Status of DQW cavity and auxiliary systems production

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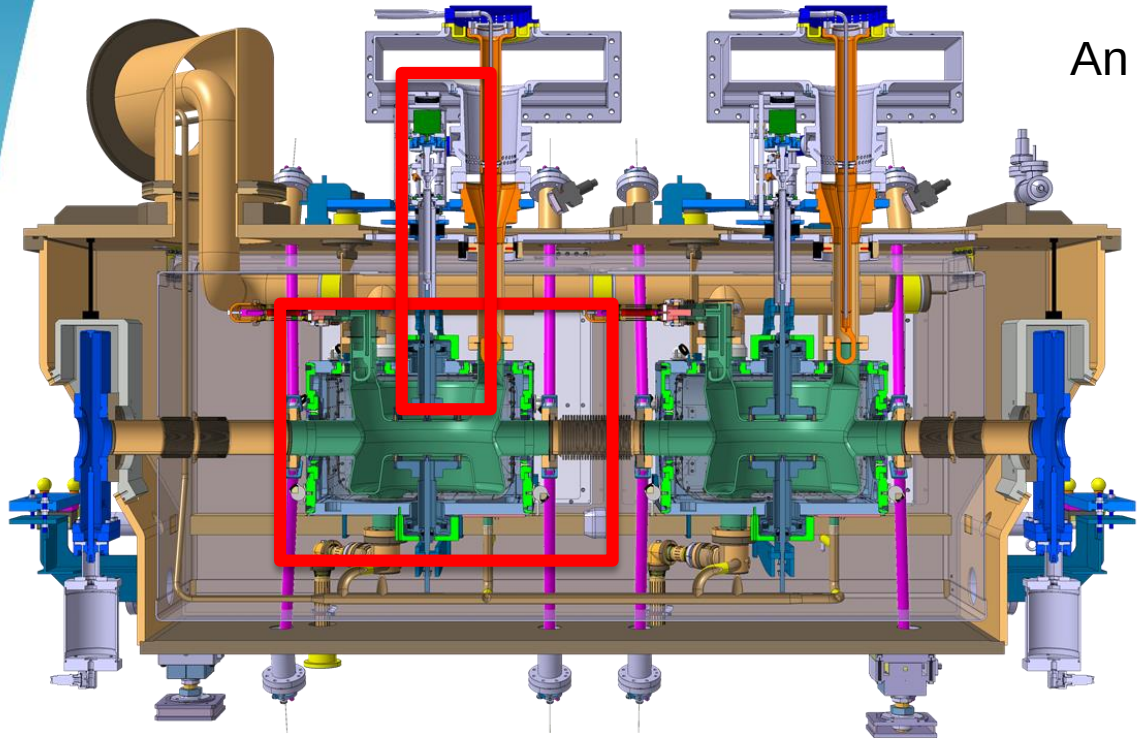
On behalf of EN-MME & Crab Cavity Manufacturing Collaboration

Joint LARP CM26/Hi-Lumi Meeting – SLAC – May 2016

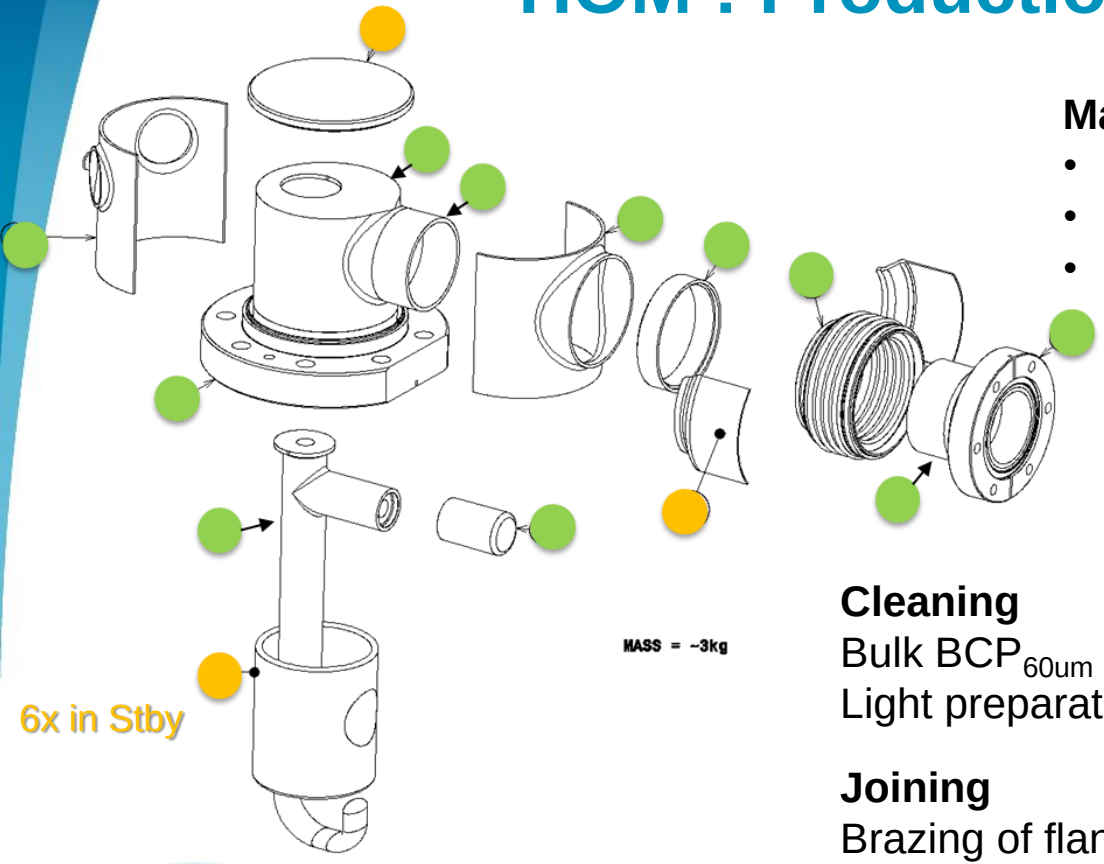
Overview



An update of production inside out..

- HOM
- Cavity
- Pick-up
- Feedthrough
- Cold Magnetic Shield
- Tank
- Tuner

HOM : Production Status



6x in Stby

Machining

- ~ all Nb parts have been produced
- steel parts and tools (EB, brazing) ready
- Prototype assembly for EB test ready

Cleaning

Bulk BCP_{60um} done

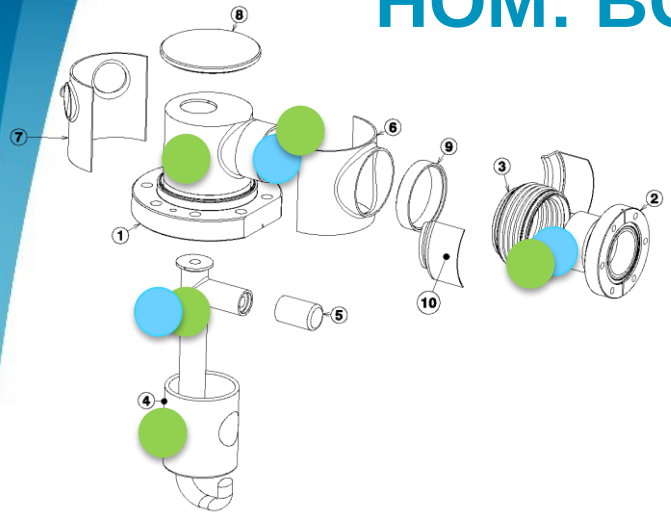
Light preparation for brazing done

Joining

Brazing of flanged extremities ongoing (by end May)

EB: see next slide

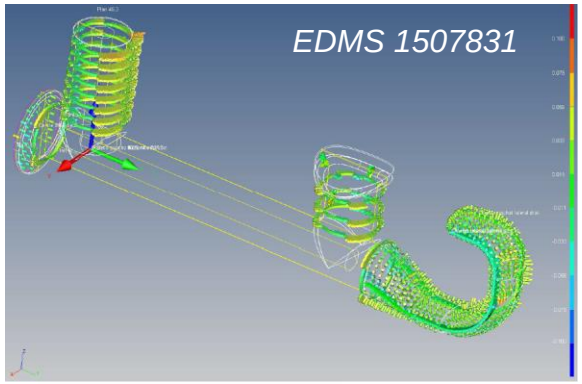
HOM: BCP Results & Metrology



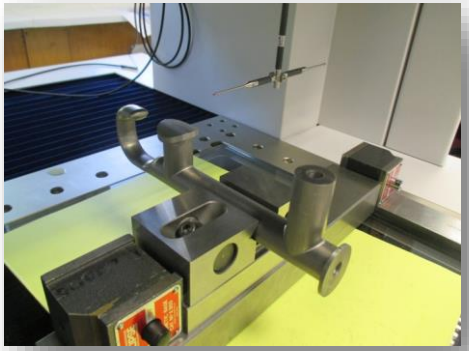
= metrology

= BCP Test

All pieces conform to dimensional requirements



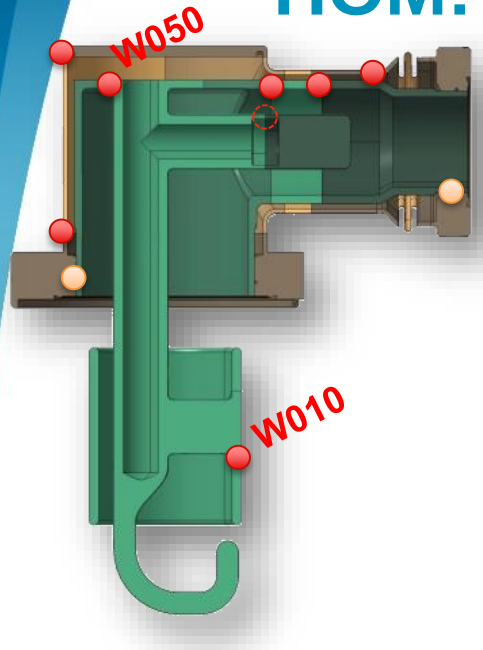
Hooks: profile tolerances below ±0.15mm
(spec.: 0.3mm profile band on hook)



BCP

- Initial tests: 20um / 30um / 60um
  → variability among BCP: = ± few um
- Production : 60um
  →variability among pieces = ±10um

