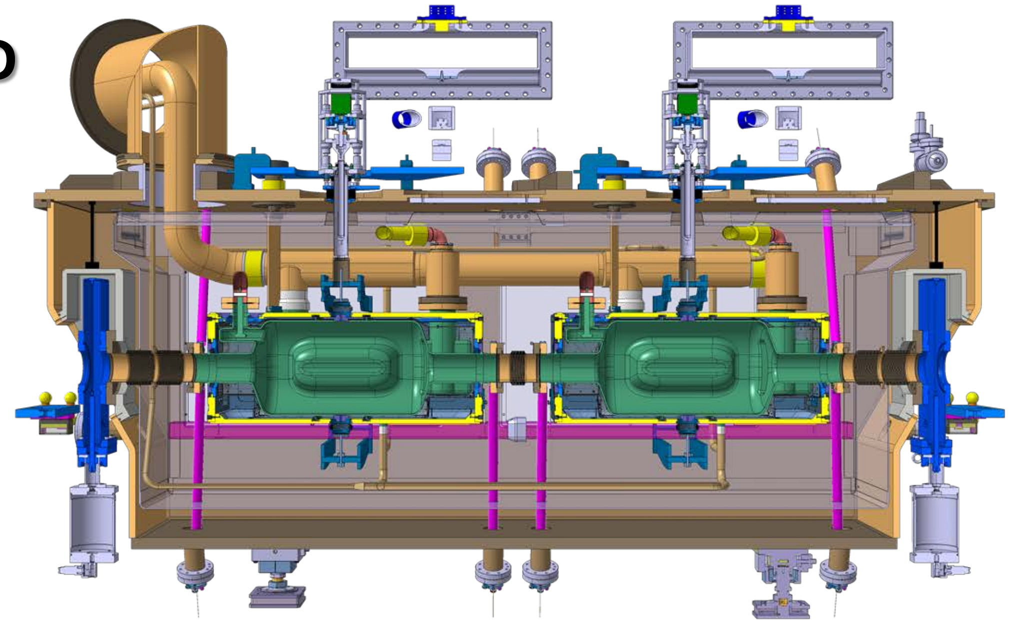
HOM:
Review of Design & Production Status

M. Garlaschè
on behalf of CRAB Collaboration

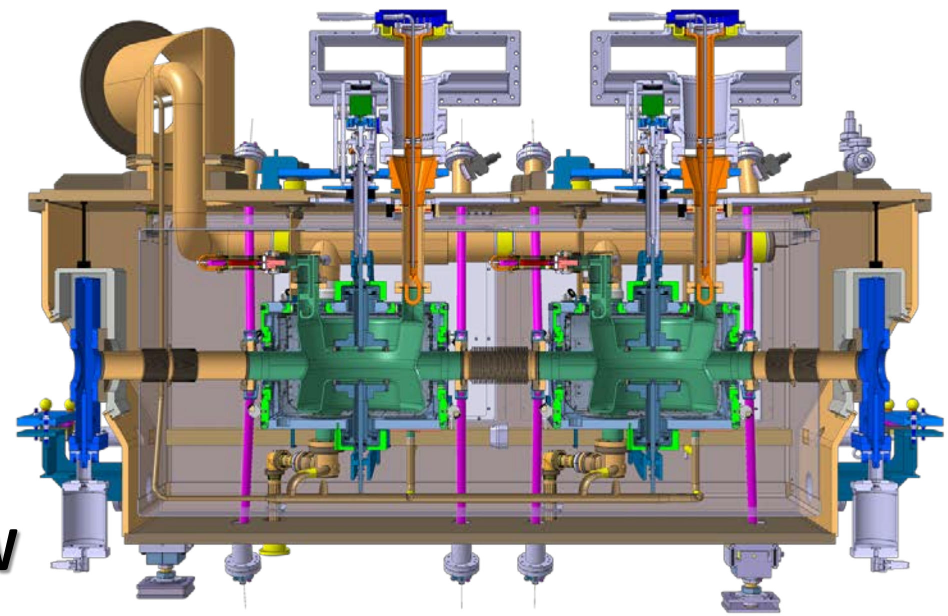
The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

Outline

RFD



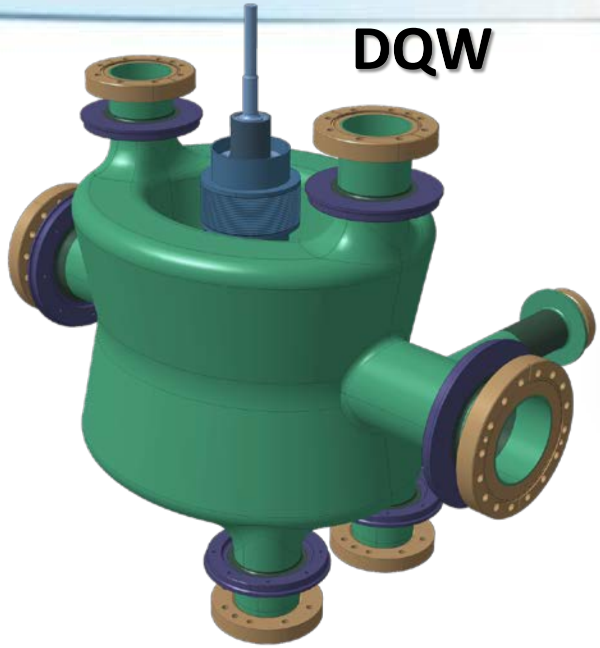
- Introduction
- Calculations
- Production Update

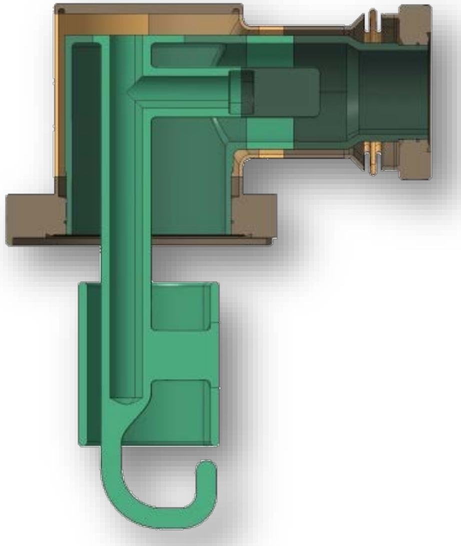


DQW

CRAB HOMs

DQW

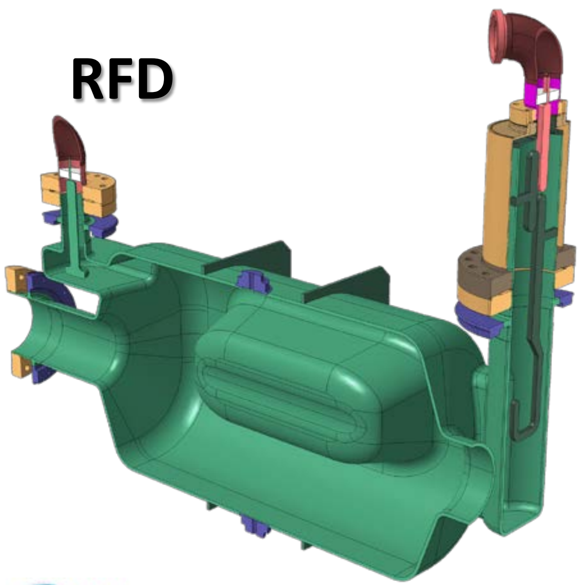


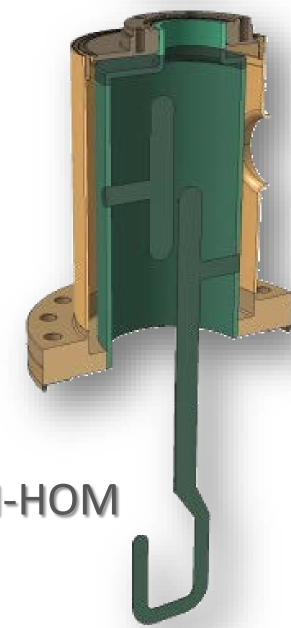


Aim: damp detrimental modes with frequencies higher than the fundamental one (400MHz)

