Update on the discussion for He vessel and tuning system

29/06/2105

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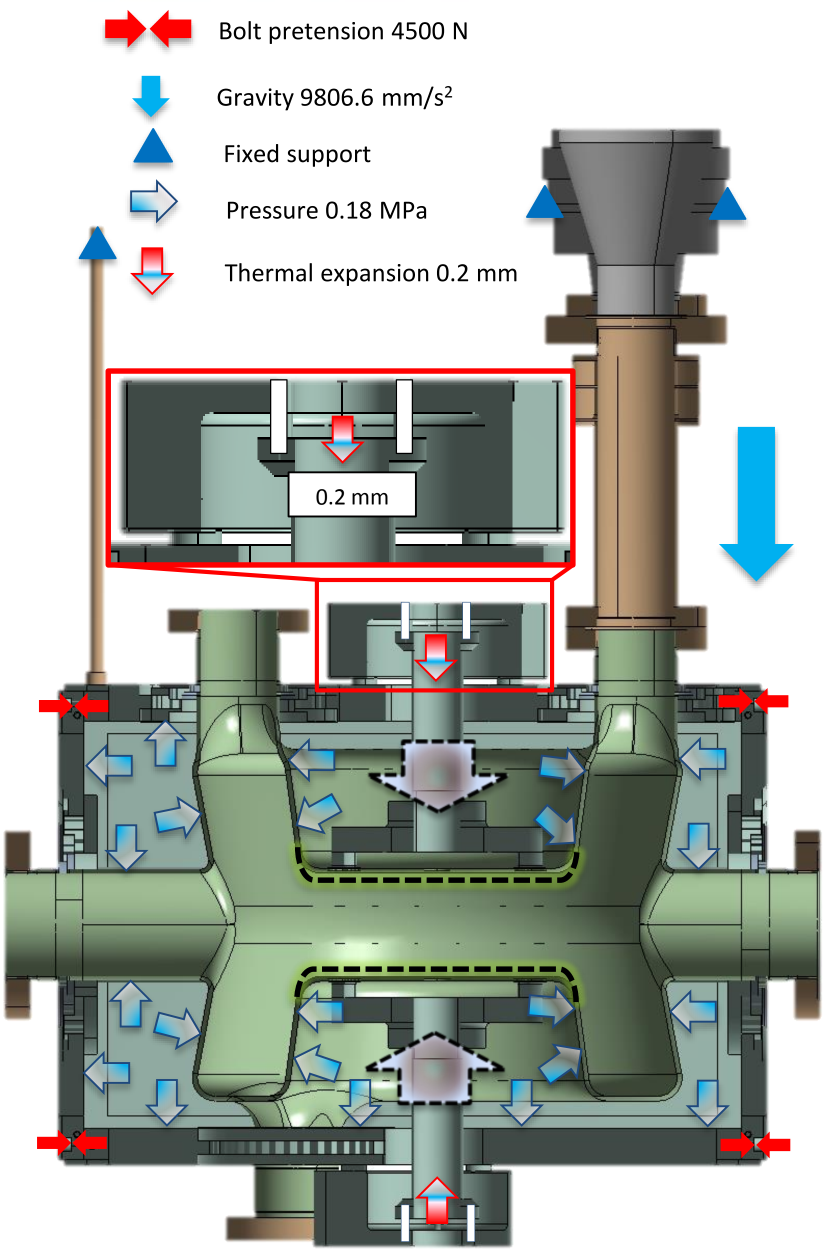
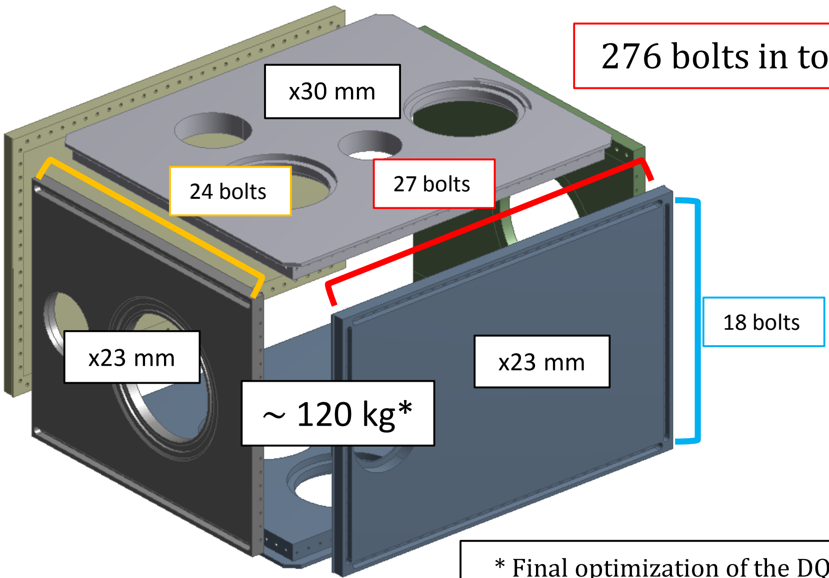
Update on simulations

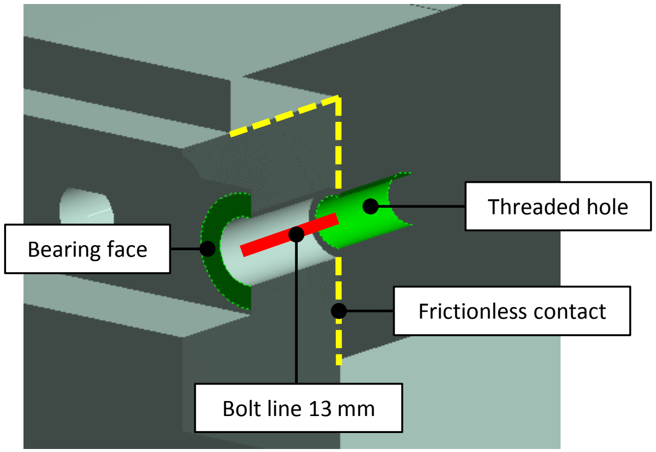
FE analysis performed for the combining effect of bolt pretension, pressurization and pretuning.



