# Crab cavity Frequency tuner

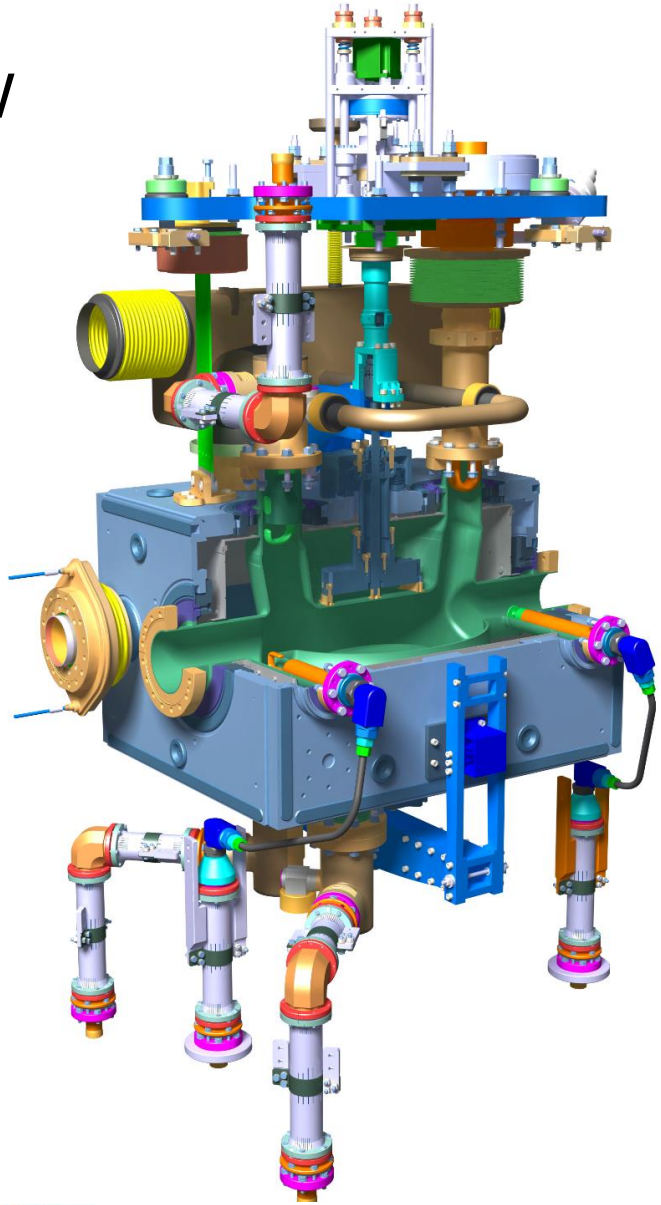
**K. Artoos for WP4**

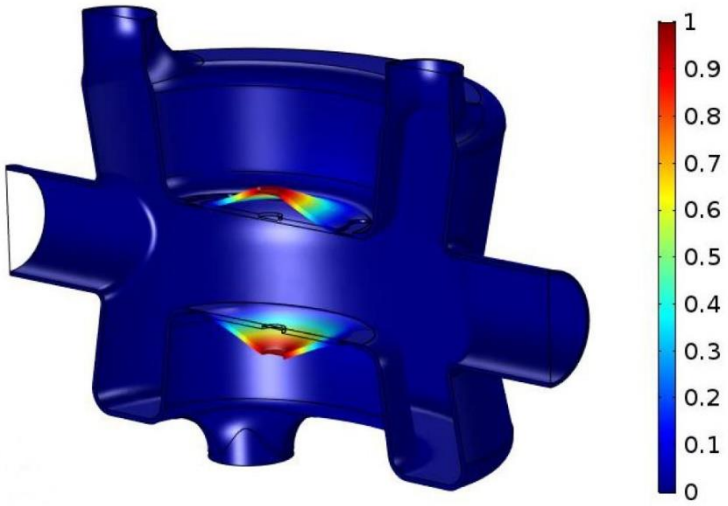
Thanks to WP4 team!

# Reminder Tuning HL LHC Crab



DQW





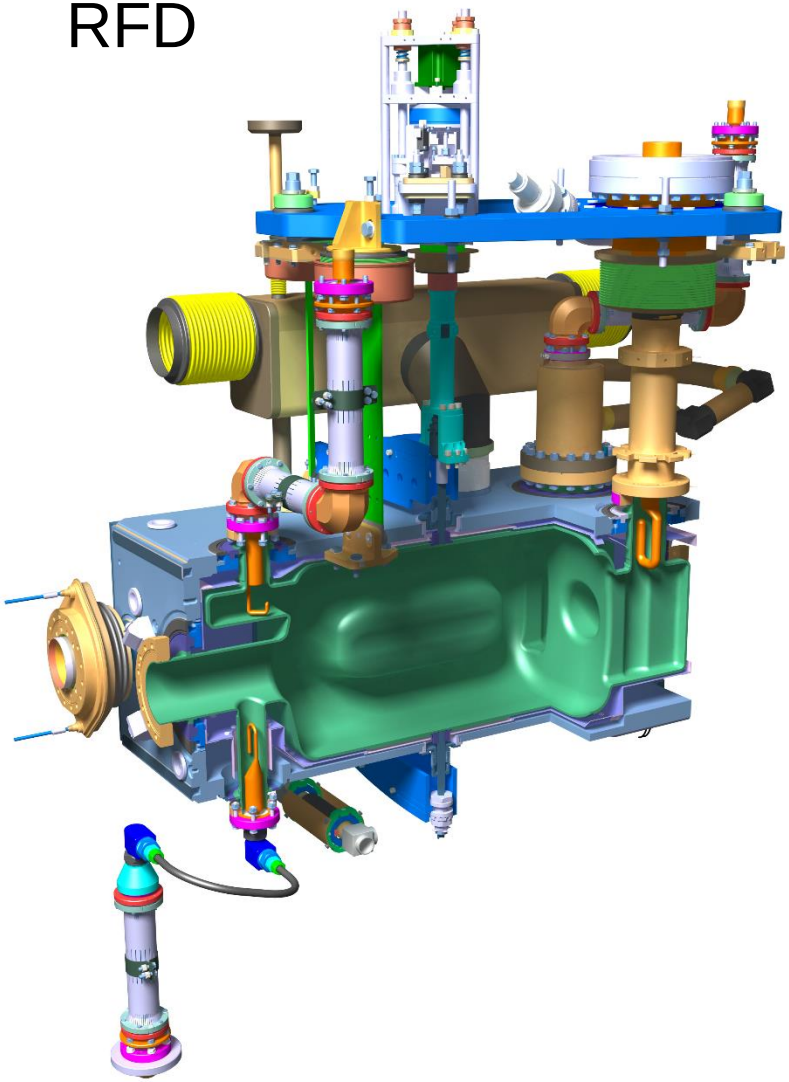

Two vertical, concentric tubes moved in opposite direction by actuator

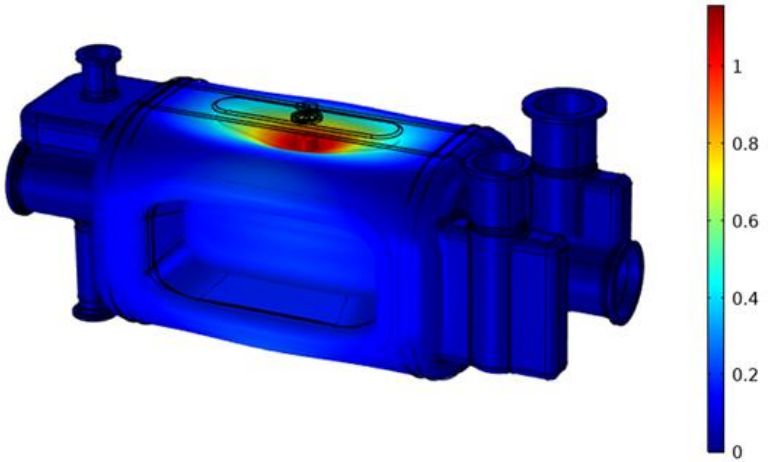
Inner deforms top cavity
Outer deforms bottom through tuning frame

# Reminder Tuning HL LHC Crab



RFD



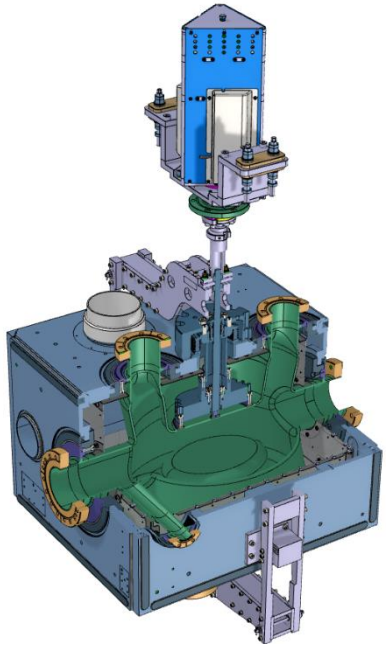



Both tuners very similar
Differences only due to dimensions
And geometry
Same actuator

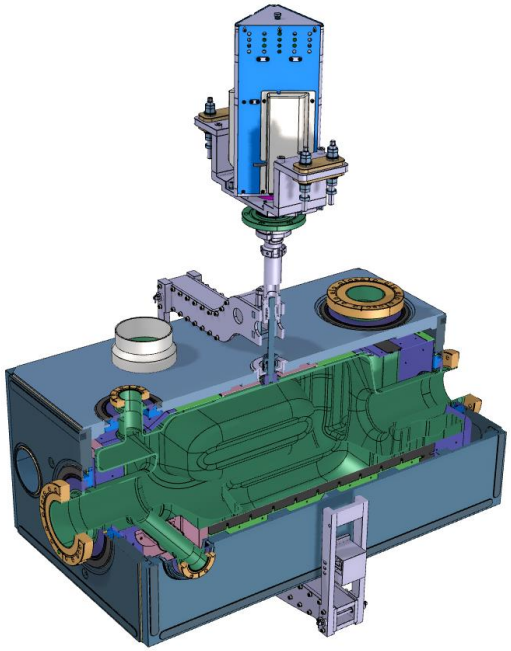
# Tuning sensitivity and range (COMSOL+ ANSYS)



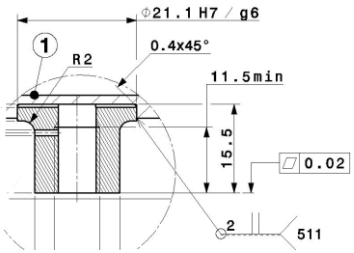
*Measured as change distance between 2 plates (≠ tuner actuator displacement)



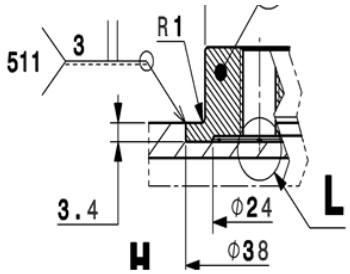
| | DQW | RFD |
|---|---|---|
| Tuning Sensitivity: | | |
| | 318 kHz/mm* | 512 kHz/mm* |
| Cavity tuning stiffness: | | |
| | 2.6 kN/mm* | 2.8 kN/mm* |
| Specified tuning range at 2 K: | | |
| | ± 150 kHz | ± 150 kHz |
| Elastic limit range at 2 K: | | |
| | ± 454 kHz | ± 1.22 MHz |
| | ±1.44 mm* |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



