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RF performances of superconducting coatings on copper for the FCC study

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On behalf of FCC RF - WP 3

FCC week 2019
Brussels

“A well-focused R&D programme on Nb thin-film coated Cu cavities could decrease the surface resistance at high RF fields by factors of two to three…”

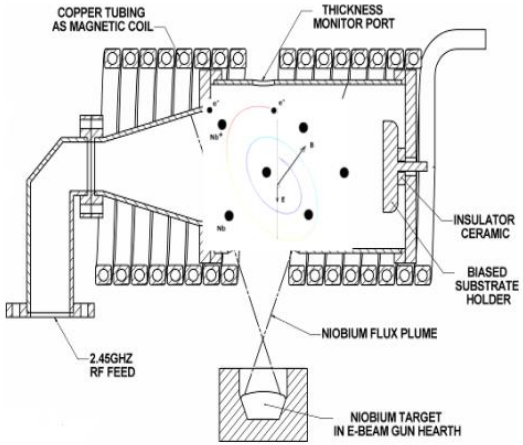
See FCC conceptual design report @ fcc.web.cern.ch

Different Nb coating techniques

A15: beyond niobium

Energetic condensation techniques are explored

Electron Cyclotron Resonance

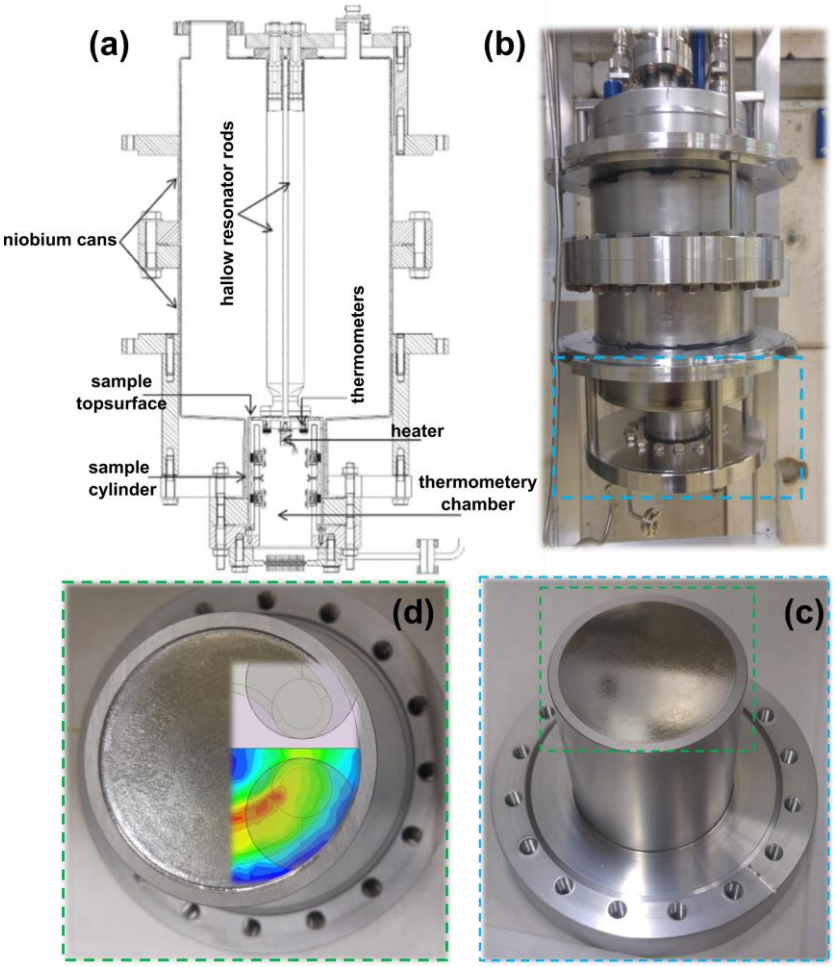


Jefferson Lab

High Power Impulse Magnetron Sputtering

See A.-M. Valente-Feliciano, et al. *Supercond. Sci. Technol.* **29** (2016)

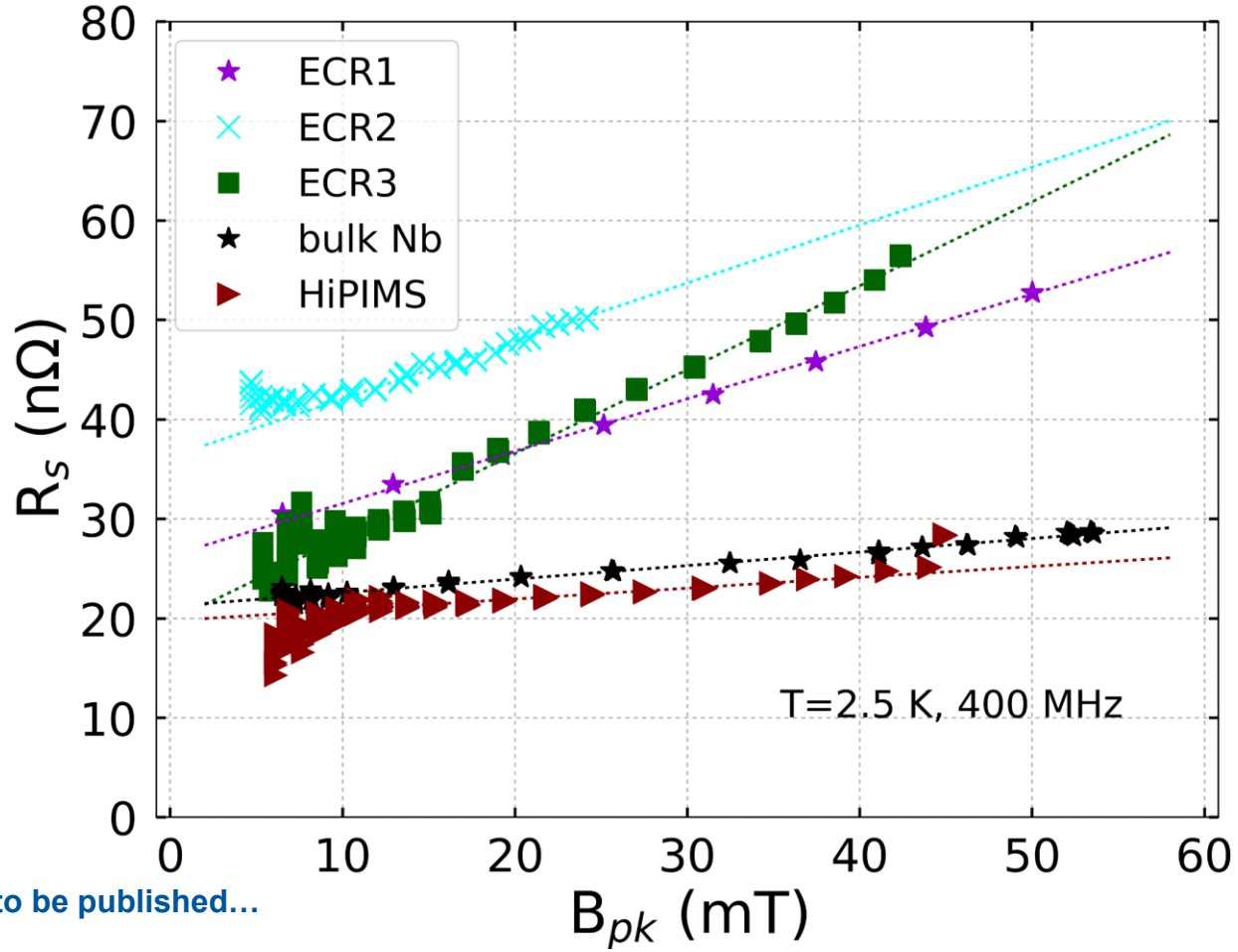
RF performances characterized via the quadrupole resonator



