RESEARCH AND DEVELOPMENT ON SRF 6 GHZ CAVITIES

Vanessa Garcia Diaz, E. Chyhyrynets, F. Stivanello,

M. Zanierato, C. Pira

EASITrain – European Advanced Superconductivity Innovation and Training. This Marie Sklodowska-Curie Action (MSCA) Innovative Training Networks (ITN) has received funding from the European Union's H2020 Framework Programme under Grant Agreement no. 764879

OUTLINE

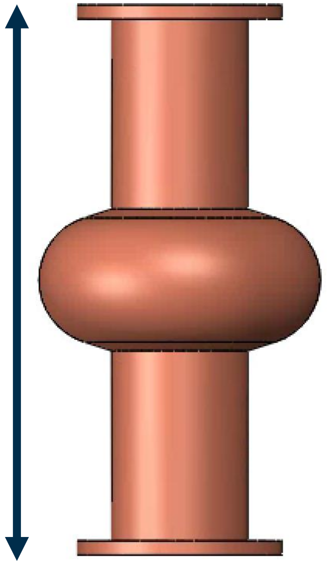
- Why 6 GHz?
- State of art on 6 GHz cavities
- Seamless motivation
- Manufacturing process
- Surface treatments
- Coating process
- RF Characterization
- Magnetic flux trapped study

Nb on Cu coated QWR (LNL)

WHY 6 GHZ CAVITIES?

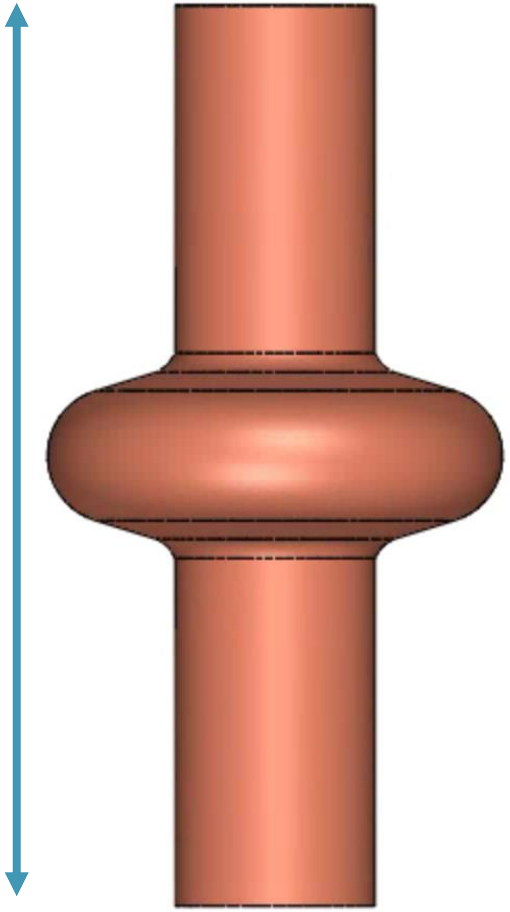
6 GHz

10 cm



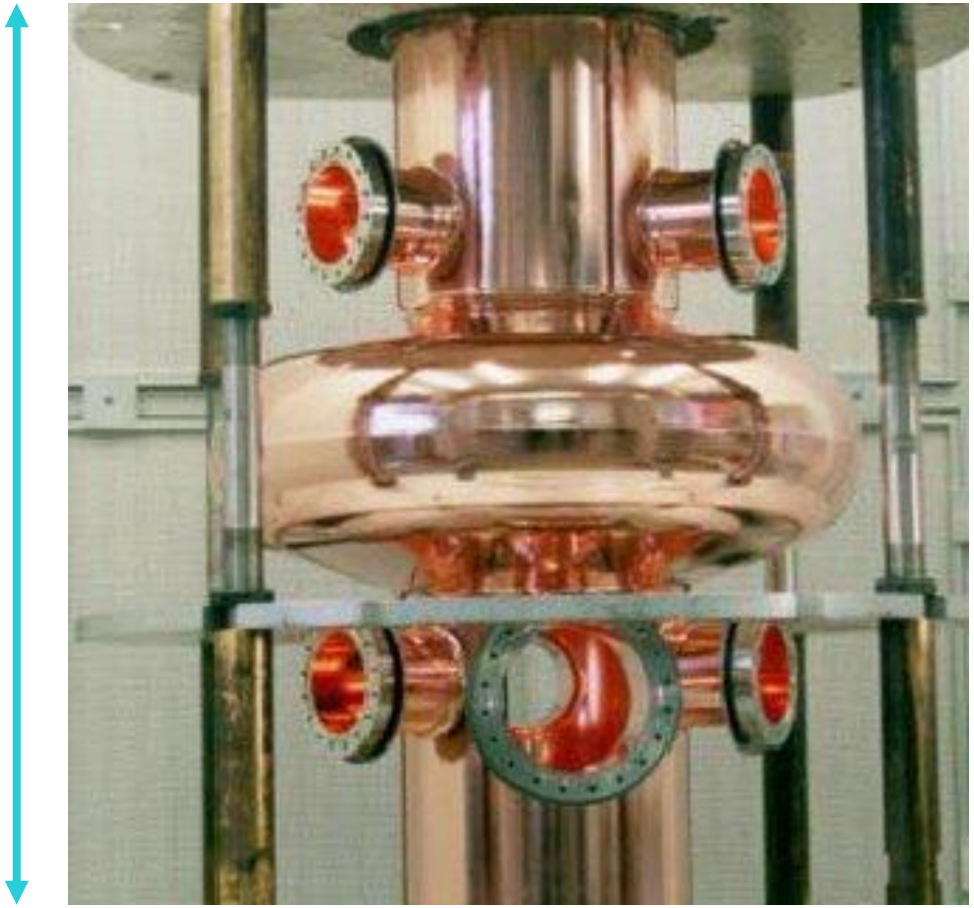
1,3 GHz

~40 cm



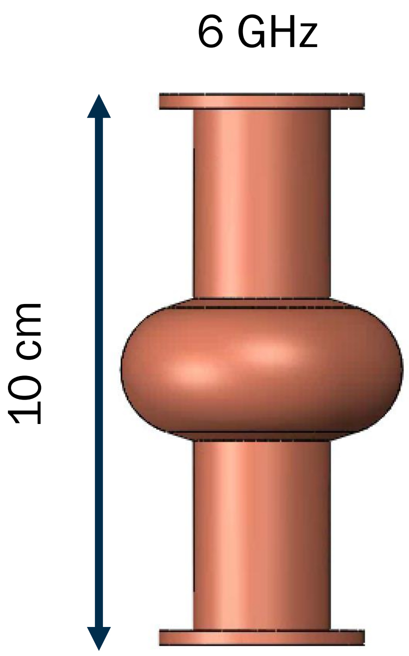
400 MHz

~ 100 cm



S. Bauer et al., TEST RESULTS OF SUPERCONDUCTING CAVITIES PRODUCED AND PREPARED COMPLETELY IN INDUSTRY, Proceedings of EPAC 2004, Lucerne, Switzerland.

WHY 6 GHZ CAVITIES?



