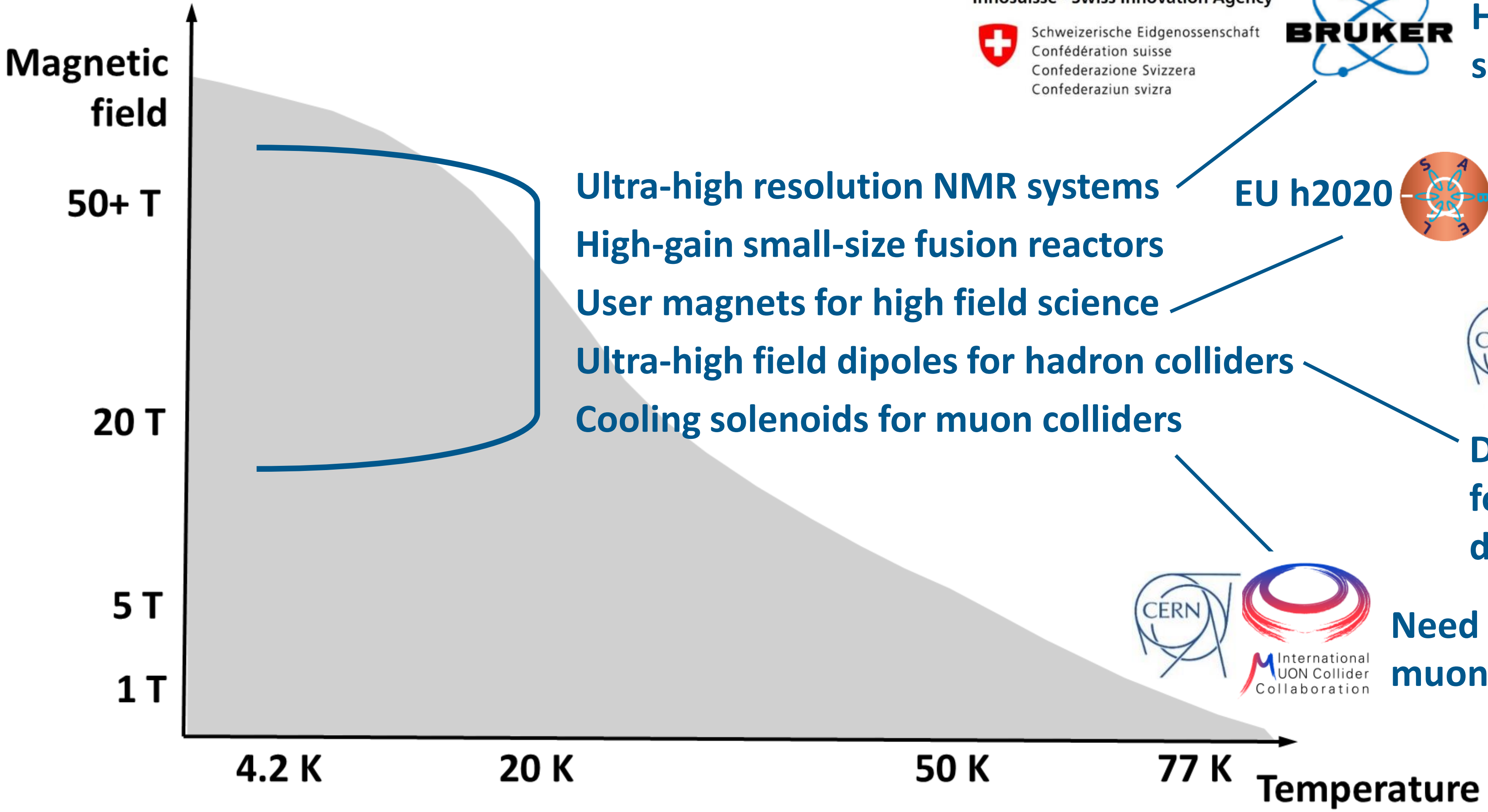
Introduction to the activities of the WP2.3 at UNIGE

~~Other HTS conductors~~
Focus on REBCO coated conductors

Carmine SENATORE, **Marco BONURA, Tommaso BAGNI, Damien ZURMUEHLE**
Department of Quantum Matter Physics, University of Geneva, Switzerland
Department of Nuclear and Particle Physics, University of Geneva, Switzerland

Applications of HTS in ultra-high magnetic field

The Group of Applied Superconductivity at UNIVERSITÉ DE GENÈVE FACULTÉ DES SCIENCES is involved in projects and initiatives for magnet applications of REBCO coated conductors



Innosuisse - Swiss Innovation Agency
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

BRUKER

HTS joints in view of 1.3+ GHz NMR spectrometers (B = 30.5 T)

EU h2020 and SuperEMFL coordinated by LNCMI

CERN FUTURE CIRCULAR COLLIDER HFM High Field Magnets

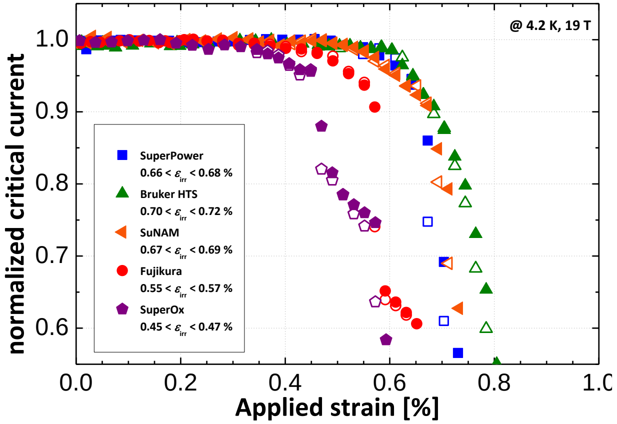
Demonstrate the suitability of HTS for accelerator magnets, aiming at dipole fields of at least 20 T

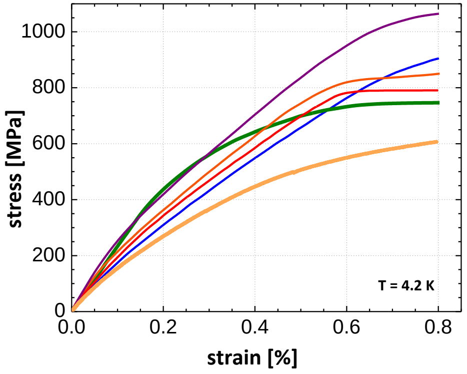
CERN International MUON Collider Collaboration

