Vibration measurements

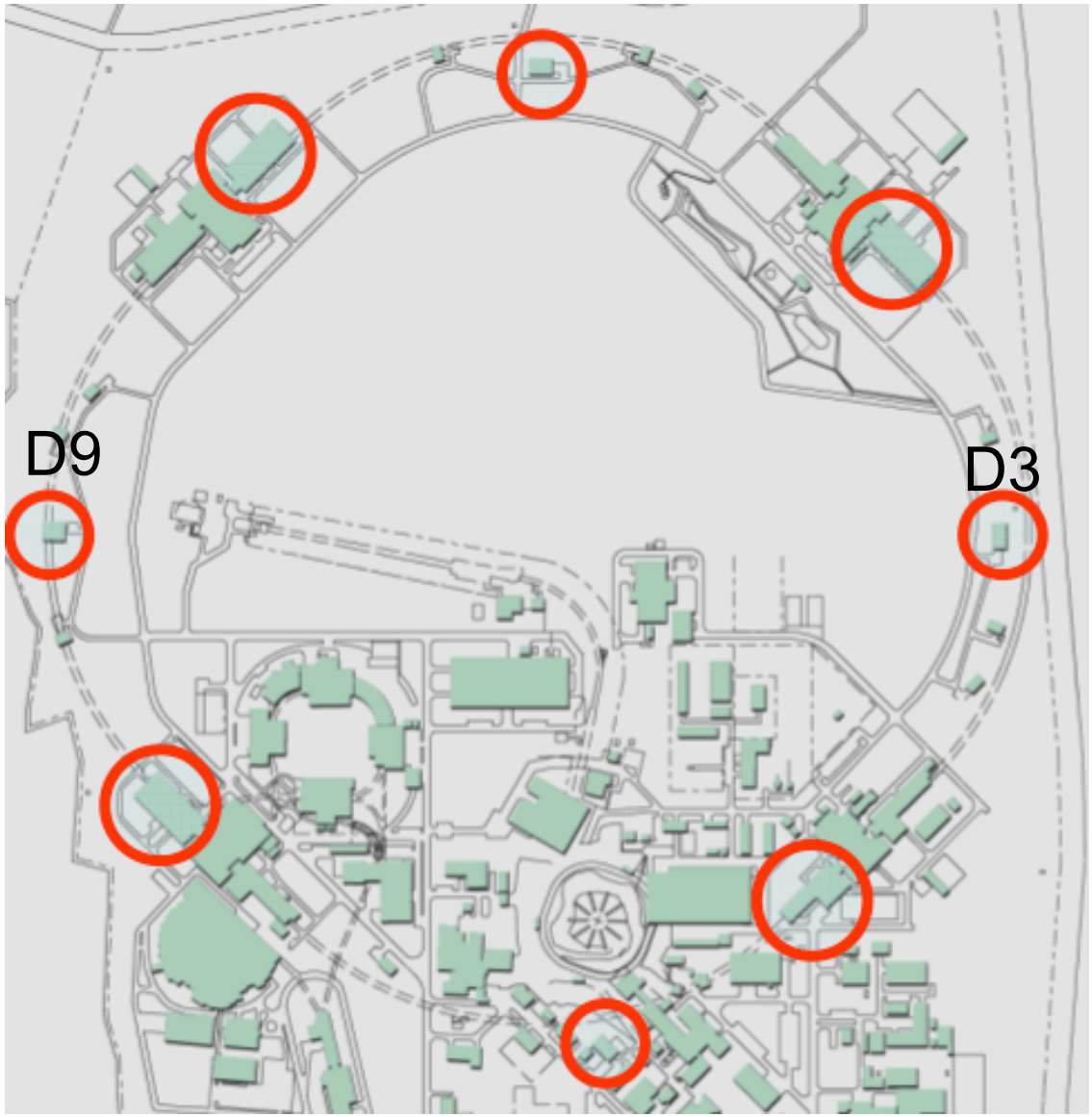
H. Yamaoka, R. Sugahara
and M. Masuzawa

Purpose of the measurements

- To characterize the vibrations.
  - Where is it that vibrates?
    - Magnets
    - Supporting table
    - floor
  - At which frequency?
    - Characteristic frequencies
  - With what amplitude?
    - Will it cause a serious degradation in the machine performance?

KEK environment

Measured by R.Sugahara et.al (KEK Report 2003-12)



~11m
below GL

Higashi-odori
road

~11m
below GL

KEK environment

Measured by R.Sugahara et.al (KEK Report 2003-12)

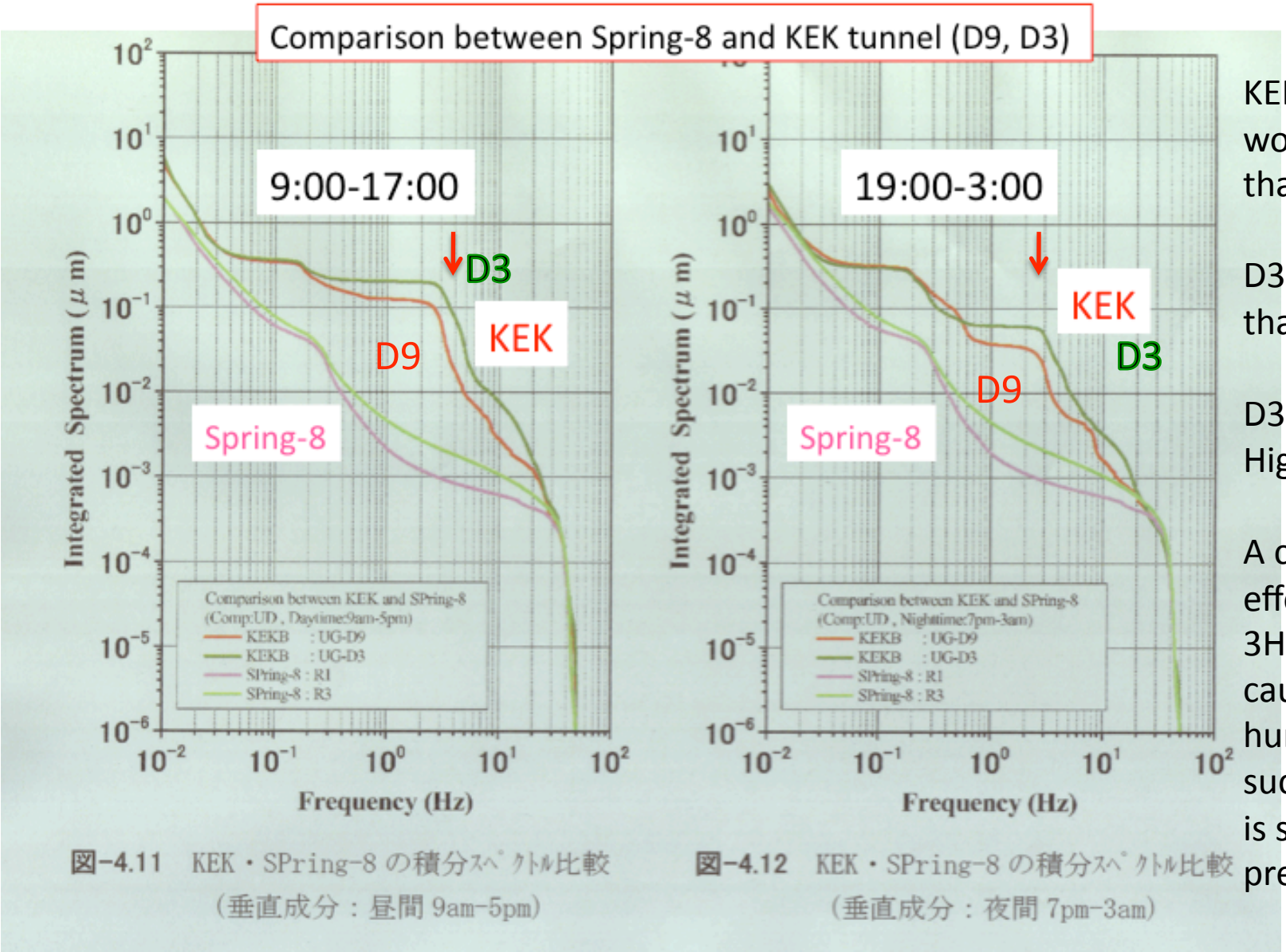


図-4.11 KEK・SPring-8 の積分スペクトル比較
（垂直成分：昼間 9am-5pm）

図-4.12 KEK・SPring-8 の積分スペクトル比較
（垂直成分：夜間 7pm-3am）

KEK site is much worse than SPring-8…

D3 is worse than D9.

D3 is closer to Higashi-Odori.

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

Sensors

We use six acceleration sensors (MG-102S, Tokkyo-kiki Corporation).
Each sensor measures one direction, 3 sensors to measure (X,Y,Z).
2 sets of sensors, one set usually on the floor and the other on the magnet for example.

Acceleration sensors: MG-102S (Tokkyo-kiki Corp.)	
Maximum Input	+/- 2 G
Sensitivity	0.5102 V s^2/m
Frequency range	DC-400 Hz
Cross talk	1/1000
Weight	160 g
Amplifier: OSP-06 (Tokkyo-kiki Corp.)	
Frequency range	0.1-400 Hz
Data logger:DS-2000 (Ono Sokki Corp.)	
A/D conversion	24 bit

Servo Accelerometer
MG－102

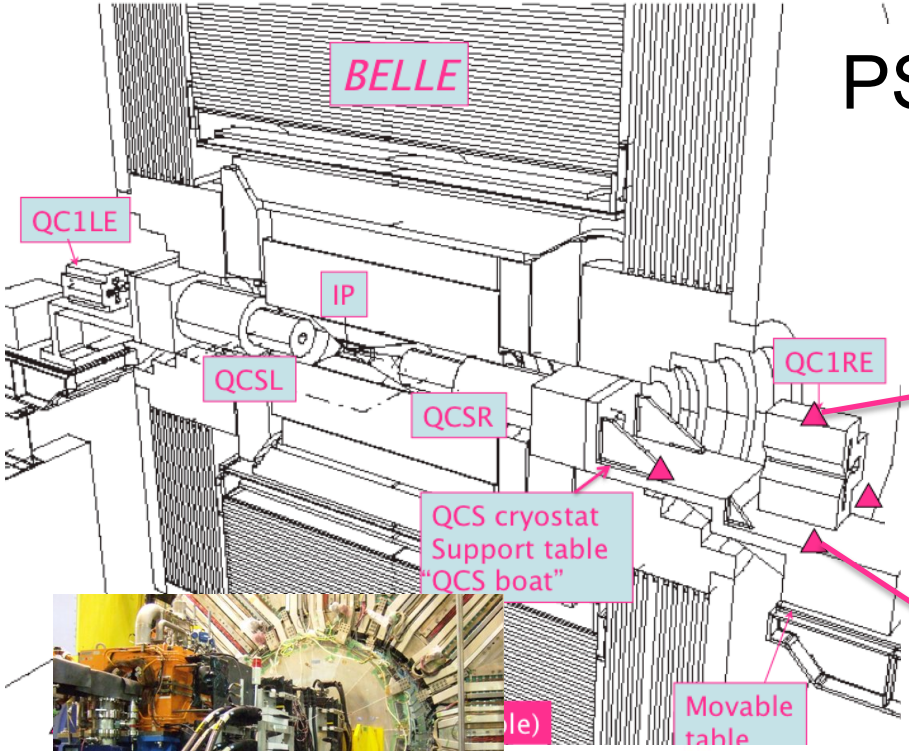
Size	40×40×50mm
Max. input	±2G
Resolution	1／10^6G

