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Latest development of CORC® cables and wires and their implementation into prototype accelerator magnets

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CORC® wire development for Canted-Cosine-Theta accelerator magnets

Program goal

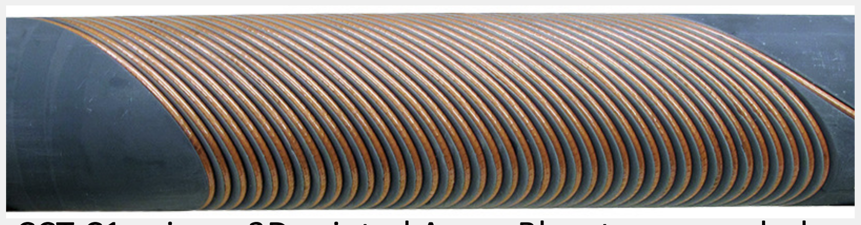
Development of high-J_e, flexible CORC® wires should enable 20 T canted-cosine-theta (CCT) dipole magnets. The technology is demonstrated by first developing high-J_e CORC® wires with increased bending flexibility and stand-alone CCT magnets from these CORC® wires before CORC® CCT insert are developed to reach 20 T in a 10 – 12 T LTS outsert.

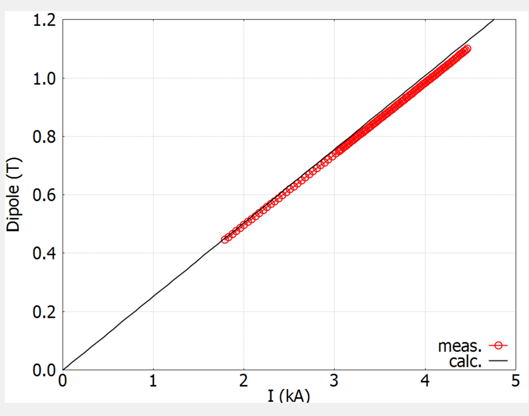
CCT-C1: demonstrated 1.2 T [1]

- 2-layer, 40 turn per layer
- Clear aperture 70 mm, minimum bending radius CORC® wire 25 mm
- 16-tape CORC® wire, 40 meters total length

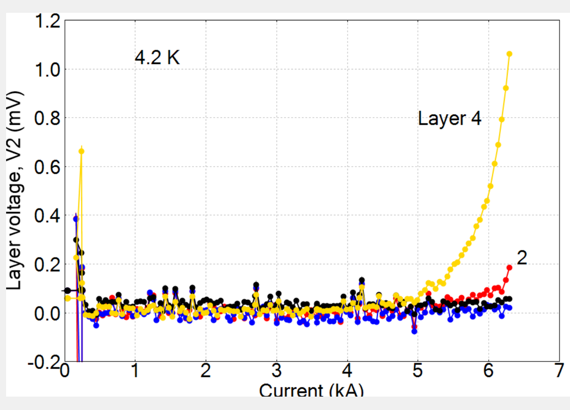
CCT-C2: demonstrated 2.9 T [2]

- 4-layer, 40 turn per layer, O.D. about 130 mm (incompatible with LTS outsert)
- ID 65 mm, minimum bending radius CORC® wire 30 mm
- 30-tape CORC® wire, 80 meters in total length


CCT-C1 using a 3D printed Acura Bluestone mandrel



CCT-C1 dipole field at 4.2 K



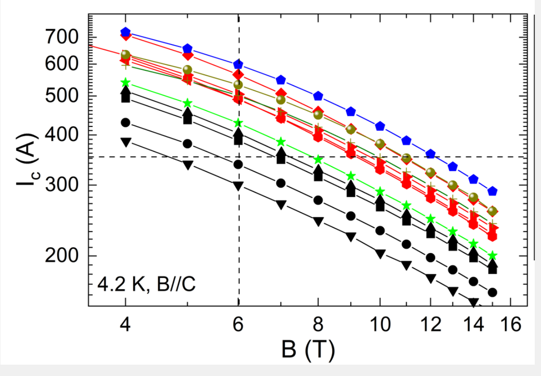
CCT-C2 dipole field at 4.2 K


CCT-C2 using a machined metal mandrel

CCT-C3: 5 T to be demonstrated in 2024

- 6-layer, 40 turn per layer, O.D. 160 mm (incompatible with LTS outsert)
- ID 65 mm, minimum bending radius CORC® wire 30 mm
- 30-tape CORC® wire, 145 meters in total length
- Minimum tape I_c(4.2K, 6 T) 350 A (2 mm wide tape)
- 8 km of 2 mm wide tape received and qualified
- CORC® wires to be delivered Q4 2023

