High Resolution Surface Resistance Studies

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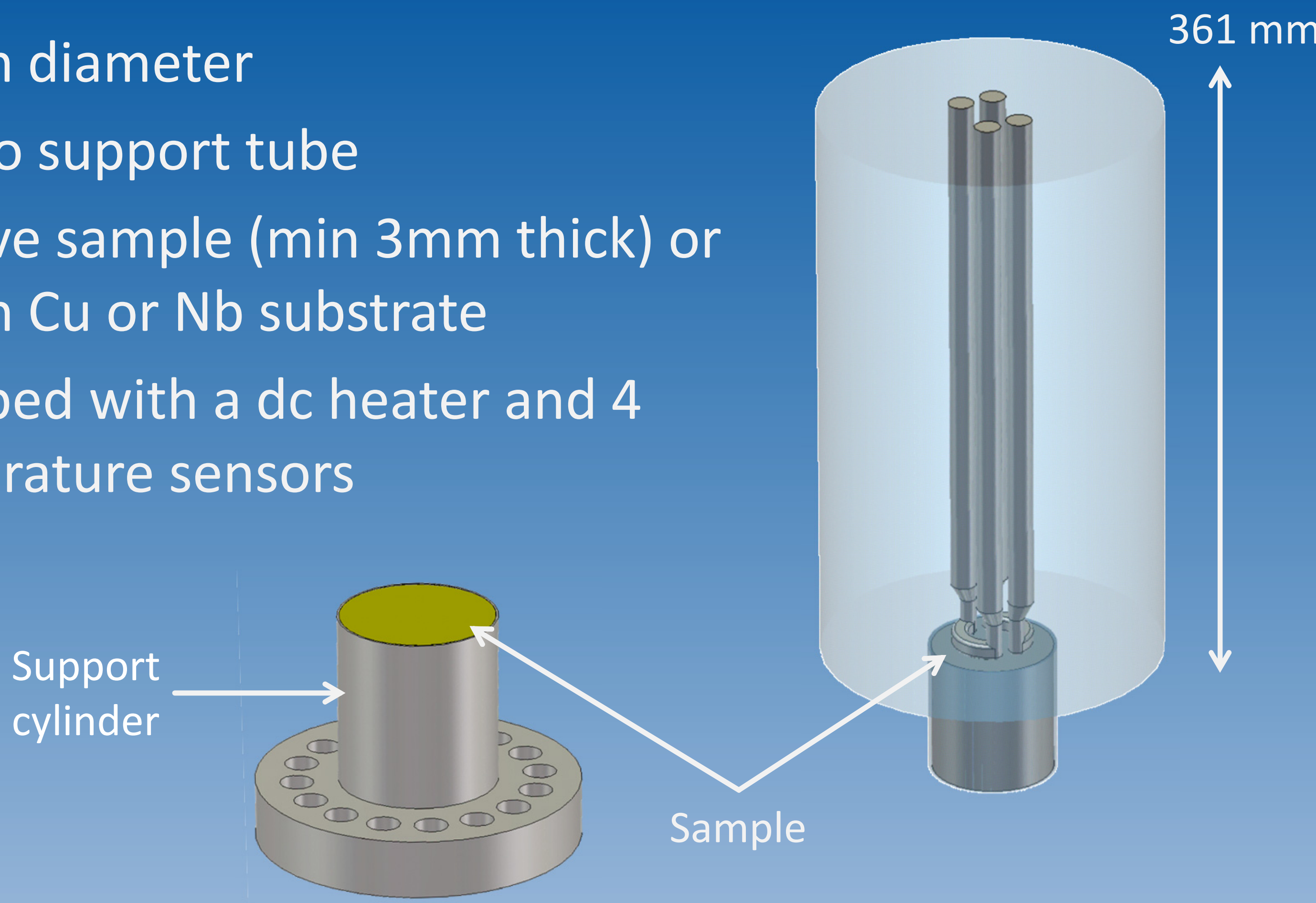
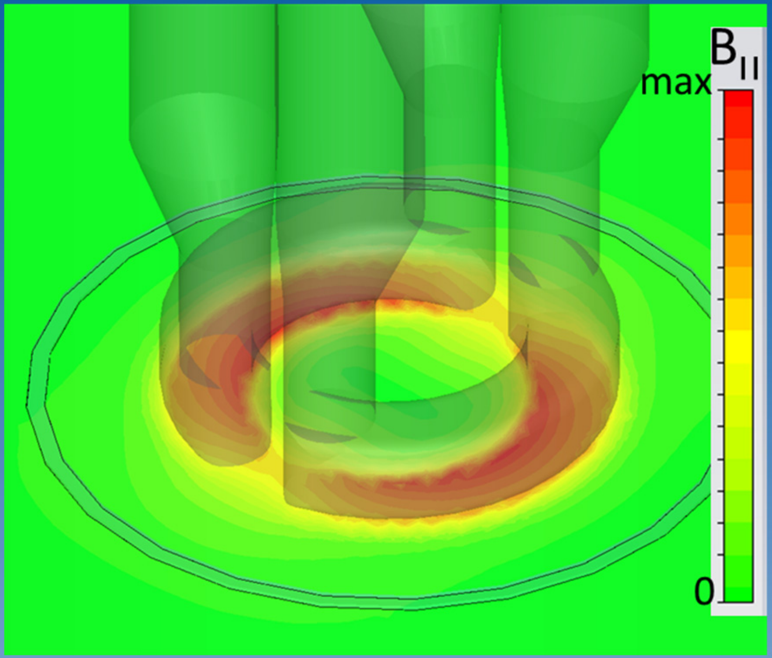
The Quadrupole Resonator

