Superconducting Magnets and Materials Thrust: Superconducting Magnets for HEP

Alexander Zlobin
Fermilab

General Accelerator Development Review

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Program Goals

- *The main goal* of the SC Magnet Program at Fermilab is the development of advanced superconducting *accelerator* magnets and baseline technologies for present and future particle accelerators.
- *The main focus at the present time* is on the development on high-field accelerator magnets based on Nb_3Sn superconductor.
- *This program thrusts also* the improvements of magnet design and analysis methods and tools, fabrication and test infrastructure, instrumentation, training of young scientists and engineers in the field of SC accelerator magnets and applied superconductivity.

Approach

- *Magnet design studies and computer simulations* to explore the performance parameter space, development of magnet design concepts, the model magnet R&D directions
- *Model magnet construction and component R&D* to verify and confirm experimentally the developed magnet designs and technology, and demonstrate magnet performance by fabricating and testing series of magnet short and long models and prototypes

Outcome and Deliverables

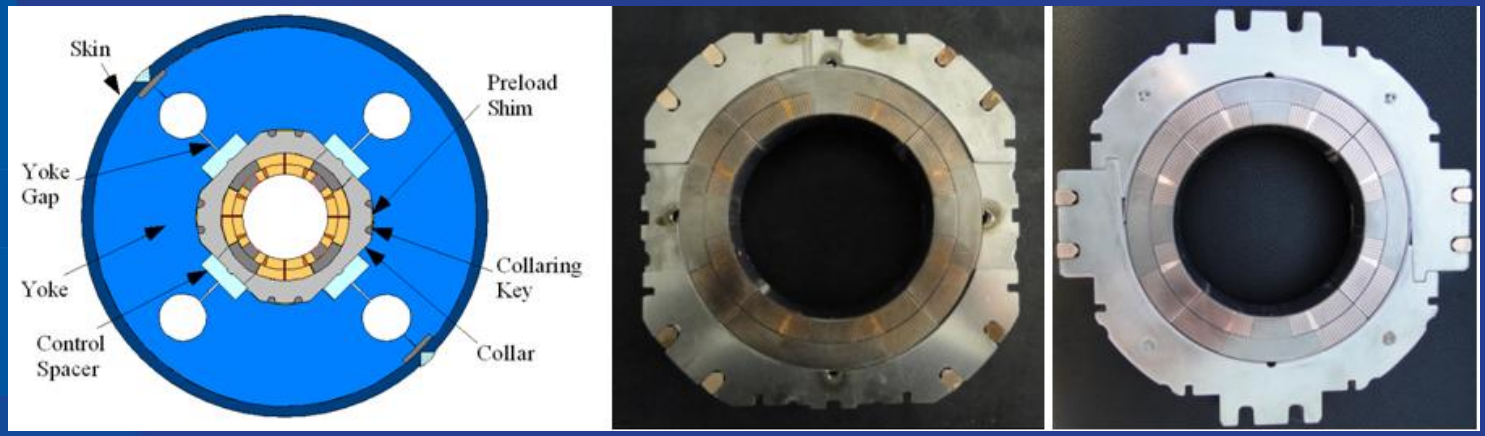
The scientific outcome and deliverables of the program includes:

- technical reports and scientific papers;
- superconductor, structural material and magnet specifications;
- technological “know-how”;
- operating magnet models and prototypes;
- proposals and justifications of practically oriented accelerator magnet projects.

Magnets for Hadron Colliders: Development and Demonstration

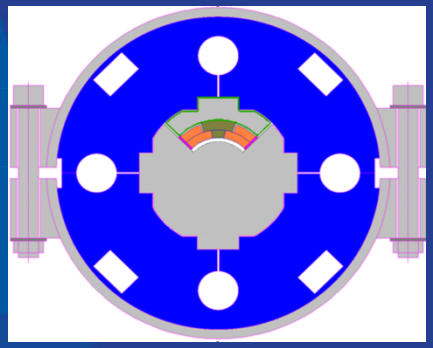
(in support of US-LARP and LHC upgrades):

- Development and demonstration of 90-mm Nb_3Sn quadrupole with Gmax~217 T/m based on collar/yoke/skin structure (modified MQXB)
- Successful demonstration collaring techniques for brittle Nb_3Sn coils
  - Quadrupole-style collar
  - Dipole-style collar



