ET-ISB Suspension Meeting

Cryostat's Simulations

Scope

- This mechanical design study investigates the **achievable stability of the base plate**, on which the **super-attenuator** (SA) is supported
- Two integration options are considered
  - Base plate above cryostat in a single-cavern design
  - Base plate in upper cavern in double cavern design

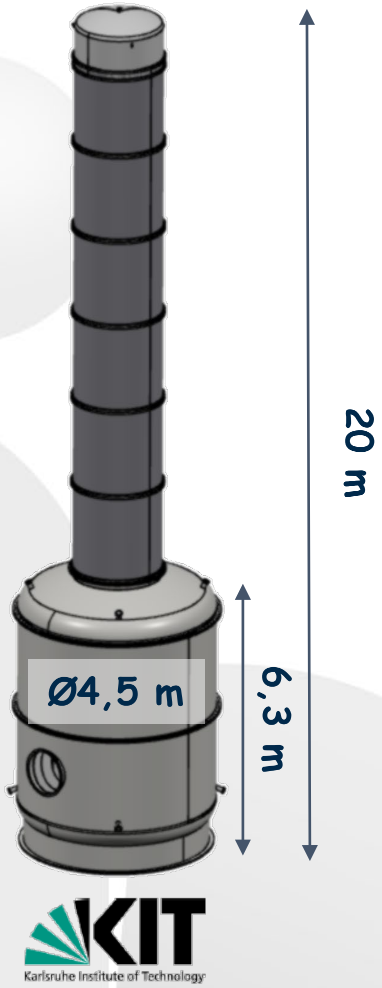
Initial conditions : Dimensions

- Following the ***ET-ISB Fall Workshop on ET-LF TM Tower Integration Concepts***, *in Elba, in September*, we decided to begin simulations of the **20m height** cryostat

- In the ***ET-LF TM Tower Design Concepts*** document's we chose that « *the outer cryostat diameter is* ***4,5m*** *and the height up to the vacuum separation between the cryostat and the room temperature upper tower is* ***6,3m*** »

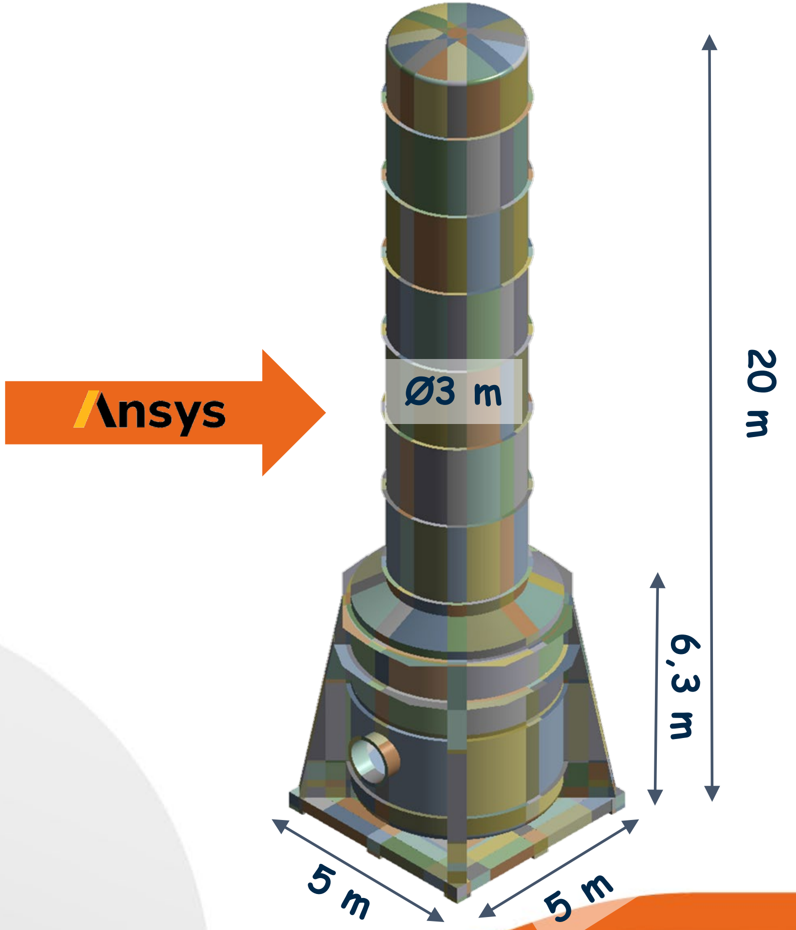
- In the ***ET Reference Detector Layout document***, we fixed the footprint base's at a max **5m²**, so we can increase it regarding the first concept of K.I.T. which was Ø4,5m

- Finally, during the detector layout, the keeping volume for the inverted pendulum was set to 2,5x2,5x17m so I decided to set up the upper diameter to **Ø3m**