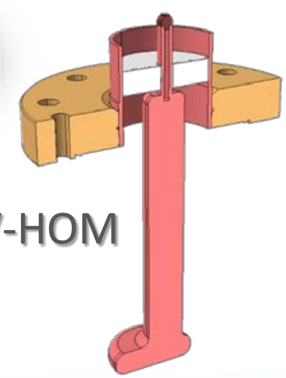
- Three HOM in DQW, two for RFD
- Bulk Nb antenna, He-cooled
- Coaxial lines evacuate 1 kW/HOM

RFD

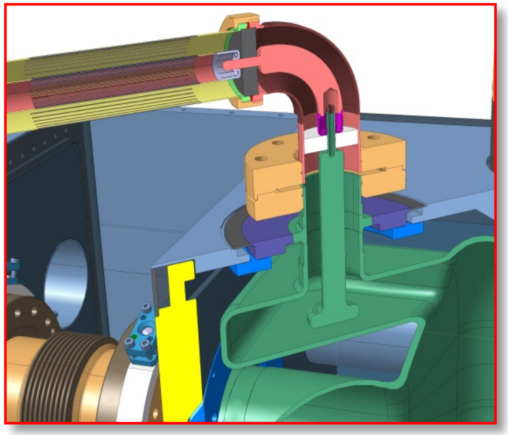




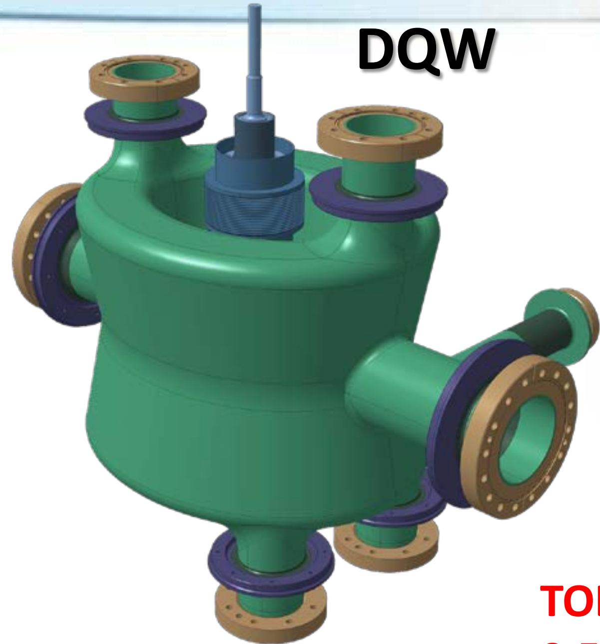
H-HOM

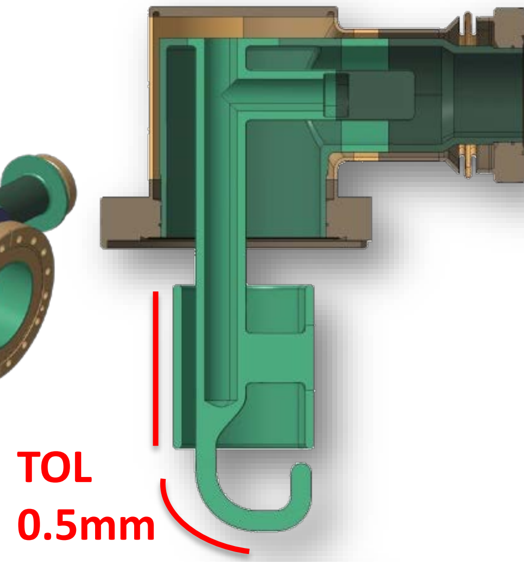


V-HOM



HOM Calculations





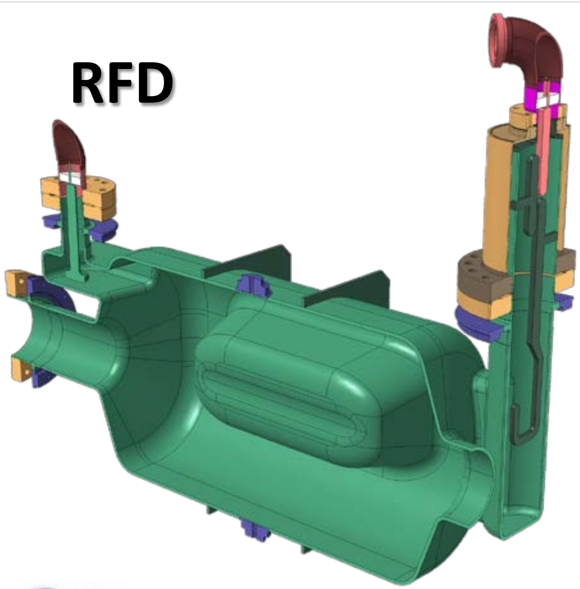
Thermal:

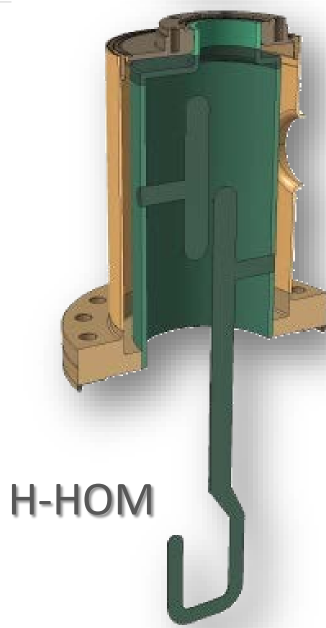
- Quench Power Limits
- Coax Cable Heat Losses

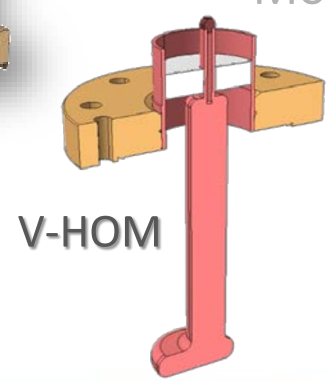
See presentation by E. Montesinos & by F. Carra

Thermo-Structural:

- Resistance to loads & maximum deformation in cool-down & working condition
- Modal performance



