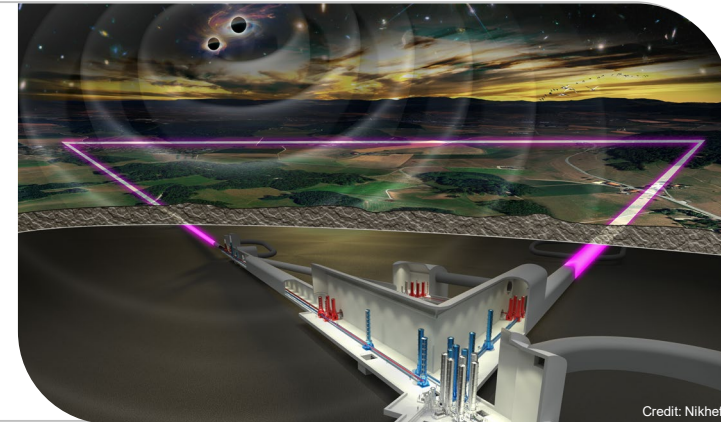
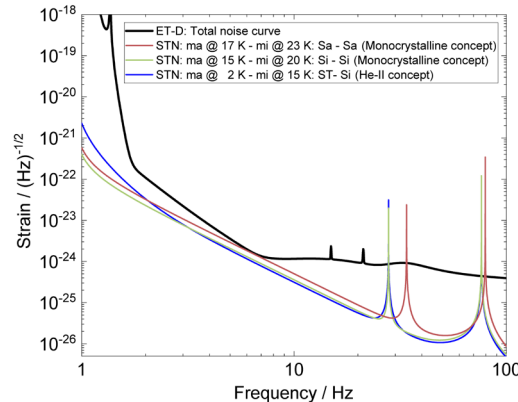
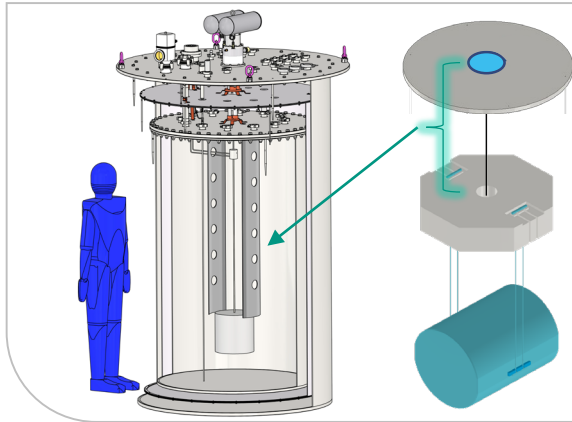


Conceptual cryostat design for cryogenic suspension studies for the Einstein Telescope

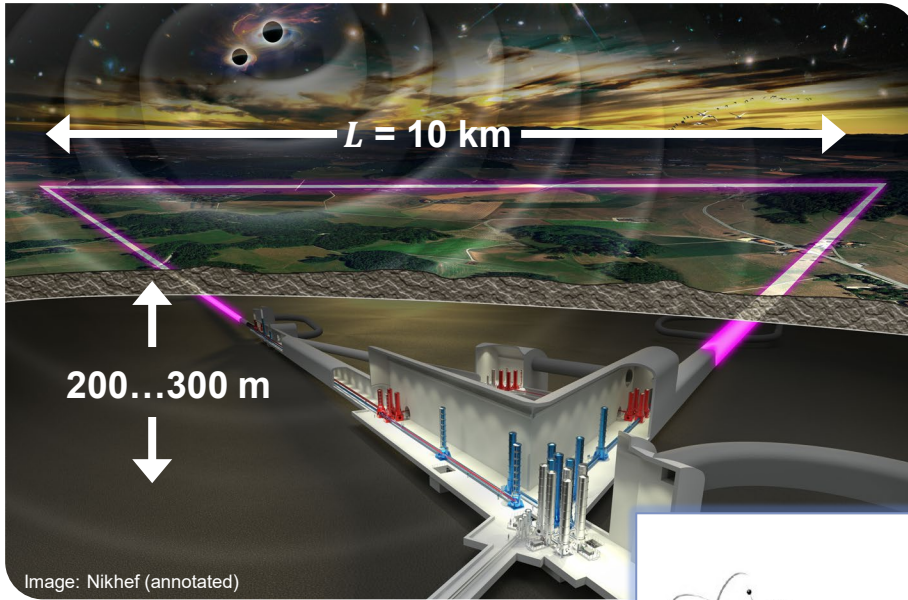
X. Korovesi, P. Rapagnani, V. Mangano, M. Stamm, S. Grohmann

CEC/ICMC 23 CEC/ICMC 23

9-13 July 2023, Honolulu (USA)