SuperPower “HM” tape

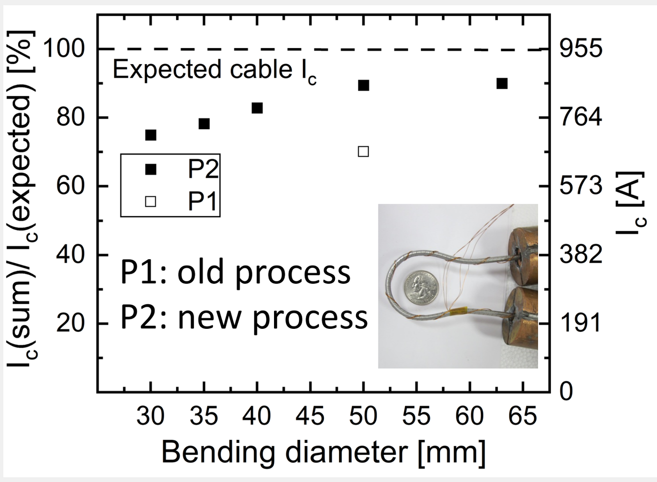


Proposed CCT-C4: 7 T to be demonstrated in 2025

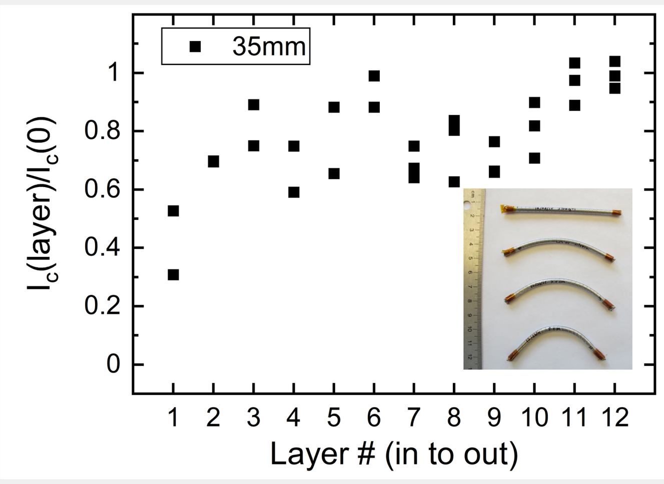
- Current design 6-layer, 40 turn/layer, 117 mm OD
- ID 45 mm, bending radius CORC® wire 20 mm
- 30-tape CORC® wire, tape I_c(4.2K, 6 T) 350 A (2 mm)
- Compatible with future 120 mm ID 11 T LTS outsert
- May generate 4 T in 11 T LTS outsert, resulting in a 15 T total dipole field

Development of highly flexible, high-J_e CORC® wires for CCT-C4

- Requirement: >80 – 90 % I_c retention at 20 mm radius for 30-tape CORC® wire
- Reached 80 % at 17.5 mm and 90 % at 25 mm radius through improved CORC® wire winding procedure