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



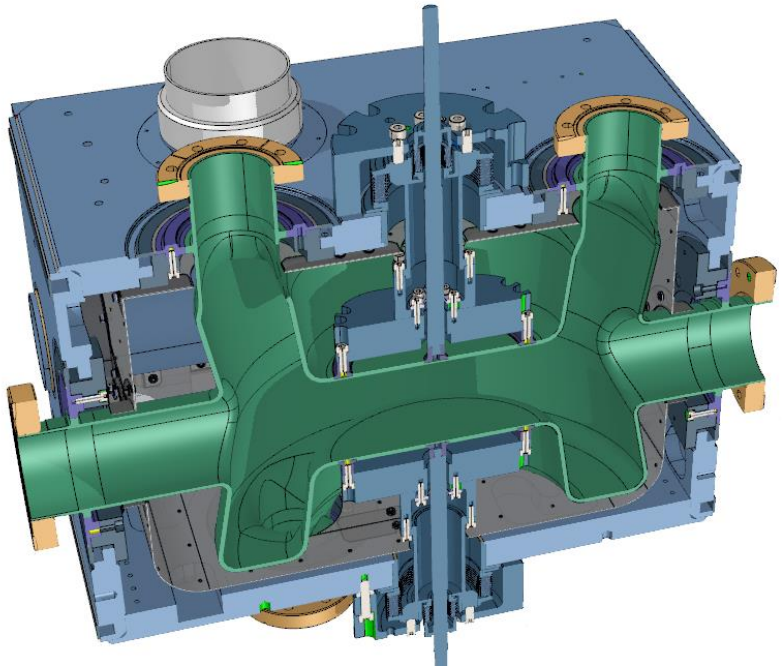

The elastic limit range are for both cavities determined by the welds between the cavity and the NbTi connection part and in second place by stresses in cavity



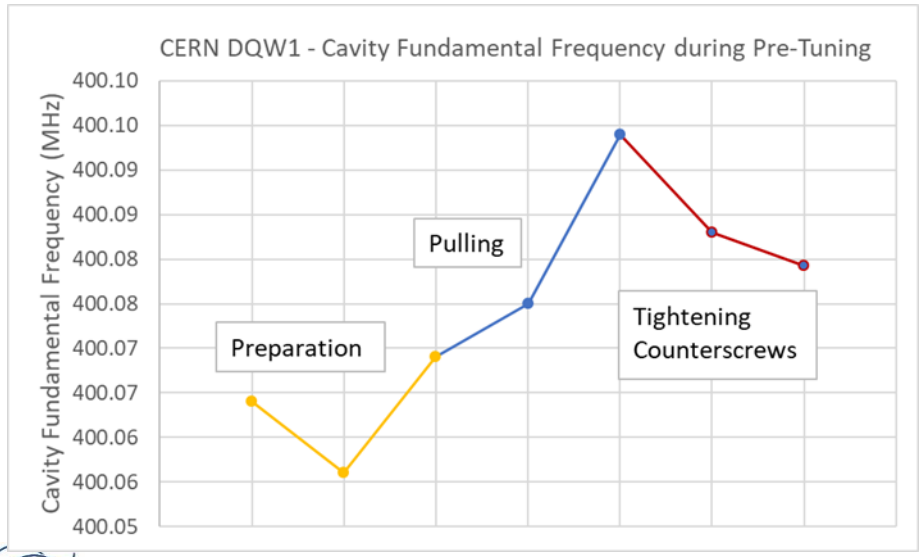

Important: tuner is a structural part of the cavity and adds to strength and stiffness, e.g. pressure test, PS, LFD

# DQW Pretuner





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



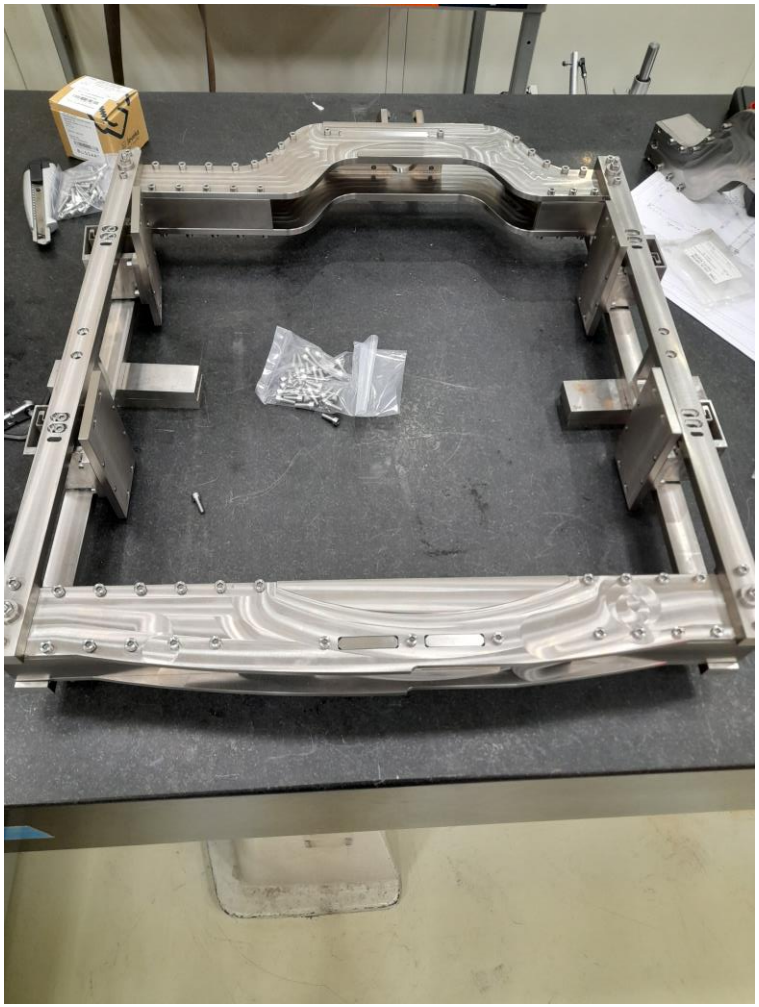

Screws are cable locked after

# Tuner assembly inside OVC

**Step 3**

**Status DQW parts (Fabrication CERN)**

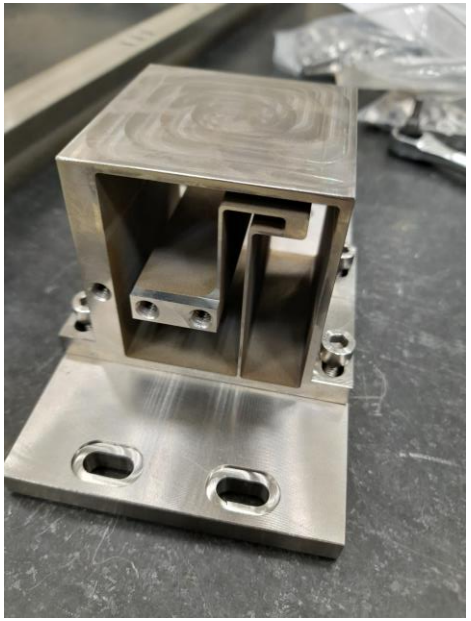
**Alex Verduyn**



2 frames fully test assembled

Some threads deeper, Cleaned

Pending: cleaning **locking washers**



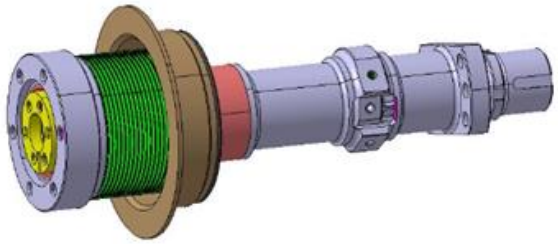
**All parts for step 3 series have been produced !**

# Tuner assembly inside OVC

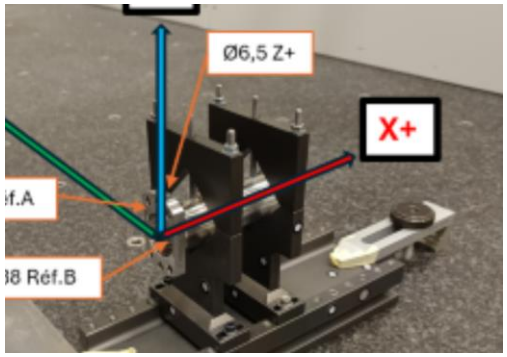
**Step 4**

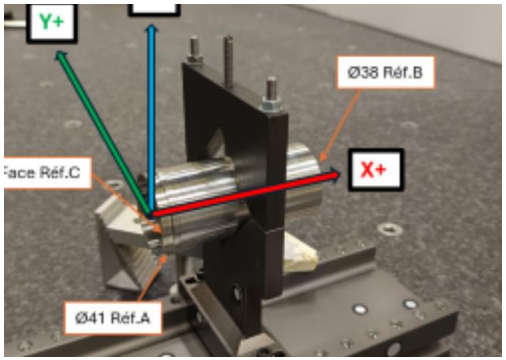
**Status DQW parts (Fabrication CERN)**

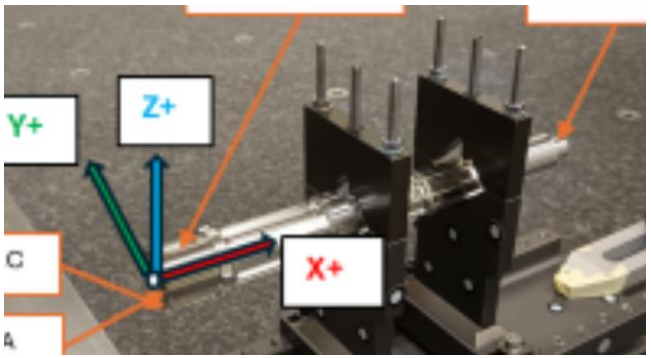
**Teresa Guillen Hernandez**



- Full series RFD and DQW OVC bellows available
- Parts for four DQW tuners produced
- Checked metrology
- Test fitted in weld tool
- Cleaned
- EBW will start in the next days



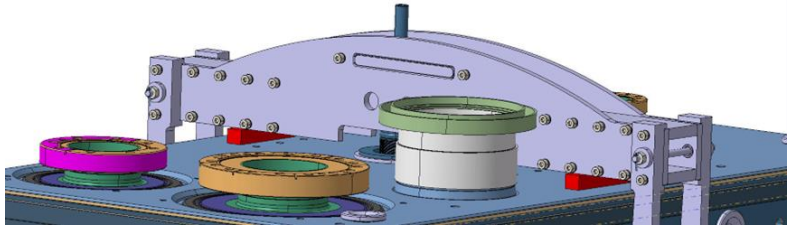

- Parts top coupling available for series
- Test fitted for 2 tuners STFC
- Cleaned

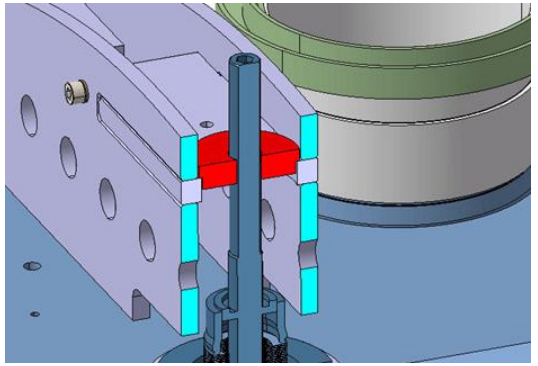
**Pending:** pre-bending locking washers

# Tuner assembly inside OVC

**Assembly instructions + tools**

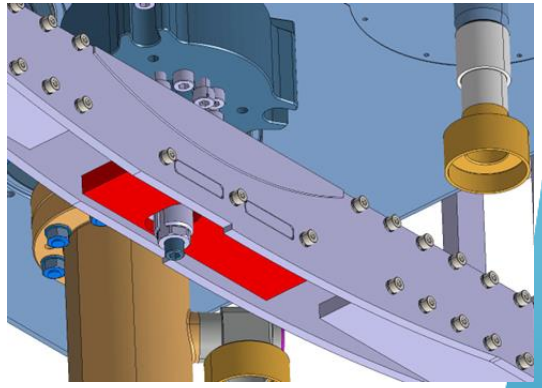
Up to step 4: EDMS 3012077 guidelines worked into STFC procedure

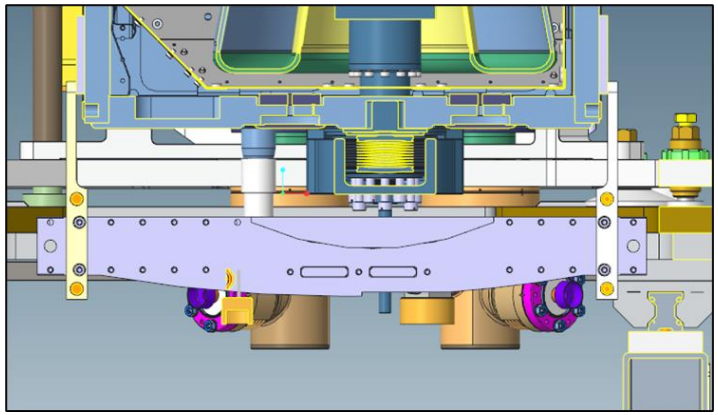


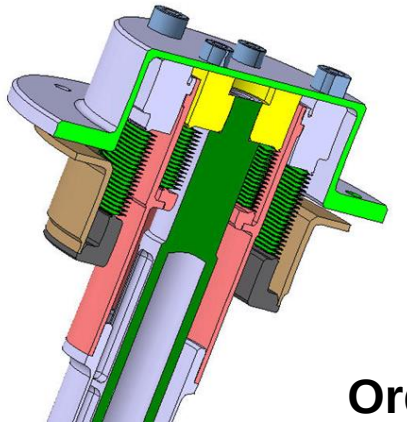


3D printed Tools: Preparation STFC ?

