UNIVERSITY OF TWENTE.

Role of UT in WP10

& (*) State-of-the-art with CORC for HEP

Marc Dhallé

(*) contributed by D. van der Laan

EUCARD II kick-off, 13-14 June 2013, CERN

Role of UTwente in EUCARD II

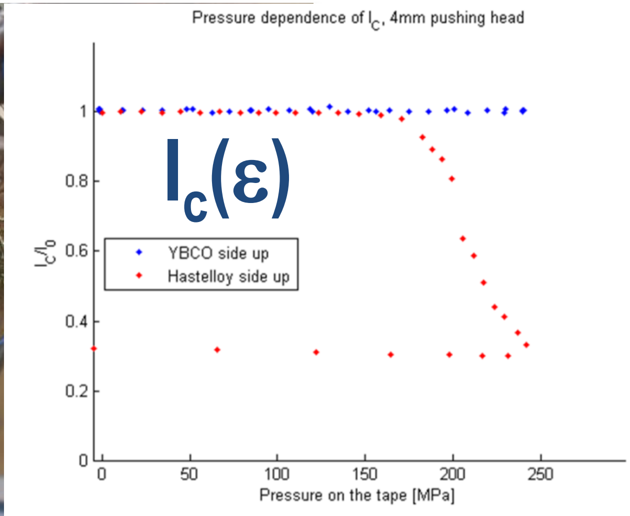
DOW: WP10,task 10.2

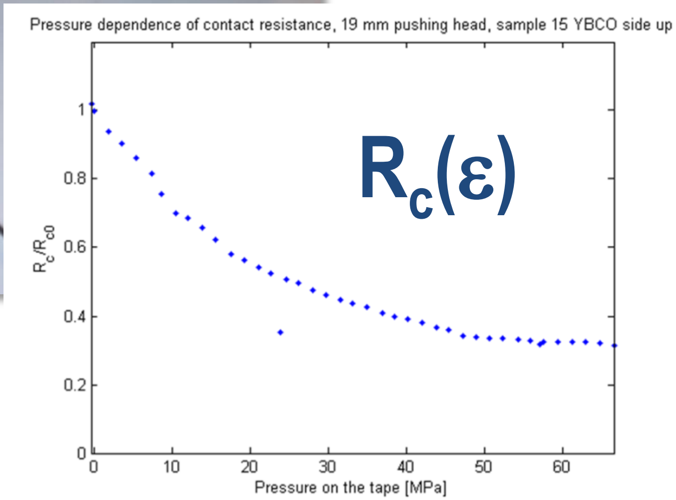
UT performs **AC loss characterization** of both wire/tape and cable samples; and

contributes I_c measurements of wires/tapes under longitudinal **mechanical stress** and of both wires/tape and cables under transverse stress.

- Infrastructure: *existing (SC magnetometer, Packman, TARSIS)*
  & <u>newly developed/adapted</u>
- people: *P. Gao (PhD student)*
  S.Wessel (Tech. Suport)
  M.Dhallé (P.I.)
  var. MsC assign.

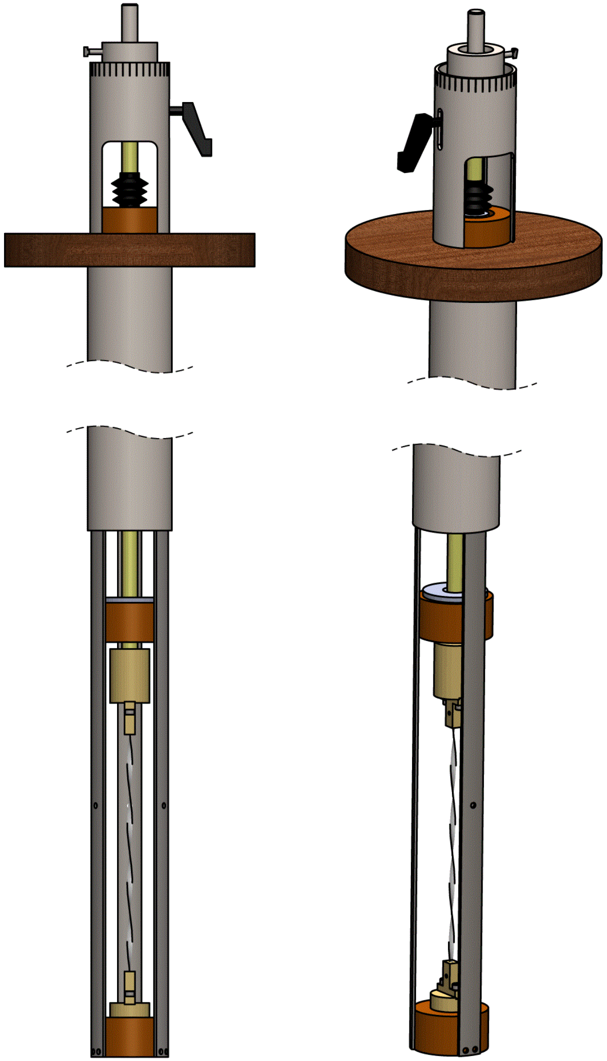
Tape contact pressure





Experimental setup with calibrated strain gauge, current leads, dedicated anvil, and voltage taps