CORC® wire I_c vs. bending diameter



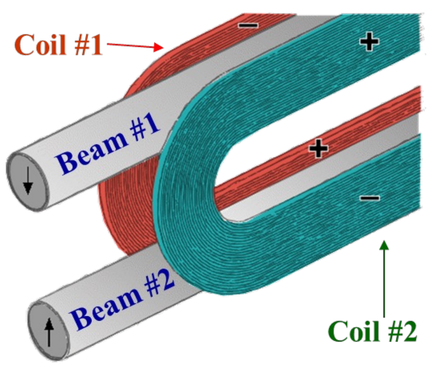
Extracted tape I_c at 35 mm diameter

CORC® cable Common Coil insert magnet development

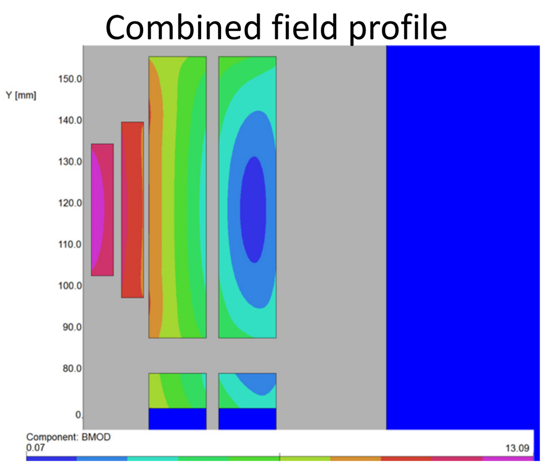
Program goal

Development of high-current CORC® cable Common Coil insert magnets to operate within a 10 T LTS Common Coil outsert. The program aims to not only achieve a combined dipole magnetic field of 13 T and will study the quench performance of high-current LTS/HTS magnets with the potential to operate the insert and outsert in series.

LTS Common Coil outsert

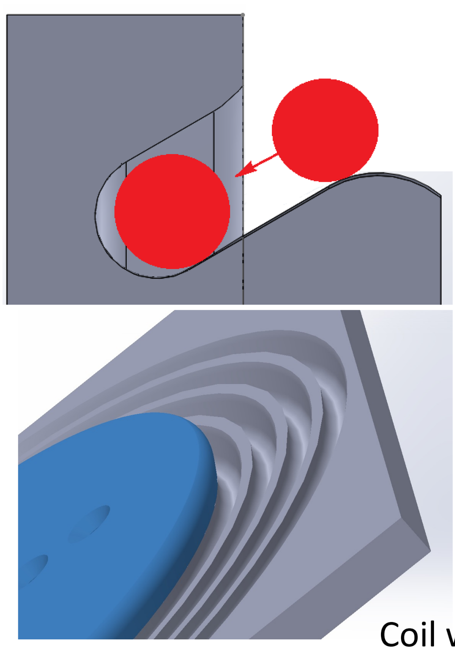


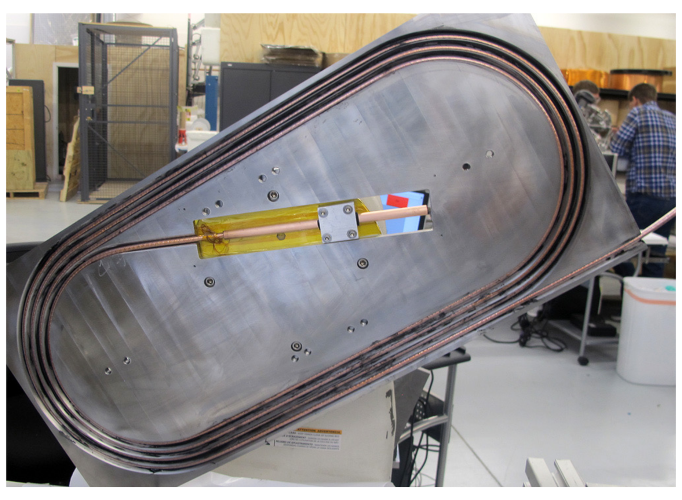
Combined field profile



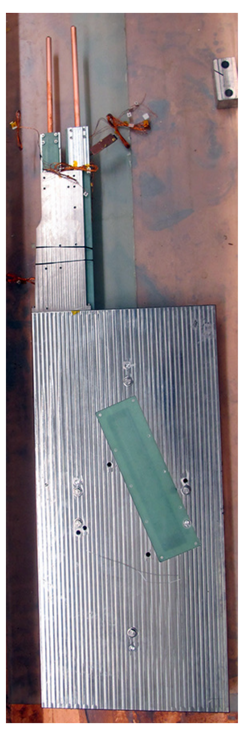
CORC® Common Coil winding technology

- Winding of the pancake coils with the CORC® cable under tension
- Using slanted grooves machined into the pancake support plates