Acc. 0.1～400Hz
Acc. 60dB = 1gal/V

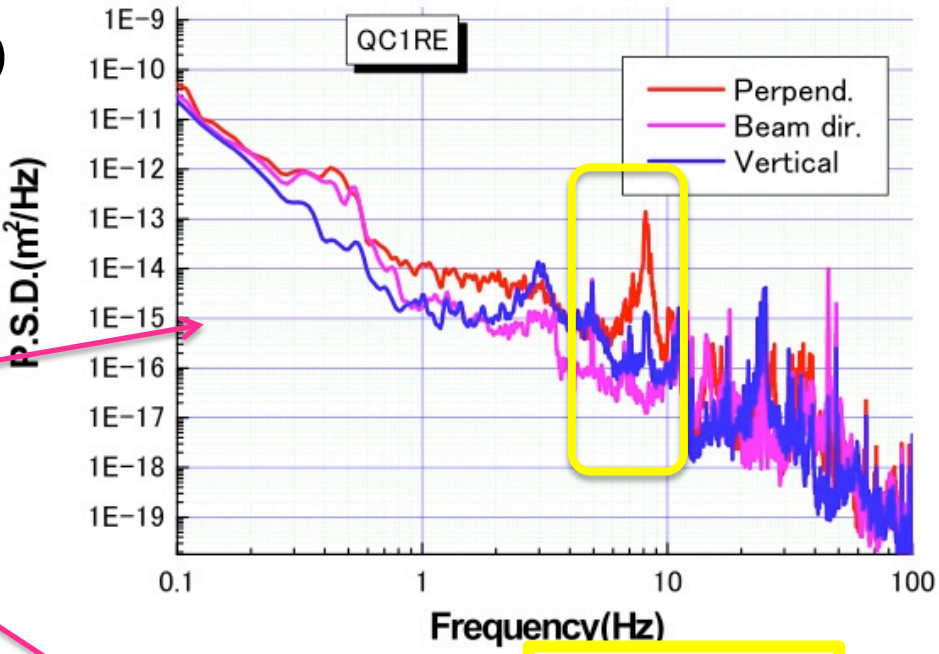
Measurements
KEKB IR

*Power Spectrum Density (PSD) plots
*Integrated amplitude (vs frequency) plots

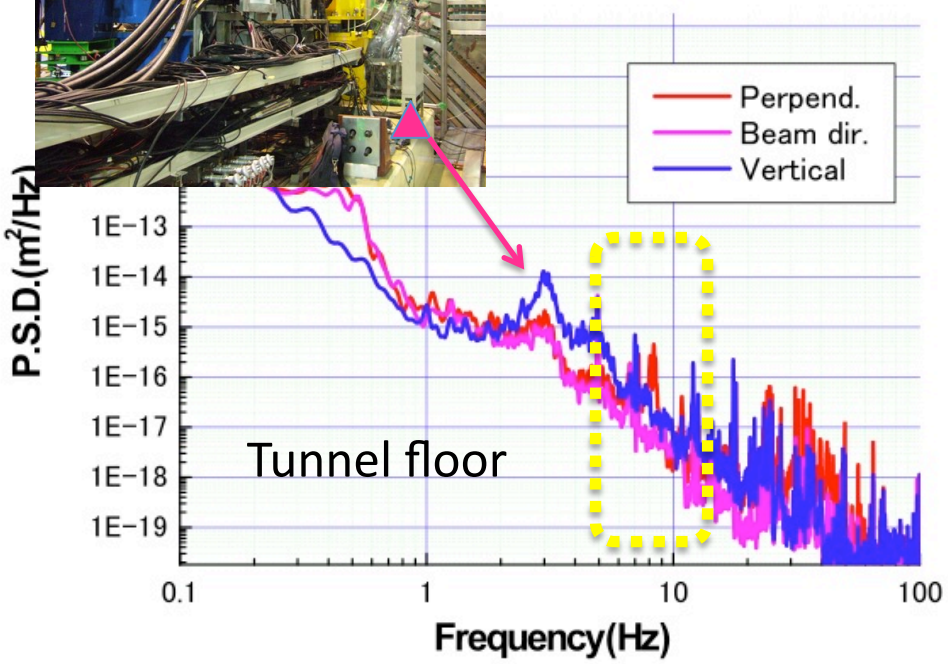
Data taken in June. 2009
when Belle solenoid, QCS and the ring magnets were turned off.

