Cryo-payload; vibration reduction

Study of radiation shield vibration in KAGRA cryostat

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ICRR The University of Tokyo, KEK[A], INFN[B]

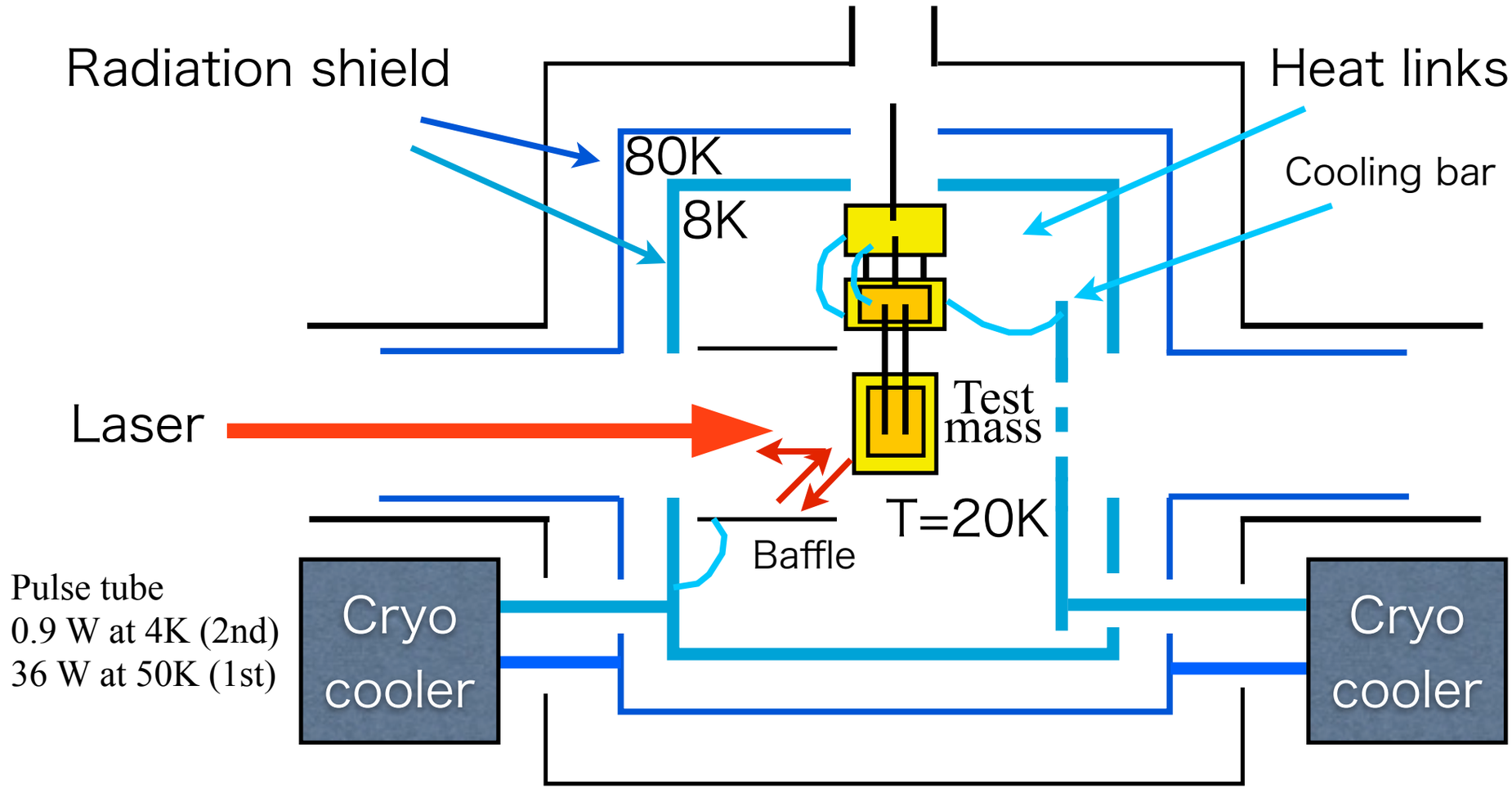
KAGRA f2f meeting 13th-15th Feb. 2014

- Outline -

- Purpose of the vibration measurement
- Measurement of the KAGRA radiation shield
- The impact on the sensitivity of KAGRA

Purpose

Measurement of the vibration of the radiation shield.



Noise of the interferometer ⟸ Vibration from the radiation shield through heat links.
Recoupling into main laser via scattered light

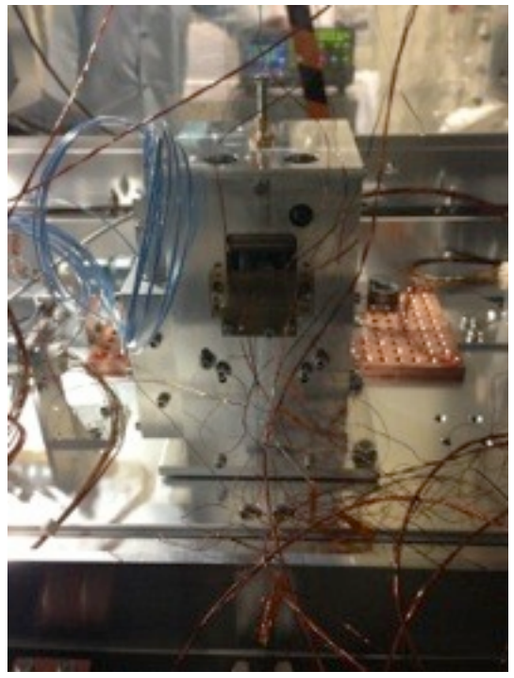
⇨ Vibration measurement of the radiation shield during the cryocooler operation (@Toshiba Keihin Product Operations, Yokohama-city near by Tokyo).

⇨ Estimate the influence on the sensitivity of KAGRA.

Accelerometers

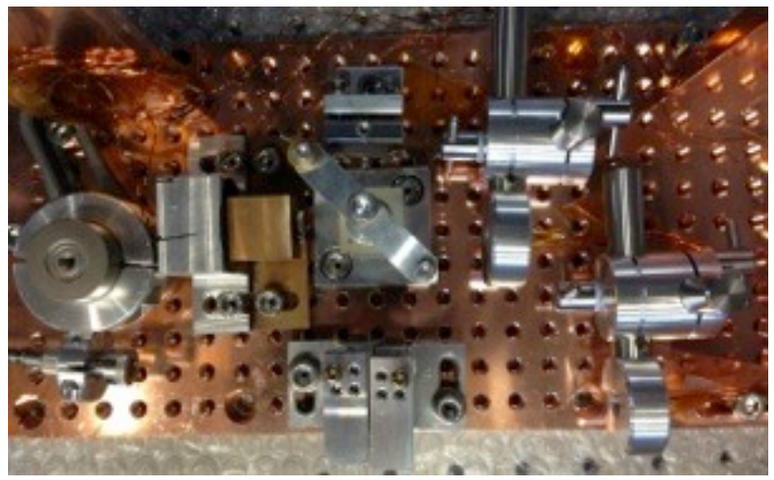
Vertical direction

We used an accelerometer developed in Rome Univ.



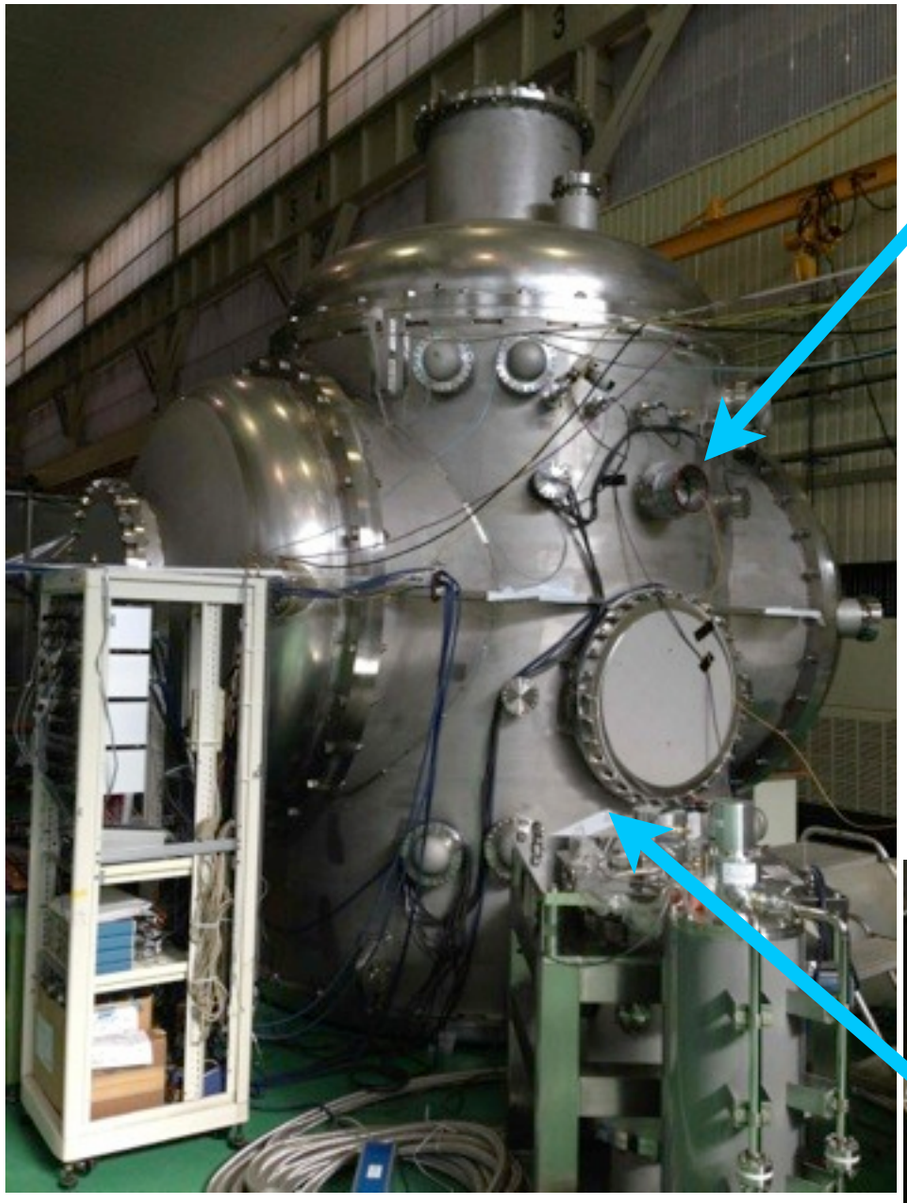
Horizontal direction

We used a Michelson interferometer as an accelerometer developed in ICRR.



