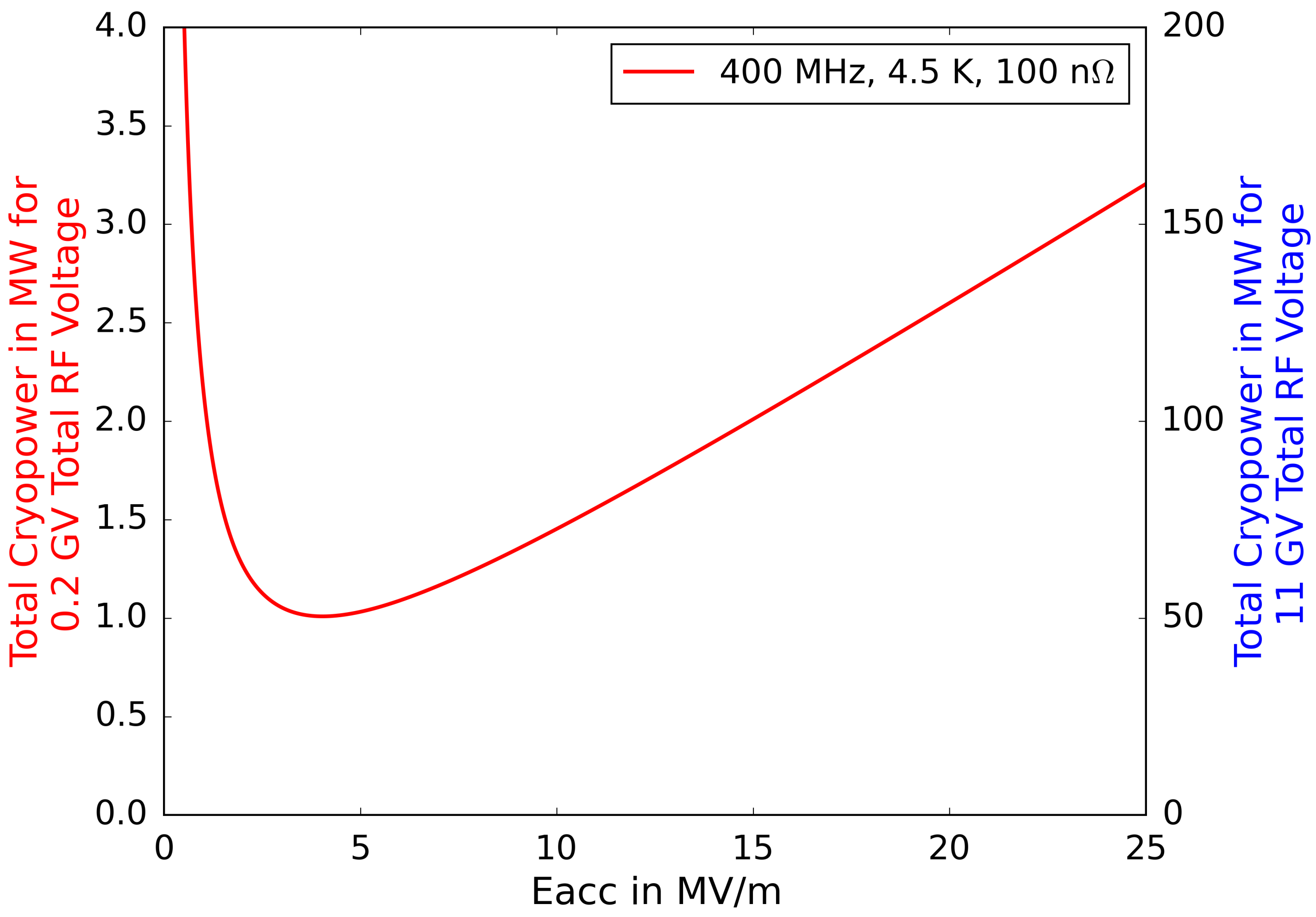
SRF Material Options for FCC

Sarah Aull
on behalf of the
FCC RF & WP3 working group

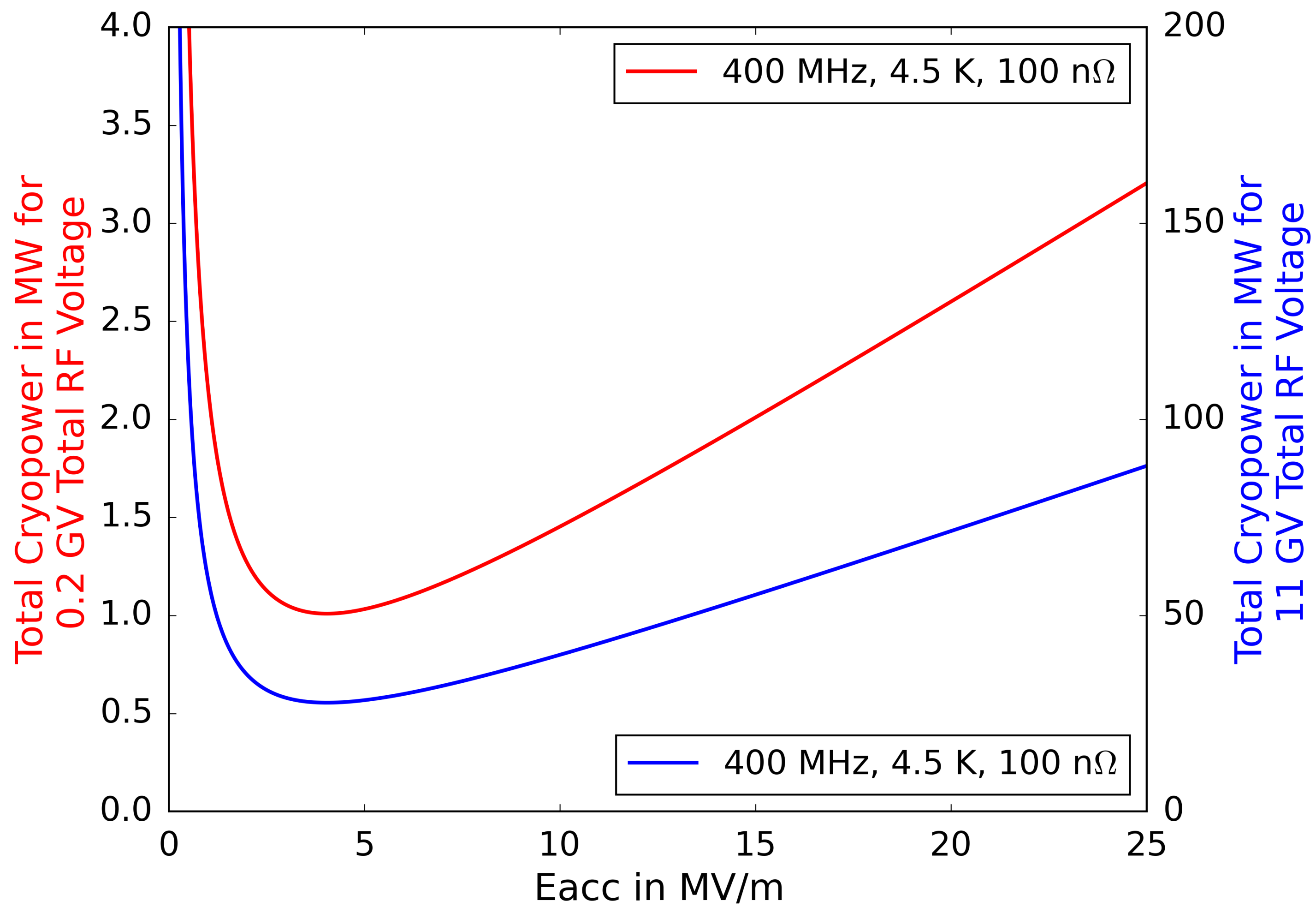
FCC Week, 10. - 15.04.2016

Cryogenic Losses in CW Machines



$$P_{dyn} = \frac{V_{RF}^2}{\frac{R}{Q} \cdot Q_0} \cdot \frac{1}{\eta_{carnot}\eta_{tech}}$$

Cryogenic Losses in CW Machines



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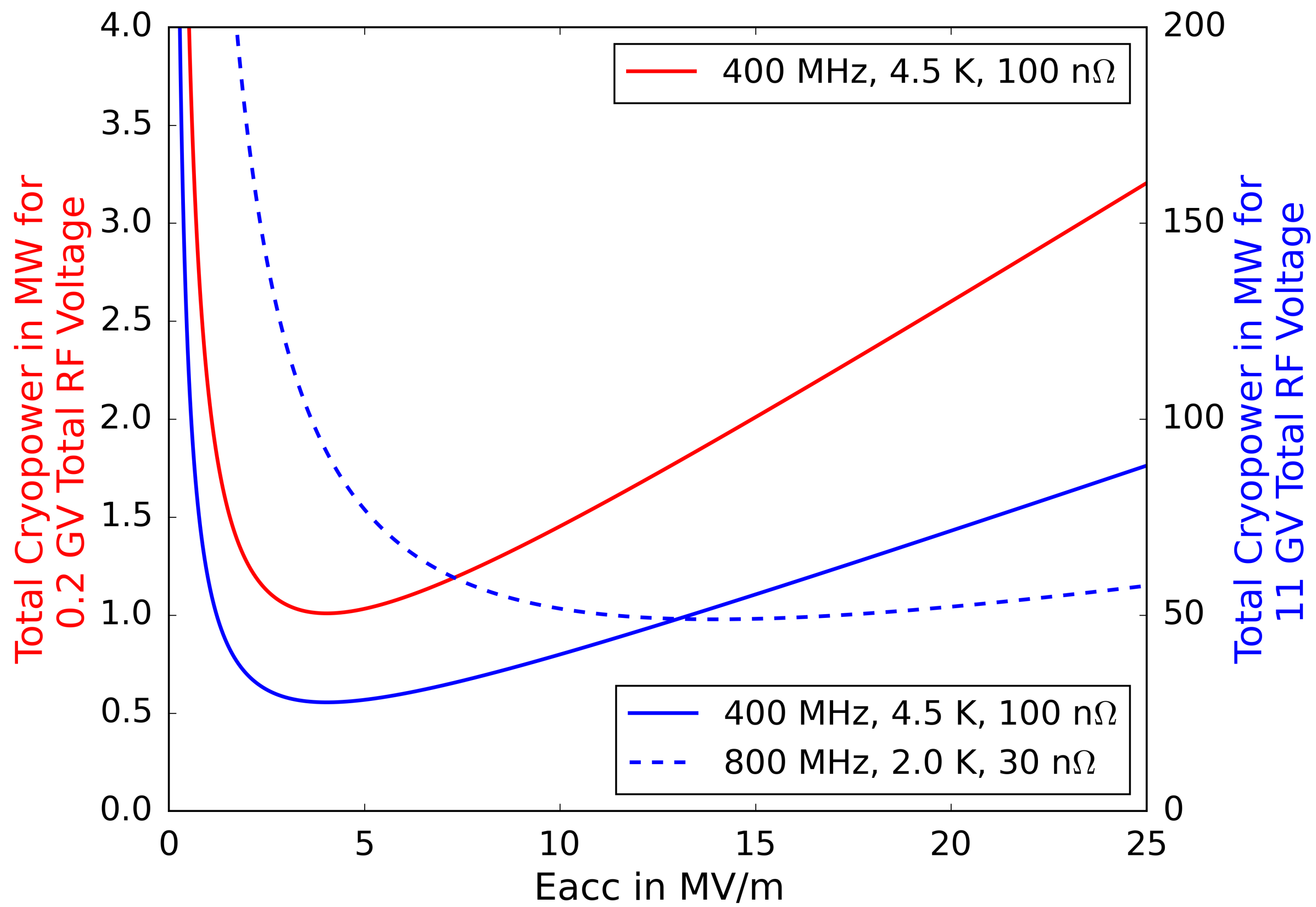

