IEEE/CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), January 2016.
Invited presentation 3OrAB_01 given at MT-24, Seoul, Korea, October 18-23, 2015.

Karlsruhe Institute of Technology

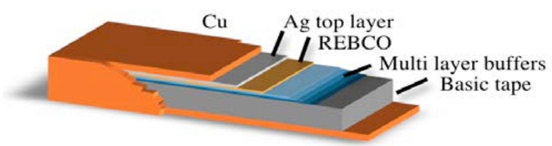
High Current HTS Cables - Status and Actual Development

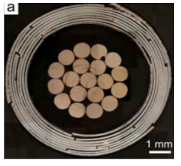
Walter H. Fietz, Michael J. Wolf, Alan Preuss, Reinhard Heller, and Klaus-Peter Weiss
Karlsruhe Institute of Technology, Institute for Technical Physics, 76131 Karlsruhe, Germany

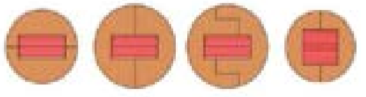
Presentation on Int. Conf. on Magnet Technol. 24, Oct. 18-23. 2015 Seoul, Korea
(Paper subm. to appear in the conf. proceedings in IEEE Trans. Appl. Supercond.)

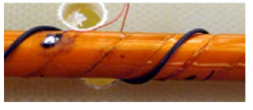
(e-mail: walter.fietz@KIT.edu.)

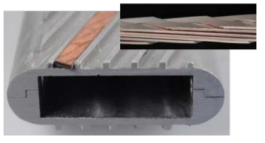
Institue for Technical Physics

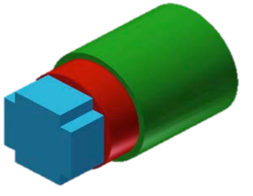












Karlsruhe Institute of Technology

The following slides are essentially identical to what was shown in Seoul.

However, one slide was removed because we have not received the courtesy to show this via IEEE CSC and ESAS Superconductivity News Forum (SNF) http://snf.ieeecsc.org/

Two slides were slightly changed by the content owner and two slides were added to give actual content (these slides are flagged in the presentation).

Karlsruhe Institute of Technology

High Current HTS Cables
- Status and Actual Development

Mini-Intro

Highlighting: **HTS Tape Property Progress**

Overview: **High Current HTS Cable Proposals**

Optimizing: **HTS-CroCo**

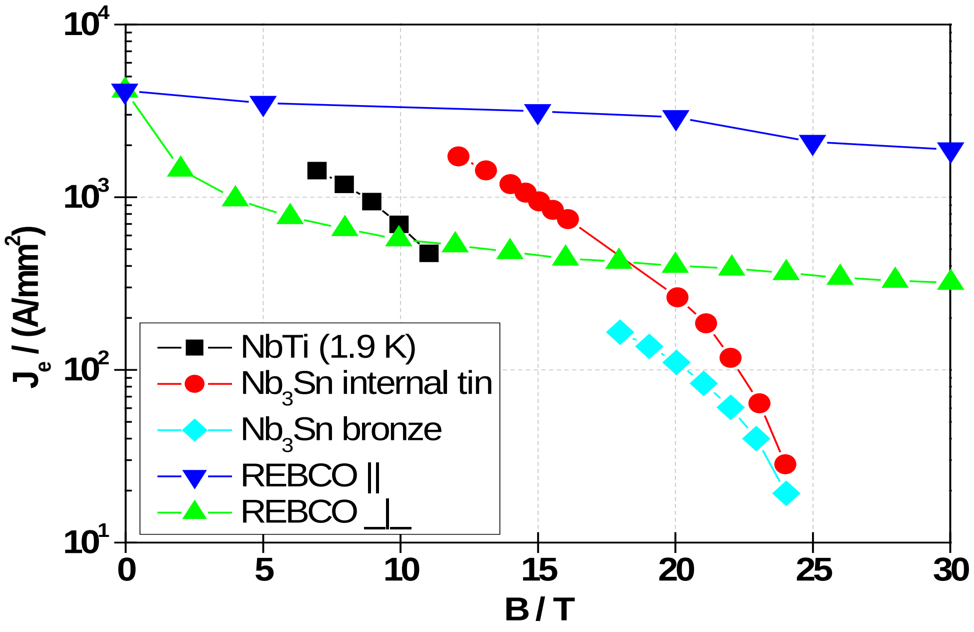
Outlook: **Consequences using improved tapes**

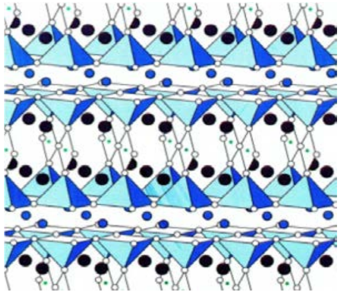
RE$Ba_2Cu_3O_{7-d}$ (REBCO)

with *RE* = Rare Earth atom e.g. Y, Gd, Nd or other

For high field *RE*BCO is superior!

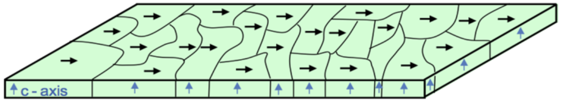
but anisotropic with respect to field orientation



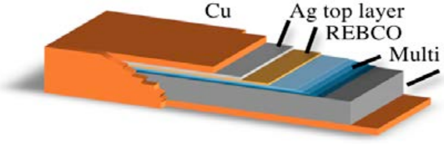


CuO_2 planes

Grain orientation mandatory

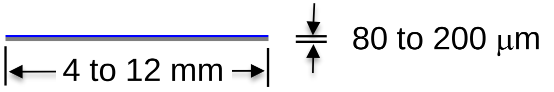


Preparation as thin films, only



HTS high current superconductor cables ?

How to come to high current cables with such tapes?



68 kA Nb_3Sn ITER TF coil cable
multi-twisted wires of 0.81 mm
cable pattern 3 x 3 x 5 x 4 x 6

- optimized for low ac losses
  (small temperature margin!)
- jacketed to withstand forces
- Quench safe
- central He channel for low pressure drop

Can we come to high current conductors built from High T_c Superconductors ?

What is the target for an HTS high current cable?

Application is determining!

Power transmission

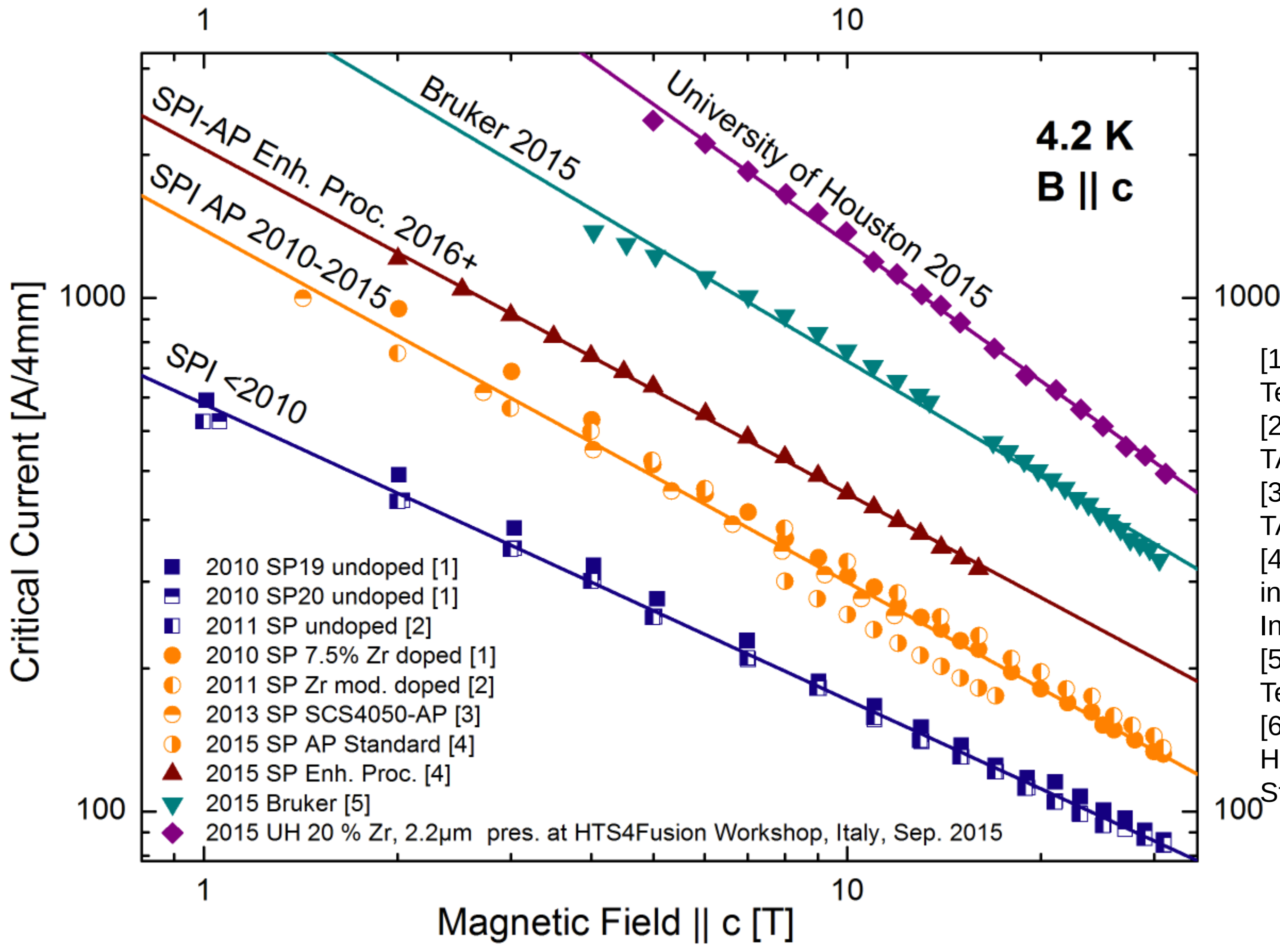
- may target temperatures up to 77 K
- needs electrical stabilization (but may be switched of fast in case of quench)
- ac loss optimization (depends on ac scenario)
- needs no major optimization for forces

High field magnet application needs

- high j_e
- optimization for transversal forces and Hoop stress
- electrical stabilization (quench detection, quench safety and hot spot analysis)
- ac loss optimization (depending on operation scenario)

We have to tailor the cable design to the application!
Let's first check HTS progress!

