

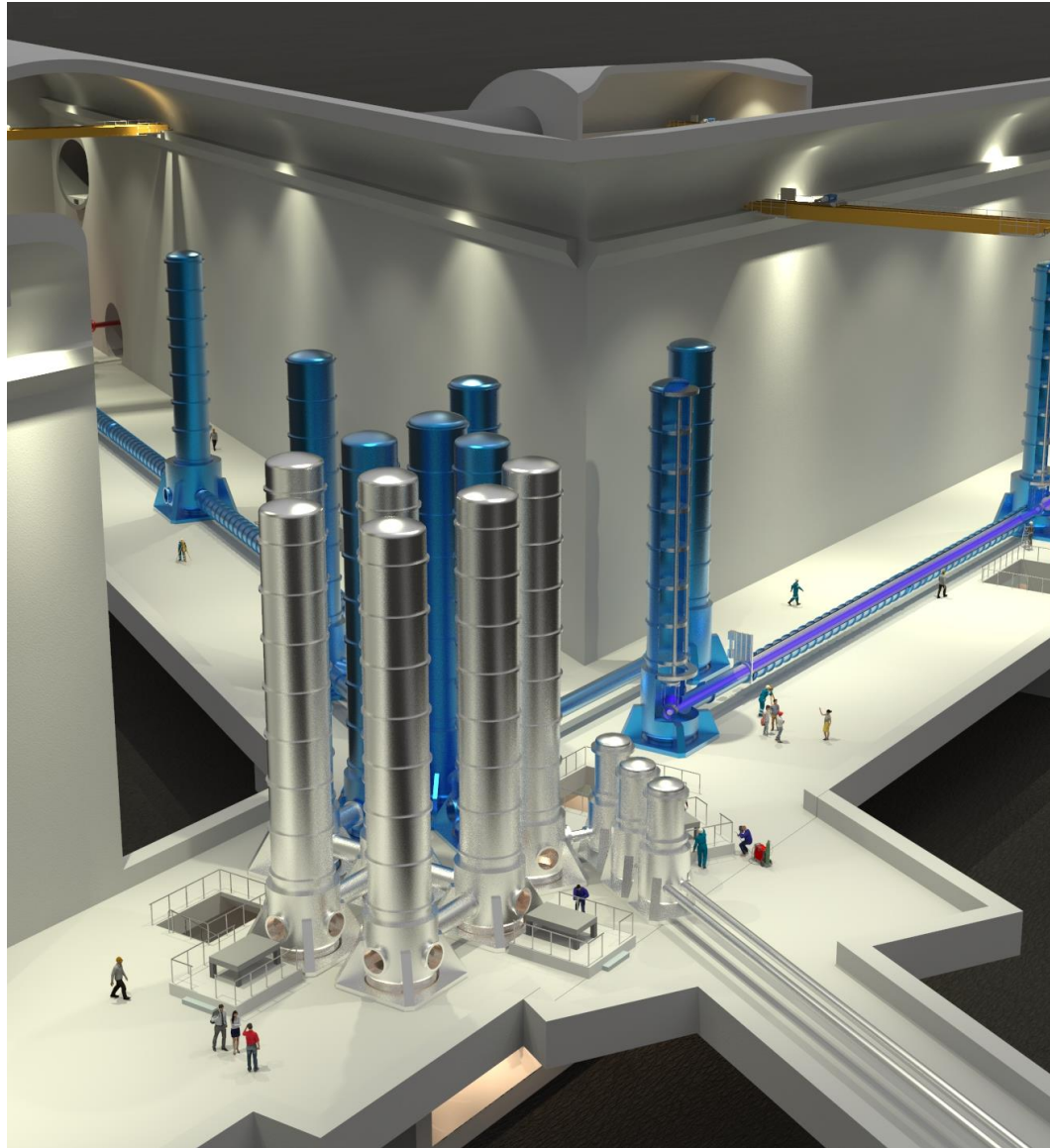
E-TEST : Einstein Telescope EMR Site and Technology

Haidar Lakkis

On behalf of Precision Mechatronics Laboratory (ULiege)

04.03.2024





E-TEST objectives

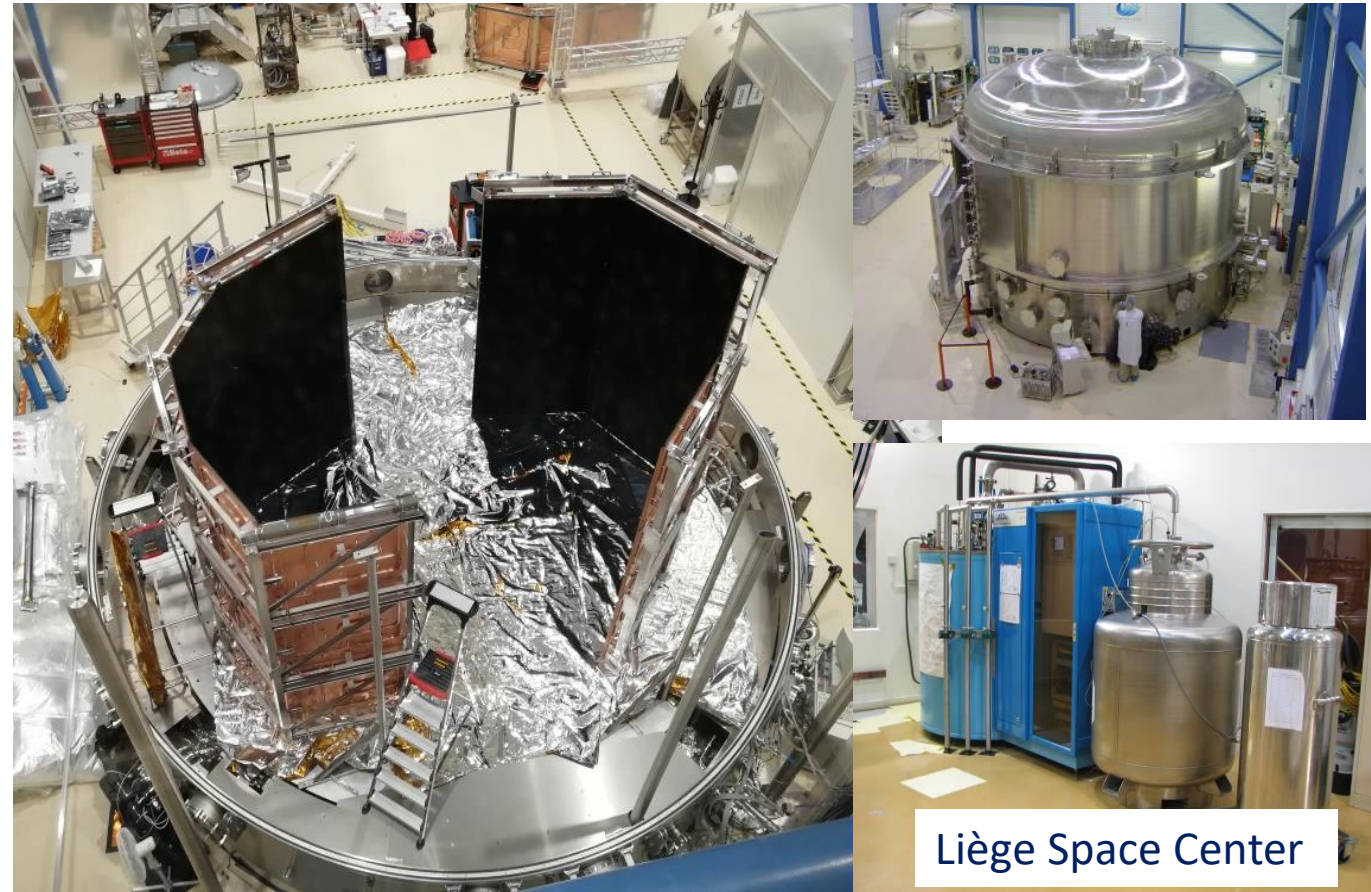
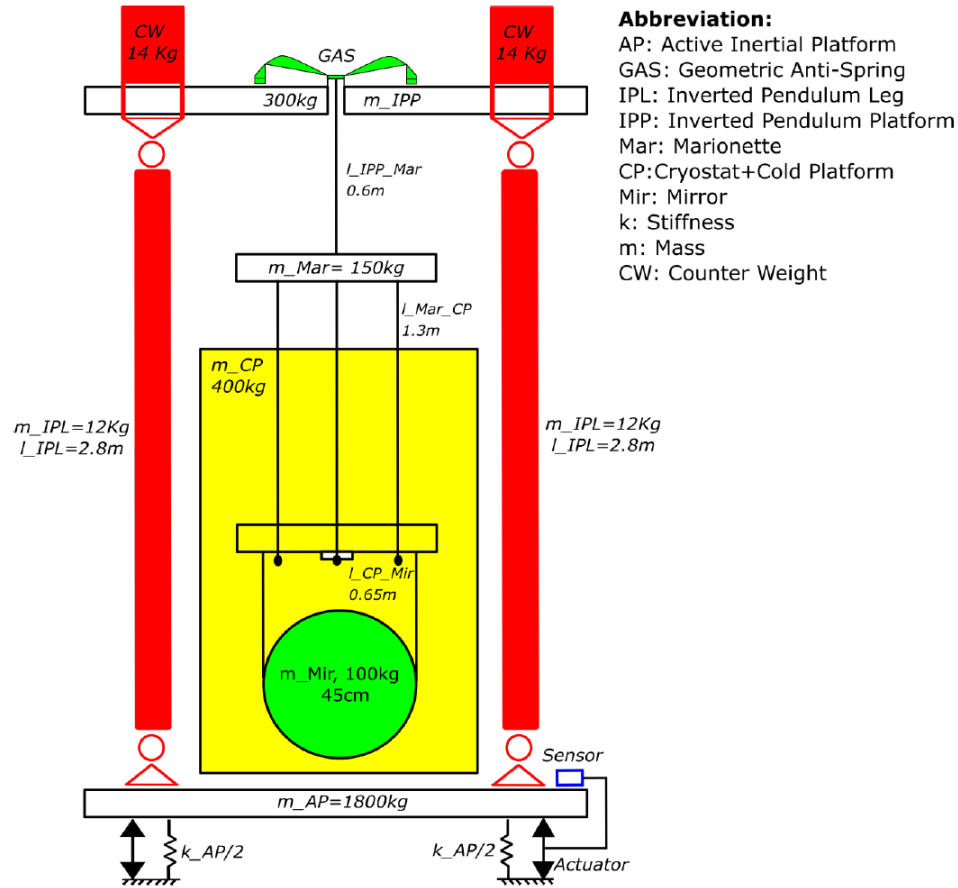
- Large mirror (100 Kg)
- Cryogenic temperature (10-20 K)
- Isolated at low frequency (0.1-10 Hz)
- Compact suspension (4.5 meters)

