Recent progress on Nb_3Sn cavities

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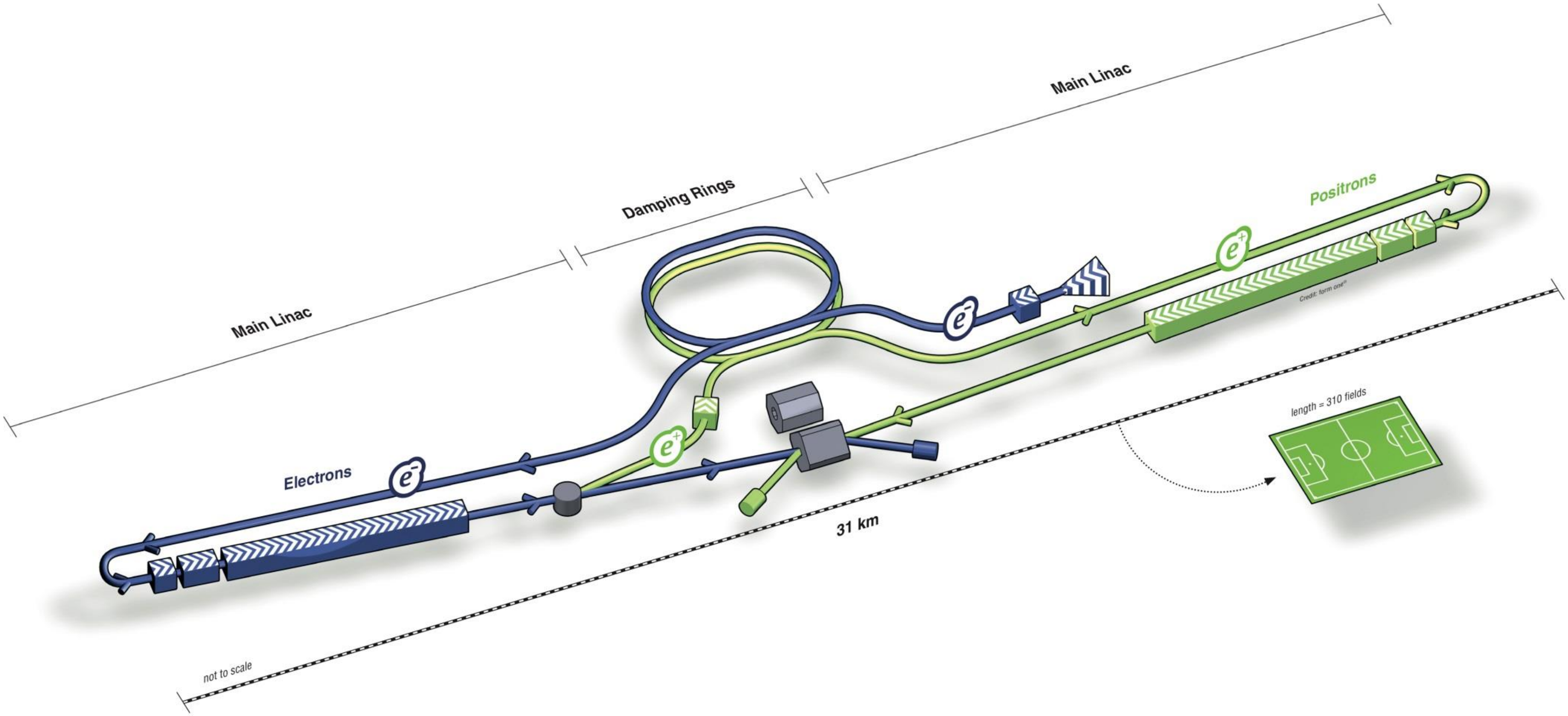
Motivation

The **ultimate gradient** achievable by accelerator cavities sets the length of colliders such as the ILC, which can be **many kilometres long**



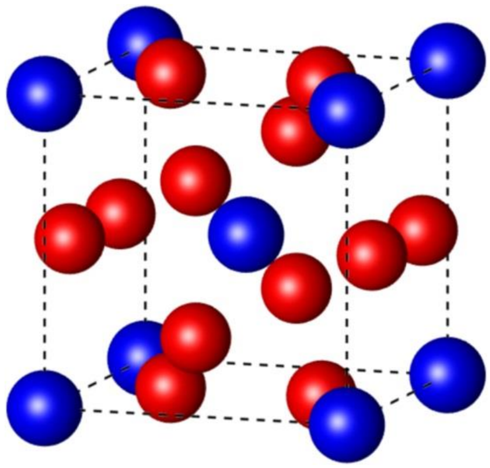
Properties of Nb_3Sn

Higher critical temperature

→ Operation at 4.2 K

Higher superheating field

→ Double the limit of niobium



Blue: tin

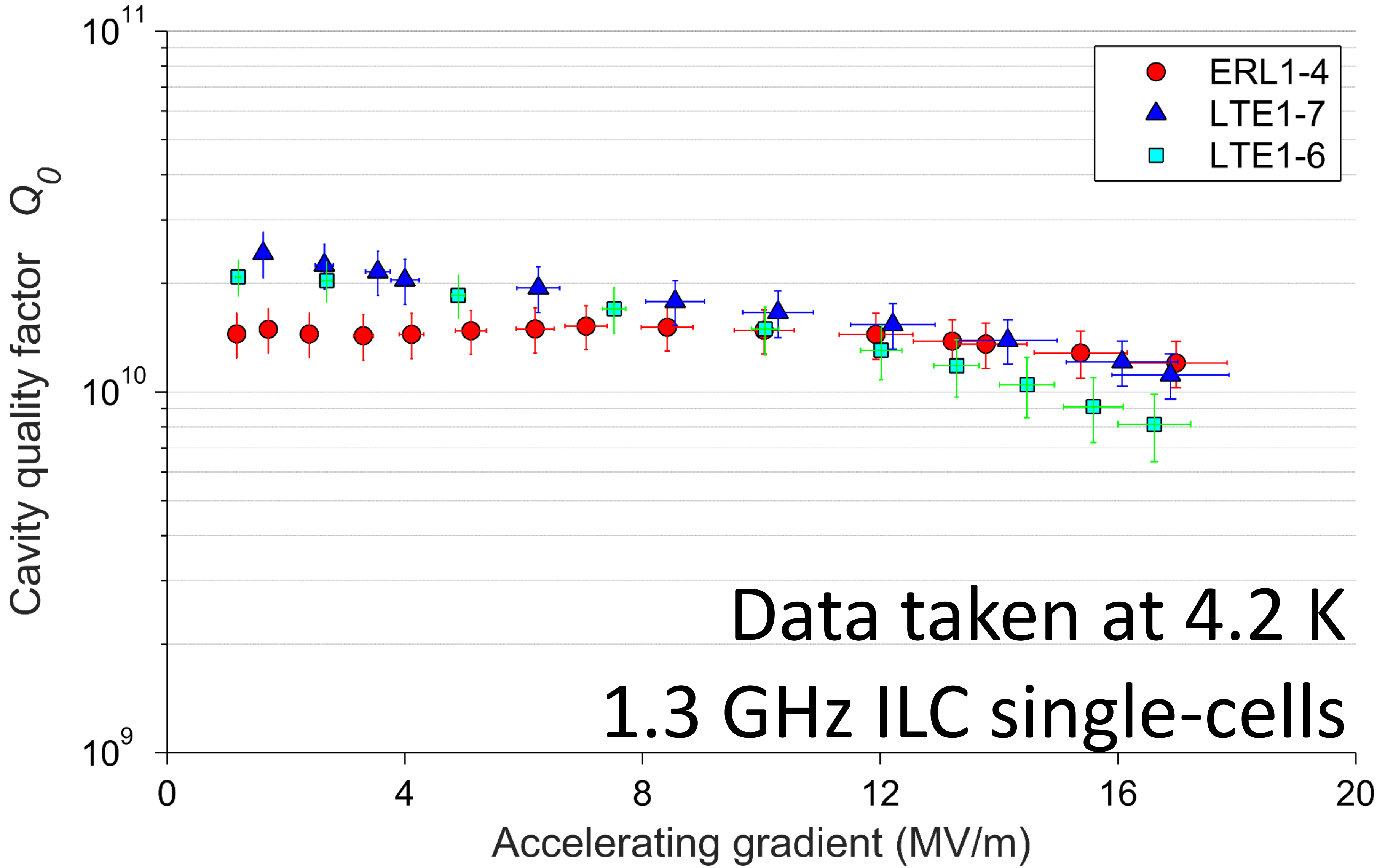
Red: niobium

Parameter	Niobium	Nb_3Sn
Transition temperature	**9.2 K**	**18 K**
Superheating field	**219 mT**	**425 mT**
Energy gap Δ/k_bT_c	1.8	2.2
λ at T = 0 K	50 nm	111 nm
ξ at T = 0 K	22 nm	4.2 nm
GL parameter κ	2.3	26

