Karlsruhe Institute of Technology

SAPIENZA UNIVERSITÀ DI ROMA

EINSTEIN TELESCOPE

Experimental plans to validate the He-II based payload cooling

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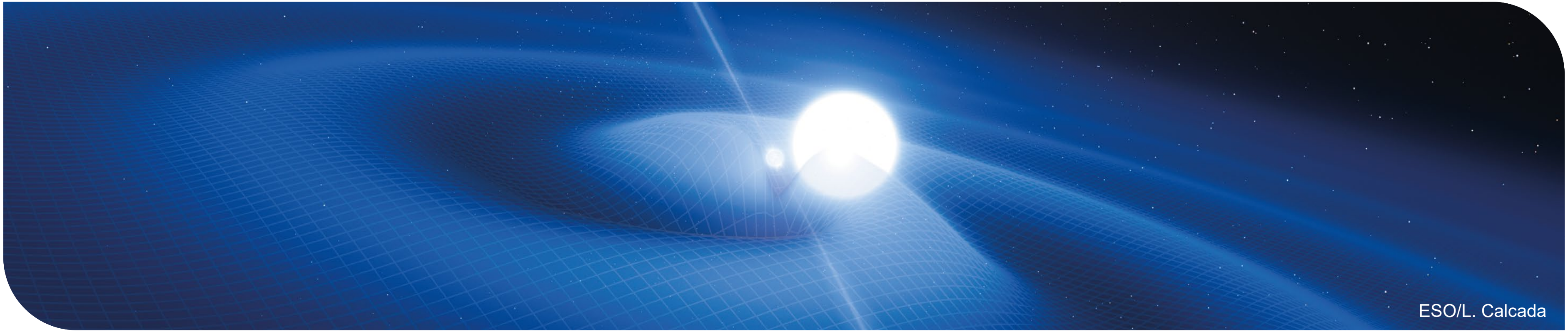


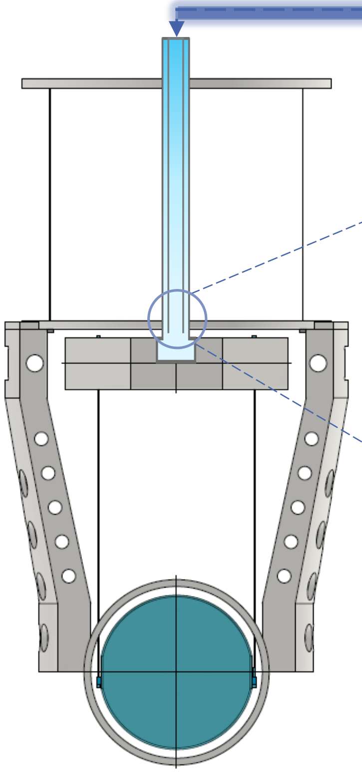
He-II based payload cooling for ET-LF

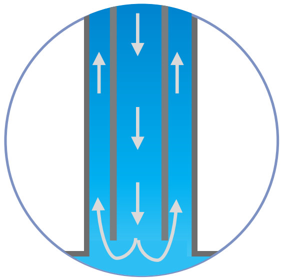
Cooling via He-II suspension tube

Platform (PF)

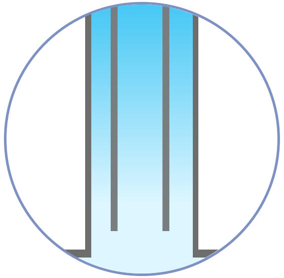
Marionette (MAR)

Mirror (MIR)

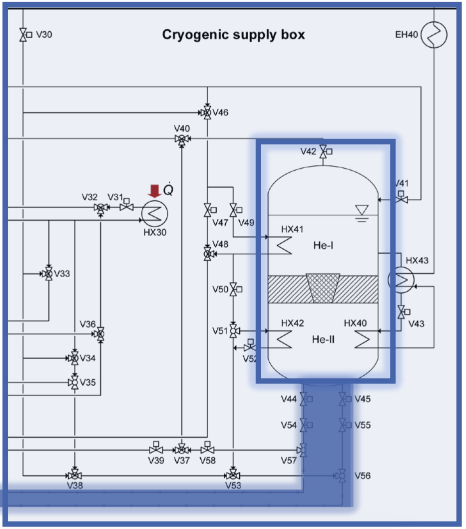




- He-I flow for cool-down



- He-II (no macroscopic flow) for steady-state operation



L. Busch (KIT, 2021)

He supply capillaries:

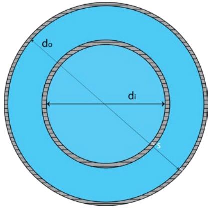
- Cryogenic supply box ↔ Payload (i.e. suspension capillary) connection
- Length ~ 10-20 m → cryogenic supply box away from cryostat tower to reduce vibration input

X. Koroveshi (2022) - Feasibility of He-II suspensions based on thermal noise modelling

Status of He-II suspension concept

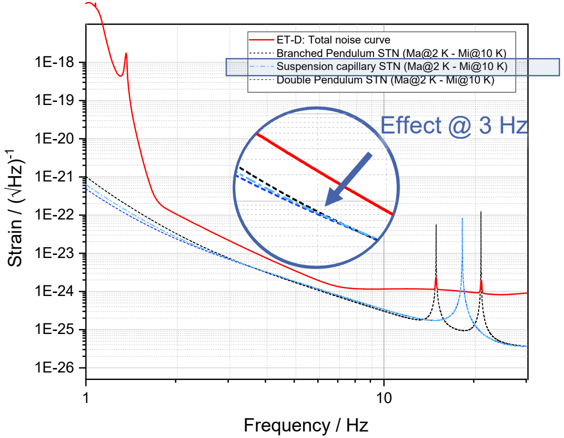
- Feasibility shown theoretically ✓
- Experimental proof of concept: **Open**

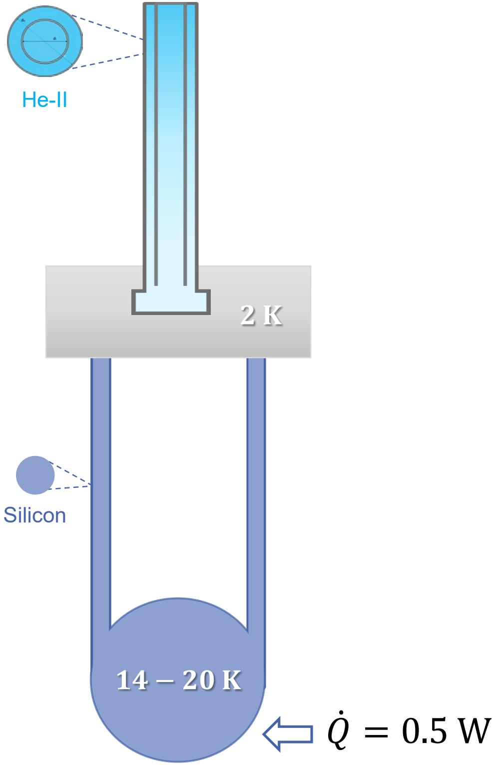
Mechanical



Thermal

Suspension thermal noise





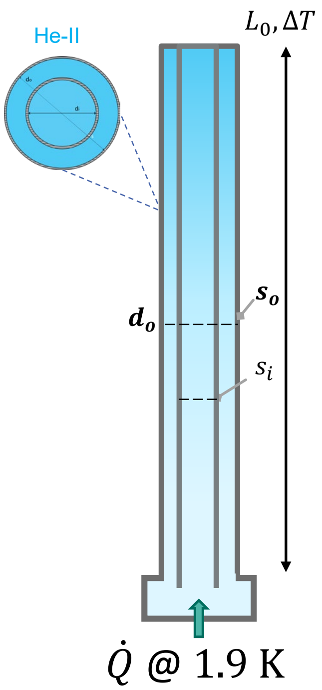
Experimental validation of concept

Experimental setup requirements

- Mechanical losses in suspensions (theoretical):

$$\Phi_{\text{fiber}}(\omega) = \Phi_{\text{bulk}} + \Phi_{\text{thermoelastic}}(\omega) + \Phi_{\text{surface}} + (\Phi_{\text{clamping}})$$

- Quality factor (Q) measurements define the actual losses
  - Ring-down method as measurement concept
  - Identification of the specific contributions to the total measured Q_{tot} is non-trivial:
    - Sensitive measurements → Step-by-step complexity increase of measurements