Calorimetric technique

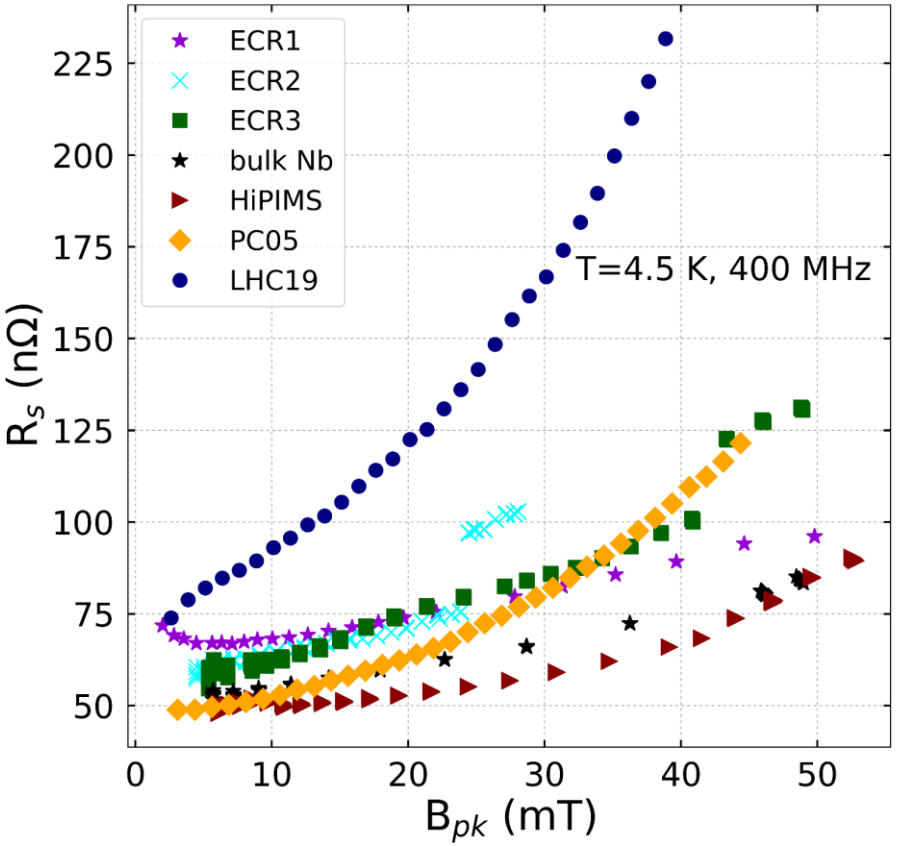
$$R_s = \frac{2\mu_0^2(P_{DC1} - P_{DC2})}{\int_{sample} |\overrightarrow{B}|^2 dS}$$

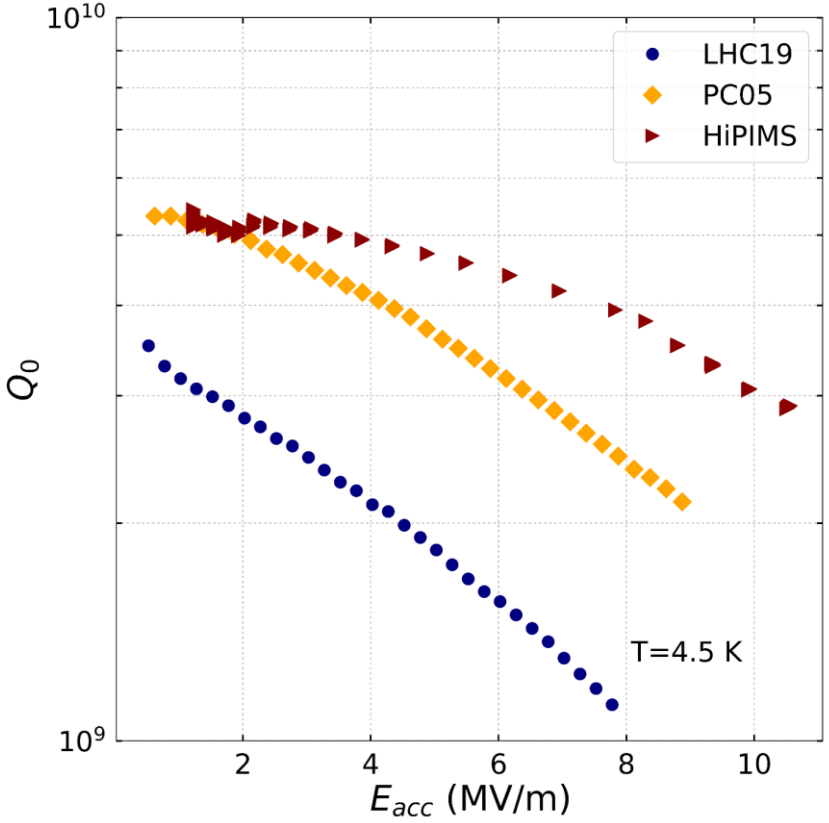
The best Nb/Cu samples in the last two years



