

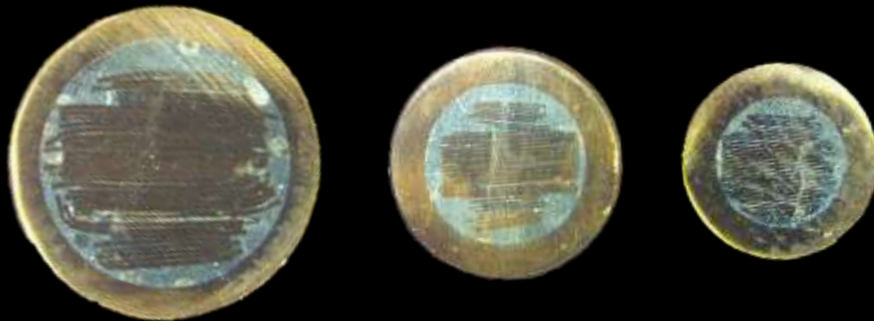
The HTS CrossConductor (HTS CroCo)

A versatile strand for large magnets and high-current DC conductors

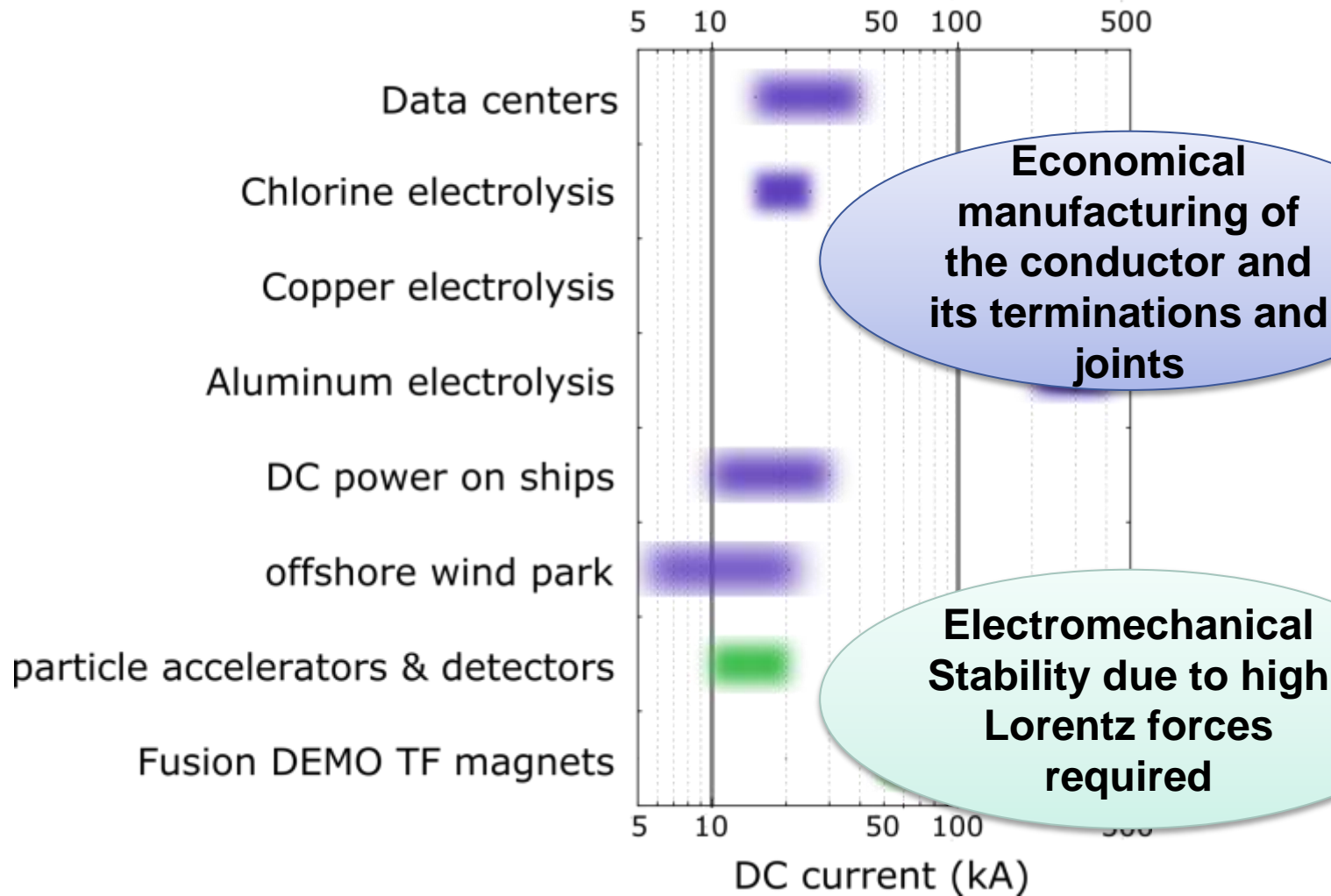
Michael J. Wolf, Nadezda Bagrets, Christoph M. Bayer, Walter H. Fietz, and Alan Preuß

CCA Workshop, Aspen, CO, September 11-14, 2016

Institute for Technical Physics



Motivation – High DC current applications



Data sources:

W. H. Fietz, et al., (2013): *Fus. Eng. Des.* 88 (6-8), p. 440–445.

A. Morandi, *Supercond. Sci. Technol.* 28 (2015) 123001 (16pp)

W. Reiser, Presentation at ZIEHL IV workshop (2014)

online, last accessed 03-18-2016: http://www.ivsupra.de/images/ziehl/zielvortrag_2014/ZIEHL_2014_Industrieanwendungen_Hochstromschienen_Vision-Electric-Superconductors_Reiser.pdf

Outline

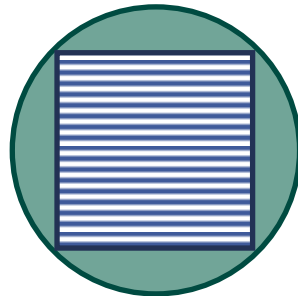
- Introduction of the HTS CrossConductor:
 - Design
 - Fabrication concept

- Electromechanical investigations of the HTS CroCo

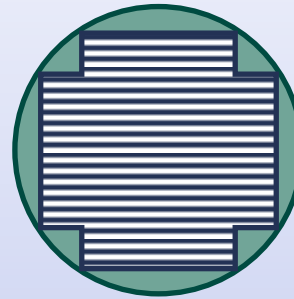
- Terminations and Connectors

- Summary & Outlook towards high-current conductors

The HTS CrossConductor



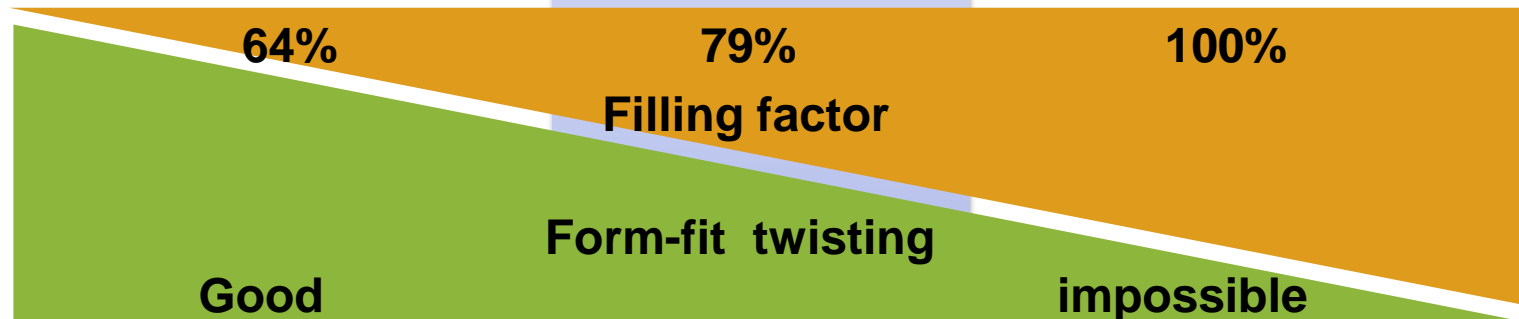
M. Takayasu *et al.* *IEEE TAS*
21 (3) (2011), p. 2340 ff.
D. Uglietti, *et al.* *IEEE TAS*
24 (3) (2014), Art. ID. 4800704