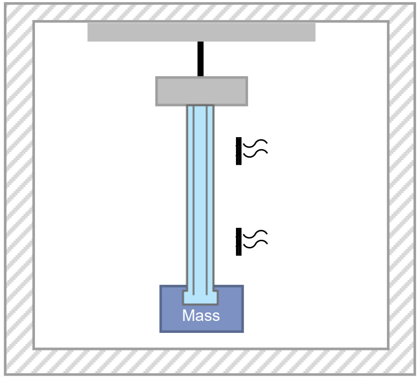
Possible stages of experimental validation

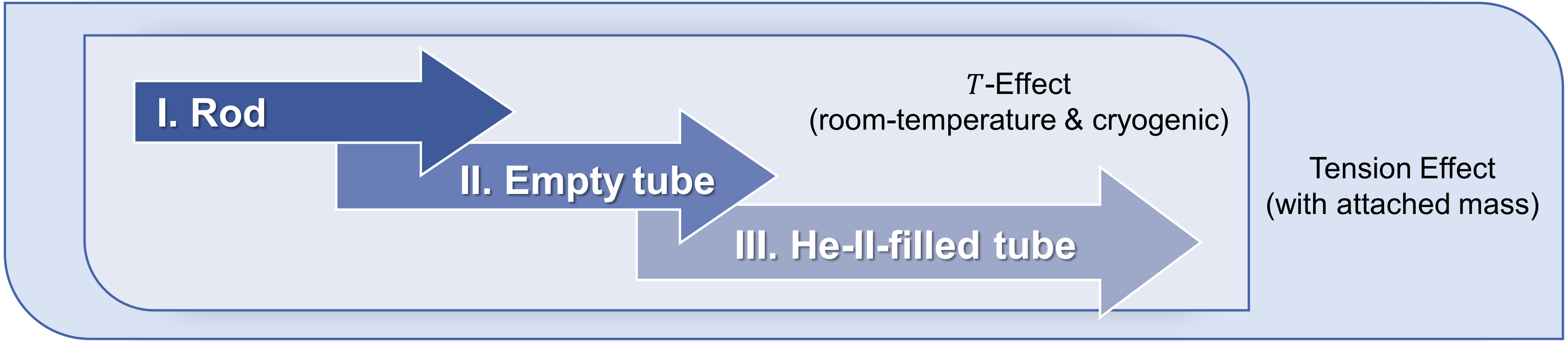
- <u>Q-Measurements of suspension:</u>

  I. As a simple suspension rod (room-temperature & cryogenic)

  II. As an empty suspension tube (room-temperature & cryogenic)

  III. As a He-II-filled suspension tube





Q-Measurements stages

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I. Rod

- Comparison with literature data
- Various materials
- Influence of T and tension on Q

II. Empty tube

- Surface effects crucial (machining of tube)
- Identification of tube's modes
- Influence of T and tension on modes & Q