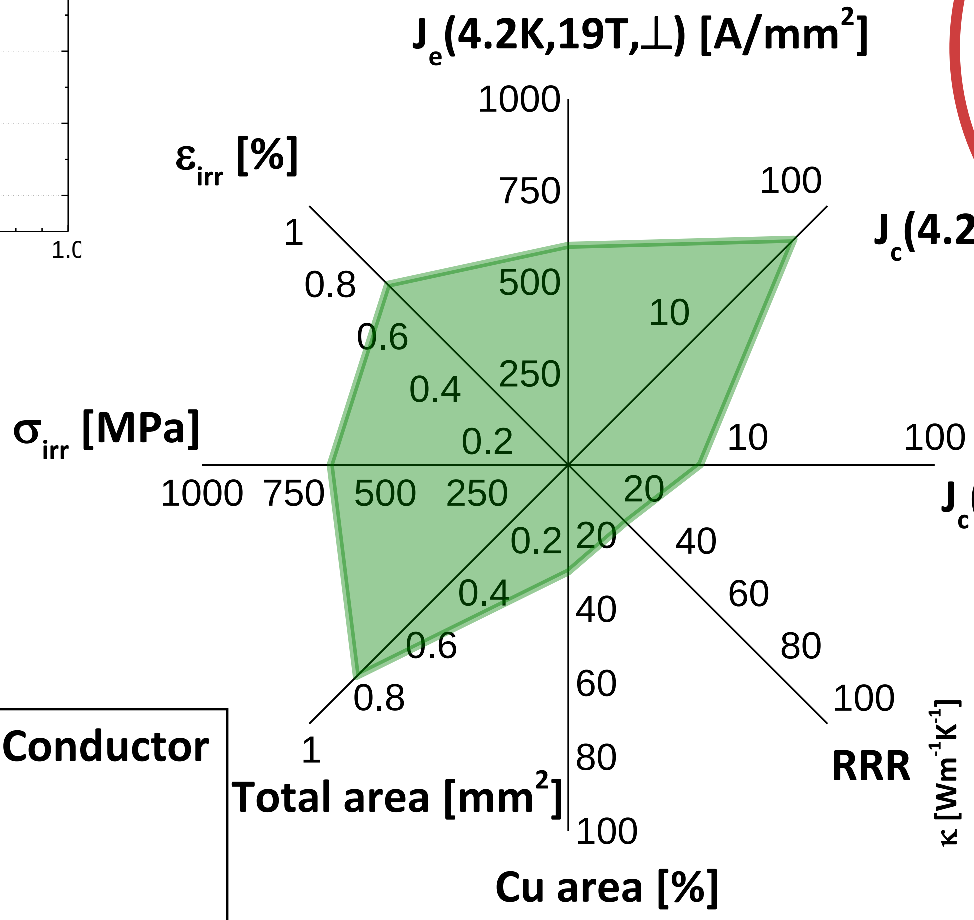
Need for solenoids ≥ 40 T for cooling the muon beams

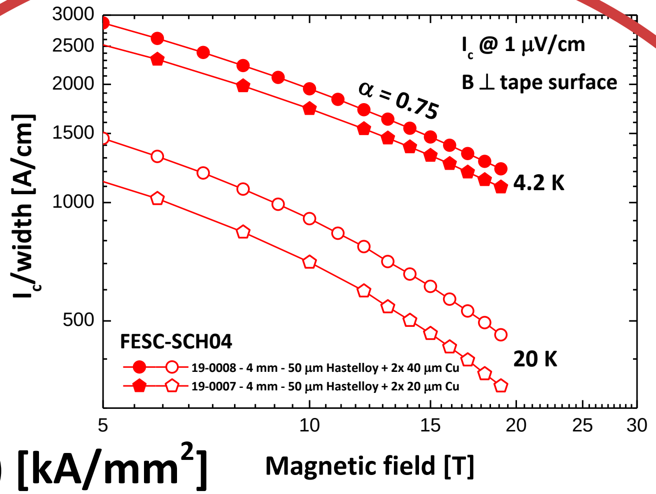
Overview of the HTS testing facilities at UNIGE

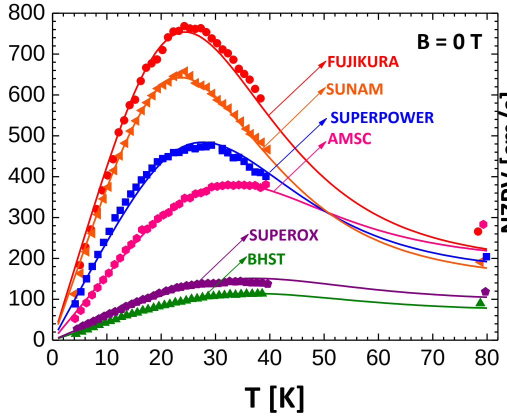
High-Field Low-Temperature characterization

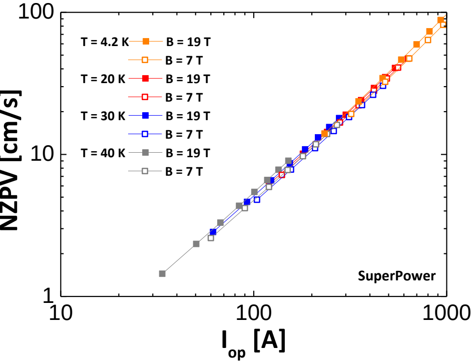








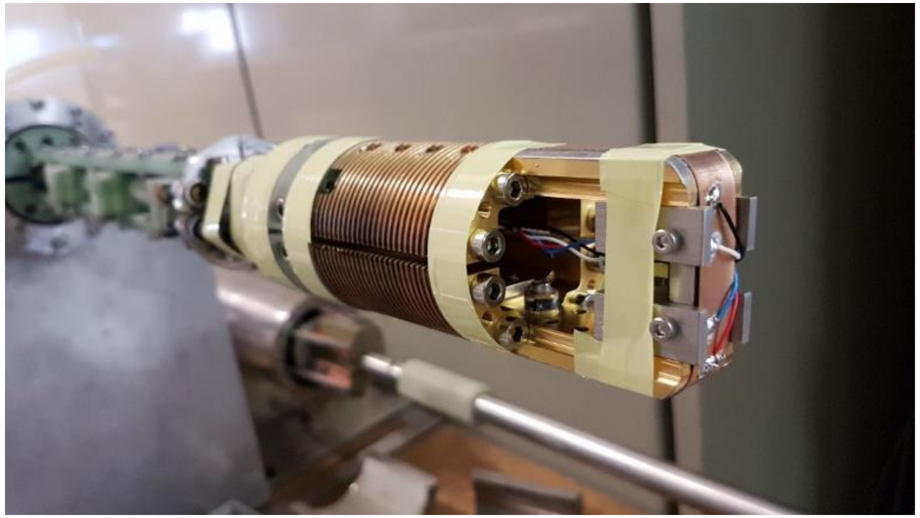


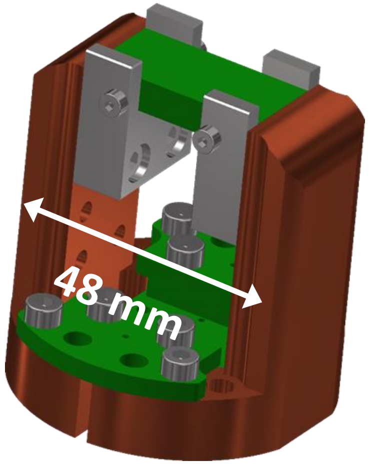


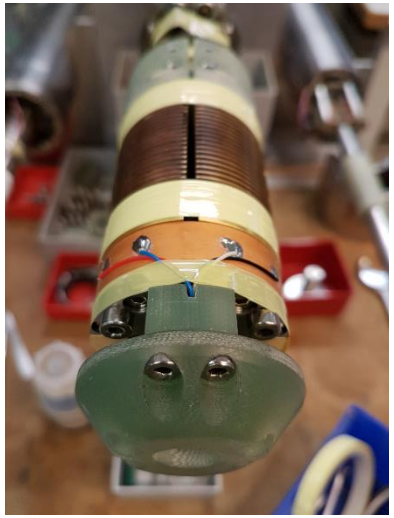
HTS Accelerator Magnet and Conductor Development in Europe
Lucio Rossi and Carmine Senatore
Instruments **2021**, 5, 8
DOI: 10.3390/instruments5010008

