Status of Vibration Analysis

H. Yamaoka

R. Sugahara

M. Masuzawa

KEK

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

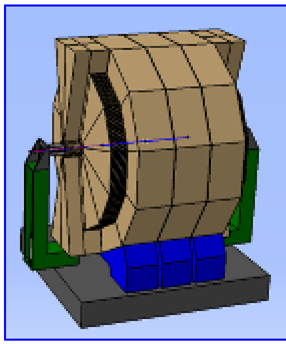
To improve vibration behavior;

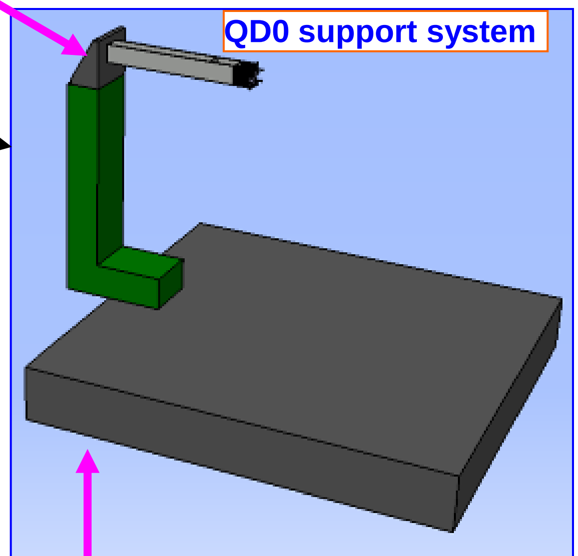
➔ **We need to solve these issues.**

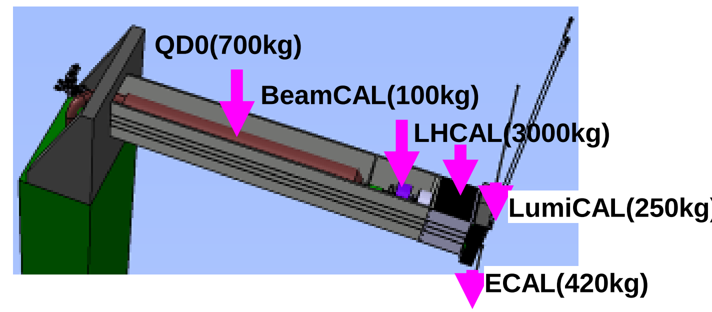
1. Design of stiff support structure

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

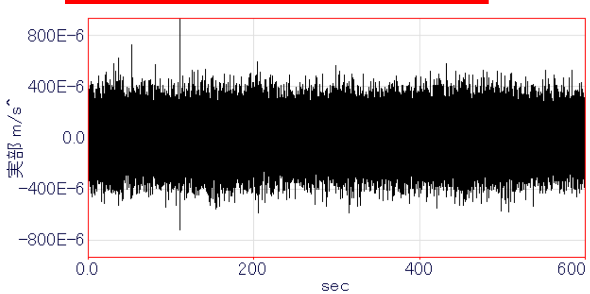
3. Correct?
Check consistency

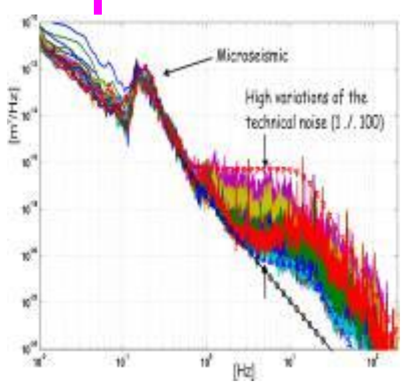






4. Vibration data
- CERN
- KEK
- Coherency?





5. Realistic data

Criteria

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

Vibration measurement at KEKB

Measurement items

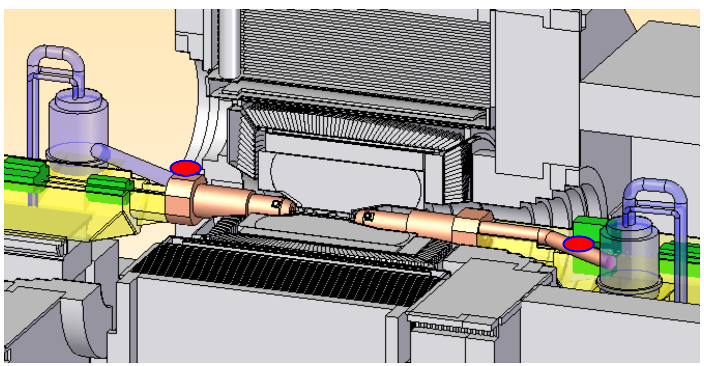
- Vibrations on each positions
- Influence of air conditioner
- Coherency between both sides

(New measurements)

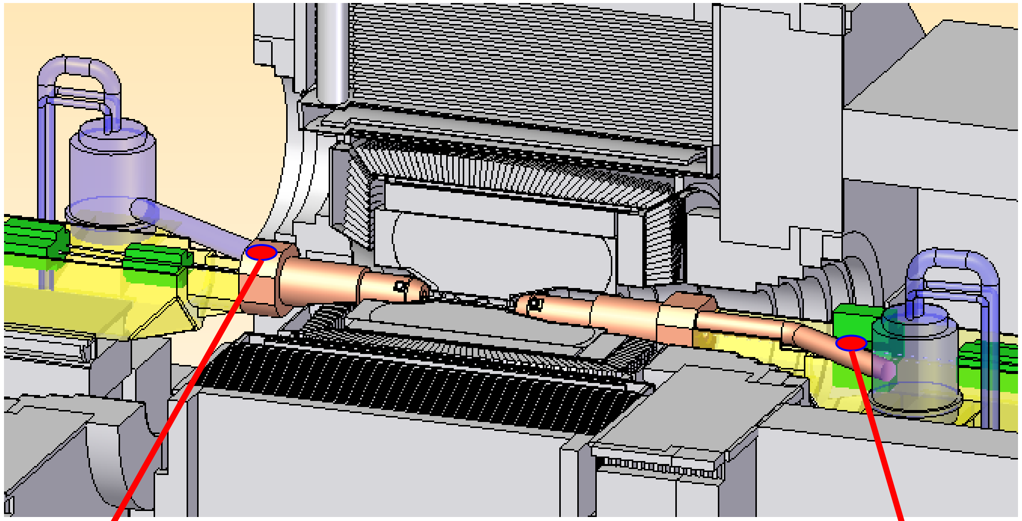
- Cooling effects of the QCS magnets
- Vibration during the magnet excitation

Servo Accelerometer MG - 1 0 2	Tokkyokiki Corp.
Size	40×40×50mm
Max. input	± 2 G
Resolution	1 / 10^6G

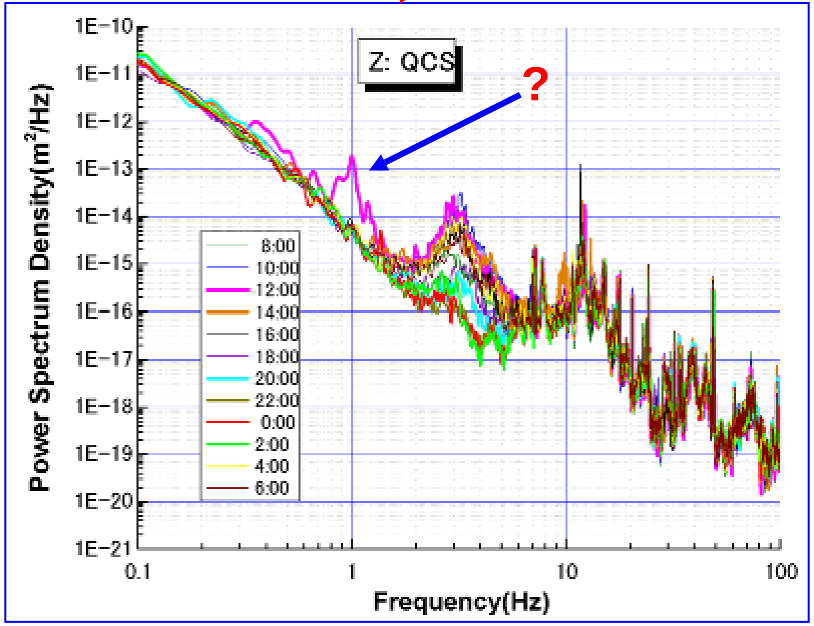
Acc. 0.1 ~ 400Hz
Acc. 60dB = 1gal/V

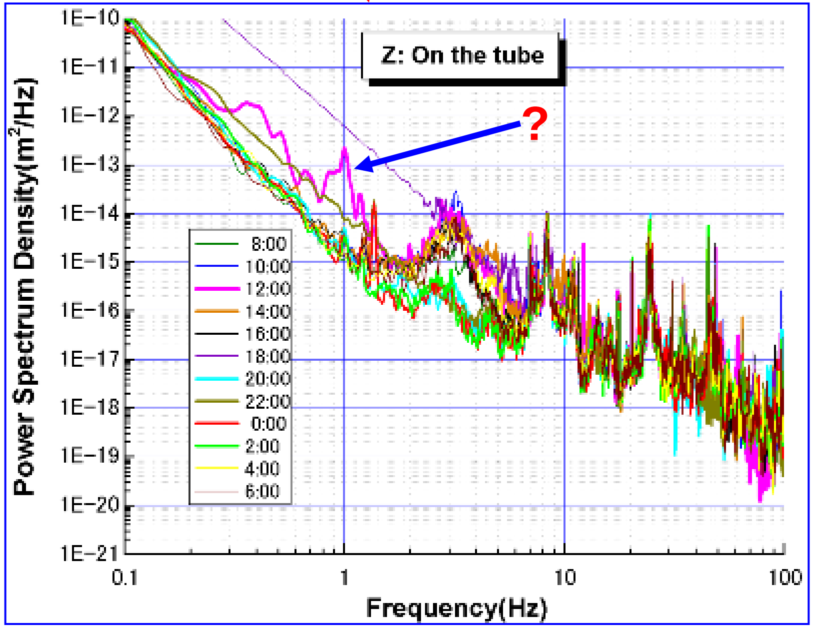


Measurements during the QCS magnet cooling-down



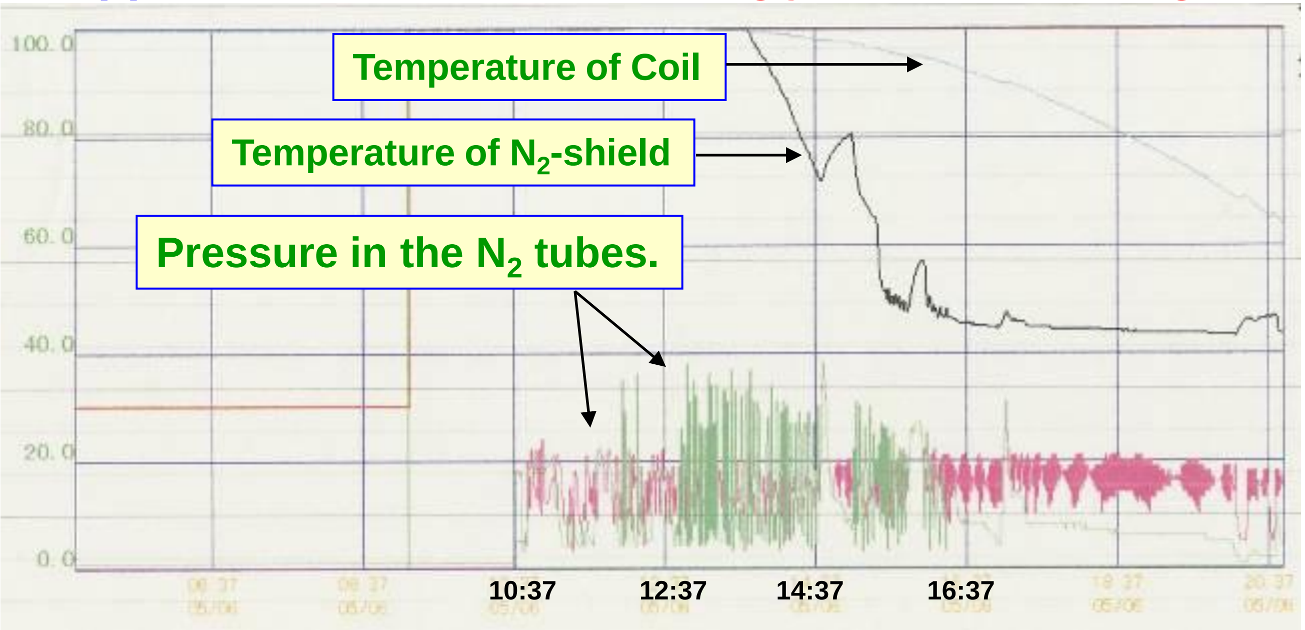
P.S.D. in the vertical direction

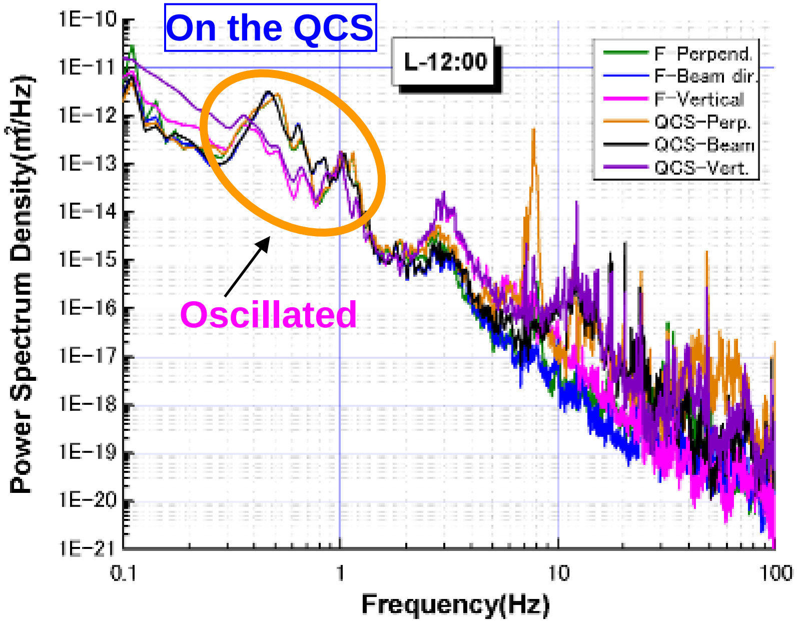


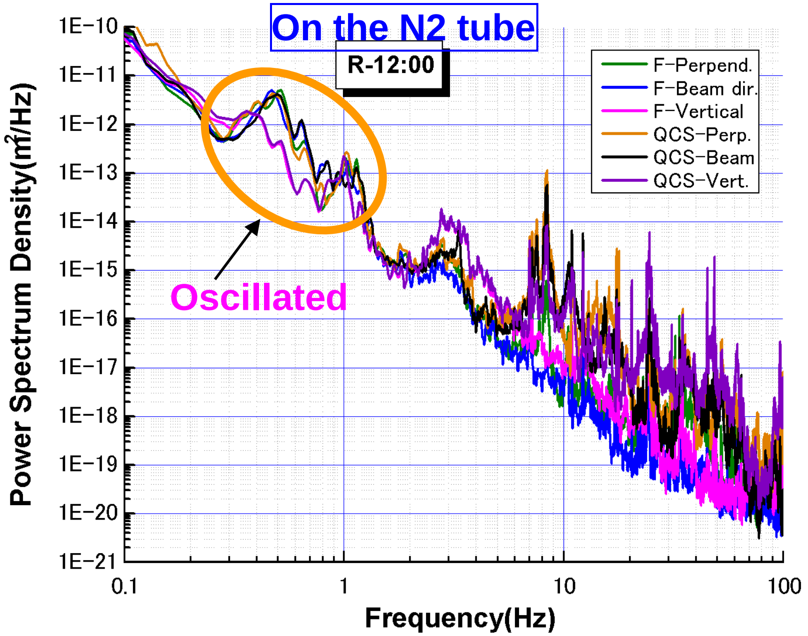


- What happened at 12 o'clock??

