

ET-France



Nov. '22

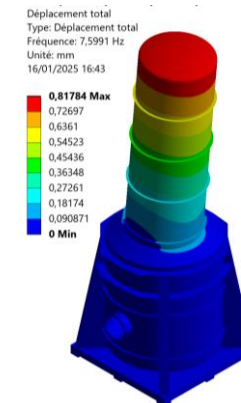
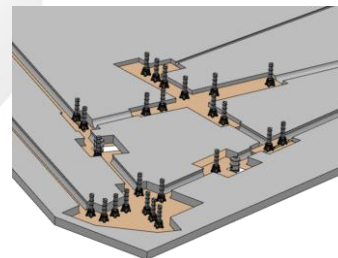
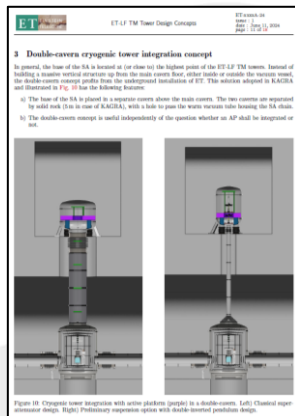
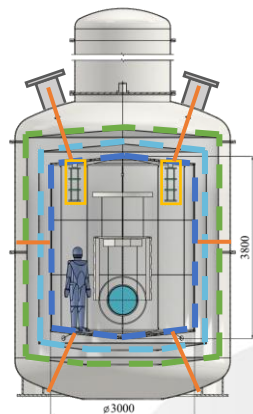
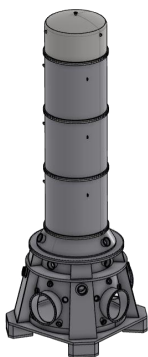
Beampipe
Virgo's state of art

M.O.U. with CERN for their support on technical topics & especially covers the work for the ET Beampipe by the CERN Vacuum Team.



The CERN vacuum team has the responsibility to deliver the technical design for the ET beampipe at the end of a three year project.

Feb. '26 - Carlo Scarcia - CERN



Nov. '22

Apr. '23

Nov. '23

Q1 '24

Q2-Q3 '24

Sept. '24

Q4 '24

H1 '25

Beampipe
 Virgo's state of art

Towers' simulations
 Virgo & E.T. first concept

Thermal Shields
 Support Structure Simulations

ET-LF TM Tower Design Concepts

Visit in Kagra

Detector Layout with
 Engineering Dept.

ET-ISB Fall Workshop on
 ET-LF TM Tower Integration
 Concepts

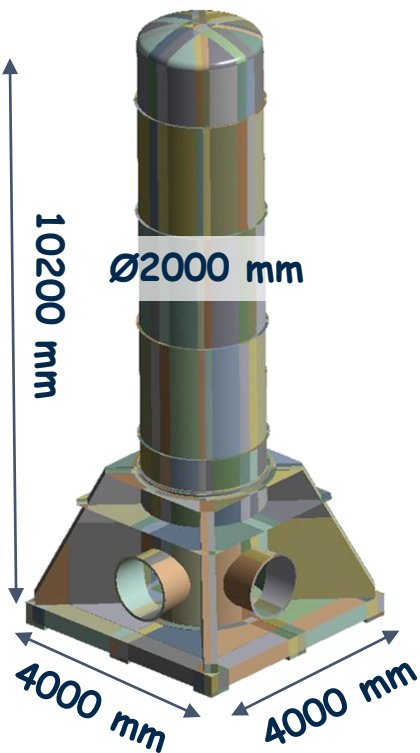
Entrée dans l'organigramme
 de E.T.O. dans le groupe
 Coordination & Integration

Cryostat simulations

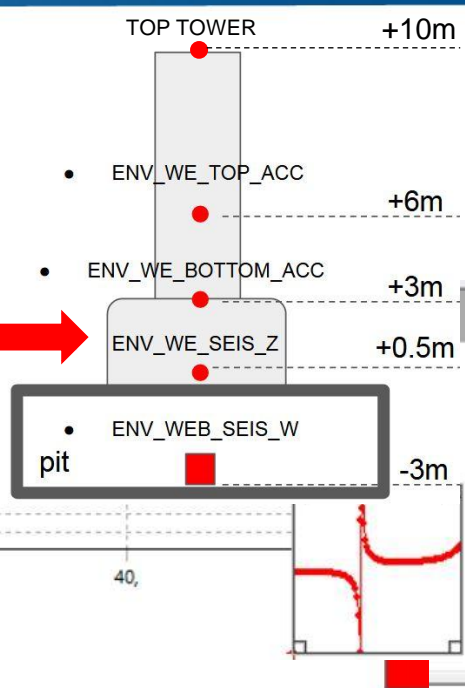
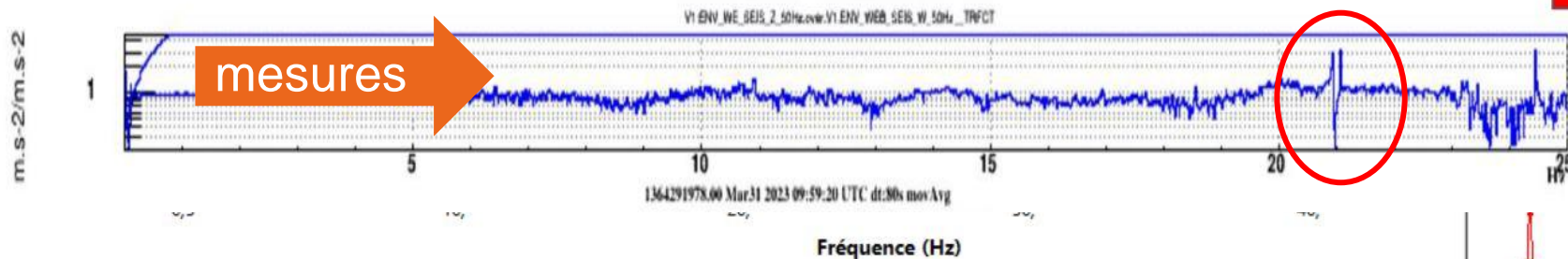
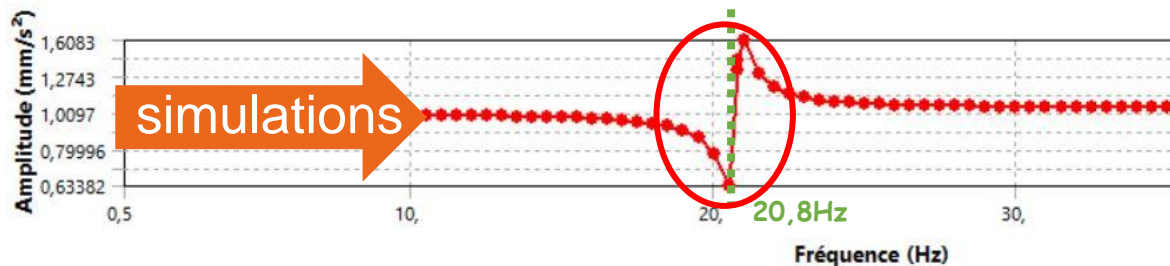
ETC-ISB

Réunion 1 mardi sur 2 à 9h

VIRGO's tower



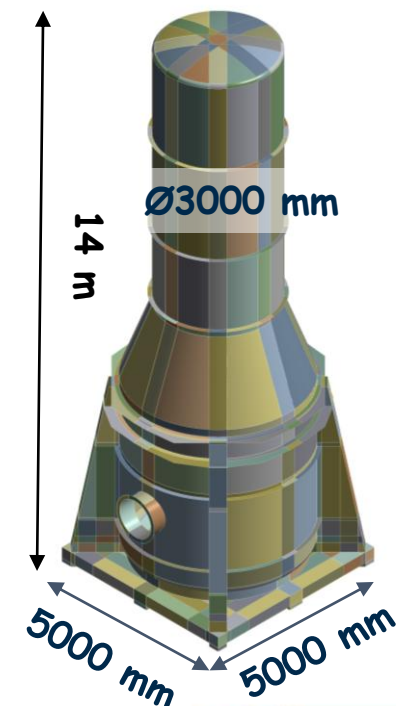
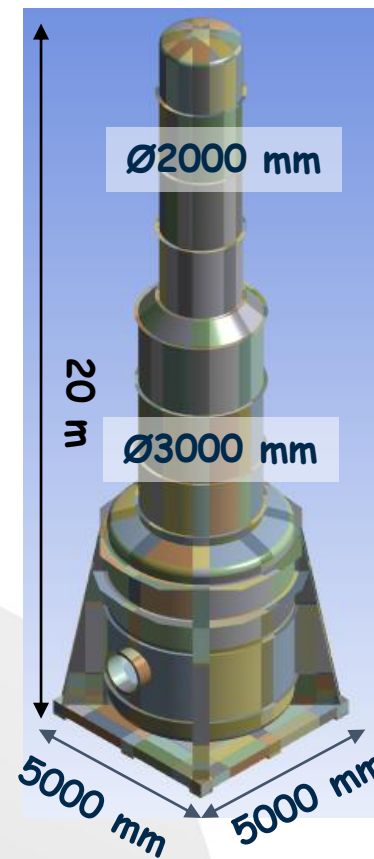
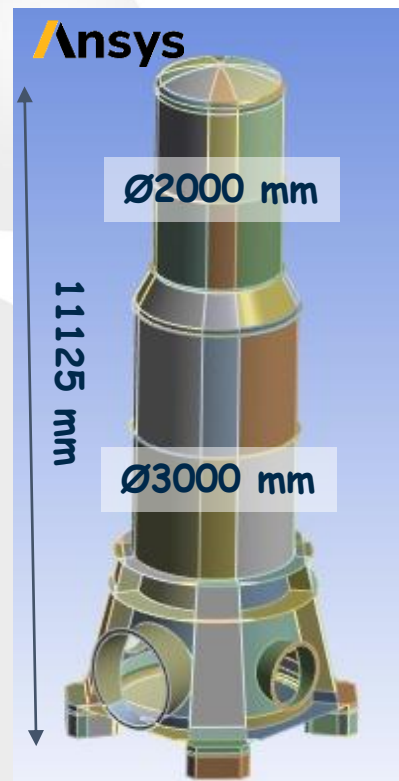
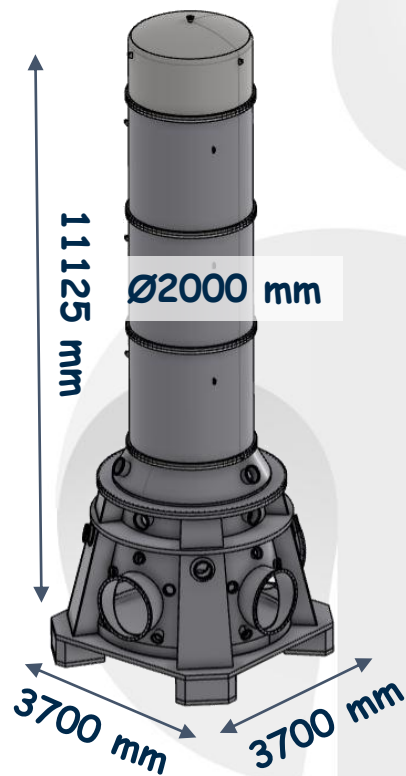
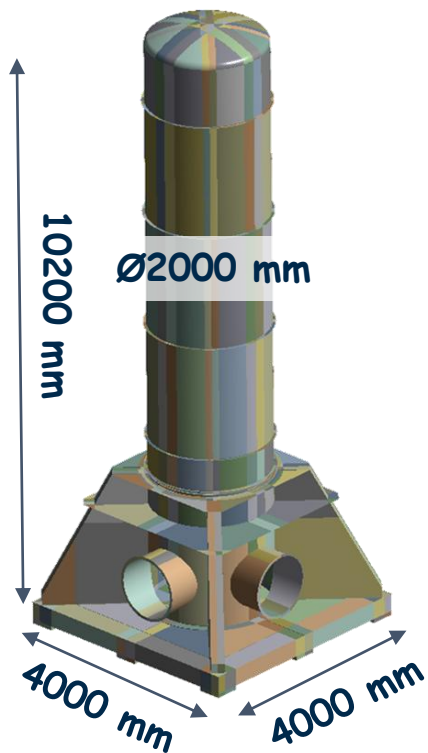
Réponse en fréquence X - Amplitude mm/s²













Einstein Telescope's Warm Tower (E.G.O.)

