Summary of the latest measurements on REBCO tapes at UNIGE

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Outline

- *CC performance overview from worldwide manufacturers*
- *Scaling relations for the temperature and field dependences of J_c*
- *NZPV dependence on the operating current*

CC performance overview from worldwide manufacturers

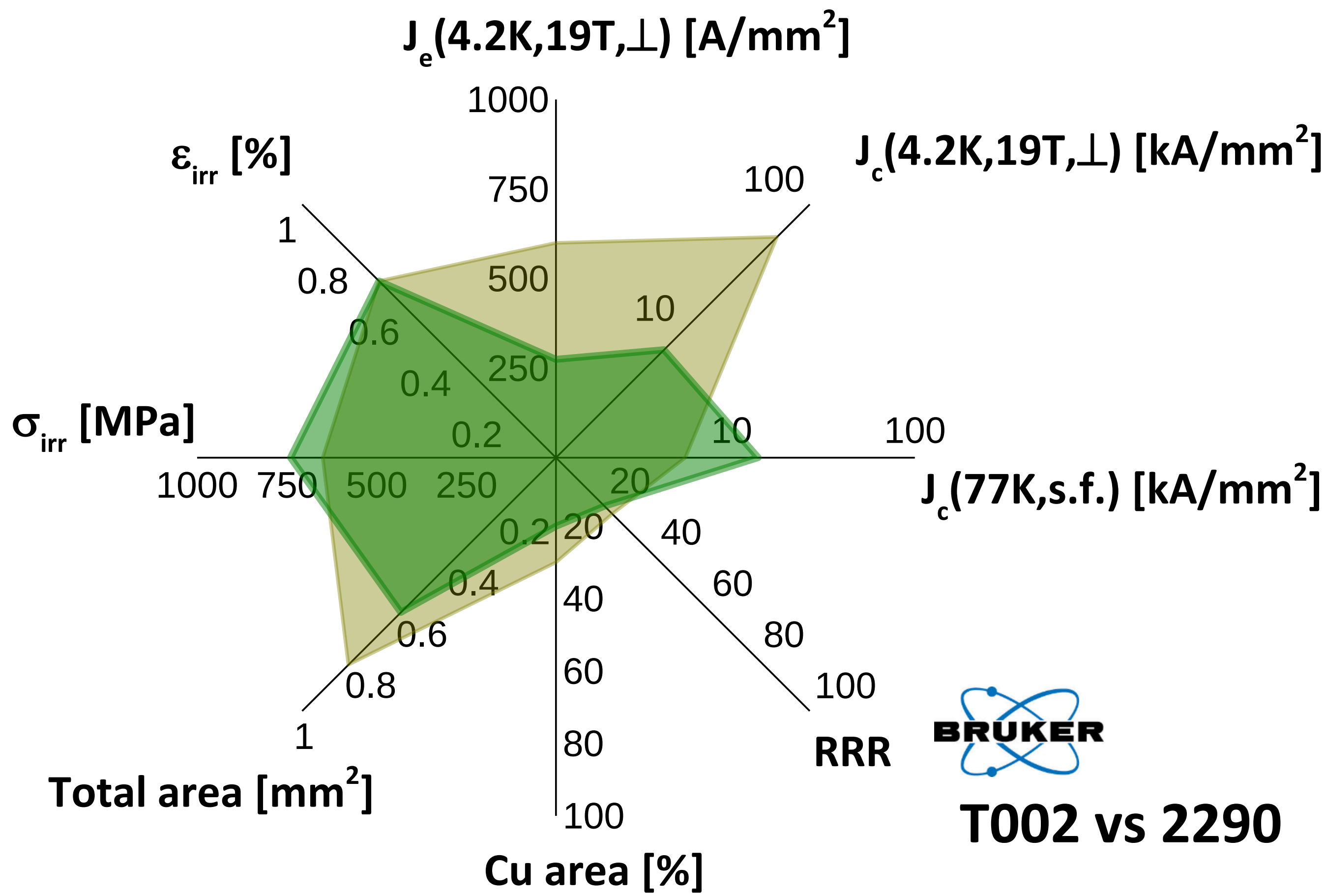
C. Barth, G. Mondonico, and C. Senatore
Electro-mechanical properties of REBCO coated conductors from various industrial manufacturers at 77 K, self-field and 4.2 K, 19 T
Supercond. Sci. Technol. 28 (2015) 045011

M. Bonura, and C. Senatore
High-field thermal transport properties of REBCO coated conductors
Supercond. Sci. Technol. 28 (2015) 025001

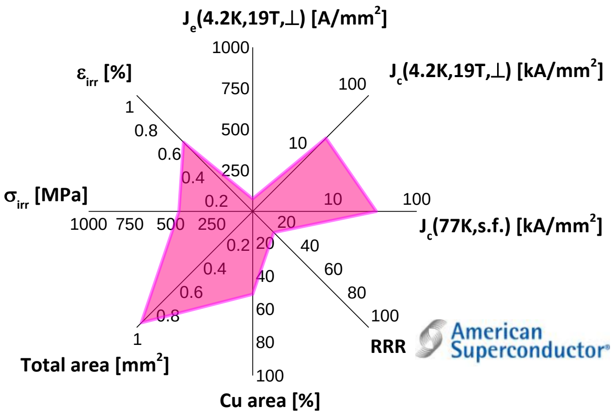
M. Bonura, and C. Senatore
Transverse thermal conductivity of REBCO coated conductors
IEEE Trans. Appl. Supercond. 25 (2015) 6601304