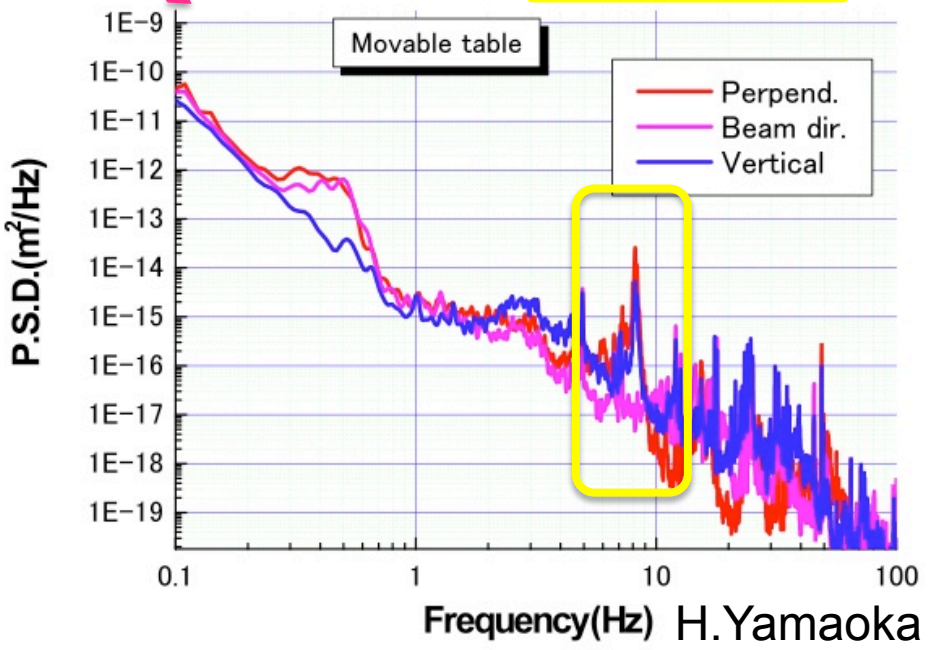


PSD



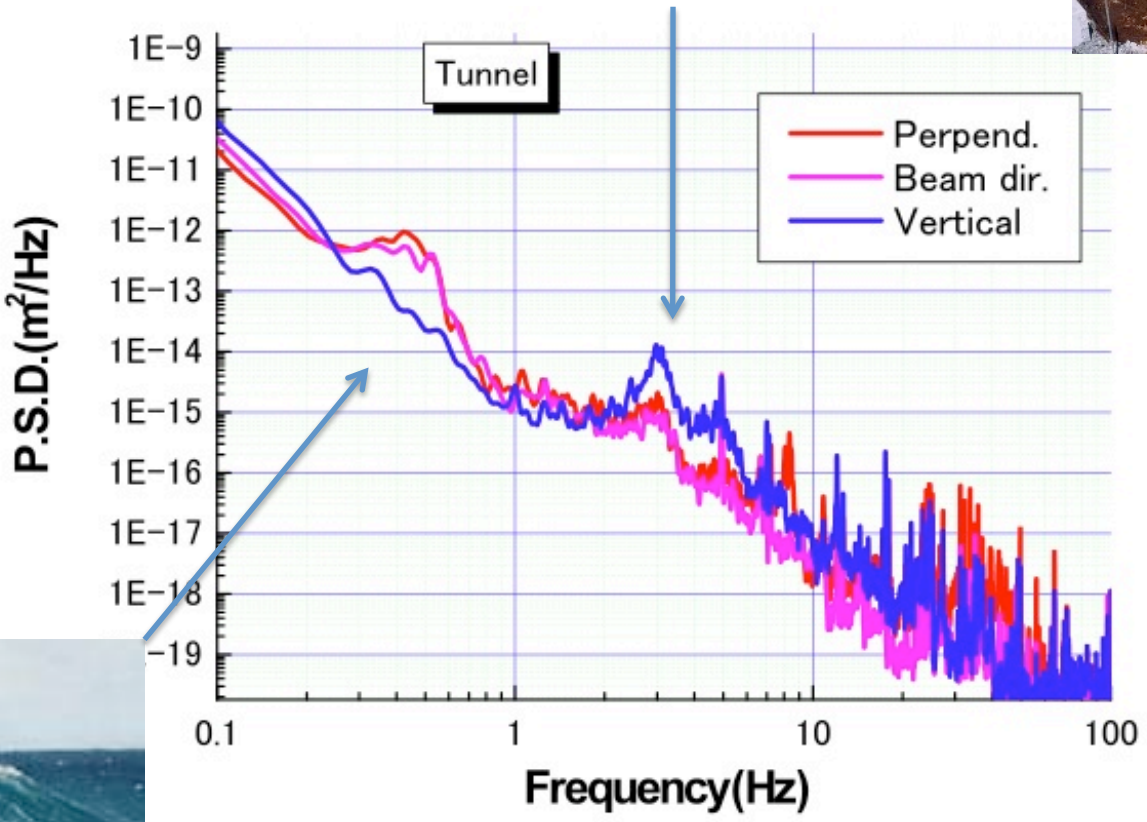
~8Hz peak



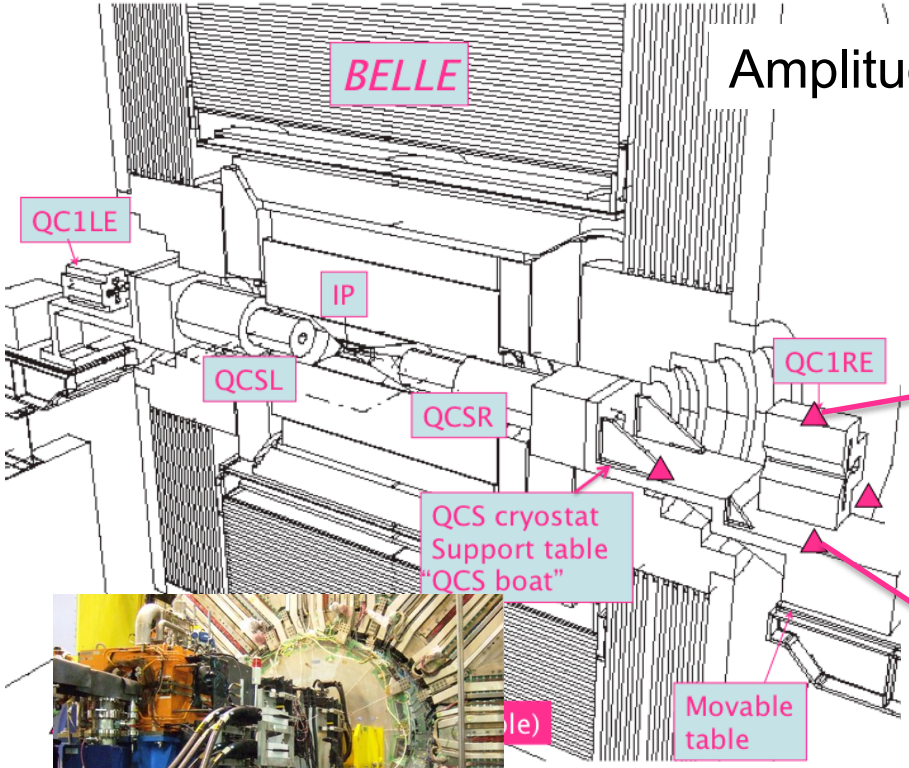


H.Yamaoka

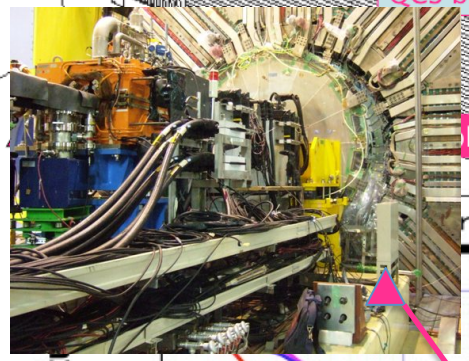
~3Hz : characteristic frequency of the soil called “Kanto loam” around KEK.
Induced by human activities,
mainly vertical vibration.
Day & night effects and weekend effects have been observed.

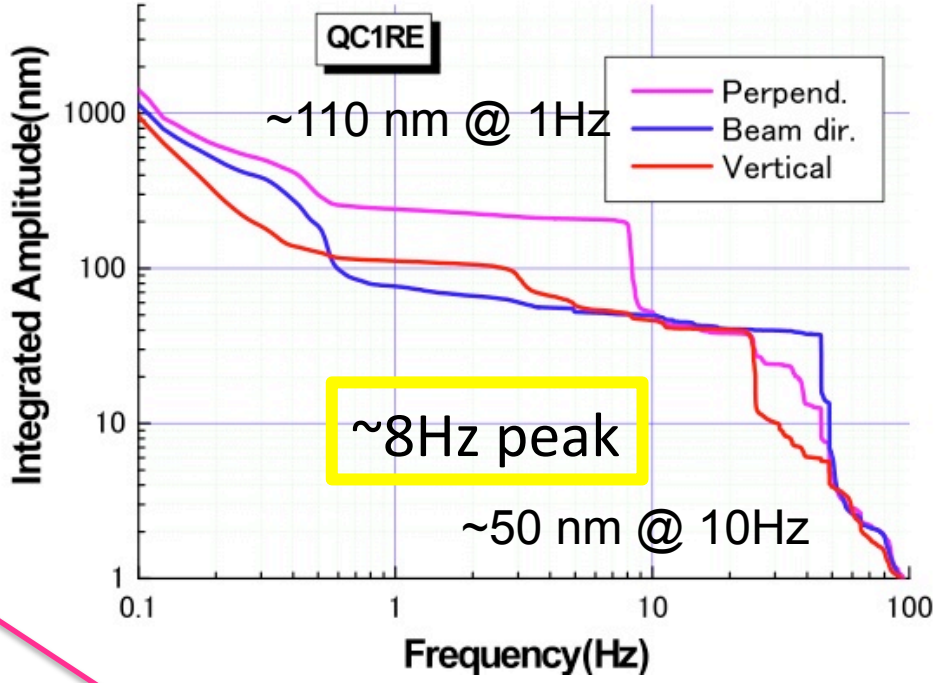


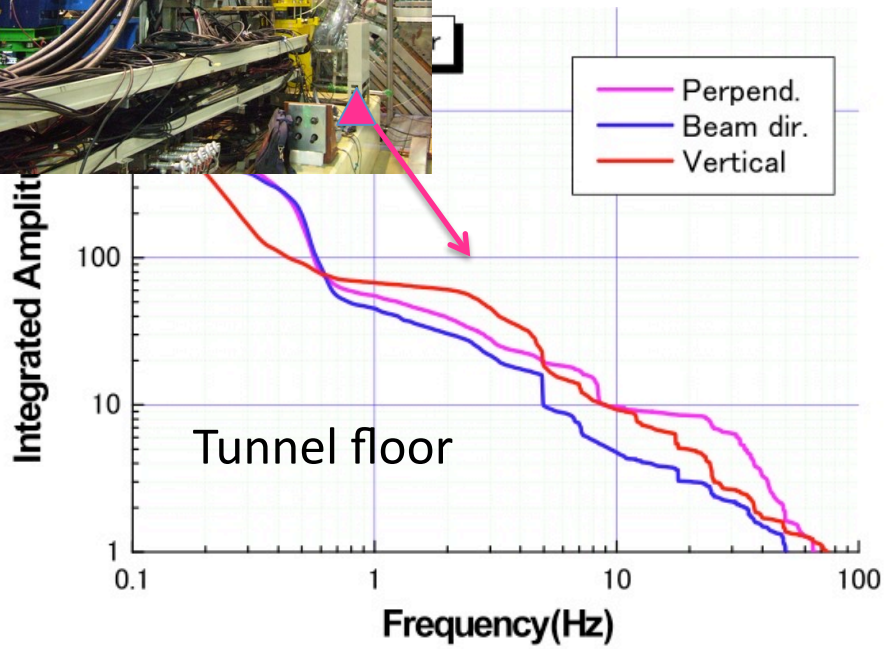
0.2~0.3 Hz: Ocean waves & wind.
Depends on the weather, mainly in horizontal vibration.



