E-TEST: Einstein Telescope EMR Site and Technology

Haidar Lakkis

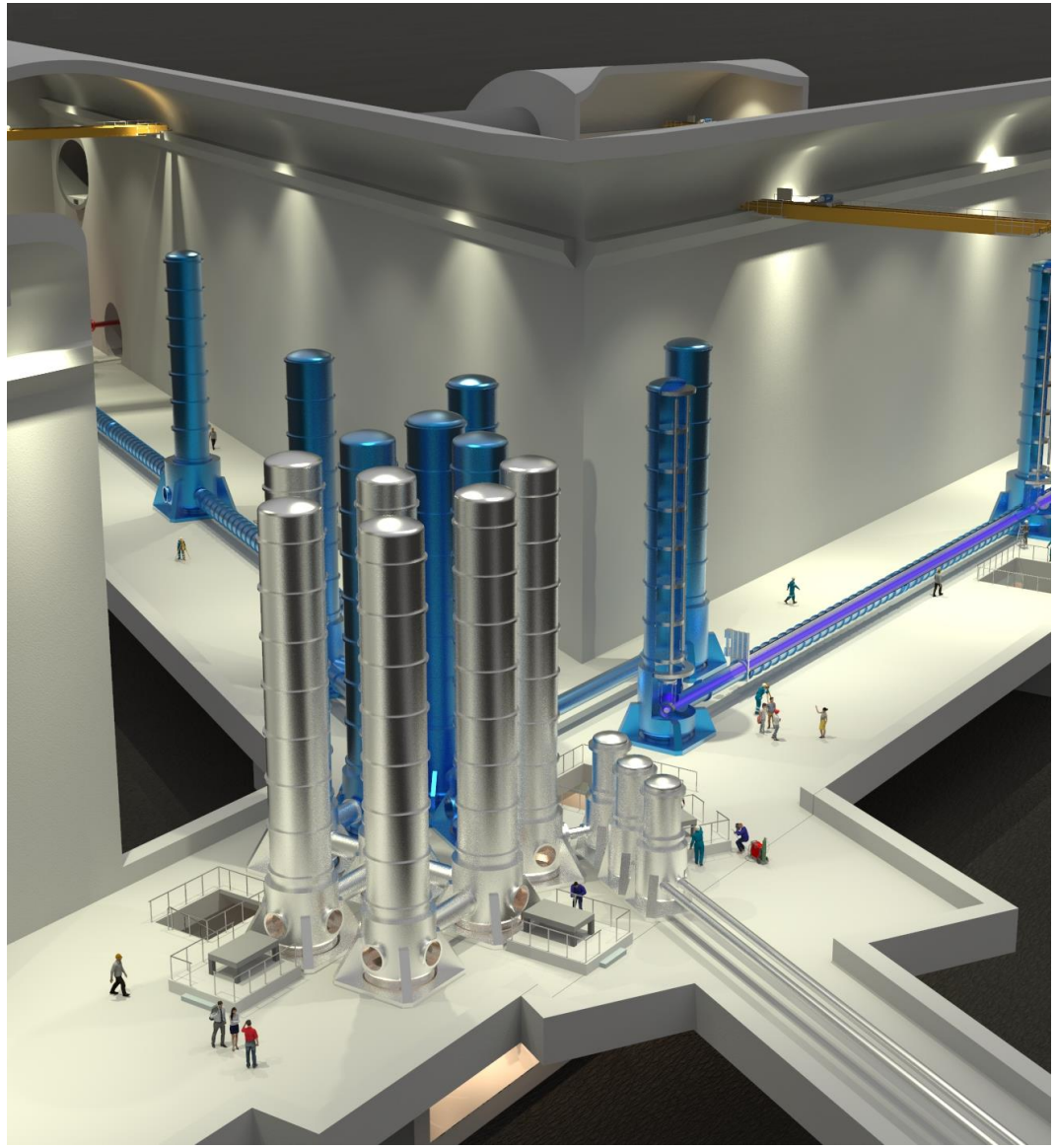
On behalf of Precision Mechatronics Laboratory (ULiege)

20.09.2024

E-TEST Einstein Telescope EMR Site & Technology

Interreg Euregio Meuse-Rhine European Regional Development Fund

EUROPEAN UNION



E-TEST objectives

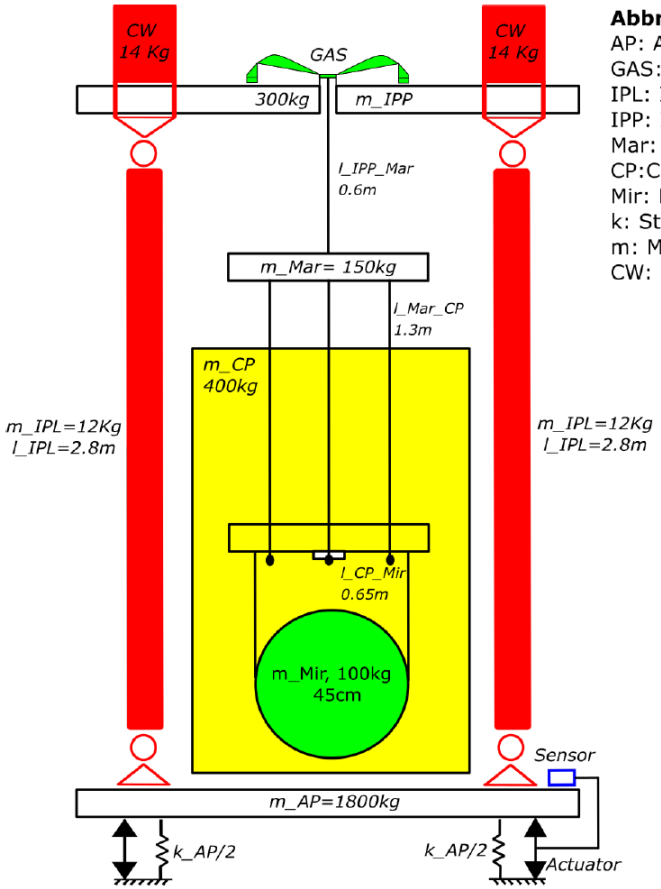
- Large mirror (100 Kg)
- Cryogenic temperature (10-20 K)
- Isolated at low frequency (0.1-10 Hz)
- Compact suspension (4.5 meters)

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.

Precision Mechatronics Laboratory
CSL Centre Spatial de Liège
RWTH Aachen University
KU Leuven
Nikhef
UCLouvain
micas KU Leuven
Fraunhofer ILT

E-TEST: how it started



Abbreviation:
AP: Active Inertial Platform
GAS: Geometric Anti-Spring
IPL: Inverted Pendulum Leg
IPP: Inverted Pendulum Platform
Mar: Marionette
CP:Cryostat+Cold Platform
Mir: Mirror
k: Stiffness
m: Mass
CW: Counter Weight

