The 59th ICFA Advanced Beam Dynamics Workshop on Energy Recovery Linacs

The Potential of Nb/Cu Technology for High Beam Current Applications

Sarah Aull, CERN

Acknowledgements
CERN BE-RF
CERN TE-VSC
Jefferson Lab

Challenges of High Current Applications

High beam current induces high HOM losses

$$P_{\mathrm{HOM}} \sim I_{\mathrm{beam}}^2 \frac{1}{R_{\mathrm{iris}}} k_{\mathrm{loss}}\left(f\right)$$

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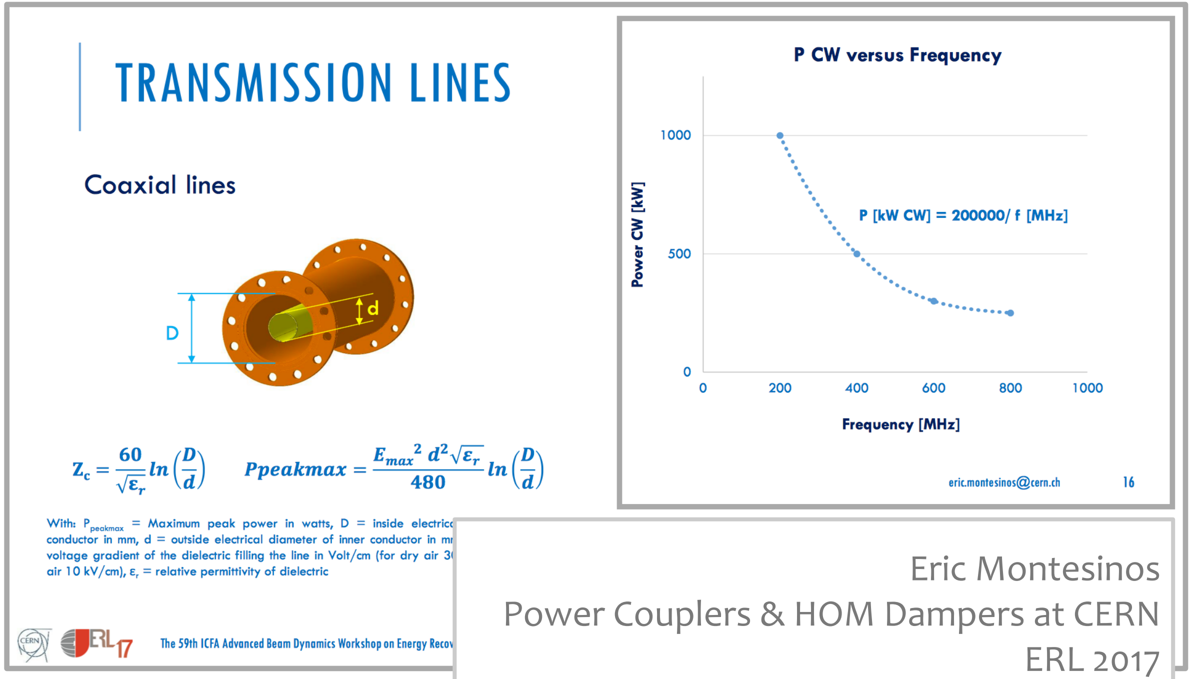
Mitigation

- bigger aperture
- low frequency
- 4.5 K operation

Challenges of High Current Applications

Higher cw power for lower frequencies

Maximum power level of FPC restricts usable accelerating gradient



Eric Montesinos
Power Couplers & HOM Dampers at CERN
ERL 2017

High beam current applications such as energy recovery linacs favour low frequency cavities and 4.5 K operation

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A case for niobium-on-copper

The History of Nb/Cu

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Increase thermal conductivity of bulk niobium:

RRR 300 as standard material

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Increase thermal conductivity of bulk niobium:

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Take advantage of the high thermal conductivity of copper and deposit a micrometer thick niobium film

Nb/Cu for Particle Accelerators

LEP2 352 MHz

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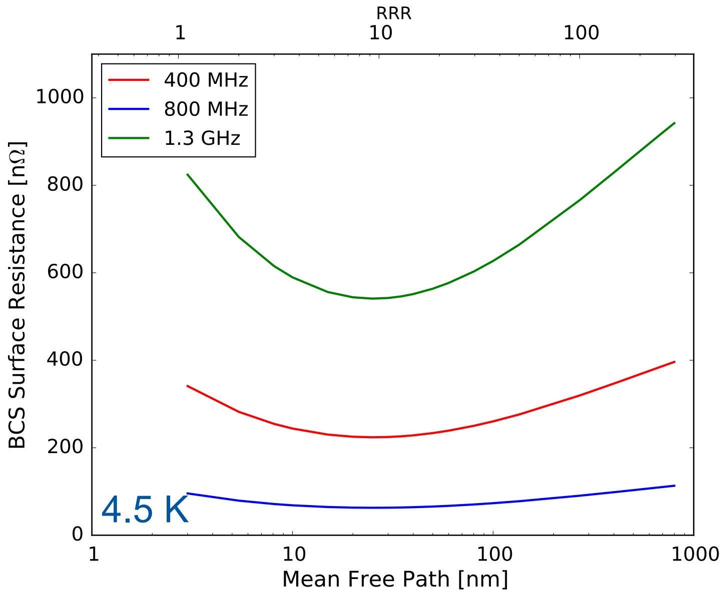
Nb/Cu for Particle Accelerators

FCC hh ee he ?