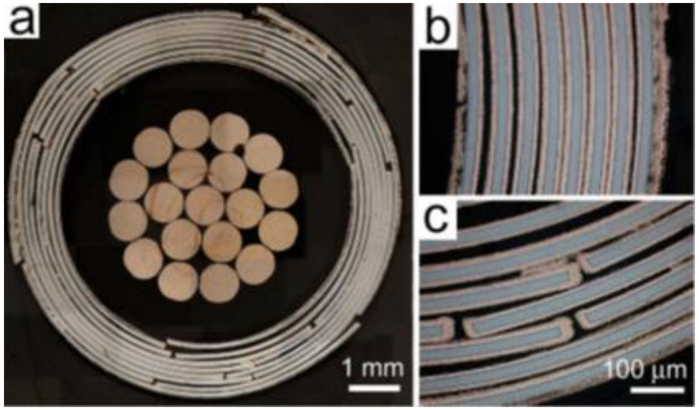
TARSIS extension for tape torsion

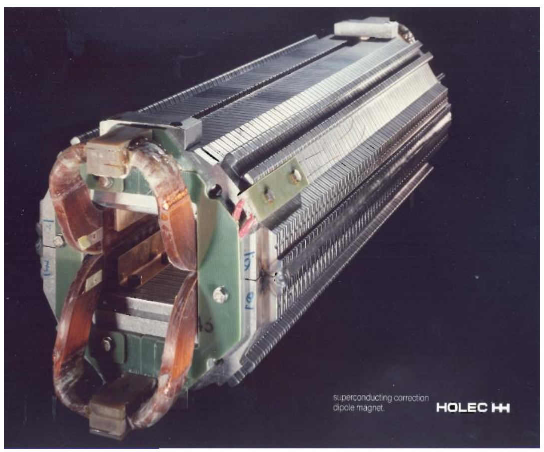


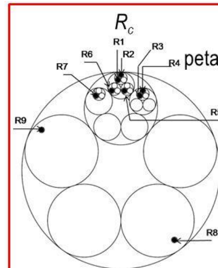
Experimental setup for effect of torsion under controlled axial load (constant axial stress) by linear stage from TARSIS facility.

First tests will be at 77 K, self field, followed by 4.2 K and parallel magnet field.

Cable AC loss & transverse pressure (ongoing)



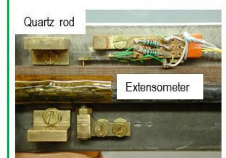




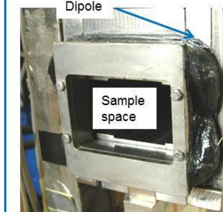
Four-point.

Strand pairs from
- Intra-petal
1st (triplet), 2nd, 3rd, 4th stages
- Inter-petal
randomly chosen

displacement



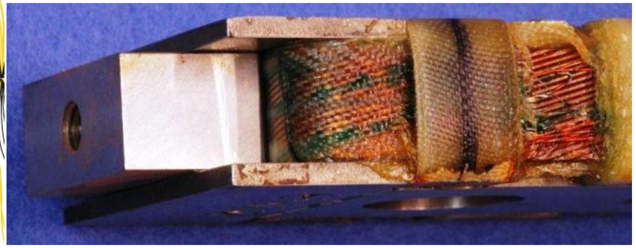
AC loss

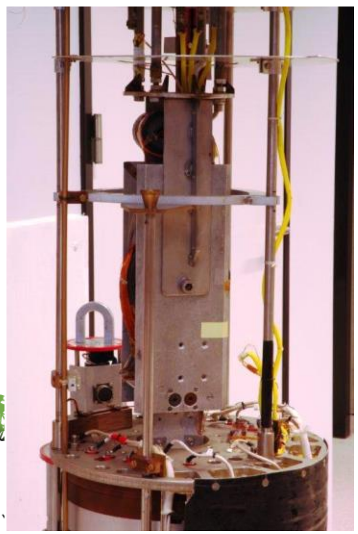


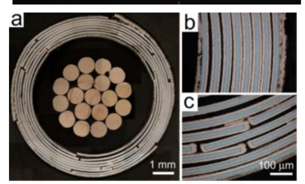
- Magnetisation calibrated by boil off calorimetry

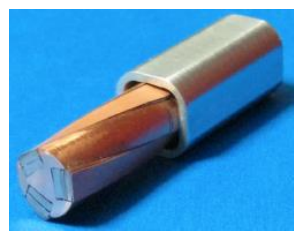
AC loss & Rc measurement on cable prototypes at 4.2 K.
Calorimetric and magnetisation is considered. No load and applied load.

