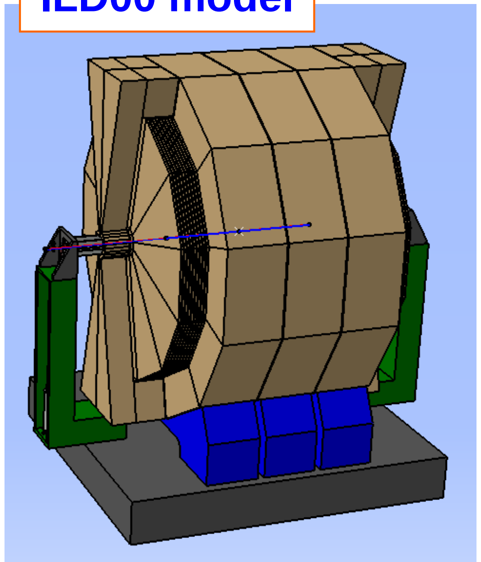
Vibration analysis of the ILD QD0-support system

KEK Hiroshi Yamaoka

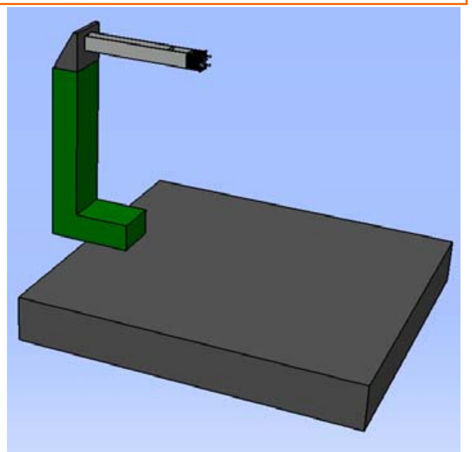
Introduction

Vibration properties of the ILD QD0 support system has been studied.

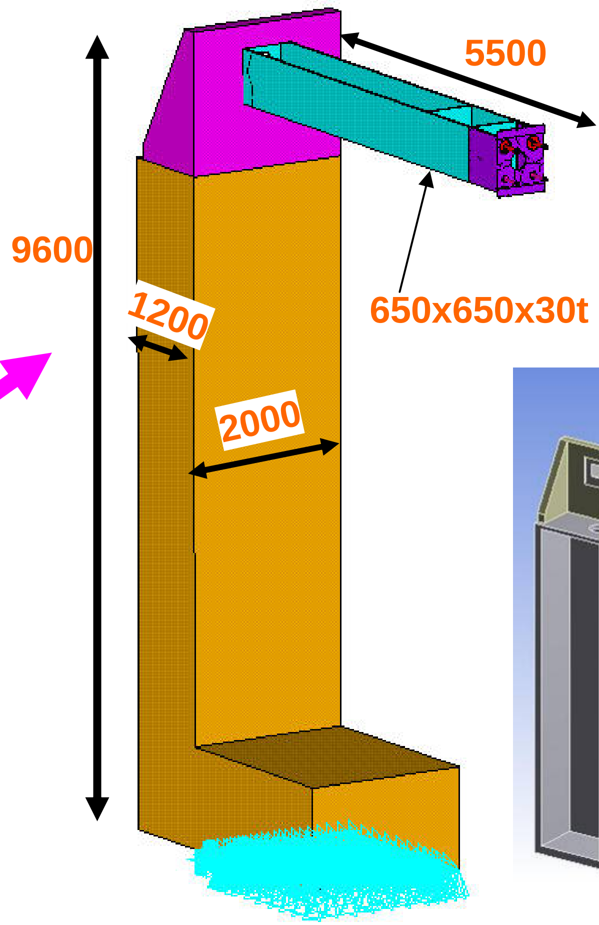
ILD00 model

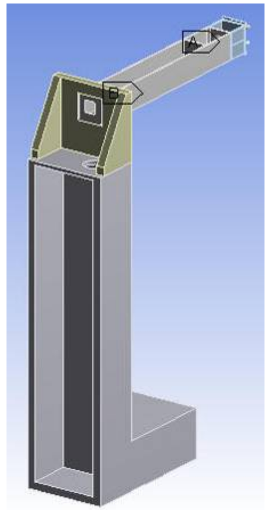


ILD QD0 support system

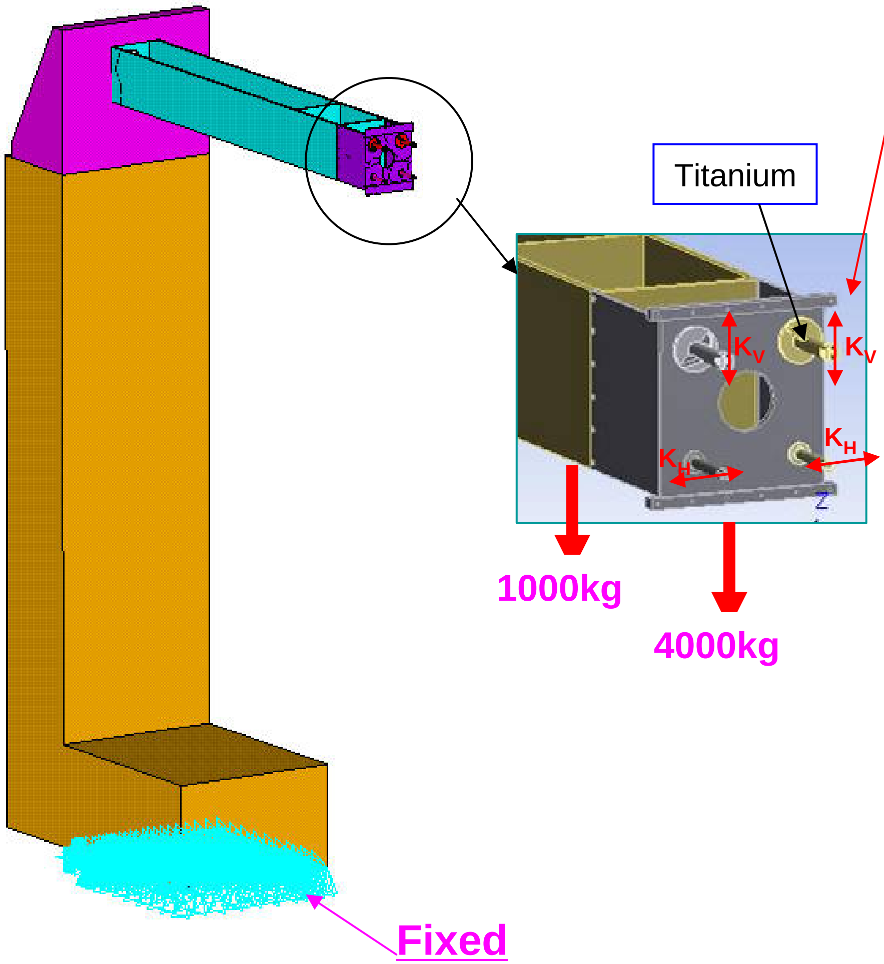


ANSYS model





Assumptions



- Spring constant
- Static loads

are defined.

Calculation of spring constant of the tension rods.

For the modeling of tension rods, spring constants are defined on the top of support rods.

Tension rods; CFRP

E=130GPa

Density: 1.5e-6kg/mm^3

$$\sigma = \varepsilon \cdot E$$

$$P/A = \frac{\Delta l}{l} \cdot E$$

$$P = \frac{\Delta l}{l} \cdot E \cdot A$$

When Δl is $1mm$, P shows the spring constant.

$$P_{vertical} = \frac{1}{3180} \cdot 1.3 \times 10^4 \cdot (50 \times 2)$$

$$= 410kg$$

$K_V = 410\,kg/mm$: Spring constant of the vertical tension rods.

$$P_{horizontal} = \frac{1}{3000} \cdot 1.3 \times 10^4 \cdot \pi (20^2 - 18^2)$$

$$= 1035kg$$

$K_H = 1035\,kg/mm$: Spring constant of the horizontal tension rods.

Approaches to know vibration behavior

Ref.: ANSYS help file

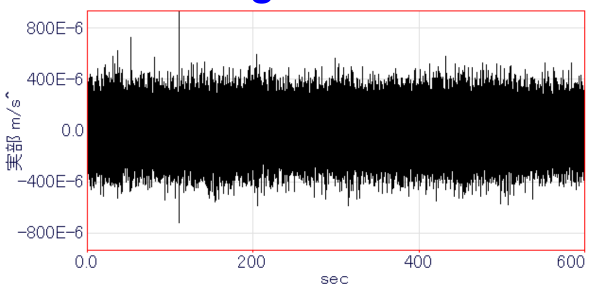
1. P.S.D. (Power Spectrum Density) analysis

A *PSD* is a statistical measure of the response of a structure to random dynamic loading conditions. It is a graph of *the PSD value versus frequency*, where the PSD may be a displacement PSD, velocity PSD, acceleration PSD, or force PSD. Mathematically, the area under a PSD-versus-frequency curve is equal to the variance (square of the standard deviation of the response).

2. Spectrum (SPRS) analysis

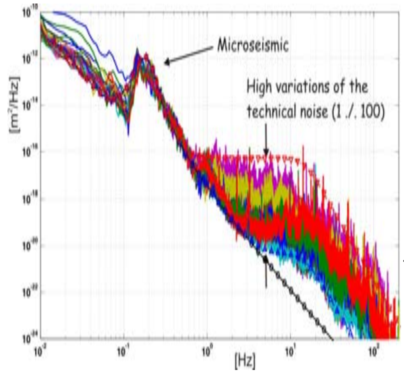
A *response spectrum* represents the *response* of single-DOF systems to a time-history loading function. It is a graph of response versus frequency, where the response might be displacement, velocity, acceleration, or force. Two types of response spectrum analysis are possible: single-point response spectrum and multi-point response spectrum.

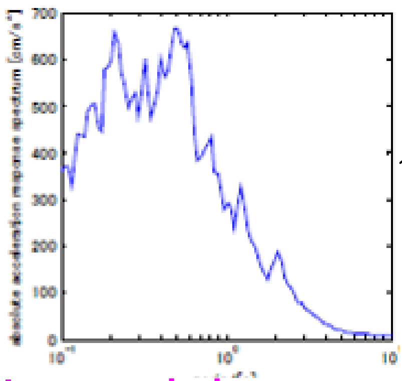
Measure ground motion



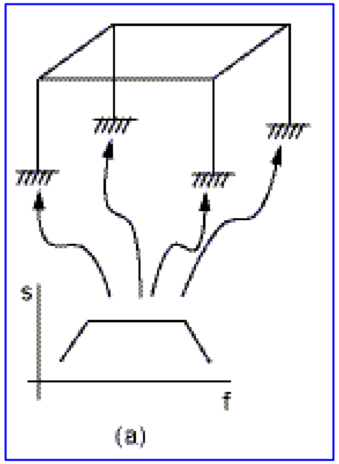
1. P.S.D.

2. Make R. spectrum





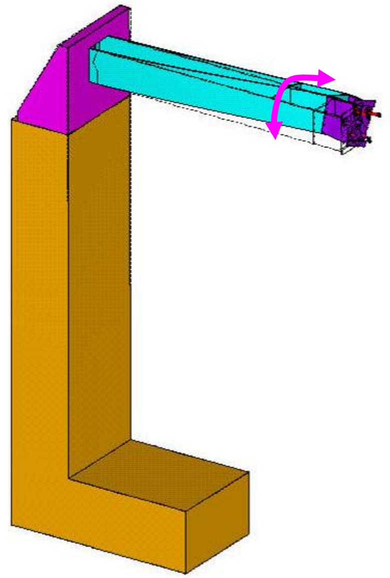
Input each data to constraints positions.



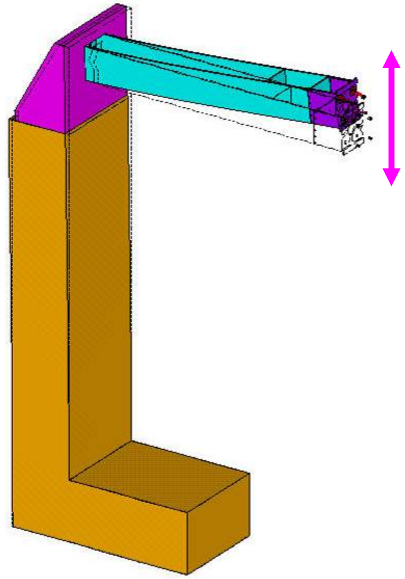
Get respond amplitude/stress at each position.

