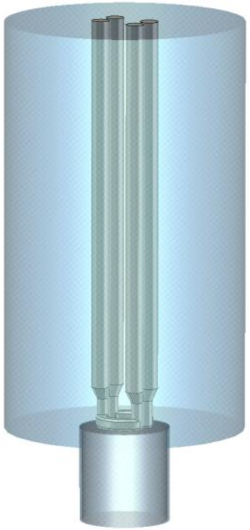
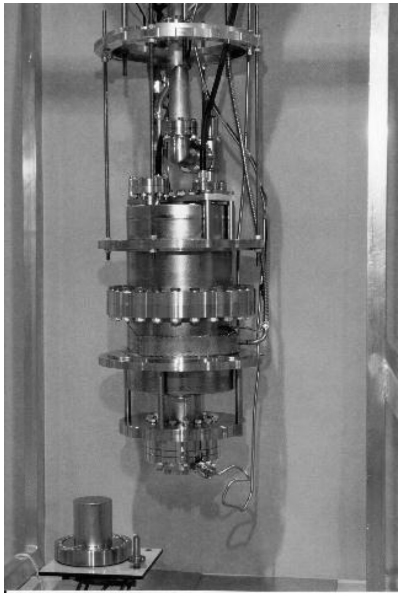
Sample Testing with the Quadrupole Resonator

A way to obtain RF results over a wide parameter range





Motivation

- Power consumption in a superconducting cavity is proportional to its surface resistance R_S
- R_S shows a complex behavior on external parameters, such as temperature, frequency, magnetic and electric field

$$P_c \propto R_S(f, T, B, E)$$

- Some open questions:
  - Origin of the residual resistance
  - Origin of the Q-Slope/Q-drop
  - Stronger Q-Slope of Niobium films compared to bulk niobium
  - Influence of magnetic and electric field
  - Influence of the surface properties

Courtesy of T. Junginger

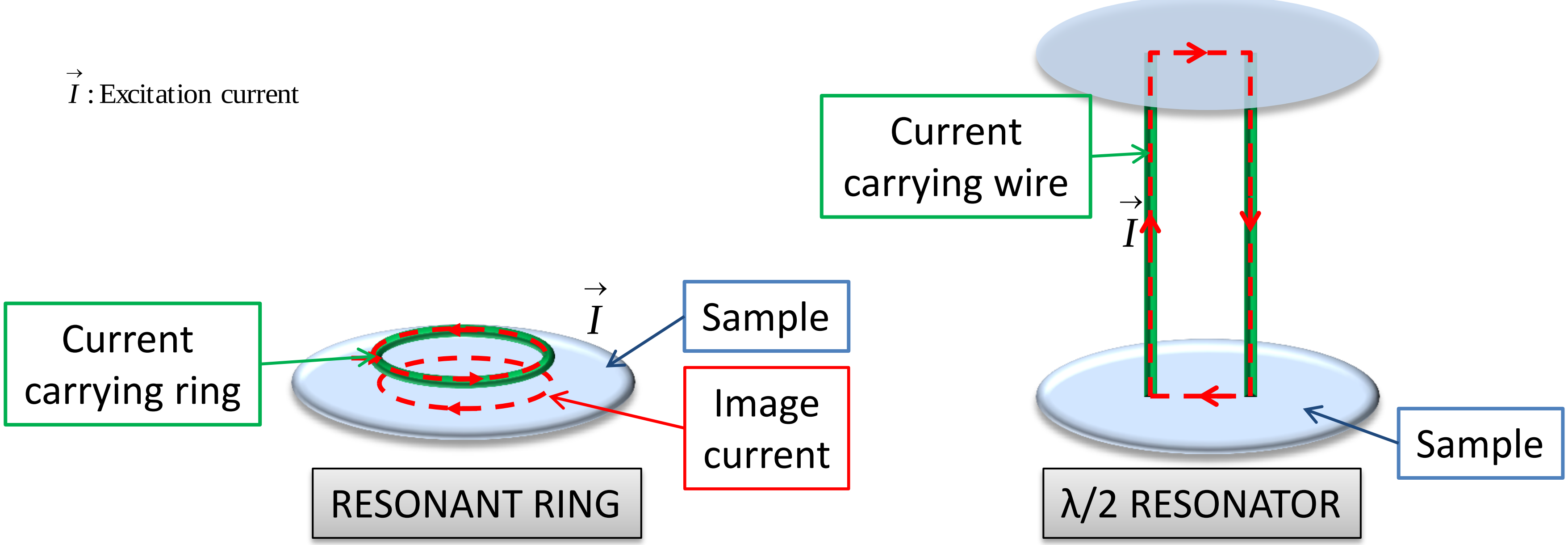
Motivation

The Quadrupole Resonator enables RF characterization of small samples over a wide parameter range

Design Ideas for the Quadrupole Resonator

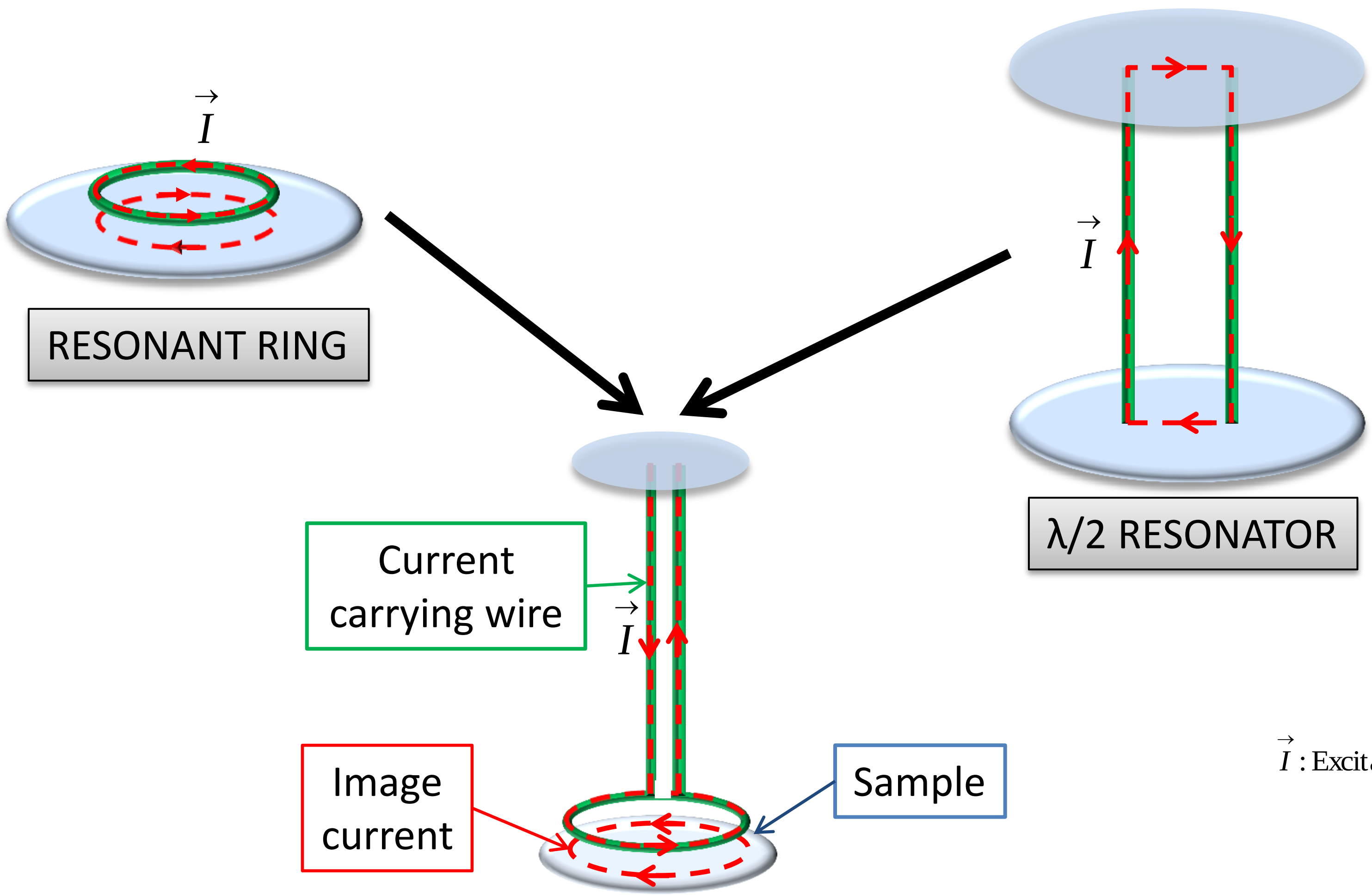
	Sample Radius for 400MHz
Pillbox Cavity	R = 0.56m
Resonant Ring	R > 0.12m
λ/2-Resonator	R independent of f

