CRAB cavities Cryomodule review

Tuner

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P. Minginette

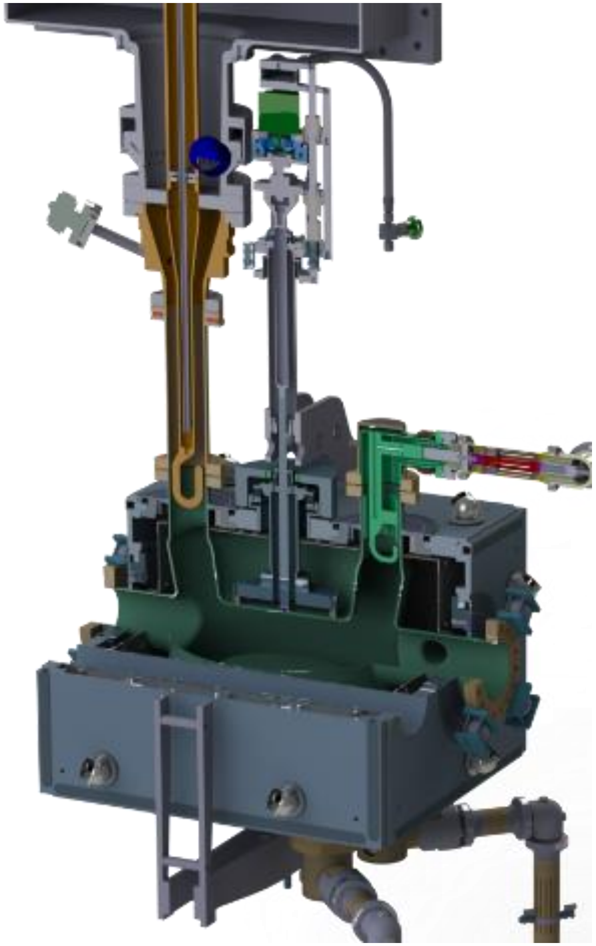
Colleagues USLARP , STFC

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

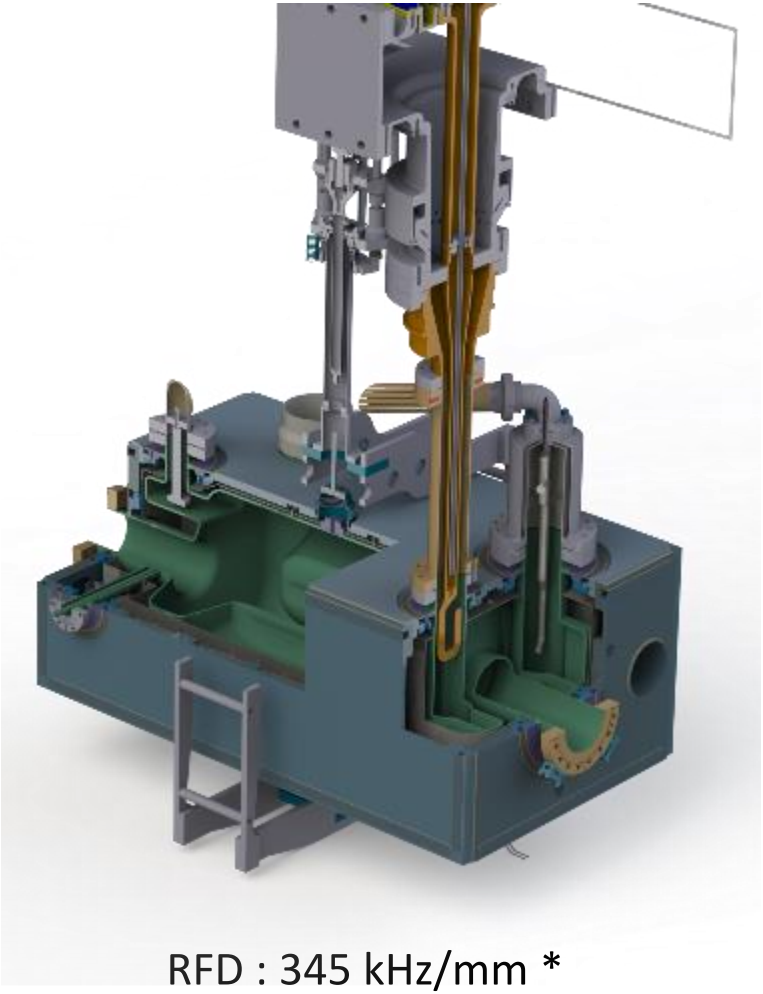
Contents

- Tuning principle
- DQW and RFD Tuning forces, stress and range
- DQW pre tuning
- Tuning frame
- Status SM18 tuner
- Studies SPS tuner

Symmetric actuation on cavity through tuner frame and concentric tubes.
Motorization outside cryostat
Centre of the actuation is floating



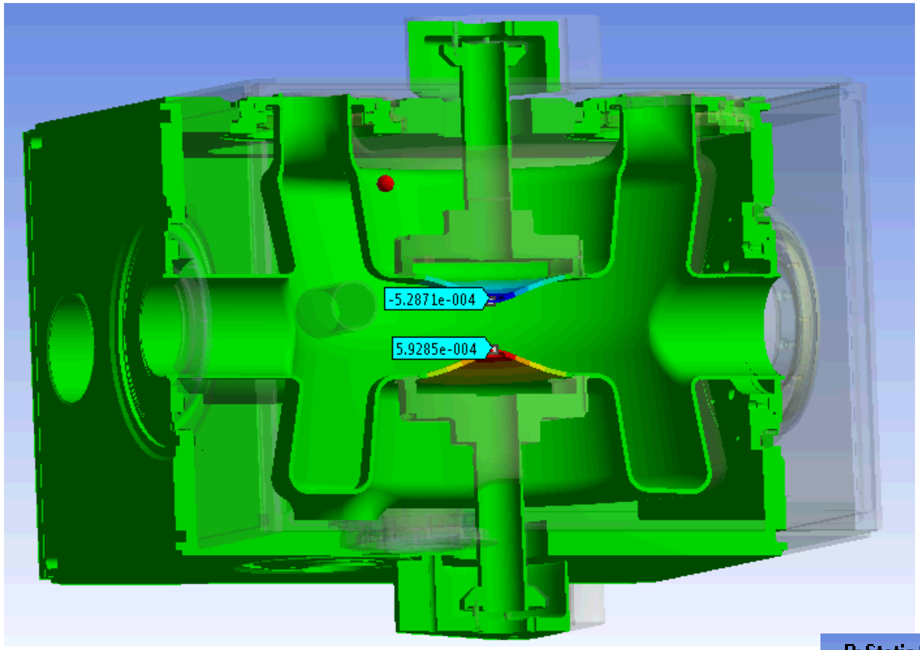
DQW : 186 kHz/mm *
S. Vérdu Andrés , B. Xiao



RFD : 345 kHz/mm *
H. Park

* Measured as tuner stroke or Δdistance between 2 plates

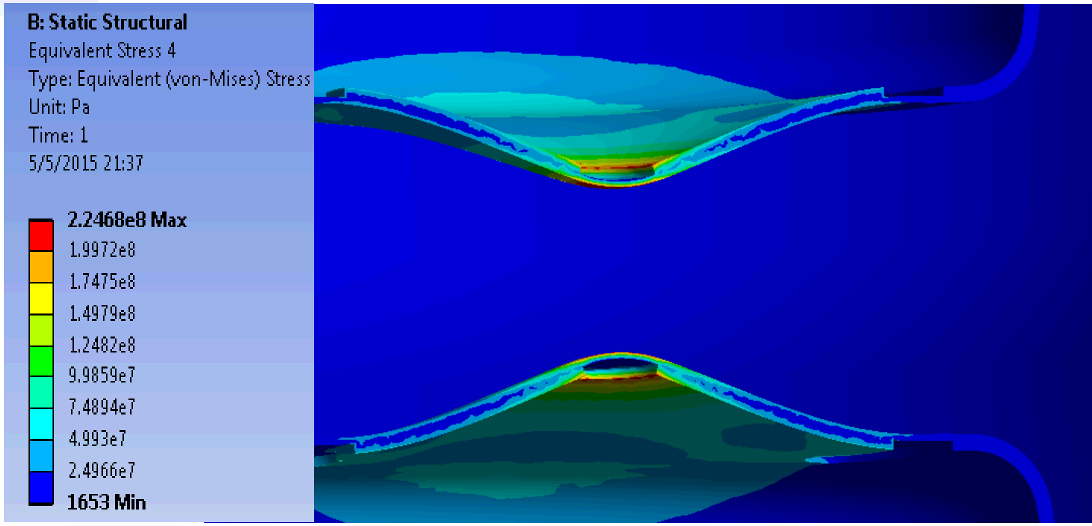
DQW



Cavity (RT , no PCB) with He vessel + pretuning device
Input force 2.5 kN

Displacement z **0.53/0.6 mm**
Maximum eq. Stress **225 MPa**
Corresponds to about **0.21 MHz (0.42 MHz pp) ***

