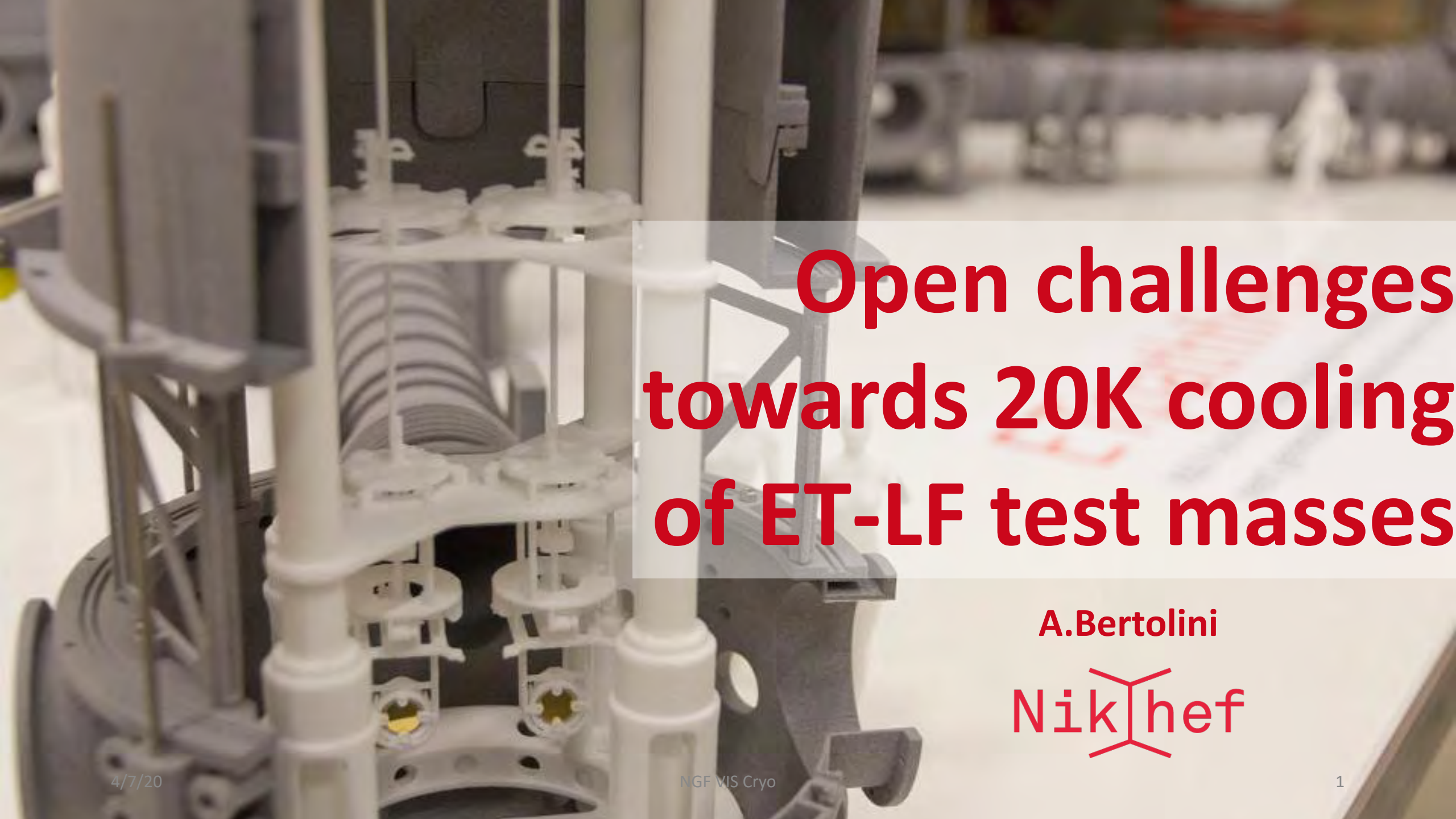


Open challenges towards 20K cooling of ET-LF test masses

A.Bertolini

Nikhef

Thermal noise in suspended optics interferometers

Thermal noise in mechanics is equivalent to Johnson noise in electronic resistors and arises from the fundamental correlation between thermodynamic fluctuations of degrees of freedom of a physical system and the associated dissipation processes

Electrical impedance

Voltage noise PSD $V_n^2 = 4K_BT\Re\{Z_{el}(\omega)\}$

Mechanical impedance $Z_m(\omega) = \frac{F_x}{\dot{x}}$

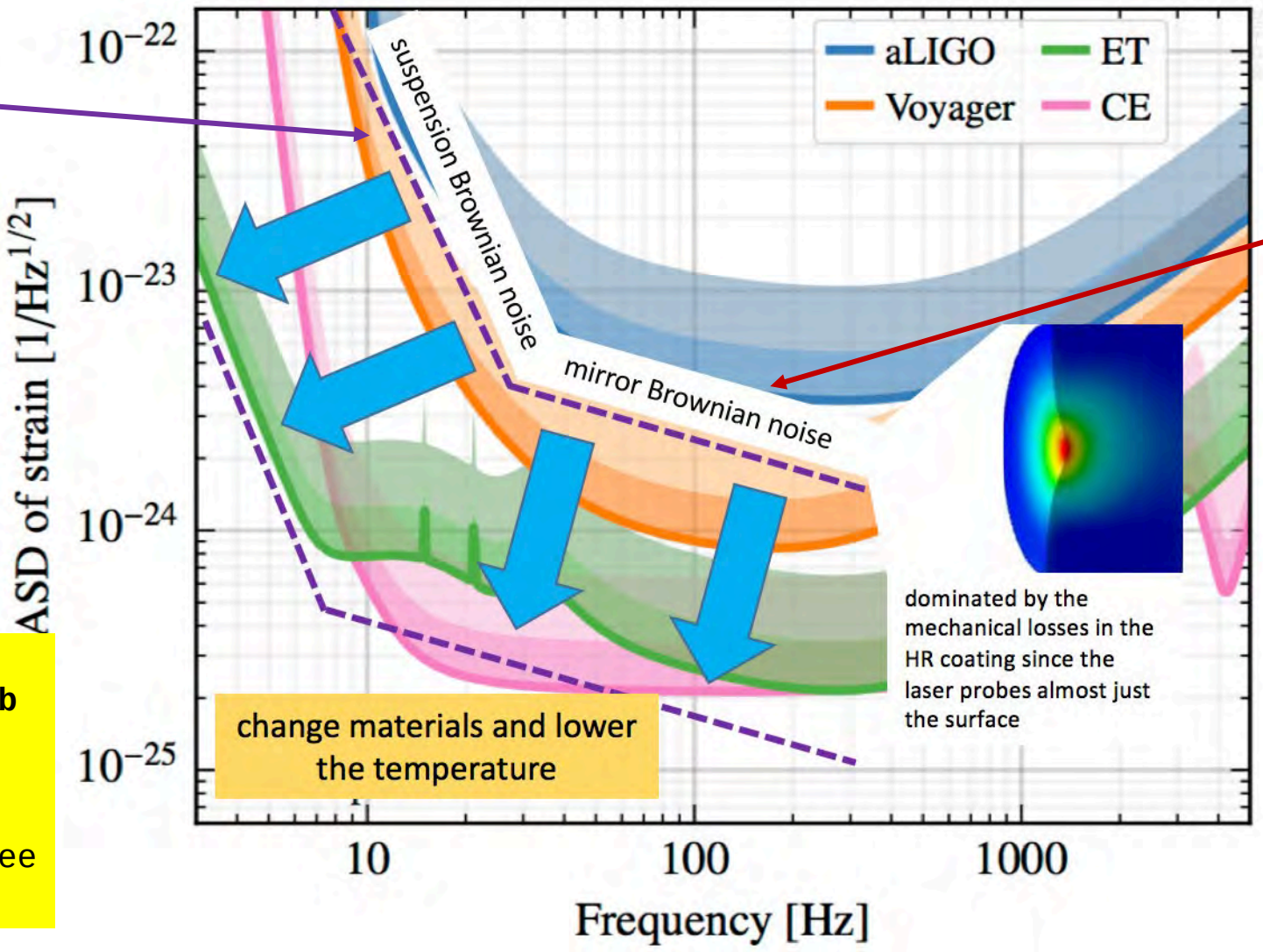
Force noise PSD $F_n^2 = 4K_BT\Re\{Z_m(\omega)\}$

