

Introduction, MDPCT1 test summary and next steps



MDP CM5

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- Nb₃Sn magnets R&D is a central part of the updated **US-MDP** plan.
- The key goals of the Nb₃Sn magnet program remain unchanged - explore the performance limits of Nb₃Sn accelerator magnets, with a focus on minimizing the required operating margin and significantly reducing or eliminating training
- To mitigate increases in coil stresses at higher fields, the program focuses on the stress management concepts for brittle strass/strain sensitive SC coils including HTS coils
- Two complementary approaches under study:
 - stress-managed cosine-theta (SMCT) dipole concept will be discussed by Igor Novitski (FNAL)
 - canted-cosine-theta (CCT) dipole concept will be discussed by Diego Arbelaez (LBNL)



US-MDP Nb₃Sn Magnets R&D



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- The SMCT program stands upon and expands the 15 T dipole R&D
- The 15 T dipole demonstrator R&D started in 2016 o a key milestone of the initial US-MDP plan
- The goal: demonstration of 15 T field level in accelerator dipole magnets
- Record Nb₃Sn dipole magnets: • **D20 (LBNL, 1997)**
 - B_{max}=13.5 T @1.9K, 12.8 T @4.4K
 - HD2 (LBNL, 2008)

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- $B_{max} = N/A @ 1.9K , 13.8 T @ 4.5K$
- FRESCA2 (CERN, 2018)
 - B_{max}=14.6 T @1.9K, 13.9 T @4.5K



15 T Dipole (MDPCT1) R&D Goal



The U.S. Magnet **Development Program Plan**



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MDPCT1 goal: demonstration of 15 T field level in accelerator dipole magnets





Parameter

Magnet aperture, mm Magnet outer diameter, mm Geometrical length including splice box, m Total magnet weight, kg Short sample bore field at 4.5 K B_{ssl}(4.5K), T Short sample bore field at 1.9 K B_{ssl}(1.9K), T Design bore field B_{des}, T



Magnet Design and Technology













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- 3 inner and 3 outer coils
- Witness sample data are close to the target I_c



Witness Sample Data and Magnet SSL

Good reproducibility of witness sample data for IL and OL coils

Magnet short sample limit: 15.2 T @4.5 K, 16.8 T @1.9 K

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U.S. MAGNET DEVELOPMEN¹ PROGRAM

Mechanical Limit and Target Coil Pre-load





mechanical analysis, develop the coil pre-stress targets





Magnet <u>mechanical limit</u> B_{ap}~15T; • P_{max} at all steps <180 MPa **Conservative coil pre-stress for** the 1st test to achieve 14 T: • P_{max} at all steps <150 MPa



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Instrumentation:

- Voltage taps
- Strain gauges
 - o skin
 - o clamps
 - o bullets
 - o poles
 - o coils
- Quench antennas
- Acoustic sensors
- Thermometers









Magnet Instrumentation and 1st test (June-July 2019)





Magnet Disassembly and Inspection (August – September 2019)





Iron lamination test with Aluminum clamp test with magnetic powder die penetration technique







- L3/L4:
- lost SG and VTs
- no coil/pole separation in straight sections
- coil/pole separation in coil ends









MDPCT1b Modifications and Reassembly (October 2019 – February 2020)

Radial



- **Outer coil VTs repaired**
- The coil azimuthal pre-load increased by ~20 MPa to achieve the test goal of 15 T
- The end plates modified to improve the coil axial support
- end plates for IL and OL coils





Separate 50-mm and 32-mm



plates with bullets

rods

Stainless steel



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MDPCT1b Quench Performance in TC1 (June 2020)







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MDPCT1b Quench Performance in TC2 (July 2020)





No retraining, all quenches in coil 5, RE, pole turn

MDPCT1b reached its conductor limit at both temperatures 18% performance degradation wrt TC1





MDPCT1b Performance Summary and Open Questions











- U.S. MAGNET DEVELOPMENT PROGRAM
- August 2020 magnet removed from VMTF
- September 11, 2020 magnet displayed in ICB demonstration to DOE Office of Science Director C. Fall October 2020 – test data first analysis complete,
- results reported at ASC'2020 and MDP meetings
- December 7, 2020 presentation to TAC, <u>magnet</u> autopsy proposed and supported
- December 2020 magnet prepared and sent to VMS
- January 2021 skin cutting started
- February 1, 2021 <u>review of magnet disassembly and</u> inspection plan
- February 23, 2021 magnet returned to IB3A for disassembly
- March 2021 magnet disassembly and inspection



Post-test Events and Plans

Fermi National Accelerator Laboratory

MDPCT1b disassembly and inspection readiness review

February 1st, 2021

- **Review Committee:** G. Ambrosio (FNAL), R. Bossert (FNAL), G. Chlachidze (FNAL), P. Ferracin (LBNL), P. Lee (ASCNHMFL), F. Nobrega (FNAL).

Questions to the review committee:

- Is the disassembly and inspection plan available and sound?
- Is the disassembly traveler available?
- 3. Are the magnet disassembly schedule and resources realistic and available?
- Are the main risks identified and mitigated?









- The MDPCT1 R&D program is complete • the goals of MDPCT1 program have been achieved
 - graded 4-layer coil, innovative support structure, magnet fabrication procedures were developed
 - magnet performance parameters were tested
 - B_{max}=14.5 T @1.9 K is 97% of the program goal
- The field levels achieved in MDPCT1 @4.5 K and 1.9 K (with FRESCA2 result @1.9 K) set <u>new world records for Nb₃Sn accelerator</u> magnets.
- The performance limitations of MDPCT1 are being studied, they are being addressed using coils with stress management and optimized mechanical structure – *details in Igor's talk.*



Conclusions







PROGRAM

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