Commissioning of the UHH Quadrupole Resonator at DESY

Ricardo Monroy-Villa on behalf of the SRF R&D team

Grand Rapids, 29.06.2023

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Bundesministerium für Bildung und Forschung

Universität Hamburg
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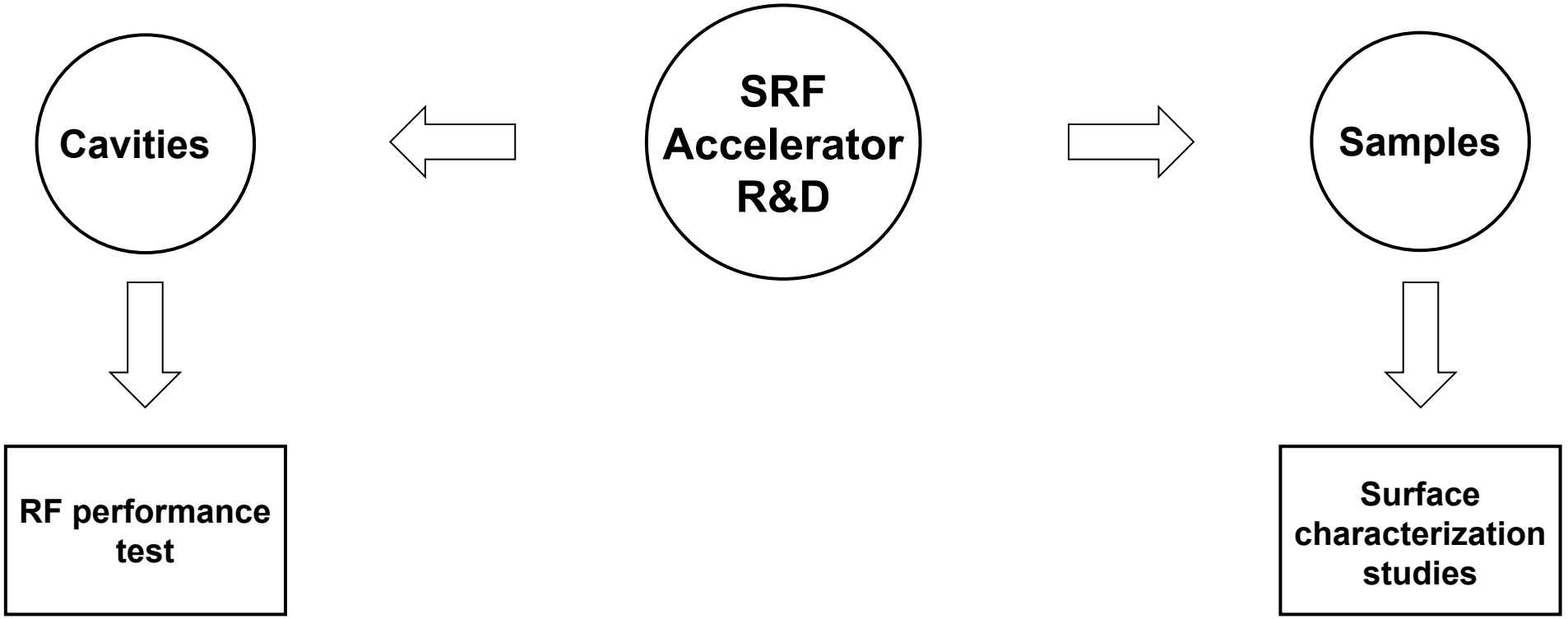
MATTER AND TECHNOLOGIES
ACCELERATOR RESEARCH AND DEVELOPMENT

SRF 2023 GRAND RAPIDS

DESY.

Why is the QPR important?



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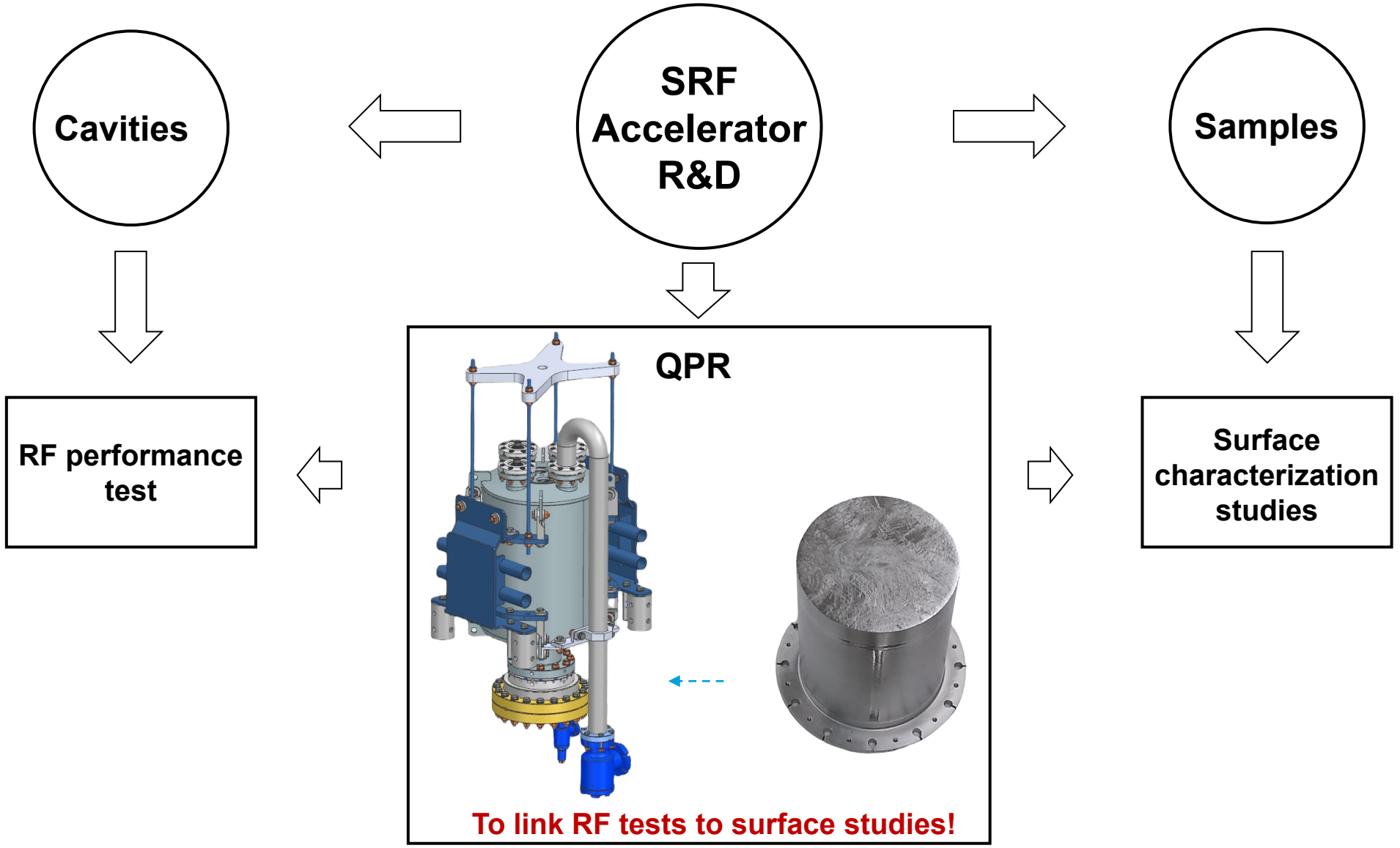
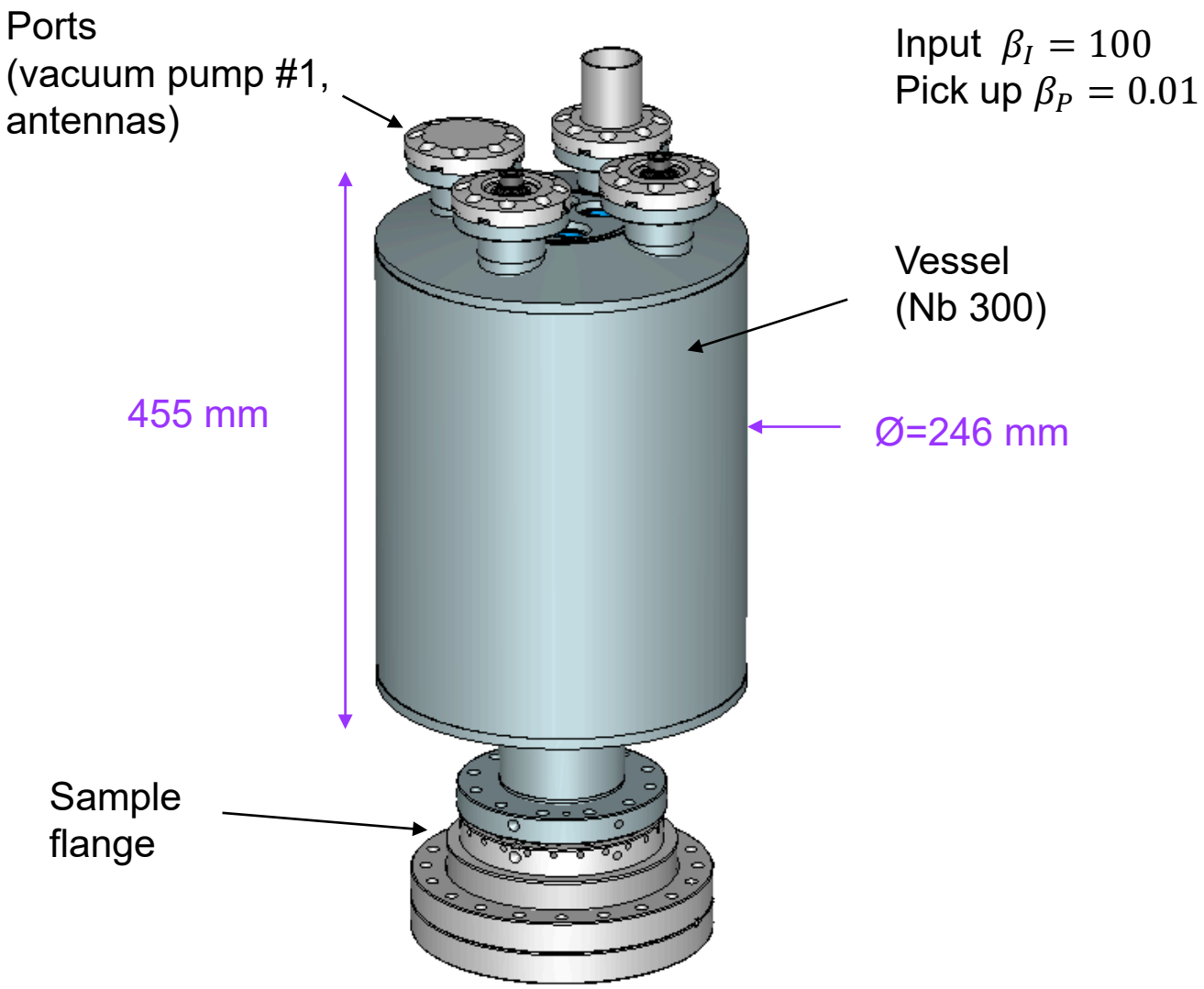


Overview of the QPR

University of Hamburg (UHH) and DESY



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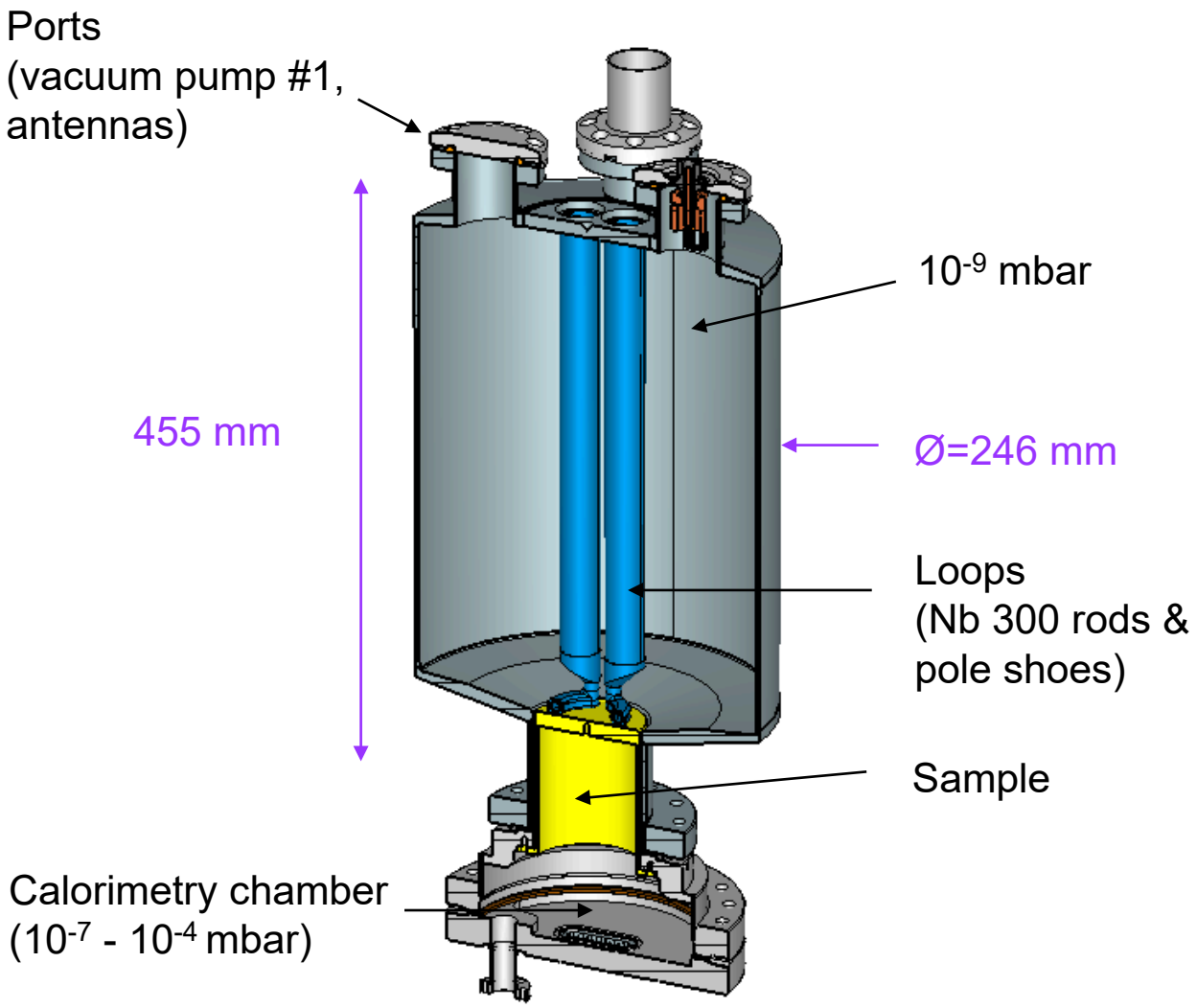