- What was happened at 12:00?? ➔ Cooling just had been begun.

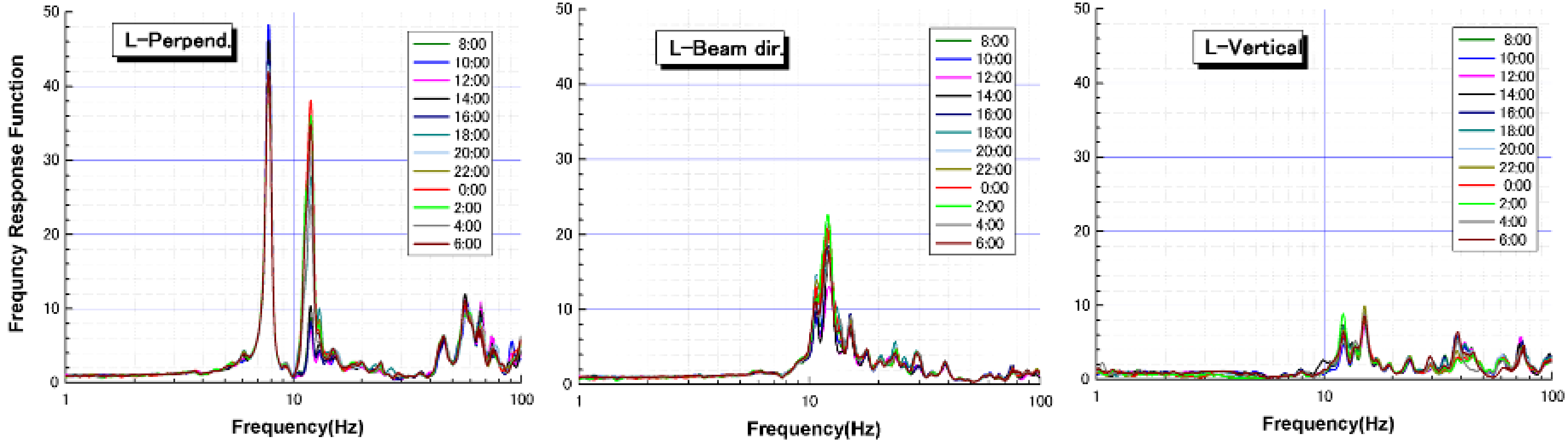




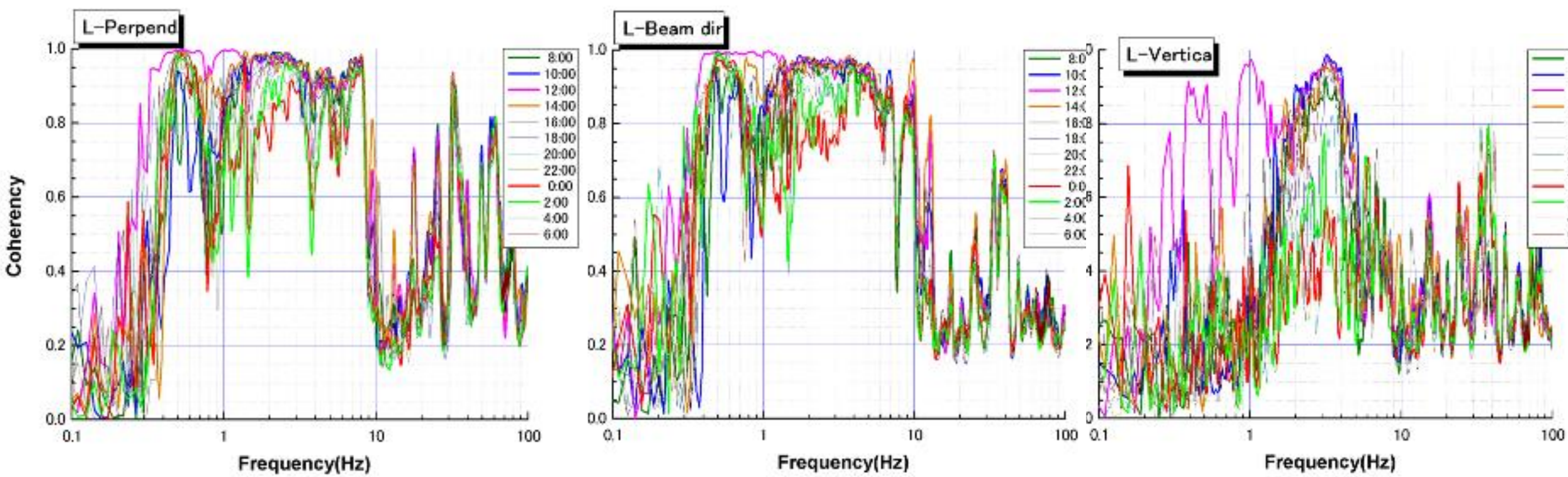


→ Oscillations around 1Hz at 12:00 were observed in all directions.

Frequency Response Function (QCS – Floor)



Coherency (QCS – Floor)

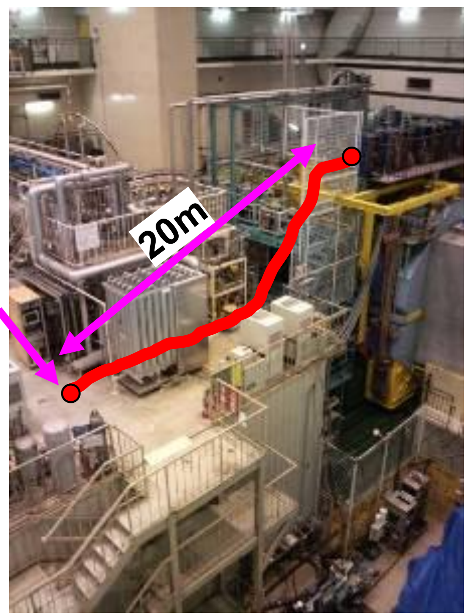


→ Coherency around 1Hz measured at 12:00 became better than other data.

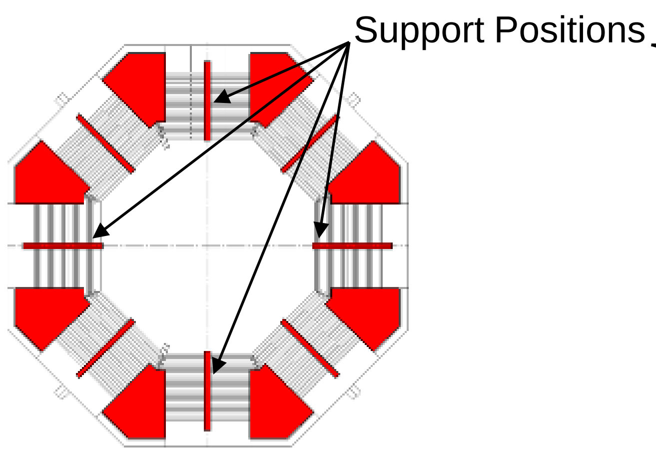
Vibration measurement during the magnet excitation

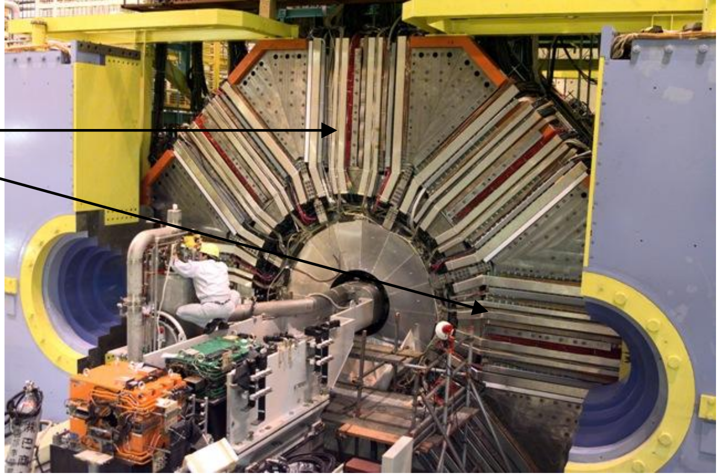
Operating principle:	Electrochemical motion transducer with high damping coefficient
Output signals	Velocity-flat response
Output signal swing	+/-20V (40 V p-p differential)
Dynamic Range	120 dB @ 1Hz
Bandwidth	1 – 75 Hz; *Optional*: 100Hz
Sensitivity	1 nm @ 10 Hz
Generator constant	*Standard*: 2000 V/m/s; *Opt.*: 350 – 20,000 V/m/s
Mass Lock	**NONE REQUIRED**
Mass Centering	**NONE REQUIRED**
Maximum installation tilt	Std +/-10 deg (*Optional*: fully operational at any random orientation)
Mechanical resonances	>200 Hz
Temperature range	Standard: -12 to + 55 °C
Dimensions	75 x 110 x 150 mm
Weight (Al housing)	Appx 0.75 kg
Power – Standard	10 – 15 Vdc; 12 Vdc nominal
Supply current	30 mA

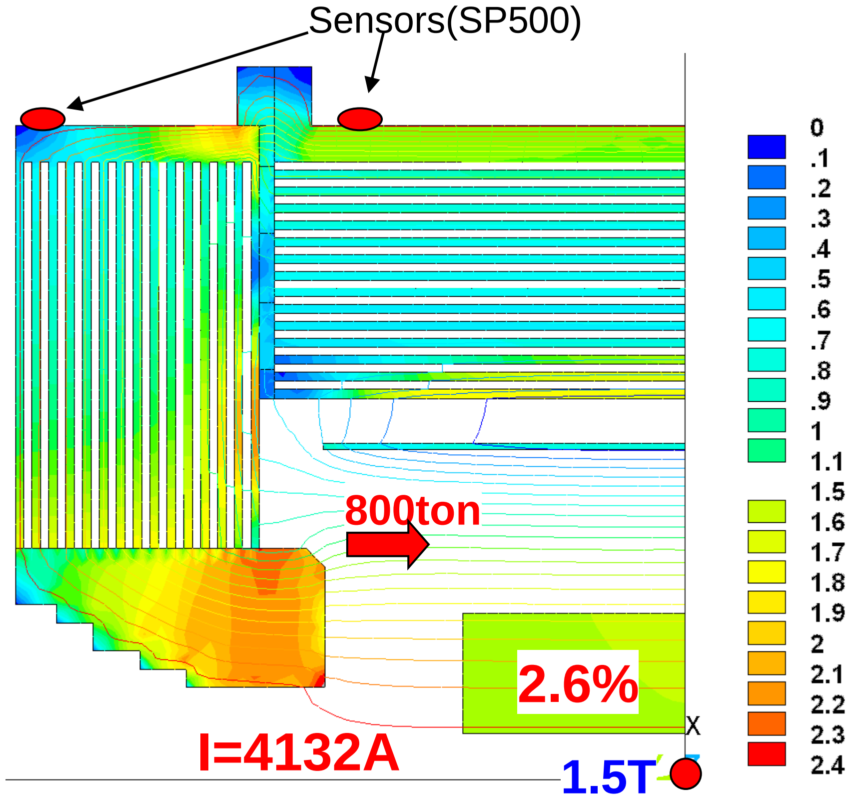
- Power supply
- Data logger



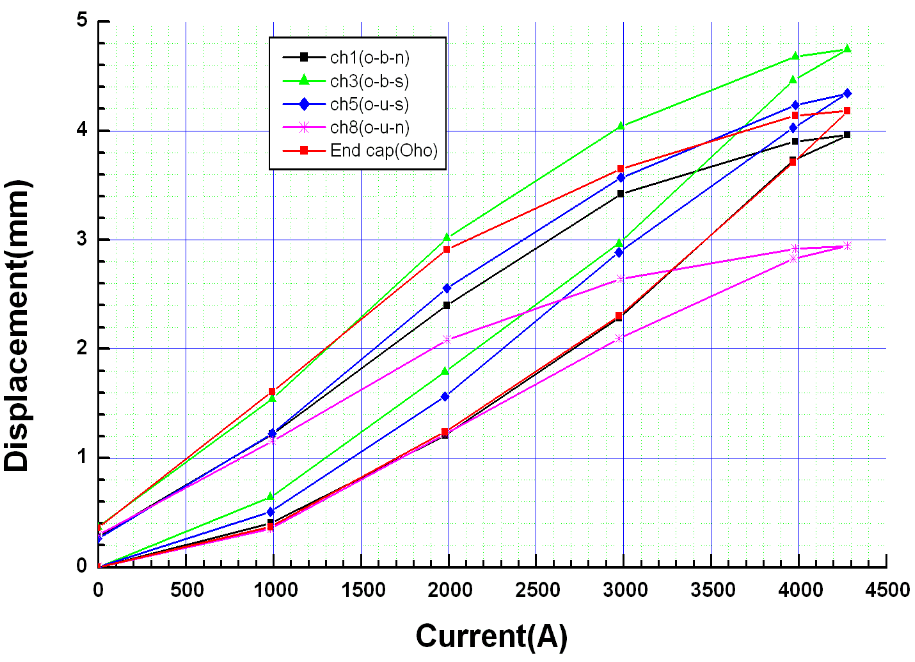
The Belle solenoid magnet/Yoke







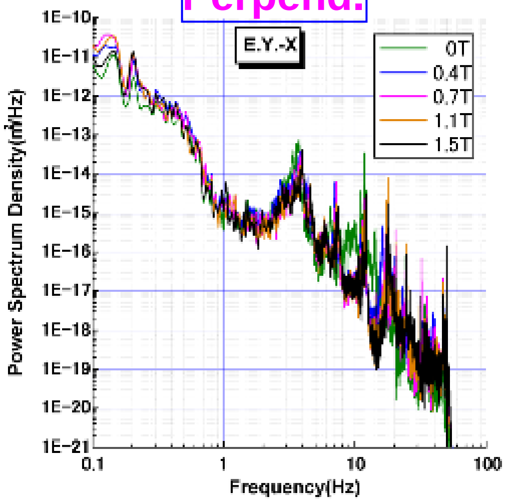
Measured E.Y. static deformations



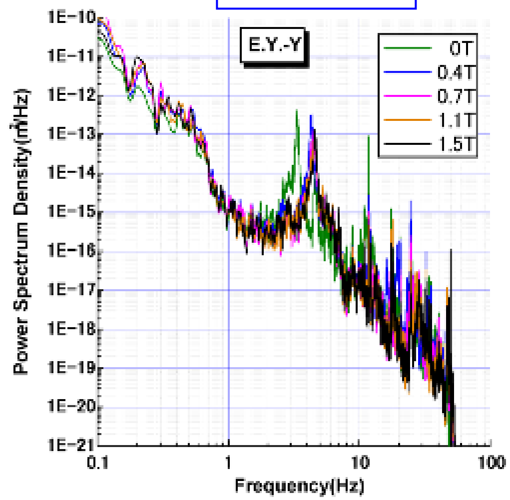
Vibration Measurements at the Belle

End-yoke

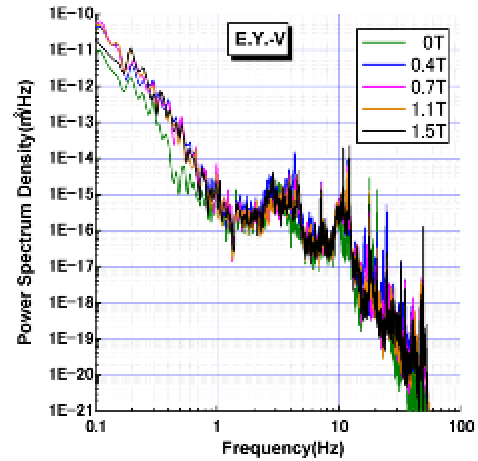
Perpend.