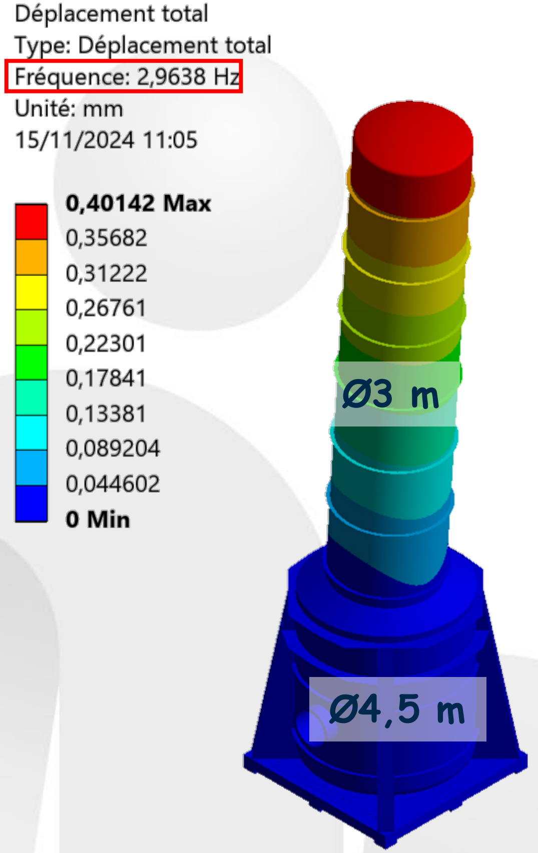
Concept

E.T.'s 20m height cryostat first concept

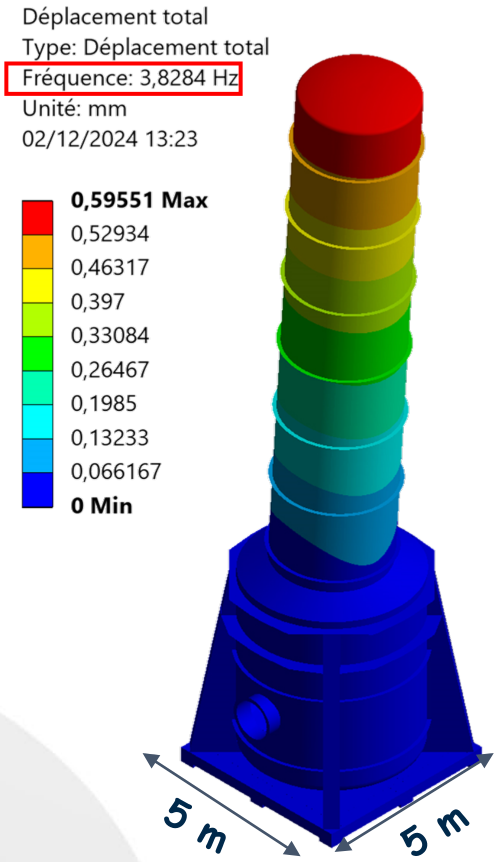


20m height – Ø3m upper part
Aluminium Upper part

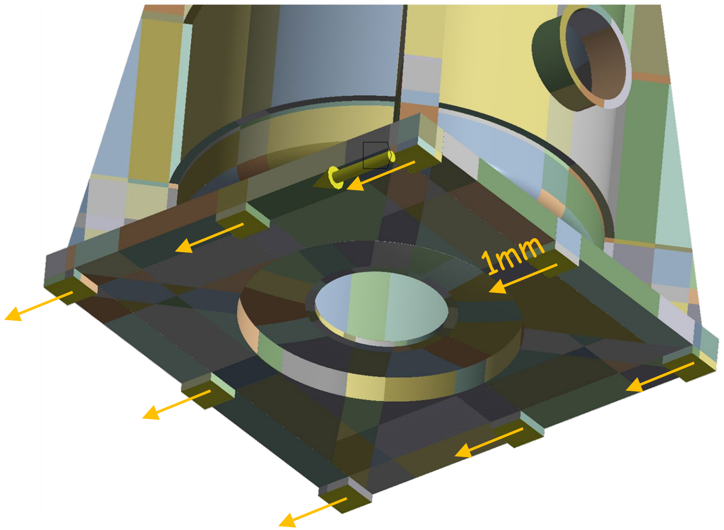
- The first modal response is very low due to the height of the tower
- After a first review, Jacques Lionel, from Liege, suggested to make the upper part in aluminium
- For an aluminium upper part of Ø3m, to obtain a multiplier charge for buckling greater than 4, I applied a thickness of 20mm to the upper part

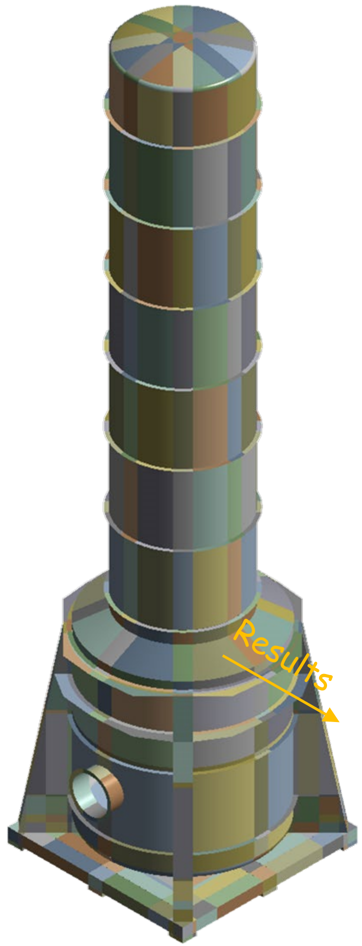


Stainless Steel Upper Part
Solution n°8
Mass : 68 T



Aluminium Upper Part
Solution n°18
Mass : 57,3 T





- <u>Boundaries conditions :</u>
  - Fixing recessed faces
  - Earth gravity on the structure
  - The vacuum chamber and the upper tower are under vaccum => 0,1 MPa
- 1mm input on X, Y or Z axis
- 0-50Hz applied on earth node fixed
- We apply 2% as damped coeffiscient regarding Eurocode 8

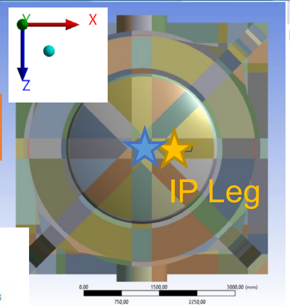
- <u>Reference</u> :
  - Eurocode 8 - Design of structures for their resistance to earthquakes

Table 3: Values of the damping coefficient

	Welded assemblies	Bolted Assemblies
Steel Structure	ξ = 2 %	ξ = 4 %
Mixed steel-concrete structure	ξ = 4 %	ξ = 4 %

20m height – S18 - Ø3m upper part
Aluminium Upper part

Champ d'application	
Méthode de champ d'application	Sélection de géométrie
Géométrie	4 Arêtes
Système de coordonnées	Système de coordonnées global
Coordonnée X	1000, mm
Coordonnée Y	5350, mm
Coordonnée Z	0, mm
Emplacement	Cliquez pour modifier