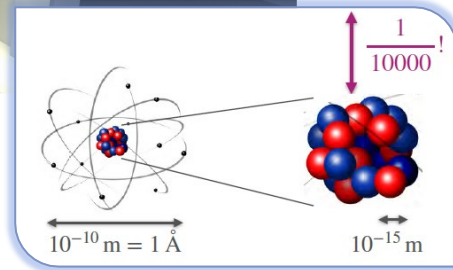
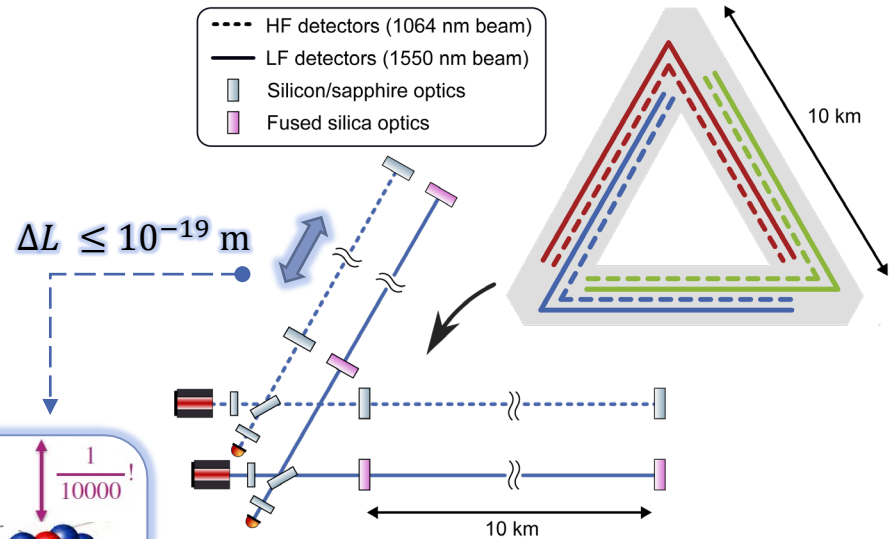


Einstein Telescope (ET)



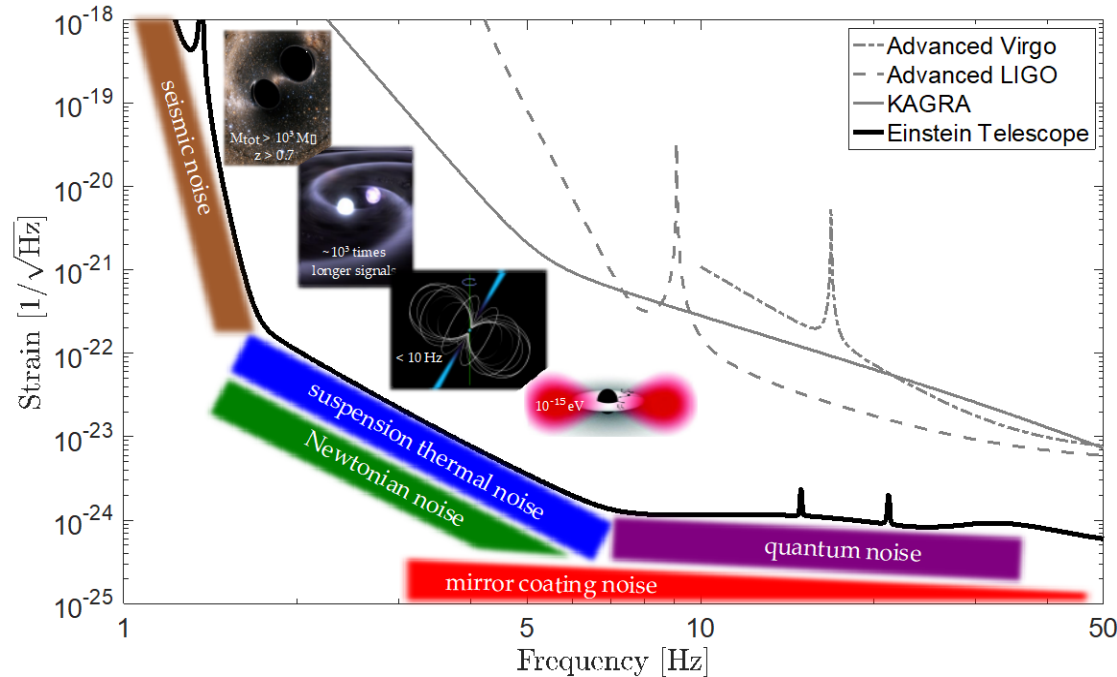
3. Generation Gravitational Wave Detector

- HF detectors (1064 nm beam)
- LF detectors (1550 nm beam)
- ▭ Silicon/sapphire optics
- ▭ Fused silica optics



Reference: Design Report Update 2020 for the Einstein Telescope. [Tech. Report ET-0007B-20](#) (adapted)

Sensitivity of ET vs current detectors



Suspension thermal noise (STN)

- Dominant noise source at $f < 10$ Hz
- Reduction strategy:
 - Cryogenic operation of ET-LF
 - Low dissipative materials

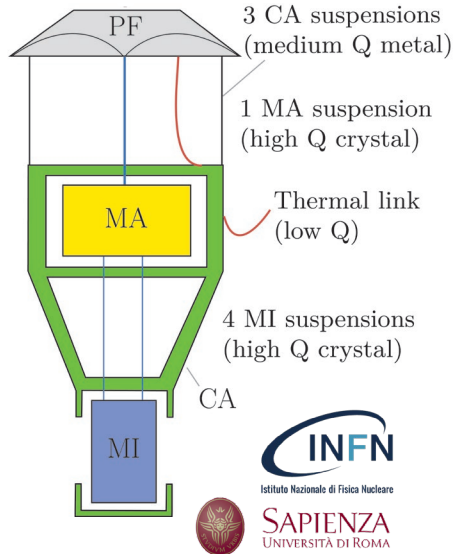
$$\text{STN} \sim T \phi_{\text{susp}}$$



Reference: S. D. Pace et al. (2022), DOI: [10.3390/galaxies10030065](https://doi.org/10.3390/galaxies10030065)

