LBNL Bi-2212 magnets status and milestones adjustment

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With inputs from

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National High Magnetic Field Laboratory

Outline

- **Having fabricated single racetrack coils (RC1-6), 4.7 T common coil dipole magnet RC7n8, and a single CCT coil BIN5aOL, BIN5c1 magnet, the first (but short, 39 cm long) Bi-2212 CCT magnet.**
- **MDP milestones updates/adjustments, rationales, and risk analysis.**
- **Task status.**

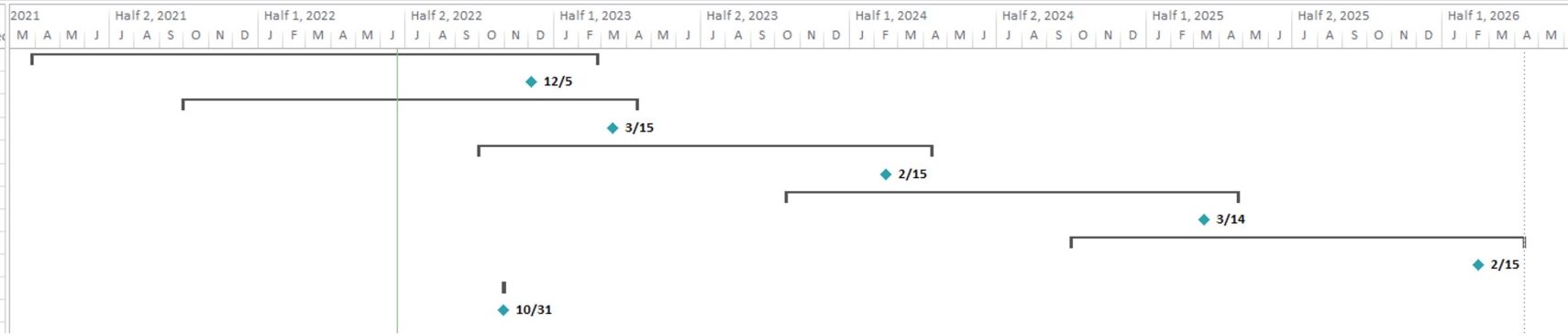
MDP milestones updates – CCT effort within the Bi-2212 area of the MDP

- **First (but short) CCT dipole magnets, fab & design verification, operation experience.**
- **Hybrid magnet of 8-10 T, from fab (e.g. assembly) to operation (e.g. quench protection)**
- **Scale up to 1 m long magnets.**
- **Increase dipole field generation (SSL from 4.6 T to 6.4 T, or expected field from 3.5 T to 5 T) with cables with varying sizes and strand design.**
- **Hybrid magnet(s) of >11 T.**

Milestones for the CCT effort within the Bi-2212 area of the MDP				
Milestone #	Description	Status *	Updated Target	Comments
AIIa-M1a	Build and test two 2.4 T, 40 cm long BIN5c dipole magnets.	Completed		BIN5c1 magnet tested. BIN5c2 coils fabricated (but not tested) and are backup for the AIIa-M2a.
AIIa-M2a	Hybrid magnet test with a total field generation of 8-10 T at 4.2 K. Assemble and test BIN5c in the background field of the Nb_3Sn CCT5	In progress	Dec-22	Modify description to "Hybrid magnet test with a total field generation of 8-10 T at 4.2 K. Assemble and test BIN5c inside th 90 mm bore Nb_3Sn CCT5 magnet."
AIIa-M3a	Build and test two 3.5 T, 80 cm long, Bi-2212 dipole magnet with 17-strand, 7.8 mm wide Rutherford cables.	In progress	2023-Feb and 2025-Oct	Modify description to "Build and test two Bi-CCT1, a 3.5 T, 40 mm bore, 85 cm long CCT Bi-2212 dipole magnets with 17-strand, 7.8 mm wide Rutherford cables made from 0.8 mm strands."
AIIa-M4a	Two -> one. Build and test two 5 T, 80 cm long, Bi-2212 dipole magnet with 27-strand, 12 mm wide Rutherford cables.	In progress	Feb-24	Modify description to "Build and test one Bi-CCT2, a 5 T, 40-50 mm bore, 85 cm long Bi-2212 CCT dipole magnet with 12 mm wide Rutherford cables made from 1.0 mm strands." Note that only one magnet is going to be built.
AIIa-M5a	Hybrid magnet test with a total field generation of >14.5 T at 4.2 K. Assemble and test magnets from AI-M3c and M4c inside a background field of the 120 mm, 11 T Nb_3Sn magnet from the area I.	Not started	Feb-26	Modify description to "Hybrid magnet test with a total field generation of 11-15 T at 4.2 K. Assemble and test Bi-CCT1 inside the 120 mm bore, >11 T Nb_3Sn magnet from the area I."