Beam-dir.

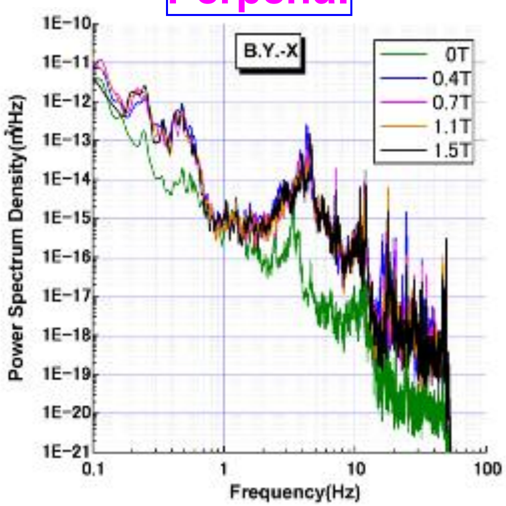


Vertical

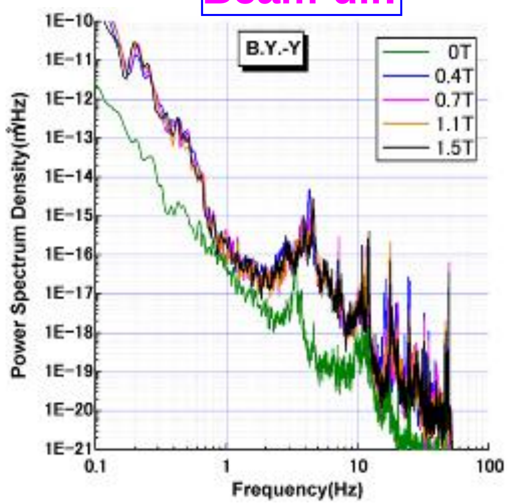


Barrel-yoke

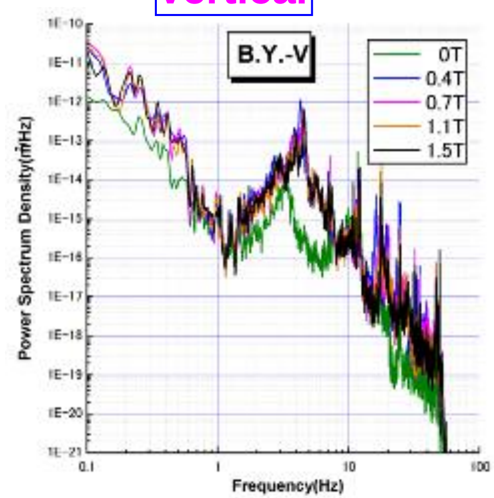
Perpend.



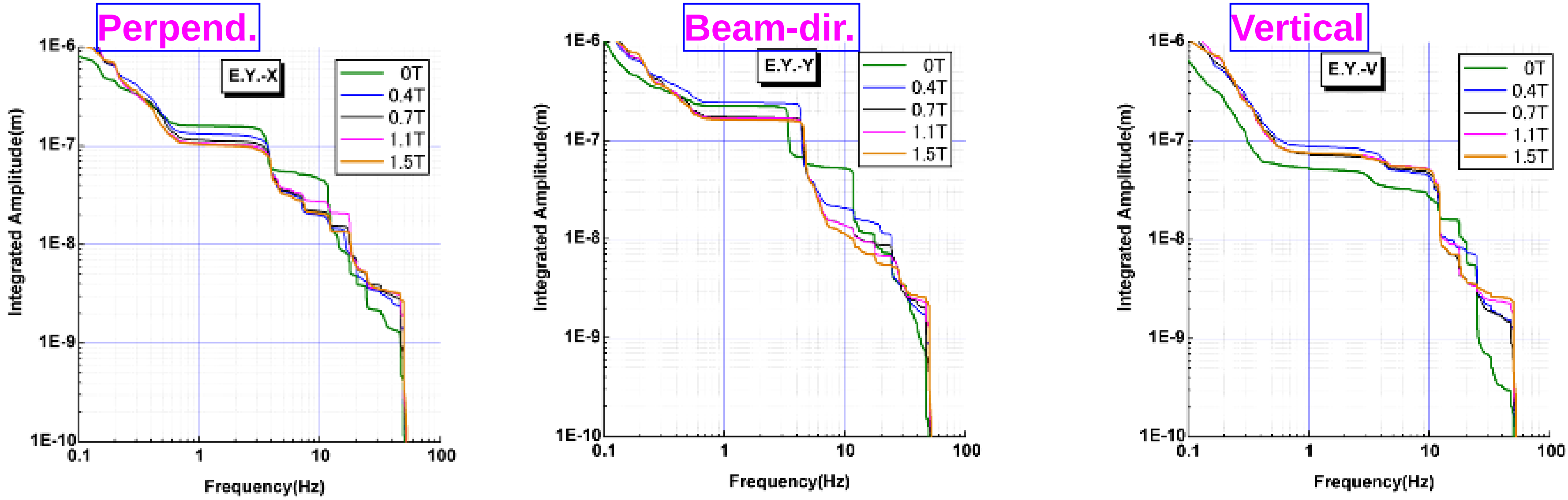
Beam-dir.



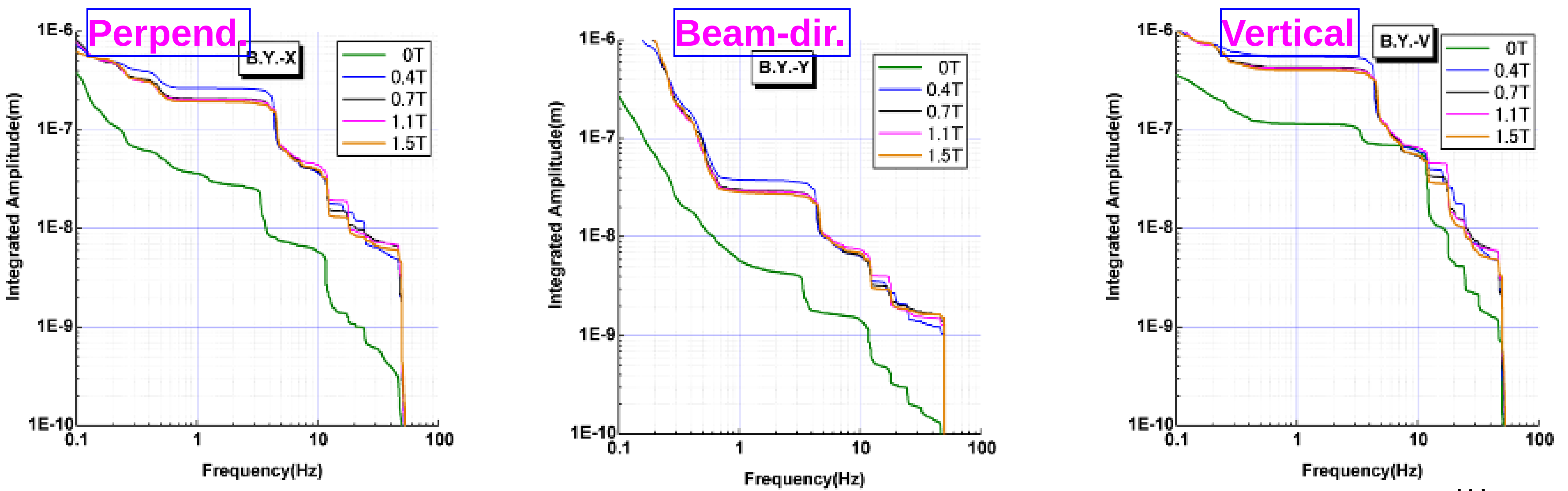
Vertical



End-yoke

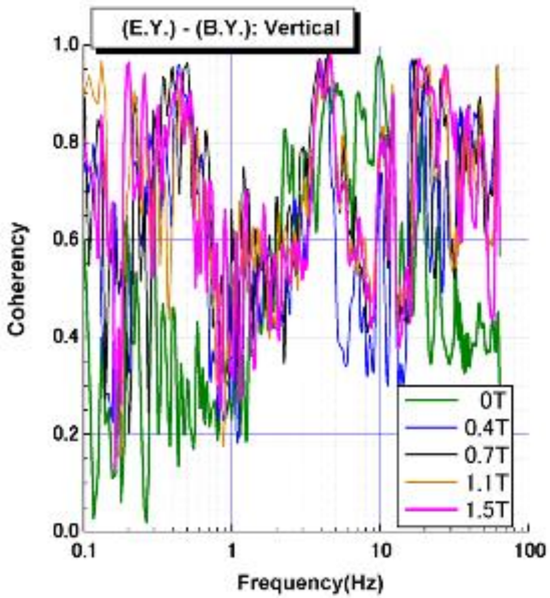


Barrel-yoke

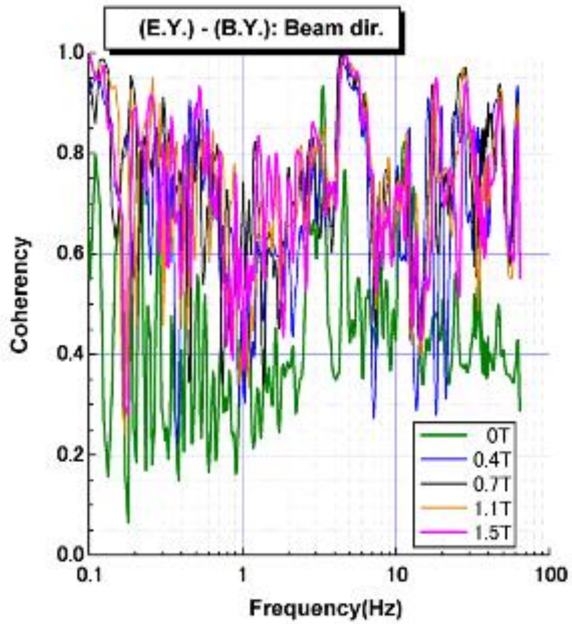


Coherency(End yoke - Barrel yoke)

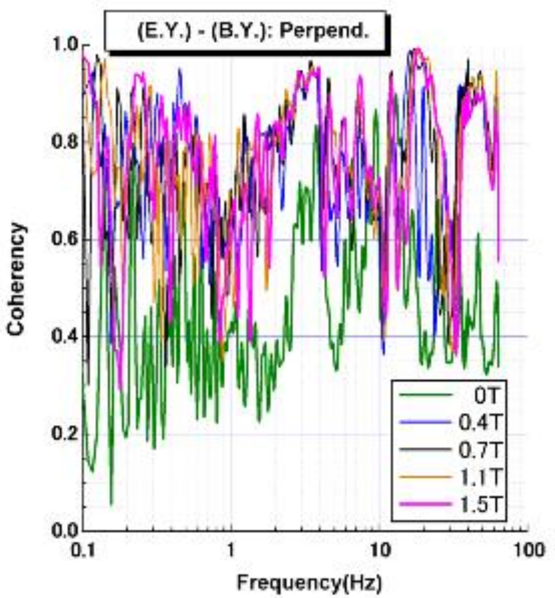
Perpend.



Beam-dir.

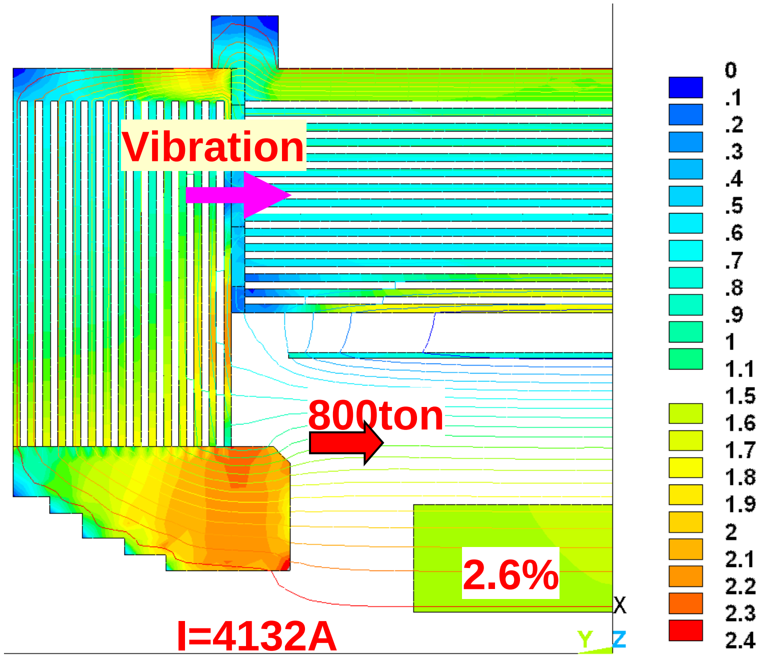


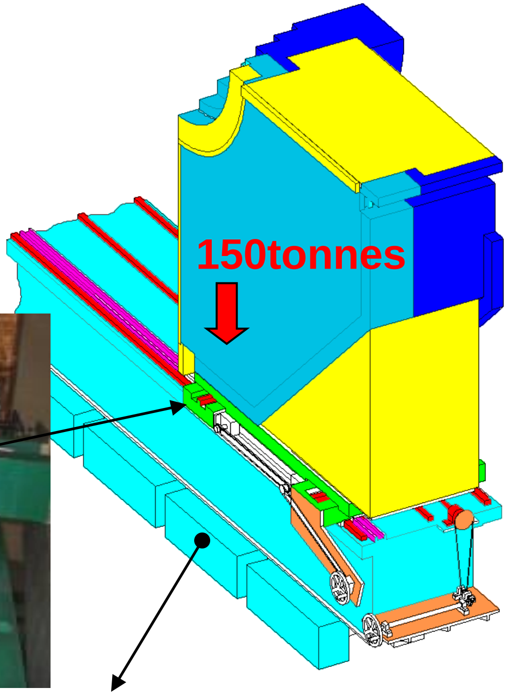
Vertical

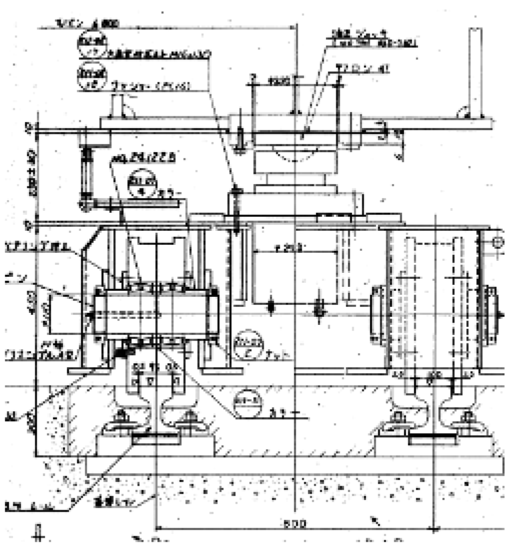


Measurement results

- Resonant frequency in the beam-dir was increased. → Stiffer
- Amplitudes on the B. Y. were vey incresed when the solenoid is excited.
- Coherencies are slightly improved when the solenoid is excited.

