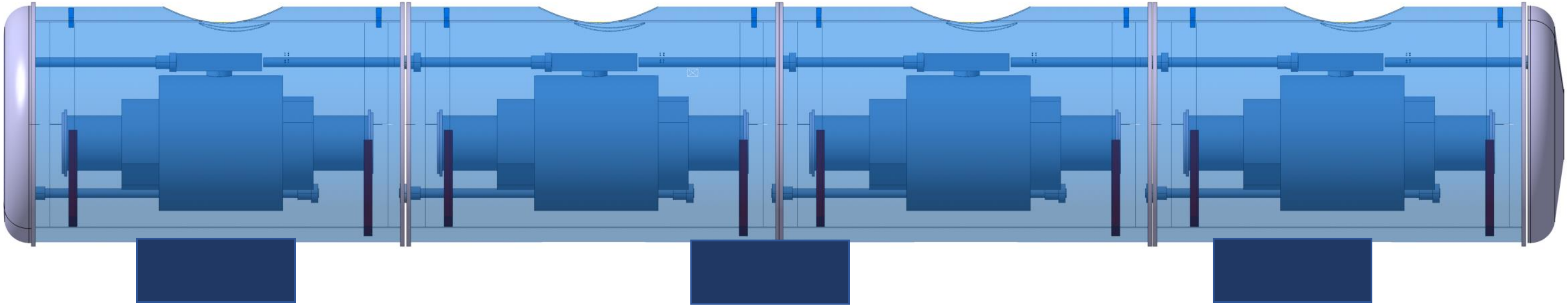
Group Presentation

Technical Training: Cryostat Engineering for SC devices
CERN, 7-9 November 2022

Task 1. Cryostat design and assembly

1. Conceptual design of a cryostats for the 400 MHz cryomodule containing 4 cavities. Assembly procedure



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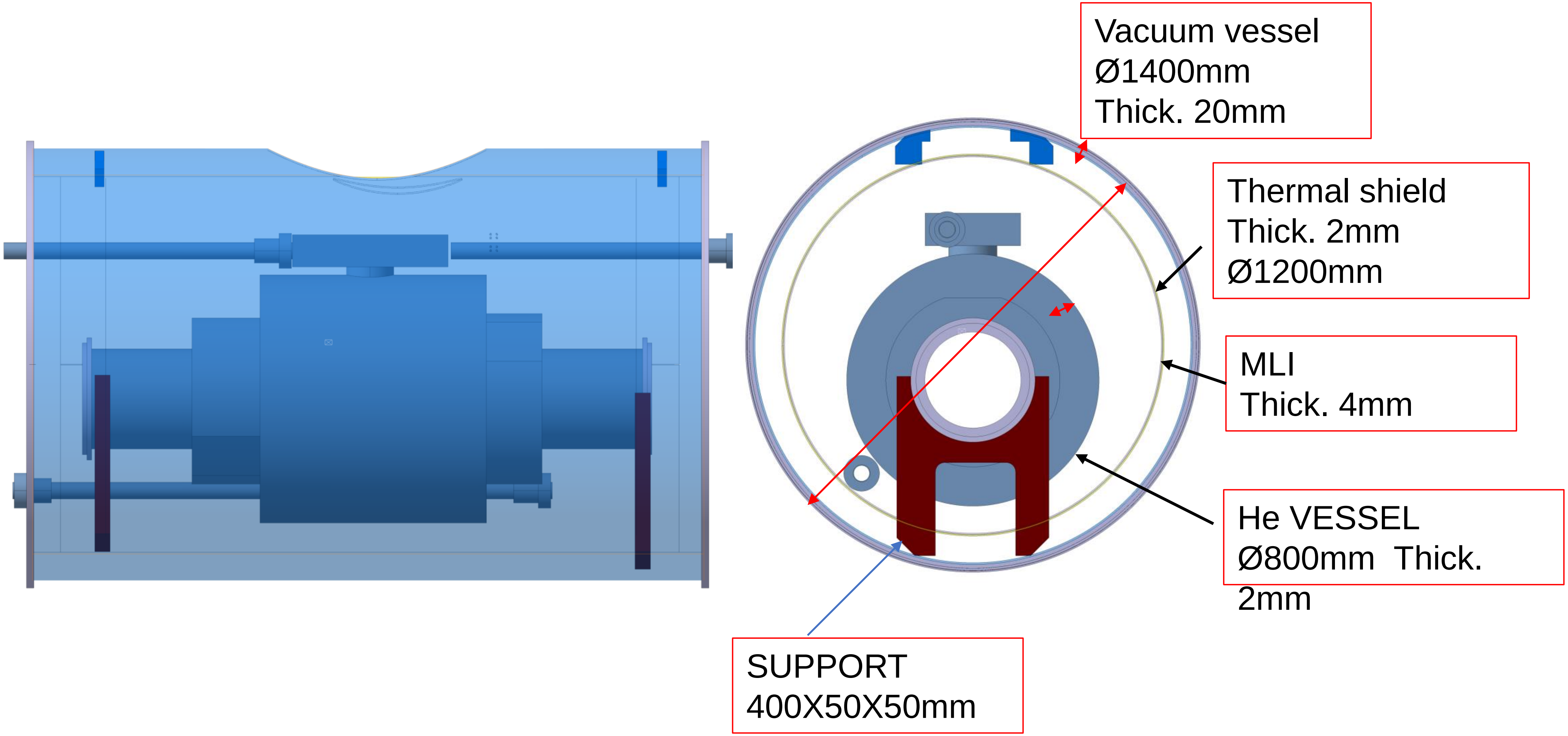

