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Nature of Quality Factor Degradation in SRF Cavities due to Quench

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Introduction

- Q_0 degradation due to quench in bulk niobium cavities attributed to trapped magnetic flux[1].

- Where does this flux come from?
  - Thermocurrents at the quench spot[1]
  - Trapped RF field
  - Ambient field[2]

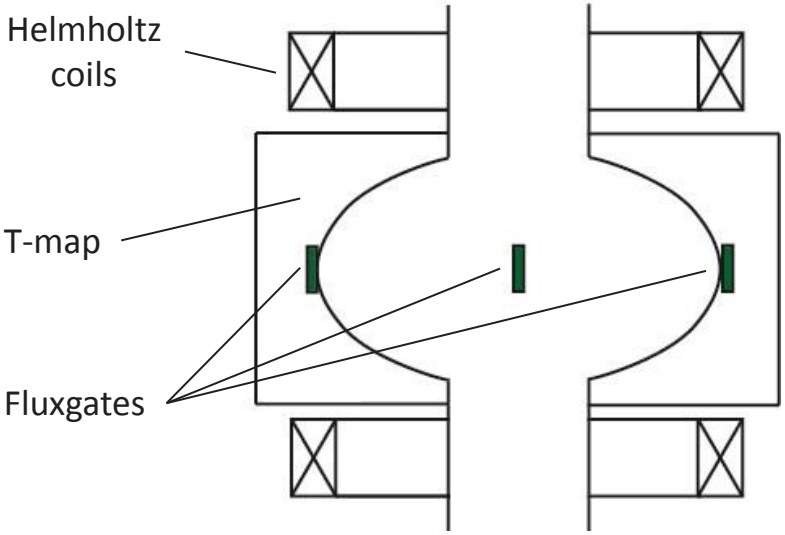
- We have proved that the Q_0 quench-related degradation mechanism is due only to the trapping of ambient magnetic field.

[1] J. Knobloch, H. Padamsee, *Proceedings of the 8th Workshop on RF Superconductivity*, Abano Terme, Italy (1997)
[2] I.M. Terechkine *et al.*, *Proceedings of 13th International Conference on RF Superconductivity*, Paris, France (2013)

Experimental Set-up & Procedure

Set-up:

- Helmholtz coils
- 4 Fluxgates magnetometers
- T-map system



Procedure:

1. Q_0 vs E_{acc} before any quench
2. Cavity quench with RF field
   i. Different values of external magnetic field
   ii. Field compensation till H < 1 mOe
3. Q_0 and T-map measured after the quench

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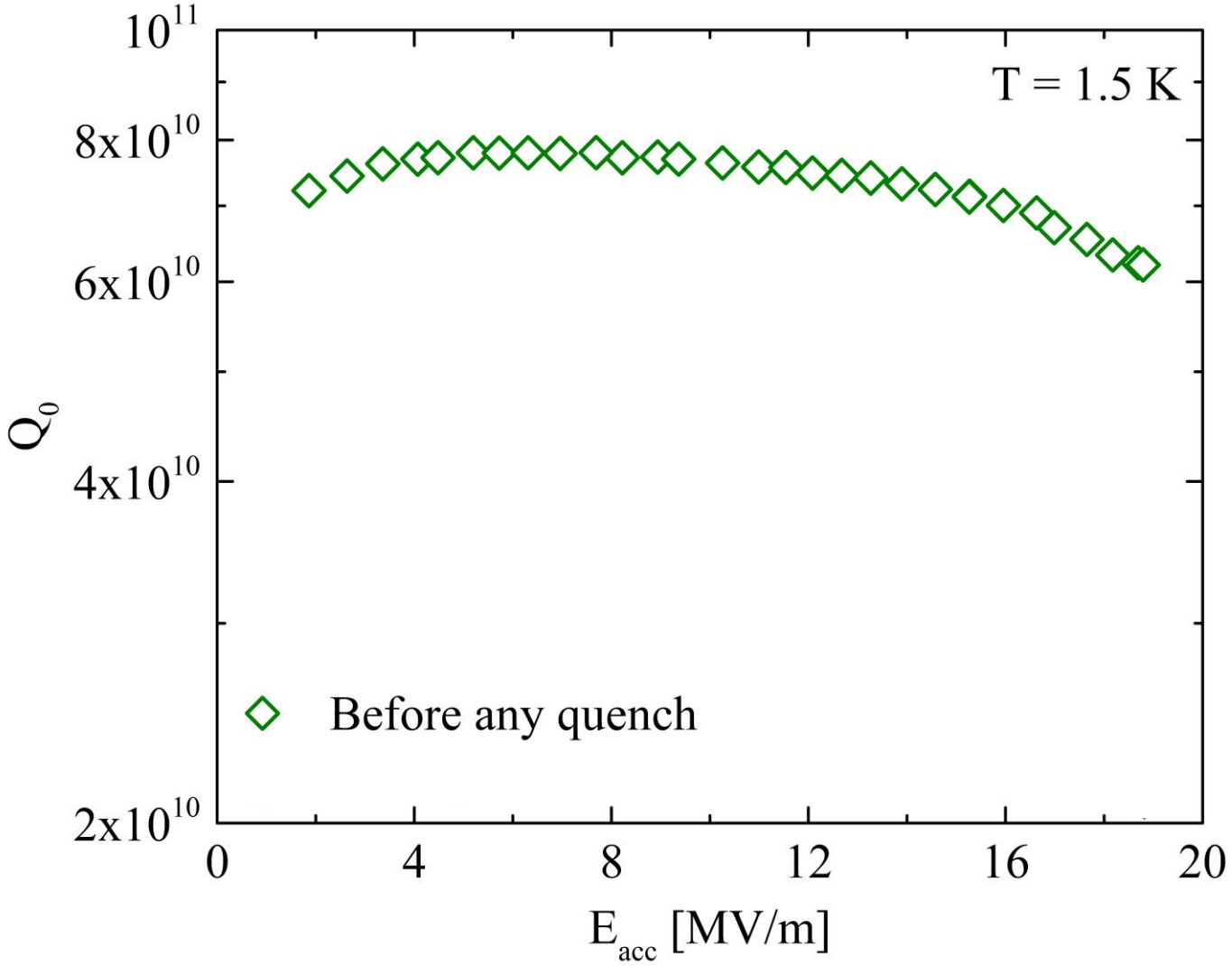
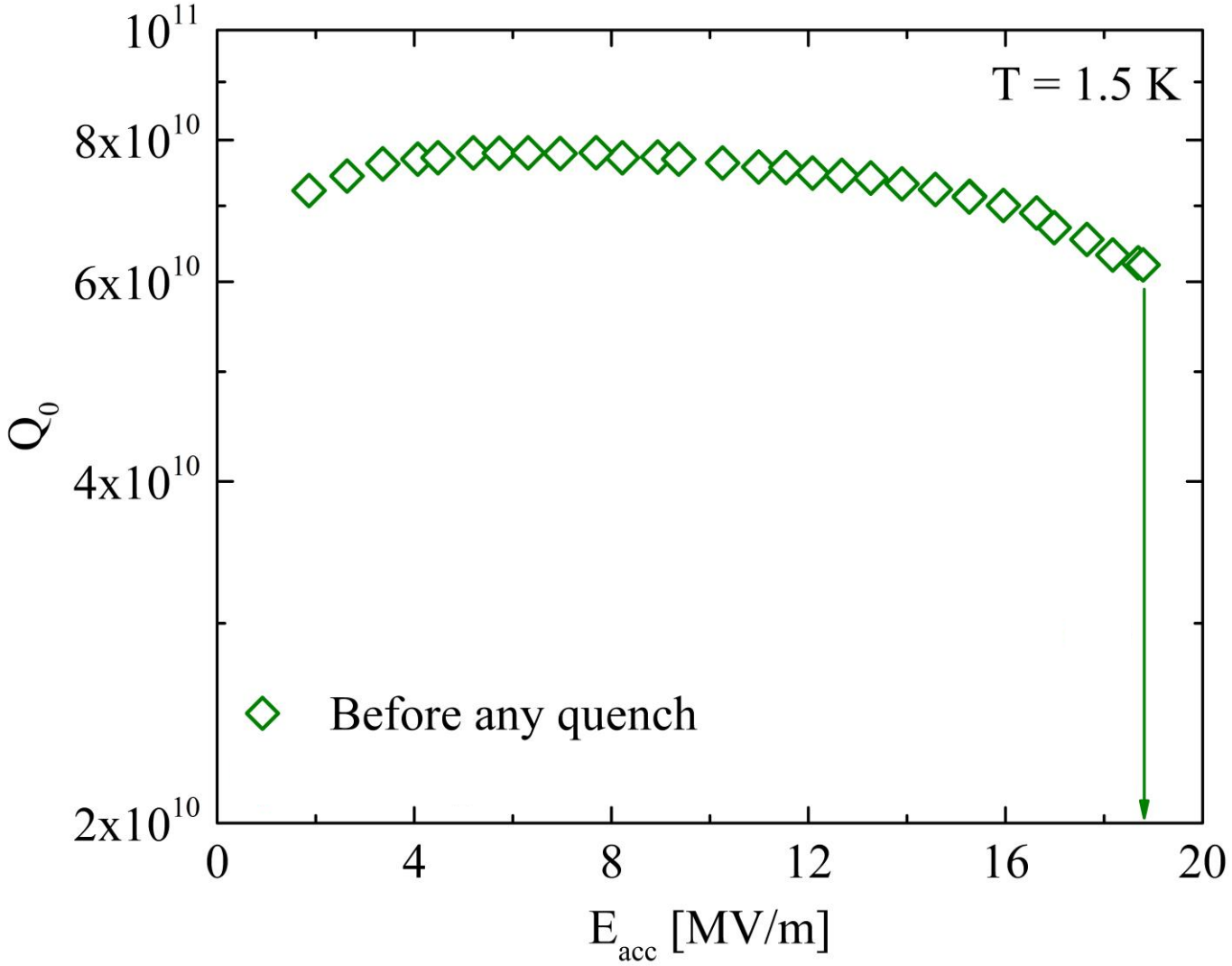
Q_0 recovery and origin of trapped magnetic flux