Differences between Bulk Nb and Nb/Cu



$$R_\mathrm{S} = \frac{G}{Q}$$

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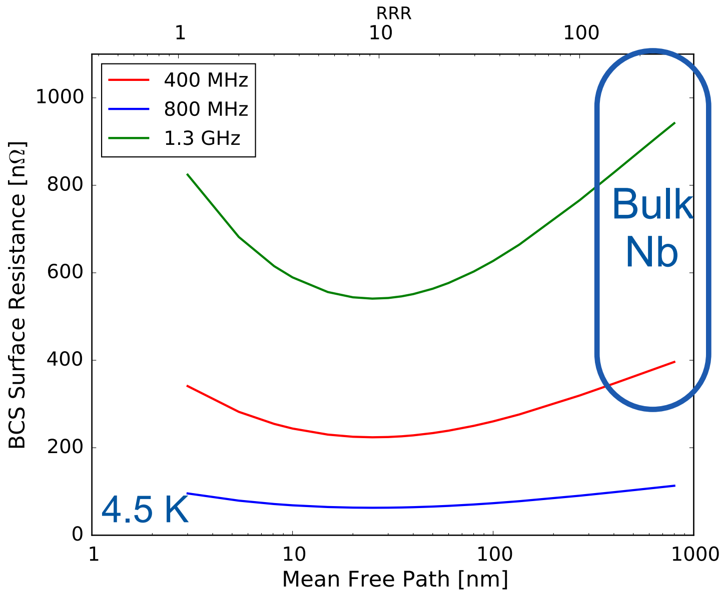

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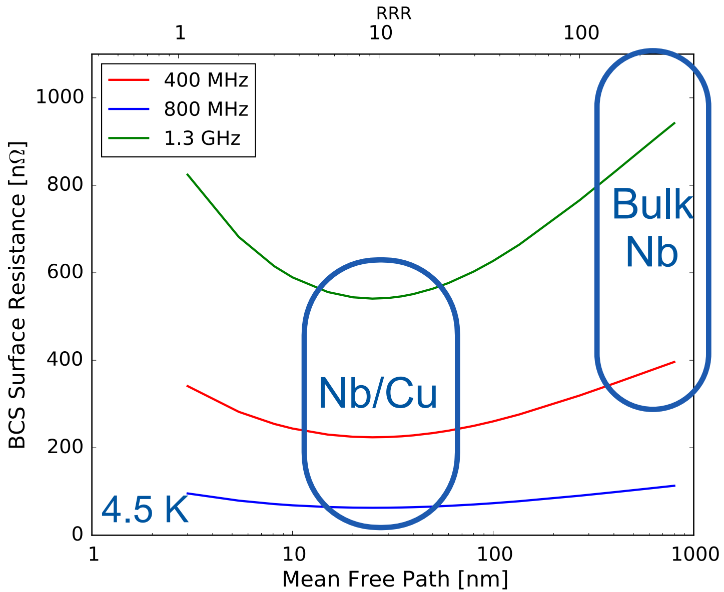

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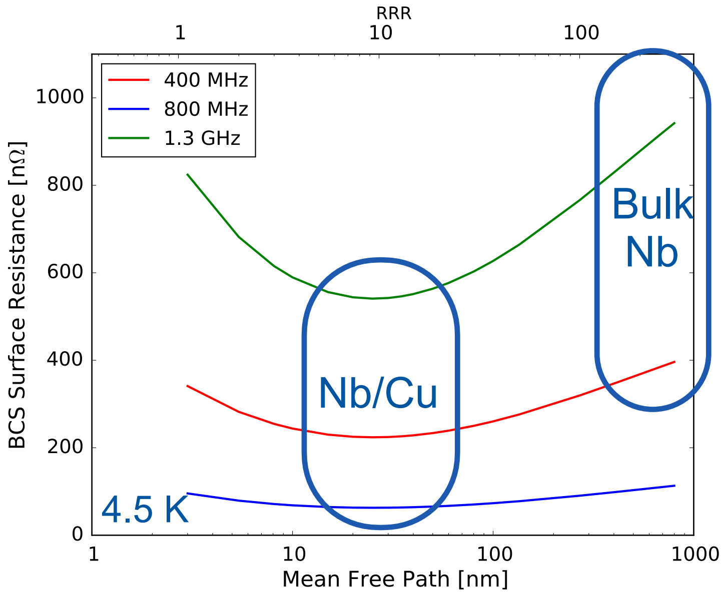

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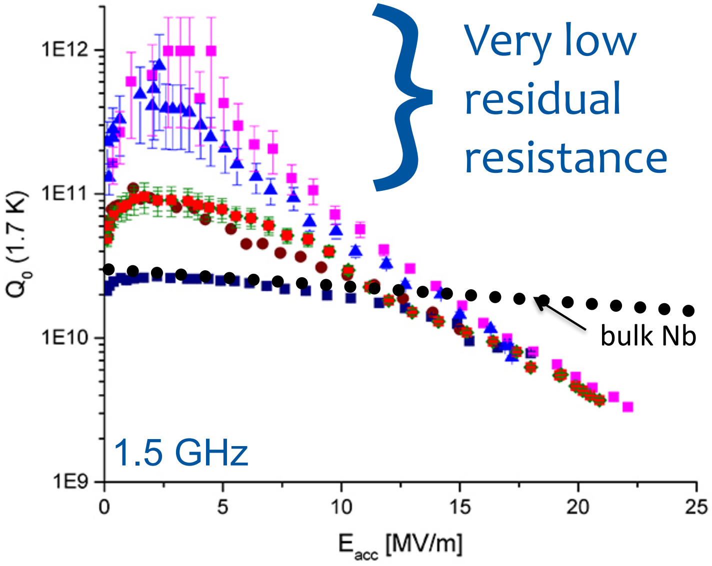