Cable Ic & transverse pressure (planned)









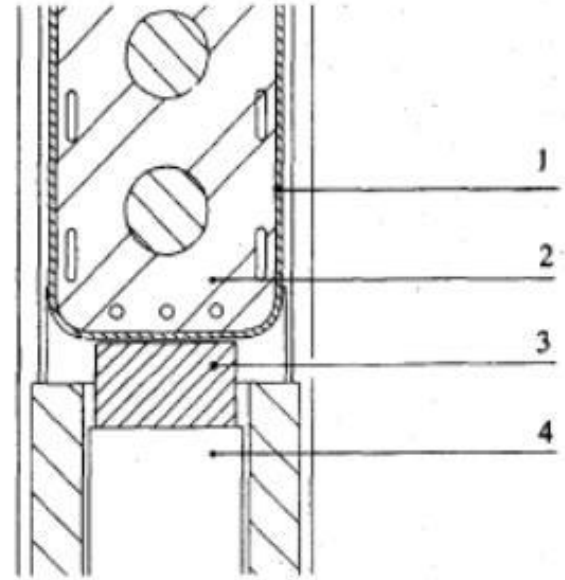


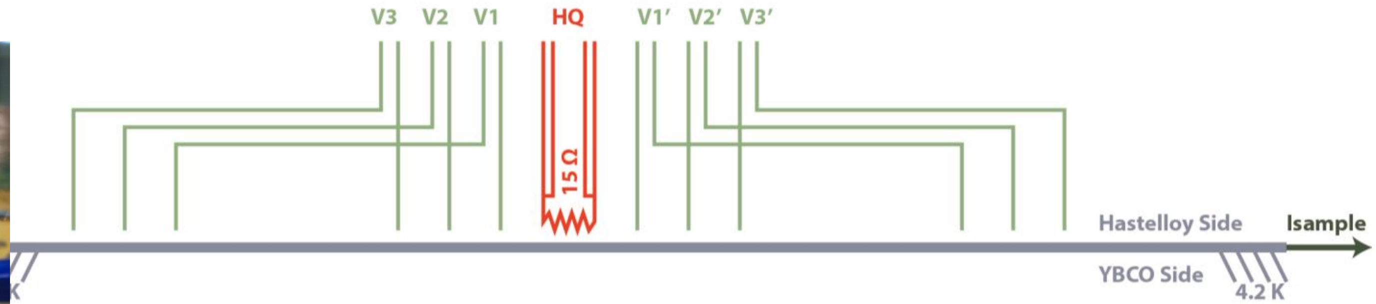
Fig. 1 The central part of the pressing arrangement: (1) U shape cable, (2) sample holder, (3) pressure block, (4) pressure pin.

Cryogenic transverse press (with S.C. transformer)

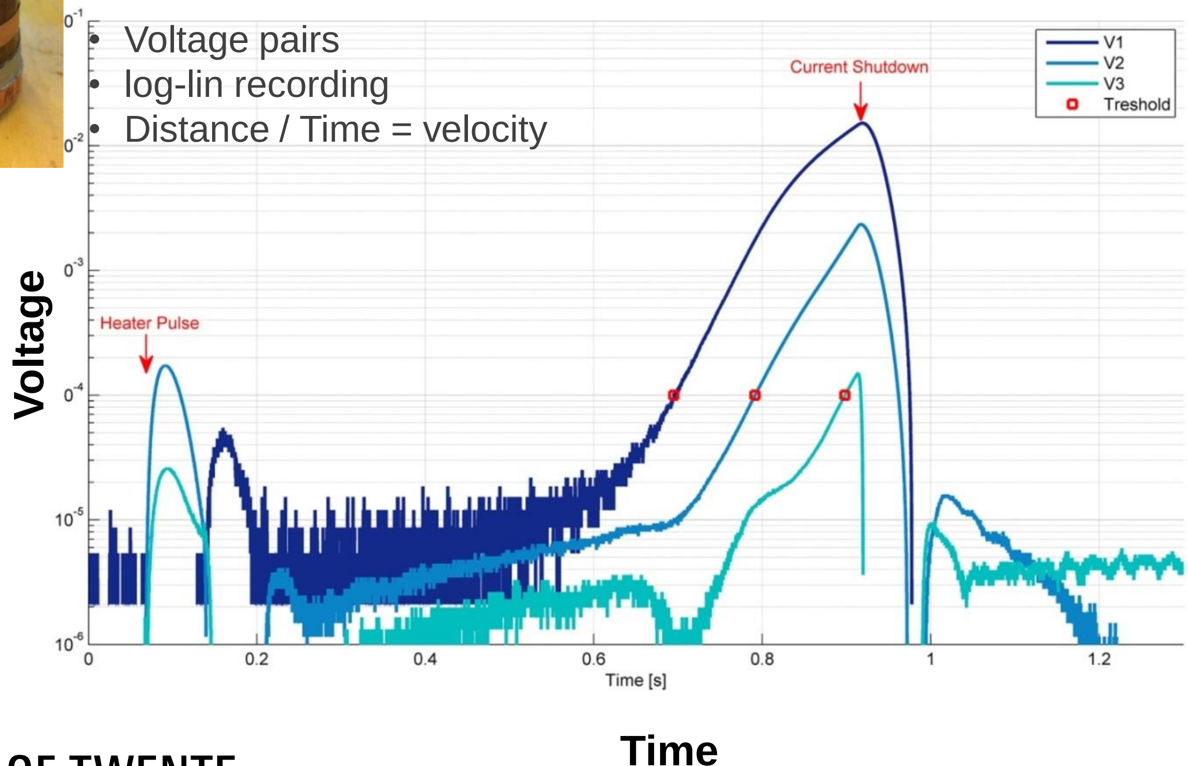
Ic measurement on cable prototypes and production lengths up to 15 T at 4.2 K.