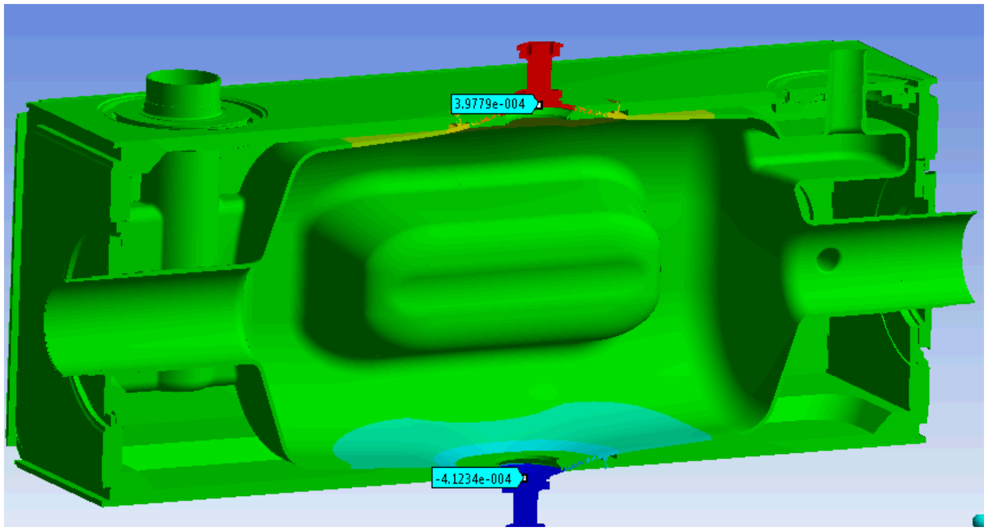
For 400 MPa/1.2= 333 MPa -> 0.31 MHz (0.62 MHz) range (linear), 3.7 kN, ±1.6 mm



Force/tuner stroke **2.2 kN/mm**
199 MPa/mm

At RT for 50 MPa , 0.25 mm maximum tuner stroke for 0.5 kN

RFD

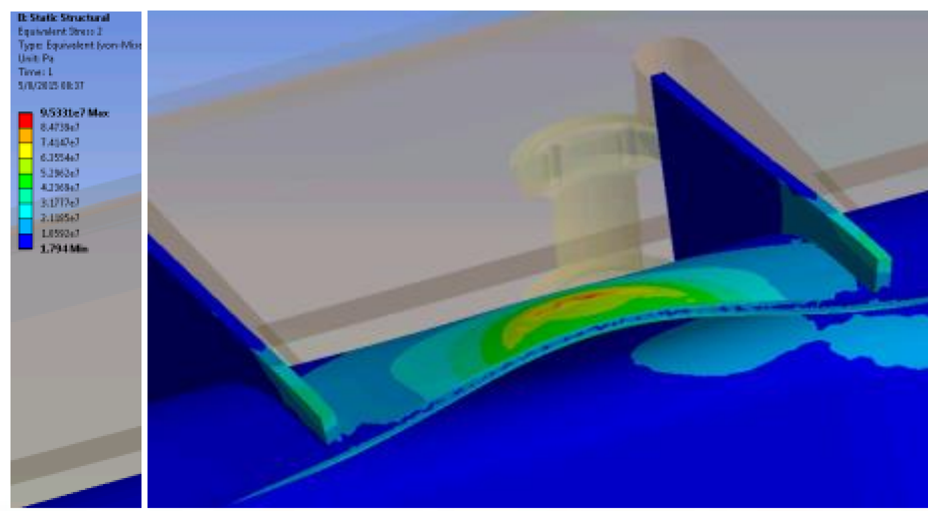


Cavity (RT , no PCB) with He vessel
Input force 2 kN

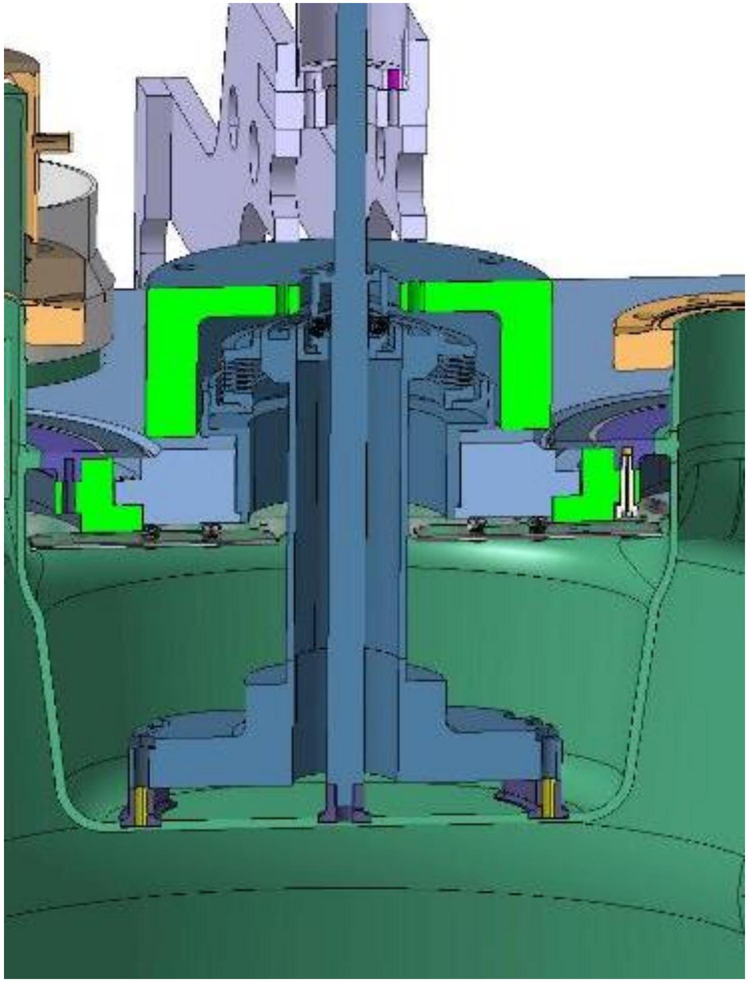
Displacement **z** 0.4/0.41 mm
Maximum eq. Stress **95 MPa**
Corresponds to about **0.280 MHz (0.560 MHz pp)**
For 400 MPa/1.2= 333 MPa -> 0.980 MHz (1.96 MHz) range (linear), 7 kN, ± 2.8 mm

Force/tuner stroke **2.5 kN/mm**
115 MPa/mm

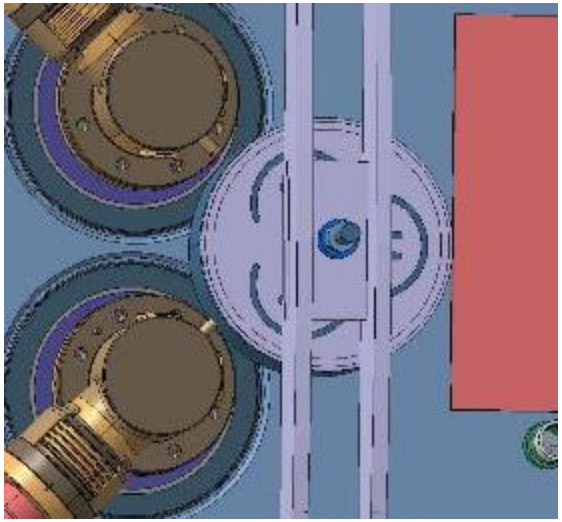
At RT for 50 MPa , 0.42 mm max tuner stroke for 1 kN