ET-Test Mass Tower

VIRGO's tower

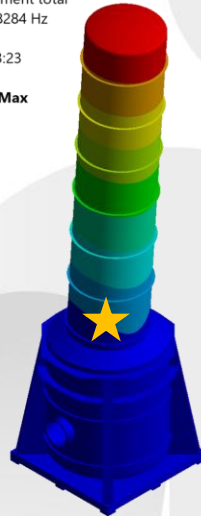
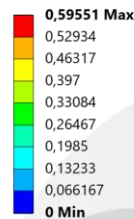


																															
Configuration	Footprint (m)	5x5	5x5	5x5	5x5	5x5	6x6	5x5	5x5	5x5	5x5	5x5	5x5	5x5	5x5	5x5	6x6	5x5	5x5	5x5	5x5	5x5	5x5	5x5	5x5	5x5	5x5	5x5	5x5		
	Height (m)	20	20	20	20	20	20	20	20	20	20	15	15	15	15	15	15	15	20	20	15	15	15	15	15	15	15	15	20	20	
	Ø tubes Top Chamber	2	2-3	2-3	2-3	2-3	2-3	3	3	3	2	2	2-3	2-3	2-3	2-3	2-3	2-3	2-3	3	3	2-3	2-3	2-3	2-3	3	3	2	2		
	Cover	Bombé	Bombé	Conique	Conique	Conique	Conique	Bombé	Conique	Conique	Conique	Bombé	Bombé	Conique	Conique	Conique	Conique	Conique	Conique	Conique	Conique	Bombé	Bombé	Bombé / Coni	Bombé	Bombé / Coni	Bombé	Bombé / Coni	Conique	Conique	
	Staged	Non	Oui	Oui	Oui	Oui	Oui	Non	Non	Non	Non	Non	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	
	Stiffeners to Sup. Plate	Oui	Oui	Oui	Oui	Non	Non	Oui	Non	Non	Non	Oui	Oui	Oui	Oui	Non	Non	Non	Non	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	
	Stiffeners to Top Cham	Non	Non	Non	Non	Oui	Oui	Non	Oui	Oui	Oui	Non	Non	Non	Non	Oui	Oui	Oui	Oui	Oui	Oui	Non	Non	Non	Non	Non	Non	Non	Non	Non	
	Structure	Non	Non	Non	Non	Oui	Non	Non	Non	Non	Non	Non	Non	Non	Non	Oui	Non	Non	Non	Non	Non	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	Oui	
	Material	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox	Inox / Alu	Inox / Alu	Inox / Alu	Inox / Alu	Inox / Alu	Inox / Alu	Inox / Alu	Inox / Alu	Inox / Alu	Inox / Alu	Inox	Inox
	Thickness (mm)	Chamber	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Top Chamber		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	
Bridges Top (x2)		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Montant		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Bridges Chambres (x2)		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Stiffeners		30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	
Beampipe DN 1000 - Tu		15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
Beampipe DN 1000 - Fla		40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	
Bottom Access - Flange		40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	
Bottom Access - Tube		15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
Results	1st Modal Response	1.4	2.3	5.6	5.8	11.3	13.4	1.97	2.99	10.8	30.8	3.1	4.47	11	11.34	13.2	20.4	5.3	3.8	13.5	11.3	11.8	17.6	13.7	19.6	18.9	20.3				
	Linear Buckling	6.4	6.4	6.4	8	6.4	6.6	6.4	6.6	6.6	4.1	6.4	6.4	6.4	8.1	6.4	6.4	6.2	4.1	5.3	4.2	4.7	6	6.1	4.8	4.7	3.9				
	Mass [T]	62.247	65.4	65.175		92.887	142.7	68.064	67.987	95.157	94.6	58	61.55	61.4		74.2	93.5	59	57.3	53.1	85.9	103.1	132.8	132.6	127.8	128	162				
											Upper chamber	35.9														Upper chamber	35.9				
										Bottom chamber	50.2															Bottom chamber	124.8				

- 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

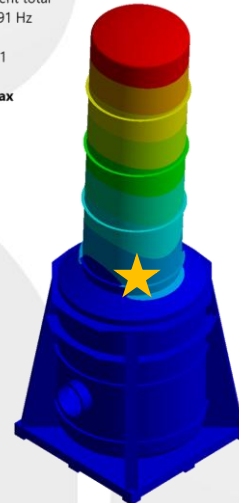
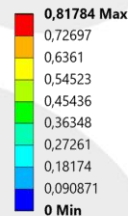
Déplacement total
Type: Déplacement total
Fréquence: 3,8284 Hz
Unité: mm
02/12/2024 13:23



Solution n°24
Mass : 57,3 T

14,5m Height

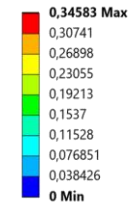
Déplacement total
Type: Déplacement total
Fréquence: 7,5991 Hz
Unité: mm
20/01/2025 17:21



Solution n°26
Mass : 53,2 T

14,5m Height

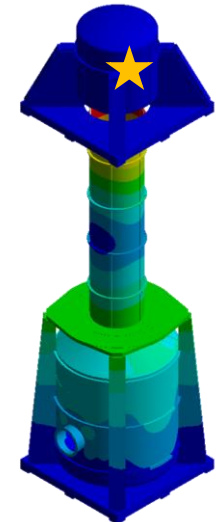
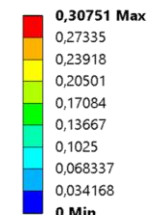
Déplacement total
Type: Déplacement total
Fréquence: 19,42 Hz
Unité: mm
13/12/2024 15:36



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

Double Cavern

Déplacement total 3
Type: Déplacement total
Fréquence: 20,311 Hz
Unité: mm
16/12/2024 14:56

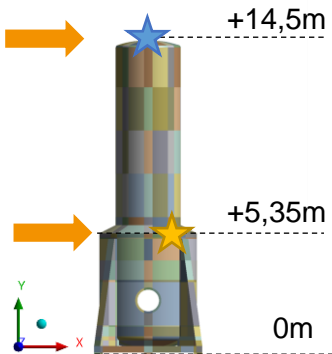
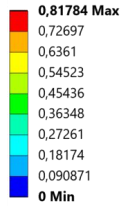


Double Cavern
Solution n°18
Total Mass : 162 T

★ IP Legs

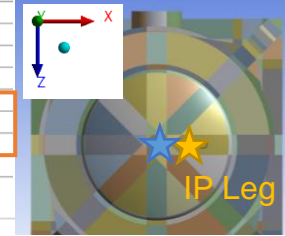
- We observe a "bump" at 7.6 Hz by a factor of 2.8 involving 6% of the total mass of the chamber, which is the upper chamber, and the rest at more of 32 Hz.

Déplacement total
Type: Déplacement total
Fréquence: 7,5991 Hz
Unité: mm
20/01/2025 16:12

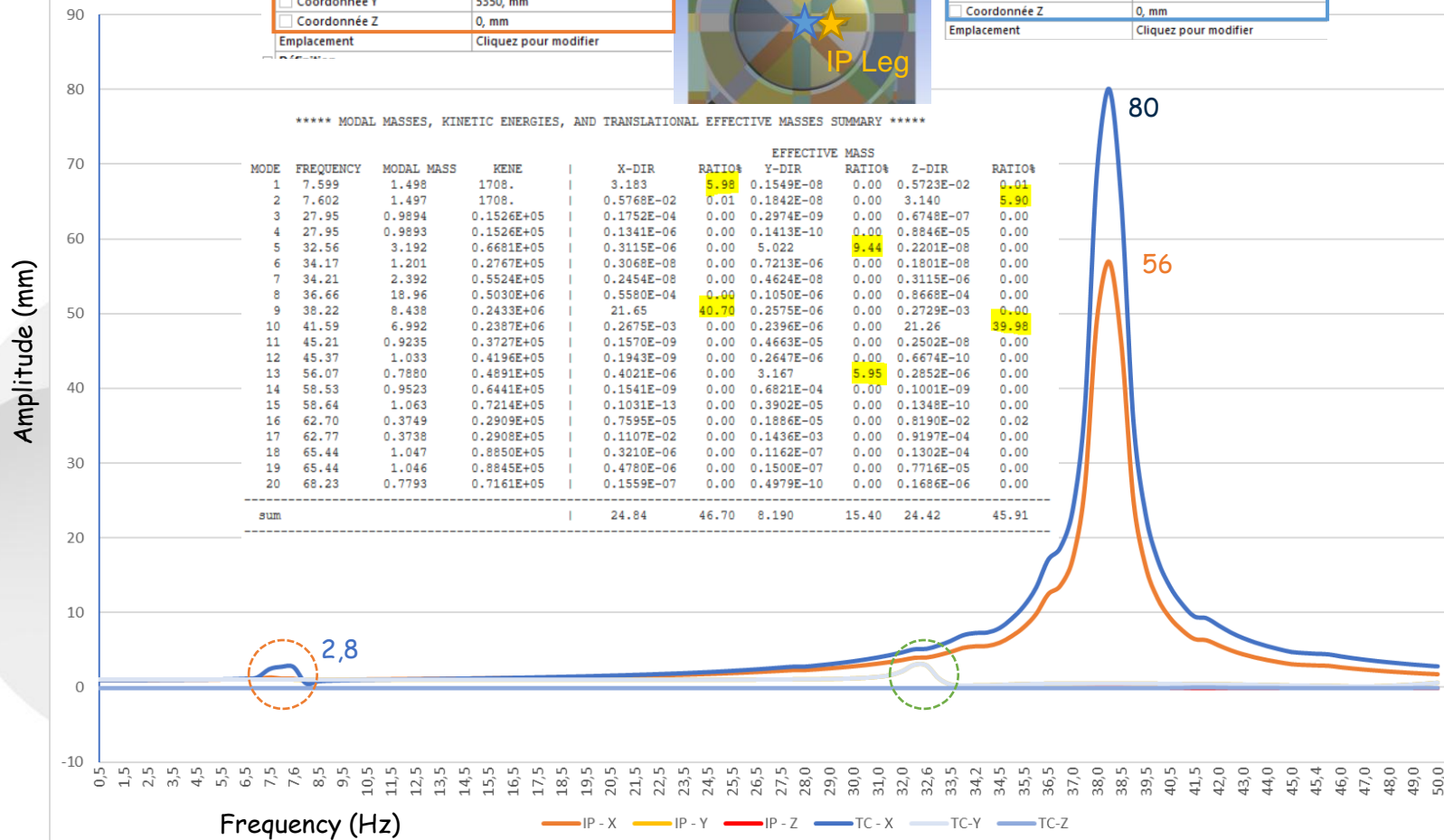


Solution n°30 -
March '25
Mass : 53,2 T

Champ d'application	
Méthode de champ d'application	Sélection de géométrie
Géométrie	4 Arêtes
Système de coordonnées	Système de coordonnées global
<input type="checkbox"/> Coordonnée X	1000, mm
<input type="checkbox"/> Coordonnée Y	5350, mm
<input type="checkbox"/> Coordonnée Z	0, mm
Emplacement	Cliquez pour modifier