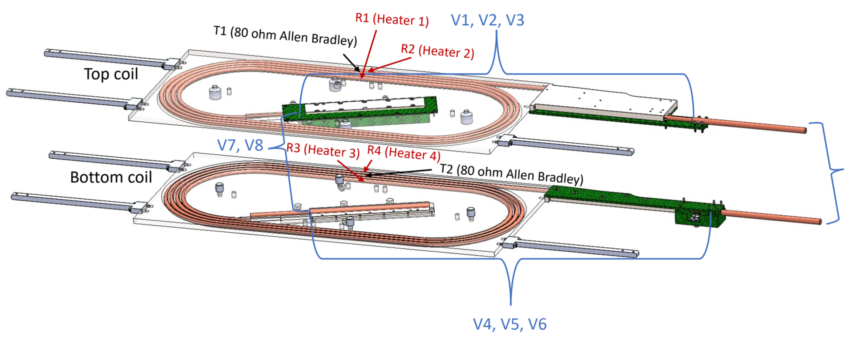

“MDP” CORC® Common Coil insert

Coil winding using slanted grooves

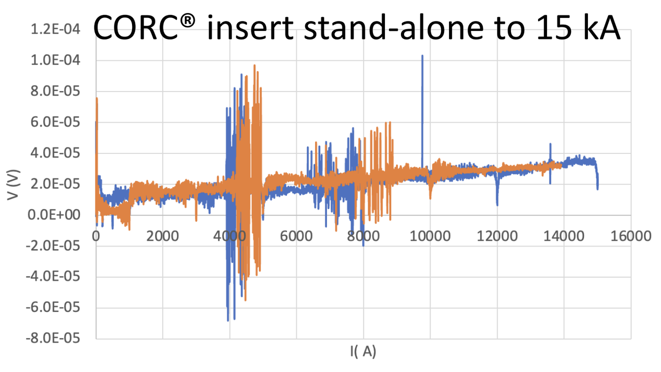


Step 1: Subscale “MDP” CORC® Common Coil insert

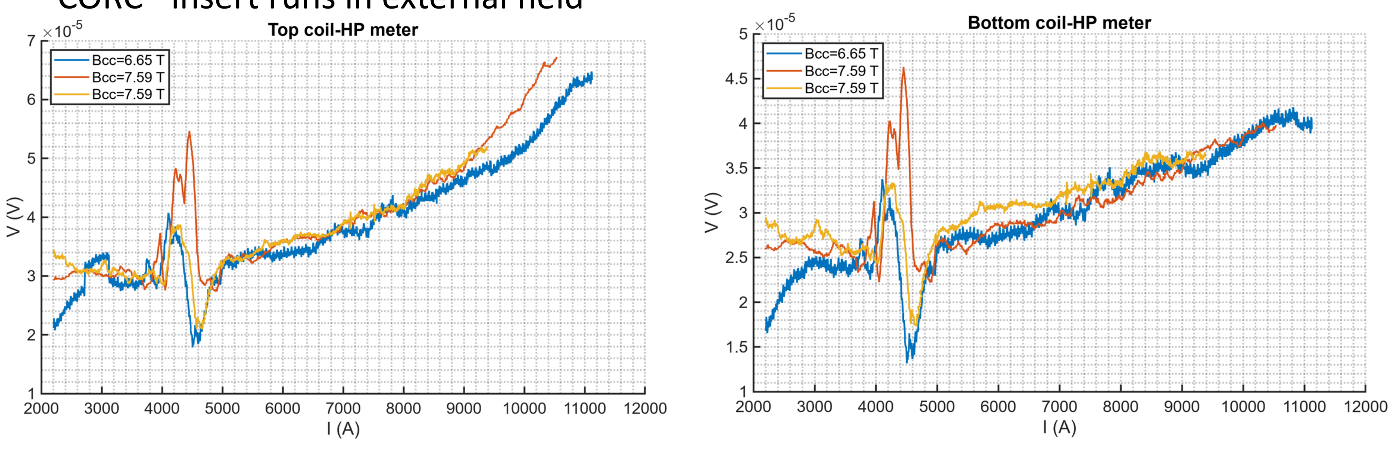
- Two single CORC® pancakes, 4 turns per pancake
- Exploring the coil winding technique and verification the mechanical support
- Quench detection using voltage wires, Hall arrays and acoustic waveguides
- Parallel operation at 7 kA within Common Coil outsert at 10 T



CORC® insert stand-alone to 15 kA



CORC® insert runs in external field



Initial analysis shows

- LTS outsert can’t be operated above about 8 T with the insert being energized
- No degradation in Common Coil insert
- Heater-activated quench data being analyzed

