INFLUENCE OF THE COOLDOWN AT THE TRANSITION TEMPERATURE ON THE SRF CAVITY QUALITY FACTOR

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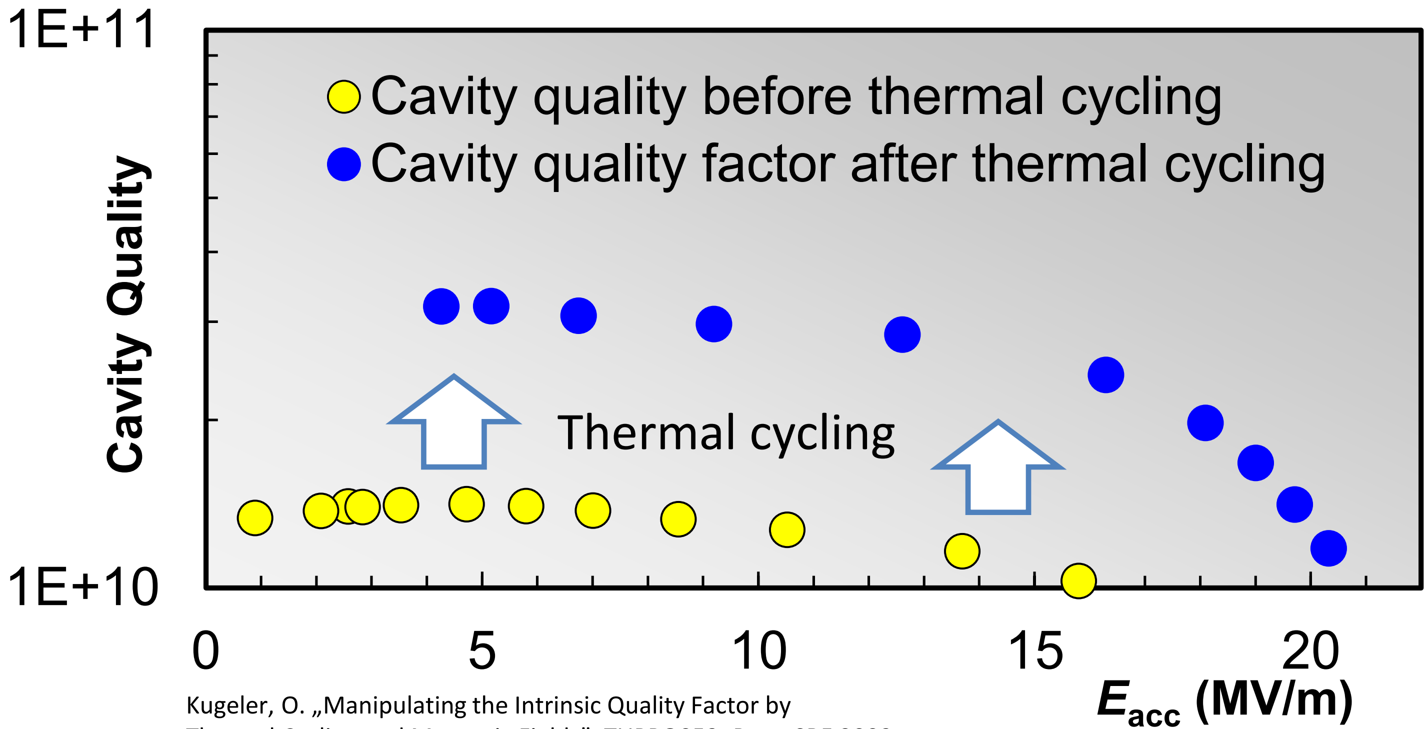
Introduction

- Many new accelerator applications require CW SRF. Focus shifts to dynamic losses.
- Cryogenics = cost driver
- Minimize cryogenic load $P_{diss} \sim R_{surf} E_{acc}^{2}$
  - Want low surface resistance at moderate gradients
- $R_{surface} = \underbrace{R_{BCS}(f,T)}_{\text{physics}} + \underbrace{R_{residual}(?)}_{\text{originates to great fraction from trapped vortices (incomplete Meissner effect)}}$
- We found that cavity cooldown procedures have an impact on R_{res}
  - presumably due to the generation of additional flux from thermo currents

