ETIC-IR0000004-Missione 4
PRIN LoVeC-ET 2020BSYXCB

Updates on ARC: R&Ds for ET, cryogenic strategies without cryo-liquids

E. Benedetti[2], A. Cruciani[2], V. L. Hoang[1], E. Majorana[1,2], V. Mangano[1,2], L. Naticchioni[2], M. Orsini[1], D. Pasciuto[2], M. Perciballi[2], S. Pirro[3], P. Puppo[2], P. Rapagnani[1,2], F. Ricci[1,2], M. Ricci[1,2]

1. Department of Physics, University of Rome Sapienza, Italy 2. INFN Sezione di Roma, Italy 3. INFN Laboratori Nazionali del Gran Sasso, Italy

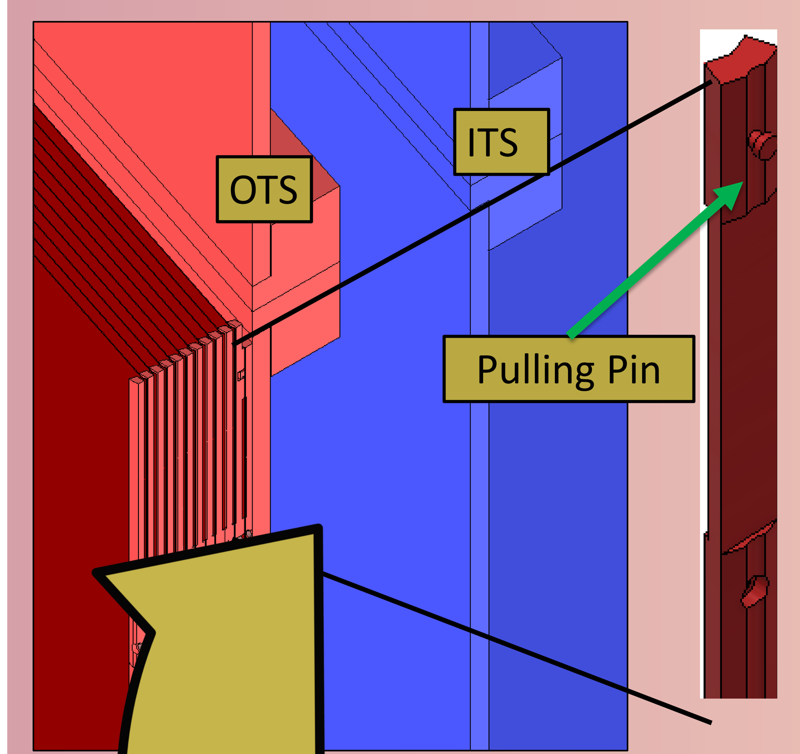
The Amaldi Research Center (ARC), located in Sapienza University of Rome, will host the first experiment of a cooling system for an actual-sized cryogenic payload. Following the solid conduction cooling scenario*, two low-vibration refrigeration lines, each driven by two Pulse Tubes cryocoolers, will be used to cooldown a cryogenic payload hosted in a specifically designed 3 m tall cryostat.
While one refrigeration line has already been built, the other, along with the cryostat and the payload, is now under construction and will be delivered in 2025. This is funded by both ETIC and ARC, and it might eventually be integrated into the Einstein Telescope.

The infrastructure hosting the large cryostat under development does not allow the implementation of a seismic isolation system. However, the payload hosted in the cryostat allows the study of the suspension elements involved in the heat extraction; the soft heat links used to connect the refrigeration lines to the payload must mitigate the vibrations coming from the cryocoolers. The test mass is surrounded by two radiation shields, the Inner Thermal Shield (ITS) and the Outer Thermal Shield (OTS). In the last one, we designed a new radiation isolation system. Thermal transient analysis are also being conducted on the whole model, considering a payload of ca. 500 kg and thermal shields (ITS, OTS, RML) of 2000 kg. The latest results show a full cooling down in less than 2 months.

