SRF 2015 WHISTLER

On the Understanding of the Q-Slope of Niobium Thin Films

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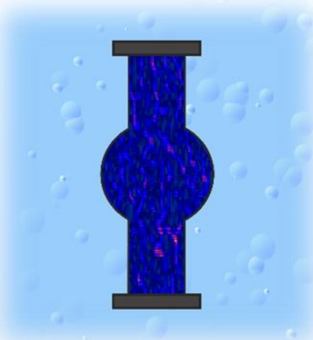
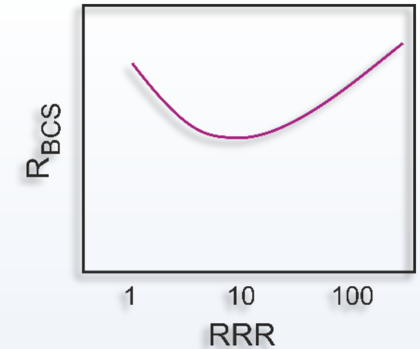
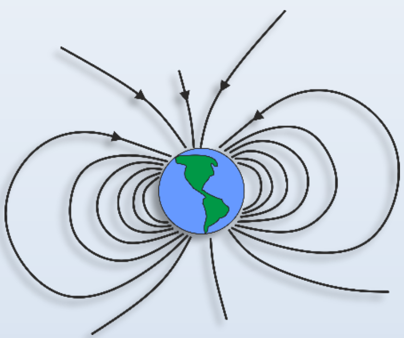


No thermal runaway



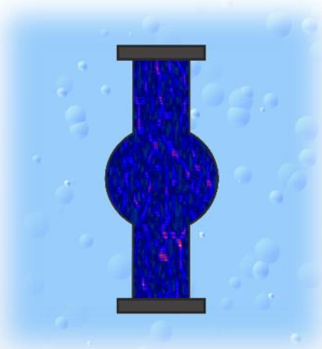
Minimize BCS losses



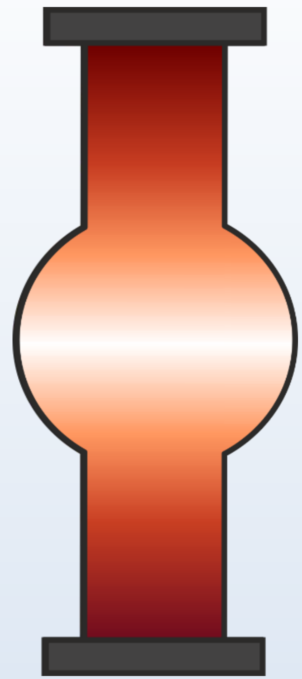
No magnetic shielding

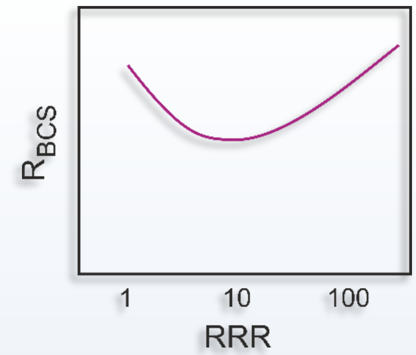
Save on raw material

Nb/Cu Technology

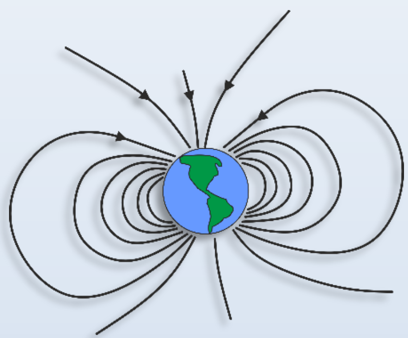


No thermal runaway





Minimize BCS losses

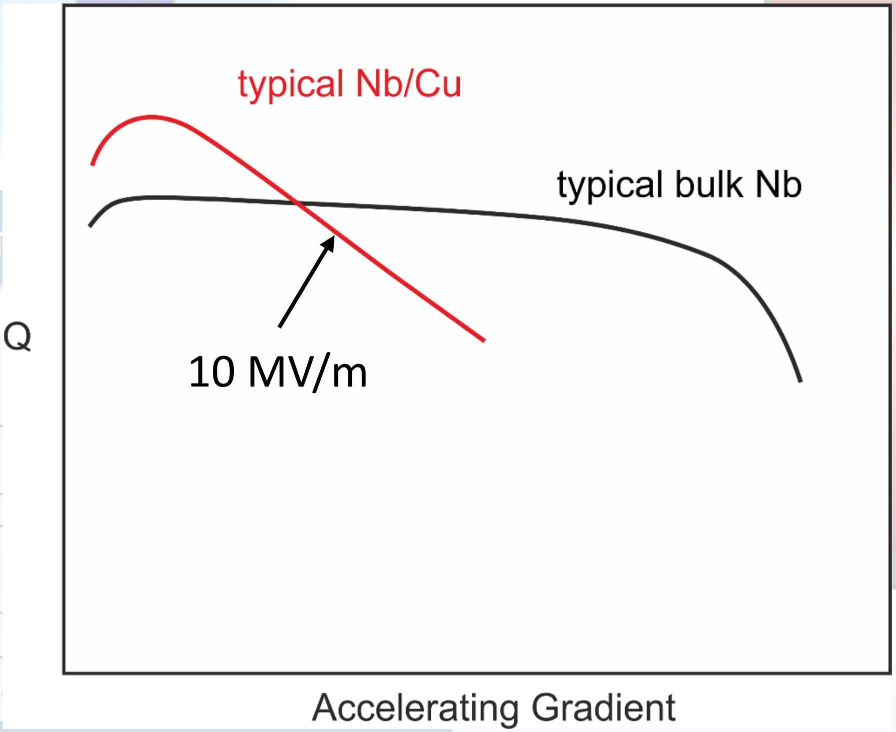


No magnetic shielding

Save on raw material

Niobium Film Technology

No therm



Q-Slope limits Nb/Cu technology to low accelerating gradients

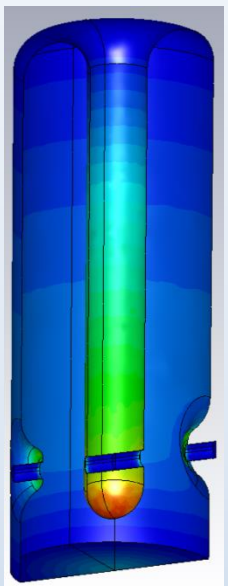
No magnetic shielding

WHERE ARE WE TODAY?

