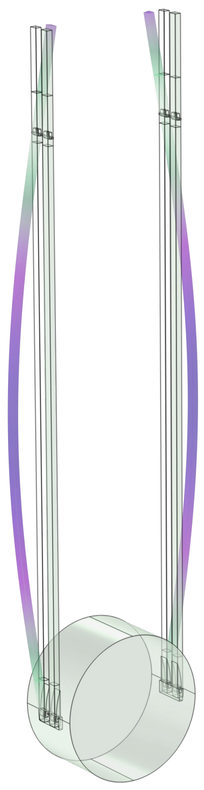
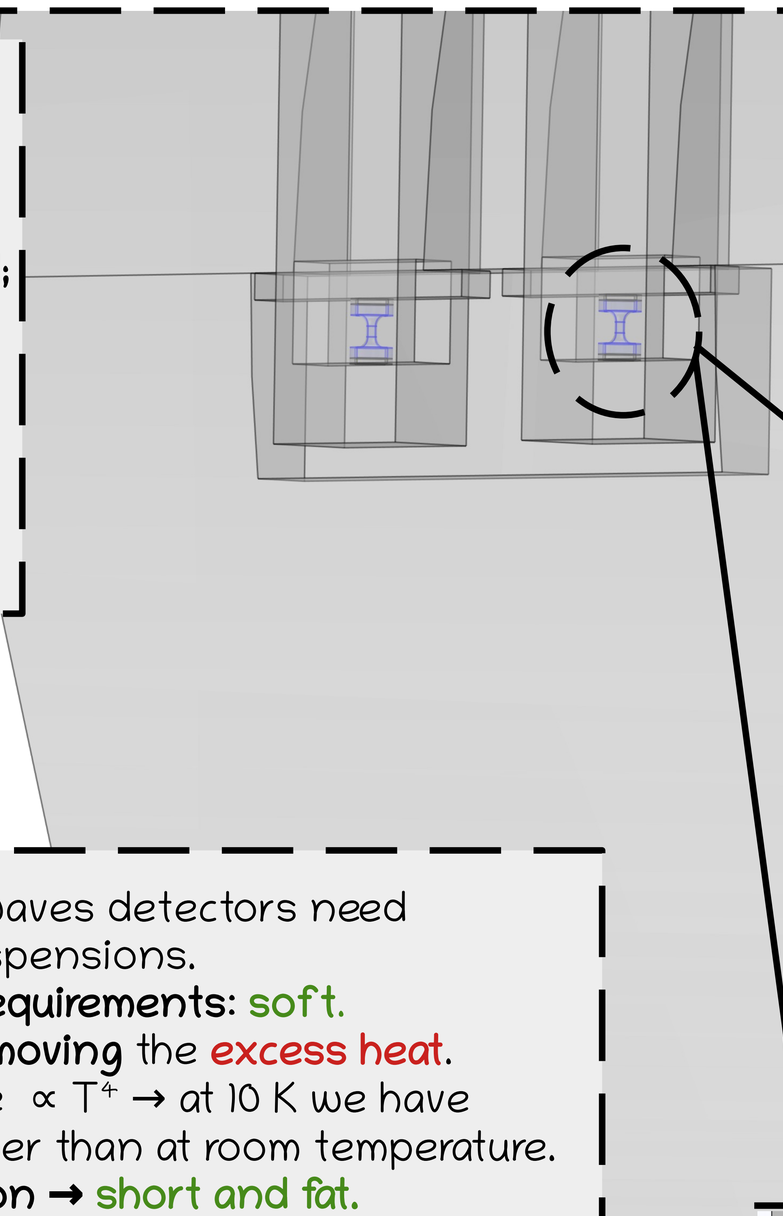
A new approach for suspending cryogenic mirrors

Francesca Badaracco[1], Kazuhiro Agatsuma[2], Alessandro Bertolini[3], Andrea Chincarini[4], Joris van Heijningen[1], Luca Naticchioni[5], Paolo Ruggi[6], Stefano Selleri[7], Riccardo DeSalvo[8]