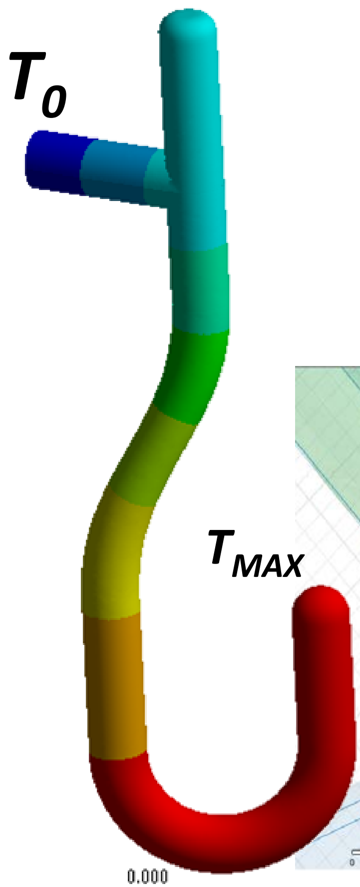




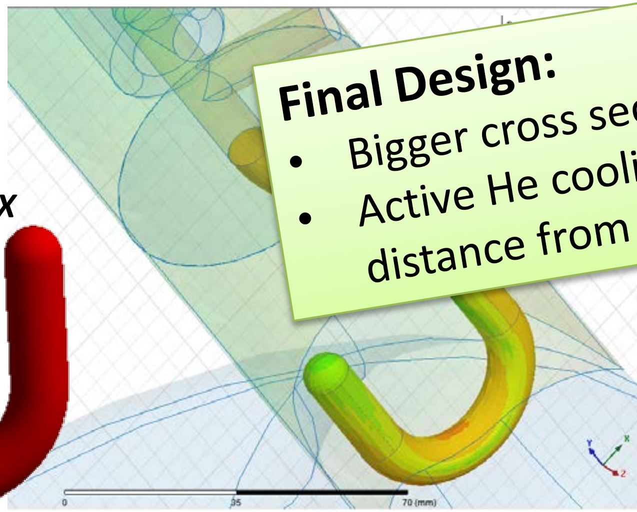
HOM Review, 25th Feb 2015

DQW: Thermal Calcs

Temp. Gradient



- Iterative lumped calculation HFSS/ANSYS, to assess HOM temperature distribution
- $Rs_{Nb} = f(T)$; $\lambda_{Nb} = f(T)$
- Initial DQW geometry (**No active cooling**)



Courtesy S.Verdu Andres - BNL

Final Design:
- Bigger cross section
- Active He cooling @ 2K : 100 mm distance from tip

…ions studied

[illegible]	[illegible]	[illegible]	T_{MAX} [K]	P_{RF} [mW]
[illegible]	[illegible]	-	3.1	5
2	f(T)	380	3.4	9
2	f(T)	40	X	
4	f(T)	300	4.8	35

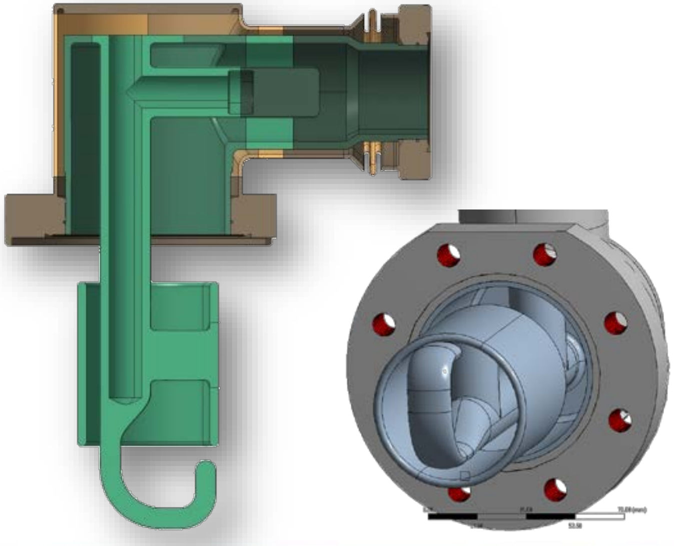
Cu option **not viable**
RRR > ~250, for acceptable λ_{Nb}

DQW: Thermostruct. Calcs

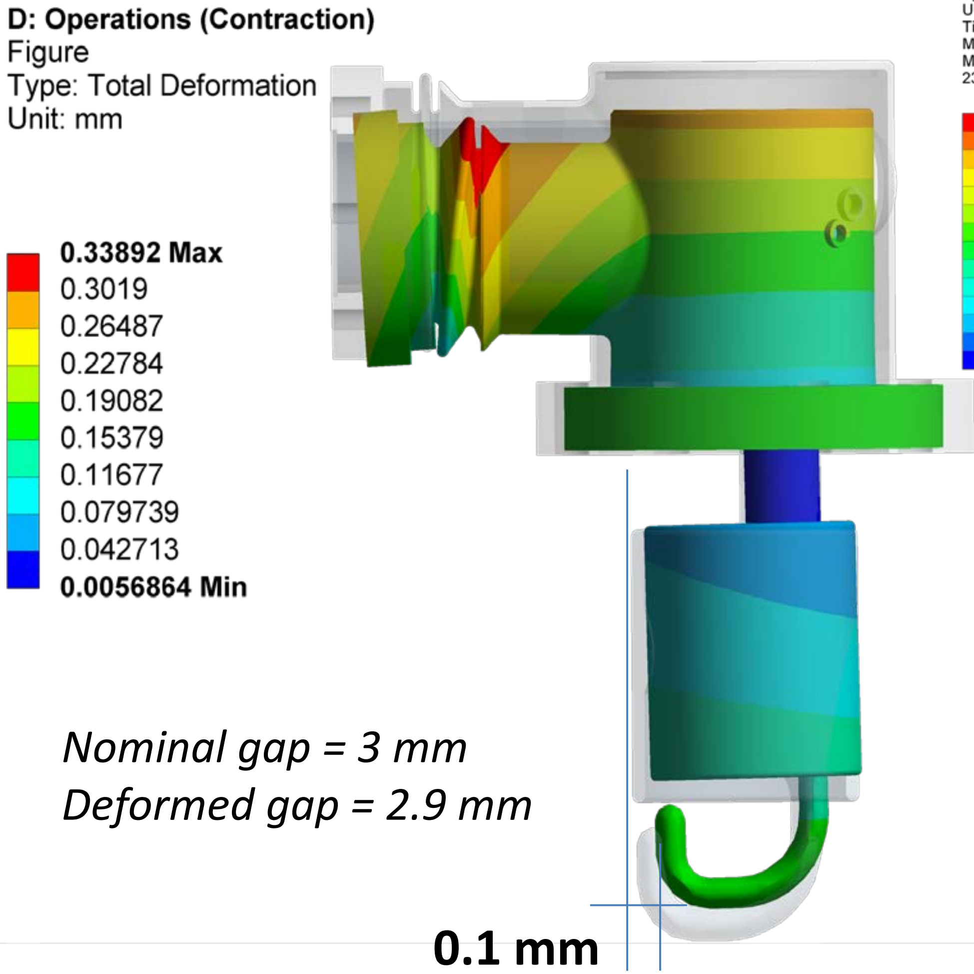
	Load Value	Verification criteria
Normal Operation (Load Case #1)	**No** pressure Thermal Contraction: **300K → 2K** Coax Line: **20 N**	**Displacement** of the hook (wrt the flange). Total budget 0.5 mm
Maximum Stress (Load Case #2)	Internal He pressure: **0.18 MPa** Thermal Contraction: **300K → 2K** Coax Line (w/ margin): **50 N**	**Yield** strength at 2K
Maximum Stress (Load Case #3)	Internal He pressure: **0.18 MPa** Coax Line (w/ margin): **50 N**	**Yield** strength at 300K

Further Assumptions:

- Nb-316LN **welds not modeled** (*bonded contact* in the flange internal cylinder).
- Uniform temperature.
- **Neglected temperature dependence** of Elastic modulus and Poisson's ratio.