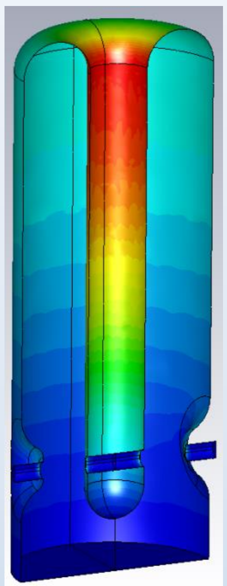
Nb/Cu Technology for HIE Isolde

See also TUPB027

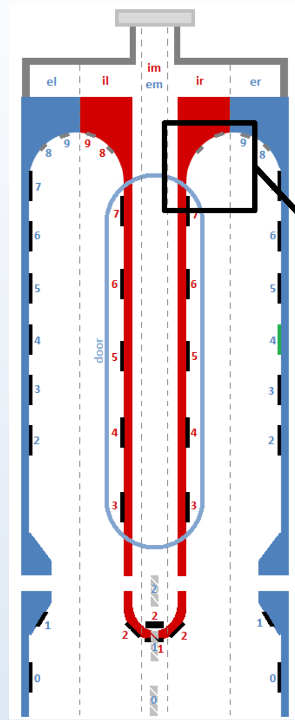
Quarter-wave Resonator	
Frequency	101 MHz
E_{acc}	6 MV/m
G	30.7 Ω



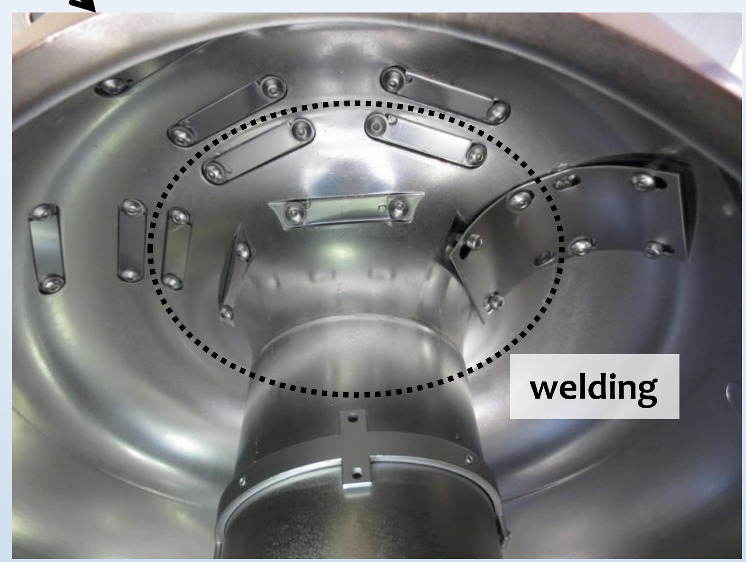
|E| field



|H| field



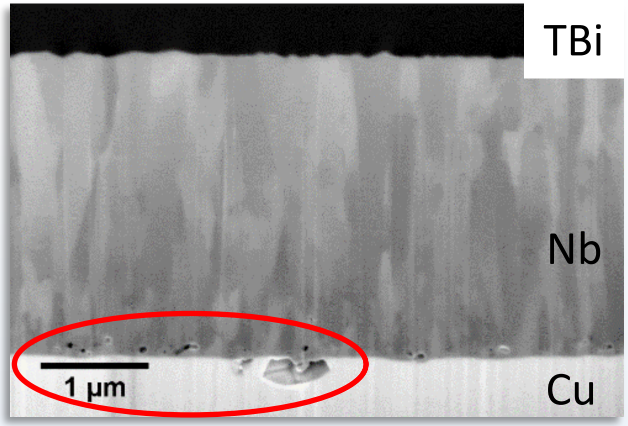
Mockup cavity for coating samples comparable to cavity coatings

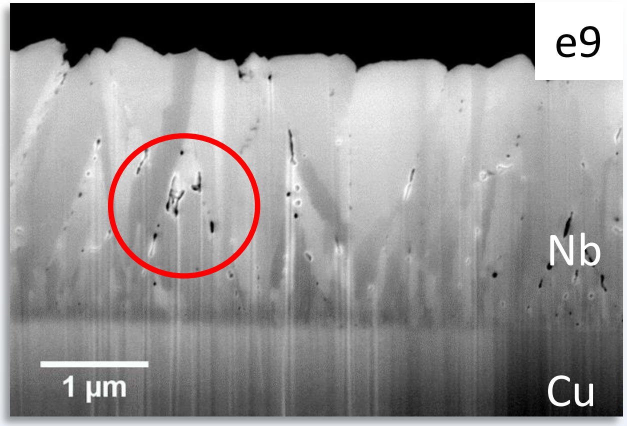


Microstructure and RF Performance

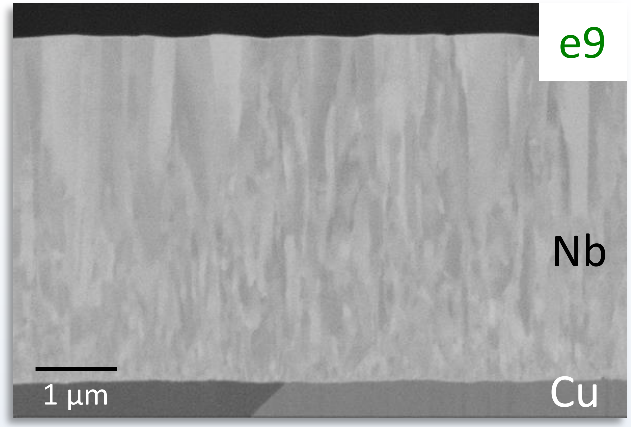
See also TUPB027

Courtesy B. Bartova (CERN)

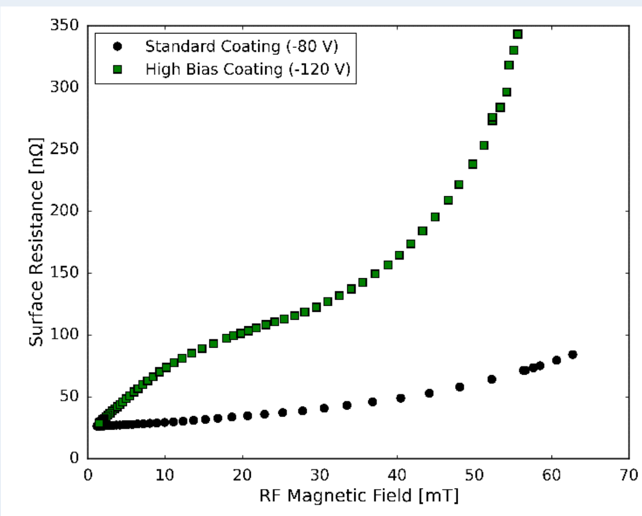


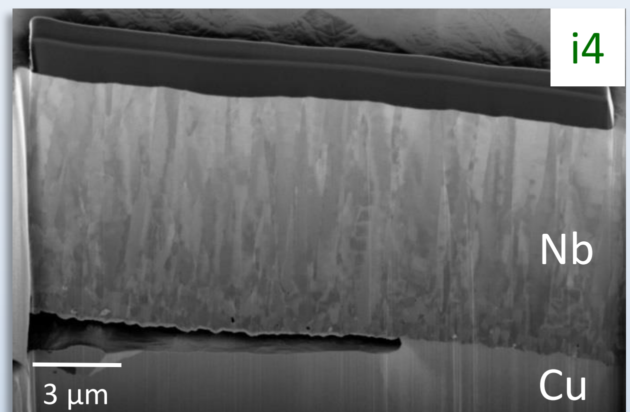


Standard coating bias (-80 V)



High coating bias (-120 V)





High coating bias (-120 V)

Very dense film but delamination due to high stress in the film

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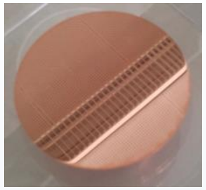
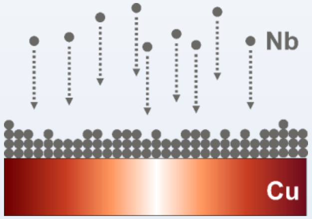
Sample Preparation

