OUR EXPERIENCES WITH VIBRATION AND DAMPING MATERIAL

M. Masuzawa and H. Yamaoka
KEK, Tsukuba, Japan

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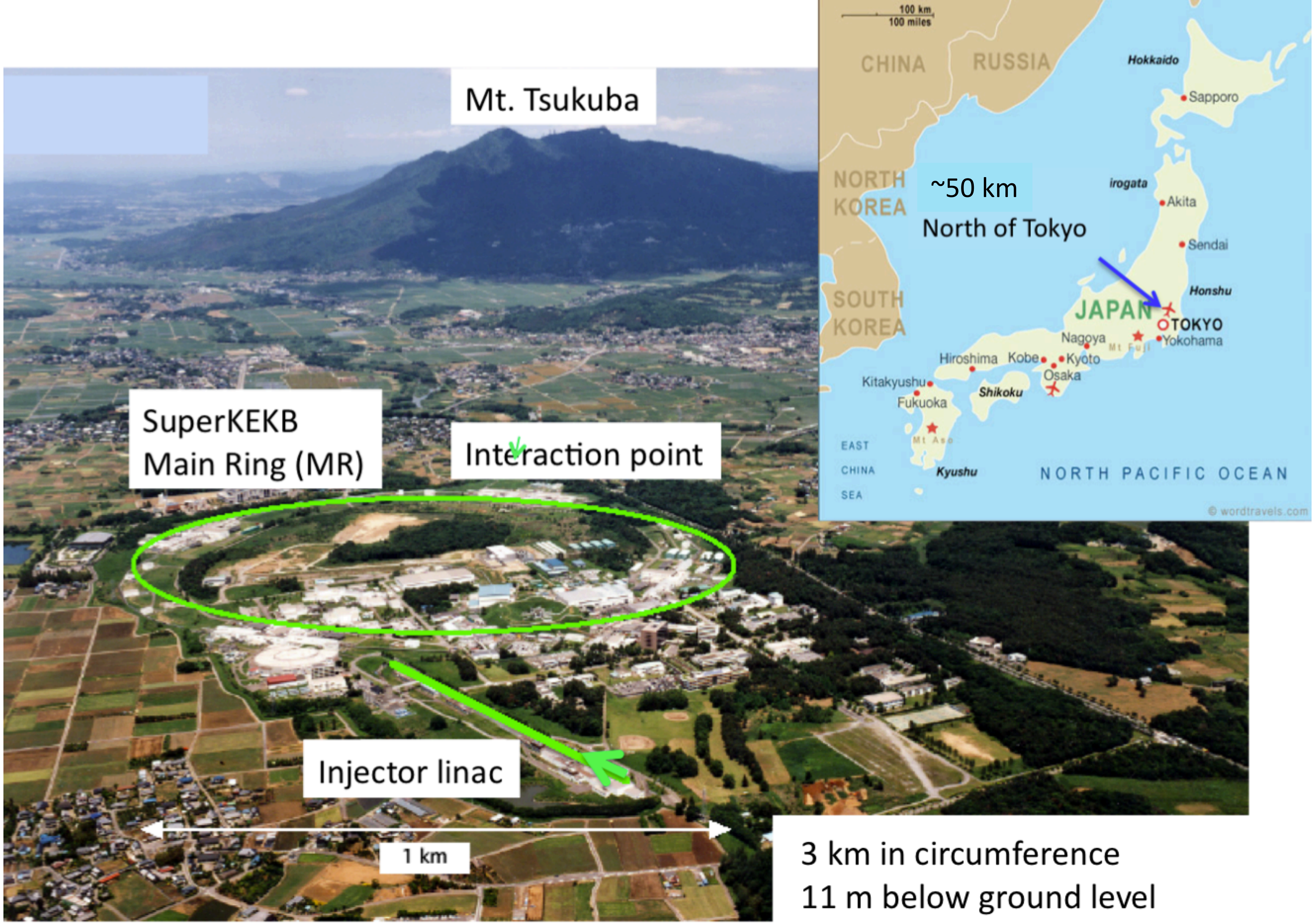
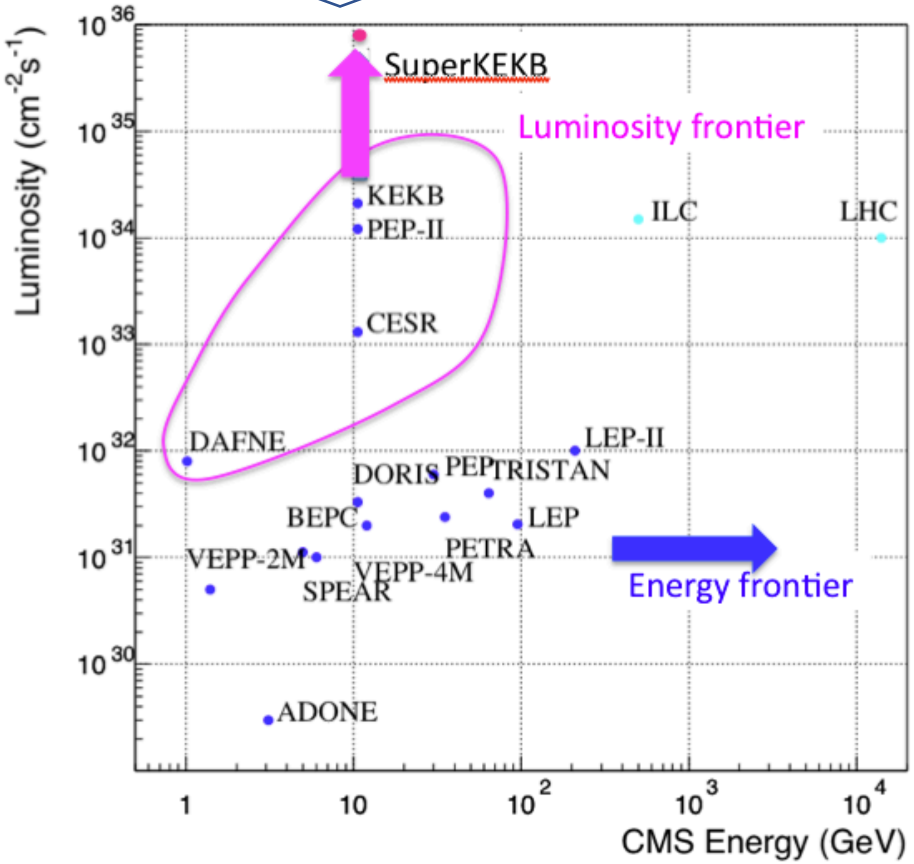
5. Summary

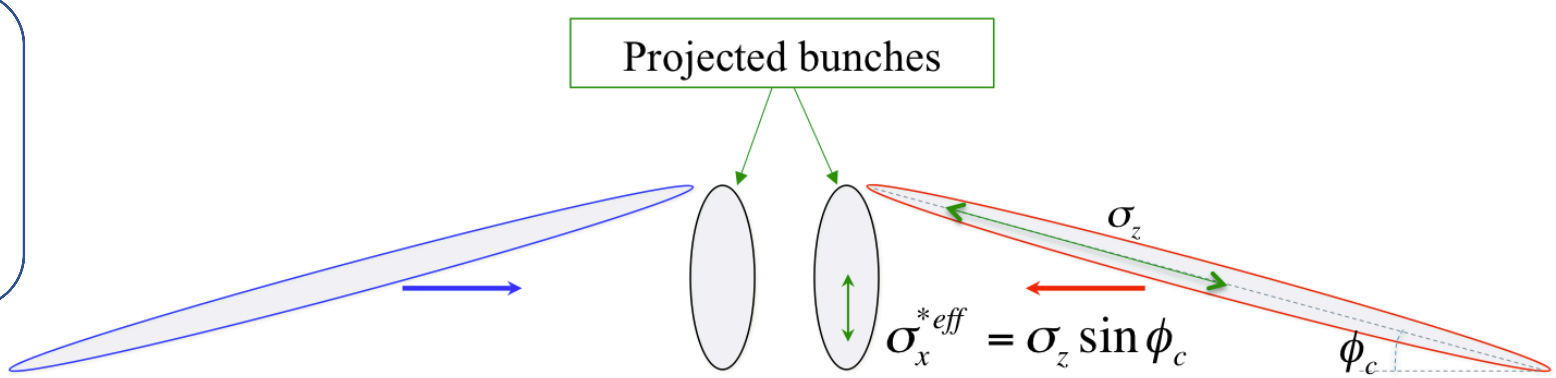
1. Introduction
   - Vibration issues at SuperKEKB
   - KEK site

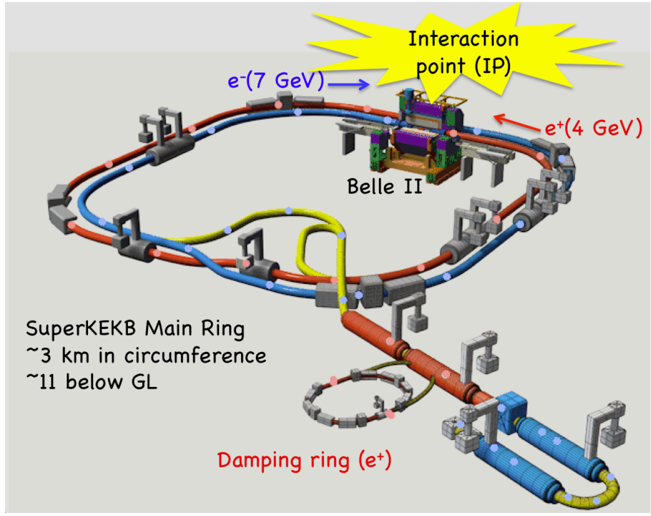


3 km in circumference
11 m below ground level

SuperKEKB
Super-high luminosity machine.
Never achieved by any other machines
Actually KEKB has the world record peak luminoisity



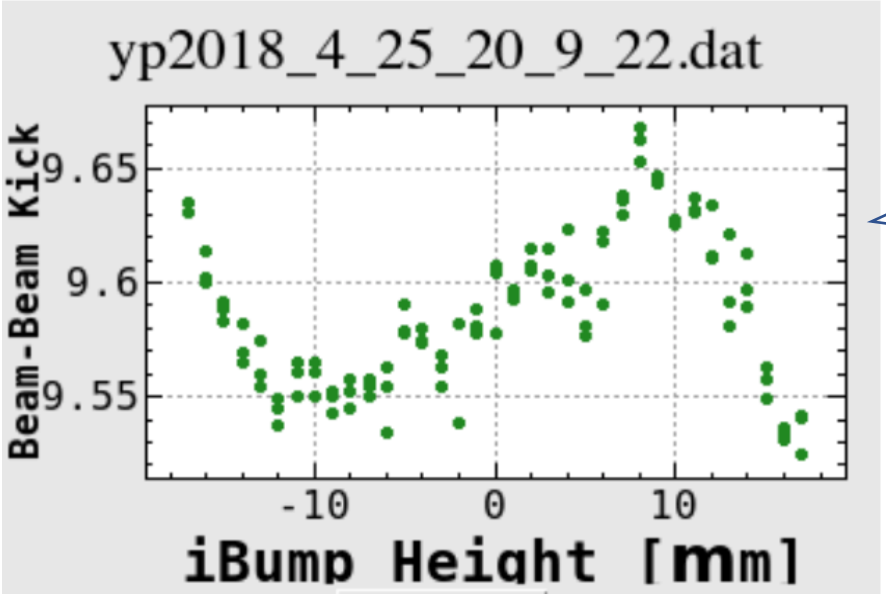




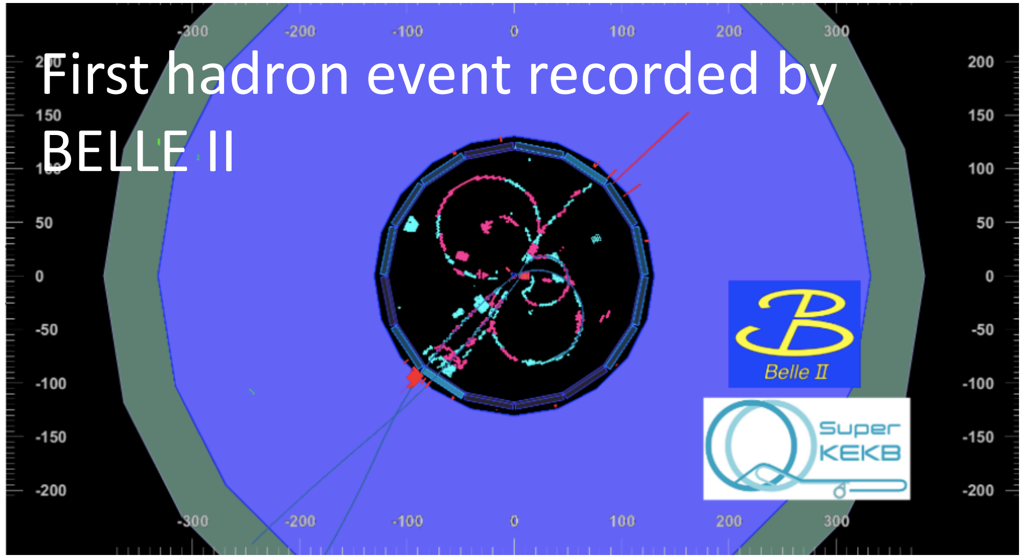
parameter	Design LER/HER
σ_x^*	10.1/10.7 μm
σ_y^*	48/59 nm
σ_z^*	6/5 mm
Crossing angle	83 mrad

Vibration in the tunnel, especially at the IP, could be a critical issue that may result in luminosity degradation.

