PATHWAY TO INCREASING THE QUALITY FACTOR OF SRF CAVITIES

Oliver Kugeler, Julia Vogt, Jens Knobloch, Sarah Aull

IPAC 2013 Shanghai, China

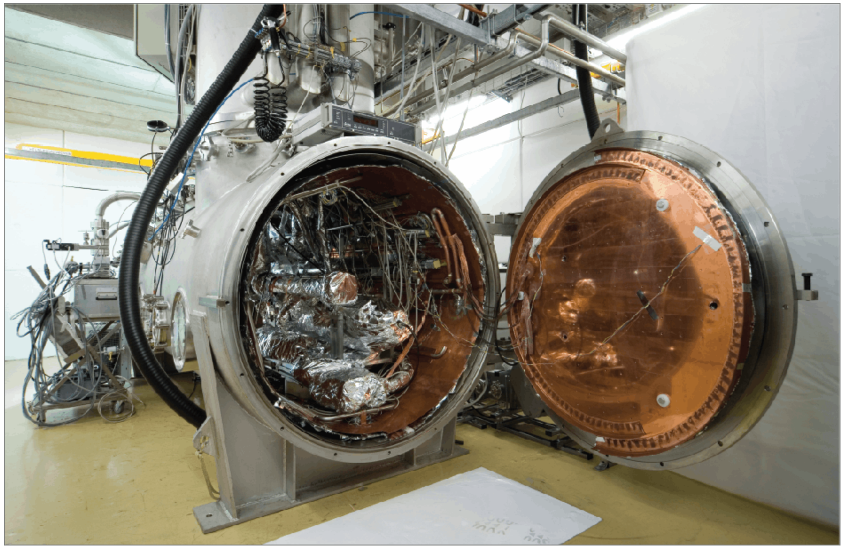
Introduction

- CW operation of SRF cavities
- Cryogenics = cost driver
- Minimize cryogenic load $P_{diss} \sim R_{surface} \sim 1/Q_0$
- $R_{surface} = \underbrace{R_{BCS}(f,T)}_{\text{physics}} + \underbrace{R_{residual}(?)}_{\text{originates to great fraction from trapped vortices (incomplete Meissner effect)}}$

- We found a way to reduce trapped flux

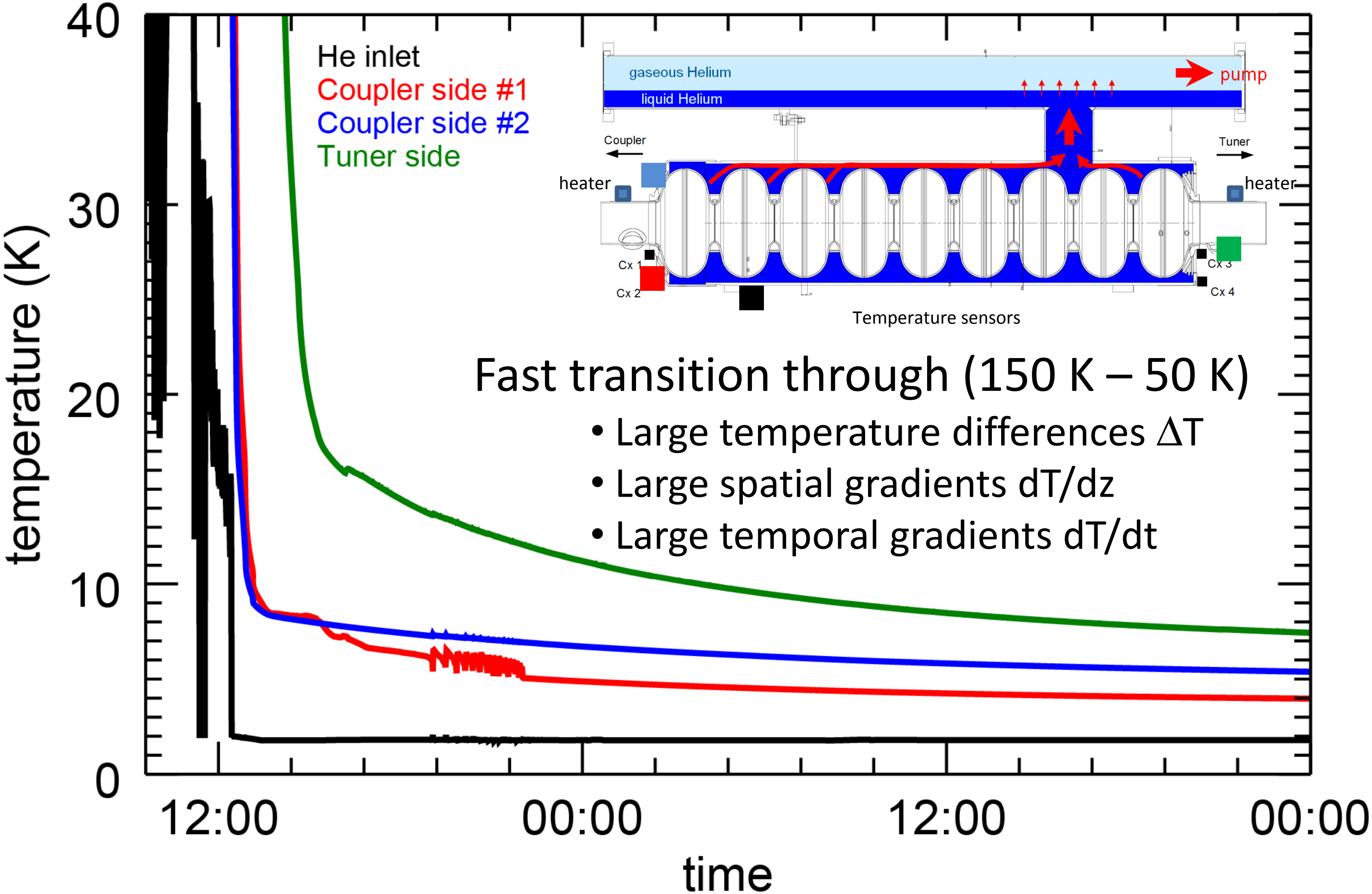
Q_0 measurements

- HoBiCaT test facility
- Temperatures down to 1.5 K
- Horizontal, fully
  equipped cavity
  weld into Helium tank
- Near β=1

