Research Program for improving SRF cavity performances at CEA
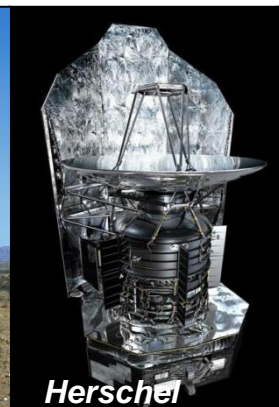

Double Chooz *ALICE* *Edelweiss* *HESS* *Herschel* *CMS*

Déchiffrer les rayons de l'Univers

Thomas Proslier

31/10/2019

<u>Team</u>:
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Future Post-doctorant.
Internship: R. Dubroeucq, S. Habhab

<u>Collaborations</u>:
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HZB: O. Kugeler
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CERN: G. Rosaz, S. Calatroni (thin films)
STFC: R. Valizadeh (thin films, Nb3Sn)
INFN: C. Pira (thin films)
JLAB: A-M. Valente, G. Ciovati, D. Patshupati (Bulk Nb, thin films)
FNAL: S. Posen, A. Romanenko, A. Grassellino (Bulk Nb, Nb3Sn)
ANL: A. Glatz − Theory (theory simulations)
IIT: J. Zasadzinski
TRIUMPH: T. Junginger (measurements)
Cornell: M. Liepe (Nb3Sn)

Research for improving SRF cavity performances at CEA

- Unique Characterizations tools with predictive power
  - Point Contact Tunneling spectroscopy
  - Magnetometry

- Thin films developements

- Chemistry: Vertical electropolishing

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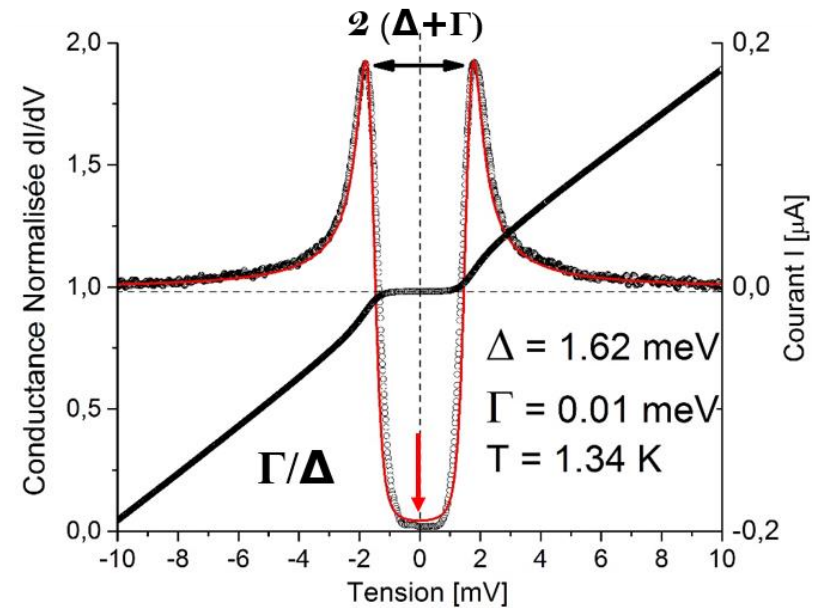
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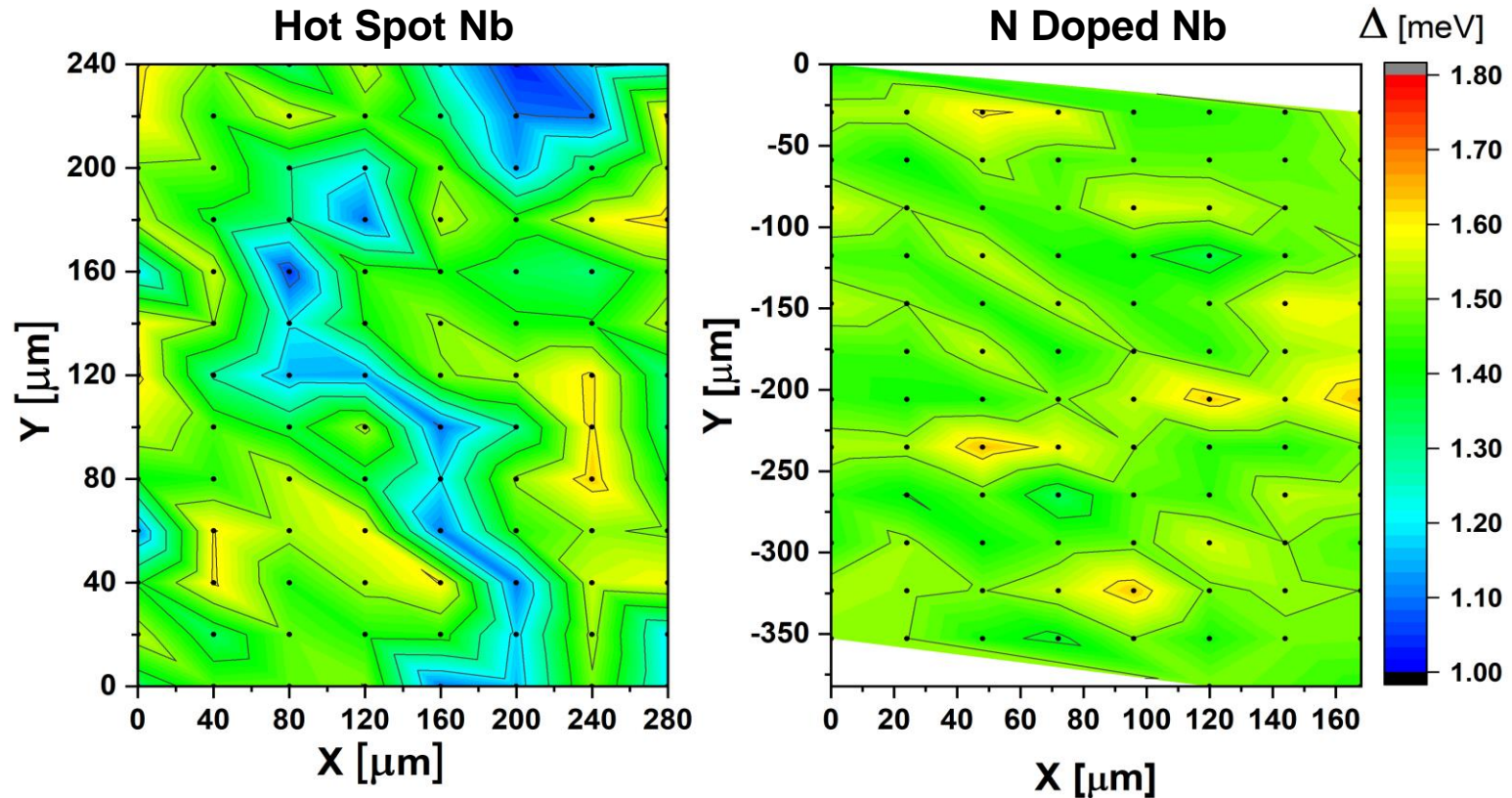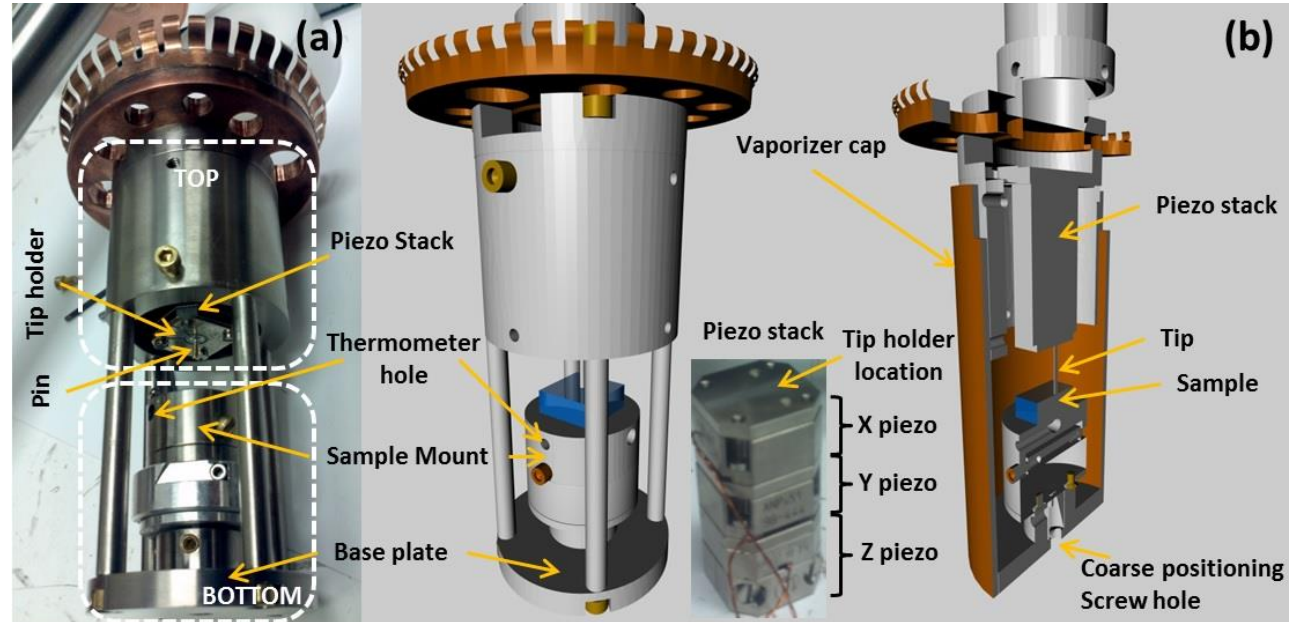# Tunneling spectroscopy: what do we measure and why?

