NGSA

New Generation Super Attenuator

PI: Luciano Di Fiore (INFN-NA)

Durata: 3 anni (2022-2024)

Unità INFN coinvolte:

INFN-NA - A.Bertocco, M.Bruno, R. De Rosa, L. Di Fiore(RN), L. Trozzo (RL)
INFN-PI - F. Frasconi (RL), A. Gennai, L. Lucchesi, L. Orsini, F. Pilo, P. Prosperi, F.R. Spada
INFN-CA/Univ. di Sassari, N. Davari, D. Durso, D. Rozza (RL), V. Sipala

Partecipazione esterna:

European Gravitational Observatory (EGO) (P. Ruggi)

NGSA (New Generation Super-Attenuator)

The project is organized in two parallel research lines:

1) *<u>Traditional solution:</u>* optimized SA, starting form the AdV SA architecture:

- ➢ optimization of the mass distribution along the isolation chain
- ➢ improvement of the performance of the Magnetic Anti-Springs (MAS) of the single filters
- the goal is to keep the total SA length around 12 m
- if necessary, an active pre-isolator platforms, at the base of the IP, will be considered

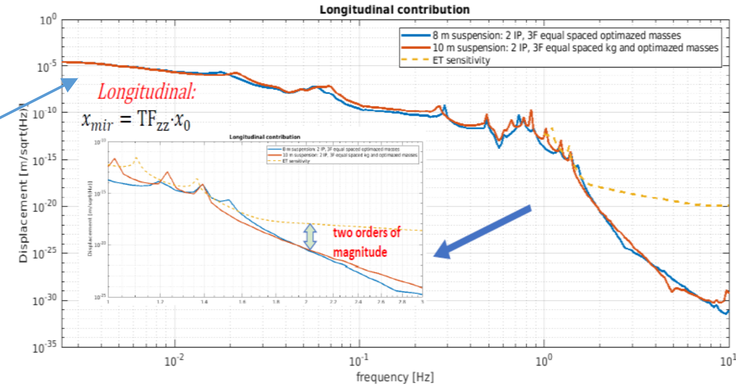
2) *<u>Innovative solution:</u>* two-stage Nested Inverted Pendulum (NIP)

- ➢ Better horizontal attenuation of the pre-isolator but never experimentally demonstrated.
- Open questions to be addressed: reliability, stability, control systems, cross talks and vertical and angular noise suppression.
- ➢ A dedicate prototype (in 1:2 scale) will be realized to experimentally validate this configuration
- Goal is to keep the total SA length around 10 m

Final goal, after comparison of the two alternatives, will be the definition of a Conceptual Design of the SA for the ET Antenna.

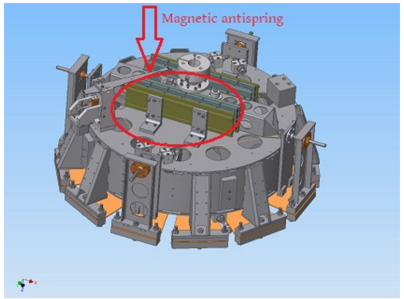
NGSA project Organization : WP

The project is organized in 4 WP:

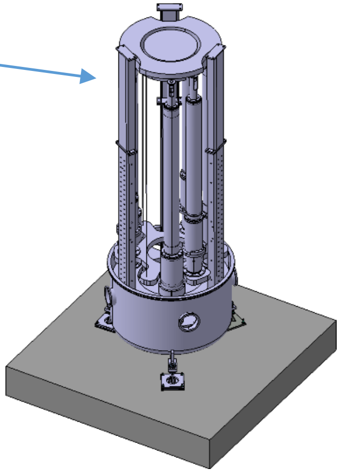


WP1 – Simulation and optimization of the Superattenuator
Coordinator: L. Trozzo (INFN-NA)

WP2 – Mechanical filter with improved Magnetic Anti-Spring (MAS)
Coordinator: F. Frasconi (INFN-PI)



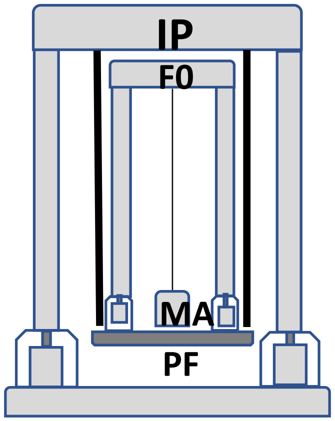
WP3 – Development and test of a Nested Inverted Pendulum (NIP)
Coordinator: R. De Rosa (INFN-NA)



WP4 – Sensing and Control (S&C)
Coordinator: A. Gennai (INFN PI)

