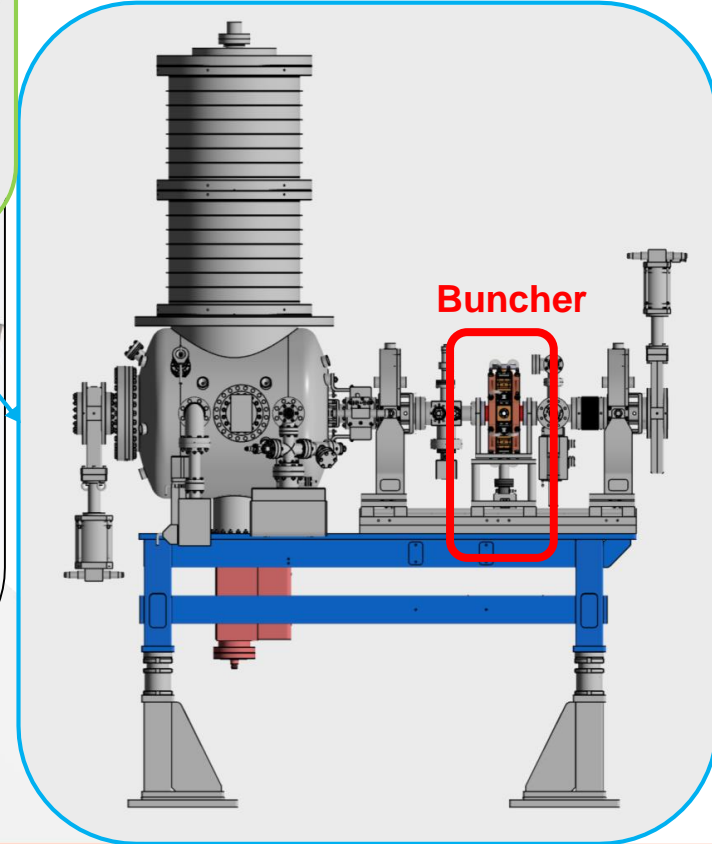
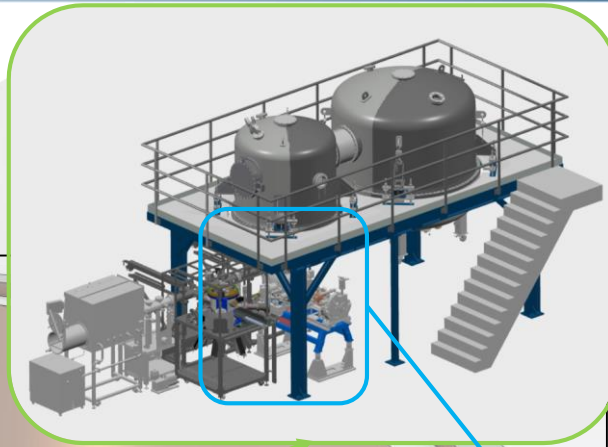
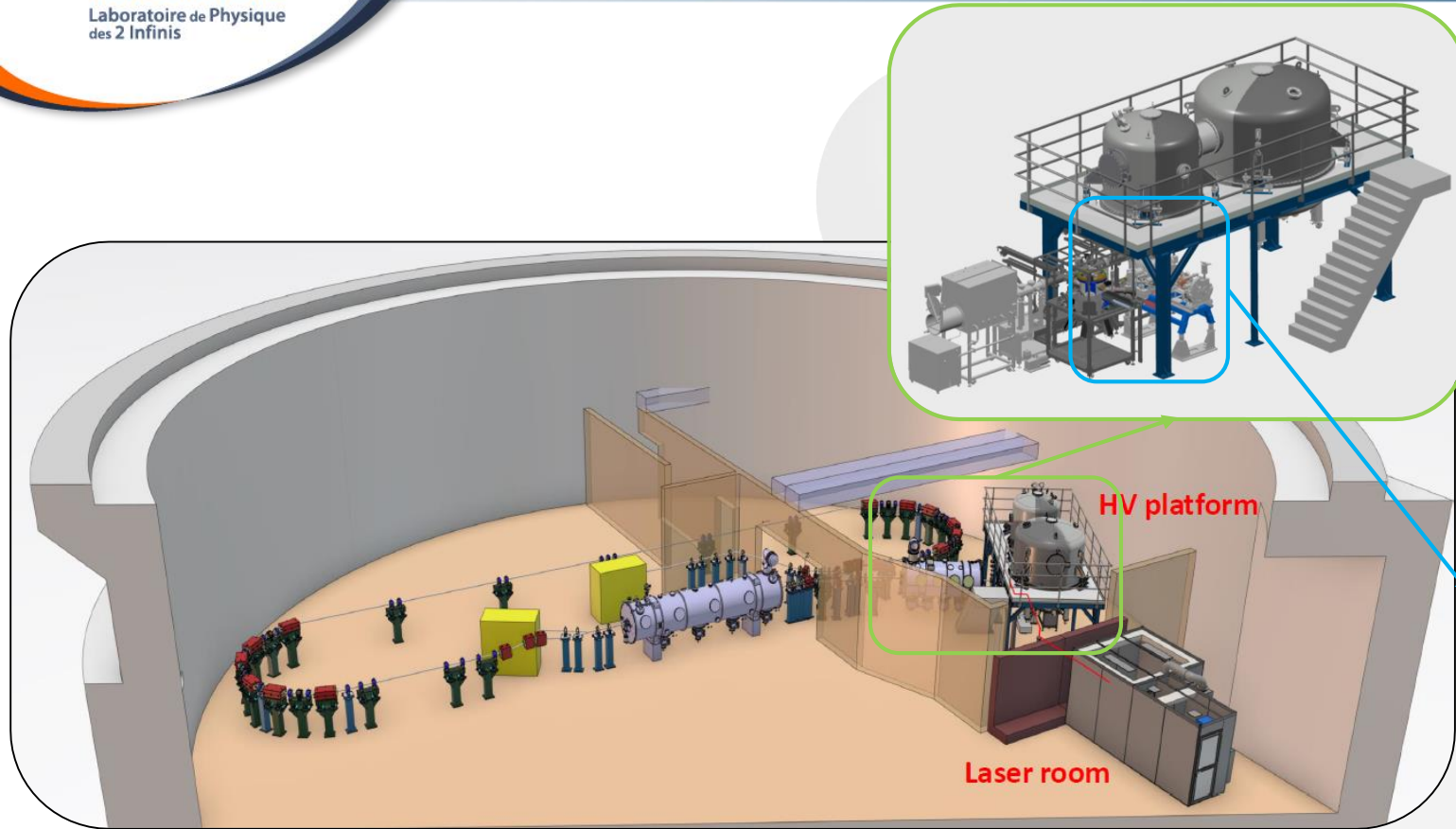




Perle Buncher design review

Mechanical design : specifications / cooling / Manufacturing

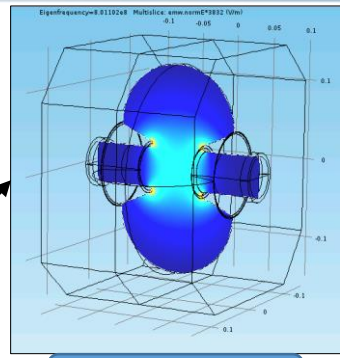
Samuel Marchal



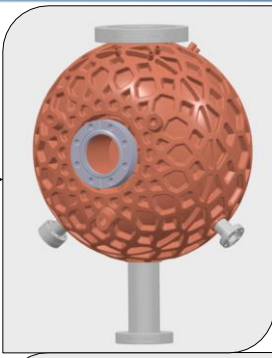
Specifications :

- Frequency = 801 MHz
- Maximum length = 200 mm
- Targeted temperature = 30°C
- Power dissipated = 1,4kW or 5kW
- Material : OFHC
- Beam axes flange : CF50
- 2 ports : CF 16
- Vacuum port : CF40
- RF power coupler port : ?

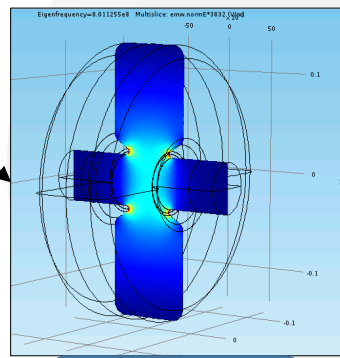
Buncher



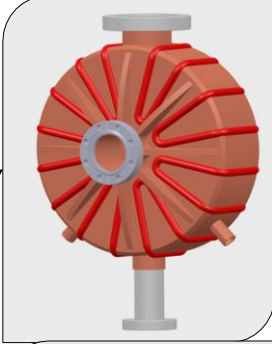
Cerl type



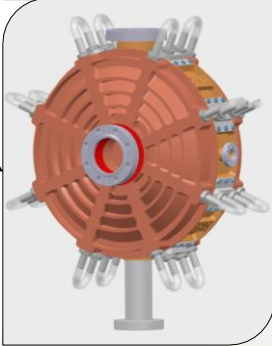
Cerl Type buncher :
 Manufacturing with 3D printed copper



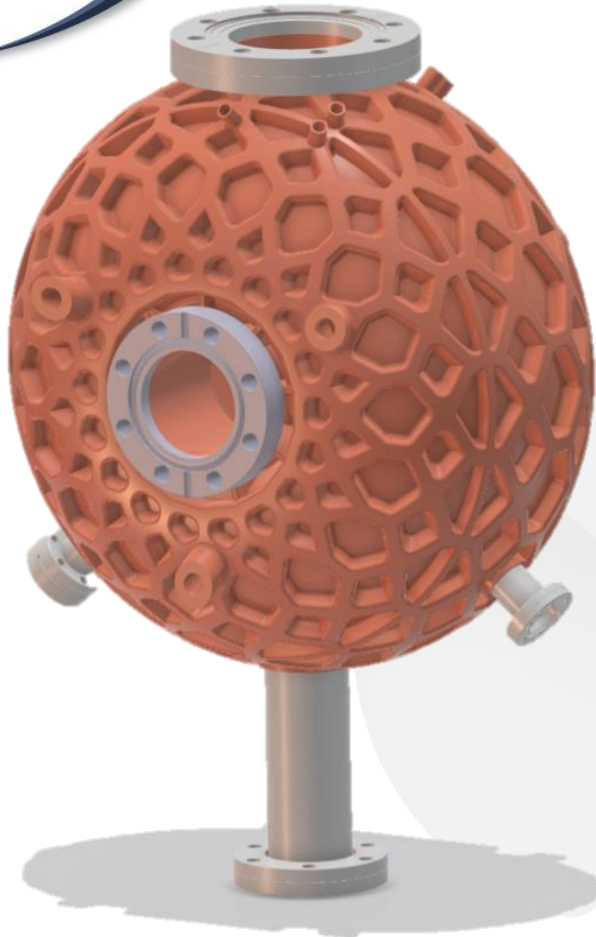
Nose Cone type



Nose Cone type buncher with cooling system brazed :
 Classic machining
 Cooling system brazed



Nose Cone type buncher with cooling system machined :
 Classic machining
 Cooling system machined



Cerl Type buncher

3D printed

Jean Louis Munoz from ESS Bilbao Simulation's

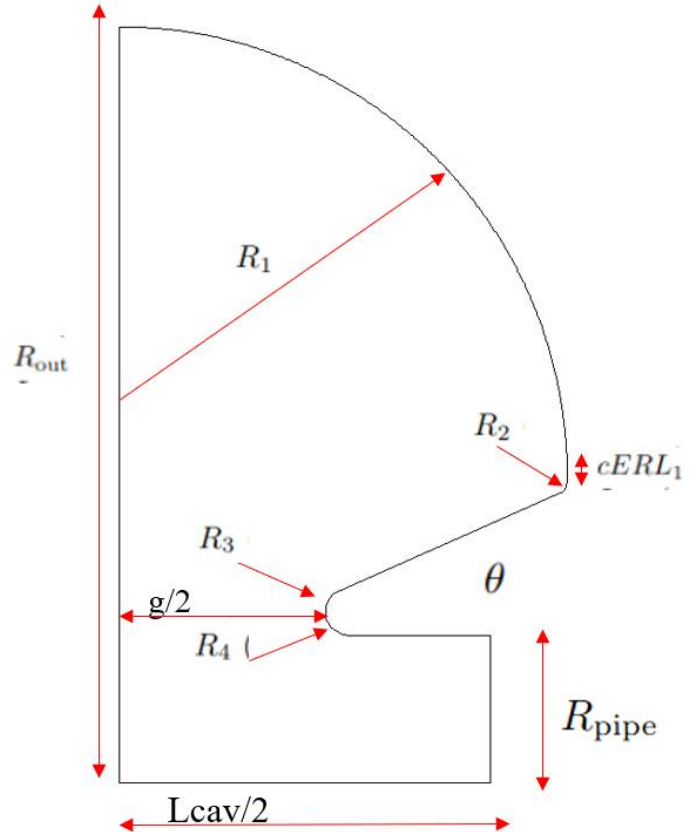
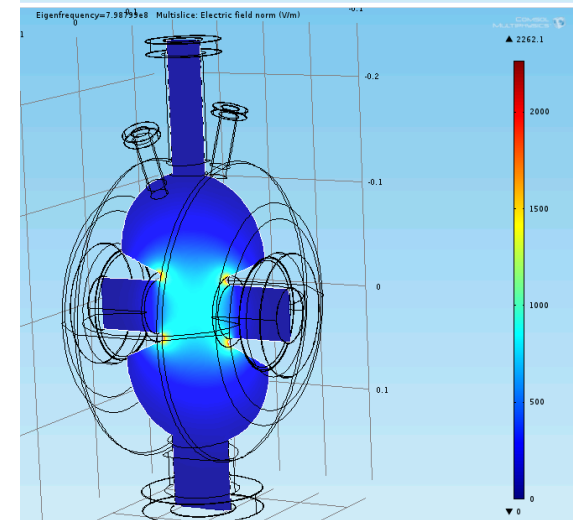
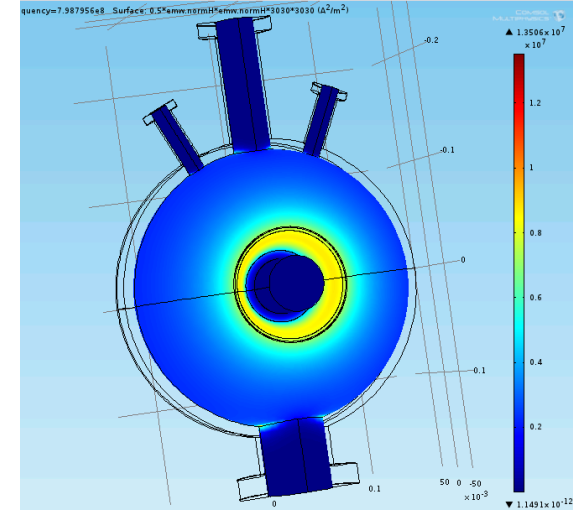
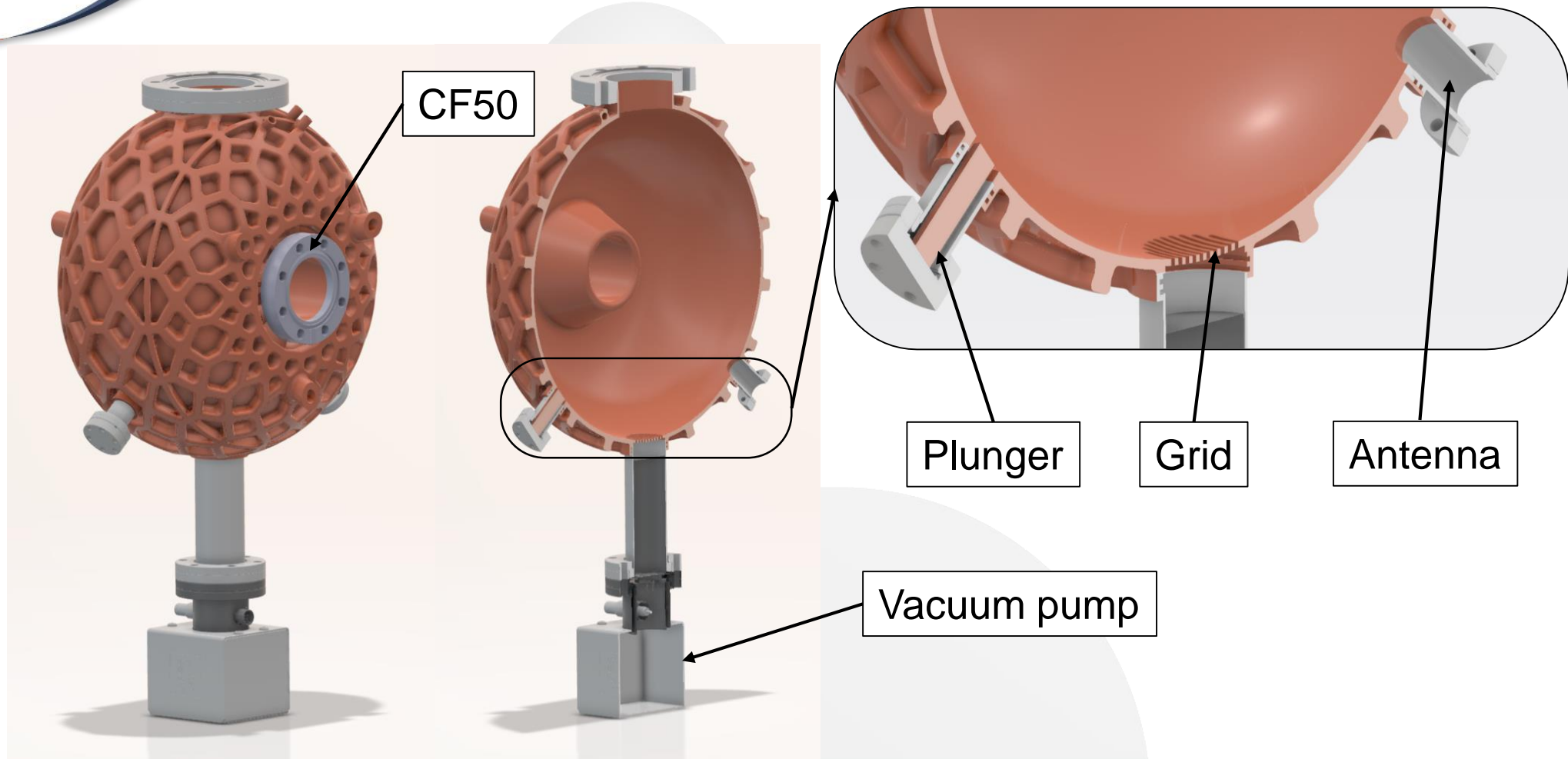
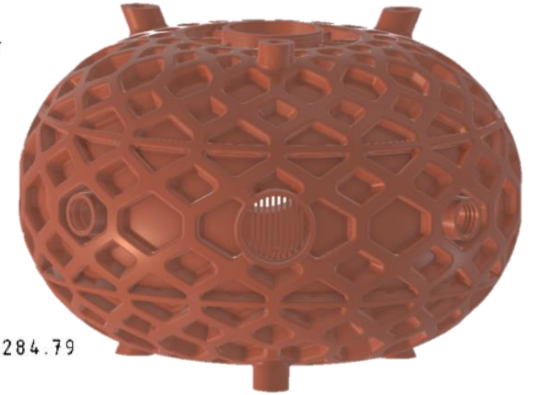
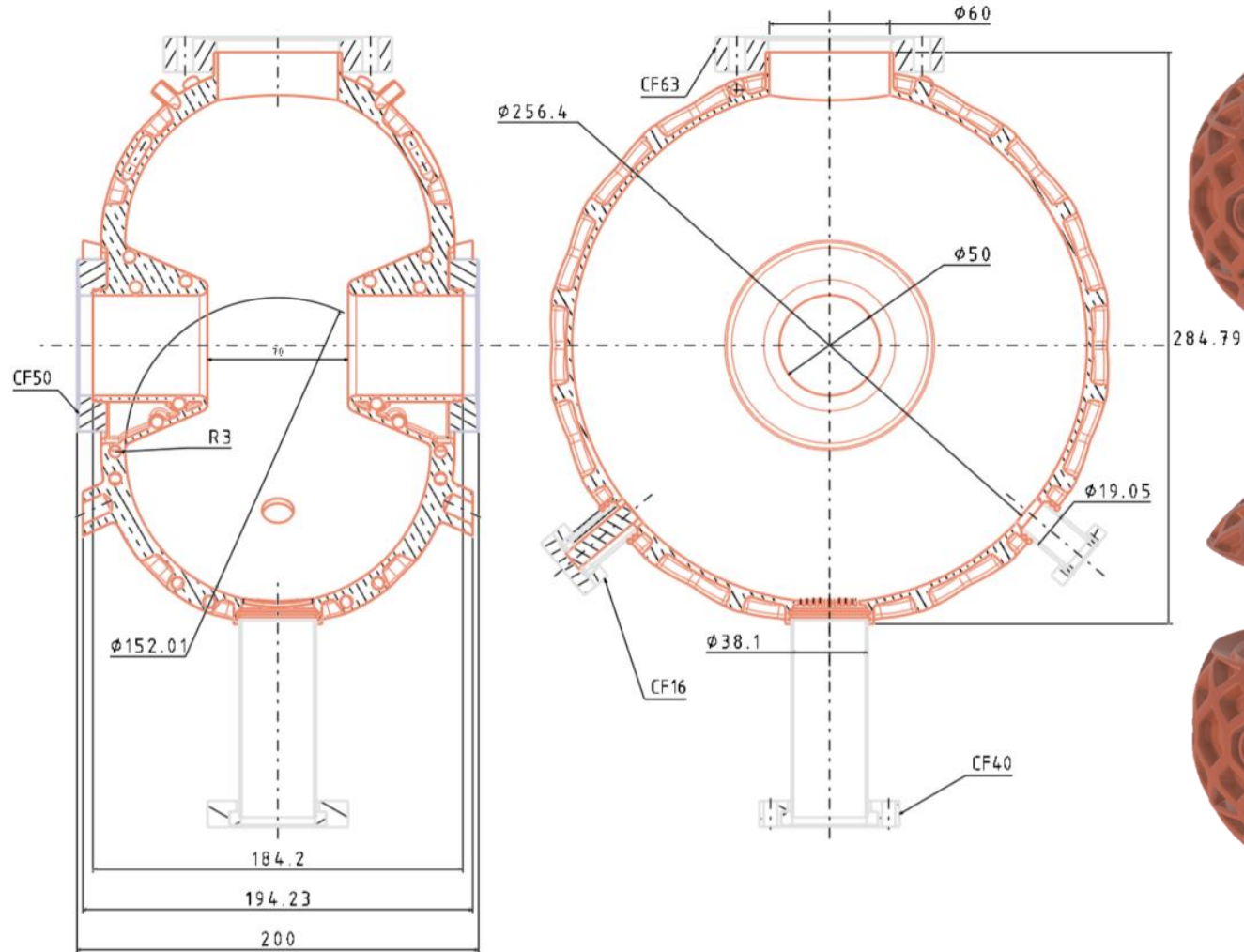
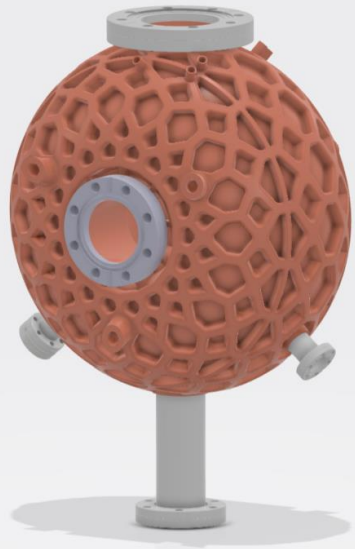