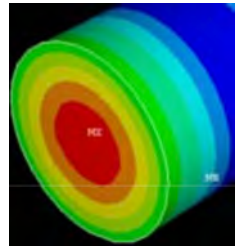
it also acts directly at the level of the suspended mirror => not shieldable

Thermal noise in suspended optics interferometers

The degrees of freedom we care most about

pendulum mode
f~0.5Hz





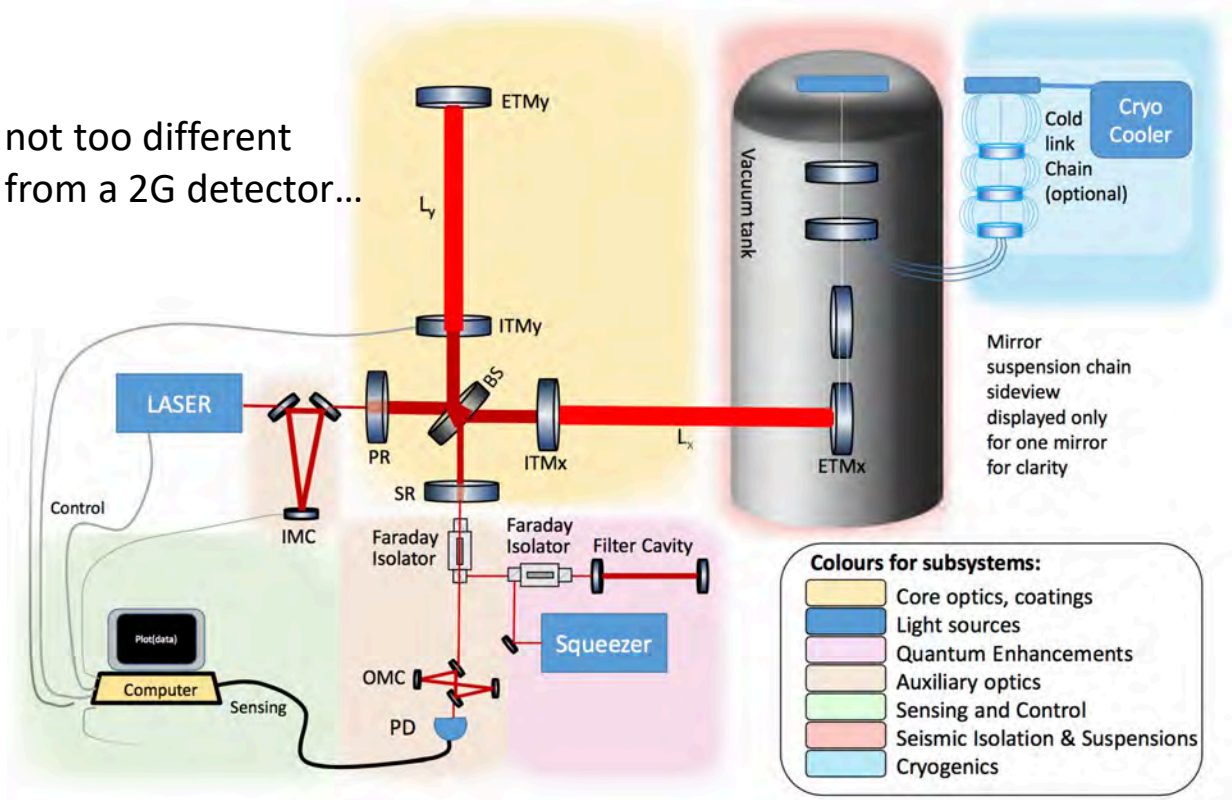
first
internal mode
f~ few kHz

TARGET
less than **0.1 ppb** energy loss per cycle of oscillation !!!
…or >200 years free decay time

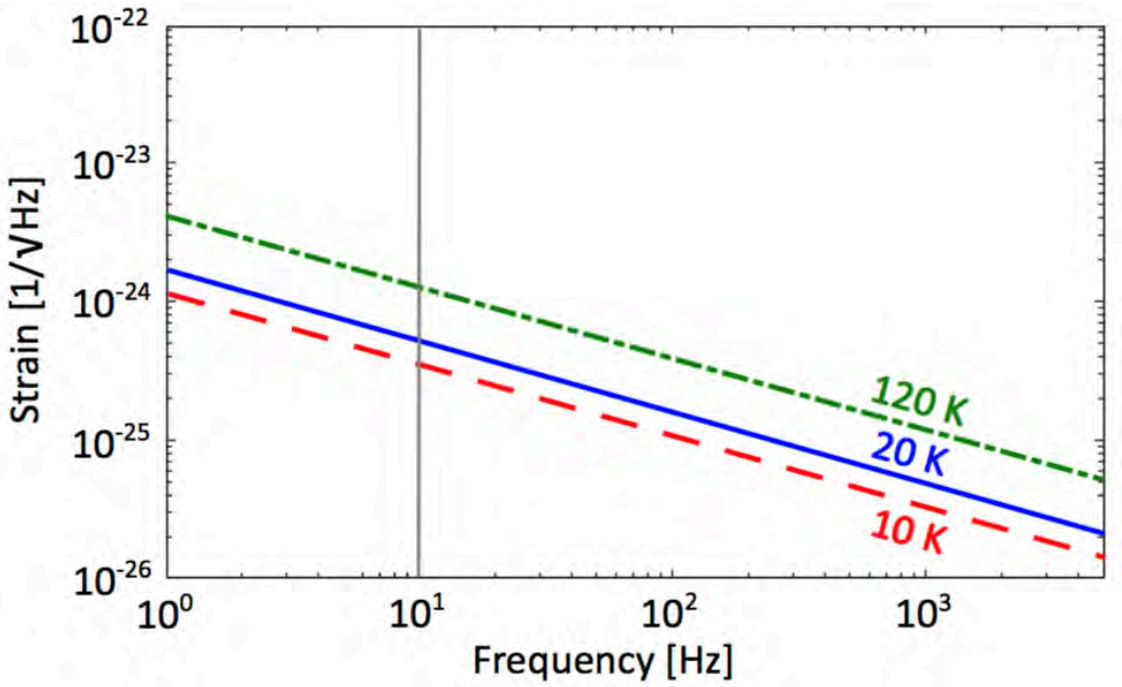
…the colder the better but without jeopardizing the detector at low frequency (f<30Hz)

LF Einstein Telescope: what is about

not too different
from a 2G detector…



ET mirror thermal noise – which temperature ?