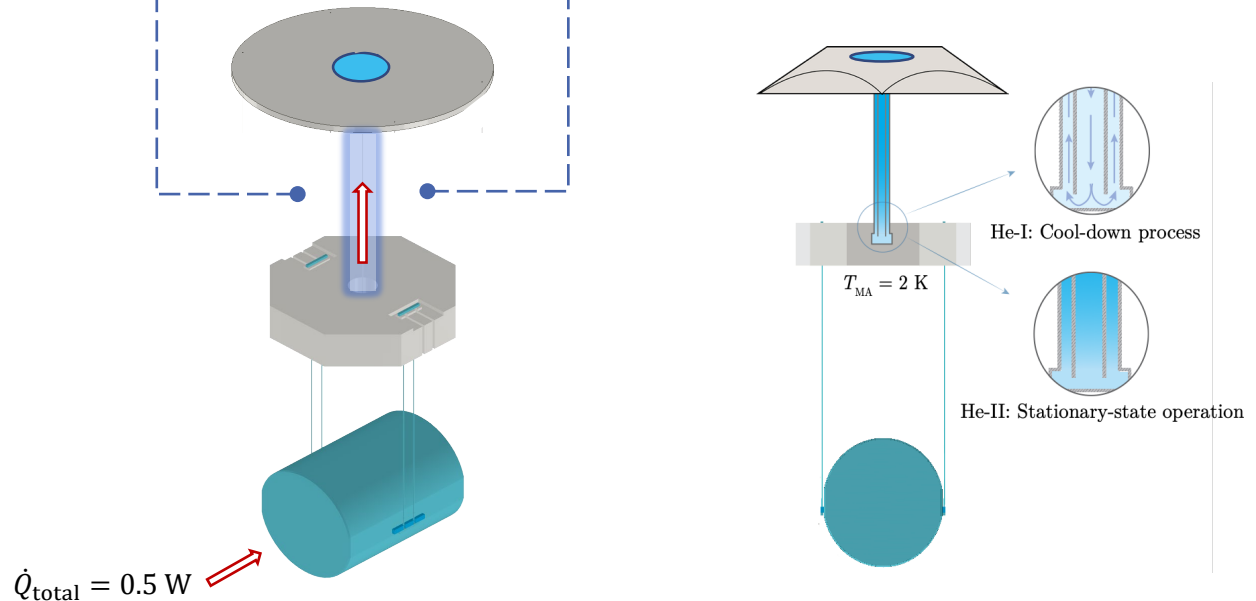
Baseline design of ET-LF cryogenic payload

■ Monocrystalline suspension



Two heat extraction concepts

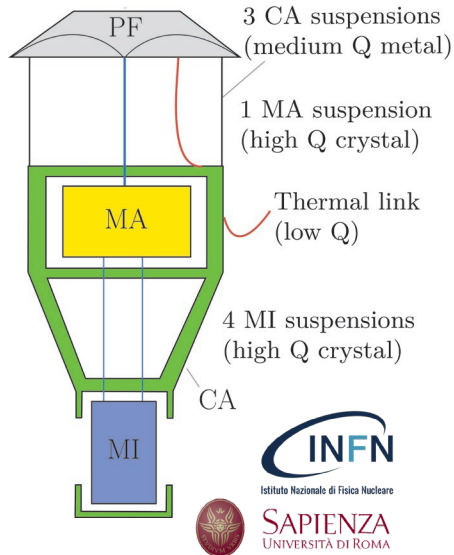
■ He-II filled suspension tube



Reference: X. Korovesi, L. Busch, E. Majorana, P. Puppo, P. Rapagnani, F. Ricci, P. Ruggi, S. Grohmann (2023), DOI: [10.48550/arXiv.2305.01419](https://doi.org/10.48550/arXiv.2305.01419)

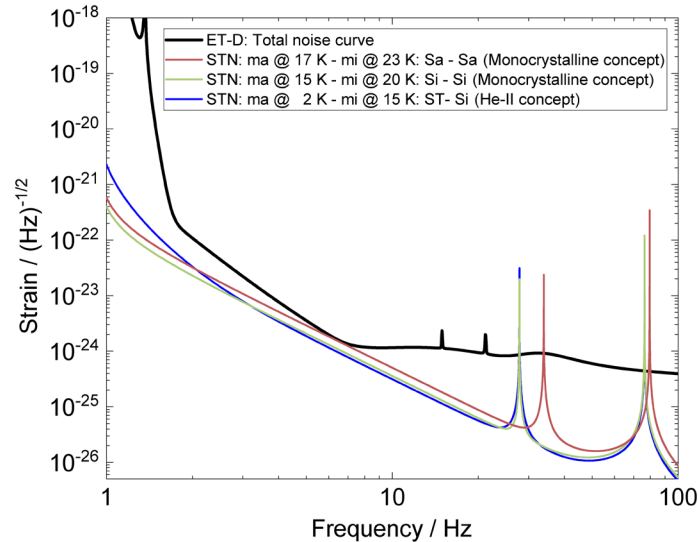
Baseline design of ET-LF cryogenic payload