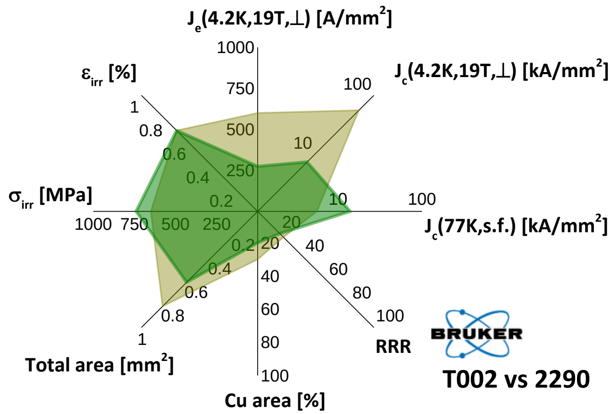
C. Senatore, C. Barth, M. Bonura, M. Kulich, G. Mondonico
Field and temperature scaling of the critical current density in commercial REBCO coated conductors
Supercond. Sci. Technol., in press

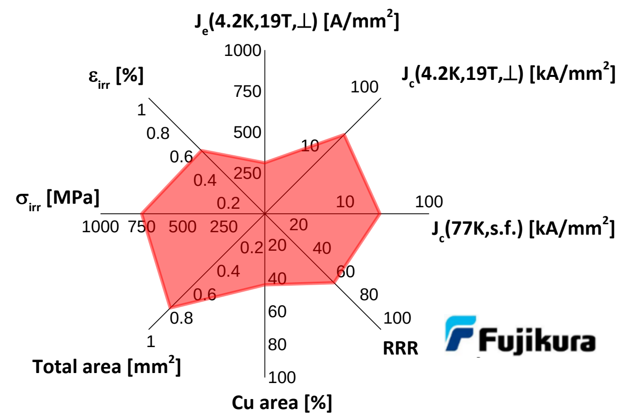
Main parameters at a glance

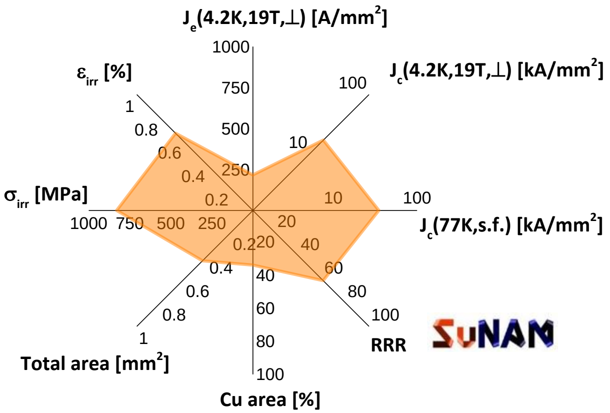


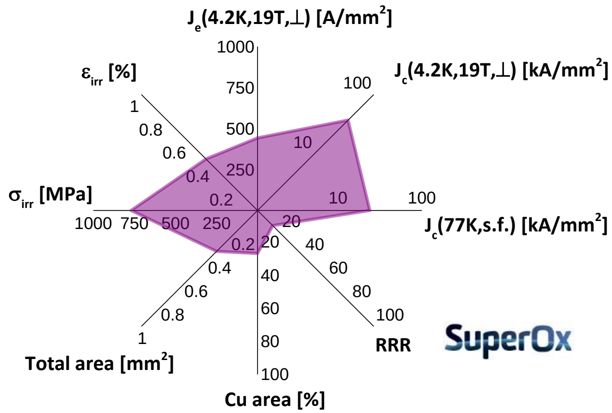
Main parameters at a glance

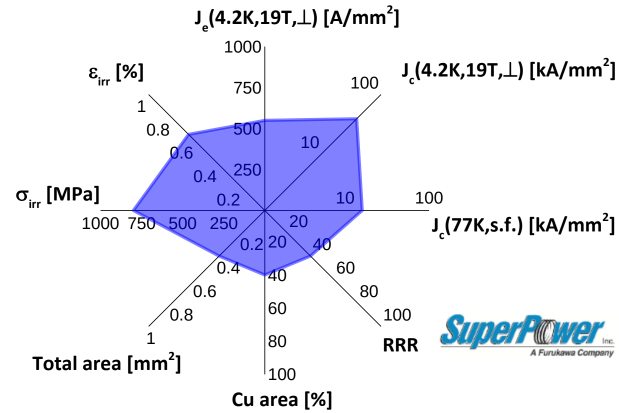




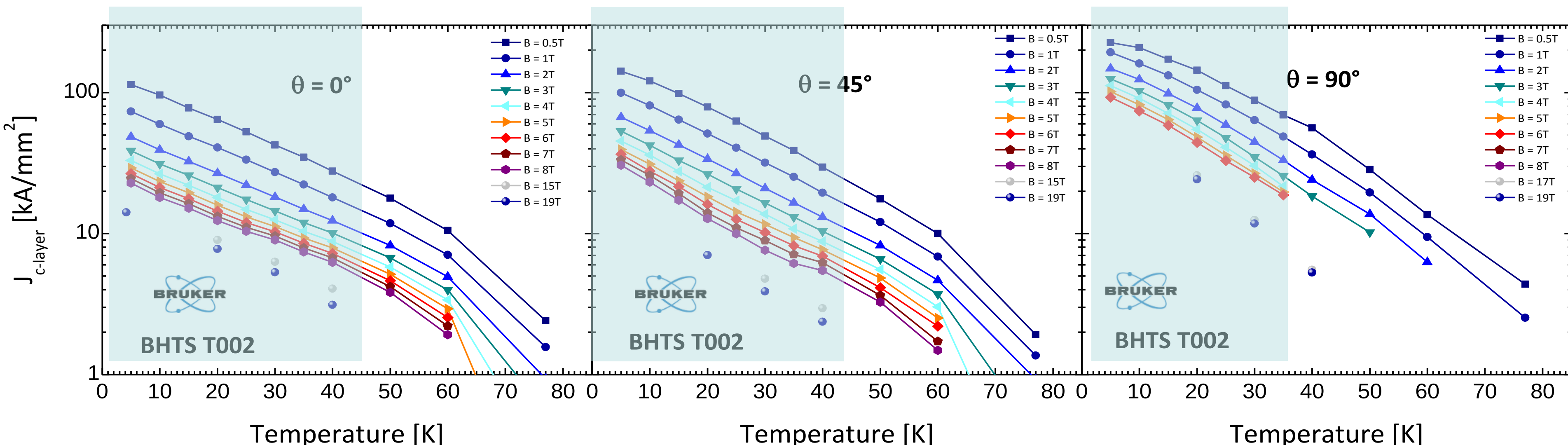