J_c (B) Progress Overview



[1] V. Braccini et al., Supercond. Sci. Technol. 24 (2011) 035001
[2] V. Selvamanickam et al.,, IEEE TAS, VOL. 21, NO. 3, JUNE 2011
[3] Gianluca De Marzi et al. IEEE TAS VOL. 25(3), JUNE 2015
[4] www.superpower-inc.com/system/files/2015_SPI_New_Innovations.pdf
[5] D. Abraimov et al. Supercond. Sci. Technol. 28 (2015) 114007
[6] V. Selvamanickam et al., HTS4Fusion workshop Pieve S. Stefano, Sept. 11-12, 2015

Increasing REBCO Layer Thickness

Critical current density above 15MAcm^{-2} at 30K, 3T in 2.2μm thick heavily-doped (Gd,Y)$Ba_2Cu_3O_x$ superconductor tapes

V Selvamanickam et al. Supercond. Sci. Technol. 28 (2015) 072002

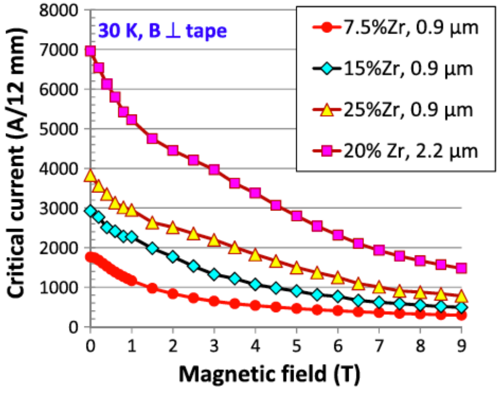


Figure 2. Magnetic field dependence of critical currents of a 2.2 μm GdYBCO tape with 20 mol% Zr addition and the best 0.9 μm thick (Gd,Y)BCO tapes with 7.5%, 15% and 25% Zr addition at 30 K in the orientation of field along the *c*-axis.

Decreasing Substrate Thickness to 30 μm

"Improved Current Density in 2G HTS Conductors Using Thin Hastelloy® C276 Substrates"
D.W. Hazelton et al., ASC Conference Charlotte, 10-15- Aug.

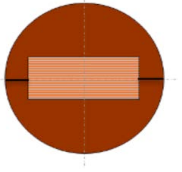
more tapes in the same cross-section!

High Current HTS Cable Proposals

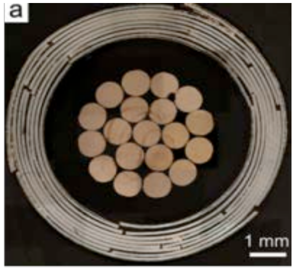
Different approaches for high current *RE*BCO cables:

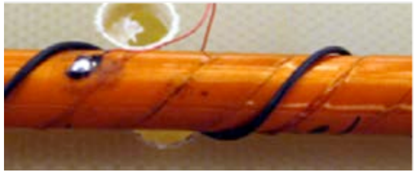
Twisted Stacked Cable (TSTC) (MIT)

Round TSTC (CRPP)

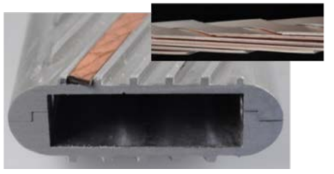


CORC
(Advanced Conductor Technologies LLC**)**



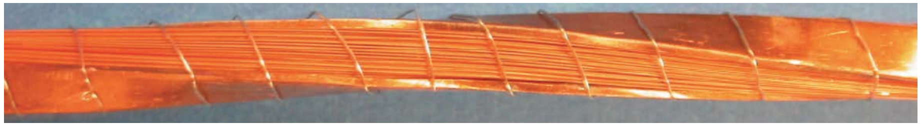


Roebel-Rutherford (KIT)



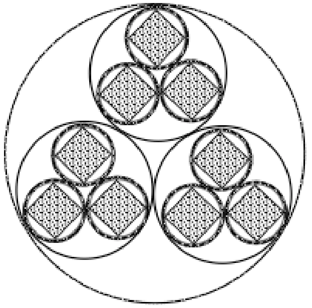
Twisted stacked-tape cable conductor

Makoto Takayasu, L. Chiesa, L. Bromberg and J.V. Minervini,
Supercond. Sci. Technol. 25 (2012) 014011



A twisted stacked-tape cable demonstrator made by MIT with 40 superpower tapes of 4 mm width has been measured in KIT in the FBI facility and carried a current of 5.4 kA at 4.2 K and 12 T
(C. Barth et al., SUST 28 (2015) 045015)

A 9-conductor cable (3x3) of 35 mm diameter may provide 15 kA at 77 K in self-field and 60 kA at 20 T / 4.2 K.



M. Takayasu (MIT)
HTS4Fusion workshop
Pieve S. Stefano
Sept. 11-12, 2015

TSTC Conductor : Scale-up industrial fabrication

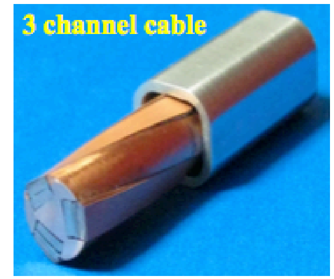
H-Channel TSTC Conductor

40 tape dual-stack cable

CICC mockup of TSTC conductor

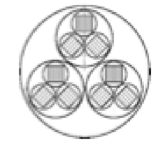
12 mm x 12 mm, copper diameter 9.5 mm

40 YBCO tapes

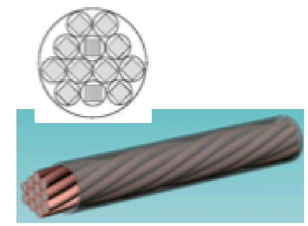


20 YBCO tapes in each helical groove

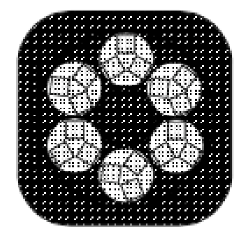
Multiple-stage cable



3x3 cable



12 sub-cable conductor



3x6 CICC

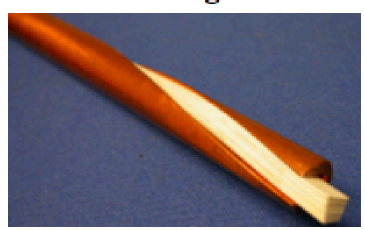
M. Takayasu (MIT)
HTS4Fusion workshop
Pieve S. Stefano
Sept. 11-12, 2015

Challenges with the use of a deep channel

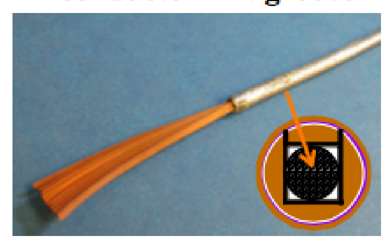
Tapes dislocated with twisting.

Solutions

Vertical stack in helical groove



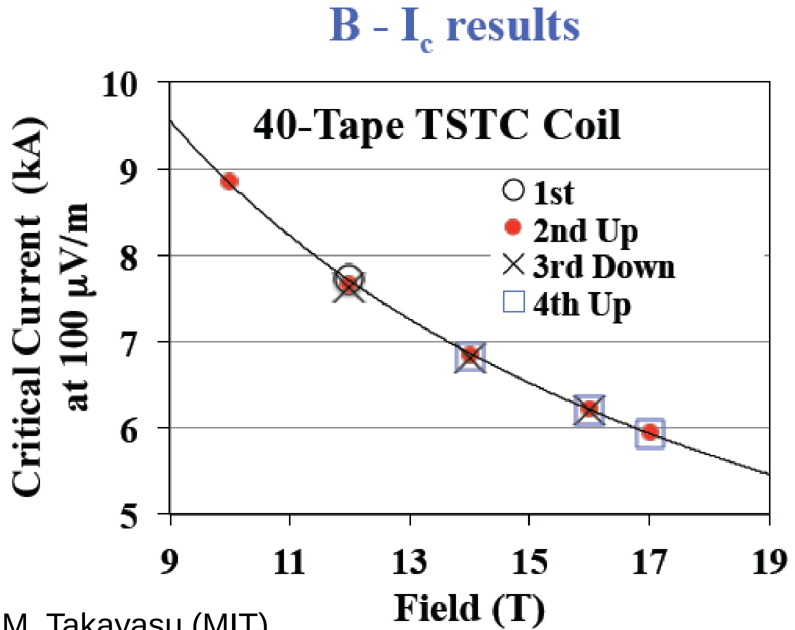
Mount TSTC basic conductor in a groove

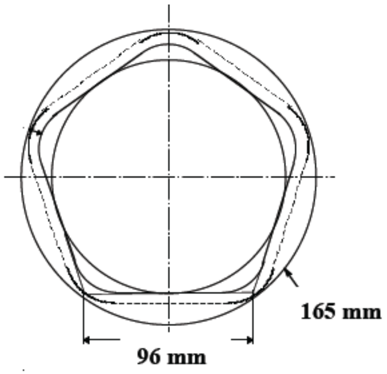


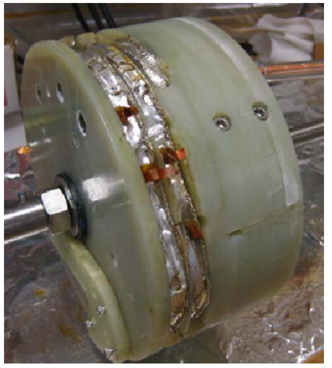
14

Pentagon Coil Test at NHMFL

TSTC conductor of 40-tape,
4 mm width, 0.1 mm thick REBCO Tapes (SuperPower 120 A at 77 K)
reached I_c = 6.0 kA (n=35) at 17 T







40-tape TSTC wound on braided copper in groove and soldered.

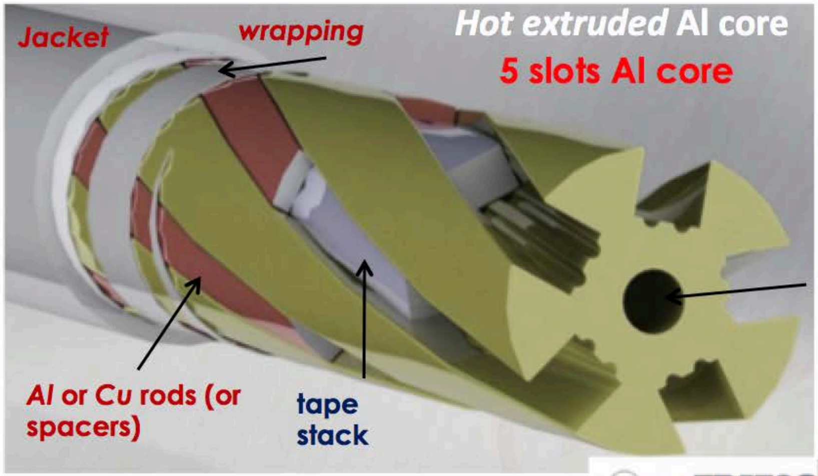
M. Takayasu (MIT)
HTS4Fusion workshop
Pieve S. Stefano
Sept. 11-12, 2015

2G-wire slotted core CIC Conductor: Cable concept

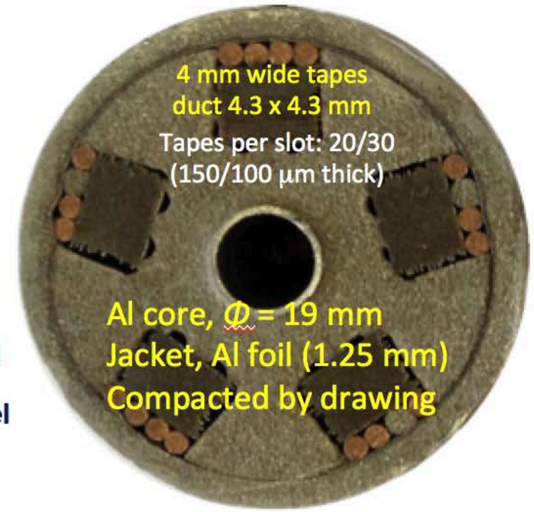
ENEA

ENEA - TRATOS design for **20 kA – class cable**

Design driver: *industrial process feasibility*



Total cross section = 360 mm^2



cooling mechanisms:

coolant flows in central channel and slots

more efficient cooling of stack and heat excess removal

Cable composition (for 20 x 5 tapes)