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Karlsruher Institut für Technologie



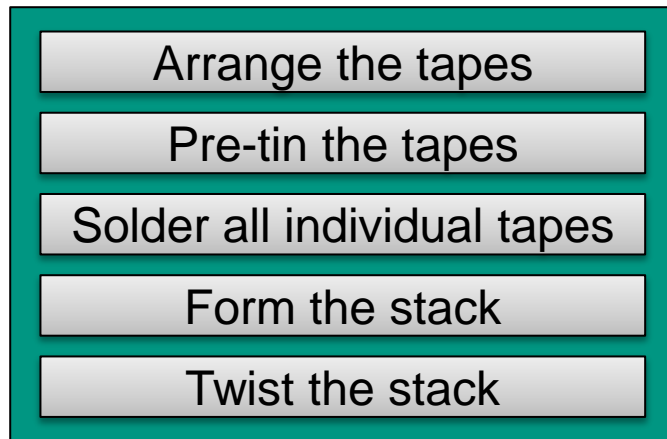
Ideal circular shape



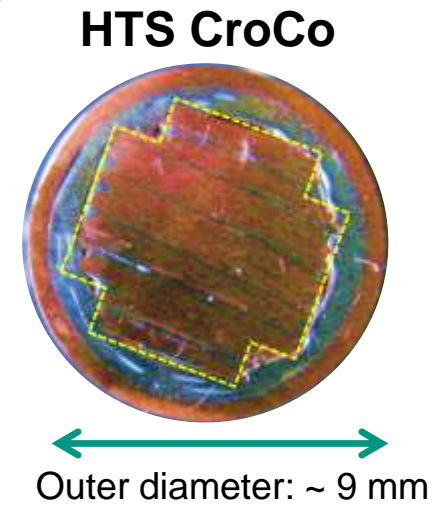
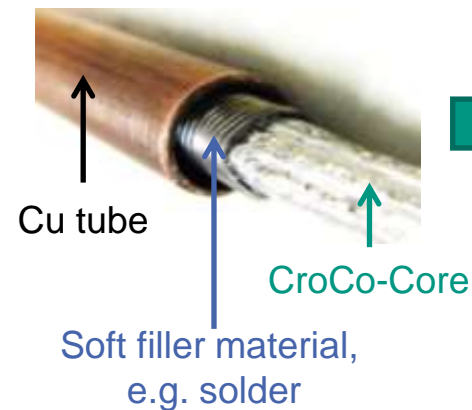
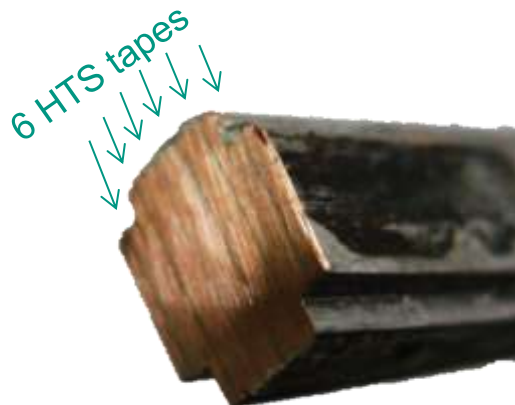
**Use a soldered stack of REBCO tapes
of two different widths to improve the filling factor
of a Round Twisted Stacked Conductor**

HTS CroCo fabrication

„All-in-one“ fabrication of the HTS CroCo core:
From single *REBCO* tapes to a soldered & twisted stack in one step



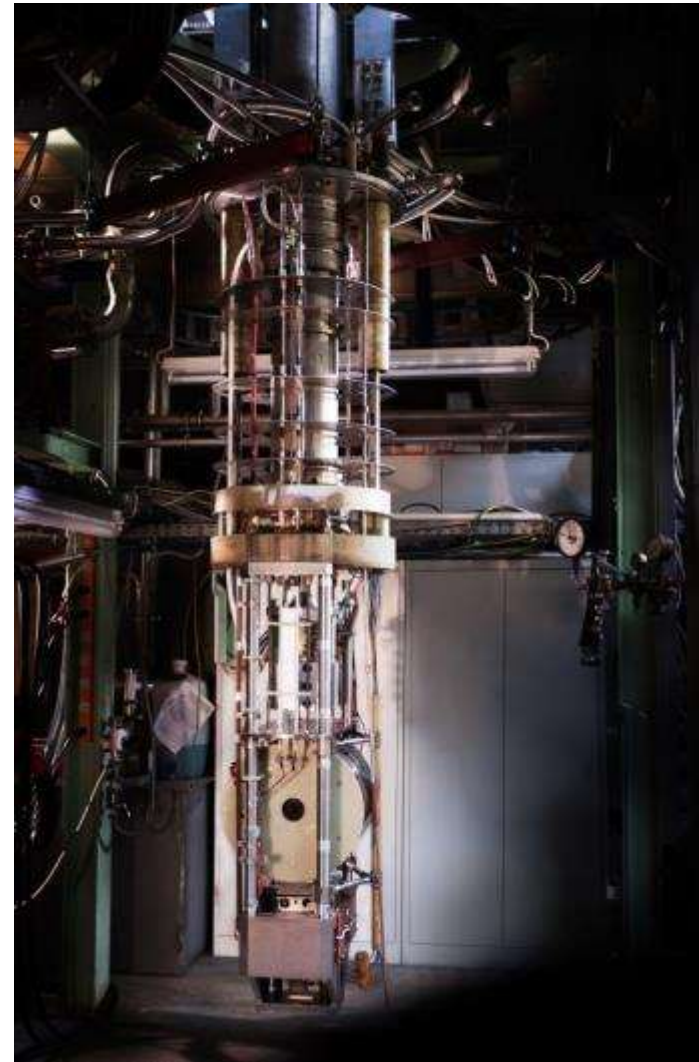
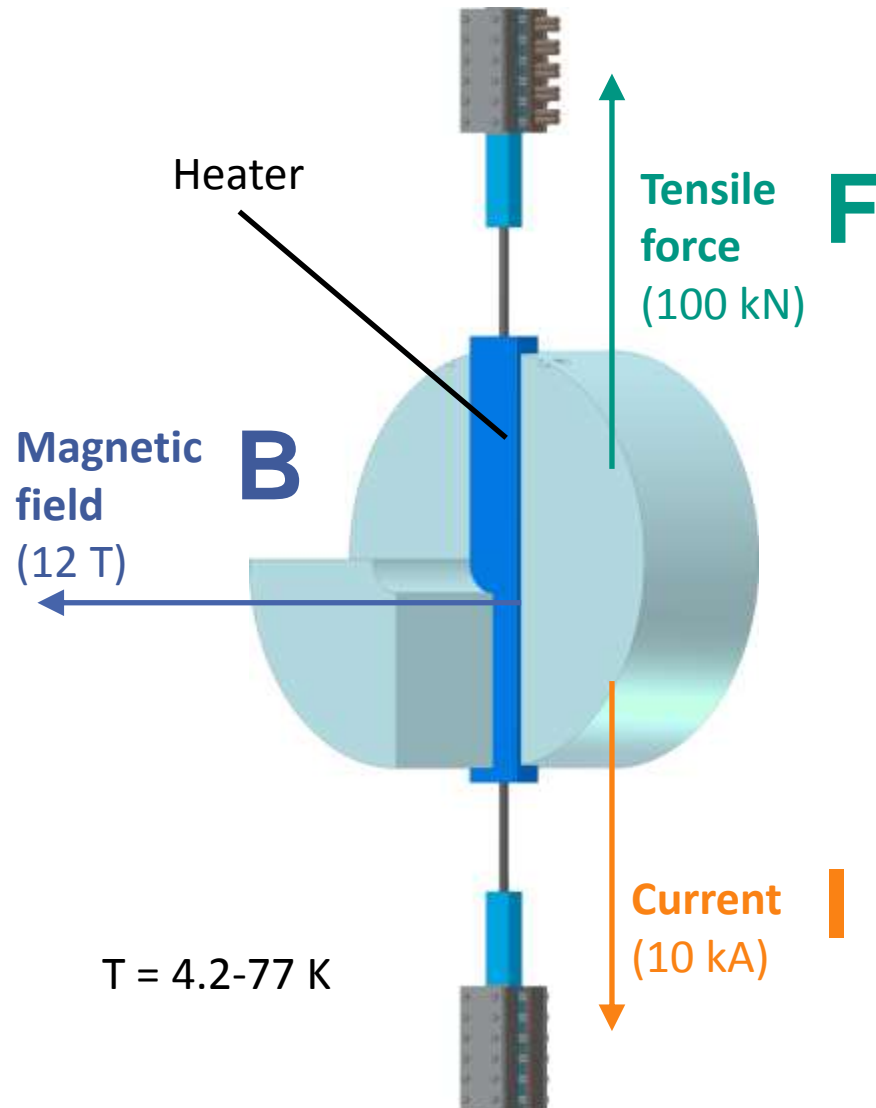
HTS CroCo core