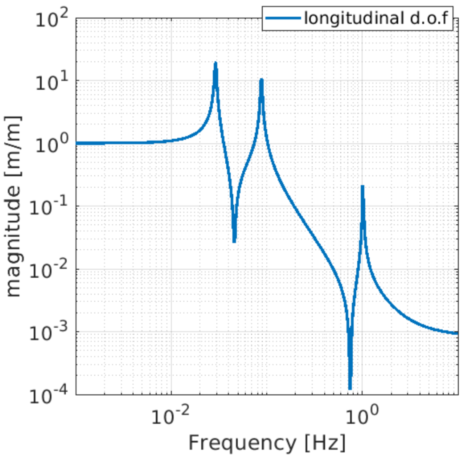
WP1 – Simulation and design of the NIP prototype

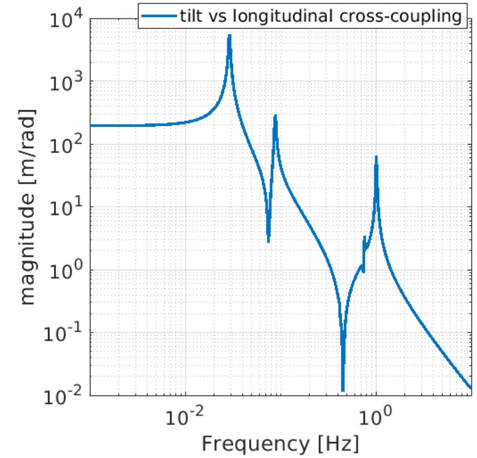
- The simulation tool (Octopus) is based on the impedance matrix formalism and was developed for the Virgo Project.
- Masses, flex-joints, legs, etc. have been defined
- Al the TFs have been computed with Octopus
- This was the starting point for the mechanical design of the prototype
- Simulation tools are crucial to evaluate the effect of mechanical design choices on system performance



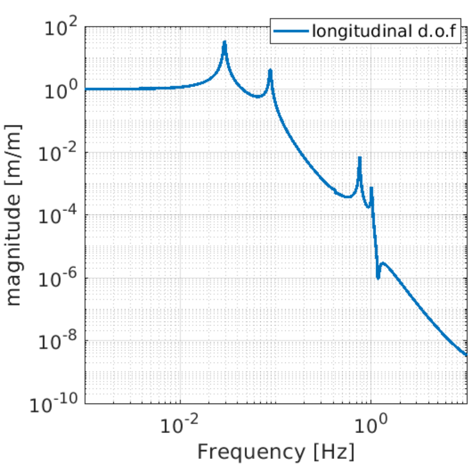
TF examples

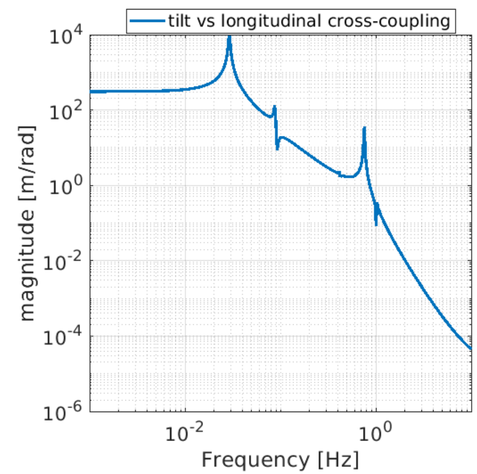
Ground to F0 TFs





Ground to Ma TF





The goal is to built and test a NIP prototype in 1:2 scale, to be tested in the Gravitational Physics Laboratory at INFN-Napoli