Metal Stabilizer = 206.49 mm^2 **57.4%**

Al = 47.4% Cu_{rods} = 4.4% Cu_{tapes} = 5.6%

Void = 38.9 mm^2 **10.8%**

SS = 40.0 mm^2 **11.1%**

Jacket = 74.6 mm^2 **20.7%**

Expected $J_e \approx 70$ A/mm^2 **SC/non SC = 1.5 ‰**

slide adapted Nov 2015
by G. Celentano

G. Celentano *et al.*, *IEEE TRANS. APPL. SUPERCOND.*, VOL. **24**, NO. 3 (2014)

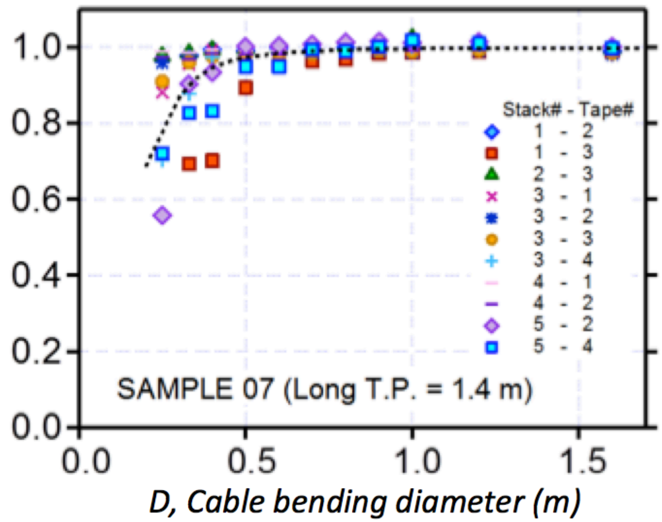
Cable characterizations & performances

ENEA AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Bending test

Massachusetts Institute of Technology

Tufts UNIVERSITY

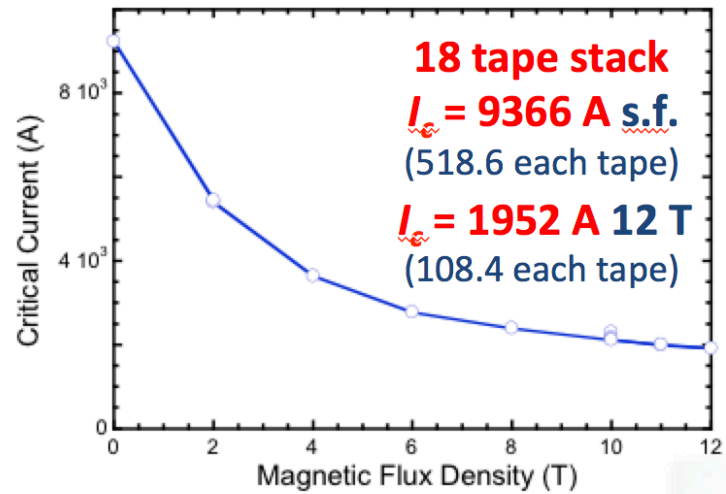


@ *D* = 550 mm: no relevant I_c degradation observed

tapes are allowed to slip improving the bending properties

Electric test @ 4.2 K in magnetic field at FBI facility

KIT Karlsruhe Institute of Technology



FEM Code Calculated Cable (5 slots) I_c
@ 4.2 K, 12 T

9 kA with **SuNAM** SCN04150 tapes

20 kA with **SPI** SCS4050-AP

new slide added Nov 2015
by G. Celentano

G. De Marzi *et al.*, MT24 October 21th 2015, *IEEE TRANS. APPL. SUPERCOND.* submitted

G. De Marzi *et al.*, *IEEE TRANS. APPL. SUPERCOND.*, VOL. **25**, NO. 3 (2015)

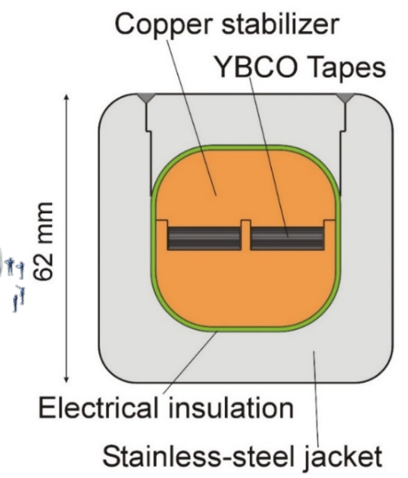
slide adapted Nov 2015 by N. Yanagi

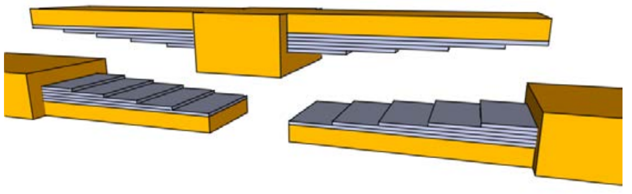
100 kA-class HTS Conductor for FFHR-d1
"STARS" (Stacked Tapes Assembled in Rigid Structure)

Major Specifications

Operation current	94 kA @ 12 T
Operation temperature	20 K
Conductor size	62 mm × 62 mm
Current density	24.5 A/mm^2
Superconductor	YBCO tapes
Cabling method	Simple Stacking
Cooling method	Helium gas
Joint	Mechanical bridge-type lap joint

LHD-type
Heliotron Fusion Reactor
FFHR-d1





N. Yanagi (NIFS)
HTS4Fusion Conductor Workshop
Pieve S. Stefano, Sept. 11-12, 2015
***e.g. NUCL. FUSION* 55 (2015) 053021**

S. Ito (Tohoku Univ.)
HTS4Fusion Conductor Workshop
Pieve S. Stefano, Sept. 11-12, 2015
***e.g. Plasma* and Fusion Res. 9 (2014) 3405086**

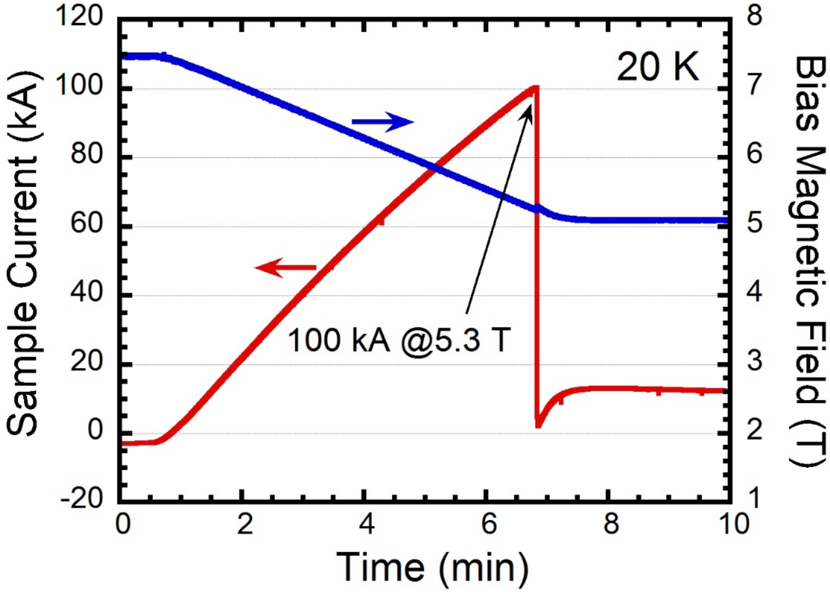
No twist foreseen in heliotrons
It's planned to introduce multiple joints!
Details in 4OrBC_07 Nagato Yanagi at MT24.

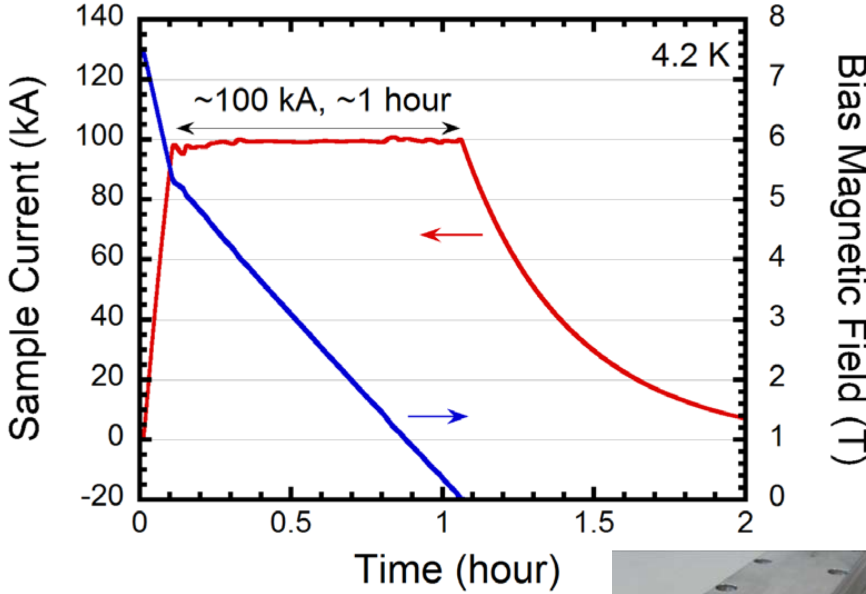
IEEE/CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), January 2016.
Invited presentation 3OrAB_01 given at MT-24, Seoul, Korea, October 18-23, 2015.