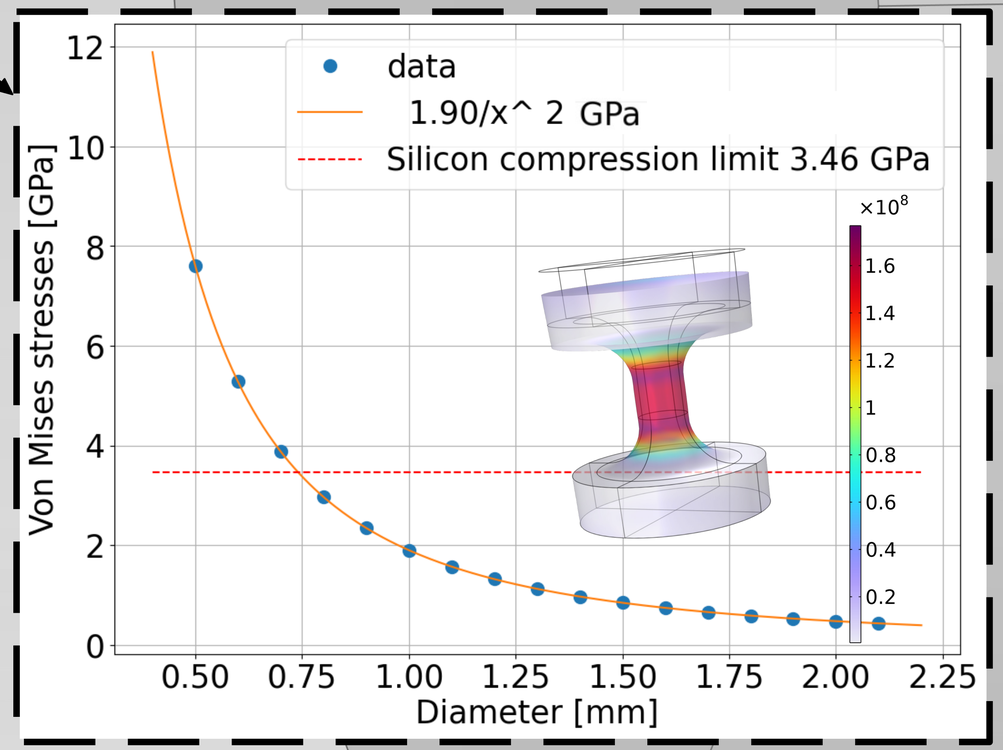
[1] Université catholique de Louvain
[2] University of Birmingham
[3] Nikhef
[4] INFN sezione Genova
[5] INFN sezione Roma
[6] European Gravitational Observatory
[7] Università di Firenze
[8] University of Utah



Banana and other rod internal modes must be damped; counterweights above the top flexure used to tune the centre of percussion