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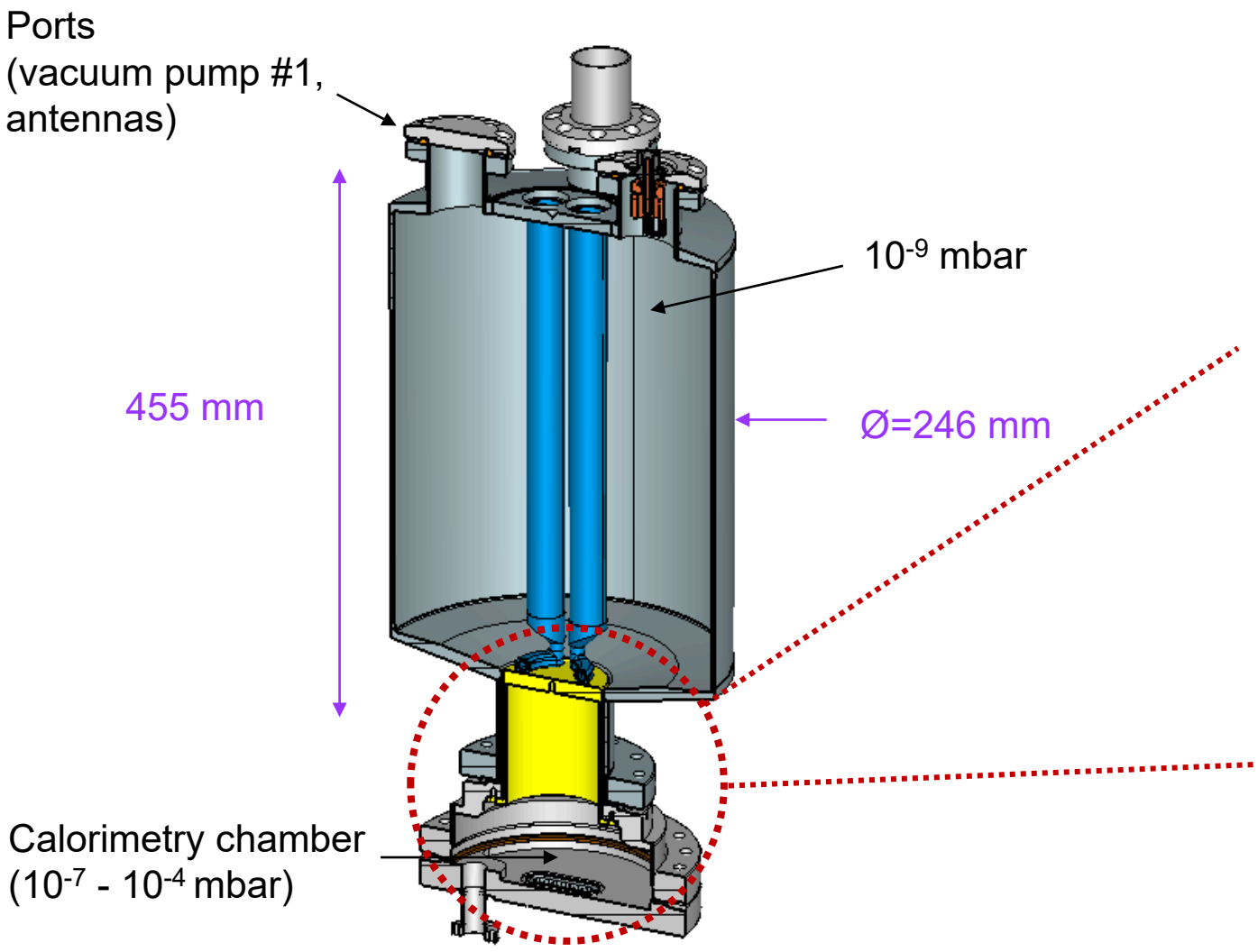

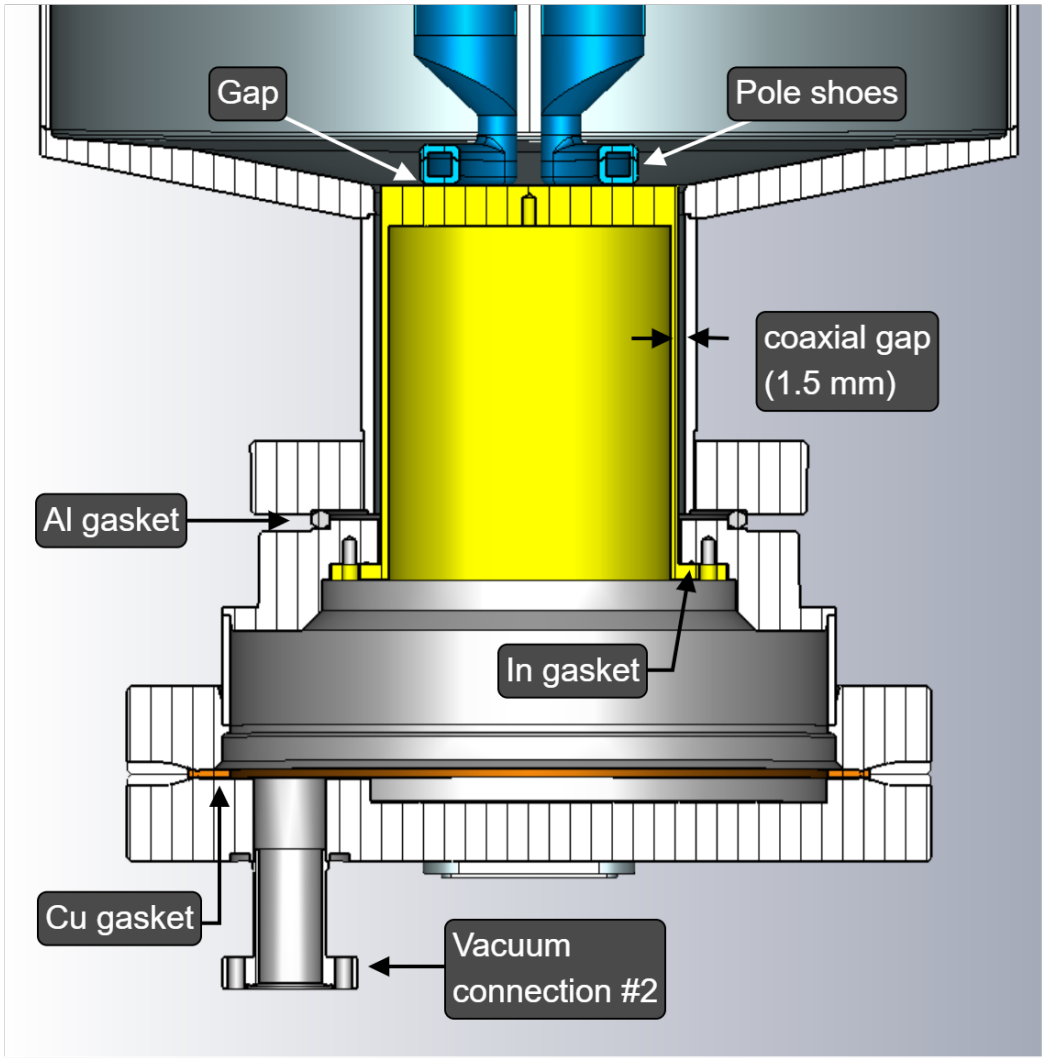

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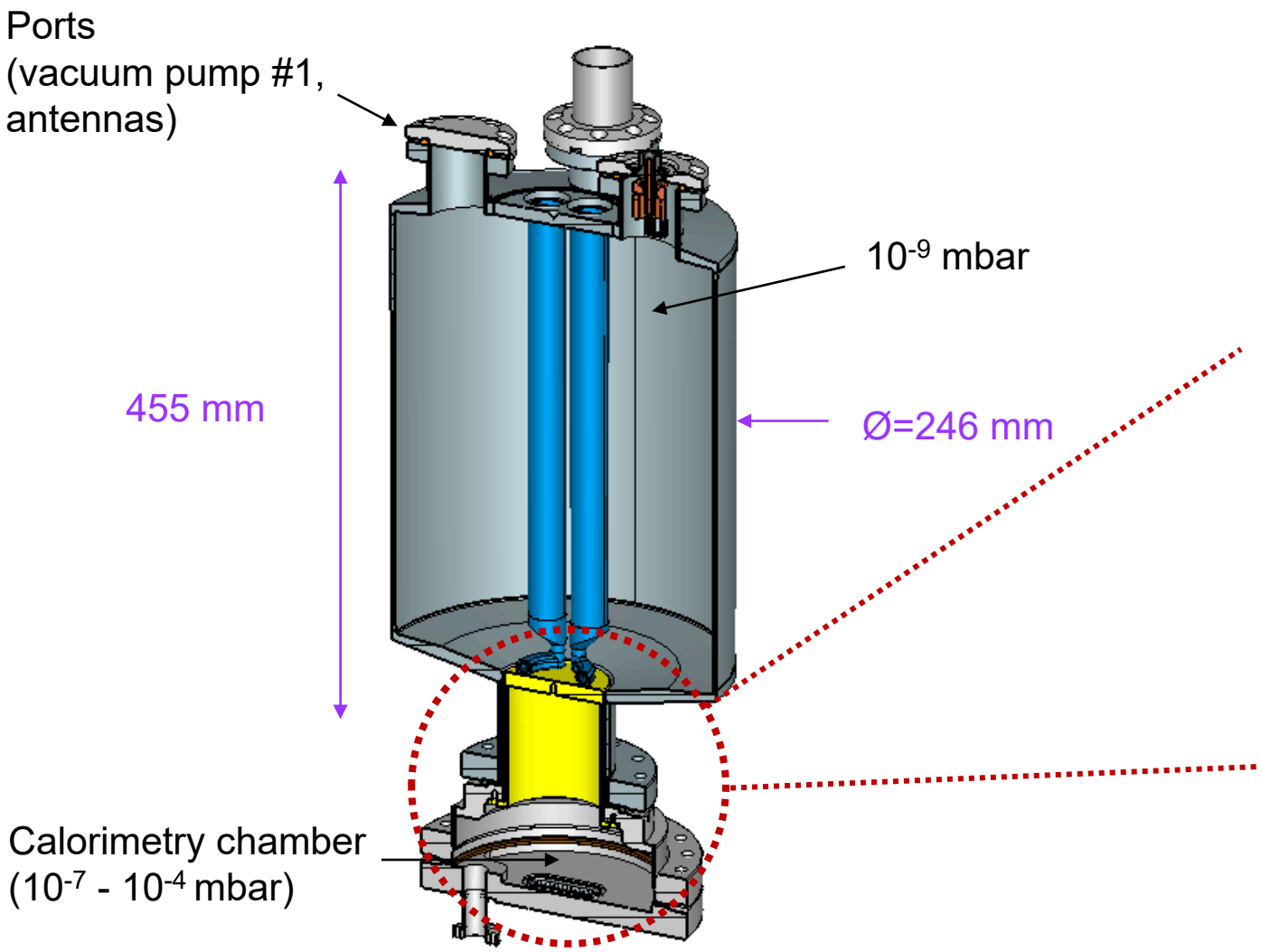
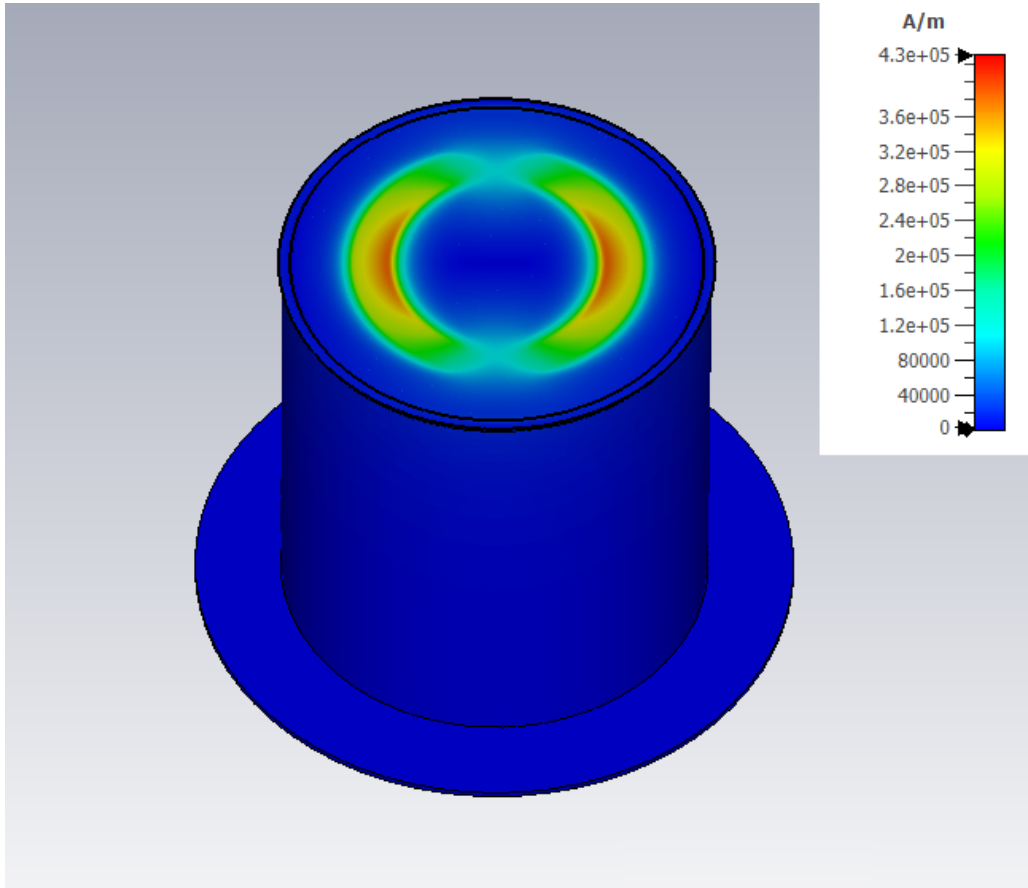
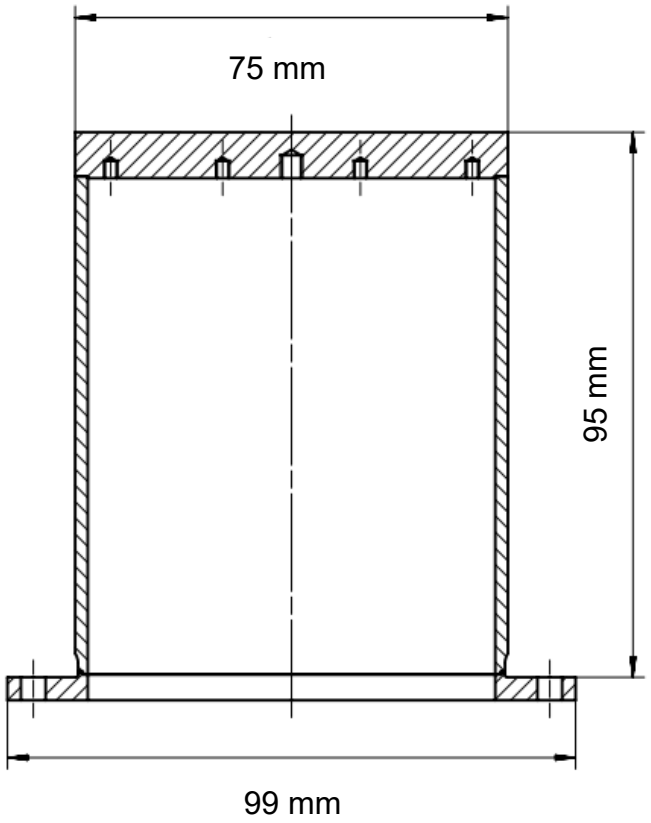




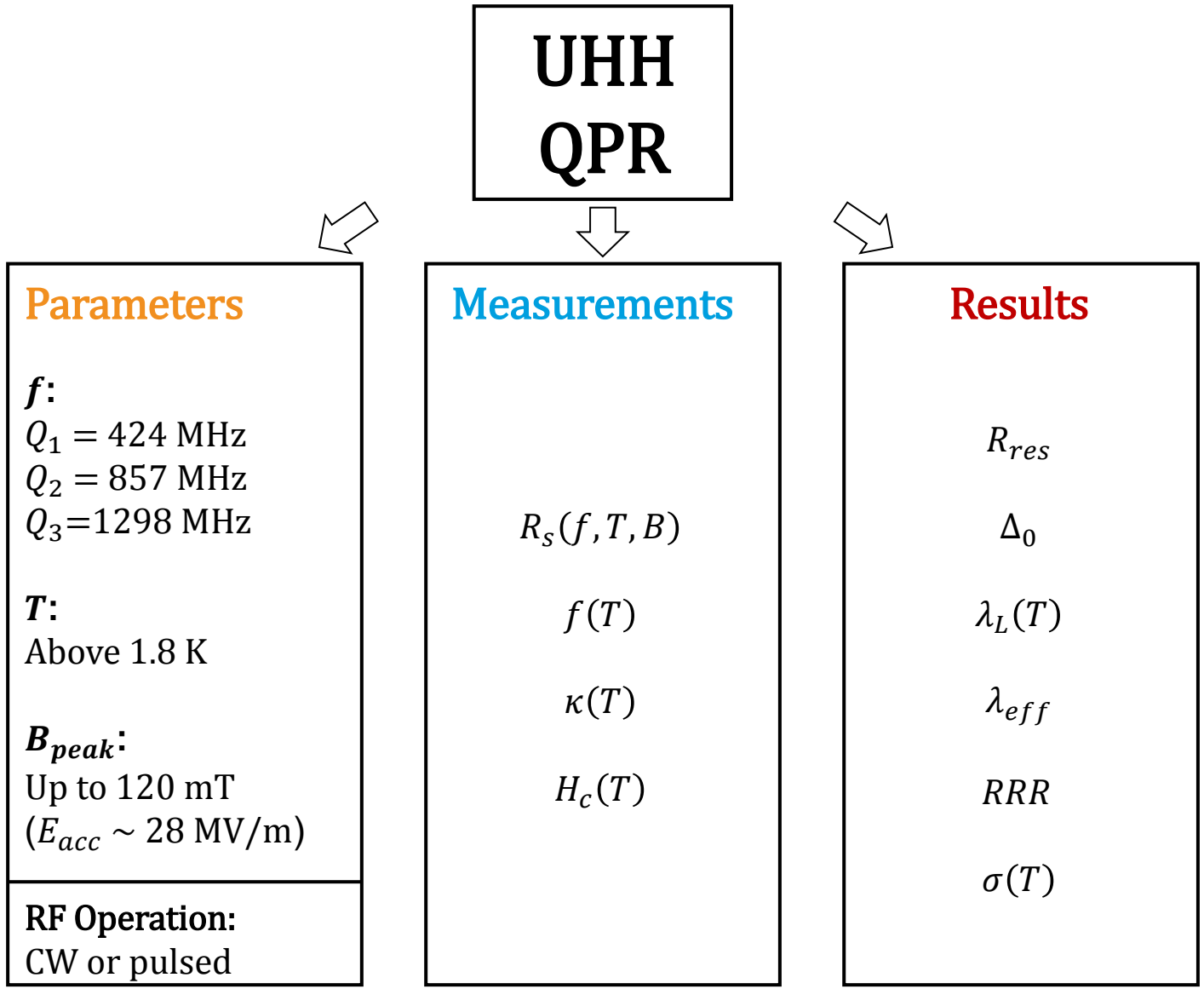
QPR used for RF characterization of flat cylindrical samples