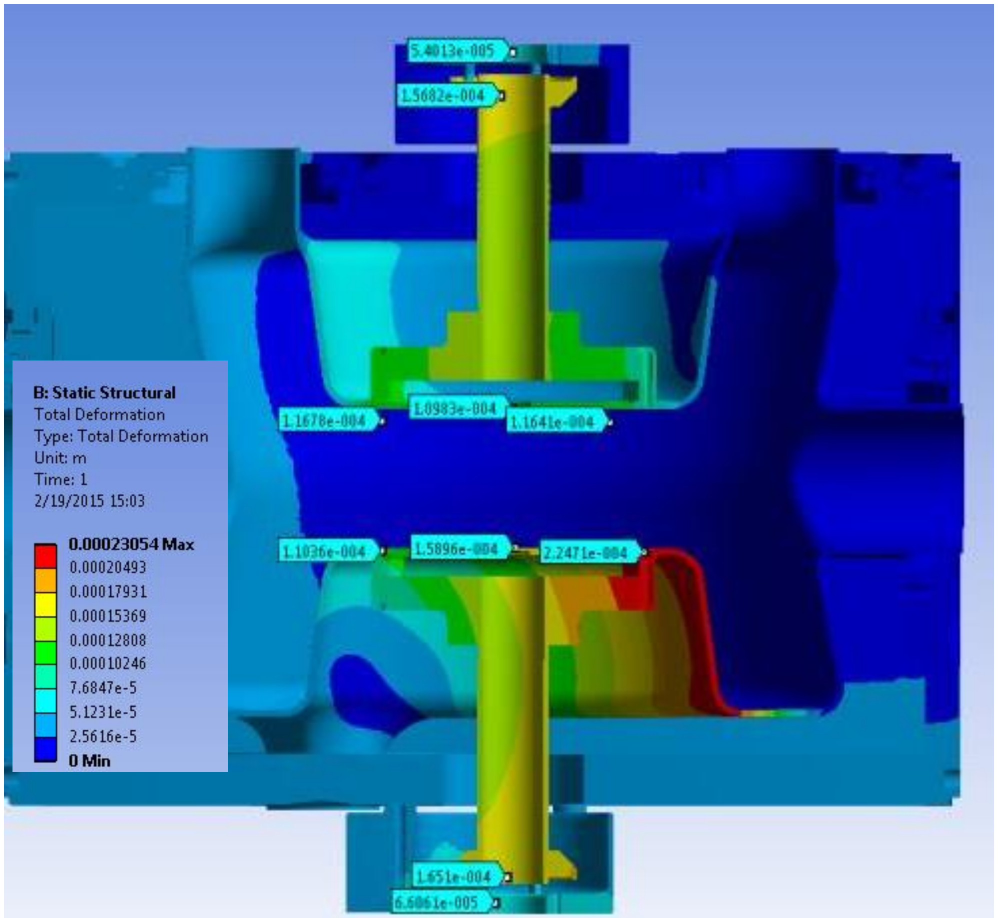
Pre tuning DQW



At warm
Bellows are outside of the helium vessel
3 M6 screws (pull) and studs (push)
Pitch 1 mm
Bellows (Ti) will be probably edge welded
Sensitivity 0.8023 MHz/mm (distance between plates) (Binping Xiao)

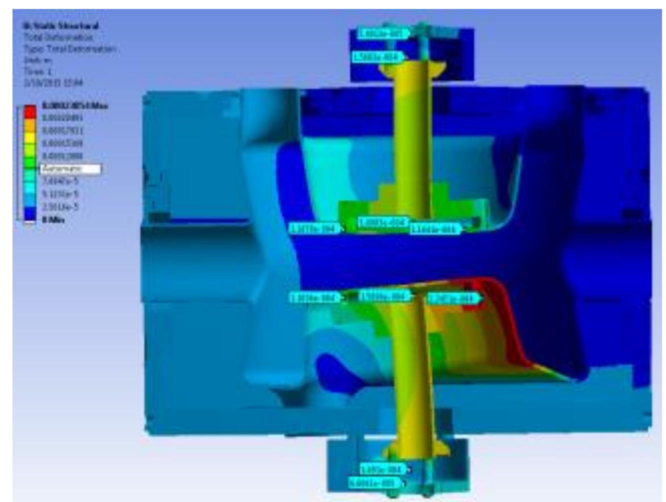


Deformation



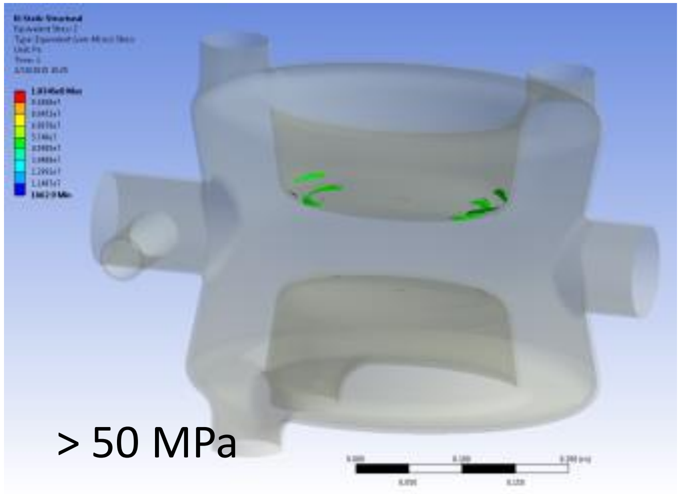
Top : 0.21 mm screw motion
-> 0.11 mm plate deformation
Bottom: 0.23 mm screw
-> 0.16 mm centre plate def.

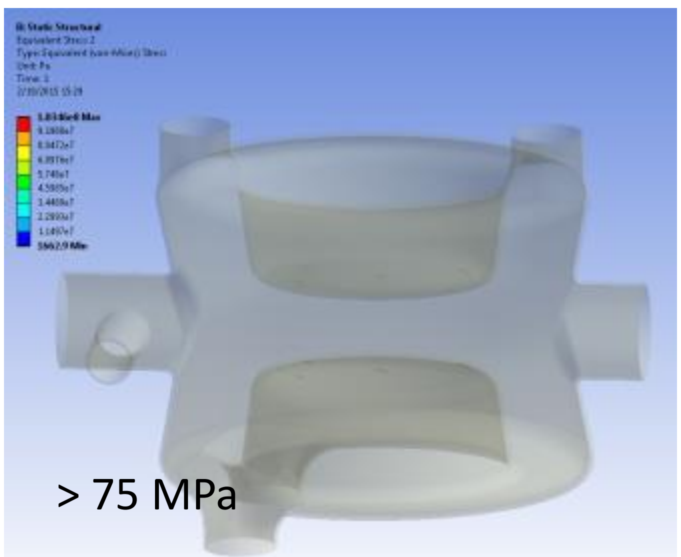
Force: about 3 kN /screw M6x1
σ_i screw = 178 MPa (0.3 friction)
Flexibility gives the resolution



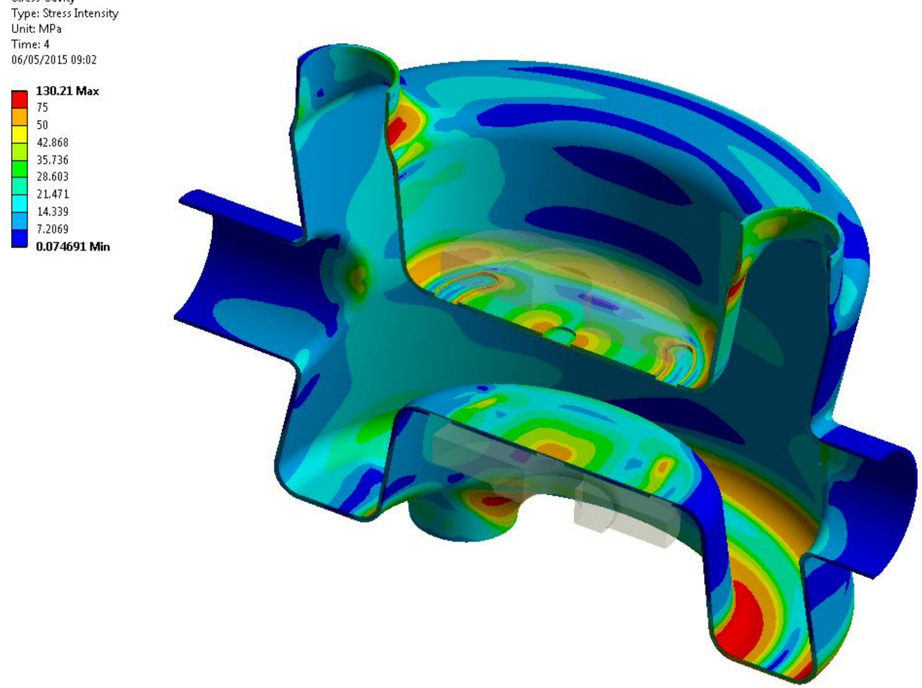
0.8023 MHz/ mm

Pretuning stress





Pre-tuning 0.2 mm (distance plates) + pressure

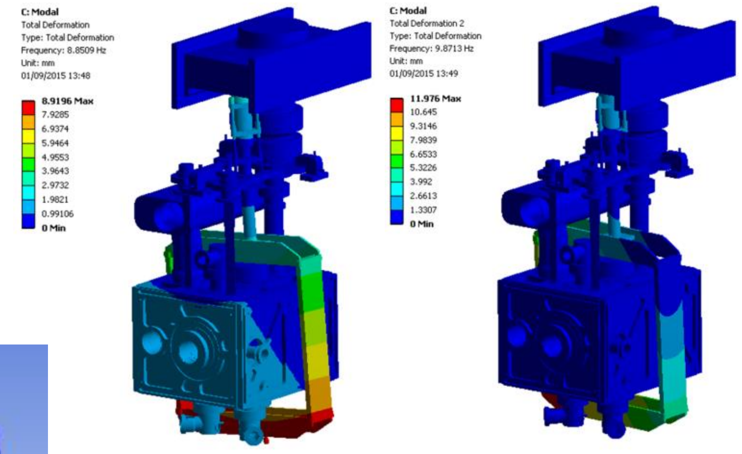


Ref. L. Dassa For the helium vessel as pressure vessel this would be a limit (needs some thinking)