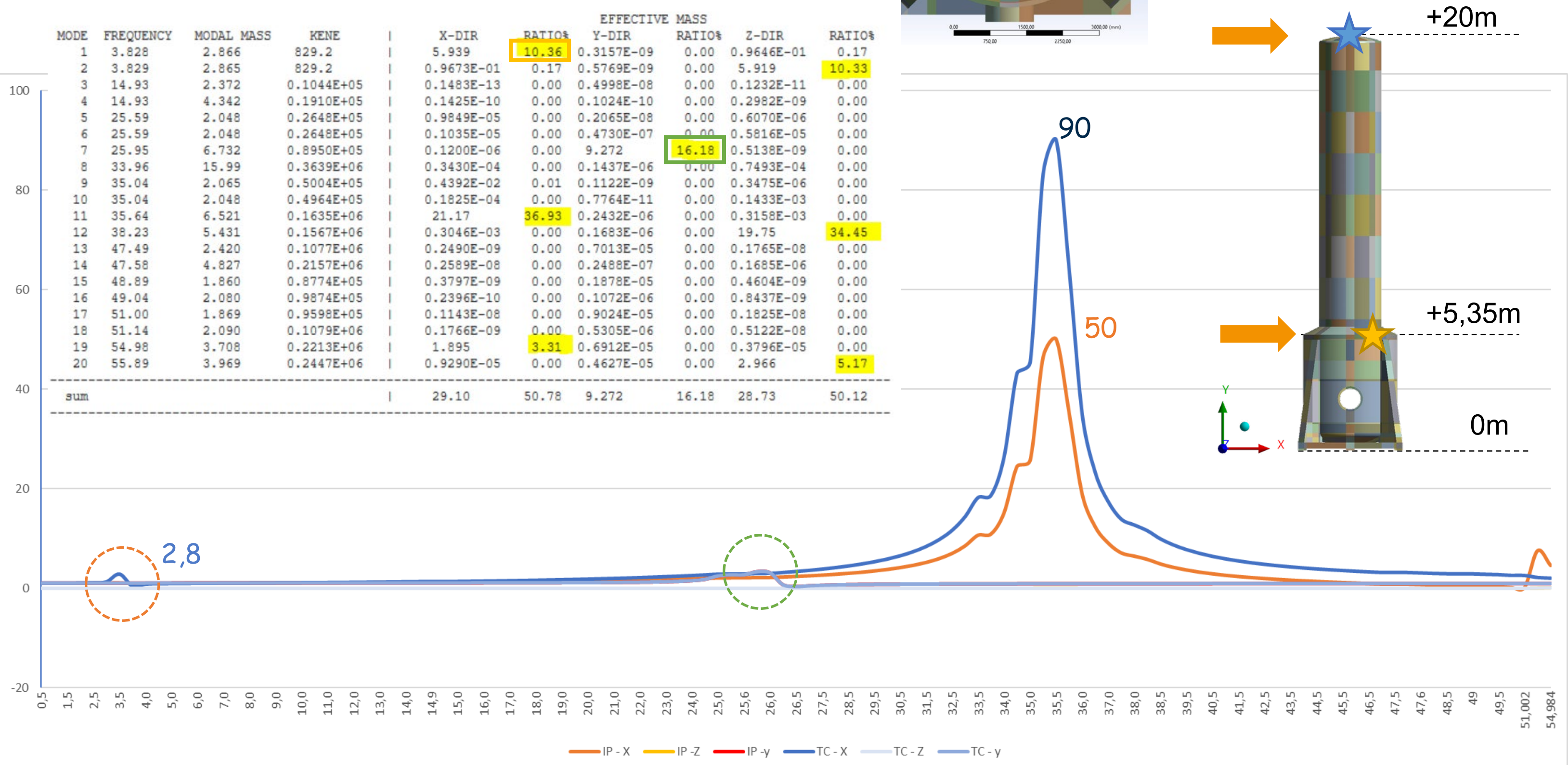
Détails de "Top Chamber"

Champ d'application	
Méthode de champ d'application	Sélection de géométrie
Géométrie	4 Arêtes
Système de coordonnées	Système de coordonnées global
Coordonnée X	0, mm
Coordonnée Y	20000 mm
Coordonnée Z	0, mm
Emplacement	Cliquez pour modifier

- Finally, thanks to harmonic response we can observe « just » a « bump » at 3,8Hz of a factor 2,8 involving 10,3% of the total mass of the chamber, which is the top chamber
- At 35Hz, the upper platform, which will welcome IP leg, begin to resonate with a factor 50
- The top plate is constrained between the vacuum chamber cover and the ferrule, increasing its rigidity.

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

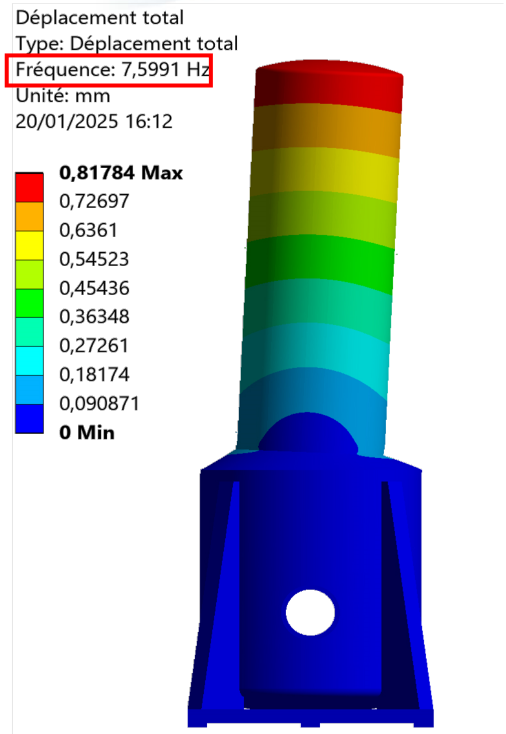
					EFFECTIVE MASS					
MODE	FREQUENCY	MODAL MASS	KENE	|	X-DIR	RATIO%	Y-DIR	RATIO%	Z-DIR	RATIO%
1	3.828	2.866	829.2	|	5.939	10.36	0.3157E-09	0.00	0.9646E-01	0.17
2	3.829	2.865	829.2	|	0.9673E-01	0.17	0.5769E-09	0.00	5.919	10.33
3	14.93	2.372	0.1044E+05	|	0.1483E-13	0.00	0.4998E-08	0.00	0.1232E-11	0.00
4	14.93	4.342	0.1910E+05	|	0.1425E-10	0.00	0.1024E-10	0.00	0.2982E-09	0.00
5	25.59	2.048	0.2648E+05	|	0.9849E-05	0.00	0.2065E-08	0.00	0.6070E-06	0.00
6	25.59	2.048	0.2648E+05	|	0.1035E-05	0.00	0.4730E-07	0.00	0.5816E-05	0.00
7	25.95	6.732	0.8950E+05	|	0.1200E-06	0.00	9.272	16.18	0.5138E-09	0.00
8	33.96	15.99	0.3639E+06	|	0.3430E-04	0.00	0.1437E-06	0.00	0.7493E-04	0.00
9	35.04	2.065	0.5004E+05	|	0.4392E-02	0.01	0.1122E-09	0.00	0.3475E-06	0.00
10	35.04	2.048	0.4964E+05	|	0.1825E-04	0.00	0.7764E-11	0.00	0.1433E-03	0.00
11	35.64	6.521	0.1635E+06	|	21.17	36.93	0.2432E-06	0.00	0.3158E-03	0.00
12	38.23	5.431	0.1567E+06	|	0.3046E-03	0.00	0.1683E-06	0.00	19.75	34.45
13	47.49	2.420	0.1077E+06	|	0.2490E-09	0.00	0.7013E-05	0.00	0.1765E-08	0.00
14	47.58	4.827	0.2157E+06	|	0.2589E-08	0.00	0.2488E-07	0.00	0.1685E-06	0.00
15	48.89	1.860	0.8774E+05	|	0.3797E-09	0.00	0.1878E-05	0.00	0.4604E-09	0.00
16	49.04	2.080	0.9874E+05	|	0.2396E-10	0.00	0.1072E-06	0.00	0.8437E-09	0.00
17	51.00	1.869	0.9598E+05	|	0.1143E-08	0.00	0.9024E-05	0.00	0.1825E-08	0.00
18	51.14	2.090	0.1079E+06	|	0.1766E-09	0.00	0.5305E-06	0.00	0.5122E-08	0.00
19	54.98	3.708	0.2213E+06	|	1.895	3.31	0.6912E-05	0.00	0.3796E-05	0.00
20	55.89	3.969	0.2447E+06	|	0.9290E-05	0.00	0.4627E-05	0.00	2.966	5.17
sum				|	29.10	50.78	9.272	16.18	28.73	50.12



