

WP 3.2: Seismic Attenuation and Controls

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FWO IRI Workshop – 8/6/2026

Overview

Research on seismic attenuation and control for ETpathfinder and Virgo:

- a) Further develop new (LVDT) sensors that improve standard Virgo designs. Prototypes can be commissioned into ETpathfinder to test in-situ performance, and could then also be used in the stable recycling cavities for Virgo O5.
- b) Construct a full suspension mechanics system at UAntwerpen. Such system can then be used to develop active control loops, test sensors, and gain further expertise in attenuation mechanics.
- c) Acquire additional DAQ hardware for ETpathfinder. Depending on the availability of components we might equip one tower with a new readout system and demonstrate its capabilities for ET.
- d) Provide person power to contribute to the construction and commissioning of new Advanced Virgo+ Phase 2 seismic isolation systems for the O5 observation runs.

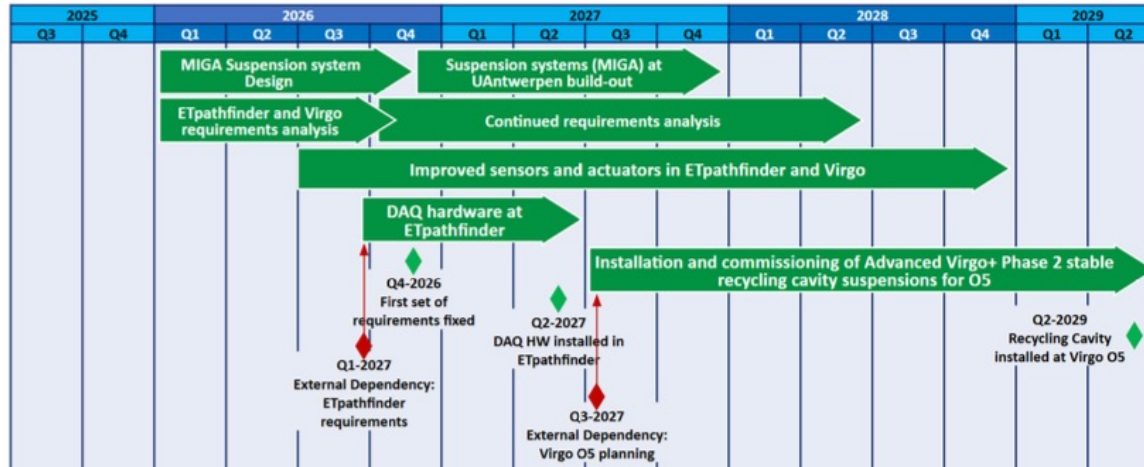
Budget:

Infrastructure: ETpathfinder DAQ hardware; Suspension mechanics; Material for prototype coils + winding machine.

Person power resources: PhD student (4-years), Postdoc (2 years)

Initial timeline

Planning and Key Performance Indicators for this Work Package



Depends significantly on ETpathfinder and Advanced Virgo+ Phase 2 timelines

KPI 1 - Q1/2027: one stage in ETpathfinder provisioned with improved sensors and actuators

KPI 2 - Q2/2027: interferometer with active control completed in one arm of ETpathfinder

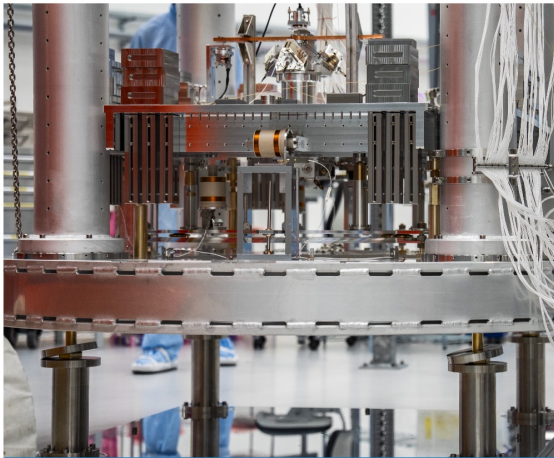
KPI 3 - Q2/2028: interferometer with active control completed in two arms of ETpathfinder

KPI 4 - Q2/2029 : new recycling cavity installed at Virgo O5: suspended, locked, sensors installed and control loops in action with active control