- Sample:
  - 75 mm diameter
  - EBW to support tube
  - Massive sample (min 3mm thick) or film on Cu or Nb substrate
  - Equipped with a dc heater and 4 temperature sensors



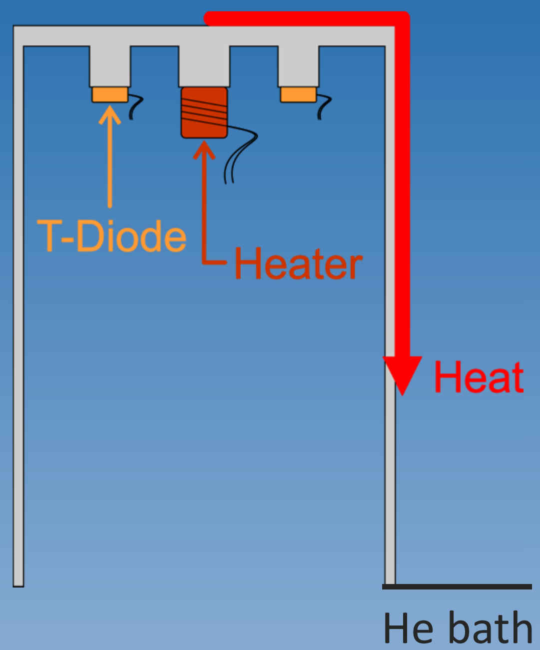
Features

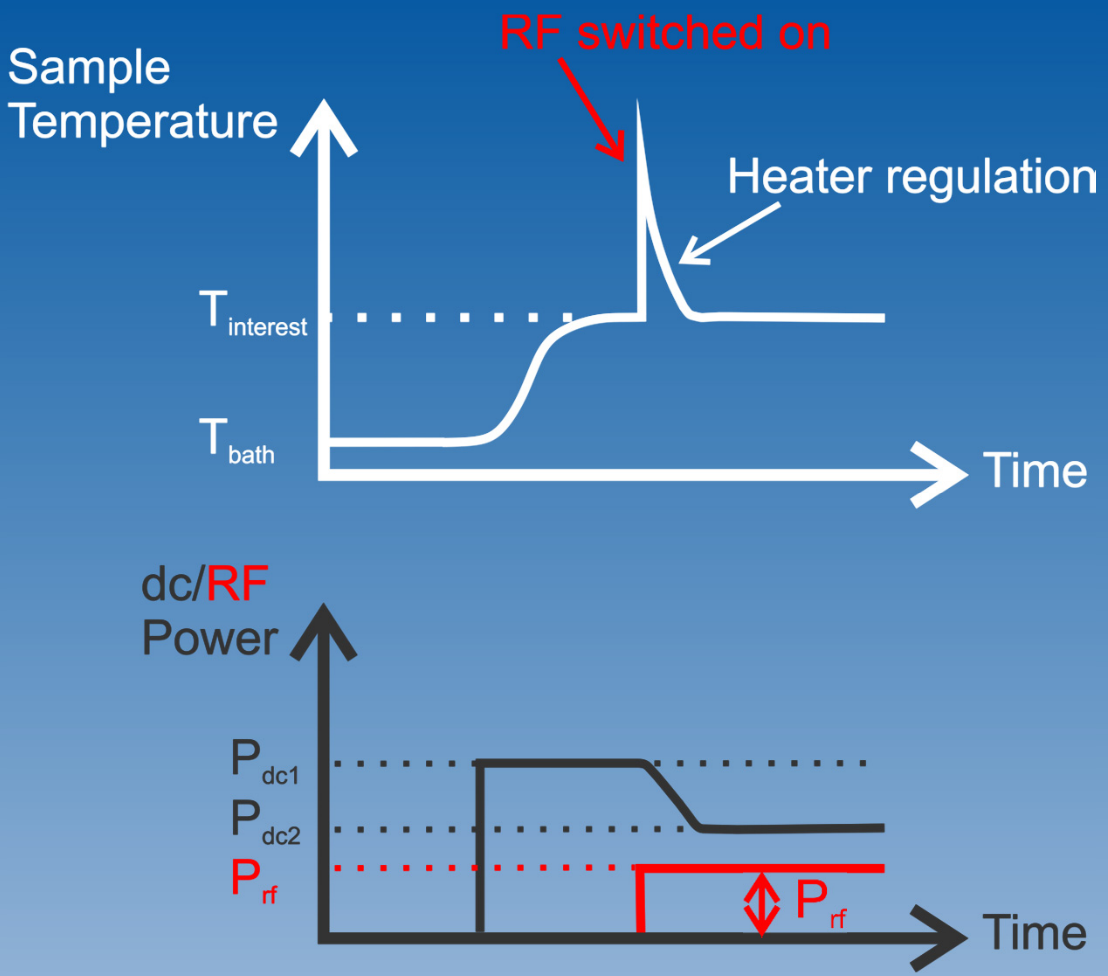
- Resonance Frequencies:
  400, 800, 1200 MHz
- Almost identical magnetic field configuration
- Ratio of B_{peak} to E_{peak} is proportional to f_{res}
- $B_{max} \approx 60$ mT
- Temperatures 1.6 -12 K