Data to be published…

Now, let's play the game…

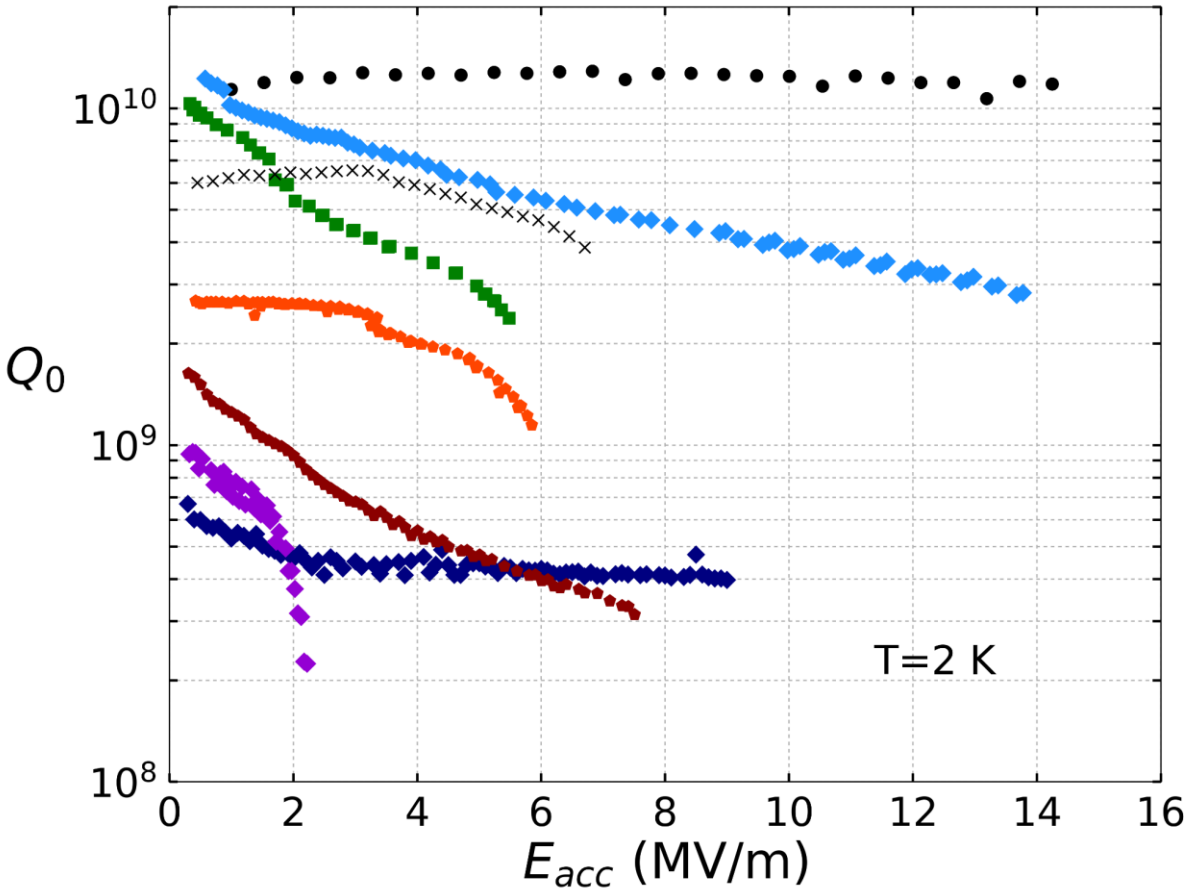




Data to be published…

G=260 Ω - $\frac{B_{pk}}{E_{acc}} = 5$ mT/MV/m

Can we replicate on a cavity?

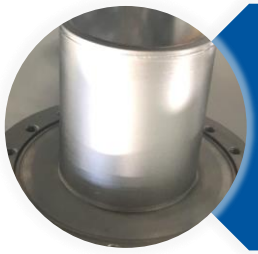


Bulk Nb
AM-SL2.1 (HiPIMS, 2019)
M 5.1 (HiPIMS -100 V, 2016)
M 5.5 (HiPIMS -50 V, 2017)
M 5.3 (HiPIMS -25 V, 2017)
M 1.7 (HiPIMS floating, 2017)
H 11.1 (HiPIMS -25 V, 2017)
N 1.1 (HiPIMS, 2019)