The SuperKEKB phase II commissioning (March 2018 ~ July 2018)



The first collision was confirmed on April 25, 2018 by observing the vertical beam-beam deflection.



The first collision signal was obtained when the electron beam (HER) was shifted by ~30 μm using a set of dipole corrector magnets.

This very small offset needed for the first collision is the result of excellent magnet alignment (and luck).

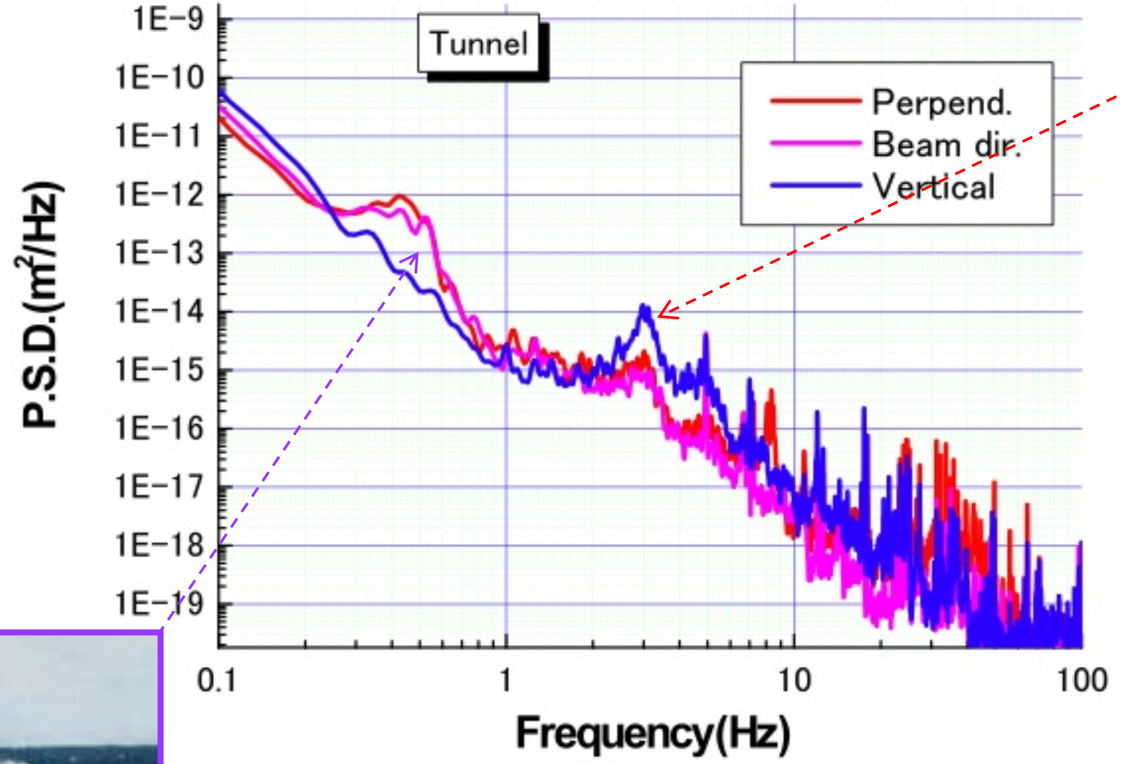
The beta-functions at Phase II was ~10 larger than the design. Colliding the beams and keeping the collision conditions will be much harder in Phase III

1. Introduction
   - Vibration issues at SuperKEKB
   - KEK site

Environment surrounding SuperKEKB

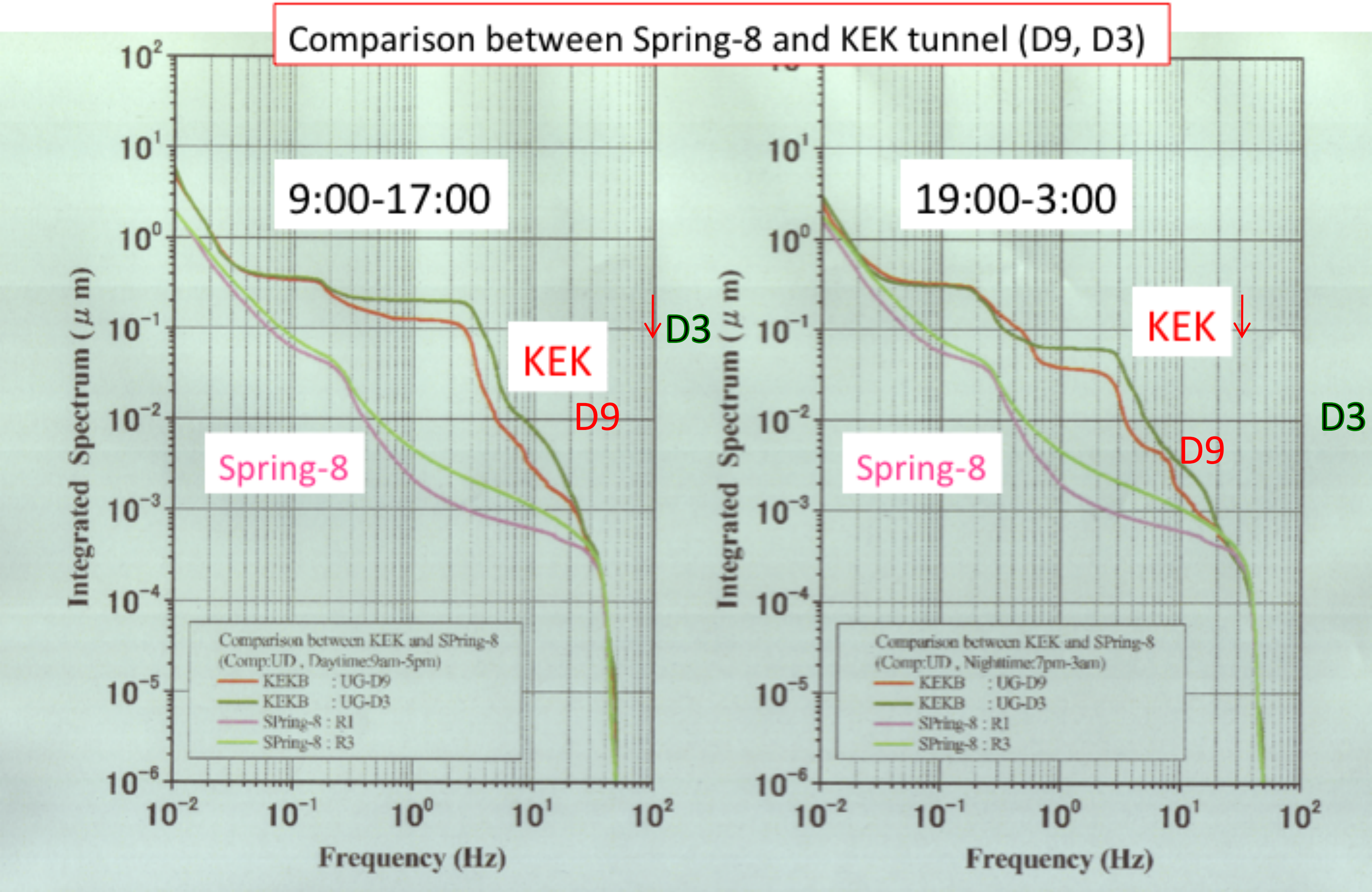
~3Hz : characteristic frequency of the soil called "Kanto loam" around KEK.

- Induced by human activities, mainly vertical vibration.
- Day & night effects, weekend effects have been observed.



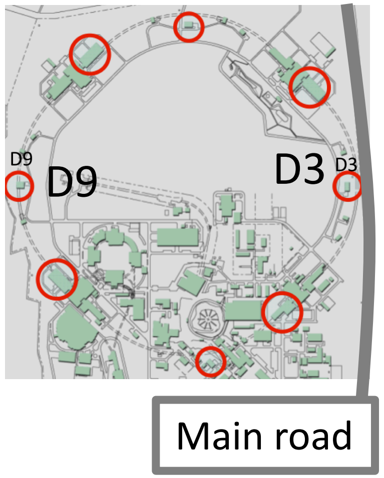
0.2~0.3 Hz: Ocean waves & wind.
Depends on the weather, mainly in horizontal vibration.

Comparison with SPring-8



図−4.11 KEK・SPring−8 の積分ｽﾍﾟｸﾄﾙ比較 (垂直成分：昼間 9am−5pm)

図−4.12 KEK・SPring−8 の積分ｽﾍﾟｸﾄﾙ比較 (垂直成分：夜間 7pm−3am)



KEK site is much worse than SPring-8…
D3, closer to the main road, is worse than D9.

A clear day&night effect around 3Hz, caused by human activities such as traffic, is seen as predicted.

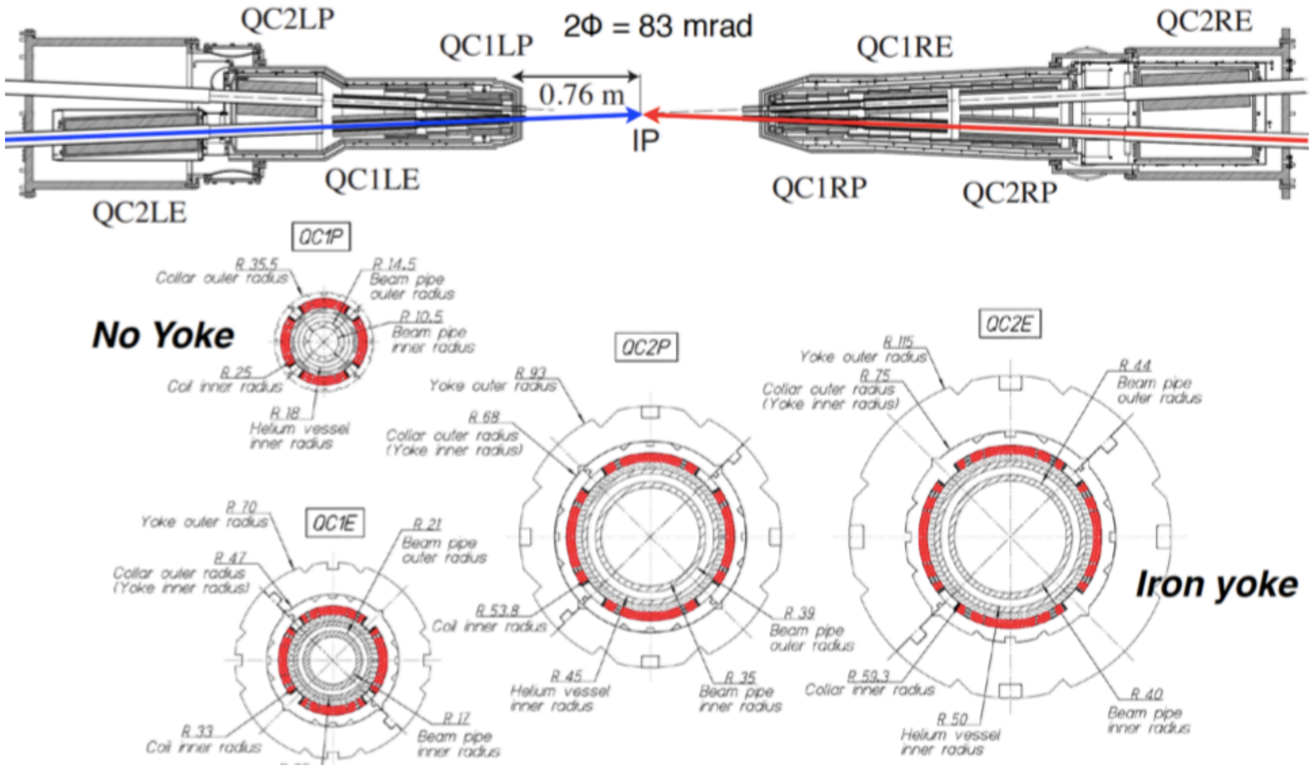
Comparison of Site Vibration

Presented by R. Deng (SINAP)@GM2017@IHEP

Location	Peak to Peak distribution Maximum pp (nm)	FWHM (nm)	without highest 5% Average RMS (nm)	SD σ (nm)	Selected Data Quiet RMS (nm)	Noisy RMS (nm)
1 Seismic Station Moxa	7	17	0.6	0.1	0.5	0.9
2 Salt Mine Asse	12	35	0.5	0.1	0.5	0.7
3 CERN LHC Tunnel	21	53	1.8	0.8	0.9	2.9
4 Spring-8 Harima	22	40	2.0	0.4	1.8	2.5
5 FNAL Batavia	23	49	2.9	0.9	2.2	4.0
6 LAPP Annecy	35	59	3.3	1.6	1.9	7.0
7 IHEP Beijing	49	18	8.4	0.5	8.1	9.0
8 SLAC Menlo Park	60	105	4.8	1.2	4.1	7.4
9 APS Argonne	68	56	10.5	1.0	9.8	11.0
10 ALBA Cerdanyola	87	125	18.3	9.5	9.1	42.0
11 DESY TESLA	104	160	17.4	8.4	9.3	35.9
12 DESY XFEL Osdorf	150	195	28.9	11.9	19.5	48.4
13 DESY Zeuthen	105	235	64.0	40.4	88.5	75.6
14 ESRF Grenoble	155	175	71.6	34.9	40.2	137.2
15 DESY XFEL Schenefeld	180	245	38.7	16.6	35.1	70.0
16 DESY HERA	170	200	51.8	18.9	34.8	77.0
17 KEK Tsukuba	170	210	78.0	36.0	38.0	125.1
18 BESSY Berlin	245	160	72.8	28.1	53.1	140.7
19 SSRF Shanghai	550	1000	292	164	102	444