Natural frequency

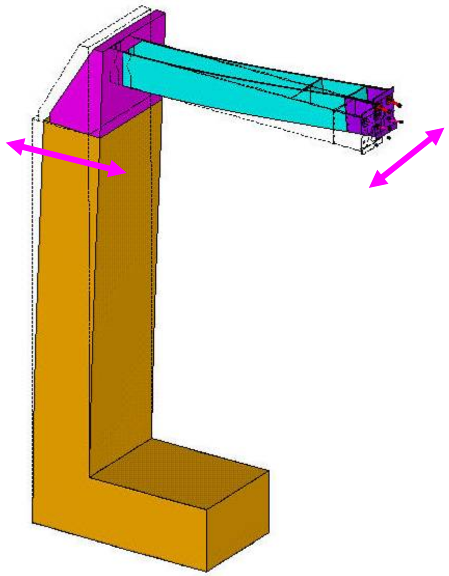
4.5Hz



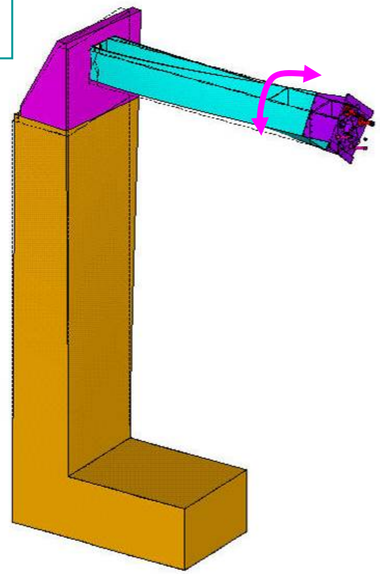
7.9Hz



10.4Hz

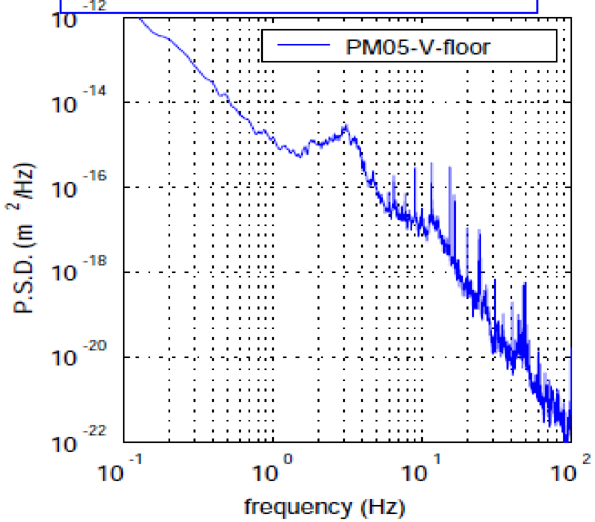


13.6Hz



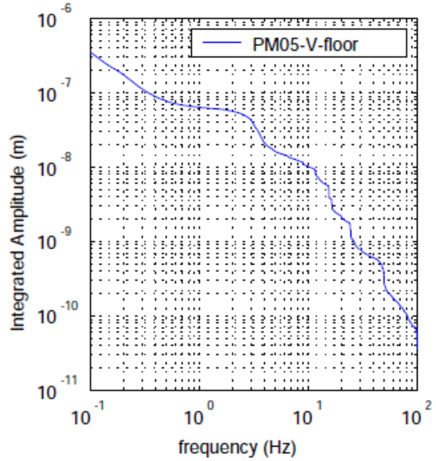
P.S.D. (Power Spectrum Density) analysis

ATF-2004Feb10-17:00UD

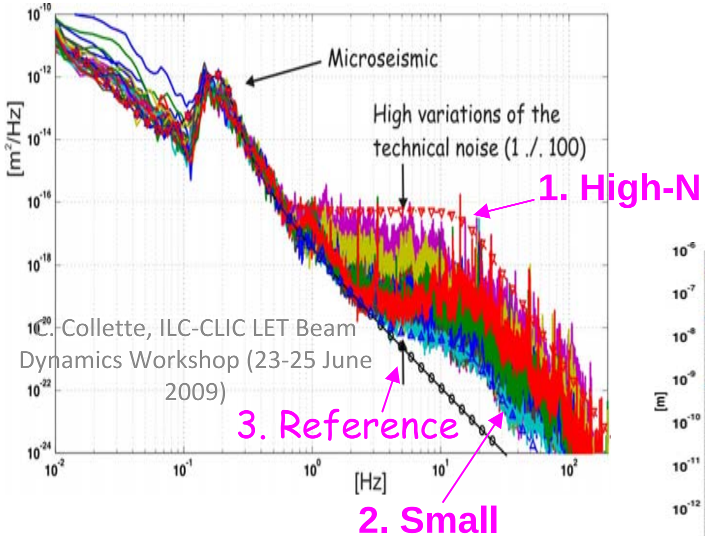


Each P.S.D. data is used.

Freq. (Hz)	P.S.D. (m²/Hz)
0.1	1e-11
0.3	1e-14
0.4	1e-13
1	1e-15
3	1e-14
200	1e-29



Vertical ground motion



1. High-N

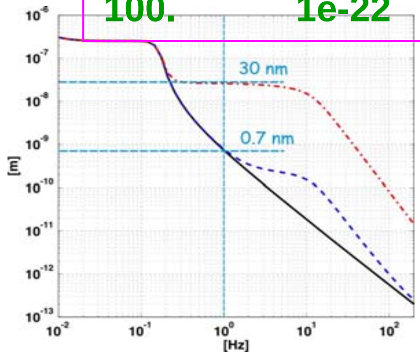
Freq. (Hz)	P.S.D. (m²/Hz)
0.1	1e-14
0.15	1e-12
0.7	8e-17
10.	8e-17
100.	1e-22

2. Small-N

Freq. (Hz)	P.S.D. (m²/Hz)
0.1	1e-14
0.15	1e-12
0.7	8e-17
4.0	1e-20
13.	5e-21
100.	3e-26

3. Reference

Freq. (Hz)	P.S.D. (m²/Hz)
0.1	1e-14
0.15	1e-12
0.7	8e-17
100.	8e-28



Allowable Amplitude
→ 50nm at 5Hz

Calculation results: ***Vertical direction***

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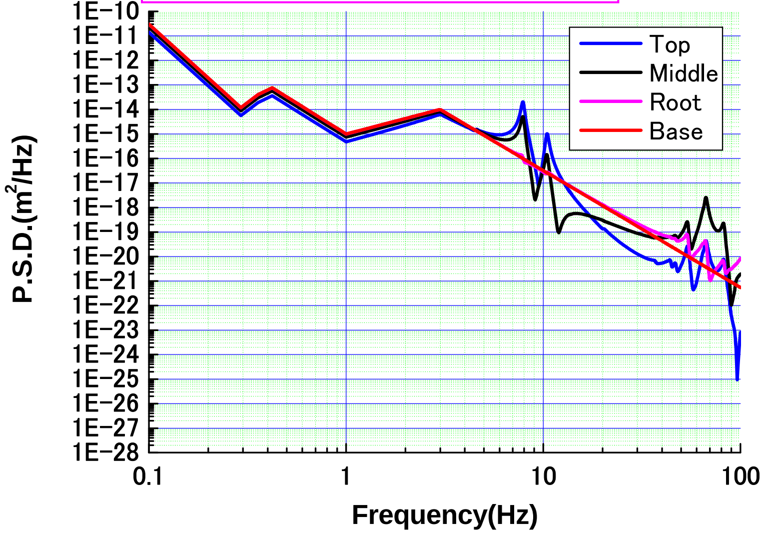
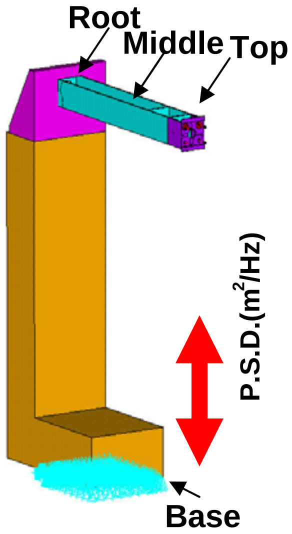
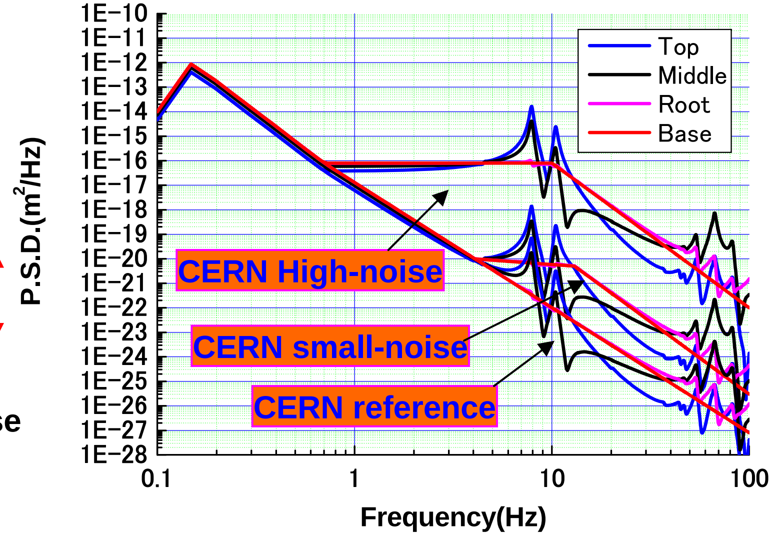
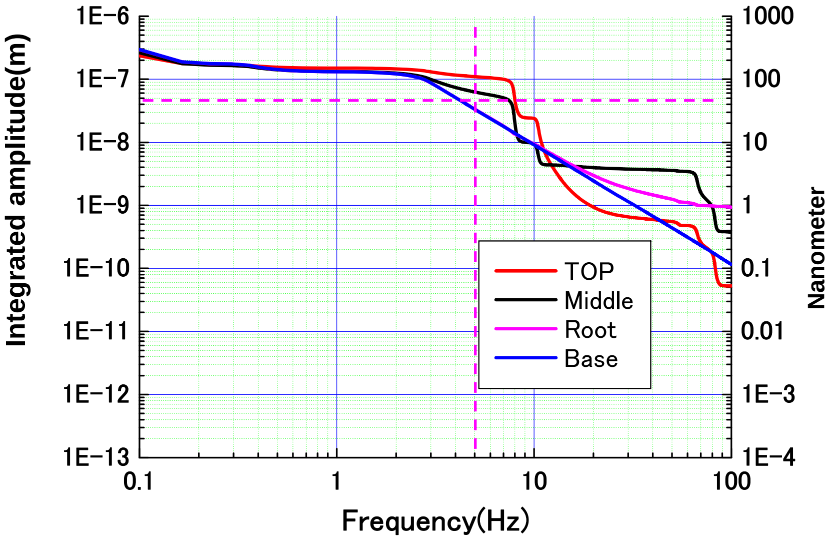
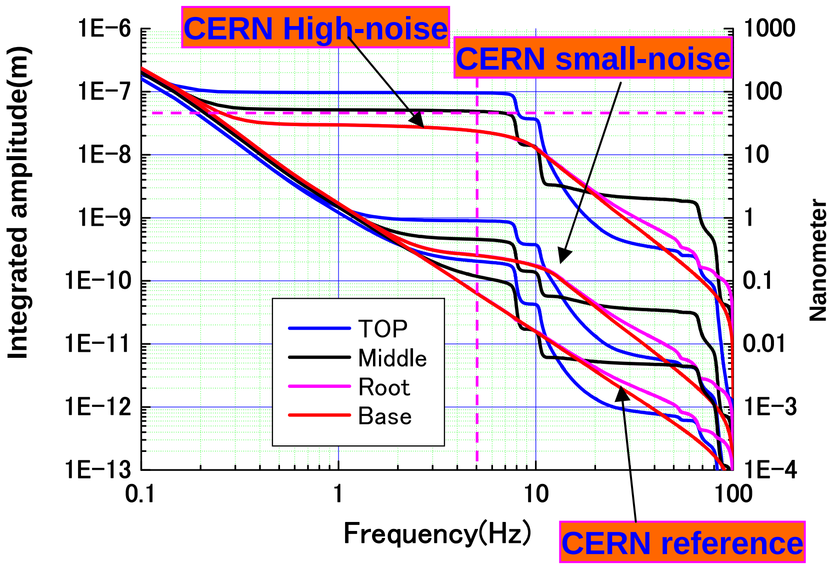




