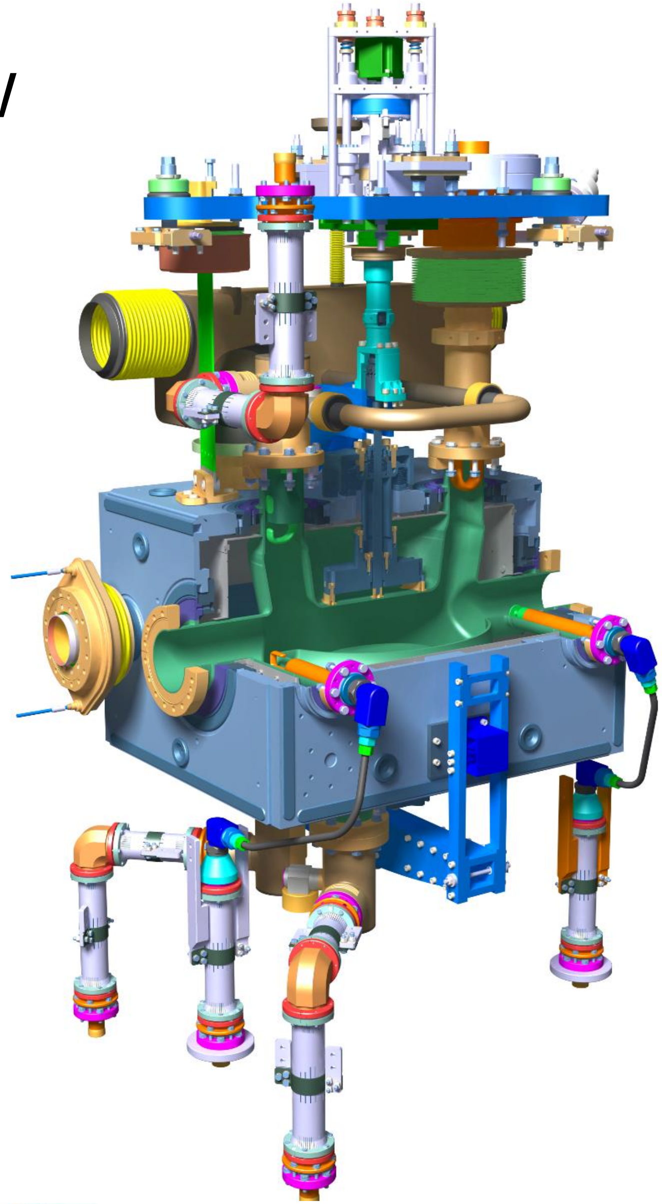
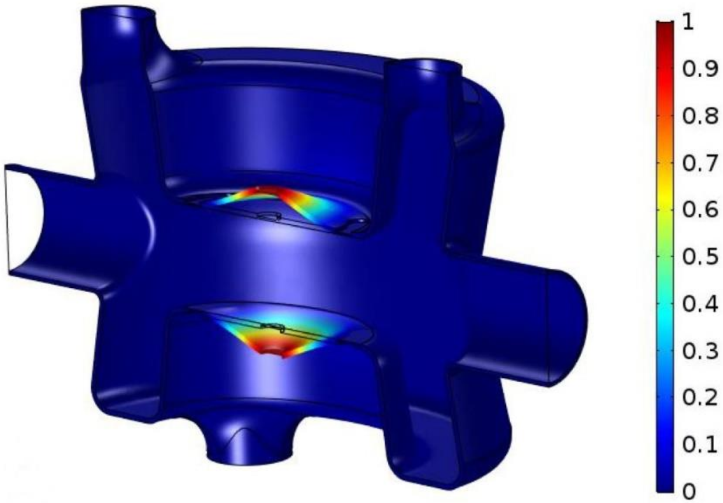
Crab cavity Frequency tuner

K. Artoos for WP4
Thanks to WP4 team!

Reminder Tuning HL LHC Crab

DQW



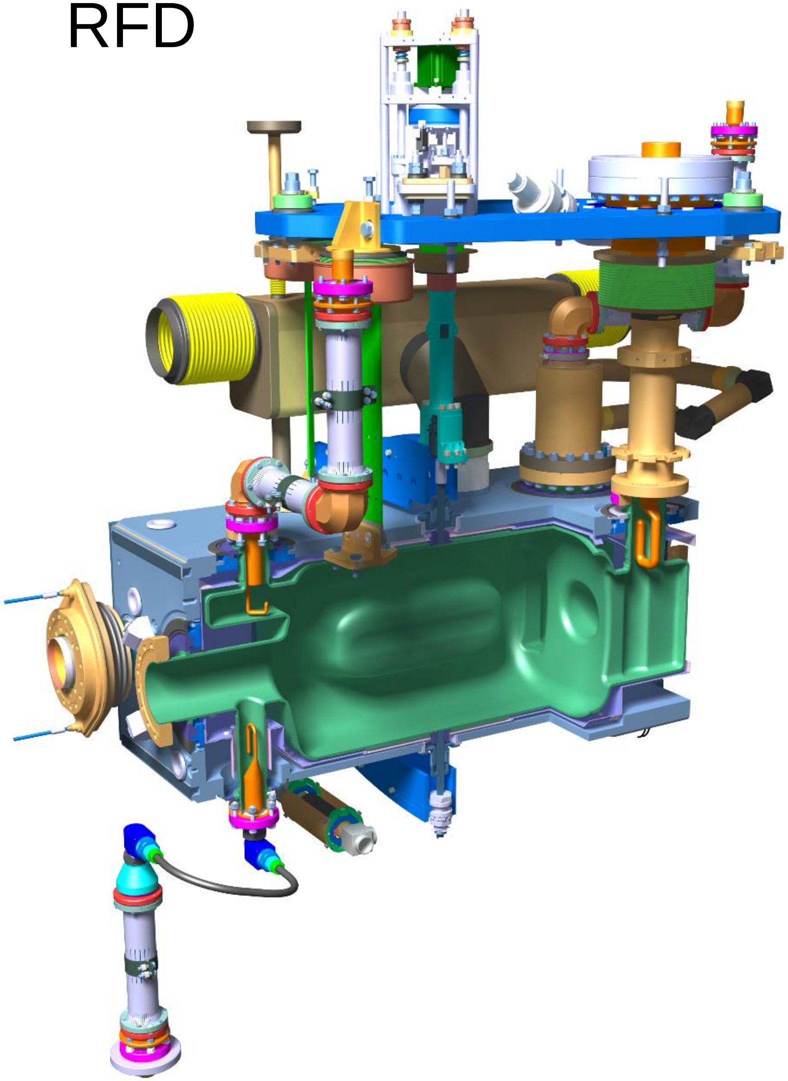


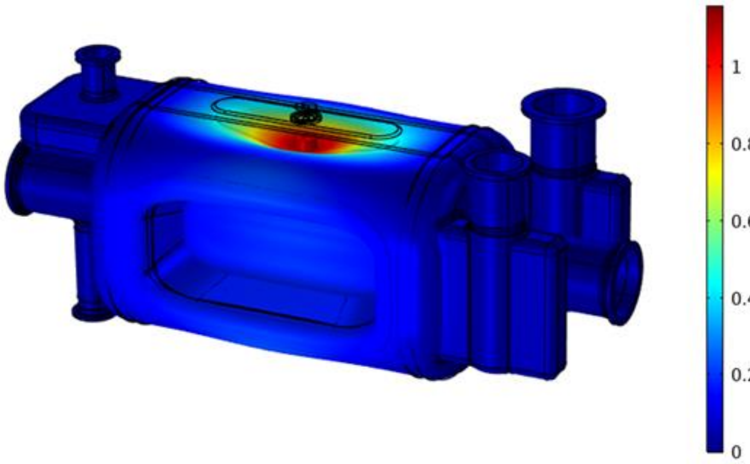
Two vertical, concentric tubes moved in opposite direction by actuator

Inner deforms top cavity
Outer deforms bottom through tuning frame

Reminder Tuning HL LHC Crab

RFD

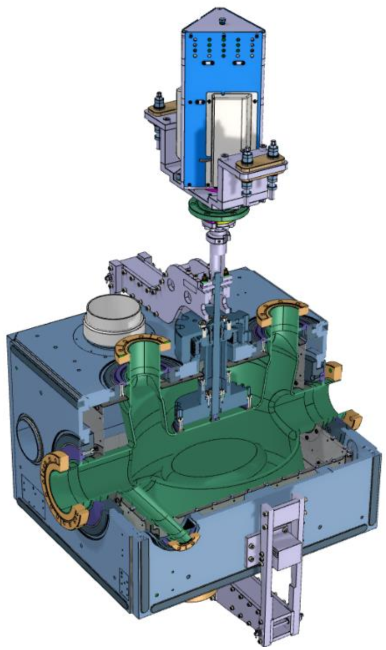




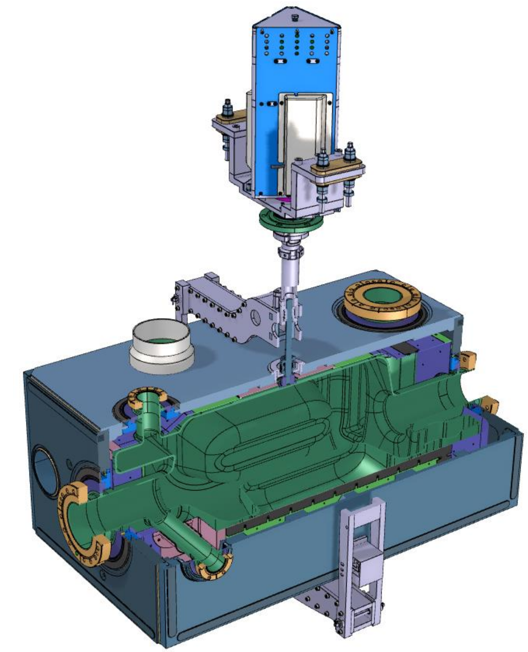
Both tuners very similar
Differences only due to dimensions
And geometry
Same actuator