Courtesy of H. Ehrlichmann

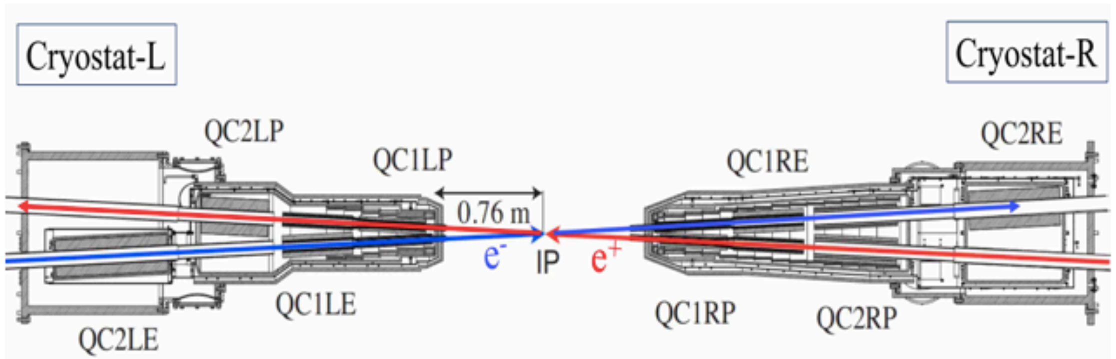
2. Vibration of SC final focusing Quads

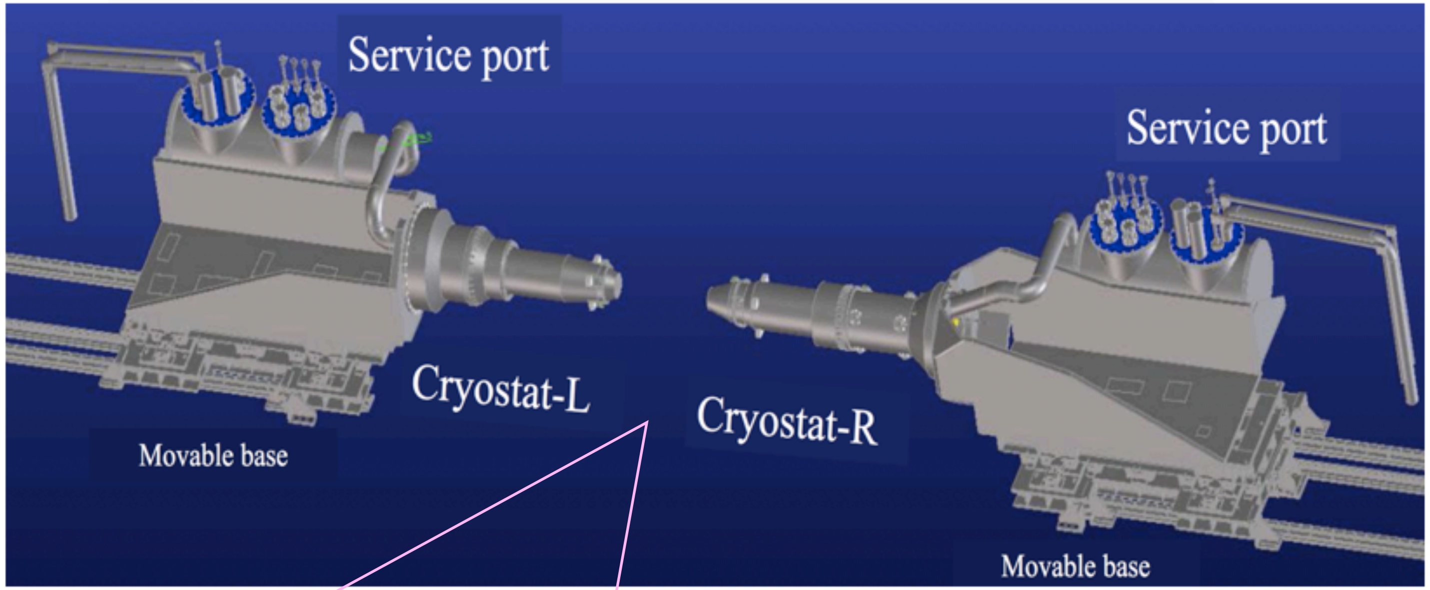


SuperKEKB IR

When the tunnel floor vibrates, magnets also vibrate @ their natural frequencies, →usually a few tens of hertz.

→The vibration of the superconducting final focus quadrupole magnets near the IP will affect the beam orbit and degrade the luminosity more seriously than any other magnets in the tunnel.

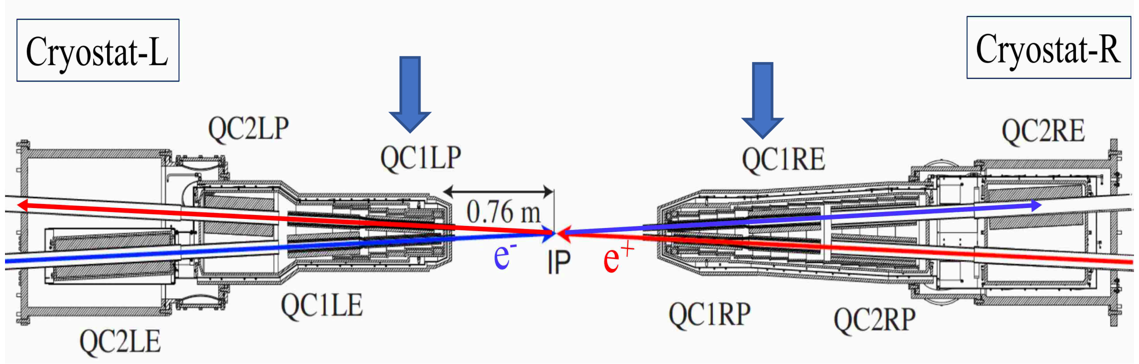




Two cryostats, at left and right sides of the IP.

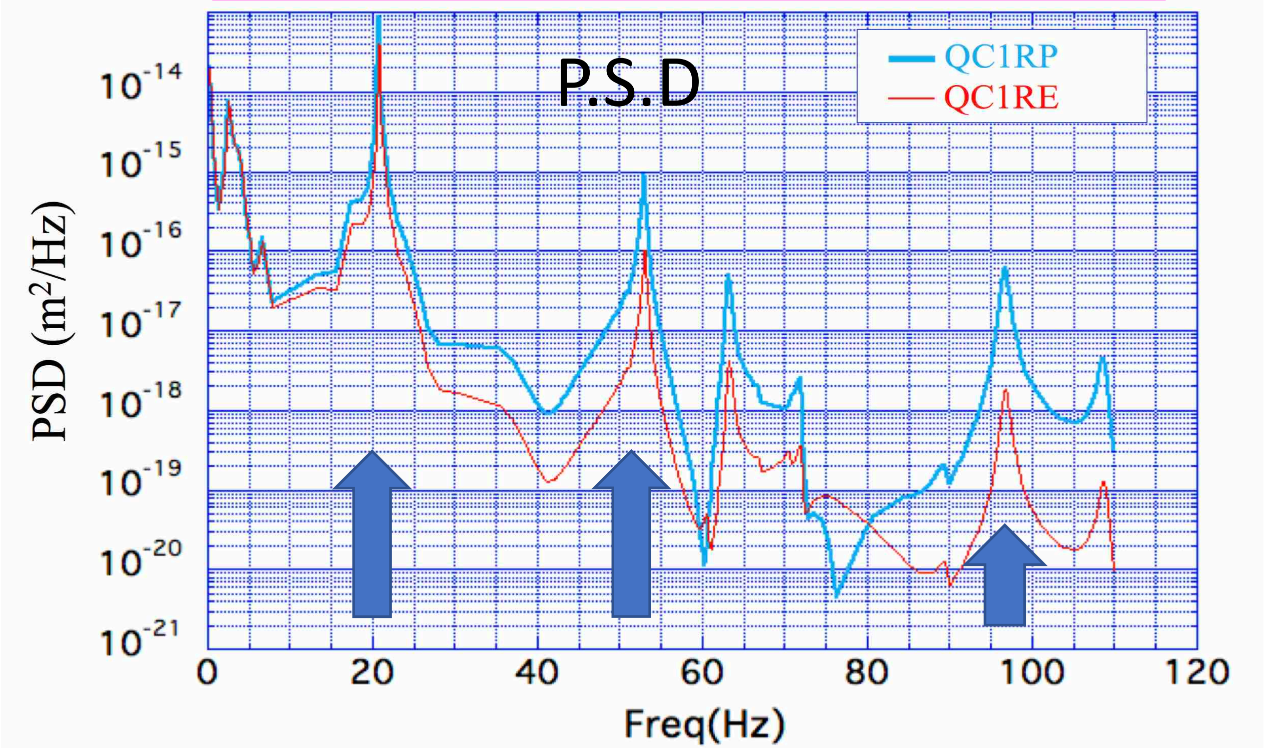
cryostat is connected to a movable base made of iron in a cantilever style

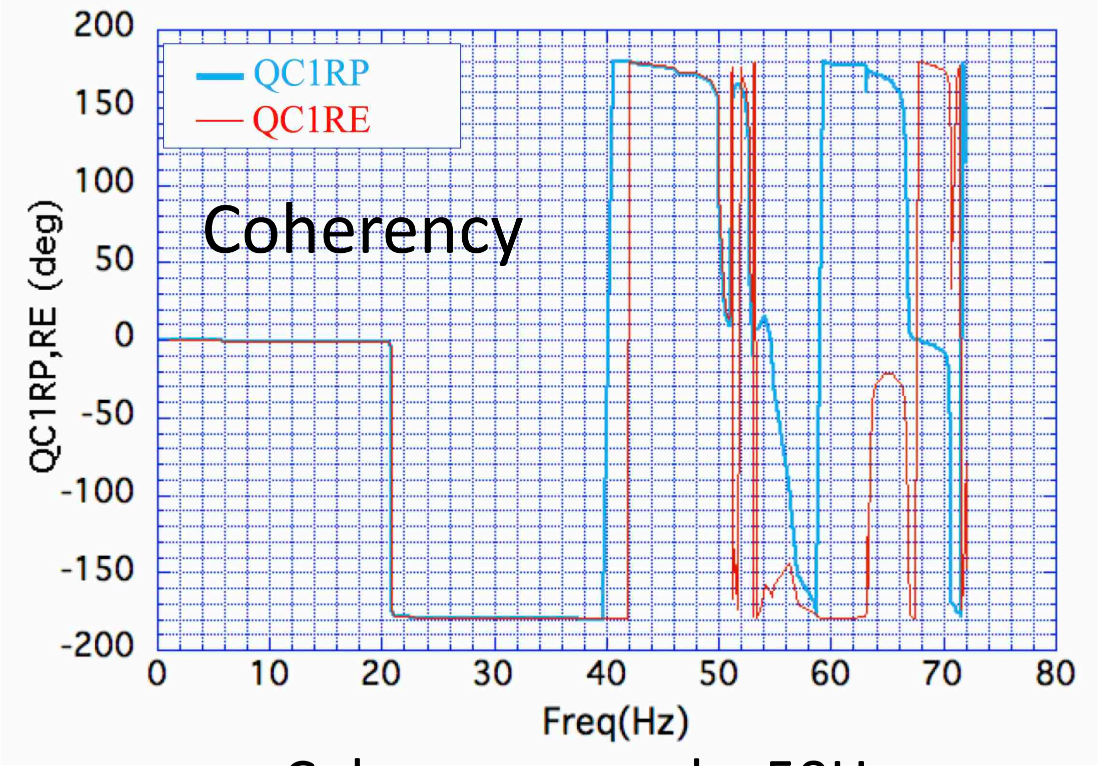
Vibration at the base will be enhanced at the SC final focusing quads.



