# Magnet alignment

Mika Masuzawa

Dec. 13, 2007

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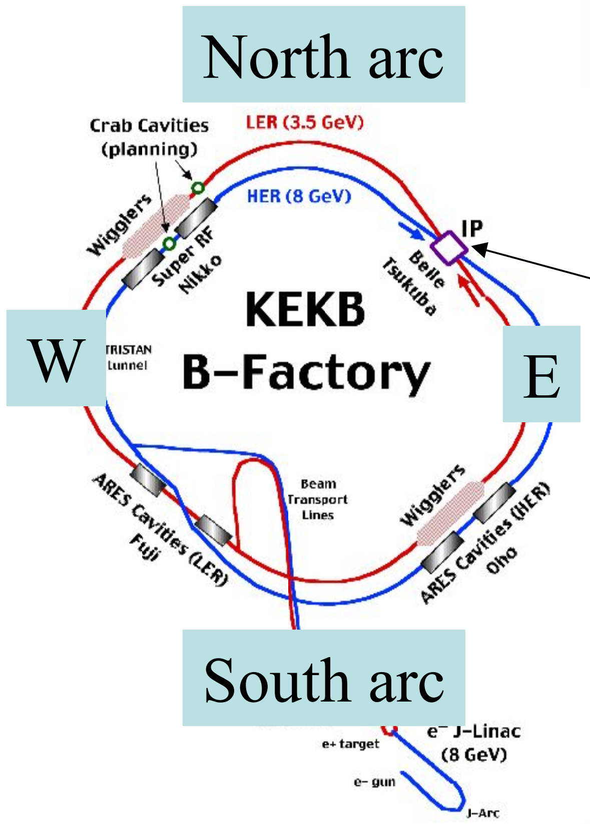
# Alignment data & tolerances




R: perpendicular to the beam
ϕ: along the beam

Table 2: Summary of the standard deviations of the alignment errors. The units are milli-meters.

| Area | LER dR | LER dPhi | HER dR | HER dPhi |
|---|---|---|---|---|
| Tsukuba | 0.08 | 0.09 | (<-- LER + HER) | |
| North Arc | 0.09 | 0.12 | 0.10 | 0.10 |
| West Arc | 0.11 | 0.14 | 0.12 | 0.14 |
| South Arc | 0.09 | 0.10 | 0.11 | 0.10 |
| East Arc | 0.10 | 0.17 | 0.11 | 0.16 |
| All Arc Sections | 0.10 | 0.14 | 0.11 | 0.13 |
| Nikko | 0.01 | 0.27 | 0.03 | 0.11 |
| Fuji | 0.01 | 0.27 | 0.03 | 0.19 |
| Oho | 0.04 | 0.08 | 0.03 | 0.14 |
| All Straight Sect. | 0.02 | 0.22 | 0.03 | 0.15 |
| Tolerance | 0.15 | 0.50 | 0.15 | 0.50 |

At the completion of construction

**KEK Preprint 99-131**
**November 1999**
**A**

# Tunnel level survey along the beamline

- South has been sinking with respect to the IP
  - A few mm per year.
  - As was reported in "Magnet issues, circumference drift" KEKB Review, 2003