Advantages:

- Direct measurement of sample
- Typical SRF conditions, e.g. 2 K, 1.3 GHz, and 20 MV/m
- Same surface can be analysed with surface characterization methods
- Easier sample preparation and exchange
- Faster turn around times and lower costs compared to cavities
- Exchange between labs (CERN, HZB, DESY, and JLab)

QPR allows study of samples across a wide range of parameters



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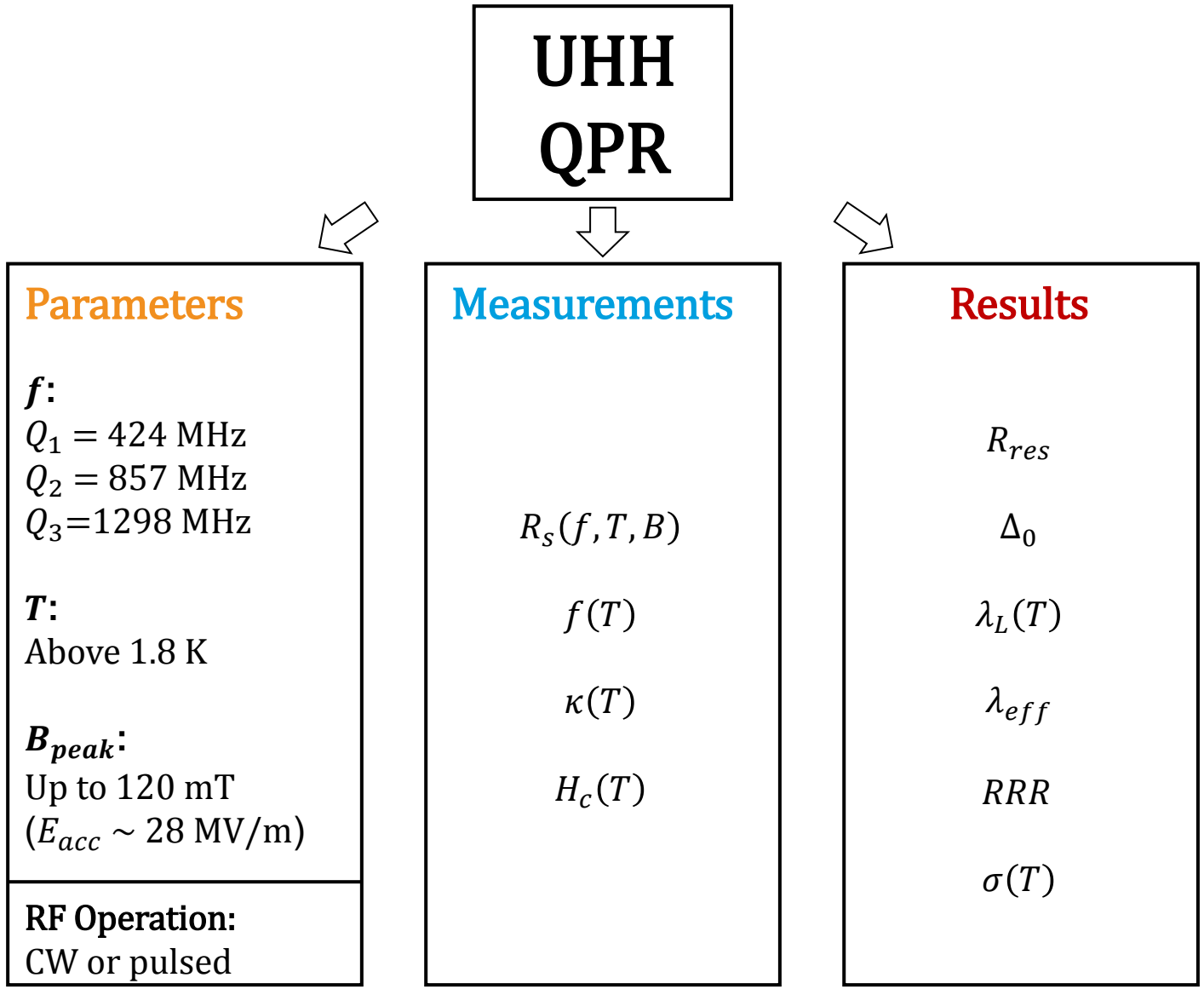


First study case:

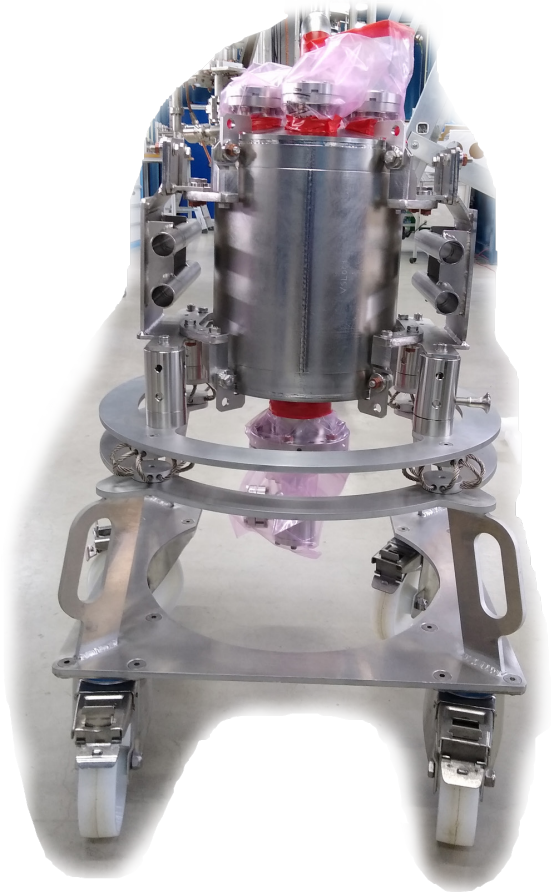
- **High RRR** sample on loan from HZB
- 110 µm BCP as a final treatment with **no 800 °C annealing**
- Highly **contaminated with H** („Q-disease“)
- Test 1 (Q_3) on 2022 and Test 2 (all Qs) on 2023

QPR successfully fabricated at Zanon R.&I. SRL

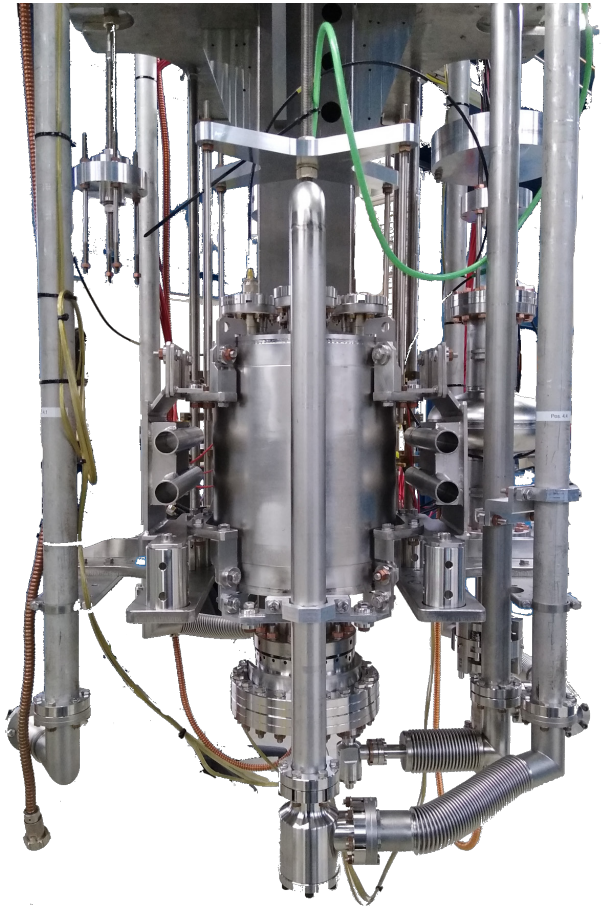
Commissioning at DESY ongoing – so far successfull

UHH QPR design based on HZB system.

Cutoff tube, vessel, rods, and pole shoe before welding.



QPR is moved around with the trolley.



QPR is installed in insert.

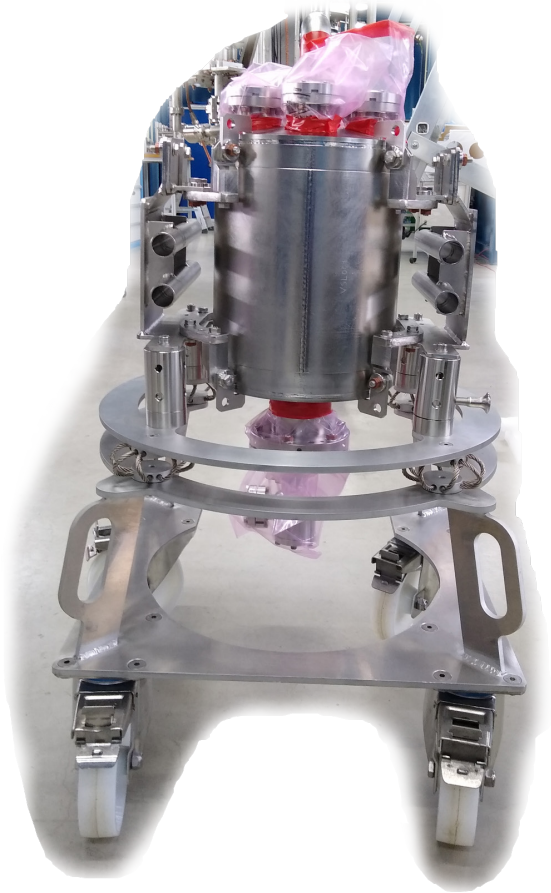
QPR successfully fabricated at Zanon R.&I. SRL

Commissioning at DESY ongoing – so far successfull

UHH QPR design based on HZB system.

After fabrication, the QPR underwent a standard chemical treatment for SRF cavities.

Cutoff tube, vessel, rods, and pole shoe before welding.



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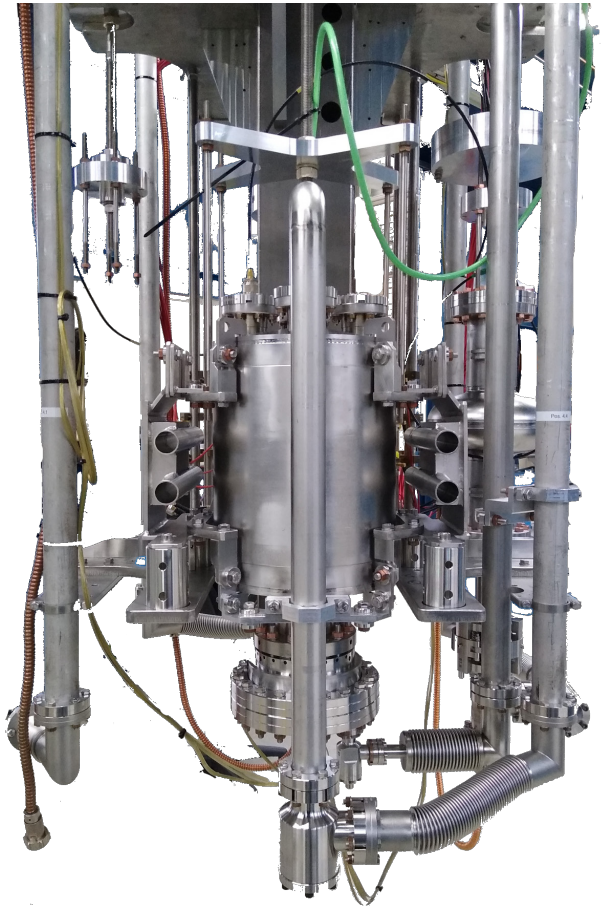

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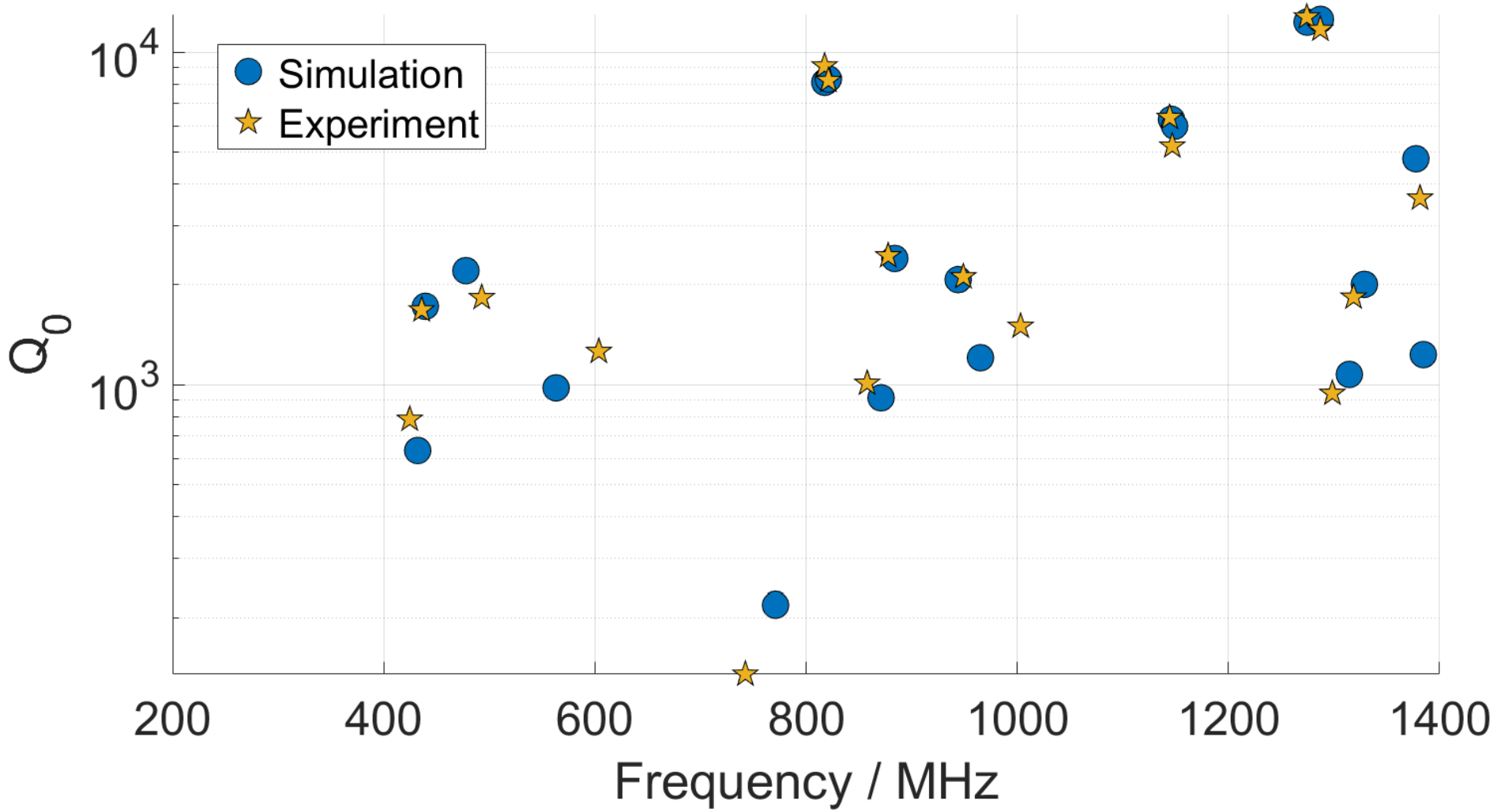
Simulations and measurements of RF modes agree

