

Seismic Isolation System (SIS)

mechanical structure: impact on cryostat, vacuum and cavern excavation.

A point of view

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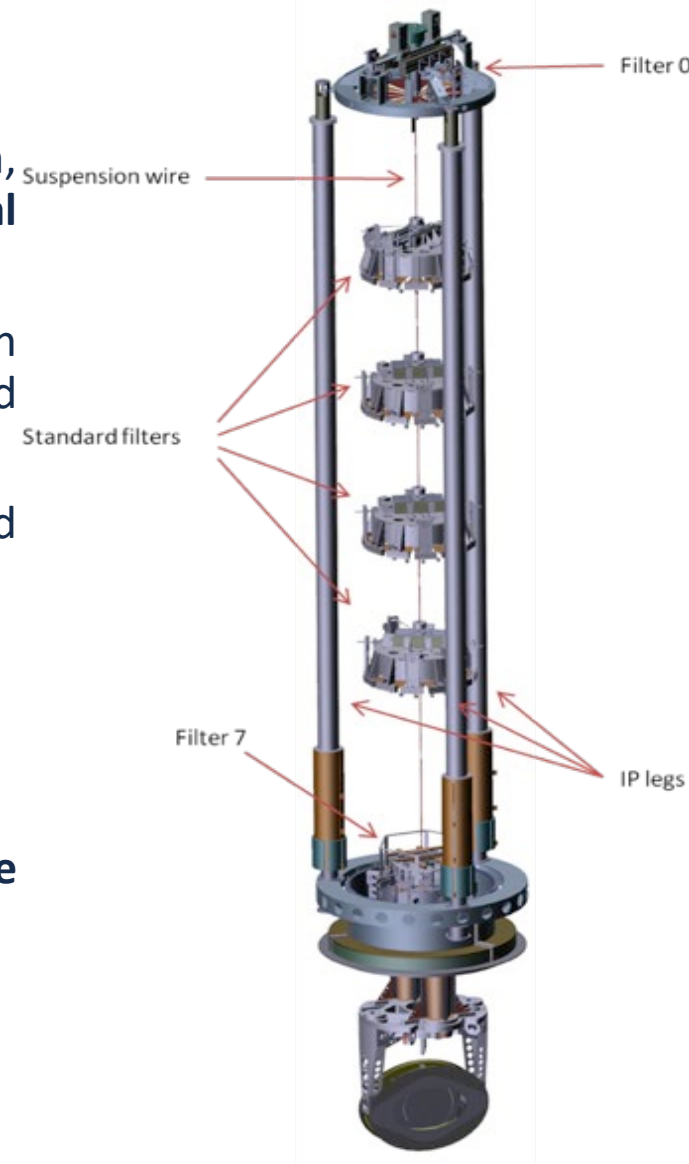
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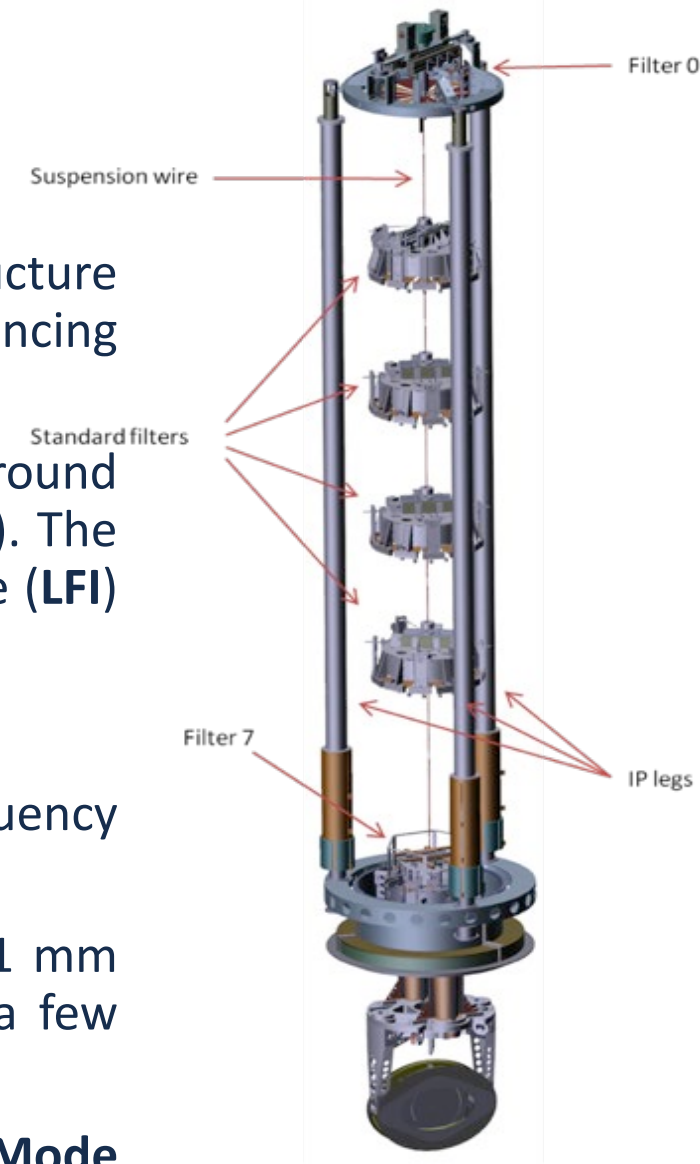
Superattenuator