HOM: Welds

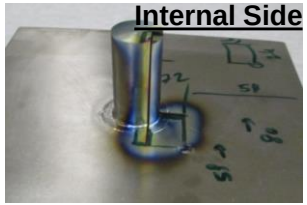


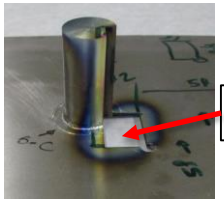
- Brazing
- EB welding

Samples for parameters & qualif. of critical welds **DONE**

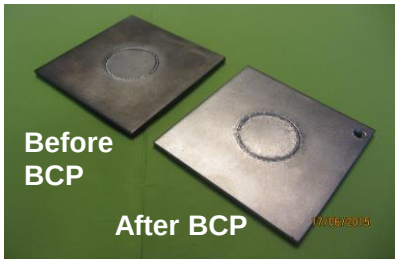
- THE WELDING PARAMETERS FOR BOTH WELDS: **OK**
- VISUAL INSPECTION ACCORDING TO ISO 13919-2 LEVEL B : **OK**
- QUALIFICATION according to EN-15613: Metallographic and Hardness Test **ONGOING**

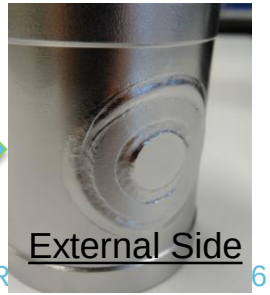
- **W050:** Niobium thickness 2mm. Welding from external side

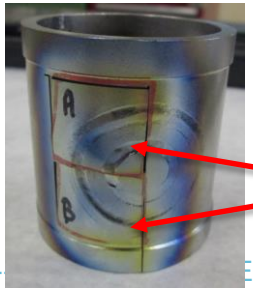




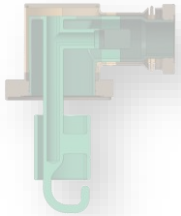
- **W010**: Niobium thickness 3.6 & 4.2mm. Welding from external side







HOM: Conclusions



Machining:

- **all** critical parts **produced**
- pieces **compliant** with specified **tolerances**

BCP:

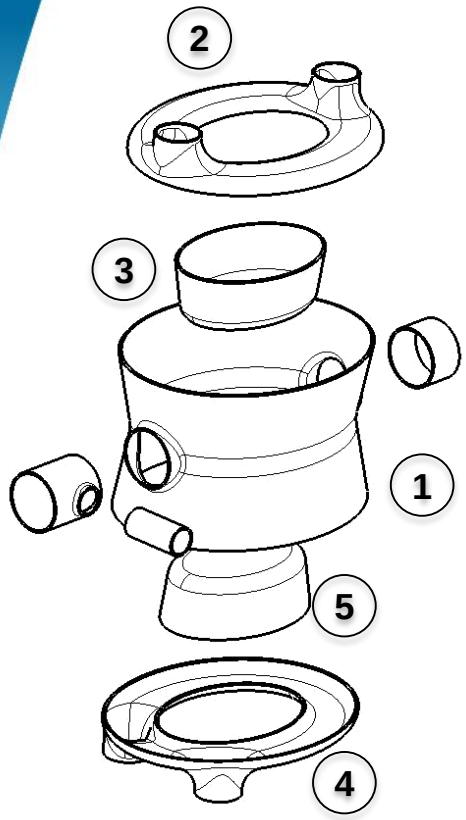
- **variability** on 60um in the order of ±10um
- **no issue** for RF performance
- accounted for on dimensions of coupled elements (e.g. flanges)

Joining:

- **brazing** by end May
- **weld test** of most difficult joints being finalized

Next Steps:

- mid June: finalize qualifications + Proto Welding + Welding

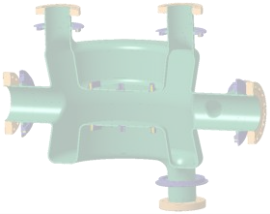


1 Main Body

2 Cap

3 Bowl

Cavity



Manufacturing Strategy

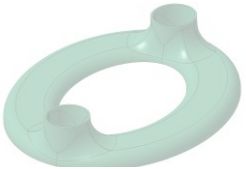
- TESTS:
  - Explore different option in **parallel**
  - Annealed **Cu→ Nb**
  - Circ. TEST / Straight TEST → Ellipt. TEST → Final Design Ready for Prod.

Circular Tests**:**

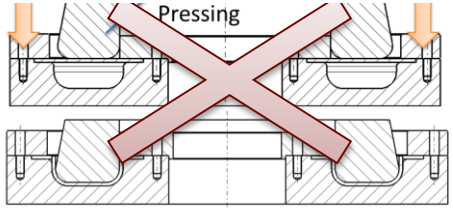
Cheaper & **easier** production for **quicker understanding & ruling out** of non-viable options

20x Tools potentially. Big effort for all stakeholders

Cap

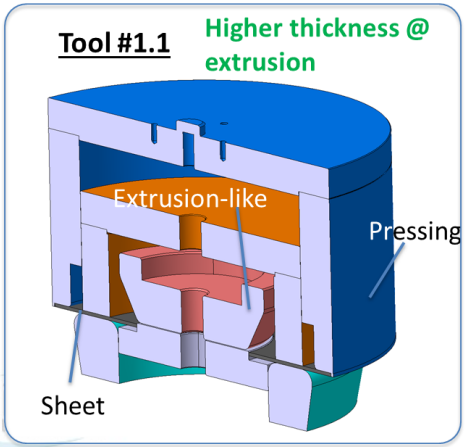


Deep-Drawing Tool



Shape precision VS. Sheet thickness

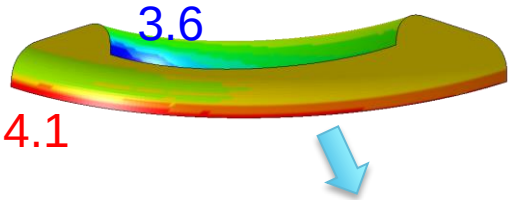
Sheet-Bending Tool

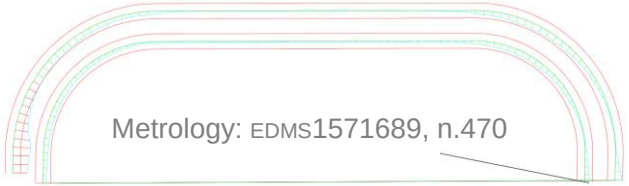


Profile Tolerance inner surface	0.6 [mm]

Shaping + **Punching**	[mm]
Planarity of flat surfaces	**0.04**
Profile error inner surface	**0.4**
Cilindricity	**0.13**
thickness	**~3.6**

LS-Dyna: Nb sheet thickness [mm]

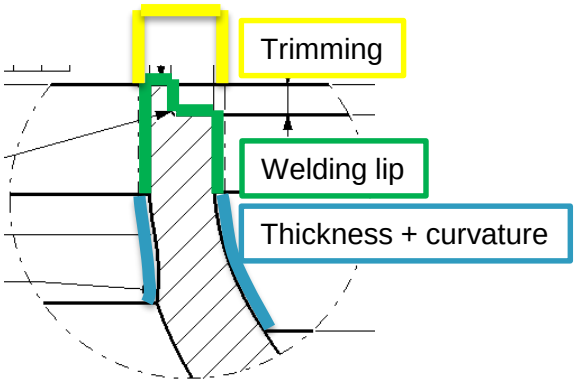




Metrology + Thickness Analysis + FE Calcs
→ Thickness **evaluation for elliptical** shape

Elliptical Tool in production, expected beg June

Cap: Machining Test

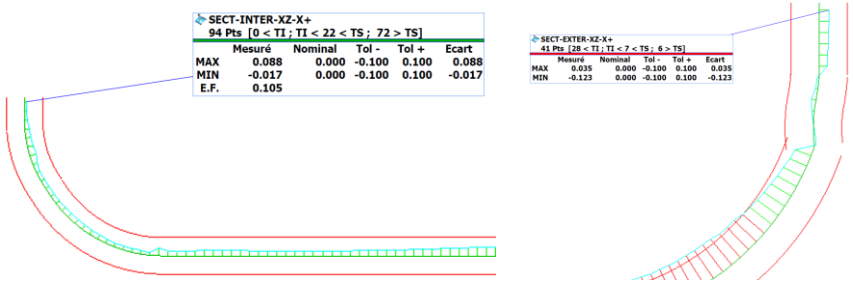


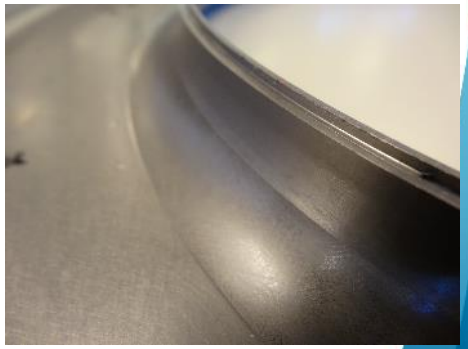
Test on:

- **Inner** & **outer** edges
- Welding **lip**, **butt weld**, **transition** to RF surface

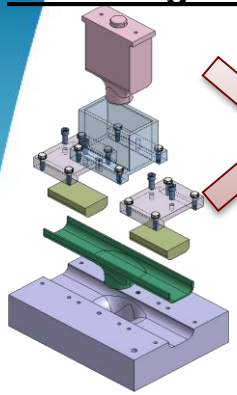
Results:

- Shape accuracy in the order of **few hundredths of mm**
  (ATTENTION: does not correct for planarity/position error after forming)
- **Smooth** continuous transition (no burrs)