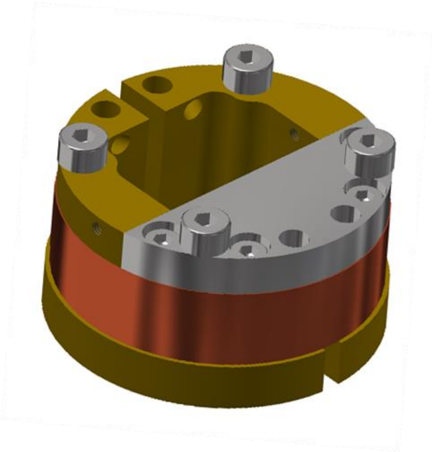
Critical current tests up to 2 kA

Magnetic fields up to 19 T/21 T and temperatures up to 50 K in a 50 mm VTI

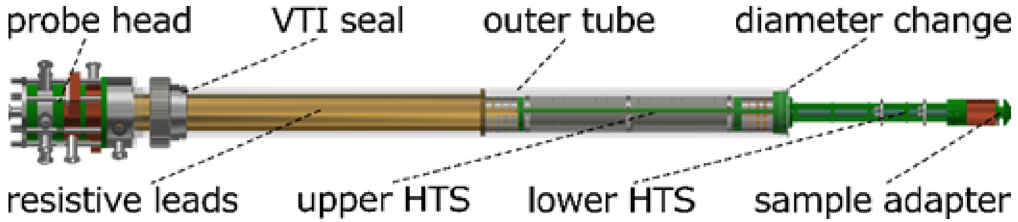


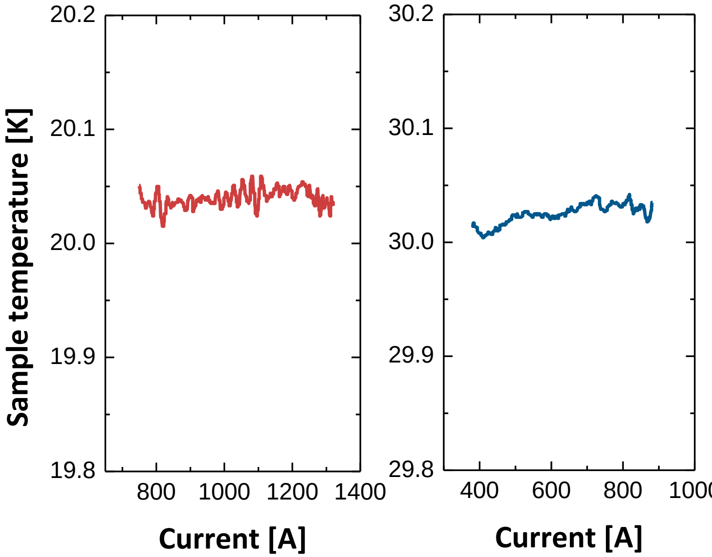


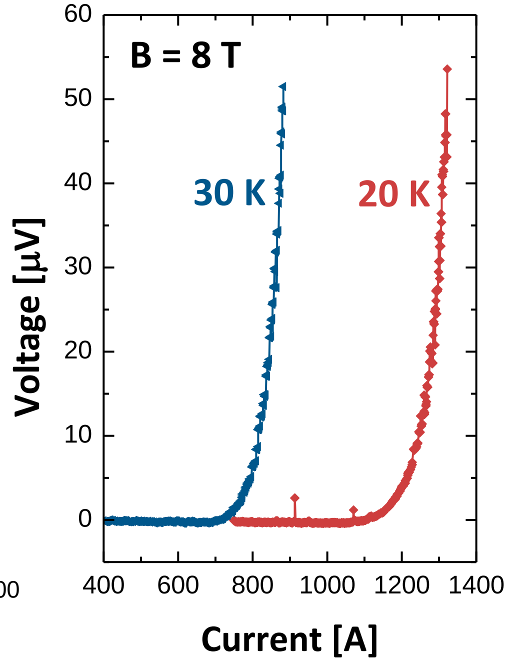




- Possible to test long samples (> 120 mm) at various angles: θ = 0°, 5°, 7.5°, 10°, 15° and 90°
- Active stabilization of the sample temperature







Barth, Bonura, and CS, IEEE Trans. Appl. Supercond., 28 (2018) 9500206
DOI: 10.1109/TASC.2018.2794199

What has been tested – Catalogue of the Tapes

	Width	REBCO Type	REBCO Thickness	Deposition Method	Pinning Type	Substrate	Cu Stabilizer
Fujikura	4 mm	EuBCO	2.5 μm	IBAD/PLD	BHO columns (artificial)	50 μm/Hastelloy	2 x 40 μm electroplated
							2 x 20 μm electroplated
SuperOx	4 mm	YBCO	3.1 μm	IBAD/PLD	Y_2O_3 particles (native)	100 μm/Hastelloy	2 x 20 μm electroplated
			2.7 μm			40 μm/Hastelloy	2 x 5 μm electroplated
上海超导 SHANGHAI SUPERCONDUCTOR	3 mm	EuBCO	3 μm	IBAD/PLD	BHO columns (artificial)	30 μm/Hastelloy	2 x 10 μm electroplated
THEVA	4 mm	GdBCO	3 μm	ISD/EB-PVD	Gd_2O_3 particles (native)	100 μm/Hastelloy	2 x 20 μm electroplated
					Gd_2O_3 particles (native) BHO particles (artificial)	40 μm/Hastelloy	2 x 10 μm PVD-plated

Fujikura tapes courtesy of S. Richardson and M. Daibo, SuperOx tapes courtesy of A. Molodyk, 上海超导 tapes courtesy of Y. Zhao and B. Song, THEVA tapes courtesy of M. Bauer and M. Bendele

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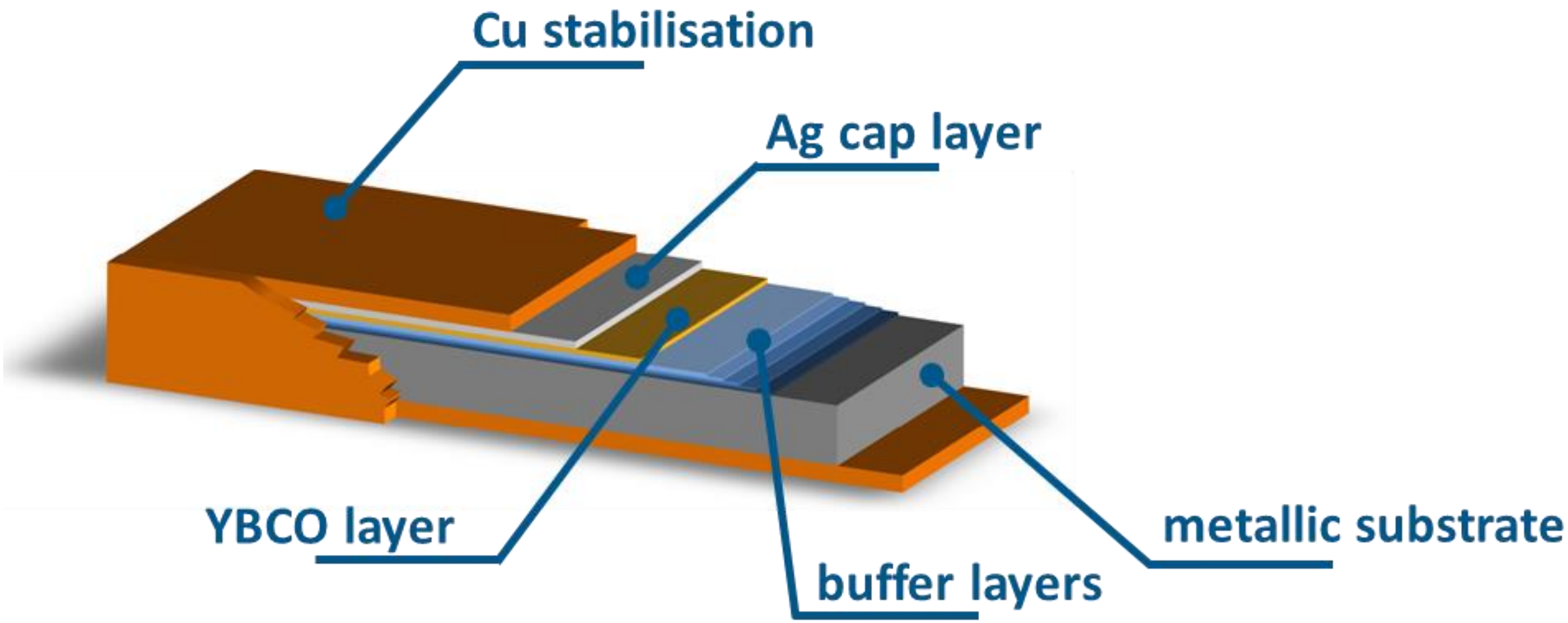
Comparison of the performance