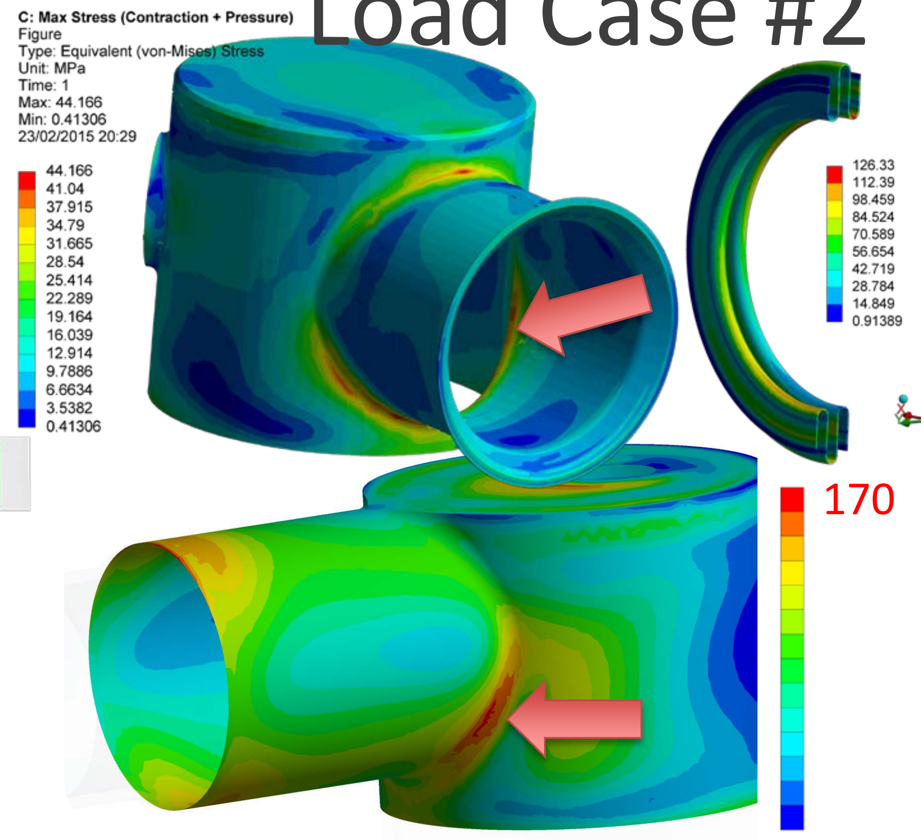
Load Case #1



Nominal gap = 3 mm
Deformed gap = 2.9 mm

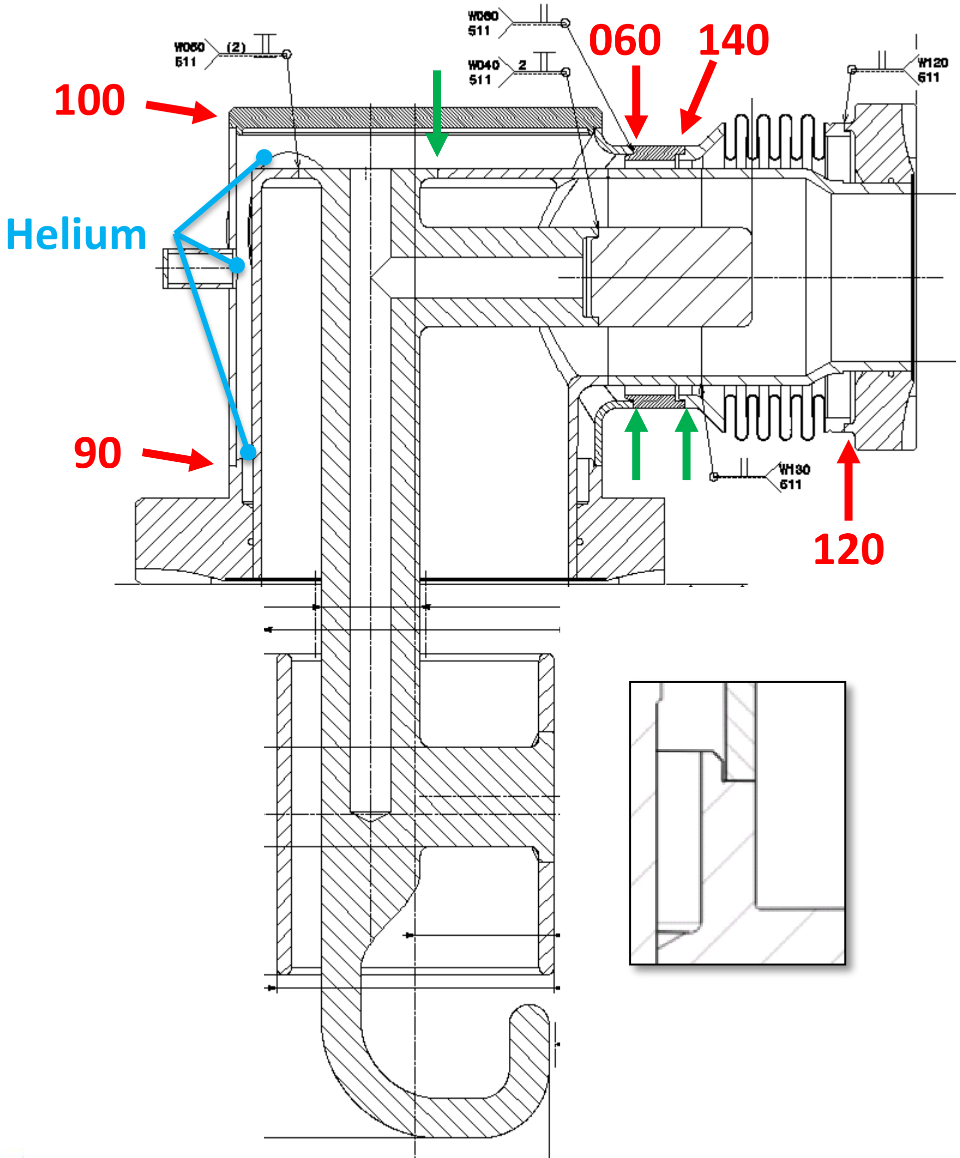
Elastic displacement – **Acceptable**
NOTA: Fabrication dimensions scaled w.r.t bulk temperature difference

Load Case #2



Part	σ_{EQ_MAX} [MPa]	σ_{Yield} / 1.5 [MPa]
SS	170	547[5]
Bellows	126	320 [6]
Nb	80	320[5]

Joints Evaluation: Pressure



Nb & SS welds : **EB weld**
Nb/SS joints : Cu-base **brazing**

Nb Welds: 100% full penetration
SS Welds: backing strip for protection of Nb components