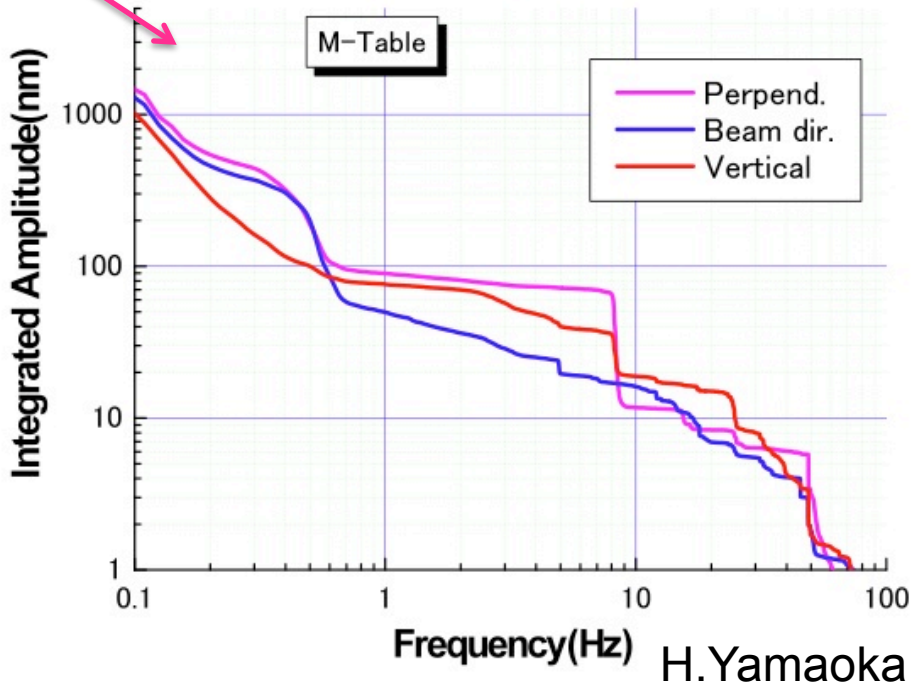
Amplitude







Tunnel floor



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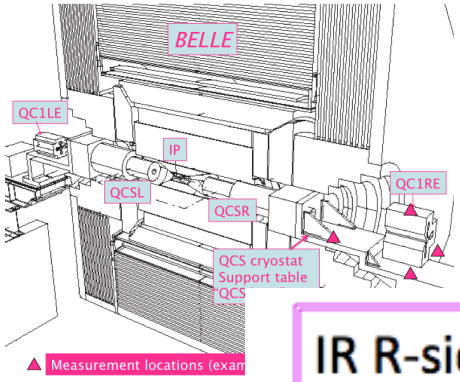
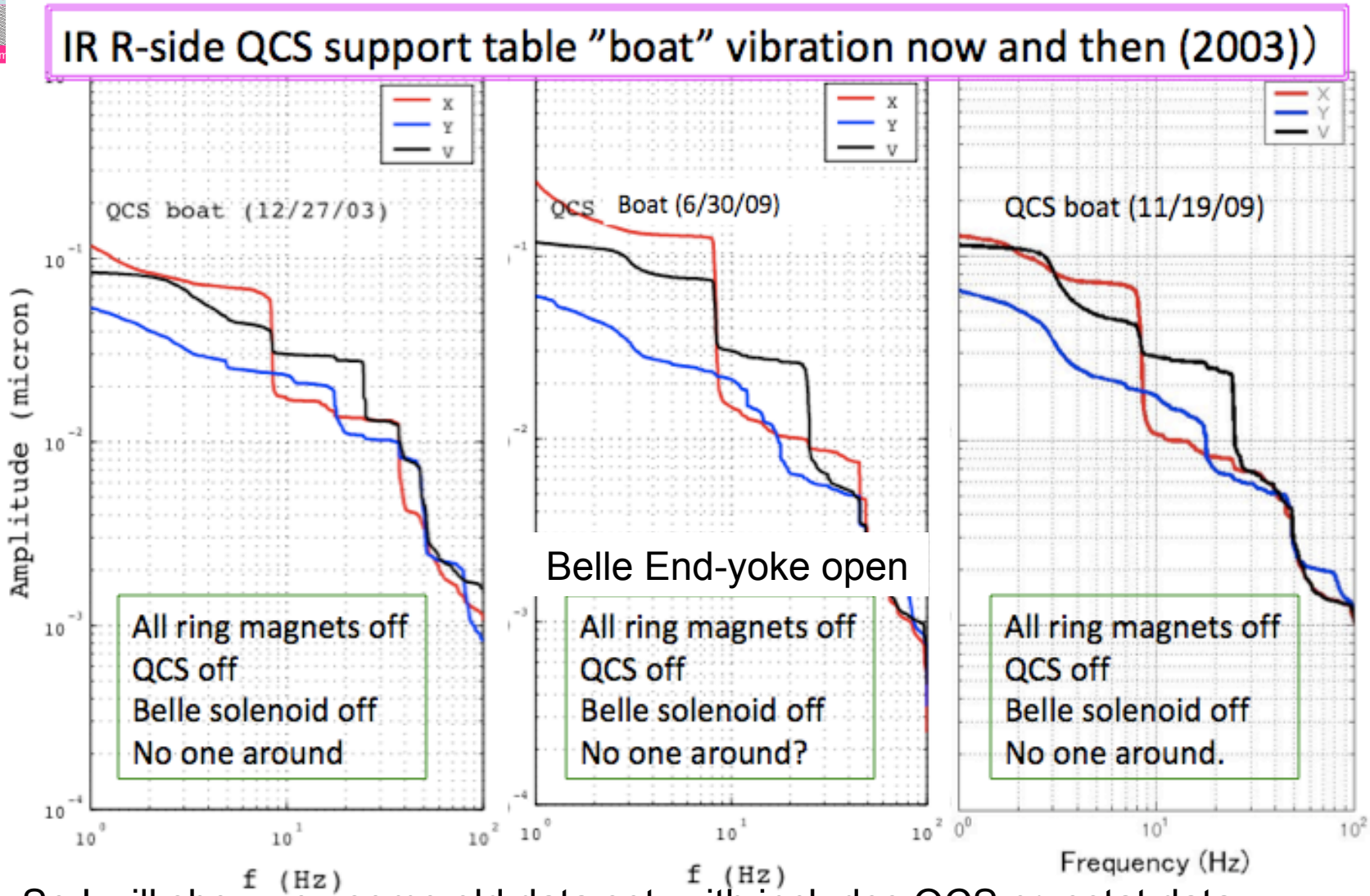
Comparison with some old data

WE have been measuring the motion
of the tunnel floor, magnets,
supports in many places since 2003.



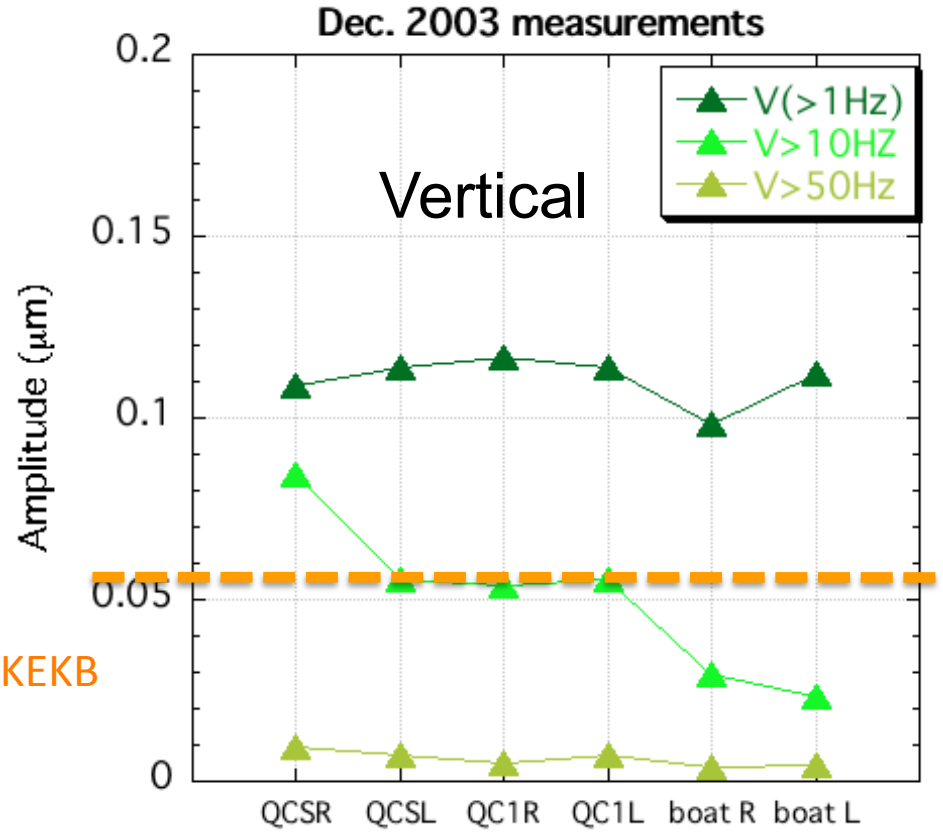
For how long has this 8Hz peak been around?

⇒ Since we started measuring



So I will show you some old data set, with includes QCS cryostat data.

IR magnet vibration (2003 data)

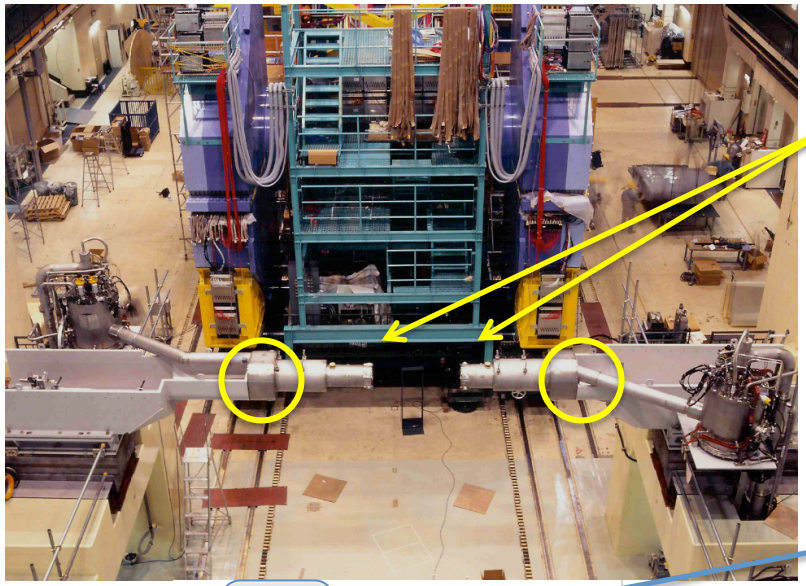


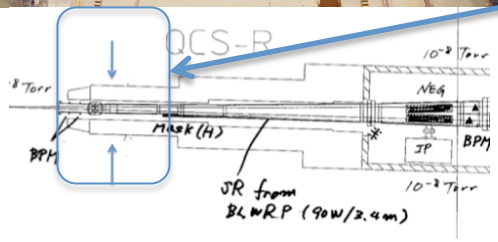
SuperKEKB
σy *

From 2009 data
@10Hz
~30 nm (QCS boat)
~50 nm(QC1RE)
@1Hz
~120 nm(QCS boat)
~110 nm(QC1RE)

Consistent !

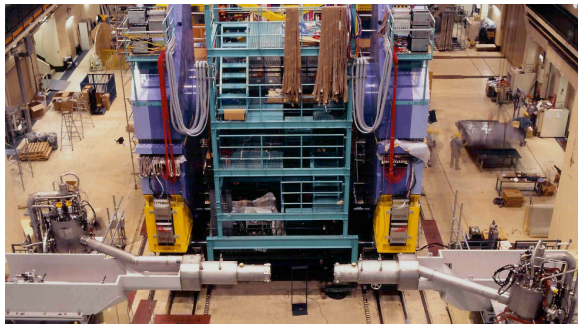
This photo was taken when
QCS was retracted (not while the vibration data were taken),



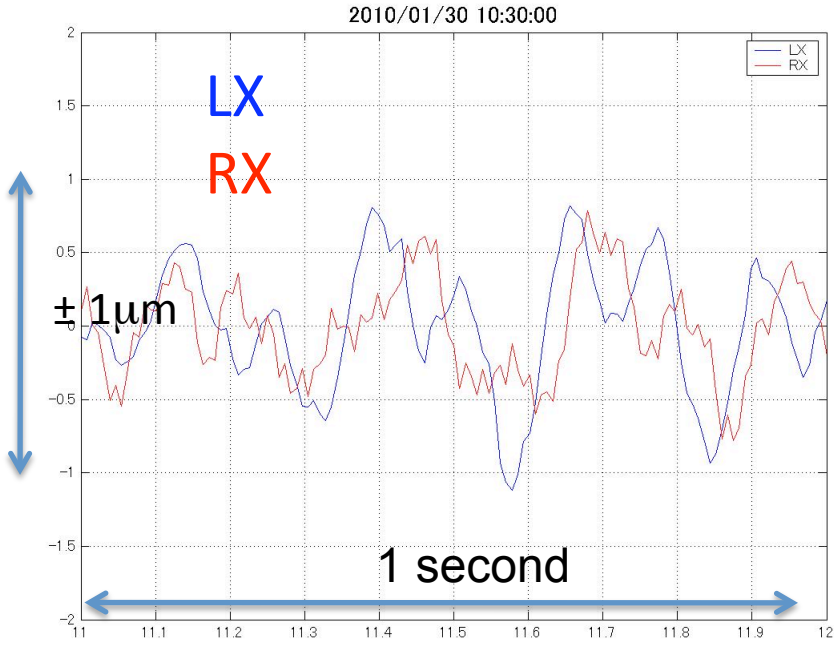


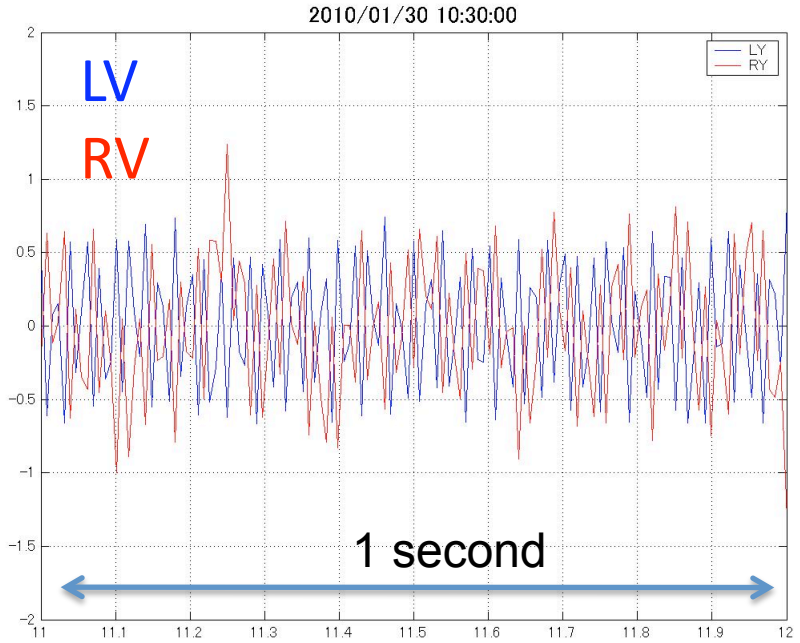
(Near the) IP vibrates more than the vibration measurement locations indicated by ◯

We can not place the vibration sensors anymore near IP but can get some information from the displacement sensors, which measure the relative distance between QCS and BELLE CDC.