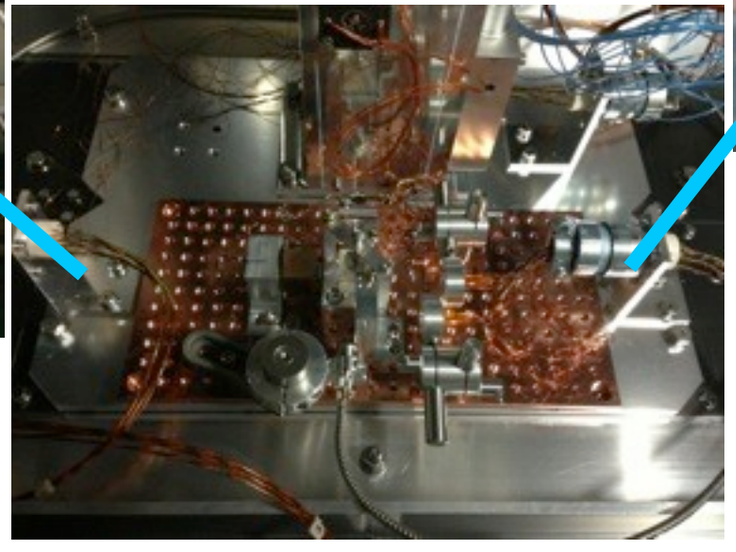
We report about the measurement result and impact on the sensitivity of KAGRA.

Installation of the accelerometer into the KAGRA radiation shield @Yokohama-city



The cryostat

Optical fiber port

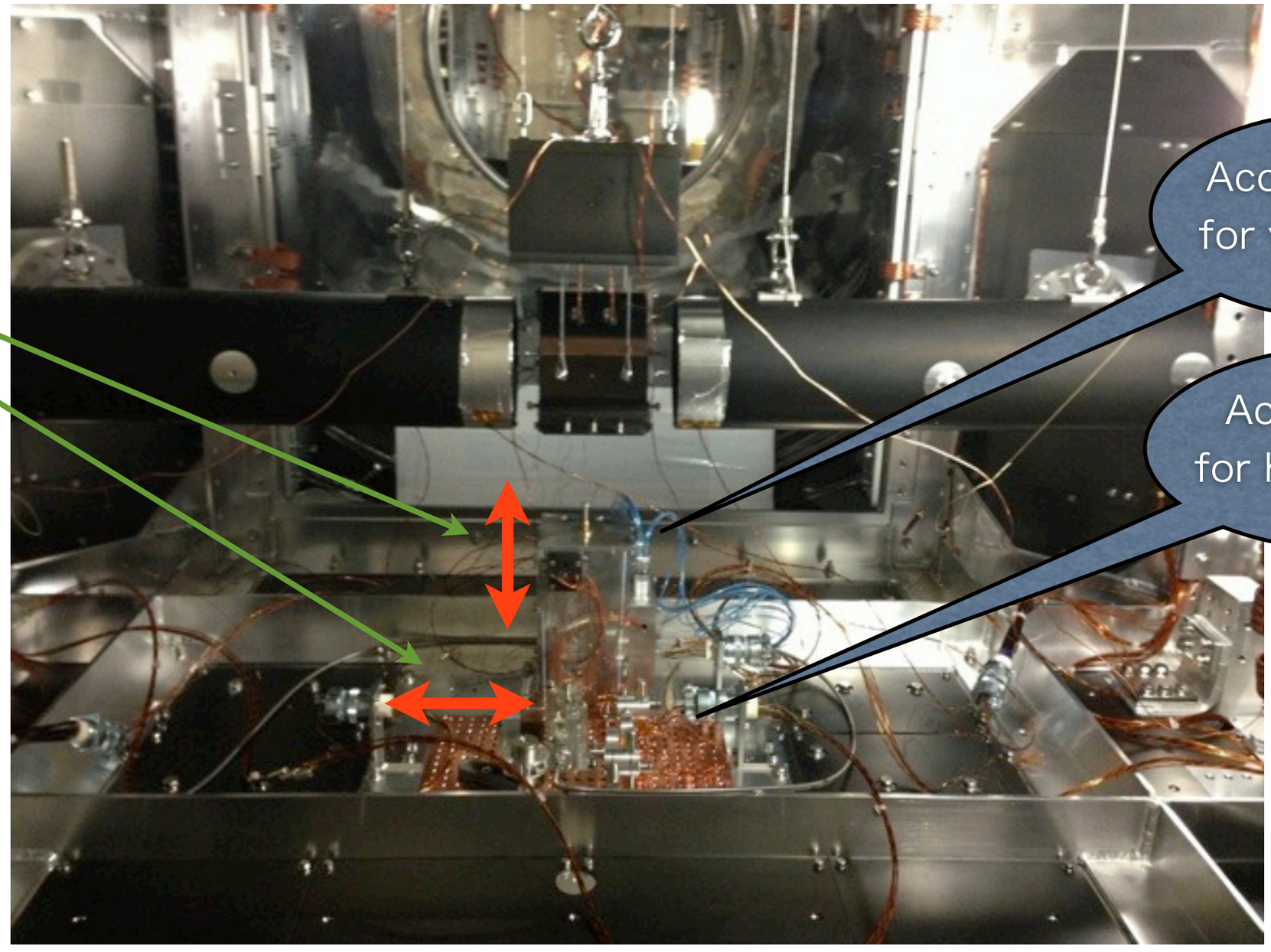


Cryogenic accelerometers

Inside of the radiation shield

Measurement in Toshiba

@Yokohama-city



Cryostat #3

Accelerometers

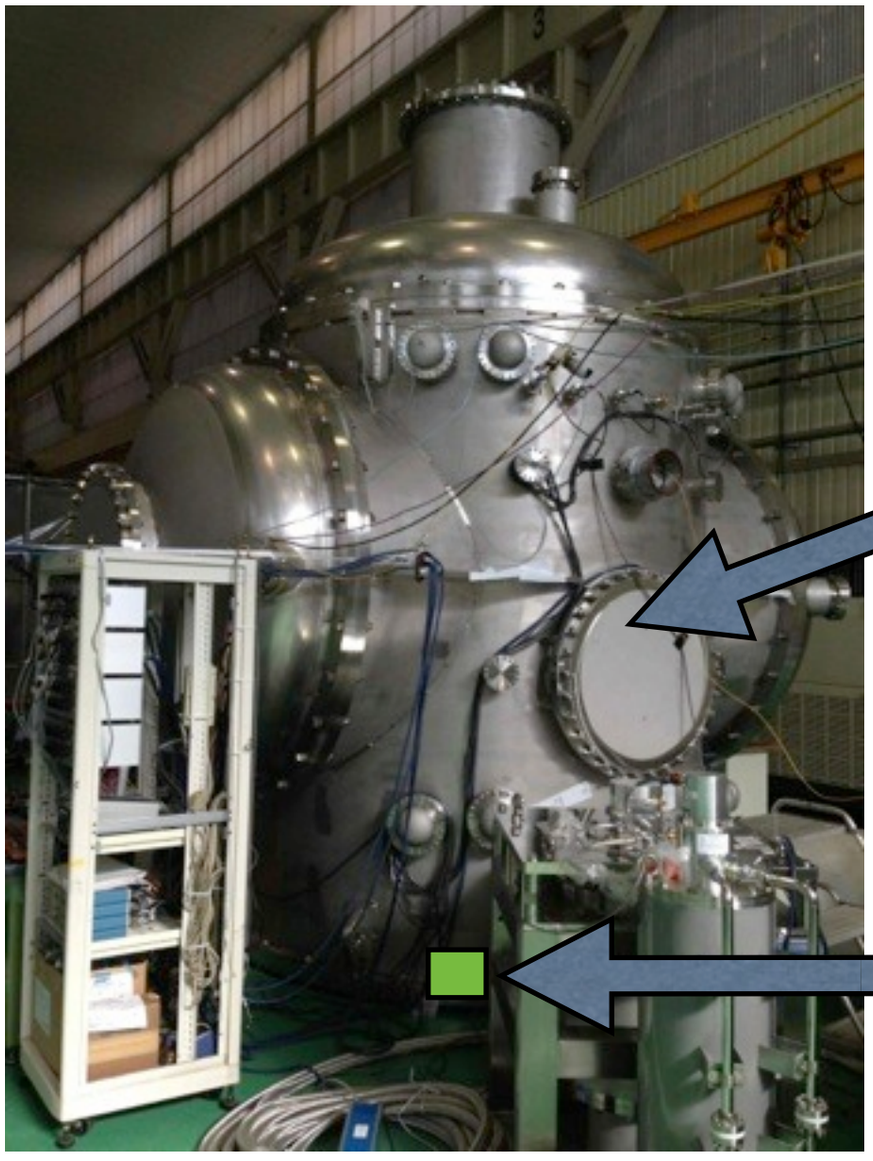
One is for the vertical component.