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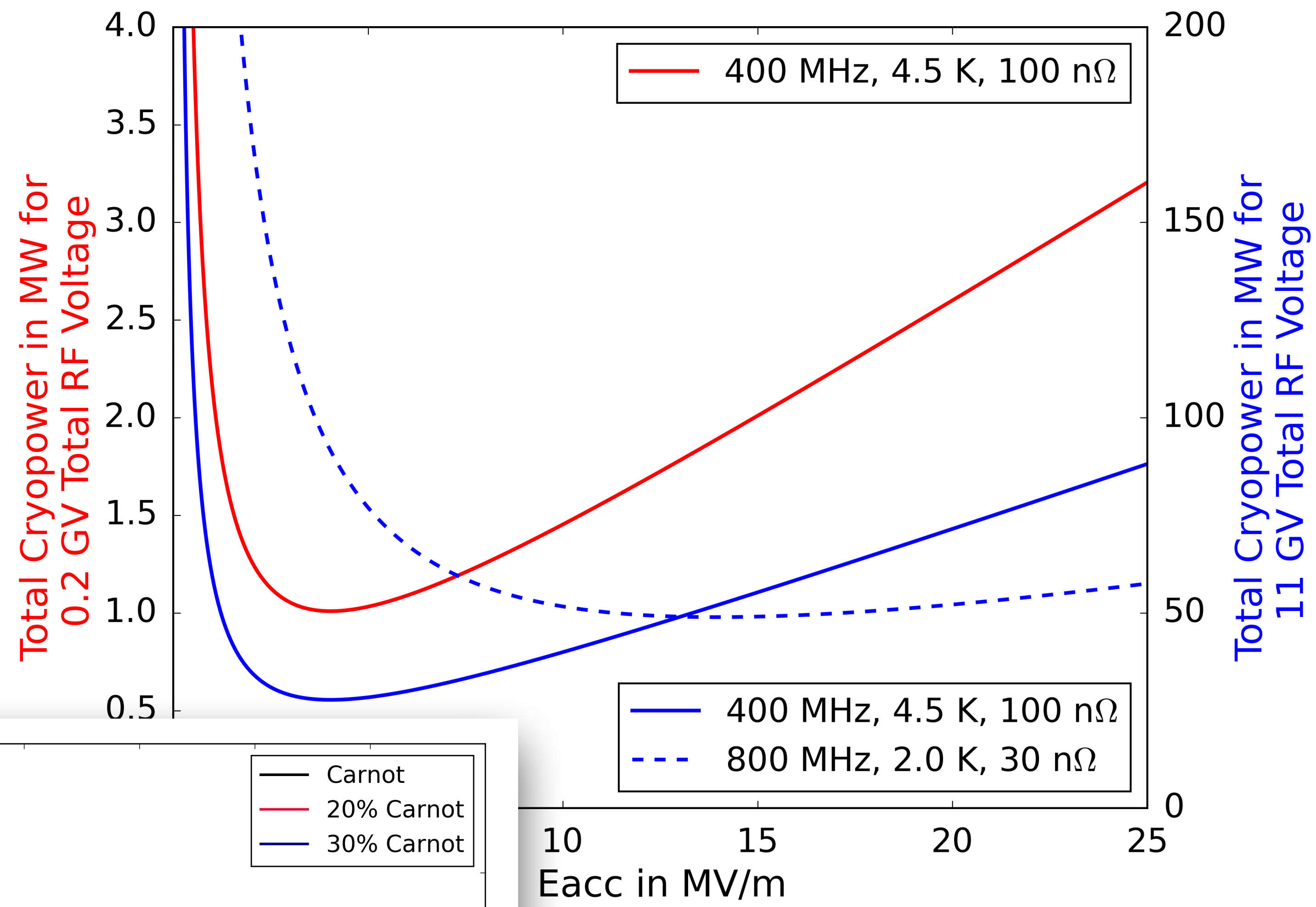

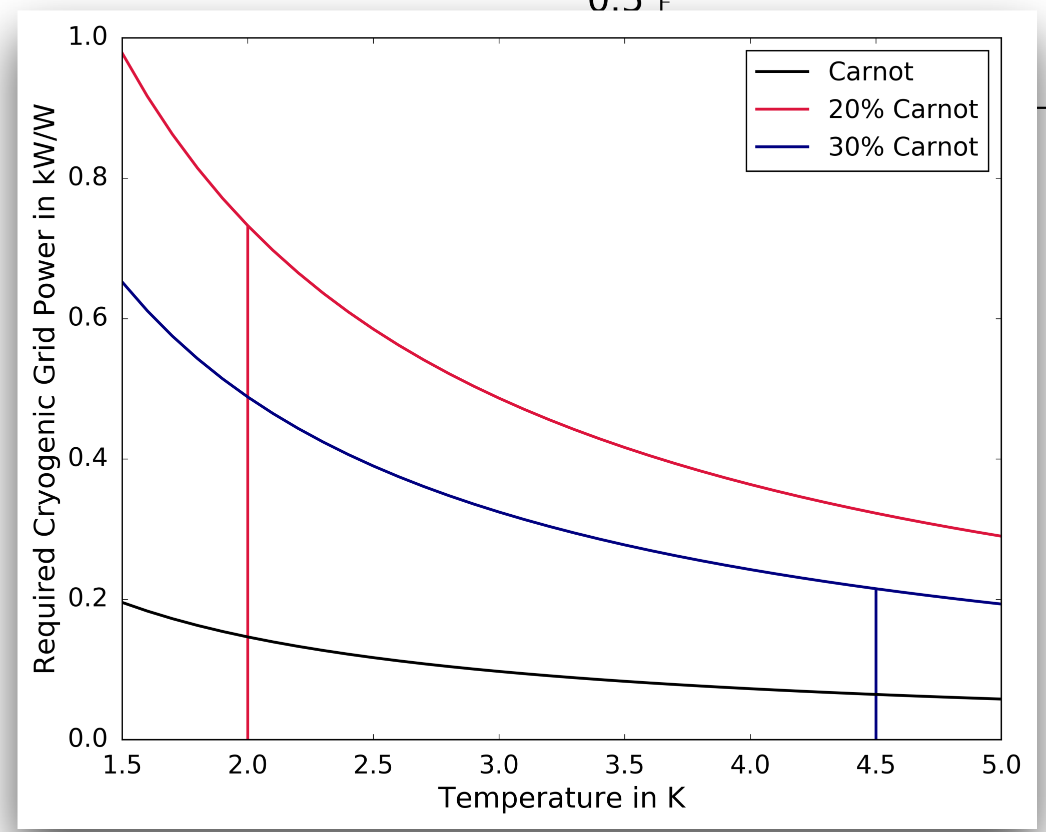

sarah.aull@cern.ch

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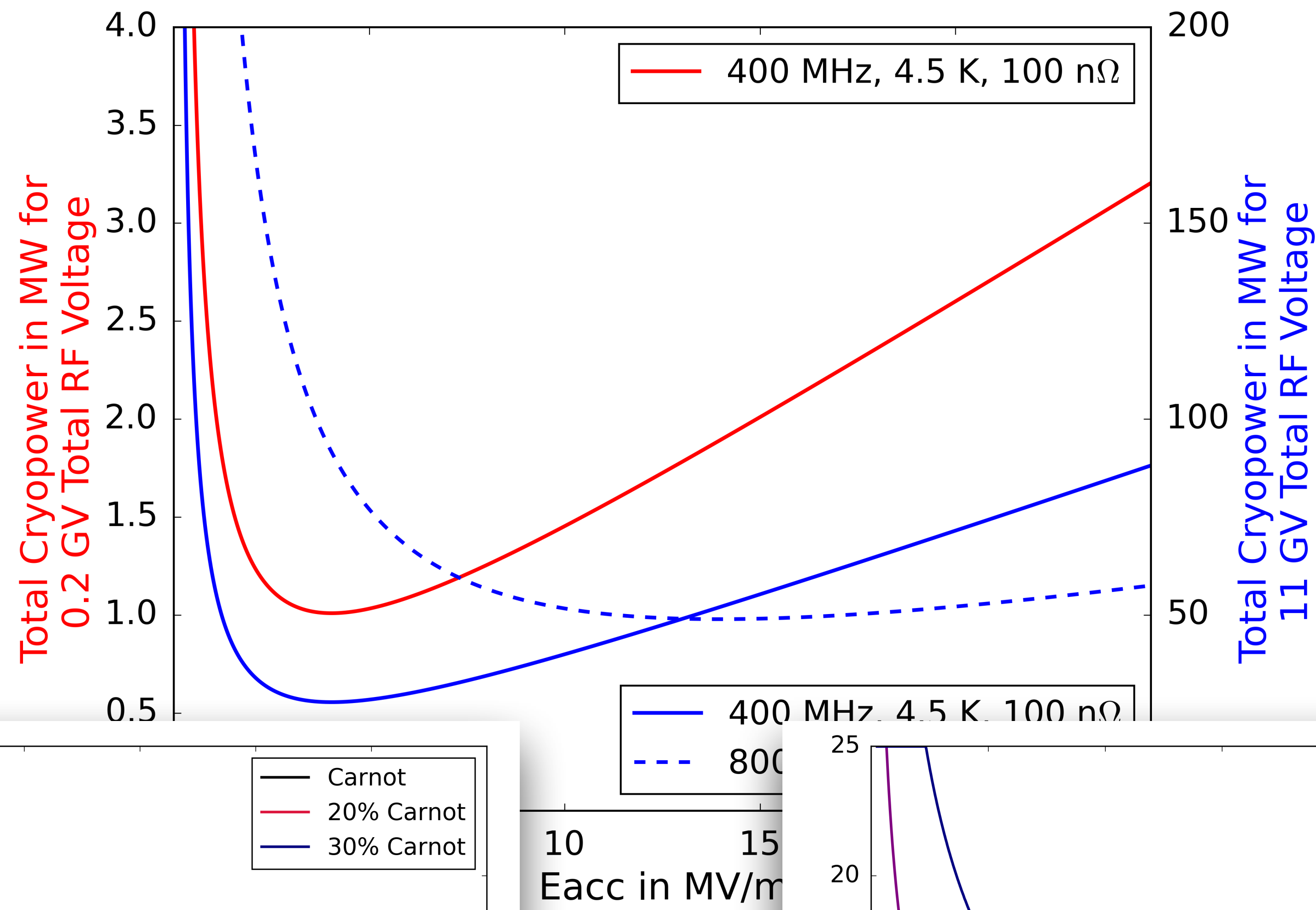

