Status of the RF testing devices: The HZB Quadrupole resonator

HZB Helmholtz Zentrum Berlin

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1st annual ARIES meeting

Riga, May 22nd – 25th 2018

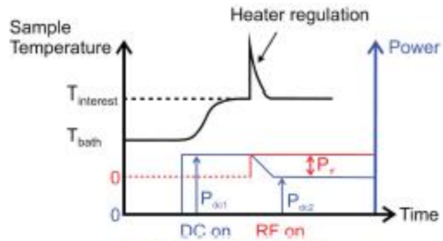
(work and slides by Sebastian Keckert, presented at IPAC2018)

SURFACE RESISTANCE MEASUREMENT

Calorimetric measurement: RF-DC-compensation technique

$$R_S = 2\mu_0^2 c_1 \frac{\Delta P_{DC}}{B^2_{sample}}$$

$$= 2\omega\mu_0^2 \cdot \frac{c_1}{c_2} \cdot \frac{\Delta P_{DC}}{P_t \cdot Q_t}$$



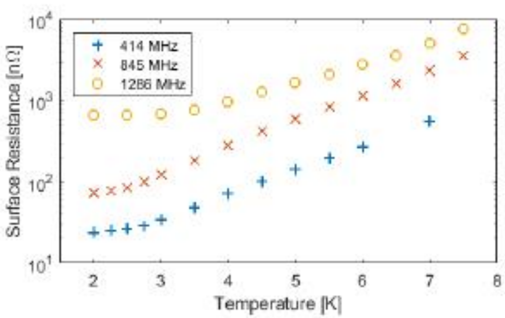
[S. Aull, SRF'13]

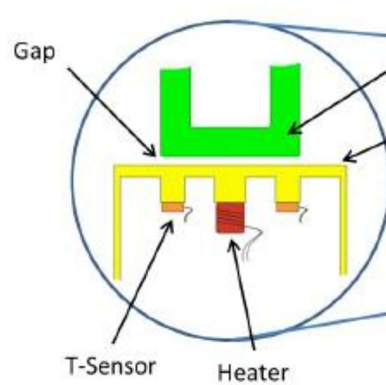
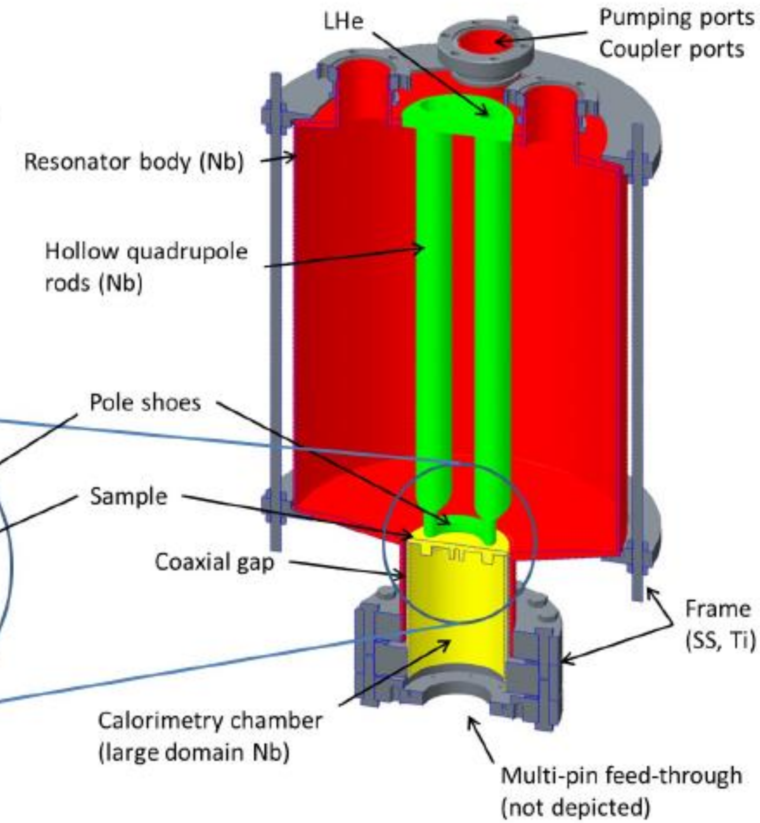
Wide and easy accessible parameter space

T_{sample} = 1.8 … >20 K

B_{RF} = 5 … 120 mT

f = 415, 850, 1285 MHz



Resolution: Minimum detectable R_S at low temperature

⇒ Resolution of heater power control loop negligible
⇒ Helium pressure fluctuations ± 80 µbar → ± 1.4 mK