CERN-Data

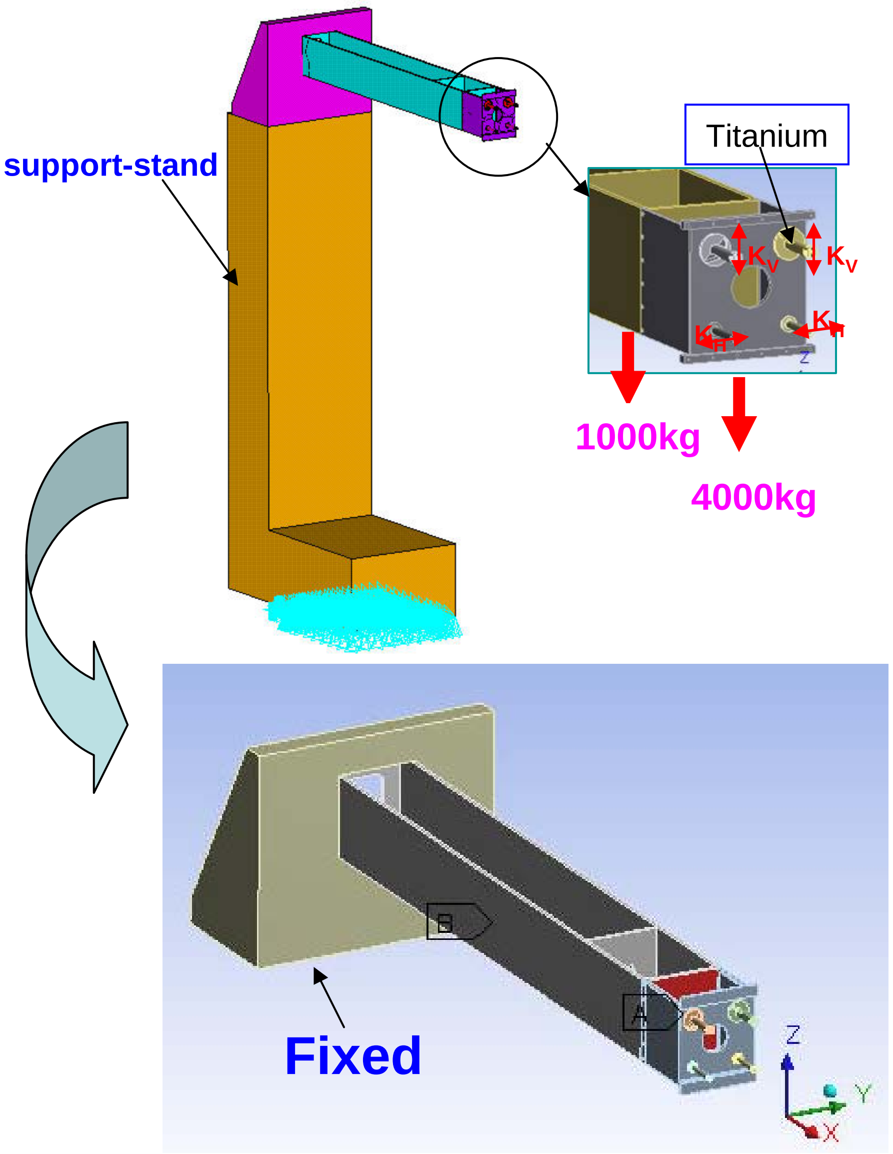


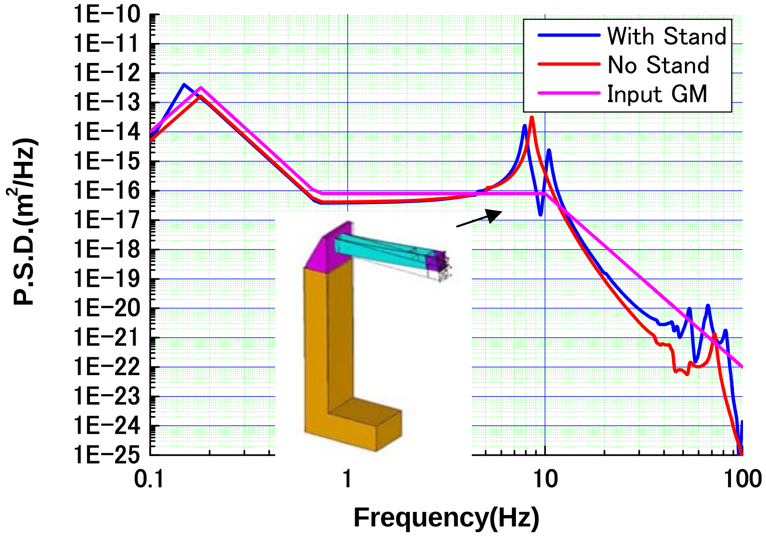


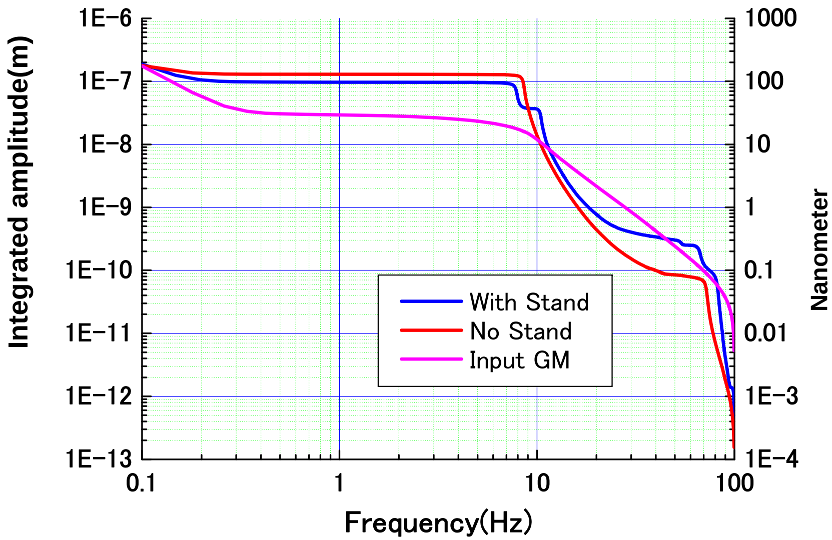


➔ **Integrated amplitude at 5Hz: Larger than 50nm.(ATF, CERN High)**
Much smaller than 50nm(CERN small, Reference)

If the support-stand was removed,





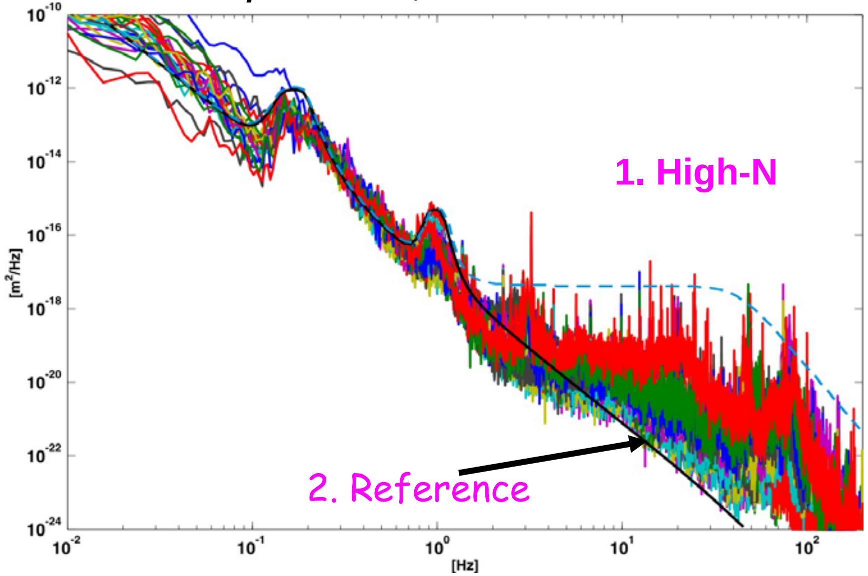


➔ Integrated amplitude at 5Hz: It is not so different.

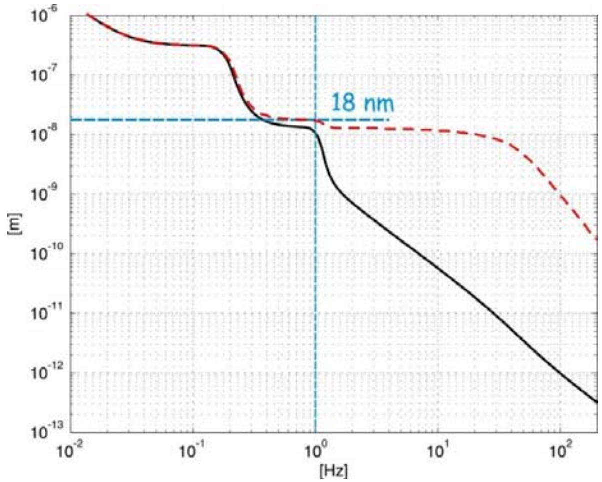
Integrated amplitude at above 10Hz: 'No-support-stand model' is smaller.

Calculation results: *Horizontal direction*

Lateral ground motion



C. Collette, ILC-CLIC LET Beam Dynamics Workshop (23-25 June 2009)



1. High-N

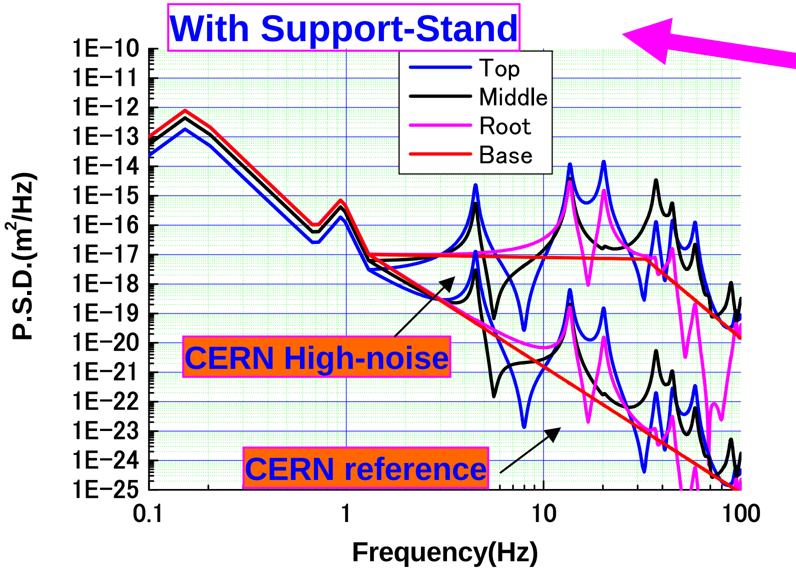
Freq. (Hz)	P.S.D. (m^2/Hz)
0.1	1e-13
0.16	1e-12
0.7	8e-17
0.95	8e-16
1.3	1e-17
33.	7e-18
200.	3e-22