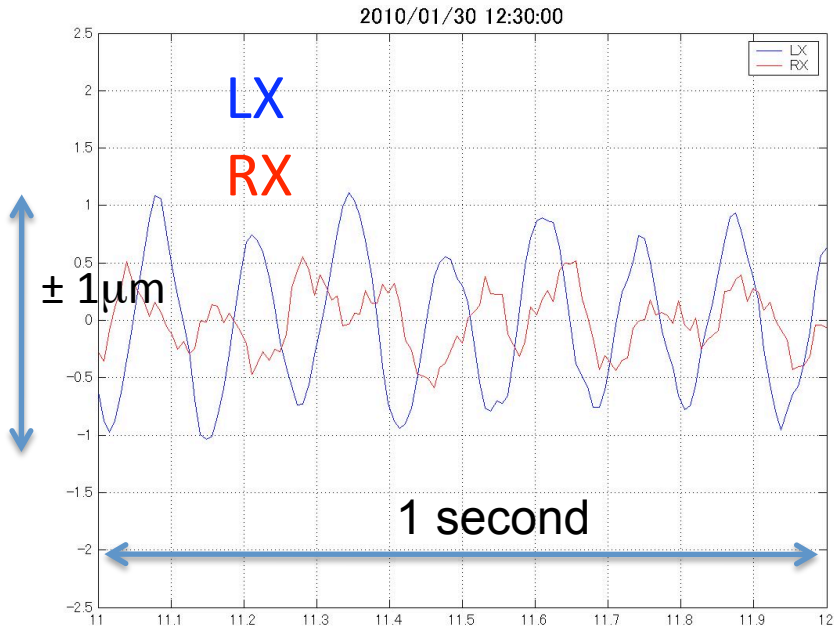


Note:
The displacement sensors were originally installed
for measuring larger displacement (several hundred microns)
Sub-micron calibration ??

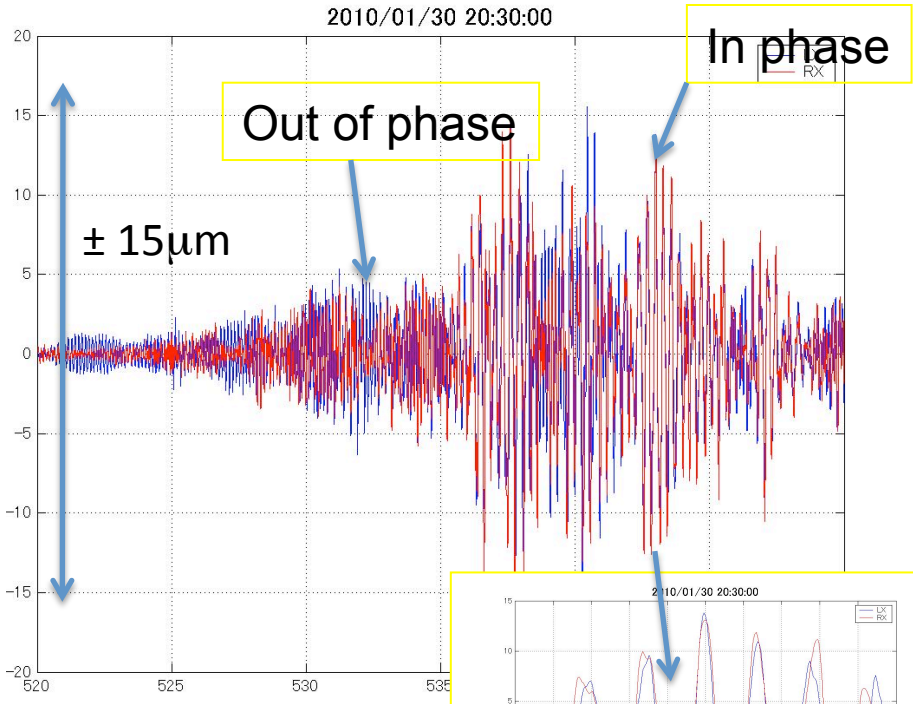


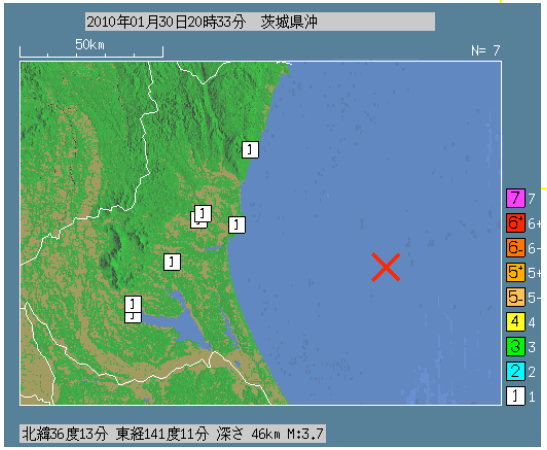


The ~4 Hz motion is in phase.
⇒ BELLE is vibrating, not QCS.

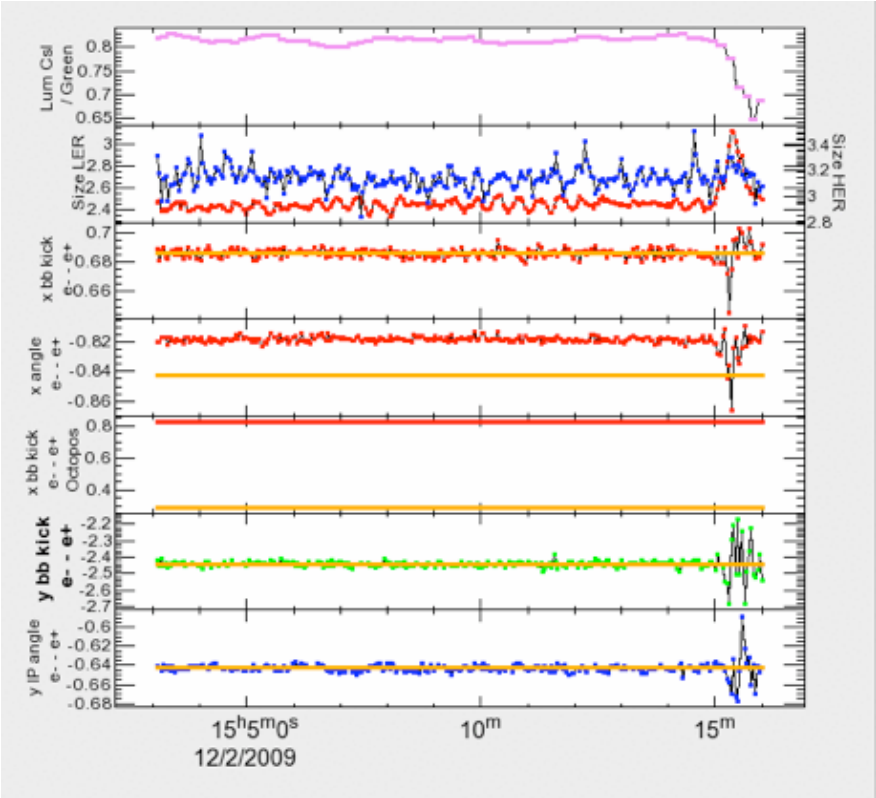


Sometimes 8Hz becomes more dominant than 4Hz.
The ~8 Hz motion is NOT in phase.
⇒ QCS L/R are vibrating independently.

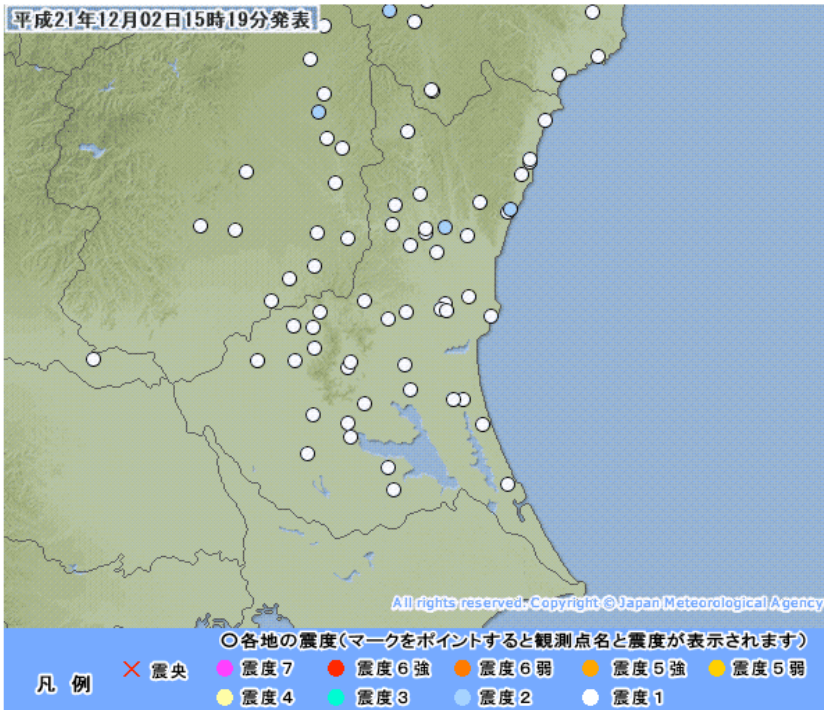




“1” in Japanese seismic Intensity scale.
Did not feel anything.



