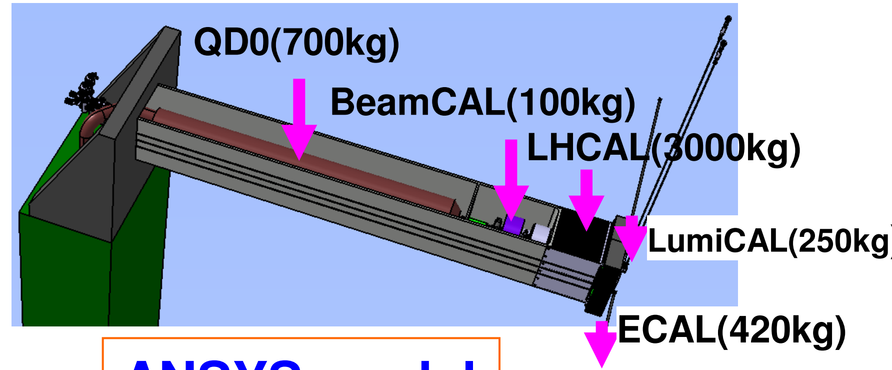
Vibration studies Overview

Hiroshi Yamaoka
KEK

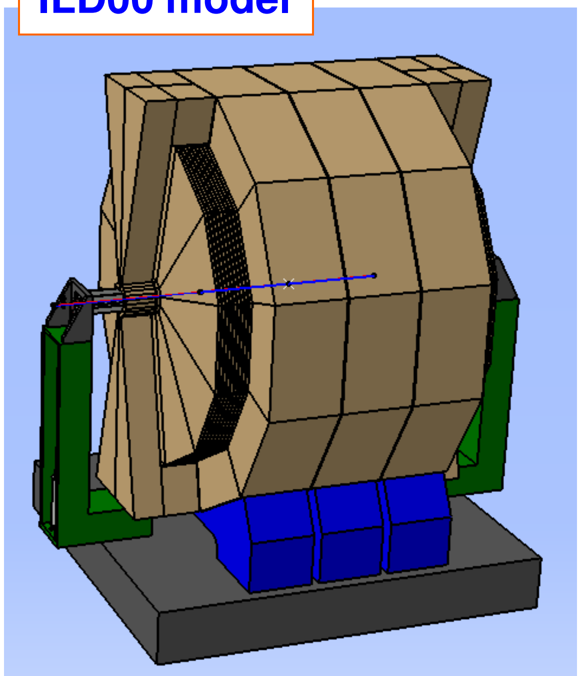
Introduction

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

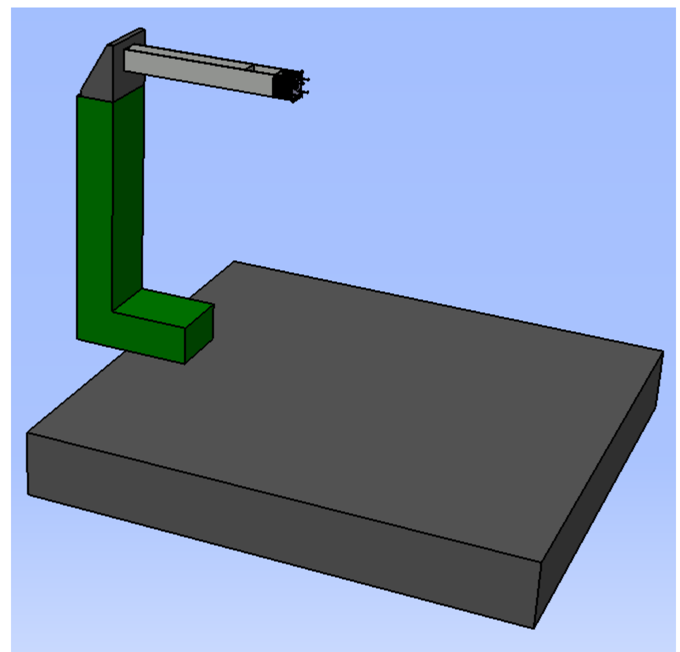


ANSYS model

ILD00 model



ILD QD0 support system



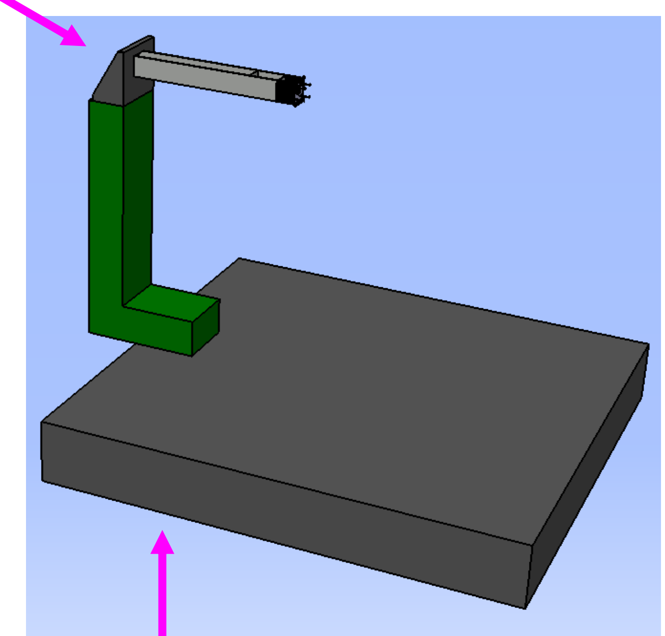
To improve vibration behavior;

➔ We need to solve these issues.

1. Design of stiff support structure

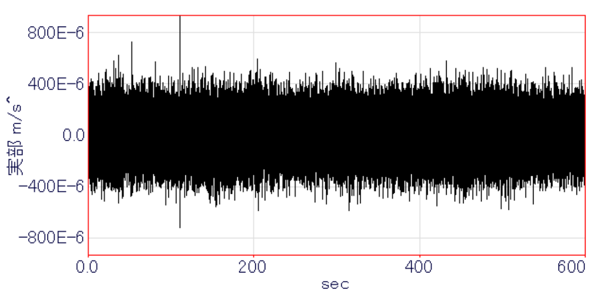
2. Calculations
- Static
- Modal
- P.S.D.

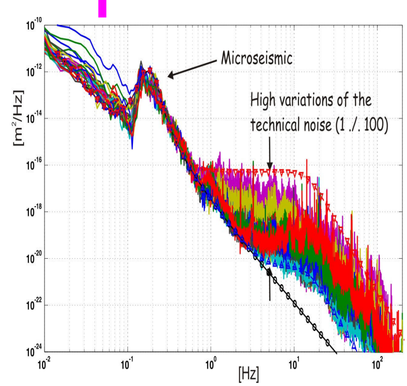
3. Correct?
Check consistency



4. Vibration data
- CERN
- KEK

Coherency?





5. Realistic data

Allowable Amplitude: < 50nm(V)
(Above 5Hz) < 300nm(H)

2. Calculations

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

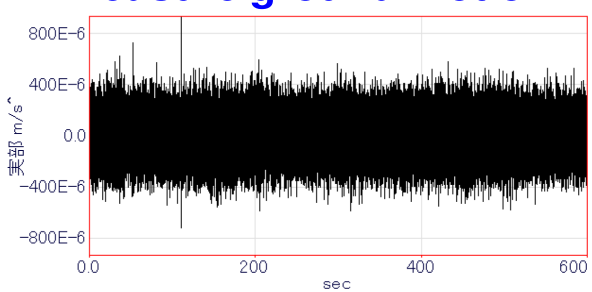
Ref.: ANSYS help file

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

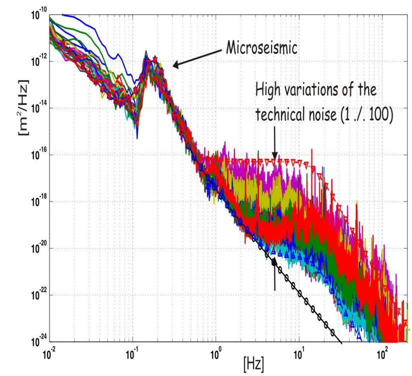
A *response spectrum* represents the *response* of single-DOF systems to a time-history loading function. It is a graph of response versus frequency, where the response might be displacement, velocity, acceleration, or force. Two types of response spectrum analysis are possible: single-point response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

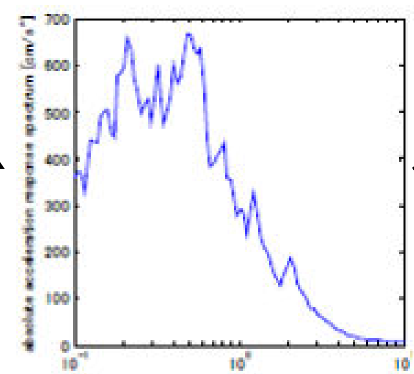
Measure ground motion



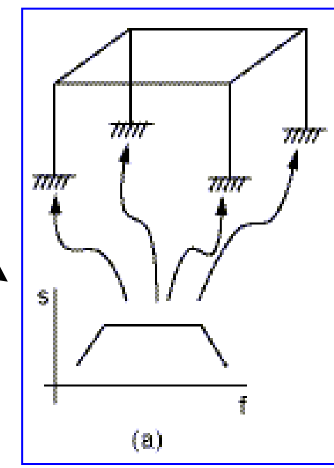
1. P.S.D.

2. Make R. spectrum





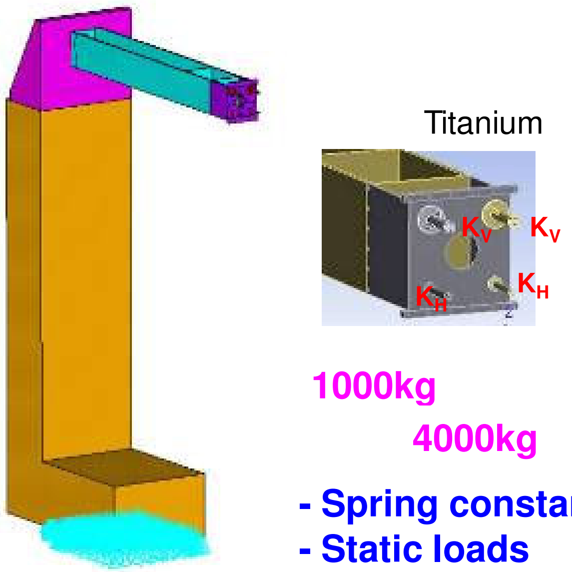
Input each data to constraints positions.



Get respond amplitude/stress at each position.

1. Design stiff support structure

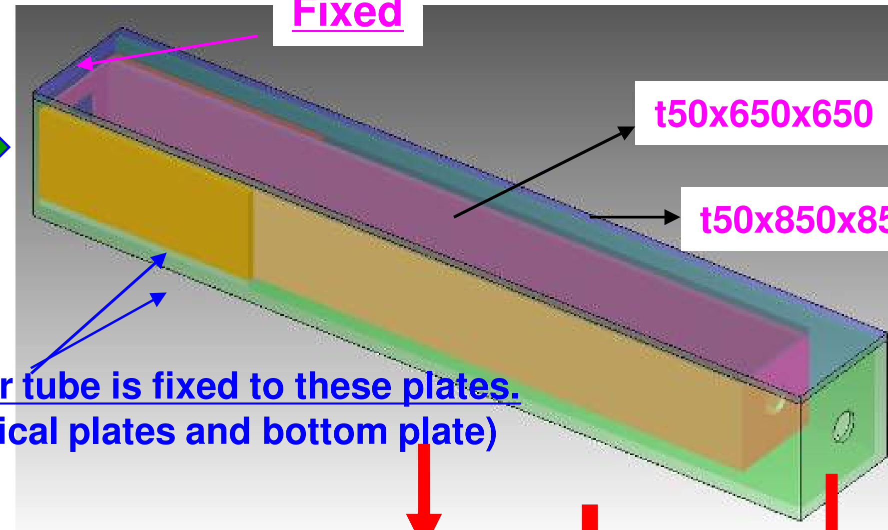
@LCWS09



- Spring constant
- Static loads

are defined.

New proposal: Double tube



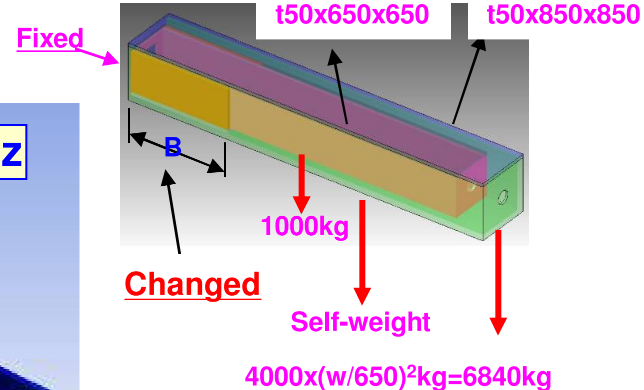
Allowable Amplitude: < 50nm(V)
(Above 5Hz) < 300nm(H)

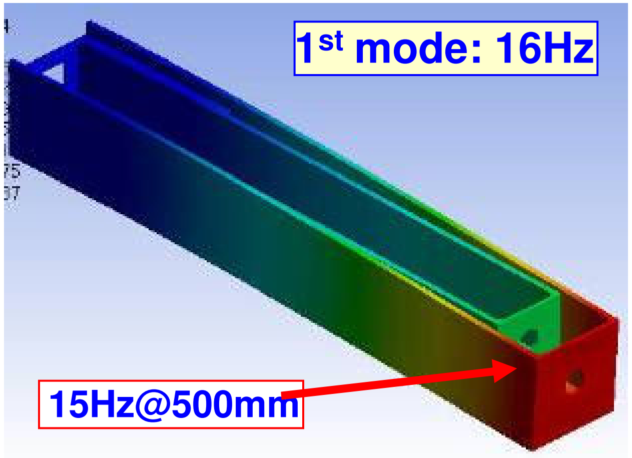
→ Integ. amplitude in case of ATF and CERN high-noise are larger than 50nm at 5Hz.

