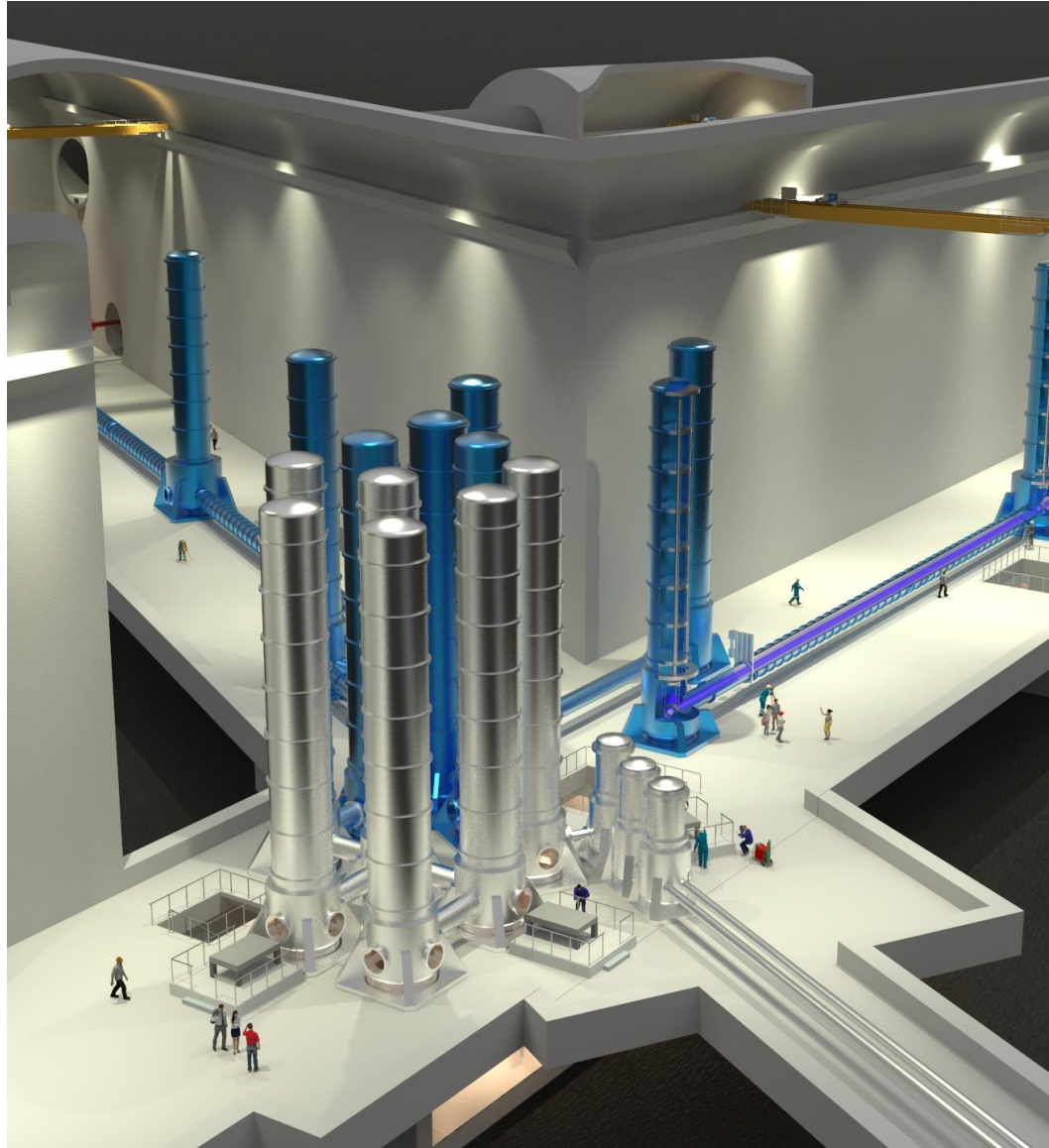


E-TEST: Einstein Telescope EMR Site and Technology

Haidar Lakkis

On behalf of Precision Mechatronics Laboratory (ULiege)

26.05.2025



E-TEST objectives

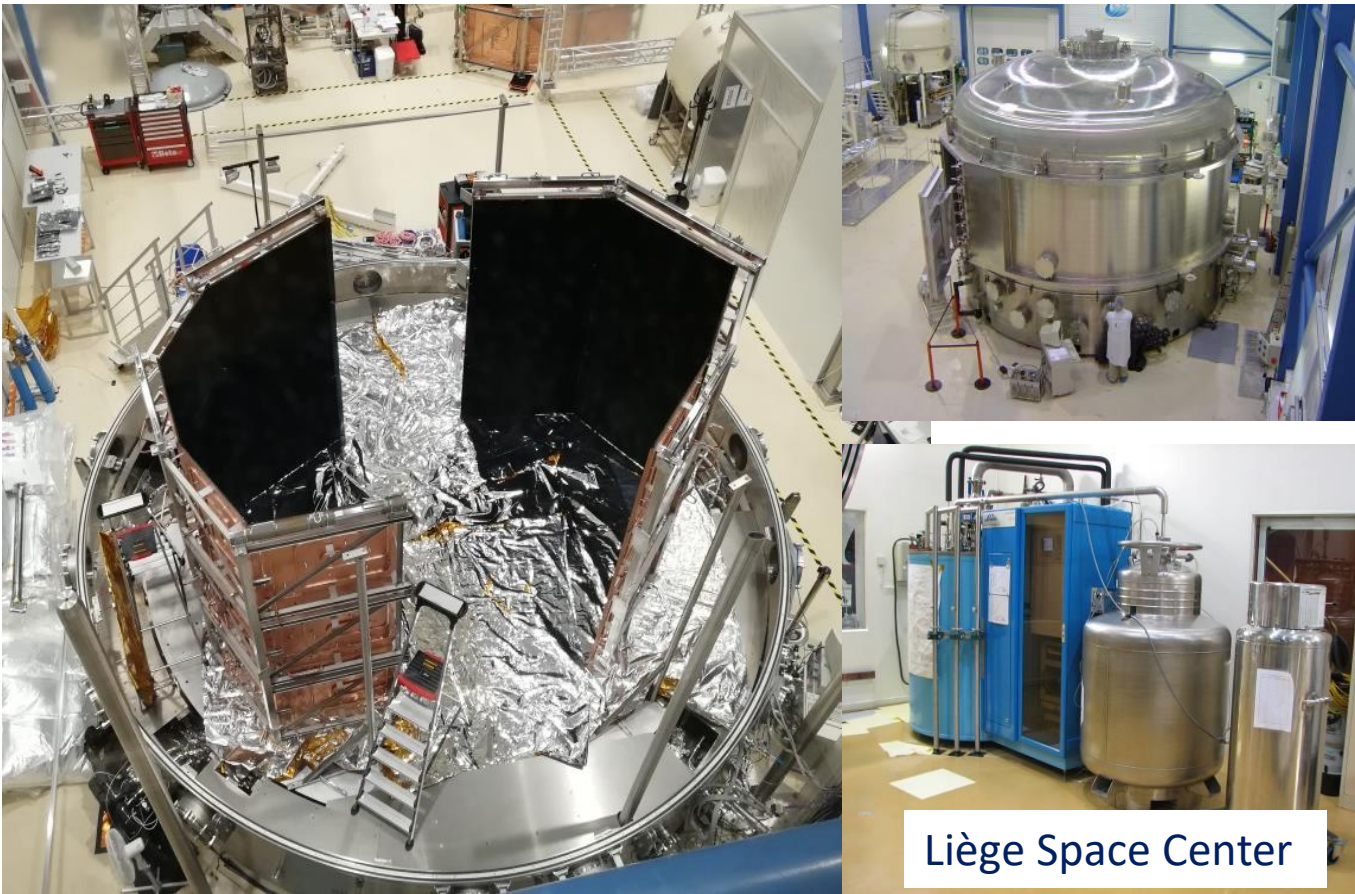
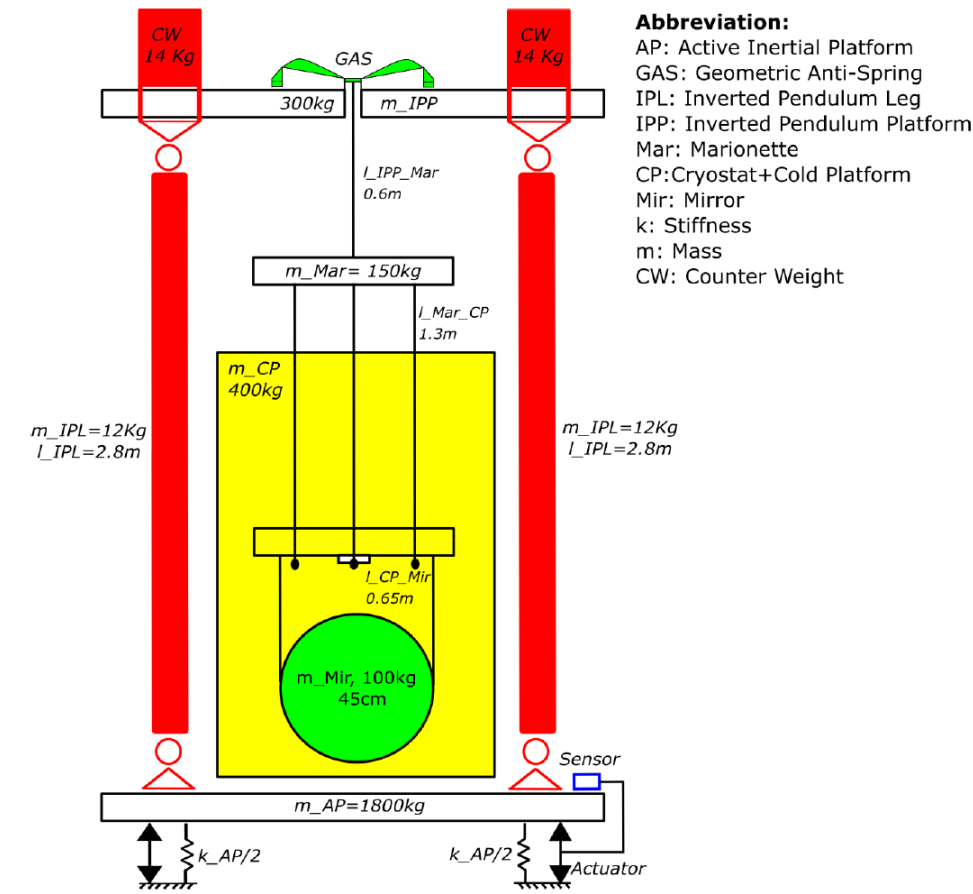
- Large mirror (100 Kg)
- Cryogenic temperature (10-20 K)
- Isolated at low frequency (0.1-10 Hz)
- Compact suspension (4.5 meters)

E-TEST feasibility strategy

E-TEST is a project funded by the Interreg Euregio Meuse-Rhine and ET2SME consortium, which allow us to capitalize on existing infrastructure at Centre Spatial Liège (CSL) for the construction of the facility.



