Millisecond flash lamp treatment for Nb-compounds and SRF accelerating cavities

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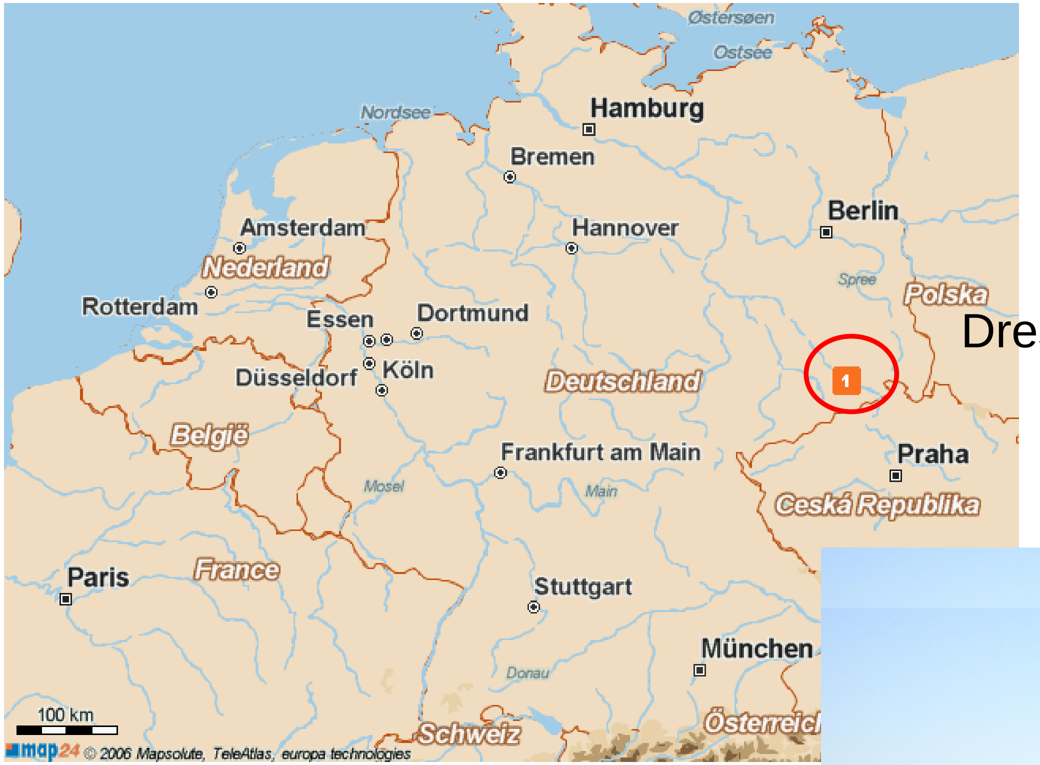
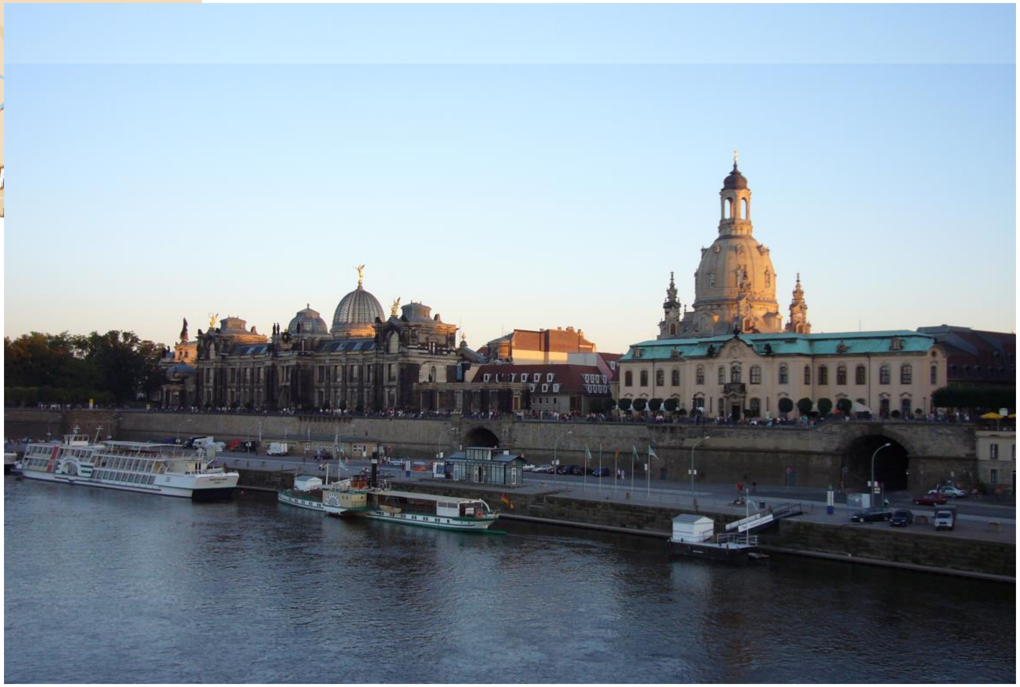
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

