Università degli Studi di Padova

Sapienza Università di Roma

PhD Year Two Recap

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National PhD Programme in Technologies for fundamental research in Physics and Astrophysics, Ex D.M. 117/2023

Mechanics curriculum

Hosting university: La Sapienza, University of Rome

Company: SpinItalia srl

Advisor: Prof. Antonio Carcaterra

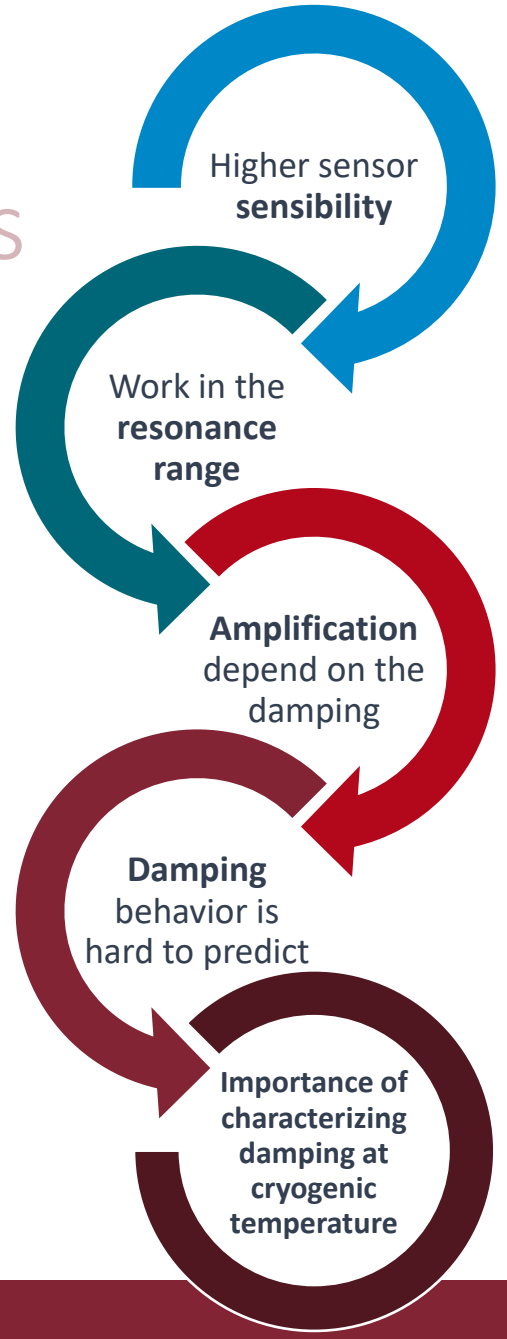
Co-Advisor: Prof.ssa Silvia Milana

Literature Gap – Low-Vibration Monitoring in Cryogenic Environments

- Essential from both **theoretical and applicative** perspectives
- Crucial for identifying **mechanical interference phenomena** that can affect the operation of quantum computers and physics detectors

Problem:

- **Low-intensity disturbances** require higher sensor sensibility
- The resonant frequency and the amplification factor depend on the **fundamental characteristics** of the dynamic system:
  - Mass
  - Stiffness
  - Damping → Estimating their dependence on temperature is crucial!



Research Topic

By characterizing damping at ultra-low temperatures, the project aims to improve the precision and stability of fundamental physics experiments requiring high-sensitivity measurements.