Step 2: Full-scale CORC® Common Coil insert

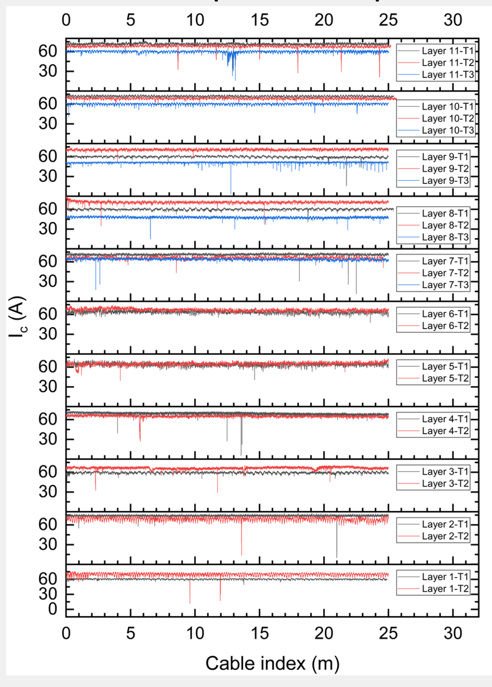
- Two double CORC® pancakes, 6 and 8 turns per double pancake
- Quench detection using voltage wires, Hall arrays and acoustic waveguides
- Parallel operation at 10 kA within Common Coil outsert at 10 T, generating 13 T
- Common Coil insert to be wound October 2023 and tested January 2024

Solenoid magnets wound from CORC® wires with tape dropouts

Program goal

Determine the impact on the performance of magnets wound from CORC® wires that contain tapes with dropouts. Will current sharing between tapes be sufficient for current to circumvent these dropouts?

Tapestar data of tapes with sharp local dropouts



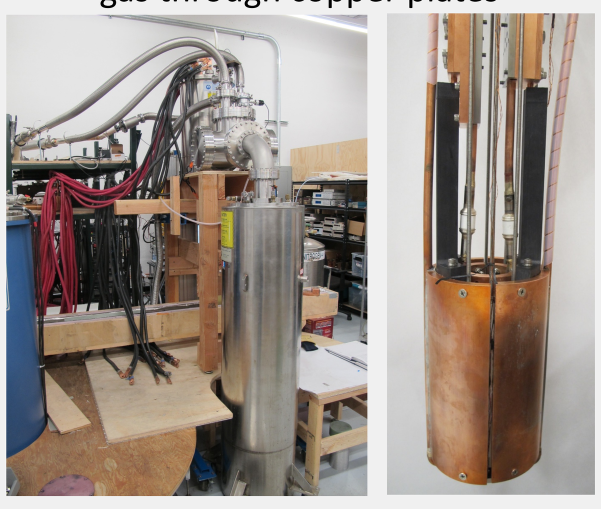
CORC® wire properties

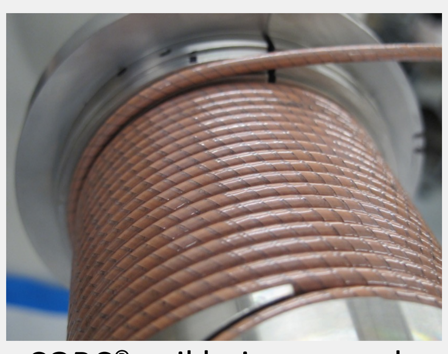
CORC OD (mm)	3.6
# of 2 mm wide tapes	27
Central Transfer function (T/kA)	0.88
Peak Transfer function (T/kA)	1.03
CORC® Length (m)	24.6

Coil dimensions

	ID (mm)	OD (mm)	height (mm)	Turns
Layer 1	74.00	81.24	69.35	19
Layer 2	83.24	90.48	73.00	20
Layer 3	92.48	99.72	76.65	21
Layer 4	101.72	108.96	80.30	21.5