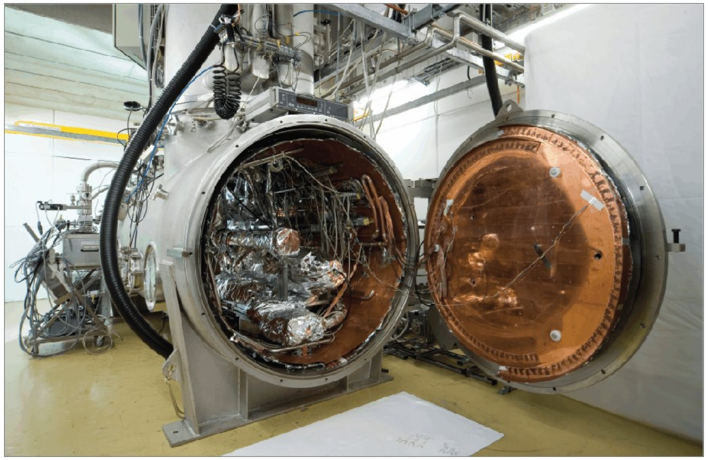
Flashback to SRF 2009



Kugeler, O. „Manipulating the Intrinsic Quality Factor by Thermal Cycling and Magnetic Fields", TUPPO053, Proc. SRF 2009

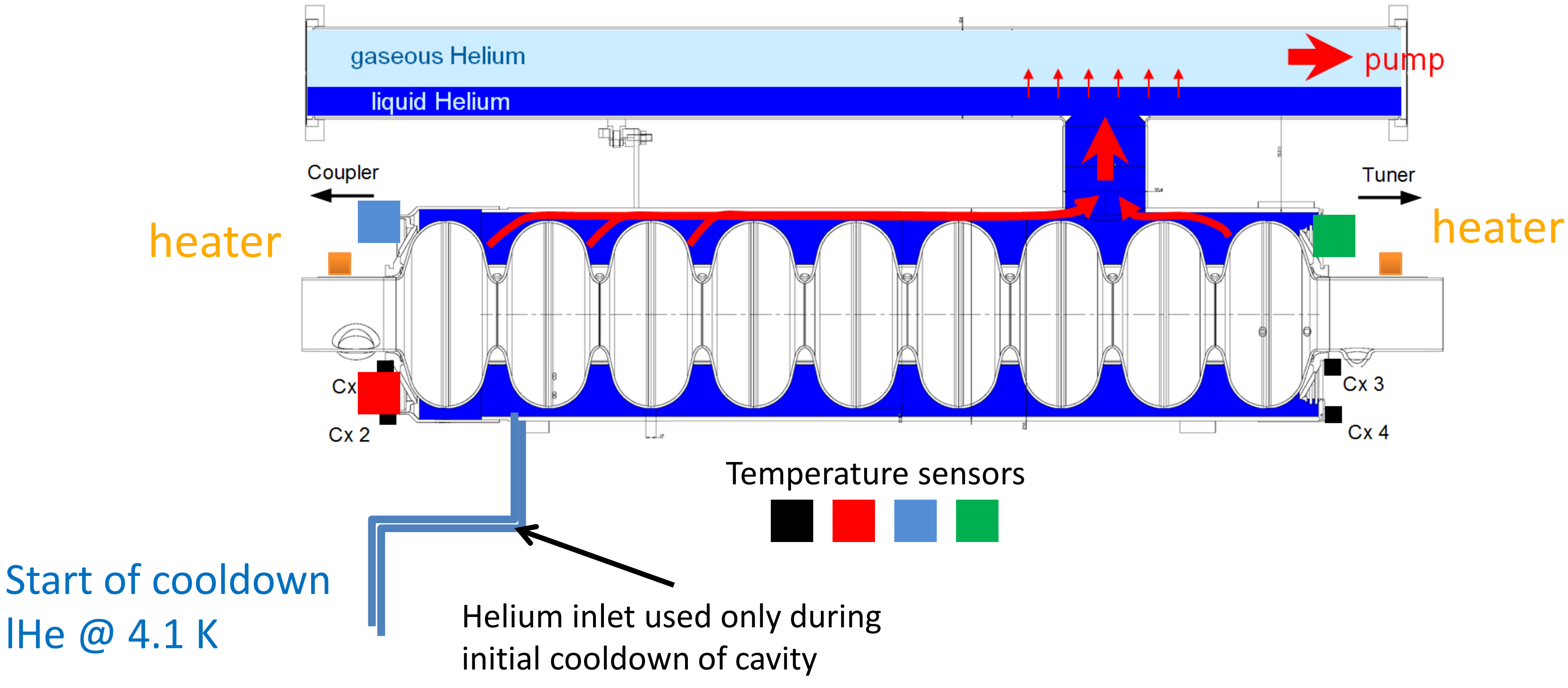
- Measured Q increase upon "thermal cycling" to about 40 K
- Effect not understood back then. New investigations have yielded an explanation: thermocurrents

