



Advancements in sensing and actuation for a Superattenuator's Active Platform

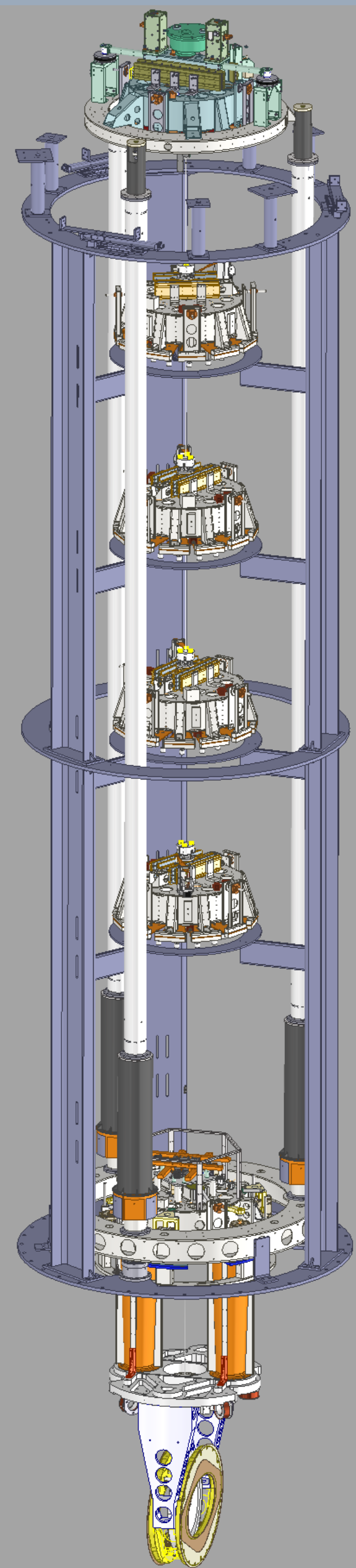
Francesca Spada

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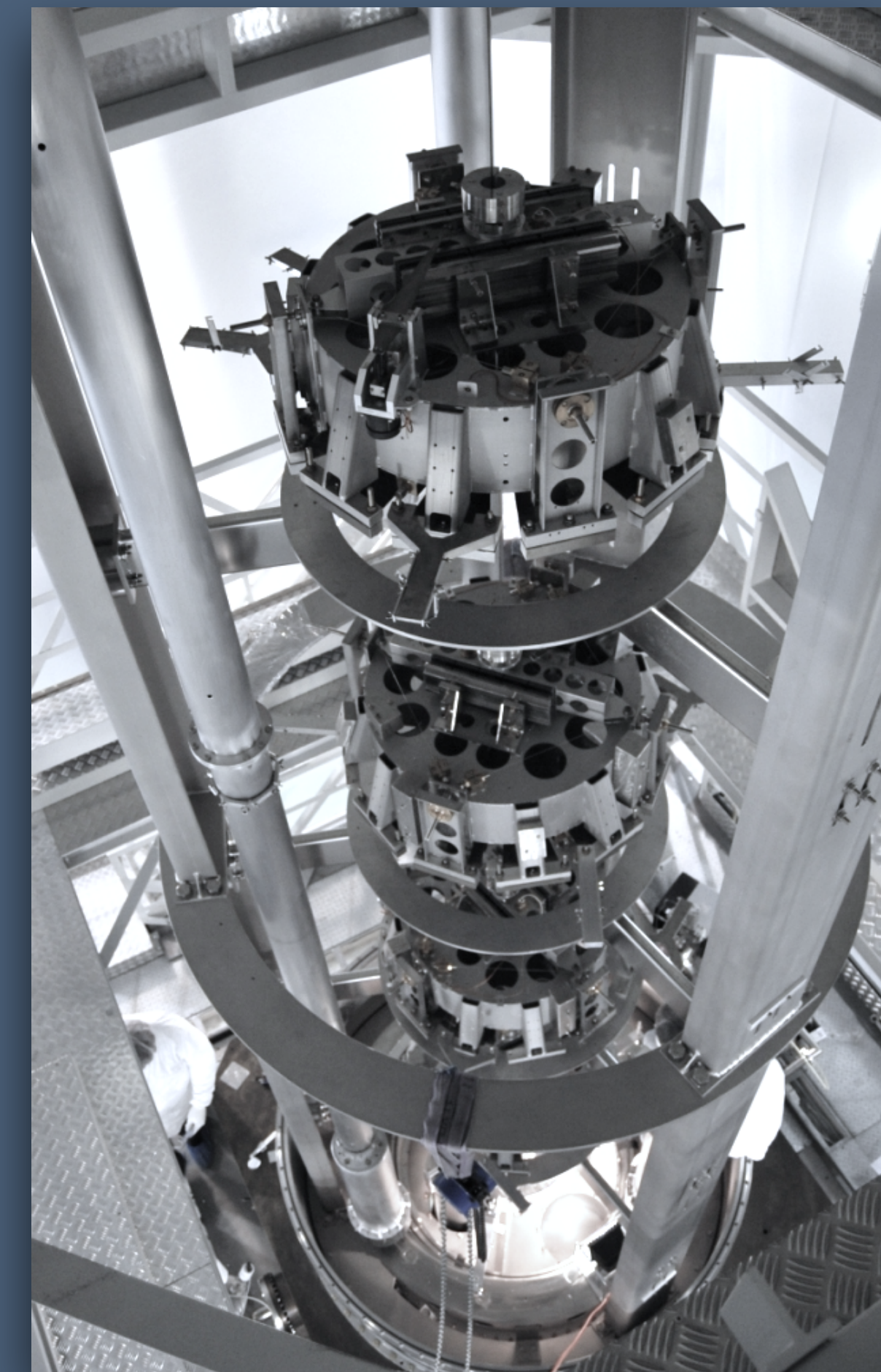
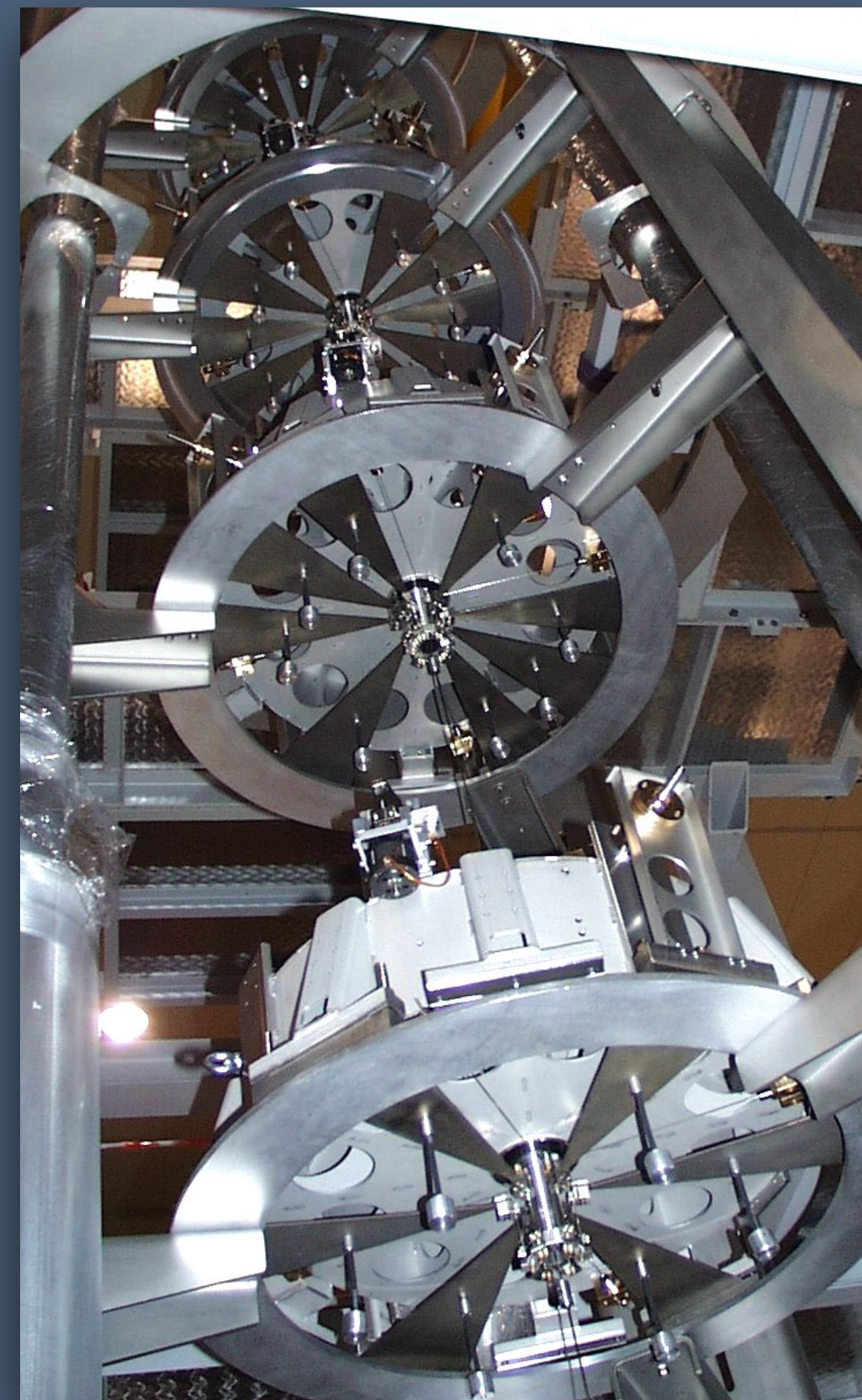
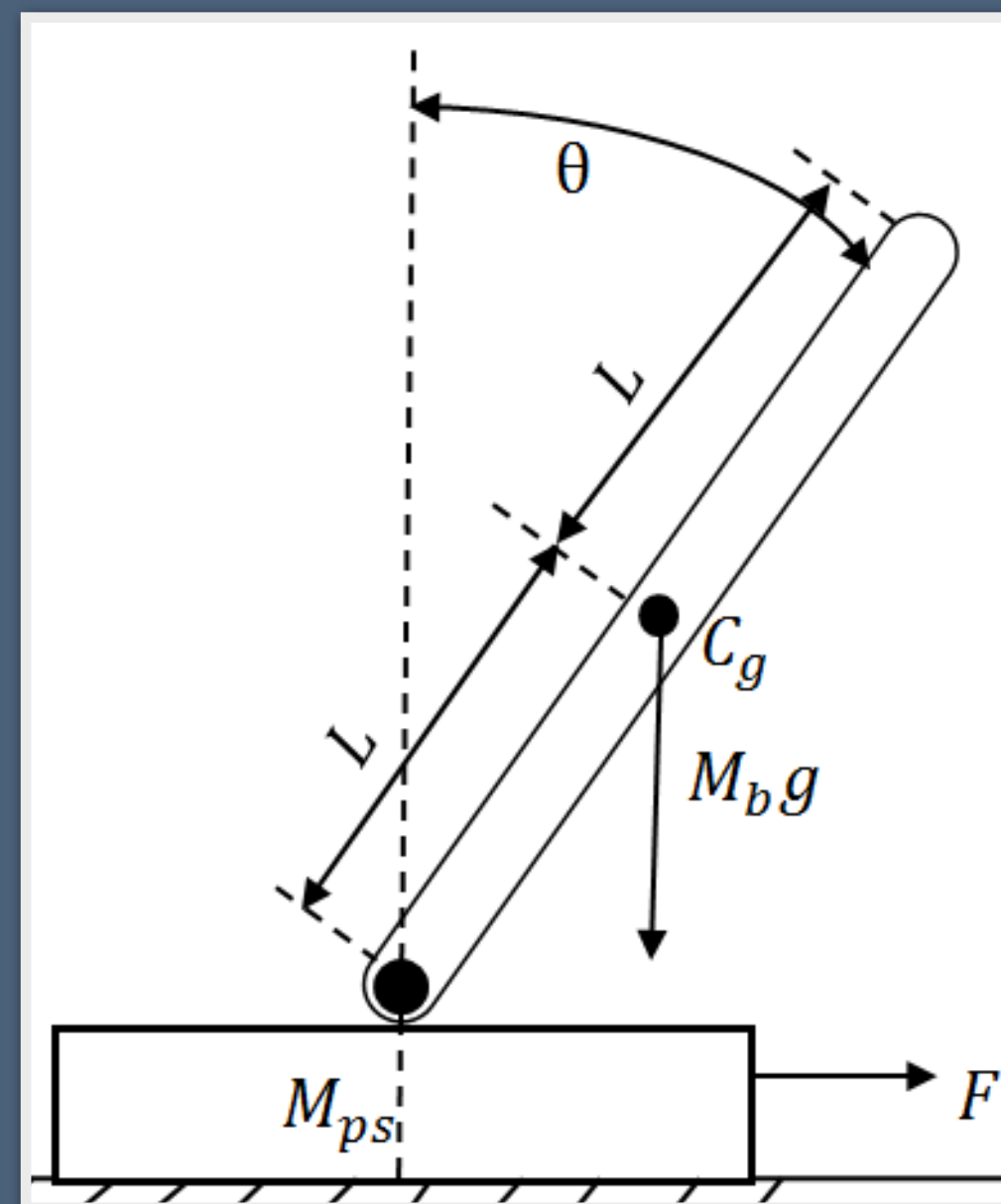
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Virgo/ET Pisa Internal Workshop – 22-23/05/2024