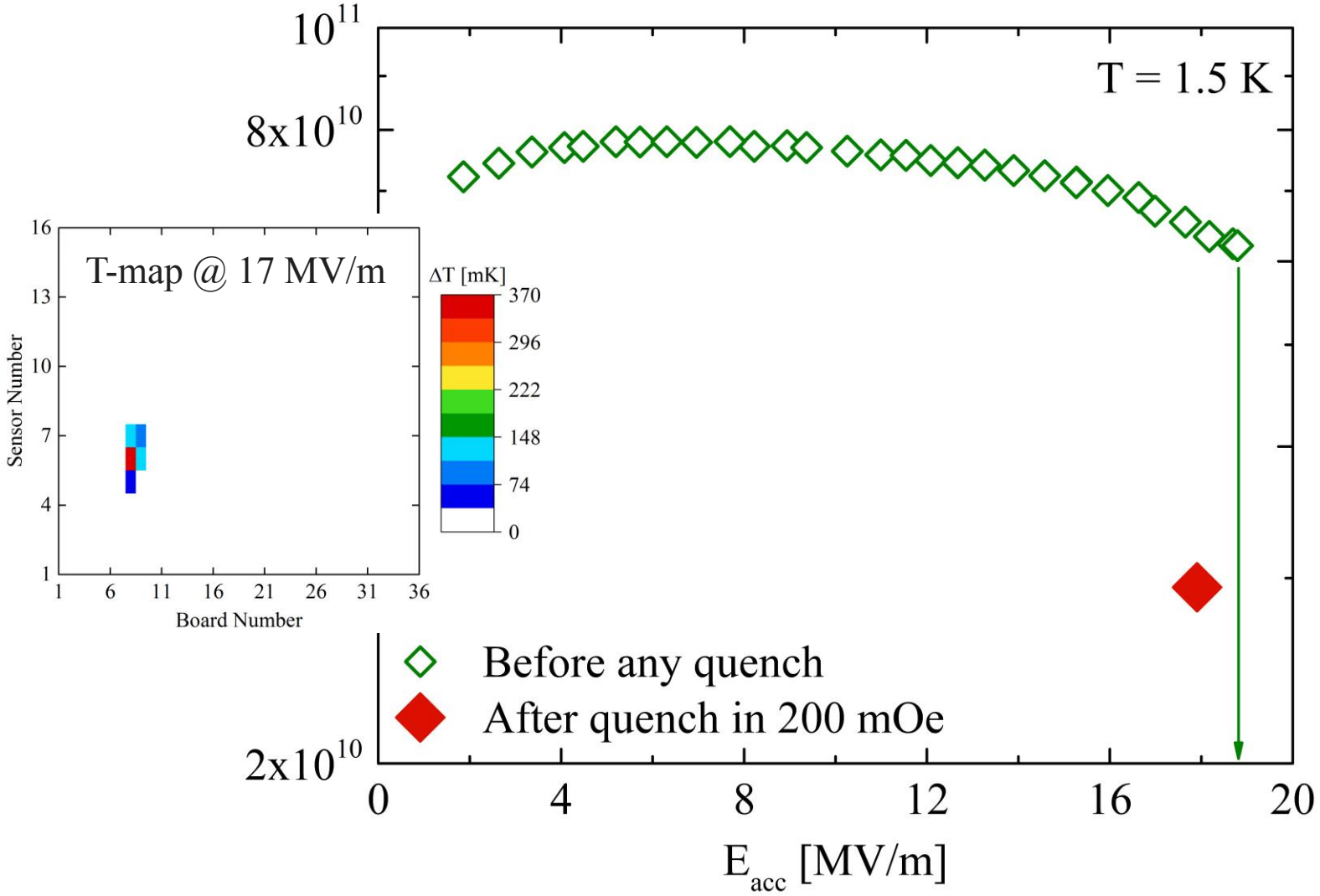
Q_0 vs E_{acc} before any quench



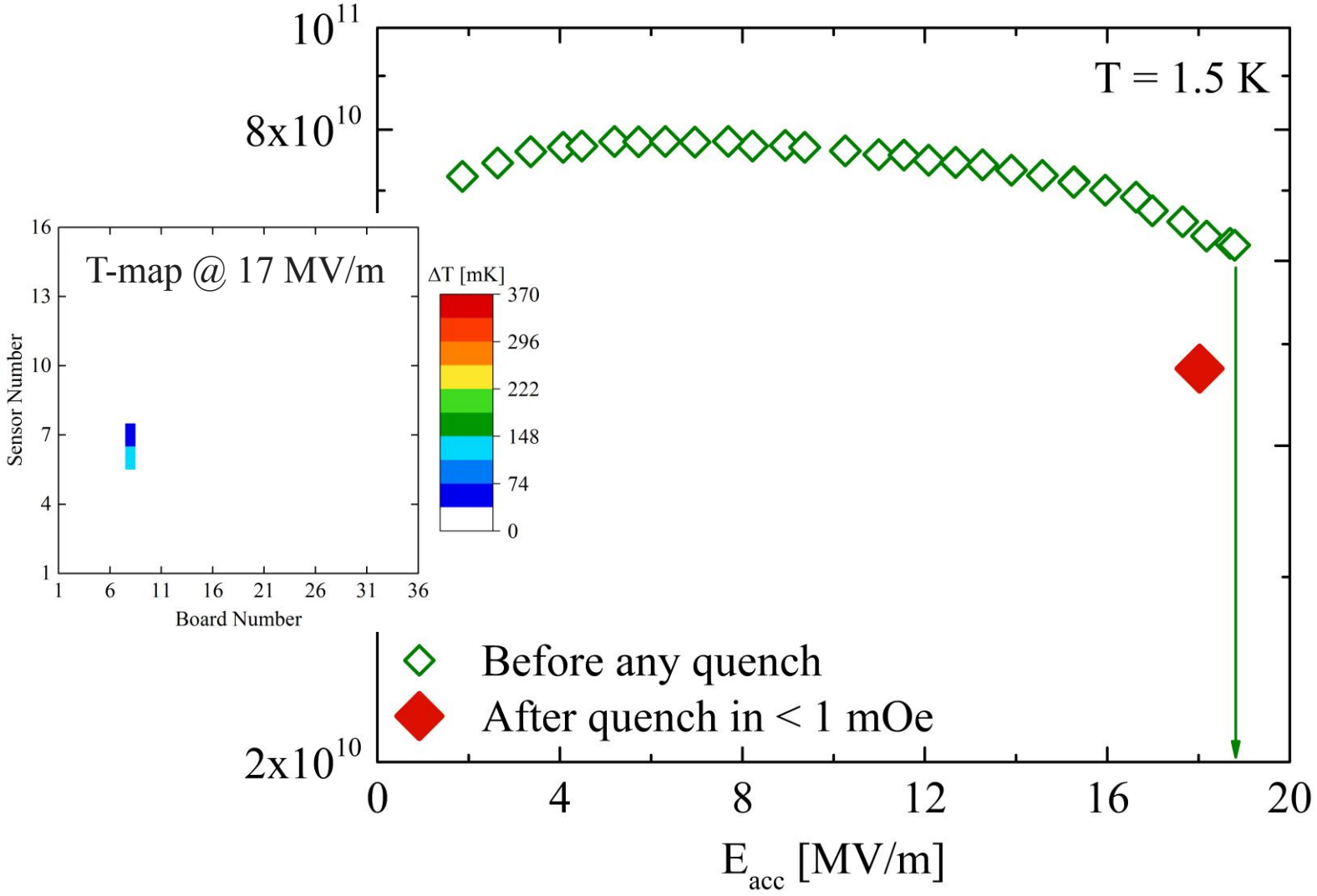
Cavity quench with RF field



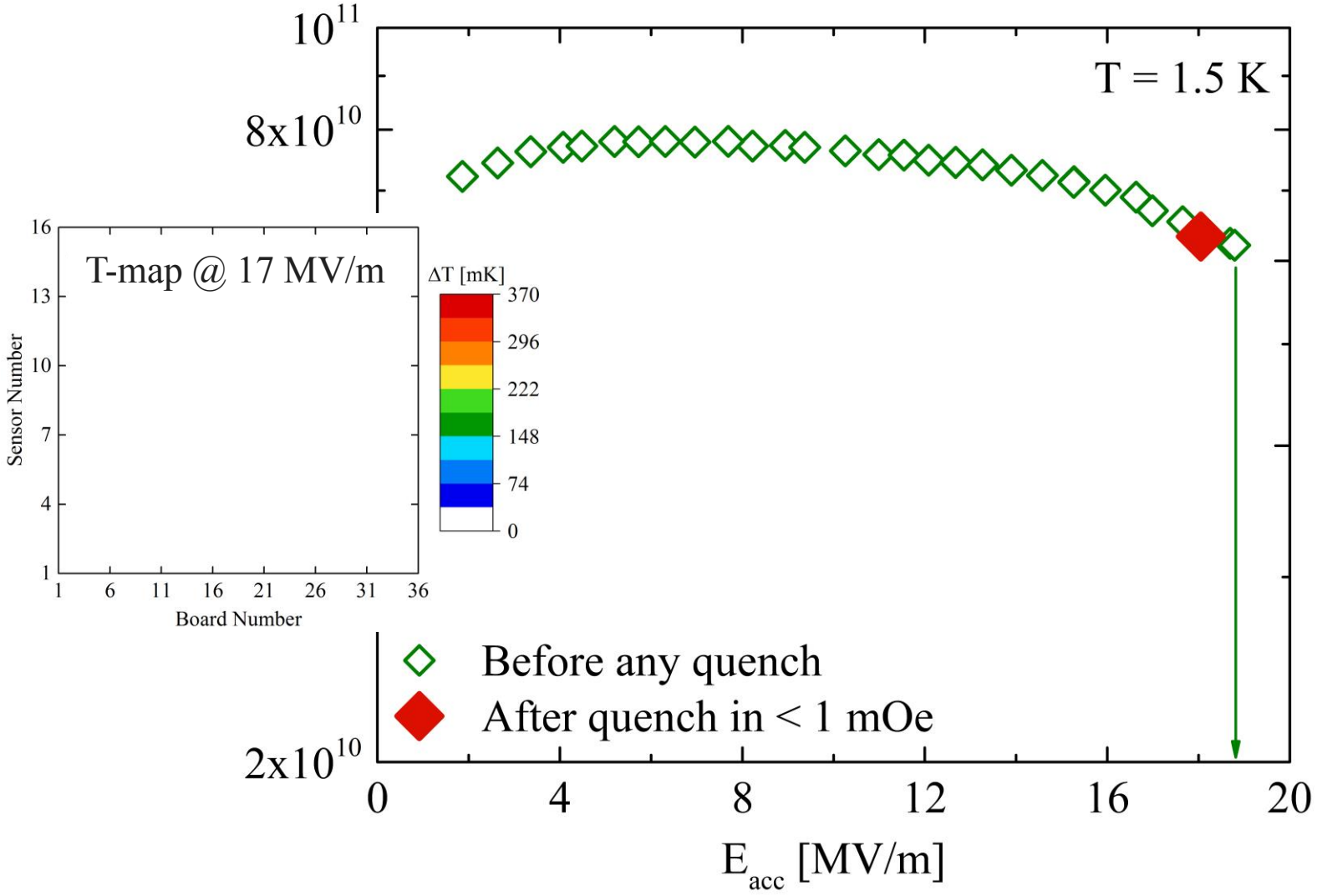
Quench in 200 mOe



Quench in < 1 mOe



Quench in < 1 mOe



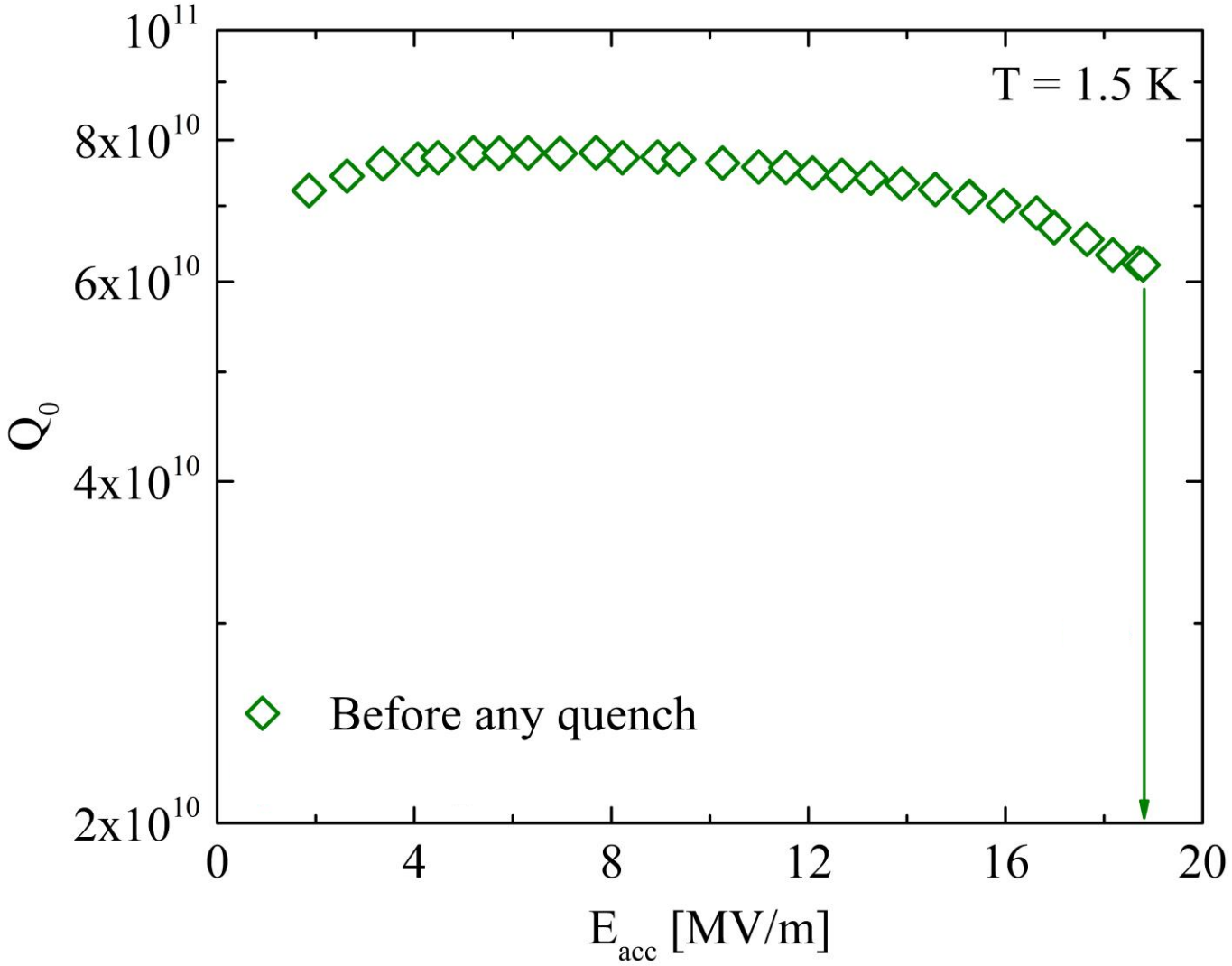
Complete recovery

Complete Q_0 Recovery!