- The "traditional" research line [based on the AdV Superattenuators](#) (Inverted Pendulum, Filter Chain, Payload) is currently considered the **baseline solution in the ET Conceptual Design**.
- For the High Frequency Interferometer (**HFI**), the AdV Superattenuator is compliant with the ET requirements: total height around 10 m, base tower with a possible increased height (? - impact on vacuum system)
- For the Low Frequency Interferometer (**LFI**), the AdV vibration isolation structure should be revised and redesigned, taking into account:
 - Presence of the cryostat
 - Shape and dimension of the base tower (conical shape about 4 m (?))
 - Heavy payload (600-800 kg)
 - Detection bandwidth to be extended around 2 Hz
- **Possible categories for different requirements of filtering noise capabilities: a qualitative approach**
 - High Performance Filtering (HPF)** (i. e.: TM suspended from long chain)
 - Intermediate Performance Filtering (IPF)** (i. e.: injection and detection benches)
 - Low Performance Filtering (LPF)** (i. e.: no relevant filtering requirements)
- **Important impact on the dimensions and cost of tunnel excavation**



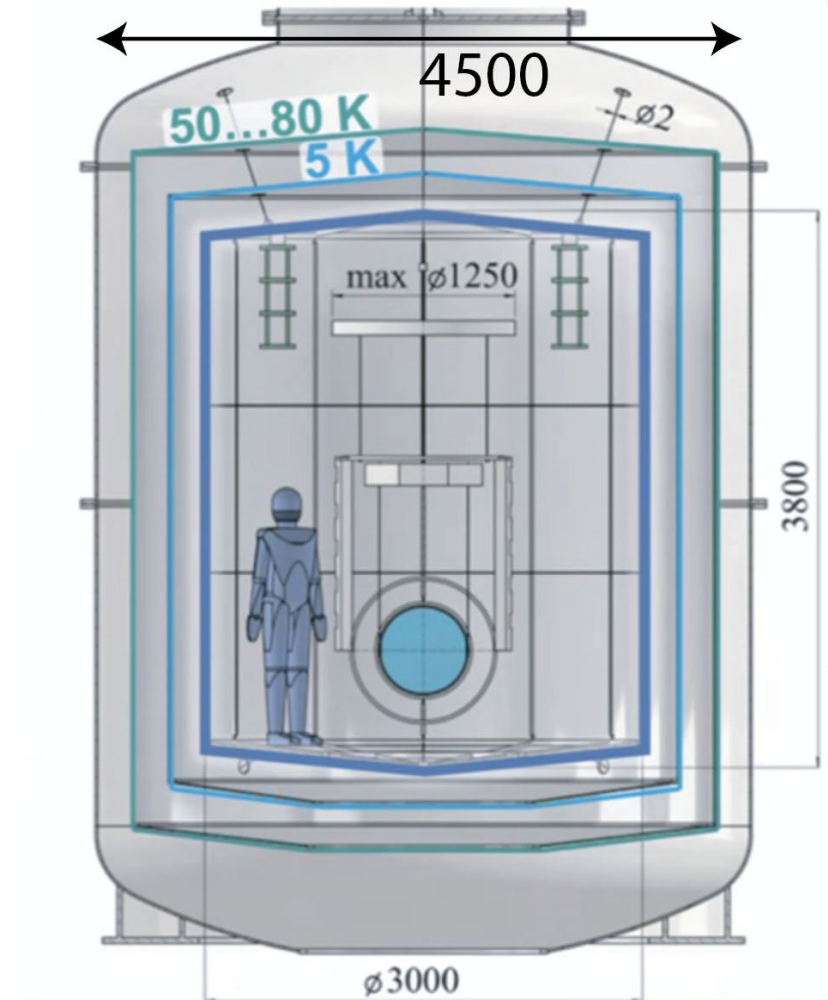
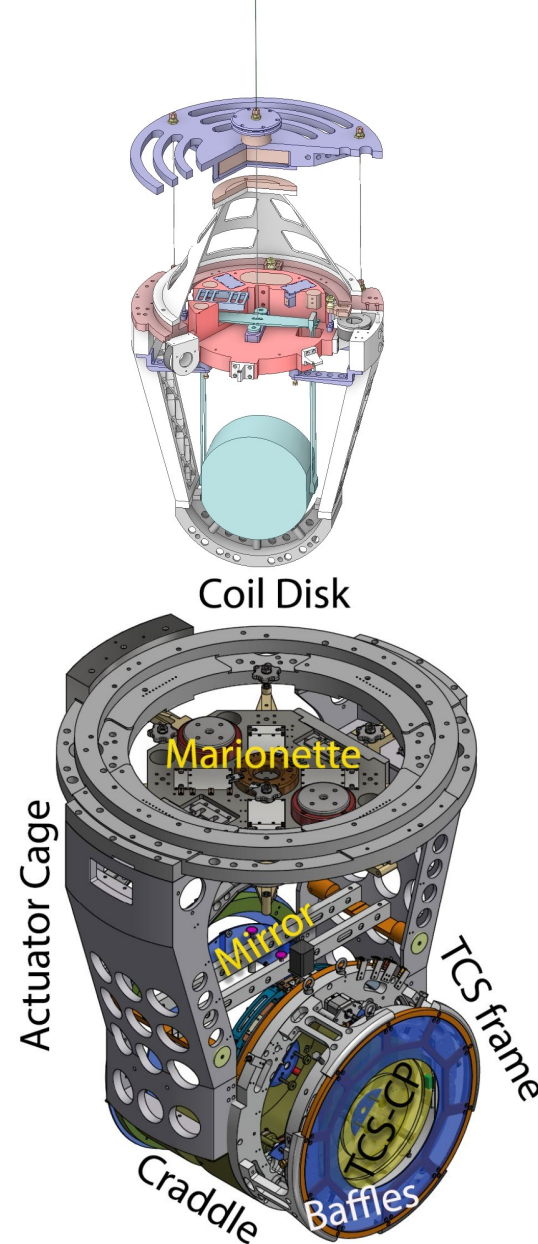
The SA, the IP and Payloads