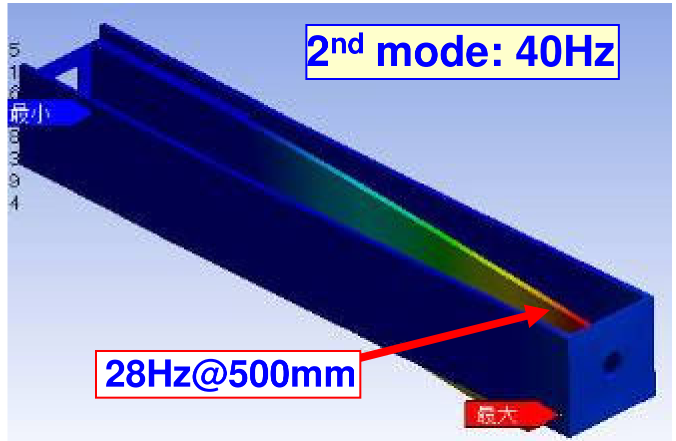
➔ Double tube is proposed.

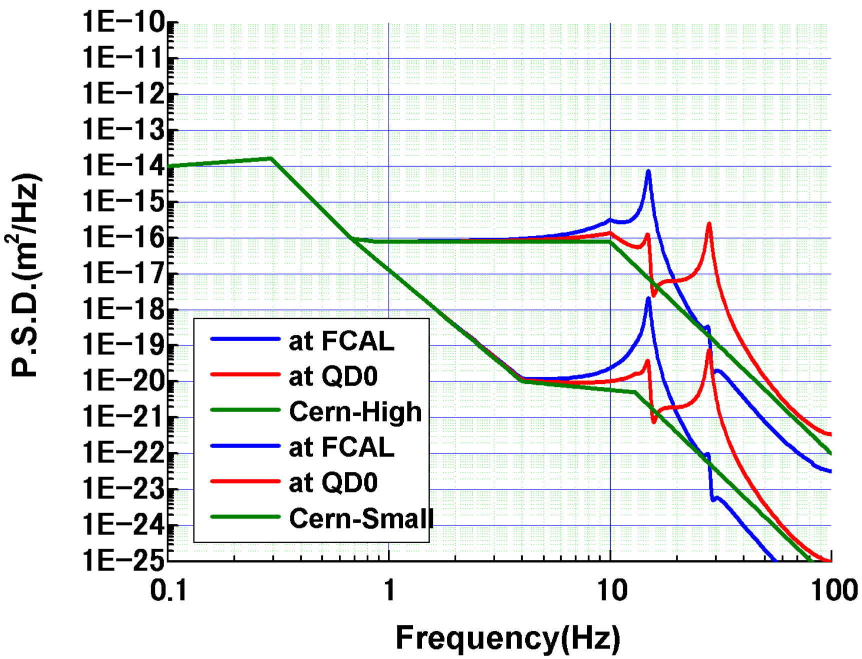
- Support tube consists of double square tube.
- Outer tube supports FCAL.
- Inner tube supports QD0.

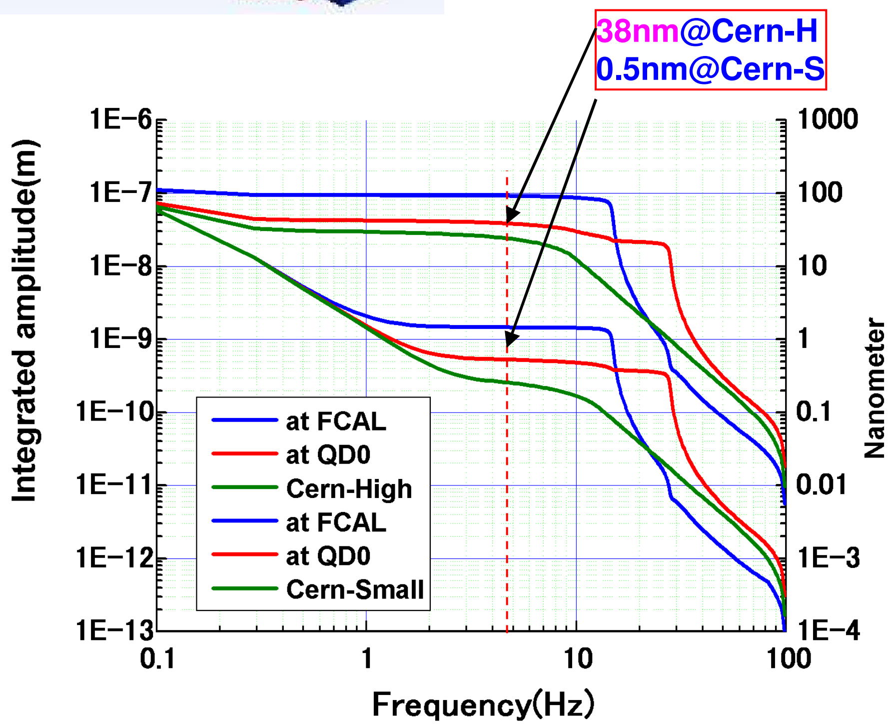
Calculation results in case of double tube







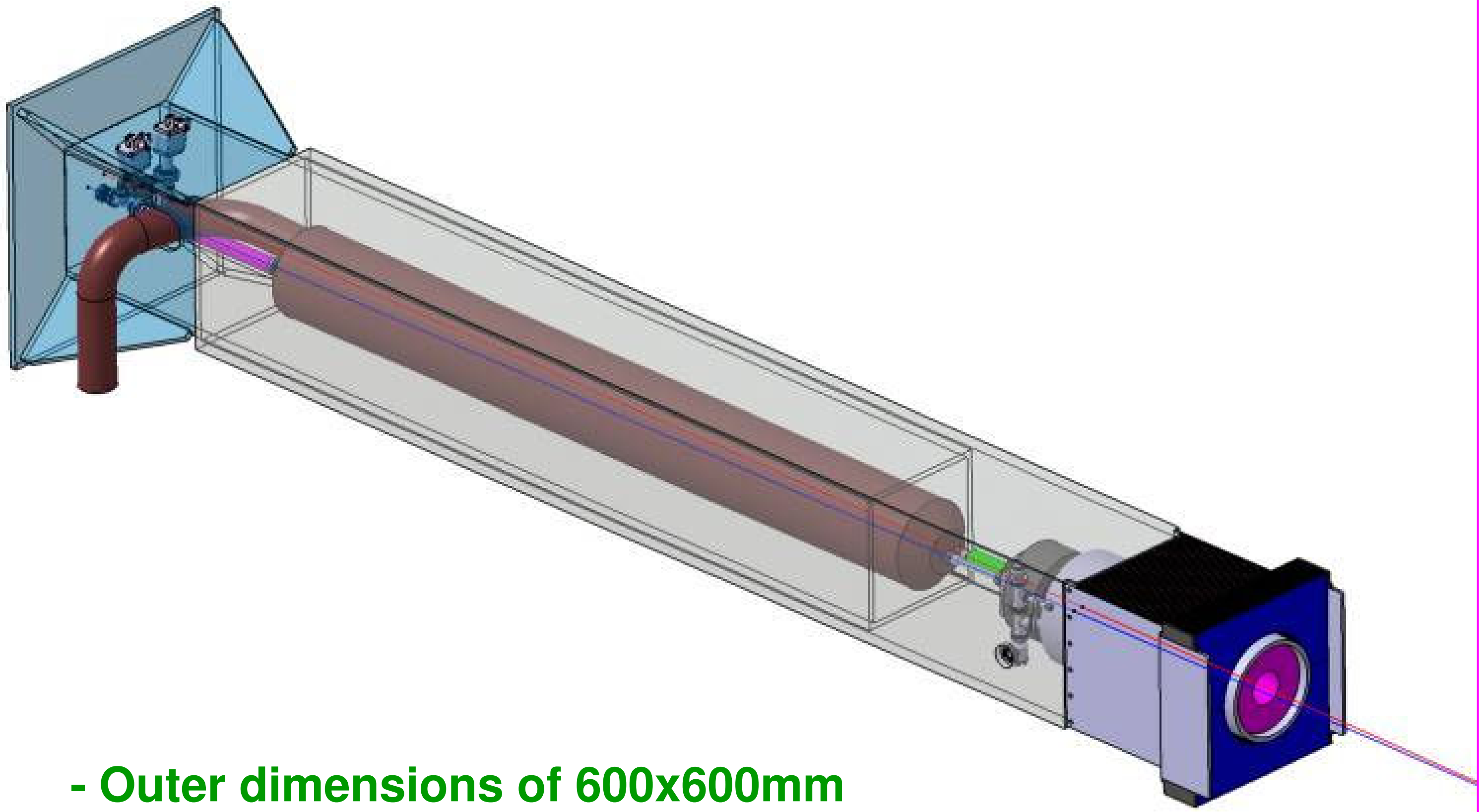




→ **Amplitude at QD0(Inner tube) can be kept within the allowable value.**

Double tube is effective → Need more realistic design.

New configuration by Matthieu san.