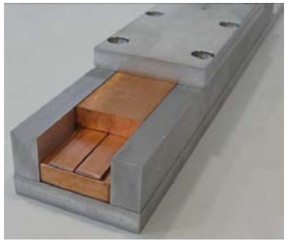
new slide added Nov. 2015 by N. Yanagi

100 kA test of prototype STARS conductor and joint

Karlsruhe Institute of Technology

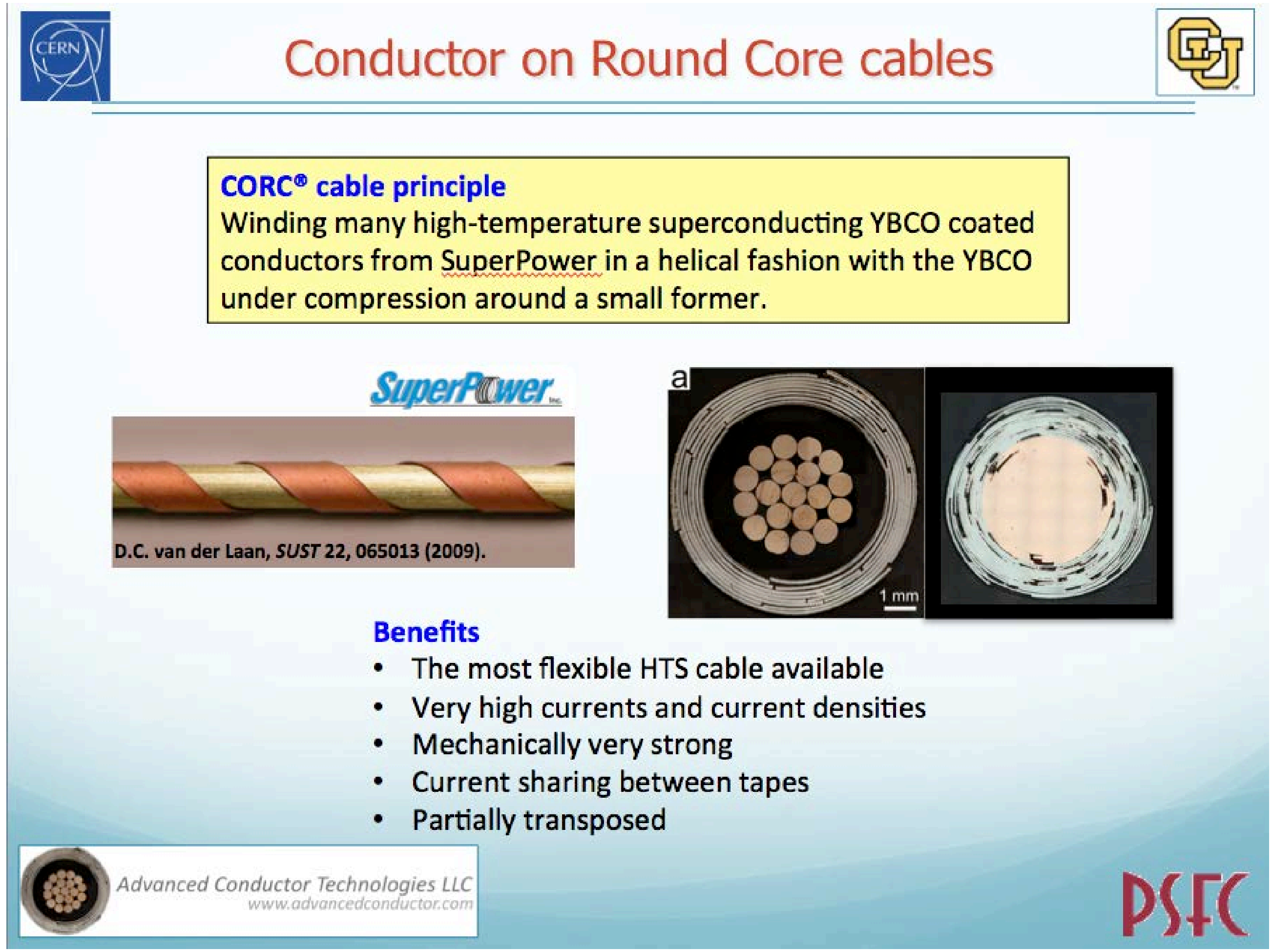






- Prototype sample (54 GdBCO tapes, 1 turn loop, mechanical bridge-type lap joint)
- 100 kA achieved @20 K, 5.3 T (quench due to a failure near joint)
- 118 kA achieved @4.2 K, 0.45 T (no quench)
- 100 kA sustained for 1 hour @4.2 K
- Joint resistance ~1.8 nΩ (evaluated from decay time constant)

Conductor on Round Core Cables



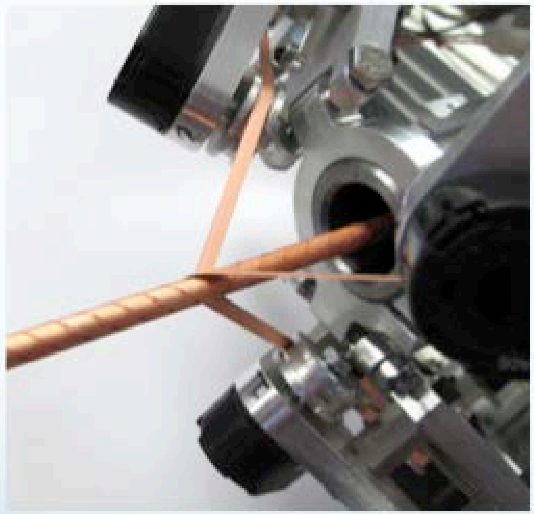
D. van der Laan,
(Advanced Conductor Technologies LLC)
HTS4Fusion workshop
Pieve S. Stefano
Sept. 11-12, 2015

Karlsruhe Institute of Technology

CORC® cable winding

Winding of long CORC® cables with custom cable machine:

- Accurate control of cable layout (tape tension, gaps spacing, etc)
- Long cable lengths possible (>100 meters)



Improved accuracy now allows winding of CORC® cables from tapes with 30 μm substrate
Tape I_c retention increased from 70 % to over 90 % during last 3 months

Advanced Conductor Technologies LLC
www.advancedconductor.com

D. van der Laan,
(Advanced Conductor
Technologies LLC)

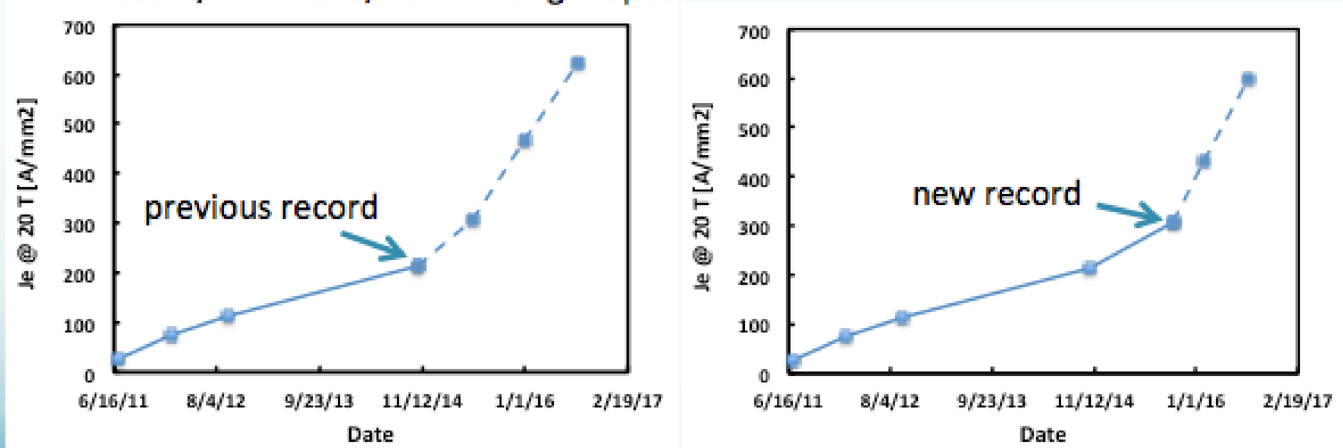
KIT Karlsruhe Institute of Technology

CORC cables are available in long lengths, right now

- Wound from tapes with 30 μm substrates
- I_c up to 6.5 kA at 20 T
- J_e of over 300 A/mm² at 20 T
- Cable quality results in 92 % I_c retention

J_e at 20 T in CORC® cables as projected at LTSW Feb. 2015

- > 300 A/mm² Sept. 2015 through tapes with 30 μm substrate ✓
- > 450 A/mm² Dec. 2015 through tapes with 15 % Zr doping (same cable layout)
- > 600 A/mm² 2016/2017 through tapes with thicker YBCO



Advanced Conductor Technologies LLC
www.advancedconductor.com

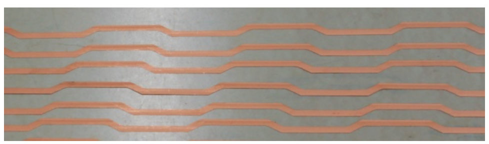
D. van der Laan,
(Advanced Conductor Technologies LLC)

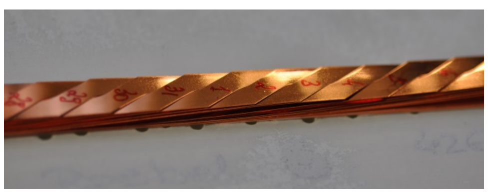
MT24 3OrAB_05

Roebel Cable prepared by KIT

Karlsruhe Institute of Technology

W. Goldacker et al, J. Phys. Conf. Series 43, (2006) p.901
First ROEBEL cable made from REBCO



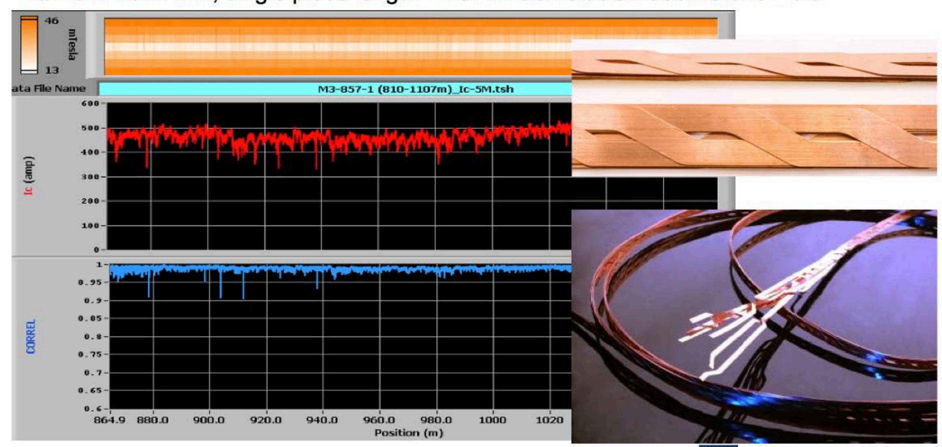


ROEBEL assembled REBCO
with 31 strands, 12 mm width
SuperOx material, **2.7 kA** s.f. 77 K
2OrAA_01, MT-24, F. Grilli et al.

