Low-Vibration Conductive Cooling of KAGRA Cryogenic Mirror Suspension

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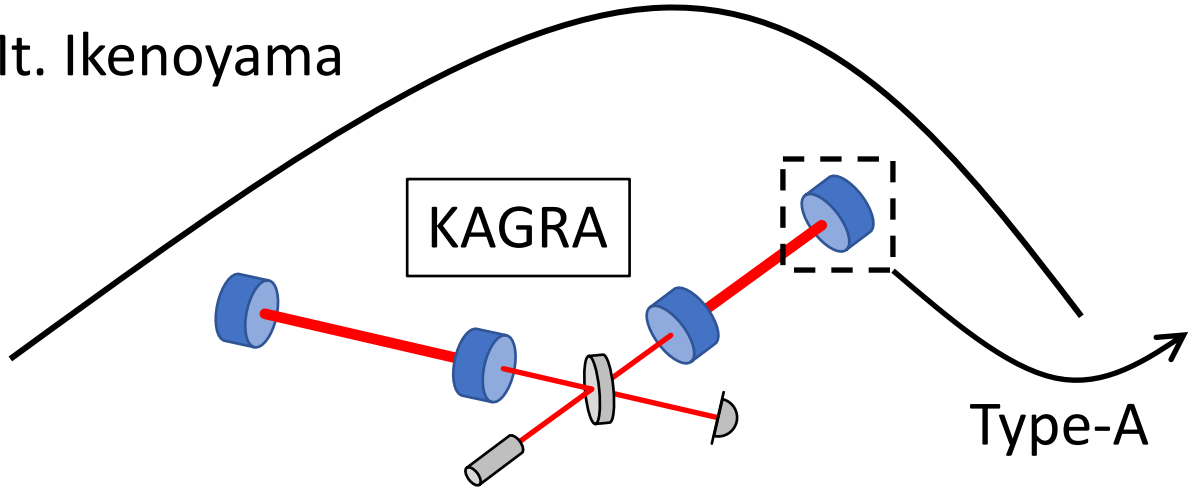
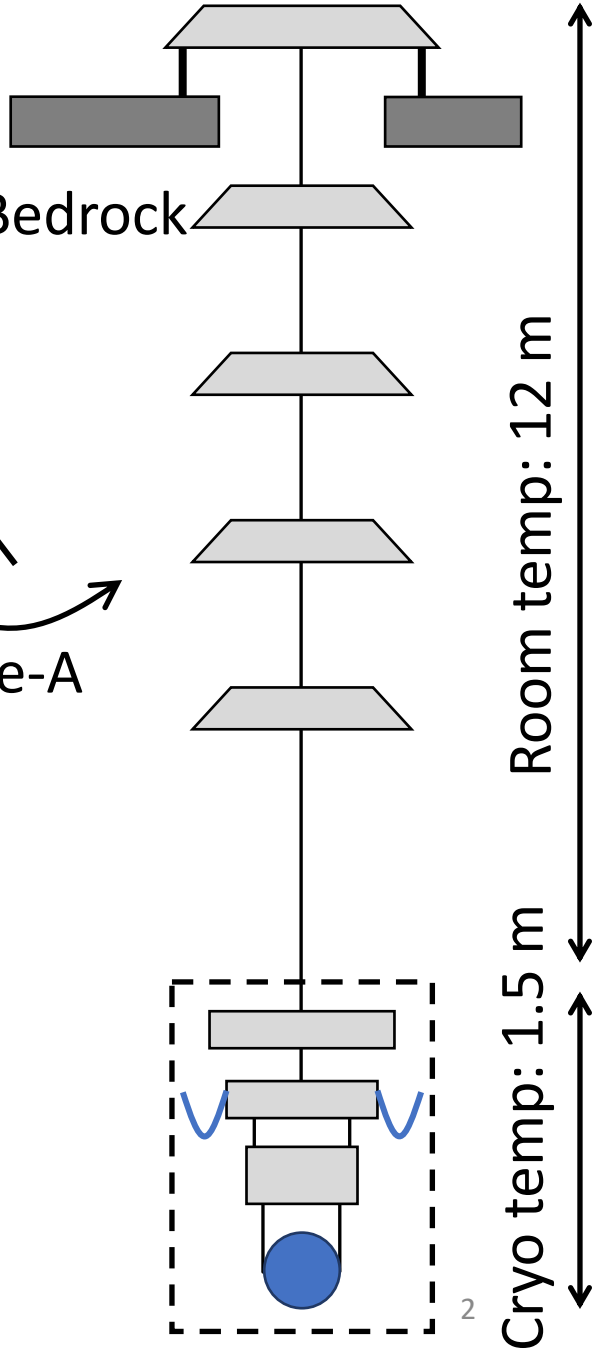
ICRR