Scaling relations
Temperature dependence of J_c : 3 orientations



θ = 0° - *B//c*

θ = 45°

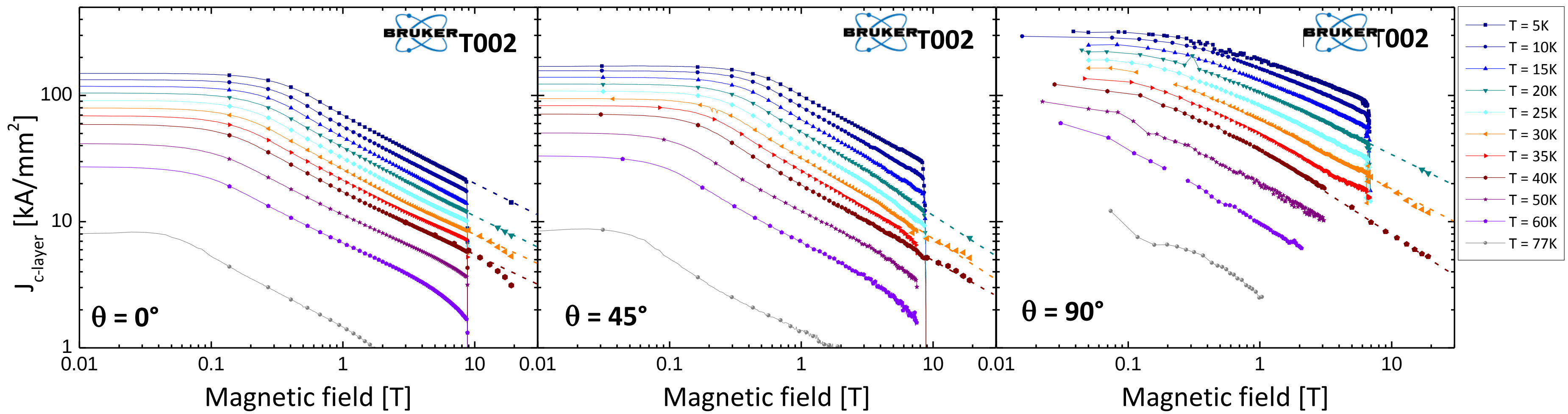
θ = 90° - *B//ab*

Temperature scaling relation

$$J_c(B,T) = J_c(B,T=0)\,e^{-\frac{T}{T^*}}$$

T* ranges between 15 K and 35 K – it depends on field and orientation

Scaling relations
Field dependence of J_c : 3 orientations



θ = 0° - *B//c*

θ = 45°

θ = 90° - *B//ab*

Field scaling relation

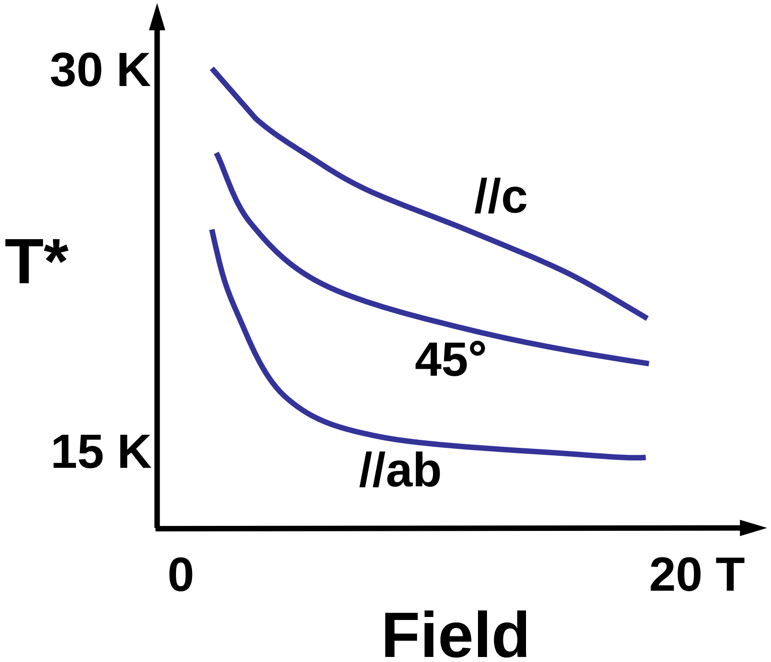