A good collision condition maintained by “iBump” system was lost, resulted in a beam loss (not beam abort).



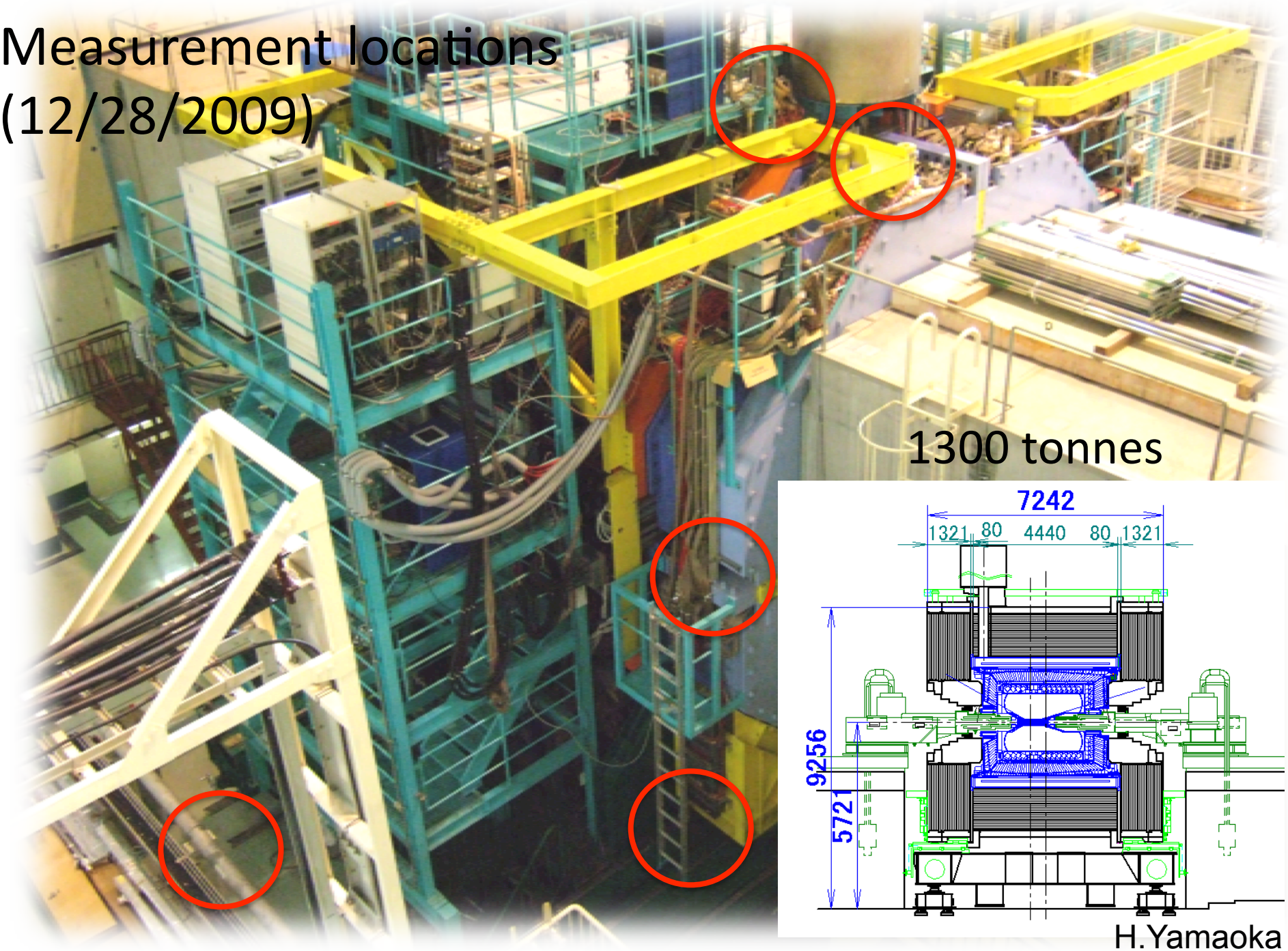
SuperKEKB
will be much more sensitive.

“1” in Japanese seismic Intensity scale.
Tiny earth quake.

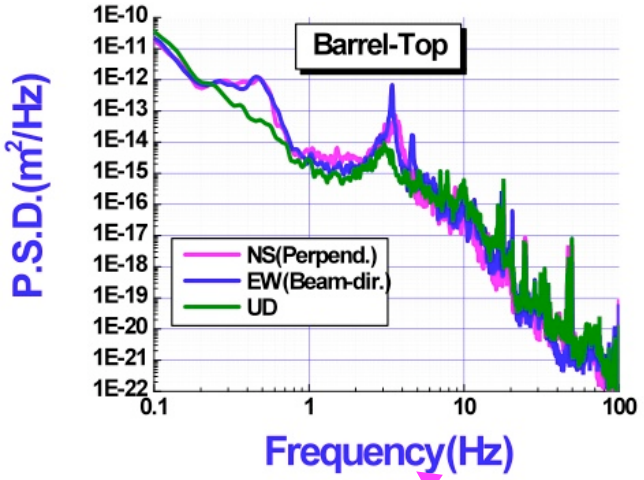
Measurements on BELLE

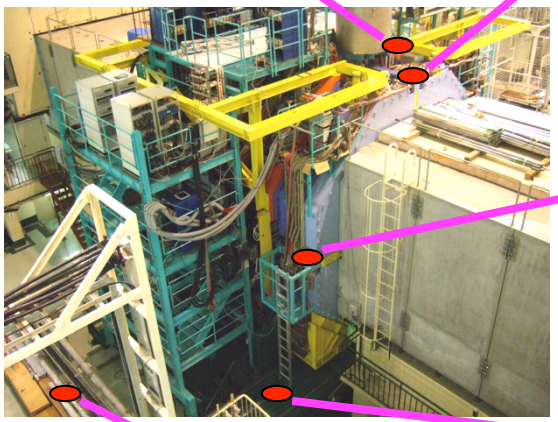
Data taken on Dec. 26 , 2009

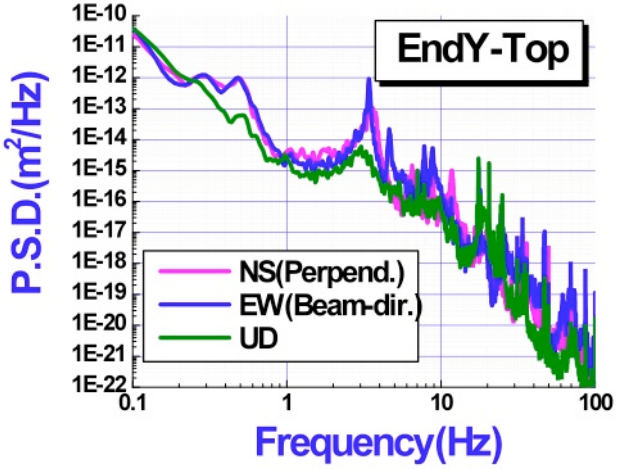
Measurement locations (12/28/2009)