- LHCACFTU0289 Tuning frame alignment spacers 13.5 mm
- LHCACFTUxxxx Bottom tuner frame support
- LHCACFTU0291 Top tuning alignment spacer
- LHCACFTU0290 Bot tuning alignment spacer
- LHCACFTUxxxx Tuner bellows alignment tool

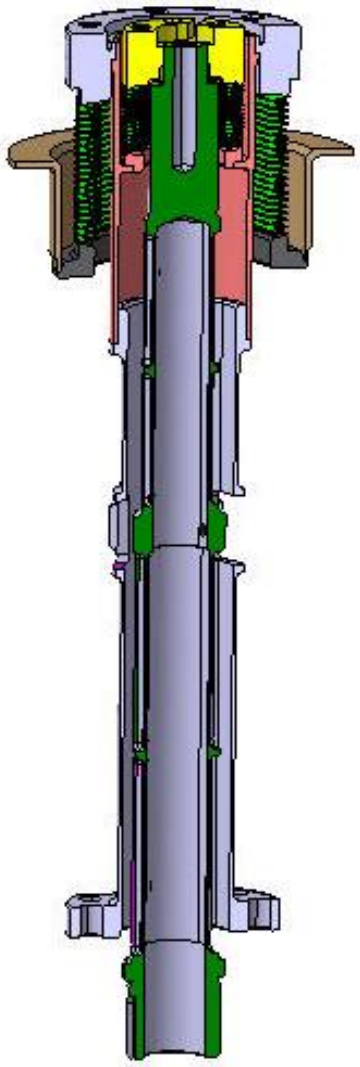






**Ordered commercial tools**

# Tuner design/ assembly inside OVC

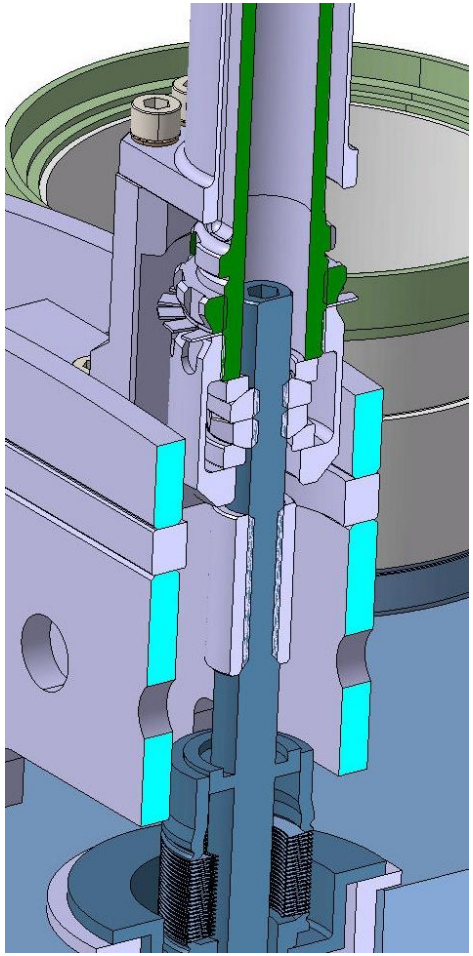


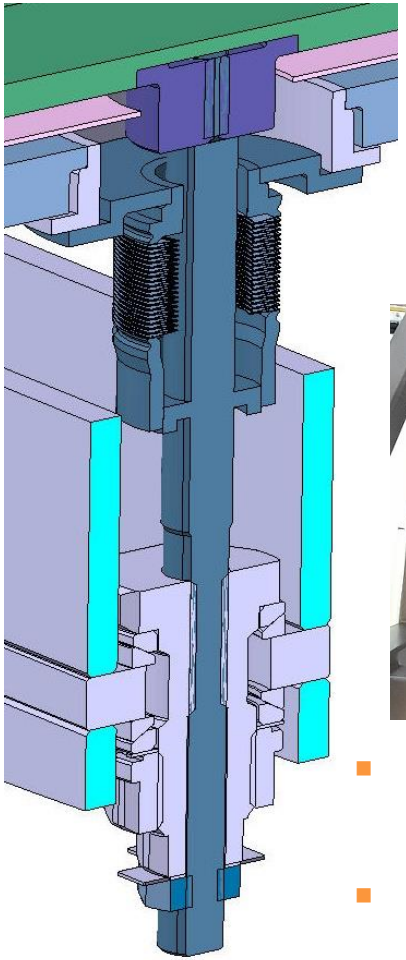
# Tuner assembly inside vacuum tank (OVC)



## Couplings Tuner to cavity

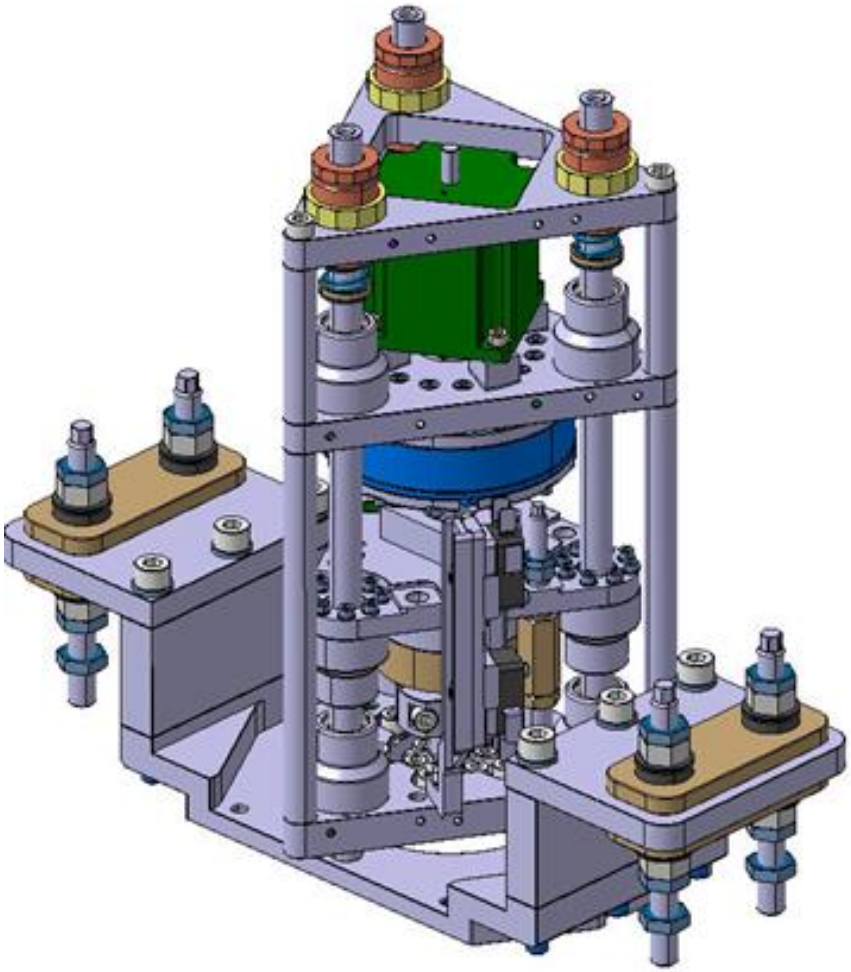
- Deals with offsets nominal dimensions cavity
- Connects tuner to cavity without deforming it

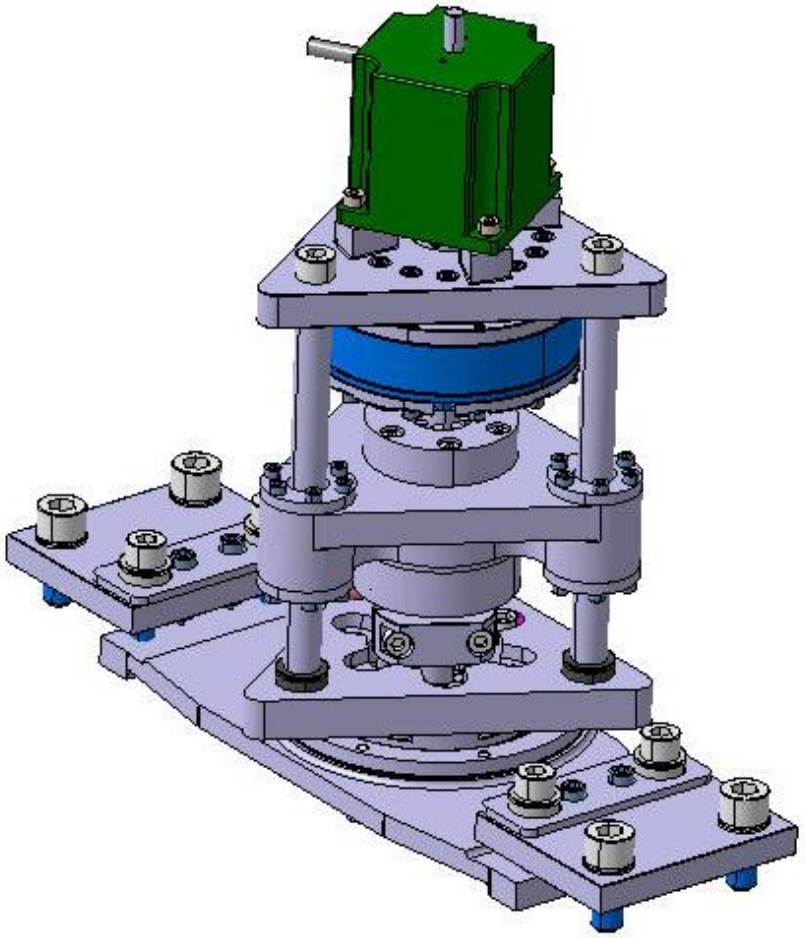




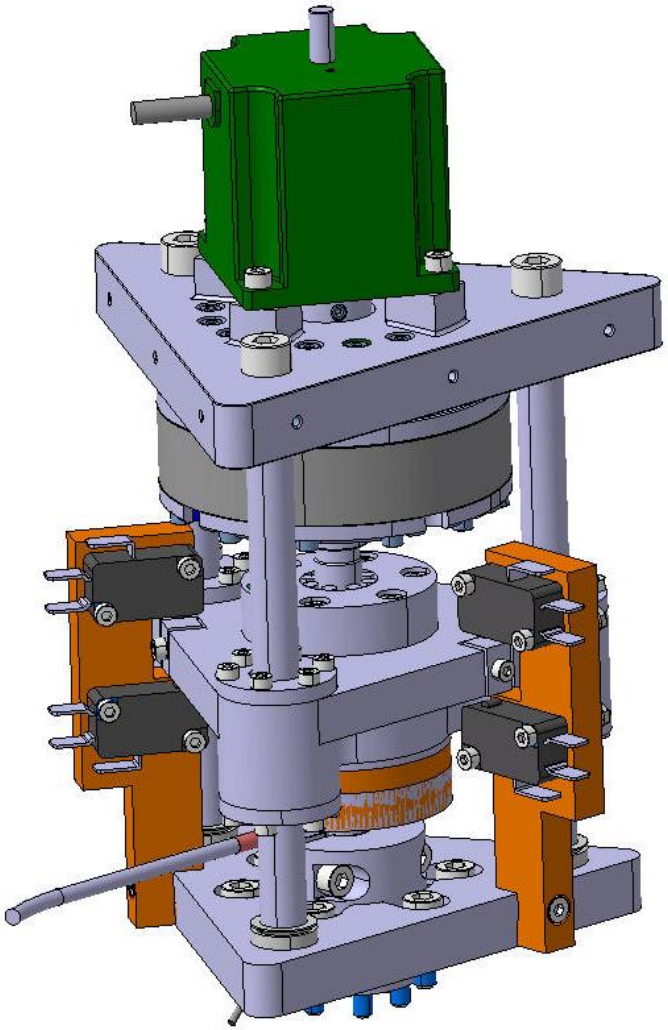
- Torque tightening + custom lip washers(locking)
- Heico locking washers instead of SChnorr
- Design considers also access for torque tools

