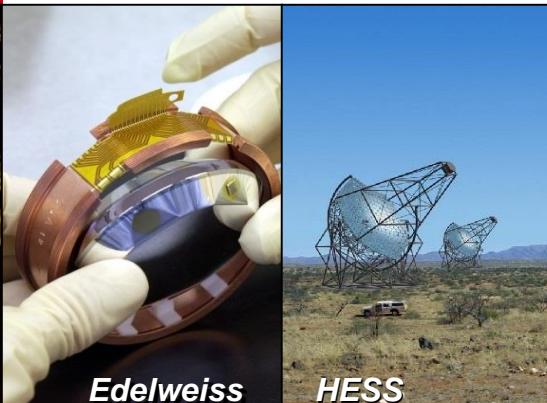


DE LA RECHERCHE À L'INDUSTRIE



Double Chooz

ALICE



Edelweiss

HESS



Herschel



CMS

Déchiffrer les rayons de l'Univers



10/11/2020

Fermilab

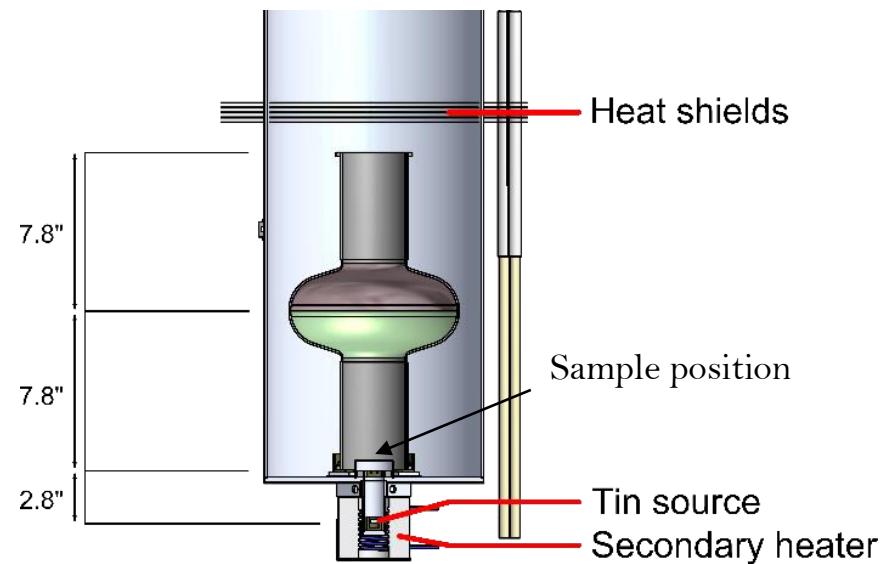
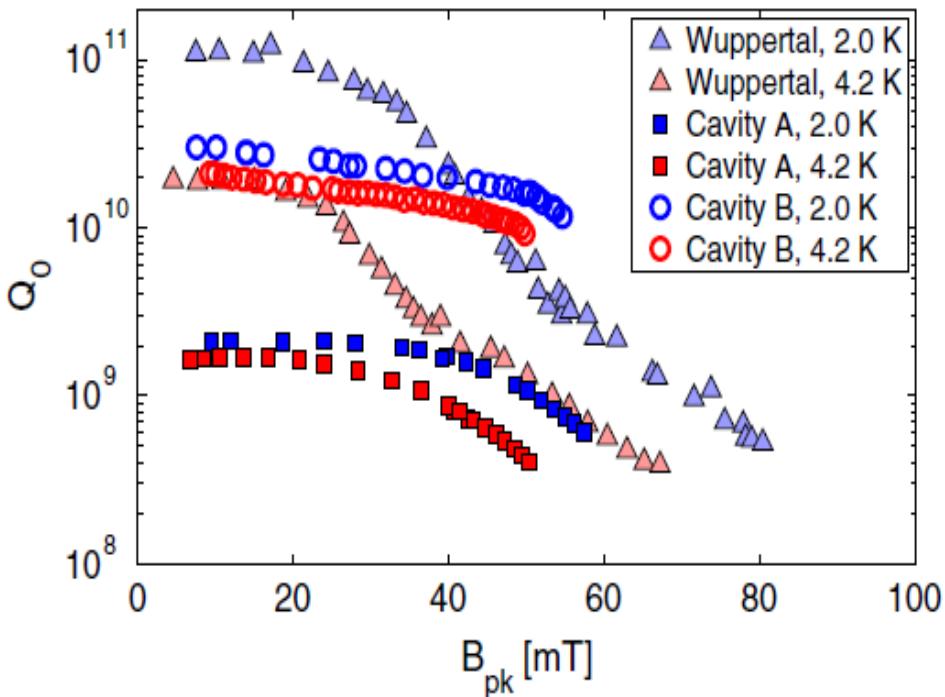


Argonne
NATIONAL LABORATORY

- Motivations
- Tunneling spectroscopy
- Results on Nb₃Sn
- Simulations

- Motivations
- Tunneling spectroscopy
- Results on Nb_3Sn
- Simulations

$\text{Nb}_3\text{Sn}/\text{Nb}$ (Cornell)