Milestones by year and risk analysis

Task Name	Duration	Start	Finish	Predec
1. BIN5/CCT5 AIIa-M2a	500 days	Sun 3/28/21	Thu 2/23/23	
Test	0 days	Mon 12/5/22	Mon 12/5/22	
Bi-CCT1_I AIIa-M3a	400 days	Fri 10/1/21	Thu 4/13/23	
Test	0 days	Wed 3/15/23	Wed 3/15/23	
3. Bi-CCT2_I AIIa-M4a	400 days	Sat 10/1/22	Thu 4/11/24	
Test	0 days	Thu 2/15/24	Thu 2/15/24	
4. Bi-CCT1_II AIIa-M3a	400 days	Sun 10/15/23	Thu 4/24/25	
Test	0 days	Fri 3/14/25	Fri 3/14/25	
5. Bi-CCT1/CCT6 AIIa-M5a	400 days	Tue 10/1/24	Mon 4/13/26	
Test	0 days	Sun 2/15/26	Sun 2/15/26	
6. NHMFL RENEGADE	1 day?	Mon 10/31/22	Mon 10/31/22	
Commision@full tempeature and full pressure	0 days	Mon 10/31/22	Mon 10/31/22	



- ***One magnet/year.***
  - *1m long magnets requires greater resources than previously built coils/magnets.*
  - *Bi-CCT1 – 3.5 T dipole*
  - *Bi-CCT2 – 5 T dipole*

- ***Opportunities**: (1) First of its own kind magnets and experiments. (2) Technology matured for significant magnet demos.*

- ***Risks**: (1) Global liquid Helium shortage. (2) Sustainable and high performance superconductor production. (3) Supply chain issues. (4) (In)Post-COVID tight and disrupted labor market.*