Vacuum vessel
Ø1400mm
Thick. 20mm

Thermal shield
Thick. 2mm
Ø1200mm

MLI
Thick. 4mm

He VESSEL
Ø800mm Thick. 2mm

SUPPORT
400X50X50mm

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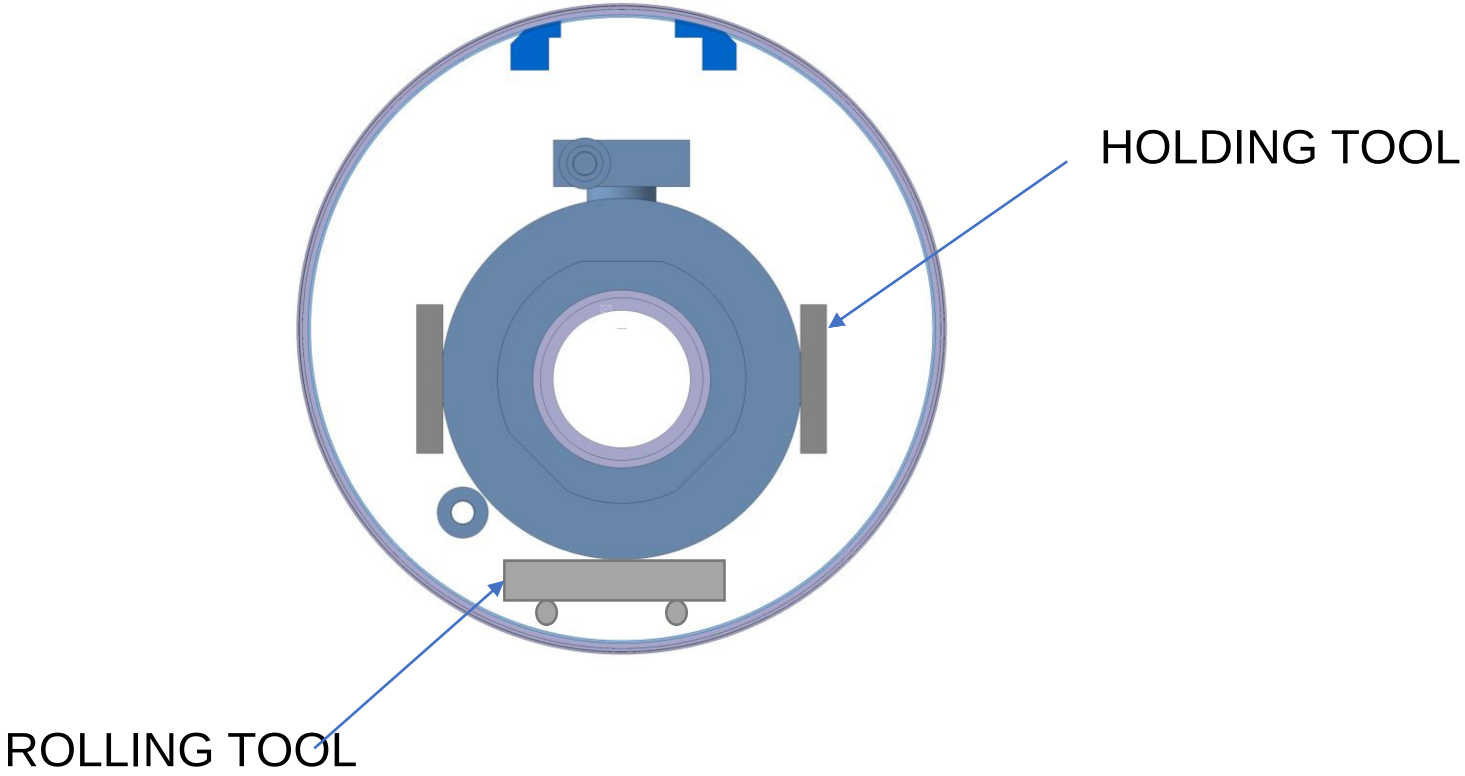