See also TUPB029

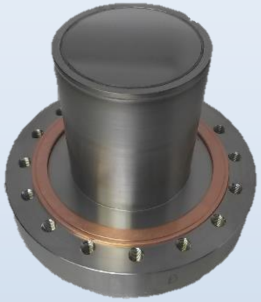
Mechanical polishing & 12 µm EP



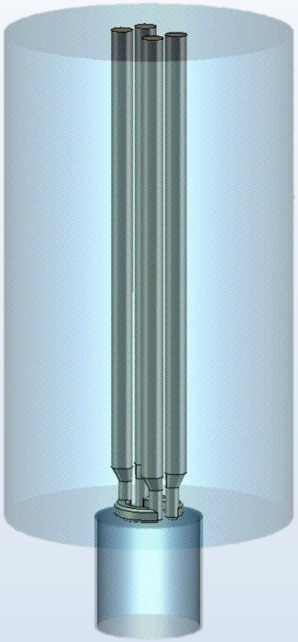
Nb coating at JLab



Electron beam welding & Ultra-pure water rinse



RF cold test in CERN's Quadrupole Resonator



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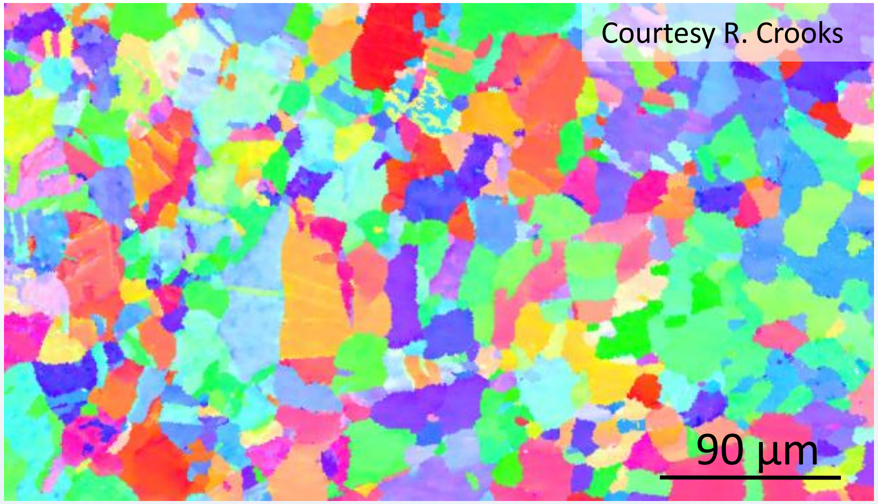
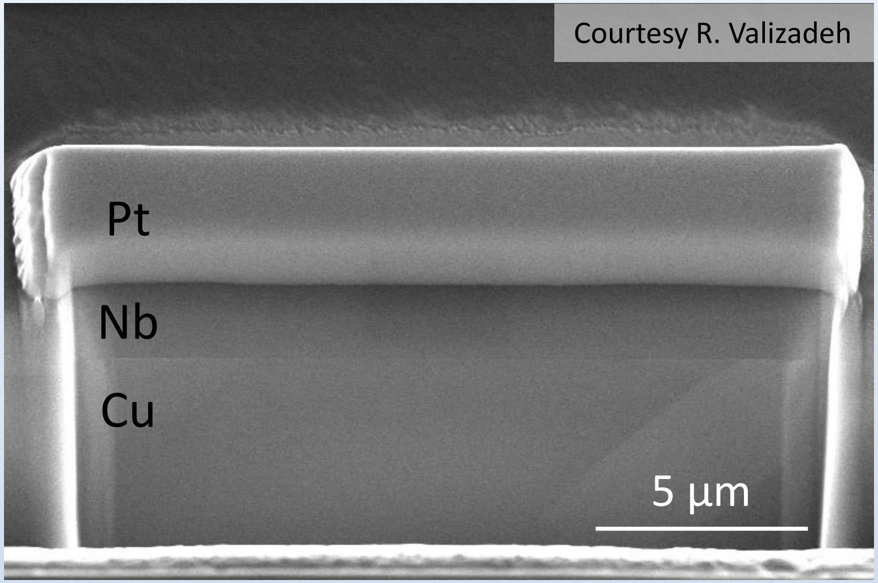
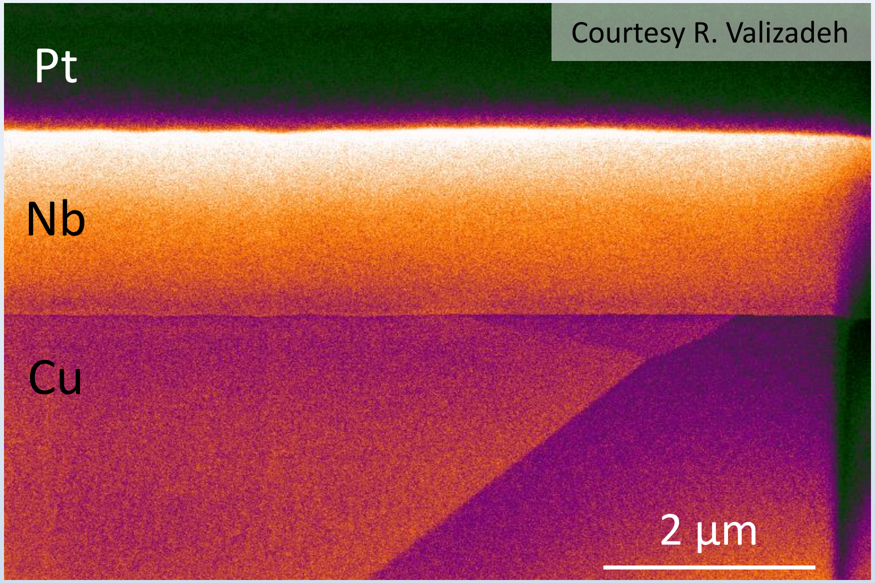
Microstructure of the Nb/Cu Sample



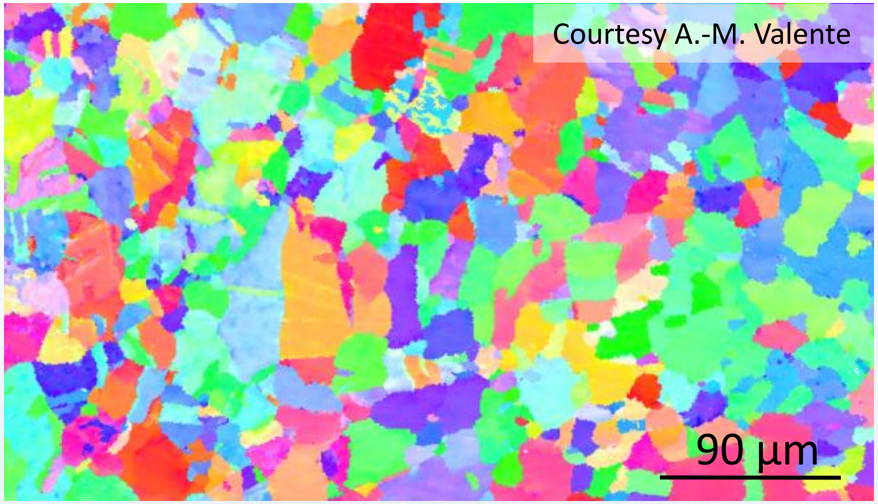
Grain size copied from Cu substrate (~ 50 µm)