Bolt modeling



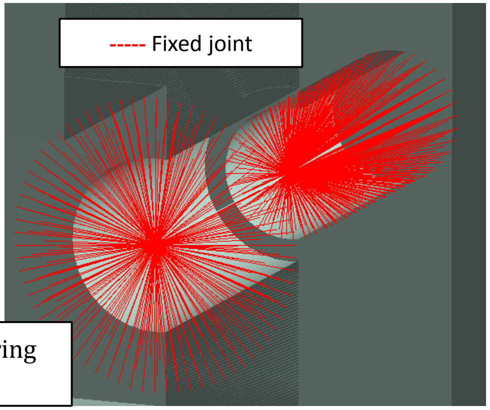
* Final optimization of the DQW He vessel done by Carlo. To be checked.



Cross section properties of the beam calculated according to VDI2230-2.

Details View

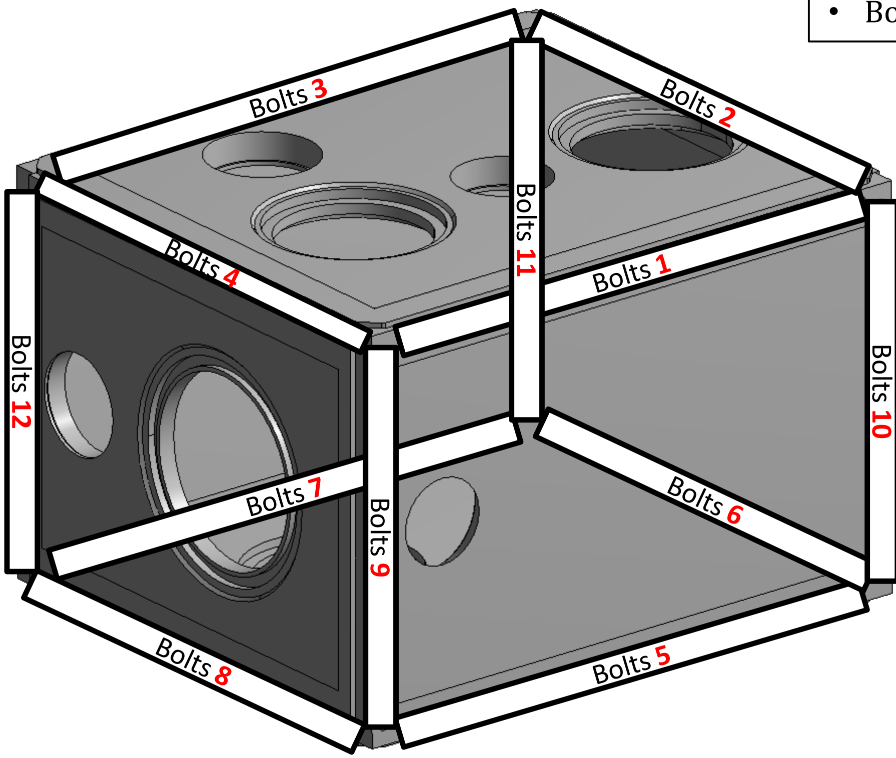
Details of M6	
Sketch	M6
Show Constraints?	No
Physical Properties: 10	
A	10.24 mm²
Ixx	17.06 mm^4
Ixy	1e-006 mm^4
Iyy	17.06 mm^4
Iw	0 mm^6
J	34.12 mm^4
CGx	0 mm
CGy	0 mm
SHx	0 mm
SHy	0 mm



Beam nodes coupled with the bearing face and the threaded hole.

Bolt results (presure + pretuning)

Results were compared for two case scenarios:
- Bolts carrying the full load
- Bolts and welds carrying the full load