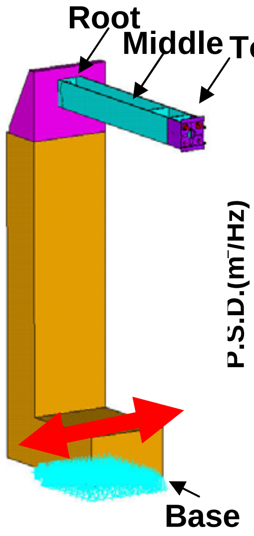
2. Reference

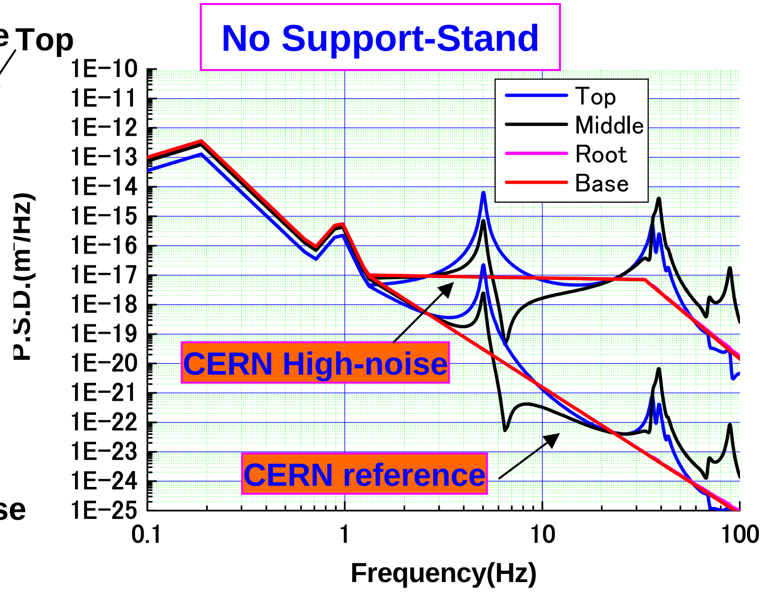
Freq. (Hz)	P.S.D. (m^2/Hz)
0.1	1e-13
0.16	1e-12
0.7	8e-17
0.95	8e16
1.3	1e-17
200.	4e-27

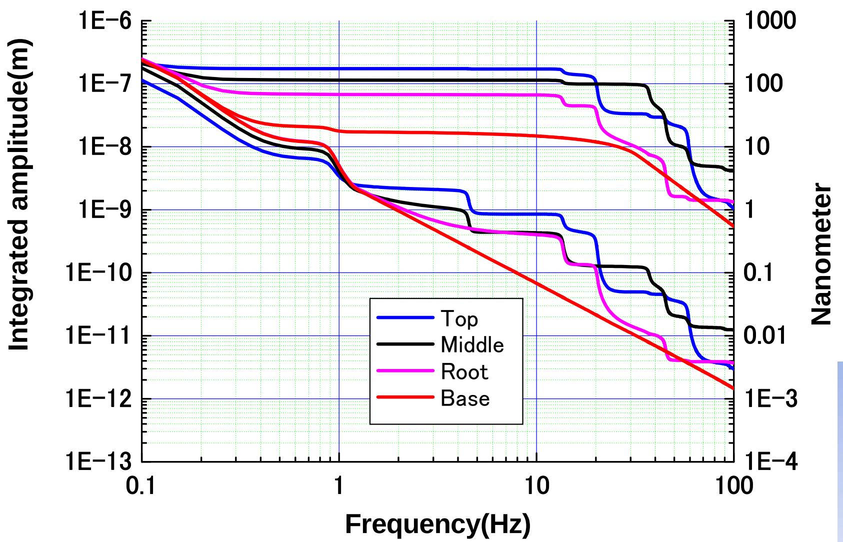
Allowable Amplitude
→ 300nm at 5Hz?

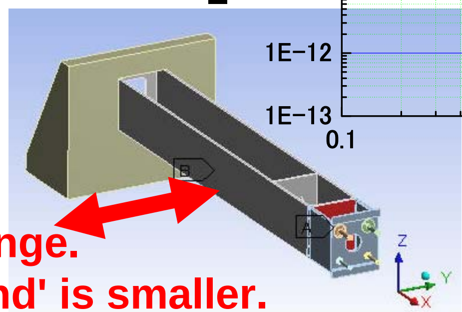
Calculation results: Horizontal direction (Y-direction.)

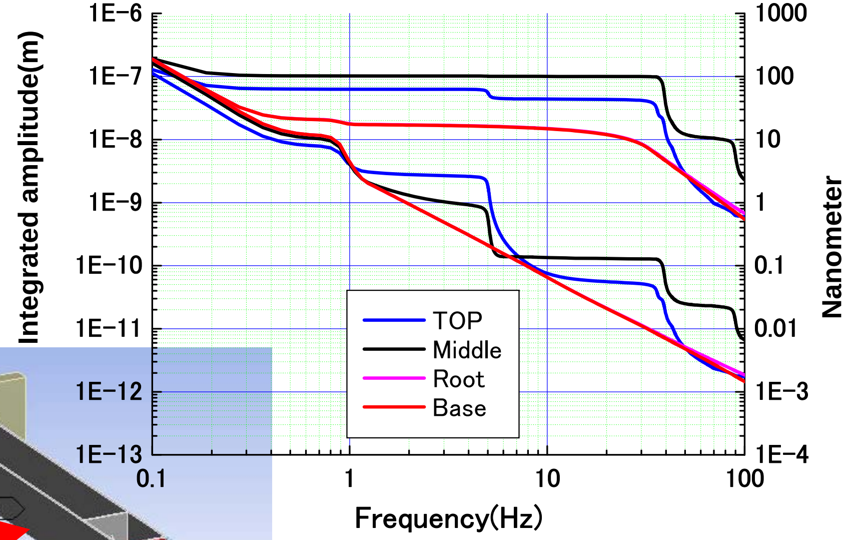






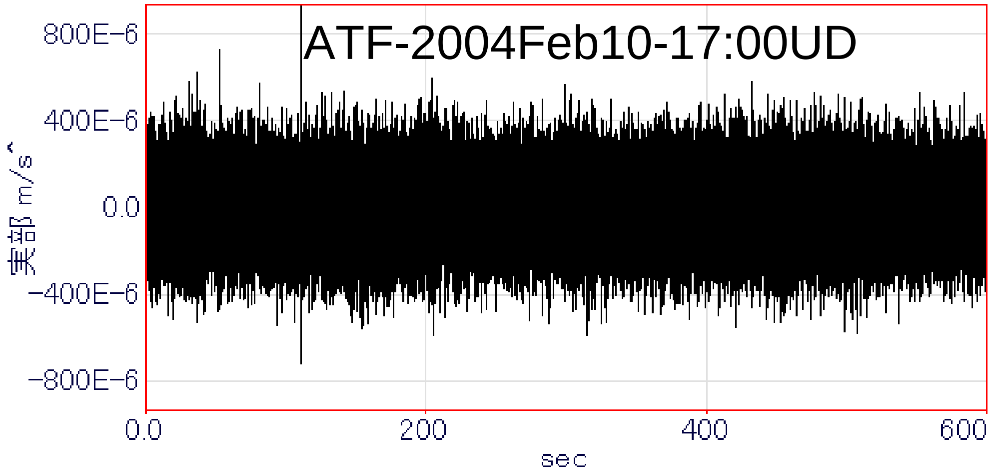




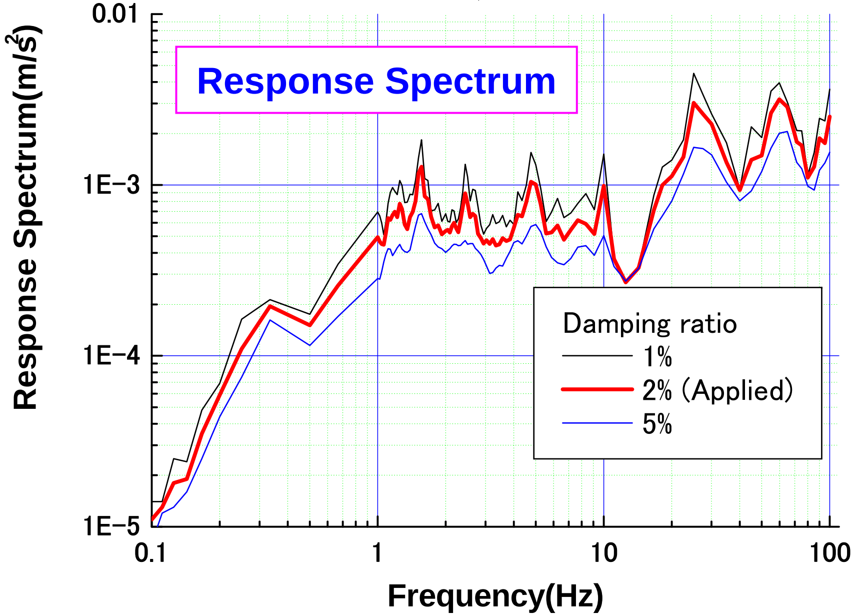


- Integrated amplitude is the allowable range.
- Integrated amplitude at 'no-support-stand' is smaller.
  But it not so drastic improvement.

Spectrum (SPRS) analysis



Make response spectrum



$$m\ddot{x}_i + c\dot{x}_i + kx_i = -m\ddot{z}_i$$

$$m\ddot{x}_{i+1} + c\dot{x}_{i+1} + kx_{i+1} = -m\ddot{z}_{i+1}$$

$$x_i, \dot{x}_i, \ddot{x}_i, \ddot{z}_{i+1}, dt = t_{i+1} - t_i$$

$$\ddot{x}_{i+1} = -\frac{\ddot{z}_{i+1} + 2h\omega\left(\dot{x}_i + \frac{1}{2}\ddot{x}_i dt\right) + \omega^2\left(x_i + \dot{x}_i dt + \left(\frac{1}{2} - \beta\right)\ddot{x}_i dt^2\right)}{1 + h\omega dt + \beta\omega^2 dt^2}$$

$$\dot{x}_{i+1} = \dot{x}_i + \frac{1}{2}(\ddot{x}_i + \ddot{x}_{i+1})dt$$

$$x_{i+1} = x_i + \dot{x}_i dt + \left(\frac{1}{2} - \beta\right)\ddot{x}_i dt^2 + \beta\ddot{x}_{i+1} dt^2$$

$$i = i + 1$$

図4.22　Newmarkの β 法

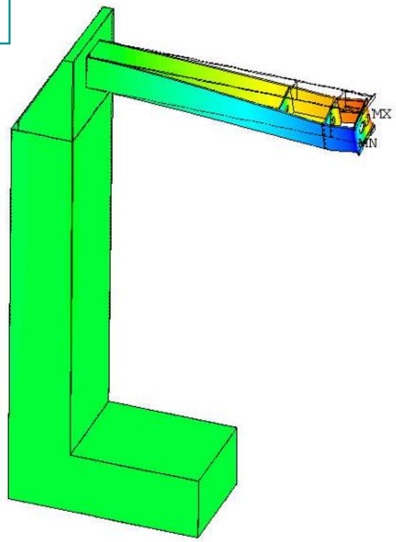
These spectrum are applied.

0.1Hz	1e-5m/s^2
1Hz	6e-4m/s^2
10Hz	6e-4m/s^2
100Hz	2e-3m/s^2

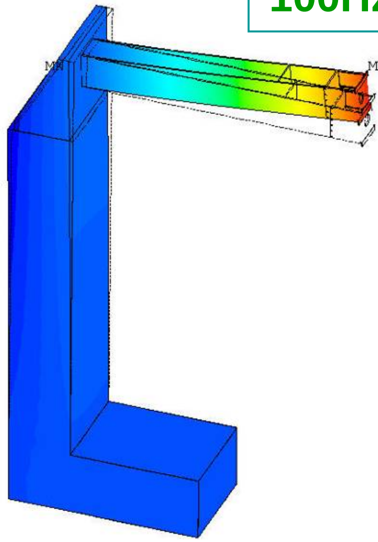
Results: Responded amplitude at each resonance.