Tuning sensitivity and range (COMSOL+ ANSYS)

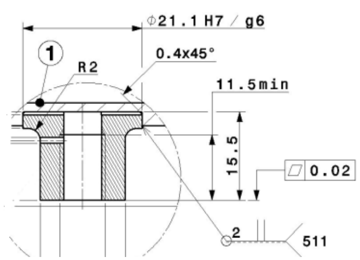
*Measured as change distance between 2 plates (≠ tuner actuator displacement)



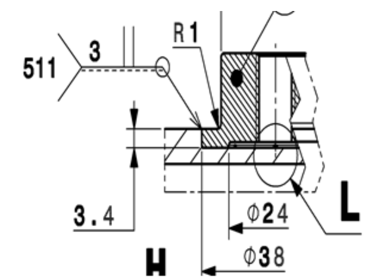
	DQW	RFD
Tuning Sensitivity:	318 kHz/mm*	512 kHz/mm*
Cavity tuning stiffness:	2.6 kN/mm*	2.8 kN/mm*
Specified tuning range at 2 K:	± 150 kHz	± 150 kHz
Elastic limit range at 2 K:	± 454 kHz	± 1.22 MHz
	±1.44 mm*	± 2.38 mm*
	± 3.6 kN	± 6.7 kN



Required unidirectional precision: ~80 Hz (~100 nm)

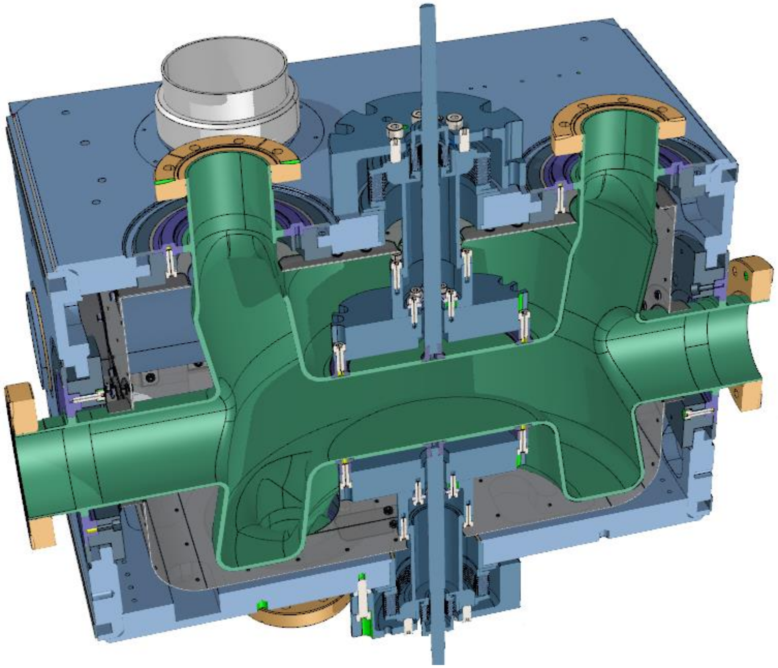


The elastic limit range are for both cavities determined by the welds between the cavity and the NbTi connection part and in second place by stresses in cavity

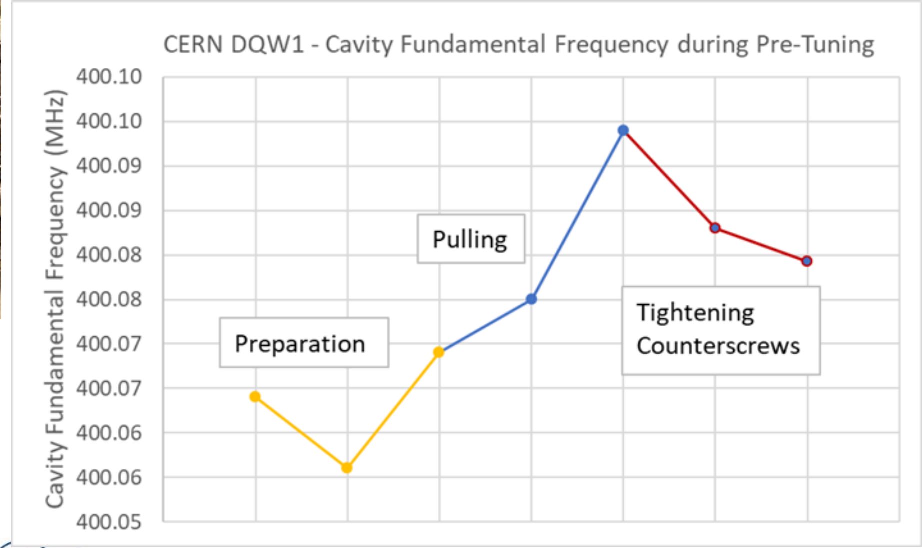


Important: tuner is a structural part of the cavity and adds to strength and stiffness, e.g. pressure test, PS, LFD

DQW Pretuner



Pre-tuning sensitivity: 1046 kHz/mm*
Pre-tuning range ± 300 kHz
Is limited by welds to NbTi connectors



Screws are cable locked after

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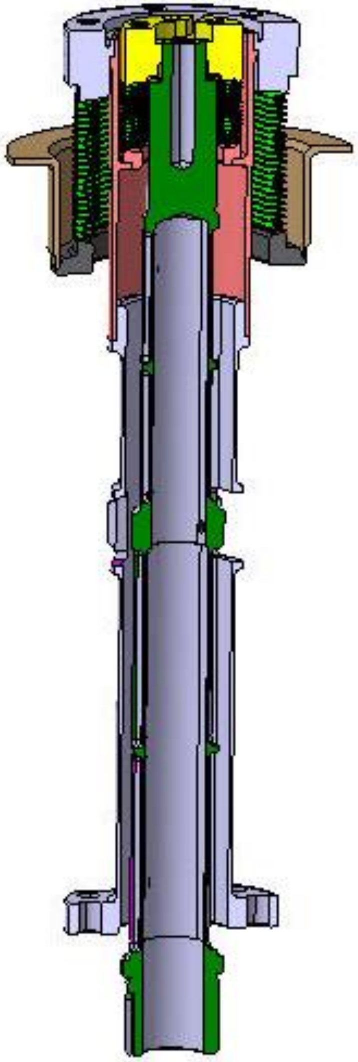
Tuner design/ assembly inside OVC



