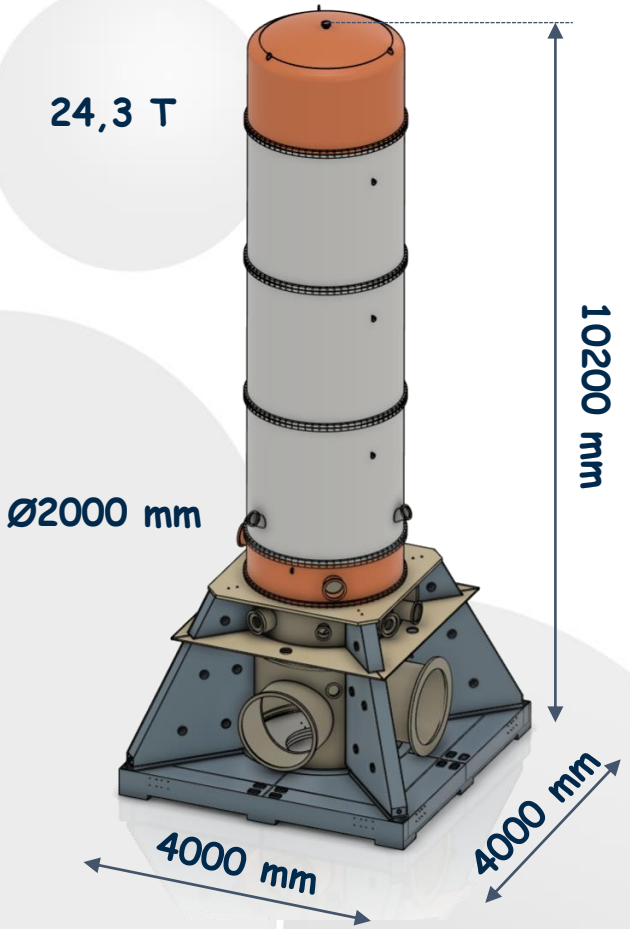
WP5 Project Office & Engineering Department
IJCLAB Participation

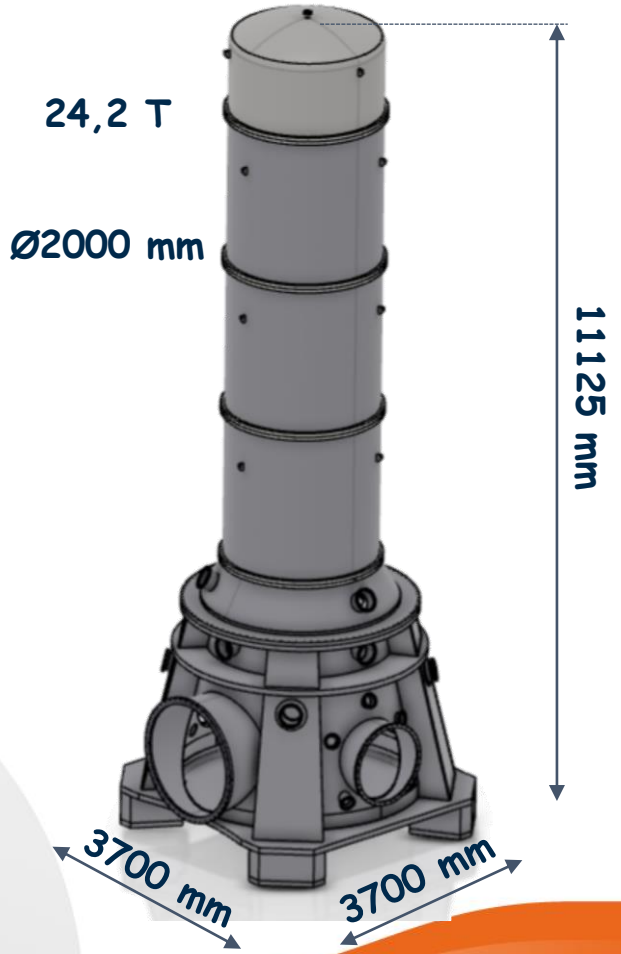
ET Warm Tower analysis

- Since November 2022, we have worked on beampipes, warm towers, cryostat & caverns solutions
- I made simulations for both towers
- For each one, I made structural, modal, buckling and harmonic responses analysis
- For ET Towers' I tried to find optimisations for 11m high
- Bigger vacuum chamber for an easy access in case of handling
- Conical shape chamber which is not convenient for optical mounts on the breadboard's border
- Towers will be higher due to Super Attenuator ~20m

VIRGO Tower's

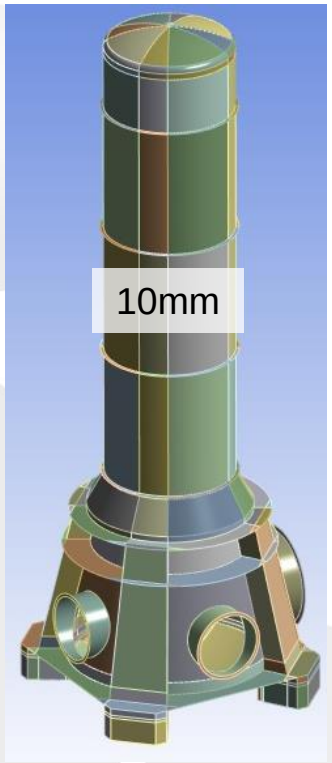


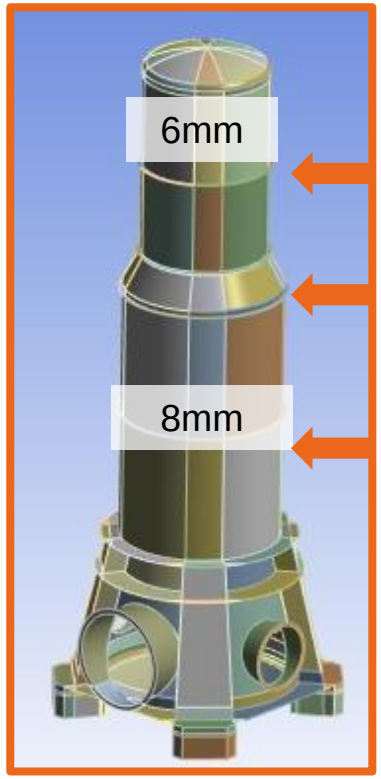
Einstein Telescope Tower's



ET Warm Tower analysis

- After I made simulations, i purposed 4 changes on tower's design
- Position's changes of the conical ferrule
- According to CODAP standards for buckling, I decreased tubes thicknesses
- Increasing the base diameter of the upper tower
- Equalize tubes lenghts of the upper tower to limit buckling effect because flanges act like stiffeners
- Increasing by 8,3Hz the first mode response
- Diminution by 800kg the mass' tower
- Next step is to made the same for higher towers ~20m