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The FBI test facility

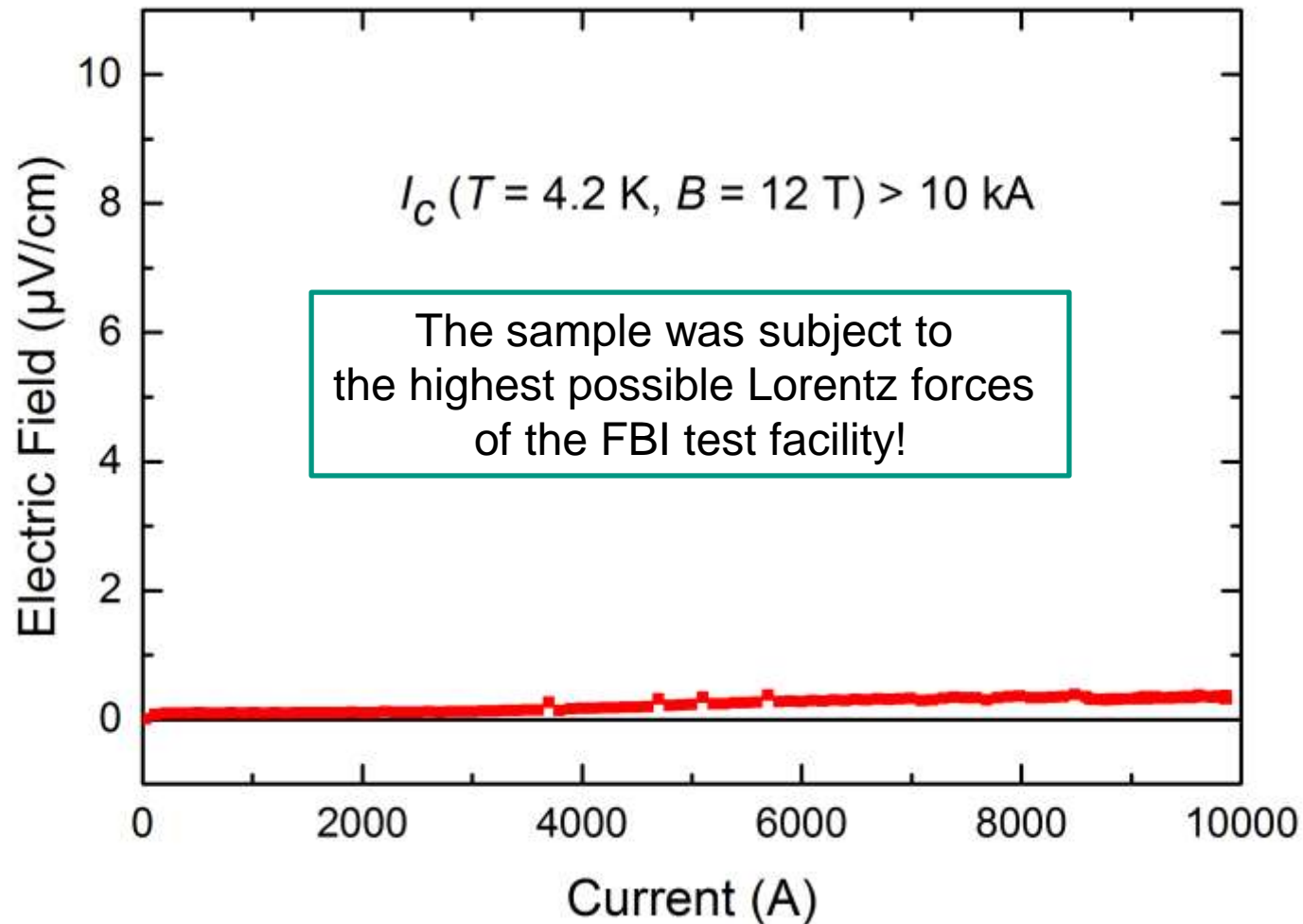


Parameters of the HTS CroCo sample for FBI testing

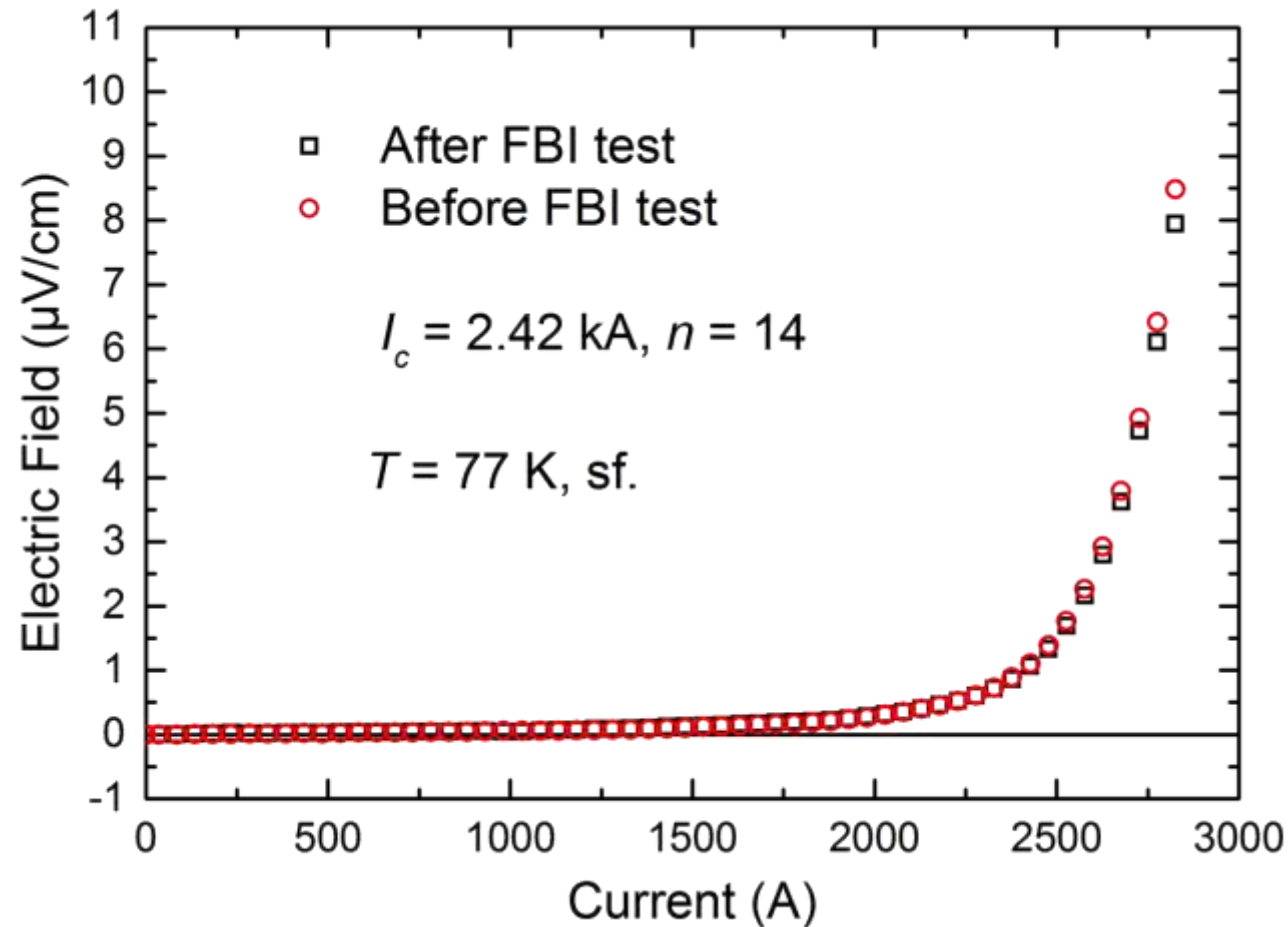
- 32 REBCO tapes: 10 x 4 mm width + 22 x 6 mm width
- Thickness of the tapes: ~ 165 μm , 110 μm Copper stabilizer
- Outer Diameter incl. tube: 9.0 mm
- Twist Pitch ~ 35 cm
