Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INFN

Modal Analysis of a new Possible ET base Tower Lay Out in CAOS

F. Bianchi[1], A. Buggiani[2], G. Capoccia[1], F. Frasconi[3], A. Grado[4,5], A. Pasqualetti[2], H. Vocca[1,6], T. Zelenova[2]

1: INFN-Perugia, 2: European Gravitational Observatory, 3: INFN–Pisa, 4: INAF-Capodimonte Astronomical Observatory, 5: INFN-Napoli, 6: University of Perugia

1 Abstract

The mechanical transfer function of the ET towers basement plays a crucial role on the response of the Super-Attenuator (SA), on the stability of the ET suspensions and in general on the low frequency performance of ET. For this reason, it is of pivotal importance to investigate the behavior of the ET tower basement system with a Finite Element modelling technique. Emphasis has been placed on the tower basement, investigating a new conical design. A new test facility, CAOS, is under realization in Perugia within the PNRR-ETIC framework, aiming to test mechanical solutions for ET. Two new towers will be realized shortly and will be a useful tool to provide feedback on: mechanical performance, construction and economic aspects, functionality of all details and real-scale operational experience with vacuum and payloads.

2 Where

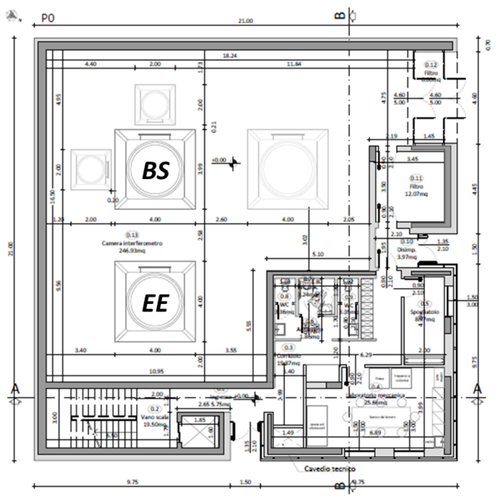
CAOS is the main ETIC infrastructure, and it is under realization in Perugia, near the Engineering Department of the University.
It will be an international and unique facility useful to develop new filtering seismic technology and low noise controls working on **ET full size vacuum towers and Super Attenuators (SAs).**

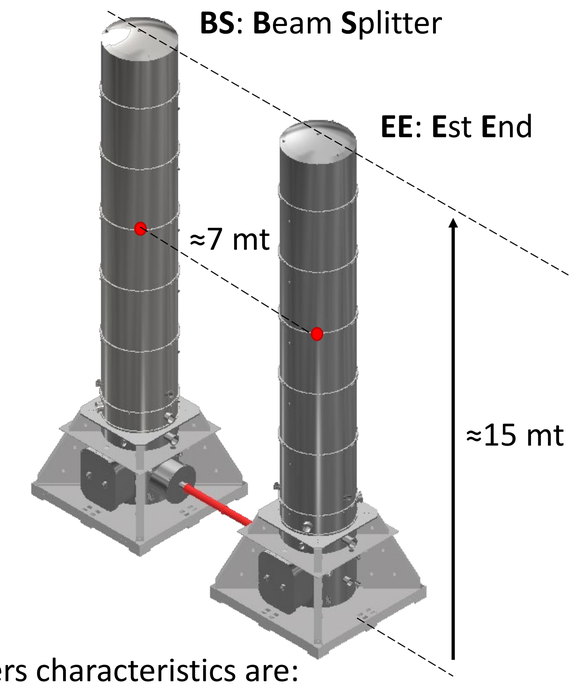
Some dimensions of the laboratory:

- Plant surface: 441 m^2;
- External height: 23 m;
- Internal height: 21 m;

3 What

The CAOS vacuum system consists of two towers to host a Fabry-Perot cavity suspended to an ET full size Super Attenuator.
In the future the system will be upgraded to three towers to host a Michelson interferometer;





The towers characteristics are:

- ≈ 15 m tall;
- ≈ 25 tons weight each;
- Lateral access;
- Distance between central axes: ≈7 m;

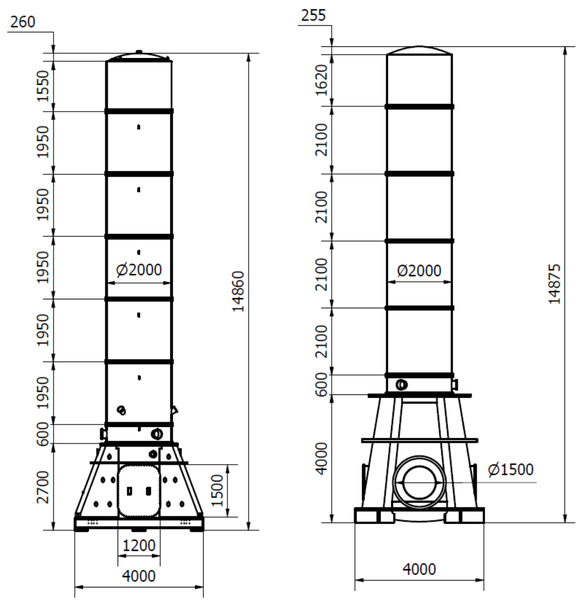
4 Why

The towers host the SA but have the capability to serve as an independent test bench:

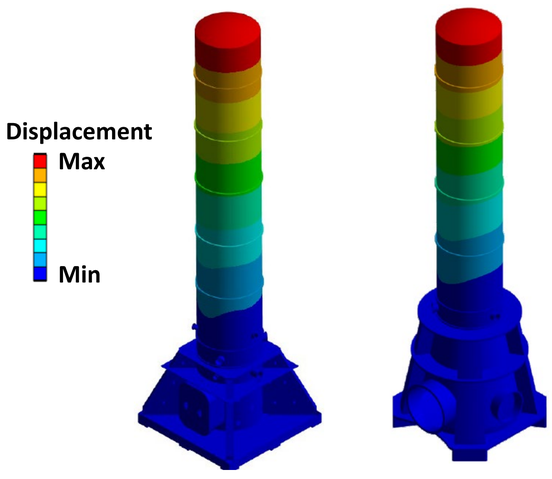
- Test lateral access;
- Possibility to evaluate robotic payload installation and manipulation;
- Test of NEG pumps in a SA environment (other type of tests are on going @EGO);
- Assessment of methods to enhance tower rigidity;
- Possibility to refine numerical and FE models on ET full size towers and SAs;

5 How

Two different tower designs are under study. A possible solution is based on the Virgo towers design and then modified to reach 15 mt in height. The second one has a different conical basement designed to improve the stiffness of the tower. The conical basement has the same footprint as the cylindrical one (4m x 4m) but is higher (4m vs 2,7m). Another big difference is the shape of the lateral entrance. In the Virgo-like tower, a rectangular entrance has been supposed instead of a circular entrance designed in the conical one. Note that the size of the lateral entrance depends on the payload dimension.



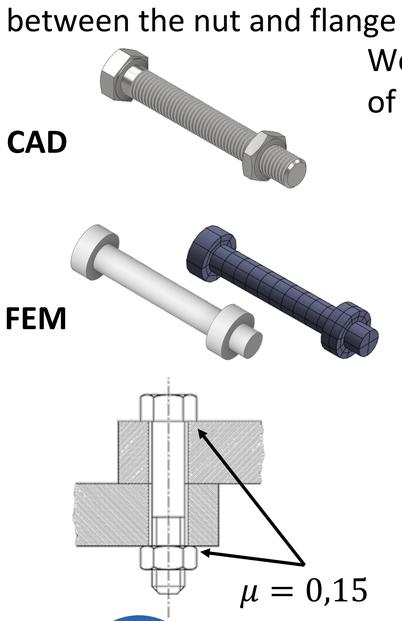
Working with the Finite Element modeling technique it is possible to perform different analyses quickly. Static and Modal Analysis have been performed, using Ansys Mechanical, to evaluate the stiffness of the two possible designs. As found in other works (G. Iaquaniello*) the conical basement provides more stiffness and increases the first natural frequency of resonance. Using *linear* FE models, we can estimate an increase of the first natural frequency of the system of about 30% (12,2 Hz Vs 9,4 Hz).

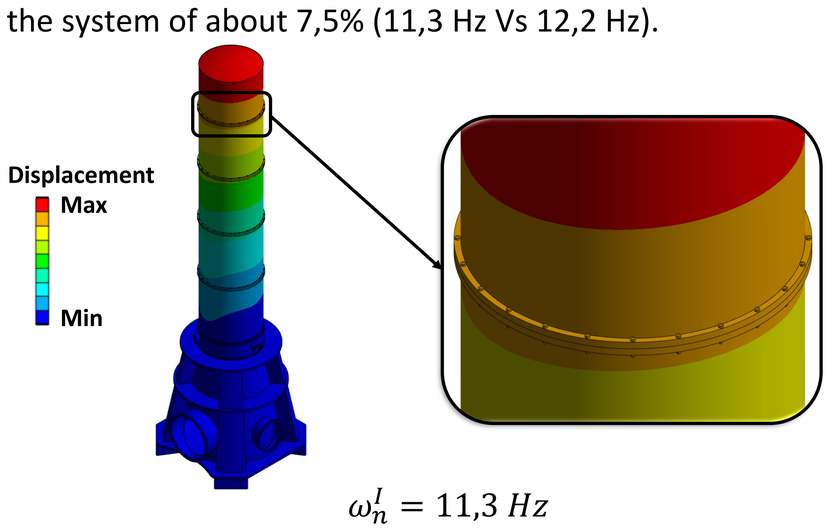


$\omega_n^I = 9{,}4\ Hz$ $\omega_n^I = 12{,}2\ Hz$

The stiffness contribution of the bolted joints between the shell rings ('virole') and any other component in contact with the tower (e.g. safety structure of the SA) is not negligible. 24 x M18 bolted joints equally spaced have been supposed for every flange to implement *non-linear* FE models: $\vec{F}(u) = \underline{K(u)} * \vec{u}$. A nominal pretension force of 85 KN and a friction coefficient of 0,15 between the bolt head and flange and between the nut and flange have been used. The threads have been bonded.

We can estimate a decrease of the first natural frequency of the system of about 7,5% (11,3 Hz Vs 12,2 Hz).





$\omega_n^I = 11{,}3\ Hz$

6 Work in Progress

By the end of July 2024 the design phase will be completed and the technical drawings will be ready to start the production.
By the end of August 2025 the realization will be ultimate and the towers will be placed in CAOS.

*ET-0376A-23