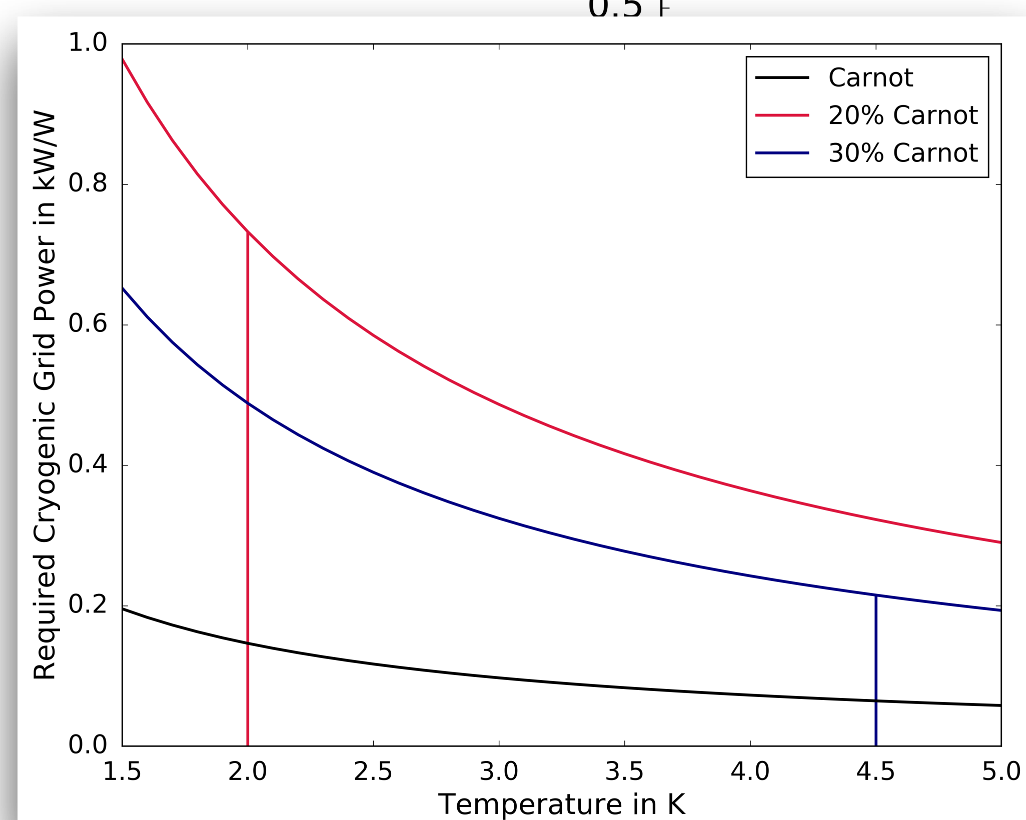

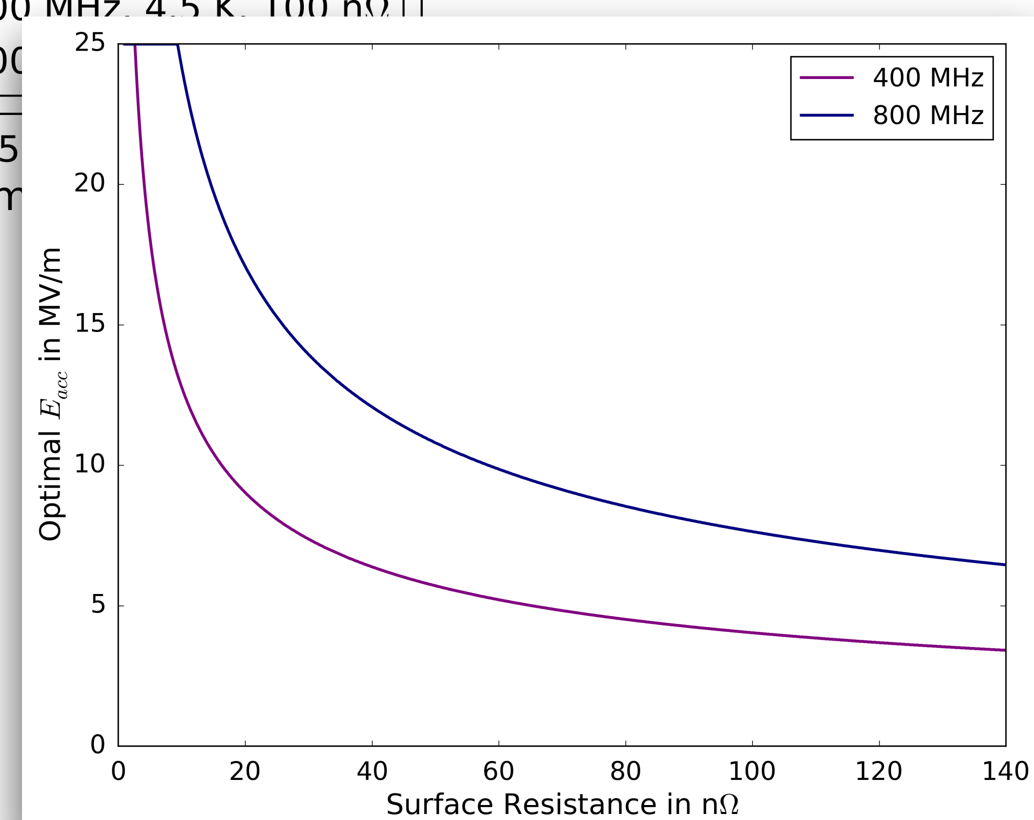

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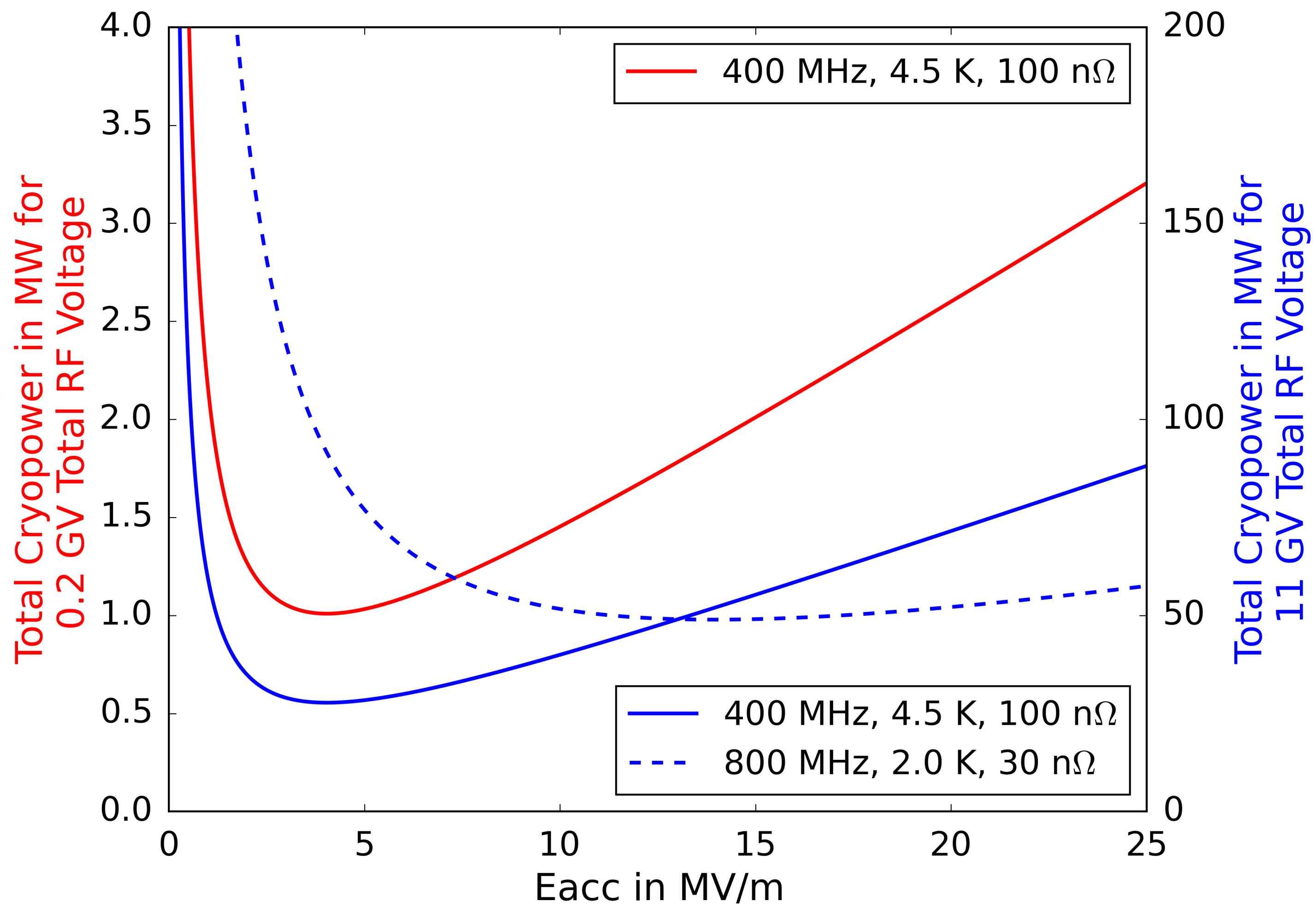

Accelerating gradient is a design choice

Qo is given by the temperature, frequency and material choice

Surface Resistance

$$R_S = R_{BCS} + R_{res}$$

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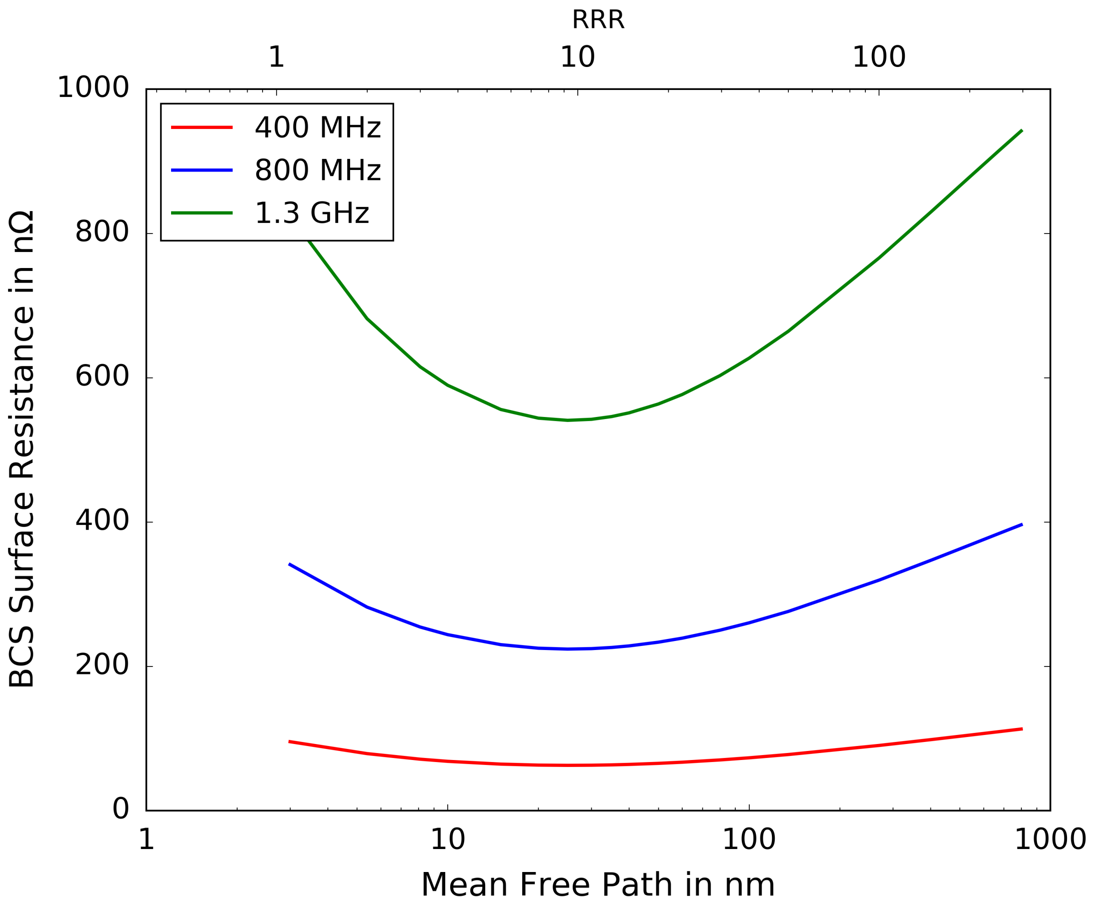
R_{BCS} increases with f^2

R_{BCS} decreases with $\exp(T/T_c)$

R_{BCS} depends on the mean free path



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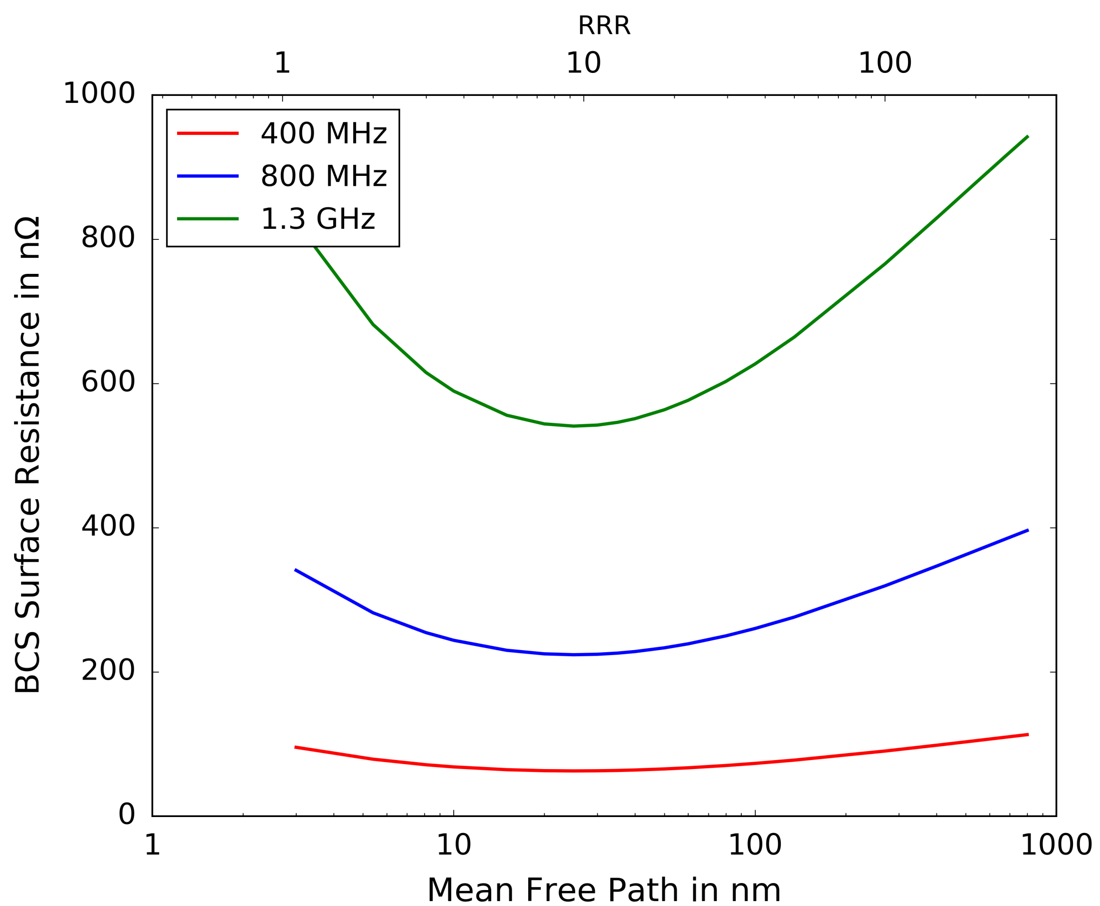