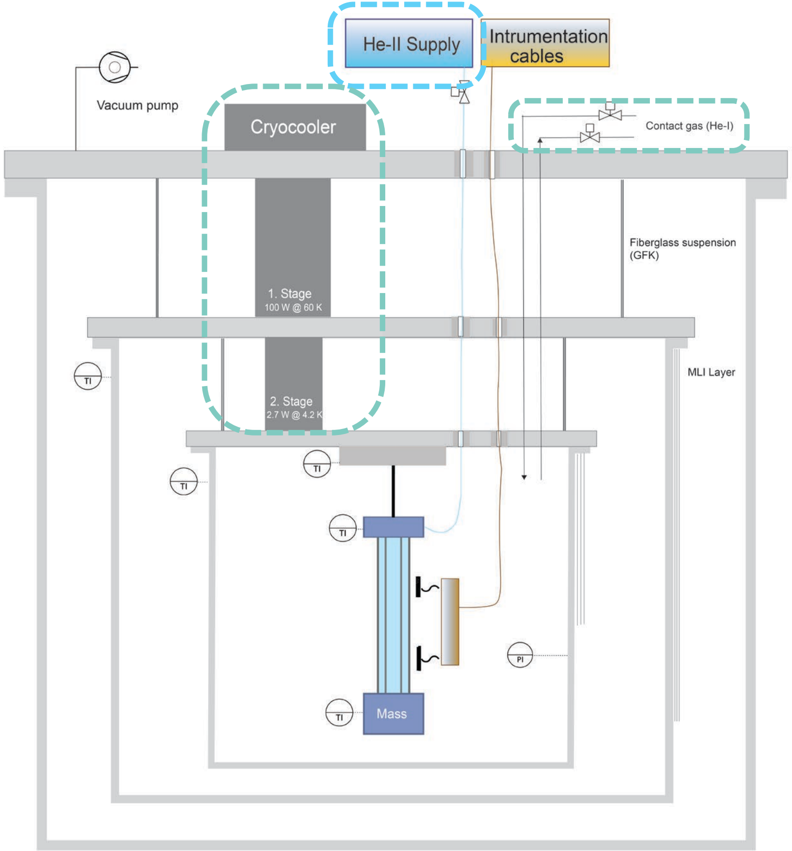
III. He-II-filled tube

Open questions:

- $\dot{M}_{\mathrm{He-II}}$ = 0, but investigation whether noise transmission in He-II as in metals/crystals?
- He-II effect on Q, extra/no dissipation?
- Influence of supply capillary ↔ suspension tube interface on Q?

Q-Measurement experimental setup

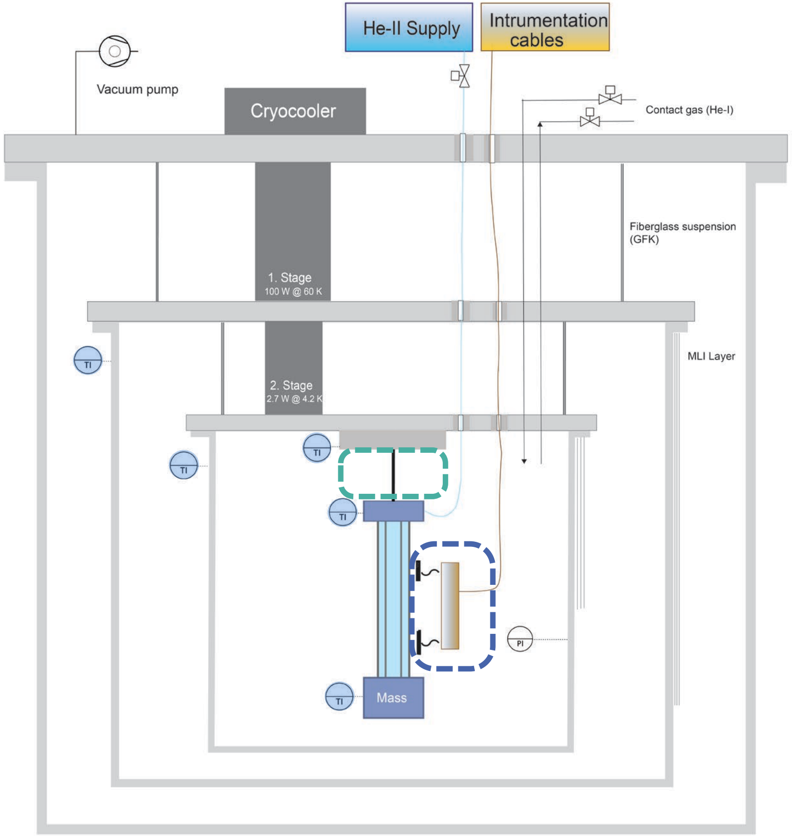
Q-Measurement Cryostat



Properties:

- Mechanical design
  - Same cryostat (test stand) for Stages I-III
    - At RT
    - Cryogenic
  - Bottom-to-top design to facilitate He-II experiments (Stage III)
- Cooling strategy
  - Cryocooler cooling, simplier and cost-efficient
  - Outer shield: CCST 1 – e.g. 100 W @ 60 K
  - Inner shield: CCST 2 – e.g. 2.7 W @ 4.2 K
  - Sample cooling: faster via Helium contact gas
- He-II supply
  - Compact He-II refrigeration system (in-house)
  - $\dot{Q} \approx x \cdot 100\ \mathrm{mW}$