NHMFL milestones

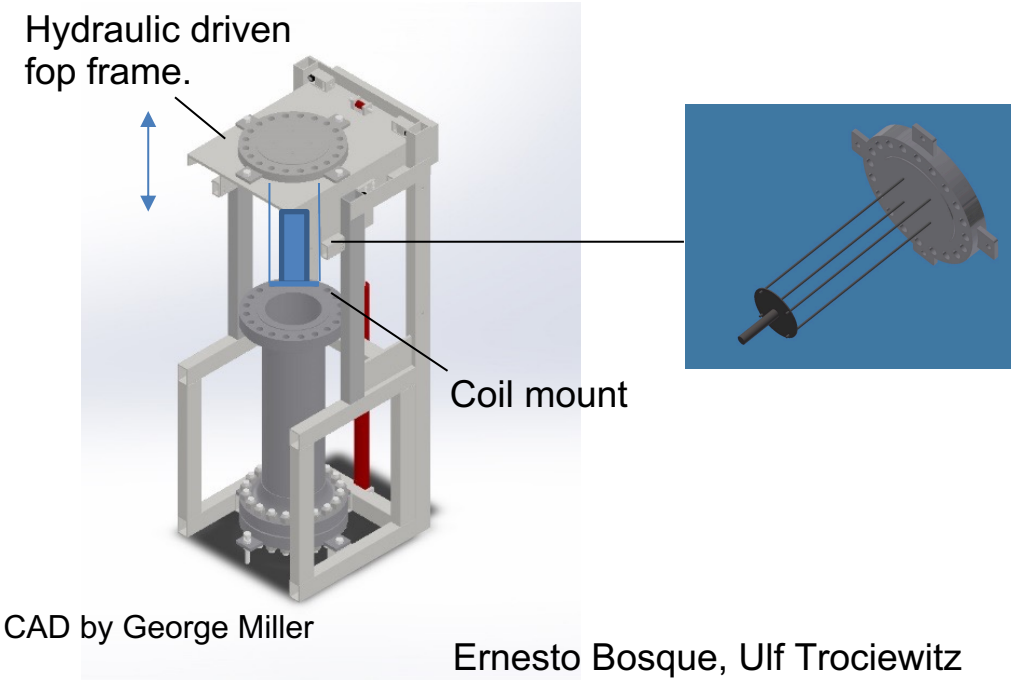
From D. Davis, U. Trociewitz, D. Larbalestier

Milestone #	Description	Target	Status *	Updated Target	Requestor	Comments
AIIa-M1c	Renegade OPHT facility upgrade. 1 m and 250 mm hot zone.	20-Dec	In-Progress	2022-Oct	Ulf	Commissioning under-way.
AIIa-M2c	16 T Rutherford cable based solenoid development	20-Dec	In-Progress	2023-Mar	D. Davis	First coil tested and post-mortem analysis complete. Awaiting installation of commercial braiding machine for second coil winding.
AIIa-M3c	20 T Rutherford cable based solenoid development	21-Jun	Not Started	2024-Jun	D. Davis	Dependent upon AIIa-M2c results
AIIa-M4c	25 T Rutherford cable based solenoid development	22-Jun	Not Started		D. Davis	As this would require additional external resources, I think we should refrain from putting a target date.

Direct braiding with pure alumina fiber, instead of inserting a cable into a mullite sleeve.
Machine investigated applicable to the 9-strand Rutherford cable used for BIN5c and the babyRuth.

RENEGADE – a new, one of its own kind OPHT facility

	DELTECH @ NHMFL	RENEGADE @ NHMFL
Capability	50 bar OPHT	50 bar OPHT
Length of homogeneity zone (cm)	~45	~100
Diameter of the homogeneity zone (mm)	~140	250



CAD by George Miller

Ernesto Bosque, Ulf Trociewitz

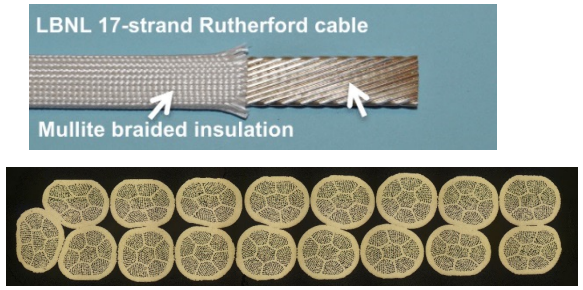
In house LabVIEW software PID control that allows flexible temperature tuning.

Lamar English

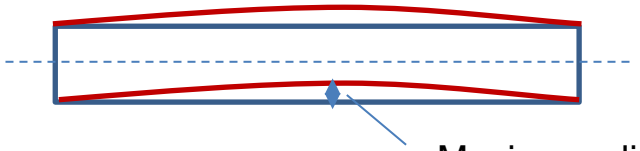
- **Furnace received operational clearance.**
- **Warmed to 600C & 600 PSI. An area of the pressure vessel too hot. Need reinsulating.**
- **Fully commissioning expected in Oct 2022.**

Bi-CCT1 (3.5 T (SSL 5 T) dipole, 40 mm bore) fabrication status and plan

- **Why: (1) Scale-up – first ~1 m long magnet, made only possible by the RENEGADE facility at FSU. (2) Suitable as an insert for 11T CCT6/11TSMCT. (3) A familiar cable with 0.8 mm dia, 55 x 18 wire.**



Blue – Before; Red – After oxidation HT.