$\vec{I}$: Excitation current



Courtesy of T. Junginger

Design of the Quadrupole Resonator



Courtesy of T. Junginger

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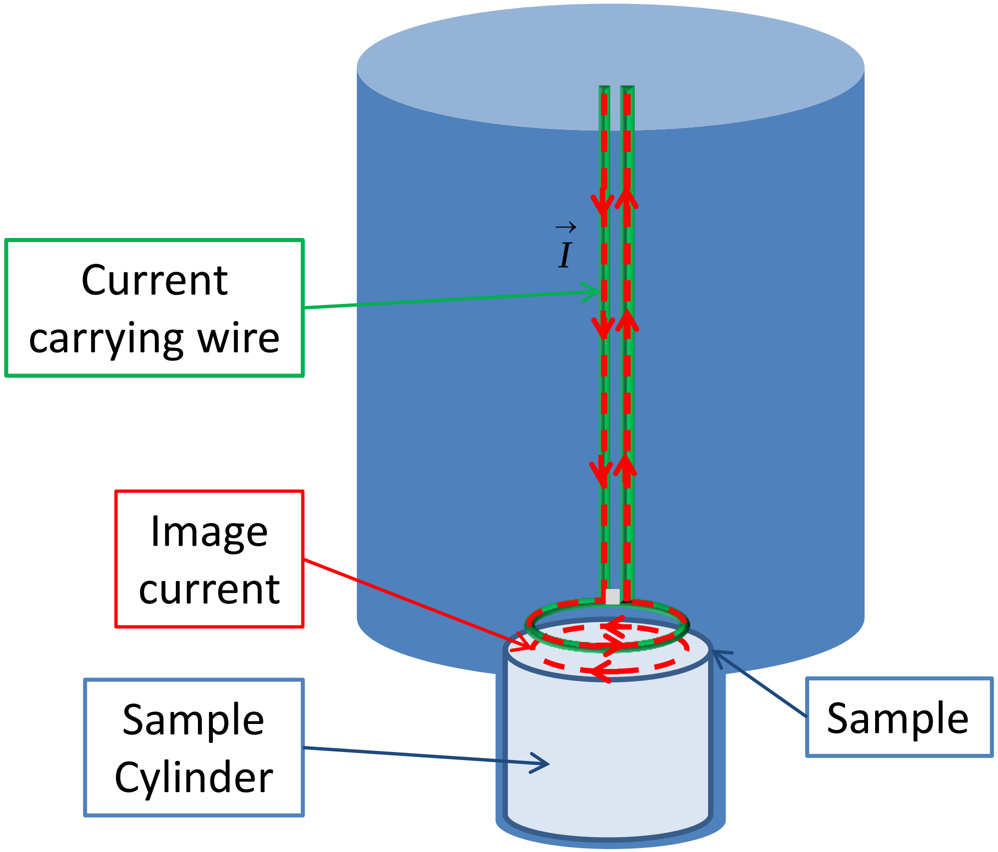
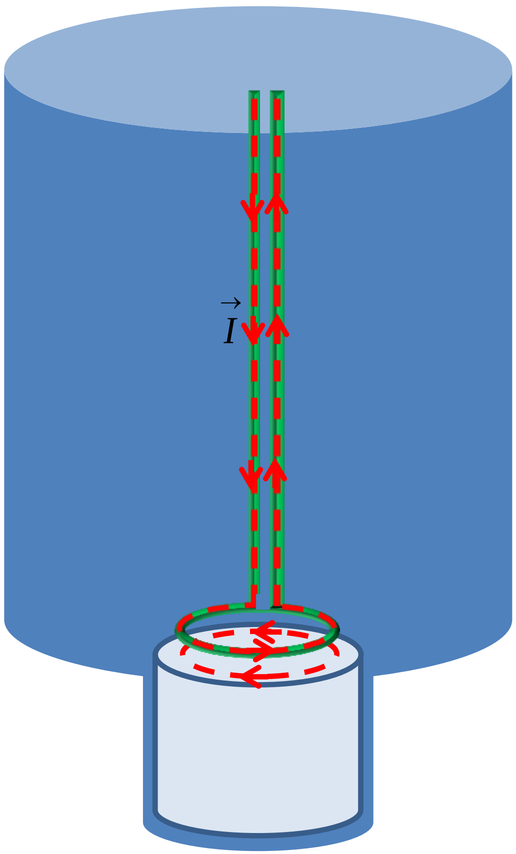


