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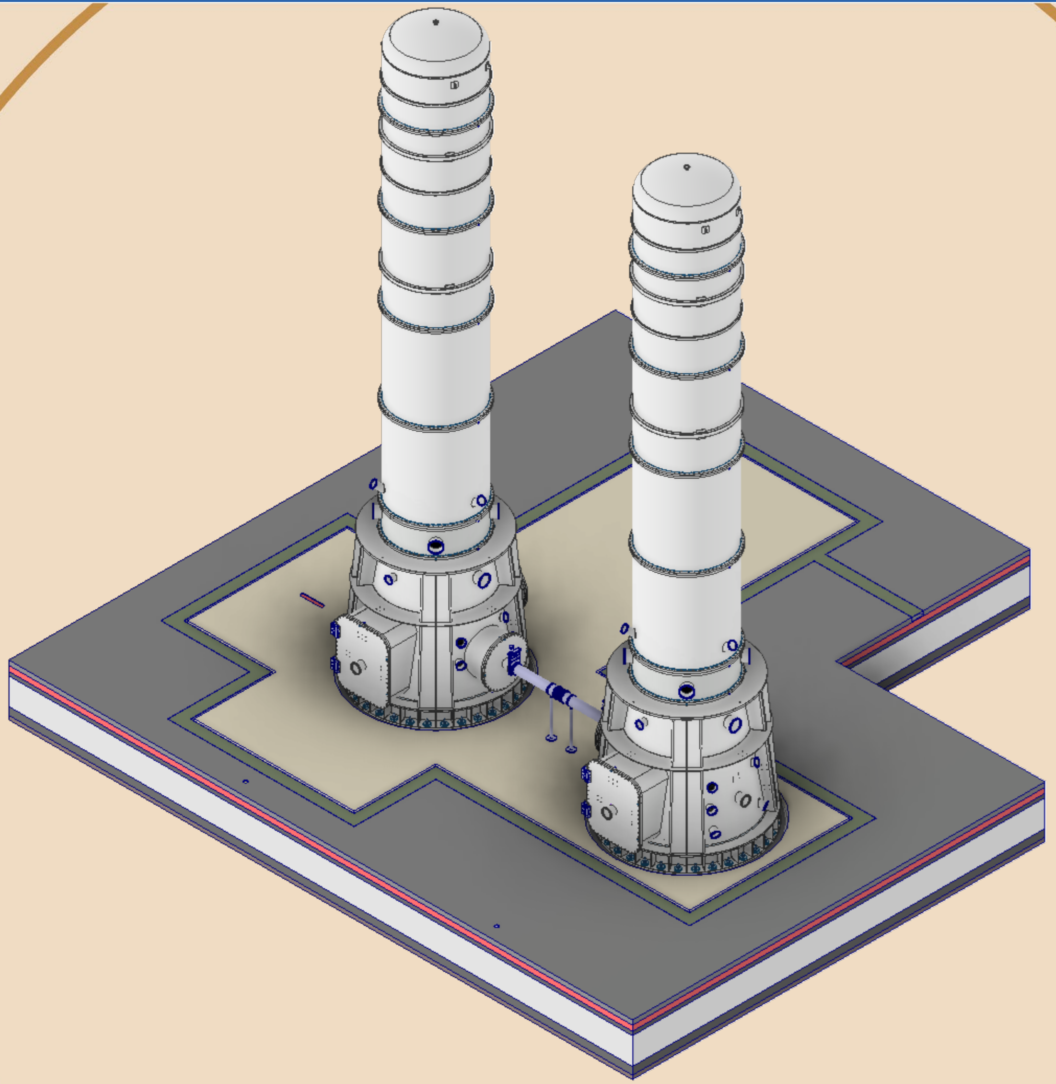
Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

CAOS: *Vacuum Towers*



Francesco Bianchi (INFN-PG);
Gabriele Capoccia (INFN-PG);
Piero Chessa (UniPG);
Franco Frasconi (INFN-PI);
Aniello Grado (UniPG);
Ettore Majorana (INFN-RM1);
Antonio Pasqualetti (EGO);
Helios Vocca (UniPG);

XV Einstein Telescope Symposium - *26-30.05.2025, Bologna*
PNRR ETIC IR0000004, "EINSTEIN TELESCOPE INFRASTRUCTURE CONSORTIUM", CUP I53C21000420006,M 4, C 2, I 3.1

CAOS: Overview

CAOS is the main ETIC infrastructure, and it is under realization in Perugia, near the Engineering Department of the University. It serves as a specialized lab for testing mechanical and optical systems for the Einstein Telescope (ET).

CAOS will host:

- A seismic-isolated Fabry-Perot cavity;
- **ET's full-sized towers** – 15 mt height;
- **ET's full-sized Super Attenuators** (SAs) – 13 mt height;

CAOS will be a fertile ground to:

- Test of NEG pumps in a SAs environment;
- Test tech solutions to enhance tower rigidity;
- Refine numerical and FE models on ET full size towers and SAs;
- Explore the potentiality of the lateral entrance for the PAY;
- Test Low Noise control systems;
- Testing of innovative elastomer seals;
- ....

Please look at *Francesco Bianchi's* talk for more details [ET-0253A-25].

