U.S. MAGNET DEVELOPMENT PROGRAM

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Development and test of REBCO canted cosθ dipole coils with CORC® wires

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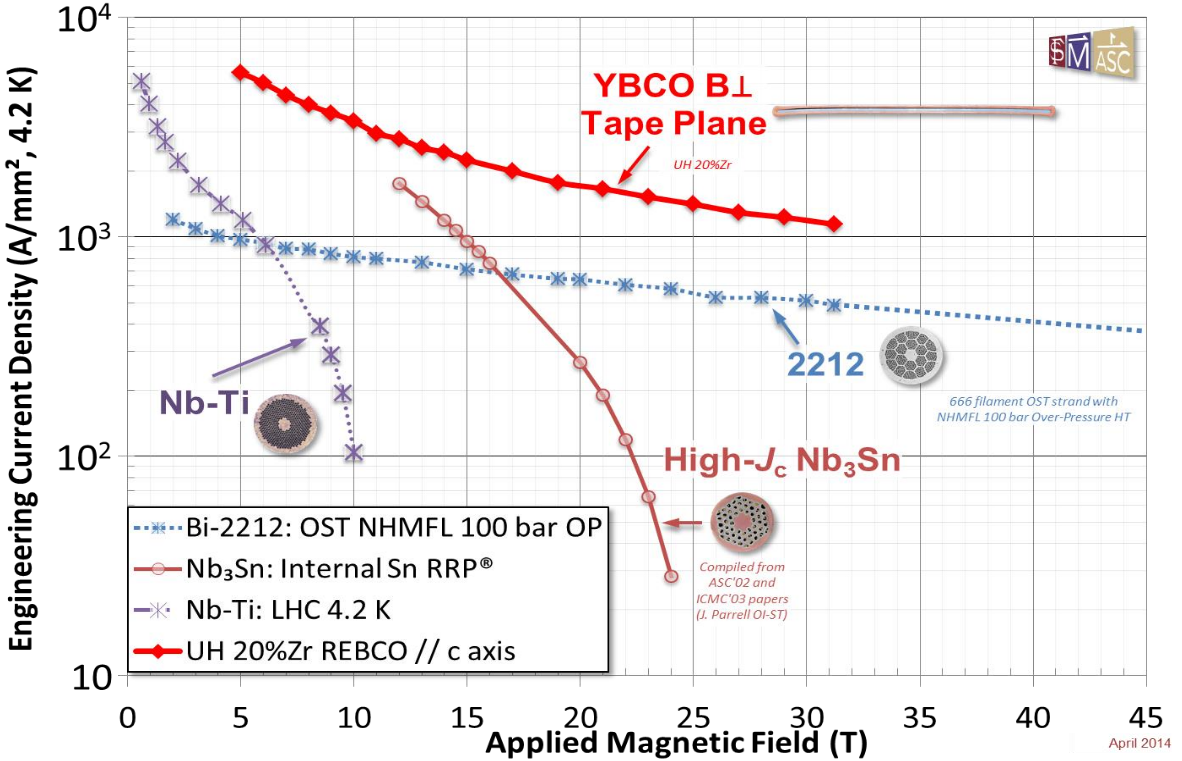
REBCO conductors can enable future dipole magnets beyond 16 T



REBCO magnet R&D is a key component of the US MDP [Soren Prestemon's talk in Thu-Mo-Or28]

Data courtesy of Peter Lee, ASC/NHMFL/FSU. REBCO data courtesy of Venkat Selvamanickam at UH, see A. Xu *et al.*, Scientific Reports, Article number 6853, 2017

We focus on canted cosθ dipole magnets using round REBCO CORC® wires

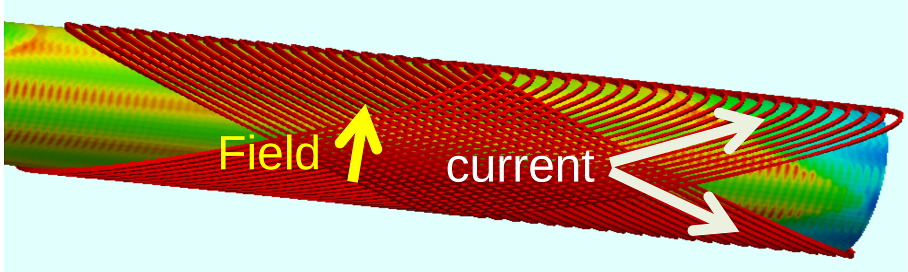
- CORC® wires (2.5-4.5 mm diameter)
  - Wound from 2-3 mm wide tapes with 30 μm substrate
  - Highly flexible with bending down to <50 mm diameter

