15 T Dipole Demonstrator: design parameters and work status

Alexander V. Zlobin

US-EuroCirCol video meeting

18 October 2016

US Magnet Development program

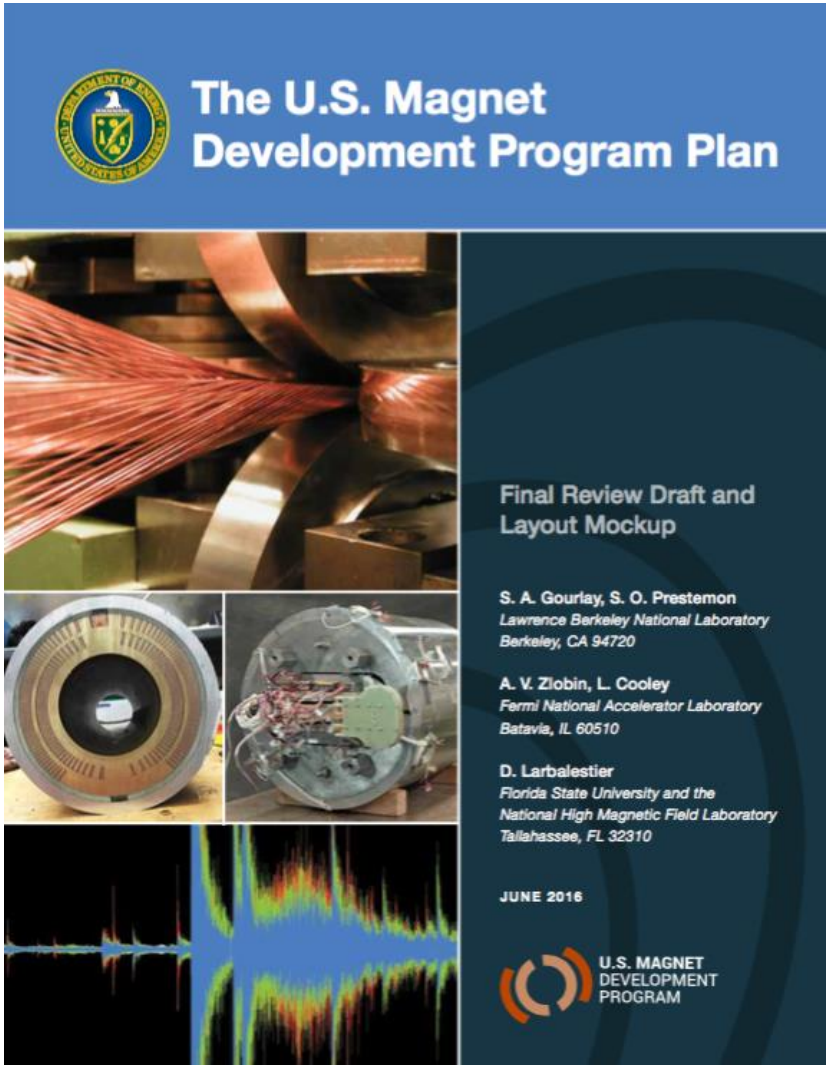


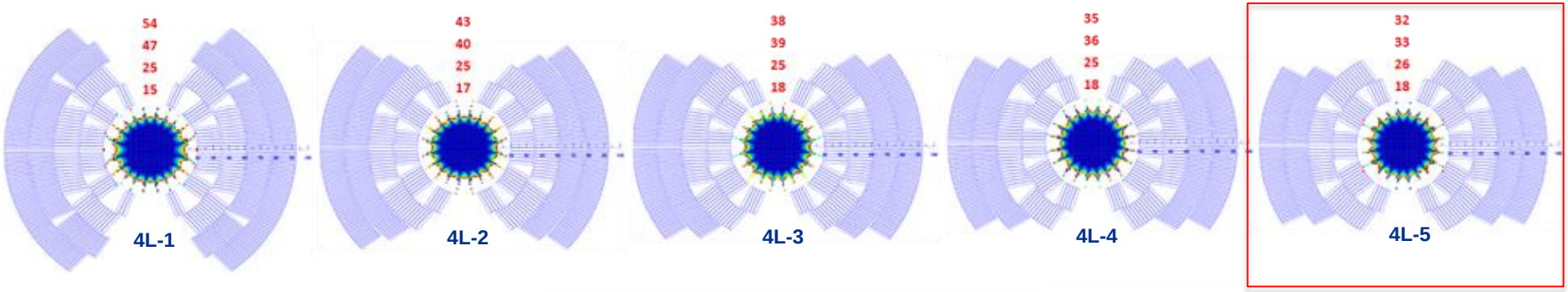
Table of Contents

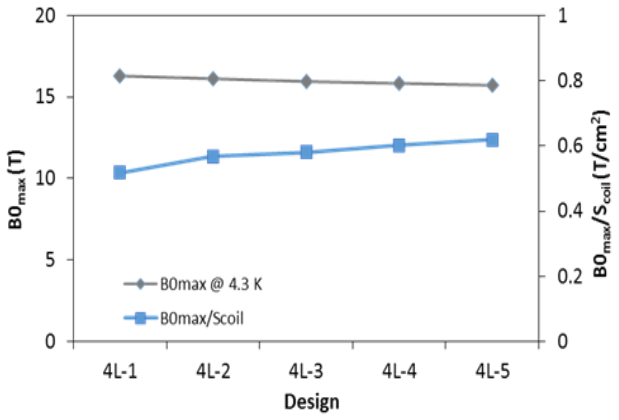
- FNAL 15 T Dipole demonstrator is the program key milestone for FY17