$$J_e = \frac{I_c}{A_{tot}}$$

Engineering critical current density

$$J_{c-layer} = \frac{I_c}{A_{SC}}$$

Layer critical current density

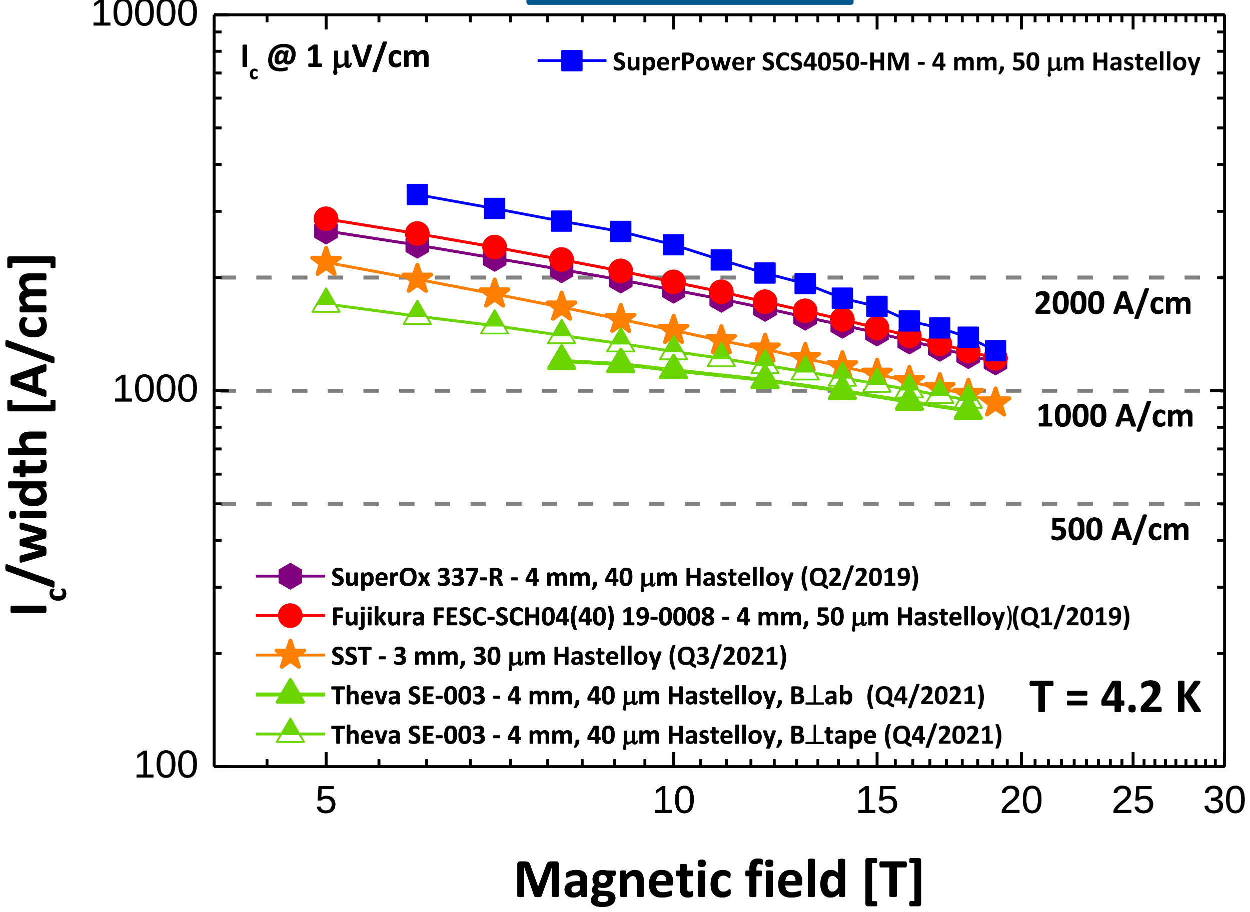
$$\text{non-Cu } J_c = \frac{I_c}{A_{tot} - A_{Cu}}$$