HELMHOLTZ ASSOCIATION

Dresden



Dresden



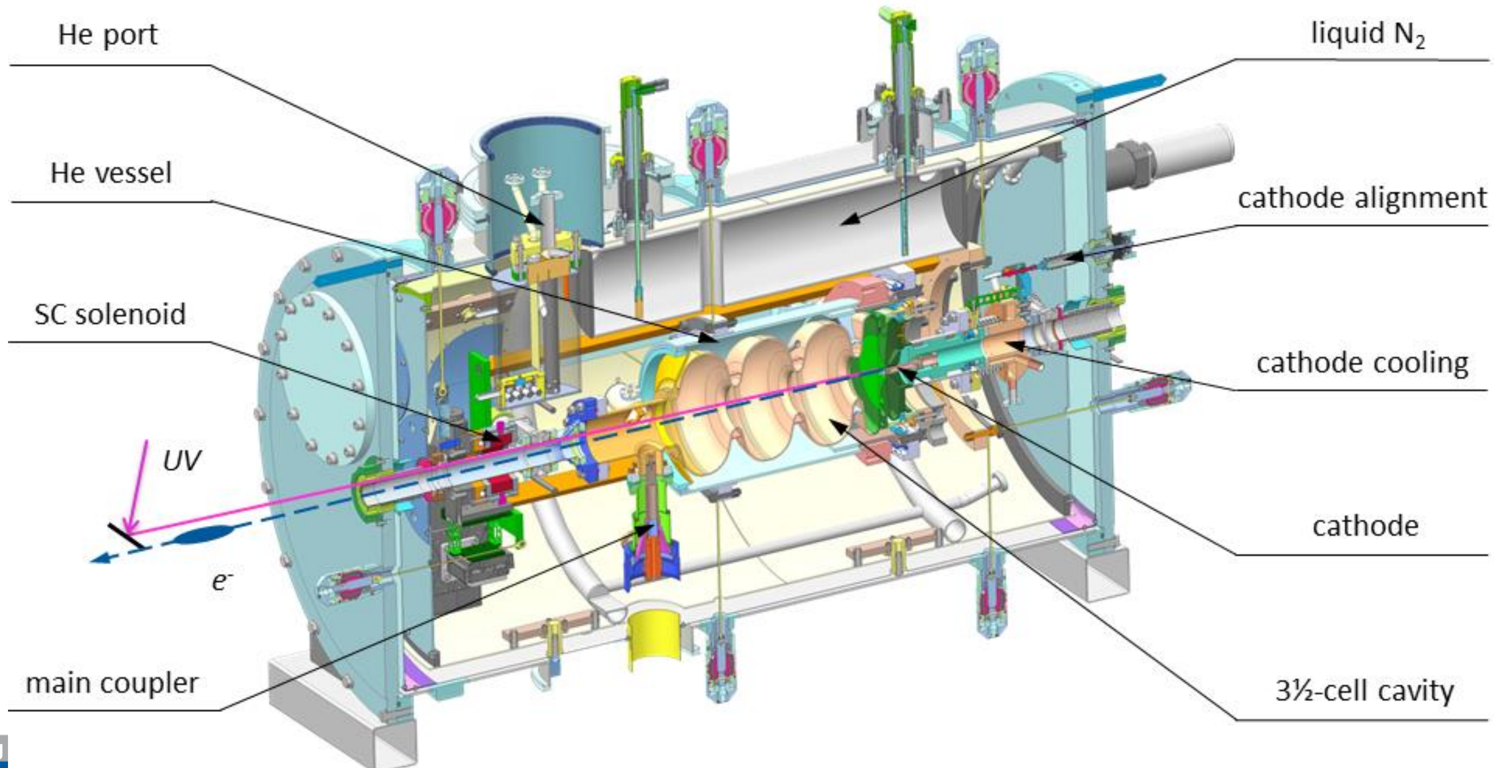
MML ■ IN-HOUSE RESEARCH

Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

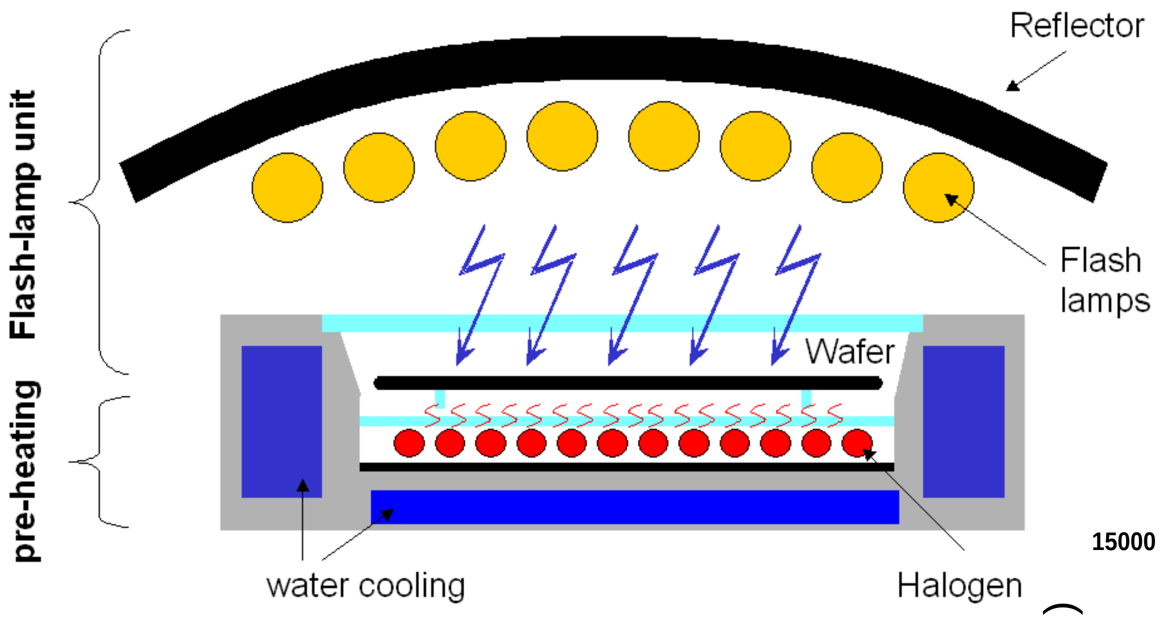
R. Xiang, et al., SRF Gun and SRF Linac Driven THz at ELBE Successfully in User Operation, 19th International Conference on RF Superconductivity (SRF 2019)