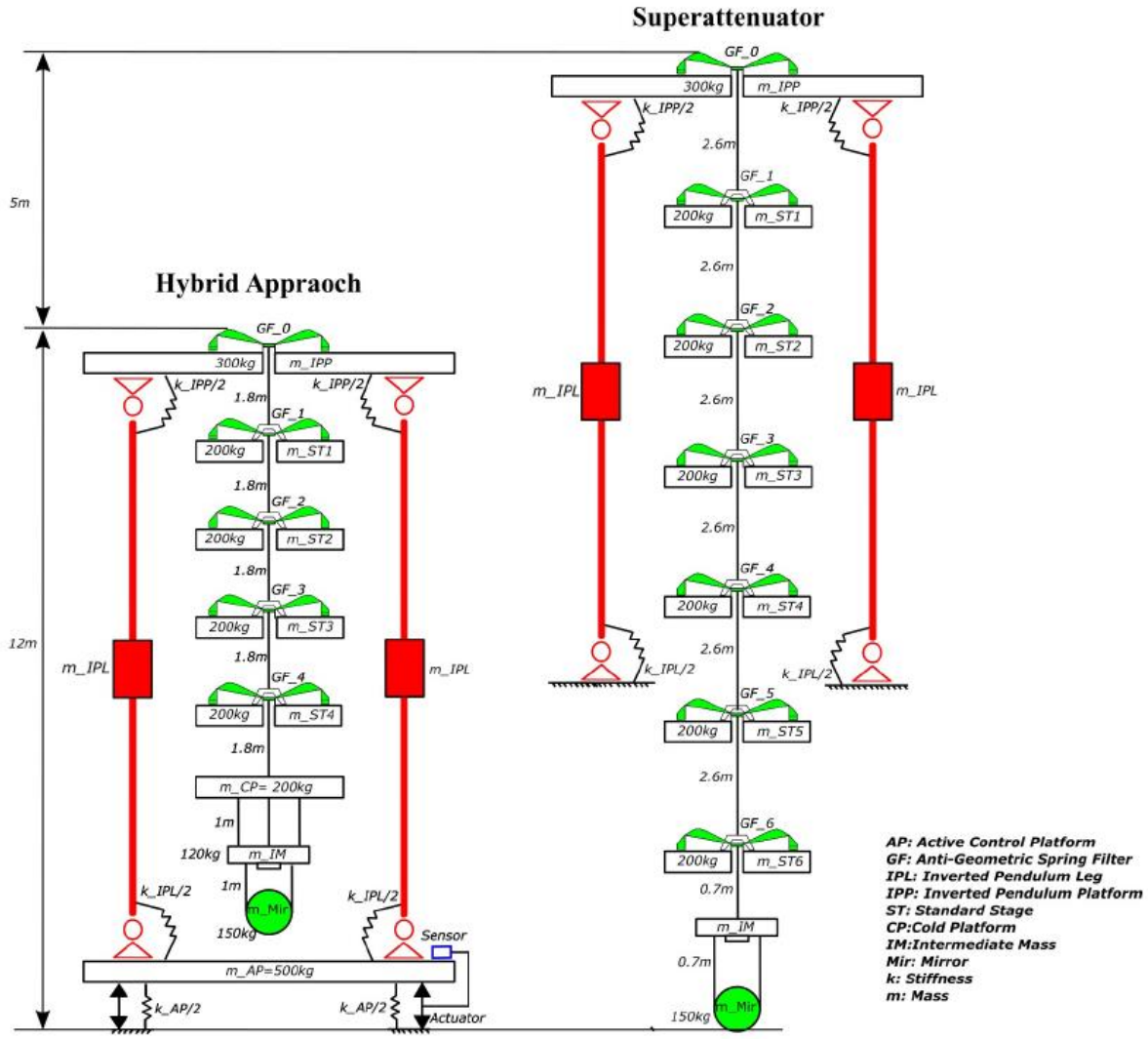
Liège Space Center

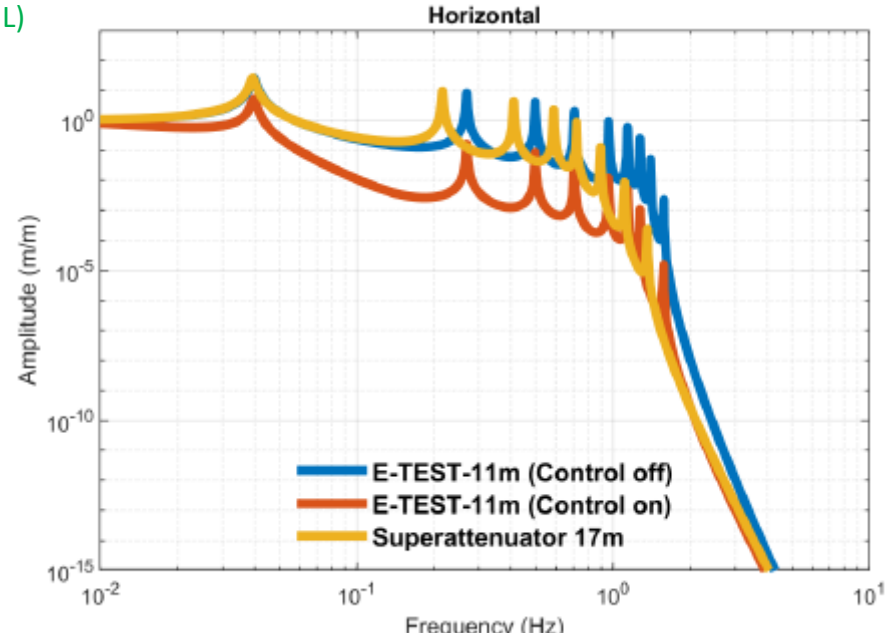
Hybrid (active + passive) isolation
Radiative cooling

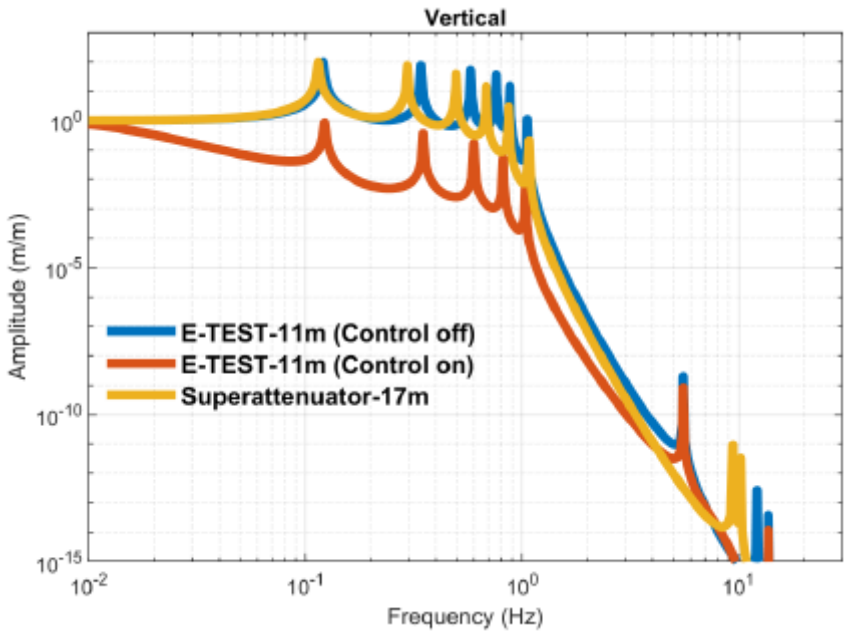
E-TEST: how it started

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

Hybrid approach = fewer stages



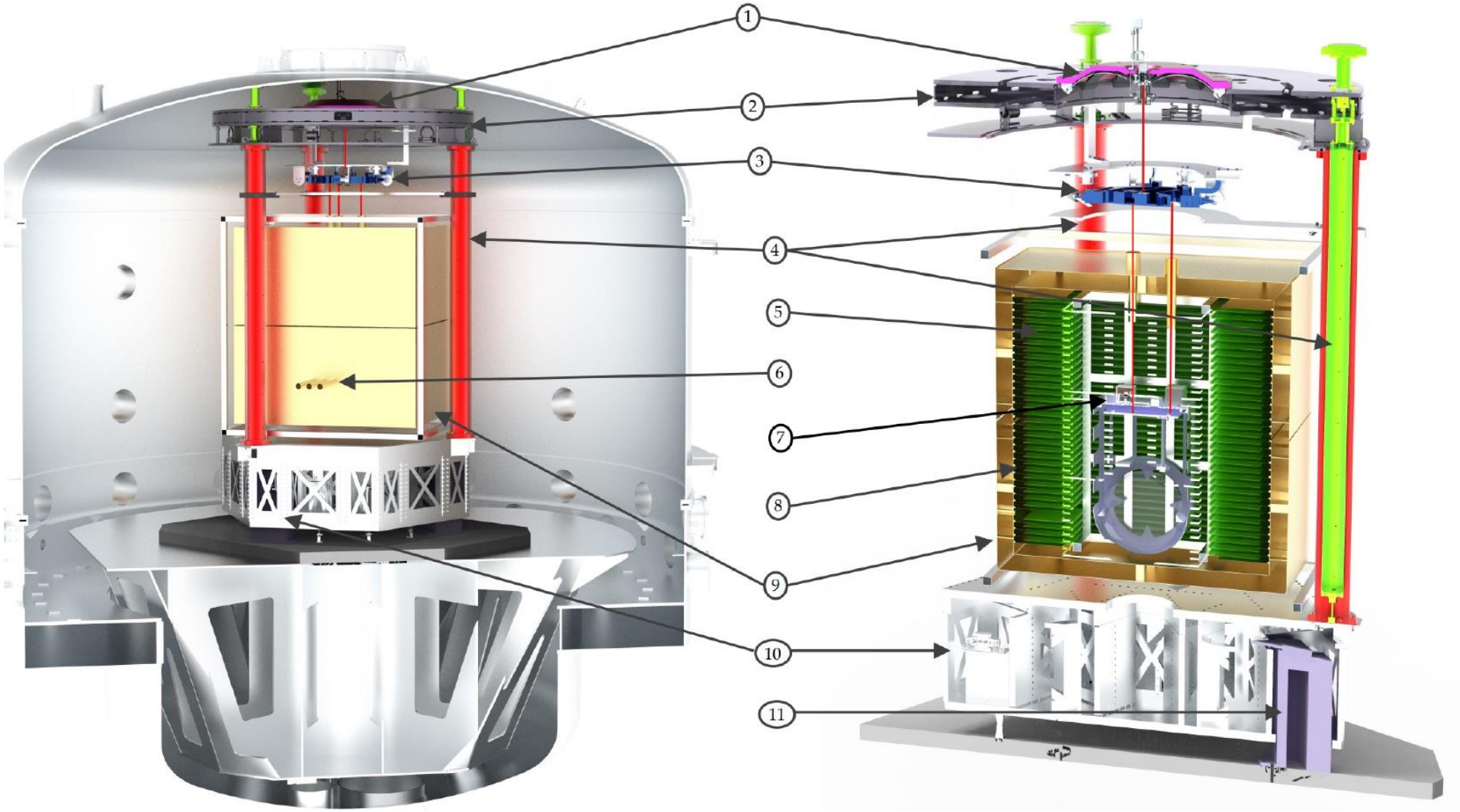




From a design concept to technical drawings

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

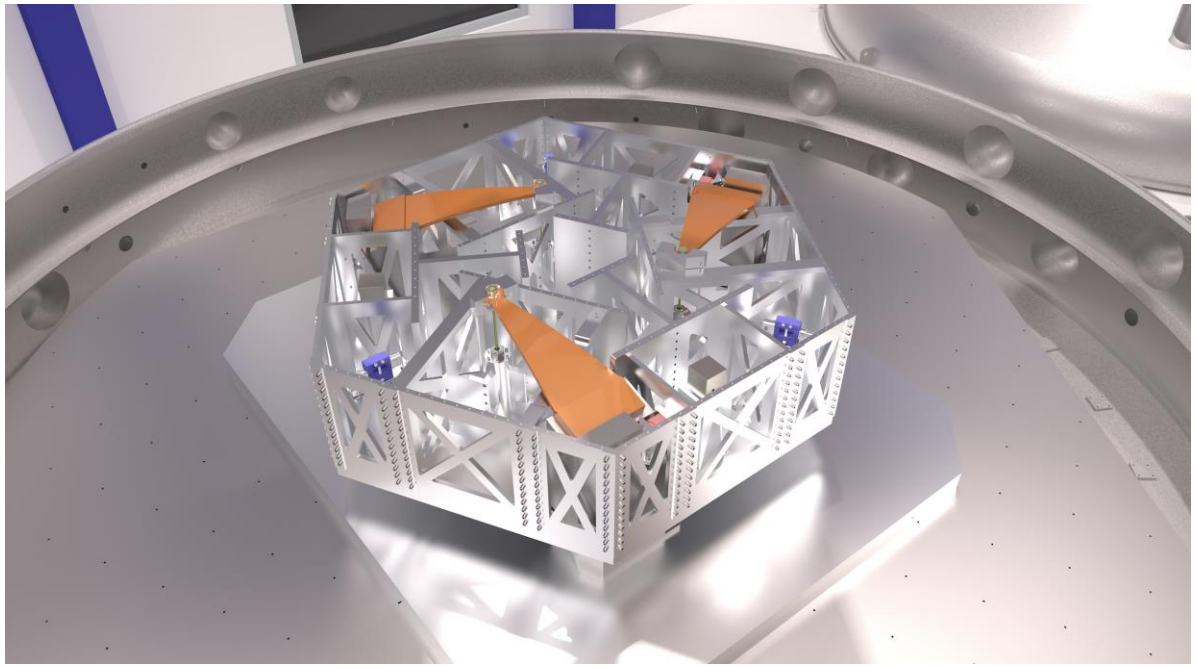
Cryogenic payload
5) Heat exchanger and cold platform
7) 25K inner thermal shield
8) 80K outer thermal shield