LVDT research and suspension commissioning

Characterization and development of novel position sensors and actuators for seismic attenuation systems in gravitational wave detectors

Pengbo Li



Supervisor Prof. Dr. Hans Van Haevermaet

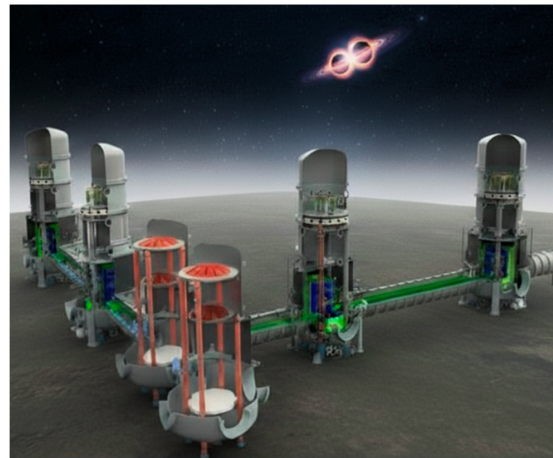
Thesis submitted for the degree of Doctor of Science: Physics
Faculty of Science | Department of Physics | Antwerp, 5 December 2025



Development of low frequency position sensors & actuators for gravitational wave detectors, and their application in seismic controls in ETpathfinder

From noise to poise

Kumar Akhil Kukkadapu



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- Construction & commissioning of local measurement setup, with precise characterization of ETpathfinder LVDT+VC combination → Submitted to JINST
<https://arxiv.org/abs/2603.06209v1>
- Simulation framework to study & optimize geometry, explore novel designs → *Sensors* **2026**, 26(8), 2564
<https://doi.org/10.3390/s26082564>
→ Type-G small IP LVDT+VC for Etpathfinder
- Commissioning of ETpathfinder BST tower: calibration, electronics, controls, ...

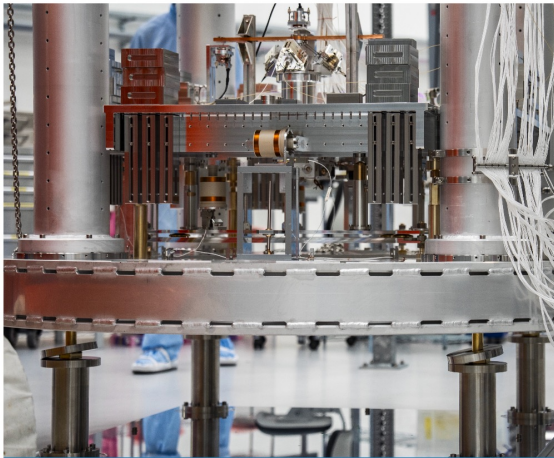
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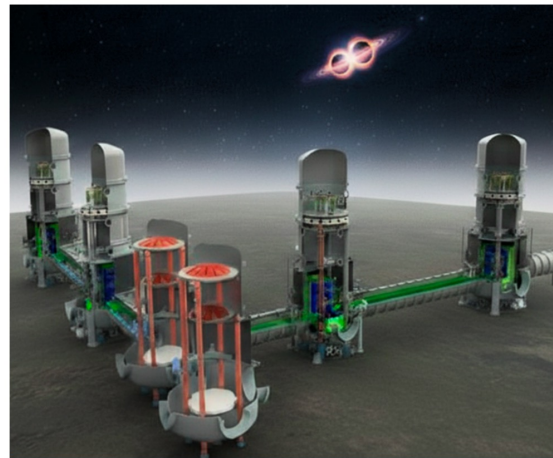
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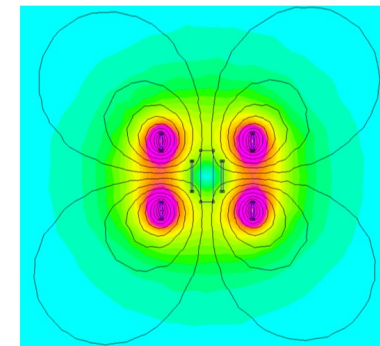
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- Exploration of novel design techniques (genetic algorithm)
- Proof of concept novel designs: reversed, CoreCoil LVDT
- Background sensitivity studies & potential shielding options (master thesis Jonas Jacobs)