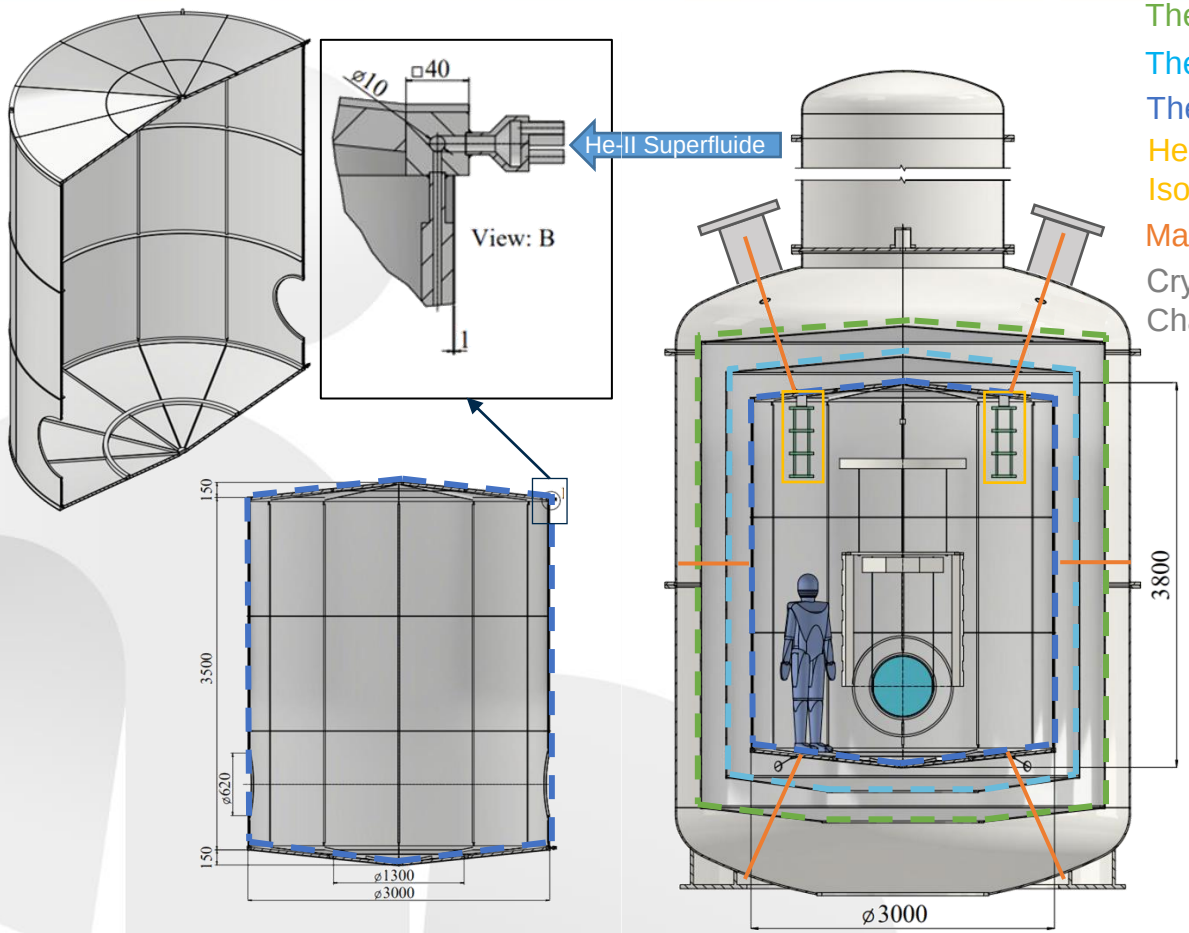


1st Mode	17,3 Hz	25,6 Hz / +8,3Hz
Buckling	10,1	3,7 / -6,4
Mass	24,2 T	23,4 T / -0,8T

Cold Towers & Cryostats

Low-noise thermal shielding

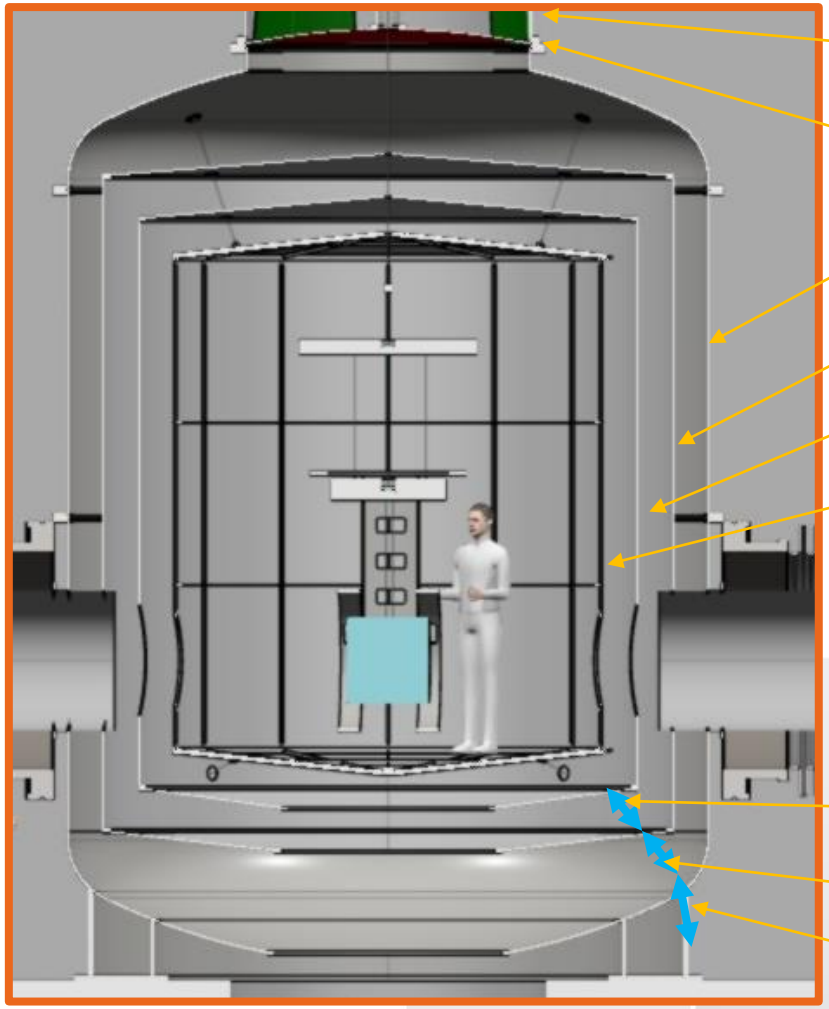
- Active cooling of the two external thermal shield respectively to **80K-50K** and **5 K** with supercritical helium flow
- The third shield is cooled at **2K** via thermal conduction through static superfluid helium He-II, avoiding macroscopic fluid flow.
- He-II is superfluid, so it allows an rapid cooling and transits less mechanical vibrations



Thermal Shield 80K-50K
Thermal Shield 5K
Thermal Shield 2K
Heat Link Vibrations' Isolation Systems
Magnetic Damping
Cryostat's Vacuum Chamber

***Reference** : L Busch, G Iaquaniello, P Rosier, M Stamm, and S Grohmann - Low-noise thermal shielding around the cryogenic payloads in the Einstein Telescope (2023)*

Summary of the CAD from KIT



0,9 T for cupola / Stainless Steel

1,2 T/tube (Ø2m / L=2m) / Stainless Steel

Cryostat : ~18,8 T / Stainless Steel

80K : 831 Kg / alu = after optimization

5K : 646 Kg / alu = after optimization

2K : 415 Kg / alu = after optimization

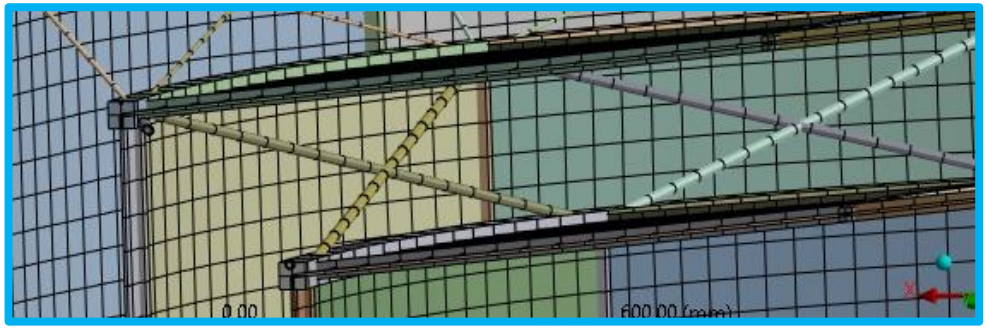
Total : 20,7 T
(without tubes, cupola, suspensions, structures …)