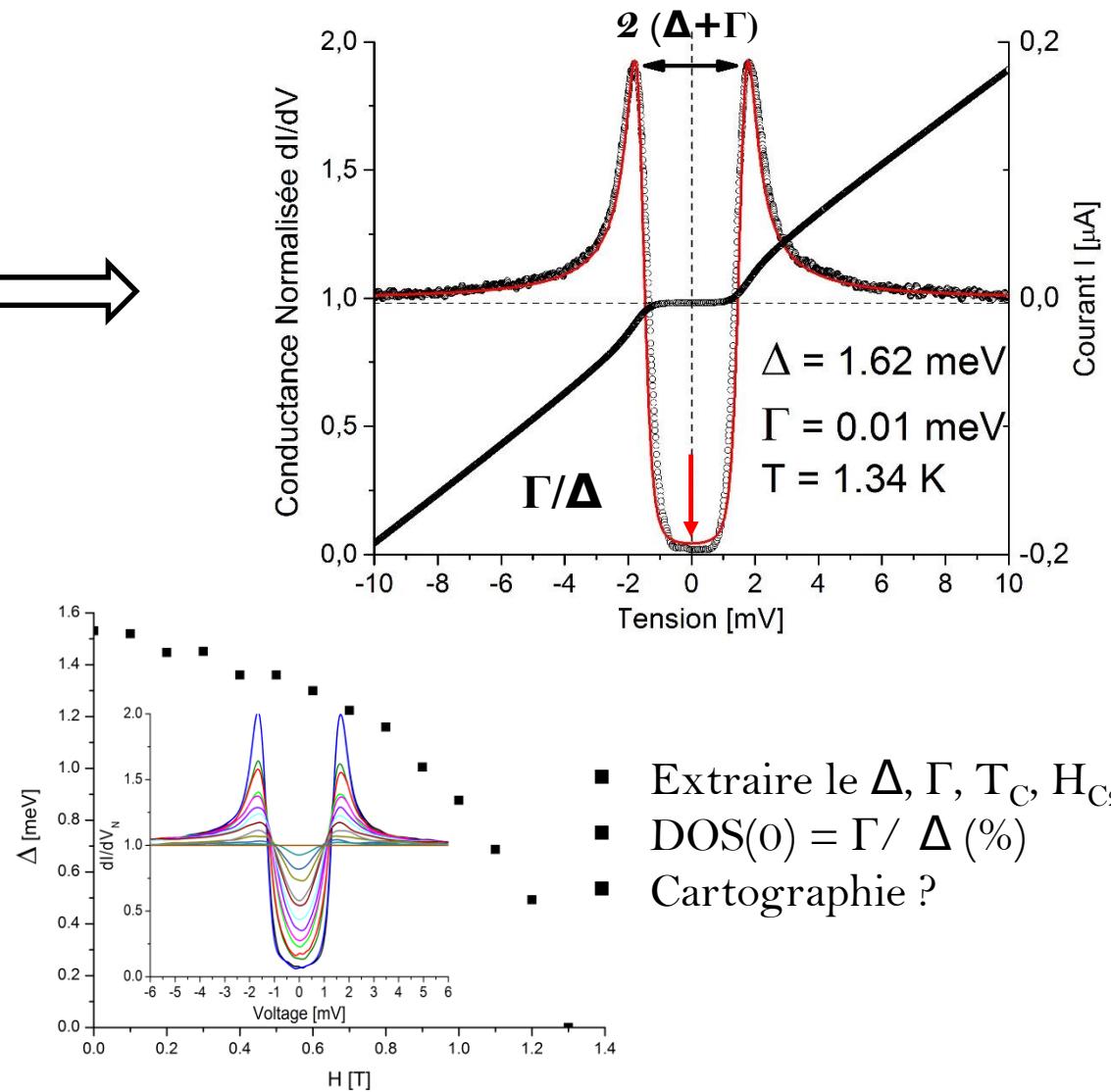
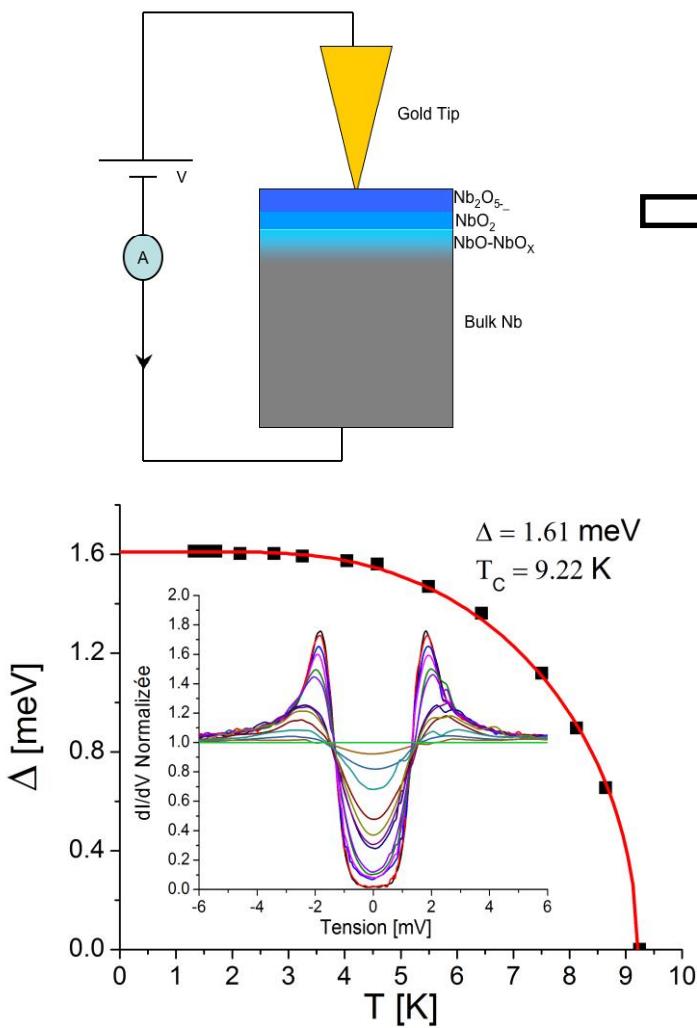


- Wupperthal method: diffusion of Sn in a Nb cavity
- Nb₃Sn Q_0 at 4,2K \sim Nb Q_0 at 2K
- Moderate increase of Q_0 between 4K to 2K -> Non-BCS
- Q_0 decrease at ~ 6 K

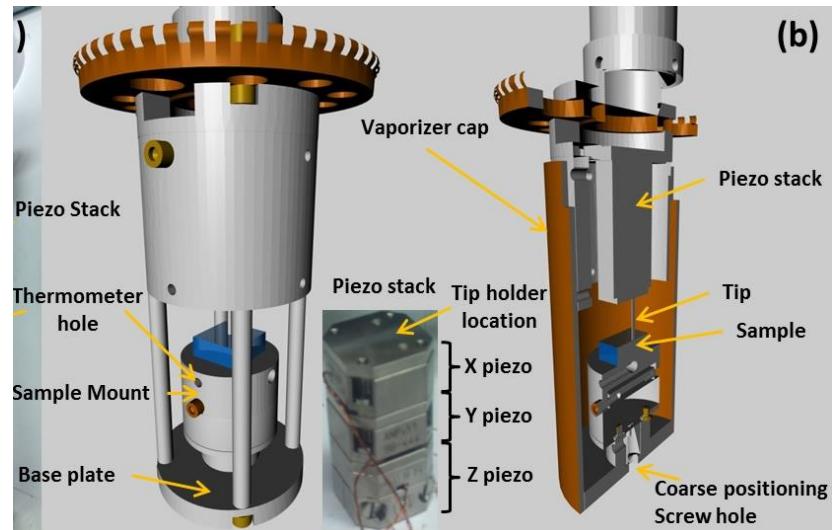
Have we reached the limits of Nb₃Sn ?

- Motivations
- Tunneling spectroscopy
- Results on Nb₃Sn
- Simulations

Measuring de DOS (Density of States): Tunneling spectroscopy

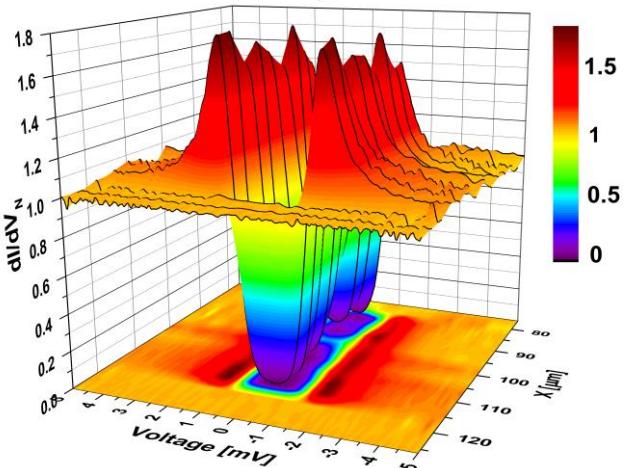
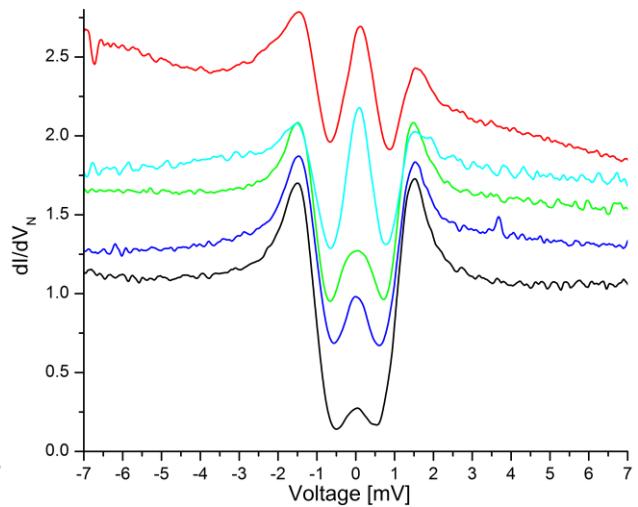
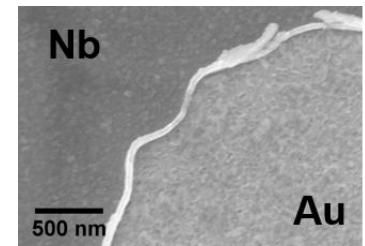
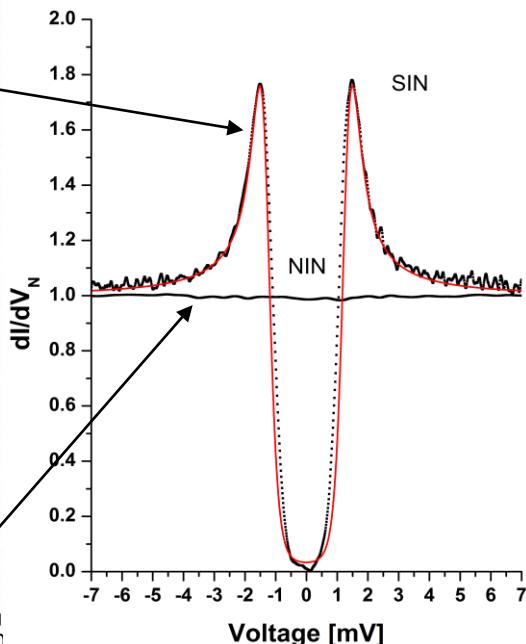
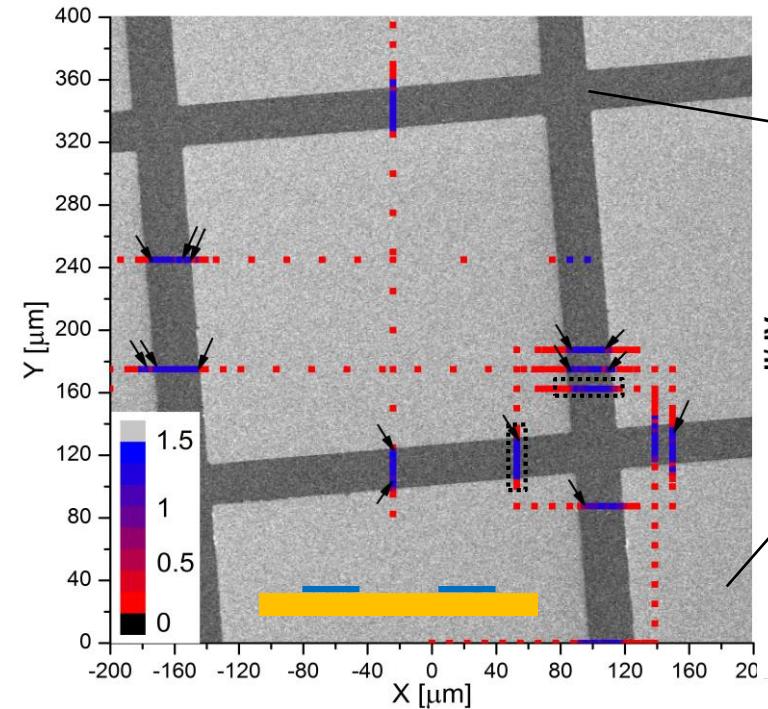