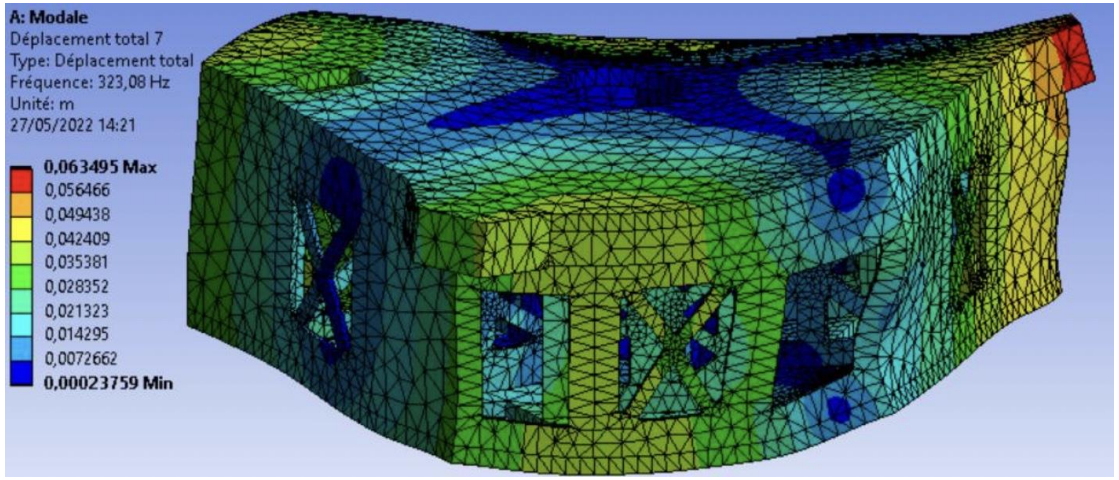


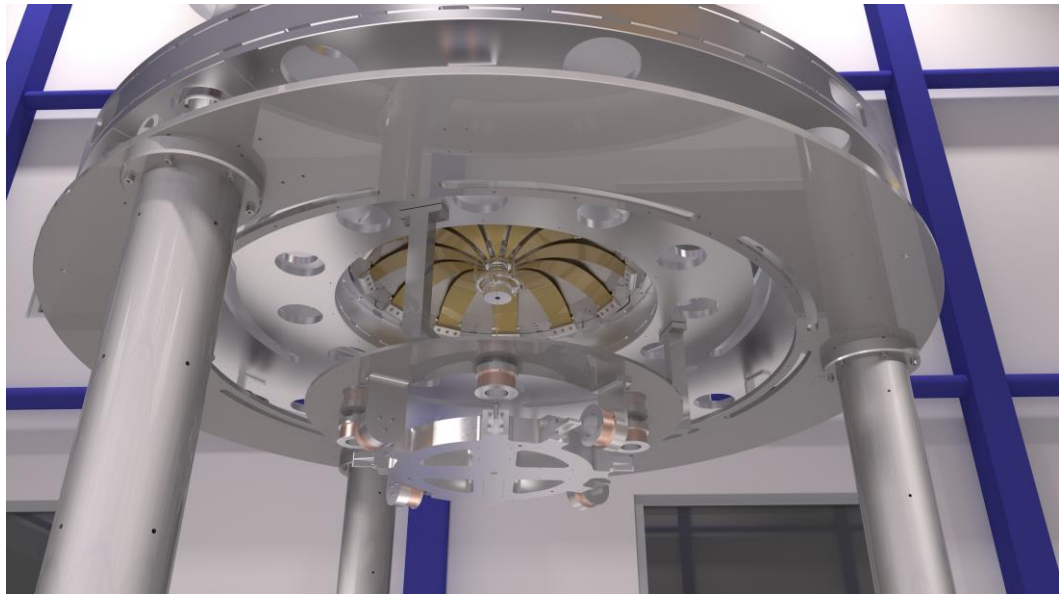
From a design concept to technical drawings

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

From a design concept to technical drawings

Radiative cooling design

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

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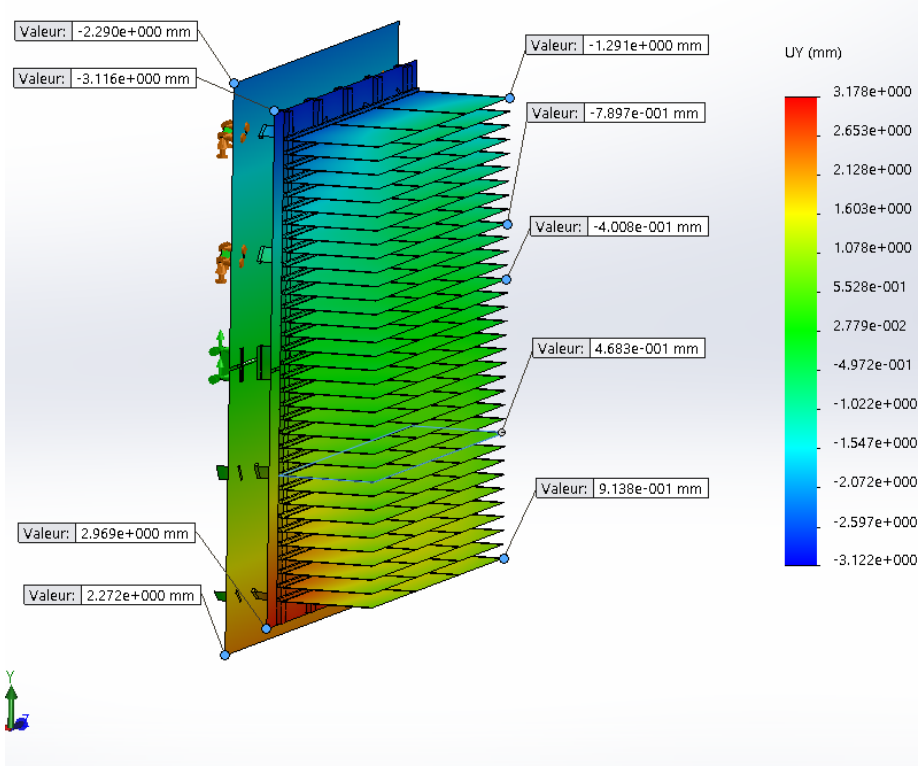
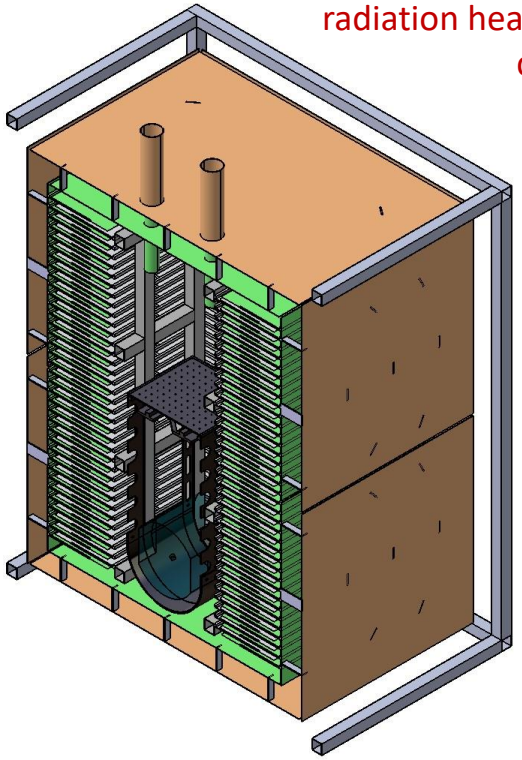
- Overall dimensions: 1.8 x 1.6 x 2 m^3
- Conventional radiator design with horizontal fins (20K)
- Three 30-mm diameter optical feed-throughs towards the mirror