Table 7: Design Parameters PERLE buncher cERL-type.1

Parameter	Value
R_{pipe} (m)	0.025
g (m)	0.07
θ (deg)	43.5
R_1 (m)	0.076
R_2 (m)	0.0027
R_3 (m)	0.004
R_4 (m)	0.004
W (m)	0.152
R_{out} (m)	0.1282
L_{nose} (m)	0.0
$cERL_1$ (m)	0.001
L_{cav} (m)	0.126
lc_1 (m)	0.001
lc_2 (m)	0.001
β	0.8048
RF frequency (Hz)	8.0156×10^8
Conductivity σ (S/m)	5.8×10^7
Gradient (V/m)	1.4×10^6
Geometry filename	perle_buncher_cerl_01_geom.dxf





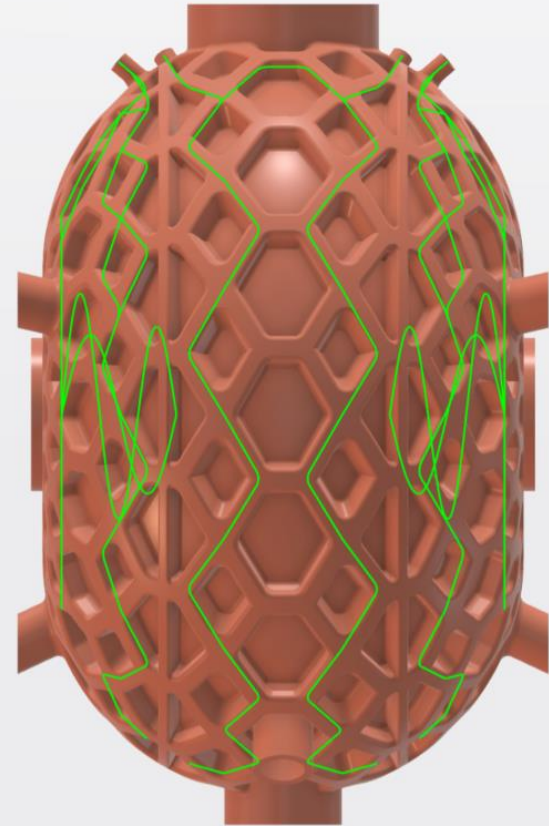
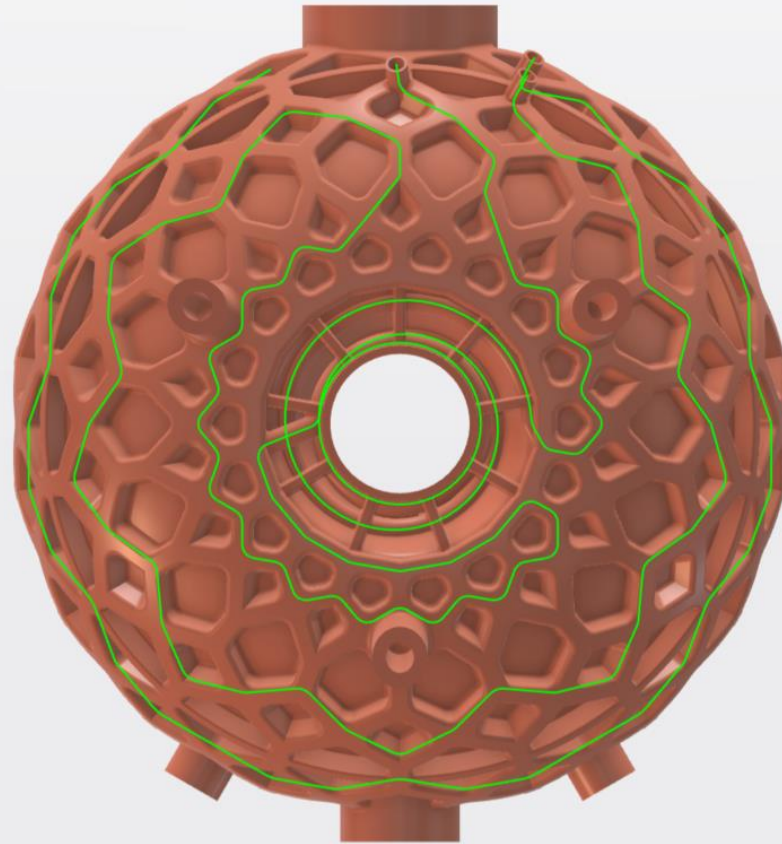


Characteristic's :

3 circuits in //

Pipe of $\varnothing 6$ mm (internal)

min radius of 5mm

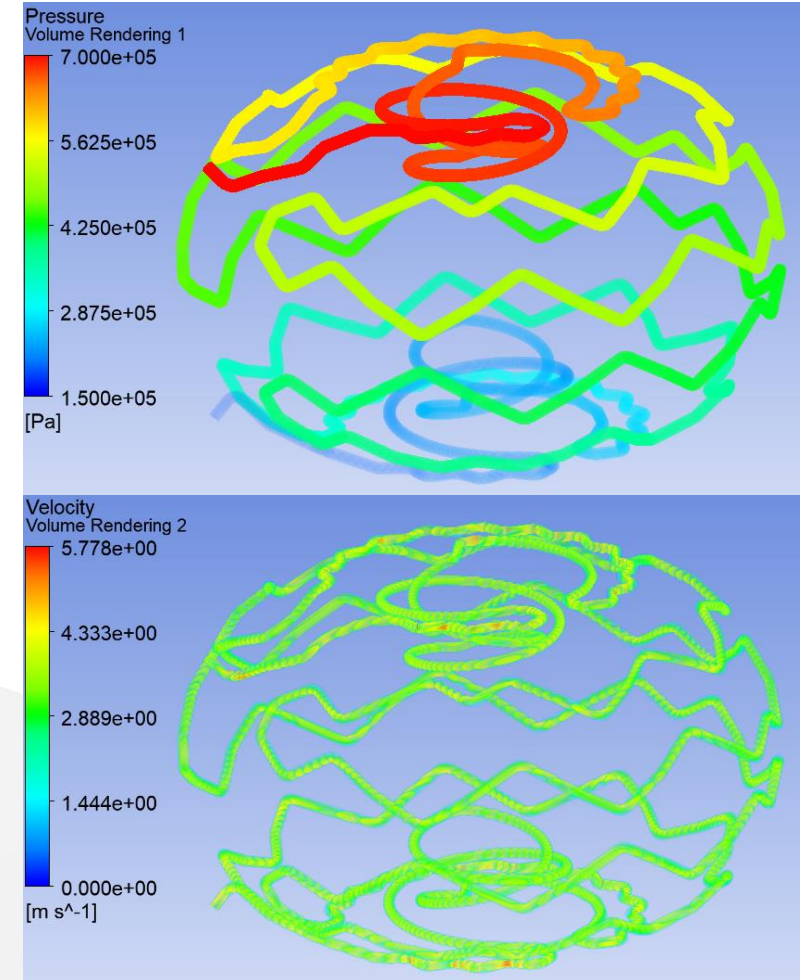


Input :

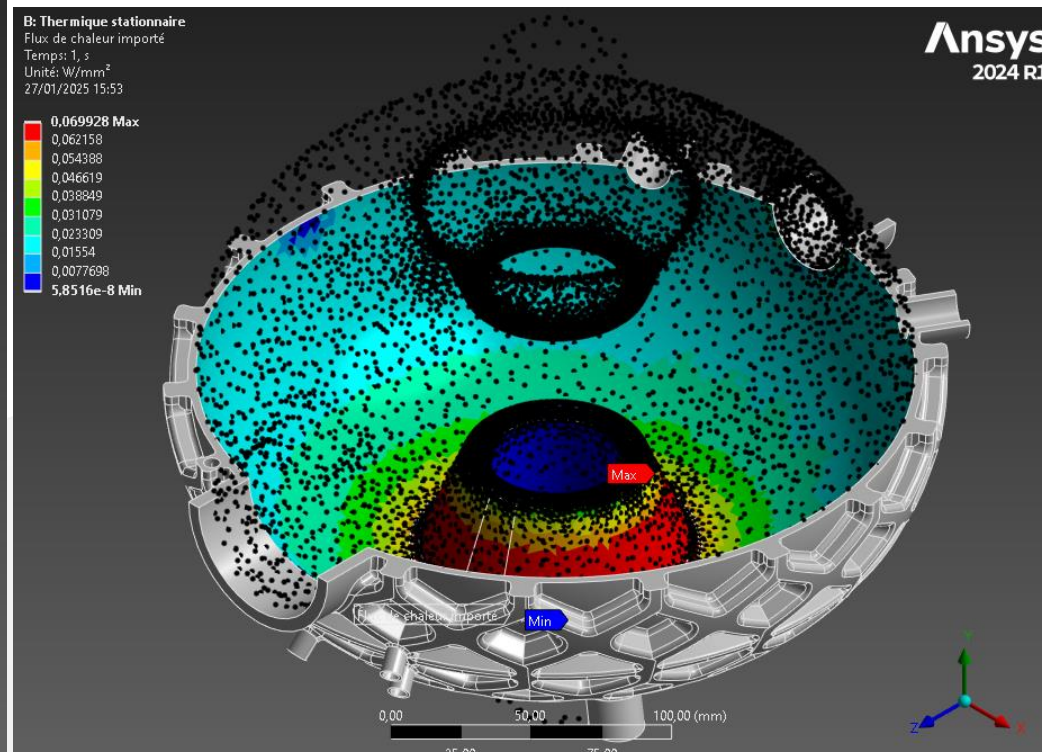
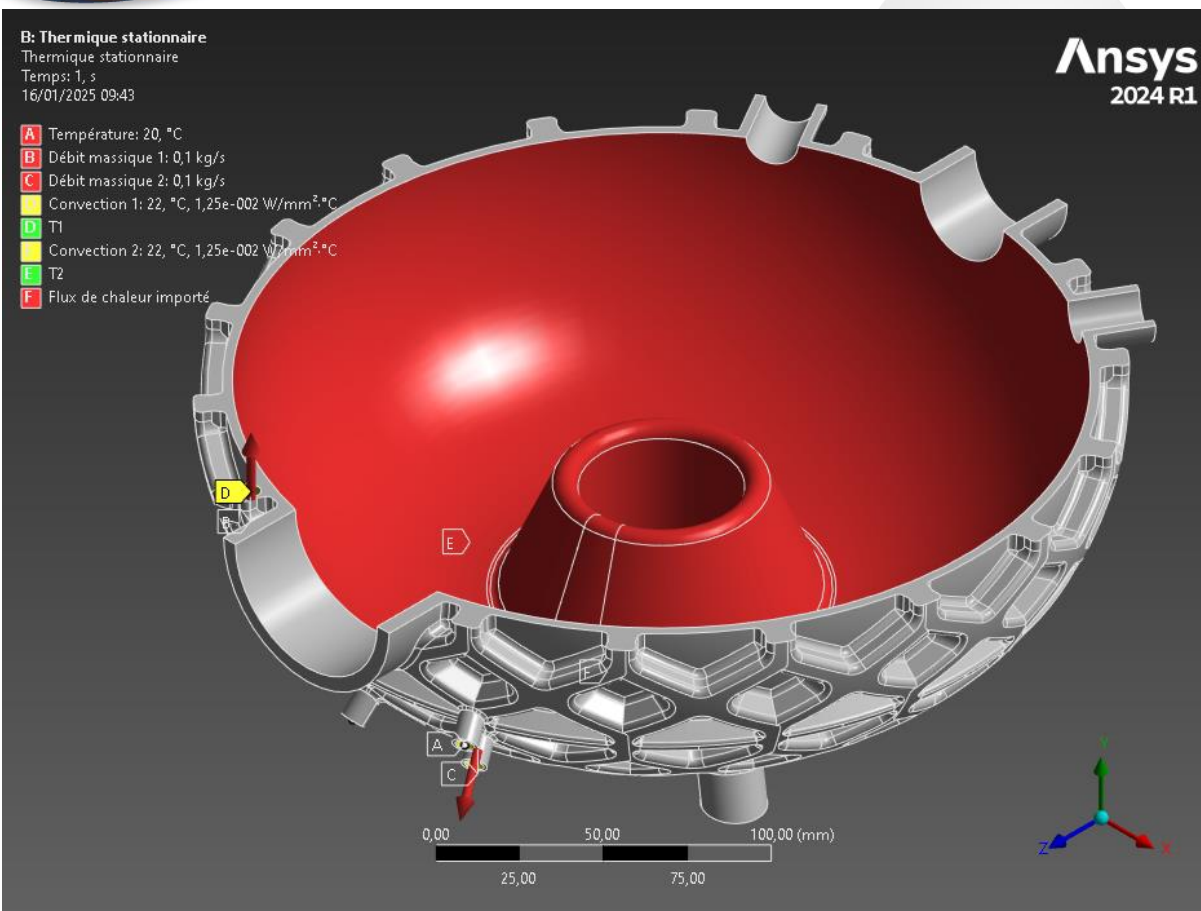
- Inlet velocity of 3,5 m/s (0,1L/s)
- Outlet pressure of 0,2 MPa
- Ra of 25 μm

Results :

- Pressure losses = 0,5 MPa (5 bar) for three circuit in series
- 0,17 MPa per circuit

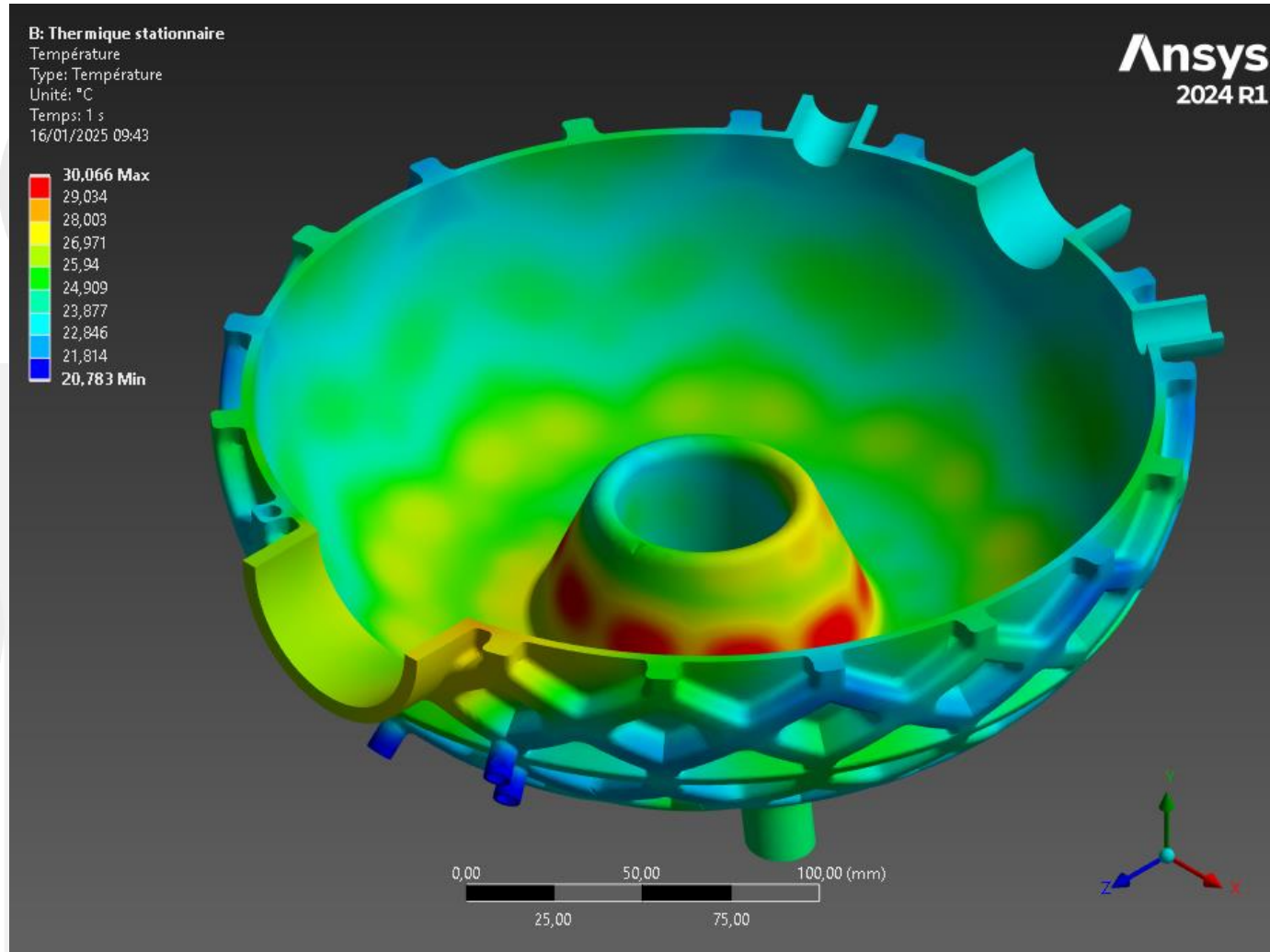


- Inlet water temperature at 20°C and a flow of 0,1 L/s
- Absorbed power of 5kW distributed **according to the heat flow field** (simulated by Patricia Duchesne)