No visible porosity
Smooth interface

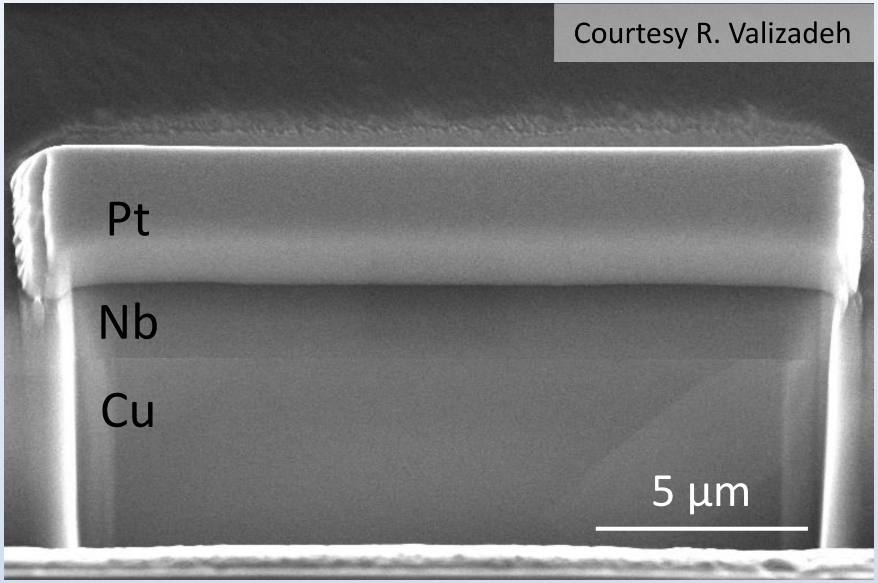


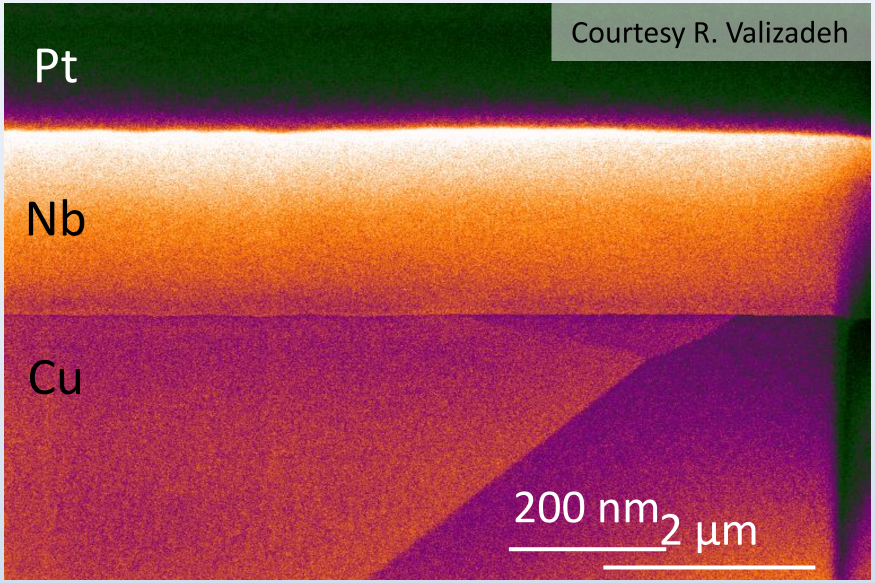


Crystal Structure of the Nb/Cu Sample

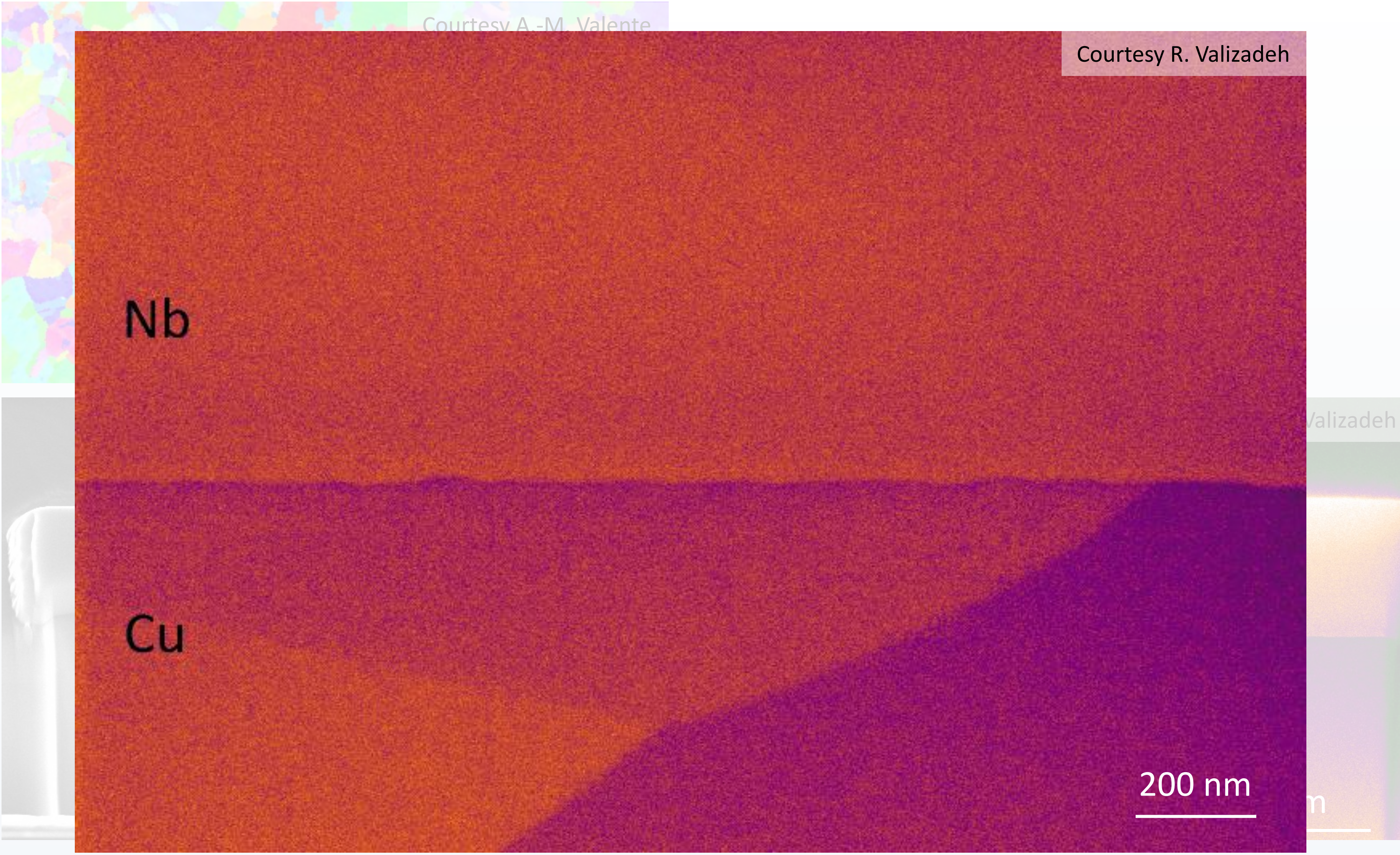


- Grain size copied from substrate (~ 50 µm)
- Dense film
- Smooth interface
- No visible porosity