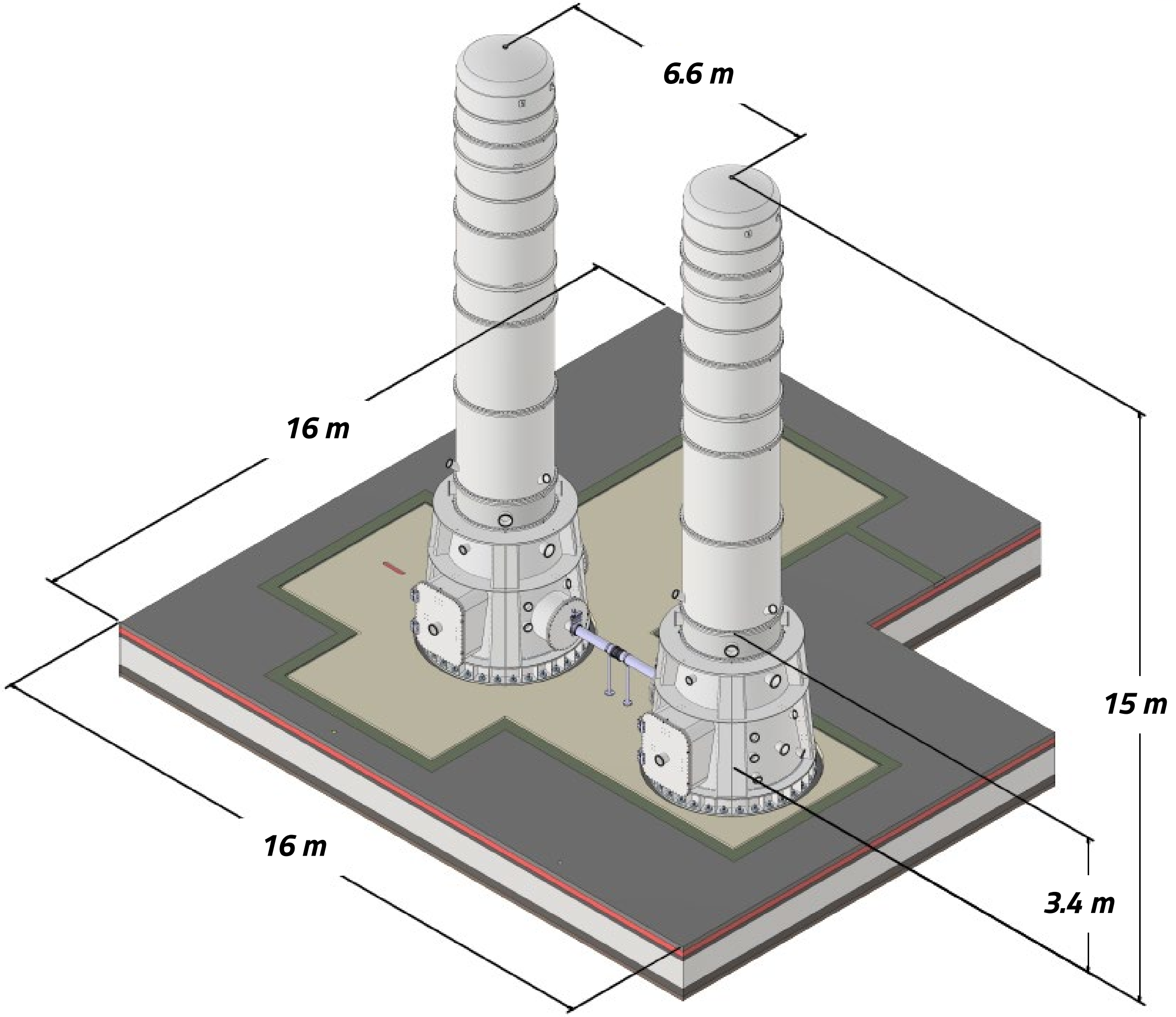
CAOS: Vacuum Towers

Overview

CAOS vacuum system consists of two towers but in the future the system will be upgraded to three towers to host a Michelson interferometer.

The macroscopic features of the towers are reported below:

Feature	Description
Height	15 m
Tower Spacing	6,6 m
Material	AISI 304 L
Operational Pressure	$\leq 10^{-7}$ mbar
SA and PAY separation	No - Implementable



