Conductive cooling of cryogenic payload in KAGRA

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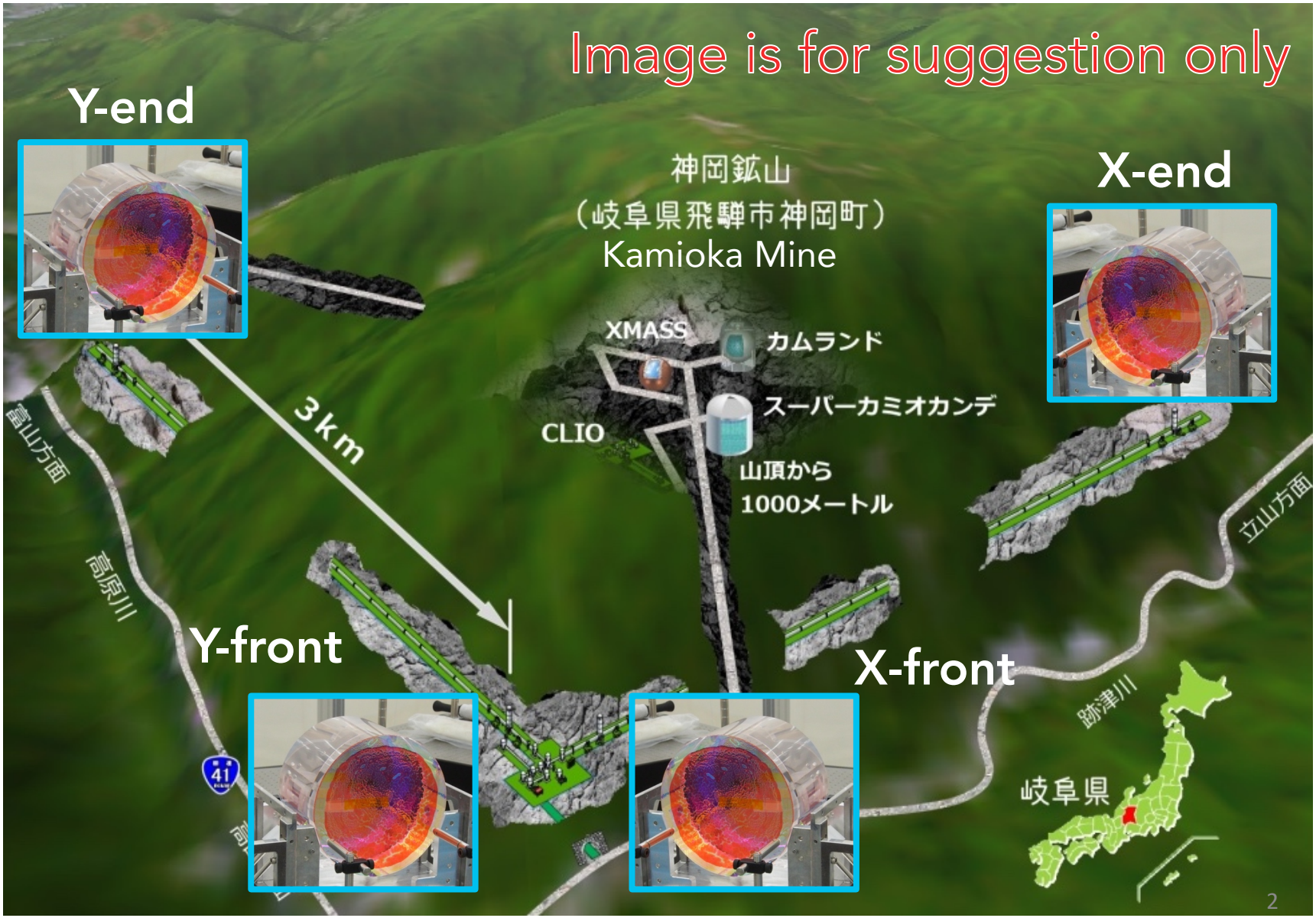
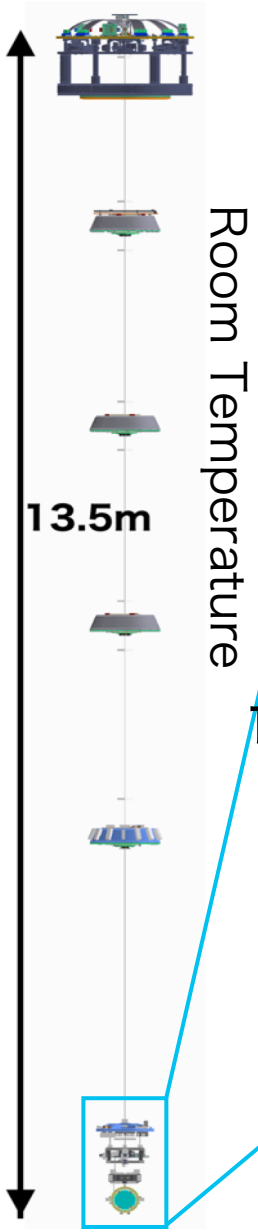
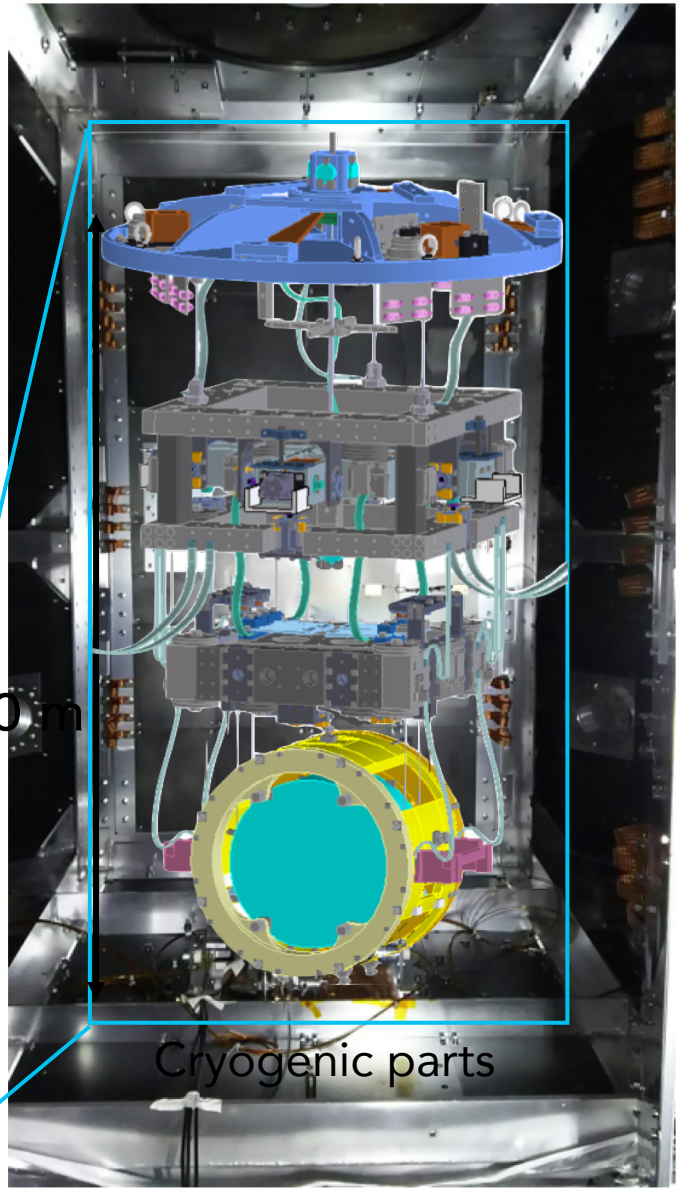
Cryogenic mirror in KAGRA



Cooling of payload





- To be quiet

  ➡ Radiative Cooling

$$\frac{dT_{pay}}{dt} = A\varepsilon\sigma\left(T_{pay}^4 - T_{shield}^4\right)$$

  - Powerful at high temp.
  - Ineffective at low temp.

- To be rapid

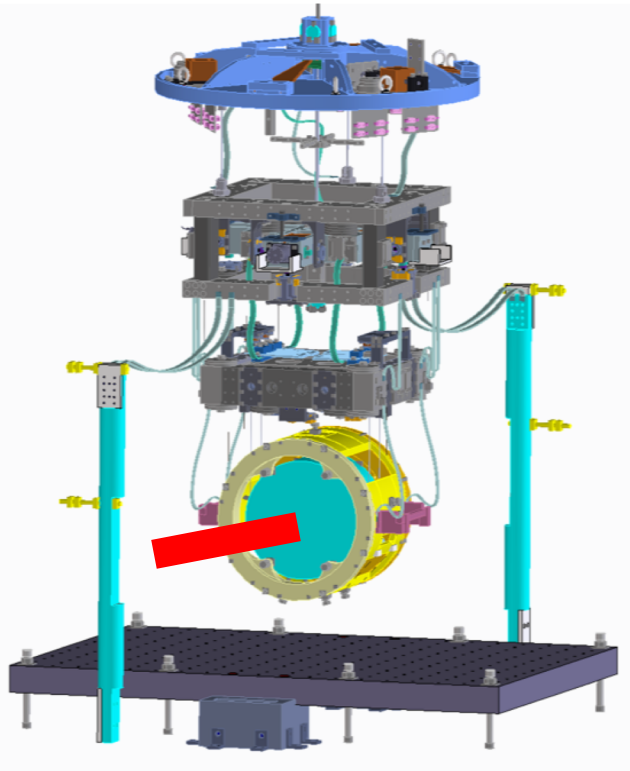
  -> Effective radiative cooling with black coating

  -> Conductive cooling

➡ High thermal conductive heat-links

Role and Concern of heat-links

Heat-links connect the payload and cooling bars(cryocoolers).