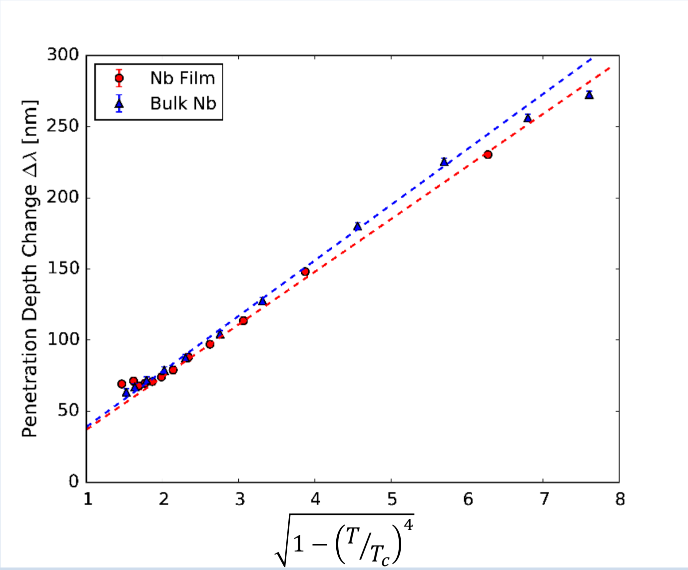
Crystal Structure of the Nb/Cu Sample

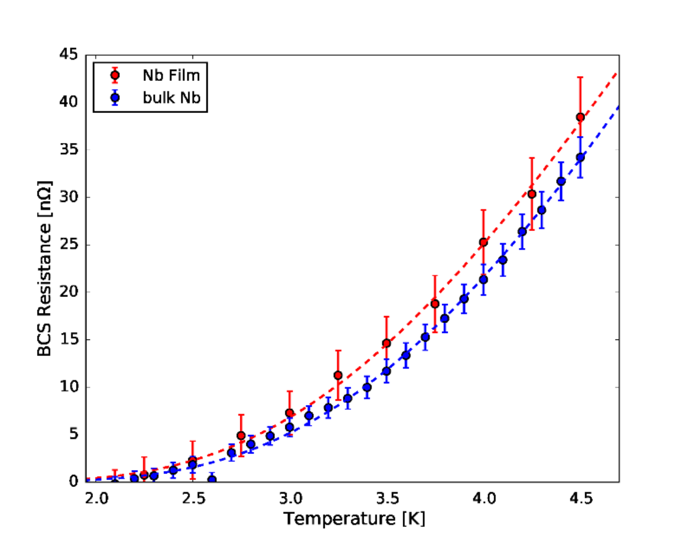


SC Properties

	Nb/Cu	bulk Nb
Penetration Depth $\lambda(0K)$ [nm]	37 ± 2	39 ± 2
Mean free path [nm]	182 ± 24	126 ± 18
RRR	67 ± 9	47 ± 7
R_{res}(400 MHz) [nΩ]		
Energy gap $\Delta/_{kT_c}$		

Nb film has bulk-like properties





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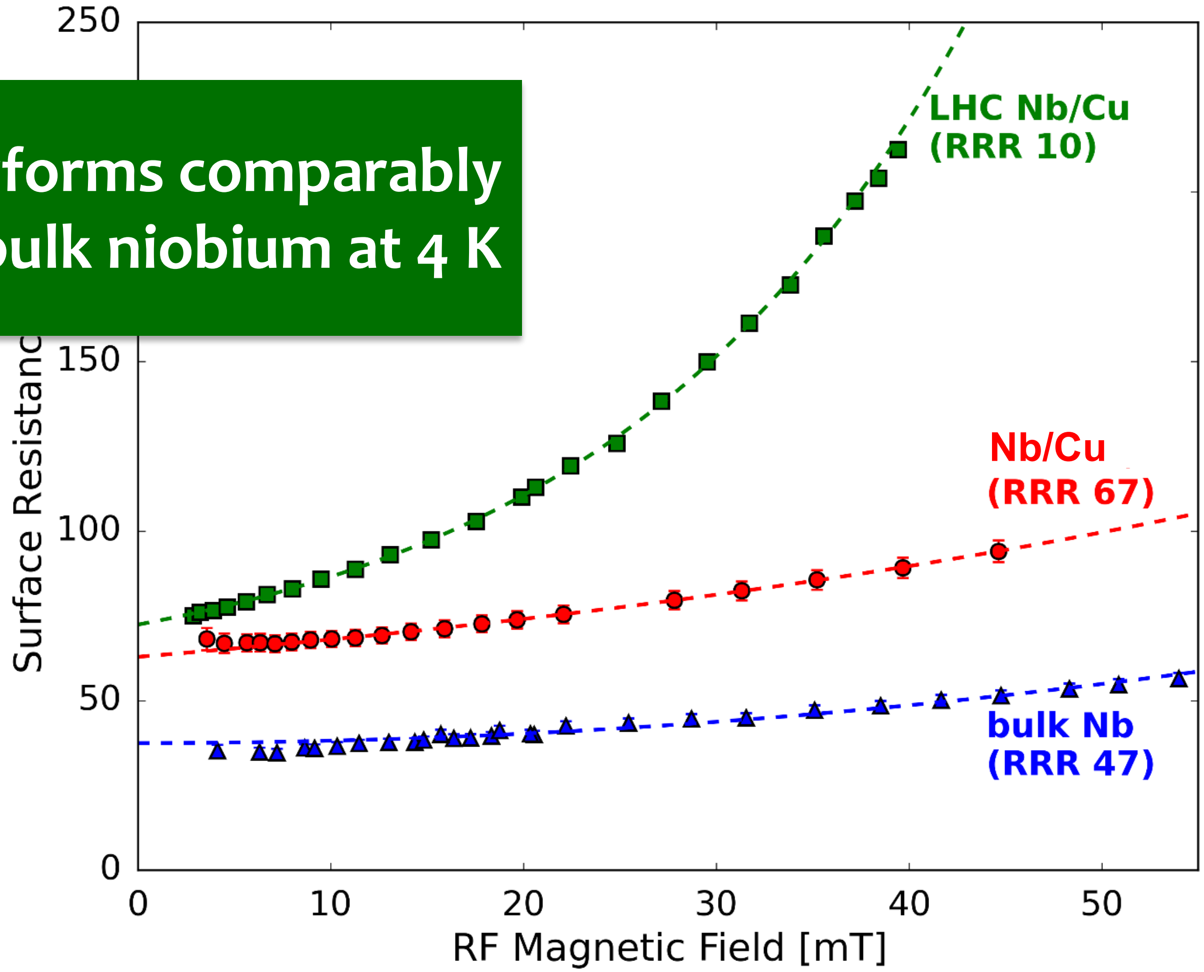
Q-Slope: Film vs Bulk