$$J_c(B,T) = J_c(B=0,T)\,B^{-\alpha}$$

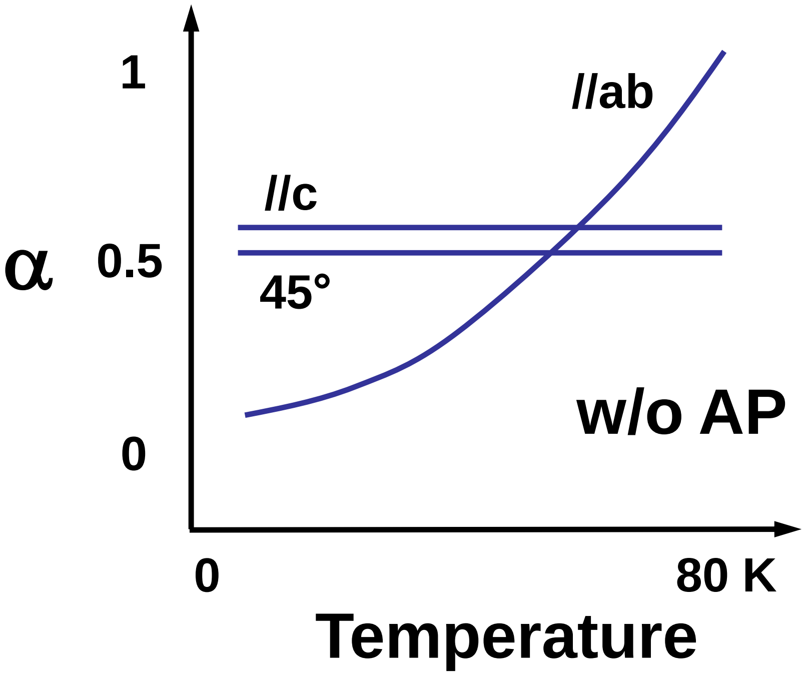
Temperature and field scaling of J_c

For temperatures below ~50 K, critical surface $J_c(B,T)$ in the form

$$J_c(B,T) = J_c(B=0,T=0)\,B^{-\alpha} e^{-\frac{T}{T^*}}$$

Scaling relation verified for $\theta = 0°$, 45° and 90°, but T and α depend on θ*





Lower T values ⇒ faster decrease of I_c with increasing T*

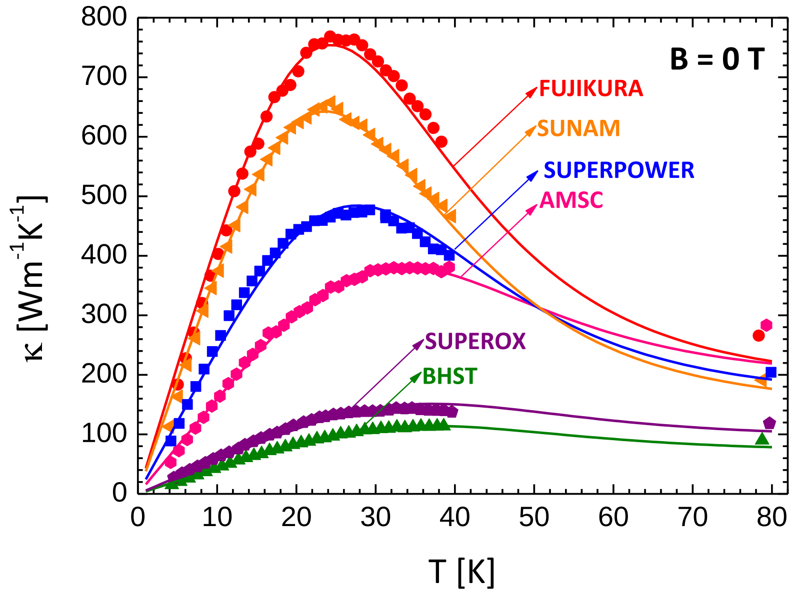
Higher α values ⇒ faster decrease of I_c with increasing B