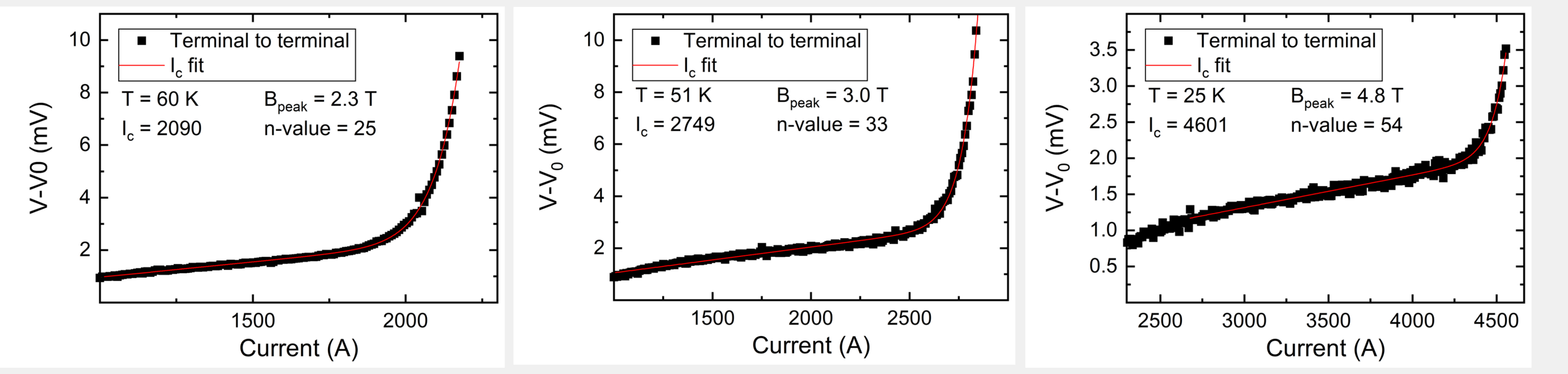
CORC® coil cooled with He gas through copper plates

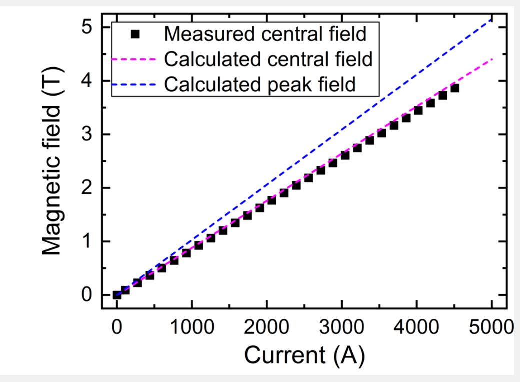


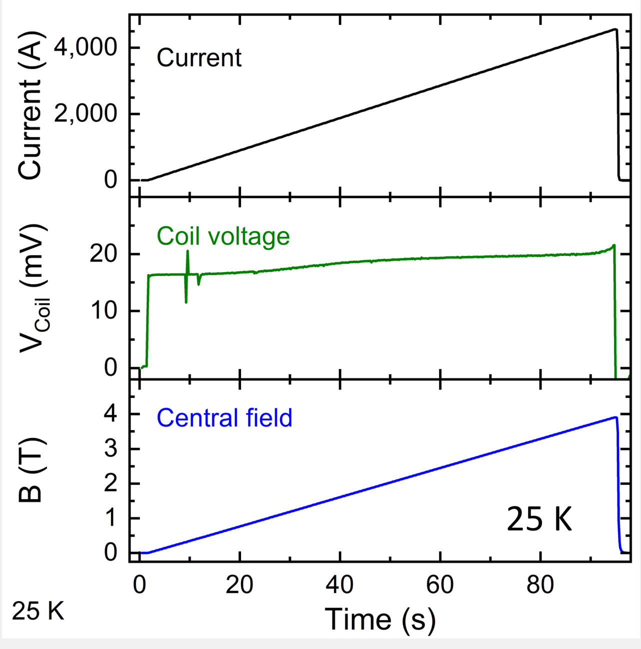

CORC® coil being wound

Coil test procedure

- Conduction-cooled through external copper shells
- Copper shells cooled with circulating helium gas at ACT
- Test temperature range 25 – 60 K at up to 5 kA continuous current







Results

- Peak magnetic field of 4.8 T achieved at 25 K
- Central field of 4 T measured at 25 K
- Coil could be ramped into transition without quench
- CORC® wire carries amount of current corresponding to the average tape I_c, not the minimum tape I_c
- Defect-tolerant CORC® wire due to current sharing

References

[1] X. Wang, et al. “*A 1.2-T canted cos ϑ dipole magnet using high-temperature superconducting CORC® wires*”, Supercond. Sci. Technol. **32** 075002 (2019)
[2] X. Wang, et al. “*Development and performance of a 2.9 T dipole magnet using high-temperature superconducting CORC® wires*”, Supercond. Sci. Technol. **34**, 015012 (2021)

U.S. DEPARTMENT OF ENERGY

Supported by grants numbers DE-SC0014009, DE-SC0015775, DE-SC0018125, DE-SC0018127, DE-SC0019934, and DE-EE0007872