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

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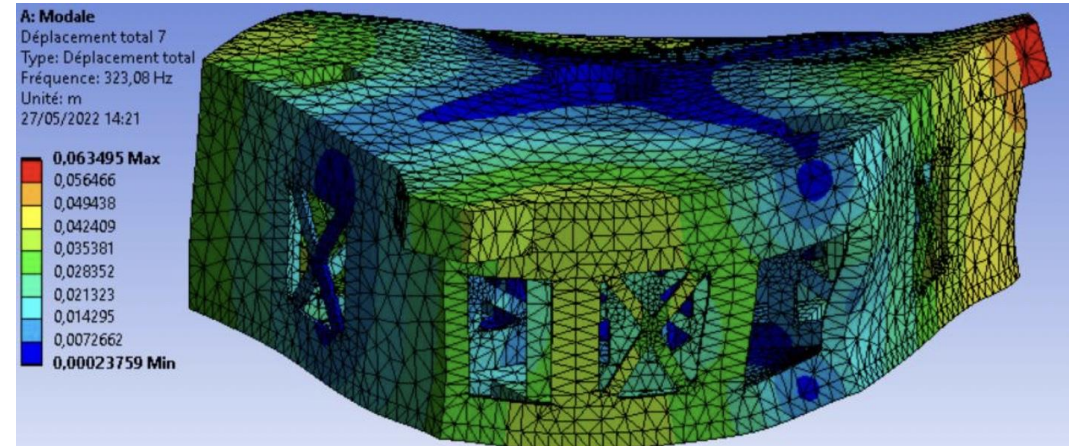
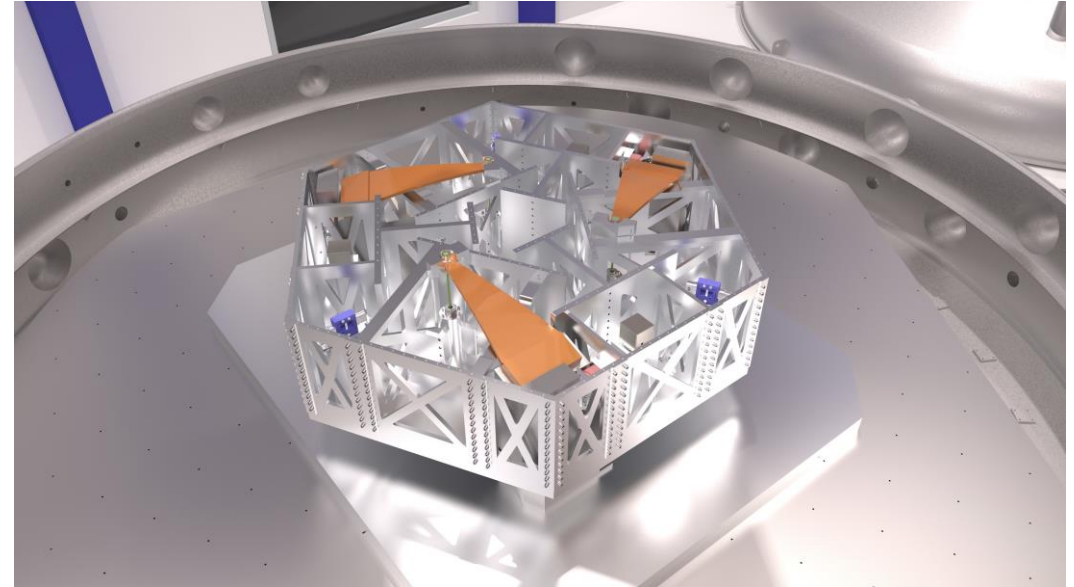
From a design concept to technical drawings

Mechanical isolation system

- Production of **the whole prototype finished!**
- All mechanical parts in production
- Assembly started in Summer 2023



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



From a design concept to technical drawings

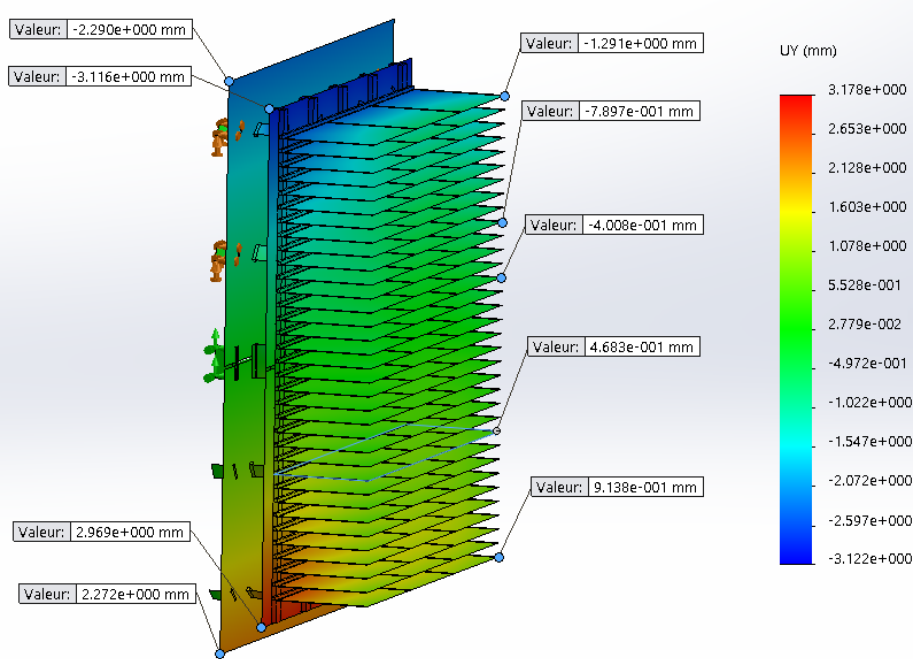
Radiative cooling design

- Overall dimensions: 1.8 x 1.6 x 2 m³
- Conventional radiator design with **horizontal fins** (25K)
- Three 30-mm diameter optical feedthroughs towards the mirror

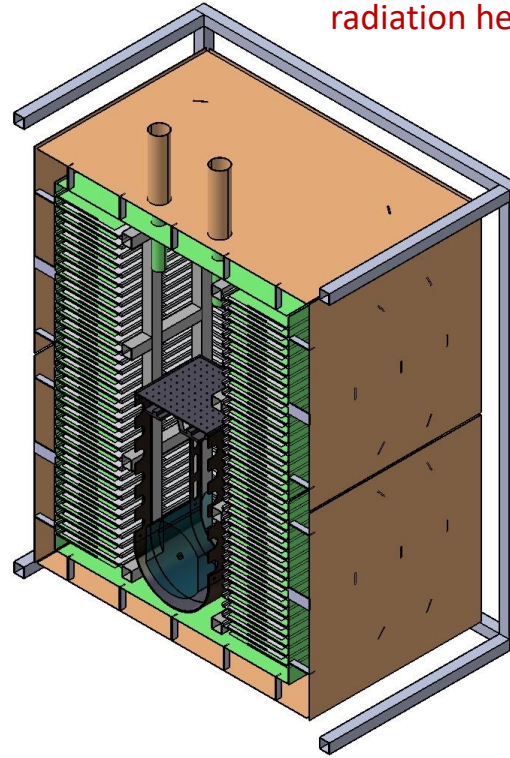
Contact: Cedric Lenaerts (CSL)
Cedric.Lenaerts@uliege.be



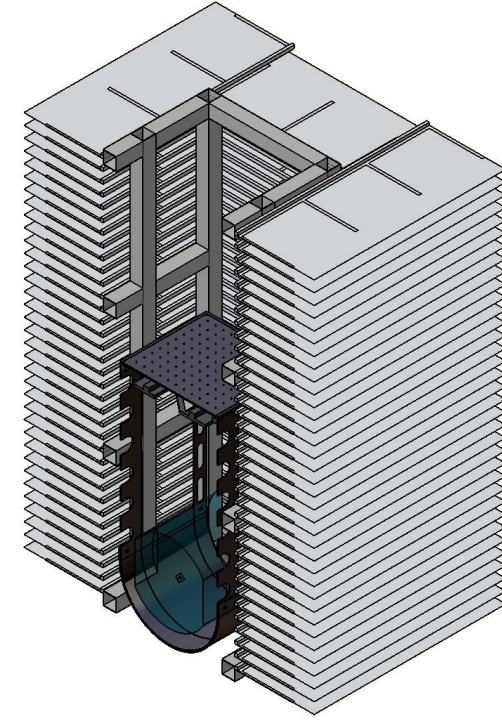
CENTRE SPATIAL DE LIÈGE



radiation heat transfer for mirror cooling



- Outer cryostat**
(connected to the vacuum chamber):
- 80K LN2 shield (brown)
 - 25K GHe panels (green)