$R_{S,10\ mT} = 0.35\ n\Omega$

$R_{S,120\ mT} = 0.002\ n\Omega$

Highest value at low field, decreases quadratically with field

Field limits

⇒ Quench limit of QPR observed at about 120 mT
⇒ Calorimetric measurement limited due to RF heating, pulsed measurements up to 50 mT at 2.5 K

Accuracy: Limited by uncertainty of RF measurement

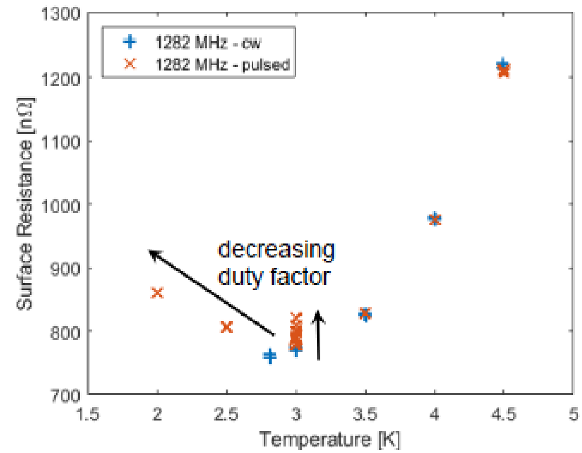
⇒ Overall accuracy of 6.5 %
⇒ Problems with 1.285 GHz mode

Issues observed during operation at the third quadrupole mode

⇒ Very high residual resistance, scaling with frequency stronger than quadratic

⇒ Pulsed RF: $R_S(T)$ rises with decreasing duty factor at low temperatures

Simultaneous excitation of neighboring dipole mode



Excluded reasons

⇒ Multipacting → observed but processable

⇒ Heater control loop → no frequency dependence

⇒ Q_{ext} → cross-checked by critical field measurement

Explanation: Significant RF losses at nc bottom flange

⇒ Asymmetric bending of rods due to Lorentz force detuning

⇒ Quadrupole symmetry broken → less damping in coaxial gap

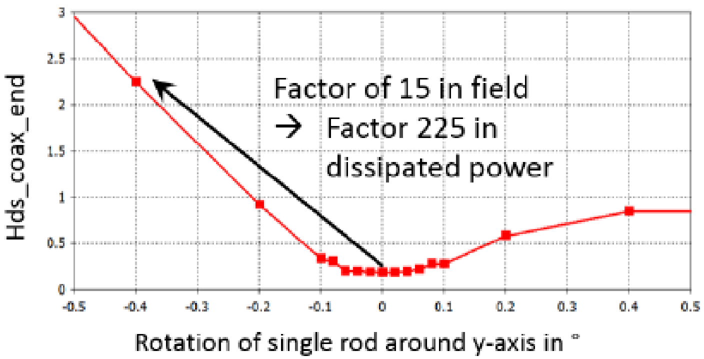
⇒ Significant RF losses at the nc bottom flange