Room temperature



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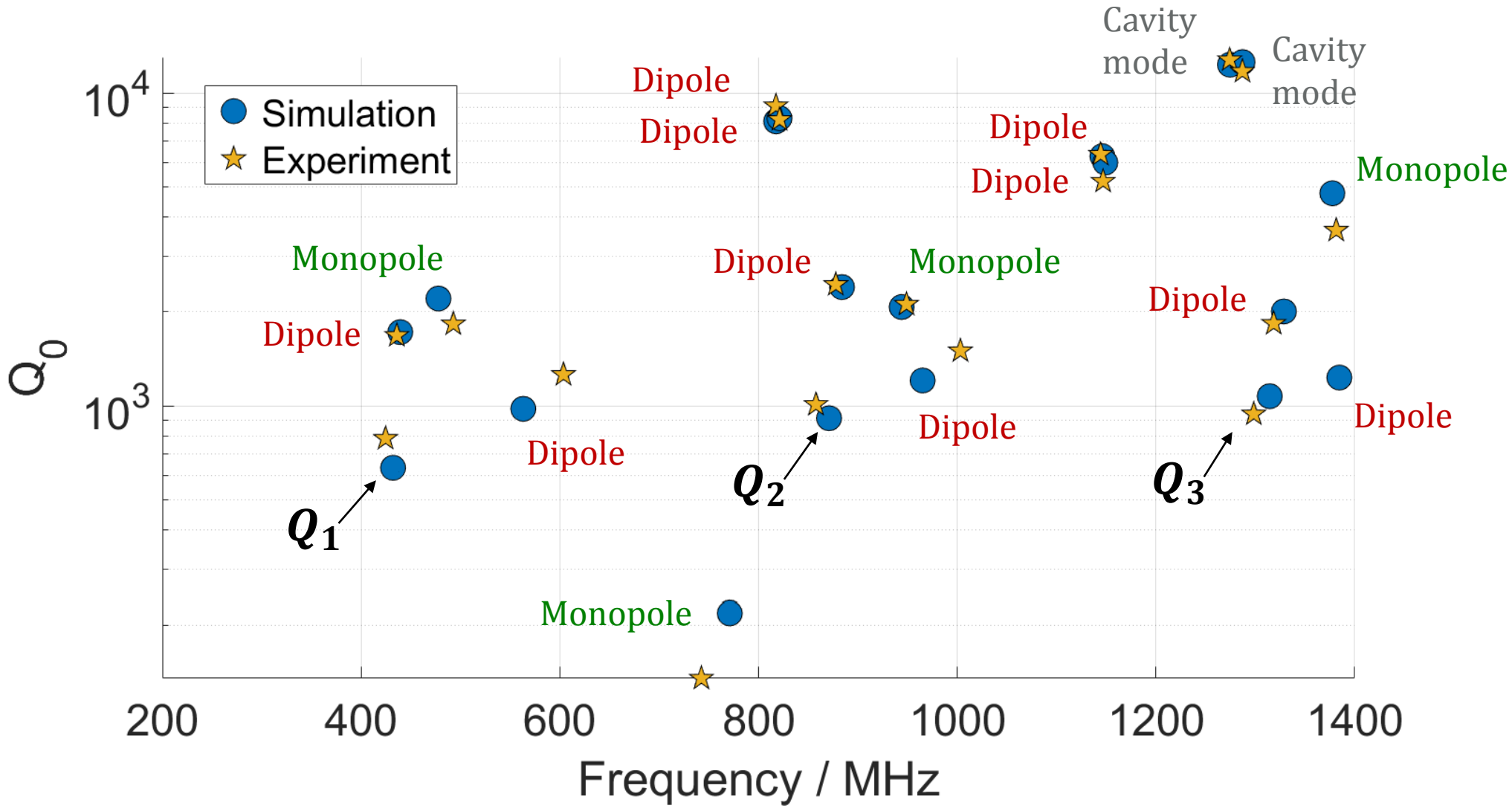

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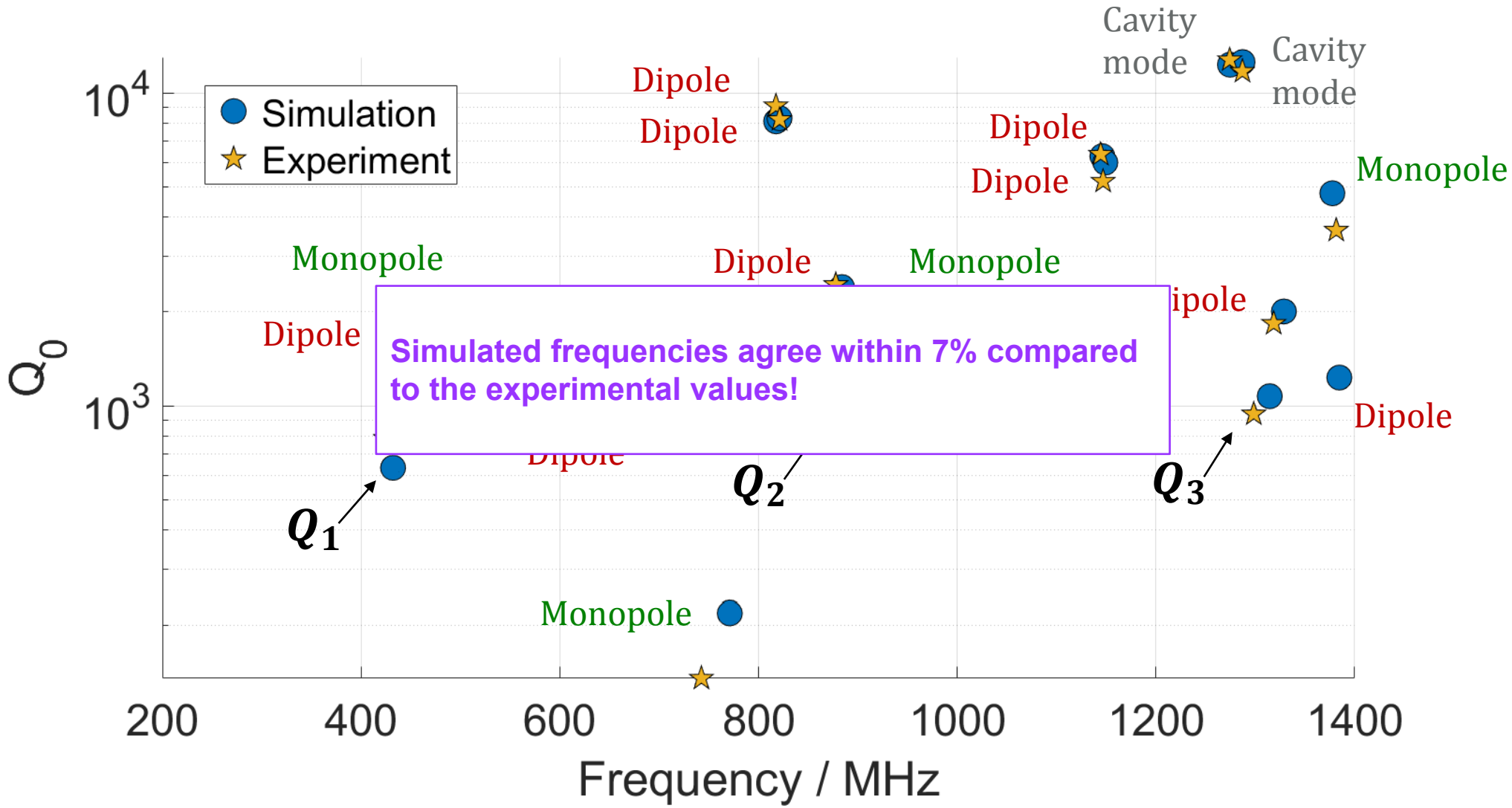
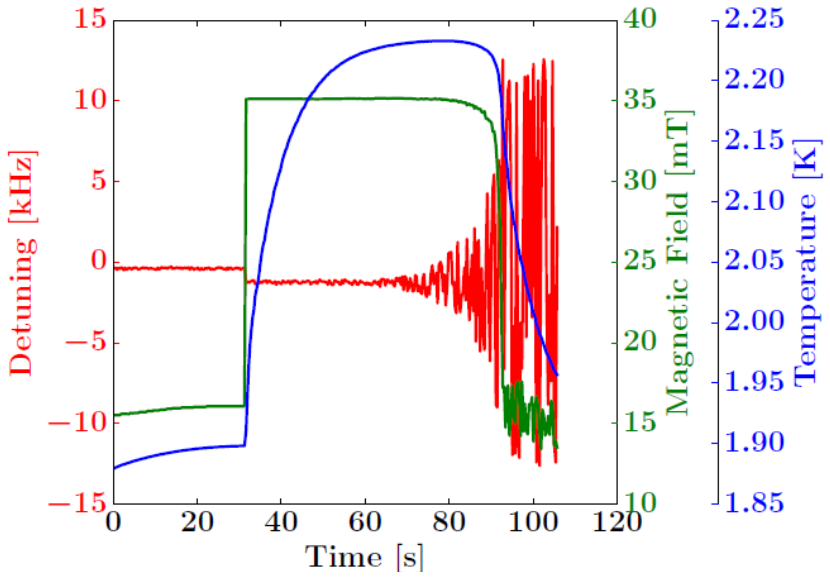
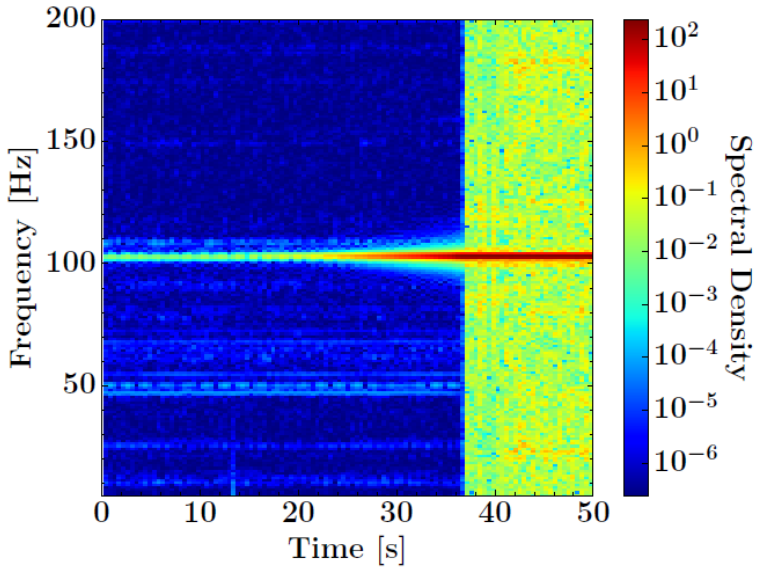


Design optimization #1: stiffening of the rods

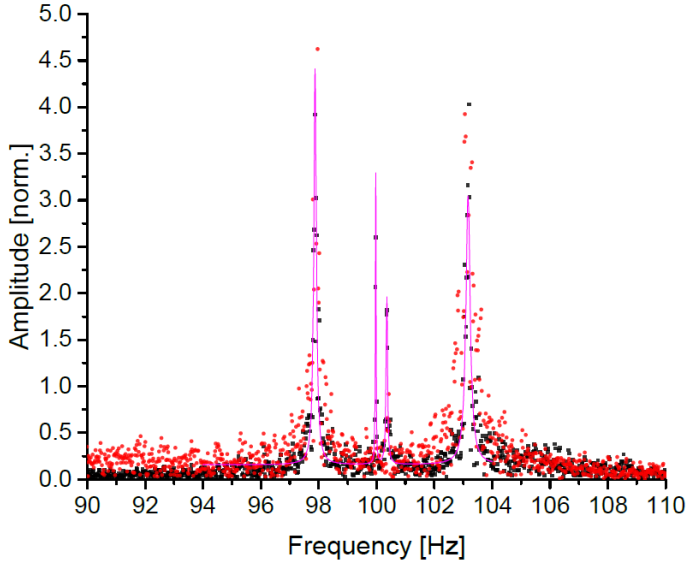
HZB QPR:



Observed detuning leads to PLL losing it's lock on the resonance peak.



Spectrogram of RF signal shows a 100 Hz contribution.



The rods have a 100 Hz mechanical mode.

⇒ **CW or pulsed RF power shouldn't have the same frequency**

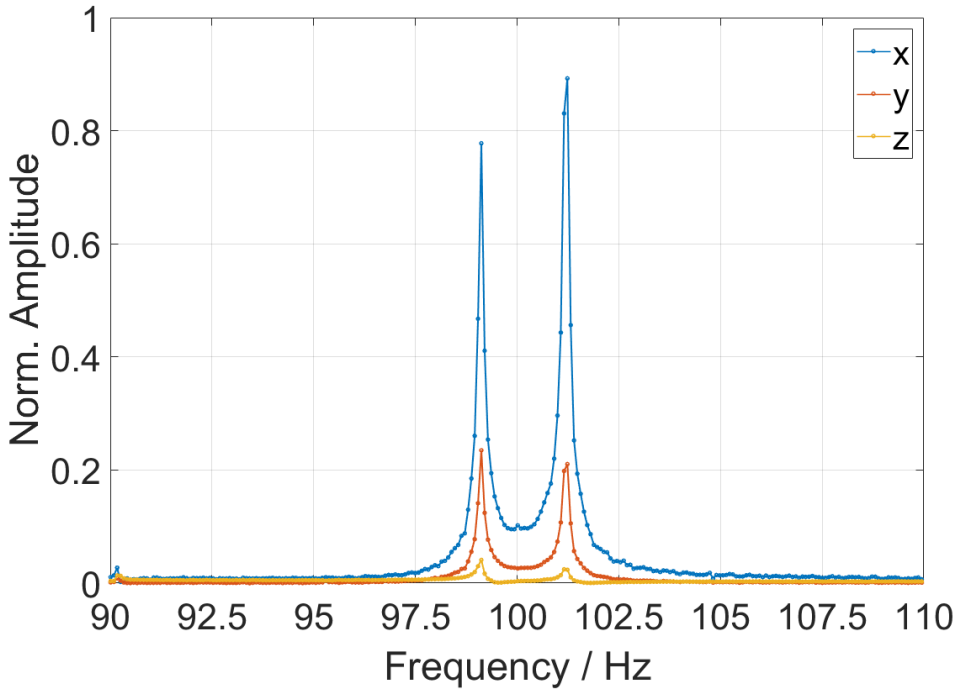
R. Kleindienst, Ph.D. Thesis, Universität Siegen, Siegen, Germany, 2017.

Design optimization #1: stiffening of the rods

UHH QPR:

Metal bars welded to the rods to enhance their rigidity.

Sensors on top in x-,y- & z-direction.



Mechanical spectrum of the rods.

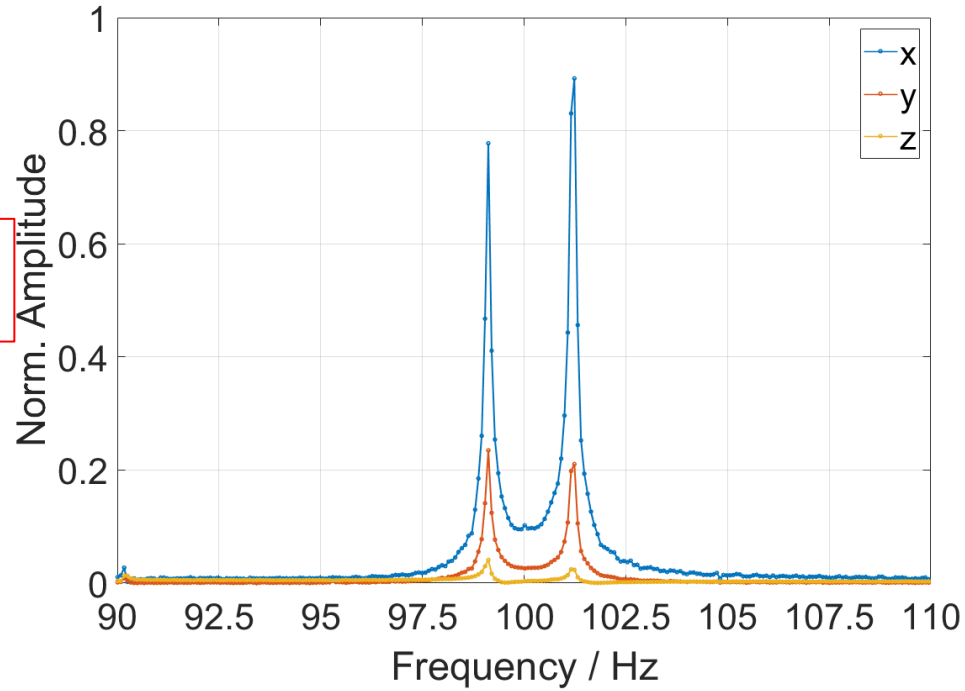
Design optimization #1: stiffening of the rods

UHH QPR:

Metal bars welded to the rods to enhance their rigidity.