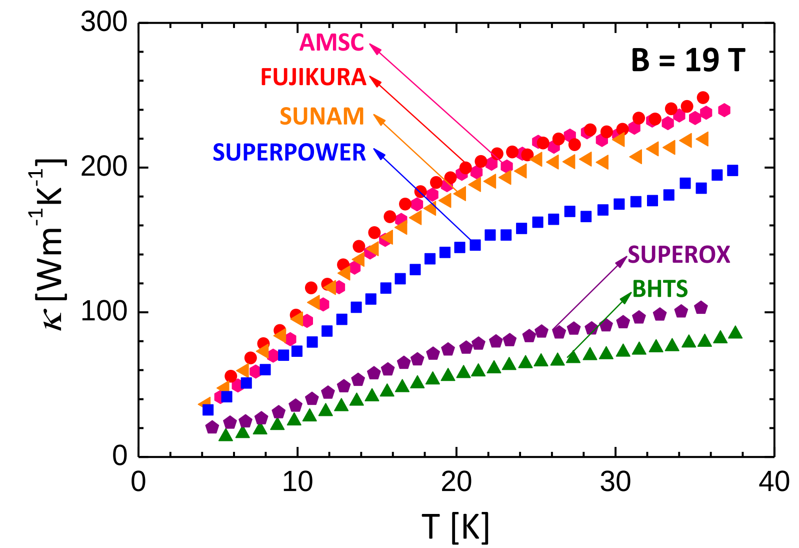
Thermo-physical properties
Thermal conductivity and RRR

$$\kappa_{exp} = \sum_i \kappa_i \frac{S_i}{S_{tot}} \approx \kappa_{Cu} \frac{S_{Cu}}{S_{tot}} \quad \text{and } \kappa_{Cu} = f(RRR_{Cu})$$

Manufacturer	RRR_{Cu} [*fit*]	RRR_{Cu} [$\rho(T)$]	S_{Cu}/S_{tot}
AMSC laminated	20	19	0.51
BHTS electroplated	14	17	0.20
FUJIKURA laminated	62	59	0.44
SUNAM electroplated	69	61	0.34
SUPEROX electroplated	13	14	0.27
SUPERPOWER electroplated	39	42	0.40