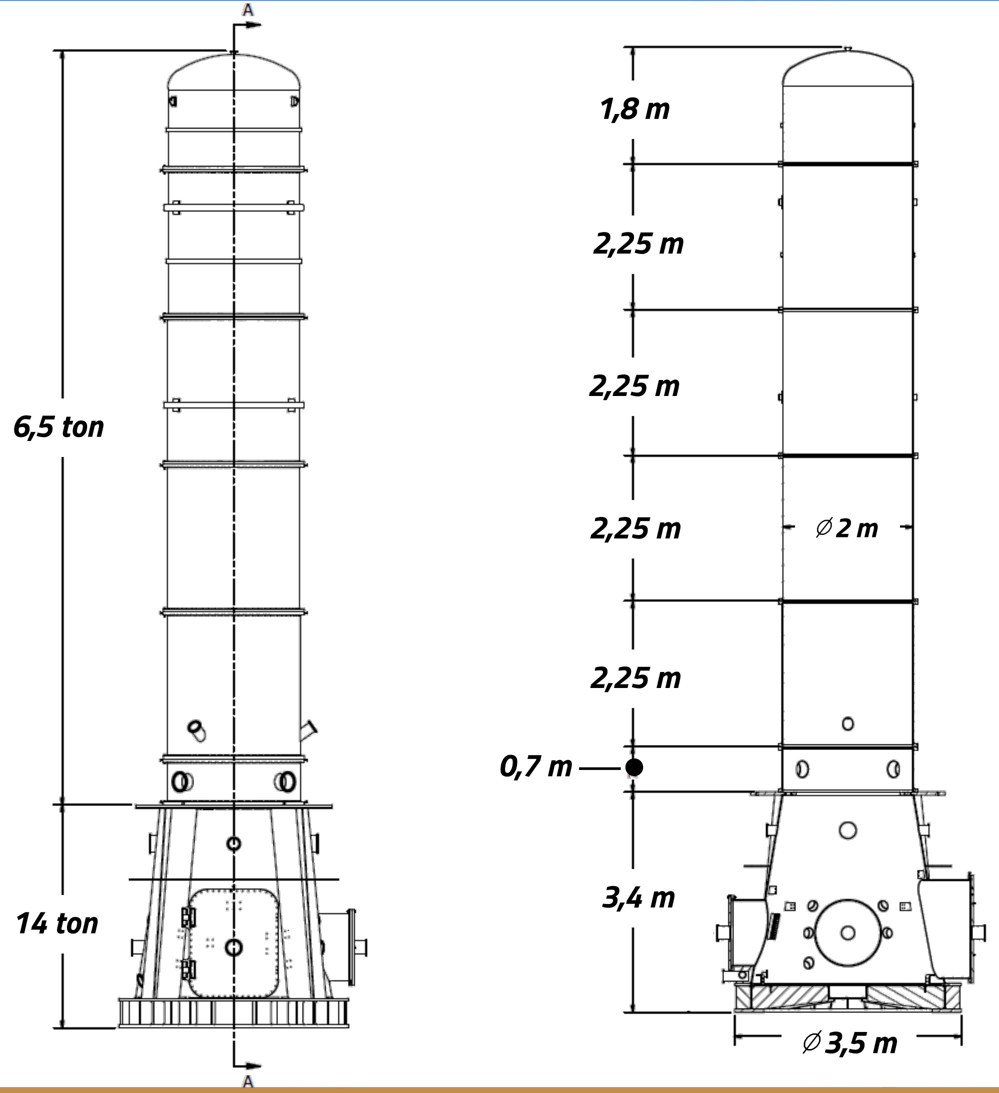
CAOS: Vacuum Towers

Overview

CAOS vacuum system consists of two towers but in the future the system will be upgraded to three towers to host a Michelson interferometer.

The macroscopic features of the towers are reported below:

Feature	Description
Height	15 m
Tower Spacing	6,6 m
Tower Weight	~20 ton each
Base Weight	~14 ton each
# Main Ferrule	4
Main Ferrule Height	2,25 m
Entrance	Lateral – 1,2 m x 1,5 m
Base Geometry	Truncated cone



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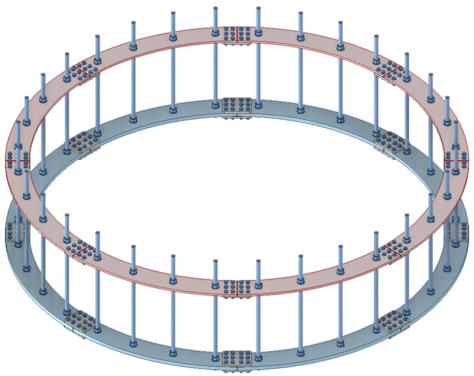
CAOS: Vacuum Towers

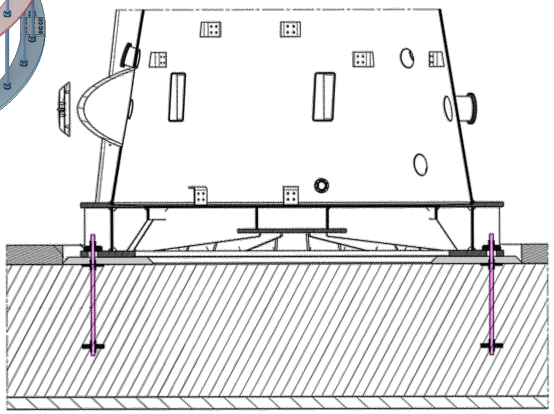
FEM Simulations

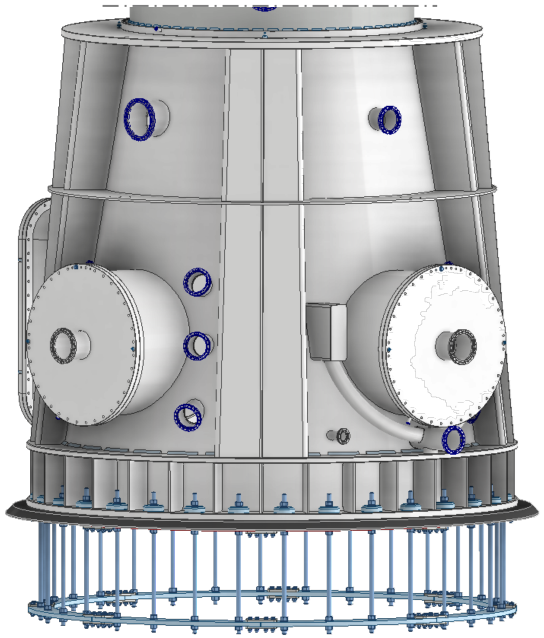
The tower studies began one year ago and much research and development work has been done making extensive use of Finite Element (FE) techniques.
The goal that guided the design was to *increase the stiffness* of the towers to raise the resonance frequency of the first natural mode.

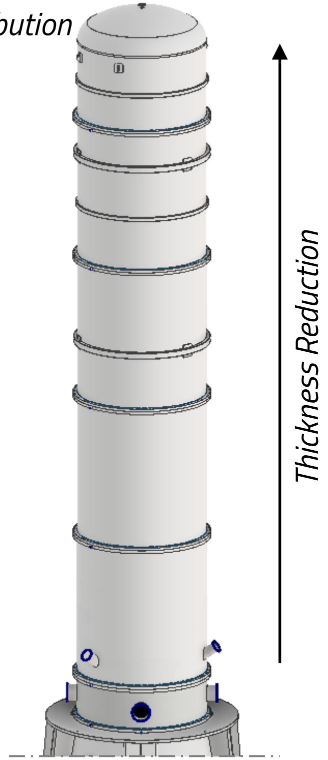
Intervention Areas: *Anchoring System* *Base Geometry* *Optimized Mass Distribution*