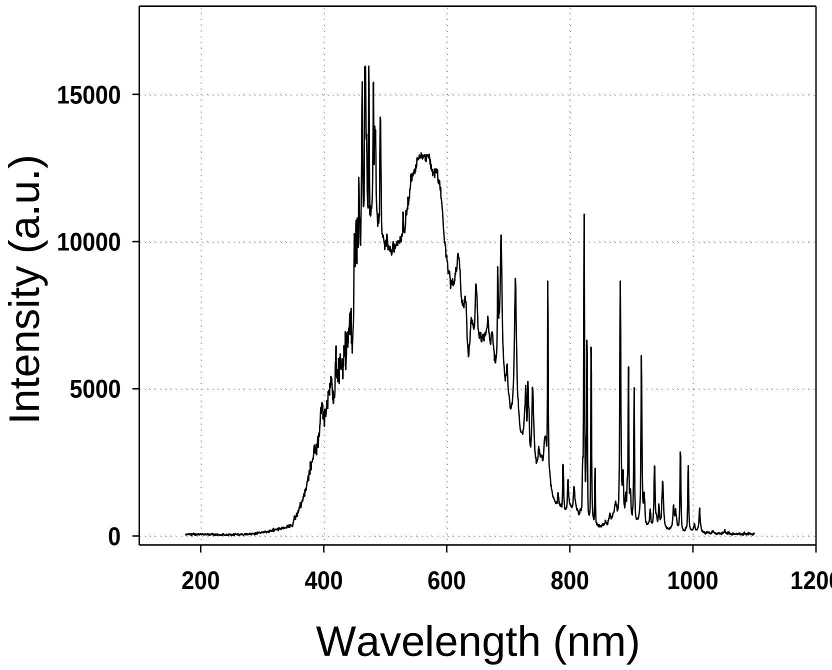
J. Teichert, et al., Successful user operation of a superconducting radio-frequency photoelectron gun with Mg cathodes, Phys. Rev. Accel. Beams 24, 033401 (2021)

2021: selected component for LCLS-II-HE



Material processing: flash lamp annealing





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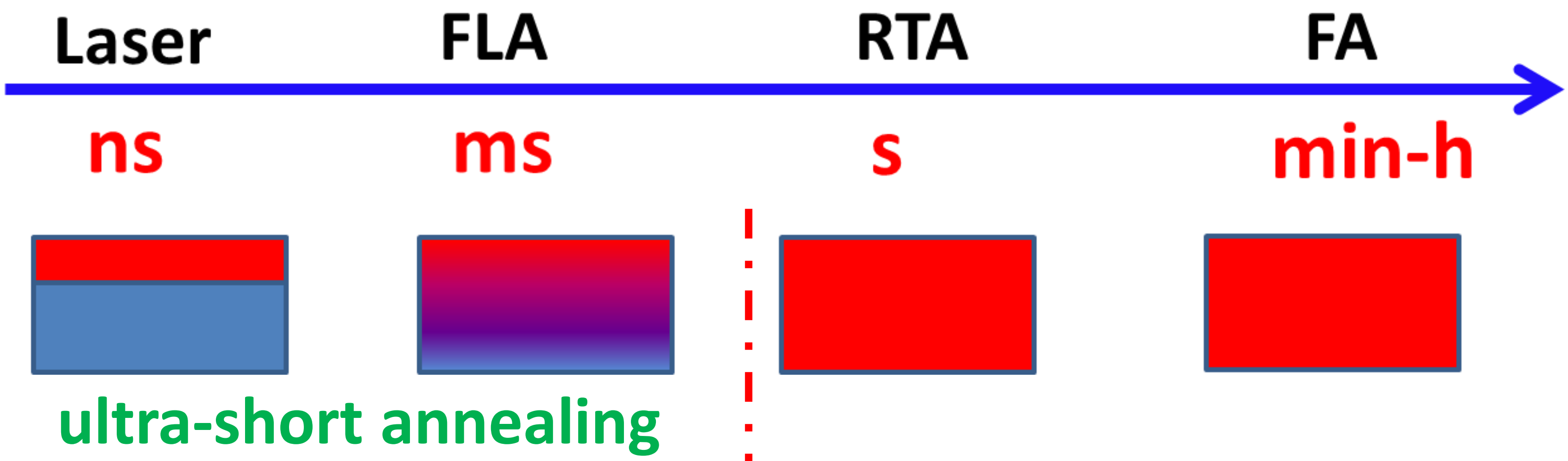
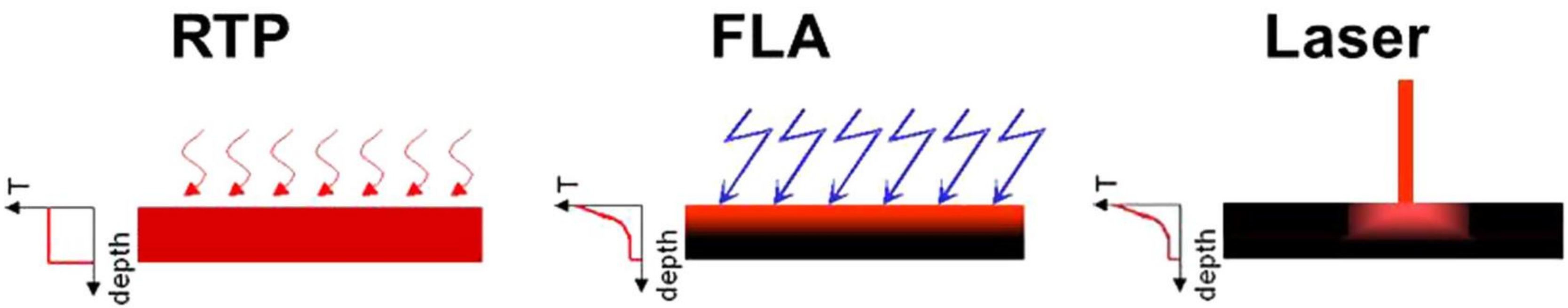
Thermal processing of semiconductors



Kun Gao PhD Thesis (2014).
Zhou, Shengqiang, et al. Sci. Rep. 5 (2015).

