US MDP Bi-2212 program progress – an update

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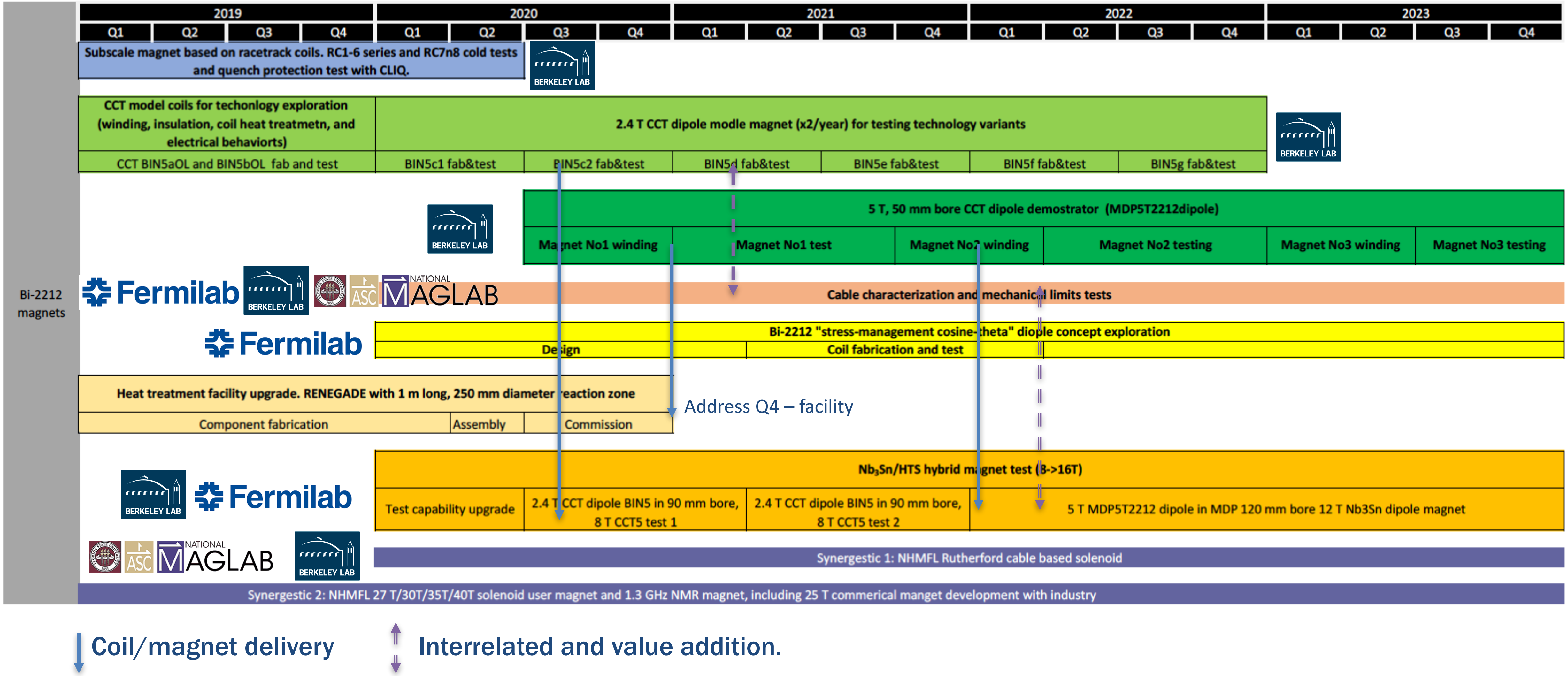
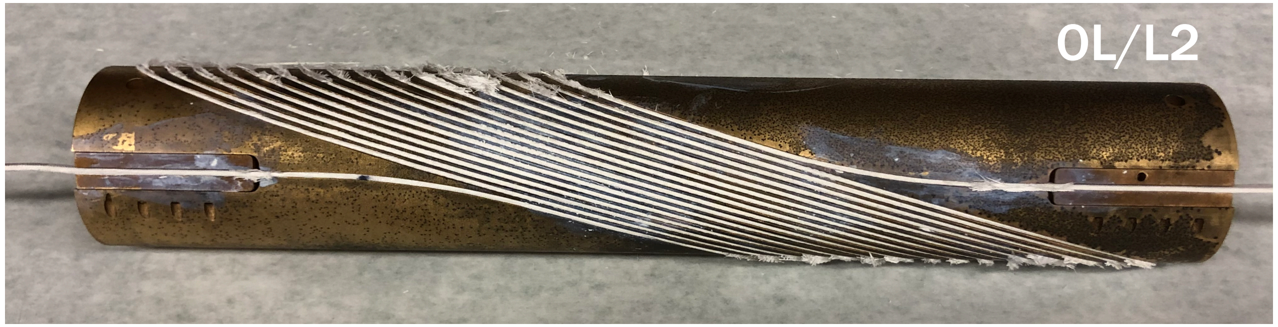
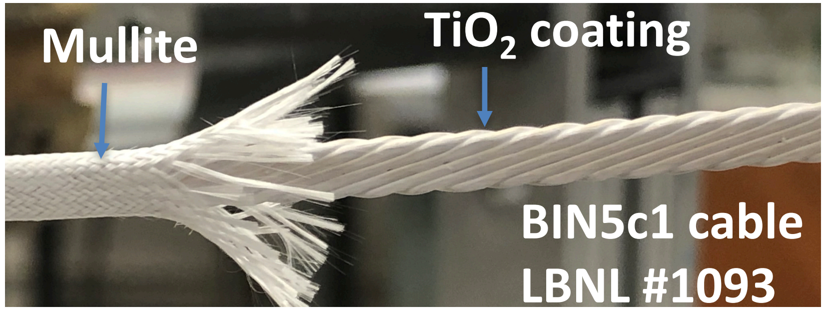
2212 roadmap presented at the 2020 US MDP collaboration meeting