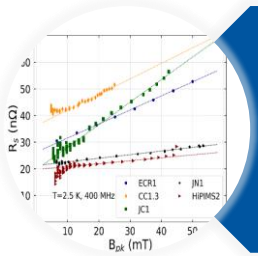
1.3 GHz elliptical cavities

Better substrates are needed

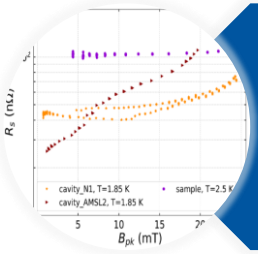
Conclusions and Outlook



Both HiPIMS and ECR high quality coatings



Both techniques mitigate the Q-slope

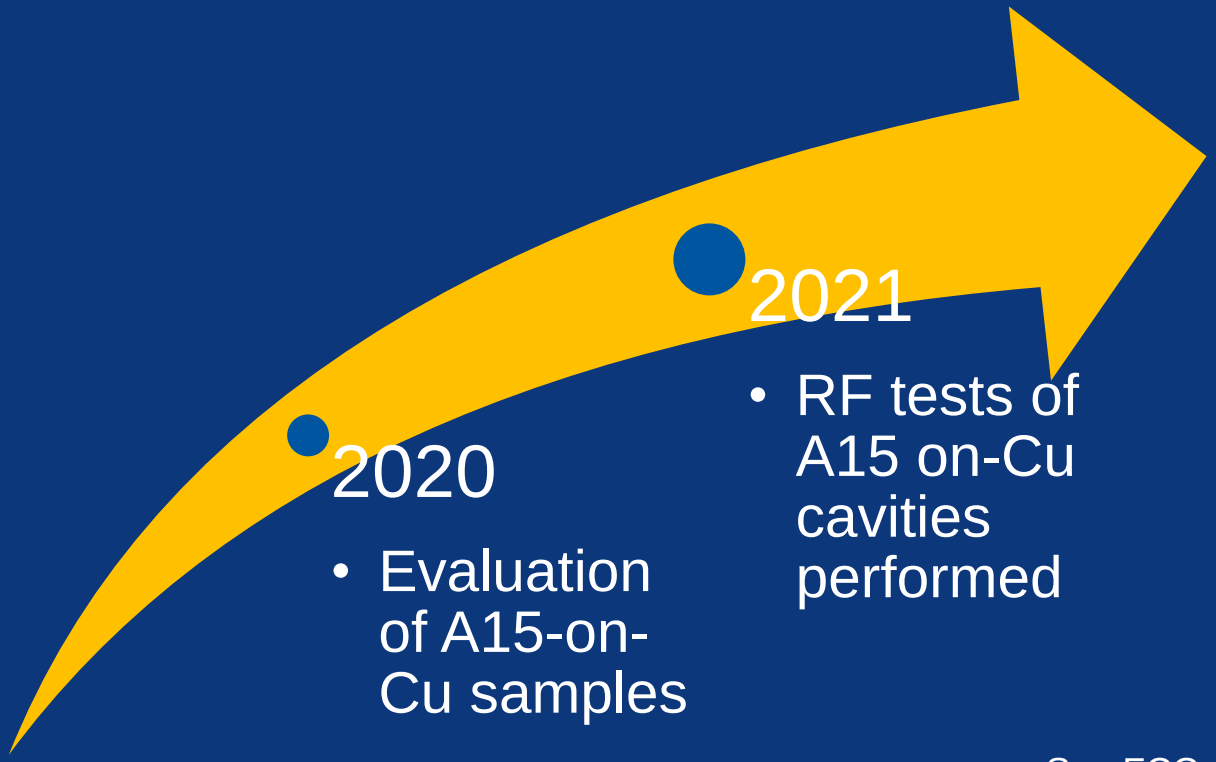


Results are still not fully reproducible on cavities

Beyond

Source: lapiumablog.com

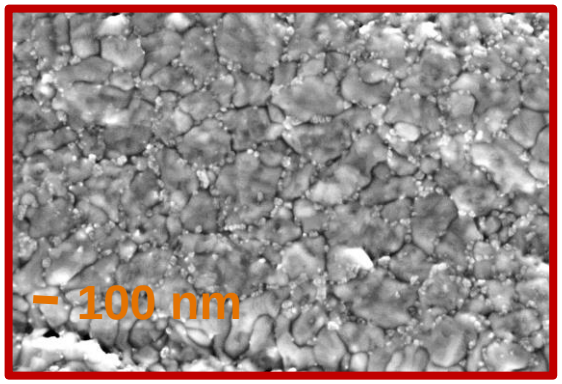
“The A15 compounds have the potential to outperform niobium…”



See FCC conceptual design report @ fcc.web.cern.ch

Two coating procedures by magnetron sputtering

reacted after coating



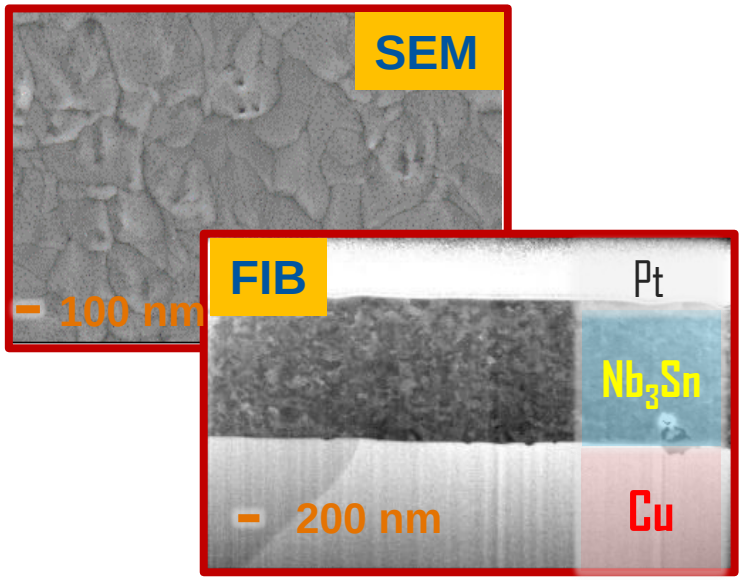
Main coating parameters:

Coating gas: *Ar* or *Kr*

Coating pressures:
$7x10^{-4}$ *mbar* … $5x10^{-2}$ *mbar*

Composition:
Sn 20 At% to 27 At%

reacted during coating



Compulsory Annealing

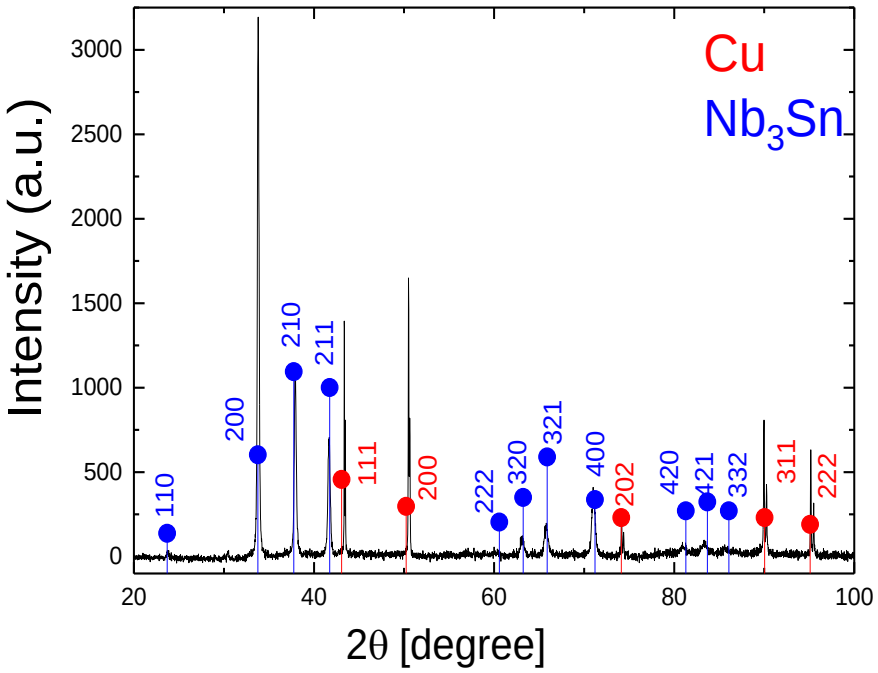
Annealing temperatures	600 - 800ºC
Annealing time	24 h… 72 h