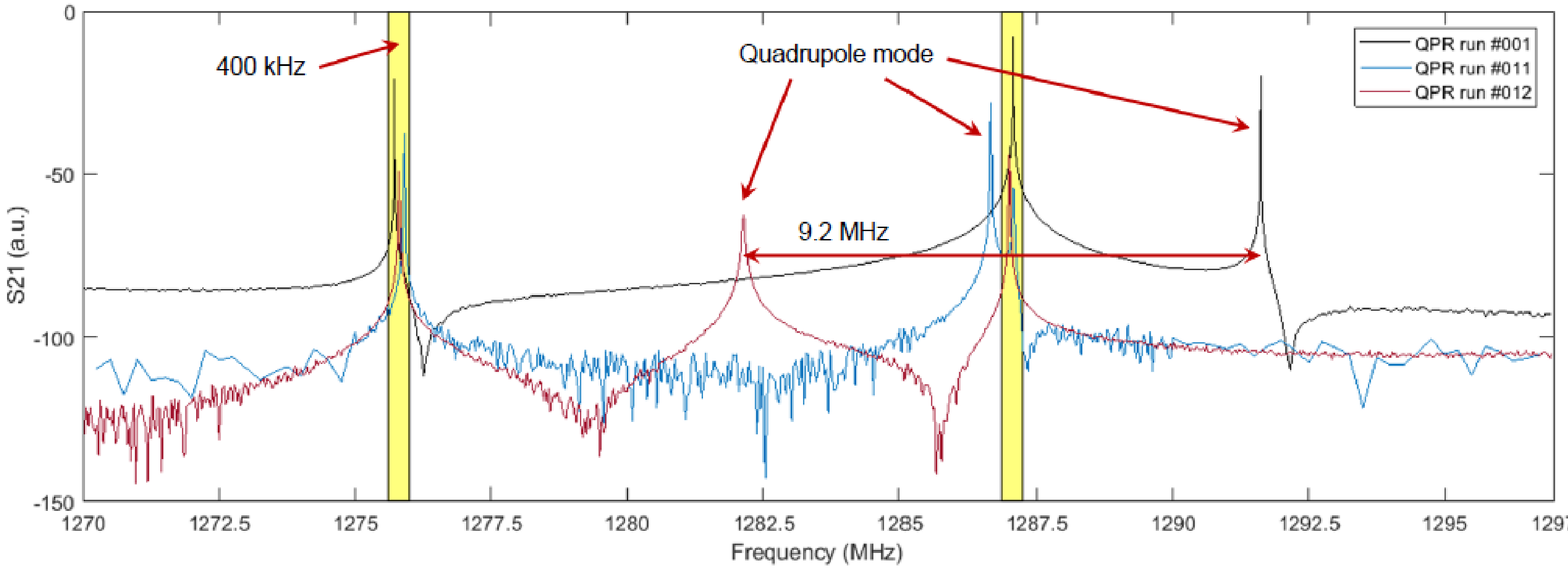
Simulation: Asymmetric bending of rods

⇒ Integral field on bottom flange increases

⇒ Significant contribution of RF heating

Baseline: bias of 2.7 nΩ @ 433 MHz





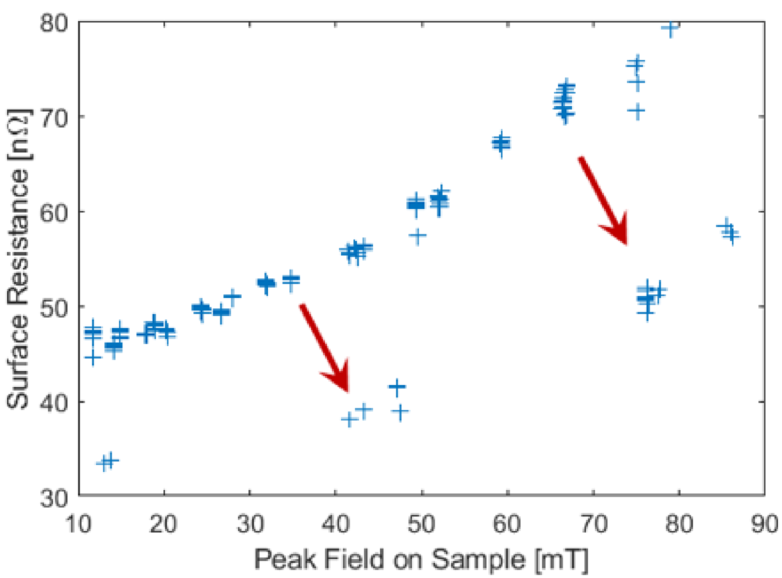
Measurement: Mode separation of third QPR mode can be critical

QPR mode frequencies depend on distance between sample and rods

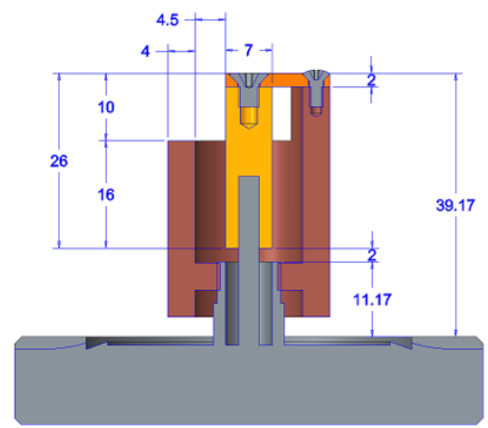
⇒ Q1: - 0.95 MHz / 100 µm

⇒ Q3: about 2x as much → up to 9.2 MHz of frequency shift observed (so far)
neighboring "cavity" modes stay within 400 kHz (span of highlighted areas)