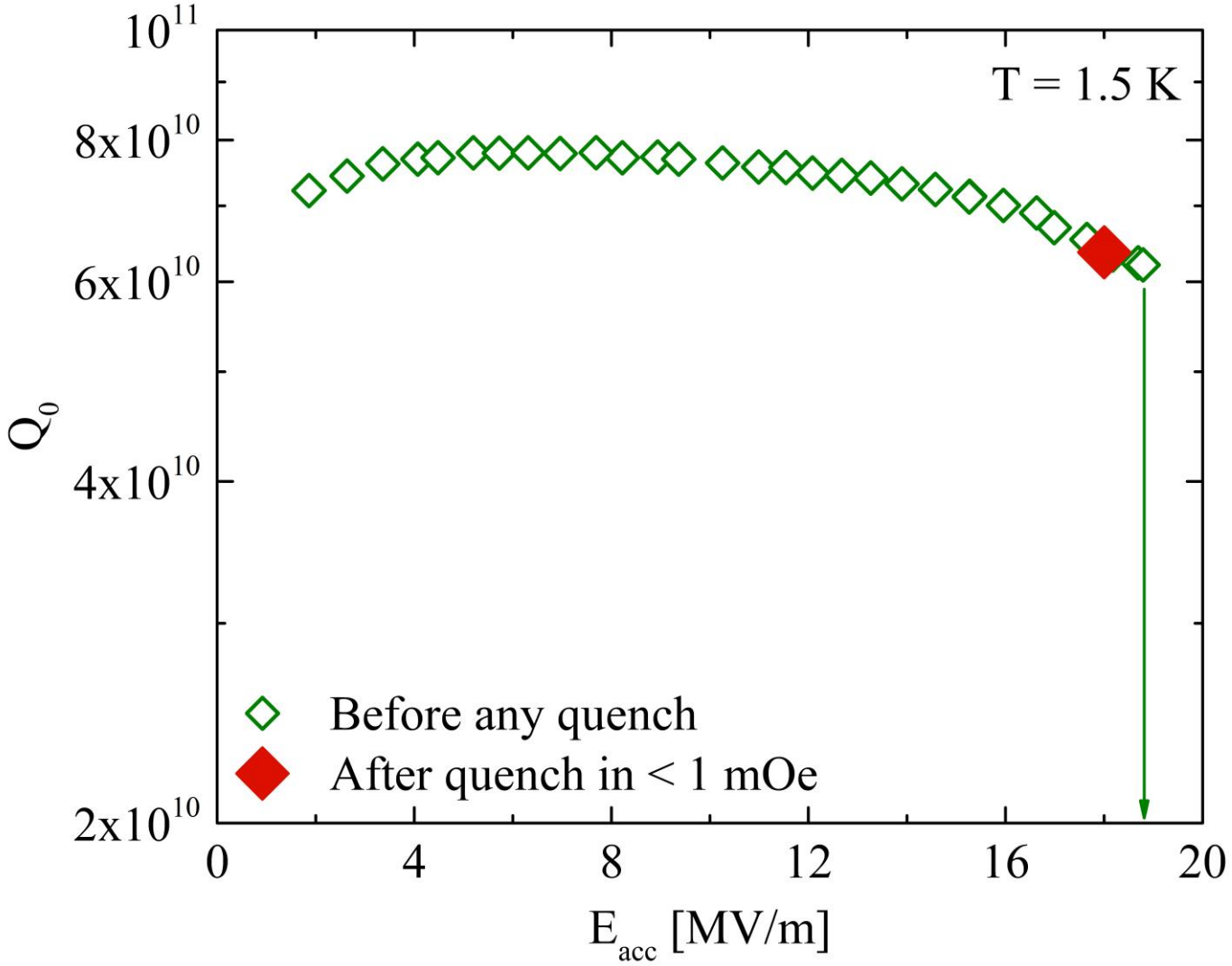
Without warming above T_c

→ First hint on the extrinsic origin of flux trapping

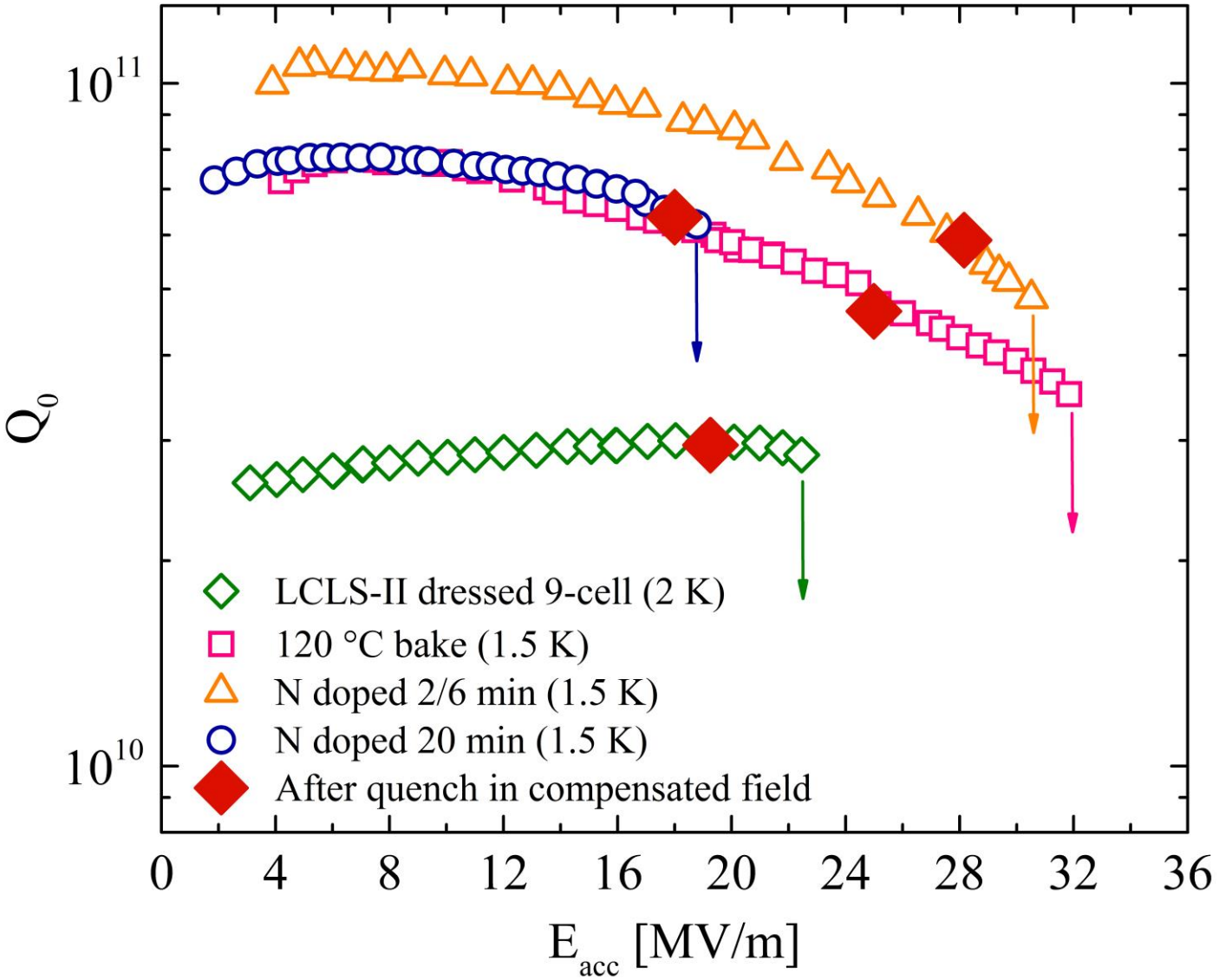
Q_0 vs E_{acc} before any quench



Quench in < 1 mOe



Quench in < 1 mOe for different treatments



No degradation quenching in < 1 mOe

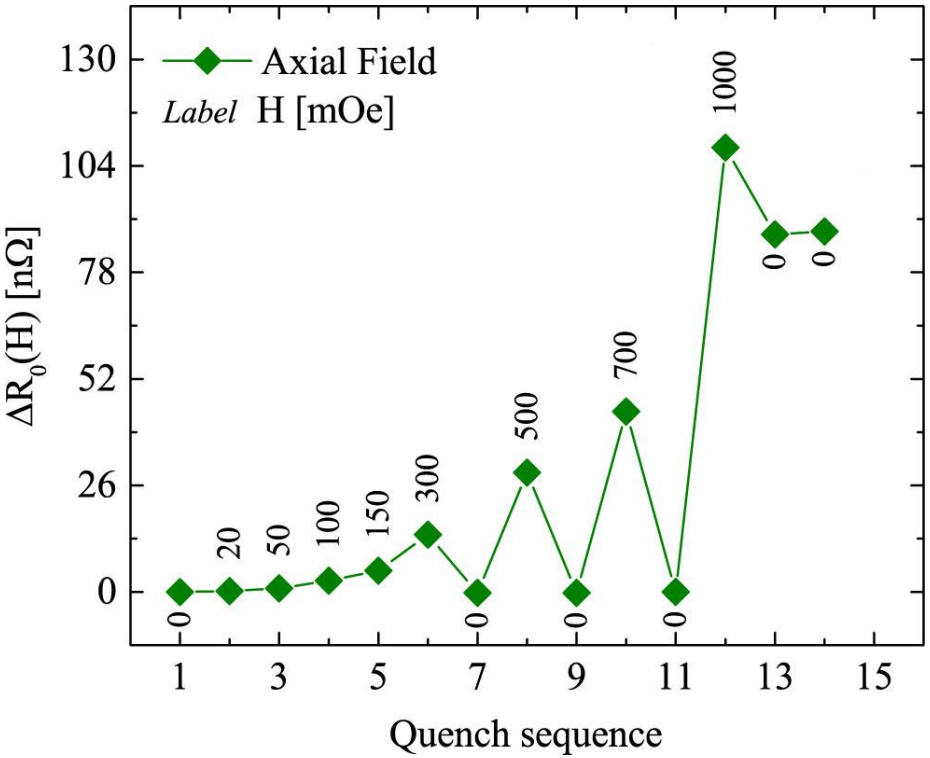
No Q_0 Degradation!

Flux trapping is an extrinsic phenomenon only!

Is Q_0 always totally recoverable?

Not complete recovery

Not always the Q-factor can be totally recovered



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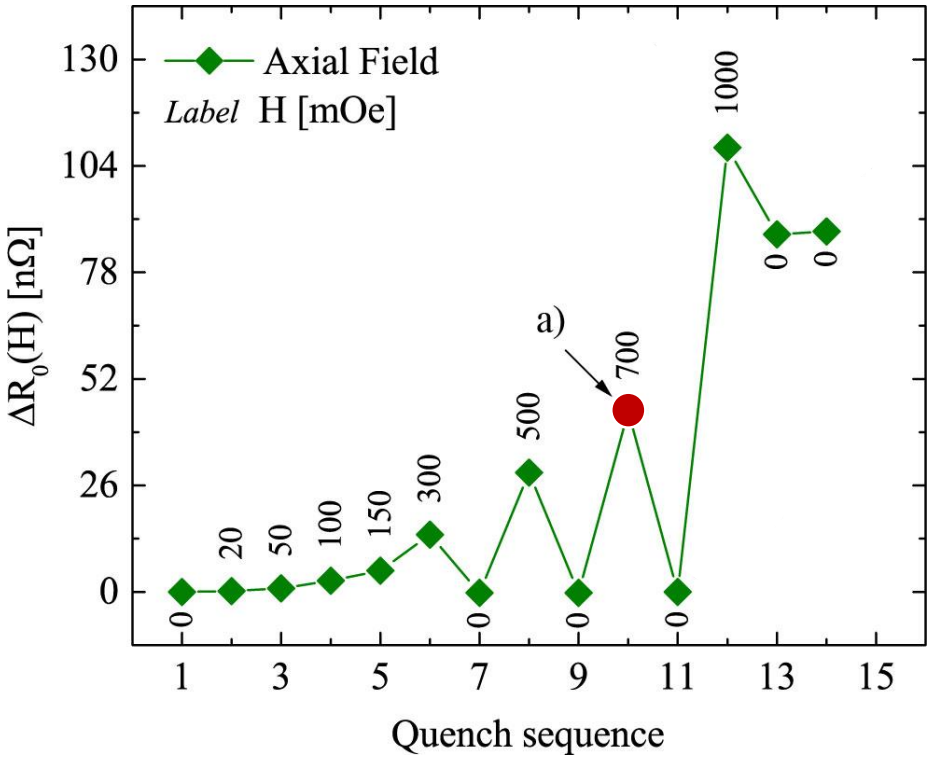

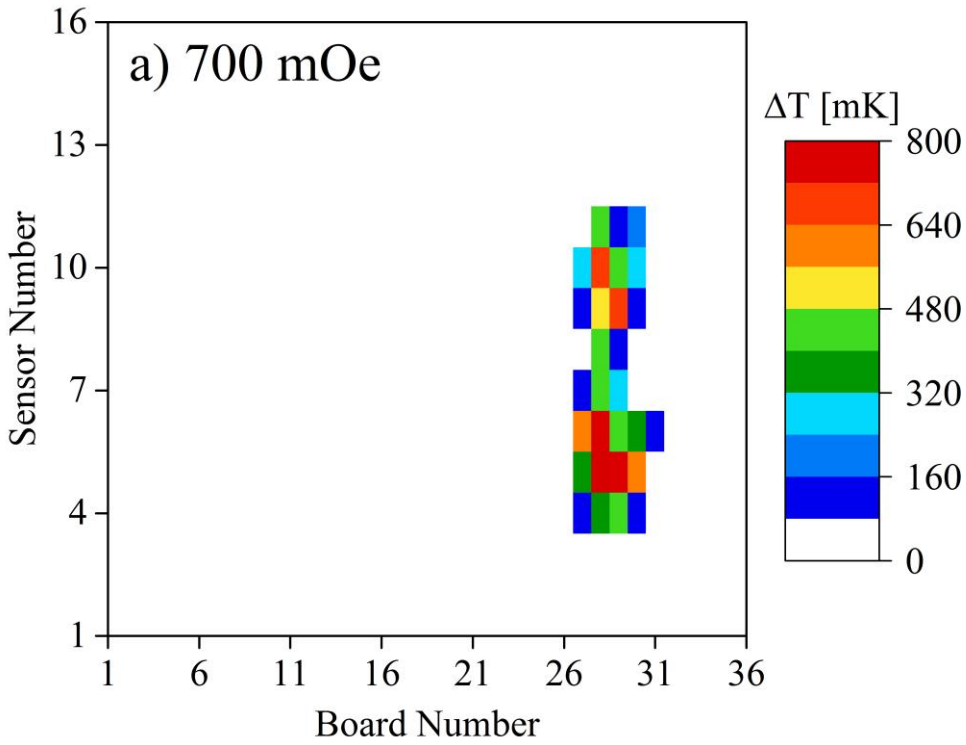

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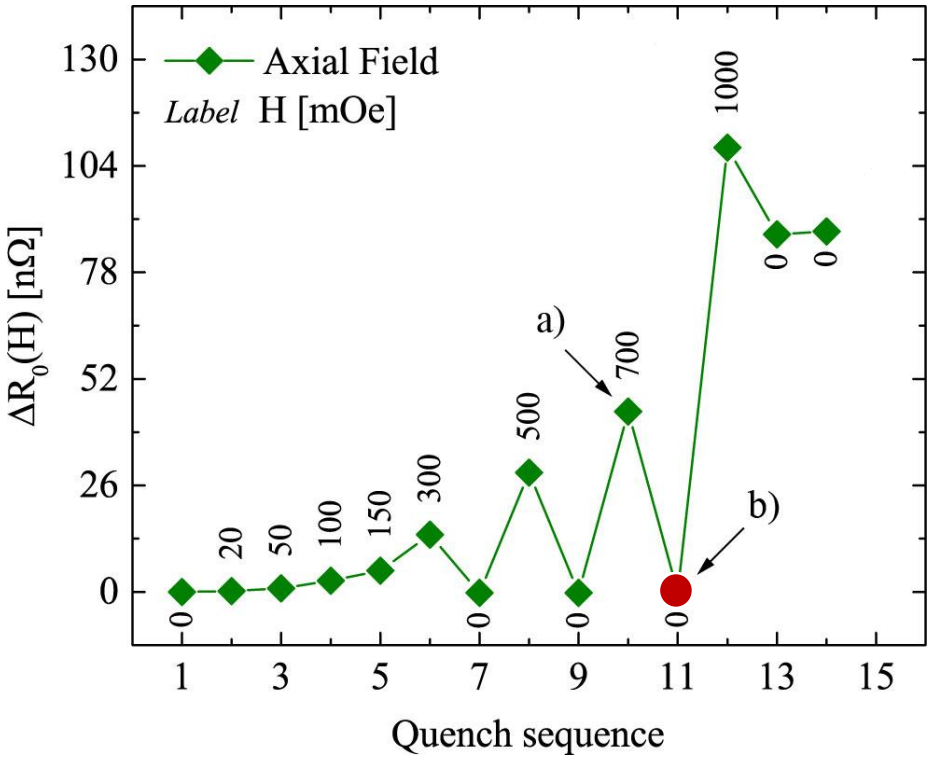