Punching Tool



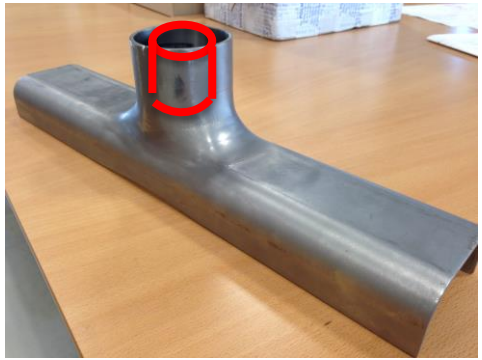
Rupture

Extreme Thickness Reduction

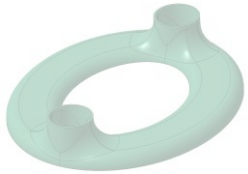
Material Loss

‘Extrusion + Punching’ Tool

Welding of intermediate collar



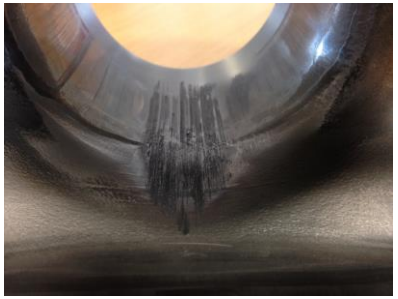
Cap Extrusion

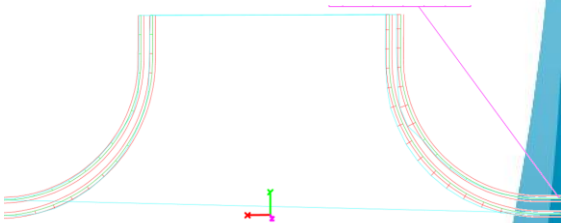


Profile Tolerance inner surface	0.6 [mm]

Shaping + **Punching**	[mm]
Profile error inner surface	<0.6*
thickness	~3.0

*Except local area due to tool nonconformity

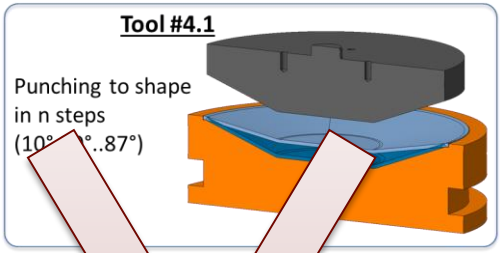




- **Friction** on Nb during last phase of shaping → **CuSn12** & Steel **1.2343** for tools sliding on Nb
- Thickness may be ameliorated via collar dimensions
- STATUS: Elliptical tool in **production**, expected beg. June

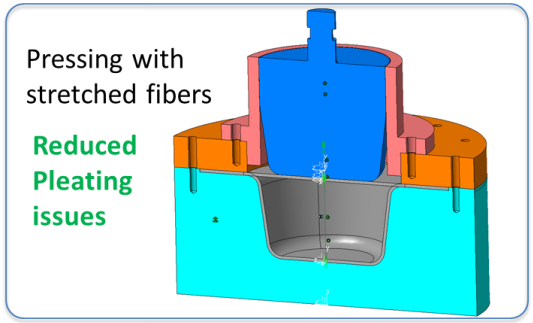
Bowl:

Punching Tool

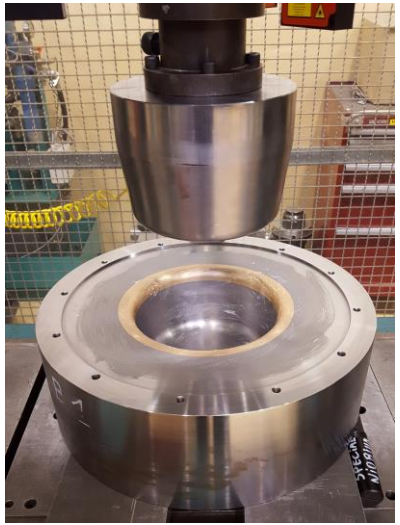


No pl...ng	Mo...ools
no friction	Longer process
Higher thickness w.r.t. tool 2	Intermediate cutting of external edges..

Deep Drawing Tool

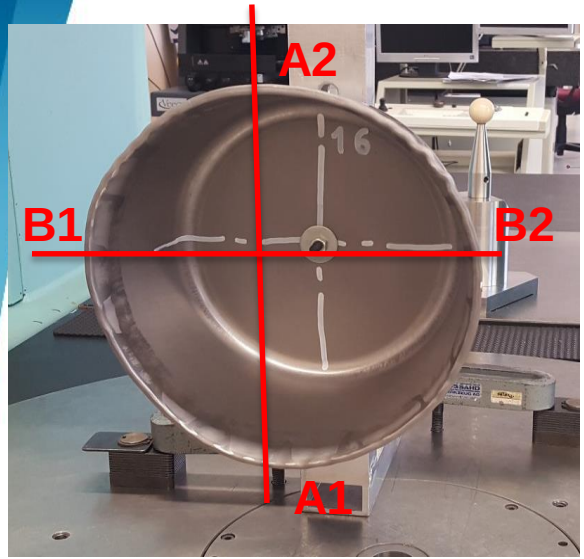


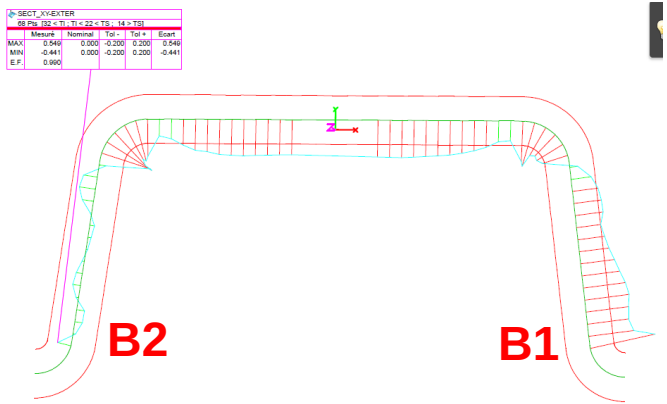
Cu Tests: many parameters permutations (press-pads) for optimal result

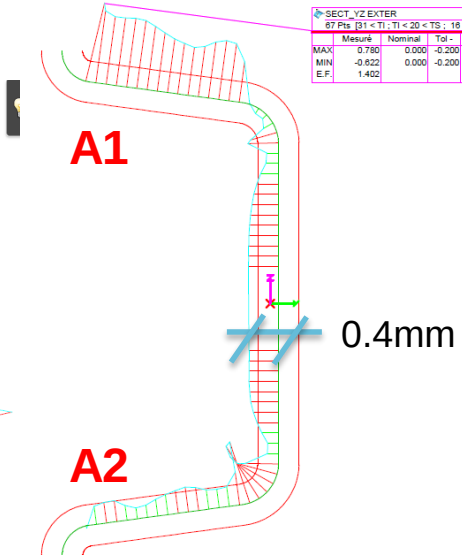


- **Bronze collar** to reduce friction
- Rougness @ **scratches** : Ra1.9 , Rt15

Bowl







Profile Toler. RF surface	0.6 [mm]
Planarity lower RF surface	0.3 [mm]

Only shaping	[mm]
Planarity of flat surface	0.3
Profile error inner surface	Up to ~1mm
Thickness	3.6 @radius

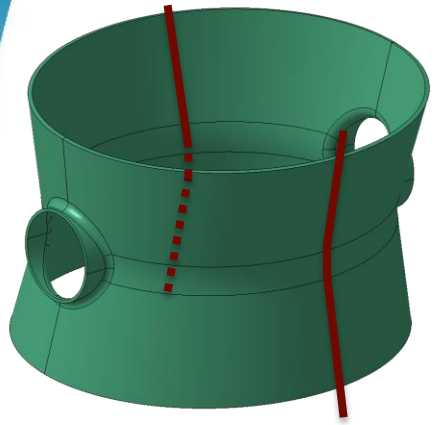
High **non-axisymmetric** results on Nb w.r.t. Cu test → **friction**

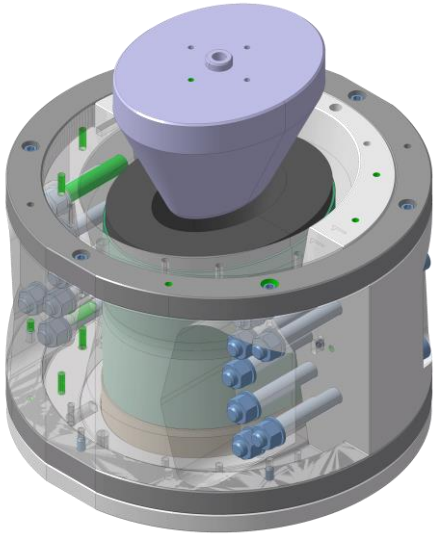
Punching step being performed this week:

- Shall reduce plate flatness (as for Cu test)
- To what extent shall it reduce conical error?

Lower-friction design for elliptical tool

Diabolo





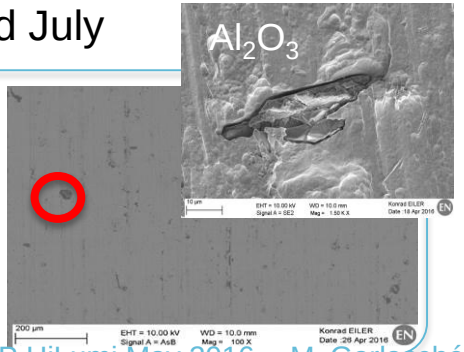
Design Change **2x** longitudinal **welds**

STATUS: All components @ CERN, Cu tests by next week

Extremities

STATUS: production ongoing, ready for welding by mid July

Alumina particles (<=25um) found on sheets by supplier
Effects of BCP and targeted removal **being investigated**
Baseline: material from **2nd supplier** for all upcoming tests/parts
BCP on already-produced parts (i.e. extremities)



BCP-ed HOM Collars

F.E Analyses

Numerical Modelling all main shaping processes (also springback, trimming)

Outputs:

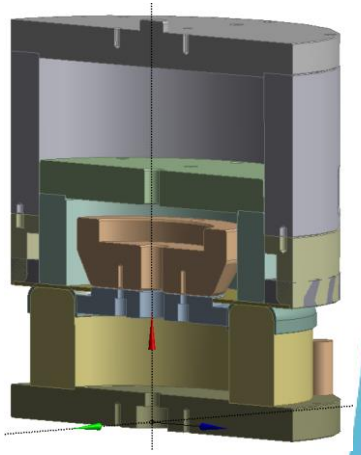
- Process feasibility (rupture, buckling) and parameters (expected loads)
- Process efficiency →tool design
- Thickness