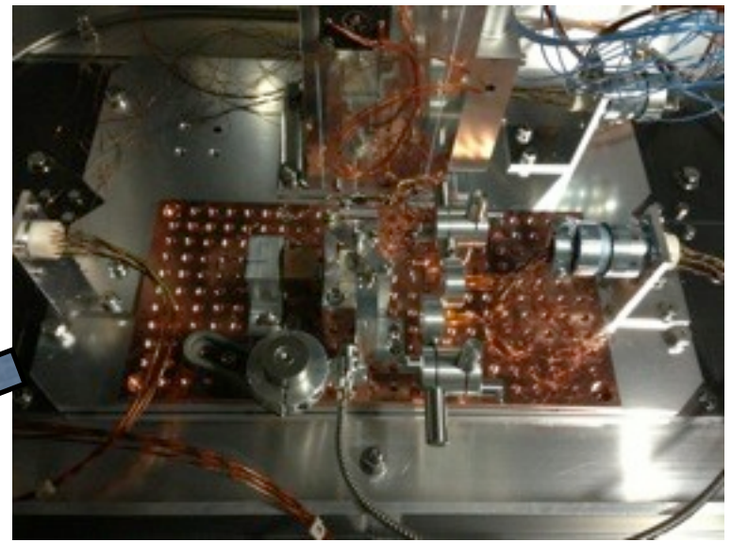
The other one is for the horizontal component.

INFN

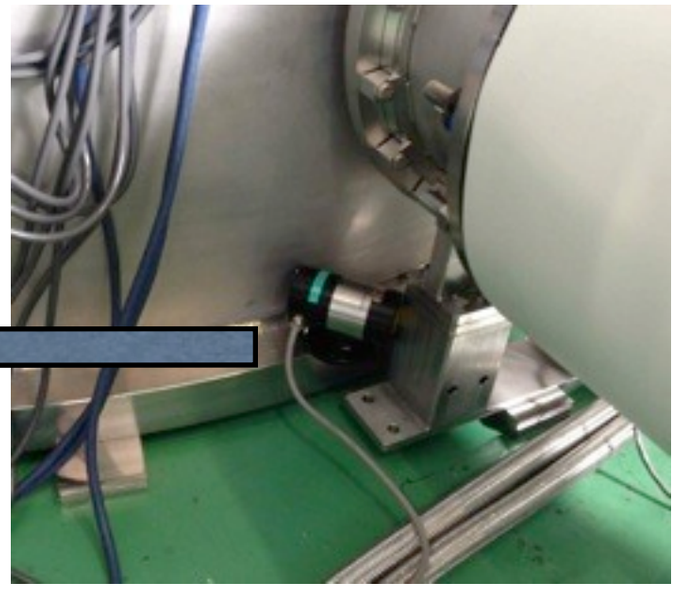
The Univ of Tokyo

Installation of the accelerometer into the KAGRA radiation shield





Cryogenic accelerometers



RION

We used a commercial accelerometer(RION) to measure the vibration outside the cryostat.

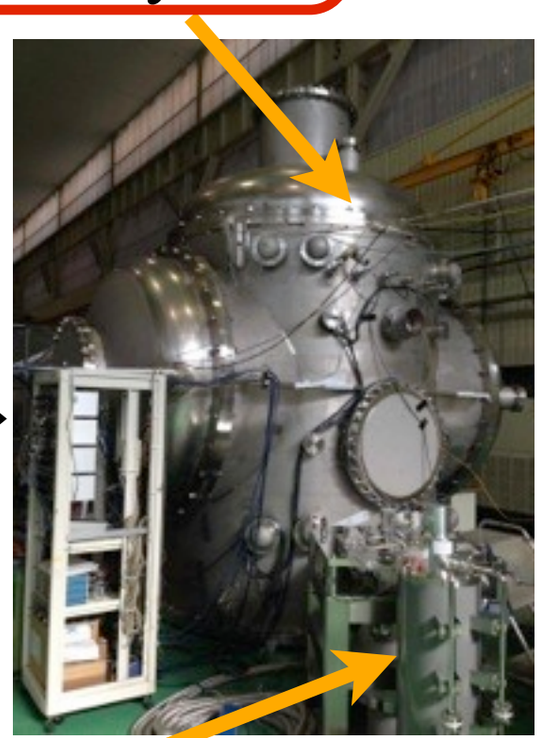
Vibration measurement during cooling

Purpose

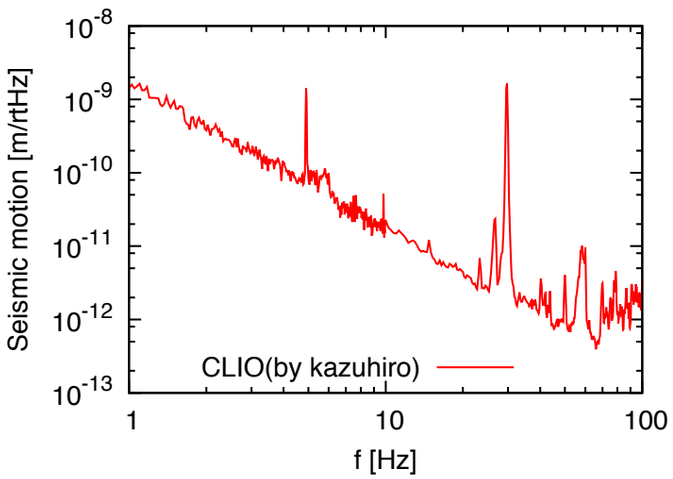
Estimation of the vibration in the cryostat at Kamioka mine during cooler operation.

The structure of the cryostat

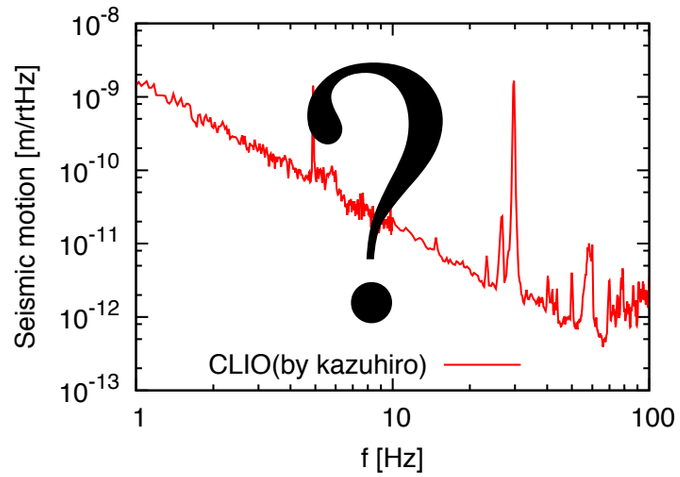
Measure the vibration both of inner shield and outside the chamber



Seismic vibration at Kamioka



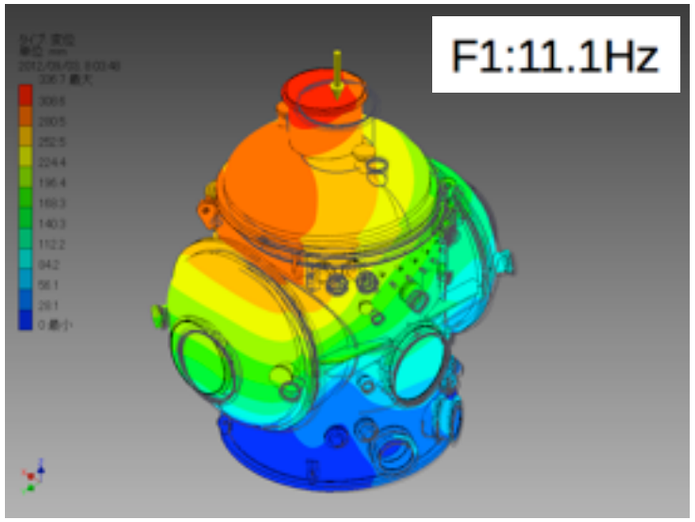
Vibration in the cryostat at Kamioka



The vibration of the coolers

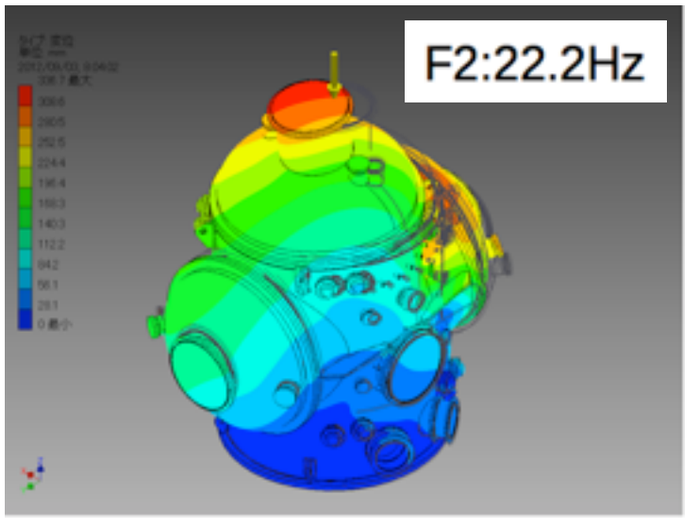
Measure the vibration with coolers ON/OFF