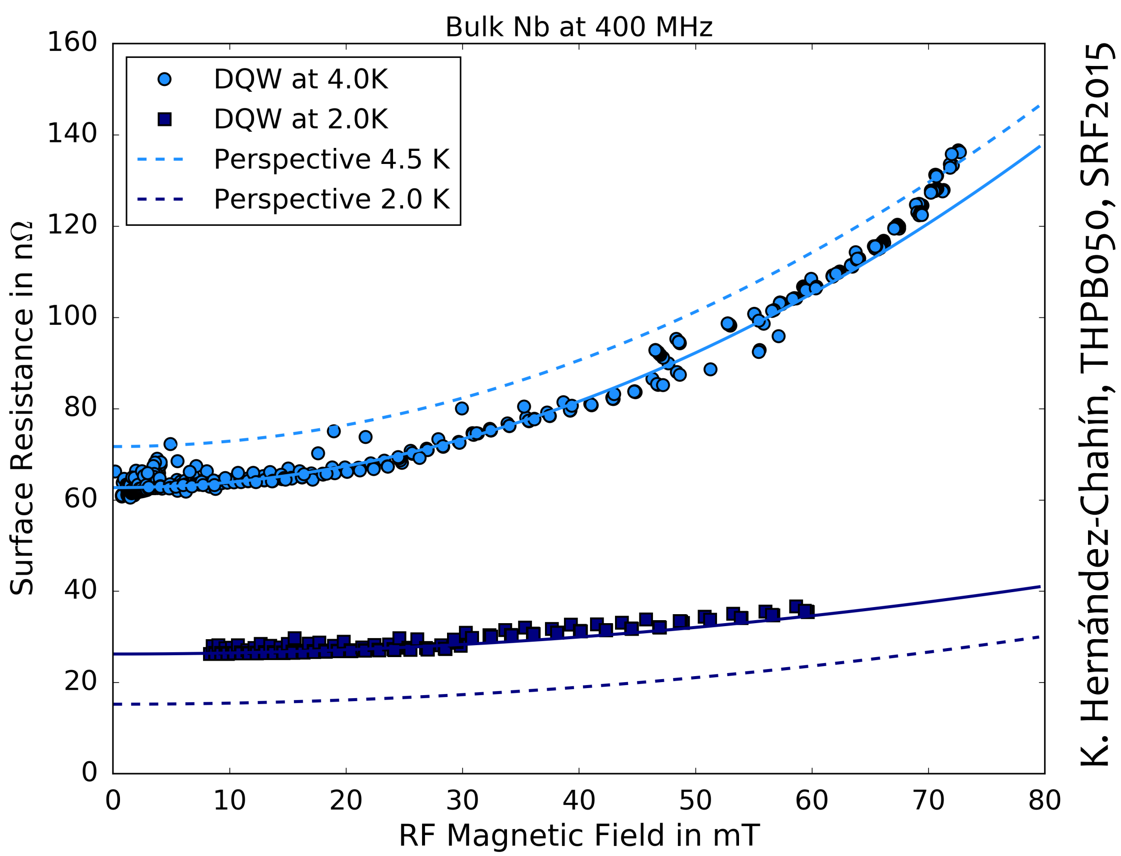
R_{res} is independent of T

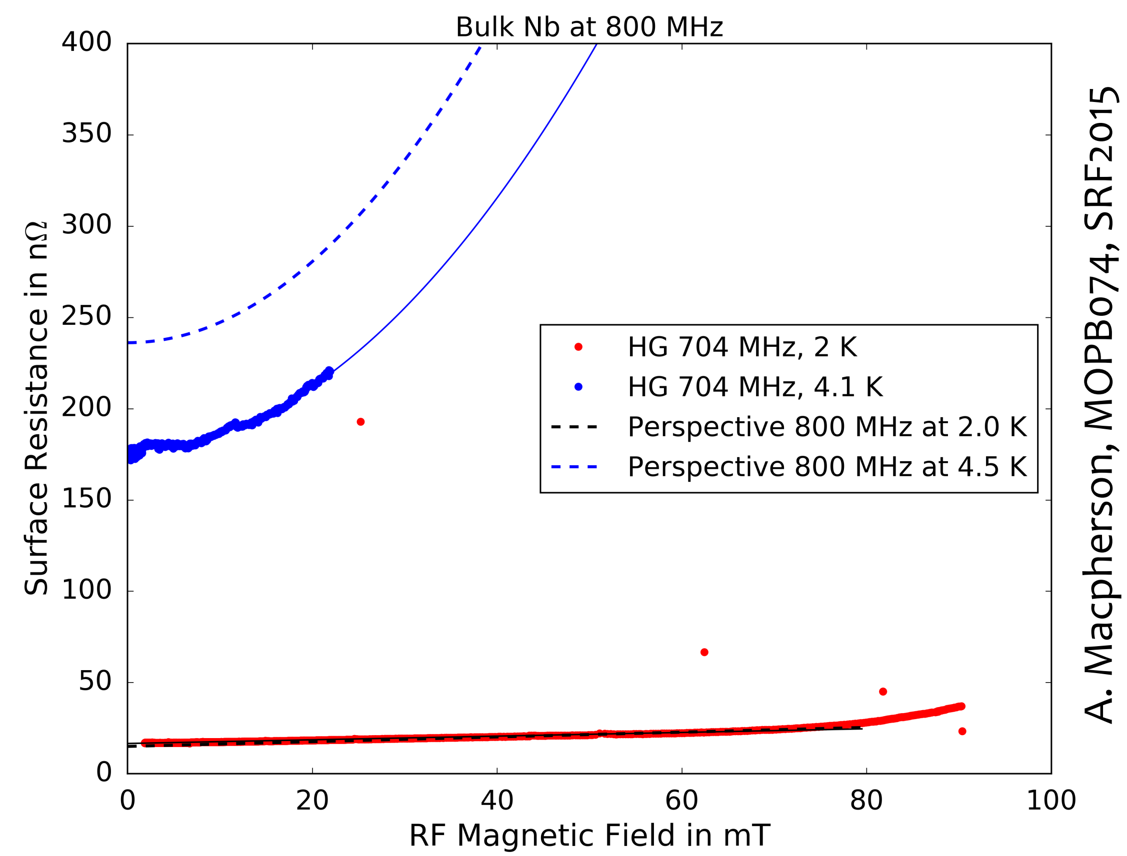
R_{res} depends only slightly on f

Field dependence depends on material

Material	Achieved	Expected in mass production
Bulk Nb	0.5 - 20 nΩ	10-15 nΩ
Nb/Cu	0.5 - 30 nΩ	20 nΩ