Q_0 vs T measurements



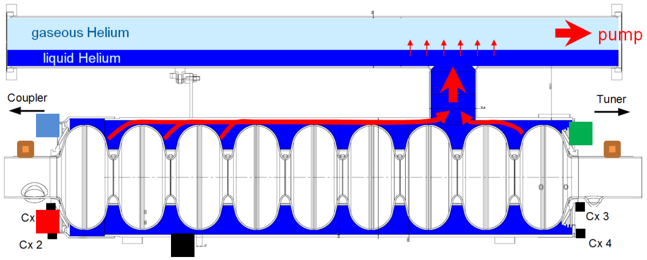
- HoBiCaT test facility used
- Horizontal, fully equipped industrial cavity welded into Helium tank
- Configuration like in accelerator module
- Temperatures down to 1.5 K
- All measurement done with one cavity in one measurement run!
- Double magnetic shielding (warm shield + cryoperm)
  Small residual fields < 1 µT
- TTF-III coupler, near critical coupling ($0.8 < \beta < 2.5$)
- Verification of RF measurements with LHe-loss measurements and Lorentz detuning
  Error assumed smaller than 10%

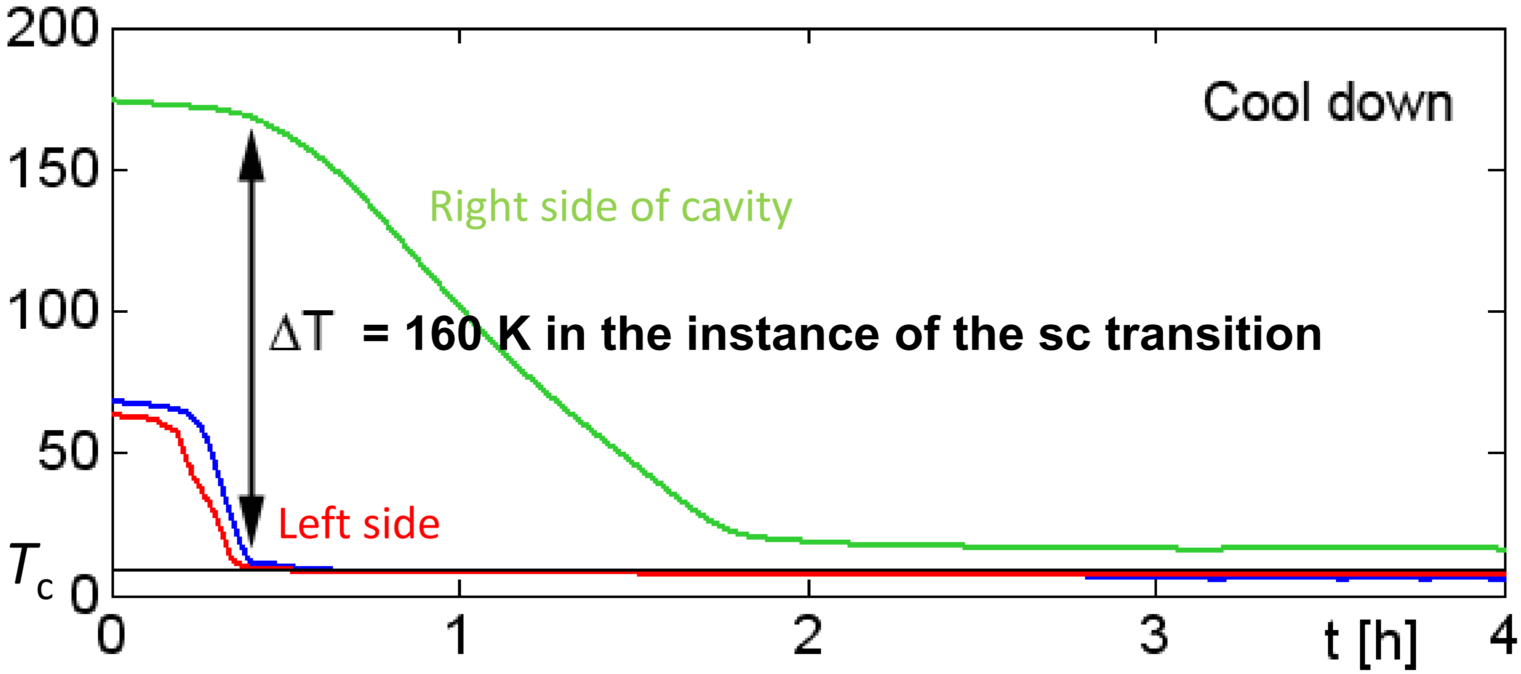
Cavity cooldown procedure



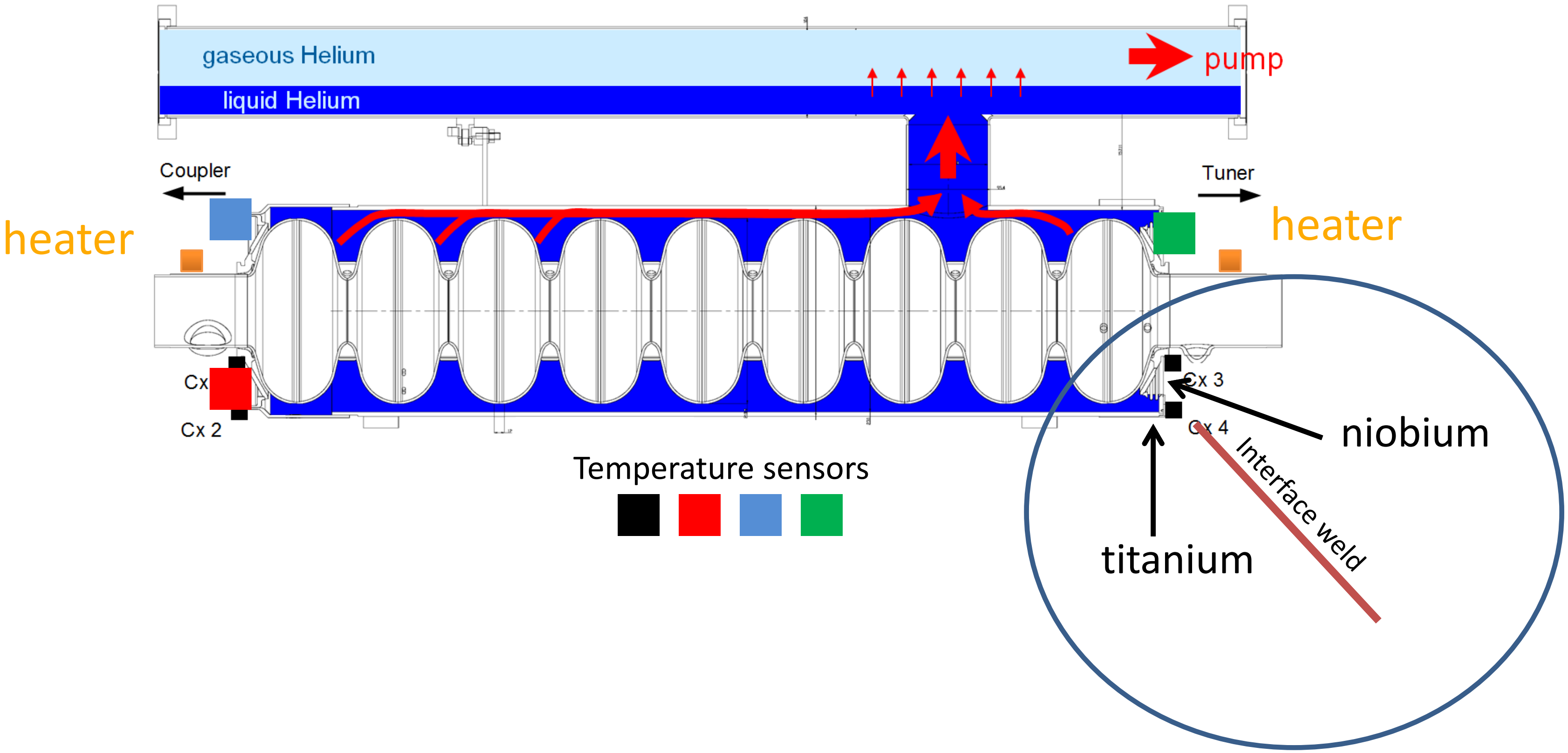
Dynamics of Helium filling leads to large temperature gradients

