Effect of cool down rate in cryomodules on cavities Q

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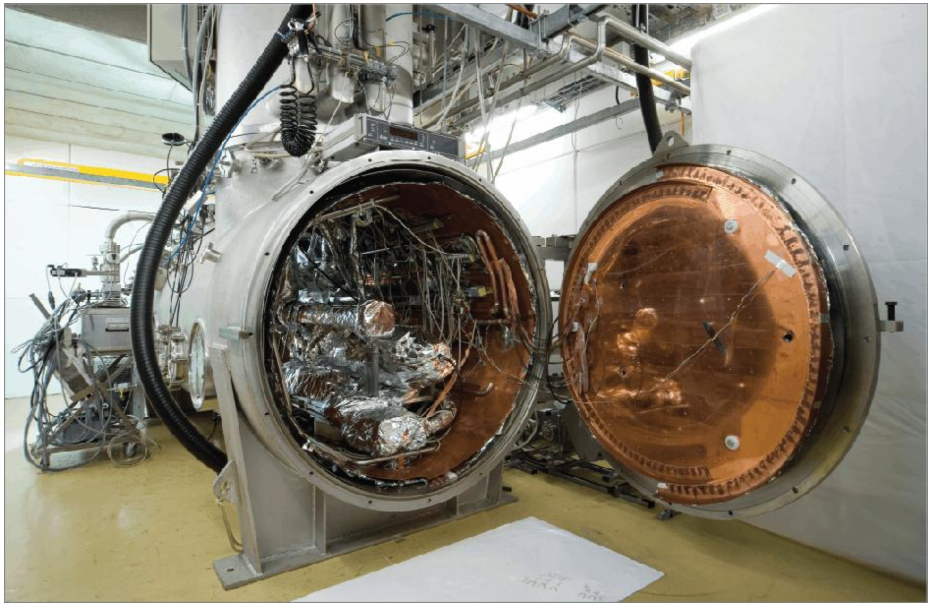
650 MHz meeting, July 30 2013

Introduction

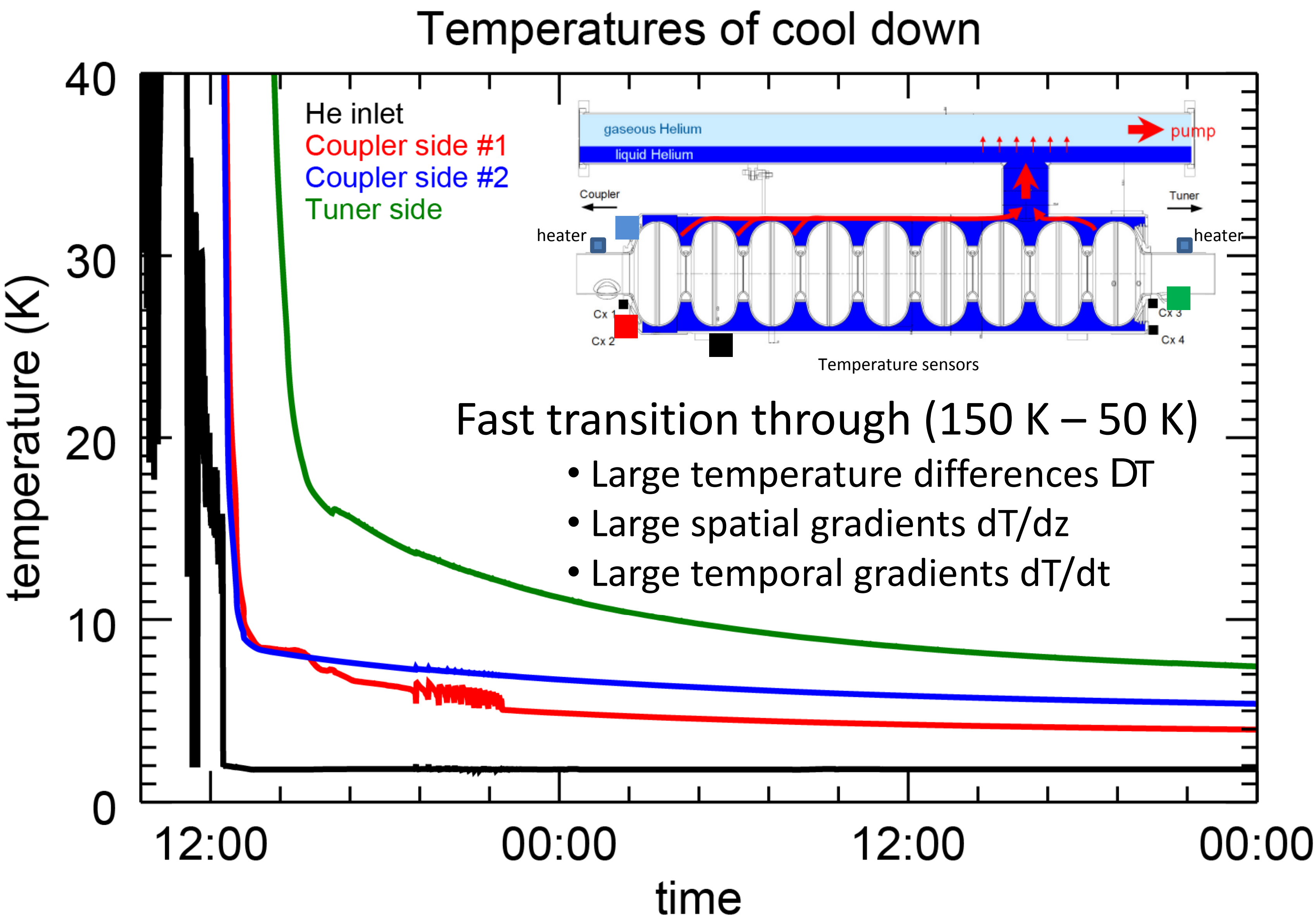
- For CW operation cryogenics is a cost driver
- Minimize cryogenic load $P_{diss} \sim R_s \sim 1/Q$
- $R_s = R_{BCS}(f,T) + R_0$
- One of the R_0 contributions is 'trapped magnetic flux', which can be substantial if there are thermocurrents generating a magnetic field, which gets trapped during cooldown through T_c