Low cost

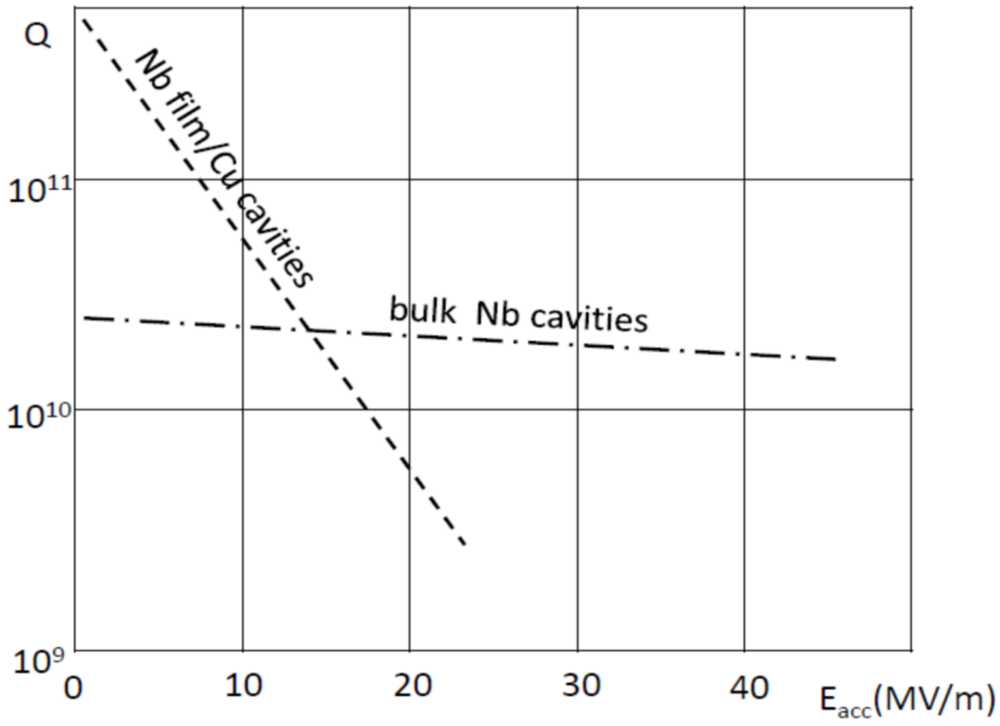
Statistic

Easy to handle

Smaller equipments

STATE OF ART NB ON CU

- High Q_0
- Thermal stability
- Cost reduction

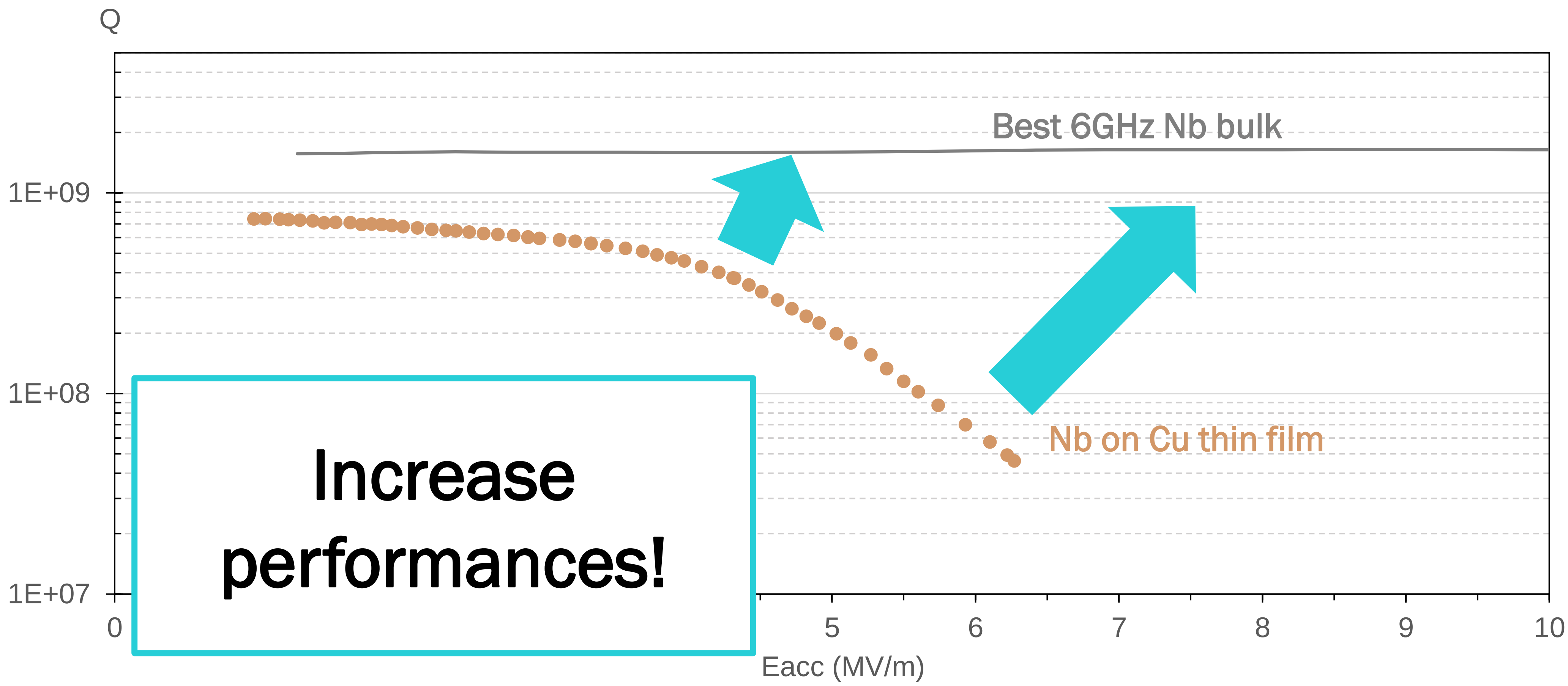


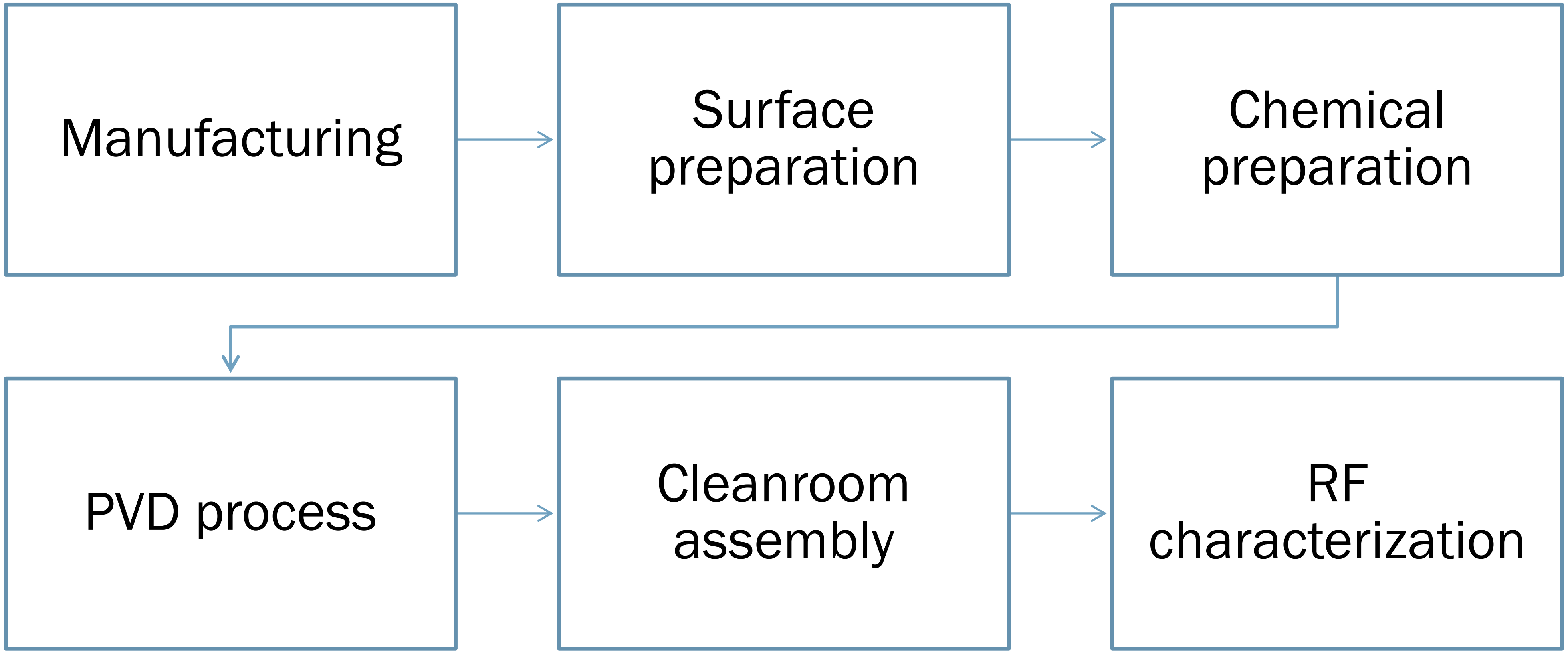
- ALPI (LNL-INFN)
- ISOLDE (CERN)
- LHC (CERN)
- LEP2 (CERN)

Bulk Nb

Nb on Cu

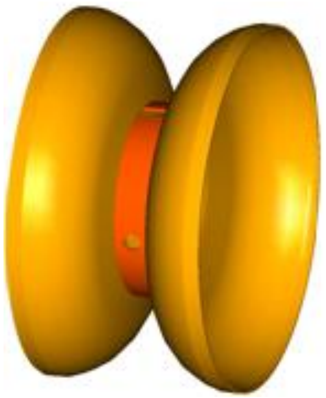
6GHZ STATE OF ART




Manufacturing
Surface preparation
Chemical preparation
PVD process
Cleanroom assembly
RF characterization

See Sertore's and Pira's *lecture (30/09)*

SEAMLESS MOTIVATION



JLAB

Imperfections

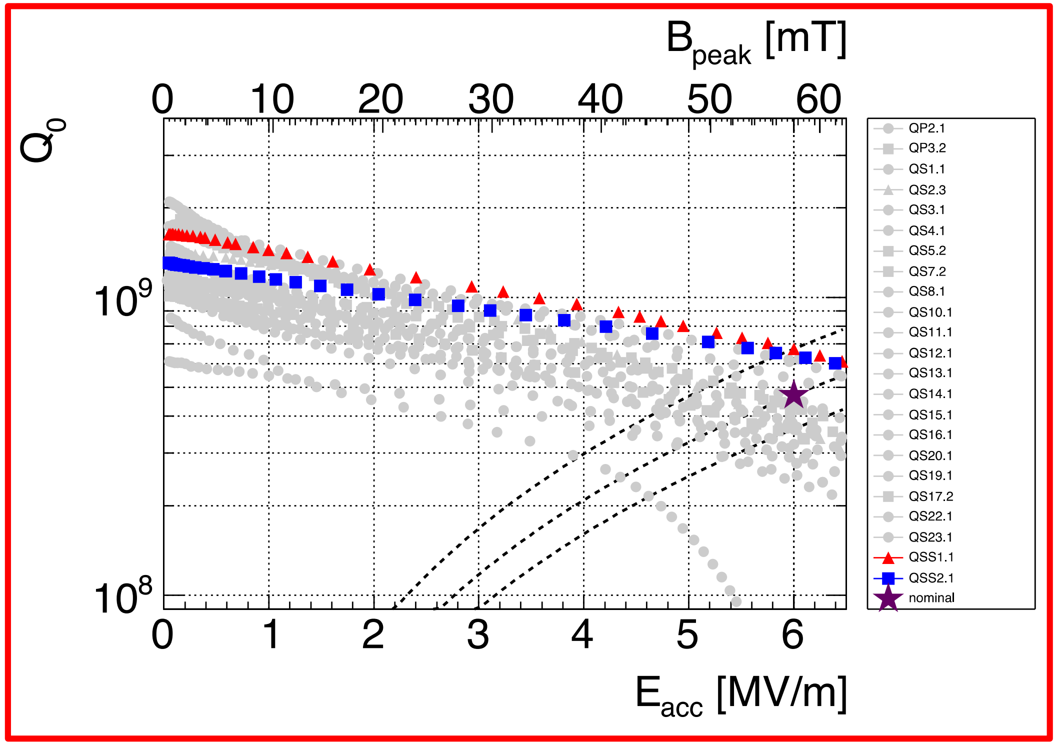
+

Roughness effect

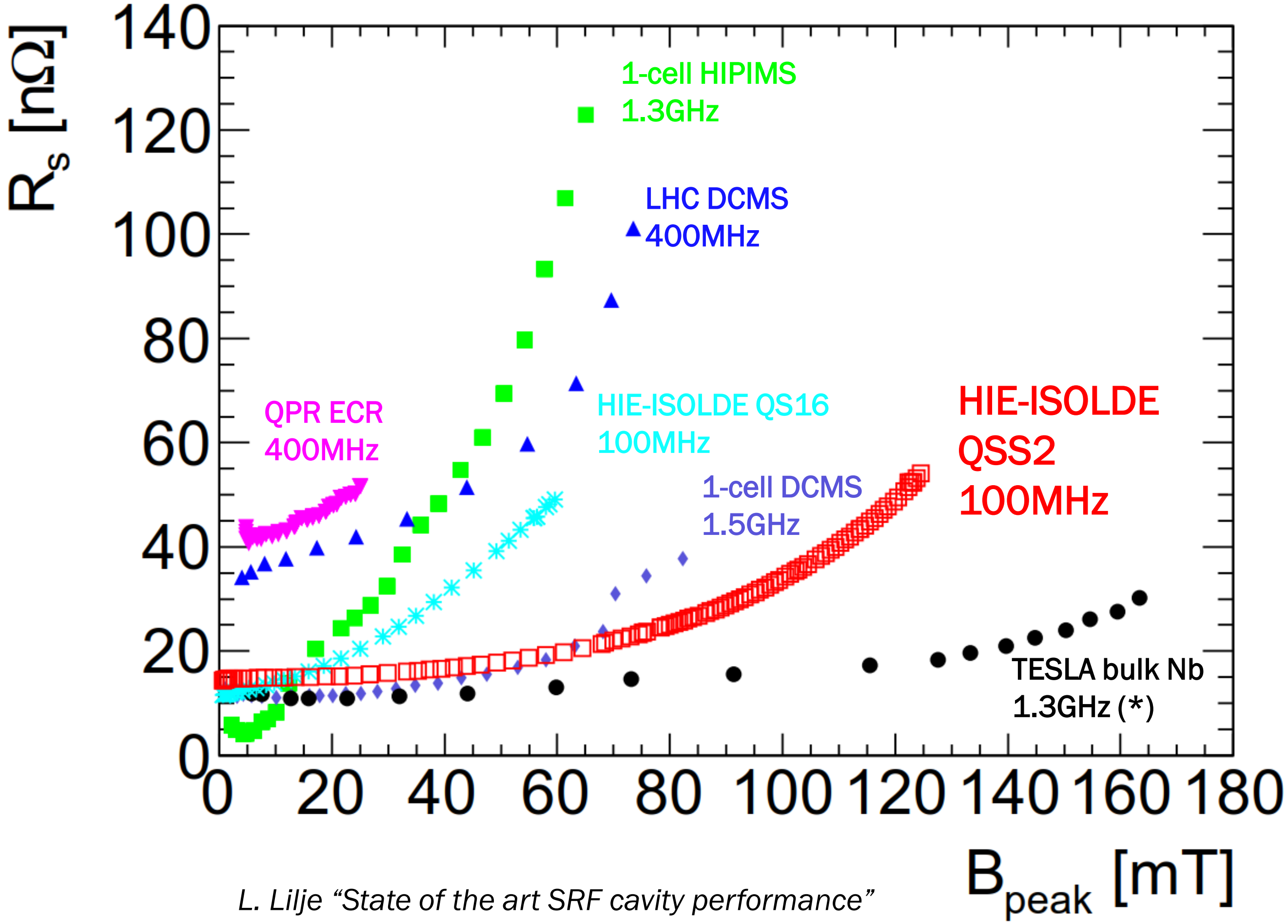
Defects in the equator!