    http://www-kekb.kek.jp/MAC/2003/

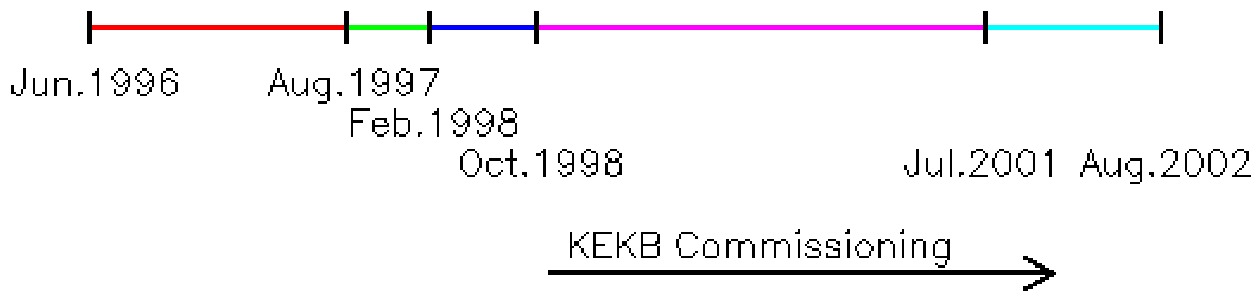
# Beam level markers

- Beam level markers were installed on the tunnel wall every ~30 m in Nov. and Dec., 1995.
  - The centers of the TRISTAN quadrupole magnets were used as reference.

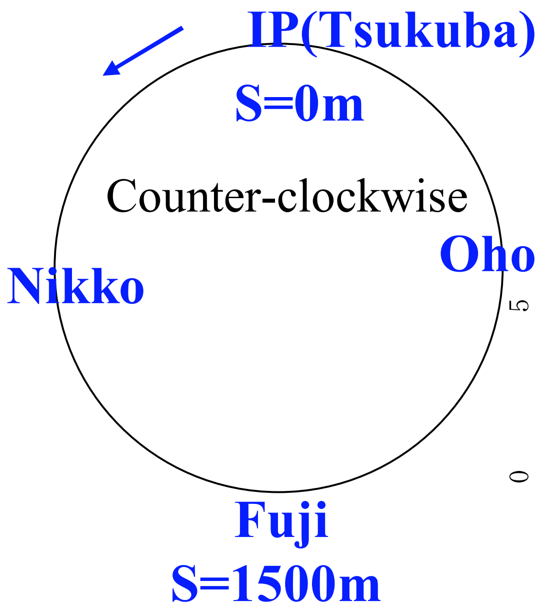
# Tunnel Level Changes
# (R. Sugahara,Y. Ohsawa)

The beam level markers on the tunnel wall have been surveyed times since 1996 (+1 in 2004)