Lower losses

Higher gradients

Current performance



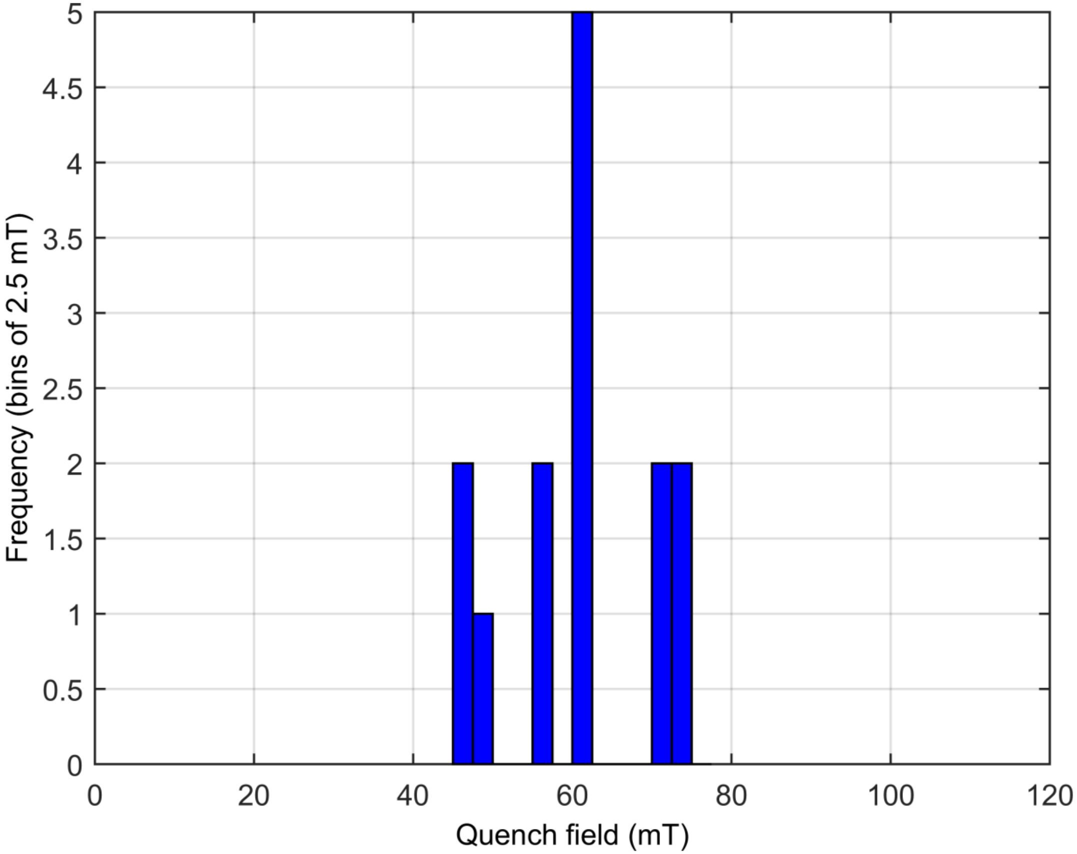
Data taken at 4.2 K

1.3 GHz ILC single-cells

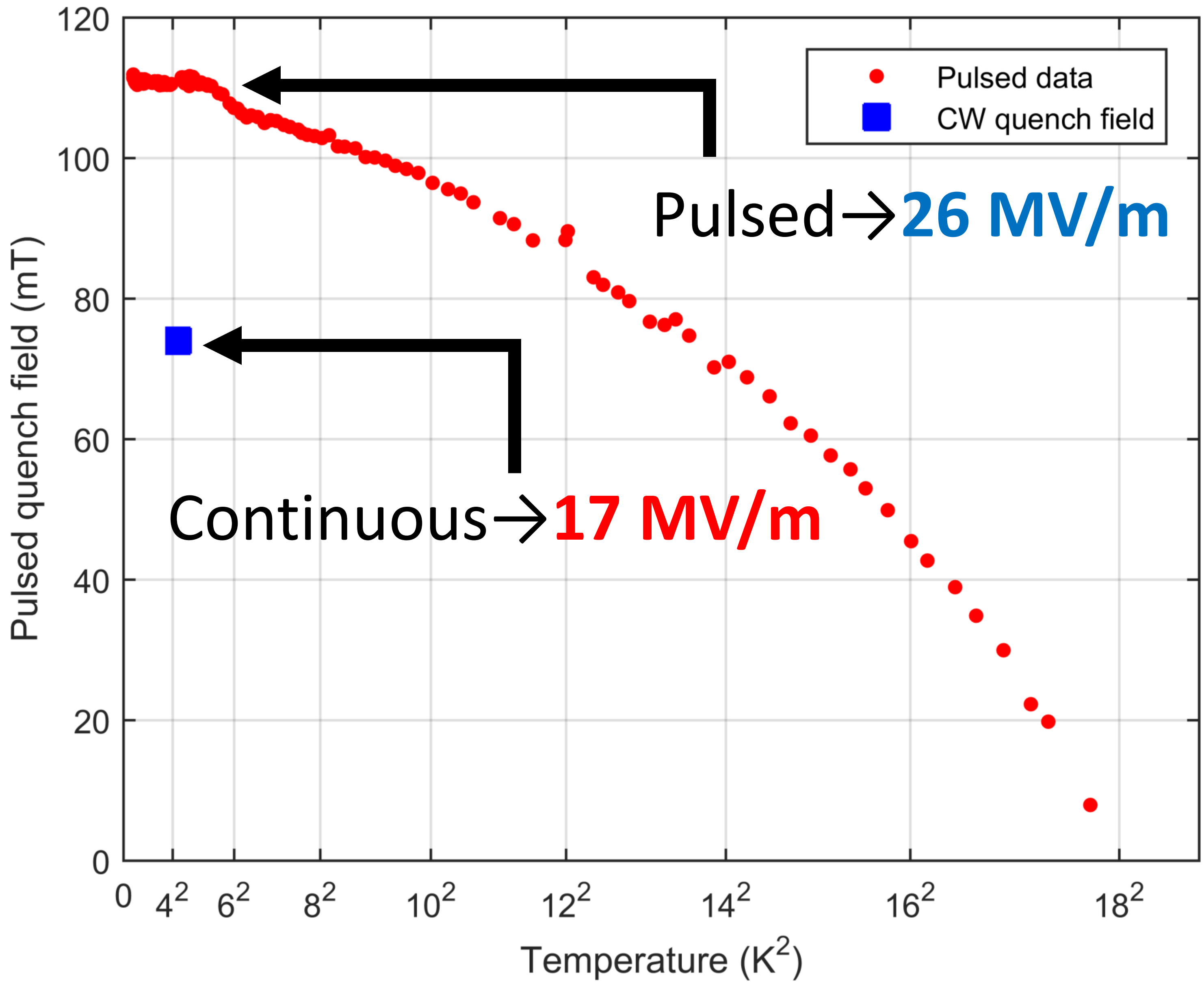
Limitations in quench field

Nb_3Sn cavities quench consistently at fields between **14 and 18 MV/m**, even in spite of changes to the coating recipe

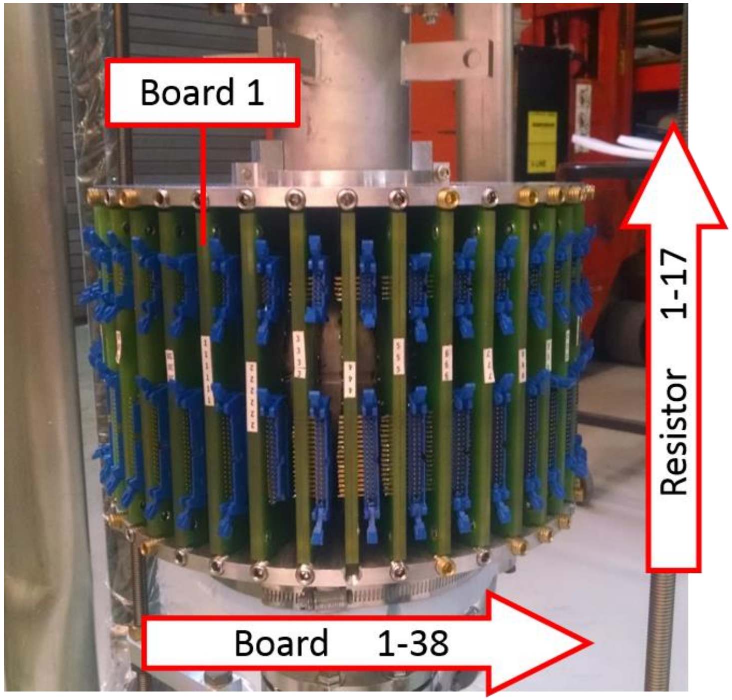
The superheating field suggests we can achieve fields up to **90 MV/m**!