Lower RF performances

SEAMLESS MOTIVATION



W. Venturini "Thin film research: CERN experience and possible future applications" TTC meeting Milano 2018



L. Lilje "State of the art SRF cavity performance" Proceedings of LINAC 2004, Lubeck, Germany

MANUFACTURING PROCESS @LNL

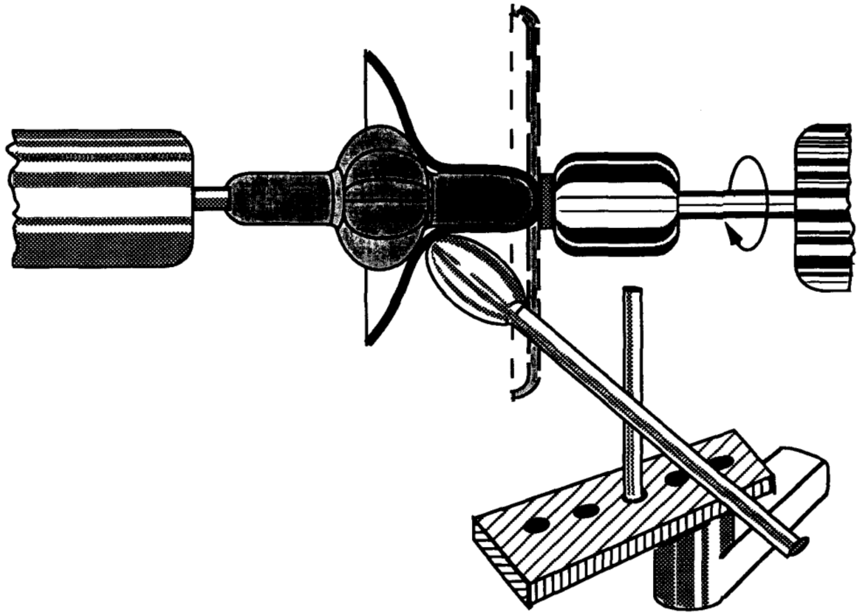


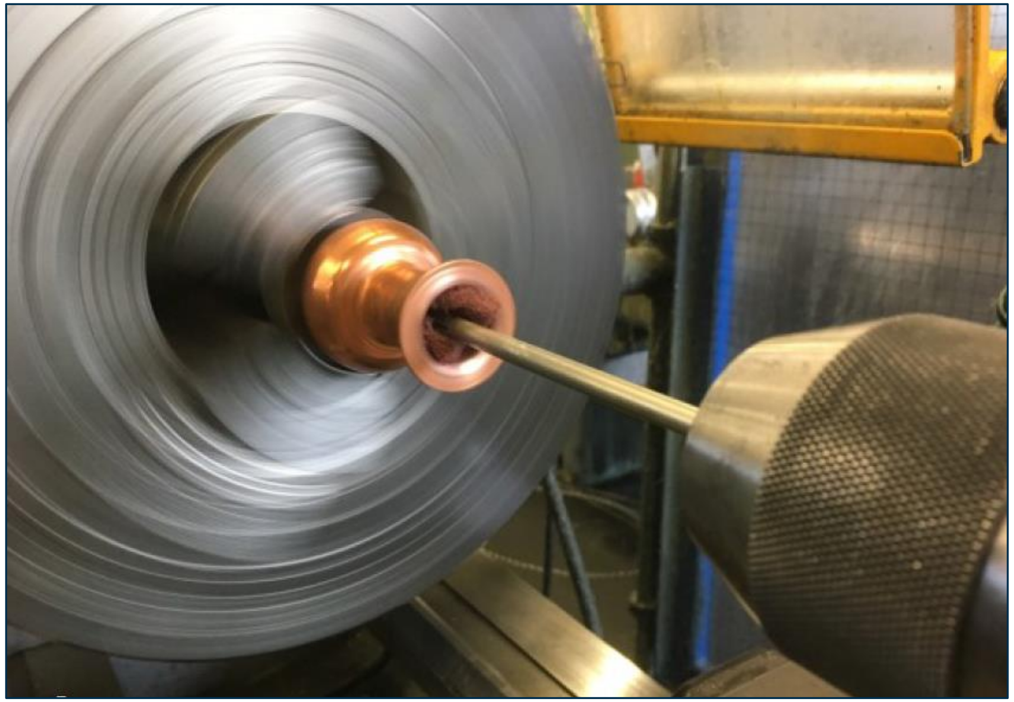
Fig. 1 Set-up for monocell cavity spinning using a simple hand tool applied as a pry bar.

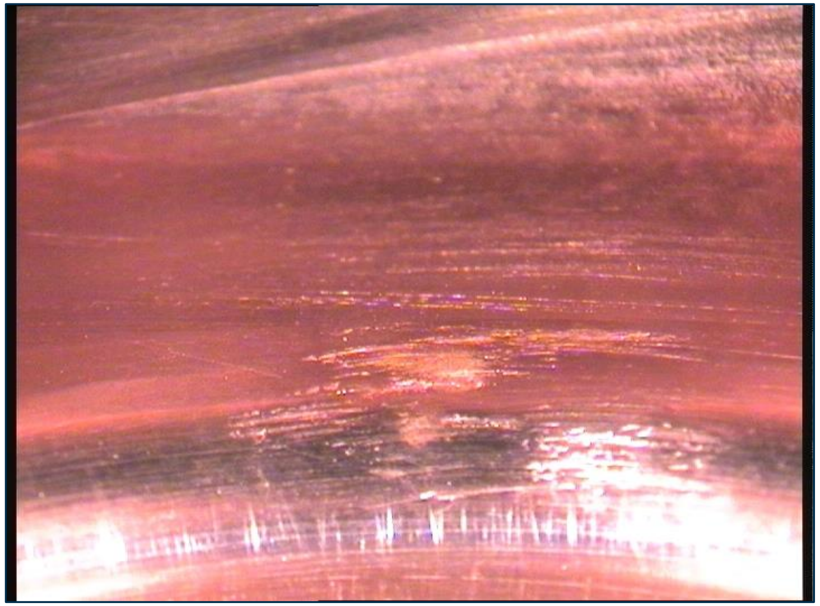
V. Palmieri «Seamless 1,5GHz cavities obtained by spinning a circular blank of Copper or Niobium» Proceedings of SRF 1993, Virginia, USA.