Credit: J.Steinlechner,I.Martin

300K
40 kg fused silica substrate
fused silica fiber suspensions

20K
200 kg single crystal Si substrate
single crystal Si rod suspensions

ET-LF payload current conceptual design

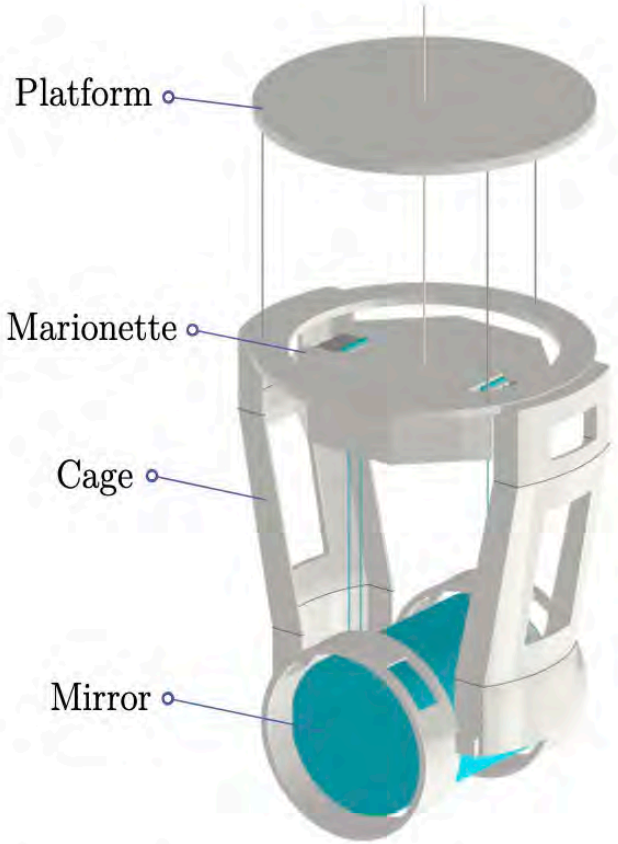
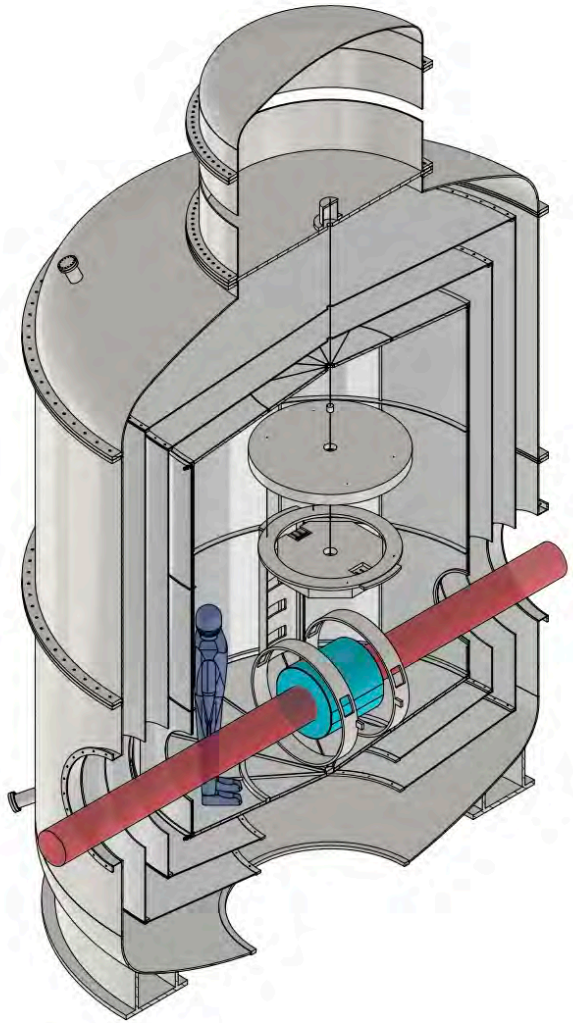


FIG. 2: Baseline design of the ET-LF cryogenic payload based on the AdVirgo double pendulum design.