- Inner cryostat**
suspended and conductively linked to the silicon mirror

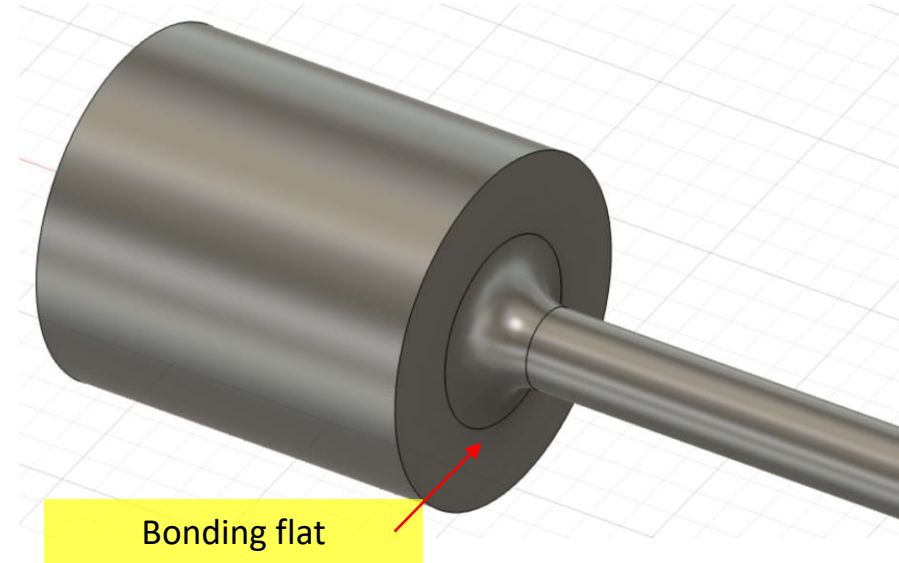
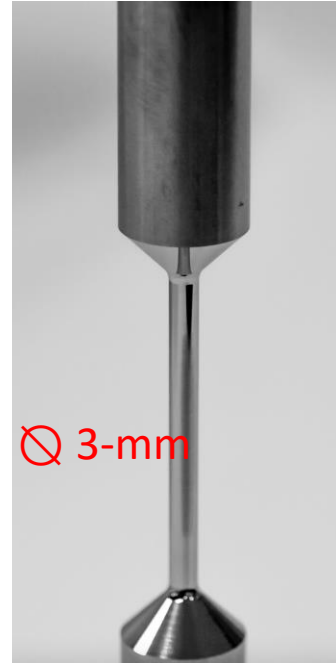
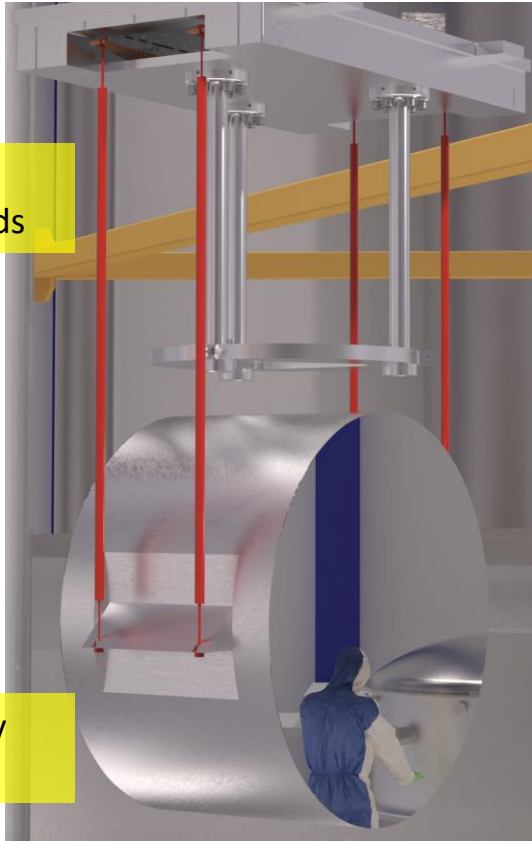
Ultra-cold vibration control

Crystalline silicon mirror suspension

- Crucial technology aspect for ET: no proven solution exists
- Four **machined** samples delivered

single crystal
Si suspension rods

Al-6061 dummy
mirror

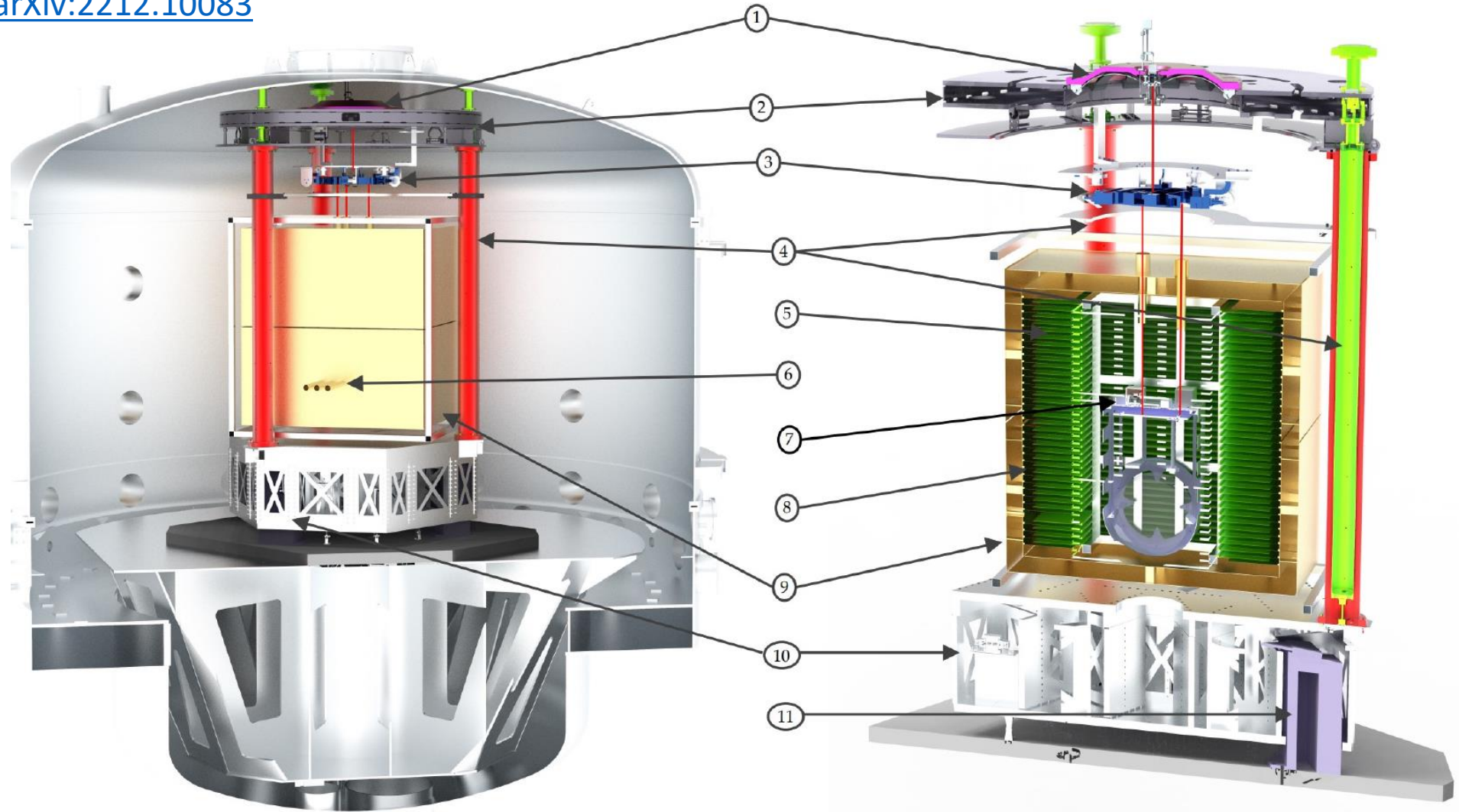


- All samples, including the new ones with bonding flats, sent to Università di Perugia for mechanical loss vs T and tensile strength measurements
- ET2SME partners Mat-Tech (NL) and MaTecK (D) will do R&D on Si-metal interfaces

Contact: Alessandro Bertolini (Nikhef)
alberto@nikhef.nl



Submitted: 12/2021
 Revised: 03/2022
[arXiv:2212.10083](https://arxiv.org/abs/2212.10083)