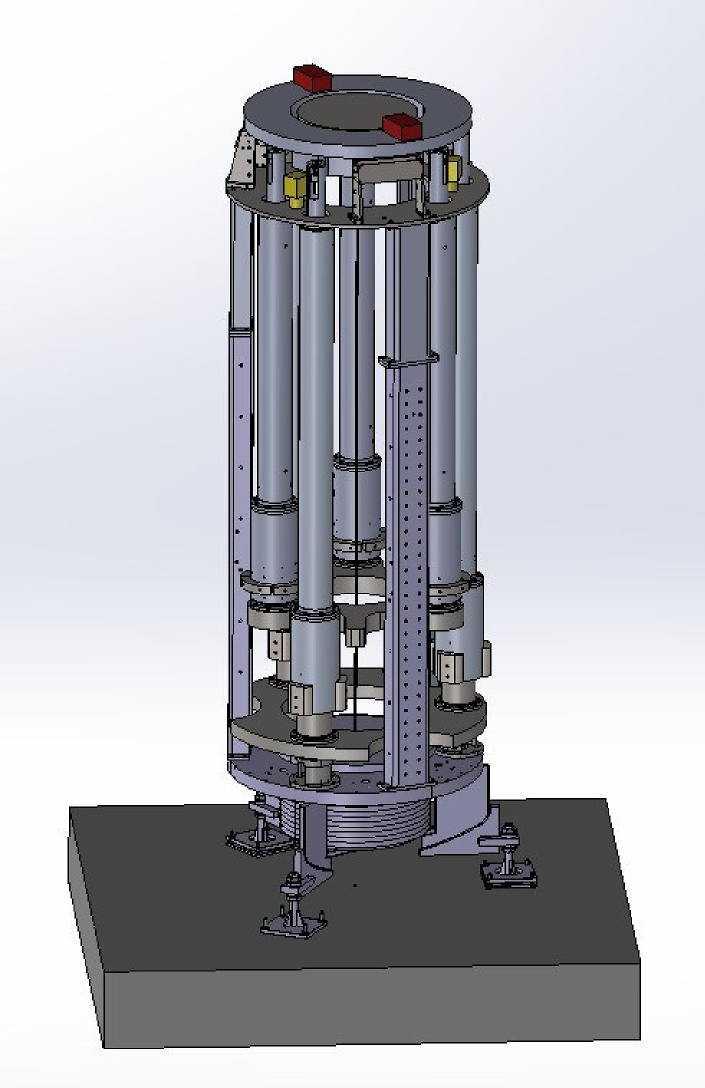
Total mass 1200 kg

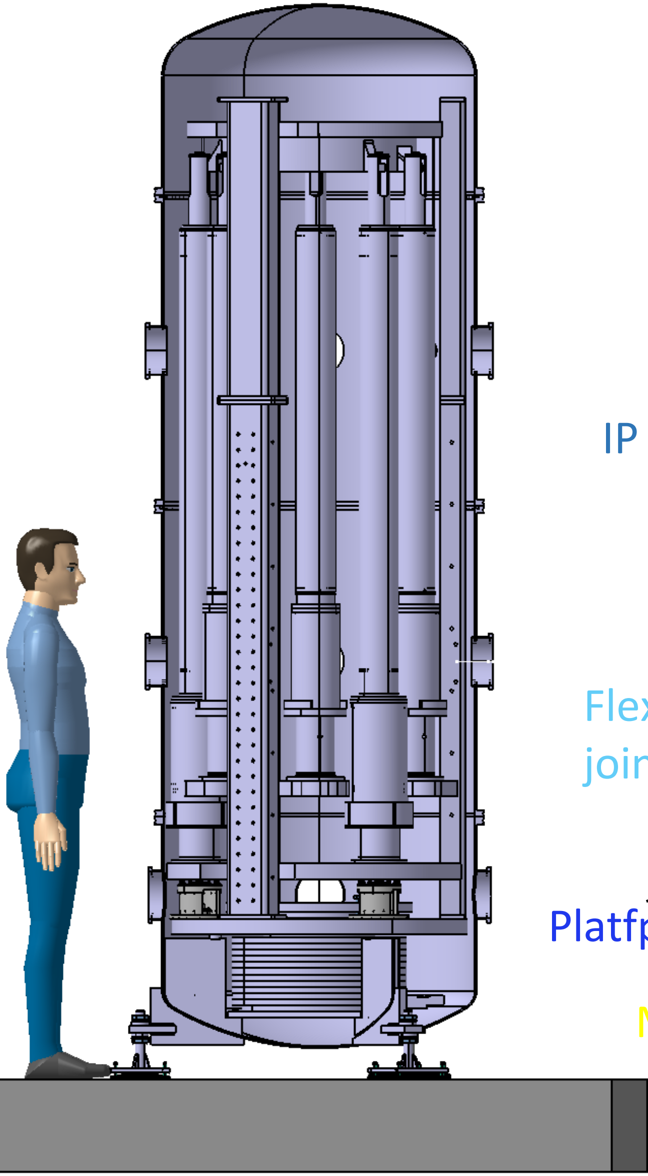
Legs of about 1.7 and 1.4 m (excluding flex joints)