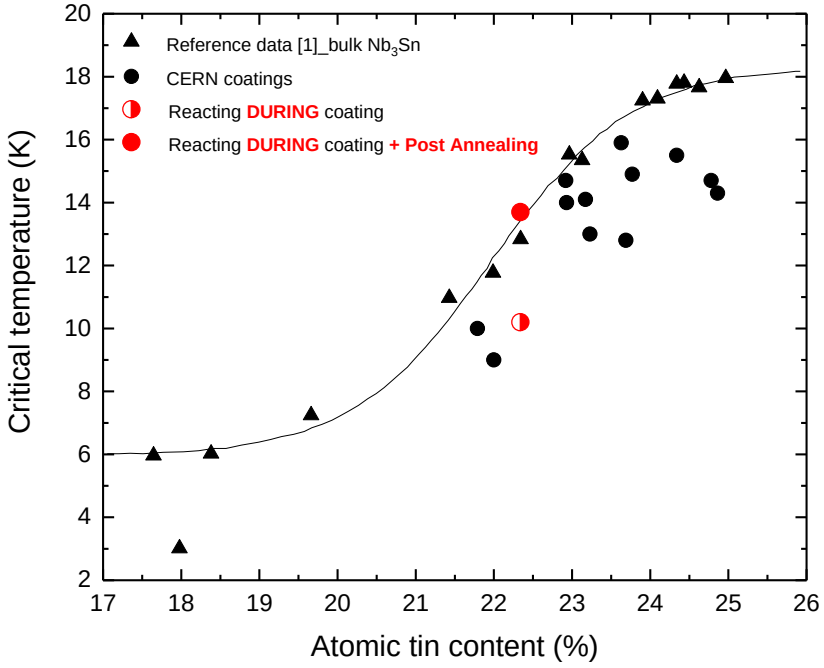
Alternative Annealing

Coating temperatures	600 - 735ºC
Alternative Additional Annealing	24 h… 72 h

For more details see: E. A. Ilyina, *et al. Supercond. Sci. Technol.*, **32** *(2019)*

A15 phase with Tc as bulk



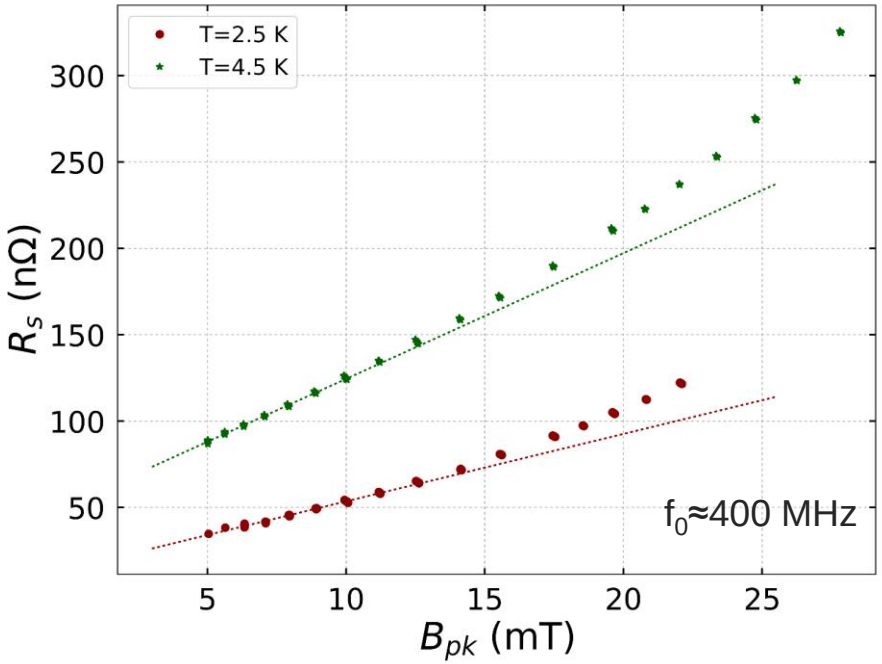


For more details see:
E. A. Ilyina, *et al. Supercond. Sci. Technol.*, **32** *(2019)*

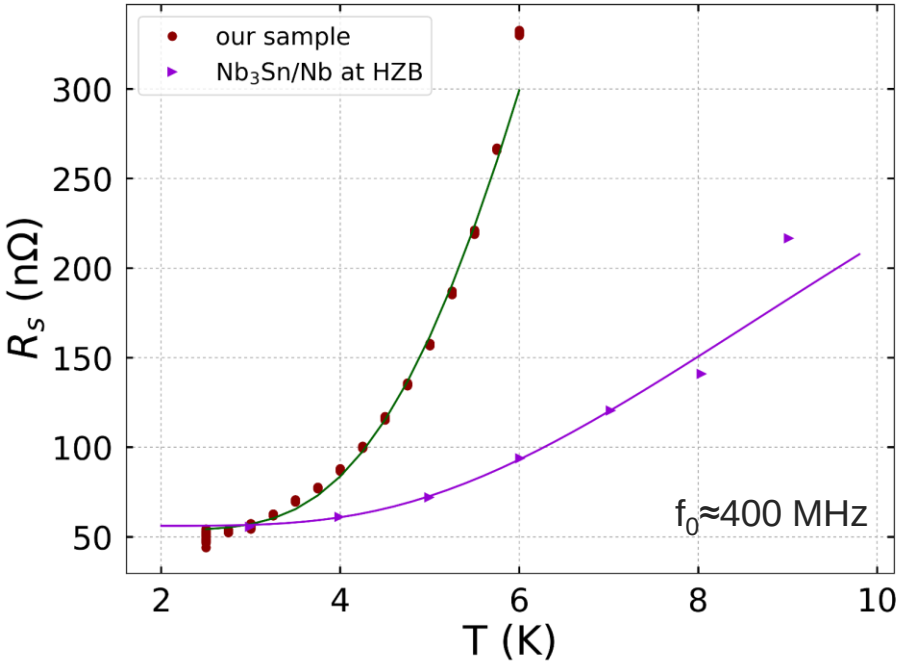
[1] A. Godeke, *Supercond. Sci. Technol.*, **19** *(2006)*