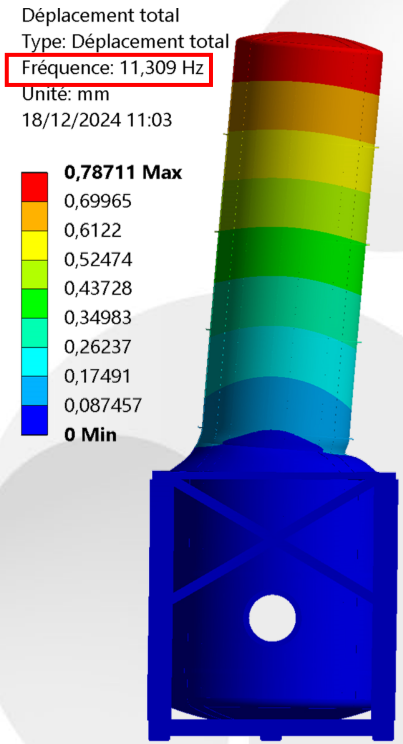
14,5m Design

- At the ET Annual @ Warsaw, we saw presentations on a 12m height inverted pendulum solutions.
- The beam height is fixed at 2,5m in the ***ET Reference Detector Layout document***
- These are solutions of 14,5m height tower VIRGO like, with an external structure, a decoupled structure with bellow between vacuum chamber and upper part, and a stiffeners solution decoupled too.

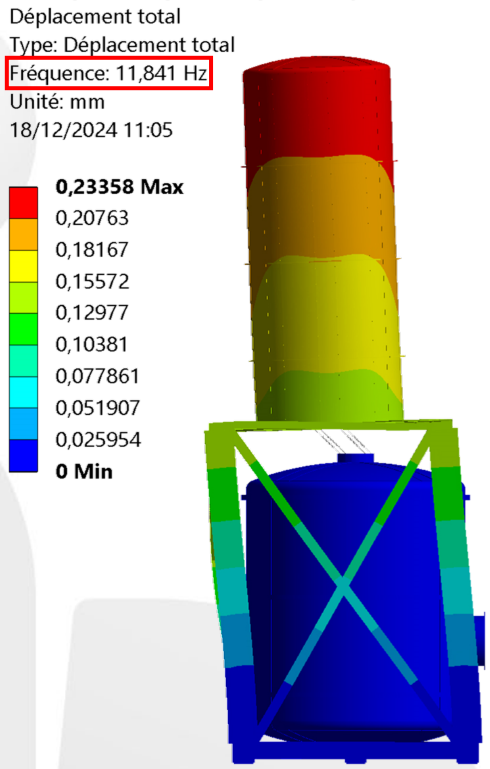
14,5m height tower - Aluminium Upper Part



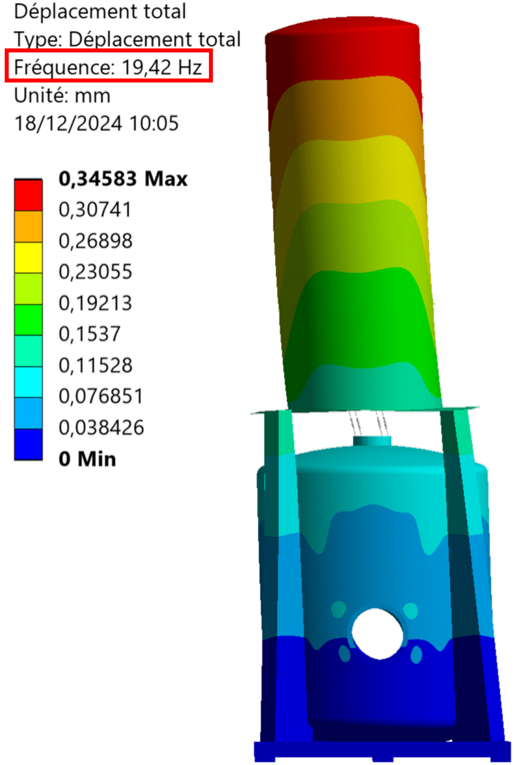
Virgo Like
Solution n°30
Mass : 53,2 T



Structure
Solution n°20
Mass : 106,7 T



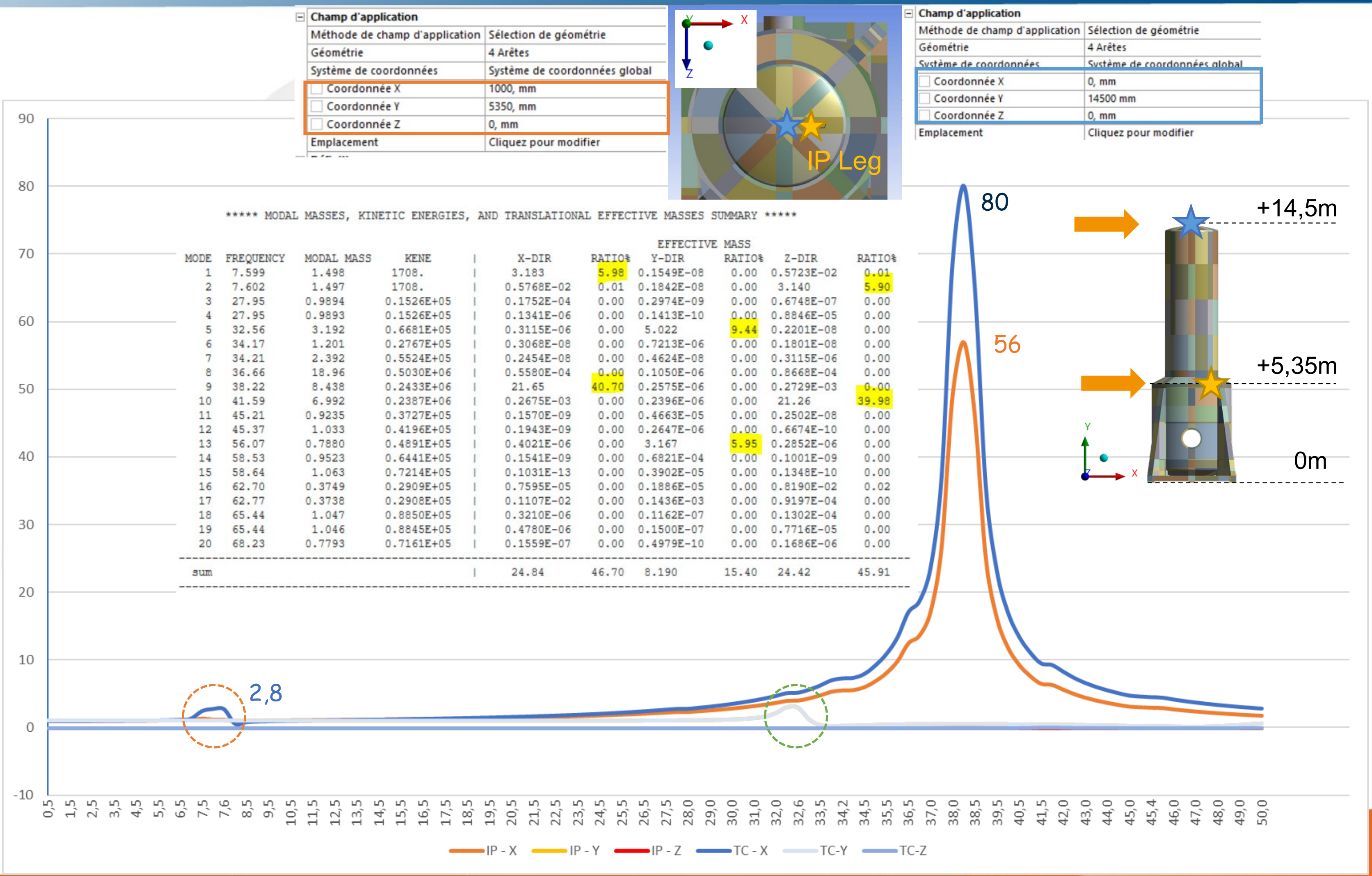
Decoupled Structure
Solution n°21
Mass : 102,6 T