CCT BIN5c_1, a two layer 2.4 T CCT dipole coils





- **Wound and being prepared for shipping to NHMFL right before the shelter-in-place public order.**
  - **L1 (IL) has a hard way bending diameter of 38 mm.**
- **Conductor the same with BIN5aOL and BIN5bOL – LBNL cable #1093**
- **With improved fabrication:**
  - **Mandrel – preoxidized. Found to develop electric shorts more easily than non-oxidized mandrel. Likely due to residual metal particles.**
  - **Cable – with TiO_2 slurry applied directly on bare cable for minimizing leakage.**
    - **VTs installation found to be manageable.**

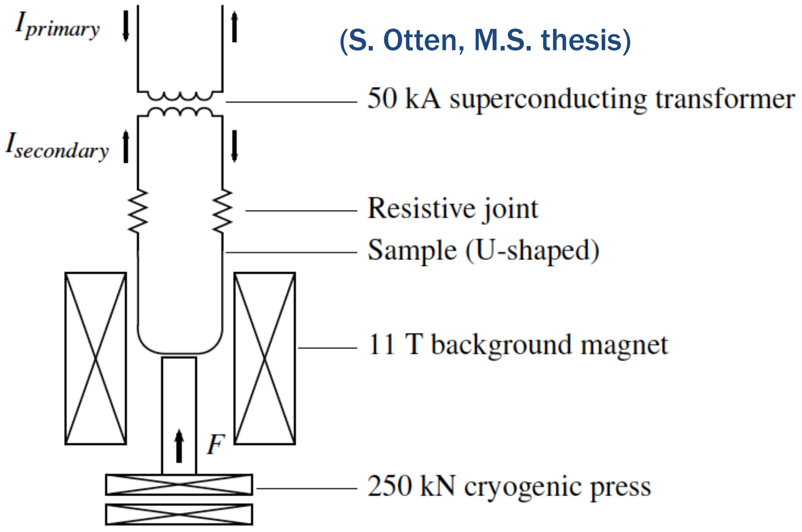
- Winding by Laura Garcia Fajardo, Jim Swanson, Mark Krutulis.
- TiO_2 slurry by Jun Lu, NHMFL. Mandrel pre-oxidied by Ernesto Bosque.
- Drawing by Ray Hafalia. Machining by Max Maruszewski and LBNL main shop.