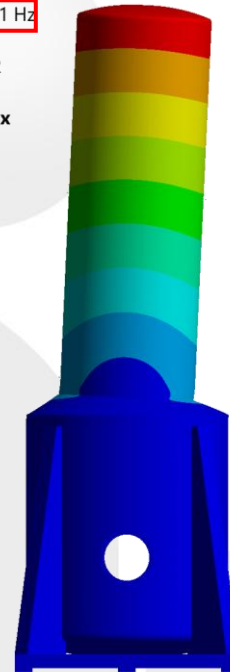
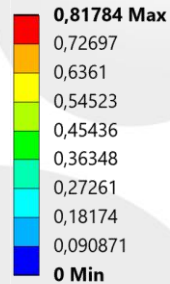
Champ d'application	
Méthode de champ d'application	Sélection de géométrie
Géométrie	4 Arêtes
Système de coordonnées	Système de coordonnées global
<input type="checkbox"/> Coordonnée X	0, mm
<input type="checkbox"/> Coordonnée Y	14500 mm
<input type="checkbox"/> Coordonnée Z	0, mm
Emplacement	Cliquez pour modifier



• Optimisation de :

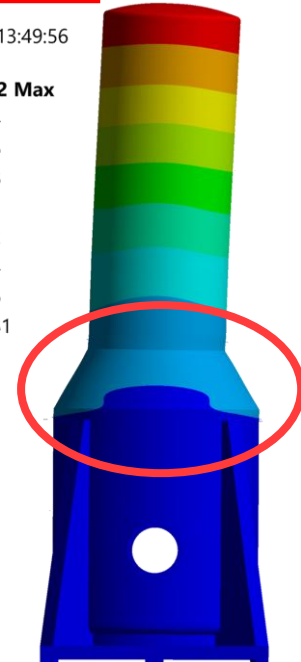
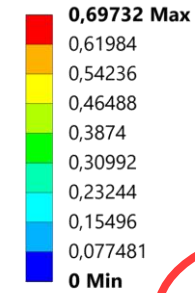
- Forme conique au sommet du cryostat (de 27° à 60°)
- Épaisseurs des tôles de la chambre
- Conception de la base
- Support de la chambre à vide
- Suppression de la plaque intermédiaire

Déplacement total
Type: Déplacement total
Fréquence: 7,5991 Hz
Unité: mm
20/01/2025 16:12



Solution n°30 - March '25
Mass : 53,2 T

Déplacement total
Type: Total Deformation
Frequency: 20,602 Hz
Unit: mm
06/11/2025 13:49:56



Solution n°30 - October '25
Mass : 40,1 T

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

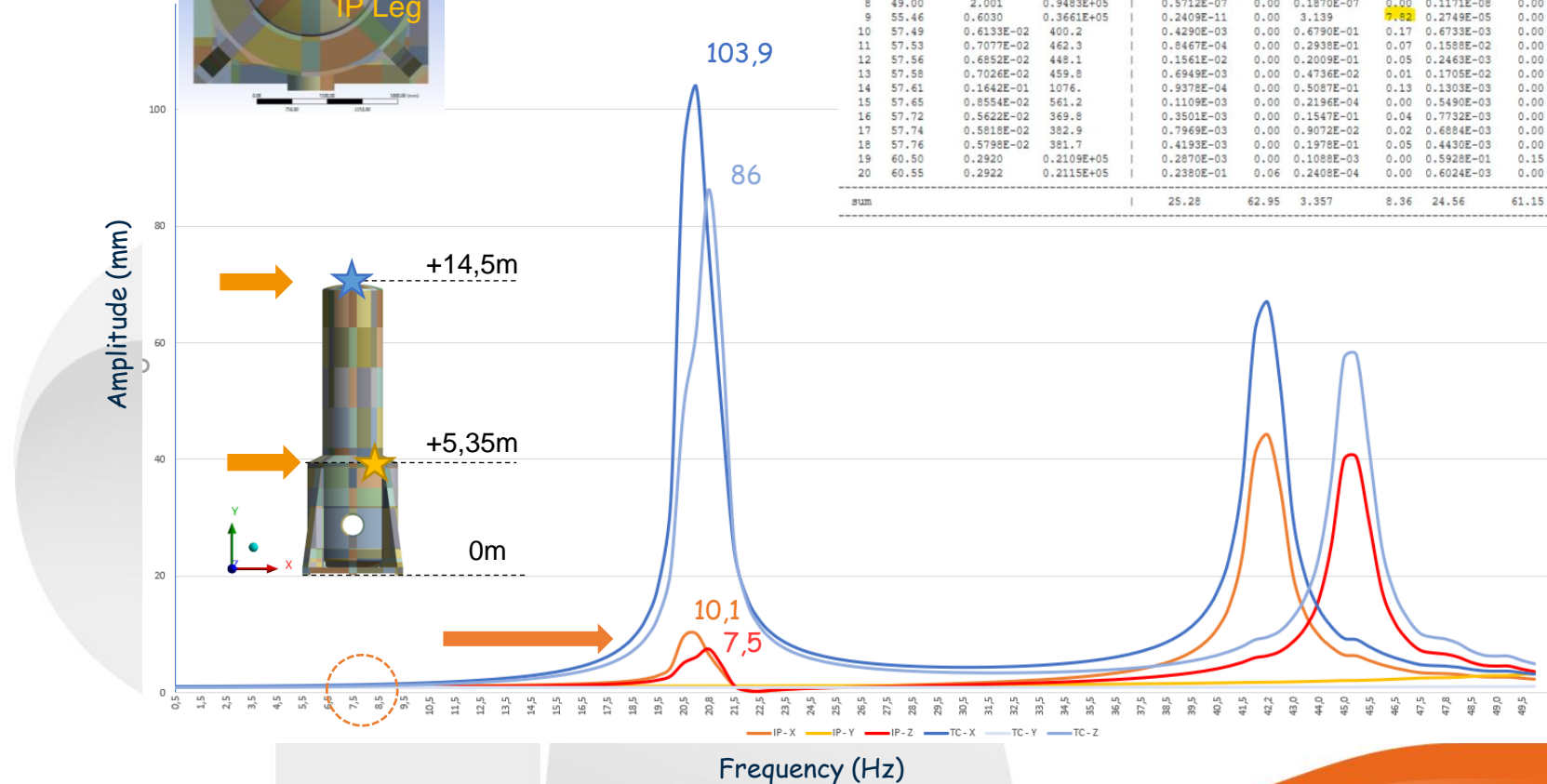


Champ d'application	
Méthode de champ d'application	Sélection de géométrie
Géométrie	4 Arêtes
Système de coordonnées	Système de coordonnées global
Coordonnée X	0, mm
Coordonnée Y	14500 mm
Coordonnée Z	0, mm
Emplacement	Cliquez pour modifier

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

MODE	FREQUENCY	MODAL MASS	KENE	X-DIR	EFFECTIVE MASS			Z-DIR	RATIO%
					RATIO%	Y-DIR	RATIO%		
1	20.60	2.057	0.1724E+05	8.890	22.14	0.3583E-09	0.00	0.1963E-03	0.00
2	20.80	2.005	0.1713E+05	0.2099E-03	0.00	0.2833E-08	0.00	8.031	26.66
3	42.17	9.138	0.3208E+06	16.36	46.73	0.4897E-06	0.00	0.1735E-05	0.00
4	45.07	9.968	0.3997E+06	0.2445E-05	0.00	0.8321E-09	0.00	16.44	40.32
5	47.68	0.7920	0.3553E+05	0.6640E-02	0.02	0.7070E-07	0.00	0.1206E-02	0.00
6	47.76	0.7867	0.3543E+05	0.3222E-03	0.00	0.1042E-06	0.00	0.2318E-01	0.06
7	48.90	1.016	0.4794E+05	0.5817E-08	0.00	0.1115E-03	0.00	0.6285E-08	0.00
8	49.00	2.001	0.9483E+05	0.5712E-07	0.00	0.1870E-07	0.00	0.1171E-08	0.00
9	55.46	0.6030	0.3661E+05	0.2409E-11	0.00	3.139	0.00	0.2749E-05	0.00
10	57.49	0.6133E-02	400.2	0.4290E-03	0.00	0.6790E-01	0.17	0.6733E-03	0.00
11	57.53	0.7077E-02	462.3	0.8467E-04	0.00	0.2938E-01	0.07	0.1588E-02	0.00
12	57.56	0.6852E-02	448.1	0.1561E-02	0.00	0.2009E-01	0.05	0.2463E-03	0.00
13	57.58	0.7026E-02	459.8	0.6949E-03	0.00	0.4736E-02	0.01	0.1705E-02	0.00
14	57.61	0.1642E-01	1076.	0.9378E-04	0.00	0.5087E-01	0.13	0.1303E-03	0.00
15	57.65	0.8554E-02	561.2	0.1109E-03	0.00	0.2196E-04	0.00	0.5490E-03	0.00
16	57.72	0.5622E-02	369.8	0.3501E-03	0.00	0.1547E-01	0.04	0.7732E-03	0.00
17	57.74	0.5818E-02	382.9	0.7969E-03	0.00	0.9072E-02	0.02	0.6884E-03	0.00
18	57.76	0.5798E-02	381.7	0.4193E-03	0.00	0.1978E-01	0.05	0.4430E-03	0.00
19	60.50	0.2920	0.2109E+05	0.2870E-03	0.00	0.1088E-03	0.00	0.5928E-01	0.15
20	60.55	0.2922	0.2115E+05	0.2380E-01	0.06	0.2408E-04	0.00	0.6024E-03	0.00
sum				25.28	62.95	3.357	8.36	24.56	61.15