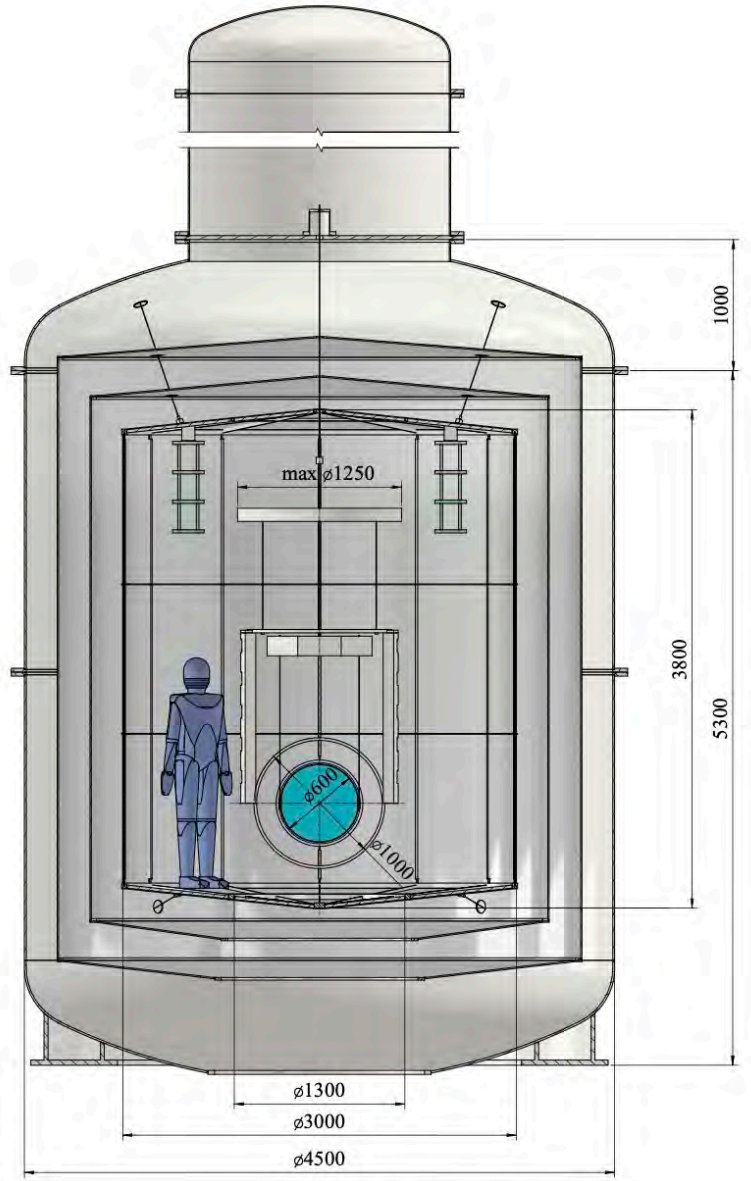
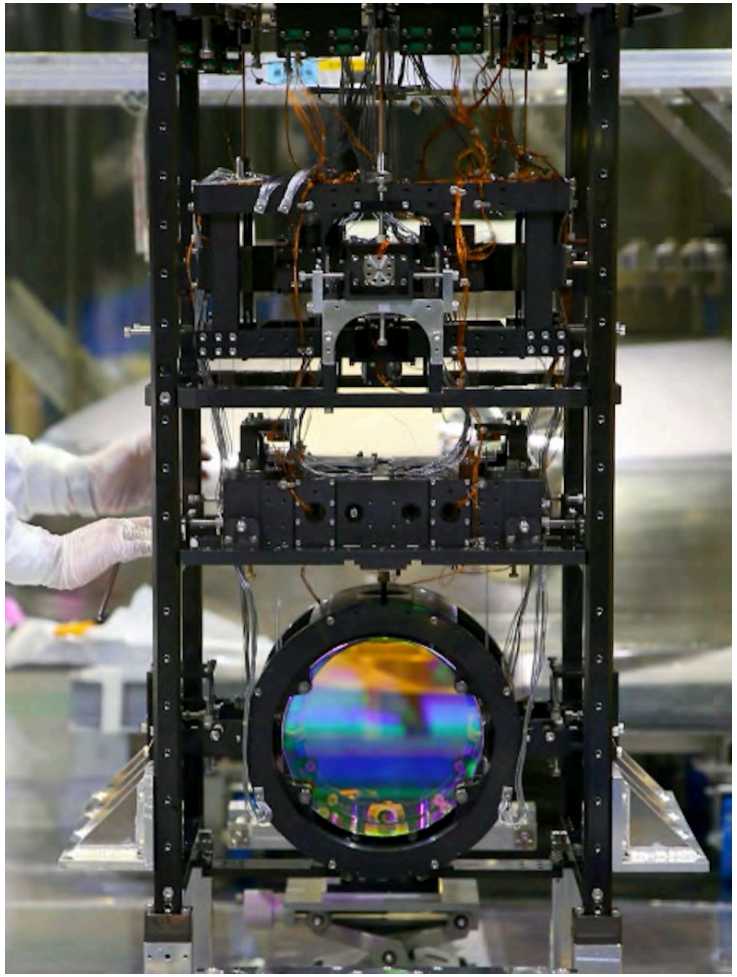
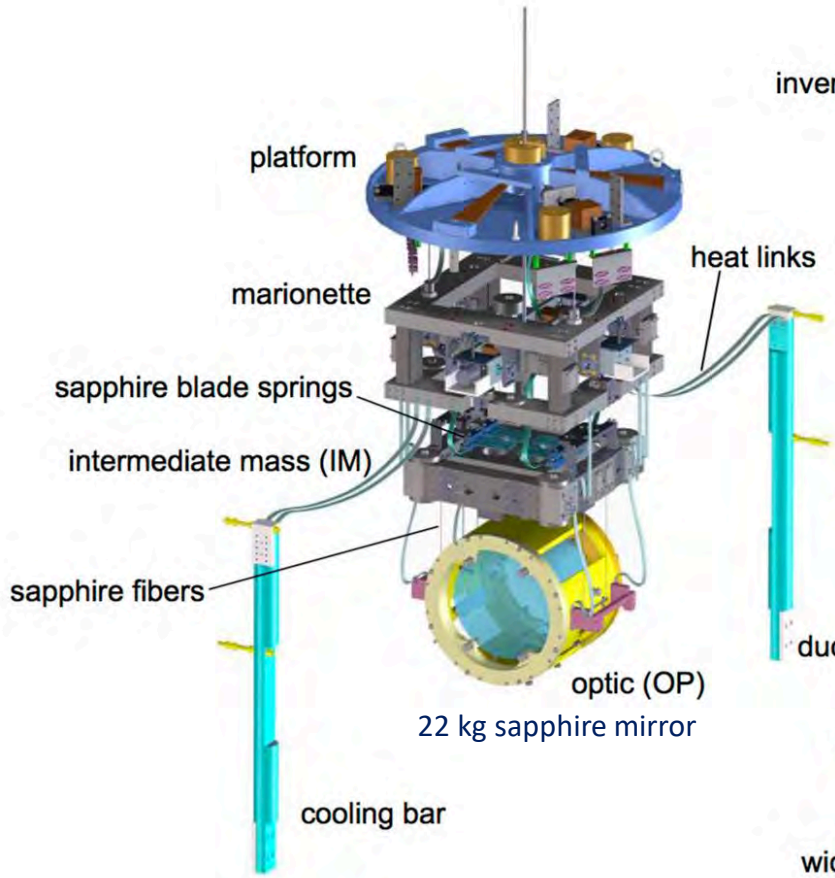


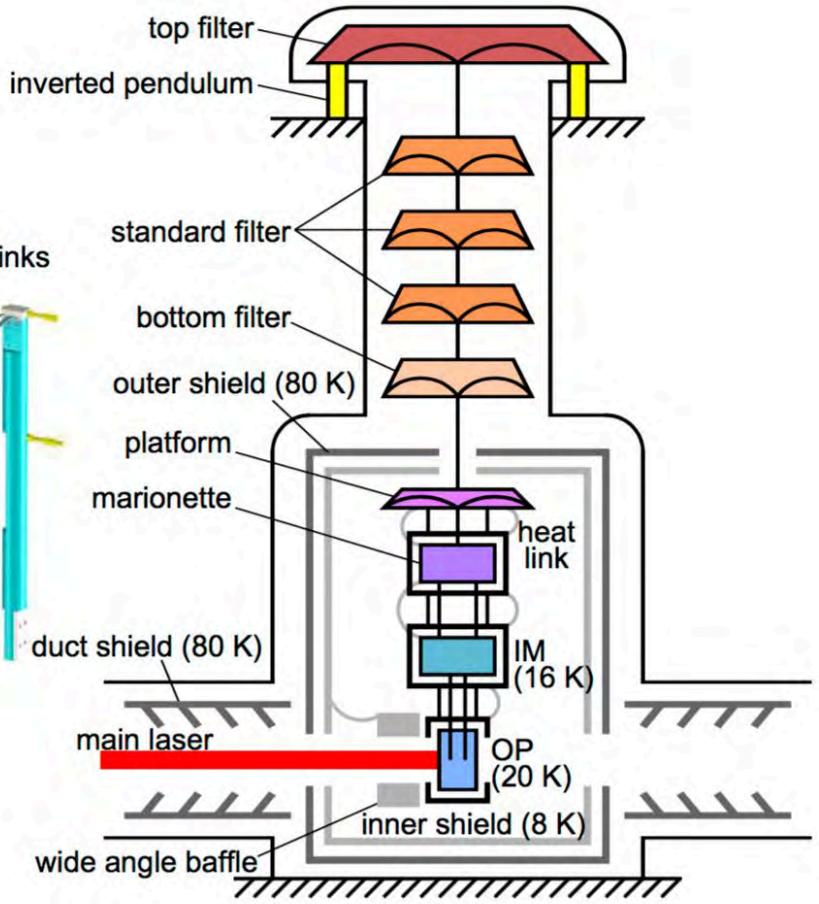
Figure 4: Conceptual design of the ET-LF cryostat.