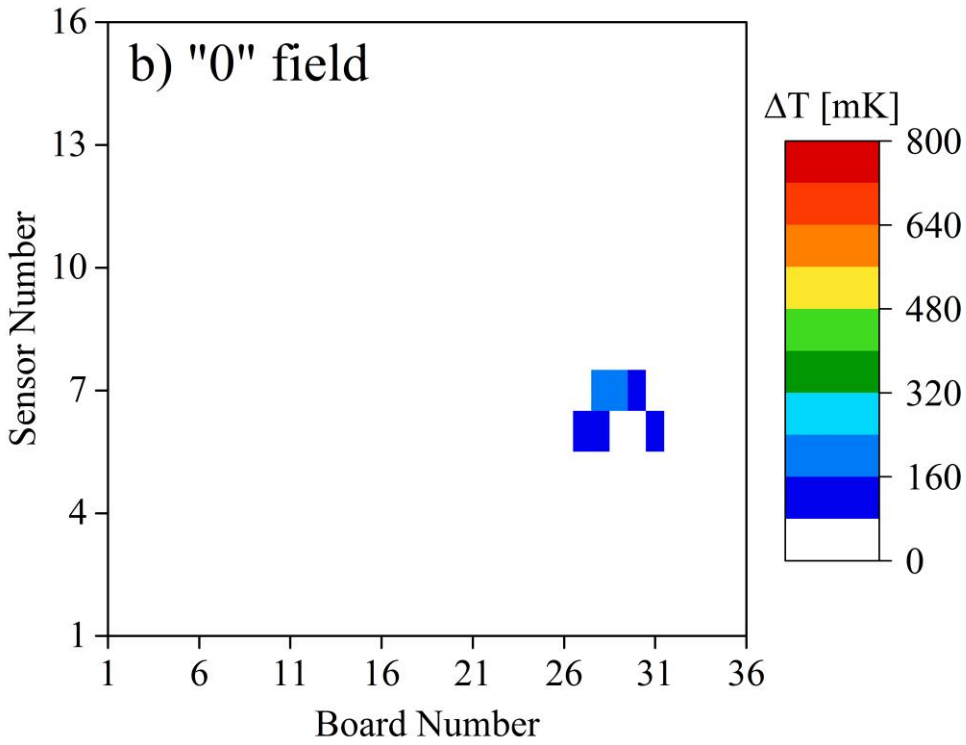

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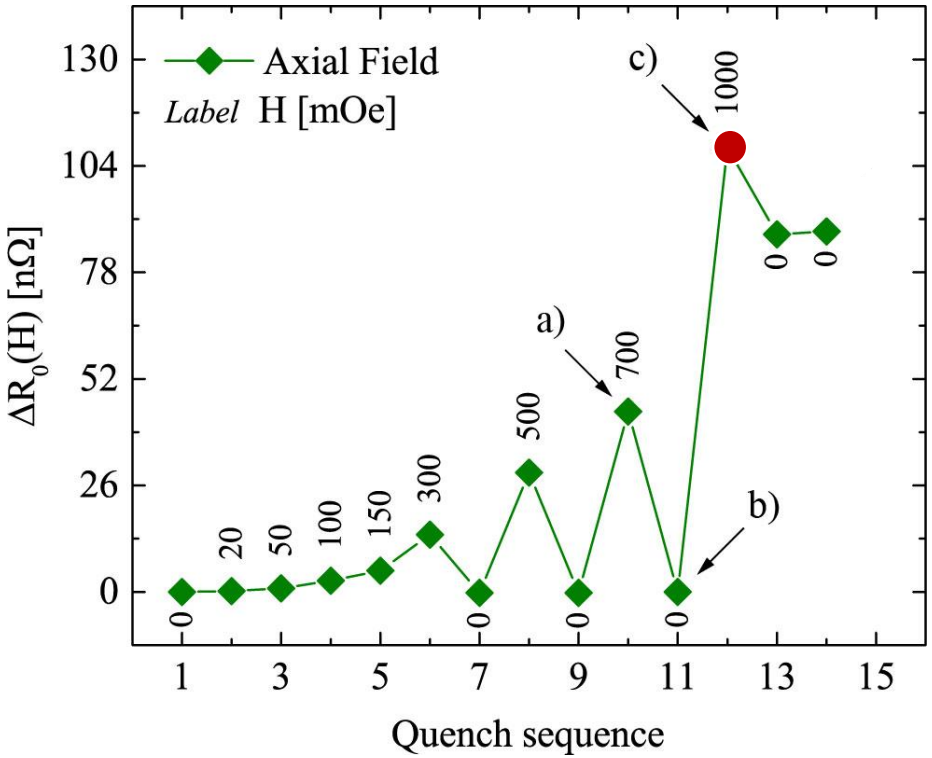

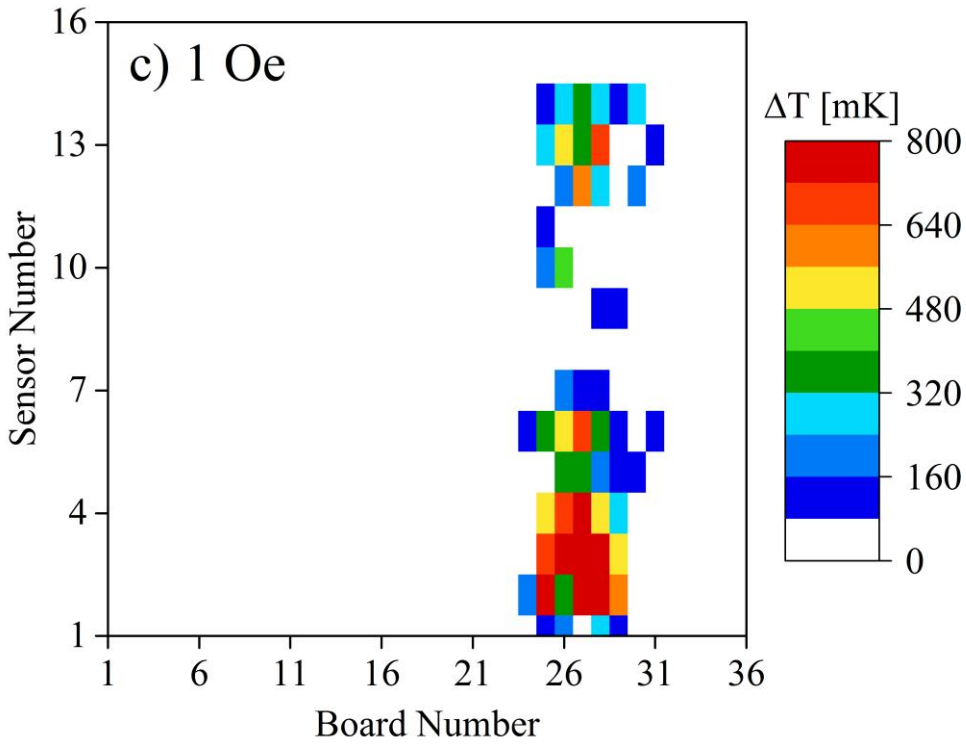

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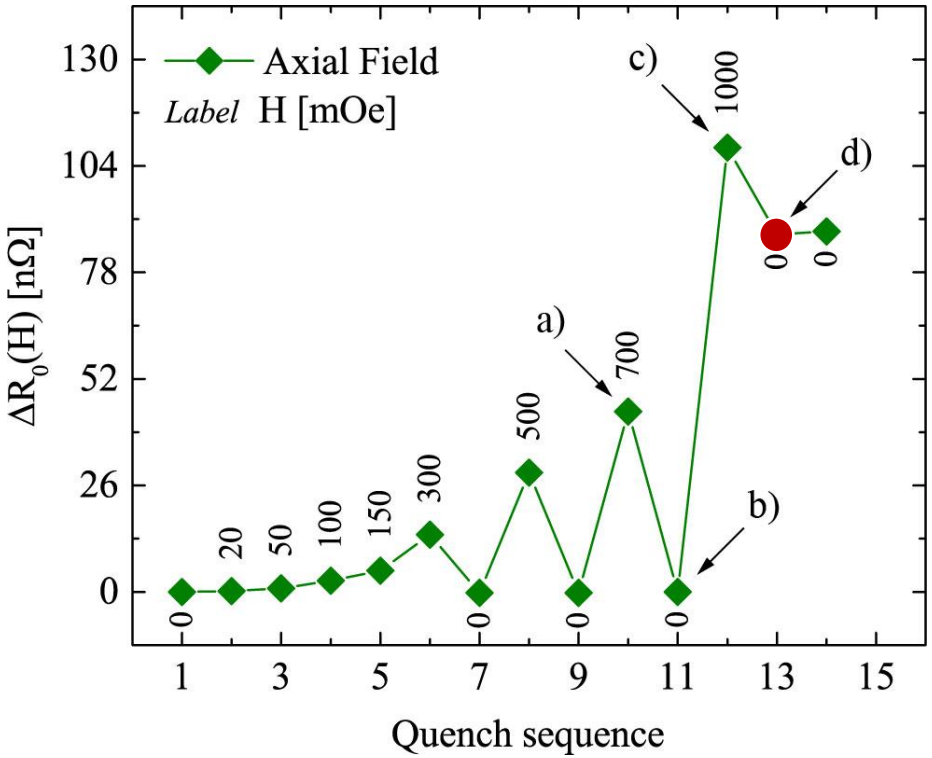

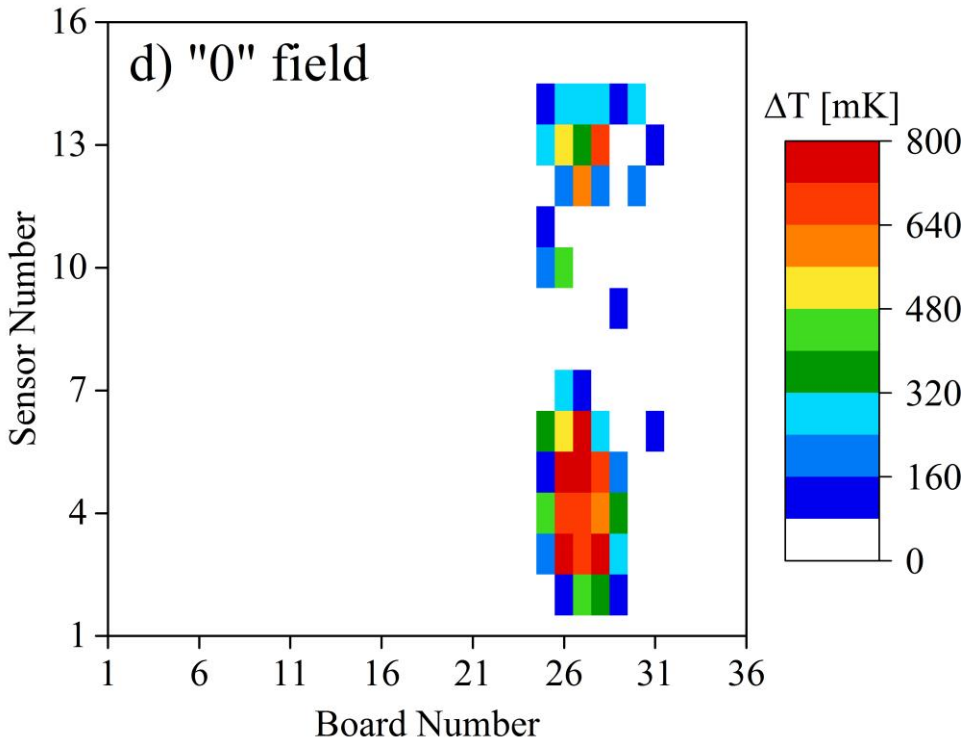

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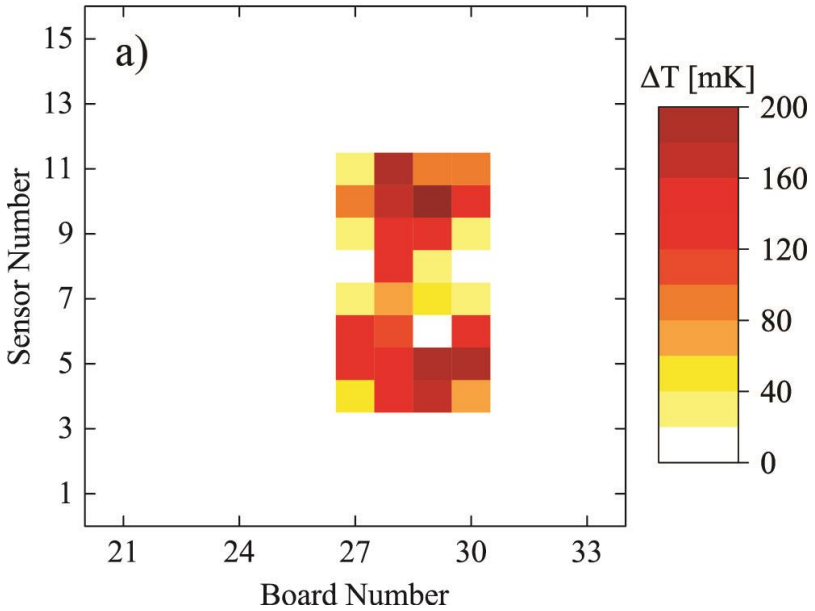
Magnetic flux migration

More on poster MOPB021

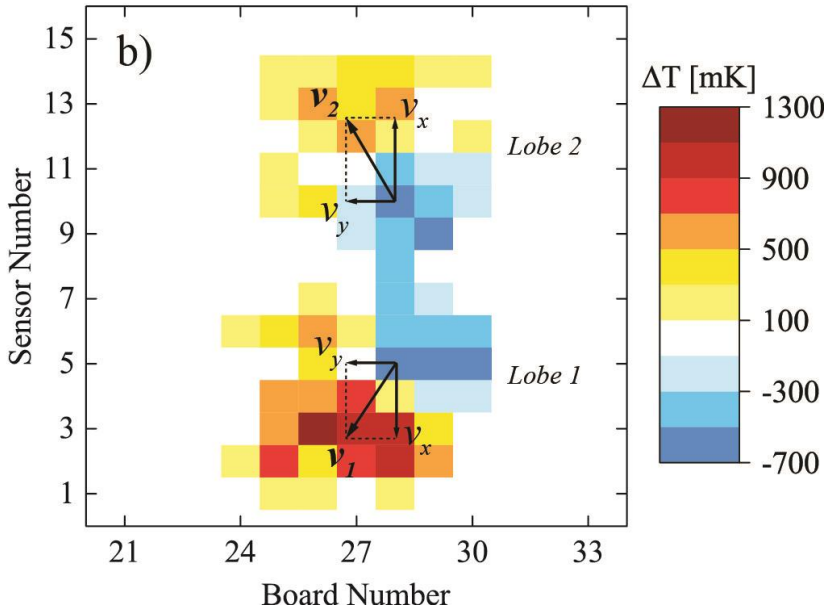
The flux migrates driven by its own thermal gradient

$$-S\nabla T - \eta\bar{v} - f n_s e(\bar{v} \times \phi_0 \hat{n}) - \bar{f}_p = 0$$

700 mOe – 500 mOe



1 Oe – 700 mOe



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How is the flux trapped?

