A New Quadrupole Resonator for SRF R&D

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Why do we need a QPR?

- Already „conventional“ niobium shows unexpected and/or unexplained behavior
  - Not done – neither experimentally nor theoretically!

- New SRF materials & structures emerge and need to be studied

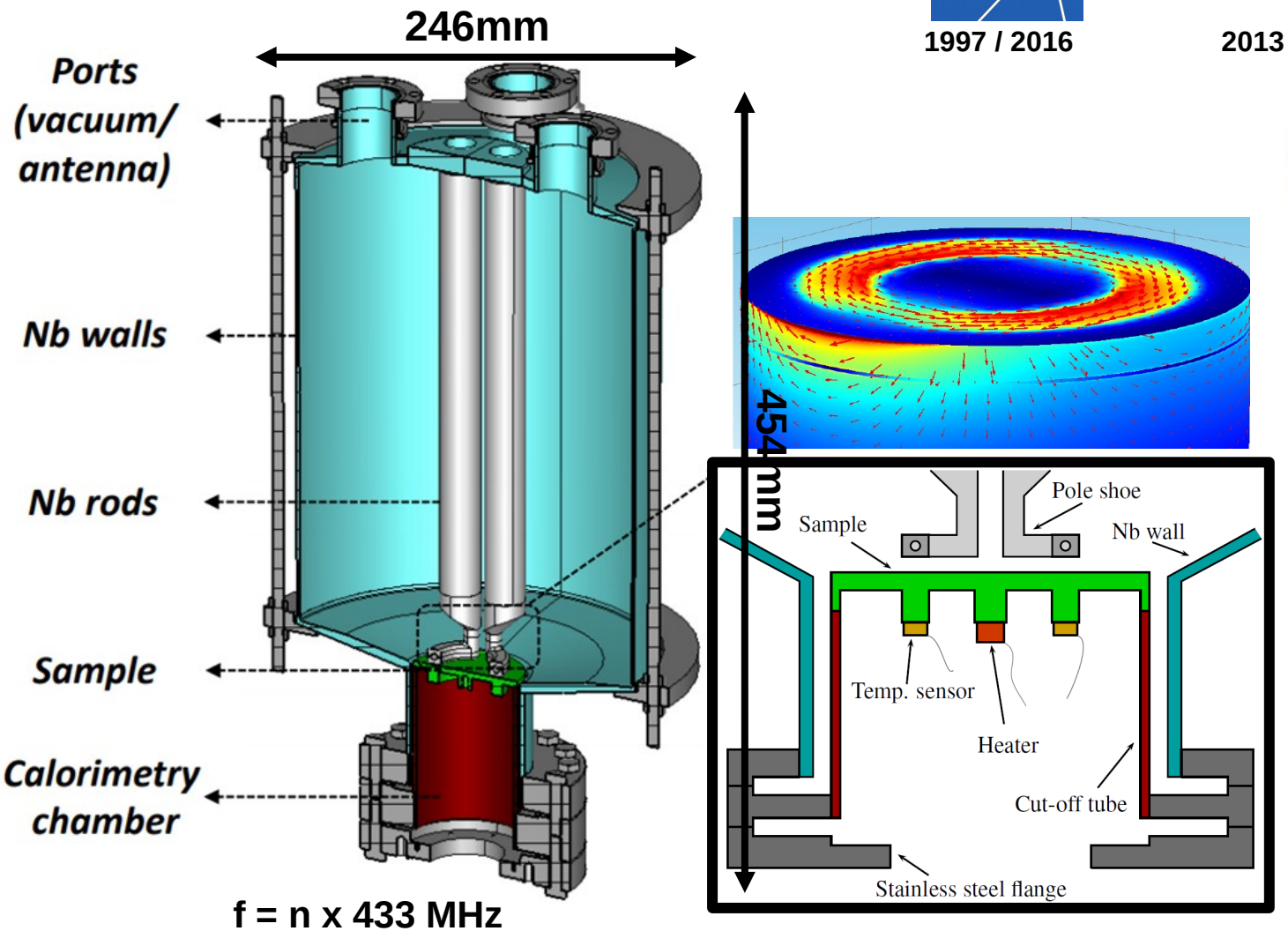
- Blind on one eye:
  - Either RF tests with a cavity or material characterization on samples
  - Transfer of results always with minor or major underlying assumptions

- Need a realistic and direct measurement of crucial RF/BCS parameters & provide easy access to the surface of interest for further direct material measurements

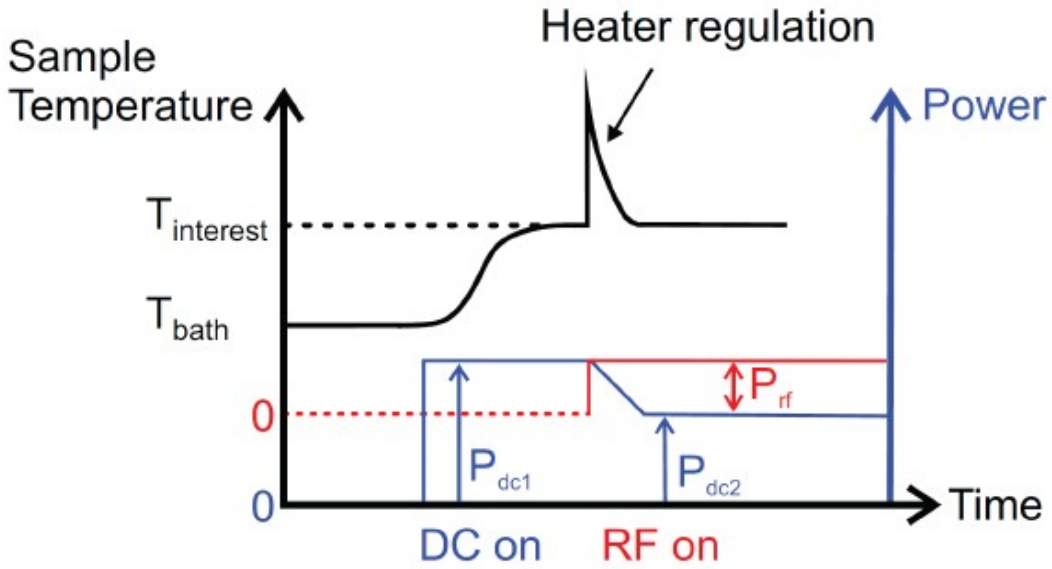
How does it work?