400 MHz & 4 K

Nb film performs comparably to bulk niobium at 4 K



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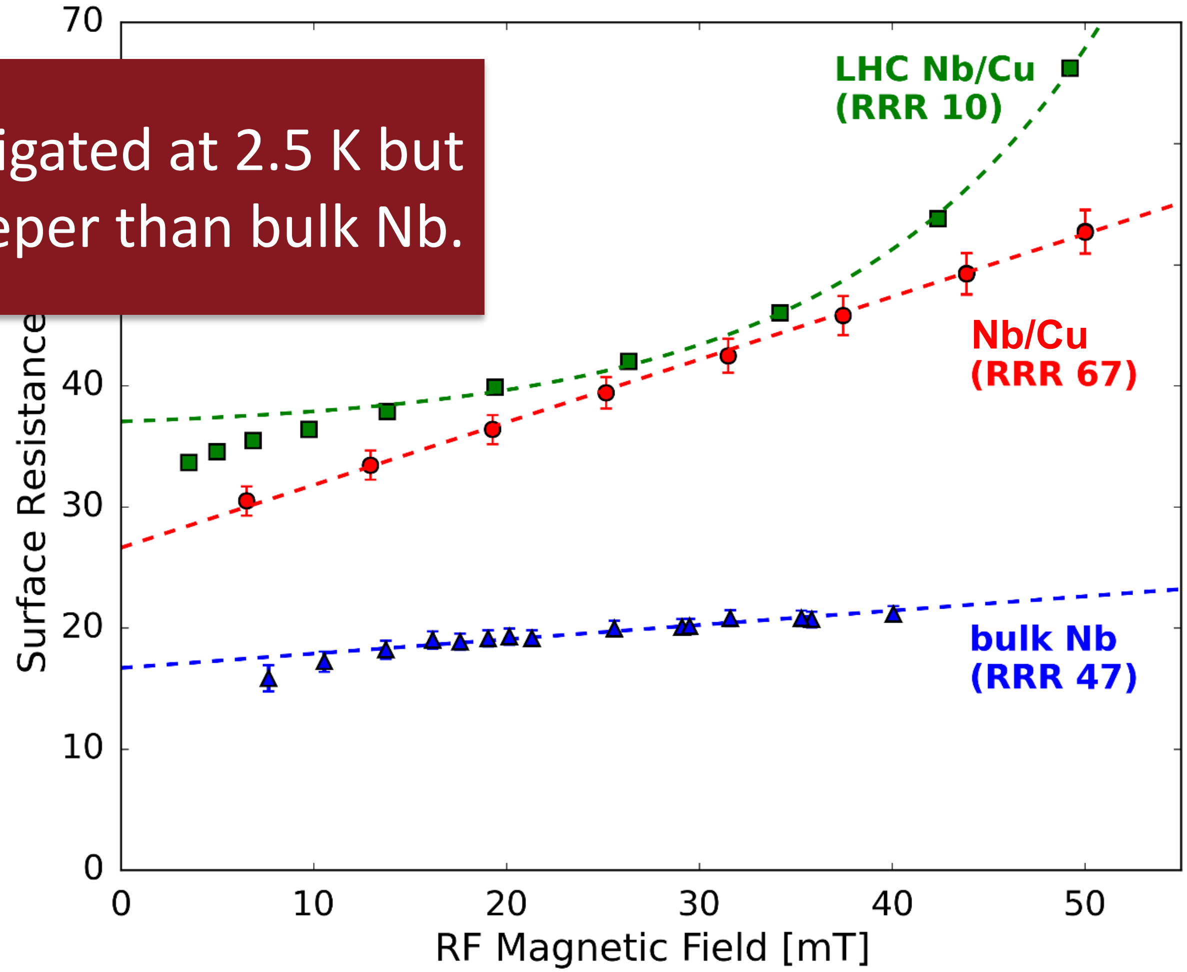
Q-Slope: Film vs Bulk

400 MHz & 2.5 K



Q-Slope is mitigated at 2.5 K but still steeper than bulk Nb.

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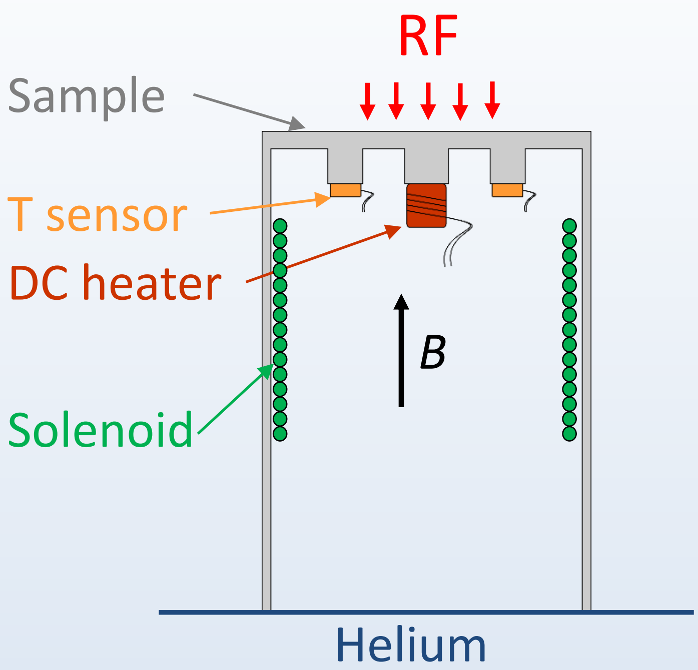
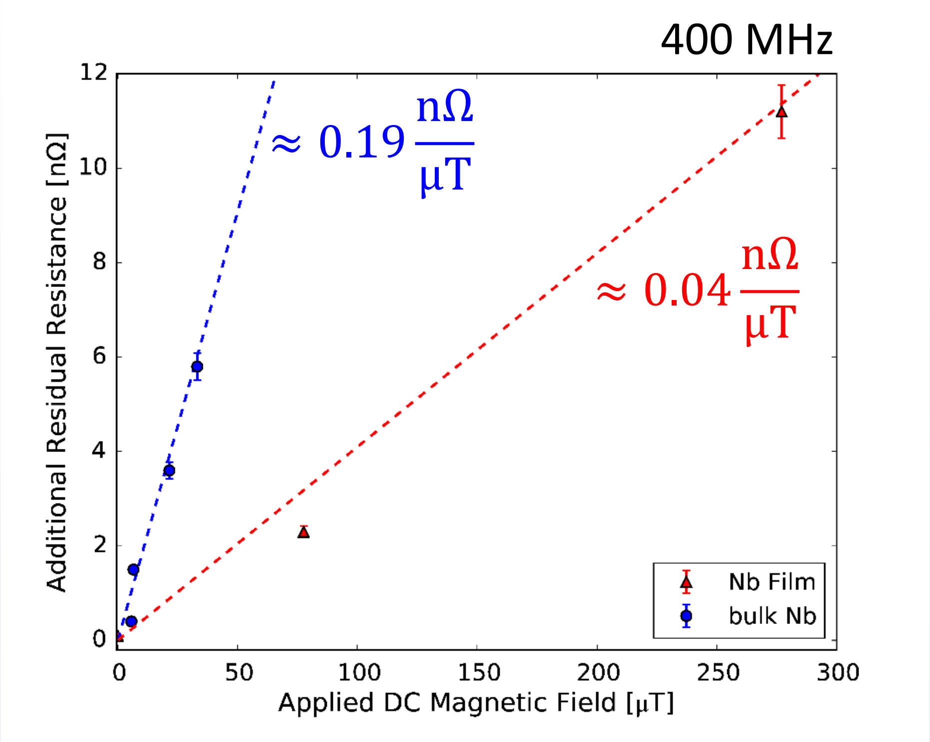
Trapped Flux Sensitivity

400 MHz



Trapped Flux Sensitivity



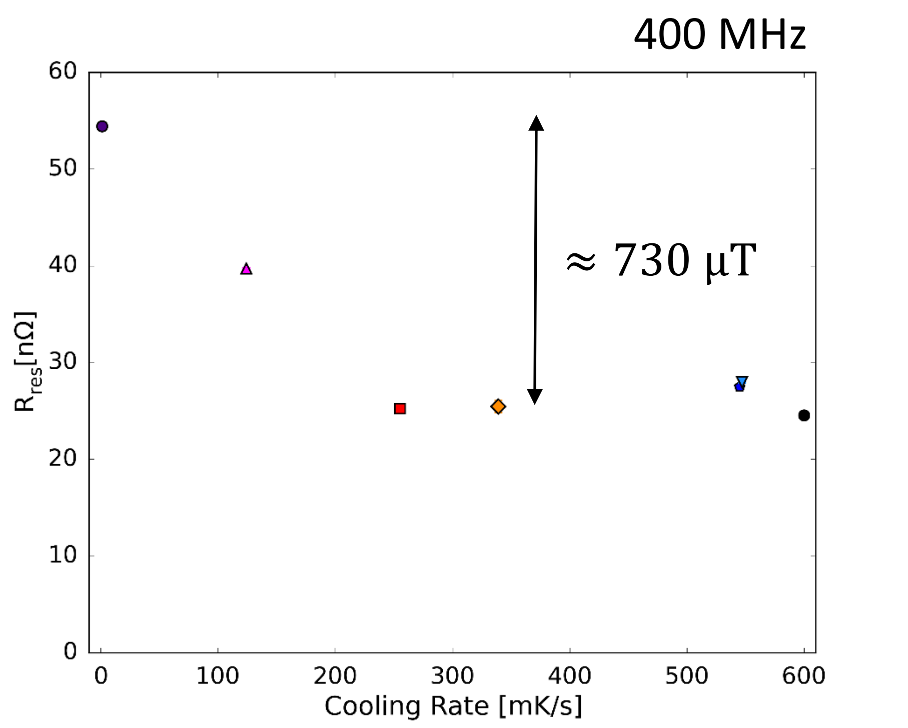
Nb/Cu film is still less sensitive to trapped flux.