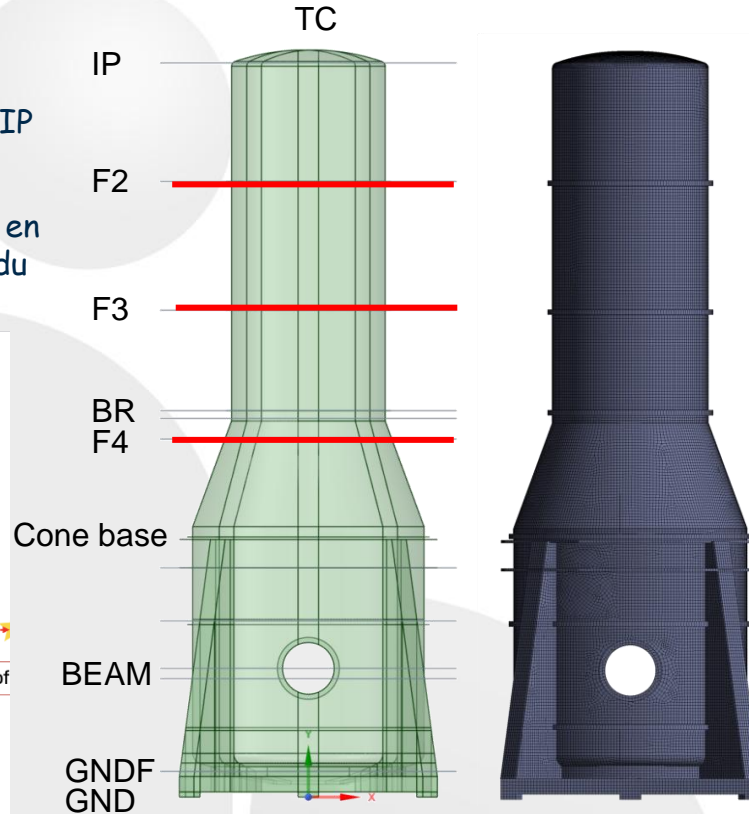
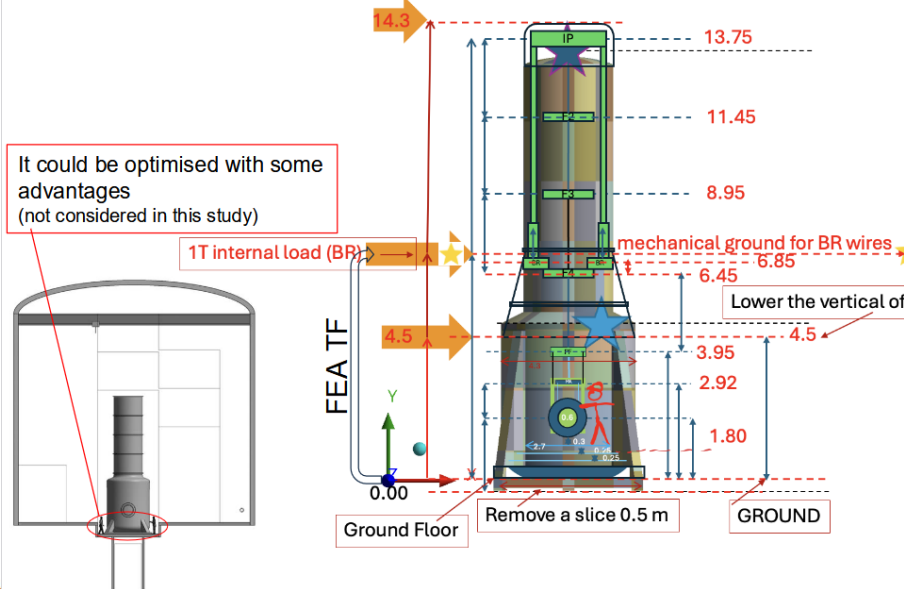
- No more bump à 7,6Hz
- We observe the first modal response around 20,6 Hz that involved 22%% of the total mass
- For a 1 mm displacement on the fixed supports, on the IP Leg there is a factor of 7,5 on the Z axis and 10,1 on the X axis, and for the top chamber, 86 on Z axis and ~104mm on X axis
- X and Z axis are the transverse axis of the tower



Solicitation de Ettore Majorana & Manuel Pinto (INFN Roma) avant le workshop ET-Test Mass avec un design de IP à intégrer à la tour

Révision de la tour avec les brides des viroles supérieures en regard des filtres en cas de maintenance et modification du cône.

A new seed model for the tower based upon reference solution



C: Flambage linéaire

Déplacement total

Type: Total Deformation

Load Multiplier (Linear): 8,1315

Unit: mm

05/03/2026 12:01:39

1,0153 Max

0,9025

0,78969

0,67687

0,56406

0,45125

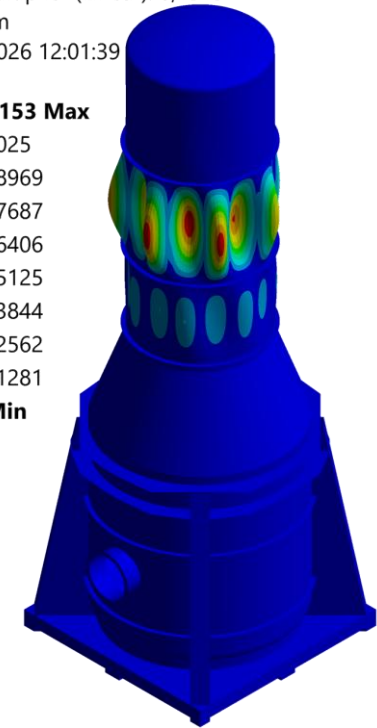
0,33844

0,22562

0,11281

0 Min

0 Min

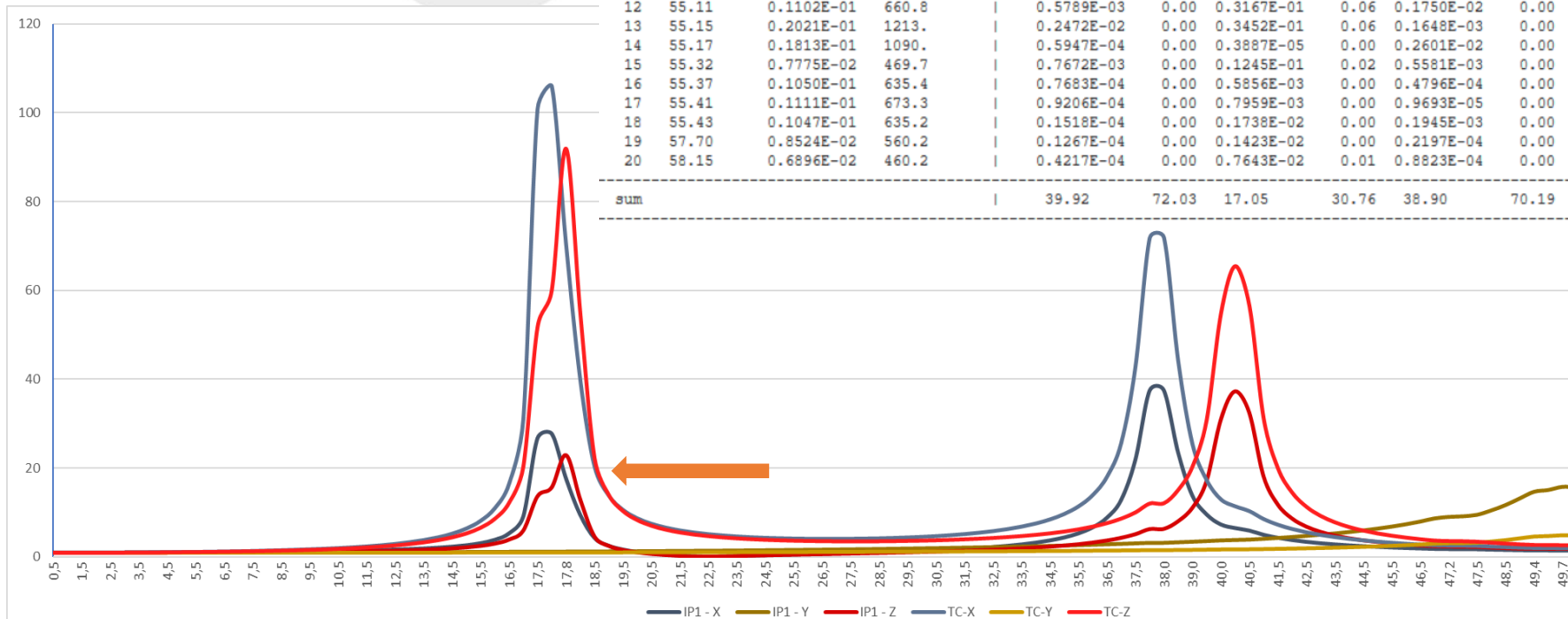
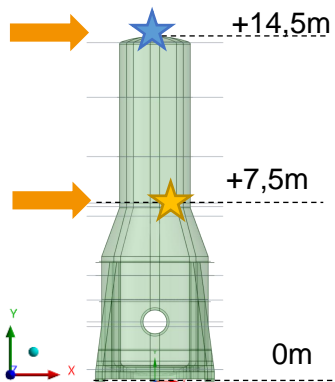


- Ajout de trois masses de 300 kg sur le bottom ring pour simuler le pendule inversé diminuent la première réponse modale à 17,5 Hz.



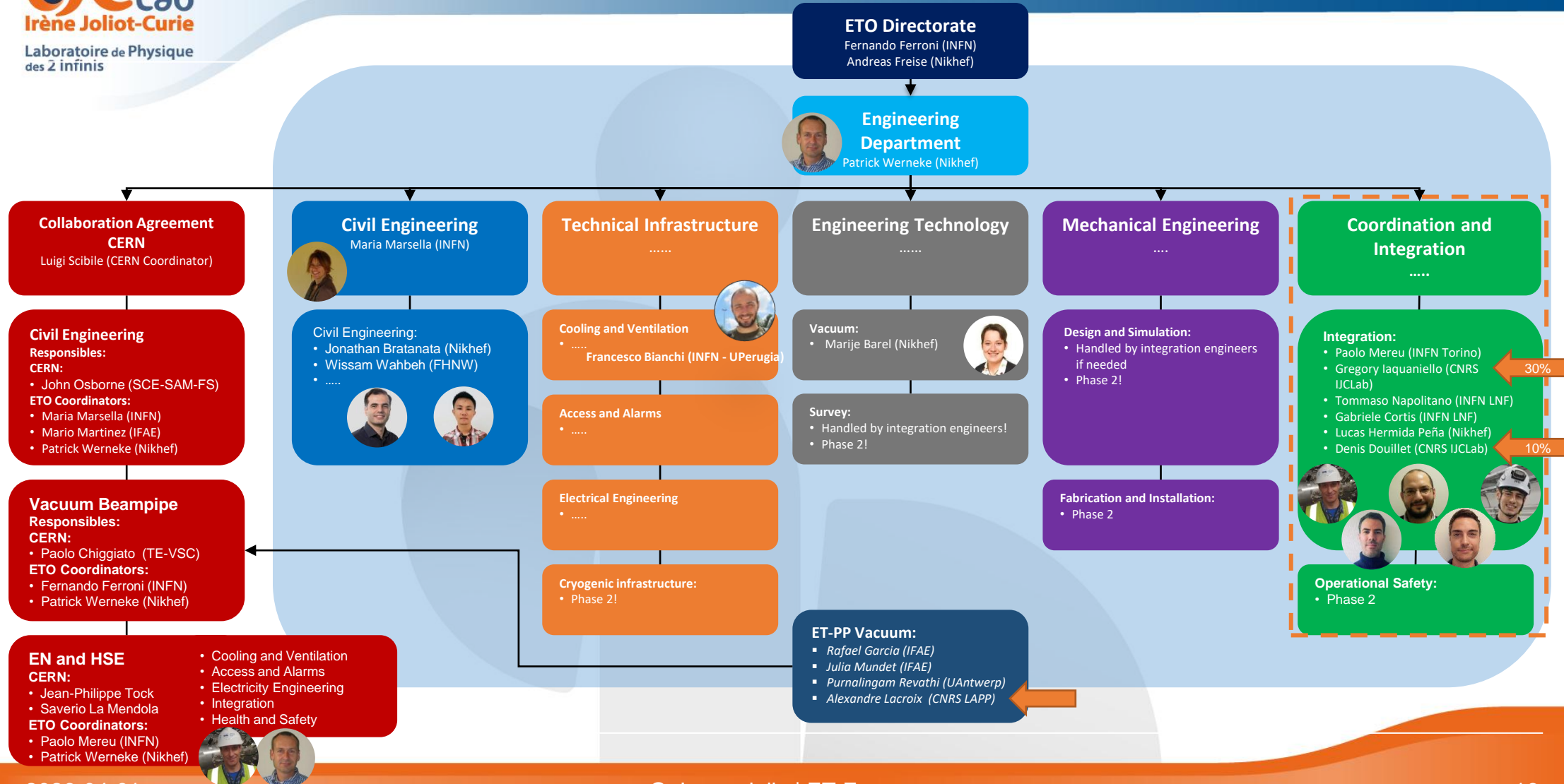
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MODE	FREQUENCY	MODAL MASS	KENE	X-DIR	EFFECTIVE MASS					
					RATIO%	Y-DIR	RATIO%	Z-DIR	RATIO%	
1	17.55	4.522	0.2750E+05	20.24	36.52	0.9640E-05	0.00	0.6810E-01	0.12	
2	17.76	4.365	0.2717E+05	0.7084E-01	0.13	0.8298E-05	0.00	18.78	33.88	
3	38.02	9.481	0.2705E+06	19.61	35.37	0.1901E-04	0.00	0.1031E-02	0.00	
4	40.27	9.821	0.3143E+06	0.1492E-02	0.00	0.1708E-03	0.00	20.04	36.16	
5	47.23	1.966	0.8653E+05	0.2239E-03	0.00	0.5314E-07	0.00	0.8899E-05	0.00	
6	47.30	1.955	0.8634E+05	0.8262E-05	0.00	0.1350E-06	0.00	0.2412E-03	0.00	
7	49.40	17.26	0.8315E+06	0.8731E-04	0.00	0.8557E-03	0.00	0.2983E-03	0.00	
8	49.66	2.590	0.1261E+06	0.4476E-11	0.00	0.1949E-03	0.00	0.2283E-08	0.00	
9	49.67	4.815	0.2345E+06	0.2531E-05	0.00	0.2733E-04	0.00	0.8640E-05	0.00	
10	51.45	0.1002E-01	523.3	0.6341E-03	0.00	0.2373	0.43	0.1793E-02	0.00	
11	53.08	0.9166	0.5098E+05	0.5226E-04	0.00	16.72	30.17	0.3987E-04	0.00	
12	55.11	0.1102E-01	660.8	0.5789E-03	0.00	0.3167E-01	0.06	0.1750E-02	0.00	
13	55.15	0.2021E-01	1213.	0.2472E-02	0.00	0.3452E-01	0.06	0.1648E-03	0.00	
14	55.17	0.1813E-01	1090.	0.5947E-04	0.00	0.3887E-05	0.00	0.2601E-02	0.00	
15	55.32	0.7775E-02	469.7	0.7672E-03	0.00	0.1245E-01	0.02	0.5581E-03	0.00	
16	55.37	0.1050E-01	635.4	0.7683E-04	0.00	0.5856E-03	0.00	0.4796E-04	0.00	
17	55.41	0.1111E-01	673.3	0.9206E-04	0.00	0.7959E-03	0.00	0.9693E-05	0.00	
18	55.43	0.1047E-01	635.2	0.1518E-04	0.00	0.1738E-02	0.00	0.1945E-03	0.00	
19	57.70	0.8524E-02	560.2	0.1267E-04	0.00	0.1423E-02	0.00	0.2197E-04	0.00	
20	58.15	0.6896E-02	460.2	0.4217E-04	0.00	0.7643E-02	0.01	0.8823E-04	0.00	
sum				39.92	72.03	17.05	30.76	38.90	70.19	