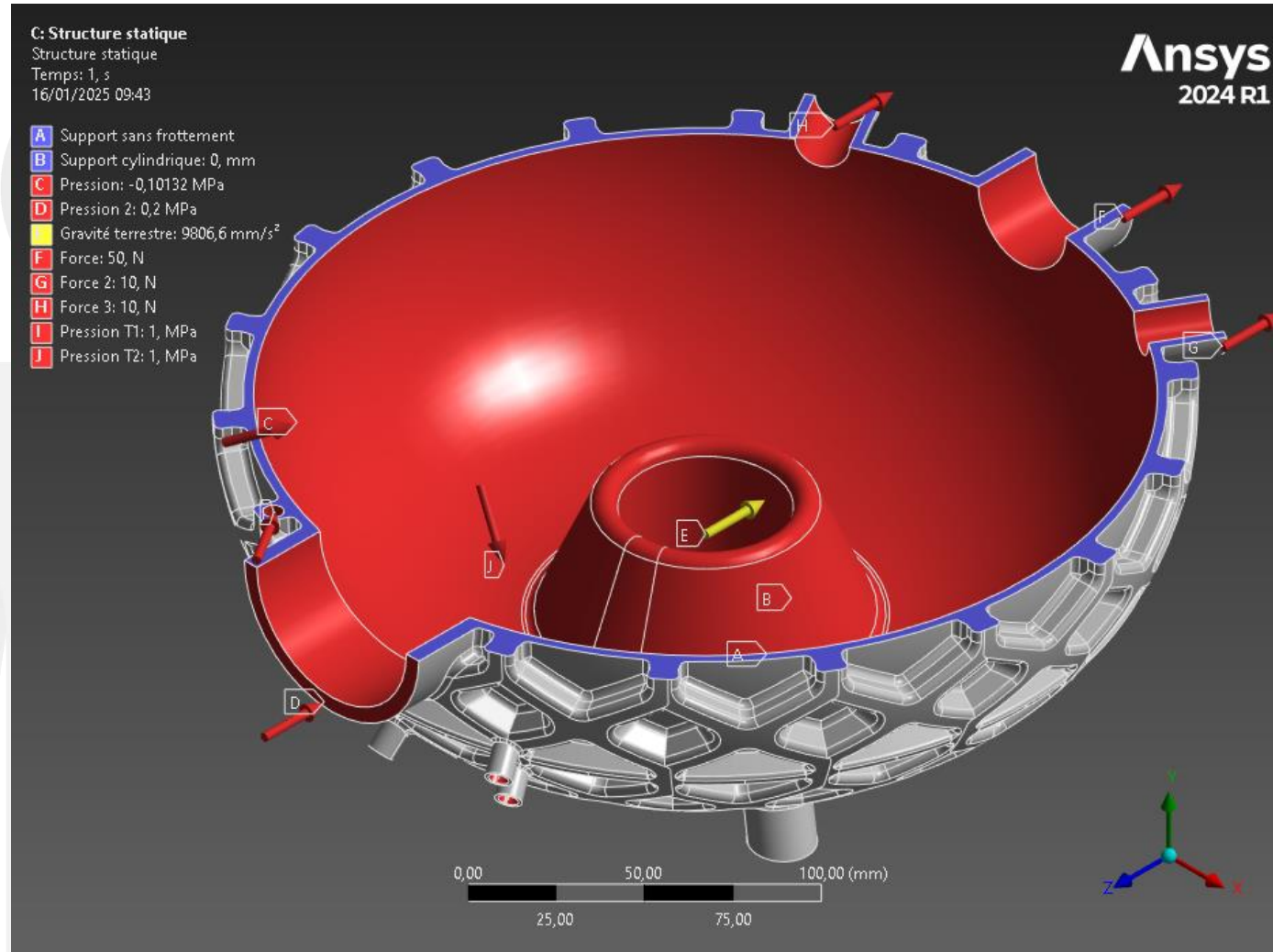
Results :

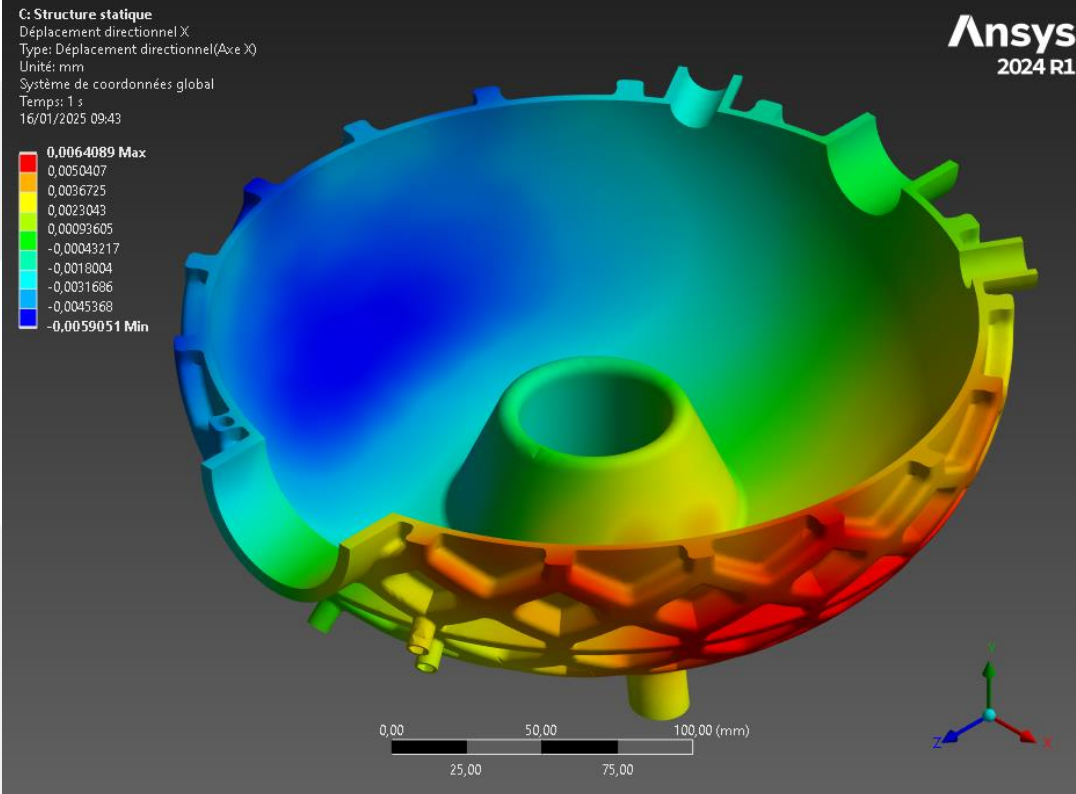
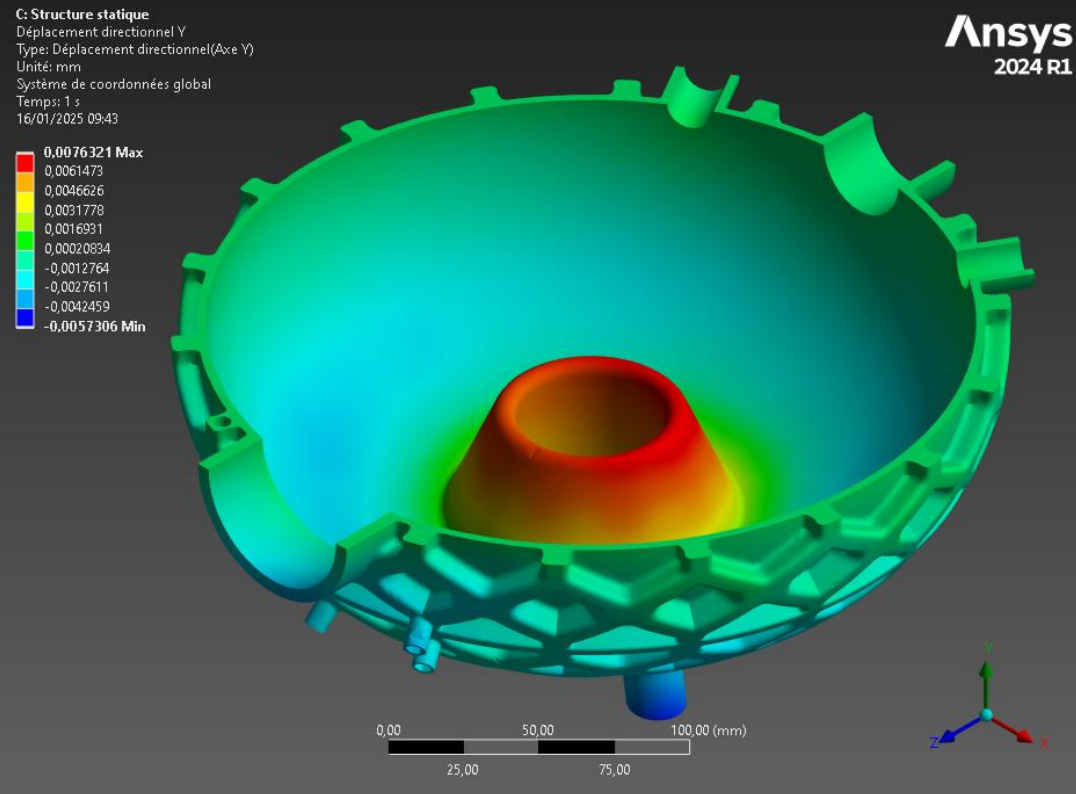
T max < 30°C



Input :

- Intern pressure : $-0,10132$ MPa
- Thermal dilatation based on thermal simulation
- Pipes pressure : 1MPa
- Pump weight : 50 N
- Gravity



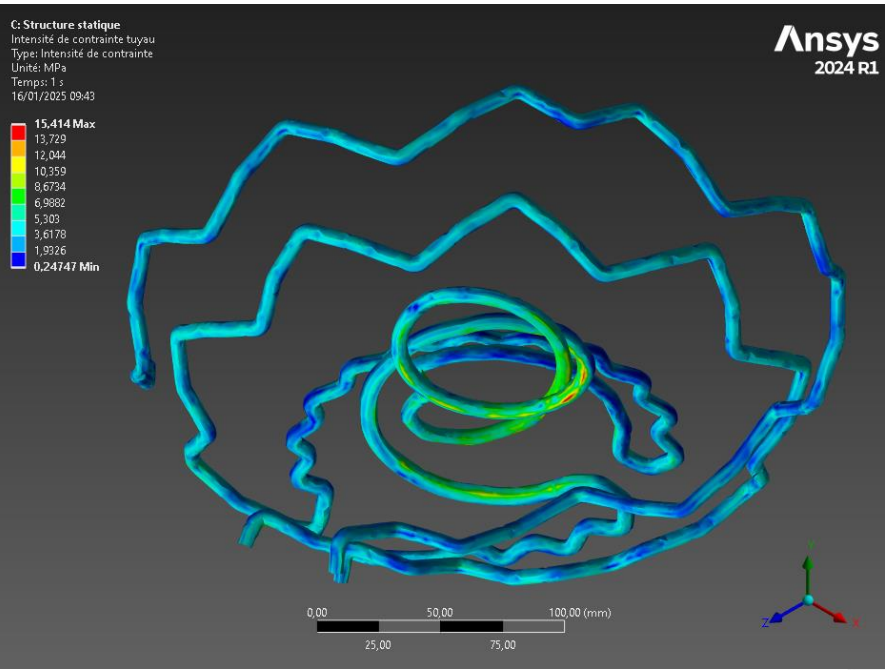
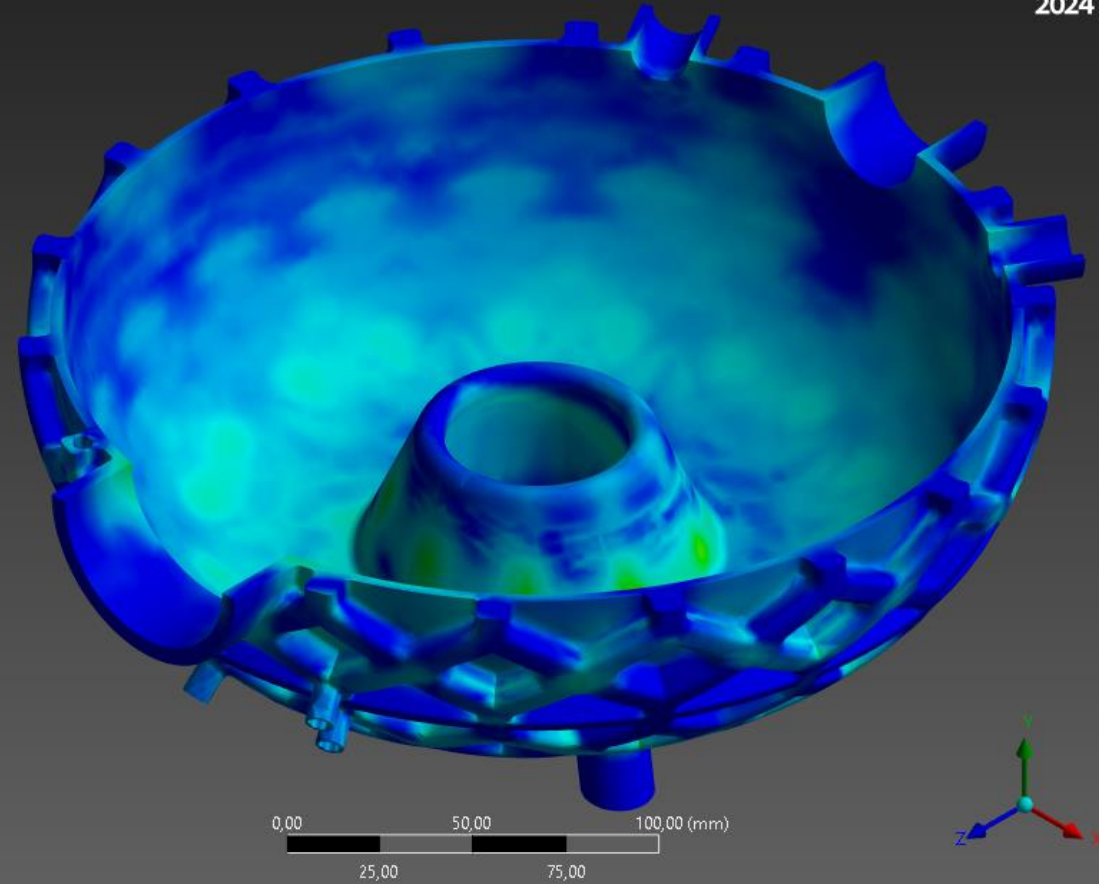
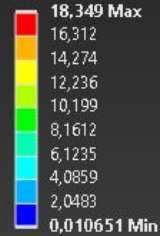


Results :
Y Deformation (Beam axes) : 0,008 mm
X Deformation : 0,006 mm

Results :
Constraint < 33 MPa

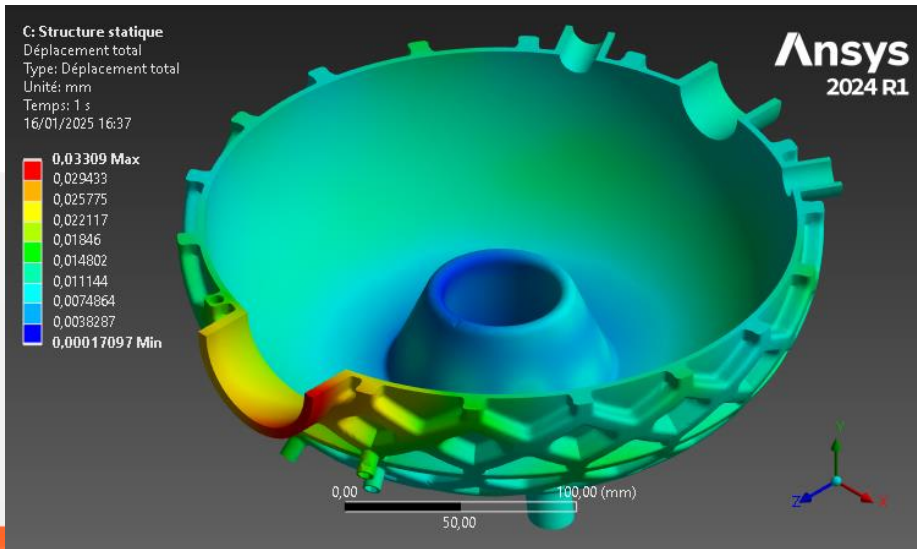
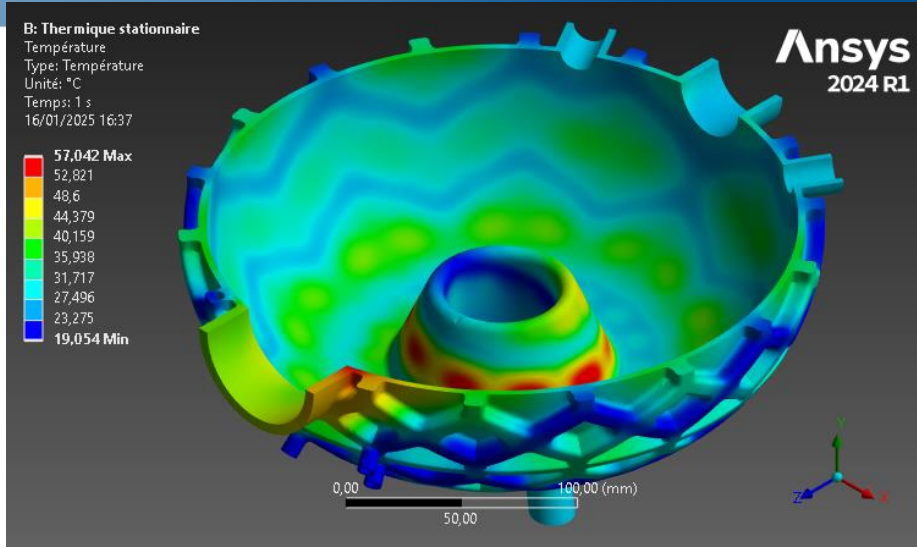
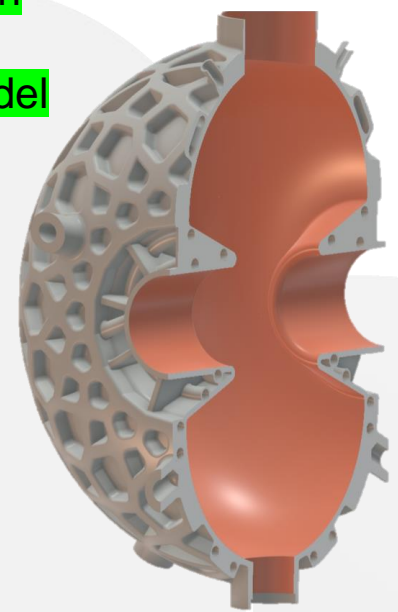
C: Structure statique
Intensité de contrainte
Type: Intensité de contrainte
Unité: MPa
Temps: 1 s
16/01/2025 09:43

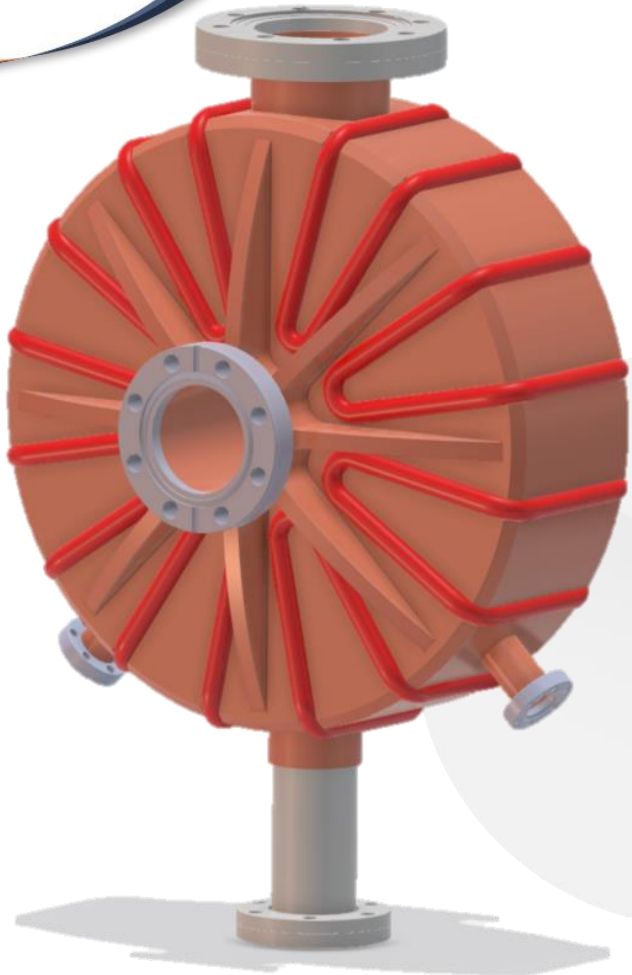
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Stainless VS copper