SS welds @ LOAD CASE #2

Weld #	Peak Stress
090	190 MPa
060	402 MPa
140	139 MPa
100	338 MPa
120	76 Mpa

$R_{p0.2}/1.5 = 547$MPa

Nb: P.E. Compliant
SS: comfortable safety factor

Ref. 'ENGINEERING DESIGN AND PROTOTYPE FABRICATION OF HOM…' C. Zanoni et al. SRF2015

DQW Calculations: Remarks

Thermal

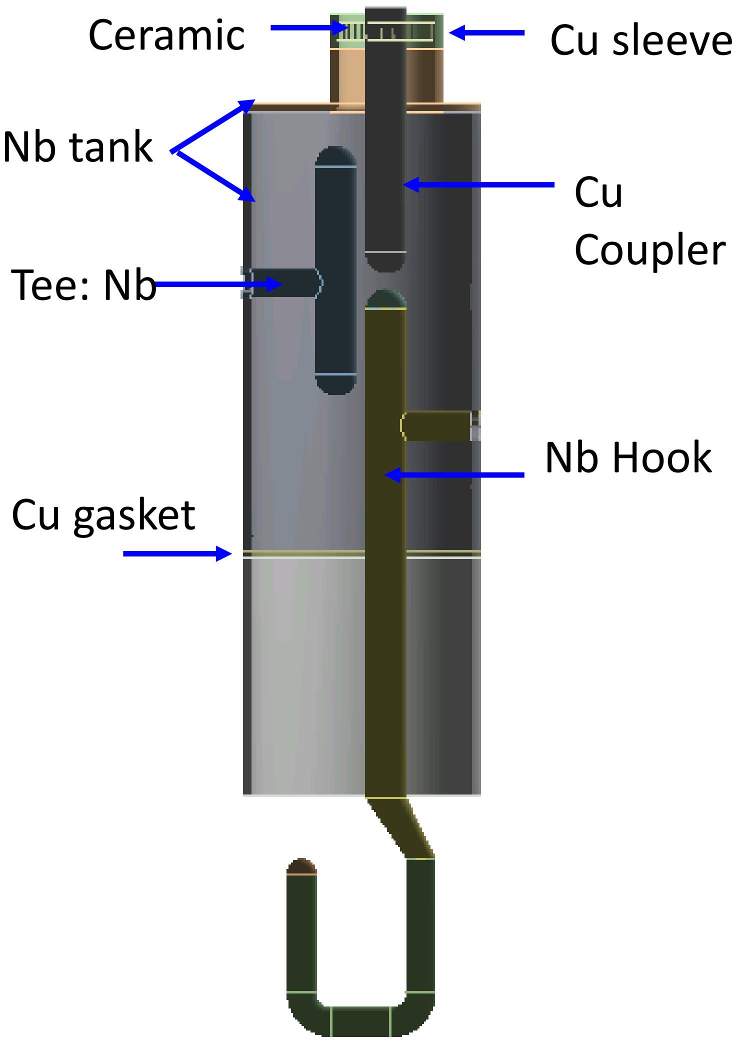
- **Hook temperature**: working condition **not critical**
- RRR_{min}= 250
- **Final design : active He Cooling** inside stem

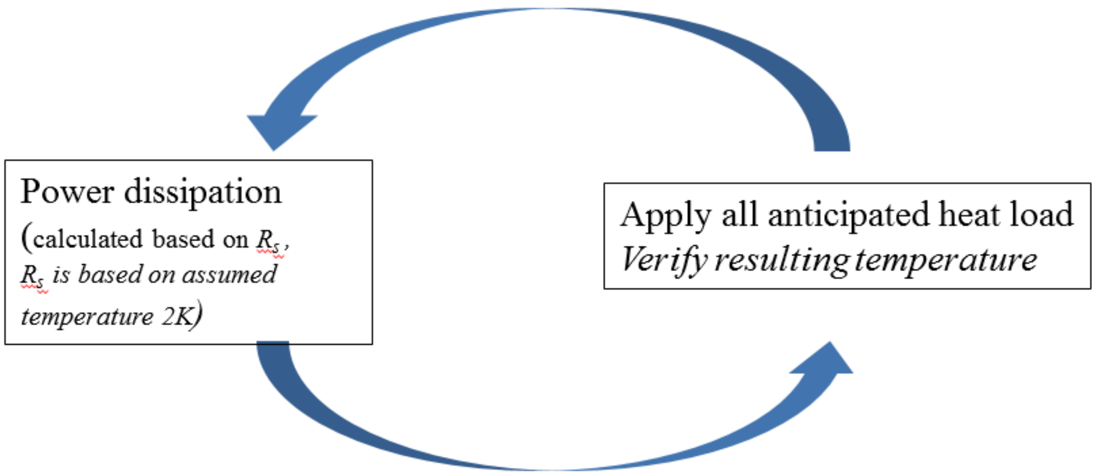
Thermo-Structural

- **HOM design is compliant** with the specified strength and deformation limits (both work. Cond. & worst Case)
- Max **0.1mm relative displacement** in the most critical area @ working condition
- **Welds** : well below safety limits