Modal Analysis of the Cryostat



mode frequency

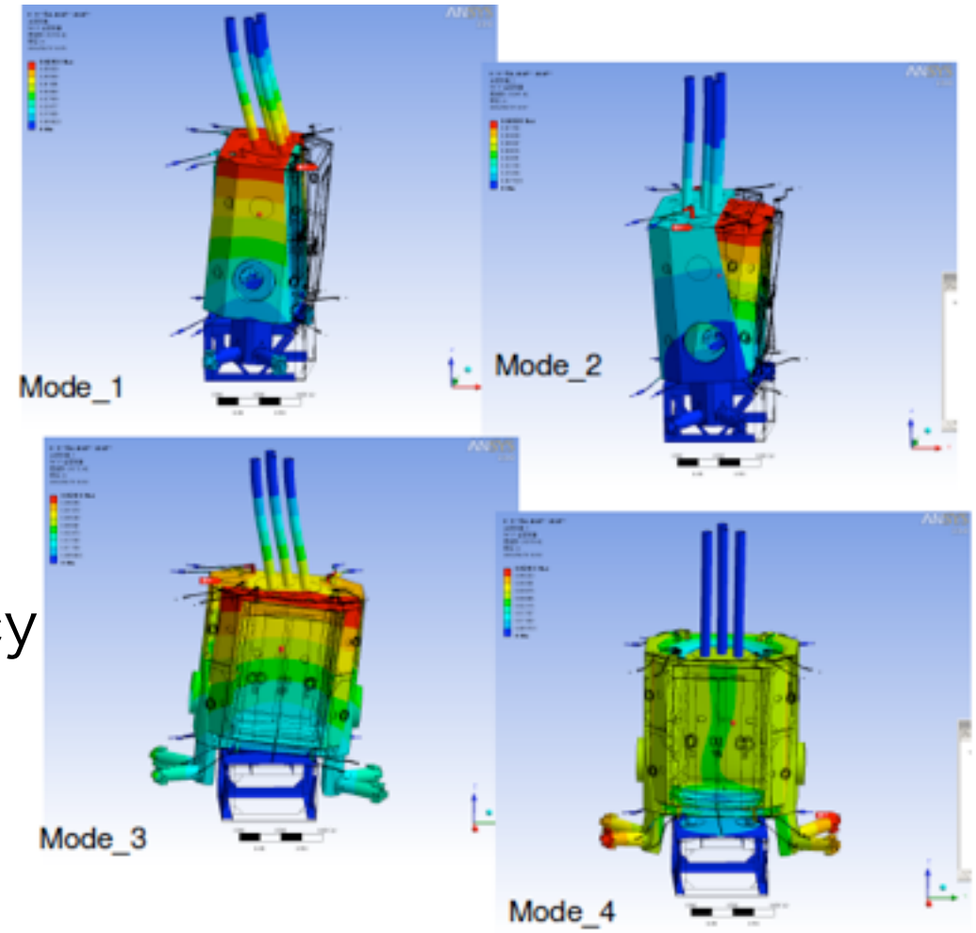
F1	11.07 Hz
F2	22.22 Hz
F3	34.72 Hz
F4	38.03 Hz
F5	43.02 Hz
F6	44.81 Hz
F7	55.97 Hz
F8	56.14 Hz



Vibration of
the vacuum chamber

mode frequency

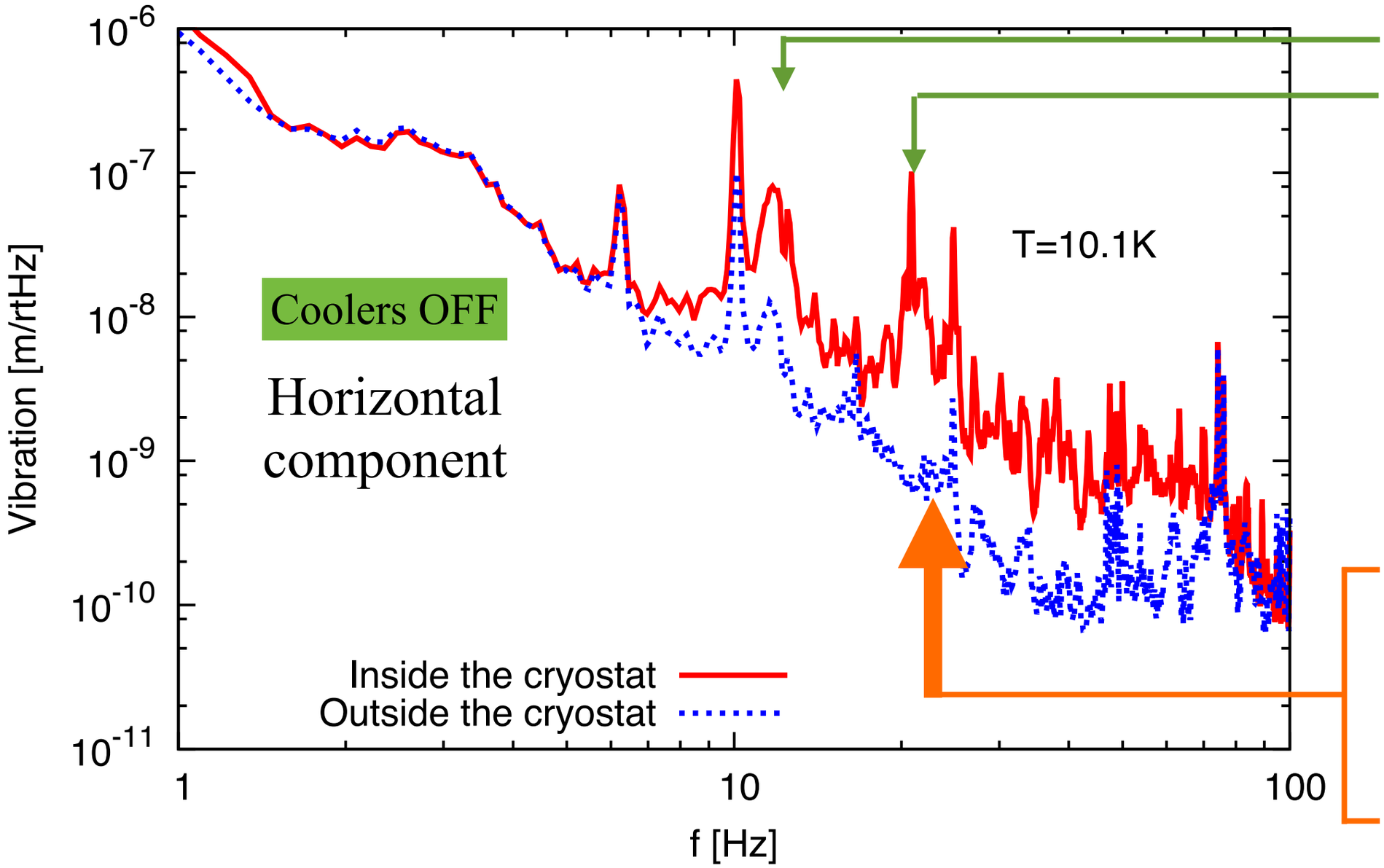
F1	20.709
F2	23.947
F3	24.712
F4	24.878
F5	30.839
F6	38.156
F7	42.182
F8	45.09



Vibration of the radiation shield

We calculated the resonance peaks of the chamber and the radiation shield

Vibration measurement at low temperature



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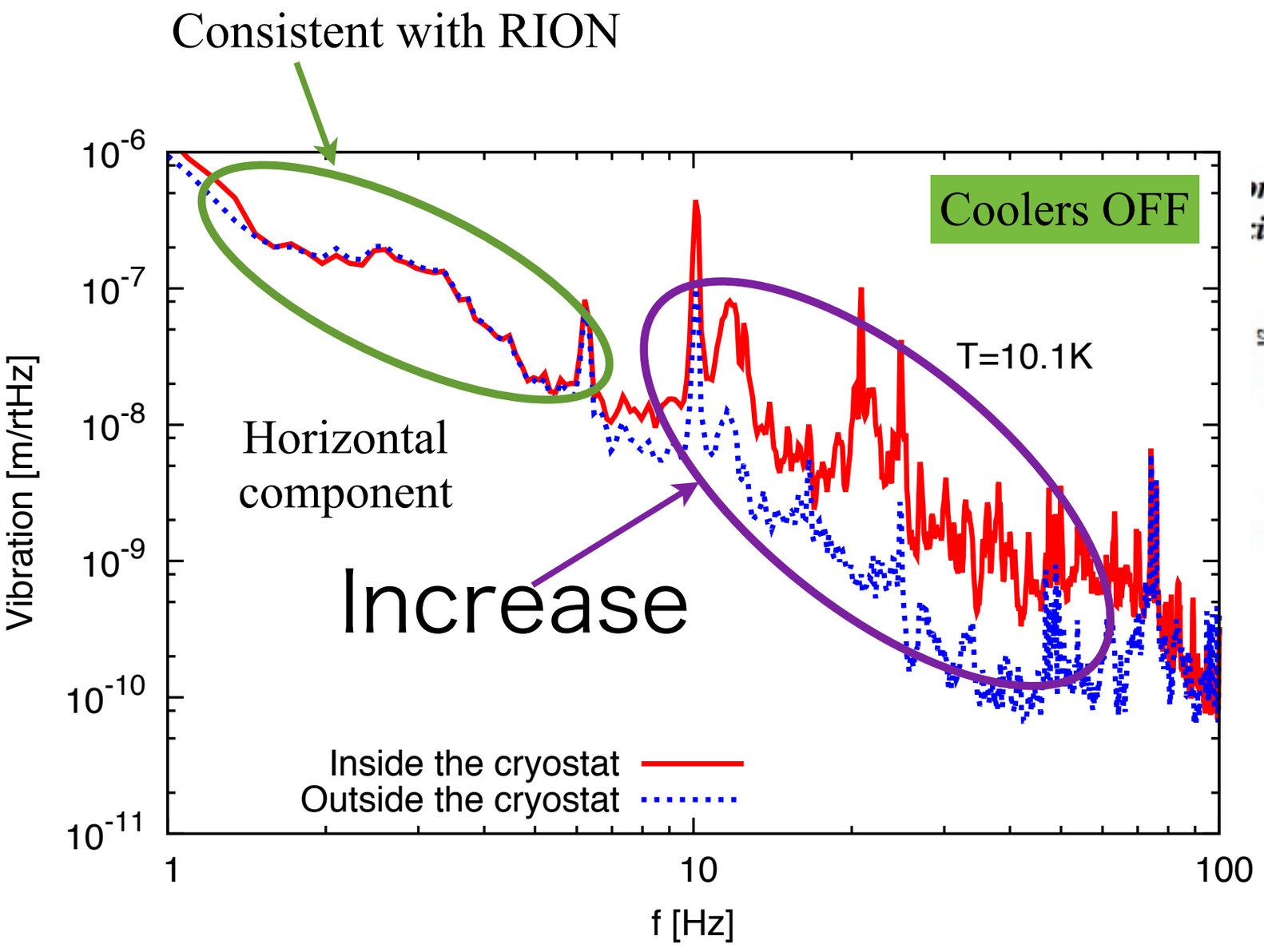
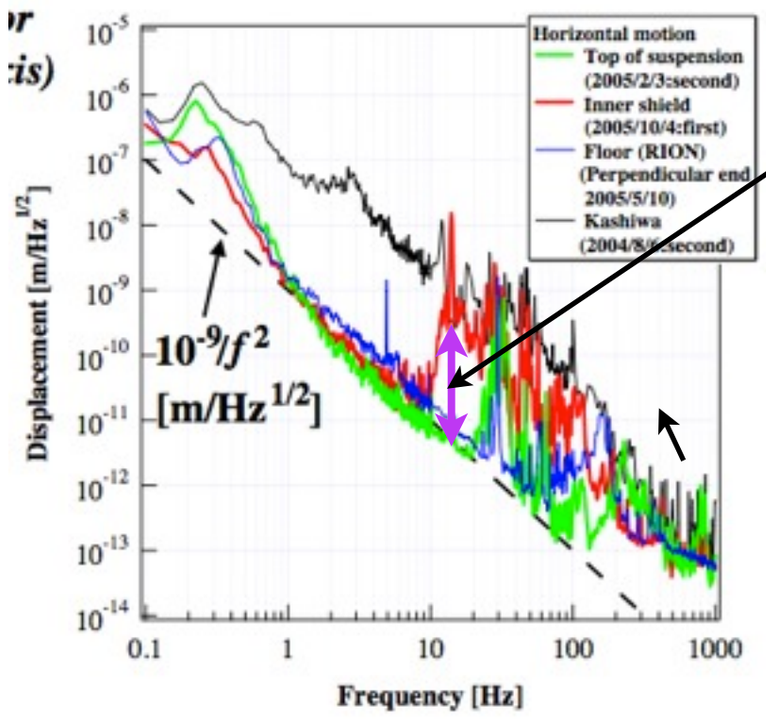
Vibration of the radiation shield