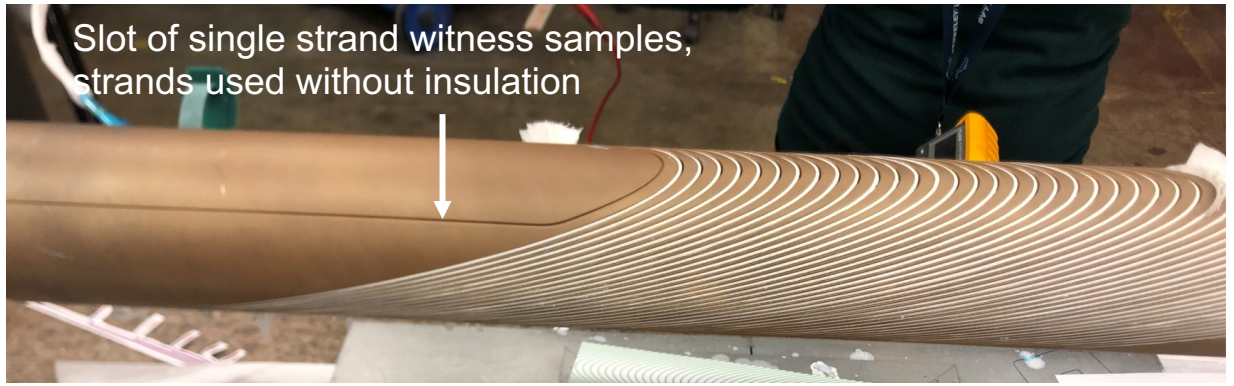
Maximum displacement:

~~1. IL – 0.135”~~

2. OL - 0.035”

Bi-CCT1 outer coil winding and conductor

Winding by Mark Krutulis

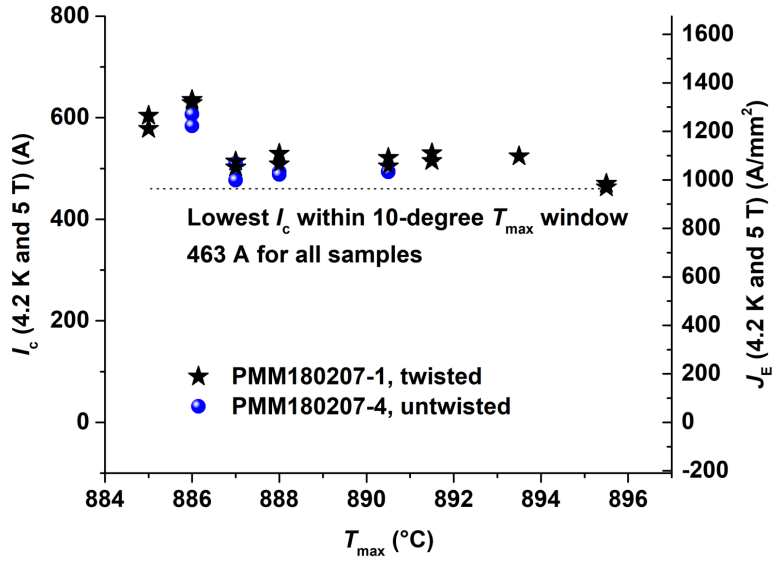


- **Winding scheme (mullite sleeve + TiO_2 coating) similar to that developed for BIN5c coils.**
- **No electrical shorts, partly contributed by machining improvement.**