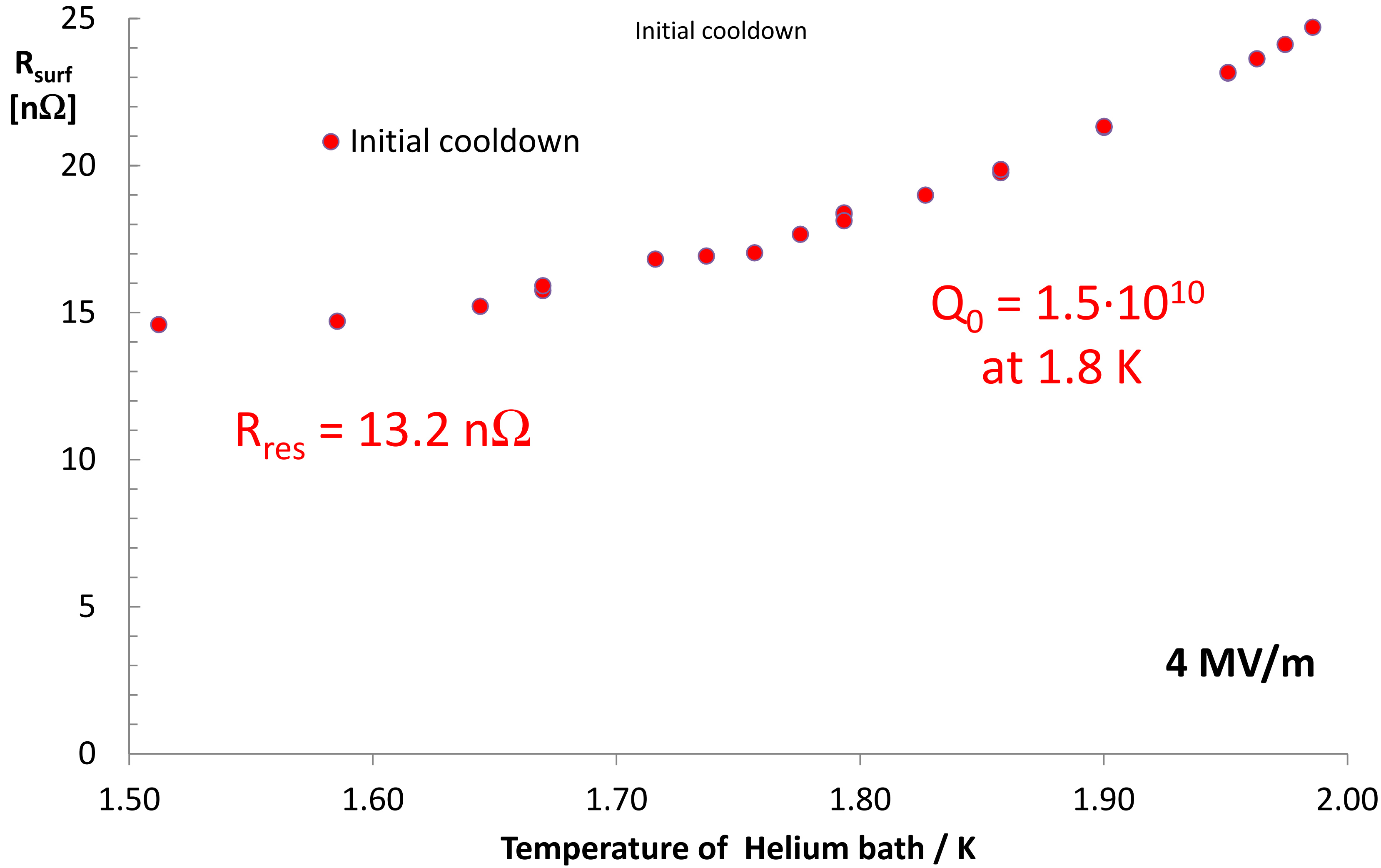


Cavity cool down procedure

Temperatures of cool down

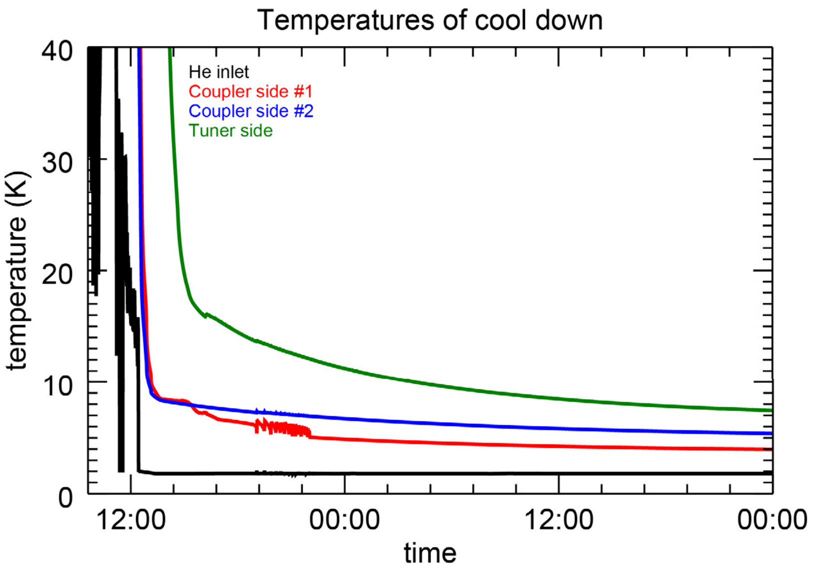


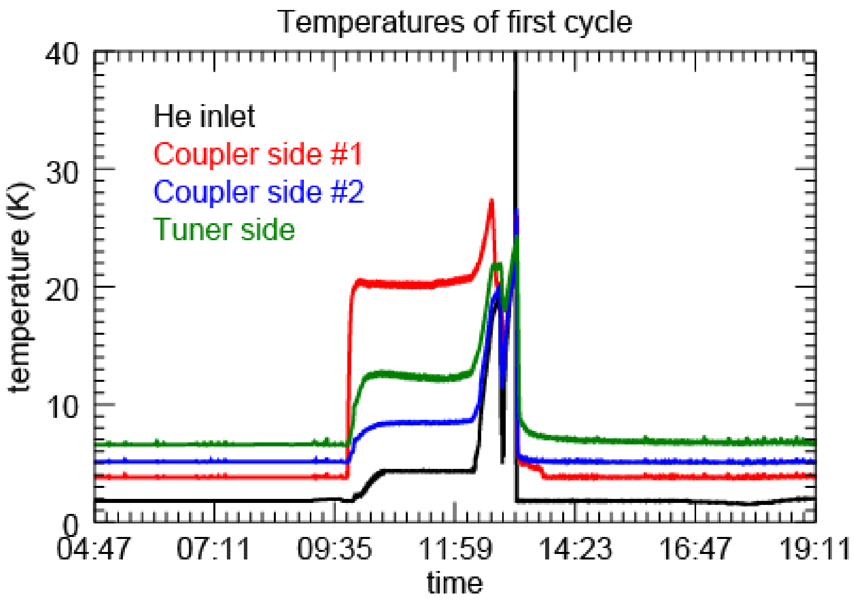
R_{surf} after initial cooldown