- Role = Heat extraction

  Heat-links must extract heat inputted to the mirror. We cannot disconnect them even during operation.

- Concern = Vibration via heat-links

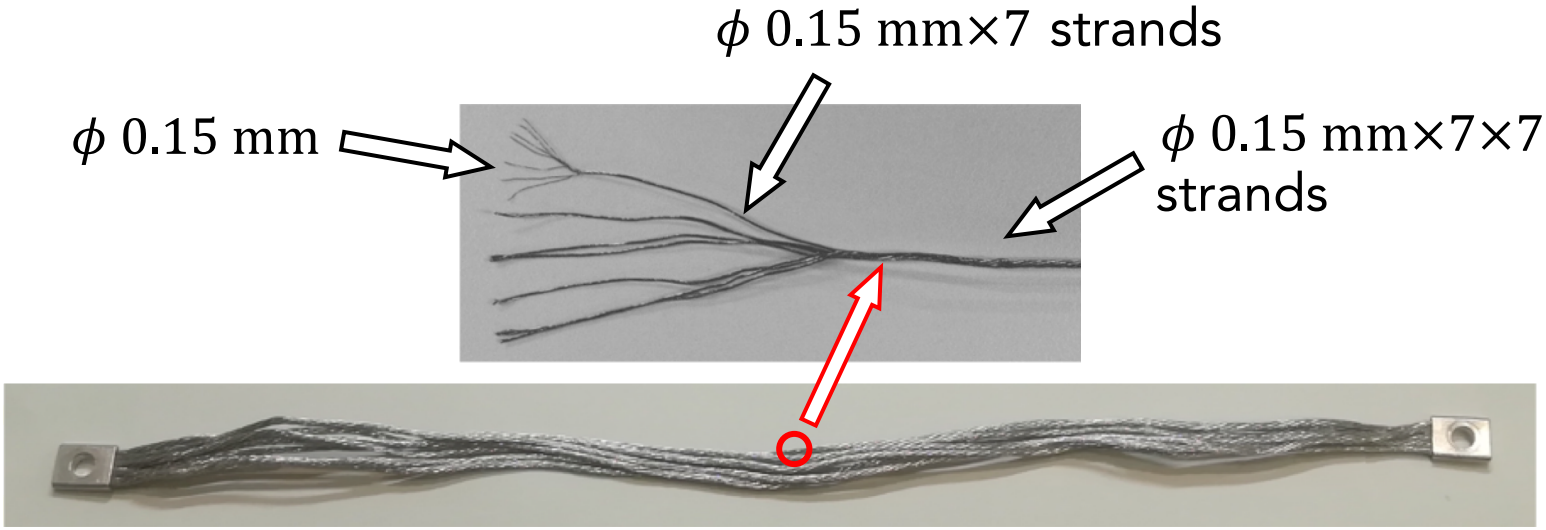
  Heat-links may introduce vibration to the payload from cooling bars.

Heat-links must be high thermal conductive and flexible as much as possible.

KAGRA heat-links

- Ultra high-purity aluminum heat-links

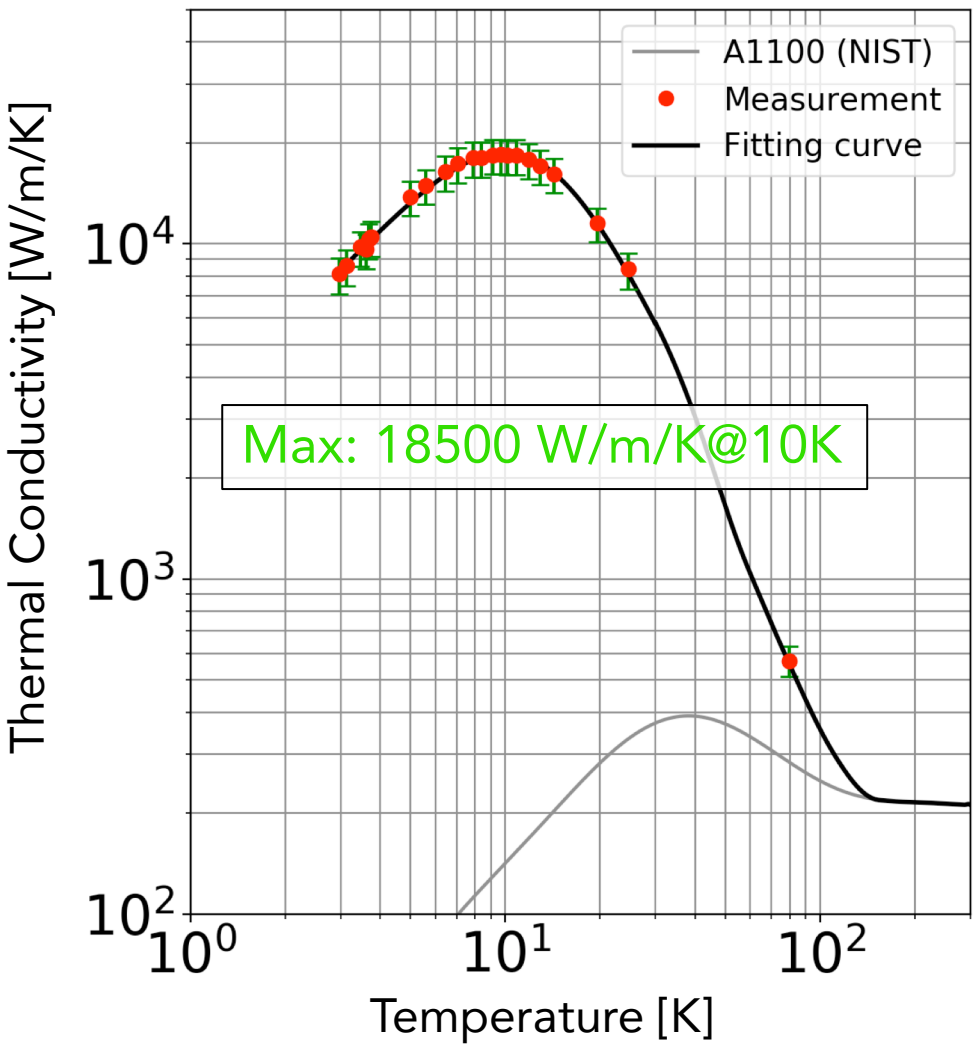
  Purity: 99.9999%, 6N (Sumitomo Chemical Co., Ltd.)



high thermal conductivity and
low spring constant(stiffness)