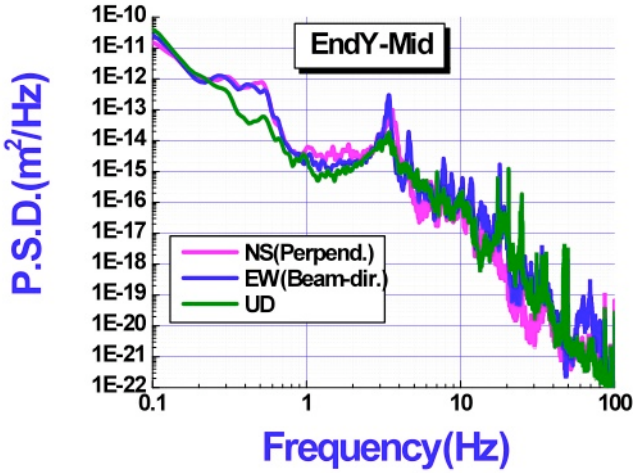


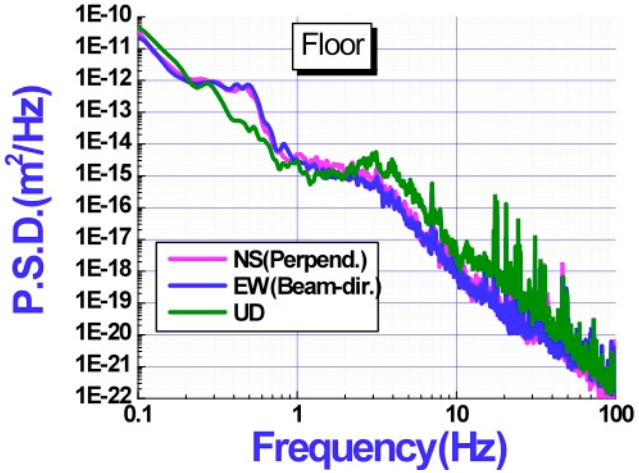
BELLE PSD

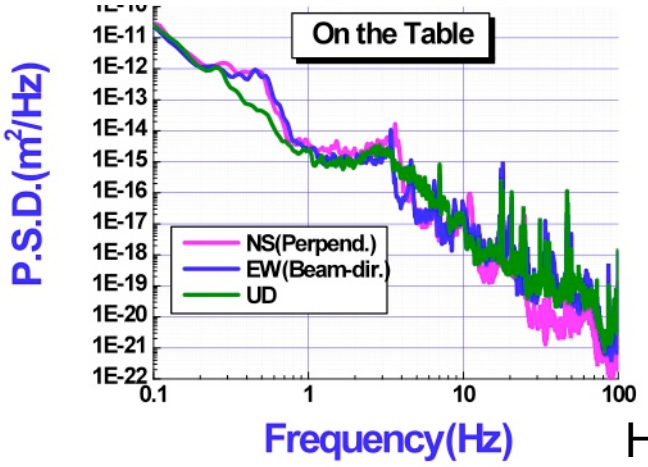








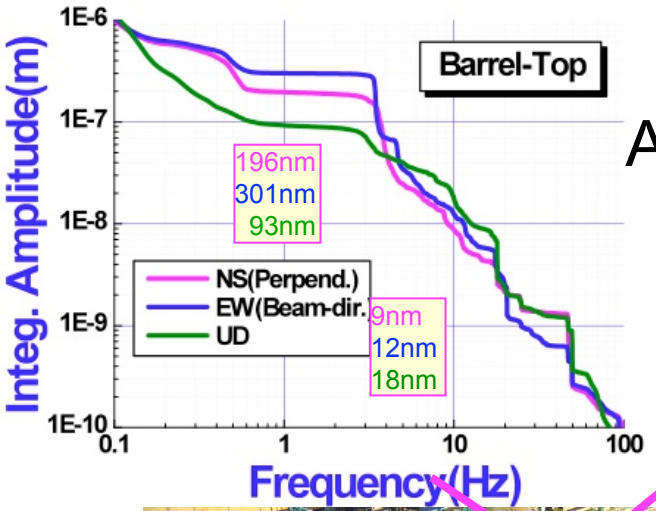


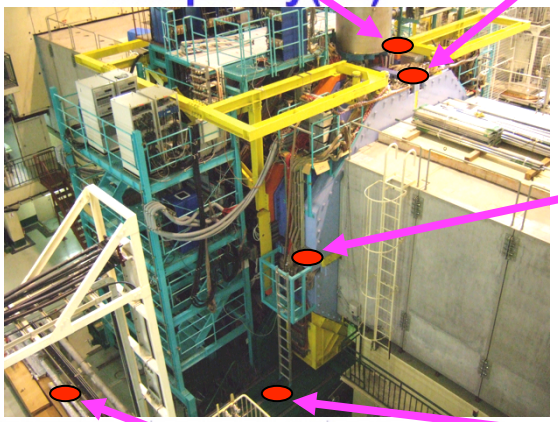


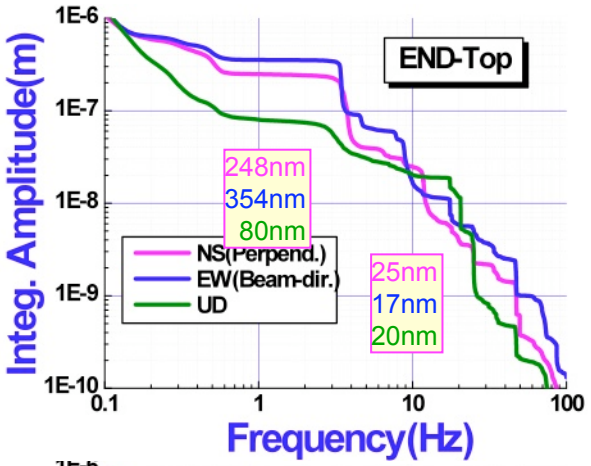
4 Hz peak grows toward the top

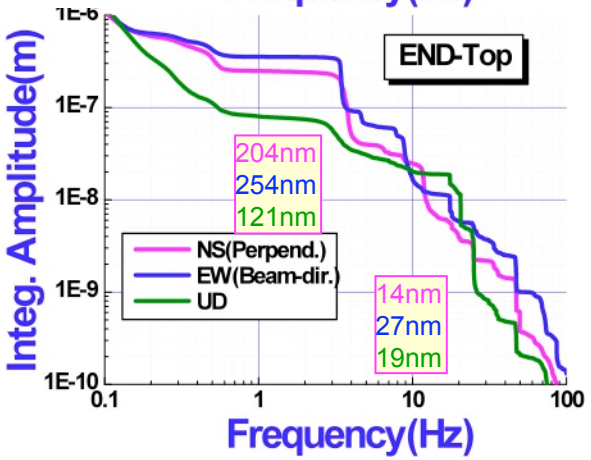
H.Yamaoka

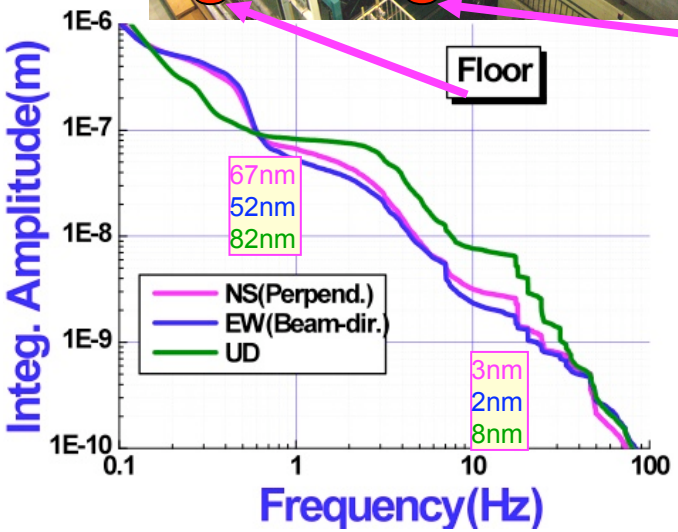
BELLE Amplitude

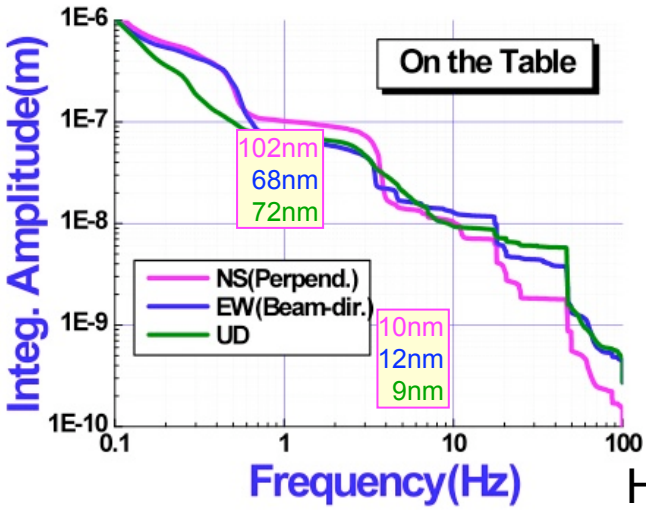










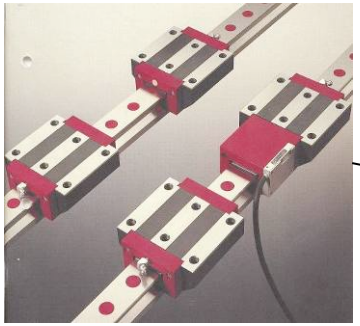


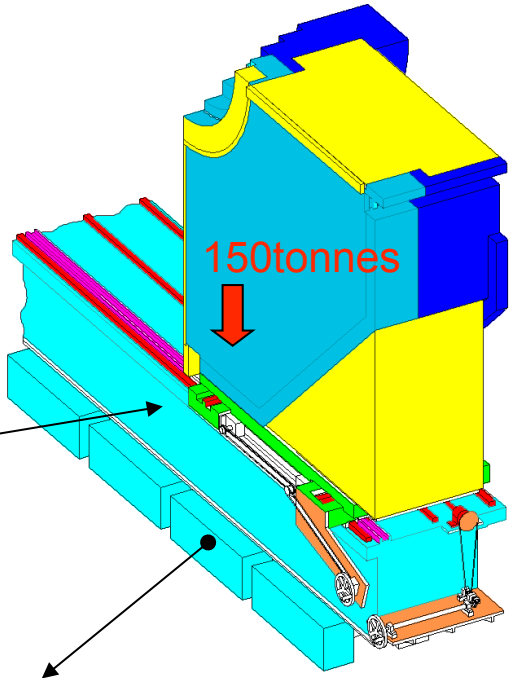
4 Hz peak grows toward the top

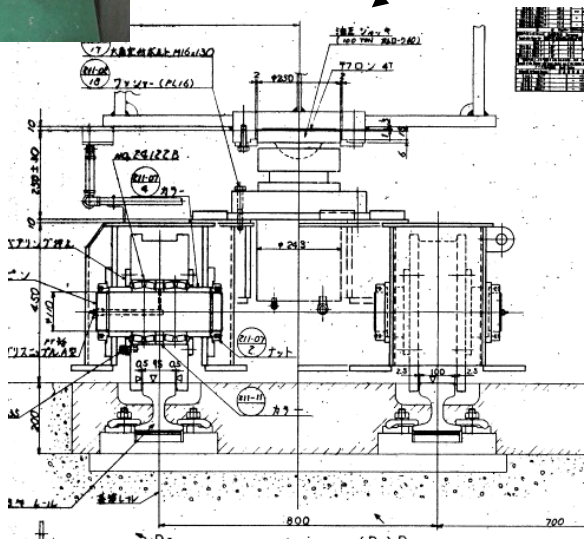
H.Yamaoka

Measurement results

- First resonance is around ~3-4Hz.
- Amplitude on the barrel is bigger than on the table.
- Amplitude on the End-Yoke increases toward the top.





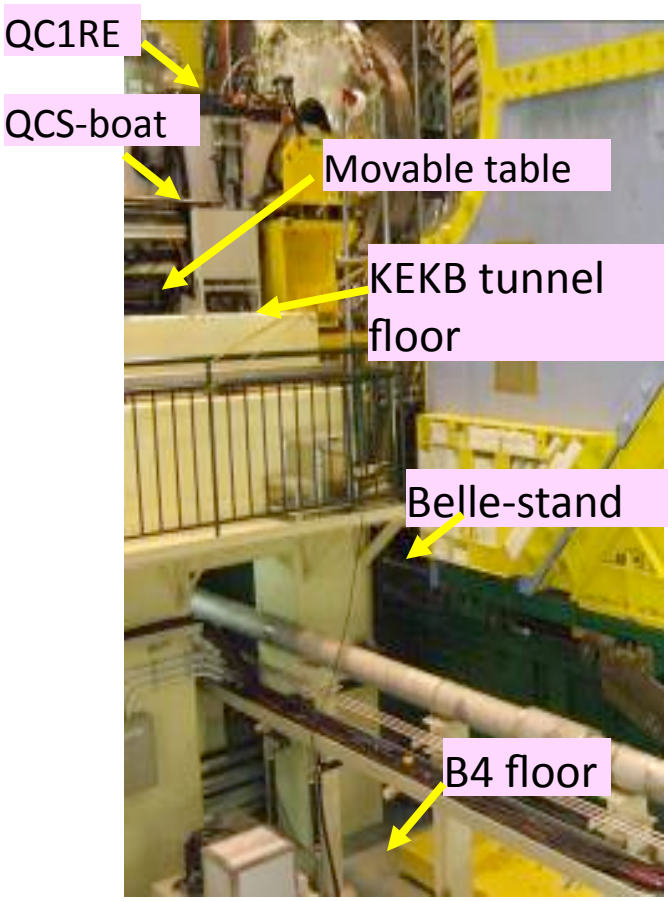


- The Belle detector is not fixed to the floor.
- The barrel yoke is just placed on the table.
- Top of the end-yoke is not fixed.

Improvements/modification are being discussed.