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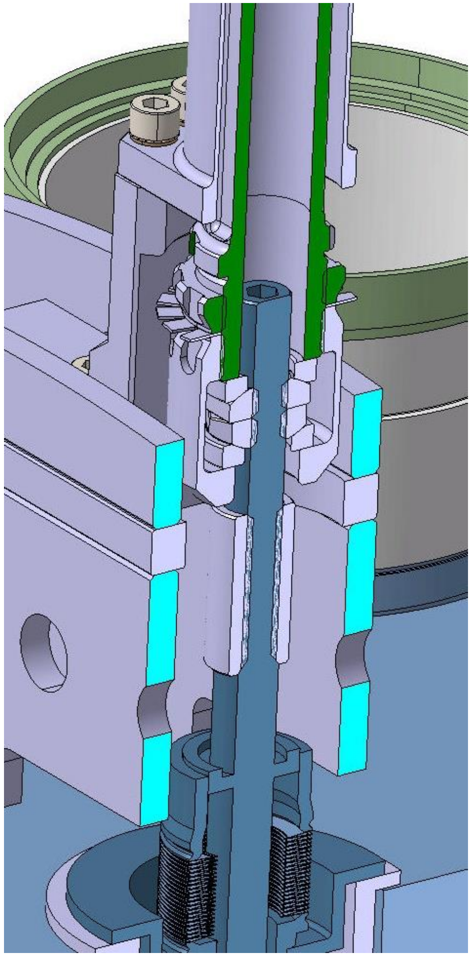
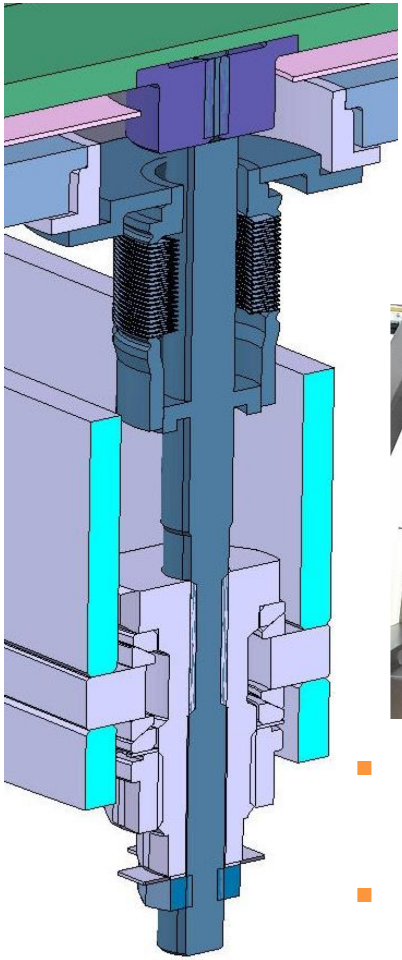
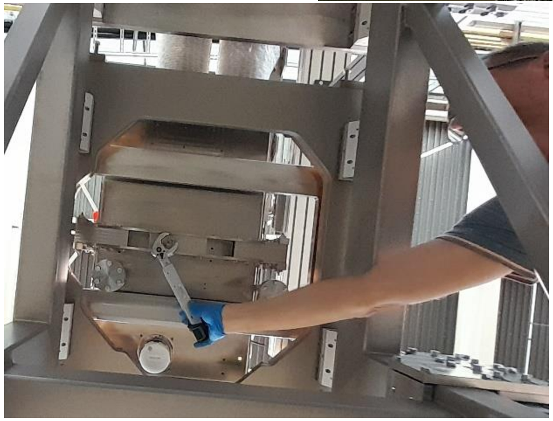
Tuner assembly inside vacuum tank (OVC)

Couplings Tuner to cavity

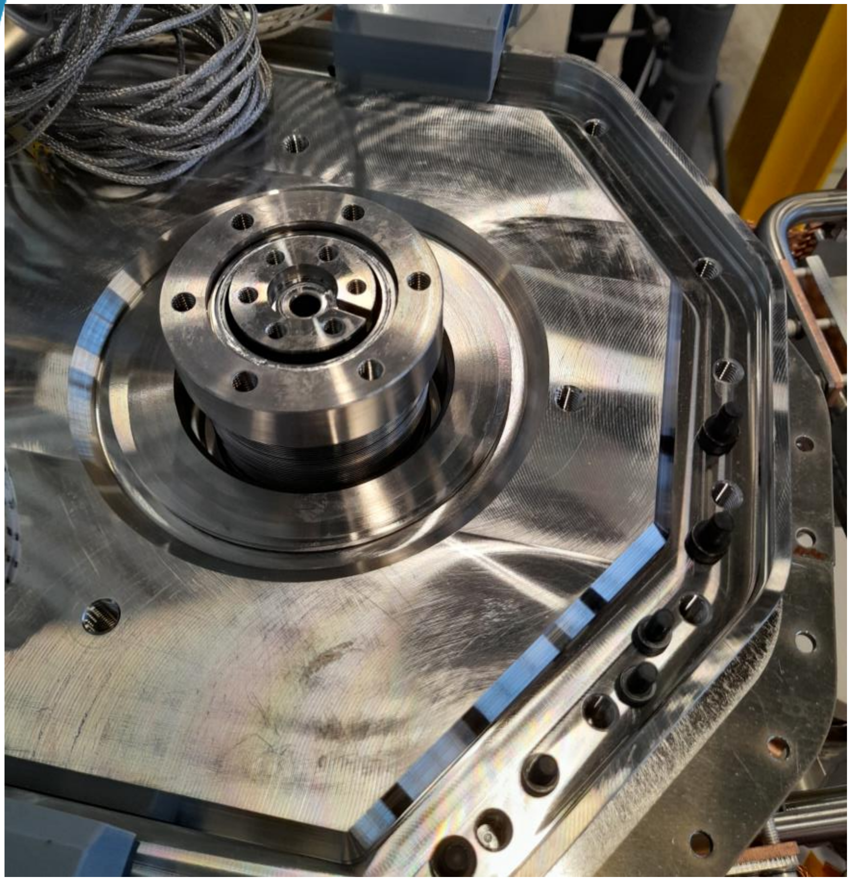
- Deals with offsets nominal dimensions cavity
- Connects tuner to cavity without deforming it







- Torque tightening + custom lip washers(locking)
- Heico locking washers instead of SChnorr
- Design considers also access for torque tools



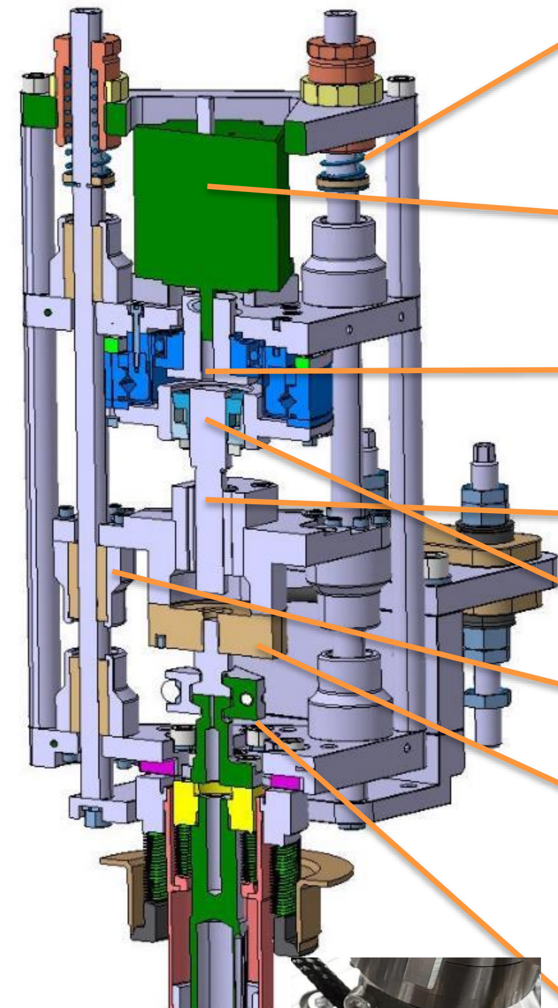
Tuner assembly inside OVC

Status for LHC:

- Design tuner inside OVC released for DQW and RFD in 2024
- This has improvements inside from SPS RFD lessons learnt
- Where possible, RFD and DQW parts are the same
- Fabrication ongoing both for DQW (CERN) and RFD (TRIUMF)
- Installation procedure + tooling finalised

Overview components

ACTUATOR SPS RFD proto



Vertical Spring pre-load from alignment plate

Stepper motor
1.3 Nm bipolar, motor step 1.8 deg, micro stepping 8000/360 , not ramped open loop, limited to 2000 steps/sec

Harmonic drive HFUS-20-100-2SO
Ratio 100, Accuracy < 1 arcmin, precision <0.1 arcmin (5 nm)
Fa Dyn 7.7 kN

Radhard grease SYNRAD 1252

Roller screw
Rollvis RV 12 x 1 static load capacity 17 kN

coupling

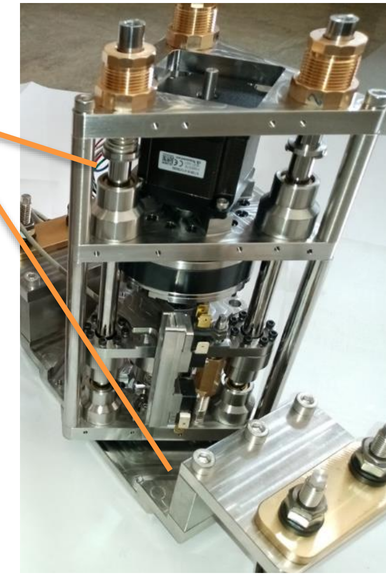
Sferax Compact GBL 1219 bearings XA +A (all metal) and guides

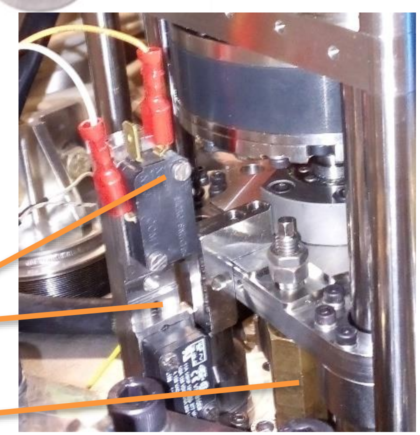
Loadcell
So far: Kistler 10 kN 4576A55C1 class 0.1