Task 1. Cryostat design and assembly

Thermal shield

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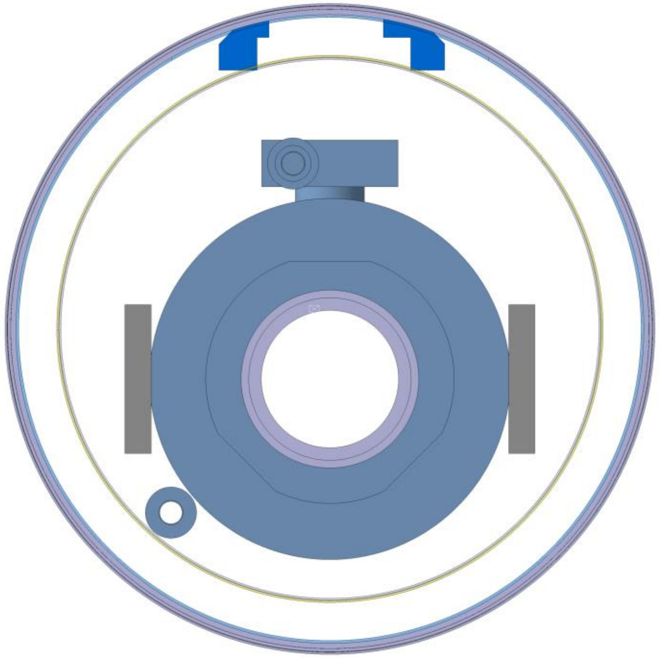

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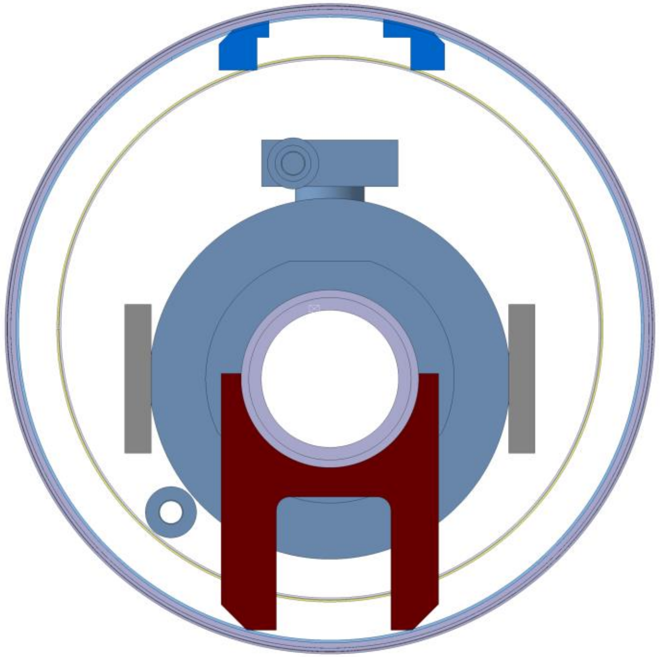
SUPPORTS

1. Conceptual design of a cryostats for the 400 MHz cryomodule containing 4 cavities. Assembly procedure



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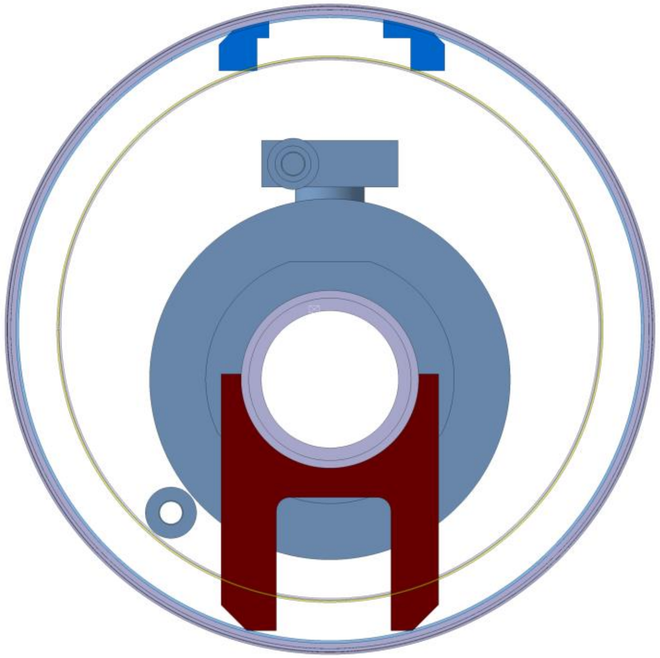