Spinning of a Brass Disc

https://www.manufacturingguide.com/en/spin-forming-discs

SURFACE PREPARATION

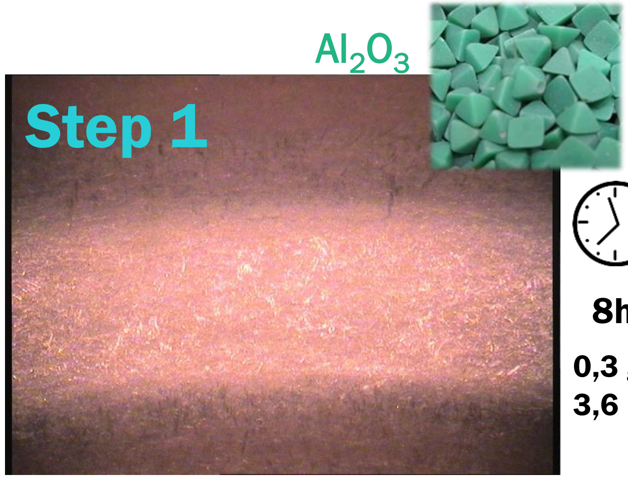




Cavity inner surface after grinding

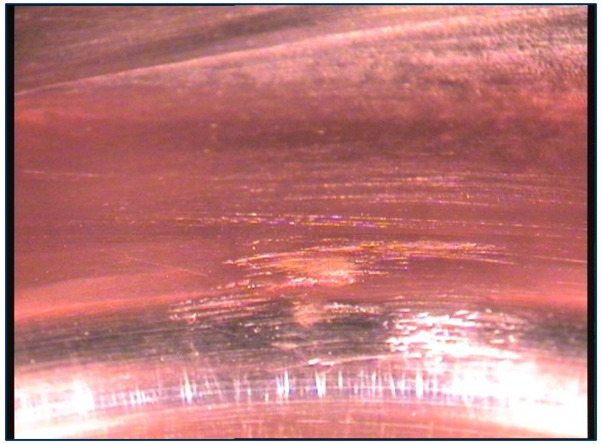
SURFACE PREPARATION

Al_2O_3



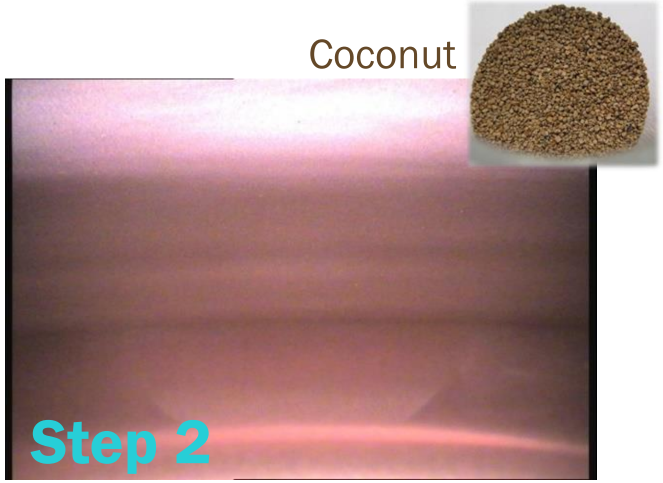
8h

0,3 g/h
3,6 µm/h



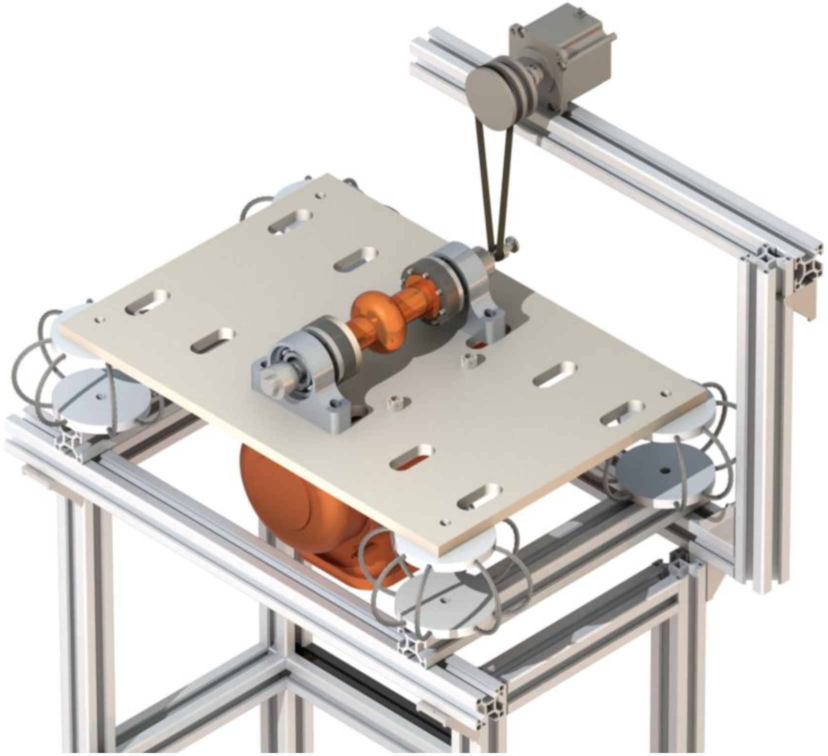
Initial surface

Coconut



4h

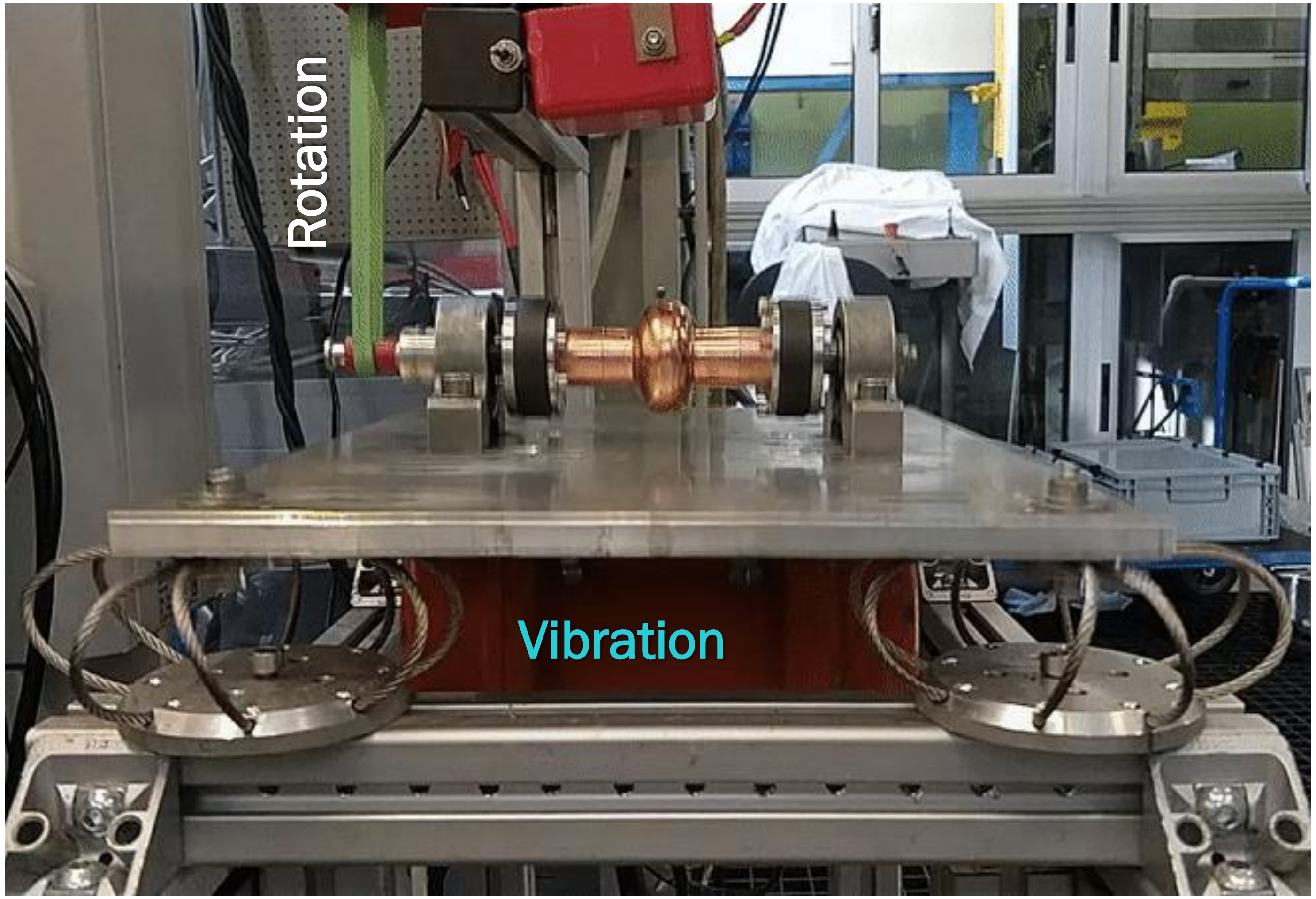
0,01 g/h
0,1 µm/h

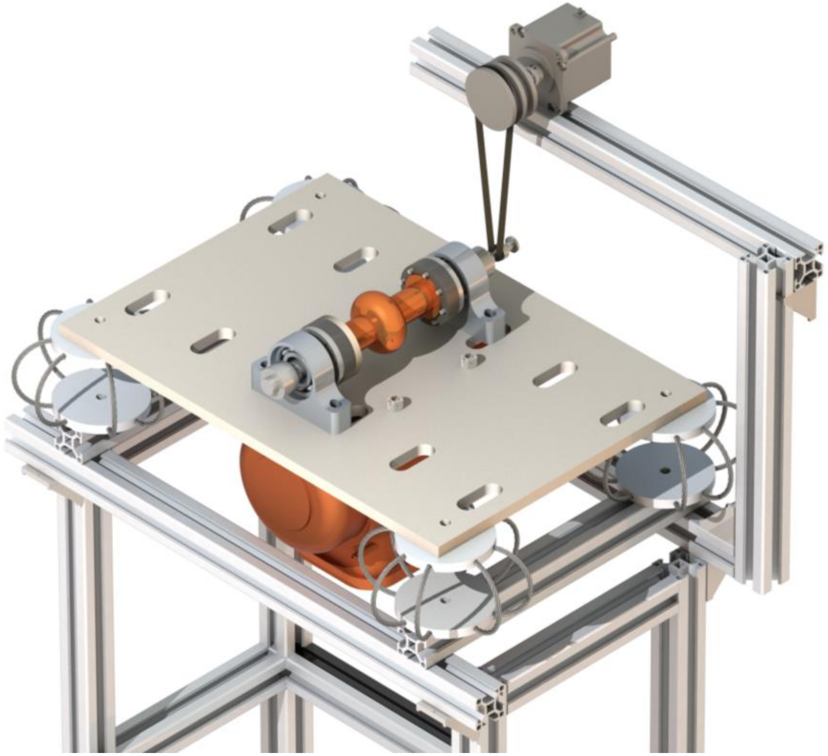


Vibrotumbling

Courtesy of Eduard Chyhyrynets

SURFACE PREPARATION



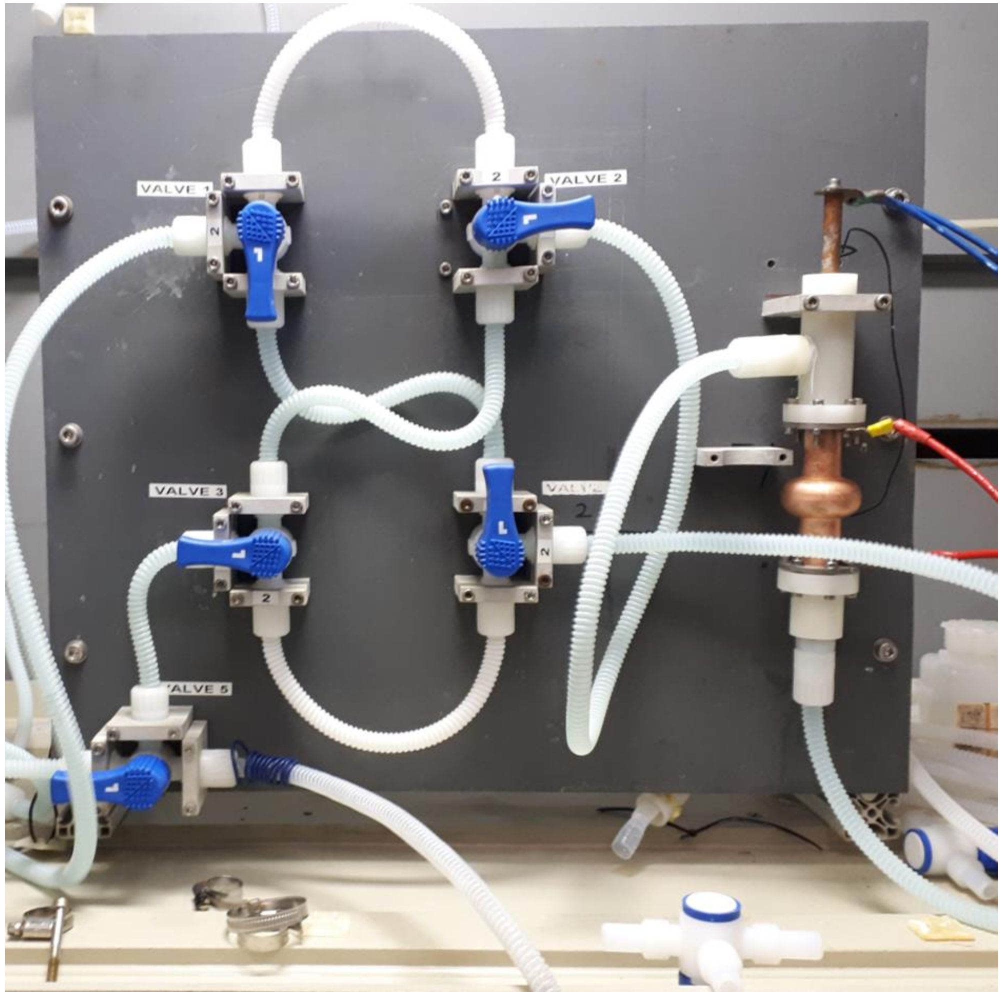


Courtesy of Eduard Chyhyrynets

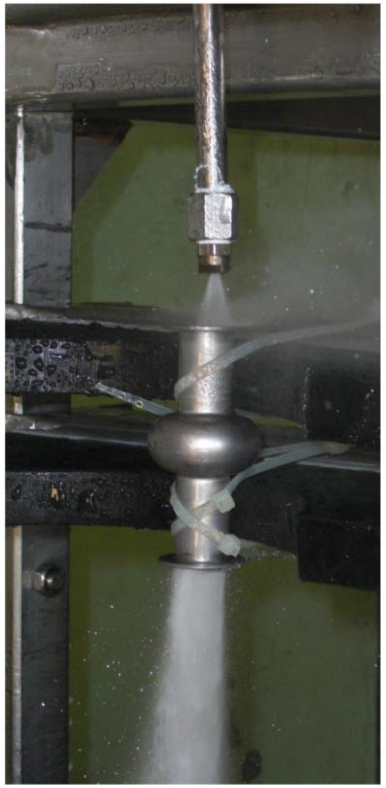
Vibrotumbling

CHEMICAL PREPARATION

- Deoxidation
- Electropolishing
- Chemical polishing SUBU
- HPR



Vertical electropolishing set up



HPR set up

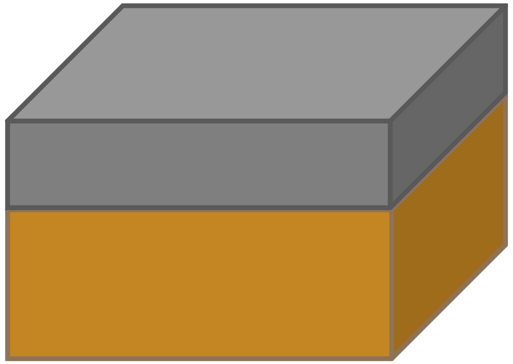
PVD PROCESS BY DC MAGNETRON SPUTTERING

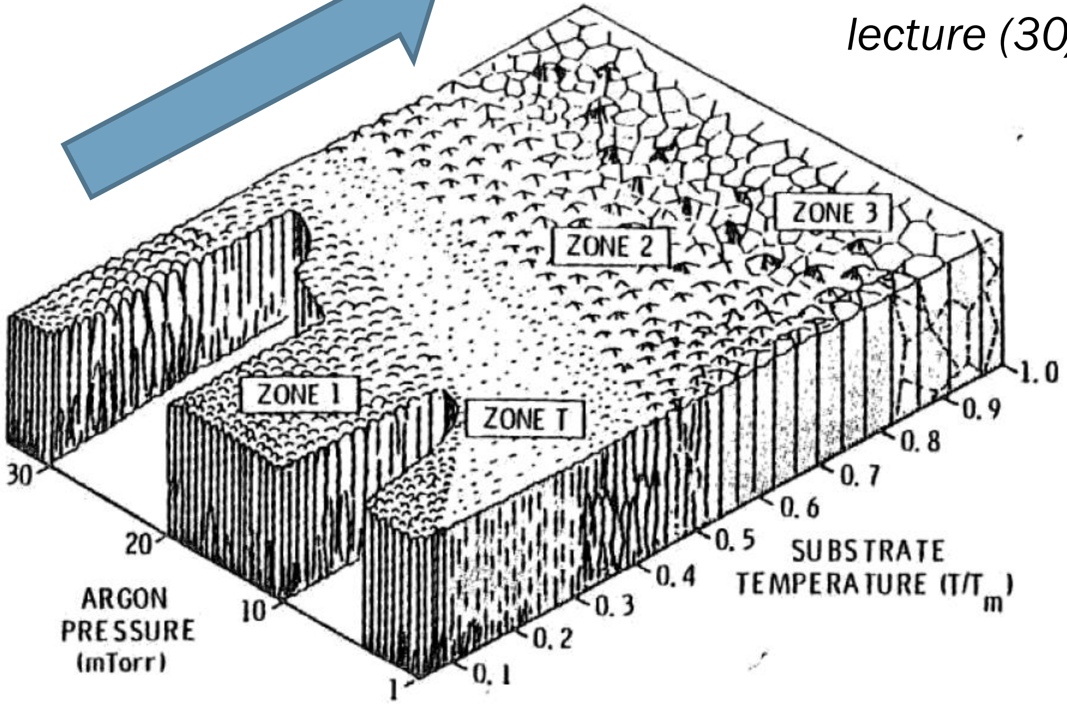
See Pira's *lecture (30/09)*

High substrate temperature

Niobium

Copper @550°C





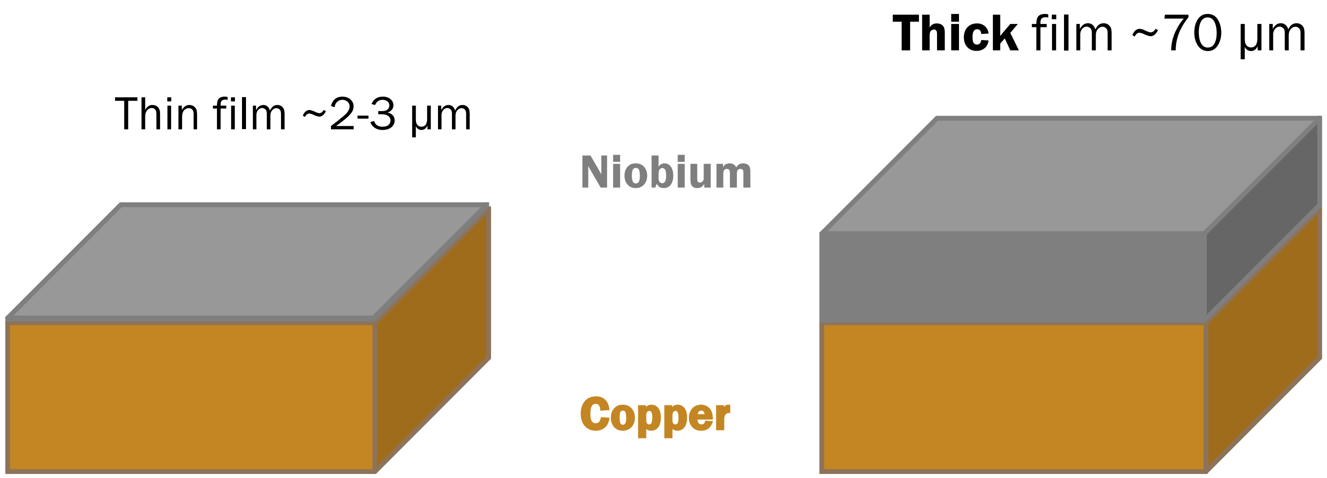
J. A. Thornton and D. W. Hoffman, "Stress-related effects in thin films," Thin Solid Films, vol. 171, no. 1, pp. 5–31, 1989.