As 100 MHz mode has been eliminated, continuous mode operation is possible!

Sensors on top in x-,y- & z-direction.



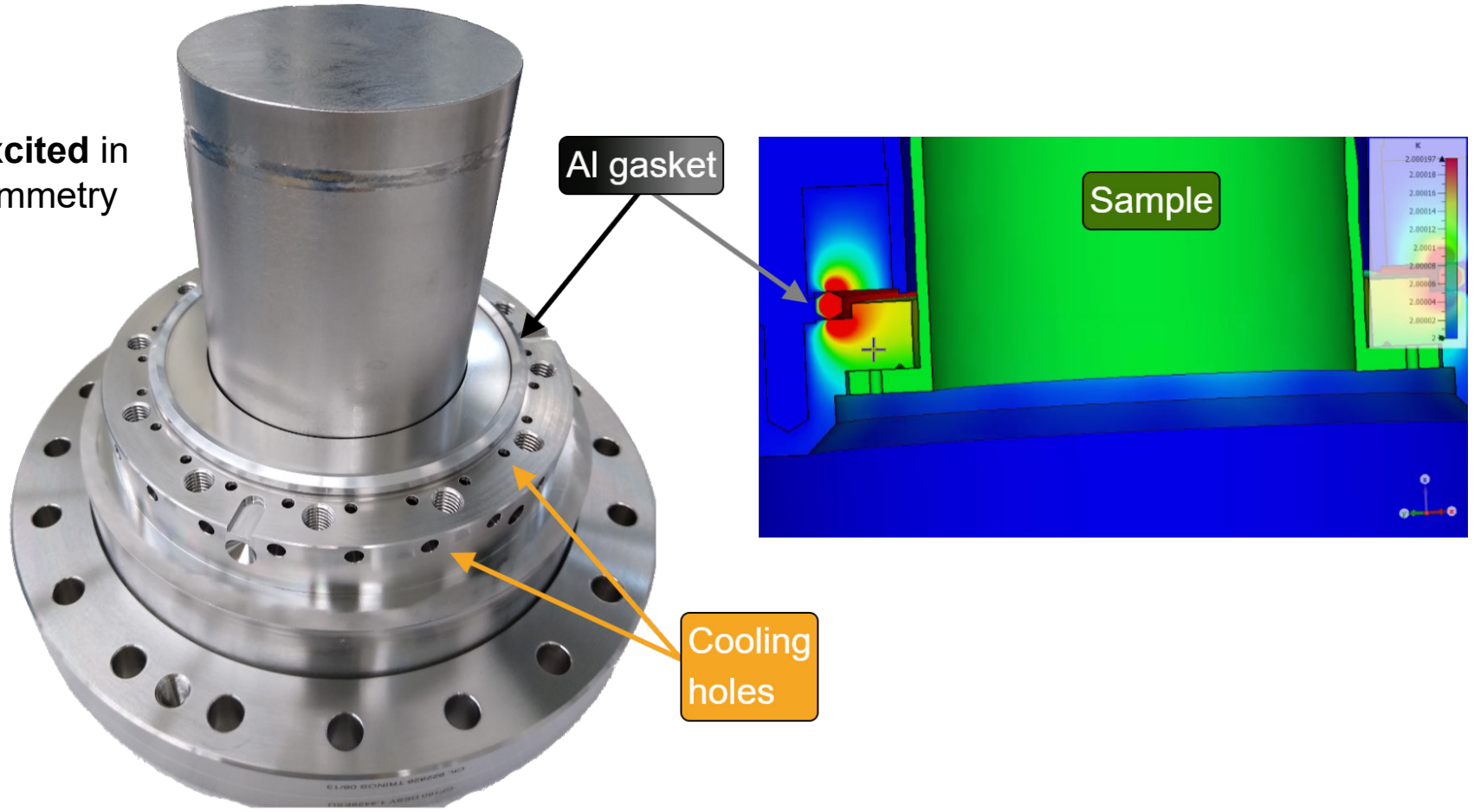
Mechanical spectrum of the rods.

Design optimization #2: prevent parasitic heating

Dipoles are inevitably excited in all QPR devices due to symmetry reasons.

Dipoles **do not vanish** in the coaxial gap and can reach the bottom!

⇒ sample heats up, leading to an **overstimation of R_s**



Design optimization #2: prevent parasitic heating

- Dipole Mode Excitation (D3)

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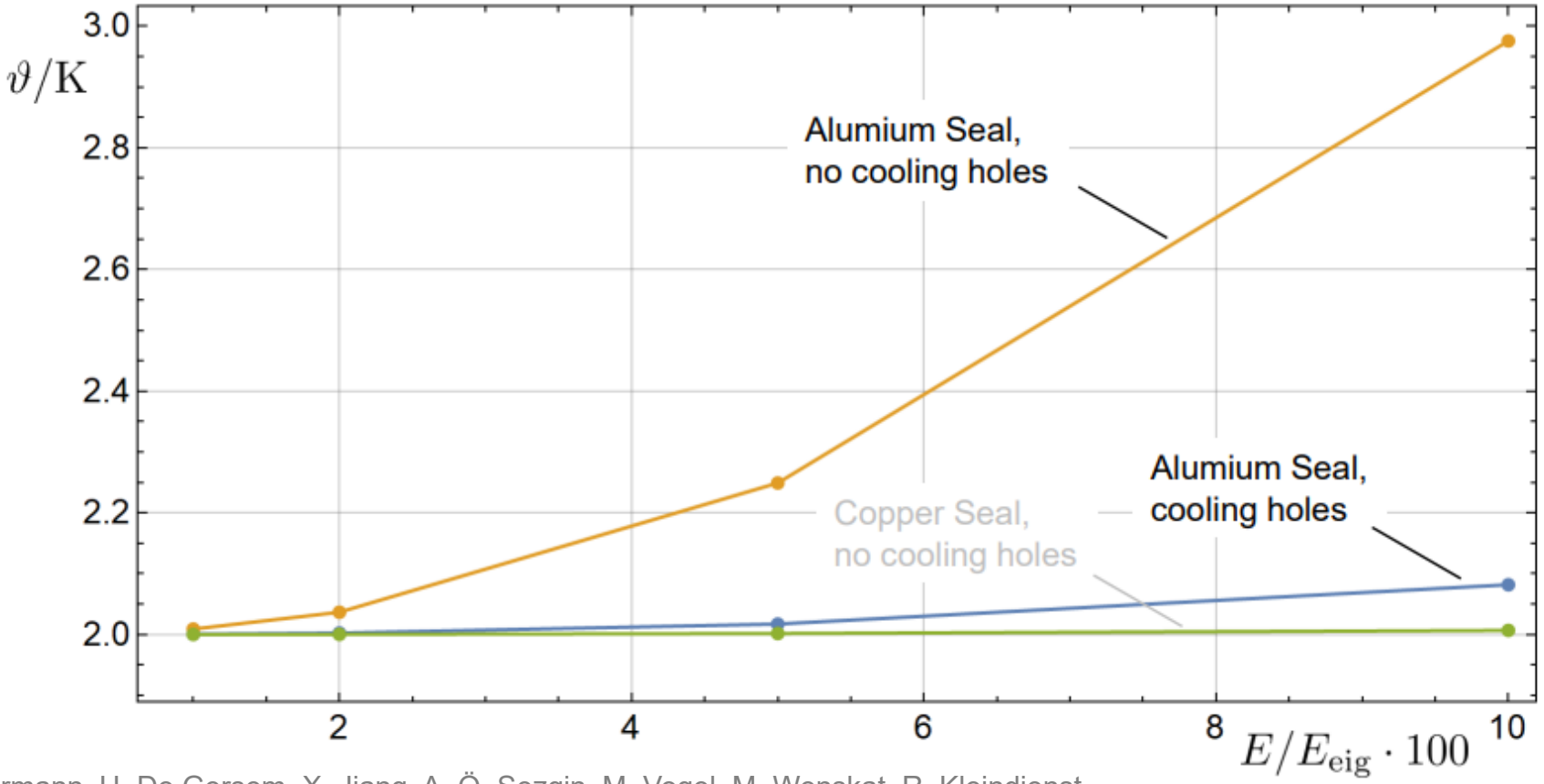

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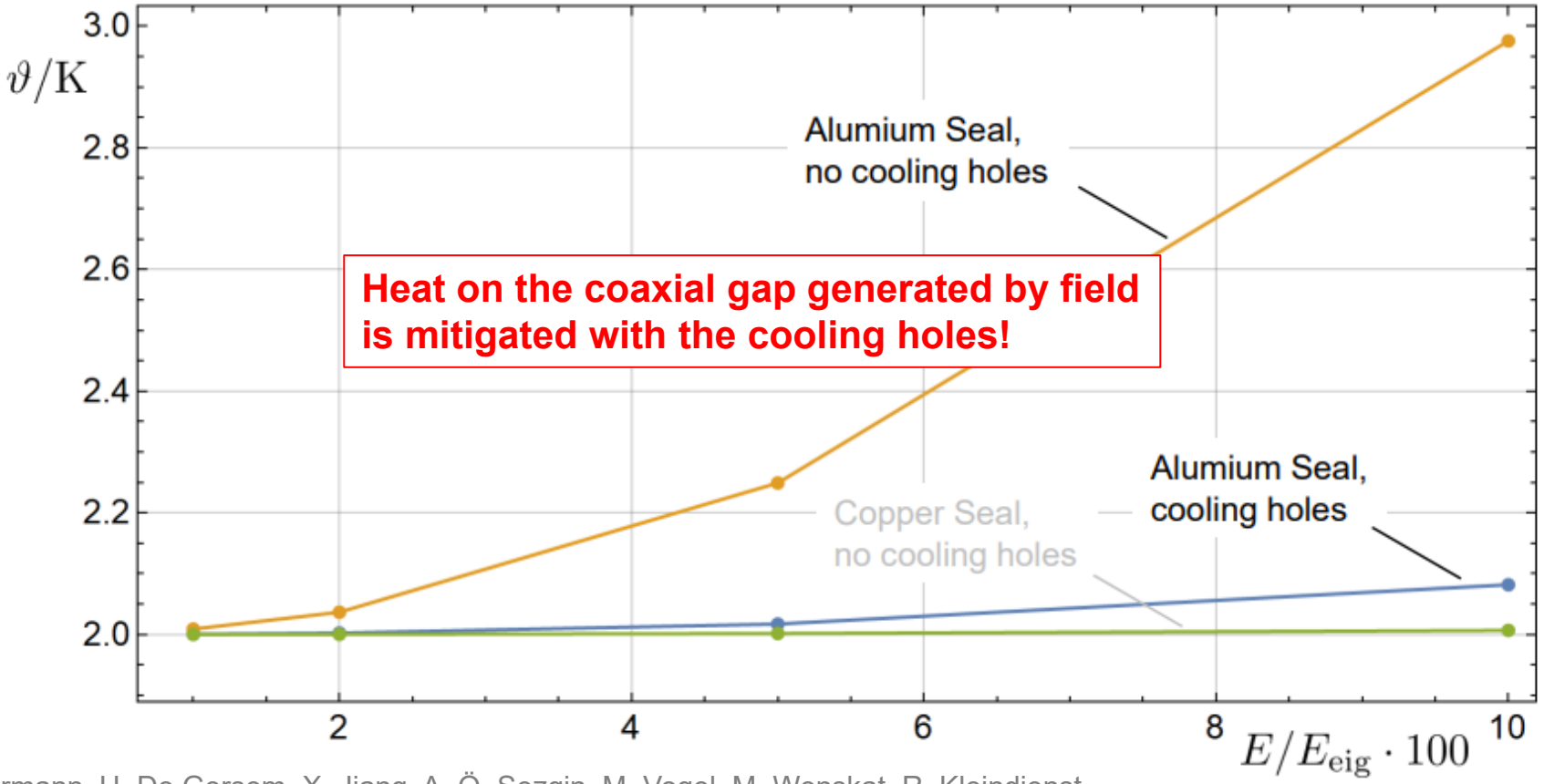

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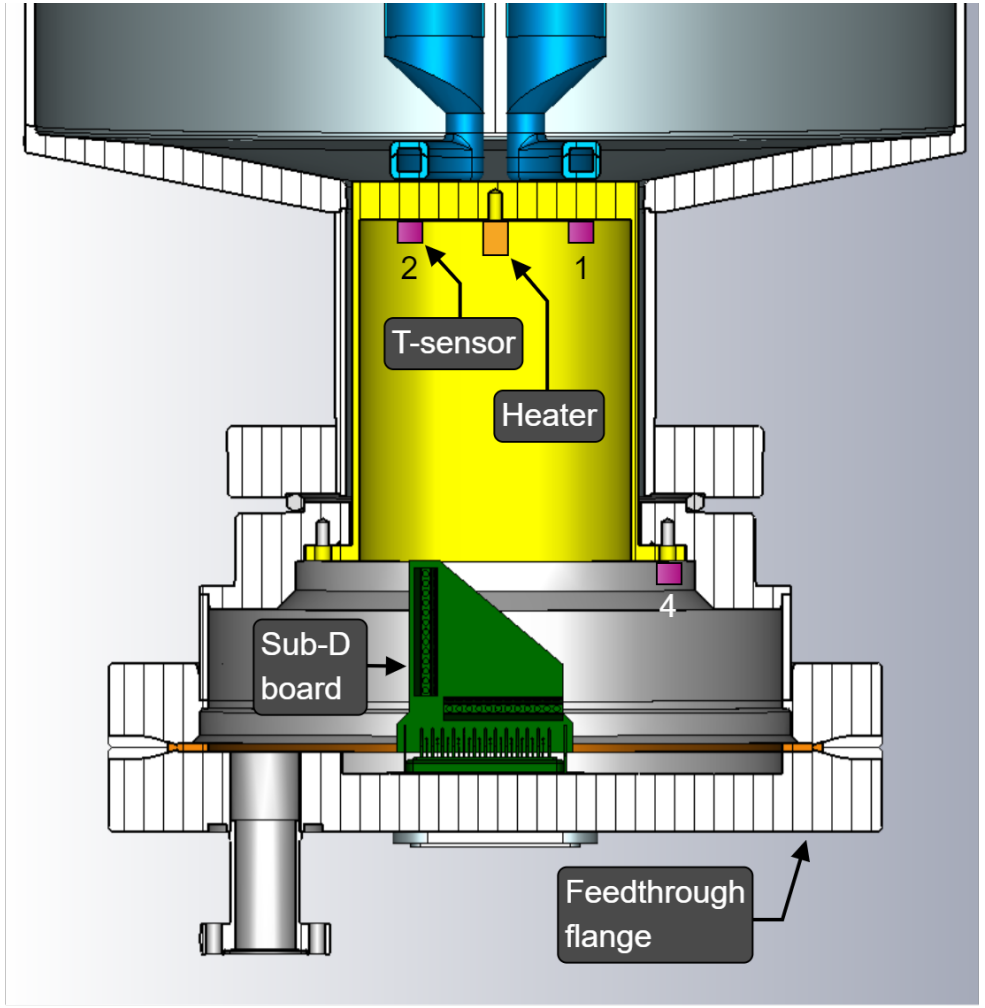
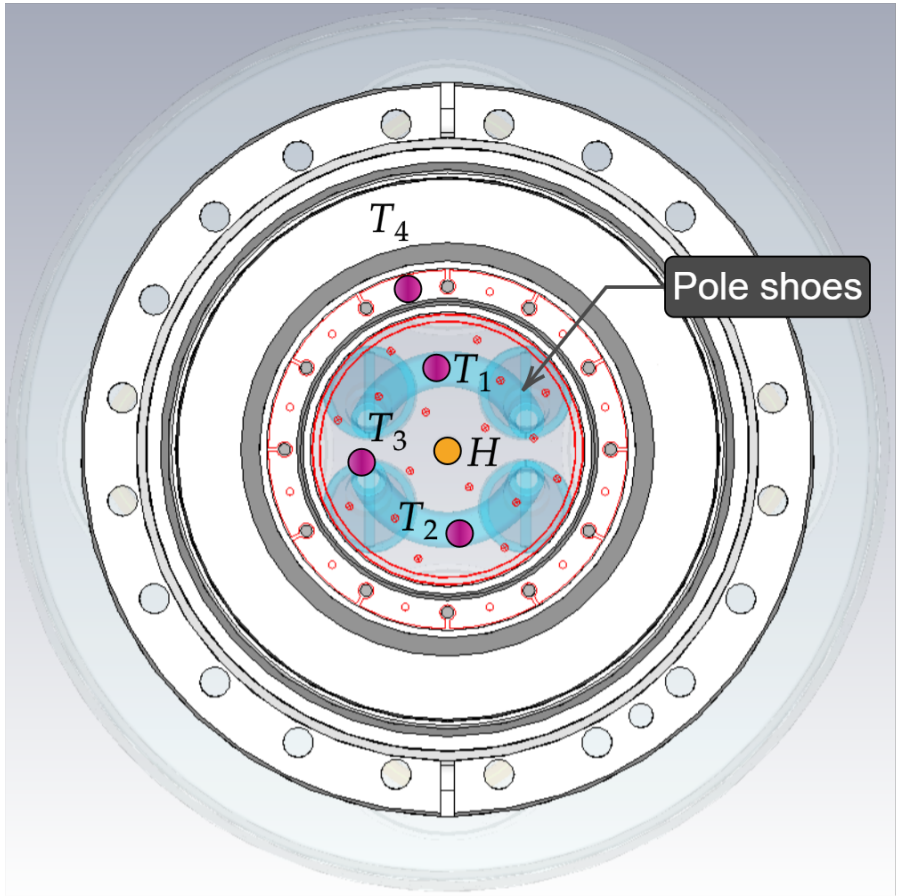
Auxiliary devices installed in the calorimetry chamber