Bulk Niobium - A Well-Known Technology





High level of expertise

High cost for raw material

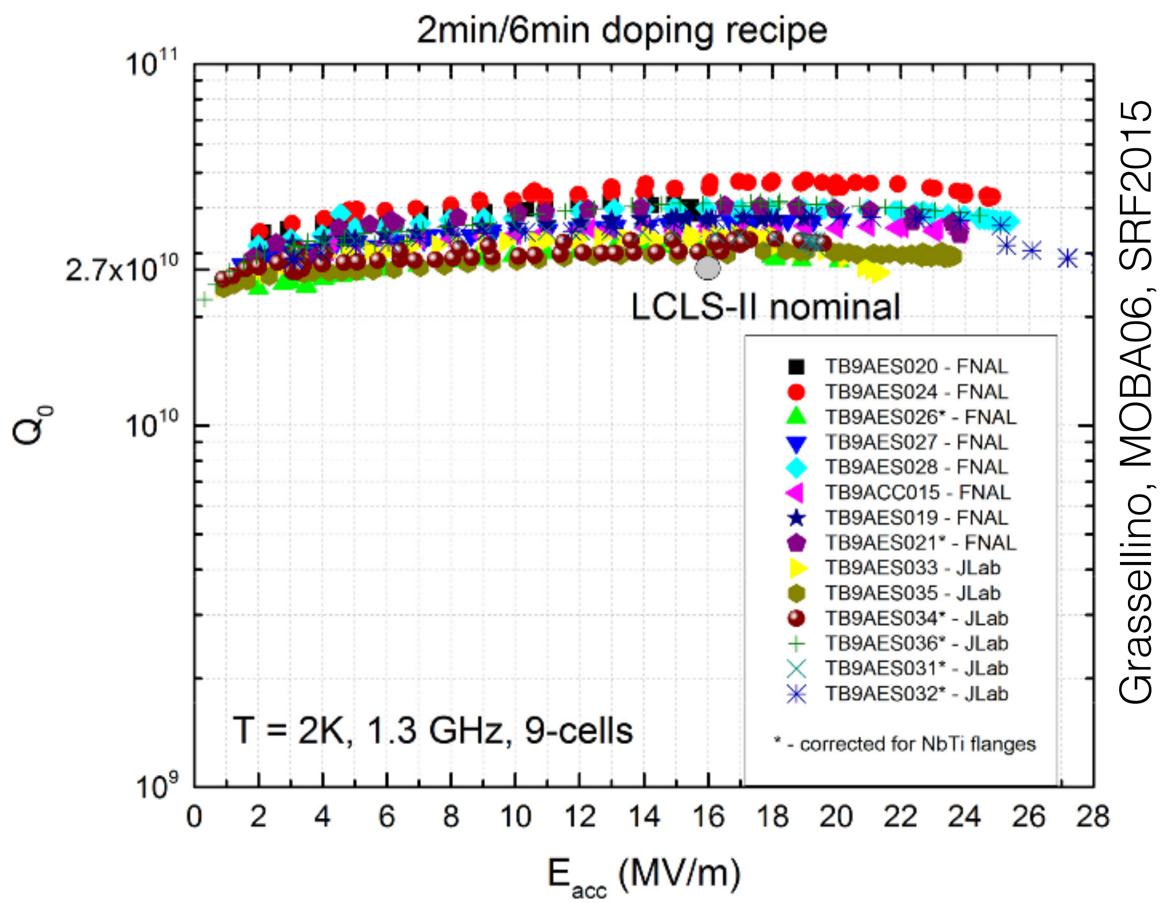
Requires magnetic shielding

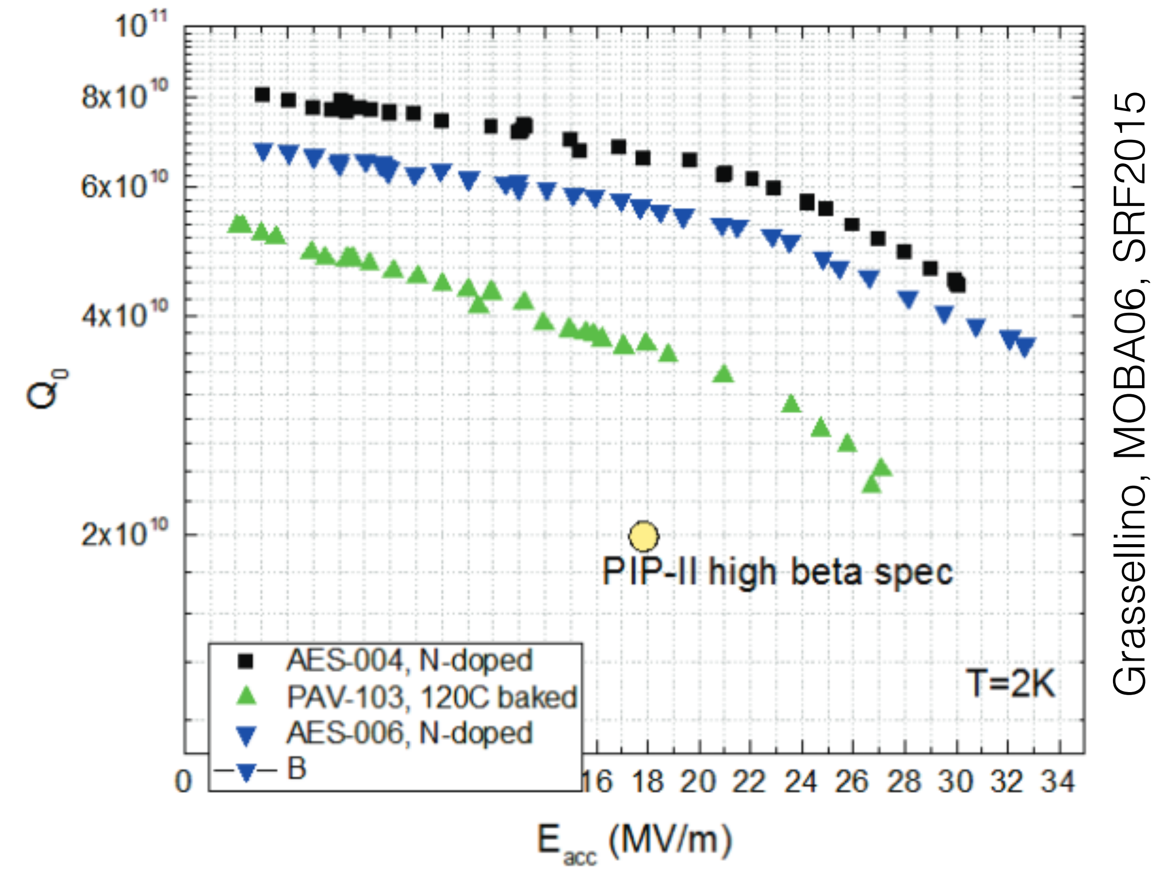
Only operation at < 2.1 K

Improved surface preparation techniques

Higher E_{acc} in mass production

N *Doping* - Pushing the Limits of Bulk Niobium

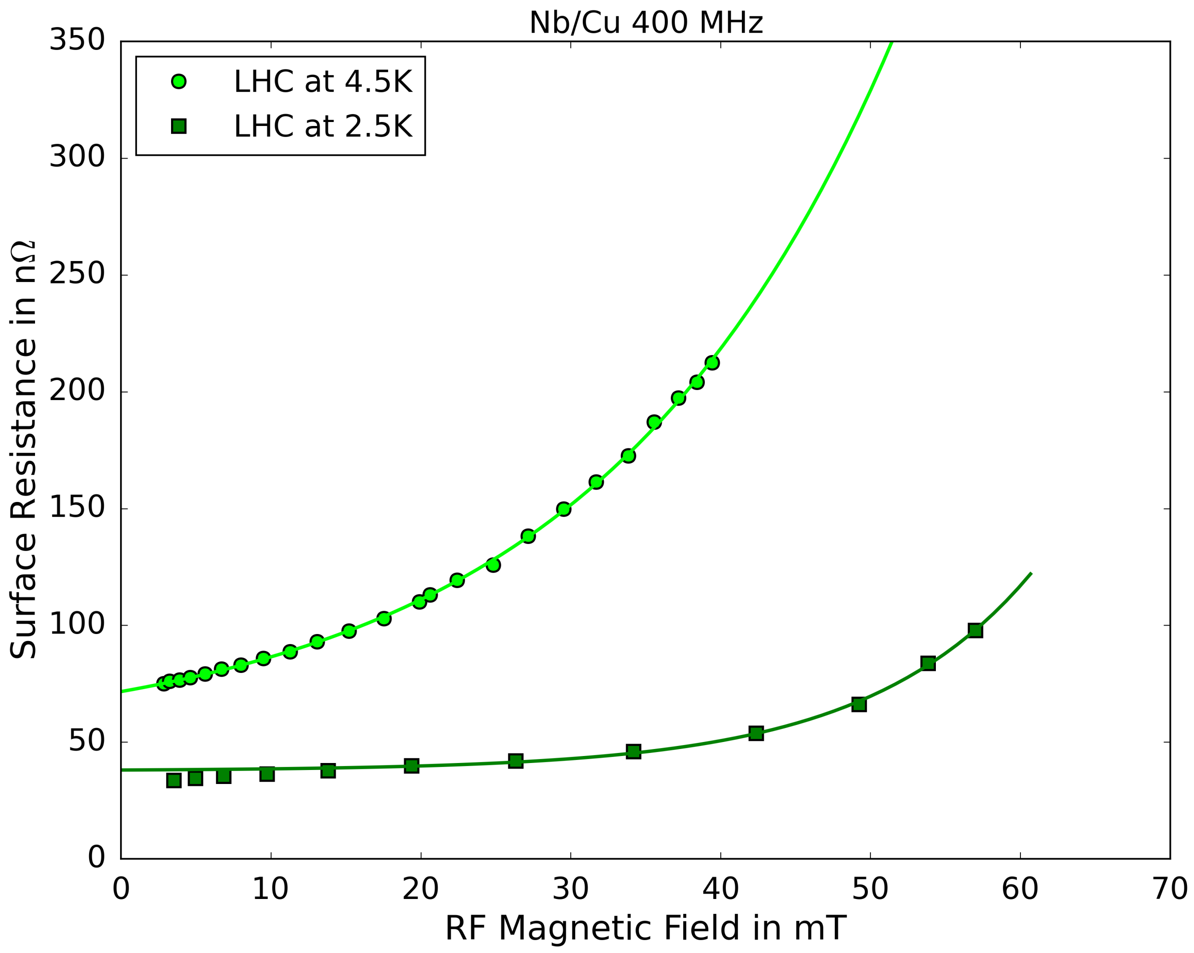




Very high Q at 2 K
High cost for raw material
Requires magnetic shielding
Reduced quench field

Performance at lower frequencies?
Performance at 4.2 K?

Nb/Cu - New Coating Techniques on the Rise



Lower raw material costs
High thermal stability
No magnetic shielding
Reduced microphonic

Only low E_{acc} due to strong Q-Slope

Mitigated Q-Slope for energetic condensation techniques

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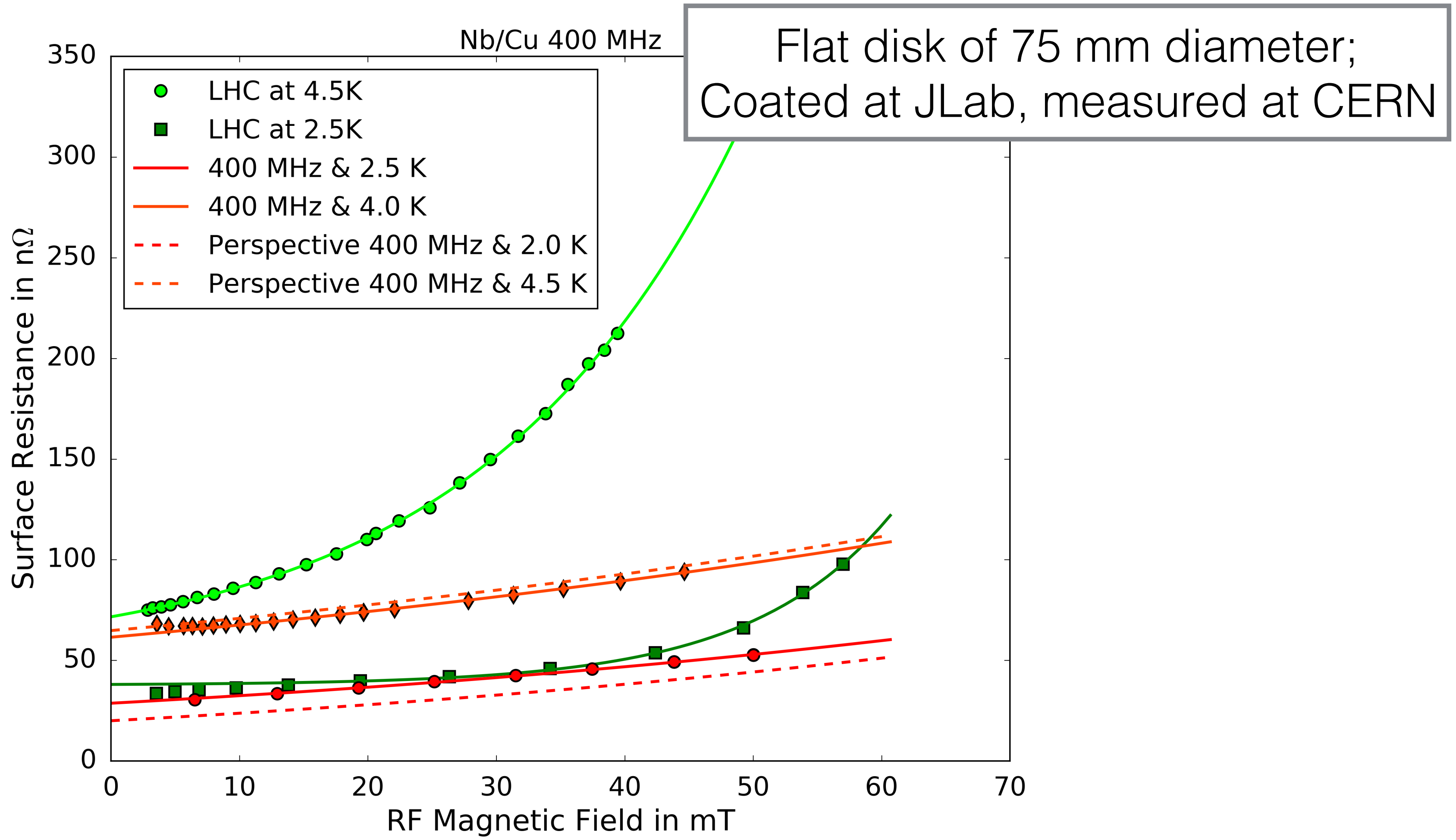

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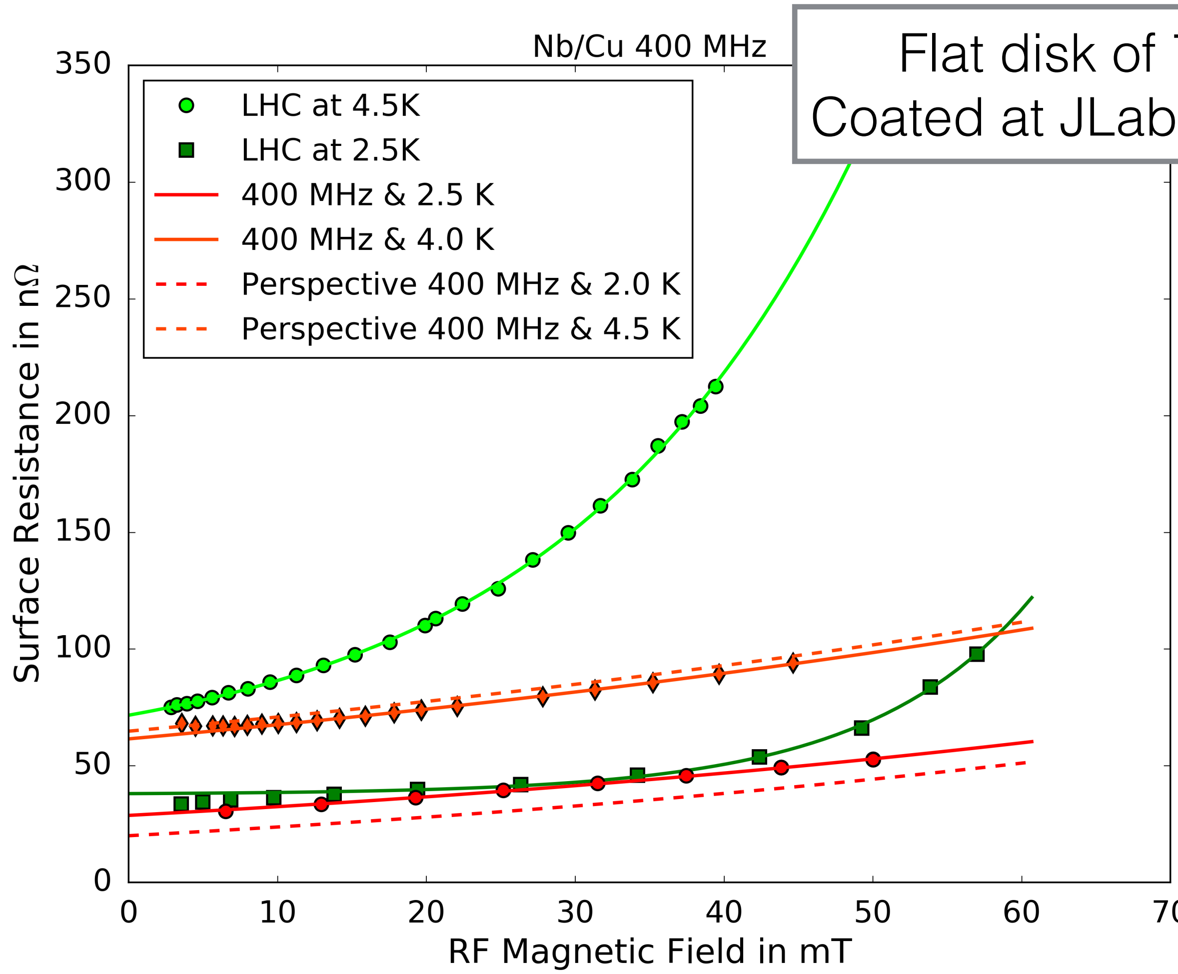
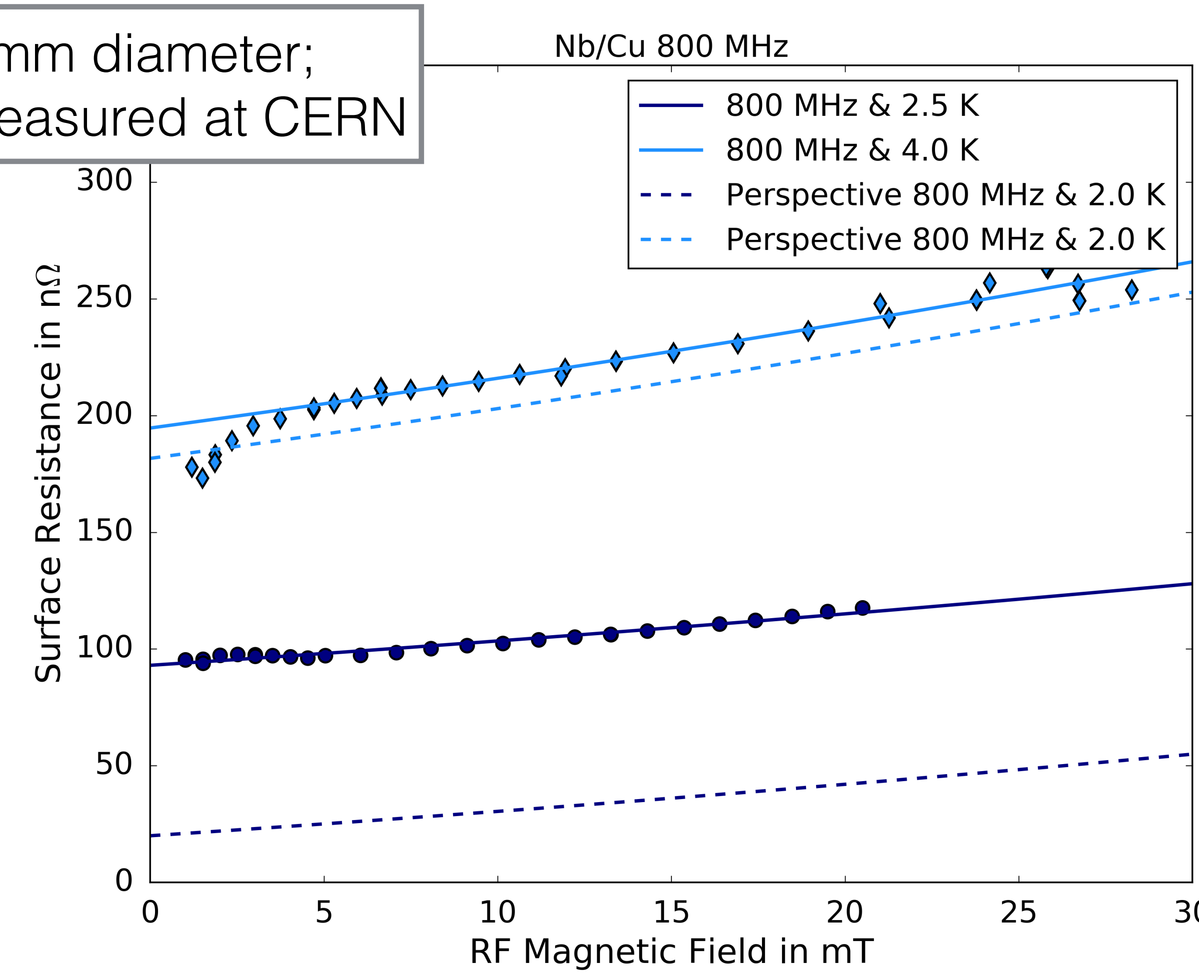
Nb/Cu - New Coating Techniques on the Rise