H.Yamaoka

Summary



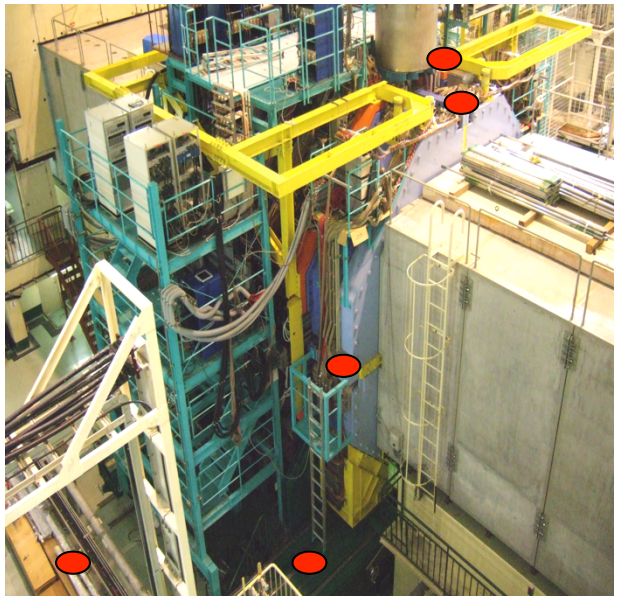
KEKB tunnel at the IP vibrates at

~ 0.3 Hz in the horizontal direction (micro-seismic)

~3 Hz in the vertical direction & horizontal direction (resonance of the “Kanto loam” soil around KEK)

In addition, magnets, QCS boat and the table vibrate at ~ 8Hz.

Summary



BELLE detector vibration

First resonance is measured around ~3-4Hz, mainly in horizontal directions.

-Amplitude on the barrel is bigger than at the table.

- Amplitude on the End-Yoke increases going towards the top.

Summary (2009 data)

Integrated amplitude(nm)						
	>1Hz			>10Hz		
	Perpend	Beam	Vertical	Perpend	Beam	Vertical
Barrel-Top	196	301	93	9	12	18
EY-Top	248	354	80	25	17	20
EY-Mid.	204	254	121	14	27	19
Belle stand	105	69	71	13	11	13
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

Summary table by H.Yamaoka

The vibration amplitude of the IR magnets are much smaller than the size of the colliding beams (~2μm vertically & ~100μm horizontally) for KEKB but comparable for SuperKEKB.

Summary

- Progress in understanding the characteristic of the IR vibration are being made.

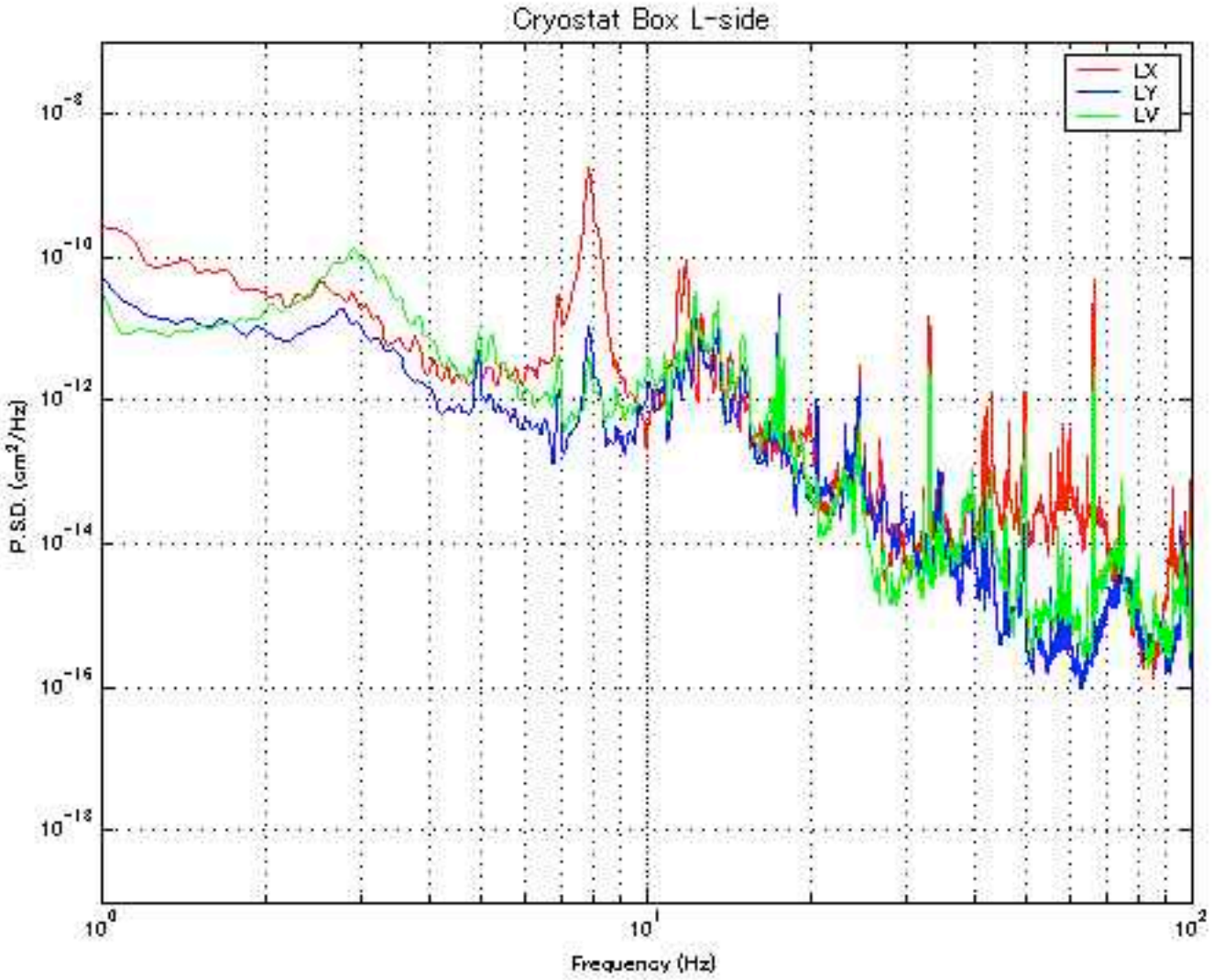
- We understand where the 8 Hz (IR) and 4Hz (BELLE) come from.

- How to reduce the vibration IR components & BELLE?
  ⇒ being discussed/investigated.

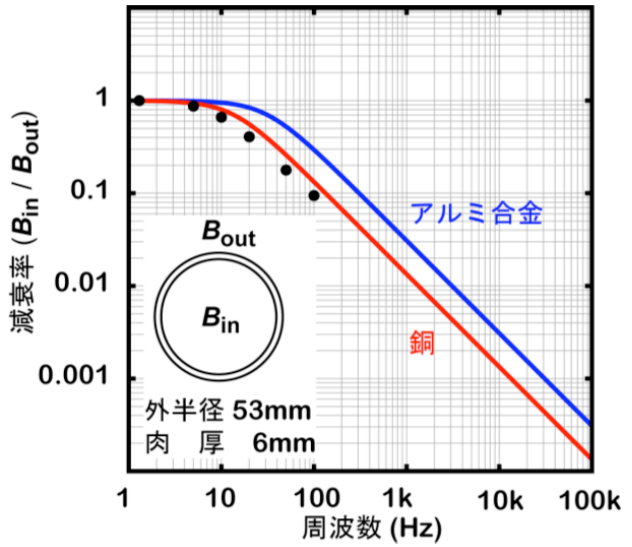
- Faster orbital (collision) feedback system will help (is a must).
  ⇒But what do we monitor?
  ⇒A faster corrector magnet ("iBump") system needs to be developed. Some study with the beam is planned.

- The effect of the helium flow will be studied in May when we turn on the cryogenic system for QCS.
  ⇒ as the data shown were taking while no helium flow.

spare


Cryostat Box L-side
LX
LY
LV
P.S.D. (gm²/Hz)
10⁻⁸
10⁻¹⁰
10⁻¹²
10⁻¹⁴
10⁻¹⁶
10⁻¹⁸
10⁰
10¹
10²
Frequency (Hz)

チェンバーによる磁場リップルの減衰



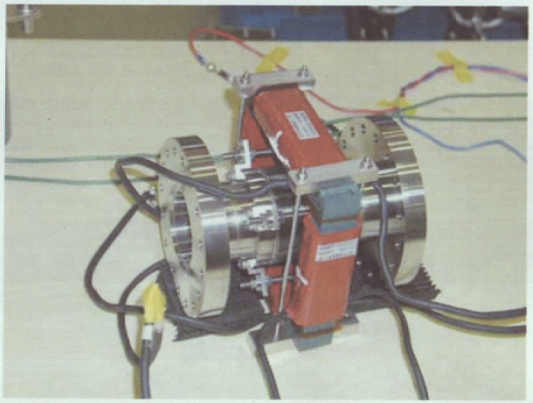
$$\frac{B_{in}}{B_{out}} = \frac{1}{\sqrt{1+\left(\frac{\mu_0}{2}\frac{bt}{\rho}\omega\right)^2}}$$

b : 外半径
t : 肉厚
ρ : 抵抗率
ω : 角周波数

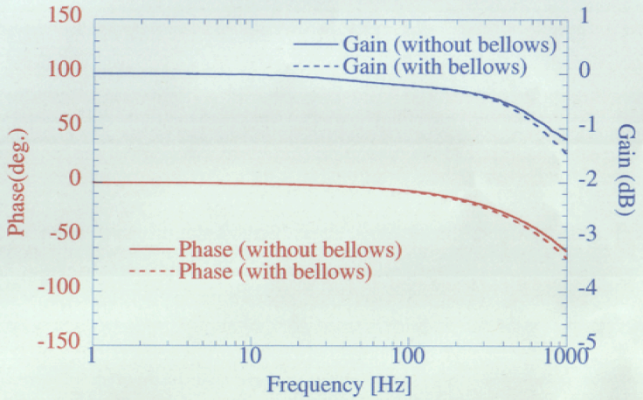
高速軌道フィードバック用補正二極電磁石シ

高速軌道フィードバック:
100Hz の軌道変動を抑えるため、補正電磁石には1kHz程度の高速応答
・コアは珪素鋼板の積層（接着コア）
・ベローズダクト部に設置

Super SOR (1.0~1.6 GeV)用補正磁石のR&D



ステアリングモデルとベローズダクト。
ベローズダクトはステンレス製、内部にCu-Beに
Agメッキした rf コンタクトを持つ。



水平方向補正磁場のホール素子による測定。
I=1 Ap-pの励磁（小型スイッチング電源）で、
ビーム中心位置で6Gの磁場。