*X. Koroveshi et al. (arXiv:2305.01419v1)

Thermal Analysis

Polyethylene terephthalate technology (PET) is a good choice to constitute a standard multilayer for OTS, but KAGRA experience shows this is a critical aspect concerning the adsorption on the the mirrors due to cryopumping**. Thus, given the much larger surface foreseen for the OTS, we designed the Rigid Multi Layer (RML),

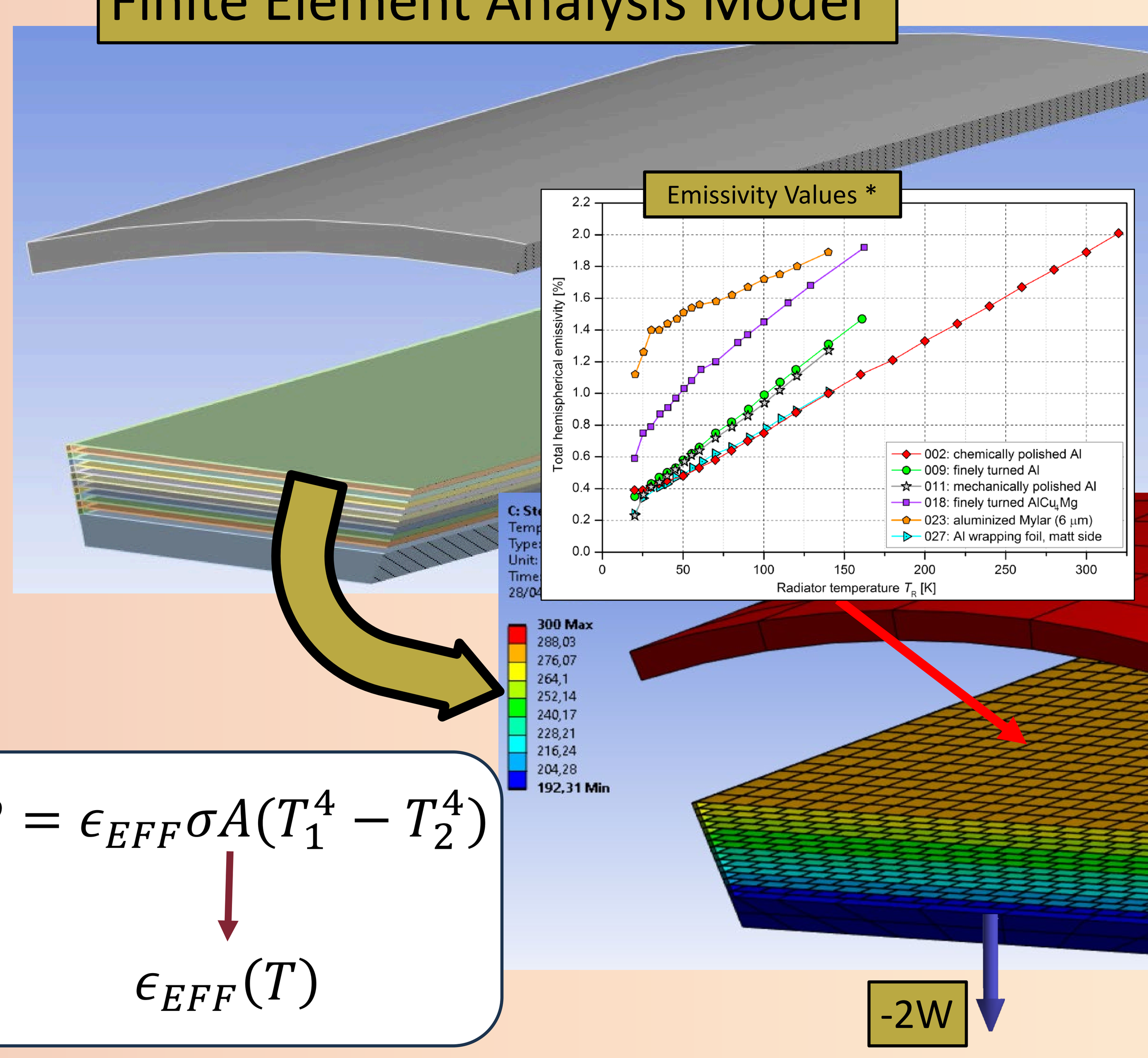