- Can be bolted instead of brazed
- Similar efficiency of the mechanical strength
- CF flanges can be integrated in the 3D model
- Lower efficiency of the cooling system
 - Deformation increasing





Nose Cone type buncher

Cooling system brazed

Jean Louis Munoz from ESS Bilbao Simulation's

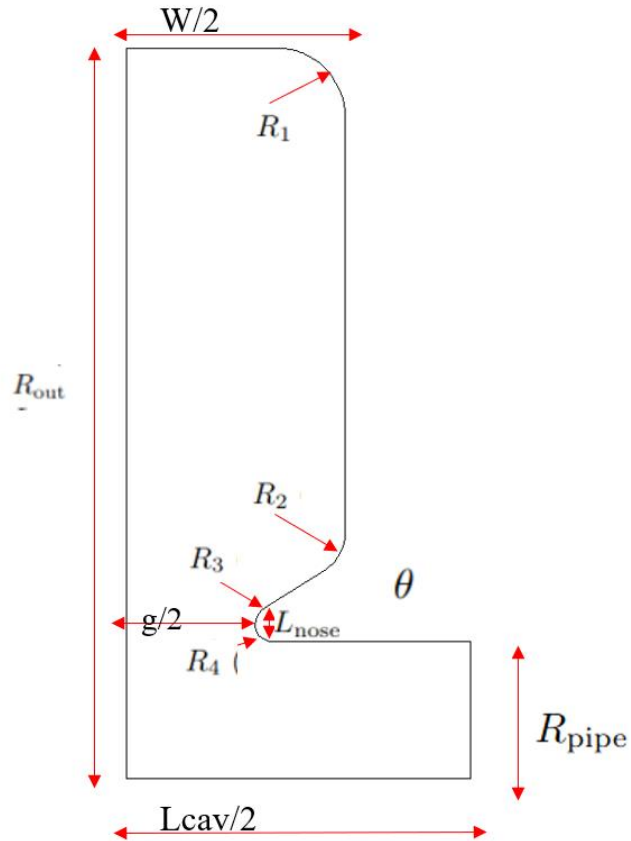
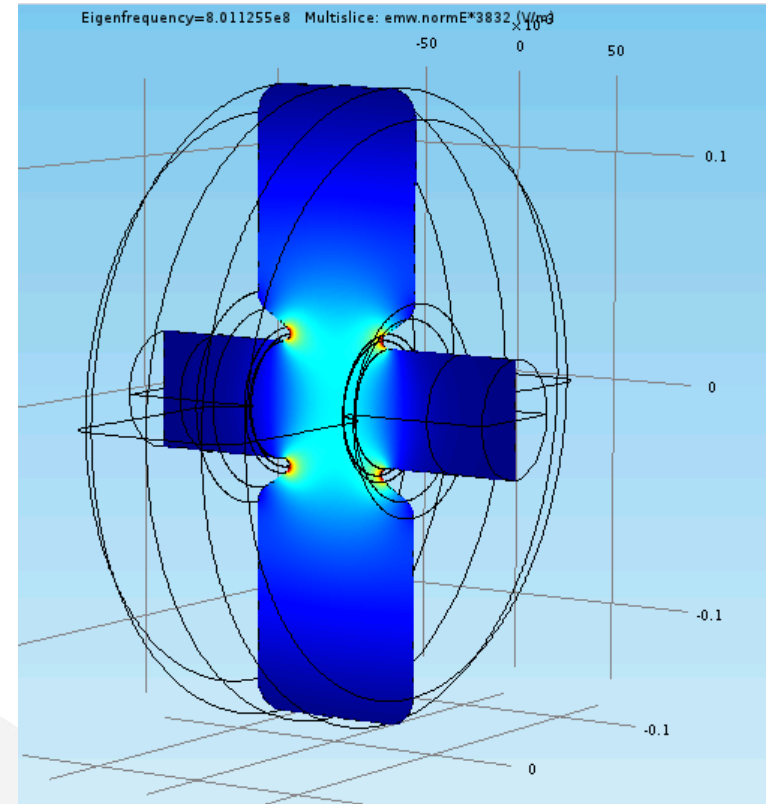
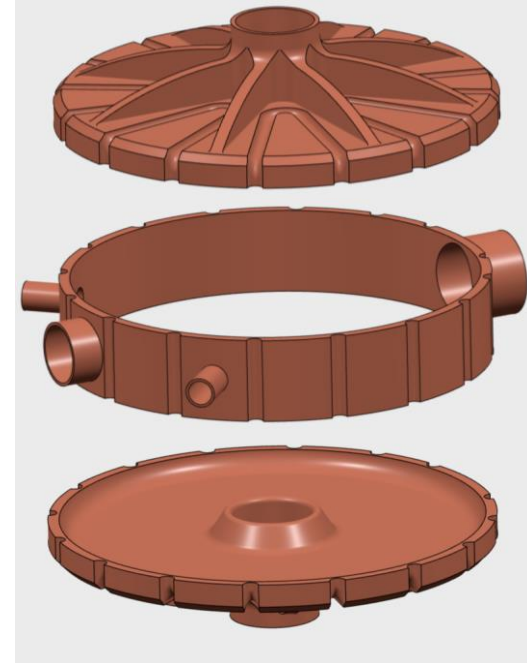
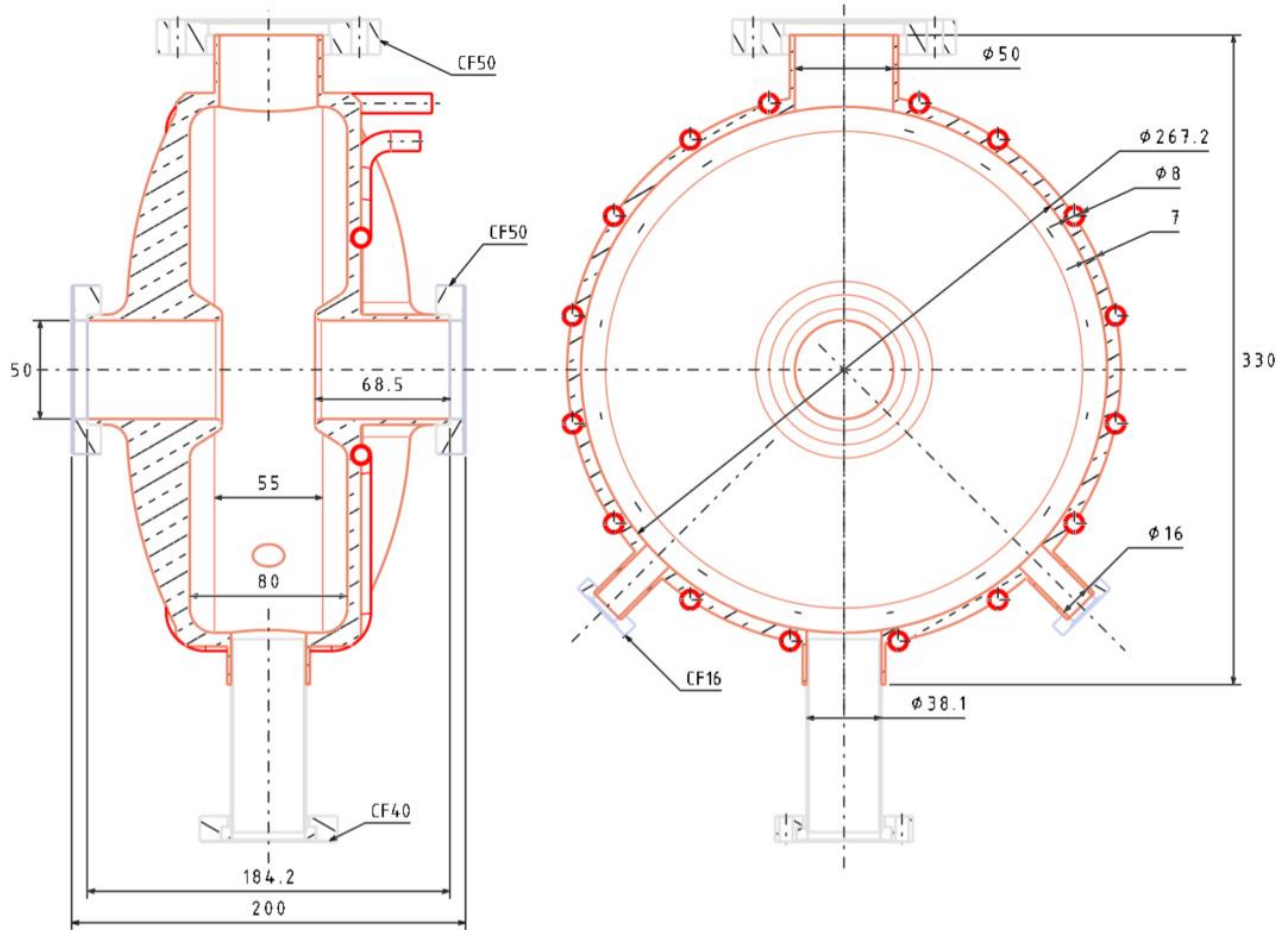
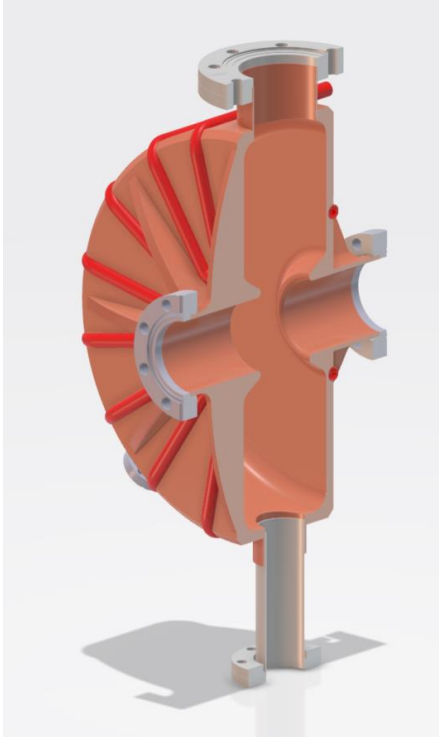


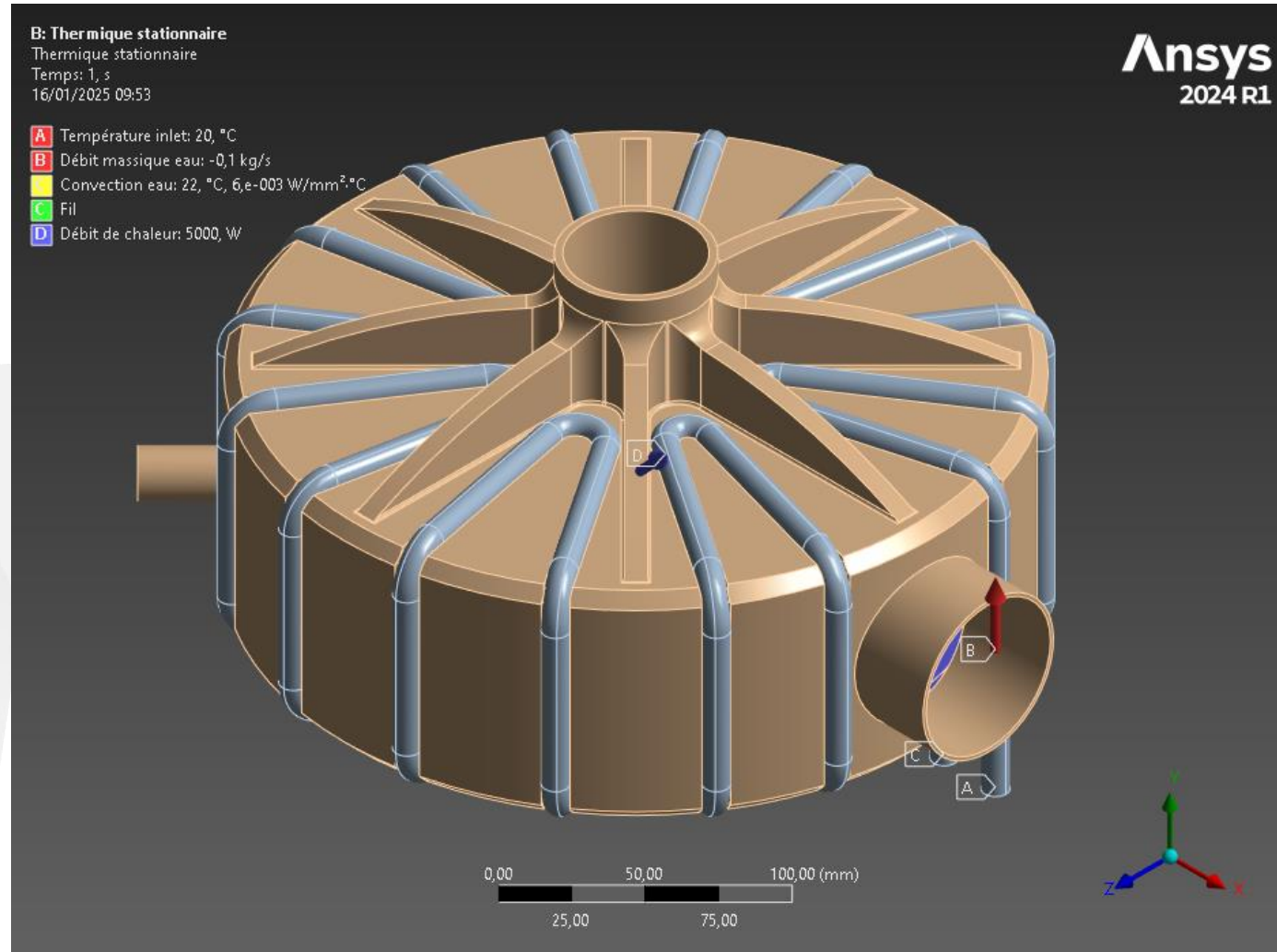
Table 6: Design Parameters PERLE buncher Nose_Cone.1

Parameter	Value
R_{pipe} (m)	0.025
g (m)	0.0472
θ (deg)	32.57
R_1 (m)	0.0125
R_2 (m)	0.0081
R_3 (m)	0.0032
R_4 (m)	0.0032
W (m)	0.08
R_{out} (m)	0.1336
L_{nose} (m)	0.005
L_{cav} (m)	0.126
lc_1 (m)	0.0002
lc_2 (m)	0.0002
β	0.8048
RF frequency (Hz)	8.0156×10^8
Conductivity σ (S/m)	5.8×10^7
Gradient (V/m)	1.4×10^6
Geometry filename	perle_buncher_nosecone_01_geom.dxf



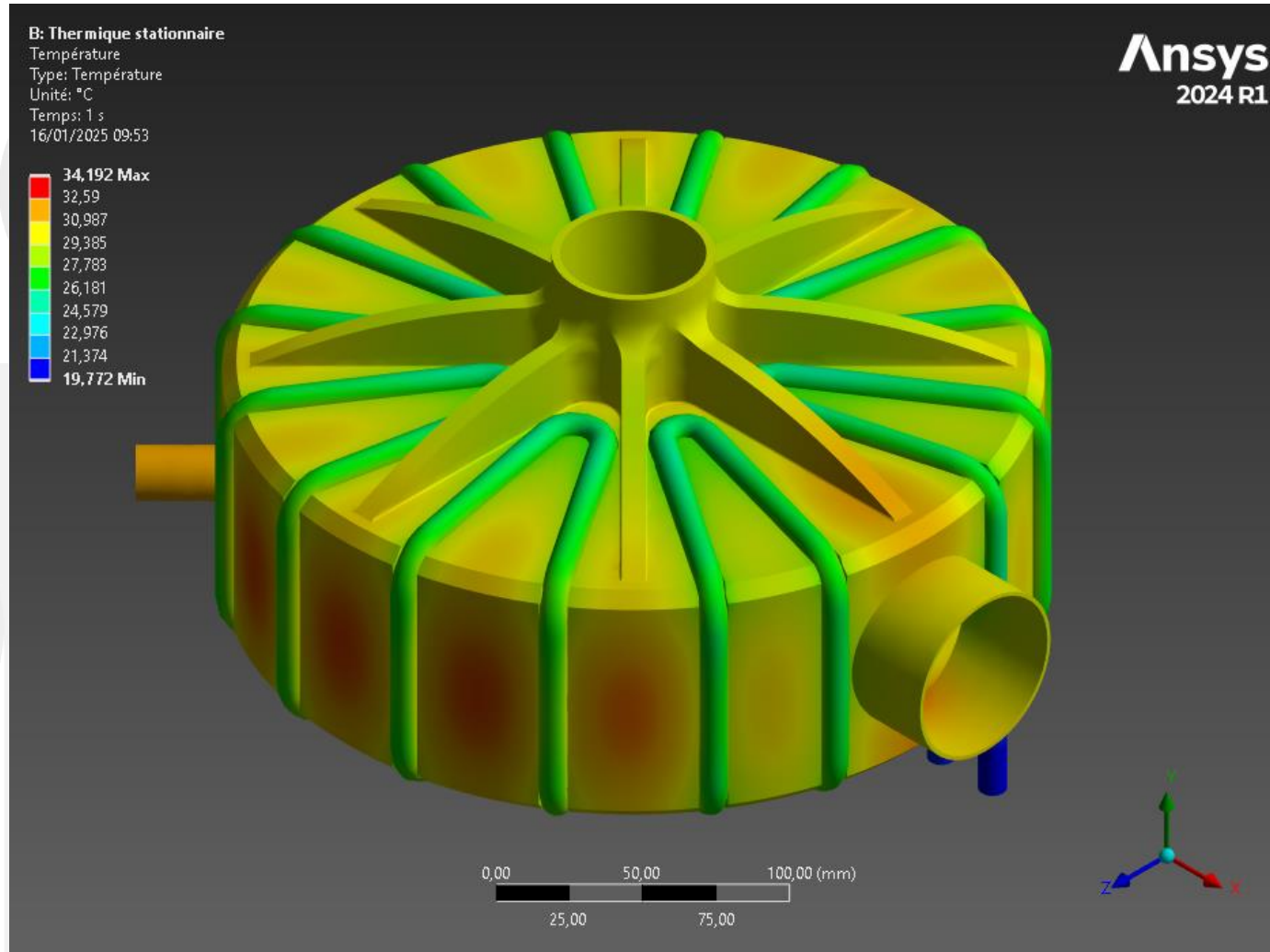


- Inlet water temperature at 20°C and a flow of 0,1 L/s
- Absorbed power of 5kW **evenly distributed**



Results :

T max < 35°C



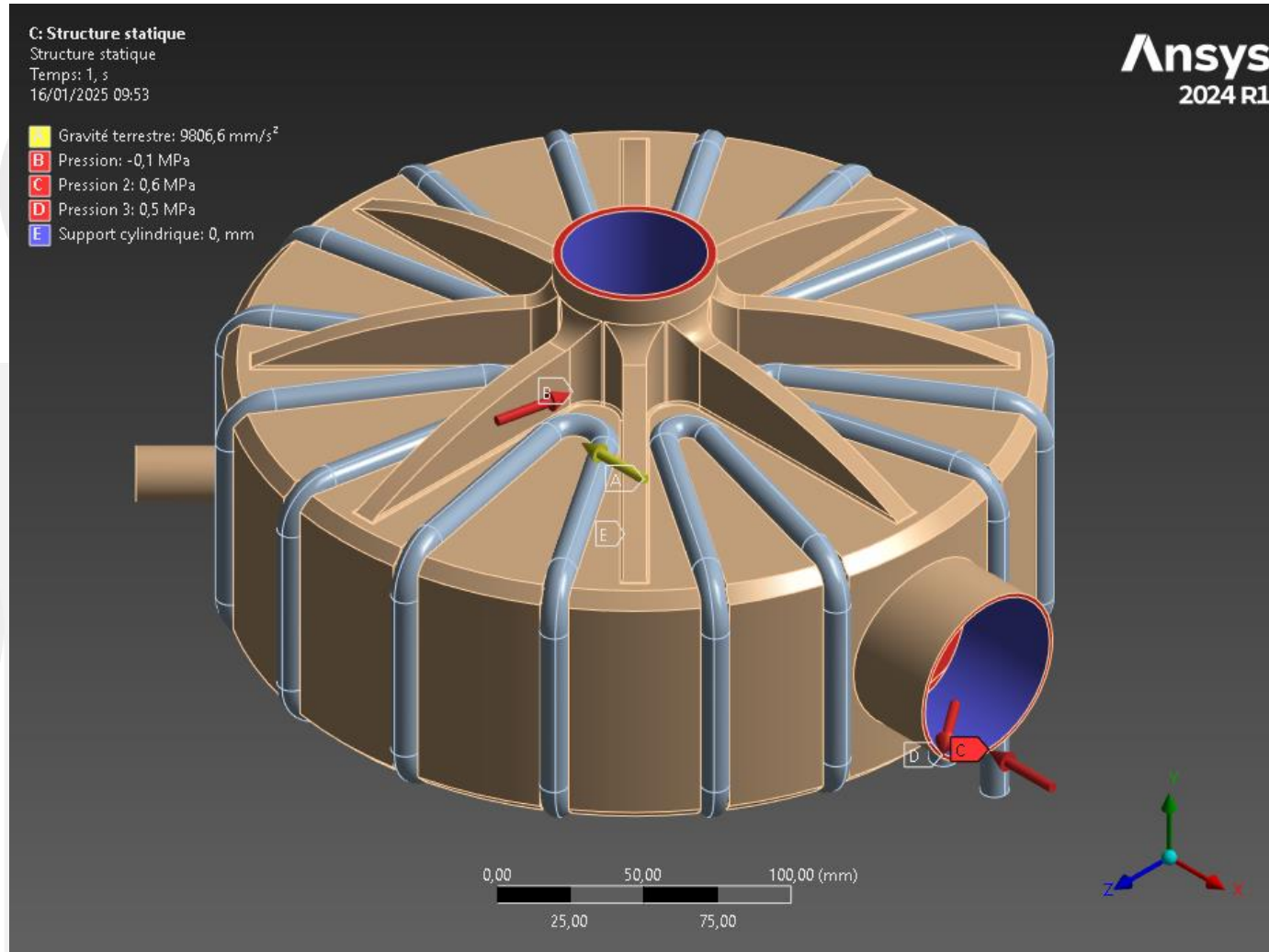
Input :