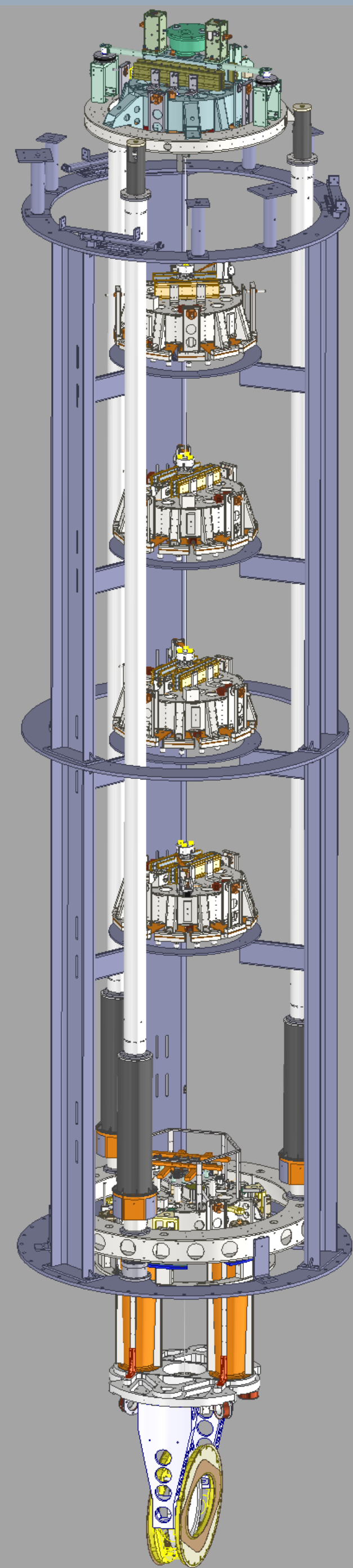
The Superattenuator



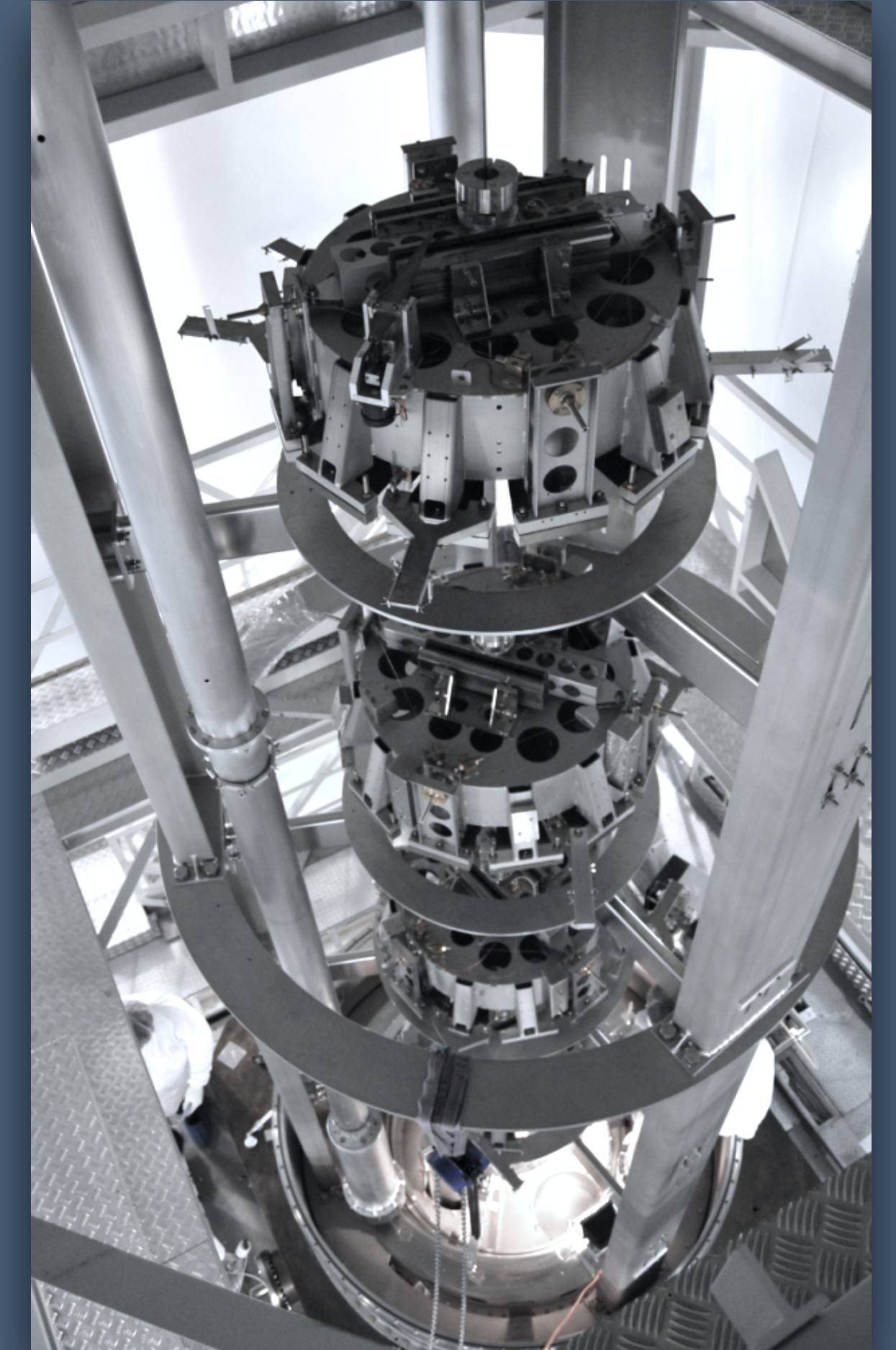
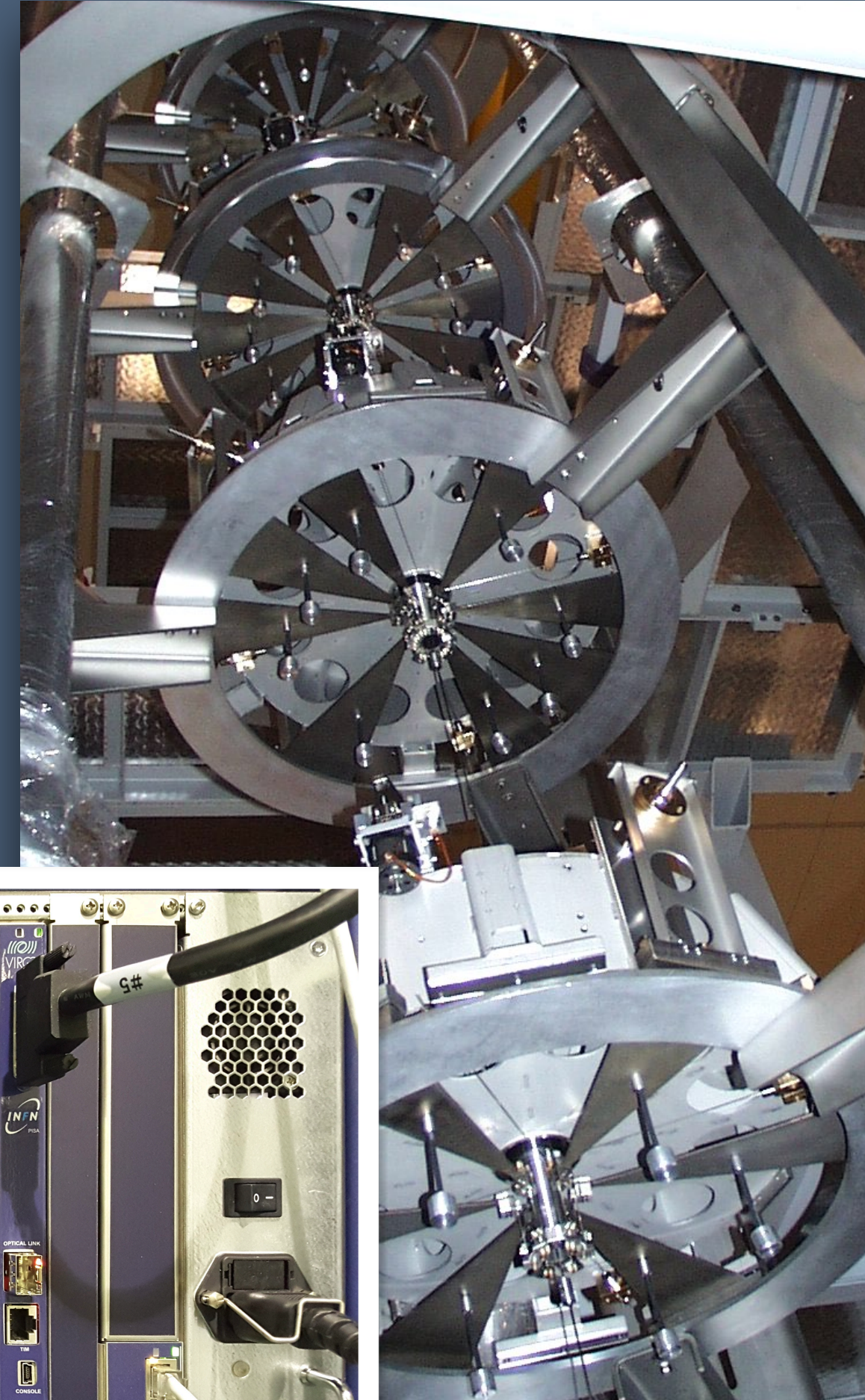
- ▶ A multi-stage attenuation system based on the **inverted pendulum** principle



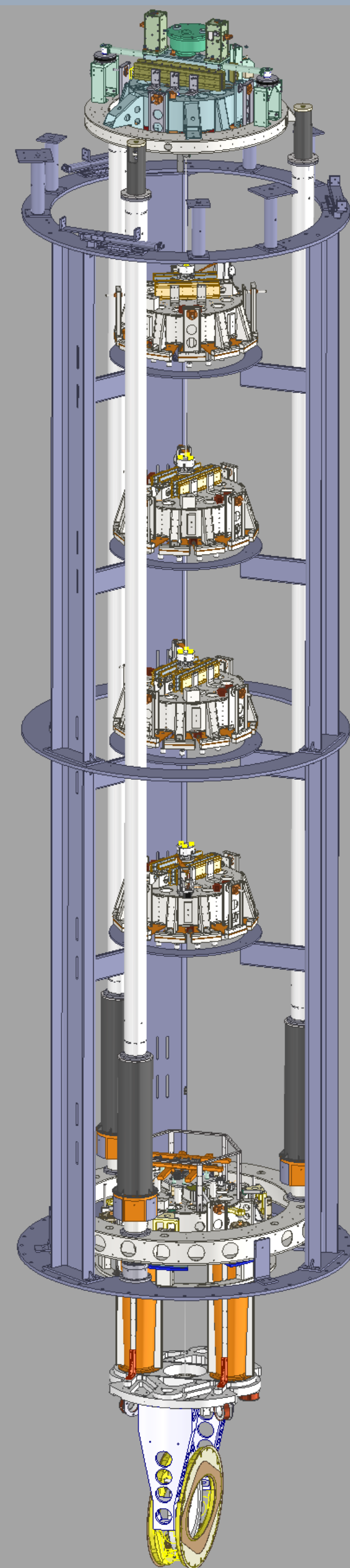
The Superattenuator



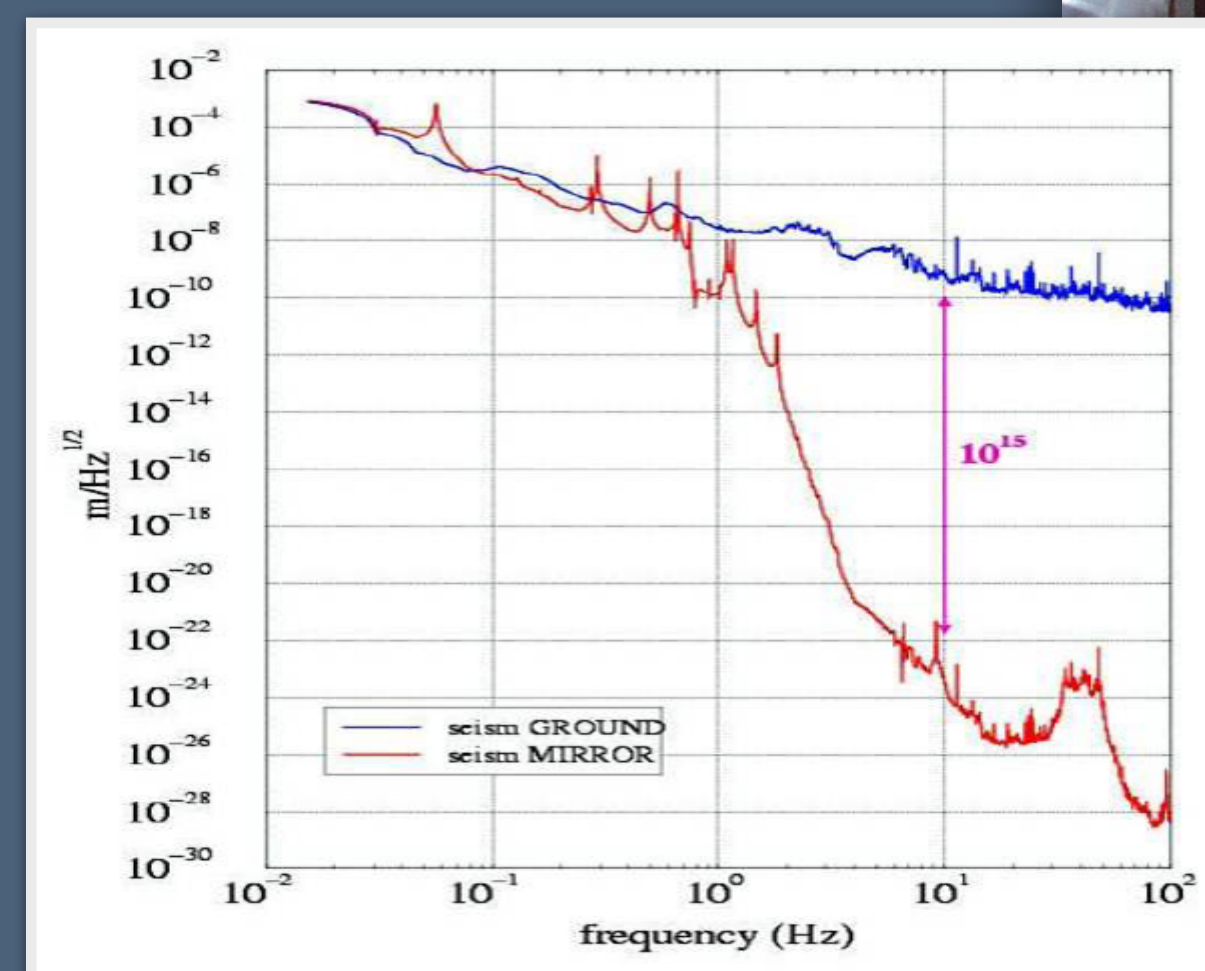
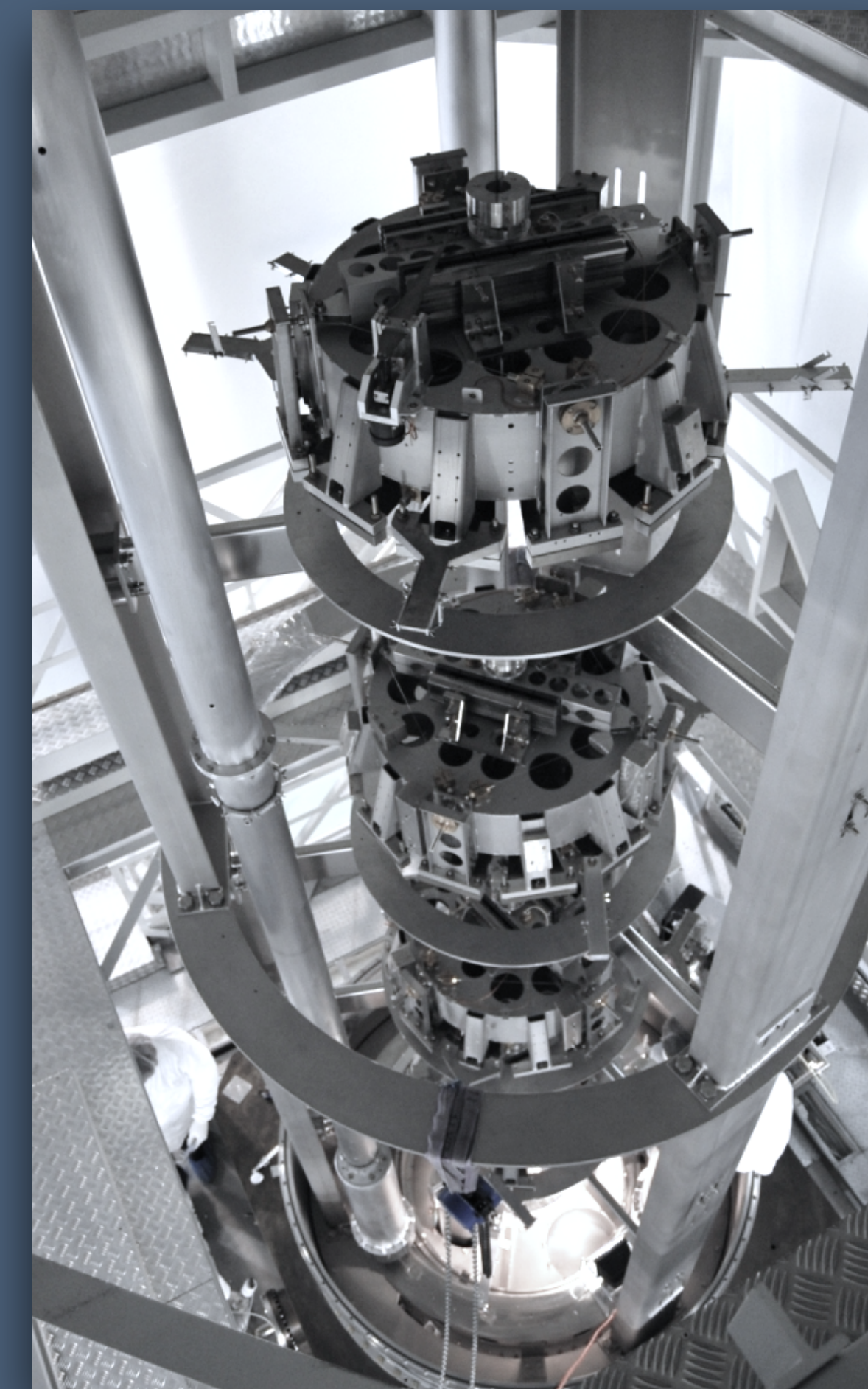
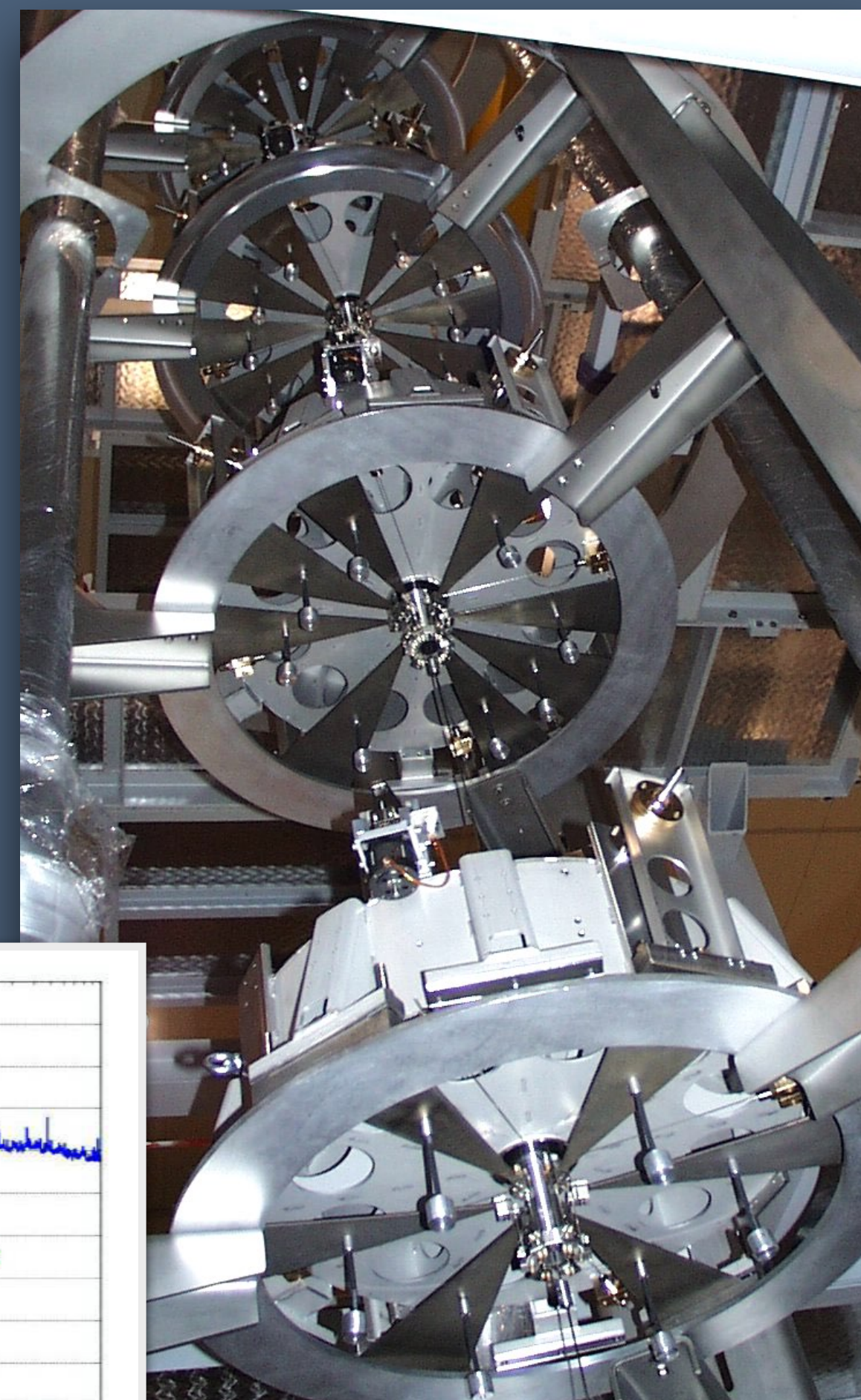
- ▶ A multi-stage attenuation system based on the **inverted pendulum** principle
- ▶ Both **passive and active** damping
- ▶ The Pisa group leads the development of **feedback control electronics and software** for SA operation