Q_0 measurements

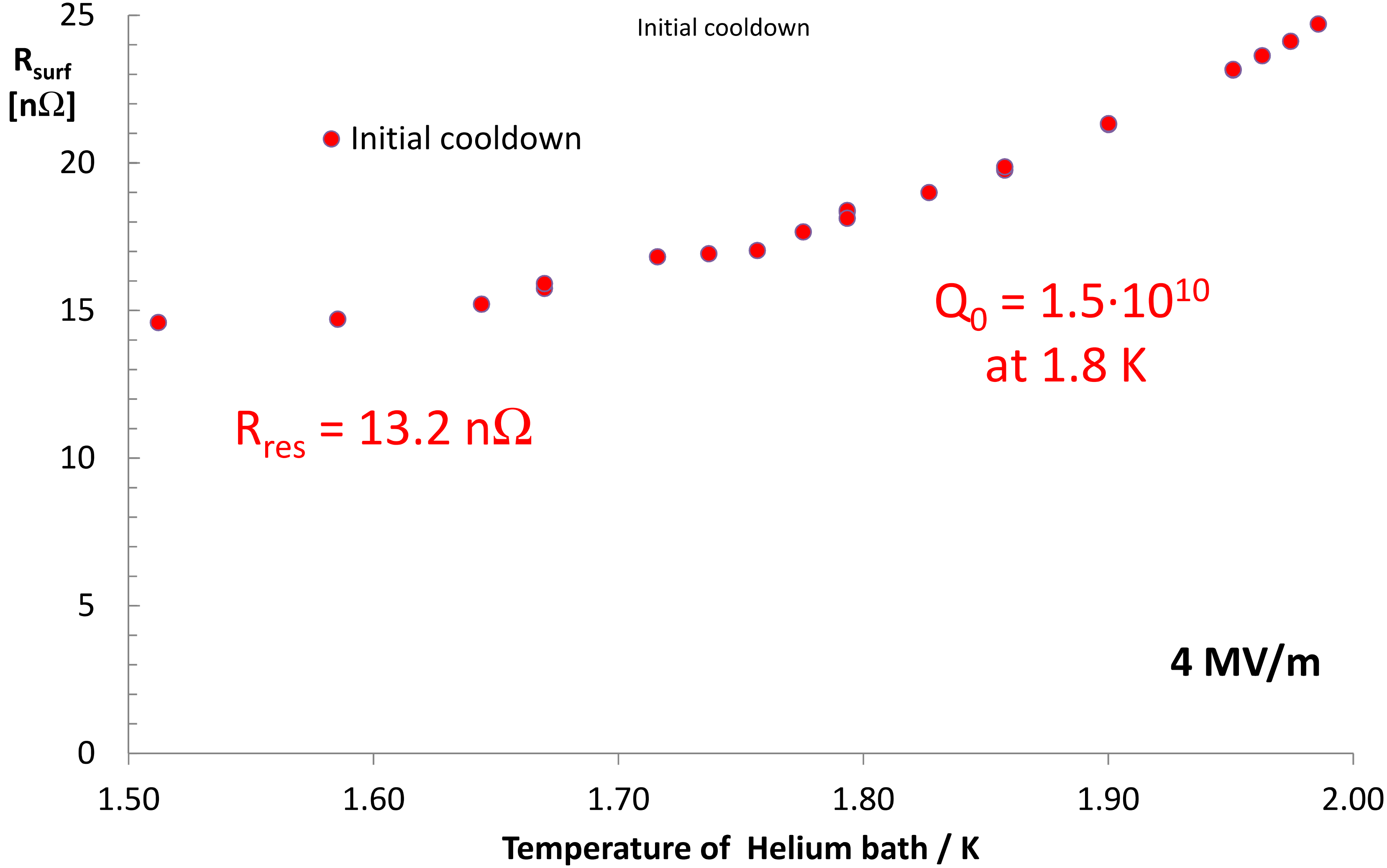
- HoBiCaT test facility
- Temperatures down to 1.5 K
- Horizontal, fully equipped cavity weld into Helium tank
- Near b=1