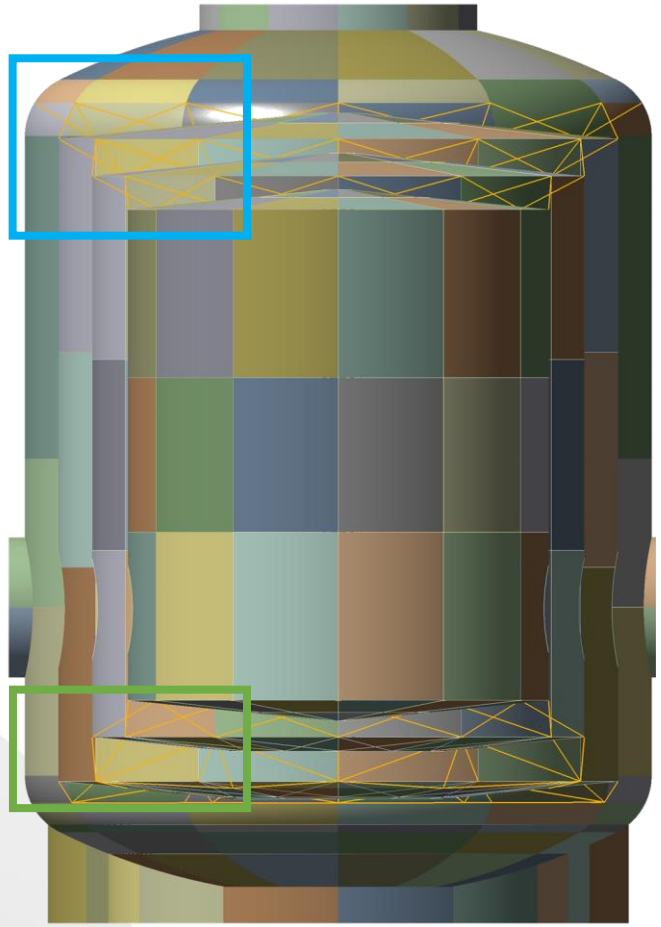
240 mm

270 mm

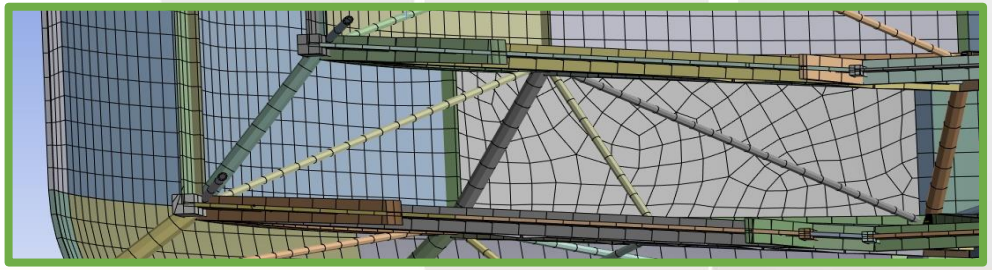
270 mm

Global model's simulation





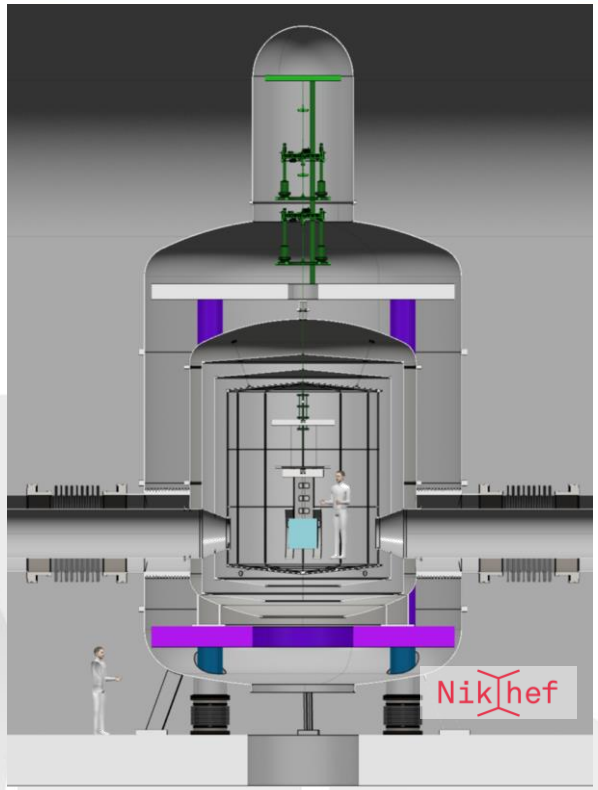
- Support structure built with stainless steel and/or glass fiber rods' and tubes'
- It was a proposal for a rigid support not sensitive to **resonant** vibration effect below 29 Hz.
  => But is still not a low vibration transmitter after 21 Hz on Y axis & 22 Hz on X axis as there is no passive vibration insulation
- In harmonic responses, ratio output / input > 1 after 21 Hz
- Magnetic dumping would be a solution to explore



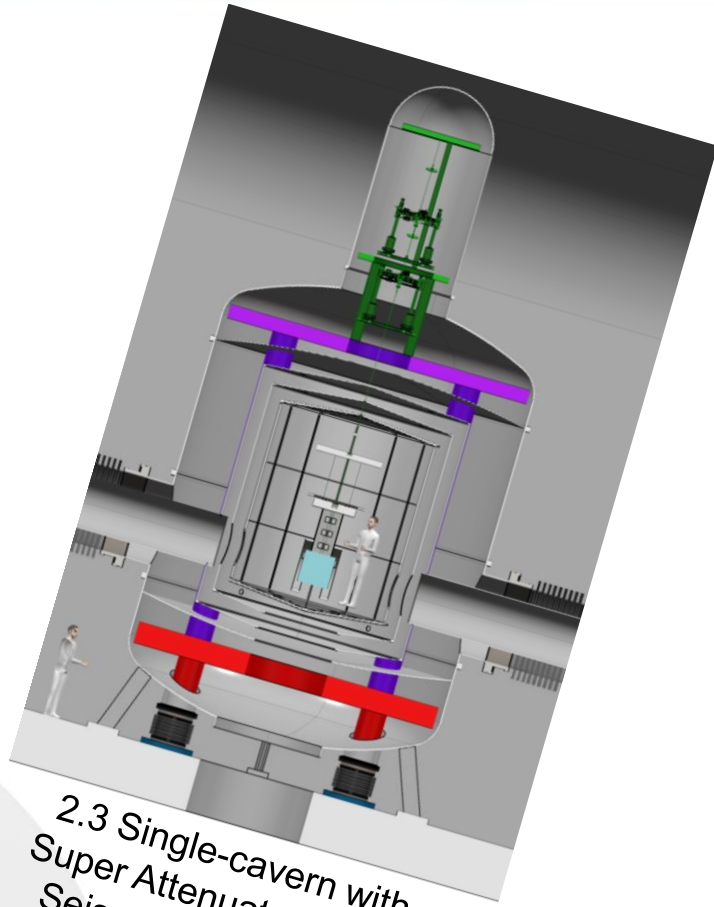
Cavern

Single-cavern solutions'