Non-copper critical current density

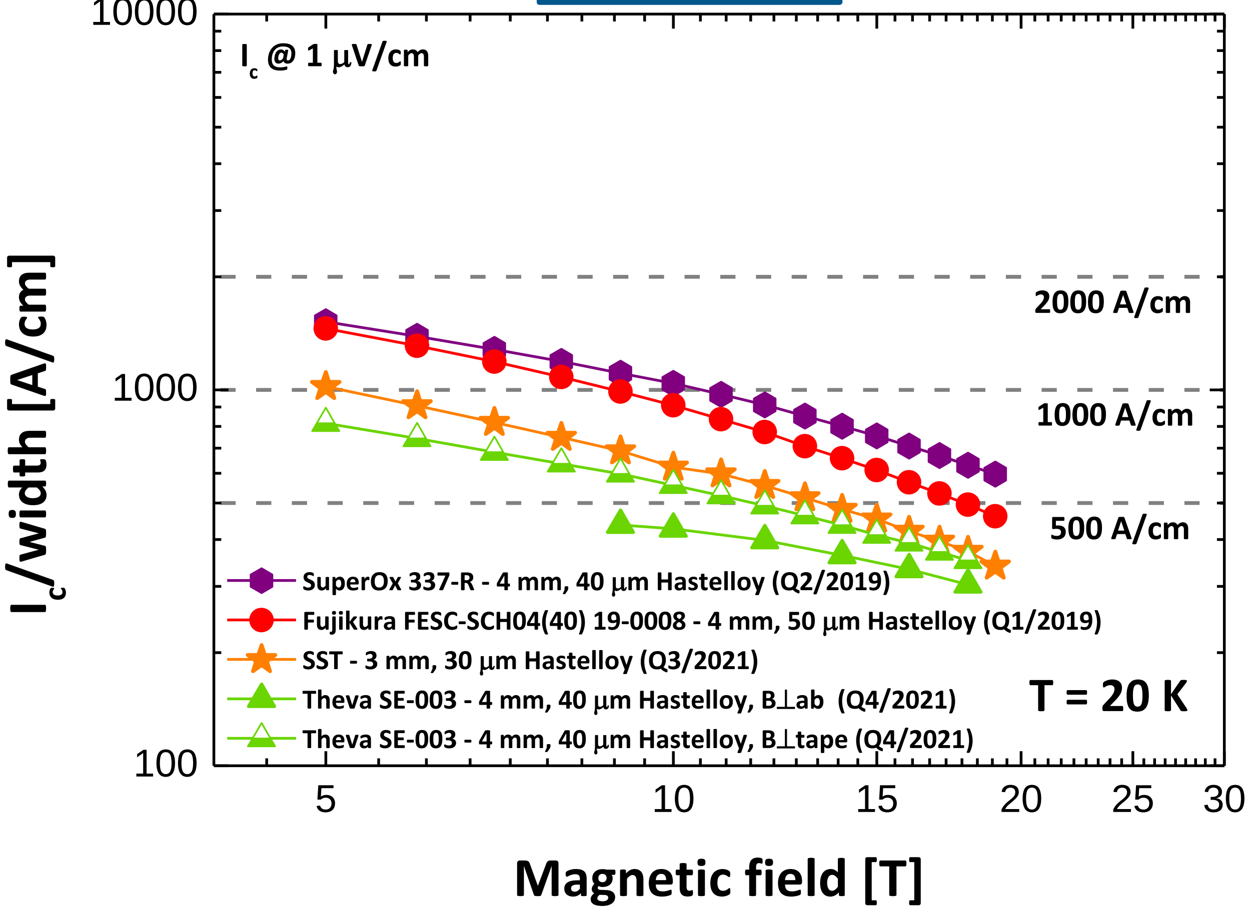
B ⊥ ab plane

Comparison of the performance: I_c / width

T = 4.2 K



T = 20 K



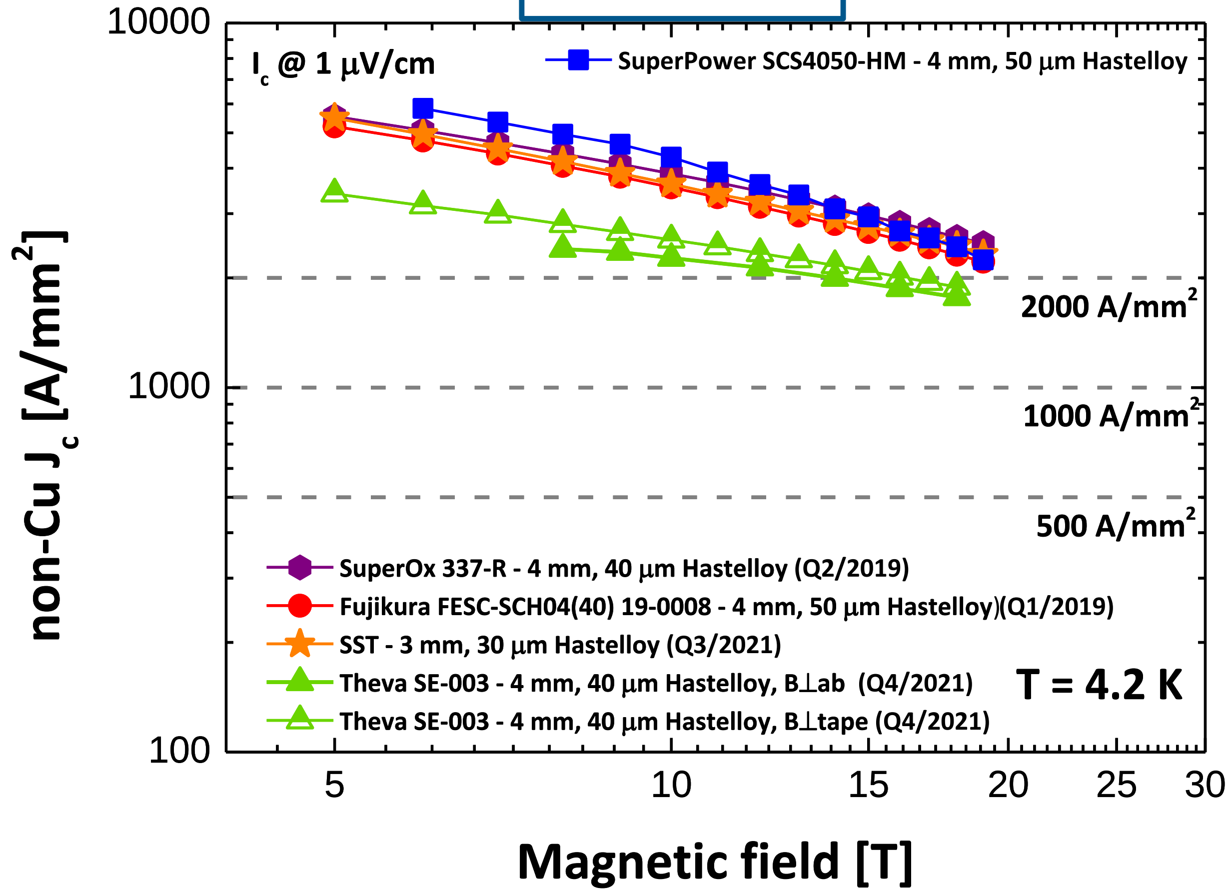
B ⊥ ab plane

Comparison of the performance: non-Cu J_c

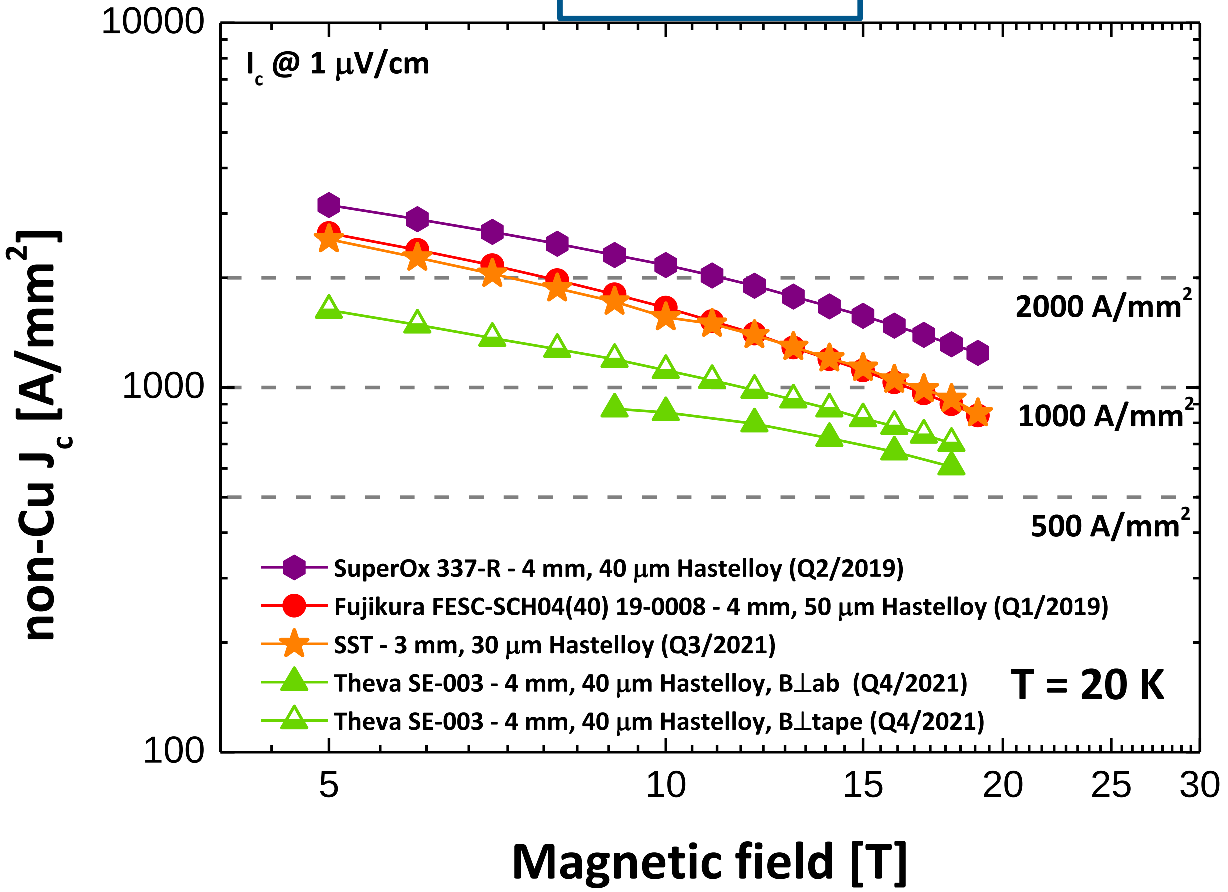
The non-Cu J_c corresponds to the critical current divided by the tape cross-section area minus the Cu area