Tunneling spectroscopy set up at CEA



- Temp: 1,4 K – Magnetic field: 6 T
- Variable junction resistance: $2 \cdot 10^2 - 2 \cdot 10^9 \Omega$.
- Cartography: $10 \mu\text{m} - 1 \text{ mm}$
- Fast measurements: 100-300 junctions/5hrs
- Transport (RRR, Tc vs H applied...)
- Hall Effect
- Sample size: 10x10 mm

La cartographie:



Standard:

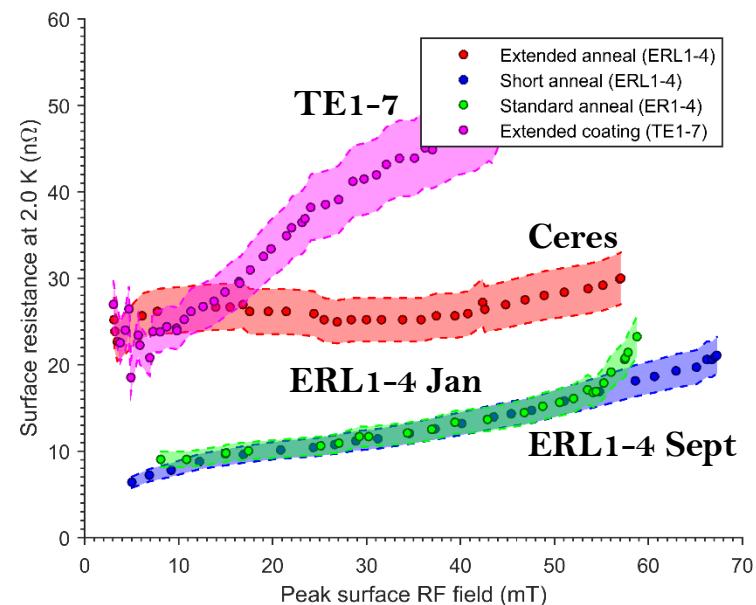
- lines of Al(6 nm)/Nb (80 nm) on Au (200 nm)
- Calibration: $X = 4,1 \text{ nm/V}$
 $Y = 4,9 \text{ nm/V}$

- Motivations
- Tunneling spectroscopy
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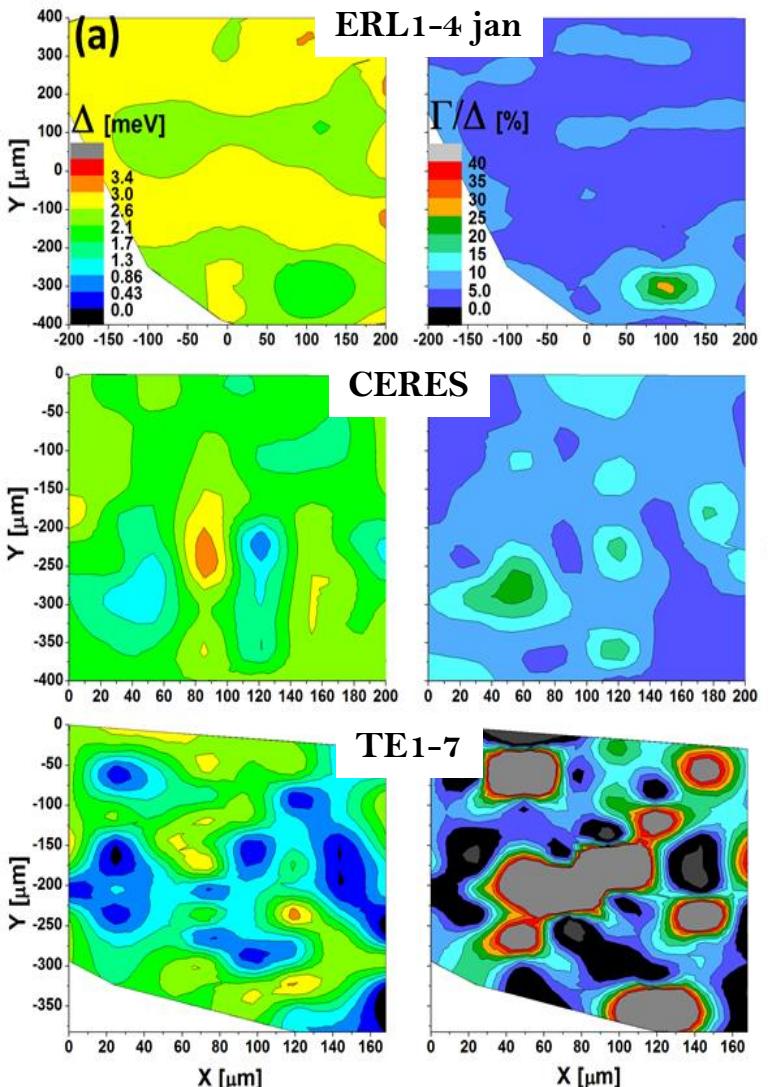
$\text{Nb}_3\text{Sn}/\text{Nb}$ (Cornell)- samples

Sample	Coating Temp (°C)	Coating Time (hr)	Annealing Temp (°C)	Annealing Time (hr)	Position	Nucleation agent (SnCl_2)	ΔT (°C)	λ [nm]	Comments
Vesta	1200	3	1100	6	Equator	NO	0		
Apollo	1200	3	1100	6	Equator	YES	0		
Ramp Test	1200	3	1100	6.5	Low	YES	0		
Jupiter	1200	3	1100	6.5	High	YES	150	198	RF test
Minerva	1200	3	1100	6.5	High	YES	150		Large Grain Nb
ERL1-4 Jan	1200	3	1100	6.5	Low	YES	150	161	RF test
ERL1-4 June LG	1200	3	1100	6.5	Low	YES	150		Large Grain Nb
Ceres	1200	3	1100	16	Low	YES	150	174	RF test
TE1-7	1200	8	1100	6.5	Low	YES	150		RF test
ERL1-4 Sept	1200	3	1100	0.5	Low	YES	150	139	RF test