Objectives

2

Characterize the **vibrations of multi-stage cryostats**

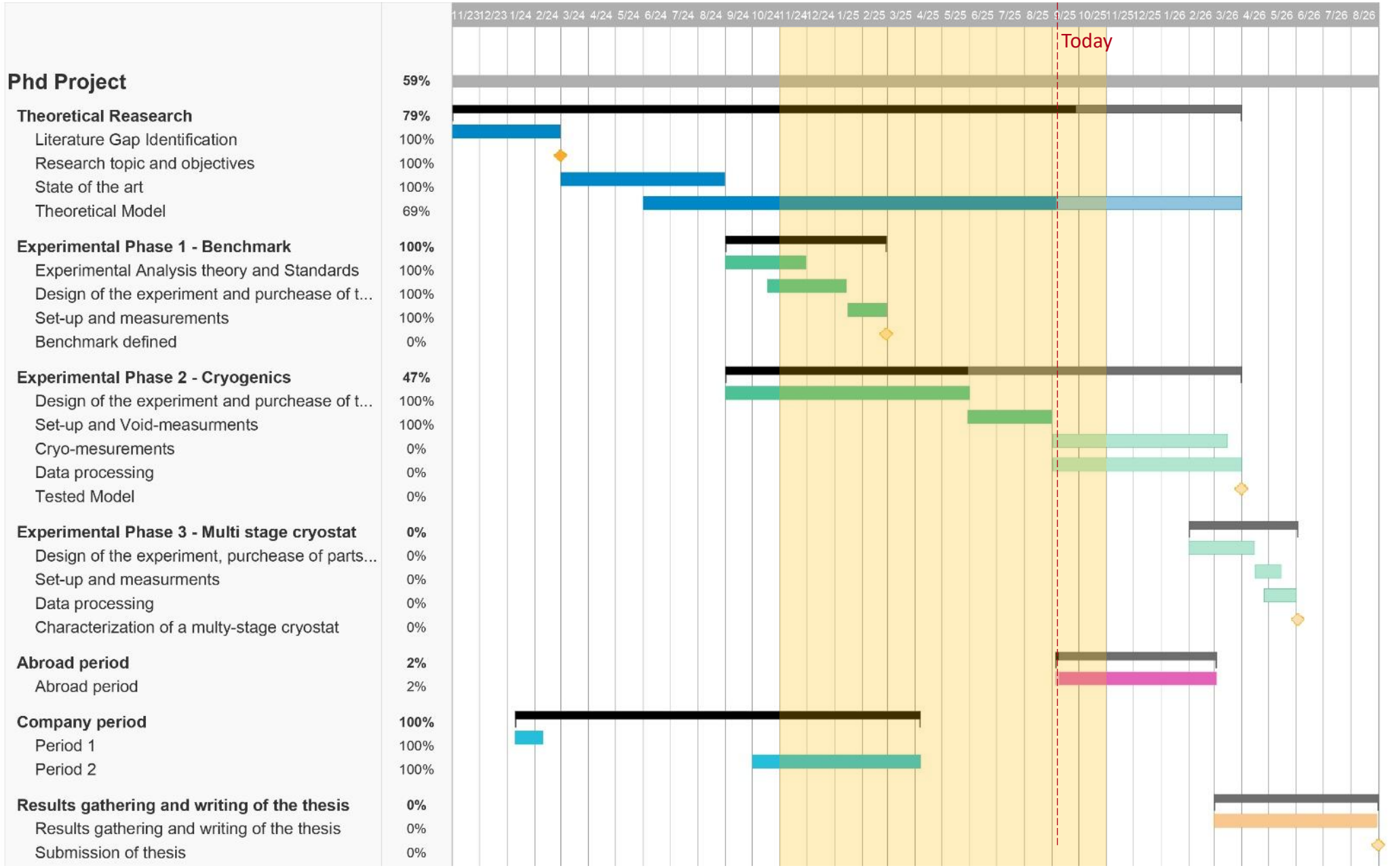
Characterize damping and its relationship with fluctuating dynamic variables **down to cryogenic temperatures**

1

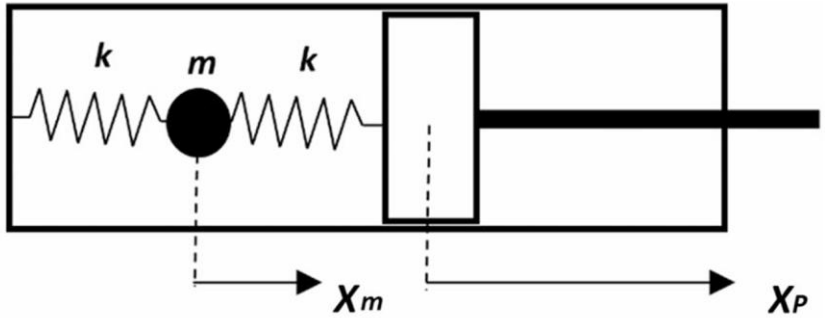
Design a monitoring system that guarantees **real-time acquisition of dynamic variables** in the proximity of fundamental physics detectors

3

3 years planning – Gantt chart



Theoretical model



- Dissipation, as the degradation of energy from macroscale ordered energy to a microscale disordered form
- Model: loss-free oscillator connected to a piston