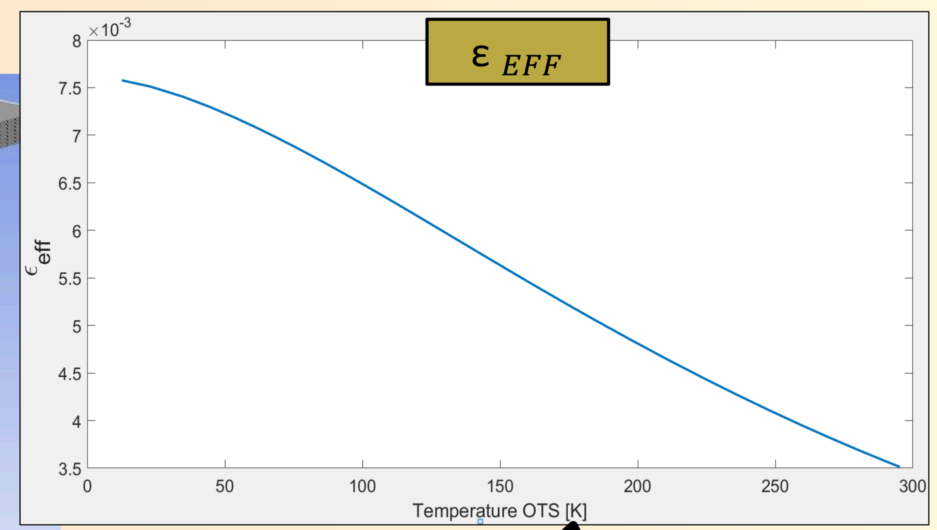
meant to reduce the surface and be more efficient than usual standard superinsulation. It consists in a series of thin reflective aluminum foils (< 0.3 mm) separated by insulating rods (PEEK) which are used both to sustain and to stretch the foils, thanks to their concave shape.

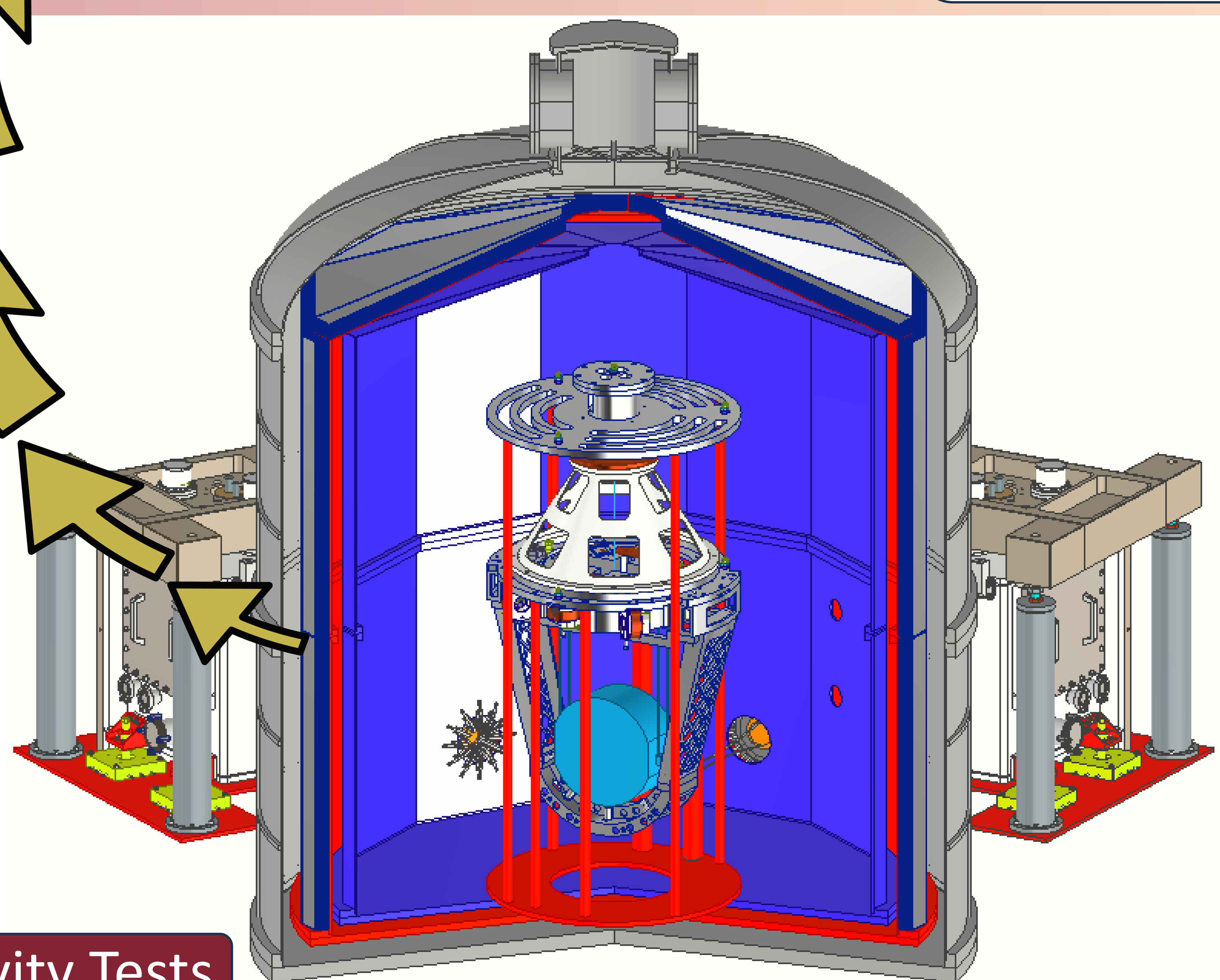
$$P = \epsilon_{EFF}\sigma A(T_1^4 - T_2^4) \rightarrow \epsilon_{EFF}(T)$$