1997 / 2016

2013



f = n x 433 MHz
T = 2-20 K
B ≤ 120 mT
ΔR≤1nΩ

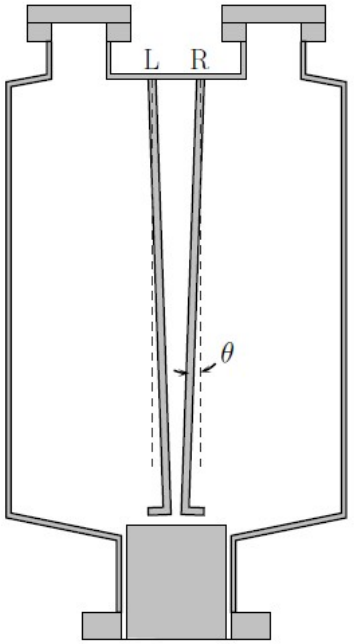


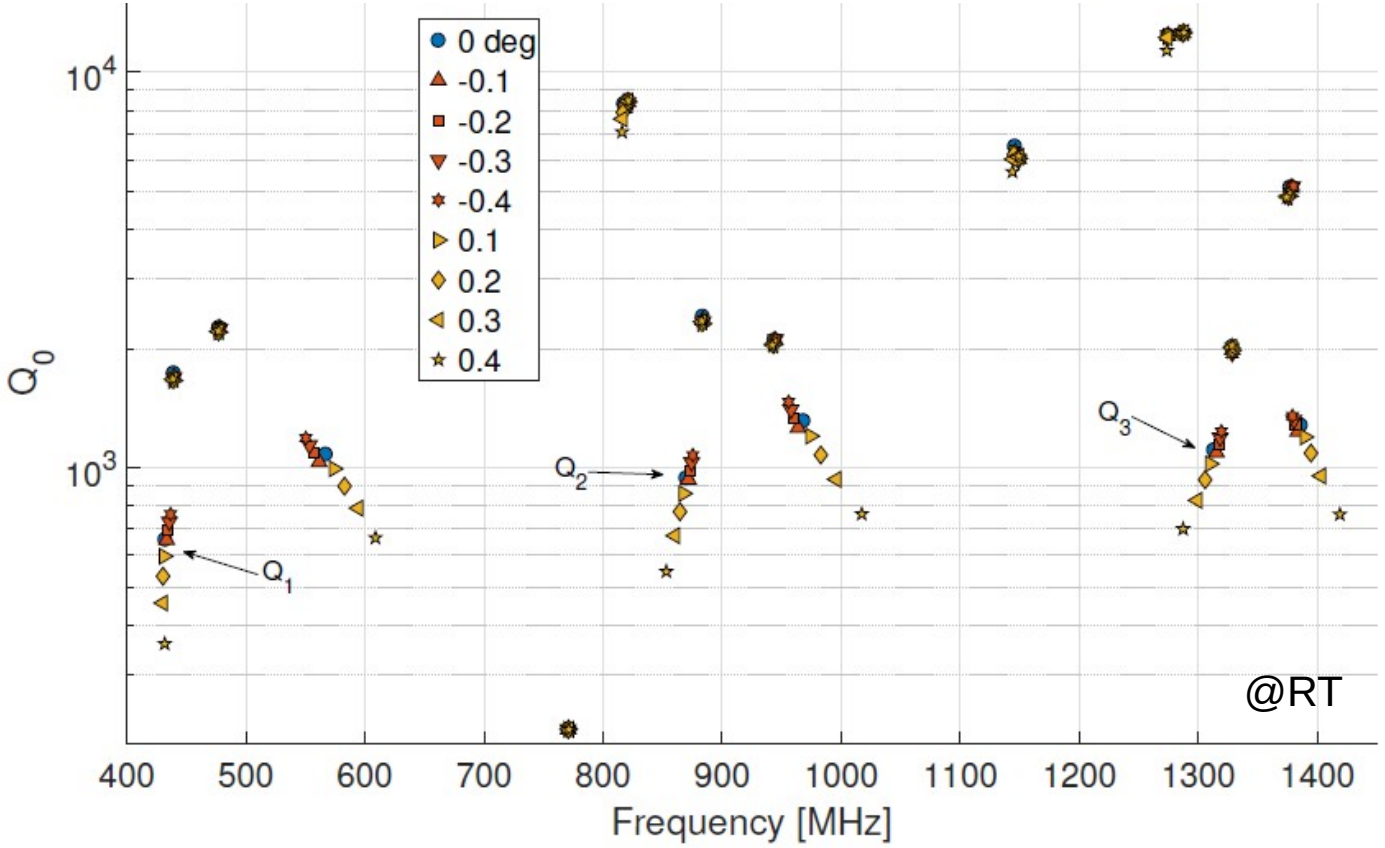
$$P_{dc1} - P_{dc2} = P_{rf} = \frac{1}{2\mu_0^2} \int R_s \left|\vec{B}^2\right| dS$$

- Surface Resistance R_s (T,B,f)
- Critical magnetic field $H_{C,1}$(T)
- Penetration depth λ_L
- Mean free path ℓ / RRR

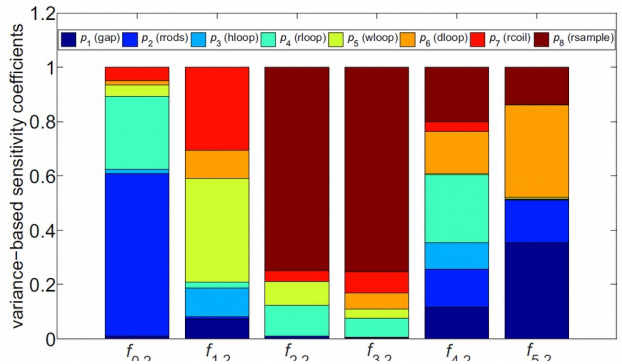
Shape Analysis

Geometric Accuracy is Important!





[Putek et al, arxiv:2004.09470v1 (2020)]