E-TEST: how it started



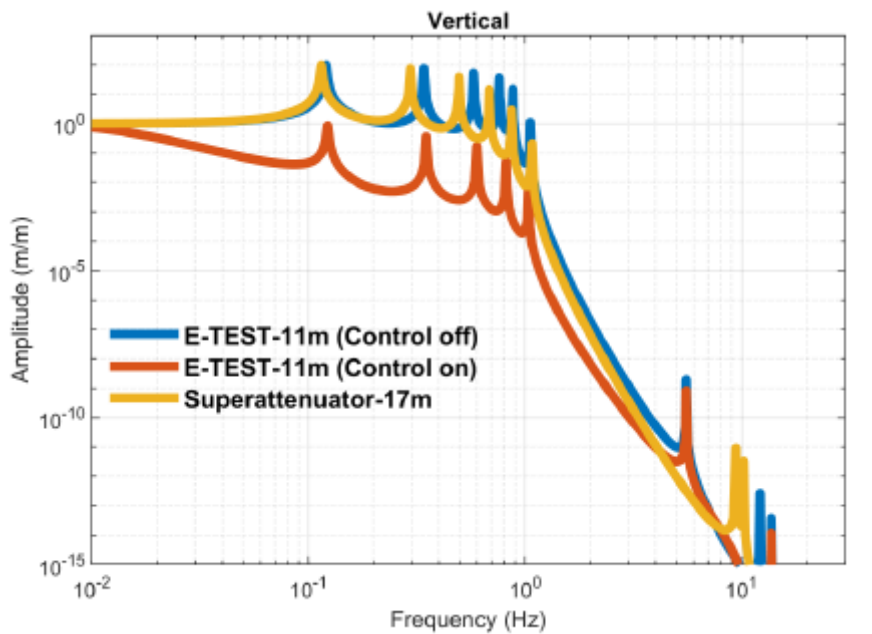
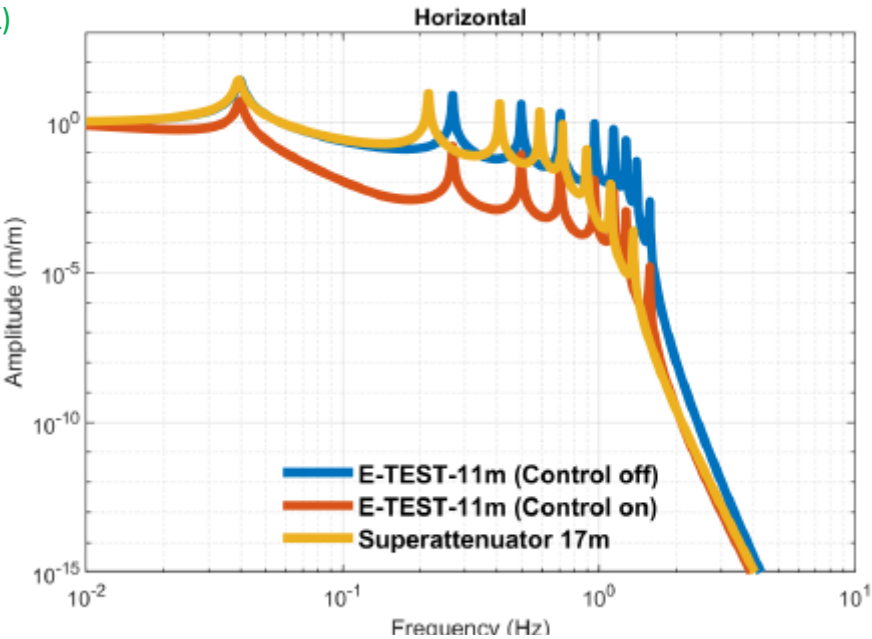
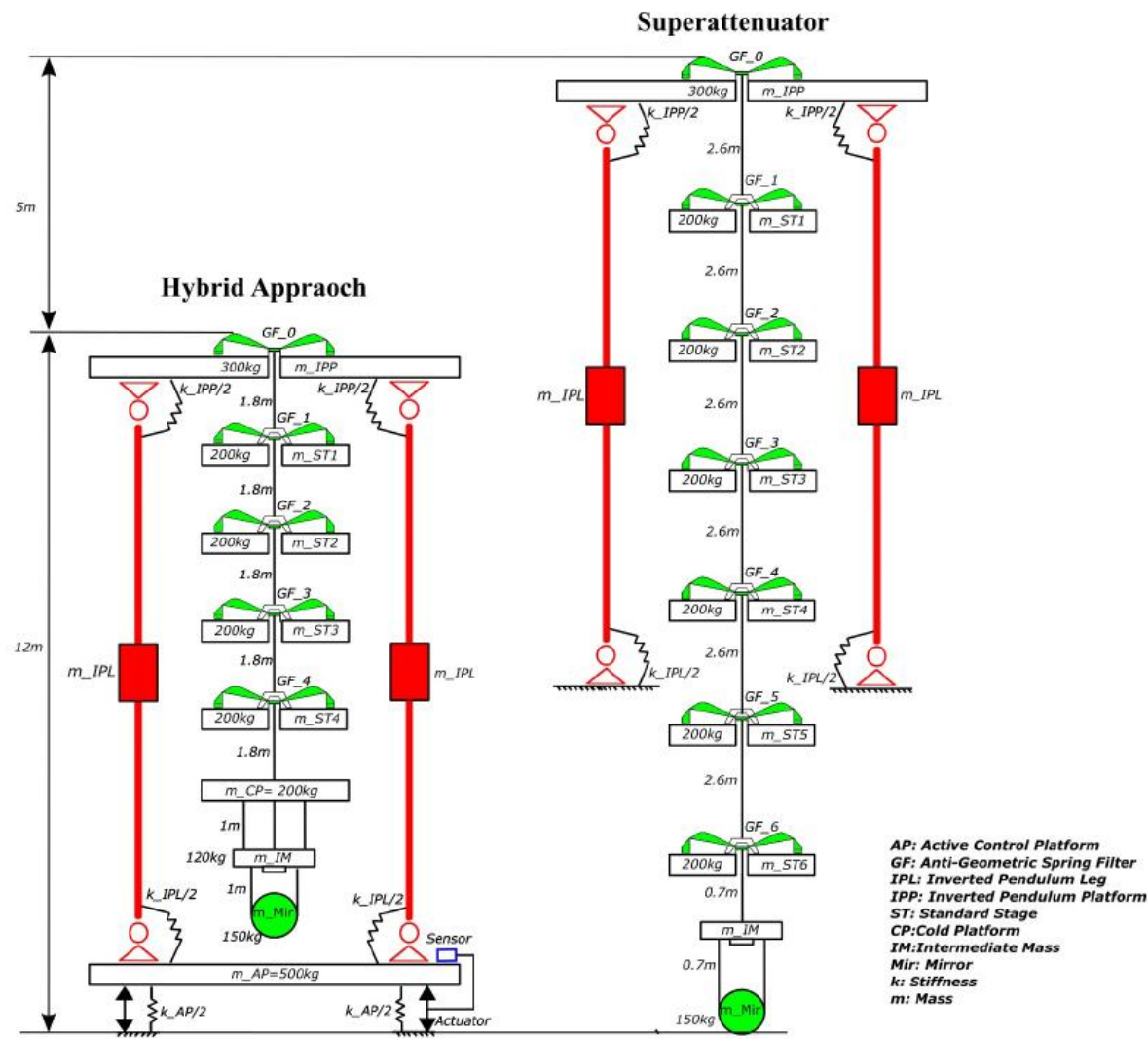
Hybrid (active + passive) isolation
Radiative cooling

26.05.2025

E-TEST: how it started

Contact: Ameer Sider (PML)
asider@uliege.be

Hybrid approach = fewer stages



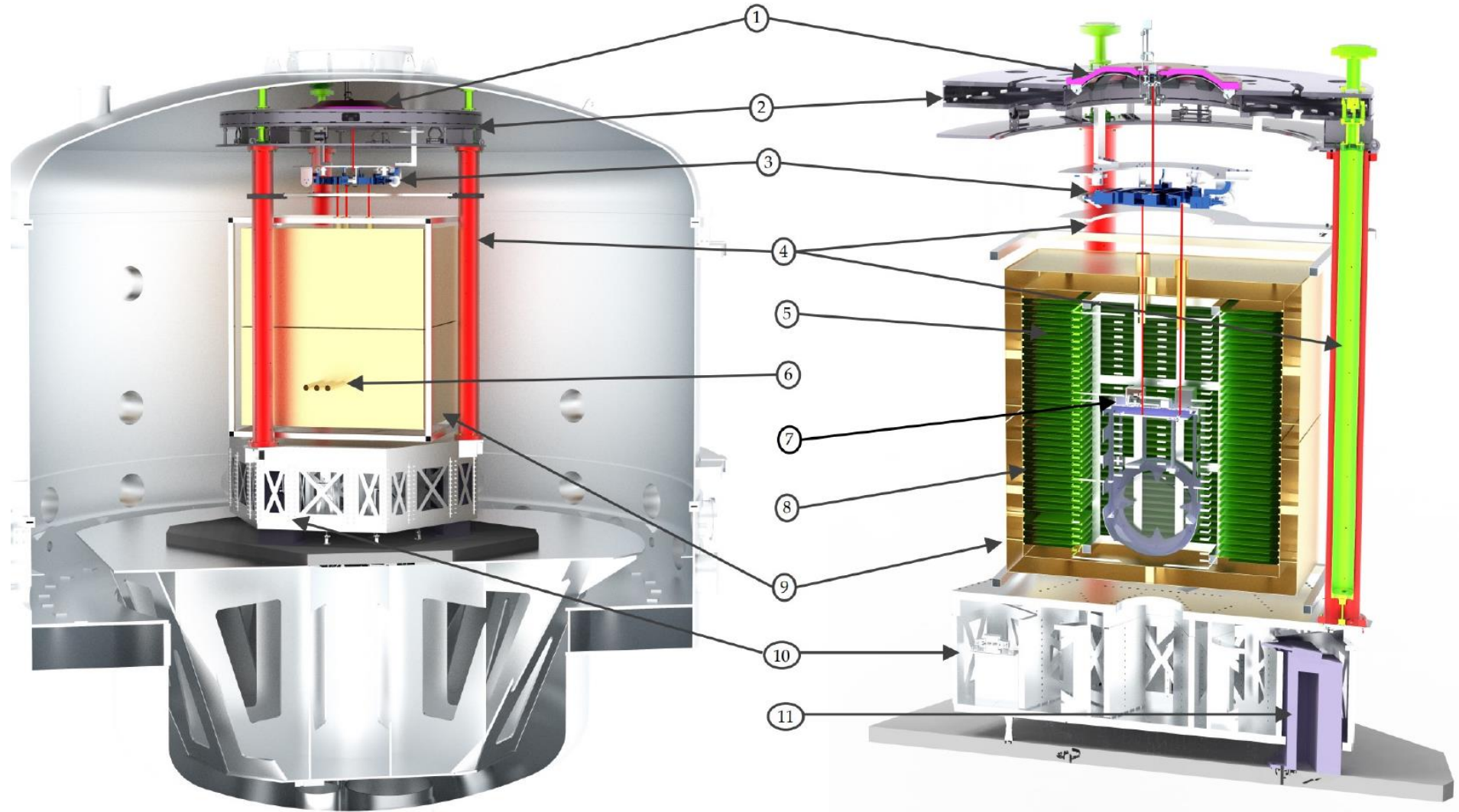
From a design concept to technical drawings

