 11 T working field, and 6 cm aperture. The dipole is a natural application of the high-field dipole strategy developed at Texas A&M, using simple pancake windings, flux-plate suppression of low-field multipoles, and bladder preloading. A short model dipole is planned.

INTRODUCTION

The LHC lattice was designed to fit within the LEP tunnel and so has very little provision of free space for insertions required for dispersion suppression, collimation, injection, abort, and low-beta insertions. One way to provide additional space at locations where it is needed is to substitute high-field dipoles for the arc dipoles, preserving the field integral but opening lattice space for needed elements.

We have prepared a conceptual design for an 11.4 Tesla dipole suitable for the requirements for the DS dipoles that are required to liberate space in the LHC lattice for the upgrade of the collimators. De Rijk et al have prepared a dual- cos θ design for the DS requirements [1]. We have prepared a block-coil design for their requirements, utilizing the design methodology and fabrication technology developed for the TAMU series of high-field dipoles [2].

BLOCK-COIL DS DIPOLE DESIGN

Our understanding of the DS specification is that each DS dipole must provide a field integral of 120 T-m, and occupy a total length of no more than 11 m in the LHC lattice (including end regions on the magnet). We envisage configuring each magnet with 10.6 m body length and operating field of 11.4 T. We envisage providing an aperture of 6 cm, which should accommodate the increased sagitta in the higher bend field.

The dipole design is shown in cross section in Figure 1. The coil in each bore consists of 6 pancake windings. The upper and lower center windings are wound two-in-hand from a single cable segment, so each bore contains three cable segments in total, connected in series by NbTi splices in a low-field region at the dipole end.

The parameters of the coil design are given in Table 1. The short-sample limit is 12.76 T, so operation at 11.4 T corresponds to 90% short sample. The load line is shown in Figure 2. The operating point reserves ~1.5 T operating margin. Figure 4 shows the calculated field distribution.

Work supported by US Dept. of Energy, grant DE-FG03-95ER40924.
ncintyre@physics.tamu.edu

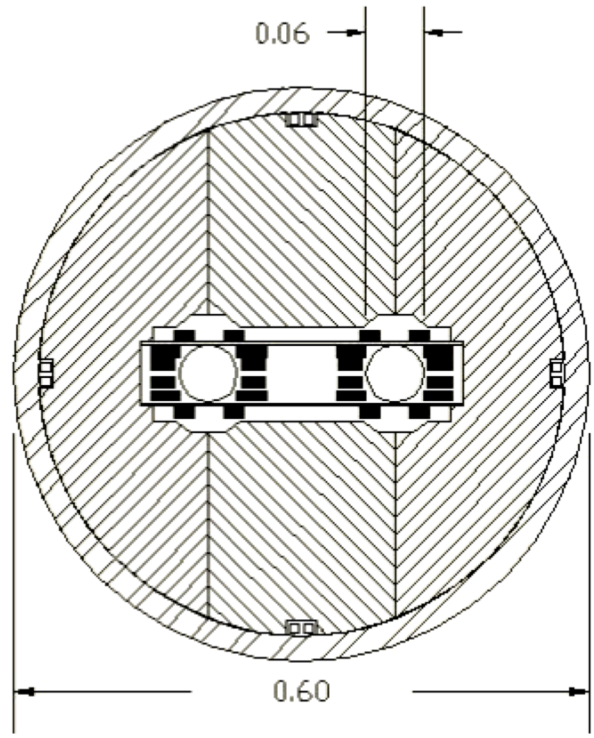

Figure 1: Cross-section of the block-coil Nb_3Sn DS dipole.

ASSEMBLY ISSUES

The center pairs of windings must be bent up/down as flared ends to accommodate the beam tube as shown in Figure 3; the outermost windings are planar racetrack windings. The conductor specifications are based upon current high-performance fine-filament 108/127 RRP Nb_3Sn/Cu strand. The choice of 0.7 mm strand diameter and small number of strands per cable (28) is made to provide good cable stability so that the ends can be flared without risk of de-registration.

The DS dipole assembly would utilize the methods developed in the TAMU series of block-coil high-field dipoles [3]. The dual dipole will be assembled within a 4-piece steel flux return, inside an aluminum stress tube (see Figure 1). An arrangement of Wood's metal-filled bladders (Figure 3) provides near-isostatic preload of all windings, including the ends, and assures that no coil motion is possible anywhere in the magnet. This should provide for simple assembly and reliable operation, and from our experience to date the dipoles should attain very close to their short-sample limit with no training.

