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Development of a 120-mm Aperture Nb_3Sn Dipole Coil with Stress Management

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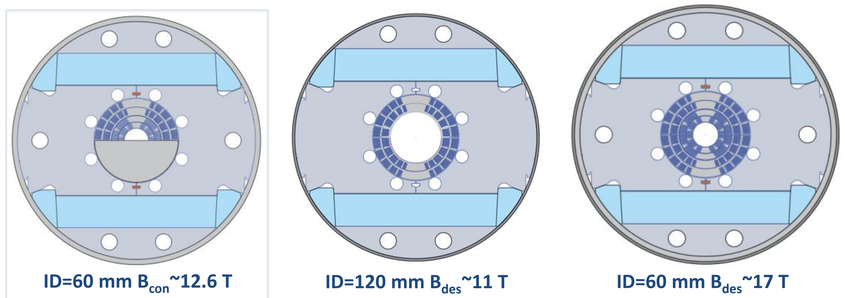
Abstract

Large-aperture high-field magnets based on Nb3Sn superconductor are needed for various accelerator systems of future hadron and muon colliders. High level of magnetic field and large aperture lead to significant Lorentz forces and mechanical strains and stresses, which can degrade or even permanently damage brittle Nb_3Sn coils. This paper describes a 120-mm-aperture two-layer dipole coil developed at Fermilab based on cos-theta coil geometry with stress management and Nb3Sn Rutherford cable. The design and main parameters of the superconducting wire and cable, the coil stress management structure design and the coil FEA in the dipole mirror and dipole test configurations are presented and discussed. A plastic model of the coil support structure was printed using 3D printing technology and used for practice coil winding. The real coil support structure was printed using 316 stainless steel. The key fabrication steps of the Nb_3Sn coil, coil instrumentation, and assembly in a four-layer dipole mirror configuration with an additional 60-mm aperture Nb3Sn insert coil are reported in the paper.

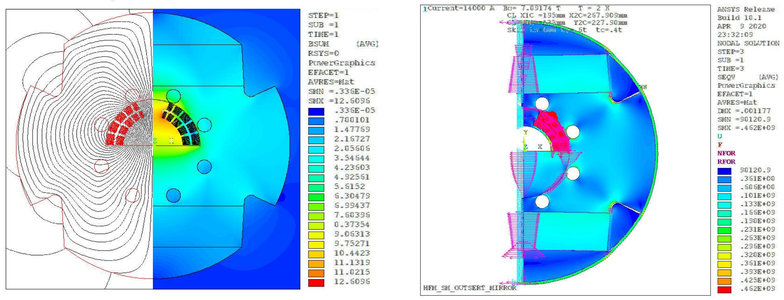
* SMCT coil - stress managed cos-theta coil

Nb_3Sn SMCT R&D goals



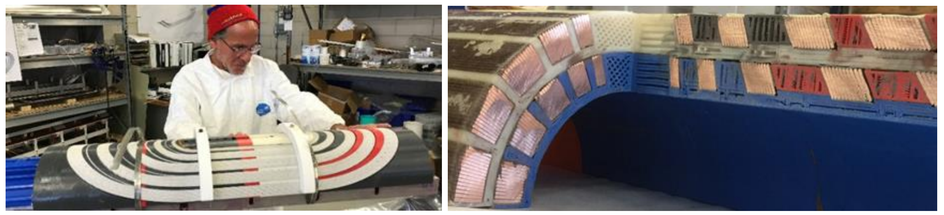
ID=60 mm B_{con}~12.6 T | ID=120 mm B_{des}~11 T | ID=60 mm B_{des}~17 T