Vibration isolator

- 1) GAS filter
- 2) Inverted Pendulum (IP) platform
- 3) Marionette
- 4) IP legs
- 10) Active platform

Cryogenic payload

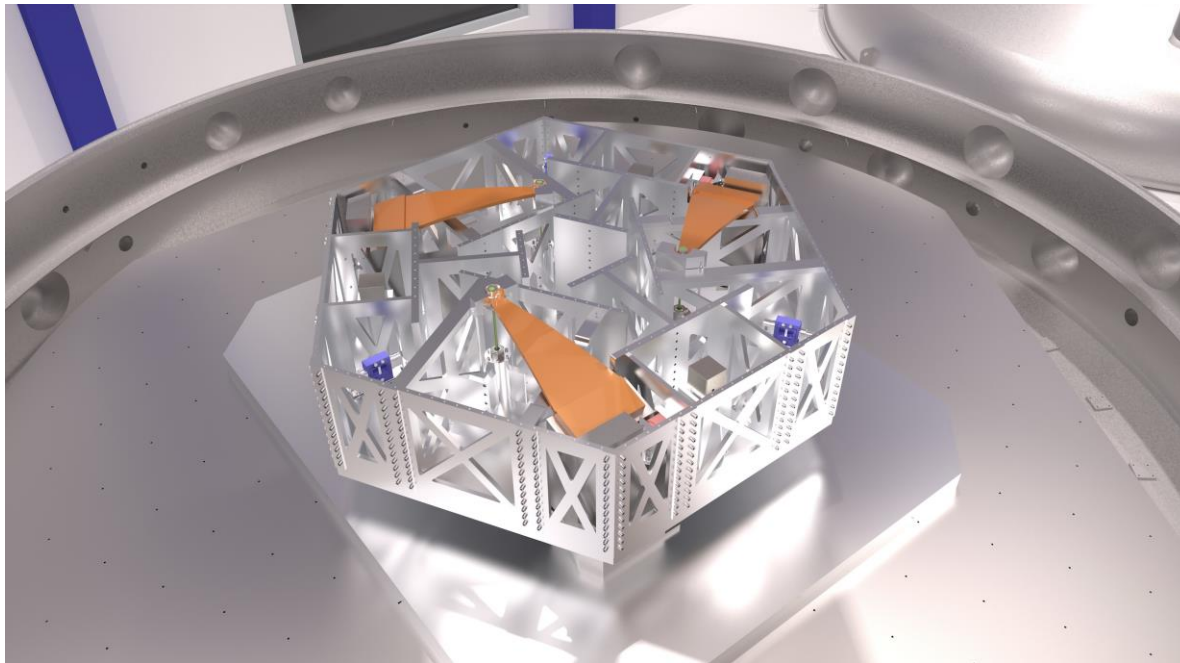
- 5) Heat exchanger and cold platform
- 7) 25K inner thermal shield
- 8) 80K outer thermal shield



From a design concept to technical drawings

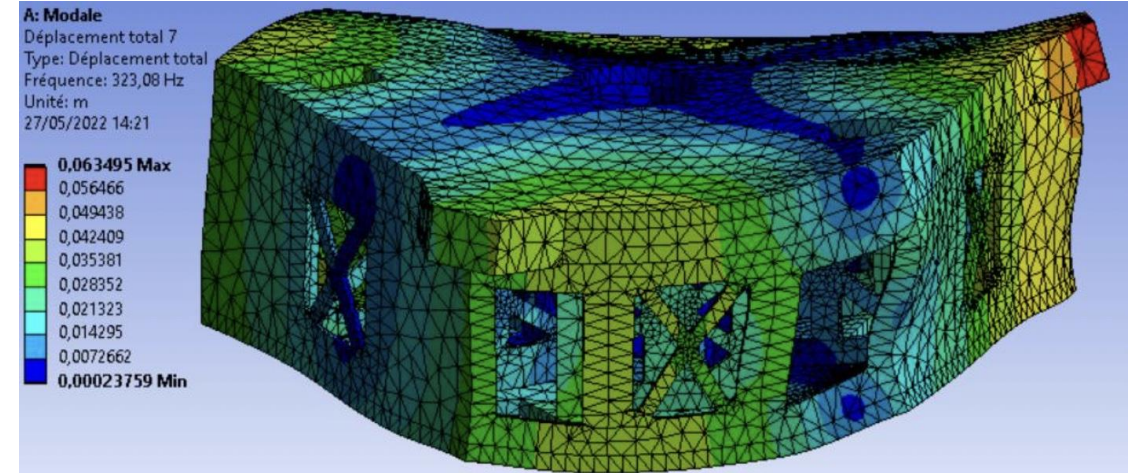
Mechanical isolation system

- Active platform is a scaled-up redesigned version of the Ham
- First flexible mode above 300 Hz



Contact: Ameer Sider (PML)
asider@uliege.be
Alessandro Bertolini (Nikhef)
alberto@nikhef.nl

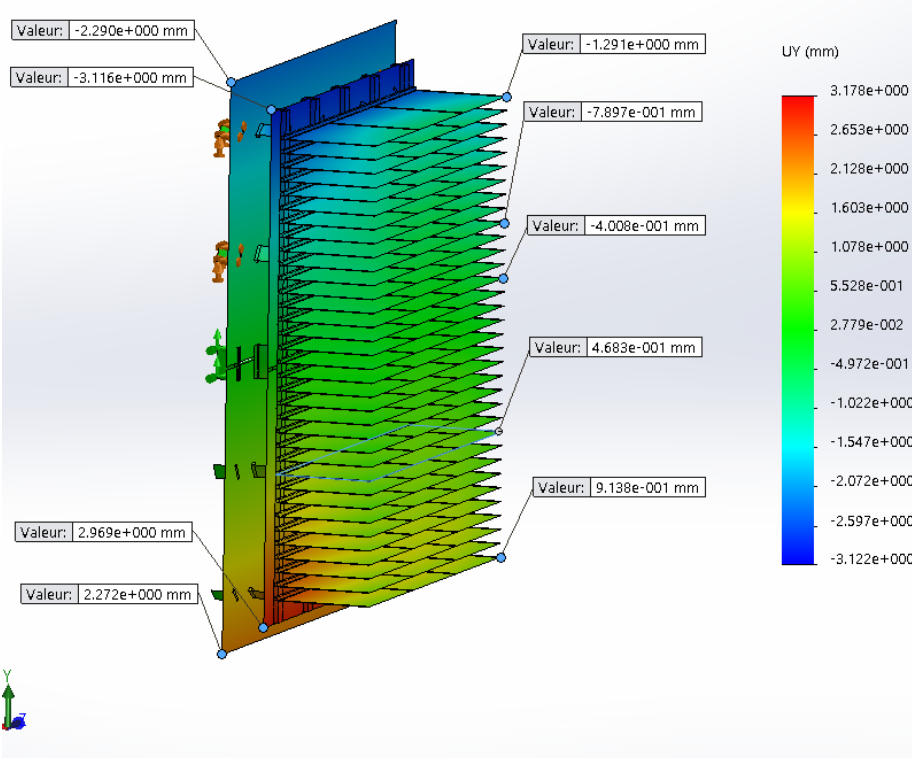
26.05.2025



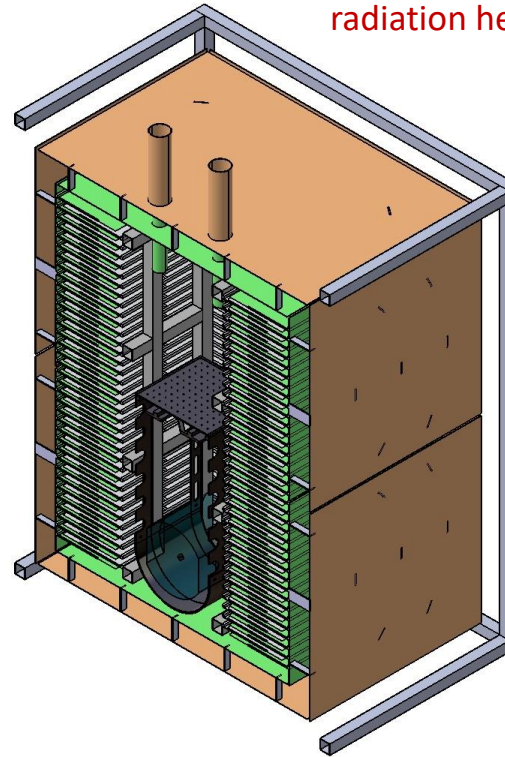
From a design concept to technical drawings

Radiative cooling design

- Overall dimensions: 1.8 x 1.6 x 2 m³
- Conventional radiator design with **horizontal fins** (20K)
- Three 30-mm diameter optical feed-throughs towards the mirror



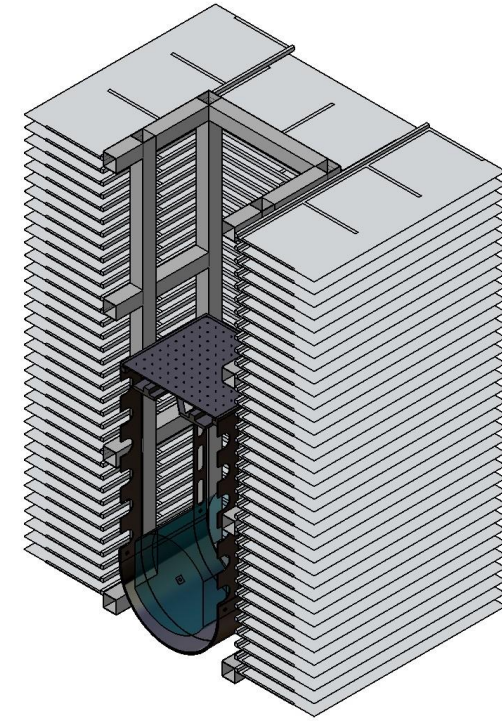
radiation heat transfer for mirror
cooling