<https://medialibrary.uantwerpen.be/files/7541/edd3161c-d914-4eff-976e-5b4b34cc2519.pdf>

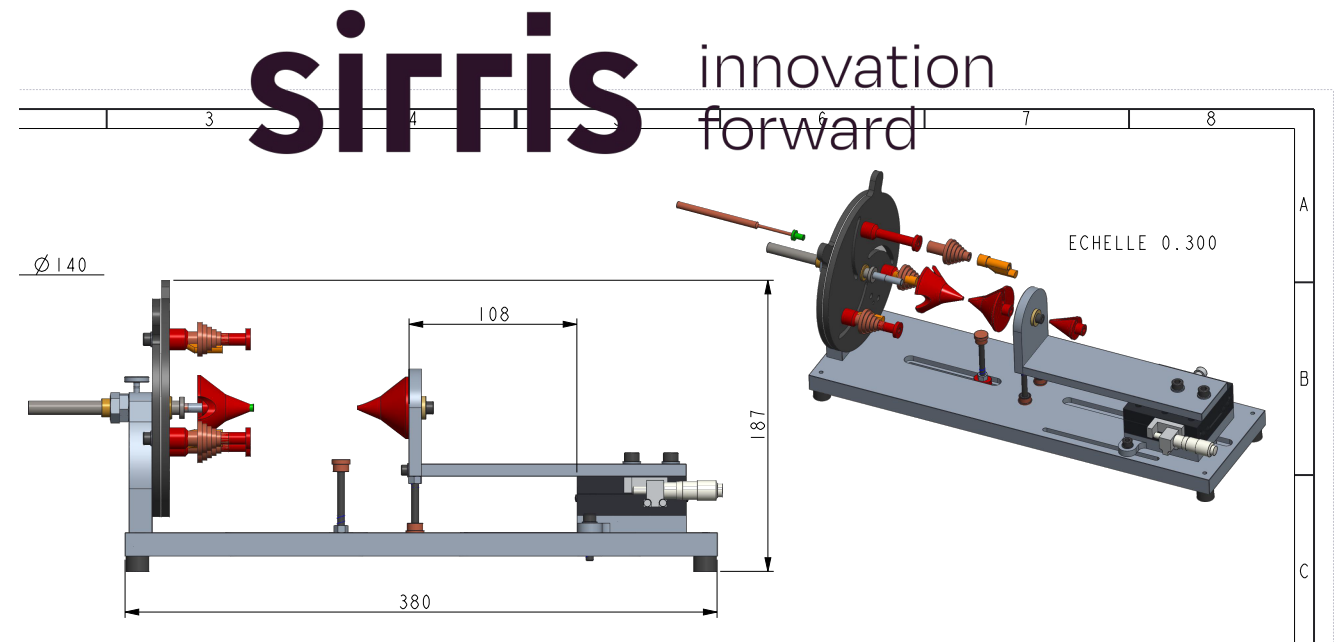
BACKGROUND SENSITIVITY STUDIES OF REVERSED LVDT'S AND THEIR POTENTIAL SHIELDING OPTIONS