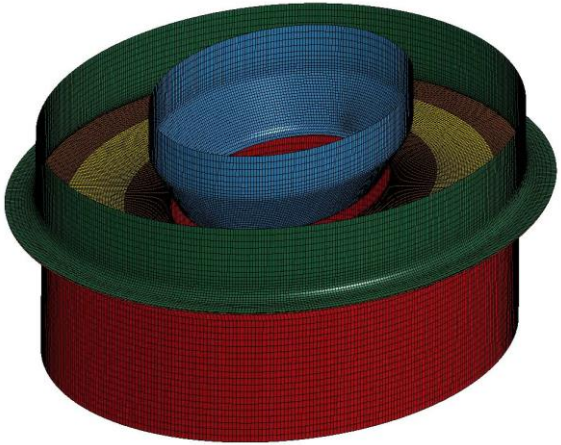
Needed **Inputs**:

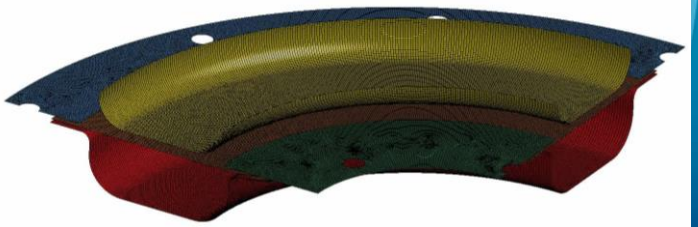
- Material properties

→ Characterization of : Nb, polymers

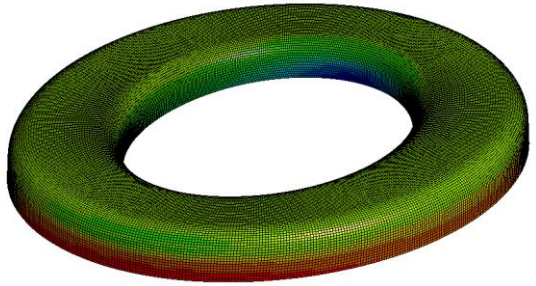
Elliptical Cap

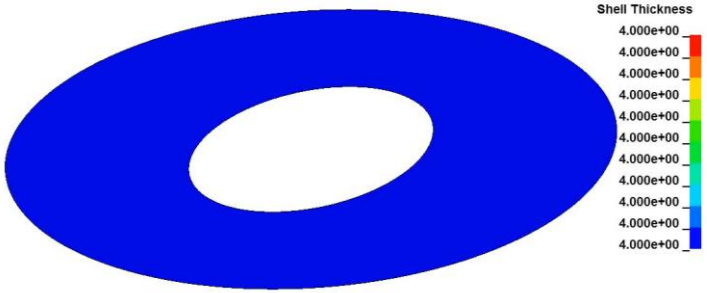




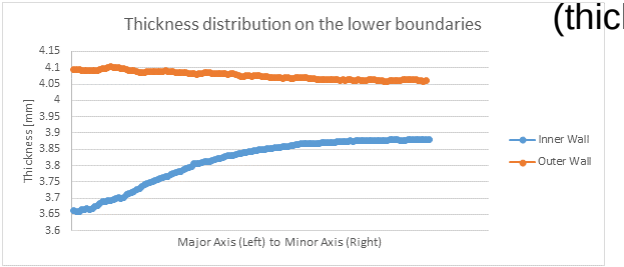


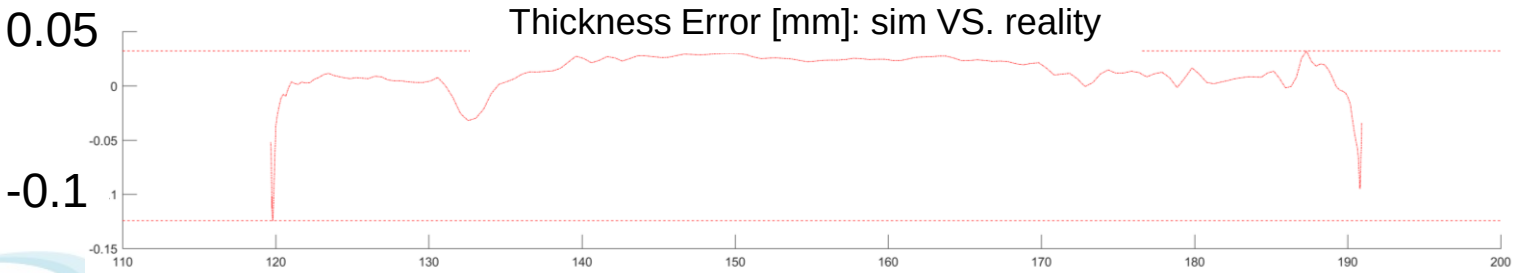
F.E Analyses: Cap Results



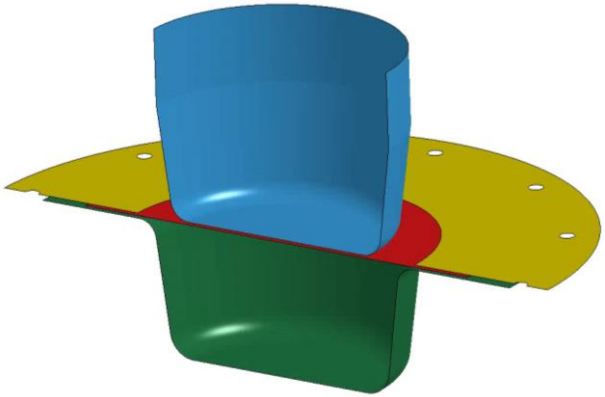


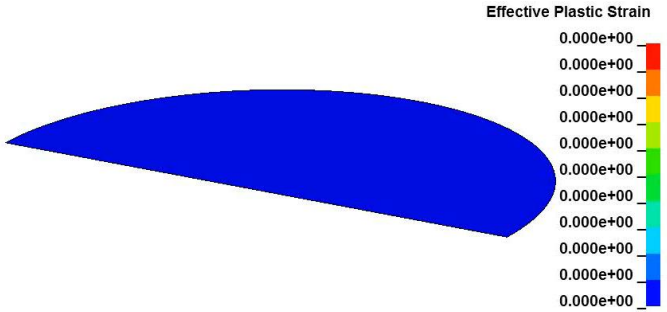
Sheet metal forming (thickness)