UNIVERSITY of HOUSTON — SuperPower Inc. — TcSUH

ROEBEL cables made with 2,000 m of coated conductor with uniform I_c and excellent 2D I_c uniformity

Ic = 341 A/12 mm, single piece length = 297 m ***Correlation coefficient > 0.9***



INDUSTRIAL RESEARCH — IRL — General Cable

V. Selvamanickam,
EUCAS / ISEC / ICMC conference, Den Haag, Netherlands
Sept. 19-23, 2011

Roebel cable

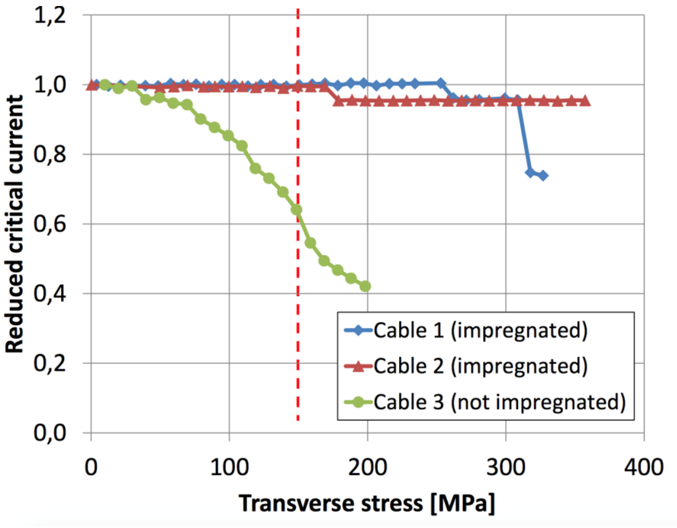
Karlsruhe Institute of Technology

A. Kario et al.
Mechanical Properties of Roebel Coated Conductor Cable
WAM-HTS-1 (1st Workshop on Accelerator Magnets in HTS), Hamburg, Germany, May 21-23, 2014

- Bending: Easy direction down to 10 mm radius for a 10 strands cable with 126 mm twist length (but depends on tape type)
- Transverse stress: Impregnation or other support needed

S. Otten et al.
Enhancement of the transverse stress tolerance of REBCO Roebel cables by epoxy impregnation
Supercond. Sci. Technol. 28 (2015) 065014

T = 4.2 K,
B = 10.5 T



Measurement in the cable press at the University of Twente

HTS for +5 T (REBCO)

Karlsruhe Institute of Technology

EuCARD-2 (task 10) feasibility-demo to use REBCO for future accelerator magnets
+5 T with REBCO in a 15 T background

L. Bottura et al.
Advances in the Development of a 10-kA Class REBCO cable for EuCARD2 Demonstrator Magnet
EUCAS 2015, Lyon, September 6th-10th, 2015

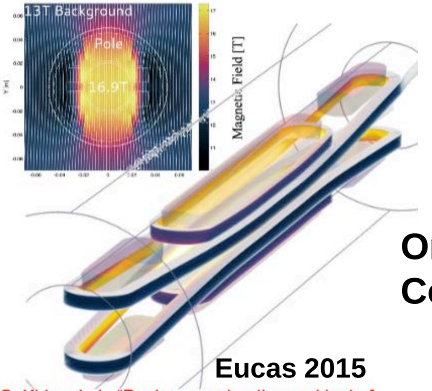
Target performance

EuCARD²

Parameter		R&D target	Minimum
J_E (4.2 K, 20 T)	(A/mm^2)	600	**400**
Unit length	(m)	100	**50**
$\sigma(I_c)$	(%)	10	
M (1.5 T, 10 mT/s)	(mT)	300	
Minimum $\sigma_{transverse}$	(MPa)		**100**
Range of $\varepsilon_{longitudinal}$	(%)		**±0.3**

Target cable I_C in the range of 10 kA

5 T HTS (YBCO) stand-alone dipole for test in FReSCa2 (40 mm bore)



One of the proposed Coil designs (CERN)

Eucas 2015

G. Kirby et al., "Design, construction and test of subscale coils with REBCO Roebel cable for the EuCARD-2 Future Magnets project", 2M-LS-O2

Main Advantages of Roebel Assembled Coated Conductor:

- transposed
- high j_E

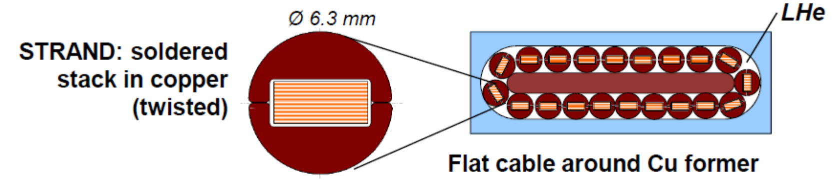
More details at MT24 in

- **2OrAC_06 Anna Kario**
- **3Po8D_09 Wilfried Goldacker**

CRPP: Forming Round strands by enclosing stacked conductor in Cu half shells

D. Uglietti et al.
Development of high current HTS conductors for Fusion at CRPP
WAM-HTS-1 (1st Workshop on Accelerator Magnets in HTS), Hamburg, Germany, May 21-23, 2014

CRPP Cable design



Why soldered stack strand?
- Mechanically solid (no voids)
- Low inter-tape resistance which is beneficial for current redistribution (inductive or during quenches)

Why flat cable?
- Limit transverse stress accumulation (see ITER cables…)
- Optimal cross section
- Less strain during winding than with a round cable

Twisted strands for large amount of transposition:
- Equal redistribution of current during ramping
- Reduction of coupling losses

Even if not fully transposed (the tapes have not exactly the same inductance), the low inter-tape resistance ensures that a small mismatch of inductance is tolerable.

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE | SWISS PLASMA CENTER

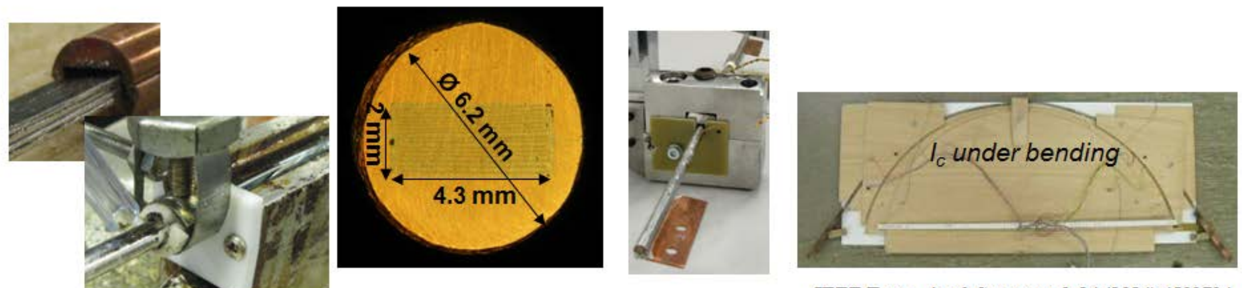
Developments at Swiss Plasma Center, Superconductivity Group

D. Uglietti et al.
HTS4Fusion Workshop
Pieve S. Stefano
Sept. 11-12, 2015

2012

IEEE Trans. Appl. Supercond. 23 (2013) 6410385

2013



IEEE Trans. Appl. Supercond. 24 (2014) 4800704

2014

IEEE Trans. Appl. Supercond. 25 (2015) 6937173

September 2014: cables prepared, I_c (77 K) measured.
Missing: terminations, jacketing, assembling in EDIPO sample.

SWISS PLASMA CENTER

Conductor design

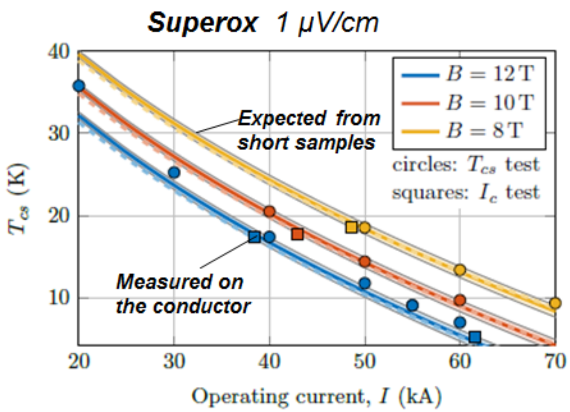
D. Uglietti et al.
HTS4Fusion workshop
Pieve S. Stefano
Sept. 11-12, 2015

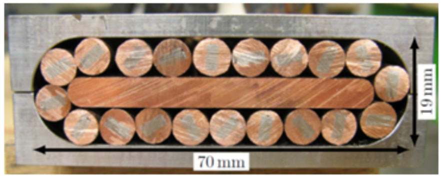
Davide Uglietti
Supercond. Sci. Technol. **28** (2015) 124005

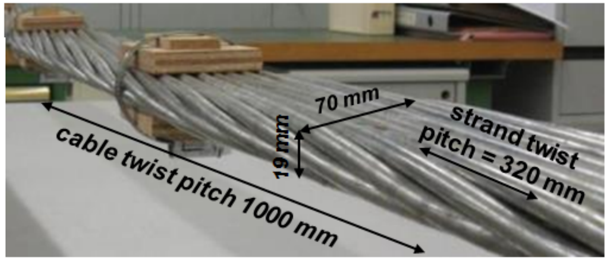
for more details see 3OrAB_04 D. Uglietti at MT24

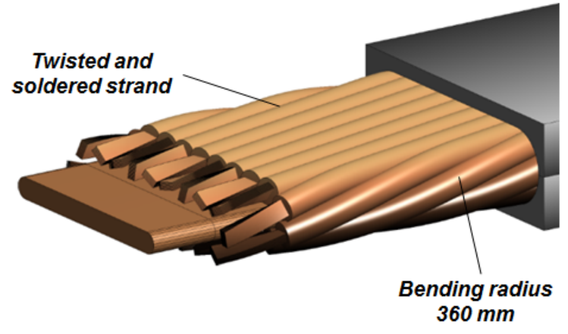
	Tot cross section (without jacket)	*Tot. copper cross section*	*Void fraction*	*Operating current and field*	*T_{cs} at operating conditions*	*Operating current density (non Cu)*
ITER TF (Nb_3Sn)	**1250 mm²**	515 mm²	32%	68 kA, 11.1 T	5.8 K to 7.0 K	**280 A/mm²**
DEMO TF (Nb_3Sn)	**1220 mm²**	675 mm²	23%	82 kA, 13.4 T	about 6.5 K	**300 A/mm²**
HTS prototype	**1250 mm²**	760 mm²	32%	50 kA, 12 T 30 kA, 12 T	8 K 21 K	**500 A/mm²** **300 A/mm²**

Current capacity and copper cross section are in the range required for fusion magnets. Fine tuning depends on the reactor design.







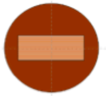


Cable length 2080 mm

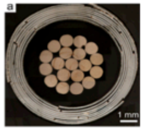
Are there possibilities to optimize ?

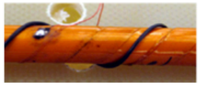
Twisted Stacked Cable (TSC) (MIT, USA)

Modified TSC (CRPP)

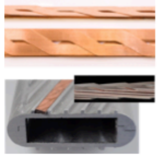


CORC (Advanced Conductor Technologies LLC)



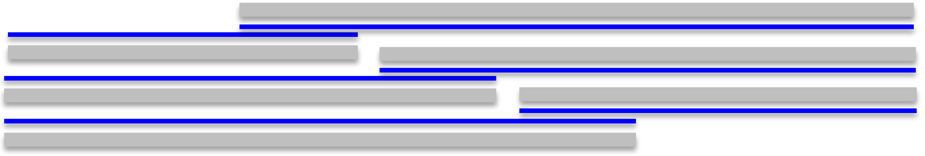


Roebel-Rutherford (KIT)



Shared problems:

- **Modular solution possible?**
- **Easy manufacturing of long lengths including twist?**
- **Building good joints is not trivial!**

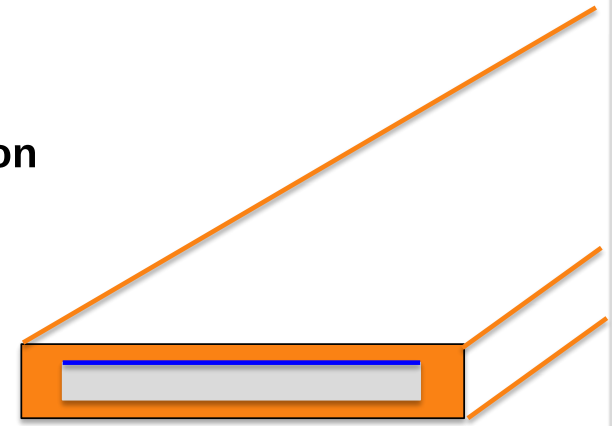


Connecting tape by tape is challenging!