The measurement is consistent with many calculated peaks.

Vibration measurement at low temperature



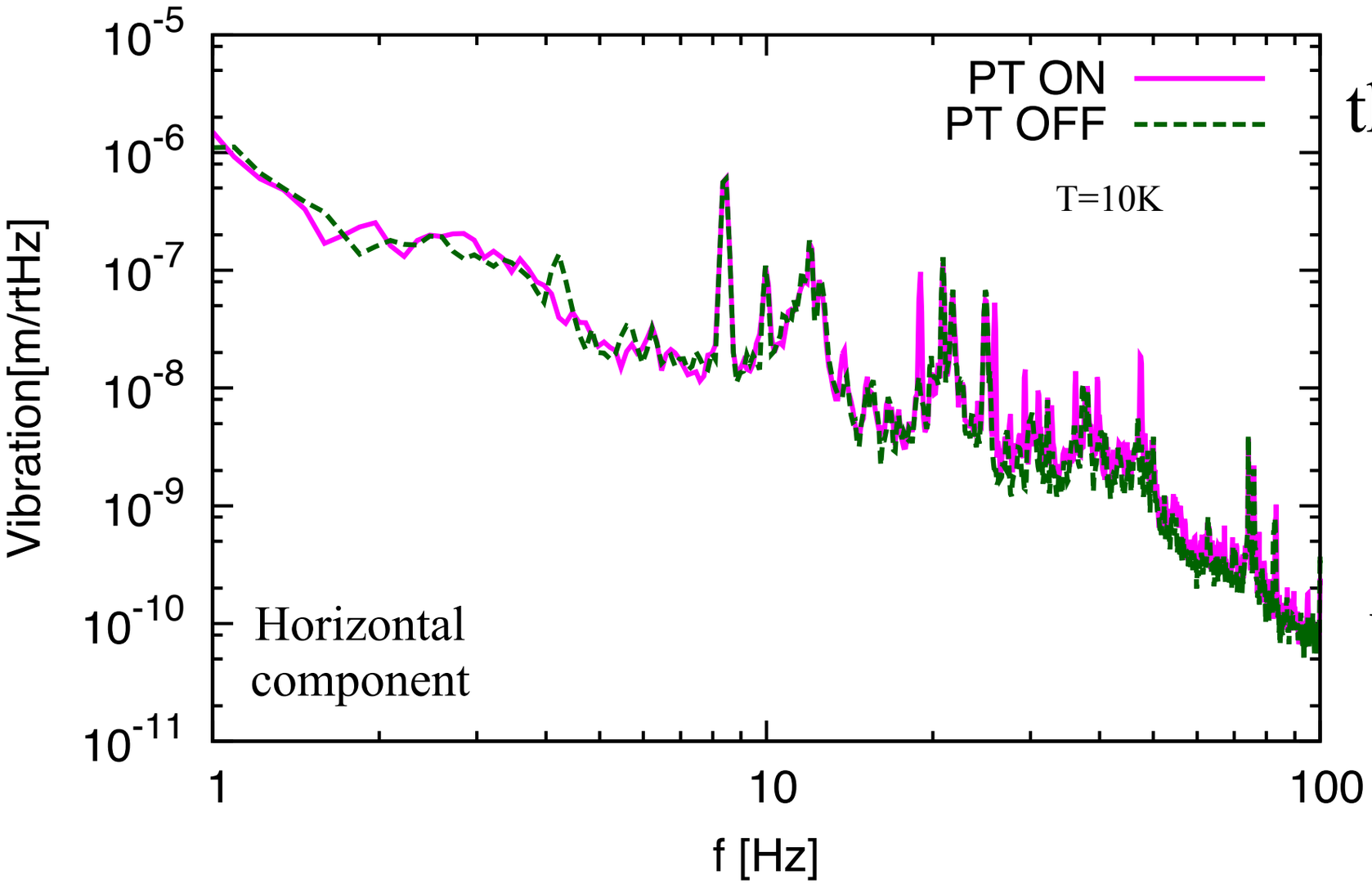


x100

The case of CLIO

We had coincidence measurements with RION.
The signals of these two accelerometers are consistent at low frequency.
Around 10Hz, the vibration increases by ~10 times (smaller than CLIO).

Vibration measurement at low temperature



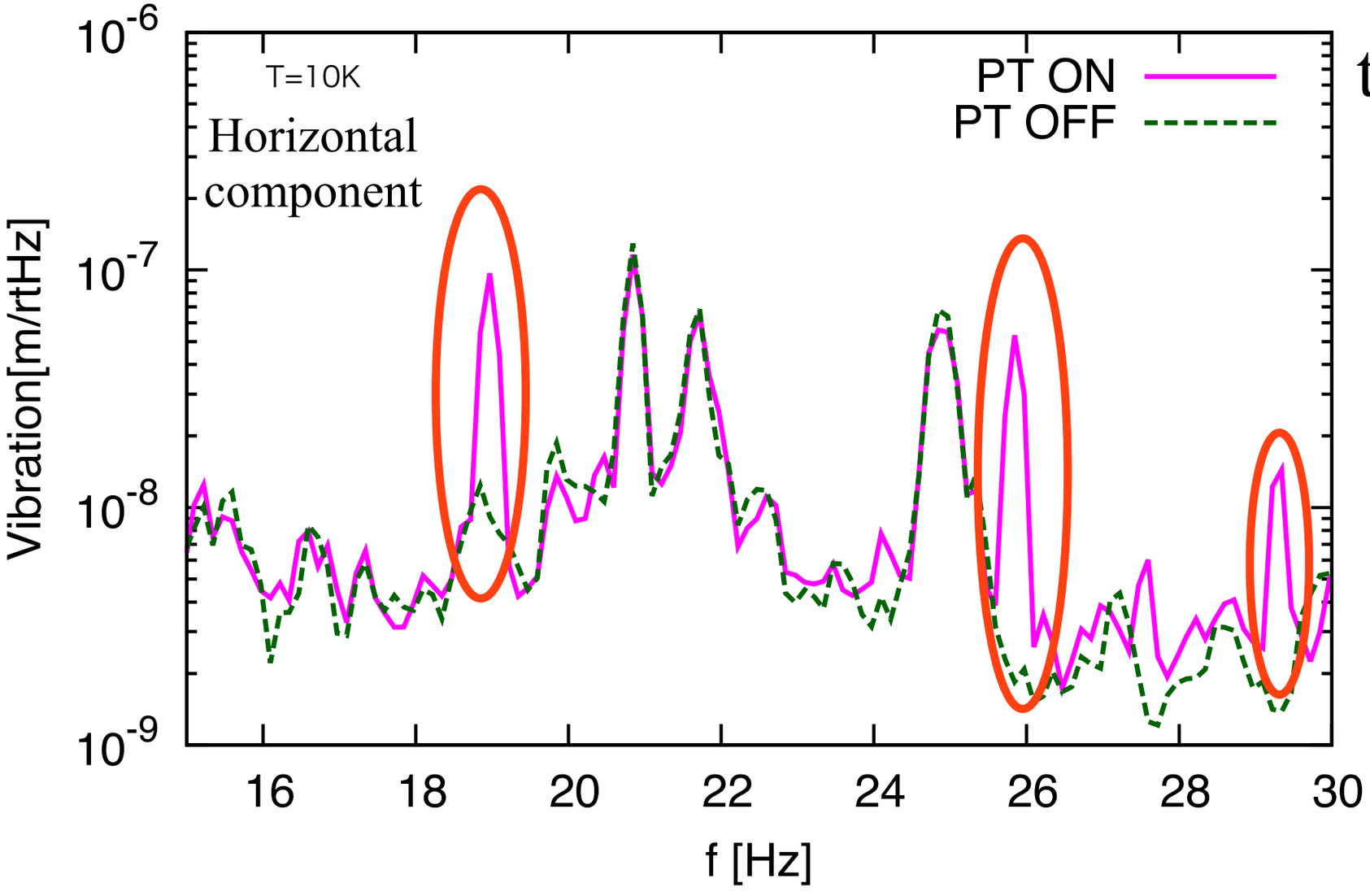
We want to know the influence of coolers

We measured the vibration with coolers ON/OFF

There is no huge change of the vibration floor level, but...