Decoupled Stiffeners structure
Solution n°24
Mass : 127,8 T

14,5m height - S30

- Same as the 20 m one, we observe "just" a "bump" at 7.6 Hz by a factor of 2.8 involving 6% of the total mass of the chamber, which is the upper chamber, and the rest at more of 32 Hz.



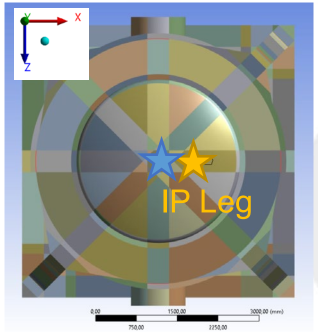
Champ d'application	
Méthode de champ d'application	Sélection de géométrie
Géométrie	4 Arêtes
Système de coordonnées	Système de coordonnées global
Coordonnée X	1000, mm
Coordonnée Y	5350, mm
Coordonnée Z	0, mm
Emplacement	Cliquez pour modifier

Champ d'application	
Méthode de champ d'application	Sélection de géométrie
Géométrie	4 Arêtes
Système de coordonnées	Système de coordonnées global
Coordonnée X	0, mm
Coordonnée Y	14500 mm
Coordonnée Z	0, mm
Emplacement	Cliquez pour modifier

***** 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	7.599	1.498	1708.	3.183	5.98	0.1549E-08	0.00	0.5723E-02	0.01
2	7.602	1.497	1708.	0.5768E-02	0.01	0.1842E-08	0.00	3.140	5.90
3	27.95	0.9894	0.1526E+05	0.1752E-04	0.00	0.2974E-09	0.00	0.6748E-07	0.00
4	27.95	0.9893	0.1526E+05	0.1341E-06	0.00	0.1413E-10	0.00	0.8846E-05	0.00
5	32.56	3.192	0.6681E+05	0.3115E-06	0.00	5.022	9.44	0.2201E-08	0.00
6	34.17	1.201	0.2767E+05	0.3068E-08	0.00	0.7213E-06	0.00	0.1801E-08	0.00
7	34.21	2.392	0.5524E+05	0.2454E-08	0.00	0.4624E-08	0.00	0.3115E-06	0.00
8	36.66	18.96	0.5030E+06	0.5580E-04	0.00	0.1050E-06	0.00	0.8668E-04	0.00
9	38.22	8.438	0.2433E+06	21.65	40.70	0.2575E-06	0.00	0.2729E-03	0.00
10	41.59	6.992	0.2387E+06	0.2675E-03	0.00	0.2396E-06	0.00	21.26	39.98
11	45.21	0.9235	0.3727E+05	0.1570E-09	0.00	0.4663E-05	0.00	0.2502E-08	0.00
12	45.37	1.033	0.4196E+05	0.1943E-09	0.00	0.2647E-06	0.00	0.6674E-10	0.00
13	56.07	0.7880	0.4891E+05	0.4021E-06	0.00	3.167	5.95	0.2852E-06	0.00
14	58.53	0.9523	0.6441E+05	0.1541E-09	0.00	0.6821E-04	0.00	0.1001E-09	0.00
15	58.64	1.063	0.7214E+05	0.1031E-13	0.00	0.3902E-05	0.00	0.1348E-10	0.00
16	62.70	0.3749	0.2909E+05	0.7595E-05	0.00	0.1886E-05	0.00	0.8190E-02	0.02
17	62.77	0.3738	0.2908E+05	0.1107E-02	0.00	0.1436E-03	0.00	0.9197E-04	0.00
18	65.44	1.047	0.8850E+05	0.3210E-06	0.00	0.1162E-07	0.00	0.1302E-04	0.00
19	65.44	1.046	0.8845E+05	0.4780E-06	0.00	0.1500E-07	0.00	0.7716E-05	0.00
20	68.23	0.7793	0.7161E+05	0.1559E-07	0.00	0.4979E-10	0.00	0.1686E-06	0.00
sum				24.84	46.70	8.190	15.40	24.42	45.91

14,5m height tower - S24



Détails de "Point distant 2"

Champ d'application	
Méthode de champ d'application	Sélection de gé.
Géométrie	4 Arêtes
Système de coordonnées	Système de coo.
Coordonnée X	1000, mm
Coordonnée Y	6850, mm
Coordonnée Z	0, mm
Emplacement	Cliquez pour m.