- The **Seismic Isolation System (SIS)** for ET will be based on a mechanical structure adopted to isolate the optical components (Test Mass and/or other optics influencing the ITF performance) from seismic activities and local disturbances.
- A passive multi-stages pendulum is hung to a top ring with three legs ground connected and conceived on the working principle of an Inverted Pendulum (IP). The Payload, the last stage of the chain, will be maintained at cryogenic temperature (**LFI**) and room temperature (**HFI**)
- Three important roles of the IP:
 - pre-isolation stage in horizontal direction (two d.o.f.) with cut-off frequency into the tens of mHz region
 - precise positioning and feedback correction of the tidal effect (about 1 mm for 10 km long arms) on the suspension point by using small forces (a few Newton per a cm displacement of 1 ton)
 - first feedback action on the resonance modes of the chain (**Active Mode Damping**)



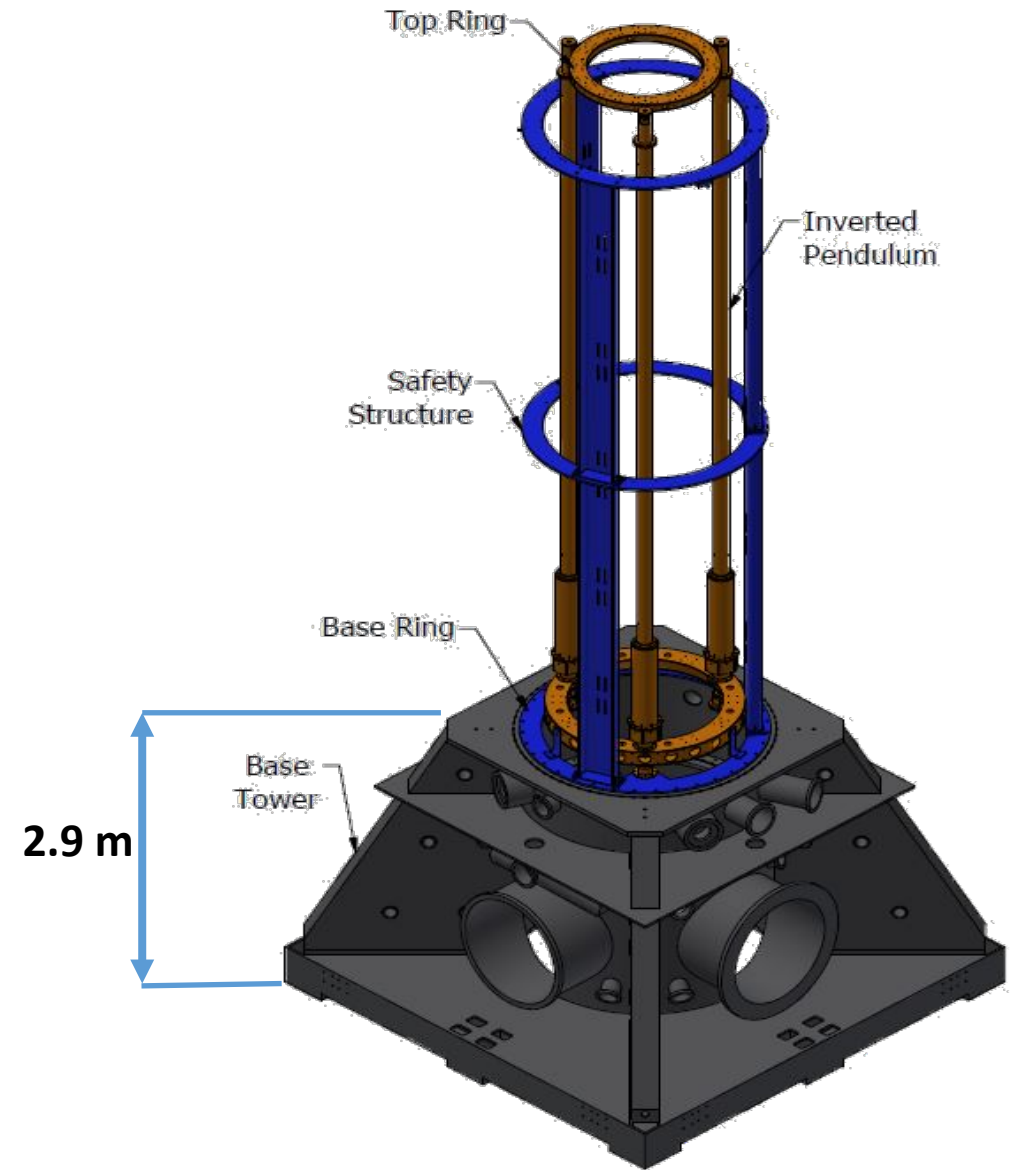
Payloads: cold and warm

- Delicate optics included in a complex mechanical structure to be feedback controlled
- **Payload for LFI** installed inside a cryostat
 - Interface with Base Tower and vacuum system