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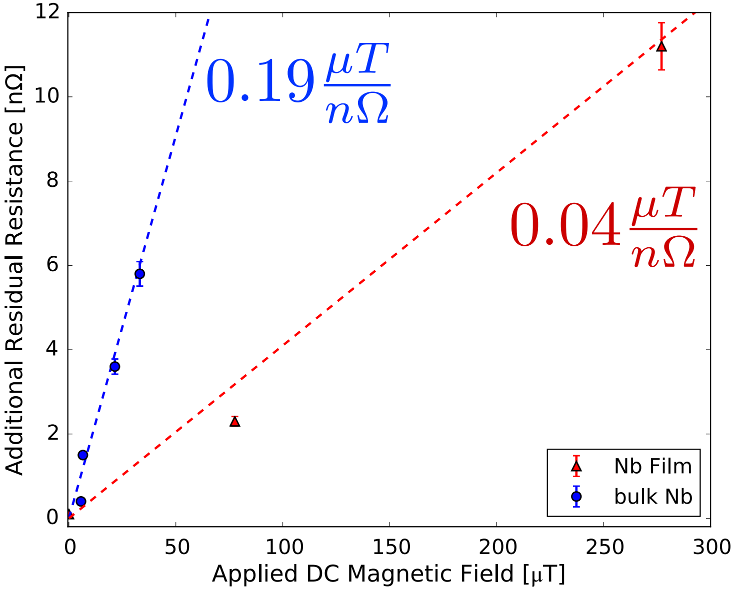
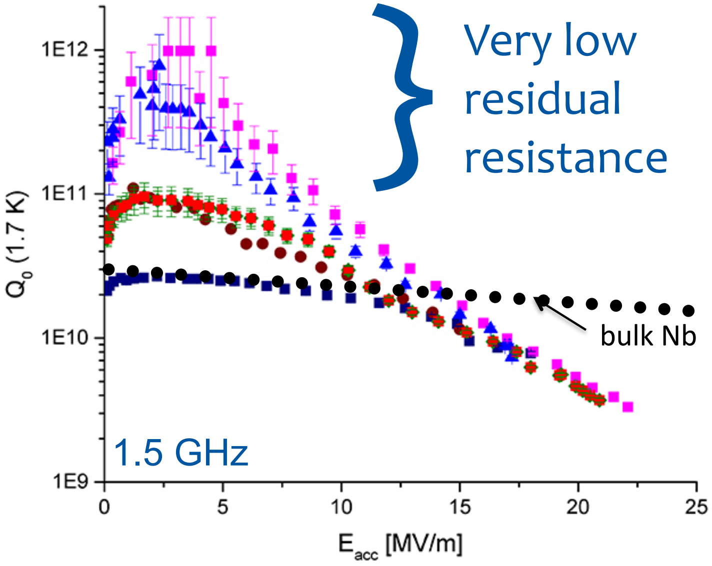
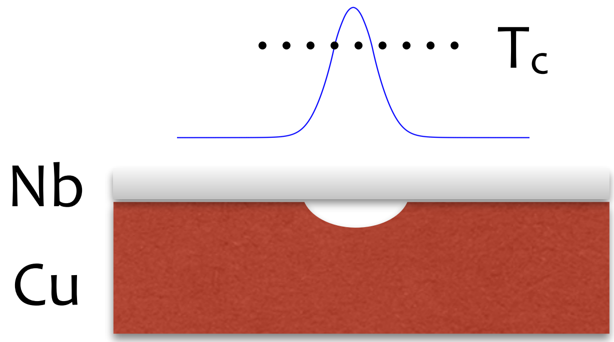




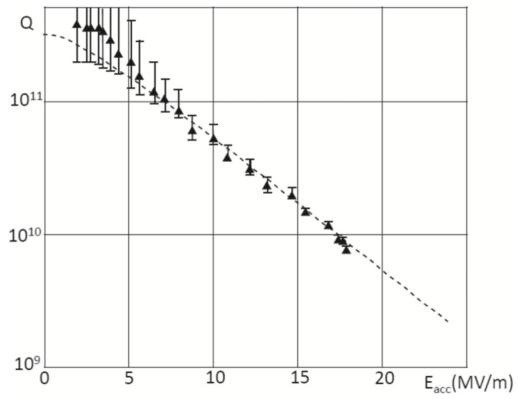
Very low residual resistance

Cause of the Q-Slope

Small defects at the Nb-Cu interface lead to microscopic quenches which cause the Nb/Cu Q-slope.