DIPOLE RESONATOR

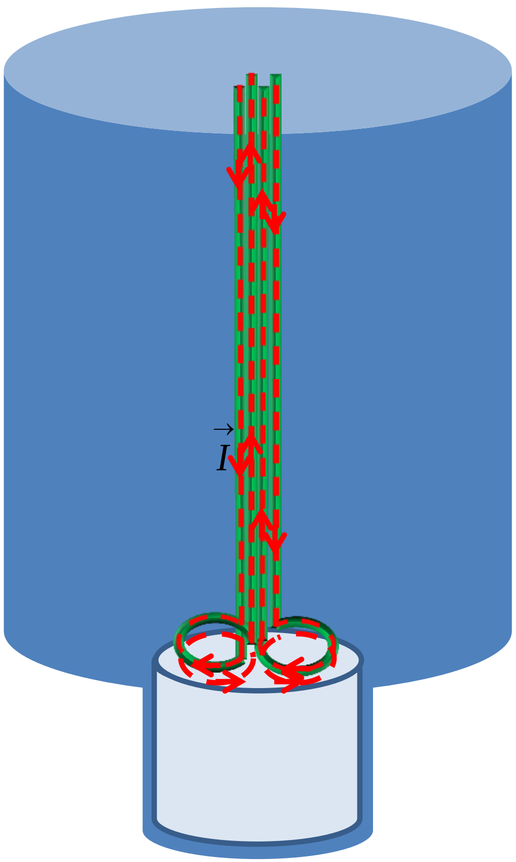
Courtesy of T. Junginger

$\vec{I}$: Excitation current

Design of the Quadrupole Resonator



DIPOLE RESONATOR

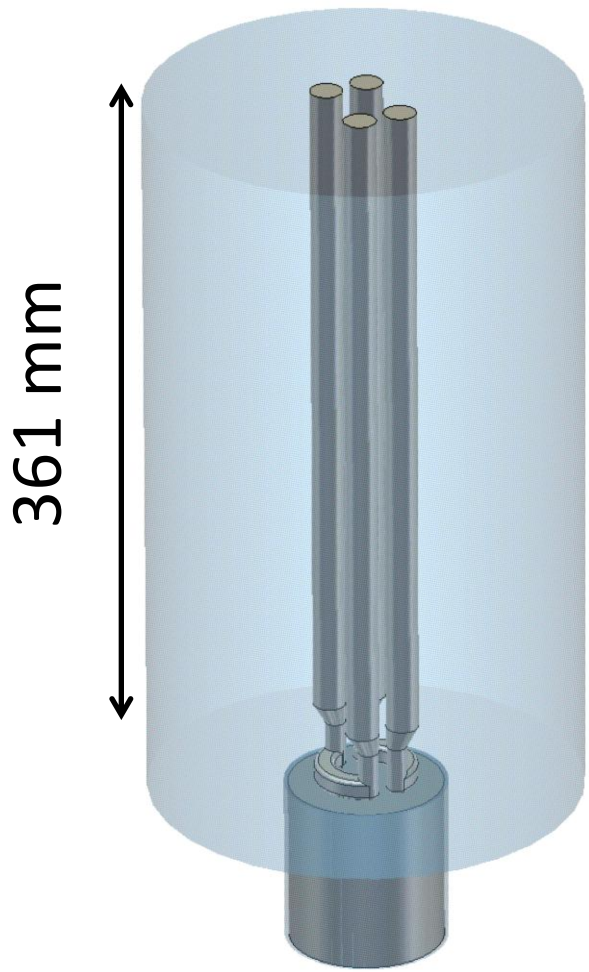


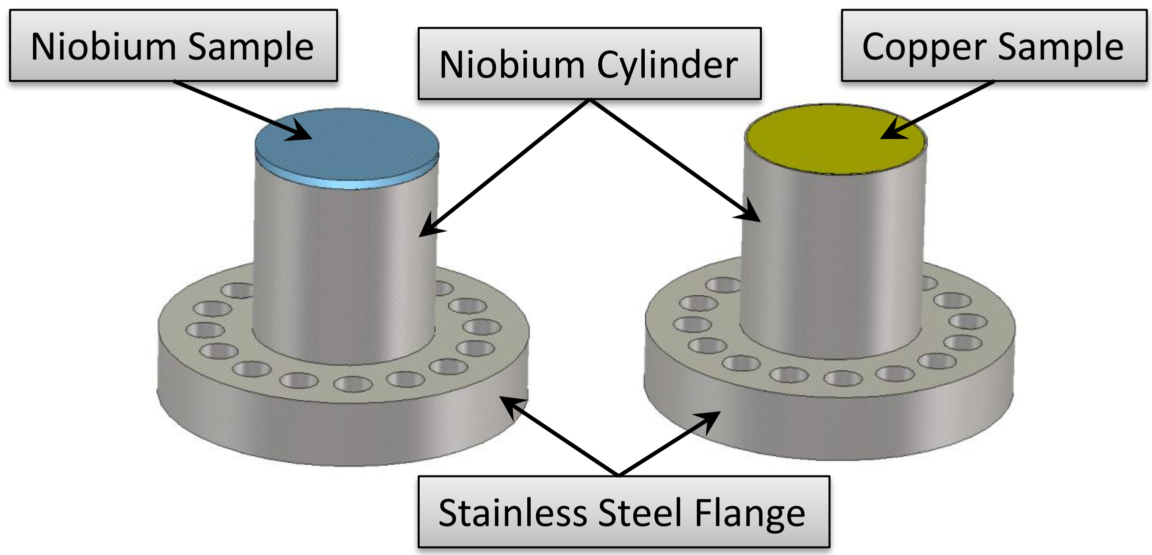
QUADRUPOLE RESONATOR

Courtesy of T. Junginger

$\vec{I}$: Excitation current

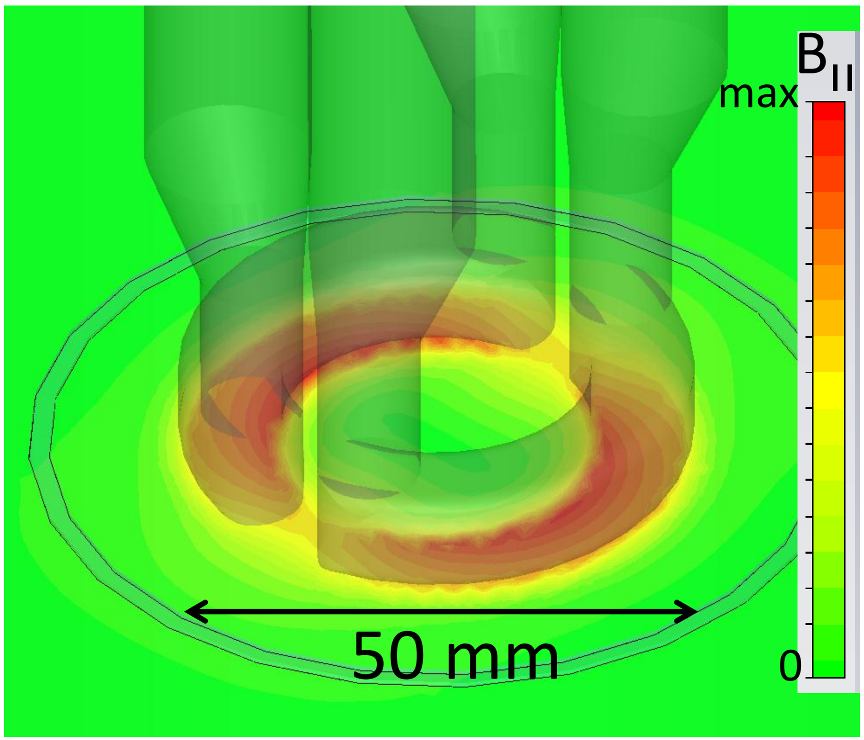
Design of the Quadrupole Resonator





- Sample diameter: 75mm
- The sample needs to be EB-welded to the sample cylinder
- Bulk niobium and copper samples are available

Field Configuration & Features



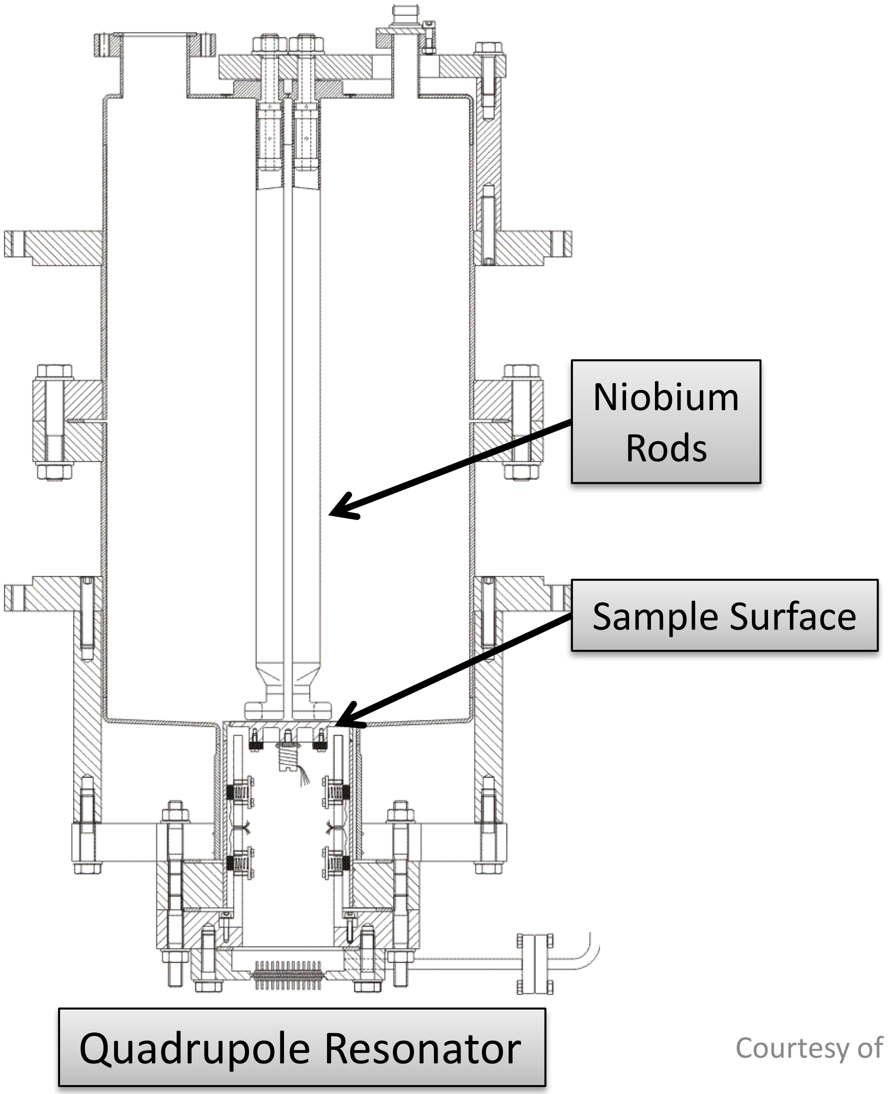
Courtesy of T. Junginger

- Resonant frequencies: 400MHz, 800MHz, 1.2 GHz
- Almost identical magnetic field configuration
- Ratio between peak magnetic and electric field proportional to frequency