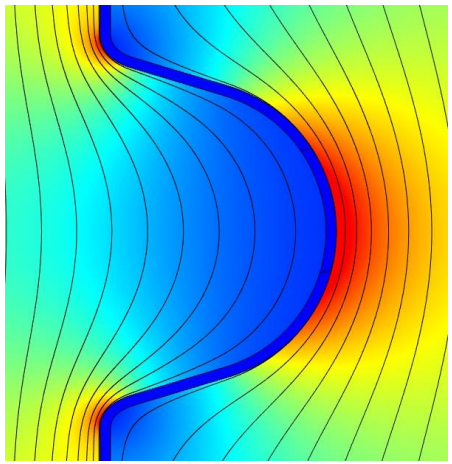
Magnetic flux trapping dynamics

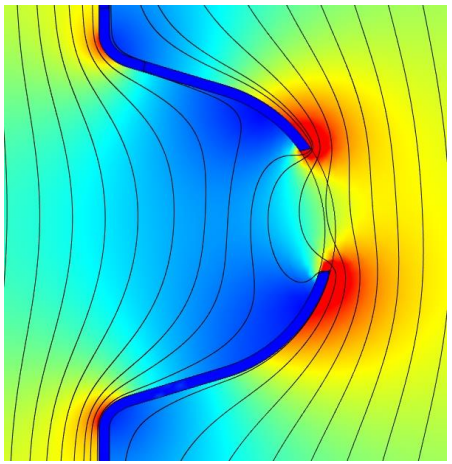
How the magnetic flux is trapped?

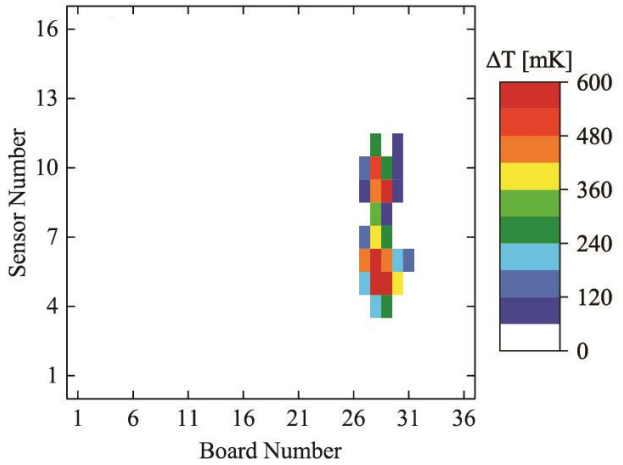
It creates a semi-loop at the quench spot

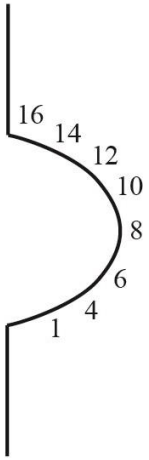
Why the magnetic flux is not expelled?

Hypothesis: field redistribution time constant > than cooling time constant







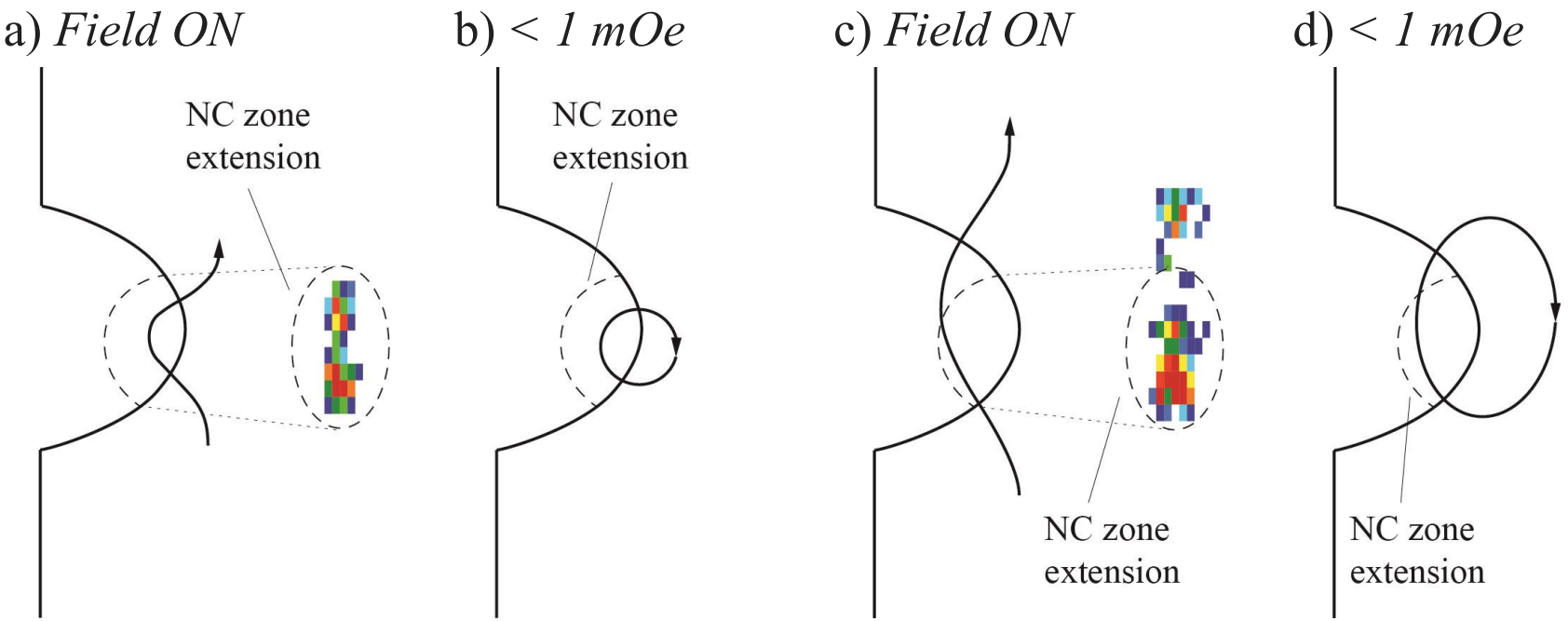


How does the recovery work?

How does the Q_0 recovery work?

Magnetic field exists only if currents are present

$$\oint \bar{B} \cdot d\bar{l} = \mu_0 I$$



Conclusions

First time demonstration: Q_0 degradation due to quench is related to ambient field only

I. No Q_0 degradation when quenching in < 1 mOe
II. Total recovery of Q_0 achieved when quenching in < 1 mOe

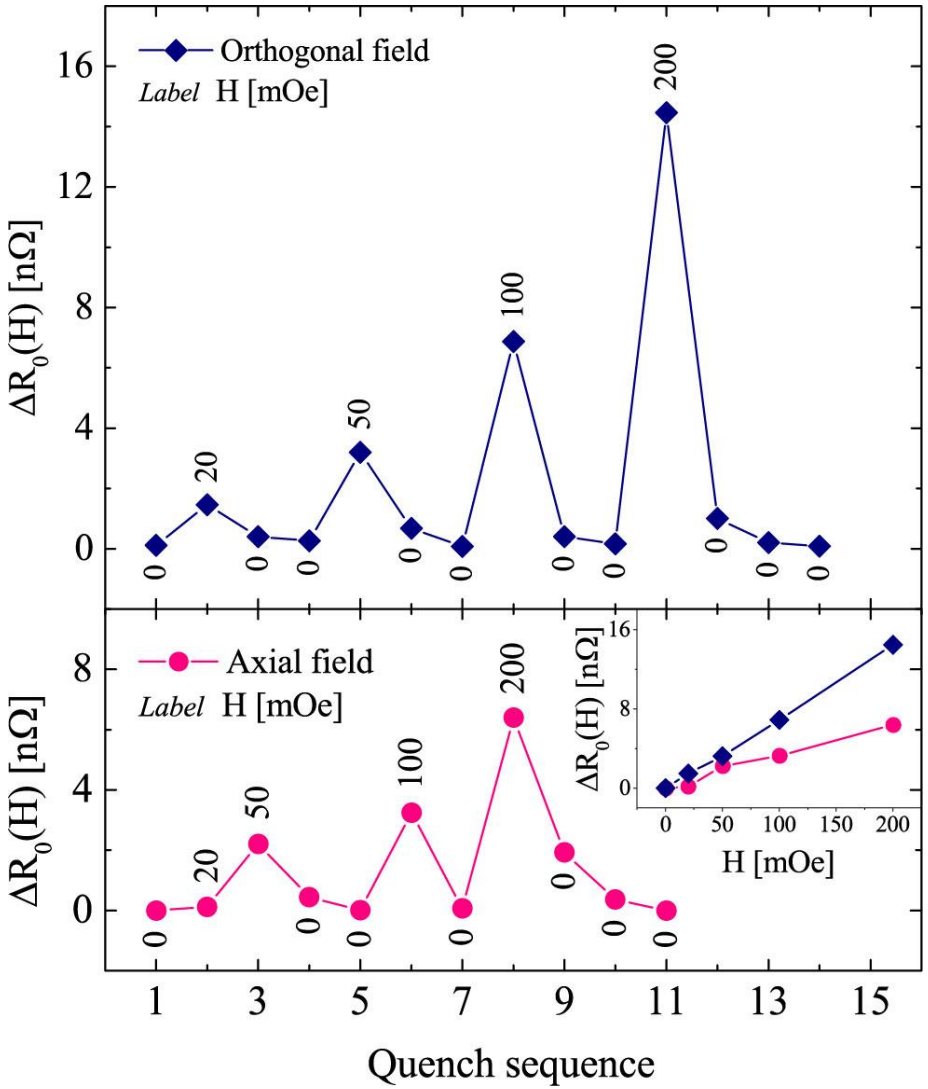
Above an external field threshold Q_0 cannot be recovered anymore

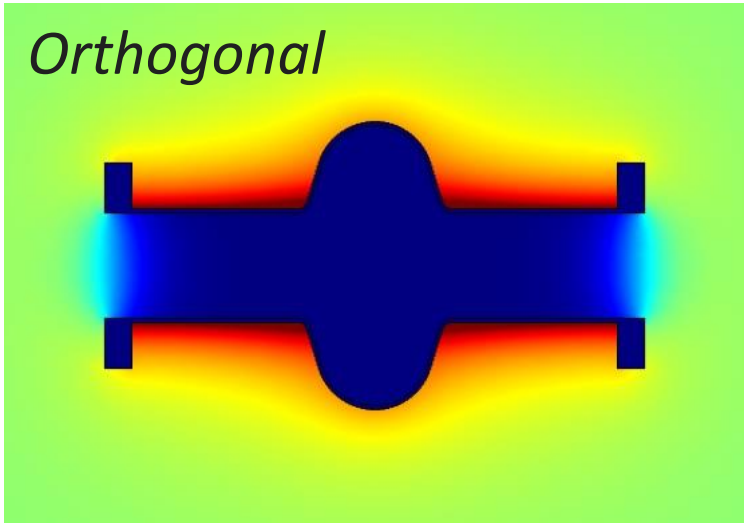
I. Trapped field can migrate driven by its local thermal gradient