Conduction cooling via high purity (6N) aluminum wires

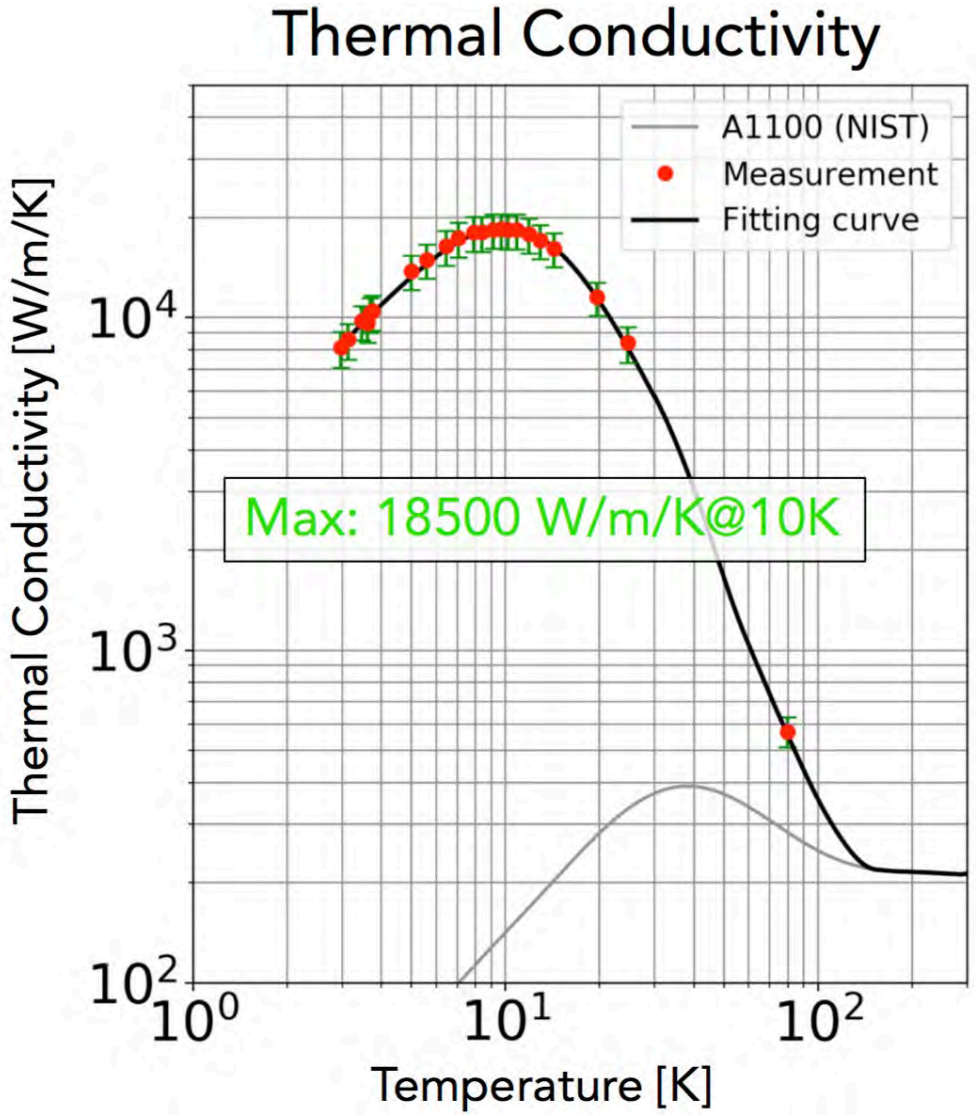


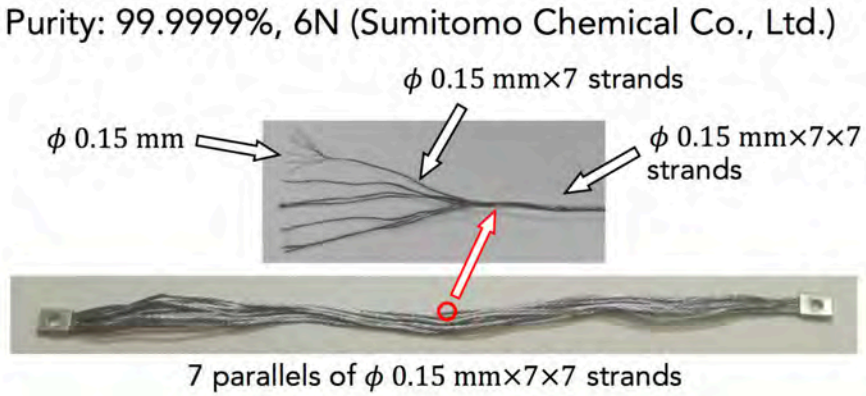
KAGRA detector





Conduction cooling via high purity (6N) aluminum wires





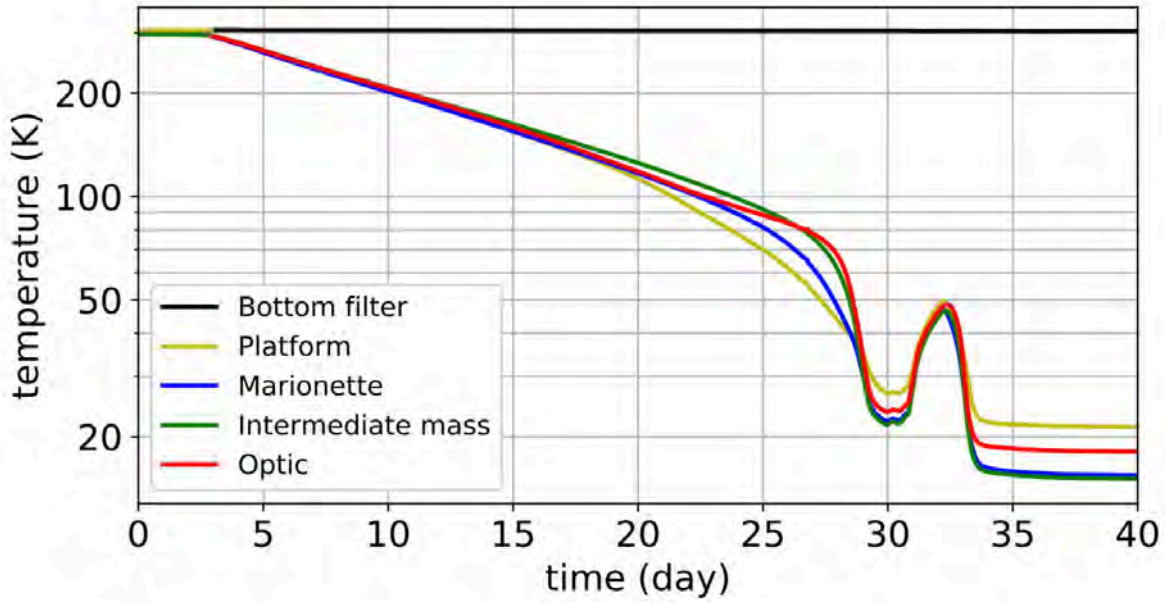