CAOS Foundations Concrete







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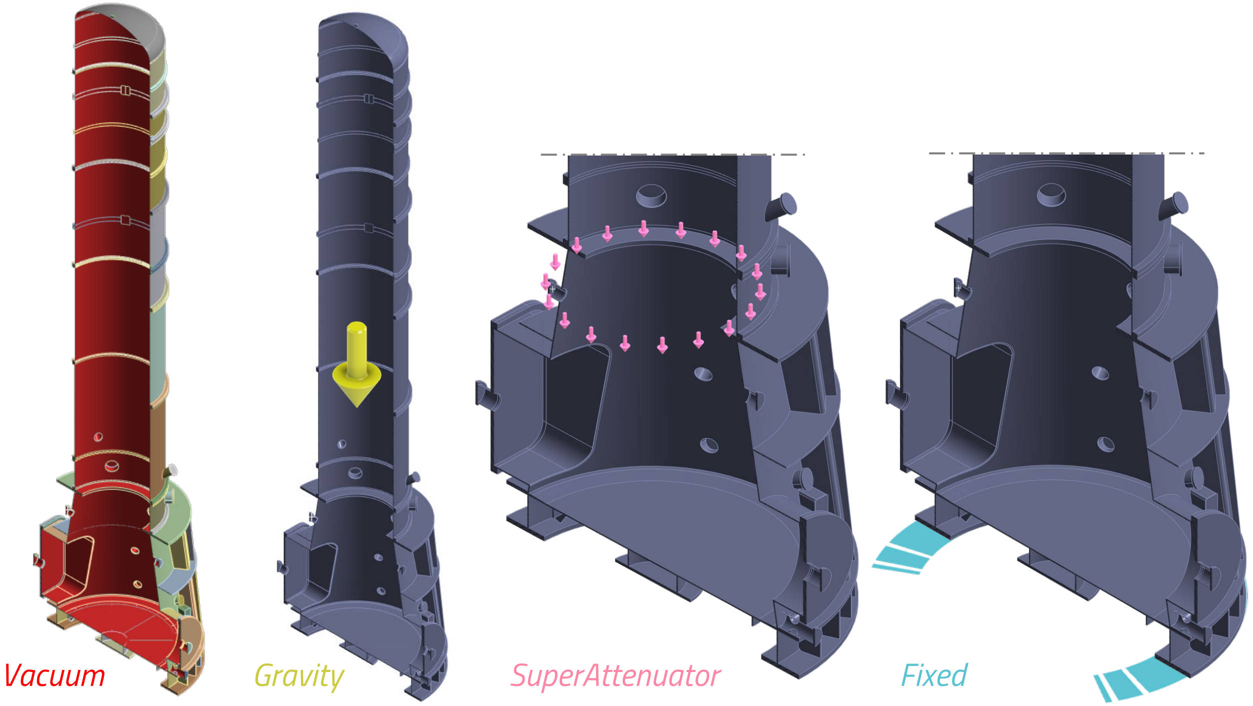
CAOS: Vacuum Towers

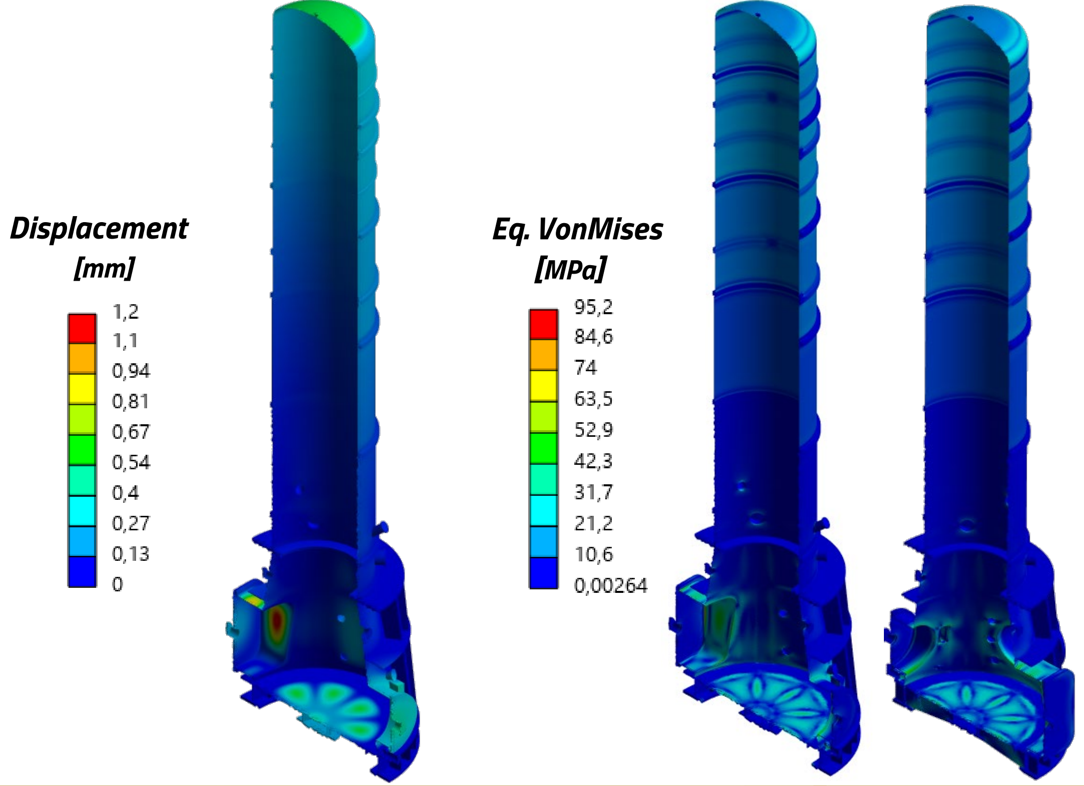
FEM Simulations – Static Structural Analysis

The tower studies began one year ago and much research and development work has been done making extensive use of Finite Element (FE) techniques. The goal that guided the design was to <u>*increase the stiffness*</u> of the towers to raise the resonance frequency of the first natural mode.