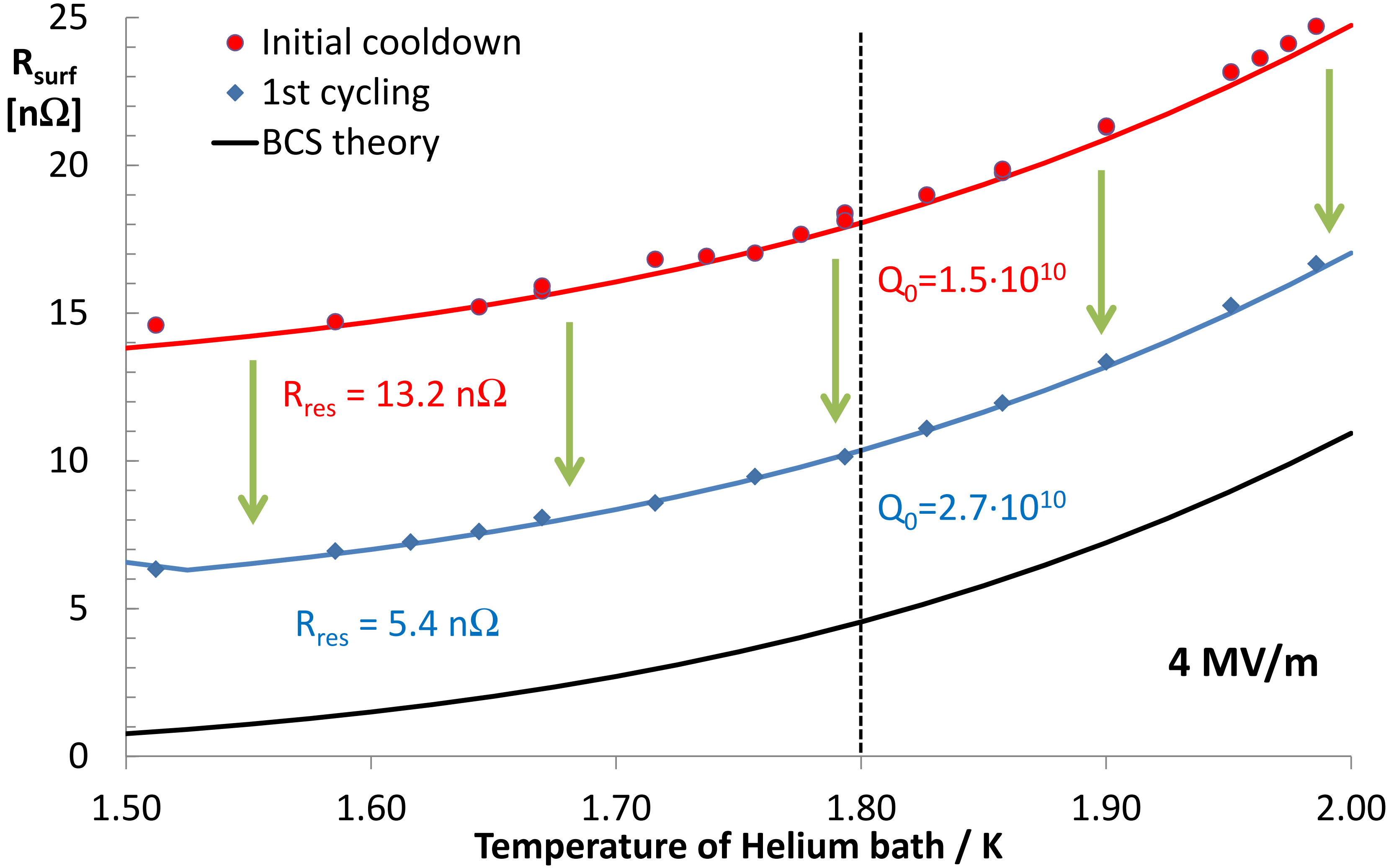
Thermal cycling procedure

- Start with superconducting cavity
- Turn off Helium supply (JT valve)
- Evaporate Helium in tank
- Wait. Make sure cavity is just above T_c and normal conducting.
- Restart cryo plant