Cavity cool down procedure

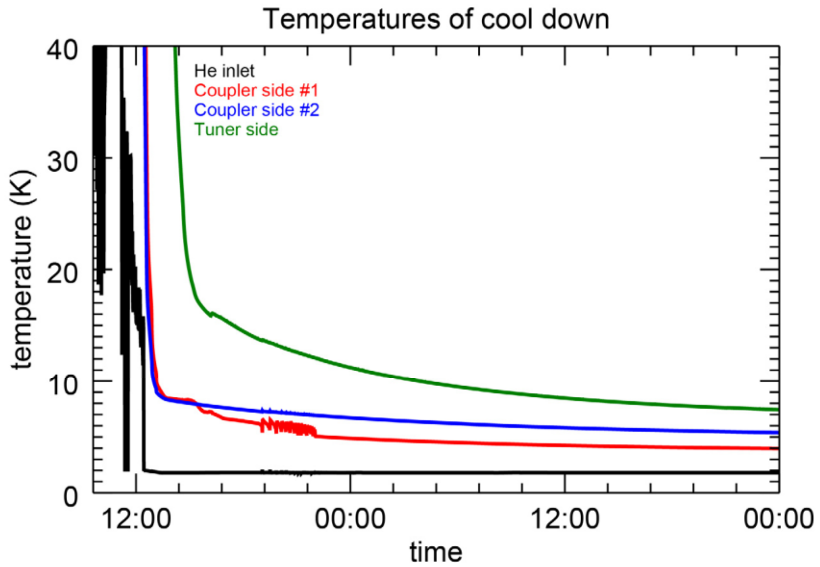


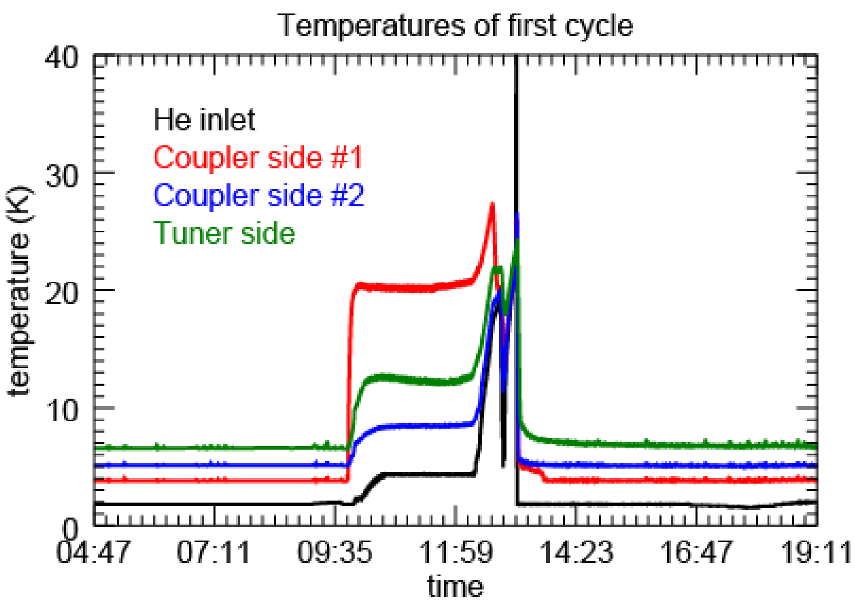
R_{surf} after initial cooldown



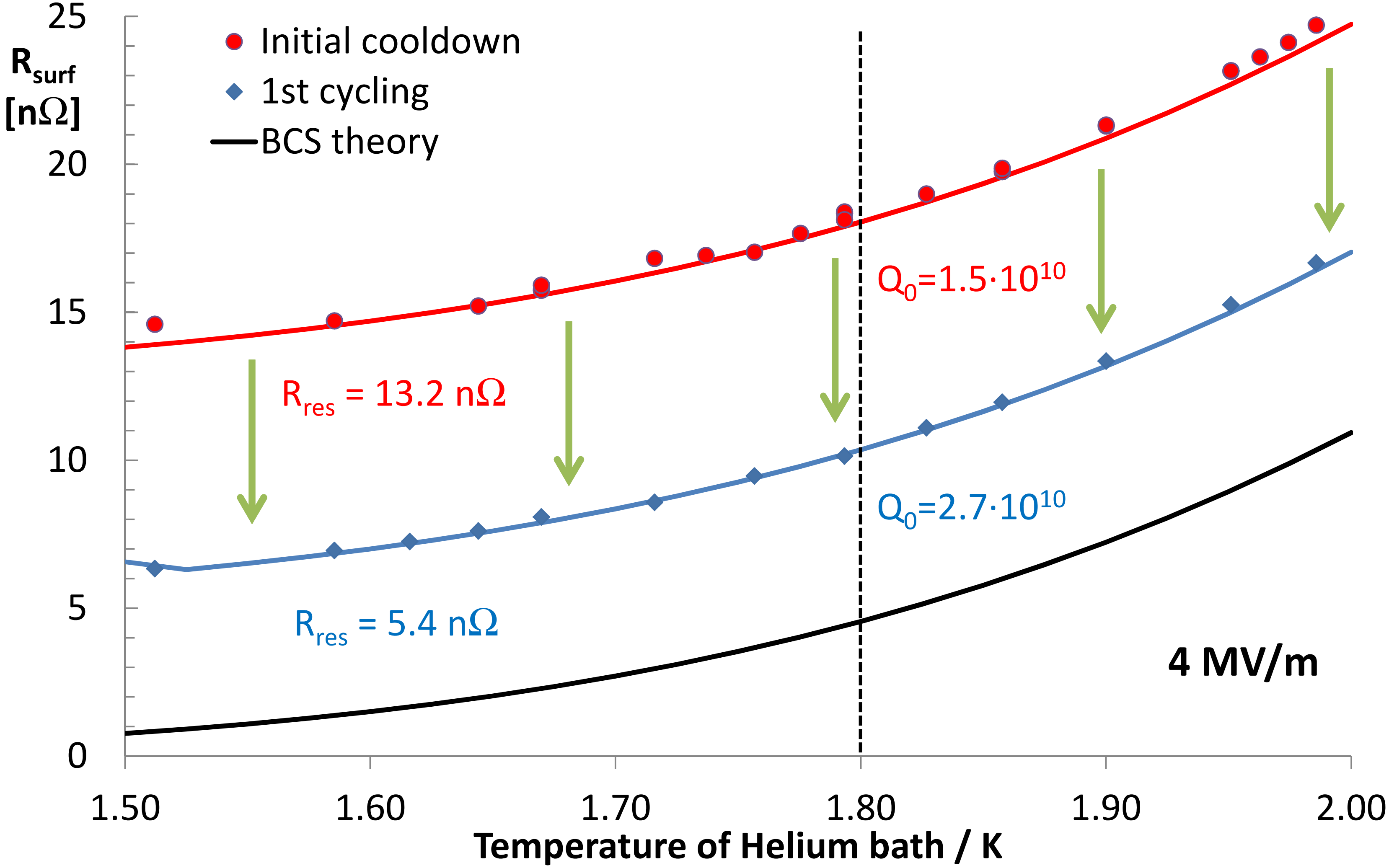
Thermal cycling procedure

- 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