Figure 5. Cooling curve of ETMY. The bump starting from around day 30 was due to the restart of the cryocoolers.

Credit: KAGRA project

ET-LF payload current conceptual design

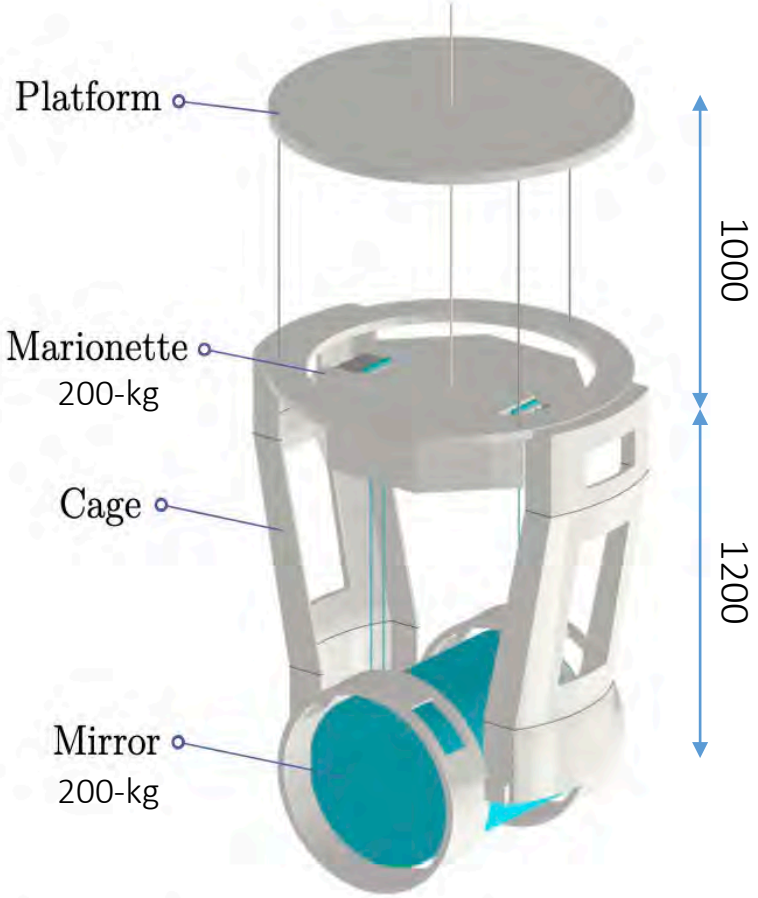
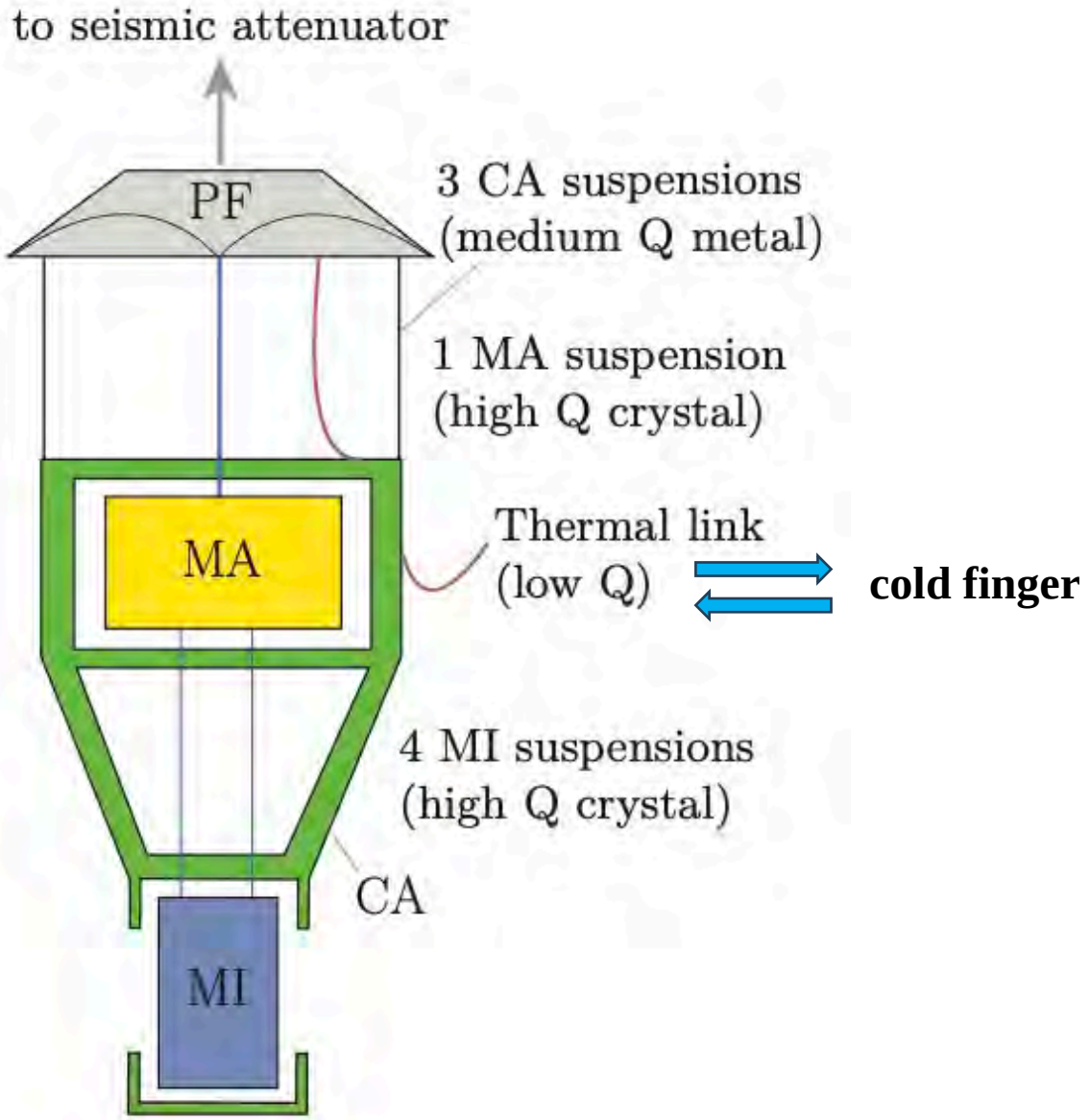
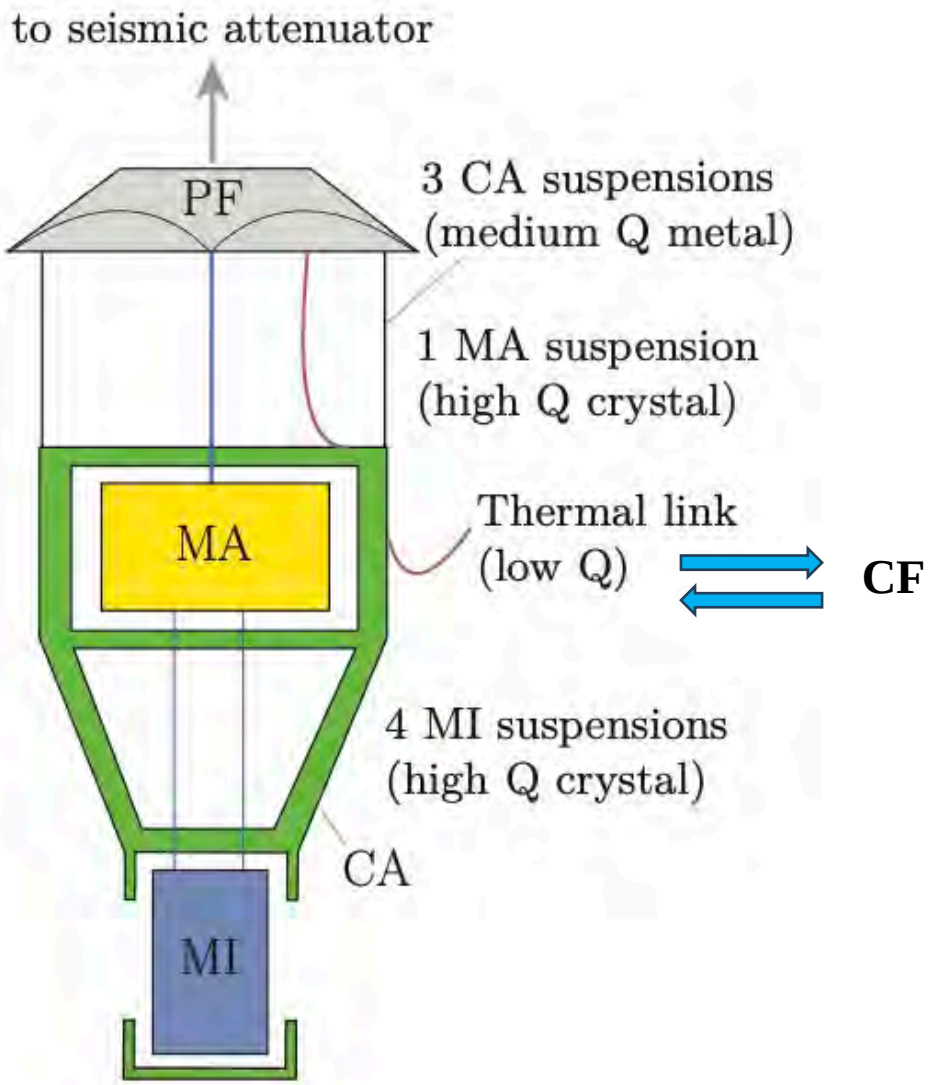