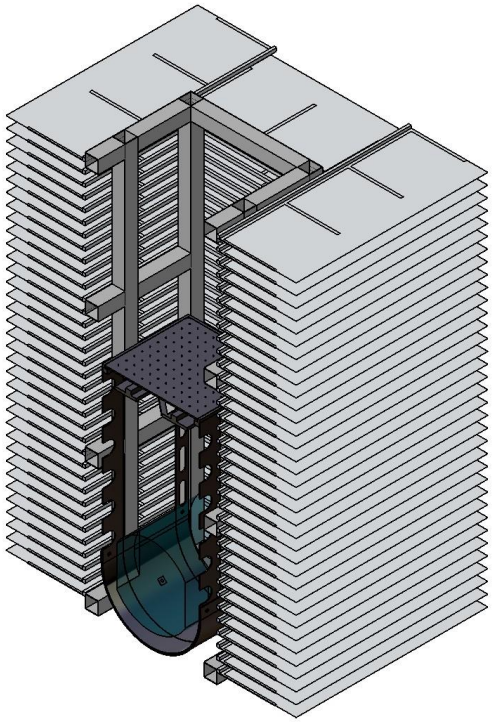


radiation heat transfer for mirror cooling



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

Inverted pendulum displacement sensing

Contact: Anthony Amorosi (PML)
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Loïc Amez-Droz (PML)
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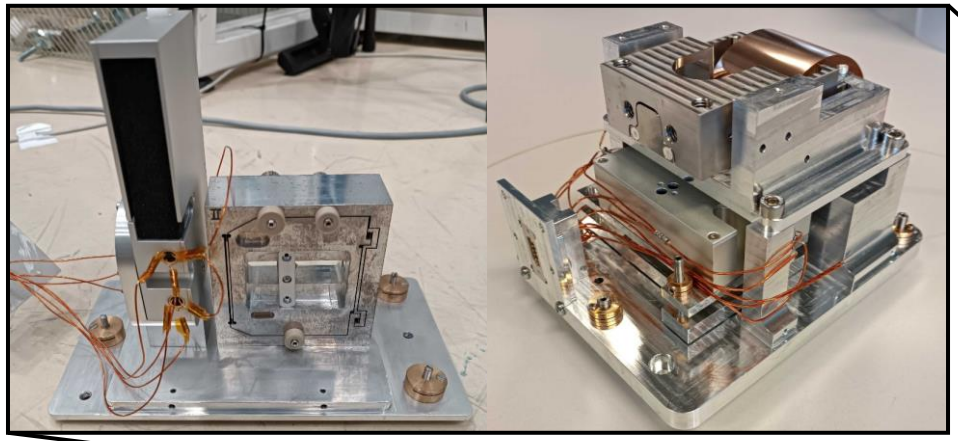
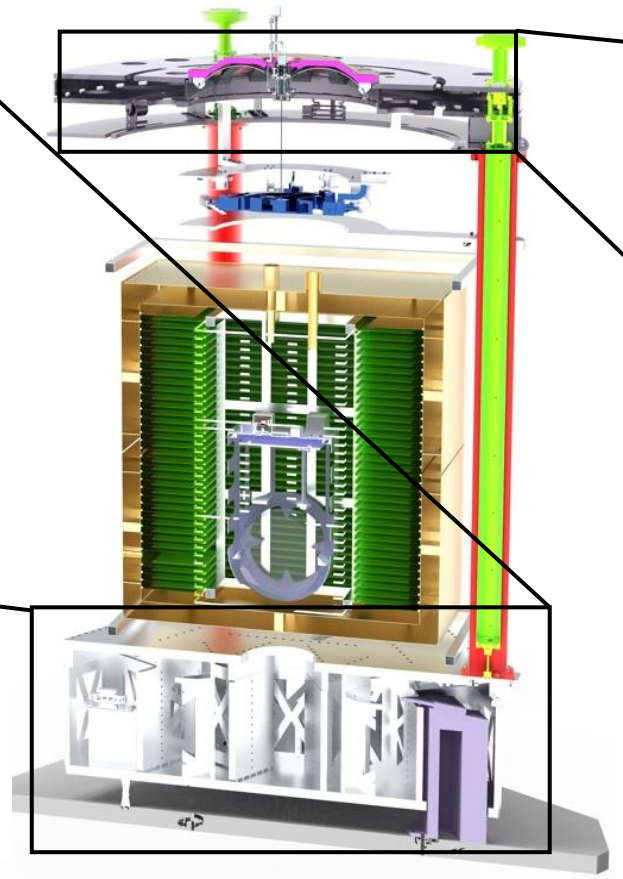
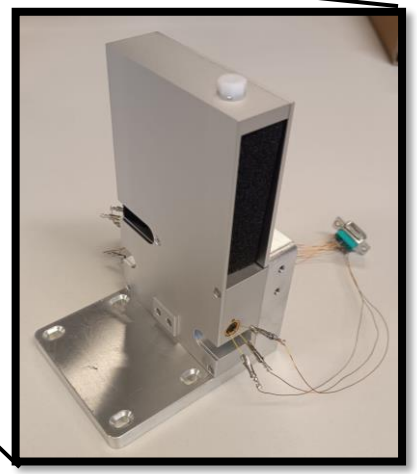
High-resolution, low-frequency, optical horizontal seismometer







- 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).

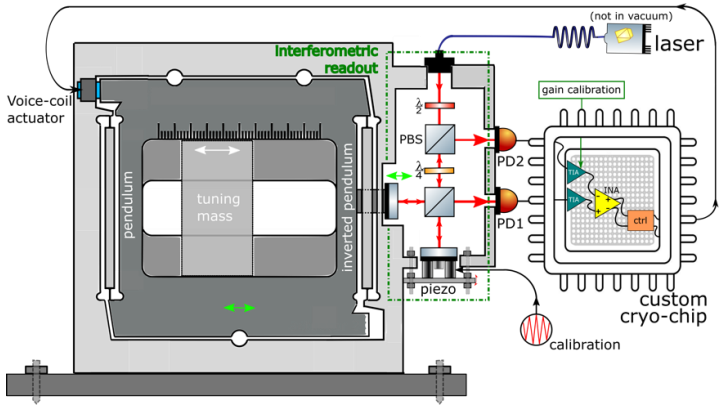
+ Additional LVDT reading for redundancy

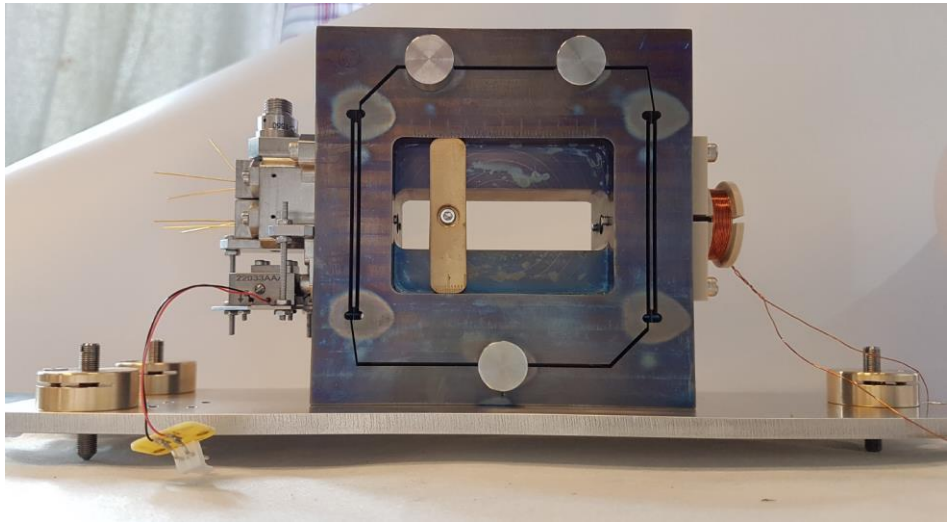
Ultra-cold vibration control

Cryogenic inertial sensors

Morgane Zeoli (PML)
morgane.zeoli@uliege.be

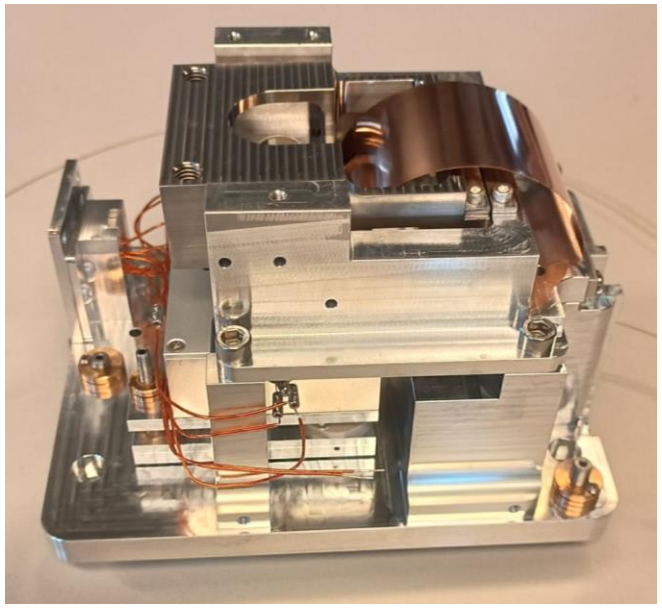
CSIS-H

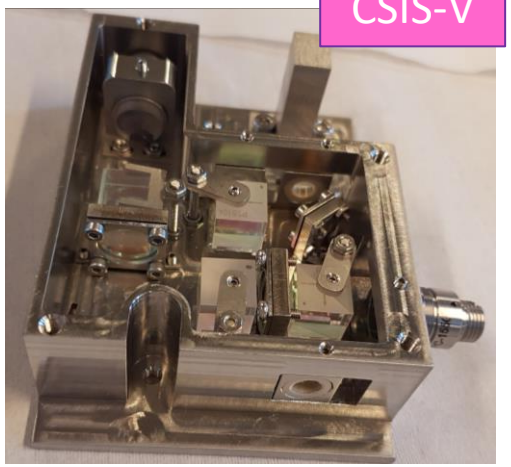




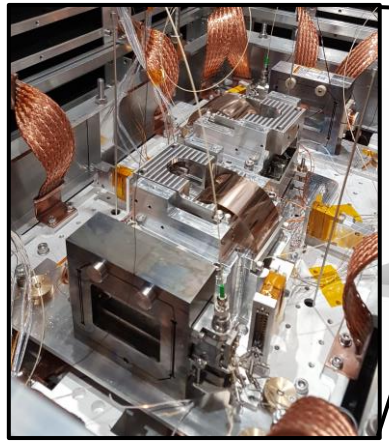
- Sub-Hz resonance frequency.
- fm differential optical readout