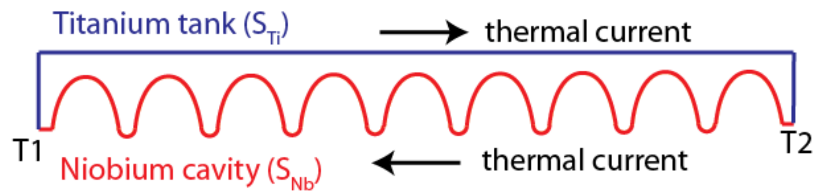


Influence of thermal cycling on R_{surf}



Thermocurrents

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



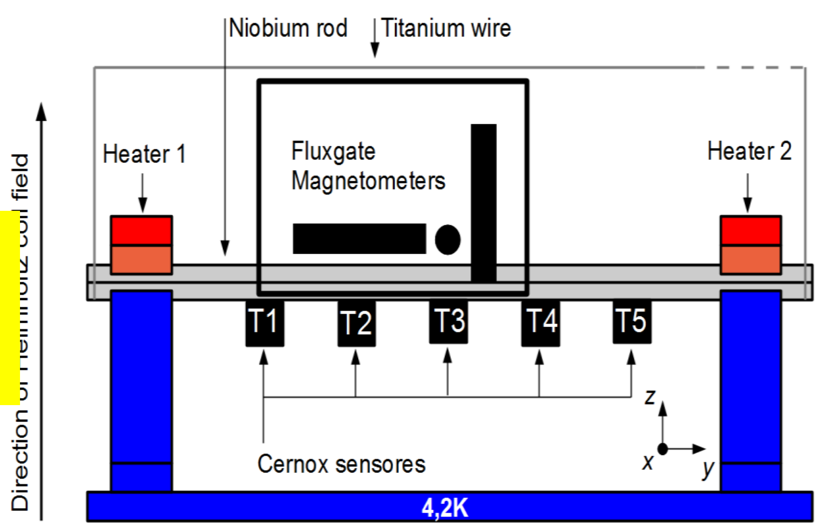
Cavity-tank system as „thermoelement"
Close circuit to obtain thermocurrent.