Cyclic transverse stress in the range 10 – 20 Mpa

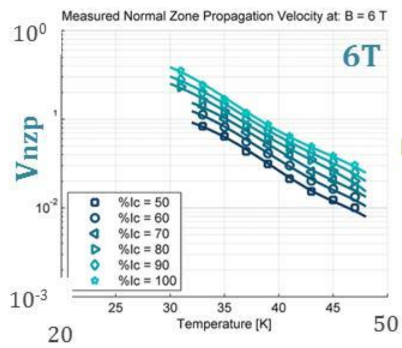
Q.A.-holder for MQE and v_{NZP} of both tapes/wires

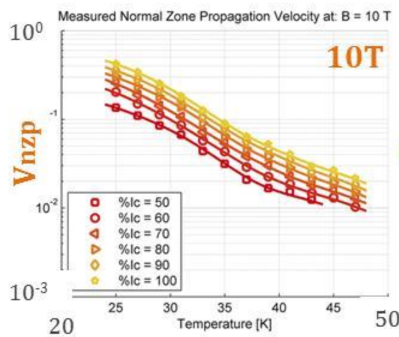


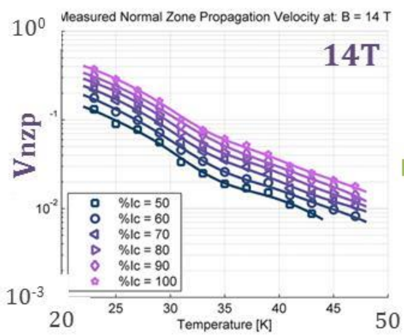
- Voltage pairs
- log-lin recording
- Distance / Time = velocity

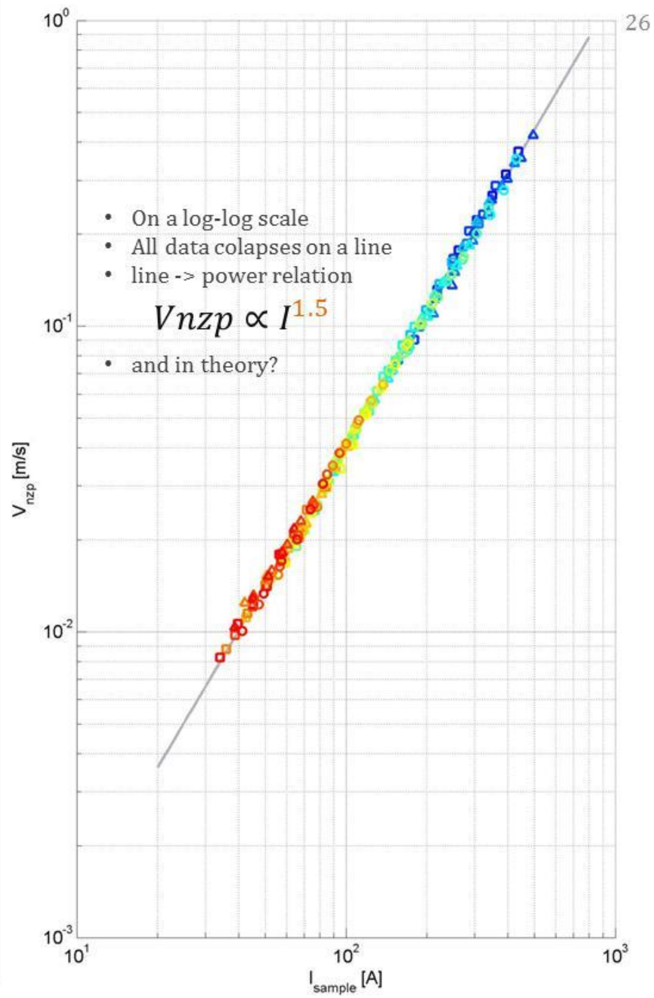


Tape MQE(T,I,B) and v_{NZP}(T,I,B) (cable if need be?)









Normal Zone Velocity

- Plot at fixed percentages of critical current
- Order of magnitude 1-10 cm/s
- The normal zone velocity
  - decreases with the temperature at fixed %Ic
  - increases with the current at fixed T

Sample exchange

Twente = characterisation lab

sample sources (CC, 2212)

Role of Task leader

monitoring / discussion priorities

High-temperature Superconducting Conductor on Round Core (CORC) Cables

Danko van der Laan
Advanced Conductor Technologies LLC and
the University of Colorado, USA

Advanced Conductor Technologies LLC
www.advancedconductor.com

Advanced Conductor Technologies LLC (ACT)

Founded in June 2011 as a spin-off from the University of Colorado and the National Institute of Standards and Technology (NIST)

Advanced Conductor Technologies focuses on the commercialization of high-temperature superconducting Conductor on Round Core (CORC) cables for high-density power transmission and high-field magnets.