principle

measure

$2\,(\Delta + \Gamma)$

Δ = 1.62 meV
Γ = 0.01 meV
T = 1.34 K

Γ/Δ

Tc

$\Delta = 1.61$ meV
$T_C = 9.22$ K
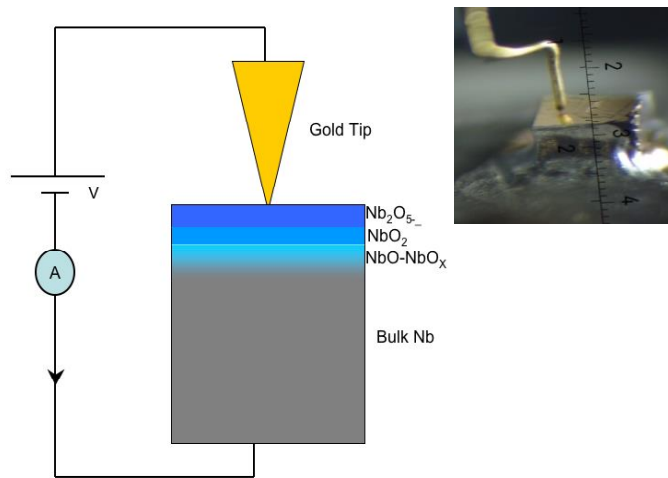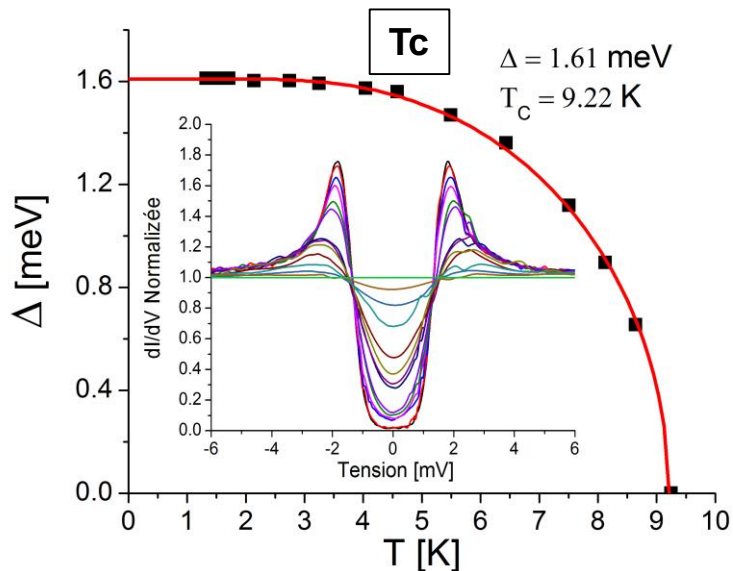
- Measure the fundamental superconducting parameters: Δ, T_C, H_{C2}
- Measure non-ideal signature: Γ.
- All of these are directly correlated to SRF cavity performances
- Cartography