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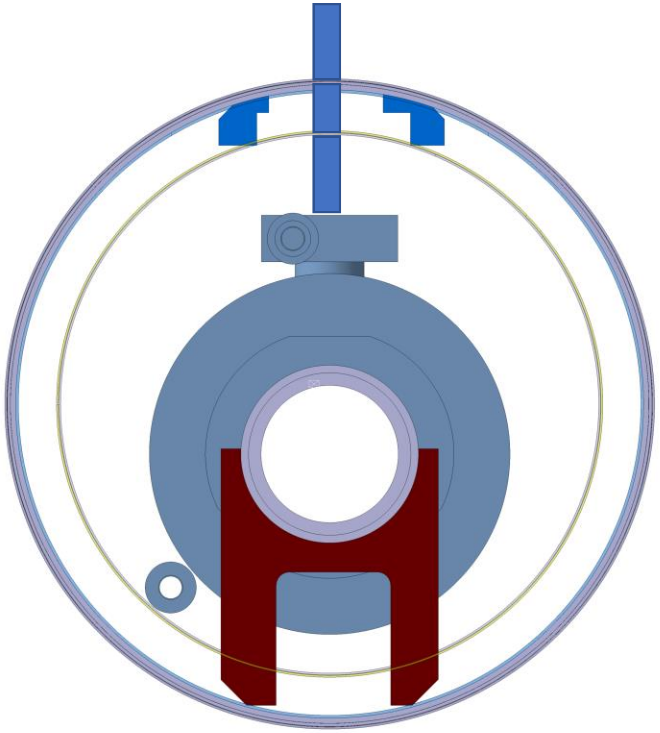

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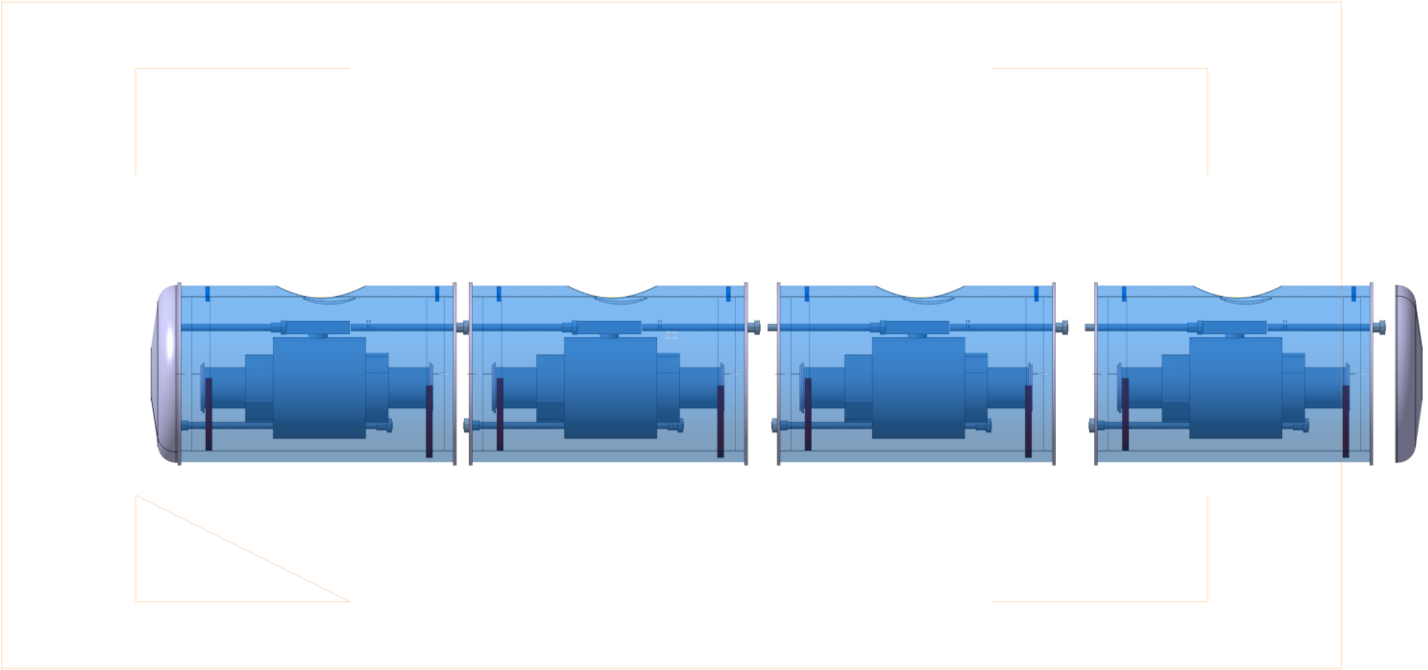