First RF results are promising

pronounced “Q-slope”

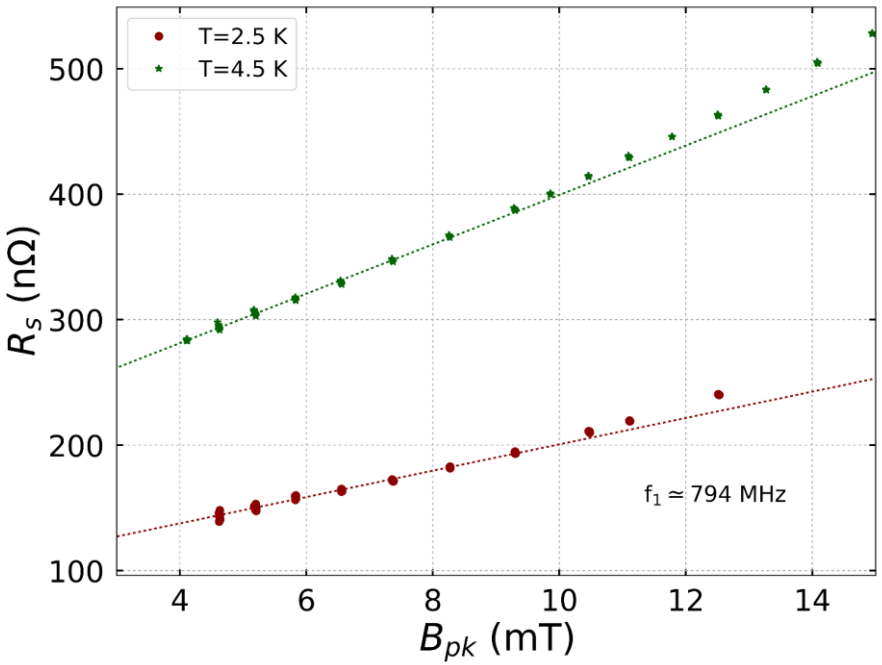


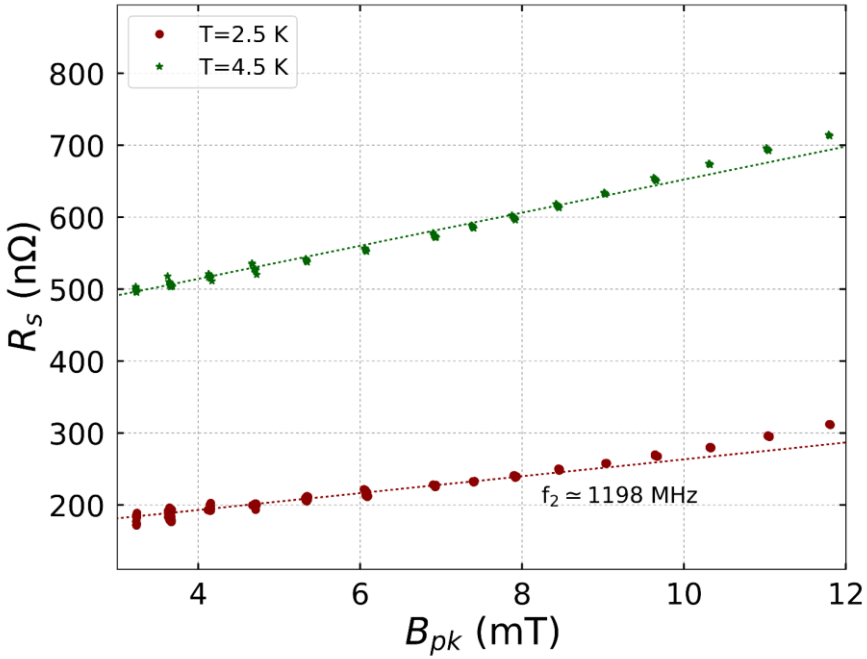
low Tc on QPR sample



Nb_3Sn/Nb data taken from
S. Keckert et al., SRF2017

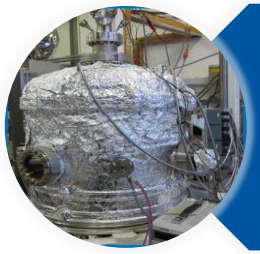
Pronounced Q-slope



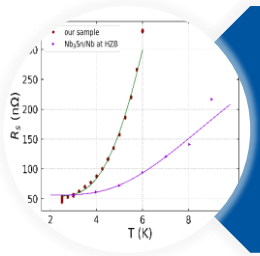


The slope increases with both temperature and frequency

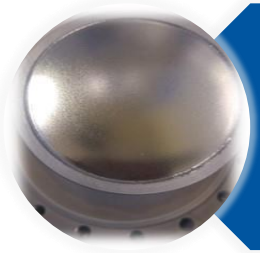
Conclusions and Outlook



Good quality of the Nb_3Sn coatings

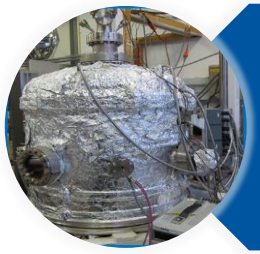


Low residual resistance



New samples are ready for RF tests

Conclusions and Outlook



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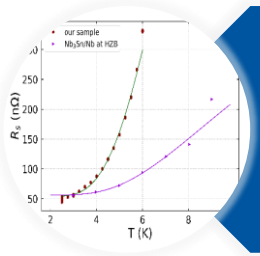
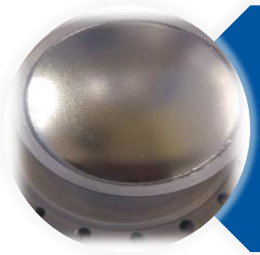