Improved design:
R. Kleindienst, TUPO74

Calorimetric Measurement





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Calorimetric Measurement

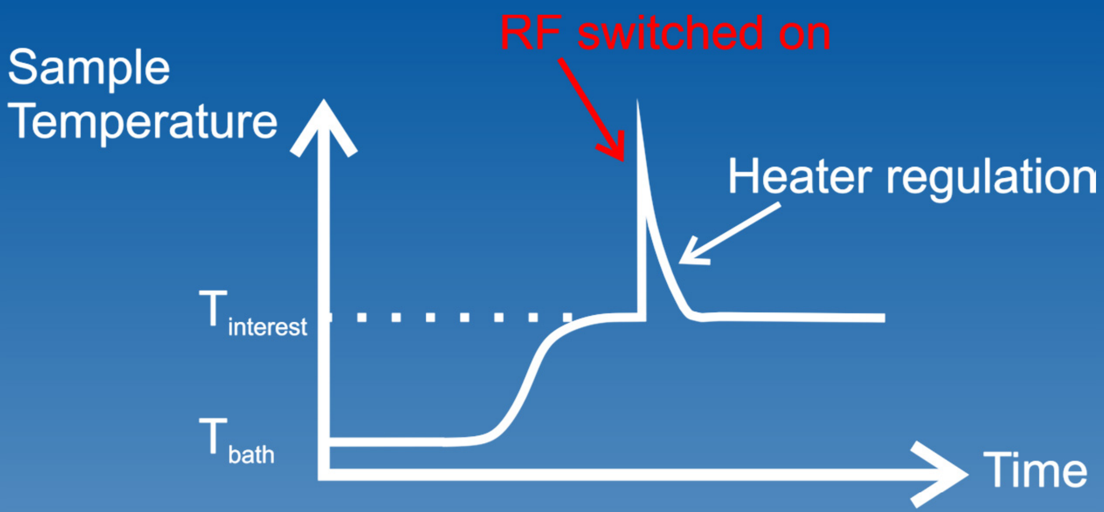
$$P_{RF} = P_{DC1} - P_{DC2} \approx \tfrac{1}{2} R_S \int H^2 dS$$

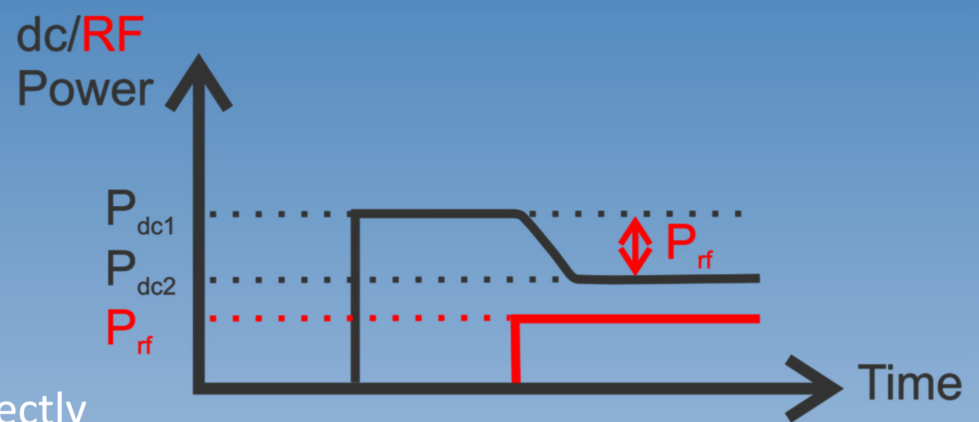
Measured directly

$$R_S = \frac{2\left(P_{DC1} - P_{DC2}\right)}{\int H^2 dS}$$

$$\int H^2 dS \sim c \cdot P_t$$

- c → Simulation
- P_t → Meas. directly





Errors & Resolution

- Temperature diodes:
  - 12 mK absolute / 0.1 mK relative
- Heater voltage: 10 µV (relative)
- Transmitted power: ΔP = 3% (absolute)
- Pressure of helium bath:
  - Changes the heat necessary for reaching $T_{interest}$
  - Pressure regulation system stabilizes ± 0.02 mbar
- Minimal heating of 0.1 mK depends on the thermal conductivity:
  - 2.5 µW at 2 K lead to smallest detectable R_s change at 5 mT and 400 MHz