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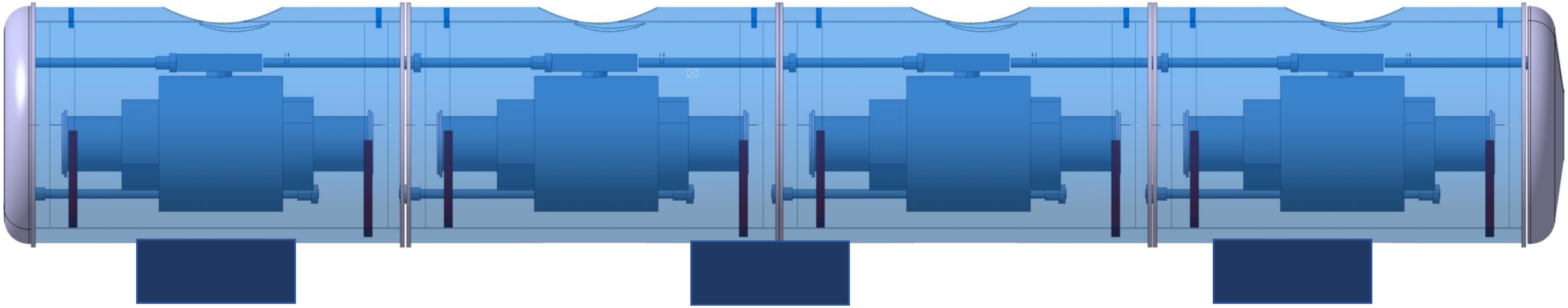
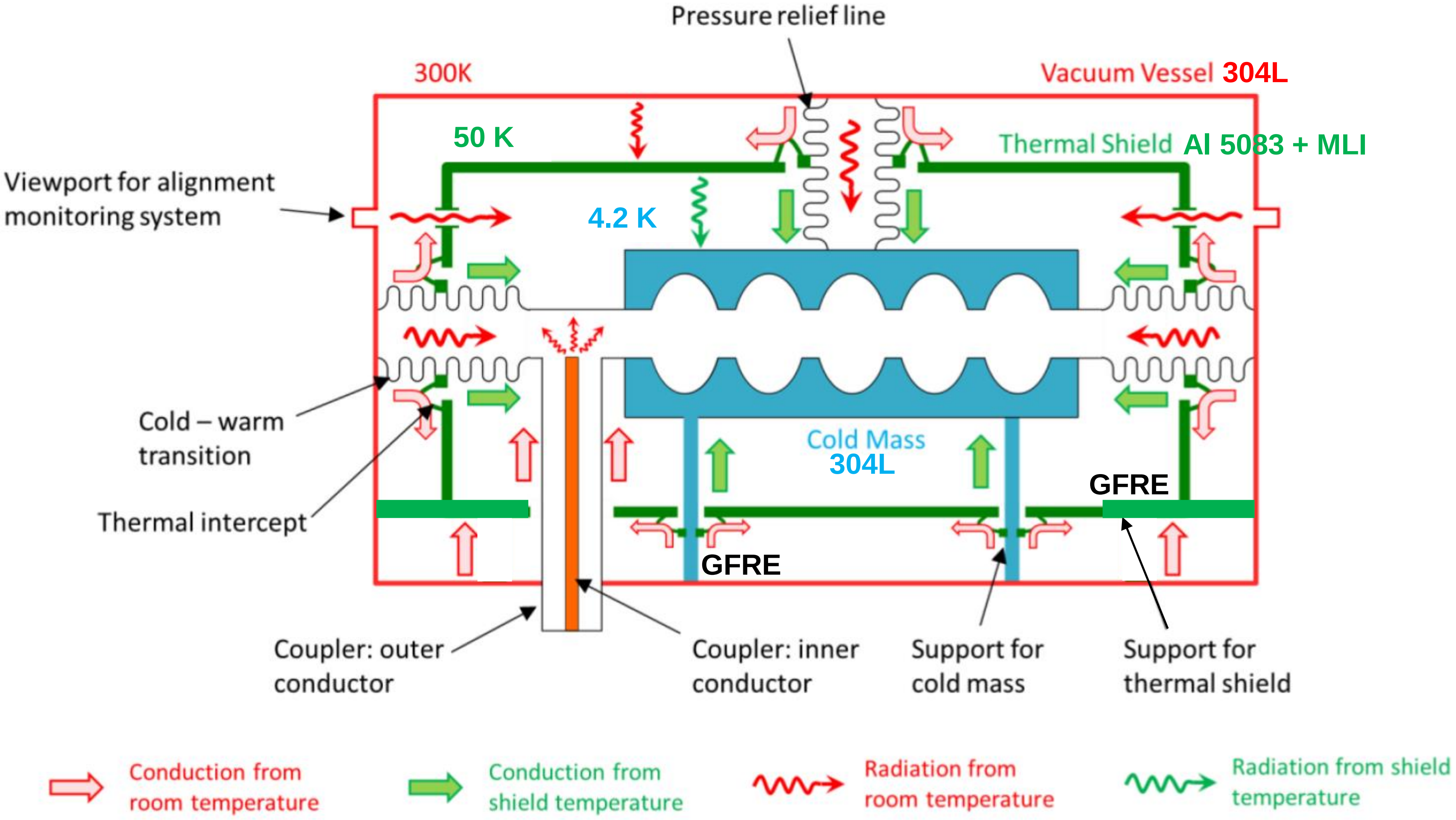