Conductors and conductor characterization

Wire	Diameter (mm)	Architecture	Length received (m)	J_E(4.2 K, 5 T) (A/mm2), 50 bar OP, peak value	J_E(4.2 K, 5 T) (A/mm2), 50 bar OP, the smallest value over 10-degree-C temperature window	Comments
PMM180207-4,-5,-6,-7	0.8	55x18	1210	1340.1	984.1	Used in cable LBNL1109

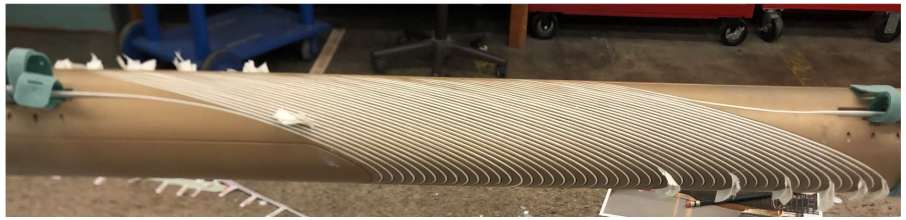
Cable No.	Specifications	Wires	Use
LBNL 1109	17-strand subscale cable, 7.8 mm x 1.44 mm nominal	Non-twisted PMM180207_4, 5, 6 ,7	Used for Bi-CCT1_I



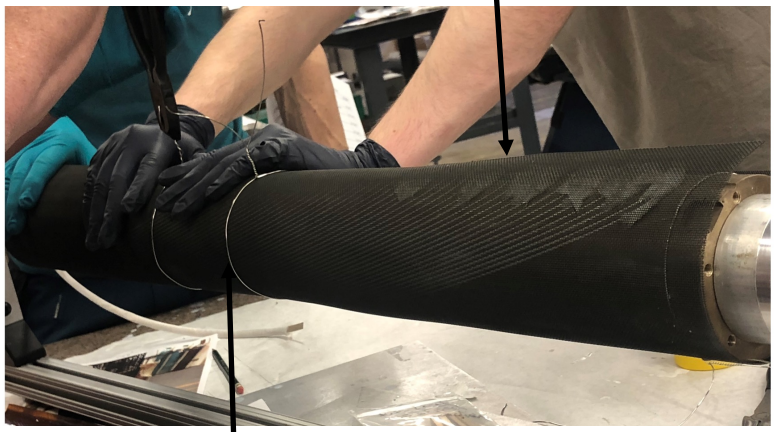
- **Sibling wire and cable (LBNL1110) used for RC7n8, and Fermilab's SMCT coil fab.**
- **One sample is being prepared for Twente Transverse Pressure Measurement (Ulf Trociewitz – NHMFL and Anna Kario - Twente)**
- **Wire performance is on par with that used for BIN5c1.**

Jiangyi Jiang, NHMFL

Bi-CCT1 outer coil winding – Inconel mesh mechanical support added for heat treatment



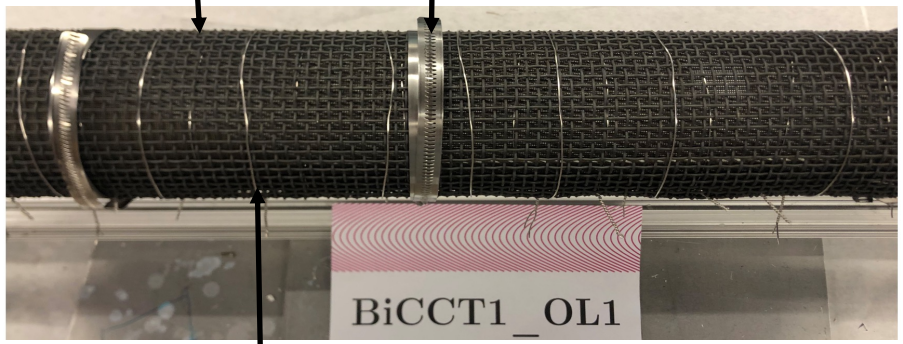
Inconel 600 wire meshes (fine wires)
Layer #1