■ Monocrystalline suspension

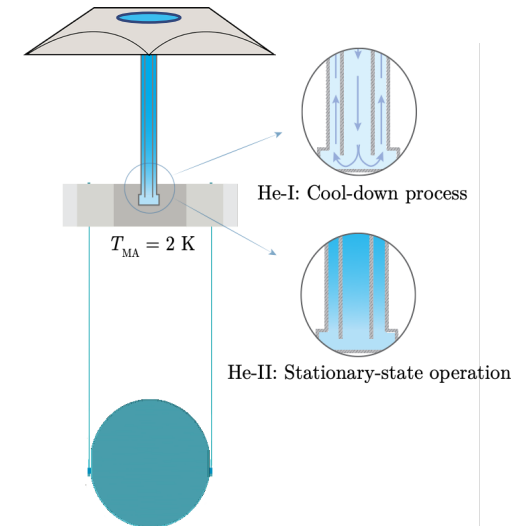


Two heat extraction concepts

Compatible with STN constrains

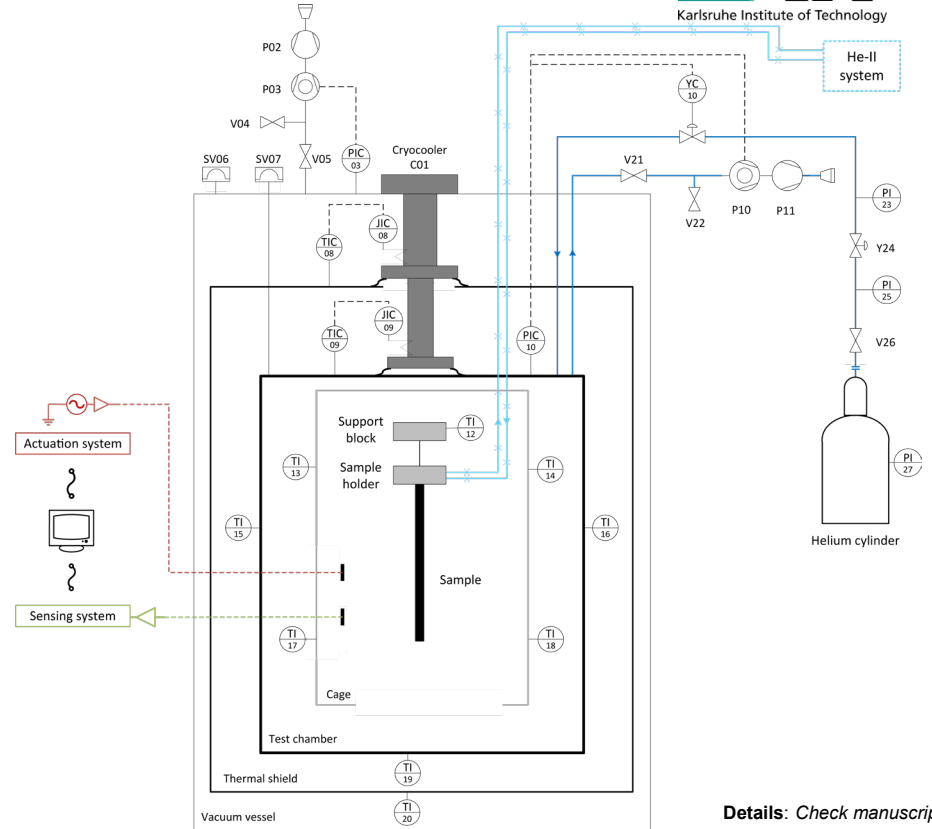
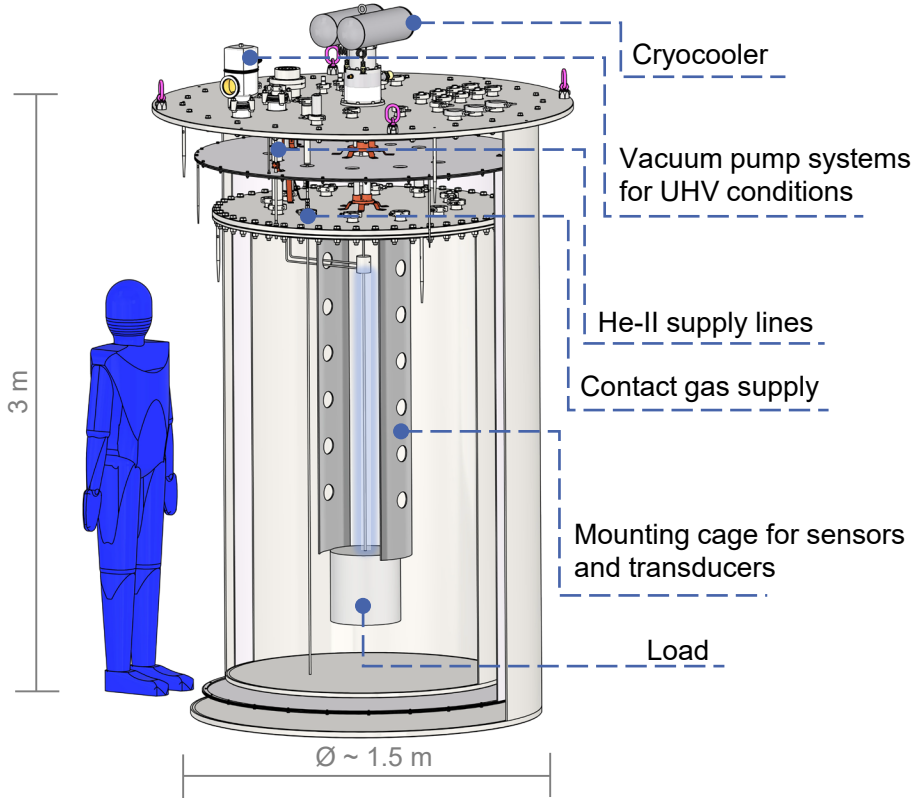