JONAS JACOBS

LVDT in-situ calibration

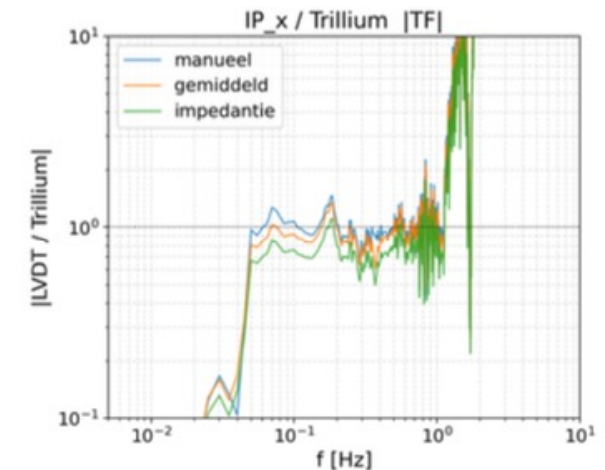
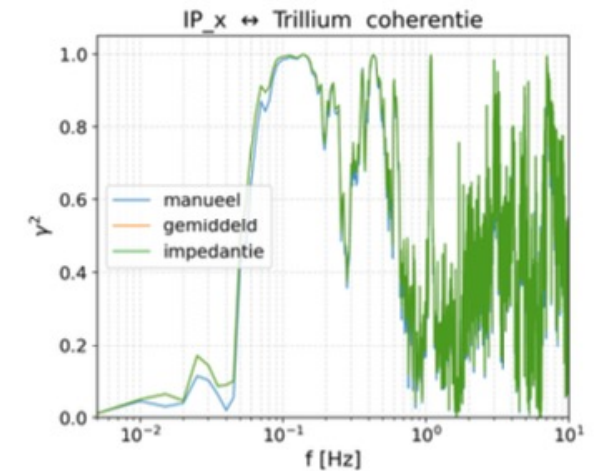
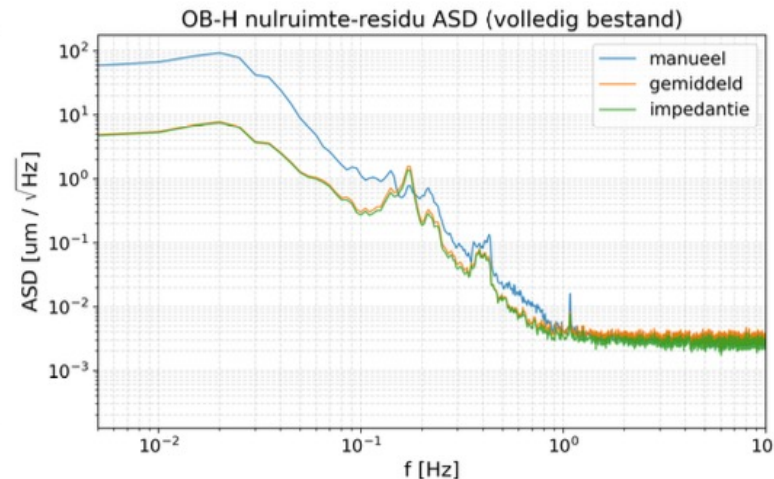
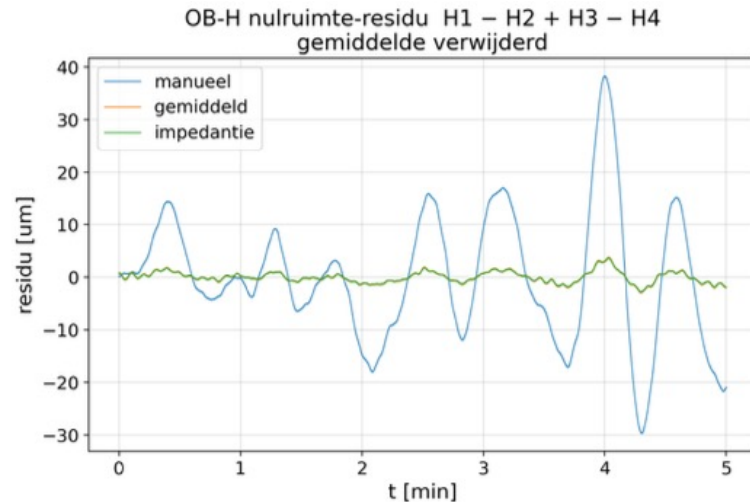
- Currently in-situ without dedicated tool: very tedious and unprecise
- Outsourced development of very simple, portable, mechanical, robust LVDT calibration setup
- Allow to calibrate LVDTs before installation, but connected through proper cabling and electronics
- Much easier, quicker, better