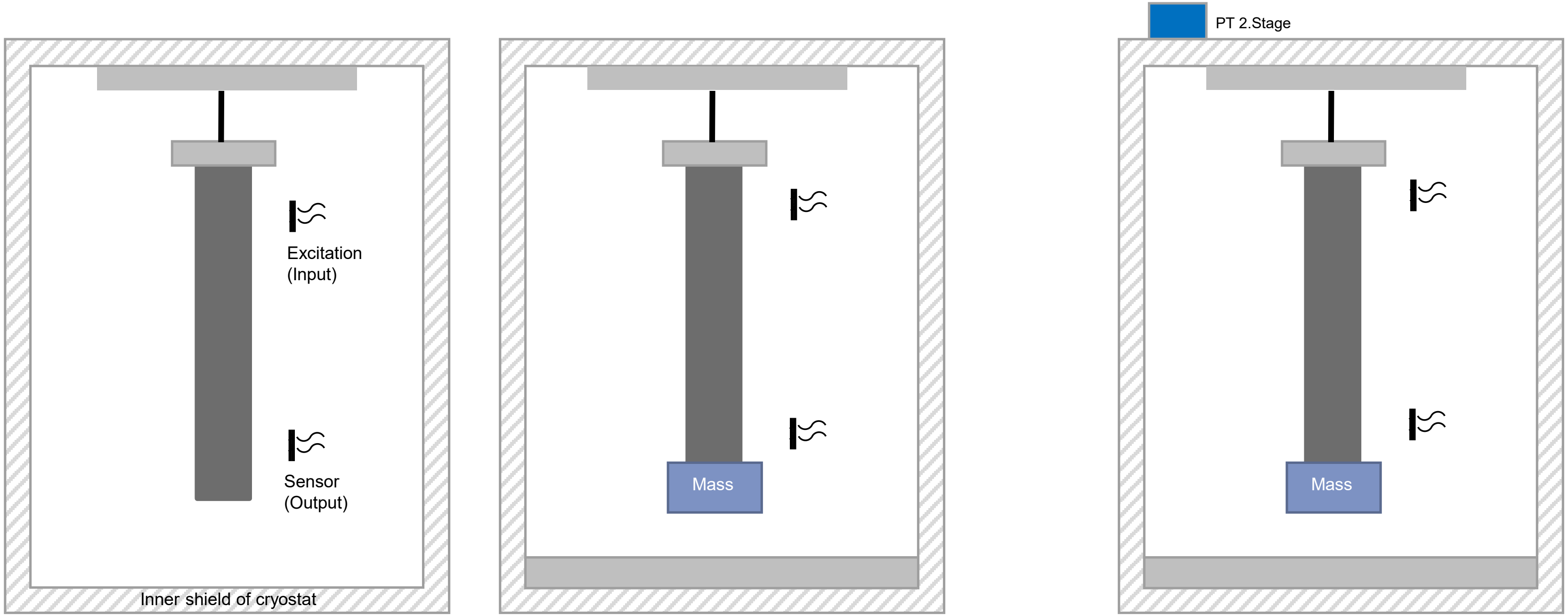
Q-Measurement Cryostat



- Instruments
  - Excitation/sensing :
    - Combination: PZCs (contact) and contactless concept
    - Excitation of the flexural mode of the tube
  - Temperature sensors on:
    - Shields
    - Suspension clamp
    - Suspension tube
    - Test mass (TM)
- Dimensions and measurements
  - Measurements @ $T = 4.2 - 300$ K (Stages I-II), @ $T = 2$ K (Stage III)
  - Load ~ 300-400 kg: CuW as possible material for TM
  - Length of tube/rod: 1.0 -1.2 m