2.1 Single-cavern with Super Attenuator and without Active Seismic Platform (ASP)

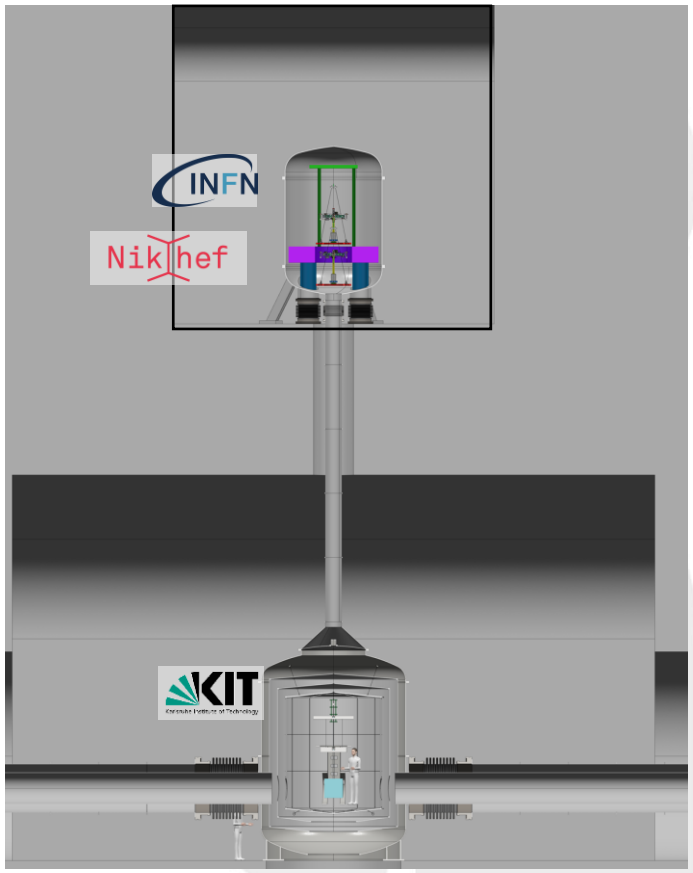


2.2 Single-cavern with Super Attenuator, Active Seismic Platform and nested vacuum

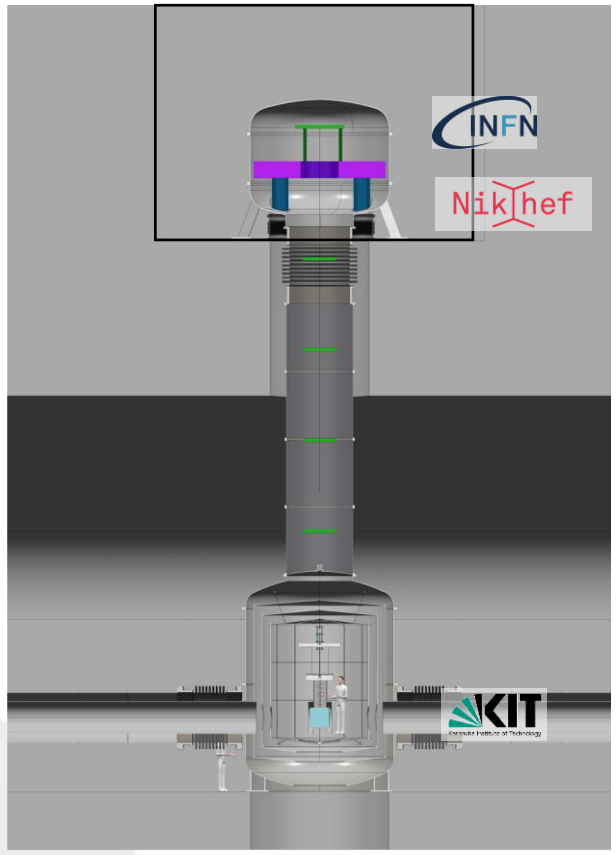


2.3 Single-cavern with Super Attenuator, Active Seismic Platform and separated vacua

Double cavern solutions'



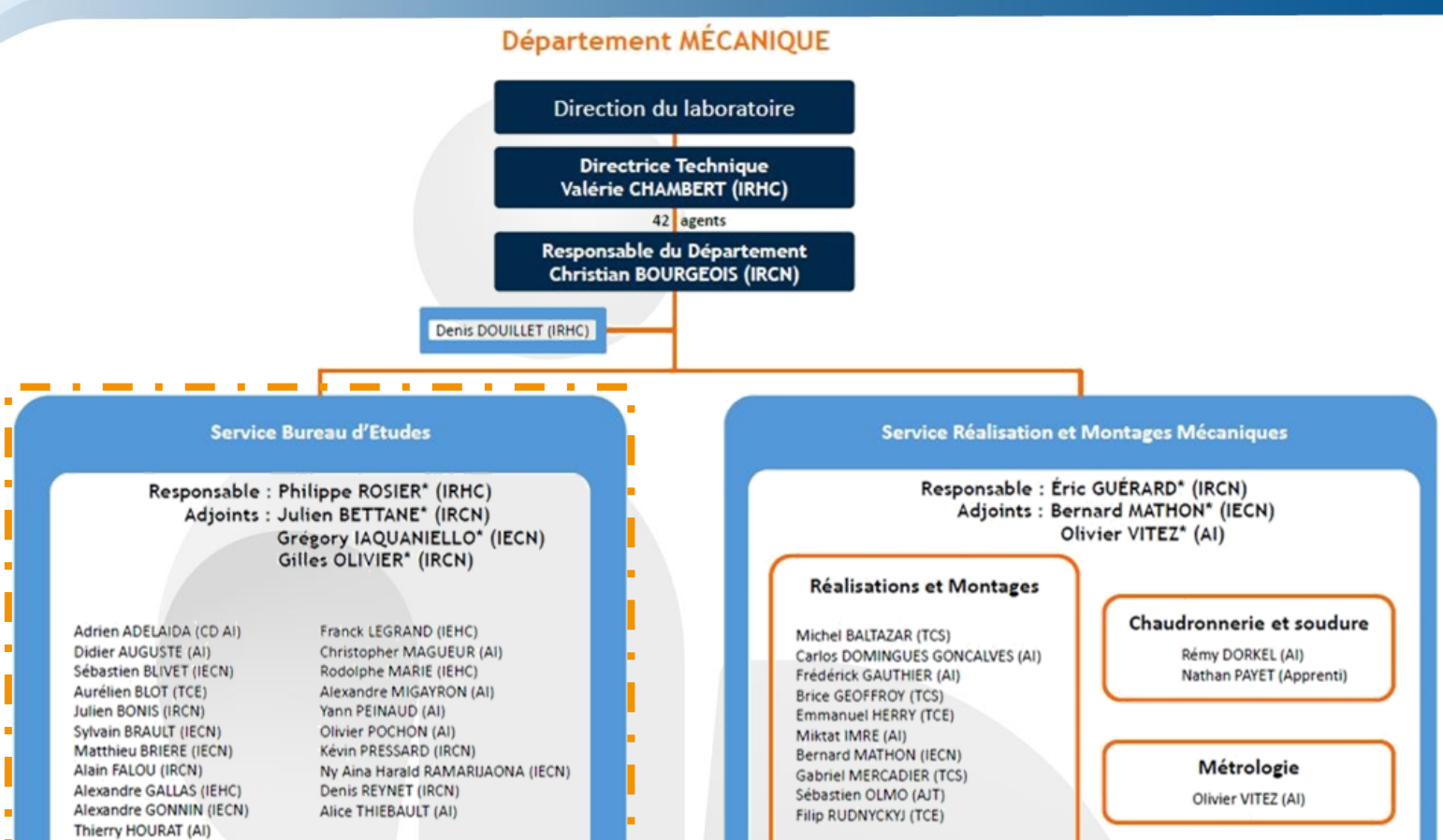
2.4 Double-cavern with Super Attenuator, Active Seismic Platform and nested vacuum



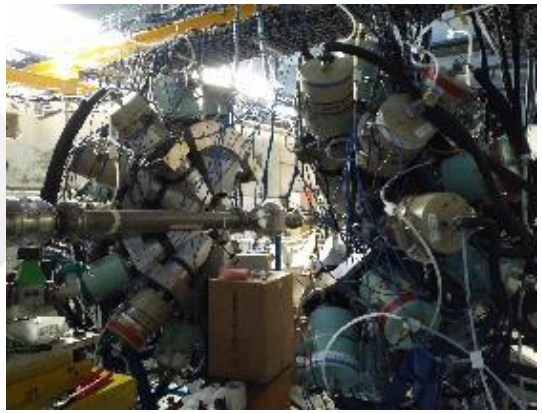
2.5 Double-cavern with Classic Attenuator, Active Seismic Platform and nested vacuum