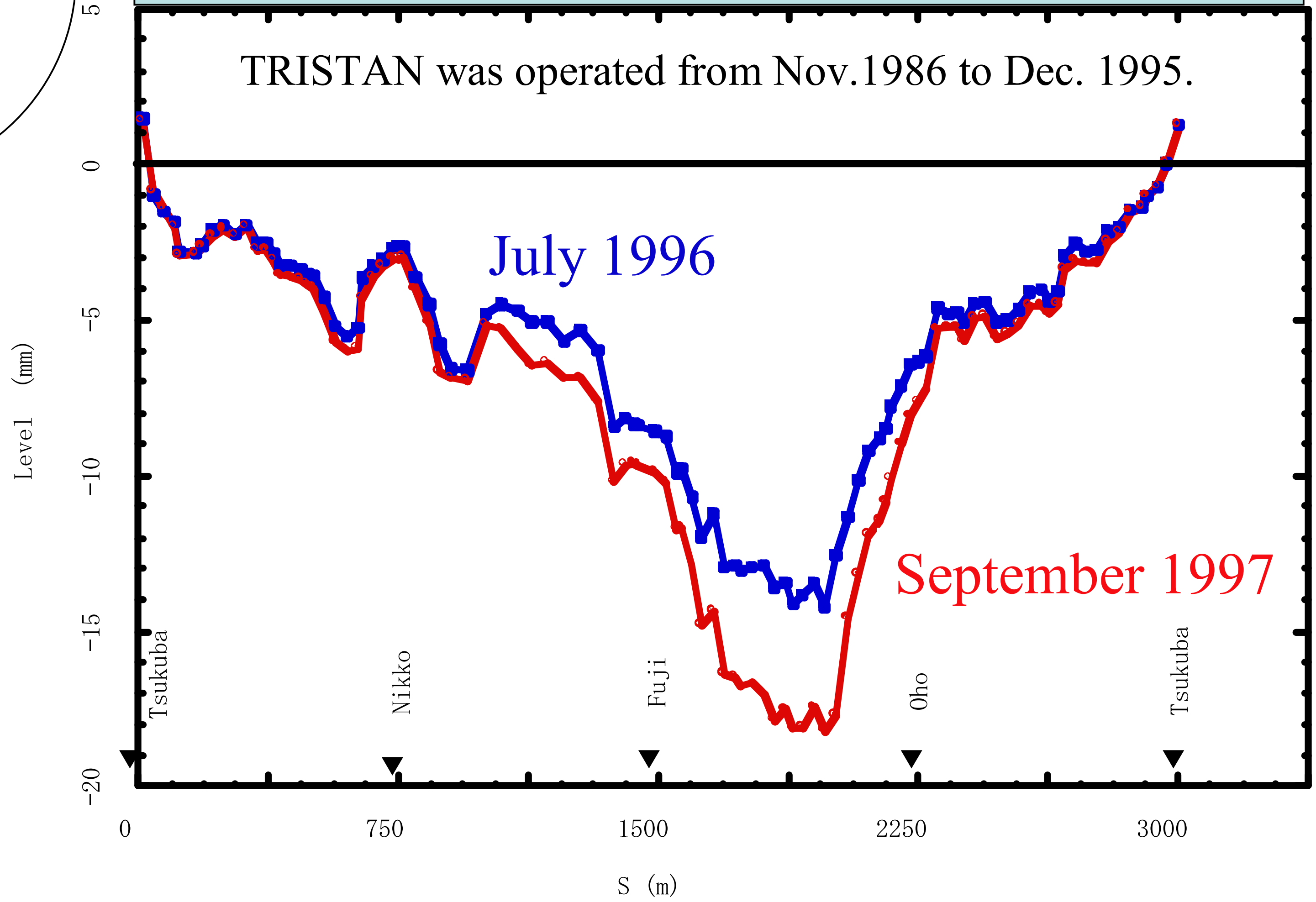
- **1st survey: June&July, 1996**
- **2nd survey: August & September, 1997**
  - **The height of the markers on the tunnel wall were re-adjusted.**
- **3rd survey:Feb. 1998**
- **4th survey: Oct.1998**
- **5th survey: Jul.2001**
- **6th survey: Aug.2002**