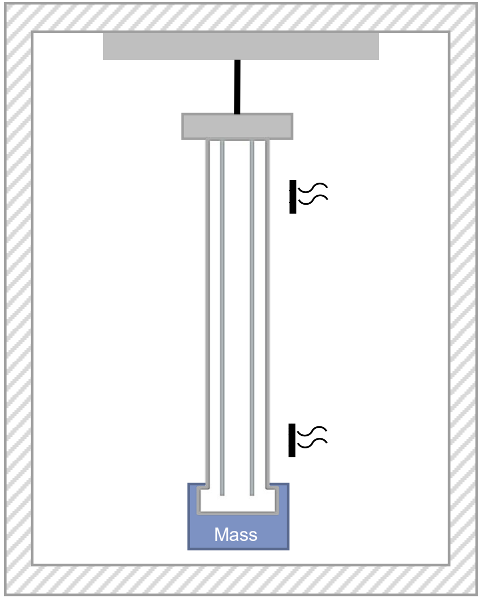
Q-Measurement experiments - Stage I

- Bulk suspension tube (RT)
  - Measurements without and with load (300-400 kg)
  - Determination of load's effect on dissipation
- Bulk suspension tube (cryogenic)
  - Measurements without and with load

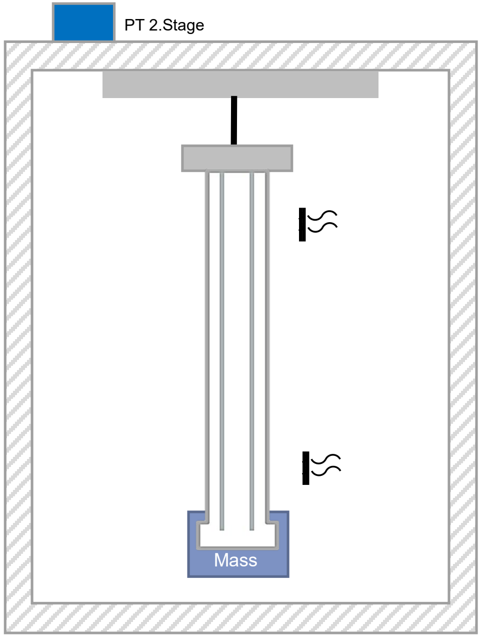


Q-Measurement experiments - Stage II

- Hollow suspension tube (RT)
  - Determination of hollow tube's effect
  - Measurements without/with load

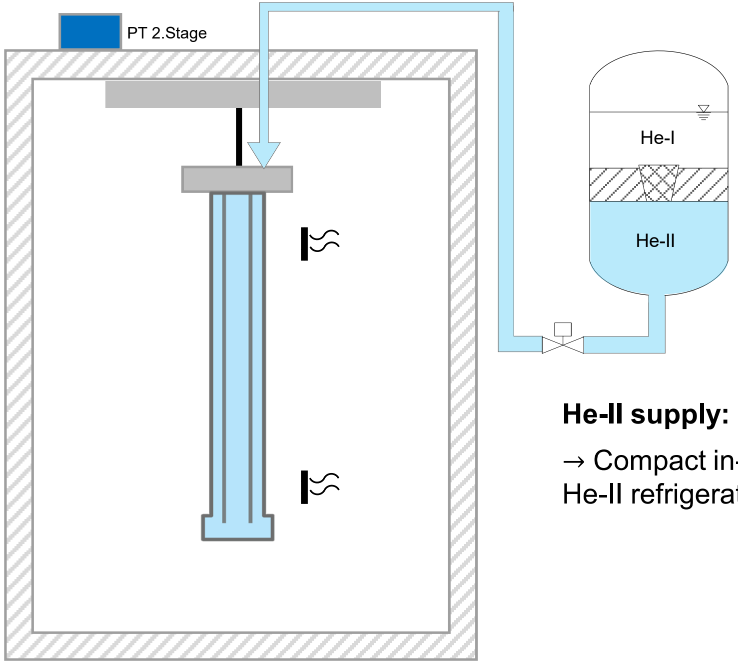


- Hollow suspension tube (cryogenic)
  - Determination of temperature's effect
  - Measurements without/with load