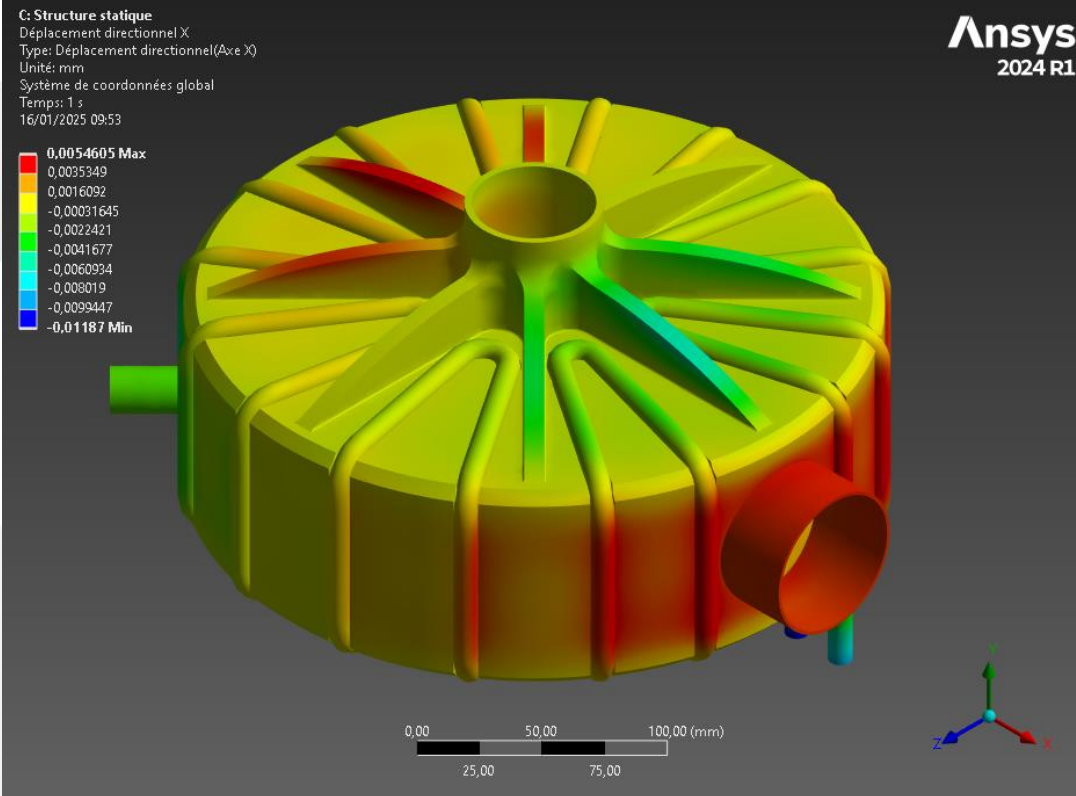
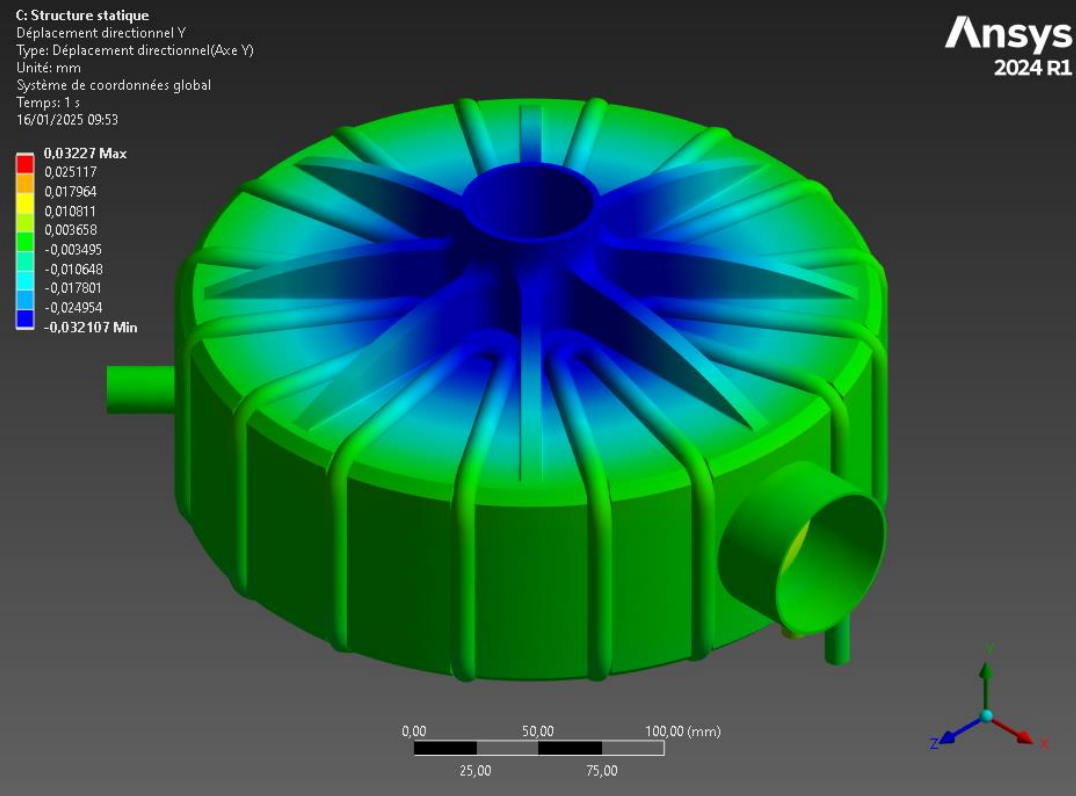
Intern pressure : -0,10132 MPa

Thermal dilatation based on
thermal simulation

Pipes pressure : 0,5 MPa

Gravity

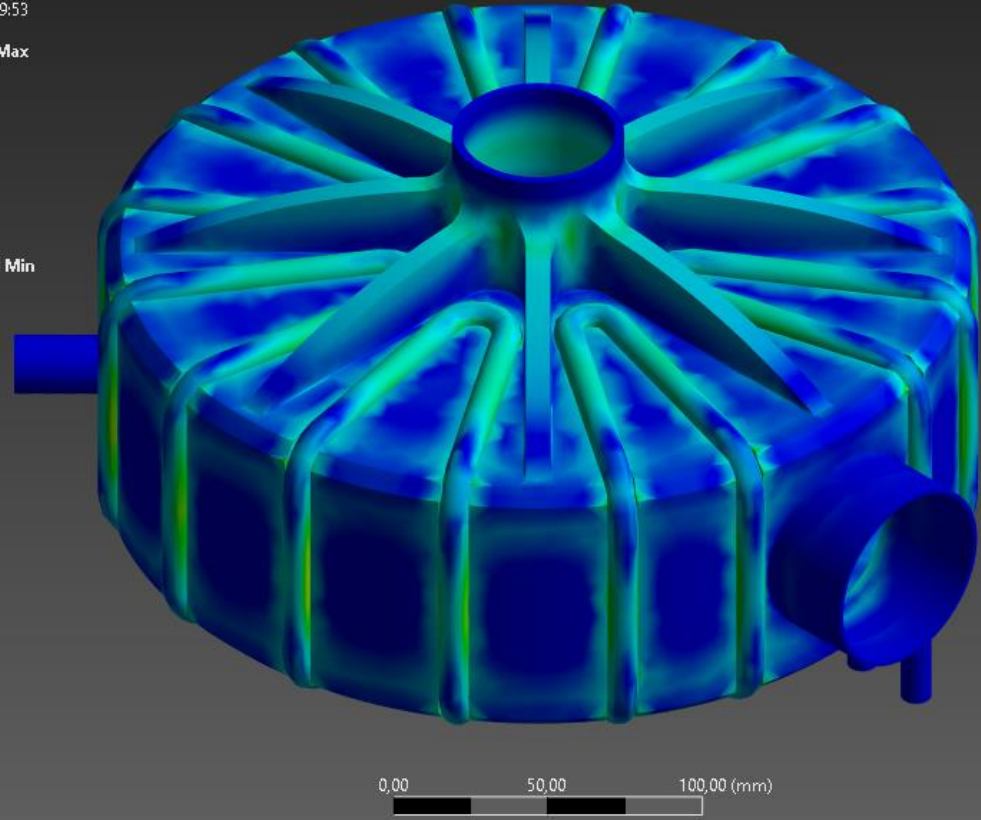
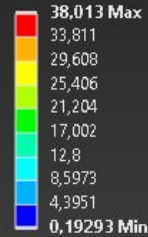




Results :
Y Deformation (Beam axes) : 0,032 mm
X Deformation : 0,005 mm

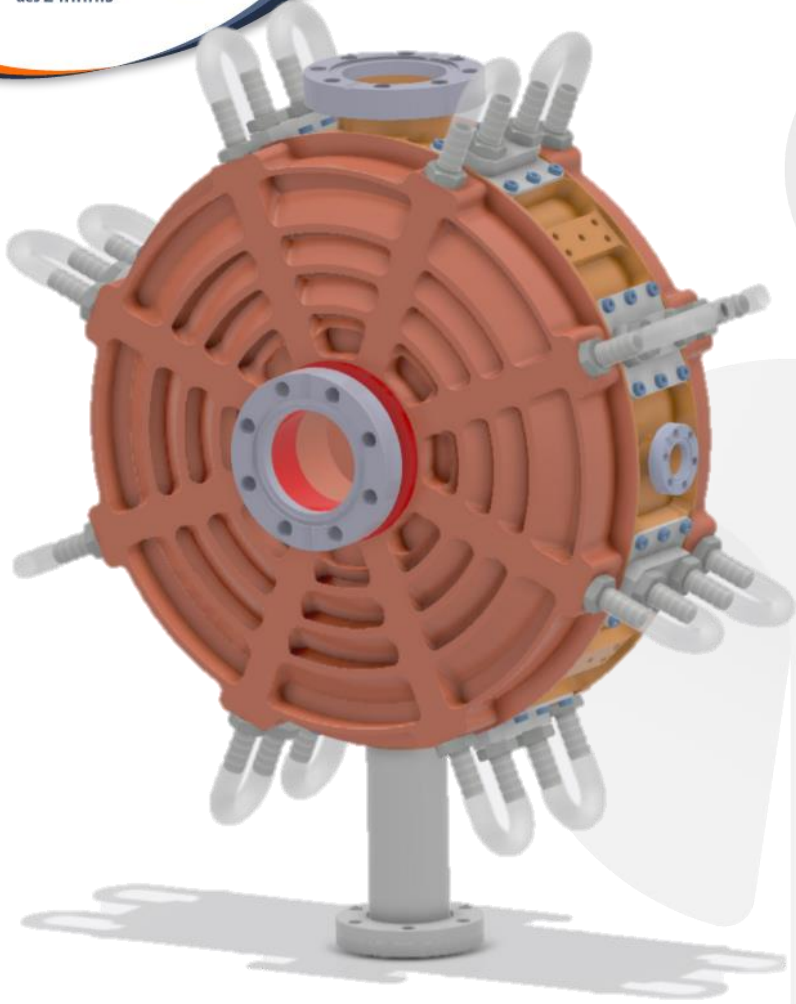
C: Structure statique
Intensité de contrainte
Type: Intensité de contrainte
Unité: MPa
Temps: 1 s
16/01/2025 09:53

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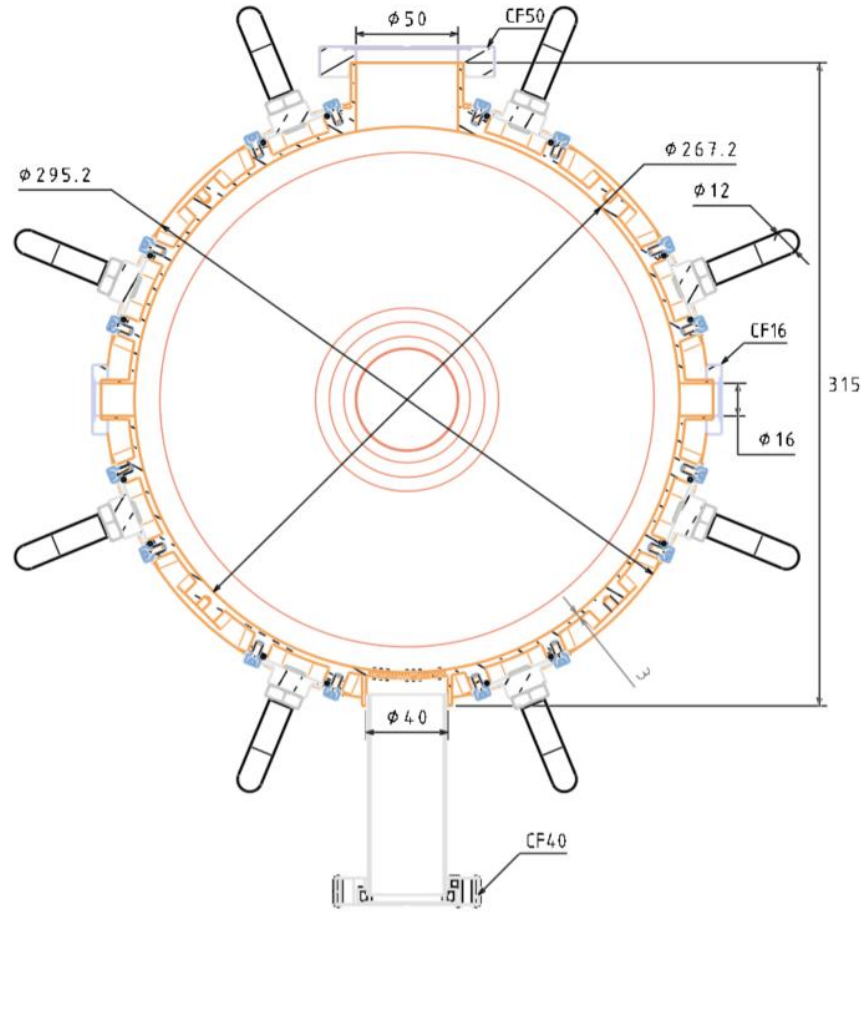
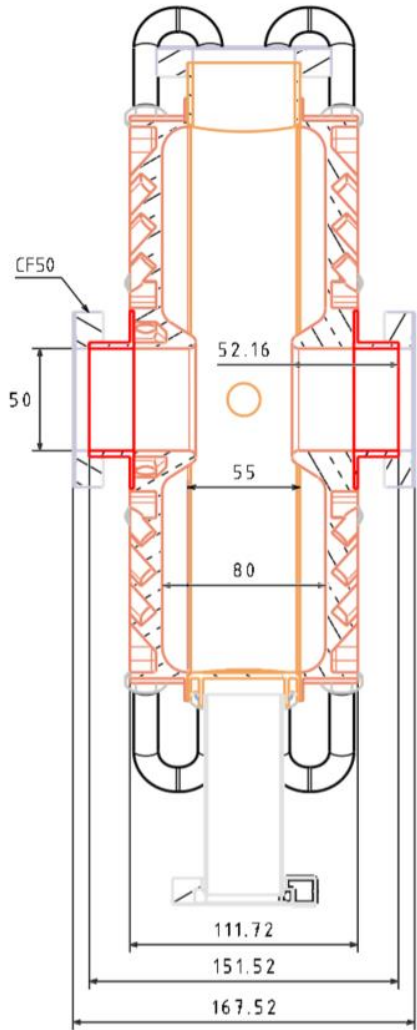
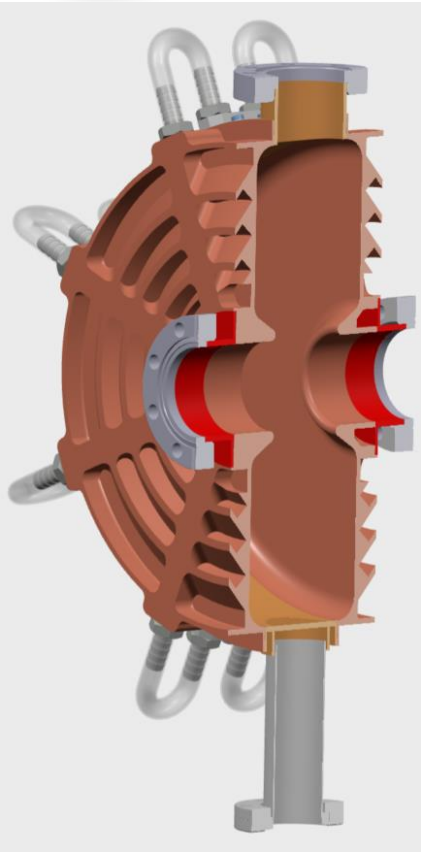
Results :
Constraint < Elastic Limit*

* The copper elastic limit is 33MPa, in some point of this simulations, the constraint is > 33 MPa. It's due to the mesh, not the real constraint