Vibration measurements during cooling

Enlarged view

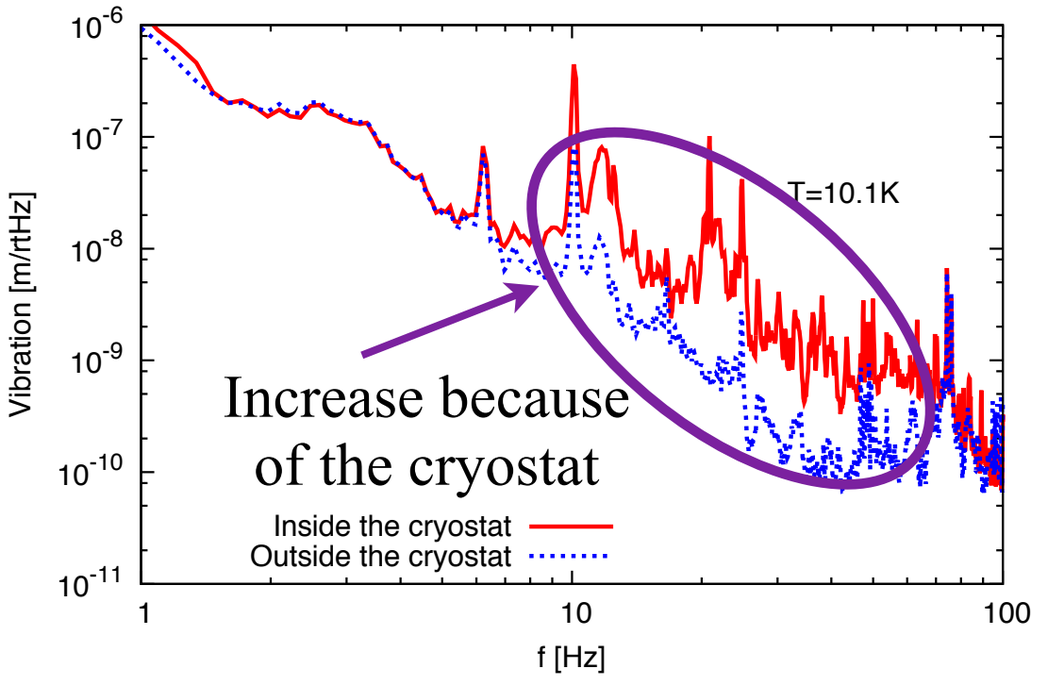


We want to know the influence of coolers

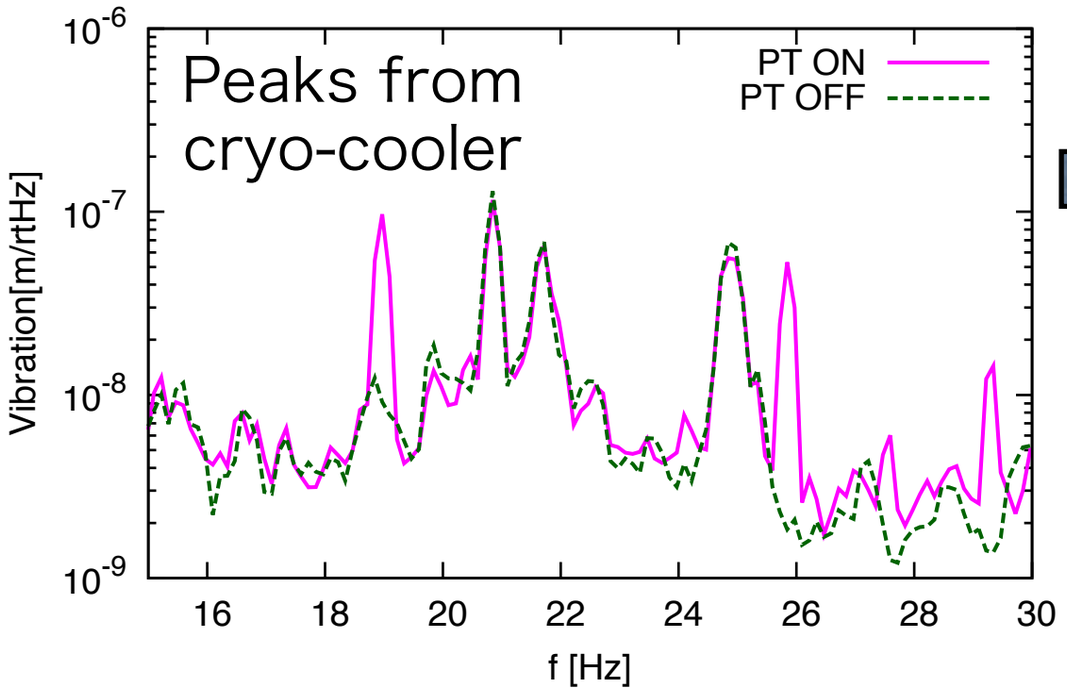
We measured the vibration with coolers ON/OFF

We can see many peaks originating from the cryo-coolers.

The impact on the sensitivity of KAGRA



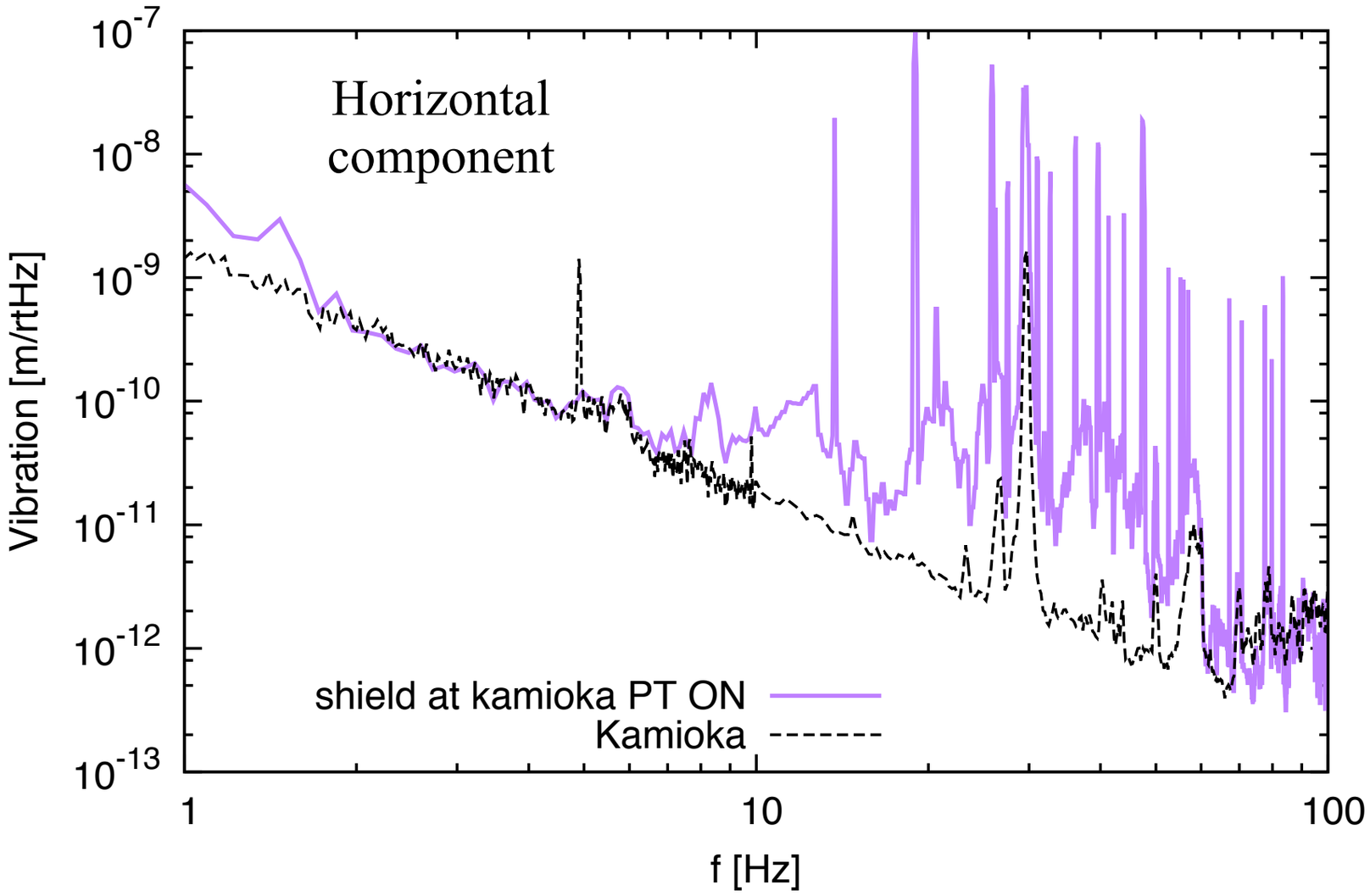
Calculate the ratio to estimate the floor level at Kamioka.