Q-Measurement experiments - Stage III

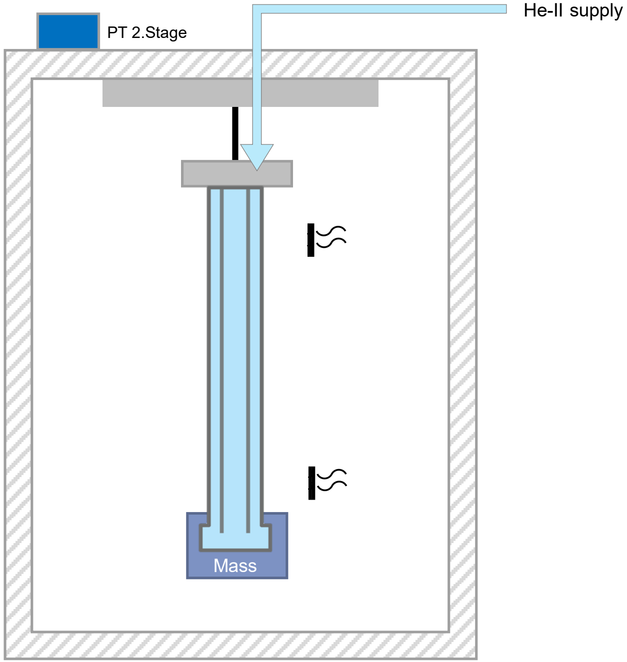
- <u>He-II-filled suspension tube</u>
  - Effect of He-II and of the clamping of He-II supply path



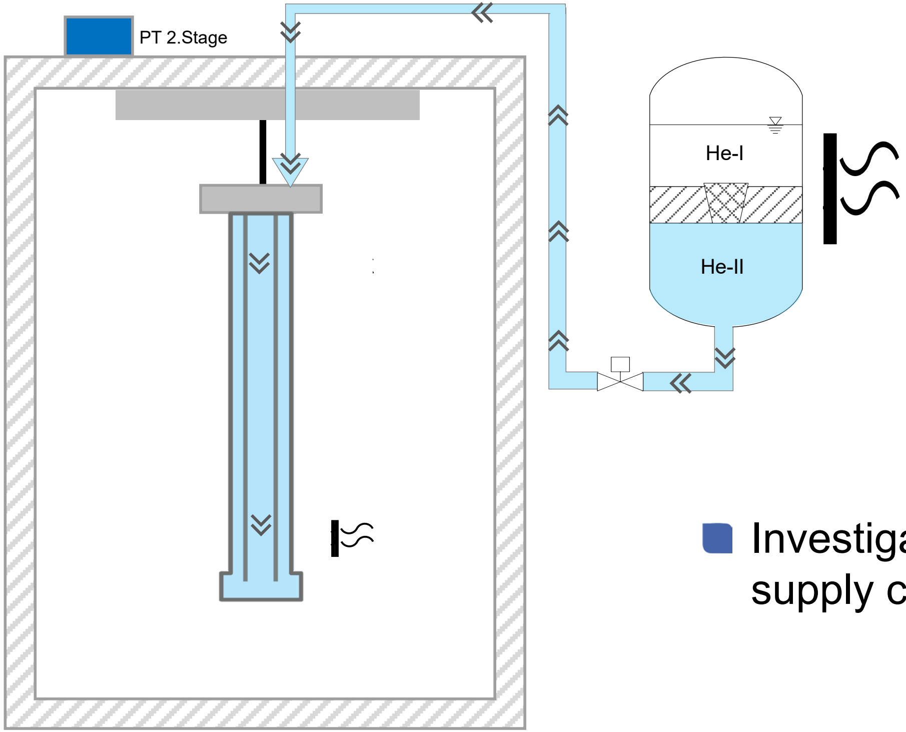
He-II supply:

→ Compact in-house He-II refrigeration system

- <u>He-II-filled suspension tube</u>
  - Load end temperature and effect of tension on dissipation