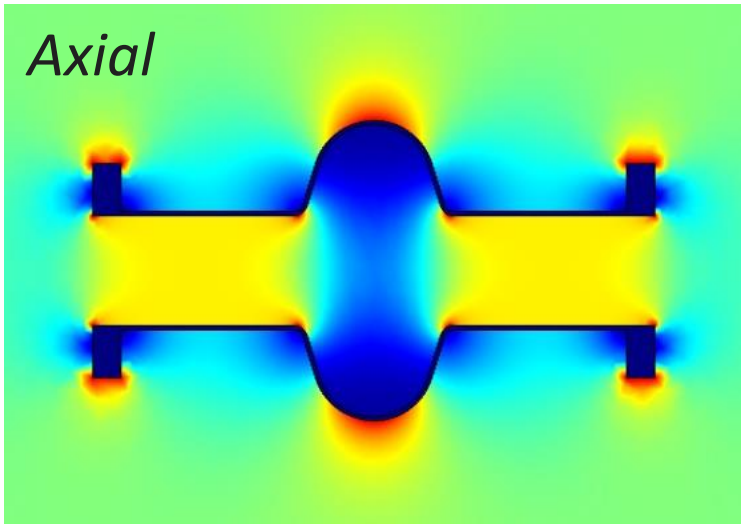
Thank you

Back-up Slides

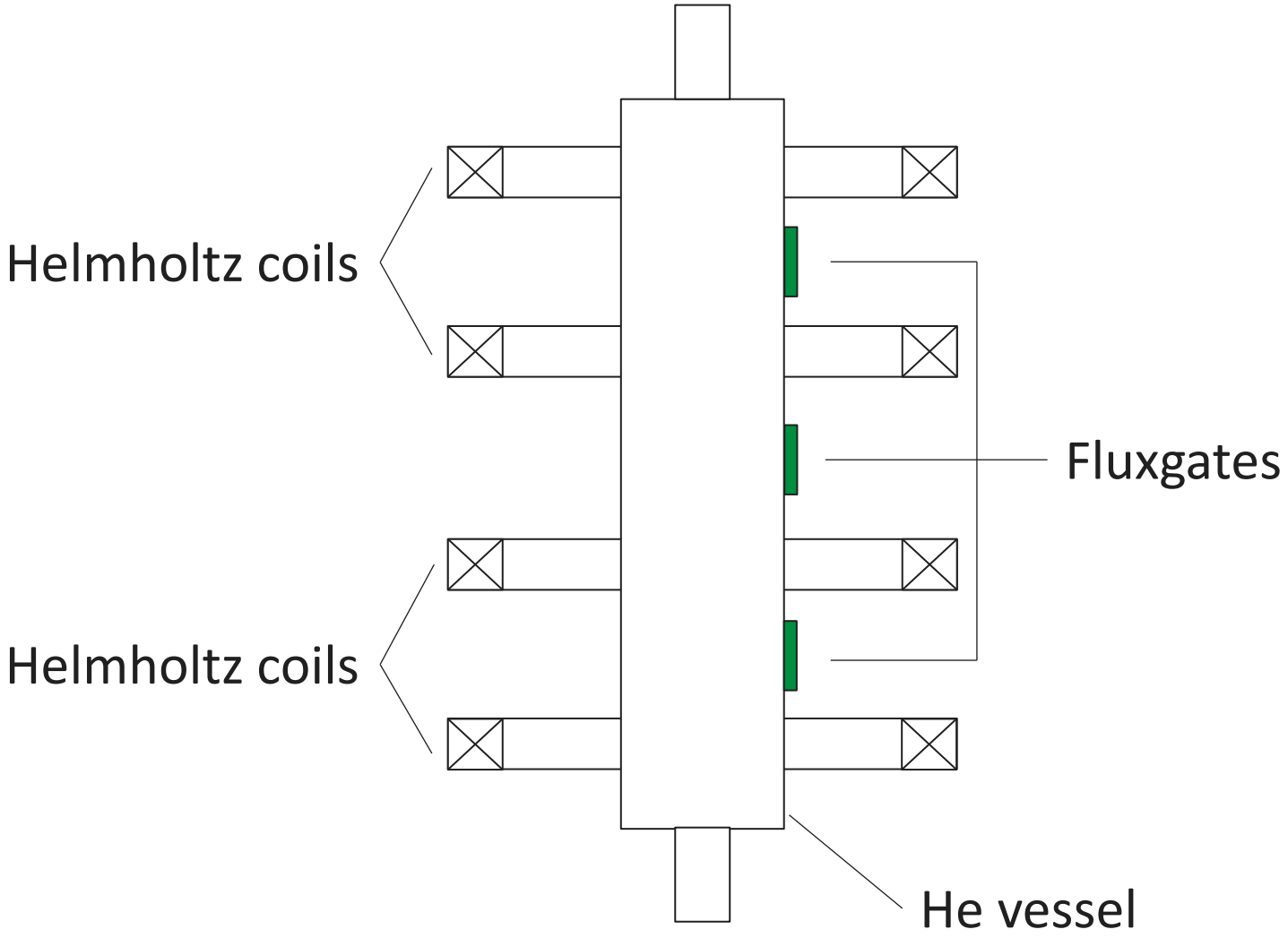
External field orientation dependence



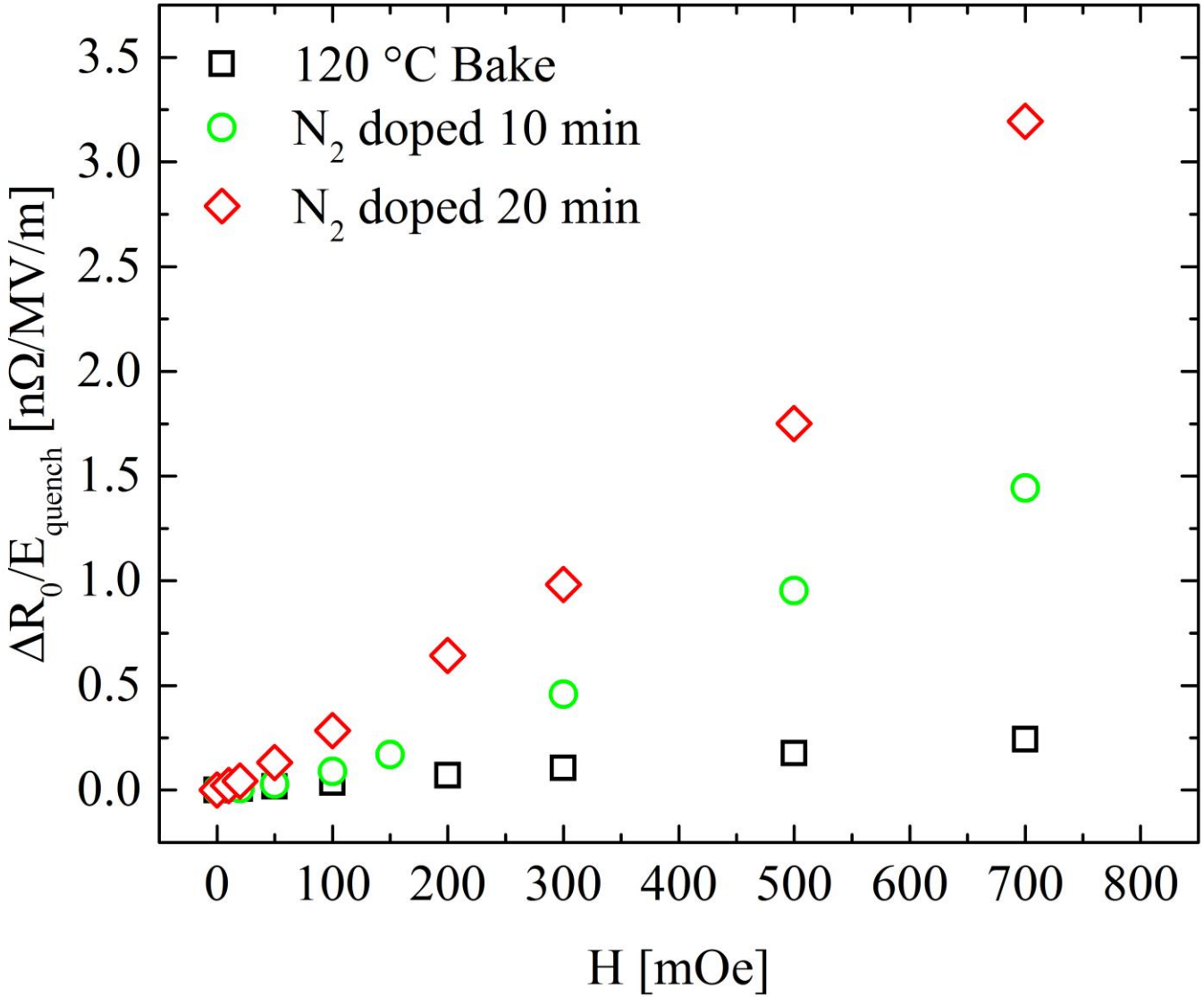




Dressed 9-cell set-up



Dissipation comparison

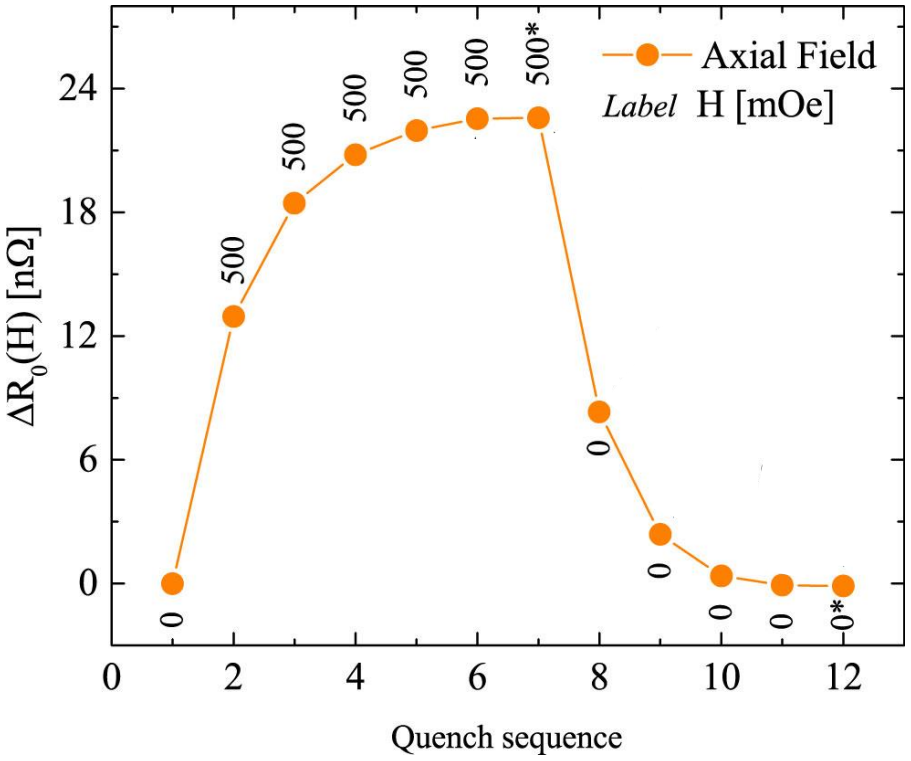


Saturation

More on poster MOPB021

I. Every quench depletes the local applied field at the quench spot

II. The extra surface resistance saturates



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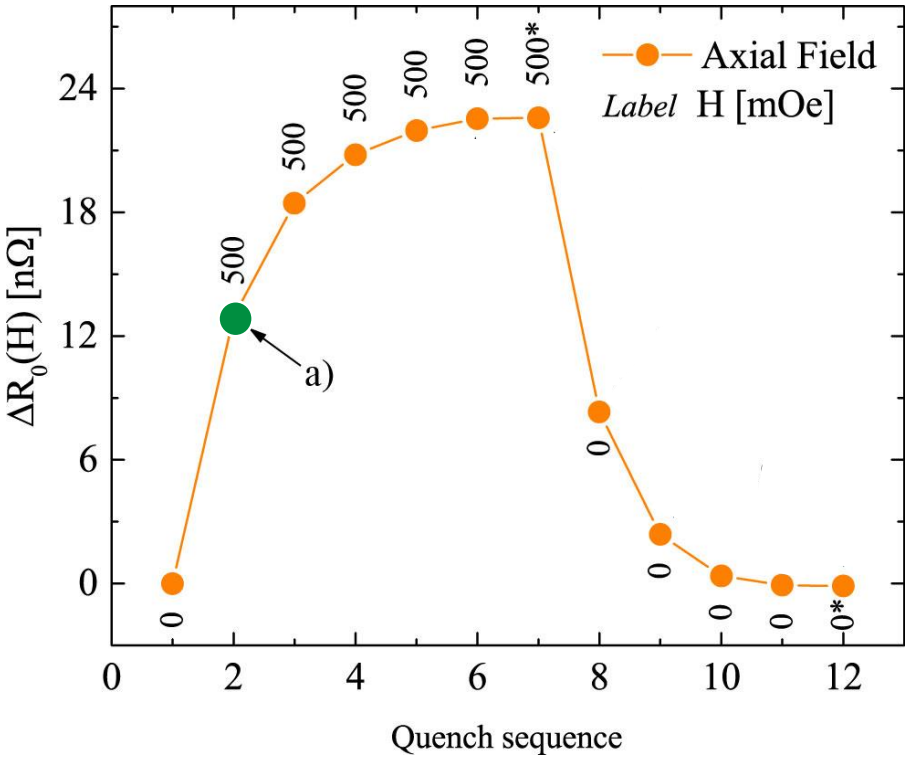

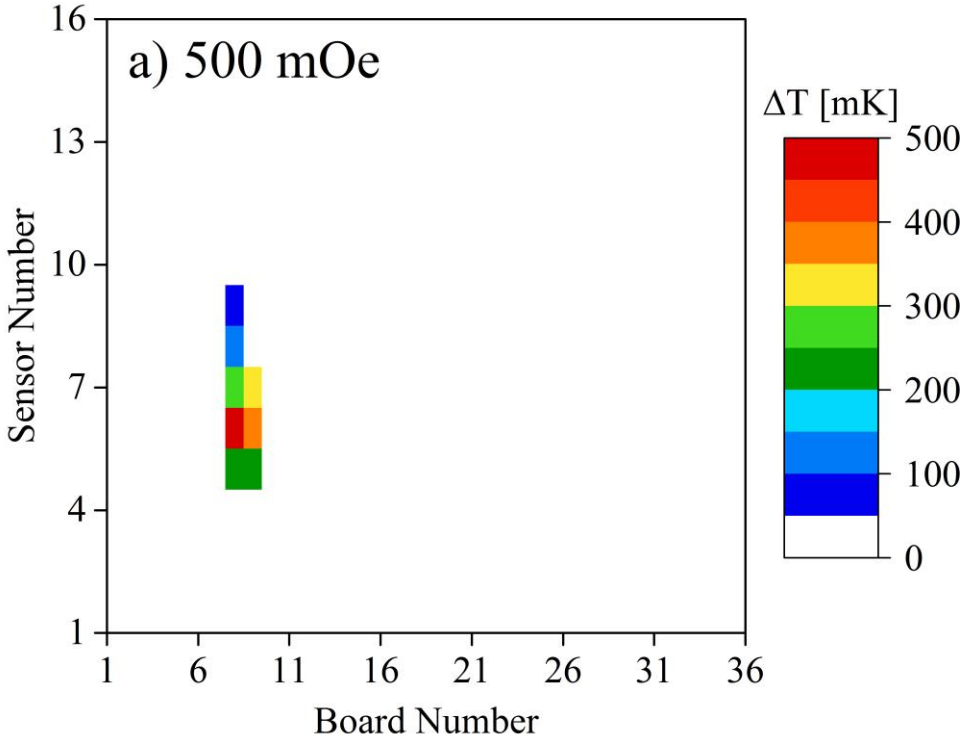

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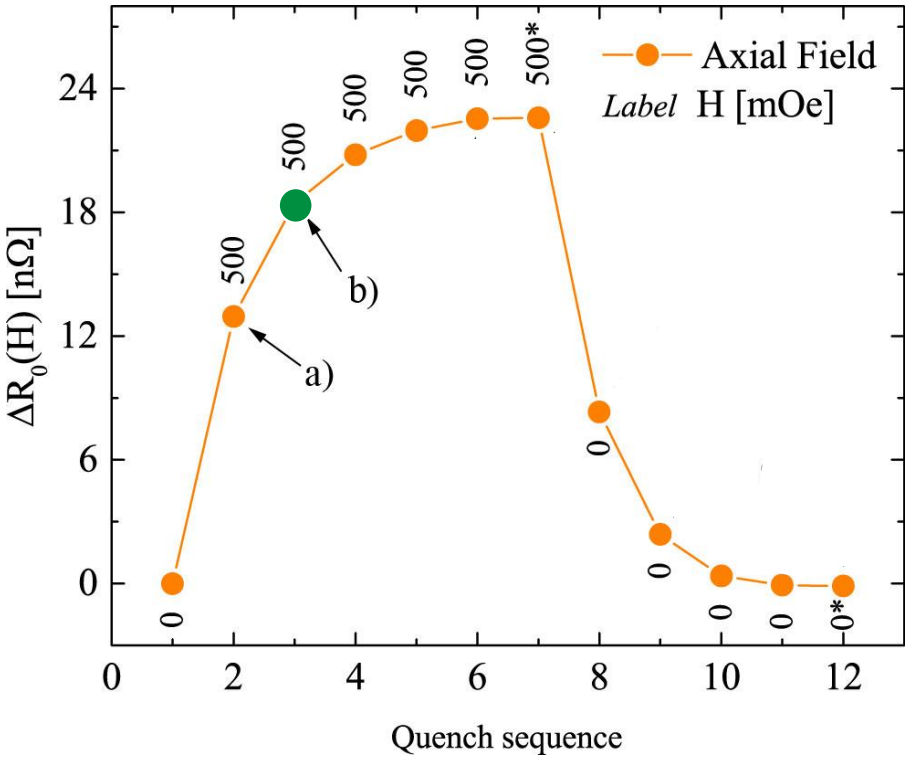