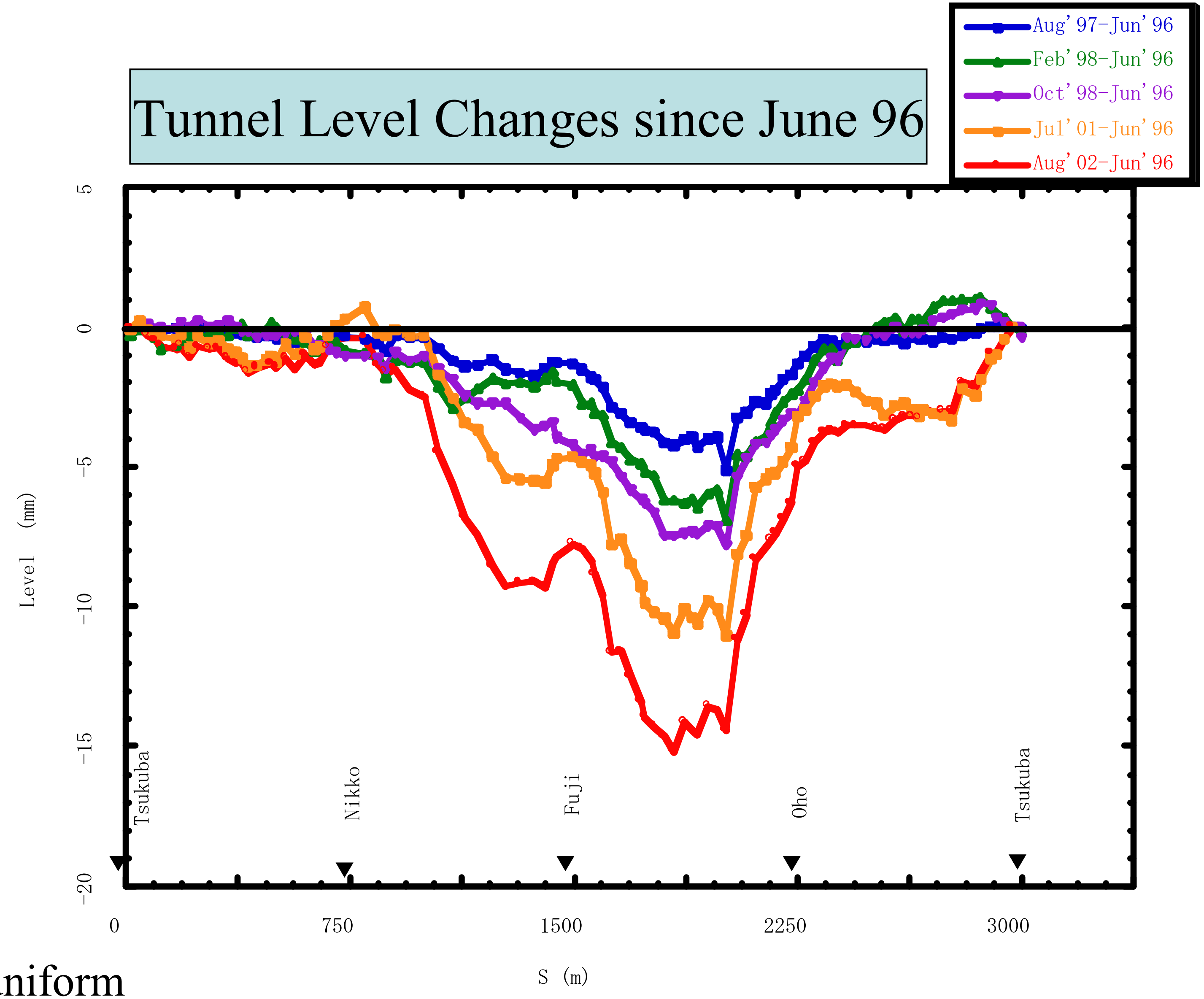
# Tunnel Level Changes




Tunnel level changes (blue line) during the 9 years of TRISTAN operation.