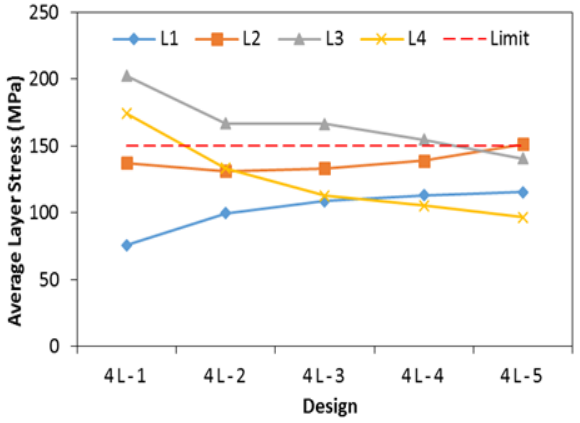
Coil Design Study [1]

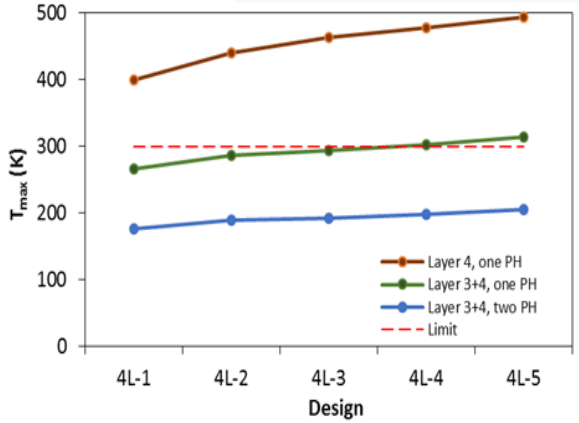
- Coil aperture: 60 mm
- Coil cross-section: 4 layers, graded
- Design parameters: B_{max}, a_n/b_n, coil volume, coil stress, quench protection

Parameter	Cable 1	Cable 2
Number of strands	28	40
Strand ID, mm	1.0	0.7
Mid-thickness, mm	1.870	1.319
Width, mm	15.10	15.10
Keystone angle, deg	0.805	0.805