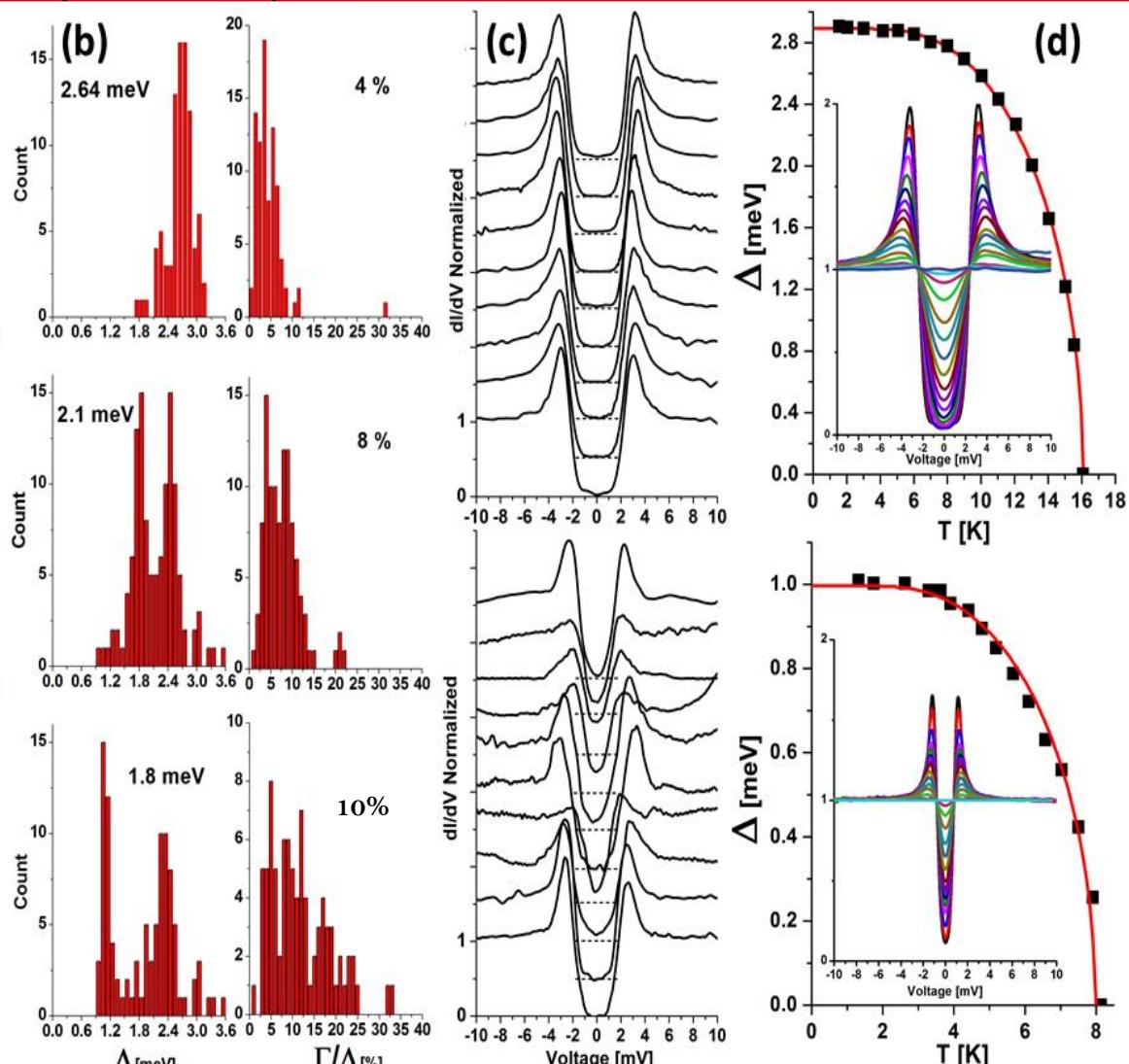
- Different coating parameters:
- Coating time
- Annealing time
- Nucleation agent
- ΔT between source and cavity
- Different position in the furnace



$\text{Nb}_3\text{Sn}/\text{Nb}$ (Cornell) - PCT

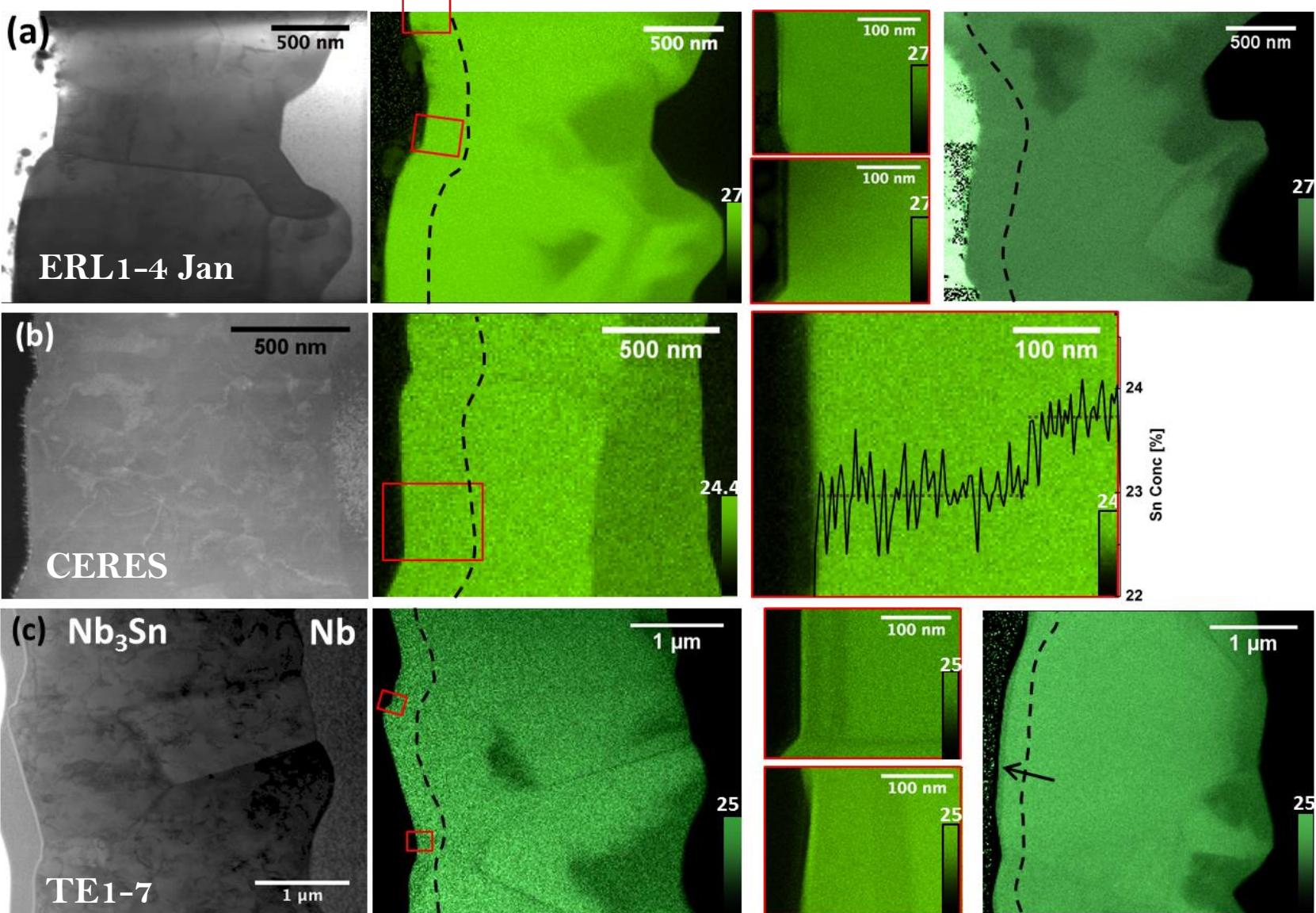


- $\Delta > \text{Nb}$ and Γ/Δ is small
-> Quality factor @ 4K is $\sim \text{Nb}$ @ 2K