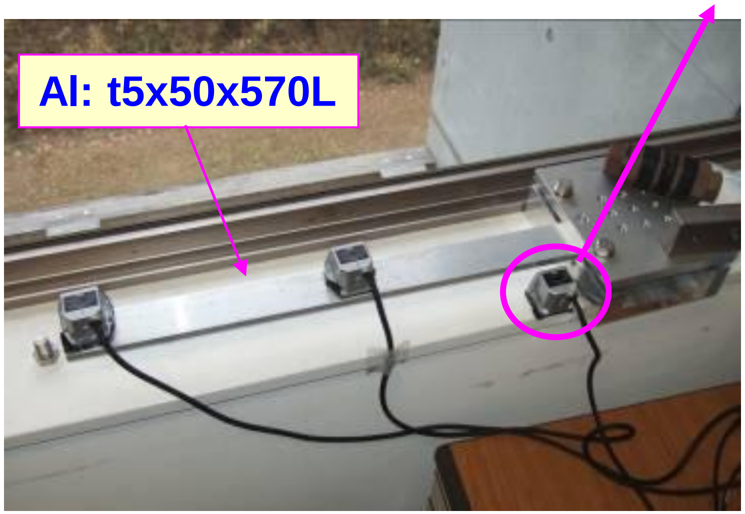


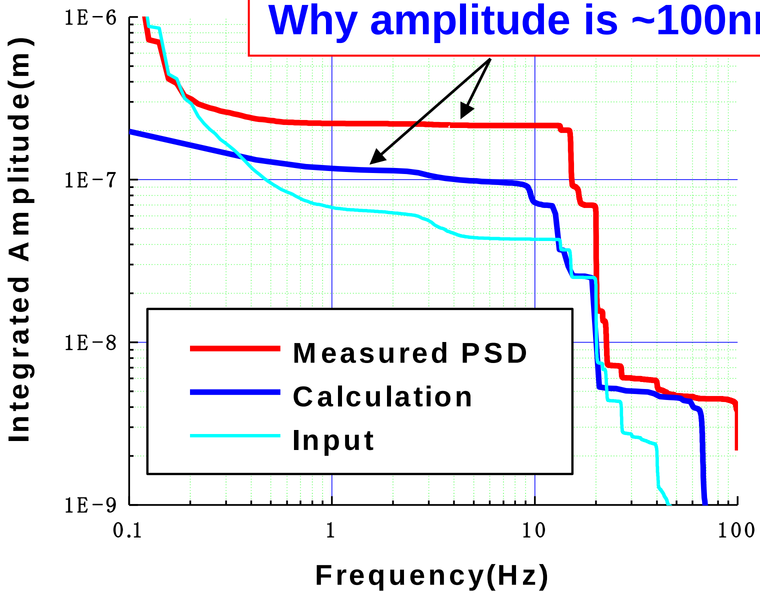




- The belle detector is not fixed on the floor.
- The barrel yoke is just placed on the table.
- Top of the end-yoke is not fixed.

Consistency between the calculations and measurements





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

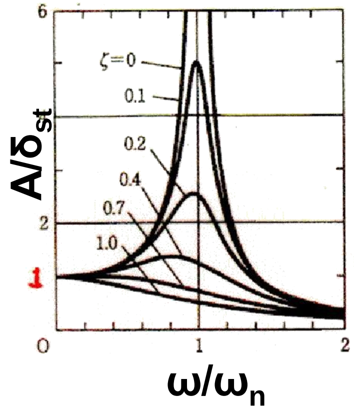
→ In ANSYS: *damping ratio= 2%*

Damping ratio(%) — Ref.: JEAG 4601-1987

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

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

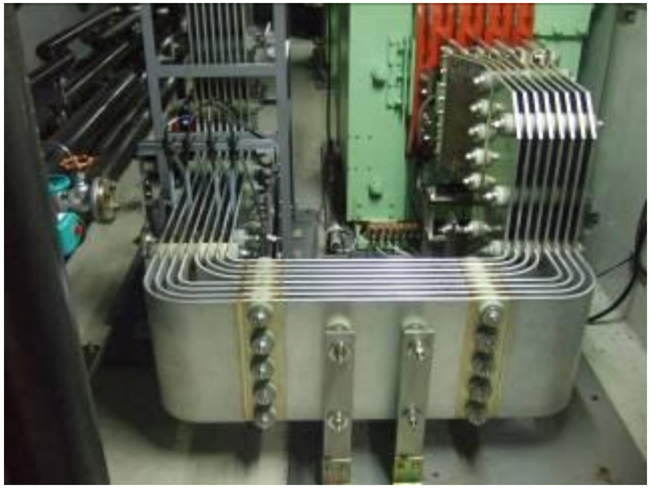
$$X = \frac{\delta_{st}}{\sqrt{\left\{1-\left(\frac{\omega}{\omega_n}\right)^2\right\}^2 + \left(2\varsigma\frac{\omega}{\omega_n}\right)^2}}$$

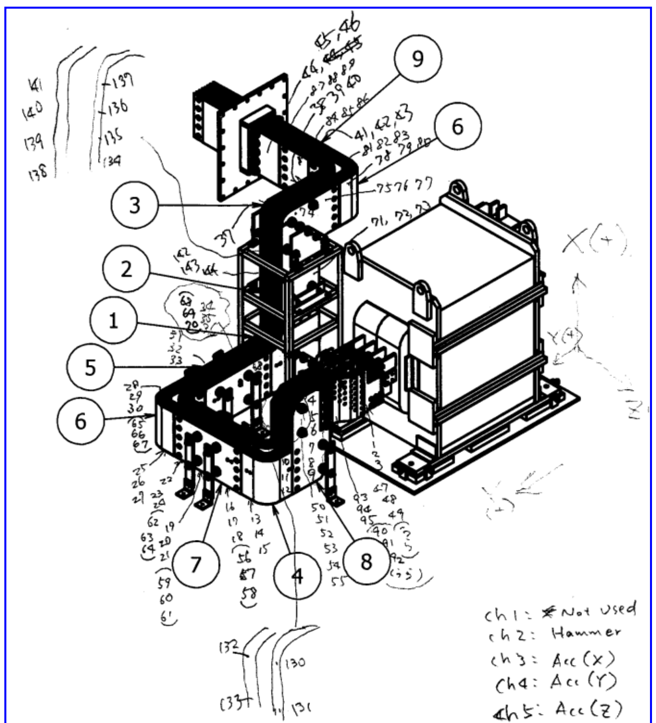


➔ Damping ratio was evaluated with some structures.

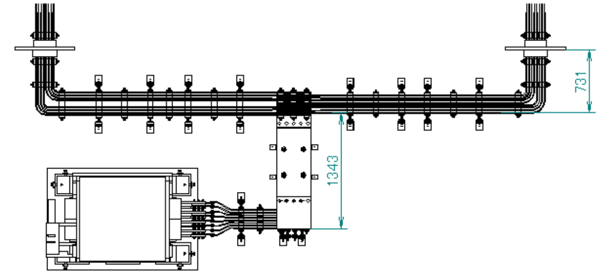
Bus bars for horn magnet for the T2K

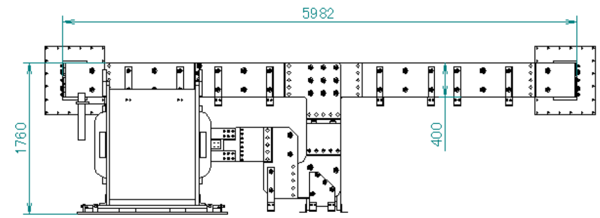
a. For the 1st horn magnet

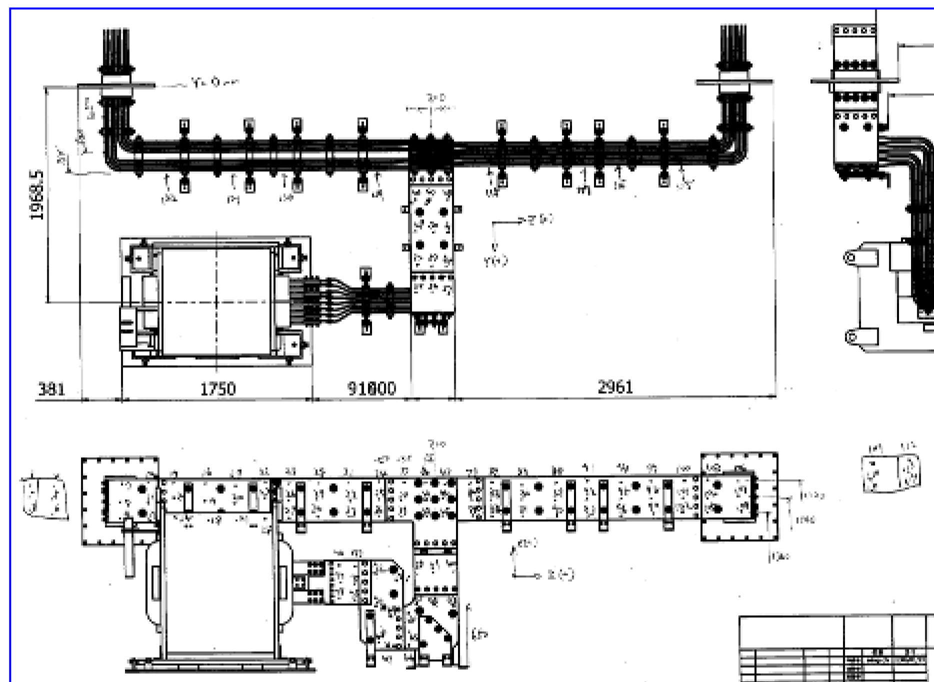




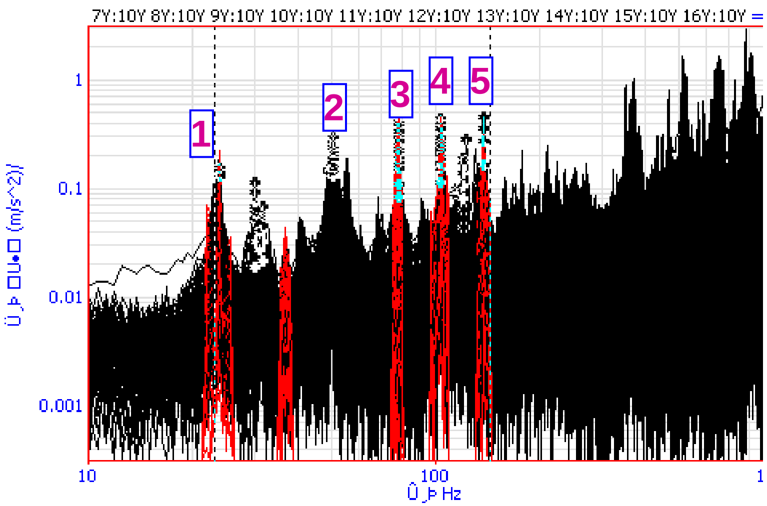
b. For the 2nd/3rd horn magnet





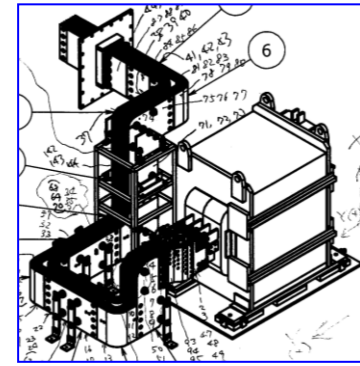


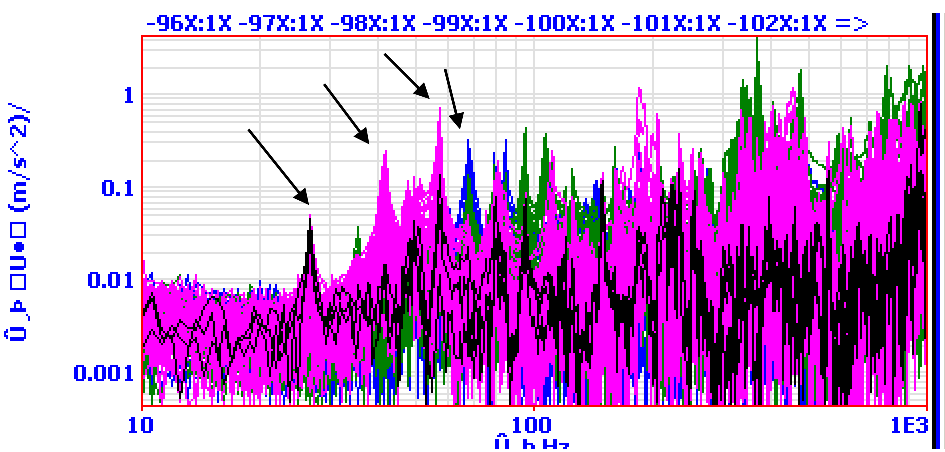
Measurement results



Measurement result-A

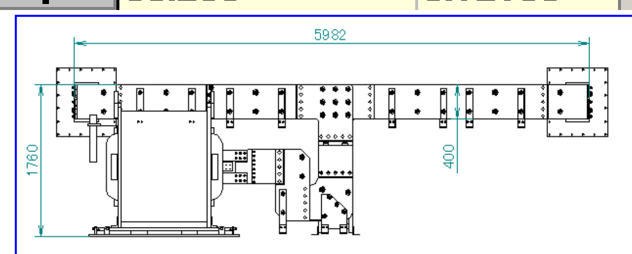
No.	Freq.(Hz)	damping (%)
1	23.7	0.196
2	50.9	0.678
3	77.8	0.276
4	103	0.842
5	137	0.474