Inconel 600 wires – for securing Inconel 600 wire meshes

Inconel 600 wire meshes (coarse wires, 0.063” diameter)
Layer #2

SS316 hose clamps



Inconel 600 wires – for securing Inconel 600 wire meshes

Bi-CCT1_OL1 reaction assembly

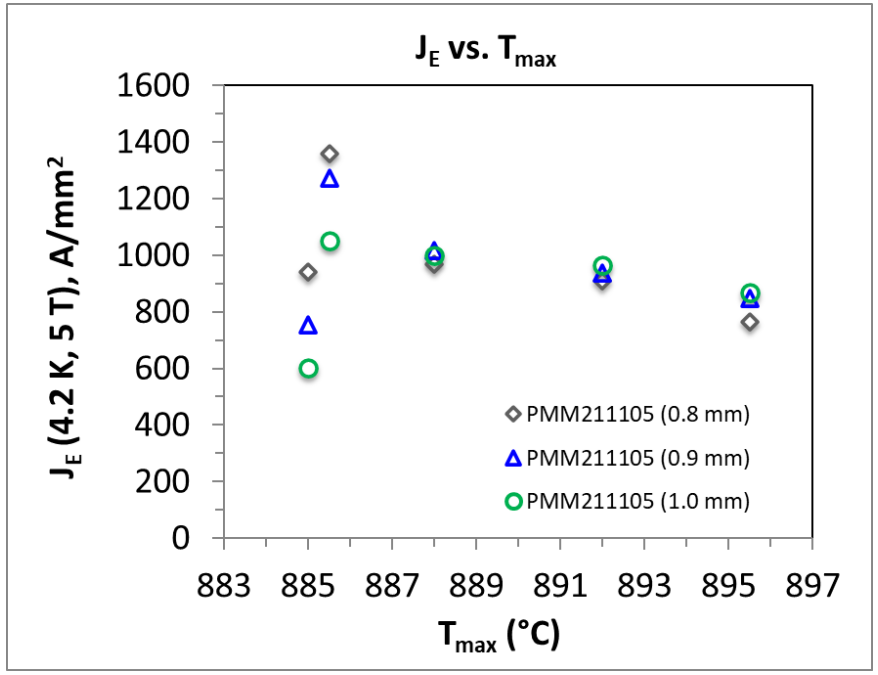
Inconel meshes for the dummy mandrel for testing the effectiveness of the mechanical support.

Shipped to NHMFL in May.

Bi-CCT2 (5 T (SSL 6.4 T) dipole, 40 mm bore) fabrication status and plan

- **Why: (1) Scale-up and a wider cable (10-12 mm wide) with 1.0 mm dia, 55 x 18 architecture wire. (2) Wider processing window. (3) Potentially less leakage.**

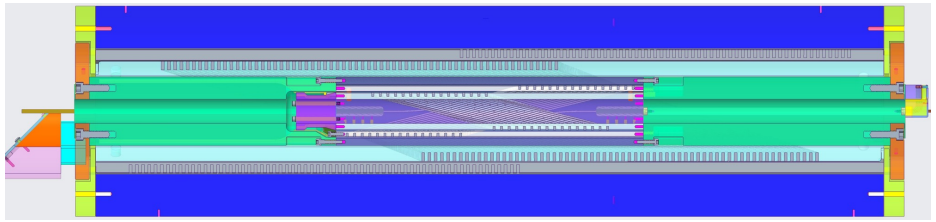
- **Conductor ordered and the first billet delivered. Cable to be fabricated.**
- **Wire performance regression: (-15% in J_c, compared to BIN5c1 wire, -21% compared to Bi-CCT1a/RC7n8 wires.)**