# Actuator status





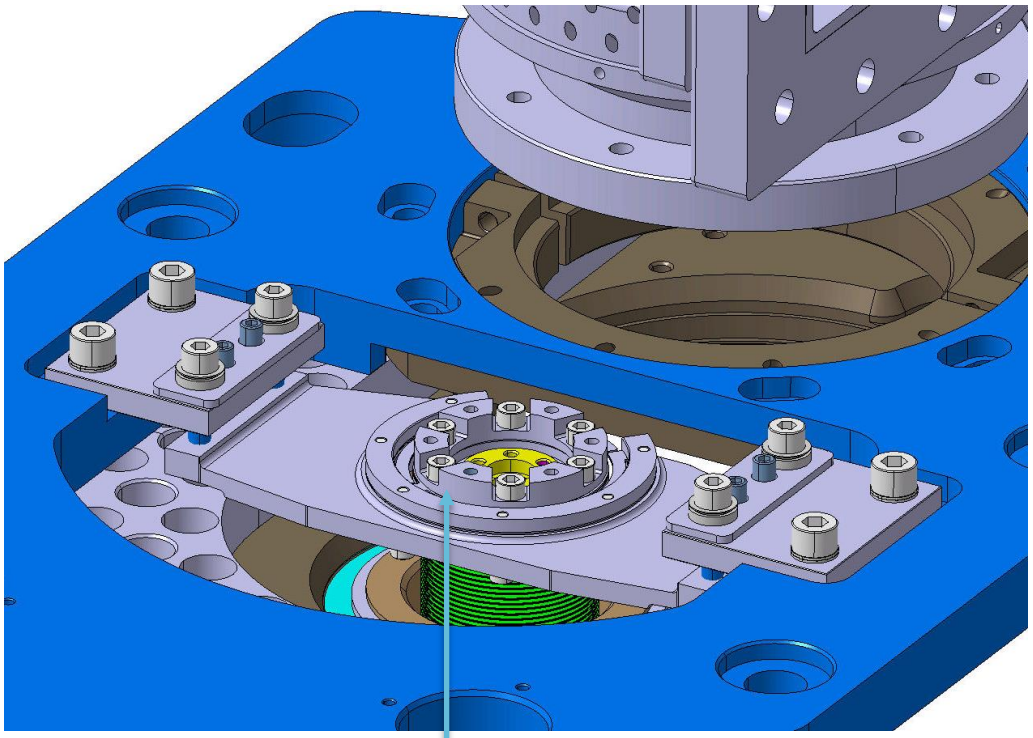
# Status

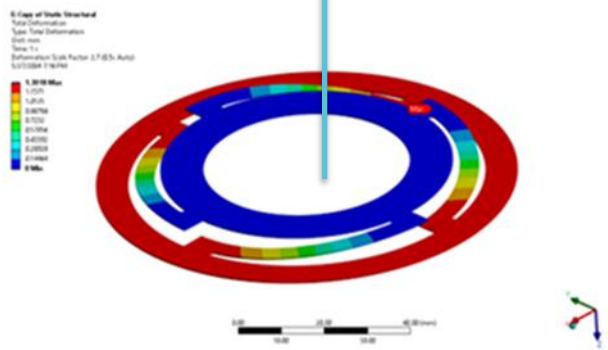


Checks + control ongoing
Load cell + limit switch design ongoing

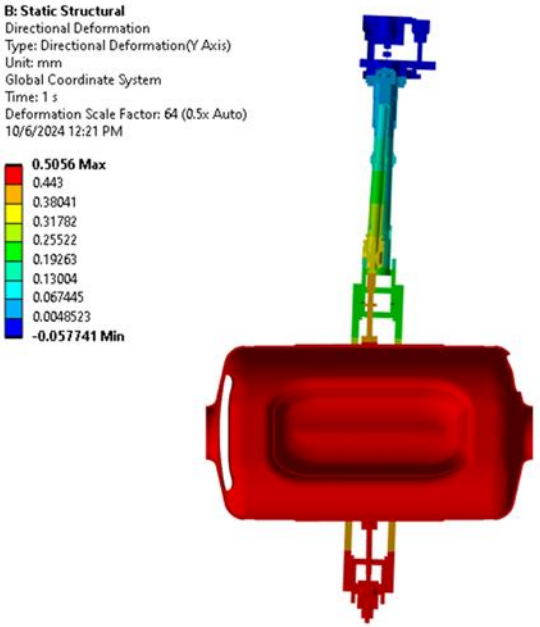
# Actuator base Guide

**Step 6***



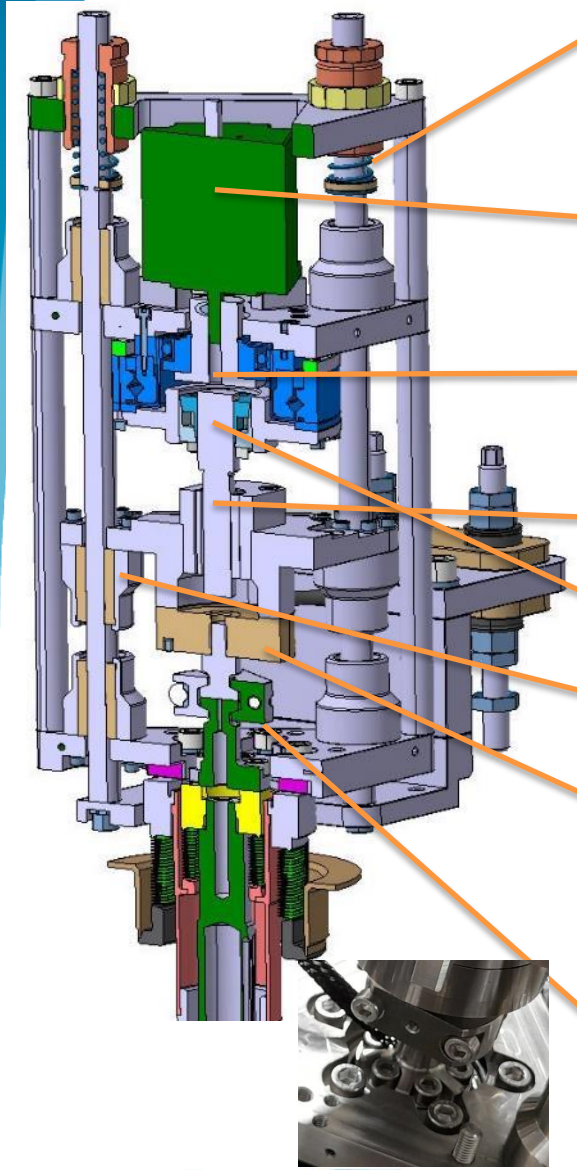


Design done
Drawings to be re-released



# 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**

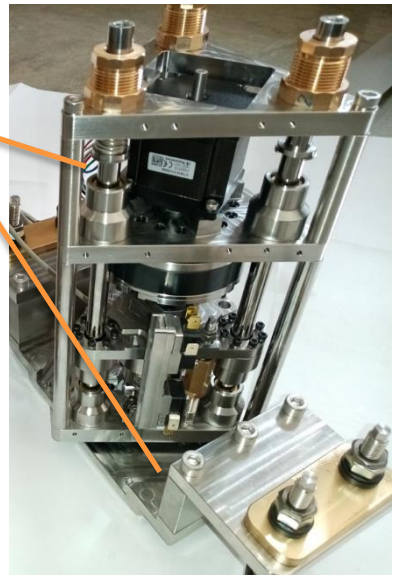
**Sferax Compact GBL 1219 bearings XA +A (all metal) and guides**

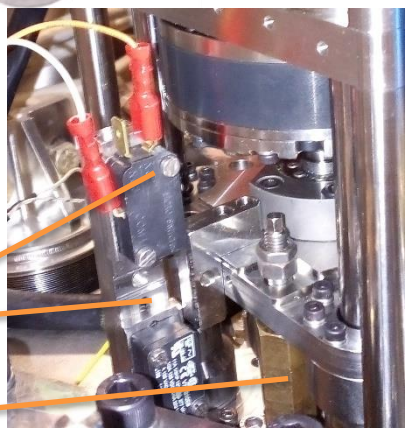
**Loadcell**
So far: Kistler 10 kN 4576A55C1 class 0.1

**Limit switches**
Difficult to set, not so reliable

**Mechanical end stops** with max load interlock on load cell conditioner

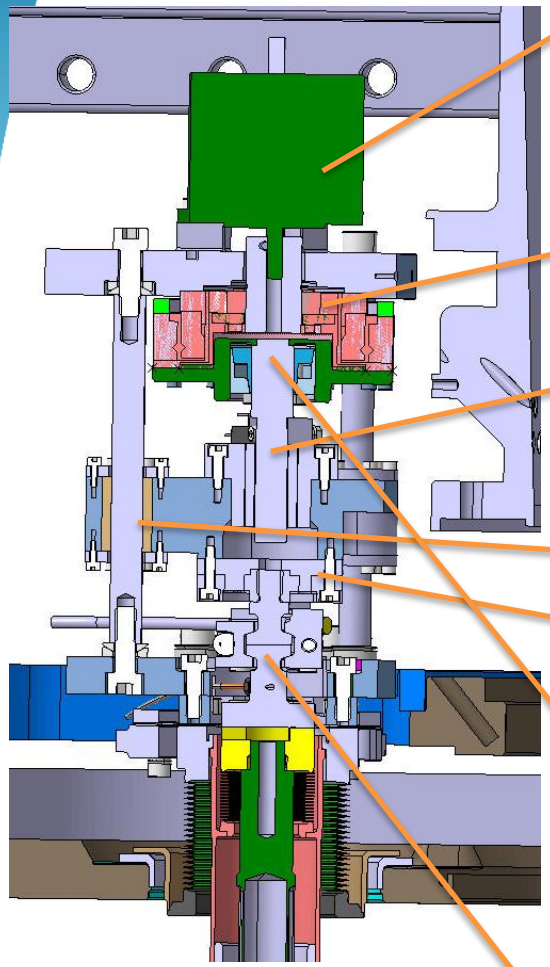
**Actuator coupling**
Allows quick change of actuator + connection without frequency change
Incorporates heater





# Overview components

## LHC CRAB Actuator



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

**Strain wave gear**
Ratio 100, Accuracy < 1 arcmin, precision <0.1 arcmin (5 nm)
Fa Dyn 7.7 kN

**Tender**

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

**Tender**

**bearings XA +A (all metal) and guides**

**Tender**

**Rad Hard Loadcell**

**CERN**

**coupling**

**Limit switches**
Design ongoing

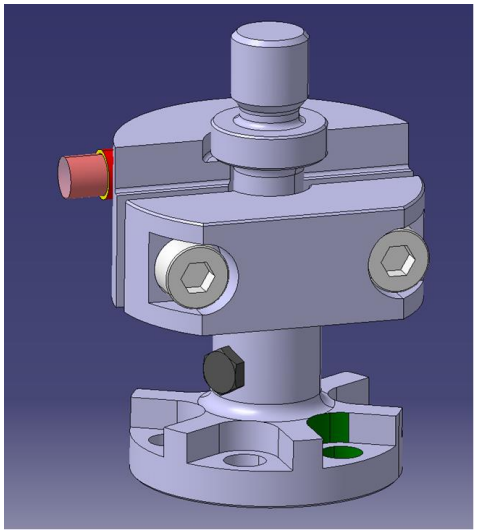
**Mechanical end stops** with max load interlock on load cell conditioner