IJCLab Design Office

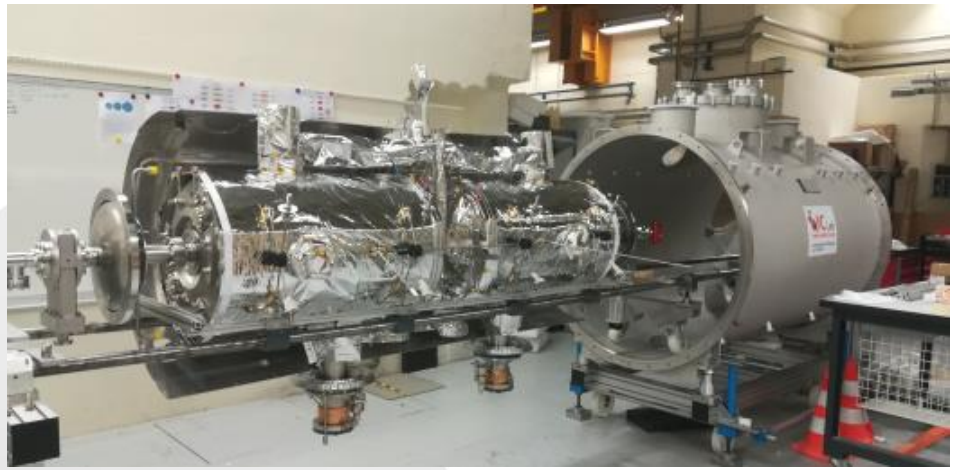
Manpower – Design Office



Various experiences

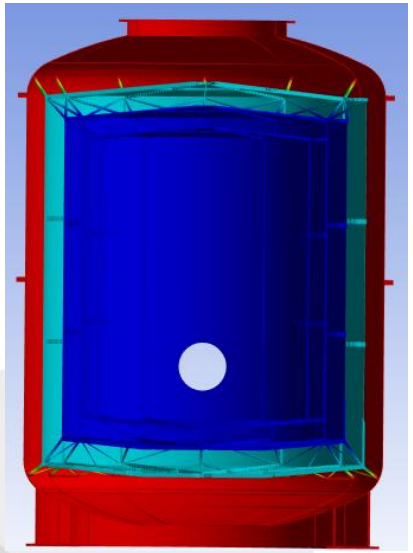


- Accelerator : E.S.S., Desy, Belle II, ThomX, Perle, Ganil, …
- Detector : Virgo, DUNE, CTA, Alice, Atlas, …

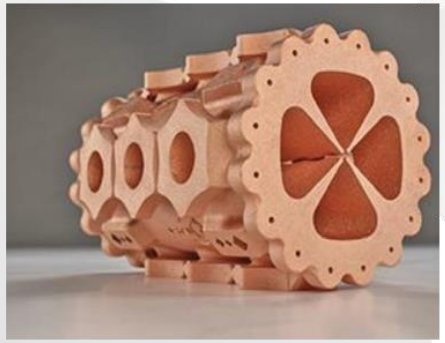


Skills

- C.A.D.
- Simulation
- Technical Groups :
  - Alignment
  - Additive Manufacturing
  - Vacuum
  - Clean Room



RFQ en cuivre pur CuC2, réalisé en fabrication additive métal (I-FAST)



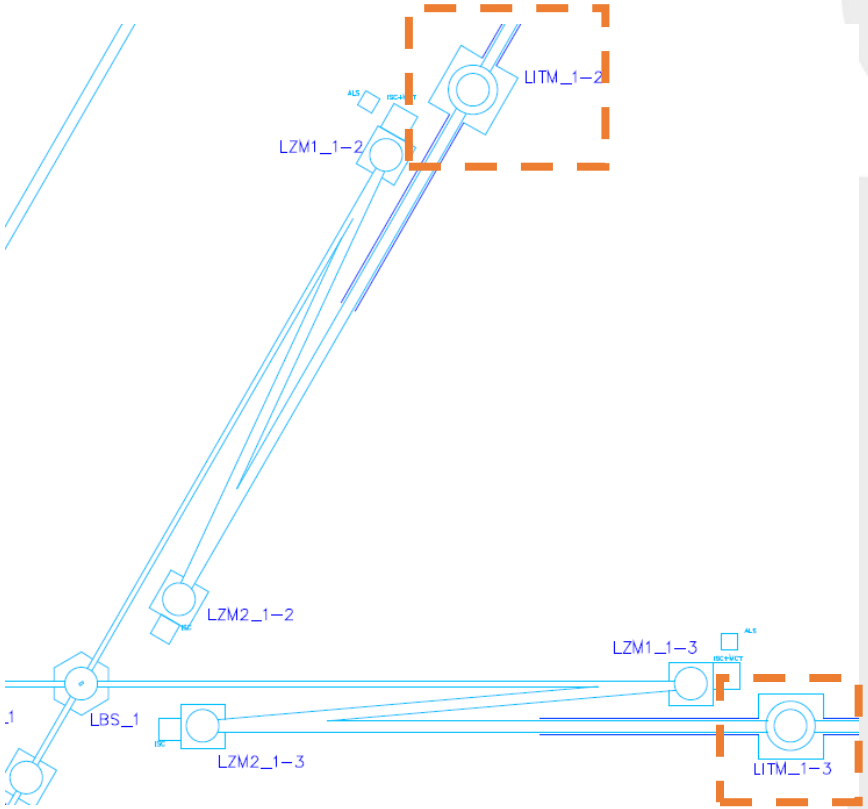
Thanks for your attention

Grégory IAQUANIELLO
Ingénieur de Recherche
Département Mécanique
Service Bureau d'Etudes
Bâtiment 208, RDC, Bureau 23

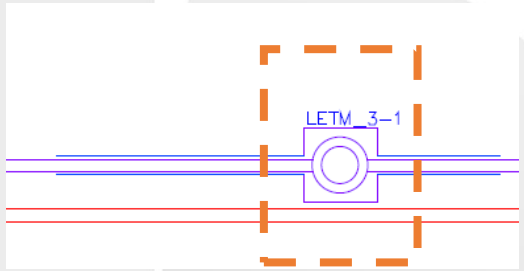
☎ : (+33) 01.64.46.86.44
@ : gregory.iaquaniello@ijclab.in2p3.fr

Work to do in the followings months

Statement



- There are 12 cryostats on ET triangle's definition.
- If we look at the optical Layout, there are 2 cryostats' configurations - LETM & LITM
- For each configuration, for some parameters, there's parallel solutions to think especially for civil infrastructure because of beampipe or tower around it



- Single or double cavern
- Acoustic
- Magnetic

Installation

- Think well, each steps, how to install the cryostat
- Estimate of which part will be lifted to estimate the maximum weight of the crane
  Not necessary to lift the entire cryostat which will do more than 21T
- One crane for one cavern, two cranes for two caverns … which it means that we need to know soon which solution will be taken
- Think about solutions to manipulate it precisely
- Process to align each cryostat vacuum chamber on arms axis'
- Estimate scaffolding size around each chamber
- Estimate scaffolding stages number
- How to fix it scaffolding & chambers on the ground if needed ?

Vacuum chamber ports

- Viewports :
  - The number and the diameter of each viewports should soon be fixed
  - Each additional viewports, means new simulations for shields to add holes on it
  - Viewports define position of shields' frames reinforcements
- Cryo infrastructure
- Vacuum level
  - Sealing helicoïl, o-ring or double o-ring
- Arm beampipe flanges' diameter
- Arm beampipe heights' regarding the ground
- Suspension shields' rods access
- Suspension cupola & tubes
- Bottom access diameter

Shields

- Link between vacuum chamber & shields (rods)
- Suspension shields' rods access
- Helium II infrastructure's for shields' frame
- Heat link vibrations isolations systems linked to the shields
- Find a system to damp shields : Magnetic damping, rigid support structure, Active Noise Mitigation …

Bottom access & Clean Room

- Find a system to handle / to lift shields & mirrors into clean room across bottom access
- Find a process for two technicians to access into the cryostat for maintenance
- Define the size of the bottom access which will have repercussions on the diameter of the cryostat
- Area of clean room will depend on the maintenance steps
- Define each clean zones' specifications
- Define if we need cranes or trolleys to move heavy parts in the clean room