RFD H-HOM: Thermal Calcs

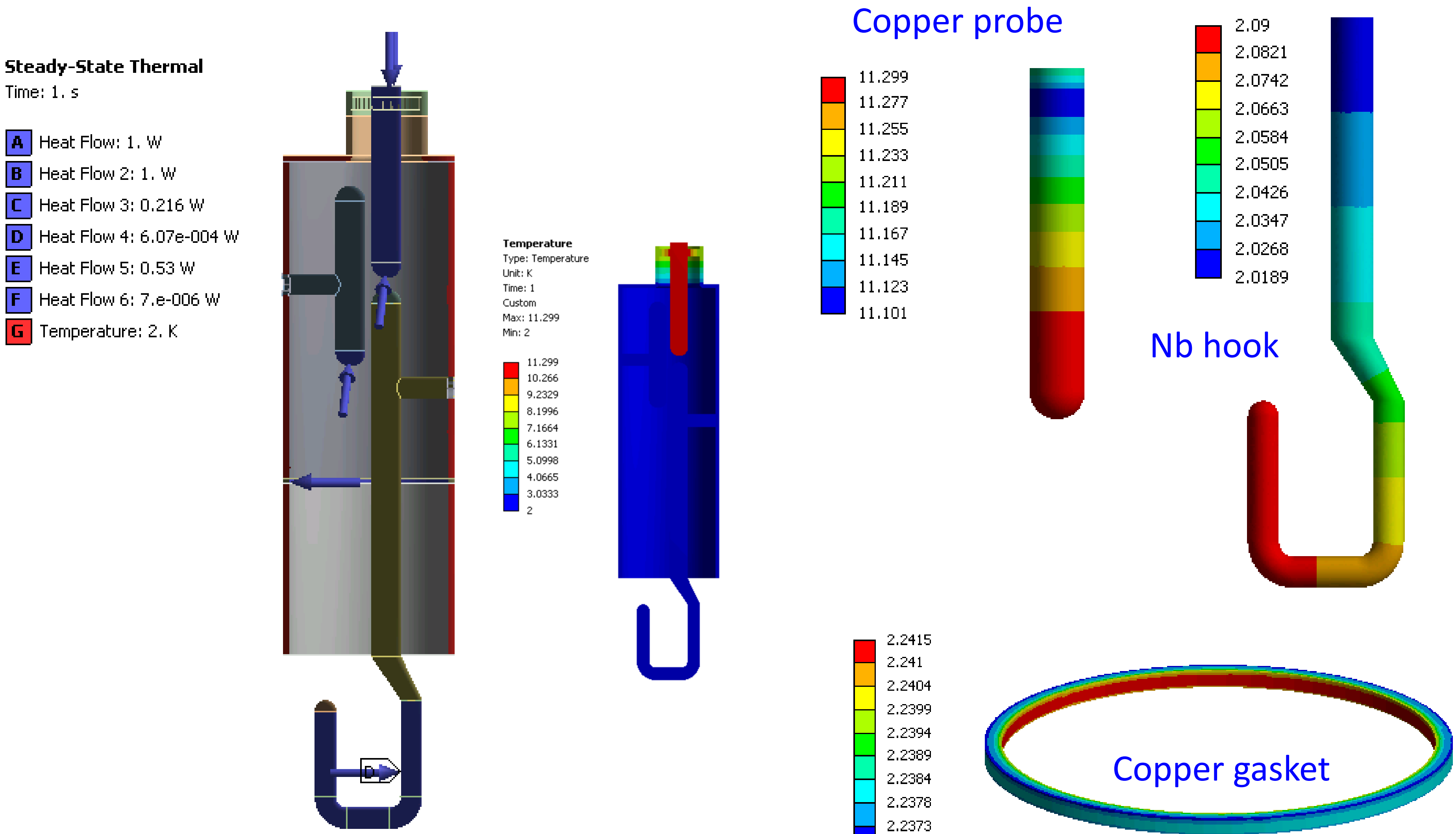
Courtesy H. Park - ODU





- Apply power dissipation from fundamental mode + HOM
- HOM power dissipation → frequency dependent
- Power dissipation on gasket → include anomalous skin effect
- Static heat load from cable
- Dynamic heat load (RF loss) of cable
- Use temperature dependent thermal conductivity

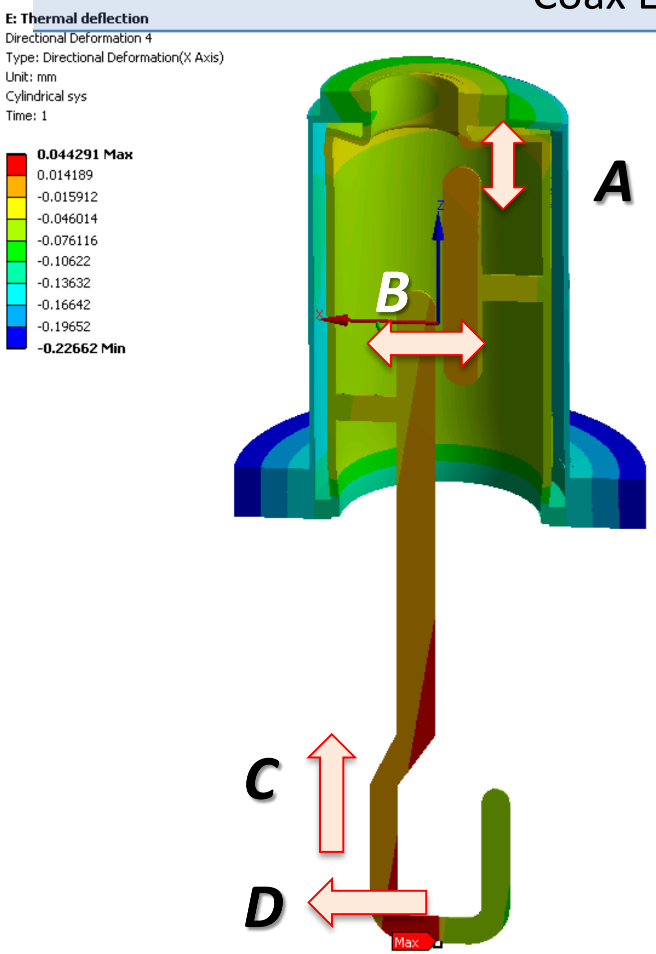
RFD H-HOM: Thermal Calcs *Courtesy H. Park - ODU*



RFD: Thermostruct. Calcs

Courtesy H. Park - ODU

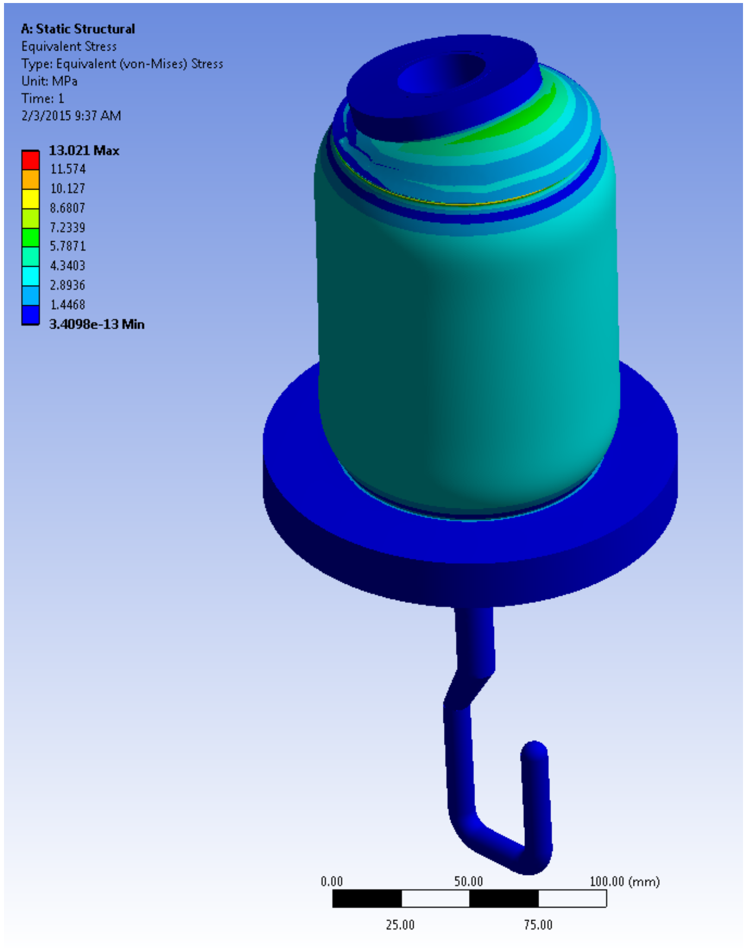
	Load Value	Verification criteria
Normal Operation (Load Case #1)	**No** pressure Thermal Contraction: **300K → 2K** Coax Line: **No load**	**Displacements** of the hook and Tee



Displ	Value [um]	Criteria
A	-200	Tolerance +/- 0.5mm
B	<+20	Accounted in Fab. Dwg
C	220	Tolerance +/- 1mm Accounted in Fab. Dwg
D	44	Disregardable

RFD: Thermostruct. Calcs

Courtesy H. Park - ODU



RFD Calculations - Remarks

Thermal:

- Niobium hook and tee maintains 10 nΩ range temperature (< 2.1 K), **no thermal runaway**.