Boundary Conditions:



Output:



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CAOS: Vacuum Towers

FEM Simulations – Modal Analysis

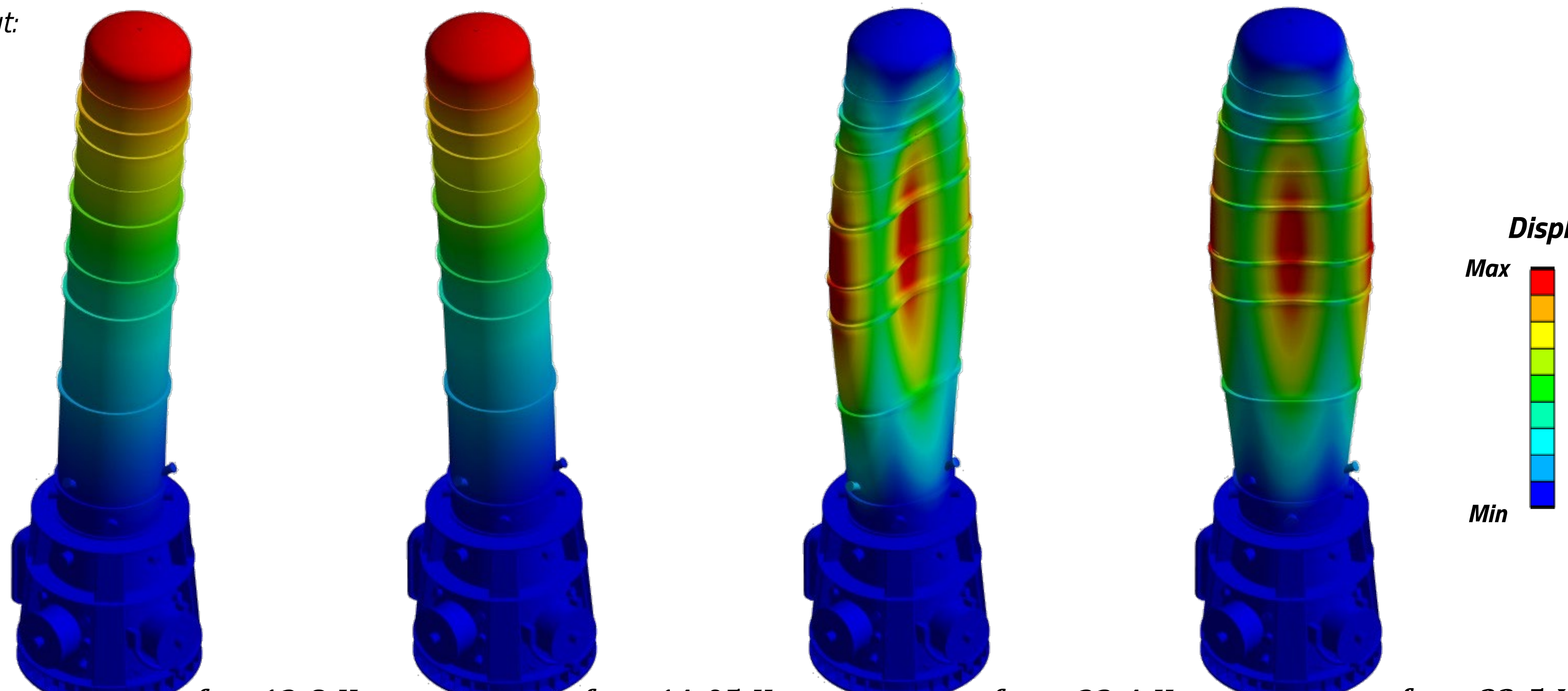
The tower studies began one year ago and much research and development work has been done making extensive use of Finite Element (FE) techniques.
The goal that guided the design was to *increase the stiffness* of the towers to raise the resonance frequency of the first natural mode.

Input:

A *pre-stressed* modal analysis has been done:

$$\left([K+S]-\omega_i^2[M]\right)\{\varphi\}_i=\{0\}$$

Output:



$f_I = 13,8\ Hz$ $f_{II} = 14,05\ Hz$ $f_{III} = 32,4\ Hz$ $f_{IV} = 32,5\ Hz$

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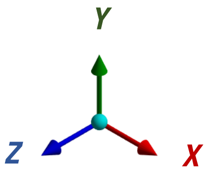
CAOS: Vacuum Towers

FEM Simulations – Harmonic Response Analysis

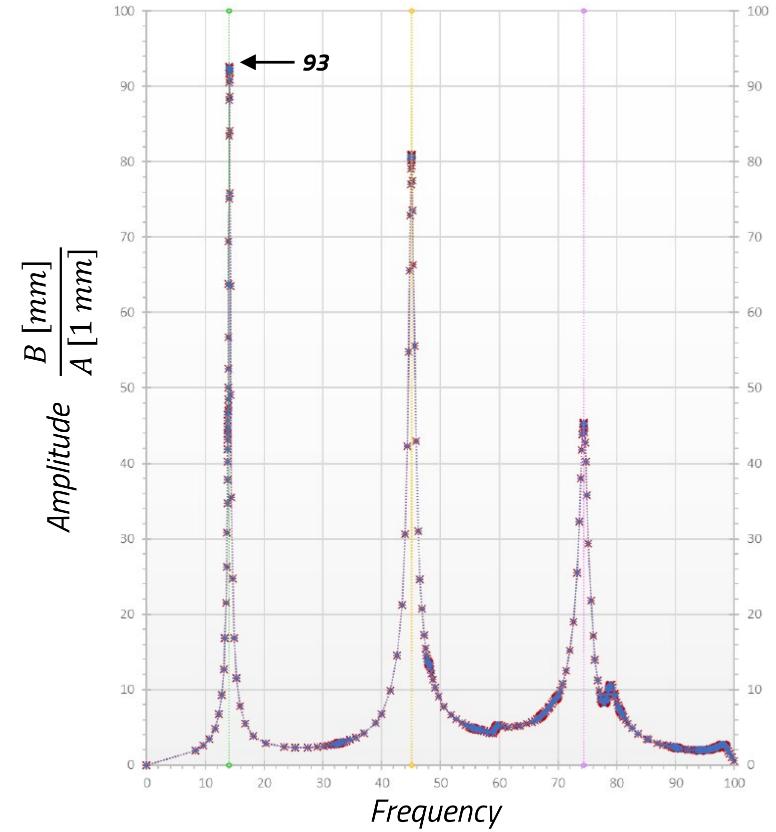
Optimization of masses and geometries was carried out taking into account the effects on the transfer function evaluated between the base and the top of the tower:

Input:

Displ. [mm]	Direction	Frequency [Hz]	Structural Damping
1 mm	X	[0,001 → 100]	0,02
1 mm	Z	[0,001 → 100]	0,02



Output:

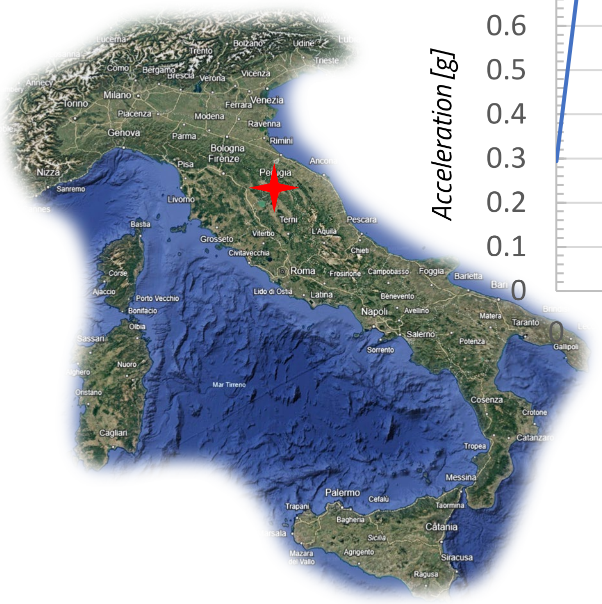


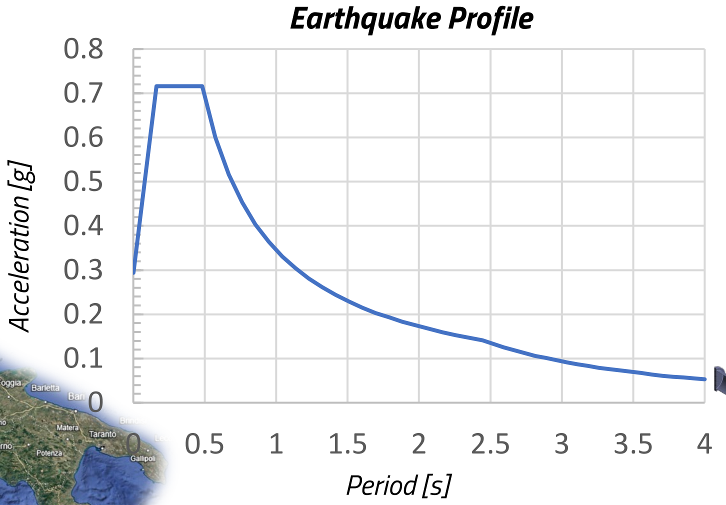
CAOS: Vacuum Towers

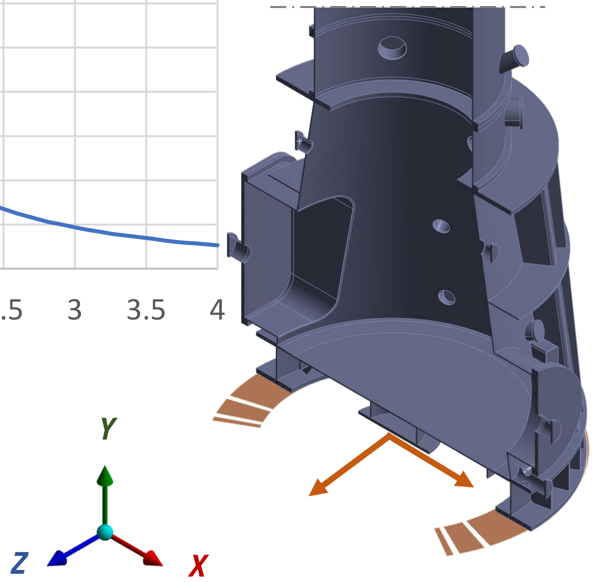
FEM Simulations – Response Spectrum & Buckling Analysis

Optimization of masses and geometries was done by stressing the structure with a possible earthquake and checking the instability of the ferrules:

Response Spectrum Analysis





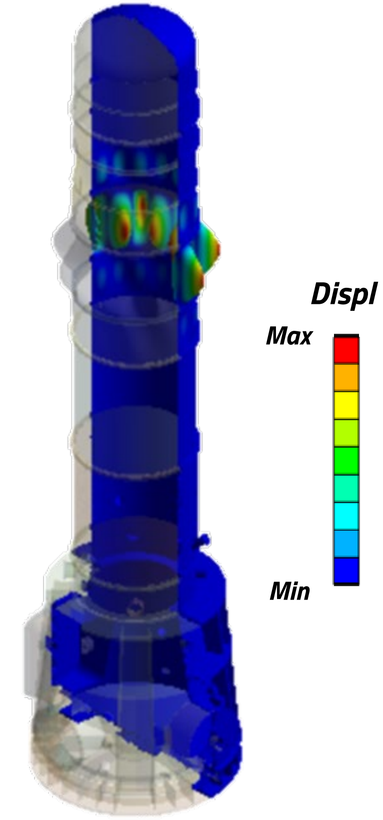


Buckling Analysis

$$\overrightarrow{\Delta F} \approx 0 \text{ leads to:}$$

$$\overrightarrow{\Delta u} \to \infty \text{ and } [K] \approx 0$$

$$\left[[K] + \alpha[K(\vec{\sigma})]\right]\overrightarrow{\Delta u} = 0$$



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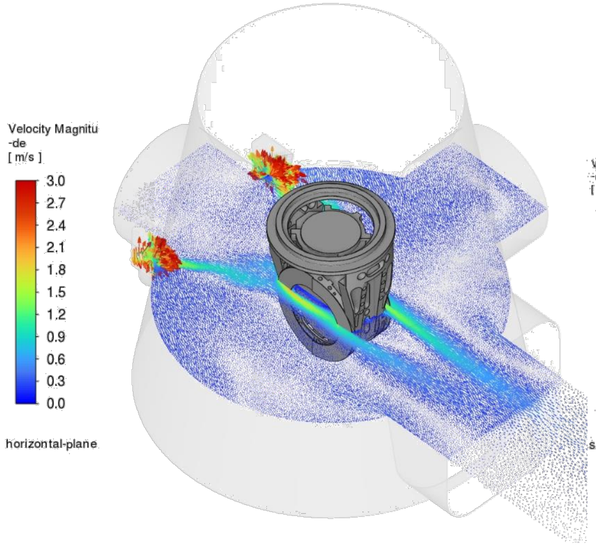
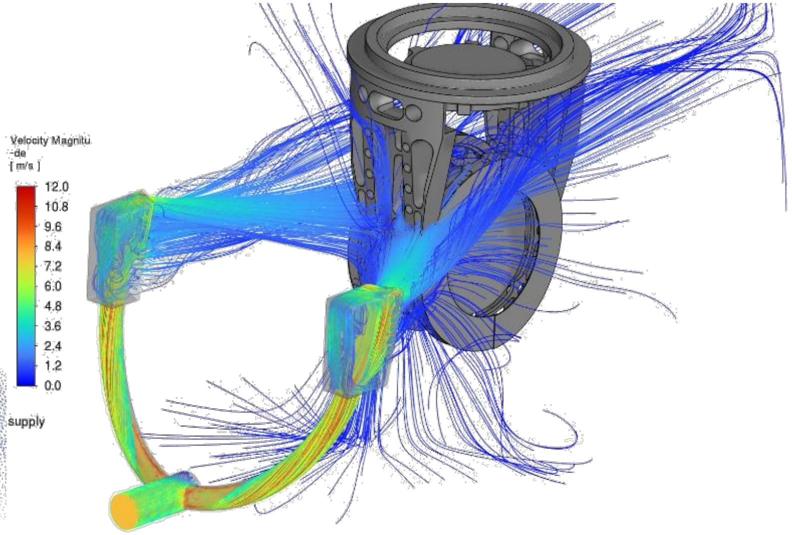
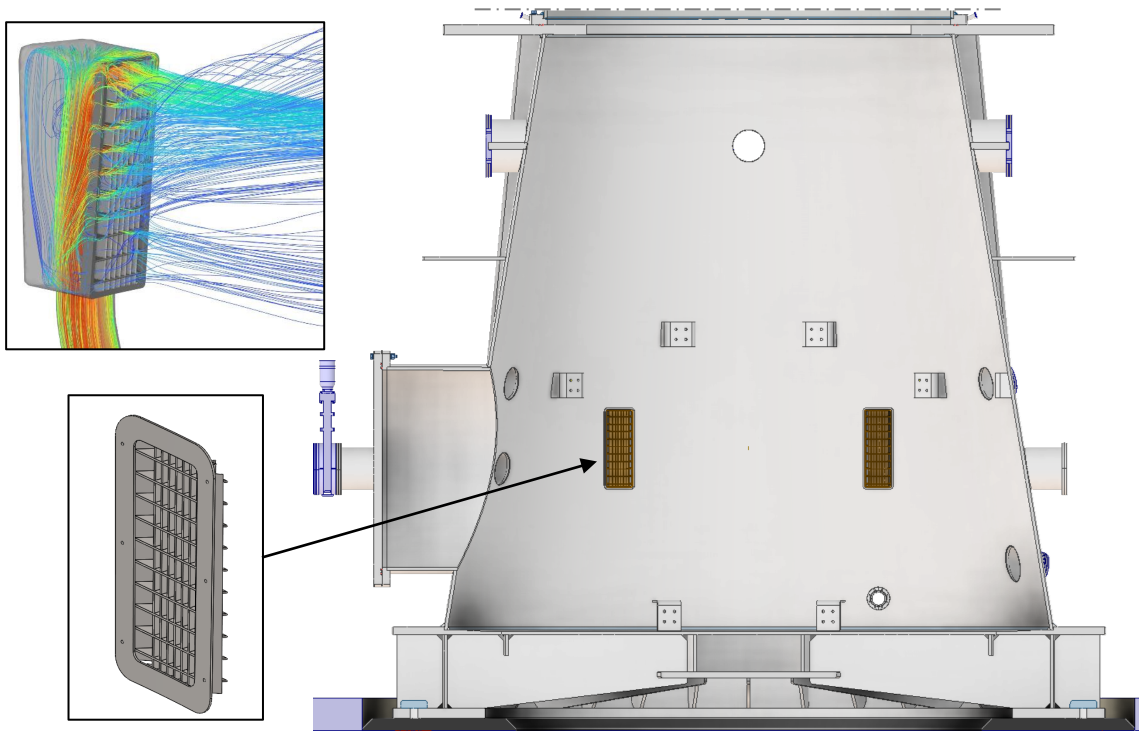
CAOS: Vacuum Towers

CFD Simulations

A lot of work has been done taking advantage of CFD simulations to develop an aeration system that provides an air blade around the mirror to limit the deposition of contaminants during open tower work.