 - Presence of heat-links (soft) for cooling system connection
 - Payload geometry and cryostat dimensions have great influence on vacuum vessel
 - Influence of the payload total load and geometry on the suspension upper part (at room temperature for LFI)
 - Large base tower (ground connected) needed
- **Payload for HFI** at room temperature (warm)
 - Dimensions and load of the warm payload (?)
 - Traditional approach and/or LIGO like solution (?)
 - Differences on Base Tower geometry (?)



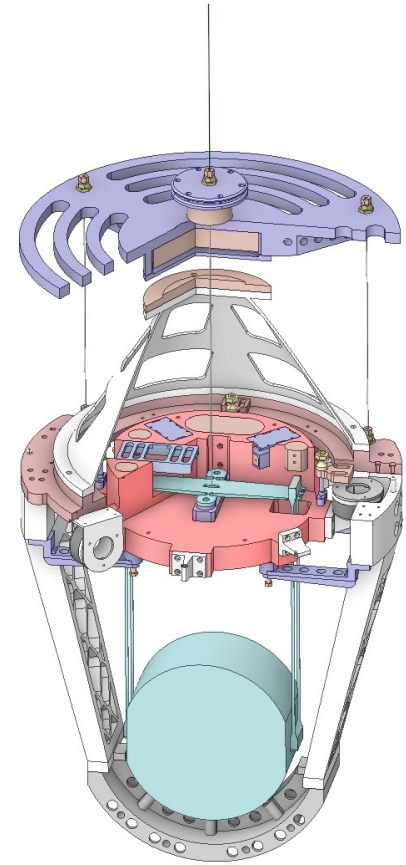
The IP and the Vacuum System

- AdV set-up: the Bottom-Ring of the **Inverted Pendulum (brown hollow body in the figure)**, is the interface with the vacuum system;
- The Base-Tower is an open volume towards the tower upper part where the IP and the multi-stage pendulum chain are installed;
- The Payload is confined into the base tower vacuum chamber (**LFI and HFI**);
- Cryostat for LFI is accommodated into the Base Tower vacuum volume : larger vacuum volume;
- LFI payload with presence of **soft heat-links** to be considered;
- Low Temperature impact on last filtering stage of the pendulum: **to be considered a dedicated selection and studies of materials for elastic element at interface (blades, wires, etc.)**.