Limit switches
Difficult to set, not so reliable

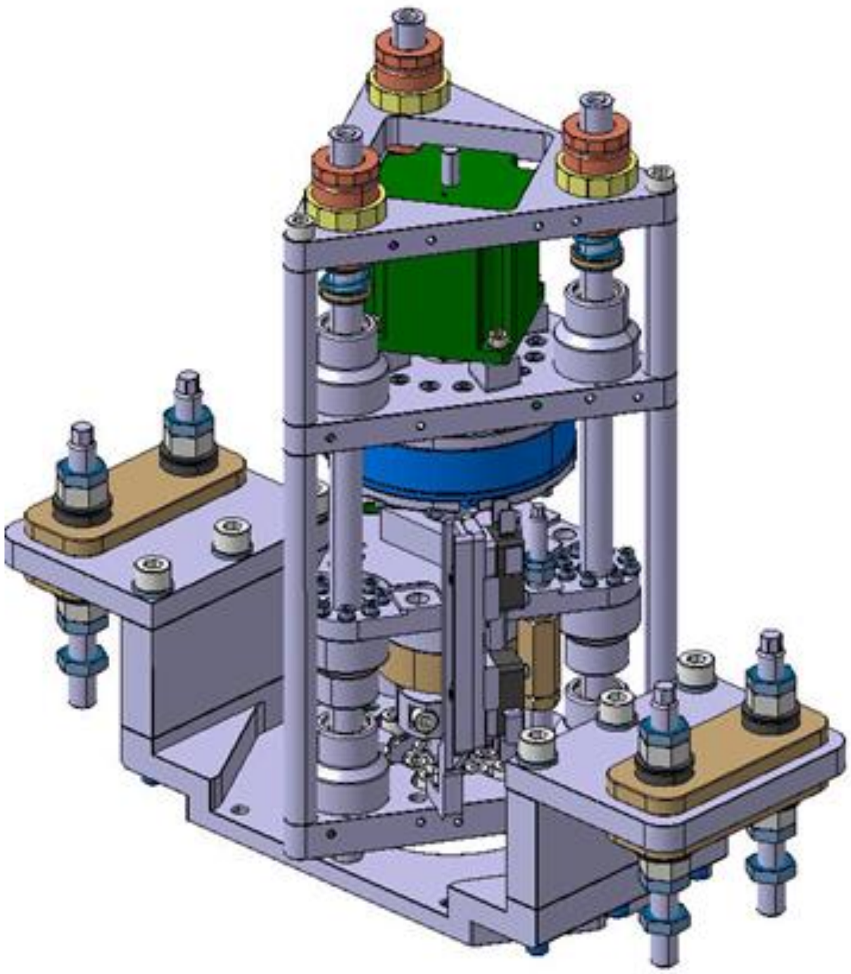
Mechanical end stops with max load interlock on load cell conditioner

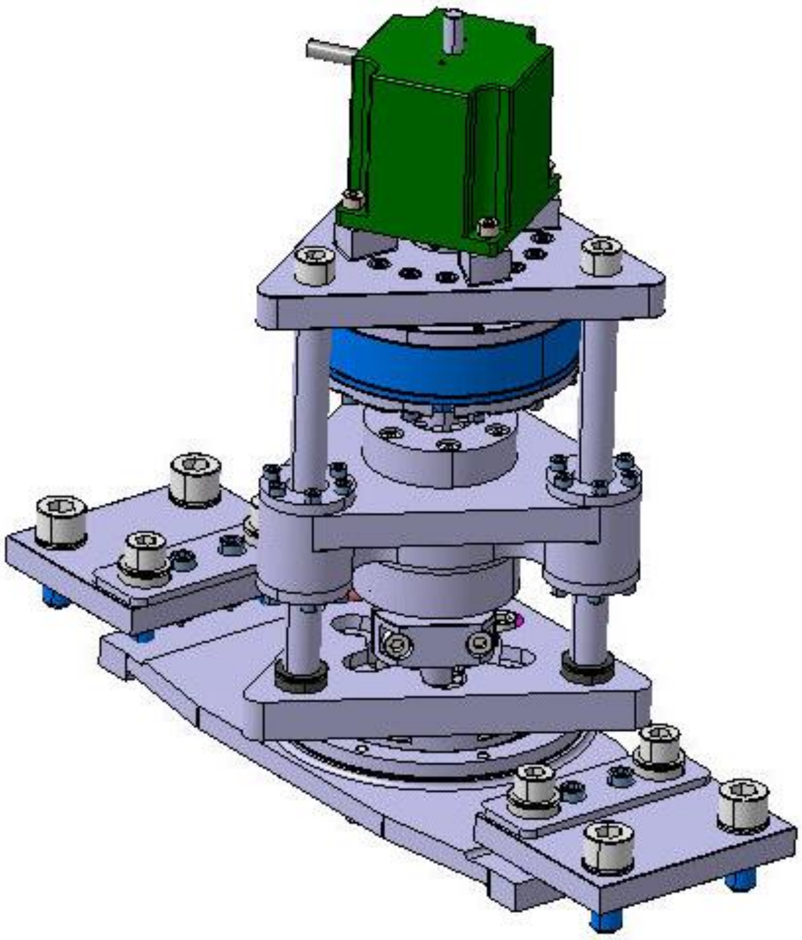
Actuator coupling
Allows quick change of actuator + connection without frequency change
Incorporates heater





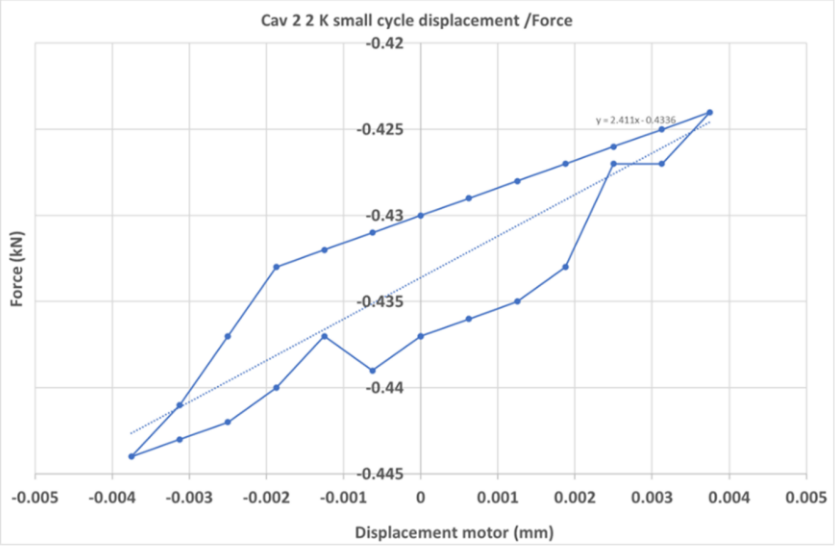
Actuator «re-looking»



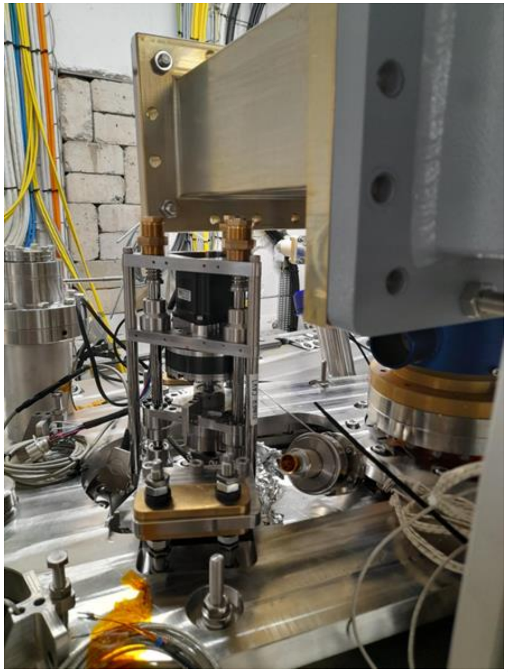


SPS RFD Assembly Actuators + CD1

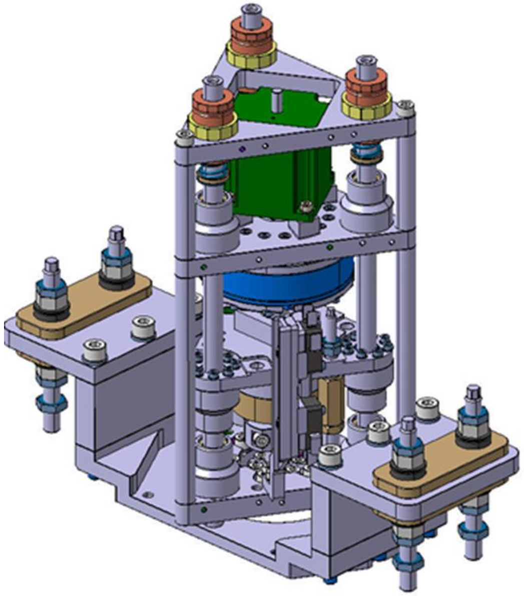
- <u>“Hard points” in guides actuator</u>
- <u>Assembly bearings over determined, planarity tolerances</u>
- <u>Buttressing in actuator support</u>
- <u>Precision 80Hz not reached for CD1</u>