Flat disk of 75 mm diameter;
Coated at JLab, measured at CERN





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Energetic Condensation

Energetic Condensation techniques like ECR and HIPIMS promise improved film microstructure and interface

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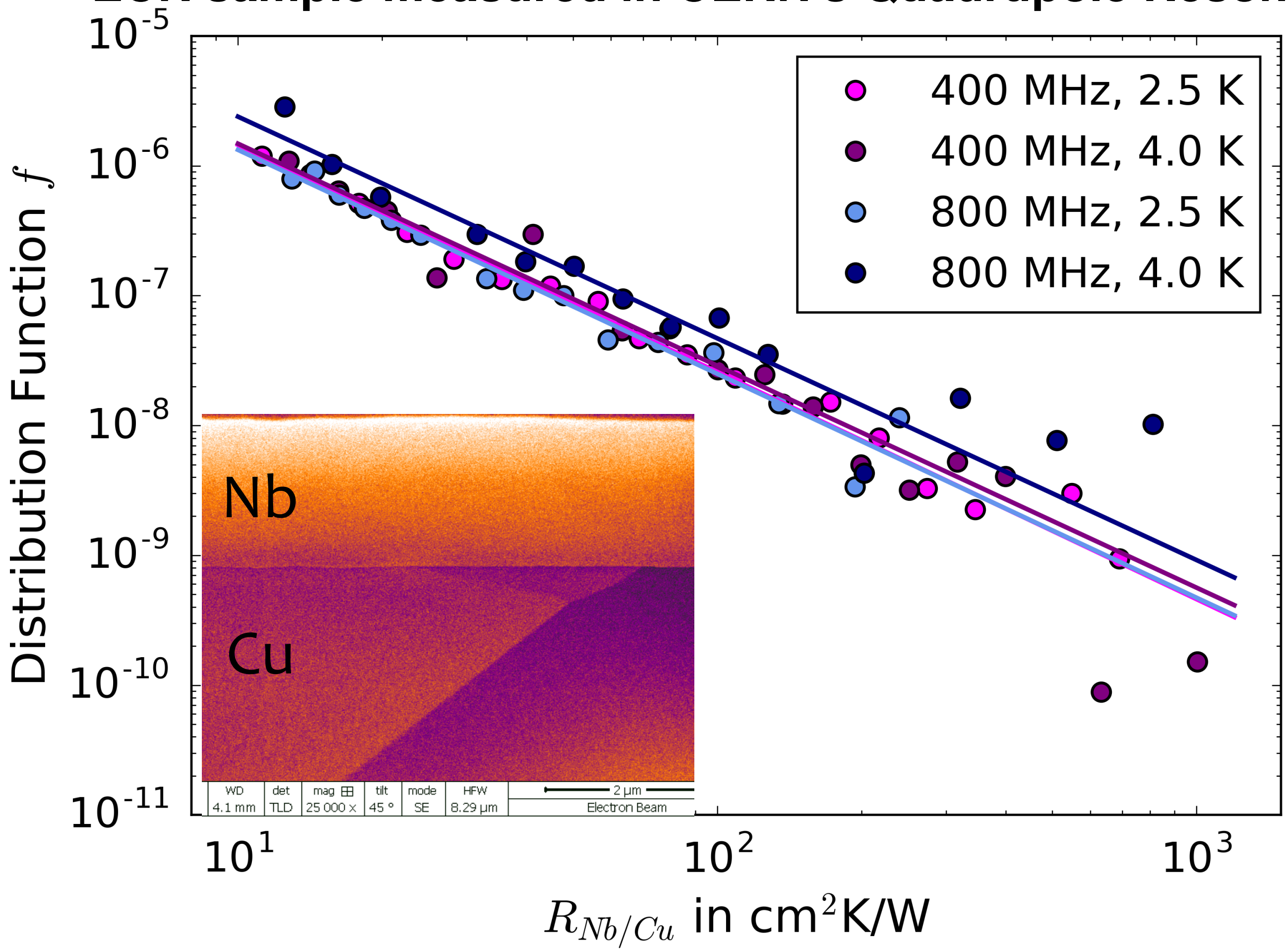
ECR sample measured in CERN's Quadrupole Resonator



Thermal boundary resistance model (Palmieri/Vaglio, SUST 29, 2016) yields 0.002 % detached surface area.

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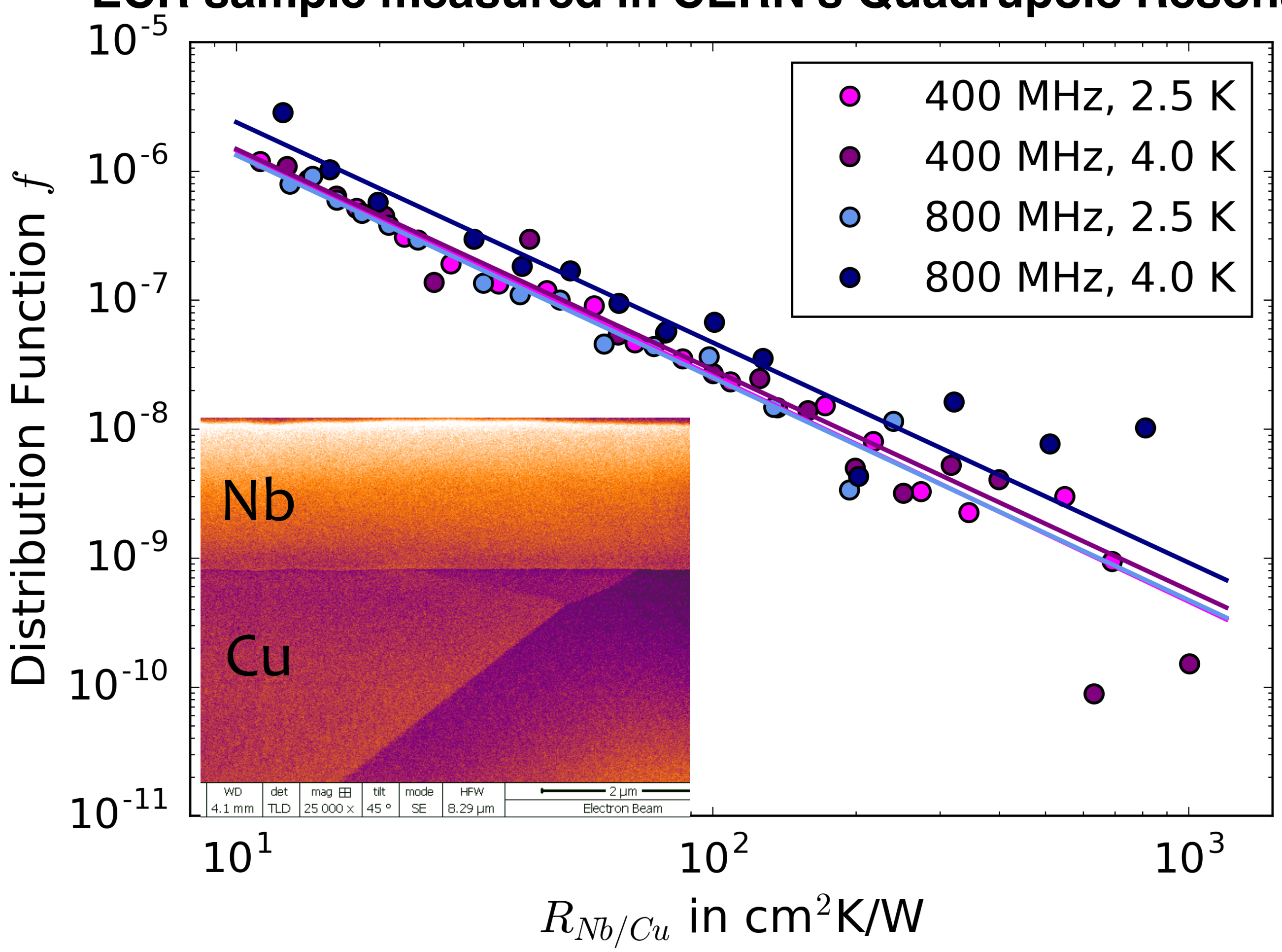