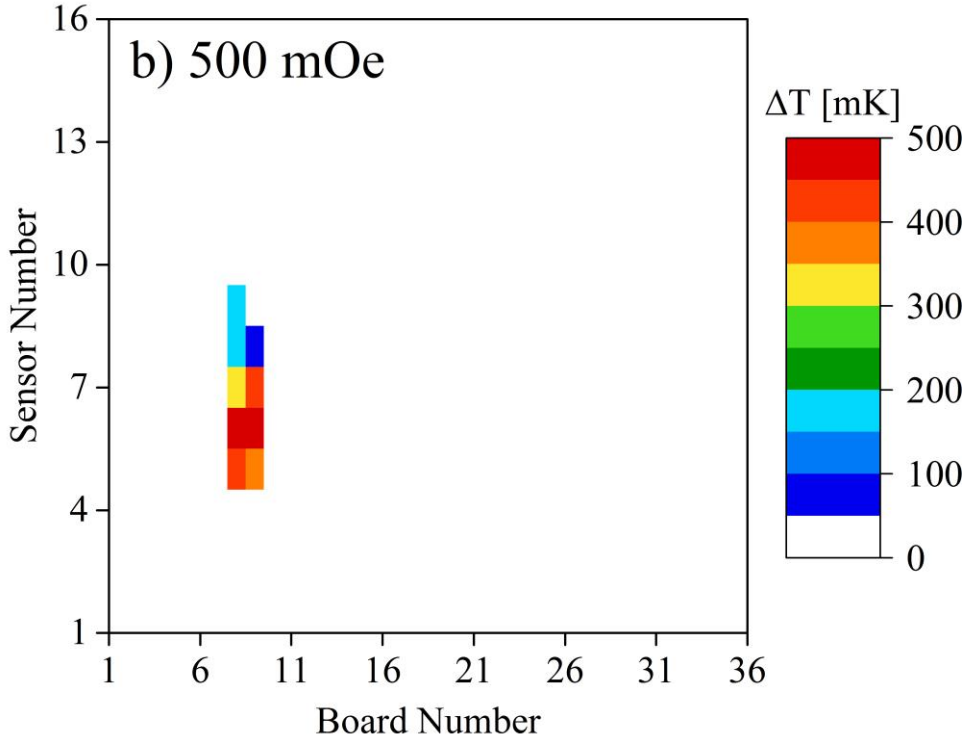

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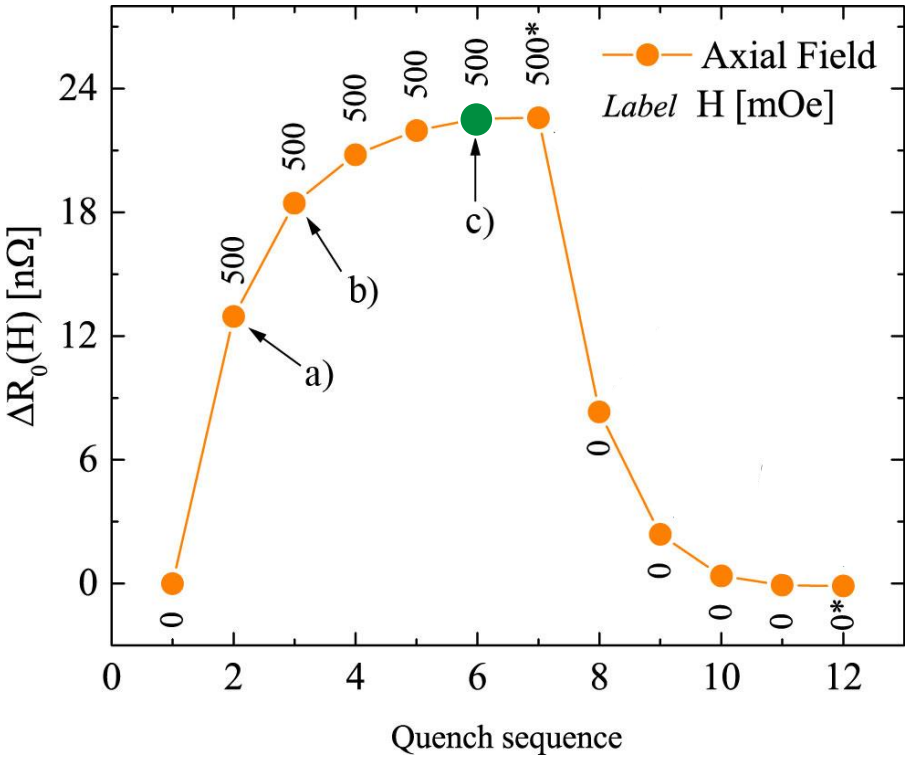

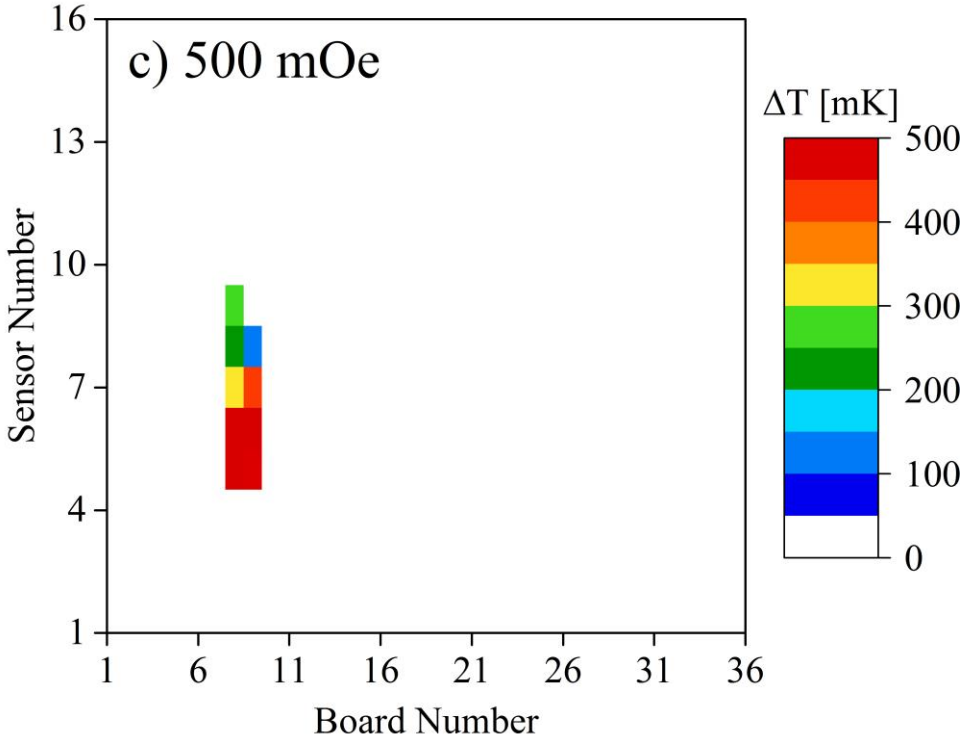

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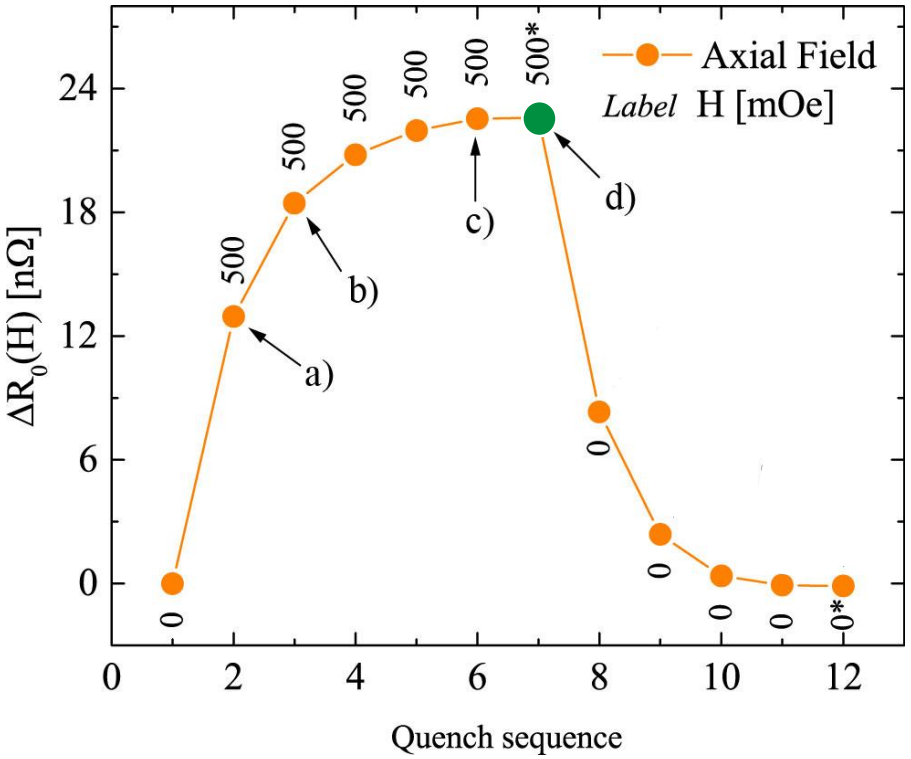

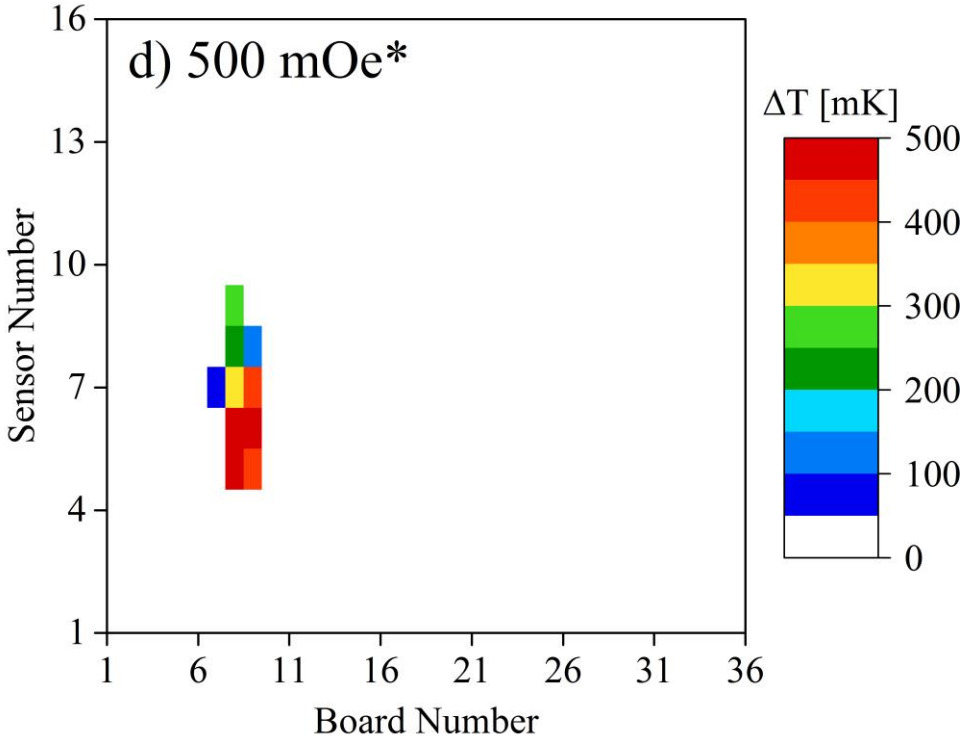

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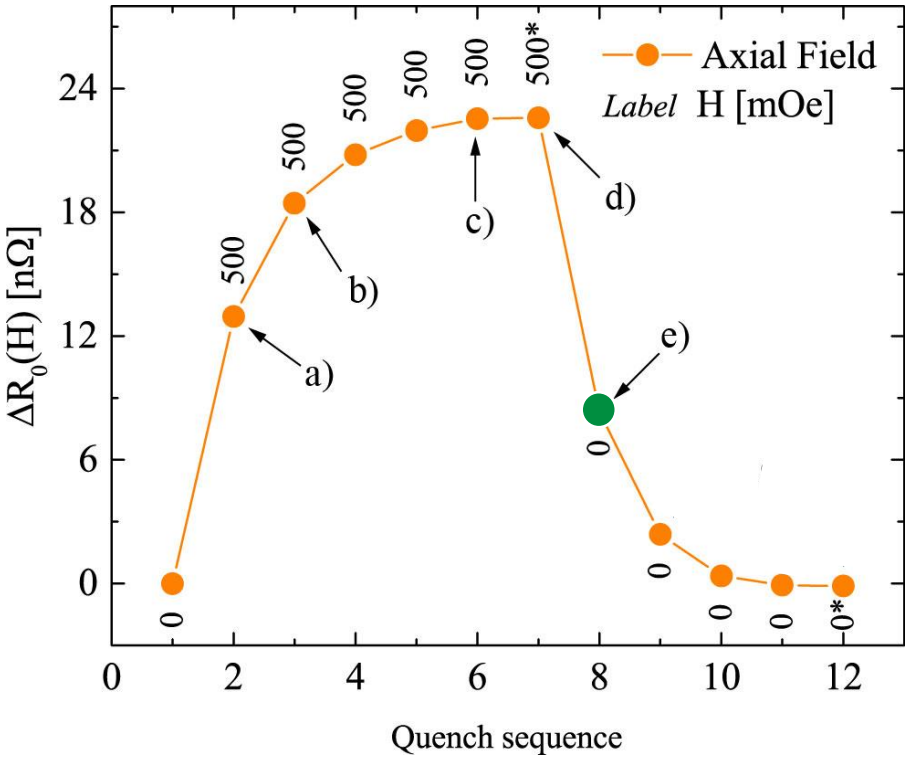
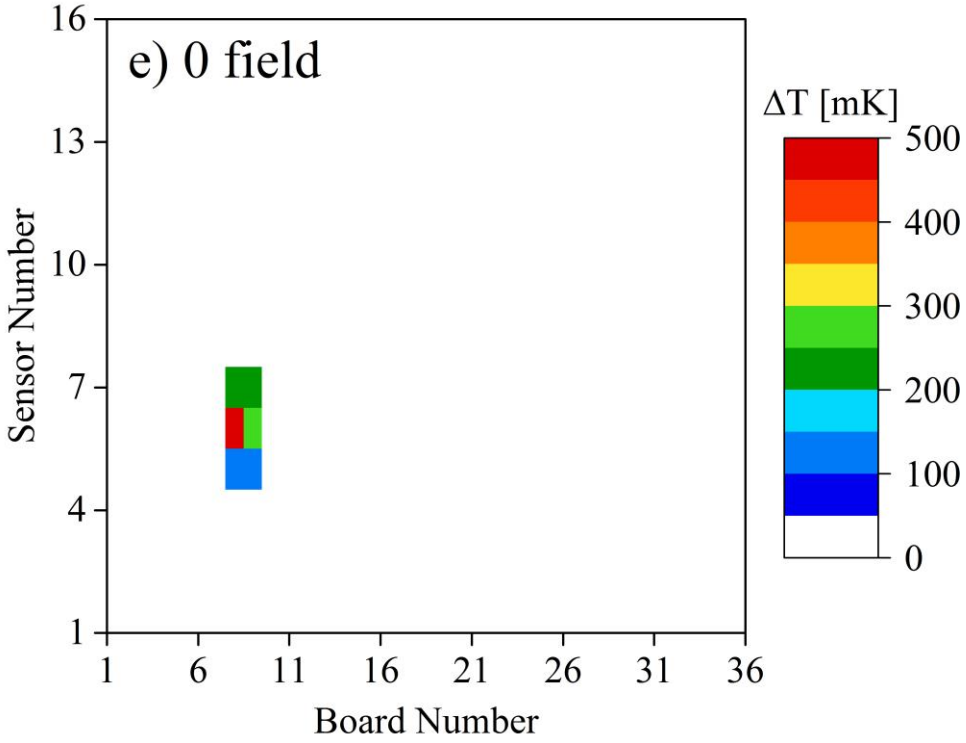
Recovery