Cartography

- N doping: Homogeneous bulk Nb gap values on the surface
- Hot spot: Regions with low superconducting gap values that can be fitting with normal metal regions on the surface (presumably hydrides)

The Point Contact system at CEA

(a)

TOP
Tip holder
Pin
Piezo Stack
Thermometer hole
Sample Mount
Base plate
BOTTOM

(b)
Vaporizer cap
Piezo stack
Tip
Sample
Coarse positioning Screw hole

Piezo stack
Tip holder location
X piezo
Y piezo
Z piezo

- Temp: 1,4 K – Magnetic field: 6 T
- Variable junction resistance: $2.10^2 - 2.10^9$ Ω.
- Cartography: 10 µm – 1 mm
- Fast measurements: 100-300 jonctions/5hrs

- Transport (RRR, Tc vs H applied…)
- Hall Effect
- Sample size: 10x10 mm

Used for Nb/Cu, bulk Nb doping, Nb3Sn, mutlilayers etc…
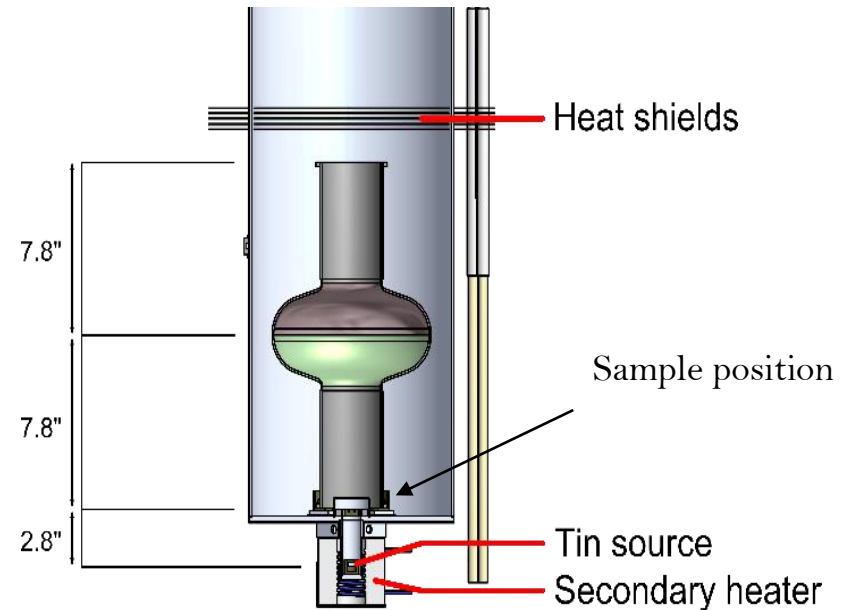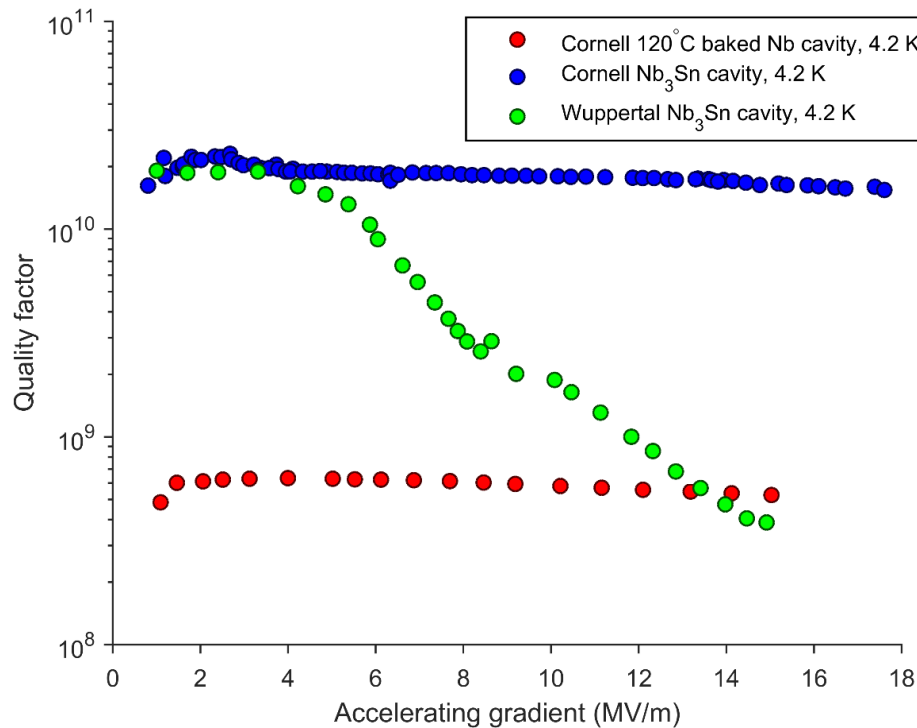
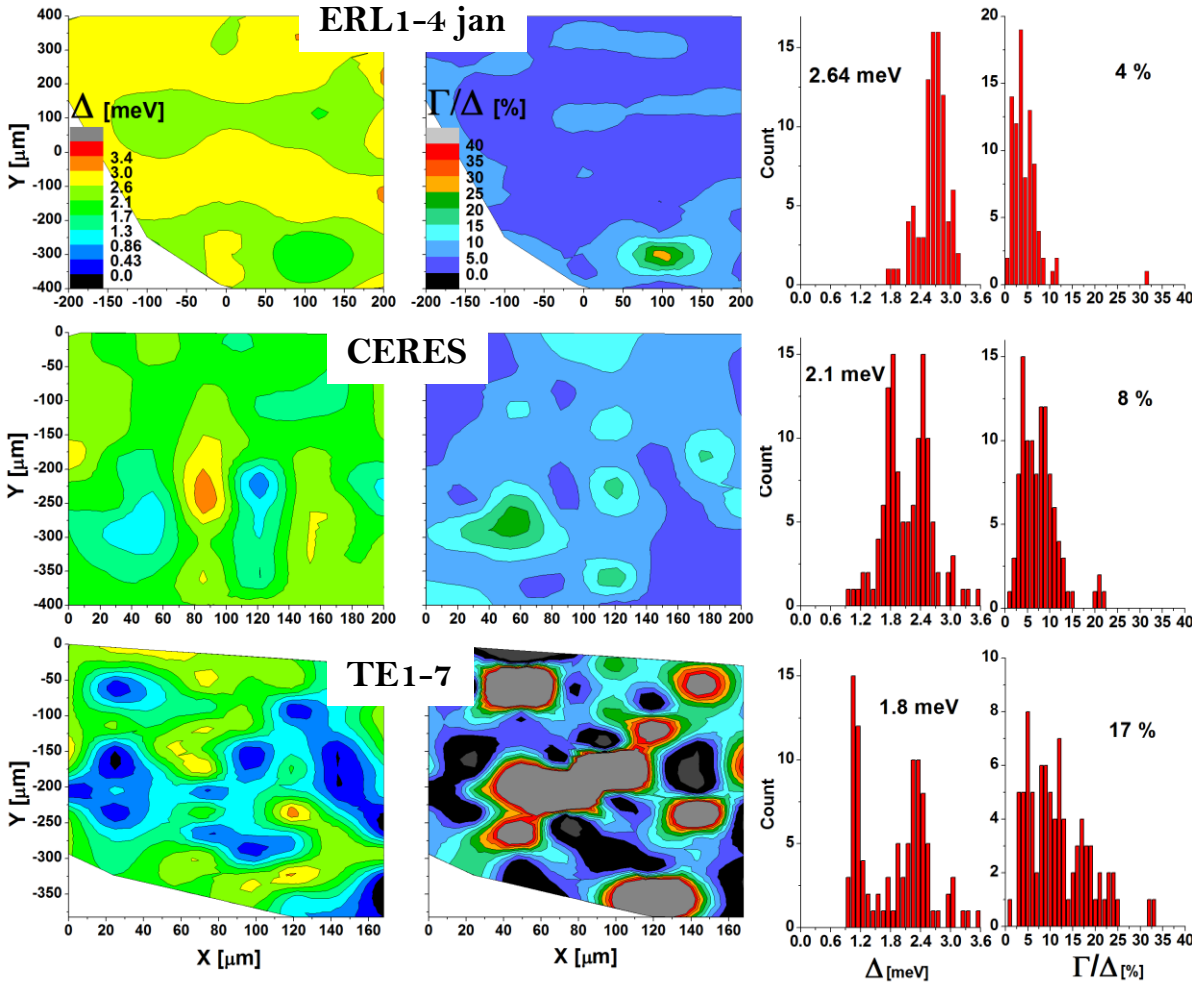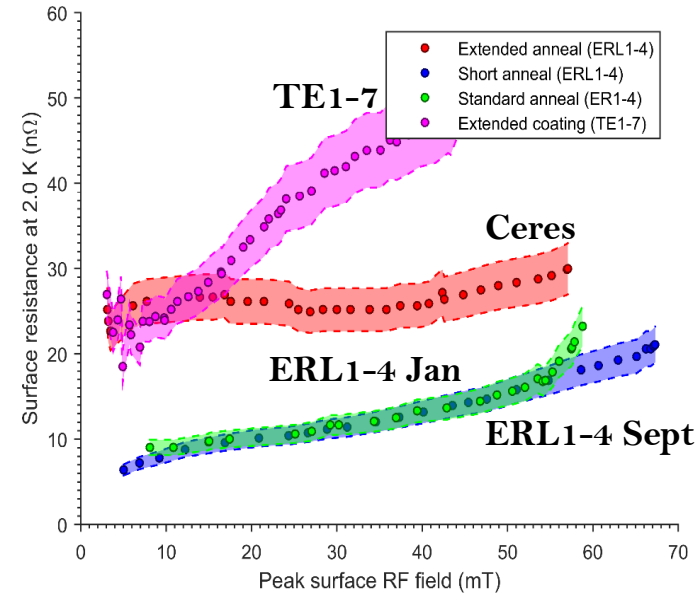- Wupperthal method: diffusion of Sn in a Nb cavity
- Nb_3Sn Q_0 at 4,2K ~ Nb Q_0 at 2K
- Moderate increase of Q_0 between 4K to 2K -> Non-BCS
- Q_0 decrease at ~ 6K