@ KEK-ATF	
0.1Hz	1e-5m/s^2
1Hz	6e-4m/s^2
10Hz	6e-4m/s^2
100Hz	2e-3m/s^2

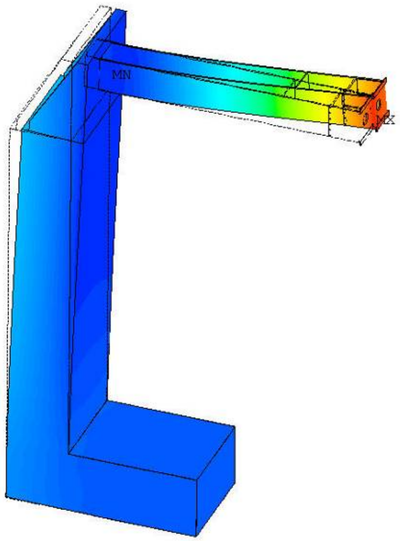
4.5Hz
1.5nm



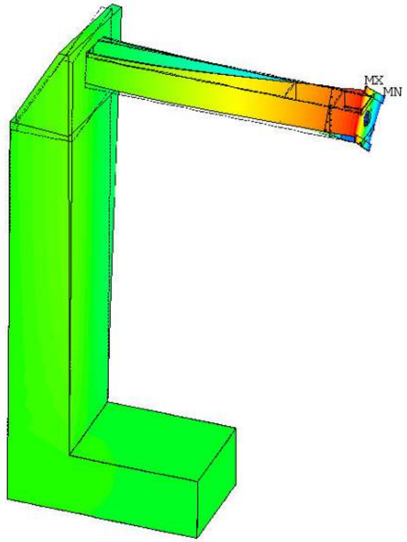
7.9Hz
240nm



10.4Hz
50nm



13.6Hz
0.3nm



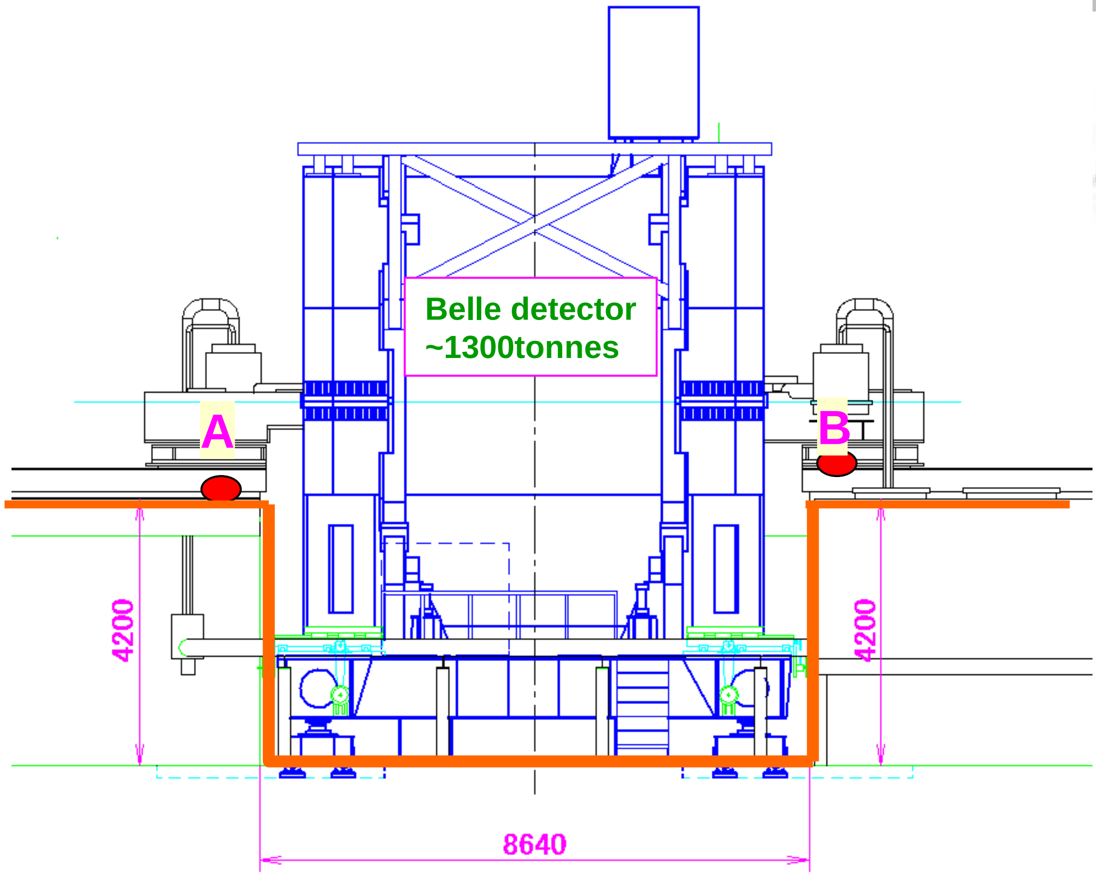
Coherency measurement at KEKB-tunnel

Measurement: A

How is the coherency between the position-A and B?
These two points keep coherency??

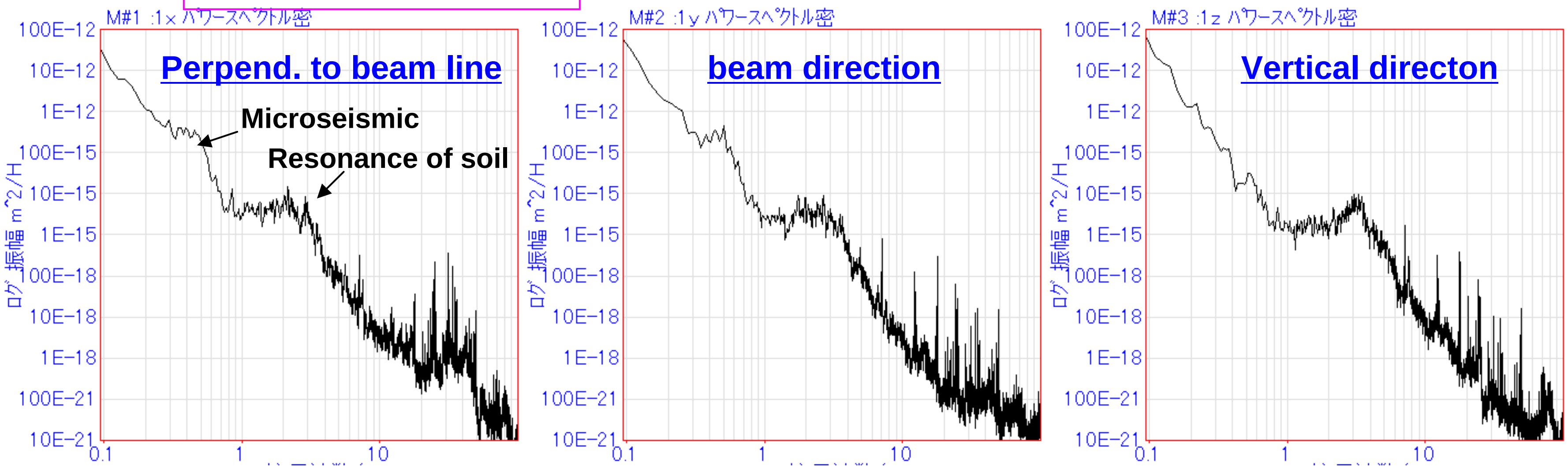
Servo Accelerometer MG－102	Tokkyokiki Corp.
Size	40×40×50mm
Max. input	±2G
Resolution	1／10^6G

Acc. 0.1～400Hz
Acc. 60dB = 1gal/V

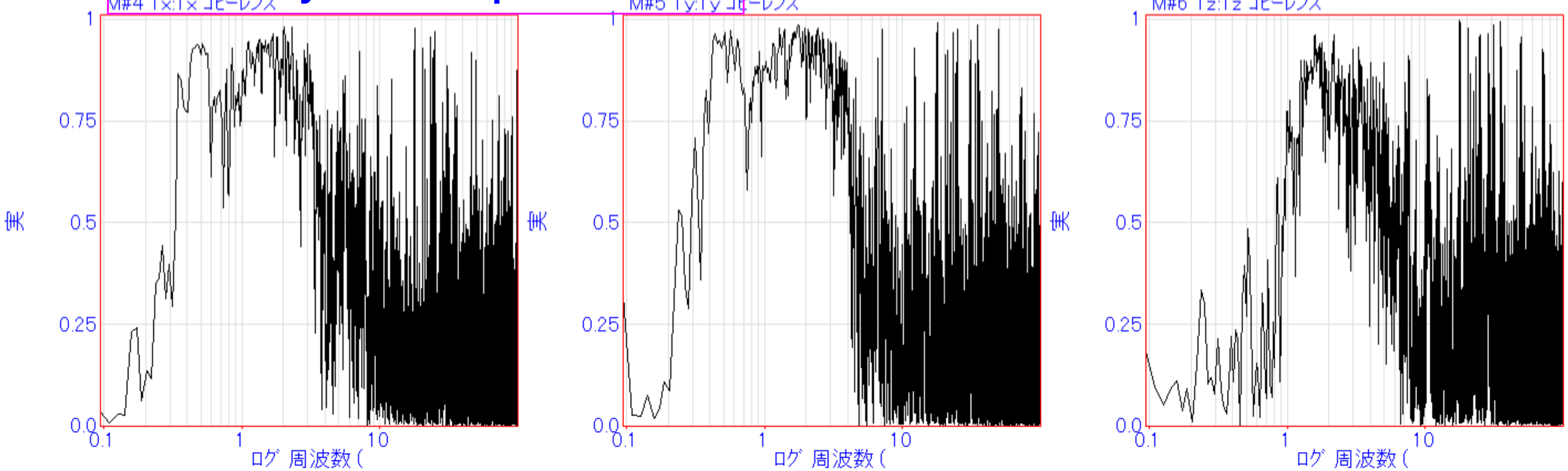


Results

P.S.D. at position-B.



Coherency between position-A/B.

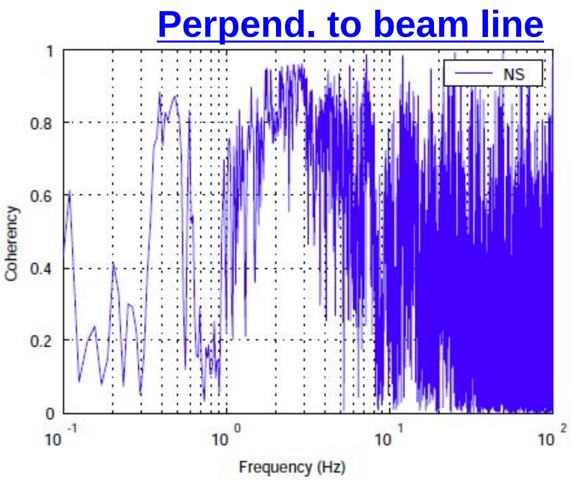


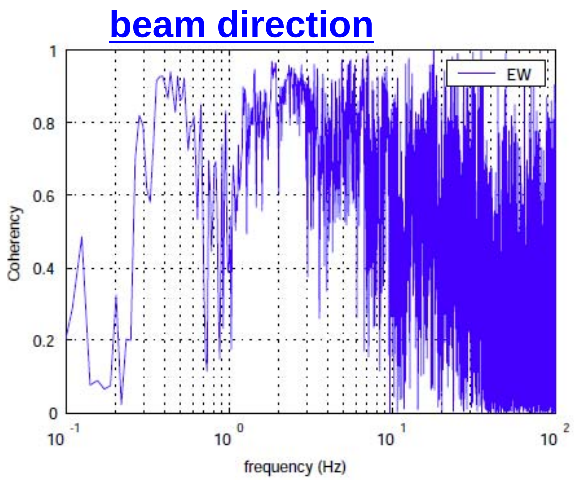
➔ It seems that there is no coherency between two positions.

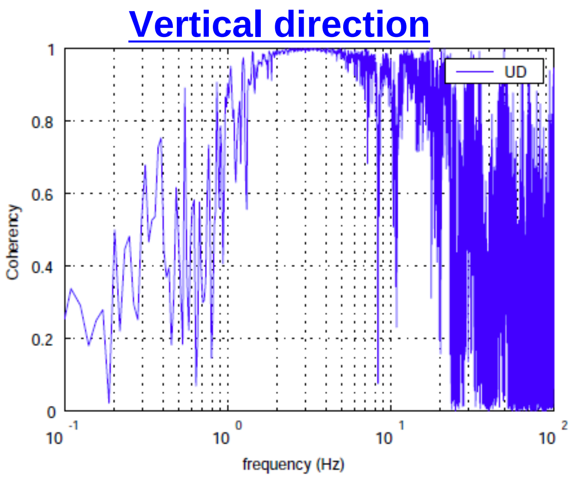
Except for the frequency of microseismic(0.XHz) and resonance of soil(~3Hz).