$$\text{non-Cu } J_c = \frac{I_c}{A_{tot} - A_{Cu}}$$

T = 4.2 K



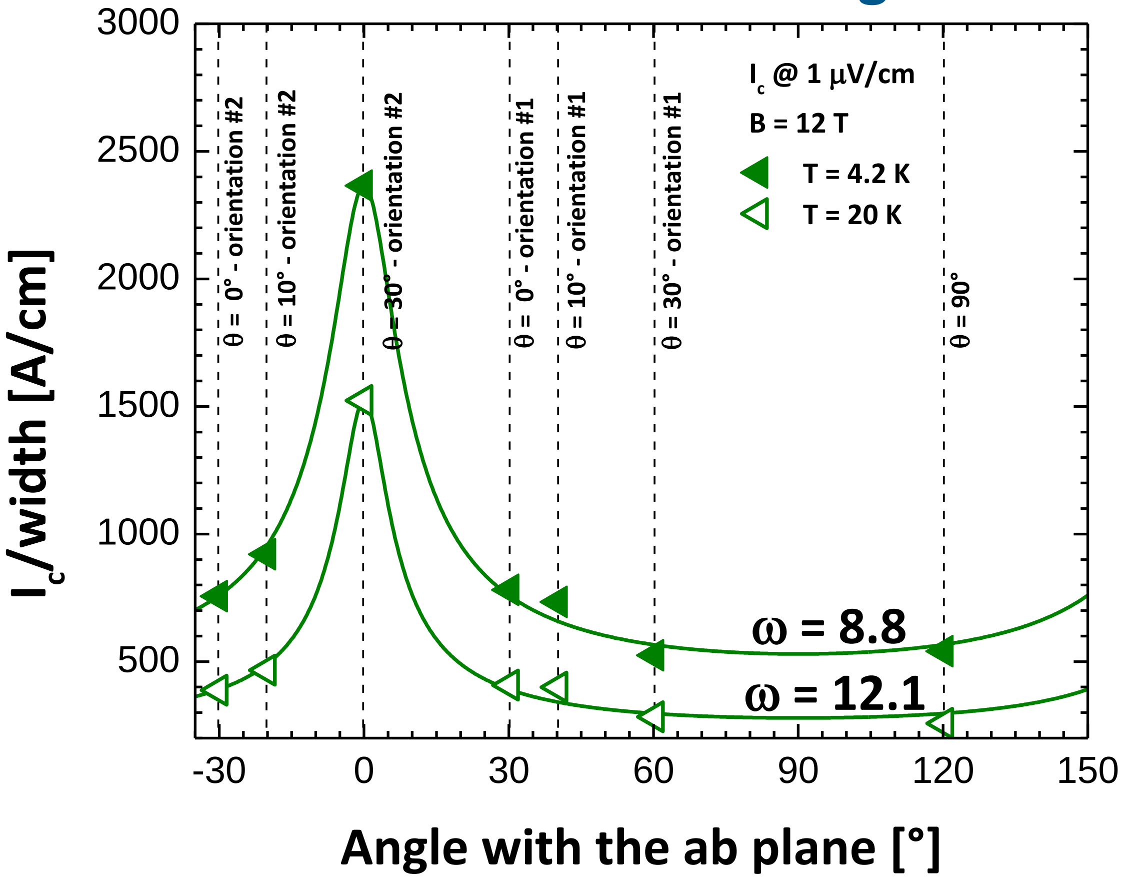
T = 20 K



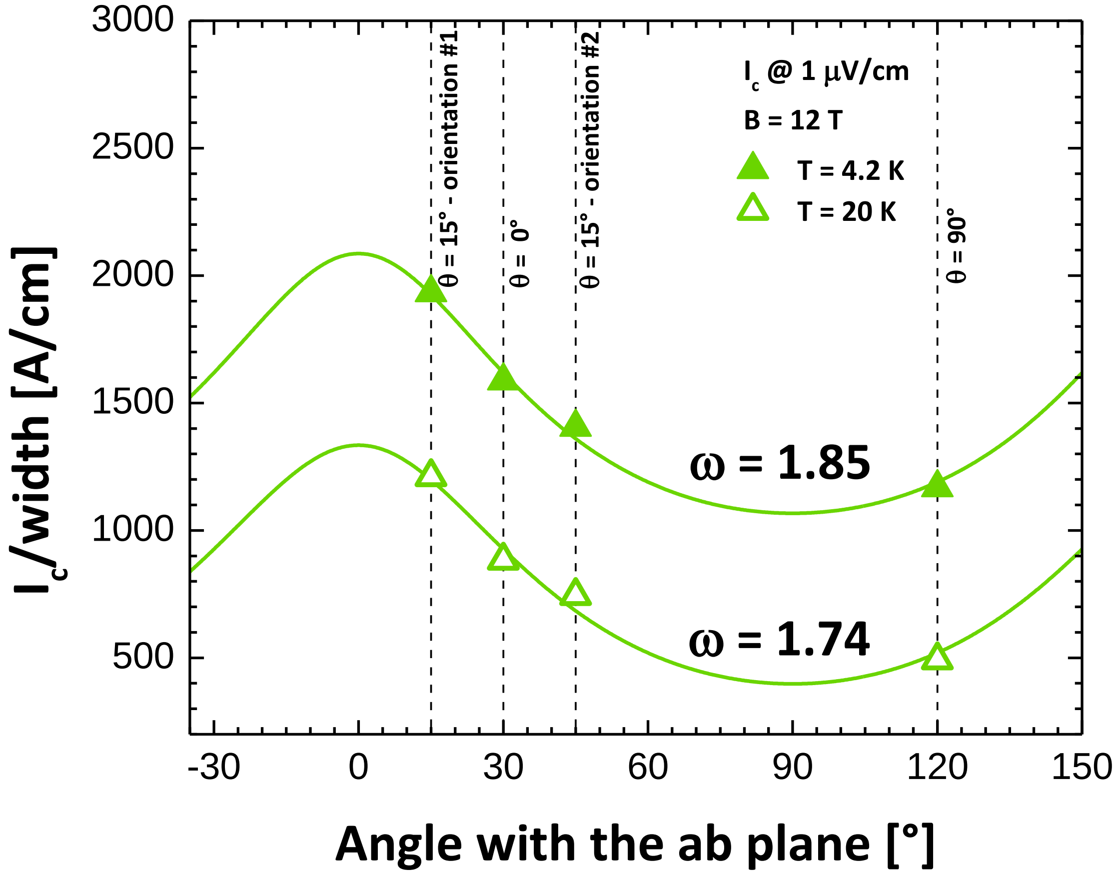
Examples of the angular dependence of I_c

Two tapes from THEVA

Without Artificial Pinning – 2018



With Artificial Pinning – 2021



Fit performed according to the Hilton model

$$I_c(B,\theta) = I_c(B,90^\circ) + \left[I_c(B,0^\circ) - I_c(B,90^\circ)\right]\frac{\omega\, f(\omega,\theta) - 1}{\omega - 1}$$

$$f(\omega,\theta) = \left[\omega^2 \sin^2\theta + \cos^2\theta\right]^{-\frac{1}{2}}$$

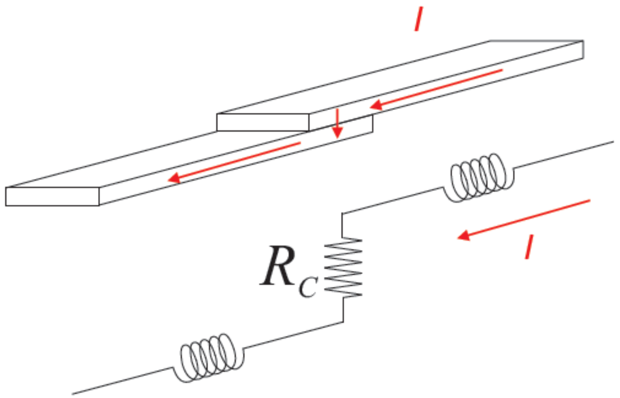
Hilton, Gavrilin & Trociewitz, SuST 28 (2015) 074002
DOI: 10.1088/0953-2048/28/7/074002