Thermo-structural:

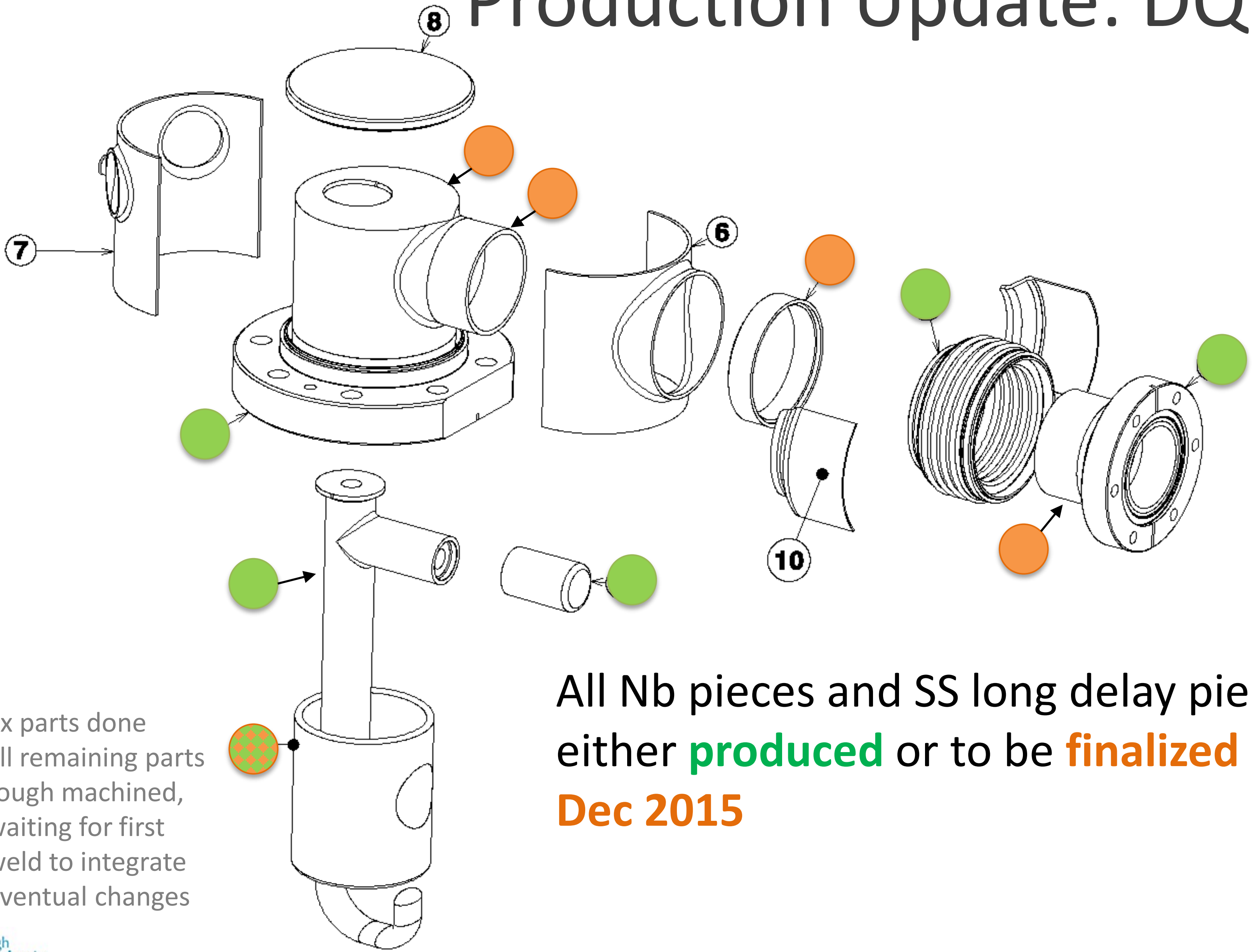
- **Stress** – Coupler is **structurally safe** and sound.
- **Deformations** caused by temperature change is well **within tolerance** level.

Maximum stress of 13 MPa occurs in the stainless steel outer shell (allowable stress ~120 MPa)

High Luminosity LHC

Production Update

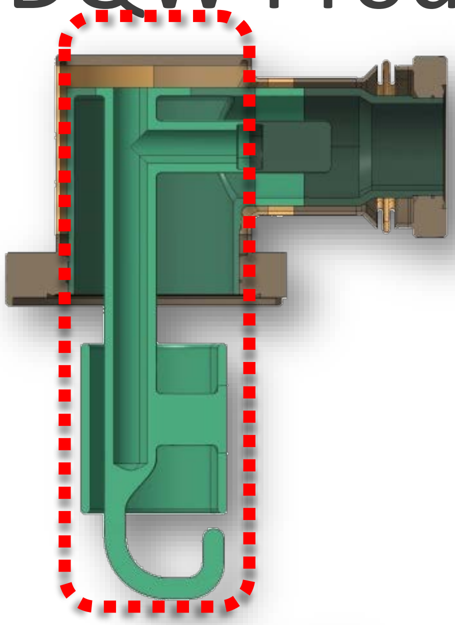
Production Update: DQW



- 2x parts done
- all remaining parts rough machined, waiting for first weld to integrate eventual changes

All Nb pieces and SS long delay pieces either **produced** or to be **finalized by Dec 2015**

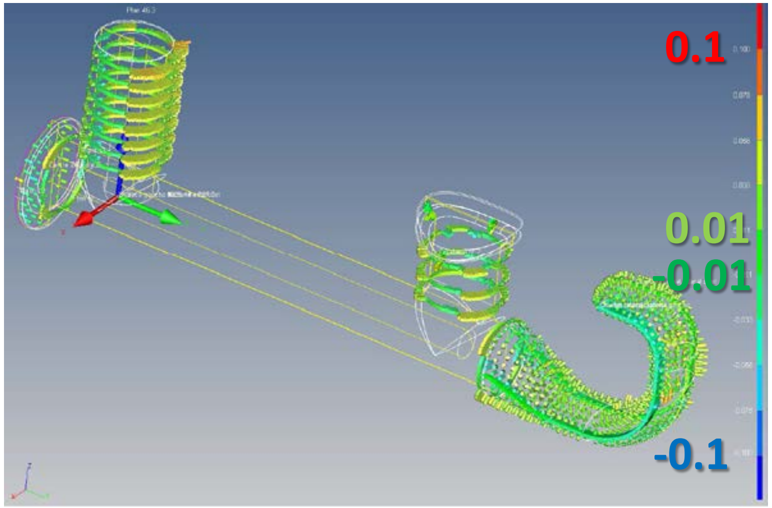
DQW Prod. Update: Hook



6x+1x parts currently produced and ready for BCP

Manufacturing

- One order of magnitude better than final tolerances
- Safe starting point due to assembly steps stack-up