*J. Frolec,Cryogenics 97 (2019) 85-99
https://doi.org/10.1016/j.cryogenics.2018.12.003
**K. Hasegawa et al. Phys. Rev. D 99, 2019

Finite Element Analysis Model



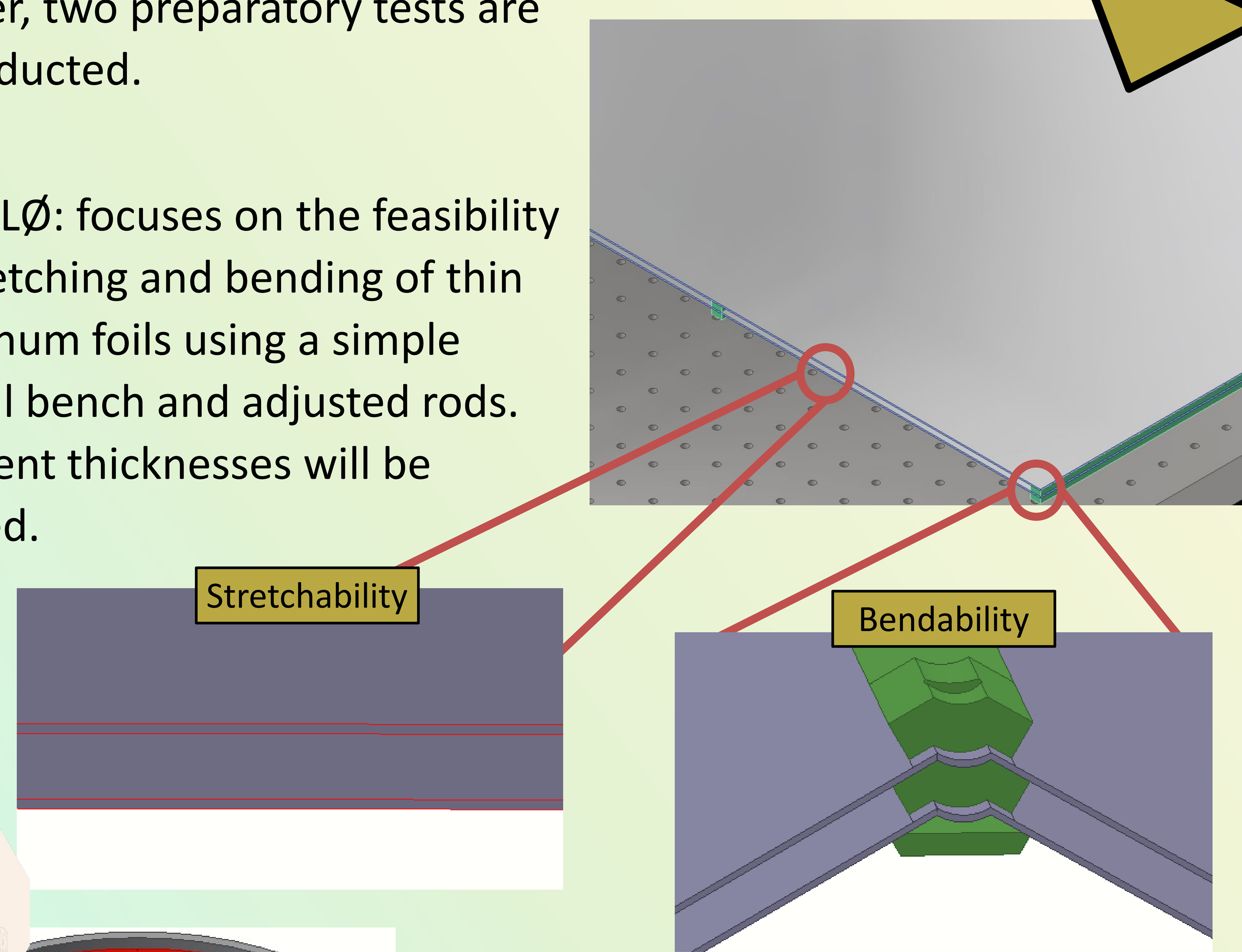


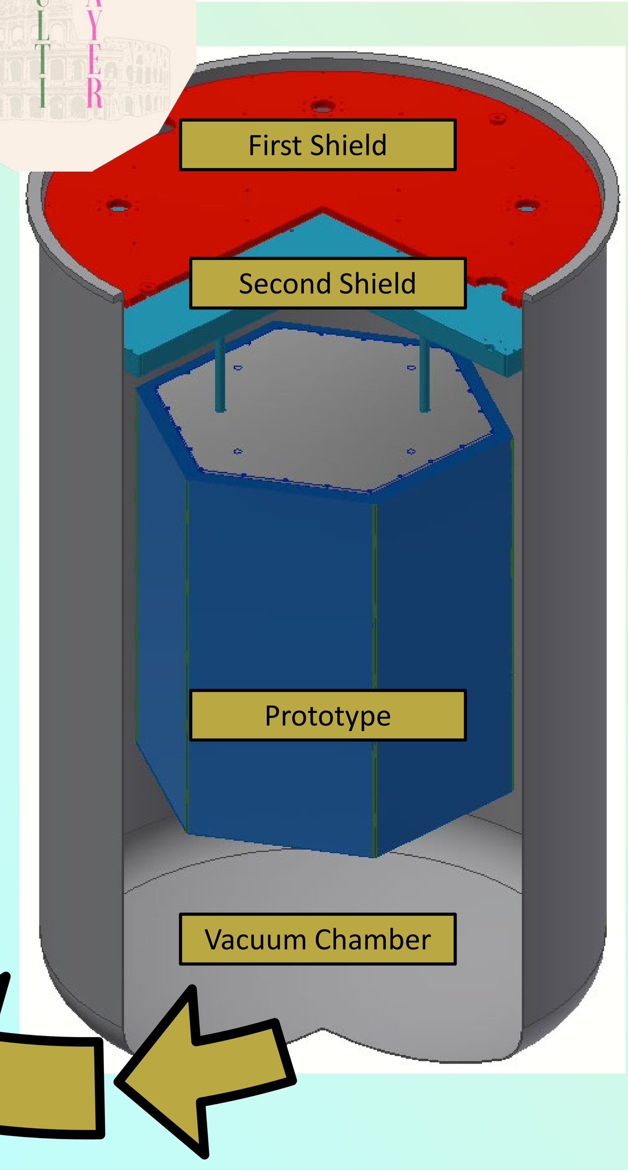


RoMoLo

To validate the design of the Rigid Multi Layer, two preparatory tests are being conducted.