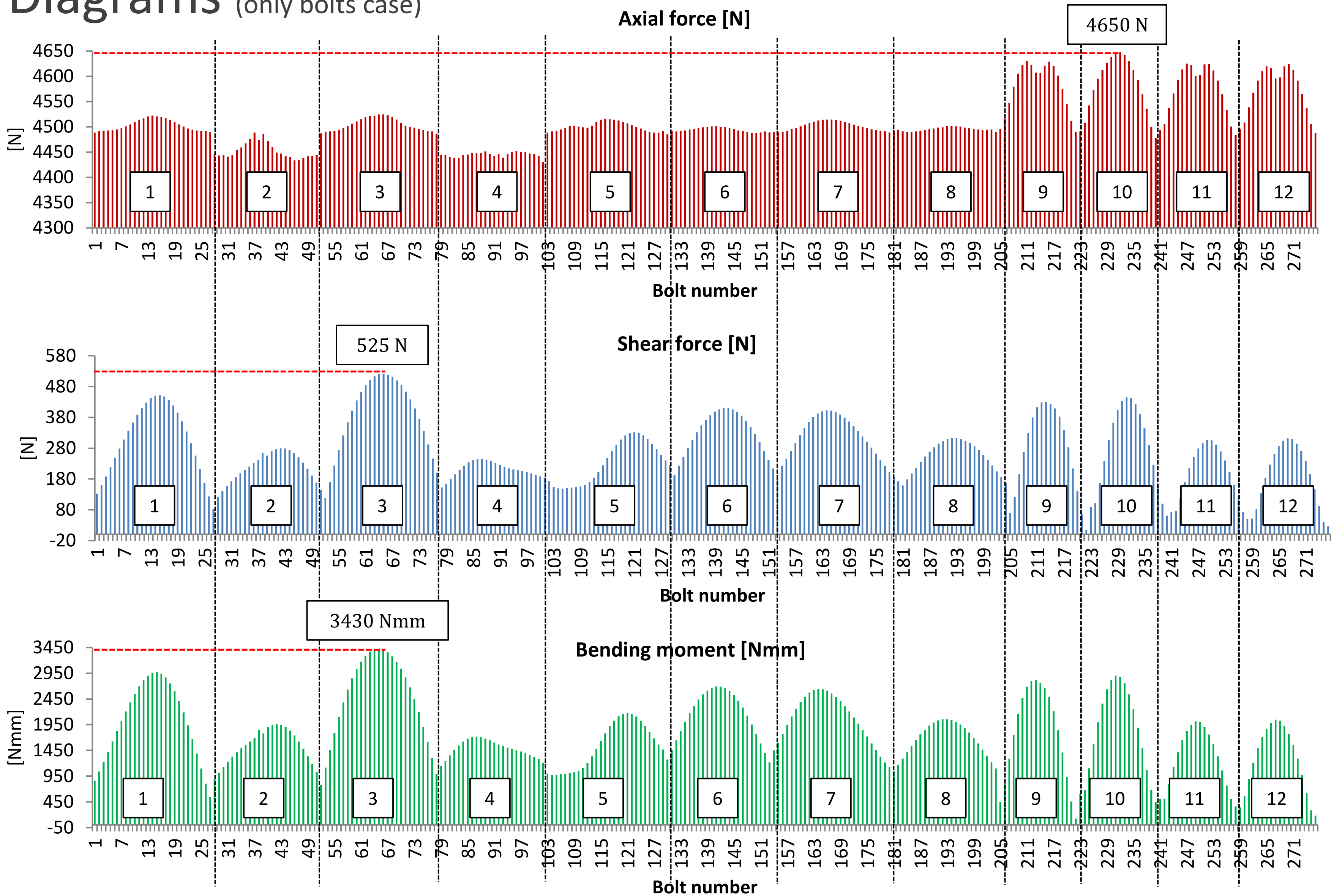


			Case	
Name	Symbol	Unit	Bolts	Bolts + welds
Preload	P	[N]	4500	
Max. axial force	F_A	[N]	4650	4655
Max. bending moment	M_b	[Nmm]	3430	1630
Max. shear force	T	[N]	525	245
Equivalent stress*	σ_{eq}	[MPa]	620	480
Ti gr.5 proof stress	S_p	[MPa]	830	
Safety factor	k	-	1.34	1.74

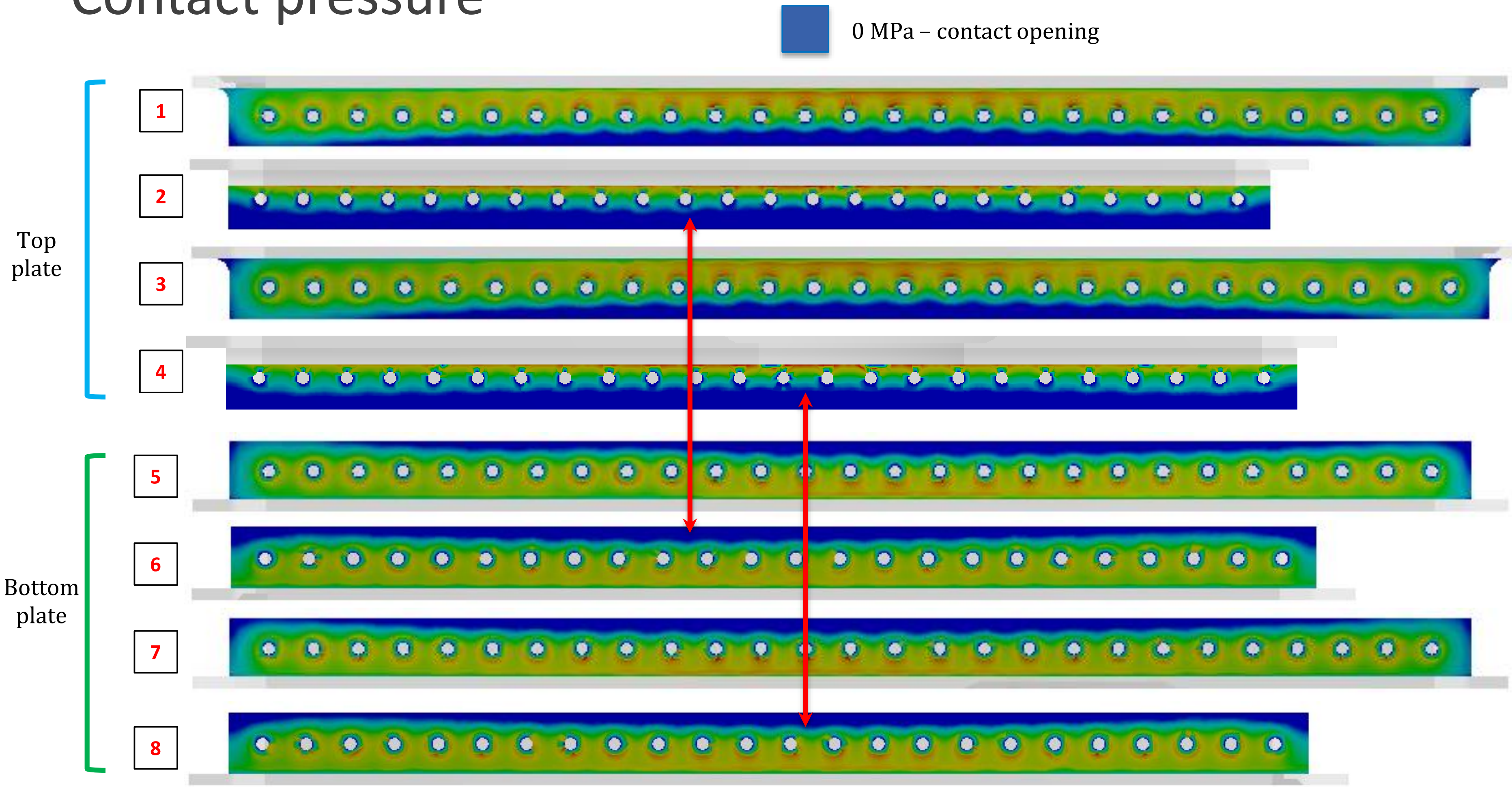
Plots with distribution of the axial forces, bending moments and shear forces through the bolt rows were used to find the maximum values and check the behaviour of particular bolts.