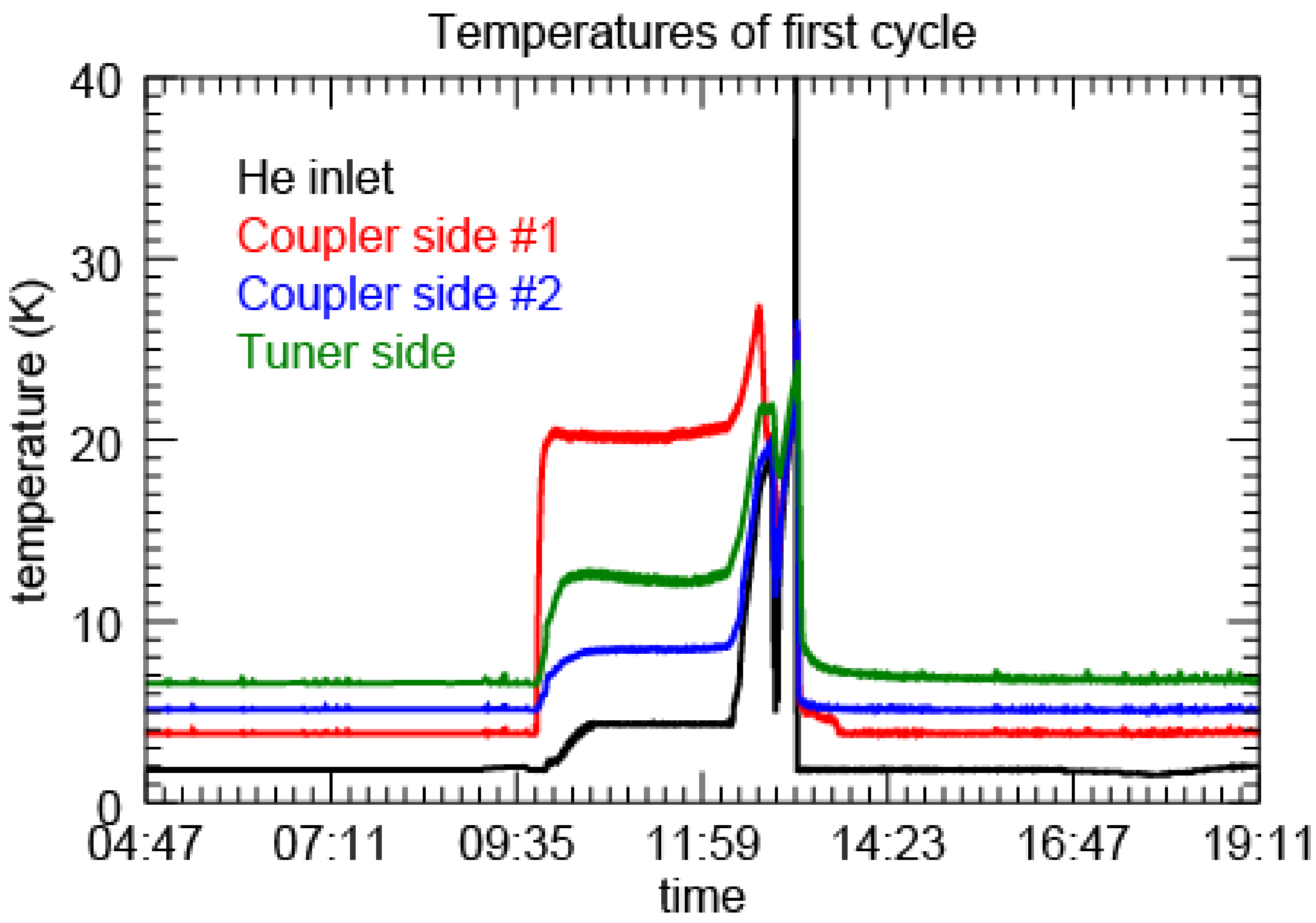




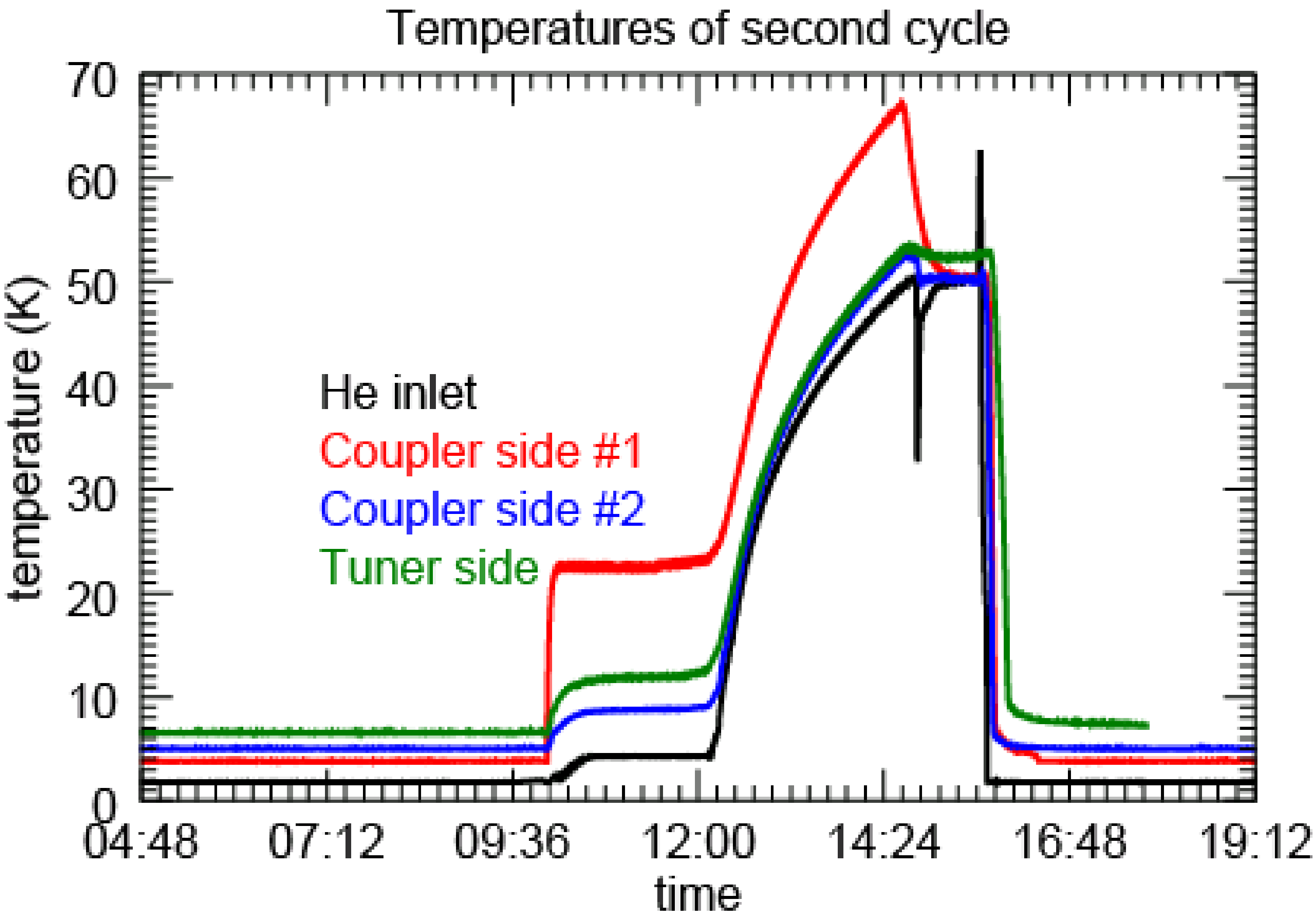