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

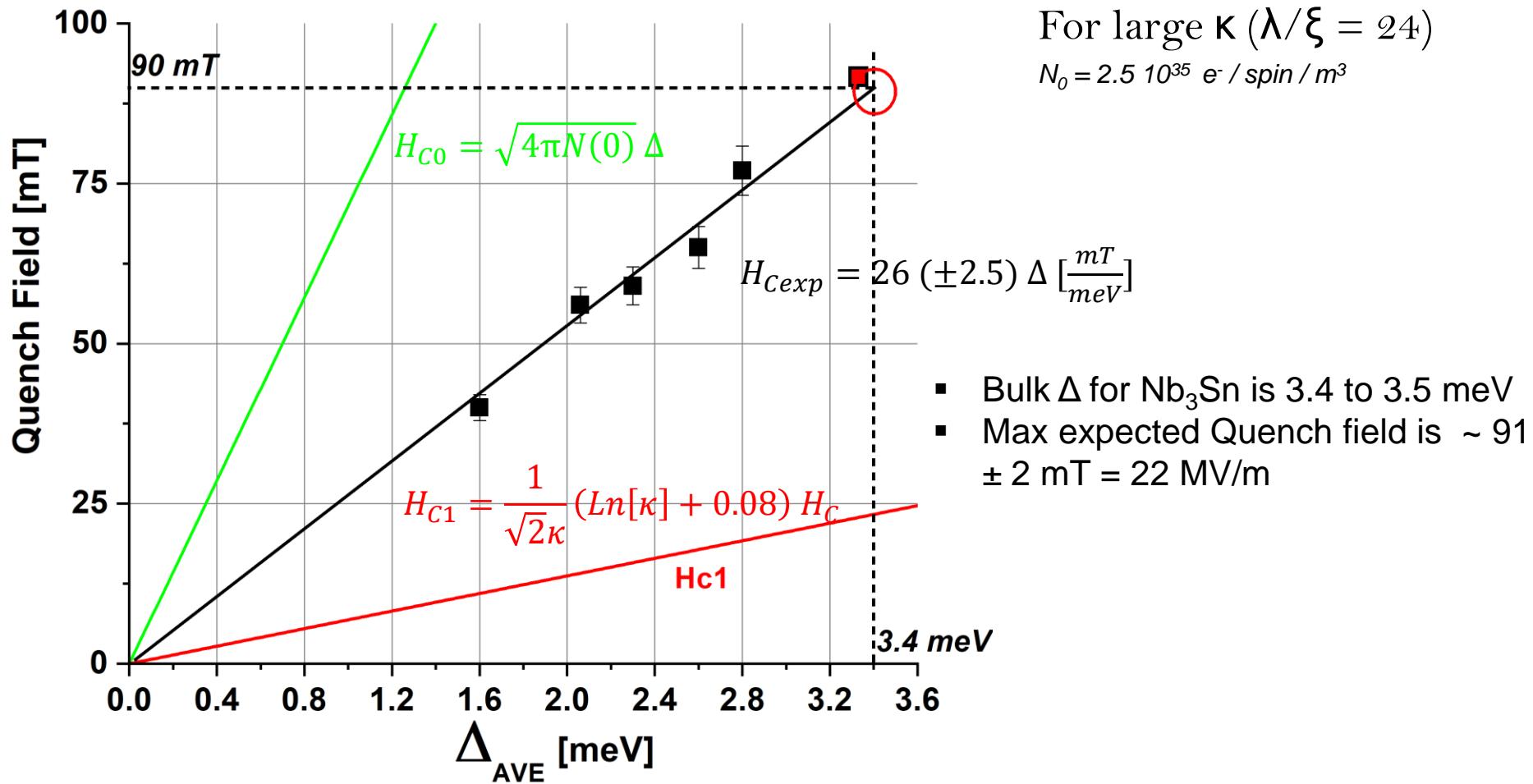
$\text{Nb}_3\text{Sn}/\text{Nb}$ (Cornell) – TEM



- Nb riche phase riche
- Interface Nb-Nb₃Sn , grain boundaries
- **Pockets near the surface**
- Crystallite ~ 200-300 nm (XRD)
- 60% Nb₃Sn

$\text{Nb}_3\text{Sn}/\text{Nb}$ (Cornell - FNAL) – PCT

Quench field vs Average Gap

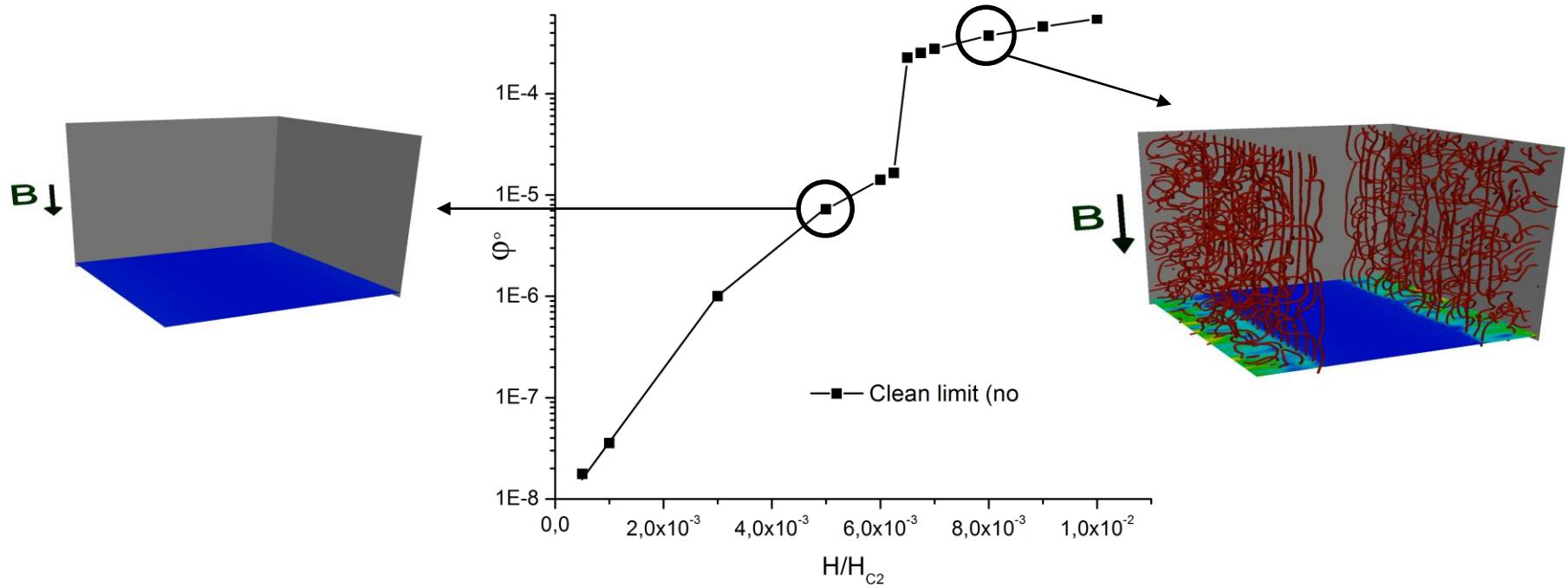


- Linear dependence of E_{max} on the average surface gap ($\sim 300 \times 300 \mu\text{m}$)
- $H_{\text{Cexp}} \sim 3.5$ times the H_{C1} but why this gap dependence? Roughness, effective penetration depth?
- A15 compounds (V_3Si , Nb_3Sn , Nb_3Al ...) are good for Q_0 and higher operation temp. (4,2 K)
- But what about E_{MAX} ? How to increase E_{MAX} ?