Dimensioning a new Seismic Isolation System

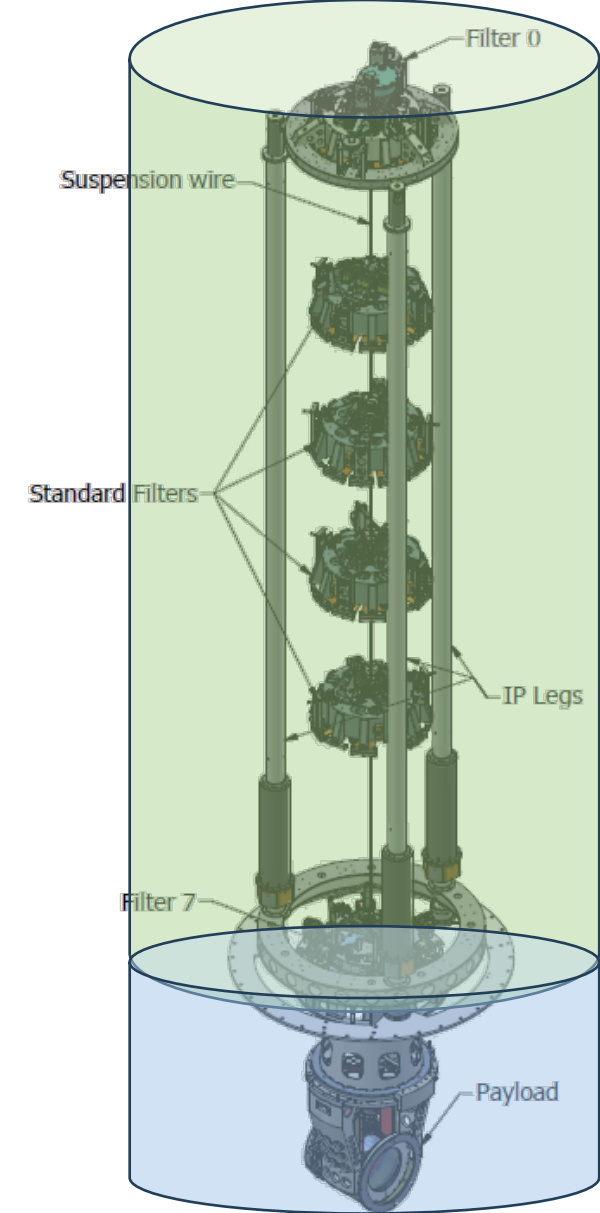
- **The Bottom-Top approach:** payload design is the starting point for the vibration isolation system project (suspension upper part). The **total load** to be suspended is a fundamental parameter for the **mechanical structure**, while the **payload geometry** plays an important role also for the **feedback control strategy**;
- **Hanging the Payload to the last mechanical filter of the chain (Filter7):**
 - **Soft Connection** using 3 suspension thin wires