LVDT in-situ calibration & INT commissioning

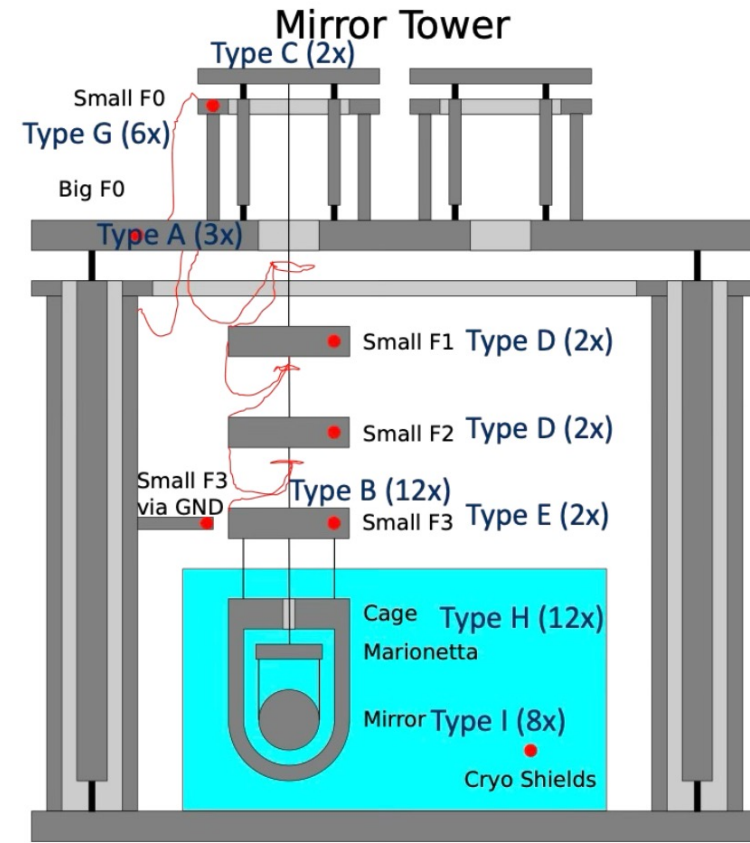
Master thesis research Simon Van Looveren (June 2026):

- Contribute to ETpathfinder INT (injection tower) commissioning:
 - Set up driving matrices, monitor controls, ...
- Explore possibility of LVDT calibration using impedance measurements
 - Clear improvement in relative calibration and control stability
 - Absolute calibration still off wrt Trillium readout: cabling effects?



LVDT production

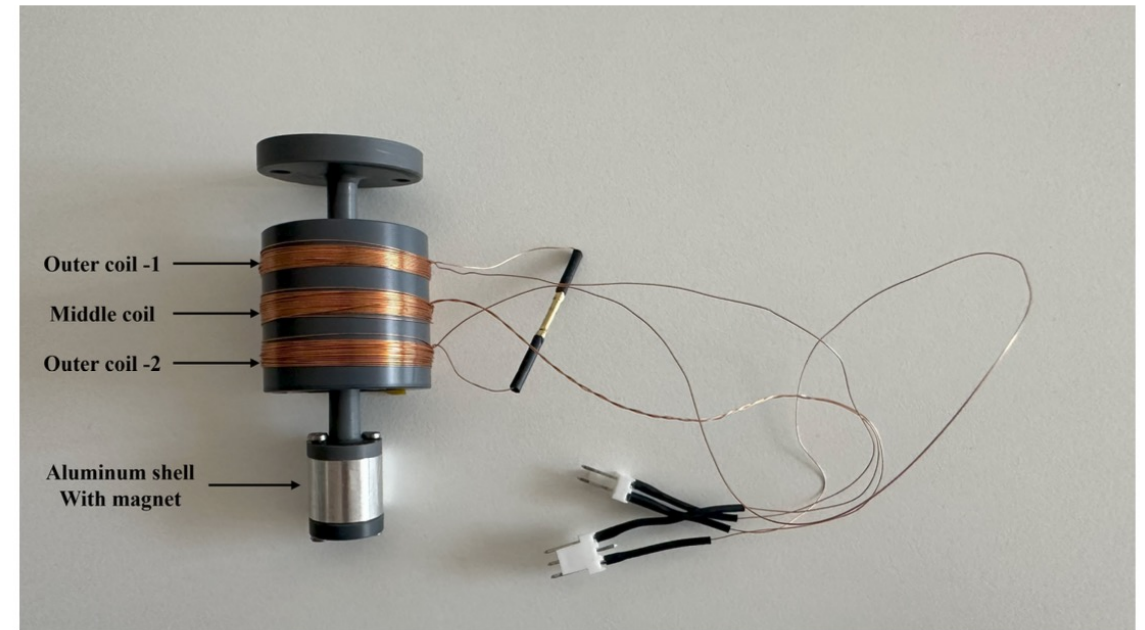
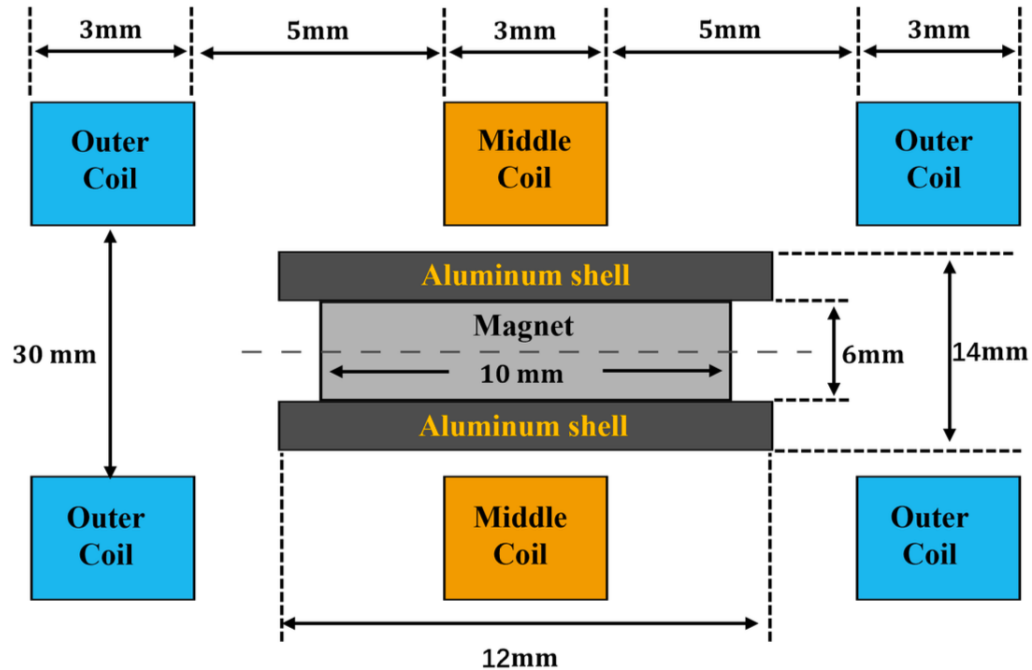
Currently producing sensors and actuators for first ETpathfinder mirror tower (South Input Tower)