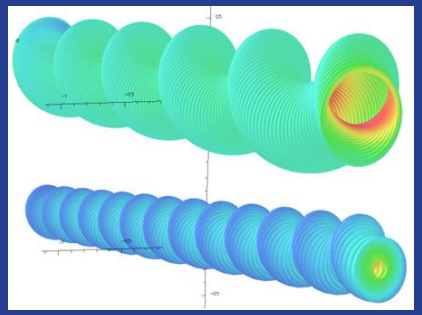
Magnets for Hadron Colliders: Experimental Studies

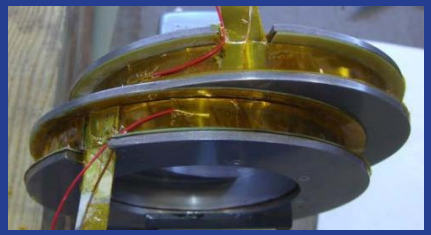
- Development and demonstration of Coil Test Structure (CTS) for single short and long shell-type quadrupole coils with 90-120-mm aperture.
- Experimental studies using 90-mm coils and CTS:
  - 0.7 mm RRP-108/127 strand performance at 1.9-4.5 K
  - cable with SS core to suppress eddy currents
  - cable insulation based on E-glass and S2-glass tapes
  - effects of coil structural materials and processing
  - the effect of coil pre-stress on its quench performance

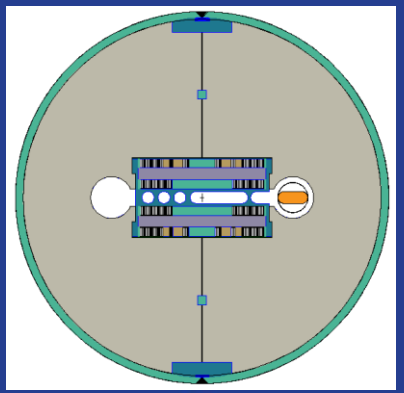


Magnets for MC and NF

- Conceptual design studies of low and high-field helical solenoids for 6D muon beam cooling
- Fabrication and test of two short large-aperture (ID-400 mm, B~5 T) helical solenoid models based on NbTi cable for the front end of 6D muon cooling channel.
- Development and fabrication of a first helical solenoid model based on 12-mm YBCO tape.
- Design studies of MC magnets based on Nb_3Sn superconductor.

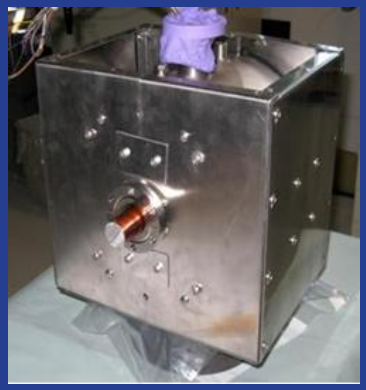


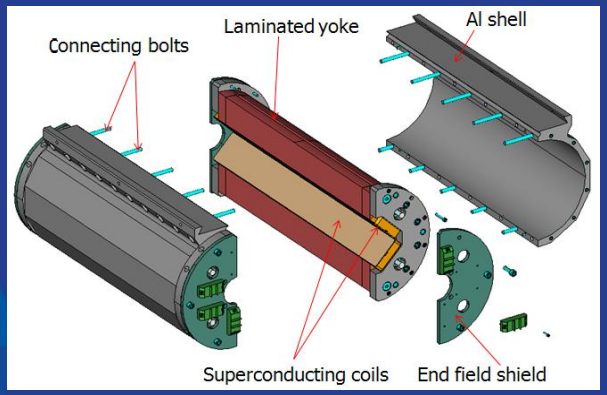


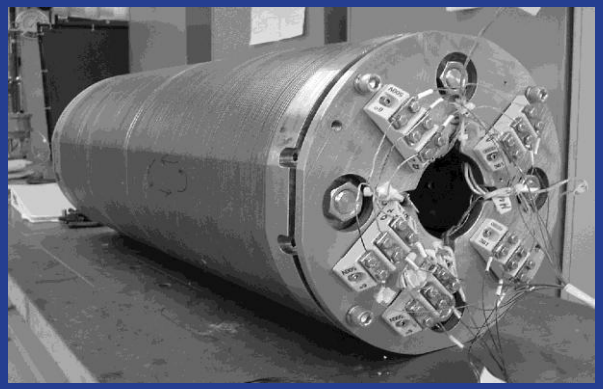


Focusing magnets for linear accelerators

- Development, fabrication and test of high-field NbTi solenoid prototype with reduced fringe fields for focusing low-energy proton beams in proximity of SC cavities.
- Development and fabrication of splittable quadrupole (ID=78 mm, G=54T/m) with indirect coil cooling for installation in SCRF cryomodule.