KAGRA



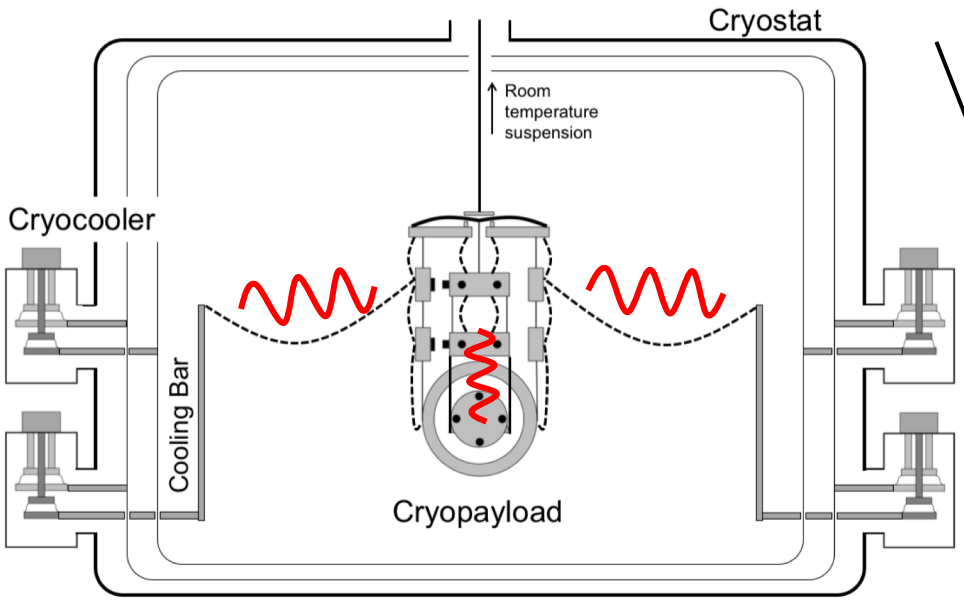


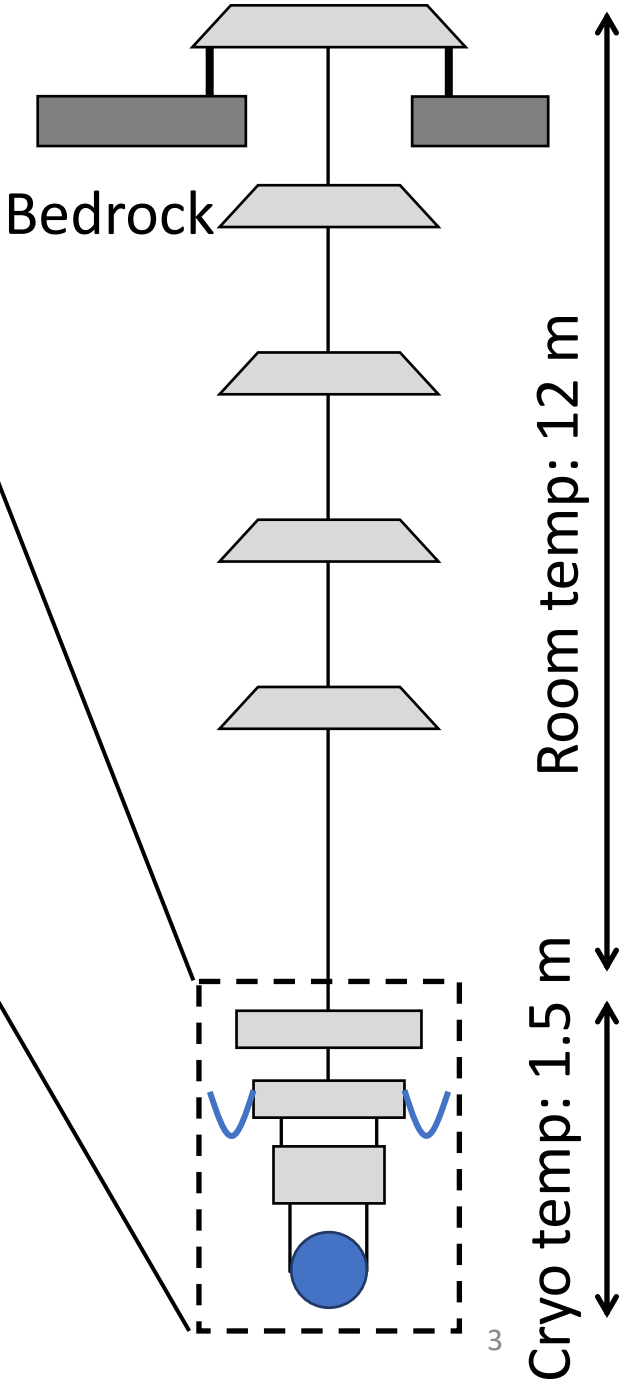
Key features

- Underground
- Cryogenic sapphire mirror at 20K

➡ Thermal noise reduction

Cooling and issue





Two ways of cooling

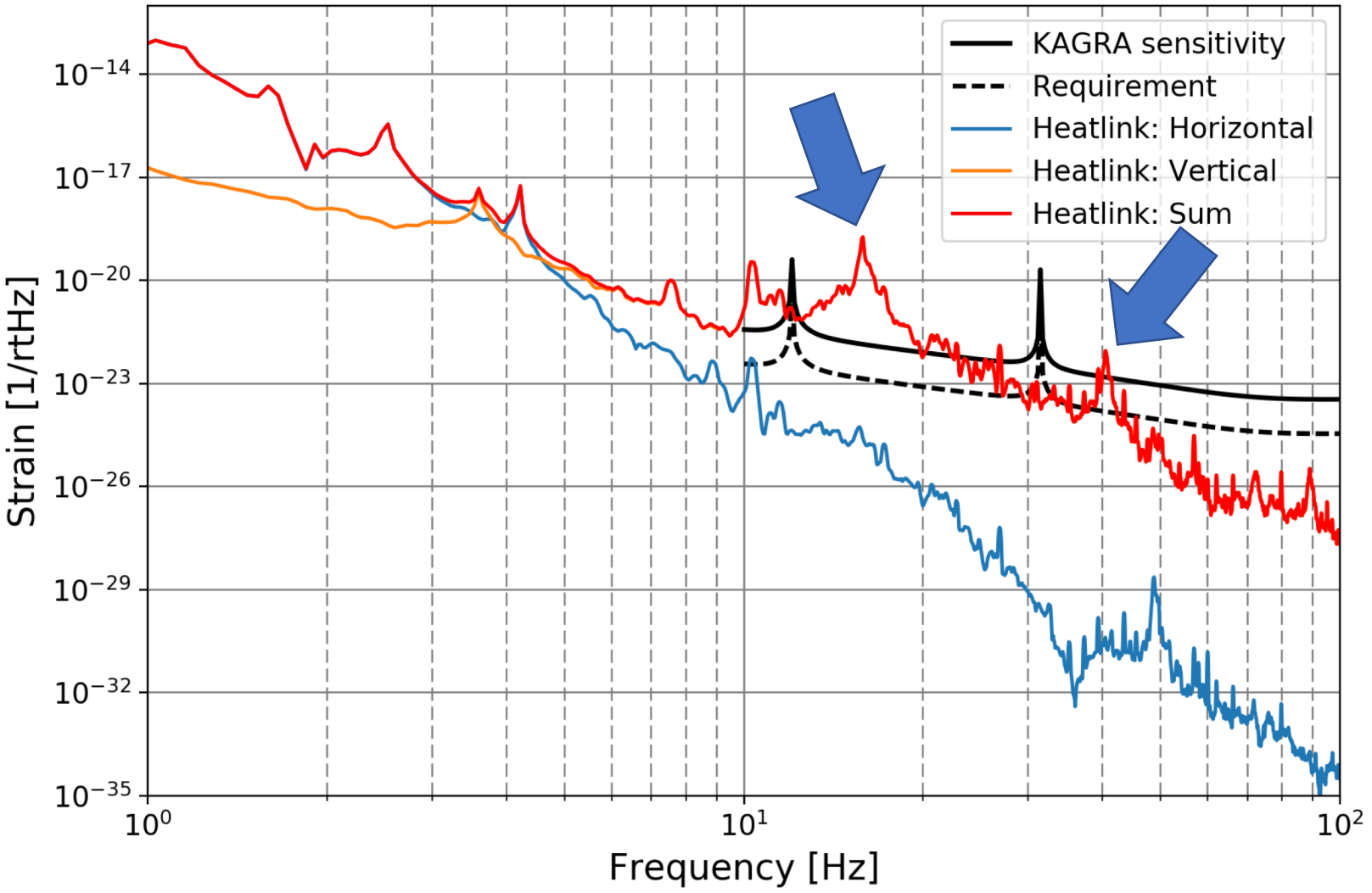
Thermal radiation

- Very effective at high temperatures
- Non-contact = no vibration injection

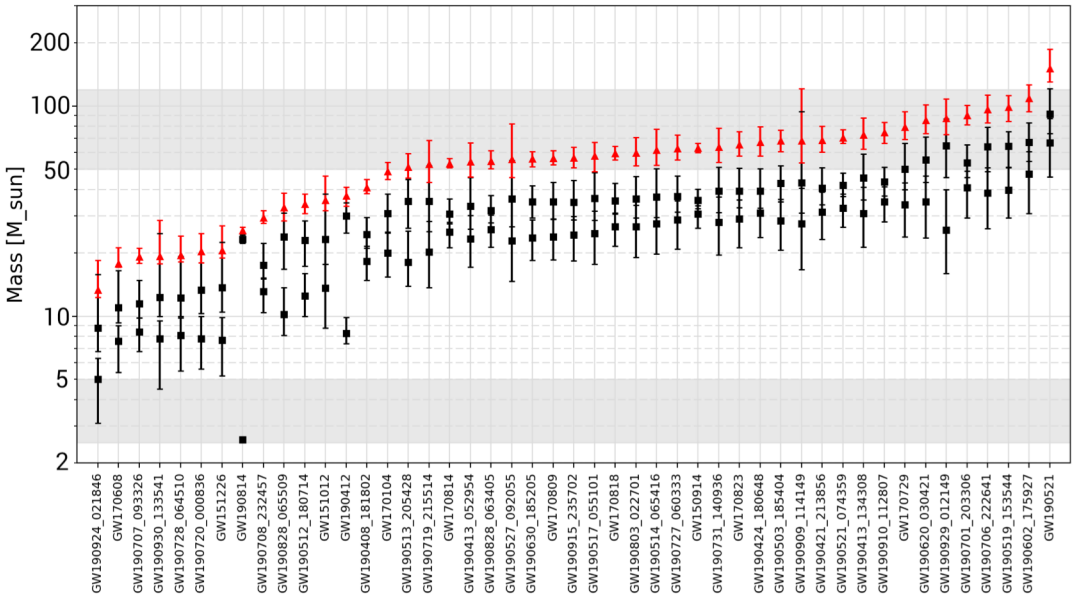
Thermal conduction

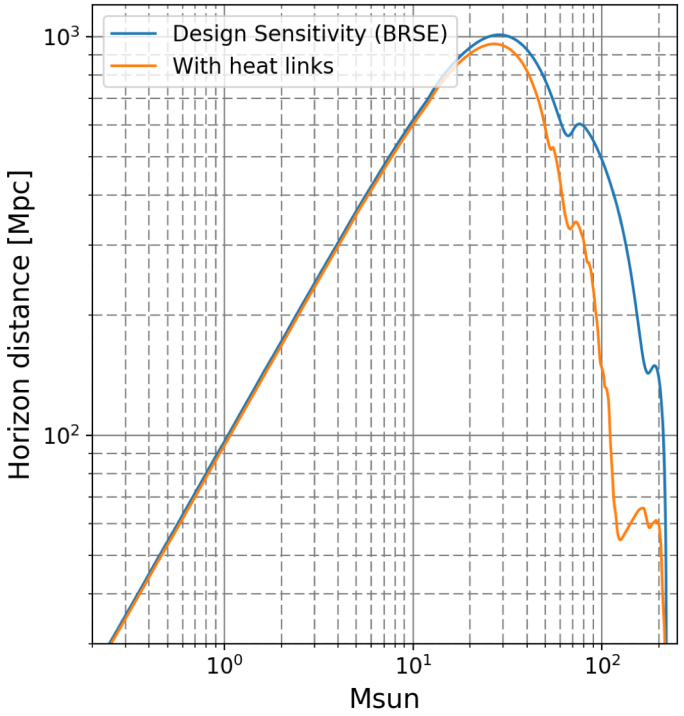
- Necessary when going to 20 K