The Superattenuator

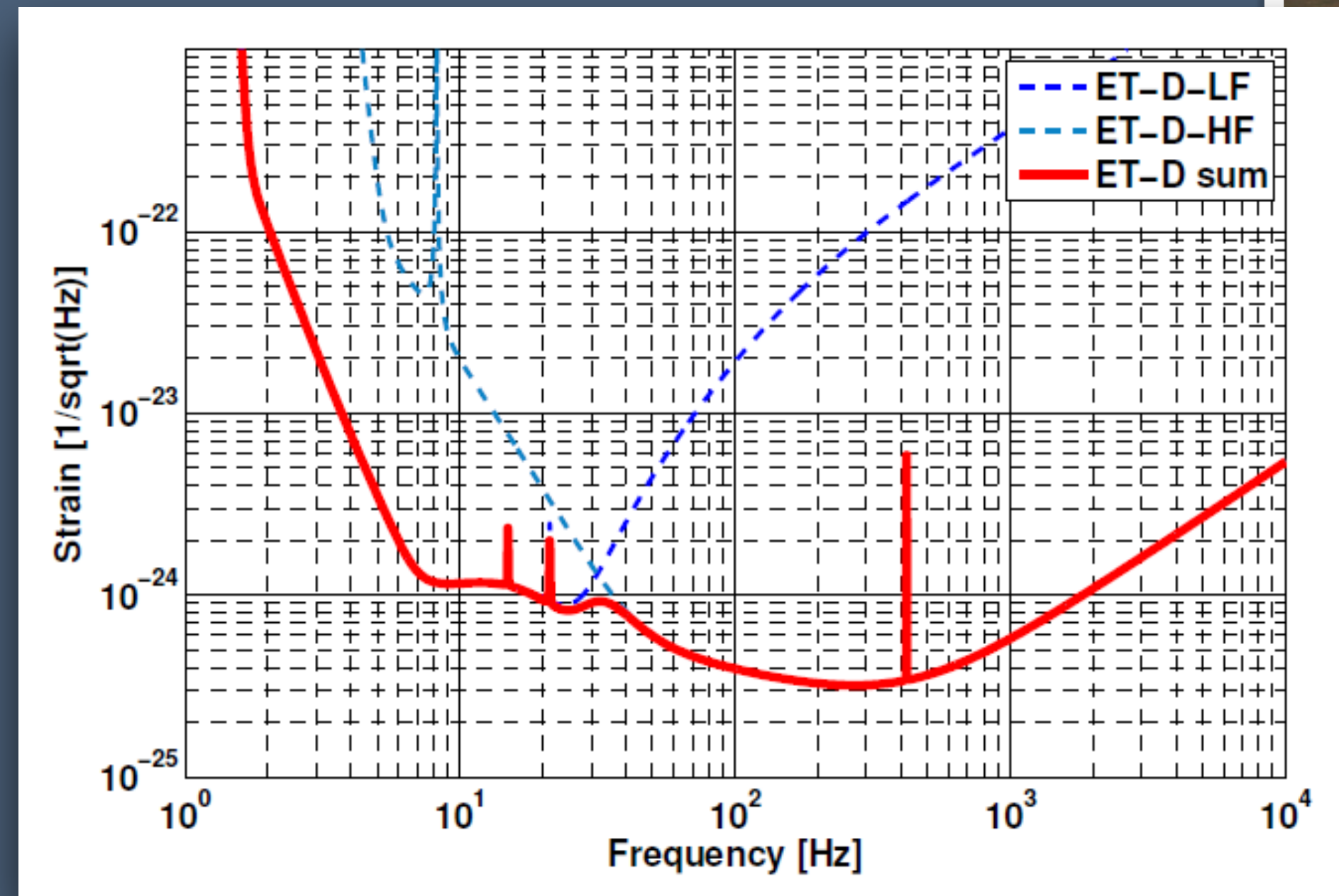
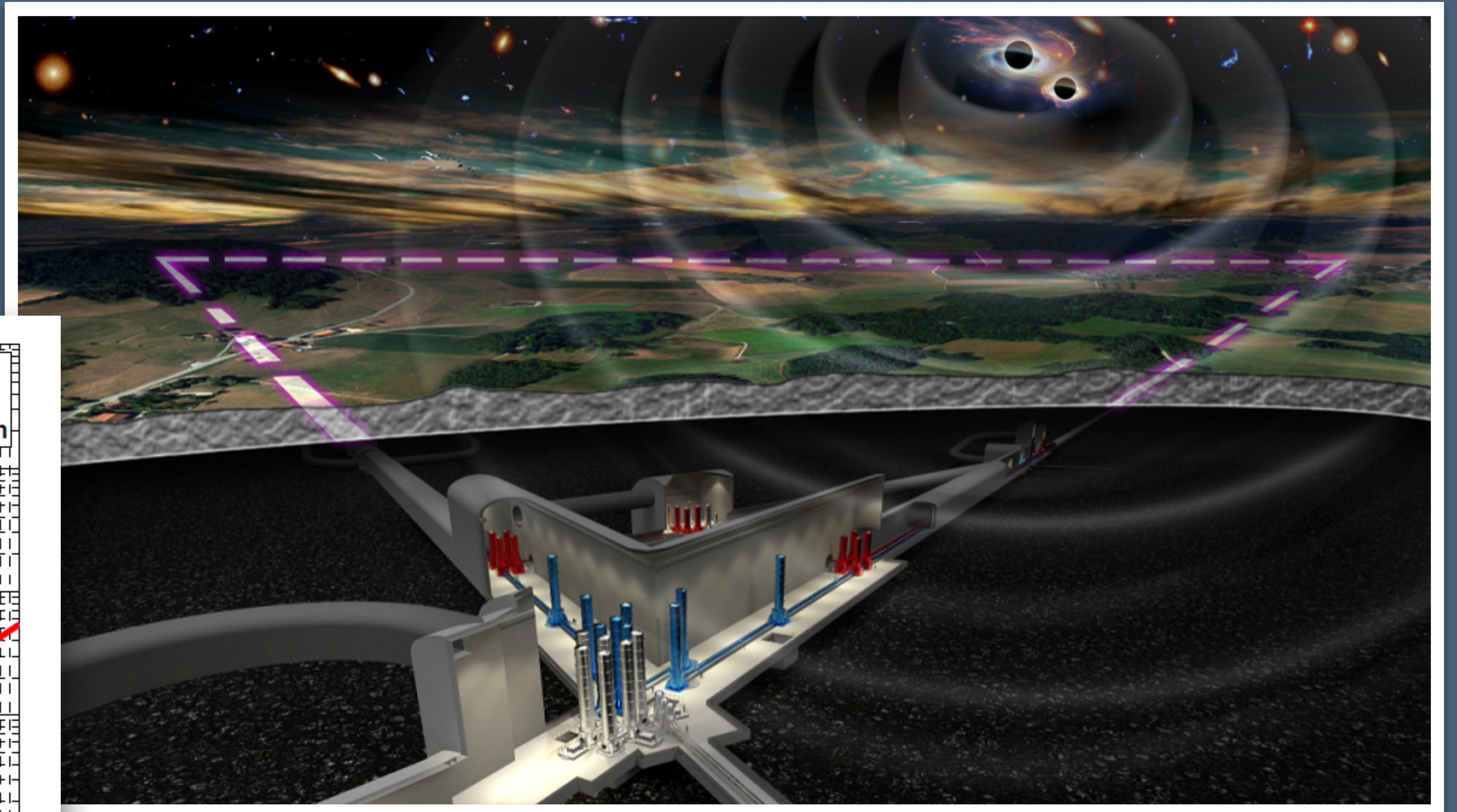


- ▶ A multi-stage attenuation system based on the **inverted pendulum** principle
- ▶ Both **passive and active** damping
- ▶ A **low-pass filter** attenuating the **ground motion** - the main source of noise in the low frequency range - by **15 orders of magnitude at 10 Hz**.

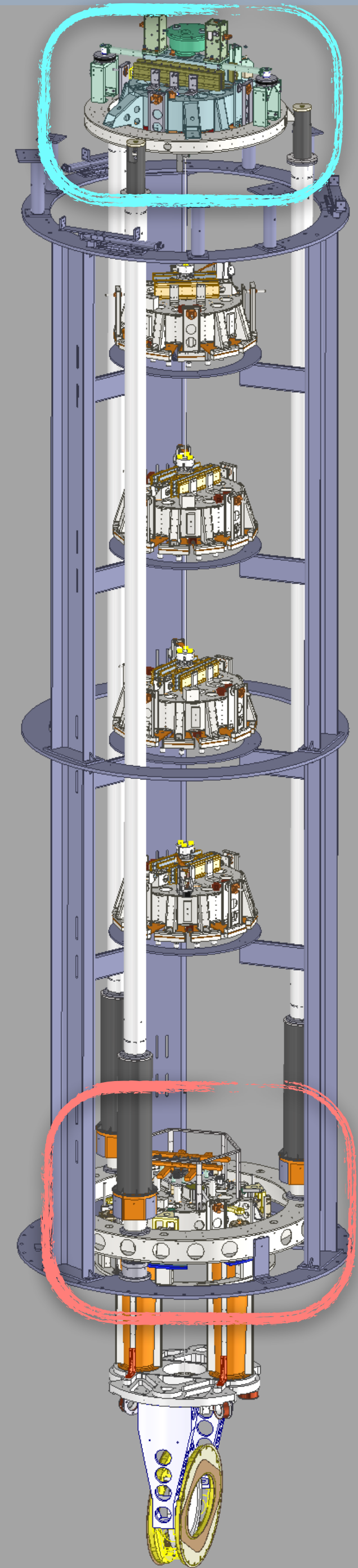


The Einstein Telescope

- ▶ Detect high-z black holes, extend GW physics to cosmological distances
- ▶ Discovery potential in astrophysics, cosmology and fundamental physics
- ▶ **Extend the sensitivity band down to 3 Hz**



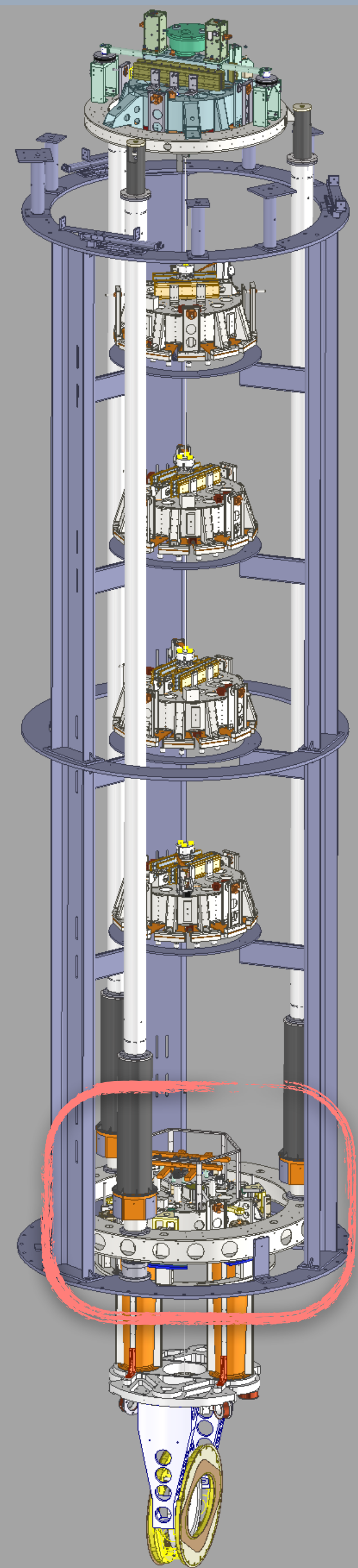
The Superattenuator



We have to work on it!

- ▶ Active platform upgrading the **Superattenuator base ring** into an active pre-isolator
- ▶ Sensors a new **accelerometer** design