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

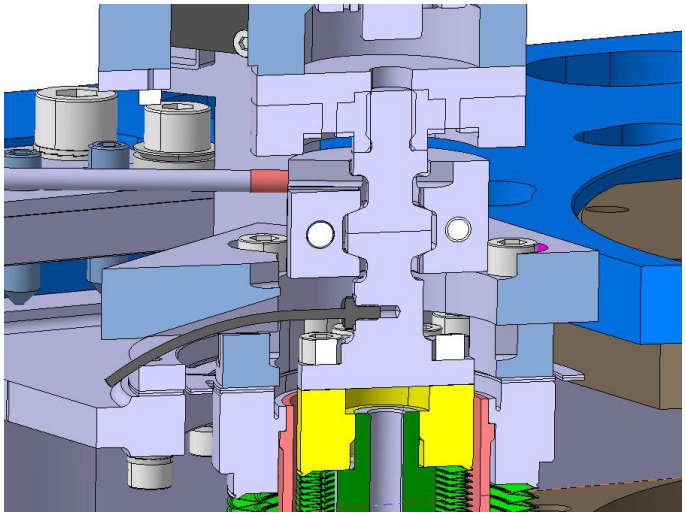
HiLumi HL-LHC PROJECT

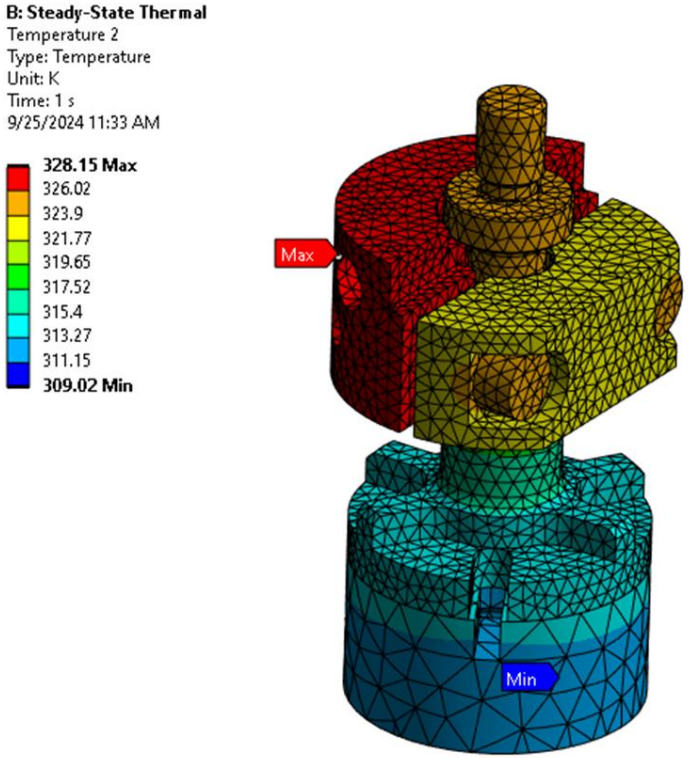
CERN

# New Integration heater and temperature gauge



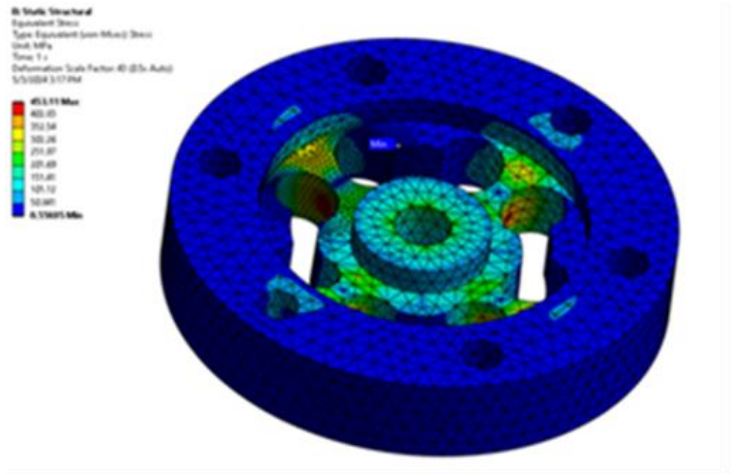
- Heater in tuner clamp
- Temperature gauge M3 (commercial part) on inner connection part (ICP)
- Clamps, screws and ICP in Cu Sn 8
- 2 to 4 W






Drawings to be controlled

# Load cell

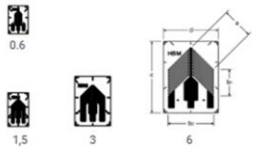


**XY41**
**Shear / torsion half bridge**
Temperature response matched to steel
with $\alpha = 10.8 \cdot 10^{-6}/K$

**XY43**
Temperature response matched to aluminum
with $\alpha = 23 \cdot 10^{-6}/K$

**XY4x**
Temperature response matched to customer's choice
see page 16

Illustrations show actual size
(indicated: grid length in mm)



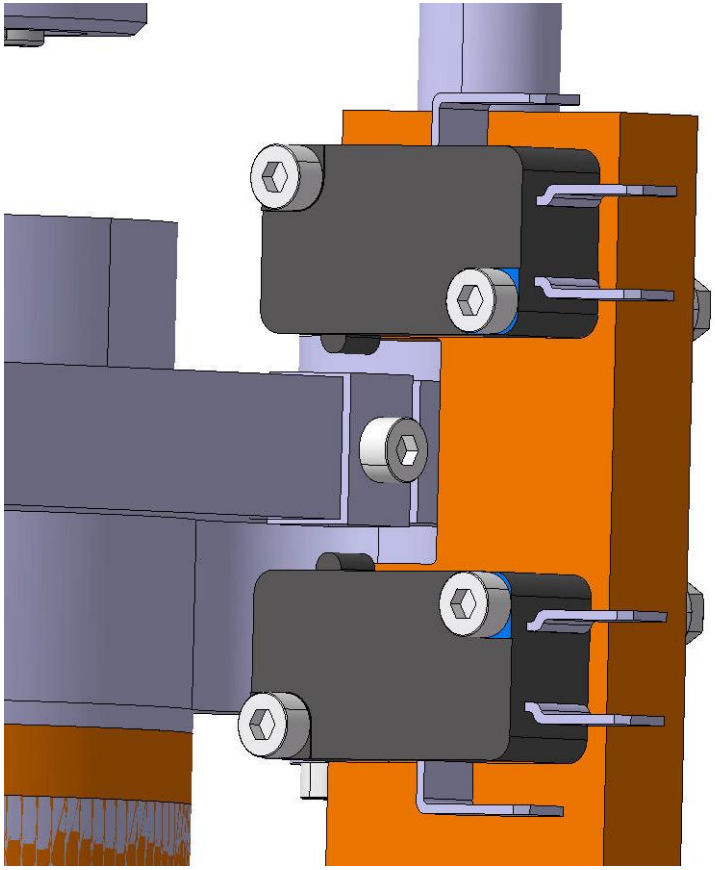

Contents per package: 5 pcs.

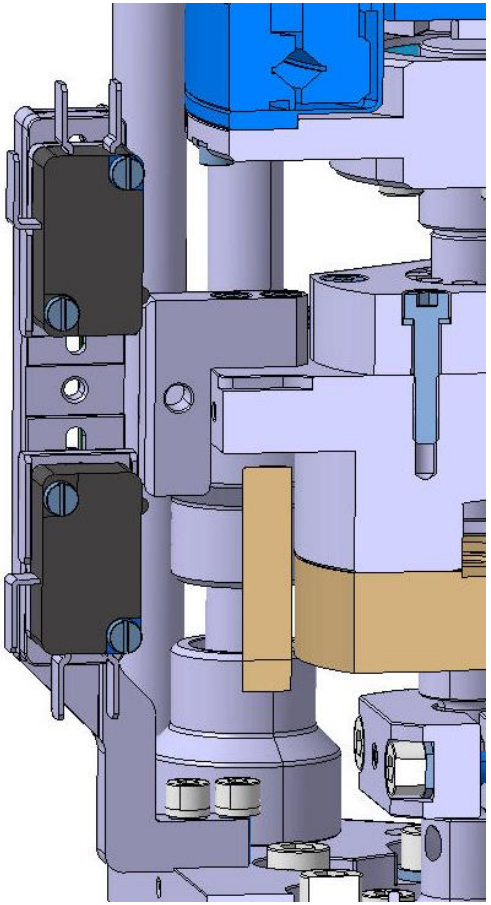
| Types available from stock | | Variants | Nomi. resis-tance | Dimensions (mm) | | | | | Maximum excitation voltage [4] | Sldr. term-inals [1] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Measuring grid | | | Meas. grid carrier | | | |
| Steel | Aluminum | Other | Ω | a | b1 | b2 | c | d | V | |
| 1-XY41-0.6/120 | | 1-XY4x-0.6/120[4] | 120 | 0.6 | 2.2 | 1.6 | 6.5 | 4.6 | 1.5 | LS 7 |
| 1-XY41-1.5/120 | | 1-XY4x-1.5/120 | 120 | 1.5 | 1.8 | 3.1 | 7.5 | 4.6 | 2.5 | LS 7 |
| 1-XY41-3/120 | | 1-XY4x-3/120 | 120 | 3 | 3 | 5.4 | 11 | 8 | 5 | LS 7 |
| 1-XY41-6/120 | | 1-XY4x-6/120 | 120 | 6 | 6 | 10.2 | 16 | 12.2 | 9.5 | LS 4 |
| 1-XY41-1.5/350 | | 1-XY4x-1.5/350[4] | 350 | 1.5 | 2.1 | 3.1 | 7.5 | 4.5 | 4 | LS7 |
| 1-XY41-3/350 | 1-XY43-3/350 | 1-XY4x-3/350 | 350 | 3 | 4.2 | 5.6 | 11 | 8 | 9.5 | LS 7 |
| 1-XY41-6/350 | | 1-XY4x-6/350 | 350 | 6 | 6 | 10 | 16 | 12.2 | 16 | LS 4 |
| 1-XY41-3/700 | | 1-XY4x-3/700 | 700 | 3 | 4.2 | 5.6 | 11 | 8 | 13.5 | LS 7 |
| | | 1-XY4x-6/700 | 700 | 6 | 6.1 | 9.9 | 16 | 12.2 | 23 | LS 4 |
| | | | | | | | | | | |

[4] Maximum excitation voltage for ferritic steel. For other temperature response matchings, the corresponding value is printed on the data sheet included with delivery.
[1] Solder terminals are not mandatory
[4] Types are only available with matching to aluminum, ferritic or austenitic steel

Status: shear Gauge selection (constantan+polyimide) + adaptation housing to cabling
Optimisation signal

# Limit switches





# Conclusions

Step 3: Parts ready (exc. locking washer cleaning)
Parts machined for all series
3D printing spacers