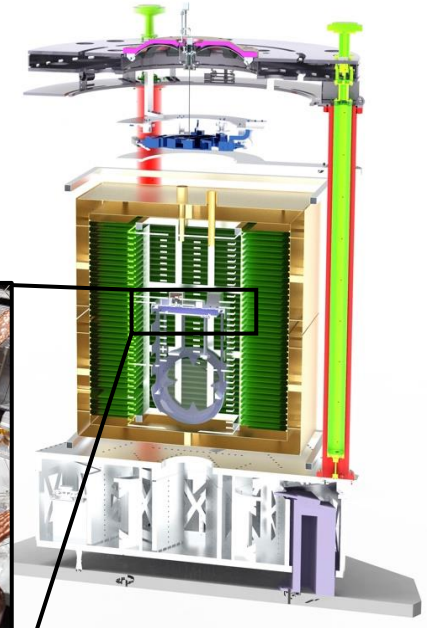
CSIS-V





- 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)
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Christophe Collette (PML)
Christophe.Collette@uliege.be
Cédric Lenaerts (CLS)
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CENTRE SPATIAL DE LIÈGE

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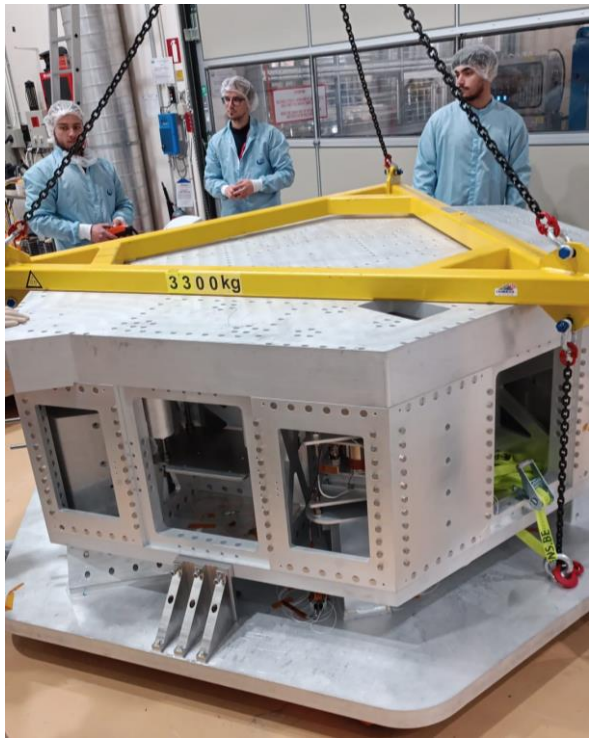
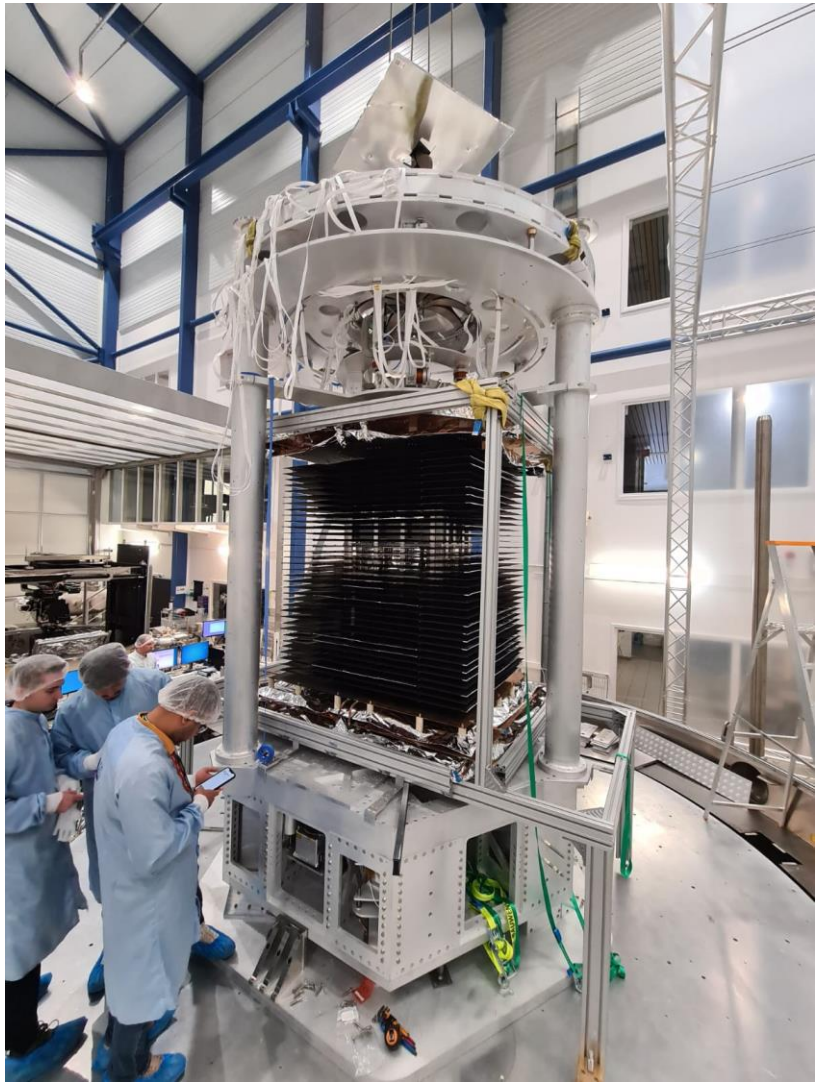
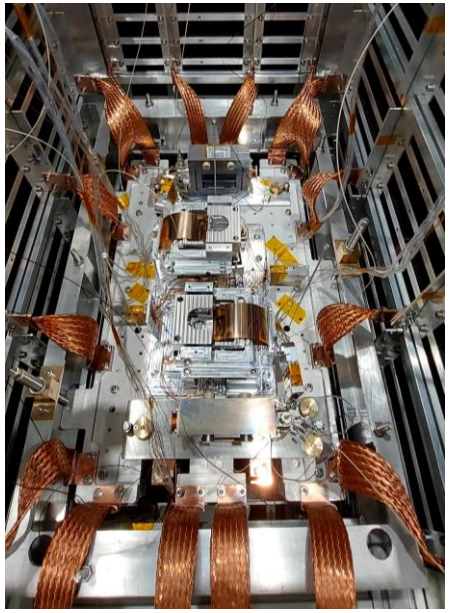
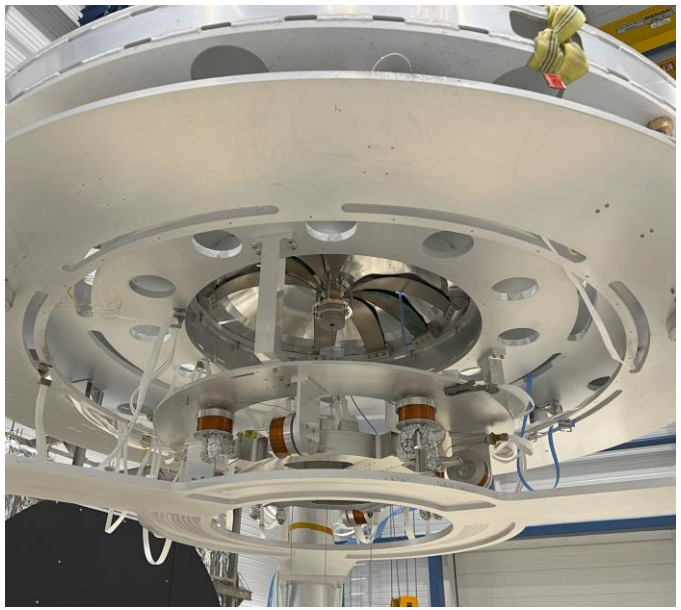
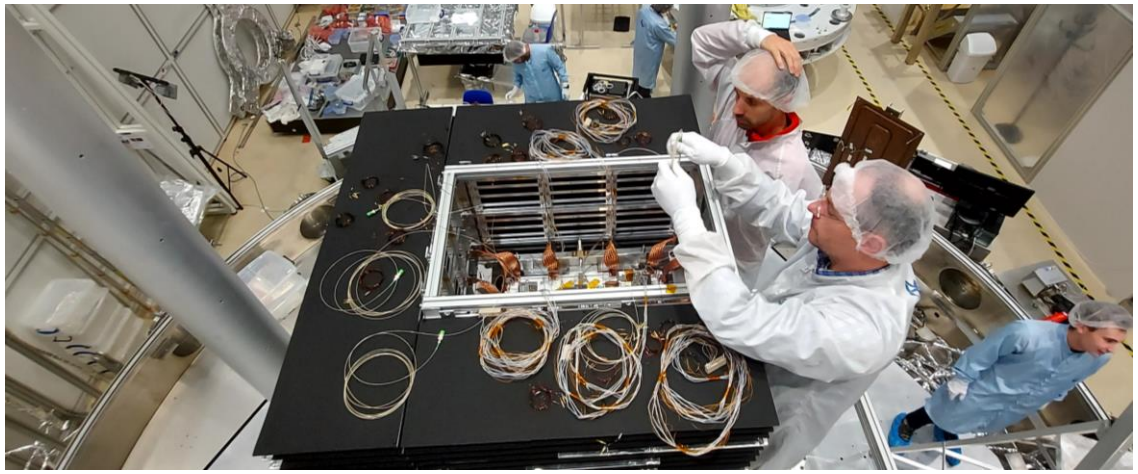