Case-1

Piston initially brought to a position –*s*, freely returns to its equilibrium

Free expansion of a gas

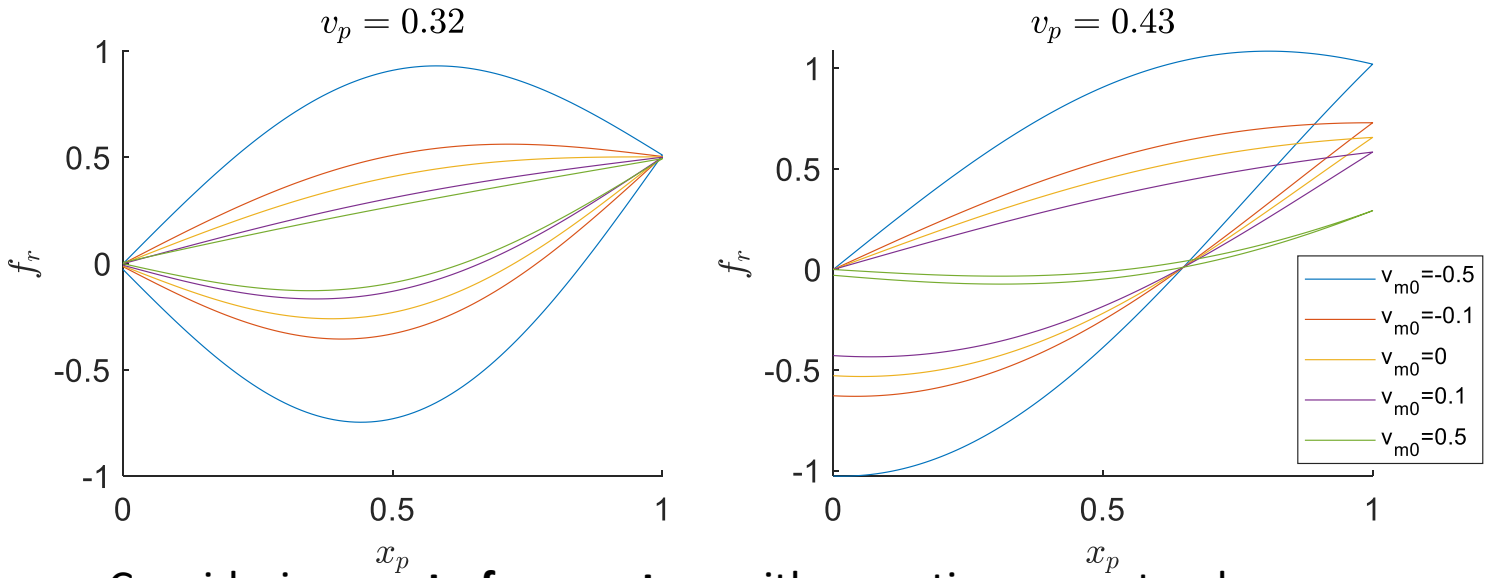
Case-2

Full cycle (forward and backward stroke) of the piston

Hysteretic cycle typical of solids

Theoretical model

Single oscillator



Case-2

Full cycle (forward and backward stroke) of the piston

Hysteretic cycle typical of solids

Considering a **set of resonators** with a continuous natural frequency distribution. An **equivalent damping force** can be calculated as:

$$F_v = \frac{ks}{8}\frac{\left(-2v_{m0}v_p^3 + 3v_p^2 + 2v_{m0}v_p\right)}{2v_p^4 + 5v_p^2 + 2}$$

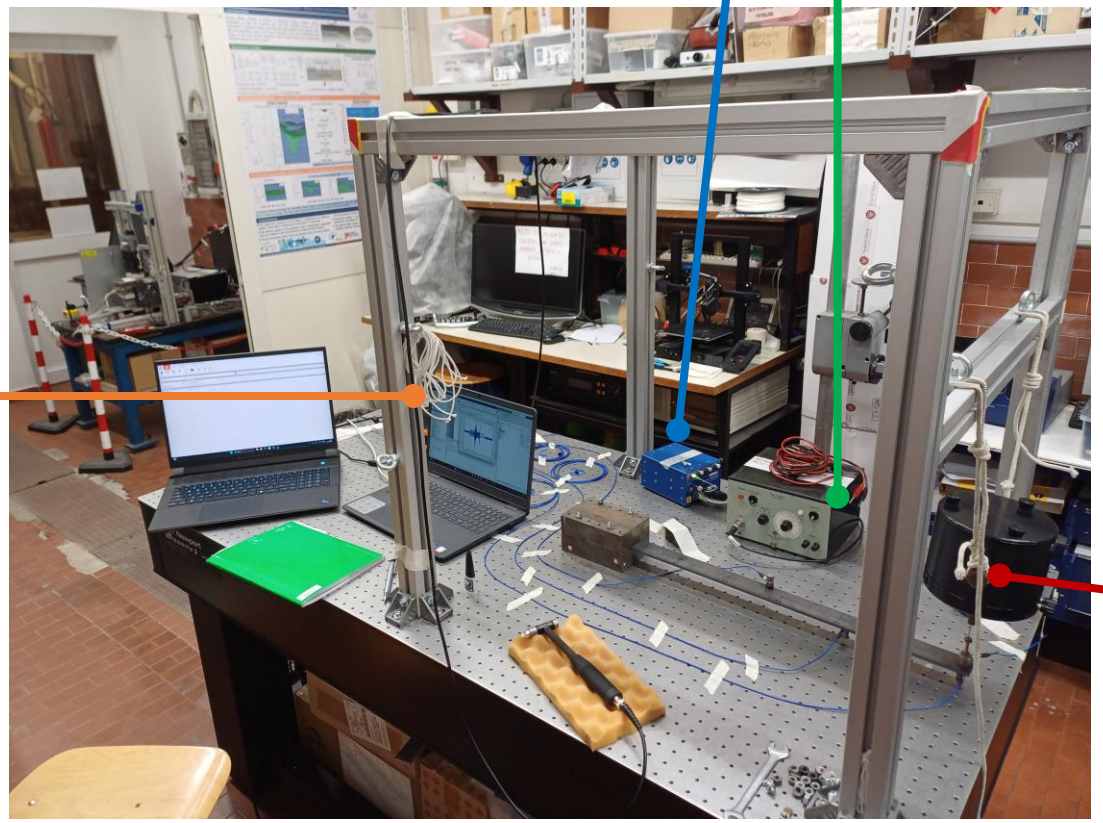
Constitutive relationship

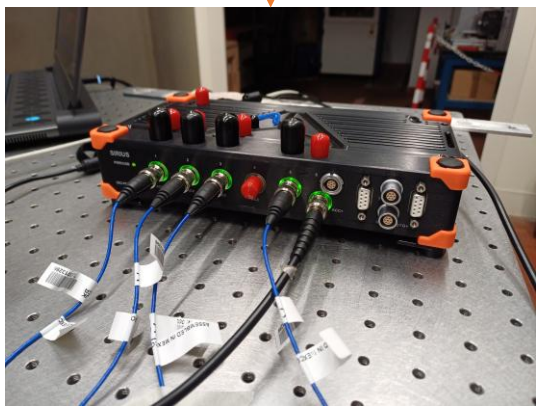
$$\sigma^* = B\frac{3\,\dot{\epsilon}^{*2} \pm \sqrt{\Theta_i}\dot{\epsilon}^* \mp \sqrt{\Theta_i}\dot{\epsilon}^{*3}}{2\dot{\epsilon}^{*4} + 5\dot{\epsilon}^{*2} + 2}$$