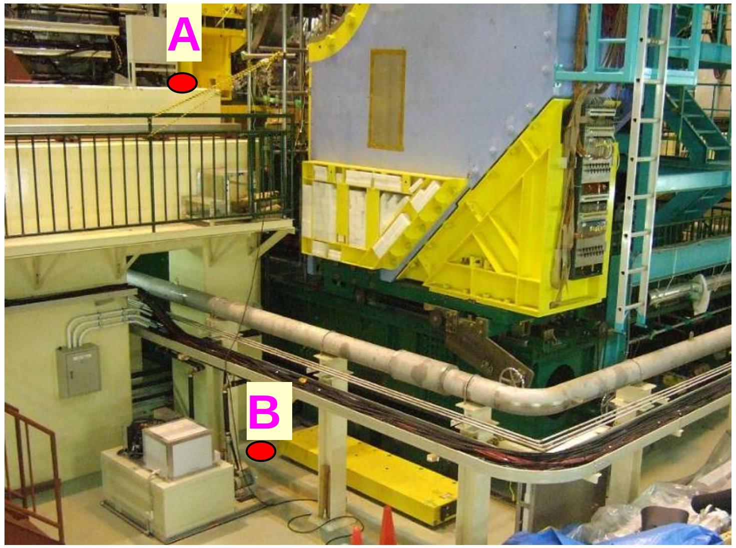
Measurement: B

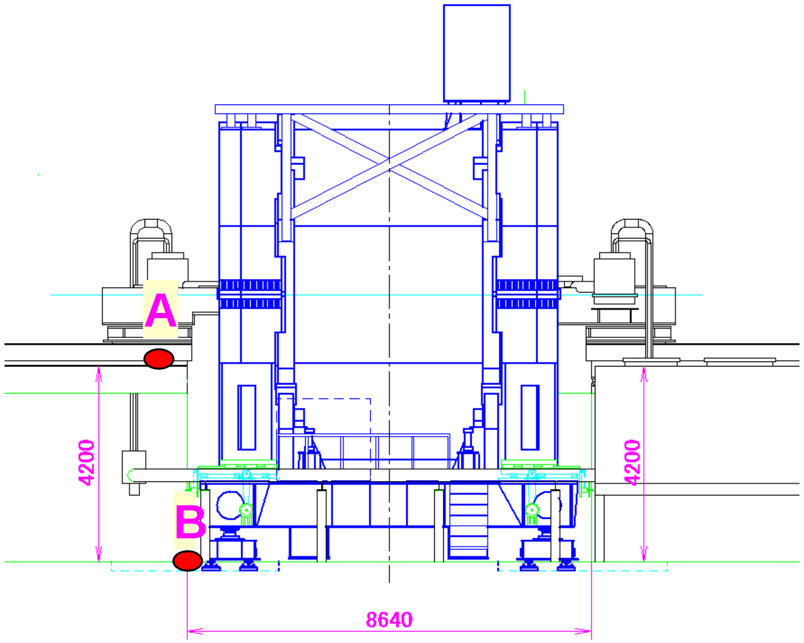
How is the coherency between the tunnel and floor?









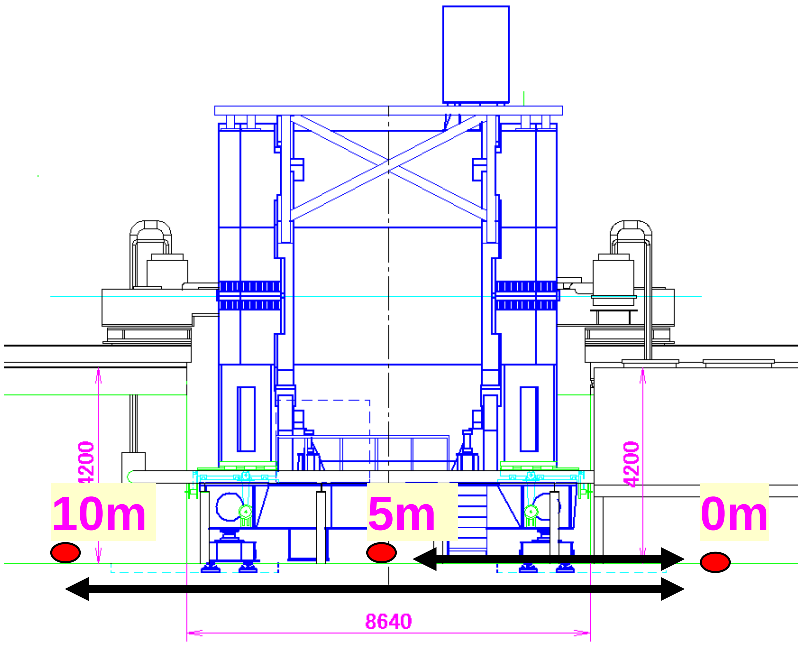


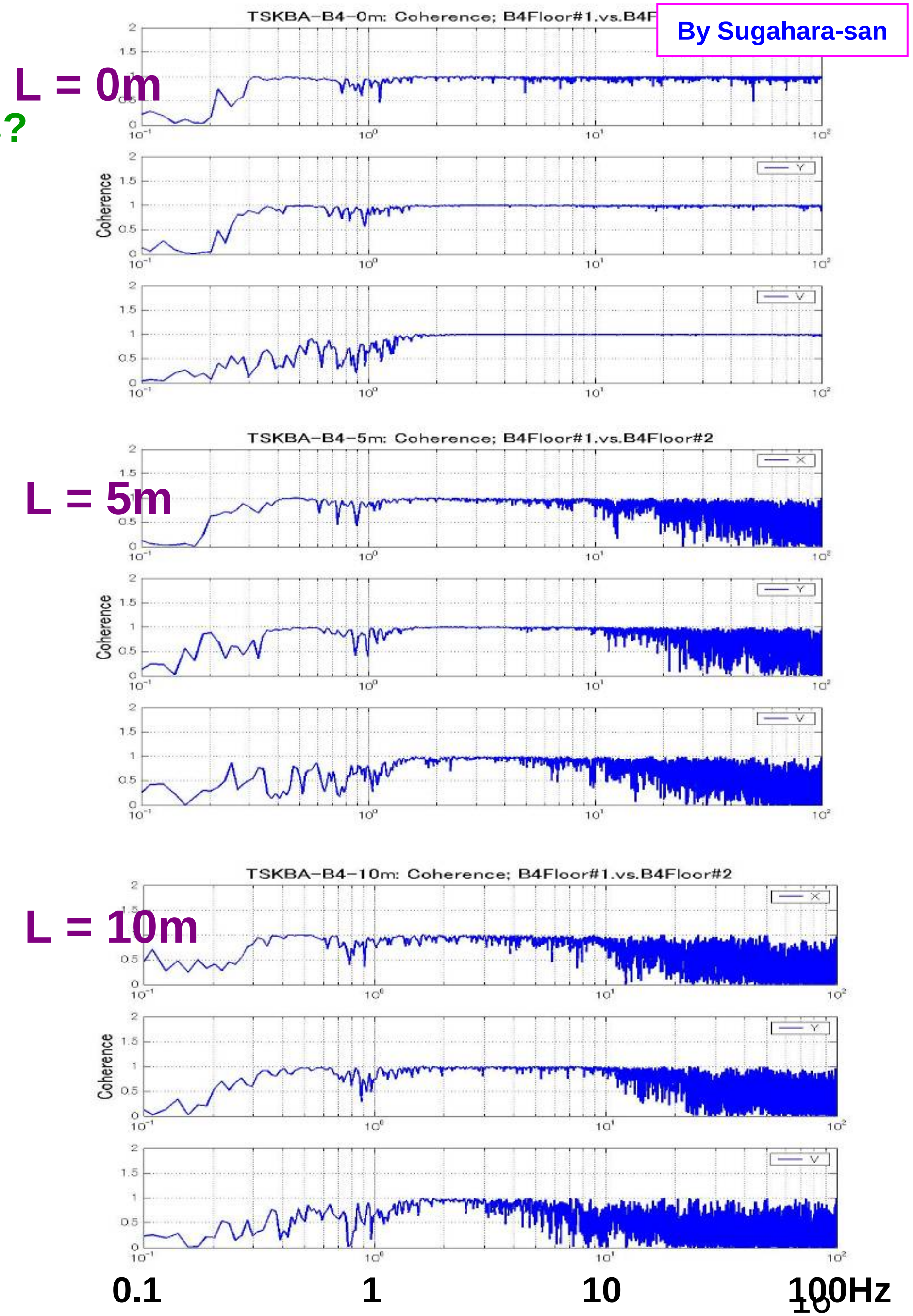
- Horizontal dir.: 0.~Hz, ~3Hz
- Vertical dir.: 1 ~ 20Hz

Measurement: C

How is the coherency between two positions?

Measure: Distance dependency.





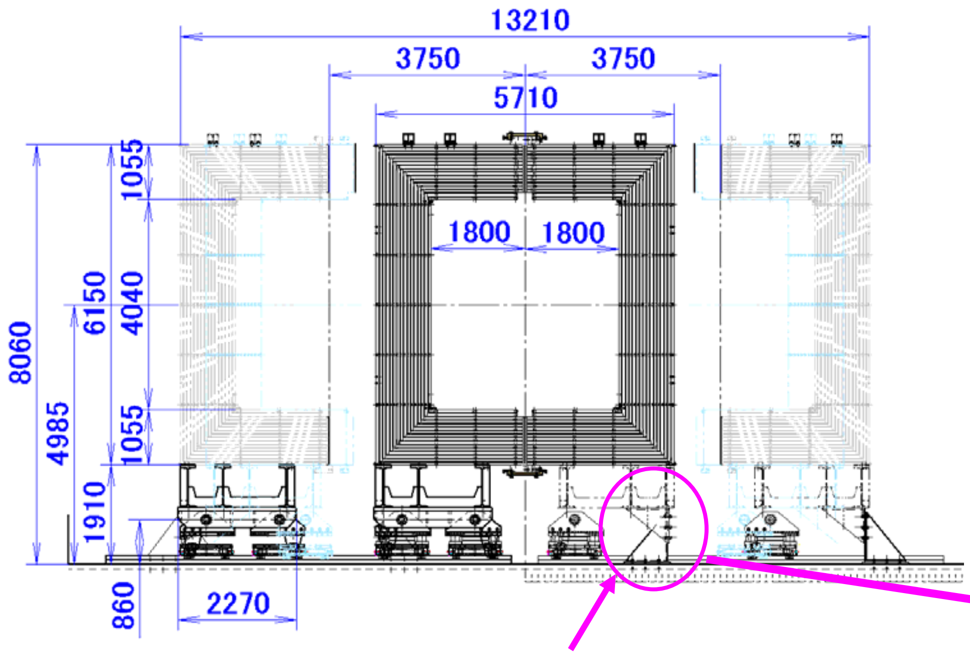
- Coherency: >10Hz is getting worse.
- Vertical dir.: <1Hz is bad.

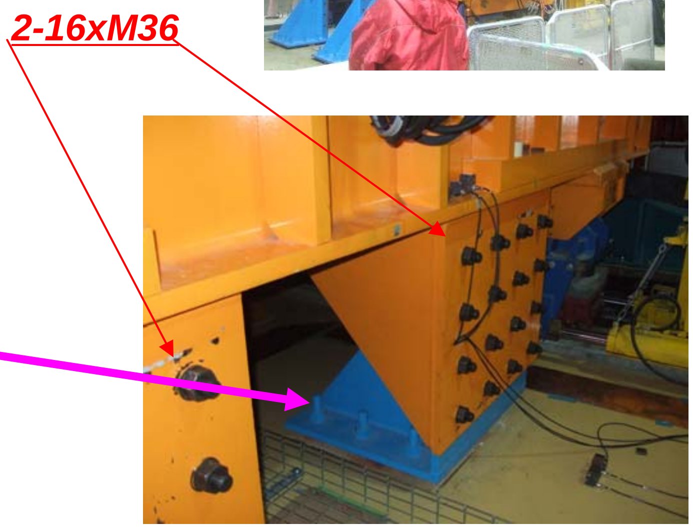
Investigations of efficiency of detector support structure

- Detector should be fixed to the floor?? or,
  Is it enough to just placed it on the floor??

➔ Difference of vibration properties between fixed and un-fixed the yoke to the support bracket were measured.