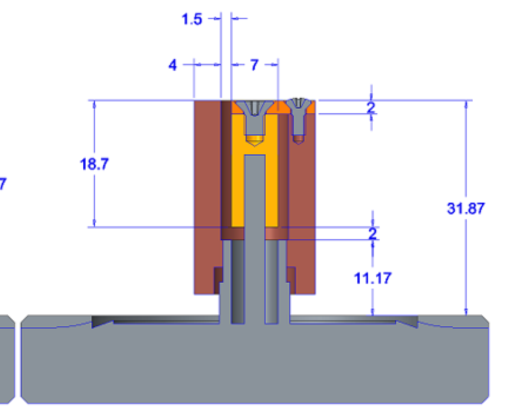
Observation of unstable coupling
⇒ „jumps“ in R_s data
⇒ no change in P_{forw} or P_{refl}
⇒ P_{heater} and P_{diss} constant
⇒ high sensitivity to rotation and mechanical instability



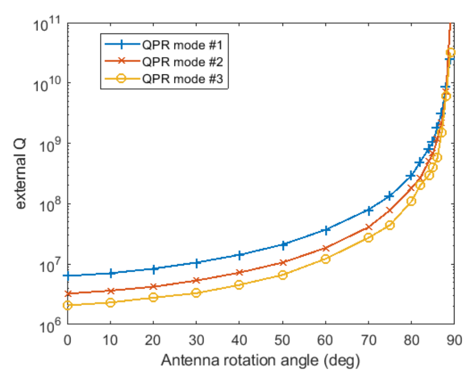
Development of dedicated pickup antenna
⇒ reduced size of coupling loop
⇒ no change of feedthrough (CF40 rotatable)

