

11 T dipole R&D at Fermilab

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**FNAL-CERN collaboration meeting
21-23 September 2015
Fermilab**



2010 - Beginning

- ❖ **July 29, 2010 - FNAL APT seminar: L. Rossi “The CERN plan for the LHC upgrade”**
 - **G. De Rijk, A. Milanese, E. Todesco, “11 Tesla Nb₃Sn dipoles for phase II collimation in the Large Hadron Collider”, sLHC Project Note 0019, 2010-07-02**
- ❖ **September 2, 2010 – “11T/11m Nb₃Sn 2-in-1 dipole for LHC upgrades (R&D program proposal)”**
- ❖ **September 22-25, 2010 – M. Karppinen visit to FNAL, dipole design studies and draft R&D plan**
- ❖ **October 6, 2010 – internal FNAL review**
- ❖ **October 9, 2010 – “White Paper on CERN/FNAL Collaboration for the Development and Construction of Nb₃Sn Dipoles for the LHC upgrades,” TD-10-021**
- ❖ **October 11-12, 2010 - FNAL visit to CERN**
- ❖ **December 15, 2010 – “11 T Nb₃Sn dipole demonstrator model magnet,” Design and Parameter specification**



2011 DOE review: original 3-year R&D plan

| Dates | Description | Comments | R&D goals |
|----------------------------|---|--|---|
| December 2011 | 2-m single-aperture demonstrator dipole | Original design (cable, coil, collar) Construction and test at FNAL | Cable technology Coil technology Coil pre-load techniques Quench performance Margins Field quality (coil magnetization) Quench protection (heater study) |
| December 2012 June 2013 | 2-m twin-aperture demonstrator 1 | Design iteration (cable, coil, collar) FNAL collared coils (2) Cold mass assembly and test at CERN | Technology transfer to CERN (cable, coil, collared coil) Coil pre-load techniques in 2-in-1 configuration Quench performance Margins Field quality (geometrical harmonics, coil magnetization, iron saturation, aperture cross-talk, end field quality) Quench protection (heater study) Performance reproducibility Two cold mass and collimator integration (alignment) |
| | 2-m twin-aperture demonstrator 2 | CERN collared coils (2) Cold mass assembly and test at CERN | |
| July 2013 | 5.5-m coil scale up | Coil 1 at FNAL Coil 2 at CERN Structure assembly and test at CERN (FNAL) | Long cable technology Long coil technology Long coil performance Long heater design and performance |
| December 2013 | 5.5-m twin-aperture prototype | Collared coil 1 at FNAL Collared coil 2 at CERN Prototype assembly and test at CERN | Accelerator quality performance |



Corrected 11 T dipole R&D plan at FNAL

❖ FNAL-CERN joint R&D program

- different design features, same technology

❖ The corrected plan for FY11-14 included 3 phases:

- Phase 1 (FY11-12): the design and construction of a single-aperture 2 m long demonstrator dipole
- Phase 2 (FY13-14): the fabrication and test of two 2 m long, twin-aperture demonstrator dipoles to confirm the final magnet design, demonstrate the magnet performance parameters and their reproducibility
- Phase 3 (FY14-15): the design and technology scale up by fabricating and testing a 5.5 m long twin-aperture dipole prototype

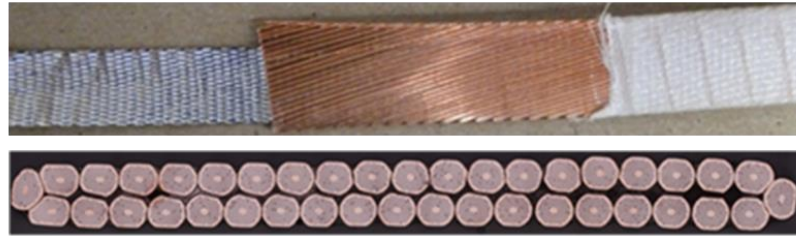


2012: 11 T demonstrator dipole development

- ❖ The 2-m long single-aperture demonstrator dipole has been developed in record time and tested in May 2012 (FY12) reaching 10.4 T at 1.9 K