1. RoMoLØ: focuses on the feasibility of stretching and bending of thin aluminum foils using a simple optical bench and adjusted rods. Different thicknesses will be studied.

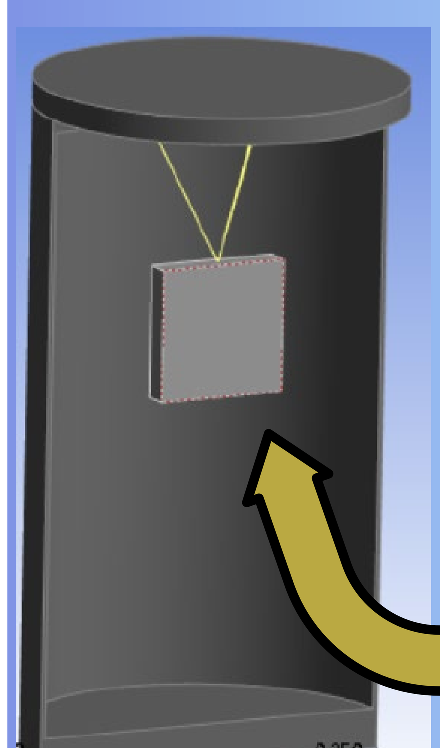




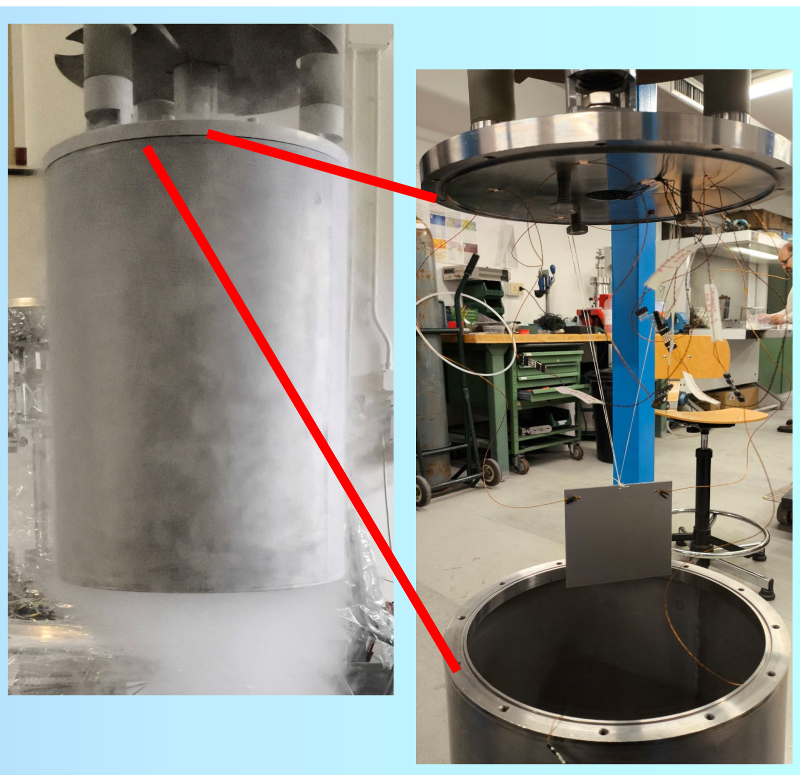
2. R0M0L0: downscaled version of OTS. A suspended hexagonal based structure (thickness 6 mm) with adjusted rods anchored by means of insulating bolts, implementing 15 layers of aluminum foil and cooled down by pulse tubes in a cryostat. This test focuses not only on the effectiveness of the isolation of the RML, but also on the feasibility, the ease of installation and the structural integrity.

Emissivity Tests

The radiation shielding performance of the RML can be accurately enhanced optimizing the thermal emissivity of the foils.



Systematic emissivity measurements at LN2 temperature on aluminum samples with different surface treatments are being performed in a small cryostat.



$$P = \epsilon(T_1)\sigma A(T_1^4 - 77^4)$$
$$Q = mc_P(T_1)(T_1 - 77)$$
$$P = Q/\Delta t \rightarrow \epsilon(T_1)$$