PVD PROCESS BY DC MAGNETRON SPUTTERING

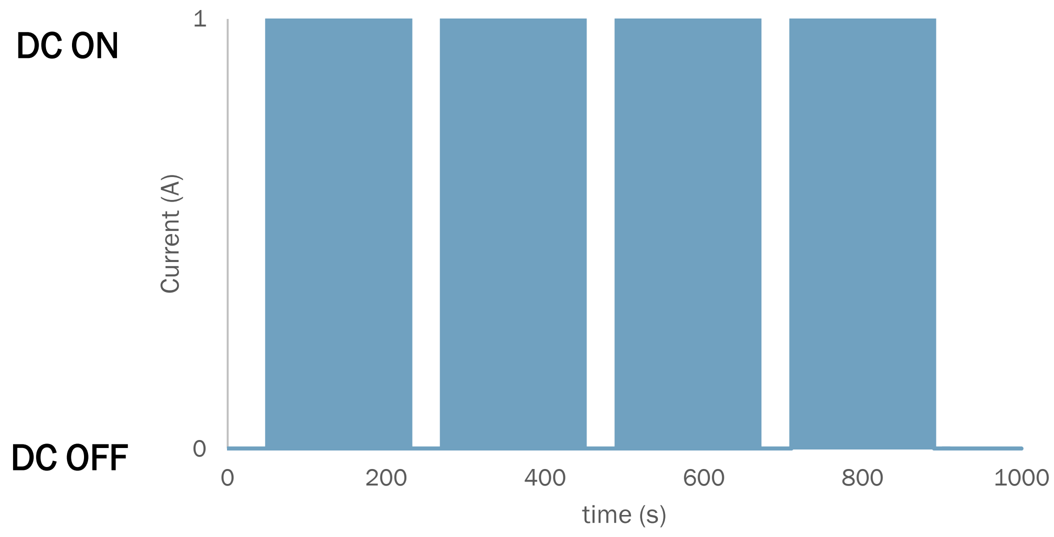
High substrate temperature

Thick film

- Nb bulk like properties
- Decrease thermal boundary resistance



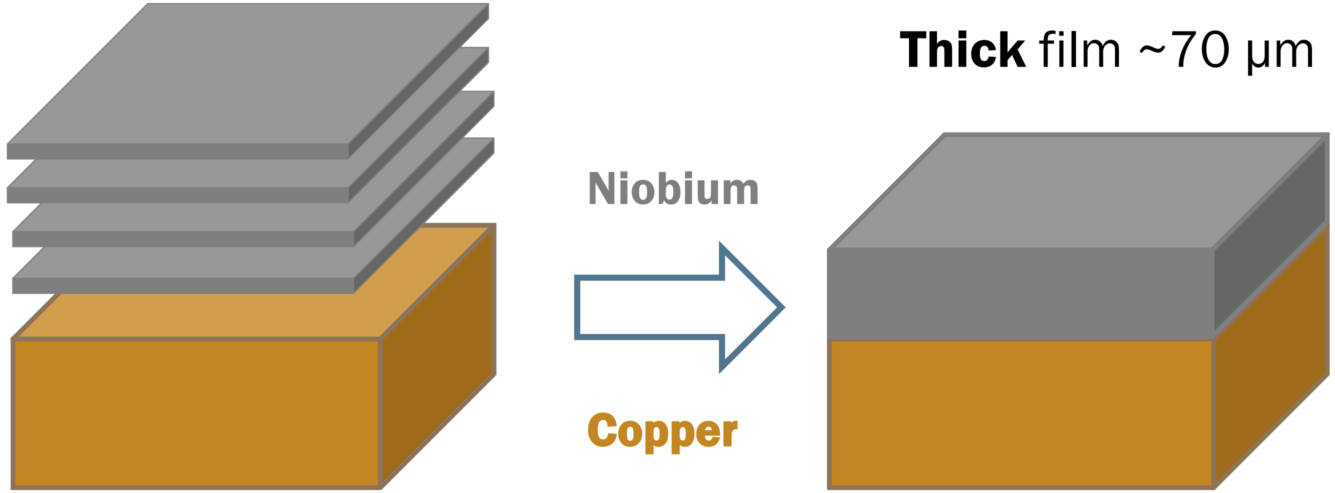
PVD PROCESS: THICK FILMS BY LONG PULSED DCMS