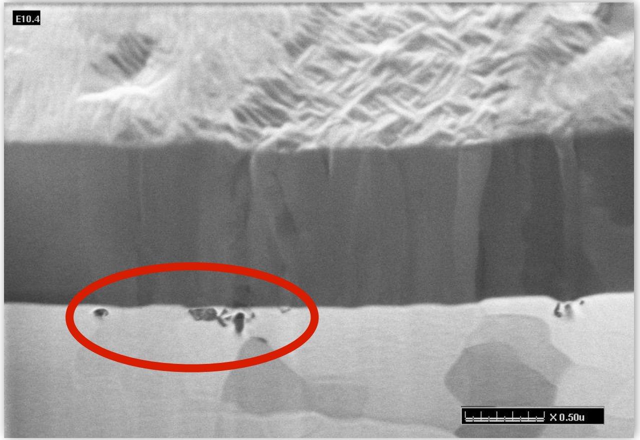
Q(Eacc) curve can be described via a distribution function of thermal contact resistances.



Palmieri & Vaglio
SUST 29 015004, 2016

How to Cure the Q-Slope

Improve Nb-Cu interface on microscopic scale



Courtesy P. Jacob

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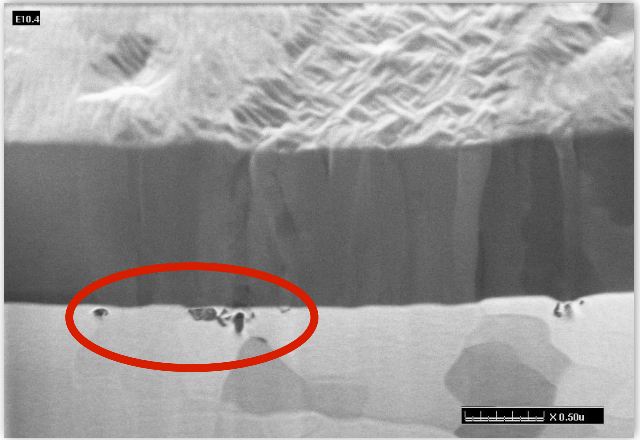

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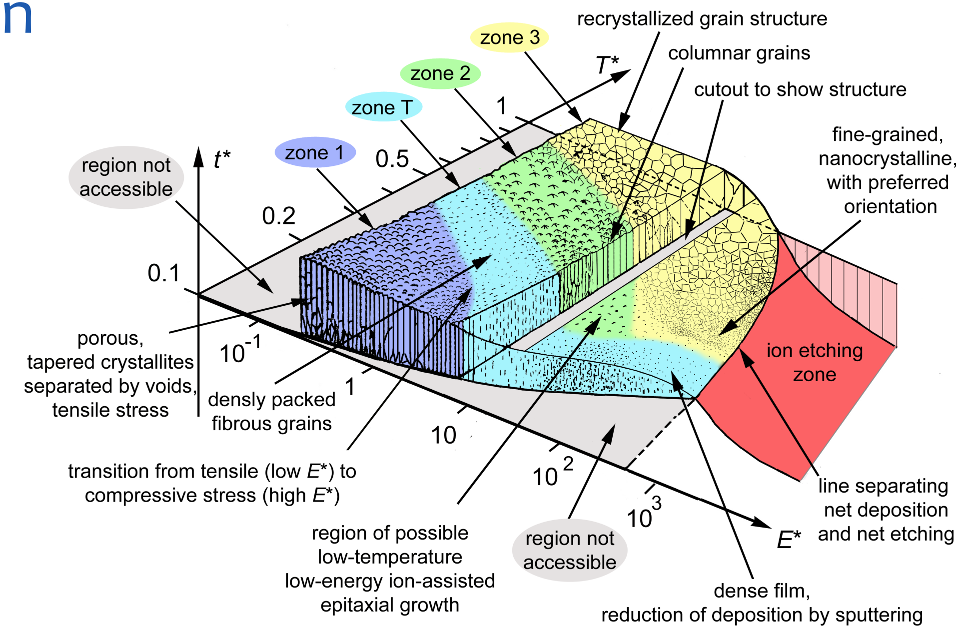
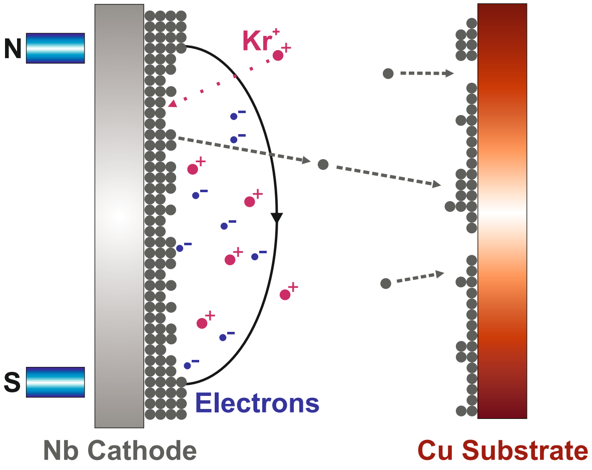