0.16 MHz (0.32 MHz) for 0.8 MHz/mm

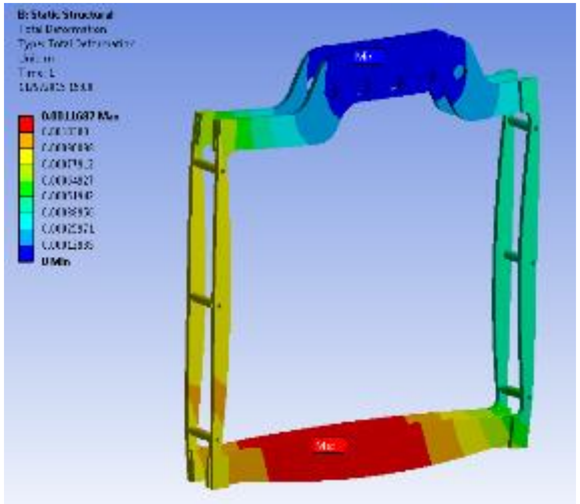
Design tuning frame

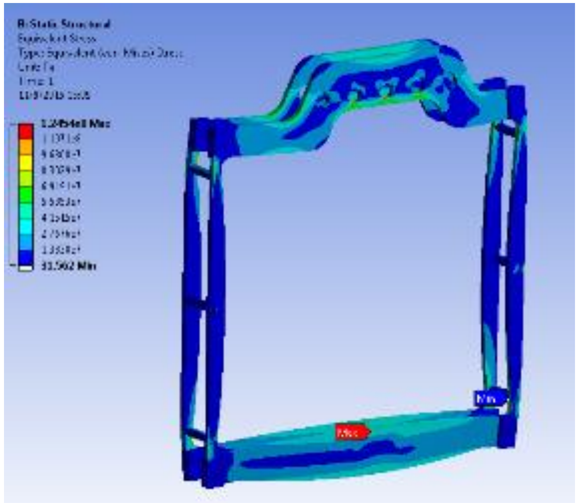
Modal analysis of the support structure indicated presence of low vibration modes of the titanium tuning frame



Calculations T. Jones

A first improvement was made to divide the mass by 2

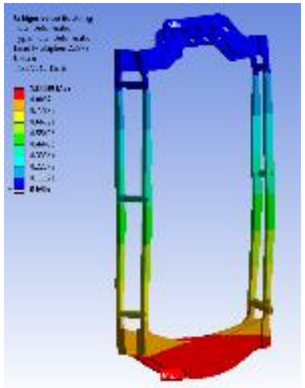




7 kN load

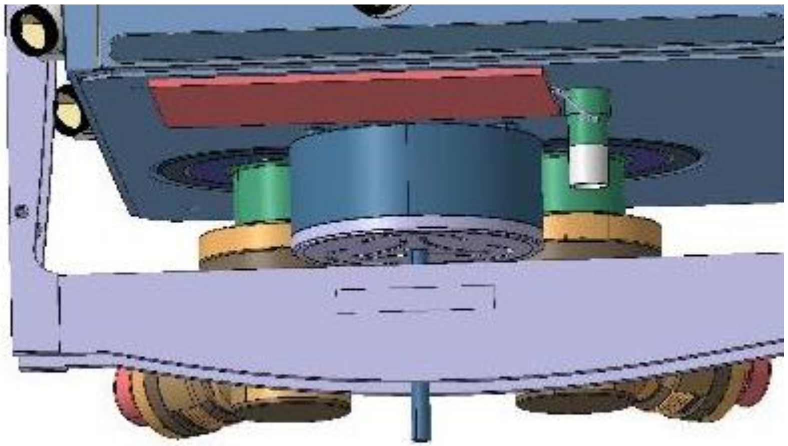
Some optimisation still to be done
Flexibility of the frame could be used to increase the tuning resolution

Buckling analysis
Multiplier 4.2

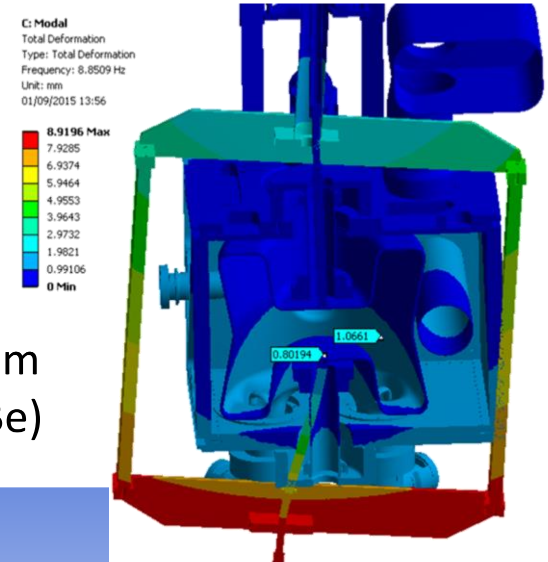


Calculations N. Kuder

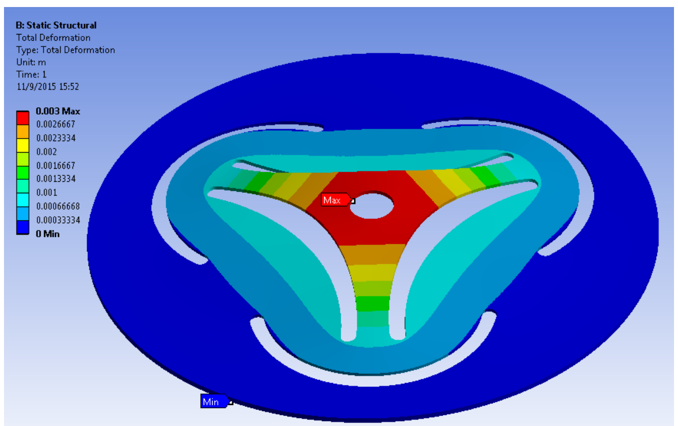
Flexural guide

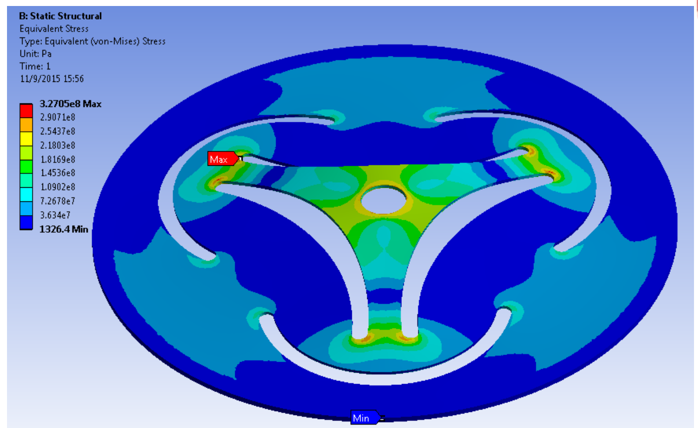


1 mm thick Titanium
Gr. 5 Plate (or CuBe)



Calculations T. Jones

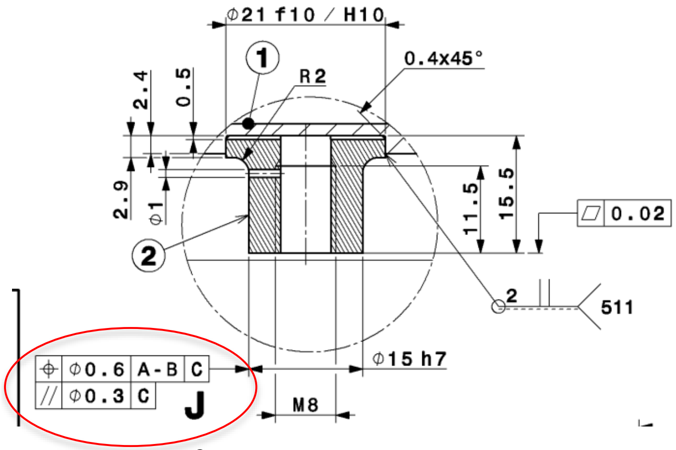




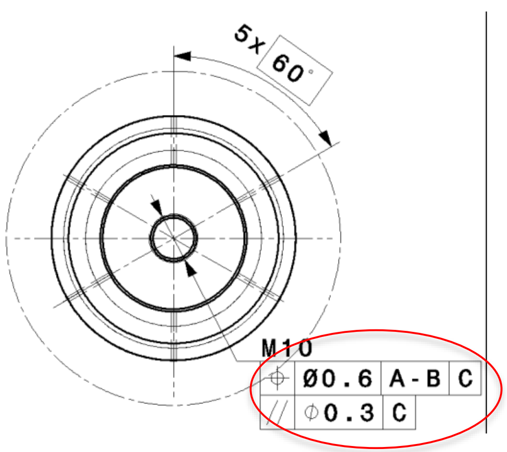
3 mm displacement
Axial stiffness 22 N/mm
Lateral stiffness 17 10^6 N/m
Torsional stiffness 0.1 mrad/Nm