Low residual resistance



New samples are ready for RF tests

There are reasons to be optimistic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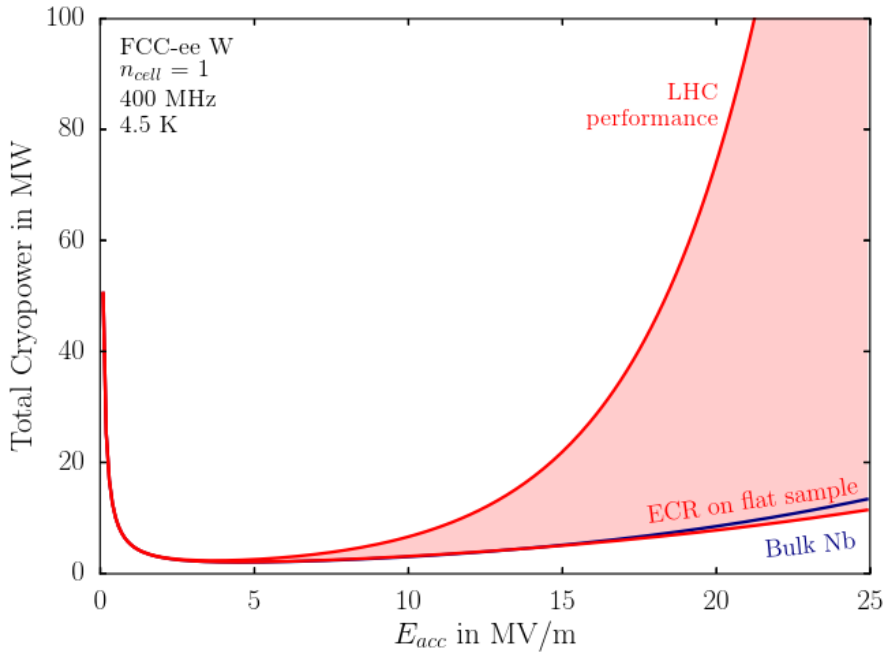
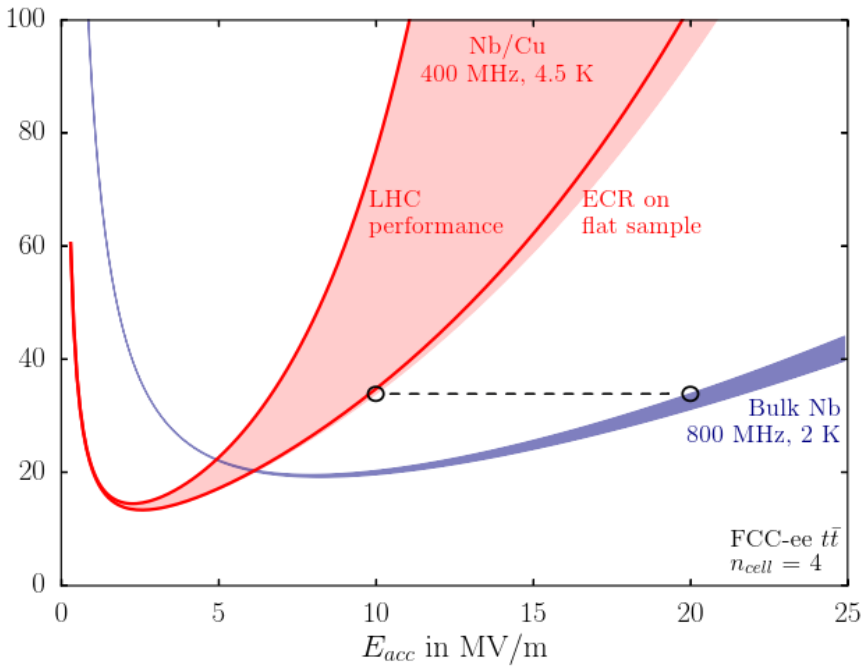
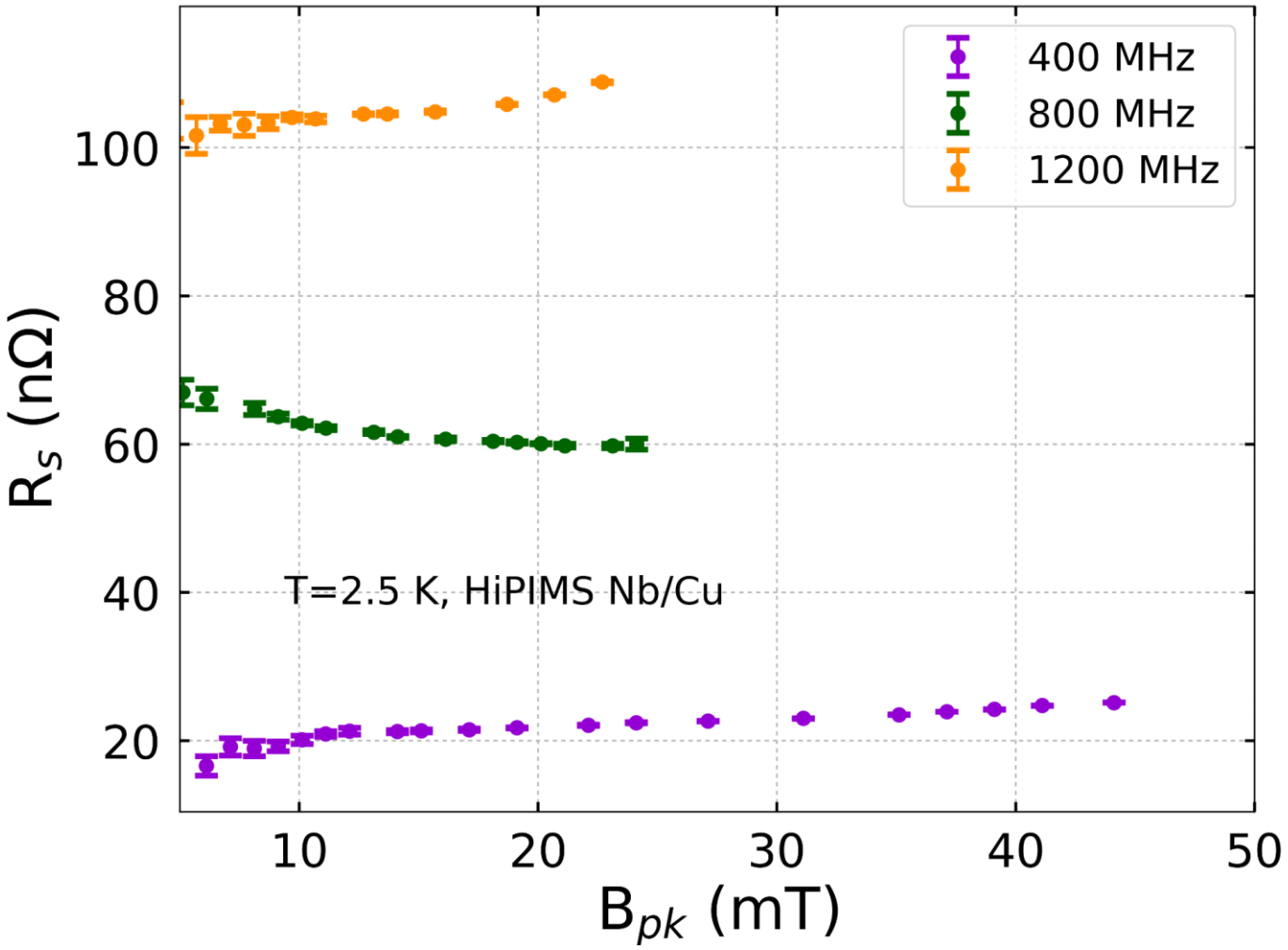
Nb/Cu vs bulk Nb for FCC-ee