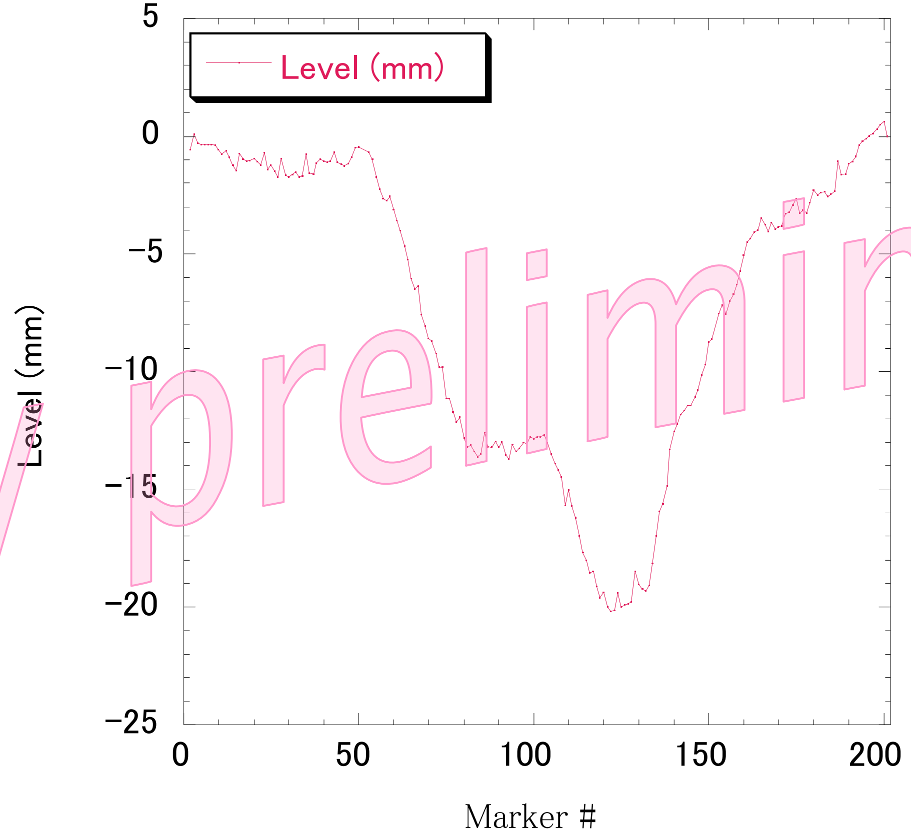
# Tunnel Level Changes




(1)Not uniform

(2)Largest shift between Fuji and Oho (south tunnel), 2.5mm/year

# Most recent beam level marker survey (July&August, 2007)




→Sank more.

# Tunnel level survey summary

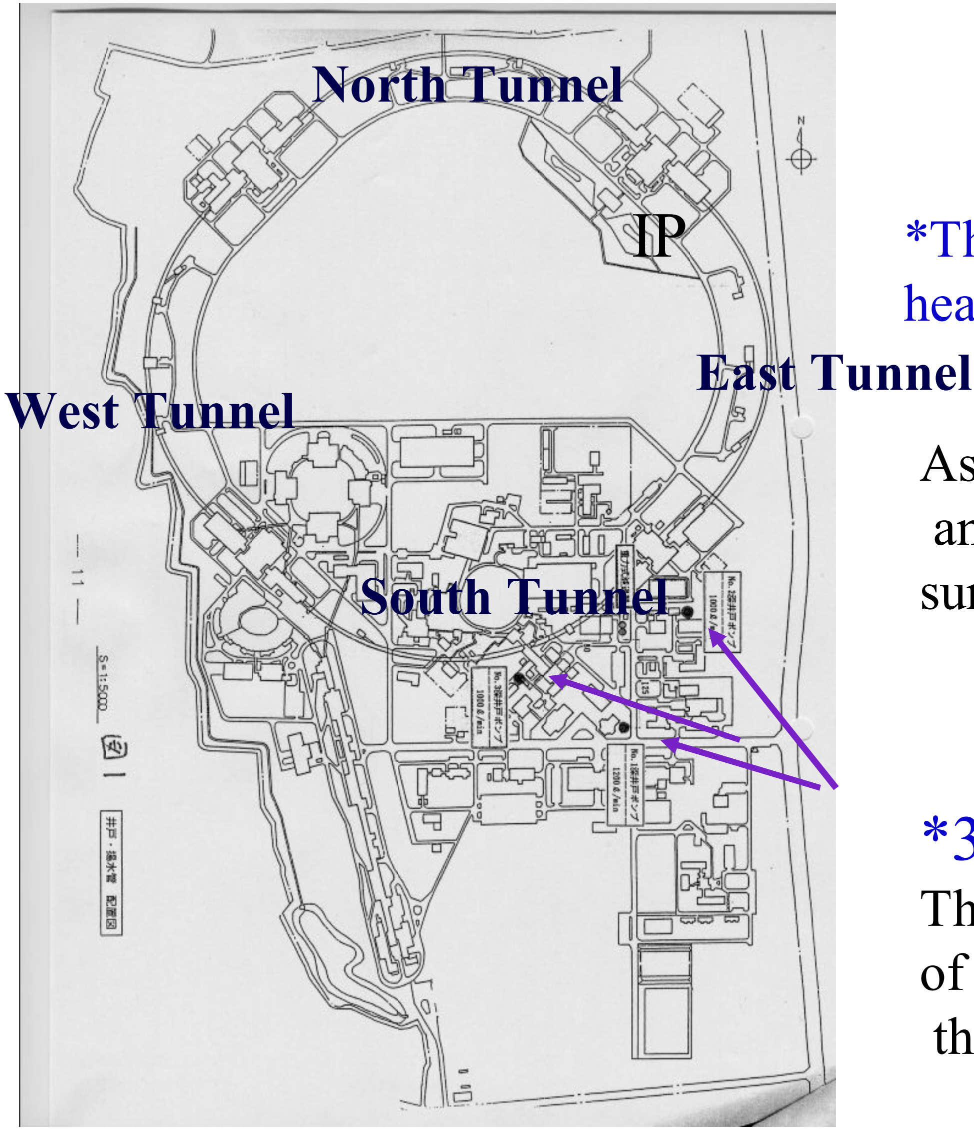
- The tunnel has become deformed since the initial magnet alignment was completed.
- The south tunnel has been sinking with respect to the IP.