CoreCoil LVDT+VC development

Working principle demonstrated through measurement of small prototype.

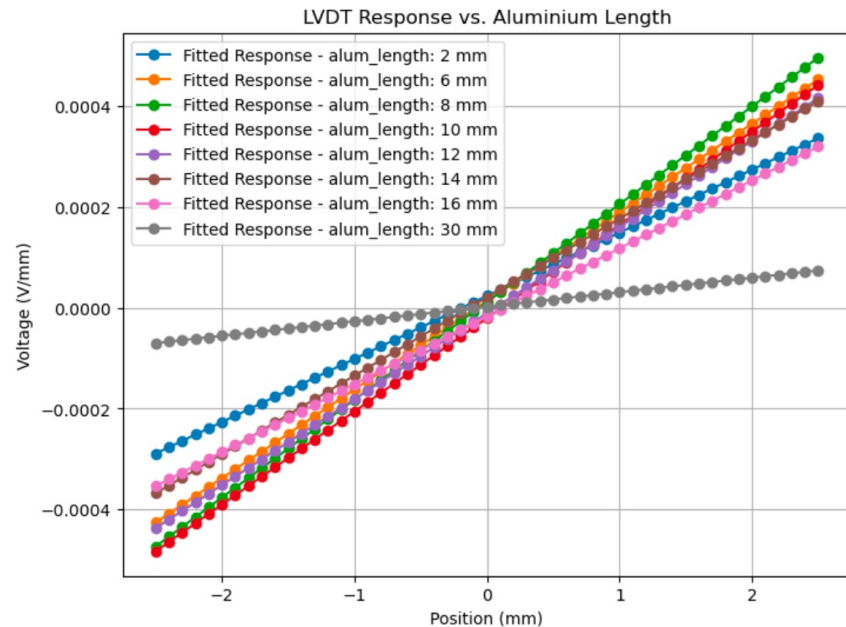
Could be useful alternative/improvement to current sensors/actuators in suspensions, HRTS, ...