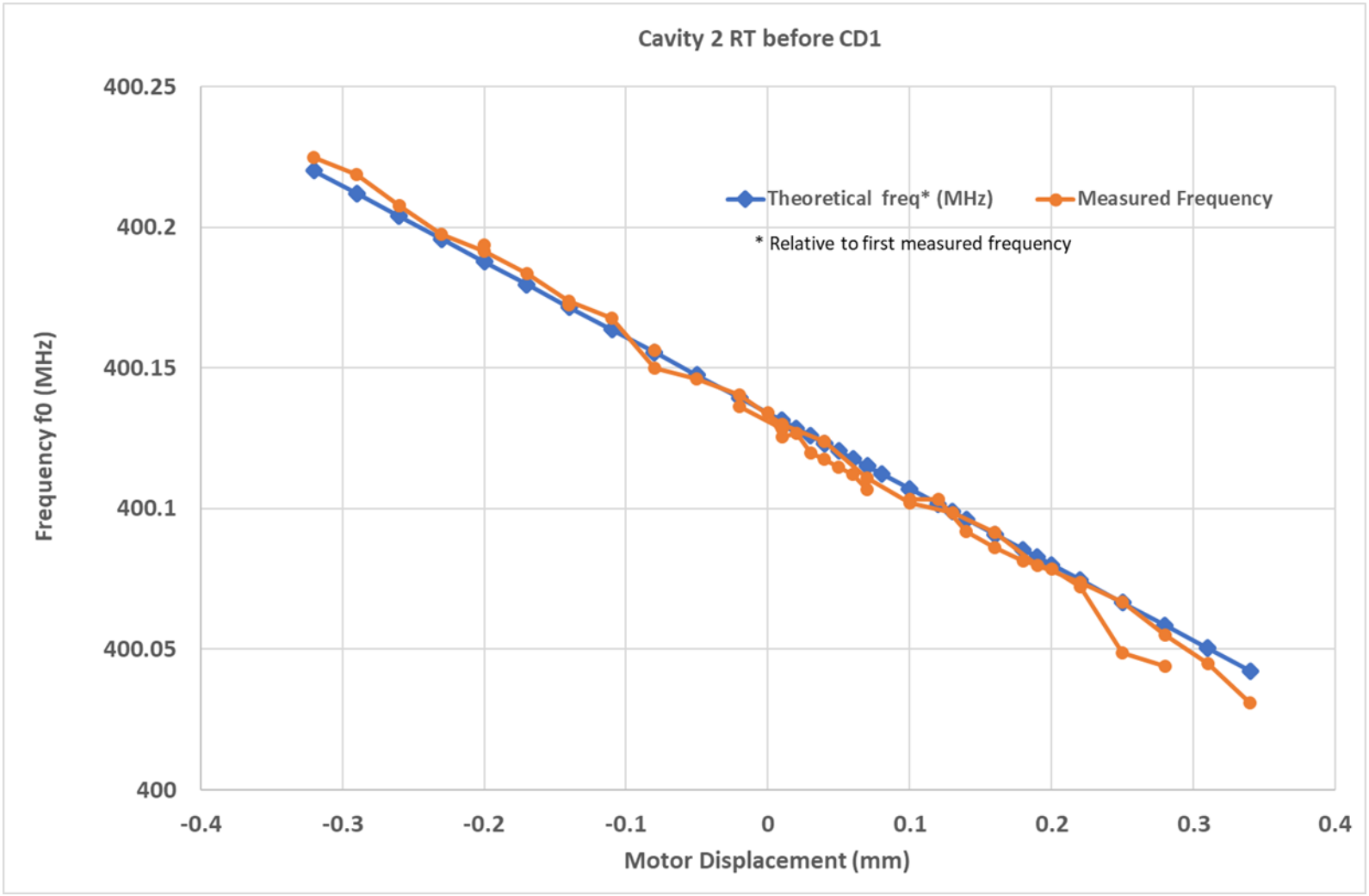
Step 4: Parts ready to be welded
Commercial tools ordered

Step 6: Actuator guide base drawings can be released this week
probably too late, replace by 3D printed spacer

Actuator: For testing adapt two SPS DQW actuators
LHC Actuator : control drawings is starting
Limit switches + load cell : finish design

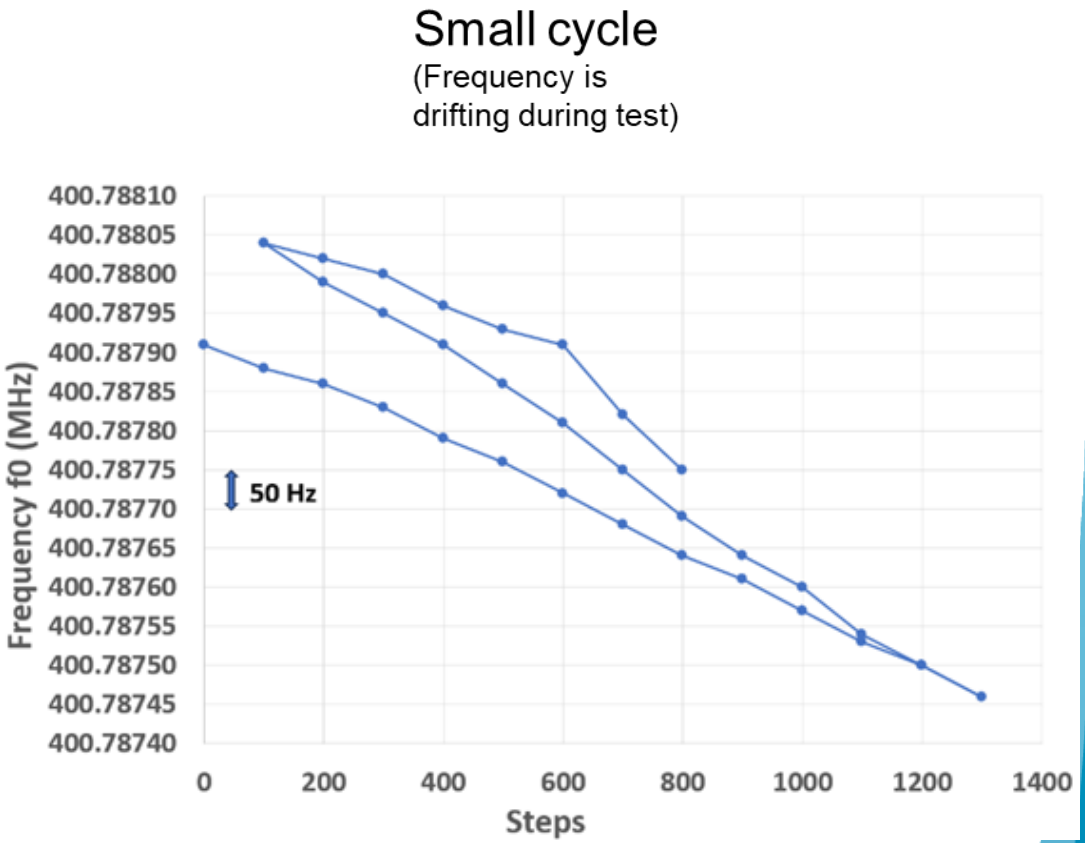
# Spare SLIDES

# RT before CD 1, OVC open



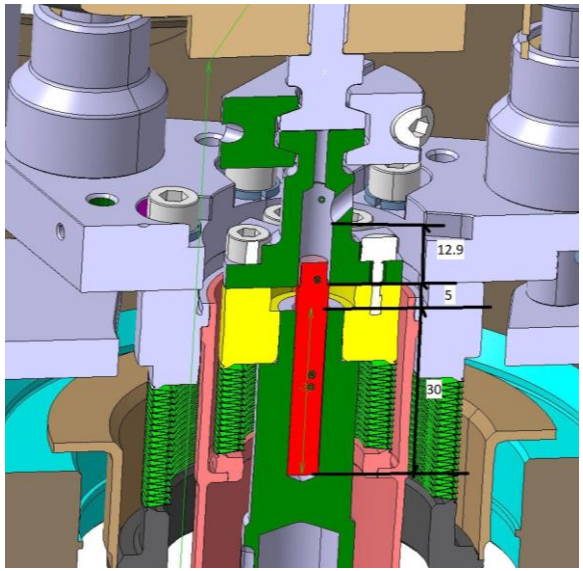

Additional: 14/11/23 Tuner and HOM measurements at RT

# « 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

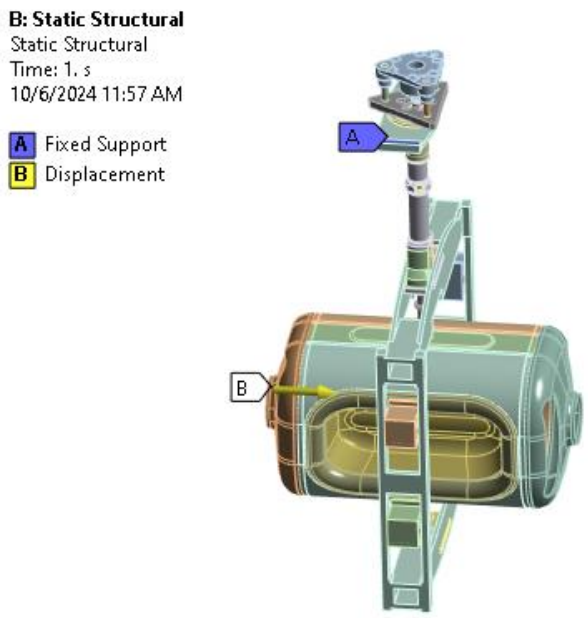
# Tuner heater problem/ ICE inner connection

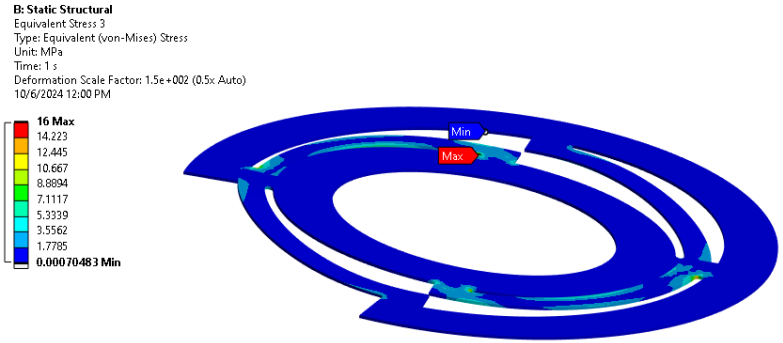


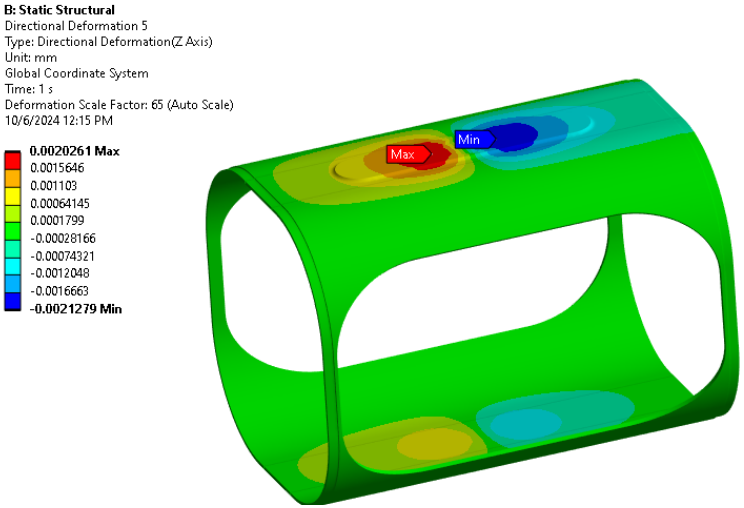

- Heaters keep breaking or sometimes switched off, reason not sure
- No place for a temperature gauge
- Heaters difficult to replace (remove fully actuator)