Measurement result-B

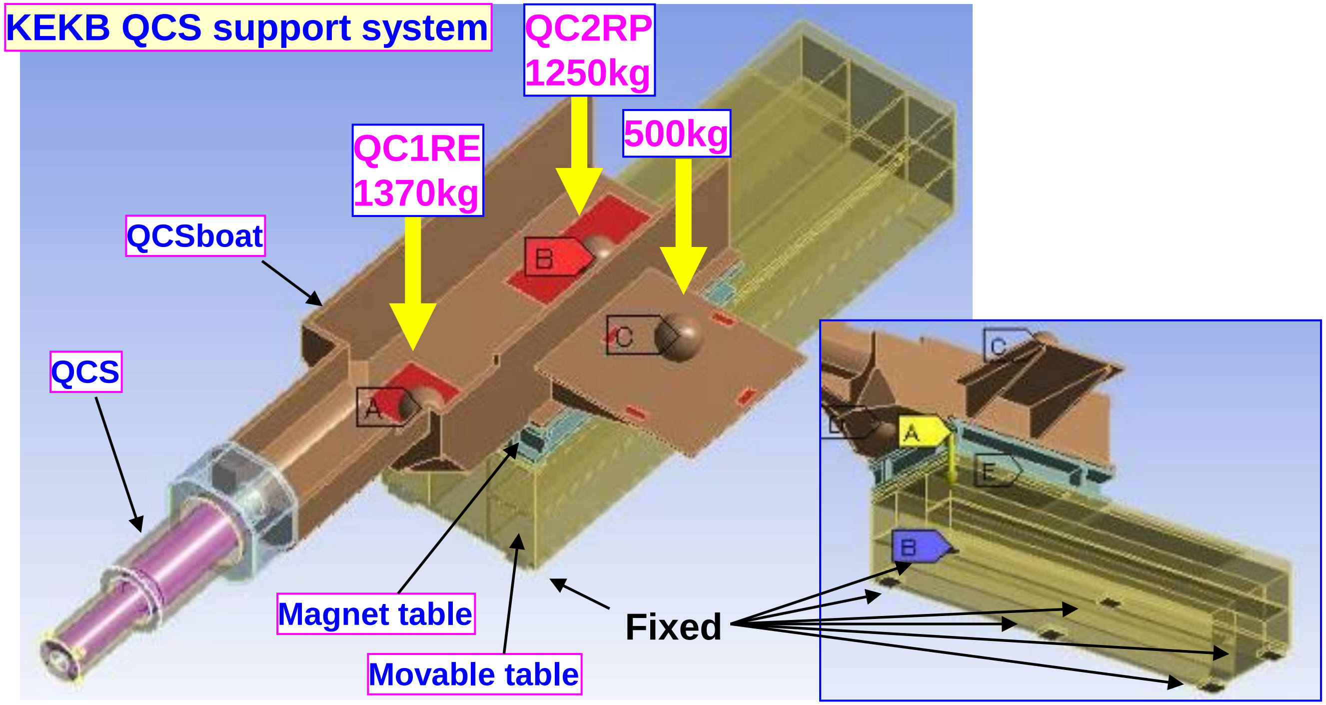
No.	Freq.(Hz)	damping (%)
1	26.861	0.66134
2	41.639	0.70658
3	57.435	0.38899
4	68.201	0.72795



→ **Damping ratio should be set to ~0.5%.**

2% damping seems too high.

➔ Respond amplitude was calculated and ***check consistency btwn calc. and meas.***



1. Loads
- Self-weight
- QC1RE: 1370kg
- QC2RP: 1250kg
- Box: 500kg

2. Materials

Cryostat: SUS
Coil: Cu
Supp.-rod: Ti-alloy
QCS table: SS400

3. Thread bolts

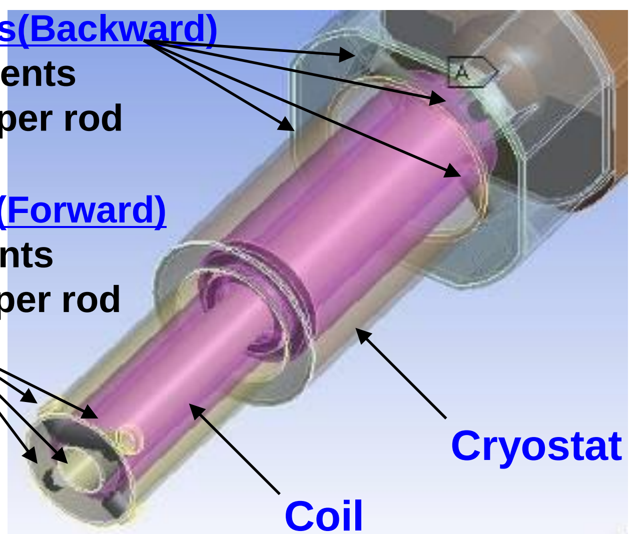
➔ 10-M30
6-M24
Pre-tension: Not defined

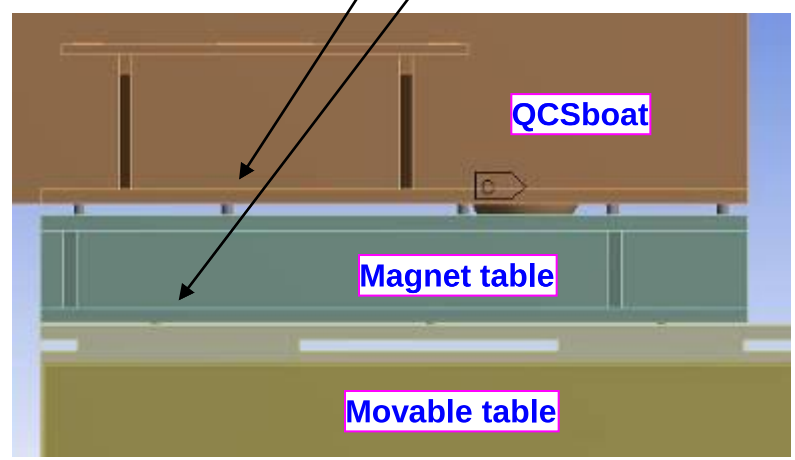
4. Support-rods(Backward)

➔ Spring elements
k=6171kg/mm per rod

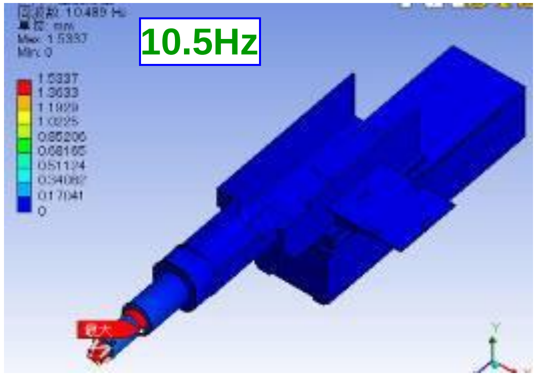
5. Support-rods(Forward)

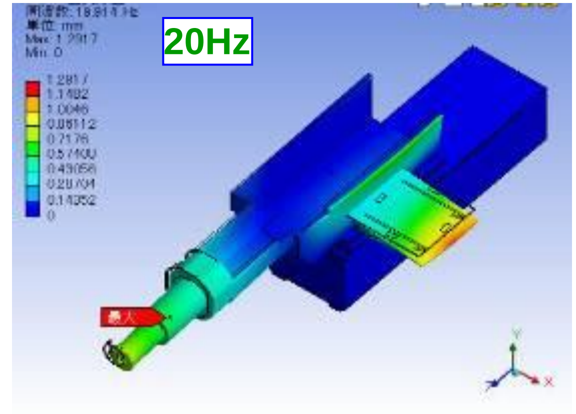
➔ Spring elements
k=12521kg/mm per rod

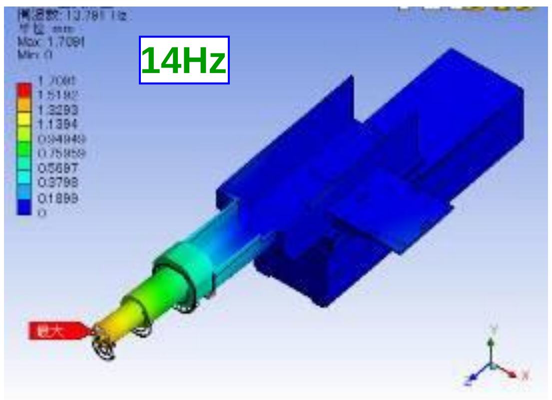


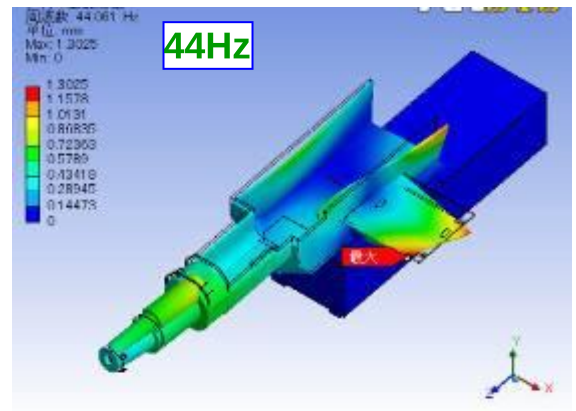


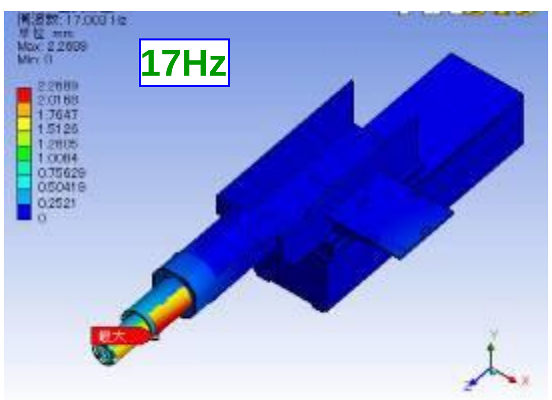
Modal calculation

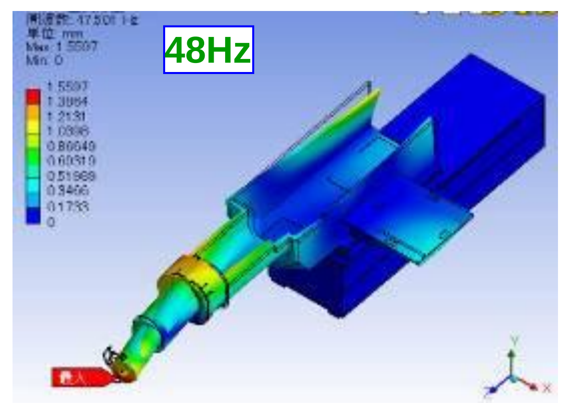






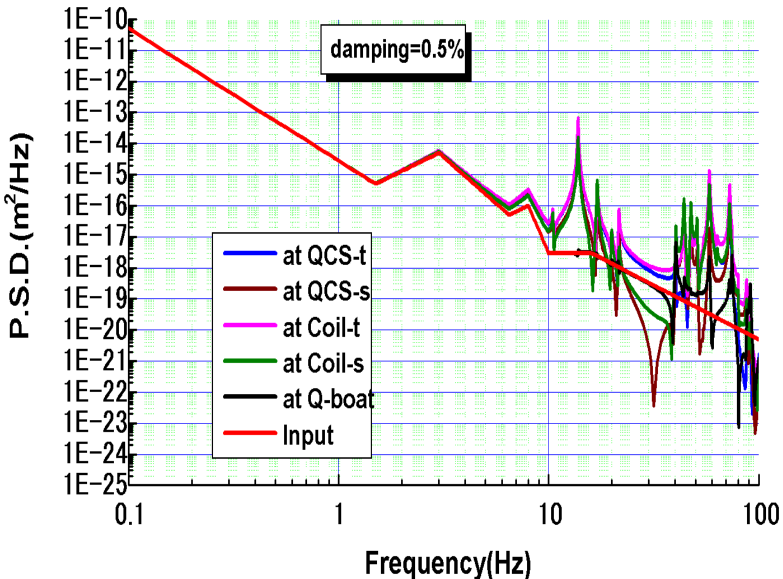


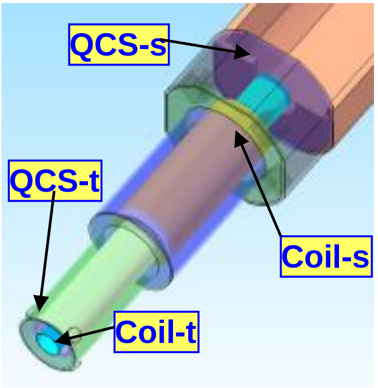




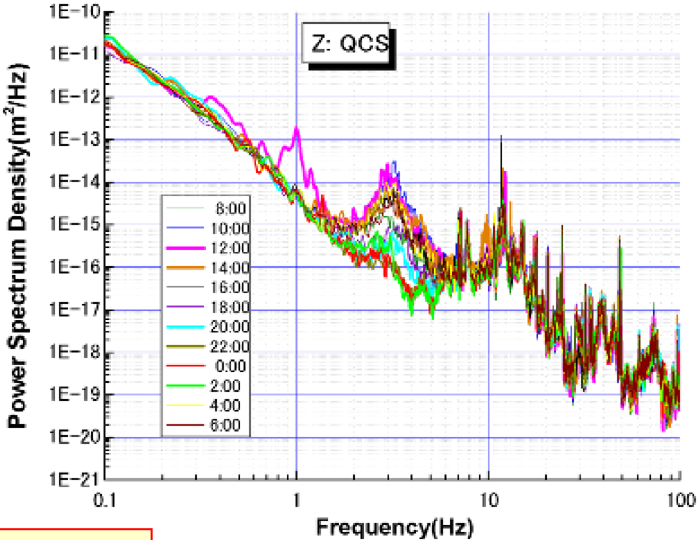
Response amplitude (*Vertical direction*)