CCT BIN5c_2, getting ready to be wound.

- **Following the design and fabrication schemes of CCT BIN5c_1.**
- **Getting ready to be wound, with a new conductor.**
  - **9-strand cable LBNL2001, 57.5 m, CPRD strand PMM190118.**
- **Insulation is being put on manually (Andy Lin).**
  - **Manual TiO_2 coating process – (1) paint, (2) dry with heat gun, (3) move to next section.**
  - **Nice to have - A reel-to-reel process.**

International collaboration – renewed cable mechanical tests at U. Twente

- A EUCARD2 task, with CERN supporting powder fabrication at Nexans. Now renewed with NHMFL and LBNL engaged.
  - Existing samples are ~10 mm wide FNAL cables made using the OST wires with Nexans' lot 82 powder, now known to have hard particles. Samples reacted at NHMFL with 50 bar OPHT.
  - Test at Twente led by Simon Otten and Marc Dhalle.
- Ongoing negotiations with CERN (David Larbalestier) for additional tests with the modern B-OST wires with Engi-mat nano-spray combustion powder.
  - 4.5 m long of the LBNL cable #1088 used in the record performance RC5/6 racetrack coils.



(S. Otten, M.S. thesis)

Cable	LBNL-1088
Width (mm)	7.8
Thickness (mm)	1.44
Number of strands	17
Pitch length (mm)	58
Insulation	Mullite sleeve
Insulatoin wall thickness (mm)	0.15
Strand	PMM170123
Manufactuer	Bruker OST LLC
Power	LXB52
Power manufactuer	nGimat (now Engi-Mat)
Strand I_c (4.2 K, 5 T) abfter NHMFL 50 bar OPHT (A)	500-900
Strand diameter - before reaction (mm)	0.8
Strand diameter - after reaction (mm)	0.778
Twisting	No

LBNL conductors for Fermilab cable studies and SMCT coils.

Cable No.	Specfications	Wires	Insulated	Use	Length made (date)	Length left (03/04/2020)	Locations	Remaining wires and location
LBNL2001	Y81OL20011A00A 9-strand CCT cable	MDP CPRD PMM190118	No.	No. Reserved for 2.5 T BIN5c2 and BIN5d. BIN5d designed to tested high packing factor coils	51.5 m	51.5 m	B58 cabinet	B58
LBNL1110	17-strand subscale cable	CDP Twisted PMM180207_2	Yes.	RC7 and RC8, 4.7 T common coil dipole magnet	45m (07/12/2018)	15 m	TS office	
LBNL1088	17-strand subscale cable	nGimat Phase II PMM170123	Yes	RC5 and RC6, record performance coils	23 m(06/14/2017)	4.5 m	TS office	

Green	Suggested for FNAL cable study.
Yellow	Potential for FNAL cable study and SMCT coils.
Grey	Also a candidate for Uni. Twente transverse pressure experiment.

- **Note that not the entire length of LBNL2001 is available for cable studies.**