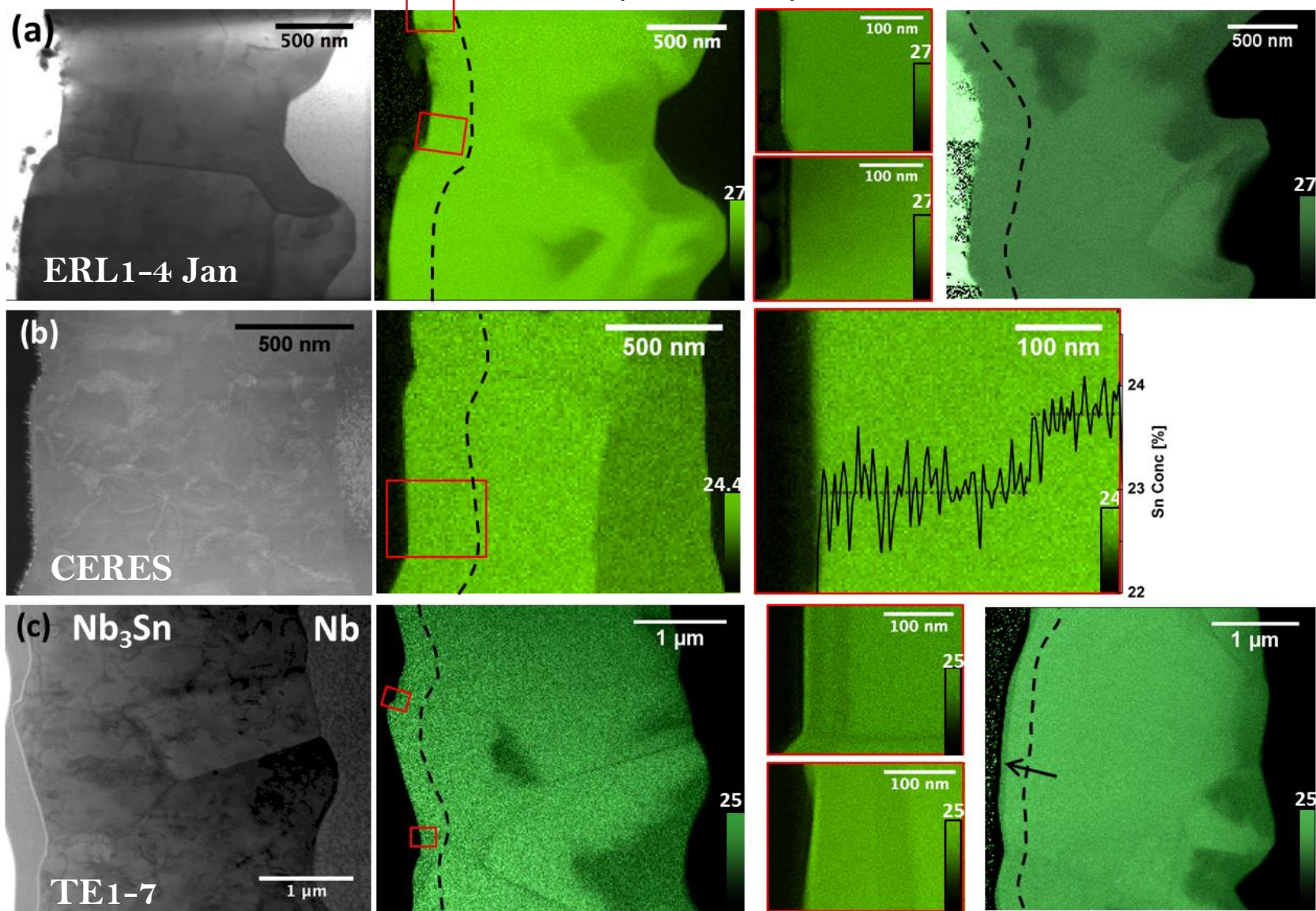Have we reached the limits of Nb_3Sn ?

PCTS measurements

ERL1-4 jan

CERES

TE1-7

2.64 meV   4 %

2.1 meV   8 %

1.8 meV   17 %

Nb3Sn cavity RF tests

- Extended anneal (ERL1-4)
- Short anneal (ERL1-4)
- Standard anneal (ER1-4)
- Extended coating (TE1-7)

TE1-7

Ceres

ERL1-4 Jan

ERL1-4 Sept

- ▪ Δ > Nb and Γ/Δ is small

-> Quality factor @ 4K is ~ Nb @ 2K

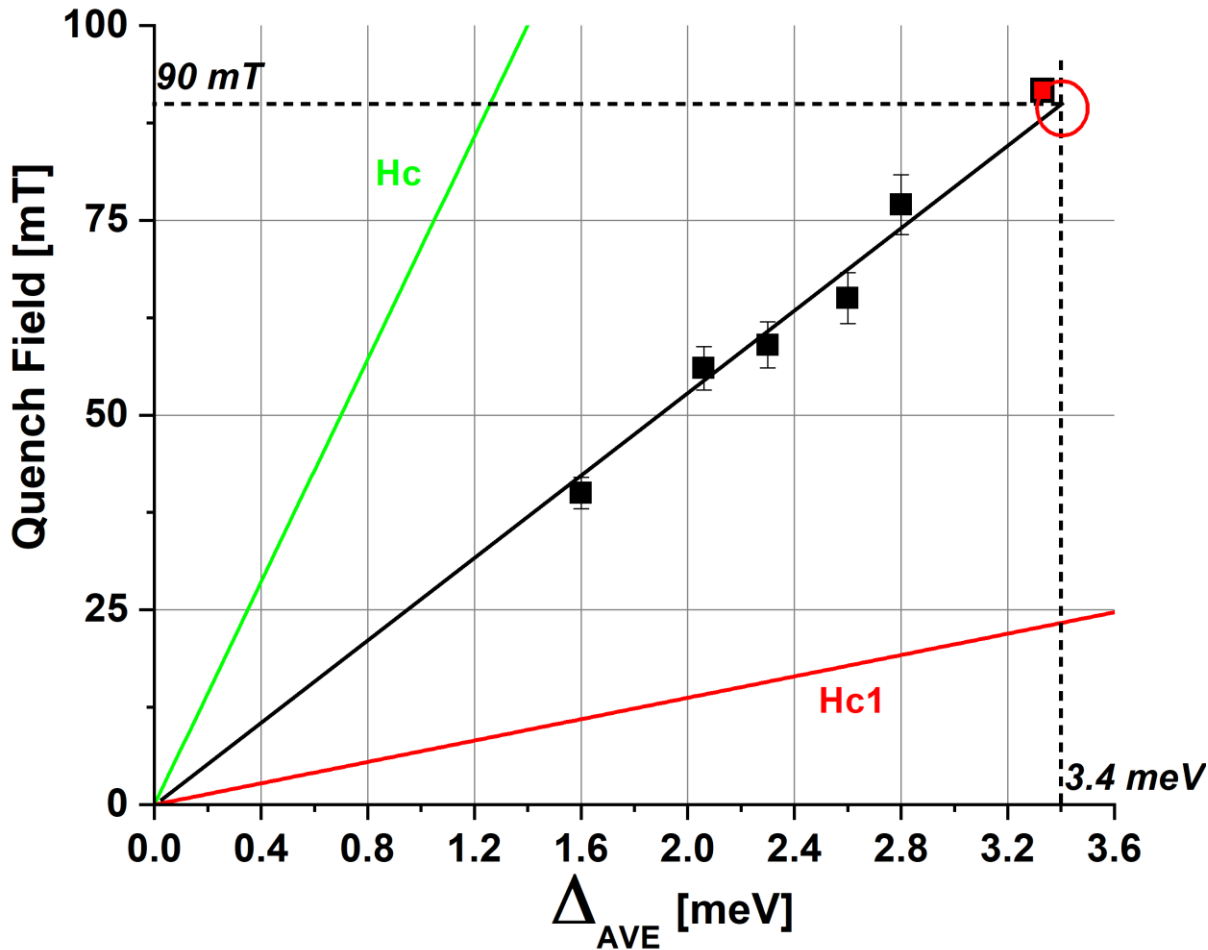- ▪ But pockets of Nb rich phases:
- Lower Tc and Δ
- Carbon contamination