Mirror magnet with SMCT coil

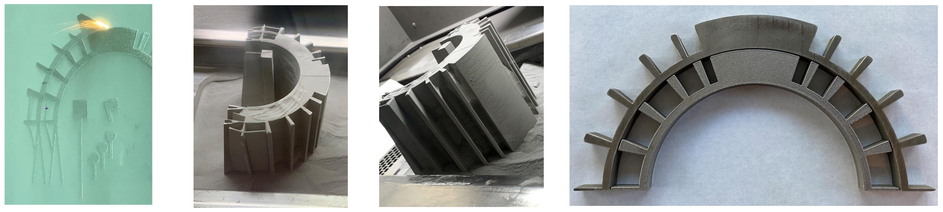


Magnetic flux map and stress distribution in the mirror magnet at 4K - 14kA

Coil Structural Design

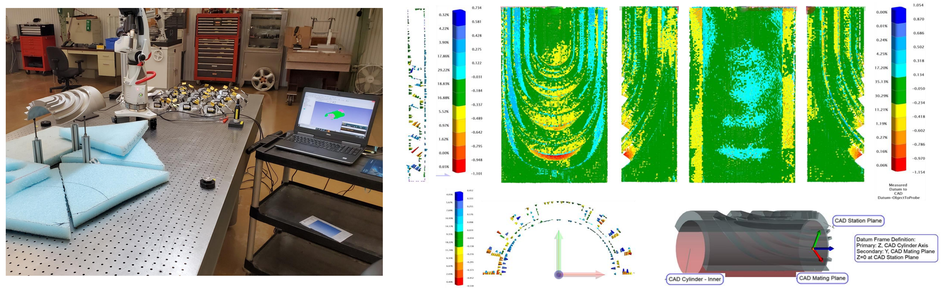


Coil practice winding and impregnation

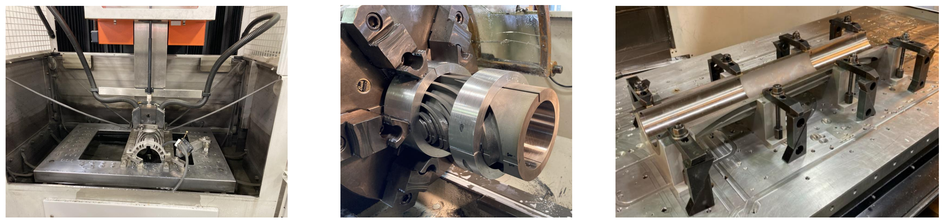


Coil mandrel production by additive manufacturing

3D printed parts for the coil mandrel : plastic-left and 316stainless steel - right

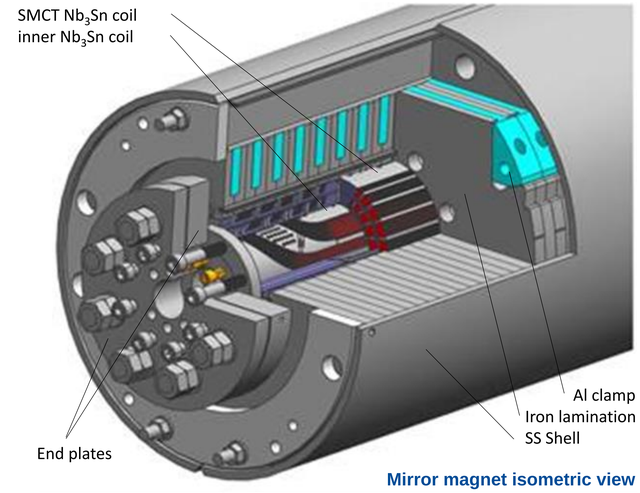


Mandrel part inspection using laser scanning

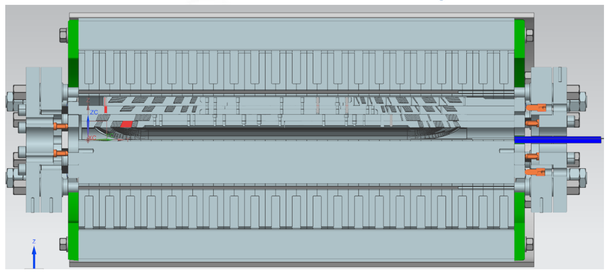


Mandrel postprocessing by wire EDM and milling operations

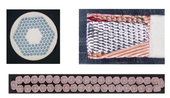
Mirror Magnet Design



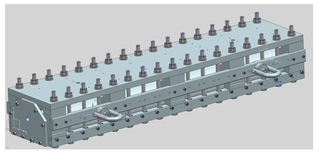
Mirror magnet isometric view



Mirror magnet 2D view



40 strand 15.1x1.319mm Nb_3Sn cable



Reaction/impregnation tooling

Coil mandrel on winding table

Summary and Next step

- A Nb_3Sn shell-type (cos-theta) coil with stress management has been designed and verified on the practice coil winding and impregnation.
- All coil parts were produced by Additive Manufacturing.
- Coil parts post-processing completed.
- SMCT coil preparation for winding is in a progress.
- A design of the mirror magnet has been developed and parts procurement started.
- The mirror magnet test is expected later next year.