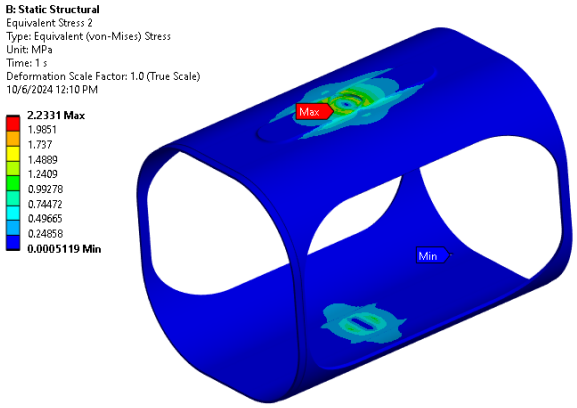
**Problem 3**

# Thermal contraction Cavity support



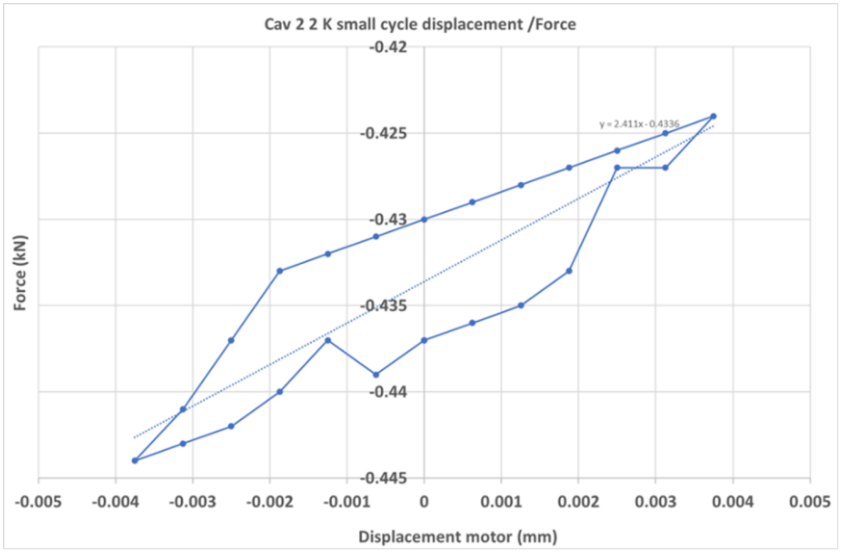



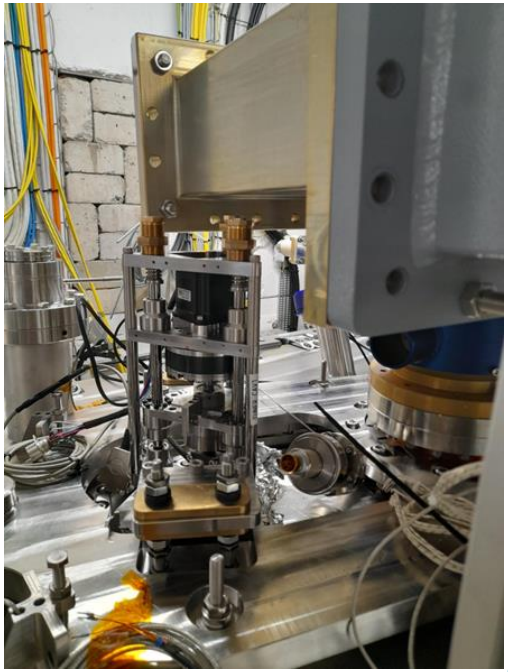



# SPS RFD Assembly Actuators + CD1

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

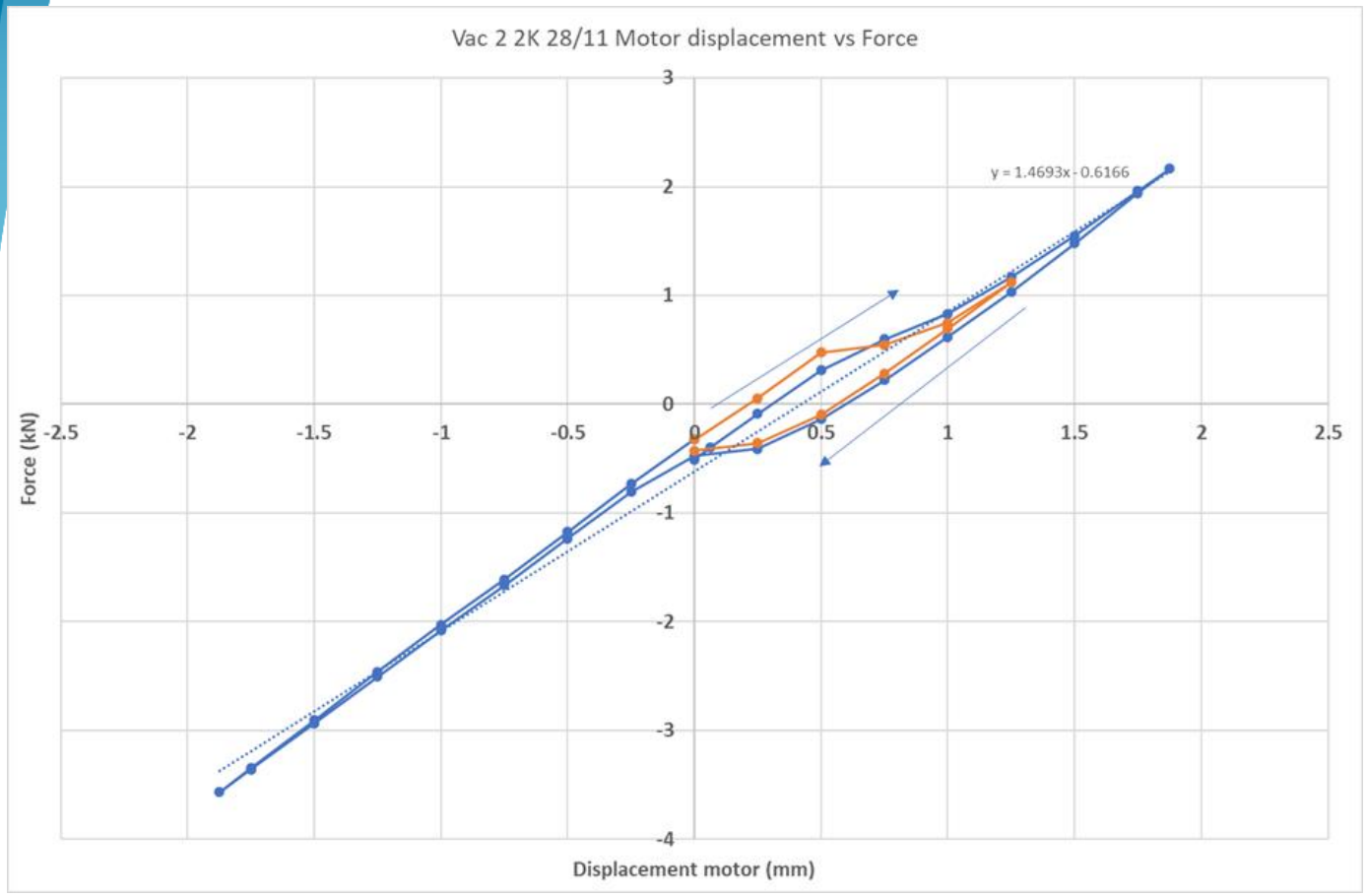


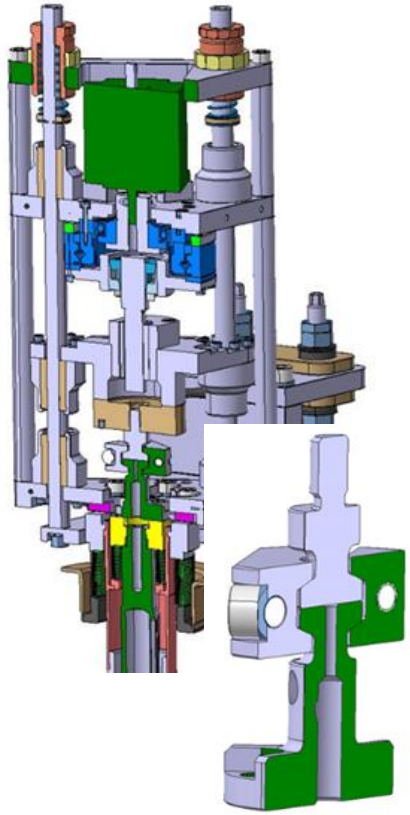

- Interference actuator springs with turned and tilted waveguide (before repair)
- Interference between cable gauge FPC with actuator support



**Problem 1**

# CD1 Backlash with a twist



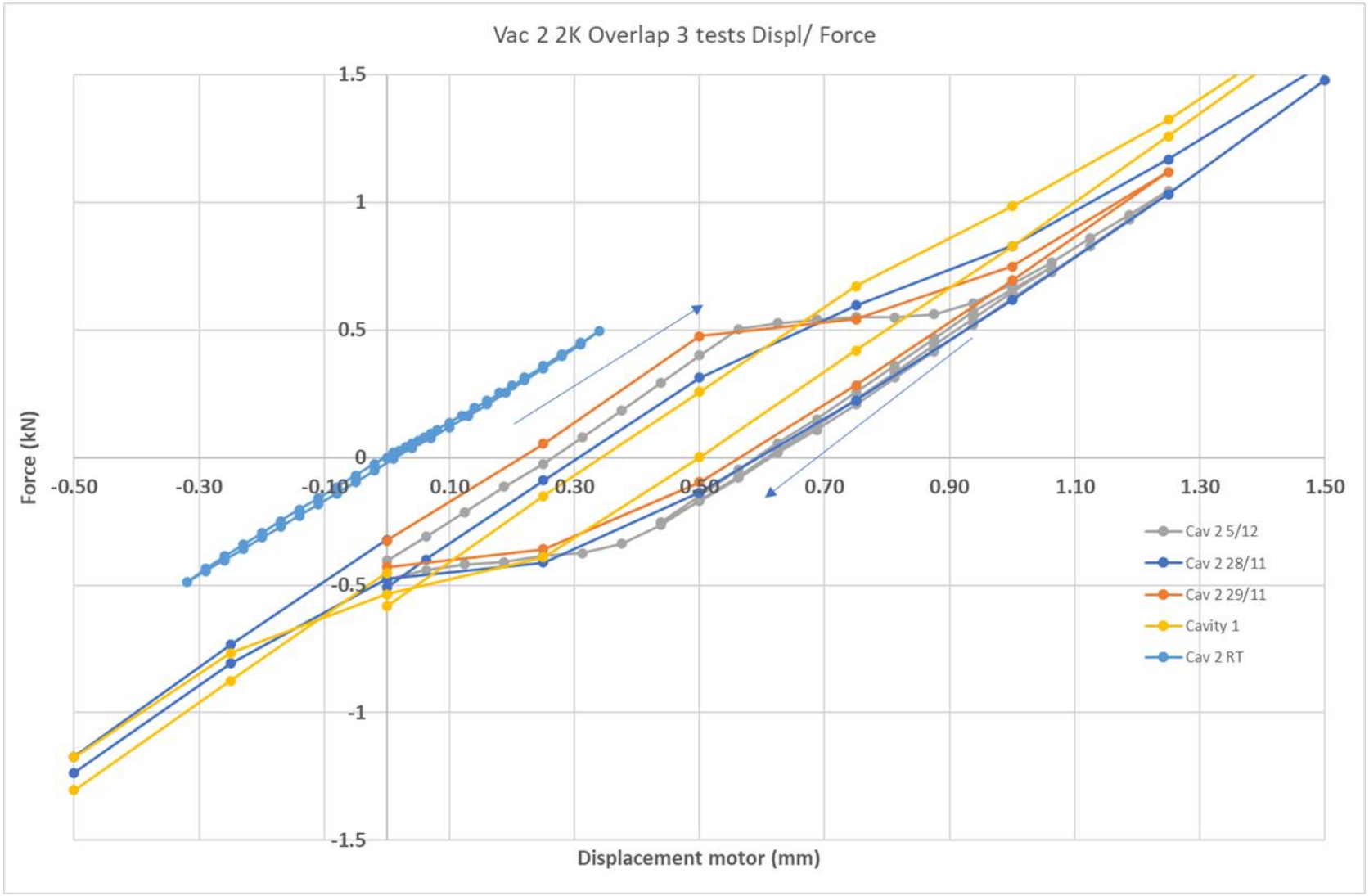



Clearance with friction in actuator clamp due to tolerances

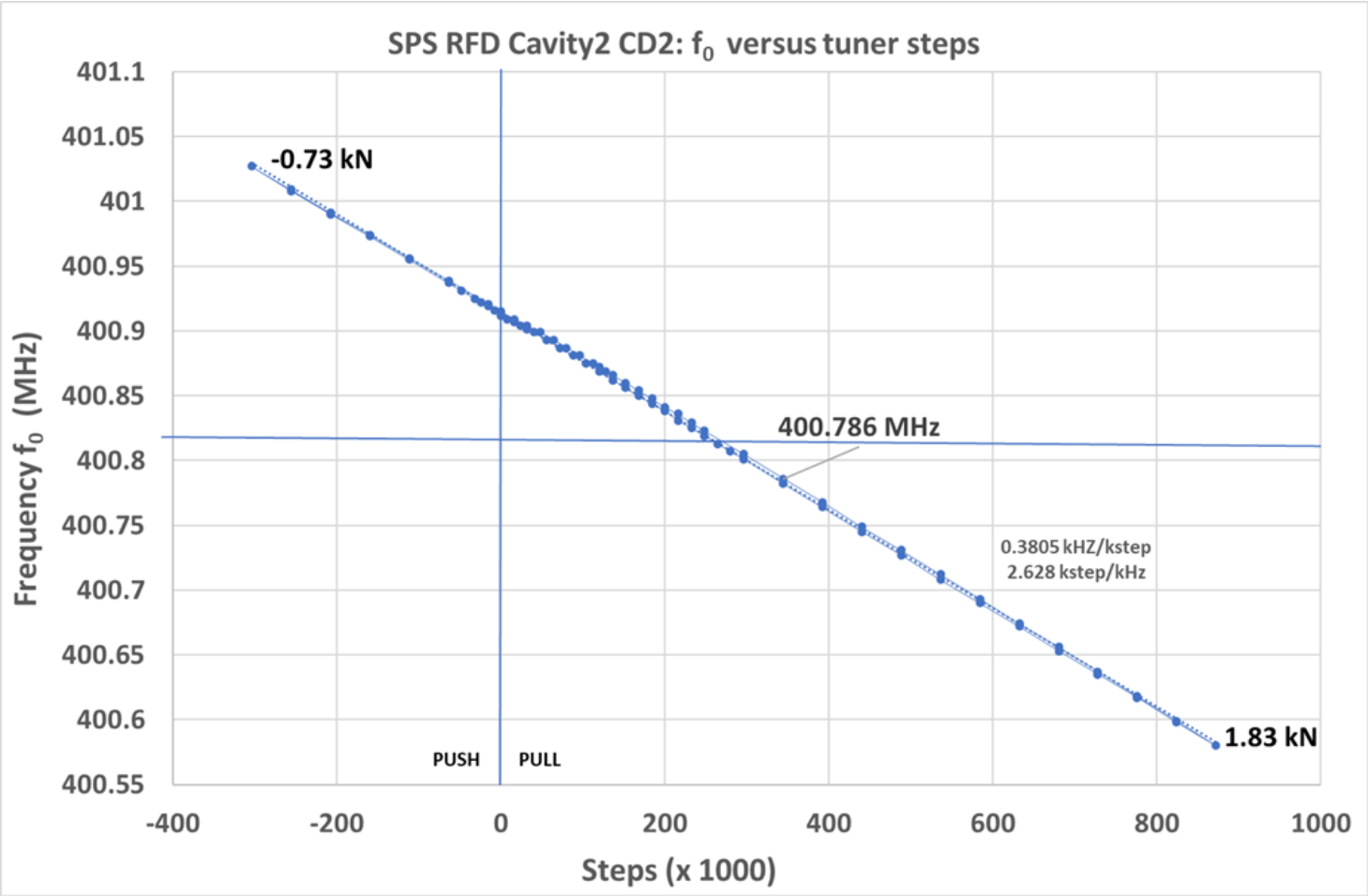
Easily solved, but asked for design improvement