Outer cryostat

(connected to the vacuum chamber):

- 80K LN2 shield (brown)
- 20K GHe panels (green)



Inner cryostat

suspended and conductively
linked to the silicon mirror

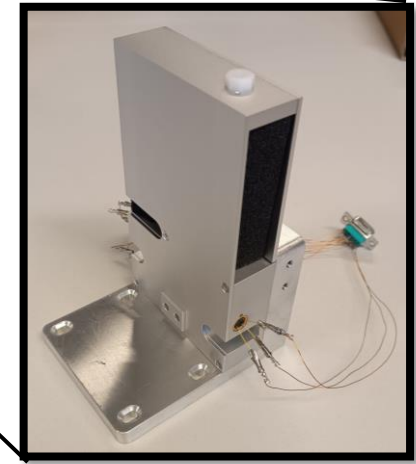
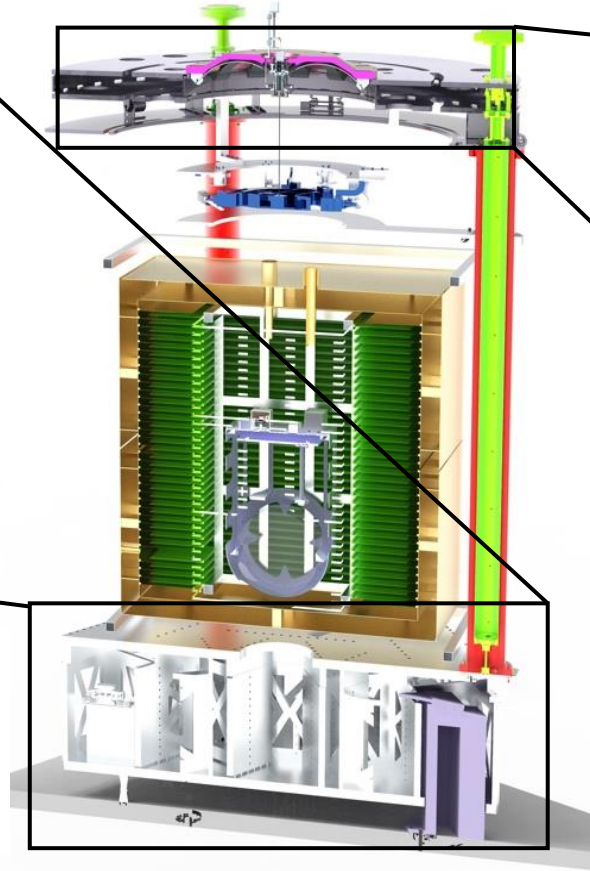
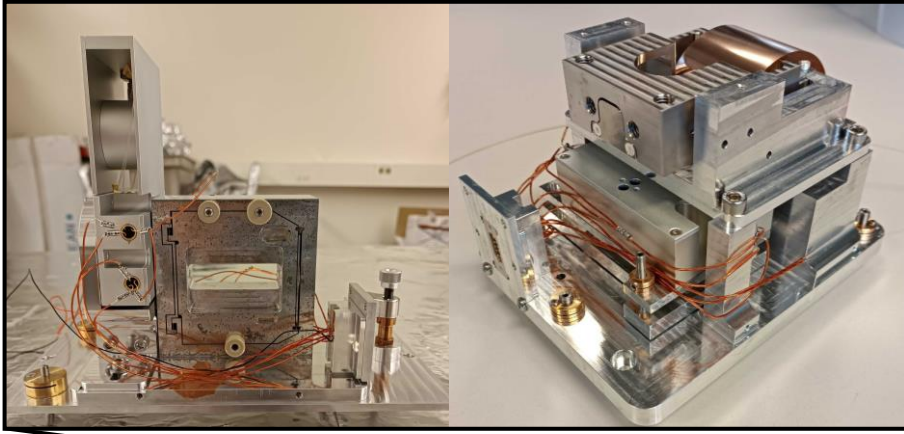
Contact: Cedric Lenaerts (CSL)
Cedric.Lenaerts@uliege.be



Inverted pendulum displacement sensing

Contact: Anthony Amorosi (PML)
Anthony.amorosi@uliege.be

High-resolution, low-frequency, optical horizontal seismometer



- Sub-Hz resonance frequency.
- pm-Michelson optical readout.
- Approx 1 Hz resonance frequency.
- pm-Michelson optical readout.

+ BOSEMs for DC and relative motion reading.

Homodyne quadrature Michelson interferometers

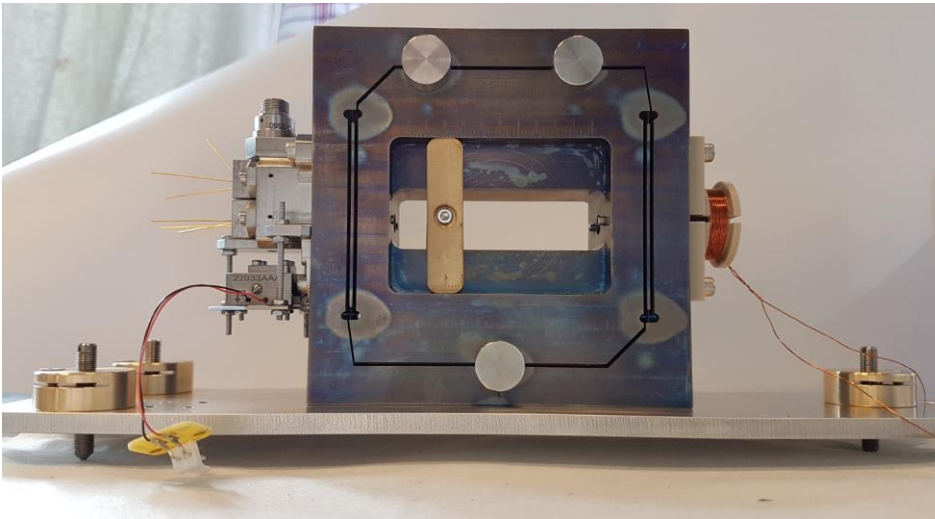
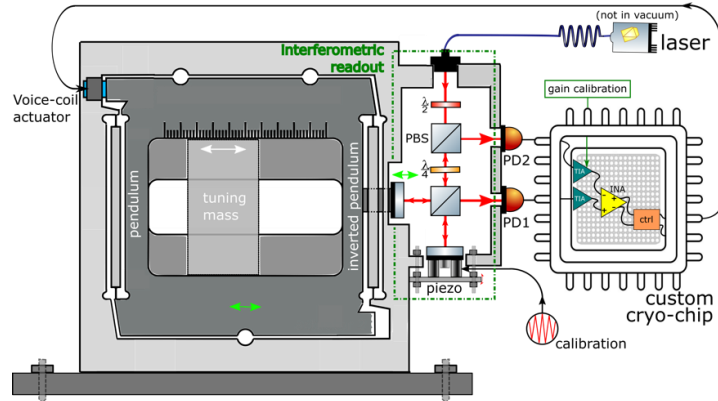
- Custom homodyne quadrature Michelson readout device.
- Sub-pm resolution.
- Long dynamic range (multi-fringe reading).

+ Additional LVDT reading for redundancy

Ultra-cold vibration control

Cryogenic inertial sensors

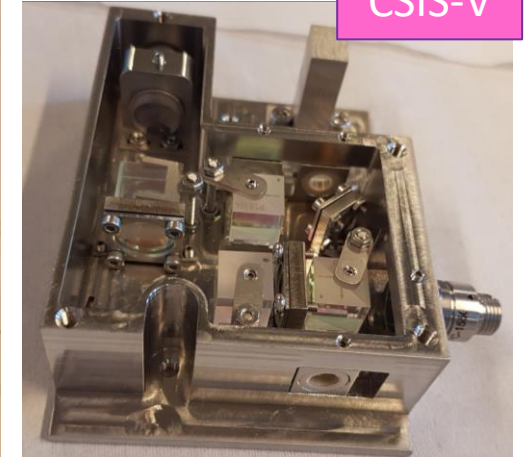
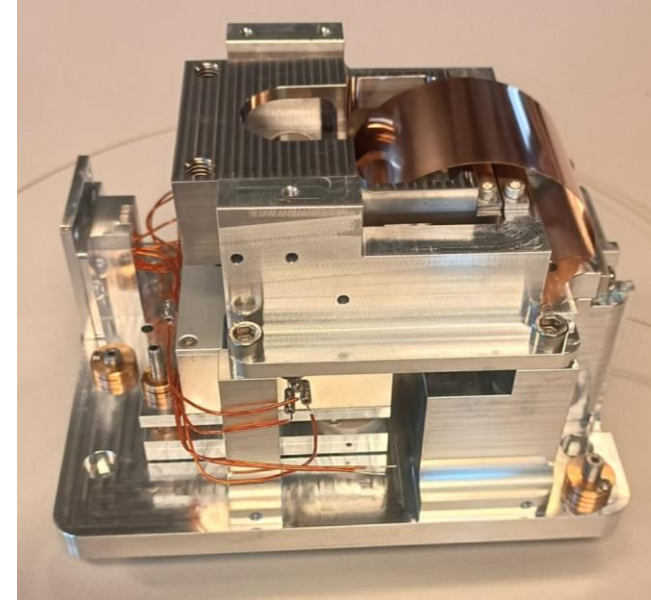
CSIS-H



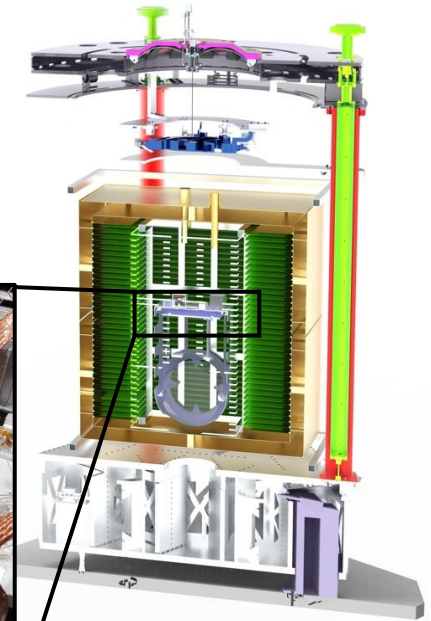
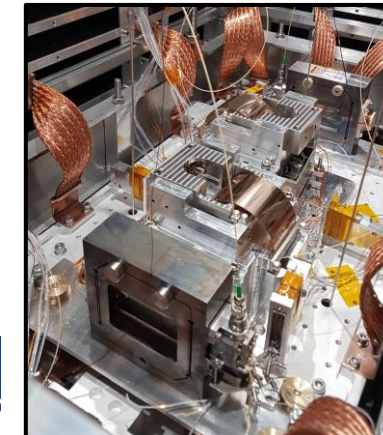
- Sub-Hz resonance frequency.
- fm differential optical readout