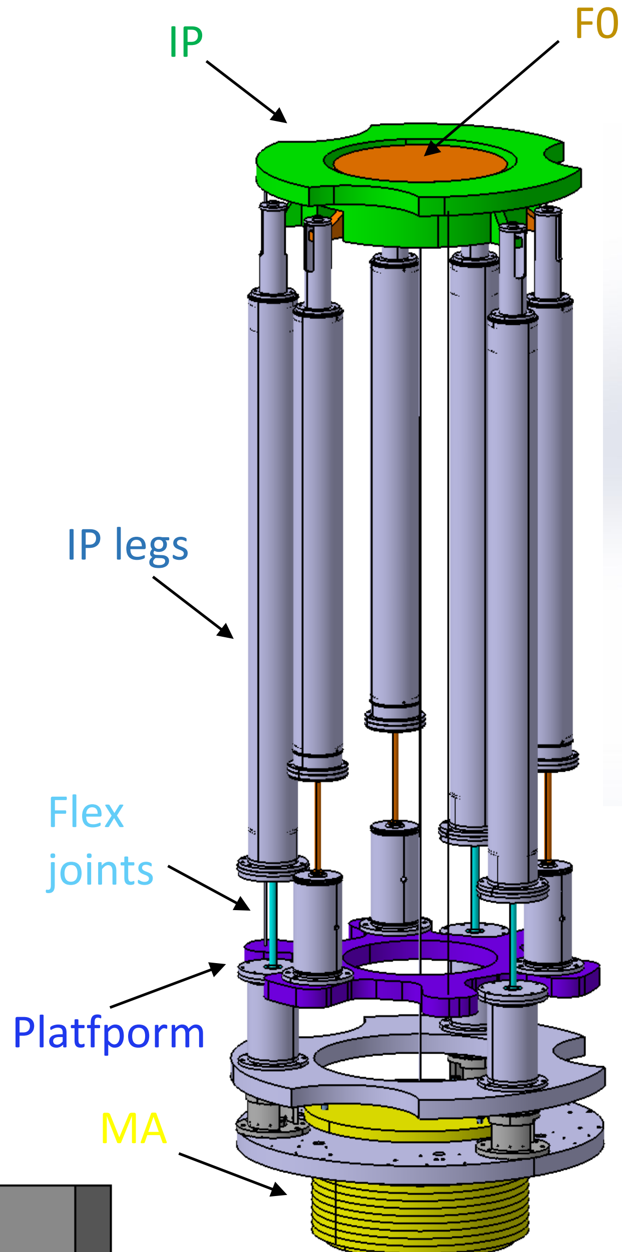
Dummy mass = 600 kg

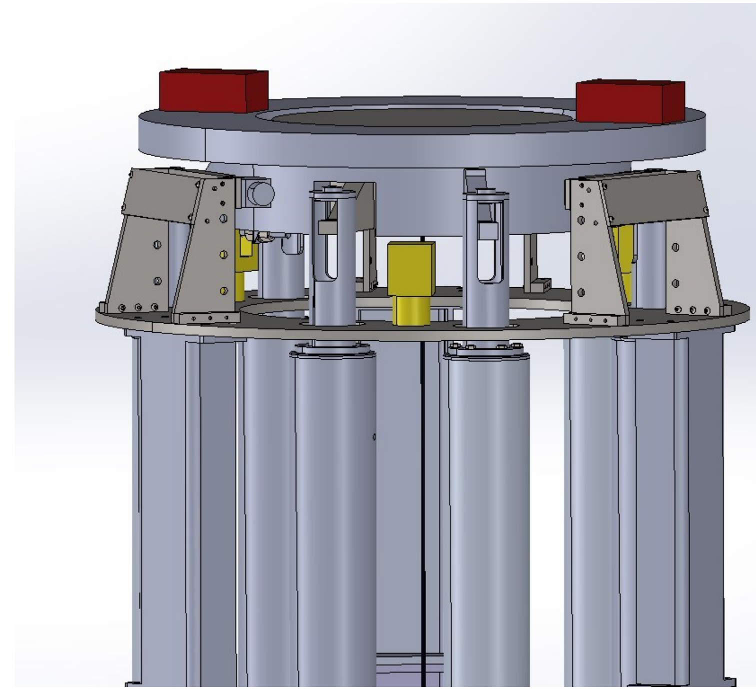
The design is based on preliminary studies with Octopus

The mechanical design is quite advanced
(it is supported by Octopus and FEM simulations)









Presently we are working to the set-up for sensors and actuators (almost done for IP, going on for F0)

WP3 – Development and test of a Nested Inverted Pendulum (NIP)

Present status:

Mechanical design is quite advanced:

- Vacuum chamber base and feet (order placed, construction ongoing)
- Base ring, Flex joints, legs, IP top stage, Platform ,FO, Dummy test mass, safety structure, supports and interfaces for sensors and actuators (ongoing)
- FEM simulation of critical components to check compatibility with system requirements

Orders have been placed for:

- legs, and the first three flex joints (due to maraging steel availability)
- Row materials for Base ring, IP top stage, Platform, FO

To do:

- supports and interfaces for sensors and actuators (ongoing)
- Wire supports and junctions

We plan to complete mechanical design in the coming months.