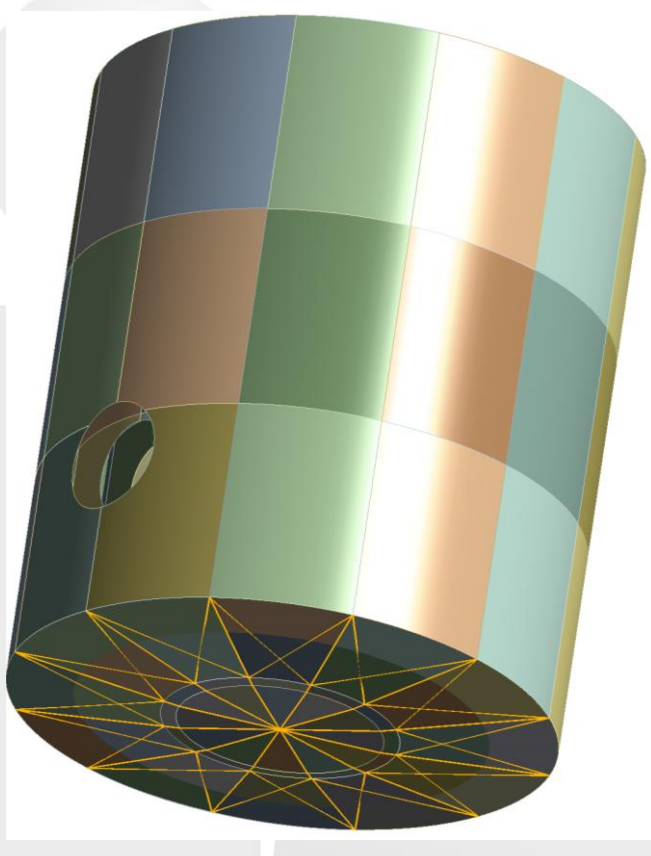
Cold Towers & Cryostats

Priority

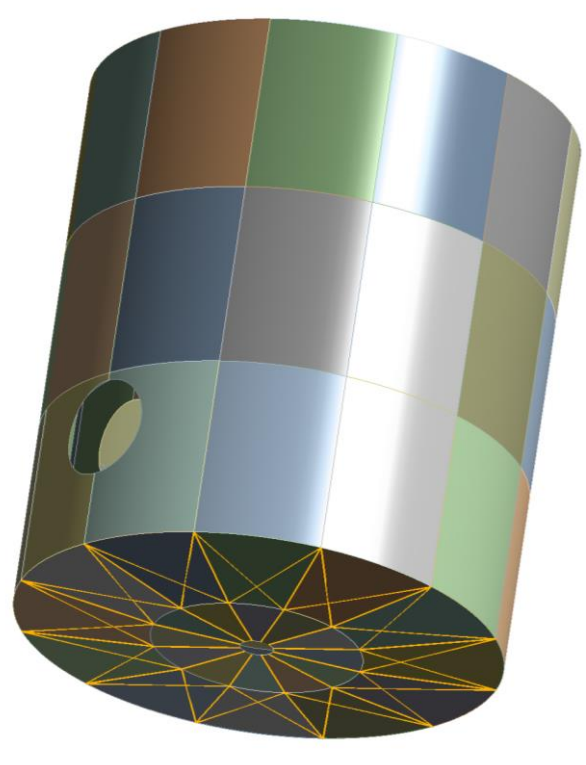
- Choose suspension system
- Choose Single or Double-Cavern
- Without theses choices, there are too many options to explore in such a short time

Reinforcements

- After the first iterations, to increase the first modal analysis responses', I had to added reinforcements, 10x50mm, on the bottom of 5K & 80K shields



80K



5K

Modal results: significant modes

First mode : 29,43 Hz on Y Axis

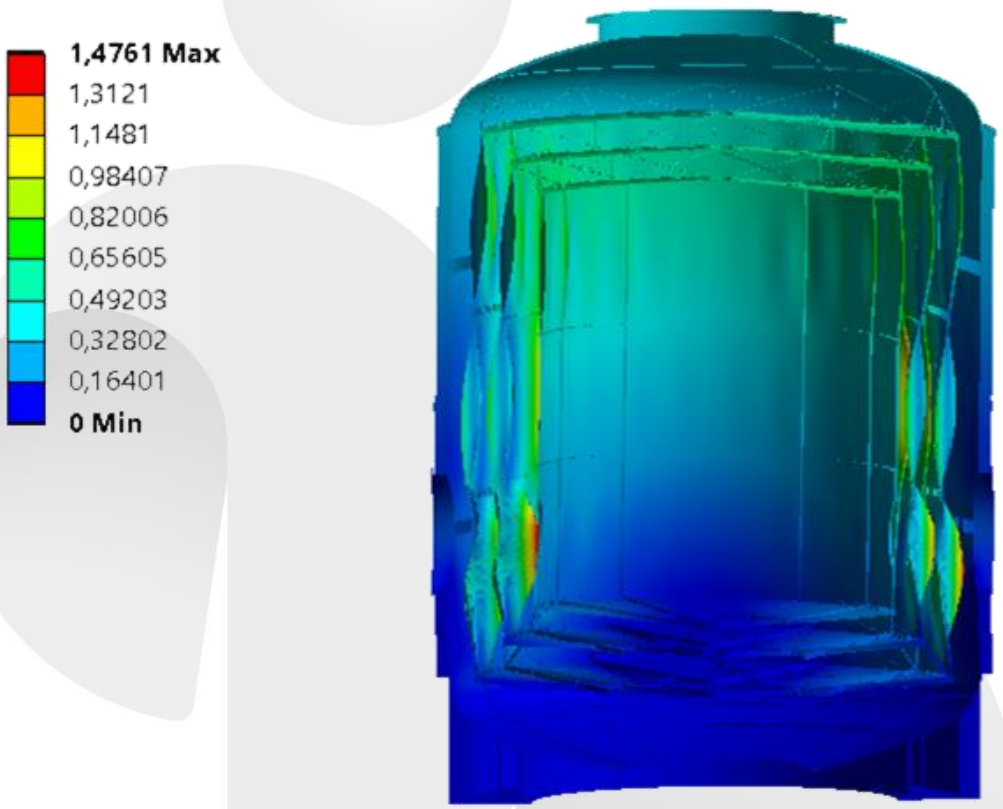
Third Mode : 30,69 Hz on X Axis

***** MODAL MASSES, KINETIC ENERGIES, AND TRANSLATIONAL EFFECTIVE MASSES SUMMARY *****

				EFFECTIVE MASS					
MODE	FREQUENCY	MODAL MASS	KENE	X-DIR	RATIO%	Y-DIR	RATIO%	Z-DIR	RATIO%
1	29.43	0.5345	9137.	0.2890E-04	0.00	8.588	41.59	0.1011E-03	0.00
2	30.64	0.2849E-01	528.1	0.3058E-01	0.15	0.1767E-03	0.00	0.3022E-03	0.00
3	30.69	0.2822	5247.	8.740	42.32	0.4712E-04	0.00	0.1158E-04	0.00
4	30.90	0.5669E-01	1069.	0.7709E-02	0.04	0.2009E-03	0.00	0.1680E-02	0.01
5	31.01	0.6856E-01	1301.	0.2795E-02	0.01	0.6413E-03	0.00	0.1034E-03	0.00
6	31.04	0.2566E-01	488.2	0.8823E-02	0.04	0.6674E-03	0.00	0.1450E-01	0.07
7	31.94	0.1227E-01	247.1	0.2985E-02	0.01	0.2800	1.36	0.8624E-03	0.00
8	32.14	0.3381E-02	68.93	0.5236E-01	0.25	0.1281E-03	0.00	0.2322E-05	0.00
9	32.16	0.6341E-02	129.4	0.7839E-01	0.38	0.2529E-02	0.01	0.1114E-03	0.00
10	32.17	0.2104E-02	42.97	0.1620E-02	0.01	0.4266E-03	0.00	0.9237E-05	0.00
11	32.27	0.2020E-02	41.52	0.2848E-05	0.00	0.3412E-05	0.00	0.2176E-04	0.00
12	32.28	0.2881E-02	59.26	0.2899E-04	0.00	0.5874E-06	0.00	0.2077E-03	0.00
13	32.43	0.1745E-02	36.23	0.3736E-02	0.02	0.1319E-04	0.00	0.4398E-04	0.00
14	32.53	0.7507E-02	156.8	0.1042E-02	0.01	0.1502E-07	0.00	0.1100E-01	0.05
15	32.54	0.1379E-01	288.1	0.1592E-05	0.00	0.2917E-03	0.00	0.3082E-01	0.15
16	32.61	0.5142E-02	107.9	0.1355E-02	0.01	0.3848E-04	0.00	0.1100E-03	0.00
17	32.69	0.1746E-02	36.82	0.3744E-04	0.00	0.3897E-04	0.00	0.4079E-02	0.02
18	32.70	0.2001E-02	42.25	0.6735E-04	0.00	0.1523E-03	0.00	0.3574E-02	0.02
19	32.73	0.2637E-02	55.76	0.1704E-02	0.01	0.1494E-03	0.00	0.6778E-03	0.00
20	32.75	0.4223E-02	89.40	0.2201E-05	0.00	0.2237E-02	0.01	0.8976E-02	0.04
sum				8.933	43.26	8.875	42.98	0.7720E-01	0.37