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CSIS-V



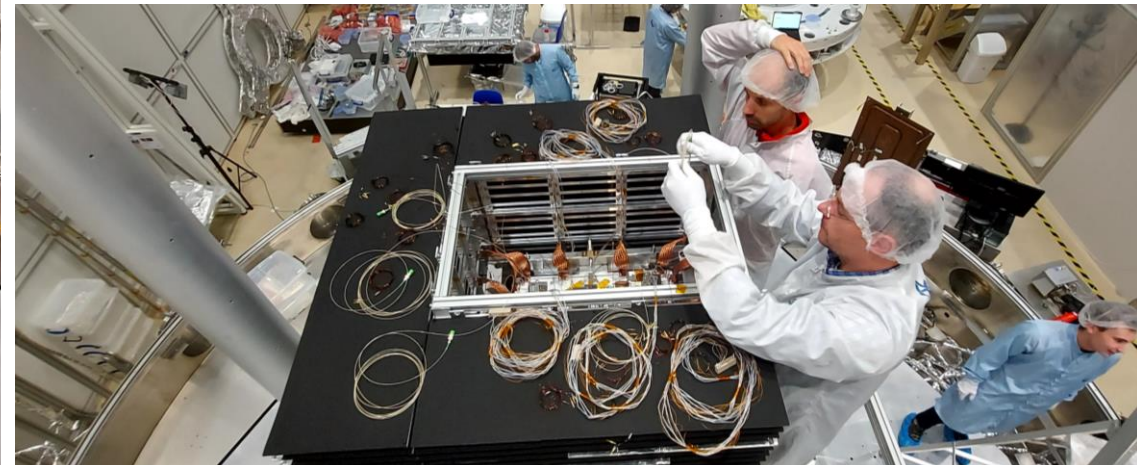
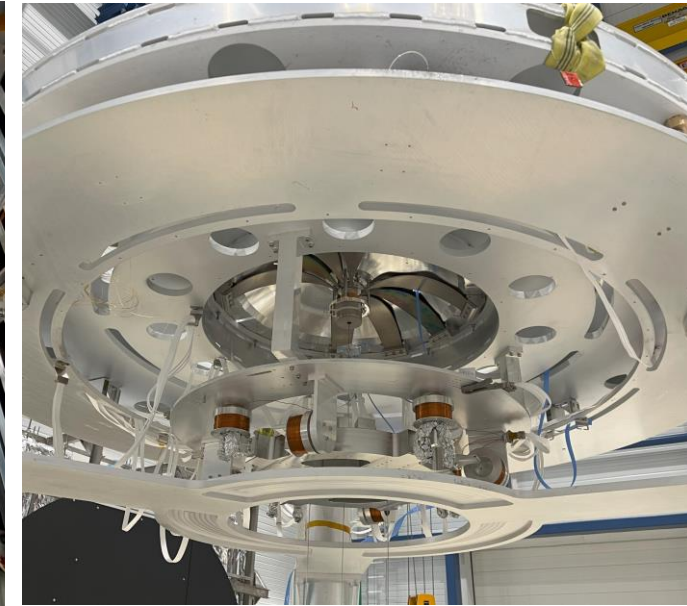
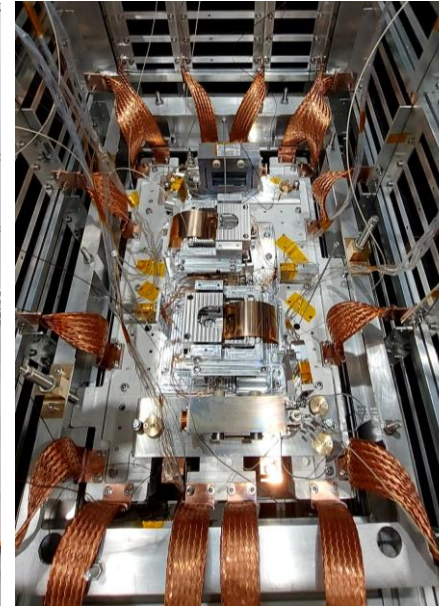
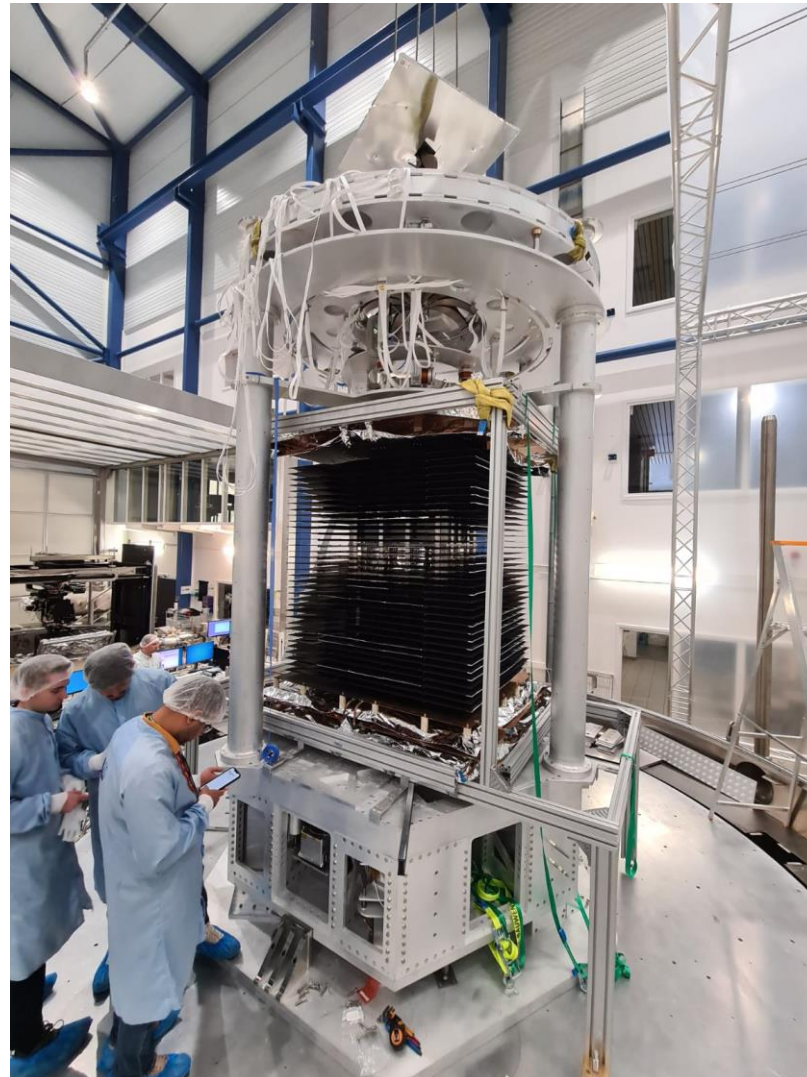
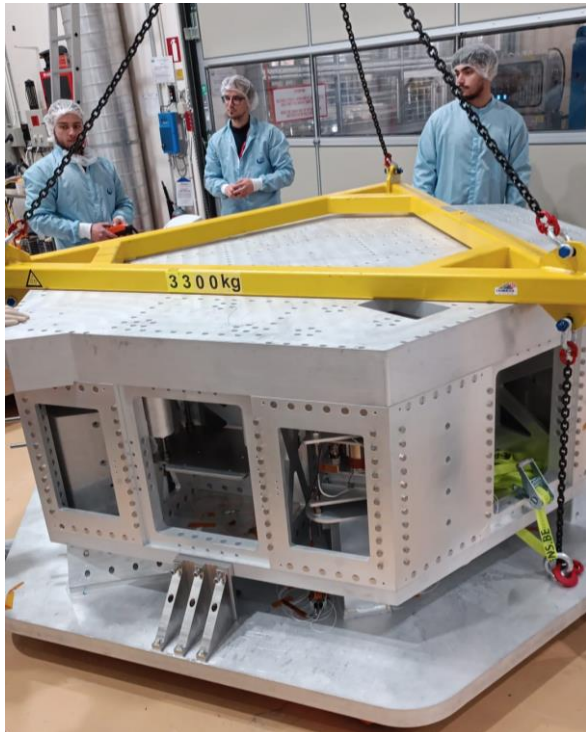
- Approx. 1 Hz leaf-spring resonance frequency.
- Homodyne, fringe-counting, optical readout.



Assembly of the prototype at CSL

Teamwork makes dreams work!!!

Contact: Ameer Sider (PML) asider@uliege.be
Cédric Lenaerts (CLS) cedric.lenaerts@uliege.be
Christophe Collette (PML) Christophe.Collette@uliege.be