- Terminations by soldering the HTS CroCo to copper profiles (details later)
- Expected I_c (4.2 K, 12 T): 8.5 – 9 kA



V(I) measurement at $T = 4.2$ K, $B = 12$ T



No degradation after the FBI test



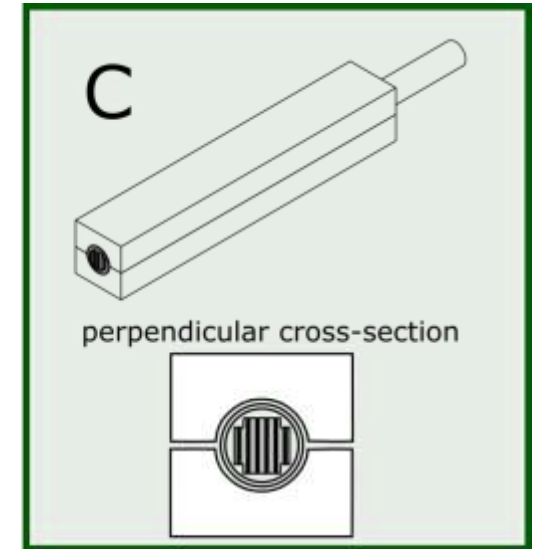
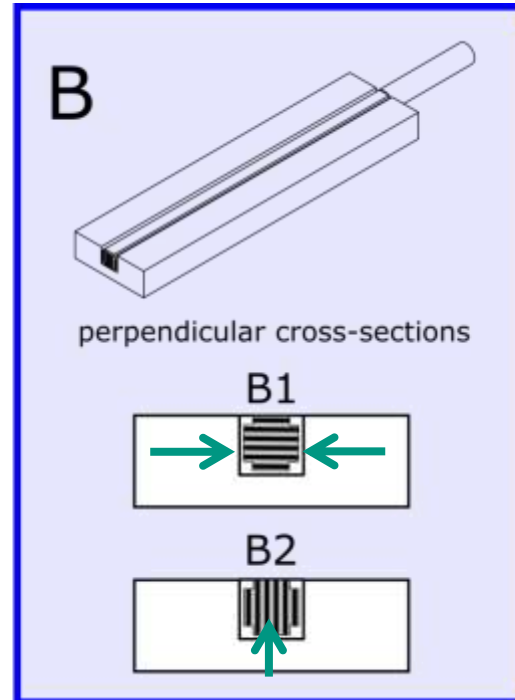
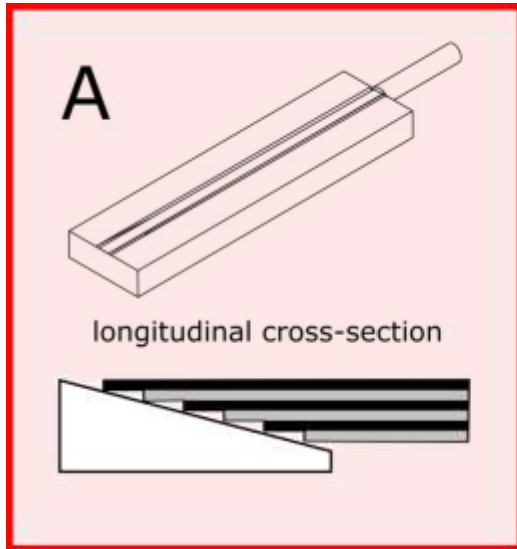
Outlook: Temperature-dependent measurements of $I_c(B)$