■ He-II filled suspension tube



Test facility for suspension studies

Cryostat conceptual design



Details: Check manuscript

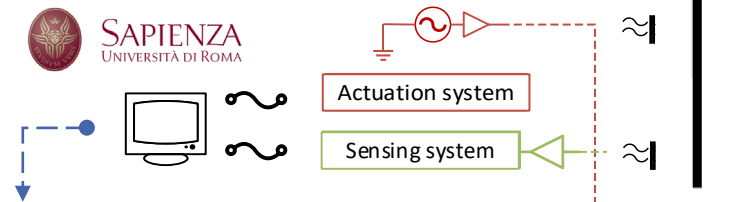
Dissipation mechanisms in suspensions

$$\phi_{\text{susp}} = \underbrace{\phi_{\text{bulk}} + \phi_{\text{thermoelastic}} + \phi_{\text{surface}}}_{\text{Intrinsic losses}} + \phi_{\text{extrinsic}}$$

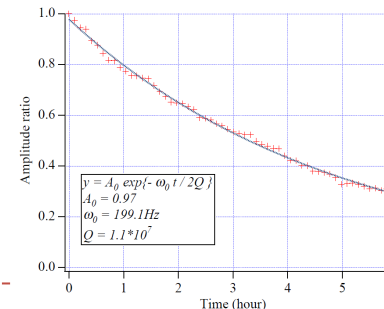
■ Intrinsic losses

■ Extrinsic losses

- Clamping losses
- Recoil losses
- Gas damping losses
- Eddy currents losses



Losses investigated via Q -factor measurements

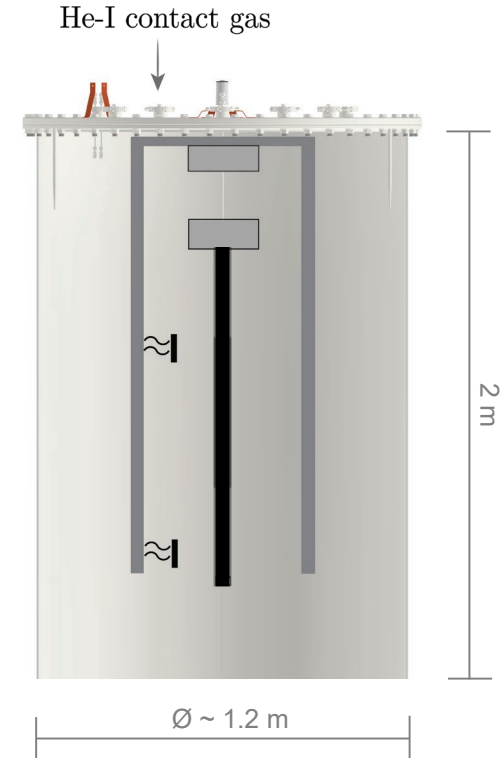


Reference: Uchiyama et al (2000),
 DOI: [10.1016/S0375-9601\(00\)00514-4](https://doi.org/10.1016/S0375-9601(00)00514-4)

Experimental campaign I

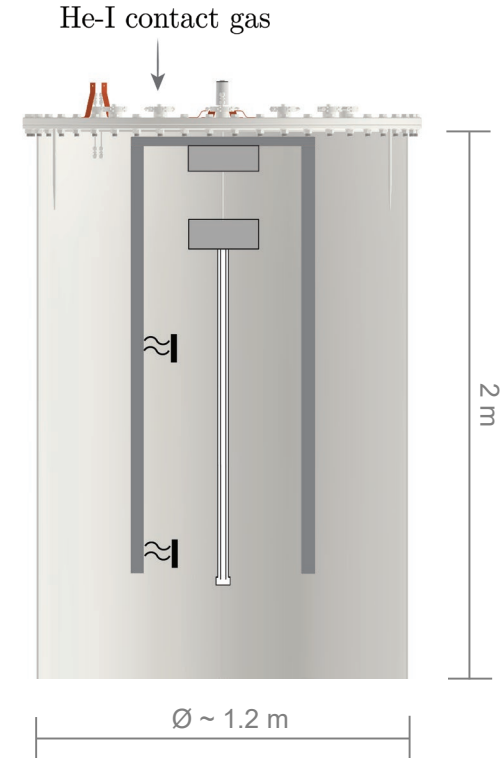
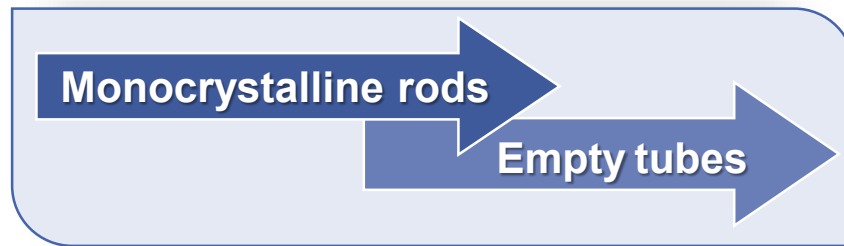
- Setup to investigate losses in full-sized suspensions:
 - Cryogen-free cryostat: Cryocooler + He-I contact gas
 - Investigation of material, geometry and load influence