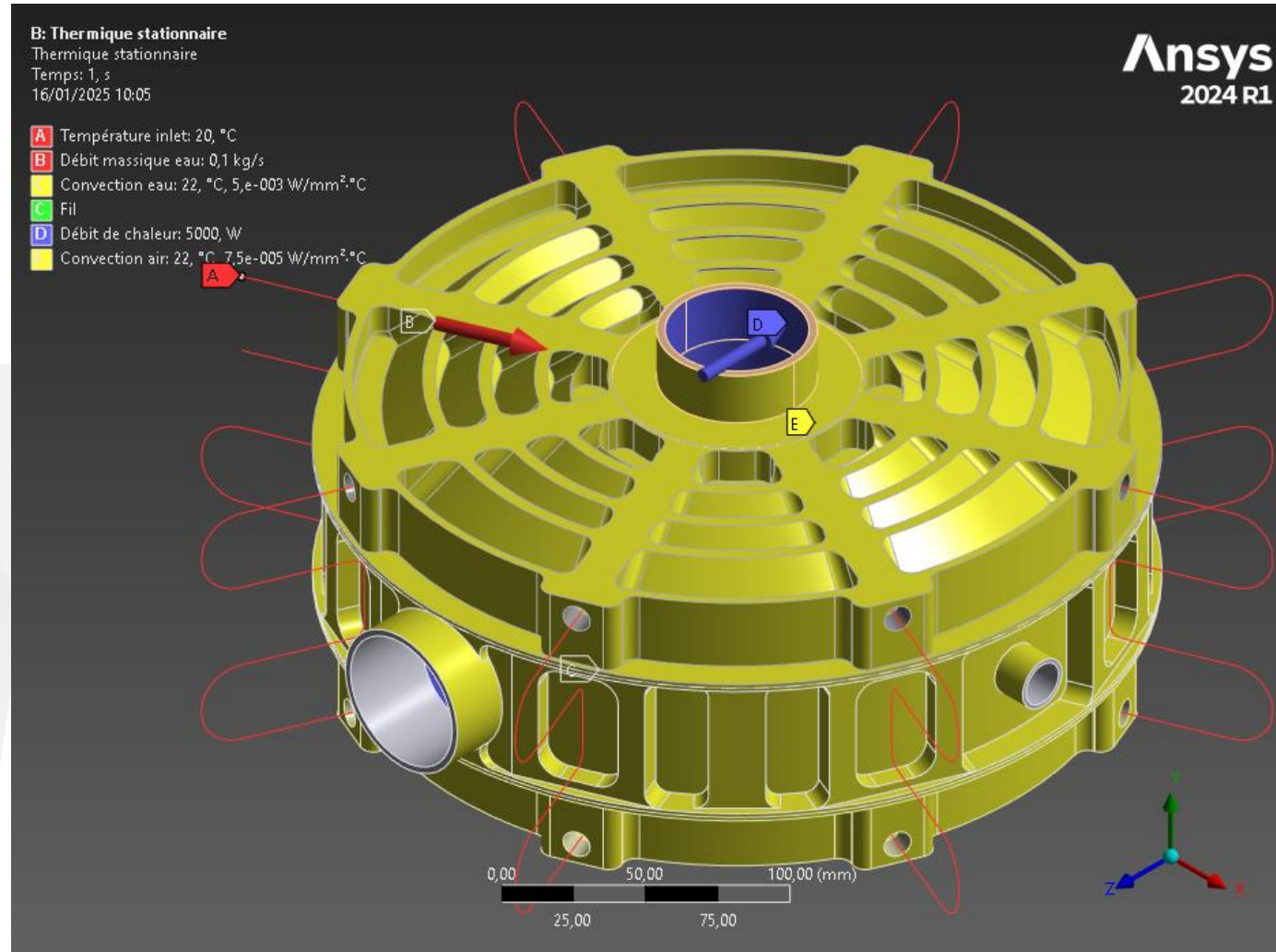


Nose Cone type buncher

Cooling system machined

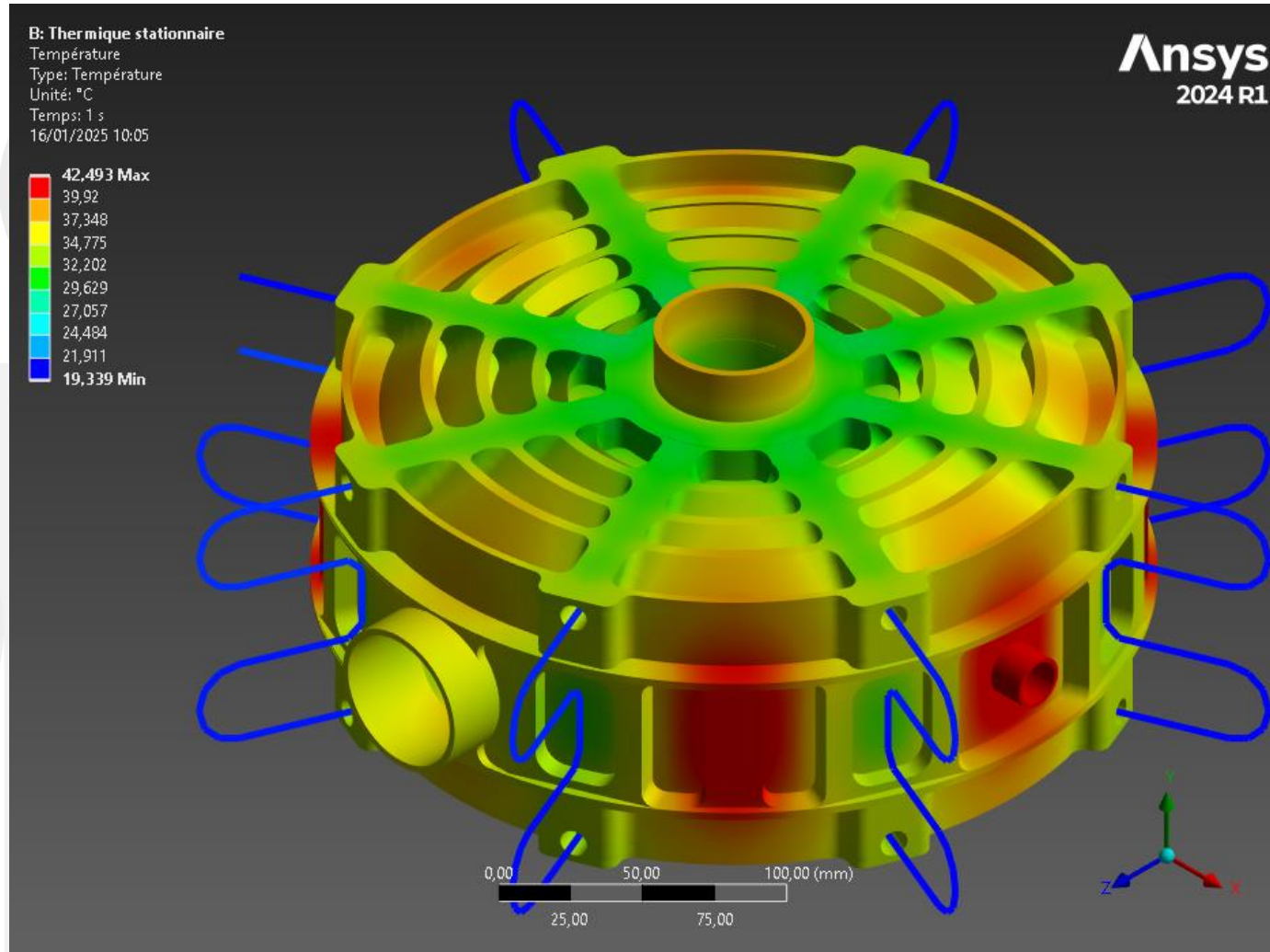


- Inlet water temperature at 20°C and a flow of 0,1 L/s
- Absorbed power of 5kW **evenly distributed**



Results :

T max < 42,5°C

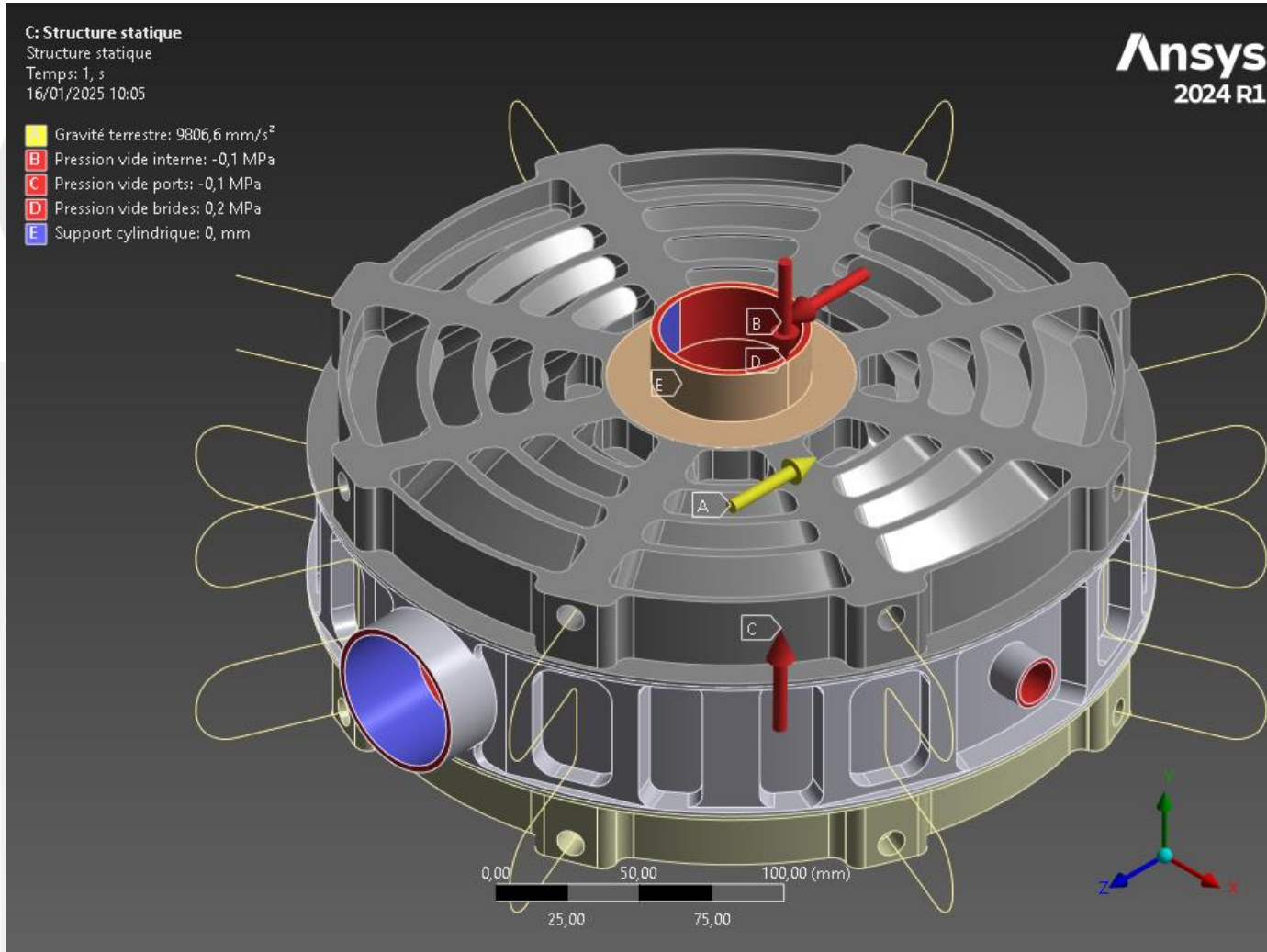


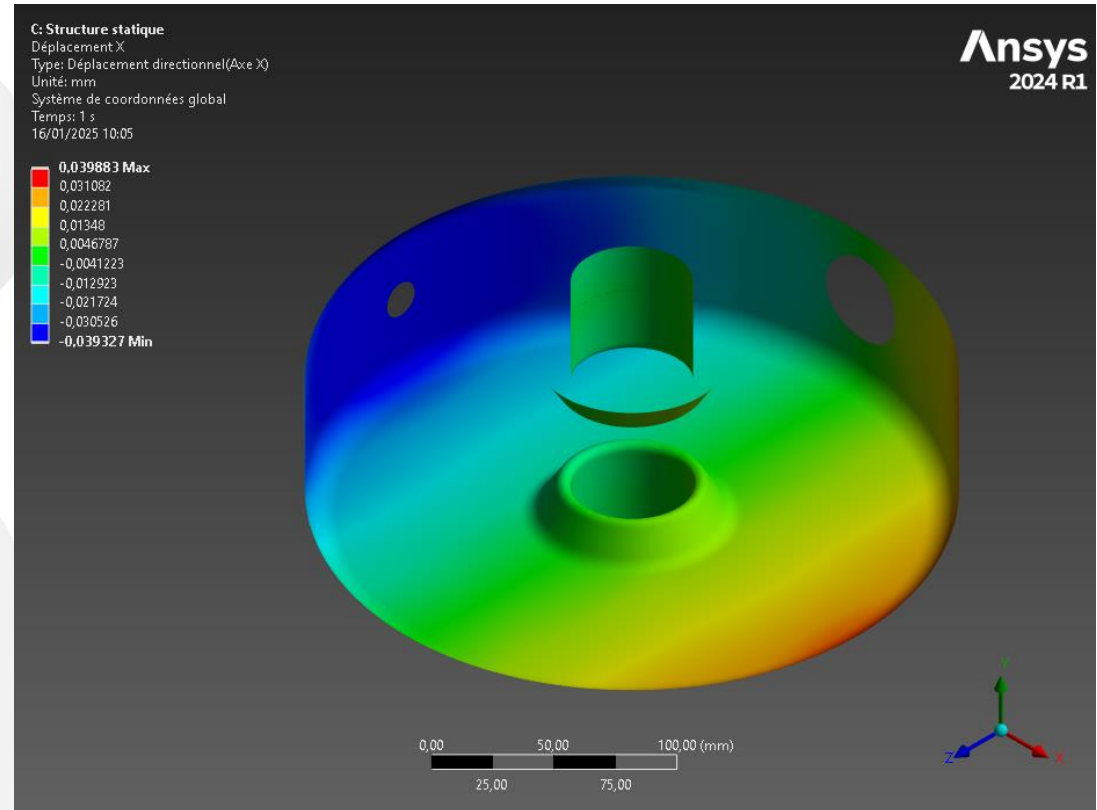
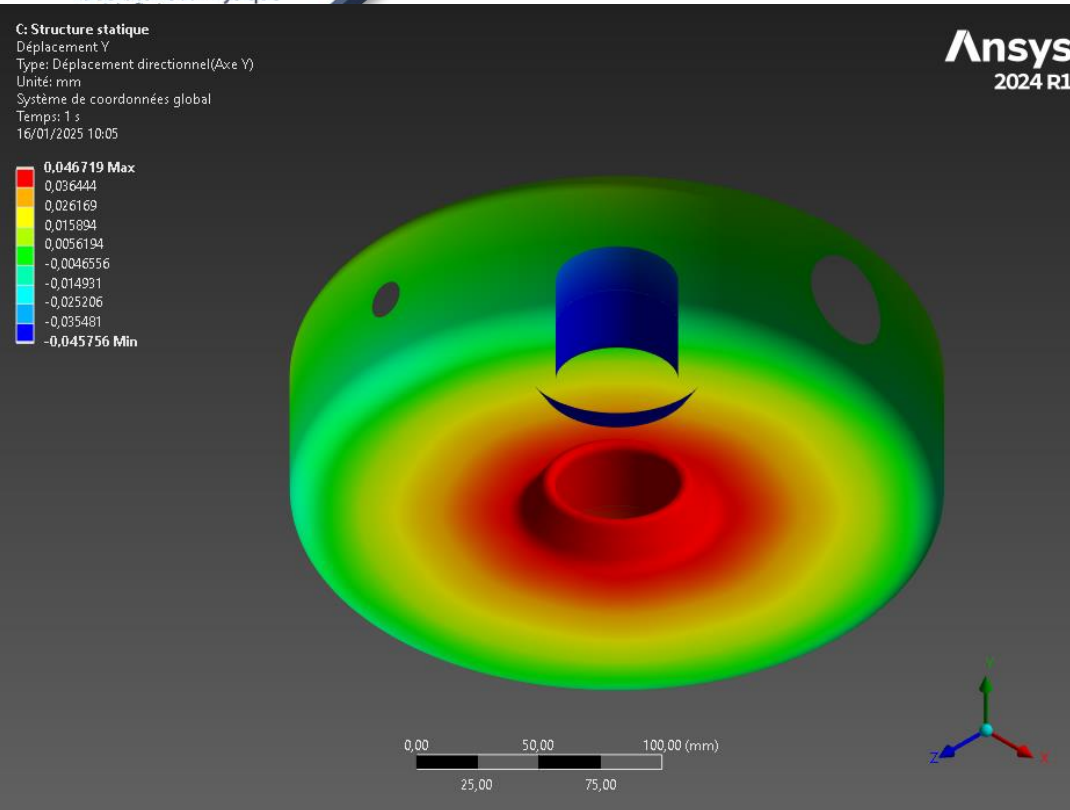
Input :

Intern pressure : -0,10132 MPa

Thermal dilatation based on
thermal simulation

Gravity

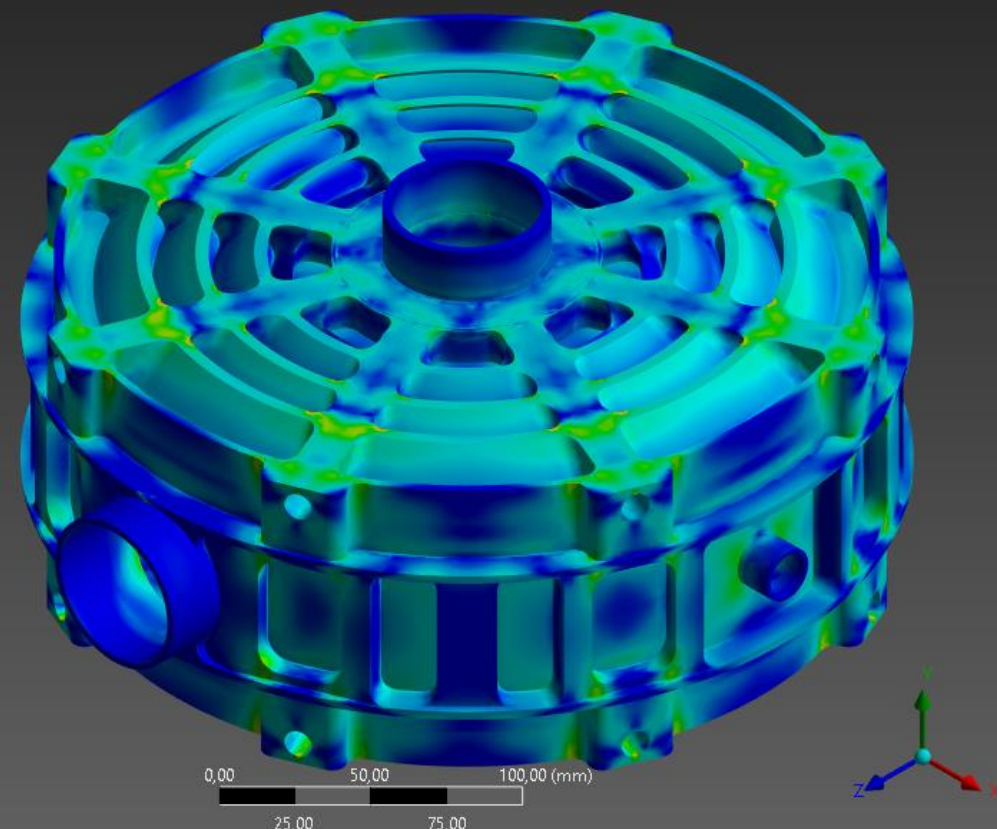
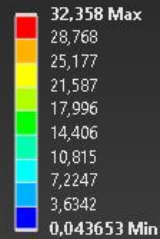




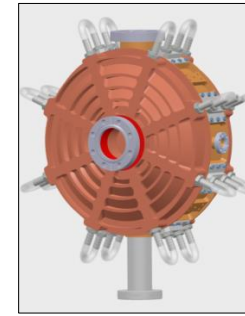
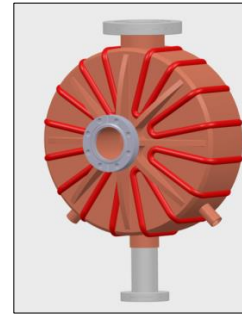
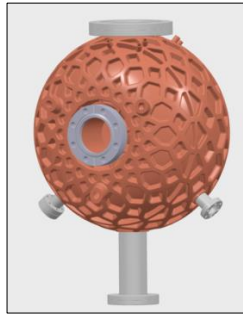
Results :
Y Deformation (Beam axes) : 0,047 mm
X Deformation : 0,040 mm

C: Structure statique
Intensité de contrainte
Type: Intensité de contrainte
Unité: MPa
Temps: 1 s
16/01/2025 10:05

Ansys
2024 R1



Results :
Constraint < Elastic Limit



Weight	12 kg	14,6 kg	15 kg
Raw material	≈ 60 kg	≈ 100 kg	≈ 60 kg
X Deformation	0,006 mm	0,005 mm	0,040 mm
Y Deformation (beam)	0,008 mm	0,032 mm	0,047 mm
Constraint	18,3 MPa	38 MPa	32,4 MPa
T max	30 �C	34,2 �C	42,5 �C
Frequency shift*	(≈ -91 kHz)	-262 kHz	-560 kHz
Feasibility	?	Hard	Feasible
Manufacturing time	≈ Days	≈ Weeks	≈ Weeks

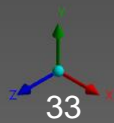
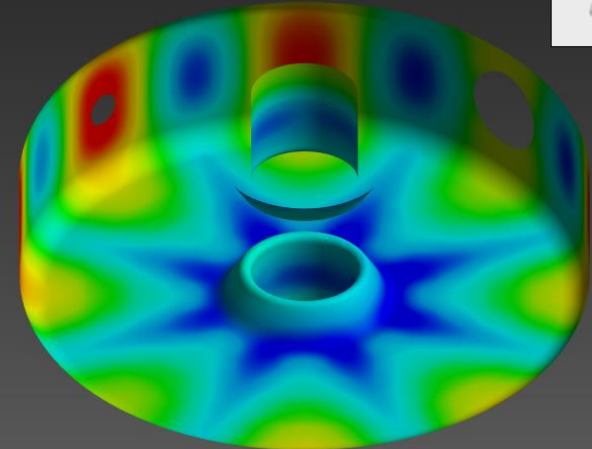
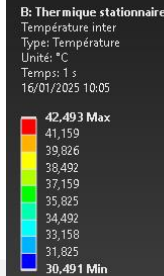
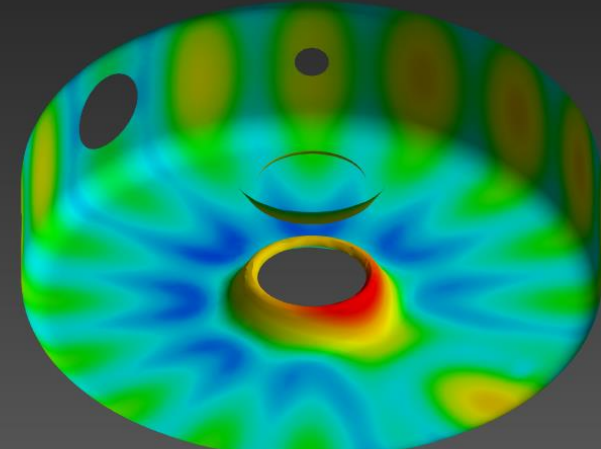
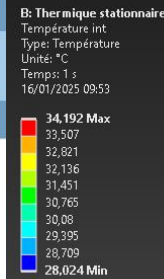
*Frequency shift due to the mechanical constraint and thermal dilatation only