Challenging due to the copper tube, solder, thick Cu stabilizer, 32-tape stack

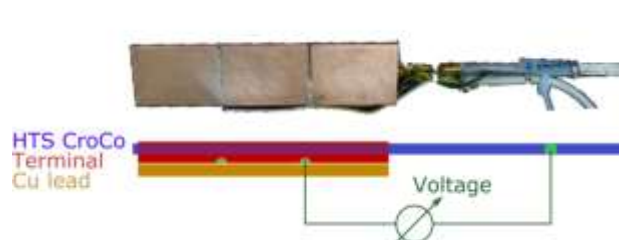
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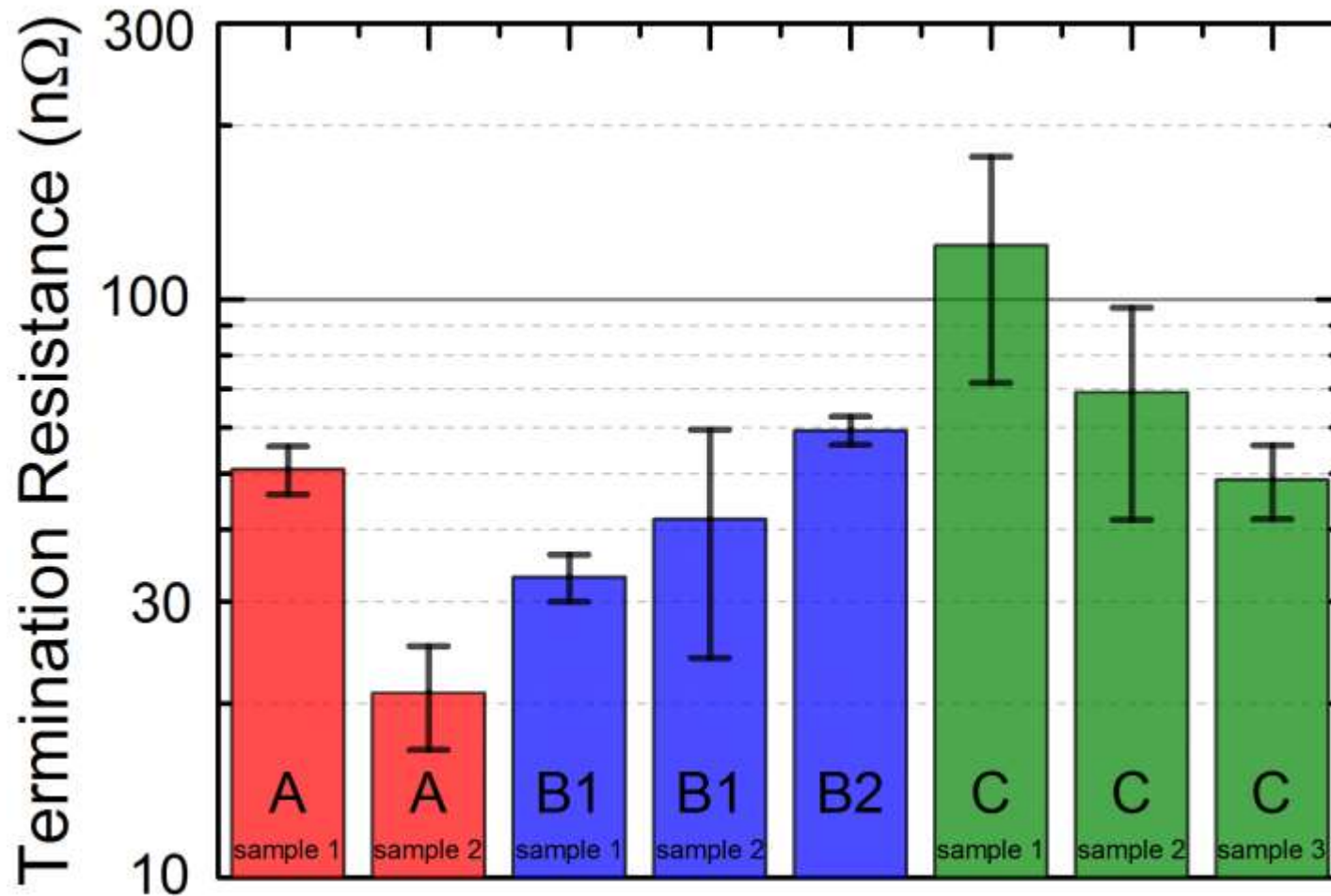
Three different types of terminations



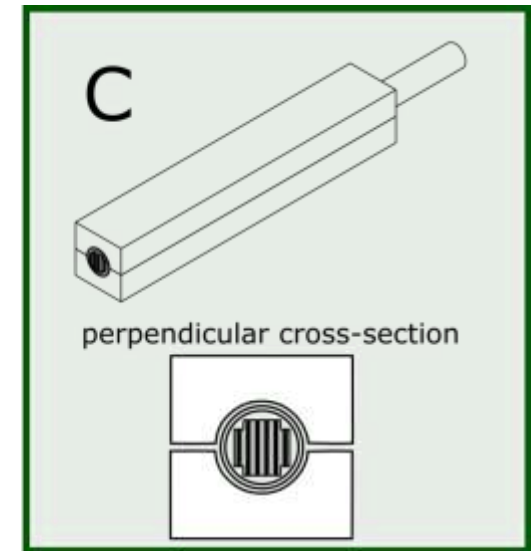
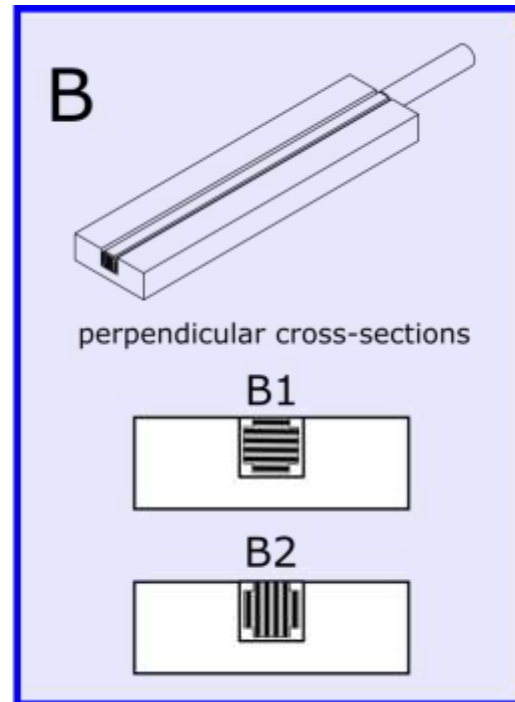
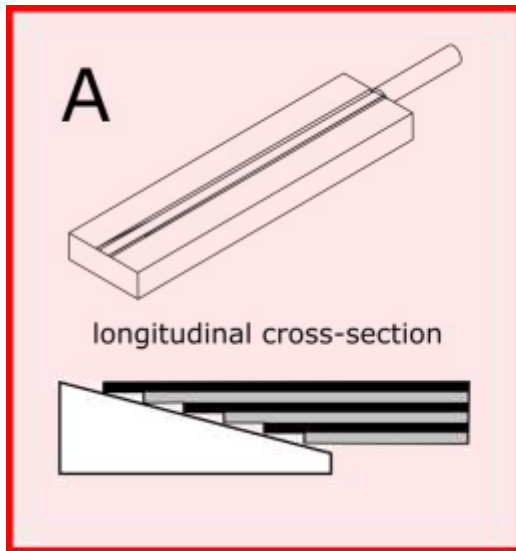
Measurements at $T = 77$ K, sf



Termination resistances at $T = 77$ K, sf.