  [Danko van der Laan's talk in Wed-Mo-Or21]

  J. D. Weiss *et al.*, SuST, 014002, 2017 and references therein

- Canted cosθ (CCT) accelerator magnets
  - Low conductor stresses
  - Excellent geometric field quality

  [Diego Arbelaez's talk in Mon-Af-Or7]



D. Meyer and R. Flasck, Nuclear Instruments and Methods, vol. 80, no. 2, pp. 339–341, 1970

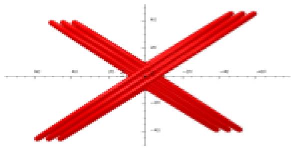
S. Caspi *et al.*, IEEE TAS, 4001804, 2014, and references therein

A phased program to address the driving questions

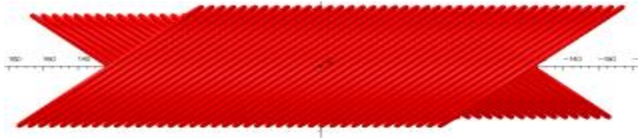
- How to make CCT magnets using CORC® wires?
- What's the magnet performance?
- What issues limit the magnet performance? How to address them?

- Subscale coil approach with increased complexity

Few-turn mini coil



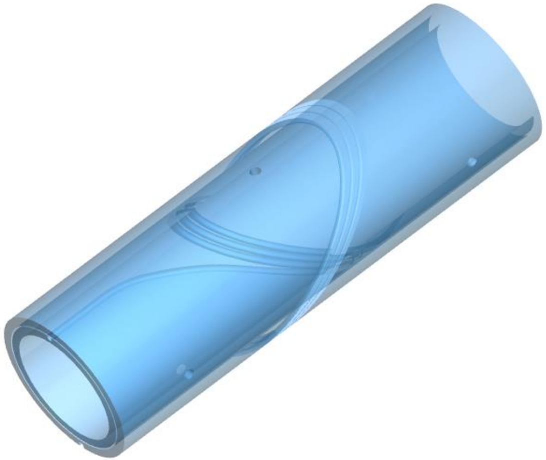
Multi-turn coil



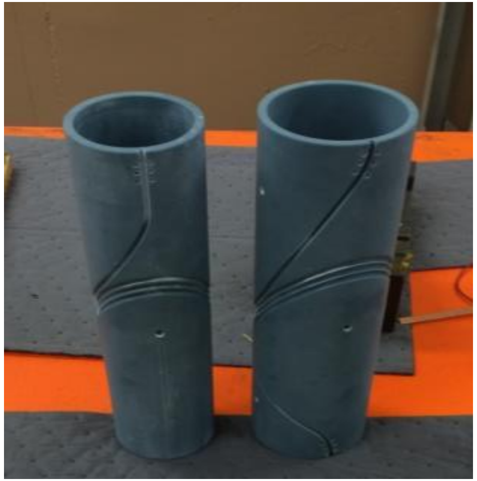
- Stand-alone test to be followed by in-field test
- Close collaboration with the community through the U.S. MDP

Simple geometry and printed mandrels facilitate the coil development

CAD model of a 2-layer assembled coil



Printed mandrels using Accura® Bluestone



- The wire minimum bending radius drives the coil design

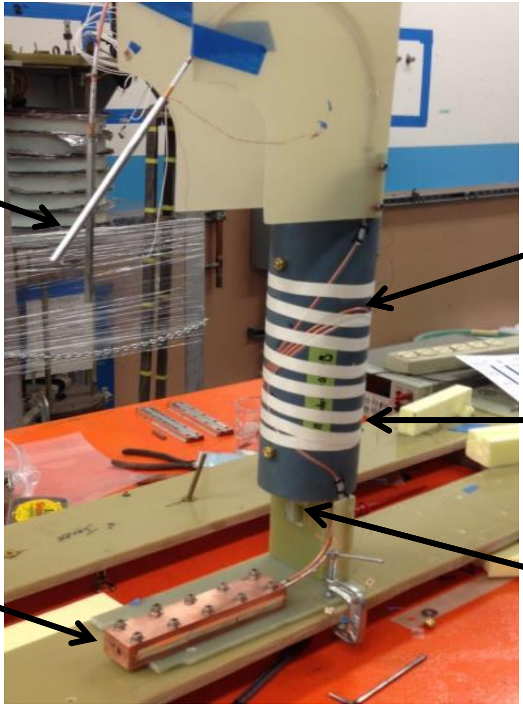
Two coils (3-turn) are successfully made and tested using CORC® wires