 - **Rigid Connection** with AdV like solution (different load distribution along the chain with last filter body in direct connection with the feedback control zone of the payload)
- For both solutions an accurate evaluation on the sensors/actuators disseminations along the lower part of the chain is needed for optimizing the feedback control strategy.



3D drawing of a LF Payload with soft connection (3 wires) to the last stage seismic filtering system. A possible solution.

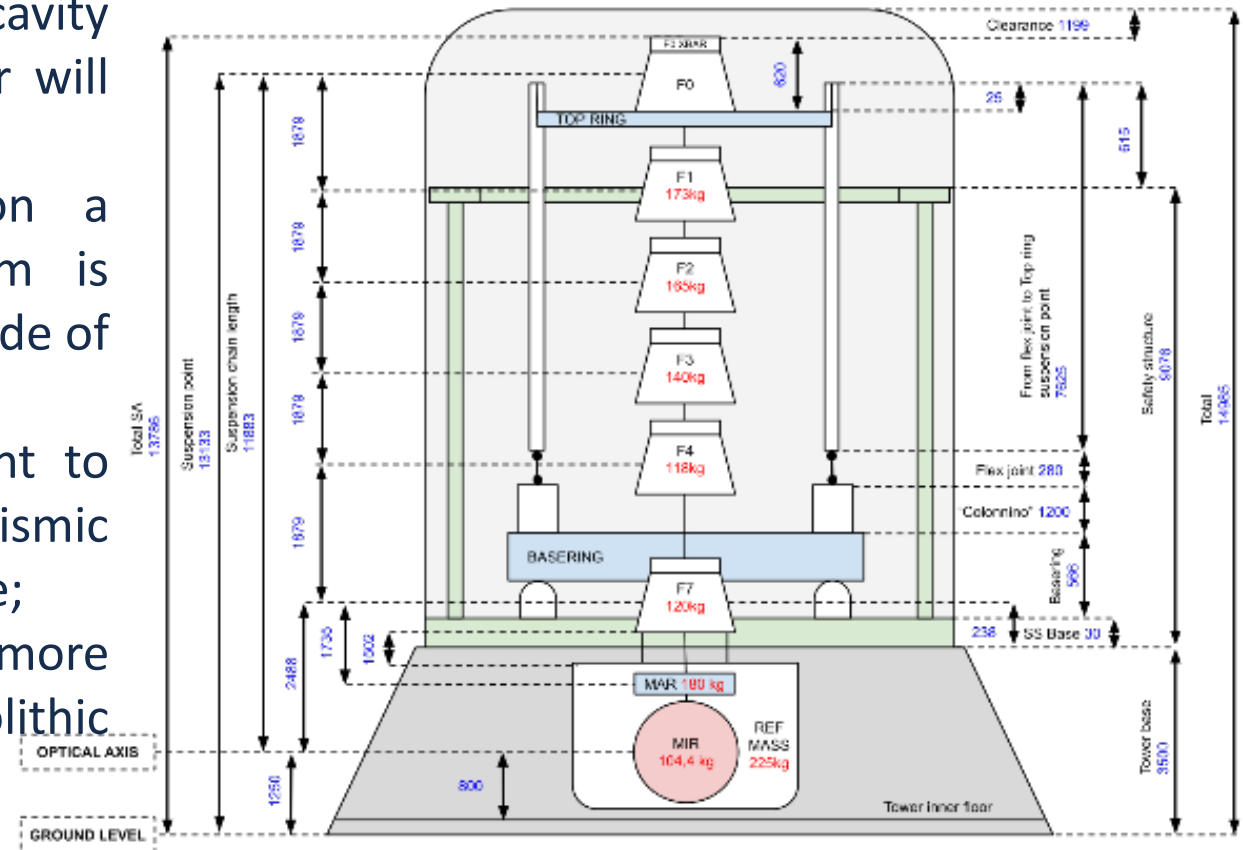
Feedback Control Strategy Impact on SIS design