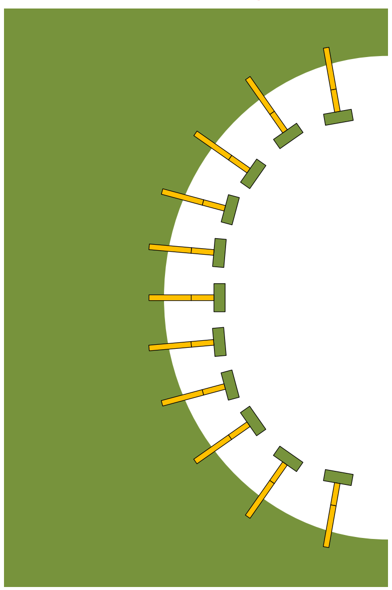


Pulsed quench field

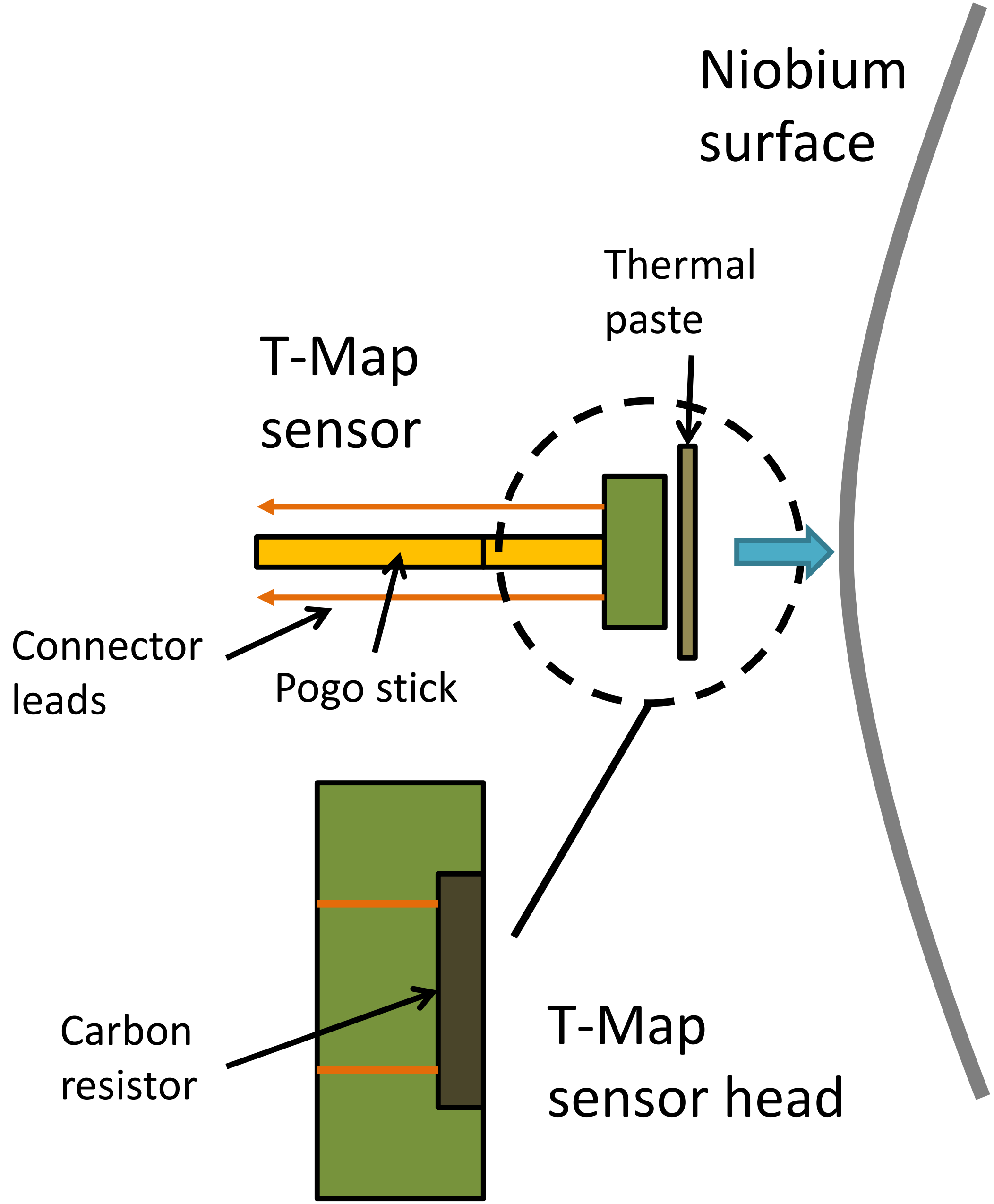


T-Map experiment



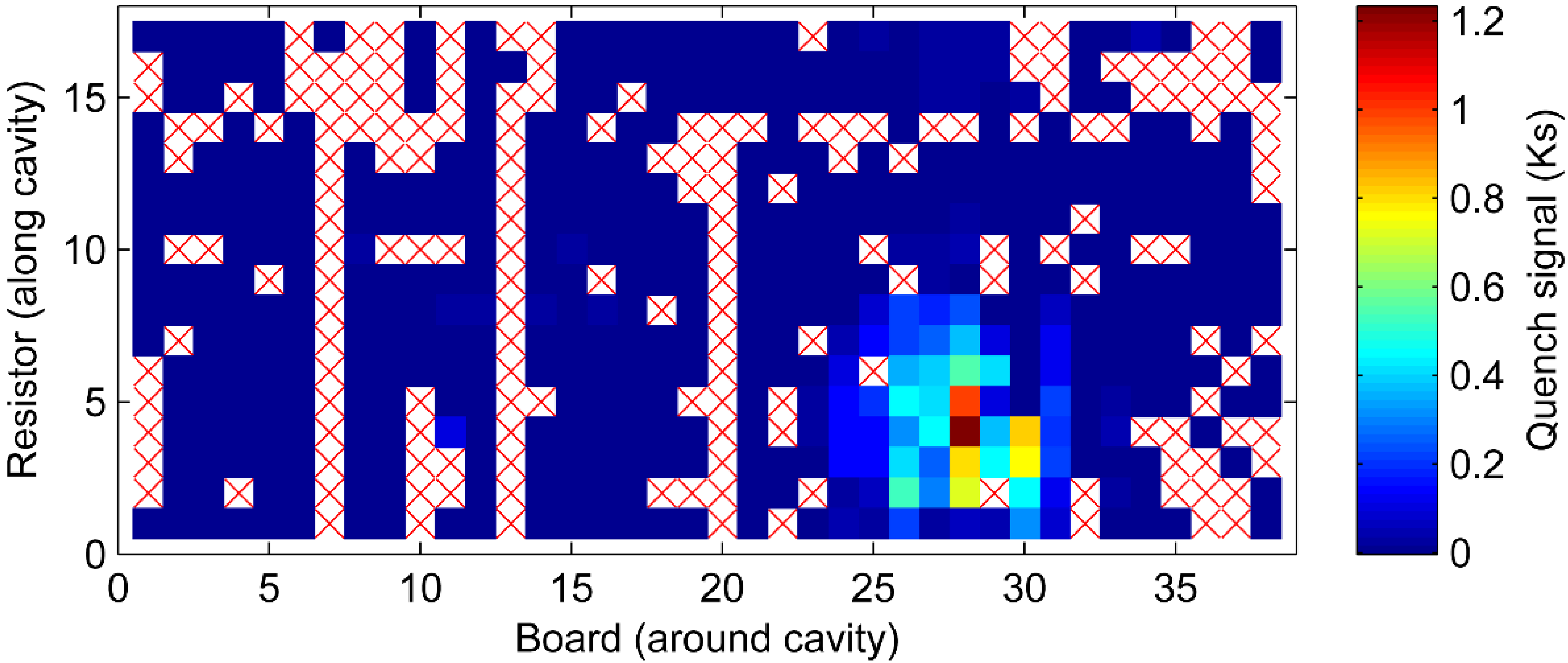


T-Map board