Static detuning: Tilt of the rods changes spectrum

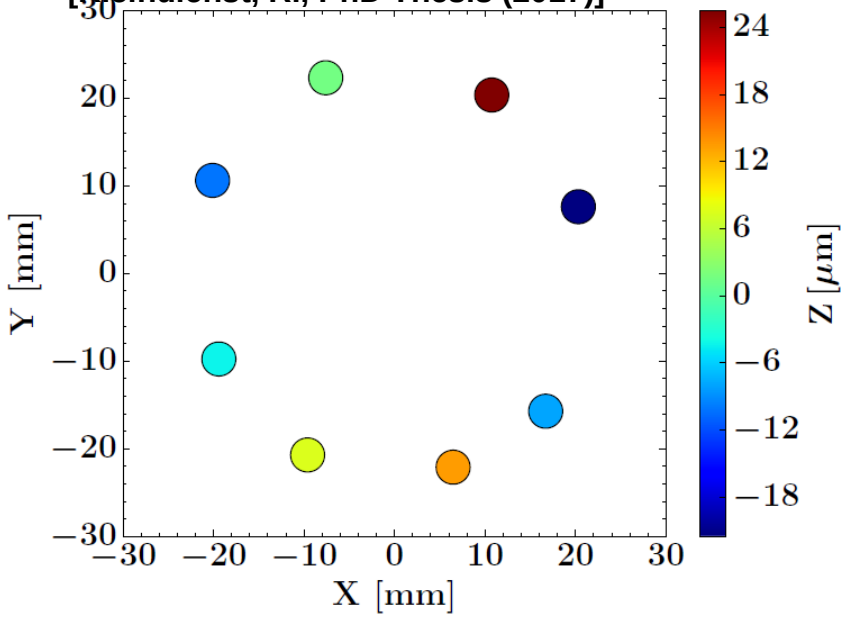
- Can cause increased fields in gap

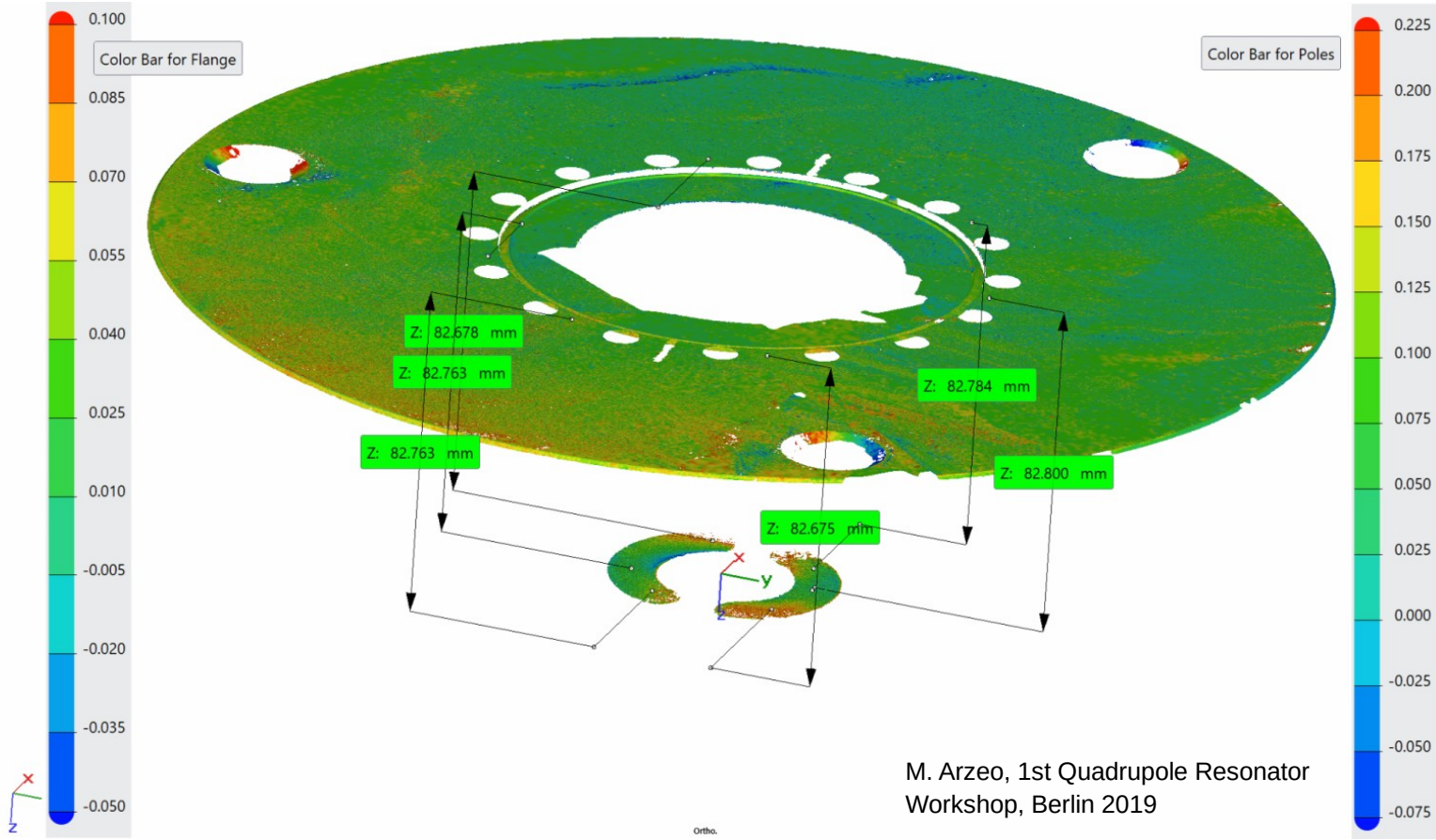
Shape variations have significant impact on performance parameters

Alignment of Pole Shoe Plane

HZB and CERN.2 QPRs

[Kleindienst, R., PhD Thesis (2017)]





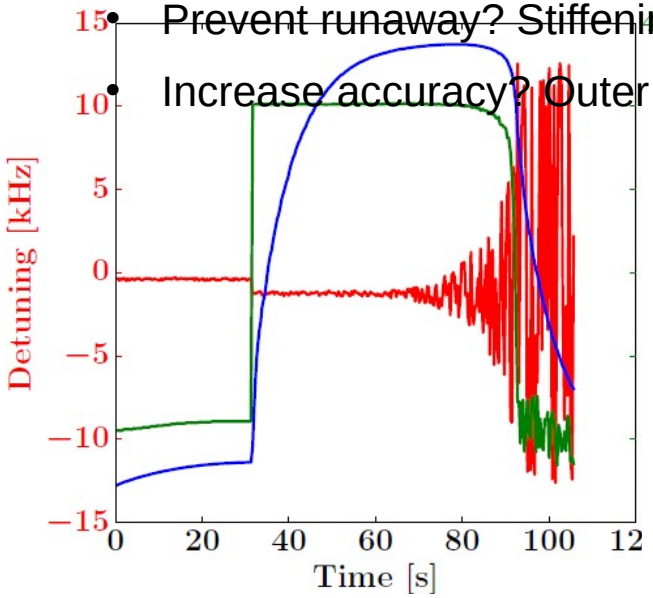
M. Arzeo, 1st Quadrupole Resonator Workshop, Berlin 2019

Simulated: 432, 869, and 1312 MHz

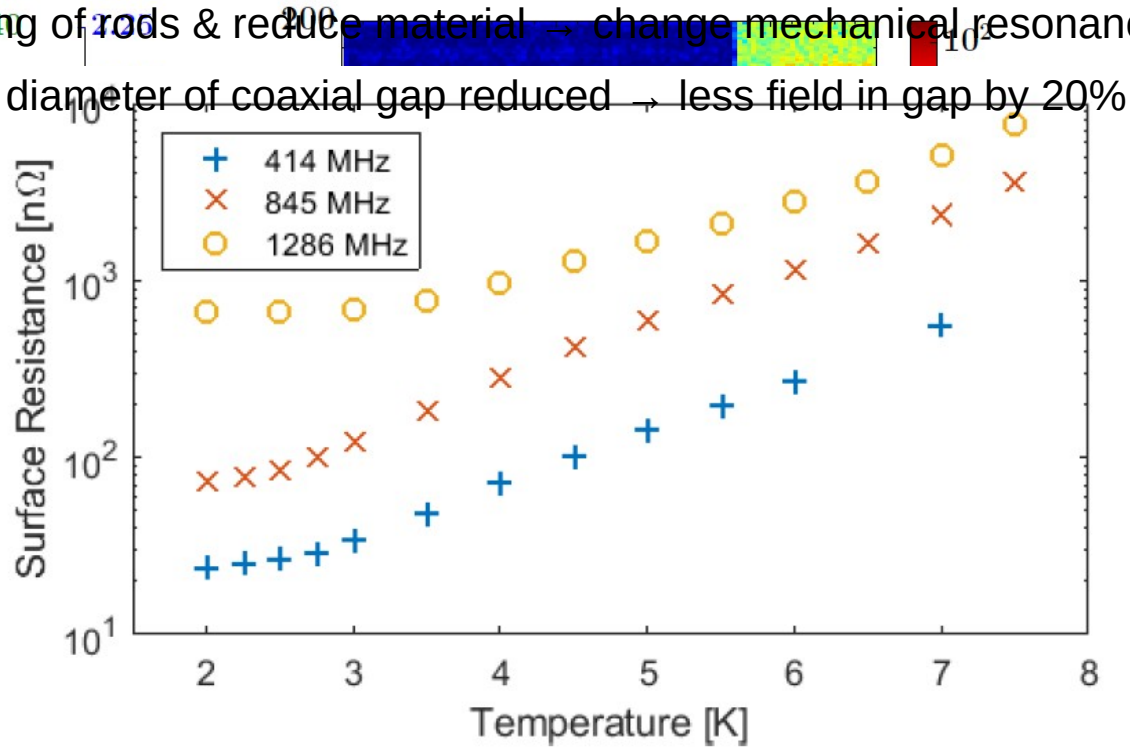
Measured: 414, 847, and 1285 MHz

New QPR: What did we change?