- Vibration inflow becomes large issue

Estimated vibration inflow via heat-links



Science reduced by heat links





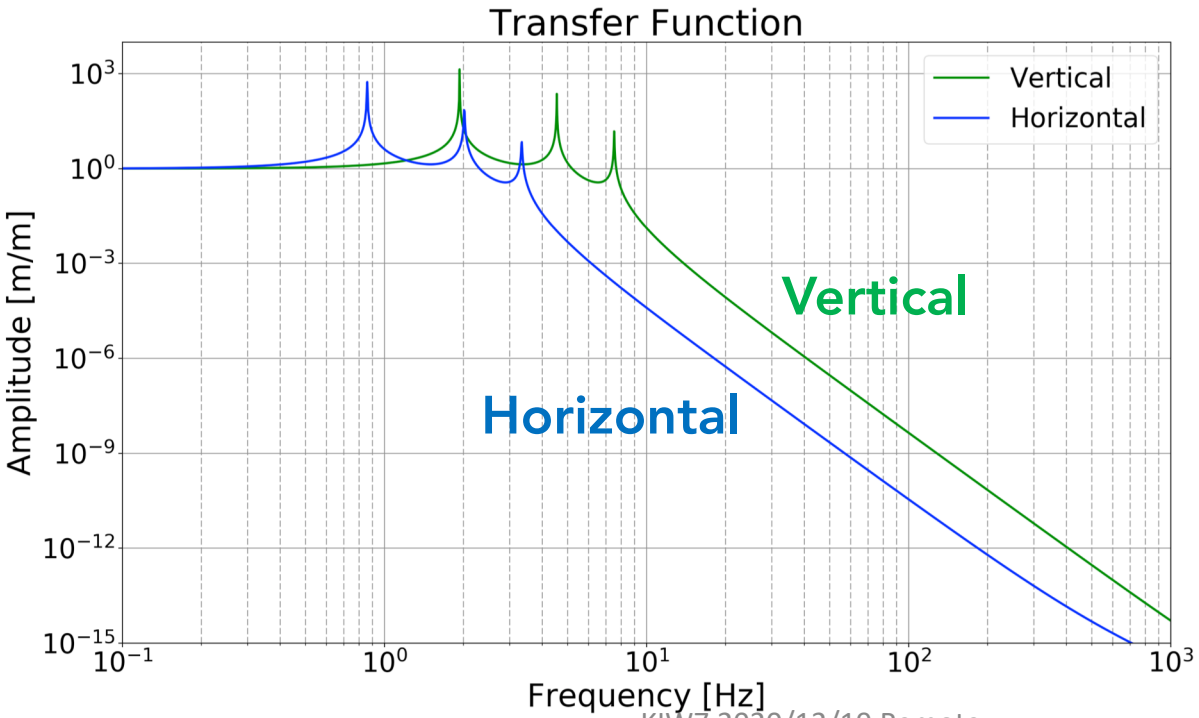
- Recently, several events that the component masses are in the “Mass gap” are detected by LV.
- Without any countermeasure in KAGRA, we will lose a lot of such scientifically interesting events.

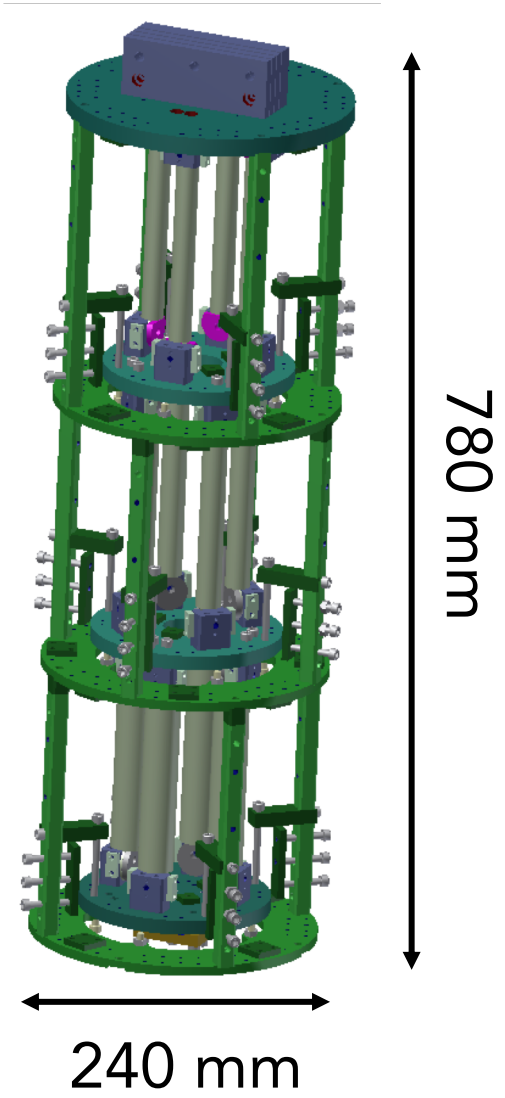
Vibration inflow via heat links must be reduced.

Heat Link Vibration Isolation System (HLVIS)