*according to VDI2230-2

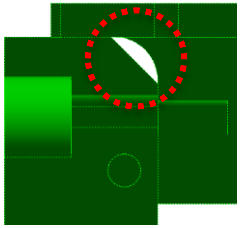
Diagrams (only bolts case)



Contact pressure

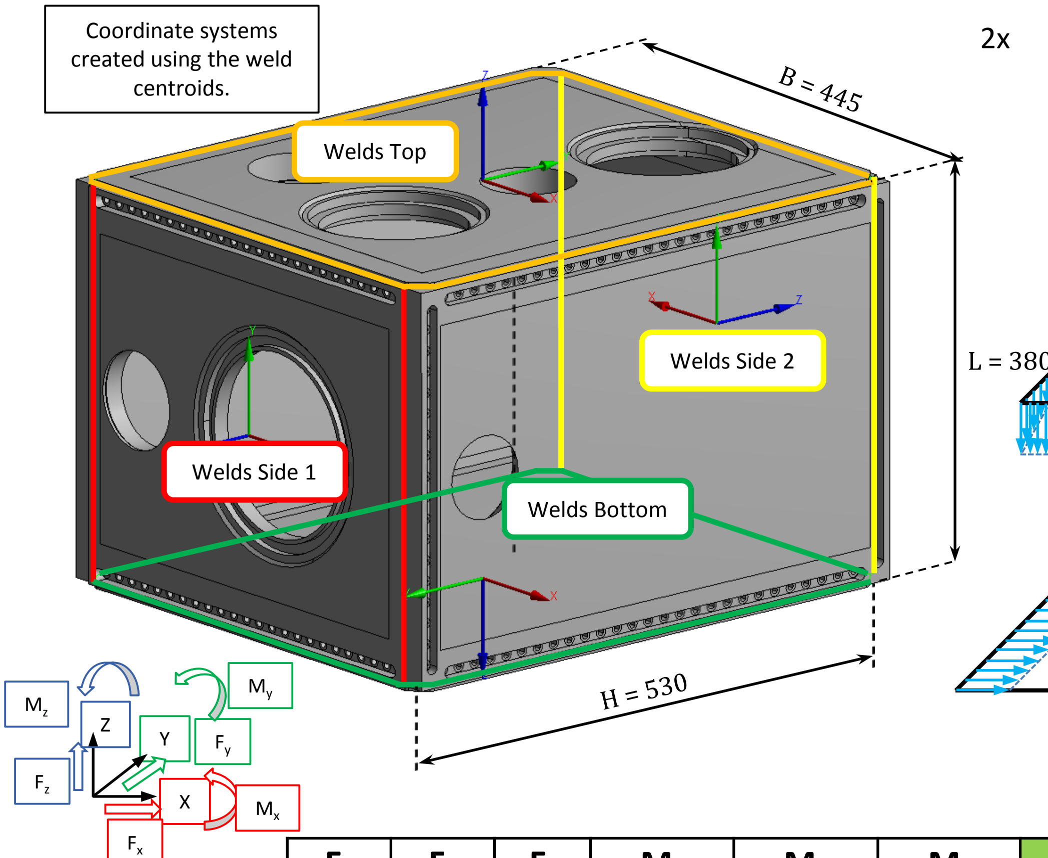


The difference between 2, 4 and 6, 8 pressure contacts due to the chamfer on the top of the side plates.