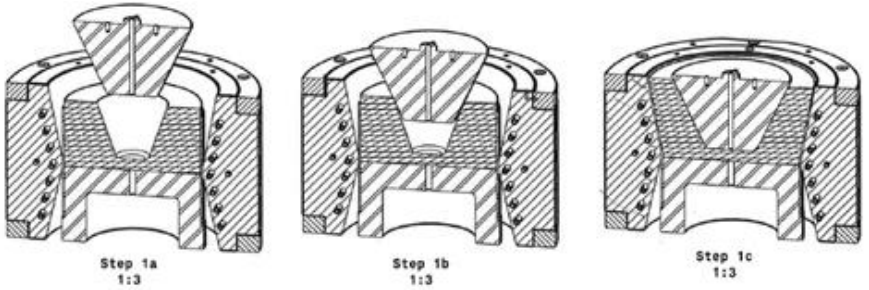


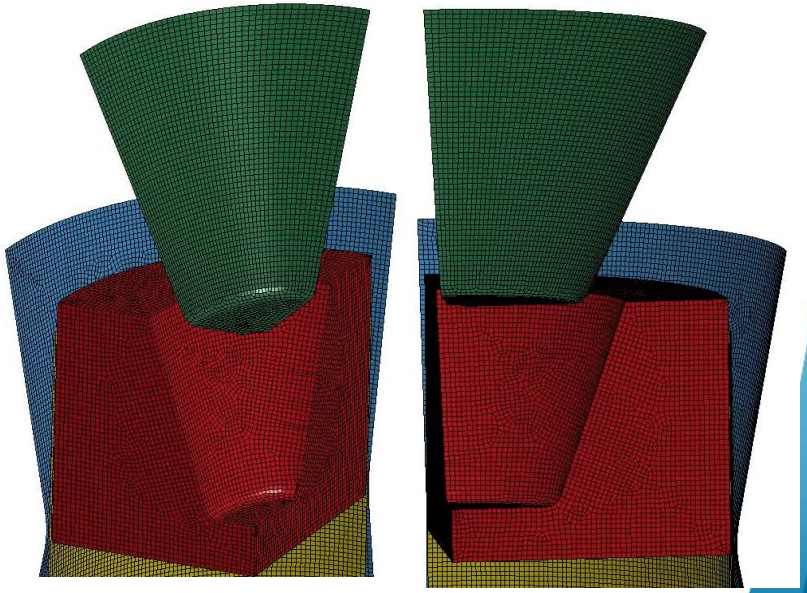


F.E: Main Body & Bowl

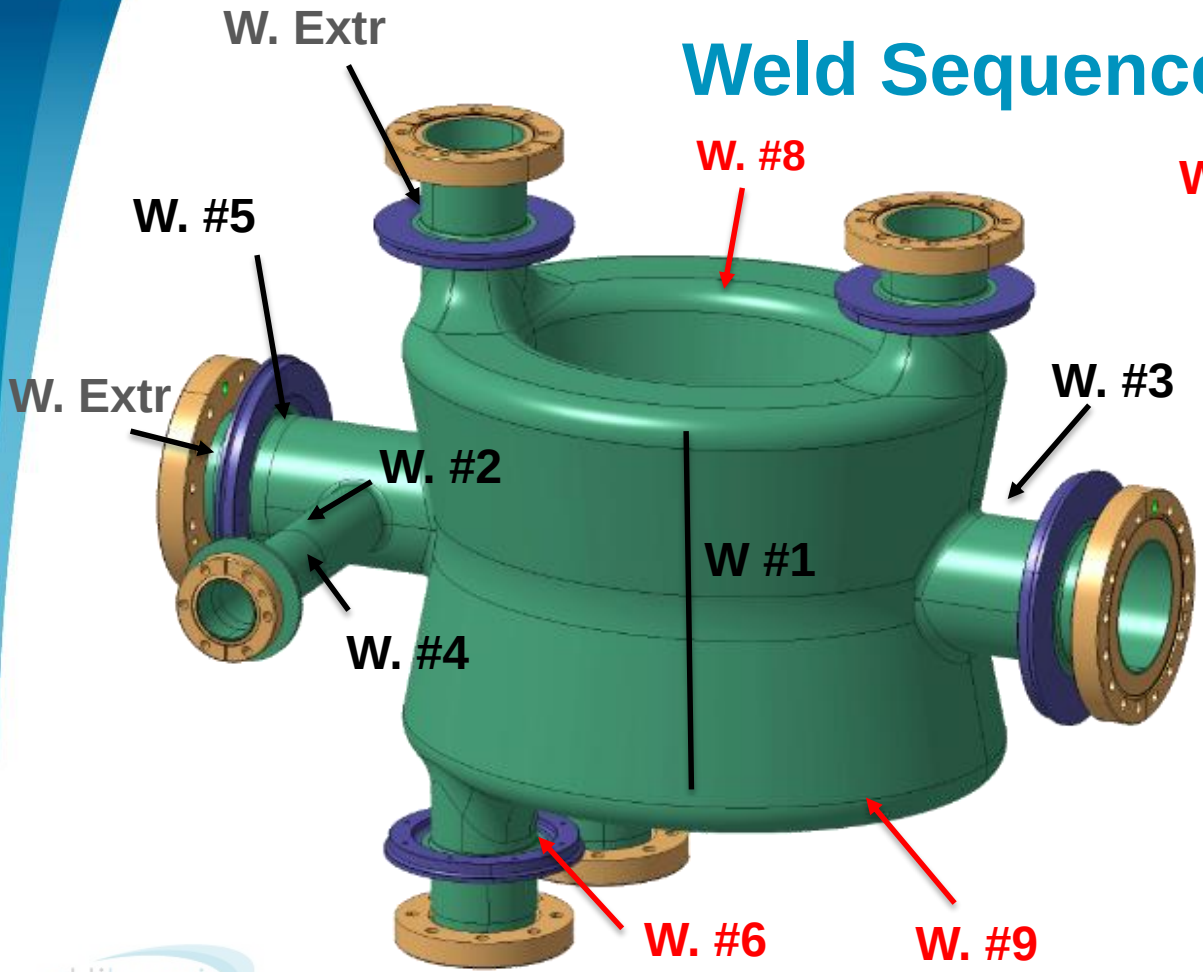


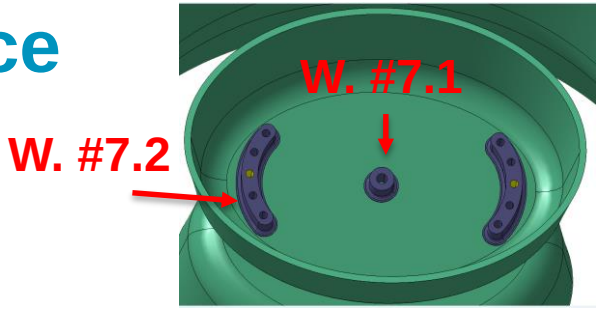






Weld Sequence





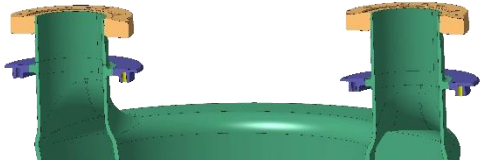
Critical Welds:

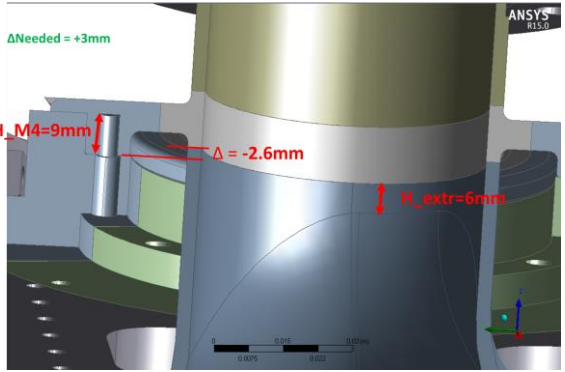
- Extremities on Cap (#6) [thck=3mm]
- Elliptical Cap & Bowl on Diabolo (#8-9) [thck=3mm]
- Half-Moons: Nb/NbTi (#7) [thck=2mm]

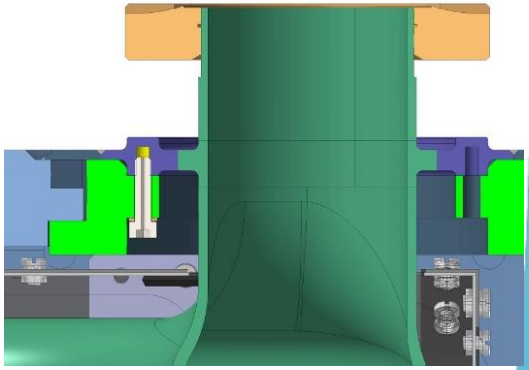
Cavity - Extremities

Welds #6

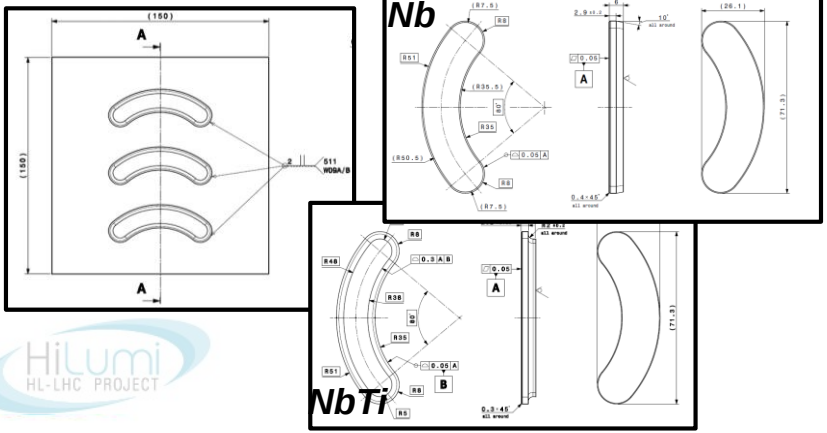
- **Staggered** weld sequence, with dedicated tooling
- **Design modification** to facilitate weld of Extremities to Cap



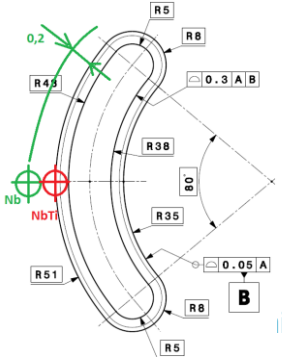




Welds #7.1 & 7.2



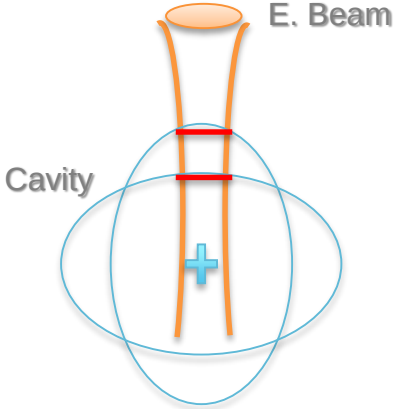
Both Nb and NbTi Half Moons to be tested
Currently developing of a program to follow the shape



Cavity - Extremities

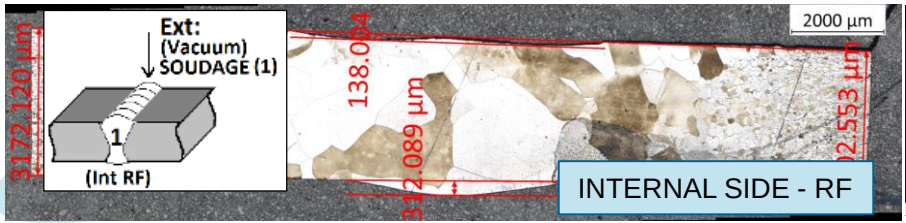
Welds #8 & #9

- Dedicated **circular and elliptical tests**
- Baseline: beam parameters w. **large acceptance**
- Options: transversal movement, change of focus
- Finalizing test equipment now



- Linear weld tests performed
- Two configurations: Key (*Clé*) and Butt Weld (*Bords droits*)

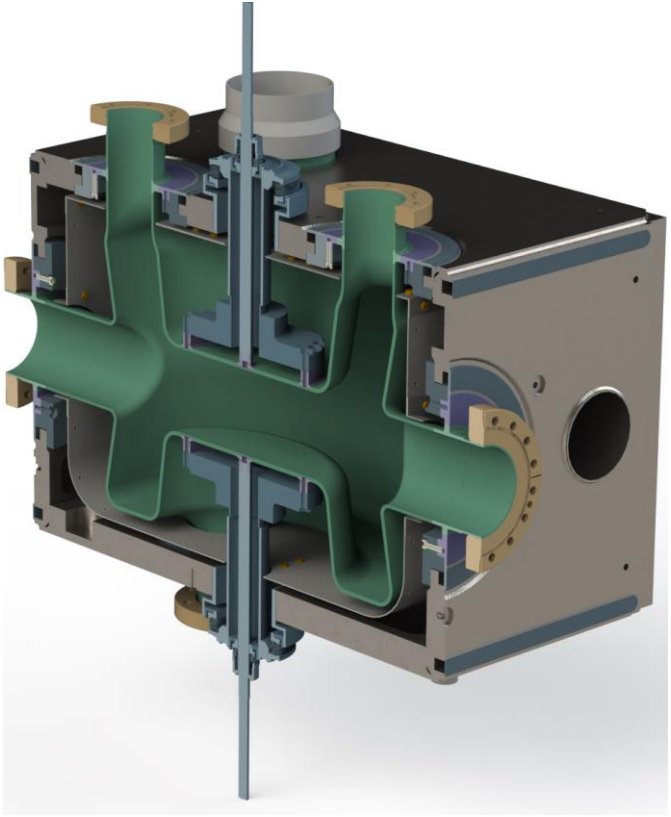
> ➢ BOTH CONFIGURATIONS WITH SATISFACTORY RESULTS
> ➢ NO VOLUMETRIC DEFECTS FOUND
> ➢ WELDING IMPERFECTIONS COMPLIANT WITH ISO 13919-2 LEVEL B