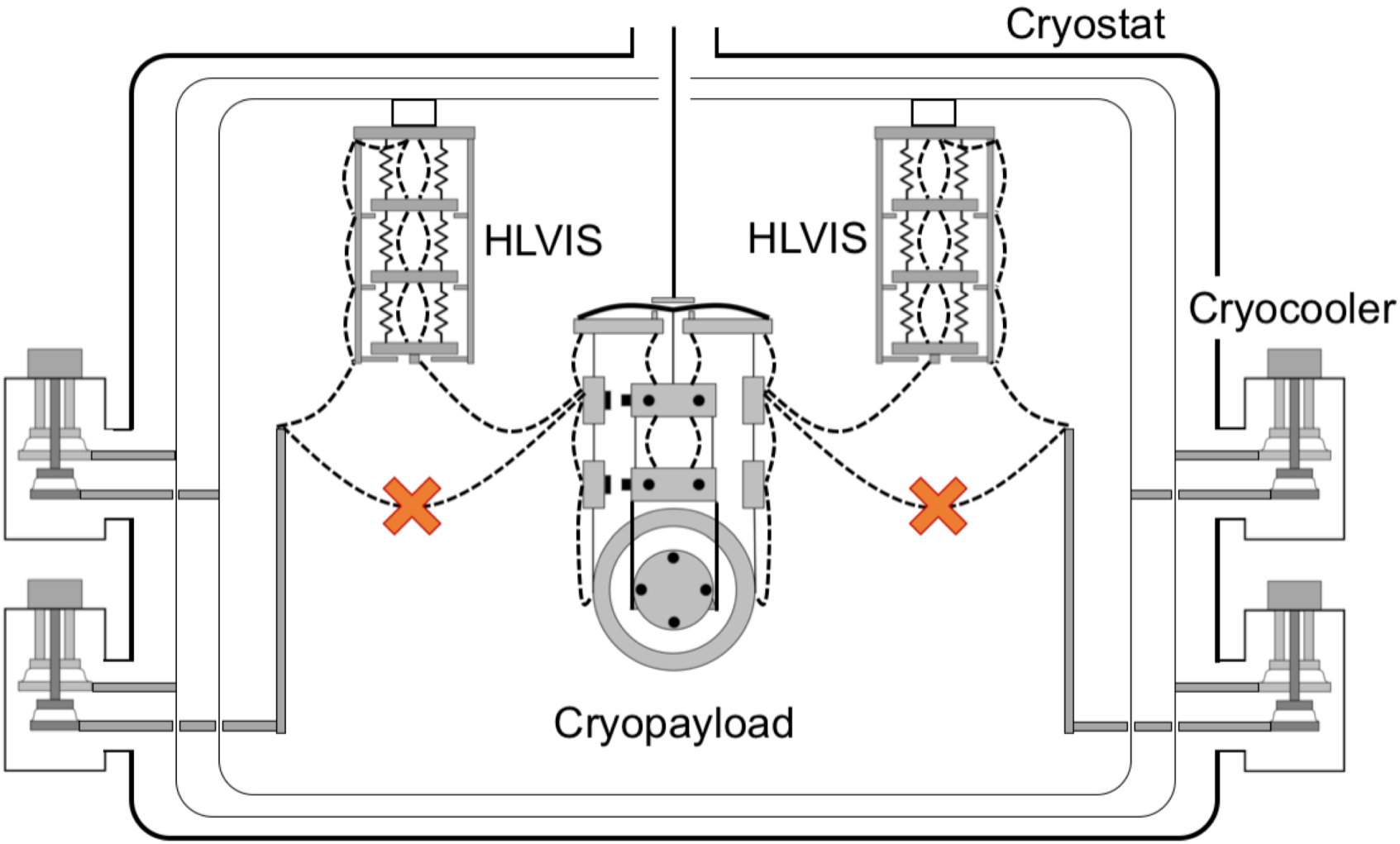
HLVIS design

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

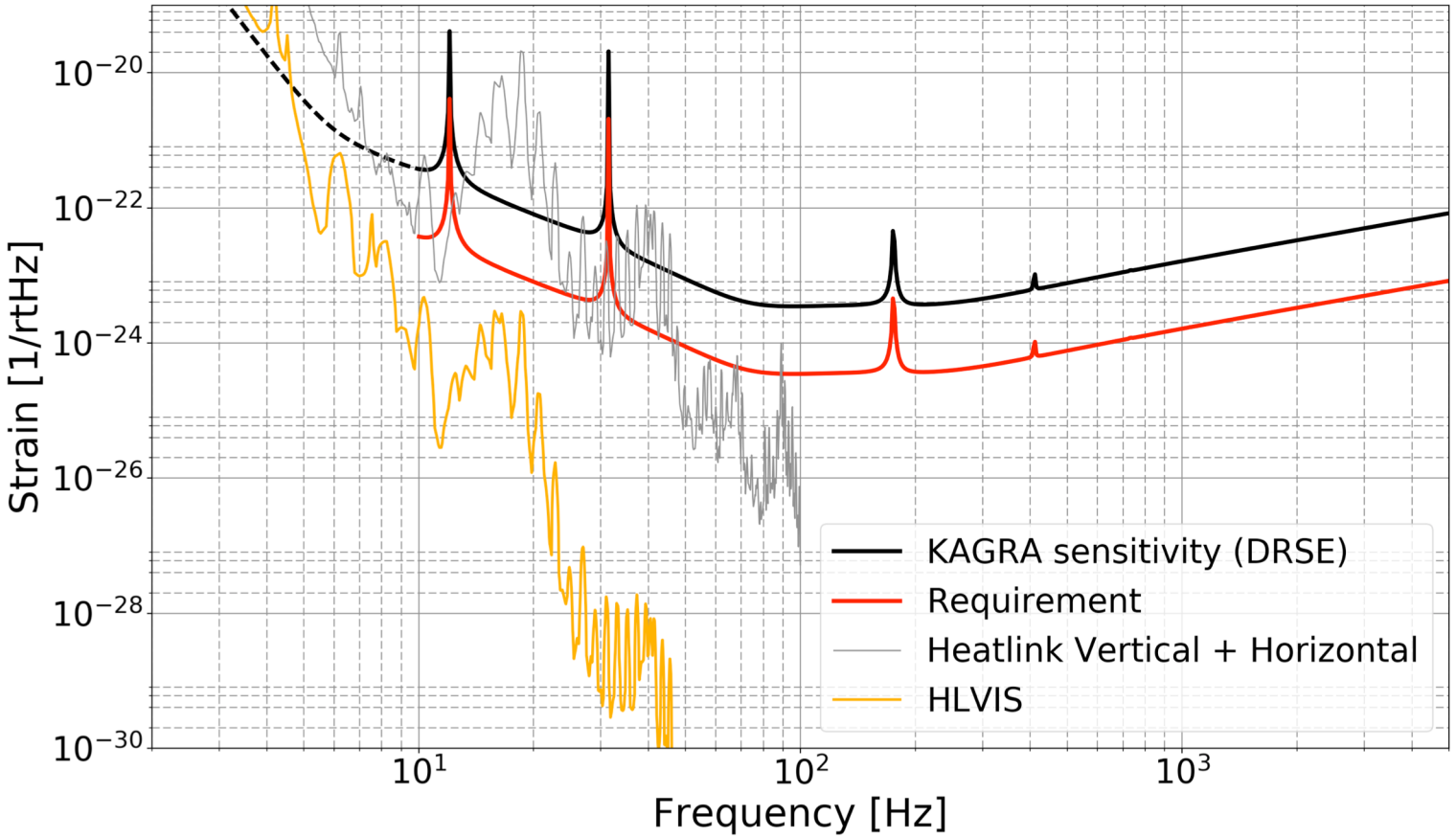




Layout

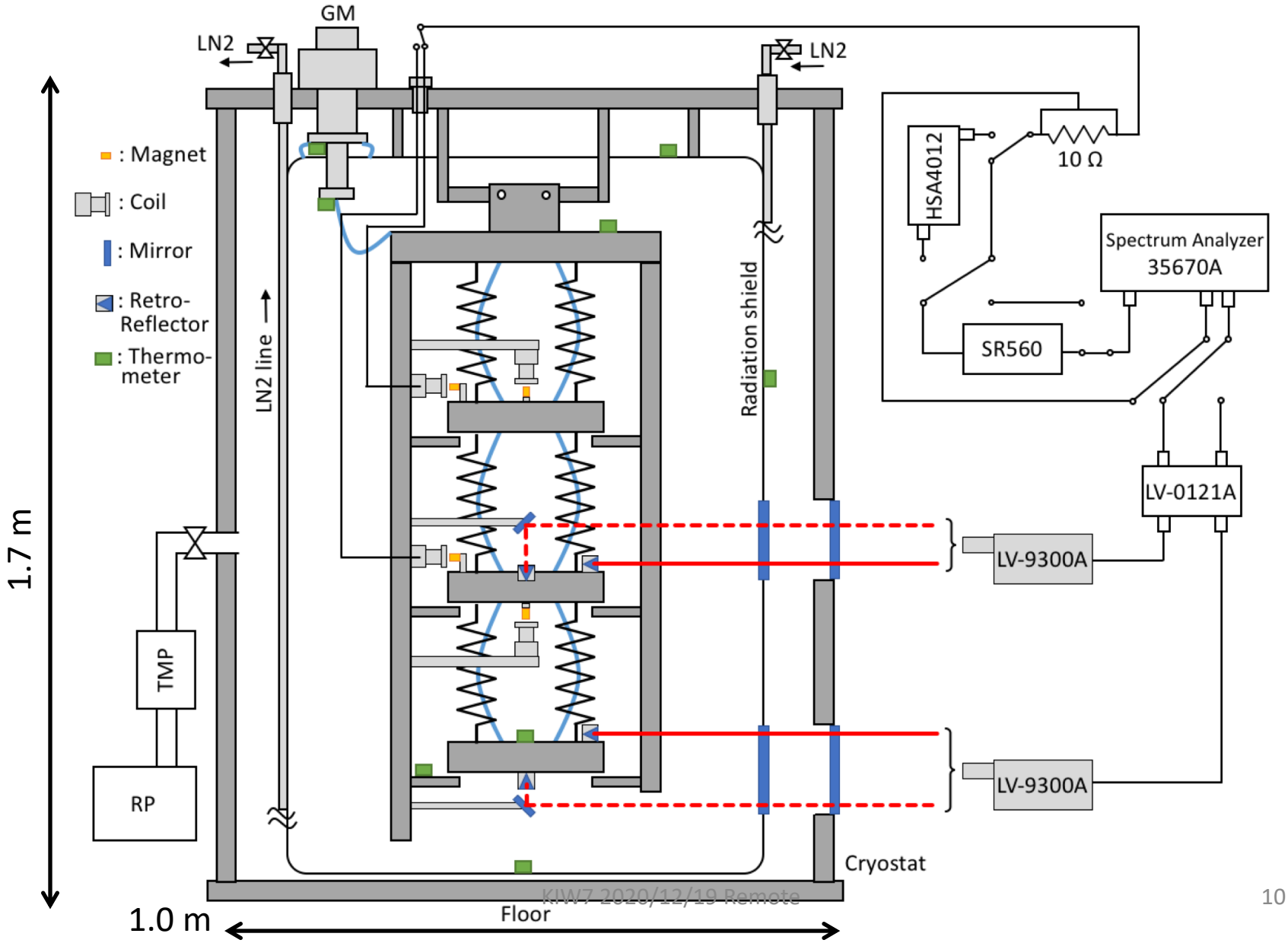