[1] E. Mahner et al.
Rev. Sci. Instrum., Vol. 74, No. 7, July 2003

[2] T. Junginger et. al
Rev. Sci. Instrum., Vol. 83, No. 6, June 2012

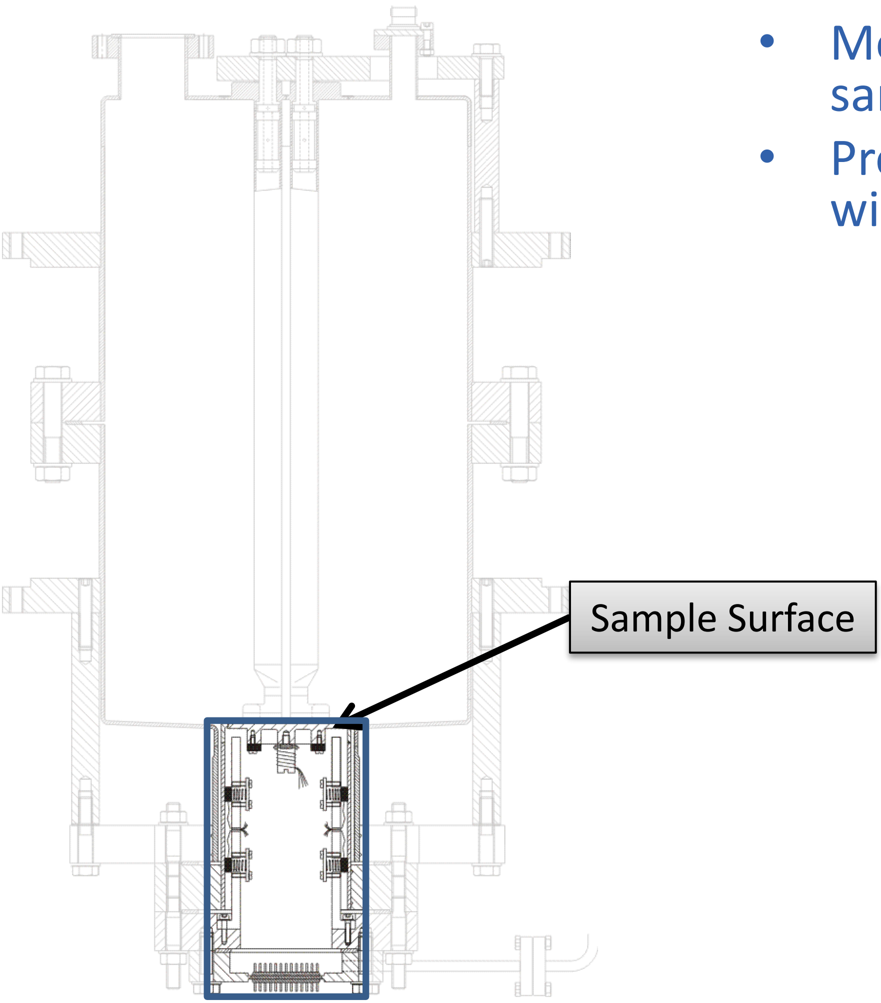
The Calorimetric Technique



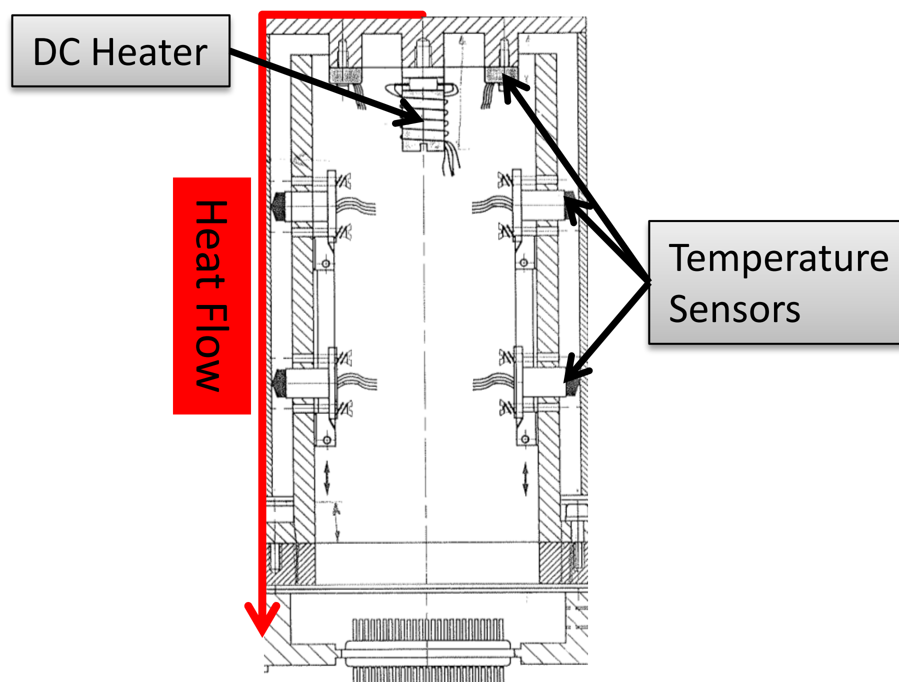
Courtesy of T. Junginger

The Calorimetric Technique

- Measuring the temperature on the sample surface
- Precise Calorimetric measurements over wide temperature range