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negligible

Relevant for low temperatures

dominant

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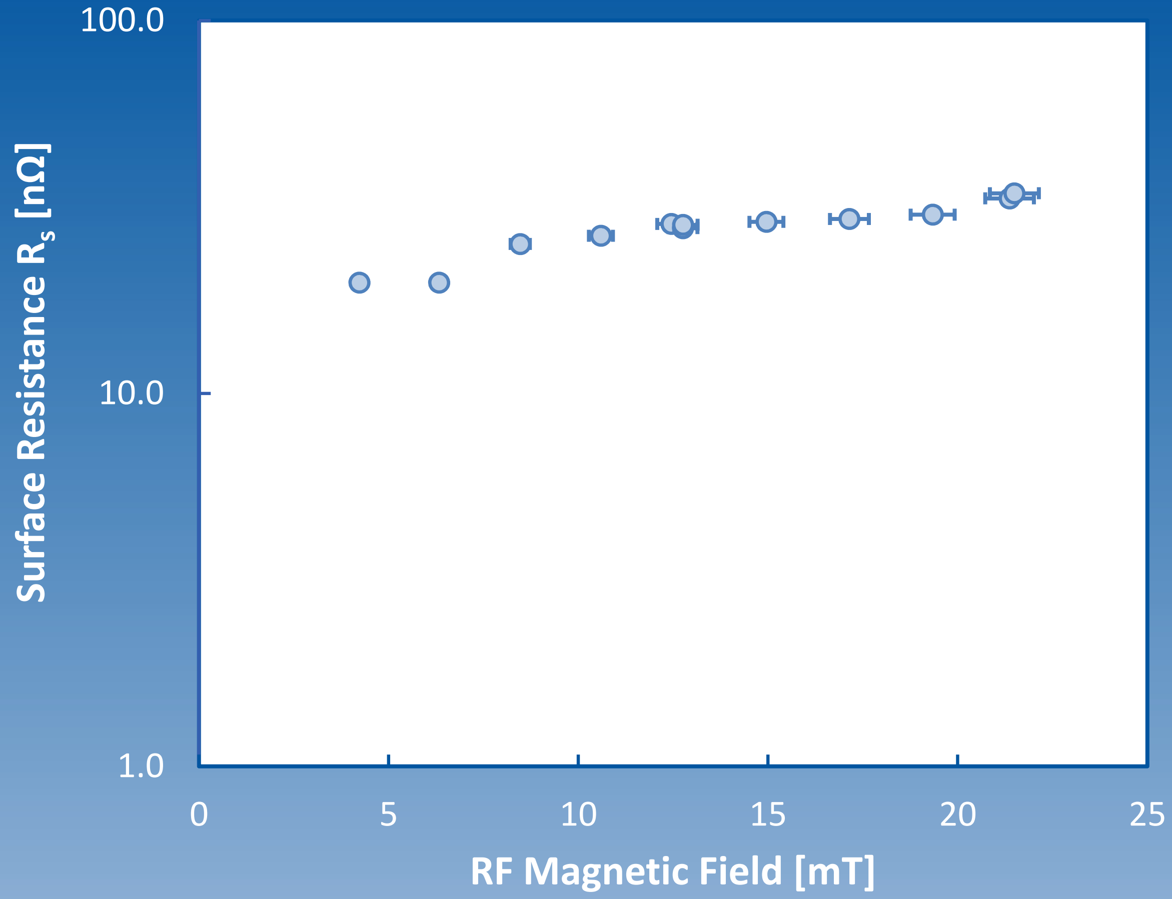
Resolution at 5mT: 0.44 nΩ