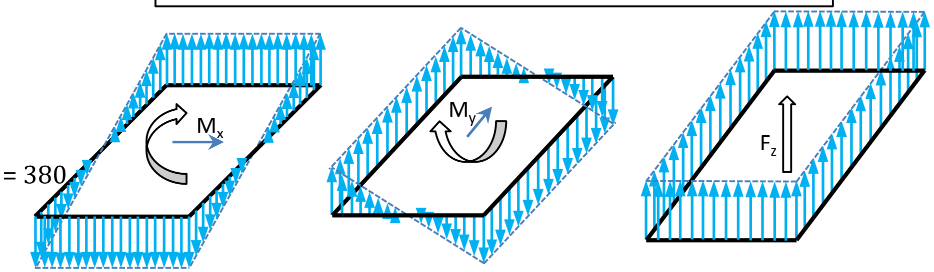


Weld calculations (pressure + pretuning)

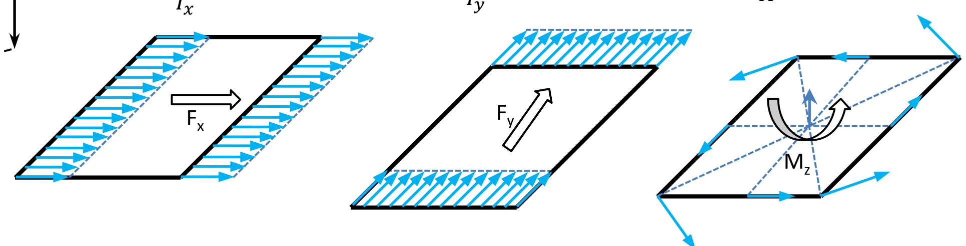
		A [mm²]	I_x [mm⁴]	I_y [mm⁴]
2x	❙❙	$2aL$	$\frac{aL^3}{6}$	$\frac{L\left((B+2a)^3-B^3\right)}{12}$
2x	▭	$2a(H+B)$	$\frac{aH^3}{6}+\frac{B\left((H+2a)^3-H^3\right)}{12}$	$\frac{aB^3}{6}+\frac{H\left((B+2a)^3-B^3\right)}{12}$



Reaction forces and moments extracted from ANSYS and used for stress assessment of the welds.



$\sigma_x = \frac{M_x}{I_x}y$ $\sigma_y = \frac{M_y}{I_y}x$ $\sigma_z = \frac{F_z}{A}$



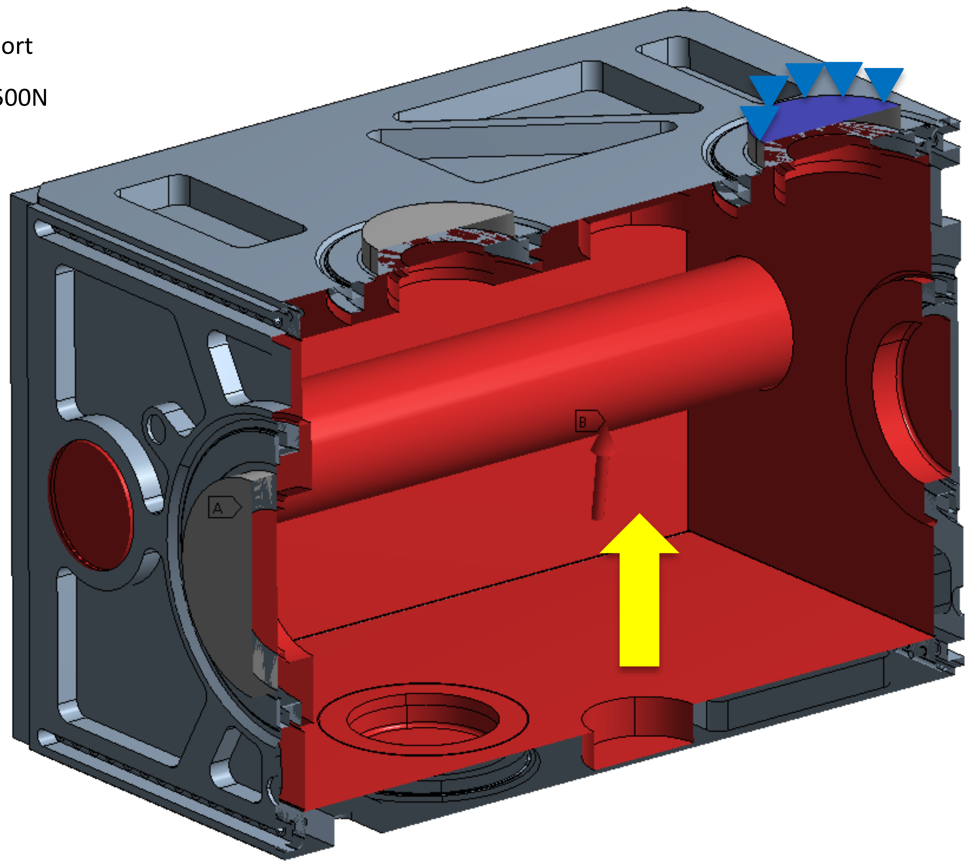
$\tau_x = \frac{F_x}{A}$ $\tau_y = \frac{F_y}{A}$ $\tau_z = \frac{M_z}{I_x+I_y}r$

	F_x [N]	F_y [N]	F_z [N]	M_x [Nmm]	M_y [Nmm]	M_z [Nmm]	σ_{eq} [MPa]
Welds Top	-504	1873	-15962	19652	-325050	164750	9.02
Welds Bottom	522	1253	-15946	430170	-283260	339480	9.90
Welds Side 1	-1406	-1980	6895	-61508	248090	63502	12.87
Welds Side 2	-47	-926	7517	-54226	-323140	-14590	12.88

$$\sigma_{eq} = \sqrt{(\sigma_x+\sigma_y+\sigma_z)^2 + 3\left[\left(\tau_x+\tau_z\frac{r_y}{r}\right)^2 + \left(\tau_y+\tau_z\frac{r_x}{r}\right)^2\right]}$$