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

Outline

ETEST in a nutshell

Mechanics and instrumentation

Cryogenic cooling

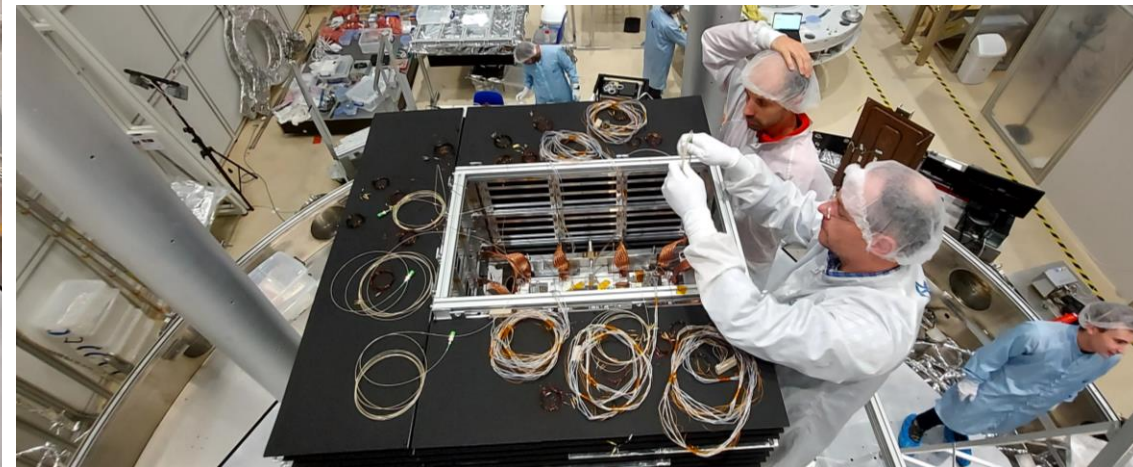
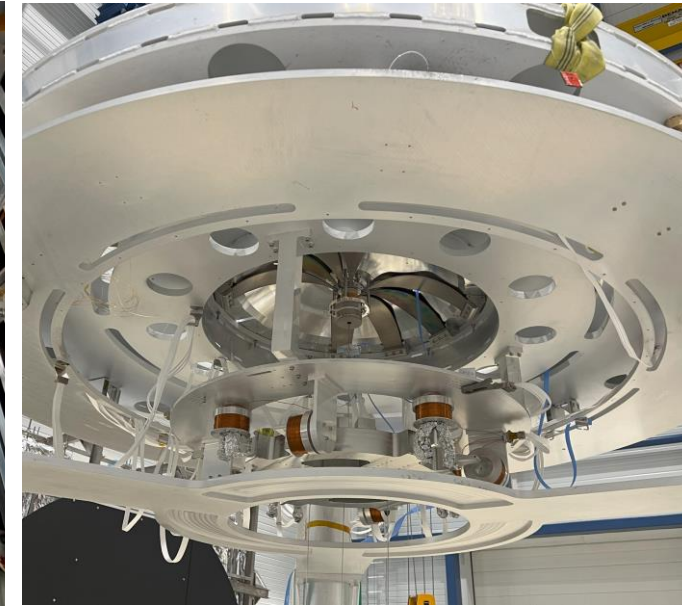
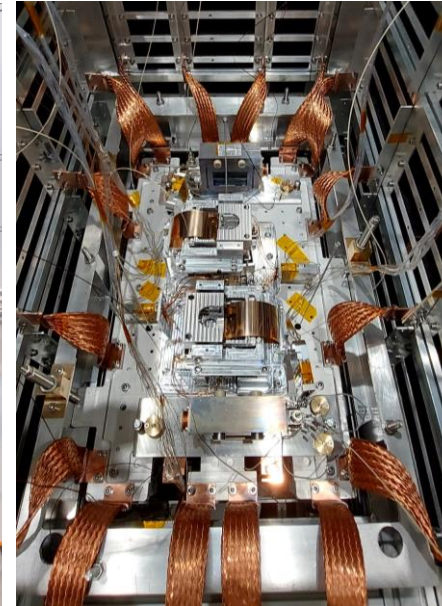
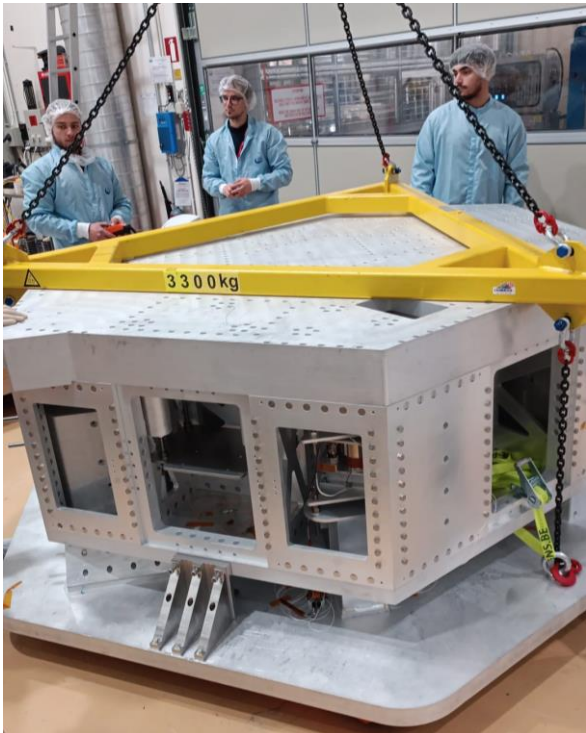
Continuation of work

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Assembly 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



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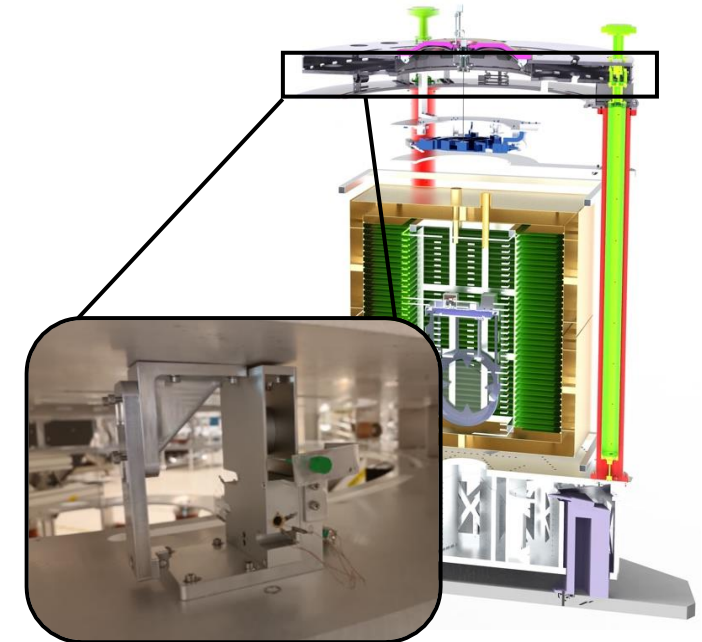
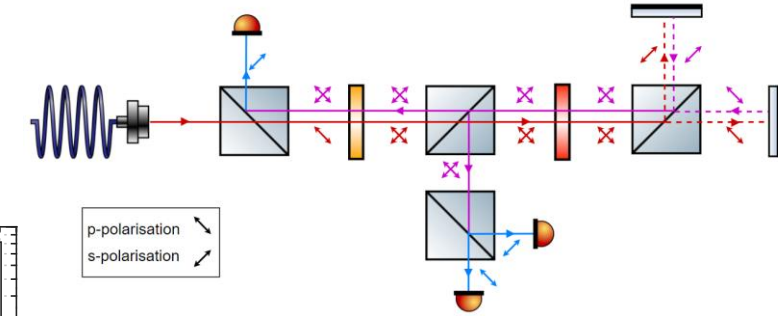
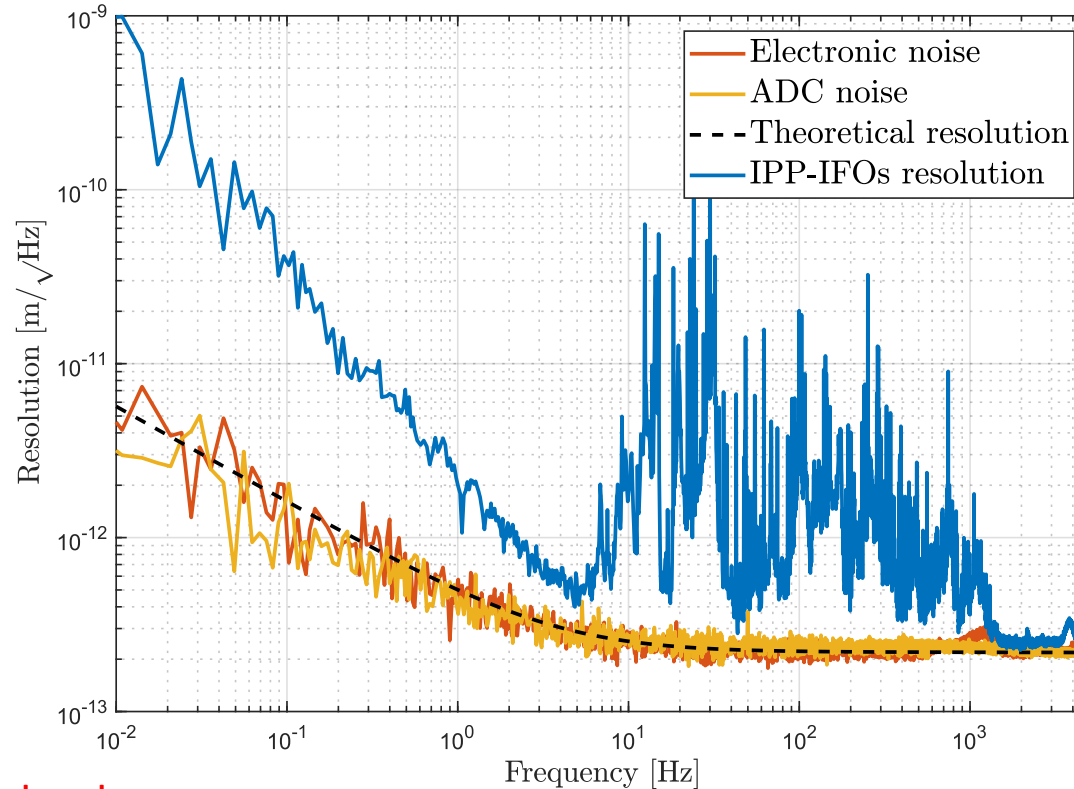
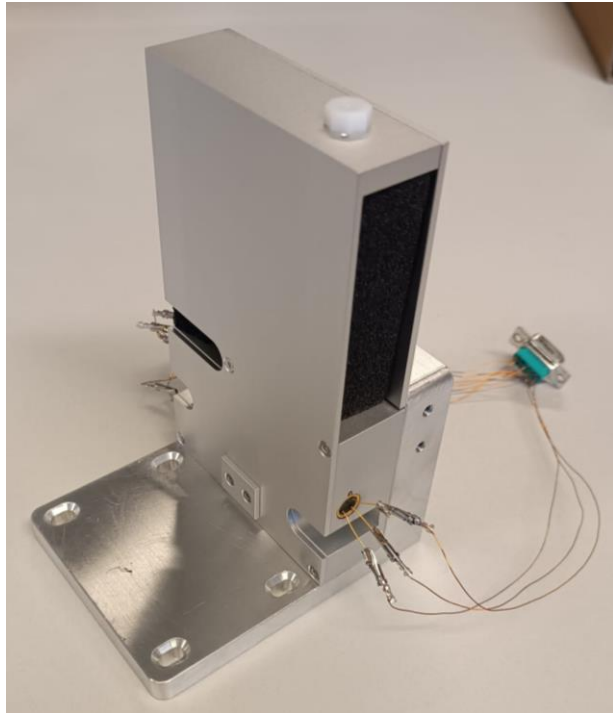
Inverted pendulum displacement sensing