A. Anders, Thin Solid Films **518** (2010) 4087

From Sputtering to Energetic Condensation Techniques



dc Magnetron Sputtering

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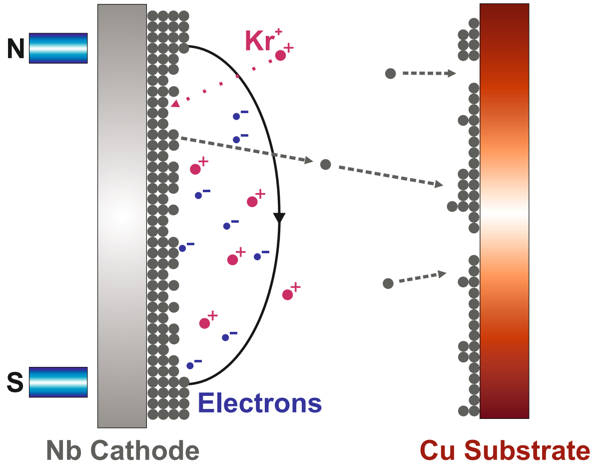

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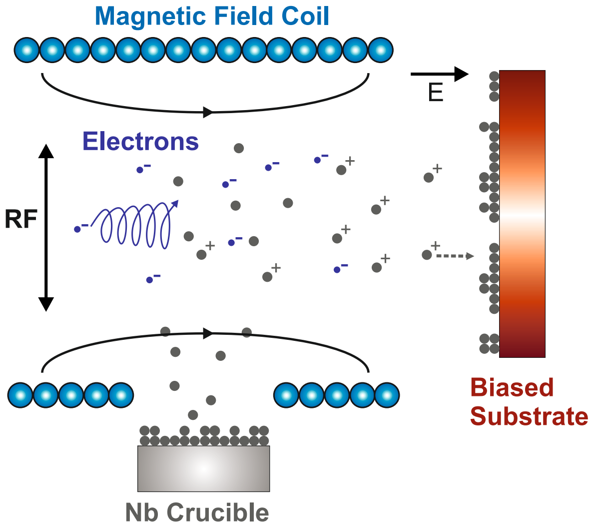
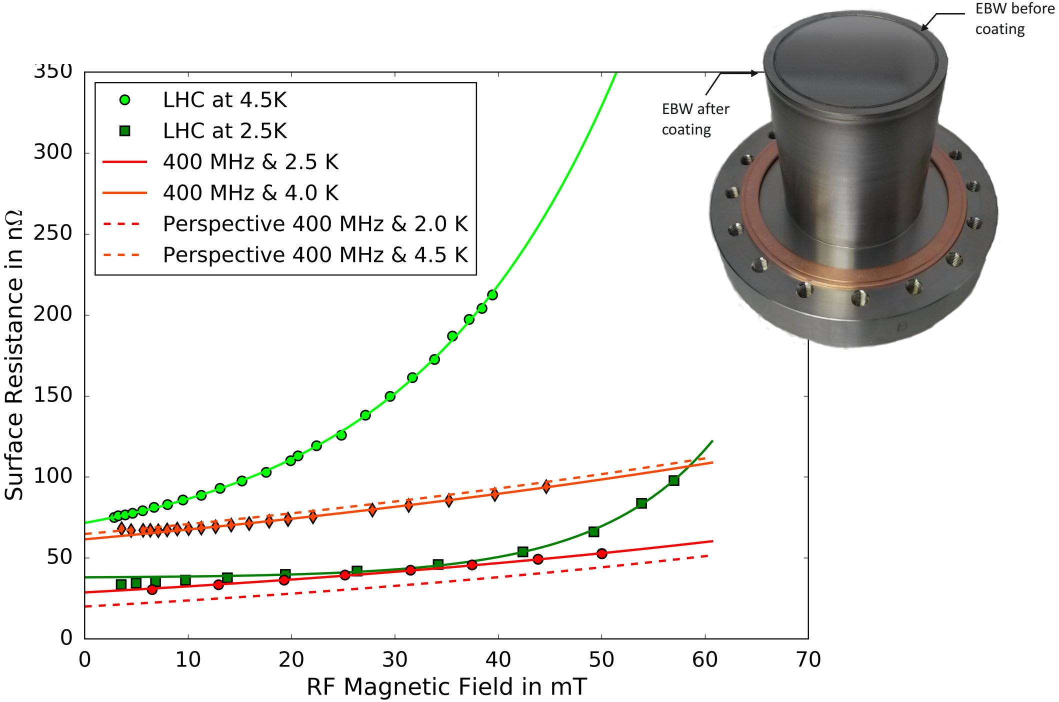


Electron Cyclotron Resonance

First ECR results

Significantly improved slope for flat ECR surface.