Assembly of the prototype at CSL

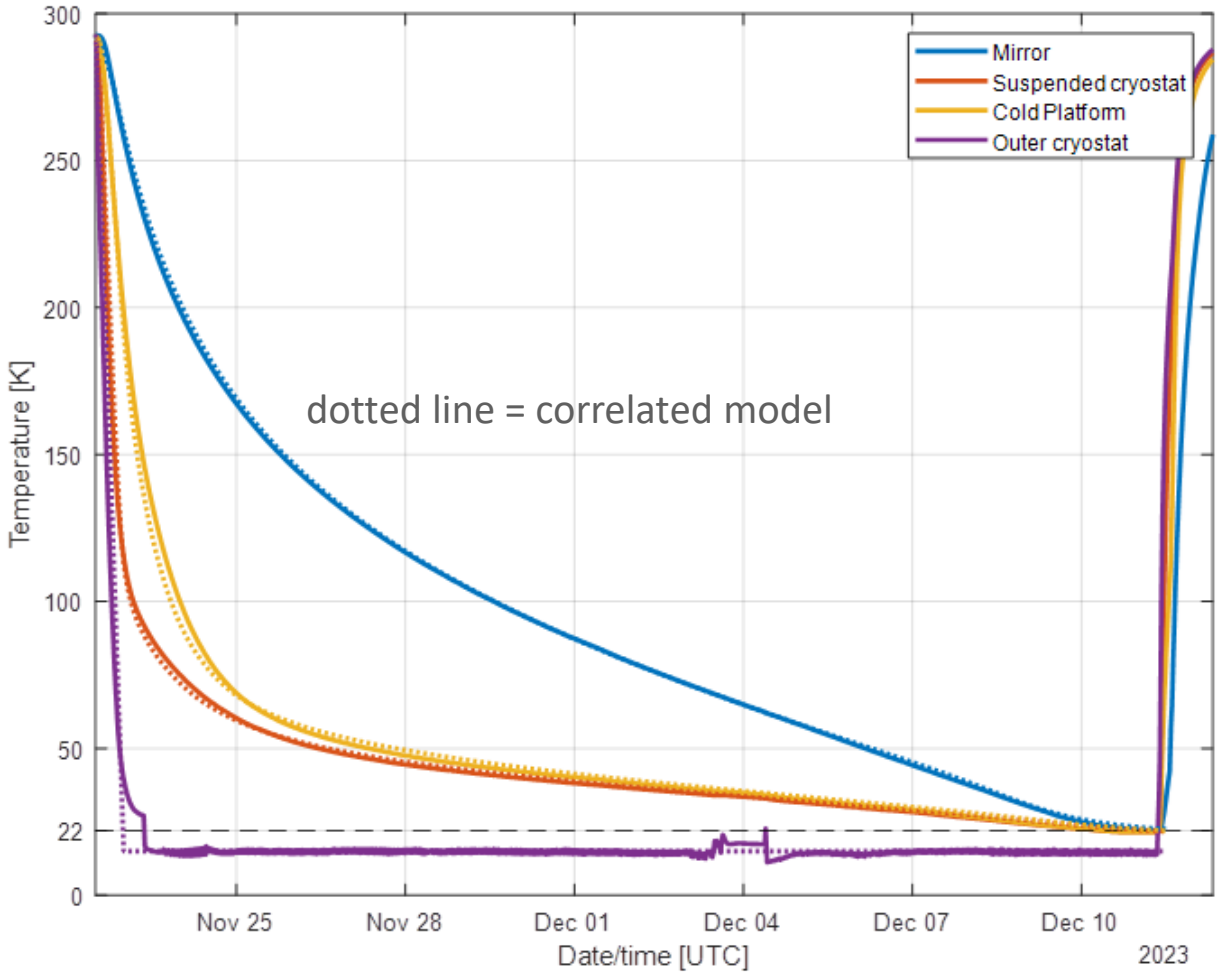
- Assembly of the prototype was finished by the end of November 2023
- Vacuum chamber closed + first run started

22K achieved in 18days

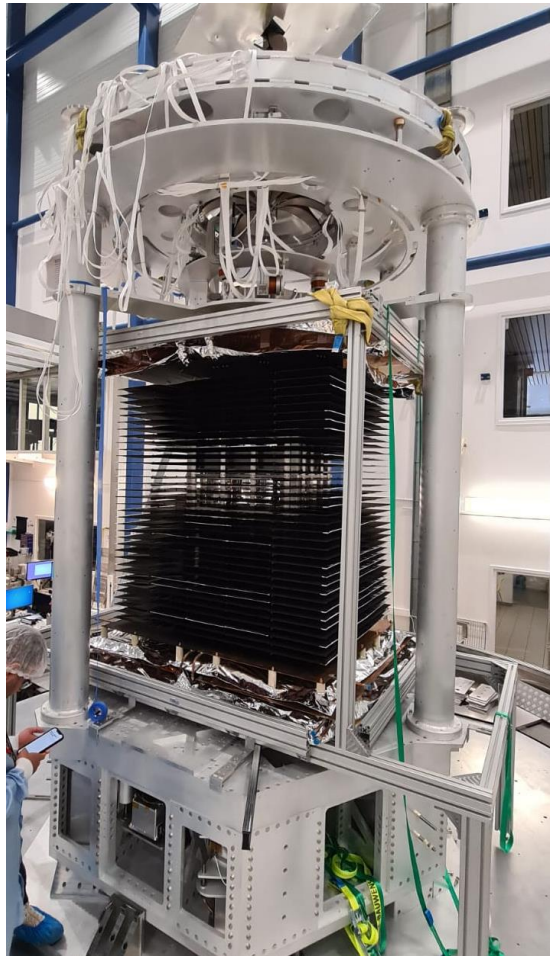
Contact :Cédric Lenaerts (CSL)
cedric.lenaerts@uliege.be

Lionel Jacques (CSL)
ljacques@uliege.be

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



Suspended inner cryostat



After integration of outer cryostat including LN_2 shield and GHe panels

Low-frequency active Isolation and preparing for the next run

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

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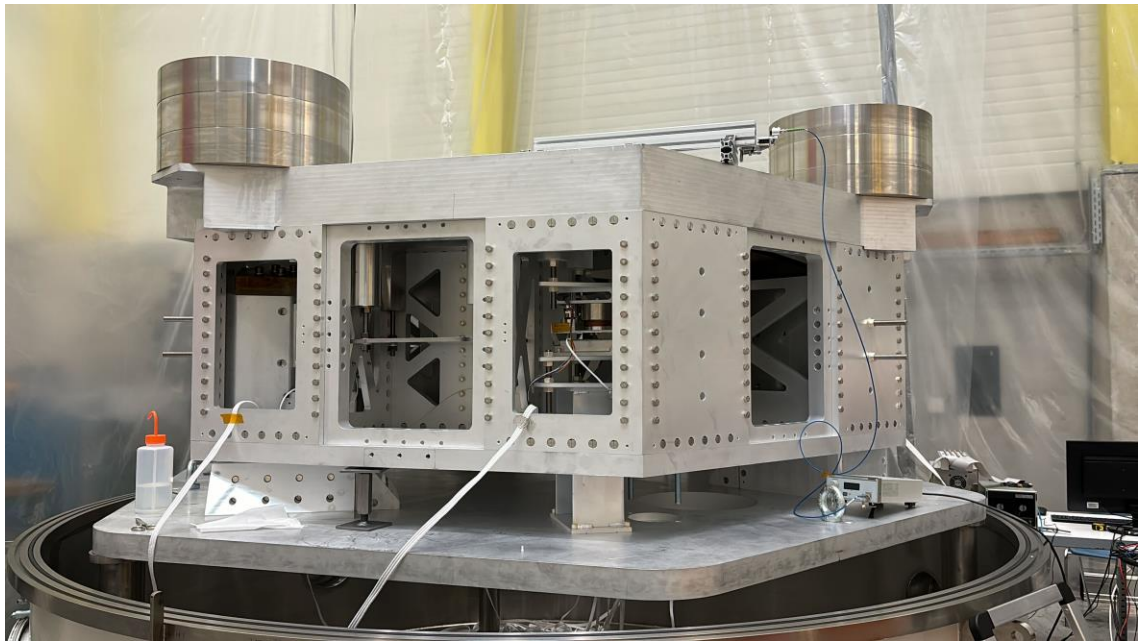
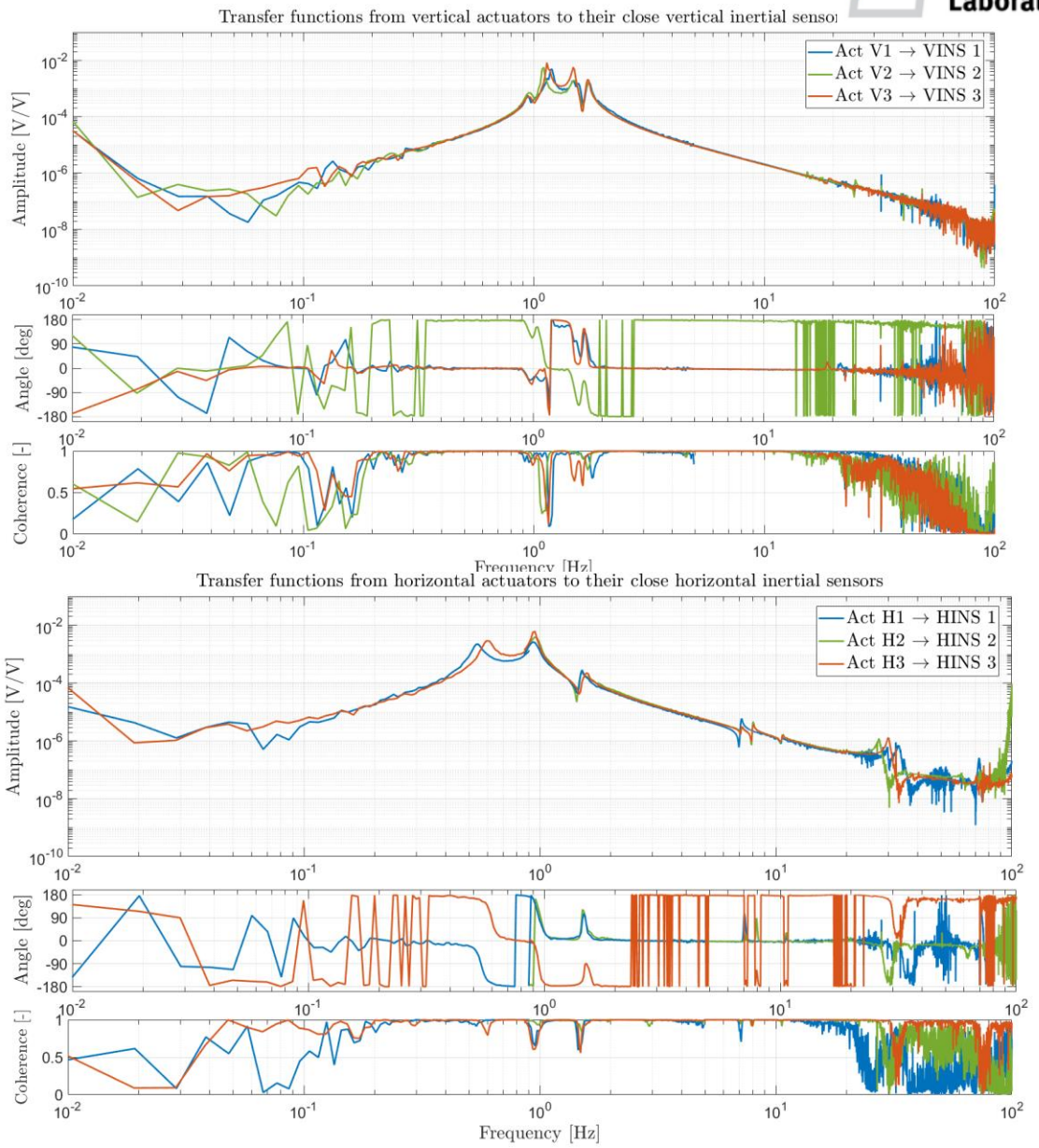