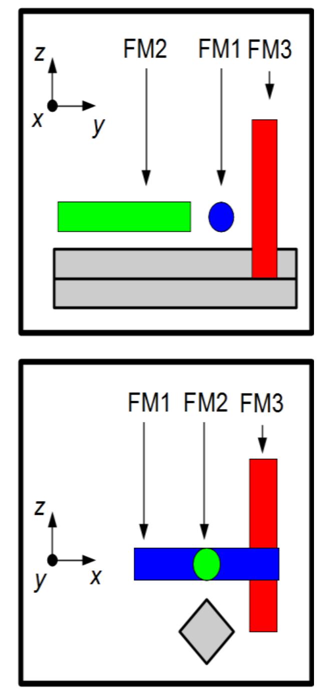
$$U_{thermo} = (S_{Niobium} - S_{Titanium}) \cdot \Delta T$$

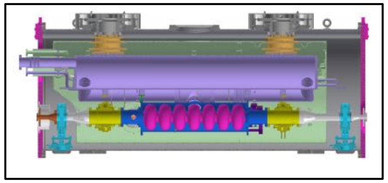
S are Seebeck coefficients

Set up model experiment

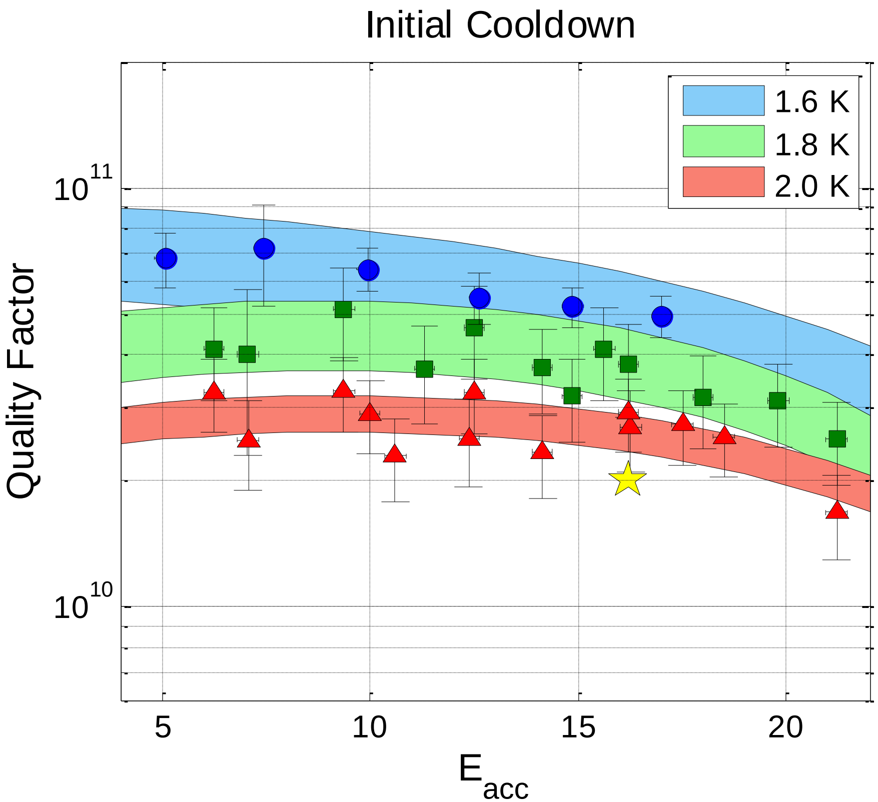
Master thesis Julia Vogt,
see poster WEPWO004
for further details