FIG. 2: Baseline design of the ET-LF cryogenic payload based on the AdVirgo double pendulum design.



ET-LF payload current conceptual design



Low Q heat links may endanger Brownian noise figures

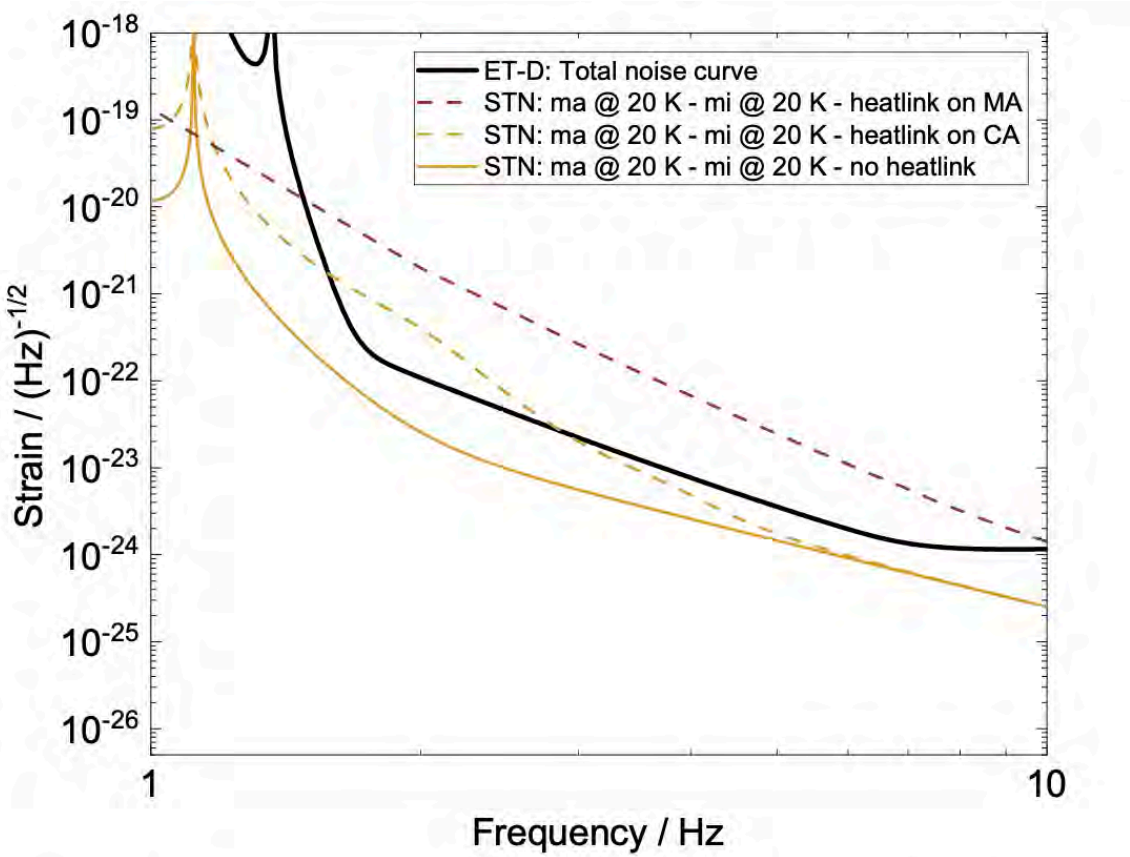
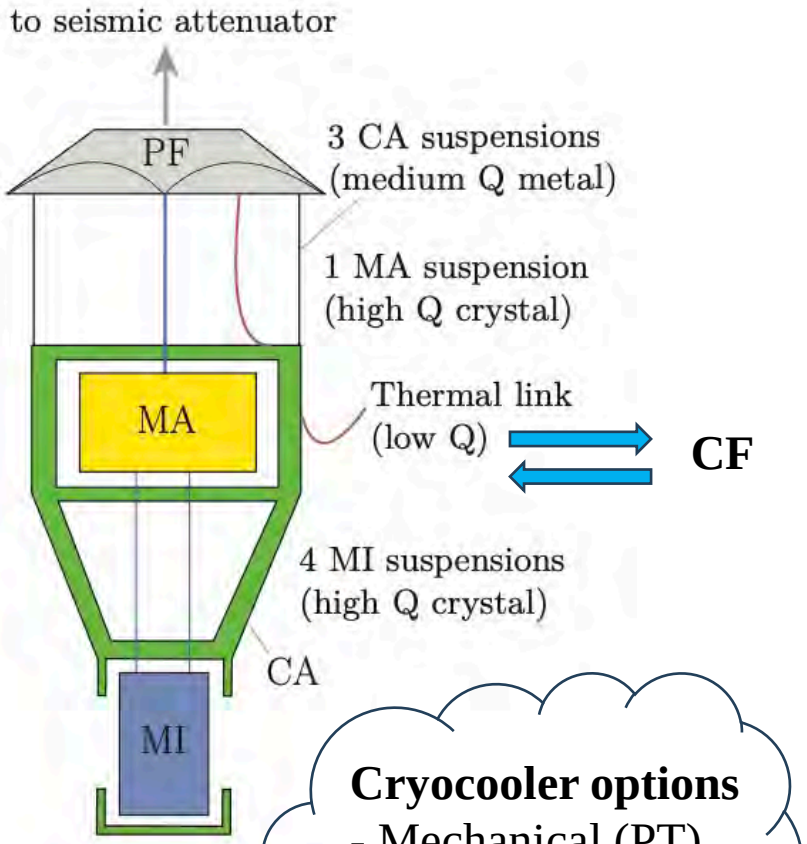