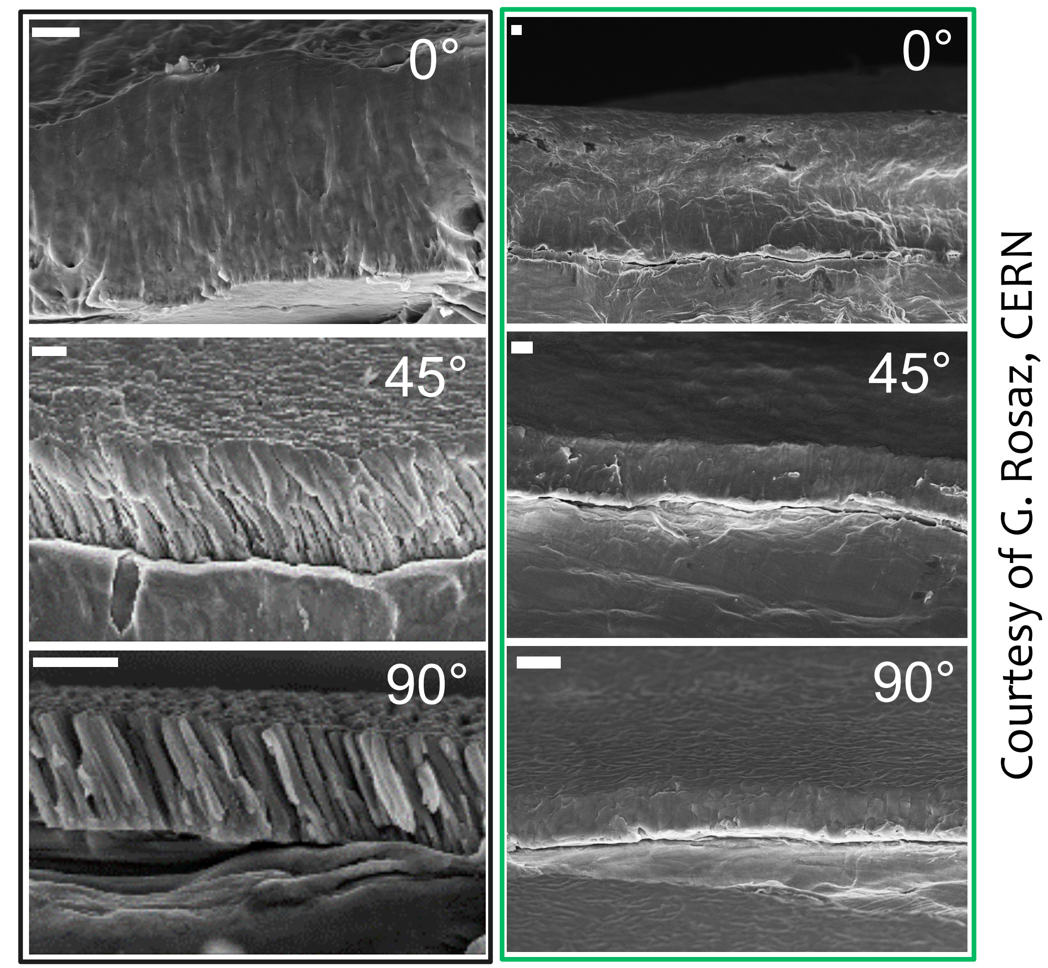

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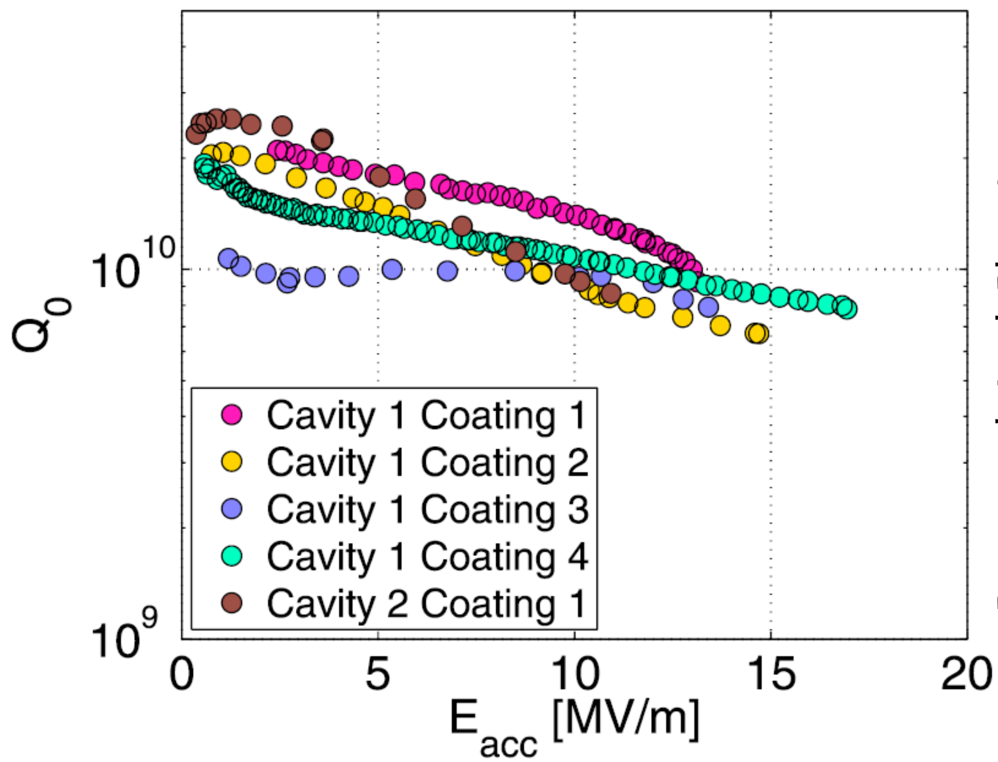
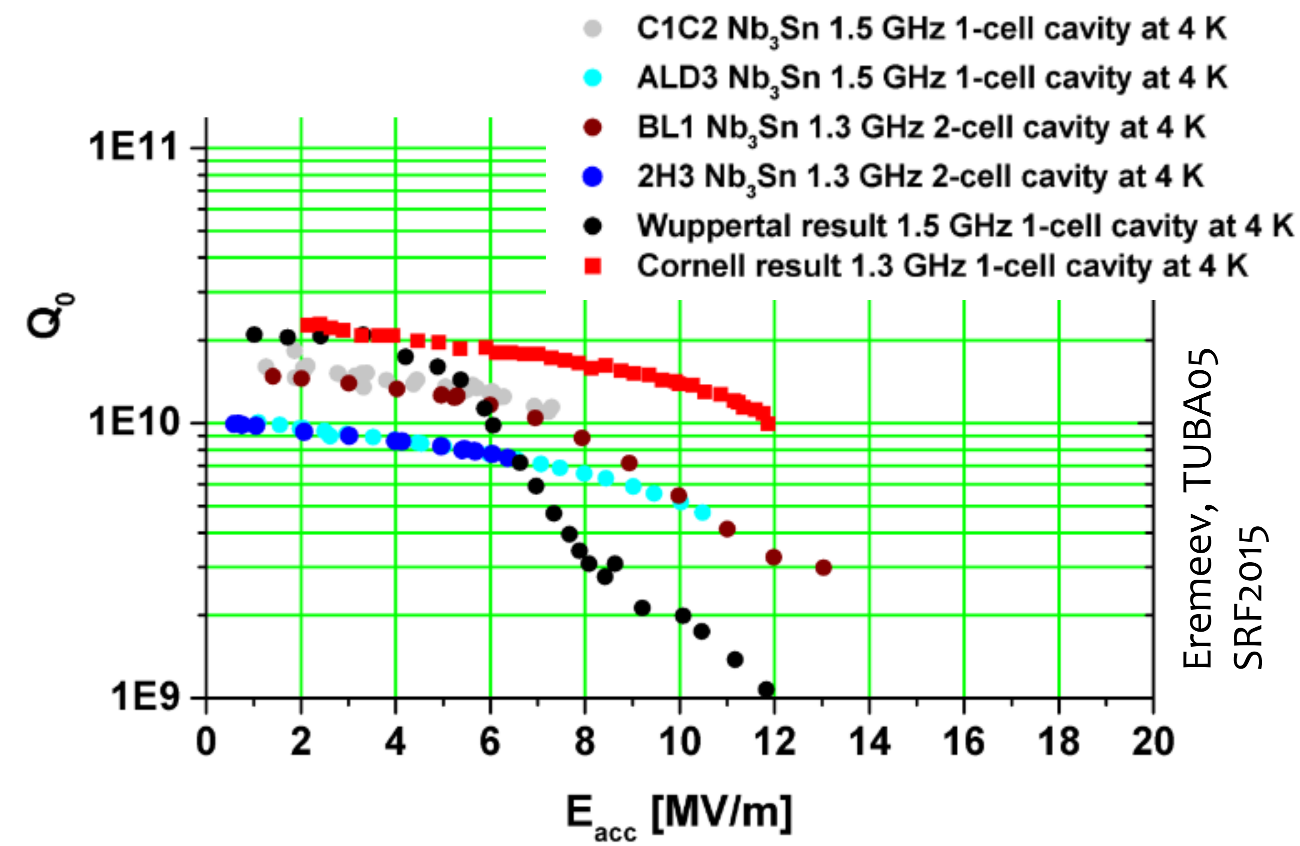
Biased HIPIMS samples show denser film for non-normal incident angle.

Nb3Sn/Nb - Beyond Niobium



Posen et al. Appl. Phys. Lett. 106, 082601 (2015)