Initial cool down



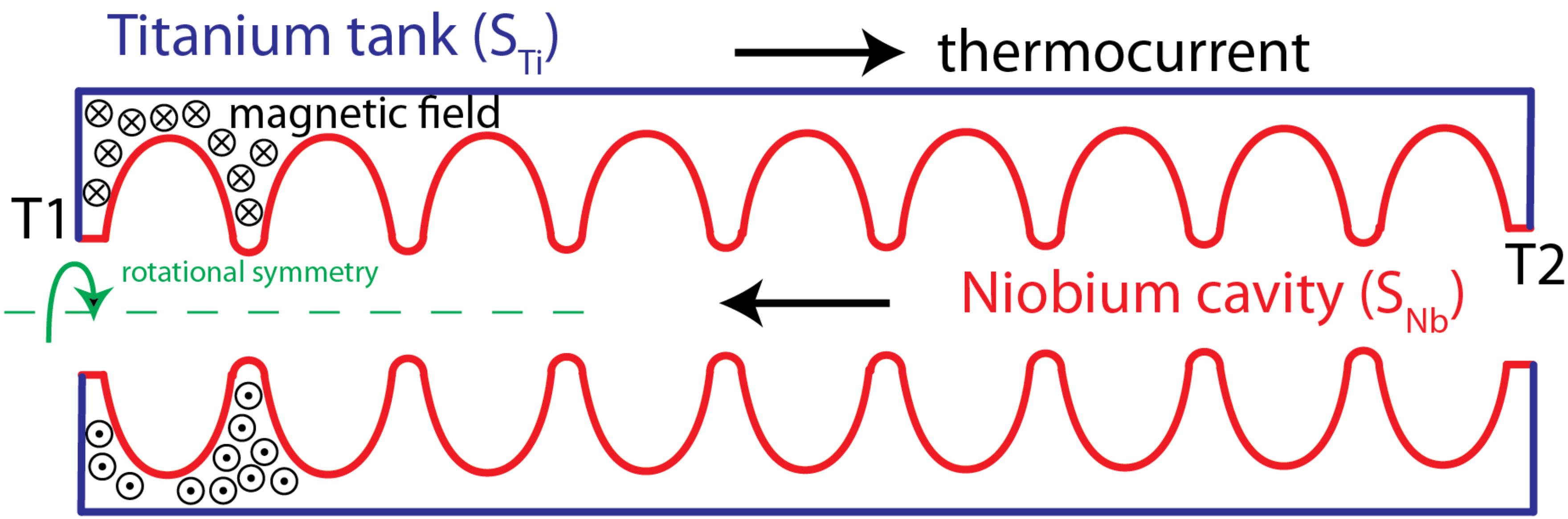


Materials interfaces in cavity with tank



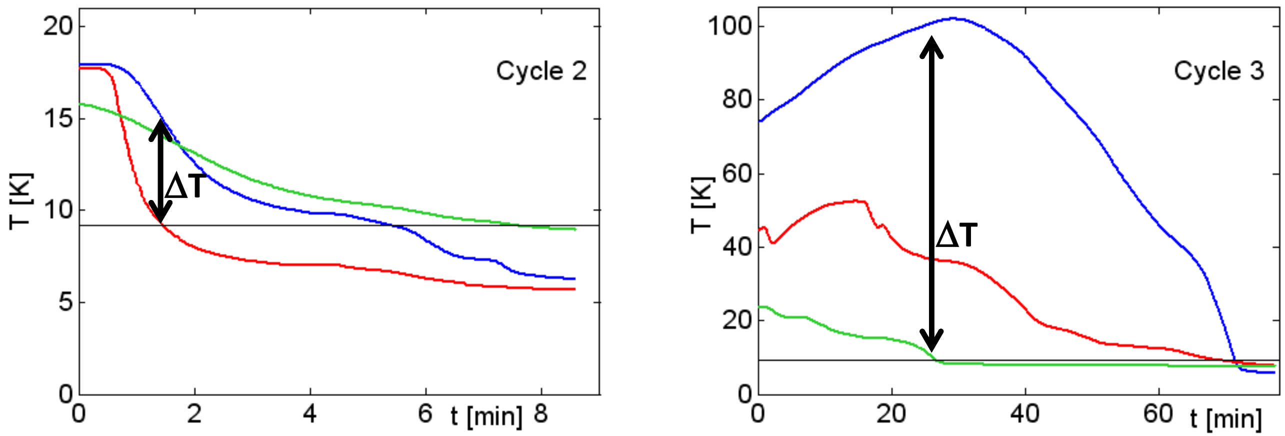
Thermocurrents

- Cavity forms thermoelement
- Different Seebeck coefficients for Nb and Ti

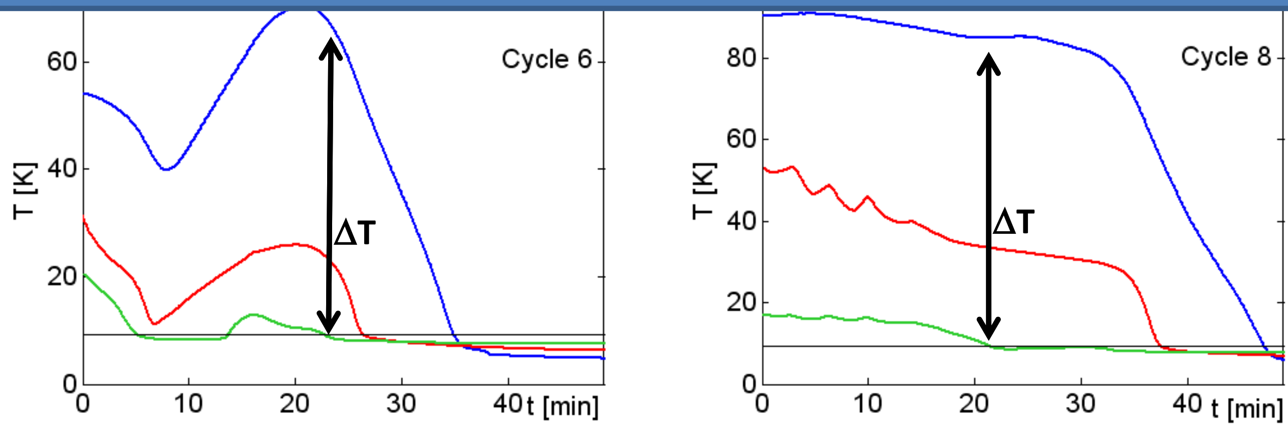


$$U_{thermo} = (S_{Niobium} - S_{Titanium}) \cdot \Delta T$$

Cycling temperature profiles

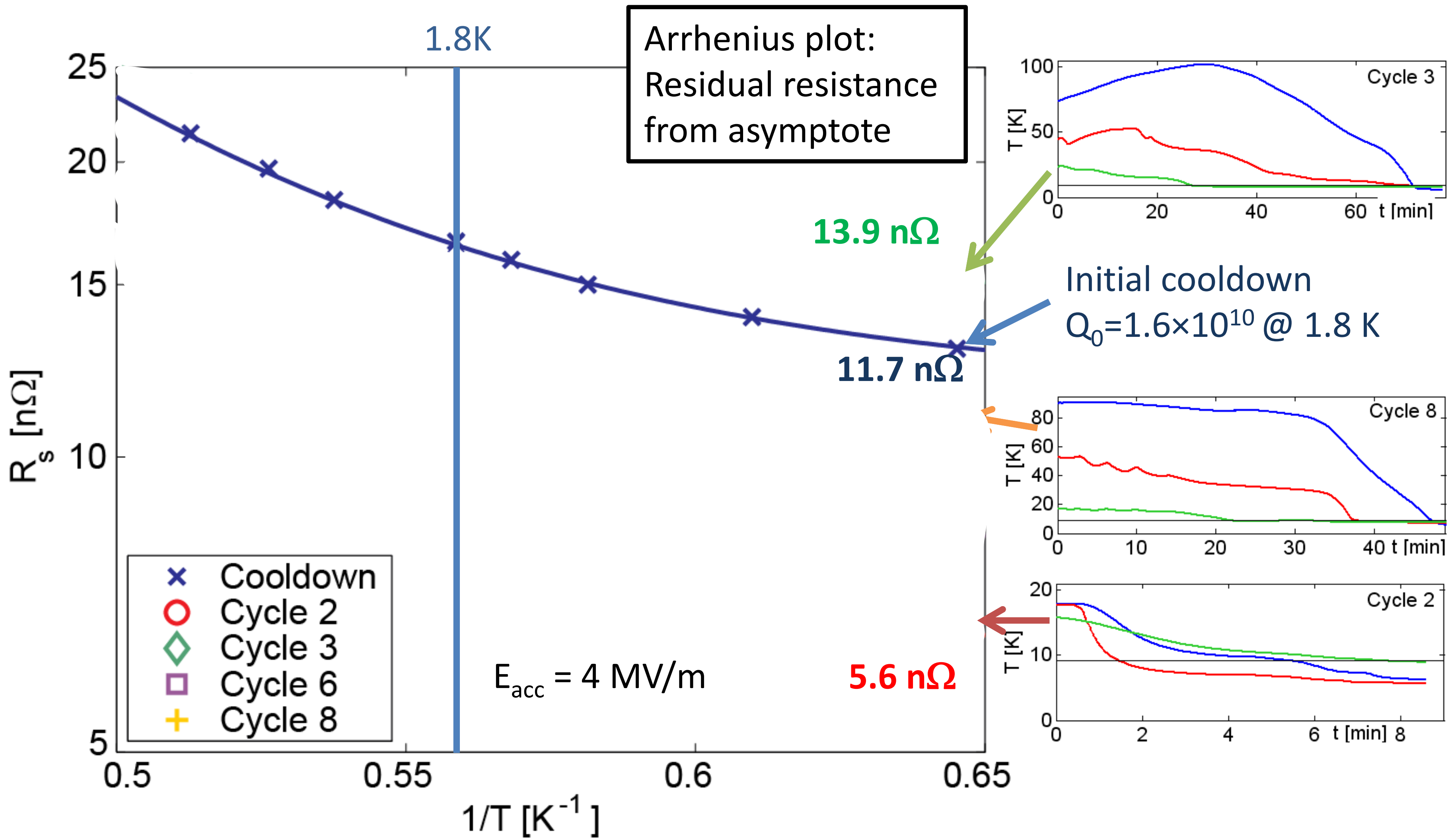


Temperature difference between cavity ends when one end is making transition

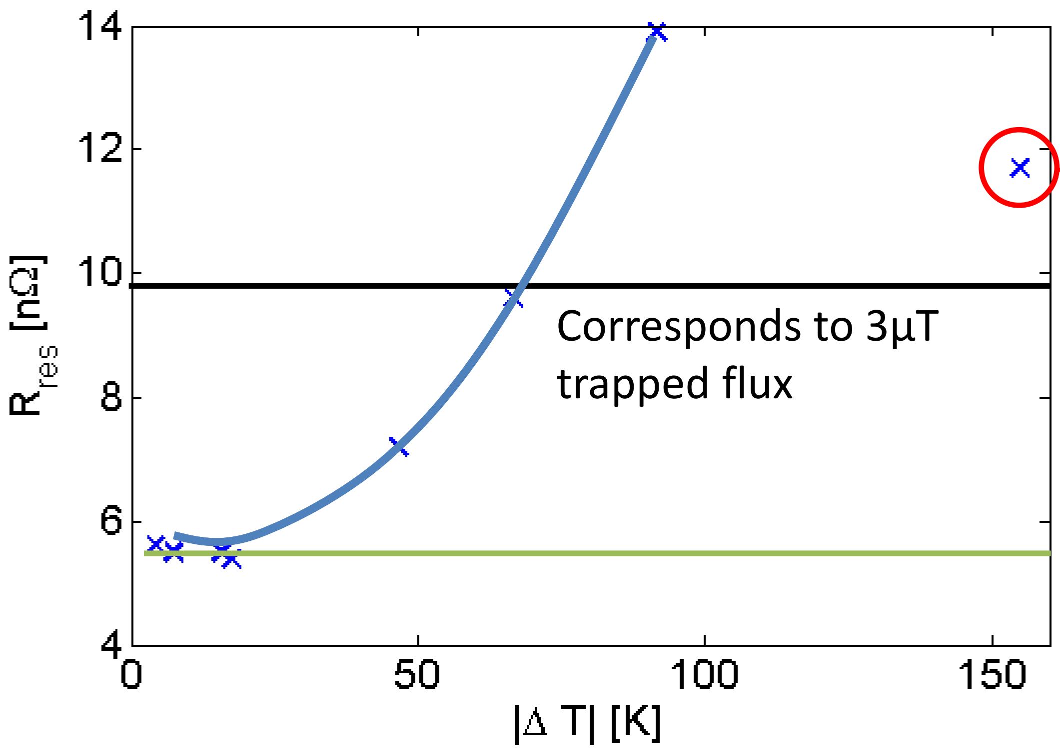


Generated temperature differences between 5 K and 90 K

Surface resistance measurements