Three different types of terminations



+ lowest termination resistance of all samples (21 nΩ for sample 2)

- time-consuming to prepare.

+ Reasonably low-resistive terminations (~ 35 – 60 nΩ)

+ easy to prepare

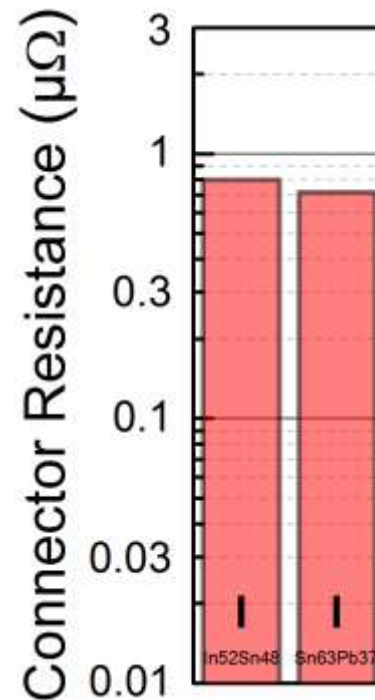
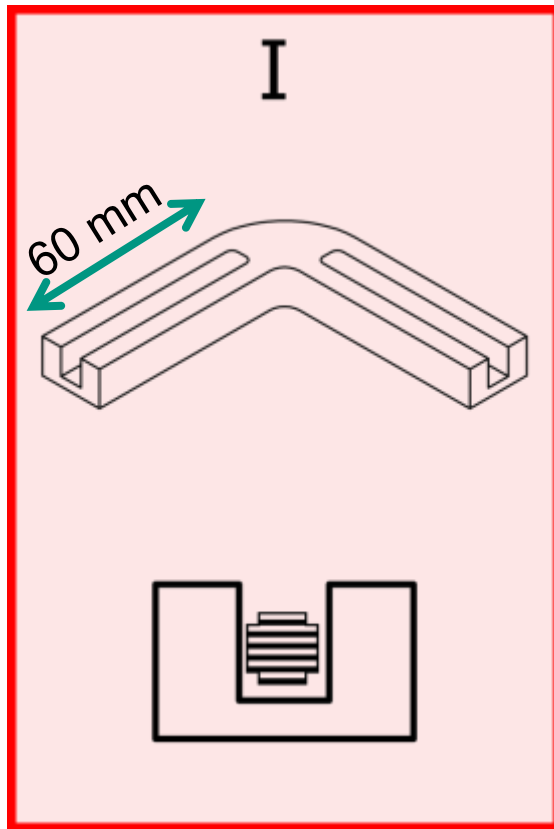
+ very easy to prepare

- highest resistances (due to geometry & more interfaces)

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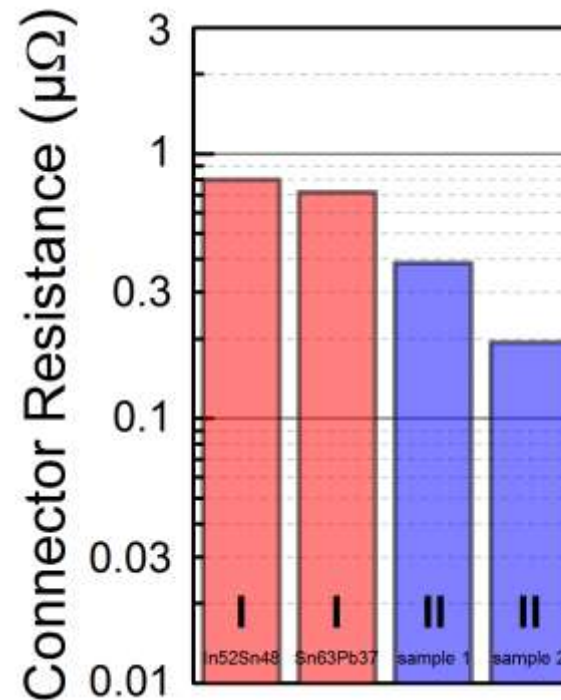
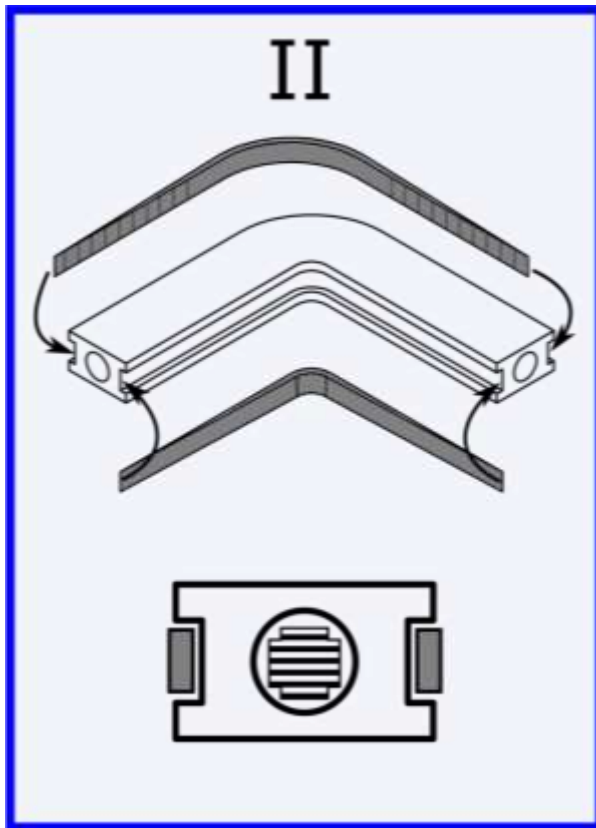
Angular HTS CroCo Connectors with $R < 50$ mm



Could we do better by adding additional REBCO tapes?