- phase riche Nb ~ 17.5%
- Interface Nb-Nb$_3$Sn , grain boundaries
- Pockets near the surface

- Crystallite ~ 200-300 nm (XRD)
- 60% Nb$_3$Sn

Quench field vs Average Gap

For large κ $(=\lambda/\xi = 24)$:

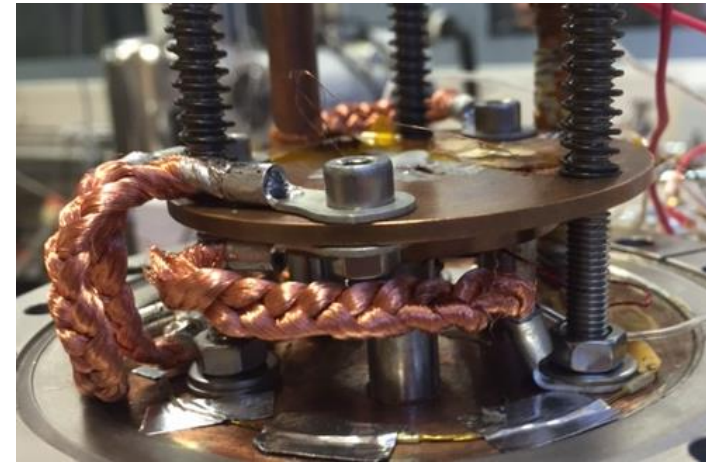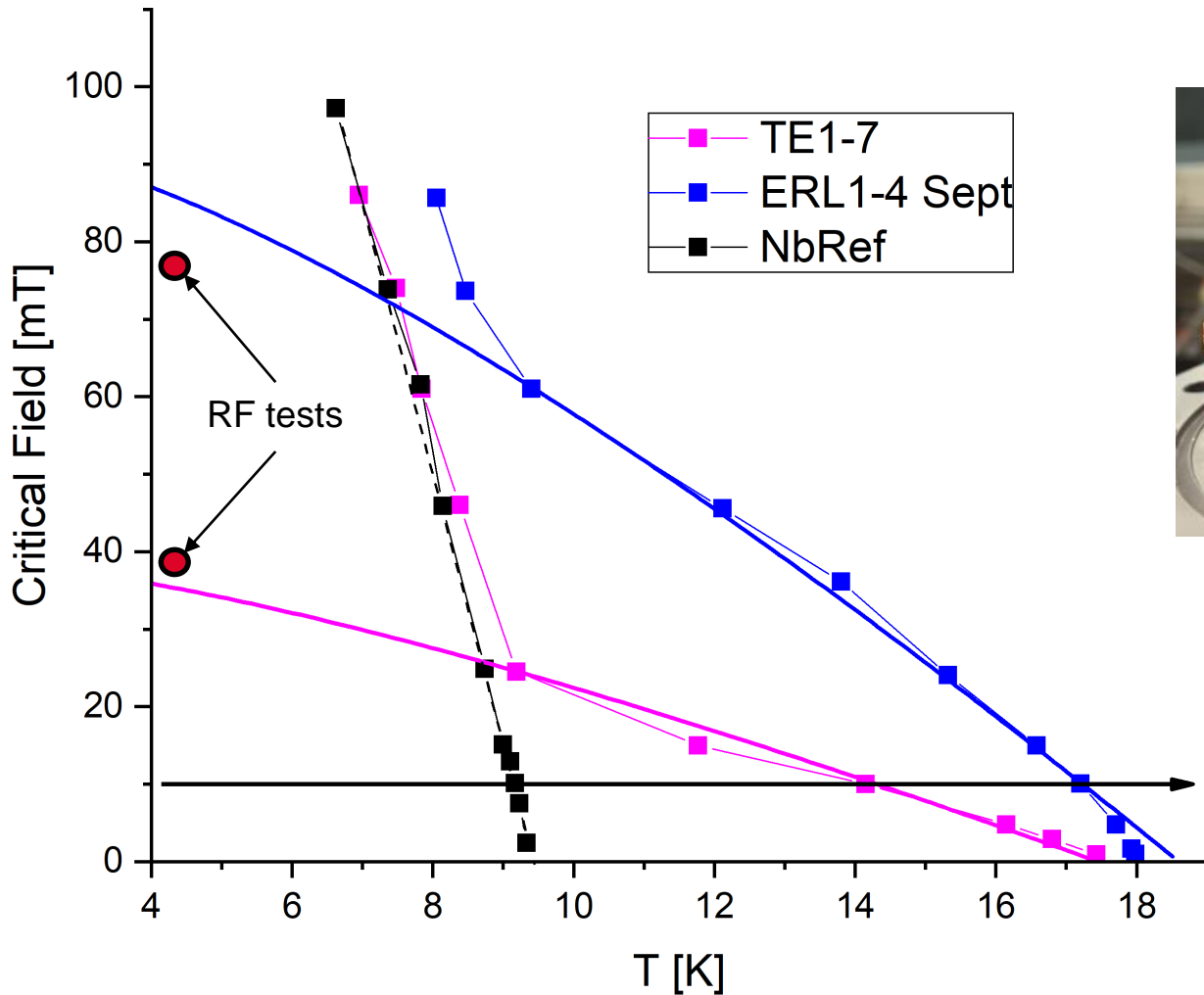$$H_{C1} = \frac{1}{\sqrt{2}\kappa}(Ln[\kappa] + 0.08)\, H_C$$