Localised quench

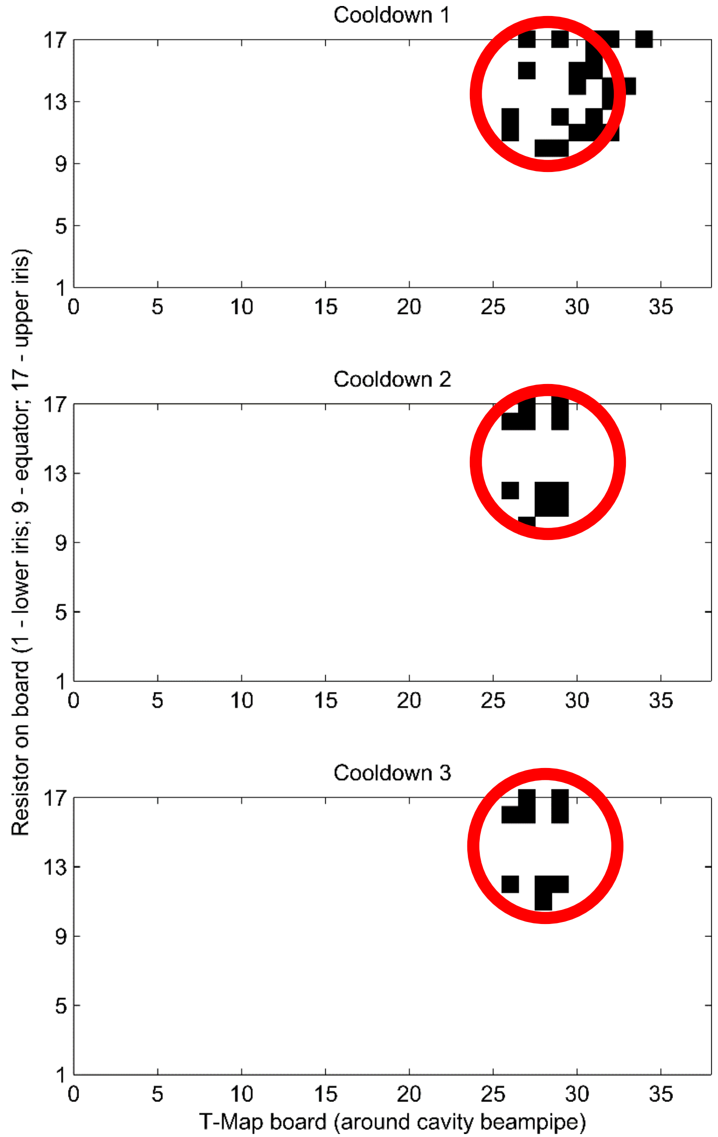
Nb_3Sn cavities are limited by a quench at a defect



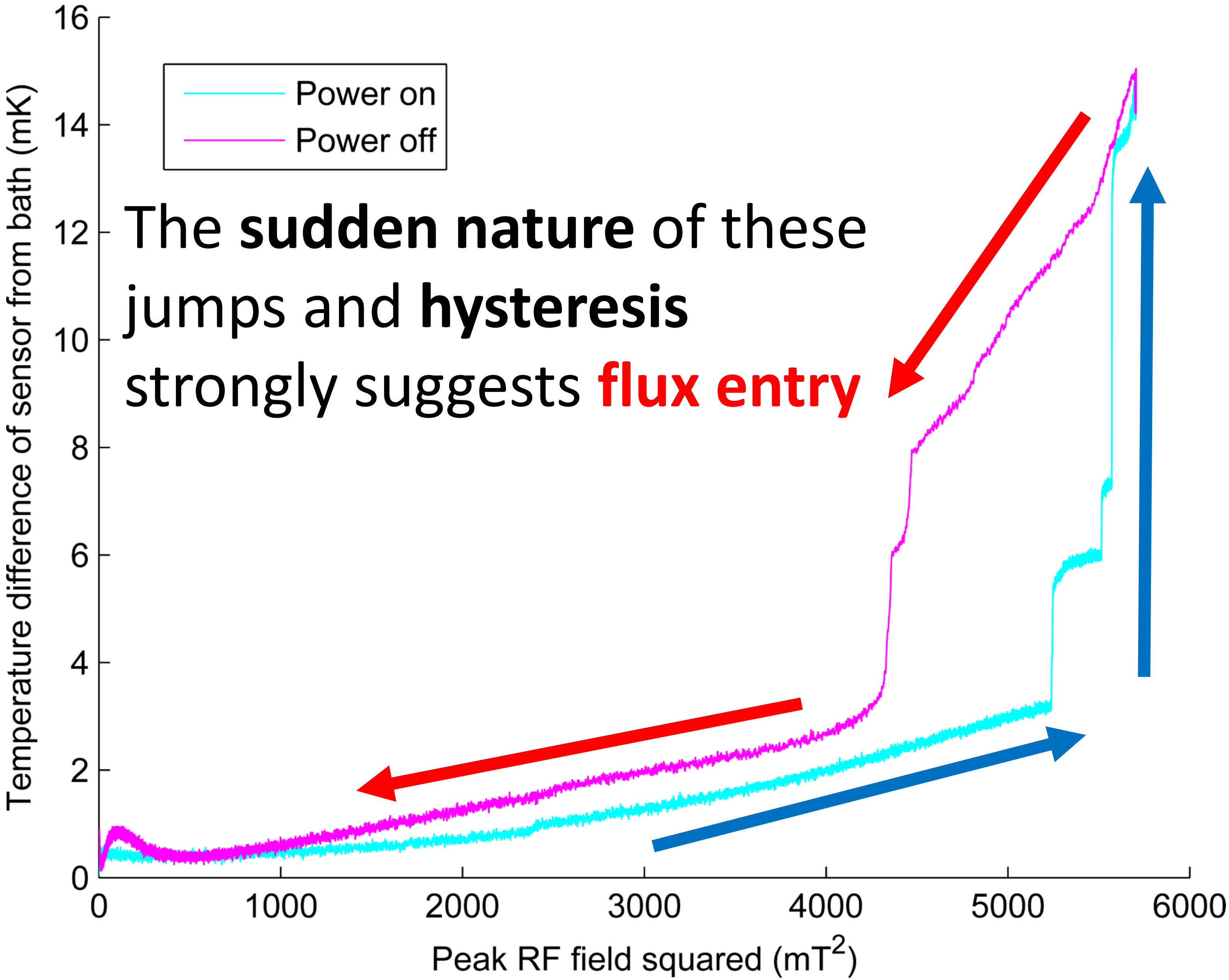
But what kind of defect, and why?