Calculation: damp=0.5%

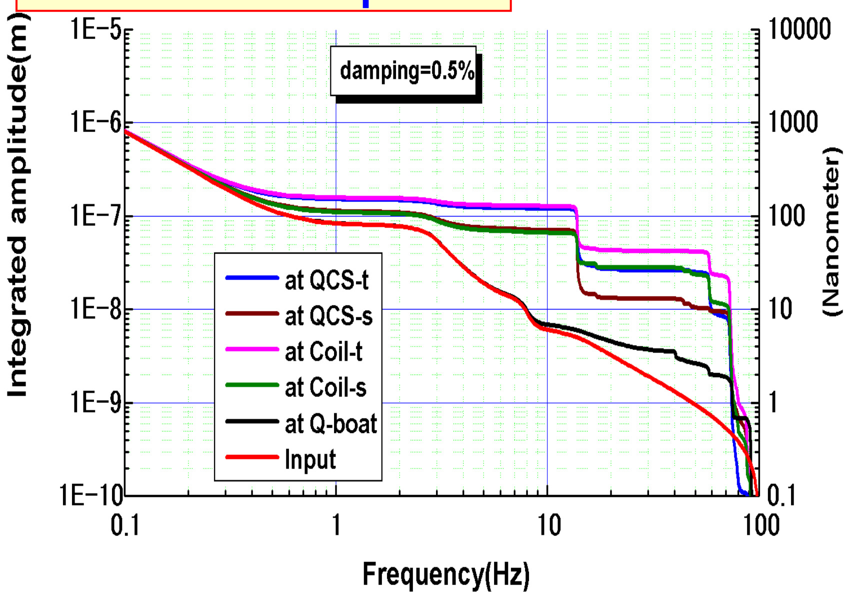




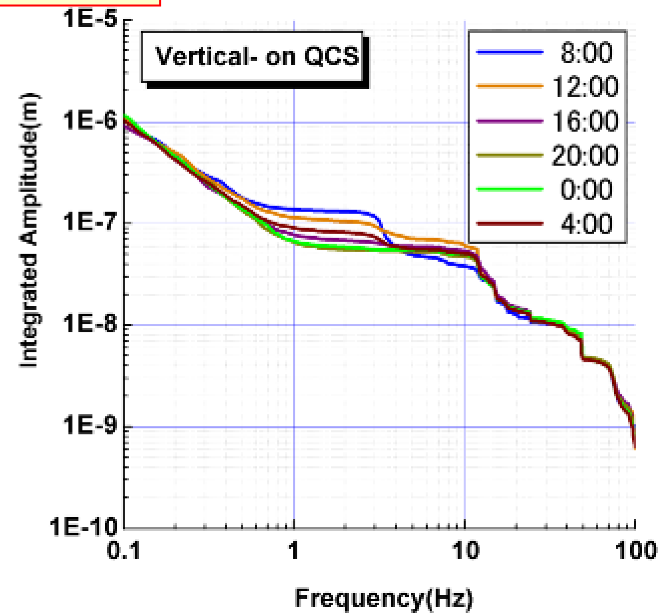
Measurements



Calculation: damp=0.5%



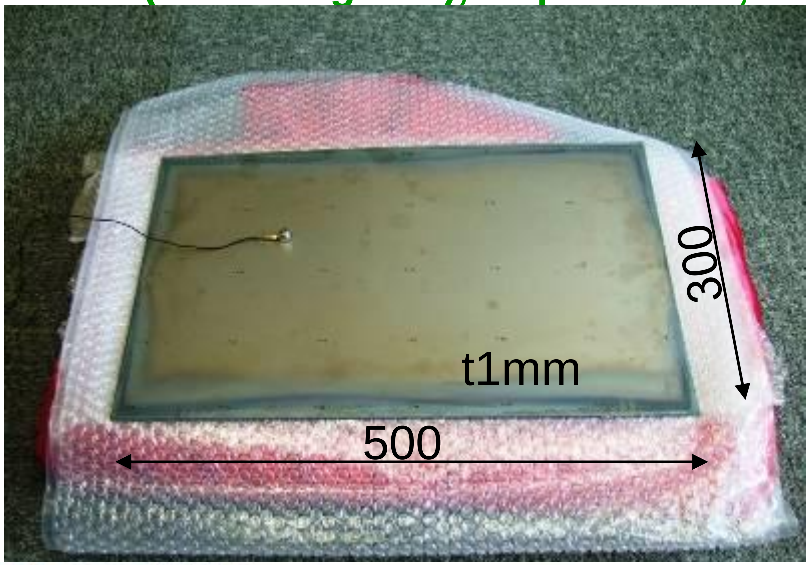
Measurements

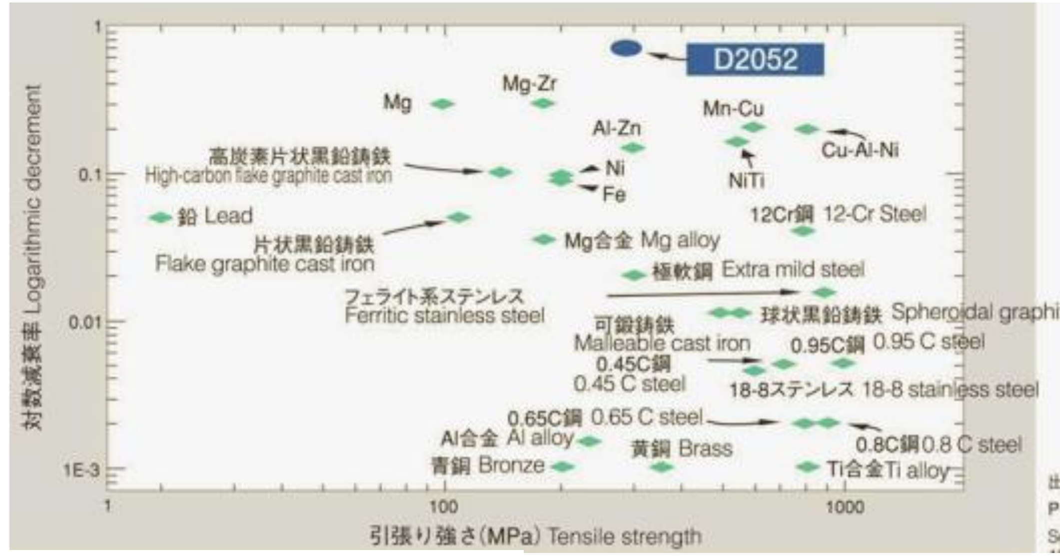


Investigations of High Damping Material

We have just started to study high damping material.

→ T2k(Horn magnets), Super-KEKB, ILD?





代表的な化学成分 Typical chemical composition

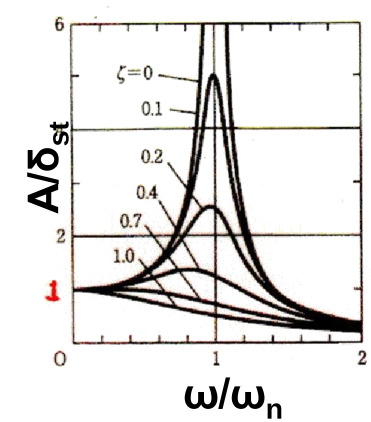
Mn	Cu	Ni	Fe	単位 Unit
Bal.	22.4	5.2	2.0	wt%
Bal.	20.0	5.0	2.0	at%

主な物性値 Typical properties

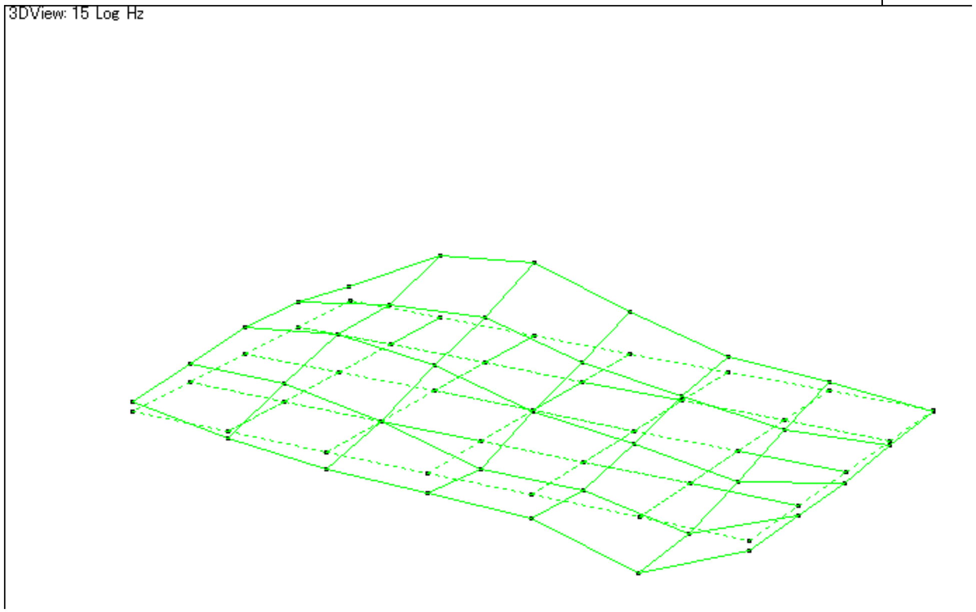
物性 Property	値 Value	近い元素 Approximate element
ヤング率 Young's modulus	80 GPa (300K)	Al, Ag, Cd
熱伝導率 Heat conductivity	10 W/(m·K) (300K)	Ti, Sb, Pb, Bi
比熱 Specific heat	512.7 J/(kg·K) (300K)	Ti, Fe, Cr
熱膨張率 Coefficient of thermal expansion	22.4 $\times 10^{-6}$/K (300K)	Al, Ag, Sn, Cu
密度 Density	7.25 $\times 10^{3}$kg/m^{3}	Fe, Mn
硬さ Vicker's hardness	120~140	

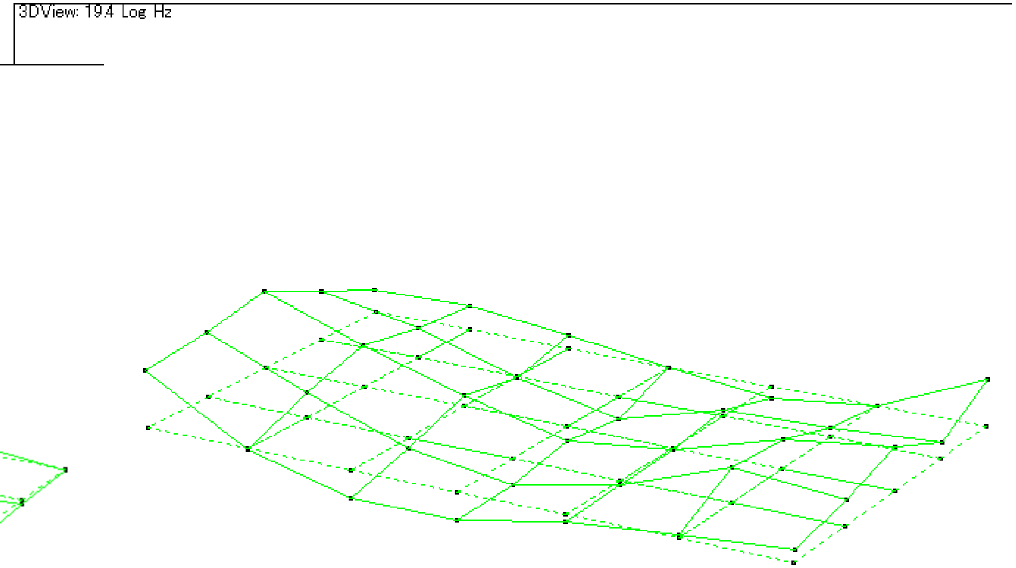
機械的強度 Mechanical strength

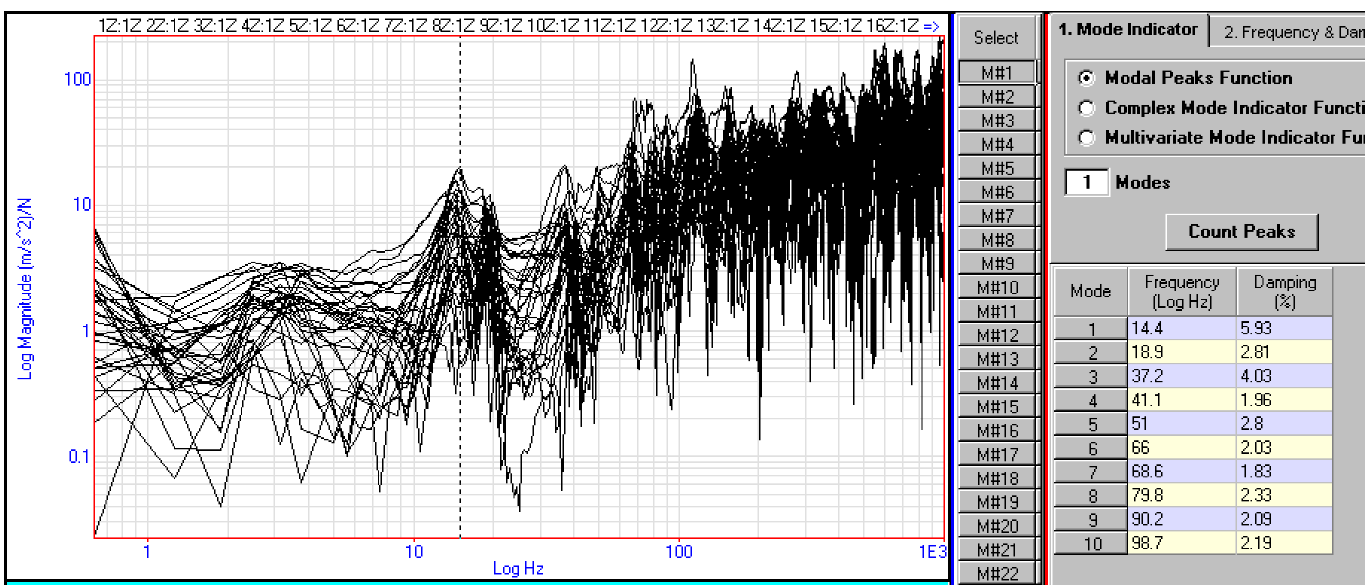
	引張強さ Tensile strength	耐力(0.2%) Yield strength	伸び Elongation	絞り Reduction of area	疲労強度($\times 10^7$回) Fatigue strength($\times 10^7$times)
標準材 Standard material	530MPa	265MPa	40%	61%	125MPa