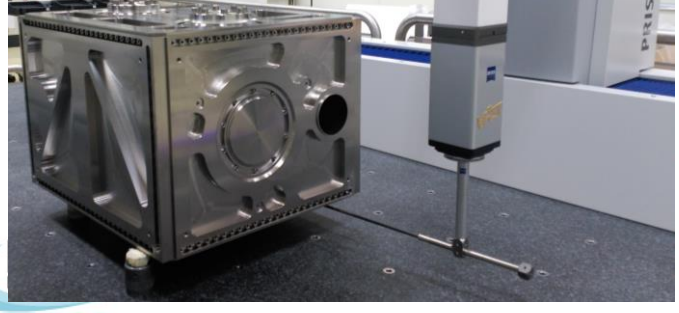
Cavity: Conclusion

- Initial ‘circular’ phase concluded (Copper & Nb)
  - Very good results for cap and extrusion
  - Watch out for Main Body & Cap (friction)
- Main parts Production in line with schedule (caveat: no major showstoppers during elliptical phase)
- Planning Milestones:
  - Extremities ready for EB @ mid/end July
  - Cavity parts shaped by summer
  - …
  - Beg. 10/2016 : main parts welded for RF
  - End 11/2016: 1st cavity ready
  - Beg 01/2017: 2nd cavity ready
- Al_2O_3 issue being addressed

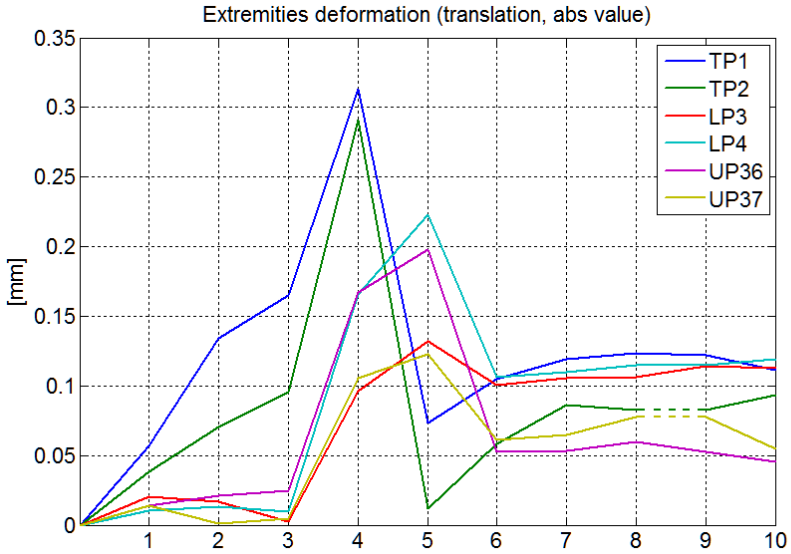
Helium TANK



Tank: Weld Test

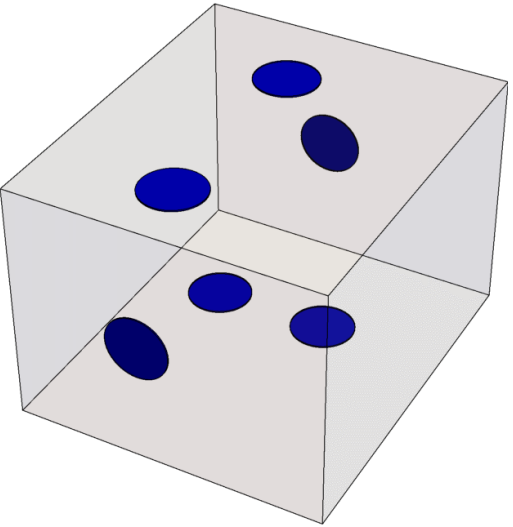


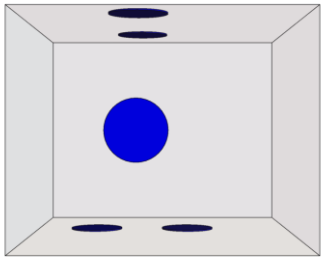
- TIG Welding of Titanium tank under protective atmosphere
- Iterative weld + metrology steps
- Maxima deformations: 0.3mm along cavity beam axis

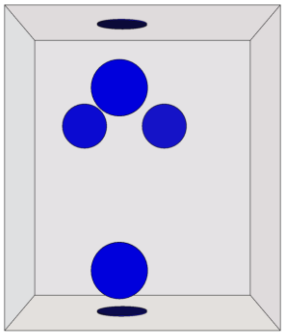


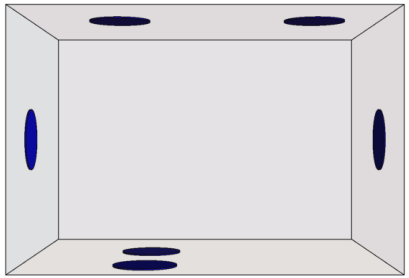
1. Tank after assembly (screws tightening)
2. Vertical (i.e. along z) welds
3. Welds around the top plate
4. Welds around the bottom plate
5. Longitudinal covers
6. Circular covers on interfaces on cavity beam axis
7. Circular covers on top and bottom faces
8. Second beam tube
9. Pressure test
10. Thermal test

Weld Results







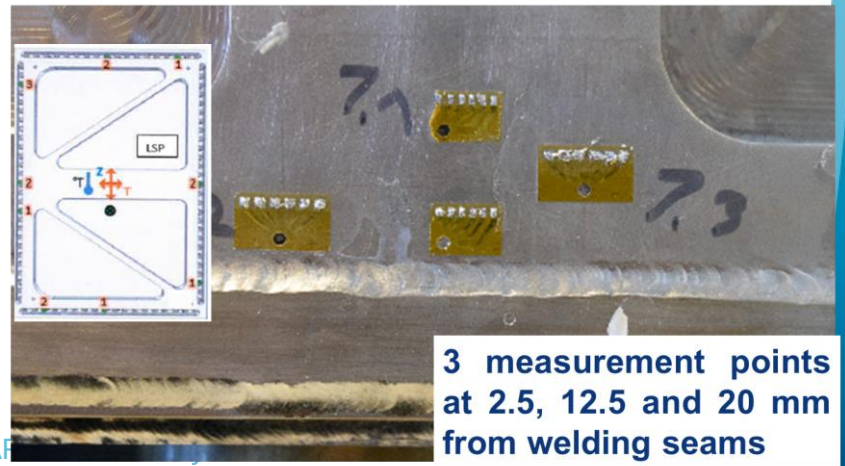


Highest deformation (0.3mm):
@ Beam Axis after top/bottom plates' weld;
cavity may still not be joined to tank

Feedback for minor redesign of weld joints: better accessibility, lower deformations

Stress @ weld (study ongoing):
Ti near to yield @ 2.5mm, well below yield @ 10mm

Comparison of Principal Stresses Along Depth – 2.5, 12.5, 20 mm from welding



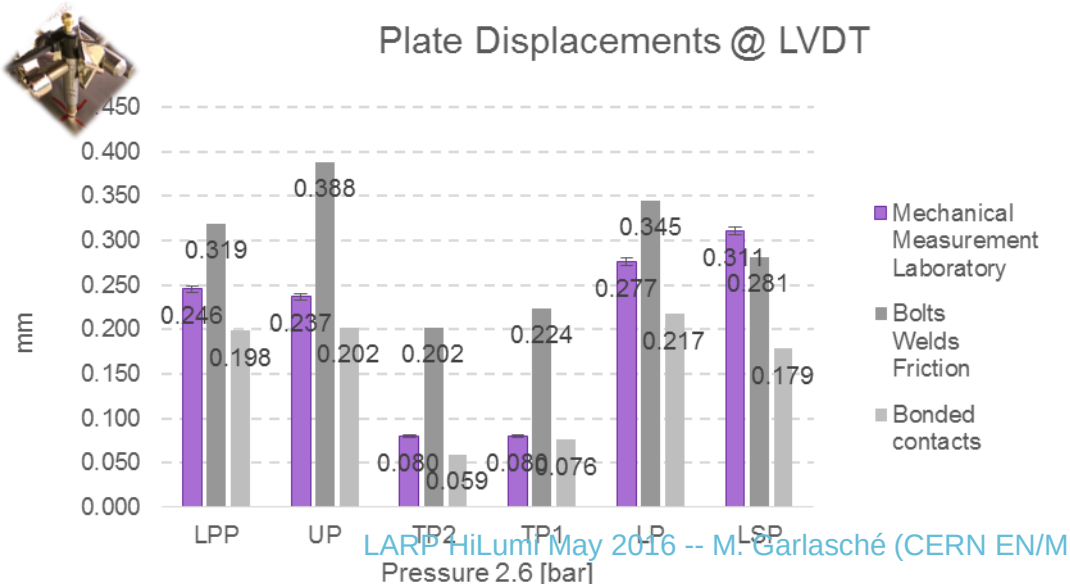
Pressure Test

Test @ p=2.6 bar

Load increment on screws not critical

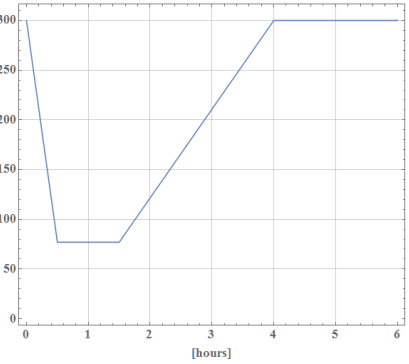
Validation of F.E. model for assembly and weld/screw behaviour

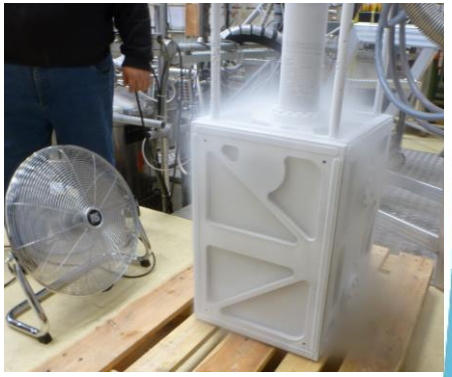
Defined preload sufficient to avoid failure of weld (no leaks / hysteresis effects on geometry)