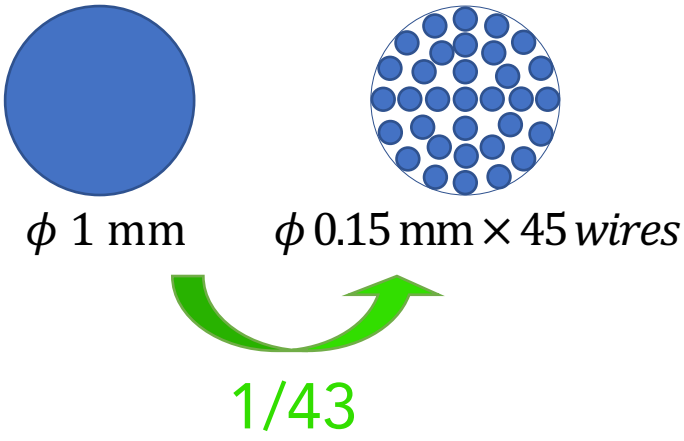
Measured Data

Thermal Conductivity



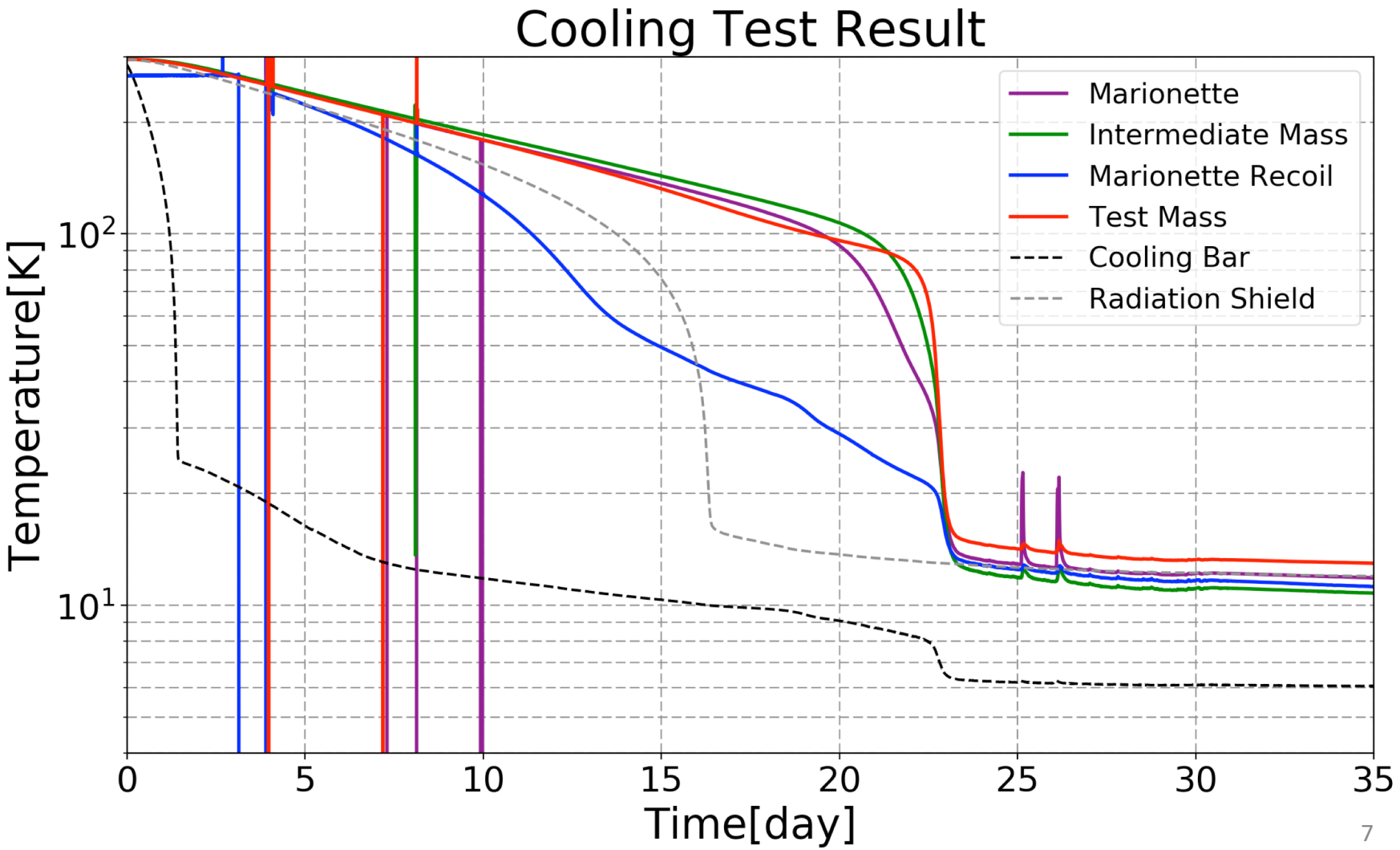
Spring Constant

- Spring constant is an index of the stiffness.
- We compared it between single thick wire and our heat-links which are both same cross-sectional area.



How powerful heat-links are.

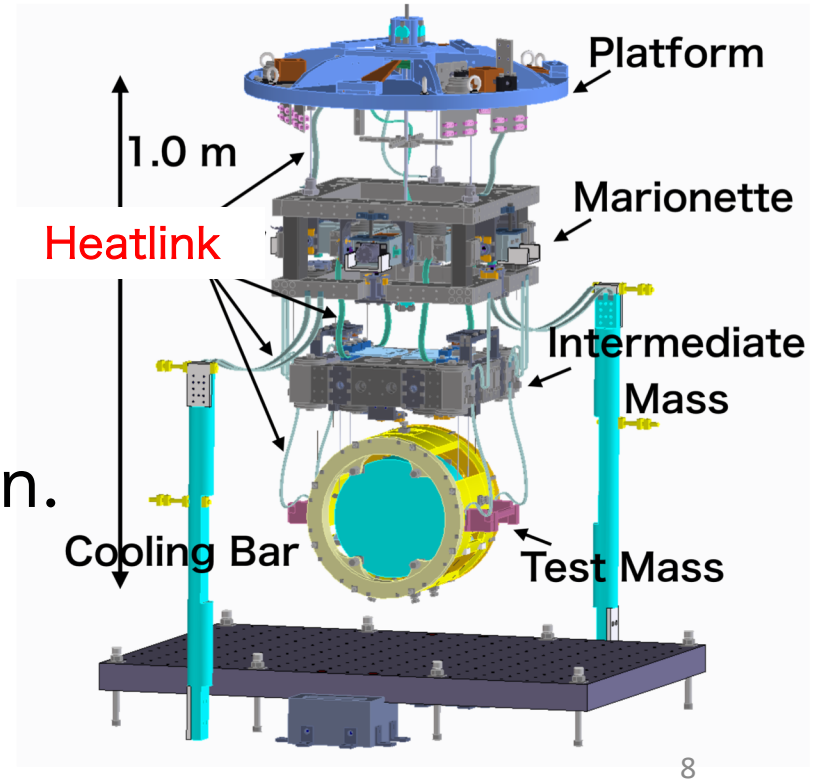
Test cooling of payload in 2017 summer



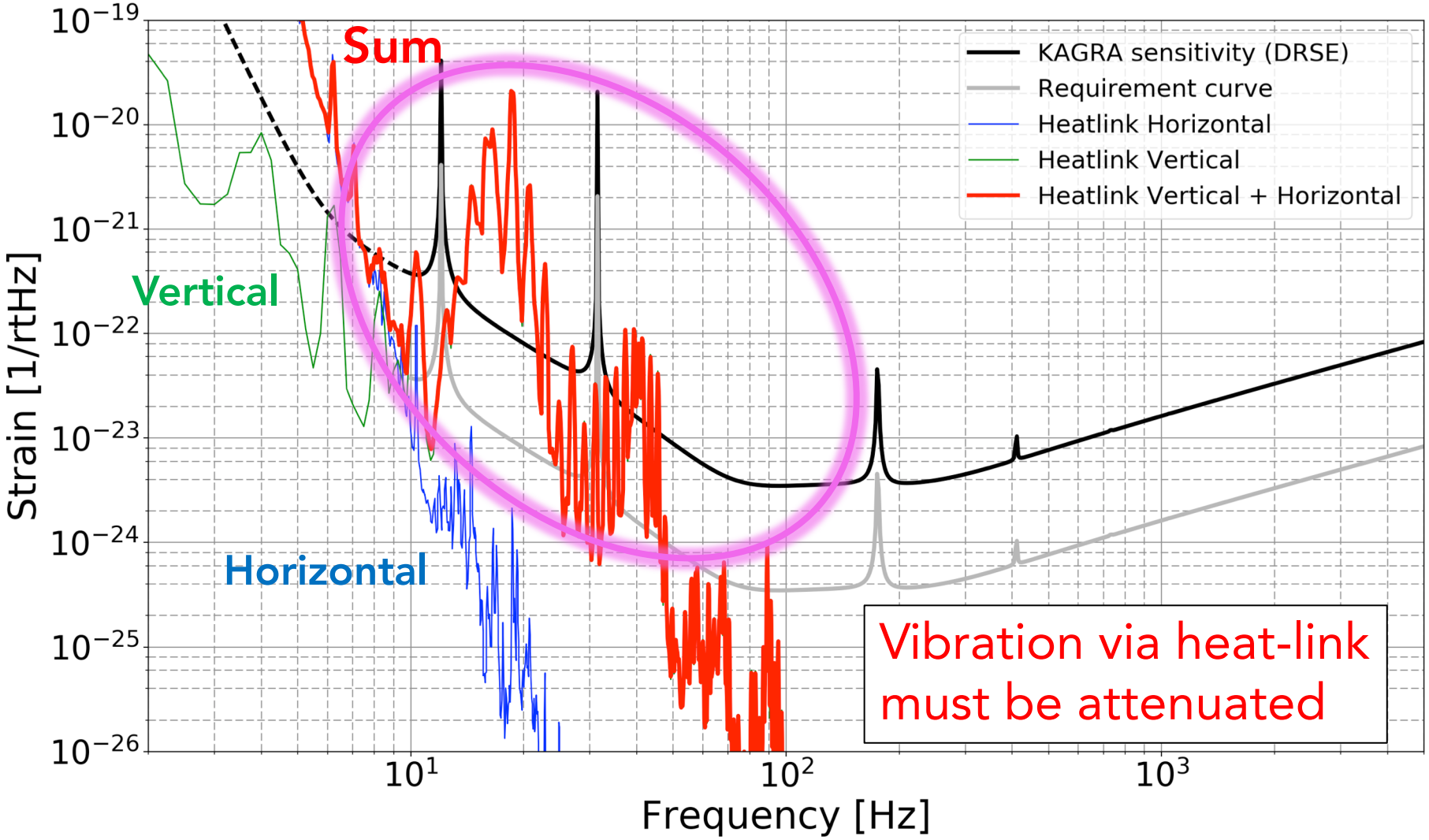
Vibration through heat-links

- Heatlinks are absolutely necessary to reach 20 K for mirror.
- However, Marionette Recoil Mass, which is connected heatlinks from cooling bars, is already suspended by Type-A and Platform stage.

- We calculated vibration transmission via heatlinks in the case of direct connection.