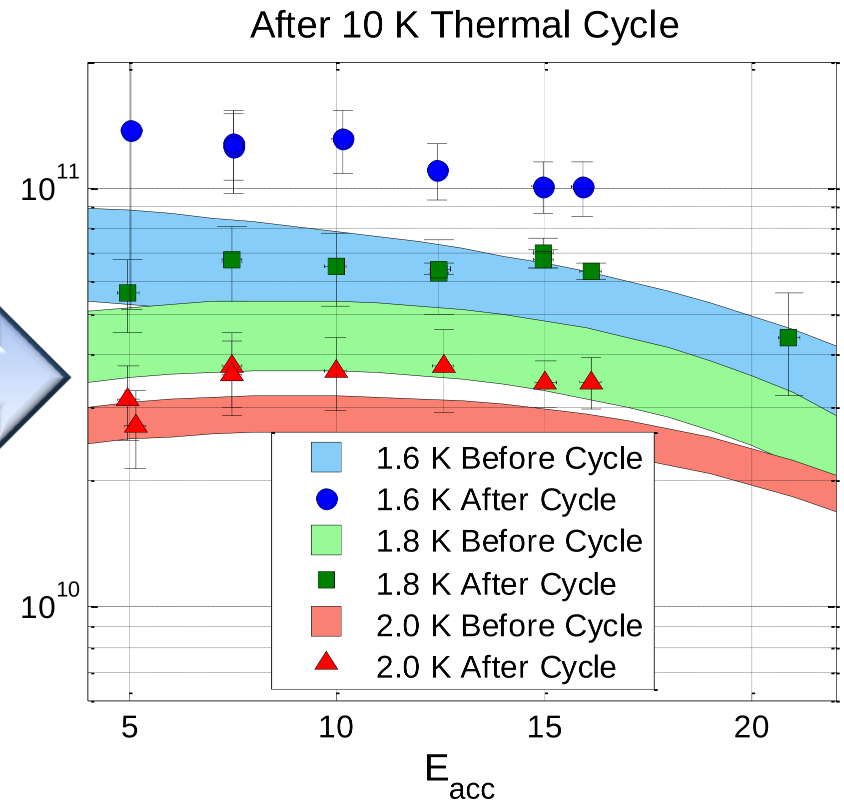






HTC-3: Results





Initial Cooldown at 16.2 MV/m

$Q(2.0\ K) = 2.5 \times 10^{10}$

$Q(1.8\ K) = 3.5 \times 10^{10}$

$Q(1.6\ K) = 5.0 \times 10^{10}$

10 K thermal cycle at 16.2 MV/m

$Q(2.0\ K) = 3.5 \times 10^{10}$

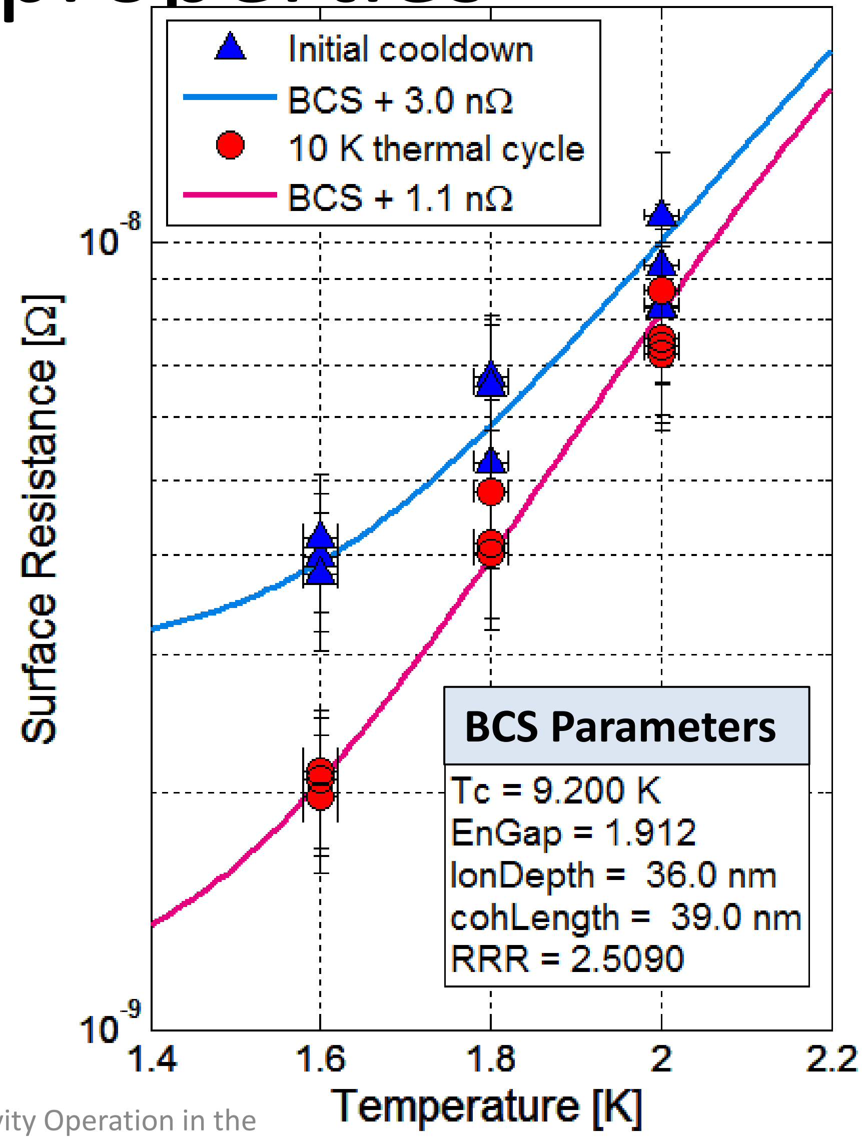