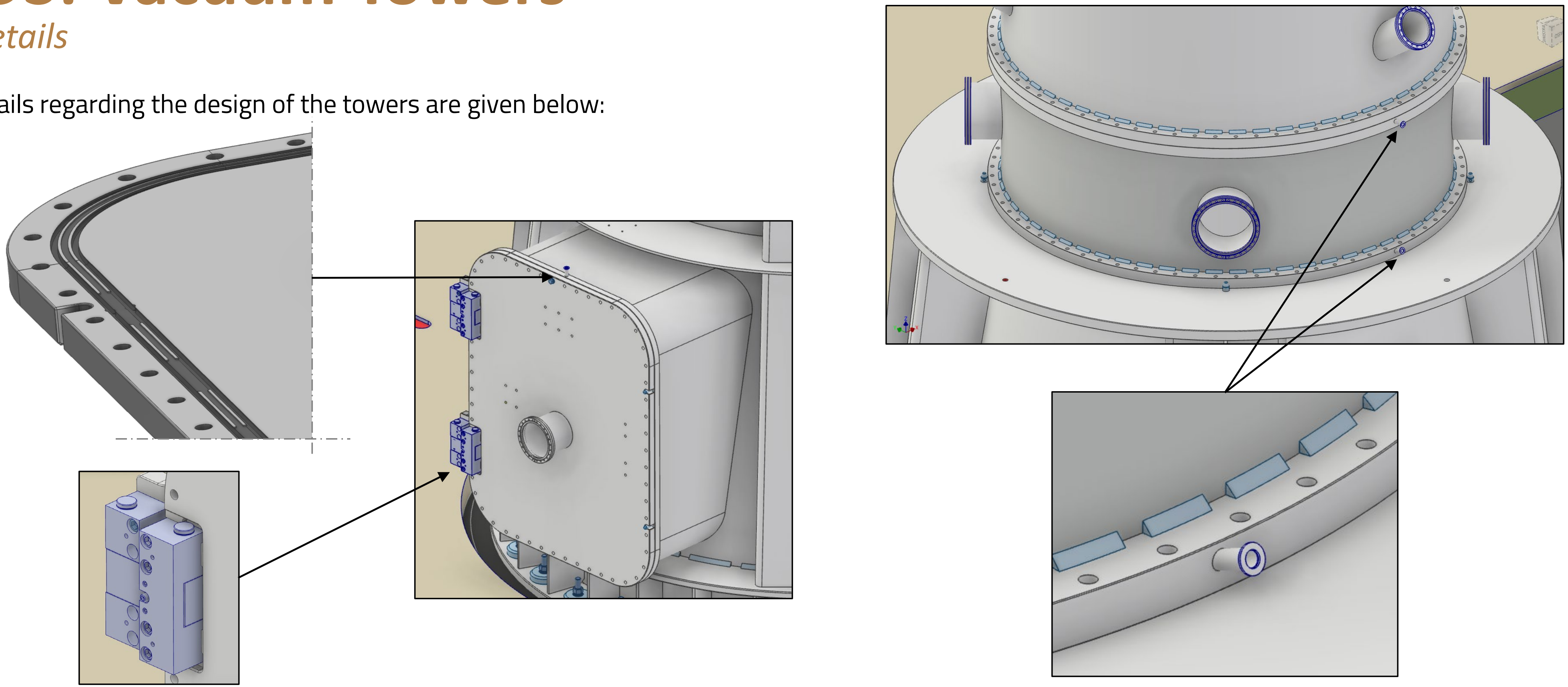


Please look at *<u>Francesco Bianchi's</u>* talk [ET-0632A-24] for more details.

CAOS: Vacuum Towers

CAD Details

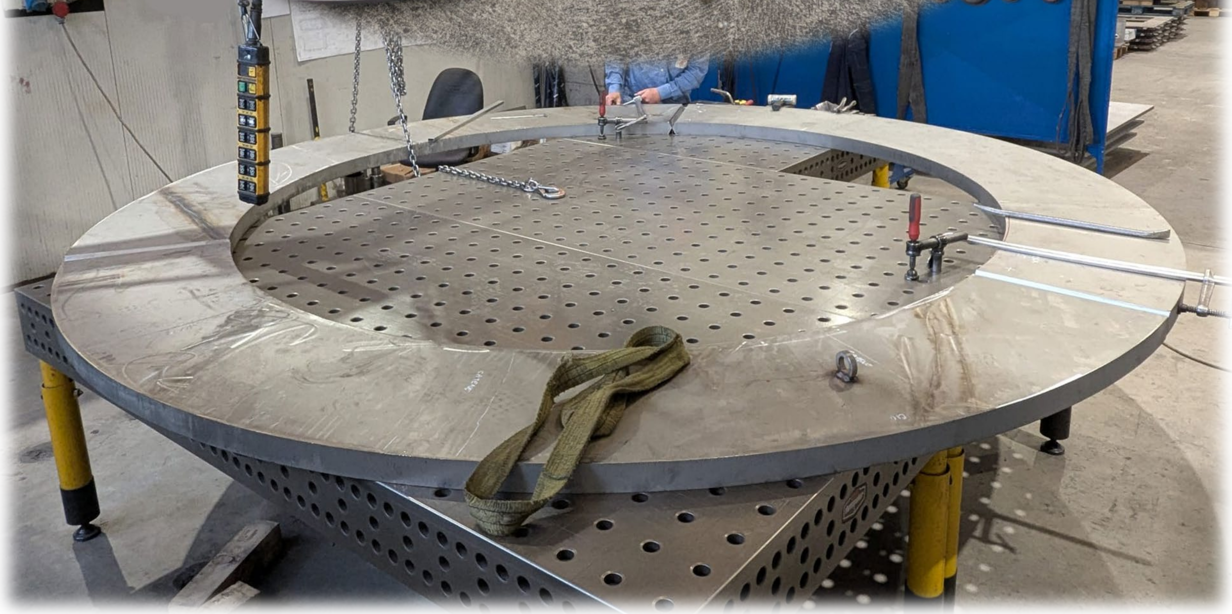
Other details regarding the design of the towers are given below:



CAOS: Vacuum Towers

Status

In the following there are some photos showing the progress of the construction work:



CAOS: Vacuum Towers

Conclusion

- A lot of design and optimization work has been done making extensive use of Finite Element (FE) techniques and Computational Fluid Dynamics (CFD);
- Many efforts are being made to optimize the production technology process;
- The towers are currently in production;
- By the end of the year they will be assembled in CAOS;

CAOS: Vacuum Towers

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- The towers are currently in production;
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Thank You!