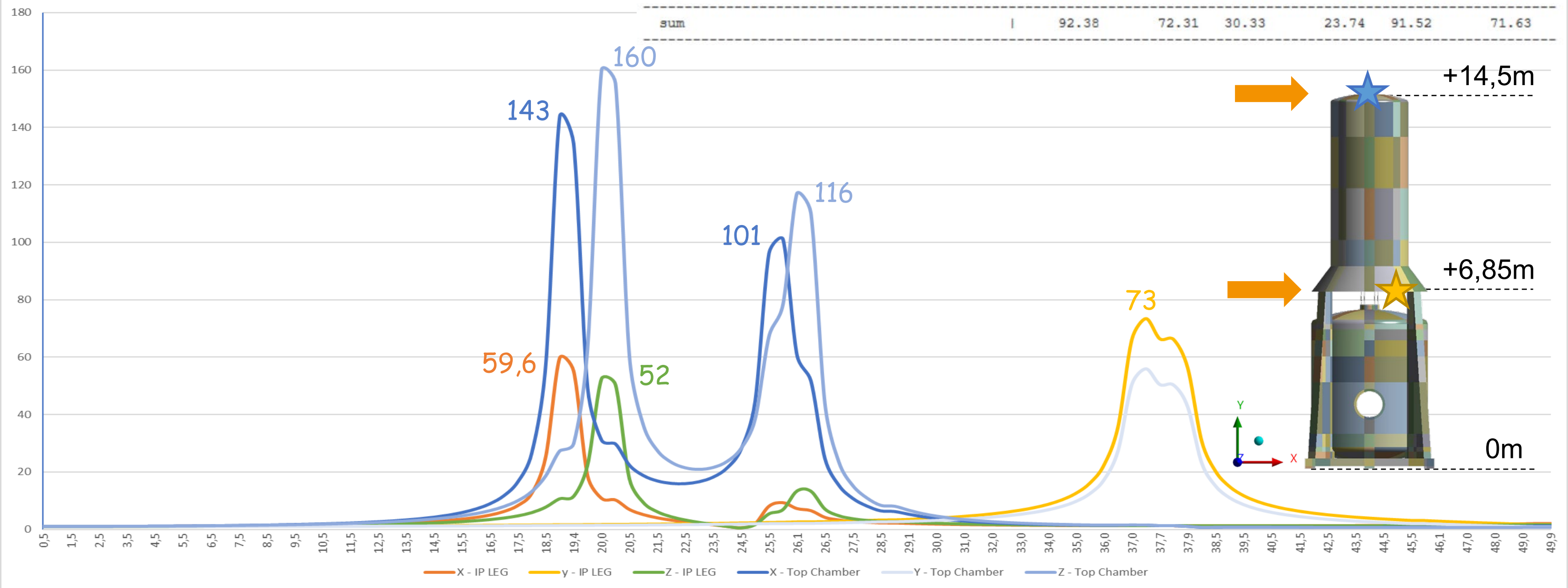
Détails de "Top Chamber"

Champ d'application	
Méthode de champ d'application	Sélection de géomé
Géométrie	1 Sommet
Système de coordonnées	Système de coordor
Coordonnée X	0, mm
Coordonnée Y	14500 mm
Coordonnée Z	0, mm
Emplacement	Cliquez pour modif

***** 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	19.42	8.303	0.6181E+05	68.56	53.66	0.2026E-03	0.00	0.1234E-03	0.00
2	20.44	5.592	0.4612E+05	0.4180E-03	0.00	0.5137E-04	0.00	62.58	48.98
3	26.09	1.438	0.1933E+05	5.867	4.59	0.6837E-03	0.00	0.2524E-02	0.00
4	26.42	1.569	0.2161E+05	0.2792E-03	0.00	0.1659E-04	0.00	9.711	7.60
5	29.09	27.98	0.4672E+06	0.4147E-04	0.00	0.3331E-04	0.00	0.8798E-03	0.00
6	37.68	6.412	0.1797E+06	0.5770E-04	0.00	19.81	15.50	0.6953E-05	0.00
7	37.86	0.8741	0.2473E+05	0.1154E-01	0.01	0.1882E-01	0.01	0.1175E-01	0.01
8	37.86	0.8811	0.2494E+05	0.1241E-01	0.01	0.1936	0.15	0.1196E-01	0.01
9	46.09	1.016	0.4260E+05	0.2662E-03	0.00	0.4896E-03	0.00	0.3502E-04	0.00
10	49.90	1.904	0.9358E+05	0.3974E-06	0.00	0.6213E-05	0.00	0.2621E-05	0.00
11	52.84	0.6804	0.3750E+05	0.8710E-04	0.00	0.5140E-03	0.00	0.4213E-05	0.00
12	53.05	0.7700	0.4278E+05	0.6049E-03	0.00	0.2085E-04	0.00	0.4107E-05	0.00
13	53.09	1.999	0.1112E+06	2.940	2.30	0.1045E-03	0.00	0.3607E-03	0.00
14	55.22	1.245	0.7492E+05	0.2131E-02	0.00	9.575	7.49	0.6849E-02	0.01
15	55.60	6.122	0.3736E+06	0.3931E-05	0.00	0.8369E-02	0.01	4.303	3.37
16	59.35	26.47	0.1841E+07	0.1317E-02	0.00	0.9351E-04	0.00	0.9949E-02	0.01
17	59.51	6.530	0.4565E+06	0.1034E-01	0.01	0.7205	0.56	0.3359E-02	0.00
18	60.80	2.893	0.2111E+06	14.97	11.72	0.5236E-02	0.00	0.6117E-02	0.00
19	61.39	8.466	0.6298E+06	0.5188E-02	0.00	0.9075E-05	0.00	14.87	11.64
20	62.13	4.312	0.3286E+06	0.1038E-02	0.00	0.1785E-05	0.00	0.2262E-02	0.00
sum				92.38	72.31	30.33	23.74	91.52	71.63

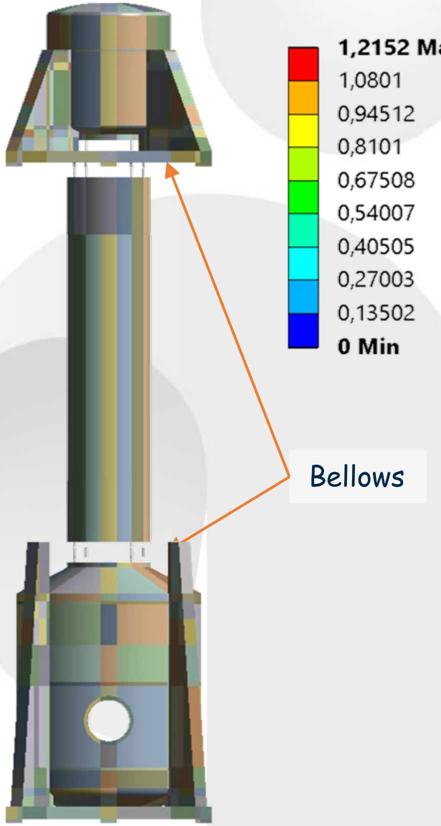
- For the « best » structure version of the previous slide, the first modal response increase at ~19,4Hz regarding the Virgo's like one <u>but</u> it involve 54% of the total mass with a factor ~60 on the upper plate (*on the Inverted Pendulum Leg point which is supposed to welcome the inverted pendulum*) and a factor 143 on the top chamber