CCT coils	C0a	C0b
Wire OD (mm)	3.09	3.63
Number of tapes in the wire	16	29
Expected J_e at 76 K, sf (A/mm^2)	140	234
Expected J_e at 4.2 K, 20 T (A/mm^2)	207	346
Minimum bending radius (mm)	25	30

Each 2-layer coil used about 5 m long wires

We gained very useful experience on coil winding, assembly and test

Lead end terminal



3 turns of CORC® wire

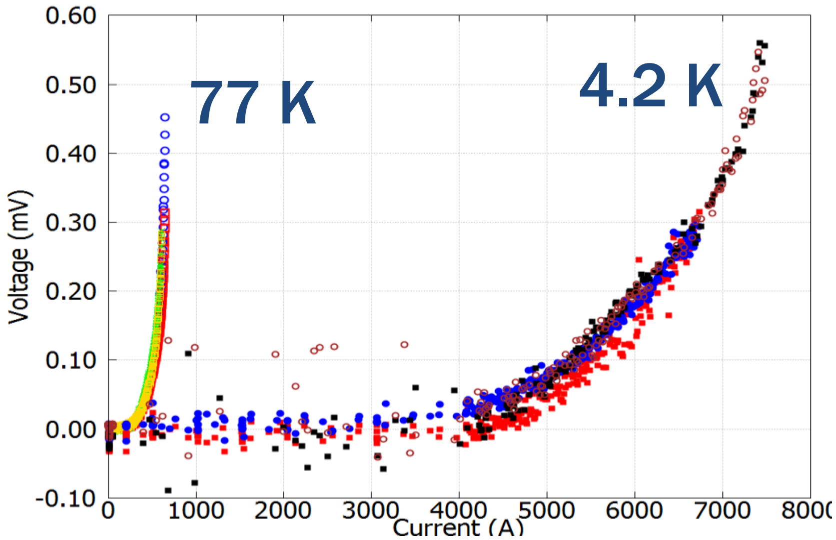
Outer layer (inner layer inside)

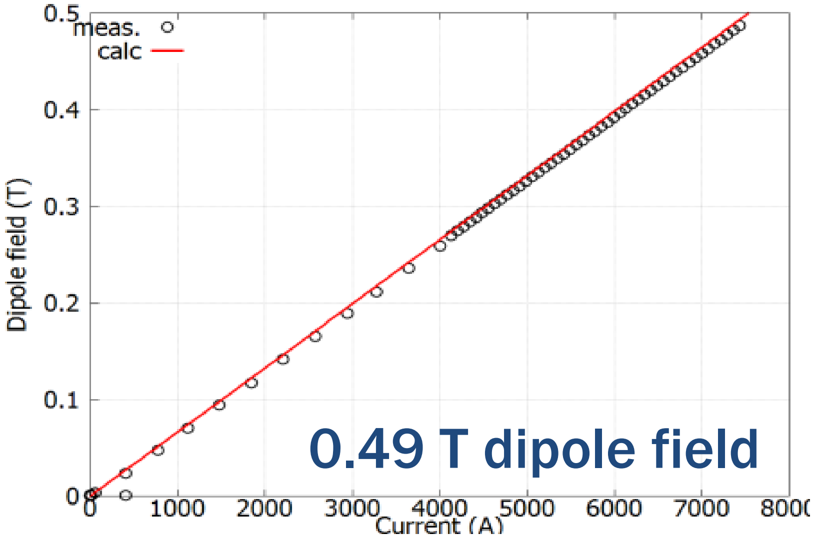
Return end joint

Hall sensor assembly

Successful tests suggest the CORC® CCT is a viable concept – C0a coil with 16-tape wire