Homodyne quadrature Michelson interferometers

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

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

Loïc Amez-Droz (PML)
lamezdroz@uliege.be



+ Additional LVDT reading for redundancy

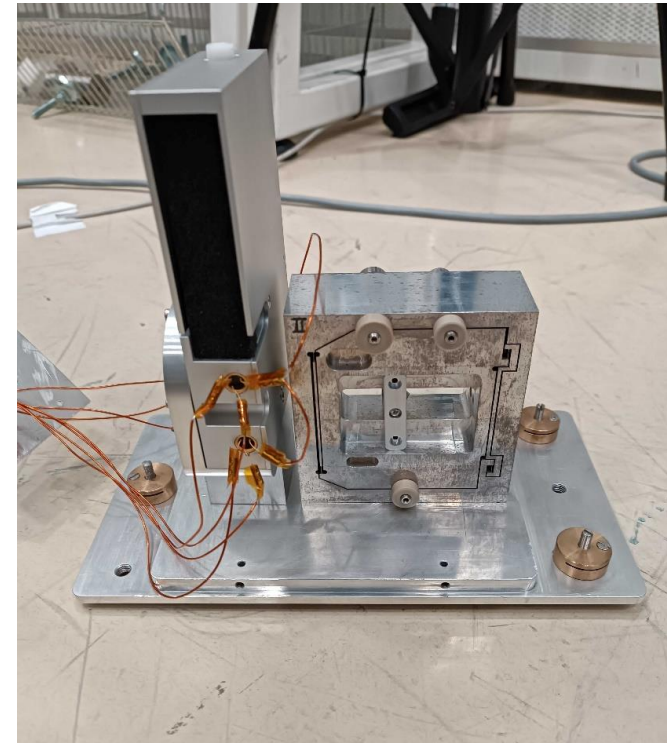
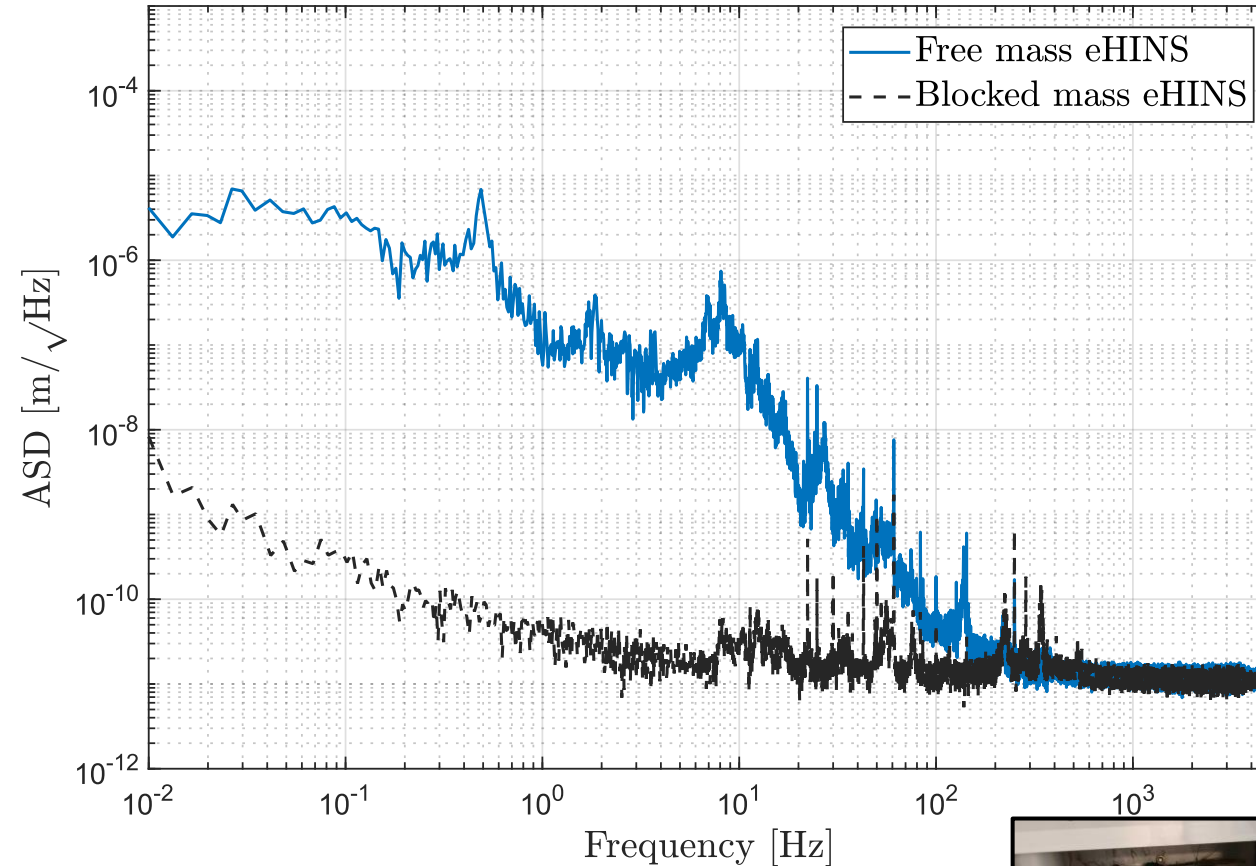
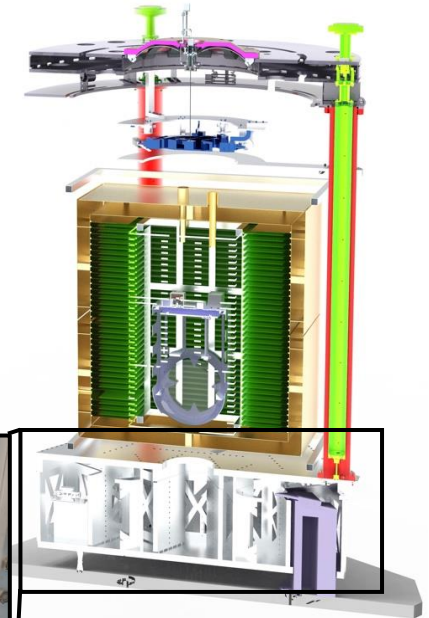
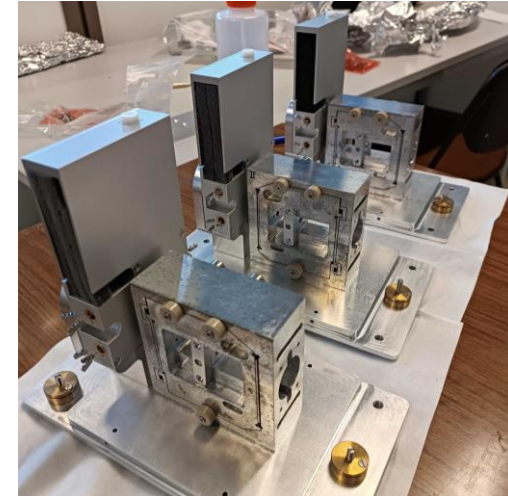
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Inertial sensing of the Active Platform

High resolution, low-frequency, optical horizontal seismometer

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

Loïc Amez-Droz (PML)
lamezdroz@uliege.be



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

+ BOSEMs for DC and relative motion reading.