Why is south tunnel sinking?

→Well

→Heavier

# Why is the south tunnel sinking?




*The south tunnel section is more heavily built up.

As it goes through cycles of expansion and contraction, it loses its grip on the surrounding sub-soil?

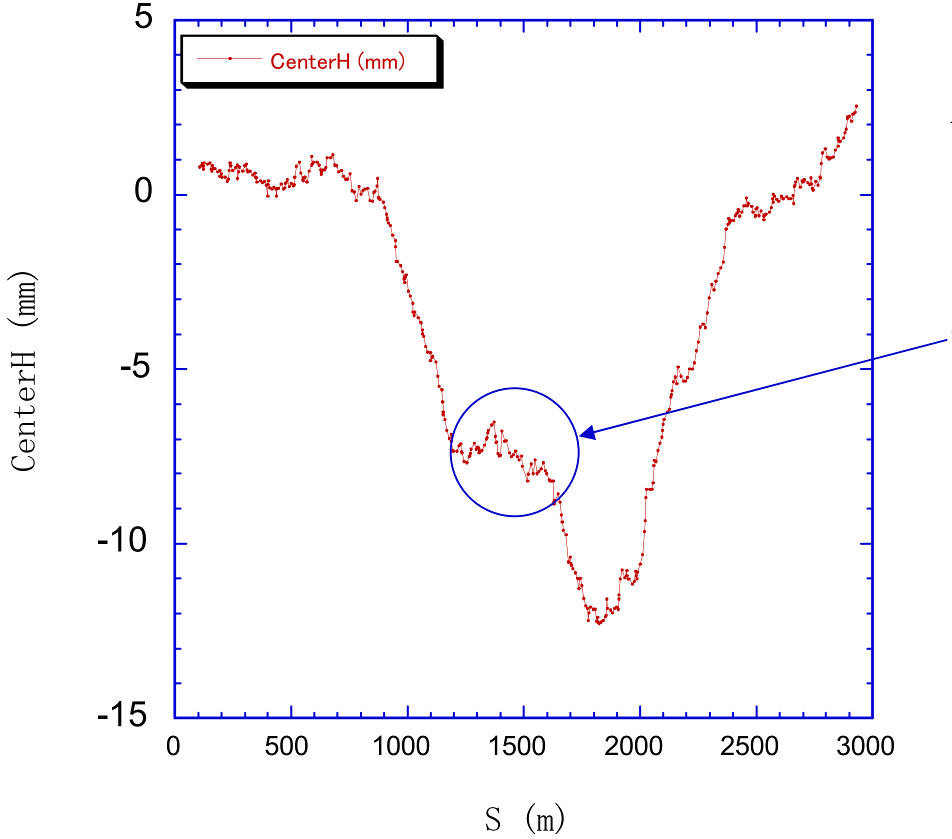
*3 wells

The ground retains a large amount of water, which is pumped up at the rate of several hundred tons/day.

# Magnet level

- The tunnel shape has been changing.
- The south arc section keeps sinking with respect to the IP.
- It is natural to expect the levels of the magnets have drifted since 1998.
  - We do not measure the magnet level as often as the markers since it is time/cost consuming, but there are data taken in 2004.