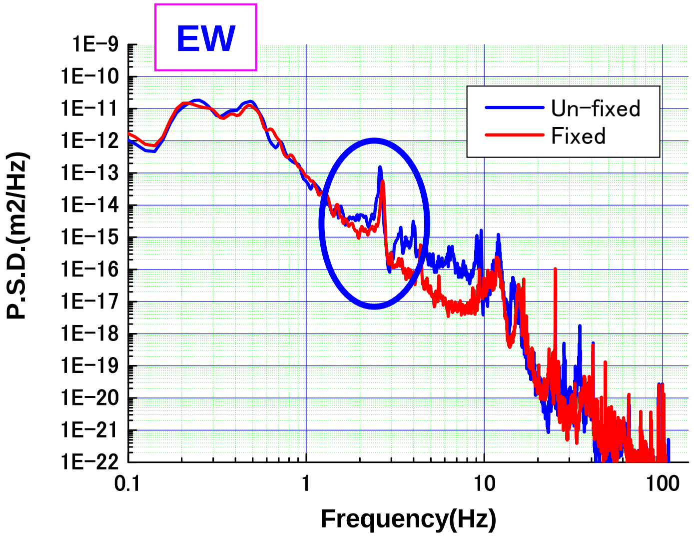
ND280 detector (Total: 1100tonnes)

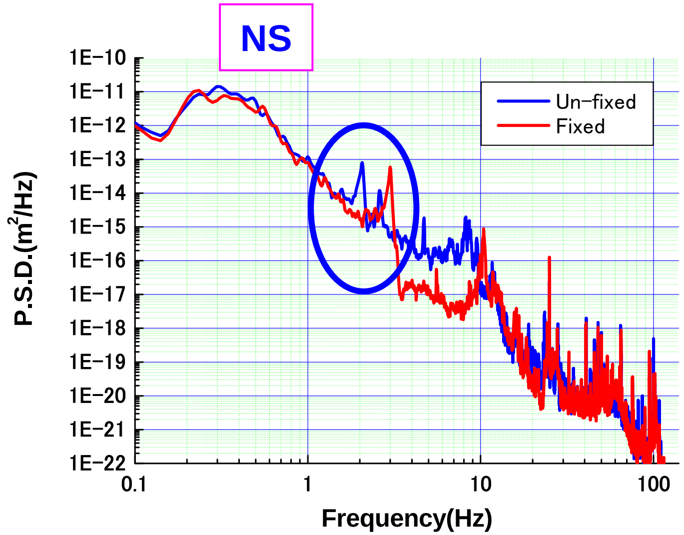


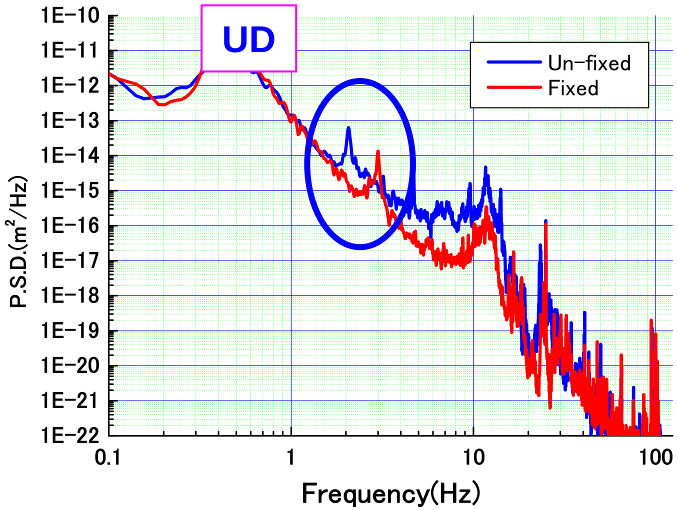


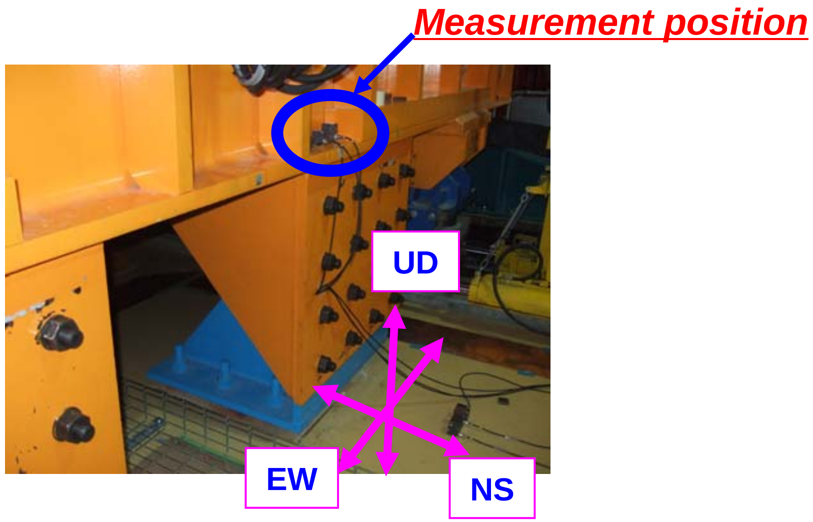
- The ND280 detector is fixed to the support-brackets with ***2-16xM36 thread bolts***.
- The support bracket is designed to withstand against ***0.5G seismic force***.

Results









→ - Natural frequency after fixed to the bracket is increased to ~1Hz(NS, UD).
- P.S.D. is reduced because natural frequency is increased.

→ Support stiffness is increased.

→ It is not so big different but it's efficient to use the support-brackets.

Conclusions

- Vibration behavior for the ILD QD0 support system was studied.
  Measurement data of ATF/CERN were input.
  Integrated amplitude of the support system was calculated.

➔ Integ. amplitude in case of ATF and CERN high-noise are larger than 50nm at 5Hz.

- Coherency between long distance(~5m, ~10m) was measured.

➔ Good coherency was measured only the frequency around microseismic(~0.XHz) and resonance of soil(~3Hz).
  Coherency below 1Hz is bad in the vertical direction.
Measurement data is still in progress of analysis...

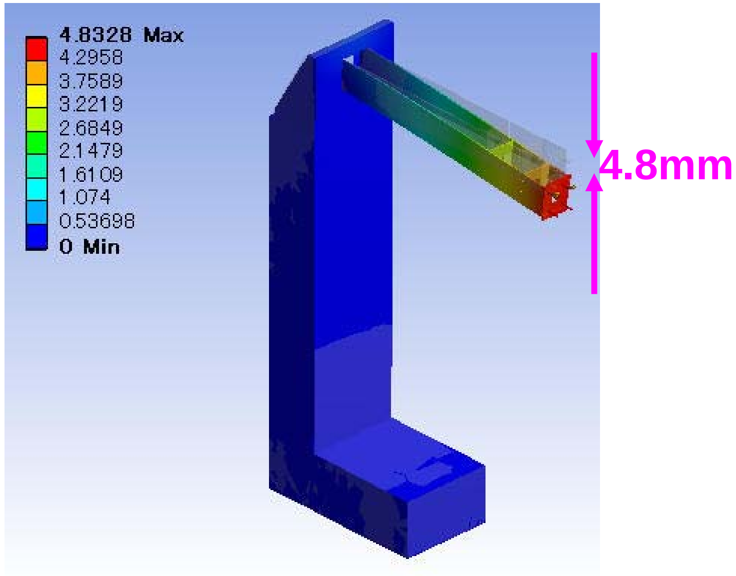
- Efficiency of support structure was investigated with the ND280 detector.
  ~ Natural frequency is ~1Hz increased after fixed the detector.
  P.S.D. is decreased because of increasing of natural frequency

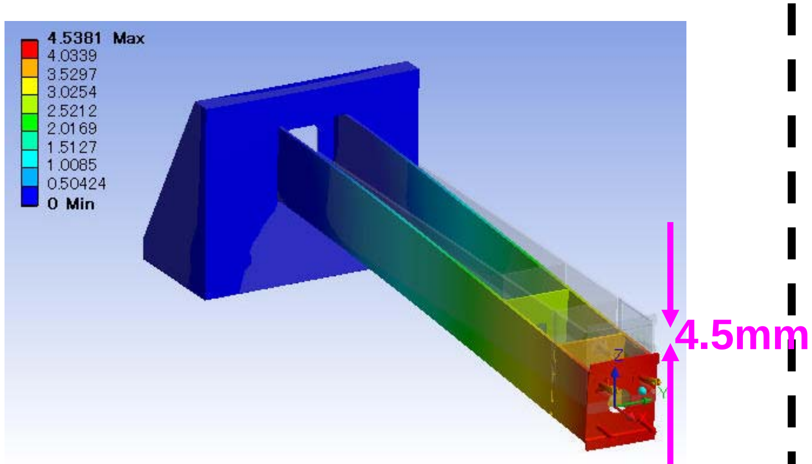
➔ Support stiffness of the detector is increased. So the support structure is efficient.