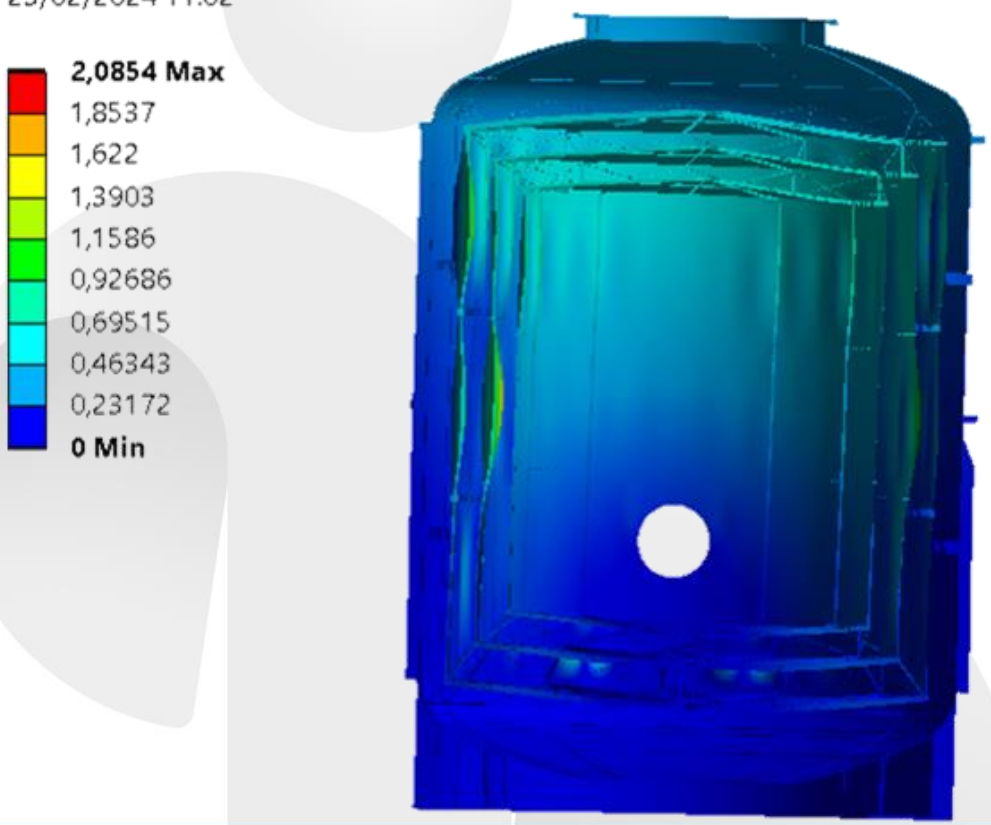
Mode 1 in vertical Y direction

H: Modal - Cryostat ALL
Total Deformation
Type: Déplacement total
Fréquence: 29,428 Hz
Unité: mm
23/02/2024 11:02

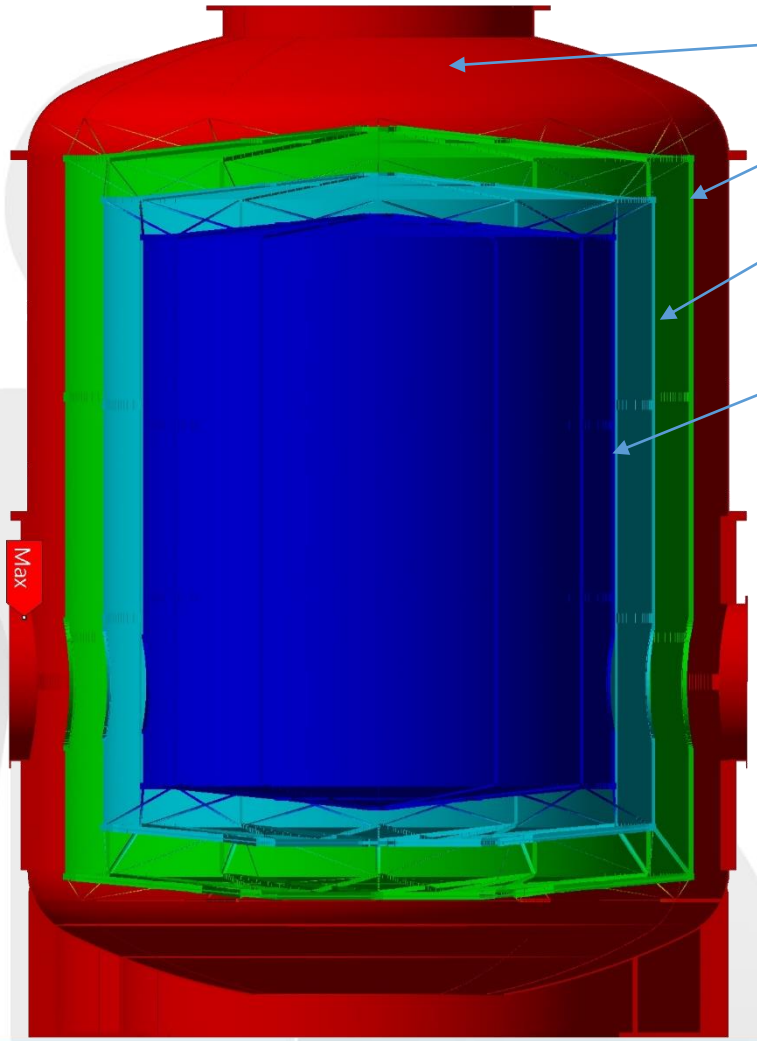


Mode 3 in lateral X direction

H: Modal - Cryostat ALL
Déplacement total 3
Type: Déplacement total
Fréquence: 30,694 Hz
Unité: mm
23/02/2024 11:02



Thermal results: conductive heat transfer total



300K stage = 17,35 W

80K stage = -7.9 W

5K stage = -9.4 W

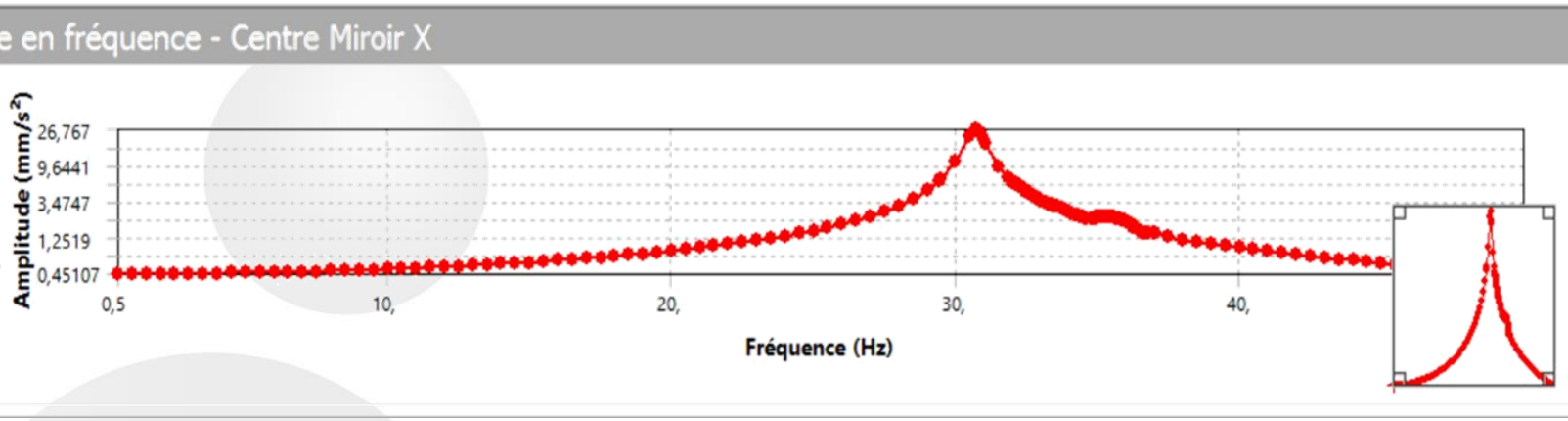
2K stage = -17mW

J: Thermique stationnaire
Température
Type: Température
Unité: K
Temps: 1 s
12/02/2024 15:58