E-TEST active platform

- 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



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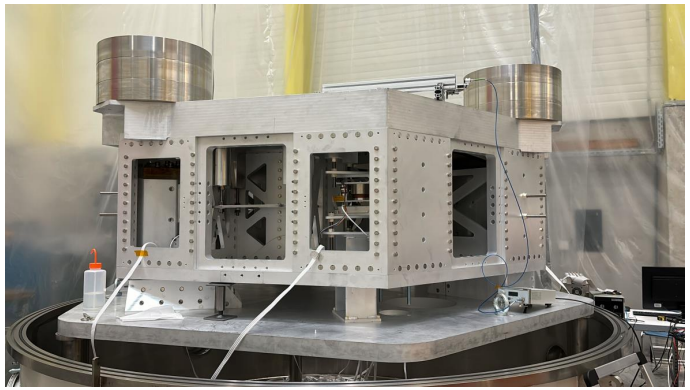
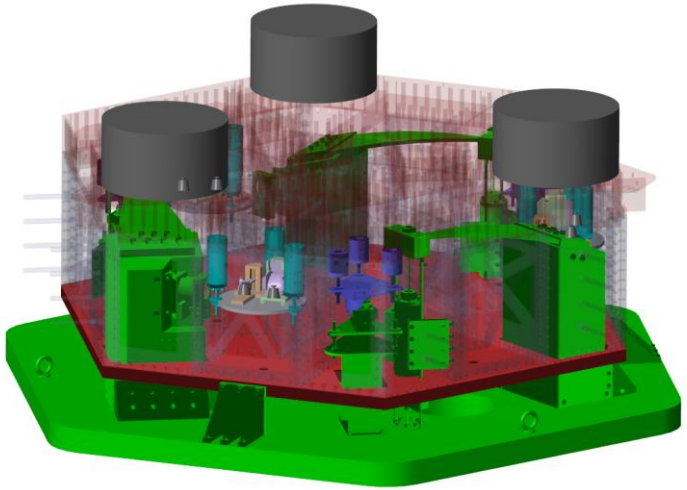
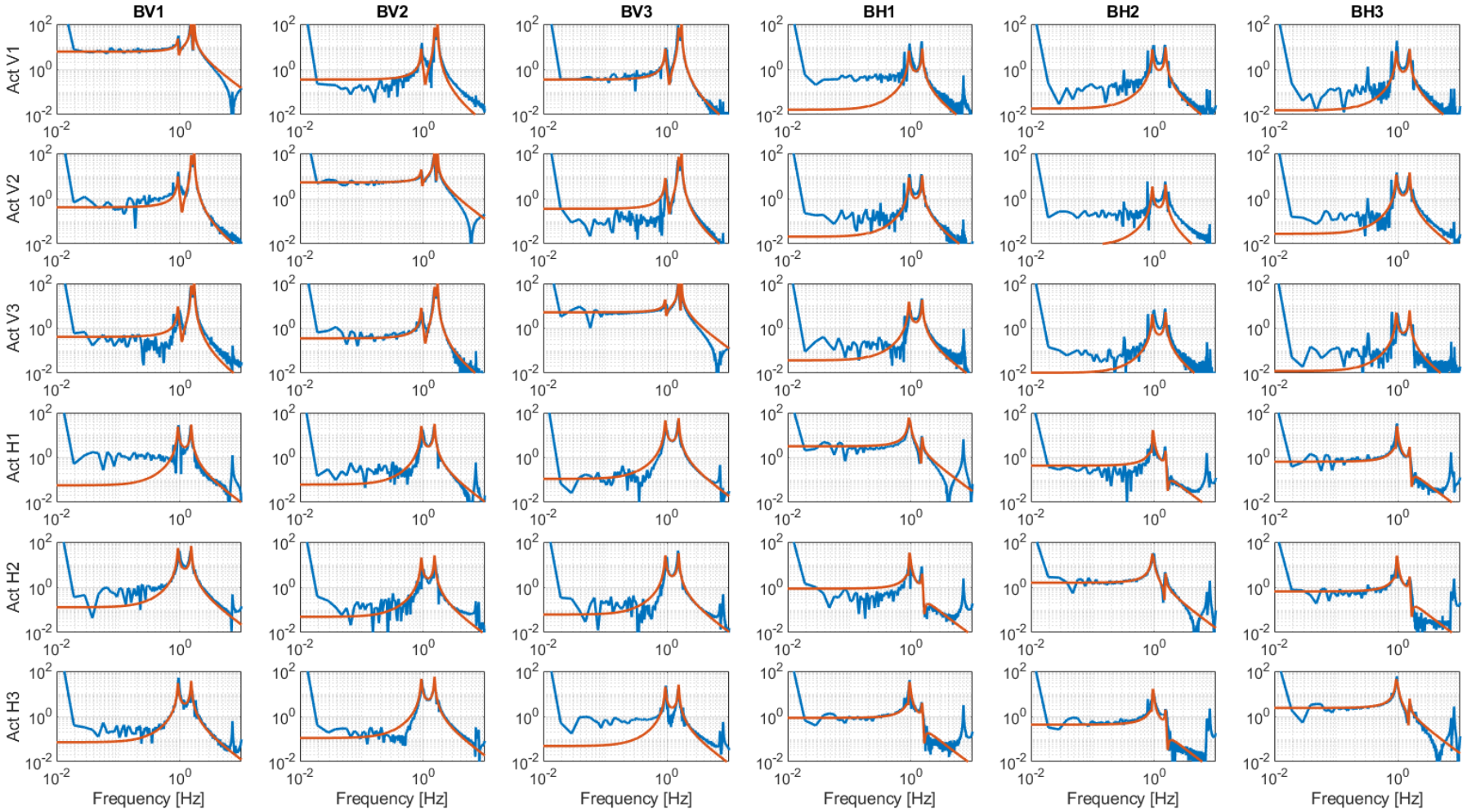
From modelling to experimental data:







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Low-frequency active Isolation and preparing for the next run