Measurement at free-mode





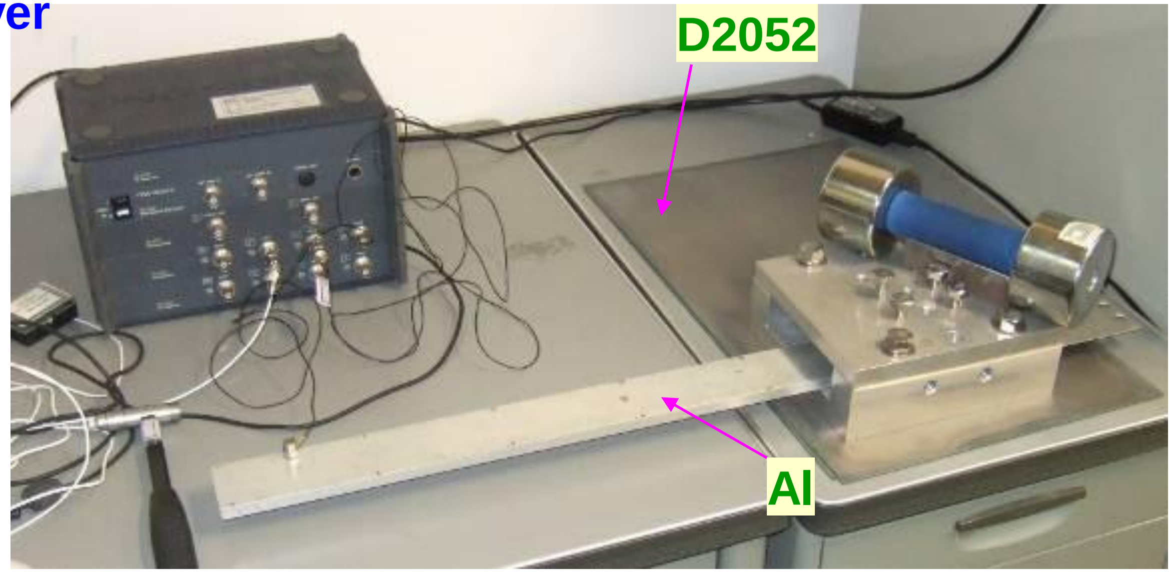


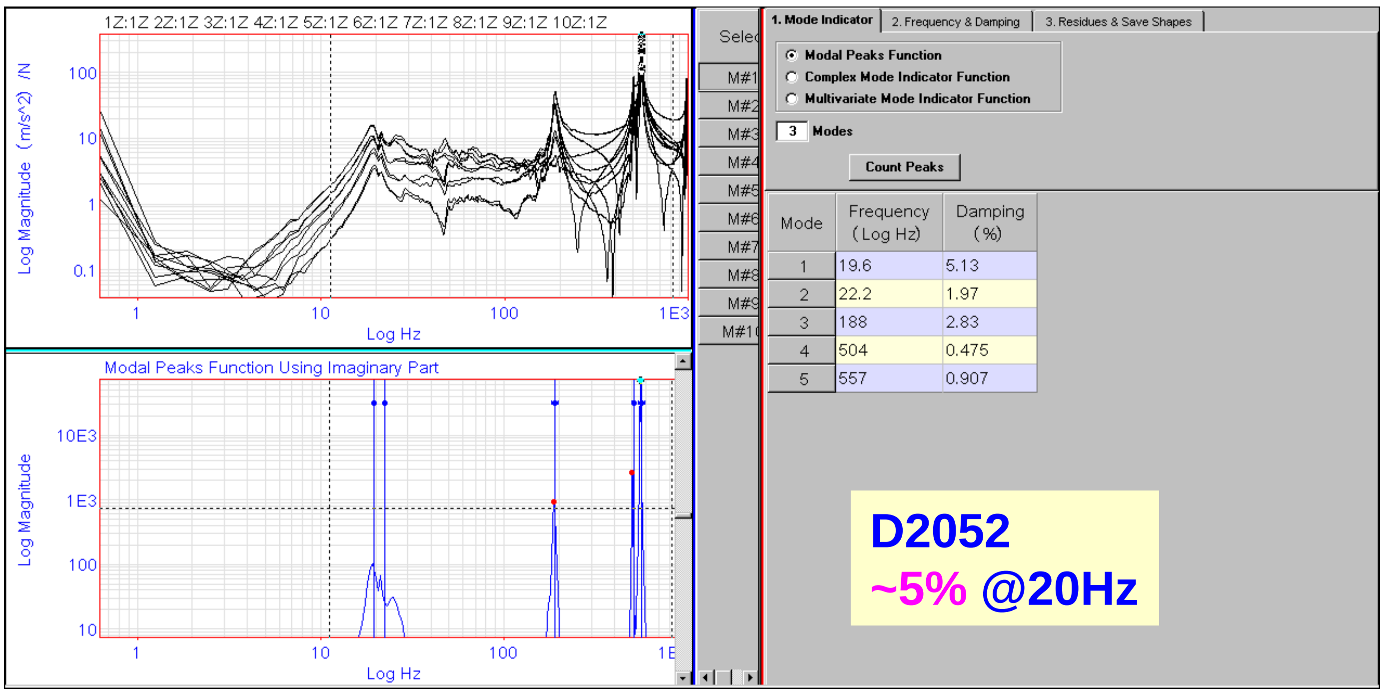
Mode	Frequency (Log Hz)	Damping (%)
1	14.4	5.93
2	18.9	2.81
3	37.2	4.03
4	41.1	1.96
5	51	2.8
6	66	2.03
7	68.6	1.83
8	79.8	2.33
9	90.2	2.09
10	98.7	2.19

D2052
~6% @14Hz

Al;
~0.3% @23Hz

Measurement at cantilever

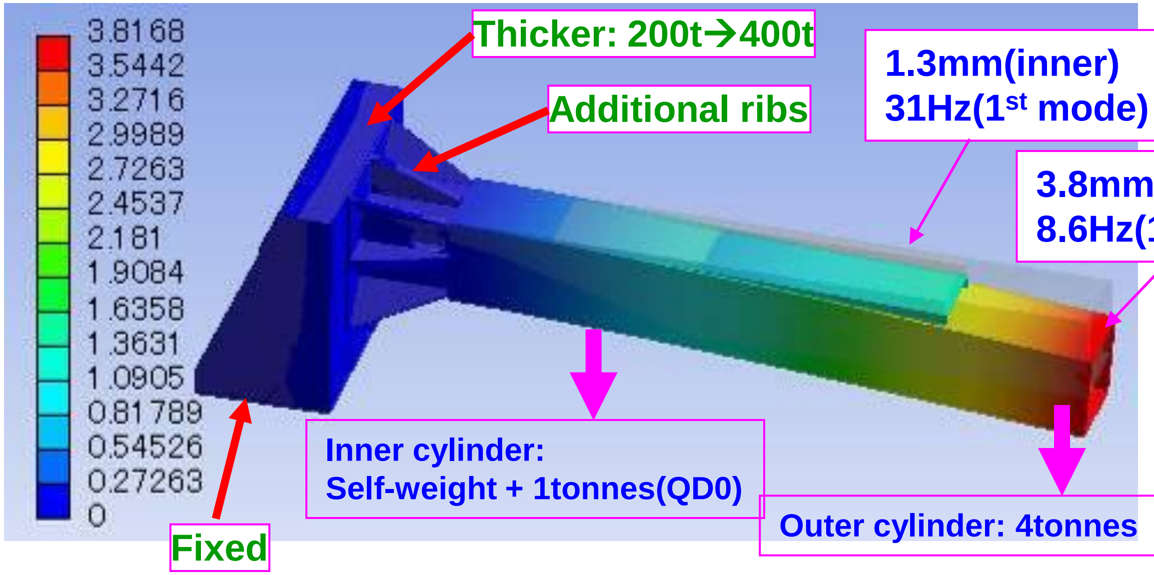


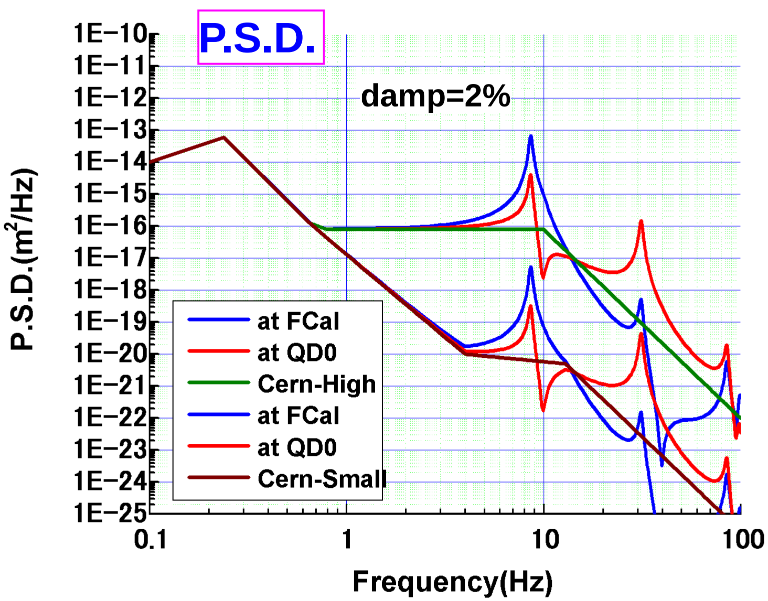


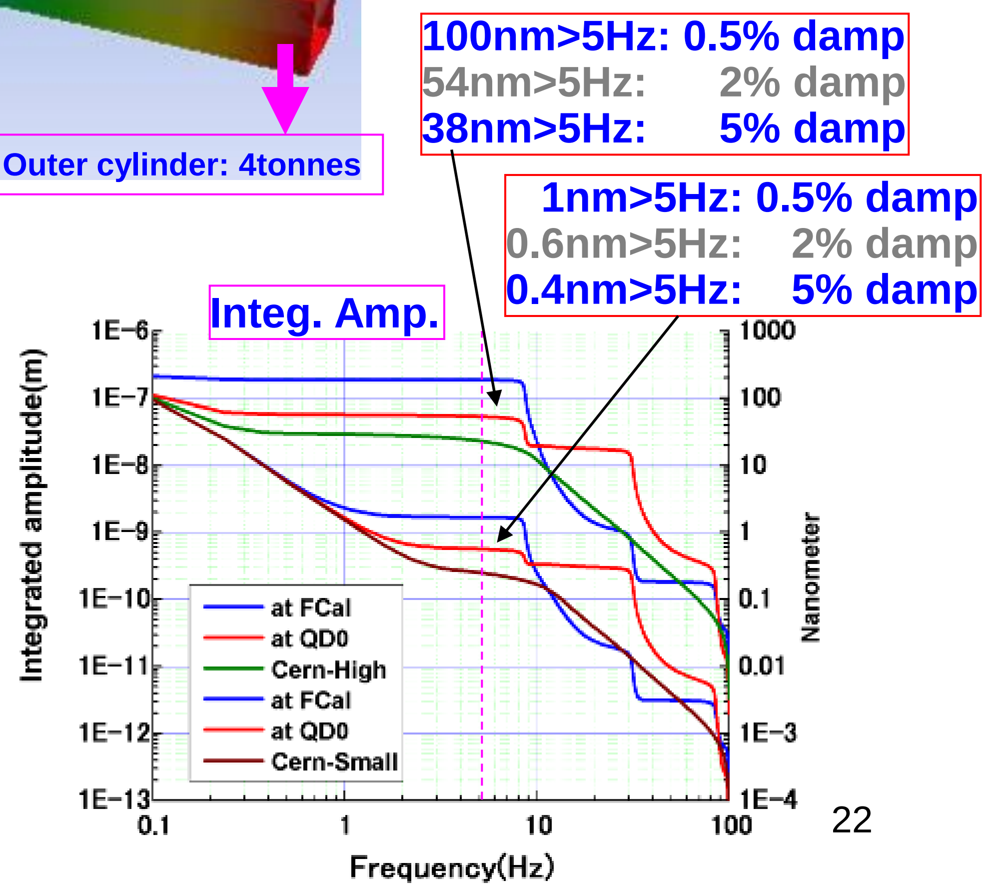
Mode	Frequency (Log Hz)	Damping (%)
1	19.6	5.13
2	22.2	1.97
3	188	2.83
4	504	0.475
5	557	0.907

Calculation(Presented at Beijing meeting)

Respond amplitude at each position is estimated.







Summary

1. Vibration measurements

We measured vibrations at the Belle/KEKB/CMS/ND280 so far.

(Belle detector)

→ Vibration at barrel yoke grows very big when the solenoid is excited.

(KEKB)

→ Effects of the QCS-coil cooling down is not so big.

The Belle/KEKB have been shutdown toward for the BelleII/SuperKEKB.

→ We have lost the chance of vibration measurement at present.

→ We will measure vibration when the Belle is roll-out.

2. Check consistency

- In progress...

→ Good consistency at the KEK QCS magnet support system if damping ratio is assumed to be 0.5%.

→ Seismic test with high damping material will be also carried out.

→ Measurement of damping ratio will be evaluated.

3. Calculations

- PSD calculations in case of difference damping ratio have been carried out.

→ About two times bigger than the previous calculation.(2% → 0.5%)

4. Design stiff support structure

- Not so big progress...

5. Realistic vibration data for calculations

CMS

END

Conclusion(@KEKB/Belle)

1. Power Spectrum Density

Tunnel: H-dir.→ ~0.3Hz (Micro-seismic) , ~3Hz(Resonancy of soil)

V-dir.→ ~3Hz(Resonancy of soil)

Q-table, magnet→ Peak around 8Hz was measured additionally.

2. Influence of Air conditioner

A small difference was measured around 1~3Hz

→ No obvious differences.

3. Coherency

(1) Both sides of KEKB-tunnel (Nikko-side ←→ Oho-side)

No coherency except for ~0.3Hz and ~3Hz.

(2) Distance dependency

Frequency above 10Hz is getting worse.

4. Cooling effects

There is no big effects to vibration behavior. It occurs at just beginning of the cooling.

SP500

Further measurements/plan;

- BELLE solenoidal field with immune to magnetic fields(SP500).→ Done
- Vibration when beam is circulating with SP500.

Integrated amplitude(nm)						
	>1Hz			>10Hz		
	Perpend	Beam	Vertical	Perpend	Beam	Vertical
B4 floor	50	46	67	4	3	9
KEKB floor	55	45	68	10	5	9
Mag.-table	90	50	76	12	16	19
QCS-boat	250	60	118	15	21	30
QC1RE	241	77	112	52	50	46
Belle stand	105	69	71	13	11	13

・ Improving the magnet/BELLE/etc support structure.

Vertical direction tolerance
0.1μm at QC1
⇒ COD of ~ σy at the IP (By Y. Funakoshi)

- An orbital FB is needed.

No active cancellation system is considered at this point.

- We are thinking about something similar to the KEKB iBump system. → To next page...

Orbital FB

SuperKEKB iBump system

Made by Masuzawa-san.

Y.Funakoshi, M.Masuzawa+Magnet group+Monitor group

☆What to monitor to maintain luminosity

Beam-beam kick using BPM data.

☆Magnets to move the orbit

Vertical & horizontal steering magnets.

Probably two systems

(1)System for scanning (finding a good collision point)

(2)System for maintaining a good collision condition.

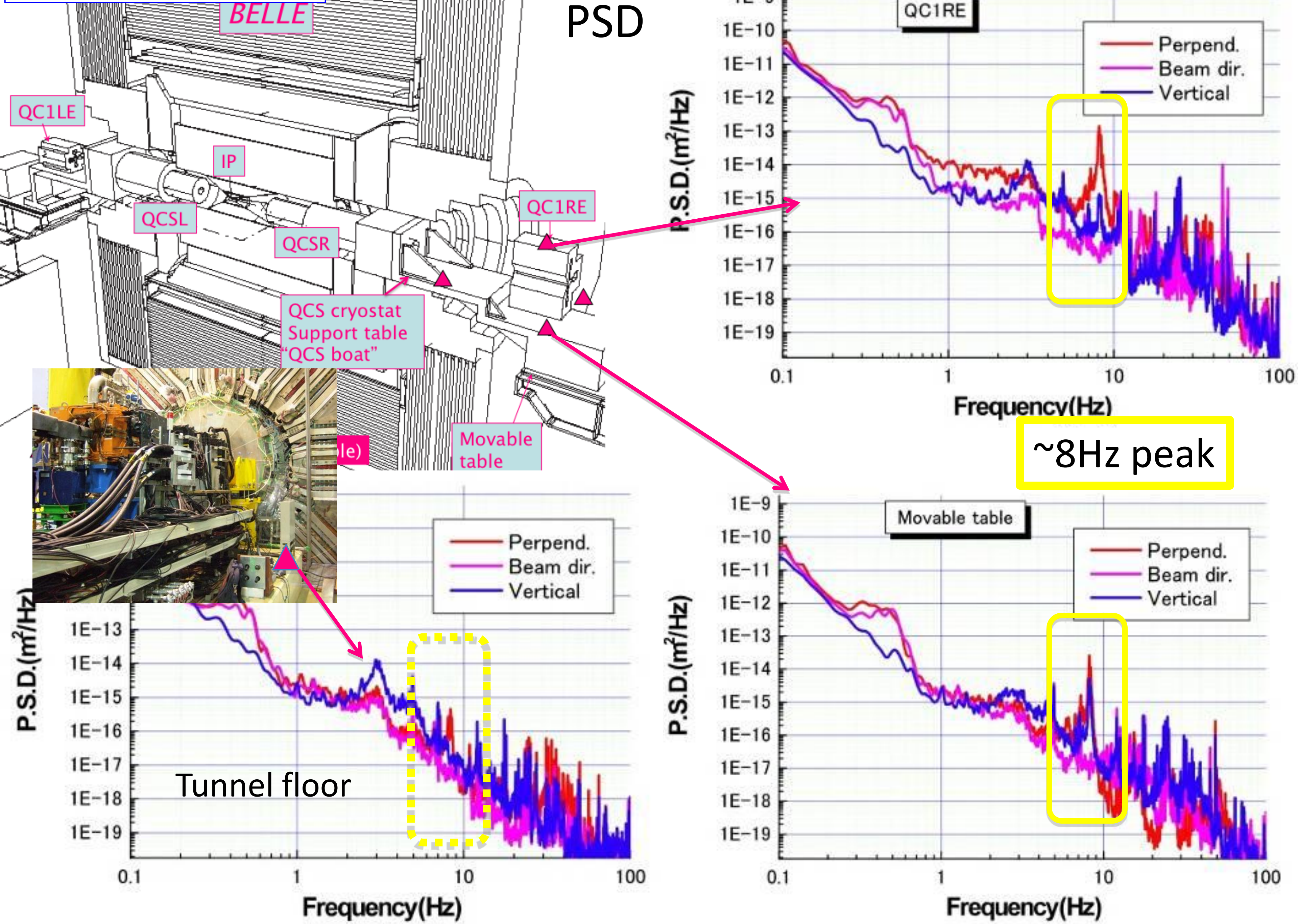
*The present iBump system does both (1)&(2).