Personnel at ACT:

1. Danko van der Laan, Ph.D.
2. Annemiek Kamphuis, M.Sc.
3. Xifeng Lu, Ph.D.
4. Fraser Douglas Ph.D. (starting July 1st)

New location (starting June 1st):

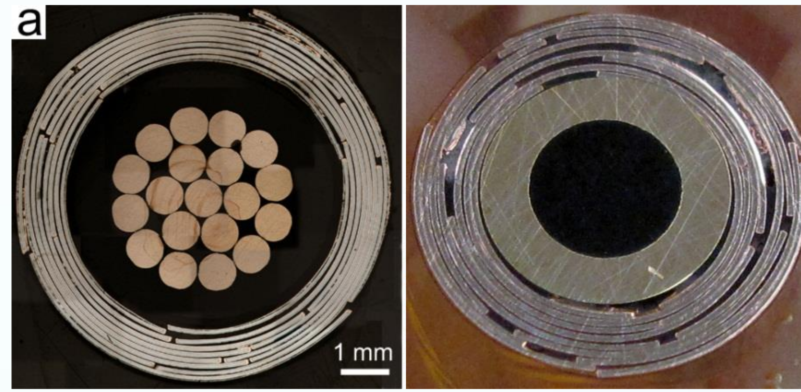
3082 Sterling Circle Unit B, Boulder, CO 80301 (2851 SF)

Conductor on Round Core cables

CORC cable concept:
Winding many high-temperature superconducting YBCO coated conductors from SuperPower in a helical fashion with the YBCO under compression around a small former.

SuperPower Inc.

D.C. van der Laan, *SUST* 22, 065013 (2009).



Benefits:

- Very flexible
- Very high currents and current densities
- Mechanically very strong
- Minimum degradation from cabling (< 10 %)

Major support for CORC cable development

ACT:

1. Department of Energy – Office of High Energy Physics
- CORC cables for accelerator magnets
- Phase I SBIR (9 months – February to November 2013)
- Subcontractor: NHMFL (Ulf Trociewitz and Matthieu Dalban-Canassy)

2. Department of Energy – Office of Fusion Energy Sciences
- Demountable magnet cables (CORC cable terminations)
- Phase I SBIR (9 months – February to November 2013)
- Subcontractor is MIT (Joe Minervini and Leslie Bromberg)

3. Department of Energy – Office of Fusion Energy Sciences
- CORC cable for fusion magnets
- Phase II STTR (2 years – April 2013 to April 2015)
- Subcontractor is MIT (Joe Minervini and Leslie Bromberg)

4. U.S. Navy
- He-gas cooled CORC power transmission cables
- Phase II SBIR (2 years – December 2013 to November 2015)
- Subcontractor is CAPS (Sastry Pamidi)

Univ. of Colorado:

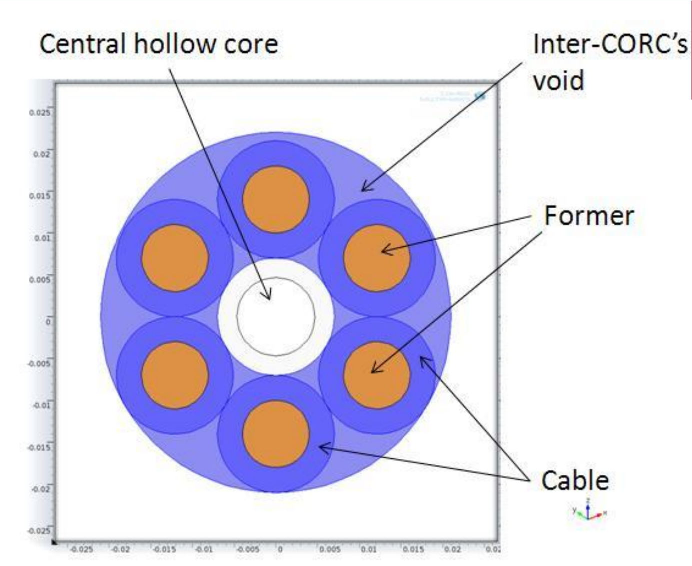
1. Department of Energy – Office of High Energy Physics
- CORC cables for accelerator magnets
- 3-year program (2012-2015)

CORC cable for fusion magnets

Goal is to reach a cable current >30 kA at 4.2 K and B > 12 T.

CORC triplet rated at potentially 3 x 5 kA = 15 kA at 4.2 K, 19 T.

CORC 6-around-1 rated at potentially 6 x 5 kA = 30 kA at 4.2 K, 19 T.



Phase I STTR DOE-Fusion Energy Sciences
Award DE-SC0007660

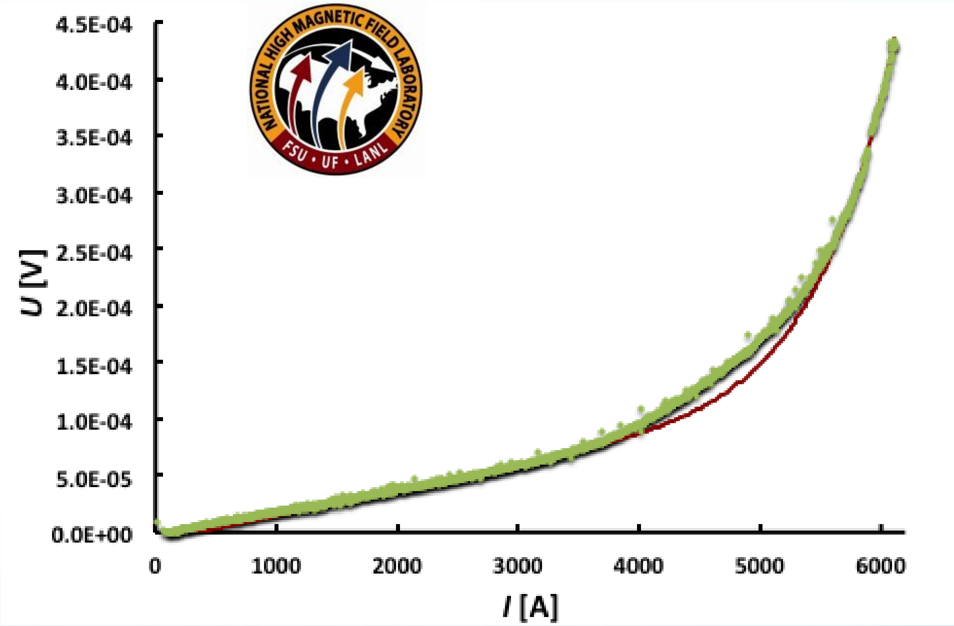
Advanced Conductor Technologies LLC
www.advancedconductor.com