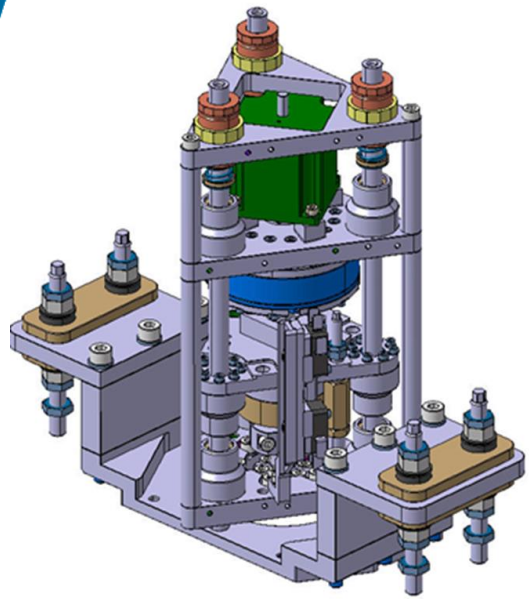
**Problem 2**

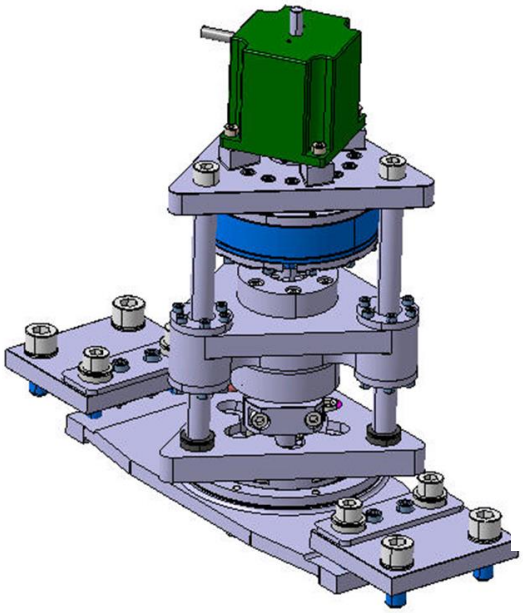
# Cav 1 + 2, CD1 several cycles

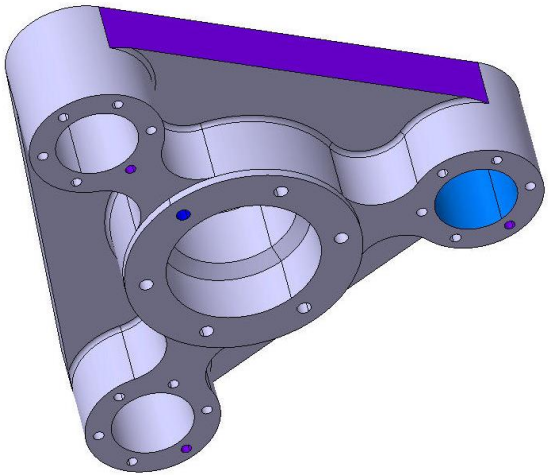


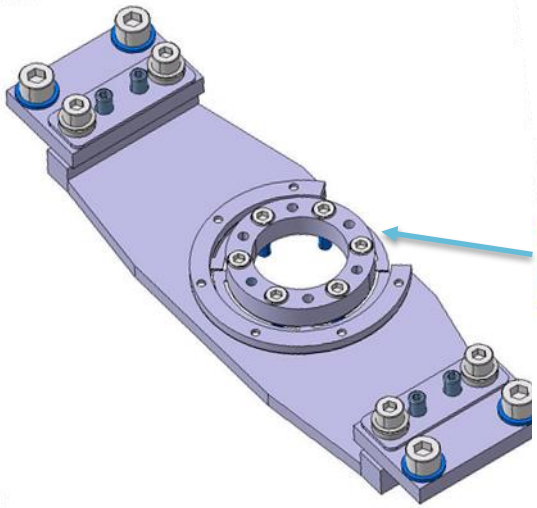
# Tuning SPS-RFD SM18 Cavity 2 CD2

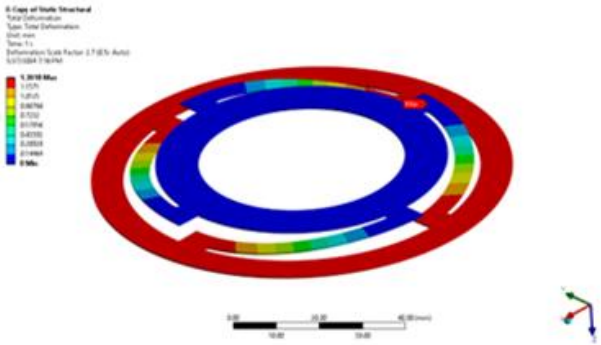


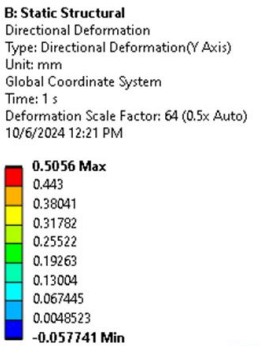


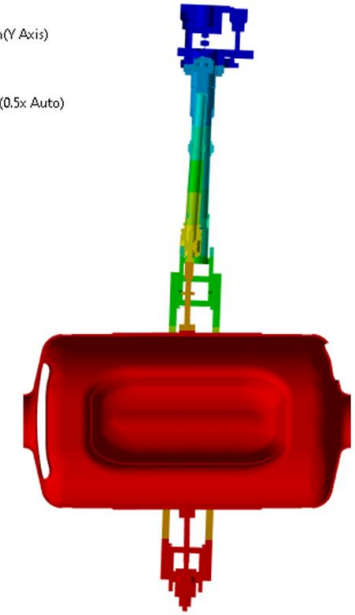






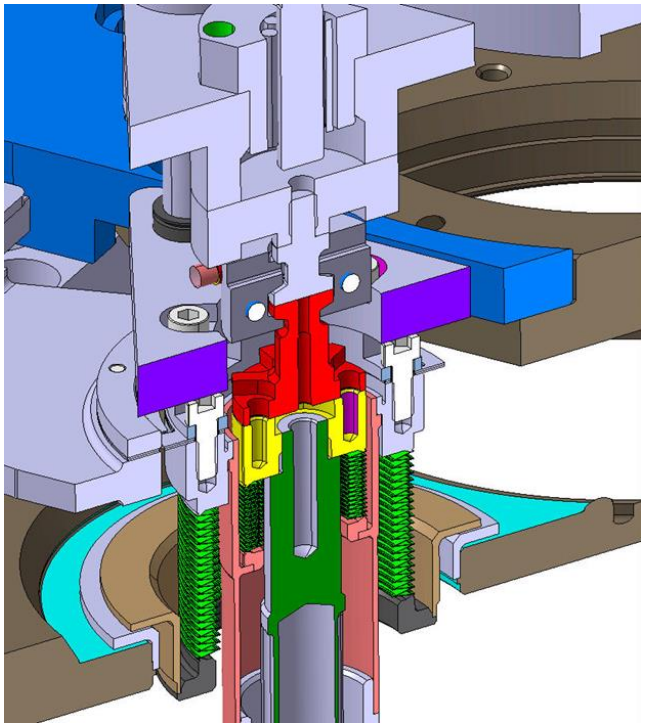


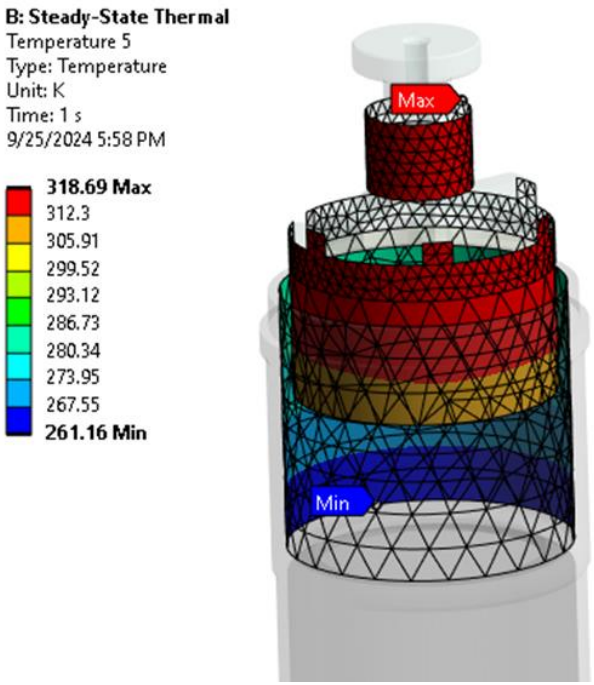

B: Static Structural
Directional Deformation
Type: Directional Deformation(Y Axis)
Unit: mm
Global Coordinate System
Time: 1 s
Deformation Scale Factor: 64 (0.5x Auto)
10/6/2024 12:21 PM
0.5056 Max
0.443
0.38041
0.31782
0.25522
0.19263
0.13004
0.067445
0.0048523
-0.057741 Min

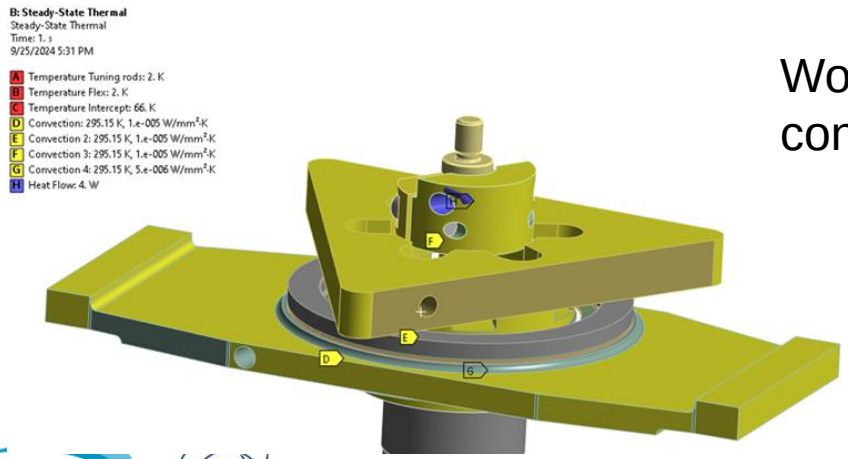


3 d.o.f.

# Possible ice inside bellows






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