Influence of thermal cycling on R_{surf}



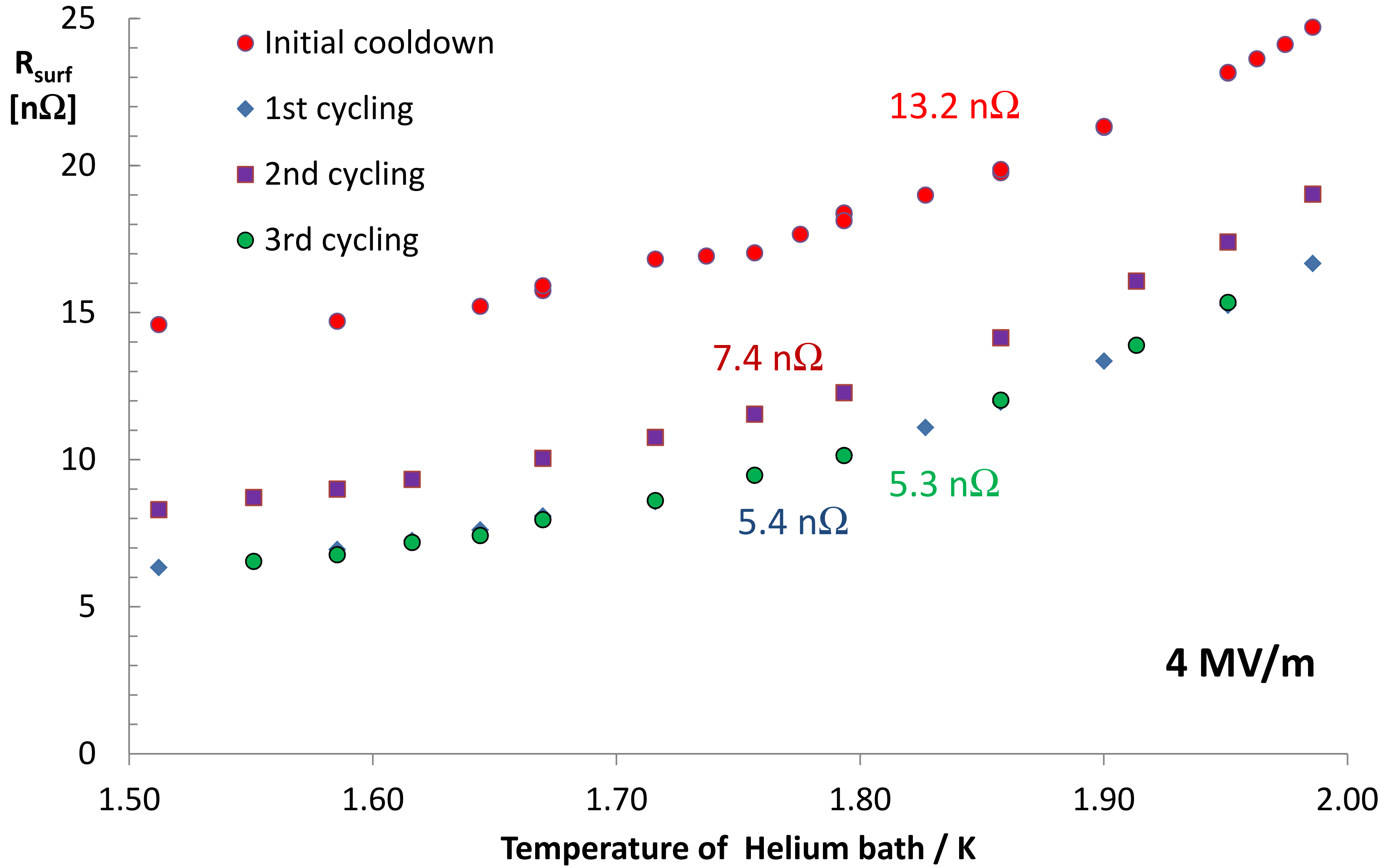
Effect reversible ?