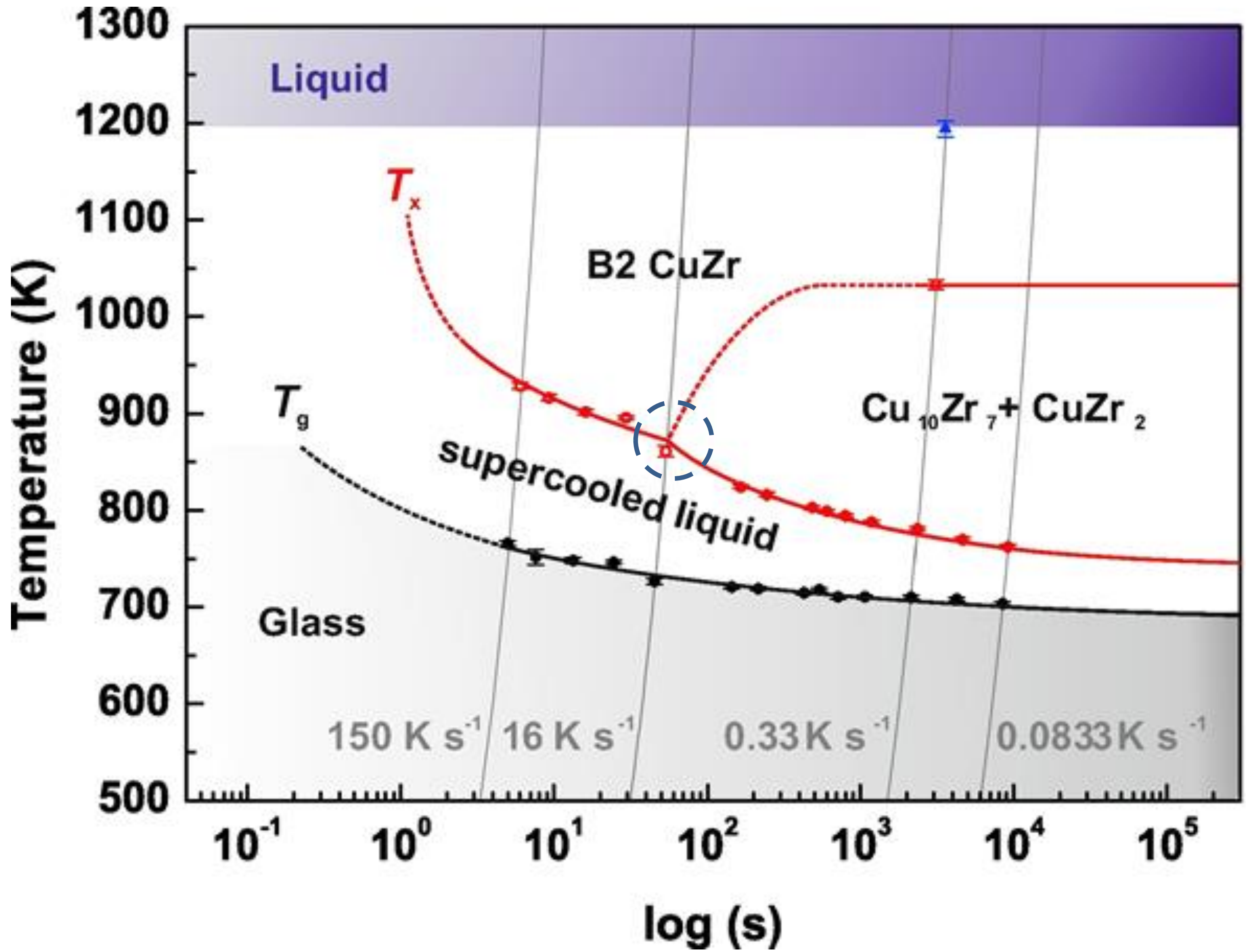
Millisecond-flash-lamp-annealing (FLA)



RTP	FLA	Laser
• whole wafer heated	• only surface heated	• only surface heated
• $T_{RS} \approx T_{FS}$	• $T_{RS} << T_{FS}$	• $T_{RS} << T_{FS}$
• 1 –100 s	• 0.5 – 20 ms	• 1 – 1000 ns, ms for cw
• up to 1300°C	• up to 2000°C	• up to 2000°C
• halogen lamps	• Xe flash lamp	• XeCl excimer (308 nm) KrF excimer (248 nm)
• broad spectrum ~ 800 nm	• broad spectrum ~ 400 nm	• discrete lines (interference effects!)
• one shot-one wafer	• one shot-one wafer	• point or line scan

L. Rebohle, S. Prucnal, W. Skorupa, Semicond. Sci. Technol. 31 103001 (2016).

Selected phase formation



Kosiba, K. et al. *Acta Mater.* **127**, 416–425 (2017).

Z. Li and S. Zhou, et al. Adv. Funct. Mater. 15, 2009723 (2021).

Nb_3Sn, NbN on Cu by Sputtering

- **Similar to Nb on Cu** cavities
- **Solve** the **Low Thermal Conductivity issue** of Nb substrate
- A first prototype of 1.3 GHz cavity is under developing in **iFAST WP9**