In compression the flexure can be less than 1 mm diameter

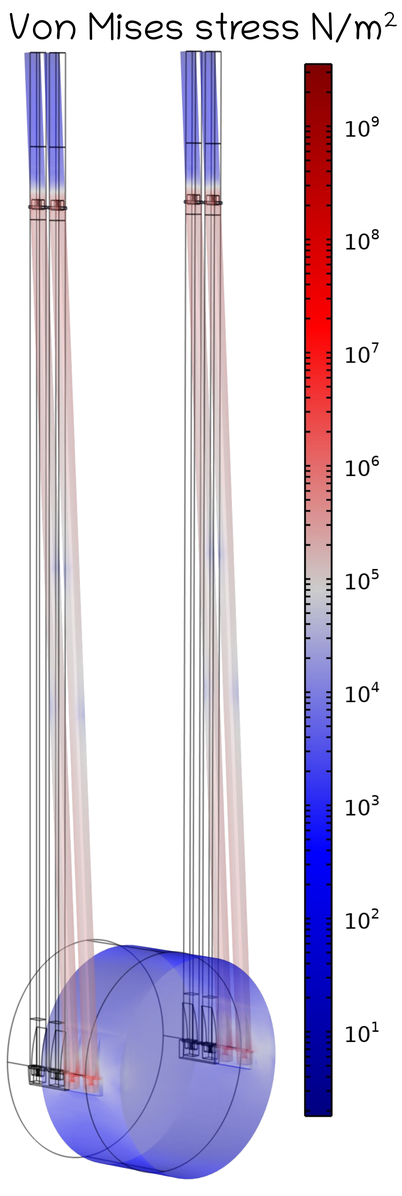


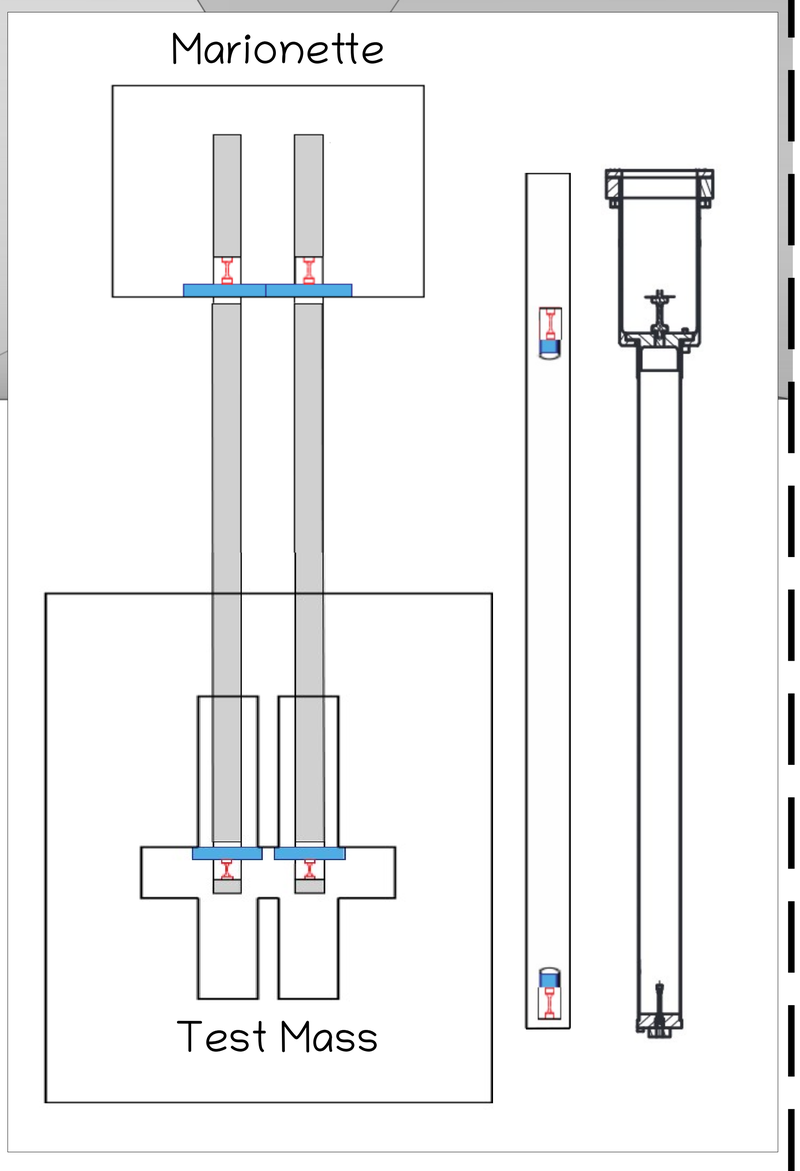
CHALLENGES

- Third generation gravitational waves detectors need **cryogenic** test masses and suspensions.
- Here we have two **conflicting requirements**: soft. suspensions + the need of **removing** the excess heat.
- Indeed, radiated power/surface $\propto T^4$ → at 10 K we have 7.5×10^5 times less radiated power than at room temperature.
- We must use **thermal conduction** → short and fat. suspensions, but this will be lead to an unacceptably large thermal noise!
- Crystals are very good heat conductors, **but** they are also very fragile under tension!

SOLUTIONS

- Crystals are more robust in compression!
- Indeed, while tensioning load confines the bending points to a short distance from the beginning of the flexure, making it effectively stiffer, compressional load distributes the bending along the length making the flexure effectively softer.
- We can combine compressive soft flexures with stiff rods: the heat can pass through the short flexures and then through the long and fat rods.
- Stiff & fat rods: **but** the soft flexures minimize the fraction of pendulum oscillating energy stored elastically, thus minimizing thermal noise.
- What about massive rod recoiling effects? → nulled using an Inverted pendulum-like counterweight in the marionetta side.





MECHANICAL ADVANTAGES

- We can separately machine all components.
- No contact points under shear, only in compression.
- We can add a thin layer of brazing material.
- The thermal noise of the brazing is negligible compared to that of the flexures.
- We can use gallium as brazing material: this allows to an easy handling of the system during maintenance.
- Gallium expands when transitioning to a solid state, thus producing a better thermal contact.

WHAT'S NEXT?

- Thermal noise model.
- Feasibility study of the fine controls with optomechanical damper.
- Tests with physical suspensions.