Map



Inspired by P. Duschene and JP. Thermeau

Task 1.1. Table of design parameters

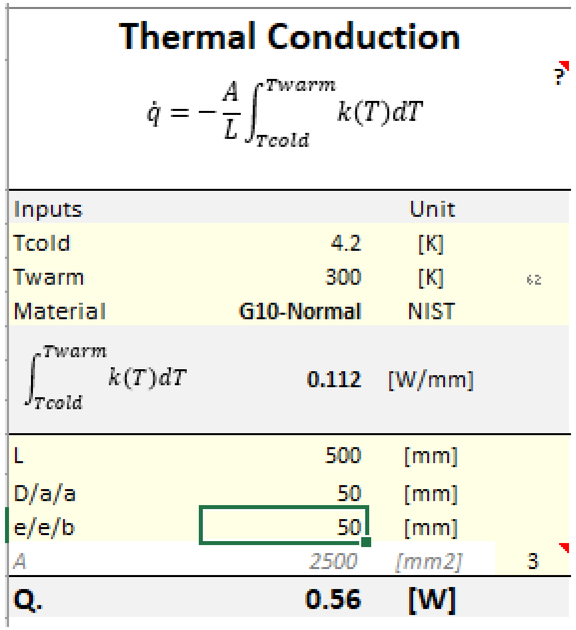
Item	Description	Value	Comments
1 a.	helium tank thickness	7 mm	Press. vessel (1 mm) vs bucking (15 mm, SF 3; 7 mm, SF 1.5)
1 b.	vacuum vessel diameter and thickness	1400 mm, (30 mm) 20 mm	Diameter to contain all the parts. With reinforcements (LHC concept). 304L.
1 c.	Thermal shield thickness	4 mm (MLI 20 layers) + 2 mm support (5083)	Slides 45 – 46. Diameter to contain cavities and pipes. (69/37.7)*(pi*0.6)^2/2/85/**20** slide 90
1 d.	Supports (mechanics and thermal)	16 pieces 50x50x400 mm3	Mech. Computation: Tsai-Wu ply failure vertical (SF>10), conservative against lateral load
1 e.	See previous slide		

Task 1.2. Table of Static Heat Loads and mass flows

Source of HL	**HL (W) @ 4.2 K**		**HL (W) @ 50 K**	**4.2 K liquid boil-off (g/s)**	**Liquefaction load (g/s)**	**Thermal shield mass flow (g/s) (with T_{in}=50K, T_{out}=55 K)**
Supports conduction	(0.56 X 16) 9		-		-	-
Beam tube cones conduction	5.5		-		-	-
RF Couplers conduction (uncooled)	(77.7 X 4) 310.8	-	-		-	-
RF Couplers conduction (ideal vapor cooling)	-	(2.4 X 4) 9.3				
Radiation, with thermal shield @ 50 K	0.24 (70 taken by shield)				-	
Radiation, without thermal shield	270		-		-	-
Radiation from beam tube cones	?		-		-	-
Totals						

Spare slides

Supports conduction

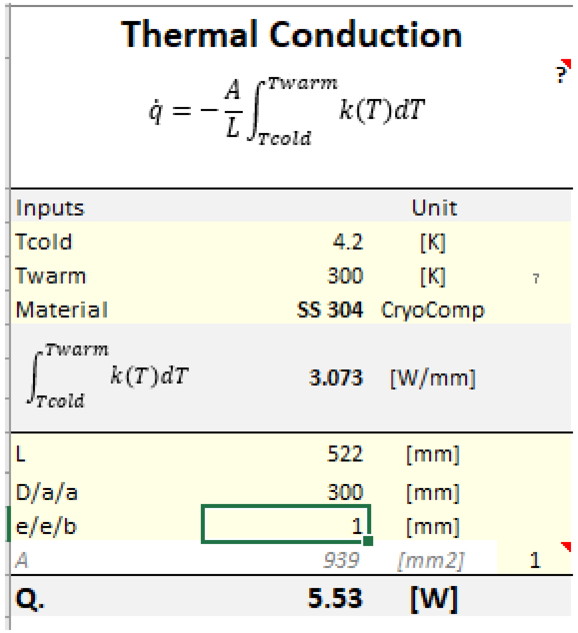


Thermal Conduction

$$\dot{q} = -\frac{A}{L}\int_{Tcold}^{Twarm} k(T)dT$$

Inputs		Unit	
Tcold	4.2	[K]	
Twarm	300	[K]	62
Material	G10-Normal	NIST	
$\int_{Tcold}^{Twarm} k(T)dT$	0.112	[W/mm]	
L	500	[mm]	
D/a/a	50	[mm]	
e/e/b	50	[mm]	
A	2500	[mm2]	3
Q.	**0.56**	**[W]**	