Seismic Isolation Platform

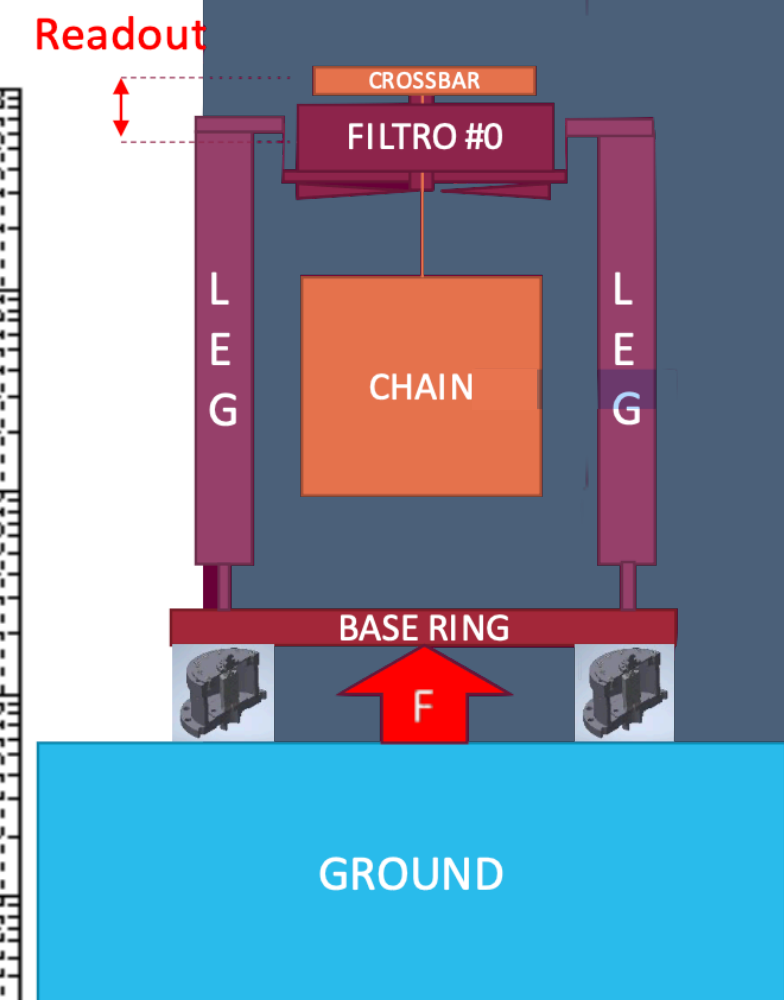
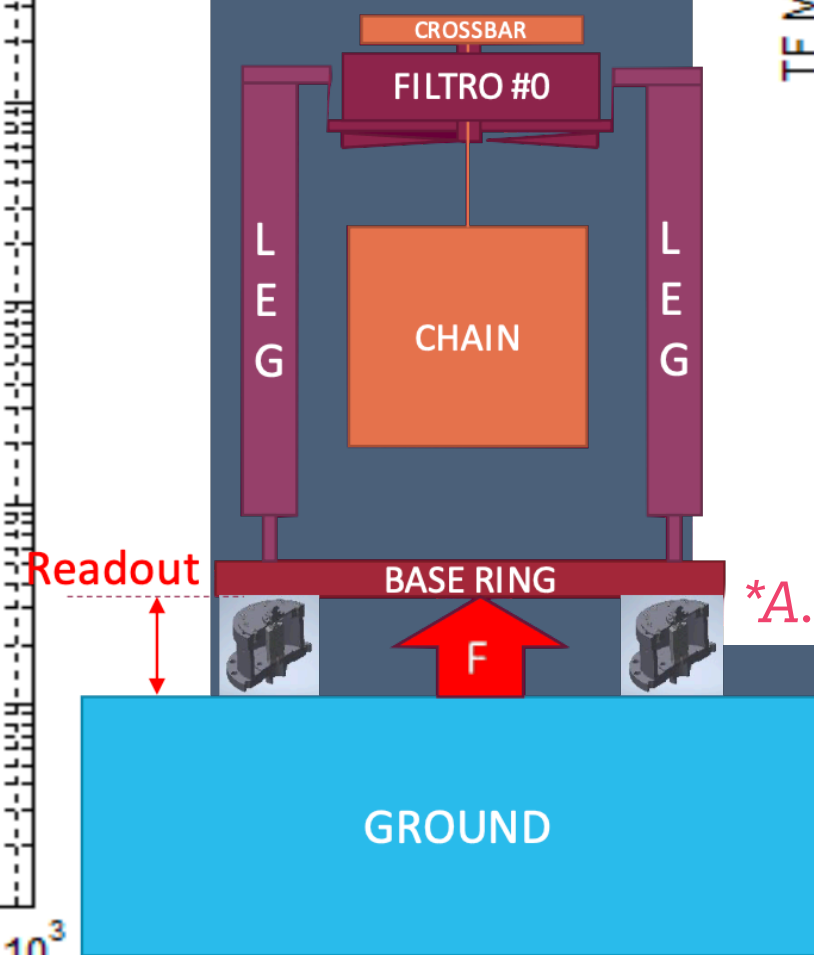
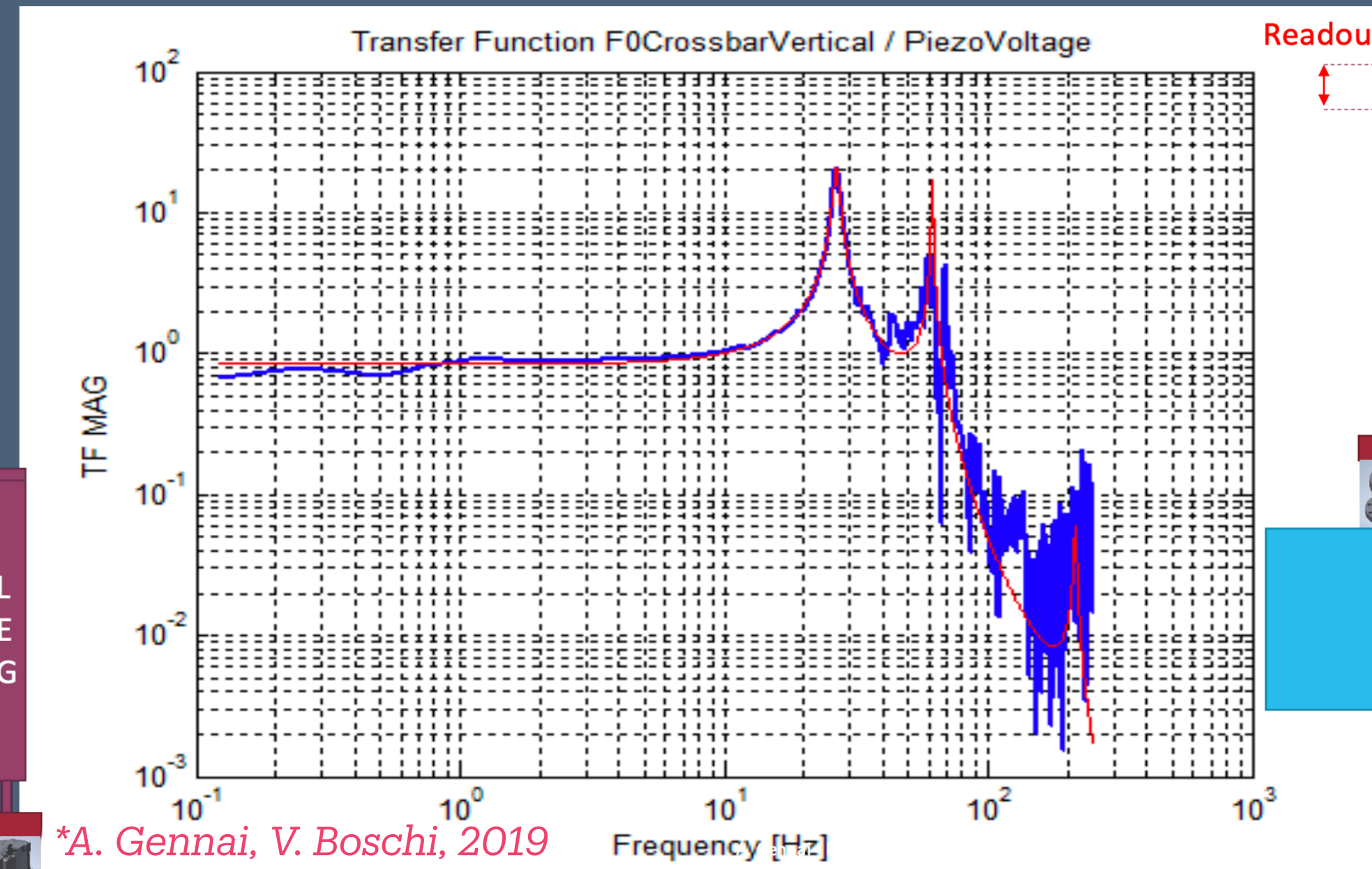
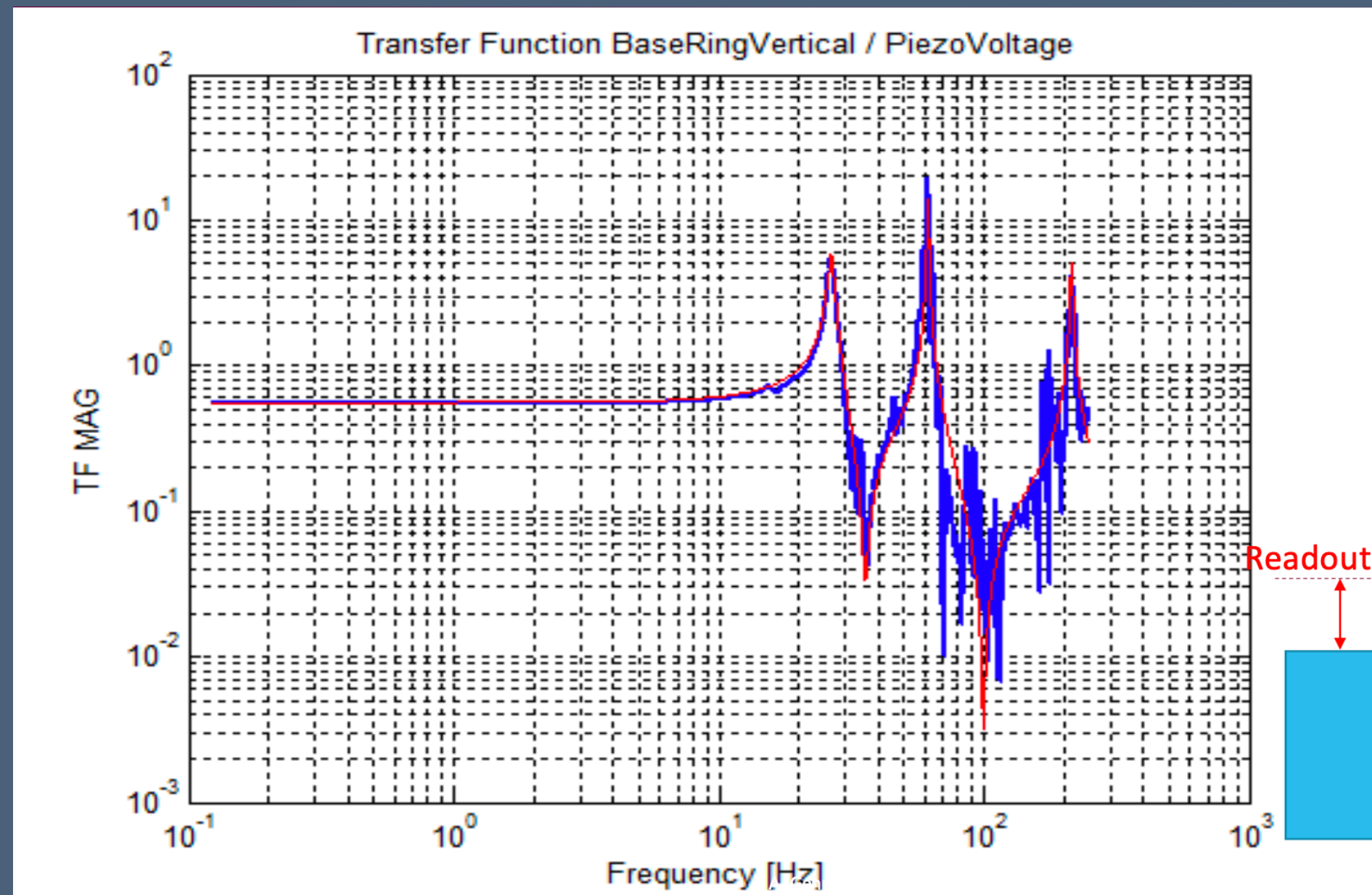


▶ Active platform upgrading the **Superattenuator base ring** into an active pre-isolator

Seismic Isolation Platform

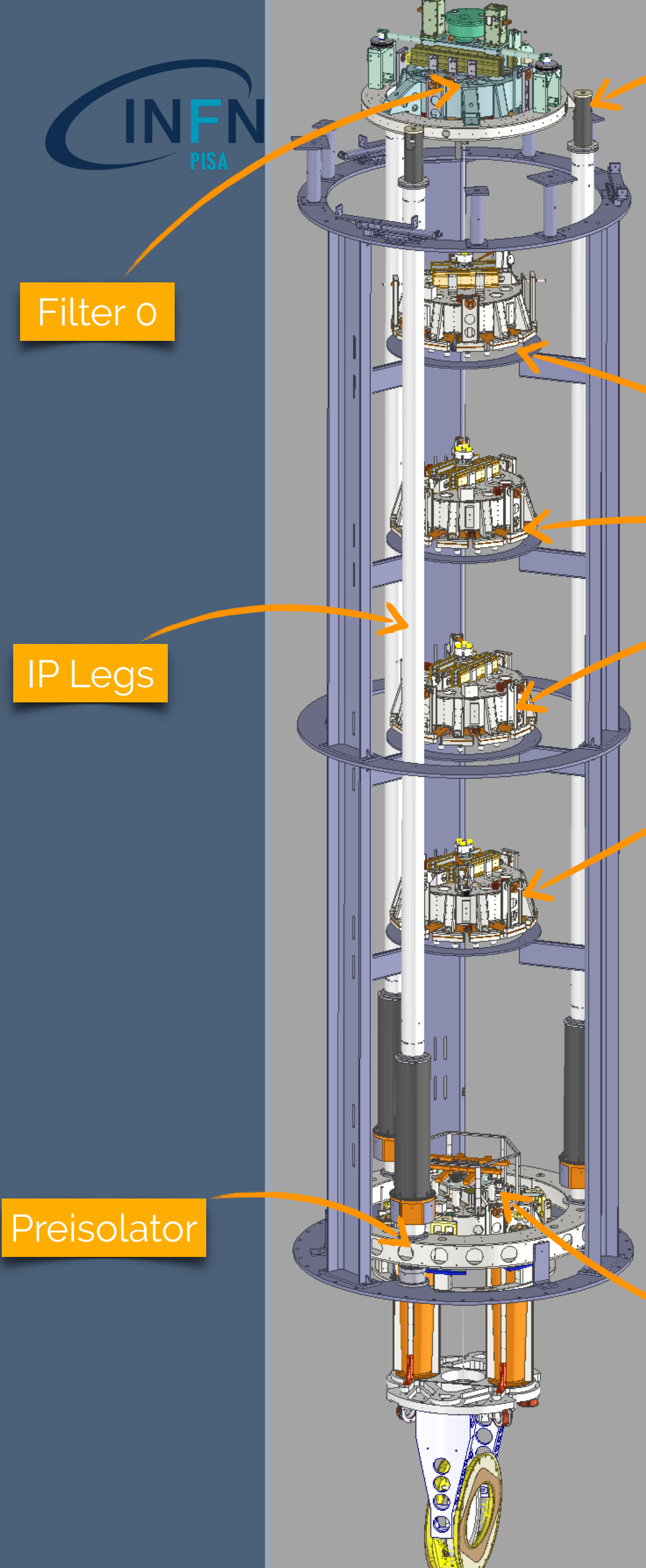


The SA base-ring was originally equipped with **piezoelectric actuators** in case the ground tilt was large enough to create either large displacements of the top stage or problems to inertial feedback applied to the top



*A. Gennai, V. Boschi, 2019

► A "clean" test environment is needed



Safety Structure

Filter 0

IP Legs

Preisolator

Standard Filters

Filter 7

A “small” SA (2m H x 1m Ø) as testbench for R&D

Testbench for **integrated performance evaluation** currently set up in the INFN Pisa Lab

+

Dedicated **standalone R&D campaigns** on each new device

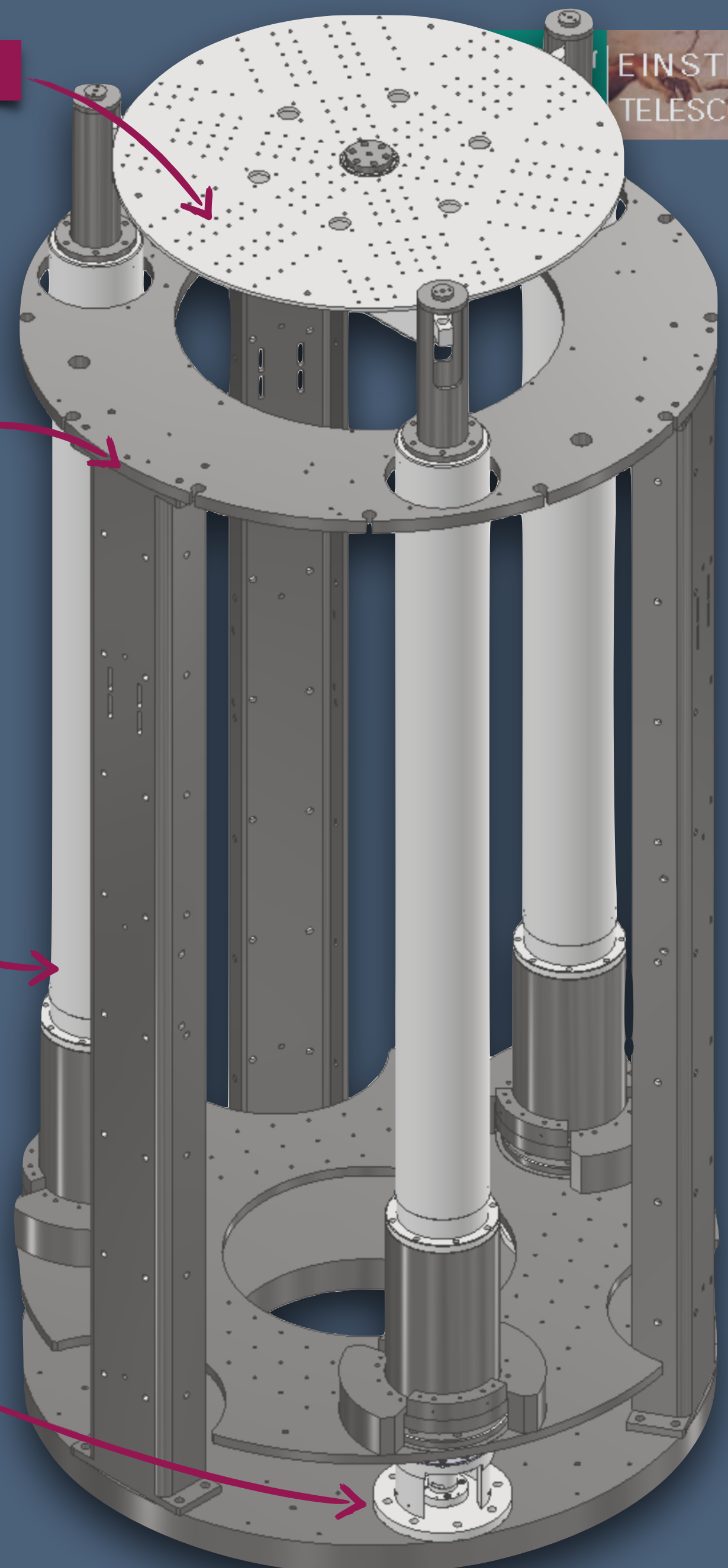
- SS, Preisolator installed;
- Disk 0 designed, currently in production
- Filter and payload to be designed;