Next activity

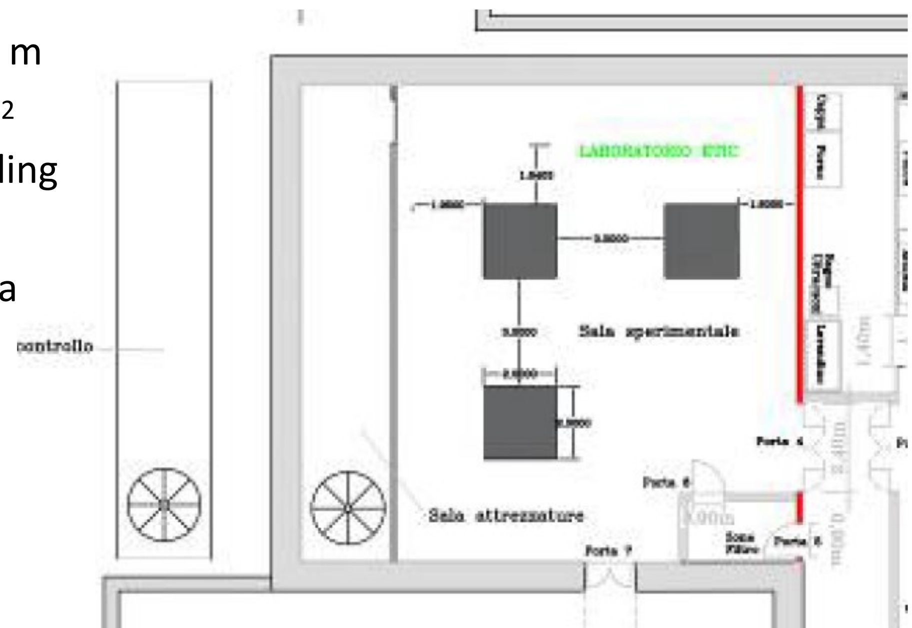
- Production of all mechanical components: ongoing)
- Assembling, integration and beginning of commissioning (January 2025)

The new PLaNET Laboratory

We will get a new lab (~170 m^2) were will install the NIP prototype (previously hosting decommissioned accelerator for nuclear physics)

The restoration and upgrading works will include:

- A general renovation of the area
- A new air processing system providing:
  - → Climatization for stable thermal condition
  - → Smal overpressure for avoiding dust contamination form outside (gray area)
- A new crane with free eight under the hook of 5 m
- Realization of 3 reinforced concrete plinths (4 m^2 each) with foundations independent of the building
- Complete equipment of the lab (optics and electronic instrumentation, optical benches, data acquisition and control systems, cleaning equipment, vacuum systems …)

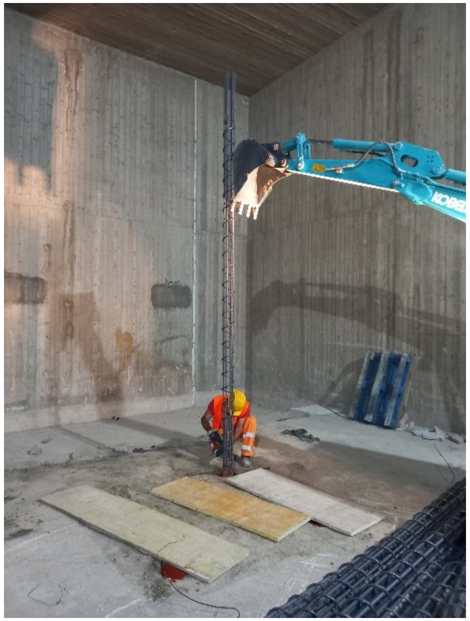


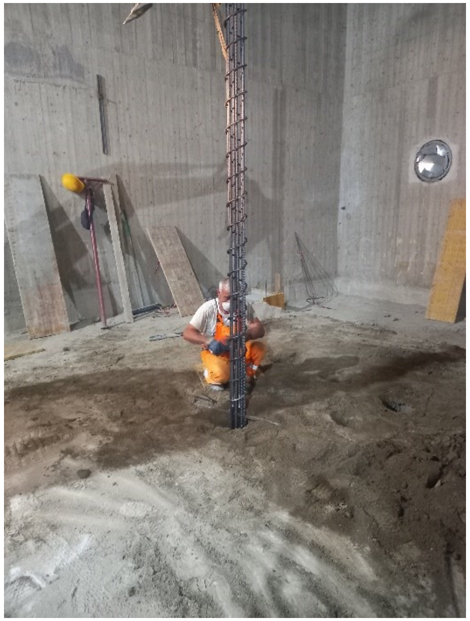
Opening of the construction January 2024