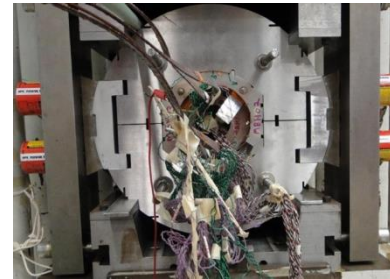
Cable fabrication



Coil fabrication



Collared coil assembly



Cold mass assembly



Magnet test





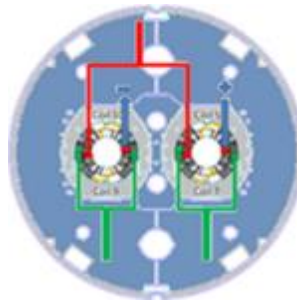
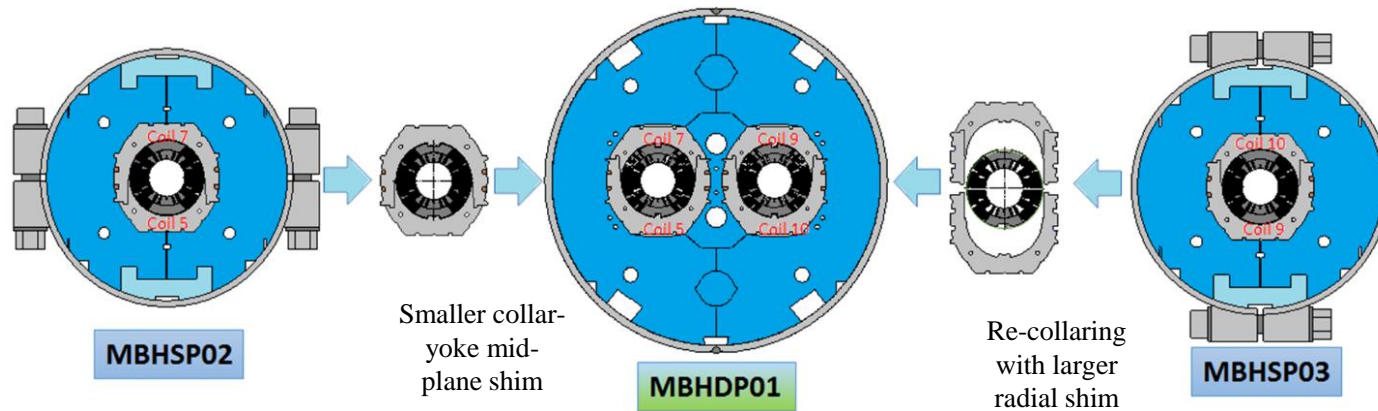
2013-2014: 11 T dipole FNAL plan modification

- ❖ **In FY13 after DOE review the FNAL plan was modified to take into account the substantial reduction of the HFM budget as well as CERN priorities and schedule for U.S. contributions to HL-LHC**
 - **the 3rd phase of the program has been cancelled**
 - **the scope of the 2nd phase has been optimized**
 - **the model length has been reduced from 2 m to 1 m to cut the cost of the Nb₃Sn cable and magnet parts (mainly collar and yoke laminations).**
- ❖ **Two 1-m long single-aperture dipole models (and one dipole mirror model) have been fabricated and tested in 2013-2014 reaching ~11.7 T at 1.9 K or 97.5% of the magnet design field.**



2015: Twin-aperture 11 T Dipole model

❖ The first 1-m long twin-aperture dipole model was assembled and tested at FNAL in 2015 reaching ~11.5 T at 1.9 K





FNAL-CERN collaboration meeting

❖ Goal

- review the original functional requirements, specs and plans
- review and summarize the results of model magnet R&D at FNAL and CERN

❖ Day 1

- Design specs and R&D plan
- Magnet design and fabrication
- Visit of the magnet and cable fabrication facility in IB3

❖ Day 2

- Model test plans and results
- Visit of the magnet test facility in IB1

❖ Day 3

- Meeting summary