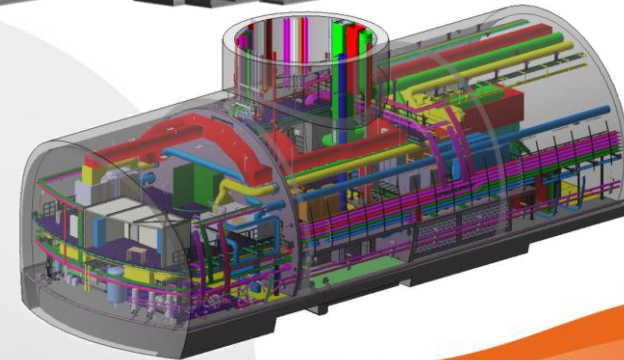
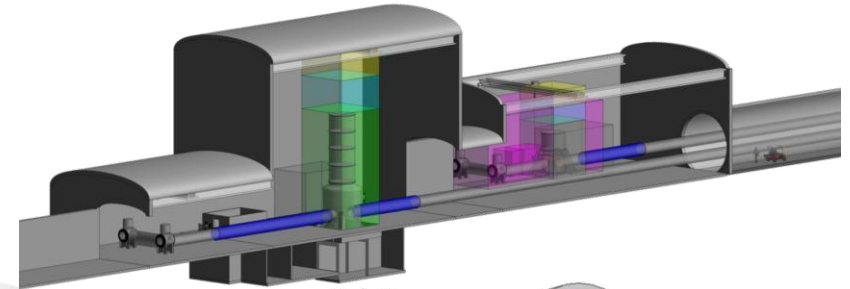
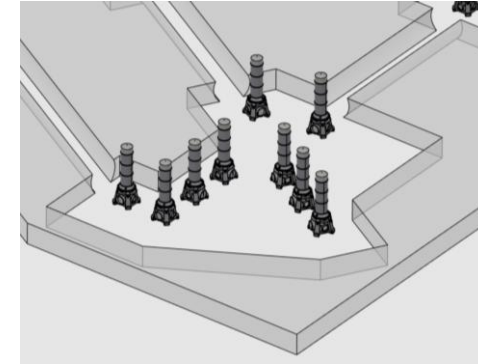
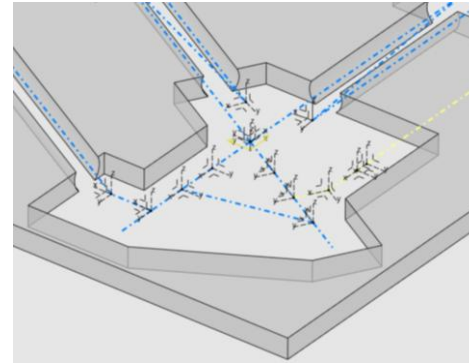


ETO - Coordination & Integration

Réunion tous les lundis à 14h



1. Studies towards a skeleton model for ET
2. Integration of End Cavern BA (structures and services):
 - Tower (envelope), beampipes, sector valves
 - Infrastructure: cavern, scaffolding, crane(s) and cleanroom(s)
 - Noisy room(s), service tunnels, HVAC, cryogenics, racks, pipes, cables,
3. PLM / CAD selection
4. Develop an integrated work process on how to combine various 3D data sources into one model!



- Nous recevons le fichier excel brut avec les coordonnées des tours
- Denis a identifié manuellement chaque trajet optique à l'aide du schéma Trimble
- Il a organisé les trajets optiques par feuilles et ajouté une colonne pour indiquer l'ordre des trajets optiques.
- Ensuite, nous avons importé les points ET-HF dans les ensembles géométriques 3DExperience grâce à une macro VBA créée par Denis.

2026-02-ETOL-mm-HF_Arm-AC+AB.xlsx - Excel

Tower	X	Y	Z	Layer	OP
1 Tower					
2 HBS_A	104857,40	55310,10	3500,00	E1-HF	1
3 HZM3_AC	98115,10	30147,70	3500,00	E1-HF	2
4 HZM4_AC	101535,40	39544,70	3500,00	E1-HF	3
5 HZM5_AC	89888,50	-3922,00	3500,00	E1-HF	4
6 HITM_AC	99888,50	-3922,00	3500,00	E1-HF	5
7 HETM_AC	1009888,50	-3922,00	3500,00	E1-HF	6
8 HCal1_AB	5056076,40	8749537,30	3500,00	E1-HF	7
9 HCal2_AB	5061272,60	8746537,30	3500,00	E1-HF	8

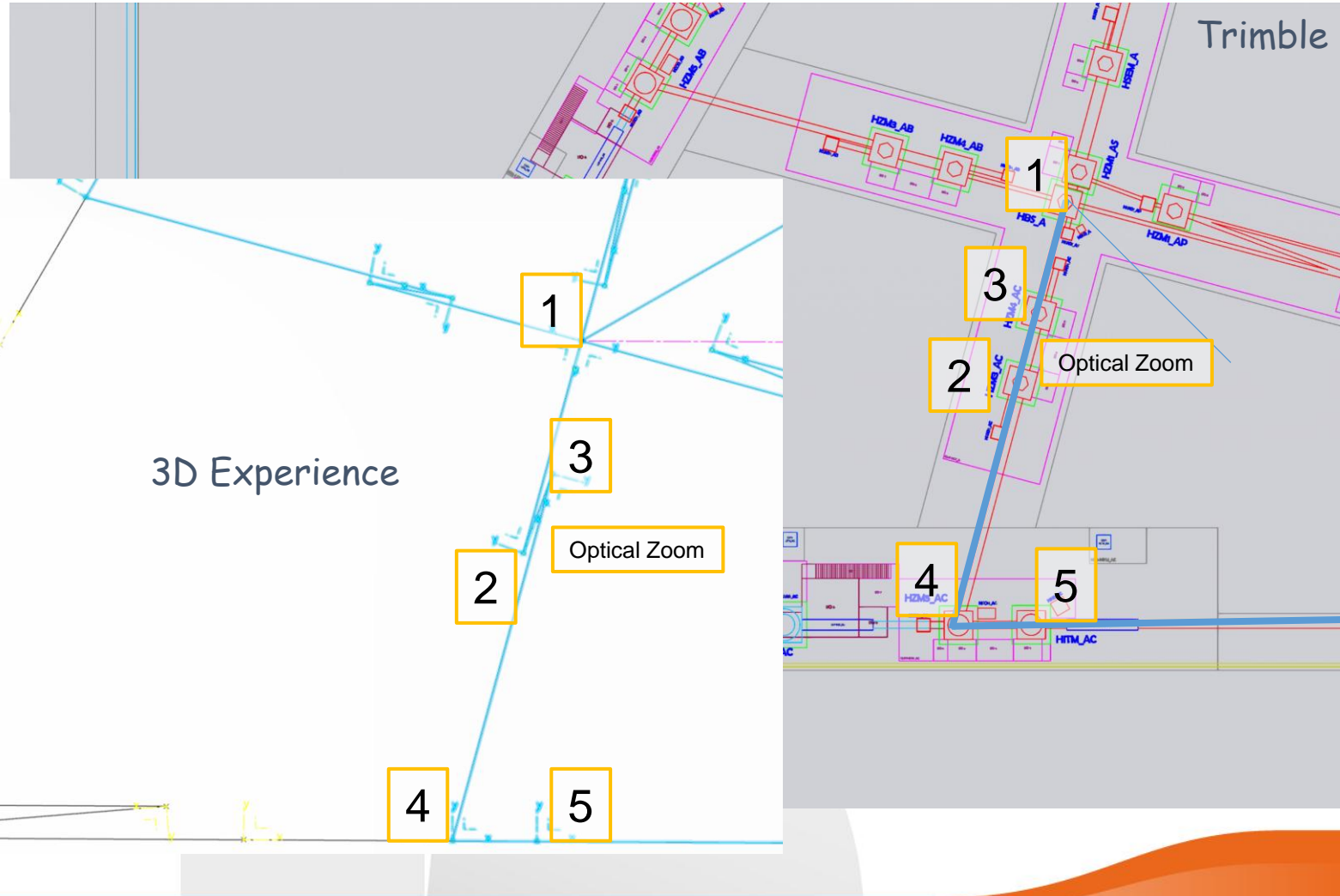
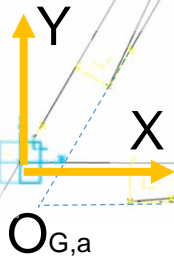
GS-HBS-ABC+G
E1-HF_AC
E1-HF_AB
E1-HF_SEM
E1-HF_PRM
E1-HF_IMC1
E1-HF_IMC2