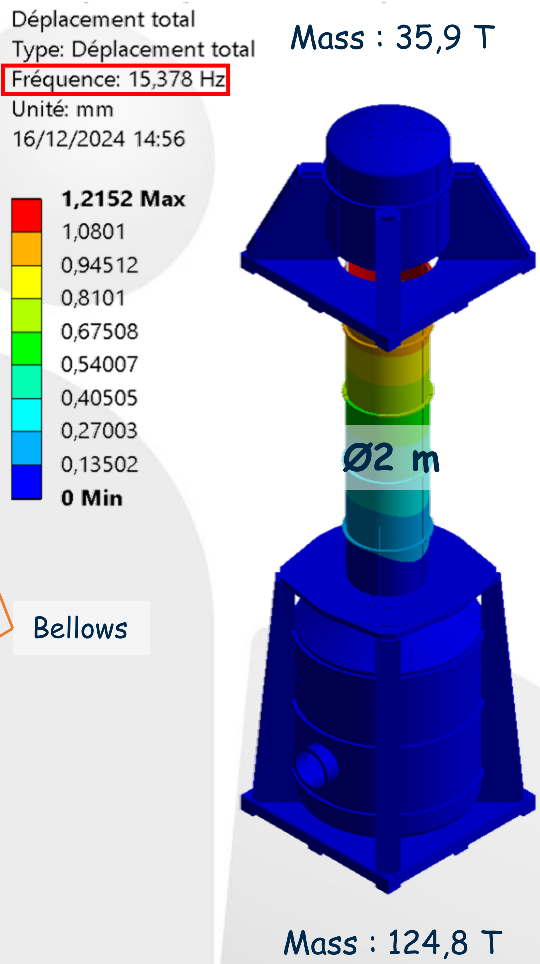


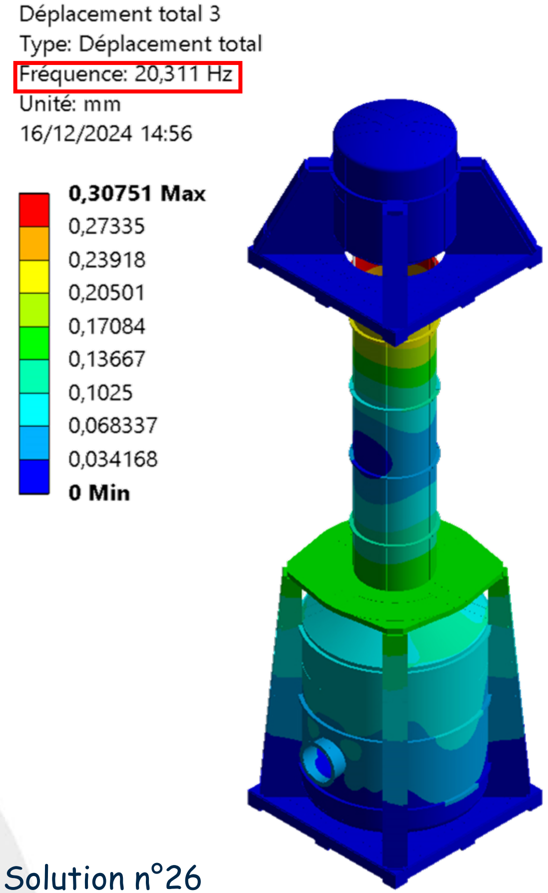
Double cavern concept

20m height - S26 - Double cavern concept

- We wanted to simulate a double cavern solution, like in Kagra, Japan
- The tube is supported by a structure, and decoupled from chambers by 2 bellows
- The feet of the inverted pendulum are 3 Ø400mm columns embedded on the upper floor
- The first mode is the one where the tube enter into resonance at 15,3Hz and the third, at 20,3Hz, is the first mode where the upper platform of the inverted pendulum enters into resonance