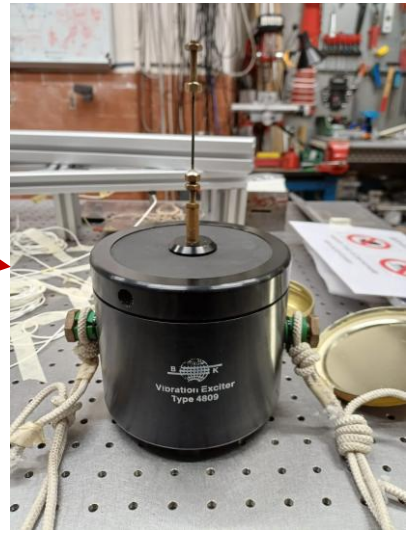
Benchmark definition

- ASTM E756-05 standard

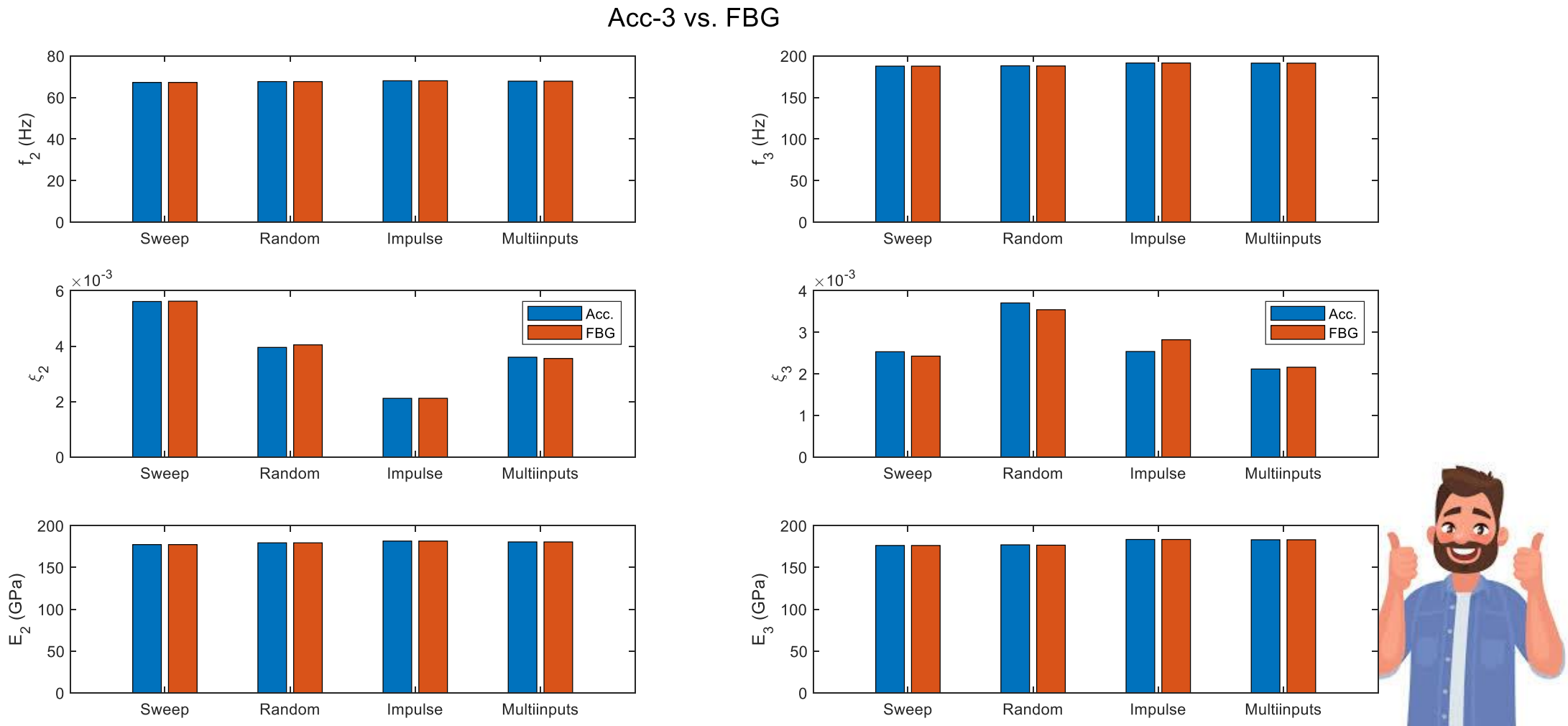
ASTM INTERNATIONAL





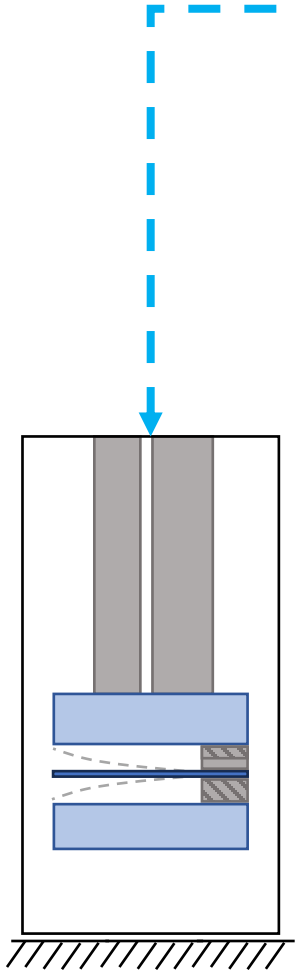


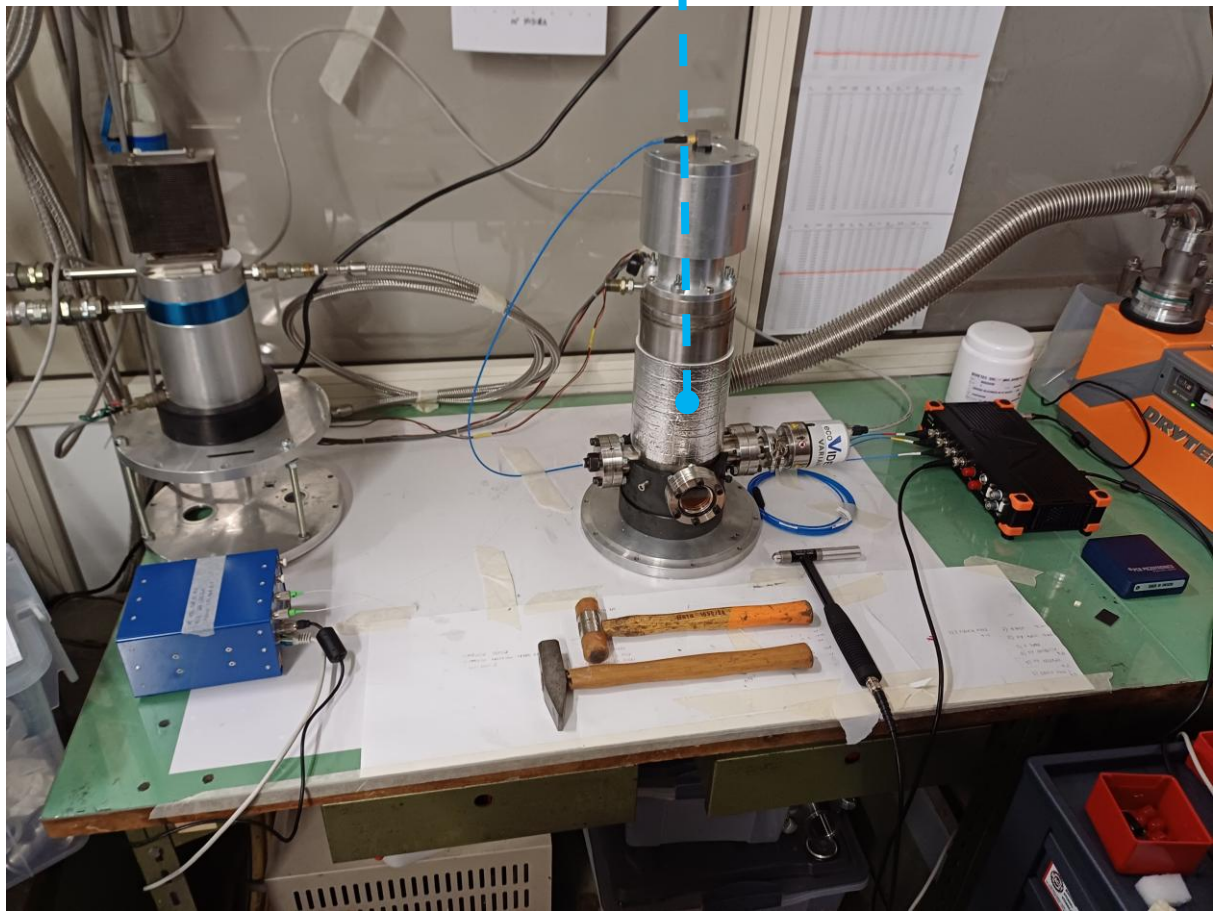