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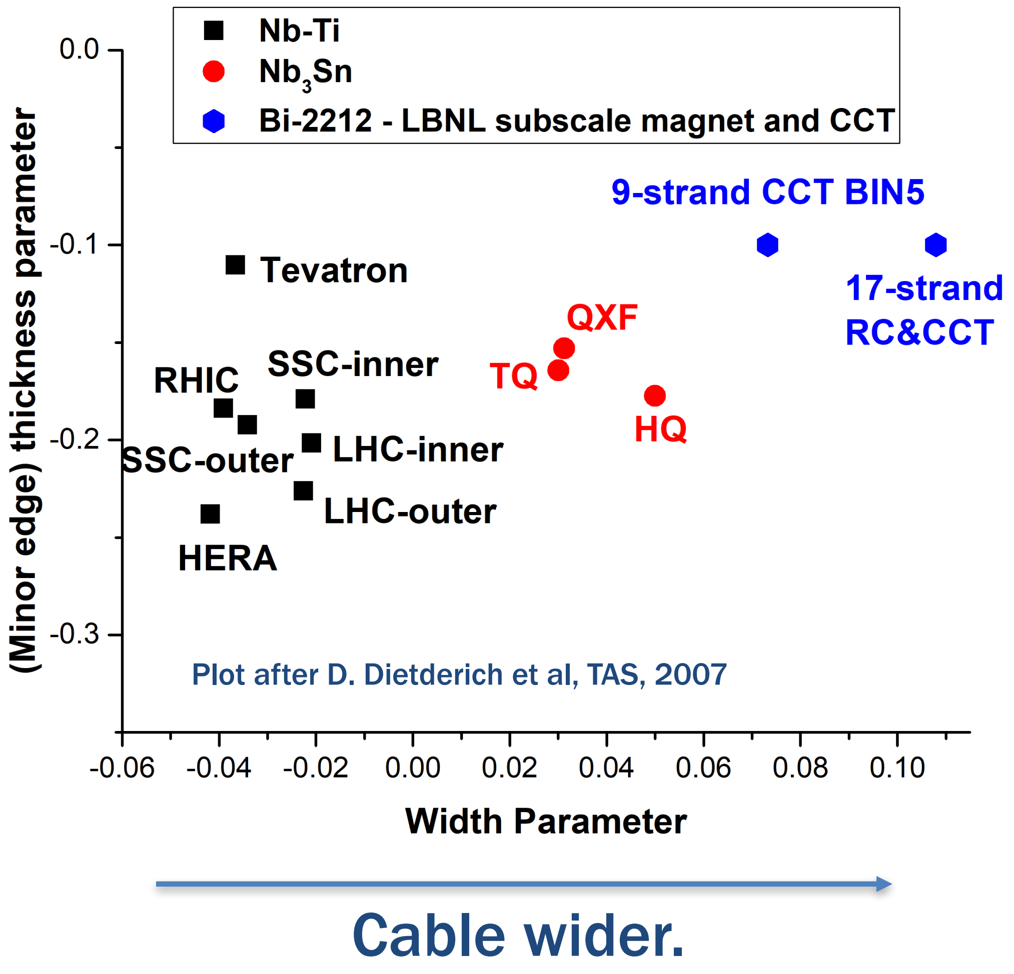
Insulatoin wall thickness (mm)	0.15
Strand	PMM180207-2
Manufactuer	Bruker OST LLC
Power	
Power manufactuer	nGimat (now Engi-Mat)
Strand I_c (4.2 K, 5 T) abfter NHMFL 50 bar OPHT (A)	460-640
Strand diameter - before reaction (mm)	0.8
Strand diameter - after reaction (mm)	0.778
Twisting	Yes
Twisting pitch (mm)	25

Cable compaction/parameters studies – why?

Project	Materials	Number of strands	Strand diameter (mm)	Cable dimensions (mm) (minor/major edge X width)	Keystone Angle (degree)	Overall packing factor (%)	Minor Edge Packing Factor (%)
Tevatron	NbTi	23	0.68	1.21/1.40 X 7.8	2.06	88	95
HERA		24	0.84	1.28/1.67 X 10.0	2.22	92.3	103
RHIC		30	0.65	1.06/1.26 X 9.7	1.21	91	96
SSC Inner		30	0.81	1.33/1.59 X 12.3	1.2	88.9	96
SSC Outer		36	0.65	1.05/1.26 X 11.7	1.01	90.4	97
LHC Inner		26	1.29	2.06/2.50 X 17.0	1.56	92.5	98
LHC Outer		40	0.84	1.3/1.67 X 17.0	1.18	92	1.01
TQ	Nb_3Sn	27	0.7	1.17/1.35 X 10.077	1	85	91
HQ		35	0.778	1.28/1.47 X 14.80	0.75	86.8	93.4
QXF		40	0.85	1.44/1.61 X 18.15	0.55	84.9	90
HTS-SC/RC	2212	17	0.8	1.44 x 7.8	0	79	N/A
HTS-CCT		9	0.8	1.44 x 4.0	0	81	N/A

- **Low compaction so far for Bi-2212 cables.**
- **Not a concern – RRR reduction: High RRR without diffusion barrier (Li et al., IOP Conf. Series: Mater. Sci. Eng., 2015; M. Bonura, Mater. Res. Express, 2018).**
- **Two concerns: (1) J_c reduction due to filament breakage. (Short sample study sufficient). (2) Edge deformation leads to increased leakage. (Need coil fab&test).**