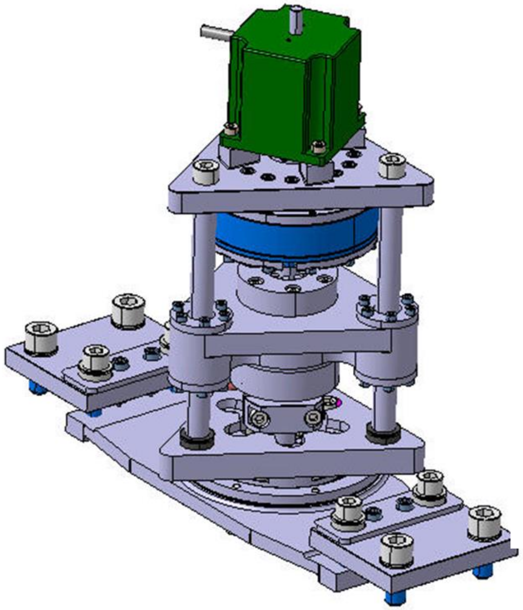


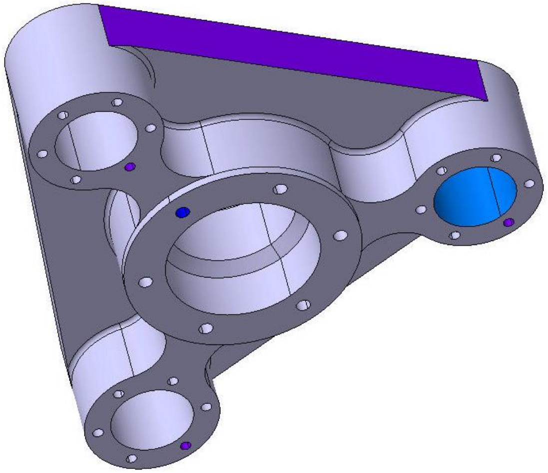
- Interference actuator springs with turned and tilted waveguide (before repair)
- Interference between cable gauge FPC with actuator support

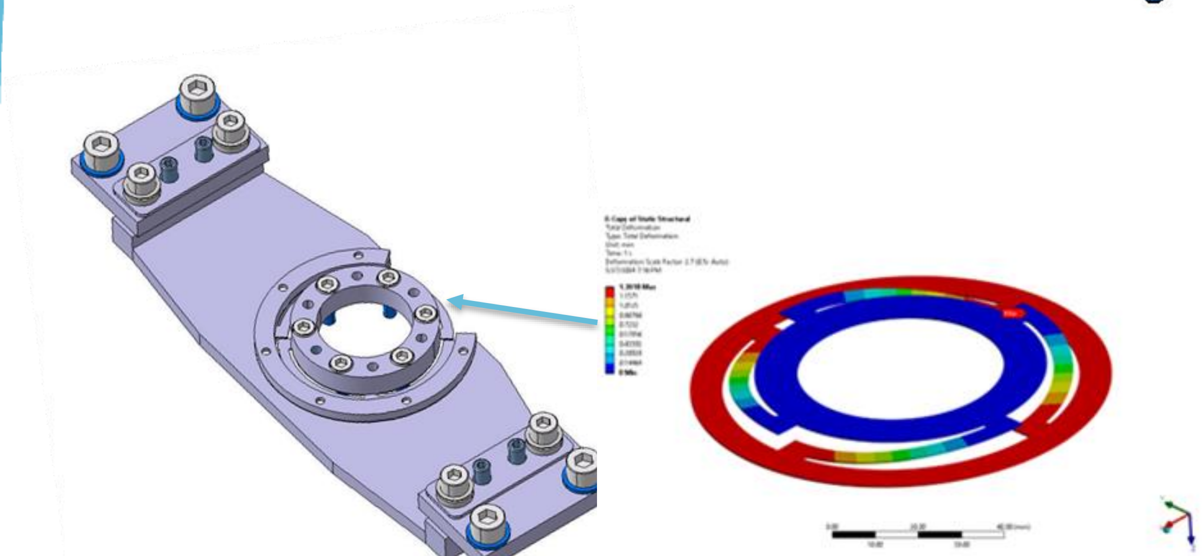


Problem 1

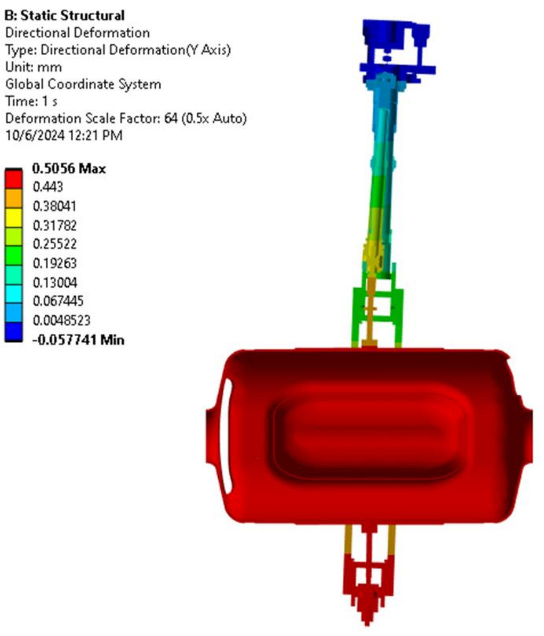




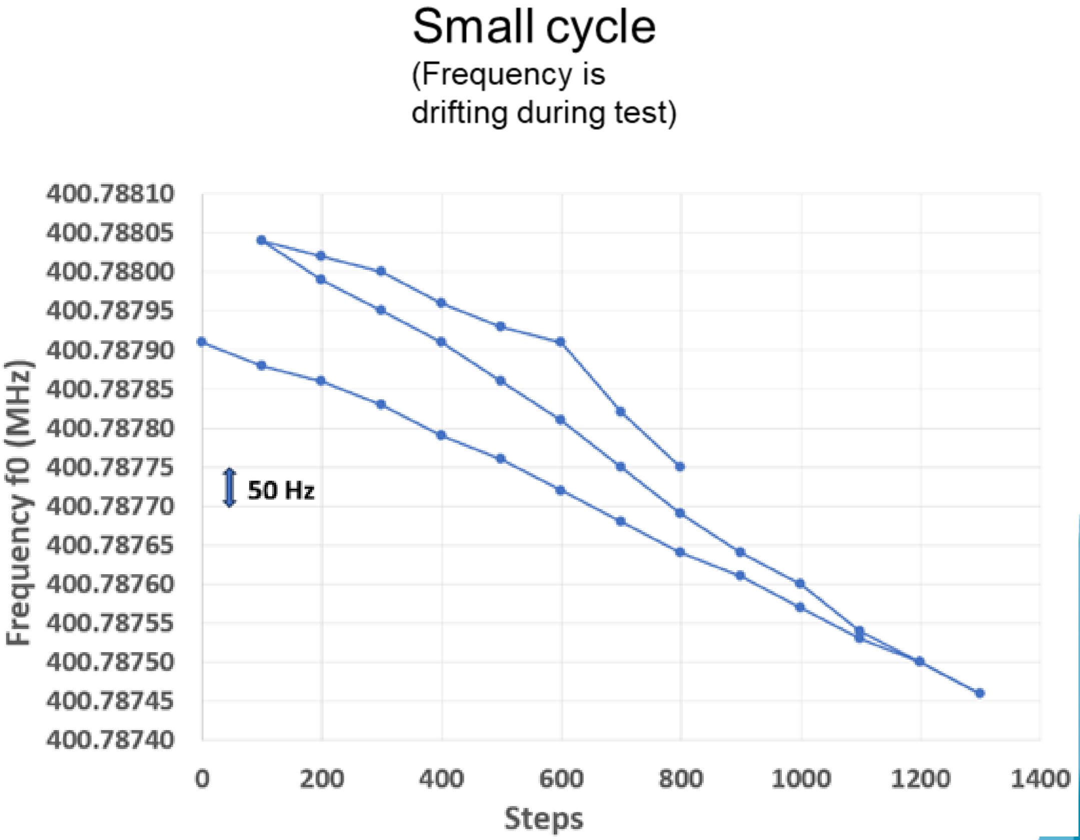




3 d.o.f.