Attenuation of vibration transmission = Design performance

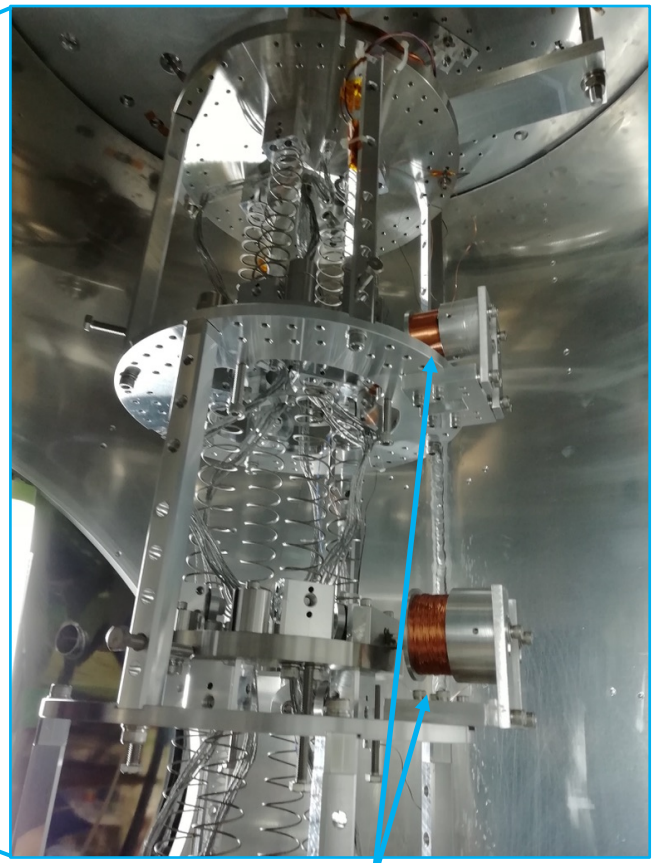


Vibration attenuation performance must be practically confirmed.