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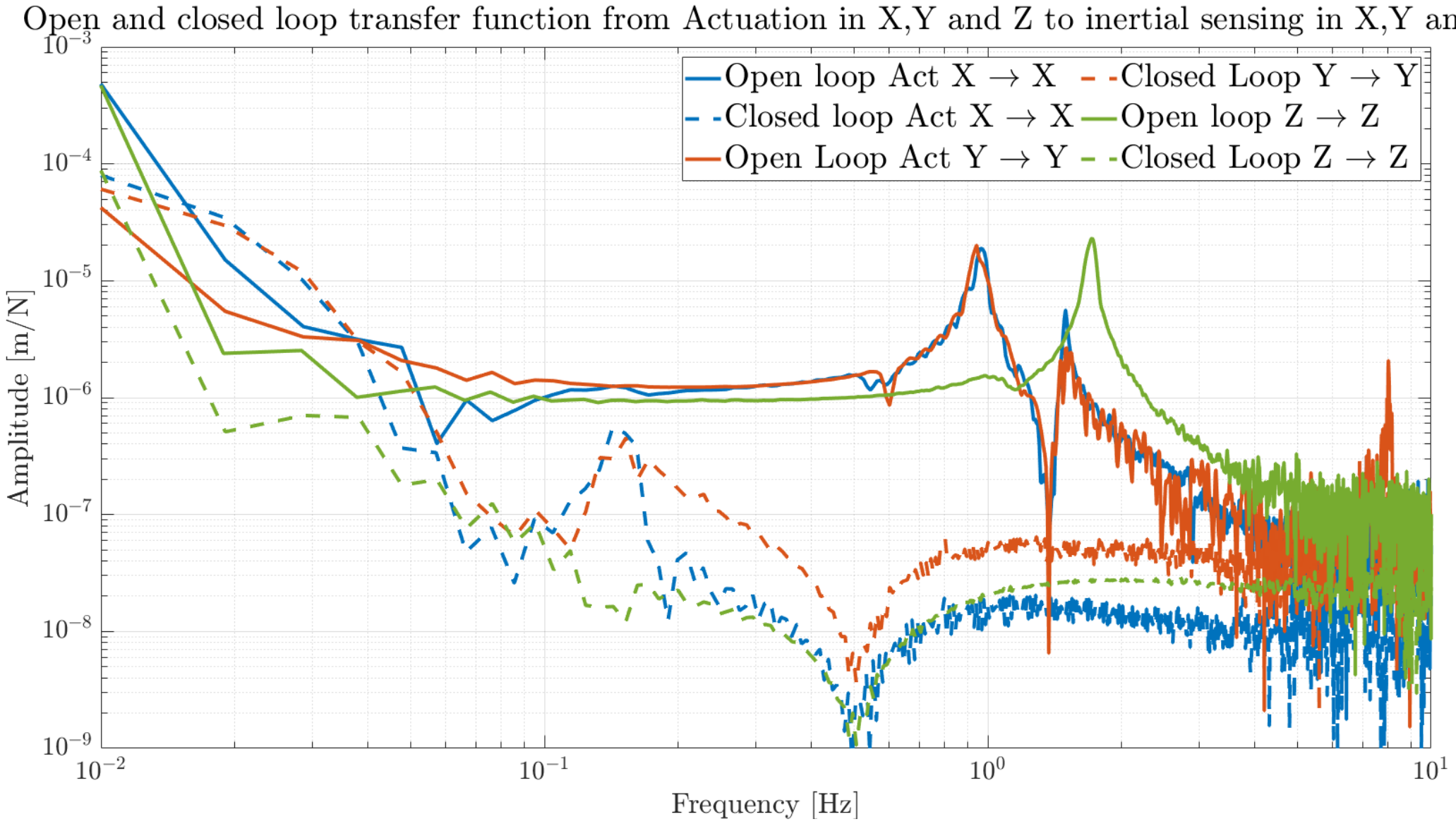

Contact : Haidar Lakkis (ULiege)
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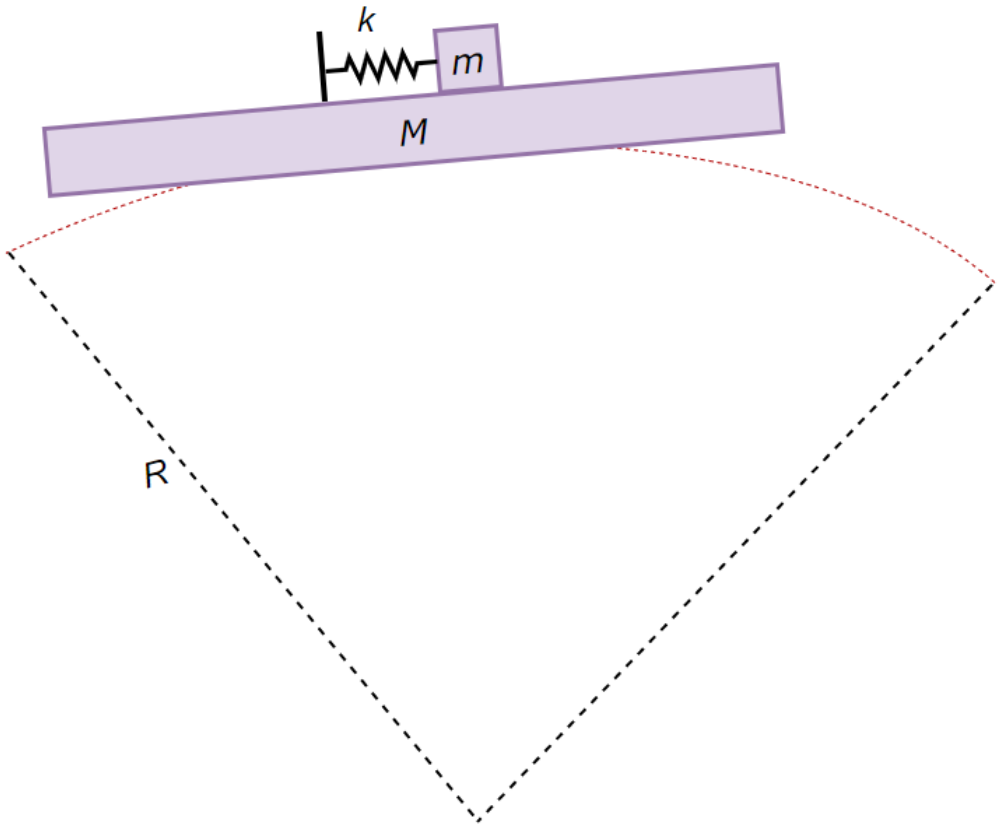
Following what is in P040022-00-R

- The frequency of NMP zero is dependent on the radius of curvature of the trajectory of the platform



$R\ (m)$	1	10	100	1000	∞
$NMP\ freq\ (Hz)$	0,498	0,158	0,0498	0,0158	0

NMP zero below $0{,}016\ Hz$

$$R \geq 1\ Km$$

Relative displacement sensors with very low cross-sensitivity for decoupling

Low-frequency active Isolation and preparing for the next run

Contact:
Christophe Collette (PML)
Christophe.Collette@uliege.be

Precision Mechatronics Laboratory

- The real-scale silicon mirror arrived last week from “Linton Crystal Technologies”
- It is being polished at AMOS
- The next run will be in less than a year with the real test mass suspended

Thank you

Contacts:

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Haidar Lakkis
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Useful links:

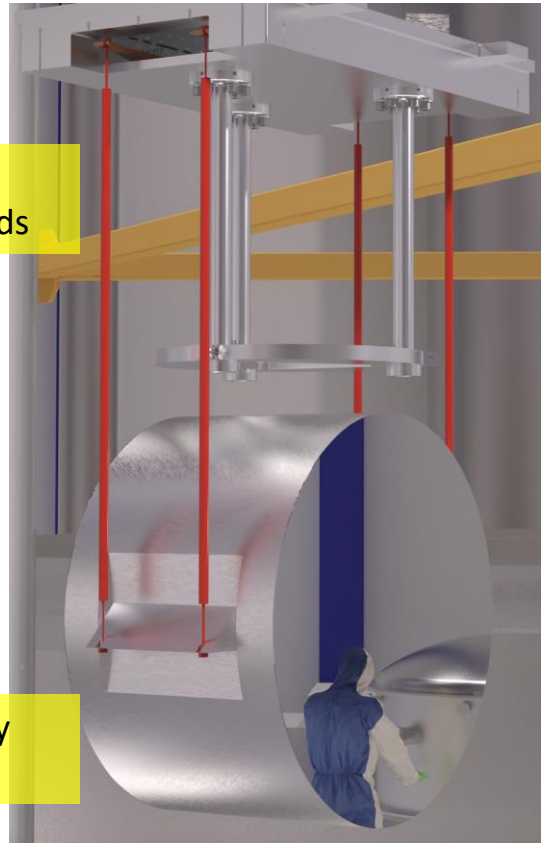
TDR
https://arxiv.org/abs/2212.10083
E-TEST Project website
https://www.etest-emr.eu/
PML website
http://www.pmlab.be/

Additional Slides

Ultra-cold vibration control

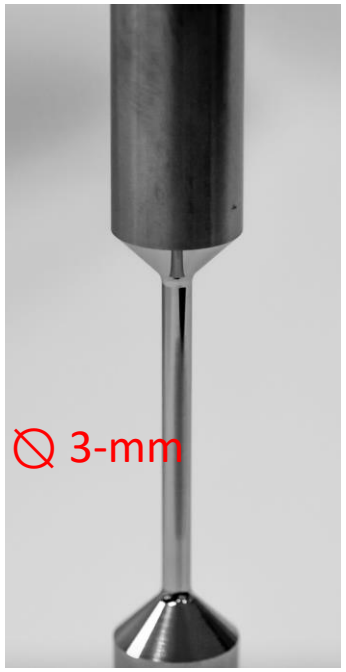
Crystalline silicon mirror suspension

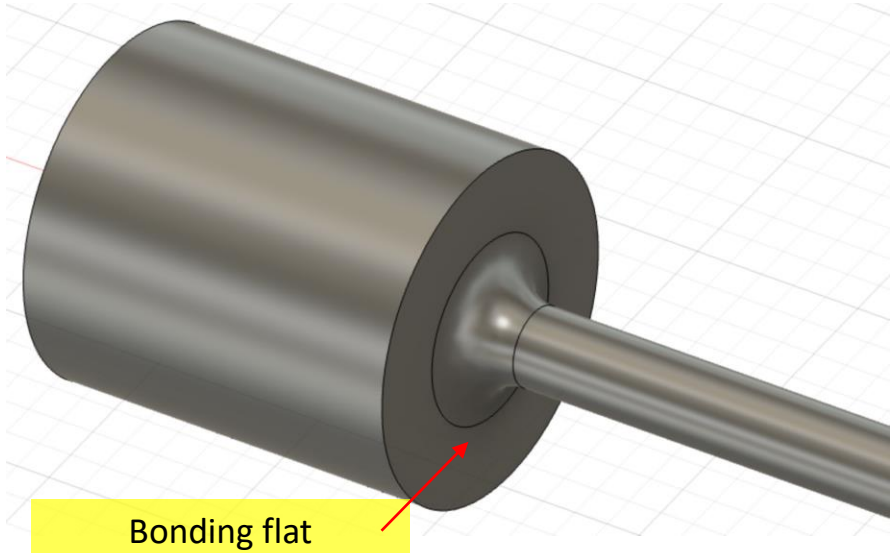
- Crucial technology aspect for ET: no proven solution exists
- Four machined samples delivered



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)
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Contactless Radiative cooling strategy

Contact :Cédric Lenaerts (CLS)
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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