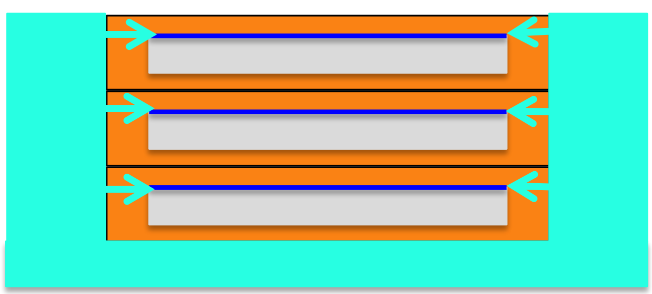
How could we come to a superconductor cable which allows simple termination / jointing?

Karlsruhe Institute of Technology

Use REBCO tapes with thick electro-plated Cu stabilization to optimize current transfer and electrical stabilization

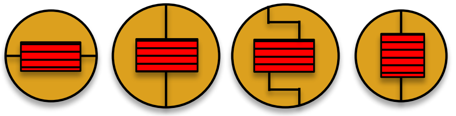


Solder stacks to allow current transfer from the sides and from tape to tape



Modular Solution?

Round stacked conductor strand of CRPP (Swiss Plasma Center) offers good modularity



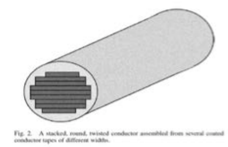
Good idea!

Can this approach be optimized to high J_E, mechanical stability and towards easy manufacturing including twist ?

Could we come to a round strand with optimized $j_{c,\ eng}$?

Karlsruhe Institute of Technology

We could try to fill the round strand almost completely with superconductor tapes.
Complete filling was already proposed in 2005

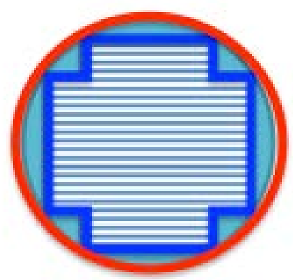


Mike Sumption et al.
IEEE Trans. Appl. Supercond.
15 (2), (2005) p. 2815–2818

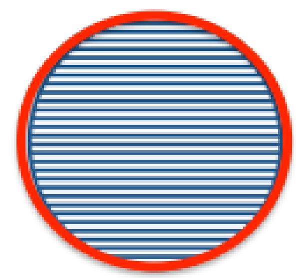
However, this is in contrast to the requests: Good twistability & easy manufacturing.

Therefore we propose a compromise between
optimal twistability **optimal filling:**

D. Uglietti, CRPP
M. Takayasu, MIT



CrossConductor



M.D. Sumption

What about easy fabrication?

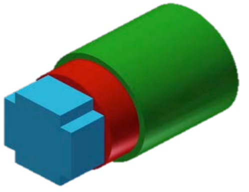
Fabrication of the HTS-CrossConductor (HTS-CroCo)

- Arrange the tapes
- Pre-tin the tapes
- Solder all individual tapes
- Form the stack
- Twist the stack

For economical fabrication of long lengths:

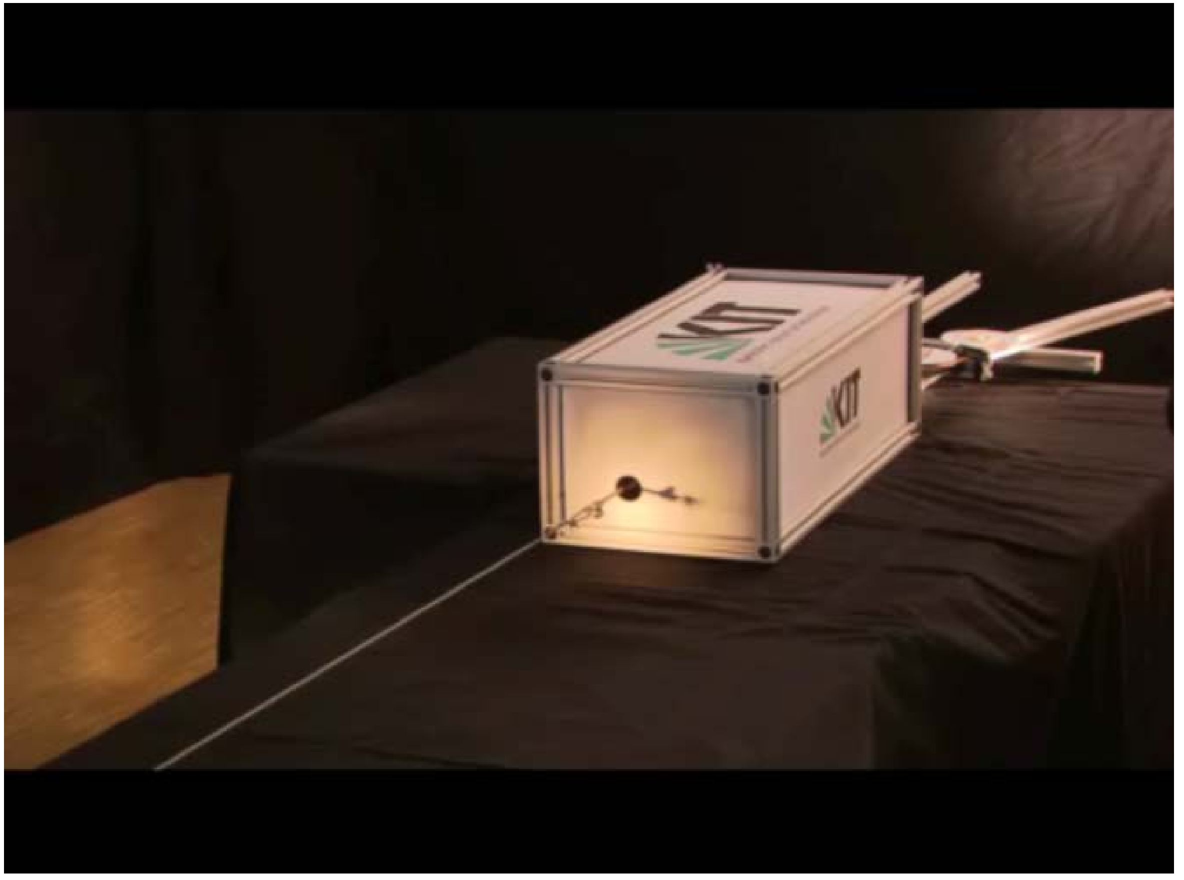
all these steps in one continuous process

- Apply a jacket or former



The fabrication routine

KIT
Karlsruhe Institute of Technology



IEEE/CSC & ESAS SUPERCONDUCTIVITY NEWS FORUM (global edition), January 2016.
Invited presentation 3OrAB_01 given at MT-24, Seoul, Korea, October 18-23, 2015.

Image of a HTS-CroCo partially equipped with HTS

First trials with in total 30 tapes,
150µm pure Cu + some HTS-tapes with ≥ 100 µm electroplated Cu

Preparation of a sample for FBI testing

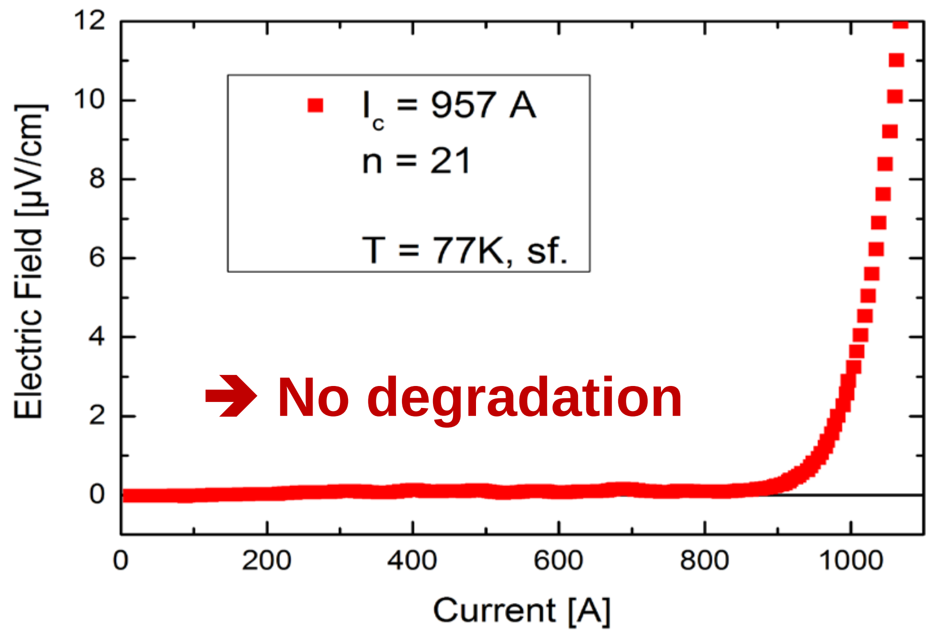
Sample Parameters:

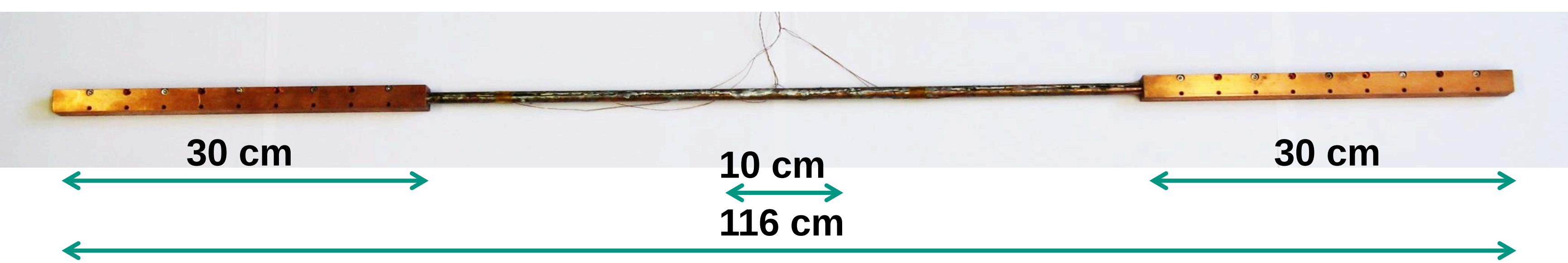
Untwisted stack,

Total of 32 tapes

- 4mm wide: **4** HTS, 8 Cu
- 6mm wide: 4 HTS, 16 Cu
- HTS tapes equally distributed between Cu tapes