More on poster MOPB021

I. Complete Q_0 recovery is not achieved with a single quench

II. Several quenches in applied field < 1 mOe are needed





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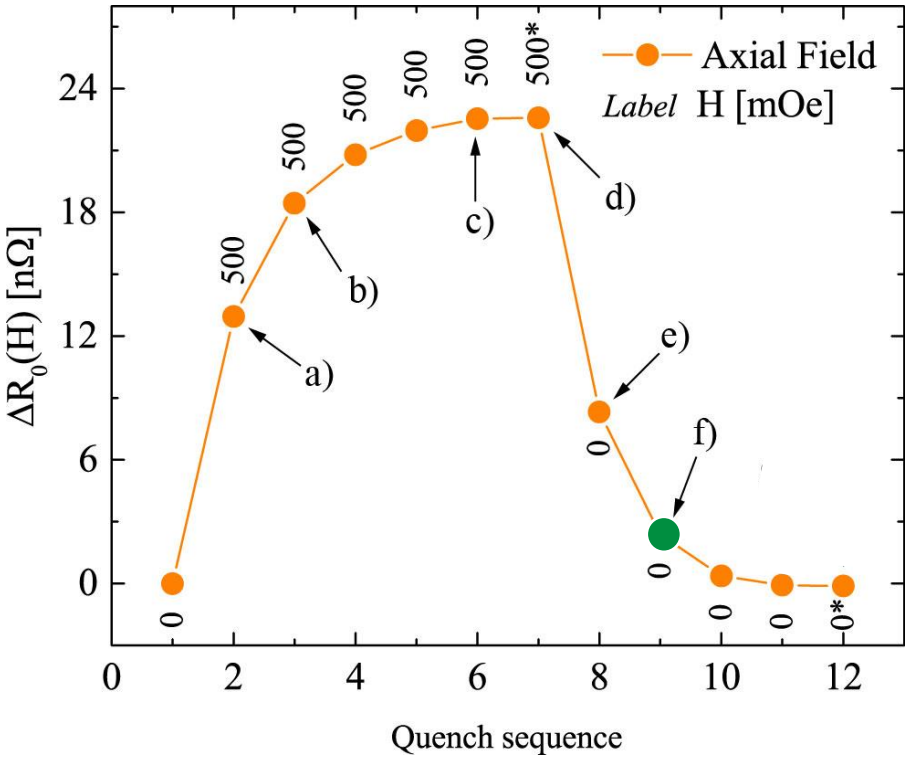

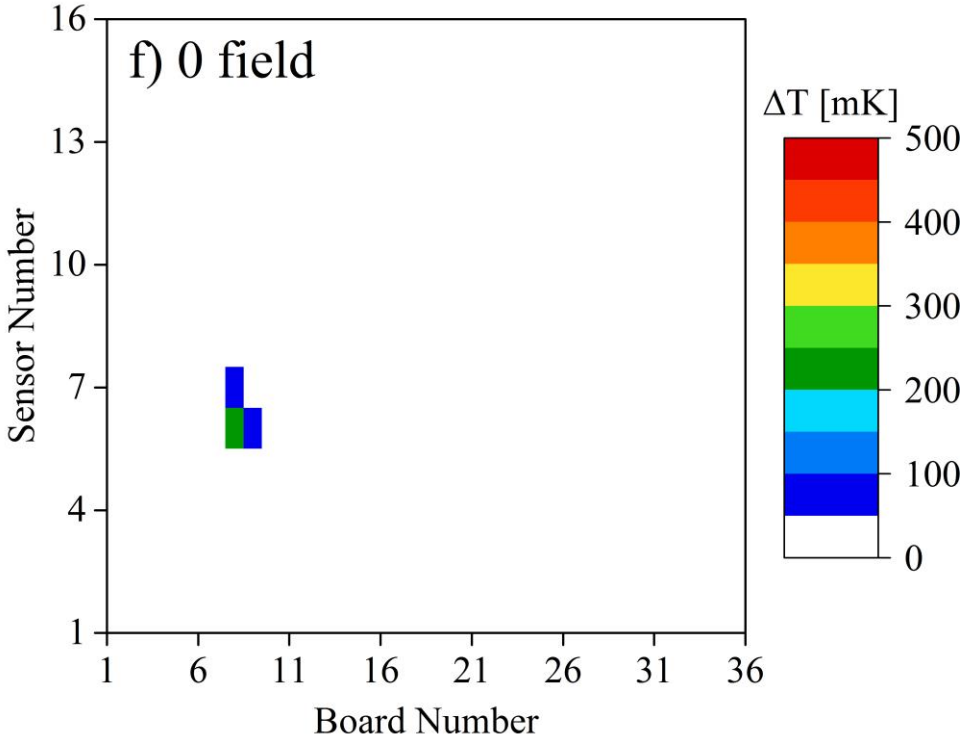

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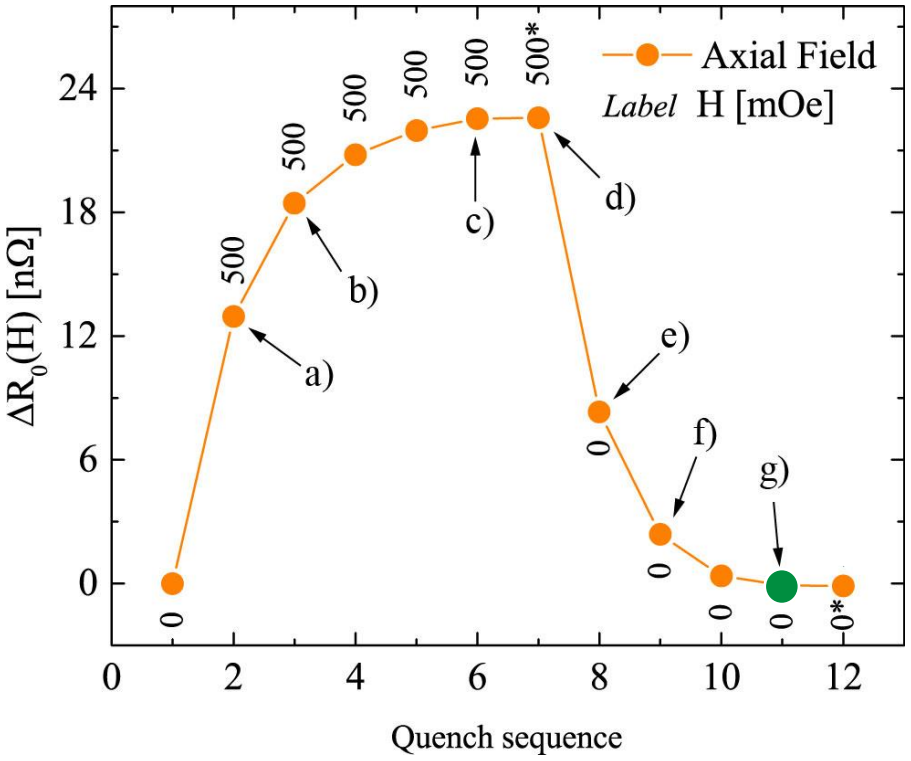

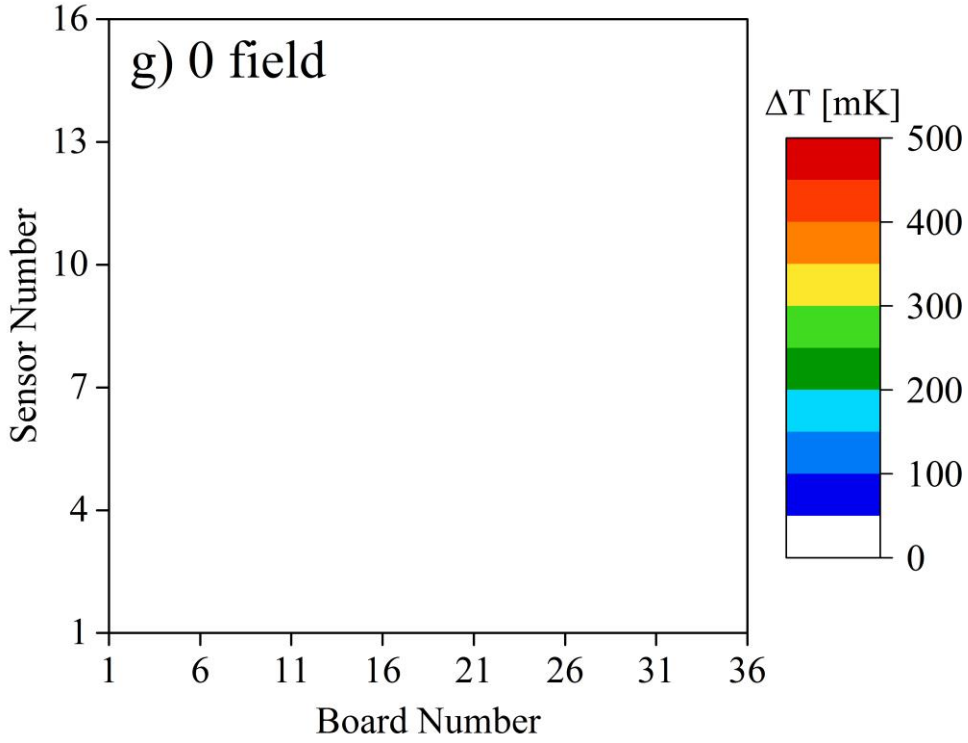

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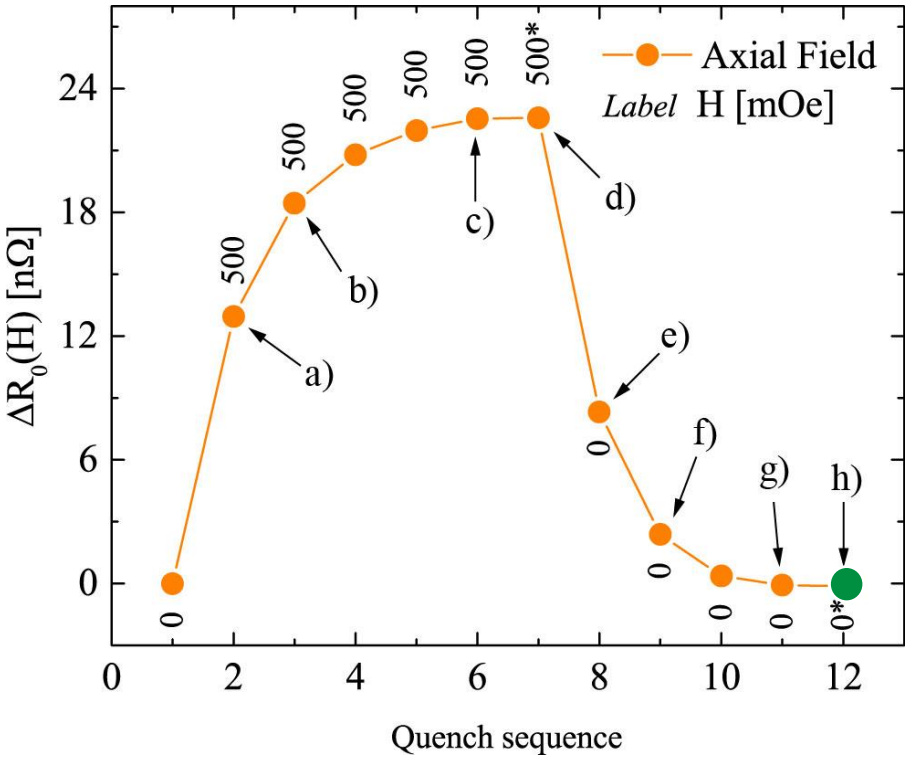

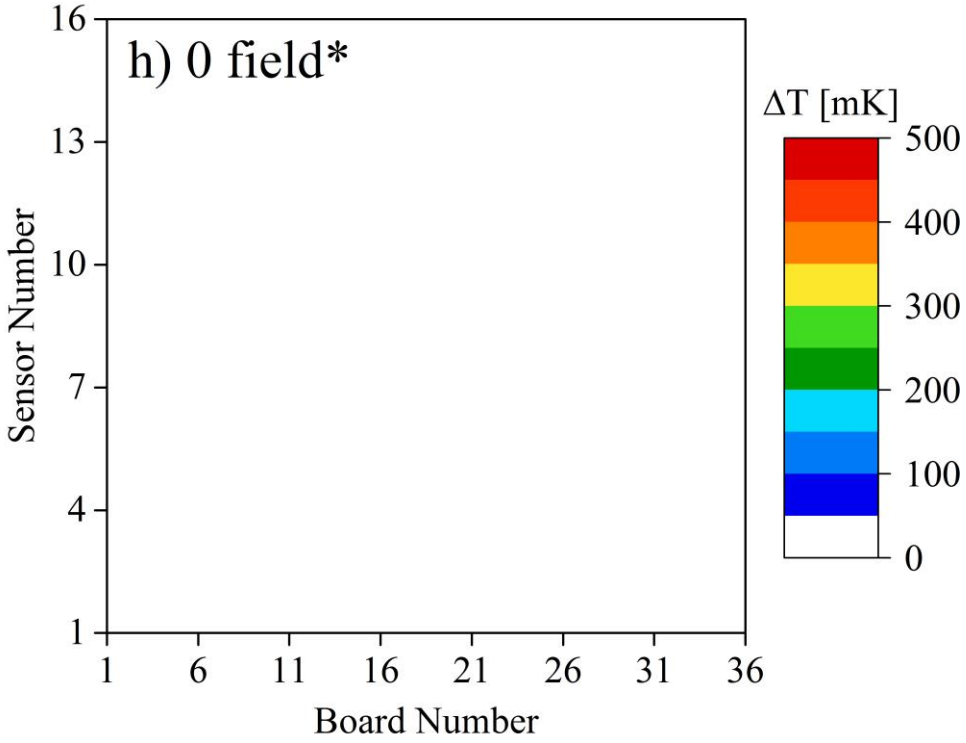

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