Consistent quench location

- The quench location does not change after thermal cycling through the transition temperature
- The quench location does not change after re-cleaning the cavity



Near quench behaviour



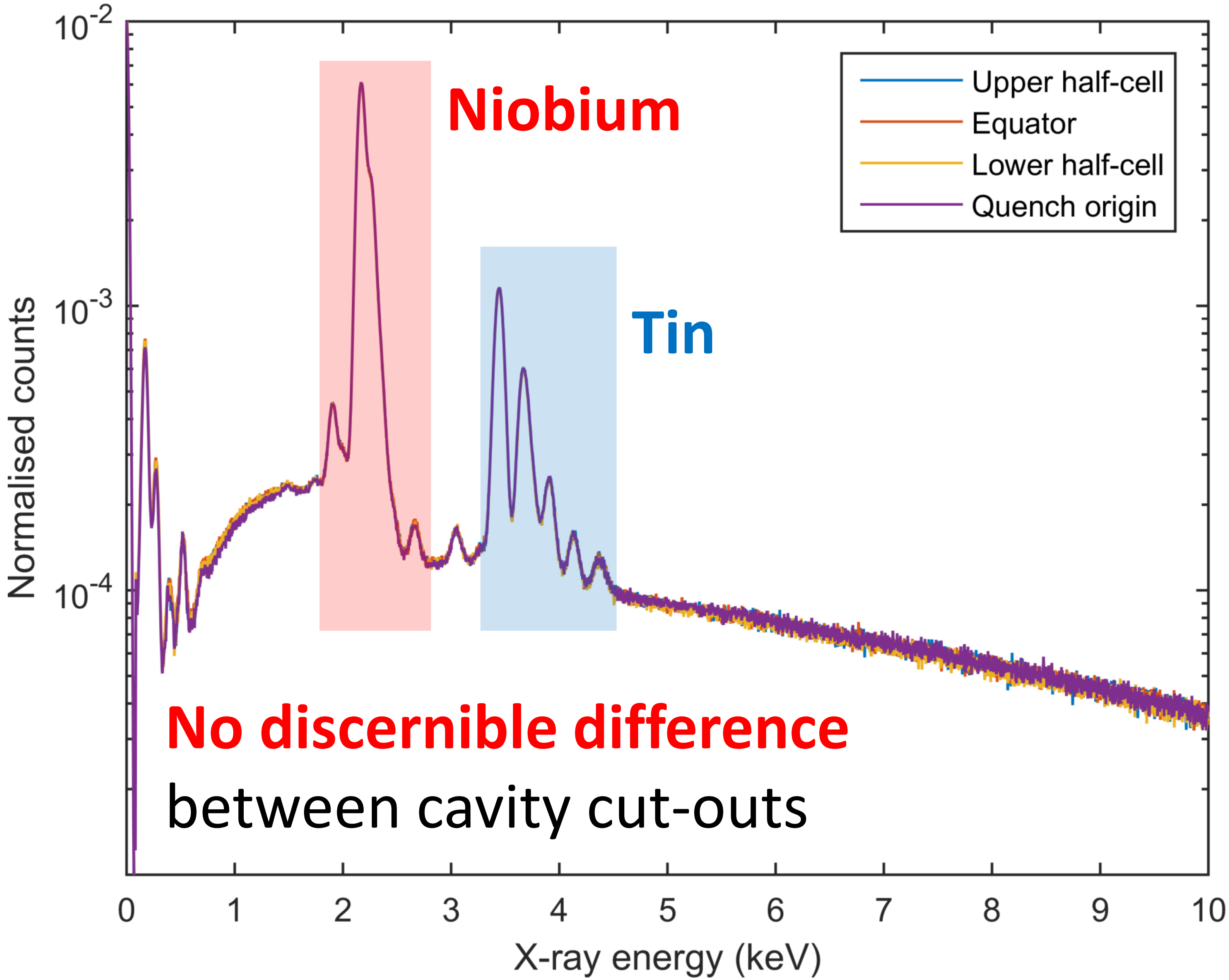
The **sudden nature** of these jumps and **hysteresis** strongly suggests **flux entry**

Cutout of the quench spot

Cut-out of the quench region on milling machine

Also cut: samples from other areas of cavity

General cavity chemistry

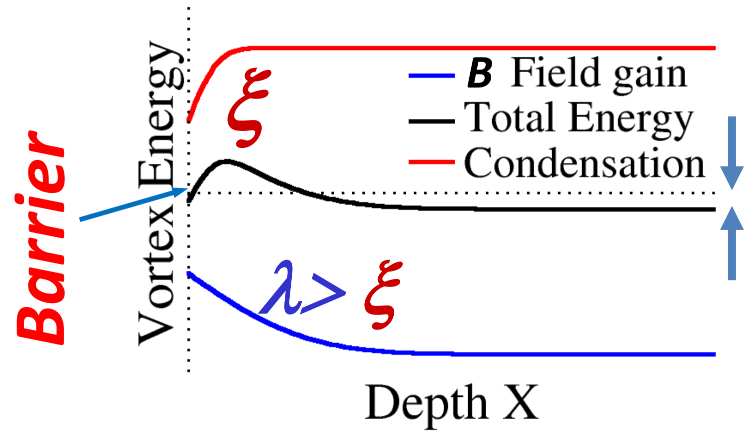


Quench by flux entry

Superconductors expel magnetic flux, but at fields above $\mathbf{H_{c1}}$ flux can enter and quench the superconductor

However – an **energy barrier** prevents this

At $\mathbf{H_{sh}}$, this barrier **disappears** and flux enters; **game over**

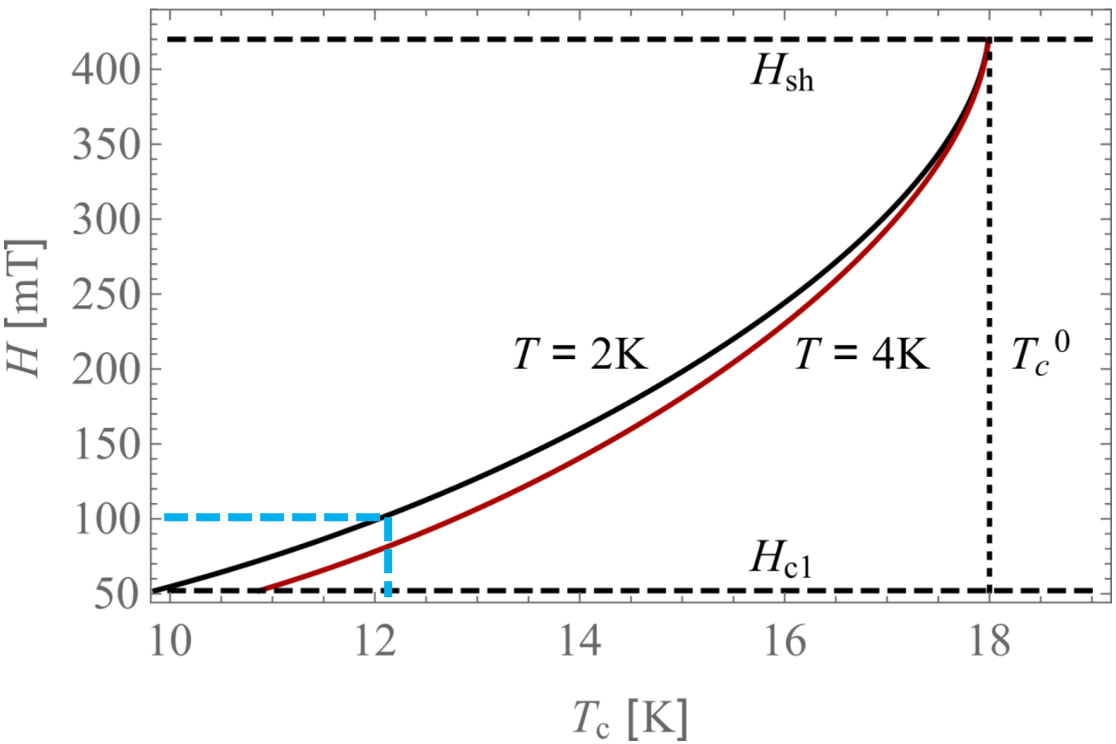


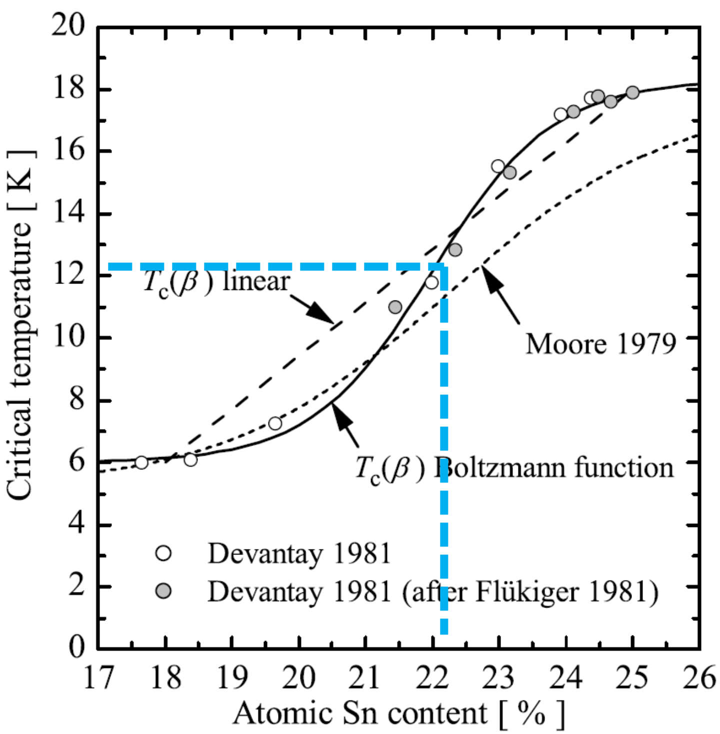
Costly core ξ enters first; gain from field λ later