Monocrystalline rods



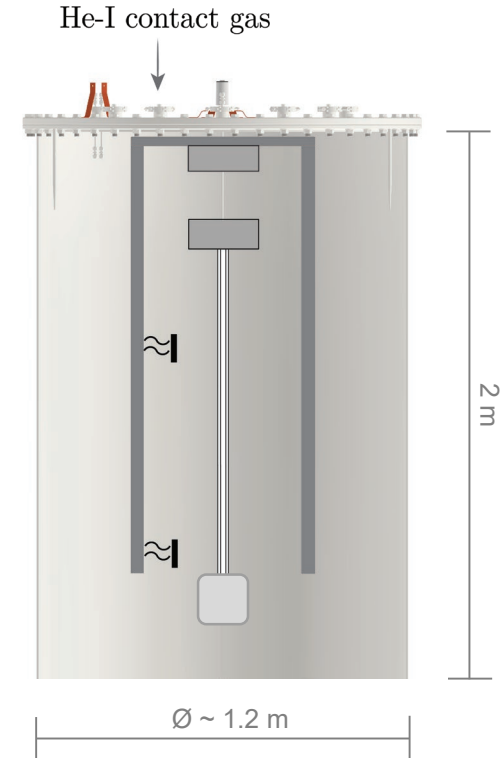
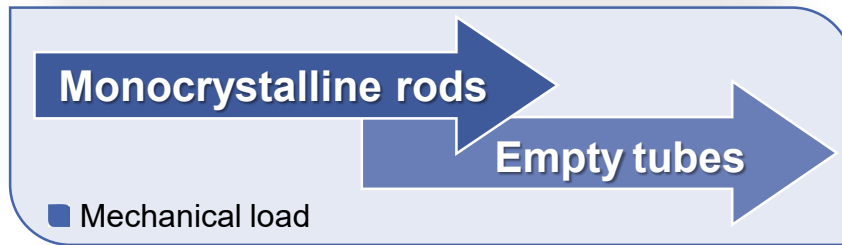
Experimental campaign I

- Setup to investigate losses in full-sized suspensions:
 - Cryogen-free cryostat: Cryocooler + He-I contact gas
 - Investigation of material, geometry and load influence



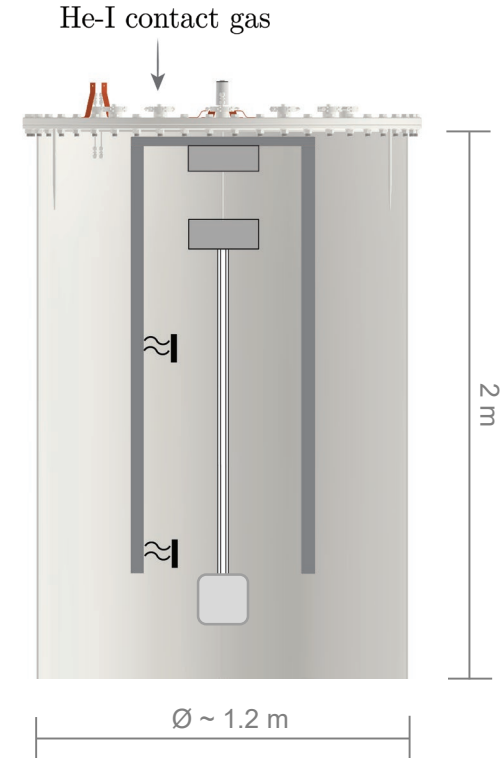
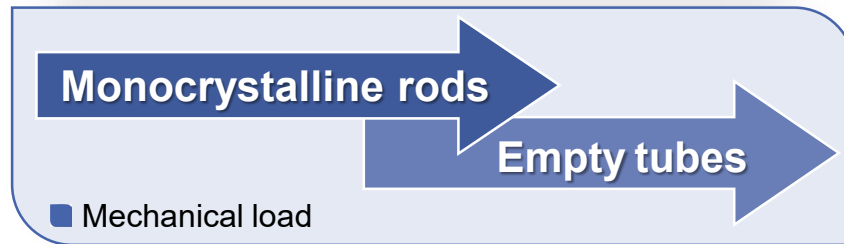
Experimental campaign I

- Setup to investigate losses in full-sized suspensions:
 - Cryogen-free cryostat: Cryocooler + He-I contact gas
 - Investigation of material, geometry and load influence