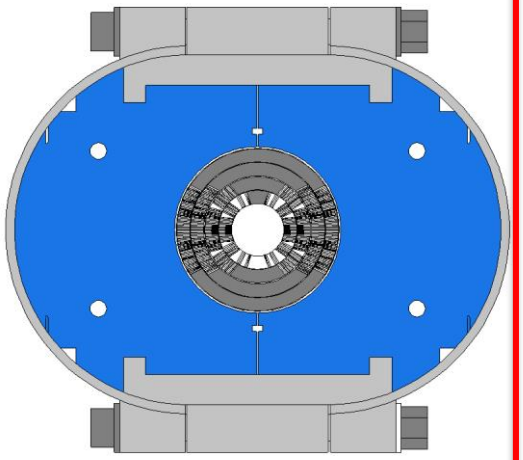


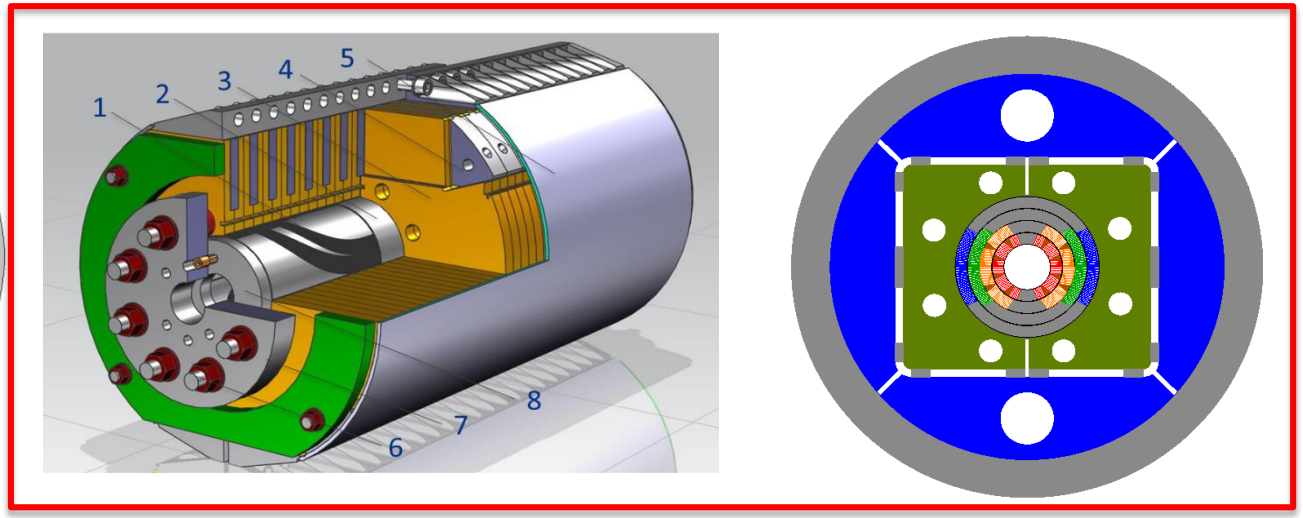




Fermilab

Mechanical Structure [2], [3], [5]





- Thin coil-yoke spacer (no collar)
- Mechanical structure:
  - Design 1: SS C-clamps and 20-mm thick skin
  - Design 2: Al I-clamps and 12-mm thick skin
  - Design 1: 50-mm thick Al shell
- Axial support: thick SS rods and end plates
- Cold mass OD<610 mm (VMTF Dewar limit)

Fermilab

Magnet Design Specifications

TD-16-004
01/22/2016

15 T NB_3SN DIPOLE DEMONSTRATOR - DESIGN AND PARAMETER SPECIFICATION

N. Andreev, E. Barzi, J. Carmichael, V.V. Kashikhin, I. Novitski, D. Turrioni, A.V. Zlobin

Abstract

A 100 TeV scale HC with a nominal operation field of at least 15 T is being considered for the post-LHC era. Practical demonstration of this field level in an accelerator-quality magnet and substantial reduction of the magnet costs are the key conditions for realization of such a machine. FNAL has started the development of a 15 T dipole demonstrator based on Nb_3Sn superconductor for a 100 TeV scale HC. The magnet design is based on 4-layer shell type coils, graded between the inner and outer layers to maximize the performance. The experience gained during the 11-T dipole R&D campaign is applied to different aspects of the magnet design. This document describes the design concept and parameters of the 15 T Nb_3Sn dipole demonstrator.

Table 7. Magnetic parameters and performance goals.

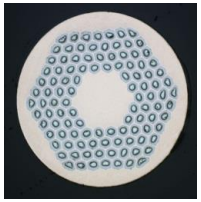
Parameter	Value
Short sample current I_c at 4.2 K, A	11.34
Short sample current I_{max} at 1.9 K, A	12.52
Maximum design field at 4.2 K, T	15.61
Maximum design field at 1.9 K, T	17.04
Peak field / central field at I_{nom}	1.041
Inductance at Ic, mH/m	25.61
Stored energy at Ic, MJ/m	1.65
Horizontal force Fx/quadrant at Ic, MN/m	7.36
Vertical force Fy/quadrant at Ic, MN/m	-4.50
Longitudinal force Fz/magnet end at Ic, MN/end	1.59

Table 8. Geometrical field harmonics (R_{ref} = 17 mm).

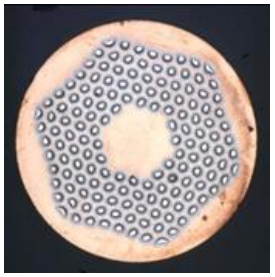
	Value
b_3	0.0018
b_5	0.0154
b_7	0.0523
b_9	0.0612

Fermilab

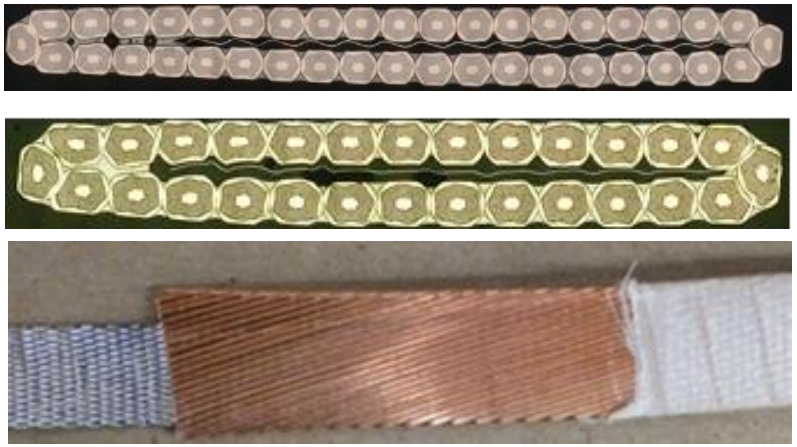
Strands and Cables [4]