26.05.2025



10

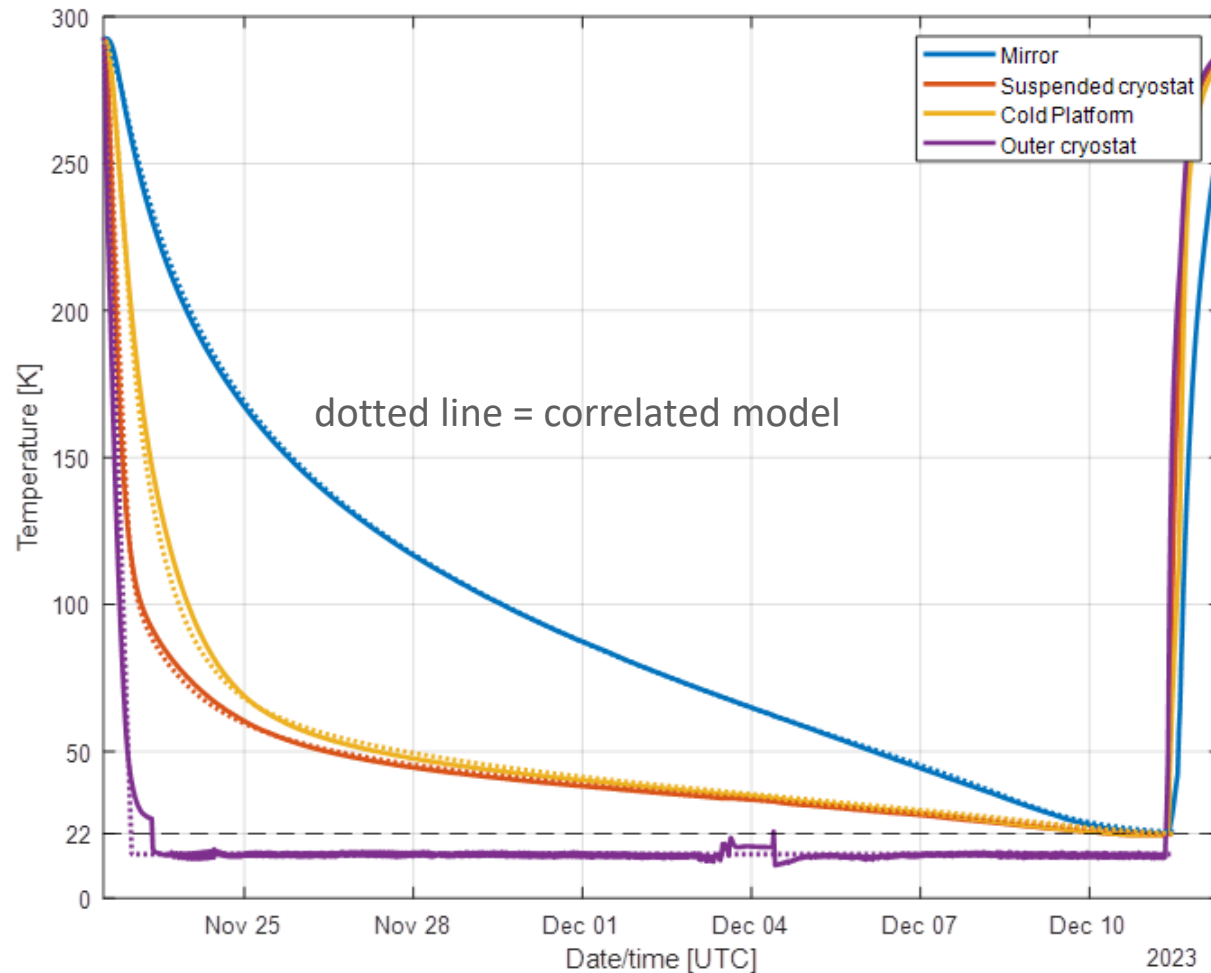
Assembly of the prototype at CSL

- Assembly of the prototype was finished by the end of November 2023
- Vacuum chamber closed + first run started



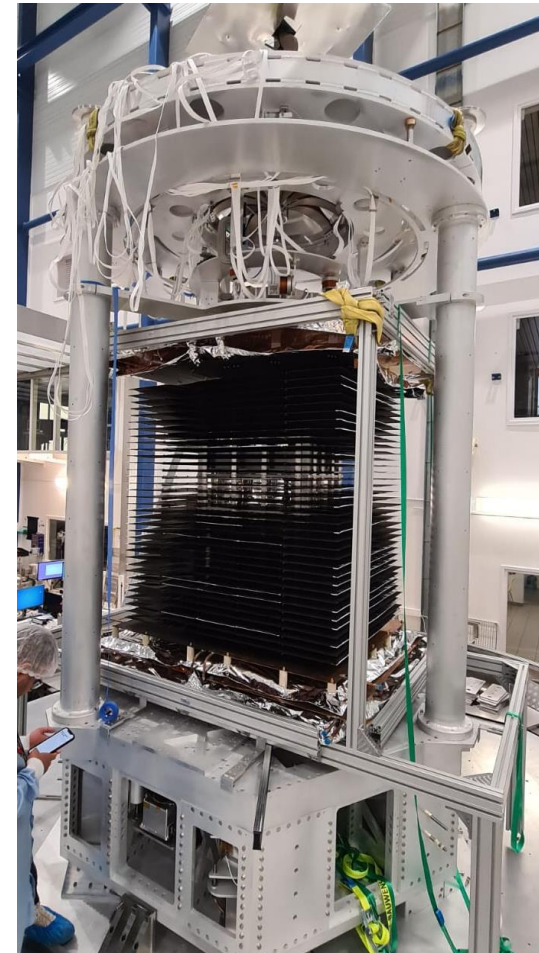
22K achieved in 18days

- Sink @16K (recirculating GHe)
- Black-paint emissivity >60% @ 22K



26.05.2025

Suspended inner cryostat

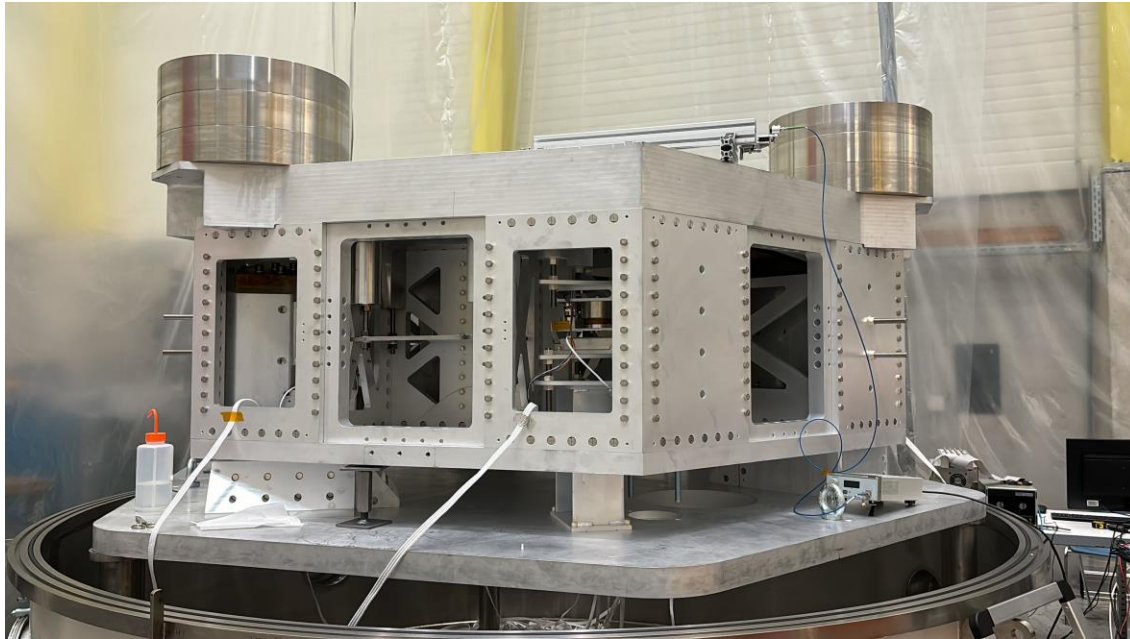


After integration of outer cryostat including LN₂ shield and GHe panels



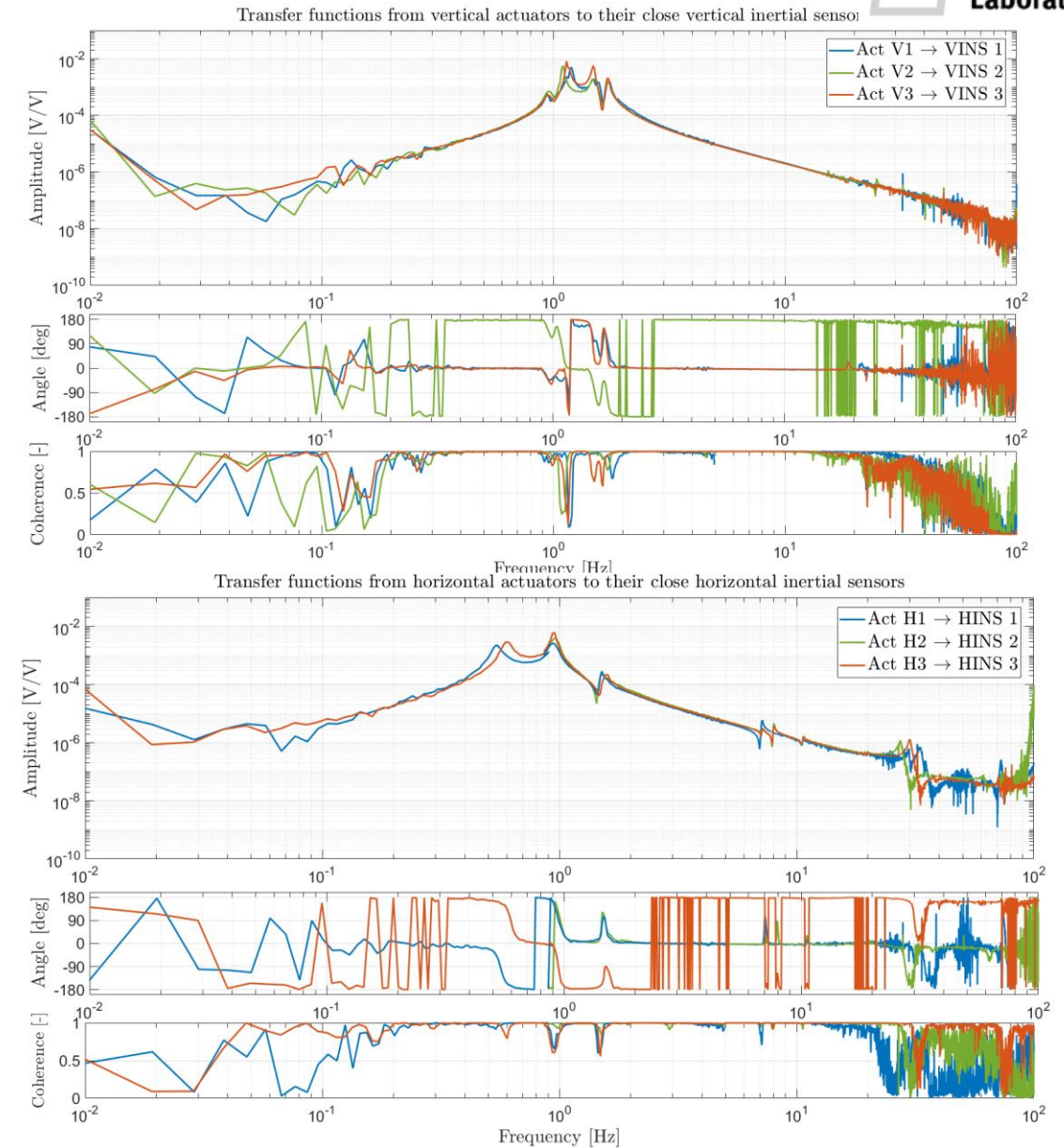
Low-frequency active Isolation and preparing for the next run