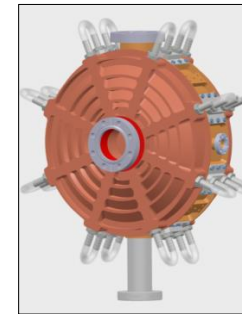
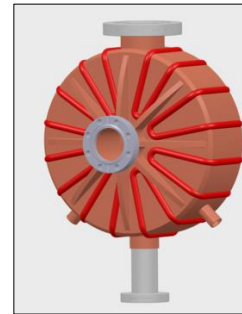
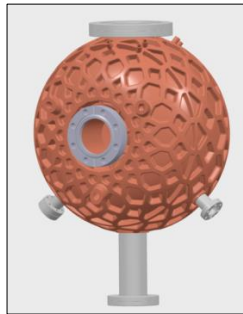
With an absorbed power of 5kW distributed **according to the heat flow field (not evenly distributed)** :







- The center of the cavity should be warmer
- The extern radius should be colder

The maximum temperature of the first cavity should increase

The maximum temperature of the second cavity should decrease





Weight	12 kg	14,6 kg	15 kg
Raw material	≈ 60 kg	≈ 100 kg	≈ 60 kg
X Deformation	0,006 mm	0,005 mm 	0,040 mm 
Y Deformation (beam)	0,008 mm	0,032 mm	0,047 mm
Constraint	18,3 MPa	38 MPa	32,4 MPa
T max	30 �C	34,2 �C 	42,5 �C 
Frequency shift*	(≈ -91 kHz)	-262 kHz 	-560 kHz 
Feasibility	?	Hard	Feasible
Manufacturing time	≈ Days	≈ Weeks	≈ Weeks

*Frequency shift due to the mechanical constraint and thermal dilatation only

Discussion with Thomas PROSLIER from CEA (17/01/2025)

- First impression
 - No technical pb with the additive manufacturing of the Buncher
 - Best way to build it : in 2 parts
 - Brazing temperature around 300 °C
- Price estimation
 - 10k / 15k € for the machining with out the powder
 - Powder : 200 €/kg => 12k € of powder
- Useful test :
 - Removing the powder in long pipe (1m or 2m) of Ø6mm



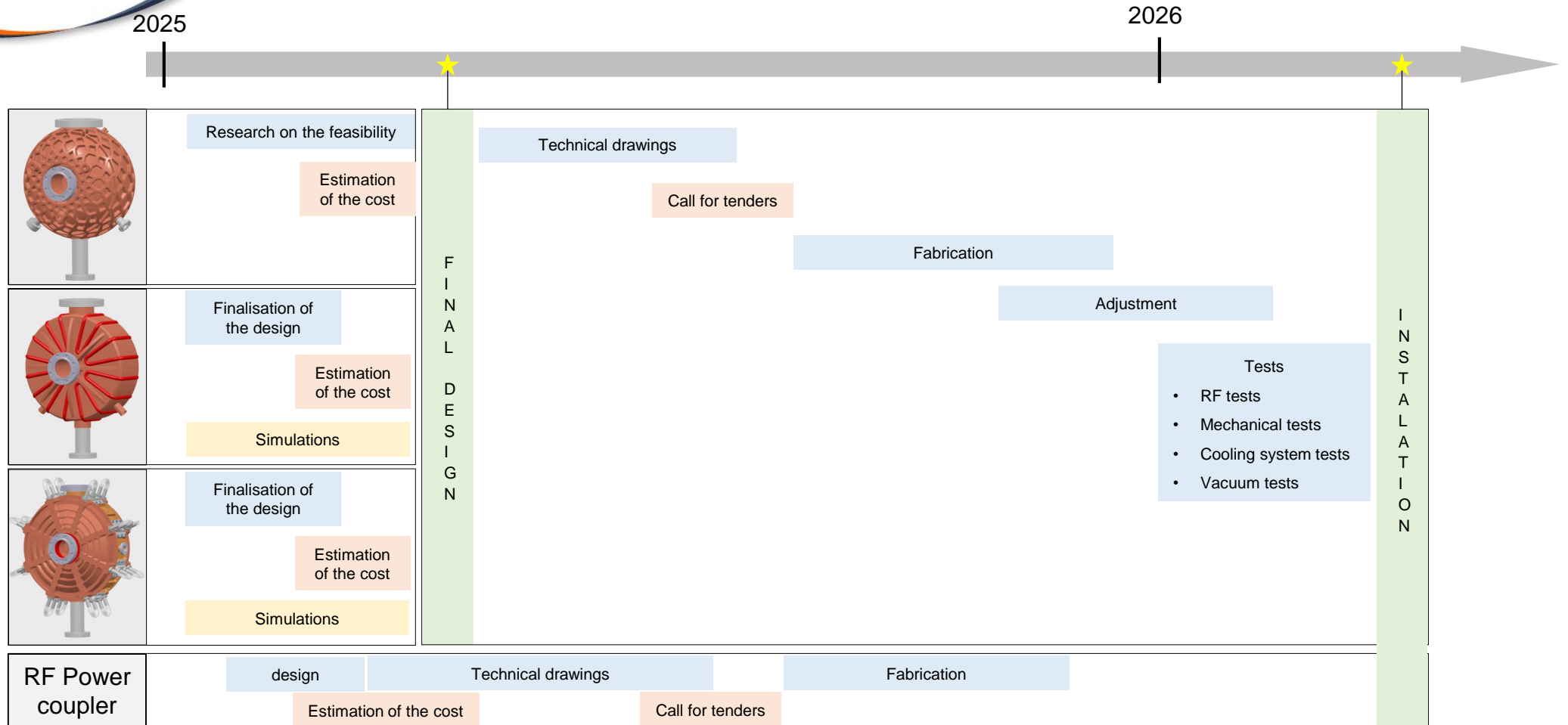
Only one machine in EU capable of printing this cavity :

- TRUMPF - TruPrint 5000 Green Edition
- At the AIDIMME Technologic institute (Spain)



TruPrint 5000 Green Edition

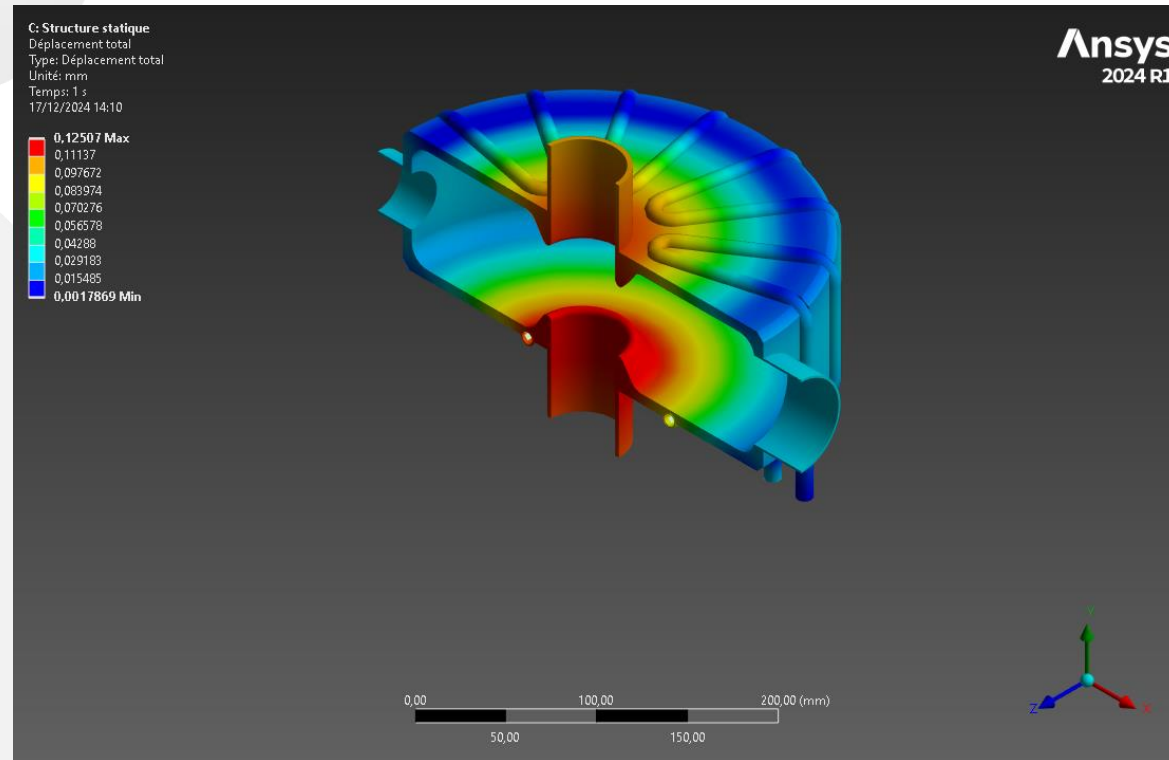
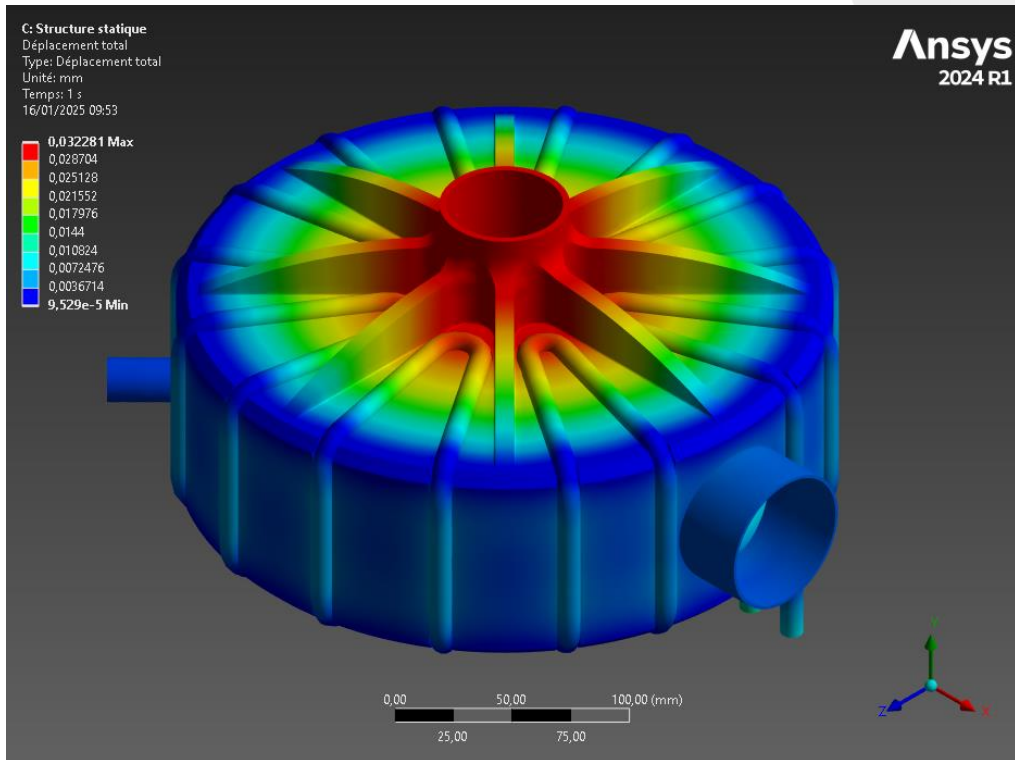
BUILD VOLUME (CYLINDER)	Diameter 300 mm x 400 mm Height
PREHEATING (STANDARD)	Down to 200 °C
MAXIMUM LASER POWER AT THE WORKPIECE (TRUMPF DISK LASER)	800 W
BEAM DIAMETER (STANDARD)	210 µm
LAYER THICKNESS	30 - 150 µm
BUILD RATE	Down to 100 cm ³ /h
CONNECTION AND CONSUMPTION	
ELECTRICAL CONNECTION (VOLTAGE)	TruPrint 5000 400 V TruDisk 1020 400 V
ELECTRICAL CONNECTION (CURRENT INTENSITY)	TruPrint 5000 32 A TruDisk 1020 16 A
ELECTRICAL CONNECTION (FREQUENCY)	TruPrint 5000 50 Hz TruDisk 1020 50 Hz
SHIELDING GAS	Nitrogen, argon
STRUCTURAL DESIGN	
WEIGHT (INCLUDING POWDER)	TruPrint 5000 7007 kg TruDisk 1020 530 kg
DIMENSIONS (INCLUDING FILTER, ELECTRICAL CABINET) (W X H X D)	4616 mm x 2038 mm x 4234 mm



A large, light gray, stylized human figure is centered in the background. It consists of a circular head, a rounded torso, and a curved base representing legs. The figure is semi-transparent, allowing the text to be seen through it.

Thanks

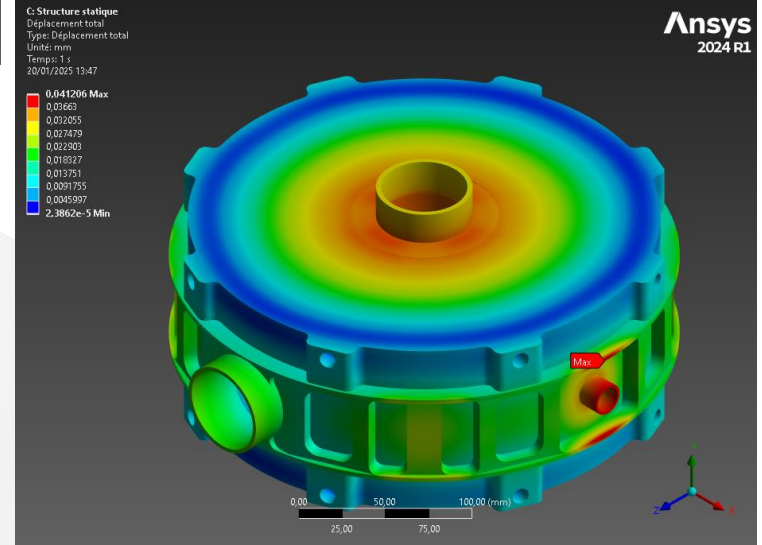
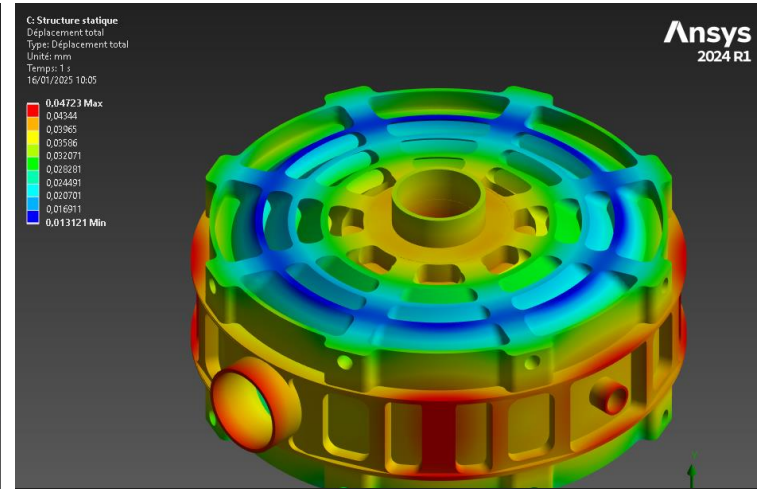
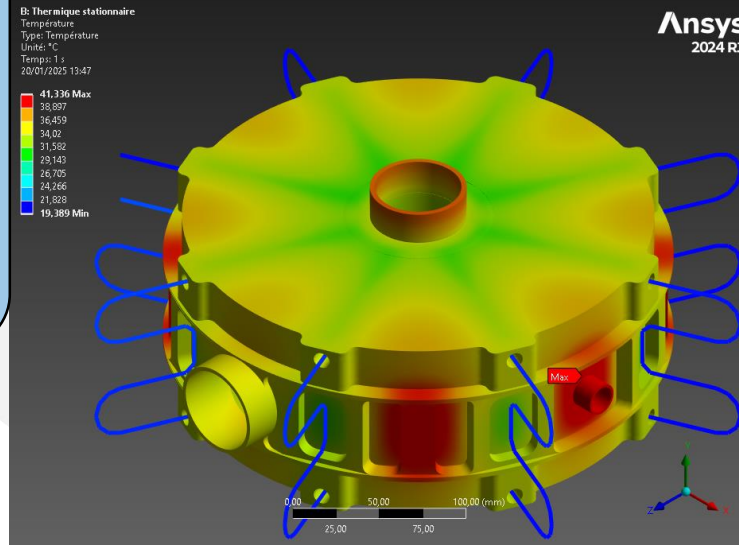
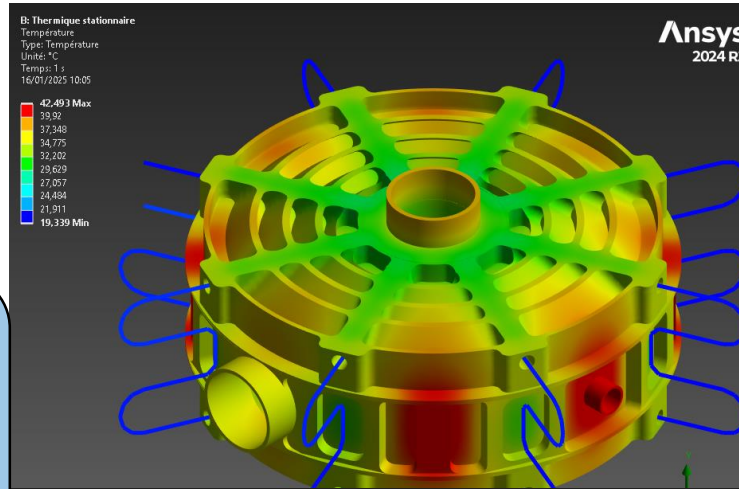
Results :
without reinforcement Deformation = 3,75 x with reinforcement Deformation



Results :