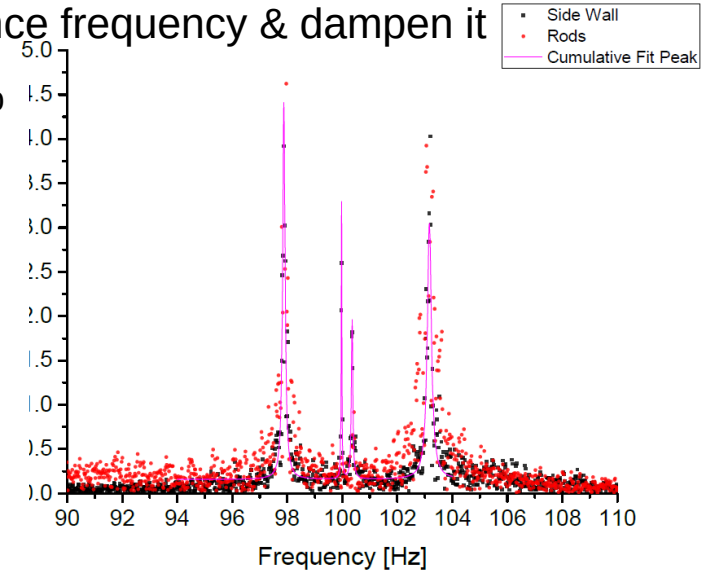
- No change in functional key parameters to preserve sample exchangeability!
- Minor modifications due to material availability – checked influence on RF properties: No problems
- Two modifications motivated to improve RF performance
  - Prevent runaway? Stiffening of rods & reduce material → change mechanical resonance frequency & dampen it
  - Increase accuracy? Outer diameter of coaxial gap reduced → less field in gap by 20%



[Kleindienst, R., PhD Thesis (2017)]

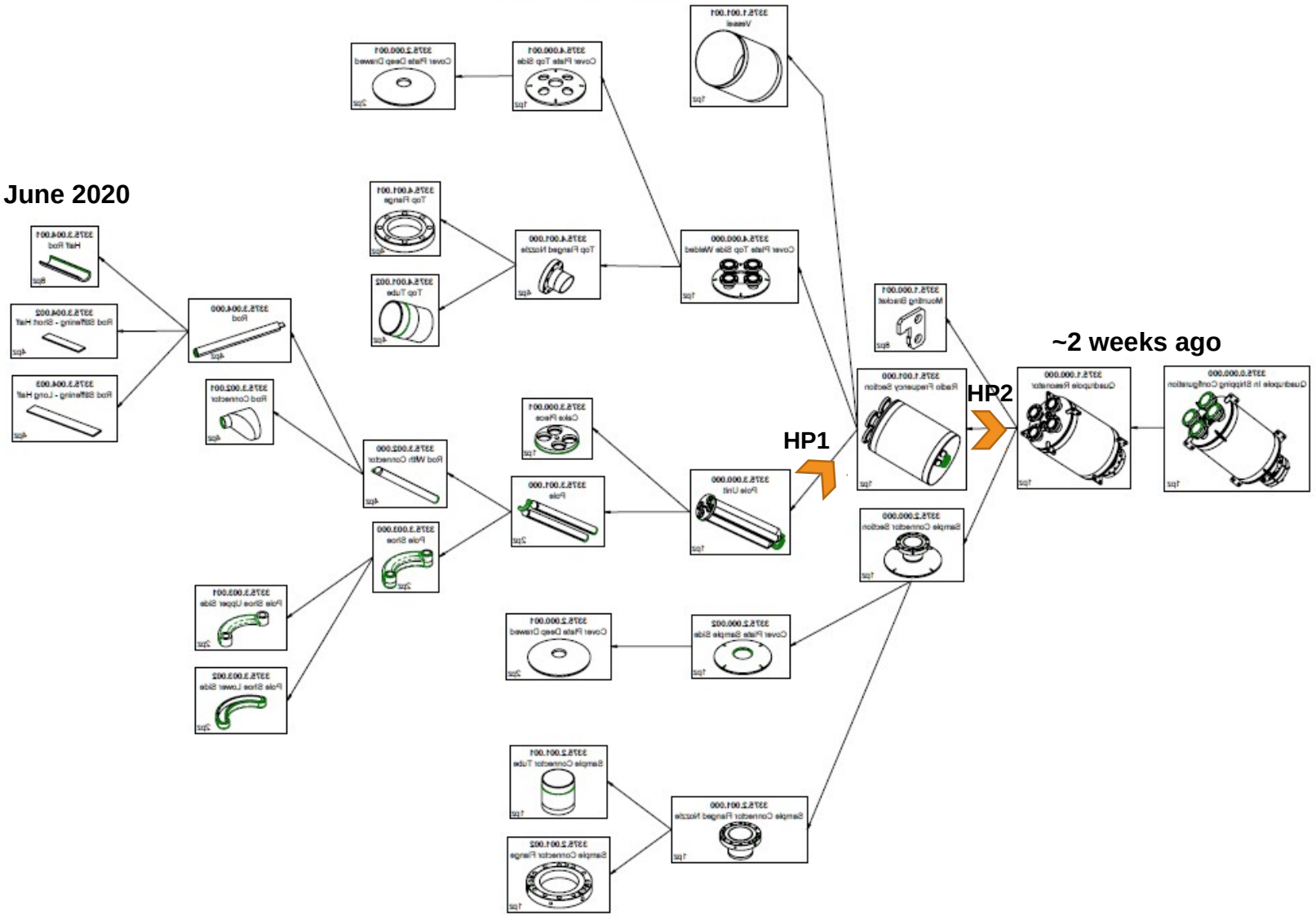


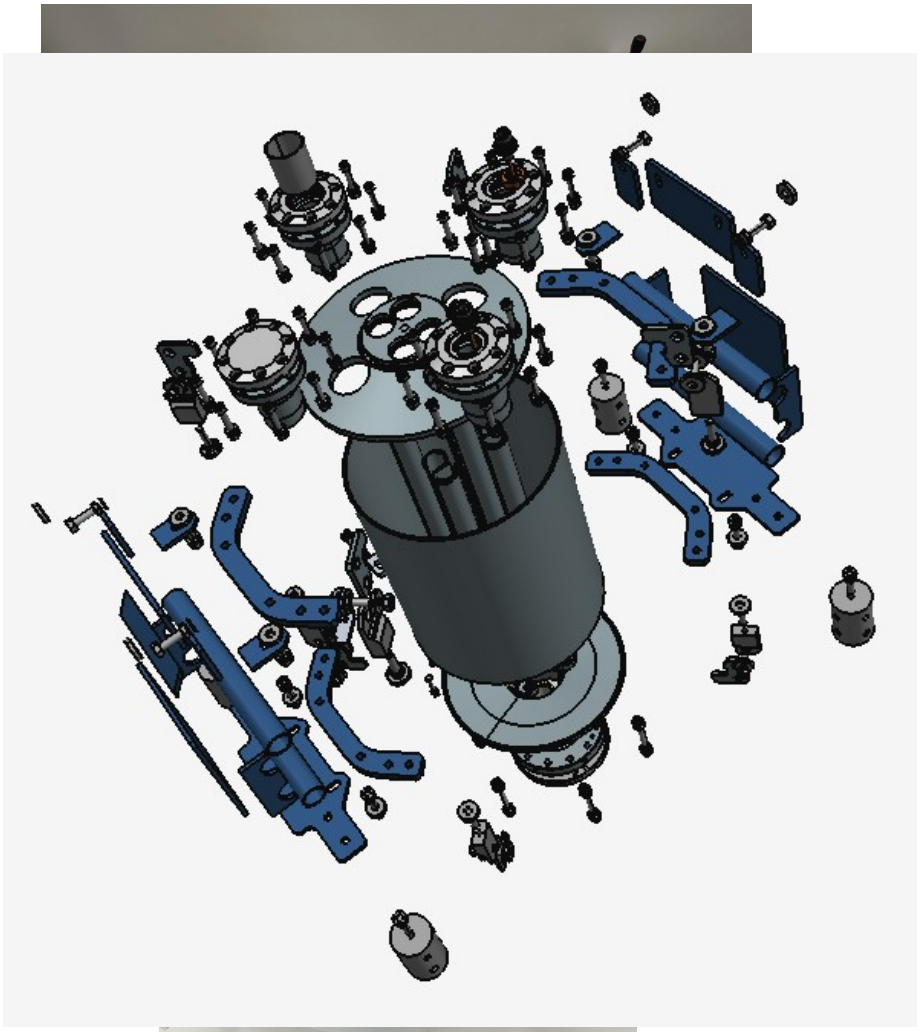
[Keckert, S. et al, WEPML049, IPAC2018]