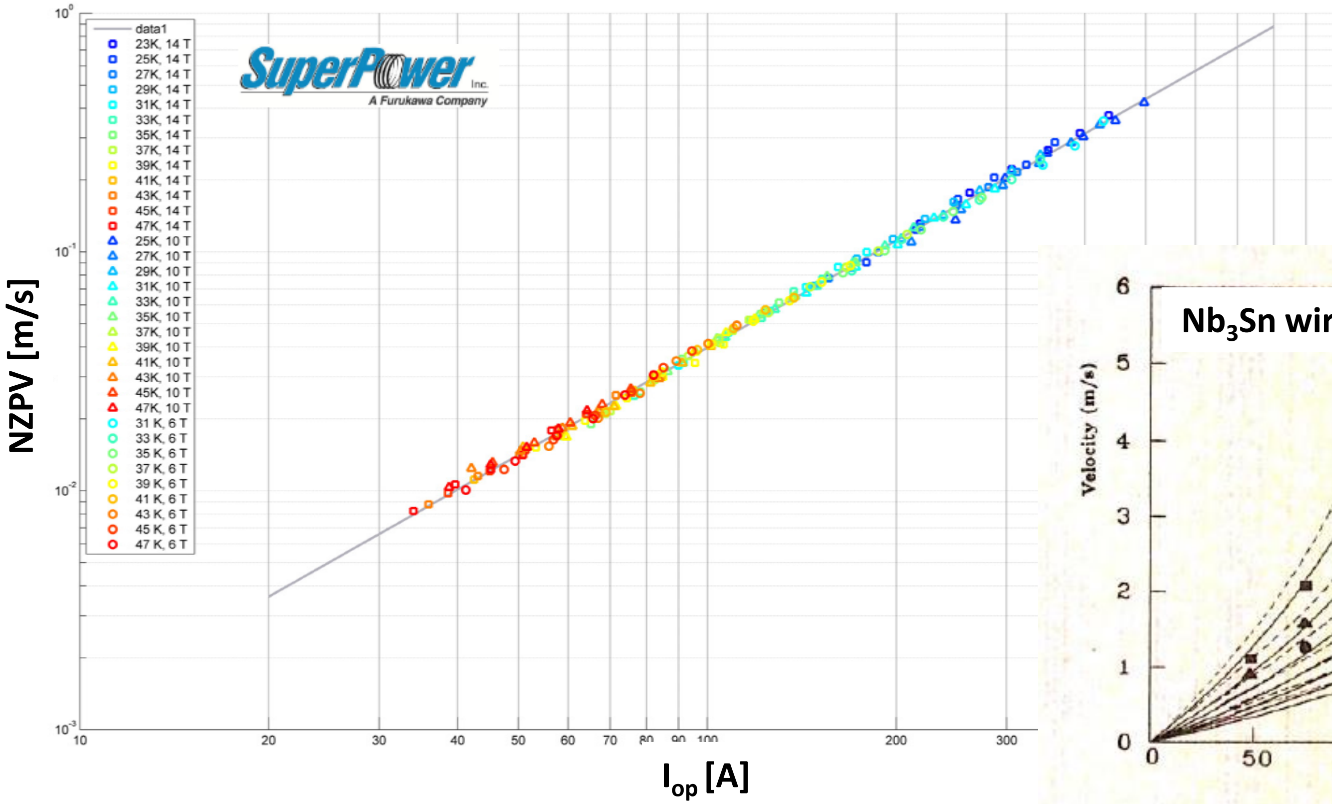
M. Bonura and CS, SuST 28 (2015) 025001





Normal zone propagation velocity

A puzzling result from the MSc report of J. van Nugteren



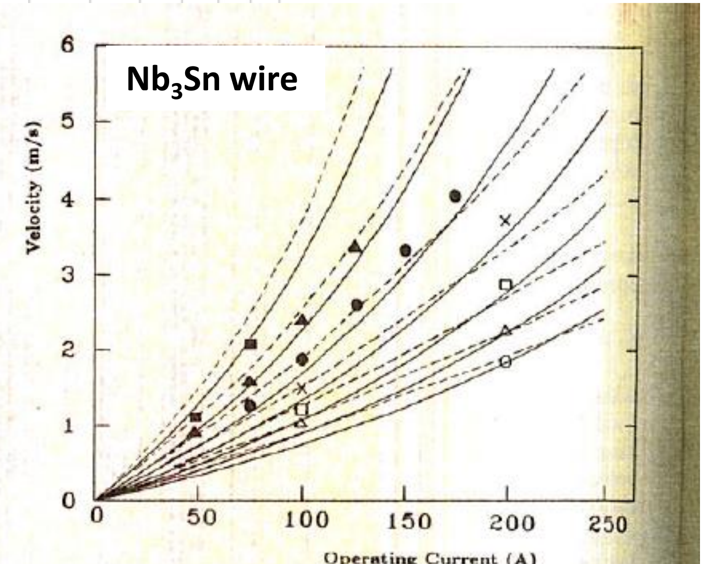


Figure 5 Comparison of the analytical results (——) and the experimental data[8] for U_l at T_∞ = 4.2 K for an Nb_3Sn composite under several ambient magnetic flux densities (in T): ○, 0; △, 2; □, 4; x, 6; ●, 8; ▲, 10; ■, 12. – – –, Analytical results presented in earlier work[8]. The wire diameter is 0.90 mm and the copper-to-superconductor ratio is 1.0

Z.P. Zhao and Y. Iwasa, Cryogenics 31 (1991) 817

Normal zone propagation velocity

From the solution of the transient heat conduction equation in an adiabatic environment

$$NZPV_L \approx \frac{I_{op}}{S_{tot}} \sqrt{\frac{\kappa(T_S)\rho(T_S)}{\int_{T_{op}}^{T_S} c_S(T_S)dT \left[c_n(T_S) - \frac{1}{\kappa(T_S)} \left.\frac{d\kappa}{dT}\right|_{T=T_S} \int_{T_{op}}^{T_S} c_S(T)dT \right]}}$$

where $T_S = T_{CS} + \frac{T_C - T_{CS}}{2}$

T_{CS} is determined by the $J_c(T)$ dependence

$$J_c(B,T) = J_c(B,T=0)e^{-\frac{T}{T^*}}$$

$$T_{CS} = T_{op} - T^* \ln\left[\frac{I_{op}}{I_c(B,T_{op})}\right]$$

T_S is ≈ 40 K and $\left.\frac{d\kappa}{dT}\right|_{T=T_S}$ is very small

The NZPV expression can be simplified

$$NZPV_L \approx \frac{I_{op}}{S_{tot}} \sqrt{\frac{LT_S}{c_n(T_S)\int_{T_{op}}^{T_S} c_S(T)dT}}$$