Estimation of the magnet vibration in the cryostat (ANSYS)

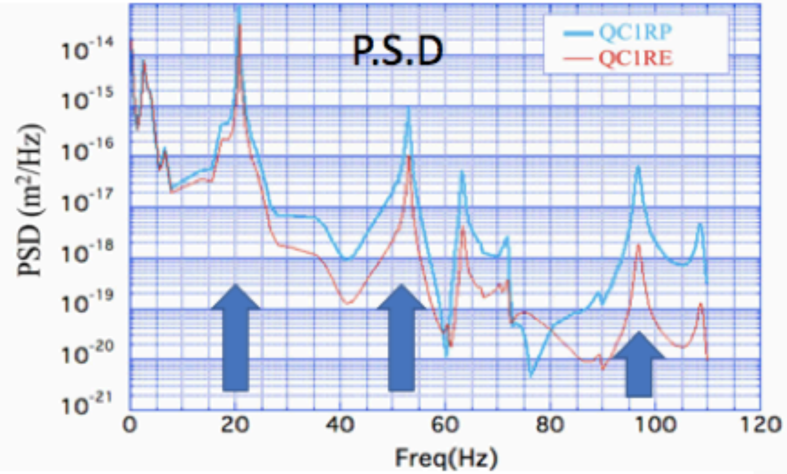
QC1RP: Positron beam line magnet
QC1RE: Electron beam line magnet

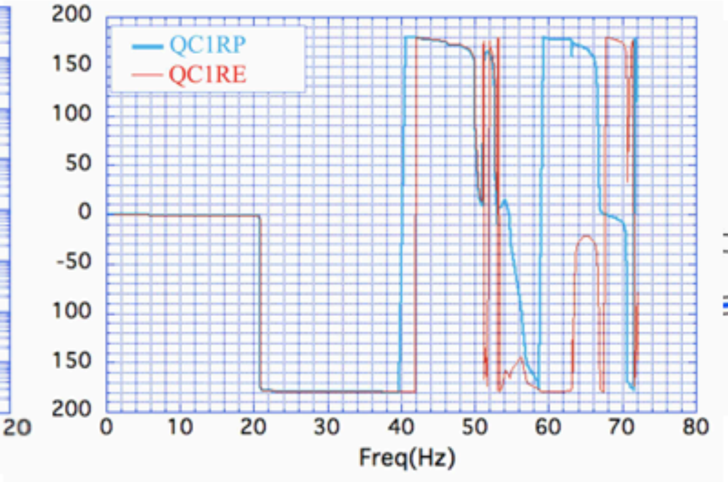


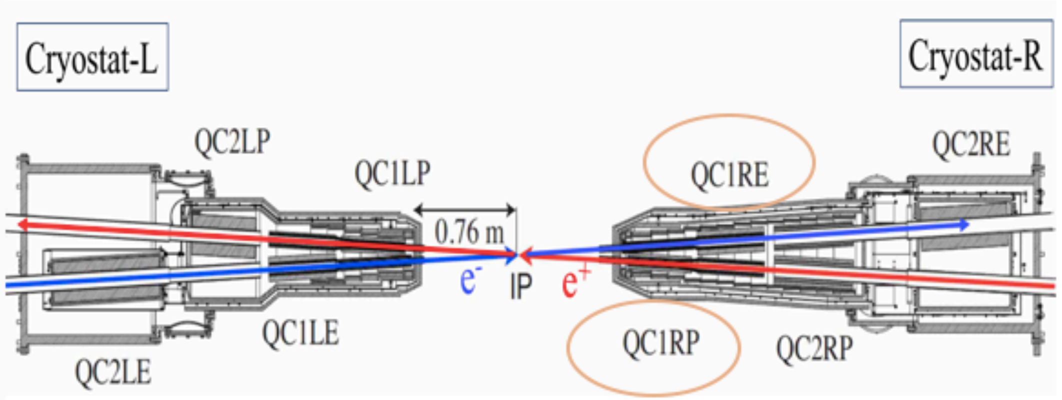


Coherency good < 50Hz
Coherency poor > 50Hz

If they vibrate coherently, OK
If incoherently, not really OK







Freq. (Hz)	Amp. (nm)	Luminosity loss (%)
21	38.9	12.0
53	21.0	5.3
97	6.6	0.9

Vibration result in luminosity degradation

There are two approaches to cope with the vibration issue
(1)damping the vibration
(2)orbit feedback at the IP

Using (non rubber) damping material

2. Damping material test

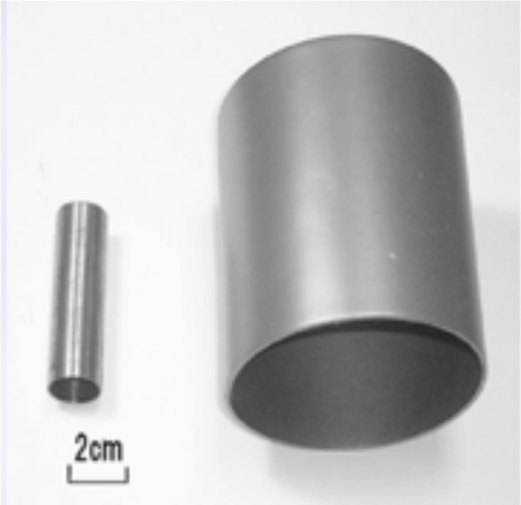
- About M2052
- Experimental setup

M2052

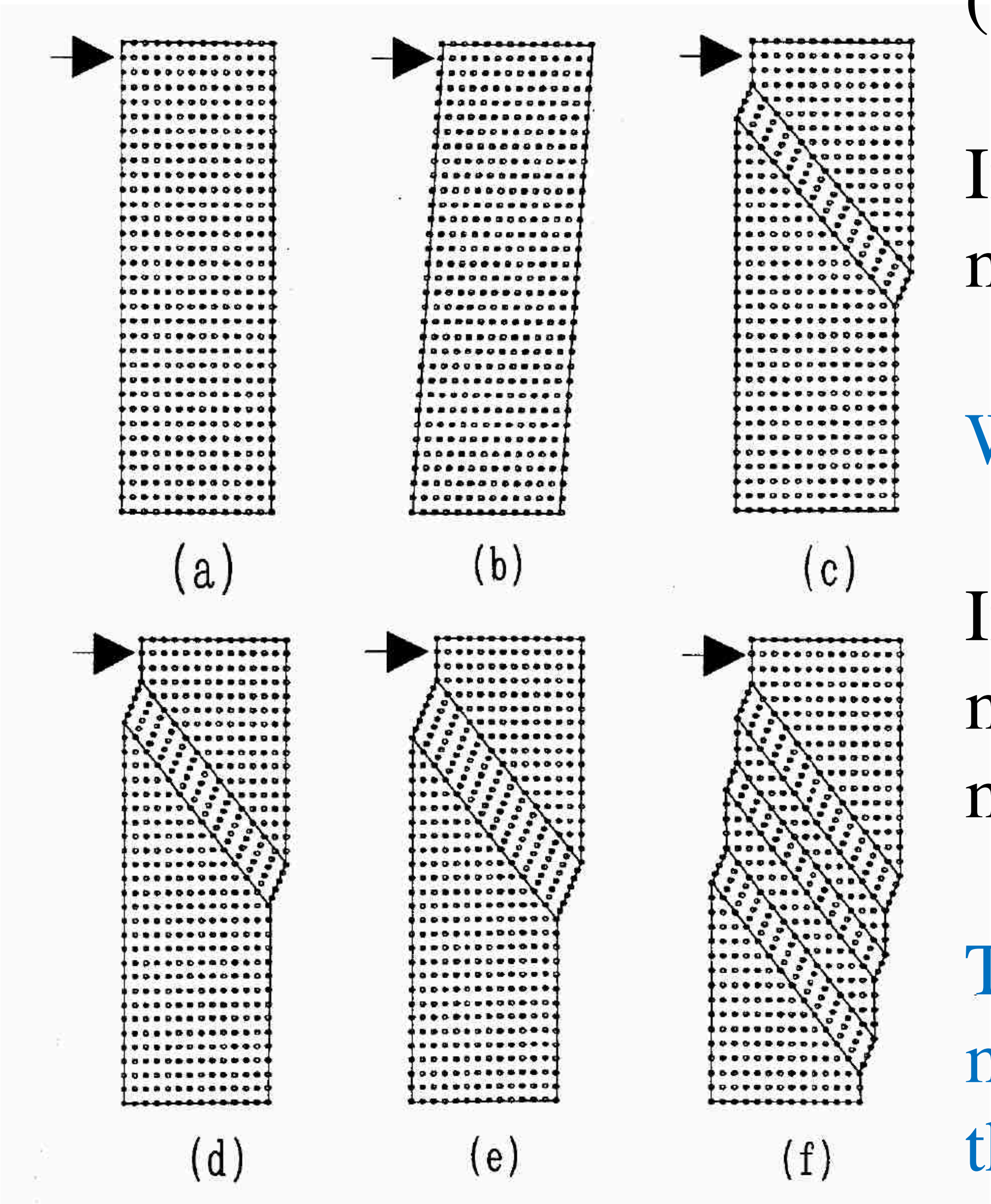
Property	Value	Similar to
Young’s modules	30 (GPa)	Al, Ag, Cd
Heat Conductivity	10(W/m·K)	Ti, Sb,Pb, Bi
Specific heat	512.7 (J/kg·K)	Ti,Fe,Cr
Thermal expansion	22.4($\times 10^{-6}$/deg)	Al,Ag,Sn,Cu
Density	7.25(g/cm^3)	Fe,Mn

- M2052 is manganese-based alloy developed by K. Kawahara at National Institute for Material Science （NIMS), Japan.
- Nominal composition of 20% cupper, 5% Nickel and 2% iron.
  Contents are nothing special heat treatment needed.

- Expensive (I think it is “Supply and demand issue”)
- Mainly been used in the audio and video field.



Damping mechanism



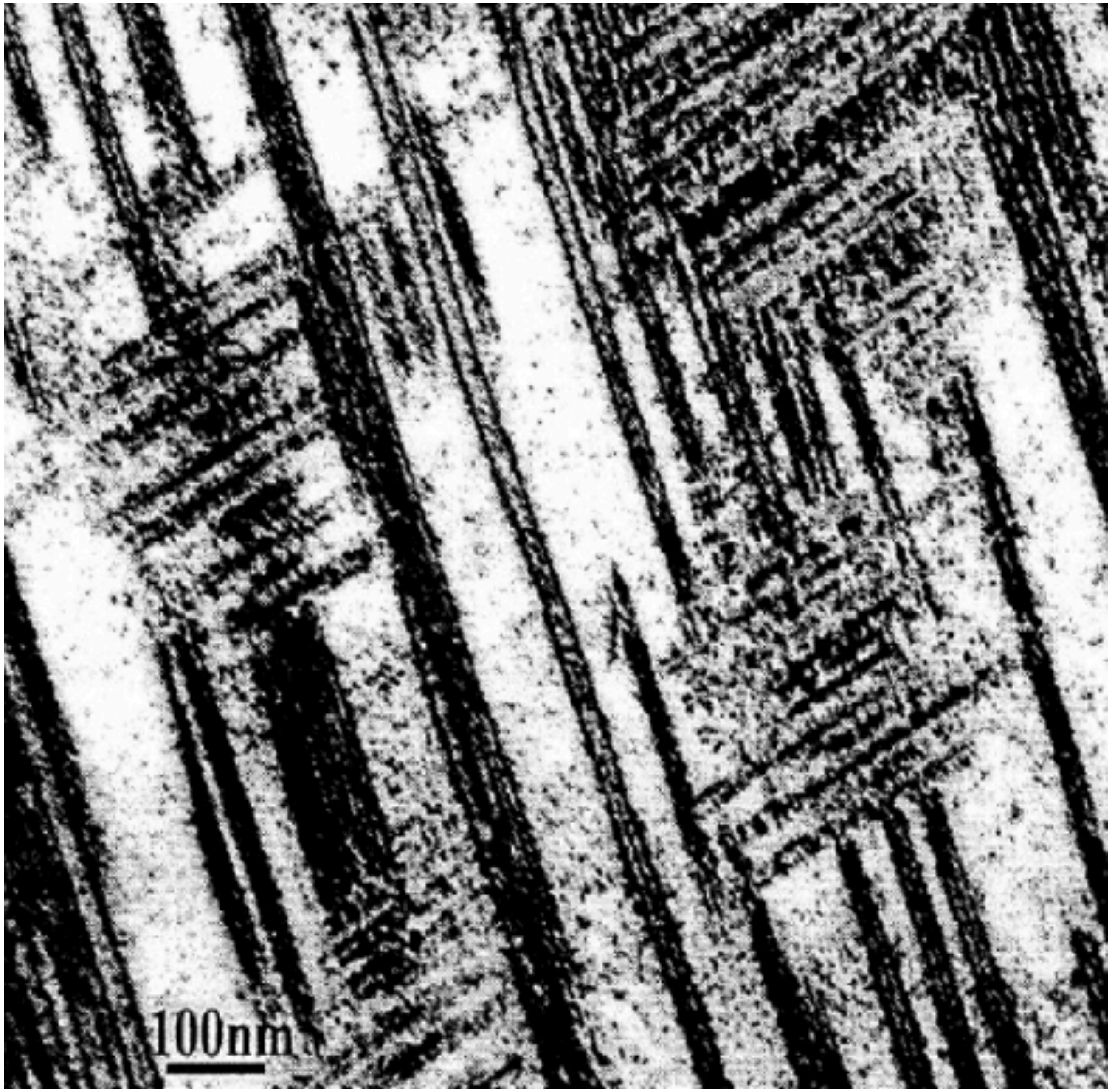
When an external stress is applied to a rigid body (a), it deforms (b).

If more stress is added, “twin displacement microstructures” develop (c).

When the stress is removed, they disappear.

If more stress is added, the width of the microstructure region becomes larger and/or more microstructures appear (d),(e),(f).

This series of appearances and movements of the microstructures changes the vibration energy into thermal energy → vibration damping.