Fabrication

Placed at Zanon R.I. in Dec. 2019

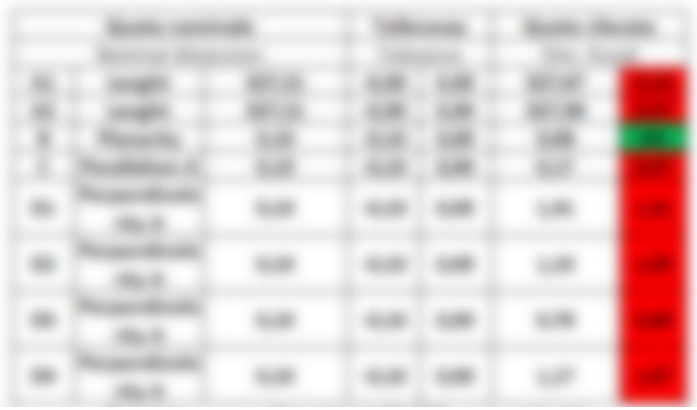


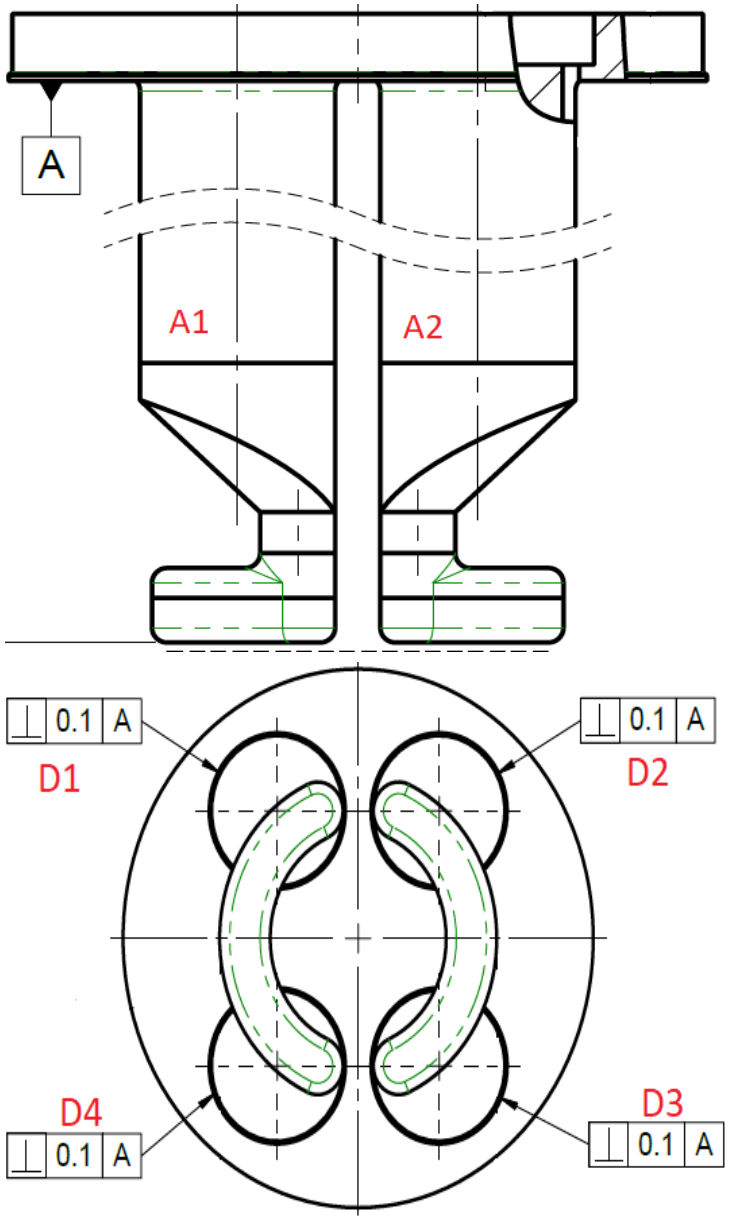


HP2: Survey of Pole Shoes and Rods

b. To be measured after the fabrication of the RF-section

- The perpendicularity of the two planes of the pole shoes to the weld joint geometry
- The distance of the two planes of the pole shoes projected in **z**-direction relative to the weld joint geometry for sample connector section





Can‘t show details – colors should be sufficient…

- Rods length difference
- Significant tilt of the rods

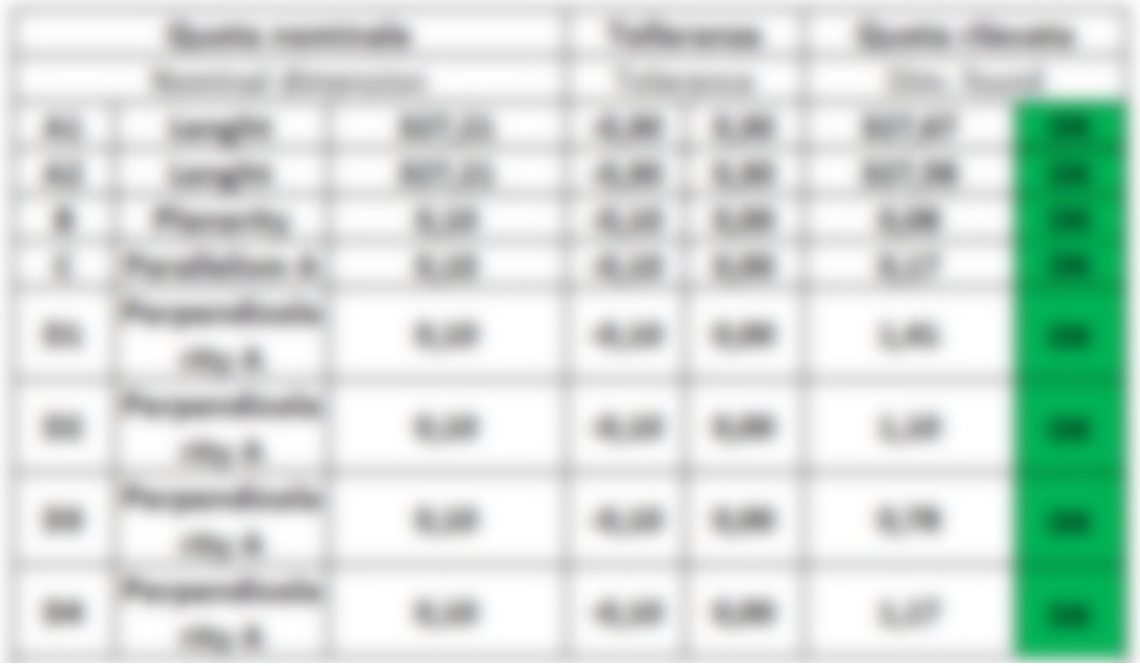
- **We planned for that in the design phase!**