FIG. 4: Impact on the STN due to a direct connection of a 1 m thermal link (made of 28 braids, each composed by 49 Al6N wires with $d = 150\,\mu$m [41] and assuming $\phi_{\rm TL} = 0.5$) on the MA and CA, respectively.

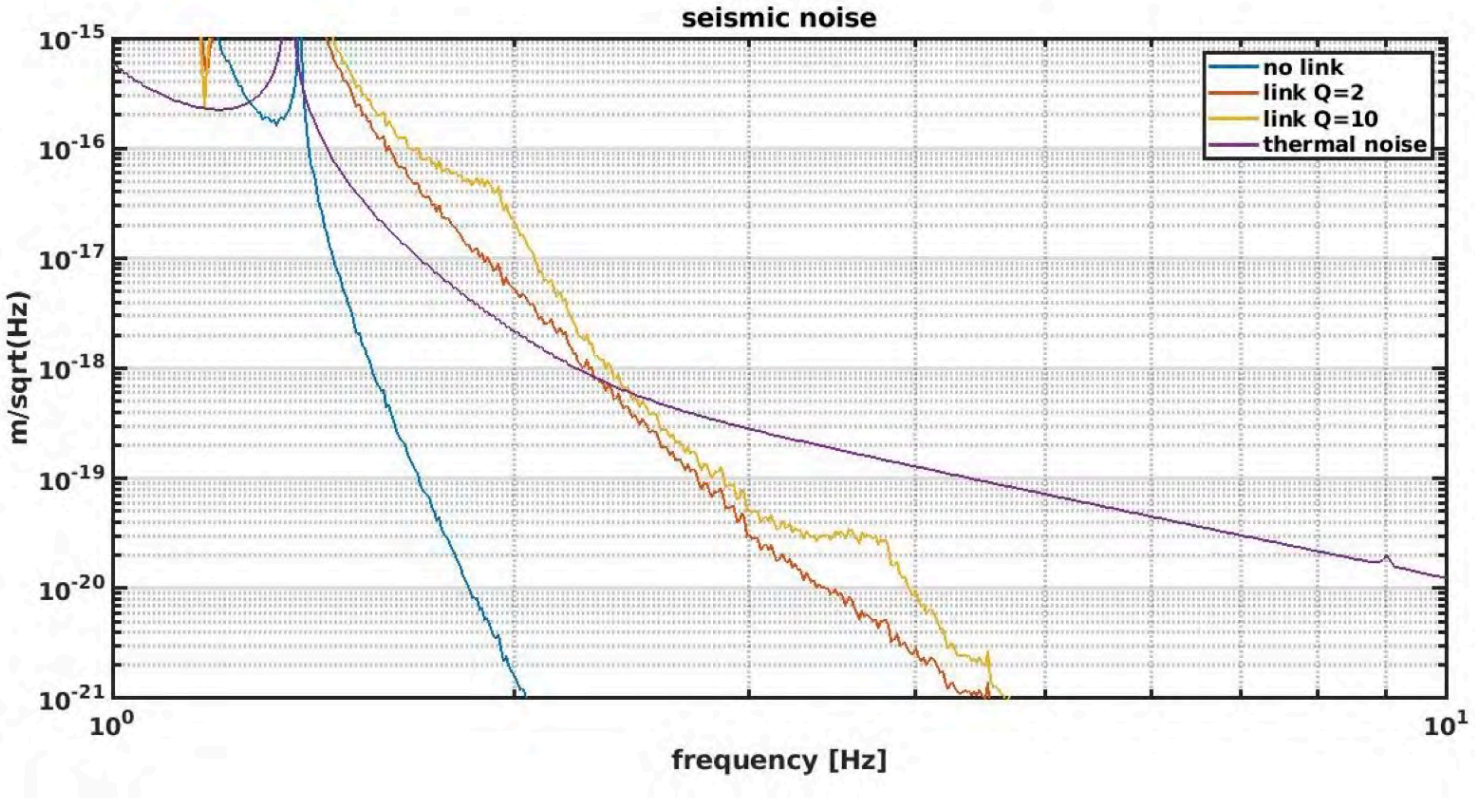
ET-LF payload current conceptual design



Cryocooler options
- Mechanical (PT)
- He-II @ 2K
- Sorption cooler

Heat links provide a shortcut for vibrations

Link ground - RM: AL E=6.9*10^{10}; ρ=2700
L=1m; d=0.15mm; N=49*28 Al69 (KAGRA like)



in the best case CF will move as the ground…