$$H_C = \sqrt{\frac{N_0}{\mu_0}}.\Delta.e$$

$N_0 = 2.5\ 10^{35}\ e^- / spin / m^3$

$$H_{SH} = 26 \pm 2.5\ \Delta\ mT/meV$$

Bulk Δ for Nb3Sn is 3.4 to 3.5 meV

-> Max expected Quench field is ~ 91 ± 2 mT = 22 MV/m

- Measure critical penetration field In Bulk and thin films samples
- Sample size: > 1 inch
- 4.2 K and 120 mT

- The critical field measured by Magnetometry correlates with RF tests Quench fields

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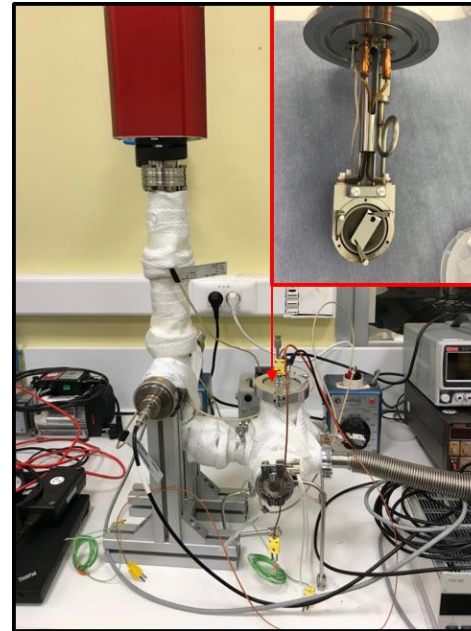
Set up of the ALD laboratory
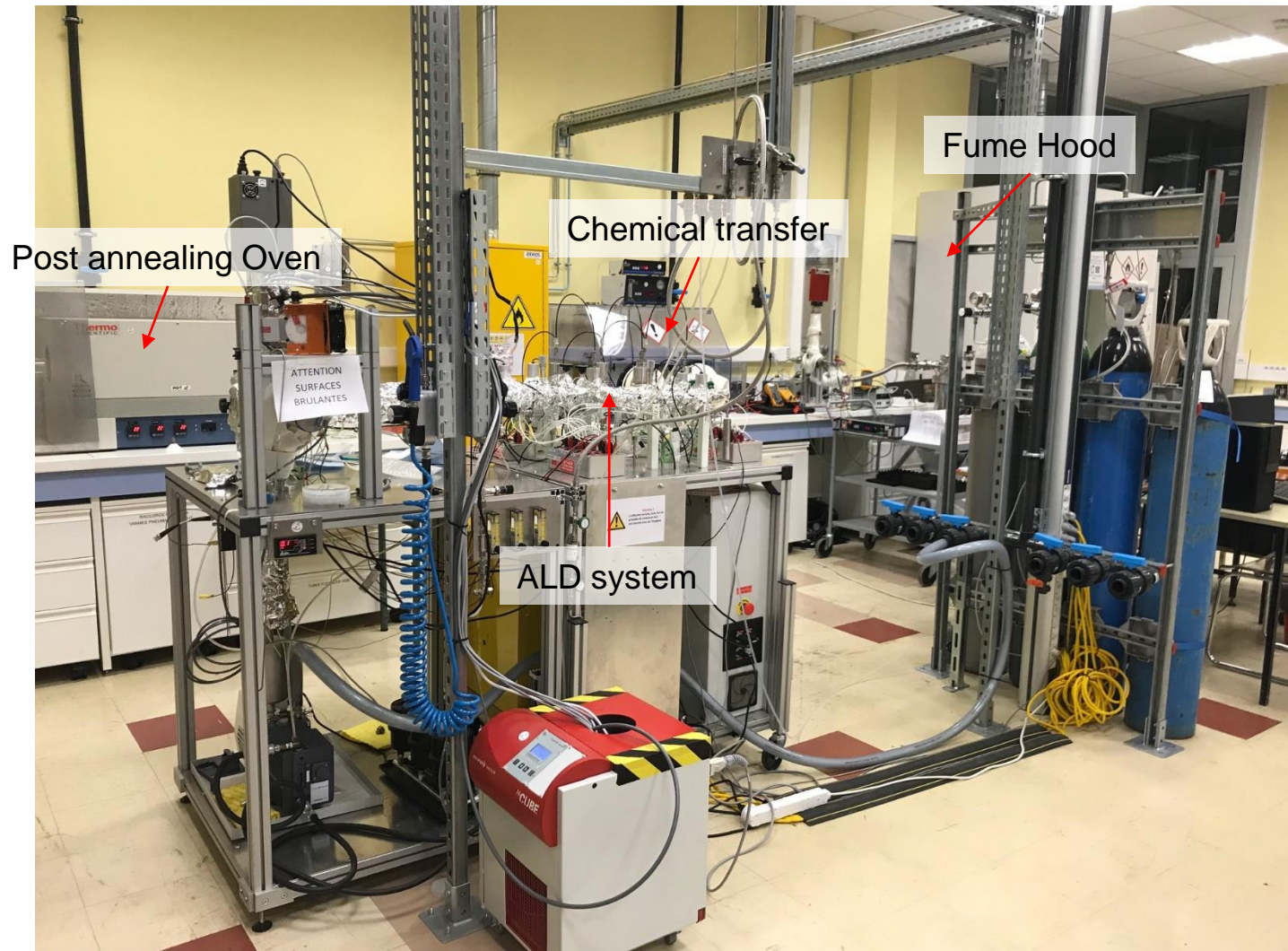
- 7 chemical precursors
- Temperature up to 500°C
- RGA and QCM in-situ monitoring
- Design to fit 3 and 1,3 GHz cavities
- Fully automated
- Deposition homogeneity < 1%