Think twice – build once

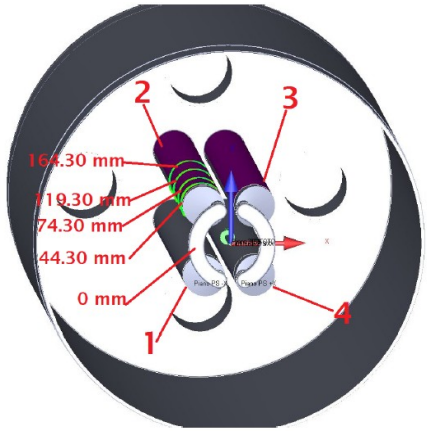
And Plan for Disaster

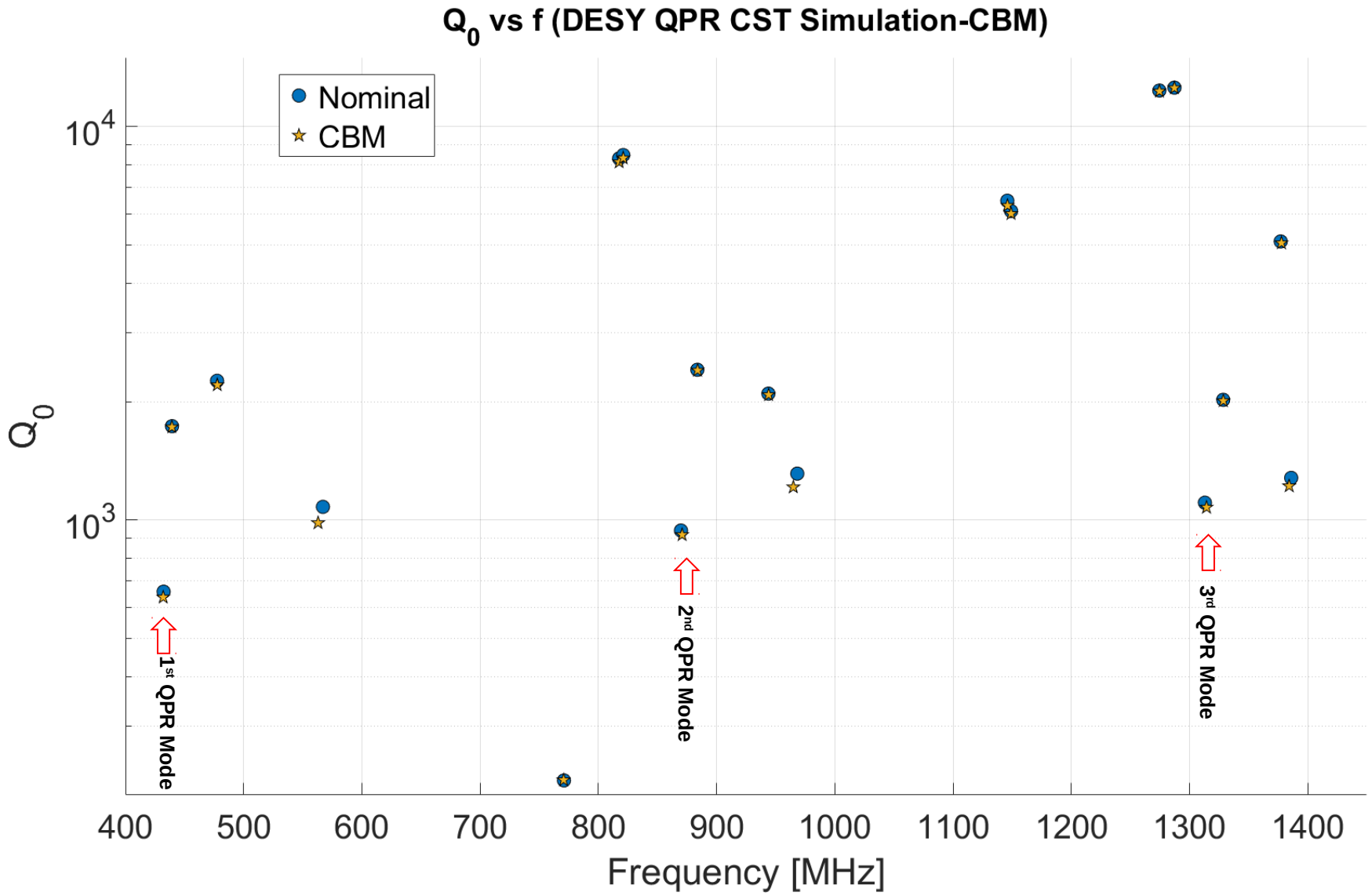
- Thorough simulations and discussions showed importance on geometric accuracy
- Holdpoints gave us a chance to detect and correct problems!
- Rods underwent 800°C anneal after welding → trigger issues while they can be observed & corrected
- Tilt:
  - Bend rods back to spec
- Offset:
  - We included „buffer material“ at the bottom of the pole shoes
  - Height difference was corrected by material removal

All Specifications are met!



RF Spectrum @ RT using CBM data





So what‘s next?

- Receive final CBM Measurement Report
- Ship QPR to UHH/DESY – ToA: End of March
- Commissioning
  - Wall thickness measurements vessel and pole shoes (Ultrasonic measurements)
  - Bridge coordinate measurement
  - Mechanical spectrum
  - RF spectrum (warm) with sample (waiting for Antennas – ToA: End of April)
  - Repeat 2 & 4 after evacuating the QPR (check for deformation)

- Surface Treatment
  - @ Zanon R.I.
  - 800°C@3h | Coarse BCP | 120°C@48h | Fine BCP

Summary

- Exciting times for SRF material R&D
- Lack of “realistic” sample test environments → Quadrupole Resonators provide that!
- Started „forensic analysis“ and joined forces with CERN / HZB + Partners
- (Hopefully) improved our design and “planned for disaster”
- Fabrication was delayed due to Corona by 6 months
- Went rather smooth: “expected problems” were solved
- Fabrication finished 2 weeks ago

- Commissioning + Surface Treatment finished end Q2 2021
- **RF Commissioning and first test: Q4 2021**

Thanks to

Andrea Muhs (DESY), Andrew Burrill (SLAC), Birte van der Horst (DESY), Carsten Müller (MSL), Daniel Klinke (DESY),Dmitry Tikonov (HZB), Hans Weise (DESY), Jens Knobloch (HZB), Lennart Trelle (DESY), Maike Röhling (DESY), Marco Arzeo (CERN), Martin Lemke (DESY), Oliver Kugeler (HZB), Ralf Bößpflug (DESY), Sebastian Keckert (HZB), Thorsten Büttner (DESY), Ursula van Rienen (URO), Walter Venturini-Delsolaro (CERN), Wolfgang Ackermann (TEMF), Zanon R.I.

Contact

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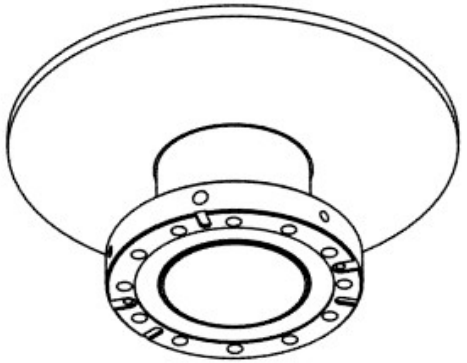
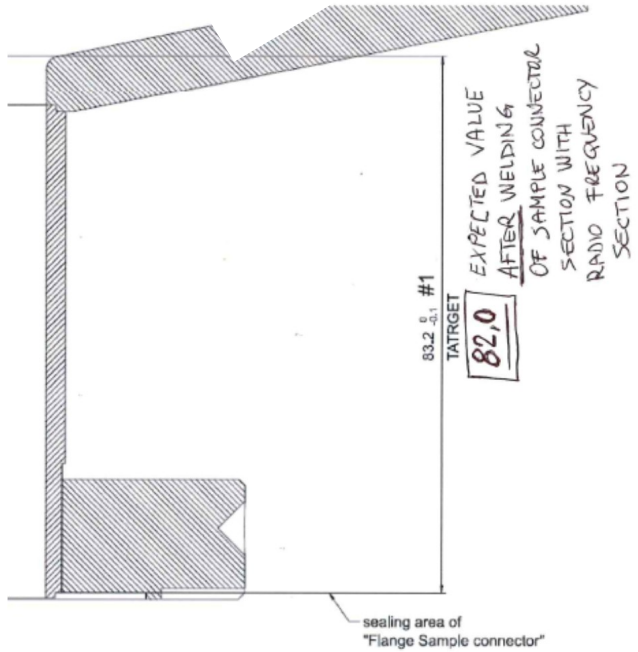
NCR - Sample Connector Nozzle

Second to last weld – ofc something had to happen….