Effect reversible ?



Influence of thermal cycling on R_{surf}



Discussion: Reason for R_{res} variation

R_{res} development: $\underbrace{13.2\ \mathrm{n}\Omega \rightarrow 5.4\ \mathrm{n}\Omega}_{\text{decrease}} \underbrace{\rightarrow 7.4\mathrm{n}\Omega}_{\text{increase}} \underbrace{\rightarrow 5.3\ \mathrm{n}\Omega}_{\text{decrease}}$

Cycling leads to decrease … increase … decrease

- Efficacy of magnetic shielding?
  No! Permeability measurements of shield yielded no temperature dependance in relevant region AND
  R_{res} increase should not be possible

- Chemistry? Adsorbate removal?
  No! R_{res} increase should not be possible.

- But! Increase could have been caused by Q-disease in heavier cycling run.
  No! Subsequent R_{res} decrease should not be possible.

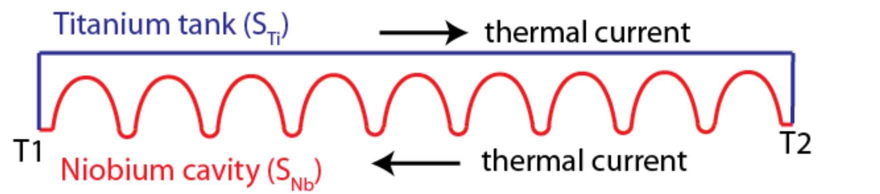
- Thermocurrents due to temperature gradients
  Possible. Performed measurements in model system

Thermocurrents

Thermoelectric effect:
Voltage due to material and temperature dependent charge carrier velocity

$$U_{thermo} = (S_{Niobium} - S_{Titanium}) \cdot \Delta T$$

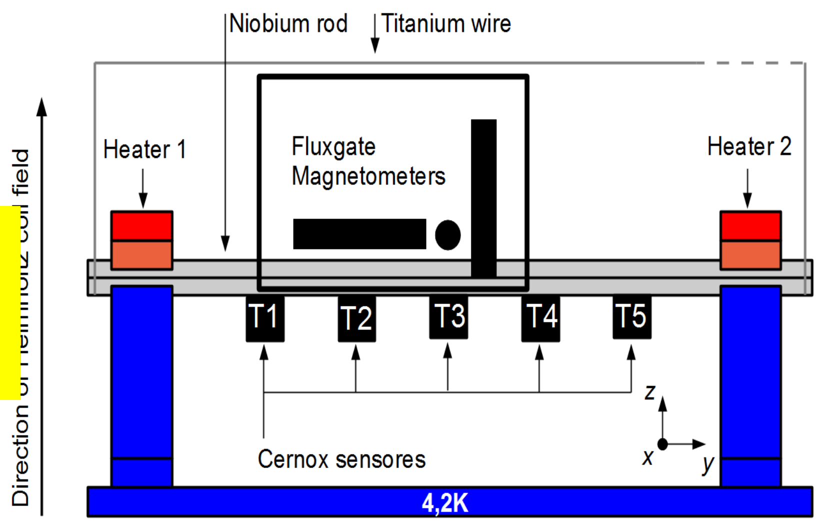
S are Seebeck coefficients

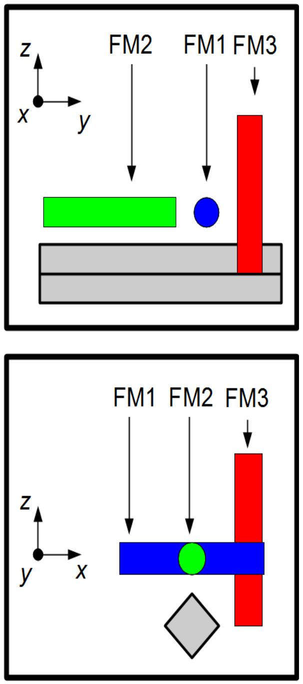


Cavity-tank system as „thermoelement“
Close circuit to obtain thermocurrent.