CORC cables for accelerator magnets

Goal is J_e of > 200 A/mm^2 at 4.2 K and 20 T at a 6 cm cable bending diameter.

Cables tested at the NHMFL in 19.8 T background field:

52 YBCO coated conductors, 17 layers, **cable O.D. 7.5 mm**:



I_{quench} = 6000 A @ 4.2 K, 19 T

I_c = 5021 A @ 4.2 K, 19 T, 1 μV/cm

J_e = 114 A/mm^2 @ 4.2 K, 19.0 T

Advanced Conductor Technologies LLC
www.advancedconductor.com

Supported in part by NSF, agreement DMR-0654118, the State of Florida, and the U.S. Department of Energy.

CORC cable performance at 6 cm diameter

Cable:

26 YBCO CC, 11 layers, cable O.D. 6.0 mm

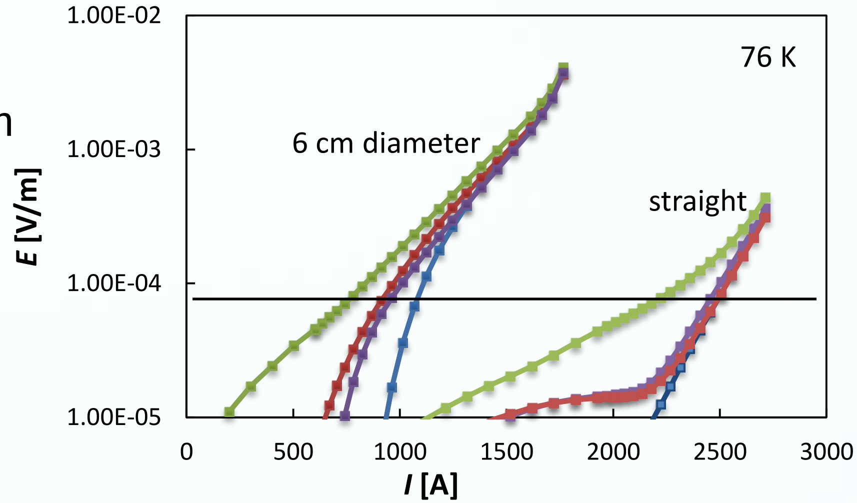
Straight: **I_c = 2425 A @ 76 K**

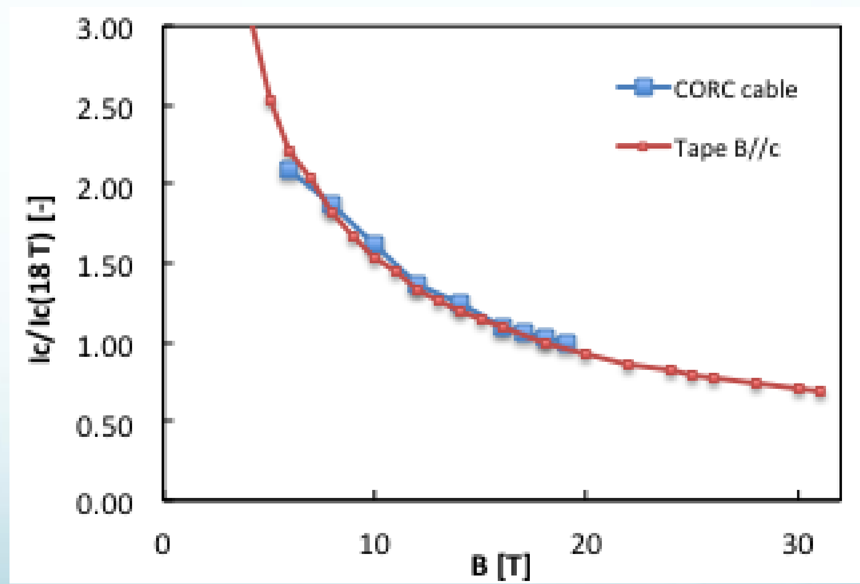
6 cm diameter:

I_c = 1057 A @ 76 K

I_c = 1264 A @ 4.2 K, 19 T

J_e= 29 A/mm^2





Large degradation of 56 % due to bending!