E1-HF_AC E1-HF_AB E1-HF_SEM E1-HF_PRM E1-HF_IMC1 E1-HF_IMC2

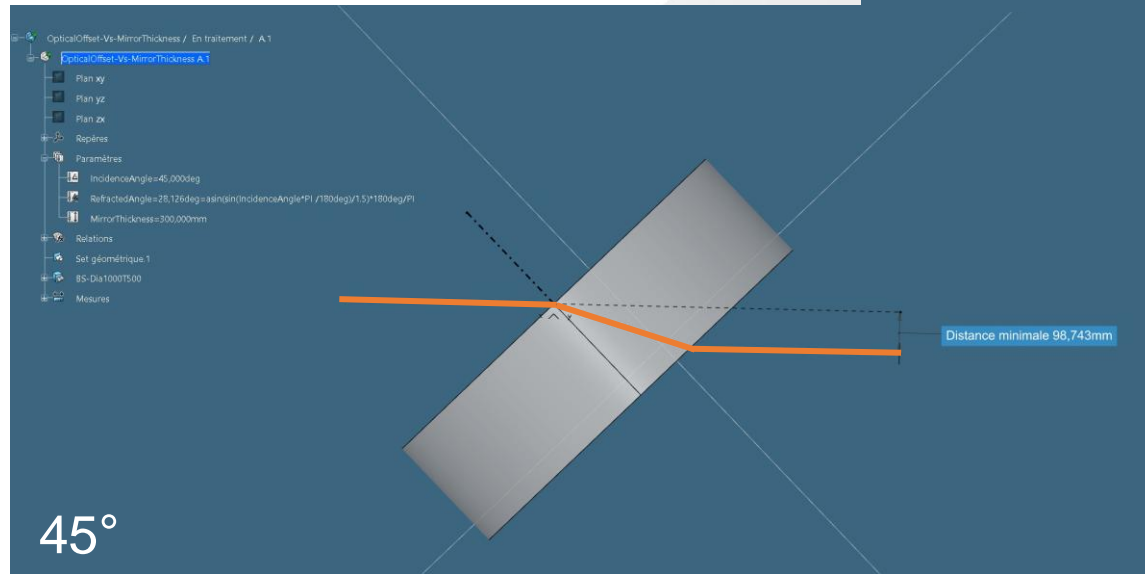
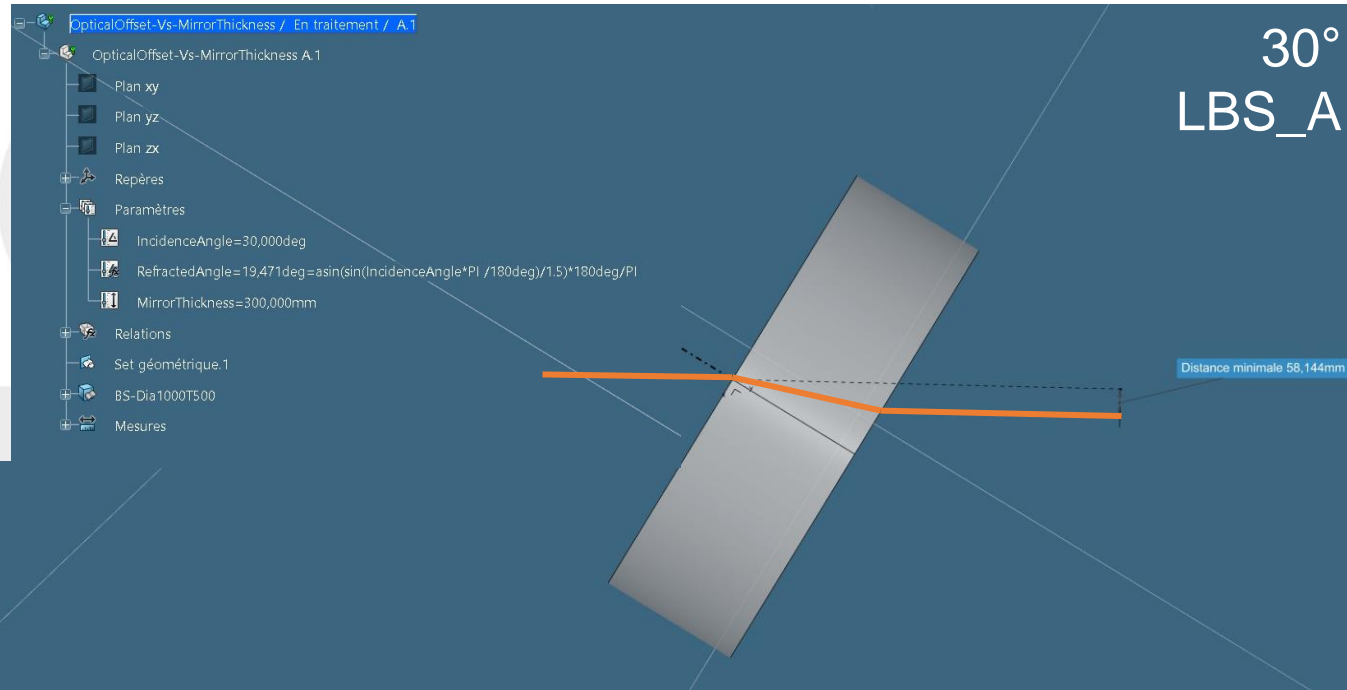
- The macro generate :

- Points
- Create lines between each points to simulate the optical path
- Create axis system on each point
- Z is always vertical
- The orientation of the X axis is given by the lines generated between the point n and n+1 into the excel sheet

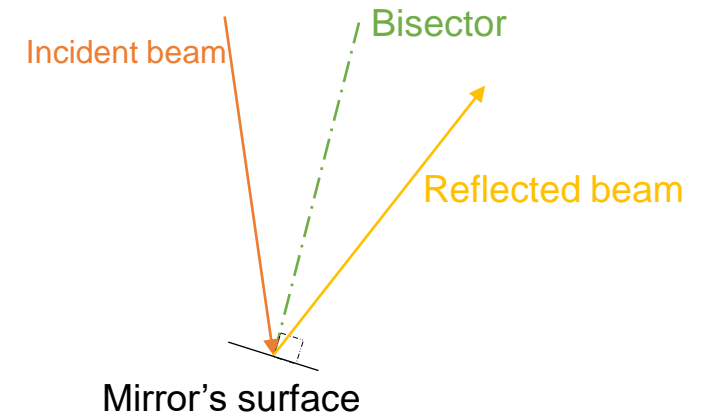
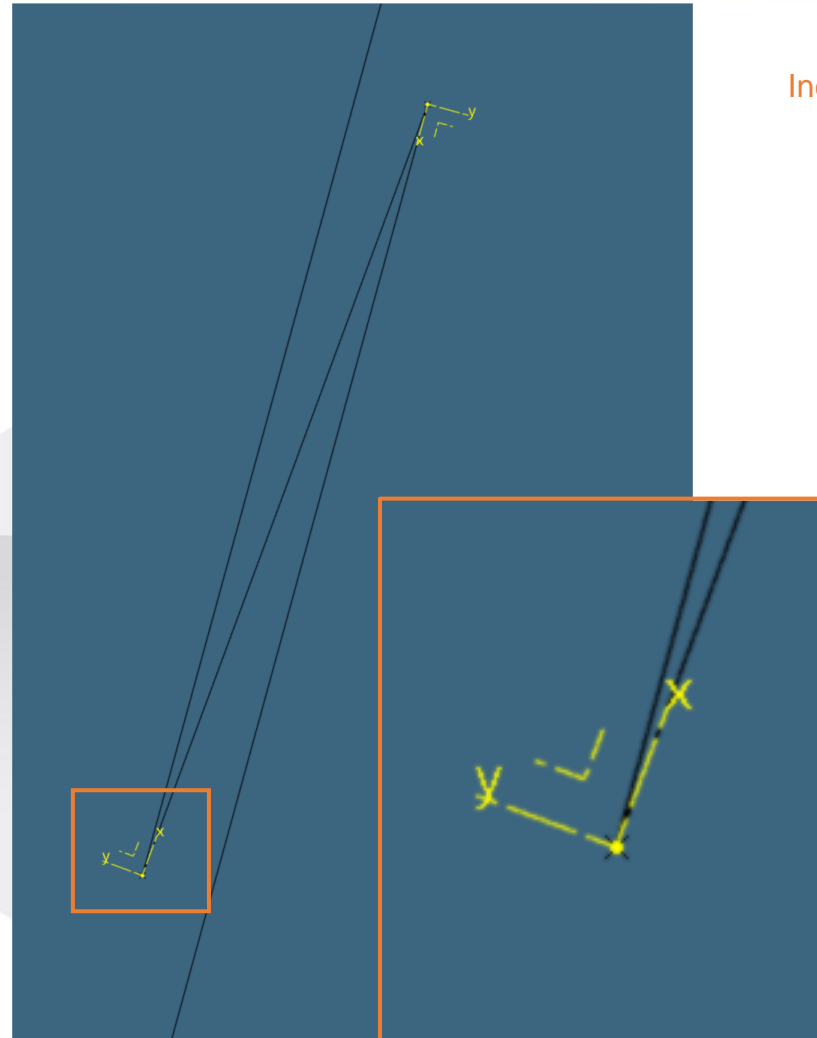
- The results was not the real optical path