- Implementation of an adequate **hierarchical feedback control strategy** within two “ideal vacuum volume”
- Lower Part (**bleu volume in the figure**) where Payload is accommodated inside the cryostat (**LFI**)
 - optimizing the feedback control strategy pass through PAY geometry definition and its total load
 - sensors/actuators (vacuum and cryo compatibles) dissemination
- Upper Part (**green volume in the figure**) where IP and filter chain are installed
 - active platform 6D compensating micro seismic motion
 - IP pre-attenuation, tidal compensation and Active Mode Damping
- **Open question:** for heavy payloads (600-800 kg - **LFI**) is the mechanical structure upper part (ground connected) enough to be considered a good recoil-mass for PAY ?



Exercise in progress: the SA for CAOS

- Two long Superattenuators, about **15m tall**, will be installed in CAOS facility at Perugia University;
- They will be used to suspend a Fabry-Perot cavity where future technologies for ET interferometer will be tested and validated;
- The Superattenuator structure is based on a traditional scheme where an Inverted Pendulum is used as mechanical structure from which a cascade of passive filters and payload are hung;
- The **conical base-tower (3.5 m high)** is meant to support properly the vacuum vessel and the Seismic Isolation System in view of the Einstein Telescope;
- A **larger base-tower vacuum volume** will be more adequate for different geometries of the monolithic suspension/payload.



Final Considerations

- The SA scheme, adopted for AdV detector, is considered the reference solution for Next Generation Seismic Isolation System with the possibility to extend the detection bandwidth down to 2 Hz;
- The project finalization needs some qualitative guide-line before starting the hot program (R&D Activities):
 - **qualitative definition of filtering performance for different uses/applications** (HPF, IPF and LPF). **Important impact on the tunnel excavation and underground lab arrangement**
 - **payload total weight and geometry. Important impact on cryostat and base tower dimensions.**
 - **bottom-top approach for SIS project: payload design has important impact on the mechanical structure of the vibration isolation system and its feedback control system**
 - **cryostat dimensions demand larger base tower vacuum volume. Important impact on the base tower weight and its accommodation in the underground lab.**
- **Open question** for heavy payloads (600-800 kg) and its impact on the mechanical structure ground connected (SA).