Contact : Haidar Lakkis (ULiege)
mhlakkis@uliege.be



E-TEST active platform

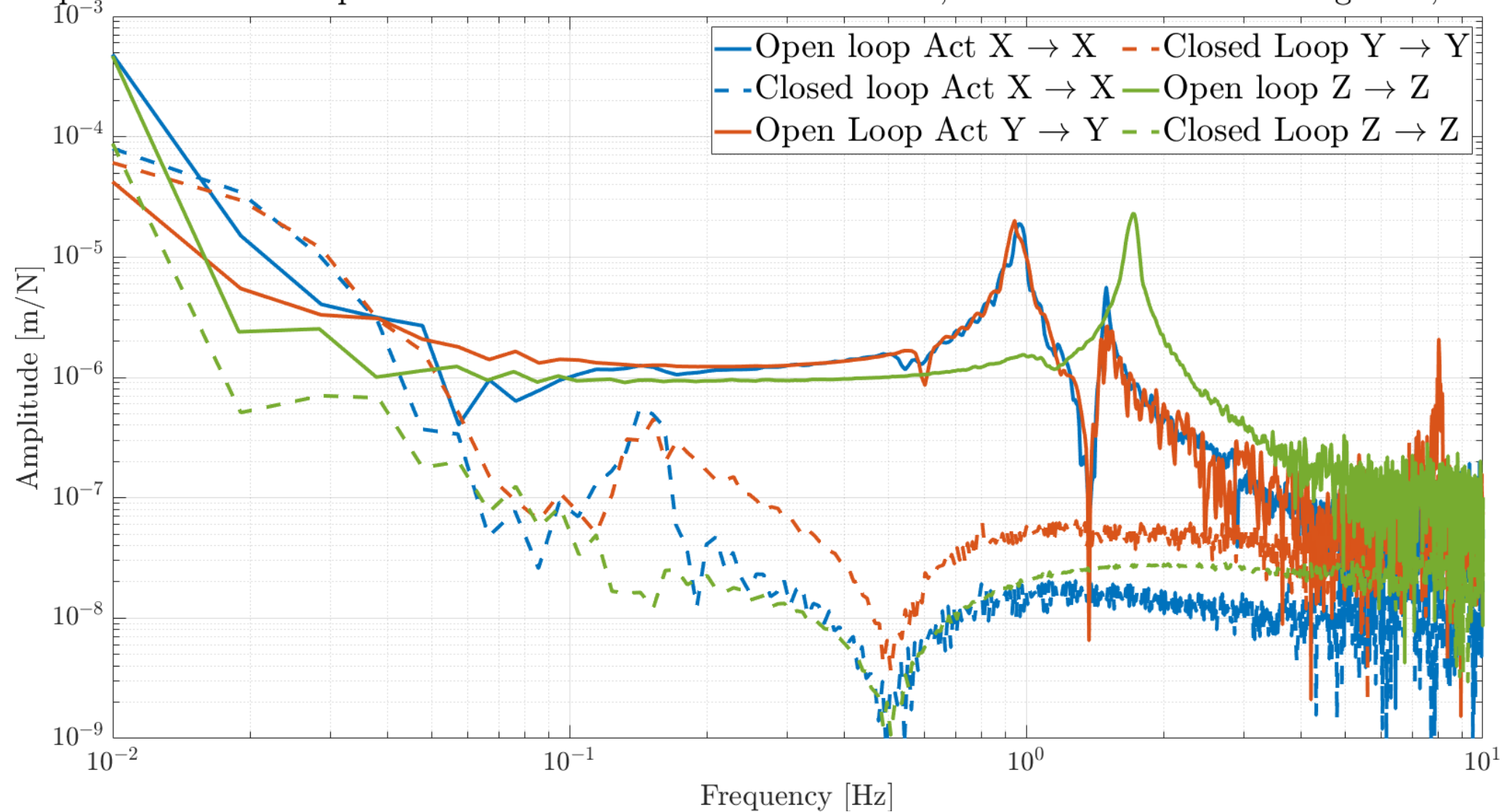
- Low-frequency Active isolation:
 - Locking platform with the ground at low frequency using BOSEMs (below 0.1 Hz)
 - Ground inertial sensors to correct BOSEM signals
 - Inertial control at mid frequencies (0.1 Hz to 10 Hz)
 - Virtual sensor fusion at high frequency



Low-frequency active Isolation and preparing for the next run

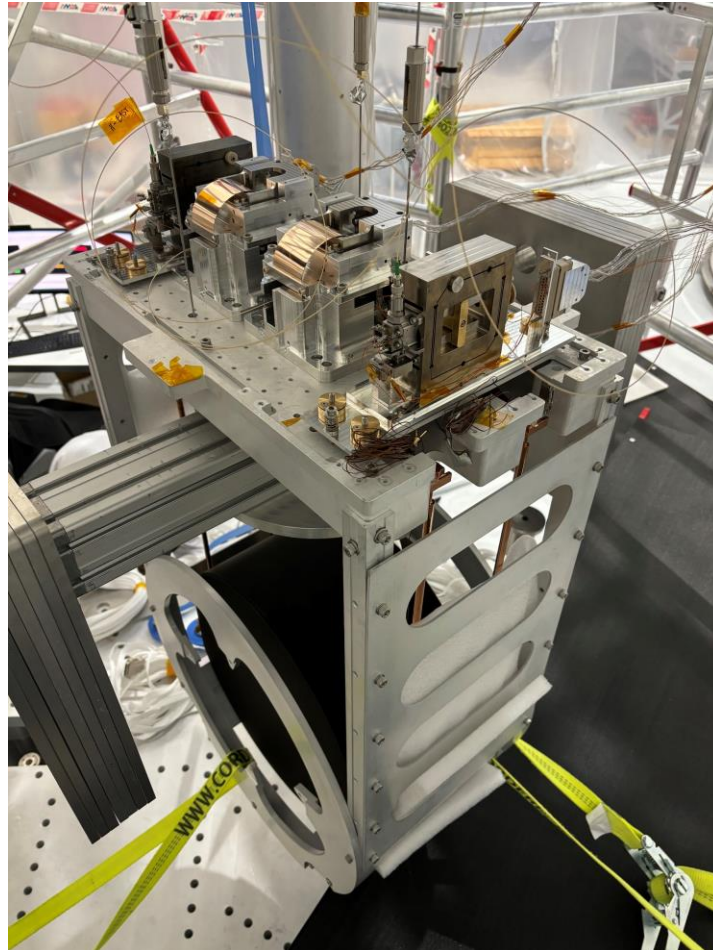
Contact : Haidar Lakkis (ULiege)
mhlakkis@uliege.be

Open and closed loop transfer function from Actuation in X,Y and Z to inertial sensing in X,Y and Z



Full prototype Active vibration isolation testing

IP and suspension chain remounted on top of the AP

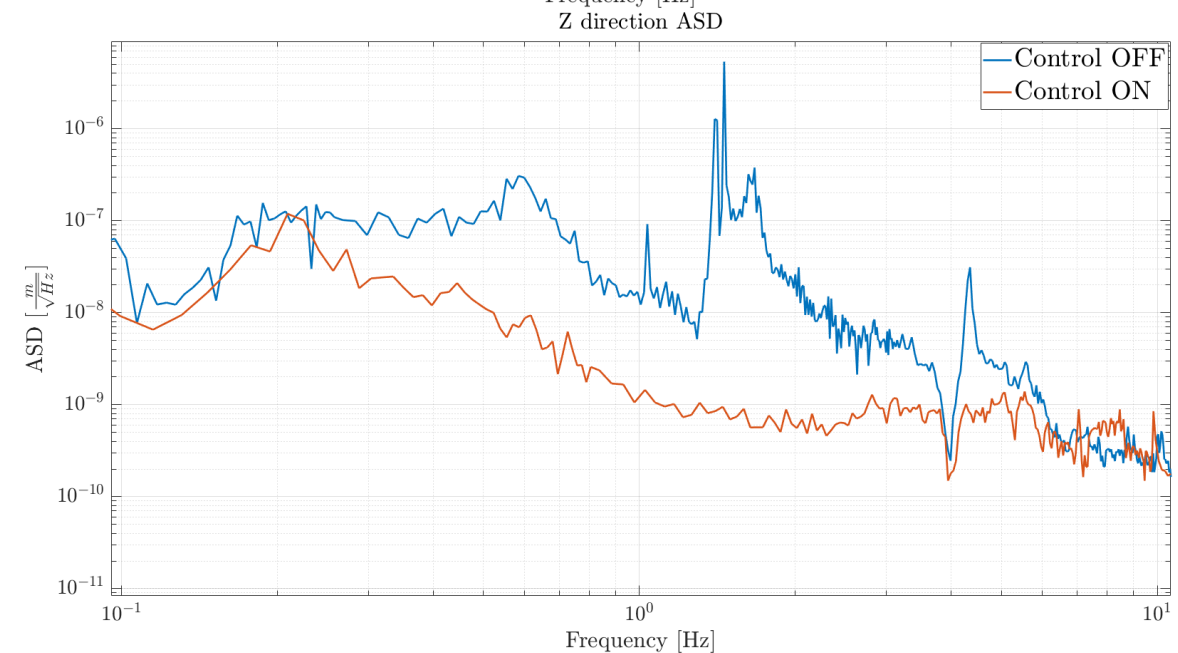
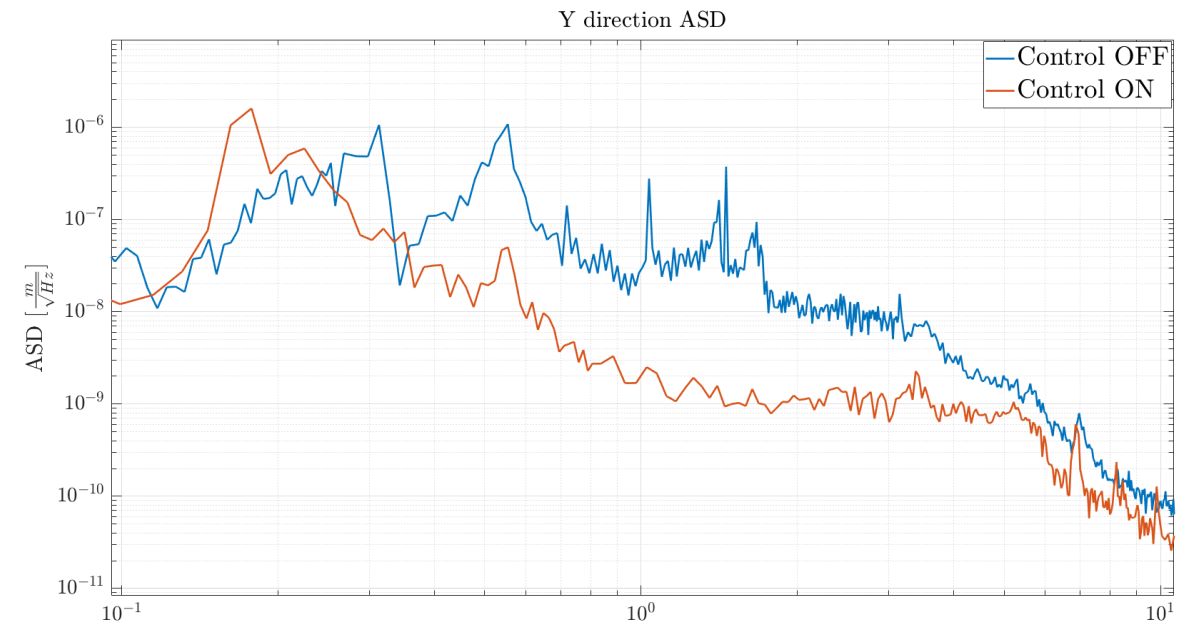
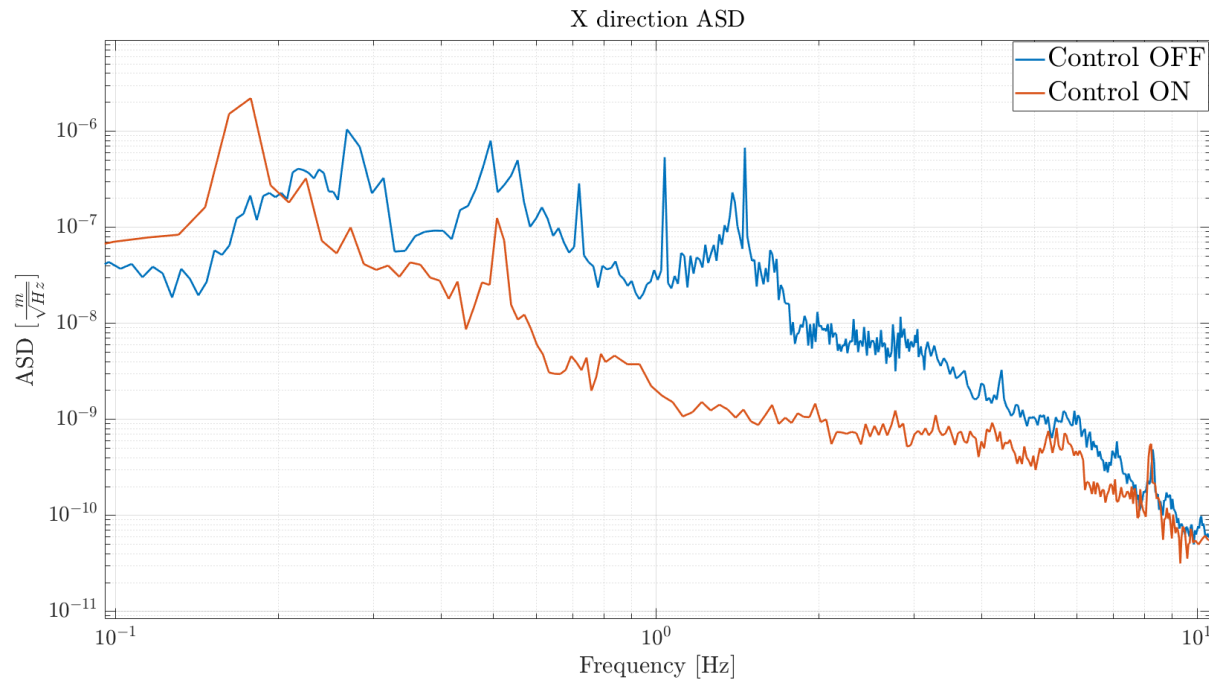