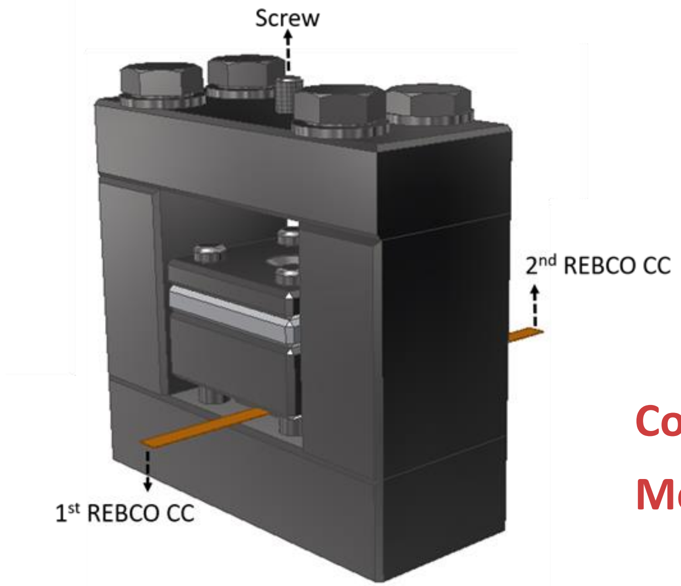
Some experiments conceived to feed magnet technology

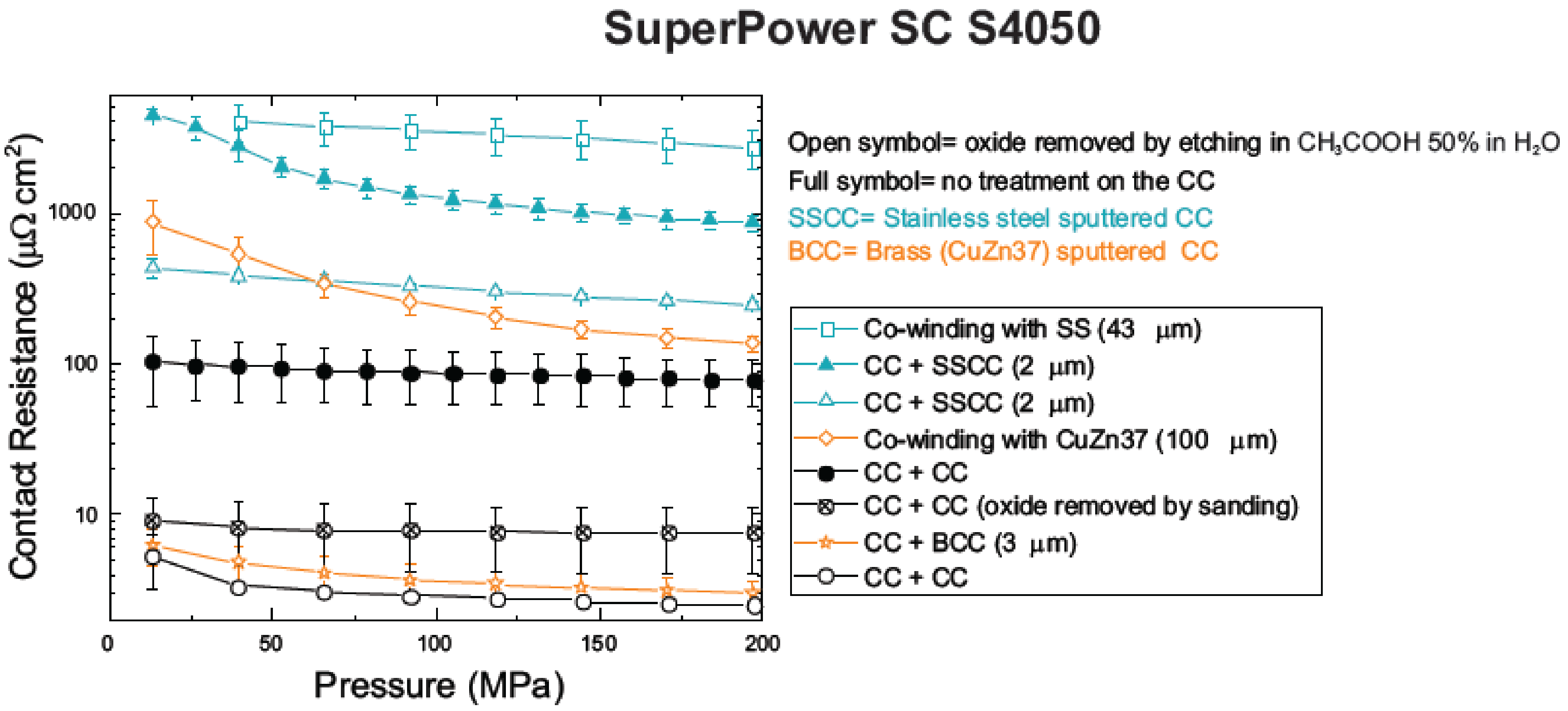
(..and other new will come in the near future)

Contact Resistance Between REBCO Tapes

Pressure Dependence in the Cases of No-Insulation, Metal Co-Winding and Metal-Insulation







Co-winding → **Stainless Steel Foil (43 μm) or CuZn37 Brass Tape (100 μm)**

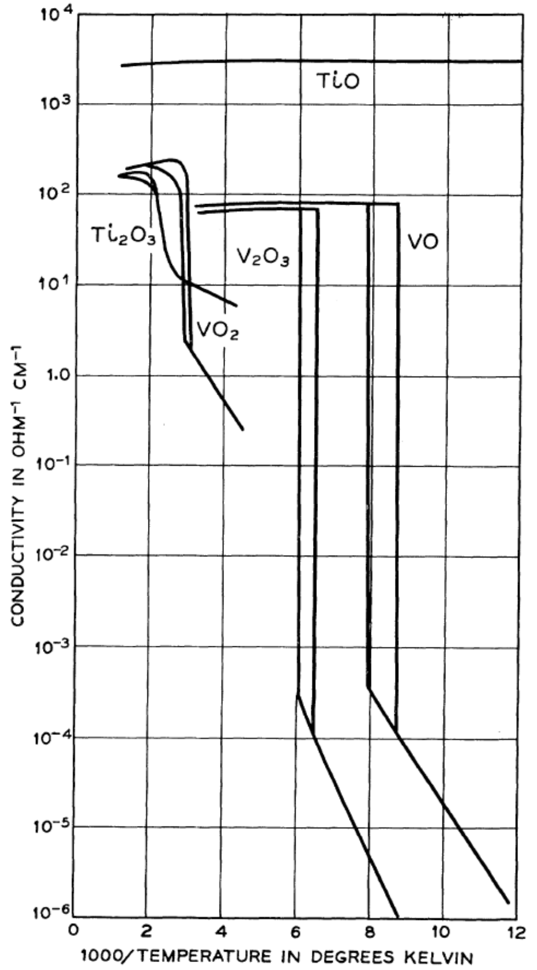
Metal-Insulation → **Metal sputtering on CC** → **Stainless Steel (2 μm) or CuZn37 Brass (3 μm)**

Bonura, Barth, Joudrier, Ferradas Troitino , Fête, and CS, IEEE Trans. Appl. Supercond., 29 (2019) 6600305

DOI: 10.1109/TASC.2019.2893564

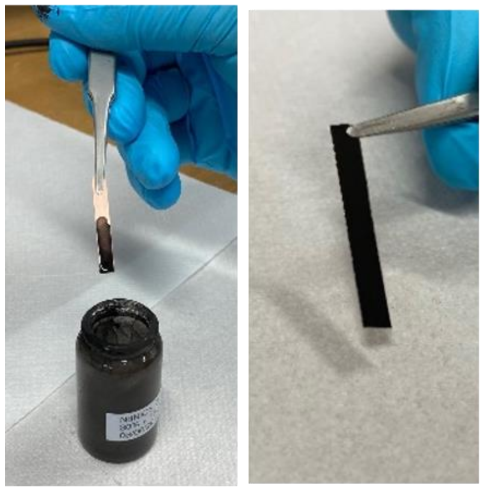
Metal-Insulator-Transition materials as a Smart Insulation