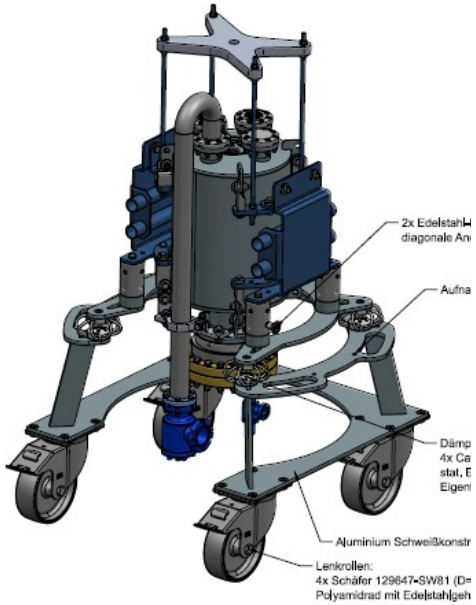
- Coaxial gap is 1.2mm shorter!
- Problem?
  - Welded samples couldn‘t be tested due to different flange design already before
  - Other samples can be installed with thicker adapter flange (+1.2 mm)
- Issue with more RF induced heating?
  - Well – 1.2 mm closer compared to 83.2 mm, max. ~2% effect
  - Simulated ΔT by TEMF: No significant difference