- Deposition on BCP, EP bulk Nb samples + Post annealing treatment in High Vacuum
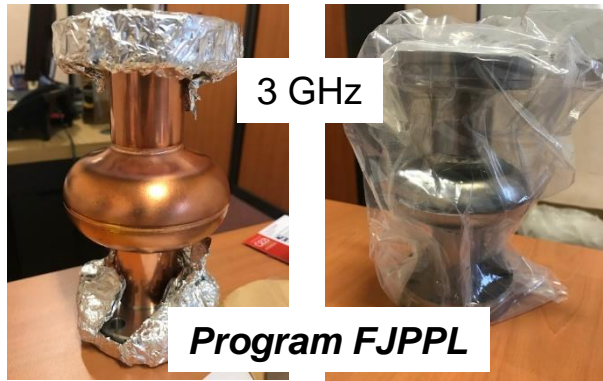

Annealing

- Up 1000°C
- 1 inch samples
- 10^{-6} mbar at 800°C
- RGA and gaz feedthroughs
- Set for Insitu X-ray studies

- Soon on 3GHz and 1,3 GHz cavities

3 GHz

Program FJPPL

Annealing

- Up 1000°C
- Up 1,3 GHz cavities
- 10^{-6} mbar at 800°C
- RGA and gaz feedthourghs

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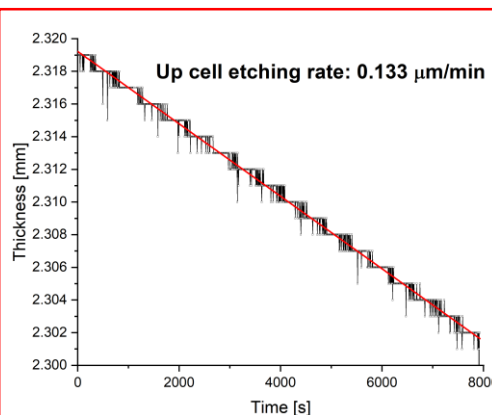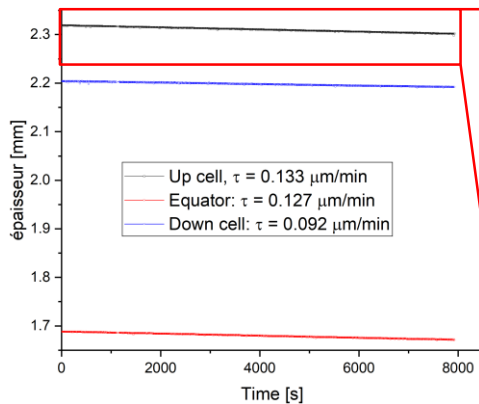- Chemistry: Vertical electropolishing

Program FJPPL: collaboration KEK + marui

➢ Vertical Electropolishing mono cell 1,3 GHz cavity: 37,5 MV/m without baking
➢ Vertical Electropolishing 9 cell 1,3 GHz cavity: On Going…

Mono 1,3 GHz

9 cells 1,3 GHz
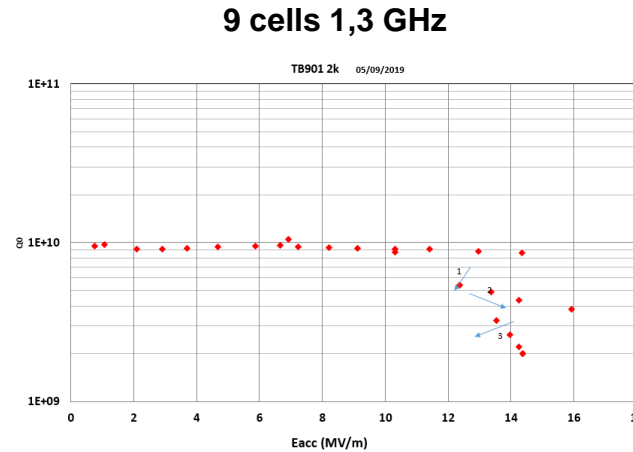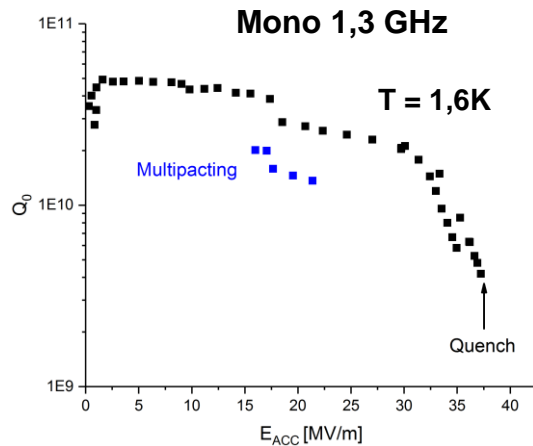
➢ Future: EPV on 704MHz cavity
➢ Real time multiple point thickness measurements during chemistry

Summary

Characterization:

- Two unique set of characterization tools with predict power for RF cavity tests

  ➢ Enable testing recipes/surface treatments/heterostructure on coupons prior to cavity tests

  ➢ Faster turner over and phase space exploration of growth parameters etc…

Thin film growth:

- Set up ready to deposit on coupons, 3 and 1,3 GHz cavities

➢ Study influence on RF properties of heterostructures made by ALD

➢ Post annealing capalities for samples and cavities

Vertical Electropolishing:

- Very good results on 1,3 GHz monocell cavities
- On Going optimization effort on 9 cells and 704 MHz cavities

The END