Trapped flux sensitivity depends on RRR, frequency and pinning centre size.

Low trapped flux sensitivity is consistent with bigger pinning centres.

Trapped Flux & Thermal Cycling

See also TUPB077



smaller ΔT ⟷ larger ΔT

Residual resistance increase by 30 nΩ can not be explained with flux expulsion efficiency.

Nb/Cu seems to be much more sensitive to thermo-electric currents due to the bi-metal interface.

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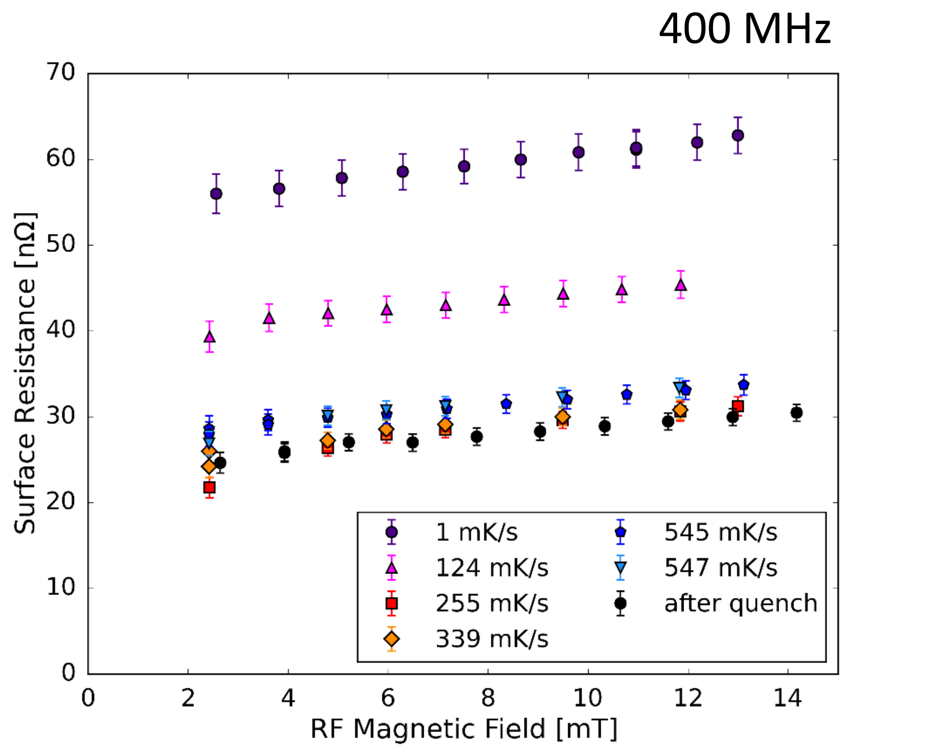
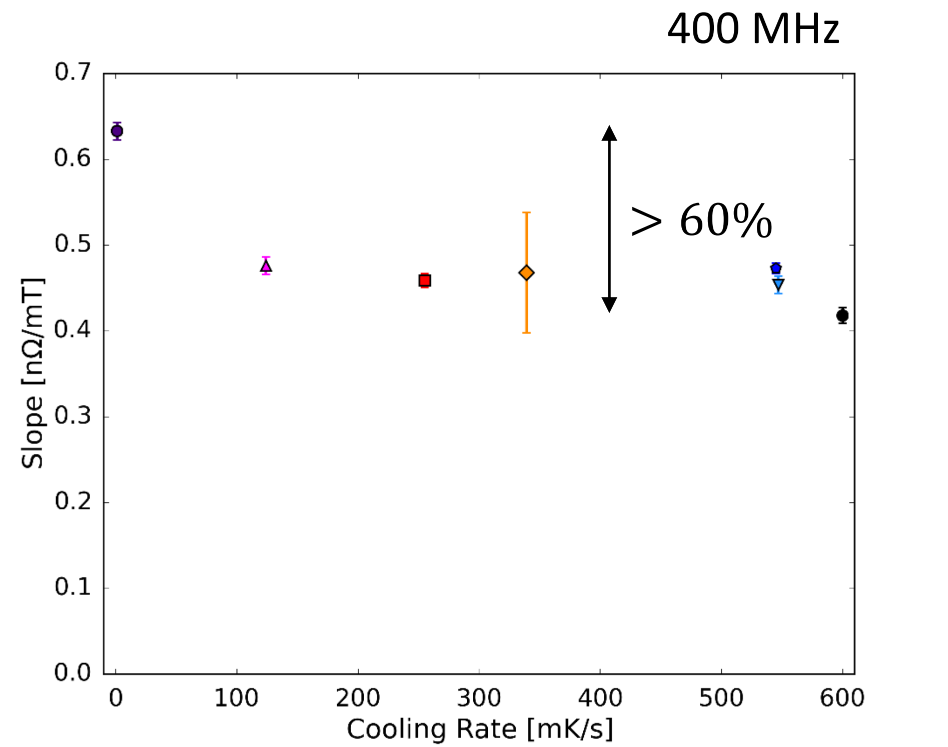
Effect of Thermal Cycling on Q-Slope