Set up model experiment

Master thesis Julia Vogt, see poster WEPWO004 for further details



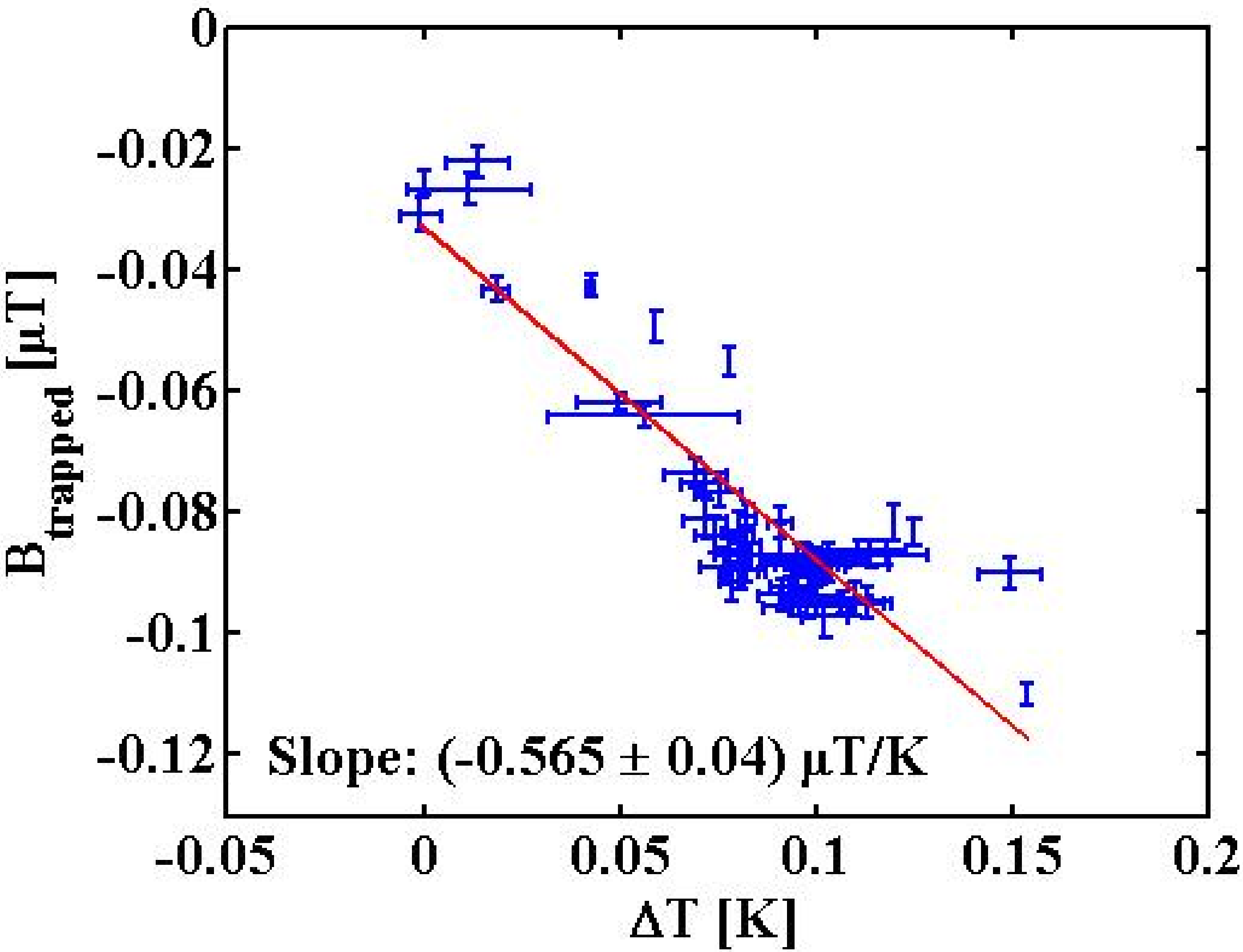


Trapped flux and temperature gradient

Findings:

- Thermocurrents could be measured (mA range)
- Thermocurrents create a magnetic field and this field can be trapped as frozen flux
- Linear correlation between trapped flux and temperature gradient