$Q(1.8\ K) = 6.0 \times 10^{10}$

$Q(1.6\ K) = 10.0 \times 10^{10}$

HTC-3: Nb properties

- SRIMP used to fit SRF properties of cavity before and after thermal cycle

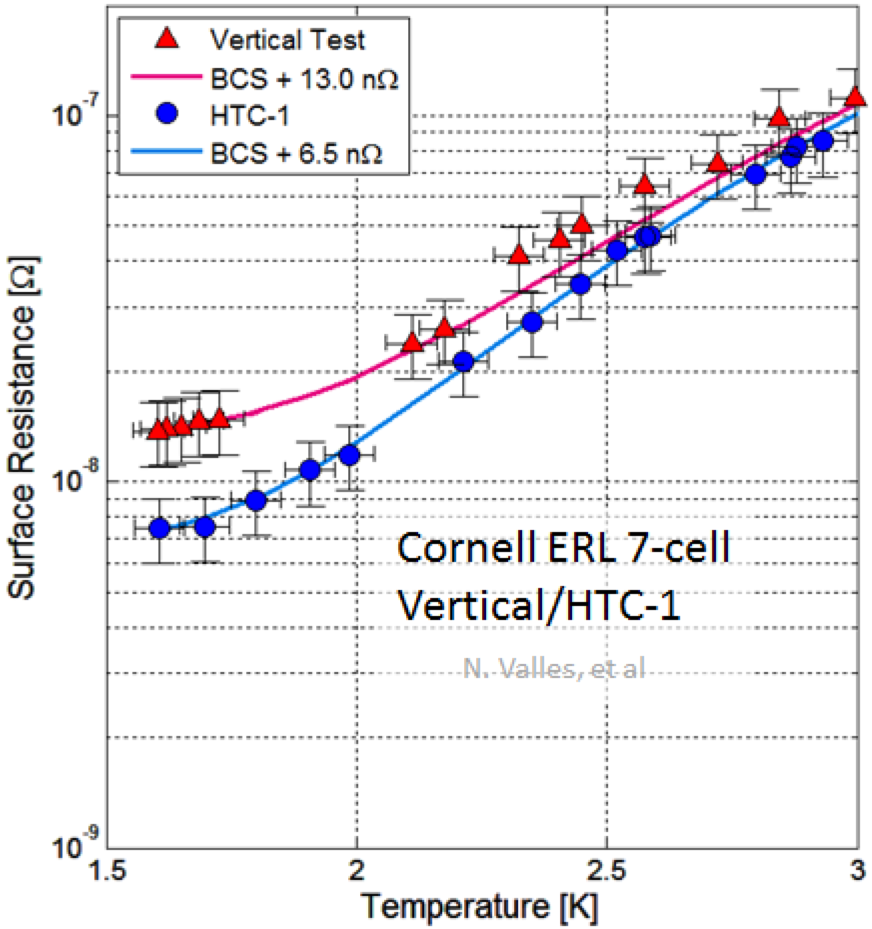
- Assumption: Material properties remain constant during cycle. Only residual resistance changes.