Disk 0

Safety Structure

IP Legs

Preisolator

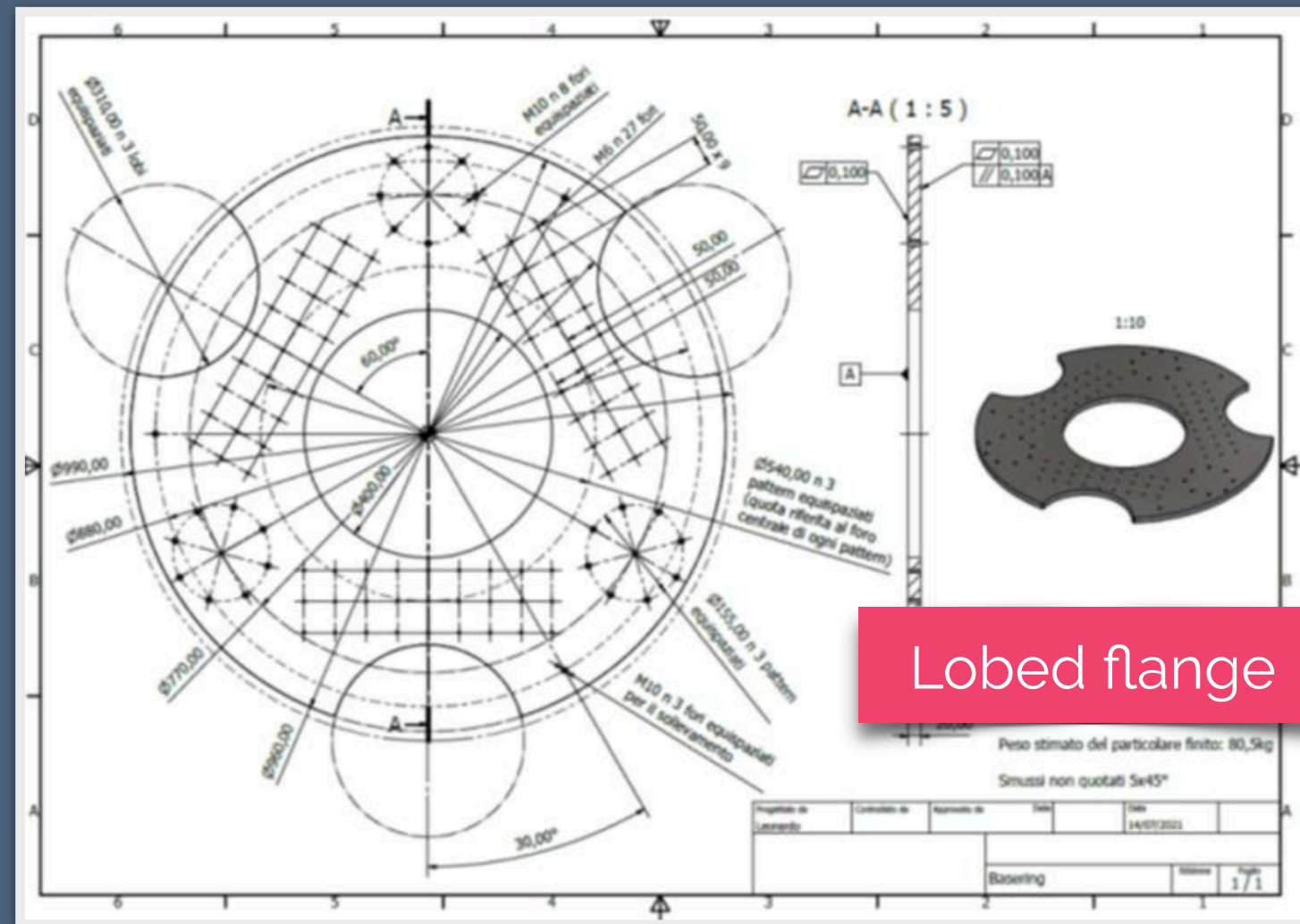
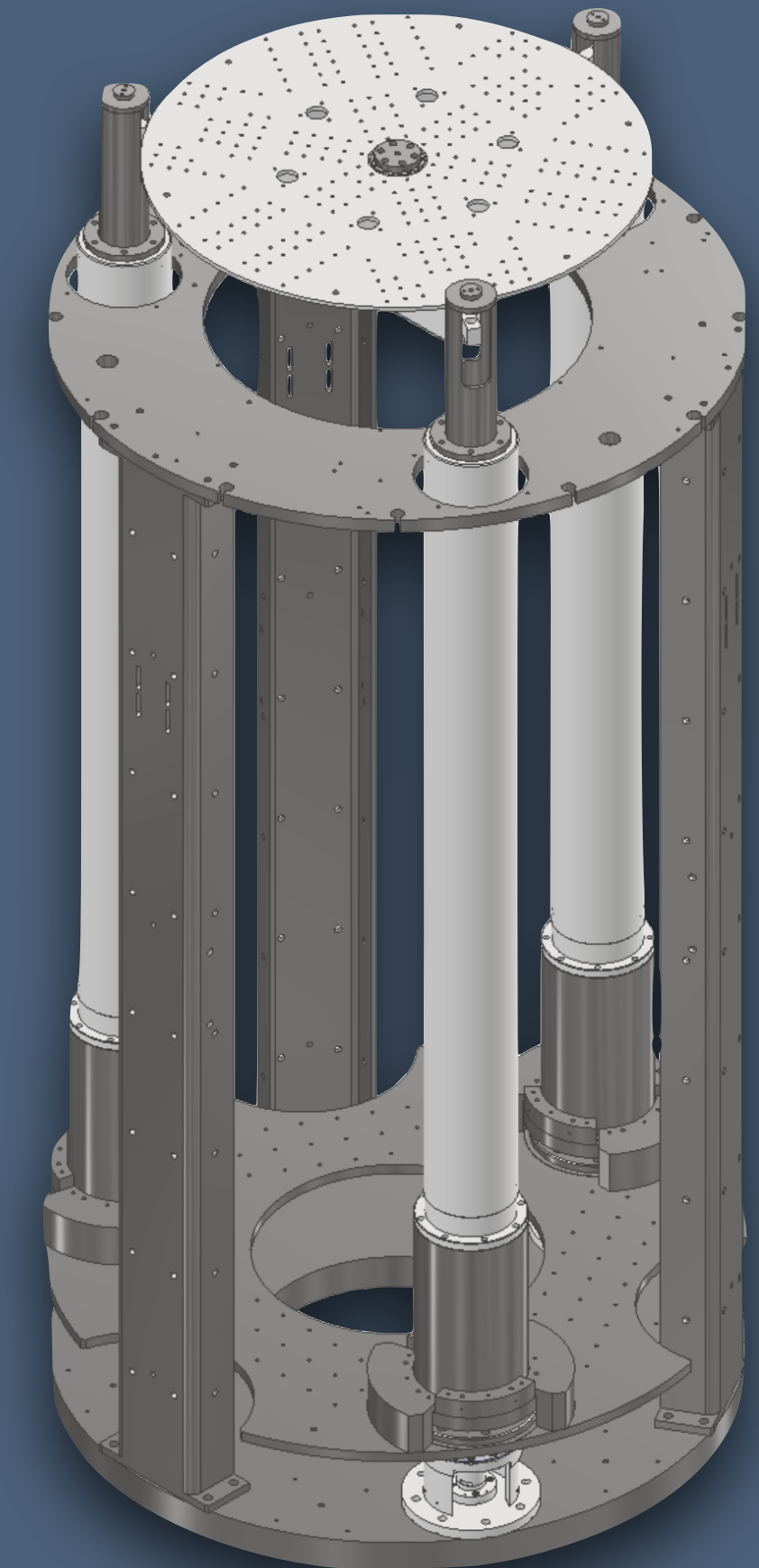
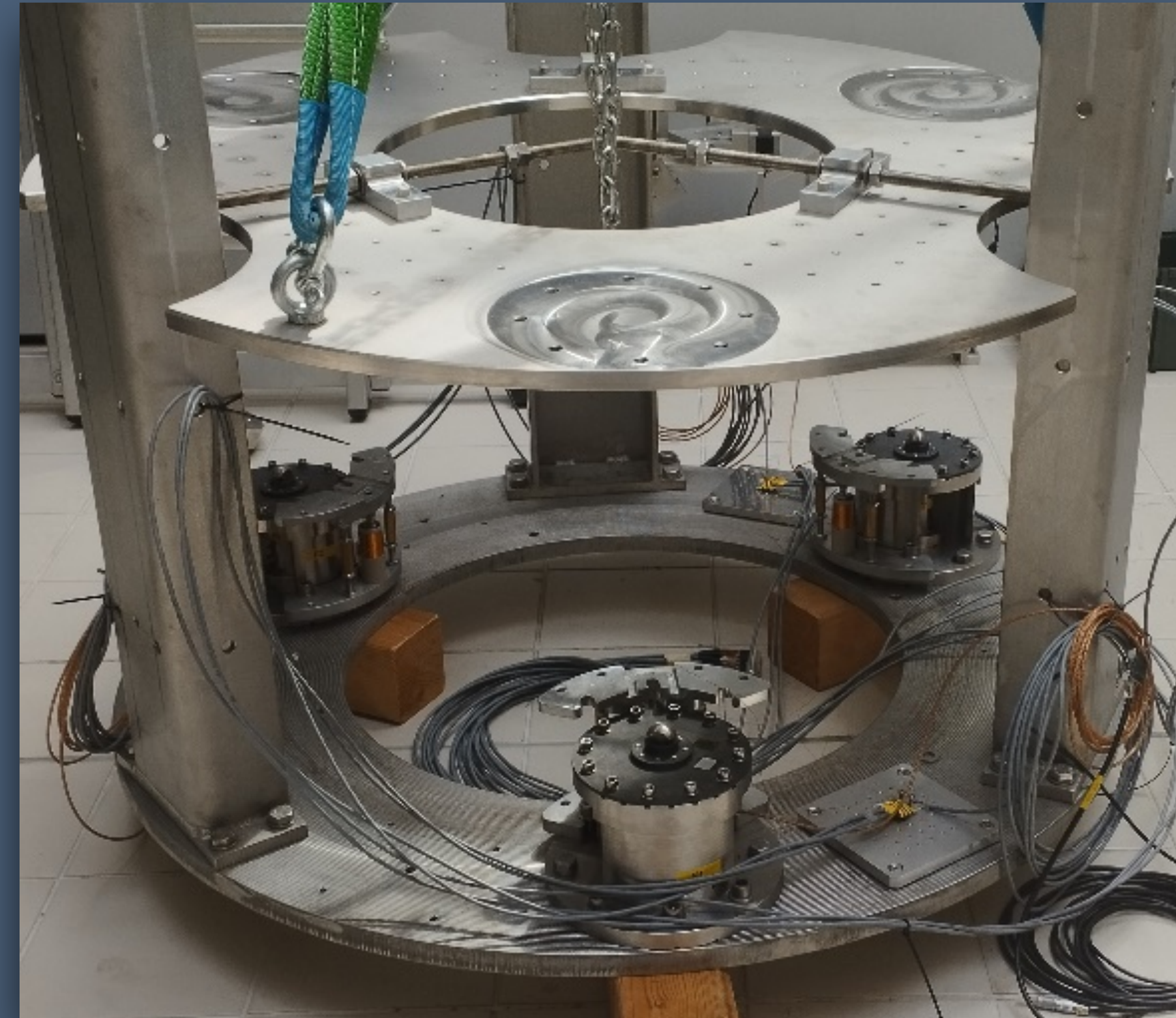
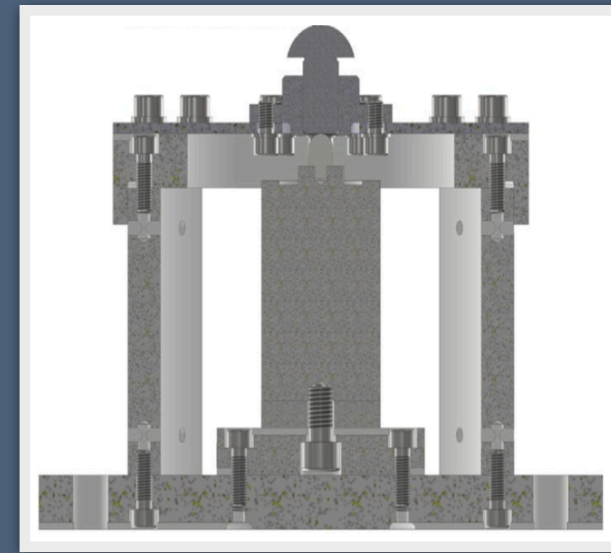


Aim:

- ▶ Better understanding of how to operate the 3DOF preisolator
- ▶ Potentially **improve the foot design**
- ▶ Explore the possibility of a **6DOF** pre-isolator

Approach:

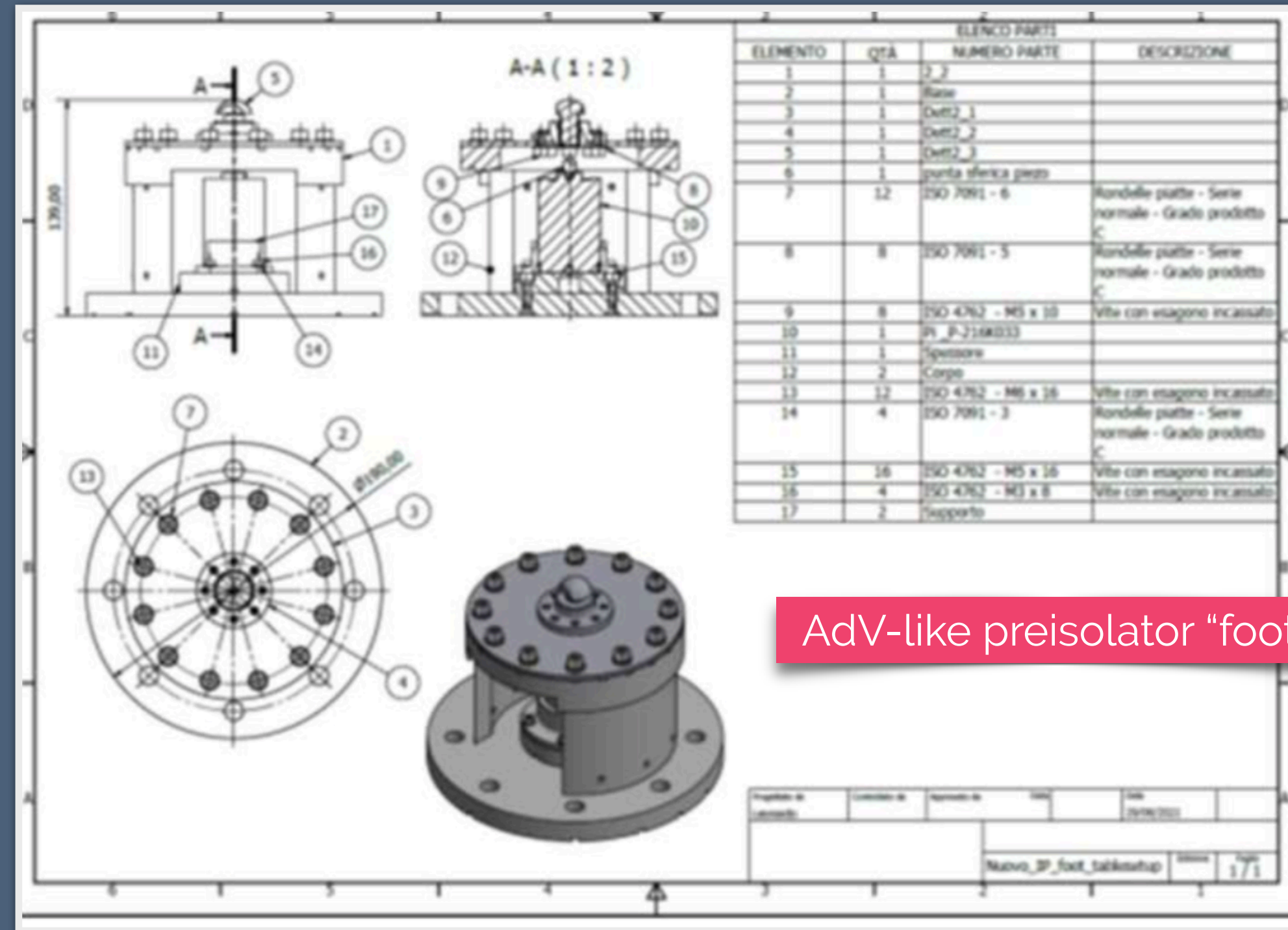
- ▶ Same **piezoelectric actuator**
- ▶ Same **foot** geometry
- ▶ Different geometry of the **platform**



Seismic Isolation Platform

Extensive standalone test campaign for the foot characterization:

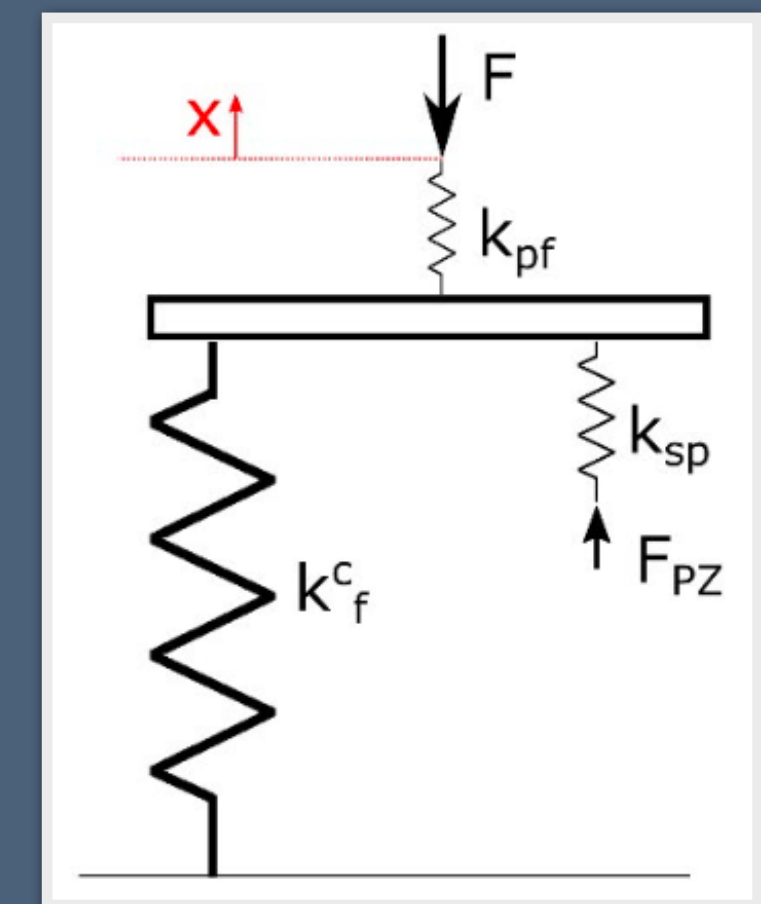
- Preload effect on the dynamics
- Repeatability and homogeneity of the response
- Long-term operation stability



AdV-like preisolator "foot"