Bottom view

- **T-sensor:** CERNOX™

T_1 used for measurements

T_2 , T_3 and T_4 for control purposes

T_4 also used for thermal conductivity measurements

- **Heater:** 50 Ω Cu resistor

⇒ Interconnected **in closed-loop controller**

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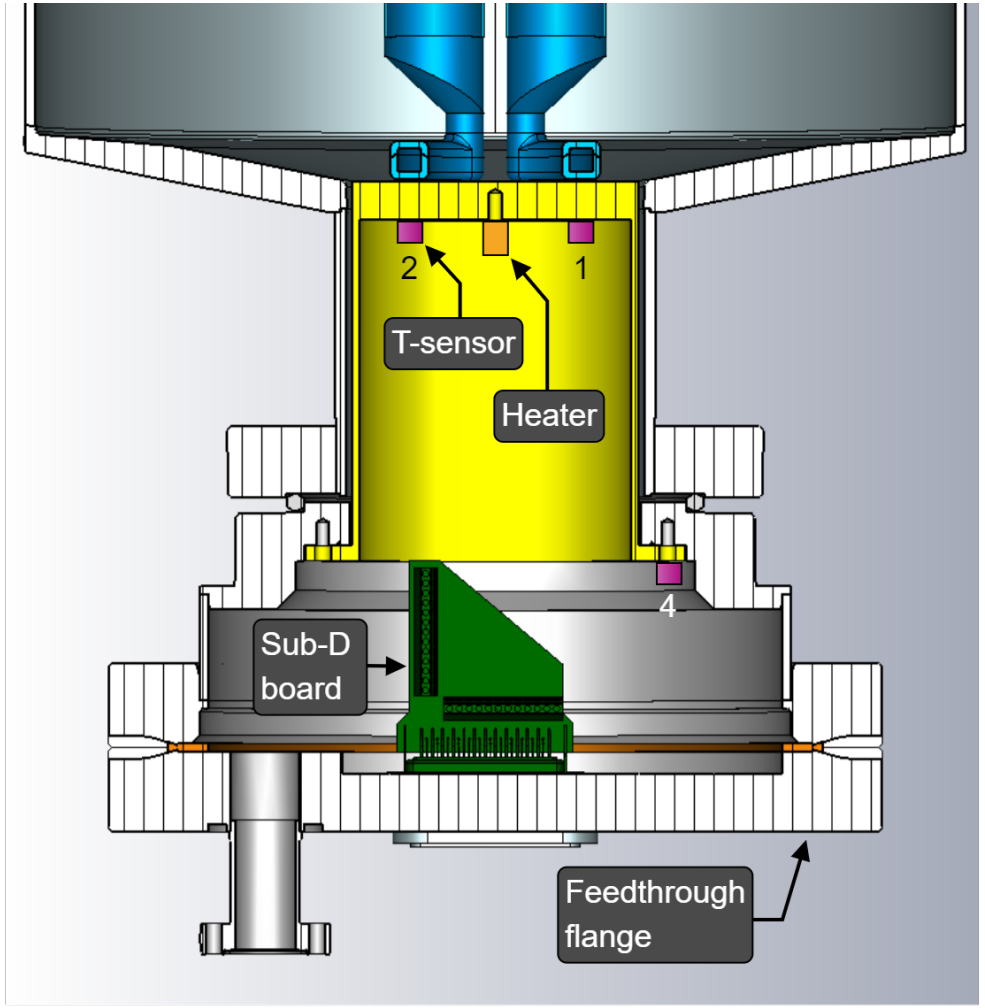

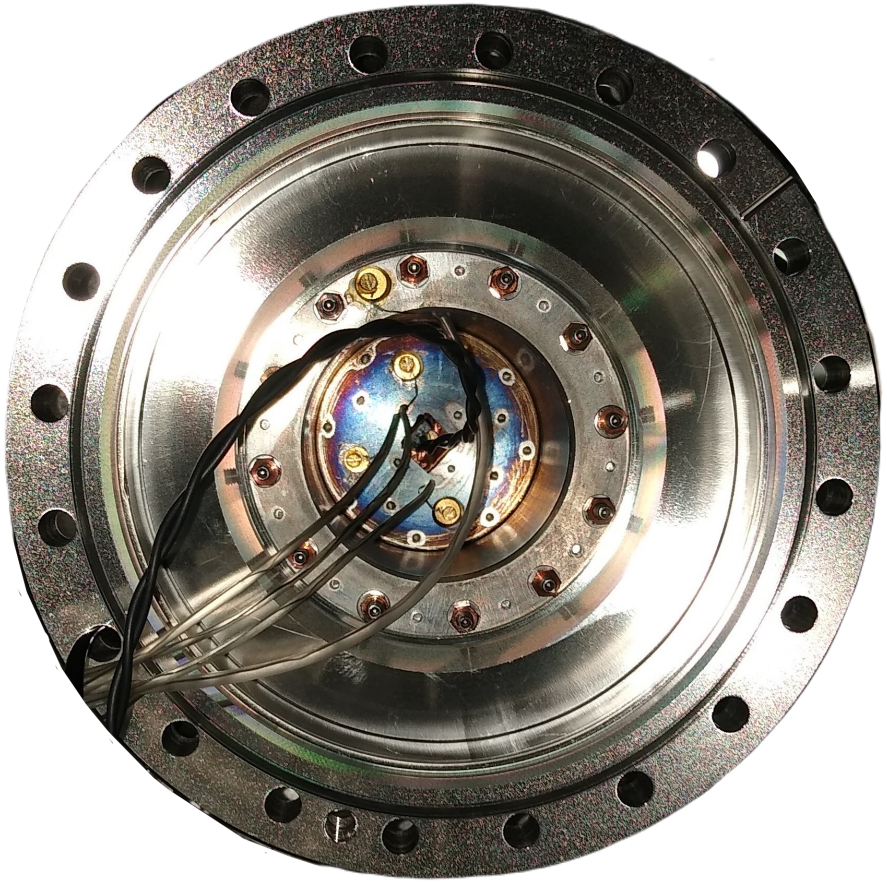

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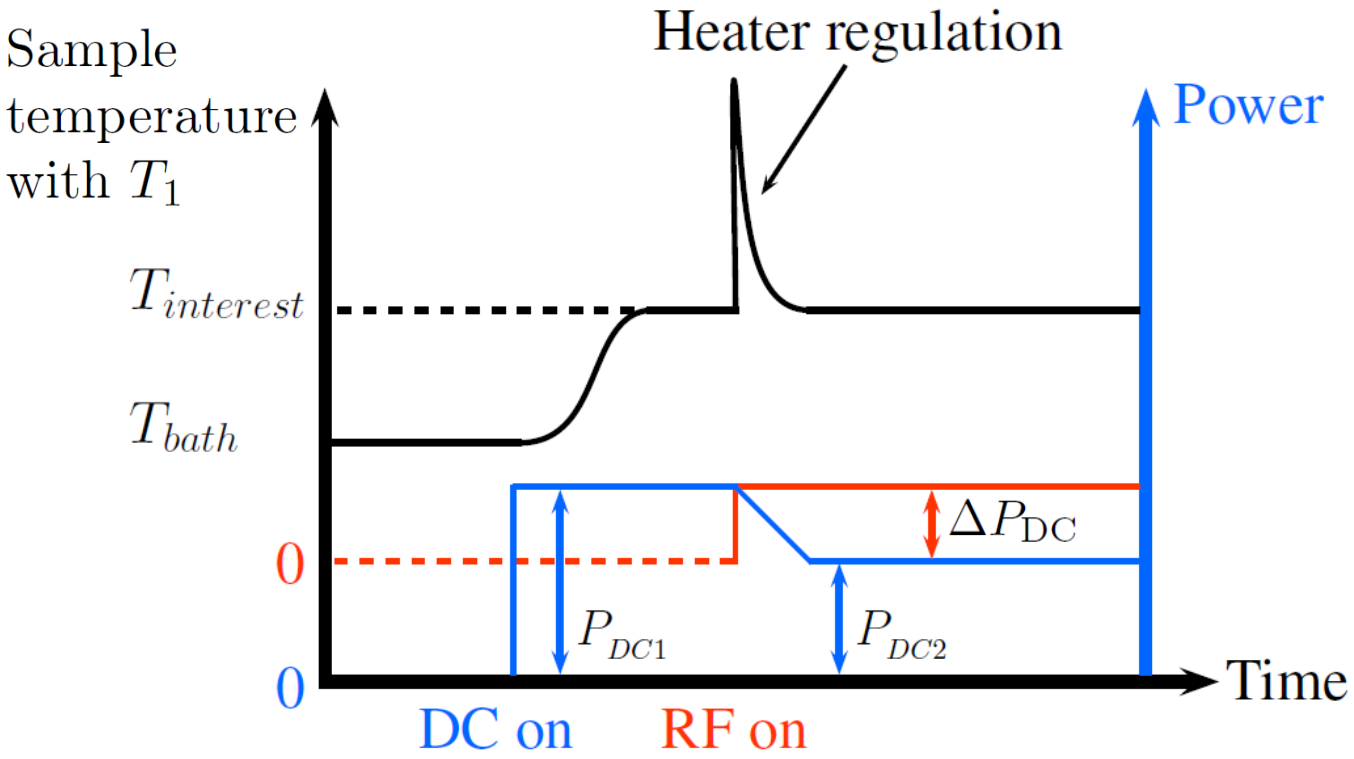
Surface resistance determined by equilibrium condition



$$\Delta P_{\mathrm{DC}} \approx \frac{1}{2} R_{\mathrm{s}} \cdot \int_{\mathrm{sample}} |\boldsymbol{H}|^2 \, dA \quad \propto \frac{1}{2} R_{\mathrm{s}} \cdot U$$

T. Junginger. Ph.D. thesis, Ruprecht-Karls- Universität, Heidelberg, Germany, (2012).

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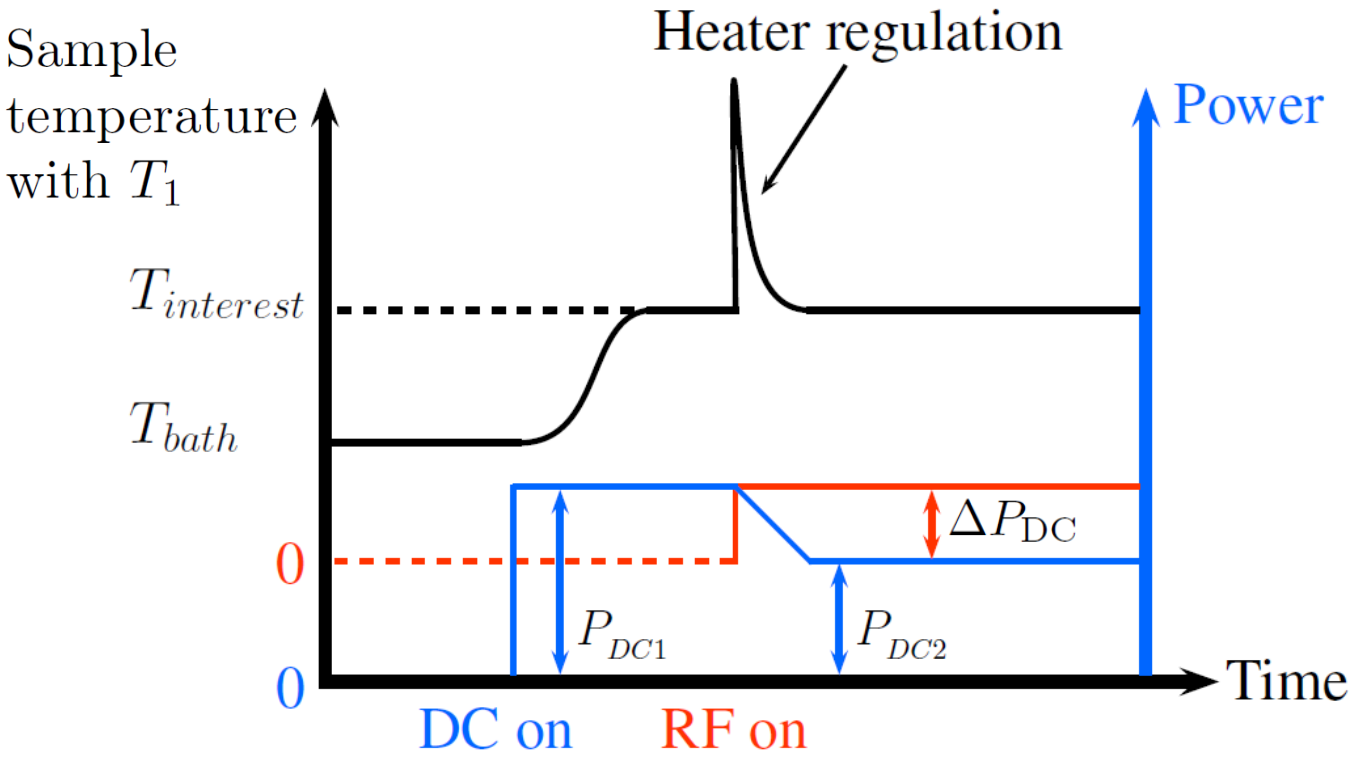