- Motivations
- Tunneling spectroscopy
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$\text{Nb}_3\text{Sn}/\text{Nb}$ - simulation

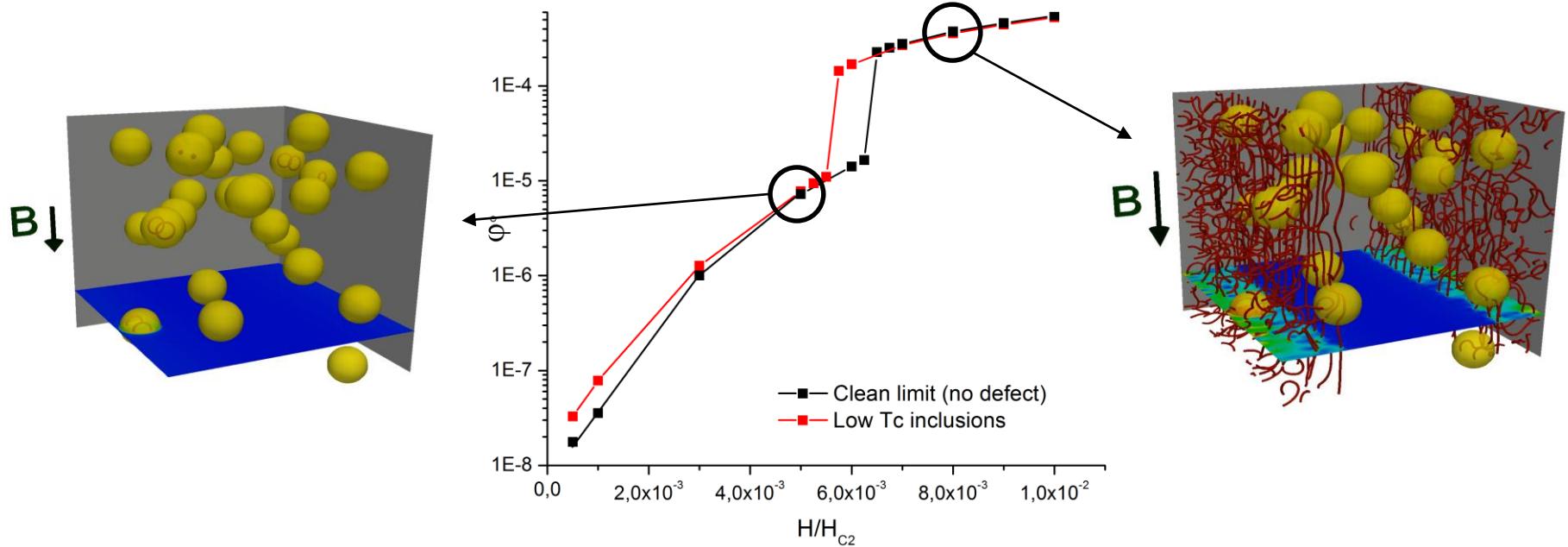
Collaboration with A. Glatz (OSCon Project = Optimizing supercond. Transport properties Through large scale simulation).



- Nb₃Sn film under AC field (1,3 Ghz) parallel to the surface, volume $(256 \xi)^3 \sim (1,3 \mu\text{m})^3$
- Approximations: Time Dependent Ginzburg-Landau (TDGL) $\rightarrow \lambda = \infty$ and $T \sim T_c$
- Dissipation $W = \langle |\partial_t \psi|^2 \rangle$, time variation of the order parameter over 100 oscillation periods (10⁹ Hz)
- \rightarrow Quench = pénétration de vortex

$\text{Nb}_3\text{Sn}/\text{Nb}$ - simulation

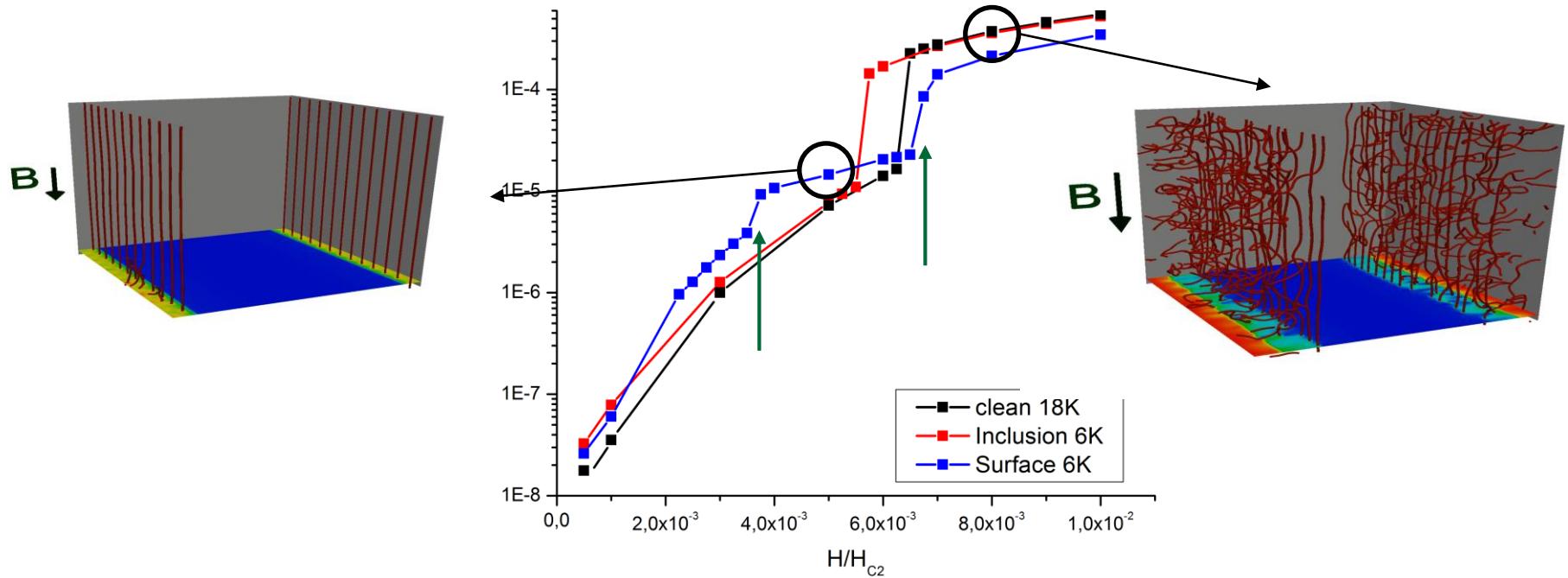
Variation of superconducting properties: Case of Low Tc inclusions 6K



- Vortex penetration at lower external field amplitude

$\text{Nb}_3\text{Sn}/\text{Nb}$ - simulation

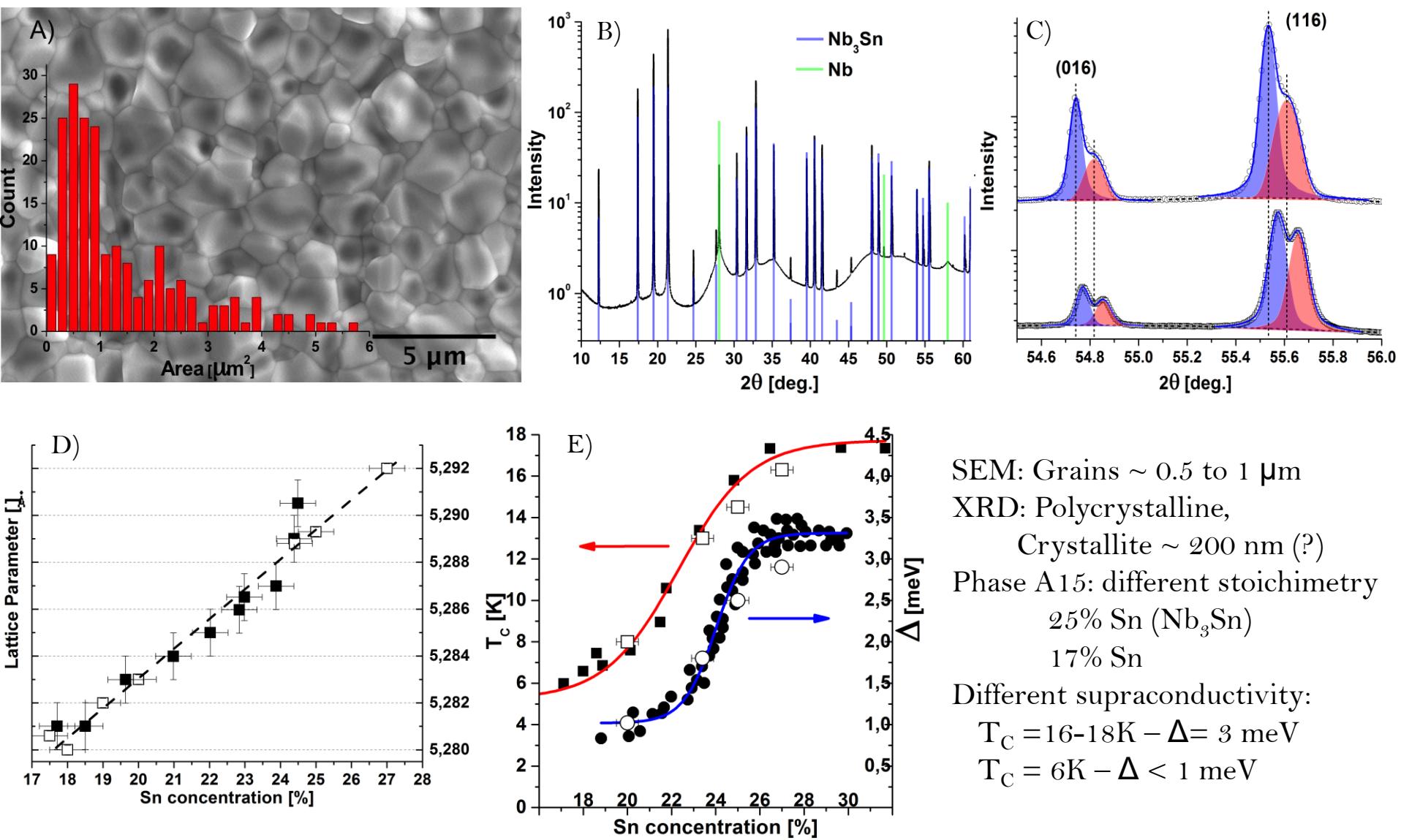
Variation of superconducting properties: Surface layer Low Tc 6K