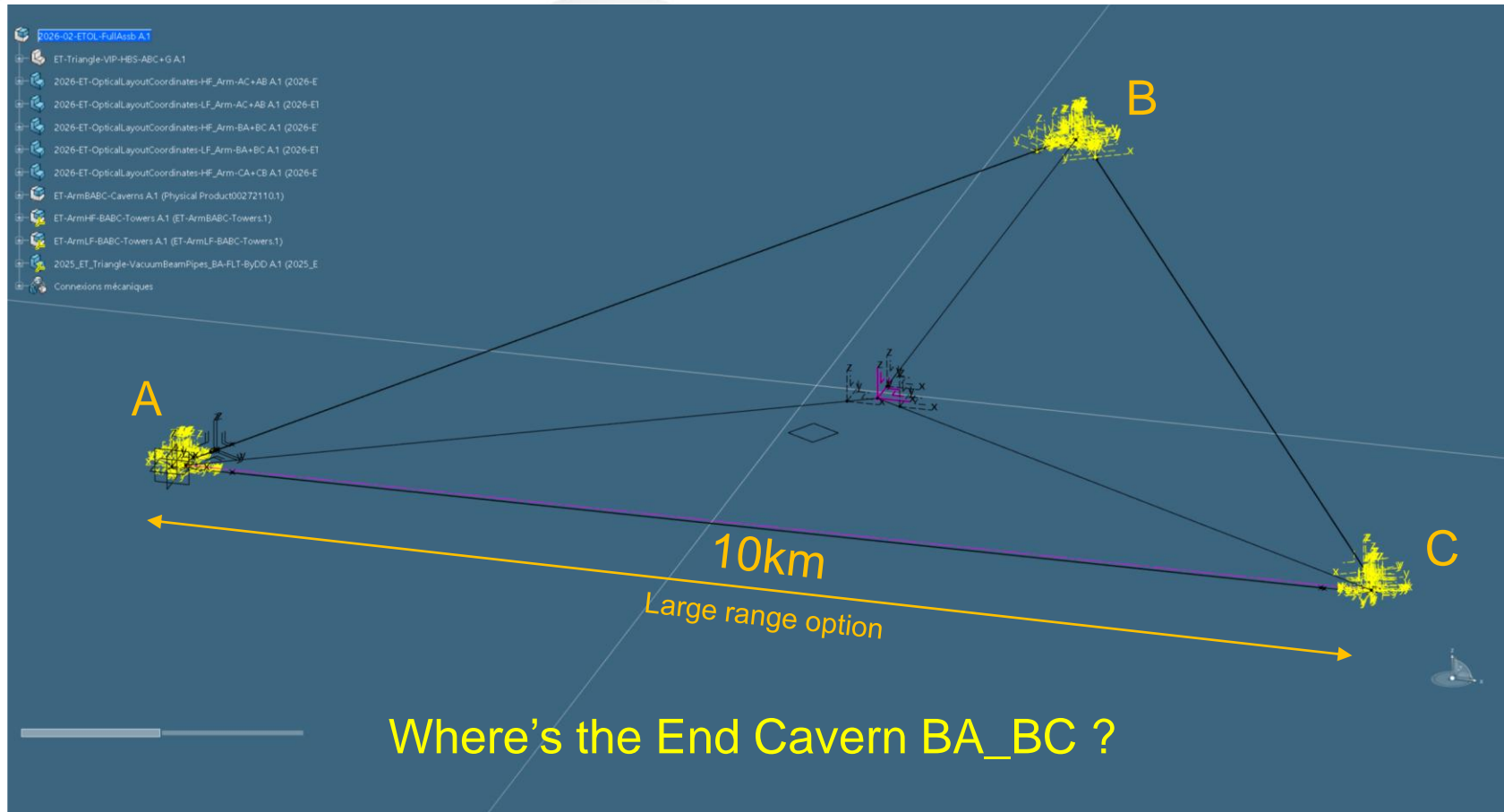


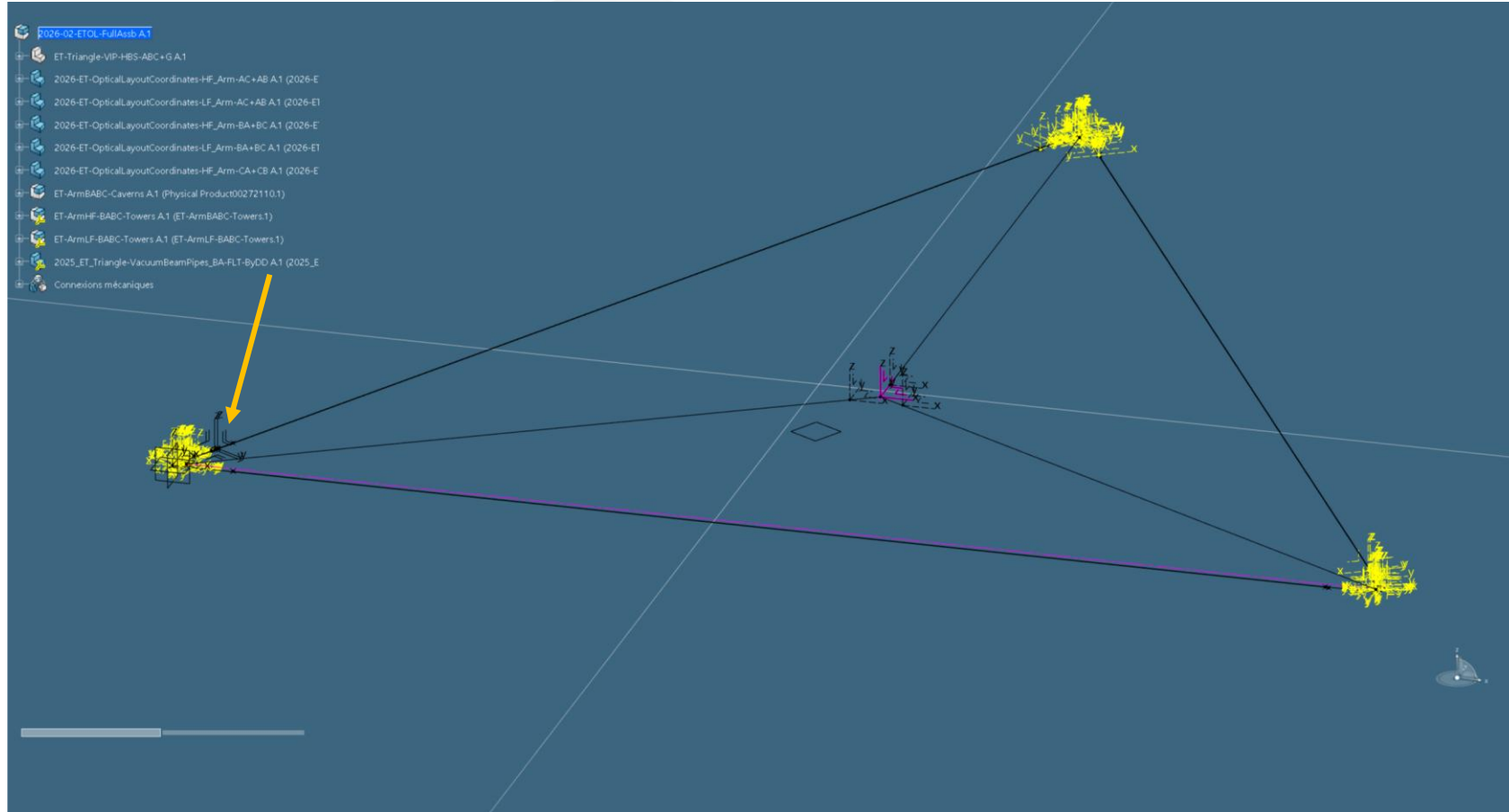
- The current optical layout doesn't take into account the optical offset due to the angle of incidence through the thick of the mirror (beamsplitter) and the material index (1,5 for glass)

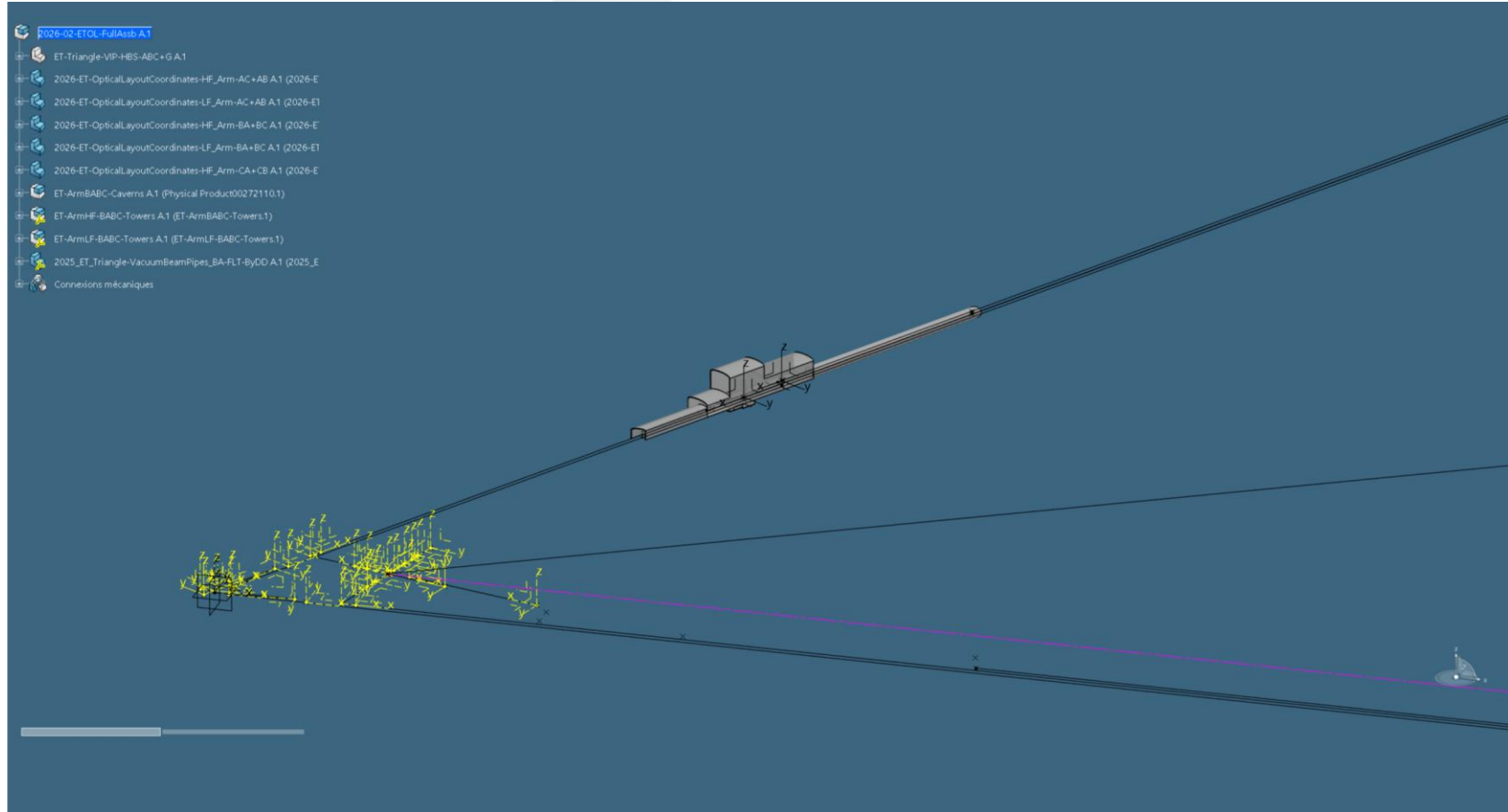


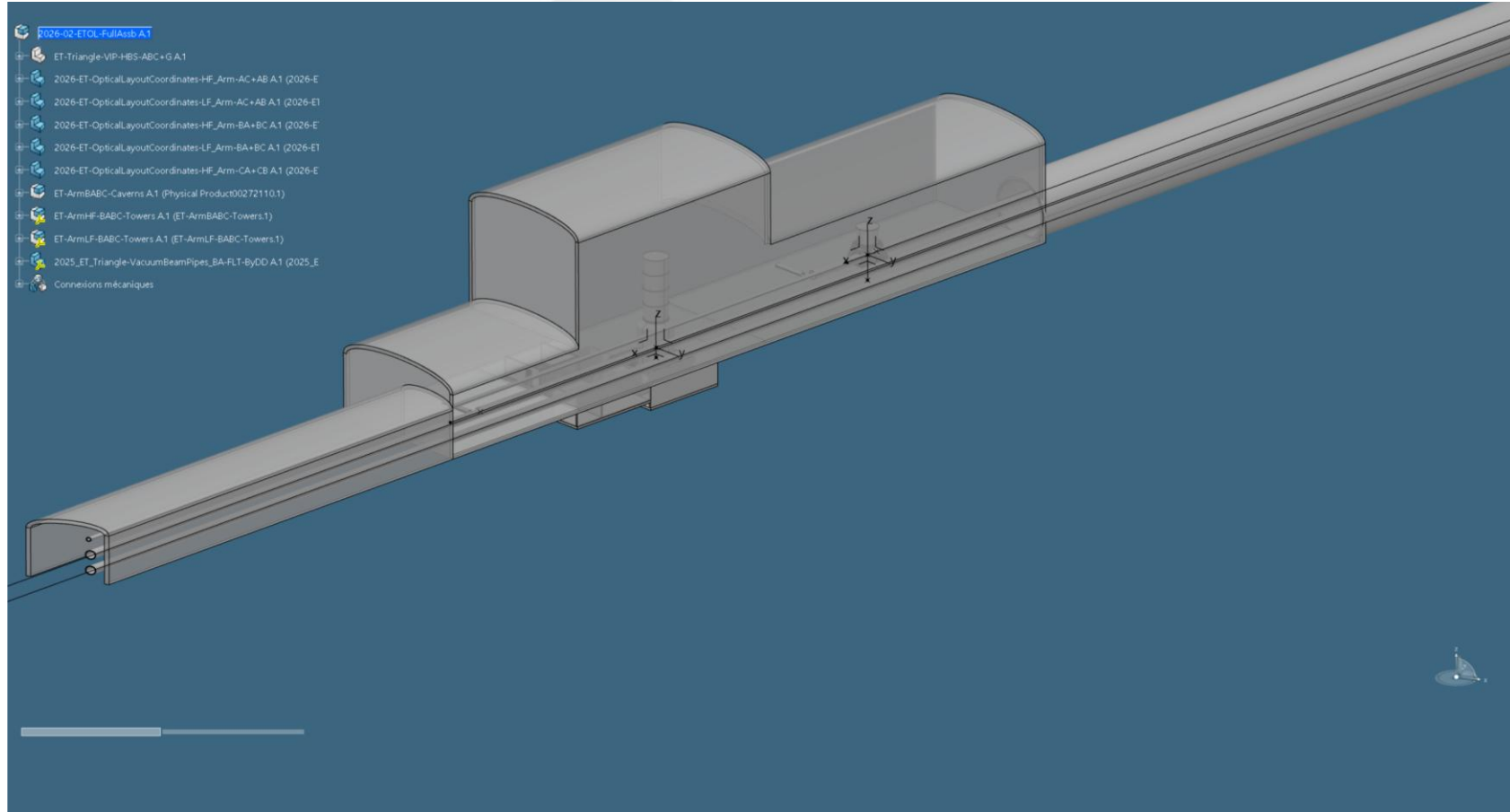
- If we want to constrain mirror on the optical layout we need to take into account the bisecting line between the incident beam and the reflected beam
- The current macro build the axis system with the X axis from the point n to the point n+1
- To constrain the normal of the mirror to the X axis, axis need to be the bisecting line except for normal incidence mirror