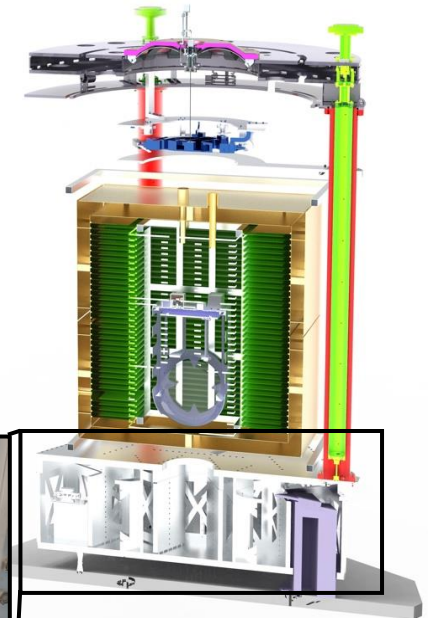
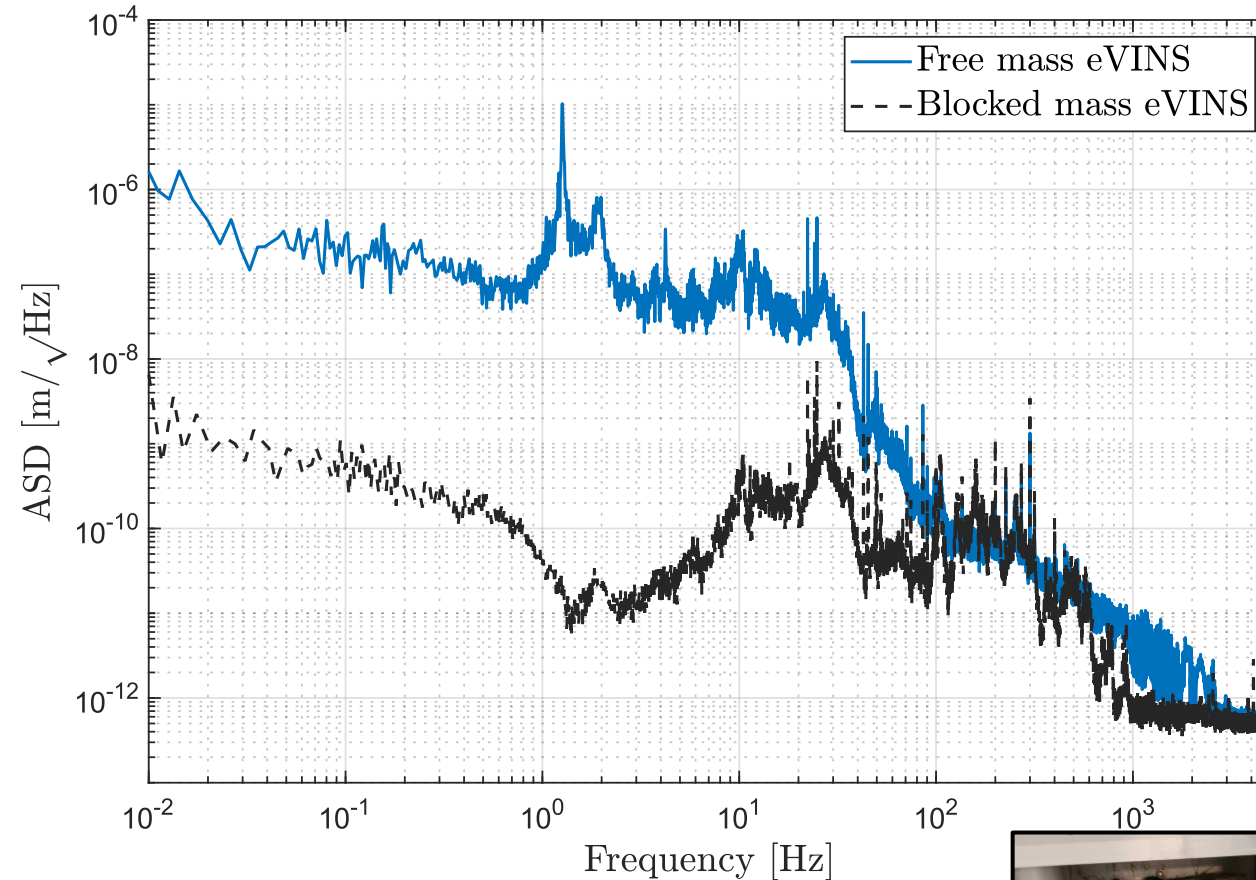
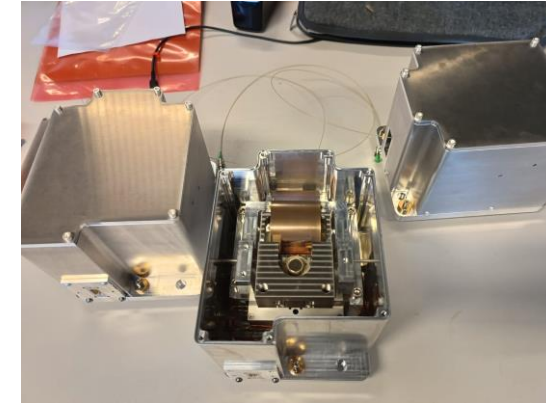
04.03.2024

Inertial sensing of the Active Platform

High resolution, low-frequency, optical vertical seismometer

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

Loïc Amez-Droz (PML)
lamezdroz@uliege.be



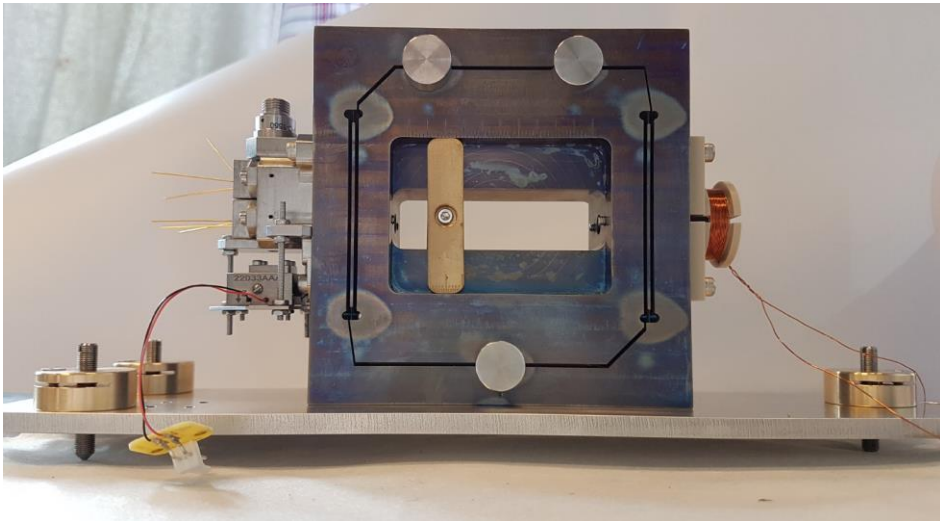
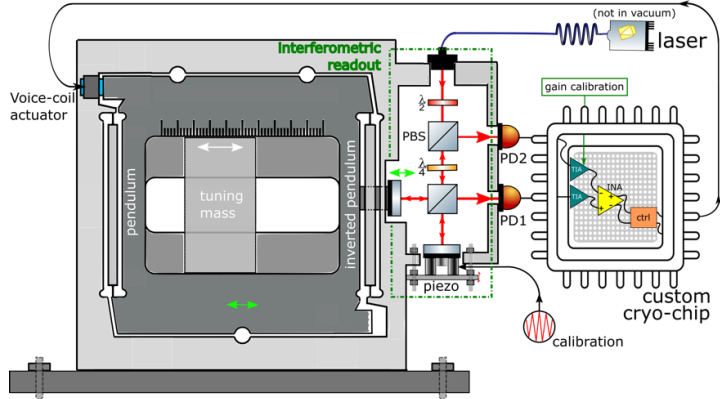
- Approx 1 Hz resonance frequency.
- pm-Michelson optical readout.
- + BOSEMs for DC and relative motion reading.

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Ultra-cold vibration control

Cryogenic inertial sensors

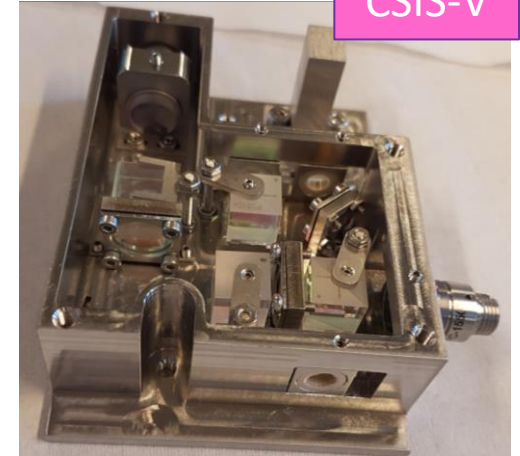
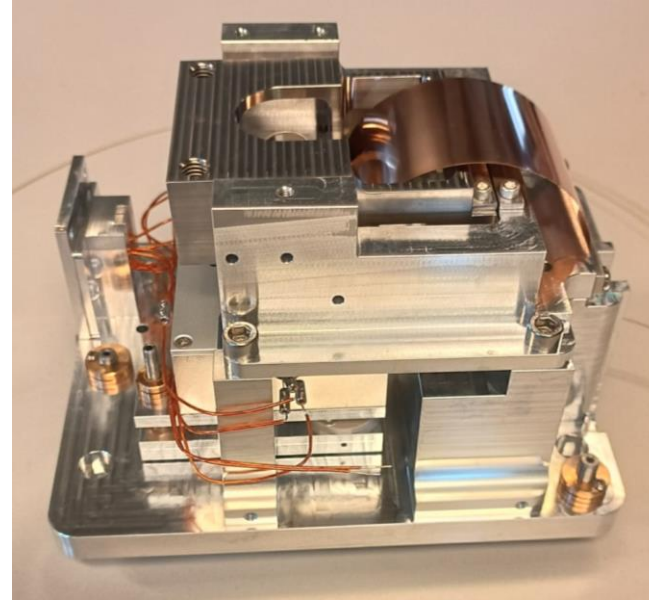
CSIS-H