Results



Clear increase of R_{res} with ΔT

Initial cool down (very different temperature profile due to LHe filling from bottom)
→ difficult to "compare apples with oranges"

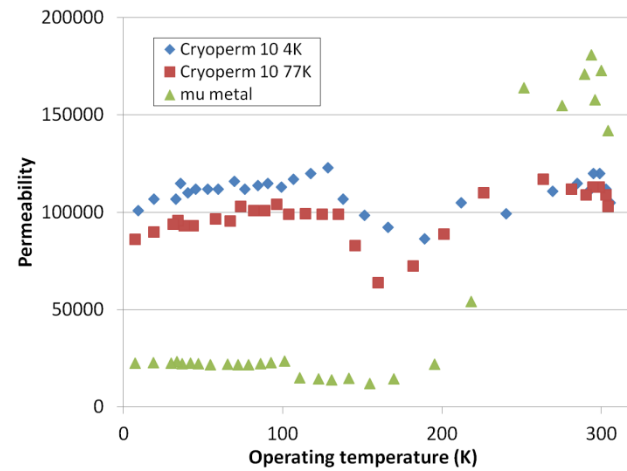
Lowest limit achieved
Residual resistance due to other mechanisms or ambient magnetic field

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

U_{thermo} drives thermocurrent and thus generates extra ambient field

Discarded reasons for R_{res} variation

Hypothetical reasons for the improvement of R_{res}	Not the reason here because
surface morphology	same cavity
RRR	
crystallinity, granularity	