- Two Vortex penetration fields: Low Tc phase and High Tc phase.

The END

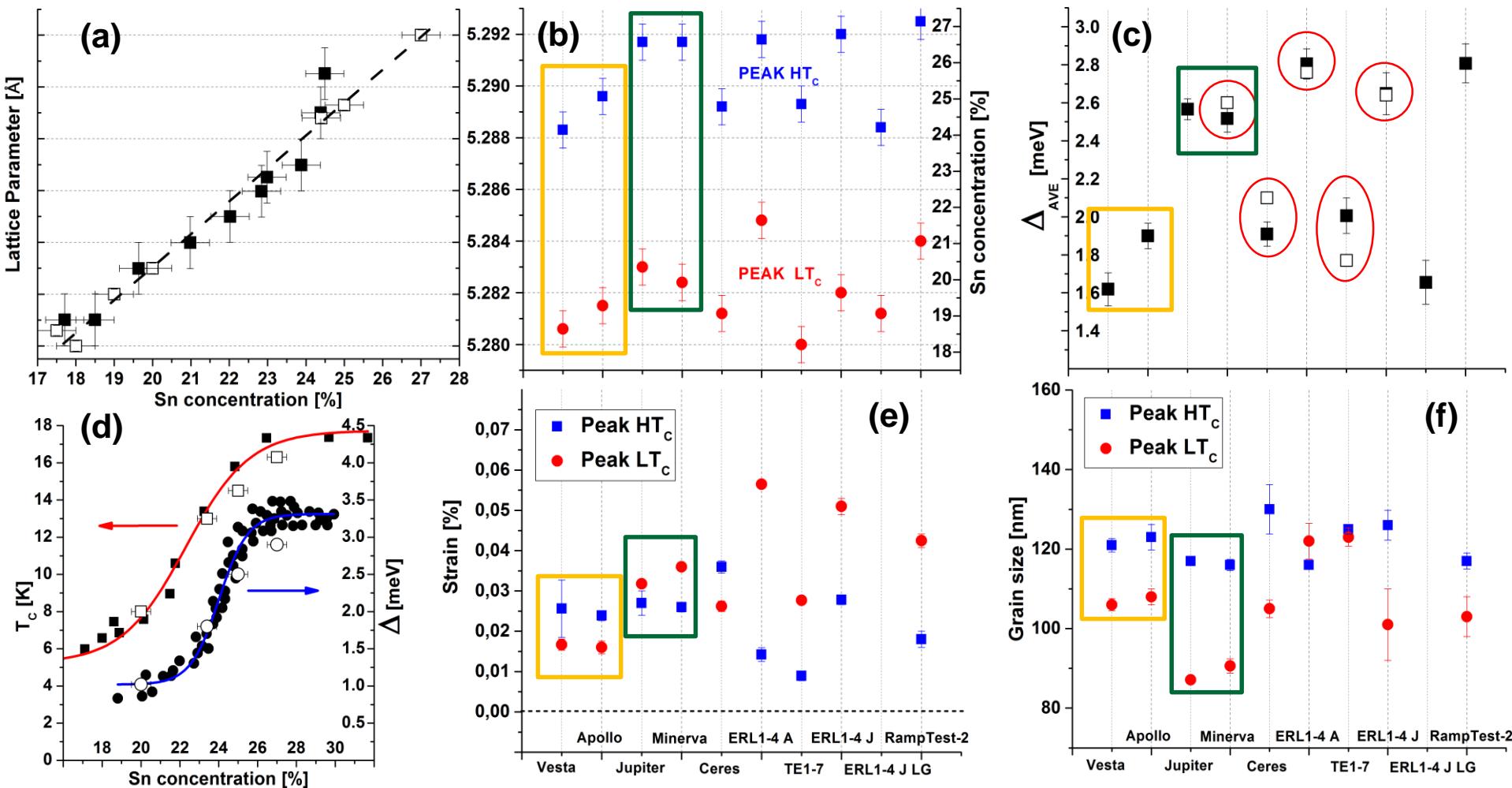
$\text{Nb}_3\text{Sn}/\text{Nb}$ (Cornell) - XRD



Devantay et al. J. of Mat. Science 1981

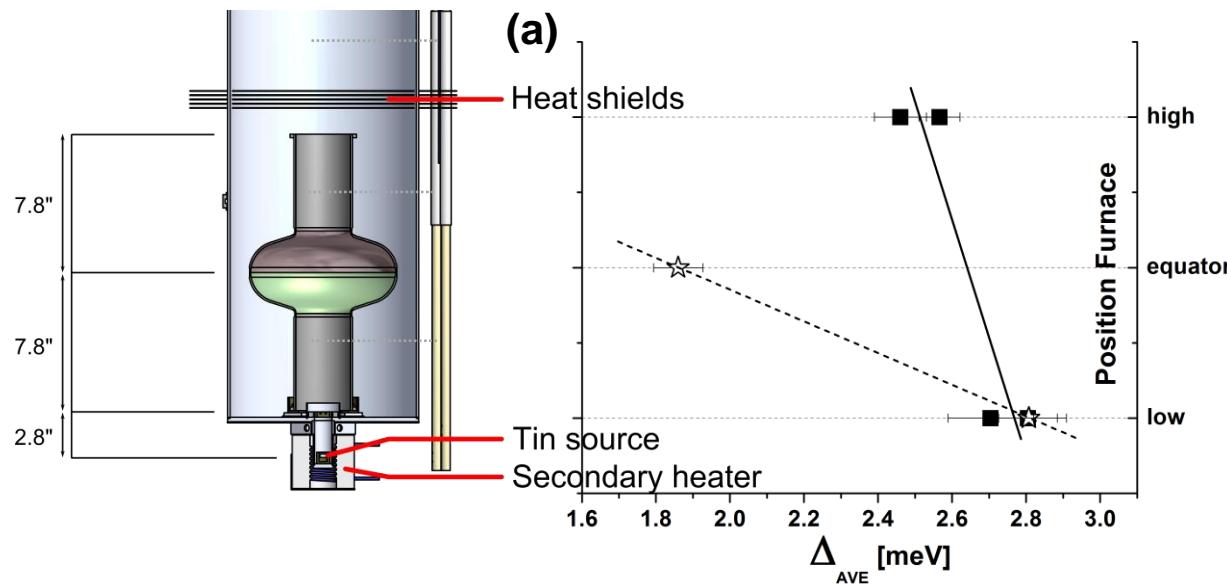
$\text{Nb}_3\text{Sn}/\text{Nb}$ (Cornell) - XRD