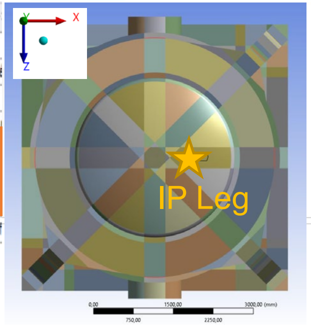


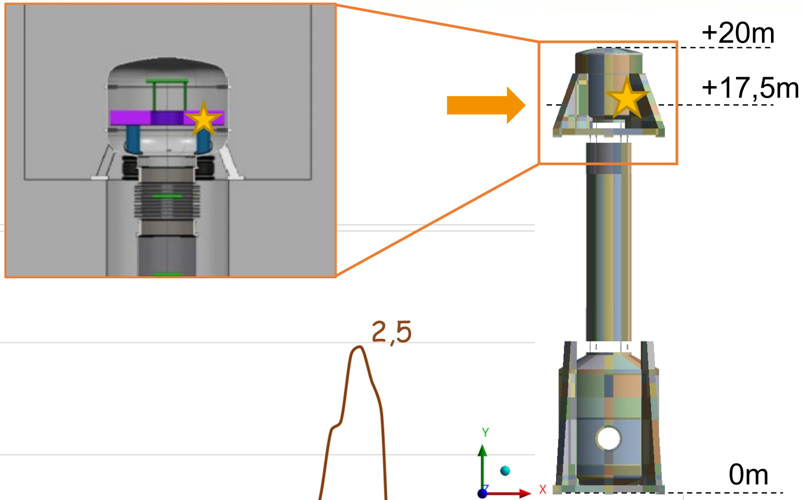


Solution n°26
Total Mass : 162 T

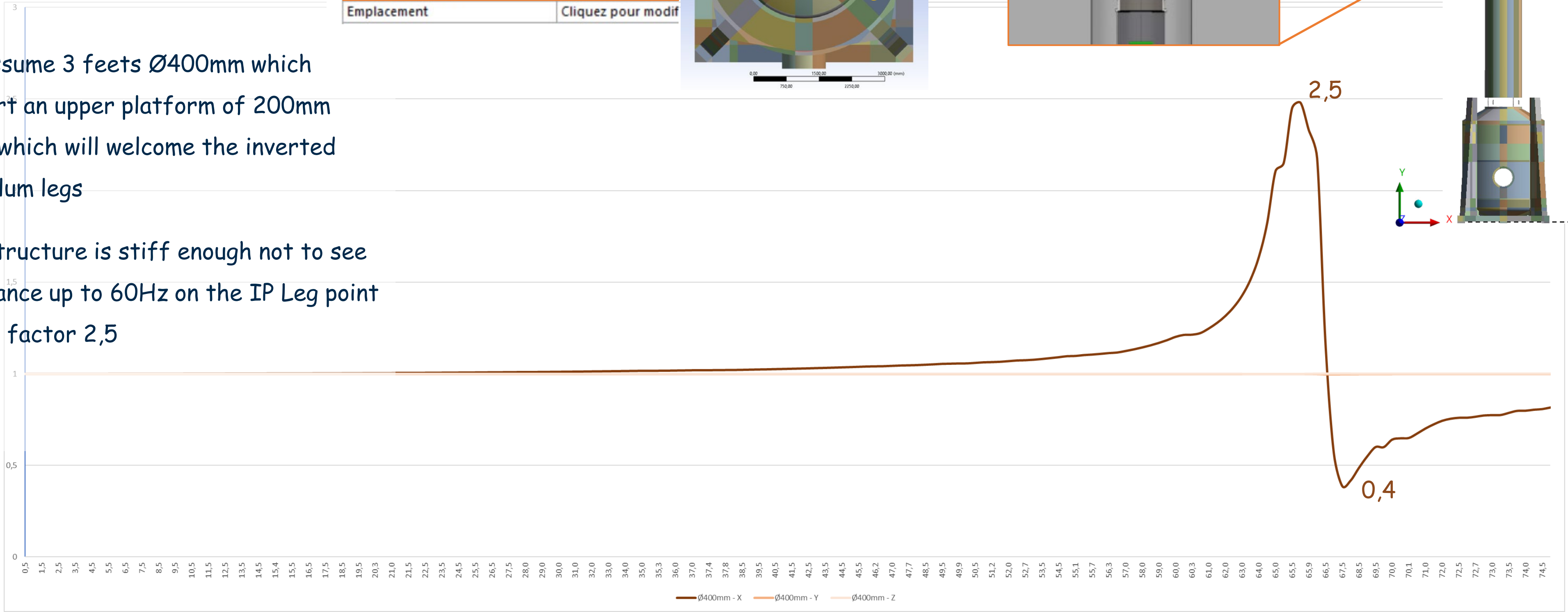
20m height – S26 - Double cavern concept

Détails de "IP Leg"	
Champ d'application	
Méthode de champ d'application	Sélection de géomé
Géométrie	4 Arêtes
Système de coordonnées	Système de coordo
Coordonnée X	1000, mm
Coordonnée Y	17500 mm
Coordonnée Z	0, mm
Emplacement	Cliquez pour modif





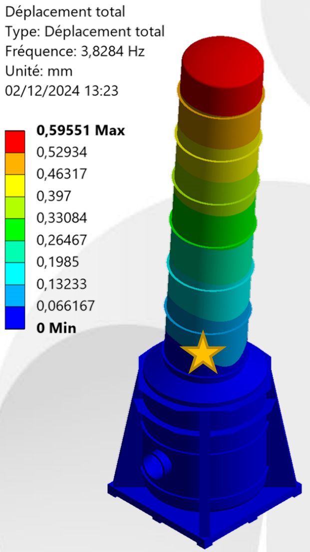
- We assume 3 feets Ø400mm which support an upper platform of 200mm thick which will welcome the inverted pendulum legs
- The structure is stiff enough not to see resonance up to 60Hz on the IP Leg point with a factor 2,5



Conclusion

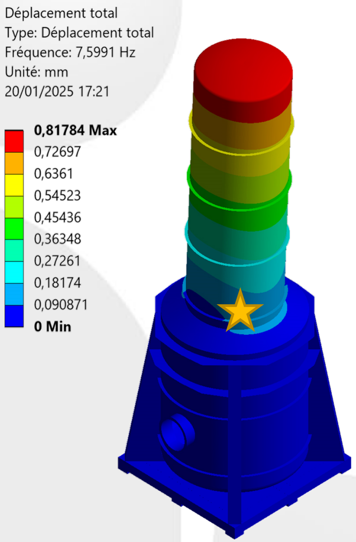
- Is-it acceptable if the upper part of the chamber resonates at less than 10 Hz, if IP Leg base-ring resonates at more than 30 Hz ?
- The double cavern is the stiffer solution regarding the harmonic response on the IP Leg
- The decoupled solution seems not a good solution regarding harmonic response
- Cryostat's mass increased a lot regarding what I present during the detector layout this summer due to the stiffeners and the base : m > 50 T without thermal shield, ANM, …

20m Height



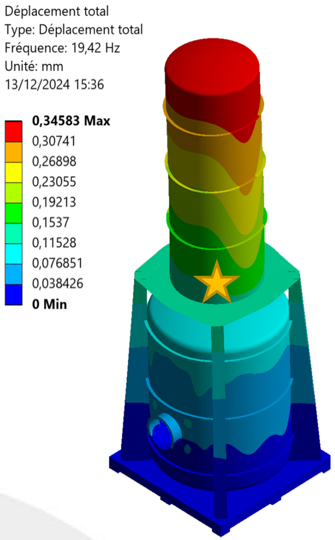
Solution n°24
Mass : 57,3 T

14,5m Height



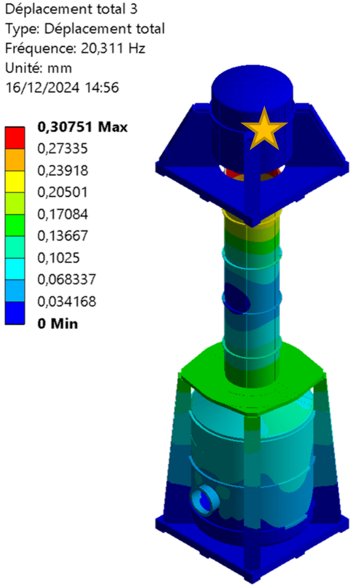
Solution n°26
Mass : 53,2 T

14,5m Height



Decoupled structure
Solution n°26
Mass : 127,8 T

Double Cavern



Double Cavern
Solution n°18
Total Mass : 162 T

★ IP Legs

Requirements

- Footprint : $5m^2$
- Cryostat keeping volume : Ø4,5 x 6,3m
- Beam's height : 2,5m

To further progress in our study we need to select among options:

Tower's height : 14,5 < x < 20m

Inverted Pendulum keeping volume : 2,5 x 2,5 x 17m or 2,5 x 2,5 x 12m

Open Questions

We need answers from PO and ISB suspension division

- Maximum mass acceptance for Civil Infrastructure : ?
- Are the first modal and harmonic responses, on 3 axes, on the upper chamber and the IP leg, sufficient to validate a concept ?
- Any other points / simulations needed ?

Then, regarding :

- The single-cavern design:
  - Are results as presented on **Slide 11** acceptable regarding stability of the base ring?
  - In general, is this a viable integration concept in terms of SA requirements?
- The double-cavern design:
  - Are results as presented on **Slide 14** acceptable?

Thanks for your attention

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