☆Frequency that we deal with

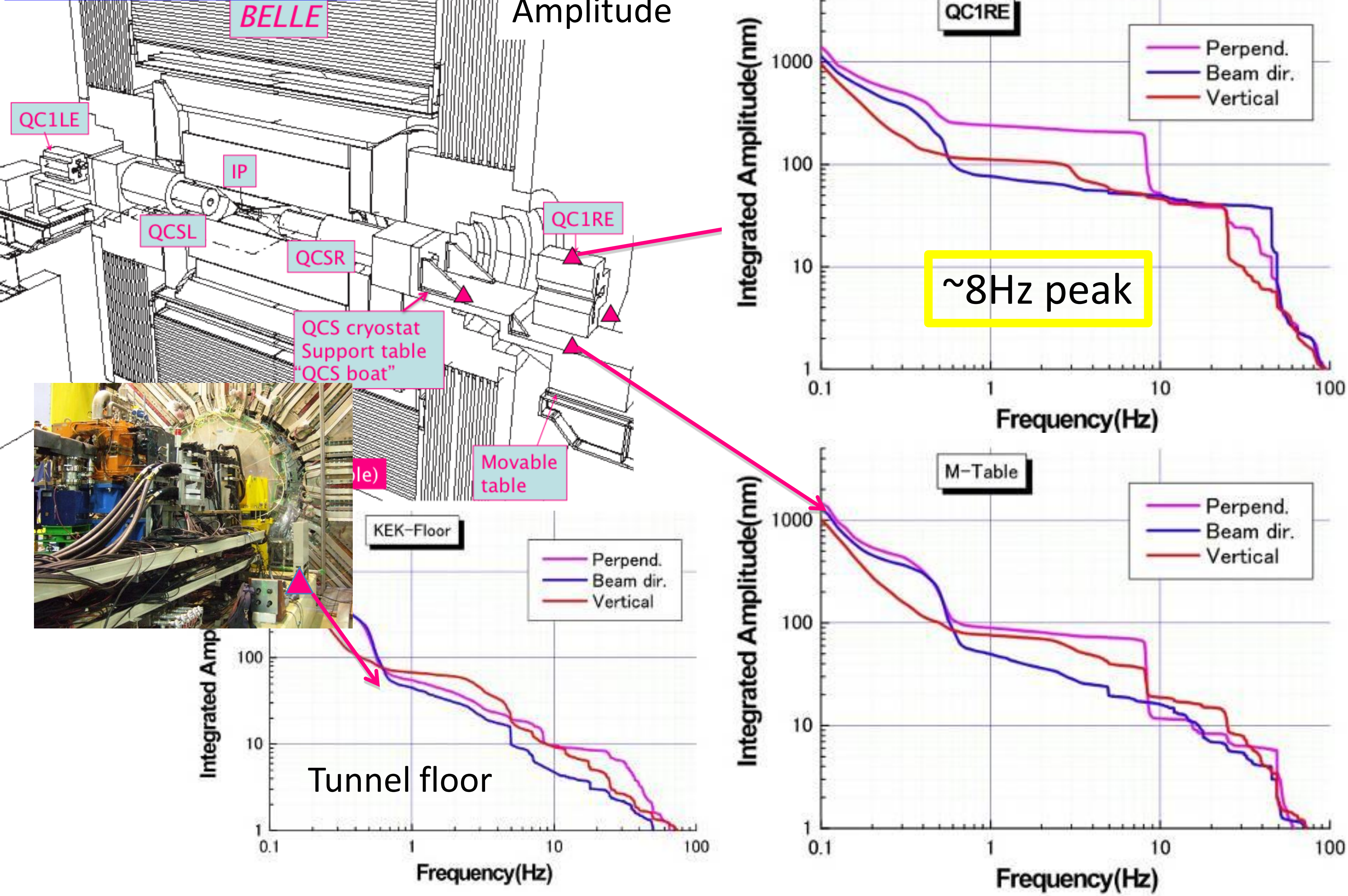
< 50 Hz (or 25Hz)

★A practice with one of the iBump magnets will be done in June.
"Practice" does not mean actual FB, but to try to see the beam response to the magnet/power supply we have with the monitor group & magnetic field response to power supply.

Vibrations around IR

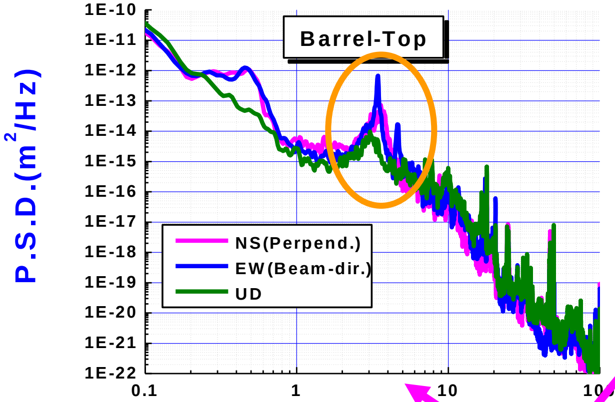


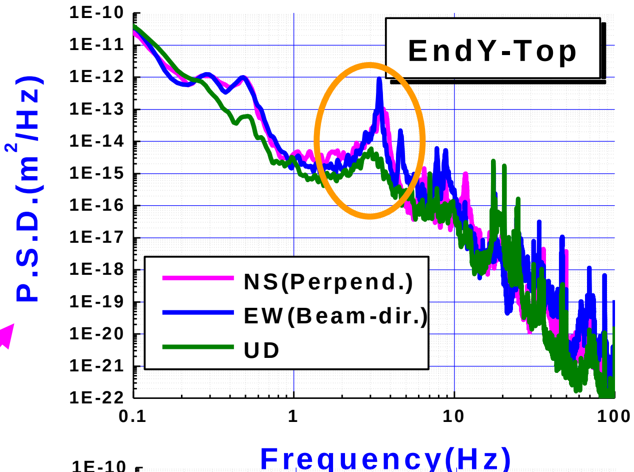
Amplitudes around IR

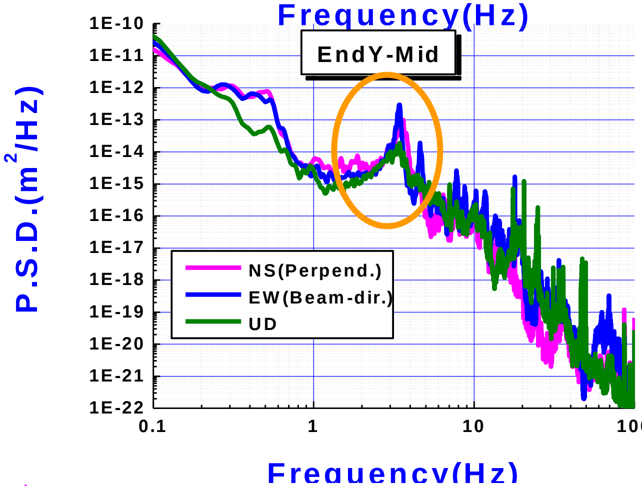


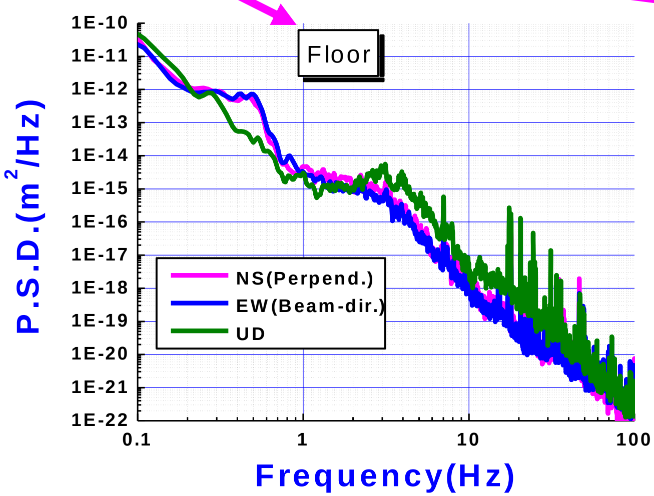
➔ **Amplitude in the perpendicular dir. is bigger than others due to peak at 8Hz.**

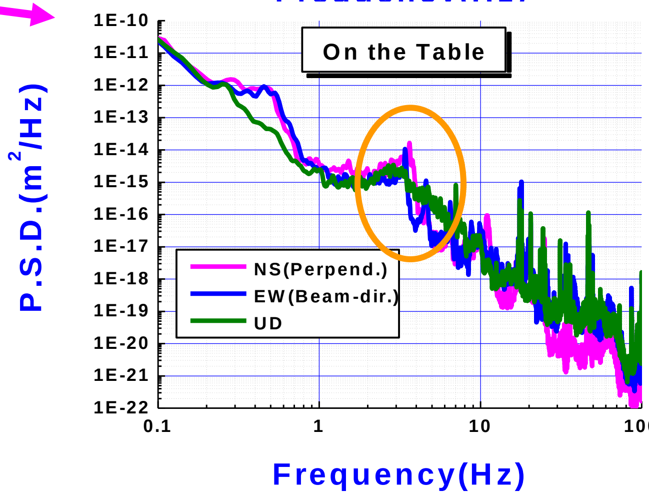
4. Vibration data@KEK





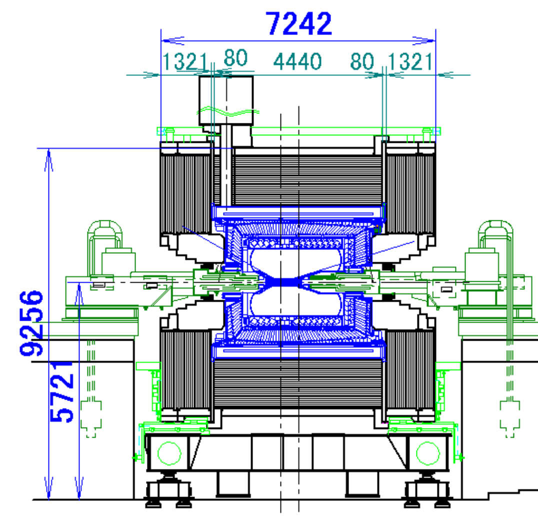


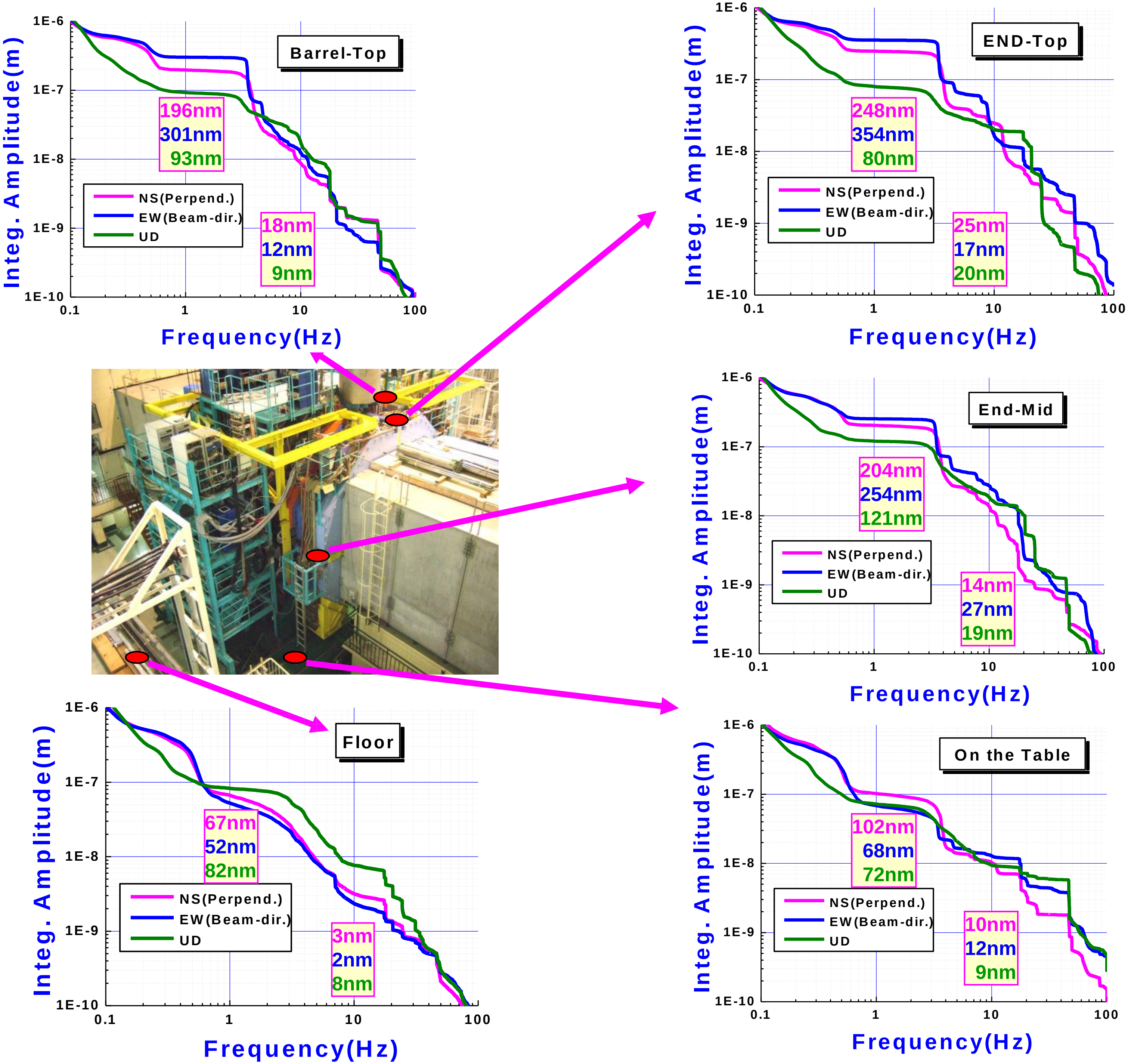




Servo Accelerometer
MG - 1 0 2

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