Cable compaction/parameters are not yet optimized



- **Cable tends to develop gaps between strands with a overly positive width parameter.**
  - **Less mechanically stable.**

Compaction studies inconclusive now

- **Compaction studies – VHFSMC days**
  - **Barzi *et al*., TAS, 2011 (1 bar HT studies)**

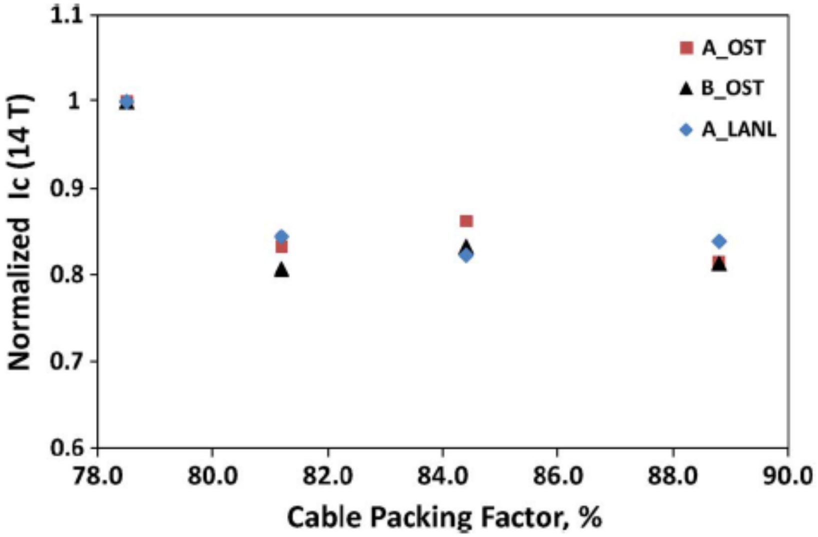
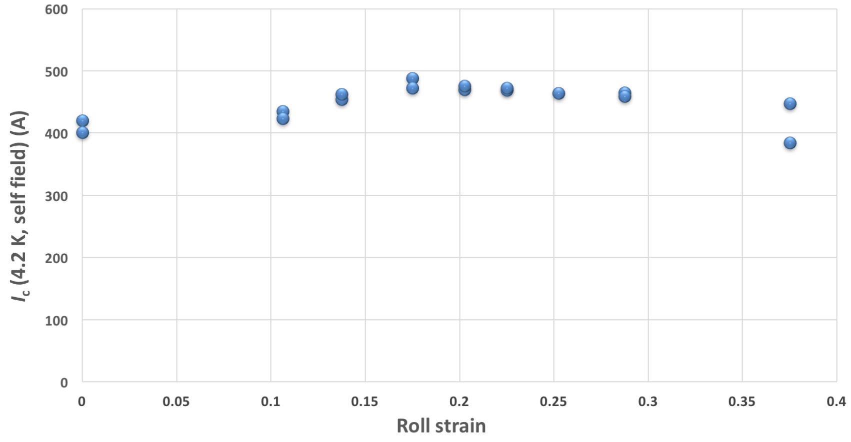
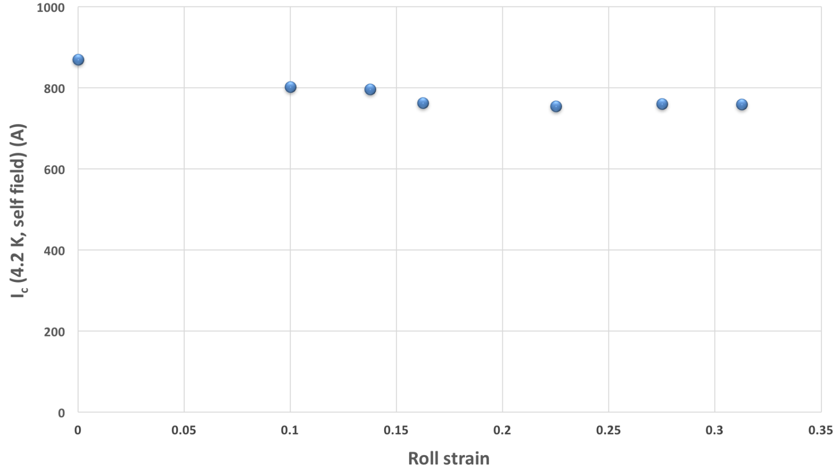


Fig. 10. Normalized I_c (4.2 K, 14 T) as a function of cable packing factor for the extracted Bi-2212 strands A and B as heat treated at OST and at LANL.