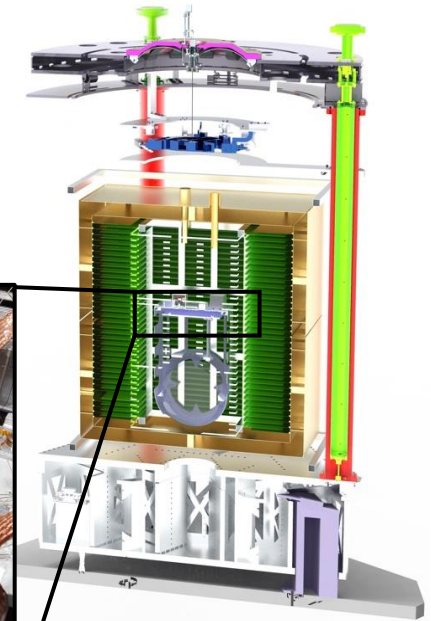
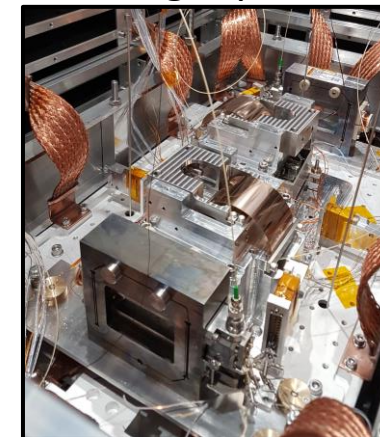
- Sub-Hz resonance frequency.
- fm differential optical readout

04.03.2024

CSIS-V



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



13

Outline

ETEST in a nutshell

Mechanics and instrumentation

Cryogenic cooling

Continuation of work

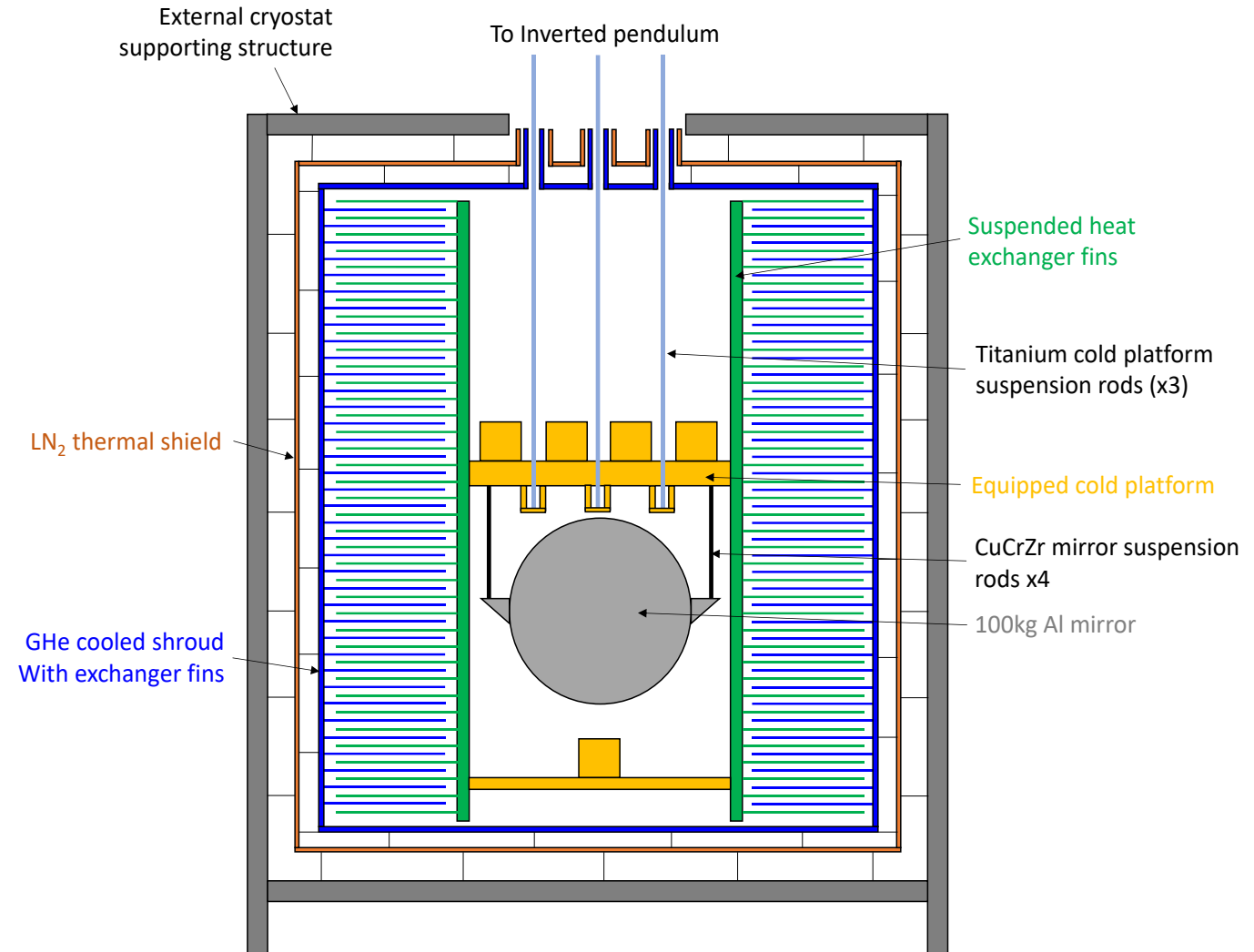
Contactless Radiative cooling strategy

Contact :Cédric Lenaerts (CLS)
cedric.lenaerts@uliege.be



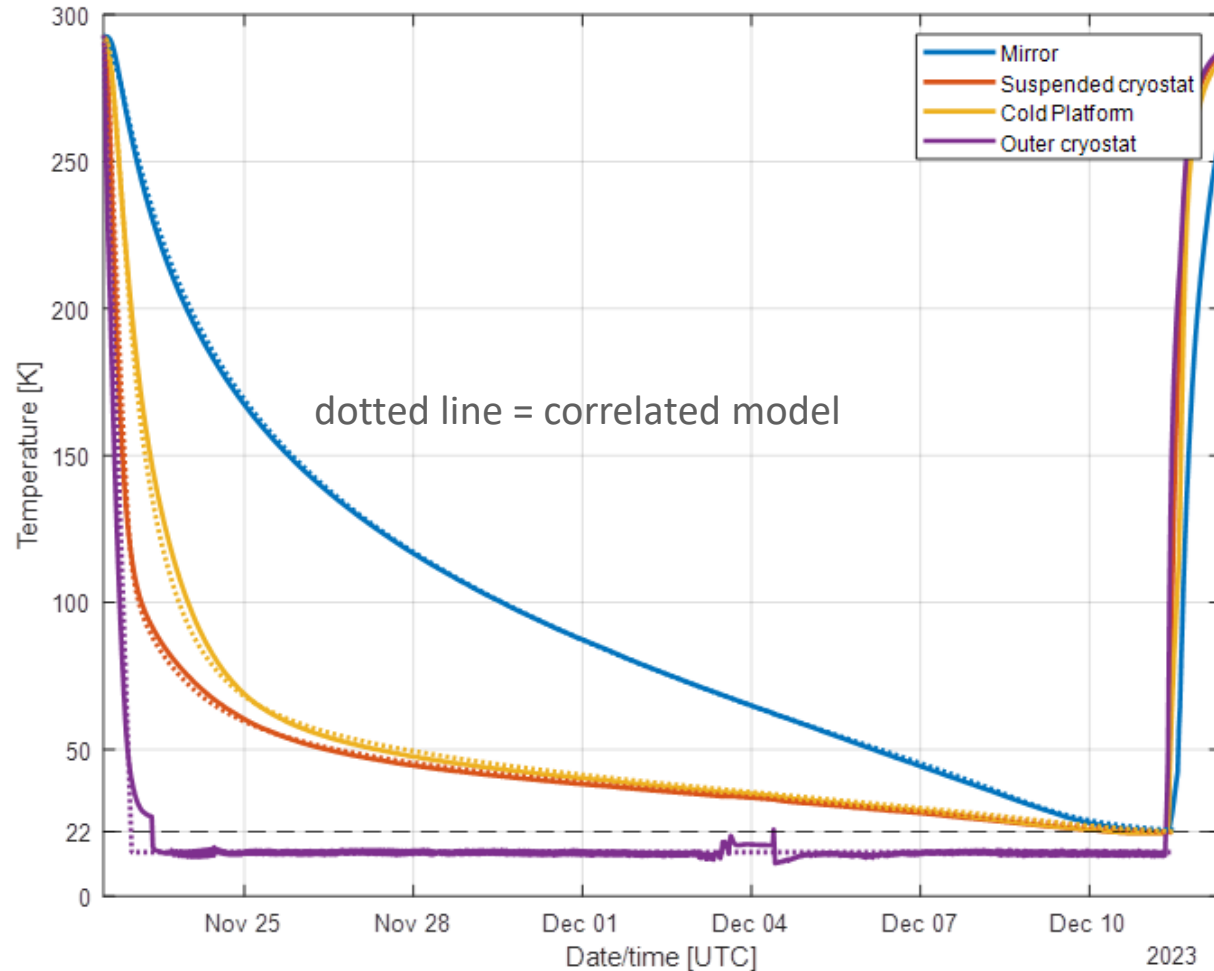
Lionel Jacques (CSL)
ljacques@uliege.be

- Compact heat exchanger:
 - 80m² for ~5m² flat surface (x16)
 - 0.2mm thick black-painted Aluminium fins
 - Lightweight to minimize cooling time
- Sized for
 - 250mW heat load
 - 25K with a sink at 20K