No coils on suspended part: use Eddy Currents and excite outer coils

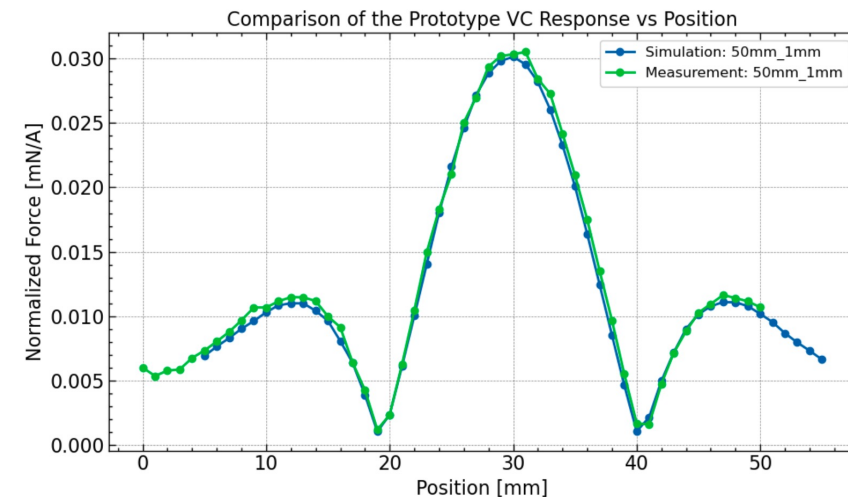
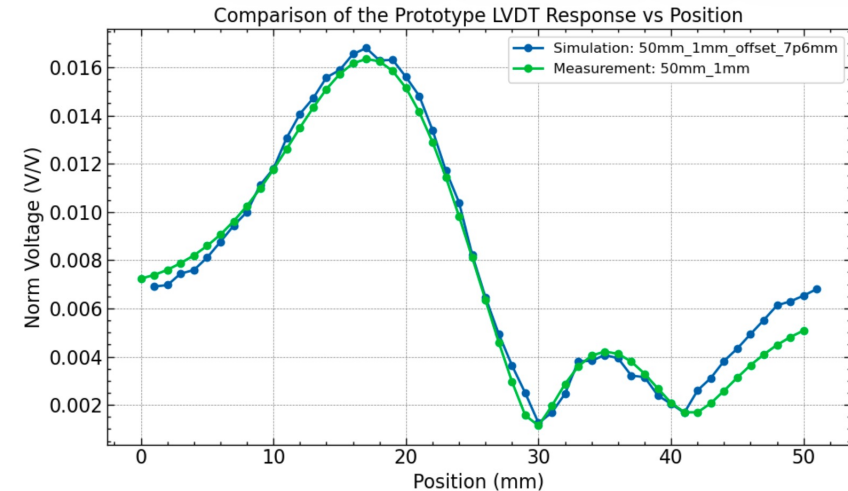
CoreCoil LVDT+VC development

Simulation studies showing dependence on radius, aluminum core width, etc. (bachelor thesis Jelle Sierens)



Further develop this into mature design within this WP

Prototype measurements by Pengbo Li



Advanced Virgo+ Phase 2

Contribute to the Advanced Virgo+ Phase 2 stable recycling cavity suspensions upgrade

→ Currently in Virgo WBS: SR1/SRB, PR1/PRB and SR3/PR3 suspensions:

Pre-assembly of subsystems @ INFN Pisa, NIKHEF

Integration, commissioning, validation and design update

Seismic attenuation chain (IP,F0,F1,F7,CAGE): pre-assembly and balancing with dummy load

→ the requested PhD & postdoc will partly work on this.

LVDT design for prototype suspension (November 2026):

- Interface ETpathfinder-like coils with PISA electronics
- New bobbin material, new coil design needed?
- Production at ETpathfinder with Virgo personpower (~ Spring 2027)
- Contribute to commissioning of the prototype at NIKHEF and/or PISA

Outlook

- Continue construction and commissioning responsibilities to ETpathfinder
- Further develop new sensor & actuator designs: CoreCoil
- Start up contributions to Advanced Virgo+ Phase 2 recycling cavity suspensions
- Ready to hire new PhD & postdoc to start later this year
- Local suspension system build up: find a good final location on campus, start working on design.
- DAQ hardware for ETpathfinder: start up discussions concerning purchase options & timing.