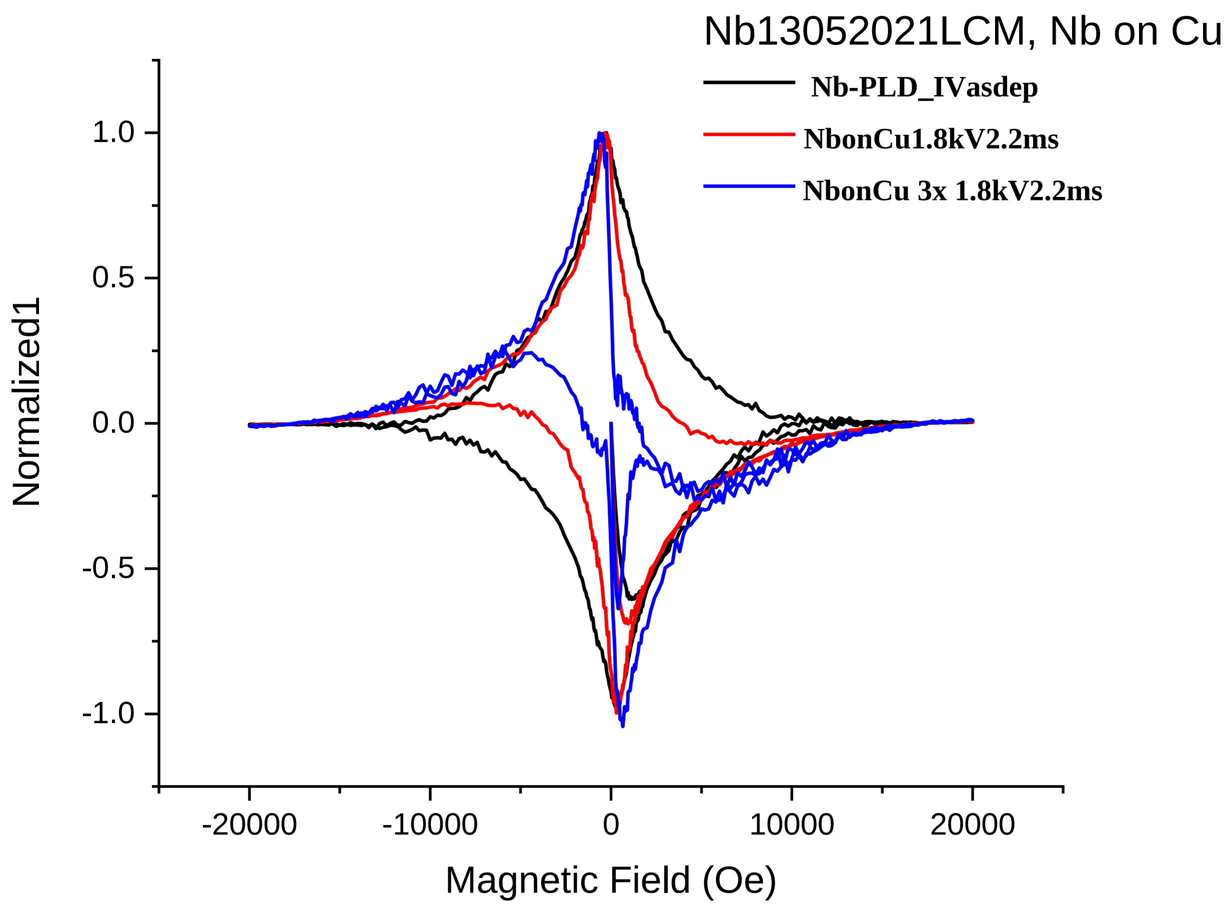
- **Low melting point of Cu** is a limitation
- 650 °C can be considered a limit in a Cu cavity
- Diffusion of Cu into Nb_3Sn