For flux to enter, the local H_{sh} **must be suppressed**

T_c suppression

A tin depletion of only **3%** reduces H_{sh} by **75%**

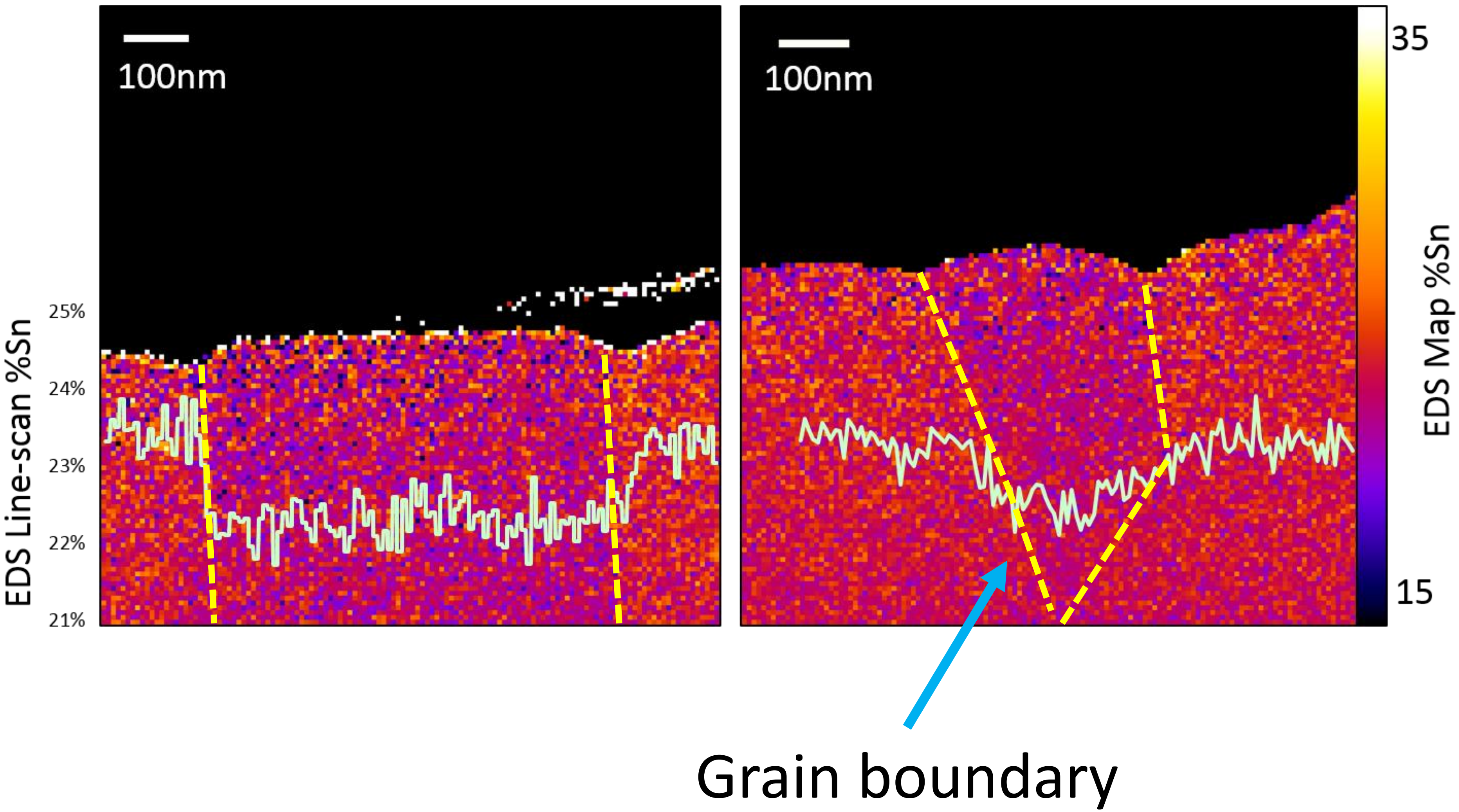




Flux entry could occur at tin-depleted surface defects

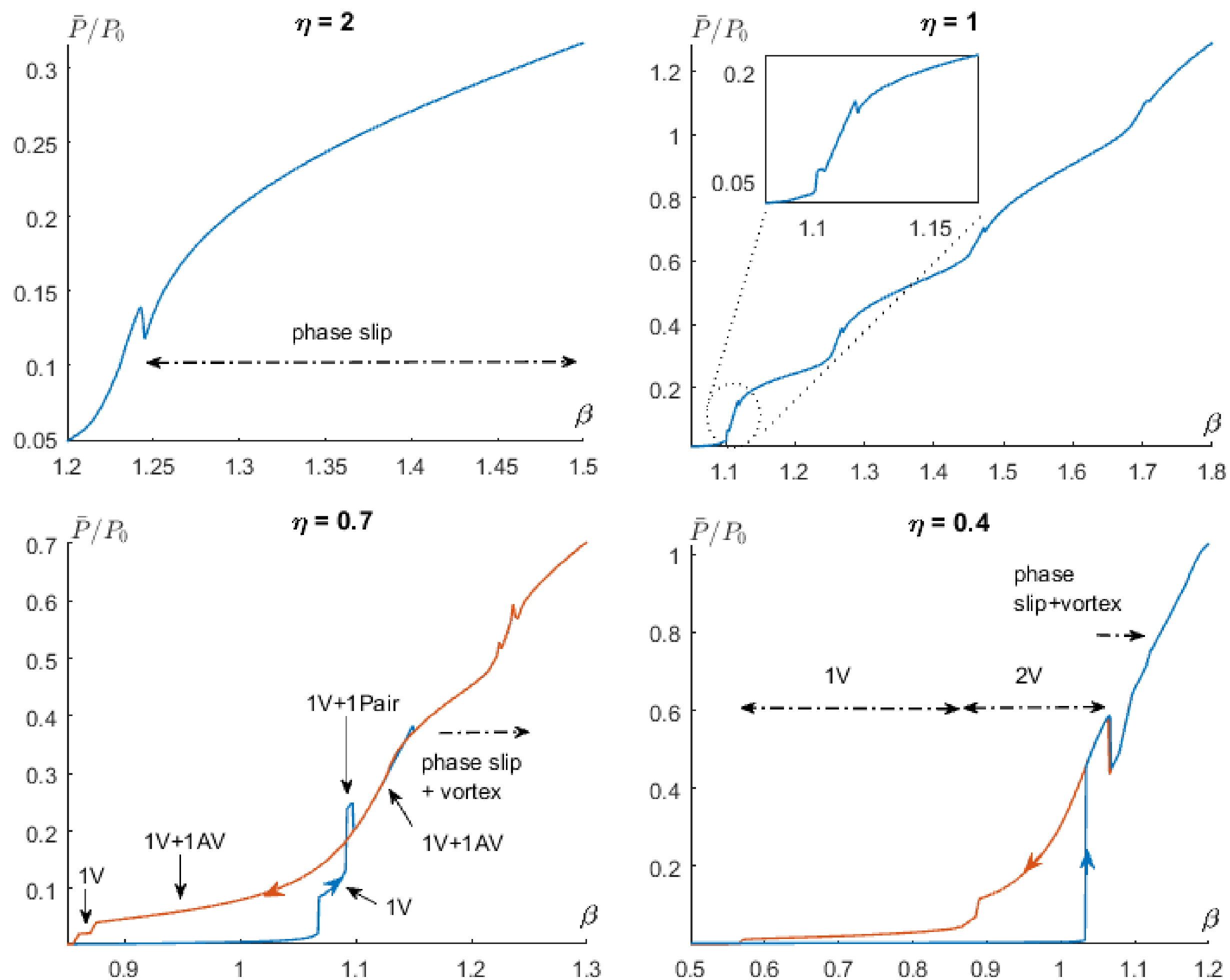
Tin-depletion in grains

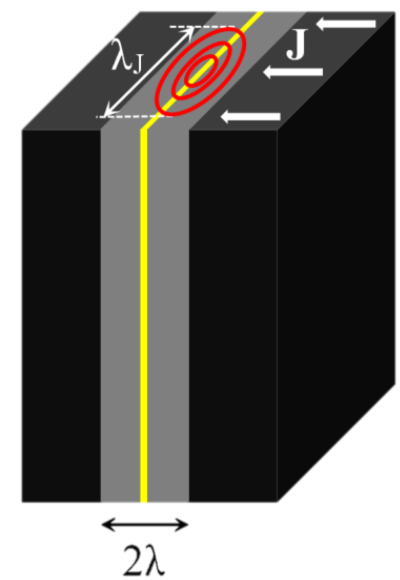
Cross-section of the Nb_3Sn RF surface



Flux entry at grain boundaries

Grain boundaries acting as vortex entry points



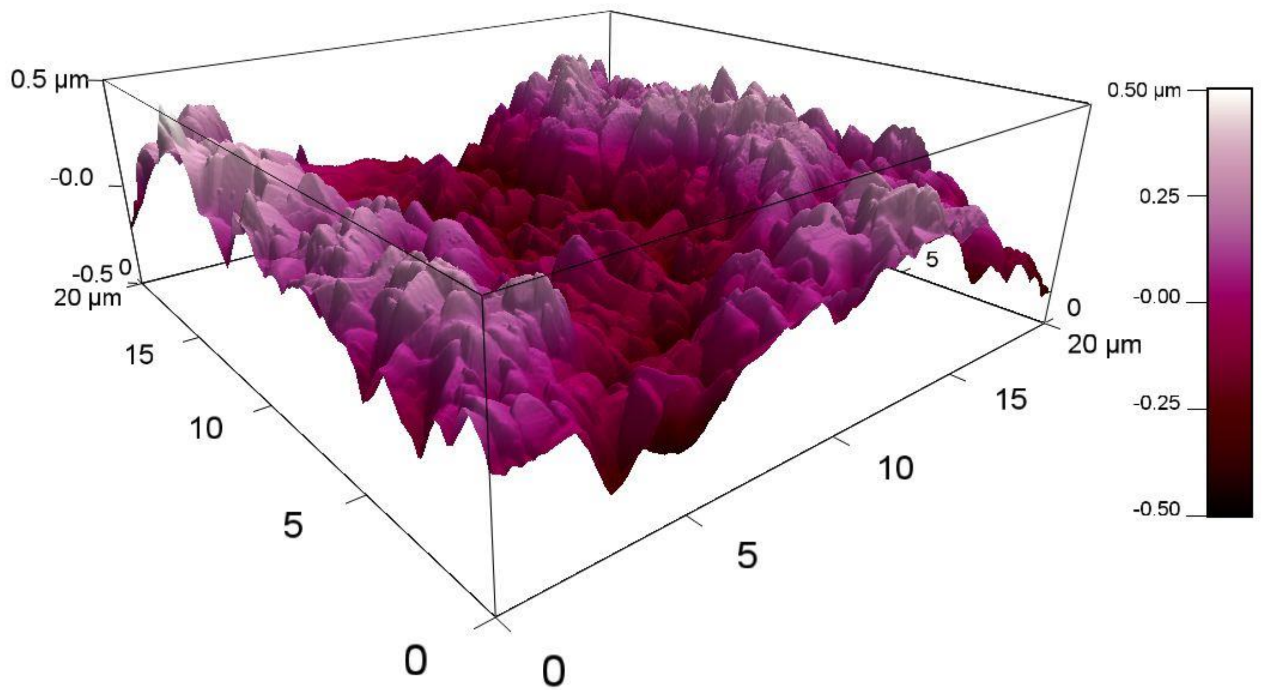


A. Sheikhzada, A. Gurevich, arXiv:1703.02843

Field enhancement

Why do we not quench globally?

The answer is likely **field enhancement** – regions of sharp topography where the **local magnetic field is enhanced**