# Magnet level along the beamline



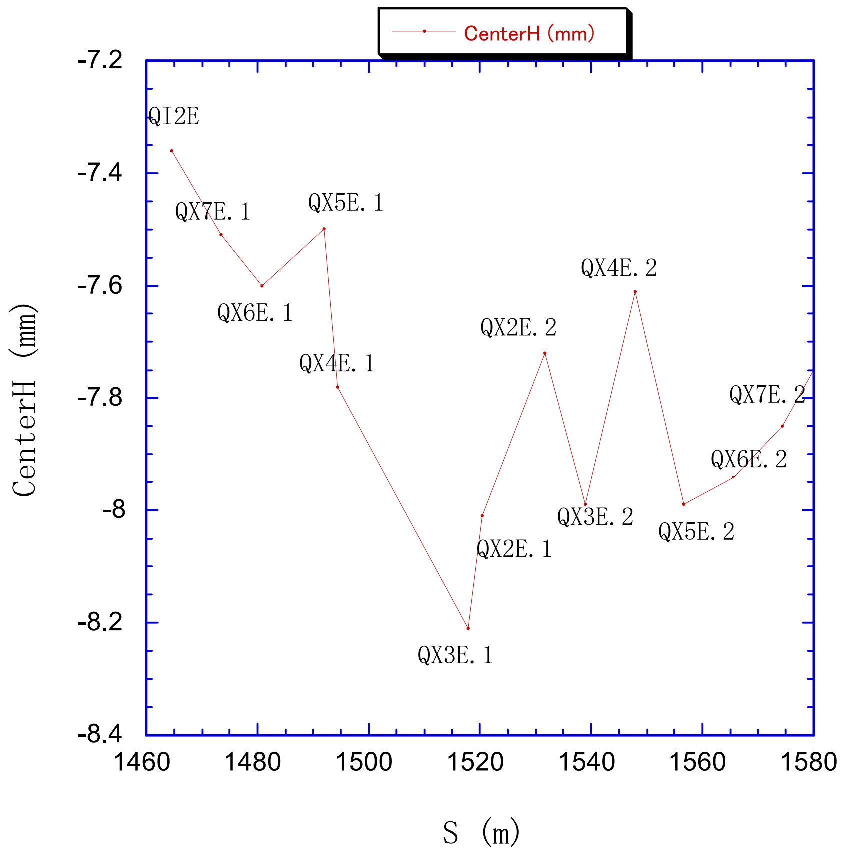

- Magnet level drift similar to the tunnel is seen as expected.

→smooth level change is probably OK.

- Some local ups and downs exist here and there.

→ This might be a problem.

# Magnet level at Fuji straight section




Not too smooth…

Better adjust the level for KEKB upgrade, at least.

# Lattice Errors

Y.Ohnishi's slide

Multipole components and fringe field have been included in the design lattice.

Following errors are produced with random numbers according to Gaussian.
The values are one standard deviation($\sigma$).

| | alignment error $\Delta x$ ($\mu$m) | alignment error $\Delta y$ ($\mu$m) | rotation error $\Delta\theta$ (mrad) | gradient error $\Delta k/k$ |
|---|---|---|---|---|
| Bending magnet | 100 | 100 | 0.1 | $1\times10^{-4}$ |
| Quadrupole magnet | 100 | 100 | 0.2 | $3\times10^{-4}$ |
| Sextupole magnet | 100 | 100 | 0.2 | $5\times10^{-4}$ |

→These were satisfied originally but things have moved around since.