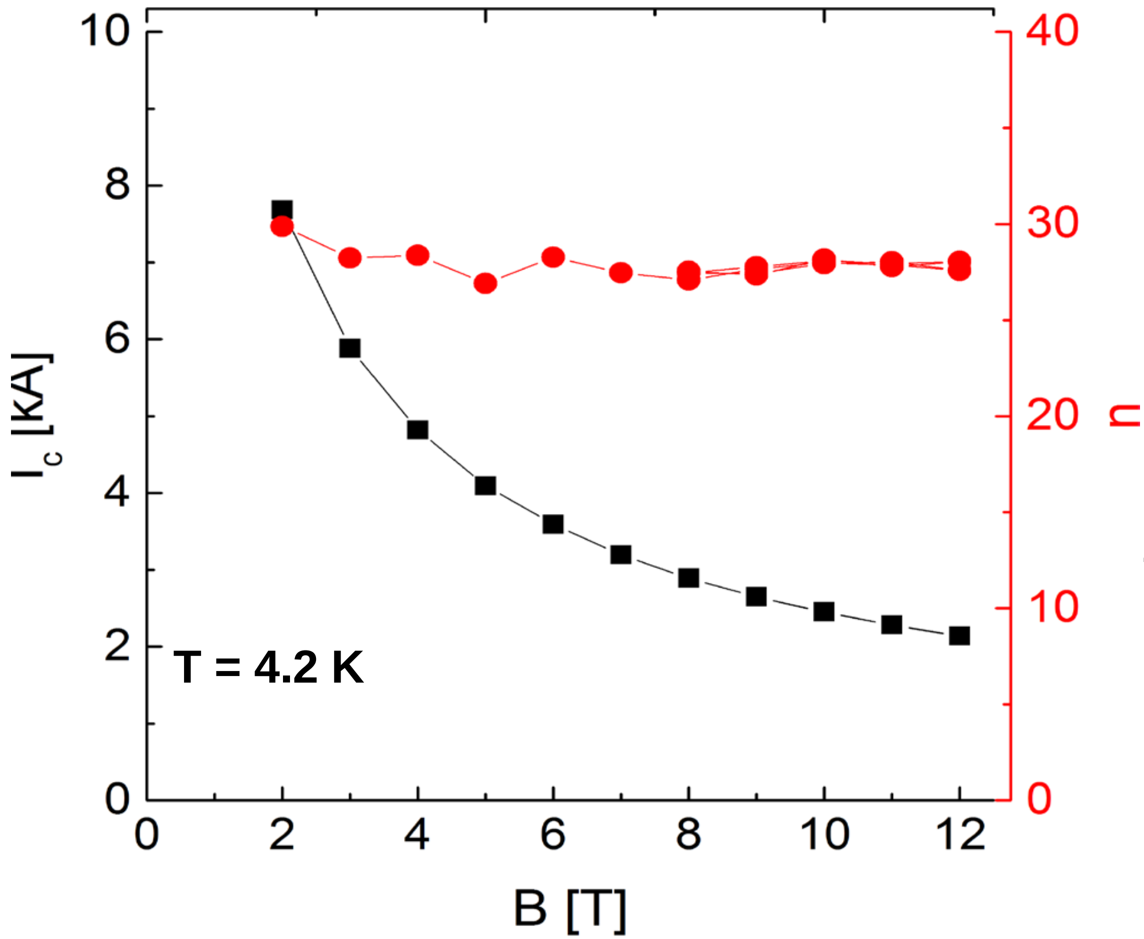
Calculated I_c: 920 A





KIT Karlsruhe Institute of Technology

Performance in magnetic fields at T = 4.2 K



I_c = 2,1 kA @ B = 12 T

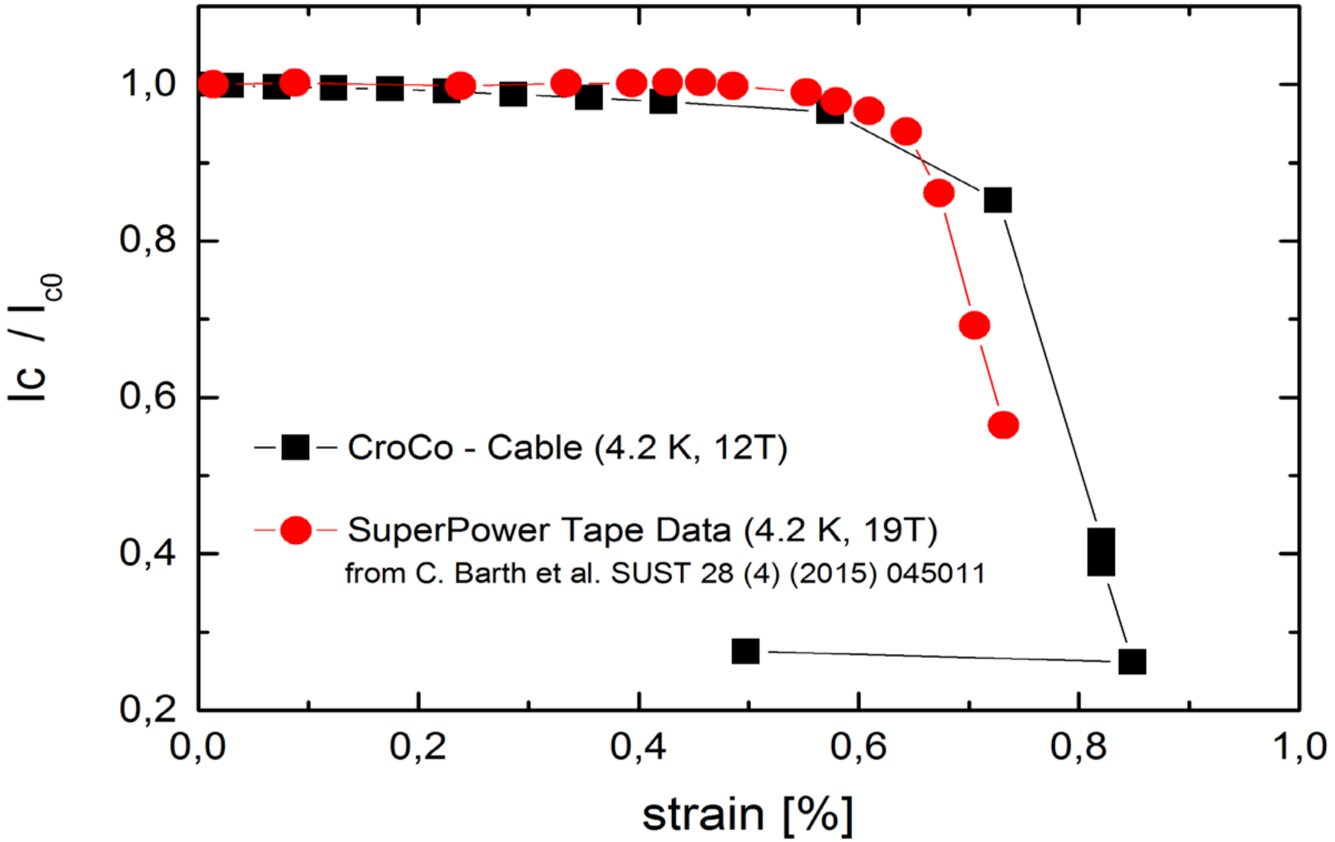
I_c = 52,5 A/mm$_{\text{HTS width}}$

SuperPower AP – Tapes show I_c ~ 45 - 65 A / mm$_{\text{HTS}}$ for B || c

Hazelton, LTHFSW (2013)
Hazelton, WAMHTS (2014)
Abraimov et al., WAMHTS (2014)
Celentano et al., WAMHTS (2014)

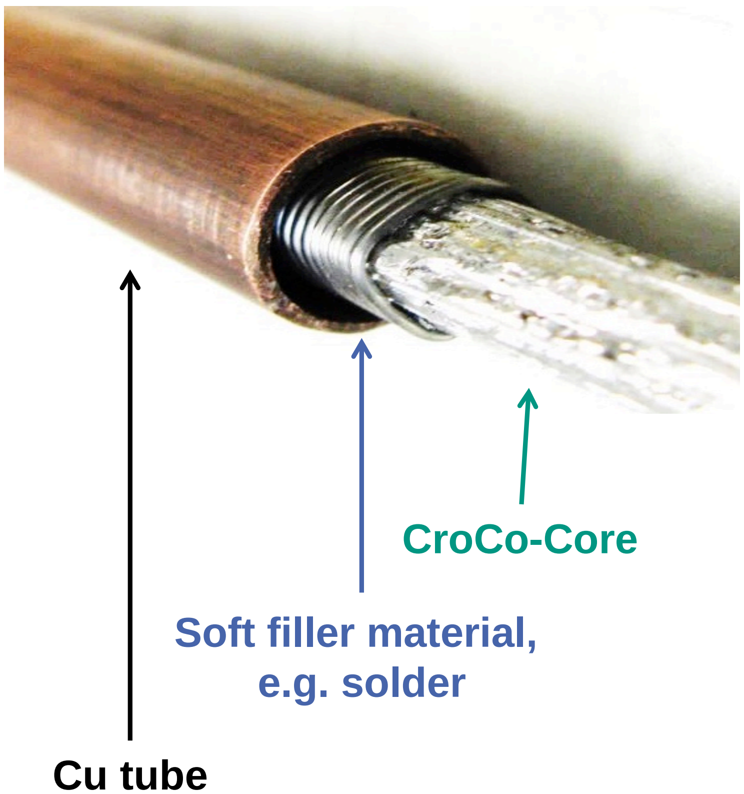
No degradation!

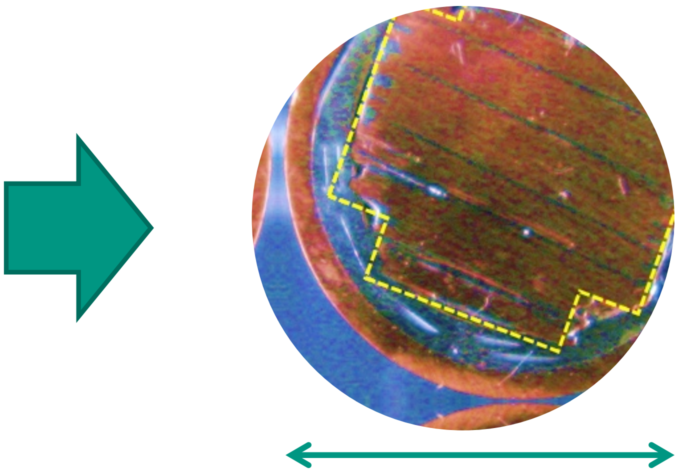
Tensile testing



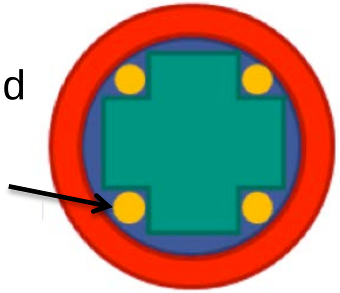
➔ **CroCo shows the same I_c-strain curve as individual tapes!**