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- When RF power is turned off:

$$U \approx \sum_{m}^{N} P_{\mathrm{ref}} \Delta t$$

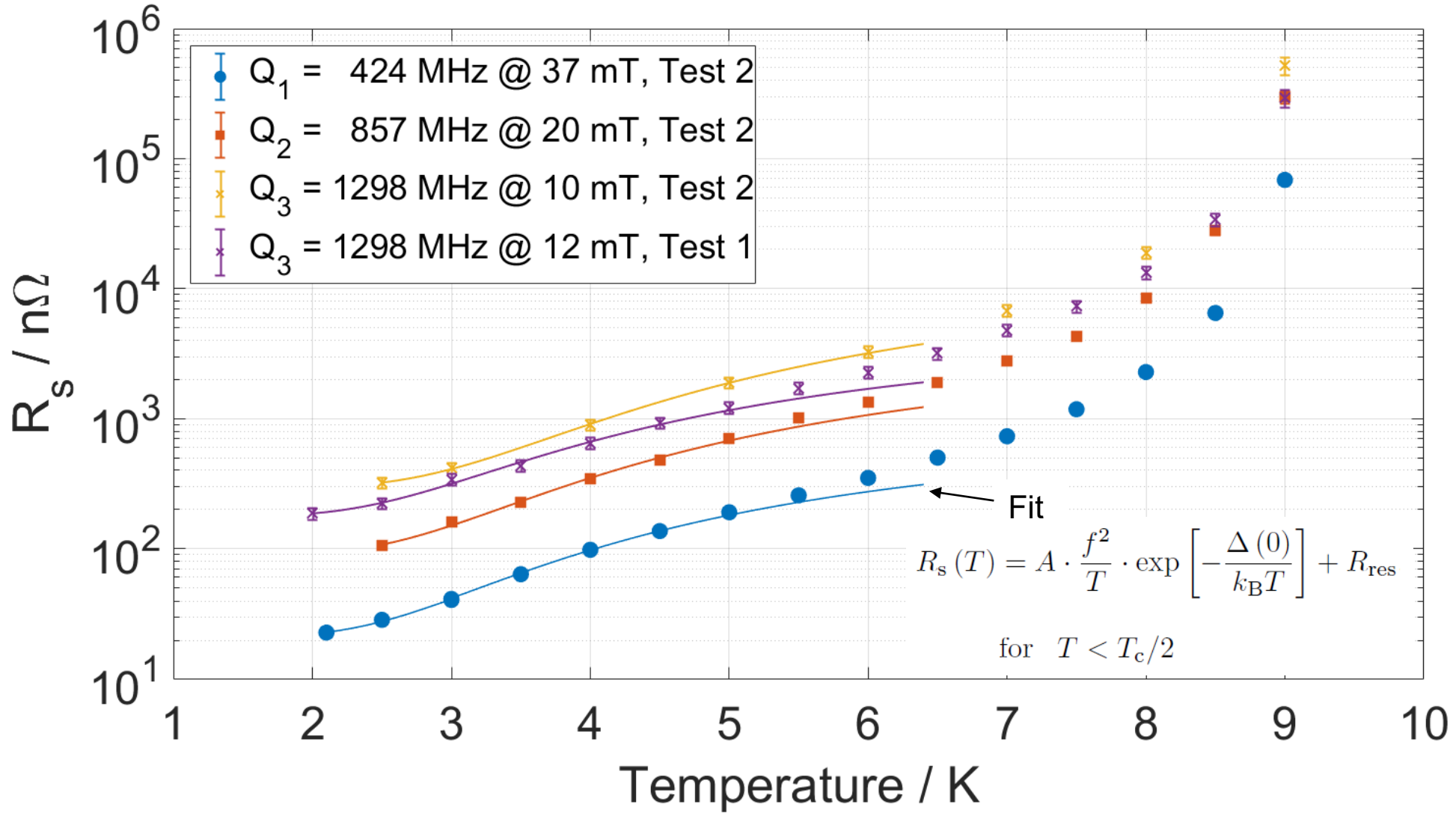
due to overcoupling, all energy decays as reflected power through the input antenna

$$\sigma_{R_{\mathrm{s}}} = \pm 10\%$$

T. Junginger. Ph.D. thesis, Ruprecht-Karls- Universität, Heidelberg, Germany, (2012).

R_s of the sample measured for all quadrupole modes

Fixed B_{peak} field or P_{for} of 1 W



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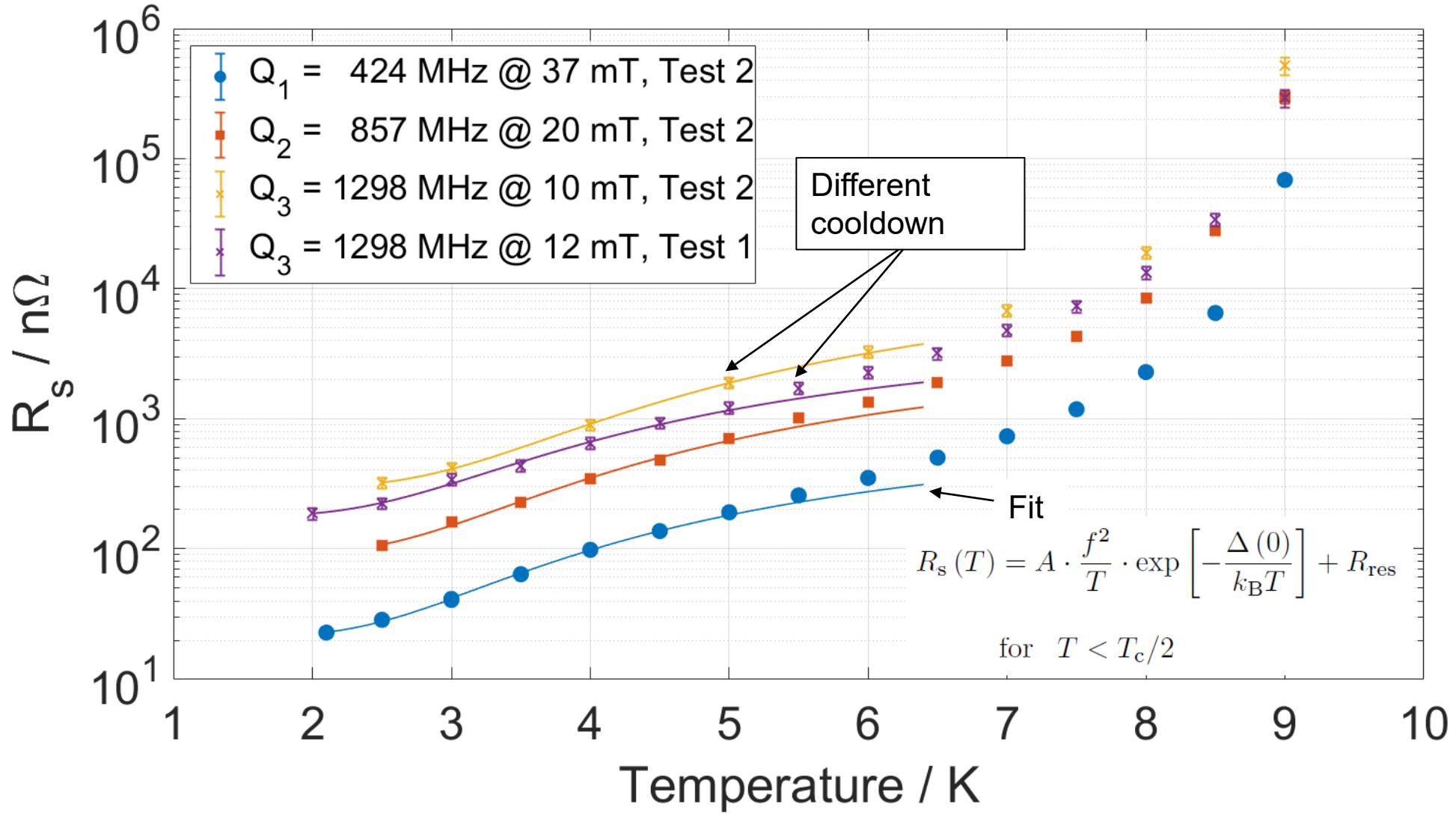
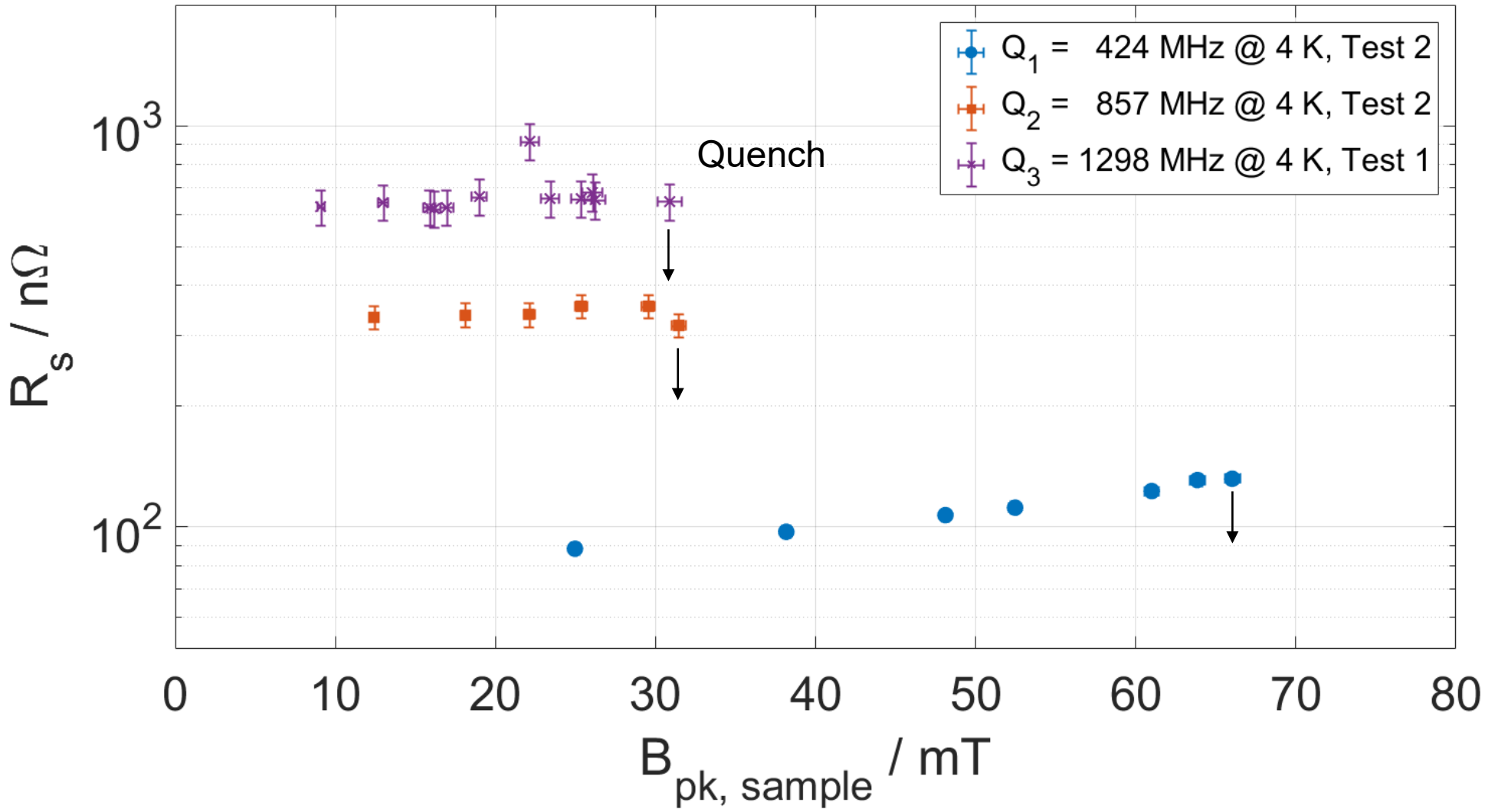


R_s of the sample measured for all quadrupole modes

Fixed temperature of T_1=4 K



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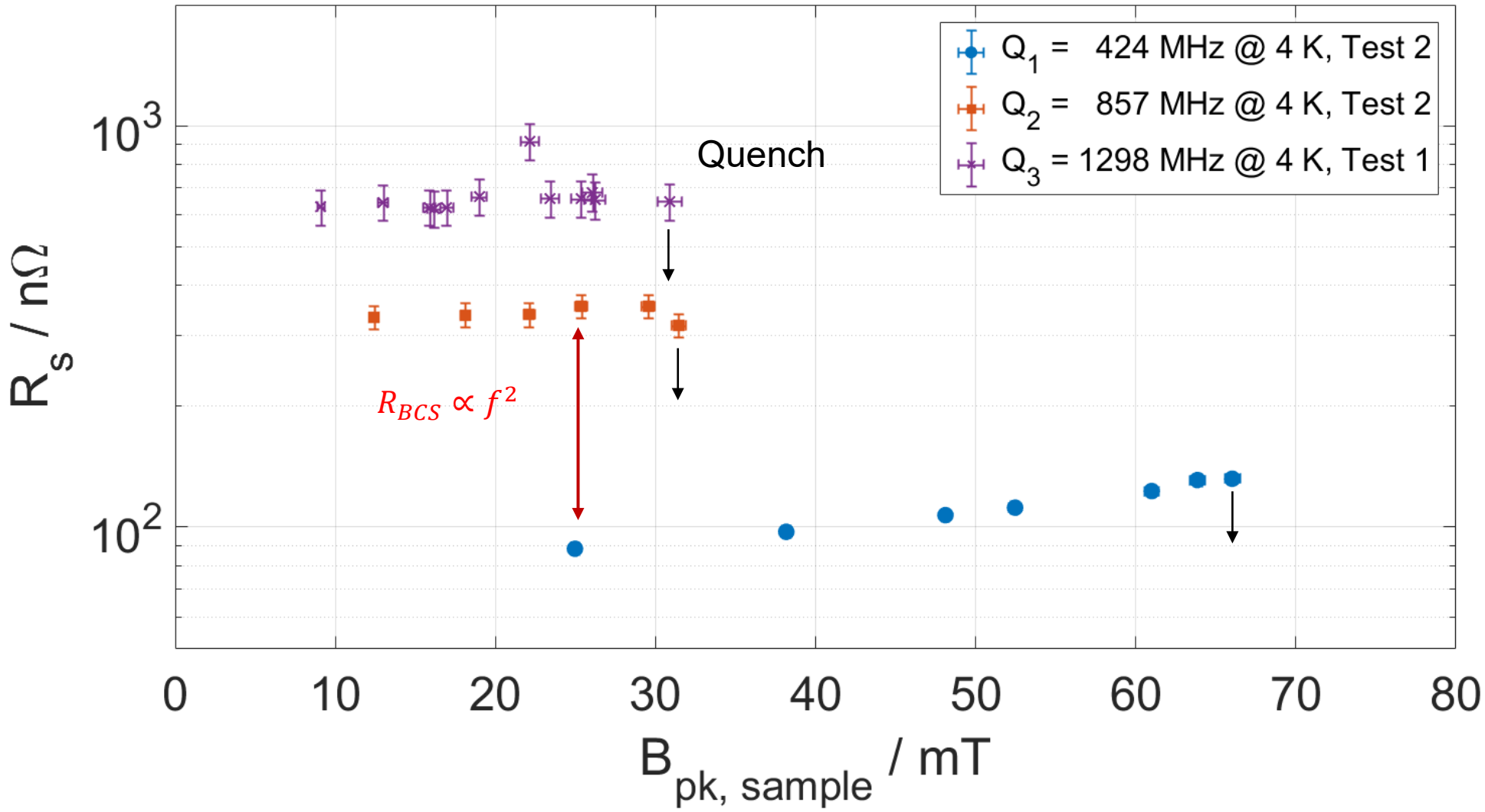
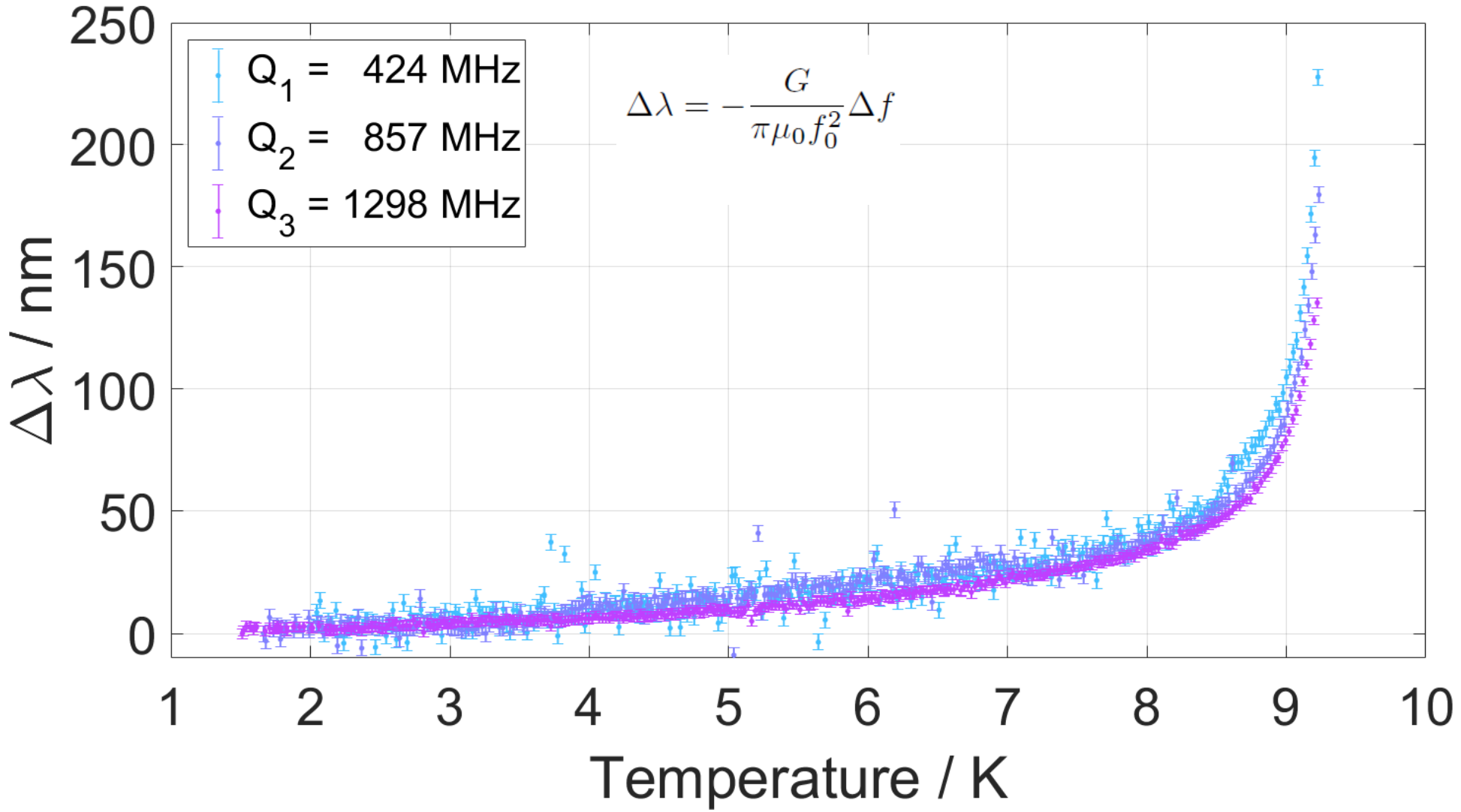