Eremeev, TUBA05 SRF2015

Very high Q at 4.2 K

High cost for raw material

Requires magnetic shielding

Premature quenching

Not a mature technology yet

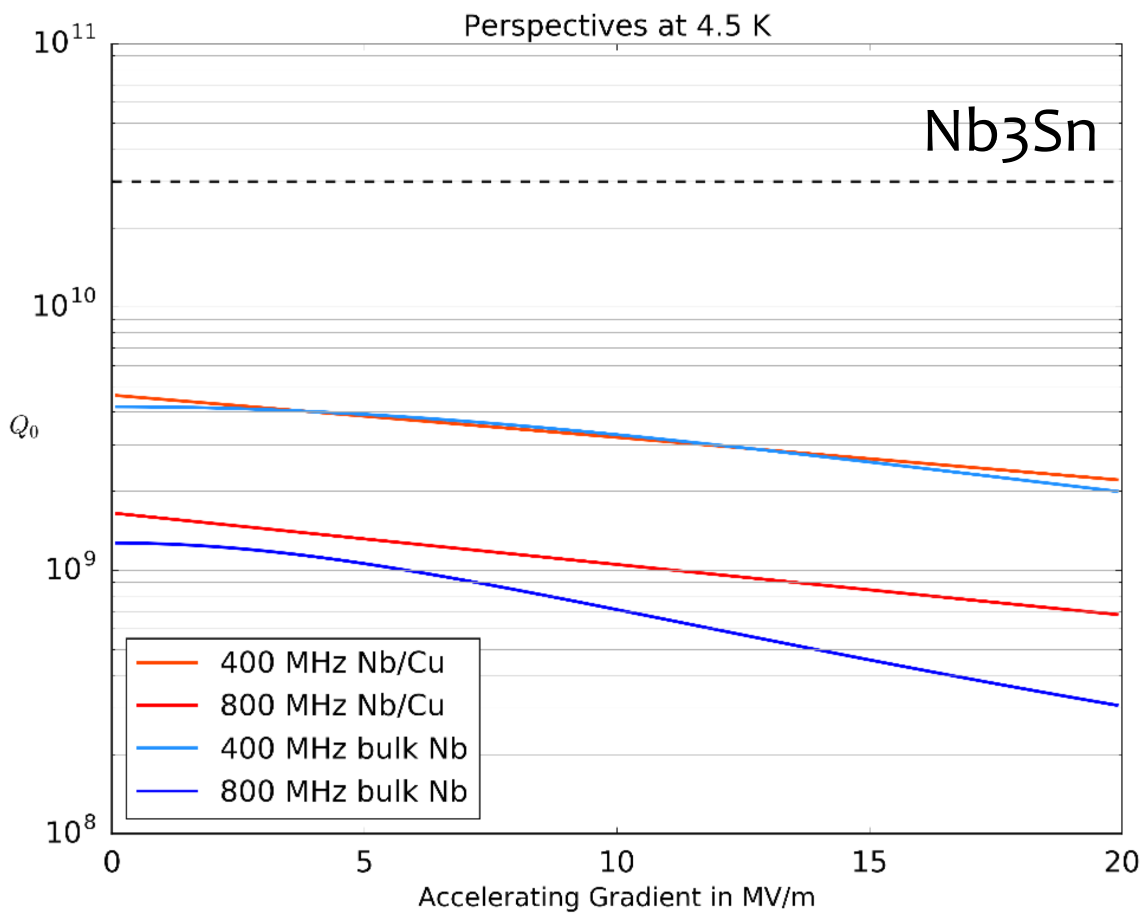
Multicell cavities

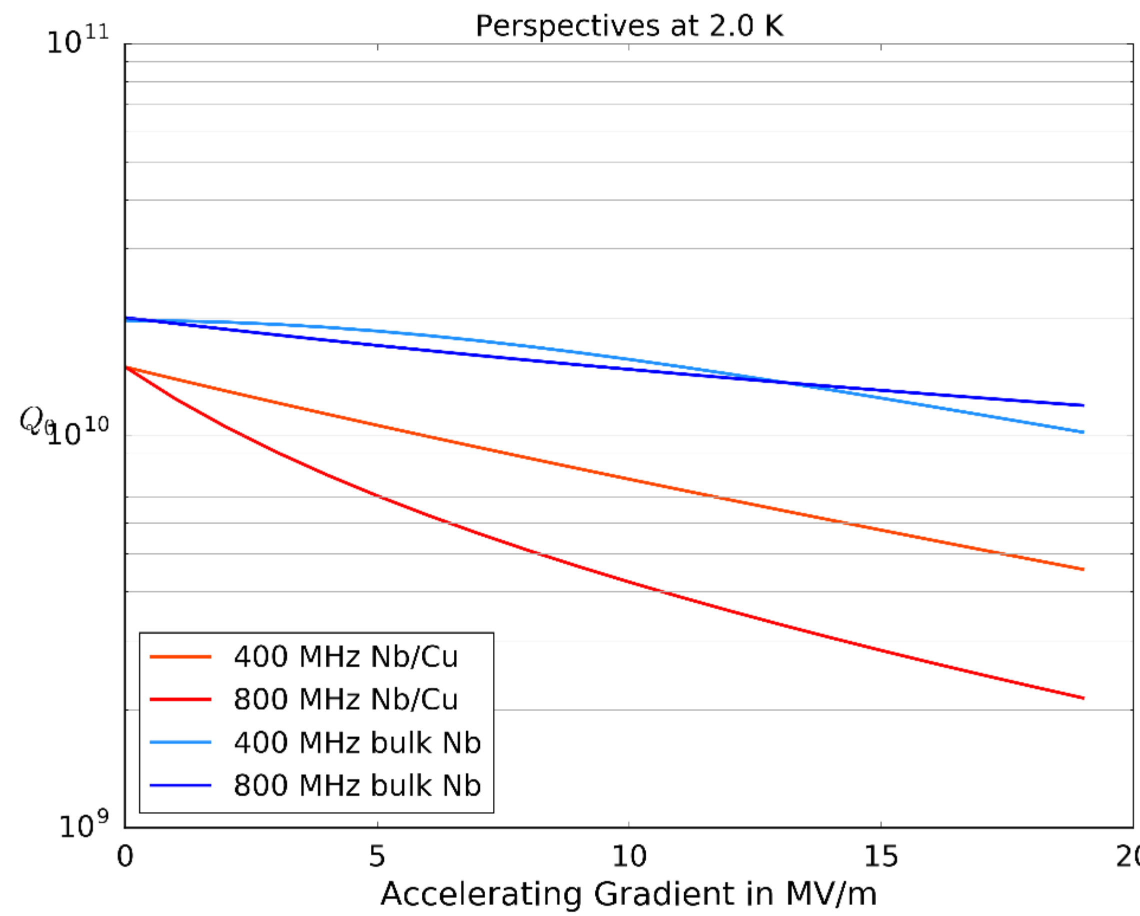
Higher quench field

Mechanical behavior

Nb3Sn/Cu (See Poster by K. Ilyina)

Perspectives for R&D





4.5 K operation:

Optimise mean free path

Cure Q-slope

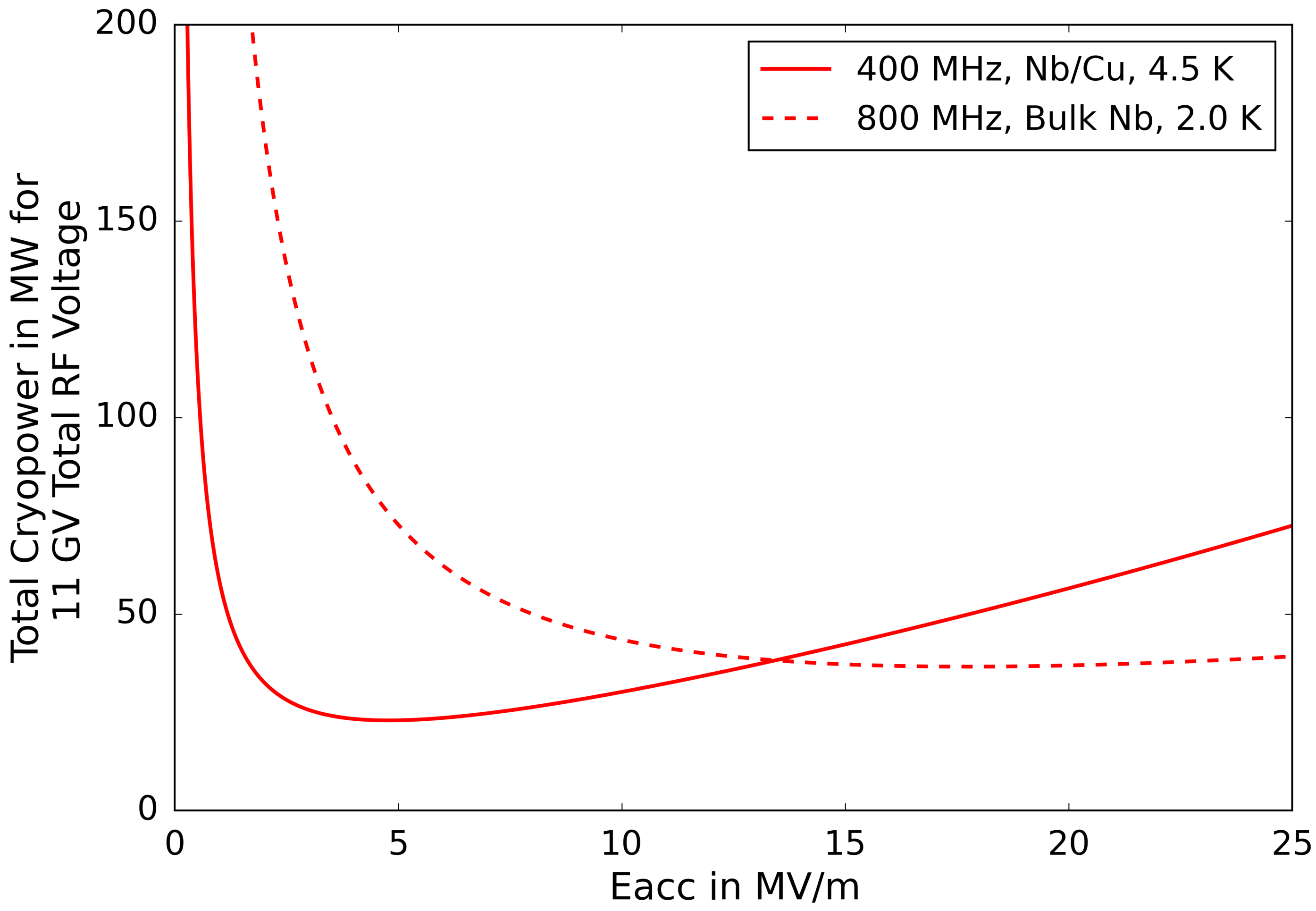
A15 materials

2 K operation:

Optimise residual resistance

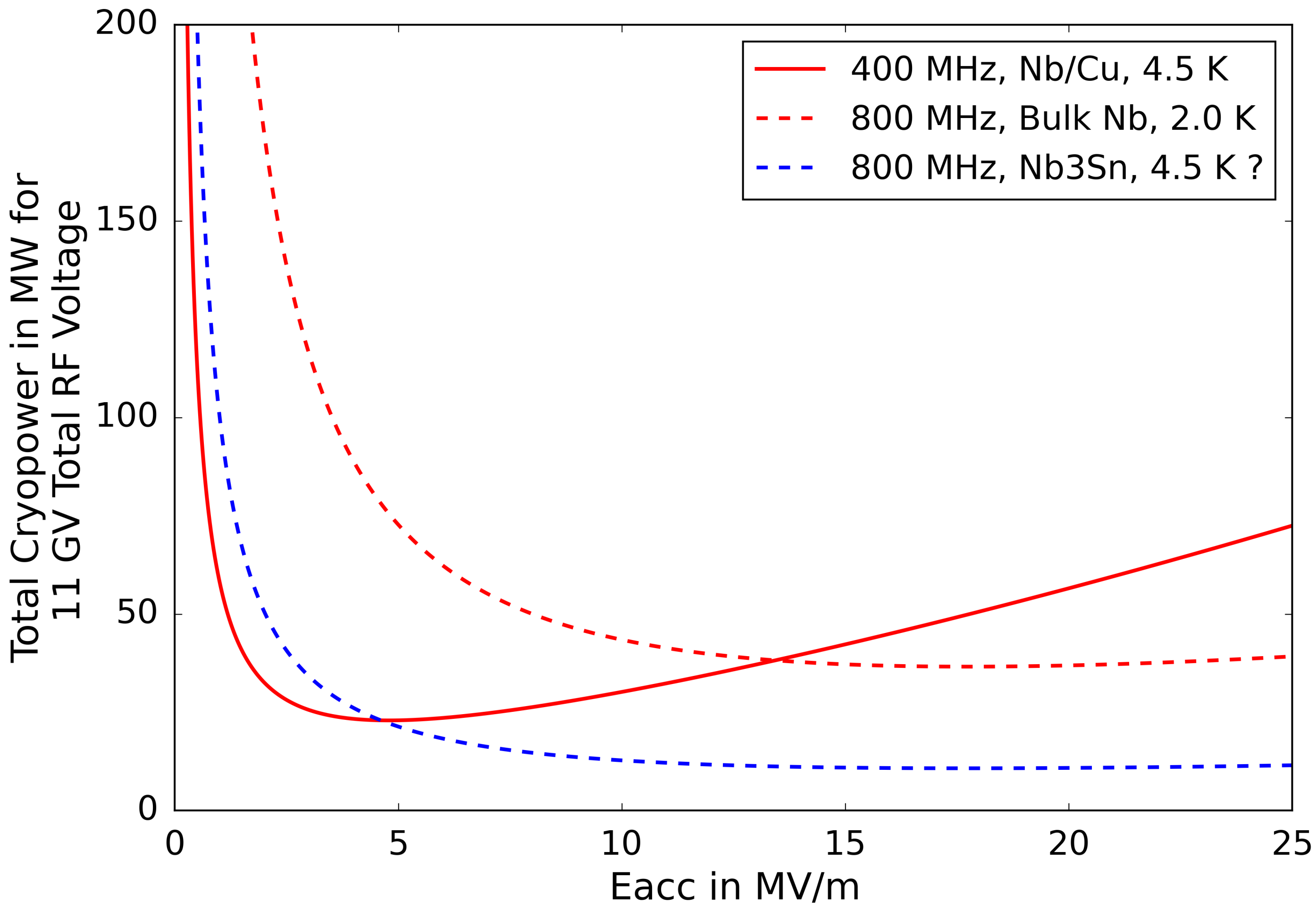
Cure Q-slope

Cryogenic Power for the Top Machine



The perspective of cavity performances yields similar cryogenic losses for Nb/Cu at 400 MHz and 4.5 K and bulk Nb at 800 MHz and 2.0 K.
A15 Materials might further reduce the cryogenic power.

Cryogenic Power for the Top Machine



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Cryo power is not everything: more considerations

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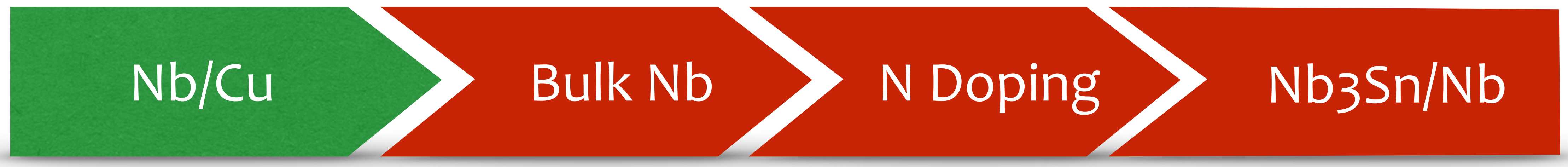
Installation Cost



Cryo power is not everything: more considerations

Installation Cost

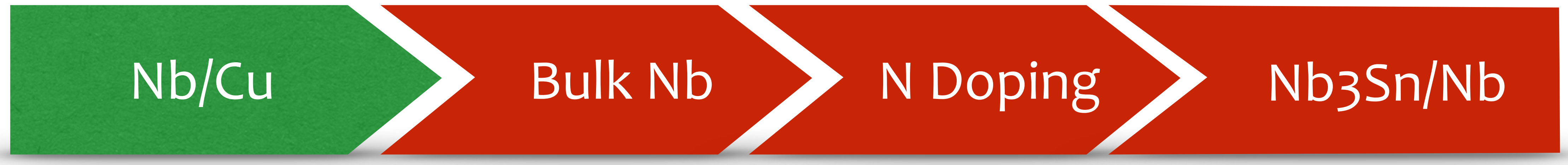
Nb/Cu → Bulk Nb → N Doping → Nb3Sn/Nb

Magnetic Shielding

Nb/Cu → Nb3Sn/Nb → Bulk Nb → N Doping

Cryo power is not everything: more considerations

Installation Cost



Magnetic Shielding

Microphonics

Conclusion

- The application of Nb/Cu technology would reduce the installation and running costs of the cryogenic system as well as the cost of cavities and cryomodules.
- Energetic condensation techniques promise cavity performances at 4.5 K comparable to bulk niobium.
- A15 materials such as Nb_3Sn may even further decrease the dynamic losses at 4.5 K.

CERN