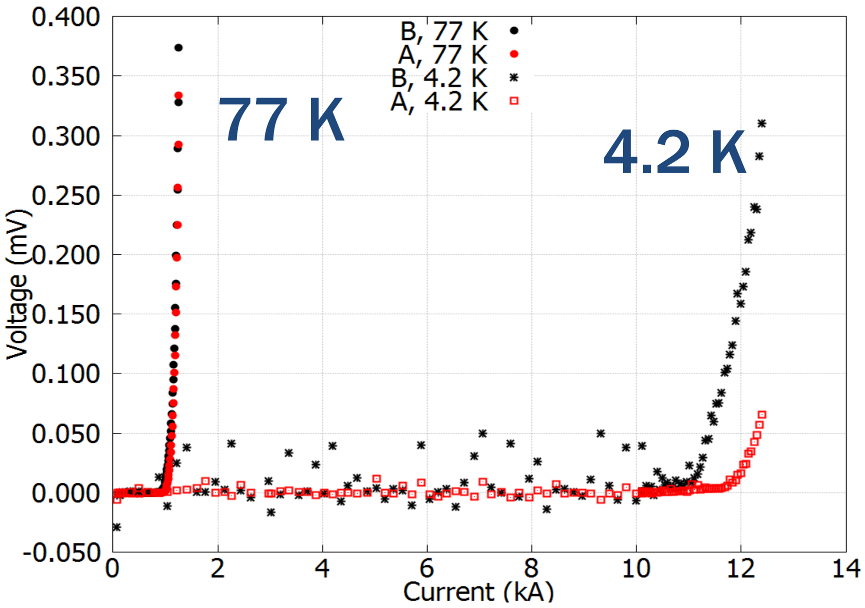
- Reached 645 A at 77 K and 7480 A at 4.2 K. Peak J_e = 997 A/mm^2 at 4.2 K, self-field





Successful tests suggest the CORC® CCT is a viable concept – C0b coil with 29-tape wire

Layer B Layer A



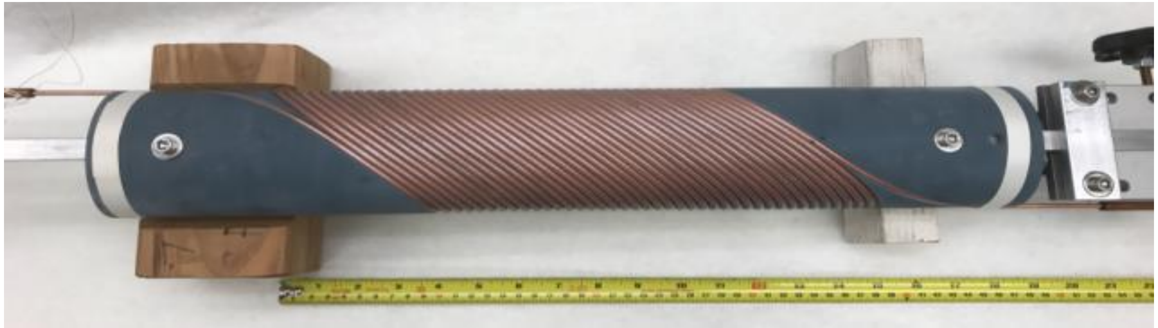
Current-carrying capacity x 11 from 77 K to 4.2 K.
Peak J_e 1198 A/mm² and a dipole field of 0.68 T

With the experience from the 3-turn CO coils, we are making a 40-turn magnet

Hugh Higley (left) and Andy Lin (right) winding a mockup coil

Inner and outer layers are ready to be assembled for test

Inner layer



Outer layer

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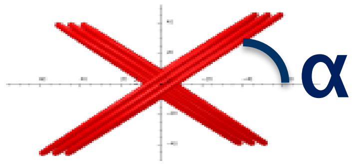
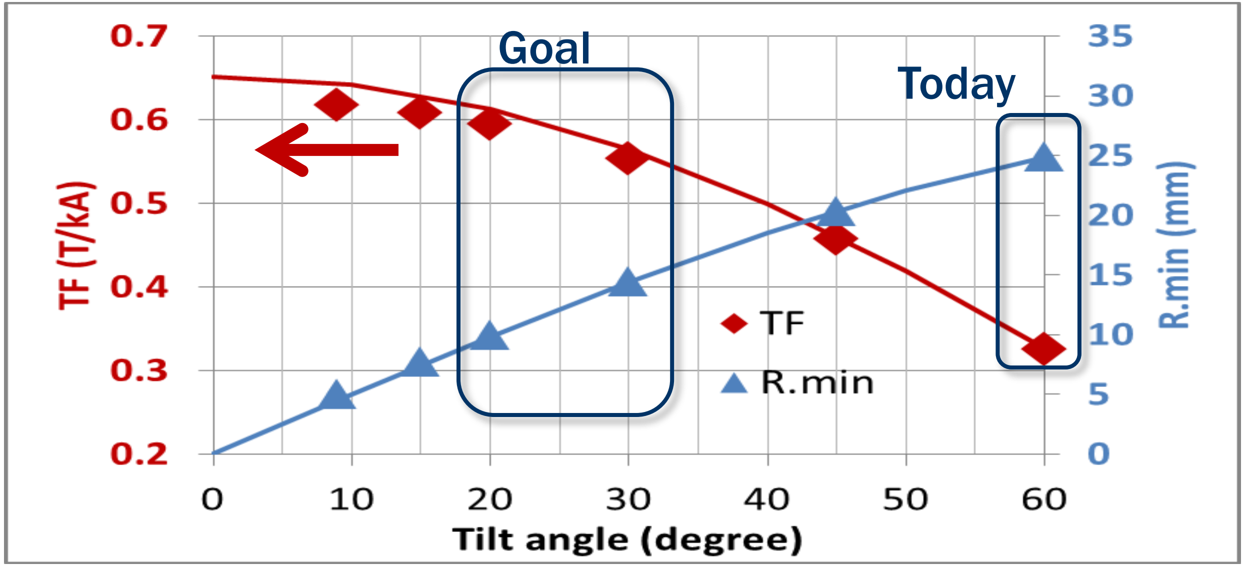
Improving J_e at small bending radii is the focus for further optimization of CORC® wires