Cold Test

- 5 cycles, LN2 bath
- *Vacuum* inside the tank

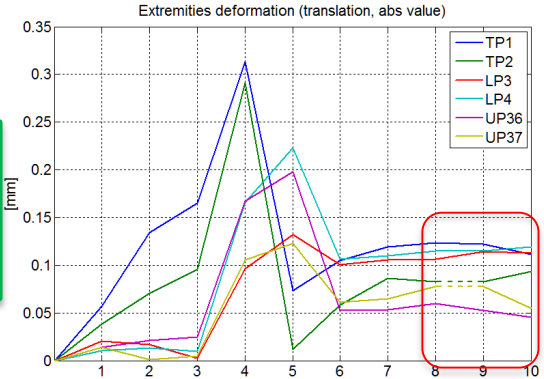




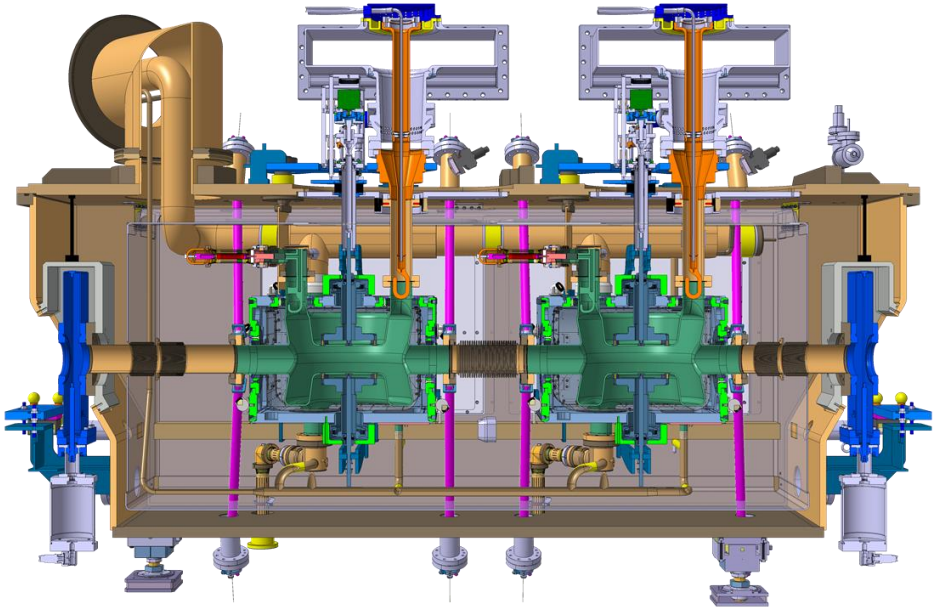
Validation of analytical model for screw preload and its evolution during Cooldown

Defined preload sufficient to avoid ‘opening’ of interfaces during cool-down

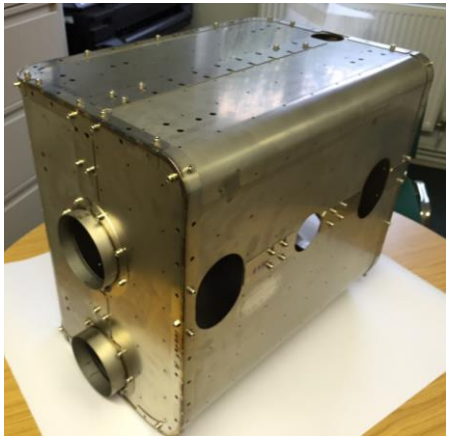
No hysteresis effects (i.e. yield) on geometry (especially @ Cavity interfaces)
Vacuum tight after all welds and cold + pressure test

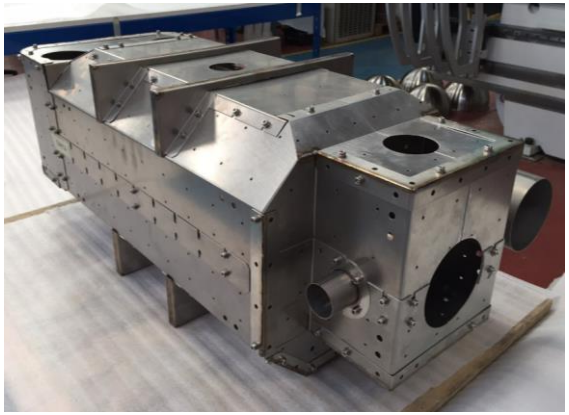


Magnetic Shields



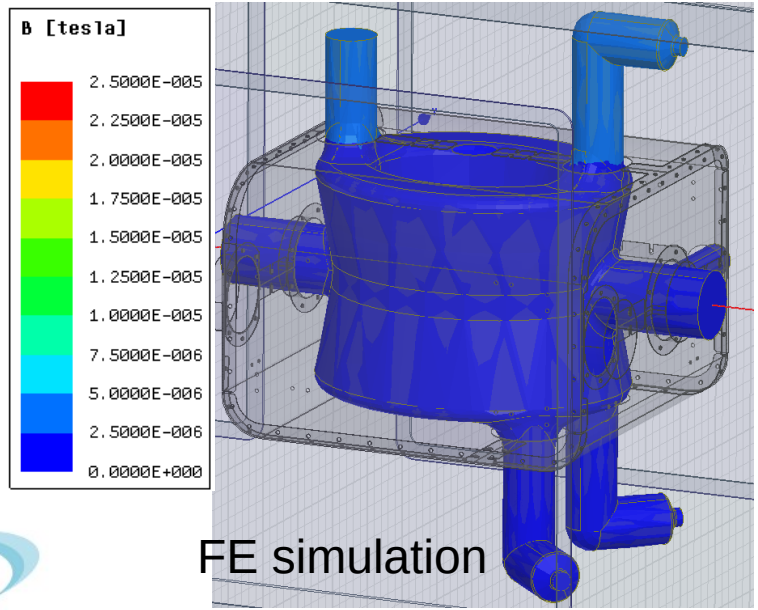
Courtesy STFC Daresbury



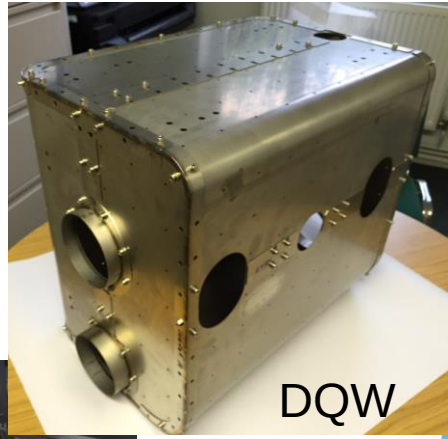


Cold Magnetic Shield

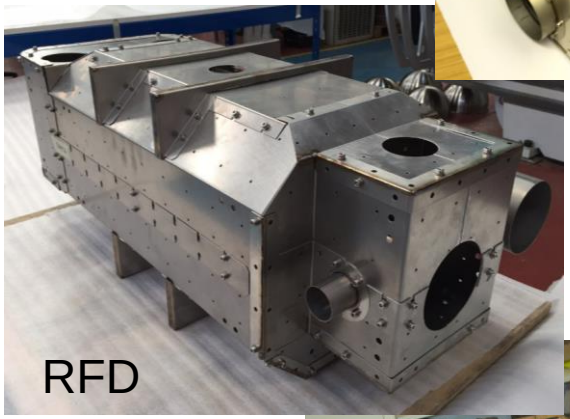
- 1 mm Cryophy, annealed
- Shield currently @ CERN
- Dimensional controls (+ magnetic measurements) foreseen