Reproducibility



Reactor grade
Nb after 48 h
mild baking
800 MHz, 2 K

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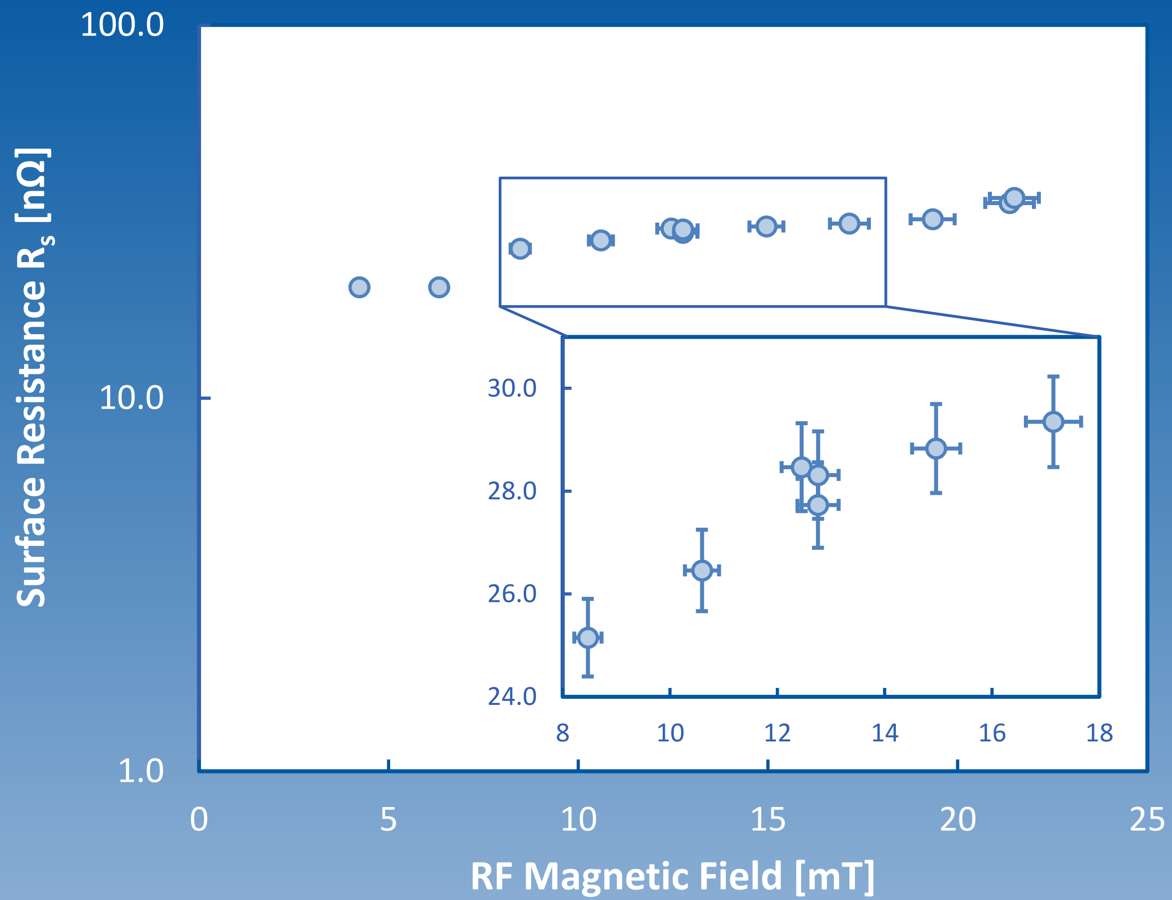

Reactor grade Nb after 48 h mild baking 800 MHz, 2 K

Samples

- Already measured:
  - Magnetron sputtered Nb/Cu
  - Bulk Nb + mild baking
  - MgB_2 (STI)

- To come:
  - Nb baked at 800 °C in N_2/Ar (FermiLab)
  - NbTiN (AASC)
  - HIPIMS Nb/Cu