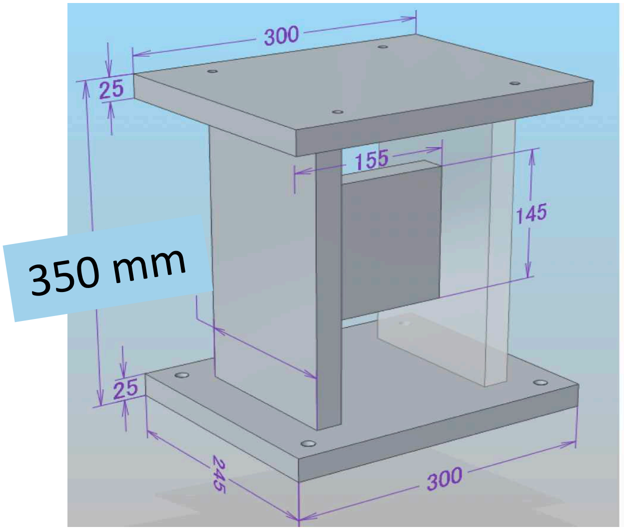


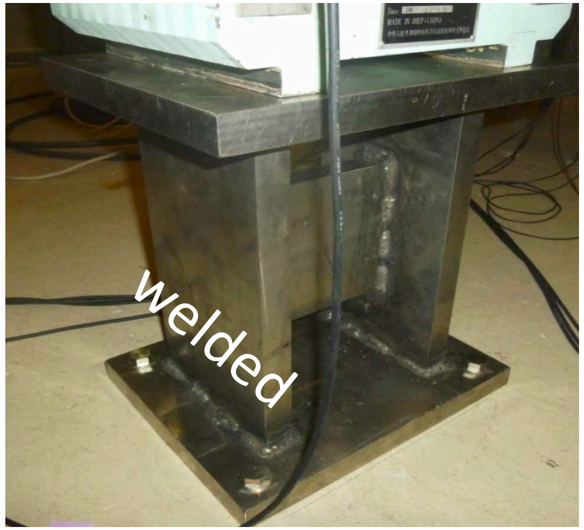
“twin displacement microstructures”

2. Damping material test
   - M2052
   - Experimental setup

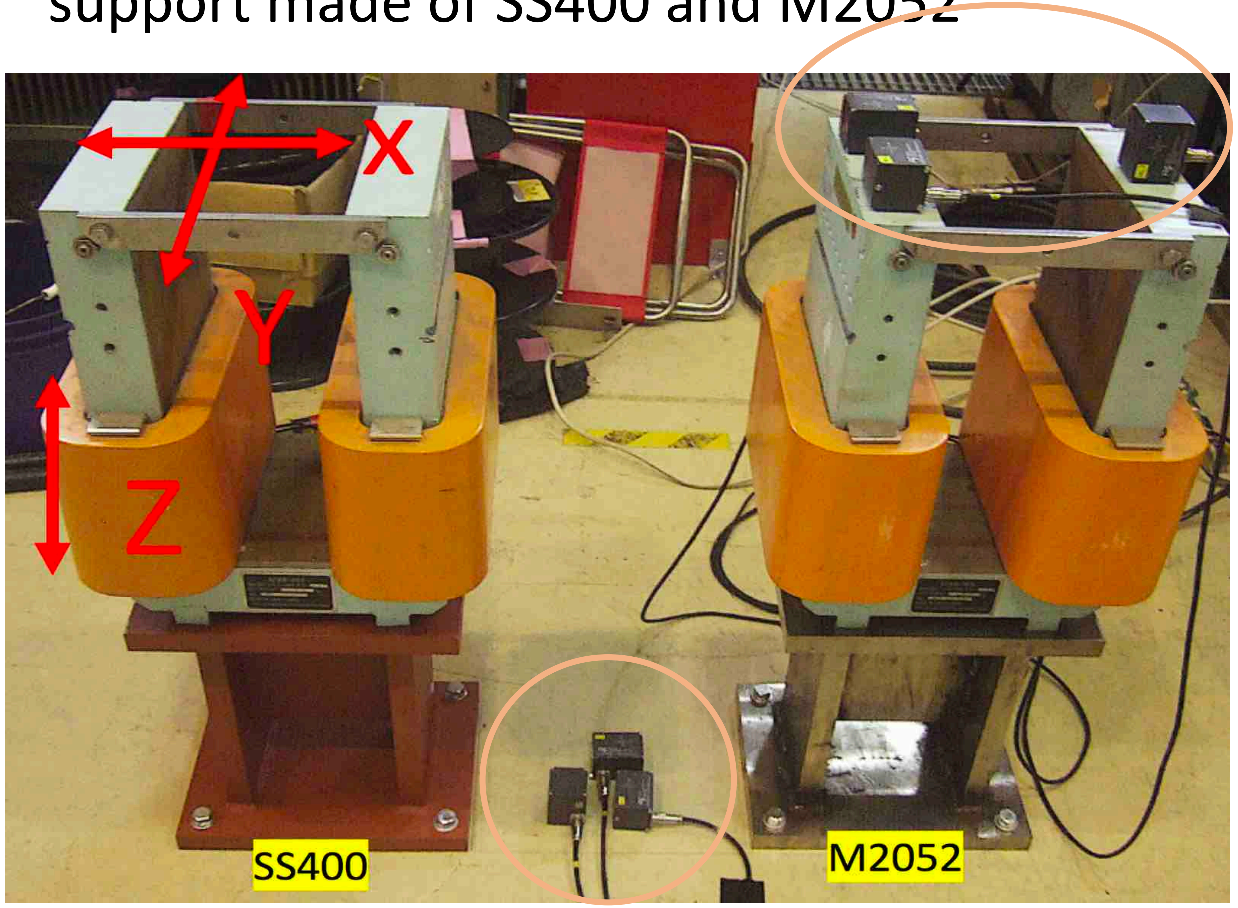
Experimental setup

Magnet support designed and fabricated for the comparison test.





Two magnets of the same type on magnet support made of SS400 and M2052



Vibration sensors (acceleration sensors) for horizontal (x and y) & vertical (z) directions

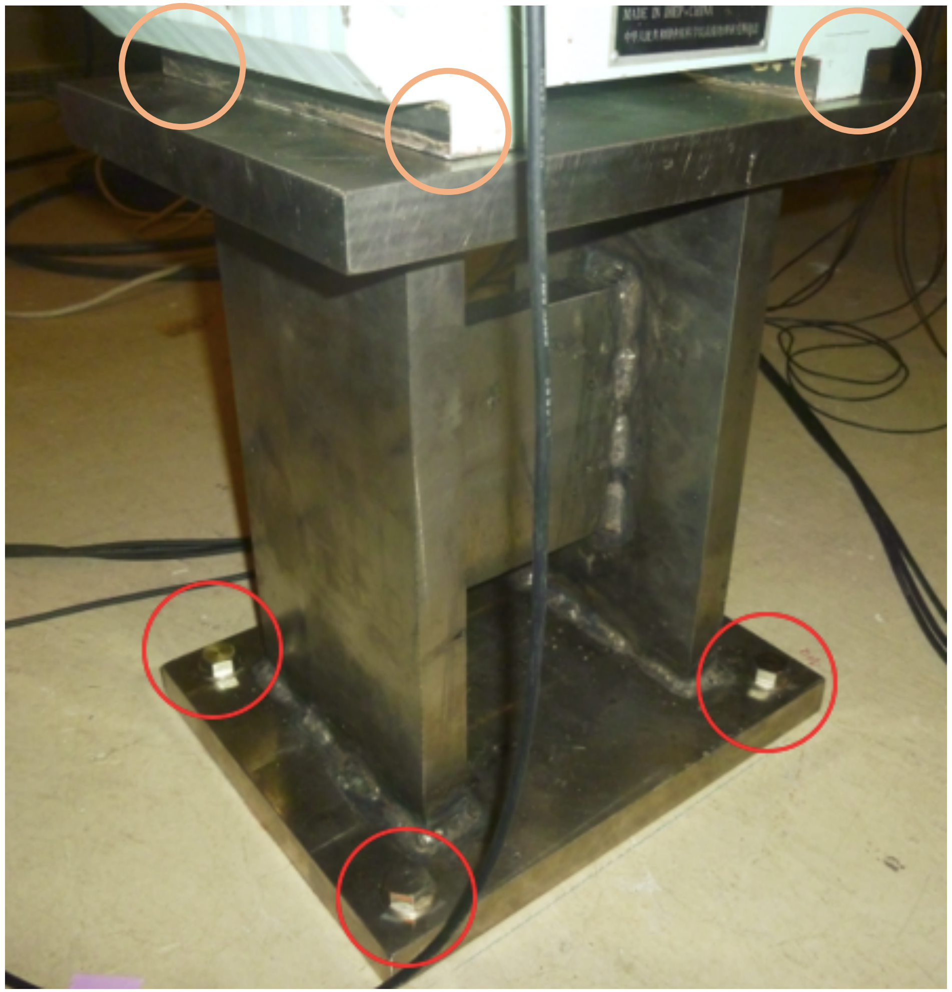
Placed on the floor, on top of the magnets.

Compare 3 cases:

(1)A magnet is mounted on a support made of SS400, where the magnet is connected to the support by bolts made of stainless steel ("SUS304") and the support connected to the floor by SUS304 bolts.

(2)A magnet is mounted on a support made of M2052, where the magnet is connected to the support by bolts made of stainless steel ("SUS304") and the support connected to the floor by SUS304 bolts.

(3)A magnet is mounted on a support made of M2052, where the magnet is connected to the support by M2052 bolts and the support connected to the floor by M2052 bolts.