total hydrogen content	
systematic differences	measurement taken in same run
calibration errors	
magnetic shielding efficacy	shield μ_r constant
adsorbate removal	process irreversible
Q-disease	never leads to decrease of R_{res}



Chronological order of measurements

Procedure	R_{res} (nΩ)	ΔR_{res}	ΔT
Cooldown	**11.7**		**150**
Cycle 1	*6*	*decrease*	*~5.5*
Cycle 2	**5.6**	**decrease**	**~5.5**
Cycle 3	**13.9**	**increase**	**90**
Cycle 4	*5.4*	*decrease*	*~5.5*
Cycle 5	*5.5*	*increase*	*~5.5*
Cycle 6	**7.2**	**increase**	**45**
Cycle 7	*5.5*	*decrease*	*~5.5*
Cycle 8	**9.6**	**increase**	**67**

Change in R_{res} reversible

Conclusion and outlook

- Improve residual resistance by thermal cycling
- Factor of 2 improvement and reduction is demonstrated depending on cycling conditions.
- Thermocurrents most plausible explanation as a source of additional magn. flux that is trapped during the SC transition.
- Implement additional step in standard cavity cooldown procedure.
  - Pause cooldown a little above T_c long enough to reach thermal equilibrium (presumably > 12 hours)
  - Alternatively, introduce additional short thermal cycle above T_c.
- Implemented in HoBiCaT procedure, but cryoplant currently down so that tests have not yet been possible.