Advances in jacketing: Rotary swaging

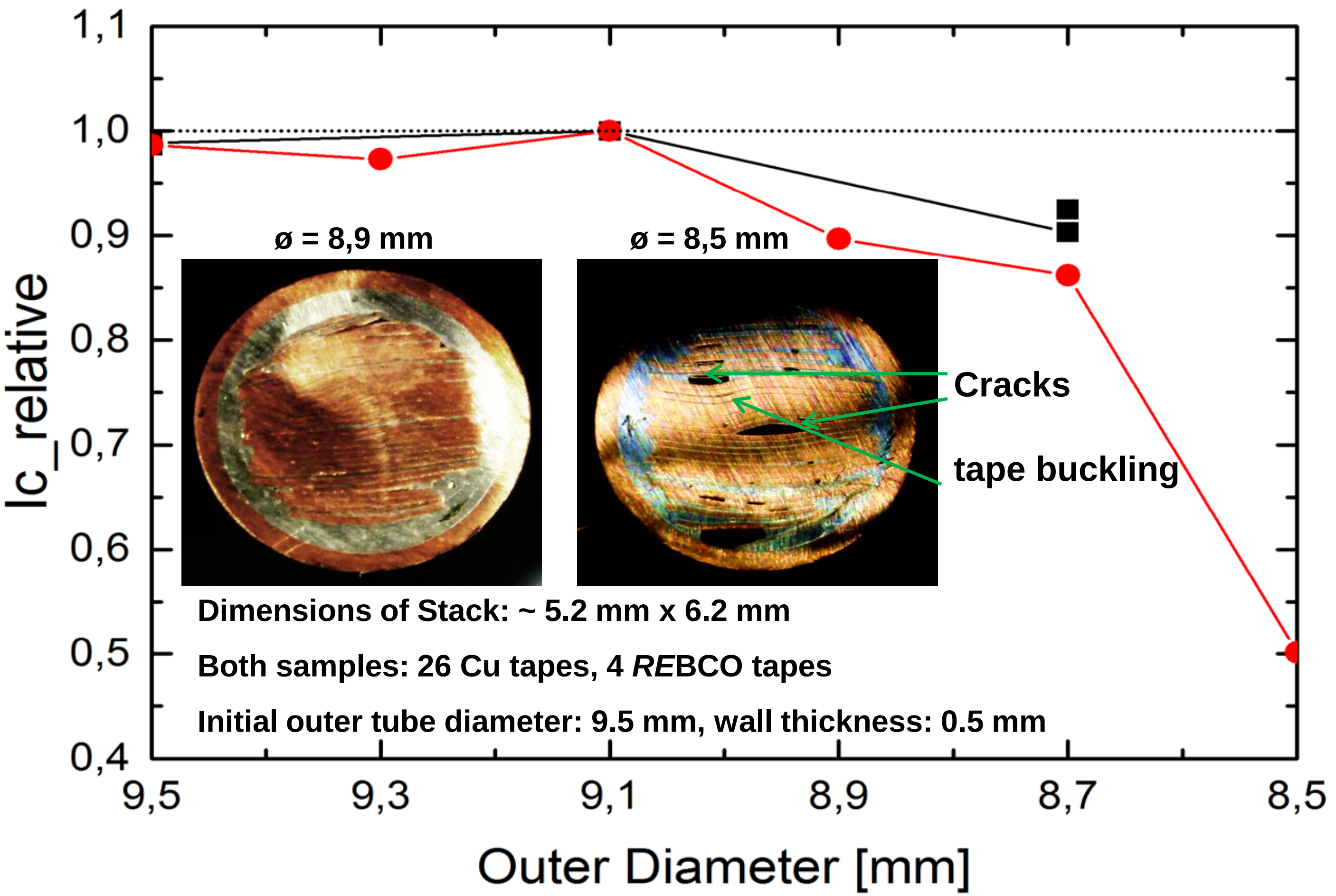




Future versions should minimize the solder content by adding Cu wires in the edges



Influence of the degree of compaction on I_c

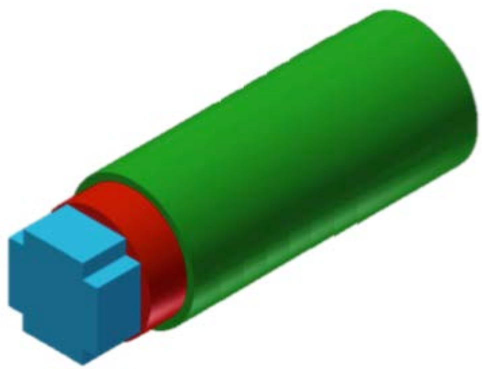


Performance of a single CroCo at 13.5 T and 4.2 K

Karlsruhe Institute of Technology

CroCo (20x 6mm, 10x 4mm, 50 µm substrate)

Each tape is well stabilized with an envelope of 50 µm Cu !



Parameter at 13.5 T and 4.2 K		SP A.P.	SP Enh. A.P.
Tape I_c (13.5 T, 4.2 K)	4mm	190 A	350 A
	6mm	285 A	525 A
I_c (kA)		7.6	14
J_E (A/mm^2)		117	215.3

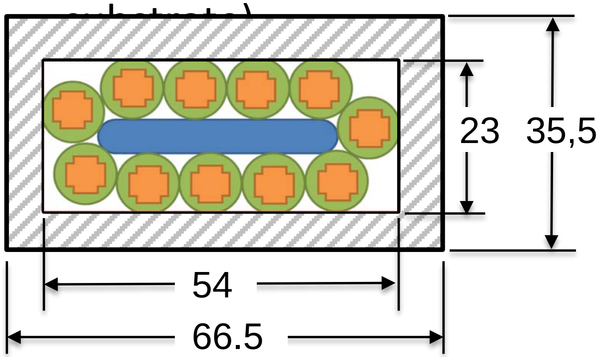
CroCo with 30 µm substrate (23x 6mm, 10x 4mm)	I_c (kA)		8.5	15.6
	J_E (A/mm^2)		130	239.4

HTS-CroCo ➔ Rutherford High Current Cable

Karlsruhe Institute of Technology

11 HTS-CroCos in a Stainless-Steel-Jacket

(each 20x 6mm + 10x 4mm tapes with 50 µm



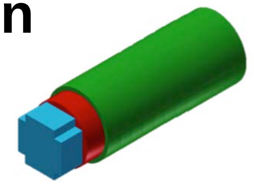
Parameter at 13.5 T, 4.2 K		SP A.P.	SP Enh. A.P.
Tape I_c	4mm	190 A	350 A
	6mm	285 A	525 A
Cable I_c with 11 CroCo		83.6 kA	154 kA
Cable operating current*		55 kA	55 kA
I_{op} / I_c		0.66	0.36
(30 µm substrate, 23x 6mm, 10x 4mm) Cable I_c with 11 CroCo		93 kA	171 kA

Next step to thicker REBCO layers not included!

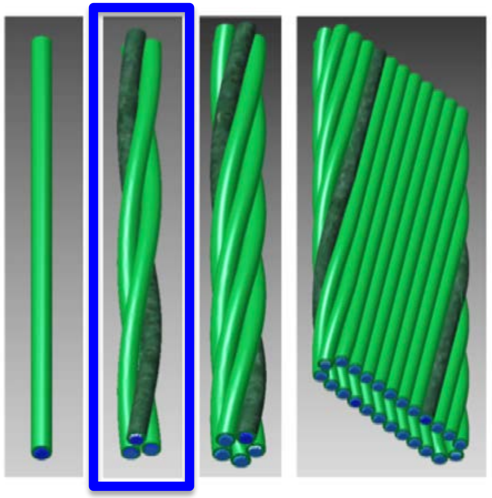
However, electric and mechanical stabilization is crucial, QD may be critical!

* R. Heller et al., MT24 3PoBB_03
"Conceptual Design Improvement of a Toroidal Field Coil for EU DEMO using High Temperature Superconductors"

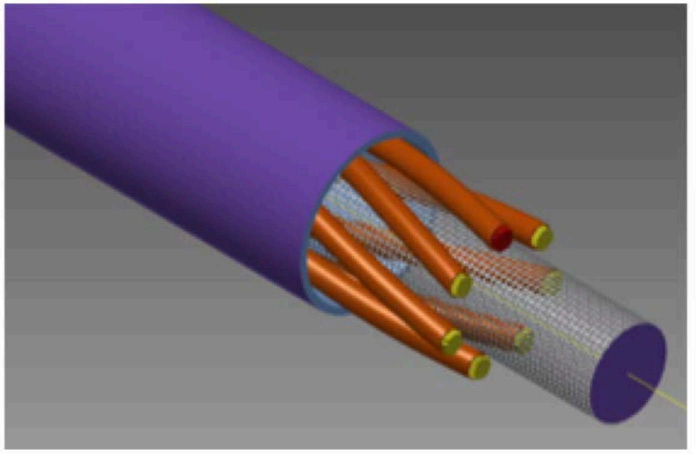
HTS-CroCo Application



Highest current density
e.g. for high field magnets



High current transport
e.g. for power transmission
(3 kA/CroCo @ 77 K, 30 kA/CroCo @ 4 K,
depending on cross-section of the outer tube)



Results on such a HTS-CroCo - Triplet and more
see poster 3PoBD_10 by M. Wolf et al. this afternoon

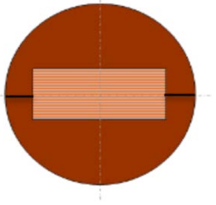
High current cable proposals made from *RE*BCO tapes

Karlsruhe Institute of Technology

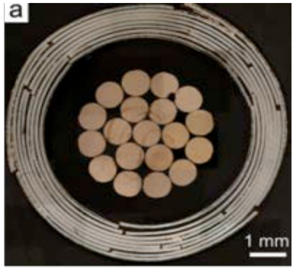
Different approaches for high current *RE*BCO cables:

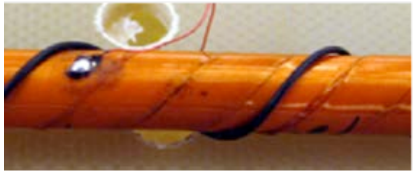
Twisted Stacked Cable (TSTC) (MIT, USA)

Modified TSTC (CRPP)



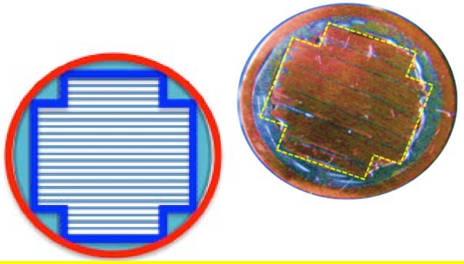
CORC (Advanced Conductor Technologies LLC**)**





Roebel-Rutherford (KIT)

HTS-CroCo (KIT)



We added the CrossConductor expecting good news in future

Summary

Highlighting: HTS Tape Property Progress
Impressive multiple progress / opens new ways / 30 K?

Overview: High Current HTS Cable Proposals
Numerous good high current HTS cable proposals,
each one with special highlights

Optimizing: HTS-CroCo
Based on the CRPP round strand
adds higher j_E, mechanical stability and easy fabrication incl. twist

Outlook: Consequences using improved tapes
Great perspectives,
but electric and mechanical stabilization crucial, QD may be critical!

Many Thanks for allowance to use their HTS data to

- Dmytro Abraimov (NHMFL),
- Alexander Usoskin (Bruker)
- Venkat Selvamanickam (University of Houston)

Many Thanks for support with slides to

- Makato Takayasu (MIT)
- Giuseppe Celentano (ENEA)
- Nagato Yanagi (NIFS)
- Danko van der Laan (Advanced Conductor Technologies)
- Anna Kario (KIT)
- Davide Uglietti (Swiss Plasma Center / CRPP)

Many Thanks for good work and support for this presentation to

- Michael Wolf (KIT)
- Reinhard Heller (KIT)
- Alan Preuss (KIT)

Thank you for your attention !