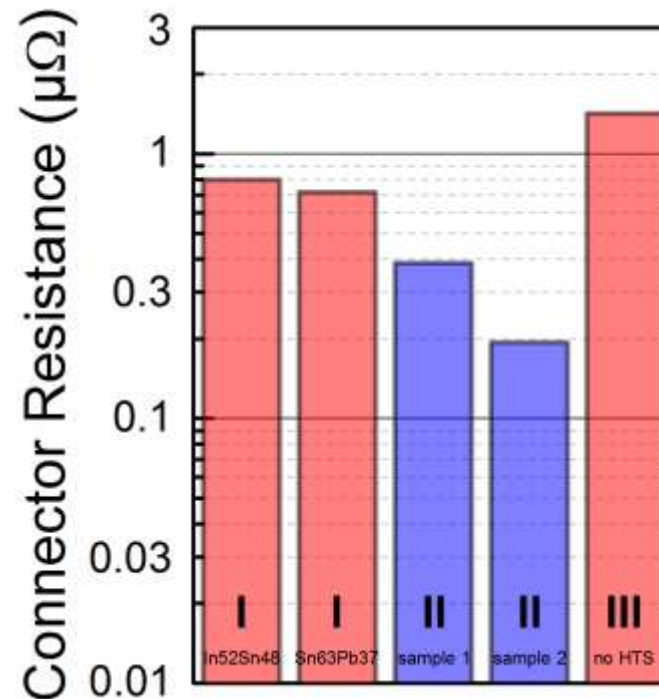
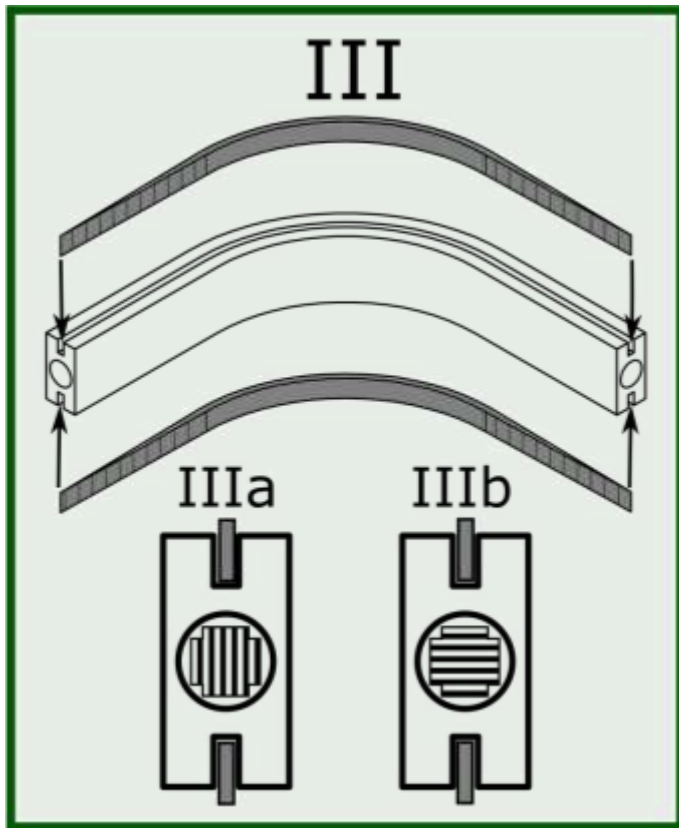
The 90° connector piece consists only of a solid copper block ($R = 15$ mm)
→ reference sample

Angular HTS CroCo Connectors with $R < 50$ mm



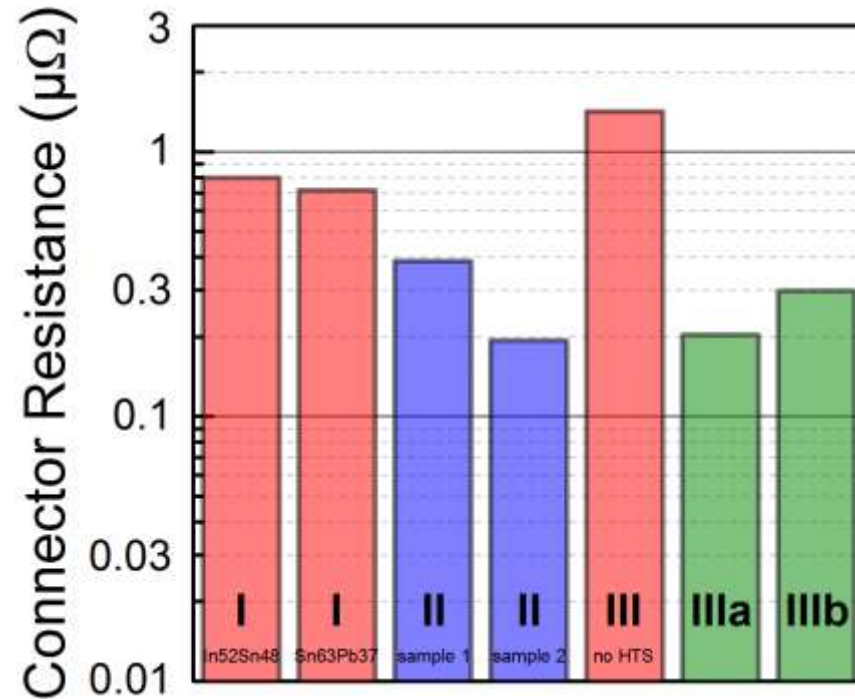
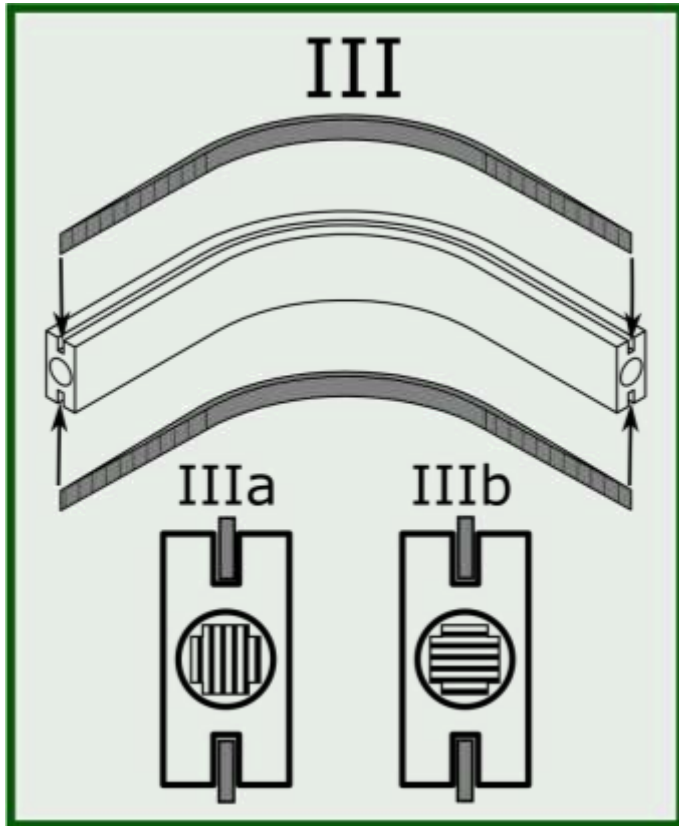
Two additional staggered REBCO tape stacks of 15 tapes (6 mm width)