Tests on dummy vessel

- Pressure 0.18 MPa
- Acceleration 9806.6 mm/s^2
- Fixed support
- Preload 4500N



Welds not modeled

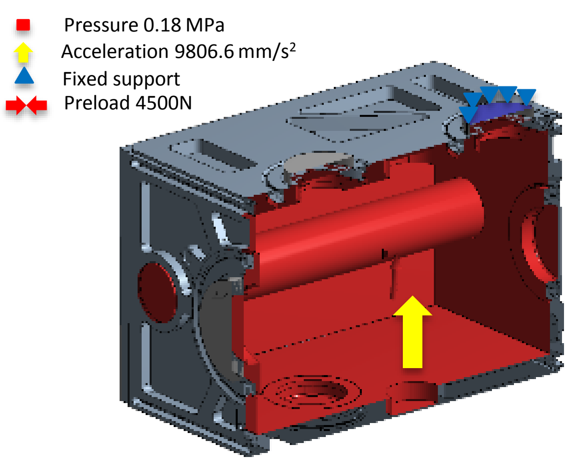
✓

Max axial force [N]	Max shear force [N]	Max bending moment [Nmm]	Max equivalent stress [MPa]	SF
4760	725	3765	655	1.26

Tests on dummy vessel

Desired measurements :

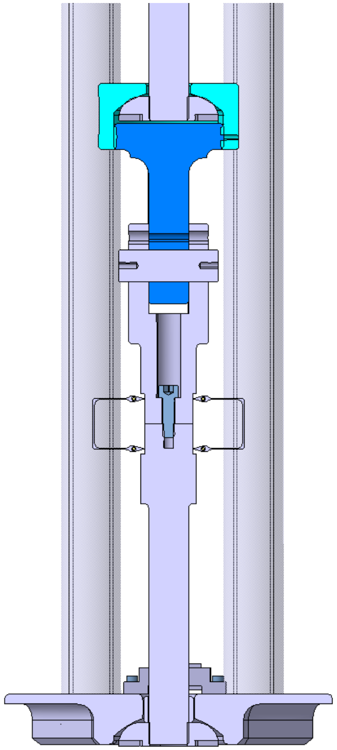
1. Strain/Stress on localized positions of the Ti plates
2. Total deformation
3. Change in bolts preload
4. Continuity of contact between covers plates

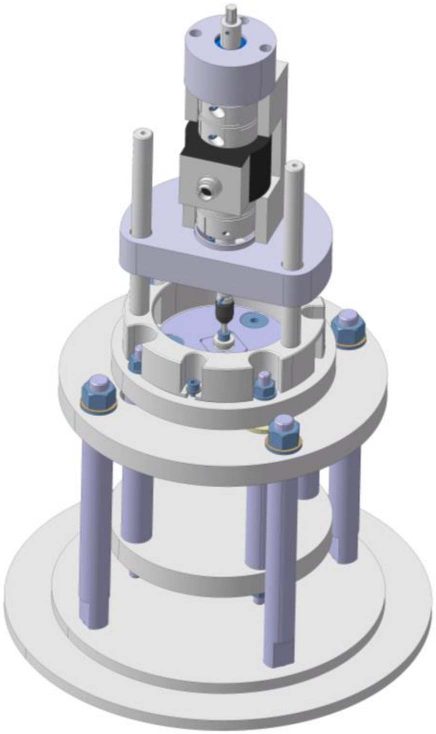


ORDER	SEQUENCE TEST	STANDARD or/and PROCEDURE
I	STATUS OF THE RAW MATERIAL	
II	WELDING TEST	
	ASSEMBLY	
III	DIMENSIONAL CONTROL	
IV	STATUS OF THE HE TANK	
	WELDING	
V	STATUS OF THE HE TANK	
VI	VISUAL INSPECTION 100% WELDS	
VII	DIMENSIONAL CONTROL	
VIII	**HELIUM LEAK TEST**	
IX	**PRESSURE TEST**	Δp = 2.6 bar T = 300K
X	**HELIUM LEAK TEST**	
XI	VISUAL INSPECTION & DIMENSIONAL CONTROL	
XII	**THERMAL TEST**	Procedure : Rate of cool down : TBD Number of cycles : 5 T_0 = 300K T_1 = 80K
XIII	**HELIUM LEAK TEST**	
XIV	FINAL DIMENSIONAL CONTROL	
XV	STATUS OF THE TITANIUM PLATES AFTER TESTS	
XVI	DISASSEMBLY, BOLT TORQUE MEASUREMENT, POSSIBLE DESTRUCTIVE TESTS	

Other tests

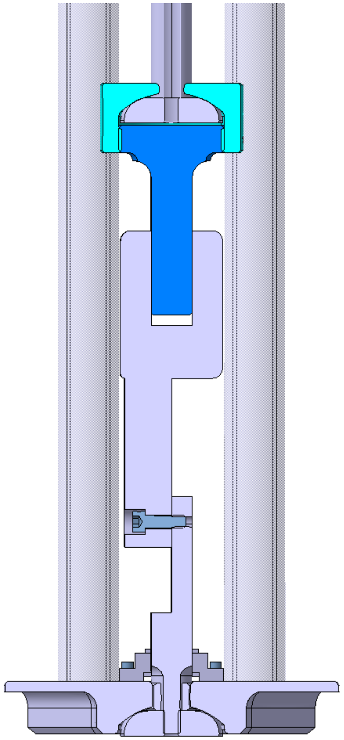
1. traction

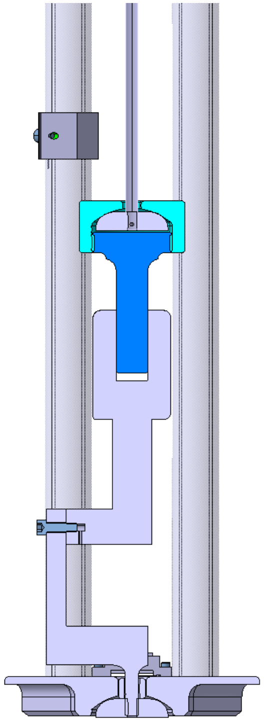




2. torque
(friction)

3. shear





4. bending

Answering to comments: bolts

Study if screws loosen during "thermal shock" (from 300K to 2K) and after several thermal cycles.