26.05.2025

Full prototype Active vibration isolation testing

In air results:

- Closing control loops from AP inertial sensors to Voice coil actuators in the three translational directions



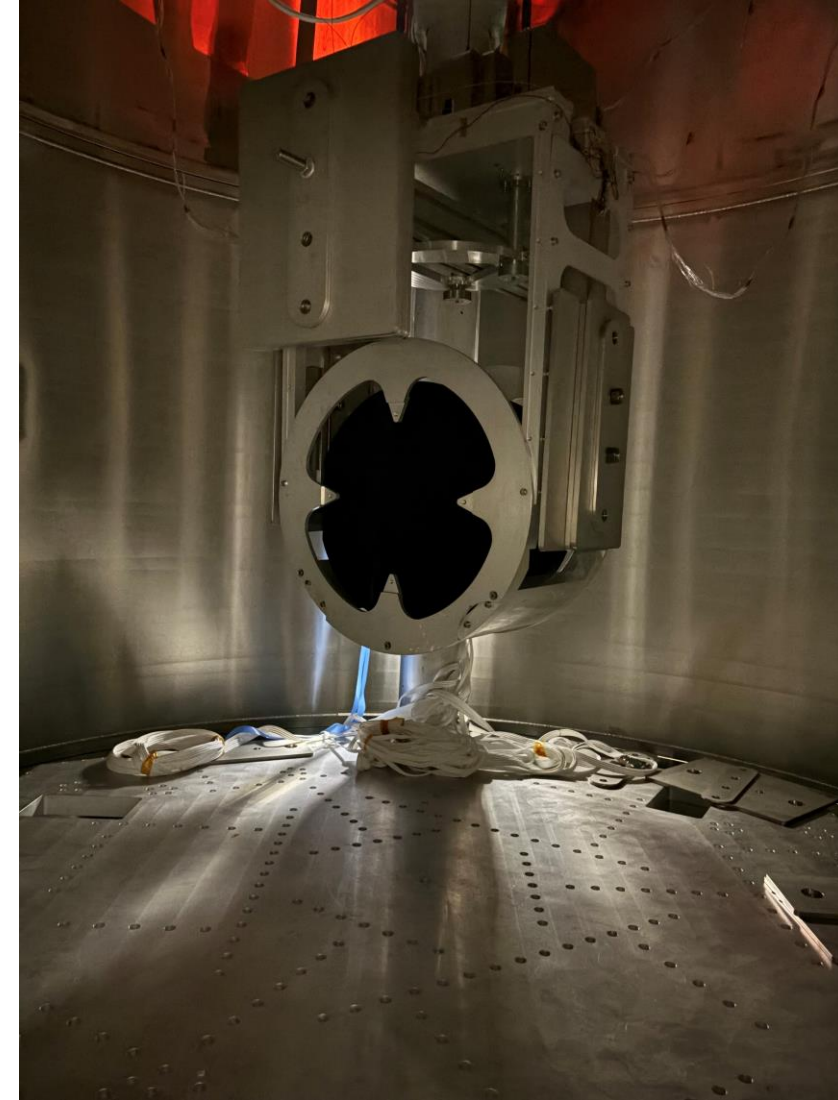
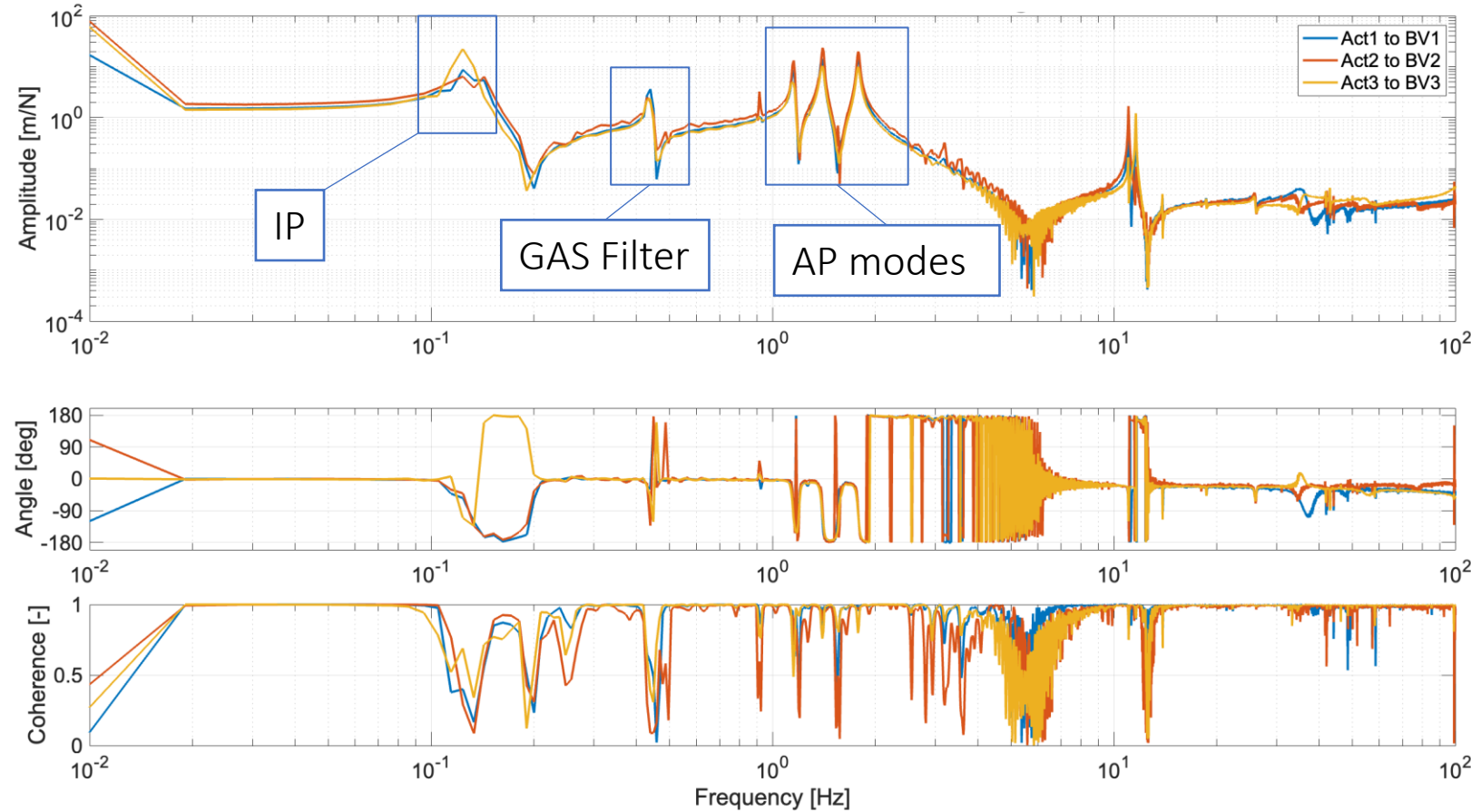
Full prototype Active vibration isolation testing

In vacuum at $1,96 \times 10^{-6} \text{ mbar}$



Contact : Haidar Lakkis (ULiege)
mhlakkis@uliege.be

Open loop transfer function from vertical actuators to collocated vertical BOSEMs



Thank you

Contacts:

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Haidar Lakkis

mhlakkis@uliege.be

Useful links:

TDR

<https://arxiv.org/abs/2212.10083>

E-TEST Project website

<https://www.etest-emr.eu/>

PML website

<http://www.pmlab.be/>