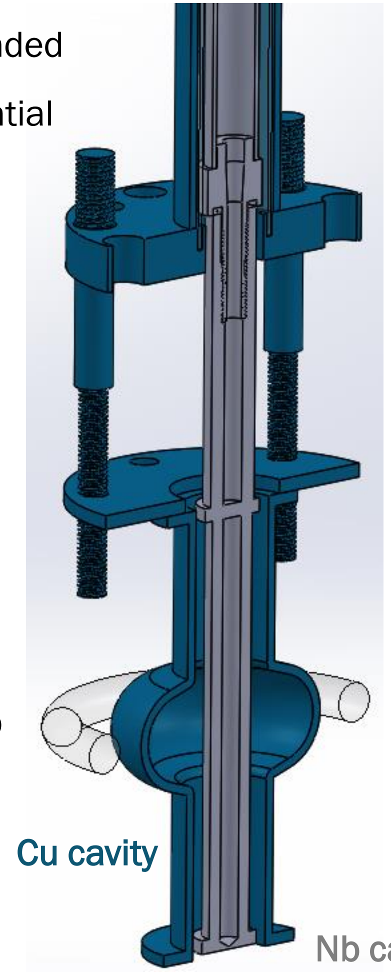
Total time of process ~ 5 hours

Single Layer thickness
100 - 500 nm

Thick film ~70 μm



PVD PROCESS: THICK FILMS BY LONG PULSED DCMS



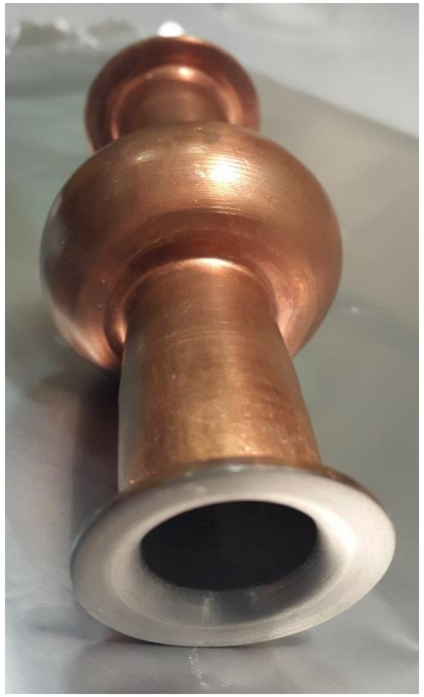
Baking = **600°C** for 48 hours

Temperature = **550 °C**

Base pressure < **1 x 10^{-9} mbar**

Magnetic Field = **830 Gauss**

Current = **1 A**

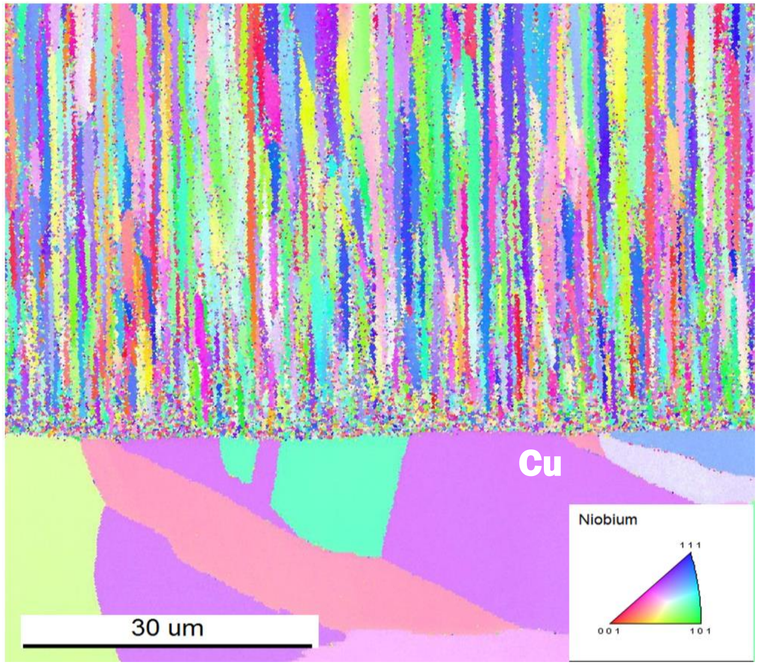


Nb on Cu 6GHz cavity

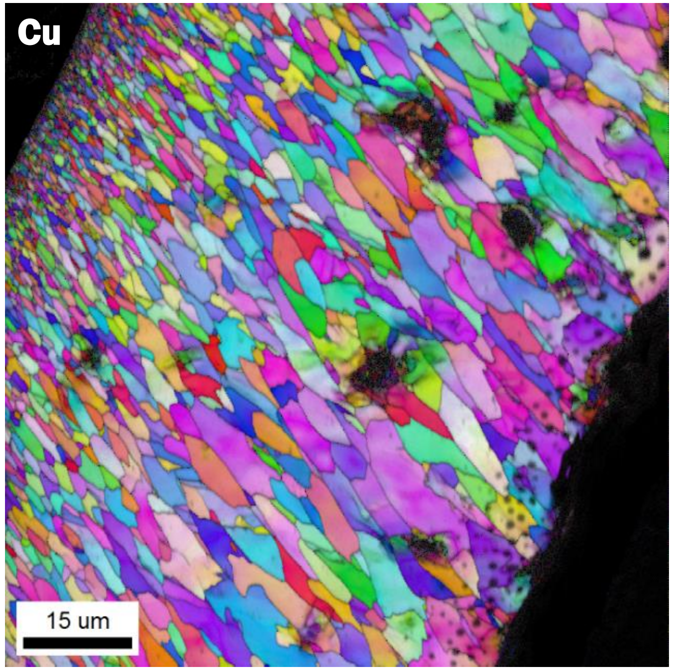
Sputtering system for 6GHz cavities

THICK FILM MORPHOLOGY BY EBSD

- Columnar growth
- Larger grains



Cav 21: 75 µm
500nm single layer thickness

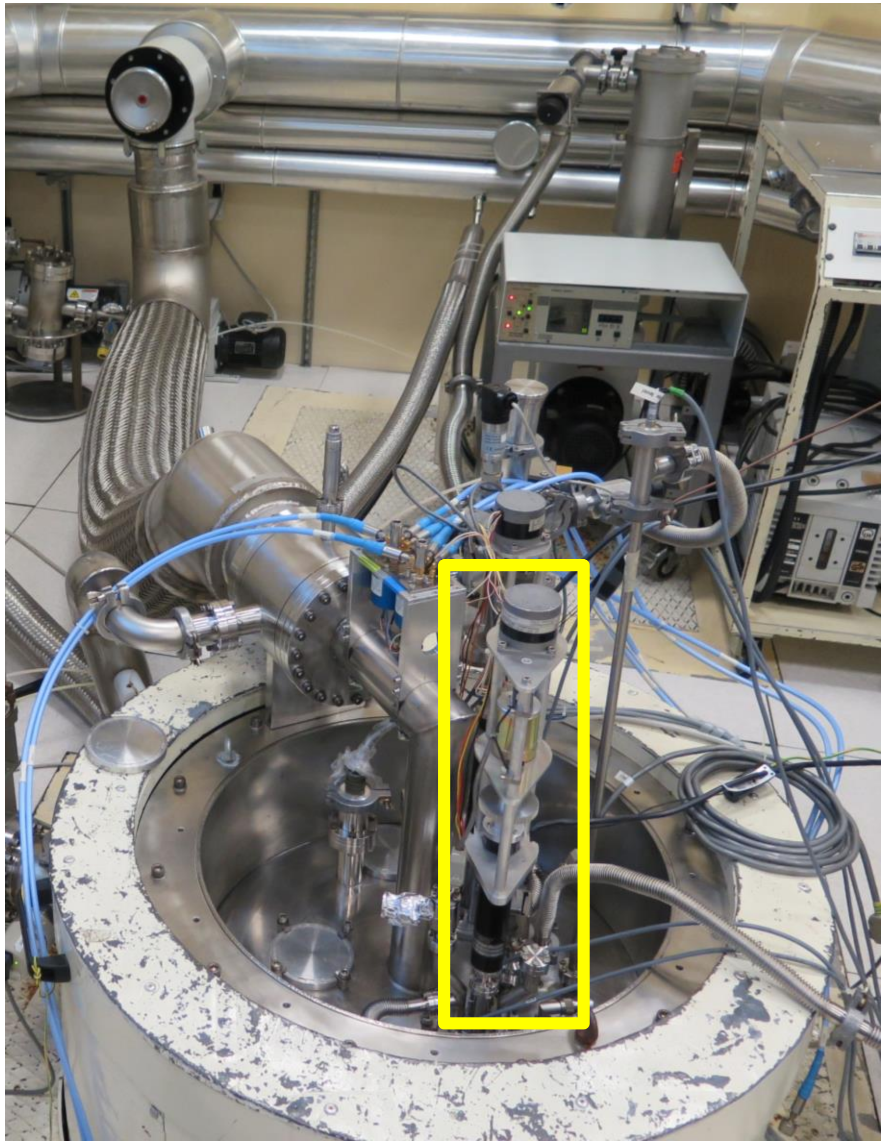


Cav 16: 75 µm
500nm single layer thickness

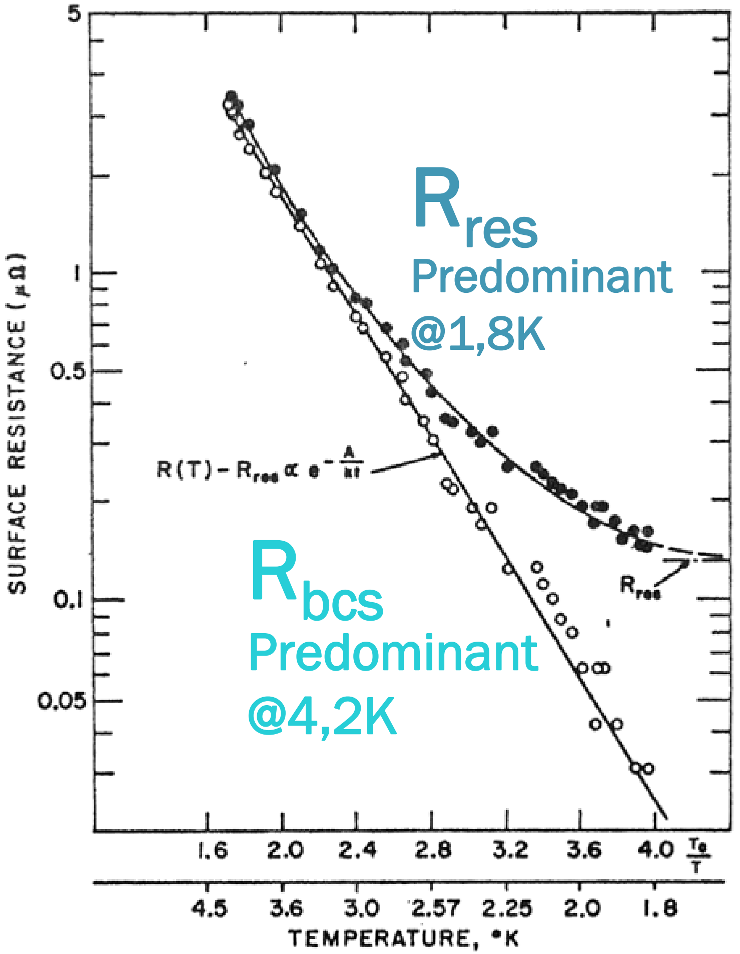
Courtesy of STFC (Reza Valizadeh)

RF CHARACTERIZATION

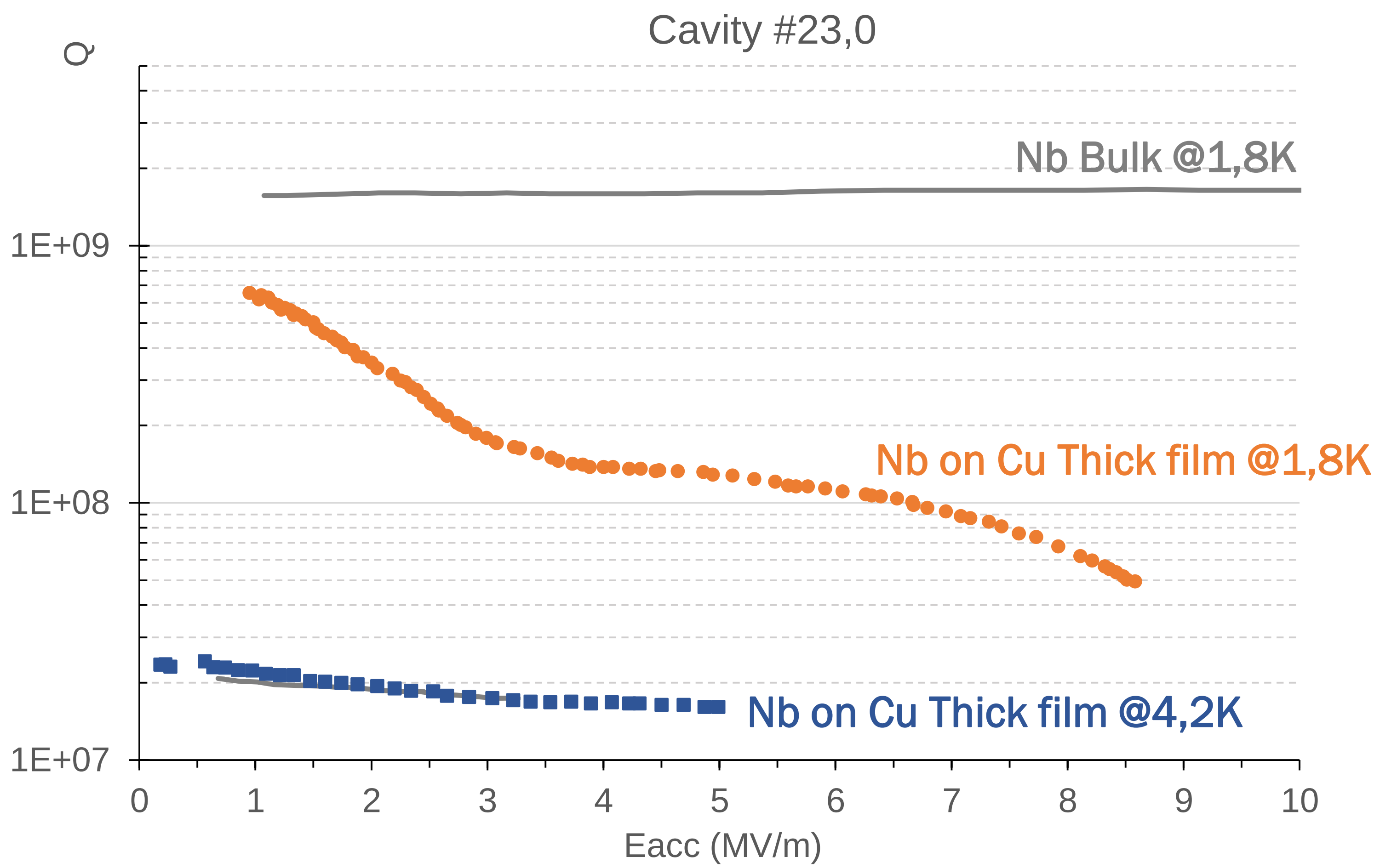
- Cavity inserted in cryostat in order to cool down
- After cool down, Q vs Eacc is measured 4,2K and 1,8K.