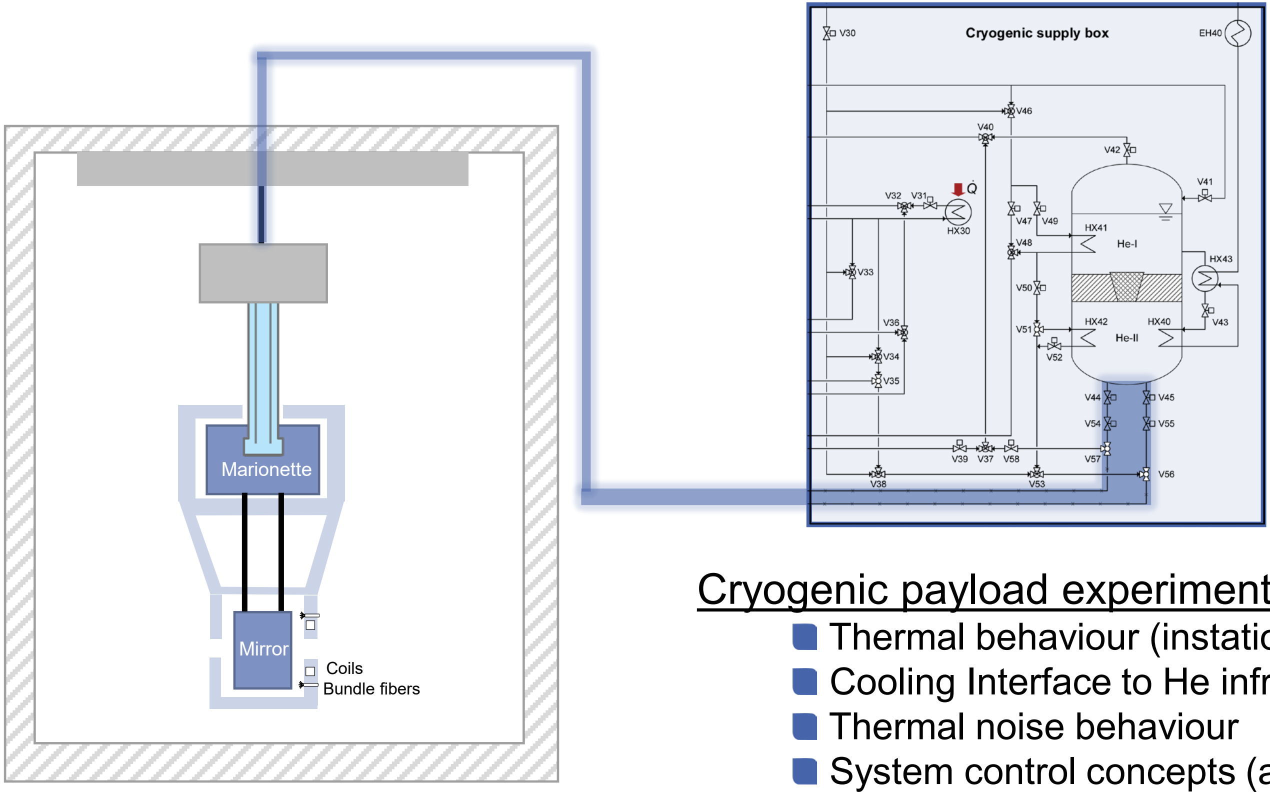
Additional vibration measurements



- Investigation of vibration propagation in He-II supply capillaries via external excitation

Prospects

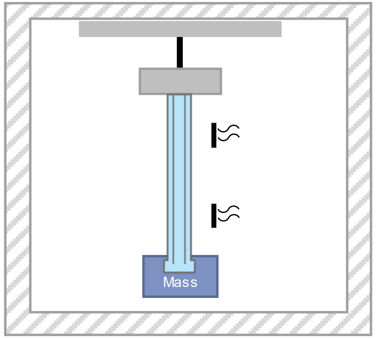
Cryogenic payload experiments



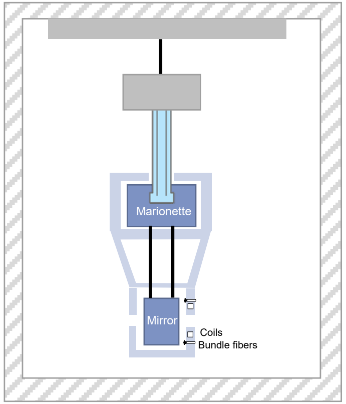
Cryogenic payload experiments for investigating:
- Thermal behaviour (instationary & stationary)
- Cooling Interface to He infrastructure
- Thermal noise behaviour
- System control concepts (actuation+sensing)

Conclusions

- 1) Q-Measurements of suspension
  I. As a simple suspension rod (room-temperature & cryogenic)
  II. As an empty suspension tube (room-temperature & cryogenic)
  III. As a He-II-filled suspension tube



- 2) Cryogenic payload experiments for investigating:
  - Thermal behaviour (instationary & stationary)
  - Cooling Interface to He infrastructure
  - Thermal noise behaviour
  - System control concepts (actuation+sensing)
  - …



Thank you for your attention

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