- Outer dimensions of 600x600mm
- 25mm thick

3. Investigation of consistency between the calculations and measurements

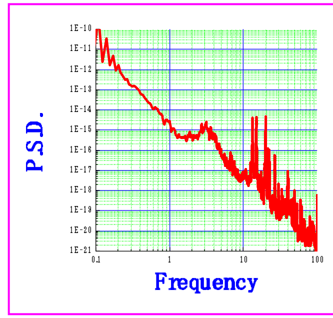
LION LS10C

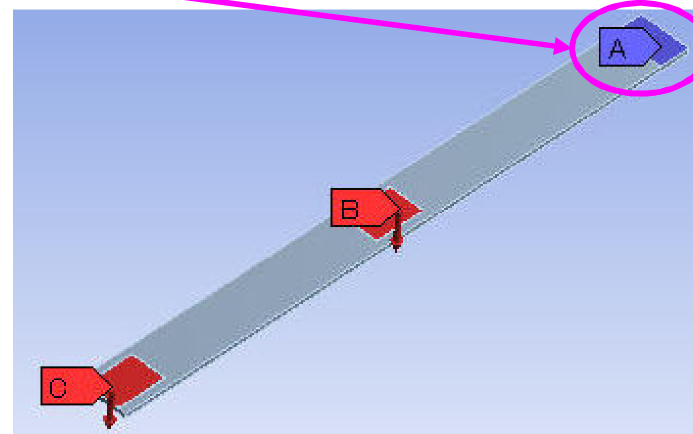
Servo accelerometer

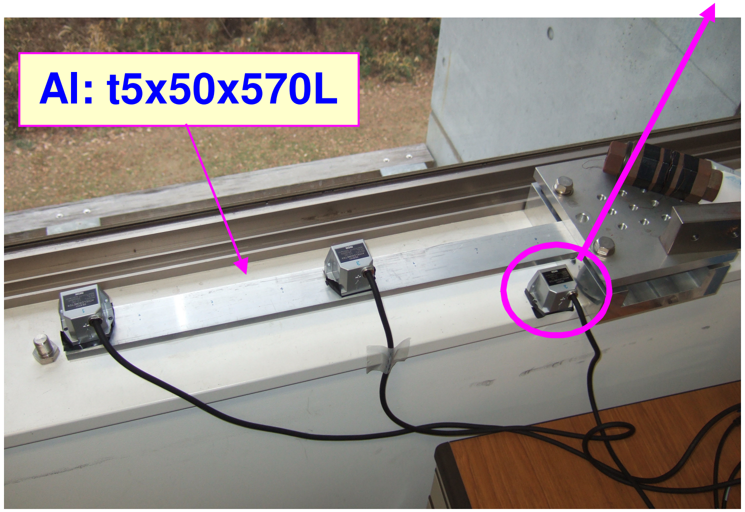
0.3V=1m/s^2

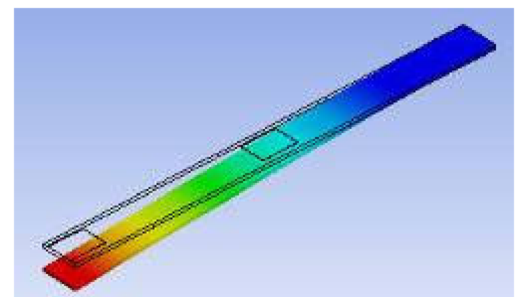
DC~40Hz

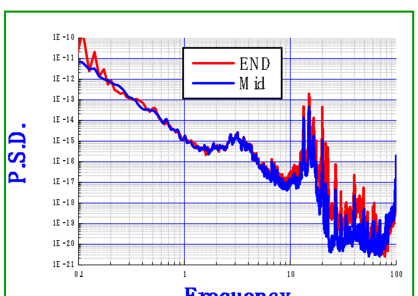
<10^{-5}m/s^2

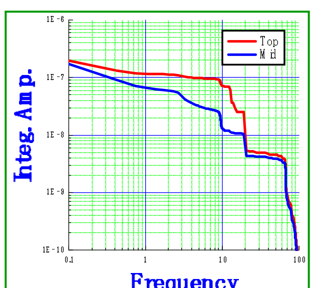


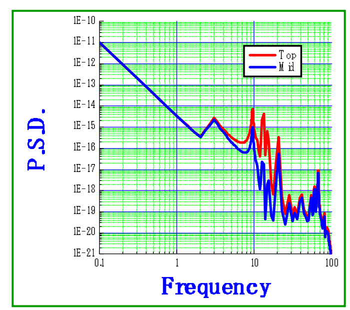


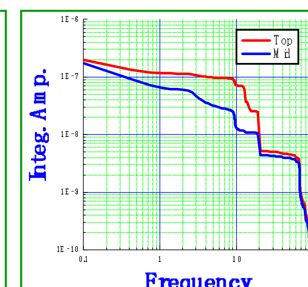






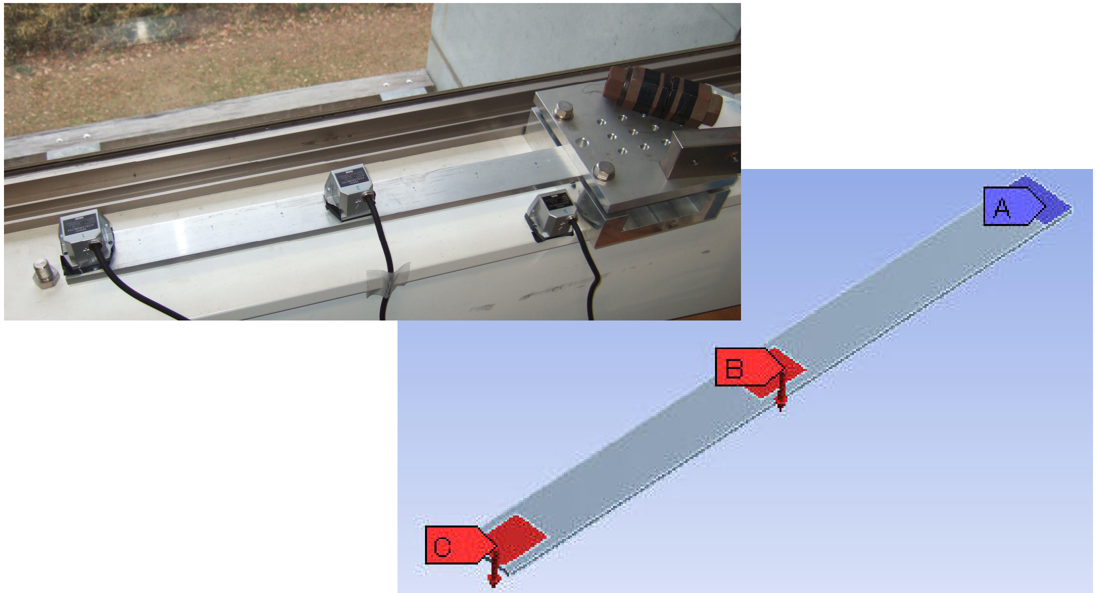


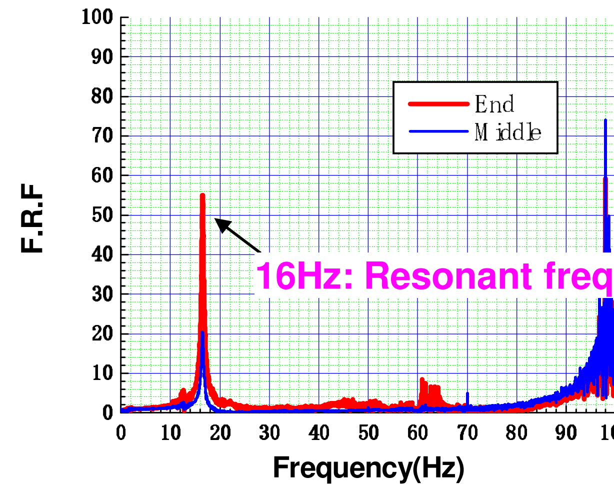


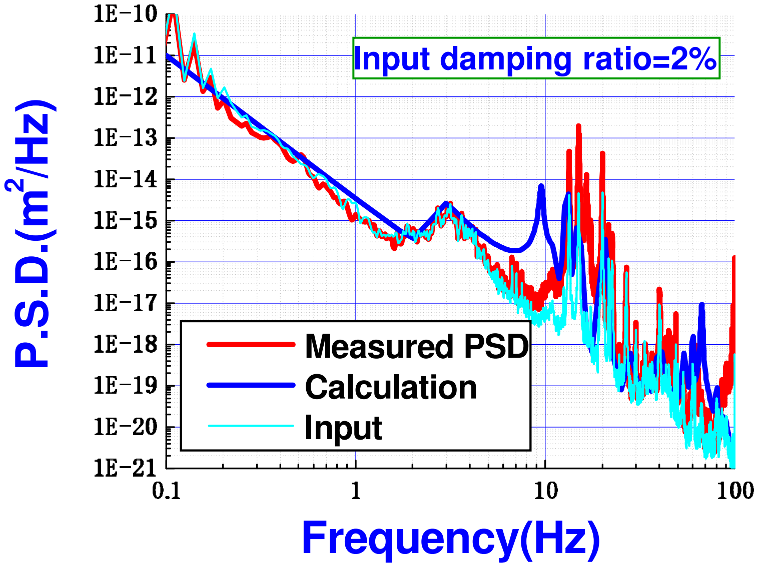


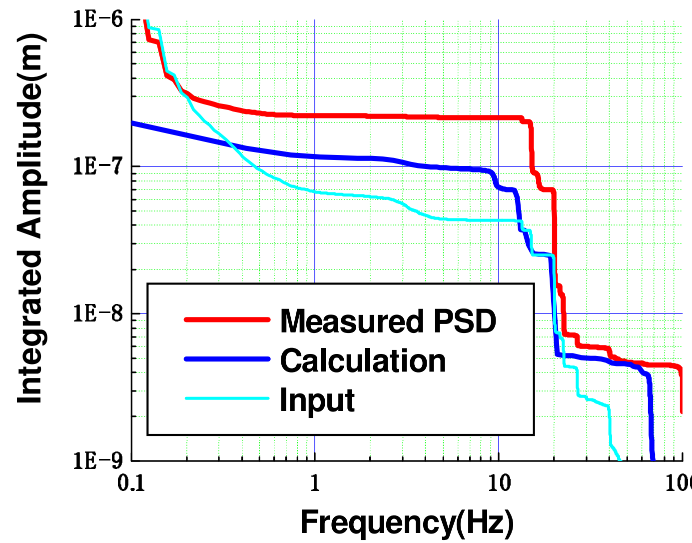
Are those values same?

Results: Comparison PSD/Amplitude.





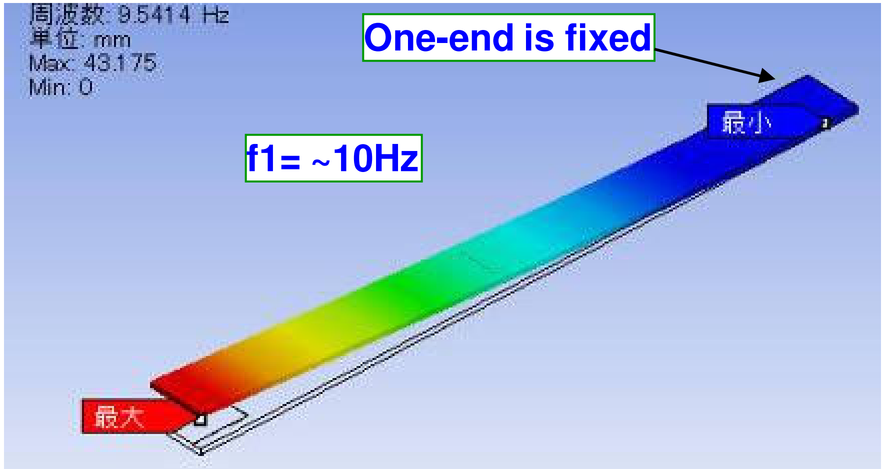




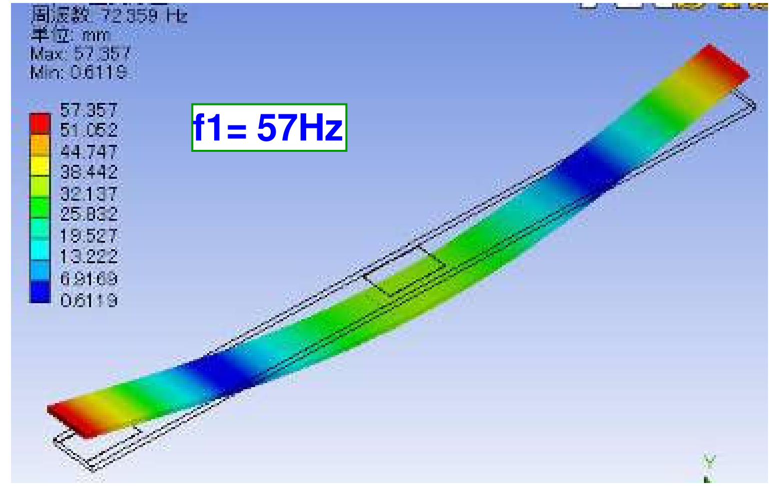
➔ - 1st mode of resonant frequency is ~6Hz different.
- Amplitude is ~100nm different.

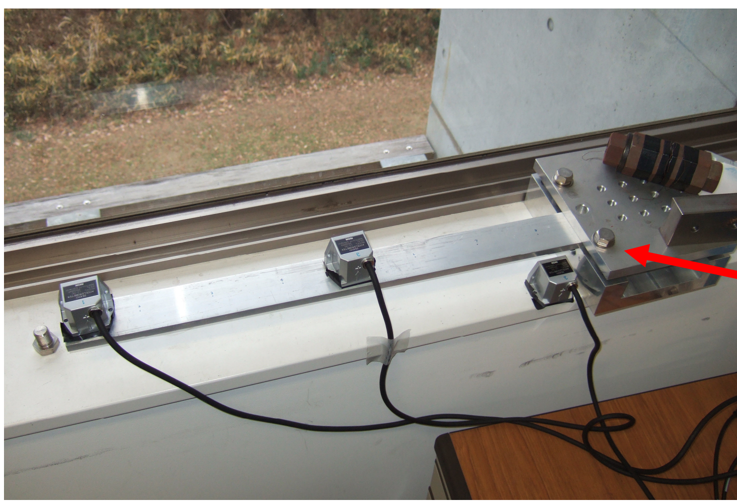
Considerations

Why is the 1st mode of resonant frequency ~6Hz different?



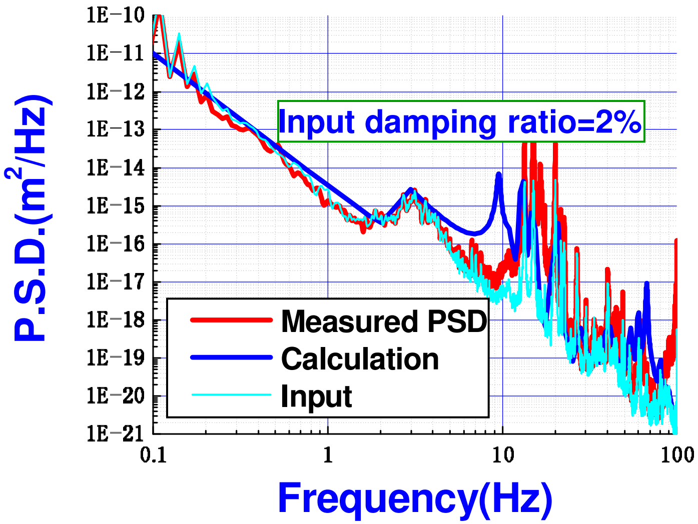
Free mode: No constraint

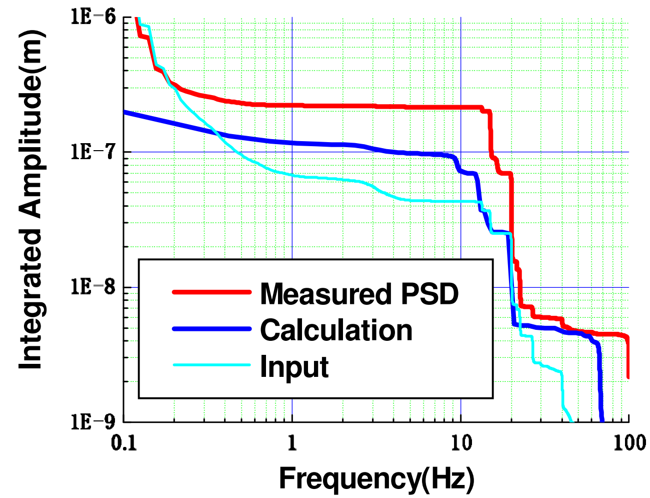




Because:
Constraint position is not ideally rigid.
Therefore, resonant frequency is moved to frequency of *free mode* condition.

Why amplitude is ~100nm different?