300 Max
251
201,99
152,99
103,98
54,978
5,9733
4,6489
3,3245
2 Min

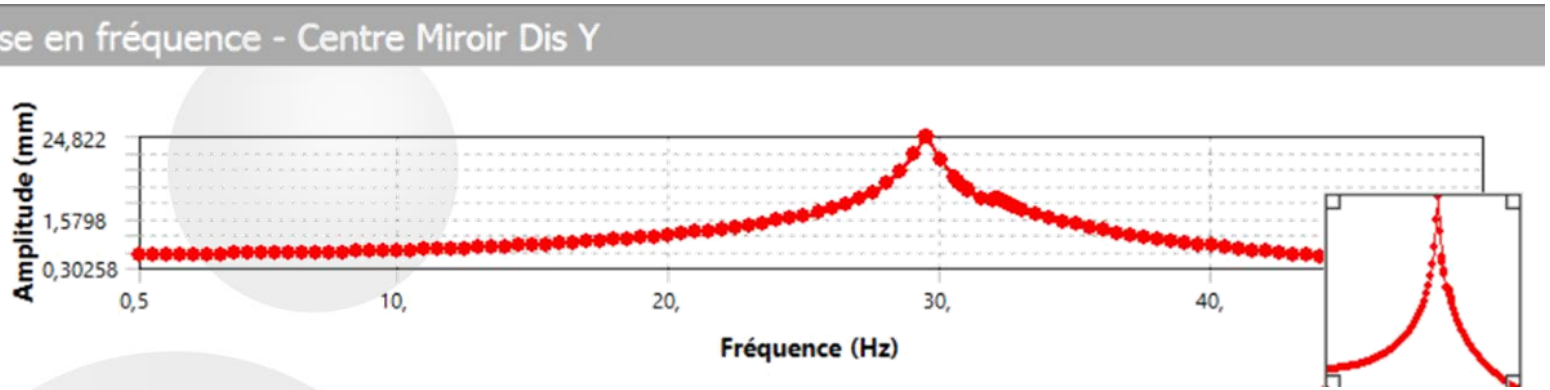
- Possibilities to decrease conductive heat transfer by :
  - Adding Fiber Glass rods instead of Stainless Steel
  - Using carbon PEEK interfaces between shields & Rods

Harmonic Responses – X Axis



- Analysis settings :
  - 2% damping for welded assemblies of steel structure according to Eurocode 8 - Design of structures for their resistance to earthquakes
  - Input 1mm on X axis on cryostat vaccum chamber's ground feet
- It's the results on centre vaccum where the mirror is

Harmonic Responses – Y Axis

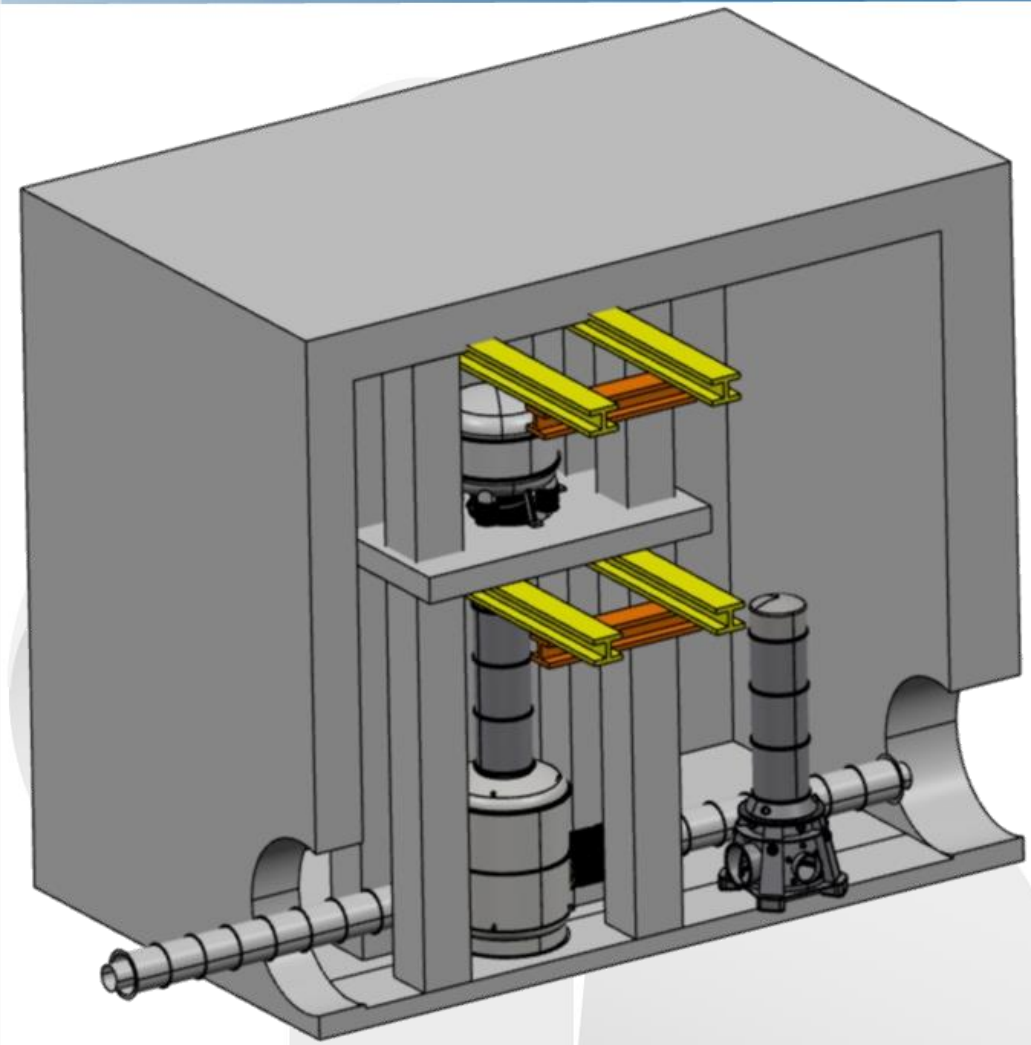


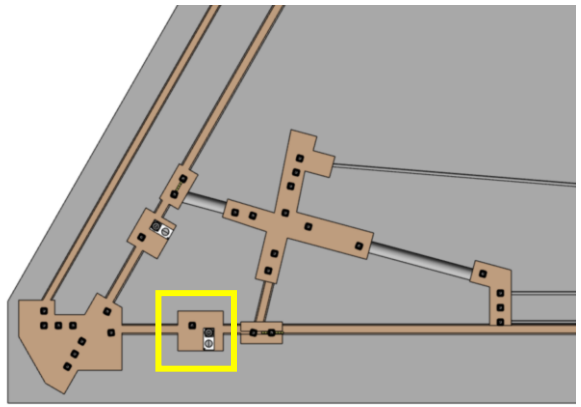
- Analysis settings :
  - 2% damping for welded assemblies of steel structure according to Eurocode 8 - Design of structures for their resistance to earthquakes
  - Input 1mm on Y axis on cryostat vaccum chamber's ground feet
- It's the results on centre vaccum where the mirror is
- Here is a proposal for a rigid support not sensitive to **resonant** vibration effect below 29 Hz.
  => But is still not a low vibration transmitter after 21 Hz on Y axis & 22 Hz on X axis as there is no passive vibration insulation (ratio output/input > 1)

Cavern

2.6 Concret Double-cavern with Classic Attenuator, Active Seismic Platform and nested vacuum

- 4 pillars 2x2m
- 2 crane for each vacuum chamber
- 1 concrete plateform 1m thick
- Additional cross section to reach 40Hz in first modal analysis





2.6 Concret Double-cavern with Classic Attenuator, Active Seismic Platform and nested vacuum