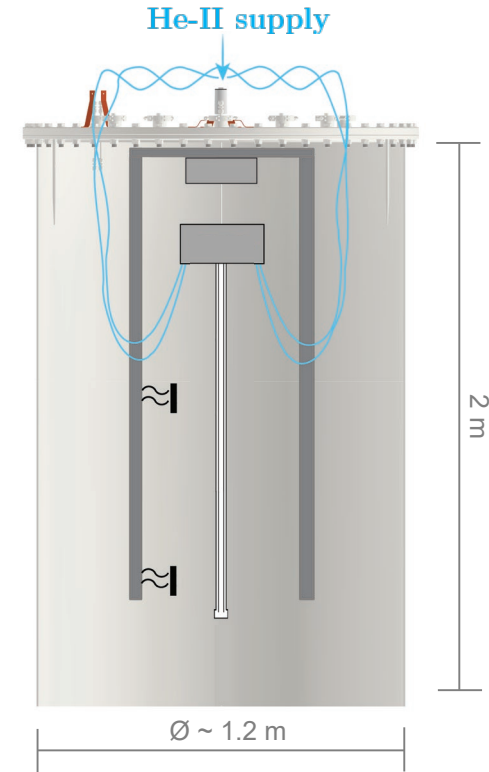
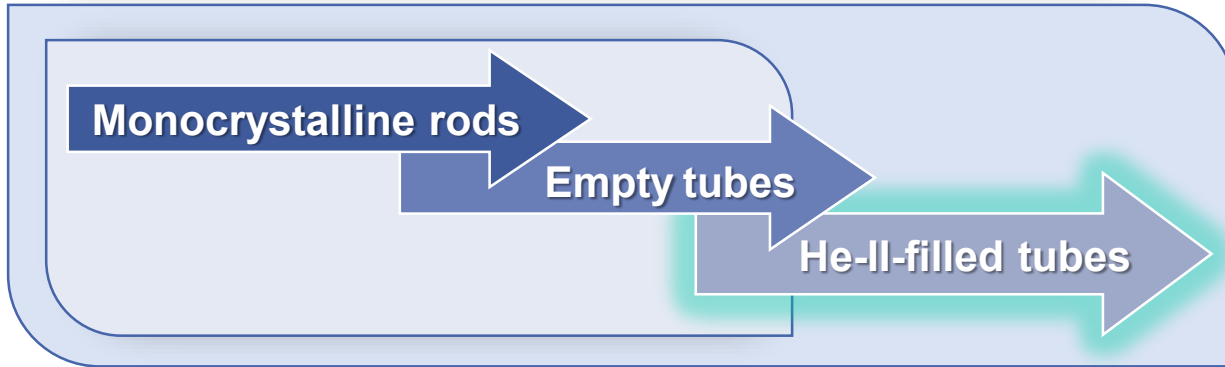
Experimental campaign I

- Setup to investigate losses in full-sized suspensions:
 - Cryogen-free cryostat: Cryocooler + He-I contact gas
 - Investigation of material, geometry and load influence
 - Methodology: Ring-down method
 - Step-by-step complexity increase to mitigate extrinsic losses
 - Clamping losses minimization via optimal sample support system
 - Indirect suspension temperature measurement via $f_0 \sim T$ relation
- Enrichment of literature data and experience gain



Experimental campaign II

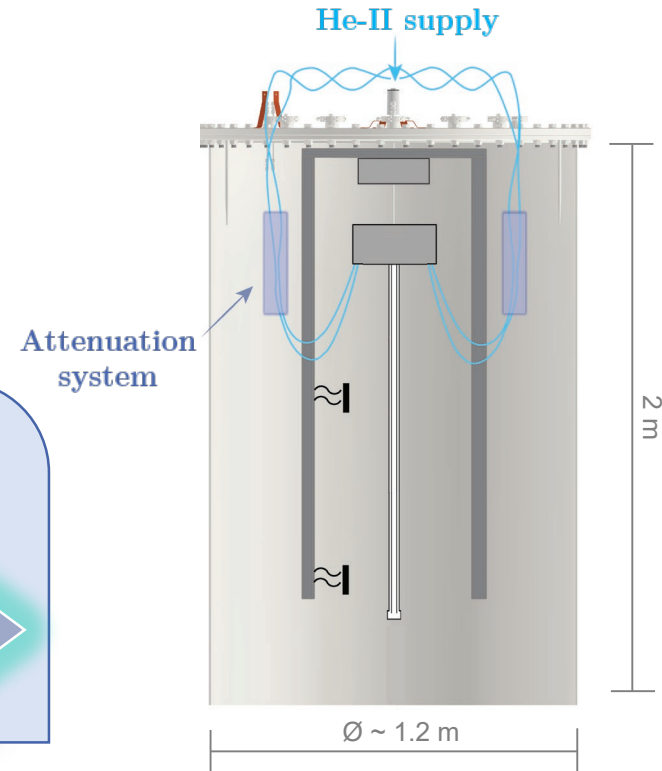
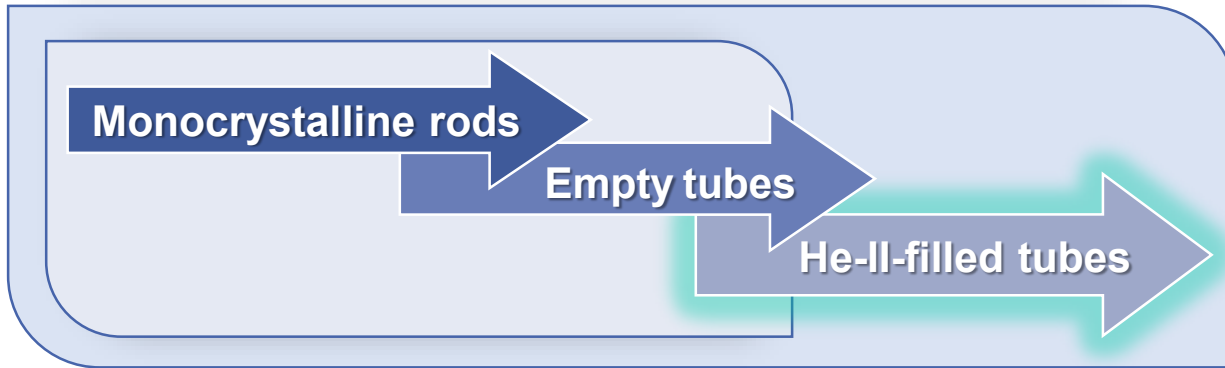
- Q measurements with He-II*:
 - He-II supply to test cryostat setup