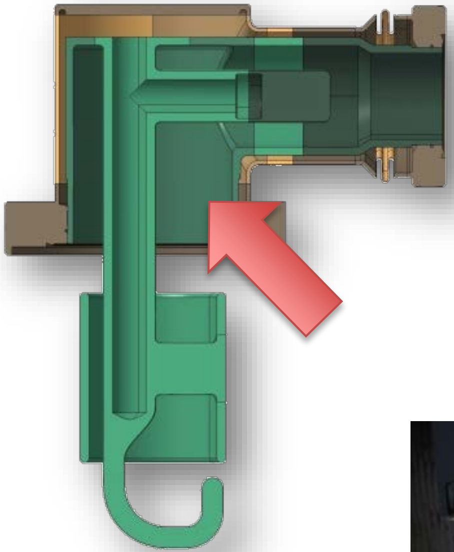


BCP Qualification

- 1st BCP$_{21um}$ + 2nd BCP$_{30um}$
- **Consistent** results

Err. Max ~10um

DQW Prod. Update

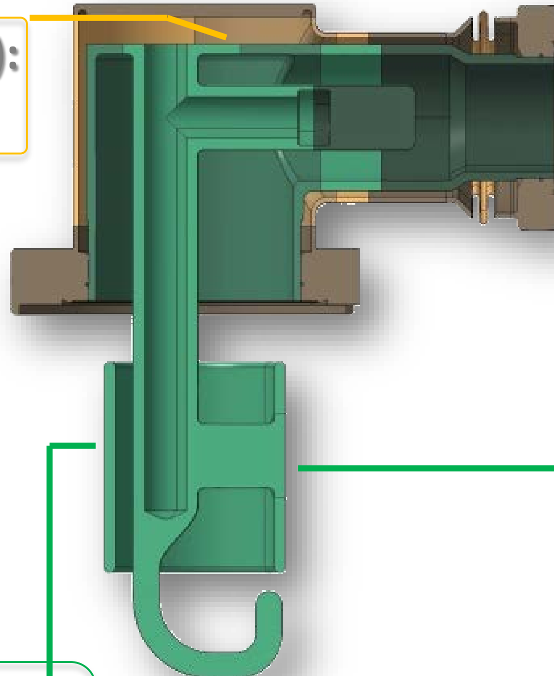


- Machining via custom-made tool
- Procedure already qualified on Aluminium prototype

8x Nb pieces 'rough machining' stage

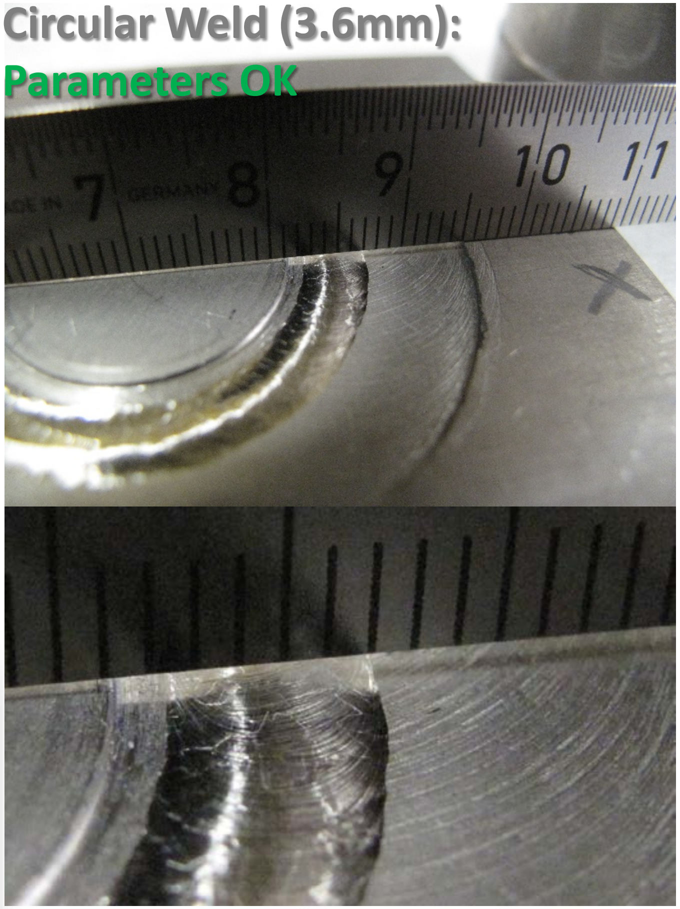
DQW Prod. Update

Longitudinal Weld (2mm):
Qualif ongoing



PLANNING:
- Welding on Jan 2016

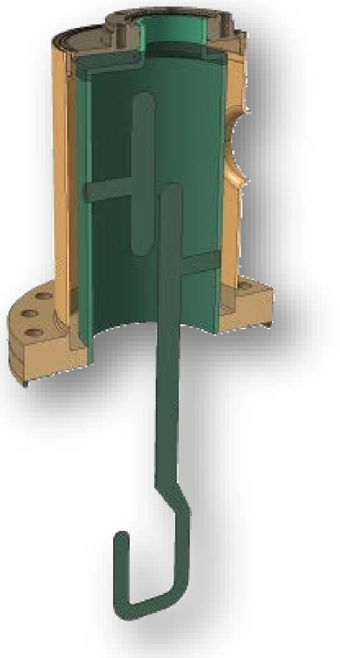
Circular Weld (3.6mm):
Parameters OK



Longitudinal Weld (3mm): OK

Different thickness

RFD Prod. Update

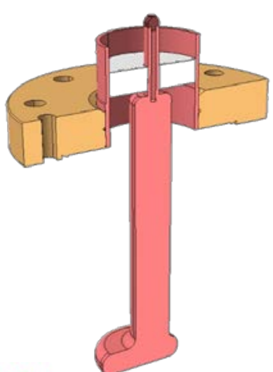


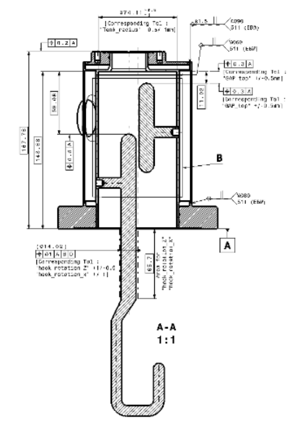
H-HOM coupler – bulk niobium

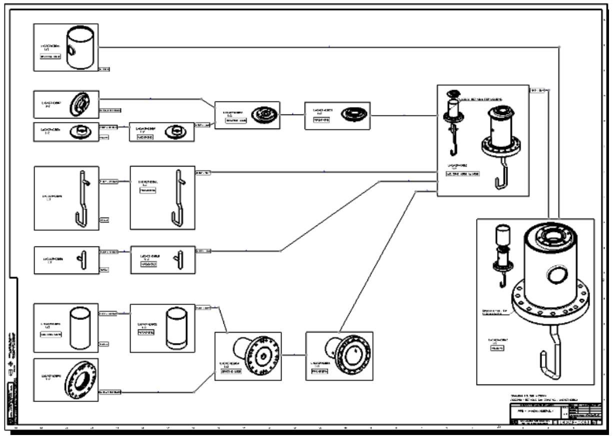
- manufacturing drawings under finalization at CERN
- Material ordered (expected WK50)

V-HOM coupler – copper

- 3D model finalized; manufacturing drawing to start







Conclusive remarks

Thermal

- **HOMs temperature**: working condition **not critical**

Thermo-Structural

- **HOMs design is compliant** with the specified strength and deformation limits (both Working Condition & Worst Case)

Production

- **Manufacturing in line with current schedule for both cavities**

High
Luminosity
LHC

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.

References

[1] Cryogenie, B.Hebral et al., pag. 11
[2] D. Vaucoret, Materials and Ansys Library for Design Office, EDMS 1291793.
[3] Tensile tests
[4] H. Kaiser, Ge. Meyer, H.B. Peters, and G. Weichert, "Helium Vessel for the TTF Cavity," TESLA Collaboration Report 94–26, October 1994.
[5]Information provided by Ignacio Aviles Santillana (CERN).
[6] "Fatigue life prediction…bellows at cryogenic temperatures" B. Skoczenet al. , LHC Project Note 012
[7] CERN specification for 1.4435 (316L) for bellows : EDMS 790771

[1]"RF Superconductivity", H. Padamsee, pag. 53