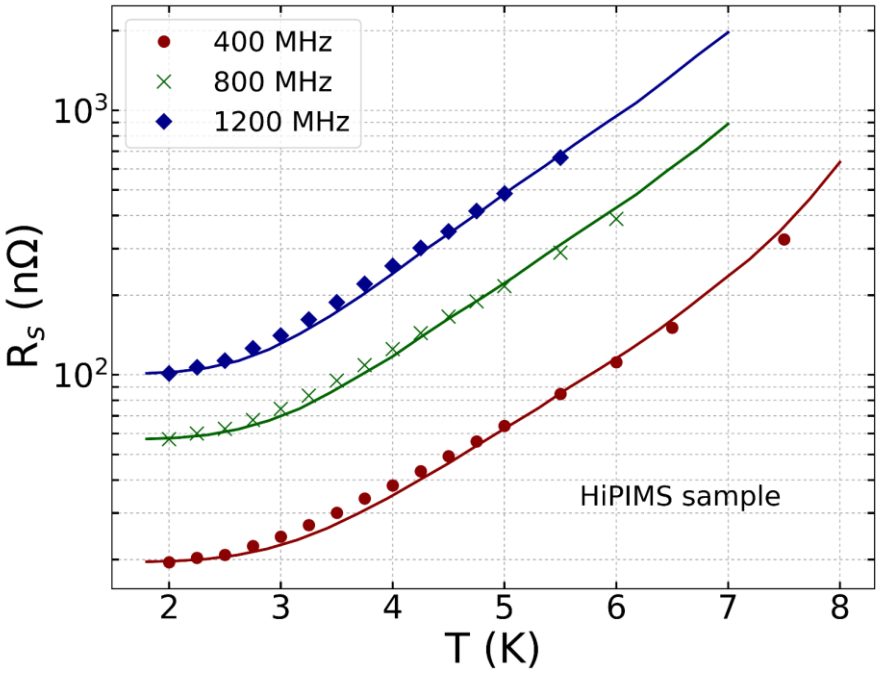


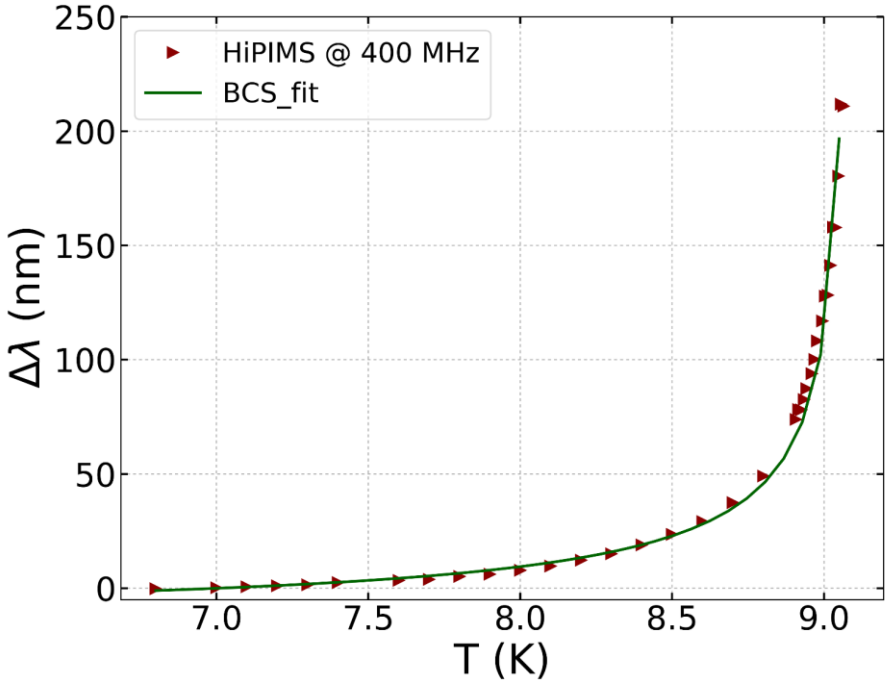
Courtesy of S. Aull, *FCC week 2017*



S. Aull, and co. *FCC-DRAFT-TECH-2017-002* (2017)


400 MHz
800 MHz
1200 MHz
T=2.5 K, HiPIMS Nb/Cu
R_s (nΩ)
B_{pk} (mT)
100
80
60
40
20
10
20
30
40
50


400 MHz
800 MHz
1200 MHz
10^3
10^2
R_s (nΩ)
HiPIMS sample
2
3
4
5
6
7
8
T (K)


HiPIMS @ 400 MHz
BCS_fit
250
200
150
100
50
0
Δλ (nm)
7.0
7.5
8.0
8.5
9.0
T (K)