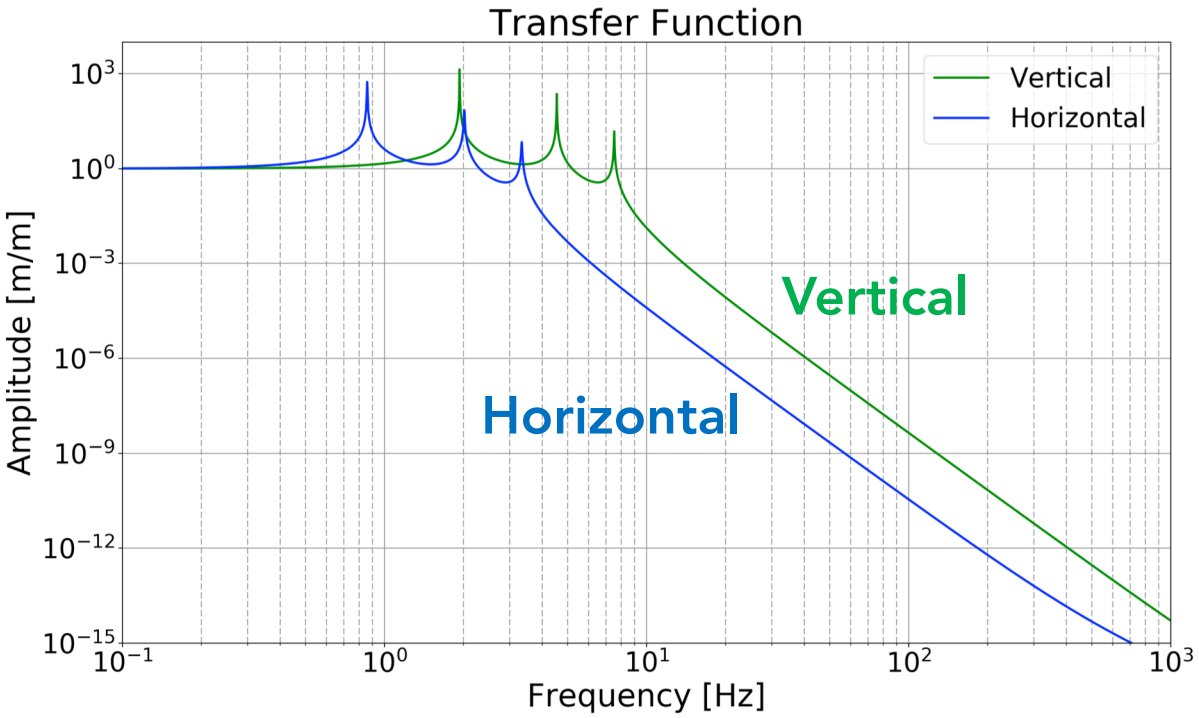


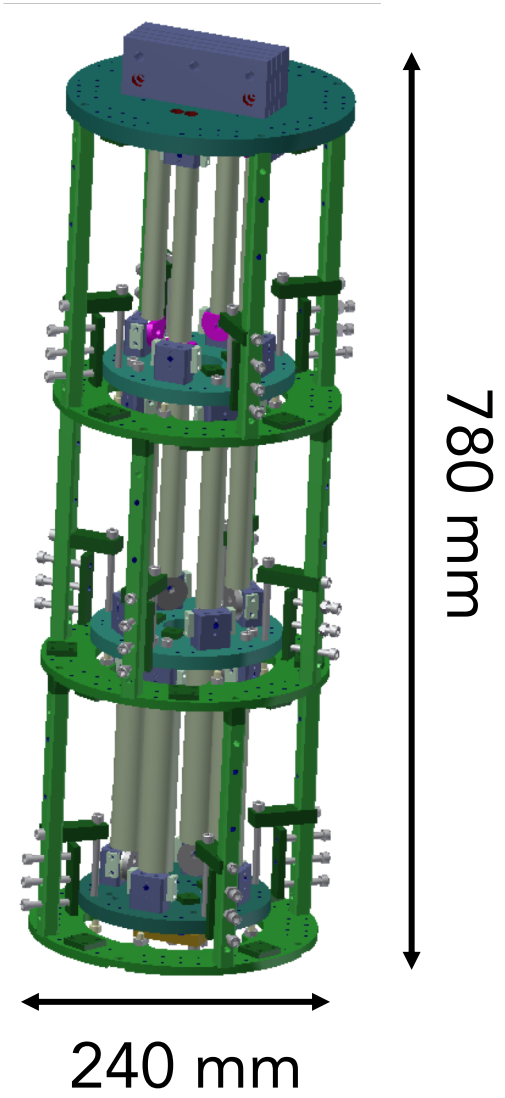
Comparison with KAGRA sensitivity



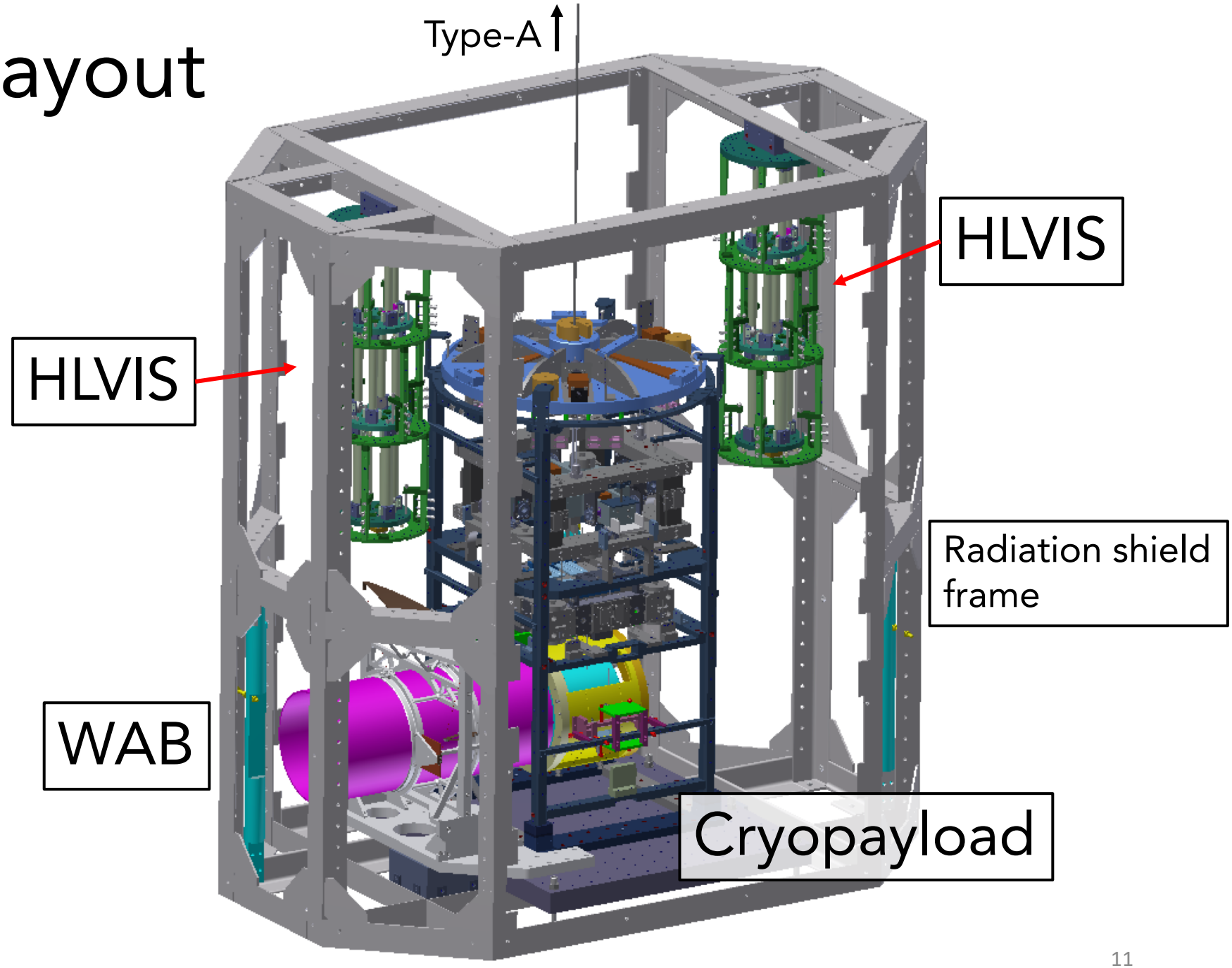
HLVIS design

- 3 Hz - 3 stages
- 4 tension springs for each stage
  (2 R-handed, 2 L-handed)
- Total mass 20 kg