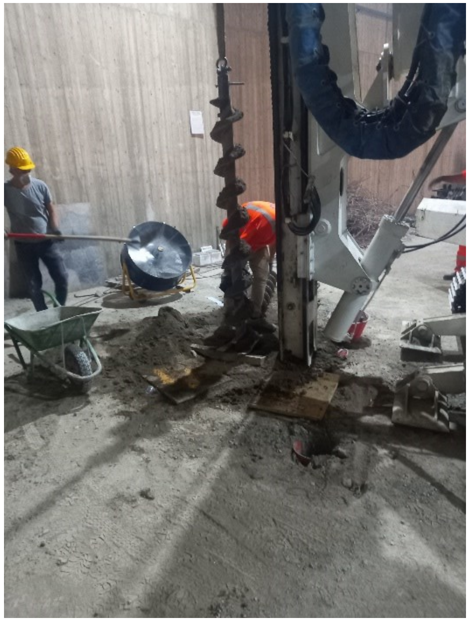
→ **work duration: 9-12 months**

→ **Chiederemo estensione di un anno (2025)**

Lavori in Corso: fondazioni plinti







Attività di simulazione

Le attività di simulazione sono andate aventi sullo studio delle sospensioni future di ET con un Nested-Inverted-Pendulum

I risultati preliminari sono stati pubblicati a maggio 2005

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Class. Quantum Grav. **41** (2024) 117004 (14pp) — https://doi.org/10.1088/1361-6382/ad407e

Note

New Generation of Superattenuator for Einstein Telescope: preliminary studies

A Bertocco[1], M Bruno[1], R De Rosa[1,2], L Di Fiore[1], D D'Urso[3,4], F Frasconi[5,*], A Gennai[5], L Lucchesi[5], M Refat[1], F Pilo[5], D Rozza[3,4], P Ruggi[6], V Sipala[3,4], I Tosta e Melo[3,4] and L Trozzo[1,*]

Sono stati considerati tre casi

- **Case A**: a NIP-SA 8 m tall with a total mass of 2650 kg
- **Case B**: a NIP-SA 10 m tall with a total mass of 2650 kg
- **Case C**: a NIP-SA 10 m tall with a total mass of 3250 kg

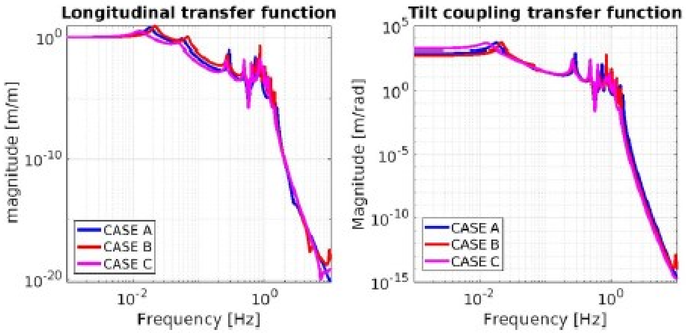
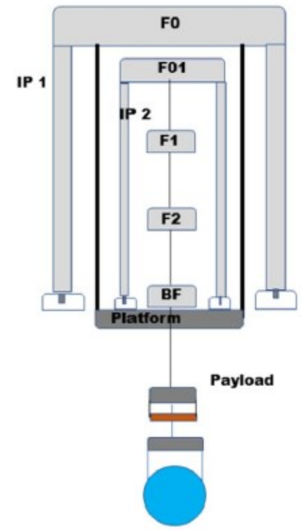


Figure 4. NIP-SA transfer function, from ground to suspended mass, longitudinal d.o.f (left panel) and tilt coupling (right panel).



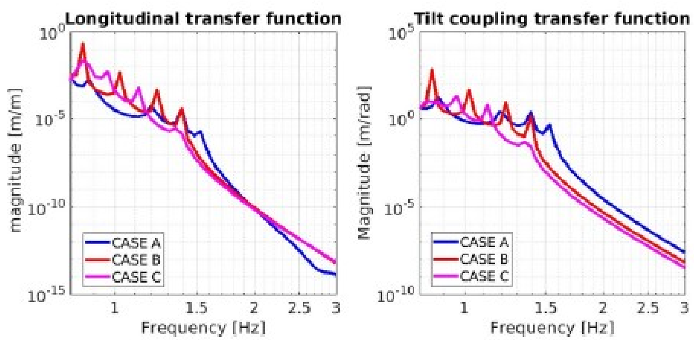


Figure 5. NIP-SA transfer function zooms of longitudinal d.o.f (left side) and tilt coupling (right side) as simulated for three different configurations. At 2 Hz, the longitudinal attenuation is about $6 \cdot 10^{-11}$, while tilt-coupling attenuation improves of a factor 16, changing from Case A to Case C.

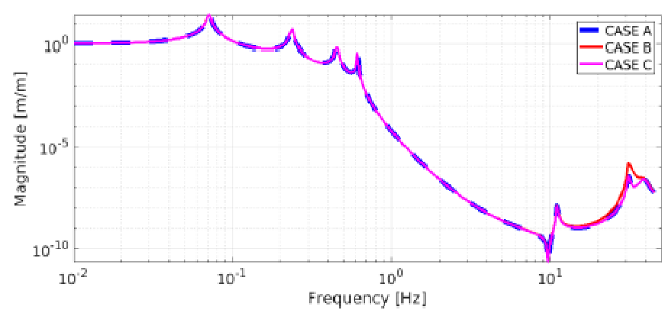


Figure 6. Vertical transfer function for three different configurations of the NIP-SA: a peak structure is visible in the frequency region 30–50 Hz.