Assume the same peak level at Kamioka as Yokohama

The vibration of the radiation shield at Kamioka

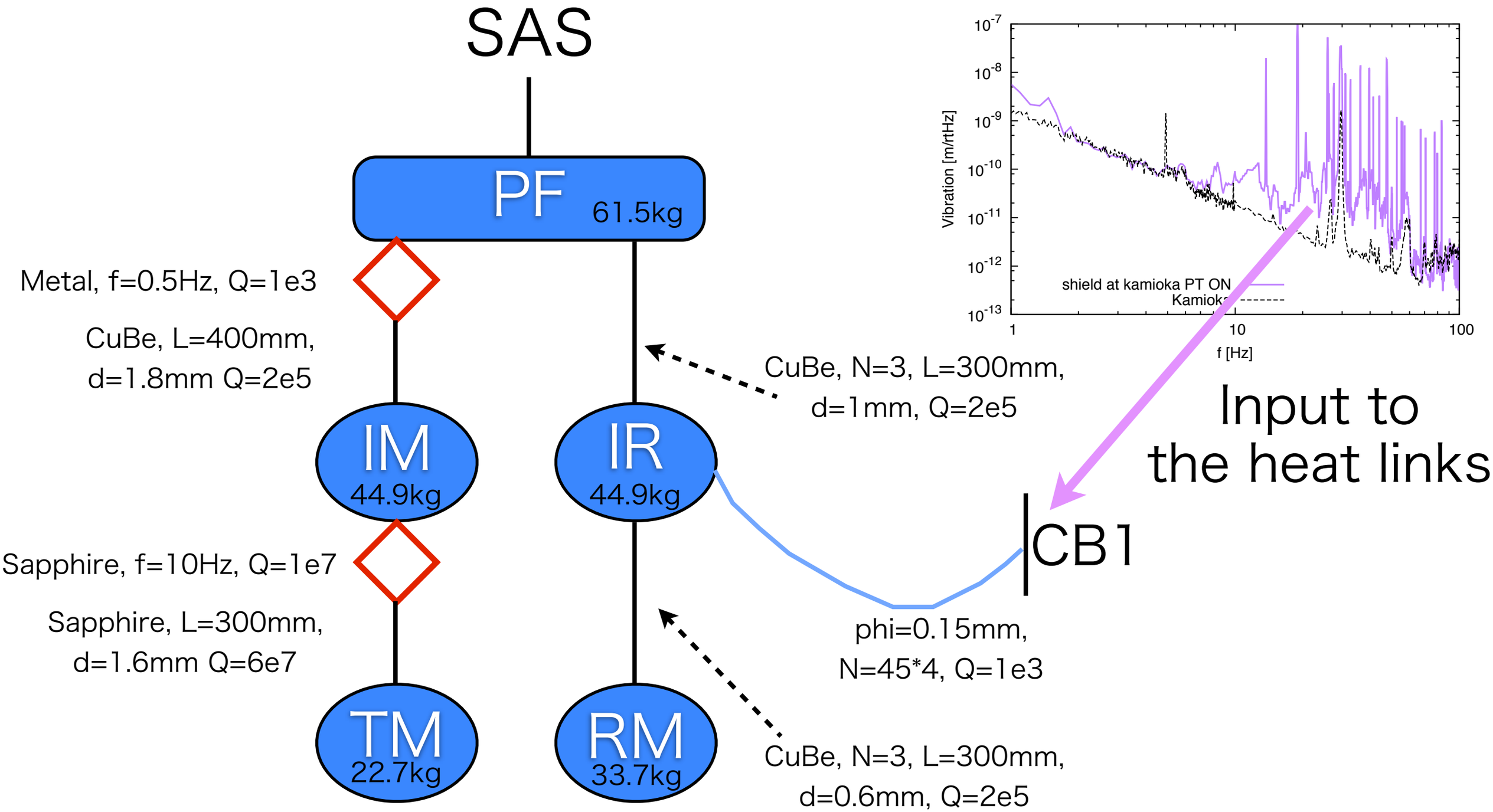
The impact on the sensitivity of KAGRA



The estimated vibration of the radiation shield at Kamioka

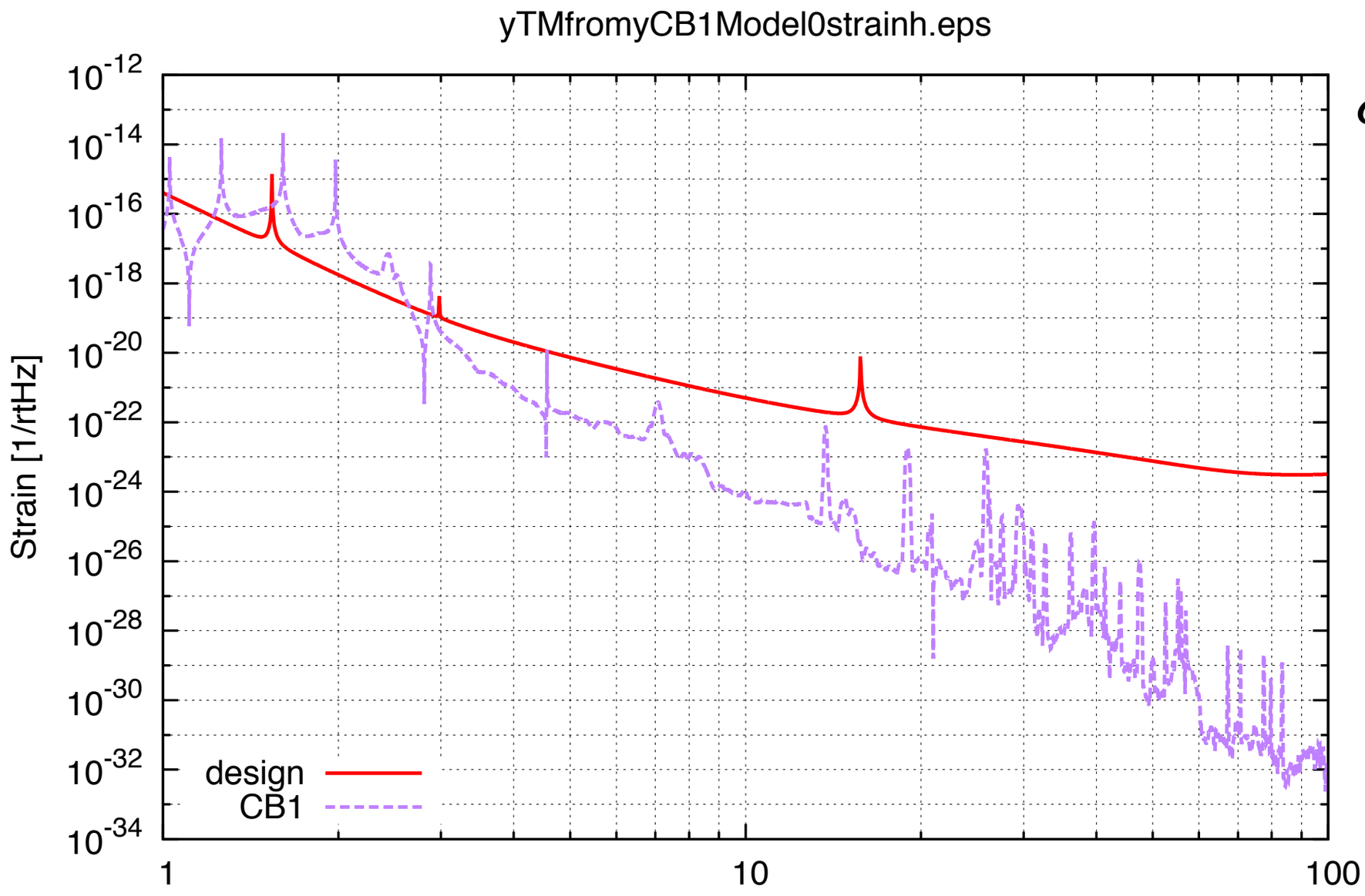
Calculate the influence on the sensitivity of KAGRA

The impact on the sensitivity of KAGRA



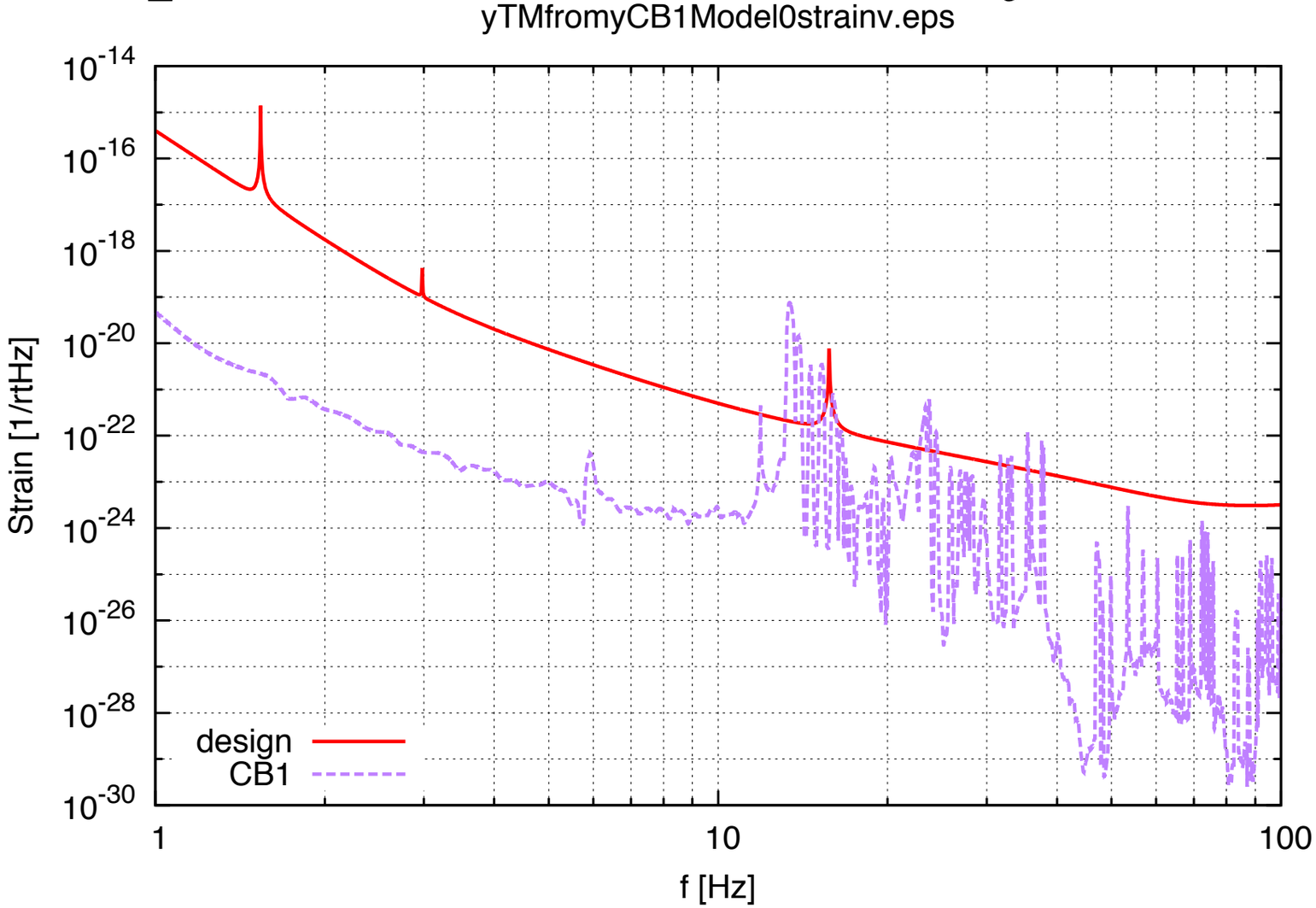
Use a Mathematica code.
The scattered light effect is not considered.