END

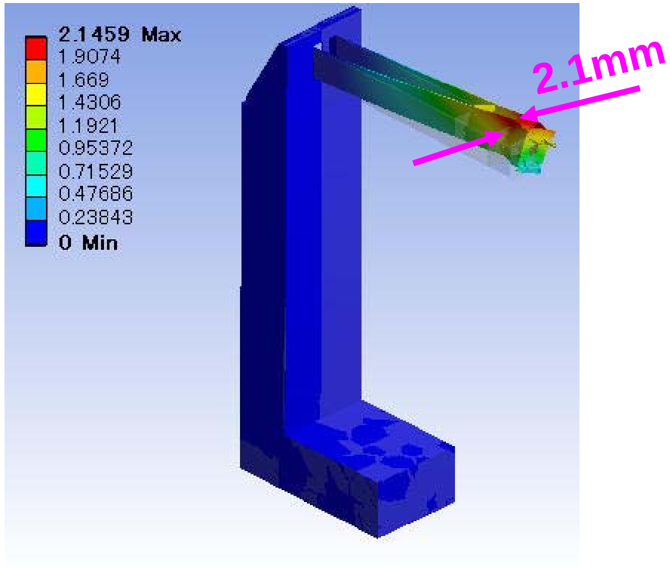
Static analysis

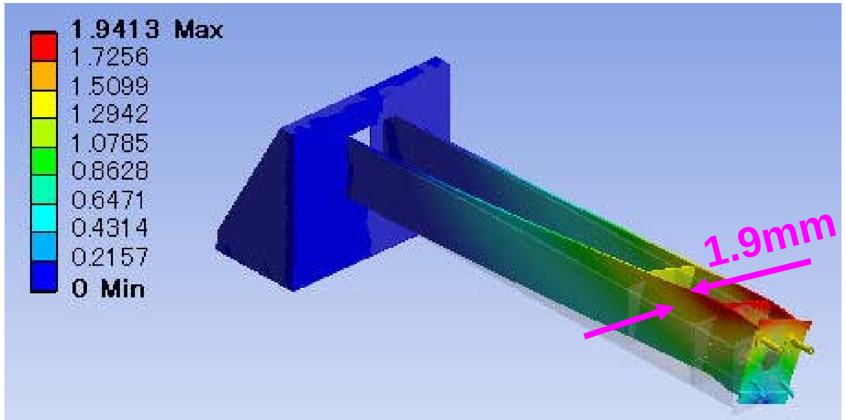
Vertical direction



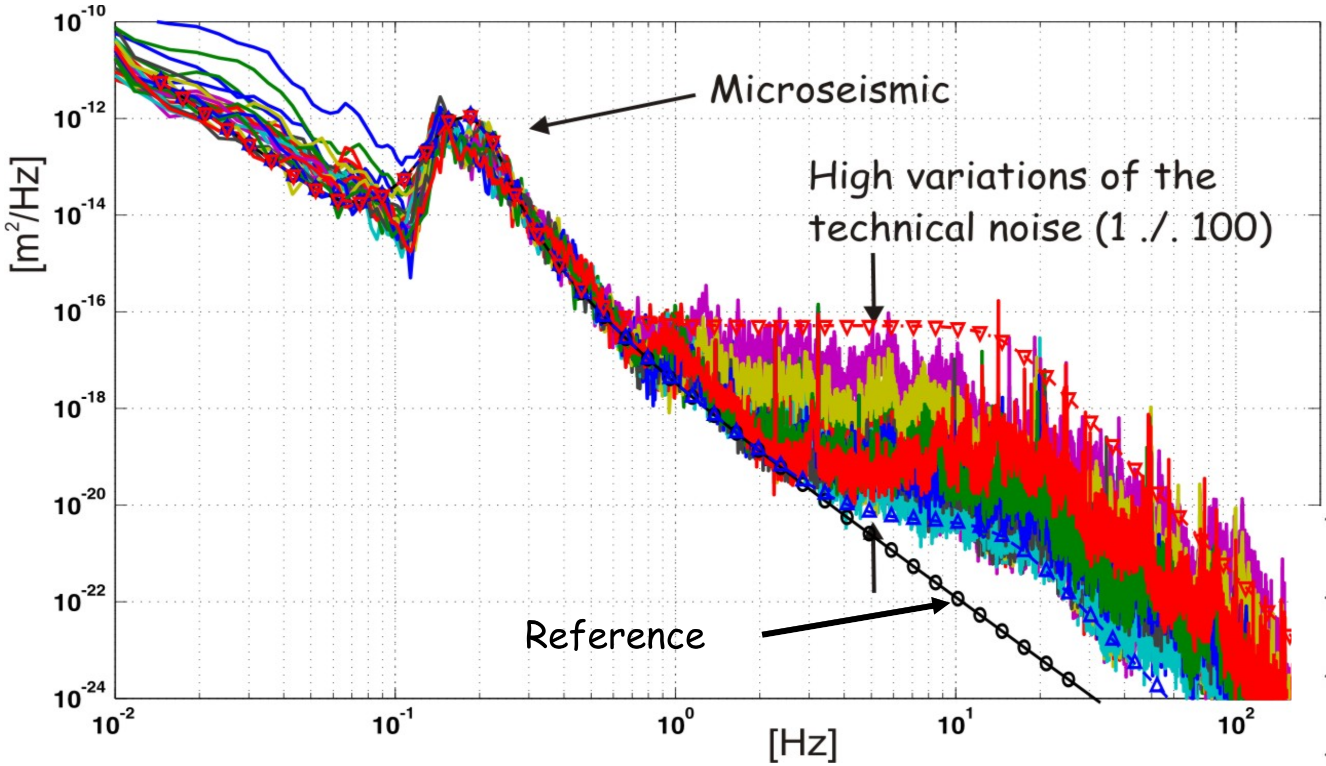


Horizontal direction(0.15G)





Local excitations Vertical ground motion



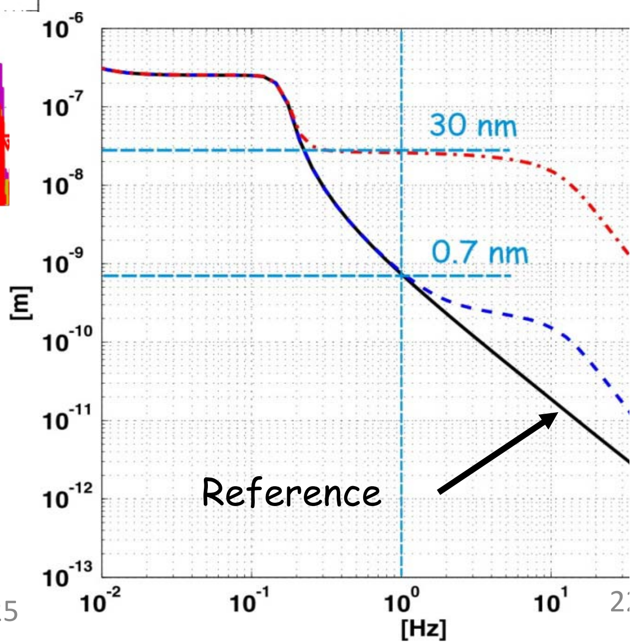
Additional technical noise:

$$N(\omega) = \frac{N_0}{1 + (\frac{\omega}{\omega_0})^6}$$

$$f_0 = 2\pi(Hz)$$

Low technical noise: $N_0 = 5 * 10^{-3} (nm^2/Hz)$

High technical noise: $N_0 = 50 (nm^2/Hz)$

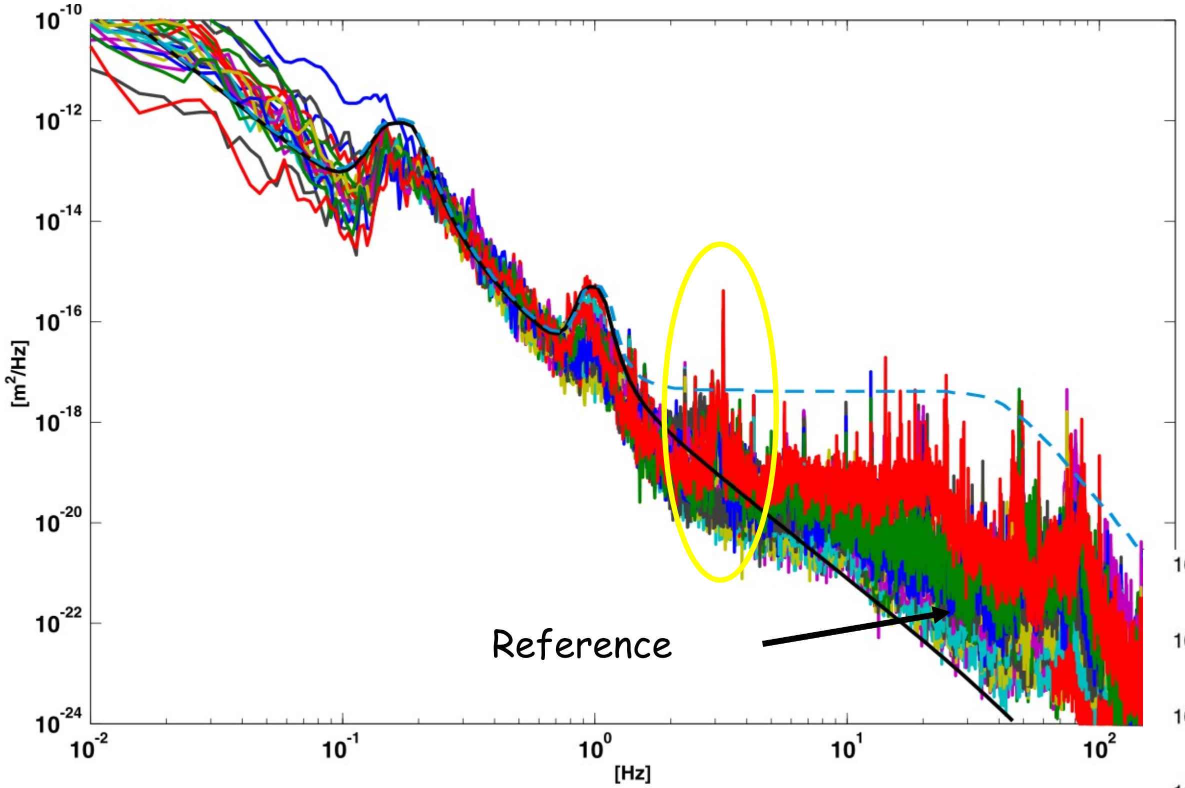


Ref. : $A = 10^{-4}\ (\mu m^2 s^{-1} m^{-1}); B = 10^{-4}\ (\mu m^2 s^{-3});$

$\omega_1 = 2\pi * 0.14\ (rad/s); d_1 = 5; a_1 = 0.1\ (\mu m^2/Hz); v_1 = 1000\ (m/s)$

Local excitations

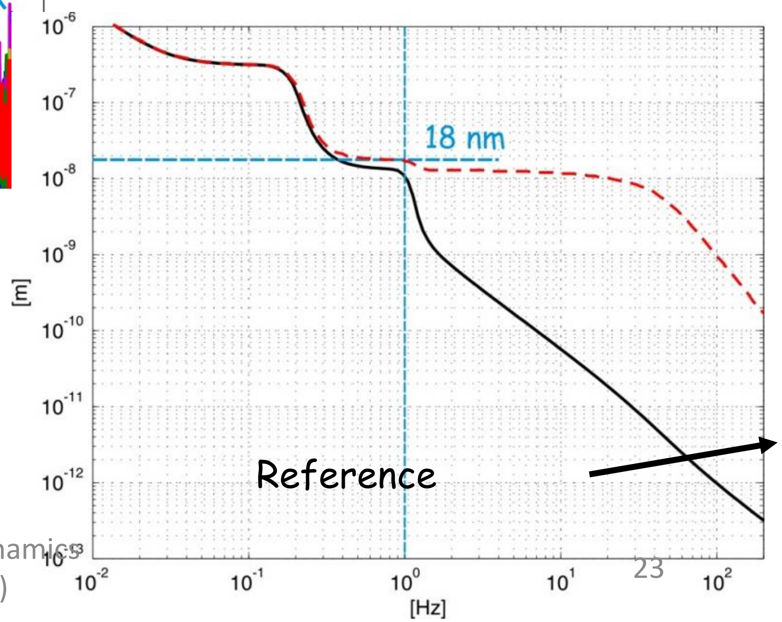
Lateral ground motion



Additional technical noise:

$$N(\omega) = \frac{N_0}{1 + (\frac{\omega}{\omega_0})^6}$$

$$N_0 = 0.5 (nm^2/Hz)$$
$$f_0 = 40 (Hz)$$

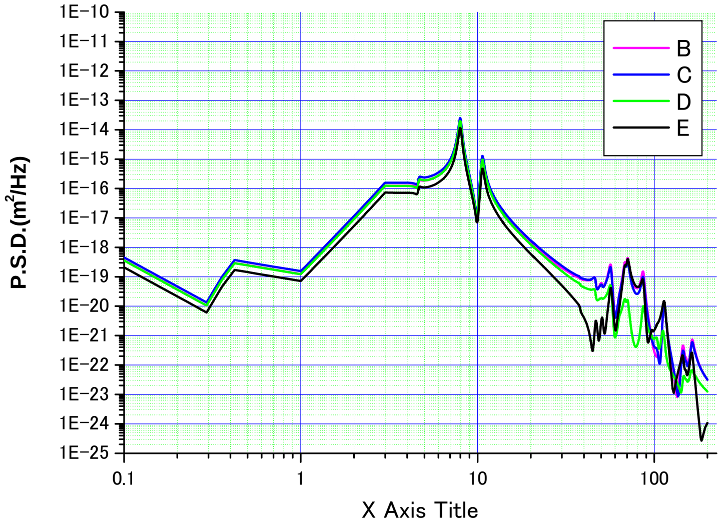


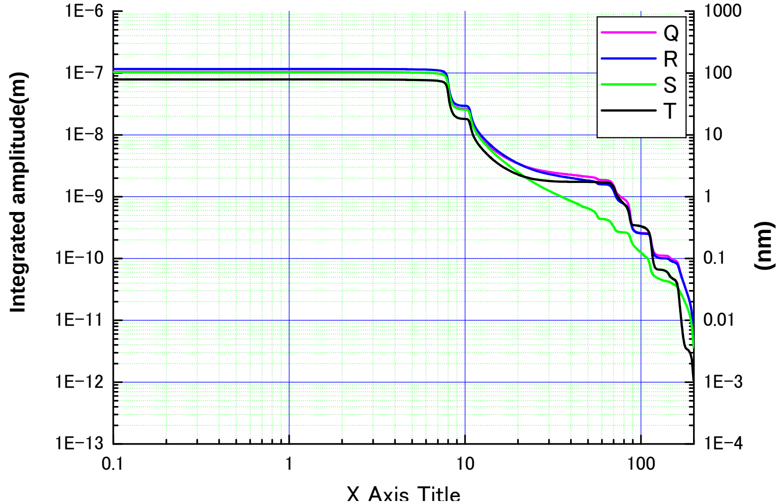
Ref. : $A = 10^{-3}\ (\mu m^2 s^{-1} m^{-1}); B = 10^{-2}\ (\mu m^2 s^{-3});$

$\omega_1 = 2\pi * 0.17\ (rad/s); d_1 = 5; a_1 = 0.5\ (\mu m^2/Hz); v_1 = 1000\ (m/s)$

$\omega_2 = 2\pi * 1\ (rad/s); d_2 = 8; a_2 = 5 * 10^{-4}\ (\mu m^2/Hz); v_2 = 400\ (m/s)$

ATF-2004Feb10-17:00UD-relative amp.





Y-No-Stand-Reinforced structure