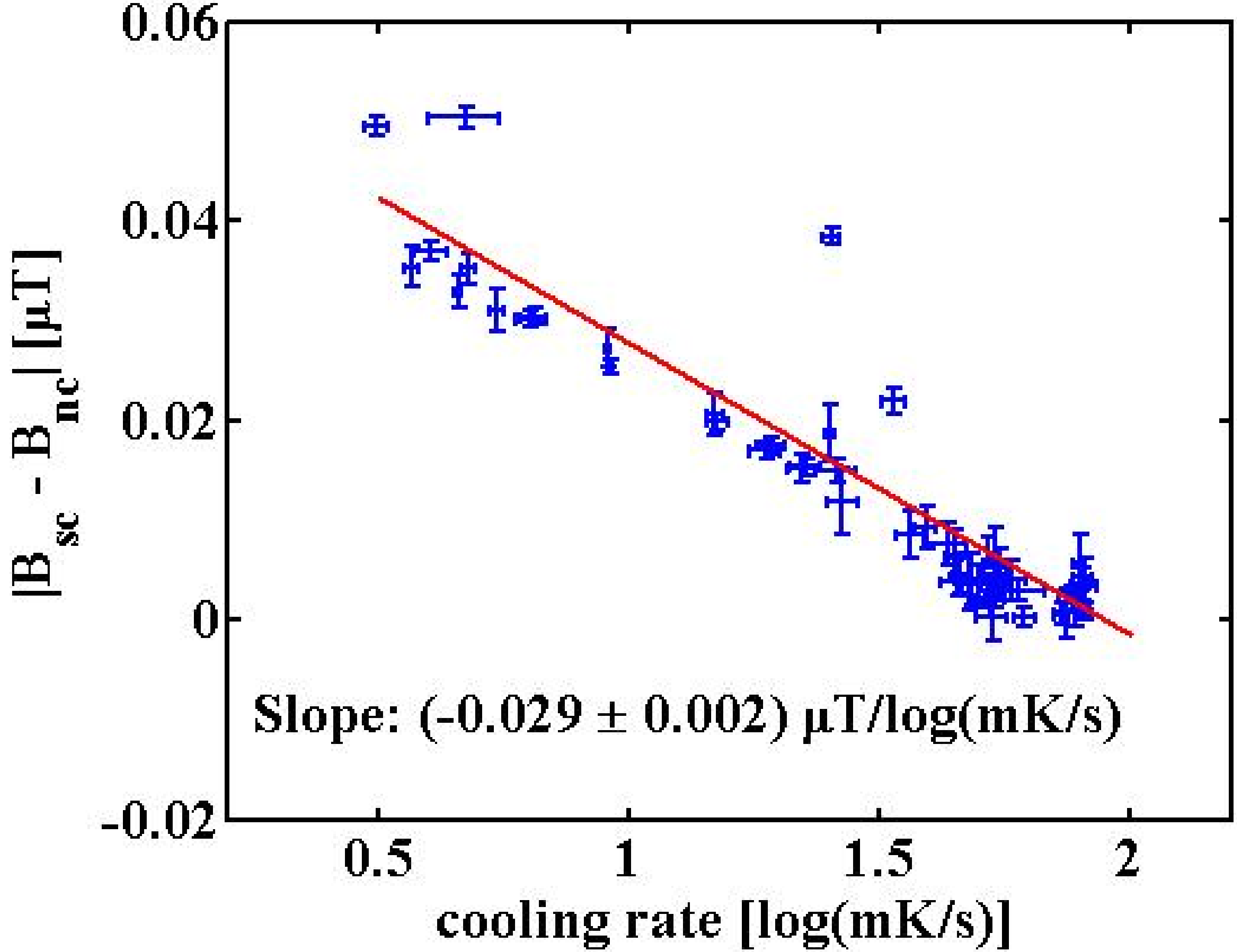
Trapped flux and temperature gradient



Flux expulsion at different cooling rates

Measurement: Keep rod isothermal and cool through Tc
Logarithmic dependence of expelled flux from cooling rate

Flux expulsion at different cooling rates



Flux expulsion at different cooling rates

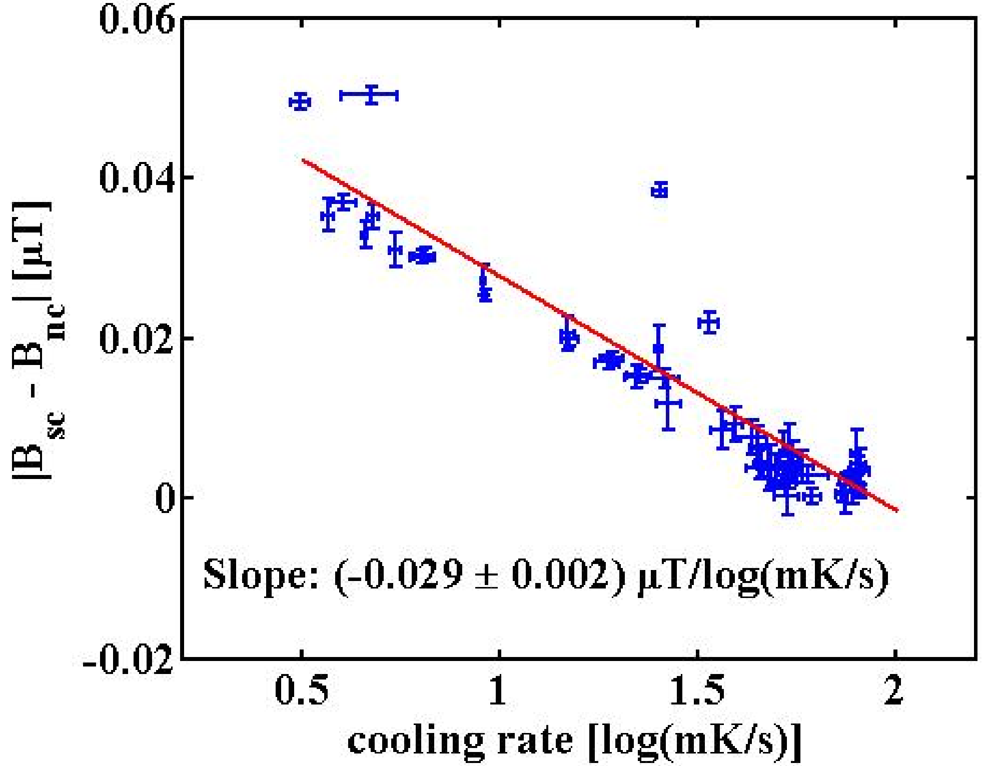
Measurement: Keep rod isothermal and cool through Tc
Logarithmic dependence of expelled flux from cooling rate

Interpretation:
- Meissner state = energetically lowest state

- Flux expulsion not instantaneous (unlike Meissner transition)

- Mobility of flux lines highest near T_c

- The less time is available in the high mobility region, the less field is expelled from the sc



Conclusion

- Improve Q_0 by thermal cycling
- Factor of 2 improvement is demonstrated
- It appears that thermal currents are responsible for extra flux trapping

Acknowledgement

- Julia Vogt (Master thesis on flux dynamics)
- Sarah Aull (Diploma thesis on trapped flux)
- Jens Knobloch
- Michael Schuster, Sascha Klauke, Andre Frahm, Dirk Pflückhahn, Stefan Rotterdam (Experimental support)
- Hans-Peter Vogel, Research Instruments (for providing Niobium rod)