FE simulation



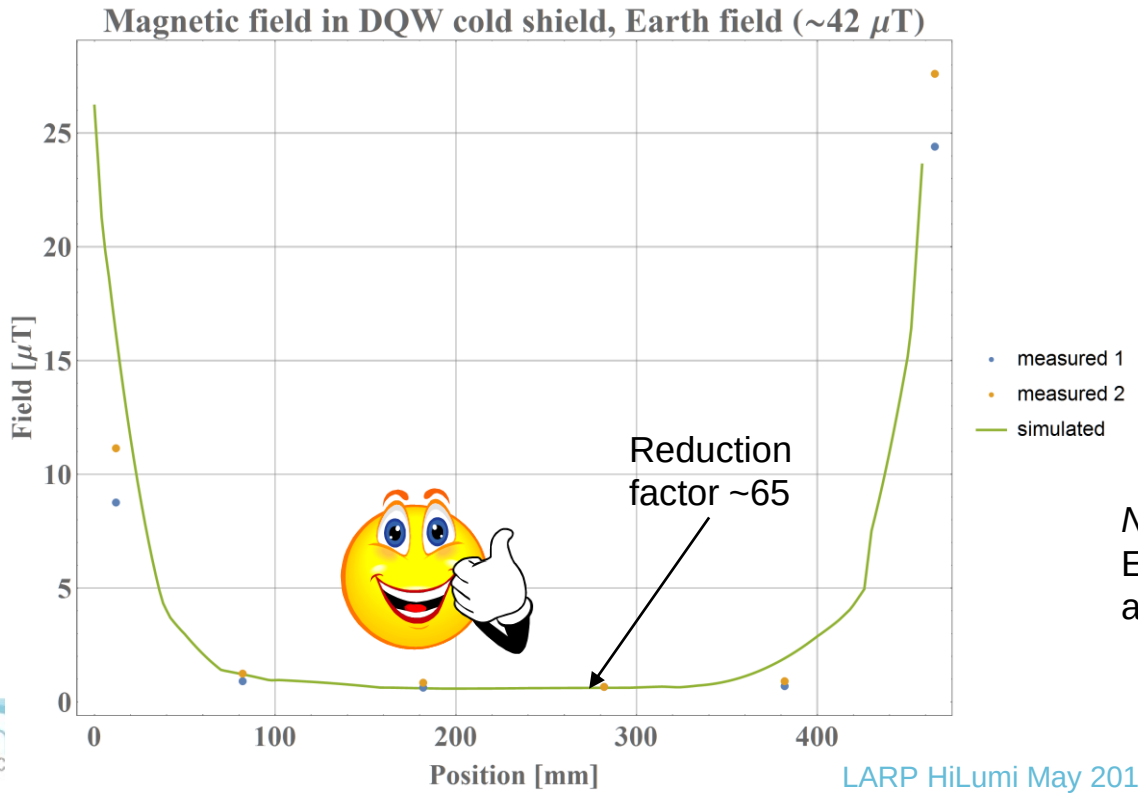
DQW

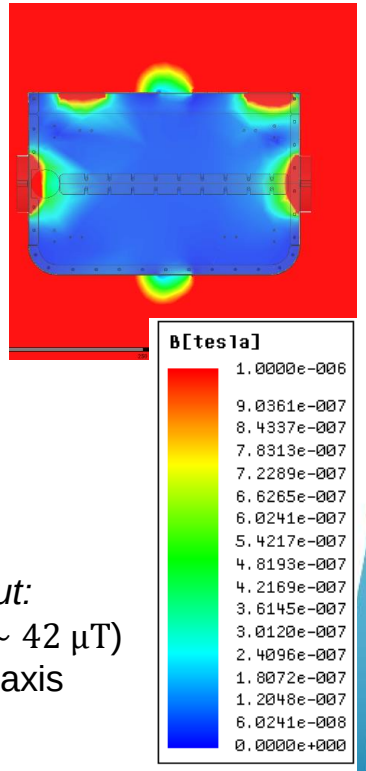


RFD

Comparison of Data and Simulations

Coherent values between requirements, measurement and FE data

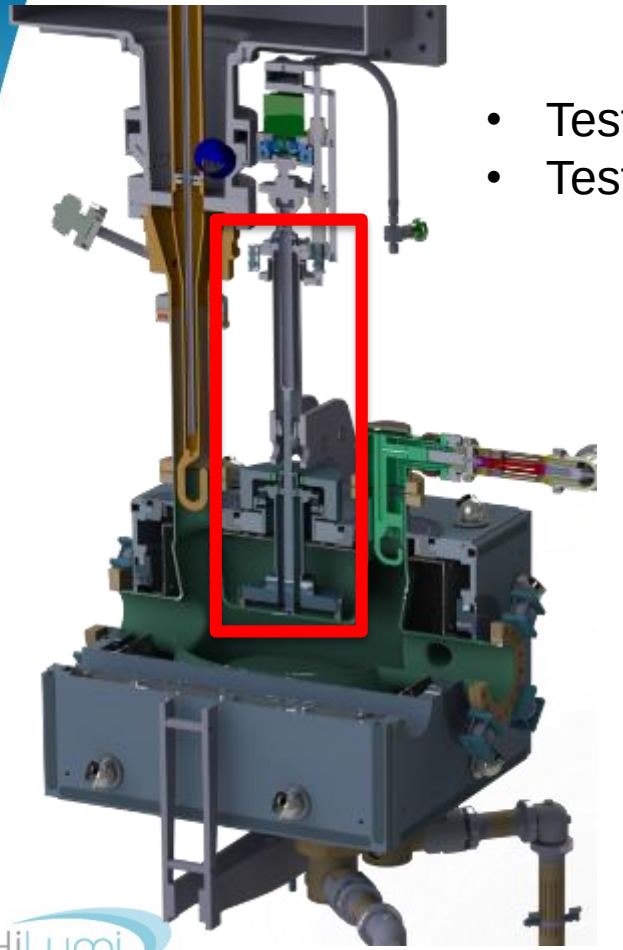


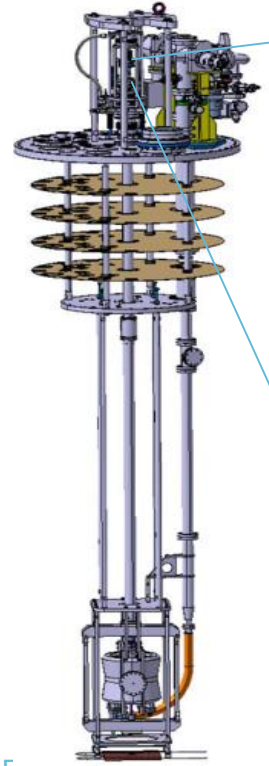


Nominal input:
Earth field (~ 42 μT)
along beam axis

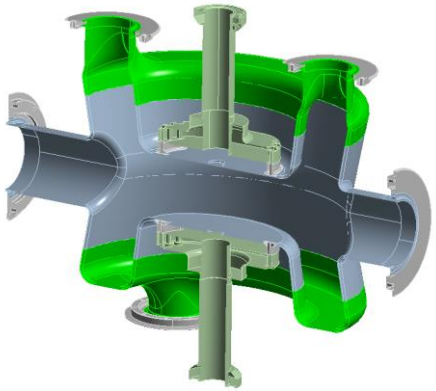
Tuner

- Tests & characterization of linear motor performed
- Test @ SM18: → ppt by A. Castilla

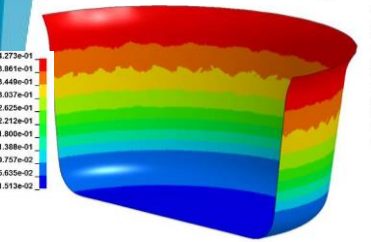


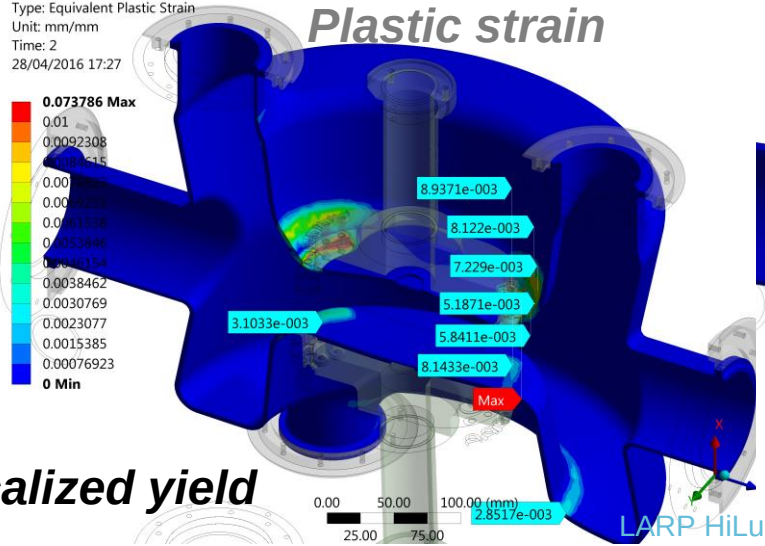


Structural assessment

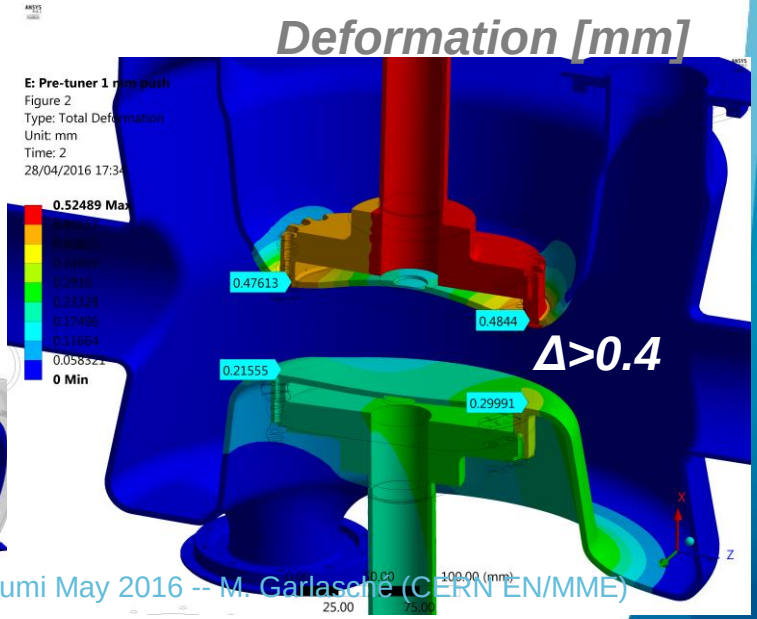


- The frequency range provided by the pre-tuner is currently limited (~200 kHz)
- New procedure explored, that would allow a larger range: pre-tuning load released before cool-down (i.e. before p_{HE}=1.8 bar)
- Calcs: F.E. plus analytical (weld). Also considering Nb hardening due to deep drawing process





Plastic strain

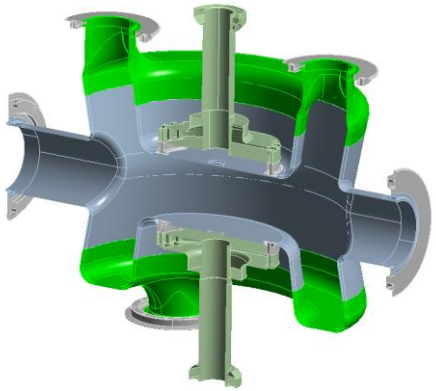


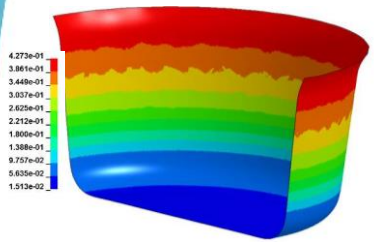
Deformation [mm]

Δ>0.4

Localized yield

Structural assessment





New procedure would allow more than twice the tuning range

Limiting factors are the stress in the NbTi tab and in the weld

Applied δ	Residual δ +	Residual δ -	Max plastic ε*	Max elastic σ**
-5 mm	-4.6 mm	-3.8 / -4.1 mm	~7 %	690 Mpa
- 2 mm	-1.4 mm	-1 / 1.29 mm	~3.5 %	560 MPa
-1 mm	-0.49 mm	-0.23 / -0.29 mm	~0.9 %	460 MPa
-0.7 mm	-0.22 mm	-6e-2 / -8e-2 mm	~0.4 %	395 MPa
0.7 mm	0.21 mm	6e-2 / 8e-2 mm	~0.4 %	400 MPa
1 mm	0.45 mm	0.22 / 0.29 mm	~0.85 %	480 MPa
2 mm	1.43 mm	1 / 1.36 mm	~ 3 %	550 MPa
5 mm	4.35 mm	3.5 / 4.9 mm	~9 %	650 MPa

* far from weld

** in the NbTi tab, peak stress, limit: 480 MPa

General Conclusions

CAVITY

- Initial **'circular' phase concluded** (Copper & Nb)
- Main parts Production in line with schedule (caveat: no major showstoppers during elliptical phase)
- Planning Milestones:
  - End 11/2016: 1st cavity ready
  - Beg 01/2017: 2nd cavity ready
- Al_2O_3 issue being addressed

HOM

Machining:

- **all** critical parts **machined**
- pieces **compliant** with specified **tolerances**

Next Steps:

- mid June: finalize qualifications + Proto Welding + Welding

TANK

- **No plasticization + Vacuum tight** = design and process validated
- Info for numerical modelling of tank joints + weld optimization

Thanks!!