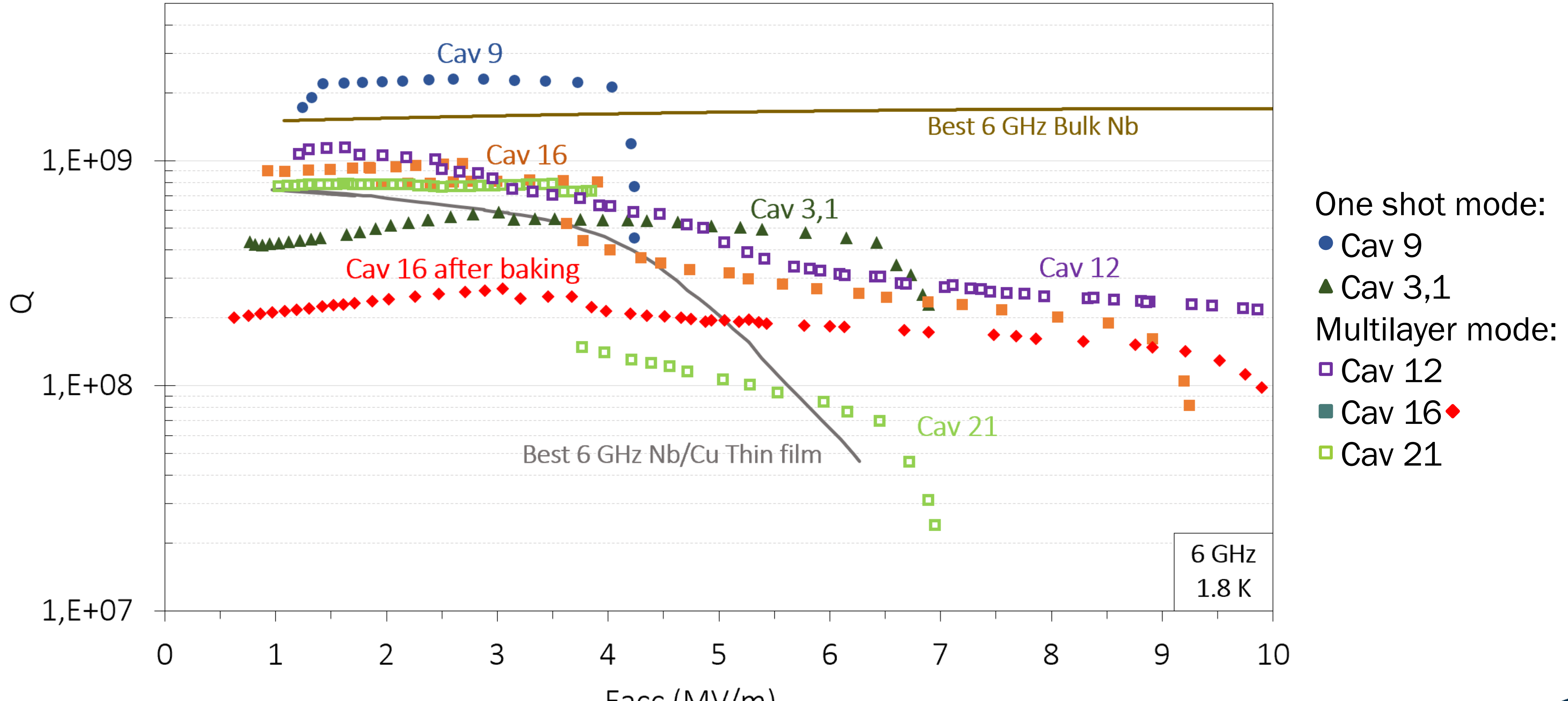
RF CHARACTERIZATION



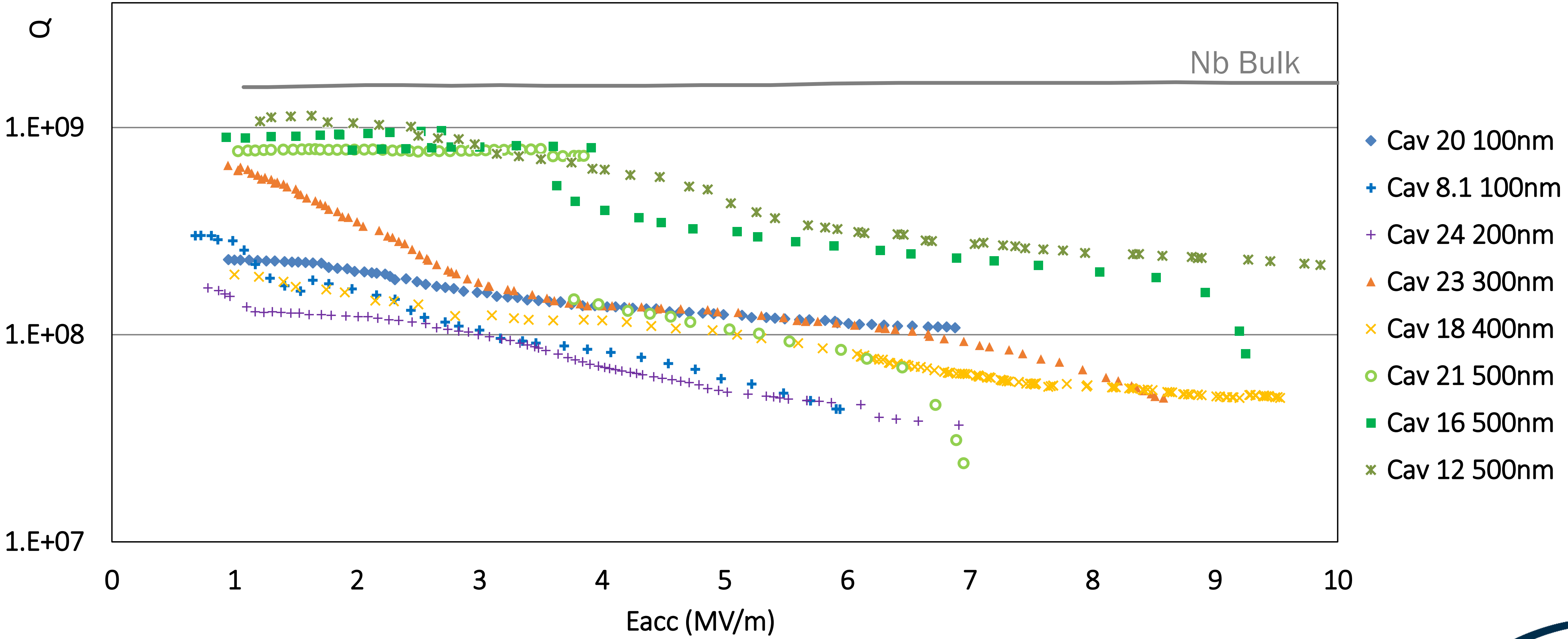
See *Vaglio's lecture*



RF CHARACTERIZATION @1,8K 6GHZ



RF CHARACTERIZATION @1,8K 6GHZ
DEPENDENCE OF SINGLE PULSE THICKNESS



RF CHARACTERIZATION @1,8K 6GHZ
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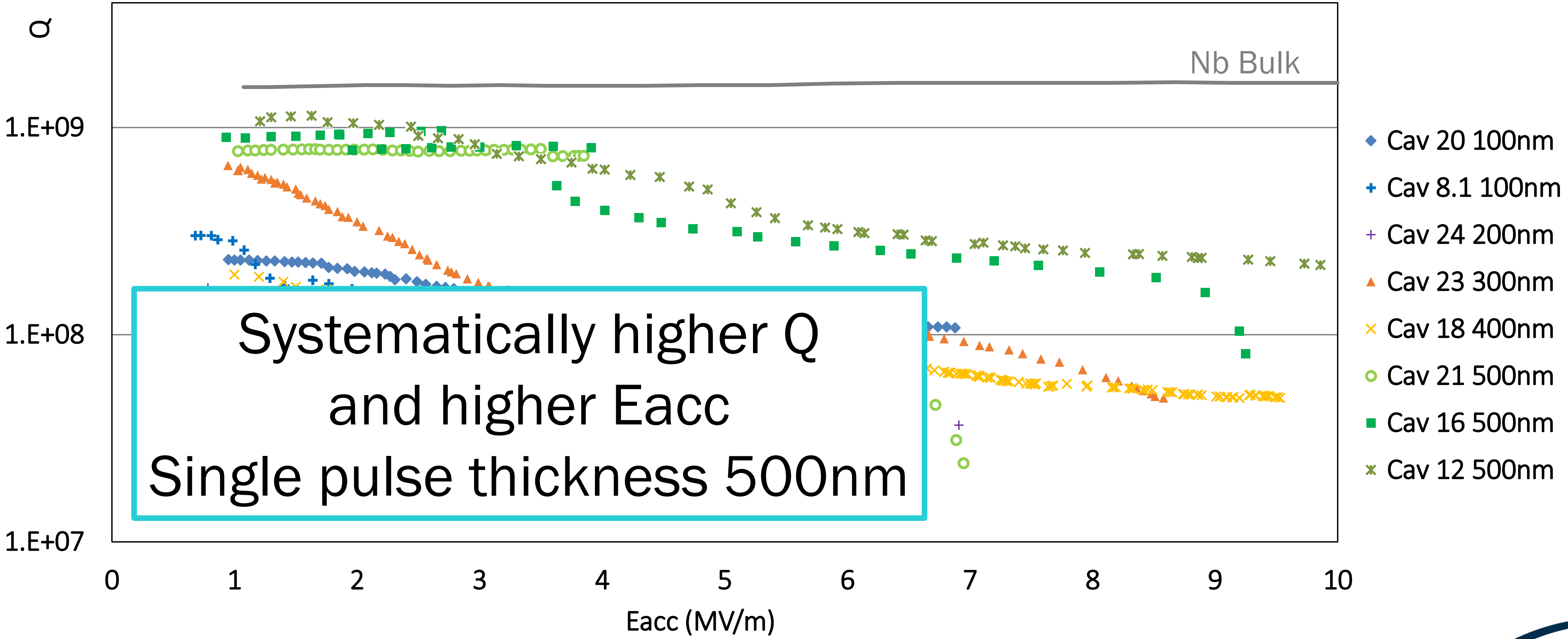


Systematically higher Q
and higher Eacc
Single pulse thickness 500nm

MAGNETIC FLUX TRAPPED STUDY

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

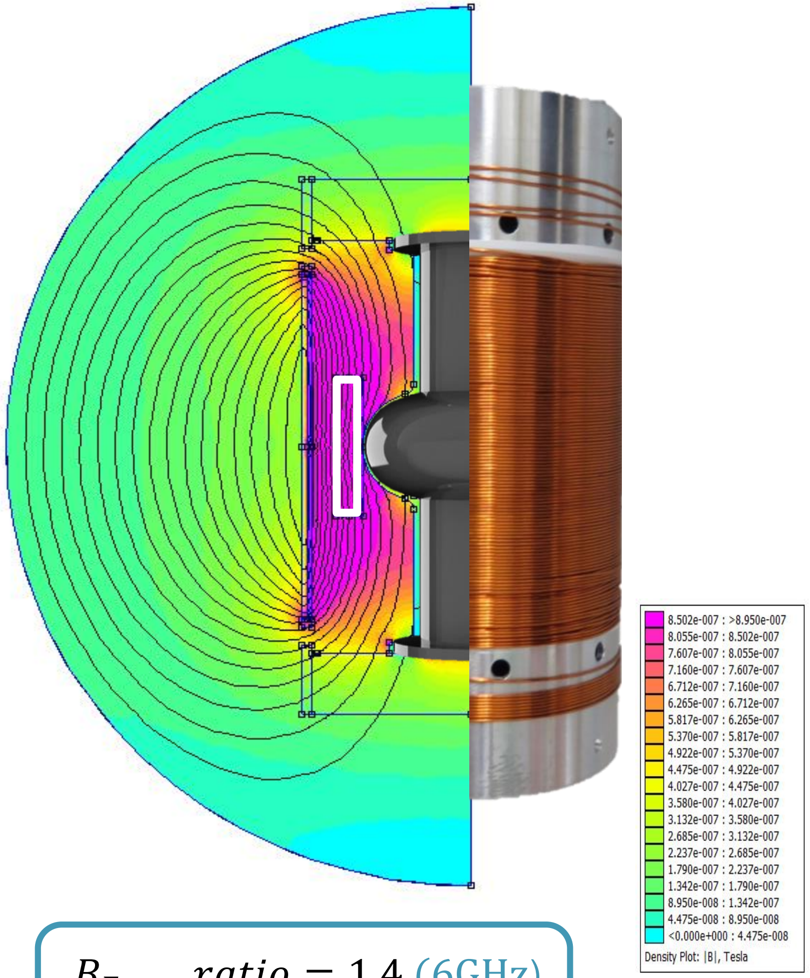
$$R_{res} = R_{s(Btrap)} + R_0$$

Trapped magnetic flux

Increase R_{res} !!

$$B_{trap}\left(B_{NC}, \frac{B_{SC}}{B_{NC}}\right) = B_{NC}\left(1 - \frac{\frac{B_{SC}}{B_{NC}} - 1}{1 - B_{F\ exp}}\right)$$

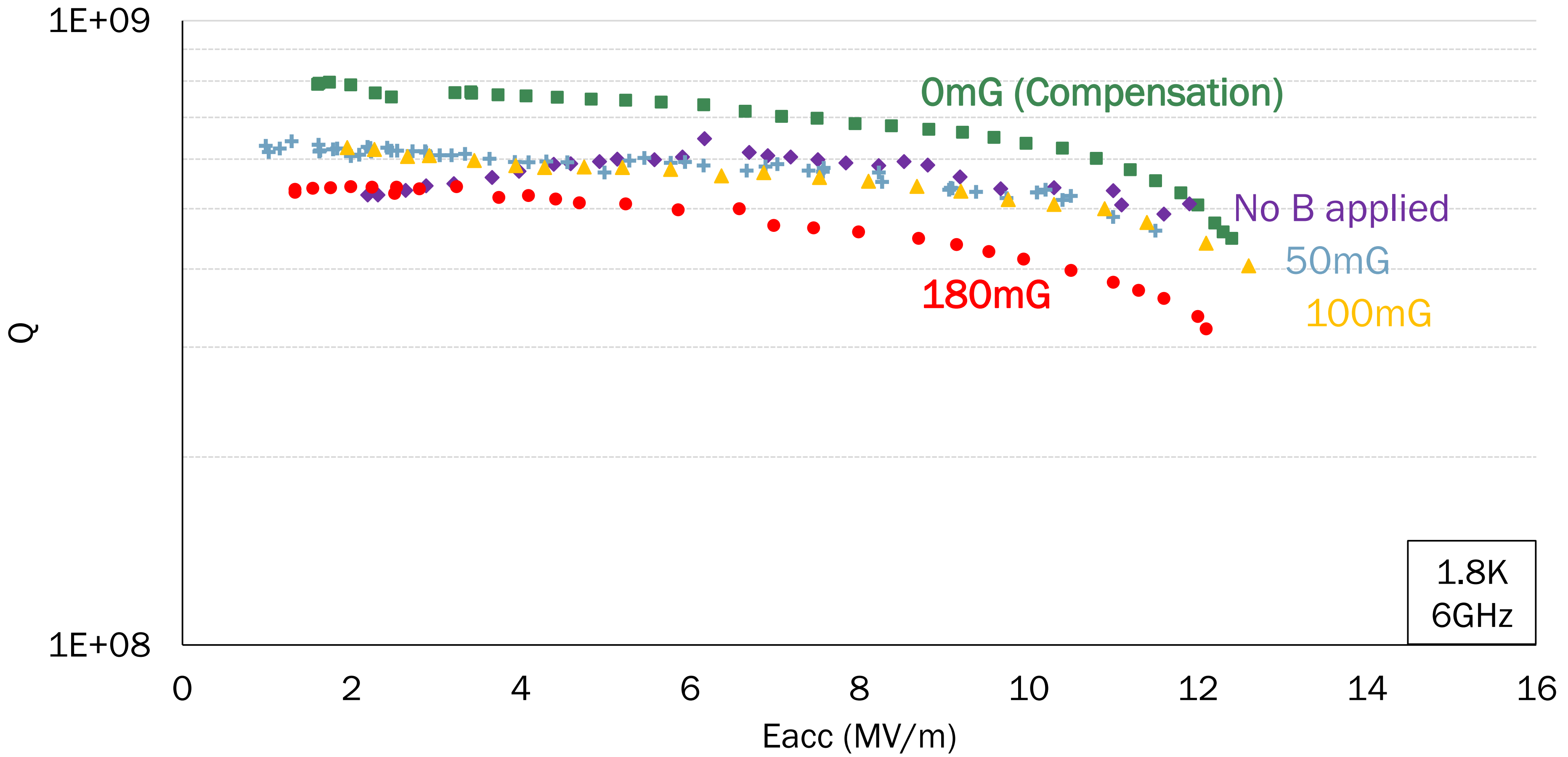
$$S = \frac{R_{s(Btrap)} - R_{B0}}{B_{trap}} \left[\frac{n\Omega}{mG}\right]$$