➔ It is supposed that ***actual damping ratio is smaller than the assumption.***

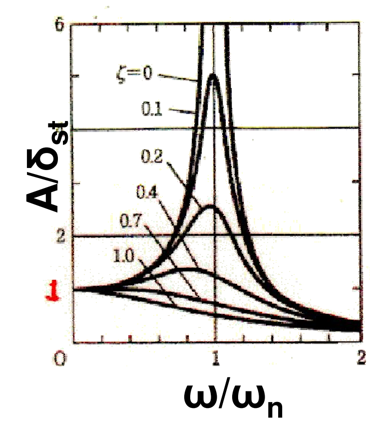
→ In ANSYS: *damping ratio= 2%*

Damping ratio(%)	
Ferroconcreate structure	: 5.0
Steel frame structure	: 2.0
Welding structure	: 1.0
Bolt/Rivet structure	*: 2.0*
Laying pipes	: 0.5 ~ 2.5
Duct for the air conditioner	: 2.5
Cable tray	: 5.0
Liquid in a tank	: 0.5

Reference: JEAG 4601-1987

$$m\ddot{x} + c\dot{x} + kx = F\cos\omega t$$

$$X = \frac{\delta_{st}}{\sqrt{\left\{1-\left(\frac{\omega}{\omega_n}\right)^2\right\}^2 + \left(2\varsigma\frac{\omega}{\omega_n}\right)^2}}$$



If ω/ω_n= 1 , ζ=0.02

X/δ_{st}=25

If ω/ωn= 1 , ζ=0.01

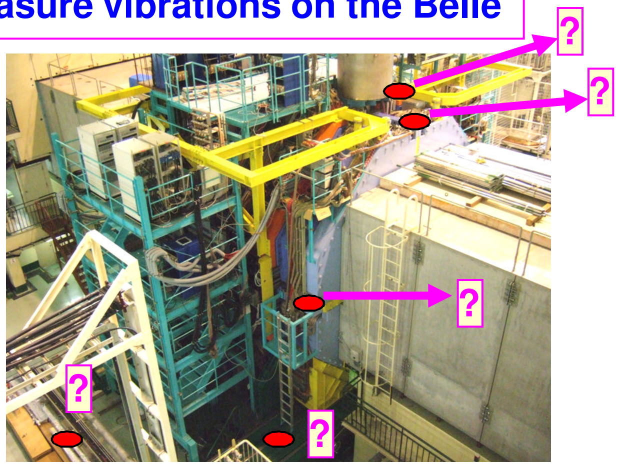
X/δst=50

Vibration measurements at the Belle/KEKB/CMS

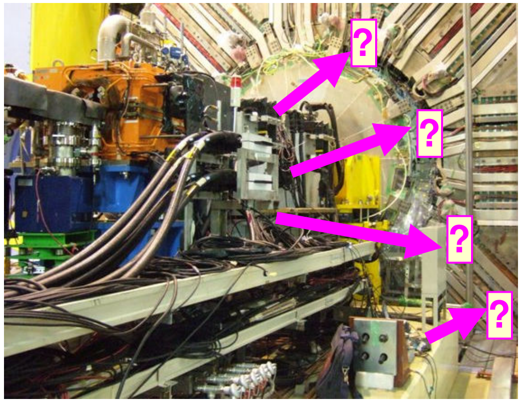
Study items

- Vibrations on each place
- Coherency between both sides

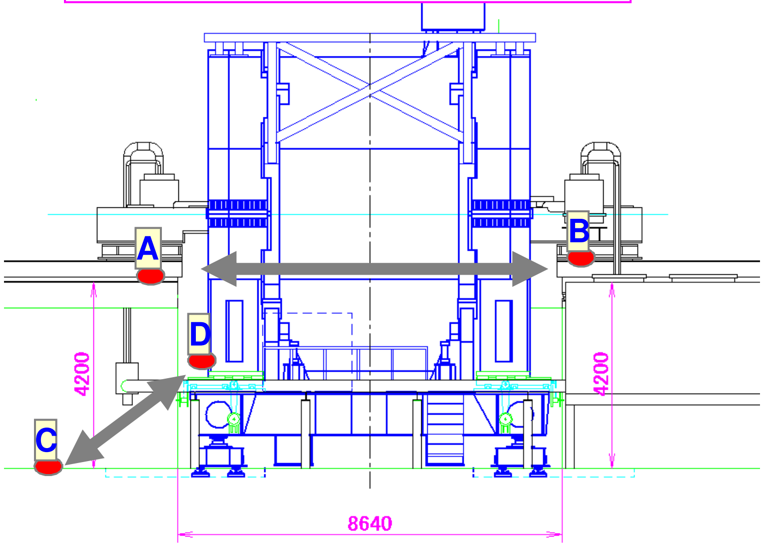
Measure vibrations on the Belle



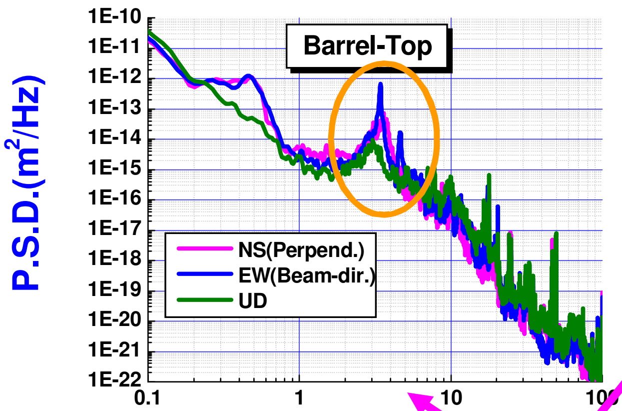
Measure vibrations on KEKB

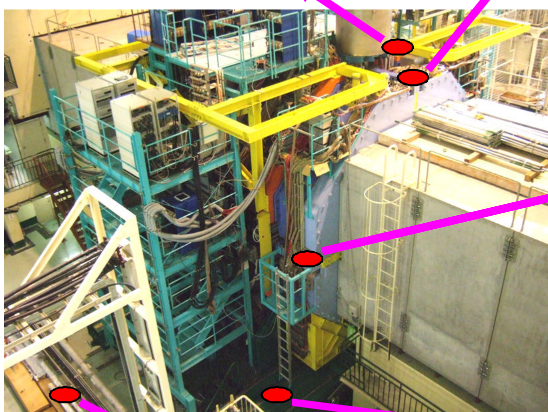


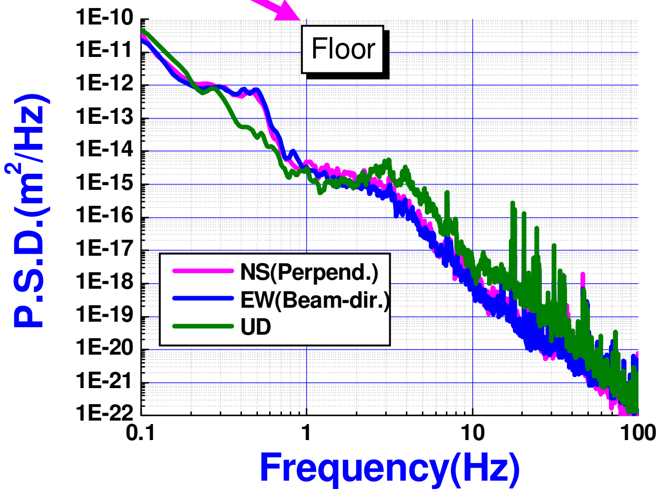
Coherency between A-B, C-D.