Benchmark definition



Experimental Phase 2 – Set up

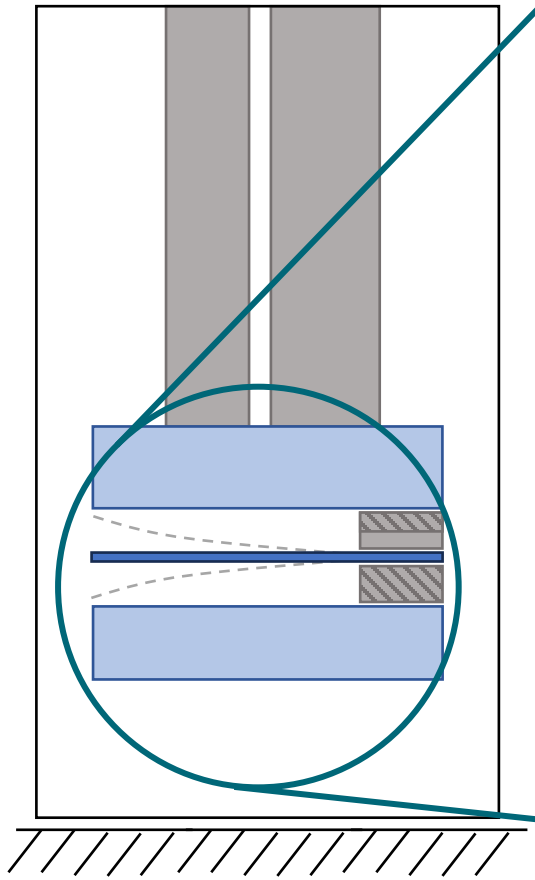
- Pulse-tube refrigerator
- Vacuum chamber
- Vacuum gauge
- 2 triaxial accelerometers
- 2 FBG
- 1 thermoresistance