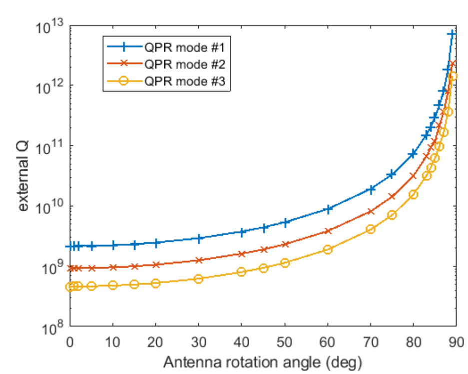


initial loop-coupler



optimized loop-coupler





Q_{ext} for all QPR modes as function of rotational angle

OUTLOOK

Ongoing upgrades of bottom flange

$\Rightarrow$ Copper and niobium coating of stainless steel are investigated

$\Rightarrow$ Implementation of bulk superconducting NbTi flange

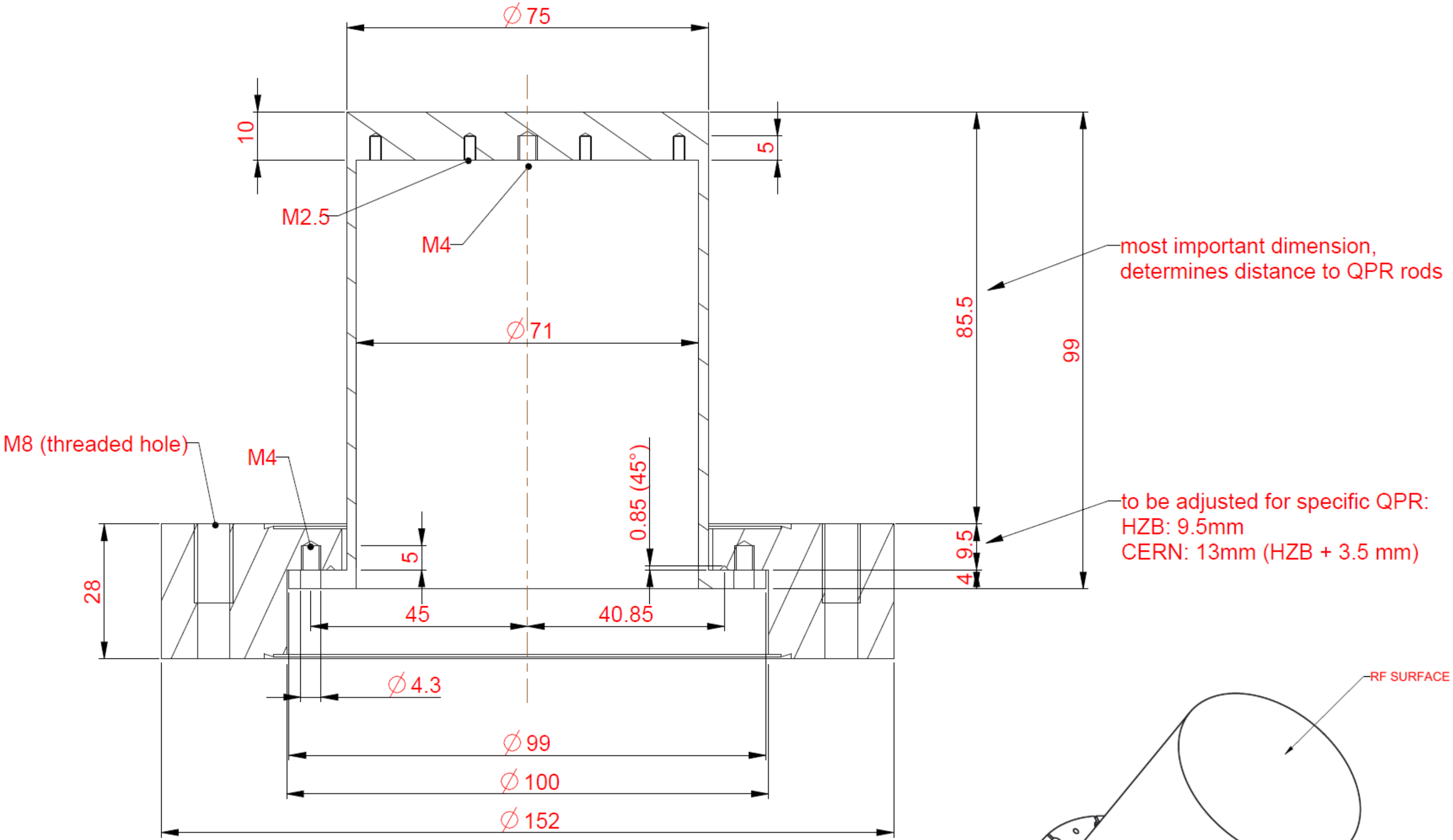
Aspects for future design optimization

$\Rightarrow$ Improved separation of quadrupole and cavity modes

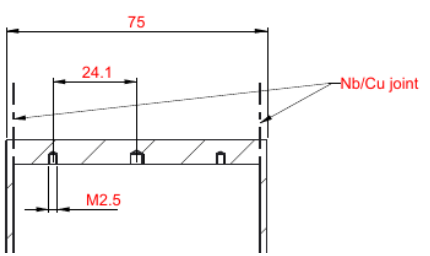
$\Rightarrow$ Reduced impact of broken symmetries on RF field distribution

PATH TO RF TESTS

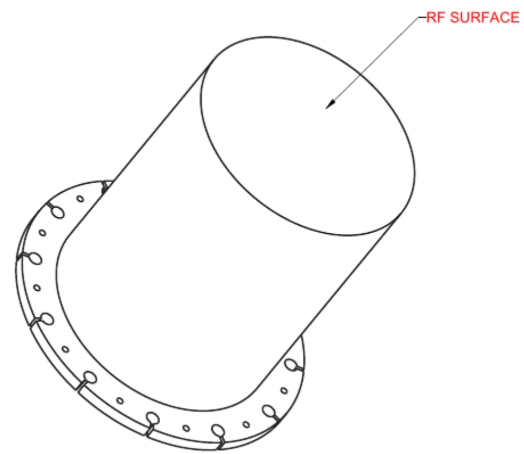
- ordered 5 Nb samples, 5 OFHC samples for QPR (46k€)
- to be manufactured at Research Instruments
- delivery by September 2018
- to be accompanied by new ESR Dmitry Tikhonov as part of his industry secondment
- samples should undergo identical treatment to best ARIES samples
- Cu samples to be pre-treated at Legnaro
- Nb coating at Siegen and Daresbury
- RF Testing of same sample at HZB and CERN possible (use of suitable adapter)



∅75
10
5
M2.5
M4
most important dimension,
determines distance to QPR rods
∅71
85.5
99
M8 (threaded hole)
M4
0.85 (45°)
5
to be adjusted for specific QPR:
HZB: 9.5mm
CERN: 13mm (HZB + 3.5 mm)
9.5
4
28
45
40.85
∅4.3
∅99
∅100
∅152



75
24.1
Nb/Cu joint
M2.5



RF SURFACE

TEST SCHEDULE HZB

- **1-2 tests in late 2018 possible**
- **2019: commissioning of second VTS at HZB**

  => increased availability of cryogenics