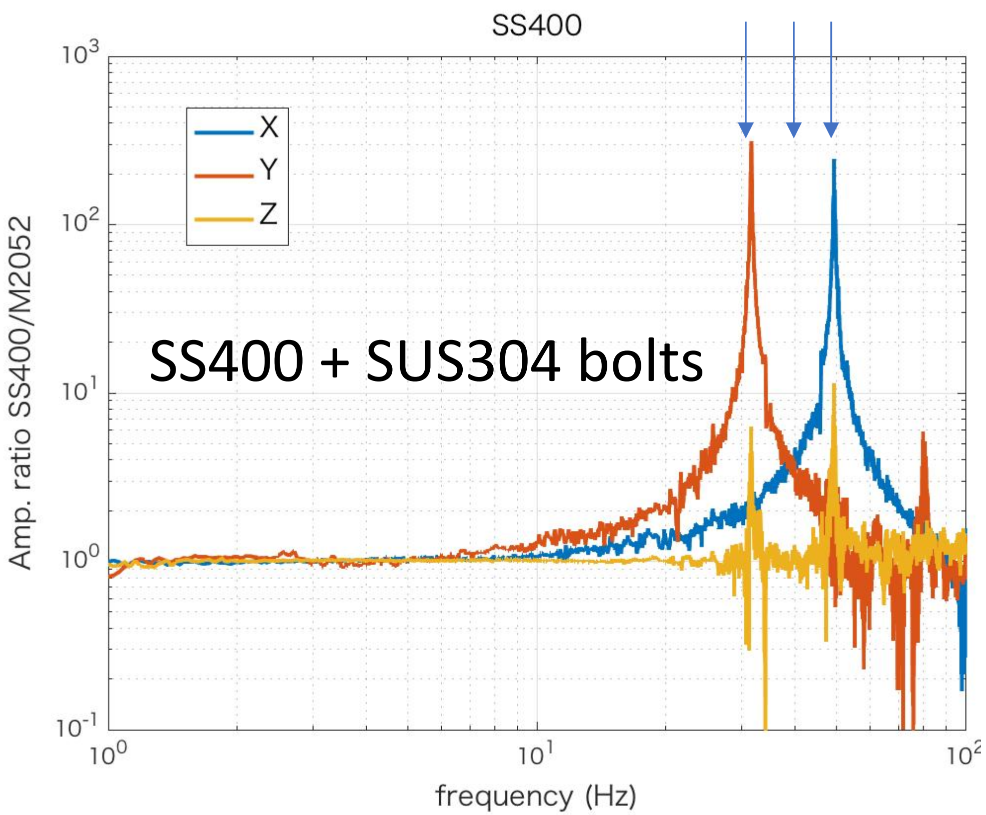


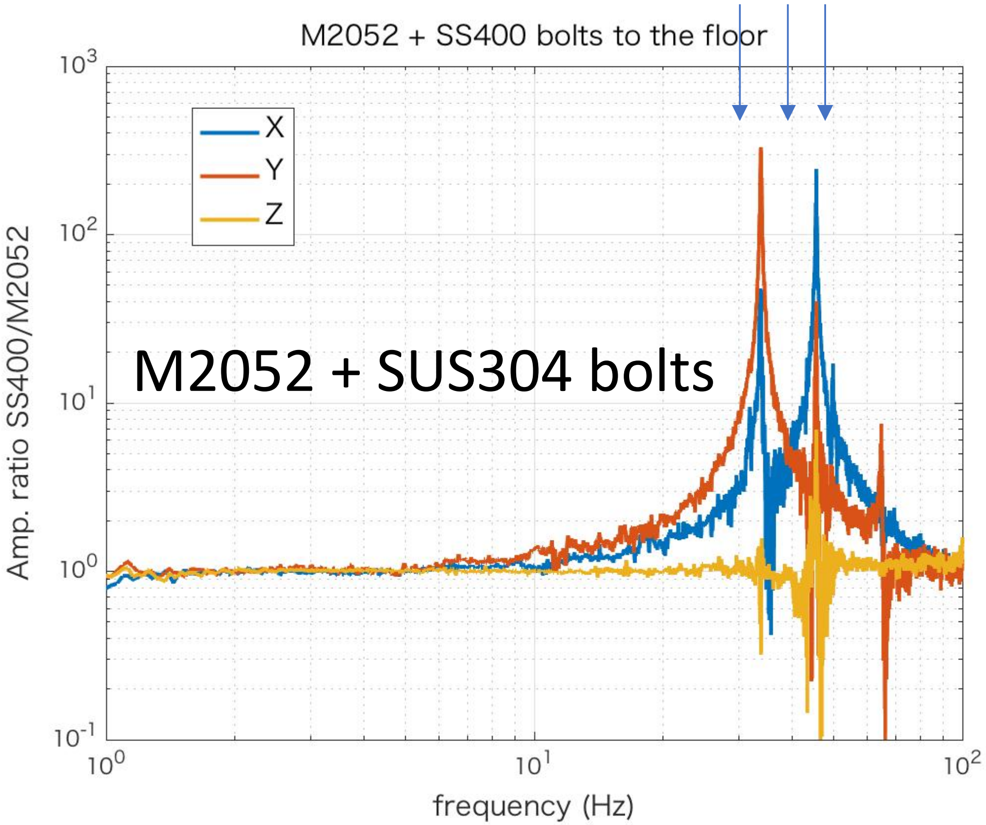
(4)SS400 support but M2052 bolts

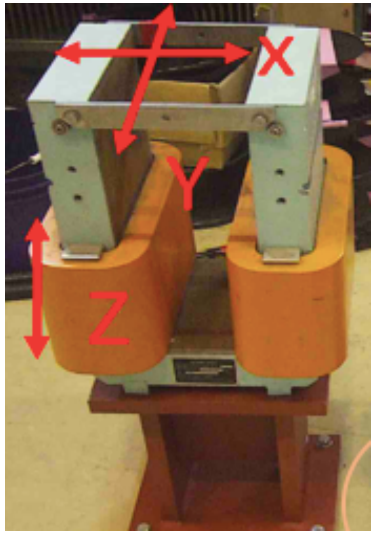
3. Results

- Comparison with non-damping SS400
- Application to cryostat

Response function
ratio to the floor (input) vibration



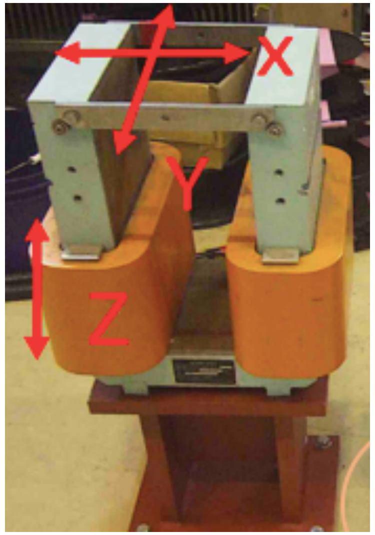




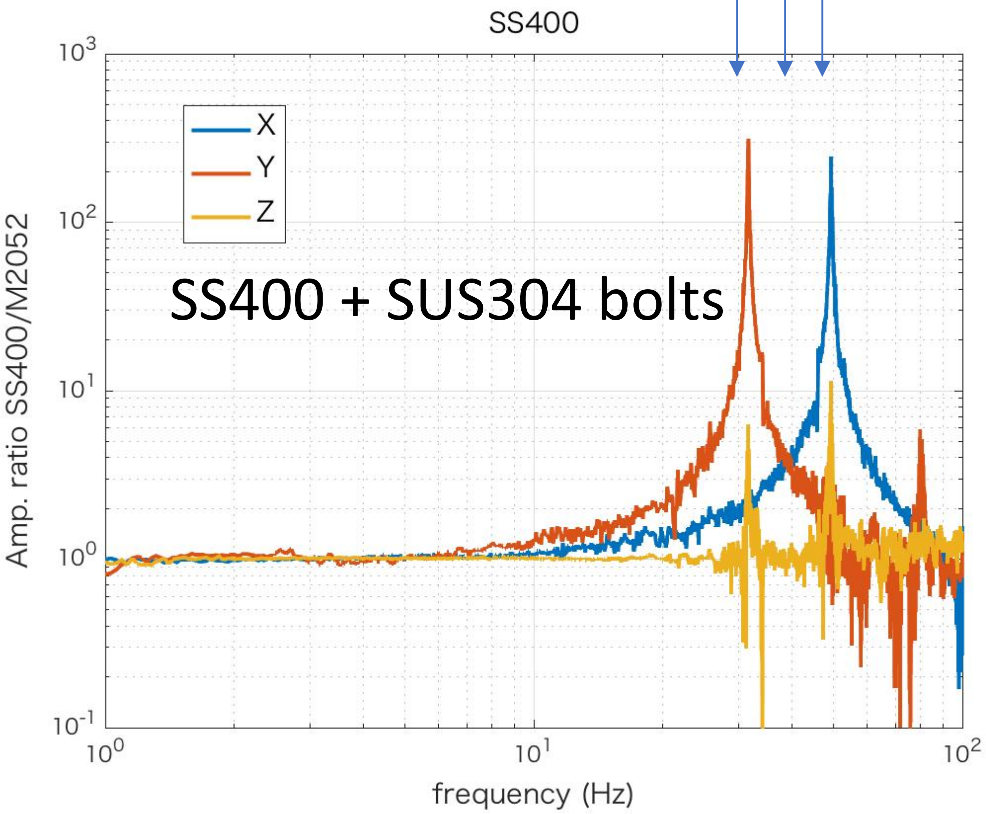
Spectrum became More complicated

Not very clear effects

Response function
ratio to the floor (input) vibration

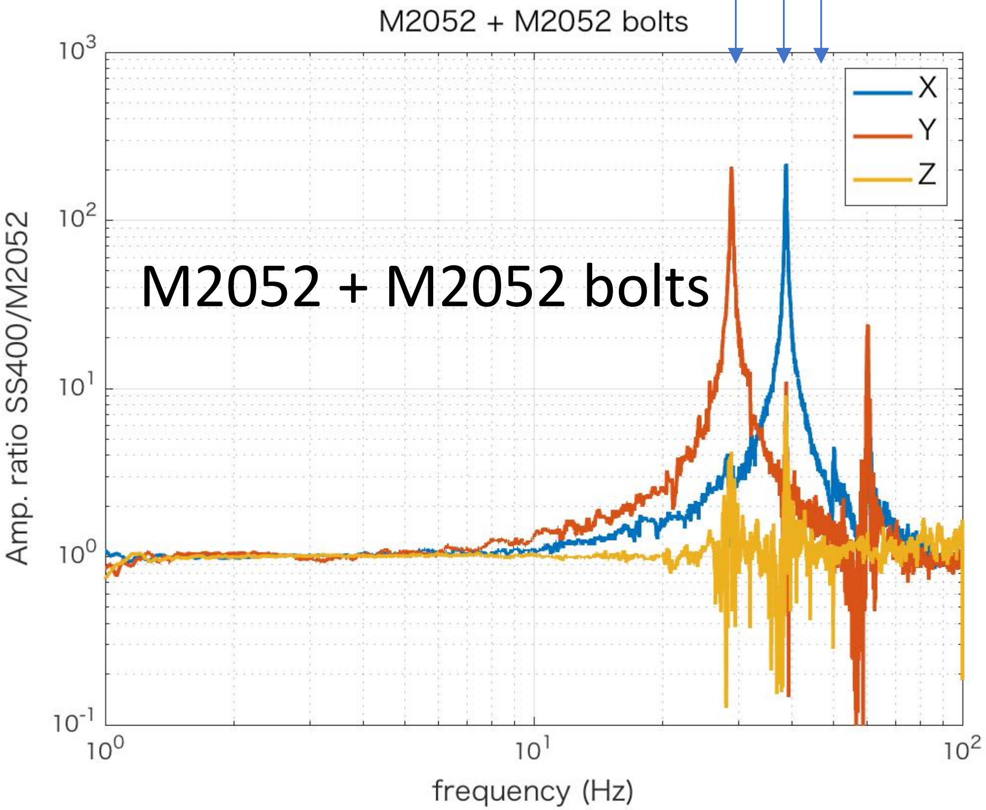


30,40,50Hz



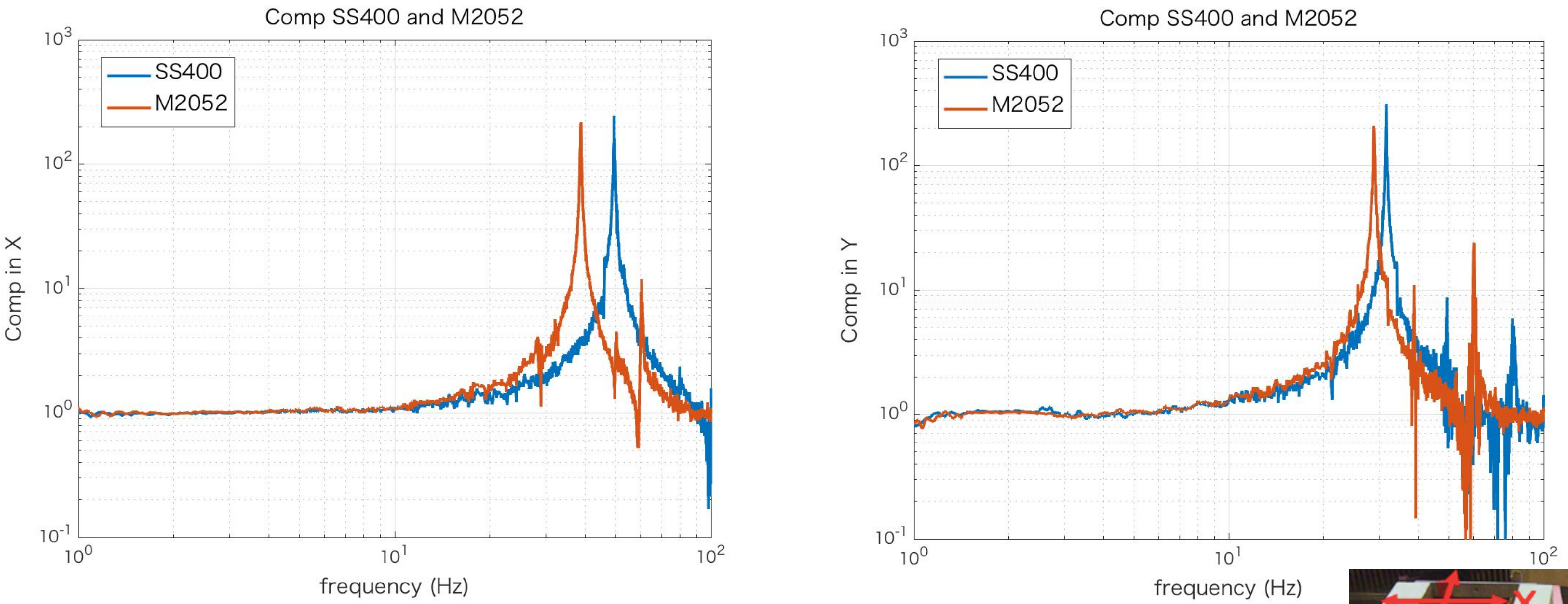
SS400 + SUS304 bolts

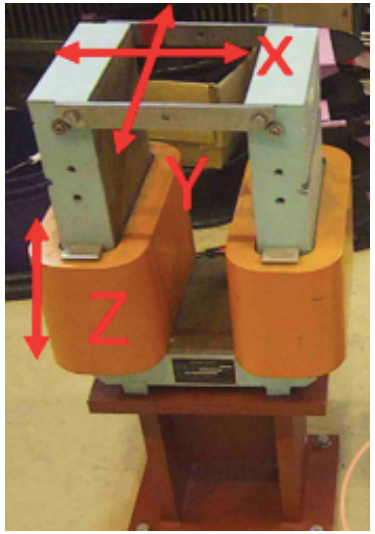
30,40,50Hz



M2052 + M2052 bolts

Let’s plot them together→

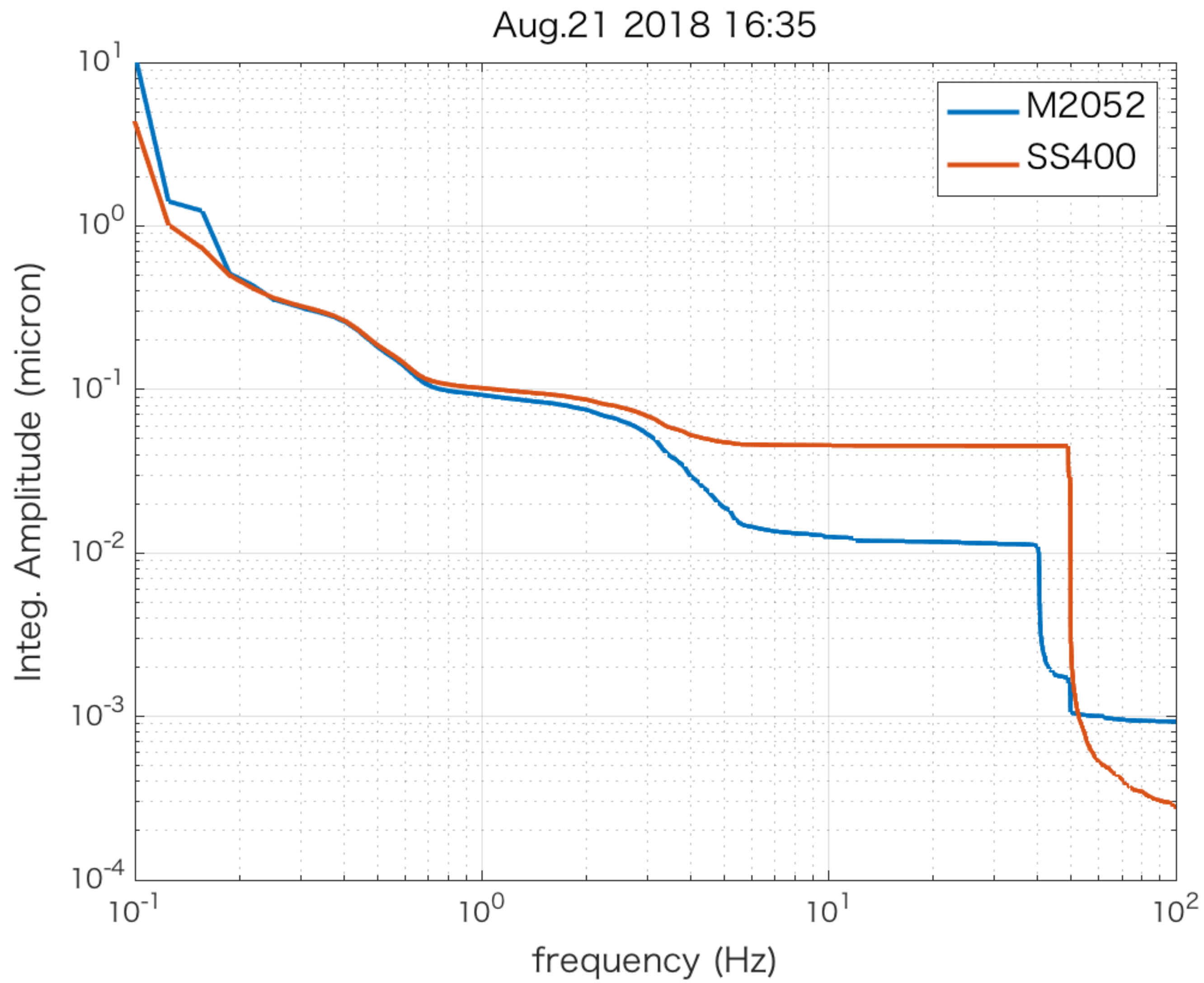




Natural (characteristic) frequency shifts to the lower
And the peak becomes smaller