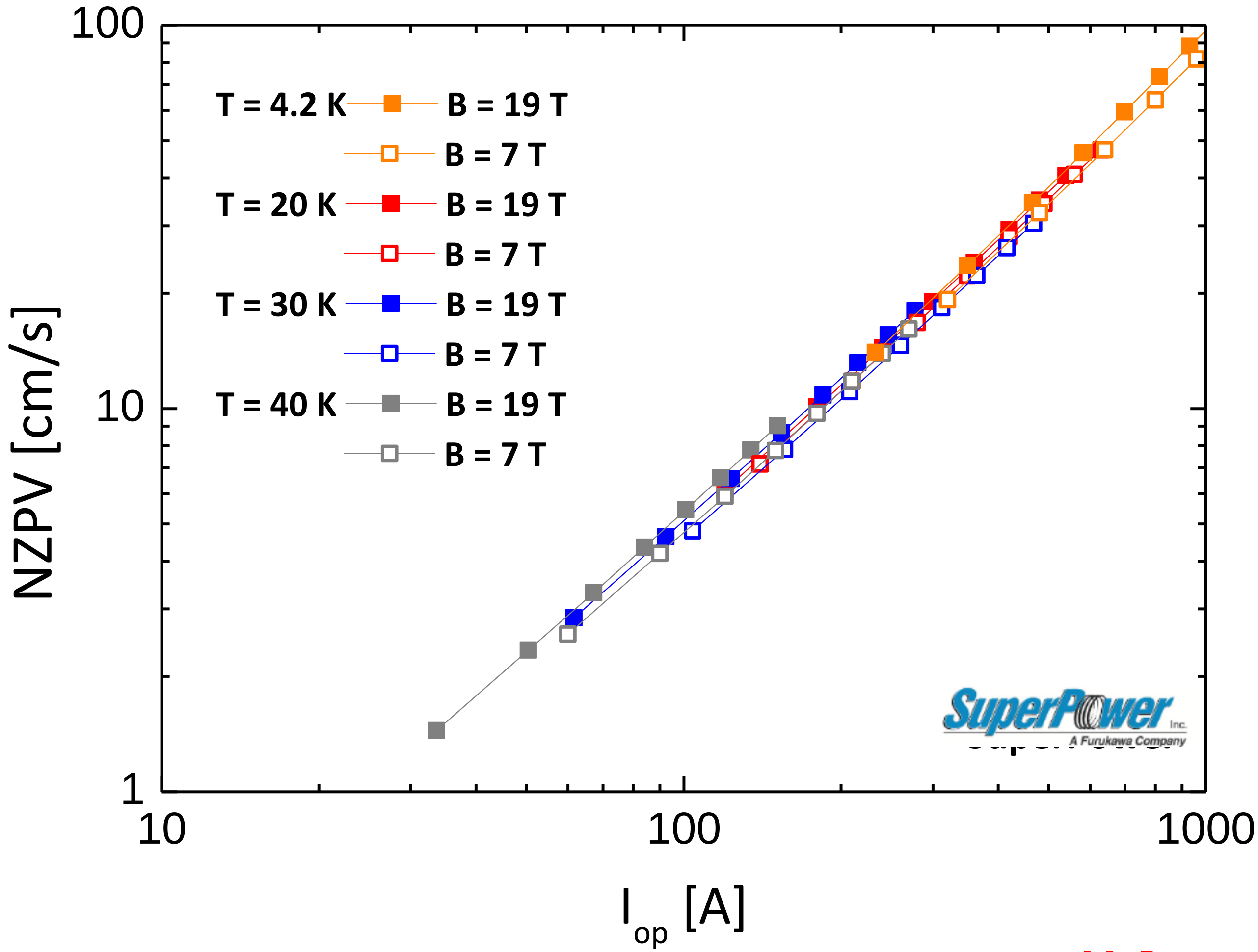
This is very different from the textbook approximation for LTS

$$NZPV_L \approx \frac{I_{op}}{S_{tot}} \sqrt{\frac{LT_S}{c_n c_S (T_S - T_{op})}}$$

M. Bonura and CS, WAMHTS-3

Normal zone propagation velocity

From the experimental κ , ρ , c , $J_c(T)$, NZPV is found to depend only on I_{op} following a power law