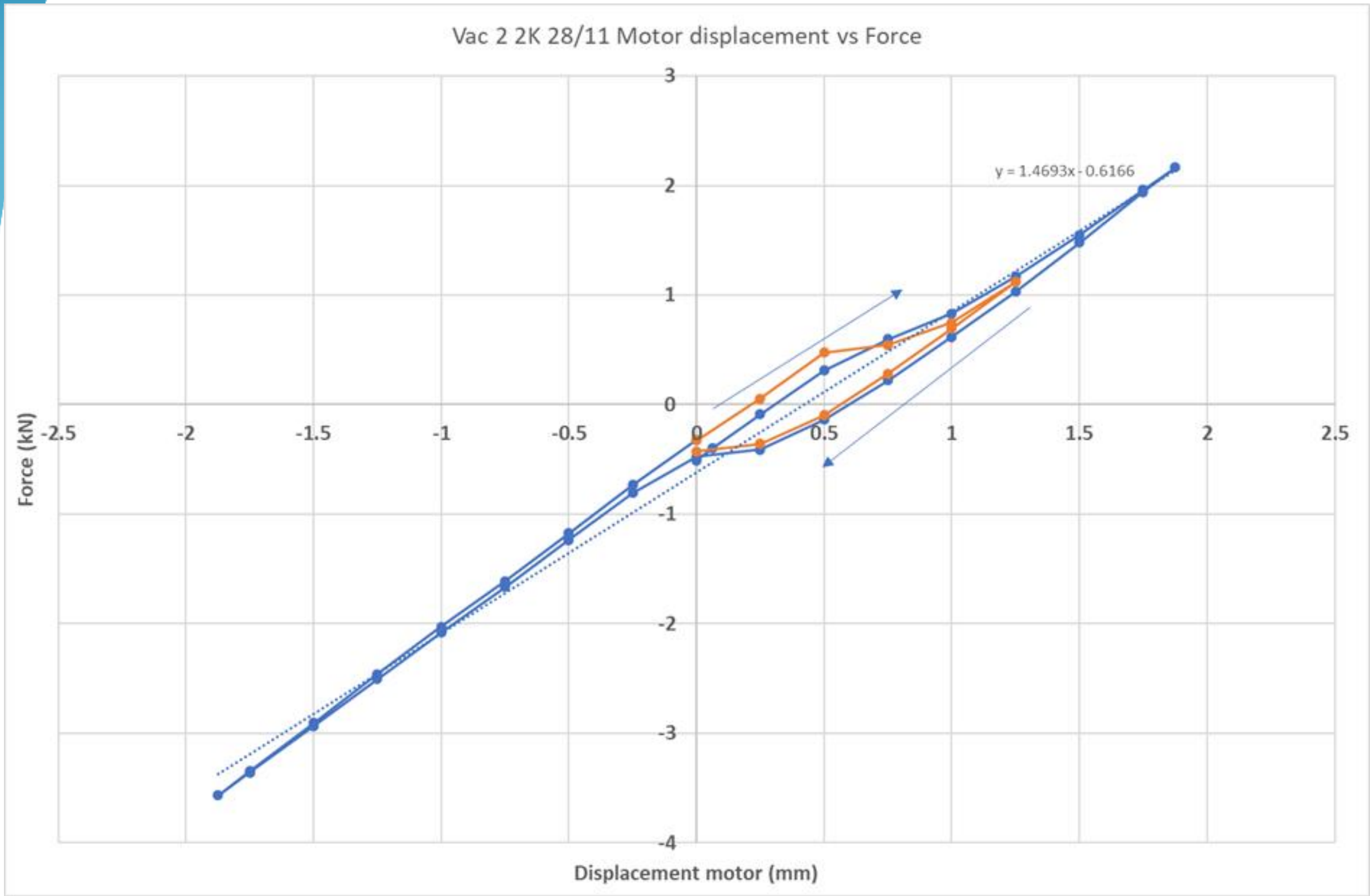

B: Static Structural
Directional Deformation
Type: Directional Deformation(Y Axis)
Unit: mm
Global Coordinate System
Time: 1 s
Deformation Scale Factor: 64 (0.5x Auto)
10/6/2024 12:21 PM
0.5056 Max
0.443
0.38041
0.31782
0.25522
0.19263
0.13004
0.067445
0.0048523
-0.057741 Min

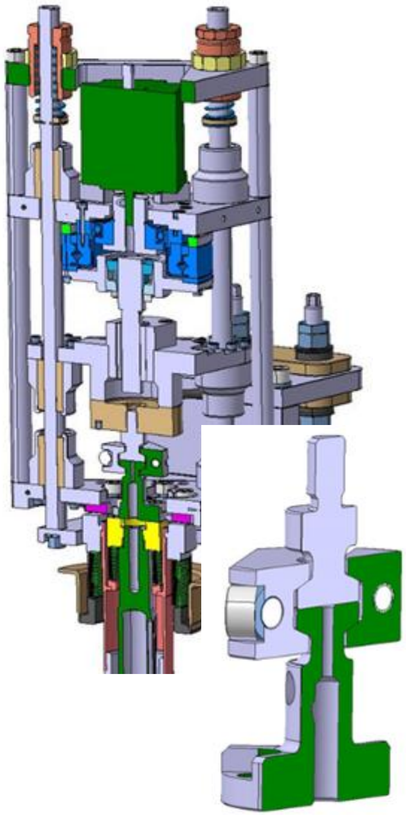
« Tested" for CD2 tuner tests



Acceptance testing tuner precision is long and difficult because of drifting frequency during tests + “noise” on frequency and force measurement

CD1 Backlash with a twist

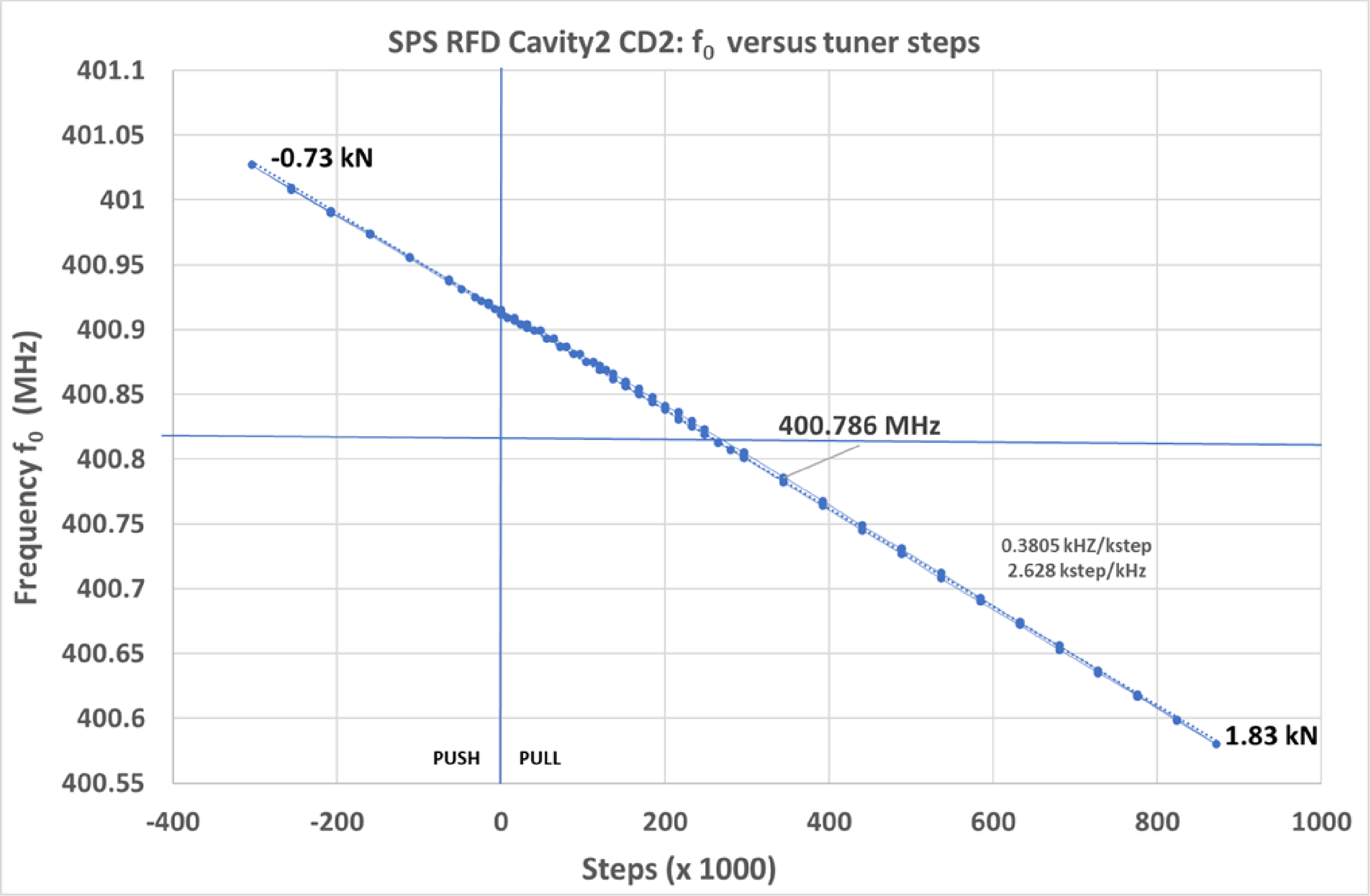




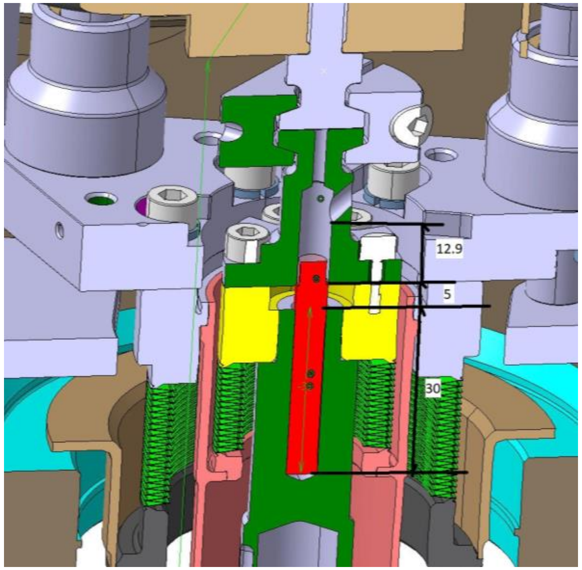
Clearance with friction in actuator clamp due to tolerances
Easily solved, but asked for design improvement