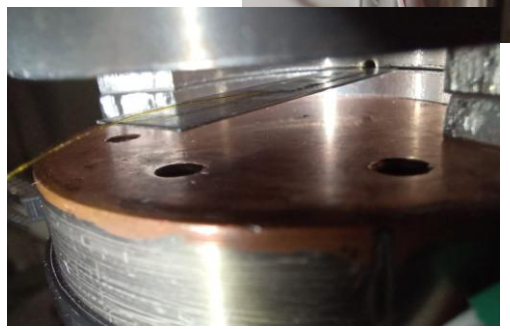




Experimental Phase 2

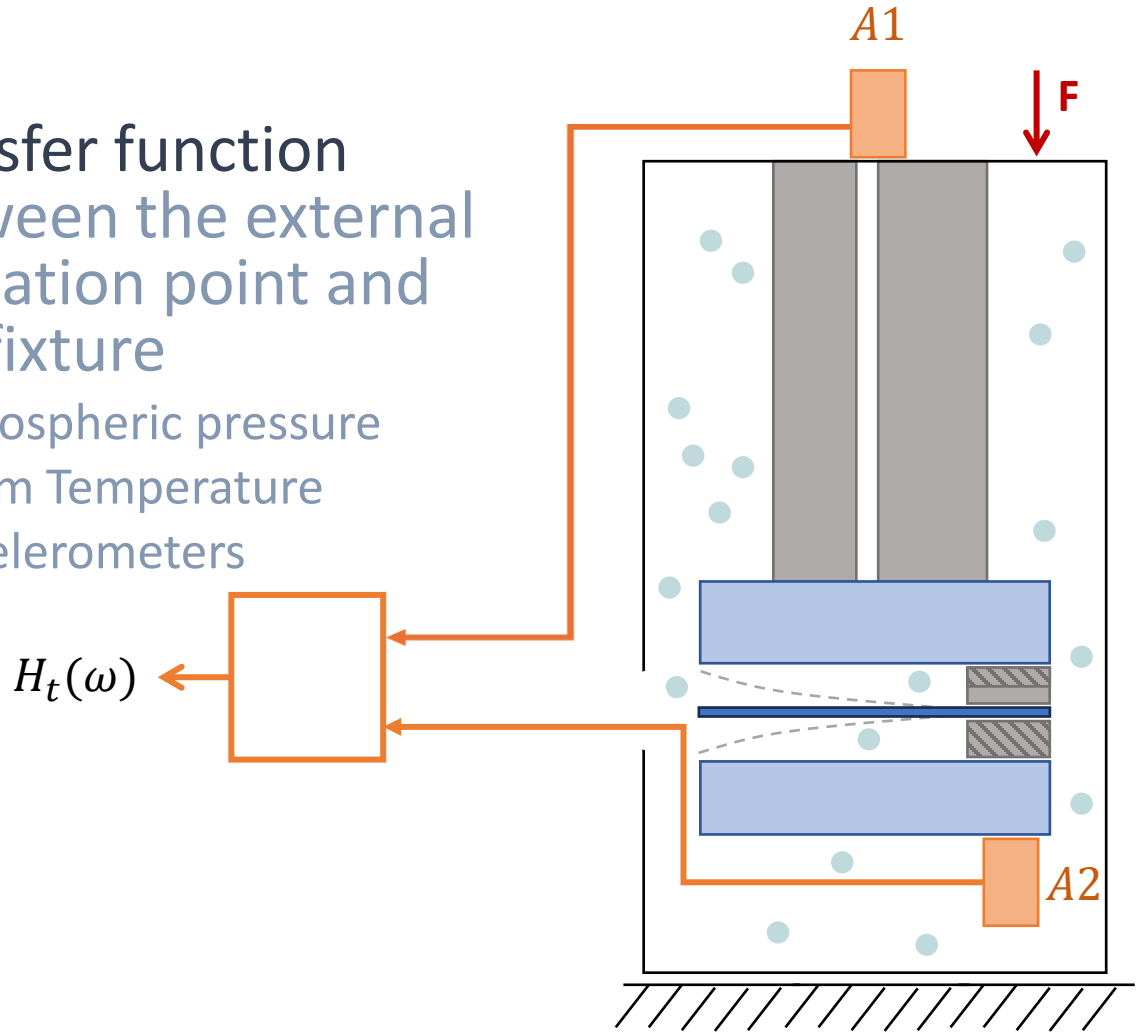
The clamping system



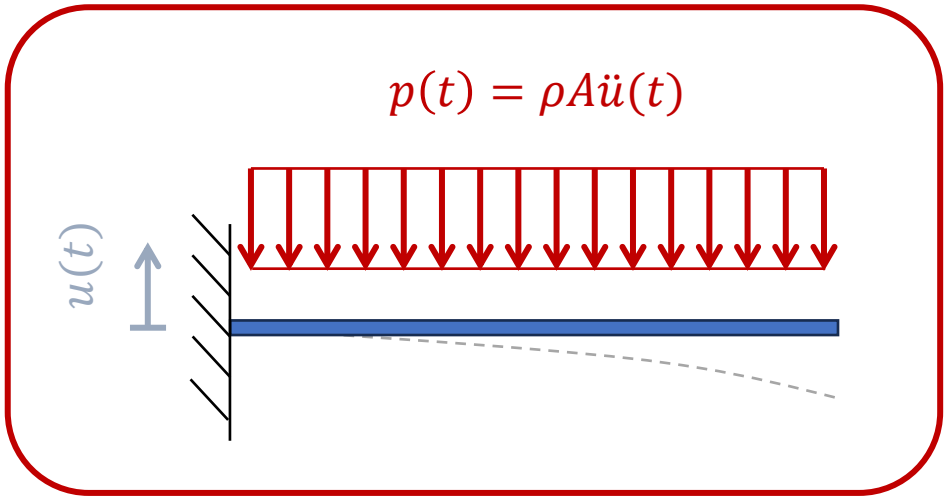


Measurements

1. Transfer function between the external excitation point and the fixture
   - Atmospheric pressure
   - Room Temperature
   - Accelerometers