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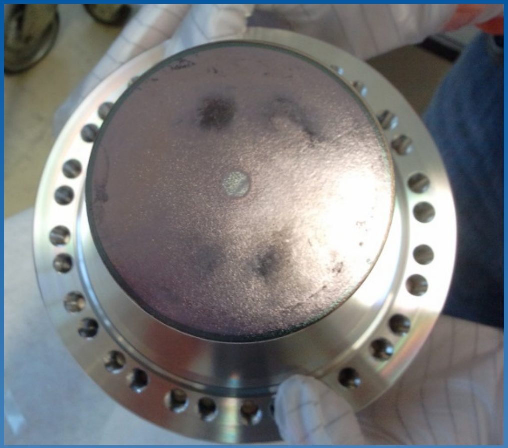
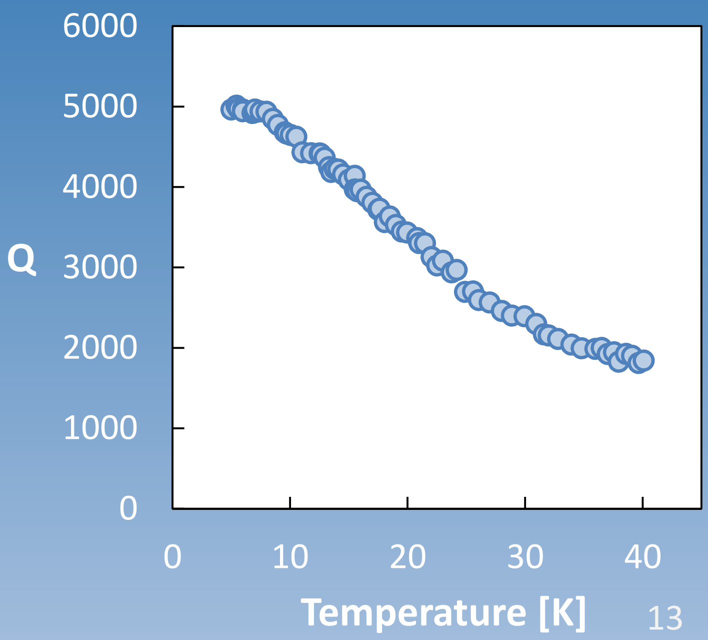
MgB_2

- 500 nm MgB_2 on a Nb substrate (deposited by Chris Yung at STI)
- Strong multipacting on 1st RF test
- After new rinsing: even stronger multipacting + „burn marks“
- Continuous transition from sc to nc state
- XPS measurements show only 70% MgB_2 (rest MgB_x)

Cause for multipacting?