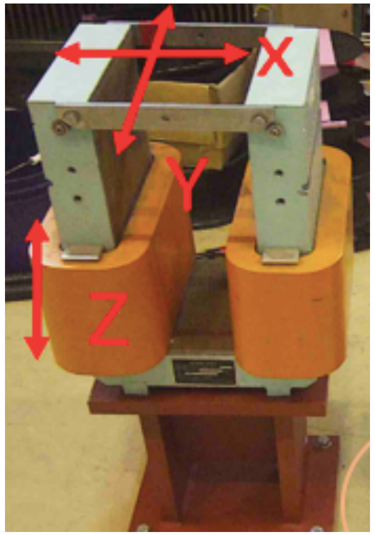
→damping

Integrated vibration amplitude in the *x* direction as an example

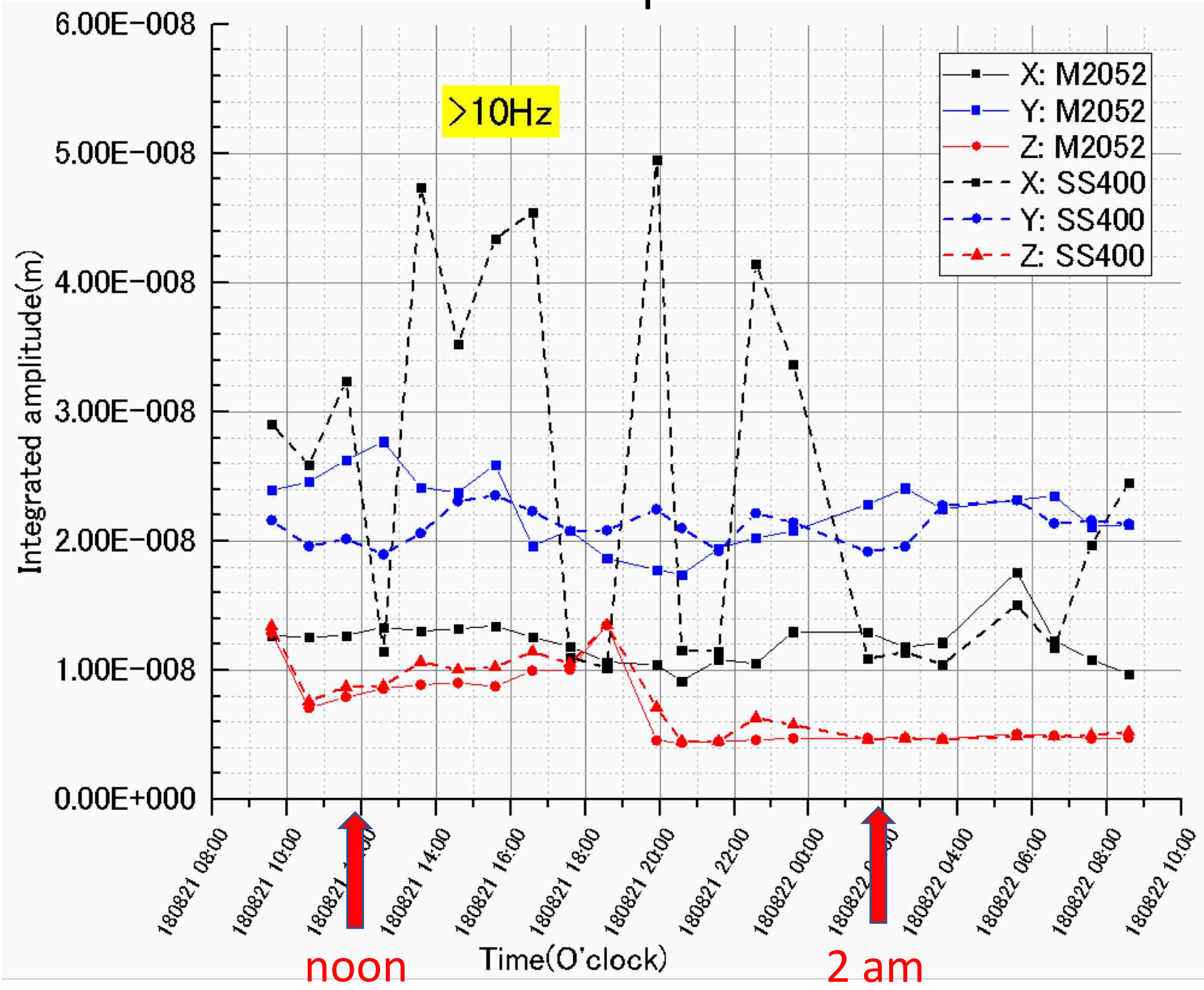


Sorry, color assignment swapped…

Damping effects are clear

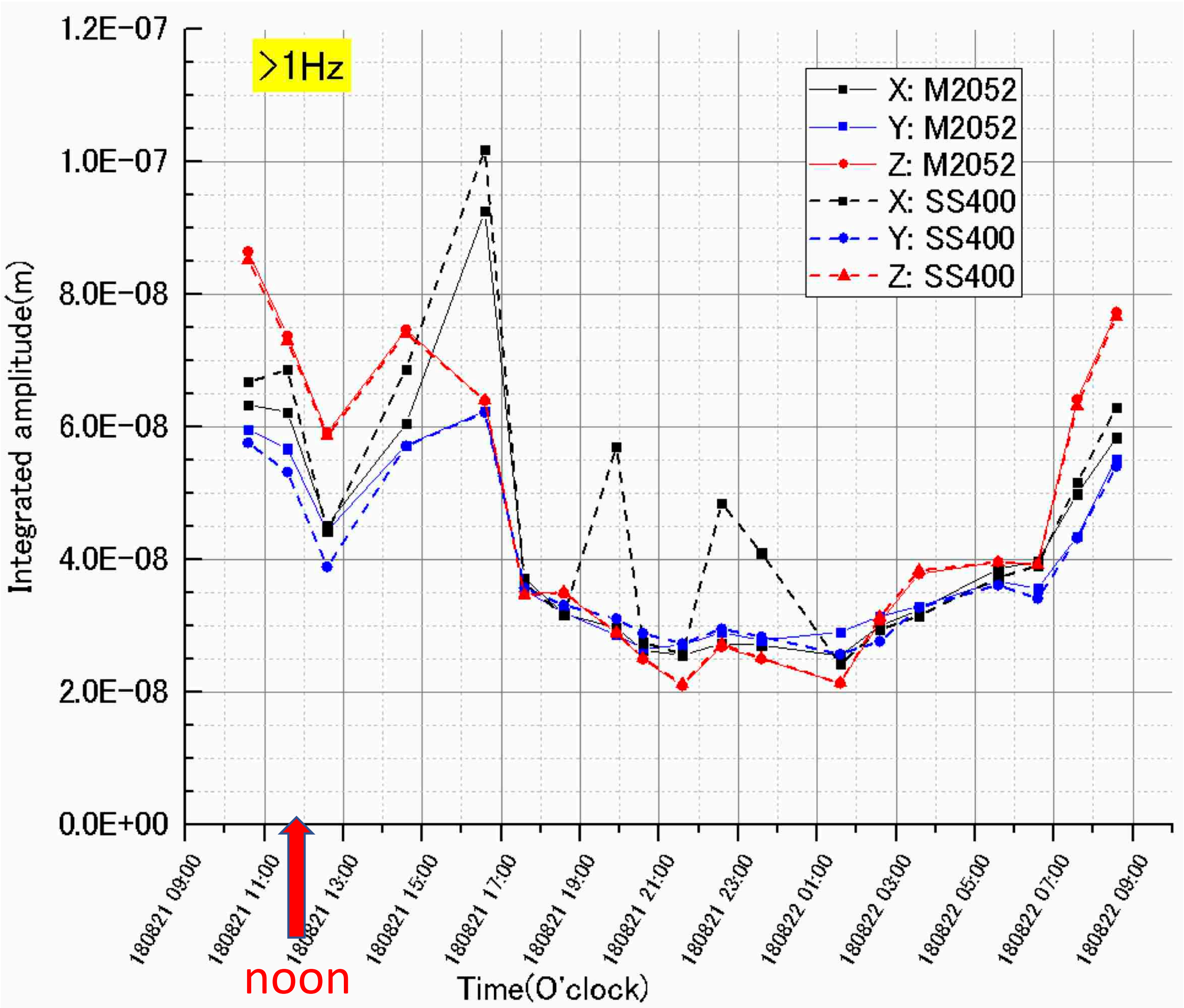


Vibration amplitude monitored for 24 hours on a weekday



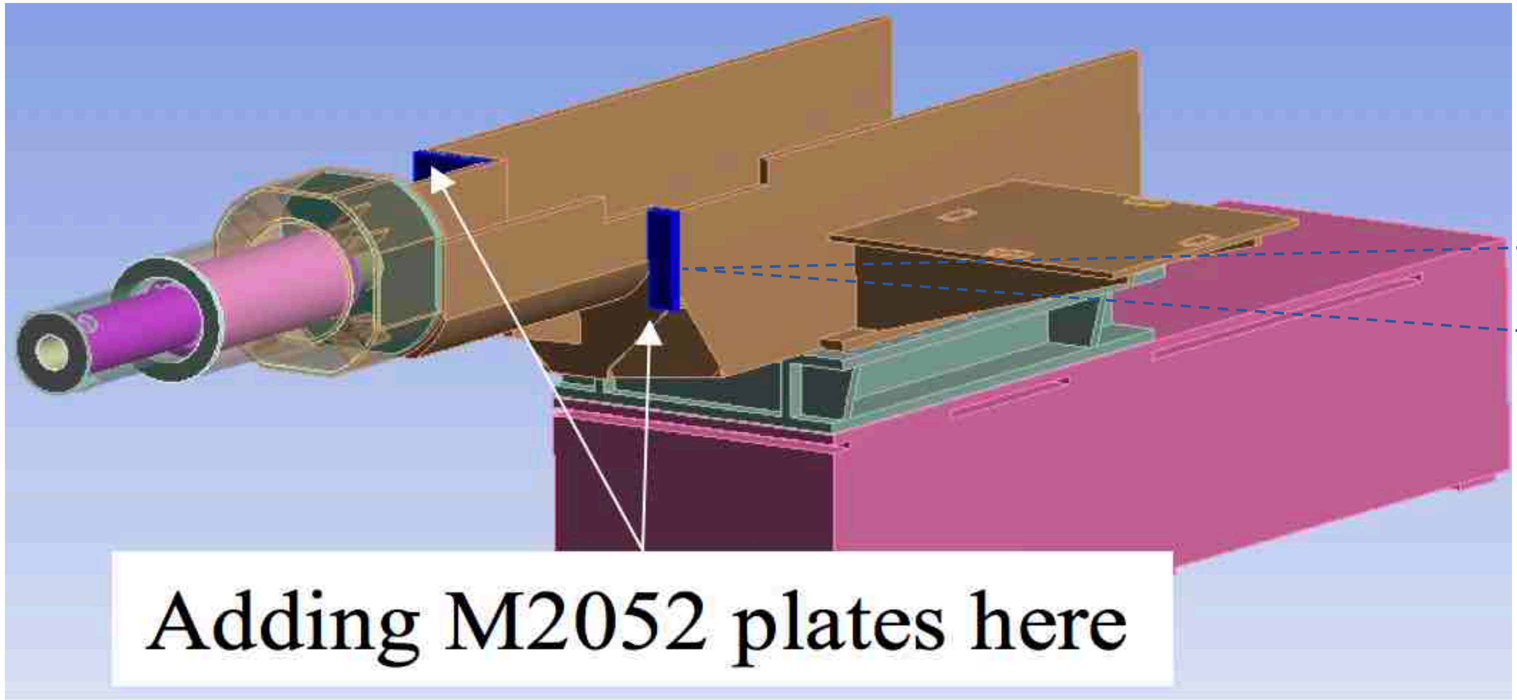
Vibration of the Magnet with M2052 support does not get affected by human activities
Because it gets damped to some level.