$B_{F\ exp}\ ratio = 1{,}4$ (6GHz)
instead of 1,8 (1,3GHz)

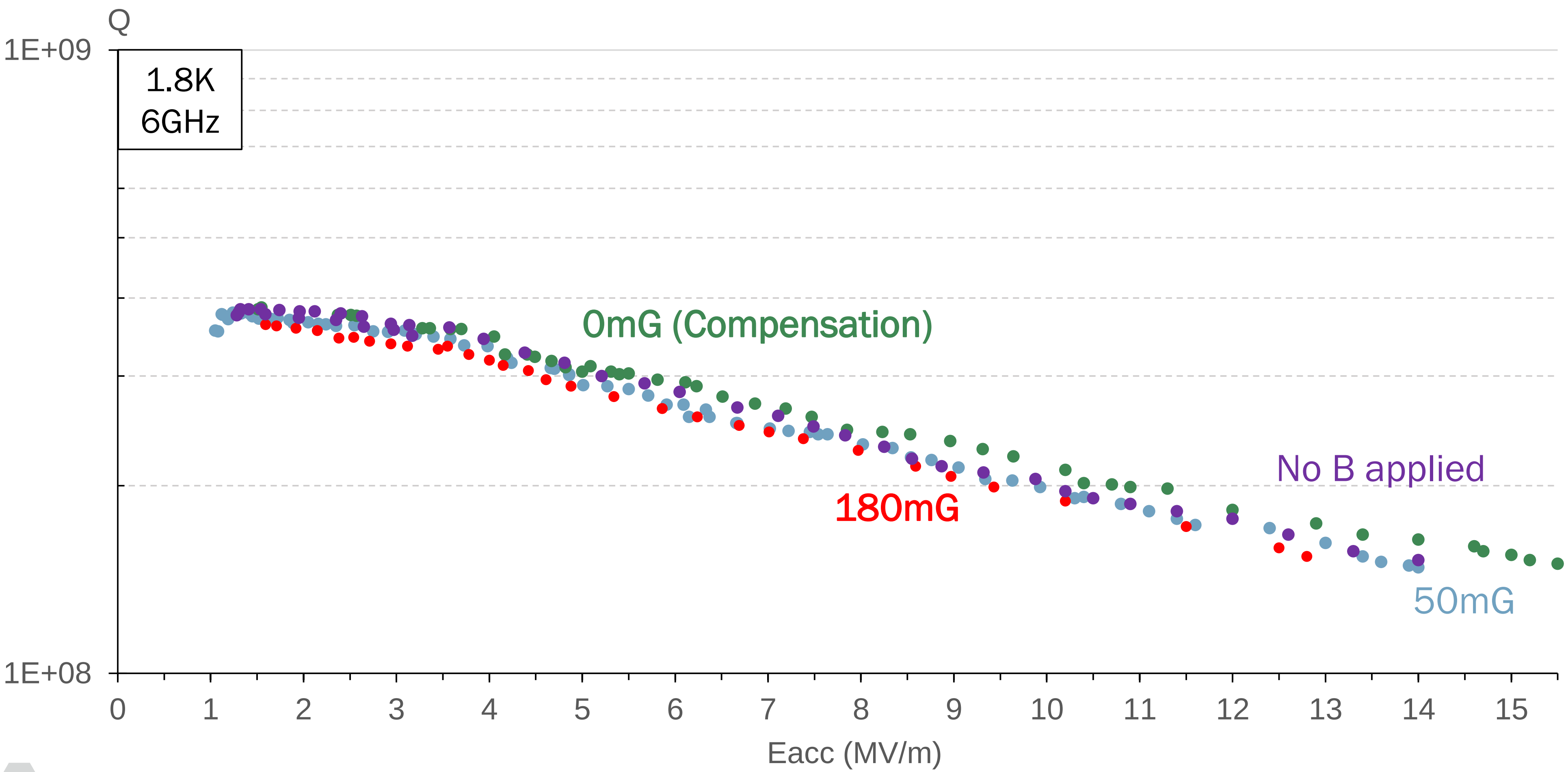
Martinello 2015, «Trapped flux surface resistance analysis for different surface treatments», Proceedings SRF2015, Whistler, Canada

MAGNETIC FLUX TRAPPED STUDY



Niobium Bulk

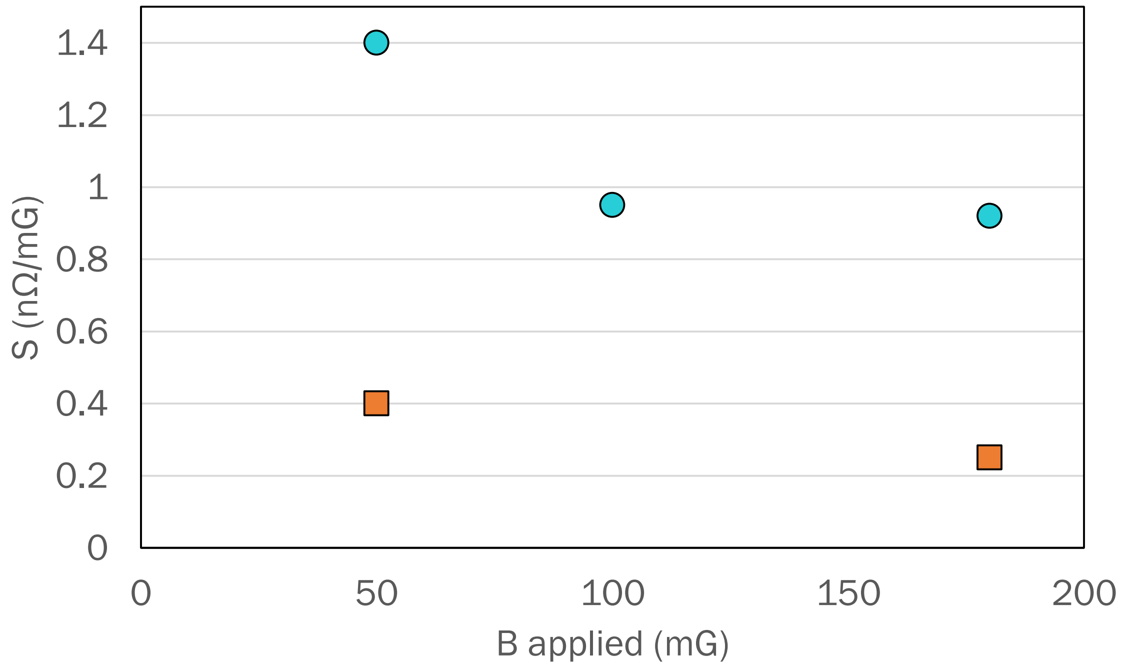
MAGNETIC FLUX TRAPPED STUDY



Nb on Cu thin film

MAGNETIC FLUX TRAPPED STUDY

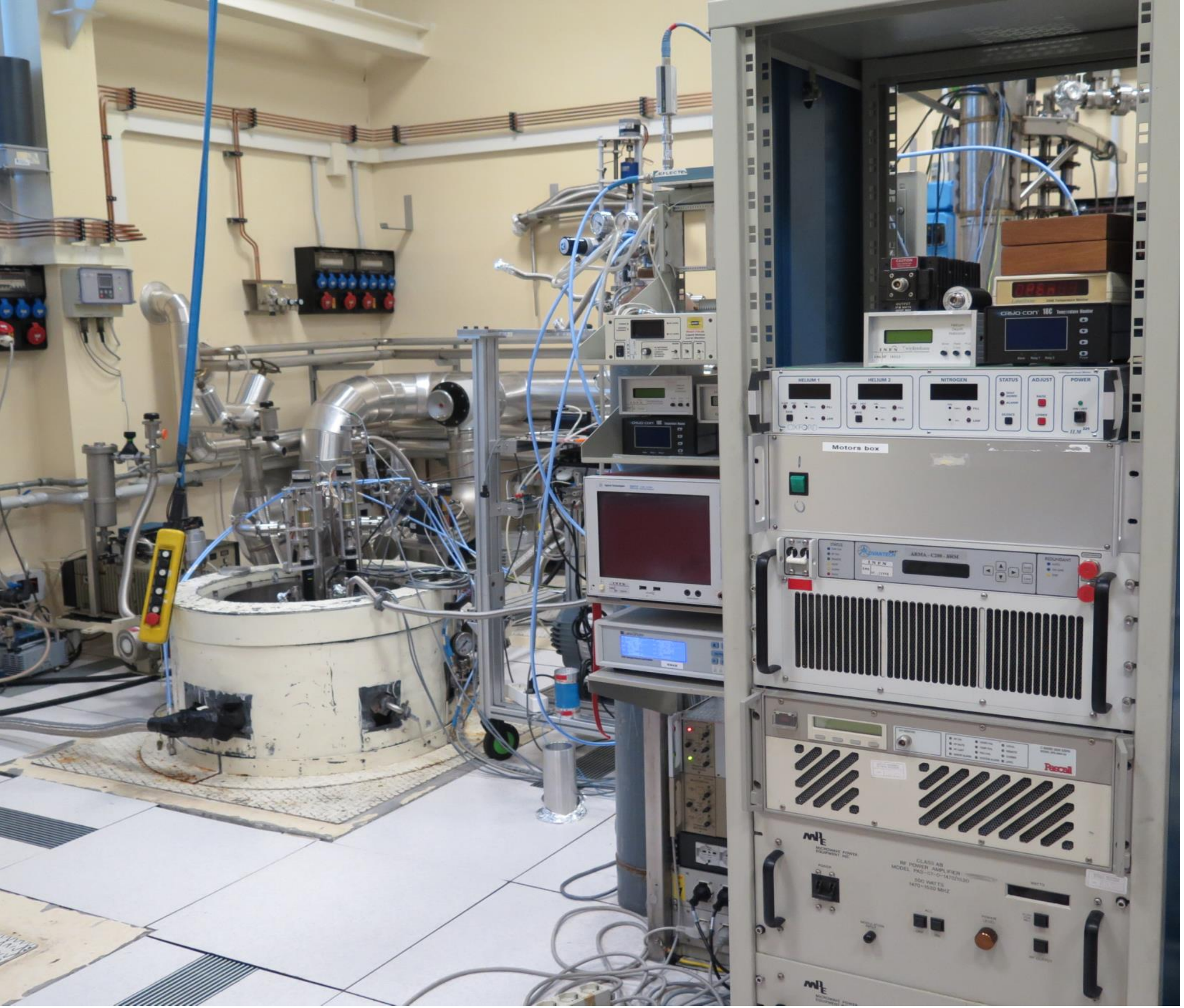
It is needed more statistic to confirm but this data indicates that Nb bulk cavities are more sensitive to magnetic field respect to thin film cavities, as expected



Effect higher in Bulk Nb
Thick films effect?...

CONCLUSIONS

- Thick film is a promising approach in order to push the limits of the Nb on Cu cavities technology.
- The effect of the surface preparation and single pulse thickness is fundamental for the cavity performance.
- Magnetic flux trapped in 6GHz cavities study will include a thick film RF characterization.


Motors box

Thank you!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