Room for improvement

I_c = 5021 A @ 4.2 K, 19 T

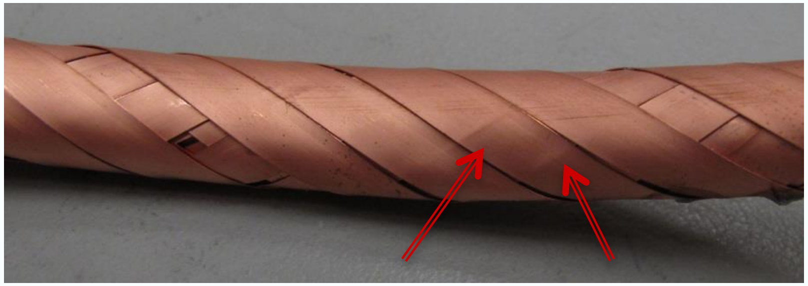
During cable inspection after test at 19T:

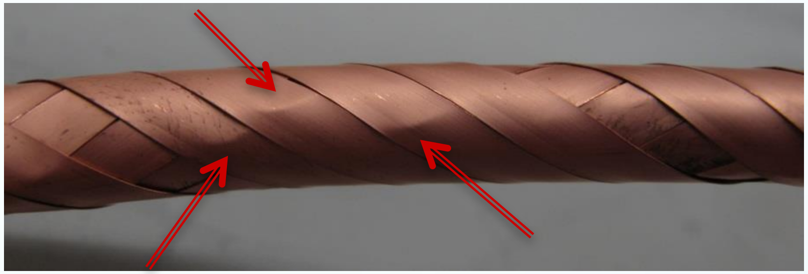
Many damaged tapes in outer layers due to cable bending!

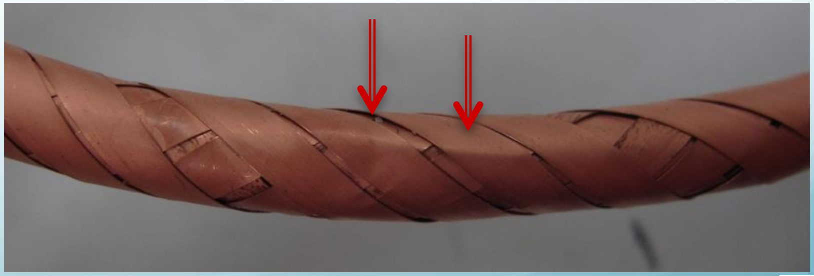
Caused by loose winding pack.

Winding pack needs to be controlled:

=> Cabling machine is needed.







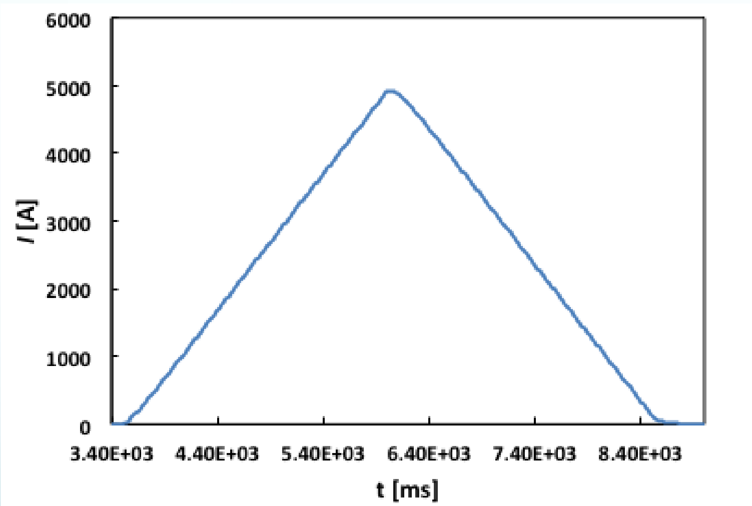
High-current ramp rates at 19 T

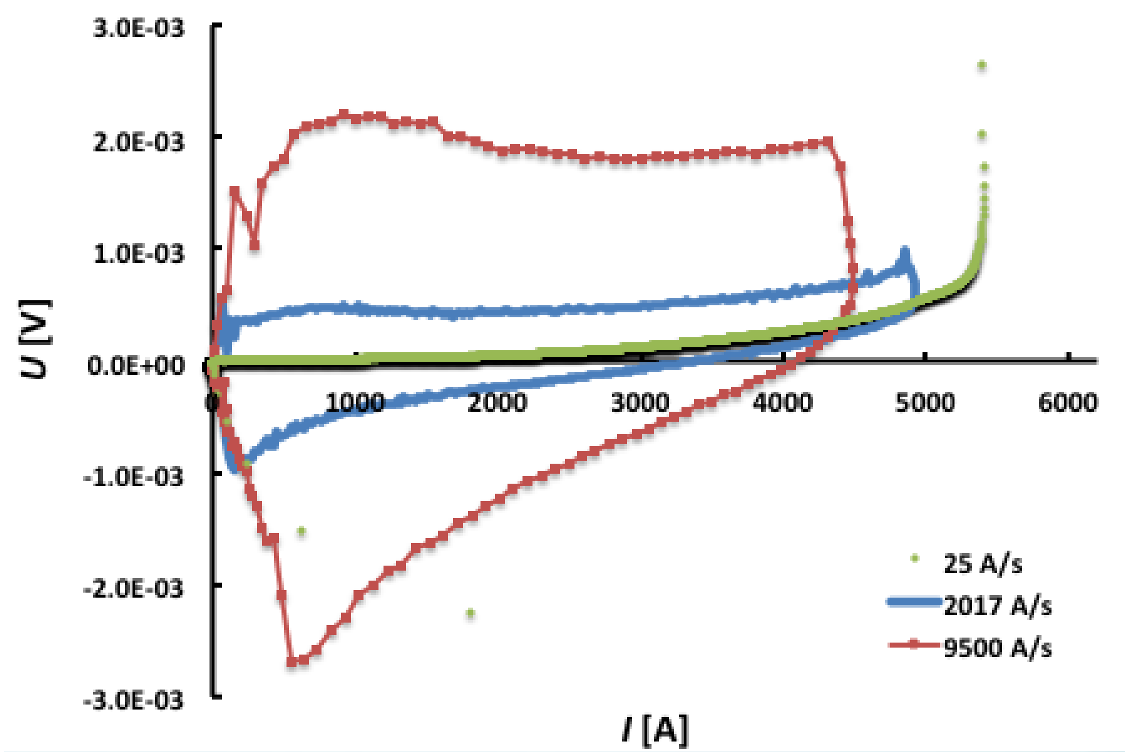
Will current distribution become inhomogeneous in cables with many layers at high current ramp rates?