Contact Resistance Between REBCO Tapes

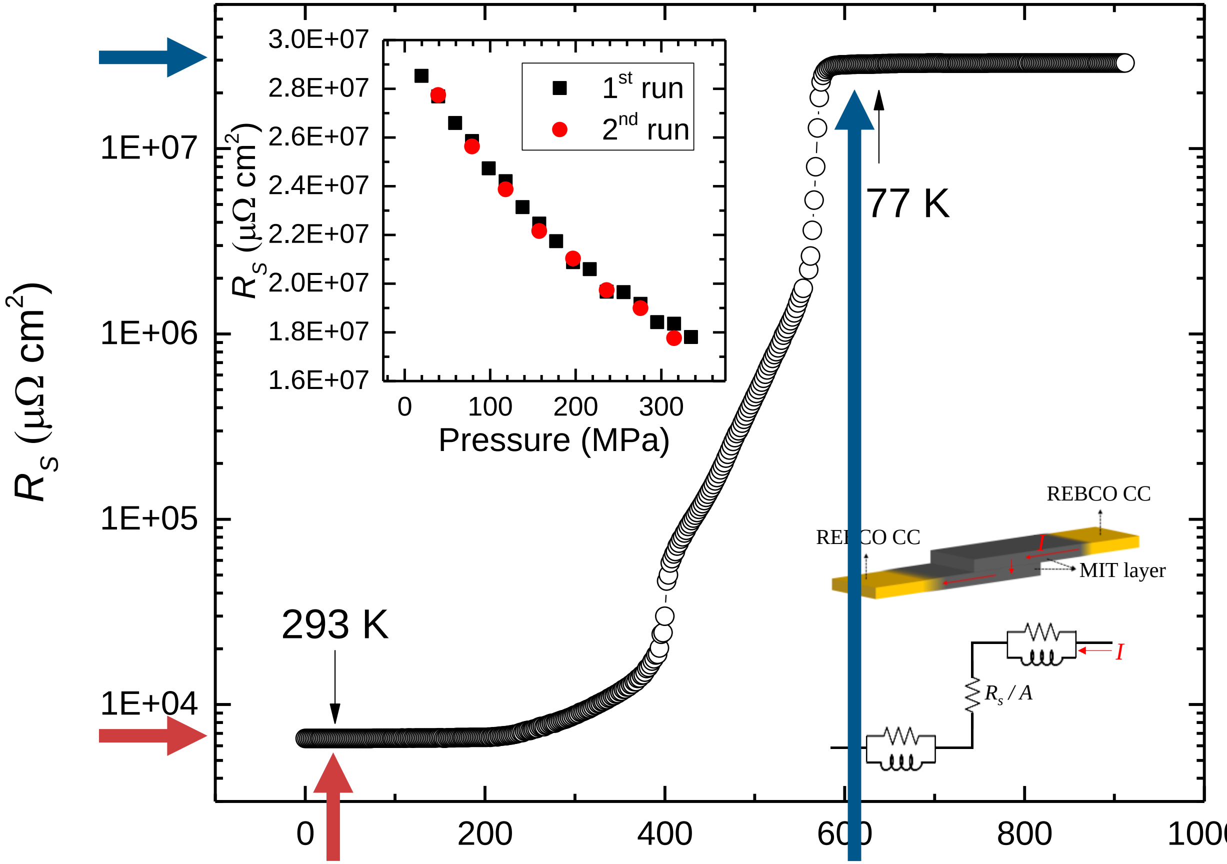

Volume 3, Number 1 PHYSICAL REVIEW LETTERS July 1, 1959

OXIDES WHICH SHOW A METAL-TO-INSULATOR TRANSITION AT THE NEEL TEMPERATURE

F. J. Morin
Bell Telephone Laboratories, Murray Hill, New Jersey
(Received June 5, 1959)



Dip or spin coating starting from colloidal solutions of V_2O_3 powders in Ethanol



Room temperature

Liquid nitrogen

Bonura, Bovone, Cayado, and CS, IEEE Trans. Appl. Supercond., 33 (2023) 8800106
DOI: 10.1109/TASC.2023.3251291

Bibliography

as a summary

Critical surface

C. Senatore, C. Barth, M. Bonura, M. Kulich, and G. Mondonico

Field and temperature scaling of the critical current density in commercial REBCO coated conductors

Supercond. Sci. Technol. 29 (2016) 014002

http://dx.doi.org/10.1088/0953-2048/29/1/014002

Electromechanical properties

C. Barth, G. Mondonico, and C. Senatore

Electro-mechanical properties of REBCO coated conductors from various industrial manufacturers at 77 K, self-field and 4.2 K, 19 T

Supercond. Sci. Technol. 28 (2015) 045011

http://dx.doi.org/10.1088/0953-2048/28/4/045011

Thermophysical properties

M. Bonura, and C. Senatore

High-field thermal transport properties of REBCO coated conductors

Supercond. Sci. Technol. 28 (2015) 025001

http://dx.doi.org/10.1088/0953-2048/28/2/025001

M. Bonura, and C. Senatore

Transverse thermal conductivity of REBCO coated conductors

IEEE Trans. Appl. Supercond. 25 (2015) 6601304

https://doi.org/10.1109/TASC.2014.2367163

Normal Zone Propagation Velocity

M. Bonura, and C. Senatore

An equation for the quench propagation velocity valid for high field magnet use of REBCO coated conductors

Appl. Phys. Lett., 108 (2016) 242602

http://dx.doi.org/10.1063/1.4954165

M. Bonura, and C. Senatore

Temperature and Field Dependence of the Quench Propagation Velocity in Industrial REBCO Coated Conductors

IEEE Trans. Appl. Supercond., 27 (2017) 6600705

https://doi.org/10.1109/TASC.2016.2632298

Contact resistance

M. Bonura, C. Barth, A. Joudrier, J. Ferradas Troitino , A. Fête, and C. Senatore

Systematic Study of the Contact Resistance Between REBCO Tapes: Pressure Dependence in the Case of No-Insulation, Metal Co-Winding and Metal-Insulation

IEEE Trans. Appl. Supercond., 29 (2019) 6600305

https://doi.org/10.1109/TASC.2019.2893564

M. Bonura, G. Bovone, P. Cayado, and C. Senatore

Contact Resistance Between REBCO Coated Conductors in the Presence of a V_2O_3 Inter-Layer

IEEE Trans. Appl. Supercond., 33 (2023) 8800106

https://doi.org/10.1109/TASC.2023.3251291

Critical current probe

C. Barth, M. Bonura, and C. Senatore

High Current Probe for $I_c(B,T)$ Measurements With ±0.01 K Precision: HTS Current Leads and Active Temperature Stabilization System

IEEE Trans. Appl. Supercond., 28 (2018) 9500206

https://doi.org/10.1109/TASC.2018.2794199

Heating induced degradation

M. Bonura, P. Cayado, K. Konstantopoulou, M. Alessandrini, and C. Senatore

Heating-Induced Performance Degradation of $REBa_2Cu_3O_{7-x}$ Coated Conductors: An Oxygen Out-Diffusion Scenario with Two Activation Energies

ACS Appl. Electron. Mater., 4 (2022) 1318–1326

https://doi.org/10.1021/acsaelm.2c00065

HTS for accelerator magnets

L. Rossi, and C. Senatore

HTS Accelerator Magnet and Conductor Development in Europe

Instruments, 5 (2021) 8

https://doi.org/10.3390/instruments5010008

Swiss Accelerator Research and Technology

HFM High Field Magnets

Thank you for the attention !

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UNIVERSITÉ DE GENÈVE

FACULTÉ DES SCIENCES