At 400 MHz & 4 K comparable to bulk Nb



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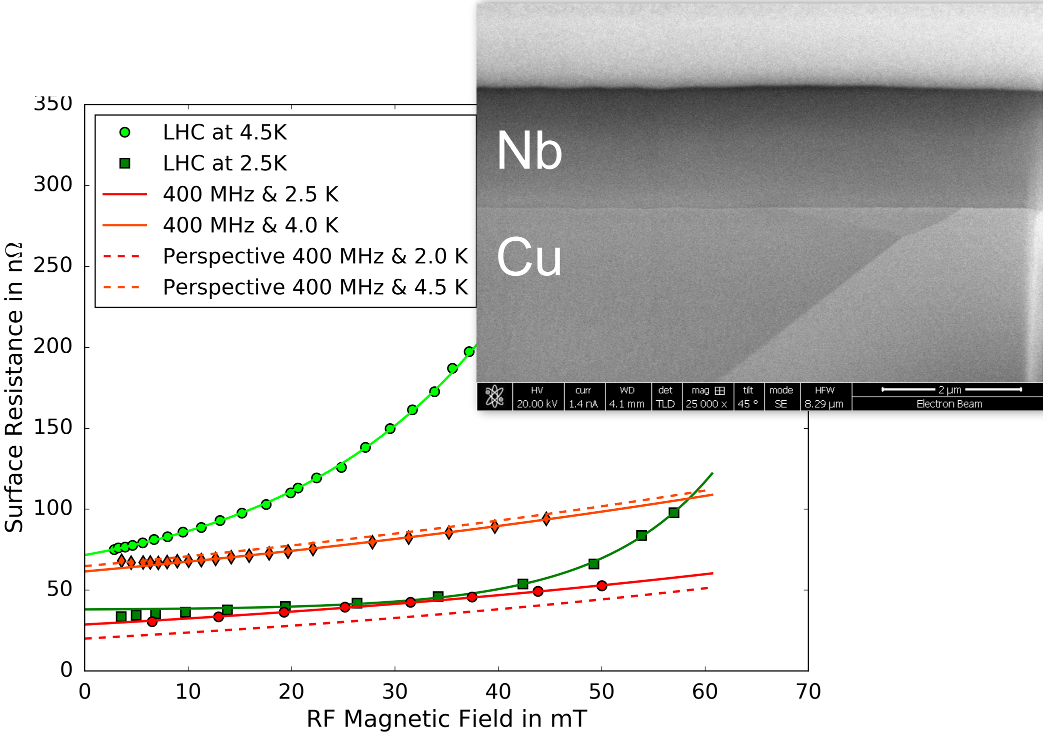
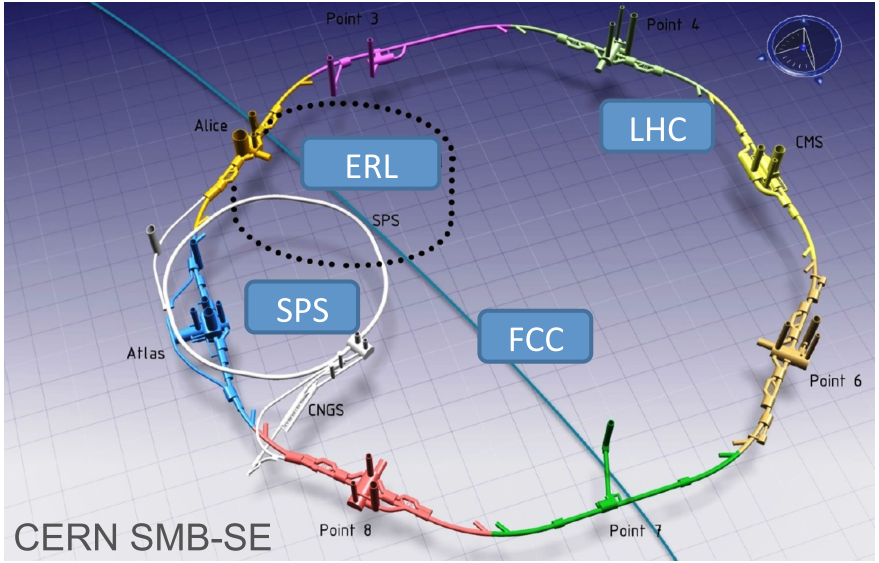
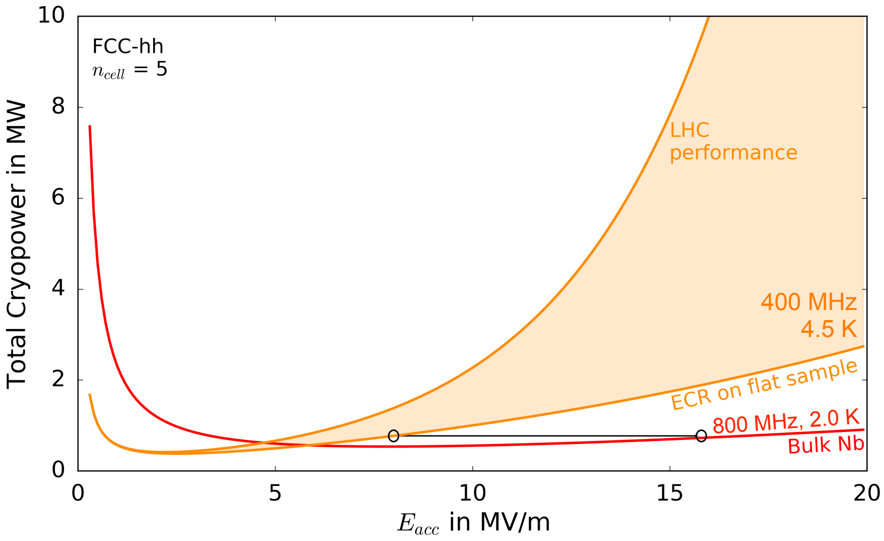