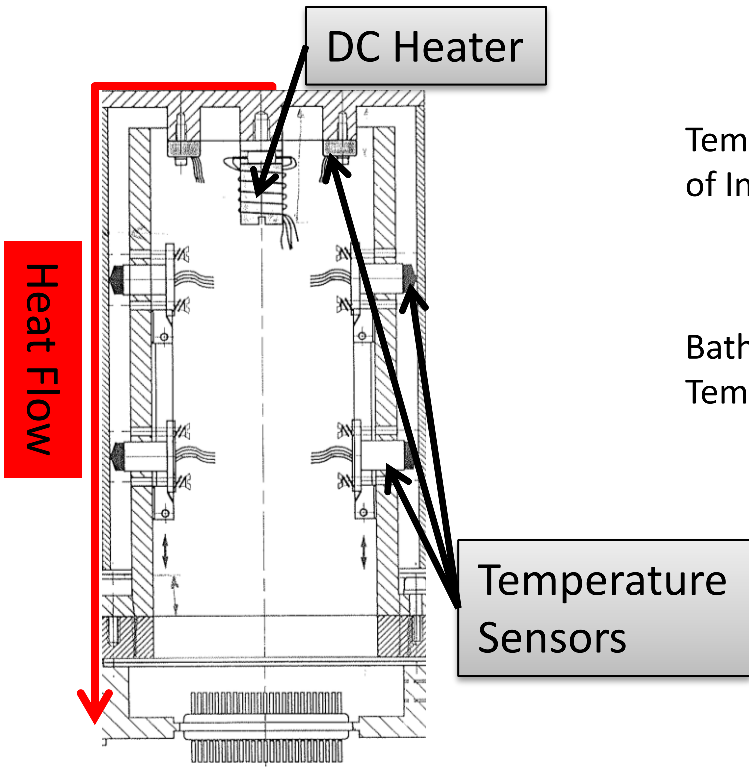
Quadrupole Resonator

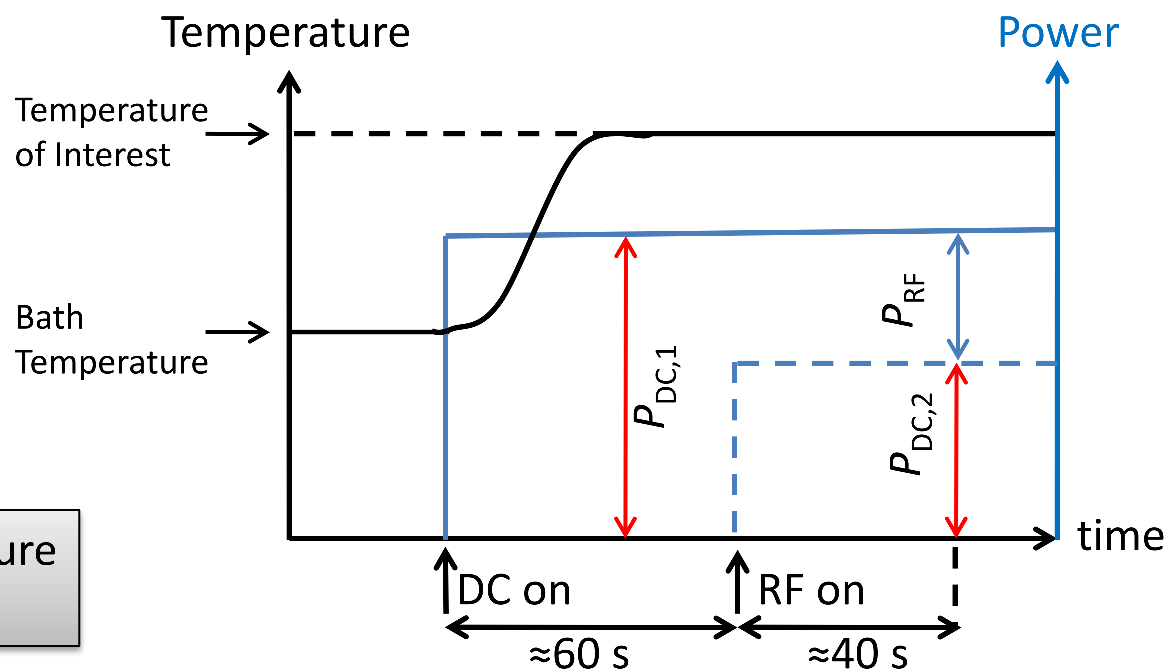


Thermometry Chamber

Courtesy of T. Junginger

The Calorimetric Technique



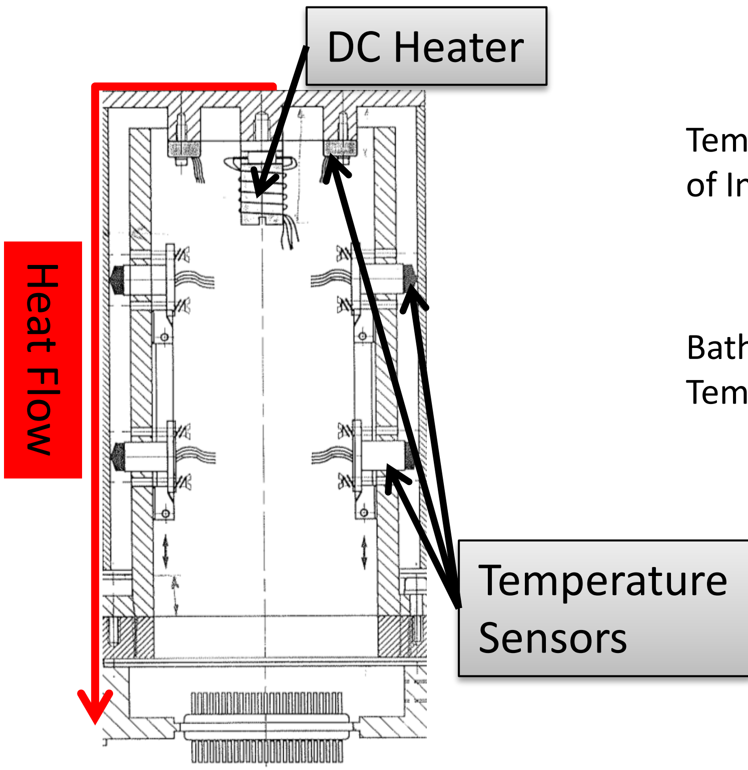


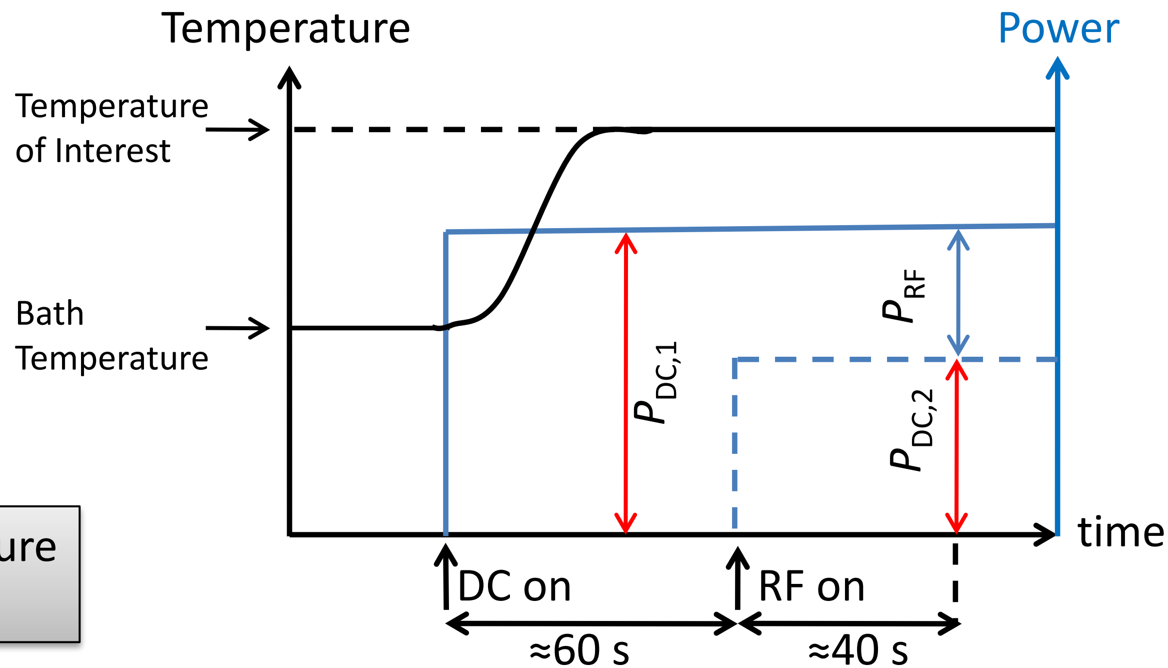
$$P_{RF} = P_{DC,1} - P_{DC,2} \approx 1/2\, R_{Surface} \int_{Sample} H^2 dS$$

$$R_{Surface} = \frac{2(P_{DC,1} - P_{DC,2})}{\int_{Sample} H^2 dS}$$

Courtesy of T. Junginger

The Calorimetric Technique





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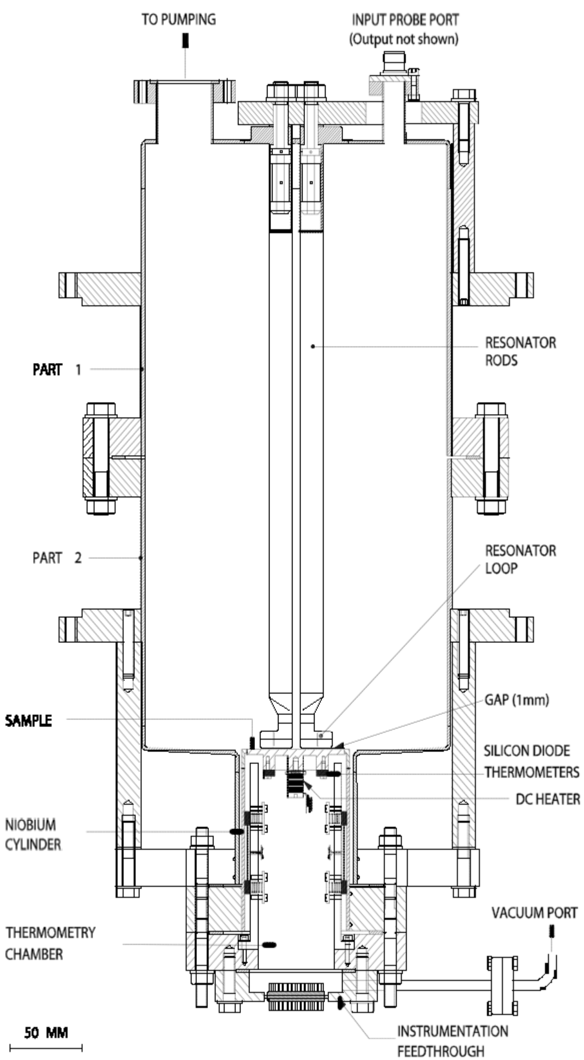
Measured directly

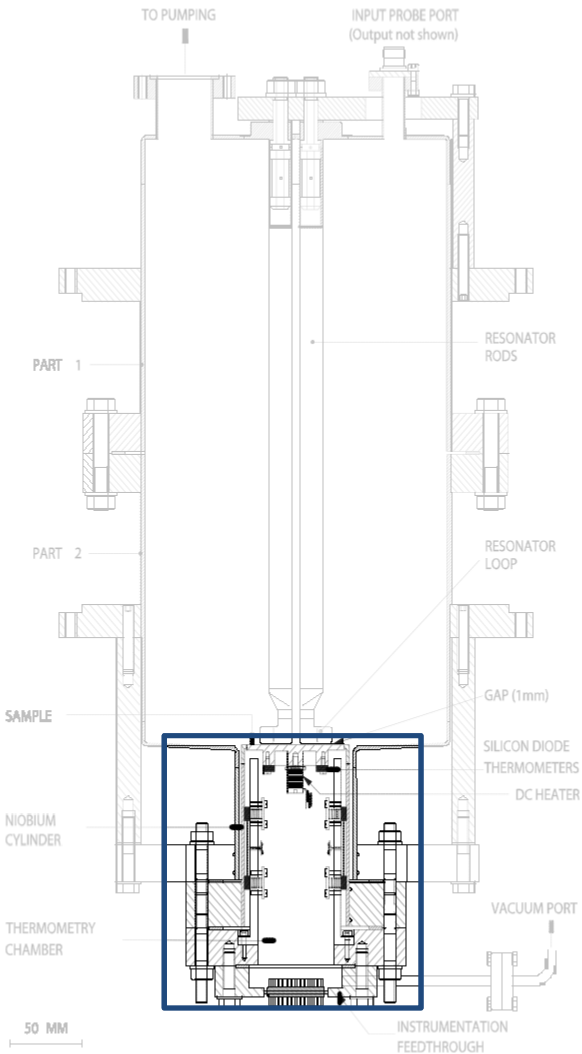
- Measurement of transmitted power P_t
- $P_t = c\int H^2 ds$, c from computer code