Studiodella stabilità del pendolo aggiungendo massa sul top stage

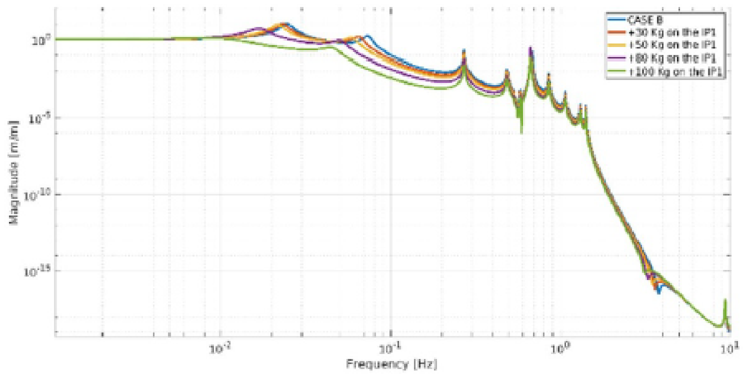


Figure 7. Transfer function of the IP1 for different ballast installed on its top stage and for the geometry of the Case B as detailed in the text. The different curves represent the response of the system when a ballast is used on the IP1 up to the instability of the system (curve labelled + 100 kg).

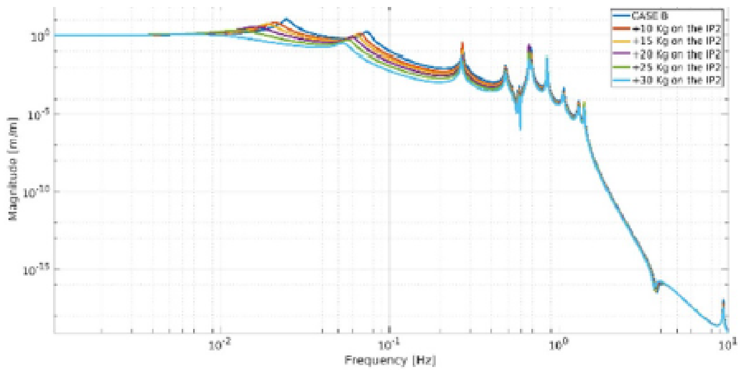
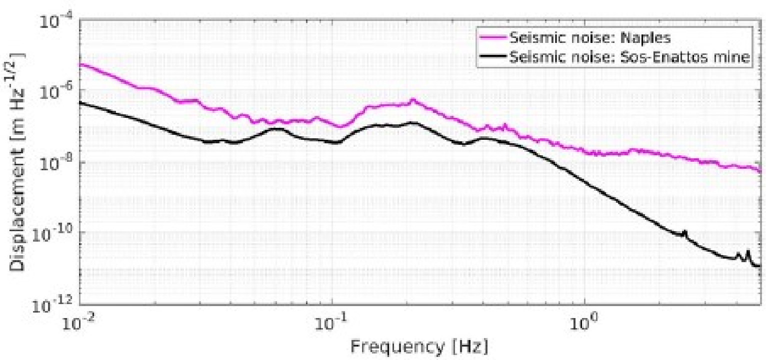


Figure 8. Transfer function of the IP2 for different ballast installed on its top stage and for the geometry of the Case B as detailed in the text. The different curves represent the response of the system when a ballast is used on the IP2 up to the instability of the system (curve labelled + 30 kg).

Proiezione del rumore sismico trasmesso



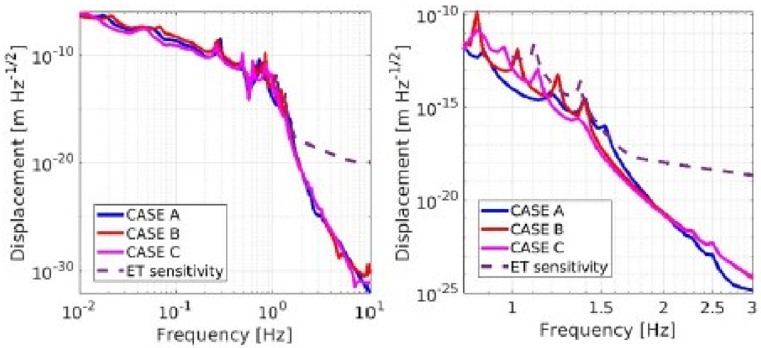


Figure 10. NIP-SA: expected residual motion of the test mass along the longitudinal degrees of freedom and due to the Sos Enattos seismic noise as represented by the black curve of figure 9. On the right-side panel, a zoom of the frequency region 0.8–3 Hz is shown.