Courtesy R.Valizadeh

Cryogenic Consumption for LHeC/FCC-he

ERL injector baseline for LHeC and FCC-he: 60 GeV, 6 mA





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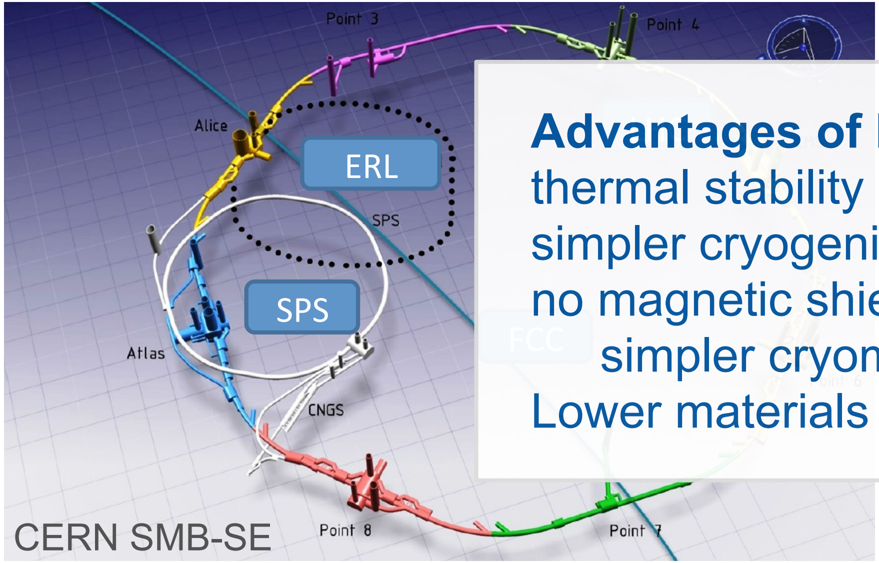
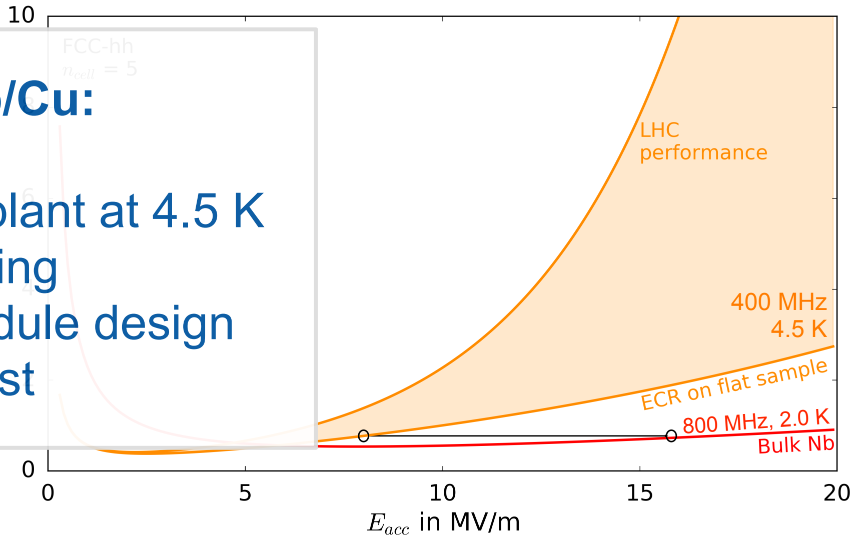
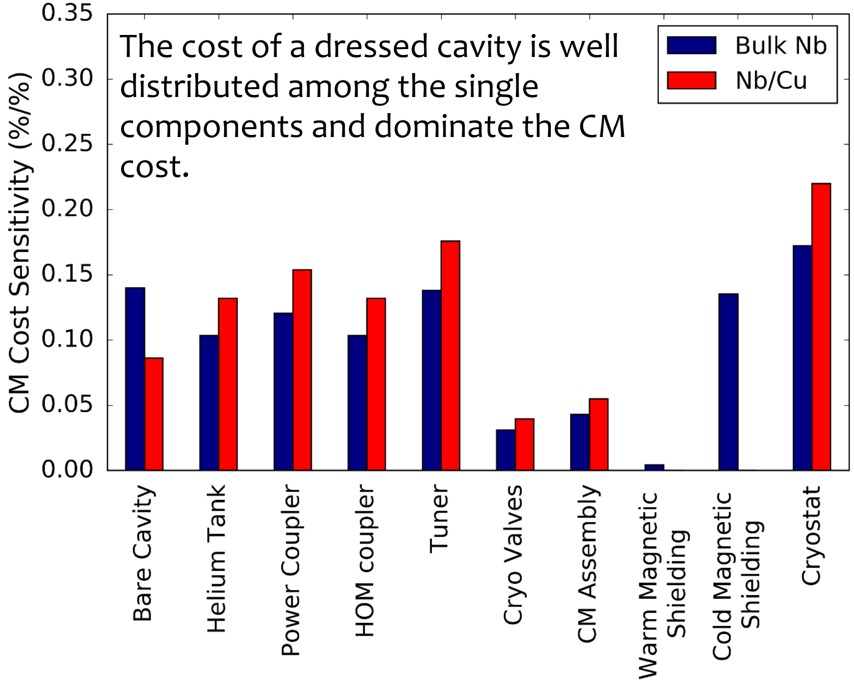


Advantages of Nb/Cu:
thermal stability
simpler cryogenic plant at 4.5 K
no magnetic shielding
simpler cryomodule design
Lower materials cost