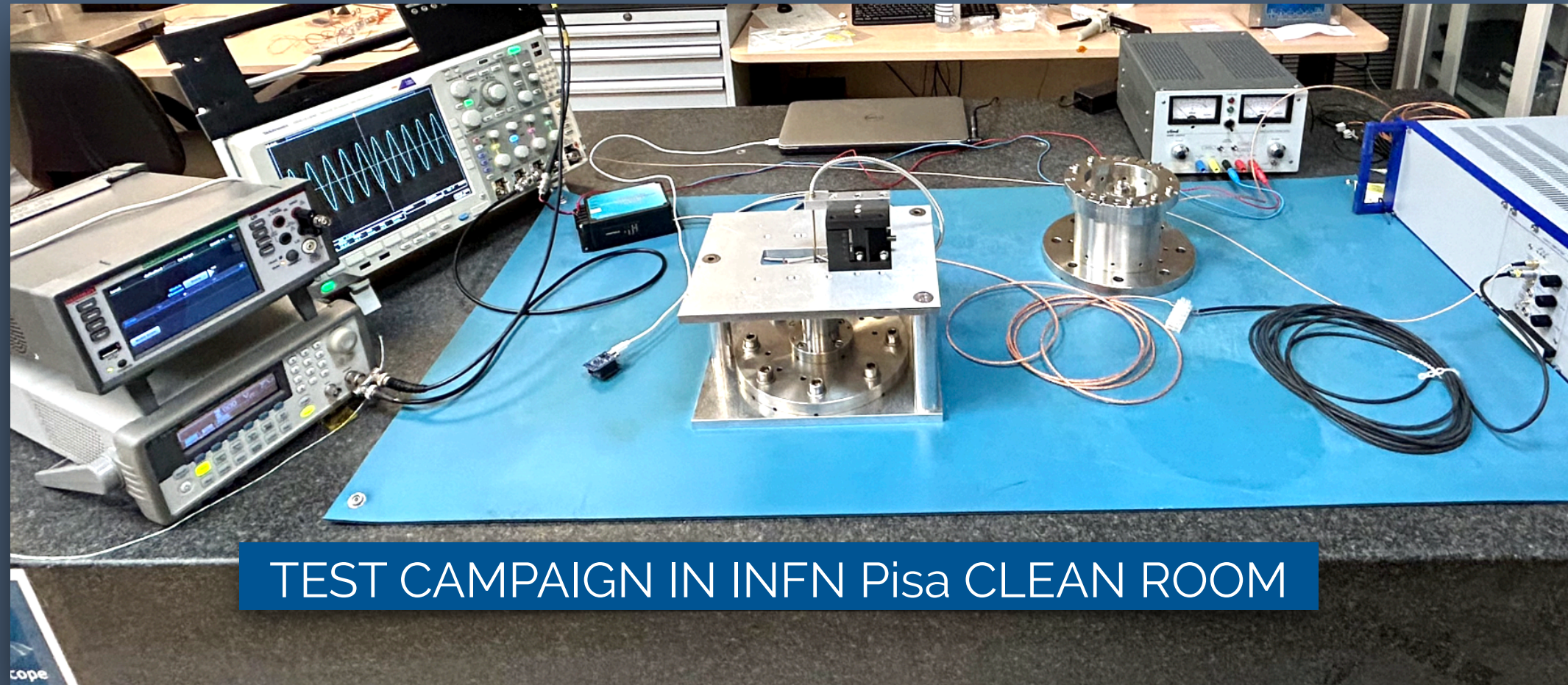
Validation of FEM simulations & Parameters determination

- ▶ Clean room long-term operation
- ▶ Tensile/compression machine measurement campaign

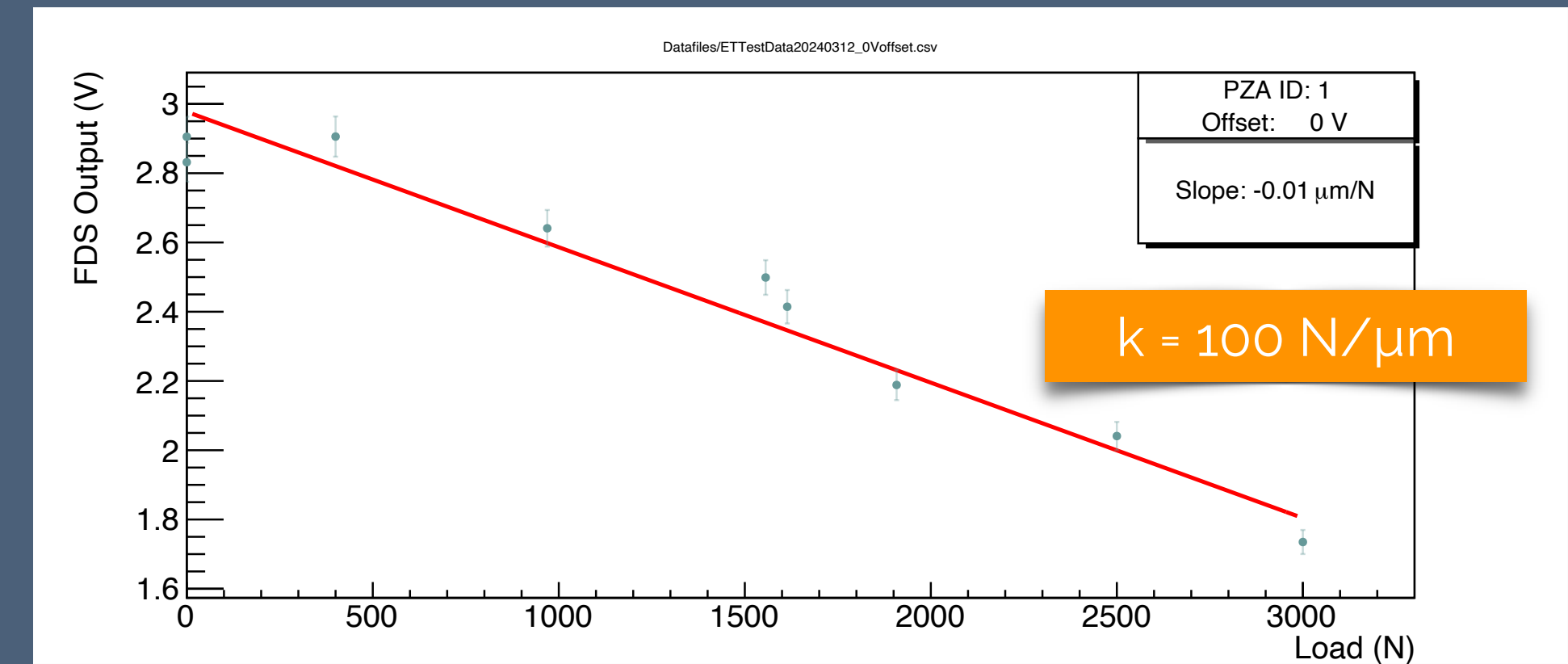
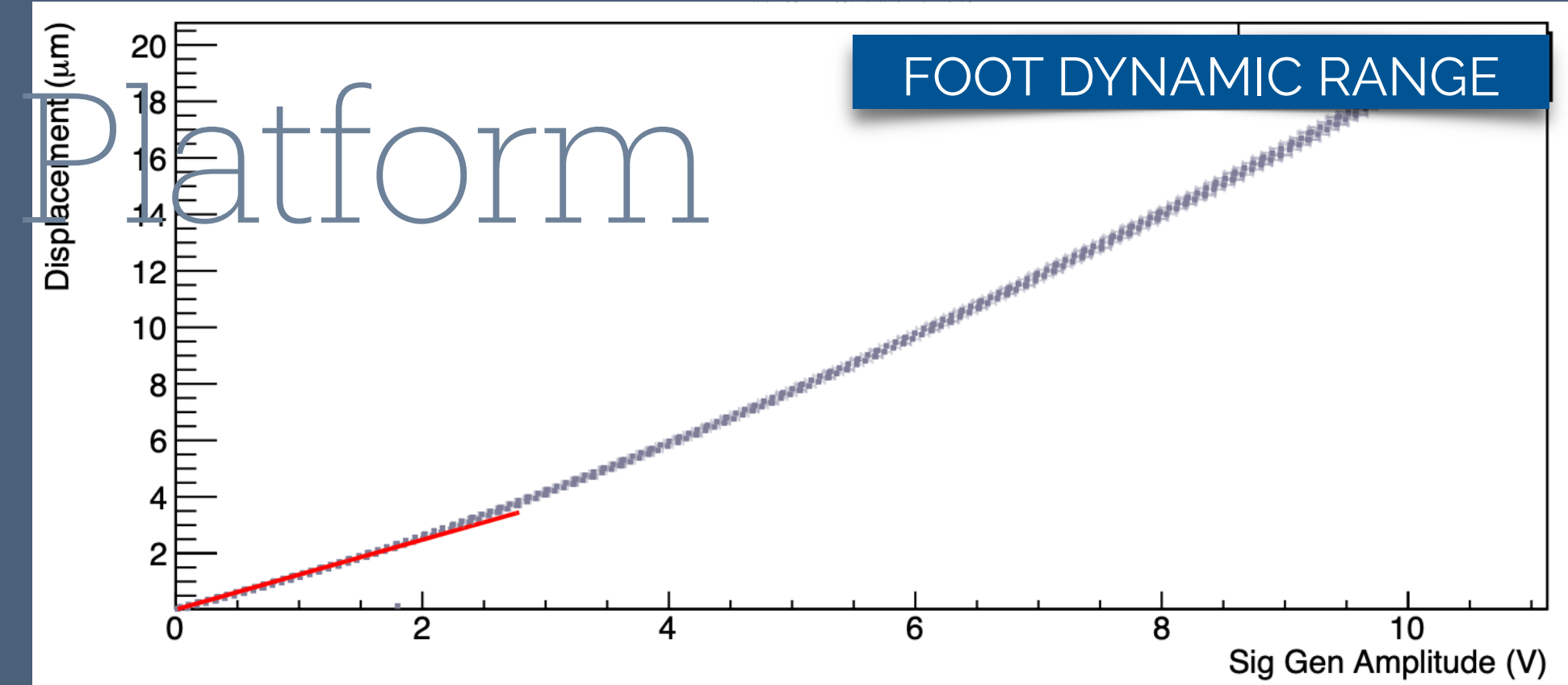
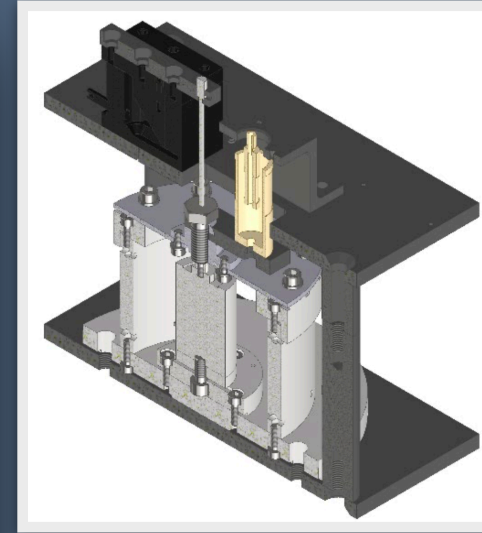


- AISI 304 stainless steel structure with 3 mm thick 250-grade maraging steel membrane
- Customized P-216K033 PICA preloaded piezo actuator

Seismic Isolation Platform



TEST CAMPAIGN IN INFN Pisa CLEAN ROOM

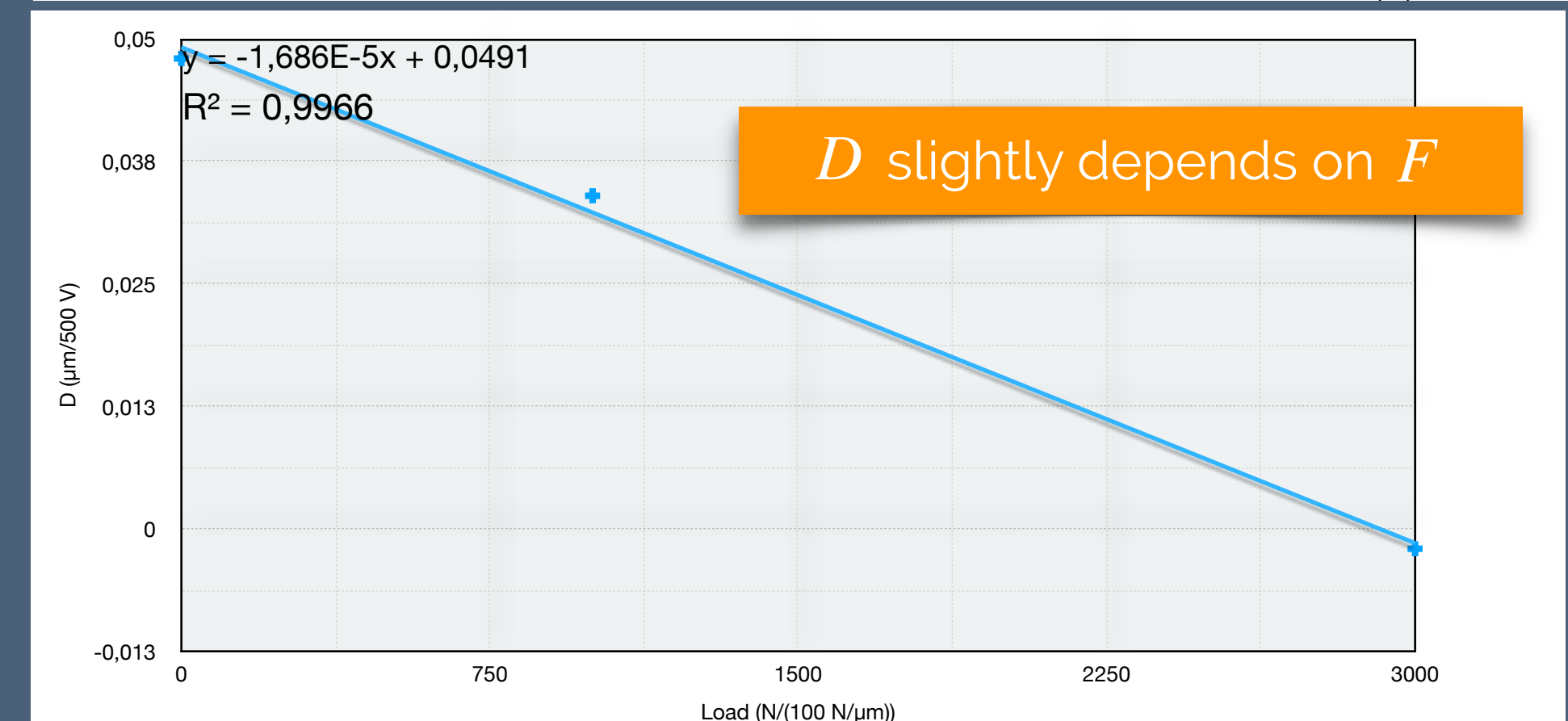
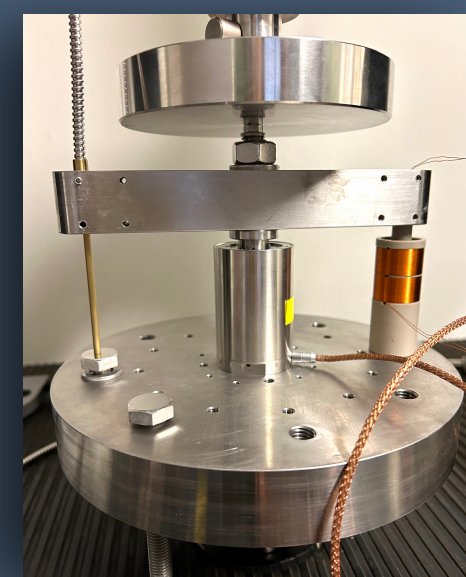


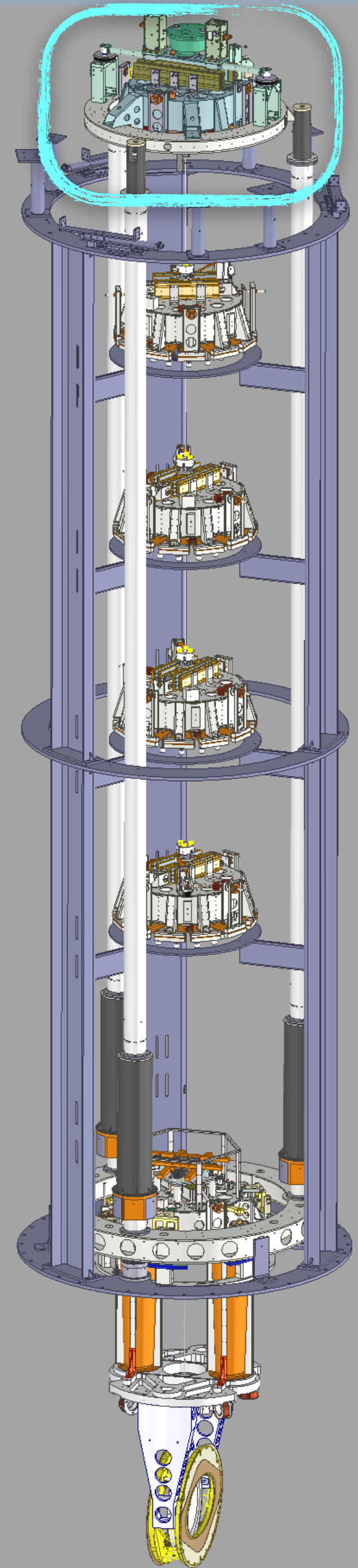
Piezoelectric actuators:

$$\Delta l = D \Delta V + \frac{F}{k}$$



TEST CAMPAIGN AT TENSILE/COMPRESSION MACHINE





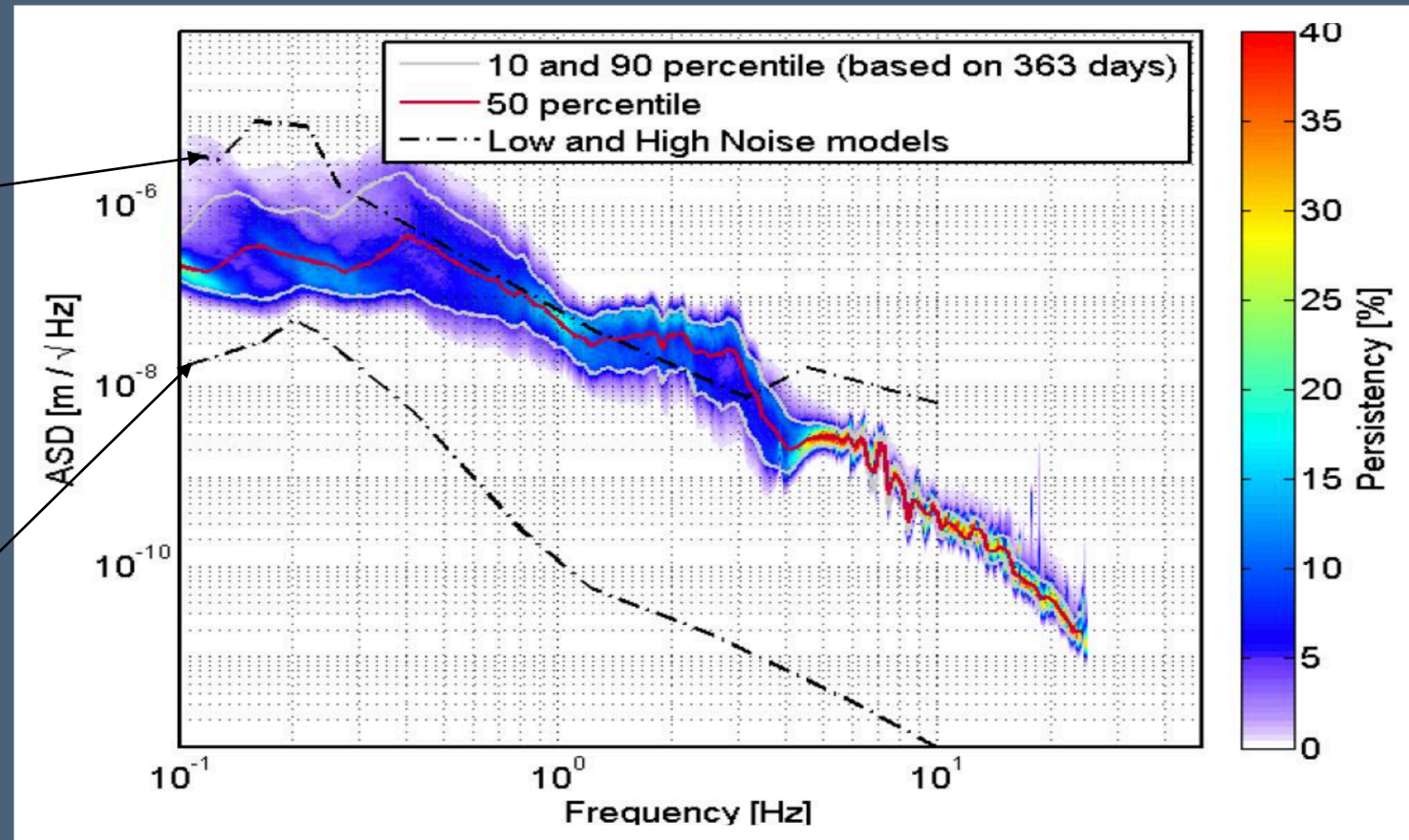
A new-concept Accelerometer

▶ Sensors a new **accelerometer** design

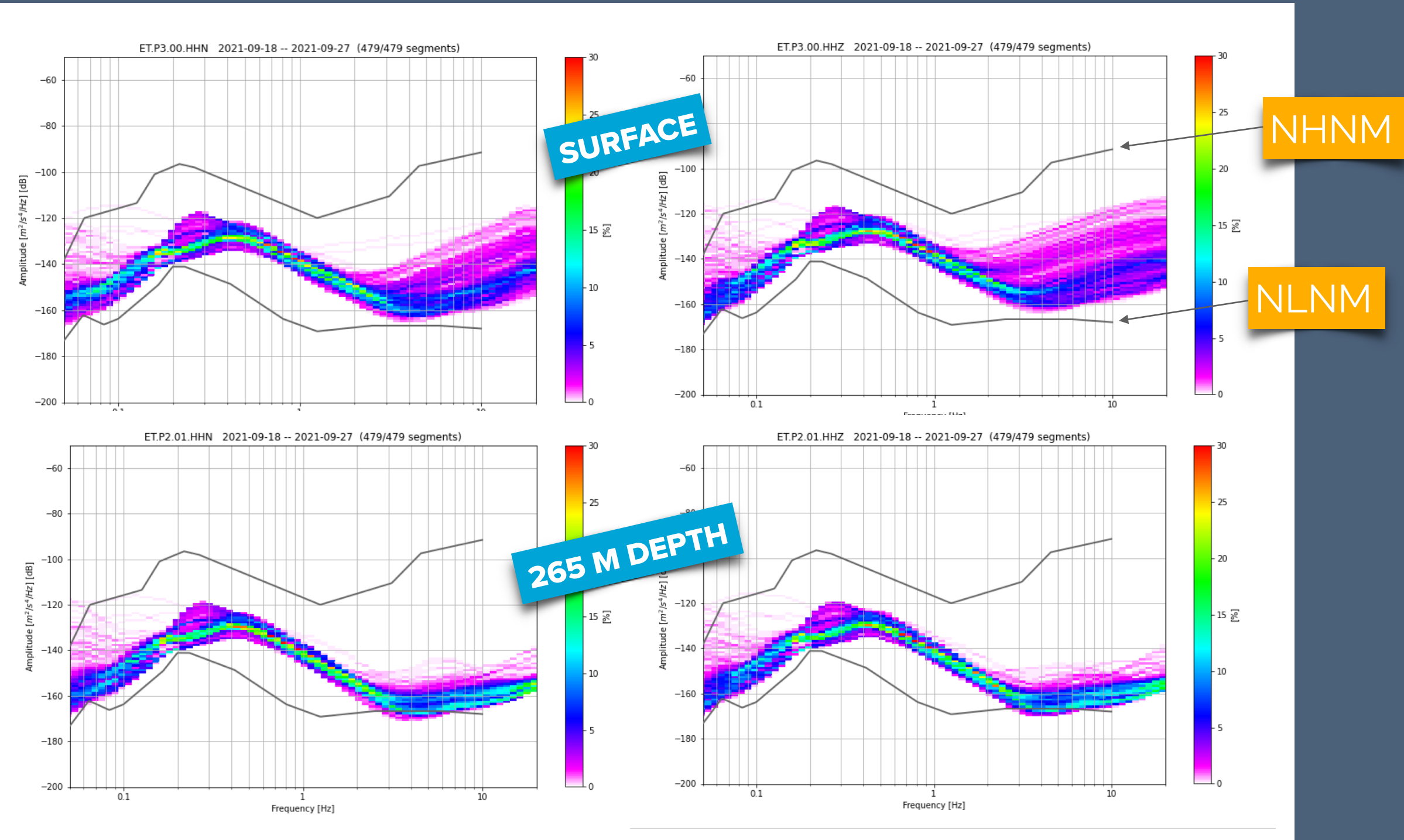
Seismic noise @VIRGO site

NHNM

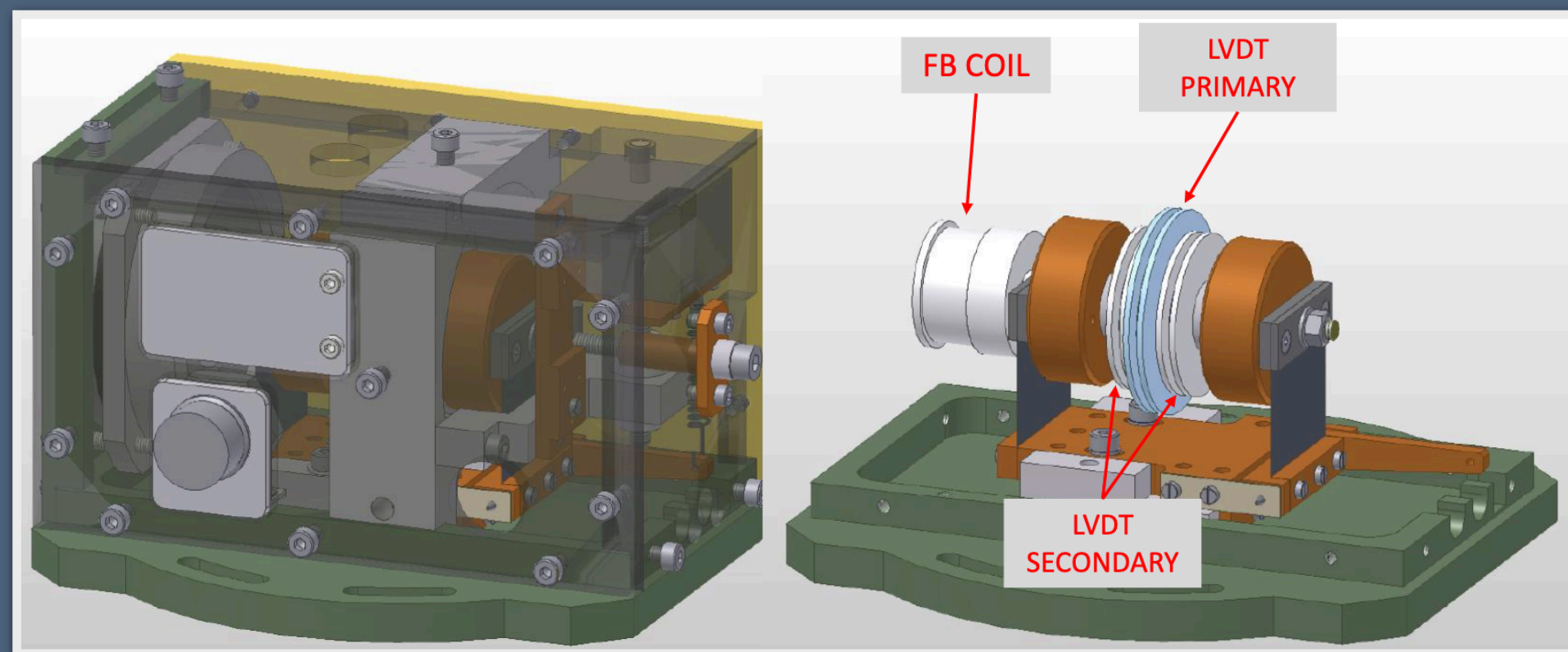
NLNM



2021 measurement campaign @Sos Enattos

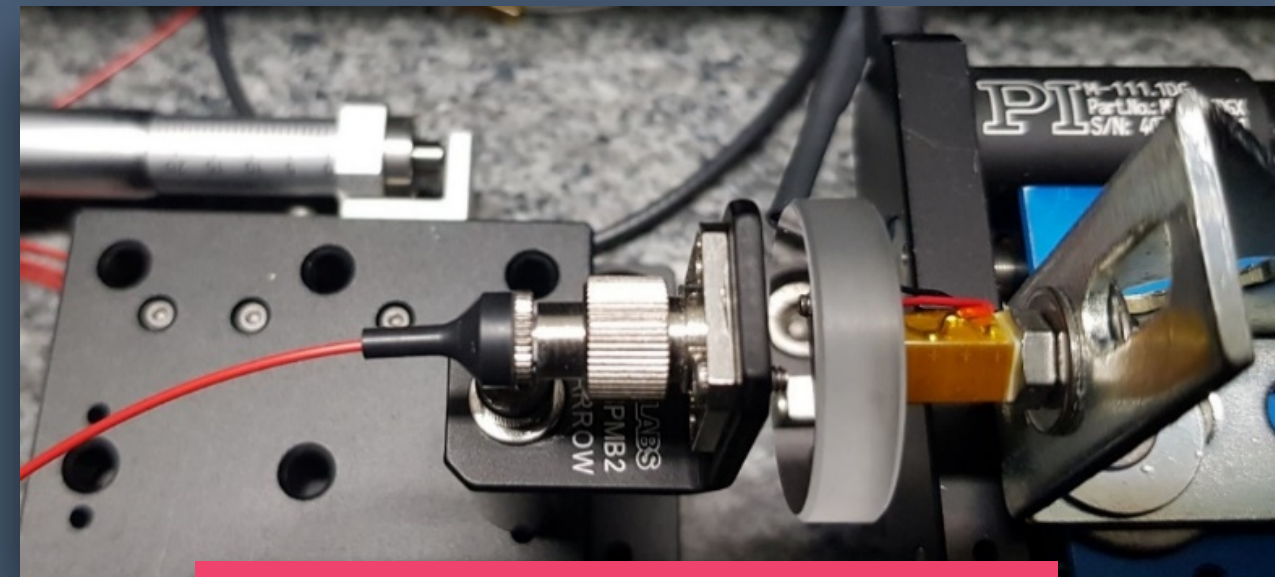
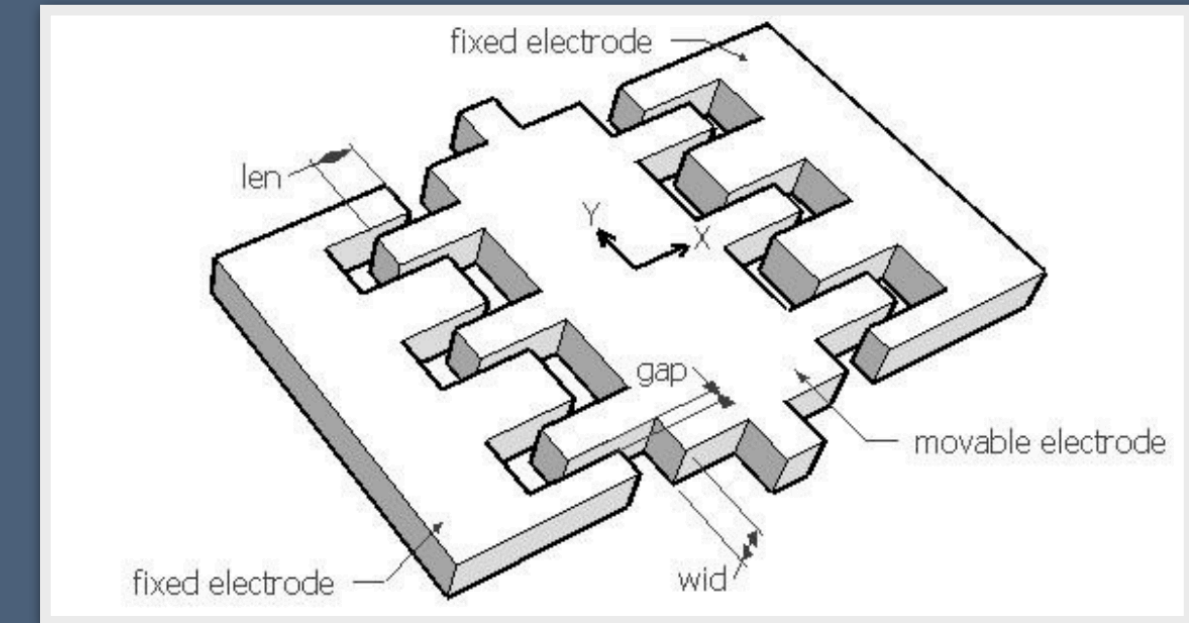
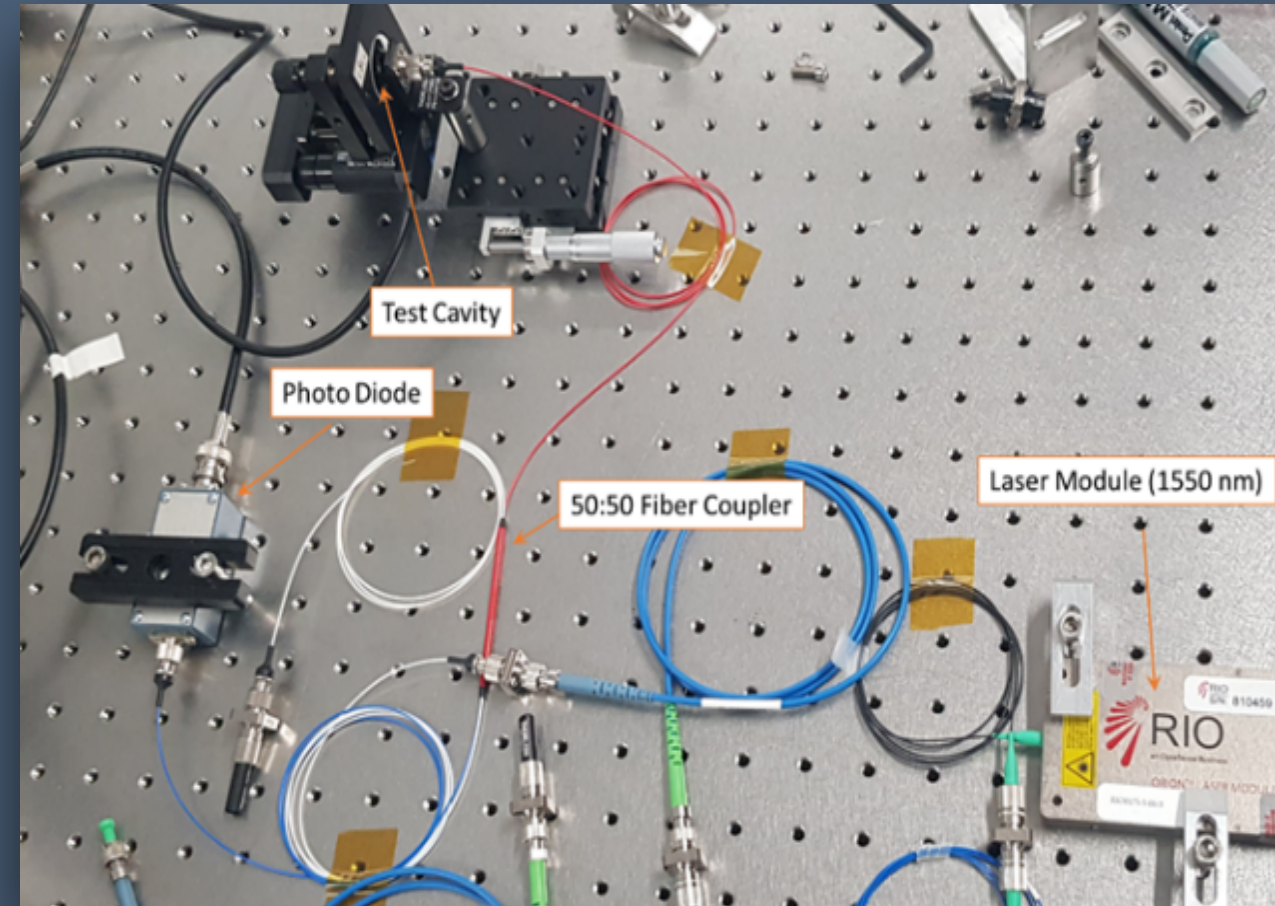
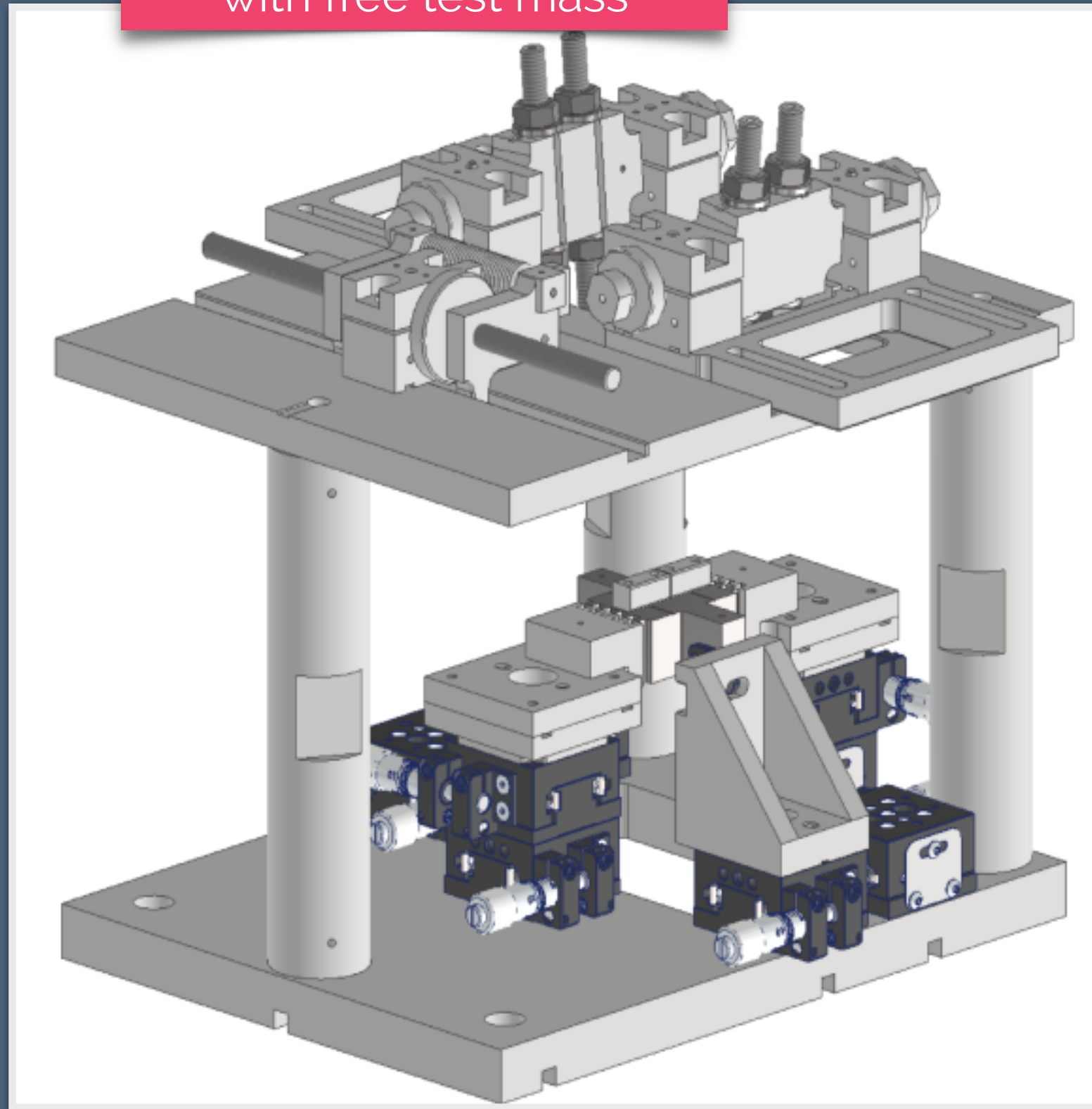