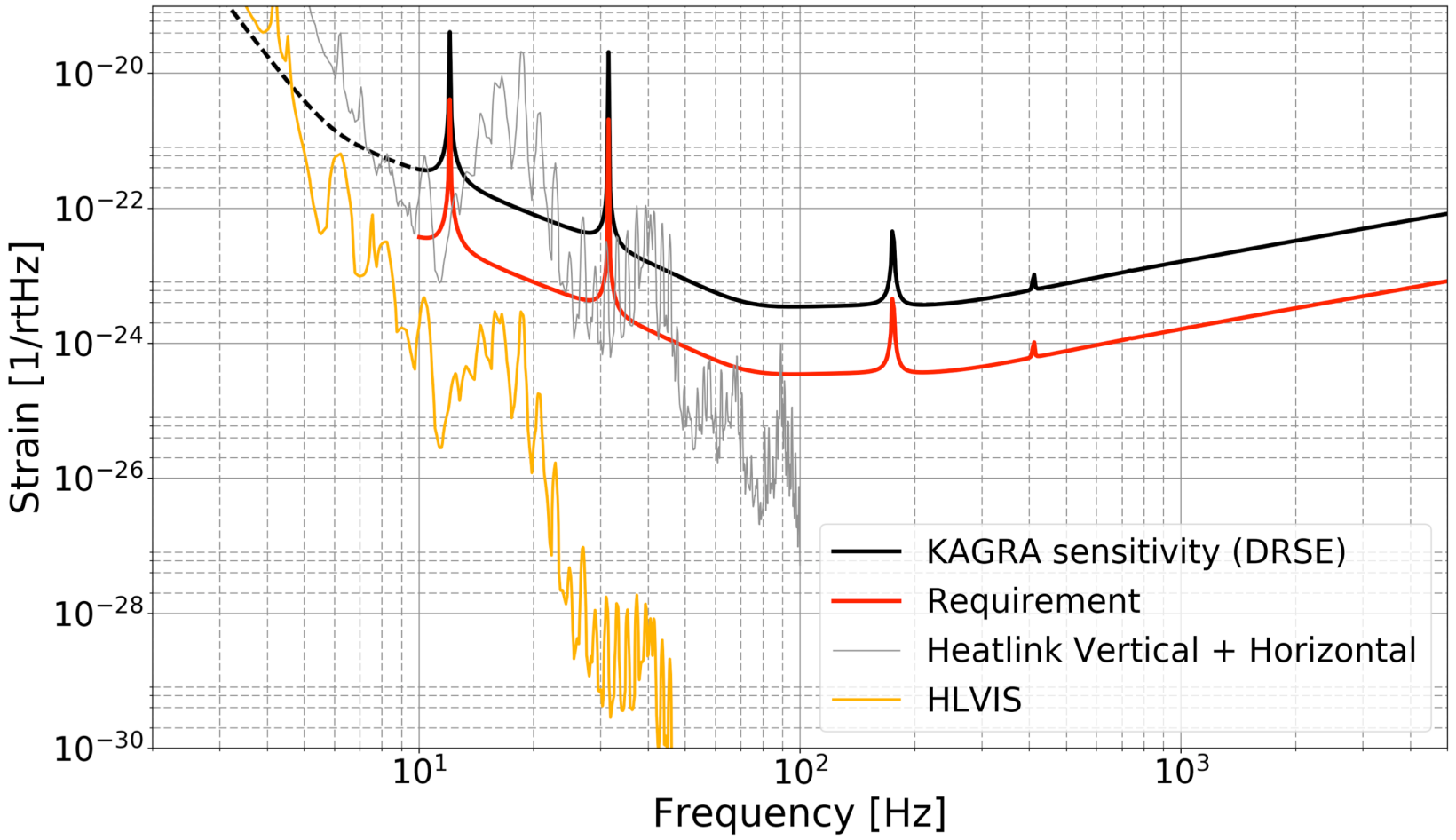




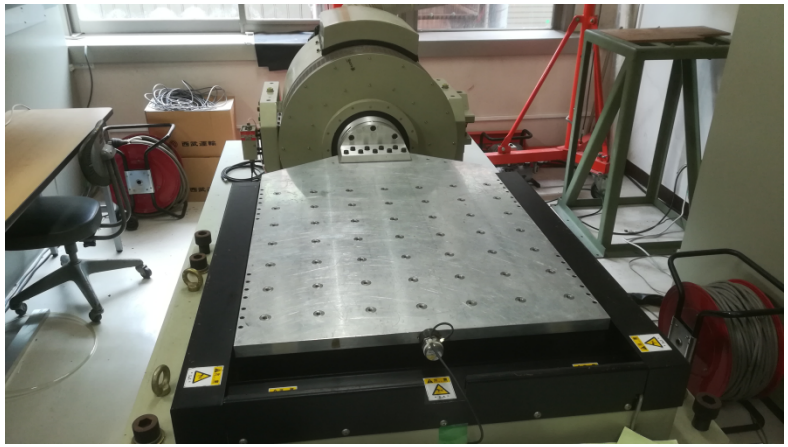
Layout

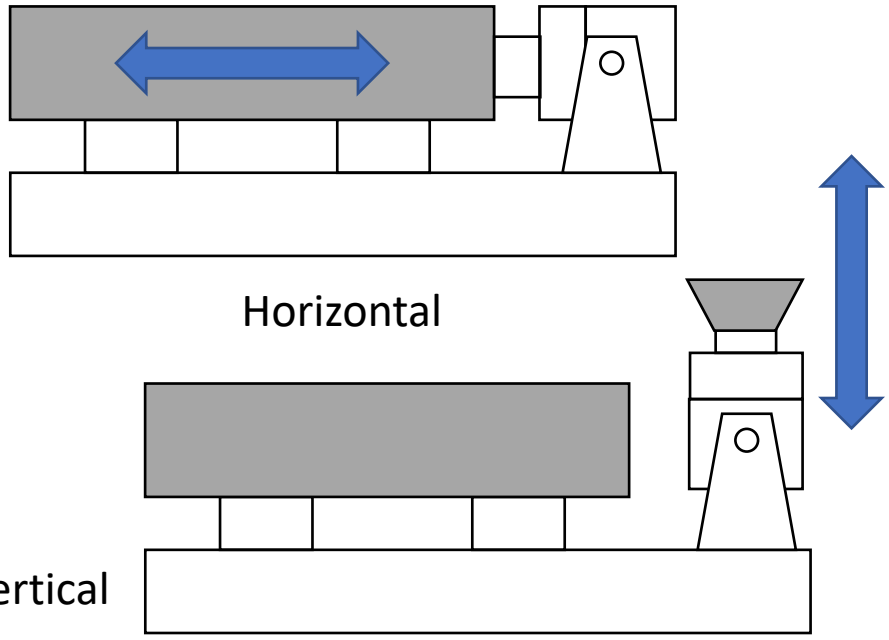


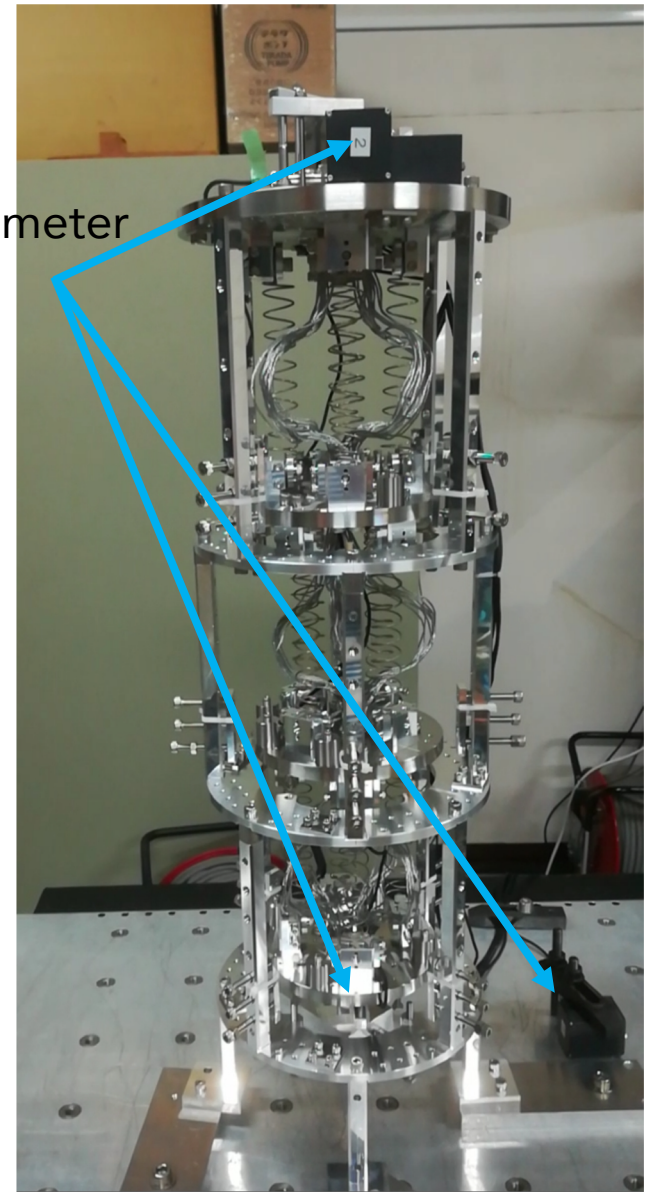
Attenuation of vibration transmission = Design performance