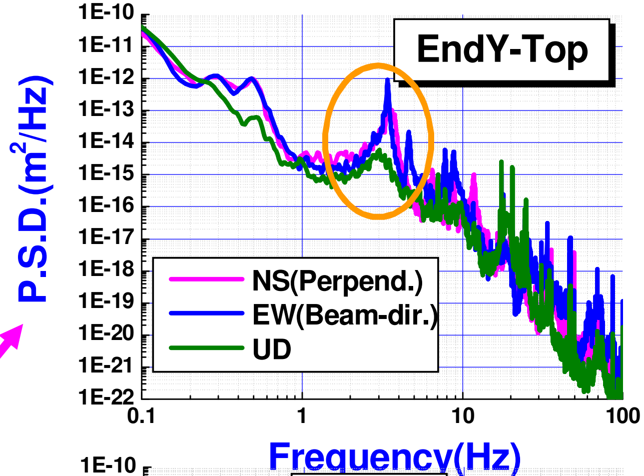


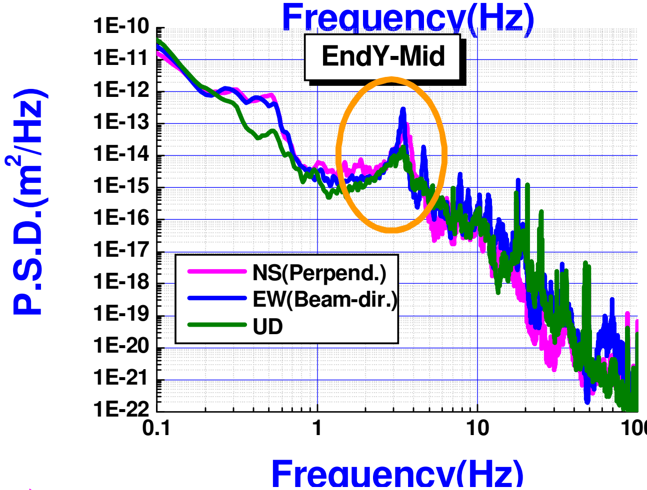
4. Vibration data@KEK

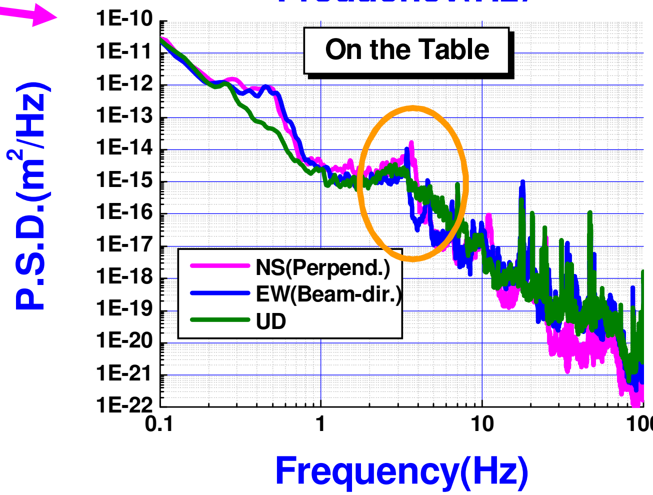






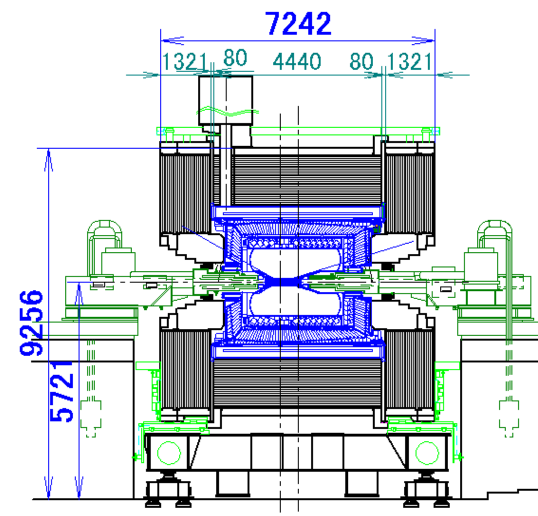


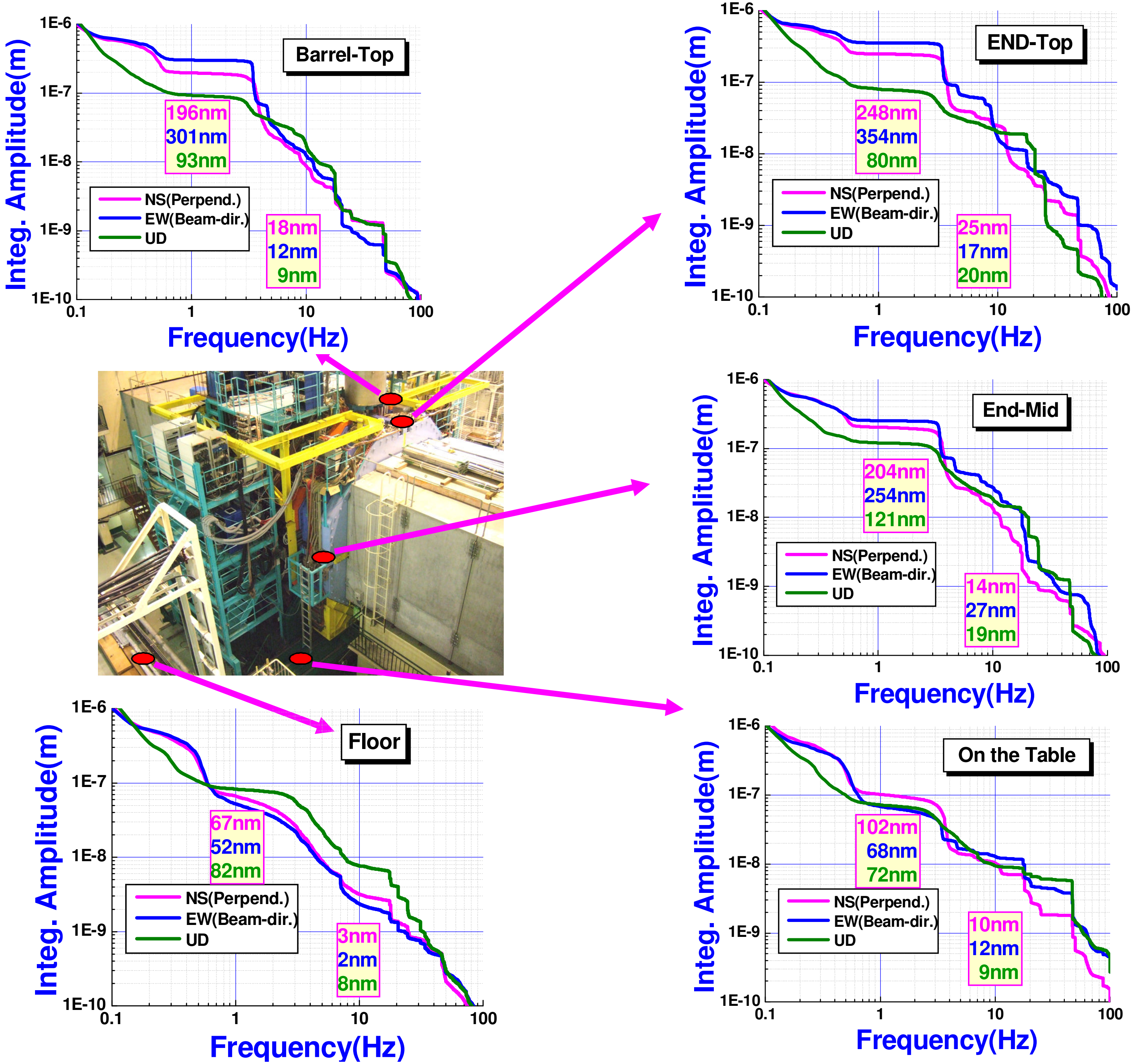




Servo Accelerometer
MG-102

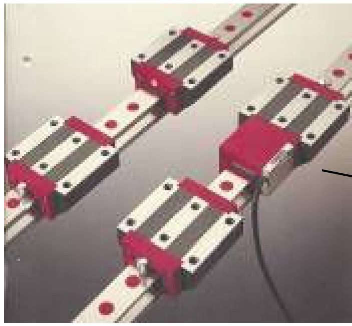
Acc. 0.1 ~ 400Hz Acc.
60dB = 1gal/V

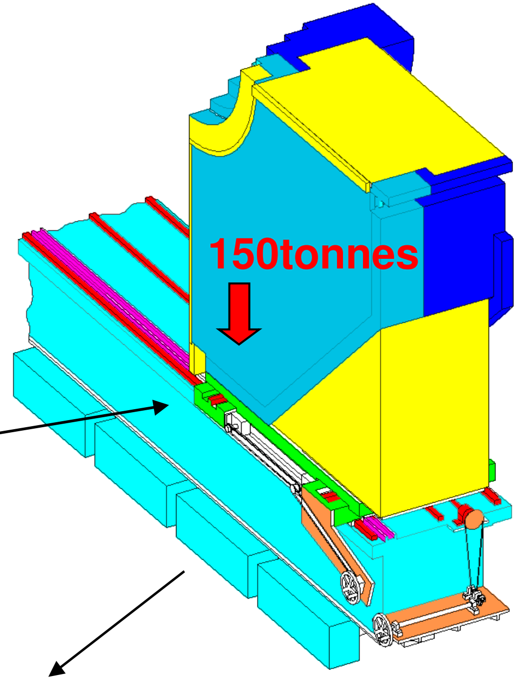



Barrel-Top
196nm
301nm
93nm
18nm
12nm
9nm
END-Top
248nm
354nm
80nm
25nm
17nm
20nm
End-Mid
204nm
254nm
121nm
14nm
27nm
19nm
Floor
67nm
52nm
82nm
3nm
2nm
8nm
On the Table
102nm
68nm
72nm
10nm
12nm
9nm
NS(Perpend.)
EW(Beam-dir.)
UD
Integ. Amplitude(m)
Frequency(Hz)
1E-6
1E-7
1E-8
1E-9
1E-10
0.1
1
10
100

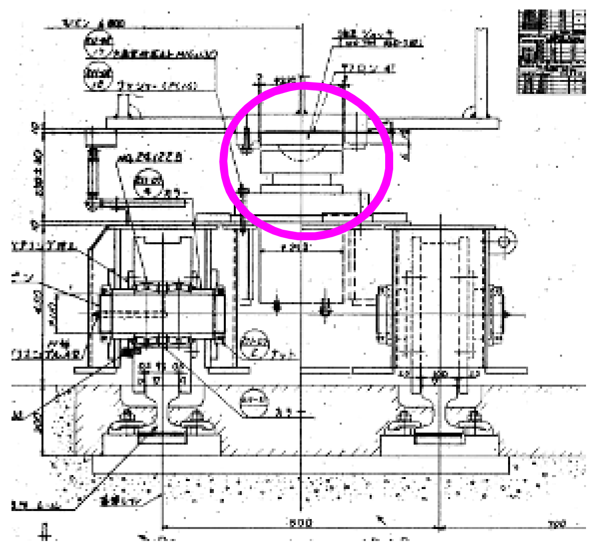
Considerations on the measurement results

- First resonance is around ~3-4Hz.
- Amplitude on the barrel is bigger than the table.
- Amplitudes on the End-Y becomes larger as the position of EY rises





Spherical support

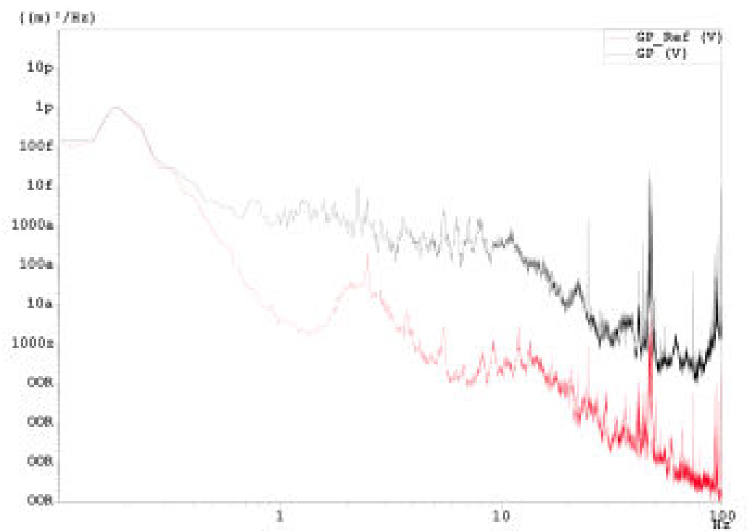


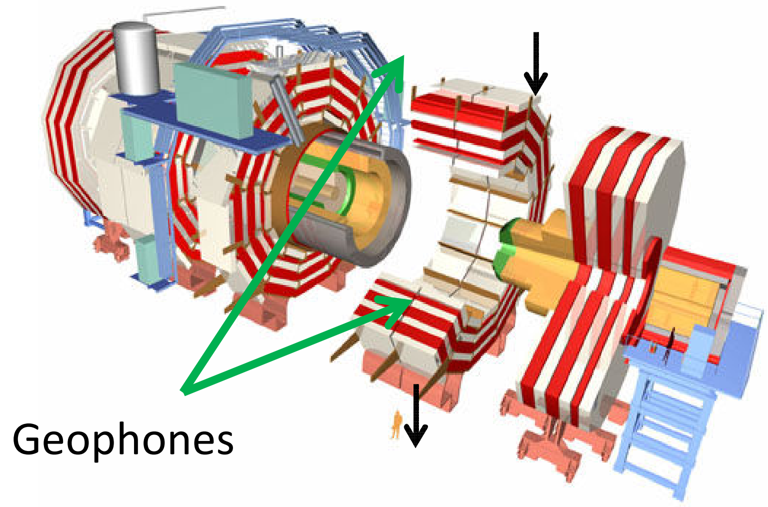
Large amplitudes on the Belle;

- The belle detector is not fixed on the floor.
- The barrel yoke is not fixed on the table rigidly.
- Top of the end-yoke is not fixed.

Measurements on quiet ground and top of CMS: Presented by Alain-san

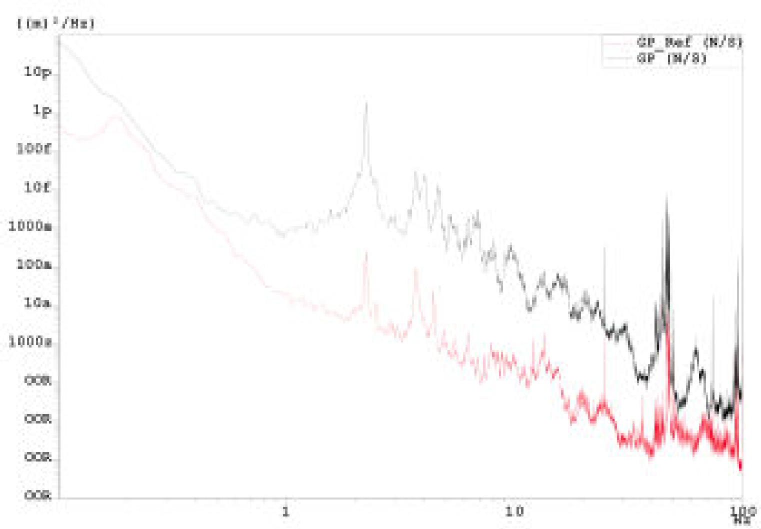
PSD of the signals Vertical direction

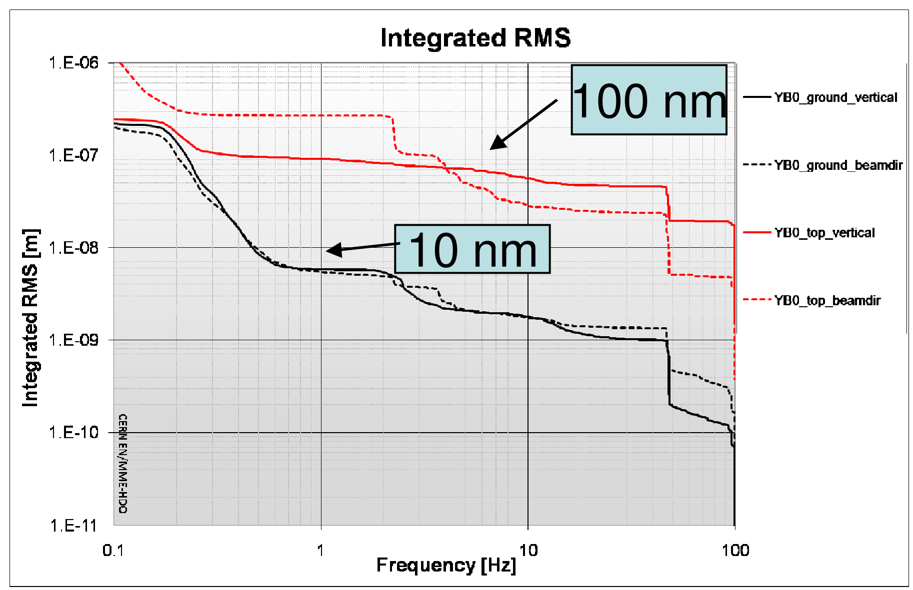




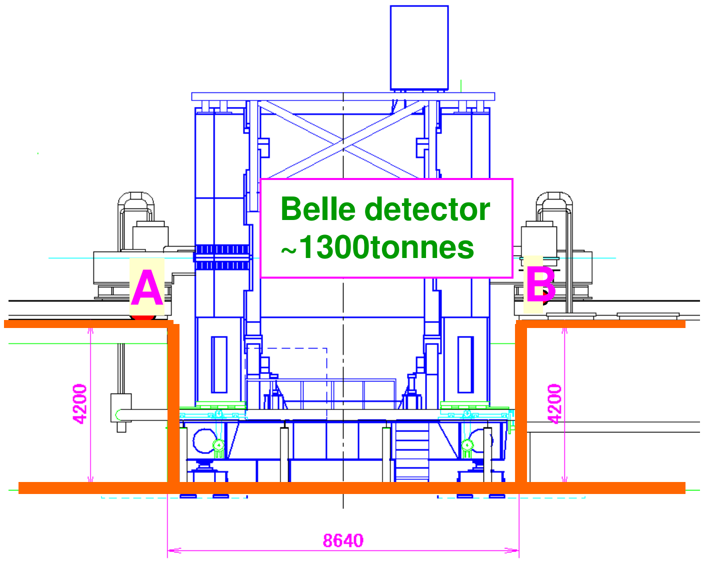
Cooling system OFF

PSD of the signals Beam direction

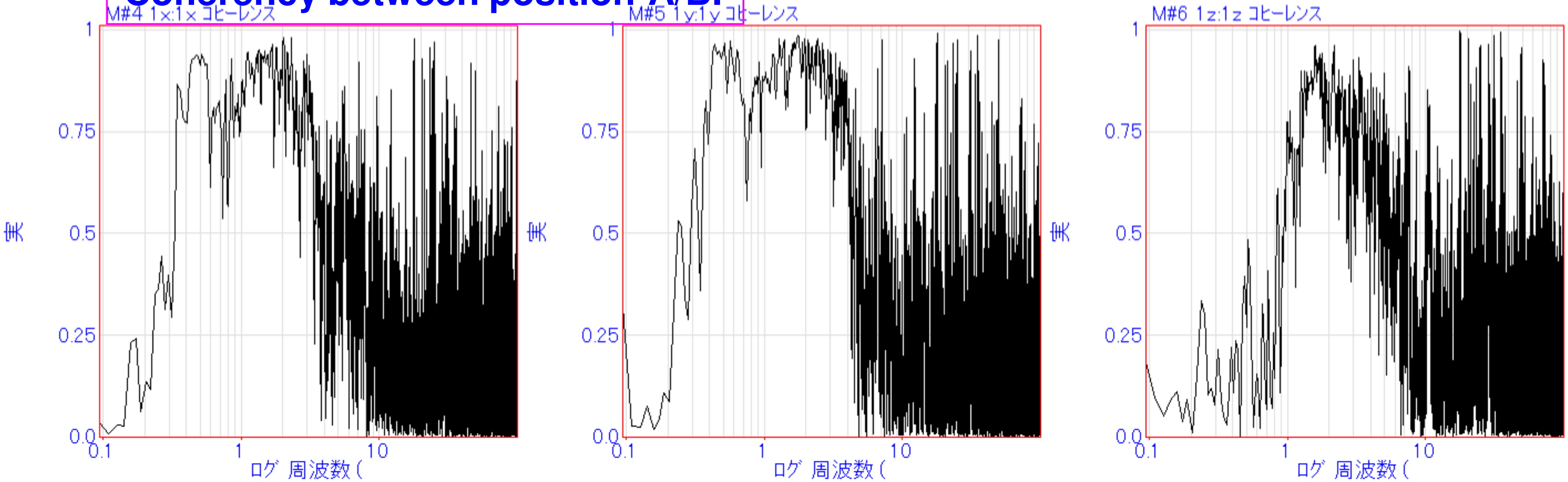




Coherency measurement at KEKB-tunnel



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).