Tests on dummy vessel consider also thermal shock and cycling (see related slide). Instrumented bolts are present. Tightening torque is checked at the beginning and at the end of the full test sequence.

Possibility to use bimetal washers to lock the bolts and ensure thermal contact.

not clear. Please clarify it (We have difficulties to select the washers: work in progress.)

Determine material for bolts.

Material for bolts selected: titanium Grade 5 (Ti6Al4V)

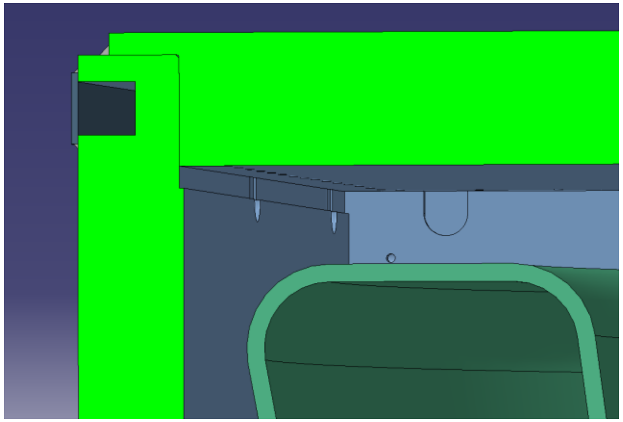
Recommendation to pay special attention during assembly: bolts should get an even torque.

Assembly procedure:

- Same torque for all the bolts, defined after tests
- Tightening in 3 steps (30% - 60% - 100 %)
- Tightening according to the "star procedure" (to be updated for rectangular flange)

Answering to comments: vacuum

Additionally to venting holes in screws, include venting port in low mechanical stress area.



Done already

It may be difficult to identify origin of leak if any.

True. The leak test on the He vessel can be performed only with all the sealing weld seams in place

Expert on vacuum leak test has been consulted:

- If no leaks are present > 2 days long test
- If leaks are present -> 20 days long test in order to find the leak.

Suggestions?

Answering to comments: weld seams (1)

In general, Ti welding is challenging by itself.

We know they are challenging but tests look very good. The dummy vessel will allow us to verify once again this point.

Test weld joints, i.e., quality of welds in corners

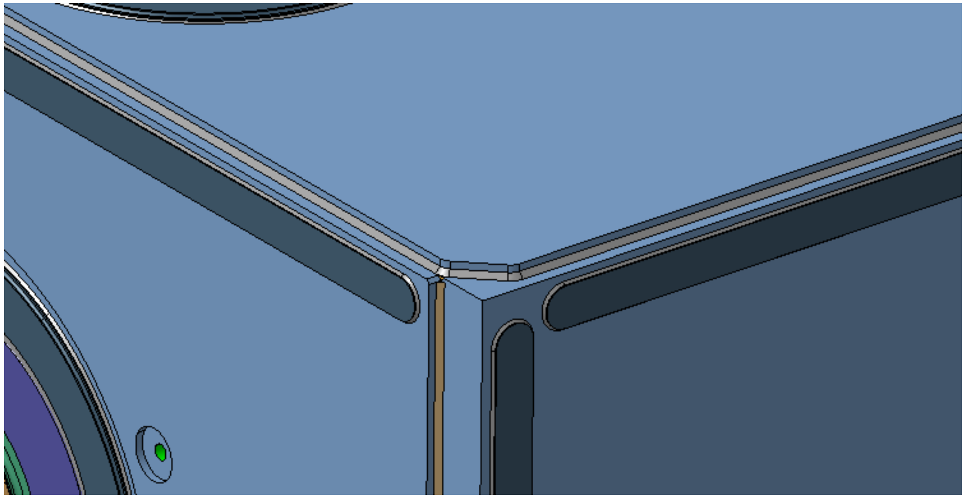
Planned. Previous tests showed no leak risk.

Is there any preparatory feature for the weld: e.g. using a flange weld?

Flange weld? The weld seams for leak tightness are added once the vessel is bolted. For sake of clarity: there are 2 types of welds

- Between plates
- For bolt covers

A tooling system that clamps the structure during welding phase is foreseen.