London penetration depth for each quadrupole mode

Results from frequency measurements



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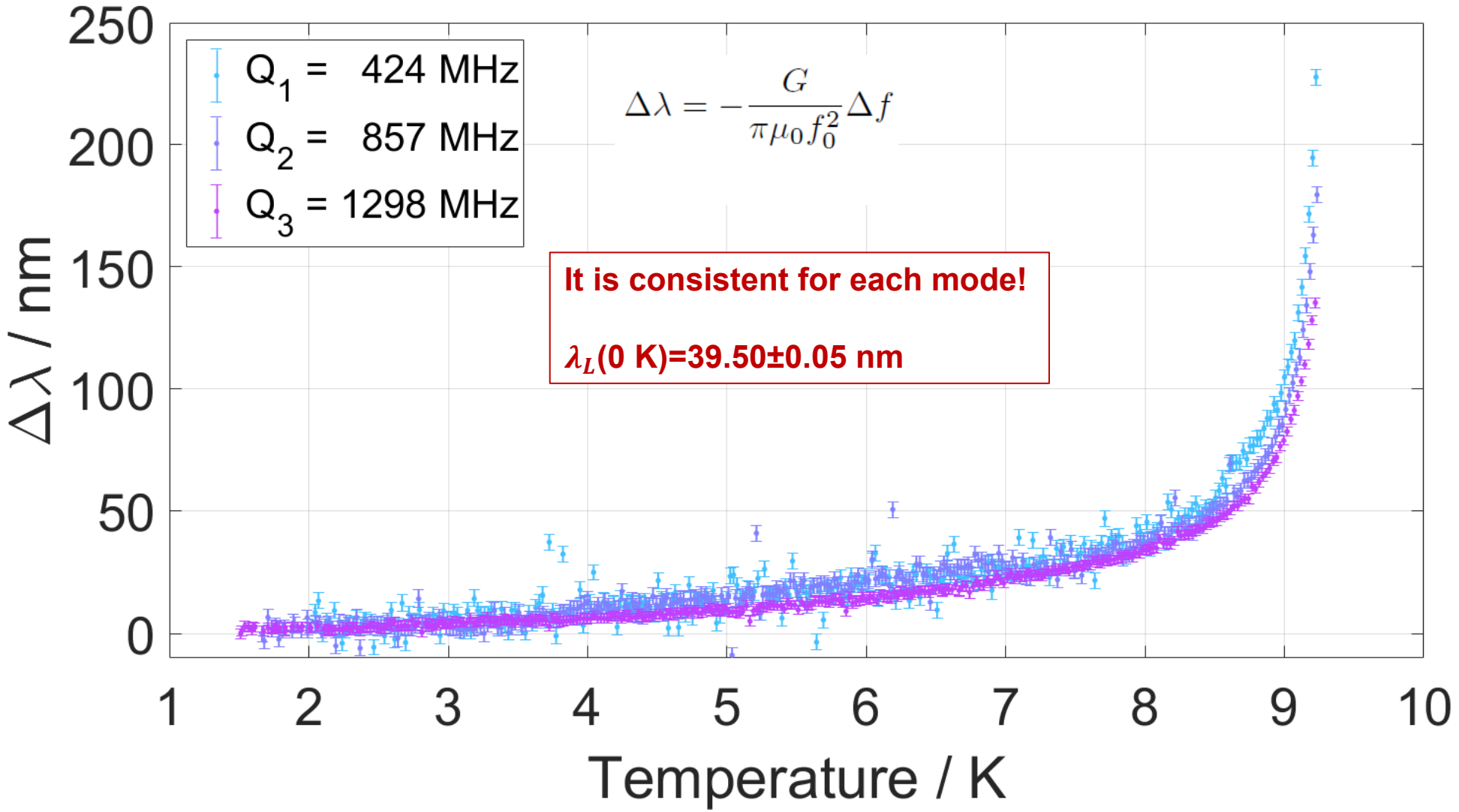
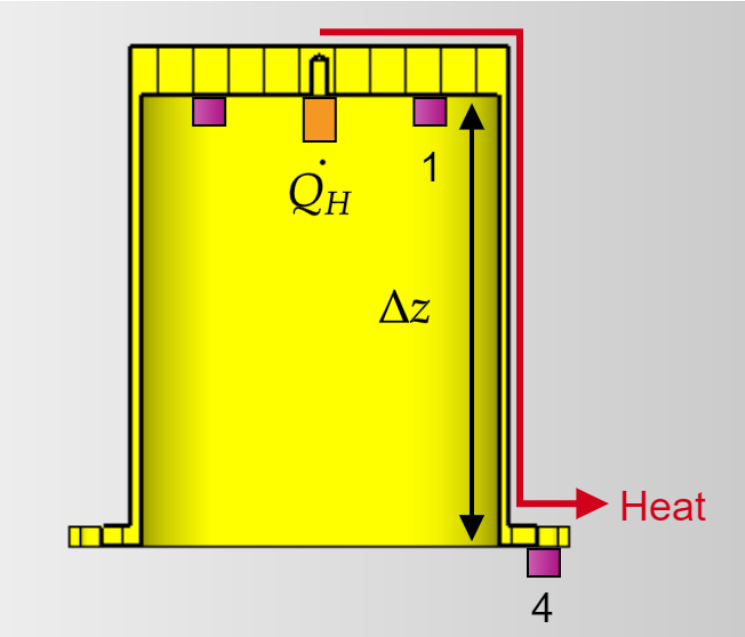
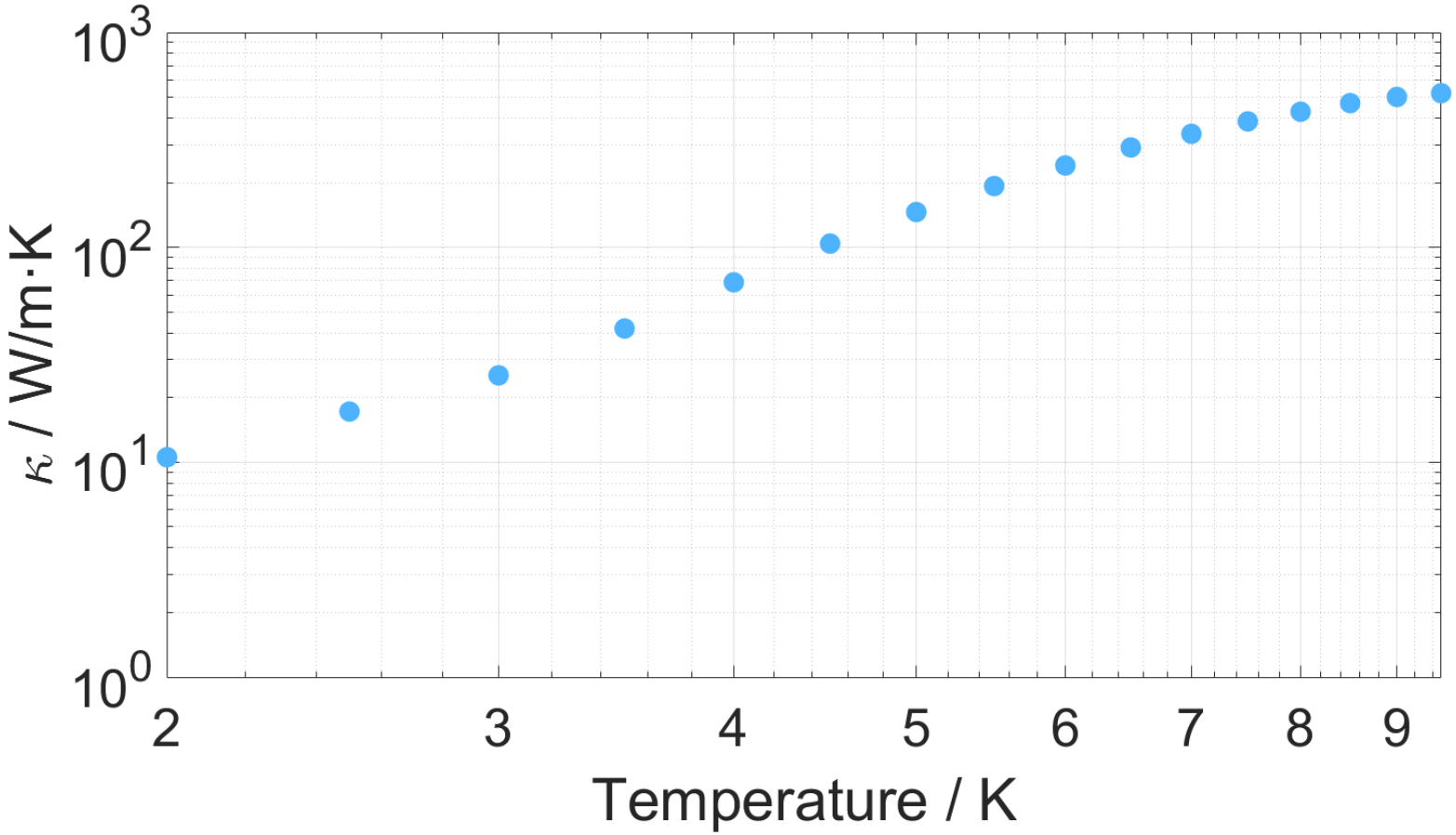


Thermal conductivity measurement





- $\dot{Q}_H = \kappa(T) \cdot A \frac{T_1 - T_4}{\Delta z}$
- $\kappa(4.2\ \mathrm{K}) = 81.98 \frac{W}{m \cdot K}$

$\Rightarrow\ RRR \approx 327.93 \pm 6$

Summary

- **QPR: a device for RF characterization of samples**
  - Study of samples under operational parameters
  - Solved fundamental problem for all QPRs of high R_s at 1.3 GHz

- **New QPR (UHH QPR), designed at UHH and DESY**
  - Based on the successful system at HZB
  - Improved rods and sample flange designs lead to simplified operation

- **Fabricated at Zanon R. & I. SRL, commissioning on going → It is alive!**
  - First cooldowns successful
  - Commissioning faster than expected

- **HZB Nb sample investigated at all QPR modes → results are as expected for sample with Q-disease**
  - Observed $R_s \propto f^2$
  - $\Delta\lambda$ independent of mode
  - κ in good agreement to high RRR

Outlook

- **Continue commissioning and transition to regular operation**
  - Switch to digital DAQ system (µTCA)
  - Improve positioning of temp. sensors for $\kappa(T)$ measurement
- **800 °C bake of Nb sample and re-test**
- **Study mid-T treated and SIS coated samples**

For more information about **κ measurements** in other samples:

Cem Saribal *MOPMB017*

For more information about **new furnace**:

Marc Wenskat *WEPWB111*

For more information about **mid-T treatment**:

Rezvan Ghanbari *SUSPB010*
Christopher Bate *MOPMB022*

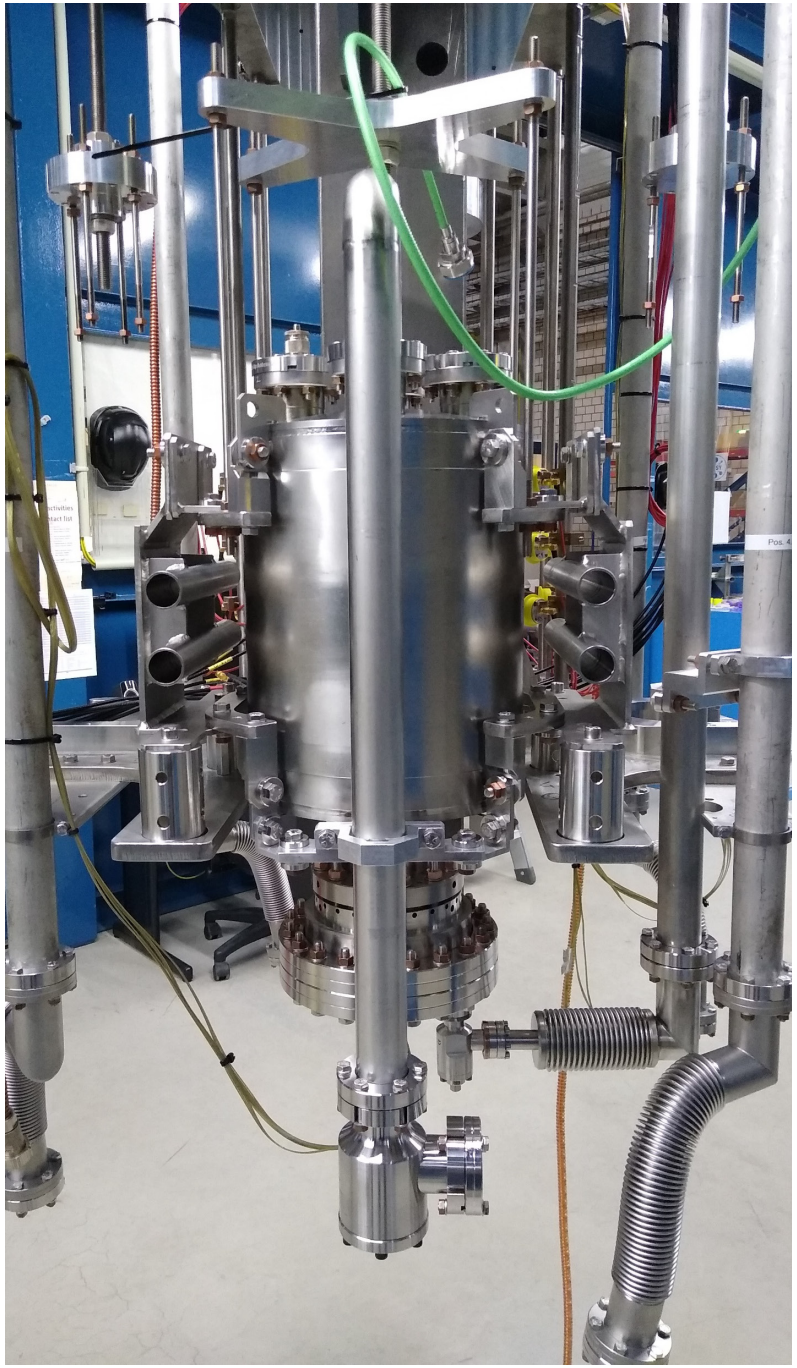
For more information about **SIS coatings**:

Isabel Gonzales *WECBA01*
Getnet K. Deyu *MOPMB016*

Thank you for your attention!

Thanks to SRF R&D teams at Universität Hamburg, DESY, HZB, CERN, TEMF, Universität Rostock, and Jefferson Lab.

Thanks to the SRF 23 committee for supporting me with through the *Student Grant Program.*



Contact

DESY. Deutsches Elektronen-Synchrotron

www.desy.de

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