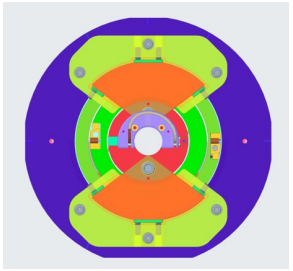


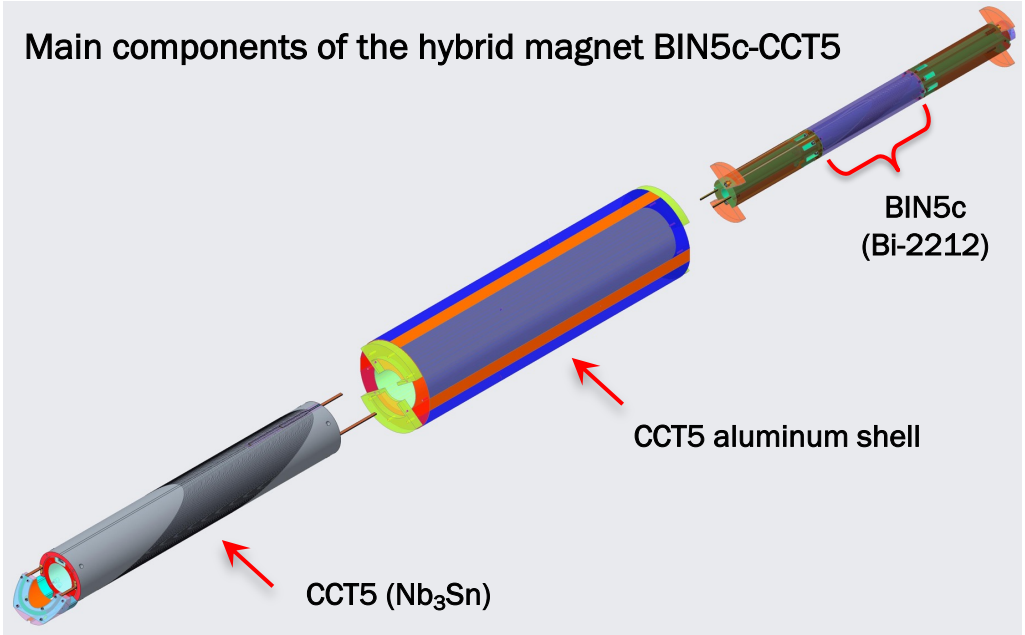
Wire	CDP/CRPDPO	Diameter (mm)	Architecture	J_E(4.2 K, 5 T) (A/mm2), 50 bar OP, peak value	J_E(4.2 K, 5 T) (A/mm2), 50 bar OP, the smallest value over 10-degree-C temperature window
Billet in fab	7596397	1	55 x 18		
PMM211005	7596397	1	55 x 18	1053	867
PMM211005@0.8 mm		0.8	55 x 18	1360	766