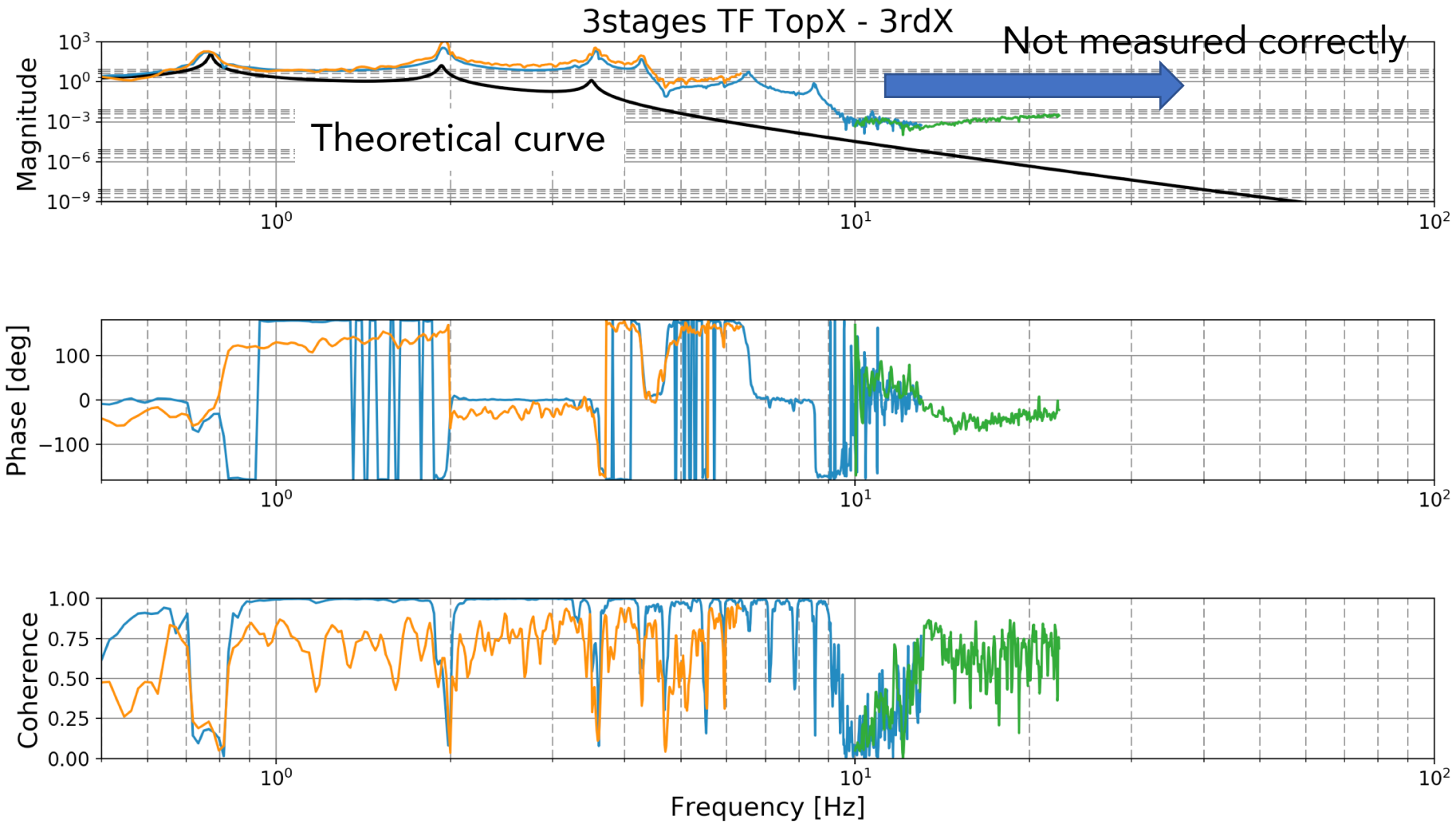
Shaking test at ERI



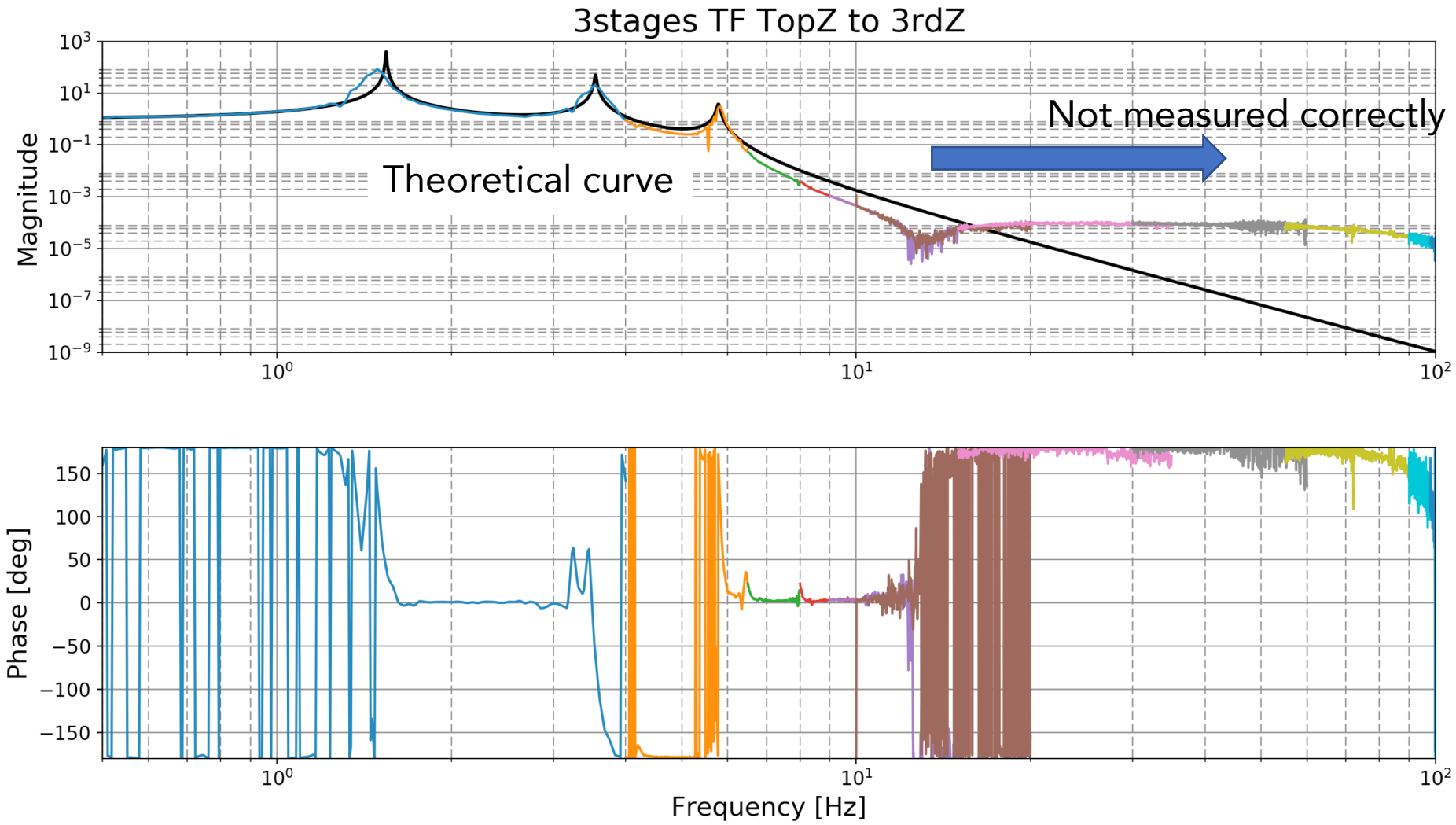




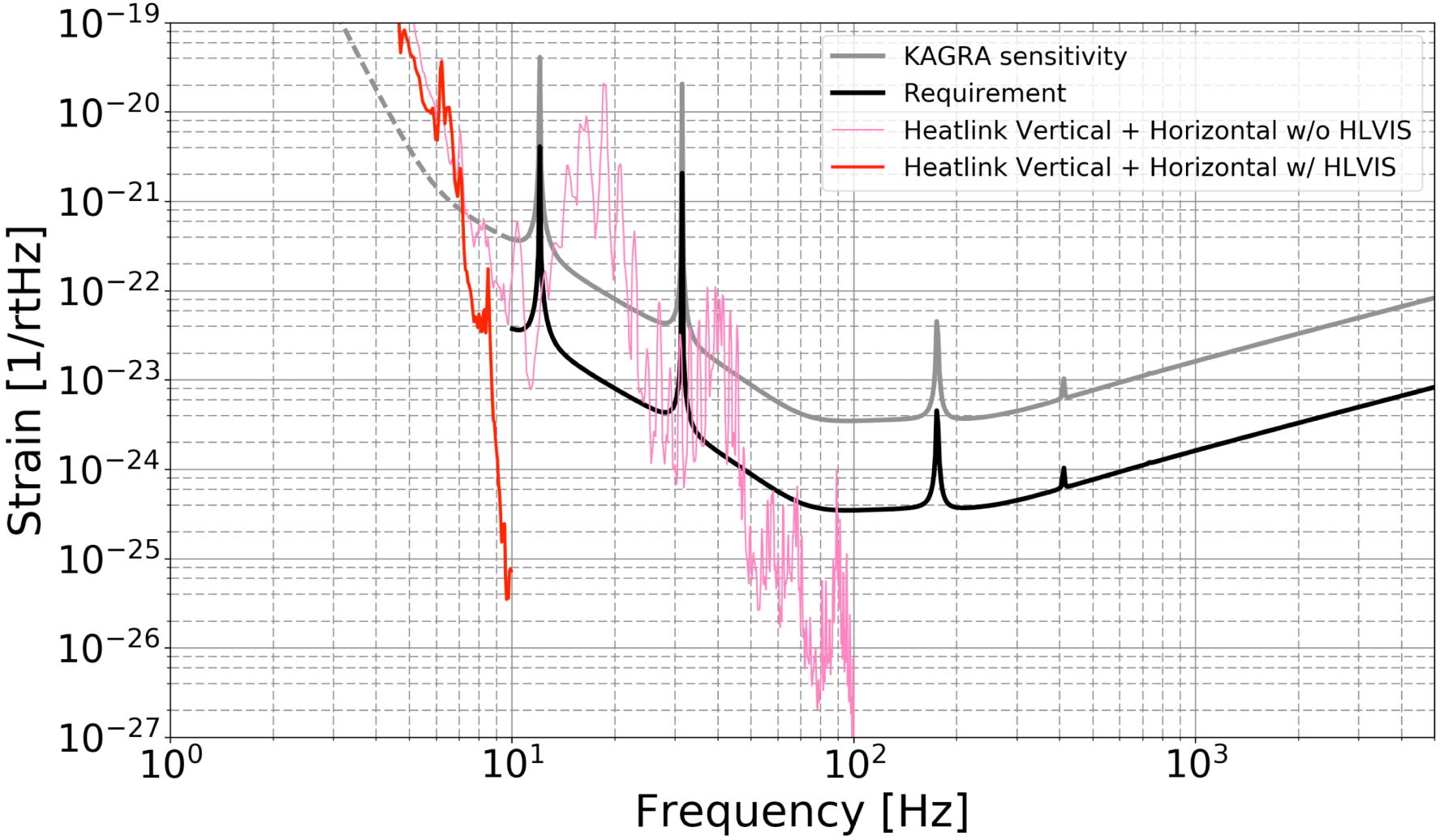
Transfer function: Horizontal



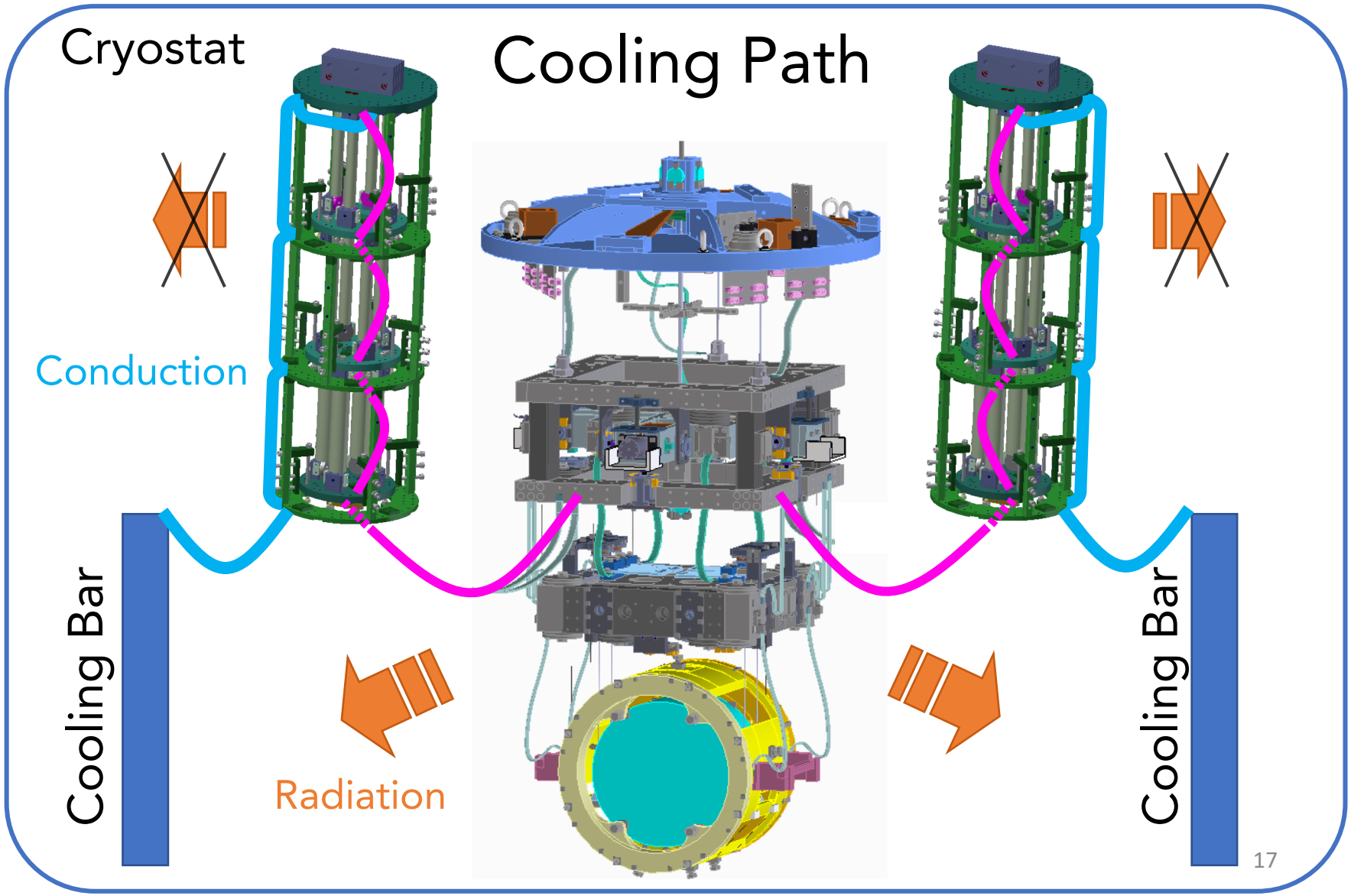