Beam tube cones conduction



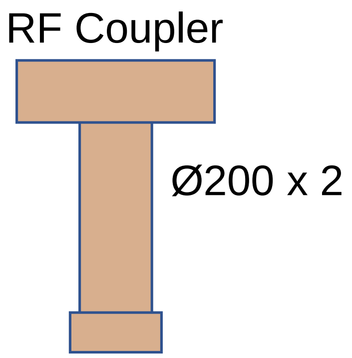
Thermal Conduction

$$\dot{q} = -\frac{A}{L}\int_{Tcold}^{Twarm} k(T)dT$$

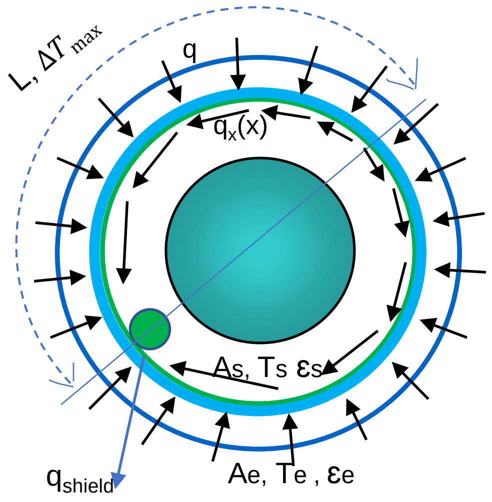
Inputs		Unit	
Tcold	4.2	[K]	
Twarm	300	[K]	7
Material	SS 304	CryoComp	
$\int_{Tcold}^{Twarm} k(T)dT$	3.073	[W/mm]	
L	522	[mm]	
D/a/a	300	[mm]	
e/e/b	1	[mm]	
A	939	[mm2]	1
Q.	**5.53**	**[W]**	

pi/4*(204^2 - 200^2)/500 * 30.6

pi/4*(204^2 - 200^2)/500 * 0.92

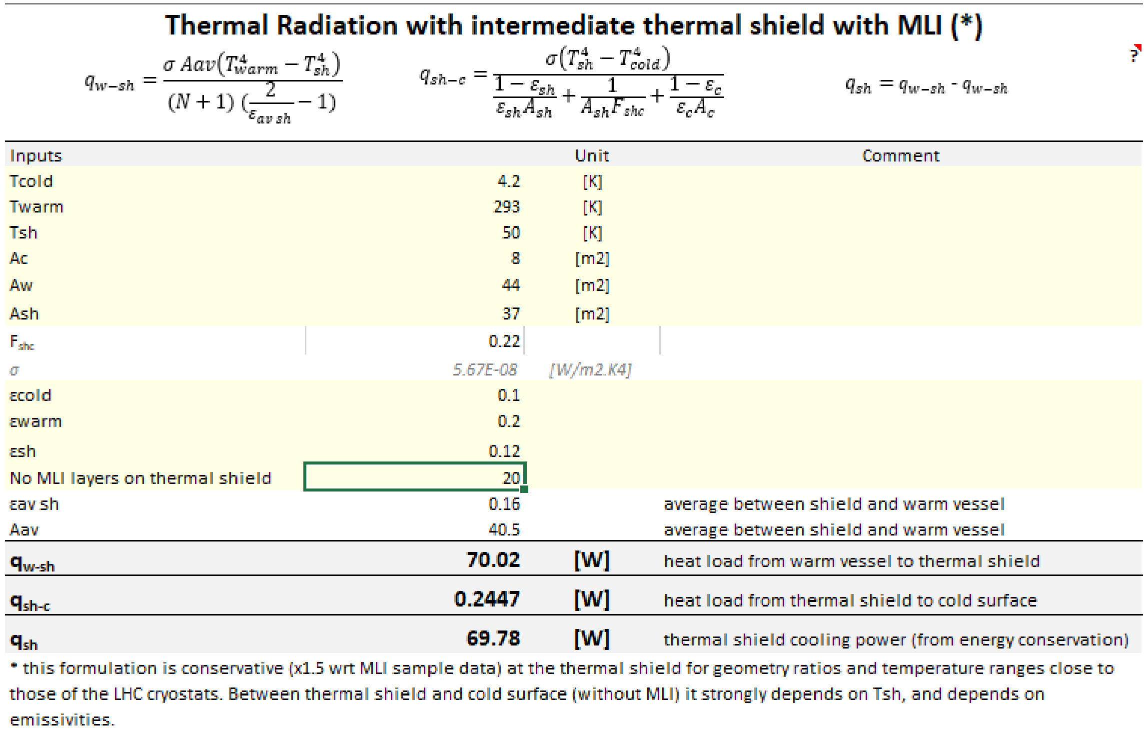


$$t = \frac{q \cdot L^2}{2 \cdot k \cdot \Delta T_{\max}}$$



Spare slides

Acier inoxydable 18-8	300 80 4	0,20 0,12 0,10
Aluminium commercial brut	300 80 4	0,25 0,12 0,07