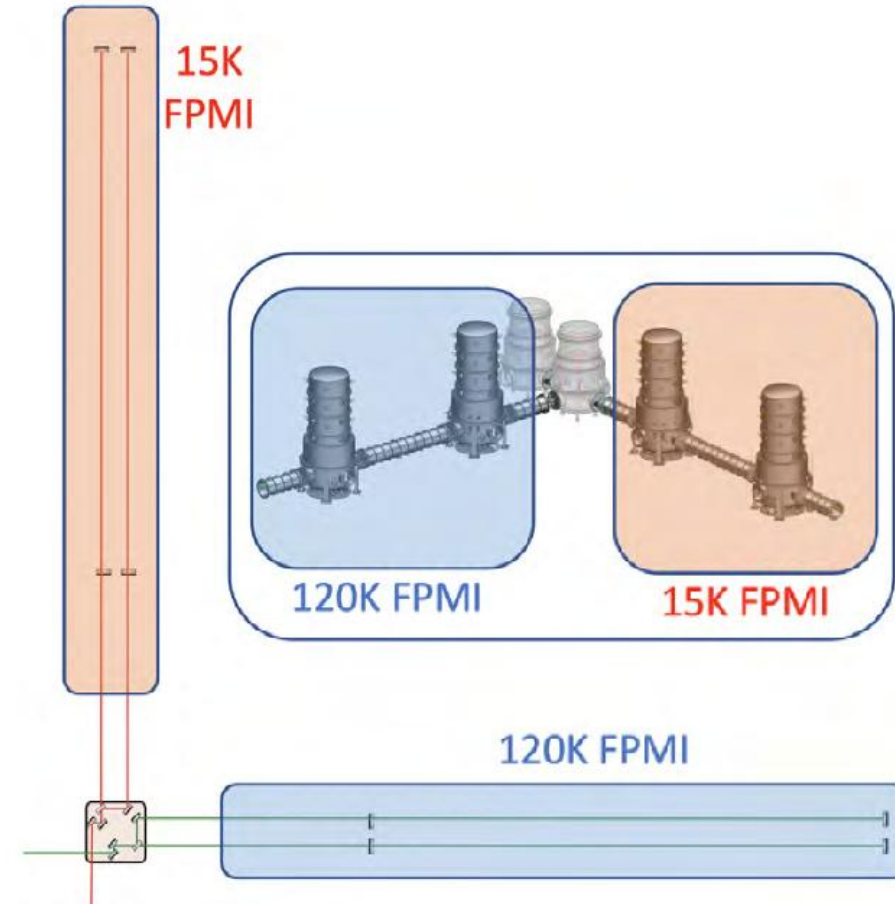


ET-Pathfinder Workshop @ Maastricht

23-24/03/2026

Facility for testing and validating new ET technology in a low-noise, full-interferometer setup at 10^{-18}m level such as :

- Infrastructure :
 - Cleanroom
 - in-situ bake-out
 - 3 vacuum systems (UHV, roughing & differential)
- Seismic Isolation :
 - Triple suspensions for optics on Beamsplitter bench
 - Inverted Pendulum
- Cryogenics Payload
 - Cooldown via closed helium loop
 - Low-vibration sorption coolers in science mode
 - Subcooled LN2 as backend
 - Four pairs of heatshields(250K, 80K, 40K, 15K)
- Silicon Mirrors





ETpathfinder timeline



Construction started early 2020



Autumn 2020



Summer 2021



Autumn 2021



Summer 2022



Now ...

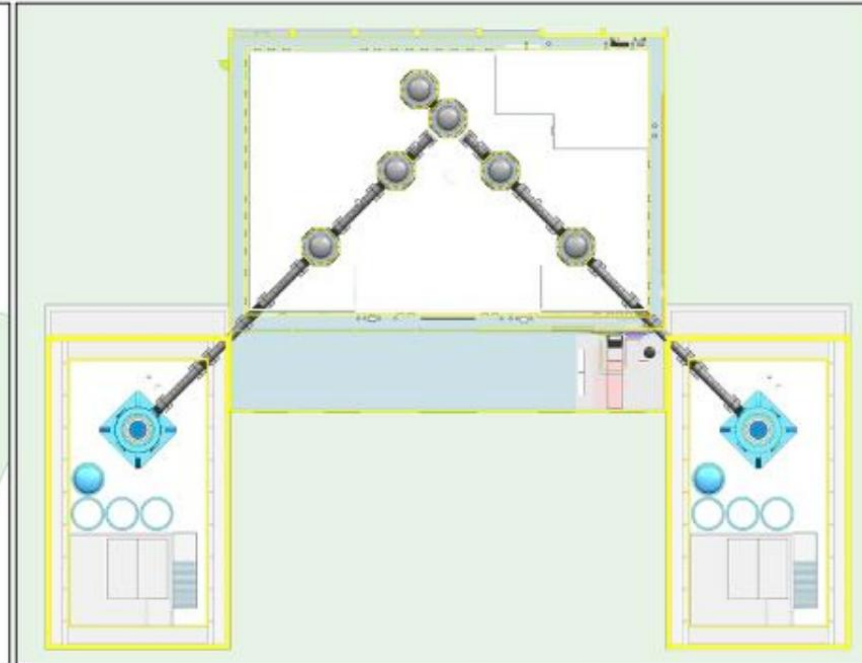
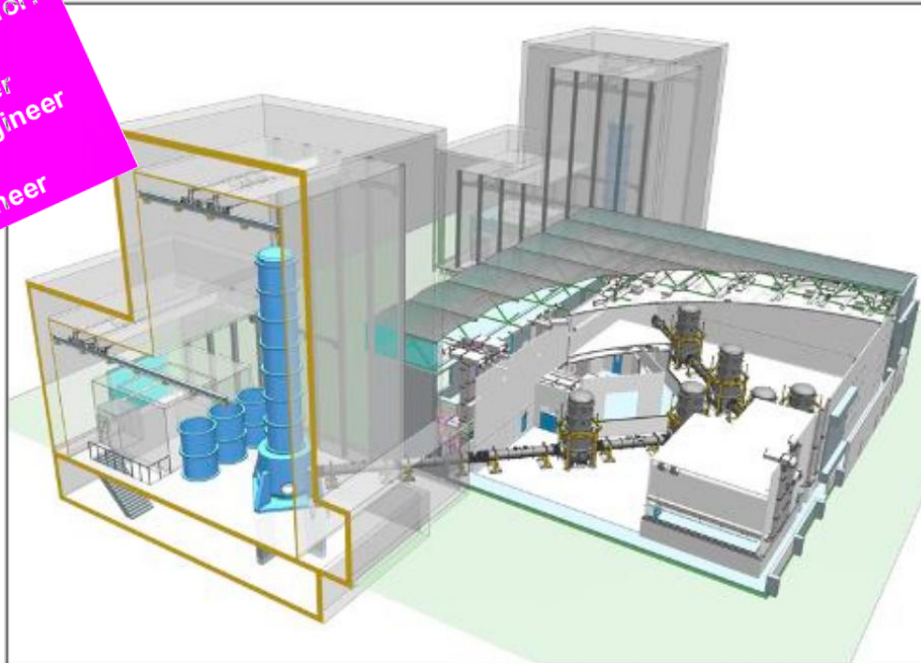




How could an ET-LFC look like?

Preparing right now job adverts for:

- Senior systems engineer
- Mechanical design engineer
- Cryogenics + vacuum engineer
- Electrical engineer
- Quality assurance engineer

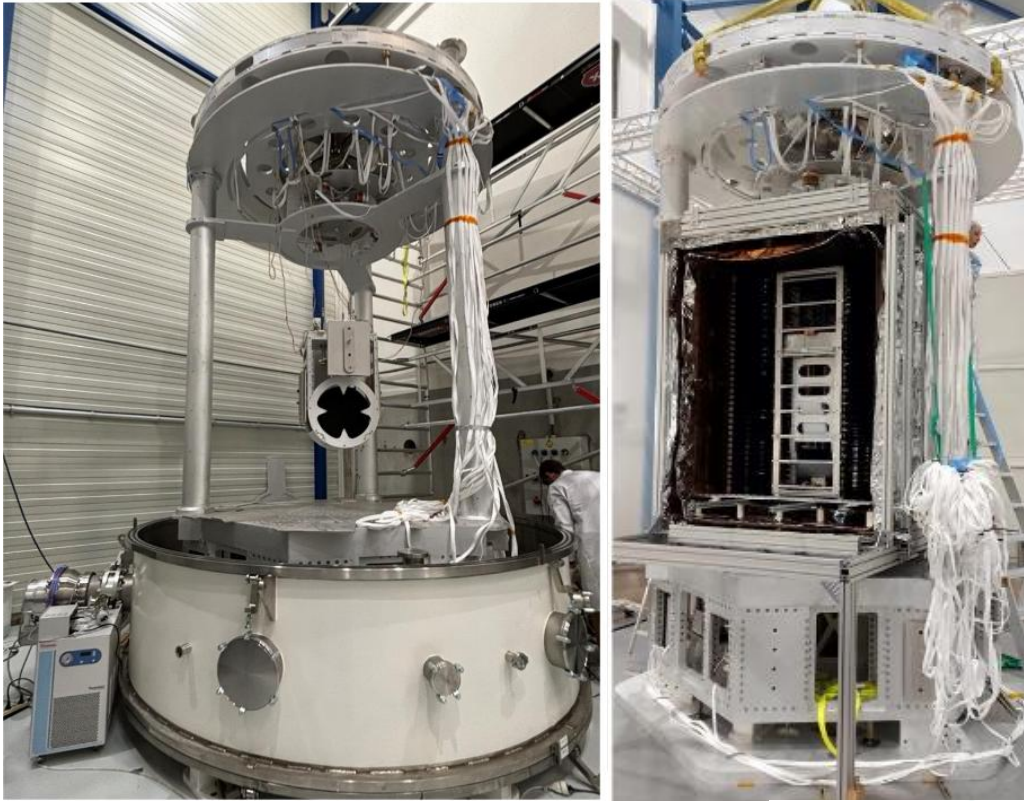


Note: The ET-LF tower design is not frozen. So this is a Gedanken-Experiment to give an idea of what such an ET-LF integration center could look like.
 Rough costs would = 51MEuro capital + 2 Meuro per year operational cost (mainly for a central team of 15 Engineers/Technicians)
 19ME tower buildings, 12ME cleanrooms, 10ME vacuum, 10ME scientific instrumentation.



Thanks for your attention

E-Test @ Liège



ET-Pathfinder @ Maastricht