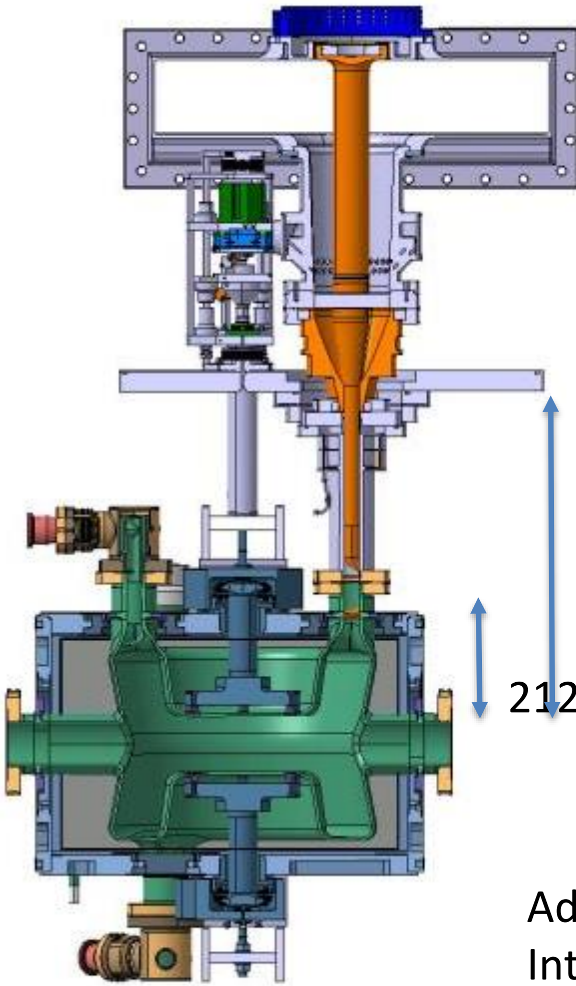
See talk T. Jones for results modal behaviour

Tolerances tuner axis



= 1.49°





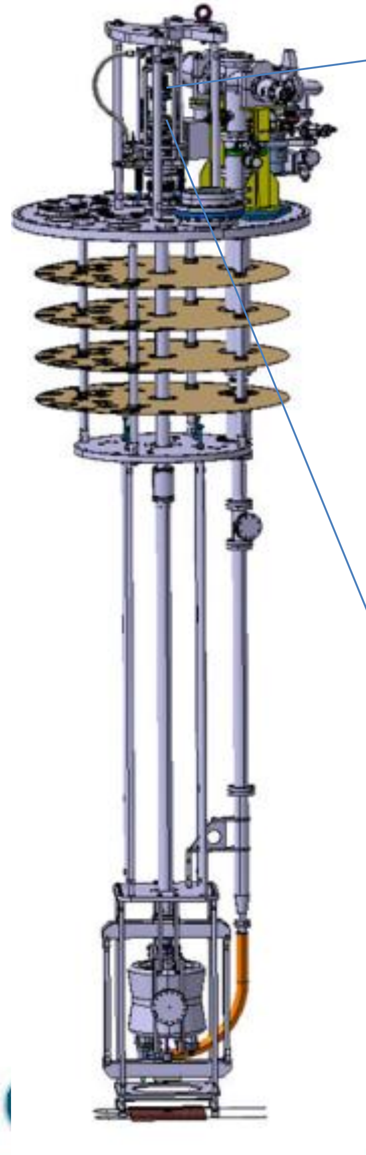
545 mm→14 mm

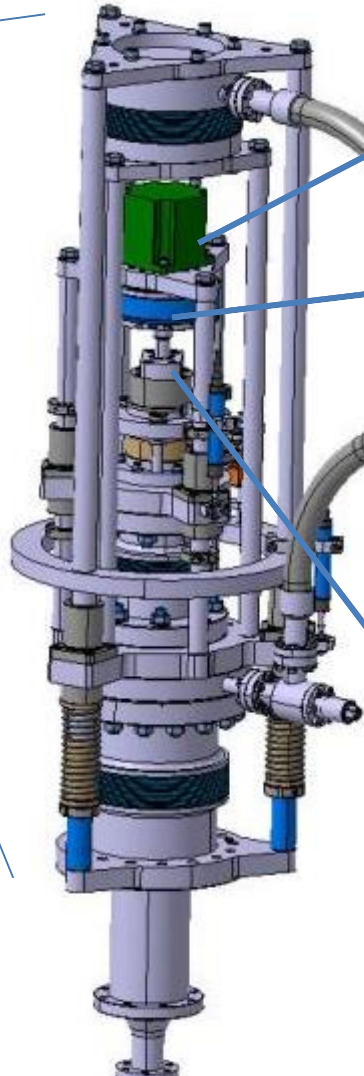
212 mm→ 5.5 mm

Adjustments to be foreseen
Introduce hinges (flexural)

Status SM18 p.o.p. tuner

Design: **P. Minginette**





Motor 1.3 Nm Bipolar Nema 23 (1.8 deg/step)

HD HFUS-20-100-2SO

Ratio i : 0.01 ,
repeat. peak Torque 82 Nm, average torque 49 Nm
Accuracy < 1 arcmin, precision <0.1 arcmin
Fa Dyn 7.7 kN, η=~0.80 (grease, 20 °C)

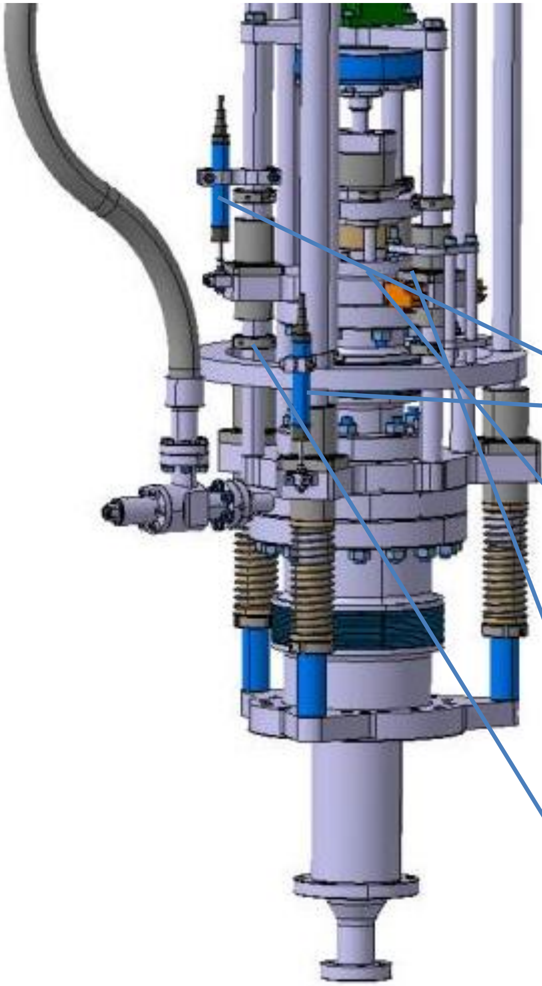
Roller screw Rollvis RV 12 x 1
η=0.79 , static load capacity 17 kN

$M = p\, i\, F / 2000\, \pi\, \eta = 0.01$ Nm F= 4 kN, p= 1

Detend torque 0.017 Nm, self locking

Instrumentation

Design: **P. Minginette**



Precision linear motor:

1 step= 1.8° x 0.01 → 0.1 µm (p=1 mm)

Precision HD 0.1 arcmin or 0.0017° → 10 nm

Altered by friction in guides

DQW ~ 20-2 Hz

RFD ~ 35-3.5 Hz

Instrumentation:

Potentiometer Megatron RC13-25 M

25 mm range , 1 kΩ, resolution **~10 µm**

Load cell Kistler

4576A55C1 class 0.1

DQW (2.2 kN/mm) →1.5 µm precision

RFD (2.5 kN/mm) → 1.3 µm precision

limit switches

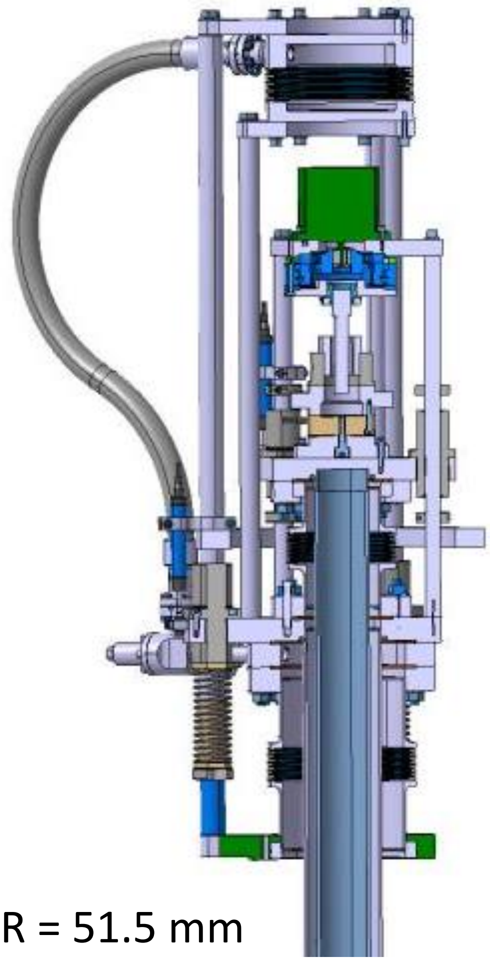
Mechanical stops

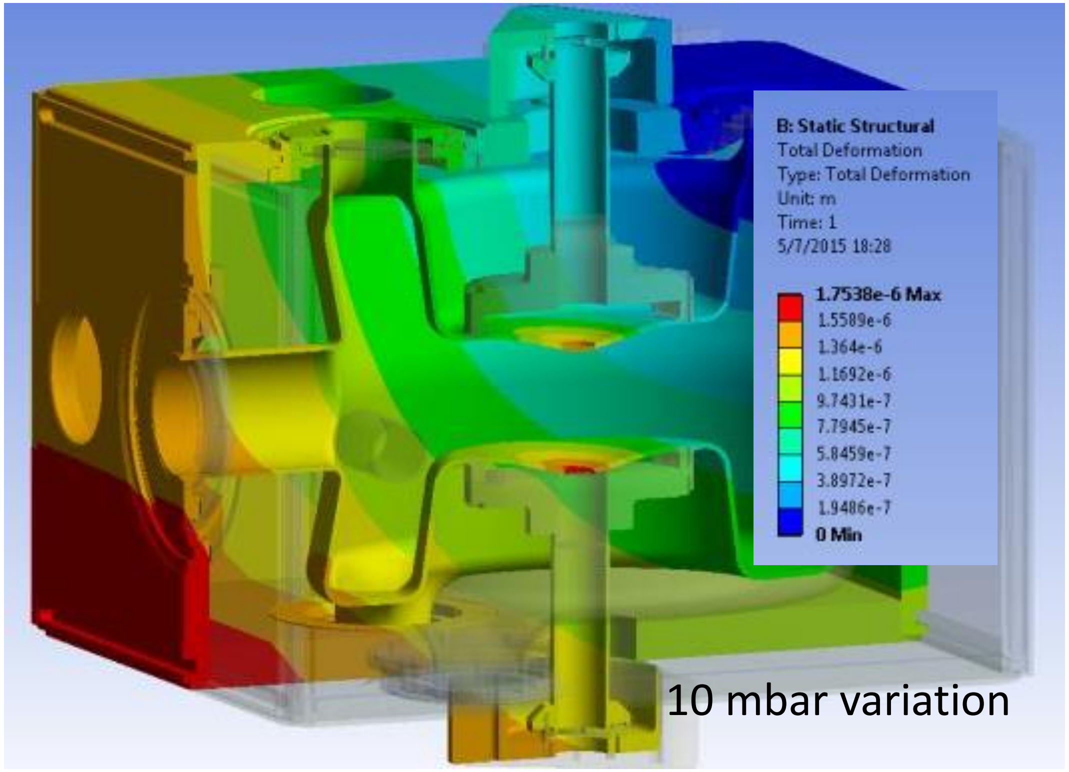
Pressure compensation

1 atm = 101.325 kPa , Force = 844 N (on 2 tuning tubes)

Day variations 3 mbar   2.5 N

Week variations 10 mbar 8.3 N





R = 51.5 mm

Surface 0.0083 m^2

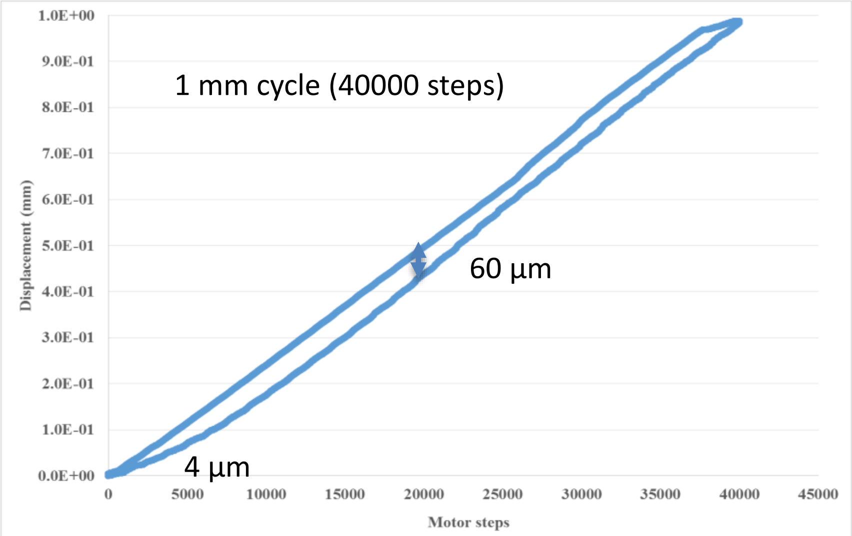
1 atm = 0.19 mm on each plate

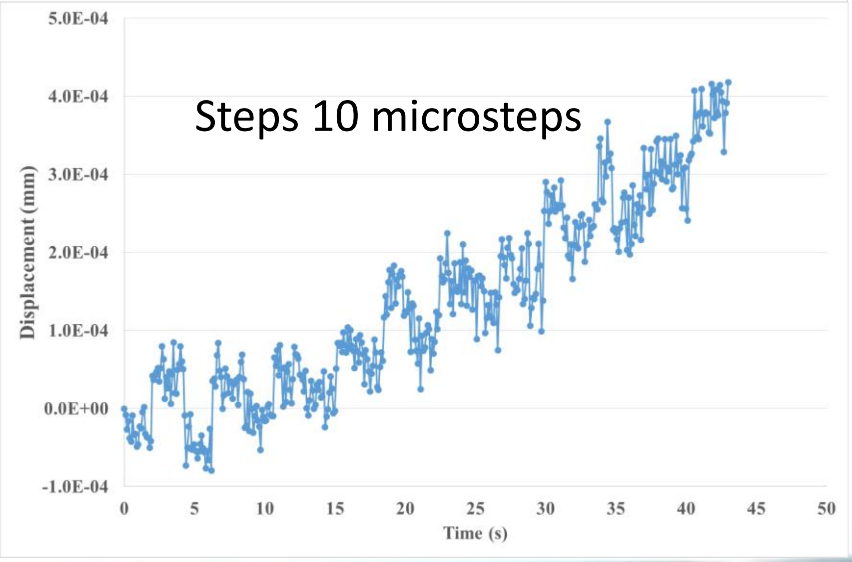
Load compensating springs : 3 x 5 N/mm

Status p.o.p. tuner test

<u>Linear motor protoype tested without load</u>

- Fully assembled and tested with 400 microsteps (<u>with LVDT</u>)





LVDT not adapted
Sensor noise
Friction in sensor
Drift (thermal ?)