Performance evaluation test in KEK

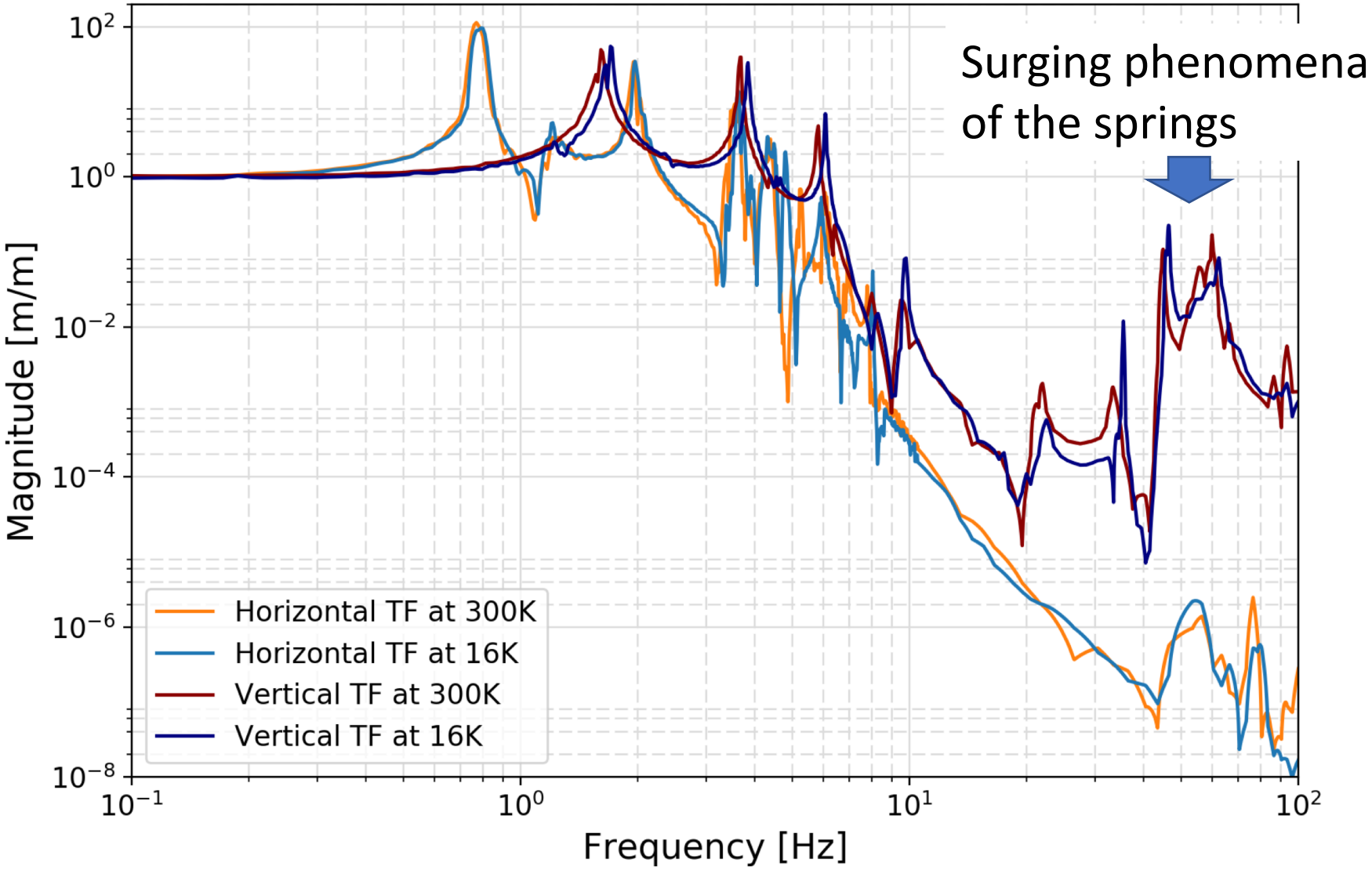


Performance evaluation test in KEK

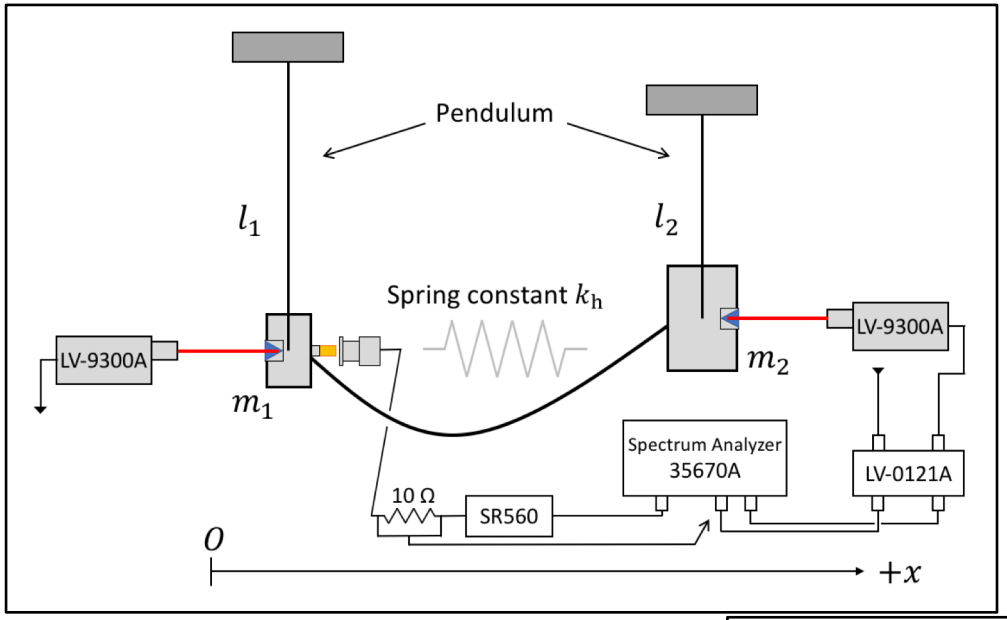


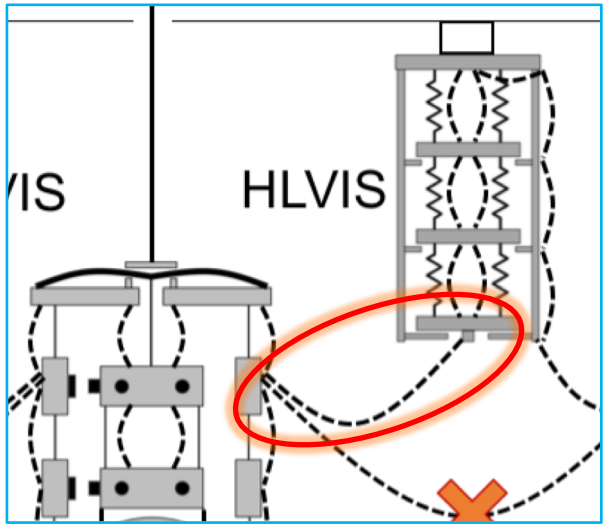
Coil-magnet actuators

Measured results



Spring constant measurement in KEK





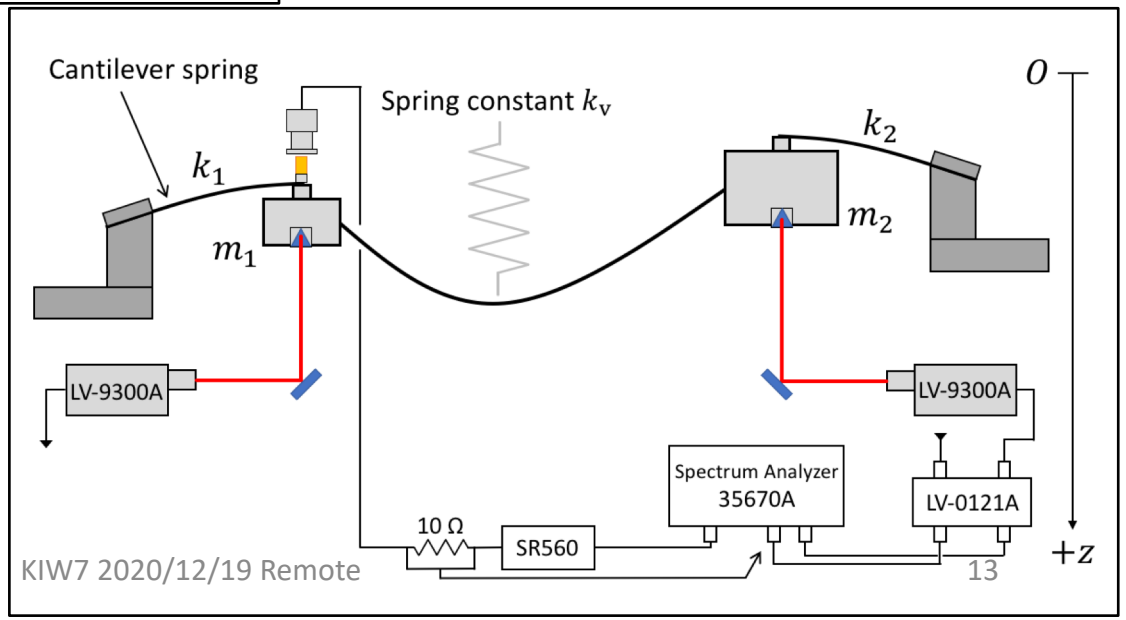
Horizontal $\dfrac{x}{X} = \dfrac{k_h}{m_2 \dfrac{g}{l_2} + k_h}$