Table 1. Expected residual motion of the test mass due to the ground-tilt contribution as estimated in section 4.1.

CASE A	$8 \cdot 10^{-18} \frac{\mathrm{m}}{\sqrt{\mathrm{Hz}}}$
CASE B	$10^{-18} \frac{\mathrm{m}}{\sqrt{\mathrm{Hz}}}$
CASE C	$4.5 \cdot 10^{-19} \frac{\mathrm{m}}{\sqrt{\mathrm{Hz}}}$

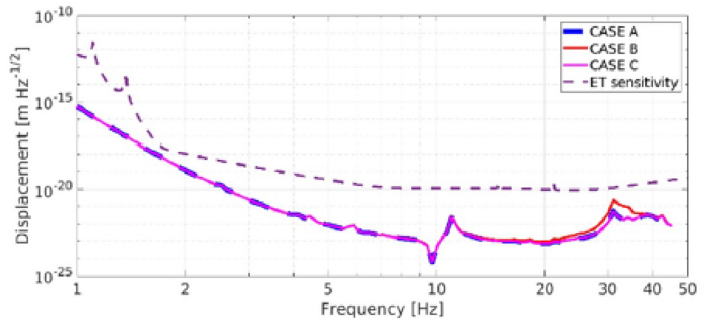


Figure 11. NIP-SA zoom of the expected residual motion of the test mass due to the vertical ground displacement in the region 1–50 Hz. In the region 1–3 Hz, the test mass displacement is about one order of magnitude below the ET sensitivity curve. In the range 5–20 Hz, the test mass displacement is more than two orders of magnitude below the ET sensitivity. Around 30 Hz, a mechanical resonance of the standard filters reaches the value of $5 \cdot 10^{-19} \frac{\mathrm{m}}{\sqrt{\mathrm{Hz}}}$.

Umore sismico totale trasmesso

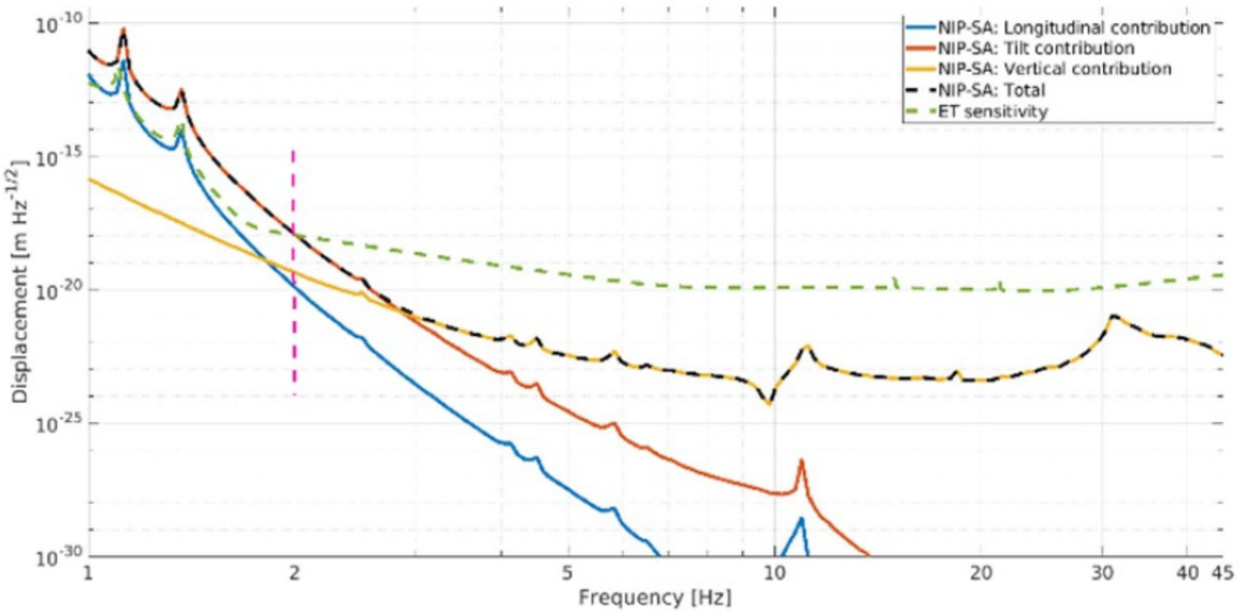


Figure 12. Expected residual motion of the test mass for the NIP-SA studied (Case B). Different contributions to the complete system response (see dotted curve labelled NIP-SA Total) are compared with the ET sensitivity (dotted green curve). A vertical dotted line at 2 Hz is marked in this plot as a reference value for all the studies carried out with this simulation activity.

Next steps → sensing e sistemi di controllo → lavori in corso

Thank you for your attention