5. Realistic data

Where?

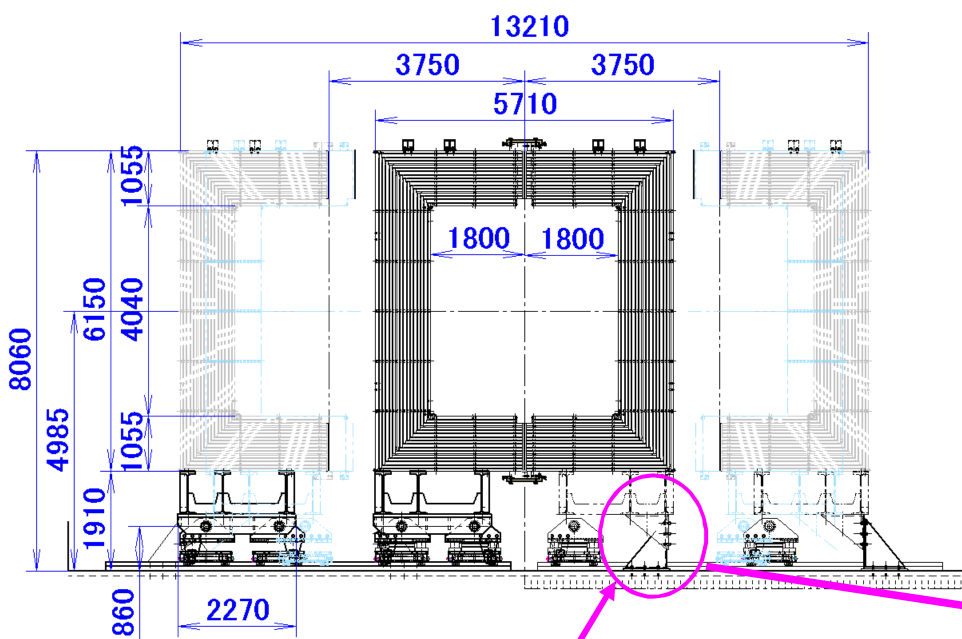
→ **Maybe CMS?**

Investigations of efficiency of detector support structure

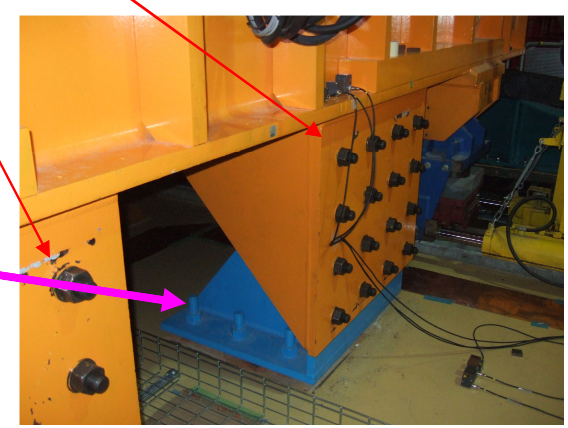
- Detector should be fixed to the floor?? or,
  Is it enough to just placed it on the floor??

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

ND280 detector (Total: 1100tonnes)

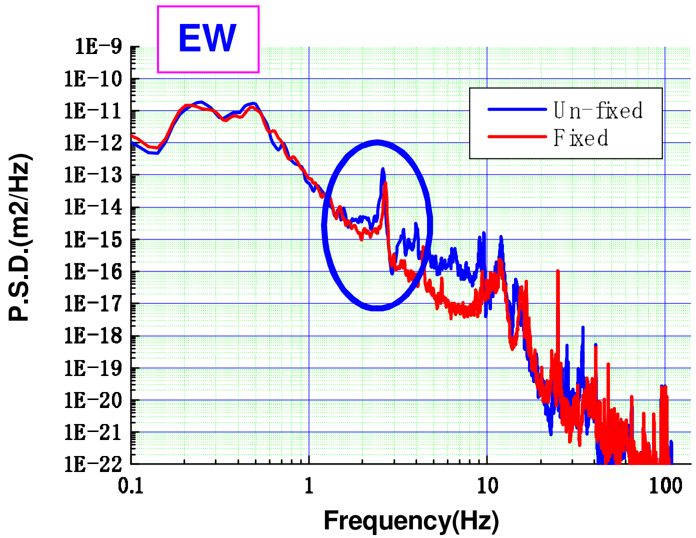


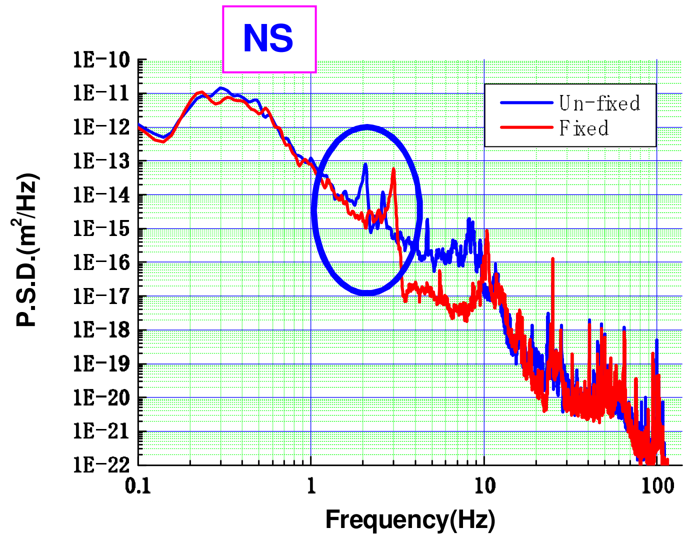
2-16xM36

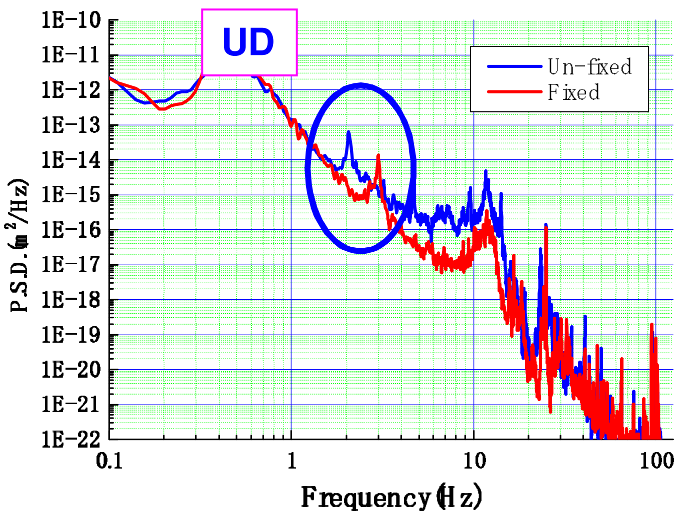


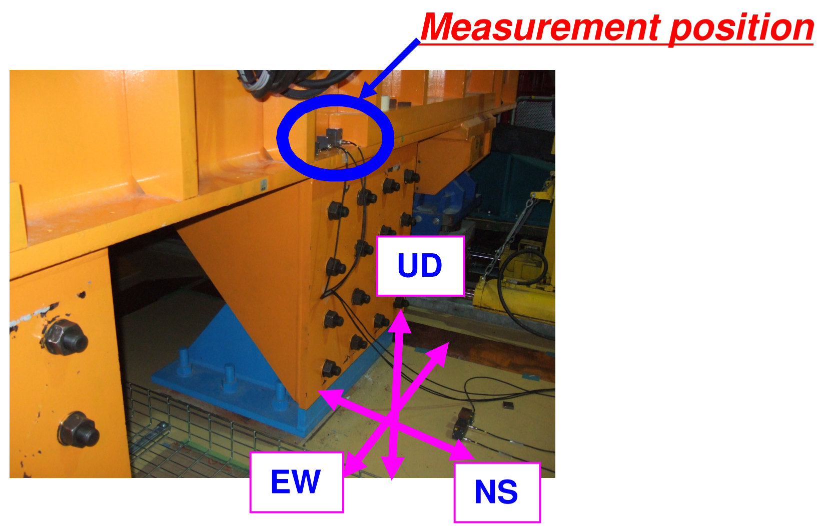
- The ND280 detector is fixed to the support-brackets with *2-16xM36 thread bolts*.
- The support bracket is designed to withstand against *0.5G seismic force*.

Results









→ - Natural frequency after fixed to the bracket is increased to ~1Hz(NS, UD).

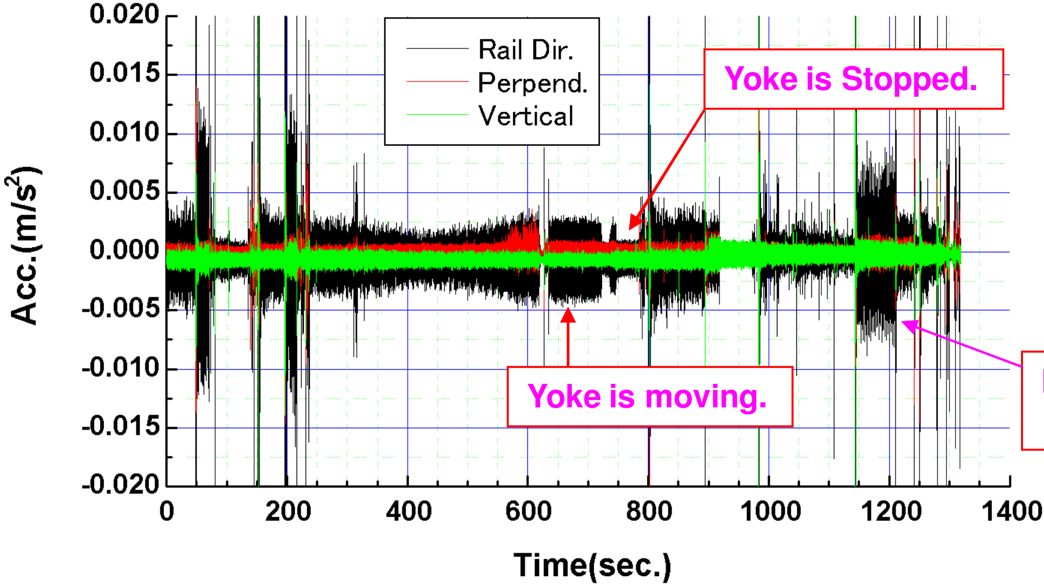
- P.S.D. is reduced because natural frequency is increased.

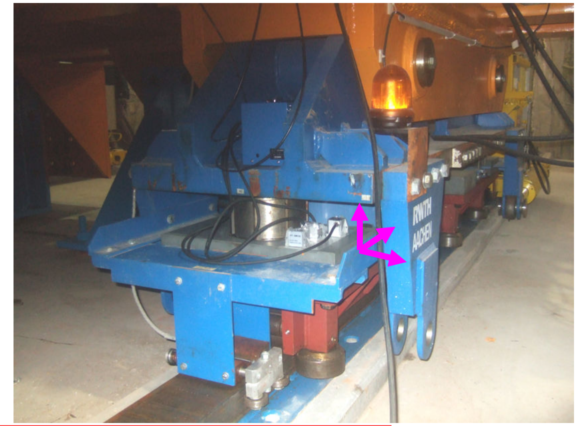
→It is not so big different but it's efficient to use the support-brackets.

→ Support stiffness is increased.

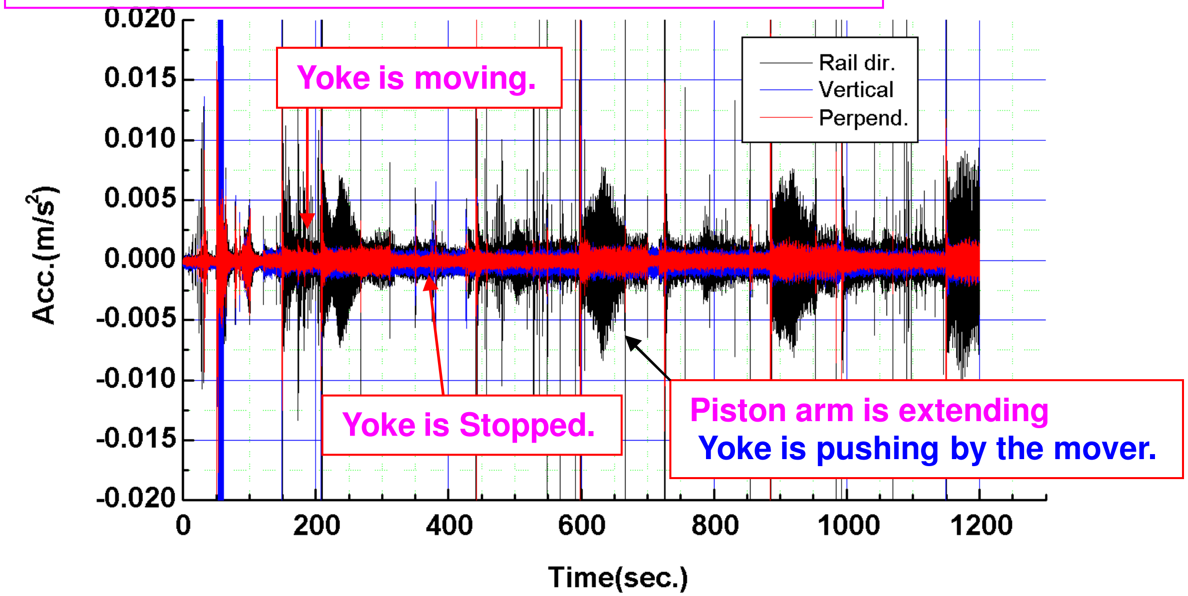
Vibration measurements during the detector moving