Recommendation to include a feature that allows a second welding in case that the first welding is not successful or needs to be removed

We prefer to remove the weld seam by machining and replace. All welds accessible for leak reparation

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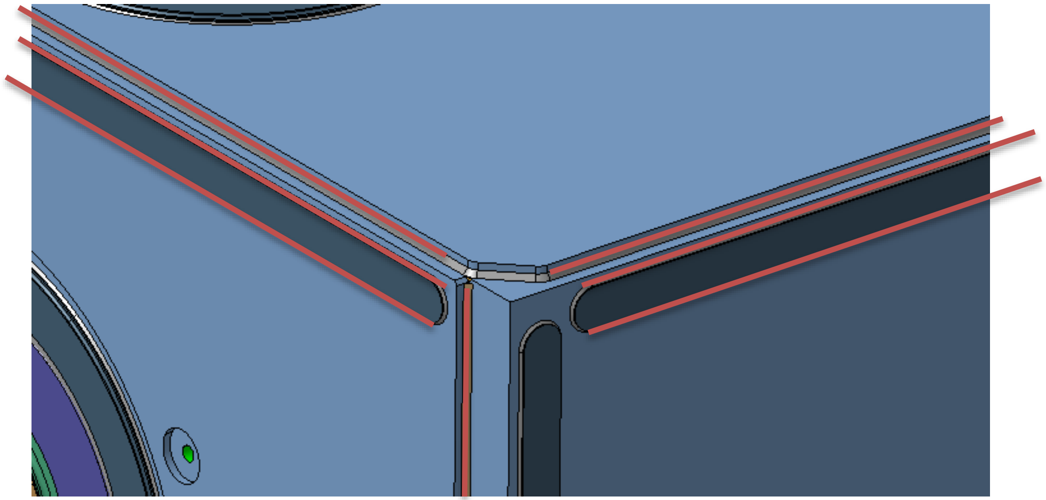

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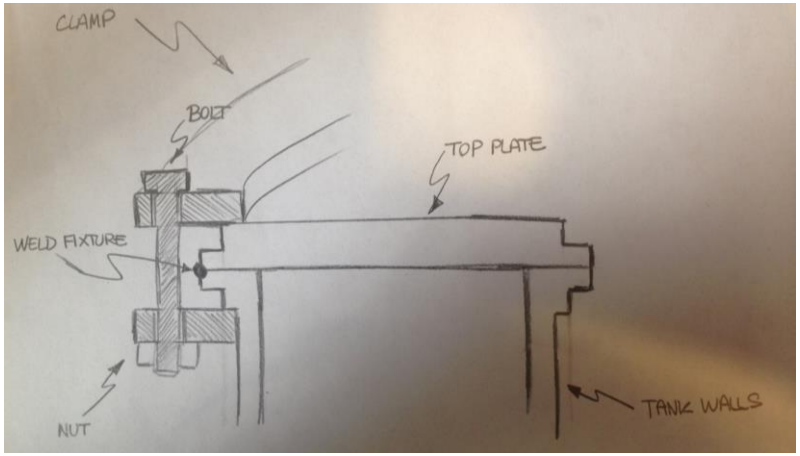
Answering to comments: weld seams (2)

Alternative: use any kind of clamping system where bolts are outside and can be easily retighten if needed (for example, see drawing below). This design would allow to precool before welding



Hard to make a full comparison between a concept and a full design at this point. The idea can be further investigated and kept as plan B for LHC in case of problems.

Answering to comments: tuning actuator and piezo

The current first choice for the tuner motorization is the version one in the presentation of the HiLumi-USLARP meeting (version 2 will however be developed)

Fabrication by EDM from a single piece (incl. blades) may be more expensive than production in different pieces, but eliminates assembly step, esp. delicate for blades. However, dismountable blades allow for easy replacement…

No monolithic by EDM (but assembled from separate blades in a tool). Additive manufacturing in Ti (superior mechanical properties for the material with respect to EDM) could be an option (estimate will be required when the design is enough evolved)

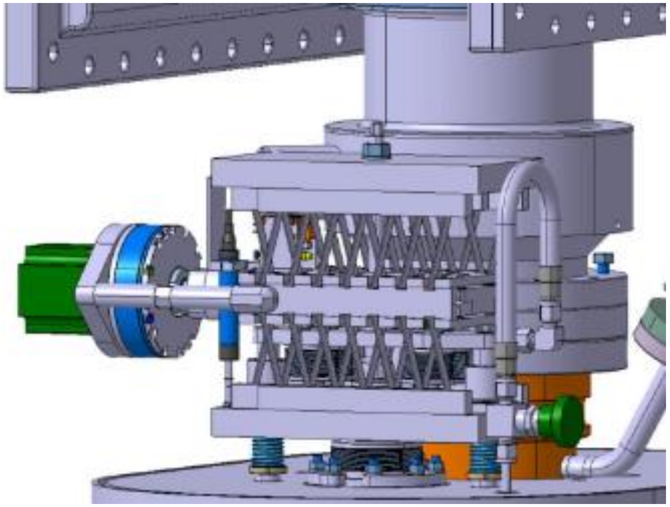
The highest stress in the Ti blades is low enough to avoid fatigue problems

Alternatives: system based on wedge and bearing (ask Skaritka for further details)

That sounds like a frictional system

Answering to comments: tuning actuator and piezo

Joints (like in the axis of the blades) will introduce friction. Friction prevents a smooth movement and control in the order of micrometers. Joints with pins are much worse than those using a bearing system. The scissor system with blades has many points where friction will appear…



No joints with friction in this design (3D drawings not completed, because the detailed design has not yet been done).

Might be interesting to use displacement sensors to monitor the behavior of the tuning system.

Blue object on the left picture

If piezo is finally included, it also minimizes the worn out of mechanical pieces used in tuning actuator.

As there are no sliding frictional contacts in this design, only lubricated rolling contacts, a range of some microns will not create wear. And this is not a pulsed accelerator (low number of cycles)

Stepper motor is pretty fast (1mm/min or 6500 rpm)…

The 6500 rpm are for the harmonic drive (HD) , stepper motors are not this fast.

High Luminosity LHC

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