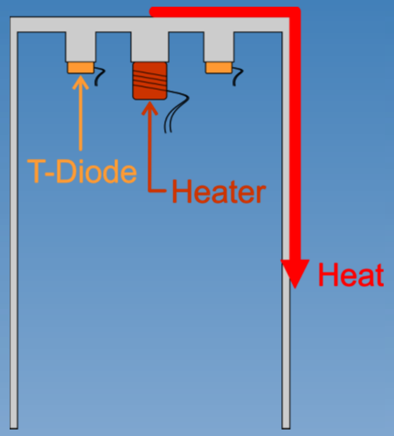


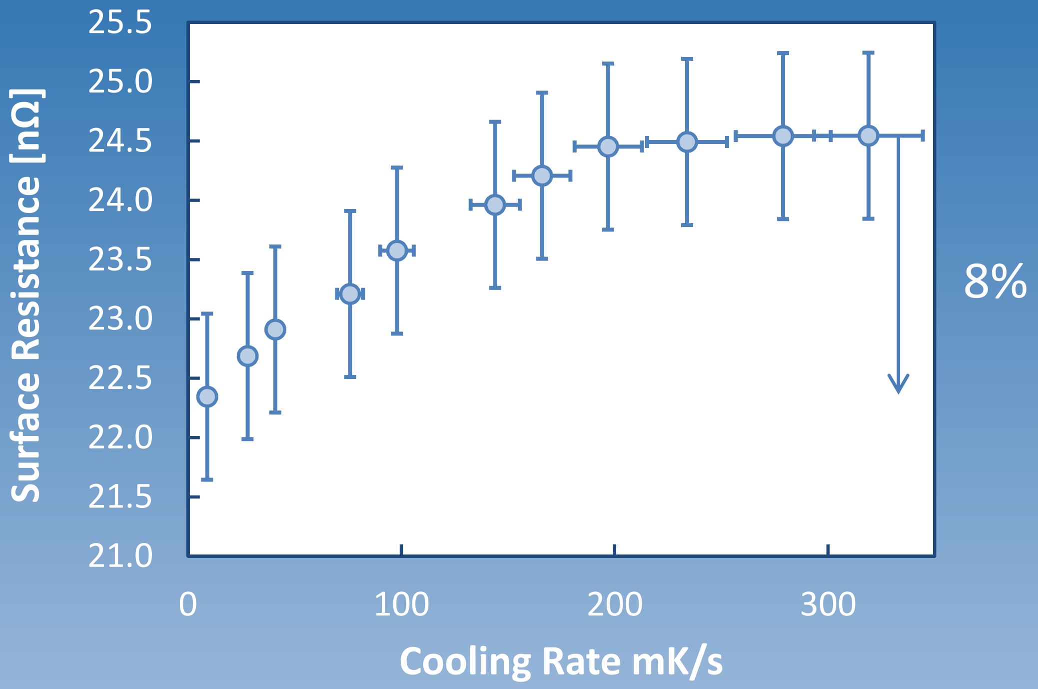


Influence of the Cooling Rate in Nb

- Reactor grade Nb
  + BCP + 48h mild baking
- 400 MHz, 2.5 K, 15 mT

- Cooling speed was varied by regulating the heater power





Possible Explanations

- Dc Heater produces an additional B field
  - B_{heater} would compensate or sum up with residual field (2µT) due to imperfect shielding.
  - Inverting the heater current reproduced results.
- Temperature dependence of magnetic shielding
  - Shield is always at the same temperature
  - Not the case for cavities (Kugeler et al, THPO011, SRF2011)

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Can be ruled out

Possible Explanations

- Nb hydride formation
  - Max T of the sample is 12 K → far away from Q-disease region
- Seebeck effect
  - Temperature gradient causes thermo voltage
  - Additional magnetic field is produced and trapped if thermal currents occur

    (Kugeler et al. THOBB201, IPAC13