Devantay et al. J. of Mat. Science 1981

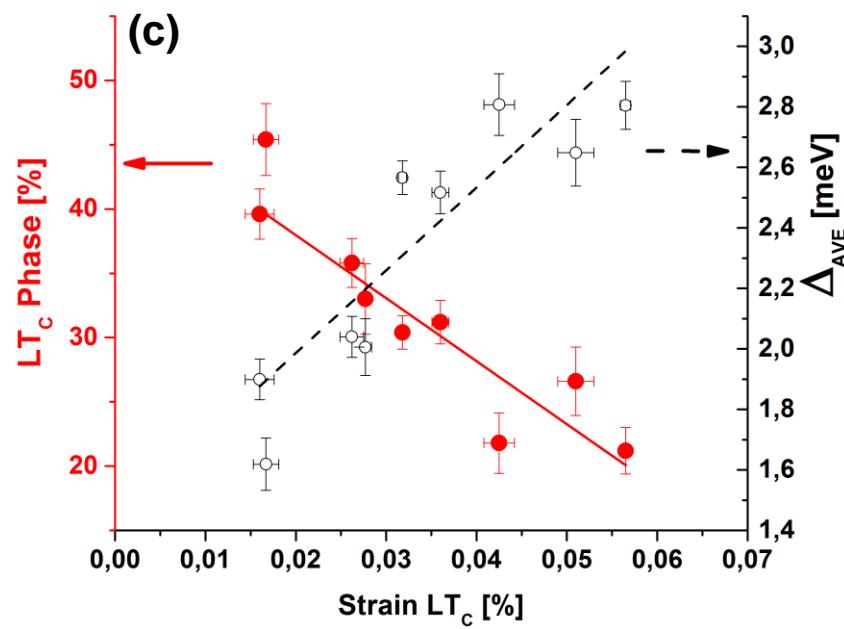
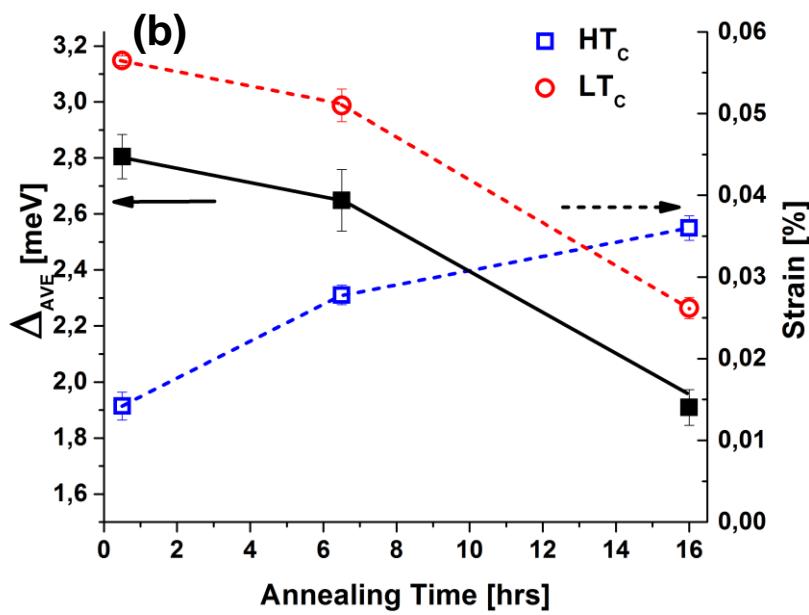


- Same conditions -> same results
- Nucleation agent -> higher Sn concentration and Average gap

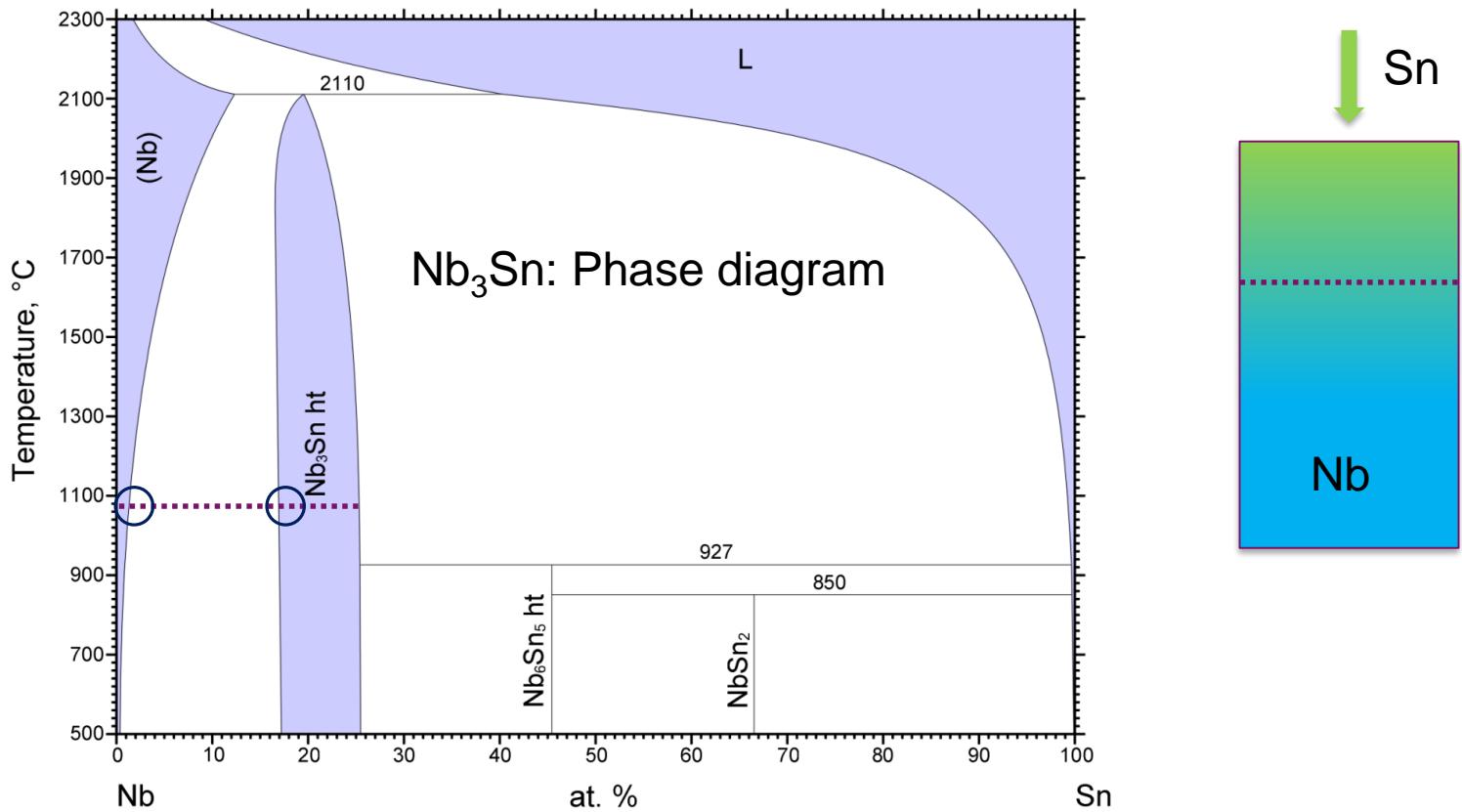
$\text{Nb}_3\text{Sn}/\text{Nb}$ (Cornell) - XRD



- Higher in furnace
-> less Sn
-> lower Average gap
-> ΔT improve homogeneity
- Annealing time:
-> lower Average gap
- Strain of the LTc phase:
-> predictive parameter



$\text{Nb}_3\text{Sn}/\text{Nb}$ (Cornell) - mécanisme



- Processus de diffusion : $1000^\circ\text{C} \rightarrow$ Segregation de phase 17% Sn and Pure Nb
- Accumulation de region à 17%
- Suggère plus haute concentration Sn