Transfer function: Vertical



Estimated vibration level below 10 Hz employing measured TFs



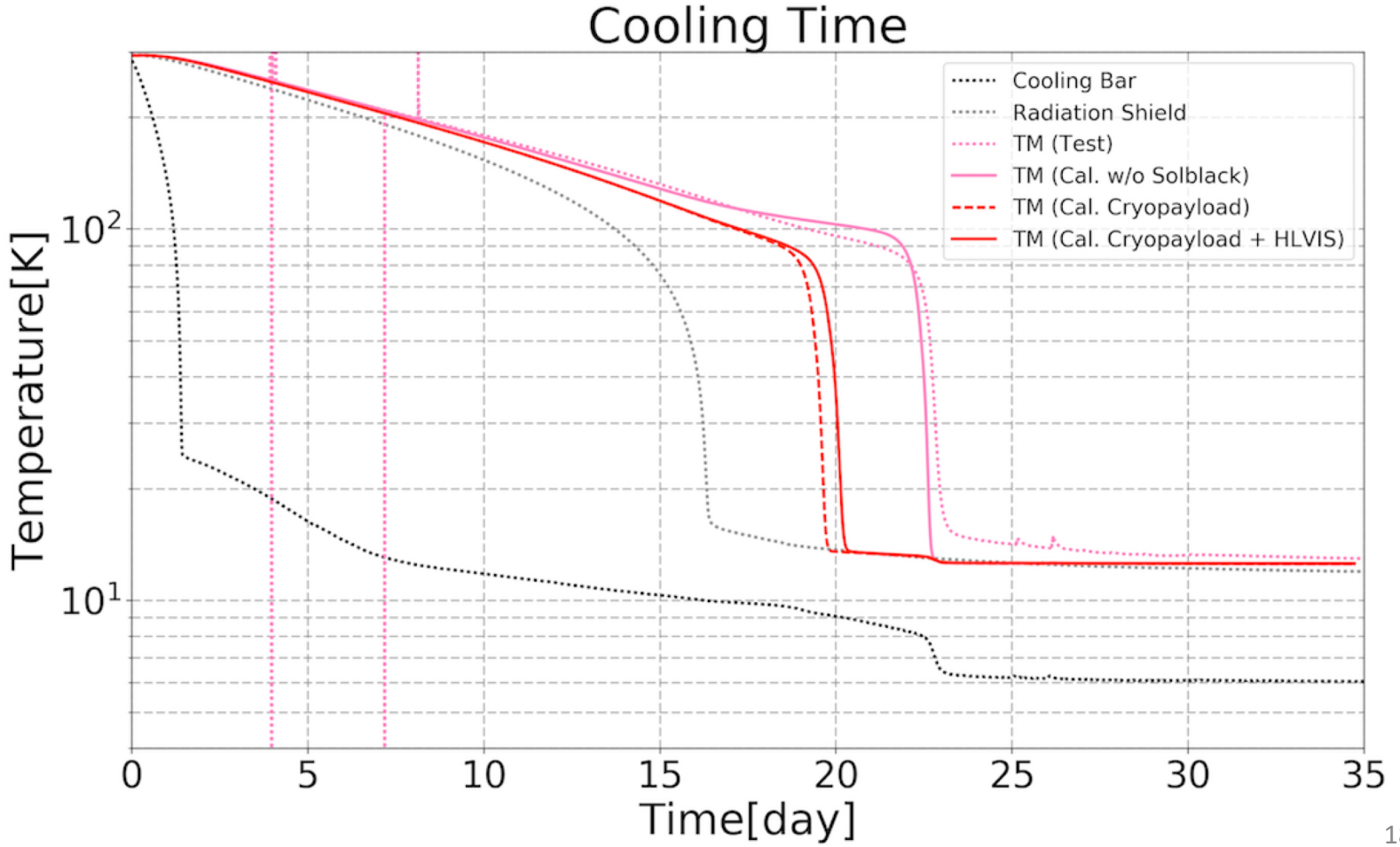
Cooling time calculation



Cooling time of TM:

Cryopayload only

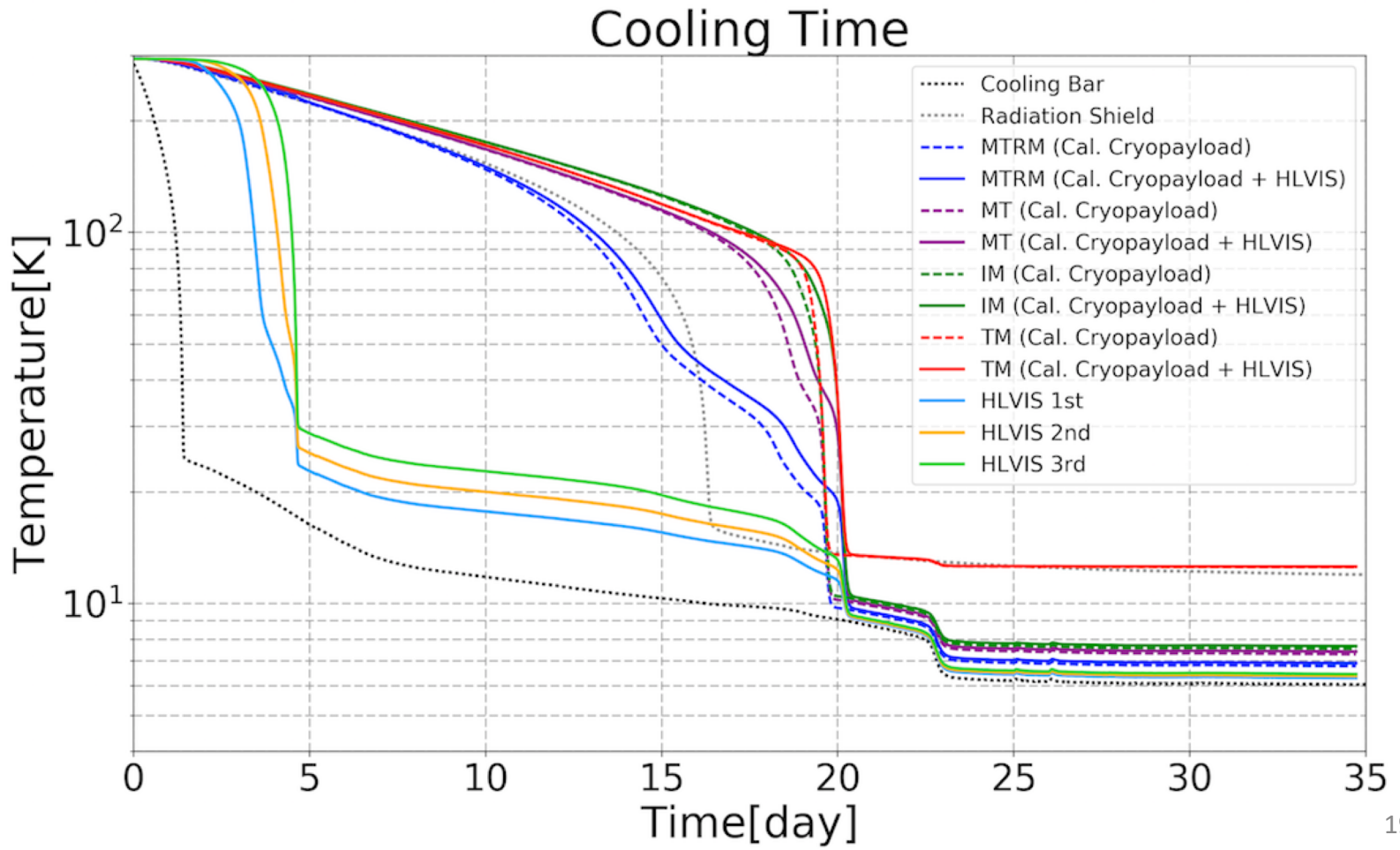
- Cooling test result
- Calculation w/o Solblack
- Calculation w/ Solblack
- Cryopayload + HLVIS w/ Solblack



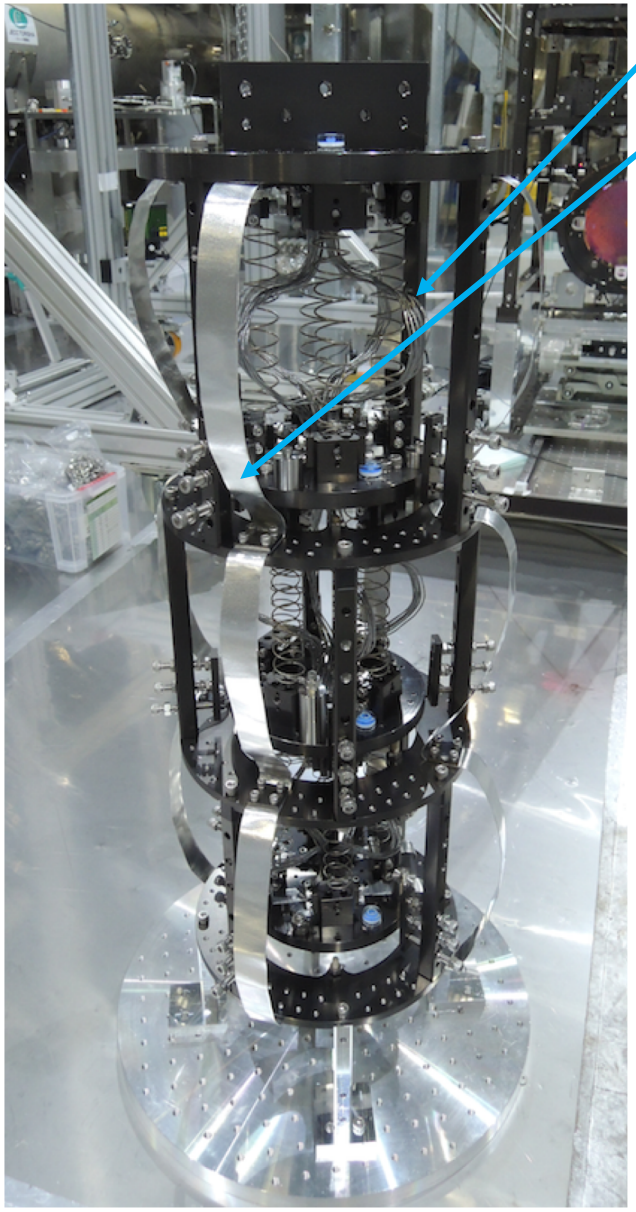
Cooling time: HLVIS & Cryopayload

Cryopayload only

- Cooling test result
- Calculation w/o Solblack
- Calculation w/ Solblack
- Cryopayload + HLVIS w/ Solblack



Assembly of HLVIS

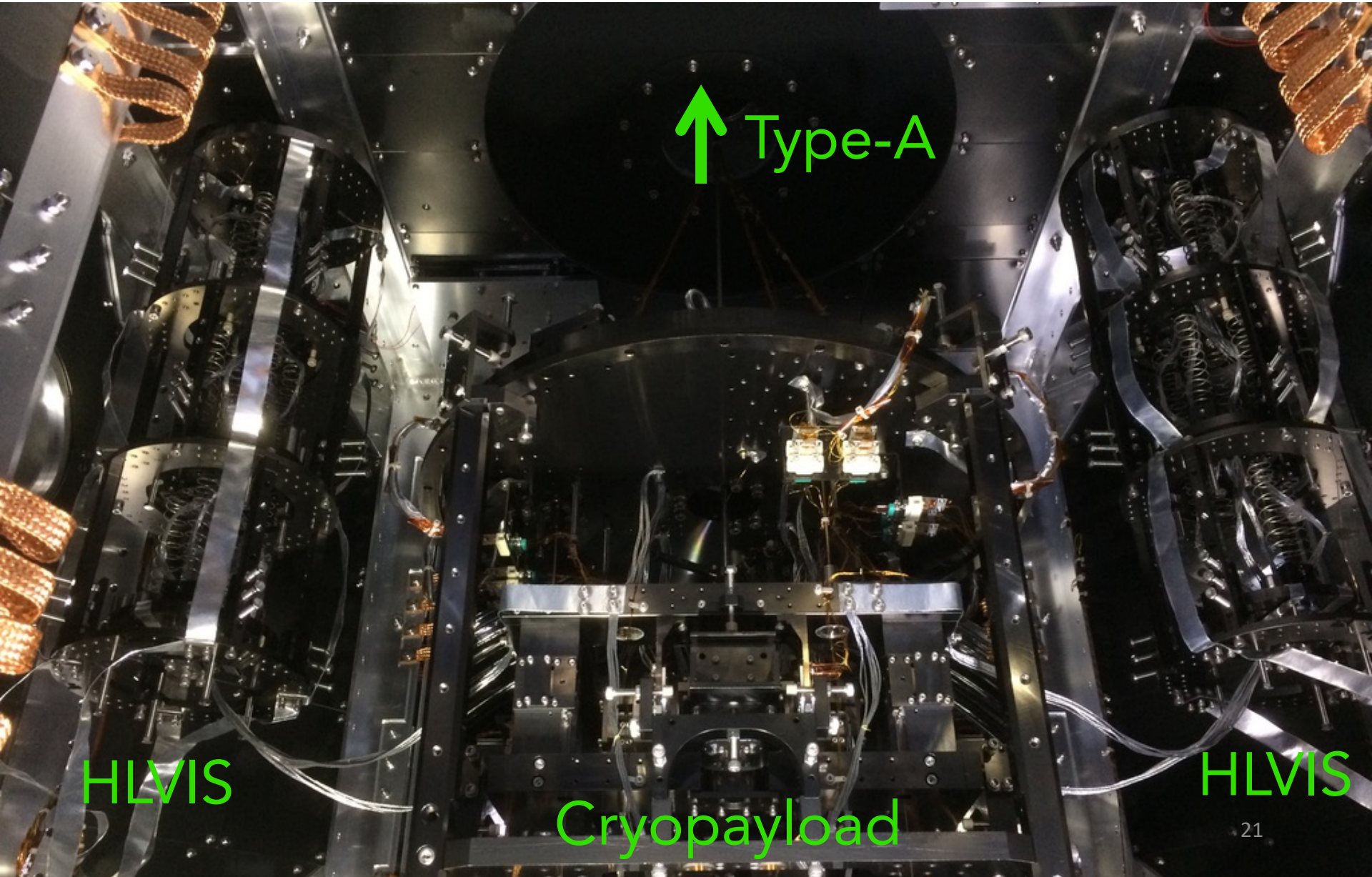


Heat-links

6N Aluminum thin band

All the HLVISs in total have been installed into each cryostat.

Best Family in the Cryostat



Summary

- We developed high thermal conductive and flexible heat-links.
- We concern about vibration transmission via heat-links.
- Heatlink-Vibration-Isolation System was developed to attenuate those vibration.

- Transfer functions of HLVIS were measured below 10 Hz at ERI.
- Cooling time considering HLVIS was calculated. HLVIS doesn't affect cooling time so much.

- *Transfer function above 10 Hz will be measured soon in KEK.*
- *HLVIS TF must be included in the Type-A suspension control.*

End