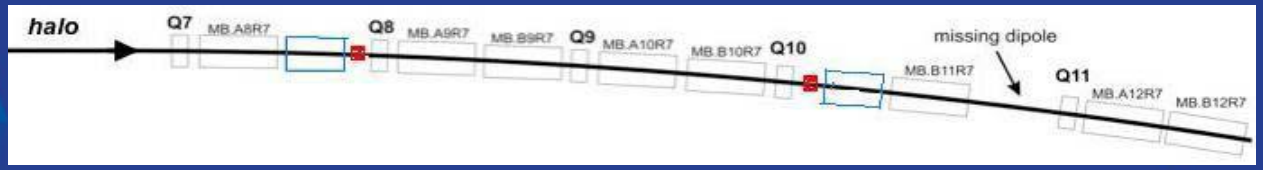






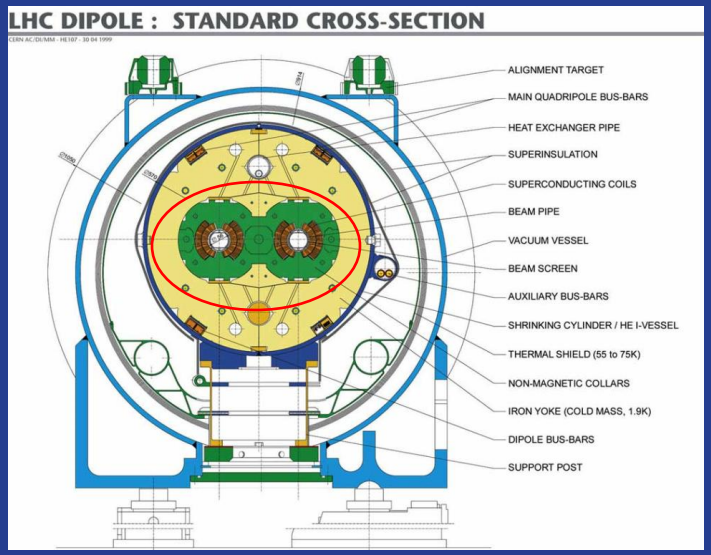
Proposed Short-term Focused R&D

- Fermilab-CERN collaboration on 11 T 11-m long double-aperture Nb_3Sn dipoles compatible with the LHC lattice and major systems to provide the required space for cold collimators.
- Following a successful demonstration and selection of these magnets for the LHC phase II collimation system upgrade, planned in 2016, a joint FNAL-CERN project to fabricate five (or more) 11 T 11-m long dipoles will be proposed.
- These magnets can be also used in the future to provide space in the LHC lattice for different insertion devices.



11T Dipole Design Constraints

- Same nominal current -11850 A
- Same cold mass OD - 570 mm
- Same distance between apertures -197 mm
- Larger aperture - 56 mm => 60 mm
- Nominal field – 11+ T
- 20% operational margin at 1.9 K - Bmax=13.8T