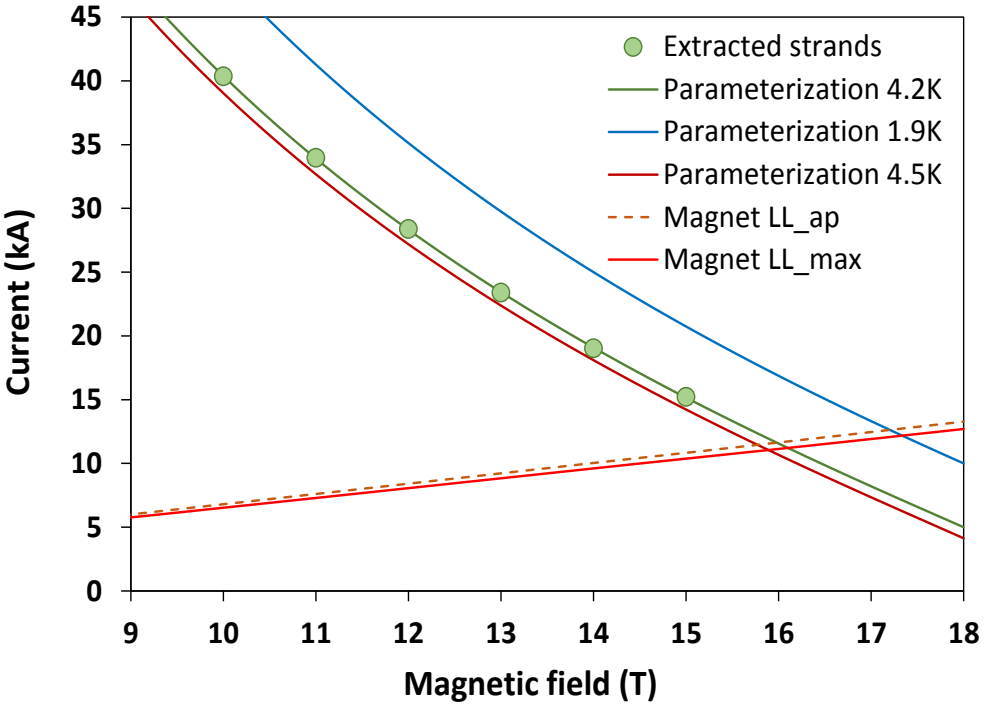


RRP108/127



RRP150/169





- Magnet short sample estimated based on the cable test data:
  - 11.1 kA (B_{ap}=15.3 T) at 4.5 K
  - 12.2 kA (B_{ap}=16.7 T) at 1.9 K

15 T Dipole Demonstrator Status

- Magnet design study phase is complete
- Magnet (design 2) and tooling engineering design is complete
  - Engineering design of design 3 is planned for Q1 FY17
- Tooling and parts procurement is in progress
- L1-L2 cable was developed, fabricated and tested
- L3-L4 cable is available from the 11 T dipole program
- Outer (L3 and L4) and inner (L1 and L2) practice coils are complete
- Coil fabrication has started
- Magnet assembly and first tests are planned for summer 2017

Publications

1. A.V. Zlobin, N. Andreev, E. Barzi, V.V. Kashikhin, I. Novitski, “Design concept and parameters of a 15 T Nb_3Sn dipole demonstrator for a 100 TeV hadron collider”, IPAC2015, Richmond, May 2015.
2. V.V. Kashikhin, N. Andreev, E. Barzi, I. Novitski, A.V. Zlobin, “Magnetic and structural design of a 15 T Nb_3Sn accelerator dipole model”, CEC/ICMC2015, Tucsan (AR), June 2015.
3. I. Novitski, N. Andreev, E. Barzi, J. Carmichael, V. V. Kashikhin, D. Turrioni, M. Yu, A.V. Zlobin, “Development of a 15 T Nb_3Sn Accelerator Dipole Demonstrator at Fermilab”, IEEE Trans. on Appl. Supercond., Vol. 26, Issue 3, June 2016.
4. E. Barzi, N. Andreev, P. Li, V. Lombardo, D. Turrioni, A.V. Zlobin, “Nb_3Sn RRP® Strand and Cable Development for a 15 T Dipole Demonstrator,” IEEE Trans. on Appl. Supercond., Vol. 26, Issue 3, June 2016.
5. I. Novitski, A.V. Zlobin, “Development and Comparison of Mechanical Structures for FNAL 15 T Nb_3Sn Dipole Demonstrator”, NAPAC2016, Chicago, Oct 2016.