BIN5/CCT5 hybrid magnet test

- **Magnet assembly in consideration of structural and electrical safety.**



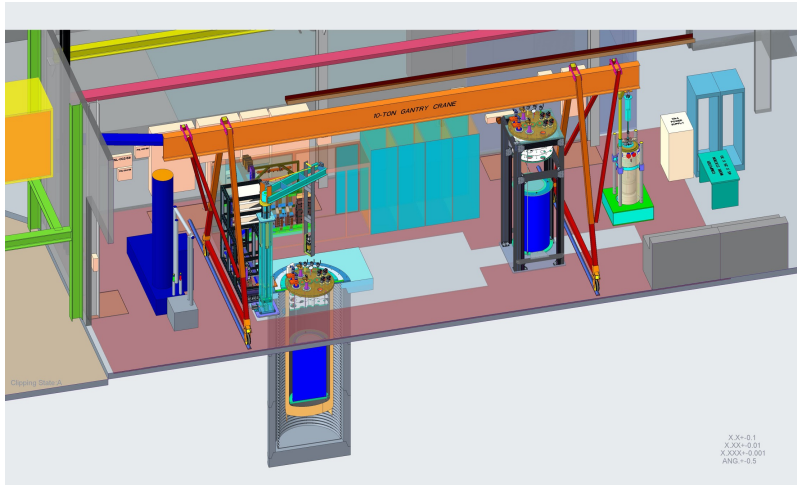




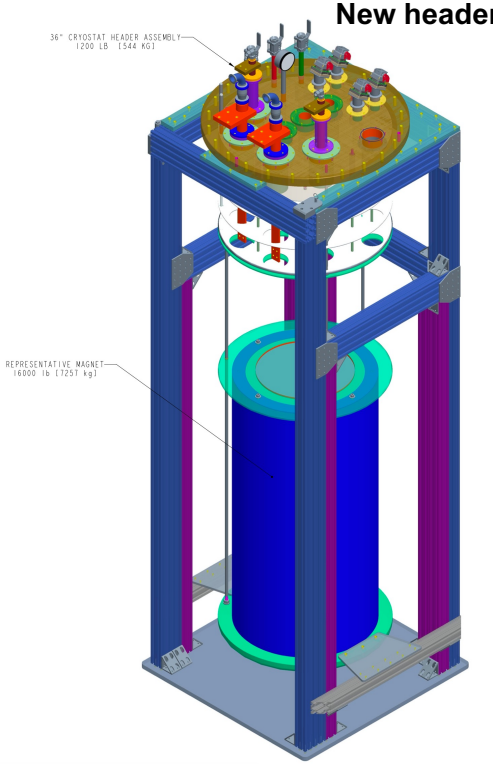
- **CCT5 magnet test.**
- **BIN5c magnet test.**
- **BIN5c coils ready. Components 50% manufactured.**
- **Currently, review and finalize mechanical assembly design:**
  - To ensure structure integrity and avoid excessive stress.
  - To avoid electrical issues and bad electrical coupling between components of BIN5c magnet and those of CCT5 magnet.
- **Generate assembly step-by-step document.**
- **Re-test of CCT5.**
- **Assembly after the re-test of CCT5.**

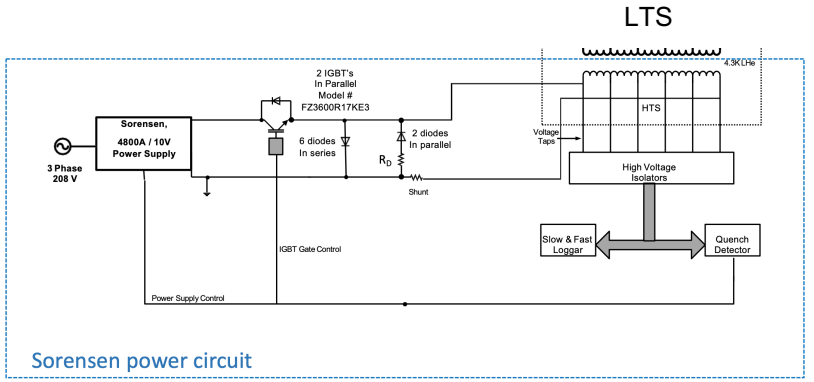
BIN5/CCT5 hybrid magnet test – test facility in preparation

- **Challenges – Hybrid magnet test facility, and upgrade existing facilities to have hybrid magnet test capabilities (Cory Myers leads) with sufficient magnet protection capabilities.**



New header with two sets of current leads.





Sorensen power circuit

Modify from a circuit template from Piyush Joshi, BNL

- Design finalized, drawings issued.
- Component fab in progress.
- Next phases – (1) Assembly (2) Commissioning.

Summary

- **We are going into a new exciting phase of Bi-2212 (CCT) magnets with new opportunities and challenges.**

- **Thank you for your attention and collaboration.**