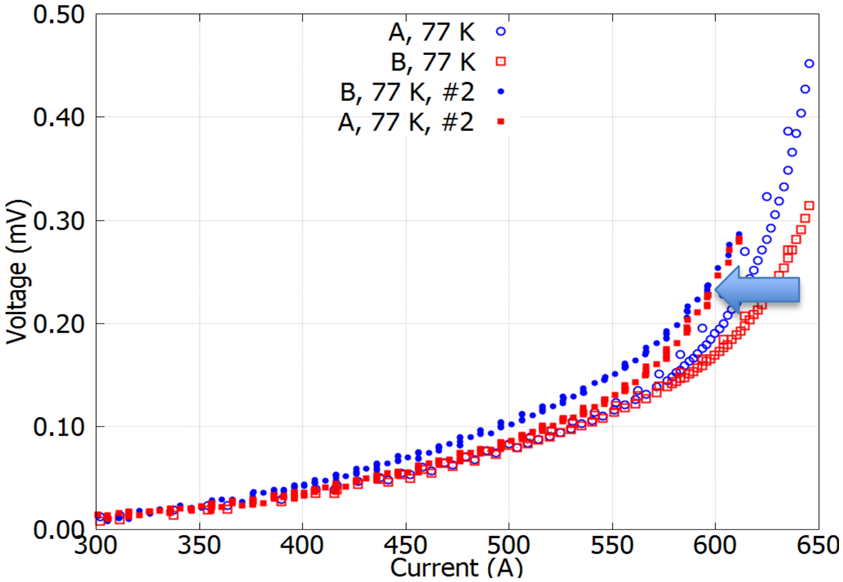
- Transfer function (TF) ∝ cos(α)
- Minimum bending radius (R_{min}) ∝ sin(α)



- Proposed R_{min} target: 10 – 15 mm (25 mm today)
- Minimum target J_e: 915 A/mm² at 6 T, 4.2 K, 15 mm R_{min}

High J_e conductors require effective quench detection

- Over heating caused issues
  - 5% - 10% current degradation in COa due to overheating at 4.2 K test
  - COb burn up at 12.4 kA



- Will study new detection schemes with future coil tests, e.g., the acoustic approach [Maxim Marchevsky's talk in Mon-Mo-Or3] and the fiber-optic approach [Federico Scurti's talk in Tue-Mo-Or15]

In-field test will prove the true capability of REBCO conductors and magnets

- 20 T dipole field requires an LTS/HTS hybrid magnet configuration [Ramesh Gupta's talk in Thu-Mo-Or28]
- Several LTS outsert dipole magnets suitable for REBCO CCT insert coils are under development, for instance,
  - CERN: FRESCA2 (100 mm aperture) [Gerard Willering's talk in Thu-Mo-Or28]
  - US: CCT (> 90 mm aperture) [Diego Arbelaez's talk in Mon-Af-Or7]
- Development of next REBCO CCT coils will aim for in-field tests

Summary

- The MDP REBCO program is developing magnet technology to exploit the unprecedented conductor performance
    - Demonstrate applications in the next 5 years to create industrial competition and drive cost down

- We successfully developed the first 3-turn CORC® CCT coils
    - Demonstrated viability of the concept – no showstoppers foreseen
    - Identified further optimization goals and issues to be addressed

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