PSFC

Cable: 52 CC in 17 layers.

Current ramp rates at 4.2 K, 19 T to 90 % of I_{quench}:
- 2017 A/s
- 9500 A/s





No effect of high current ramp rates!

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J_e Projections for CORC cables

Cable optimization:

Raise J_e(4.2 K, 20 T) to above 200 A/mm^2 and reduce degradation at low cable bending radius.

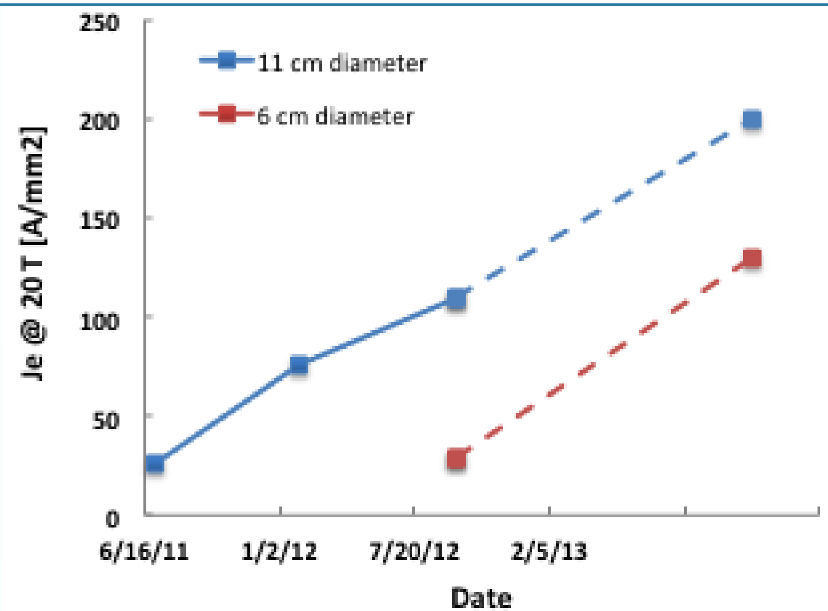
Raising J_e further by:

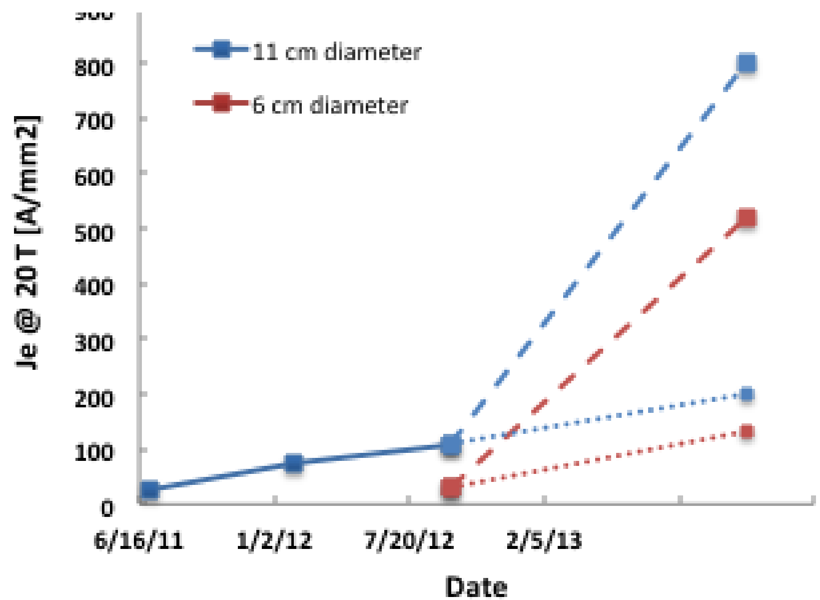
- Pinning: 2x in I_c at 4.2 K, 20 T?
- Thicker YBCO: 2x in I_c?

This would bring current J_e(4.2 K, 20 T) to 2 x 2 x 110 A/mm^2 = 440 A/mm^2!

Or two methods combined:

J_e(4.2 K, 20 T) = 4 x 200 A/mm^2 = 800 A/mm^2!





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