Estimate:
<u>Precision</u> ~0.5 µm
~ 100 Hz DQW,
175 Hz RFD

Measurement **E. Gallay**

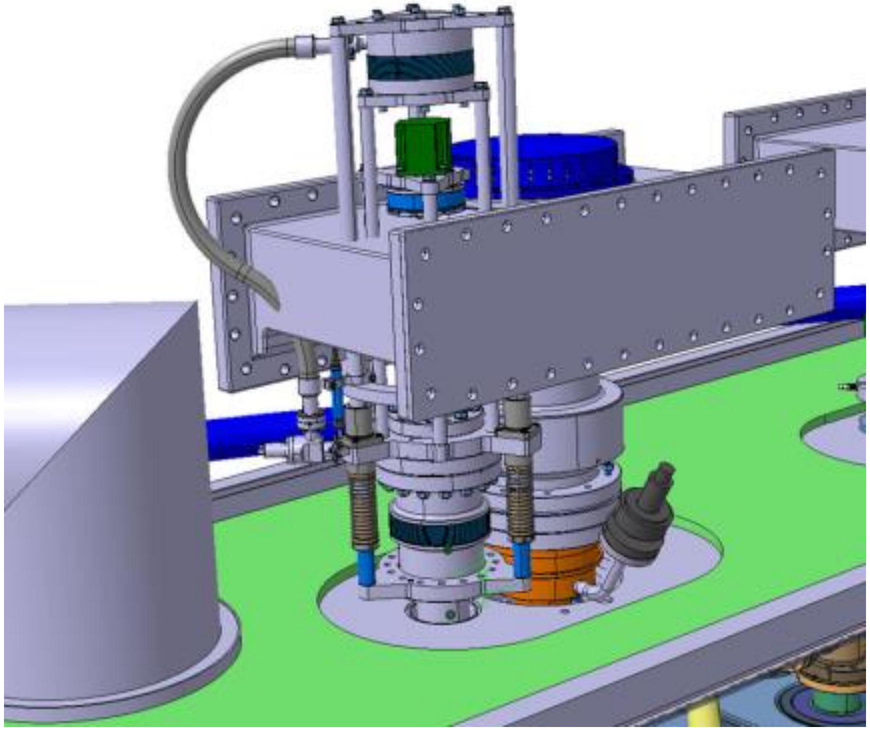
Next steps p.o.p. tuner test

Test on p.o.p. DQW in SM18 at 2 K

- Measure directly frequency resolution + precision
- Test pressure compensation
- Status: several parts available, in preparation

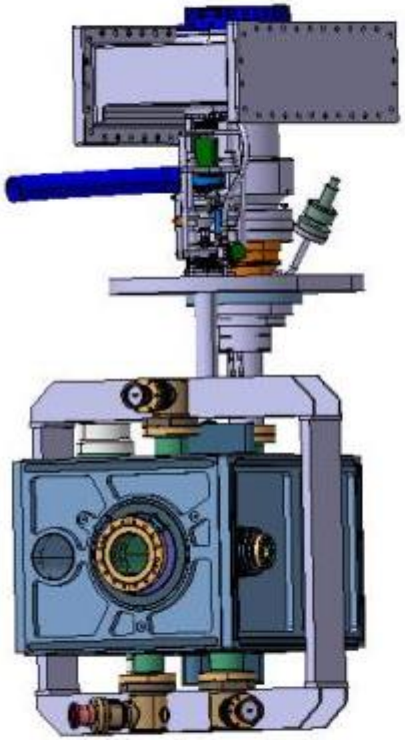
Action : Build a test bench for prototype motor testing
+ fatigue cycles + qualification radiation resistance

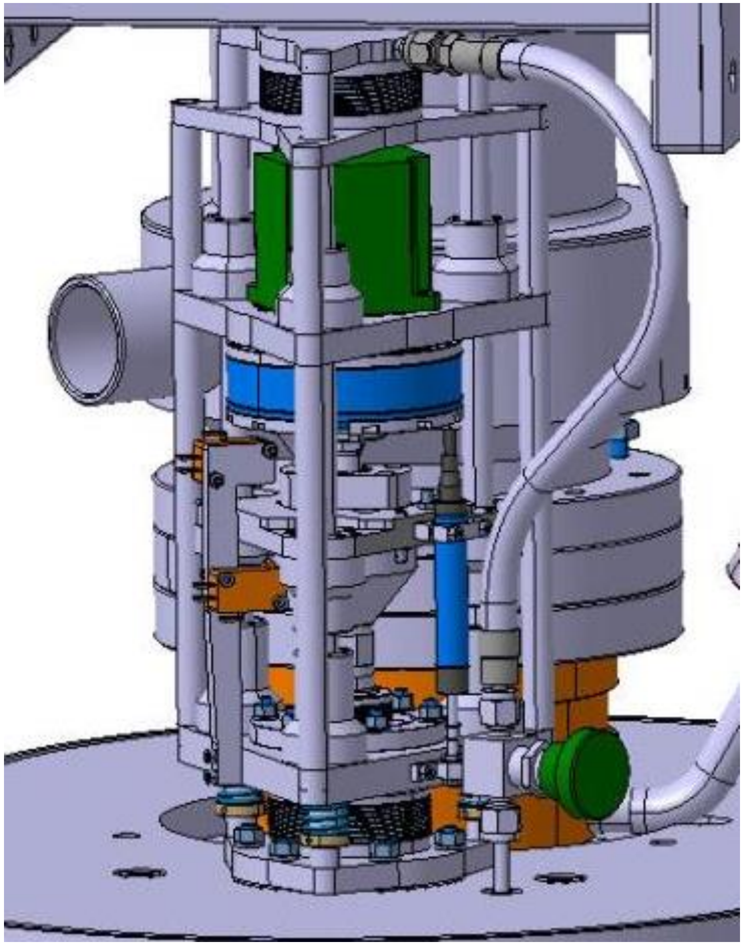
- Integrate a spring to represent the load from cavity
- Integrate an optical linear encoder without frictional guides and nm resolution
- Test in temperature stable room



Drawbacks first design:
Size …
Mass ~ 10 kg
Motorisation can not be replaced
without opening cryostat (maintainability)

Status design for SPS test (v1)

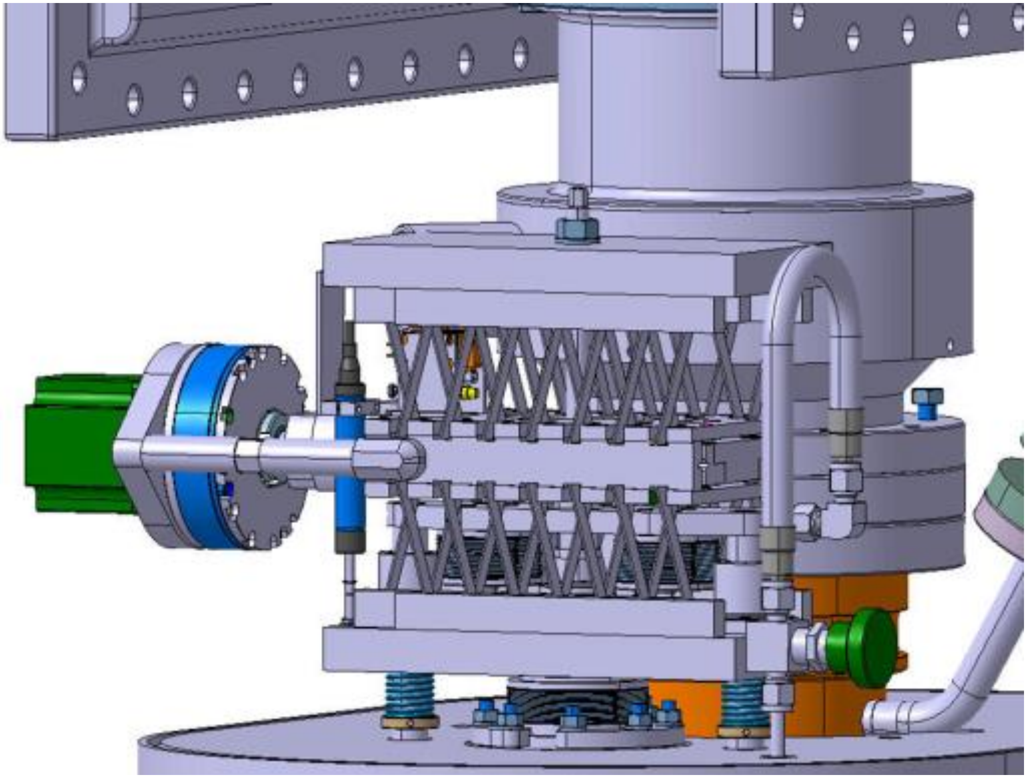


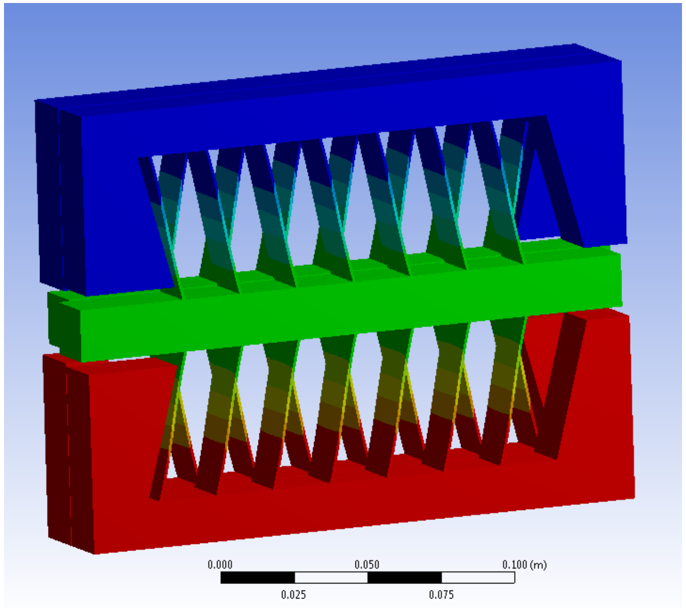


Size ok
Smaller mass
Can be
dismounted
from cryostat

Design: **P. Minginette**

Status design for SPS test (v2)