Vibration amplitude monitored for 24 hours on a weekday

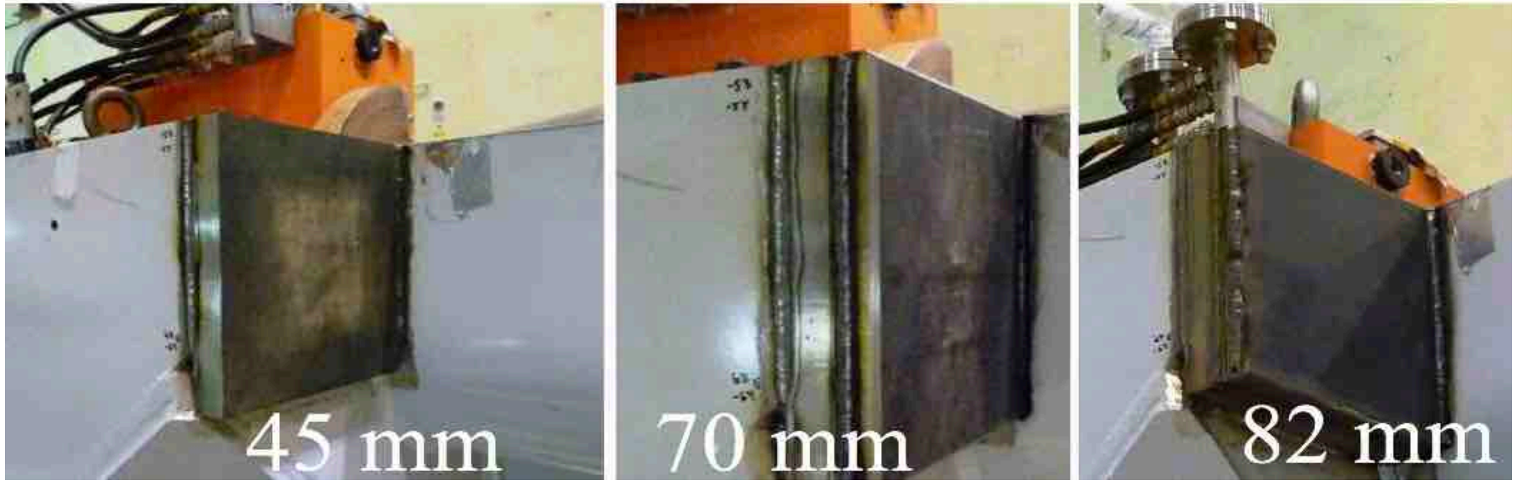


3. Results
   - Comparison with SS400
   - Application to cryostat

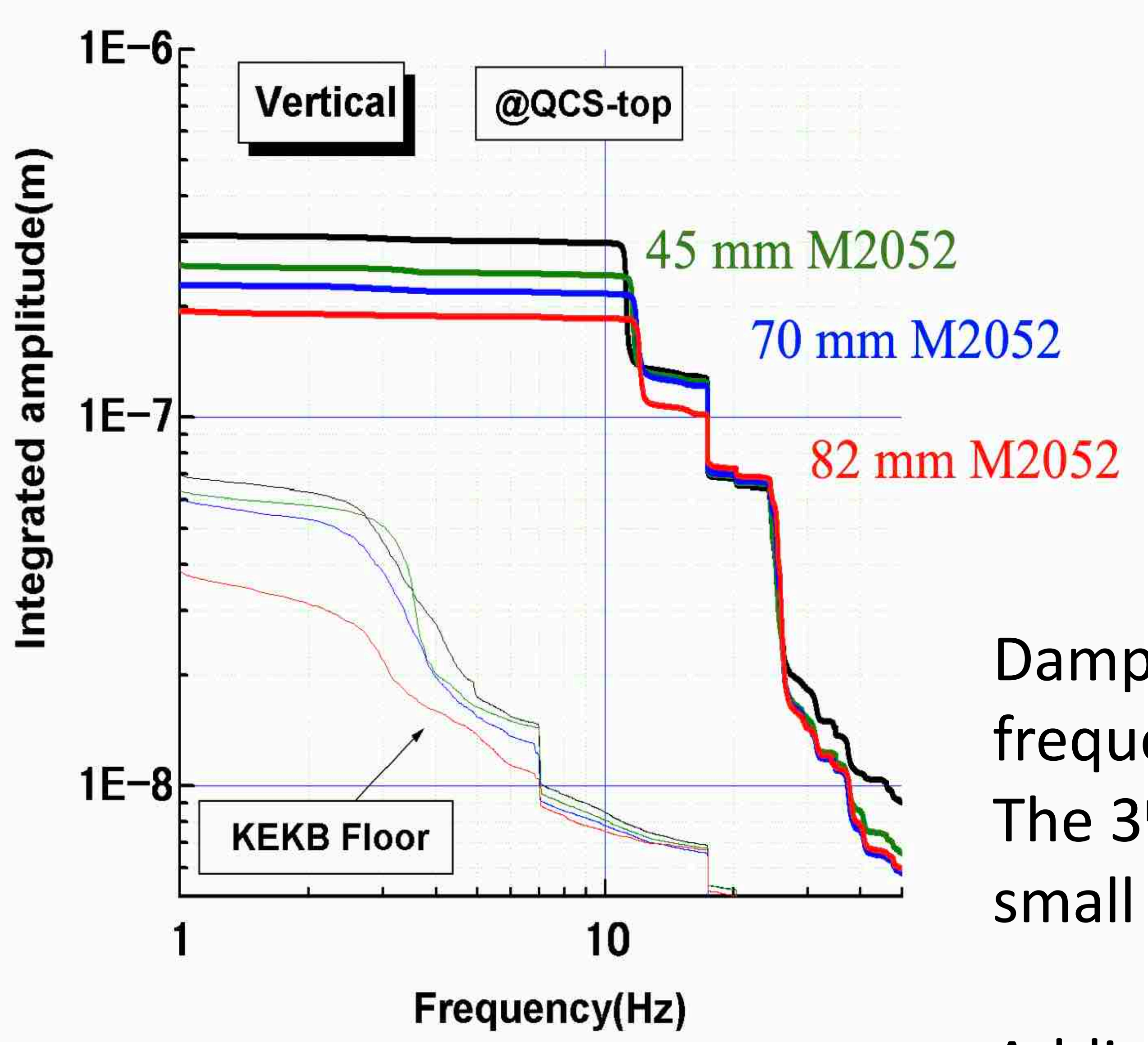
M2052 was tested with the KEKB cryostat after KEKB operation ended



ANSYS suggested to add M2052 plates here (weak spot).



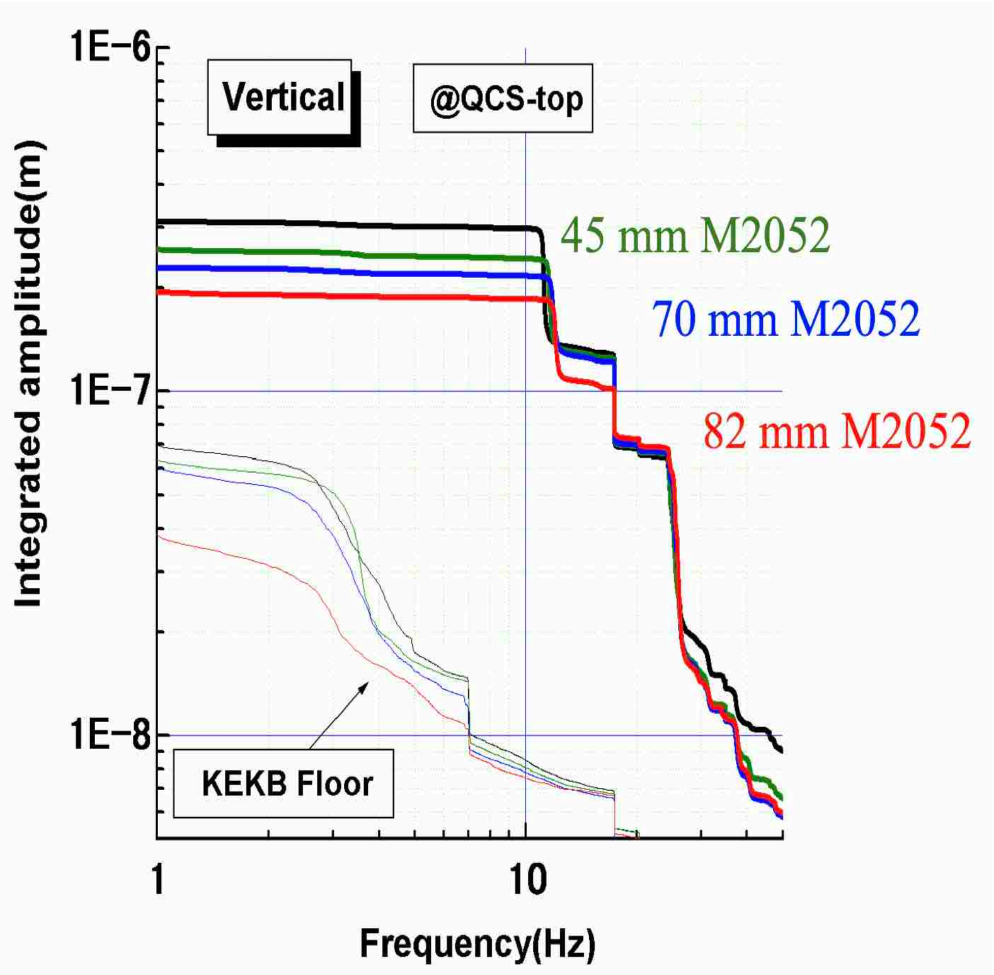
So we added M2052 plates, (welded) to see if the damping changes
And also changed the thickness of the plate.



Damping seen at 1st and 2nd natural frequencies
The 3rd mode not clear … amp may be too small

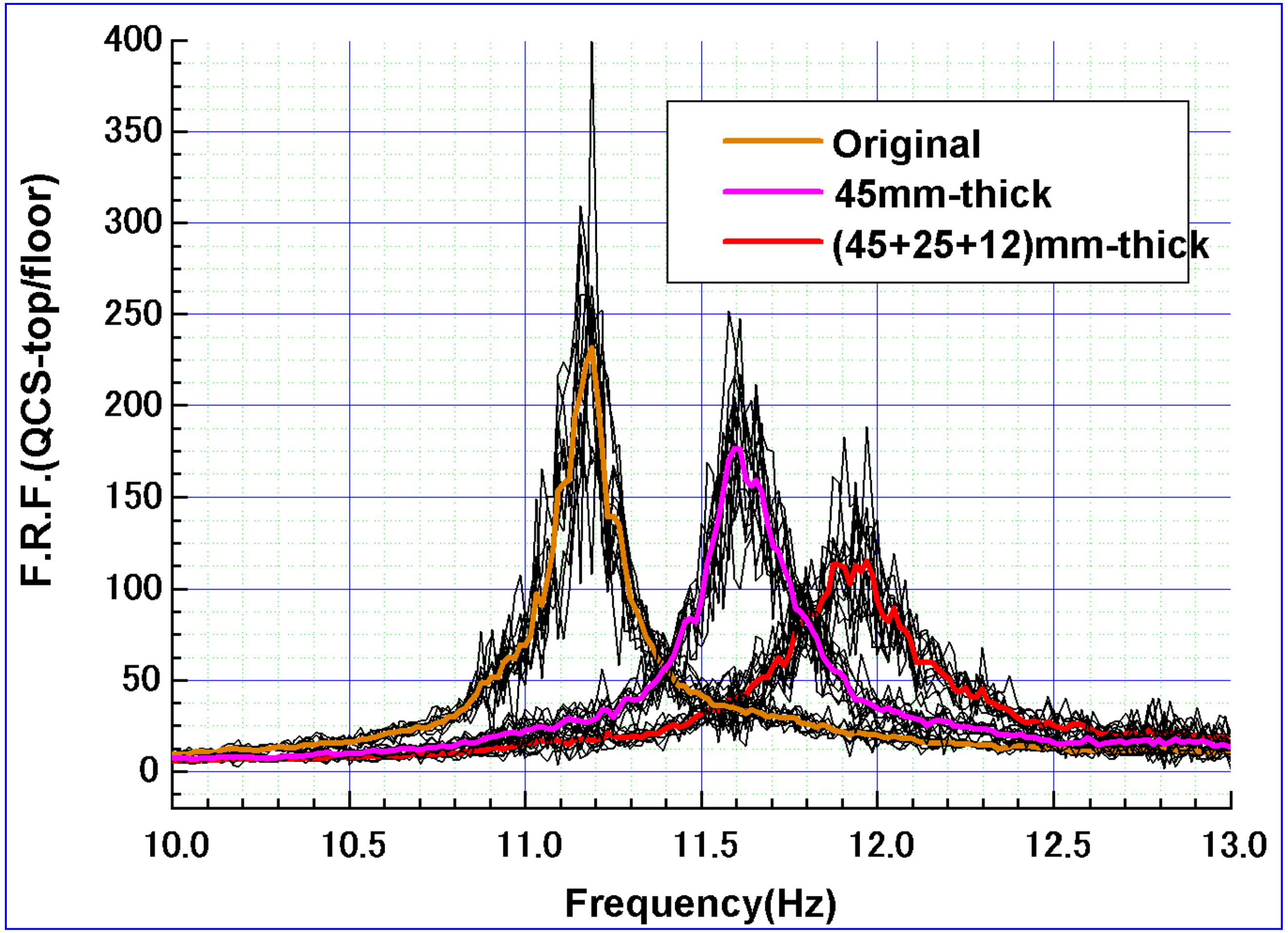
Adding more plates seems to have improved the damping effects

ANSYS prediction ~ 44% damping expected for 45 mm case



Integ. Amp. >10Hz

Bolts+Shims:	300nm:	0%
45mm-plates:	240nm:	-20%
(45+25)mm plates:	220nm:	-27%
(45+25+12)mm plates:	190nm:	-37%



Some could argue though that the ”damping” is a result of strengthening the movable base where the cryostat is attached.

Just got more rigid???

A comparison should have been made with the plates made of non-damping materials such as SS400 or SUS304.

$$E \propto A^2 \omega^2$$

4. Summary

- First collision took place on April 26, 2018. The vertical offset between the electron and positron beams was only ~30 μm, alignment was excellent!

- Vibration issues may become more serious at SuperKEKB where the design vertical beam sizes are ~50 nm.
- There are two approaches to cope with the vibration issue, one is to damp the vibration and the other is an orbit feedback at the IP.
- Some experiment on the damping material M2052 was carried out, using dipole corrector magnets mounted on a standard supporting table made of SS400, and on a special supporting table made of M2052.
- M2052 damps the vibrations at the structure's natural frequencies, which are usually in the range of a few tens of hertz in the magnet system.
- A further study needs to be made on where and how to use the material.
- M2052 may be also useful for not only colliders, but also for light sources.