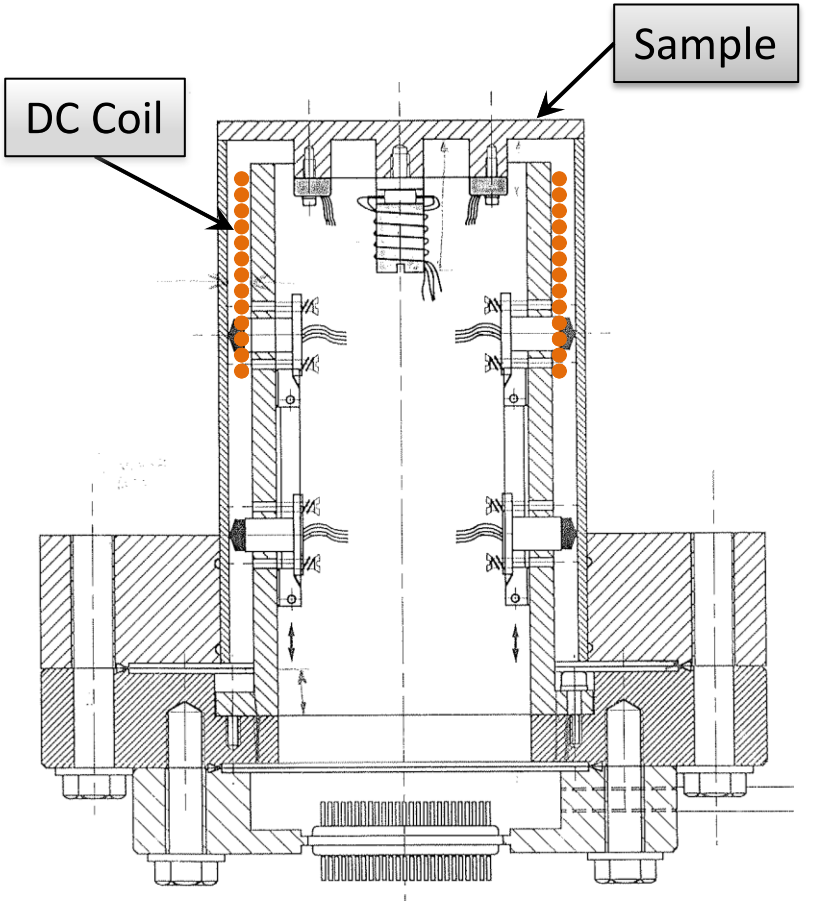
Courtesy of T. Junginger

Flux Trapping



Flux Trapping





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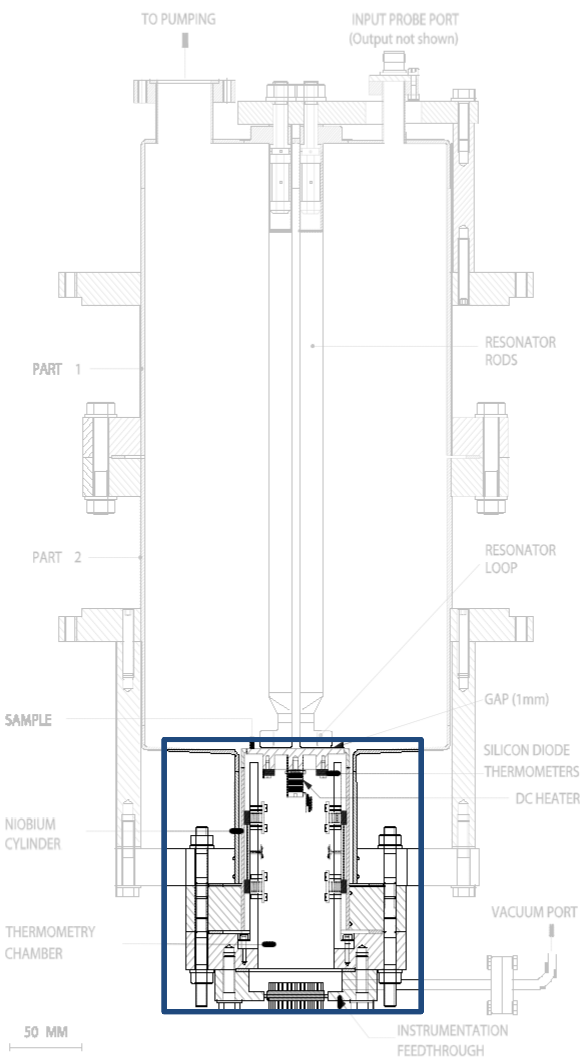
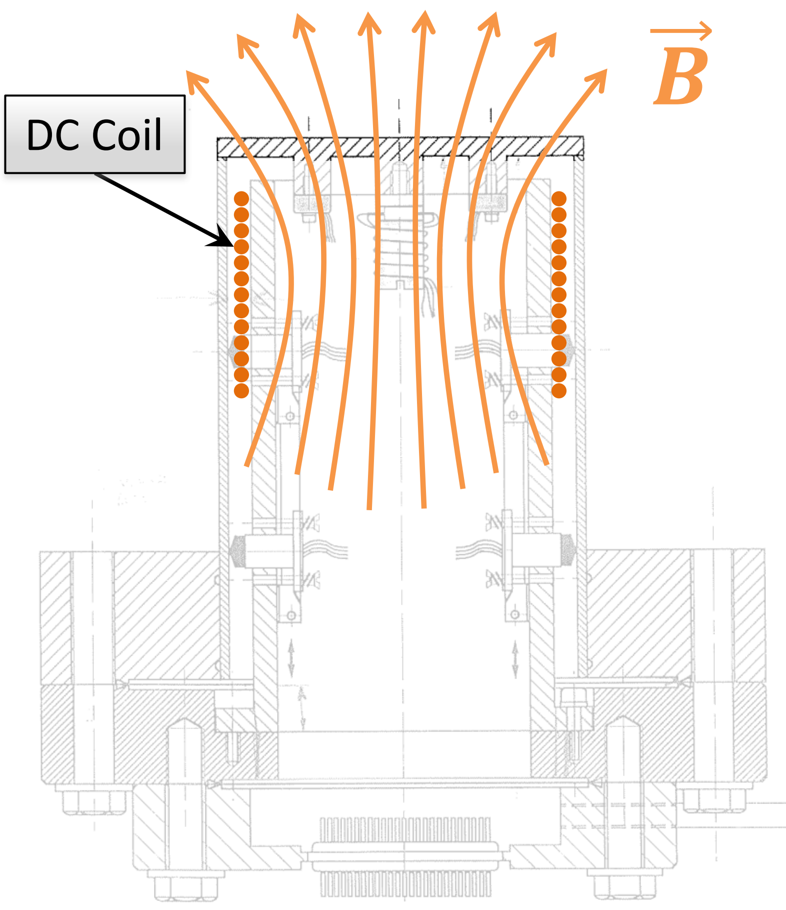
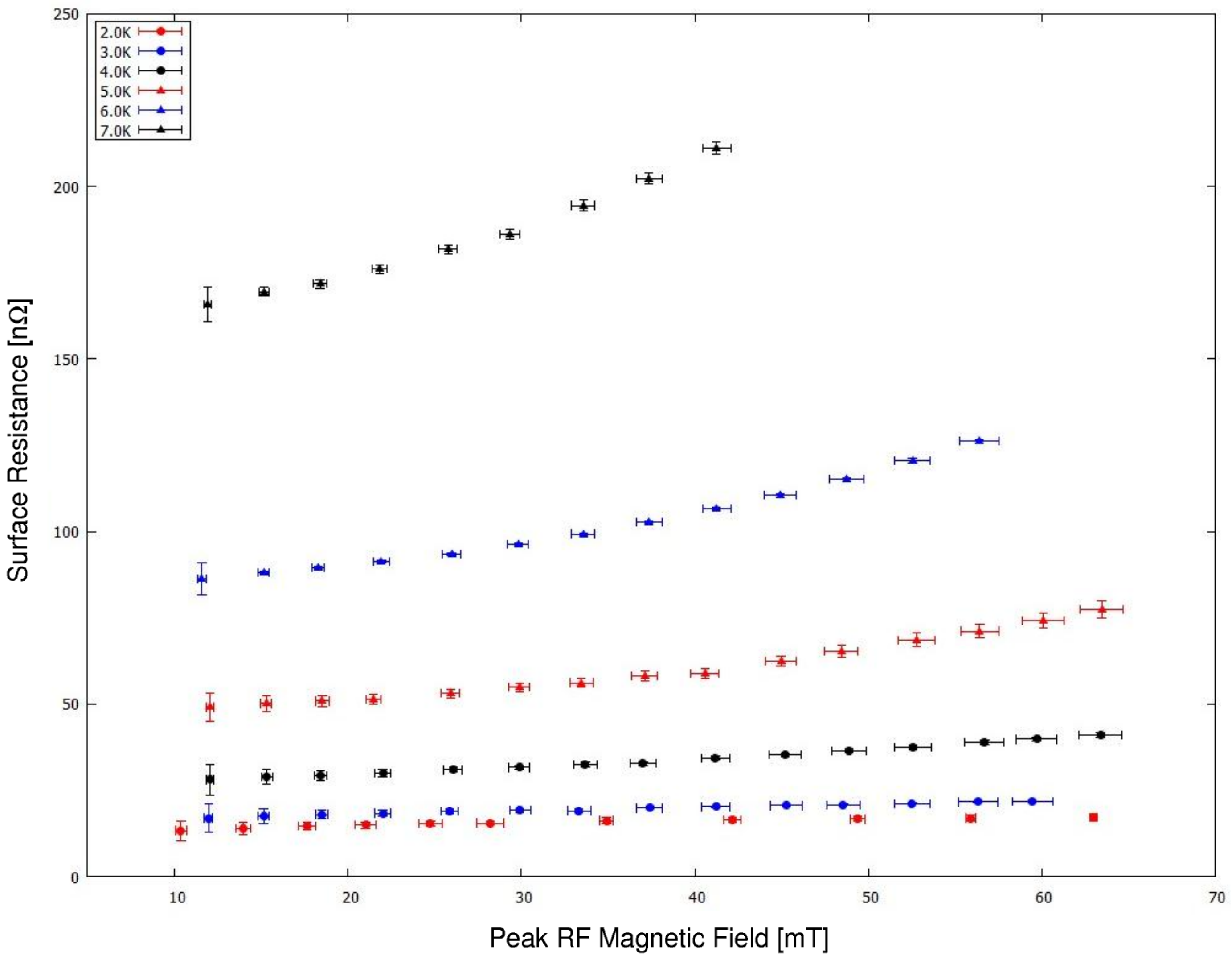