M. Bonura and CS, WAMHTS-3

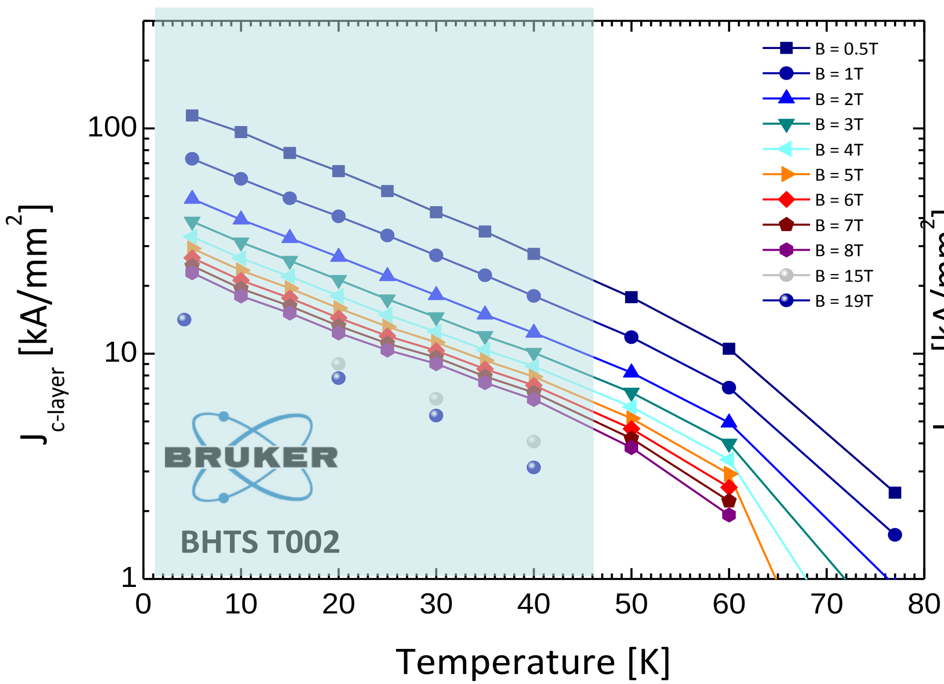
Outlook

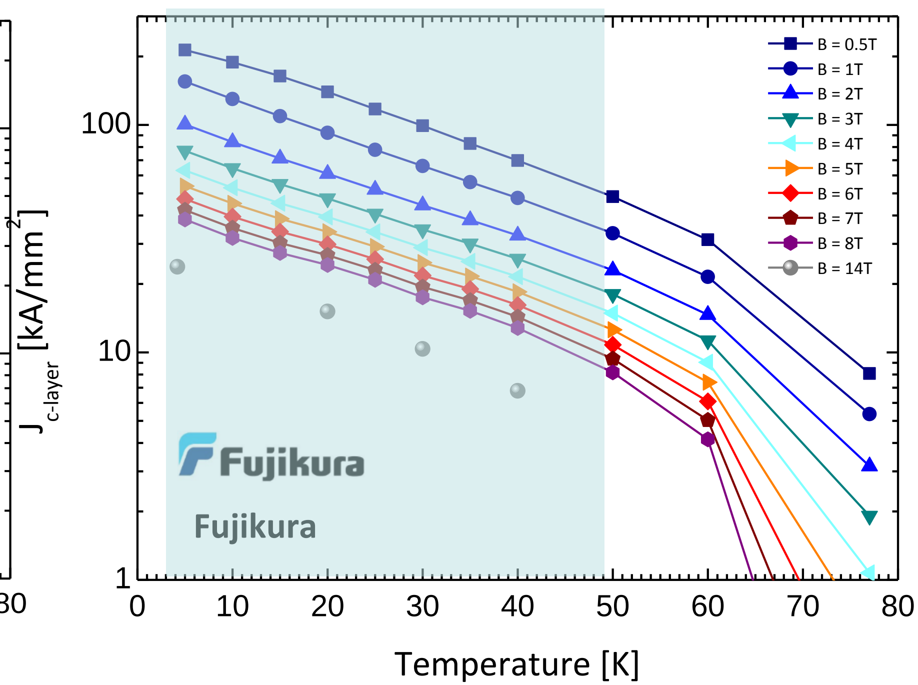
- ***Adapt the scaling relations for the tapes with enhanced pinning***

- ***Extend the NZPV analysis to the other manufacturers***

Temperature dependence of J_c

θ = 0° - B//c



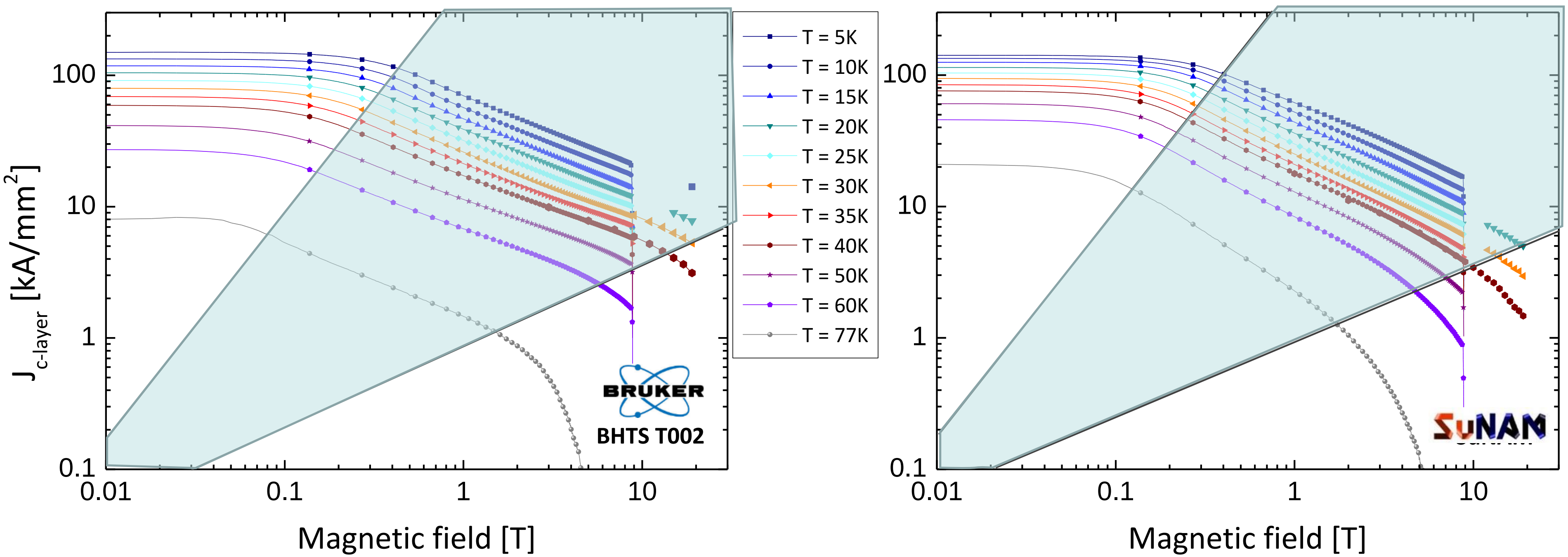


Temperature scaling relation

$$J_c(B,T) = J_c(B,T=0)\,e^{-\frac{T}{T^*}} \Rightarrow \frac{J_c(B,T_1)}{J_c(B,T_2)} = e^{-\frac{T_1 - T_2}{T^*}}$$

Field dependence of J_c

$\theta = 0° - B//c$



Field scaling law $J_c(B,T) = J_c(B=0,T)\,B^{-\alpha}$

α is almost constant below 40 K, the value varies between 0.5 and 0.8