Time data- On the roller (@South yoke)





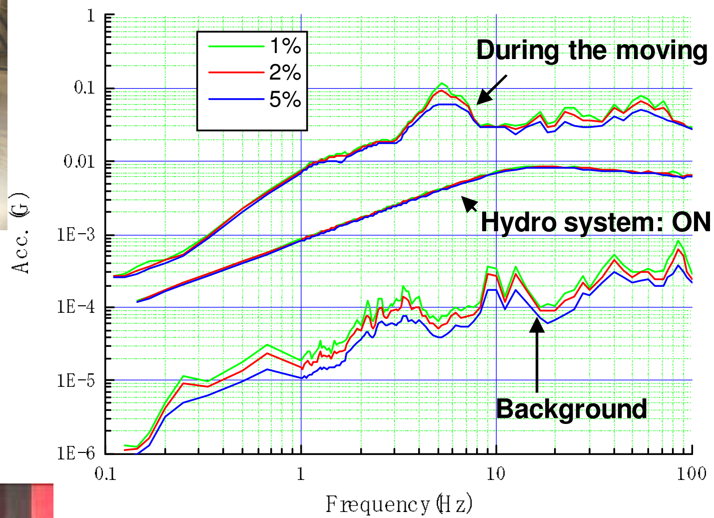
Time data- On the support stand (@North yoke)



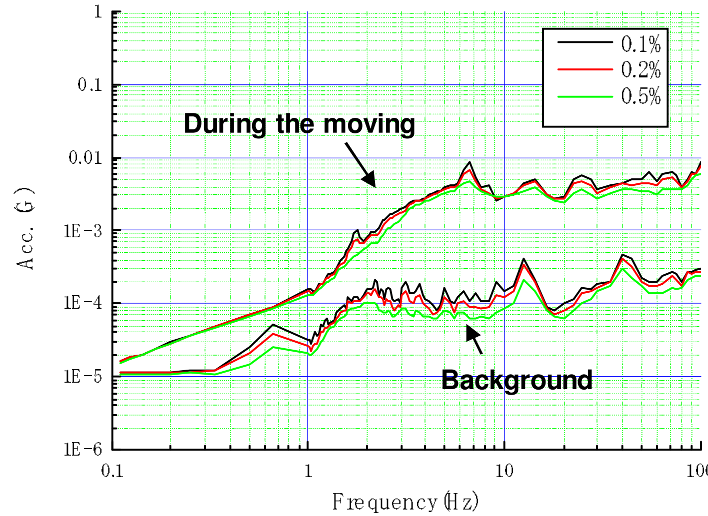
- Piezo-sensor couldn't detect these vibrations.

Measurement results (Response spectrum)

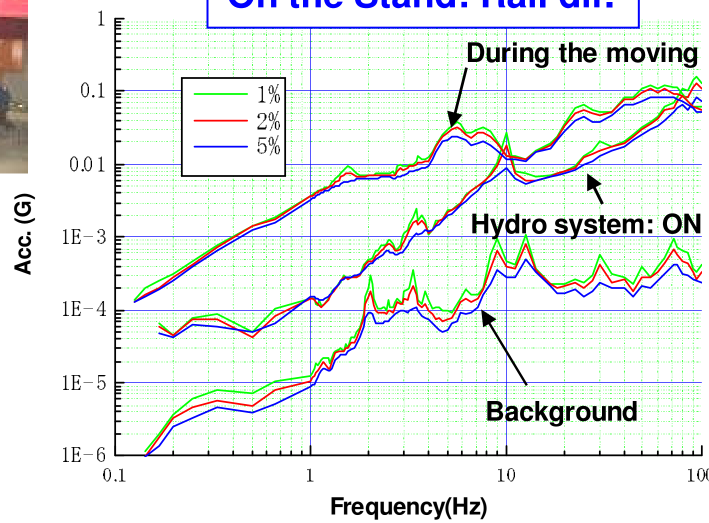
On the roller: Rail dir.



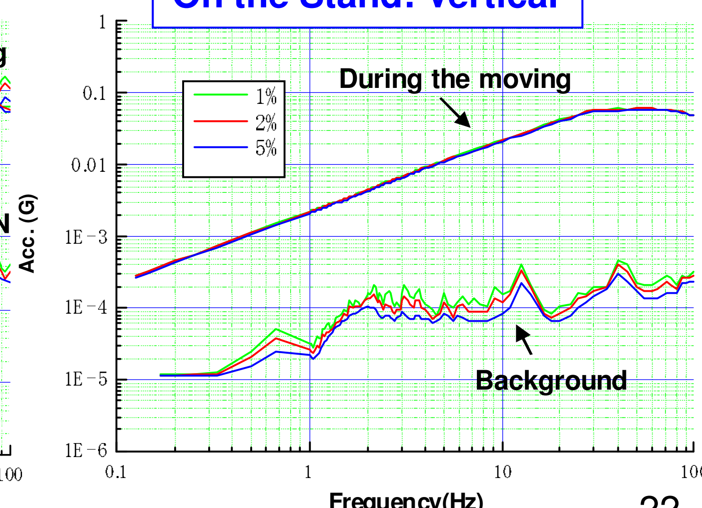
On the roller: Vertical



On the Stand: Rail dir.



On the Stand: Vertical



Summary

1. Design stiff support structure

- Double shaped tube/Realistic tube have been proposed.
- Integrated amplitude is less than 50nm.

2. Calculations

- Static, modal and PSD have been carried out.

3. Check consistency

- Simple vibration tests have been done.
  → Resonant frequency was measured lower than ANSYS calculation.
  Measured integrated amplitude was larger than ANSYS calculation.

4. Vibration measurements

Vibrations at the Belle detector/KEKB and CMS were measured.

- Amplitude on the barrel yoke is bigger than the support table.
- The integrated amplitude becomes larger when going from the bottom of the end yoke toward the top.

5. Realistic vibration data for calculations

CMS data?

6. Other measurements

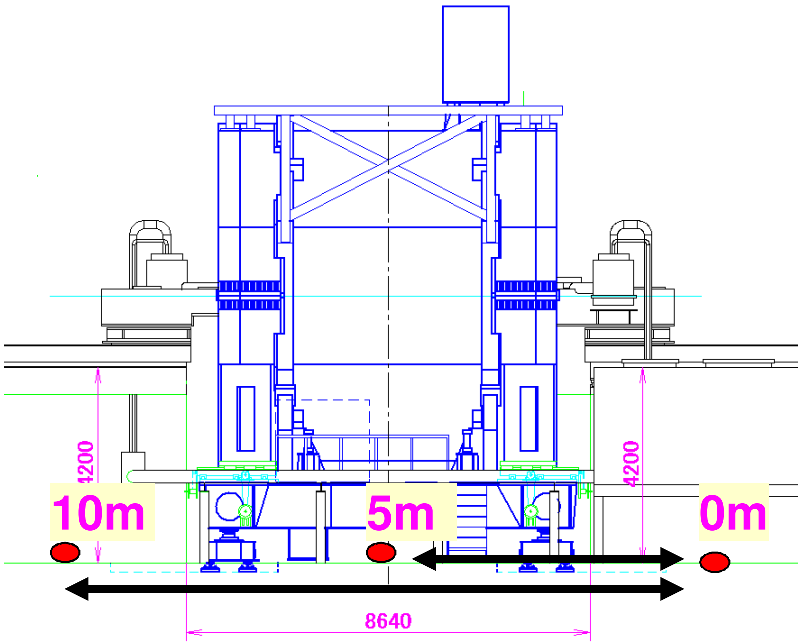
(1) Efficiency of support structure was investigated with the ND280 detector.
Support stiffness of the detector is increased.

(2) Vibration measurement during the moving on the rail was carried out.
Response acceleration was measured to 0.1G in rail direction, 0.01G in vertical.

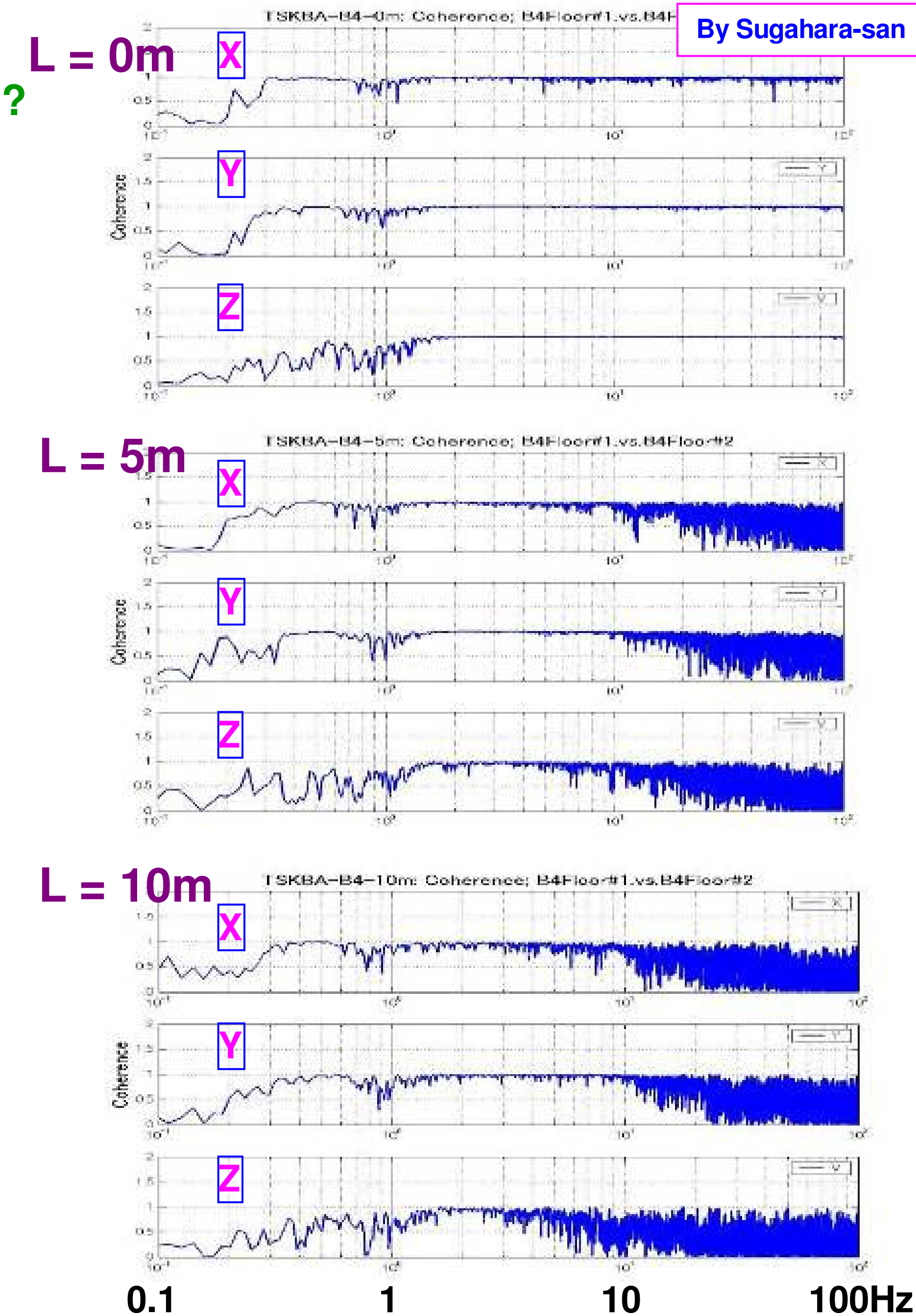
Measurement: C

How is the coherency between two positions?

Measure: Distance dependency.



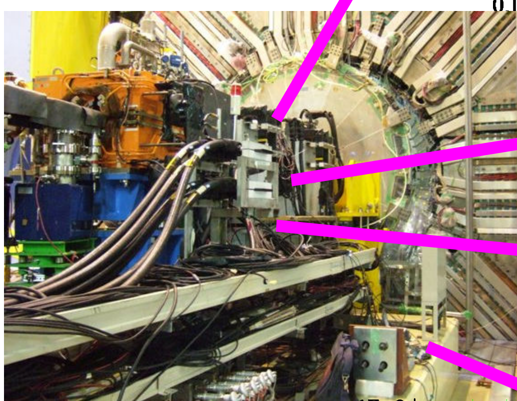
By Sugahara-san

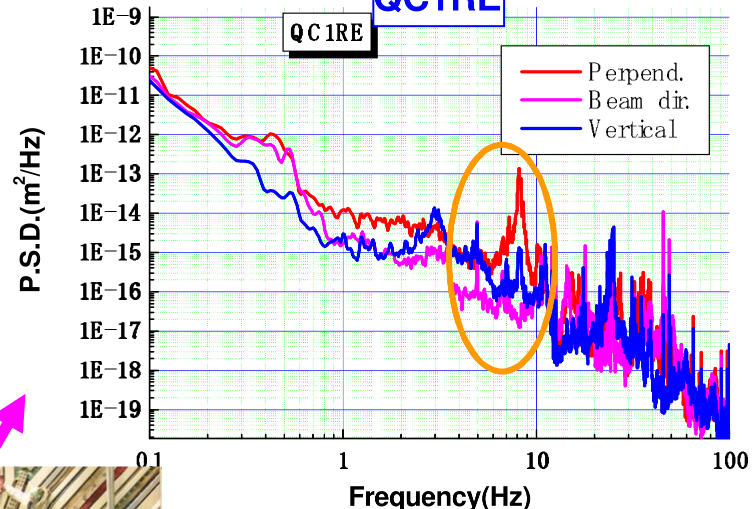


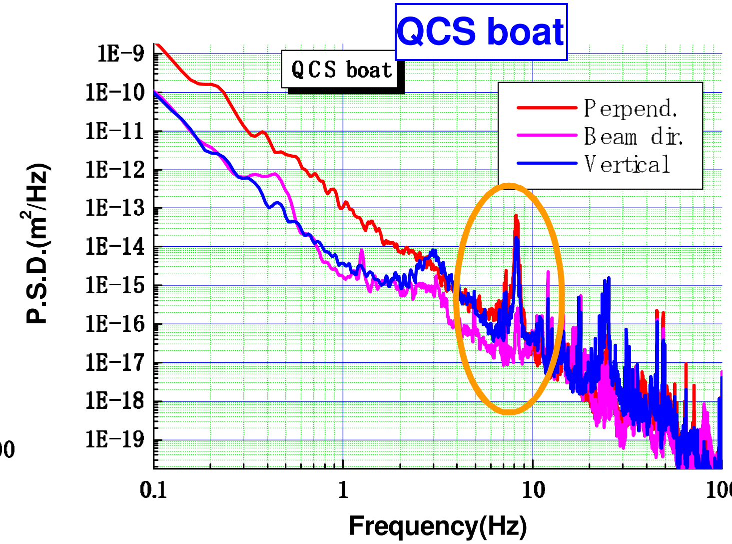
- Coherency: >10Hz is getting worse.
- Vertical dir.: <1Hz is bad.