Problem 2

Tuning SPS-RFD SM18 Cavity 2 CD2



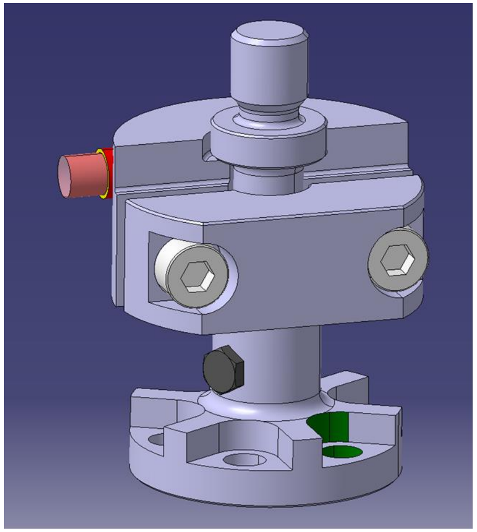
Tuner heater problem/ ICE inner connection



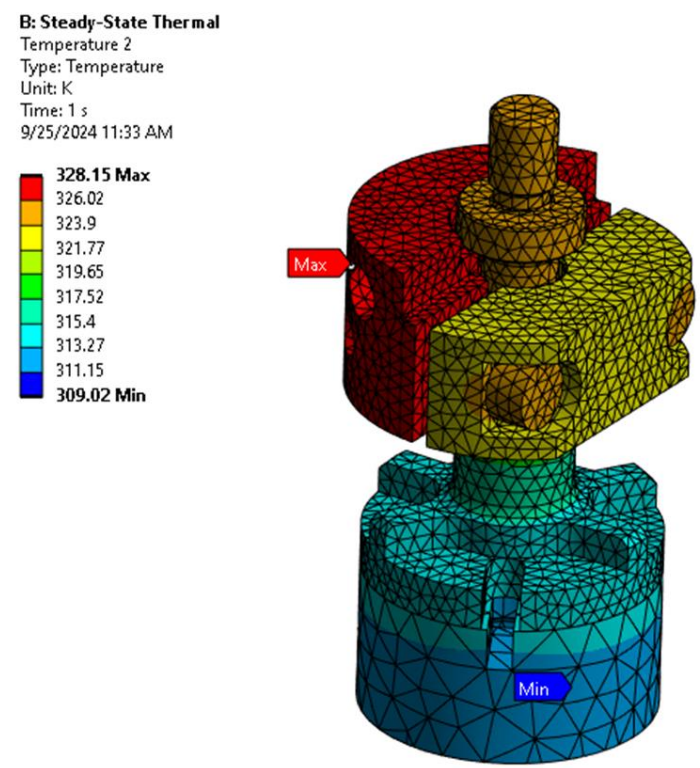
- Heaters keep breaking or sometimes switched off, reason not sure
- No place for a temperature gauge
- Heaters difficult to replace (remove fully actuator)

Problem 3

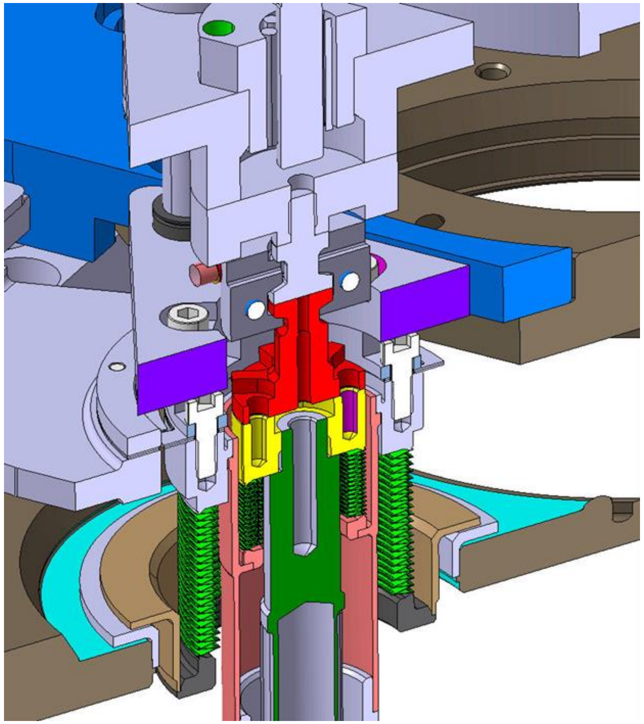
New Integration heater and temperature gauge

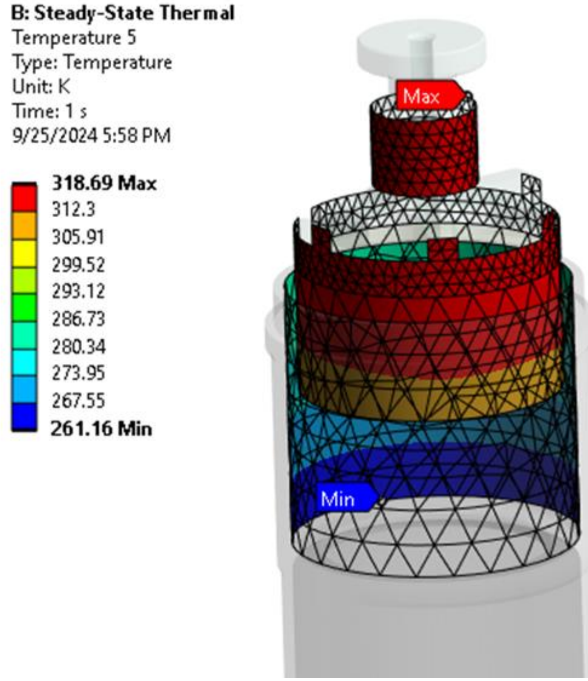


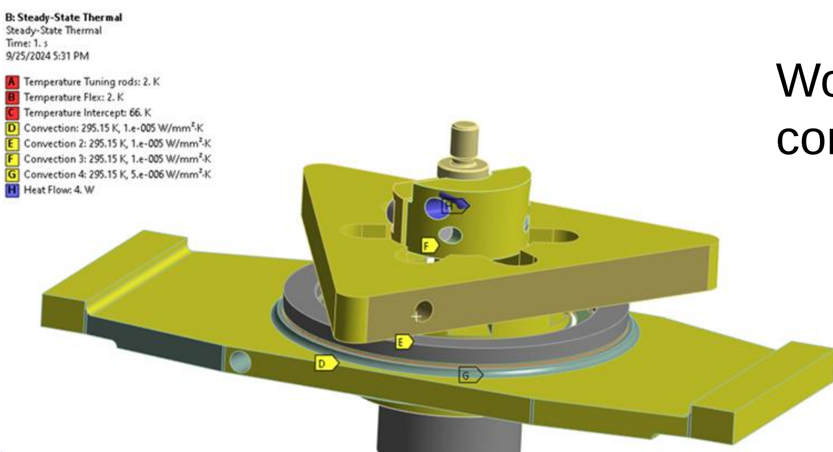
- Place heater in tuner clamp
- Temperature gauge M3 (commercial part) on inner connection part (ICP)
- Clamps, screws and ICP in Cu Sn 8
- 2 to 4 W



Possible ice inside bellows



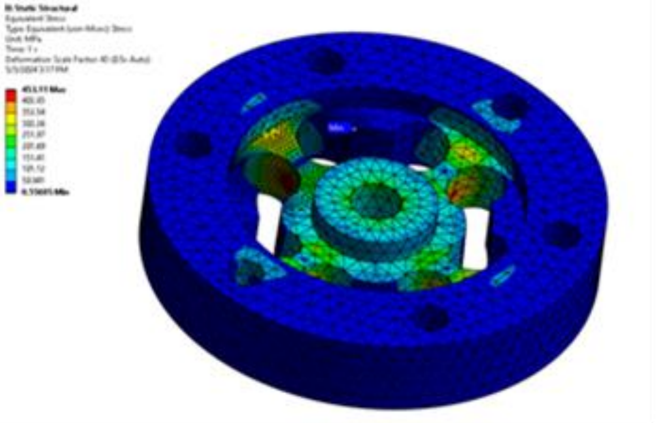




Work on adding heater patch on outer connection flange (cryo group)

Other ongoing work for actuator

- Limit switches + mechanical stops: improve reliability + easier setting: on-going, looking for simple solution
- Rad-hardness, lubrication and material adaptation commercial components: contacts and discussions with providers, preparation of technical specs for call for tender
- Fast dismountability in situ + preventive maintenance scenarios
- Adding of grease reservoirs
- Improving the load cell + rad –hardness: in house CERN design



Conclusions

- The SPS RFD cryomodule preparation and testing gave input for tuner improvements
- The inside OVC tuner part design LHC DQW and RFD released Q1 2024 and in fabrication
- For DQW the parts for 2 CM coming available
- Tuner actuator part redesign 3D under last review, first drawings were already made.
- Priority is for releasing drawings for TRIUMF provided parts for financial reasons.
- Preparation of tendering gears, lead screw, motors, bearings is ongoing.