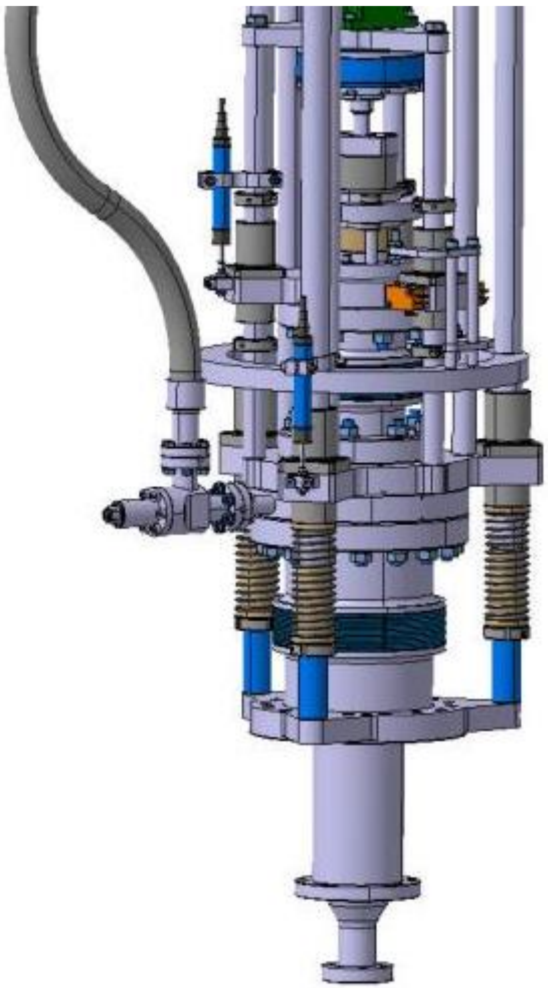
Only concept so far
Compact
10 to 20 times better resolution
Centre of actuation is materialised
Dismountable
Design: **P. Minginette**

Conclusions

- Calculations for DQW and RFD show the tuning ranges available that are smaller than the error on p.o.p.
- A first prototype of the tuner motorisation has been built, tests with p.o.p. DQW in preparation
- Options for the SPS tuner are under study, taking care of integration, resolution, pressure and load compensation and instrumentation
- To be included in study: radiation, thermal optimisation
- Test program to be prepared

Additional slide

Motor 1.3 Nm Bipolar Nema 23 (1.8 deg/step)



HD HFUS-20-100-2SO Ratio i: 0.01, η=~0.80
Roller screw Rollvis RV 12 x 1, η=0.79

Precision linear motor:

1 Motor step= 1.8° x 0.01 → 0.1 µm (p=1 mm)
Divide the curent in the stator : micro stepping
Can go up to 8000 «µsteps» or more
But:
Precision HD 0.1 arcmin or 0.0017° → 10 nm
+ Altered by friction in guides

DQW ~ 20 -2 Hz (0.1 µm-10 nm)
RFD ~ 35 -3.5 Hz (0.1 µm-10 nm)

Additional slide

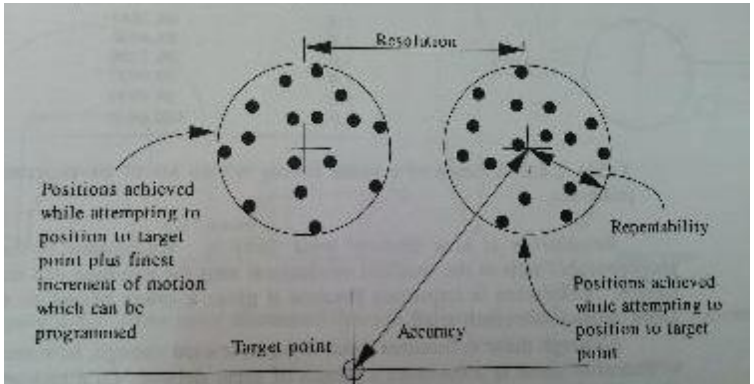
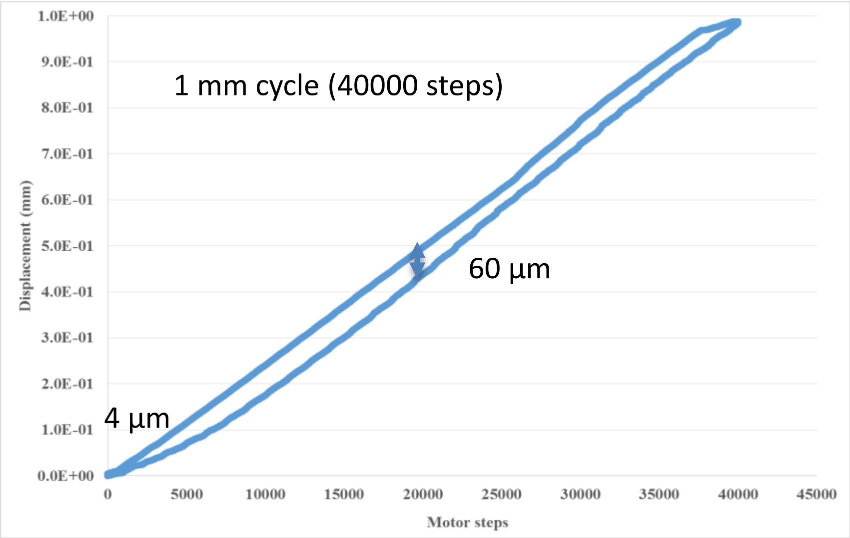
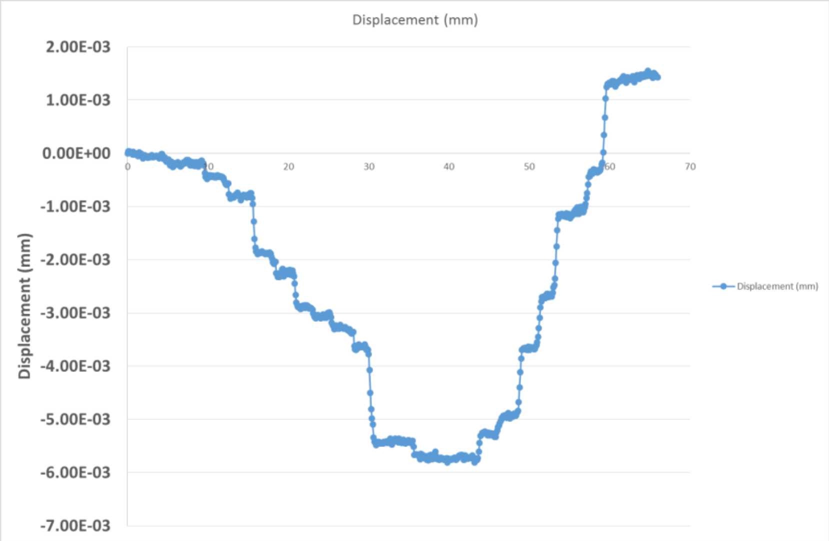
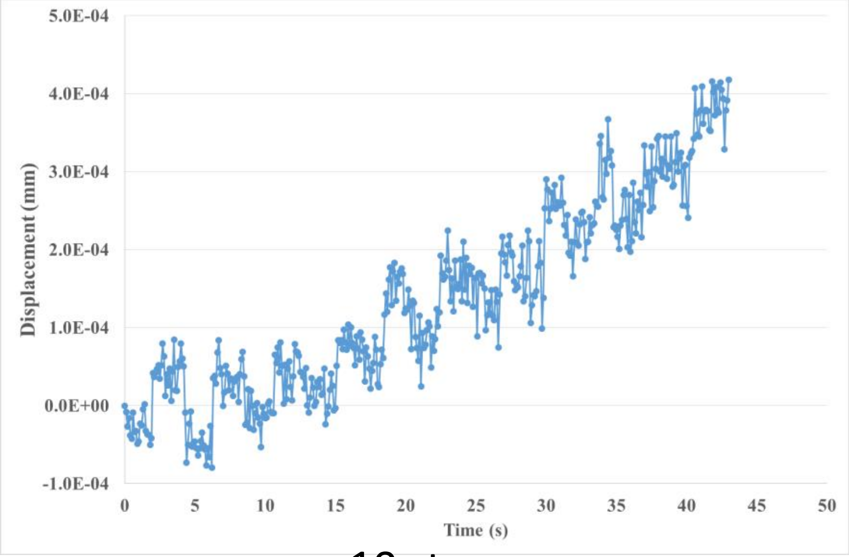


Figure 2.1.1 Defining accuracy, repeatability, and resolution.







100 steps

10 steps

Sensor with spring+ friction

- Thank you

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