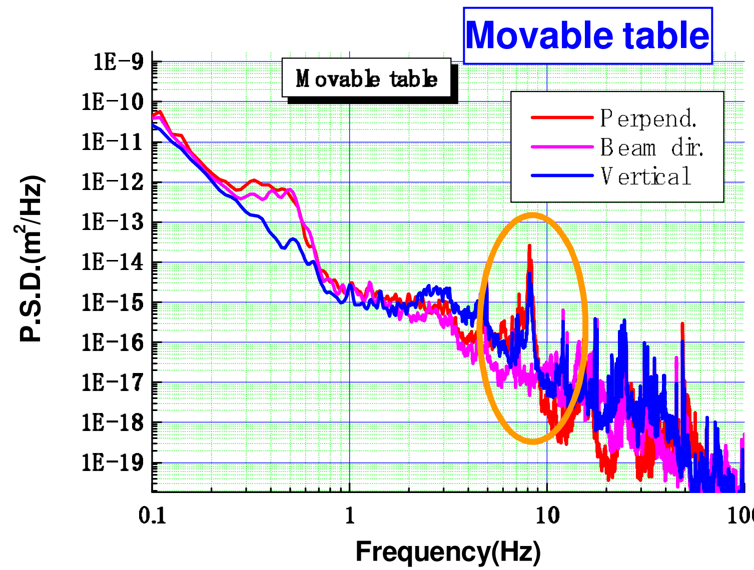
Vibrations on the KEKB

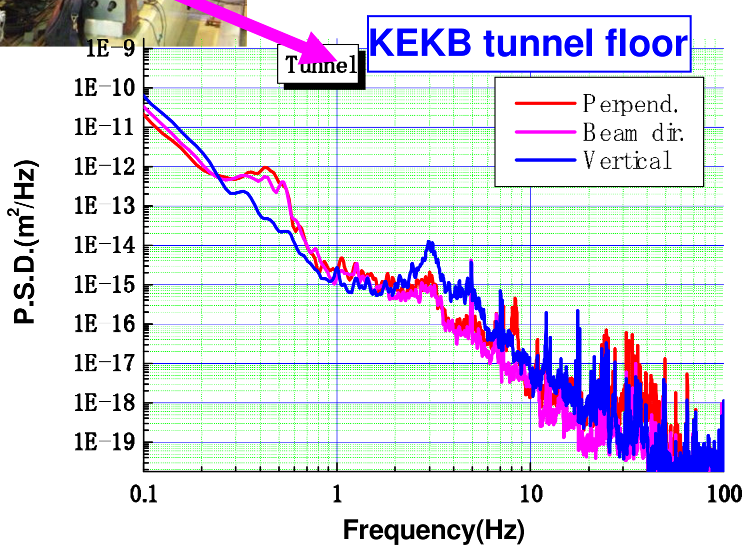
P.S.D.







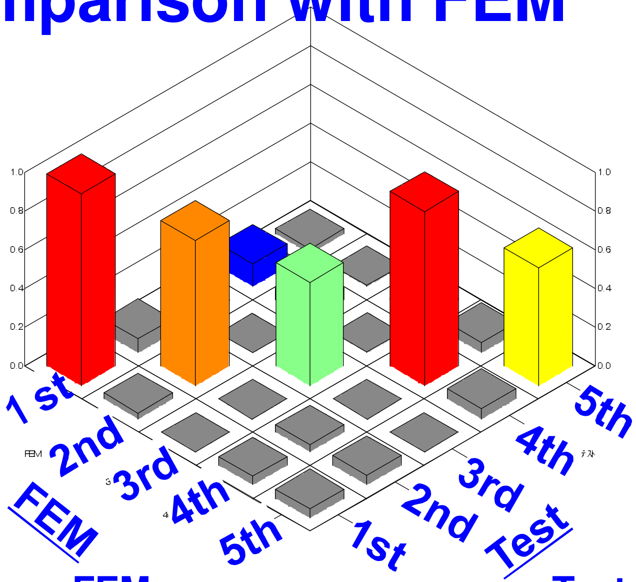




地盤状況	区分	固有周波数（Hz）
岩盤・硬質礫層	第I種	10 Bedrock
砂礫層・ローム層	第II種	3 Gravel
I、II種以外	第III種	1.3
沖積層、埋立地	第IV種	1 Alluvium

（出典：環境振動工学入門）

Comparison with FEM

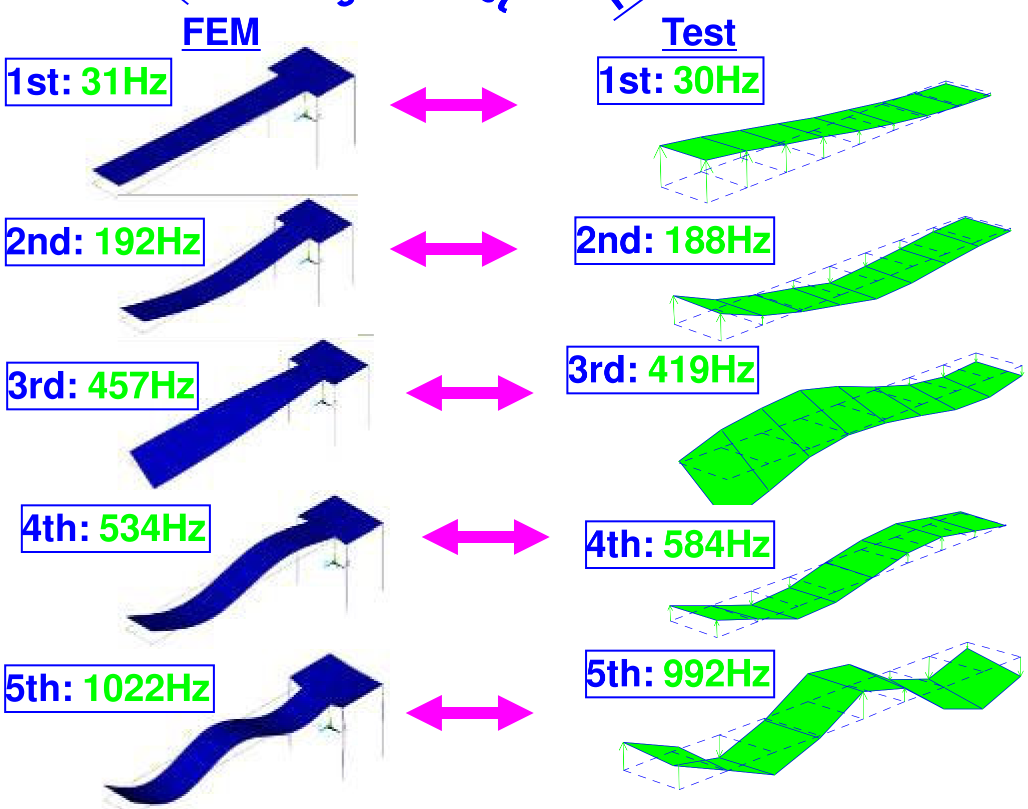


MAC(Modal Assurance Criteria)

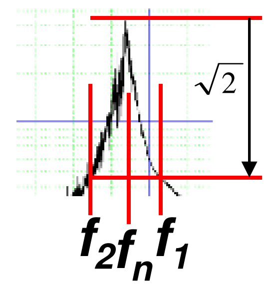
$$MAC_{rr'} = \frac{\left| \{\psi_r^{test}\}\{\psi_{r'}^{FE}\}^* \right|^2}{\left(\{\psi_r^{test}\}\{\psi_r^{test}\}^*\right)\left(\{\psi_{r'}^{FE}\}\{\psi_{r'}^{FE}\}^*\right)}$$

Modal assurance criteria quantitatively compare all the possible combinations of test and analysis mode shape pairs.

MAC=1: Mode shape pairs is exactly match
MAC=0: pairs that are completely independent



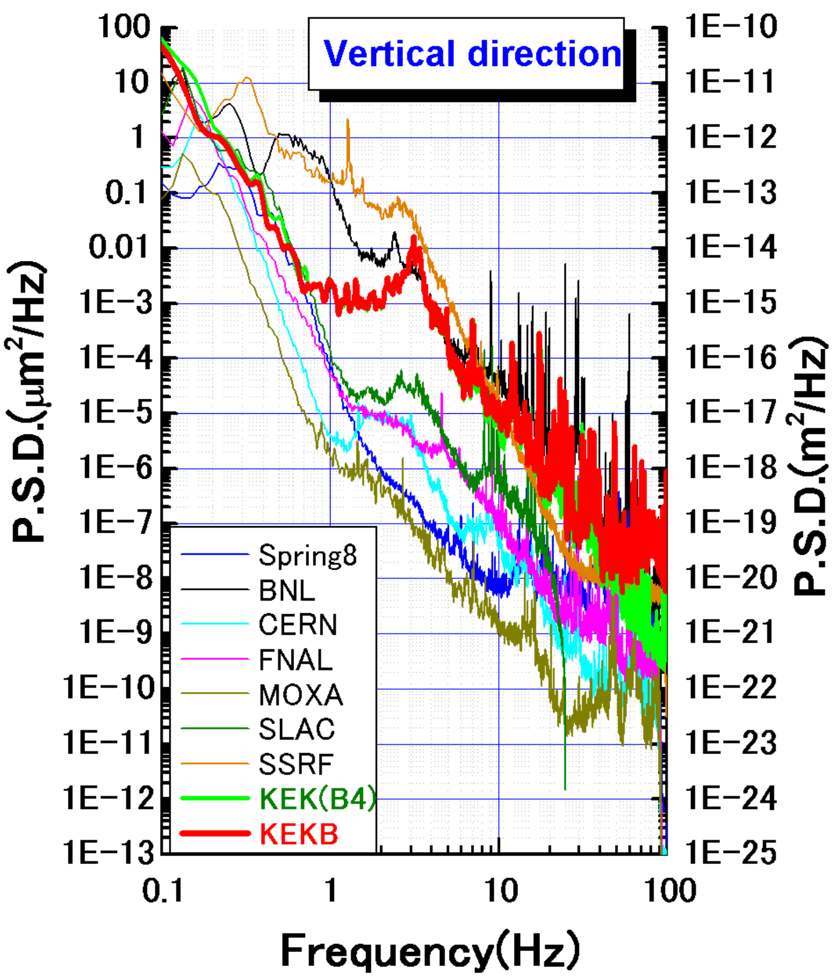
Damping ratio measurement



$$\zeta = \frac{f_1 - f_2}{2 \times f_n}$$

Mode	Freq.	Damping(%)
1	30.4Hz	1.68
2	188Hz	0.422
3	419Hz	0.303
4	584Hz	0.113
5	992Hz	8.02E-2

Comparison of ground motion with various sites



Reference: http://vibration.desy.de/overview/

Overview of Measured Sites (Vertical Direction, >1Hz)

Site location	Average rms (nm)	Day rms (nm)	Night rms (nm)
ALBA, Barcelona, Spain	18.8	42	9.1
APS, Argonne, U.S.A.	10.7	11	9.8
Asse, Germany (salt mine)	0.6	0.7	0.5
BESSY, Berlin, Germany	75	140.7	53.1
BNL, Upton, U.S.A.	89.6	135.3	29.1
CERN LHC, Geneva, Switzerland	1.9	2.8	0.9
DESY HERA, Hamburg, Germany	53.3	77	34.8
DESY XFEL, Osdorf, Germany	29.1	48.4	19.5
DESY XFEL, Schenefeld, Germany	41.1	70	35.1
DESY, Zeuthen, Germany	64.4	75.6	88.5
Ellerhoop, Germany (TESLA IP)	18.2	35.9	9.3
ESRF, Grenoble, France	74	137.2	40.2
FNAL, Batavia, U.S.A.	3	4	2.2
IHEP, Beijing, China	8.5	9	8.1
KEK, Tsukuba, Japan	80.5	125.1	38
LAPP, Annecy, France	3.6	7	1.9
Moxa, Germany (seismic station)	0.6	0.9	0.5
SLAC, Menlo Park, U.S.A.	4.9	7.4	4.1
Spring-8, Harima, Japan	2	2.5	1.8
SSRF, Shanghai, China *	292	444	102

Reference: http://vibration.desy.de/overview/

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