PMM101111 (strand similar to that or RC2/3), T. Shen, unpublished.





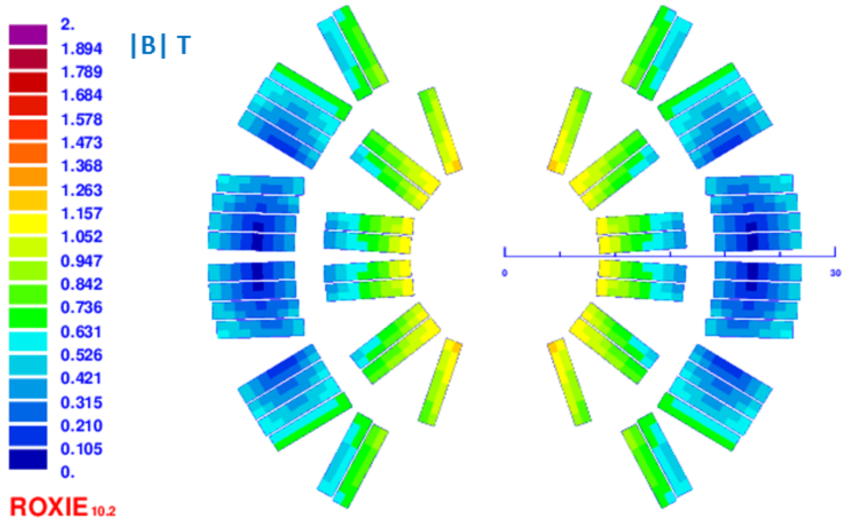
PMM101111, T. Shen and J. Jiang (NHMFL), unpublished.

Fermilab Bi-2212 SMCT magnetic models

Emanuela Barzi, Daniele Turrioni, Igor Novitski, Alexander Zlobin
Fermilab

HTS-Bi2212 Insert Magnetic Design

- **2-layer coil**
- **15 turns**
- **Coil ID: 17 mm**
- **Coil OD: 59 mm**
- **Cable length: 15 m per coil**
  - straight section: 0.3 m
  - coil ends: 2 x 0.06 m
  - average turn length: ~0.8 m
  - coil leads: 2 x ~1 m



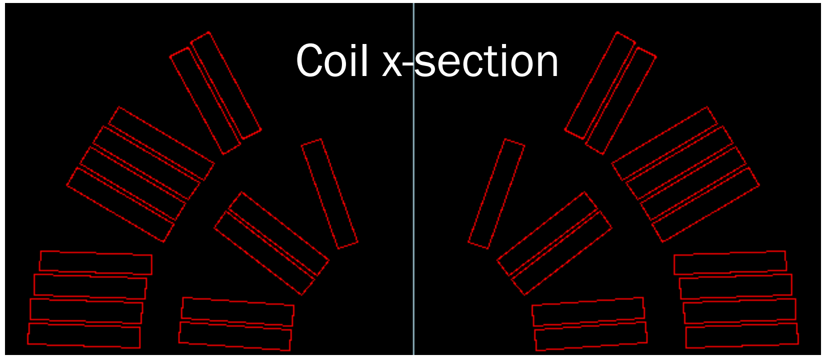


Table. Field parameters R_{ref}=5 mm

Design	B_{max}@2kA	B_1@2kA	b_3	b_5	b_7	b_9
2Lv.42-20	1.1728	1.1478	-0.05	-7.64	6.8	0.67

Prospective performance

Cable LBNL1110 – 7.8 mm x 1.44 mm (17 strands)

Cable Current, A	B_{max} , T	B_0 , T
7956	4.68	4.55
6290	13.6	13.5