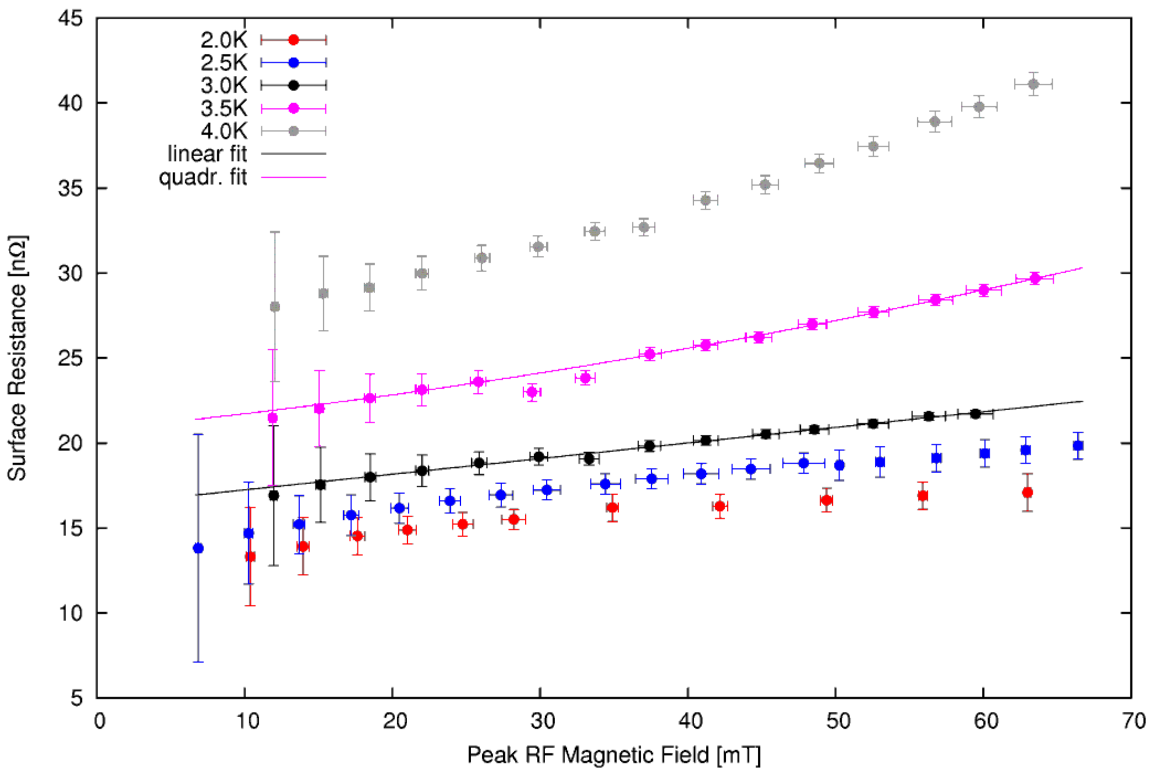
First test with trapped flux

- Bulk niobium sample
- Reactor grade, RRR $\approx$ 65
- Standard BCP, no bake out
- $R_{res} \cong 11.5\ n\Omega$

$R_S(B)$ at 400 MHz for different T

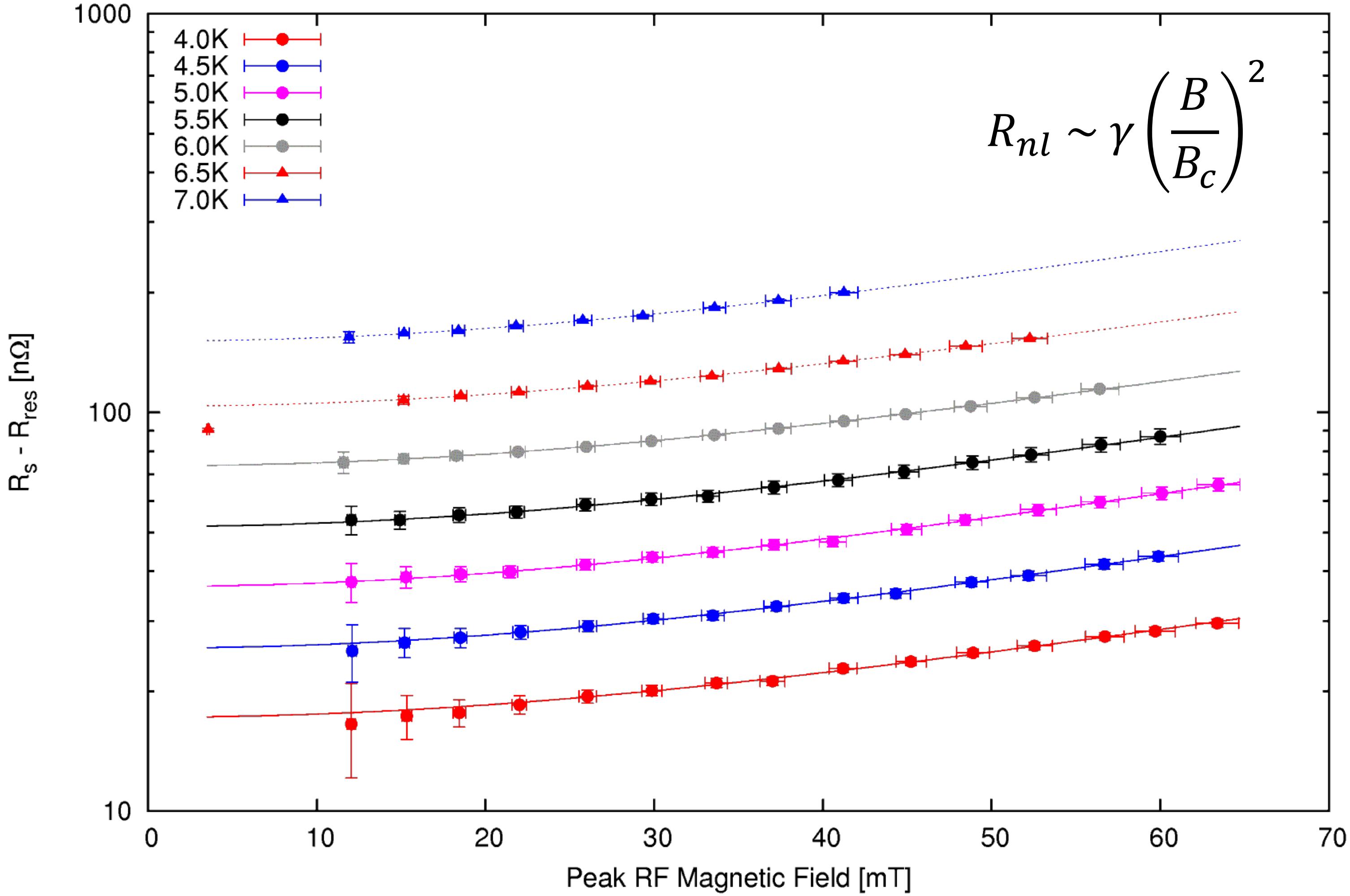


$R_S(B)$ at 400MHz, 2-4K

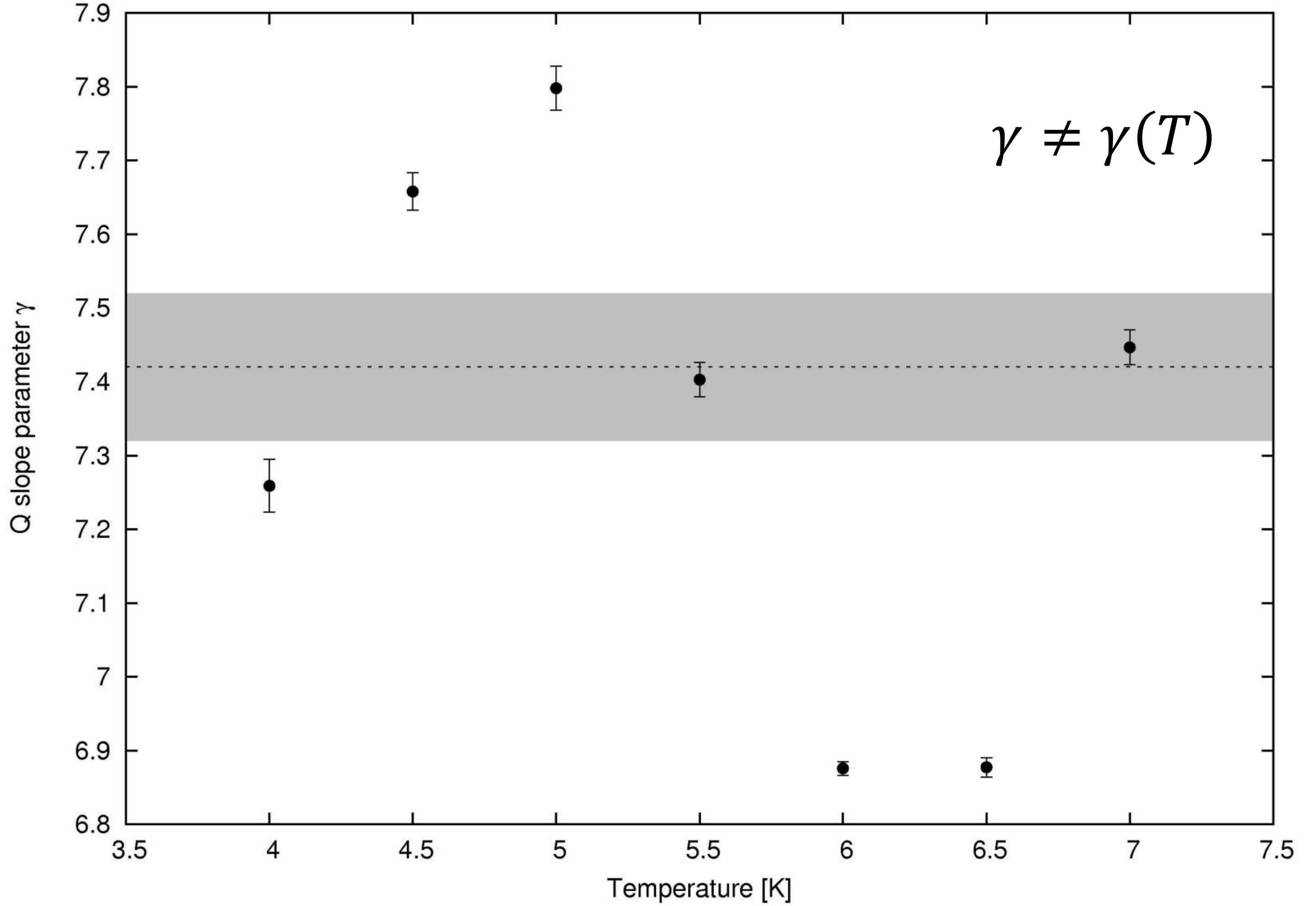


- Convex curve for $T \leq 2.5K$
- Concave curve for $T \geq 3.5K$
- Different loss mechanisms dominant