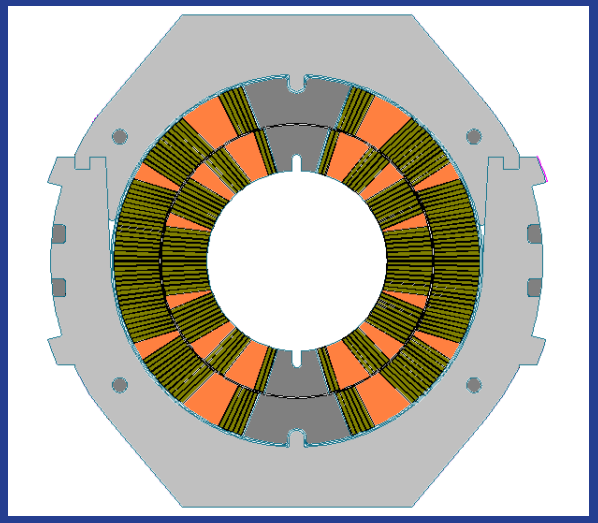
Activities and Deliverables

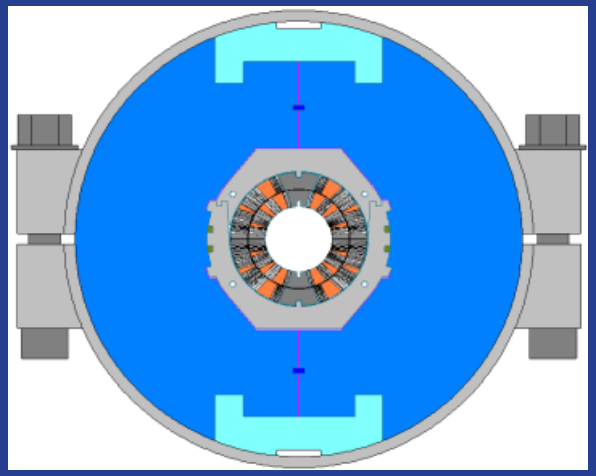
- Development, fabrication and test of 60-mm single-aperture 2-m long 11T DS dipole demonstration model based on Nb_3Sn superconductor - FY11-12
- Development and test of two 2-m long collared coils for the first 2-in-1 DS dipole model – FY12
  - 2-in-1 cold mass assembly and test at CERN
- Fabrication and test of the first 5.5-m long dipole coils for DS dipole prototype – FY13
- Fabrication of 5.5-m long collared coil for the first 2-in-1 5.5-m long prototype – FY13-14
  - Long prototype assembly and test at CERN

The work was coordinated and will be performed in collaboration with CERN

Demonstration Model Design and Parameters

- Strand: 0.7 mm RRP-108/127
- Cable: 40-strand 14.7x1.2
- Coil: 2-layer 7-block (CERN)
- Coil aperture: 60-mm
- Collar: stainless steel 20-mm
- Yoke: OD=400-mm, 2-piece
- Skin: 12-mm stainless steel
- Cold mass length 1.97 m
- Bnom=11.31T @ Inom=11.85kA
- Bmax=13.74T @ Imax=14.39kA
- Margin: Bmax/Bnom=1.215
- Stored energy: W(Inom)=800 kJ





Is success possible?

- Specific features of this program, besides its technical challenges, are its limited development time and resources.
- Nevertheless, the success is possible due to the high skill of Fermilab's magnet group, our previous successful experience with the 10-12 T Nb_3Sn dipoles and quadrupoles, established productive collaboration with CERN.
- Good progress during October-December
  - 40 strand cable prototypes with and w/o core
  - Magnet design in progress
  - Tooling design complete
  - Procurement in progress
  - Practice coil winding in February

Generic SC Accelerator Magnet Studies

- Fermilab will continue generic studies of SC accelerator magnet technologies including
  - development of Nb_3Sn strands and cables which meet the accelerator magnet requirements
  - coil technology and structural material optimization
  - technology scale up
- To reduce the cost and time, these studies will be performed recycling the available tooling and magnet components.
- These works will benefit
  - LARP plans to demonstrate long Nb3Sn quadrupoles by 2013-2014 for the LHC luminosity upgrade in 2021
  - LHC energy upgrade planned for 2030+
  - MAP plans on MC/NF feasibility studies by 2017-18.

Long-term Plan

- In the longer term, the program will thrust the development of *accelerator* magnets (dipoles, quadrupoles, multipole correctors, etc.) with operation fields above 20 T.
- Accelerator magnets with this level of nominal fields will be needed for MC Storage Ring and LHC energy upgrade.
- The progress towards this goal will rest on the successful accomplishment of Nb_3Sn accelerator magnet R&D as well as on the progress with new superconducting materials suitable for use in high-field accelerator magnets.

Efforts and Budget

- Budget request for FY11-13:

	SWF (k$)	M&S (k$)	OH (k$)	Total (k$)
FY2009	1343	403	1539	2993
FY2010	968	316	1108	2107
FY2011	1017	450	1128	2326
FY2012	1450	700	1410	3560
FY2013	1650	750	1598	3998

- At the present time the program supports ~14 FTE
  - the number of FTE's need to be gradually increased
- The M&S budget in FY11 is 450 k$
  - Nb_3Sn strand procurement for 2-m long 11 T dipoles
  - Nb_3Sn strand procurement need to be increased to ~250 k$/year starting from FY12
- Improvements to magnet R&D infrastructure need to continue in FY11-13 to support the described plan
  - additional funding of ~150k$/year in M&S

Summary

- The program is diverse and well aligned with Fermilab and US-HEP goals and priorities.
- In the near term, the program will benefit funded by DOE US-LARP and MAP by demonstrating the feasibility of Nb_3Sn accelerator magnets and technologies. In the case of success, it will make possible Nb_3Sn dipoles and quadrupoles for the LHC performance upgrades planned for 2016-2021.
- In the longer term, the program will develop advanced SC magnets and technologies for the ILC or Muon Colliders in 2020-2030, and eventually for LHC energy upgrade or next Hadron Collider in 2030 and beyond.