References

- Comsol RF calculations:
- E. Cano Pleite et al.; Numerical evaluation of the tuning frequency, pressure sensitivity and Lorentz Force detuning of RF superconducting crab cavities, Proceedings 2018 COMSOL Conference, Lausanne
- T. Guillen Hernandez et al., Numerical calculation of the Lorentz Force Detuning and the pressure sensitivity for the HL-LHC CRAB Cavity, IPAC 2023

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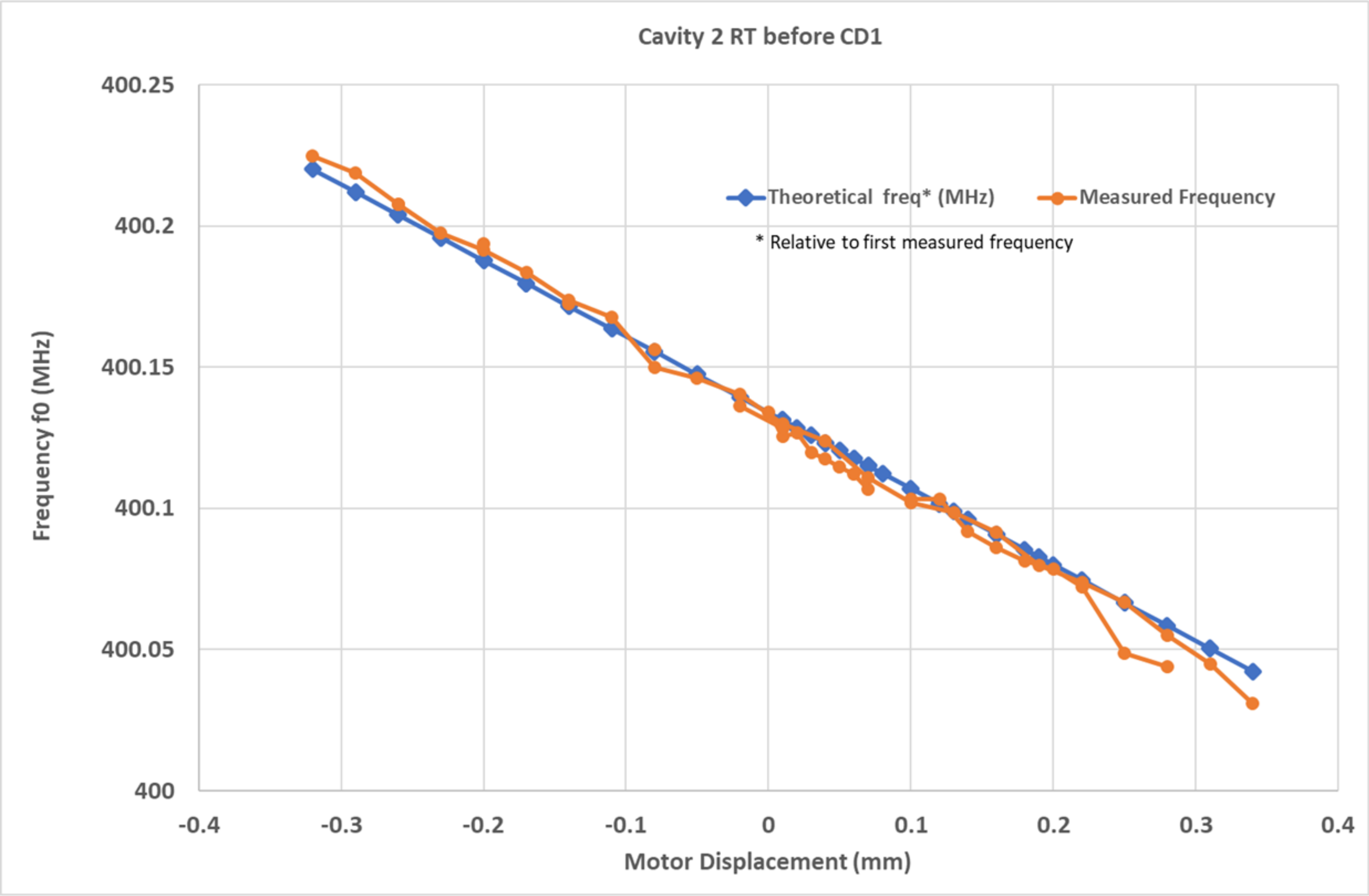
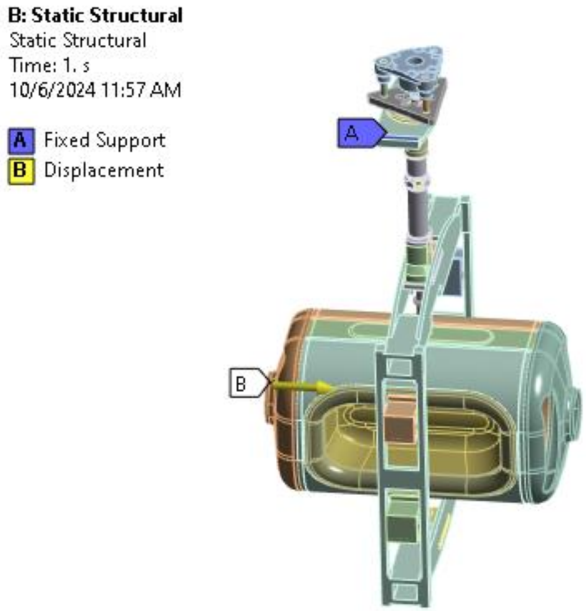
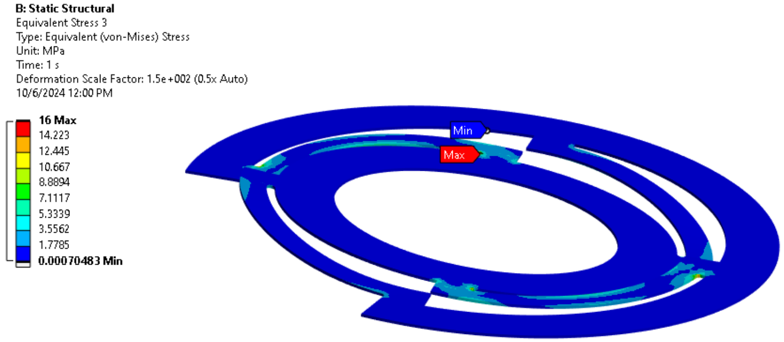
RT before CD 1, OVC open

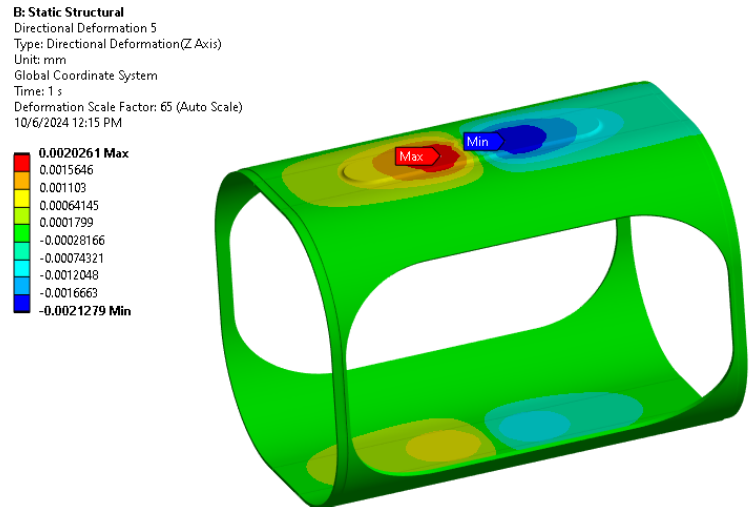


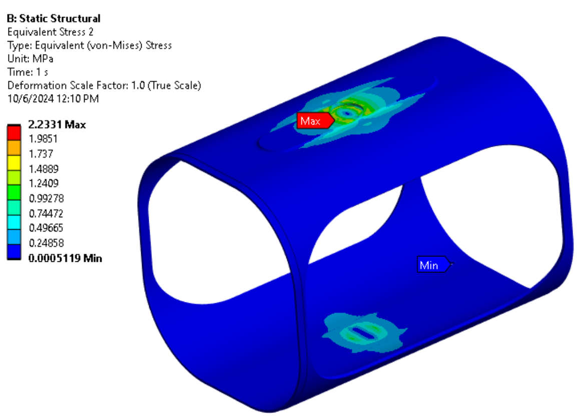
Additional: 14/11/23 Tuner and HOM measurements at RT

Thermal contraction Cavity support









Cav 1 + 2, CD1 several cycles