$k_h = 0.11$ N/m

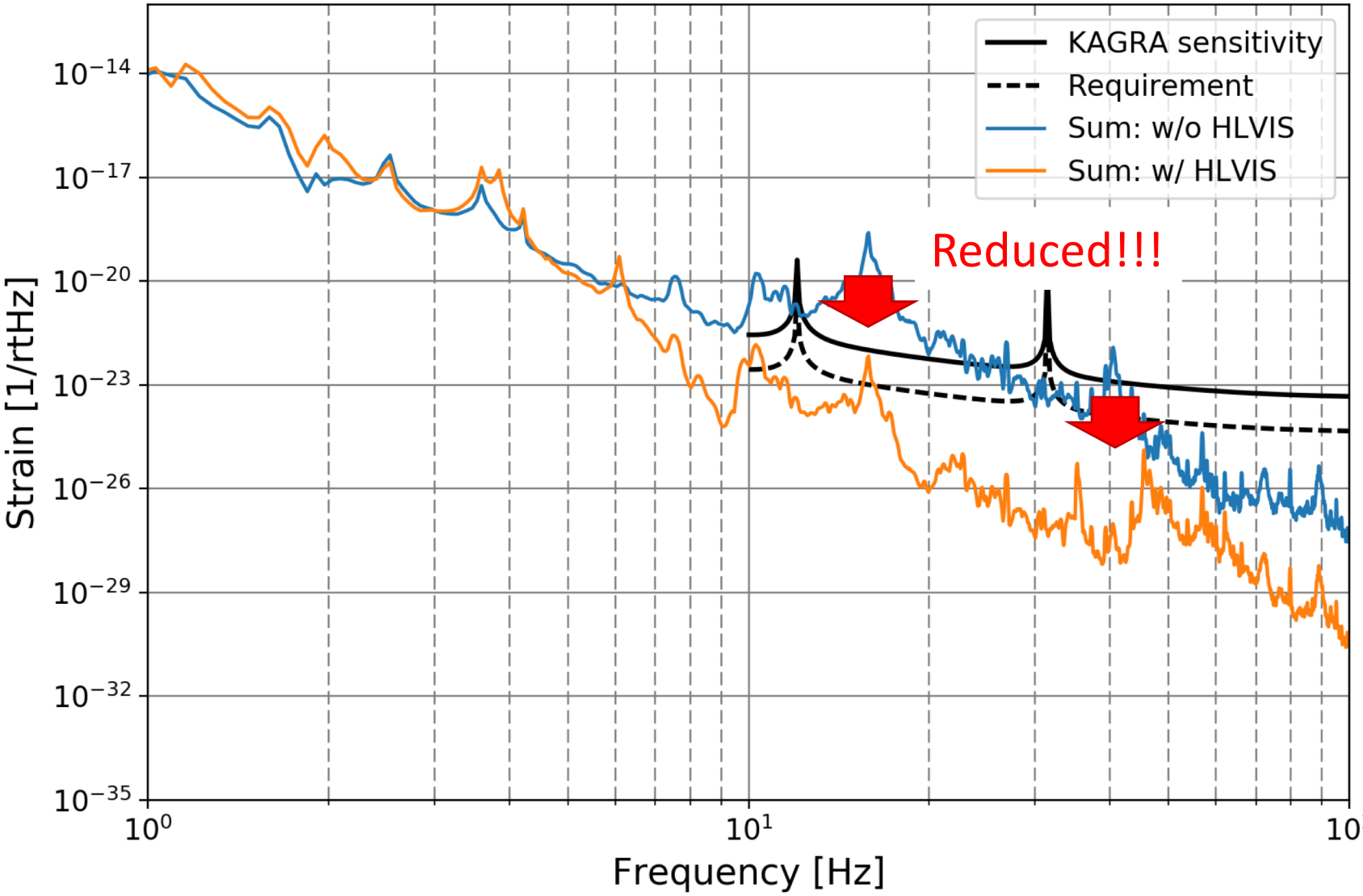
Vertical

$\dfrac{z}{Z} = \dfrac{k_v}{k_2 + k_v}$

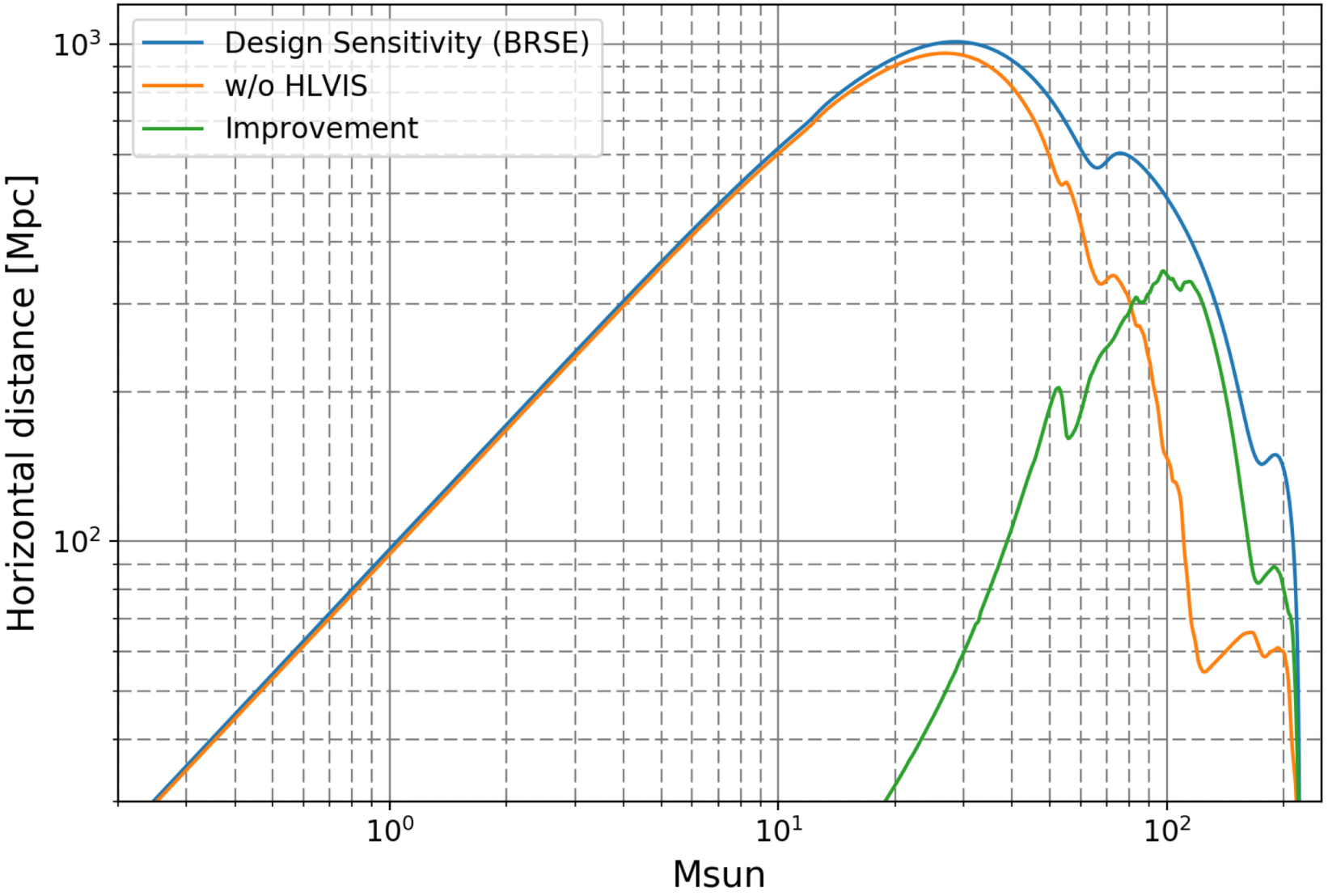
$k_v = 0.22$ N/m



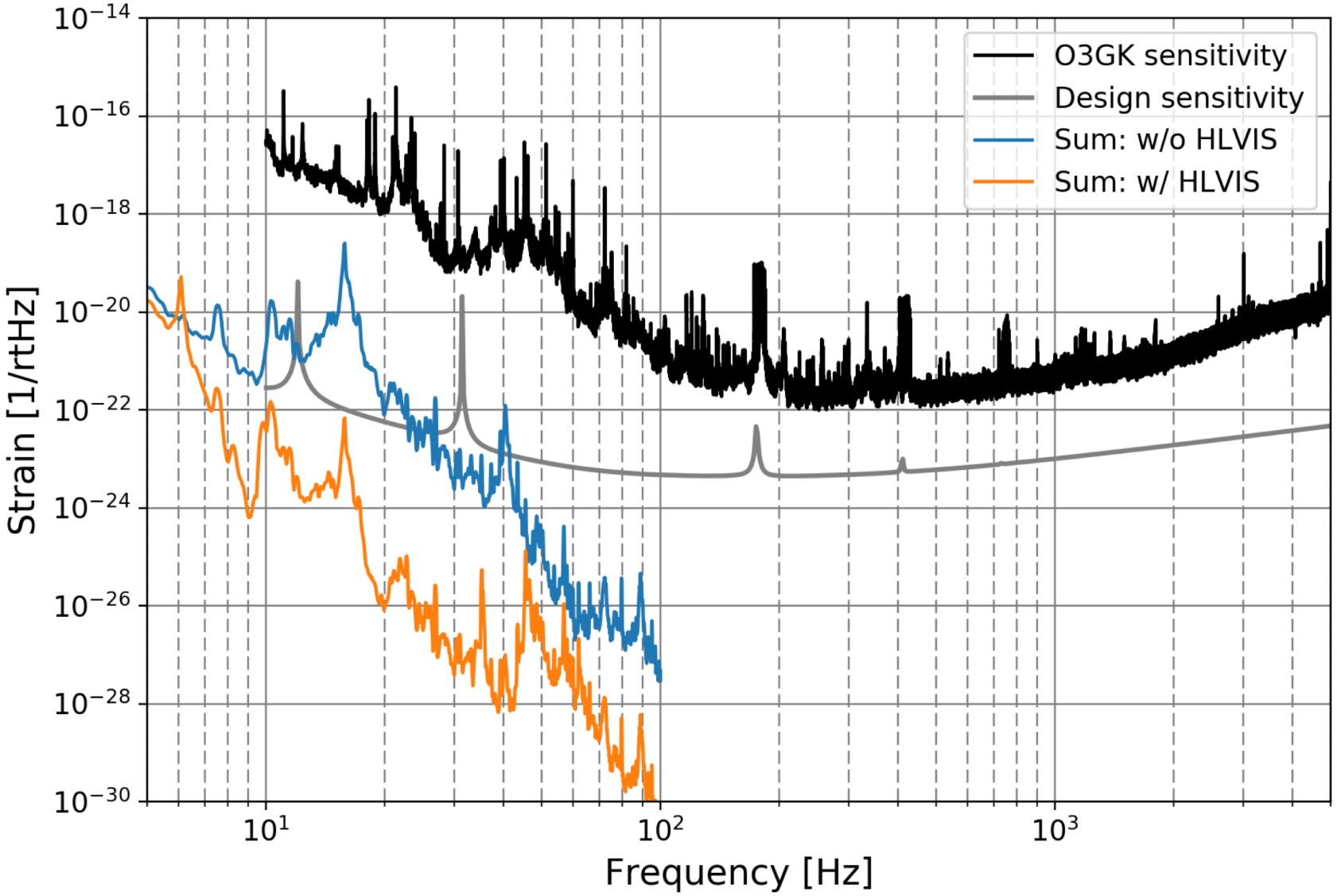
Projection


KAGRA sensitivity
Requirement
Sum: w/o HLVIS
Sum: w/ HLVIS
Reduced!!!
Strain [1/rtHz]
Frequency [Hz]
10^{-14}
10^{-17}
10^{-20}
10^{-23}
10^{-26}
10^{-29}
10^{-32}
10^{-35}
10^{0}
10^{1}
10^{2}

Improvement of the sensitivity



Where are we now?



Summary and Conclusion

- Vibration inflow via heat links was expected to decrease the detector sensitivity.