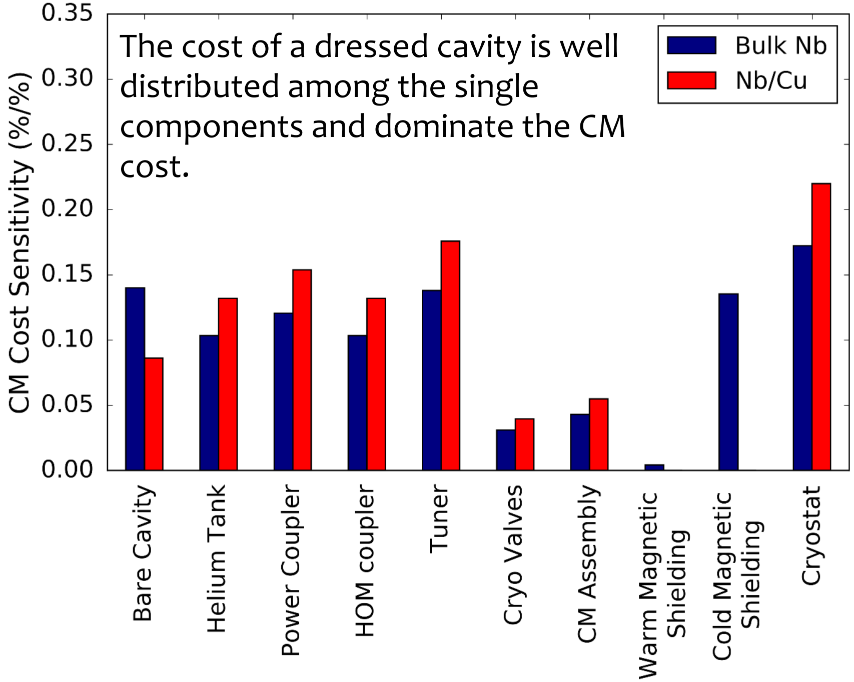


Cryomodule Production Cost

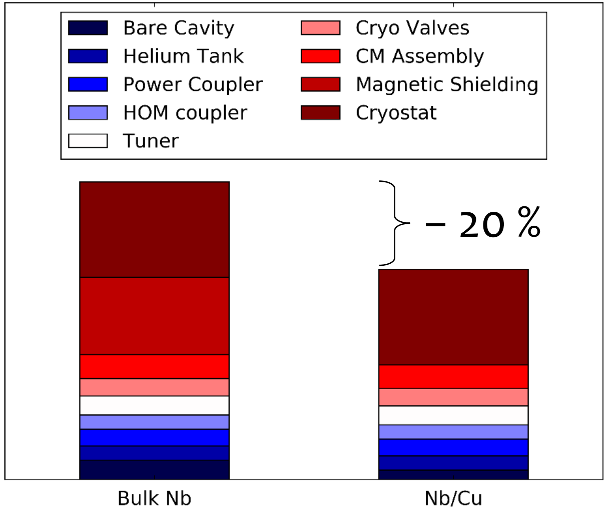


*4 cavities/CM, 2 HOM coupler/cavity

Cryomodule Production Cost



The cost of a dressed cavity is well distributed among the single components and dominate the CM cost.



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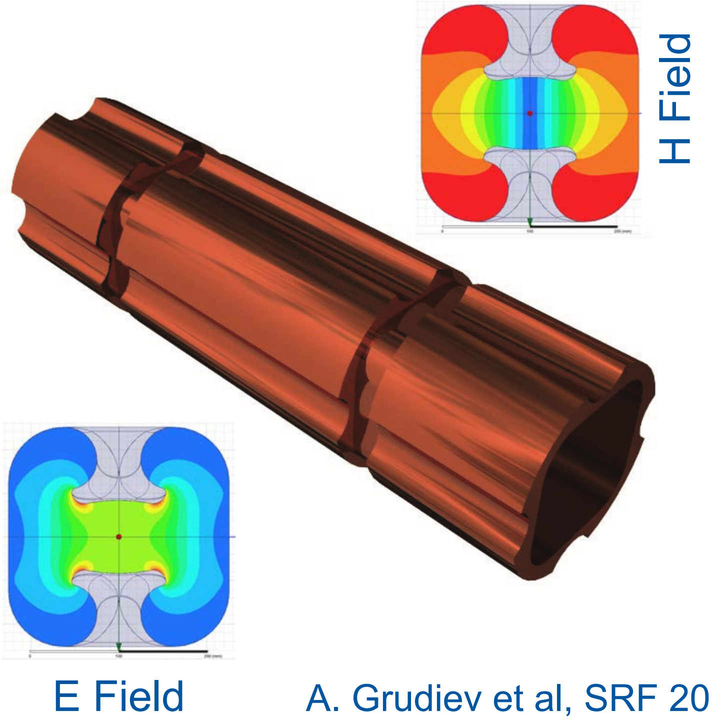
The cost for a CM with 400 MHz Nb/Cu cavities is about 20 % less than for a CM with 800 MHz bulk Nb cavities

Back to applications: Crab Cavities

Energetic condensation techniques open also the door towards coating more complex shapes, such as crab cavities*.

* WOW cavity will be sputter-coated



A. Grudiev et al, SRF 2015

Summary

Nb/Cu technology can offer great benefits over bulk Nb:

operation at 4.5 K while thermally stable

reduced CM cost & simpler design

Energetic condensation techniques promise significantly improved performance

High beam current applications could benefit from:

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If the Nb/Cu R&D for high energy colliders is successfull, the ERL community will benefit as well.

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