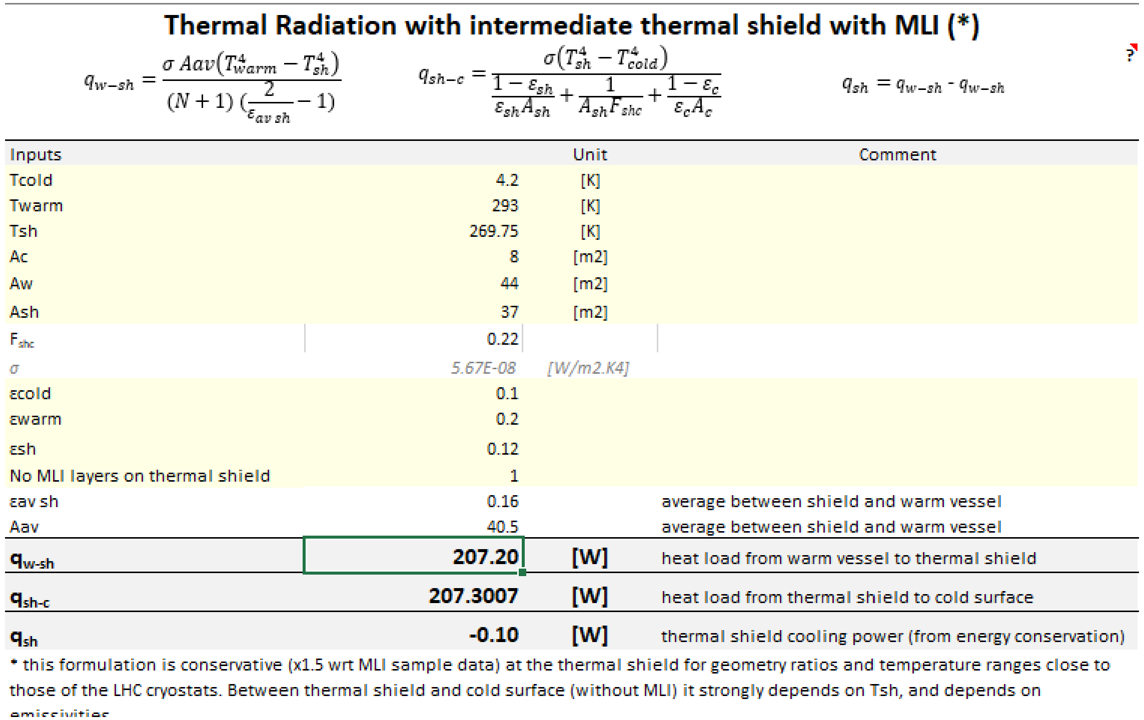


Thermal Radiation with intermediate thermal shield with MLI (*)

$$q_{w-sh} = \frac{\sigma\, Aav(T_{warm}^4 - T_{sh}^4)}{(N+1)\,(\frac{2}{\varepsilon_{av\ sh}} - 1)} \qquad q_{sh-c} = \frac{\sigma(T_{sh}^4 - T_{cold}^4)}{\frac{1-\varepsilon_{sh}}{\varepsilon_{sh}A_{sh}} + \frac{1}{A_{sh}F_{shc}} + \frac{1-\varepsilon_c}{\varepsilon_c A_c}} \qquad q_{sh} = q_{w-sh} - q_{w-sh}$$

Inputs		Unit	Comment
Tcold	4.2	[K]	
Twarm	293	[K]	
Tsh	50	[K]	
Ac	8	[m2]	
Aw	44	[m2]	
Ash	37	[m2]	
F_{shc}	0.22		
σ	*5.67E-08*	*[W/m2.K4]*	
εcold	0.1		
εwarm	0.2		
εsh	0.12		
No MLI layers on thermal shield	20		
εav sh	0.16		average between shield and warm vessel
Aav	40.5		average between shield and warm vessel
q_{w-sh}	**70.02**	**[W]**	heat load from warm vessel to thermal shield
q_{sh-c}	**0.2447**	**[W]**	heat load from thermal shield to cold surface
q_{sh}	**69.78**	**[W]**	thermal shield cooling power (from energy conservation)

* this formulation is conservative (x1.5 wrt MLI sample data) at the thermal shield for geometry ratios and temperature ranges close to those of the LHC cryostats. Between thermal shield and cold surface (without MLI) it strongly depends on Tsh, and depends on emissivities.



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Inputs		Unit	Comment
Tcold	4.2	[K]	
Twarm	293	[K]	
Tsh	269.75	[K]	
Ac	8	[m2]	
Aw	44	[m2]	
Ash	37	[m2]	
F_{shc}	0.22		
σ	*5.67E-08*	*[W/m2.K4]*	
εcold	0.1		
εwarm	0.2		
εsh	0.12		
No MLI layers on thermal shield	1		
εav sh	0.16		average between shield and warm vessel
Aav	40.5		average between shield and warm vessel
q_{w-sh}	**207.20**	**[W]**	heat load from warm vessel to thermal shield
q_{sh-c}	**207.3007**	**[W]**	heat load from thermal shield to cold surface
q_{sh}	**-0.10**	**[W]**	thermal shield cooling power (from energy conservation)

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