- Heat link vibration isolation system was newly designed, tested and installed.
- The measured vertical spring constant was slightly higher than expected value, and this affects vibration inflow.

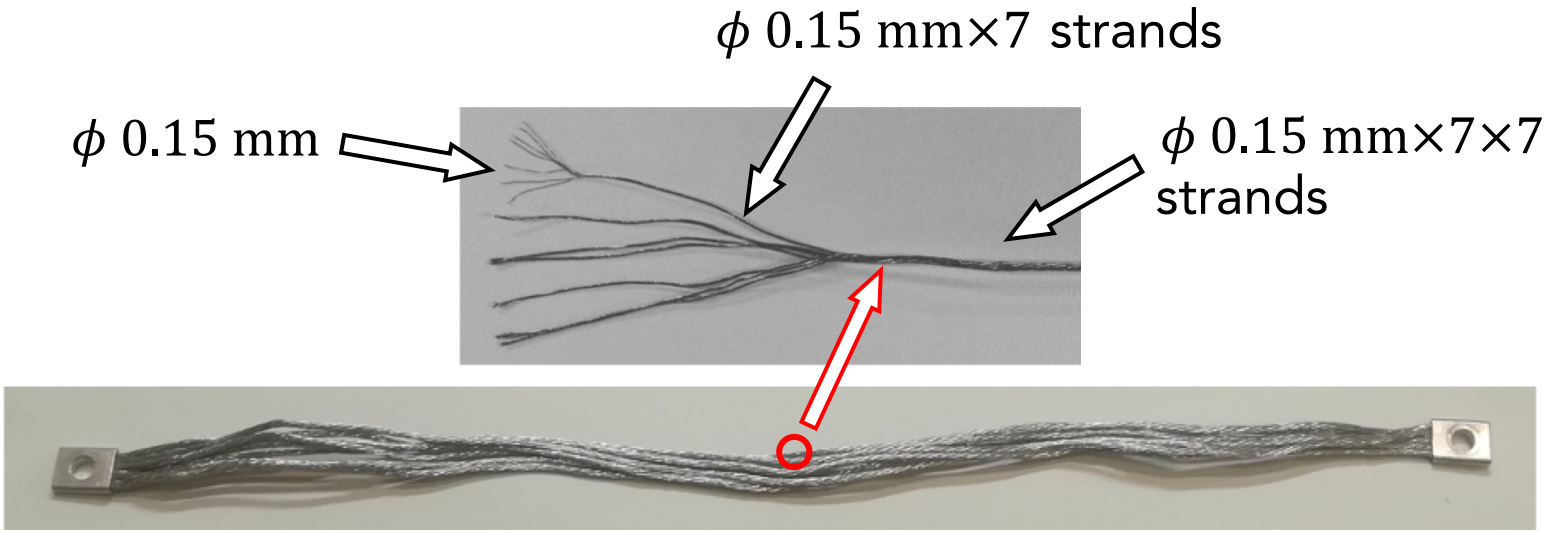
- HLVIS will improve the sensitivity and detection rates:

Mass	Horizon distance	Detection rate
30-30 Msun	60 Mpc	1.2 times
50-50 Msun	190 Mpc	2.2 times
100-100 Msun	340 Mpc	36.8 times

KAGRA heat-links

- Ultra high-purity aluminum heat-links

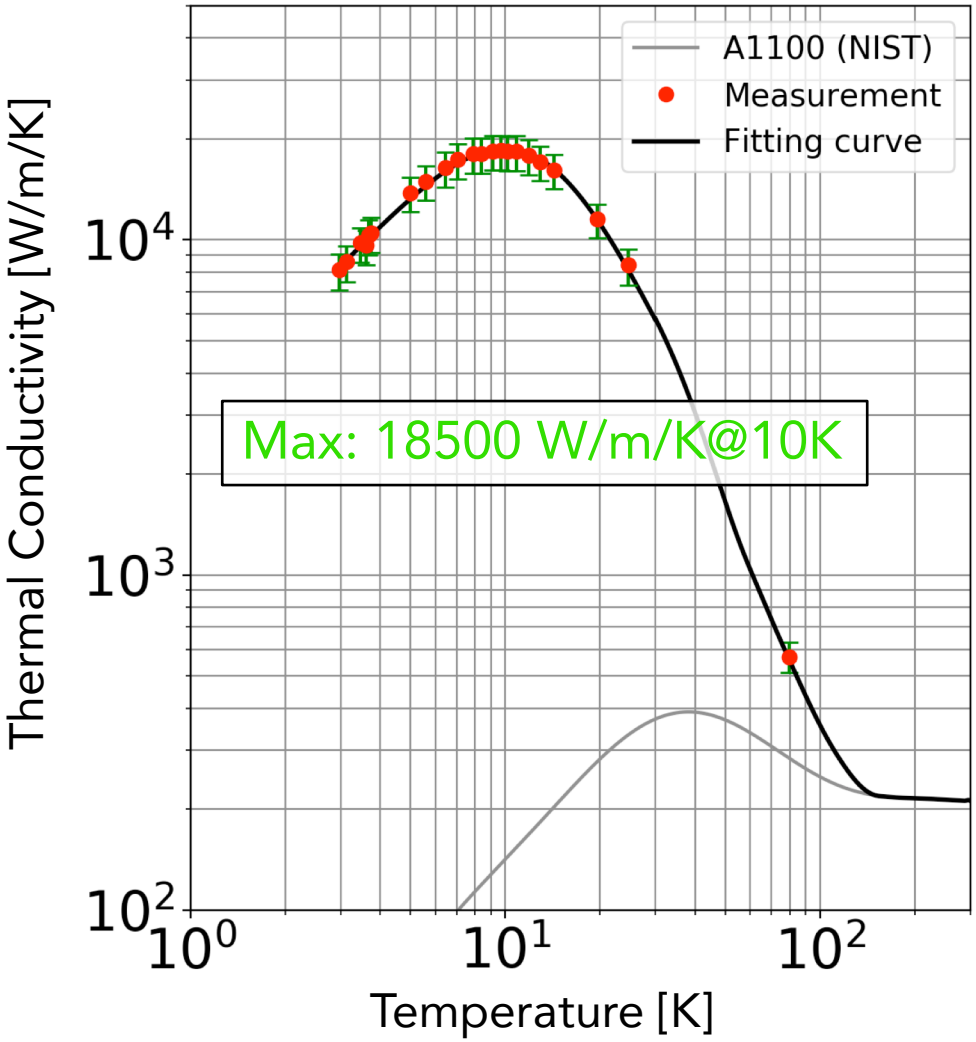
  Purity: 99.9999%, 6N (Sumitomo Chemical Co., Ltd.)



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.