Deformation : Full = 0,87 x inclined

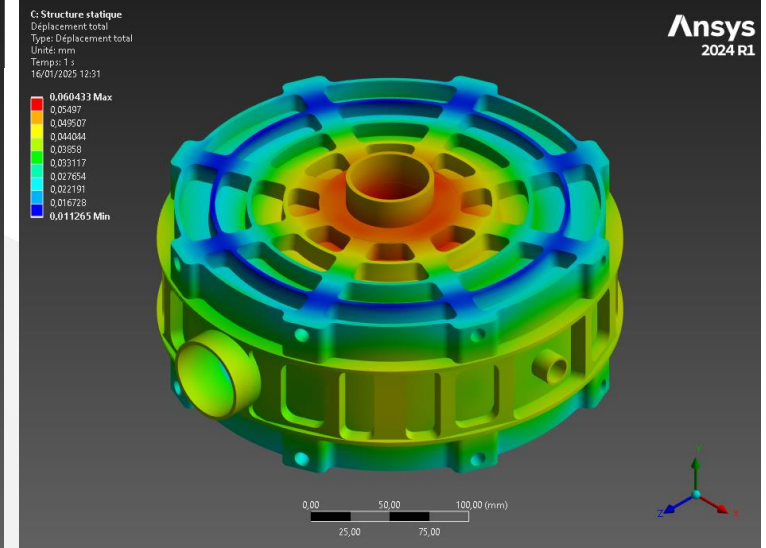
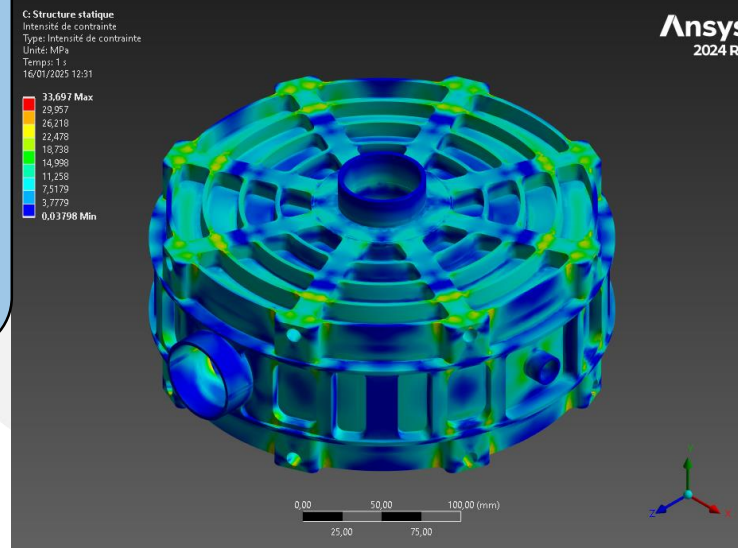
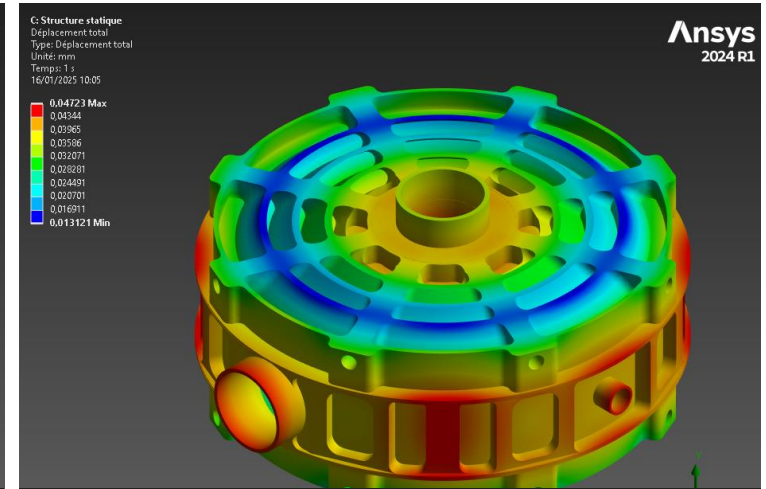
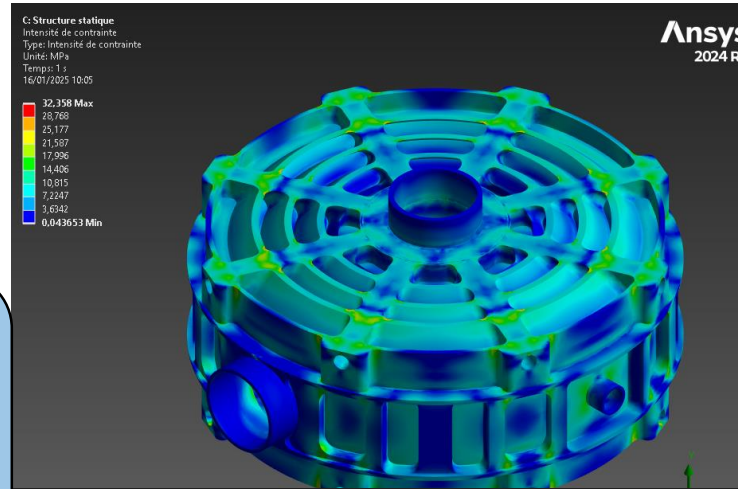
Weight : Full = 1,33 x inclined



Results :

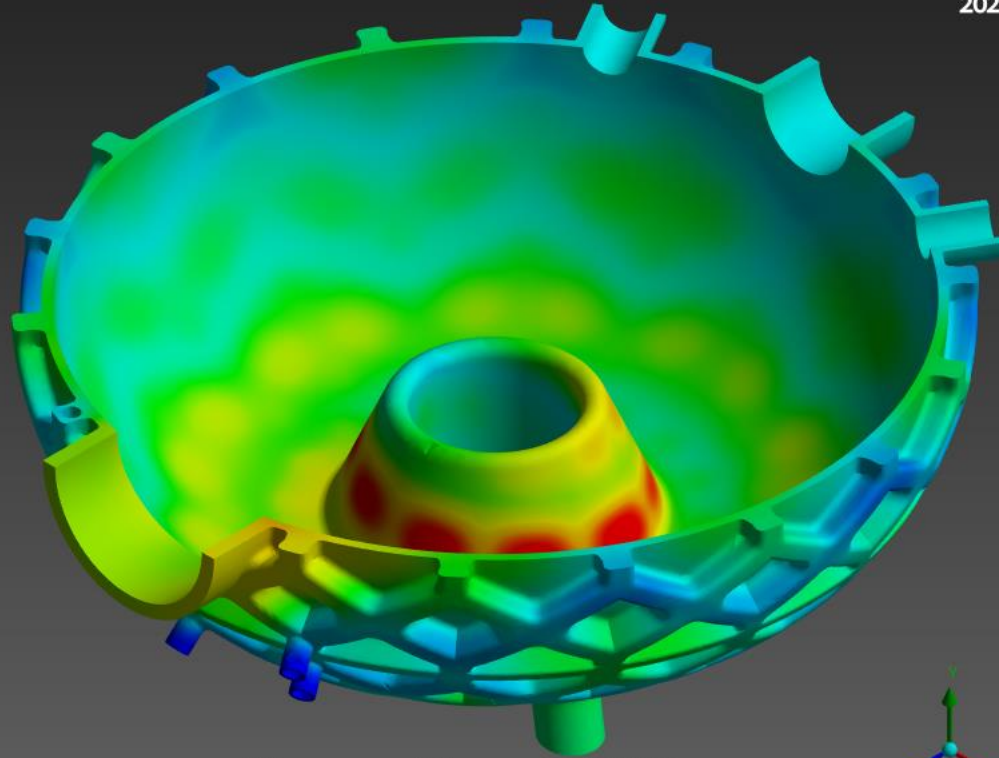
Deformation : Vertical = 1,28 x inclined

Constraint : Vertical = 1,04 x inclined

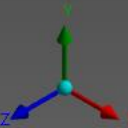


B: Thermique stationnaire
 Température
 Type: Température
 Unité: °C
 Temps: 1 s
 29/01/2025 14:01

23,208 Max
 22,879
 22,551
 22,222
 21,893
 21,564
 21,236
 20,907
 20,578
 20,249 Min



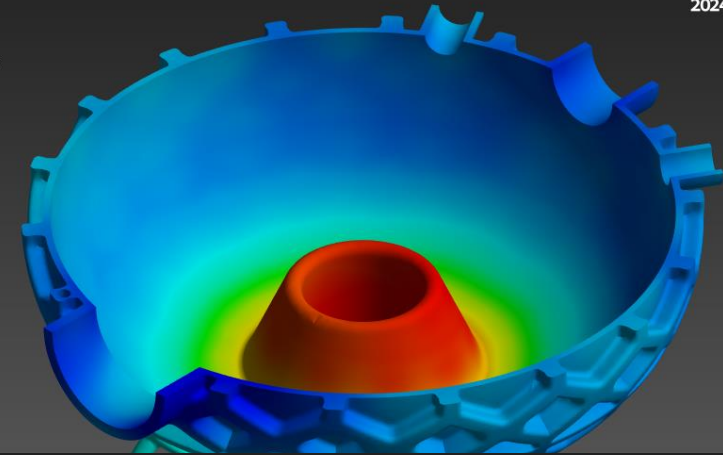
0,00 50,00 100,00 (mm)
 25,00 75,00



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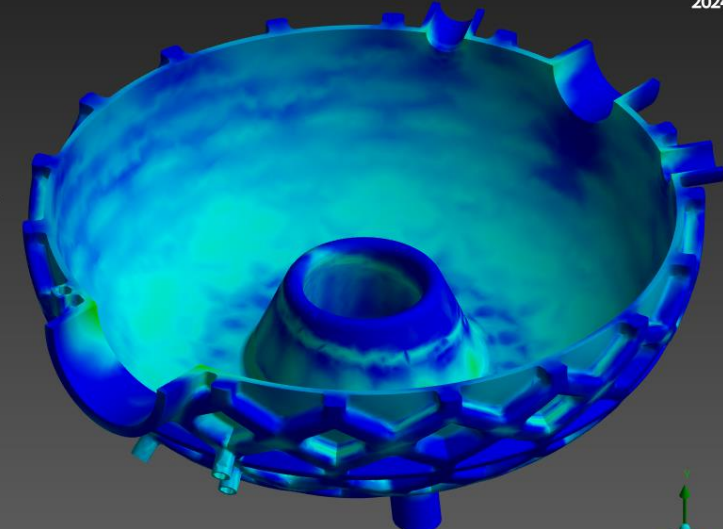
C: Structure statique
 Déplacement total
 Type: Déplacement total
 Unité: mm
 Temps: 1 s
 29/01/2025 14:01

0,0095461 Max
 0,0094878
 0,0074296
 0,0063714
 0,0053132
 0,0042549
 0,0031967
 0,0021385
 0,0010802
 2,1994e-5 Min



C: Structure statique
 Intensité de contrainte
 Type: Intensité de contrainte
 Unité: MPa
 Temps: 1 s
 29/01/2025 14:01

11,625 Max
 10,334
 9,0428
 7,7514
 6,4601
 5,1687
 3,8774
 2,5861
 1,2947
 0,0033605 Min



0,00 50,00 100,00 (mm)
 25,00 75,00

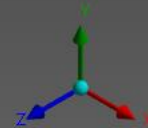
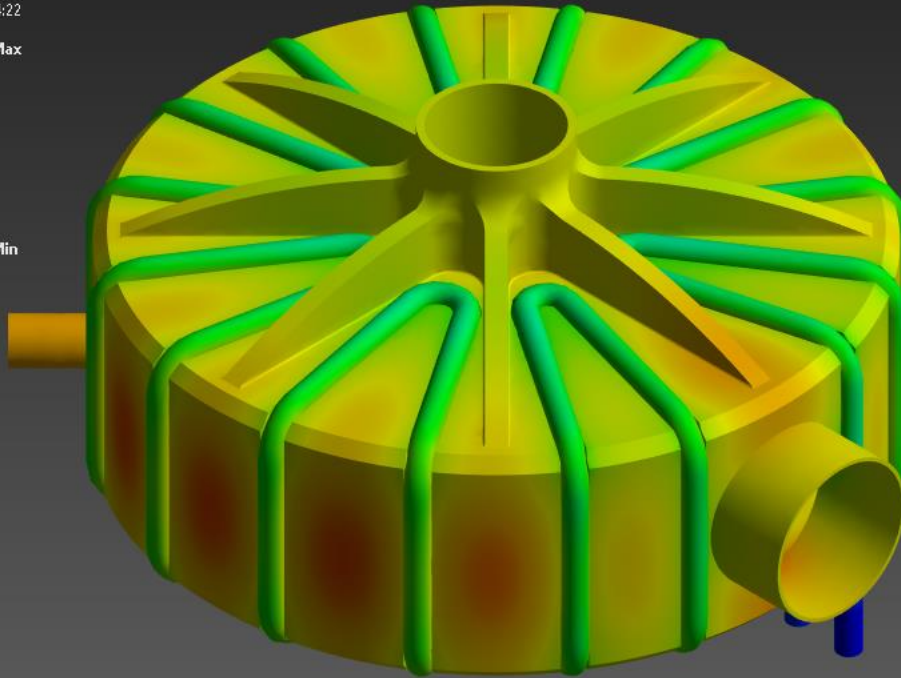


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 2024 R1

B: Thermique stationnaire

Température
 Type: Température
 Unité: °C
 Temps: 1 s
 29/01/2025 14:22

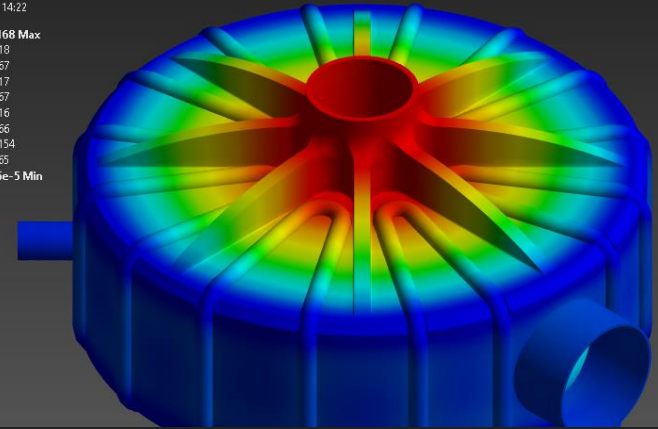
24,541 Max
 24,029
 23,516
 23,003
 22,491
 21,978
 21,465
 20,952
 20,44
 19,927 Min



Ansys
 2024 R1

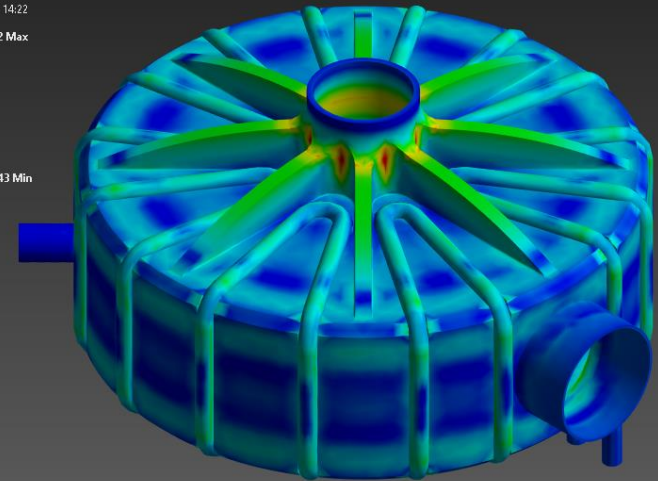
C: Structure statique
 Déplacement total
 Type: Déplacement total
 Unité: mm
 Temps: 1 s
 29/01/2025 14:22

0,030168 Max
 0,026818
 0,022467
 0,020117
 0,016767
 0,013416
 0,010066
 0,0067154
 0,003365
 1,4355e-5 Min



C: Structure statique
 Intensité de contrainte
 Type: Intensité de contrainte
 Unité: MPa
 Temps: 1 s
 29/01/2025 14:22

18,452 Max
 16,419
 14,386
 12,353
 10,32
 8,2868
 6,2537
 4,2206
 2,1875
 0,15443 Min

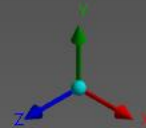
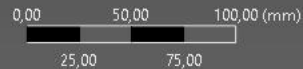
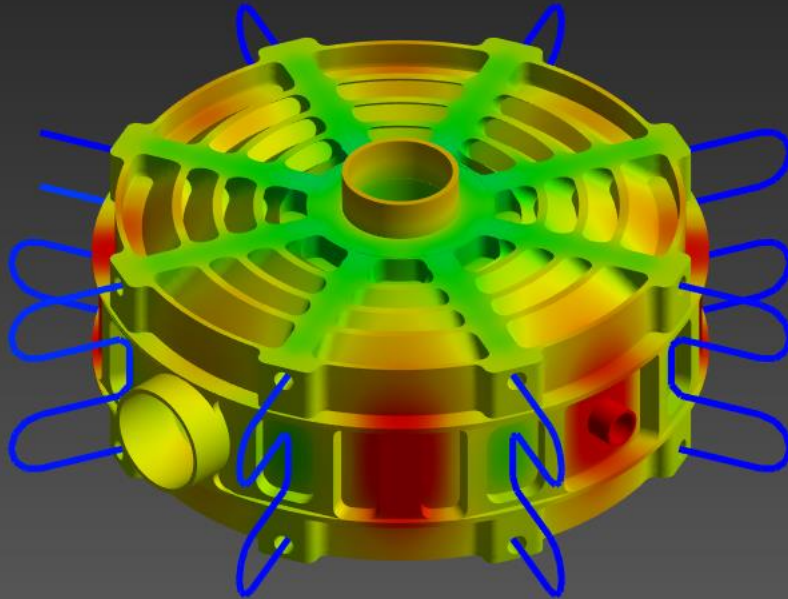


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 2024 R1

B: Thermique stationnaire

Température
 Type: Température
 Unité: °C
 Temps: 1 s
 29/01/2025 14:13

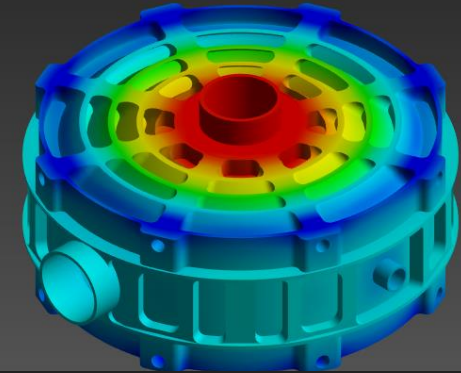
27,365 Max
 26,522
 25,679
 24,836
 23,993
 23,15
 22,308
 21,465
 20,622
 19,779 Min



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 2024 R1

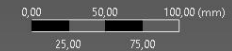
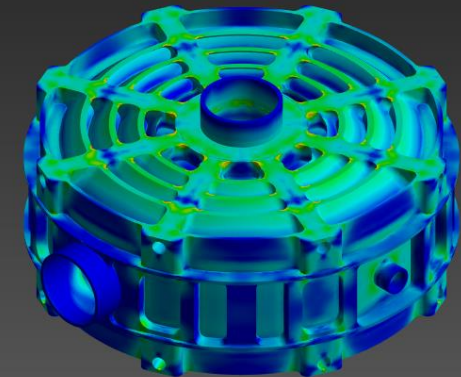
C: Structure statique
 Déplacement total
 Type: Déplacement total
 Unité: mm
 Temps: 1 s
 29/01/2025 14:13

0,045273 Max
 0,04027
 0,035267
 0,030265
 0,025262
 0,02026
 0,015257
 0,010254
 0,0052516
 0,00024898 Min



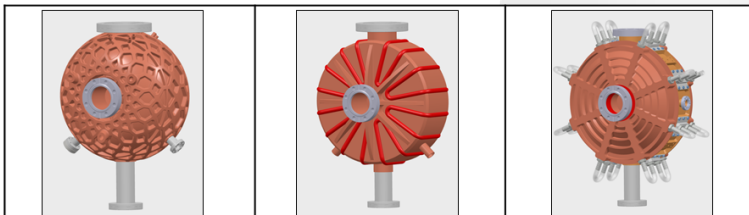
C: Structure statique
 Intensité de contrainte
 Type: Intensité de contrainte
 Unité: MPa
 Temps: 1 s
 29/01/2025 14:13

21,965 Max
 19,531
 17,097
 14,662
 12,228
 9,7936
 7,3593
 4,9249
 2,4906
 0,05625 Min



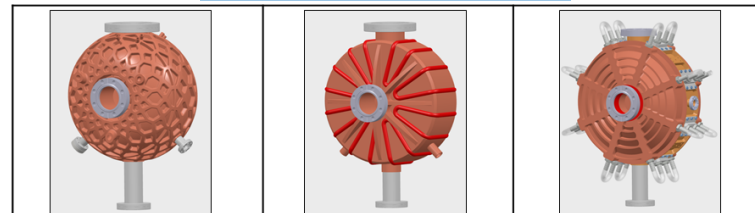
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 2024 R1

5kW



Weight	12 kg	14,6 kg	15 kg
Raw material	≈ 60 kg	≈ 100 kg	≈ 60 kg
X Deformation	0,006 mm	0,005 mm	0,040 mm
Y Deformation (beam)	0,008 mm	0,032 mm	0,047 mm
Constraint	18,3 MPa	38 MPa	32,4 MPa
T max	30 °C	34,2 °C	42,5 °C
Frequency shift*	(≈ -91 kHz)	-262 kHz	-560 kHz
Feasibility	?	Hard	Feasible
Manufacturing time	≈ Days	≈ Weeks	≈ Weeks

1,6kW



Weight	12 kg	14,6 kg	15 kg
Raw material	≈ 60 kg	≈ 100 kg	≈ 60 kg
X Deformation	0,003 mm	0,005 mm	0,012 mm
Y Deformation (beam)	0,009 mm	0,030 mm	0,045 mm
Constraint	11,6 MPa	18,5 MPa	22 MPa
T max	23,2 °C	24,5 °C	27,4 °C
Frequency shift*	(≈ -82 kHz)	-247 kHz	-395 kHz
Feasibility	?	Hard	Feasible
Manufacturing time	≈ Days	≈ Weeks	≈ Weeks

*Frequency shift due to the mechanical constraint and thermal dilatation only