* Design of He-II supply system is part of future work

Experimental campaign II

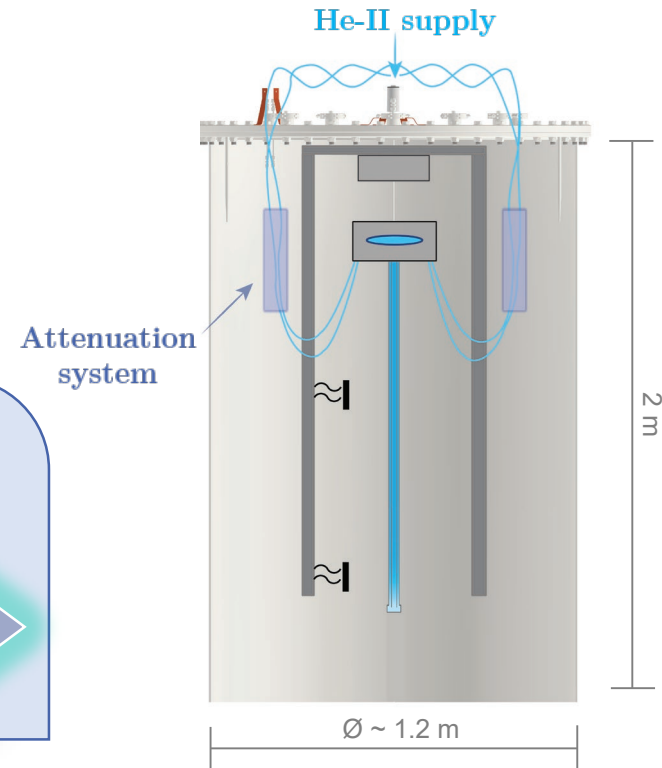
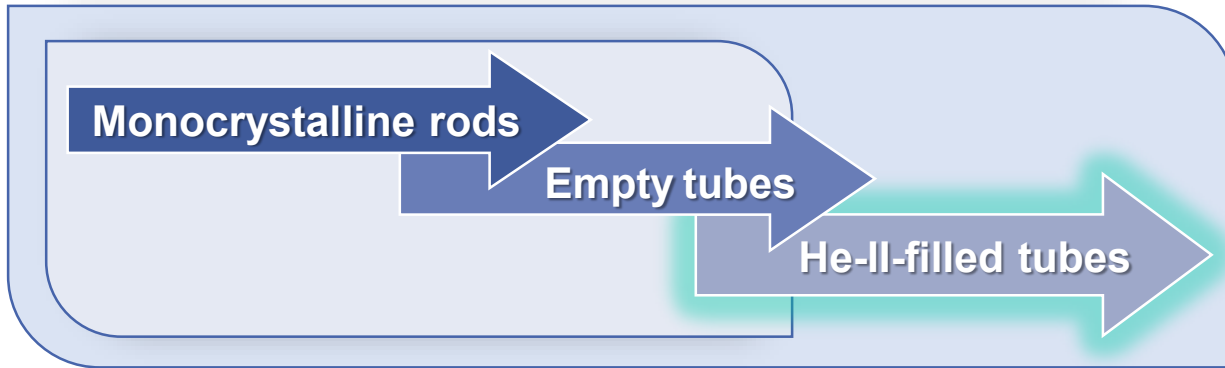
- Q measurements with He-II*:
 - He-II supply to test cryostat setup
 - Supply capillary noise attenuation system



* Design of He-II supply system is part of future work

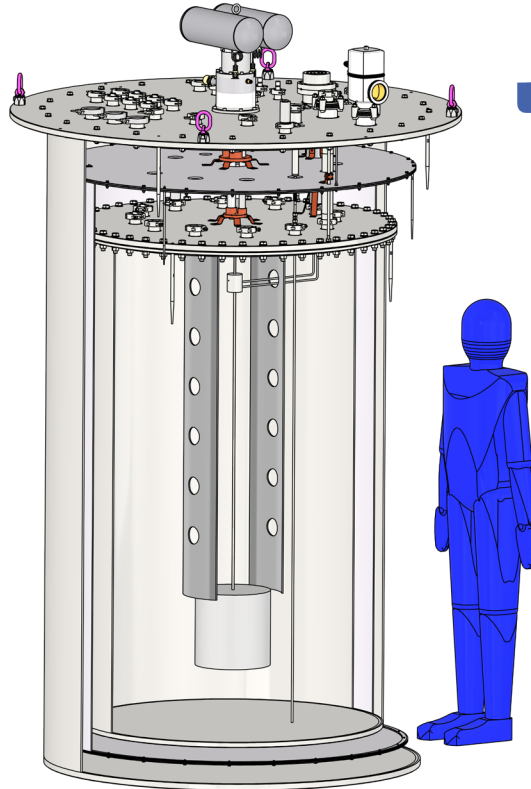
Experimental campaign II

- Q measurements with He-II*:
 - He-II supply to test cryostat setup
 - Supply capillary noise attenuation system
 - Design of He-II cooling interface on sample support
 - Dissipation mechanisms in He-II



* Design of He-II supply system is part of future work

Summary & Outlook



- Test cryostat for Q measurement test facility:
 - Full-size suspension fibers and tubes
 - Investigation of loss contributions in suspensions
 - He-II integration in Q measurements
 - Proof of concept for He-II based payload cooling for ET-LF

Monocrystalline rods

Empty tubes

He-II-filled tube

Thank you for your attention

✉ xhesika.koroveshi@kit.edu



[Organizational Unit: Refrigeration and Cryogenics at KIT - Karlsruhe, Germany](#)