Angular HTS CroCo Connectors with $R < 50$ mm



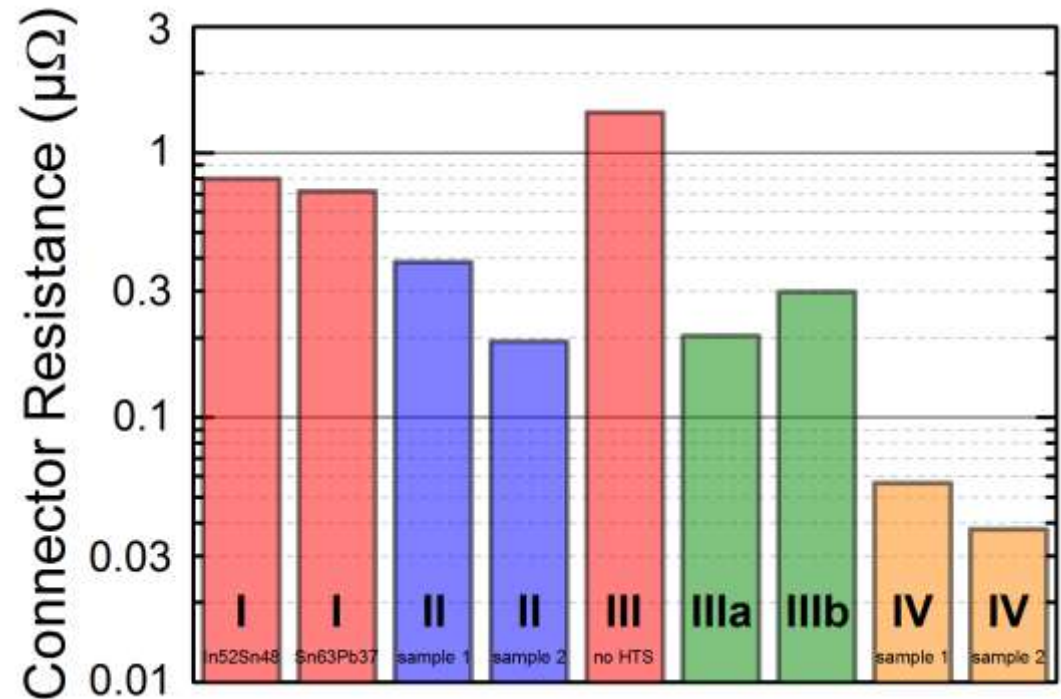
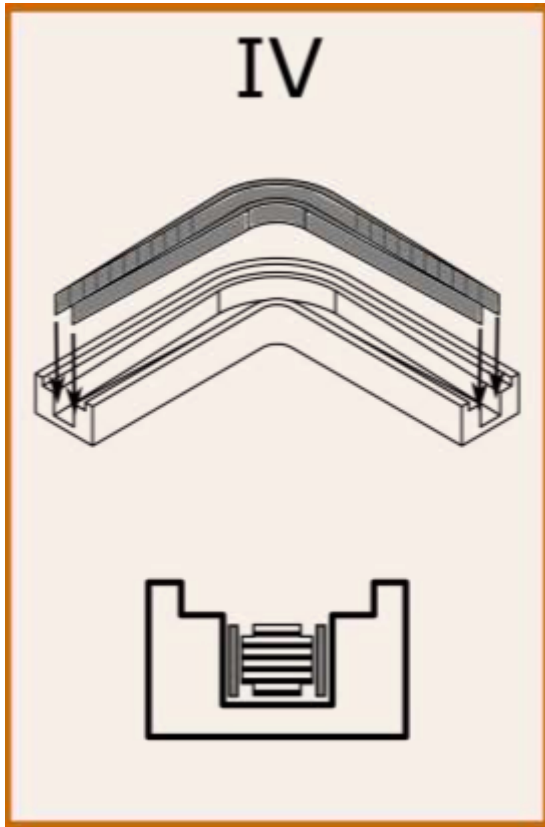
Two additional staggered REBCO tape stacks of 14 tapes in grooves $R = 50$ mm, connection length = 50 mm

Angular HTS CroCo Connectors with $R < 50$ mm



Two additional staggered REBCO tape stacks of 14 tapes in grooves $R = 50$ mm, connection length = 50 mm

Angular HTS CroCo Connectors with $R < 50$ mm



< 0.5 W of heating power at $I = 3$ kA

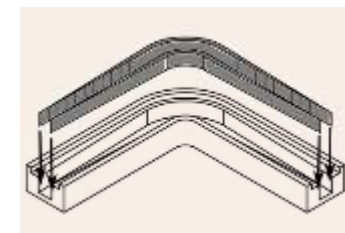
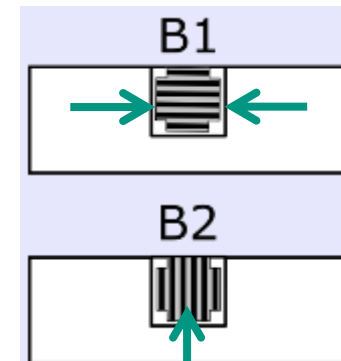
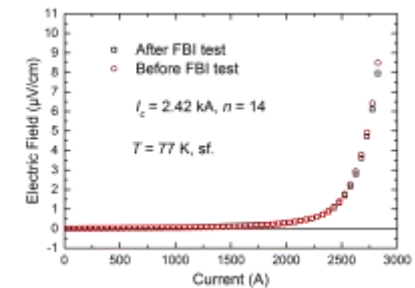
Two additional staggered REBCO tape stacks of 15 tapes in direct contact to the HTS CroCo cores.

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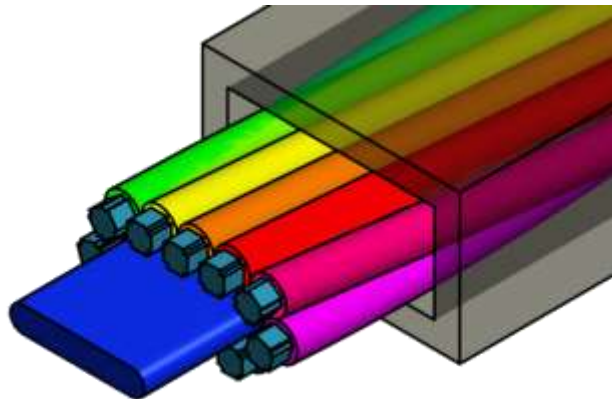
Conclusions

- No degradation of a fully REBCO-equipped HTS CroCo after Lorentz forces of > 12 kN
- Easy-to-fabricate „Side – Injection“ Terminations are achievable with low resistance (35 – 60 n Ω)
- Angular HTS Connectors with small bending radius and low resistance possible leading to a heating power of less than 0.5 W at 3 kA



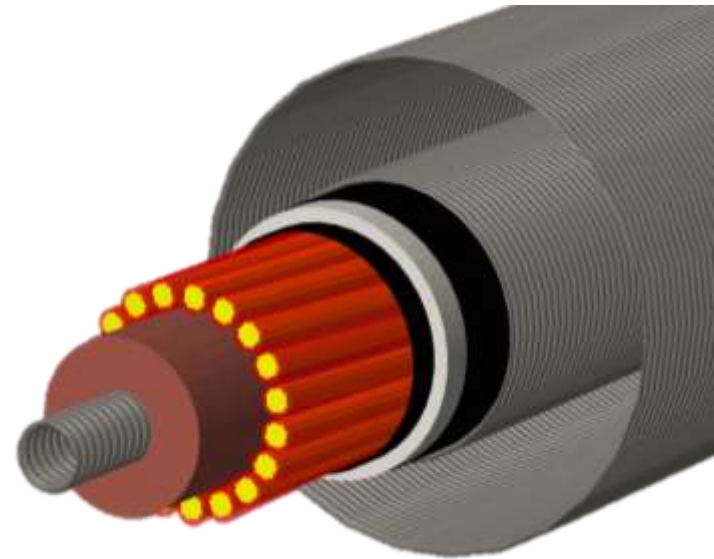
Outlook: HTS CroCo for large magnets and DC cables

- Design of a Rutherford cable made of 11 HTS CroCo strands for fusion TF magnets



- M. J. Wolf, et al., *IEEE Trans. Appl. Supercond.* 26 (4), Art. ID. 4801504, June 2016
- R. Heller, et al., *IEEE Trans. Appl. Supercond.* 26 (4), Art. ID. 4201105, June 2016

- 30 – 100 kA DC Cable with sub-cooled LN₂ cooling



- **Poster of Alan Preuss:**
Conceptual design process of high-current HTS DC cables