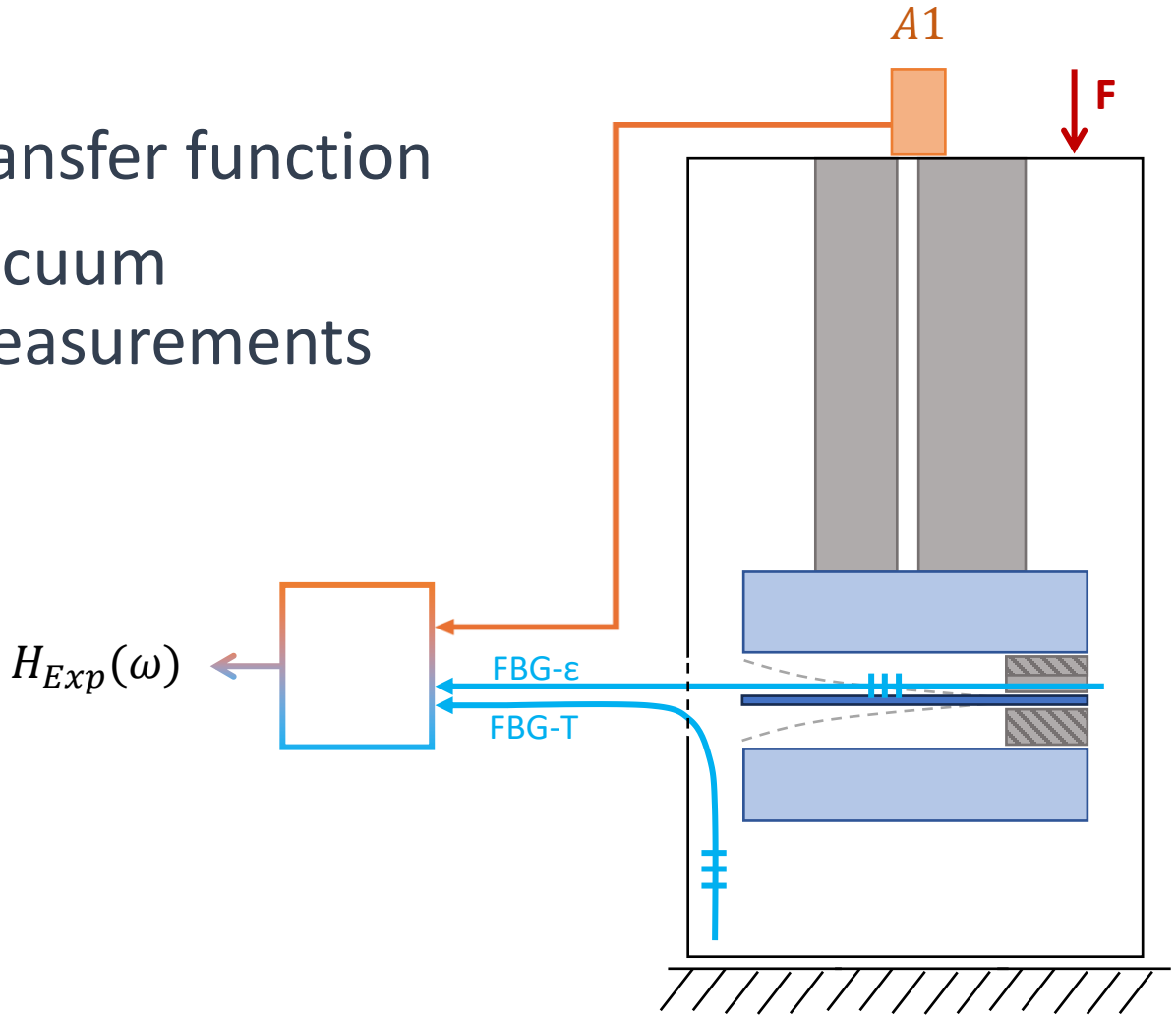


External force translates into a distributed inertial load on the beam

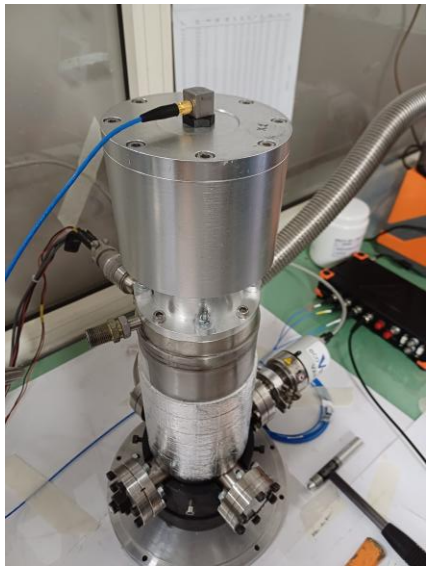


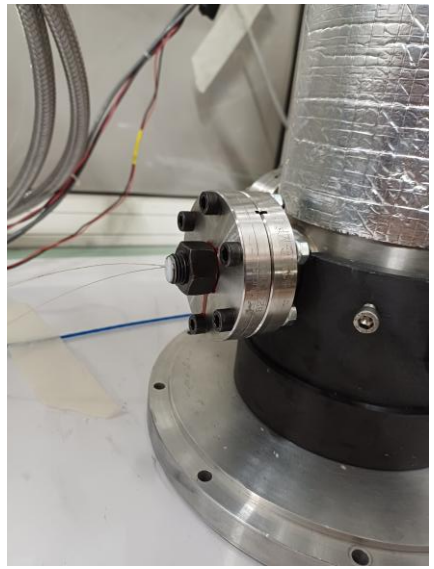
Measurements

1. Transfer function
2. Vacuum measurements



- Medium void (1-3 e^-3 mbar)
- Room Temperature
- External accelerometer
- 2 FBGs inside:
  - Strain
  - Temperature compensation





Activities

Courses	**Random Excitation and response of structures**	Ongoing
Other Activities	**Internship**	6 months at Spinitalia
	IMAC –XLIV Conference (January)	Presenting 2 papers: - *Damping Identification using FBG sensors in controlled thermal pressure conditions* - *Temperature-driven Unsupervised Damage Identification using Cepstral Features*