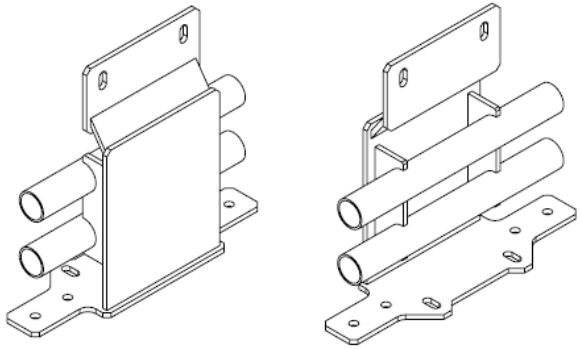
→ **Accepted the NCR**



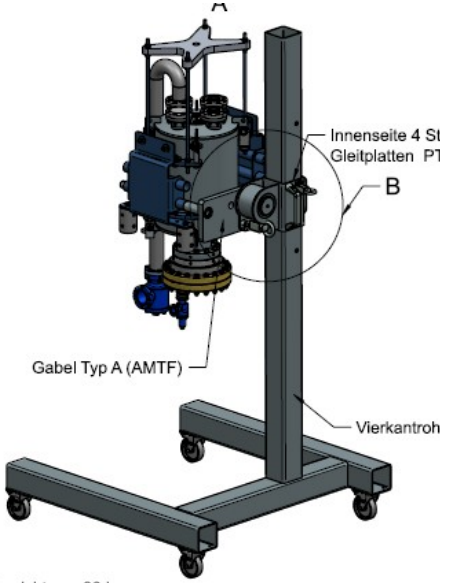


Support Structures

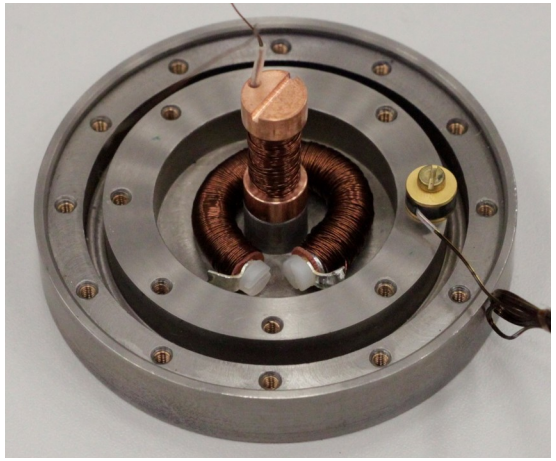




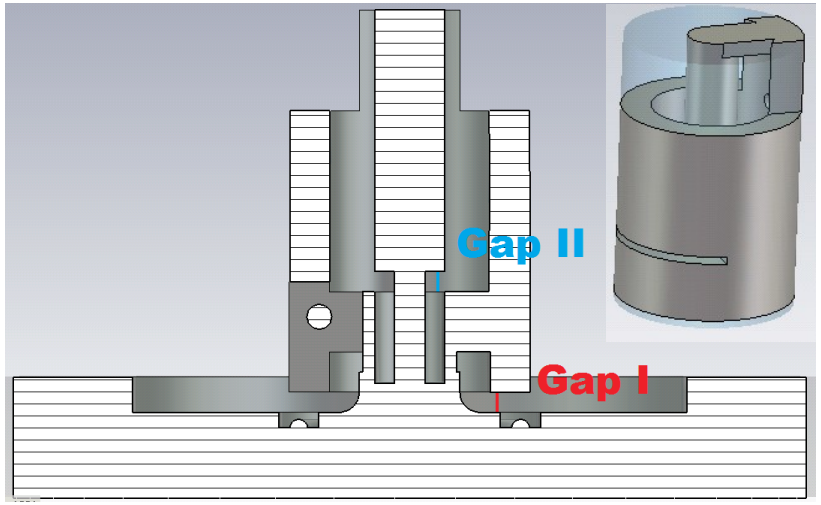
Getting welded right now –
ToA: Today



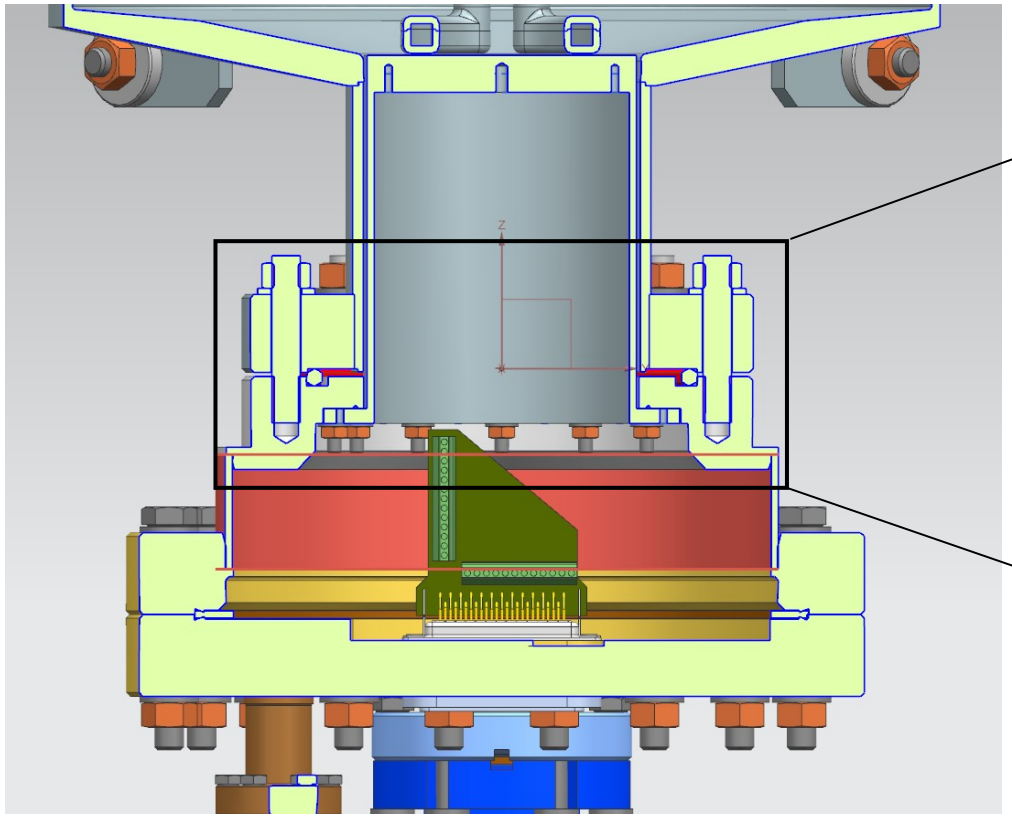
Assembly Plattform: Planned for Q3

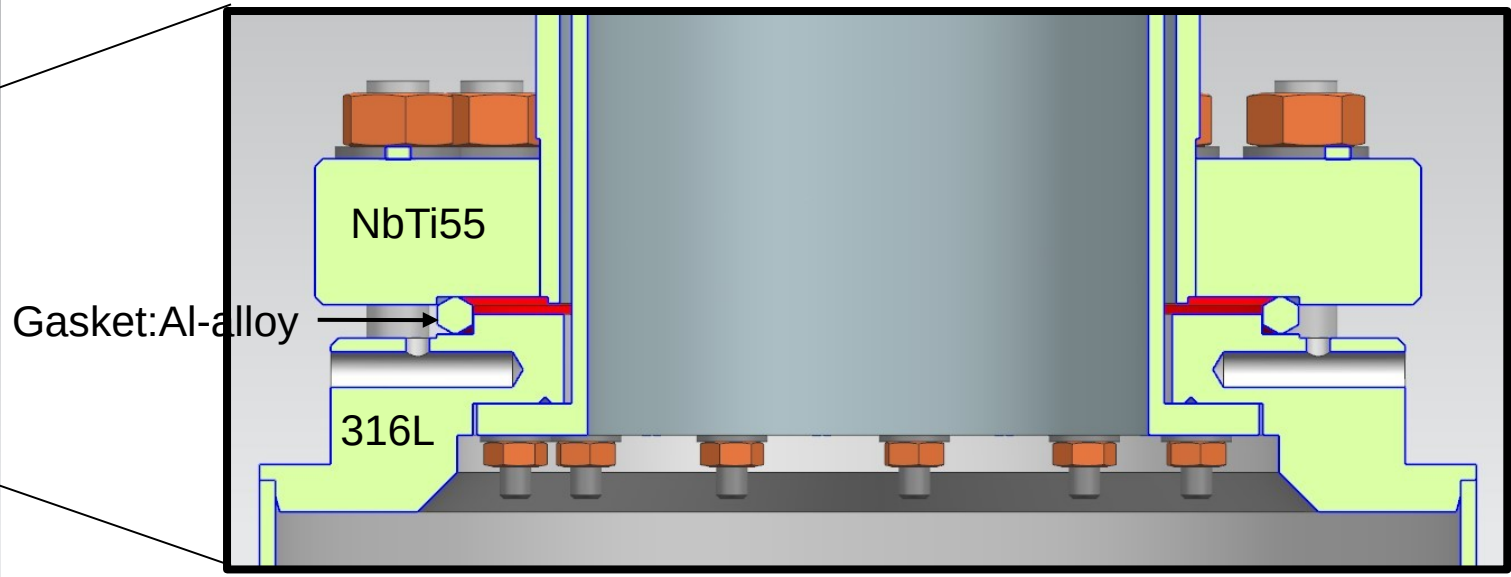


Antenna fabrication is
delayed due to Corona.
New ToA is end of April

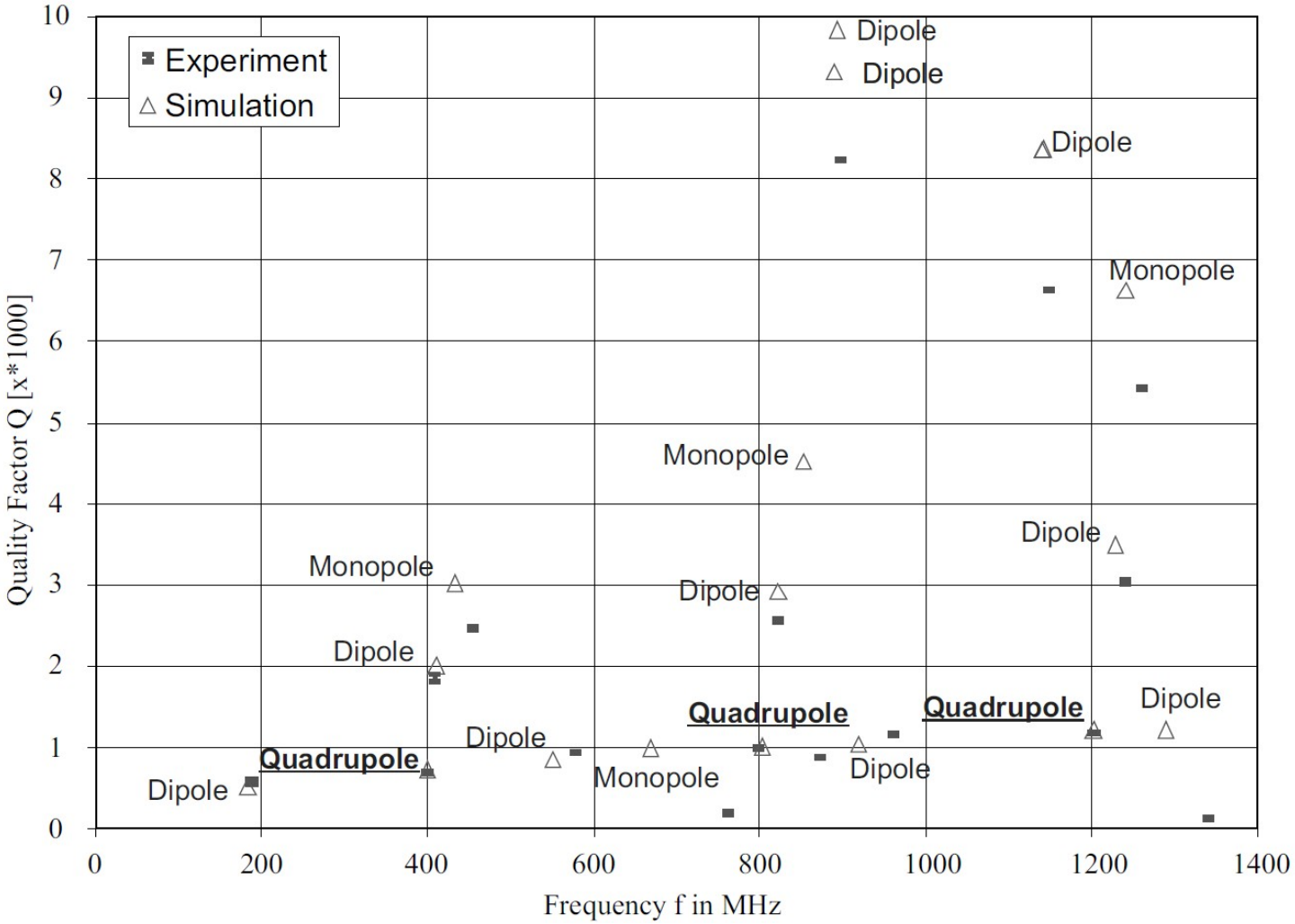


Design of adapter flange





CERN QPR modes at RT



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