See also TUPB077

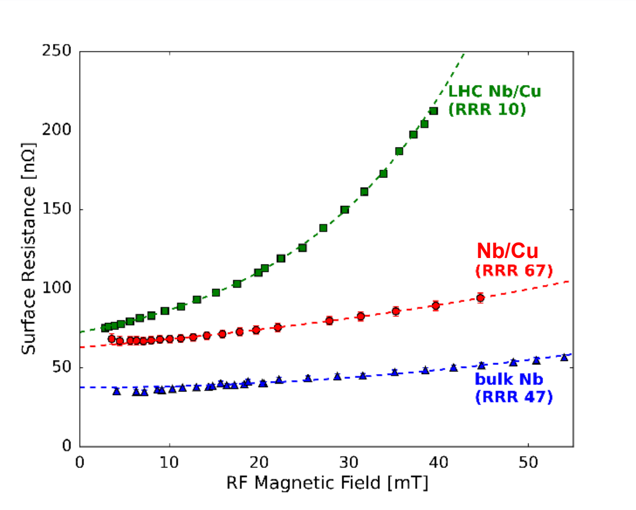


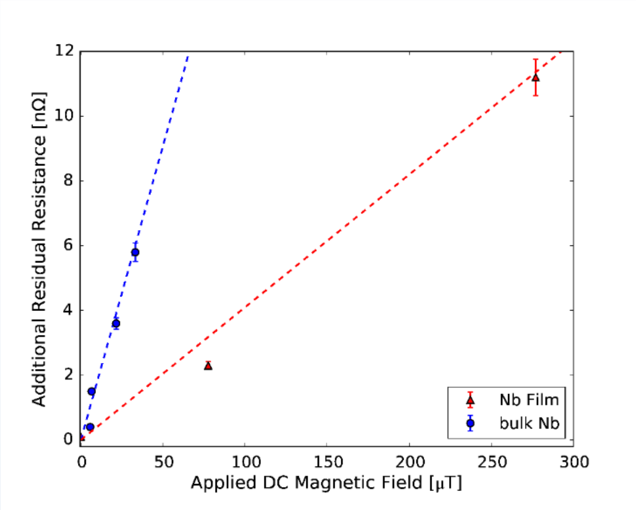


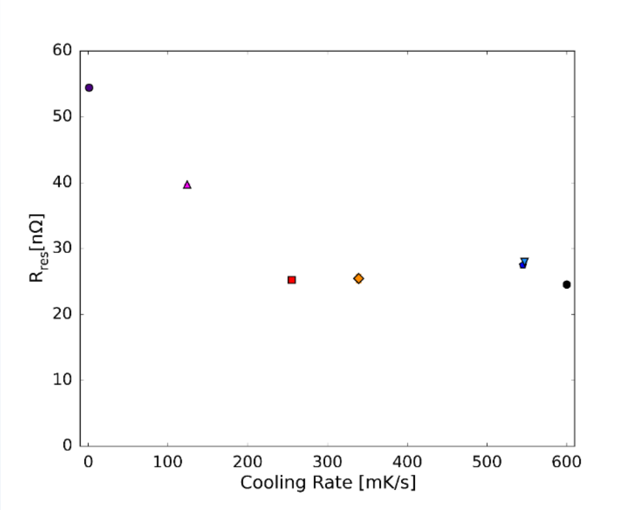
Thermal cycling also acts on the Q-Slope.

Summary

We have a bulk-like Nb/Cu film…





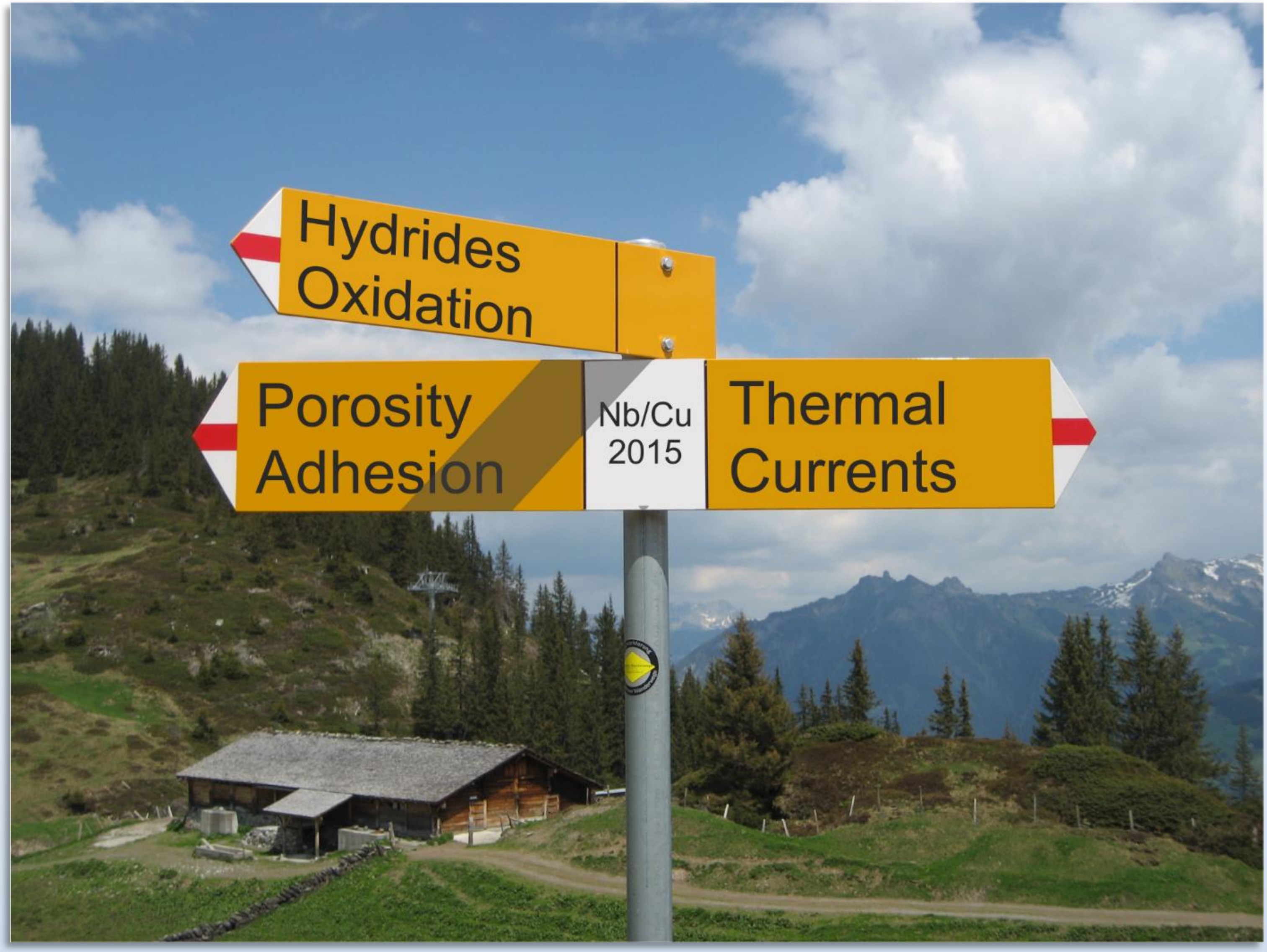


with a Q-Slope comparable to bulk niobium at 4 K

still less sensitive to trapped flux

severely affected by thermal currents?

Where next?


Hydrides
Oxidation
Porosity
Adhesion
Nb/Cu
2015
Thermal
Currents

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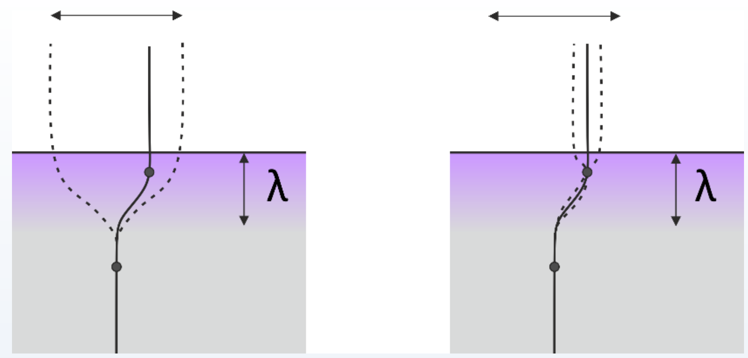
Trapped Flux Sensitivity

The trapped flux sensitivity depends on operation frequency, RRR and flux trapping efficiency.



$$S_{\mathrm{TF}} = 3.6\,\frac{\mathrm{n\Omega}}{\mathrm{\mu T}}\sqrt{\frac{f}{1.5\mathrm{GHz}}\frac{300}{RRR}} \cdot \frac{f^2}{f^2 + \left(p \cdot 673\mathrm{MHz}\,\frac{110}{RRR}\right)^2} \cdot \varepsilon_{trap}$$

Normal conducting area of the flux tube

Depinning efficiency

Trapping efficiency (depending on treatment)

http://arxiv.org/abs/1507.04105