6 GHz Nb on Cu Cavity @LNL

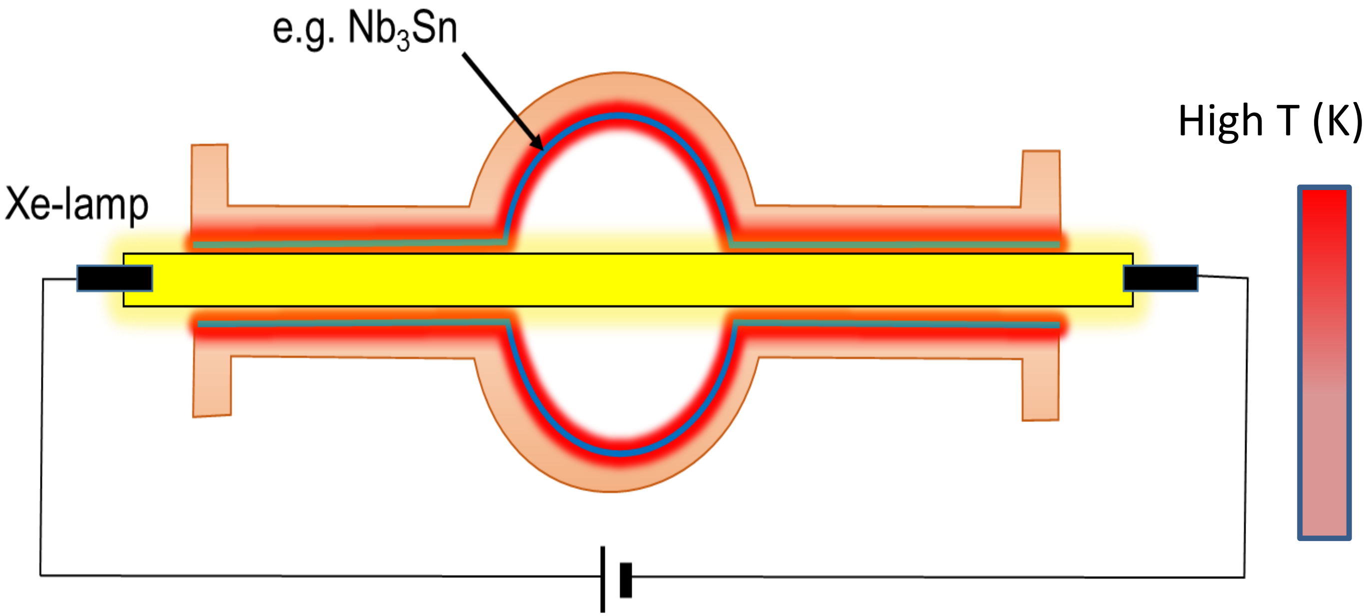
From Cristia Pira, INFN

First try for Nb on Cu

Nb13052021LCM, Nb on Cu



Easy extended to cavity size



Temperature distribution
in flashed cavity 20 ms

From Cristian Pira, INFN

Materials characterization

magnetic and electrical

SQUID-VSM
Lakeshore Hall Measurement system
1.8-400 K
up to 7 T

Raman, RBS, Positron

Materials characterization

RBS/PIXE: composition, trace impurities

Rutherford backscattering

Rutherford backscattering Spectrometry

From a method to understand the matter

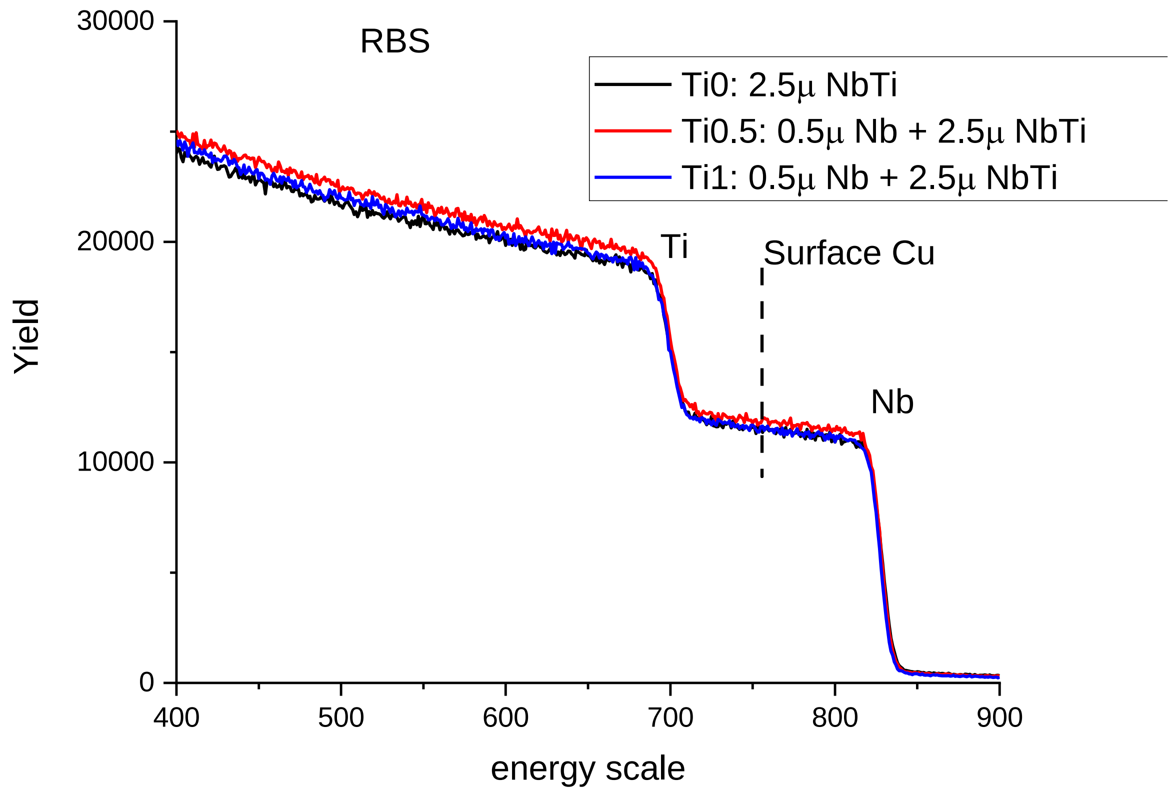
to a method for materials research

(1) Identify the element and its concentration