    Aull et al. PRSTAB 15(6):062001)
  - Here: no closed circuit → no add. trapped flux

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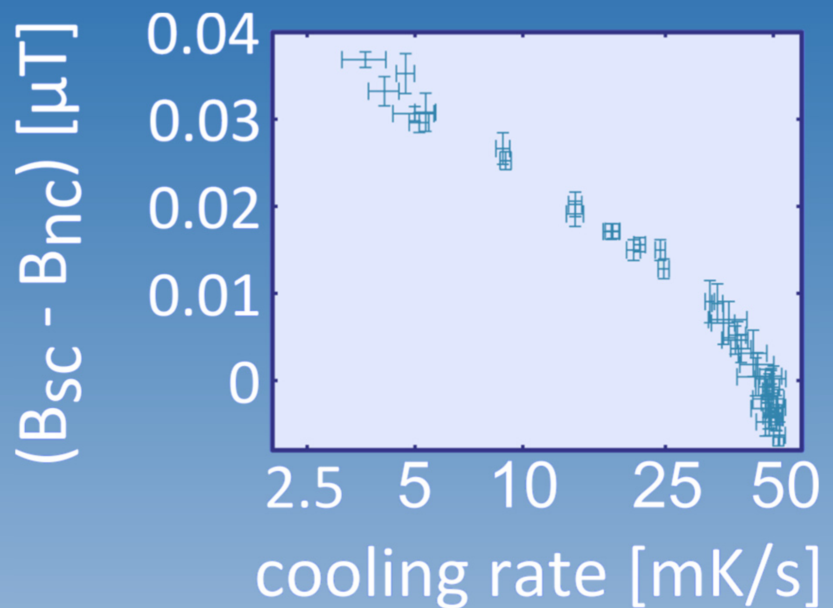
Expulsion of Trapped flux

- Trapped flux studies on samples show already that the amount of trapped field can depend on the cooling conditions.

- The more flux is expelled the slower the sample is cooled down
  (Vogt et al, accepted for publication in PRSTAB 2013)



Courtesy J-M Vogt

Conclusion & Outlook

- We found that the surface resistance decreases for lower cooling rates.
- The results are consistent with the expulsion of trapped flux while all other possible explanations could be ruled out due to the thermal decoupling of the sample from the host cavity
- In a next step we continue to study this effect under the influence of external dc magnetic fields and transfer these studies to other materials and Nb films.

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