$R_S(B)$ at 400 MHz, 4-7K

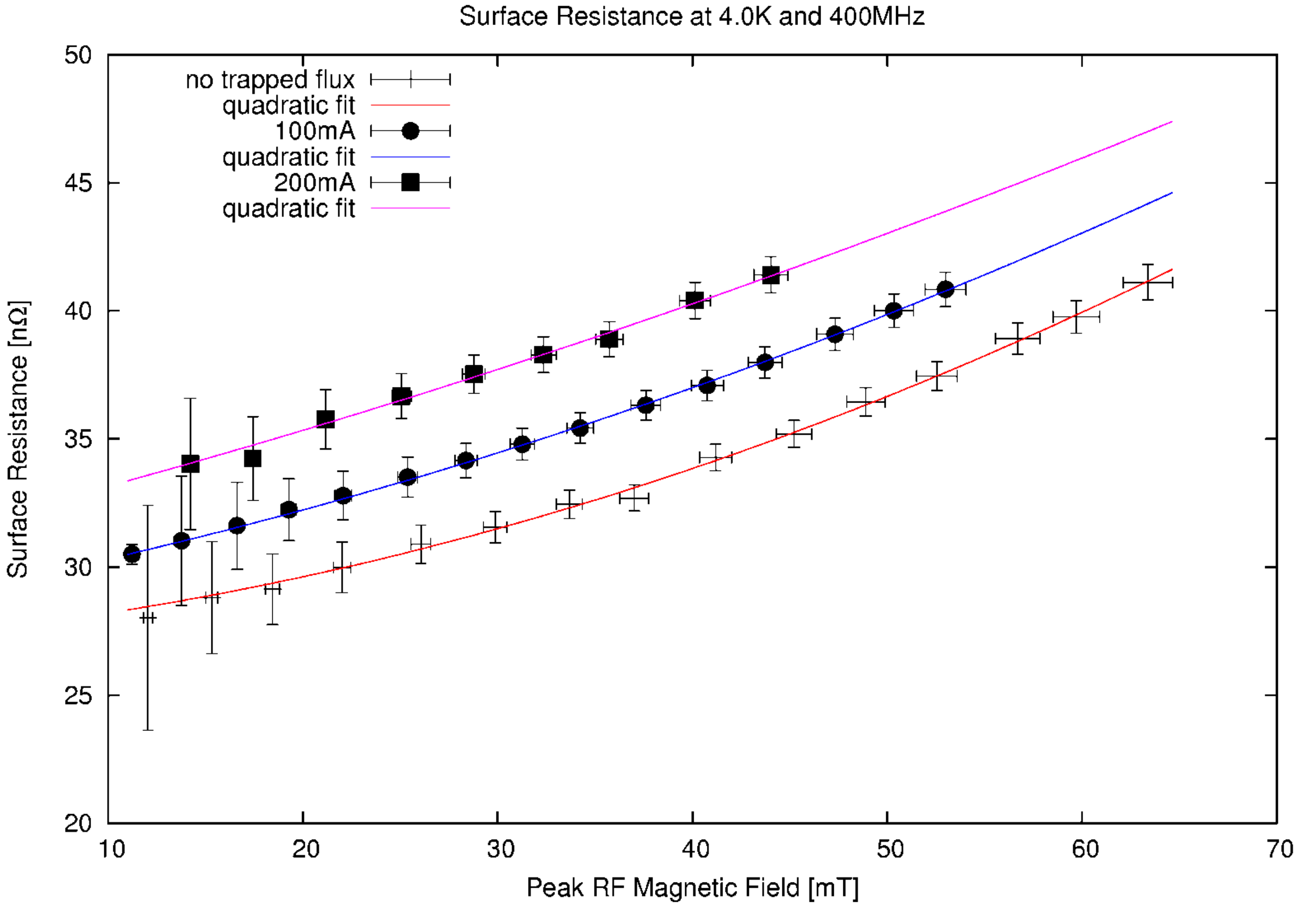


Q slope parameter γ

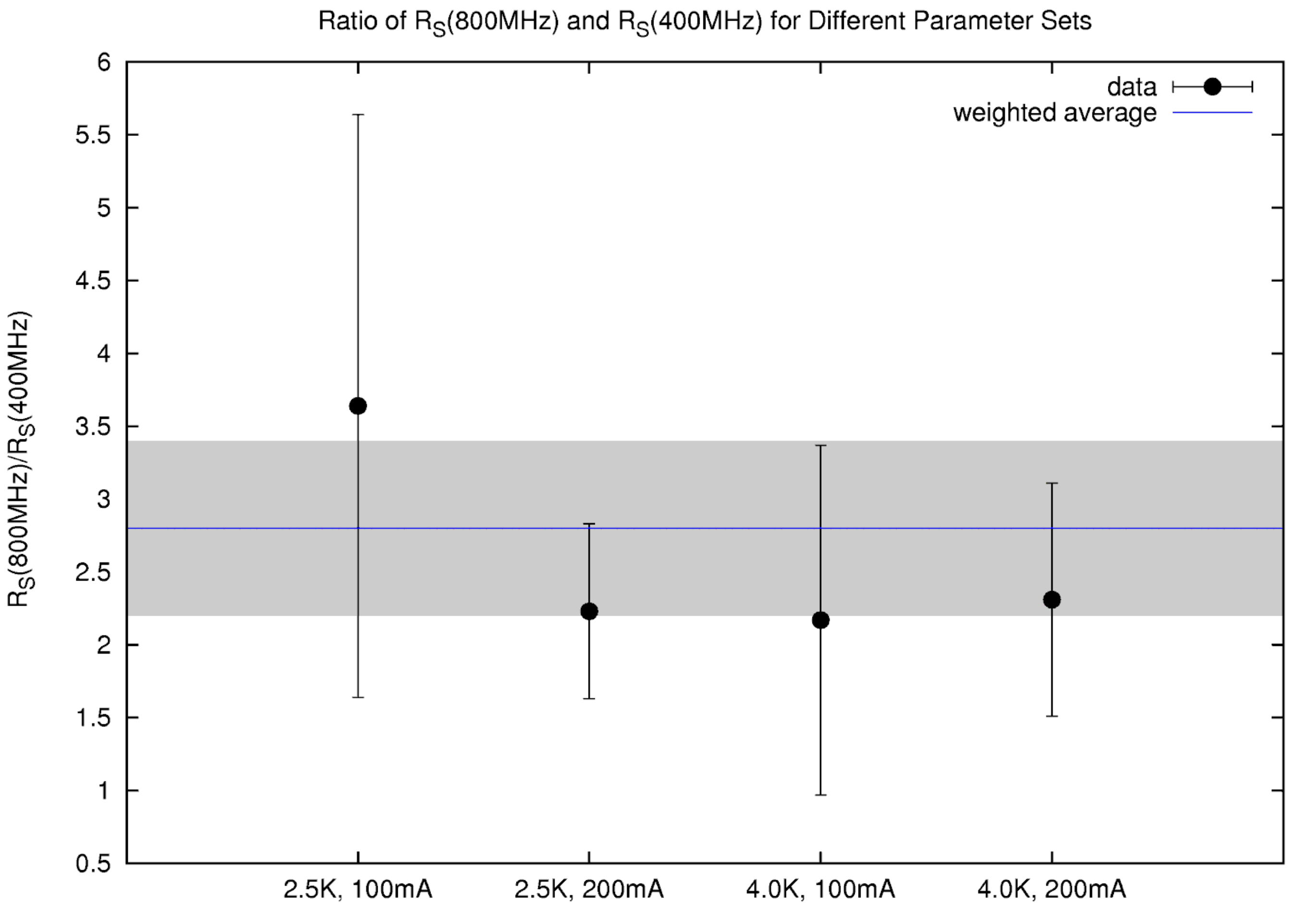


$$\gamma \neq \gamma(T)$$

Trapped Flux at 400MHz and 4K



Frequency dependence of trapped flux



Summary

- Resonant Frequencies: 400MHz, 800MHz, 1200MHz
- Broad temperature range above the bath temperature is available
- Measurement of $\mathrm{R_S}(\mathrm{B}, \mathrm{T}, f)$, penetration depth, quench field (high T), thermal conductivity, RRR
- Separate losses due to magnetic and electric field
- Study the influence of trapped magnetic flux

Outlook

- Production of HIPIMS Sample (CERN)
- Current bulk Nb sample: Diffusion of N to produce NbN (INFN)
- MgB2 (AASC) – currently surface (CERN) and composition (HZB) measurements; DC critical field measurements (CERN) being planned