Vertical Test/Horizontal Test

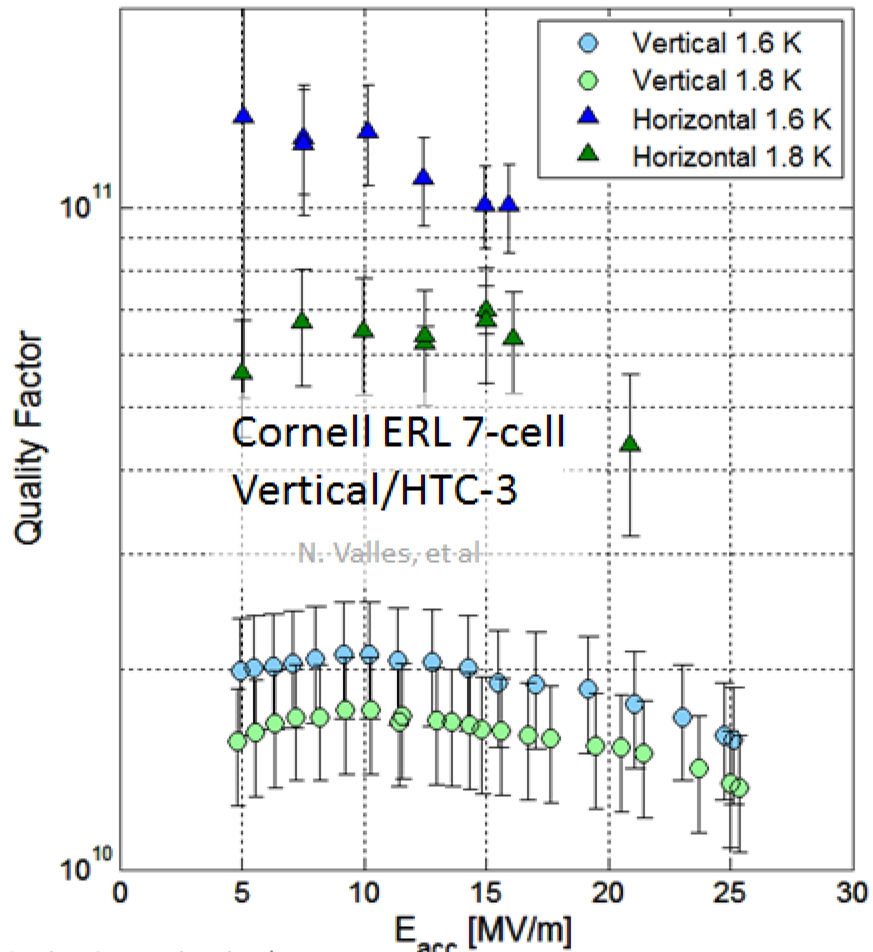
Surface Resistance Comparison

Vertical/HTC-1 Test

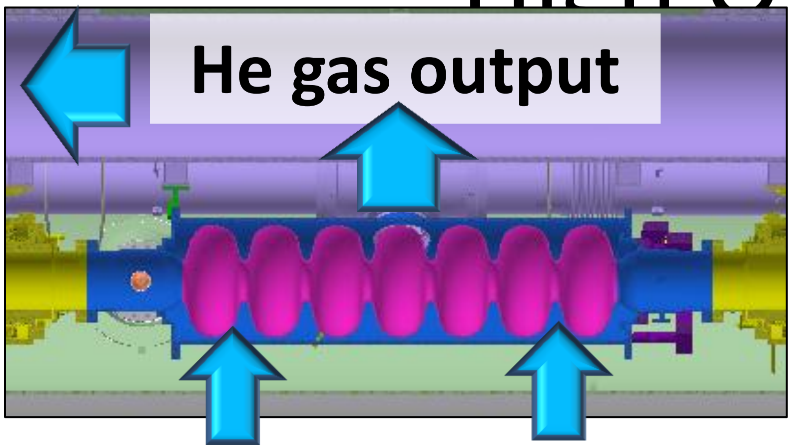


Quality factor vs Gradient

Vertical Test → HTC-3



High Q Cryomodules



- Magnetic shielding is essential
- Thermal gradients across cavity should be minimized to get high Qs
- Cavity temperature gradient ~0.2 K
- Cool down rate through T_c: ~ 0.4 K/hr

6 Cernox temperature sensors mounted on top and bottom of end cells and center cell