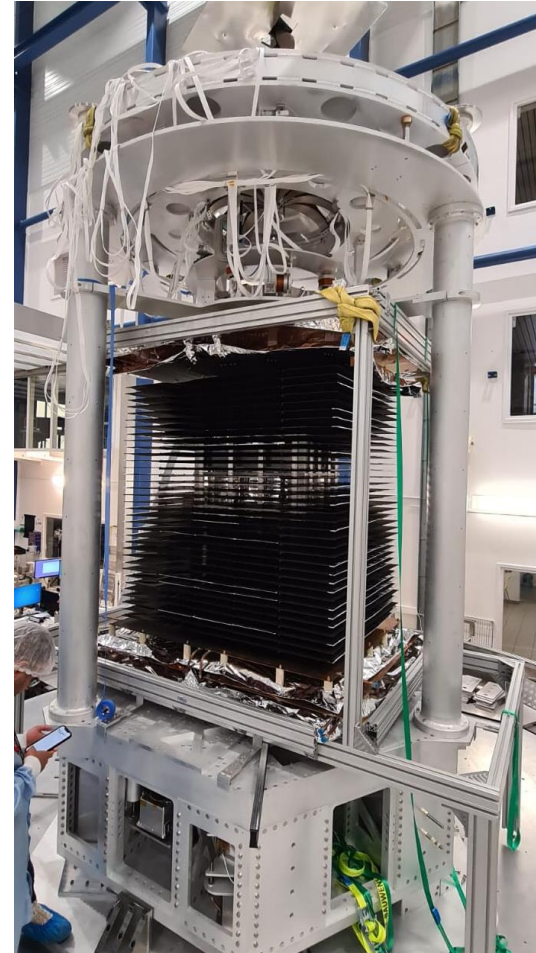


22K achieved in 18days

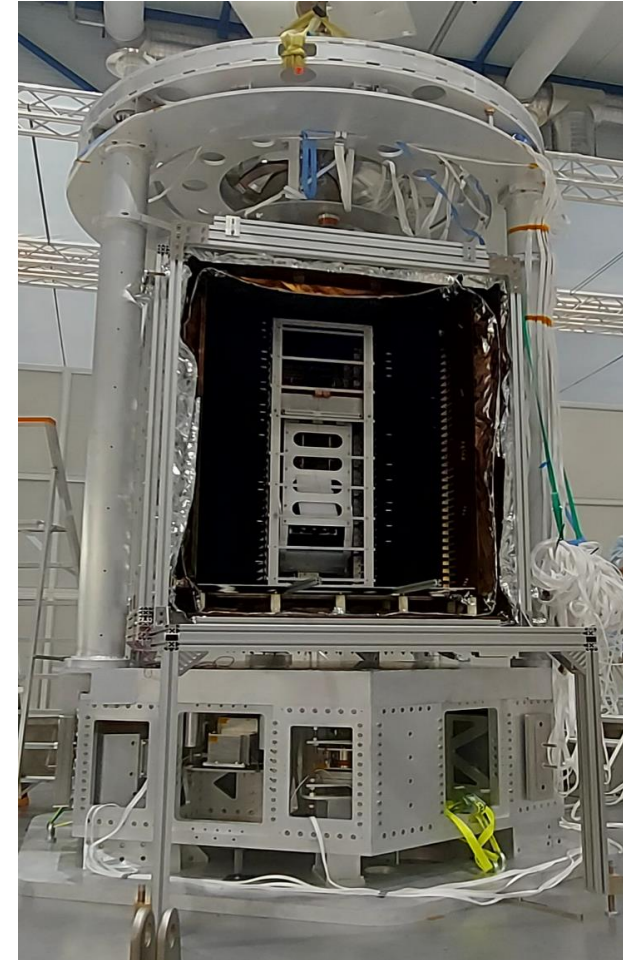
- Sink @16K (recirculating GHe)
- Black-paint emissivity >60% @ 22K



Suspended inner cryostat



After integration of outer cryostat including LN₂ shield and GHe panels



Outline

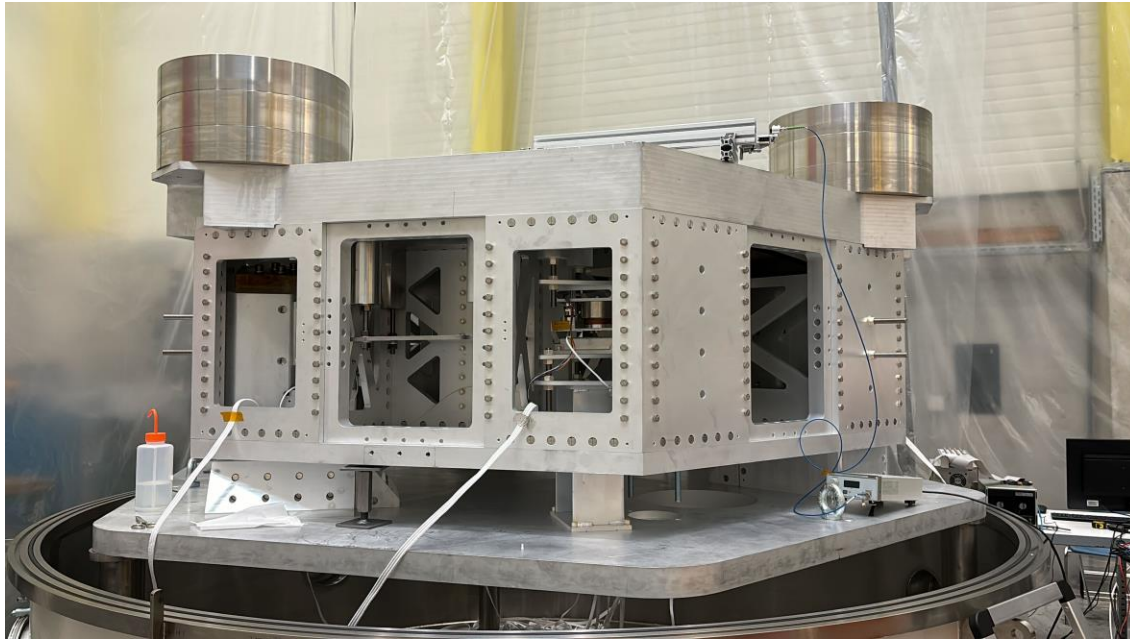
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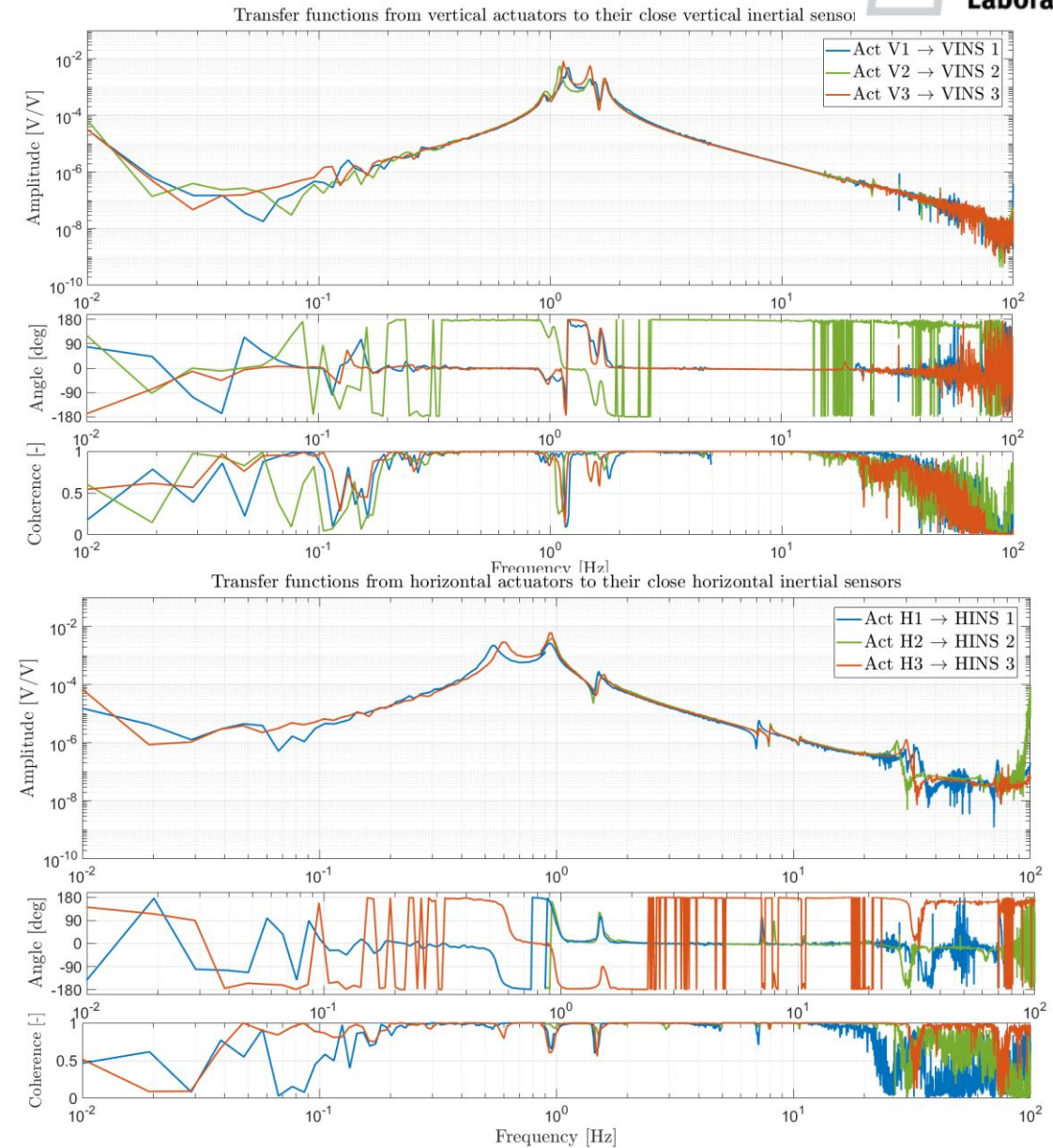
Continuation of work

Low-frequency active Isolation and preparing for next run



E-TEST active platform

- Low-frequency Active isolation:
 - Locking platform with the ground at low freq 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 freq





Contacts:

Prof. Christophe Collette

Christophe.Collette@uliege.be

Mouhamad 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/>