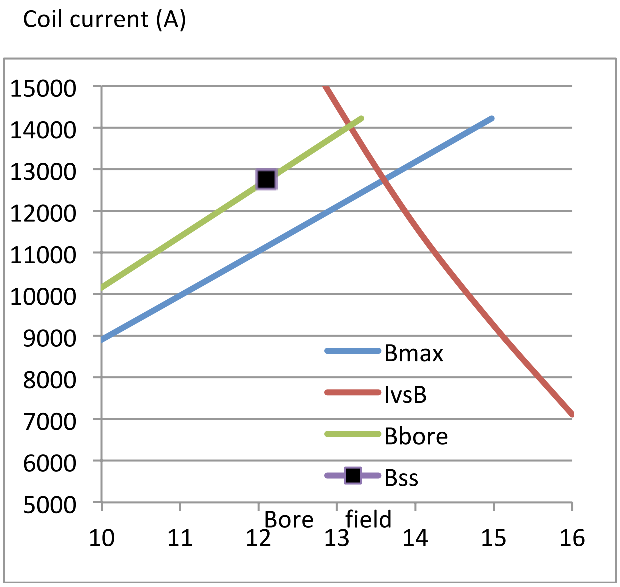

Figure 2: Load line for DS dipole.

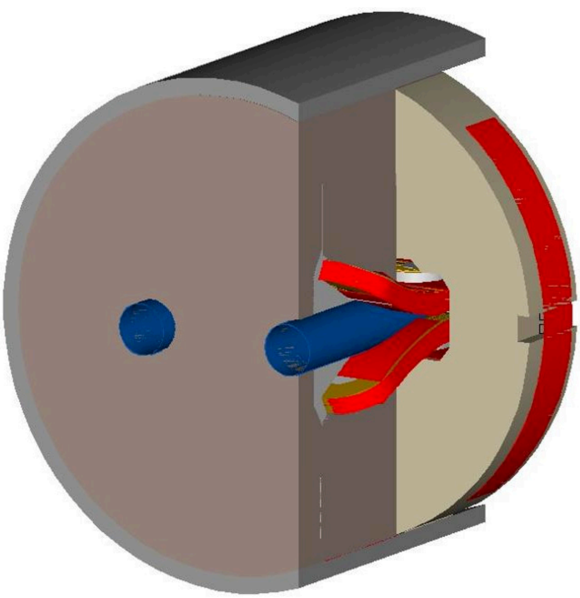

Figure 3: Isometric view of DS magnet end with cutaway, showing flared windings supported on 3-piece shoe assembly, bladder arrangement for isostatic preload of body and ends of all windings.

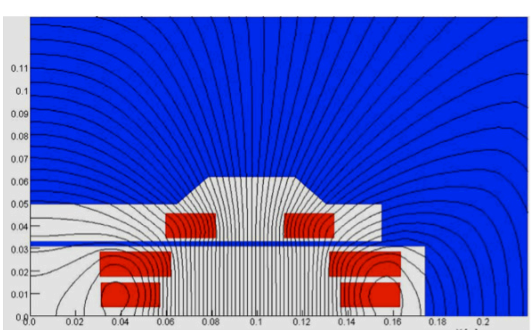

Figure 4: Calculated field distribution in DS dipole at 11.4 T.

Table 1: Main Parameters of the Block-coil DS Dipole

Bore Field	11.38	T
Bore dia.	6.0	cm
current	11.85	kA
energy	1.30	MJ/m/bore
# turns/winding	18/22/16	
# strands	28	
strand dia.	0.70	mm
J_{sc} @4.2	2000	A/cm^2
short sample limit	12.76	T
J_{cu}	2,500	A/mm^2
Area of SC	24	cm^2/bore

CONCLUSIONS

Developing the proposed design for a bock-coil DS dipole is being approached as a collaboration between the Texas A&M superconducting magnet group and Niowave, Inc. It is a natural next step for our development of high-field block coils. It would provide a proximal step in the development of block-coil dipoles that would be mainstream for longer-term objectives to develop similar geometry using Bi-2212 inserts to push to ~20 T [4].

REFERENCES

[1] G. de Rijk, A. Milanese, E. Todesco, ‘11 Tesla Nb_3Sn dipoles for phase II collimation in the Large Hadron Collider’, CERN sLHC Project Note 0019 (2010).

[2] R. Blackburn *et al.*, ‘Fabrication of TAMU3, a wind/react stress-managed 14T Nb3Sn block coil dipole’, 8th Eur. Conf. on Appl. Superconductivity (EUCAS'07): J. of Physics Conf. Series 97, 012128 (2008).

[3] E. Holik, ‘Current progress of TAMU3: A block-coil stress-managed high field (>12T) Nb_3Sn dipole’, this conference.

[4] K. Damborsky *et al.*, ‘20 T dipoles and Bi-2212: the path to the LHC Tripler’ Proc. EuCARD Workshop on High-Energy LHC, Malta, Oct. 14-16, 2010.