(2) Depth profile of concentration in thin film

Materials characterization

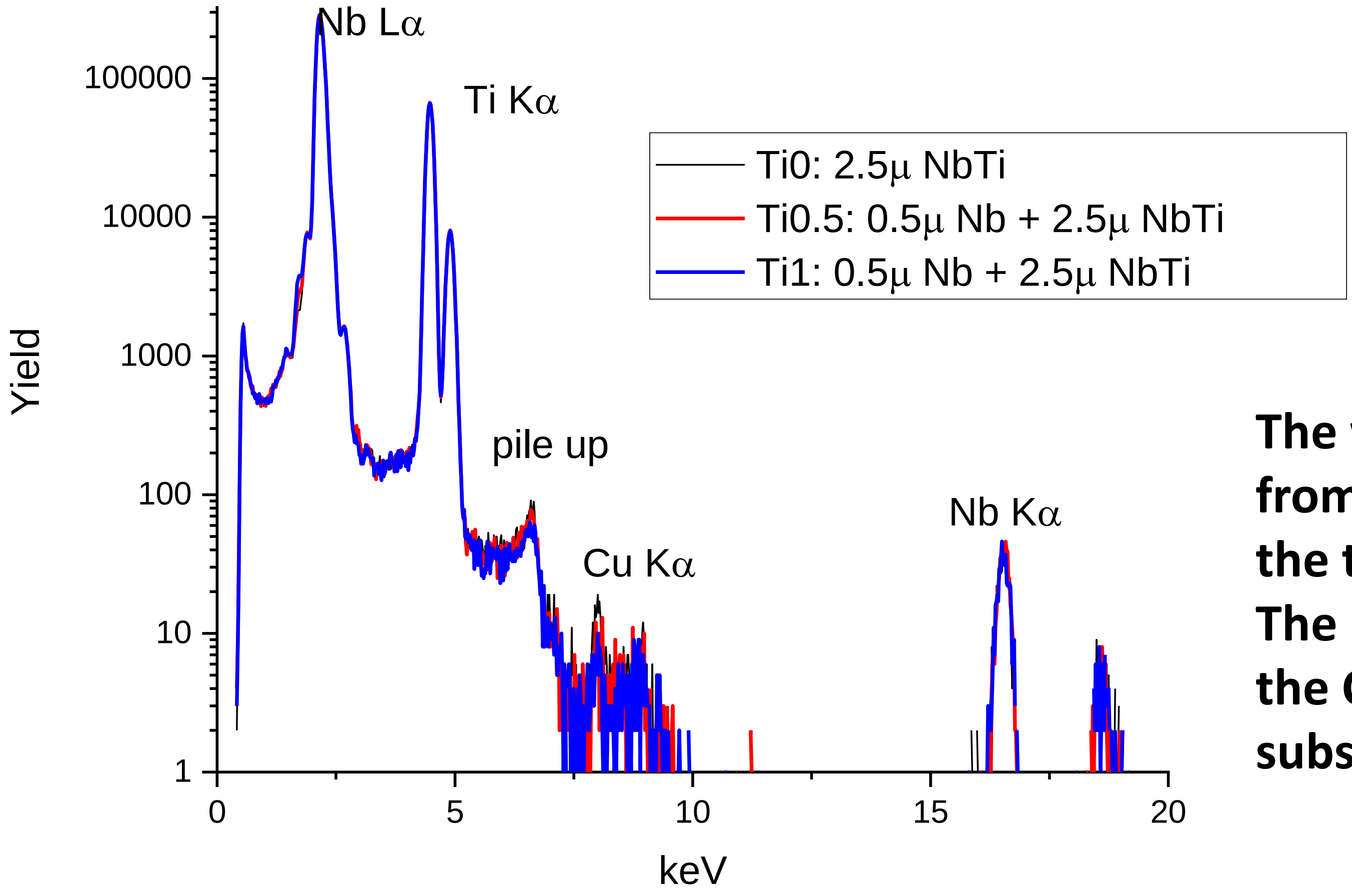
RBS/PIXE: composition, trace impurities



Samples From Cristian Pira, INFN

Materials characterization

RBS/PIXE: composition, trace impurities

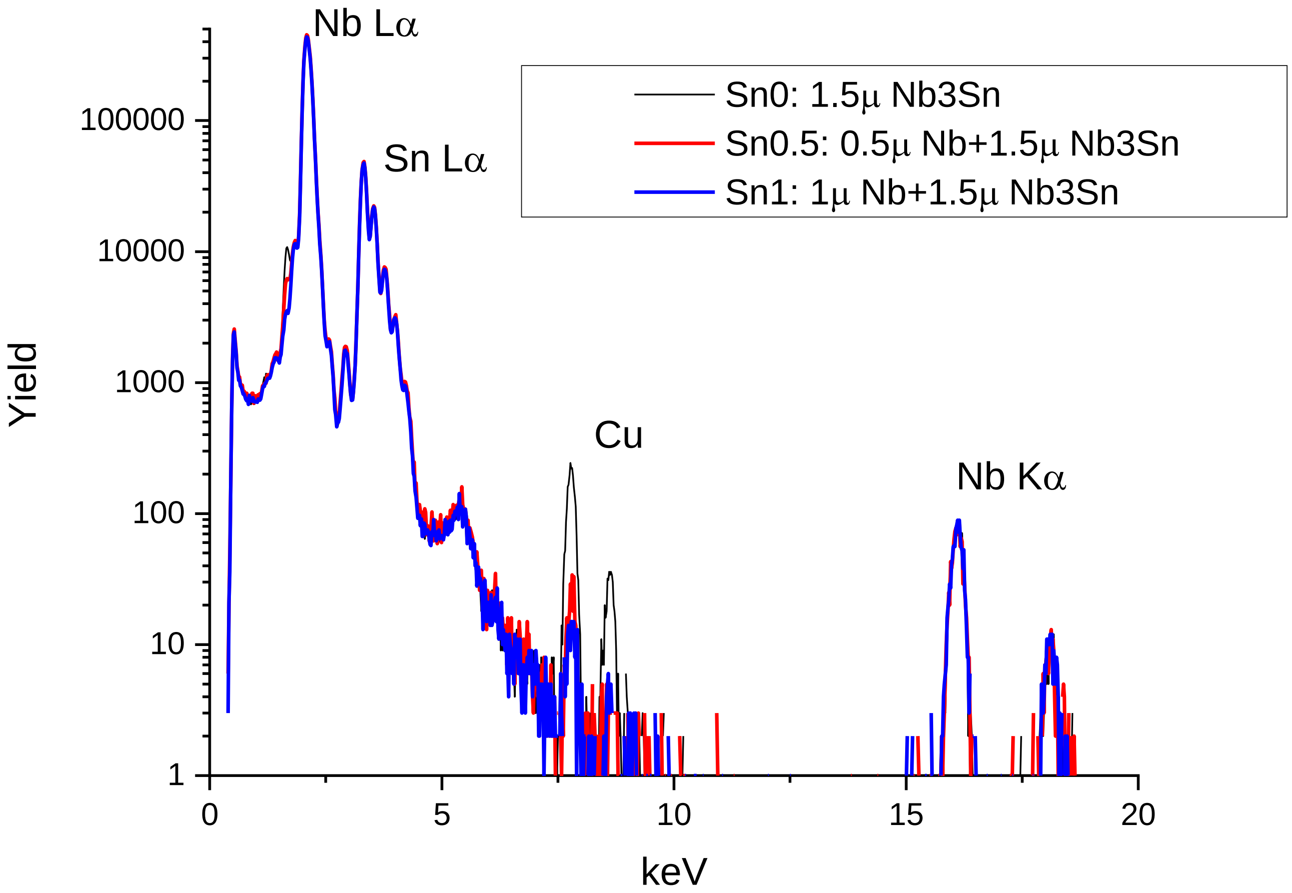


The weak Cu signal is from the substrate since the top layer is too thin The He particle excites the Cu from the substrate.

Samples From Cristia Pira, INFN

Materials characterization

RBS/PIXE: composition, trace impurities



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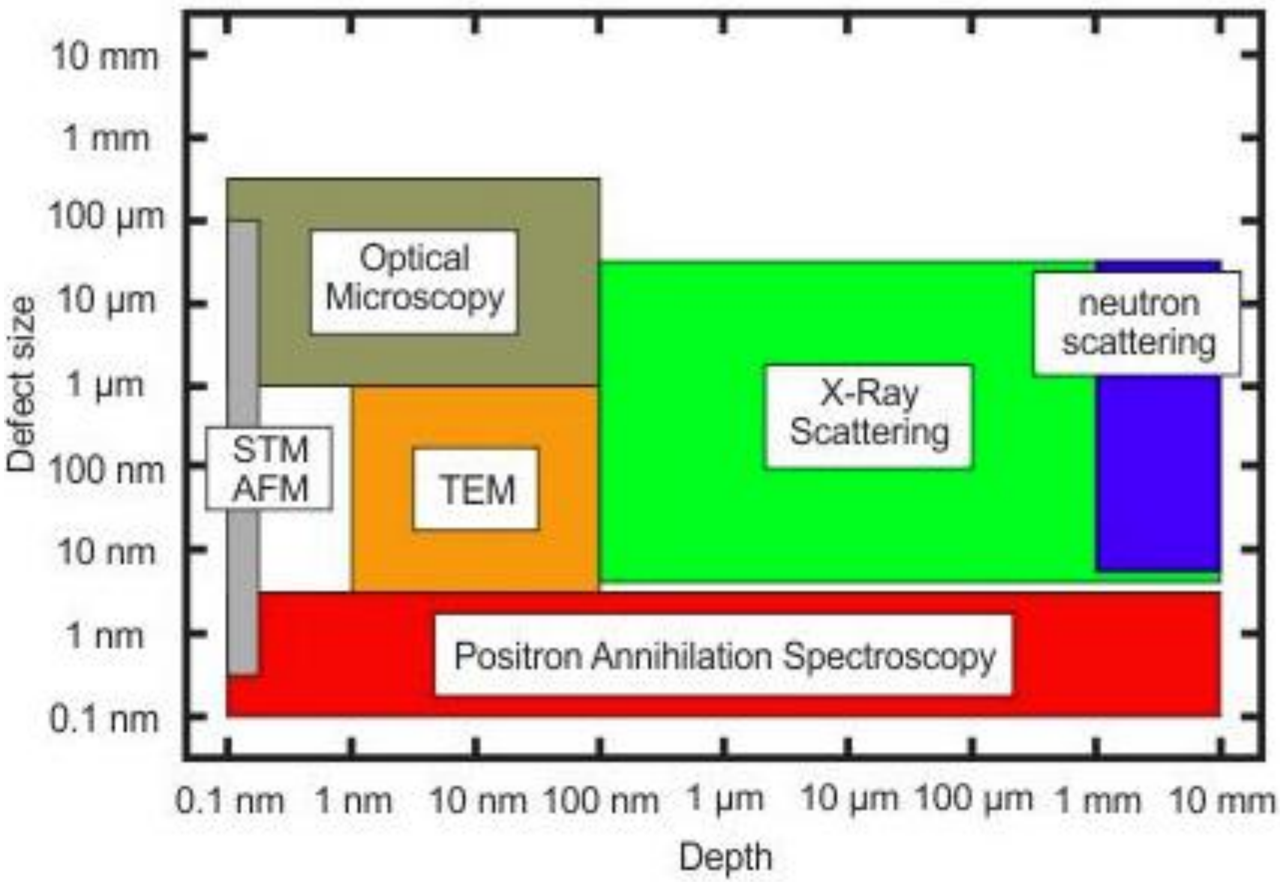
Samples From Cristian Pira, INFN