The impact on the sensitivity of KAGRA



The noise from the horizontal vibration component is lower than the design sensitivity.

The impact on the sensitivity of KAGRA



Vertical component

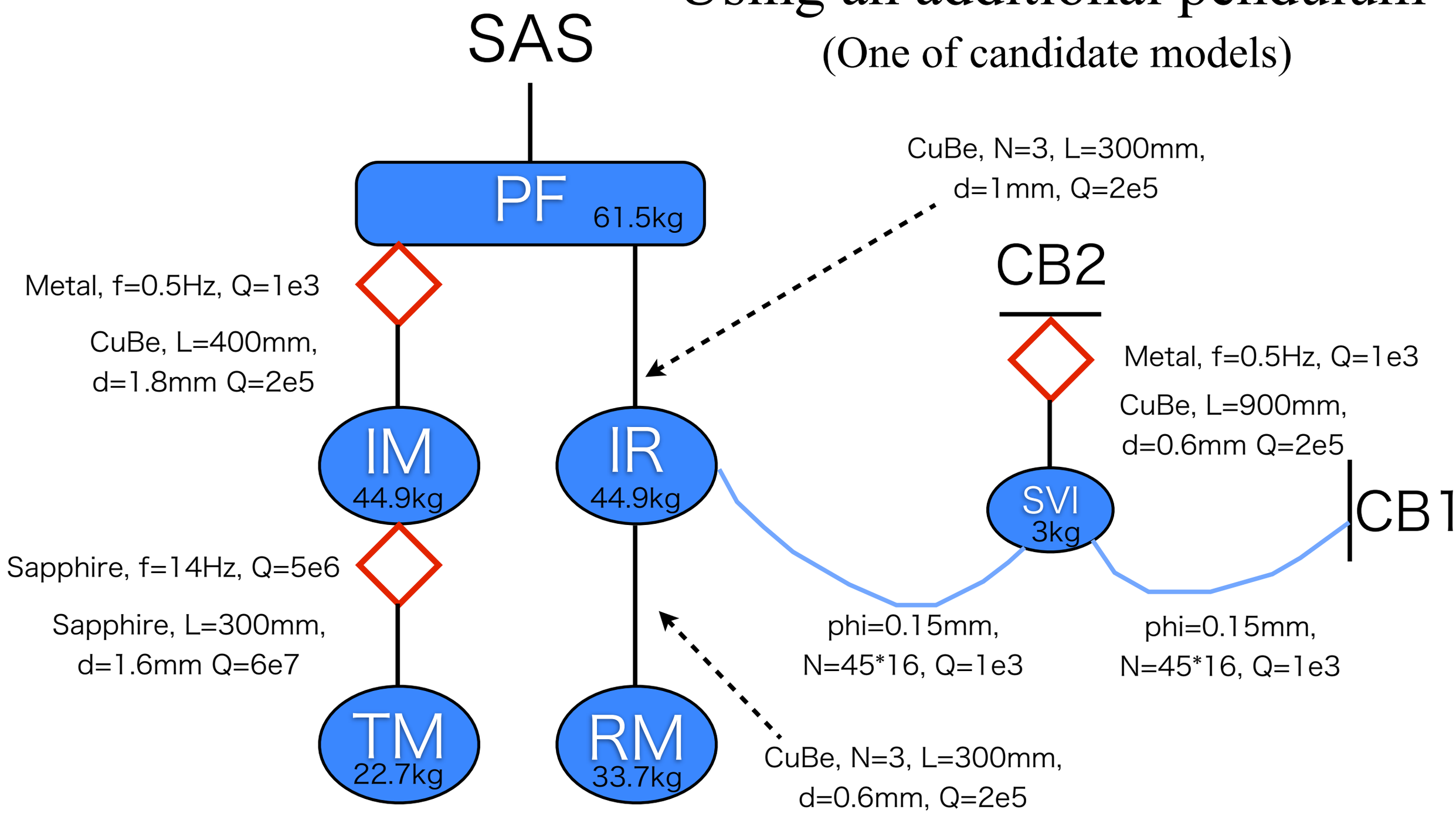
The floor level has big margin.
But the peaks are higher than the design sensitivity around 20Hz.

We need an additional vertical spring.

The impact on the sensitivity of KAGRA

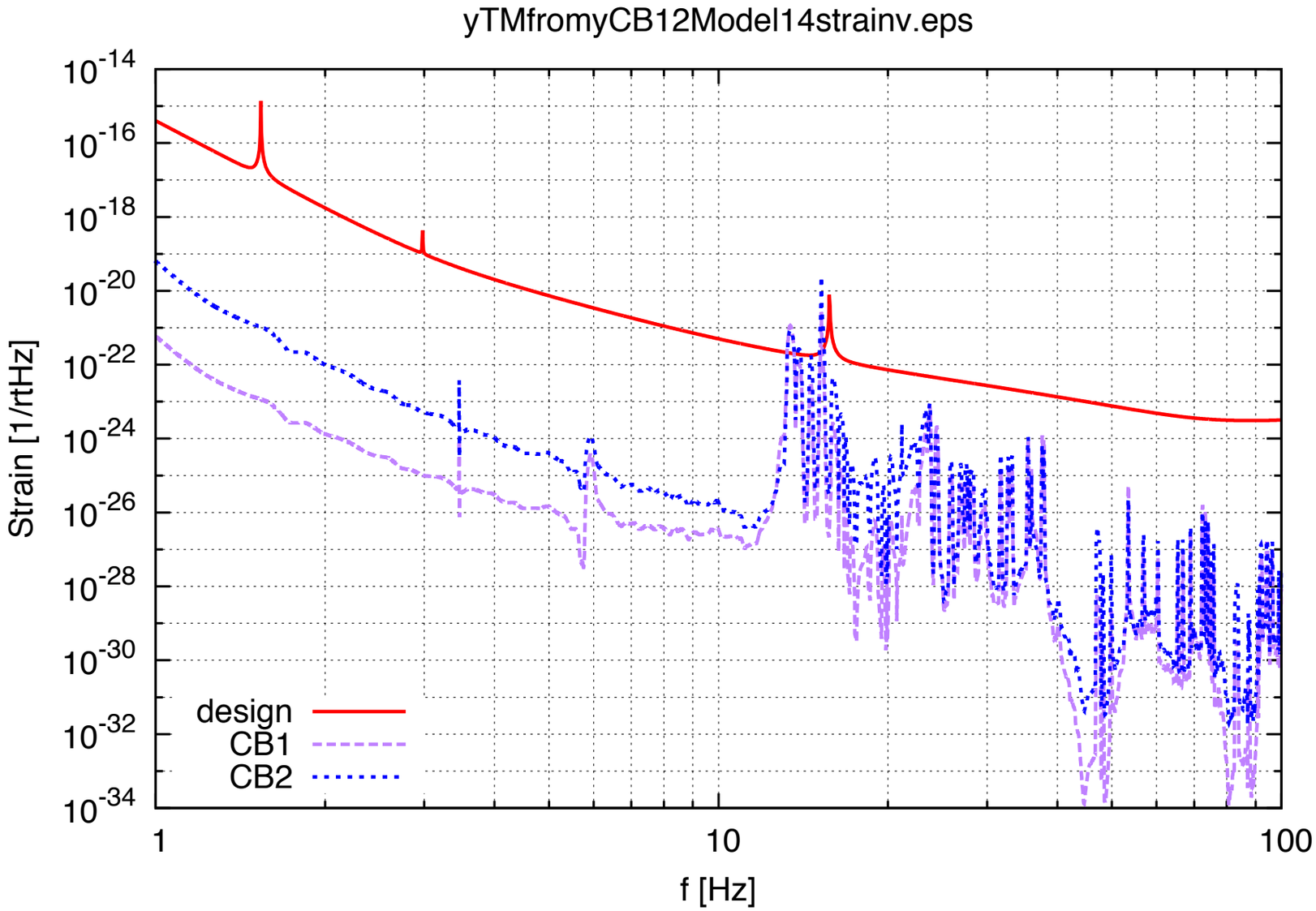
Using an additional pendulum

(One of candidate models)



Yusuke also uses this model to calculate the cooling time.

The impact on the sensitivity of KAGRA
Using an additional pendulum



The additional pendulum can reduce the vibration from the radiation shield.
We will discuss this solution in our group soon.

Summary

- We have measured the vibration in the radiation shield during cooling and at low temperature.
- From the data, we estimated the vibration in the radiation shield at Kamioka.
- In the case of horizontal component, the estimated noise from radiation shield is lower than the requirement. But in the case of vertical component, it is higher.
- We will make an additional pendulum to reduce it.

End