	School (To be defined)	Thermodynamics, statistical mechanics or cryogenics
Parallel academic achievements	**1 Publication on the matter of system analysis**	Use of Cepstral coefficients and unsupervised ML techniques

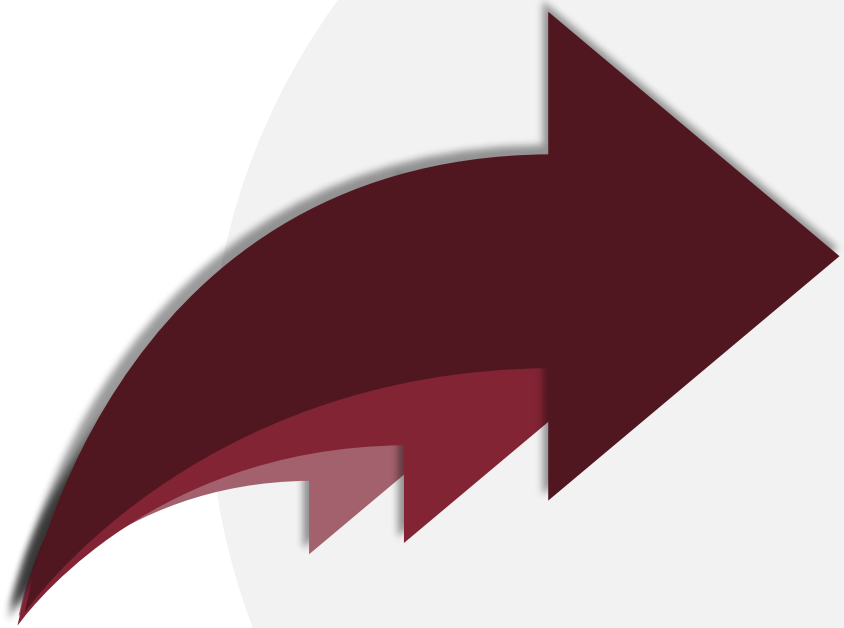
Next Steps…

Further develop the case-2 theoretical model and implement it in beam theory

Reduce the **temperature gradient** on the beam or consider it in the model

Validate the model through the experimental data

Perform **damping measurements from room temperature down to 70K**



Thank you!