Materials characterization

Positron annihilation lifetime



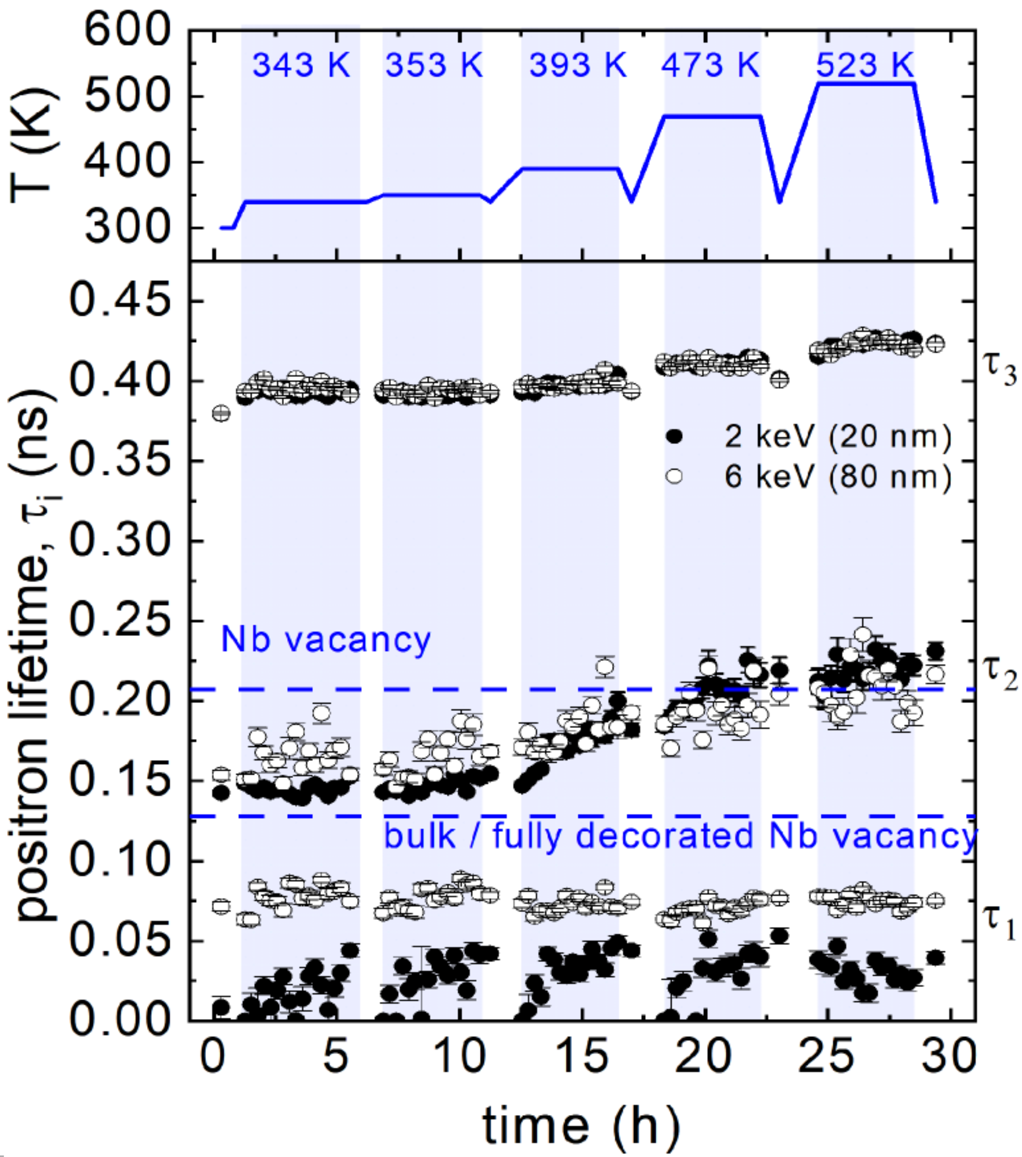
Open volume defects
Vacancy or vacancy cluster

- Single vacancy: Shorter life time

- Vacancy cluster: Longer life time

Materials characterization

Positron annihilation lifetime



Vacancy dynamics in niobium and its native oxides and their potential implications for quantum computing and superconducting accelerators
Phys. Rev. B 106, 094516 (2022)

Next step

(1) Flash lamp processing Nb3Sn and NbN, …

(2) Thin film characterization

(3) Design FLA system for cavity