Sharp features at niobium grains

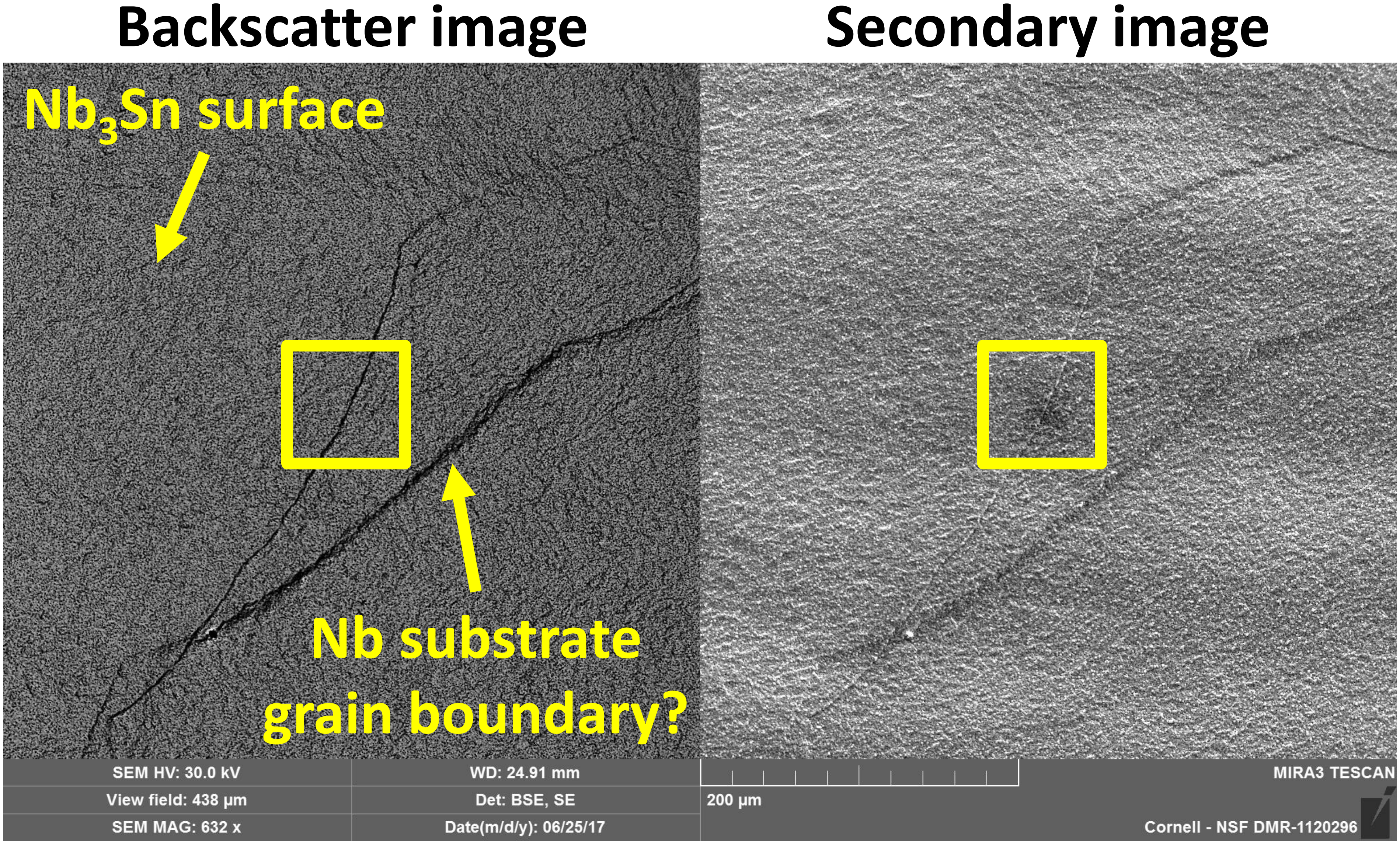


Image taken near quench origin

Sharp features at niobium grains

Backscatter image | **Secondary image**

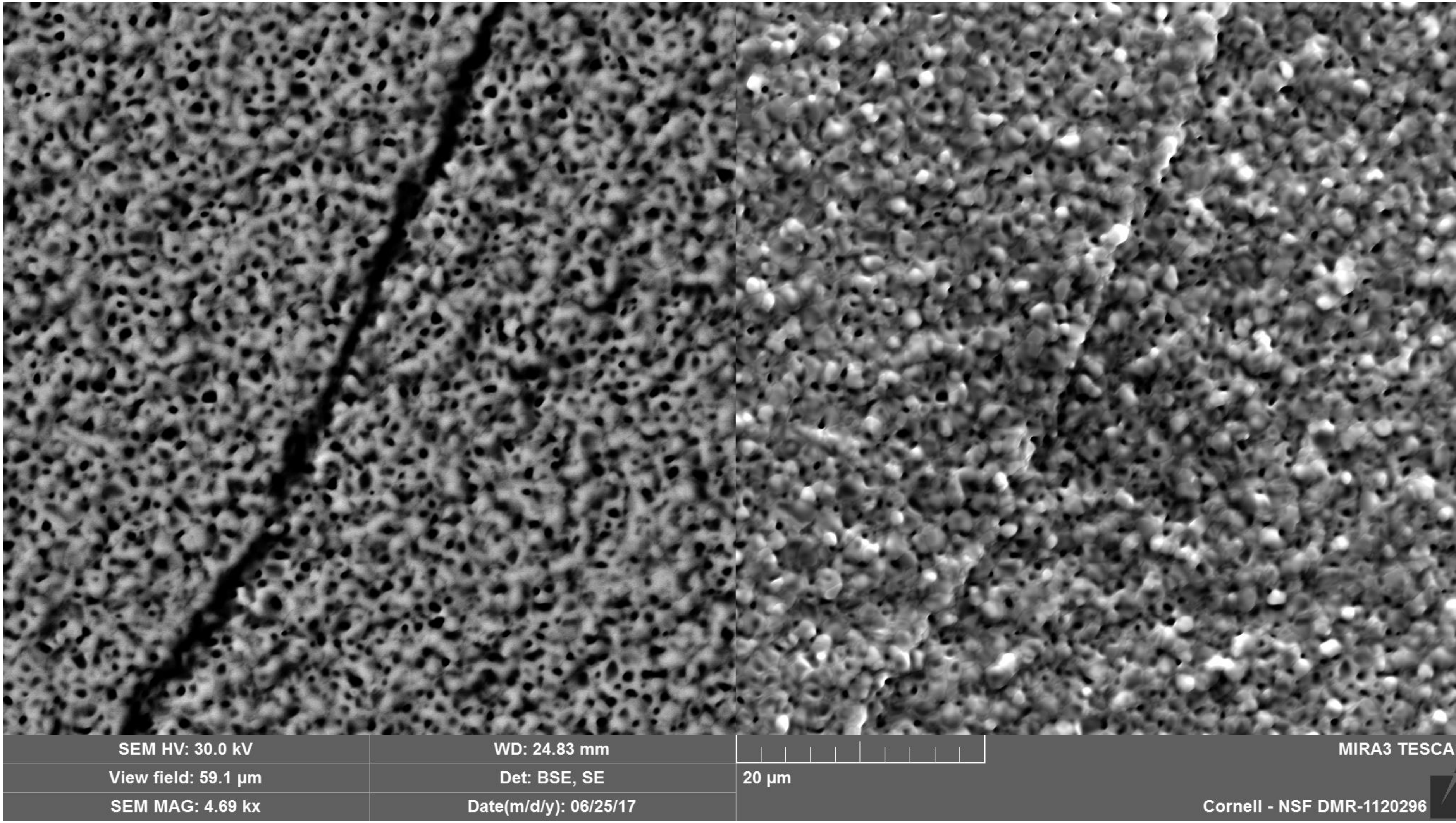


Image taken near quench origin

Sharp features at niobium grains

Secondary image **Backscatter image**

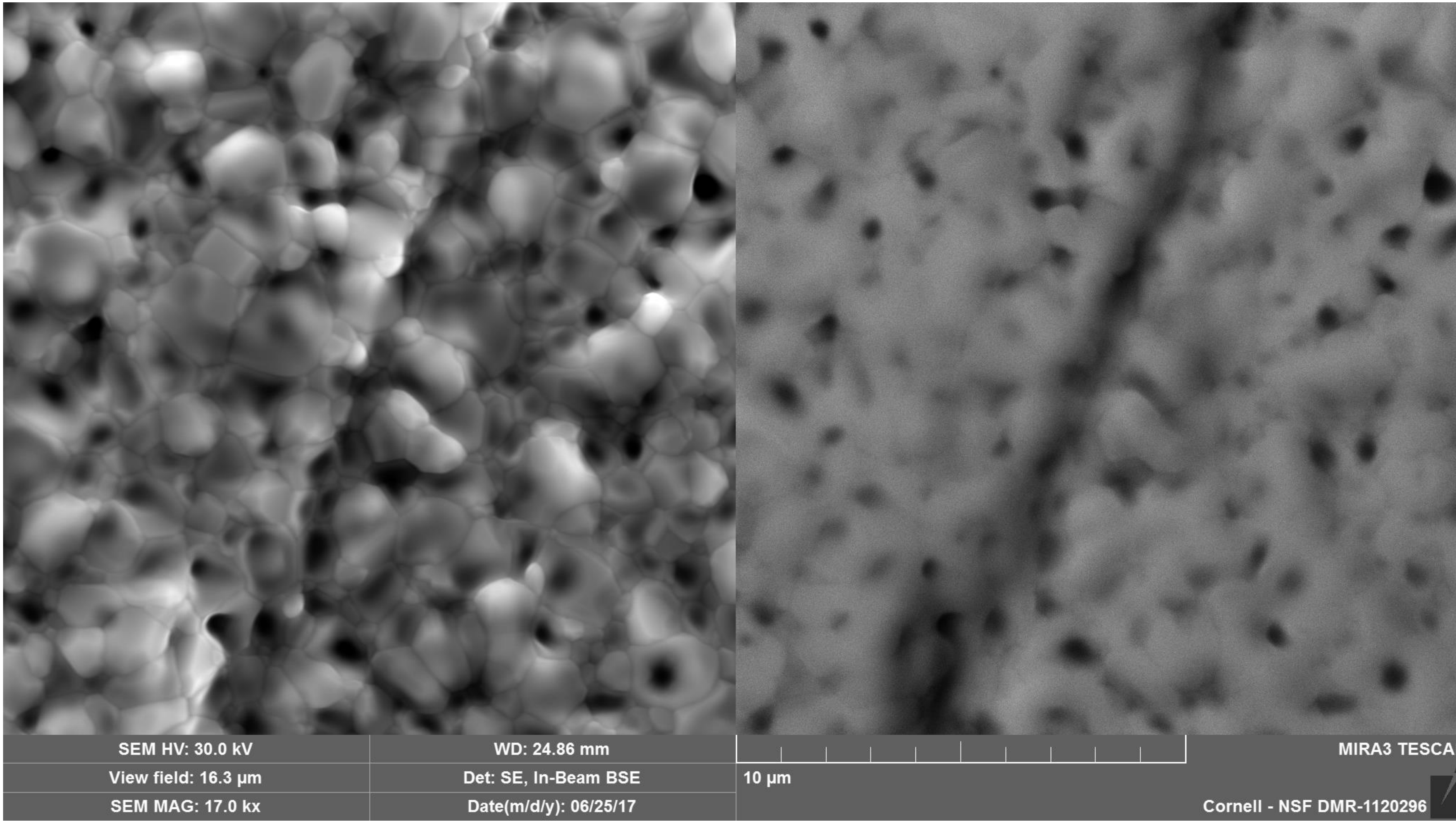


Image taken near quench origin

Conclusions

- The near-quench behaviour of the cavity strongly suggests **magnetic flux entry at a defect**

- Candidates for quench defects are **tin-depleted surface grains** supressing H_{sh} and **grain boundaries** acting as Josephson junctions

- **Sharp features** exacerbate problem by enhancing the local magnetic field

Acknowledgements

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