THE ACCELEROMETERS ON VIRGO SUPERATTENUATORS



Complete **redesign** of the inertial sensor developed in the 1990s for VIRGO

Non-inverted pendulum with free test mass



Optic cavity of the laser interferometer

Goal: sensitivity under 10^{-12} m/sqrt(Hz)

Interferometric readout of the mass displacement

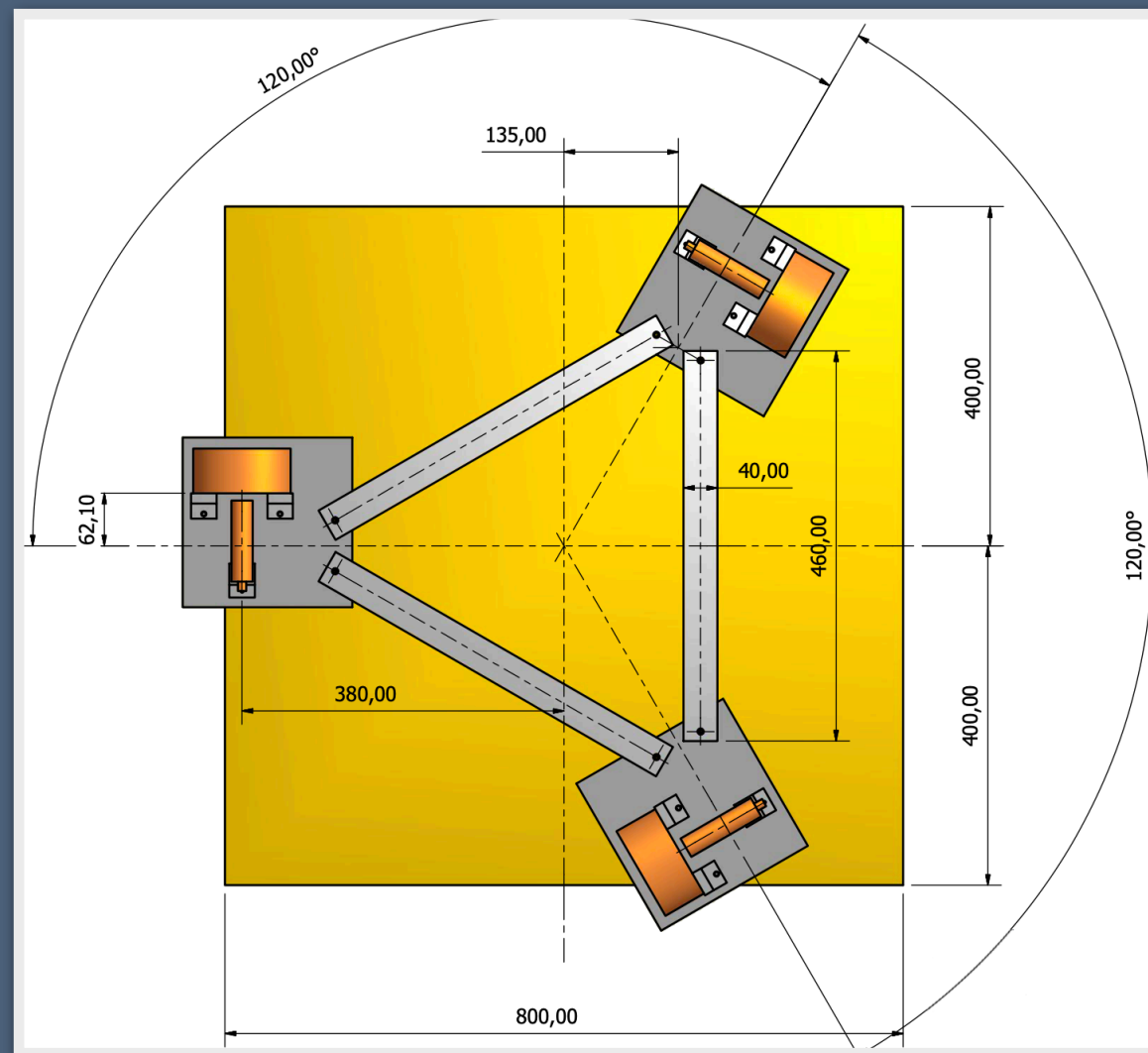
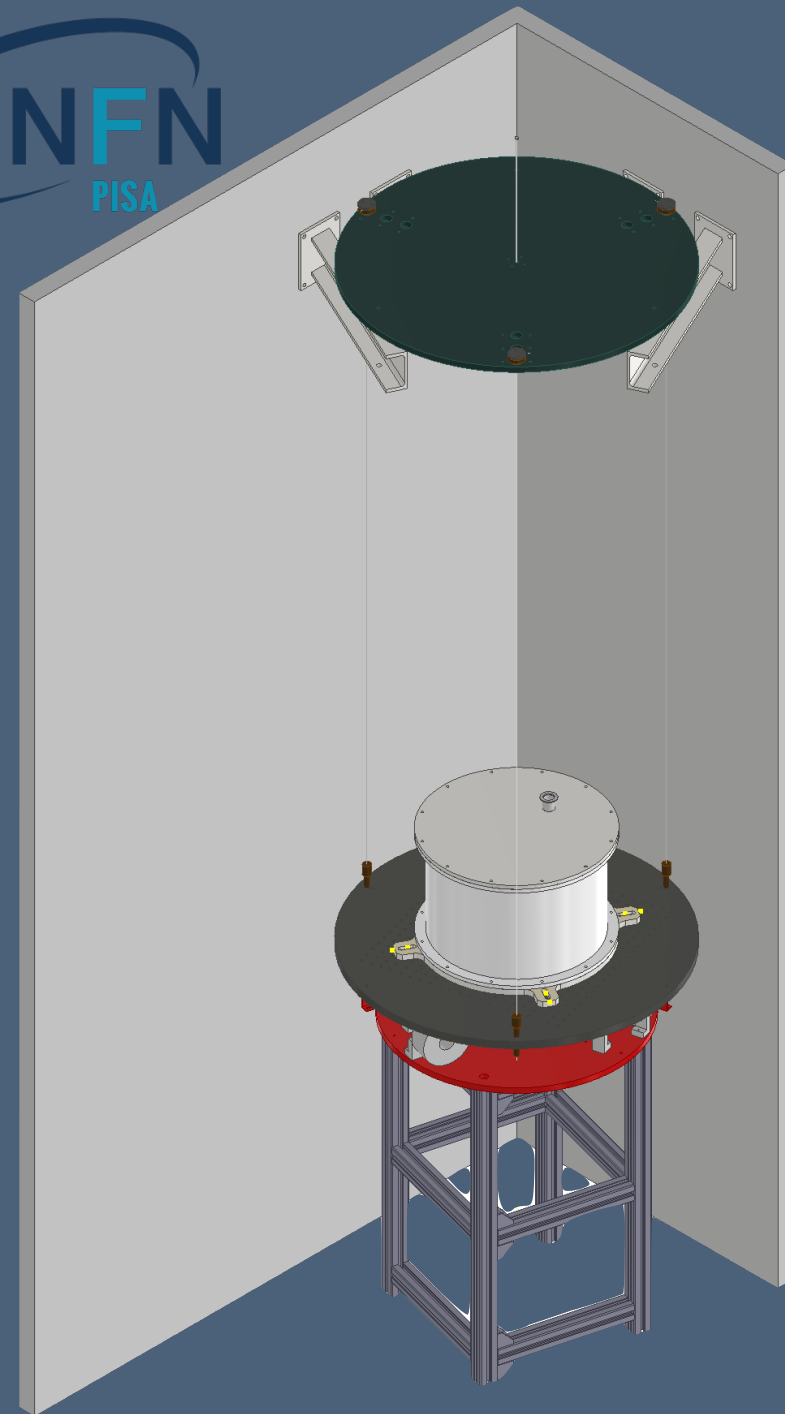
Electrostatic actuation at low voltage (<20 V)

Status: engineering model in production

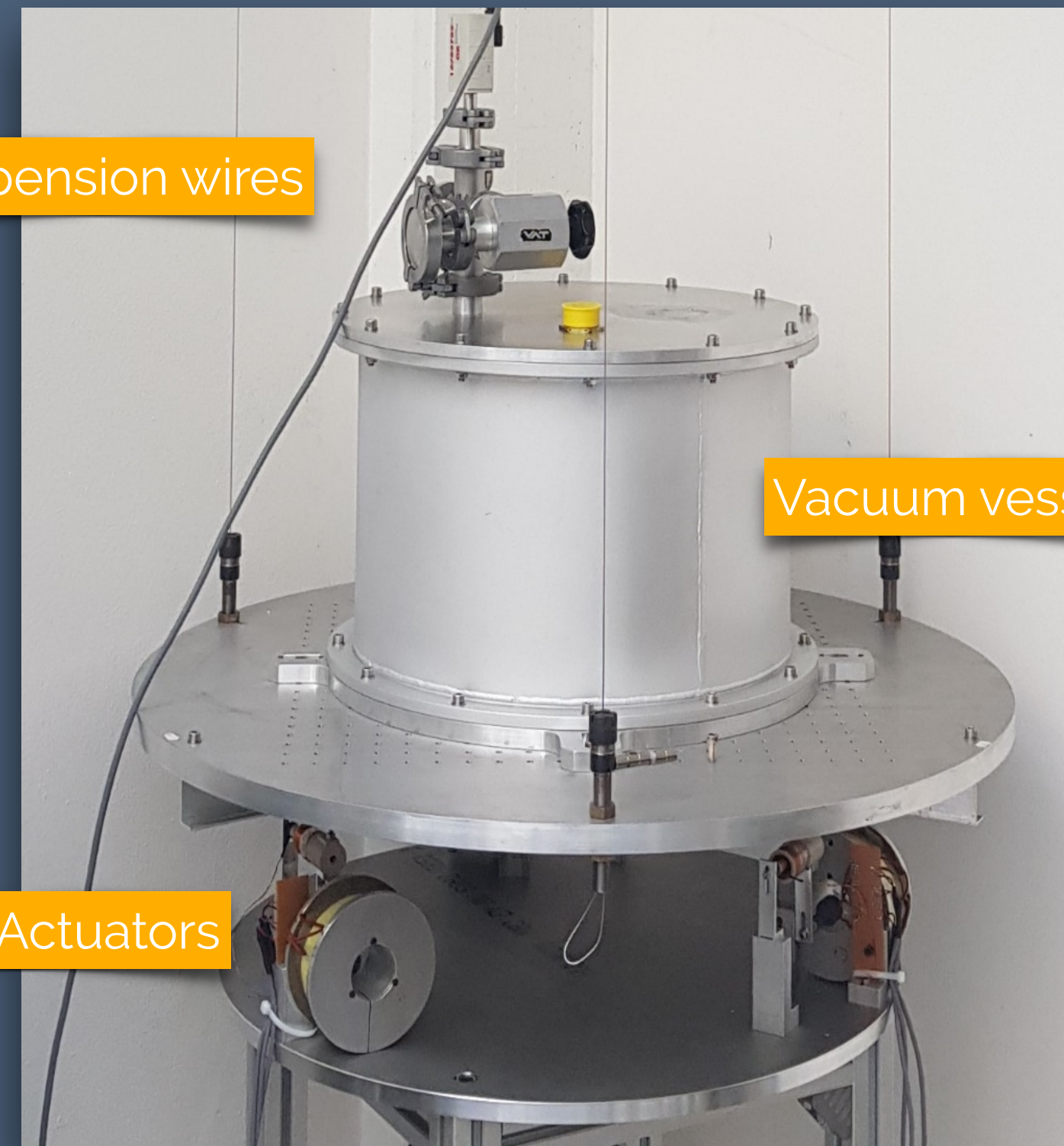
A new-concept Accelerometer

and a **dedicated test bench** providing one-stage seismic isolation

- ▶ **Vacuum vessel & thermic isolation**
- ▶ **Feedback control**
 - ▶ Actuators control and LVDT readout algorithms on DSP hardware
 - ▶ Monitoring of the LVDT signals with dedicated online software
- ▶ Multihole platform for sensors and actuators



Suspension wires



Vacuum vessel

LVDT + Actuators



The INFN Pisa group is exploiting its long-term expertise in upgrading the Superattenuator to meet the requirements of next-generation experiments

- ▶ a **2 m Superattenuator** is under installation in INFN Pisa laboratories as a **test bench** for specific elements upgrades
- ▶ a dedicated standalone **test bench with one-stage isolation in vacuum** with **feedback control** for the **new accelerometer** to meet more demanding sensitivity requirements
- ▶ ... and many other R&D activities and projects
 - * SA for the **ET** Era
 - * **AdV+** operation and upgrade
 - * **NGSA** (Open Call CSN5) improve passive performance of mechanical filter of a SA and probe new Inverted Pendulum in Nested configuration (NIP).
 - * **CAOS** (PNRR) Project @ University of Perugia: construction of two long Superattenuators (~ 15 m) for future GW detectors

Thanks for your attention!