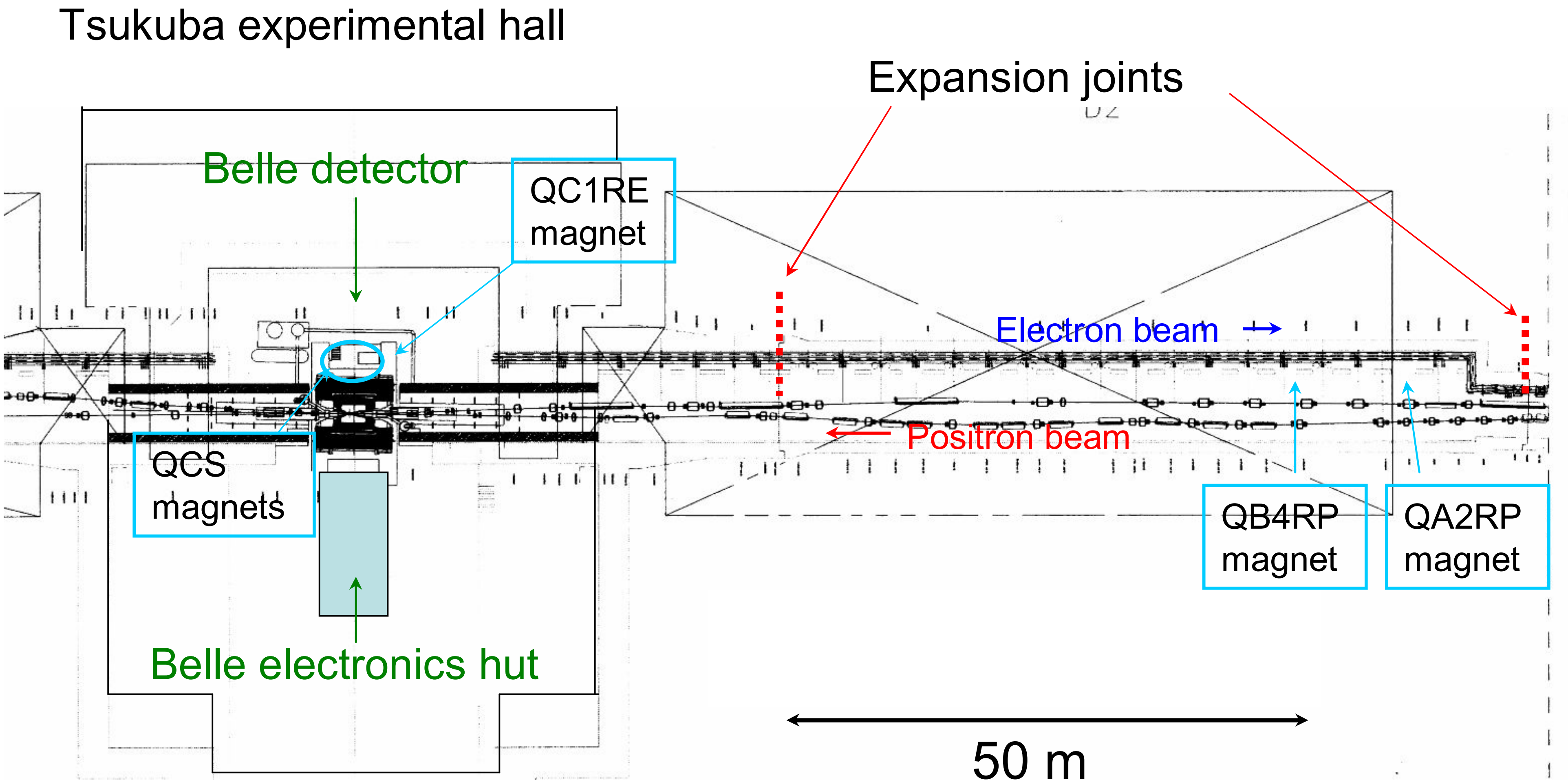
# Magnet level survey summary

- The center height (level) of the magnets has changed since the completion of construction. It follows the tunnel level in general.
- There are some local level changes seen, which might degrade the machine performance if not smoothed out, at least locally.

# Vibration measurements in the KEKB tunnel

- Depends on where in the tunnel →will be presented at some other occasion.
- Introduce *some data* presented at IWAA 2004 (International Workshop on Accelerator Alignment 2004 @ CERN)

# Vibration measurements

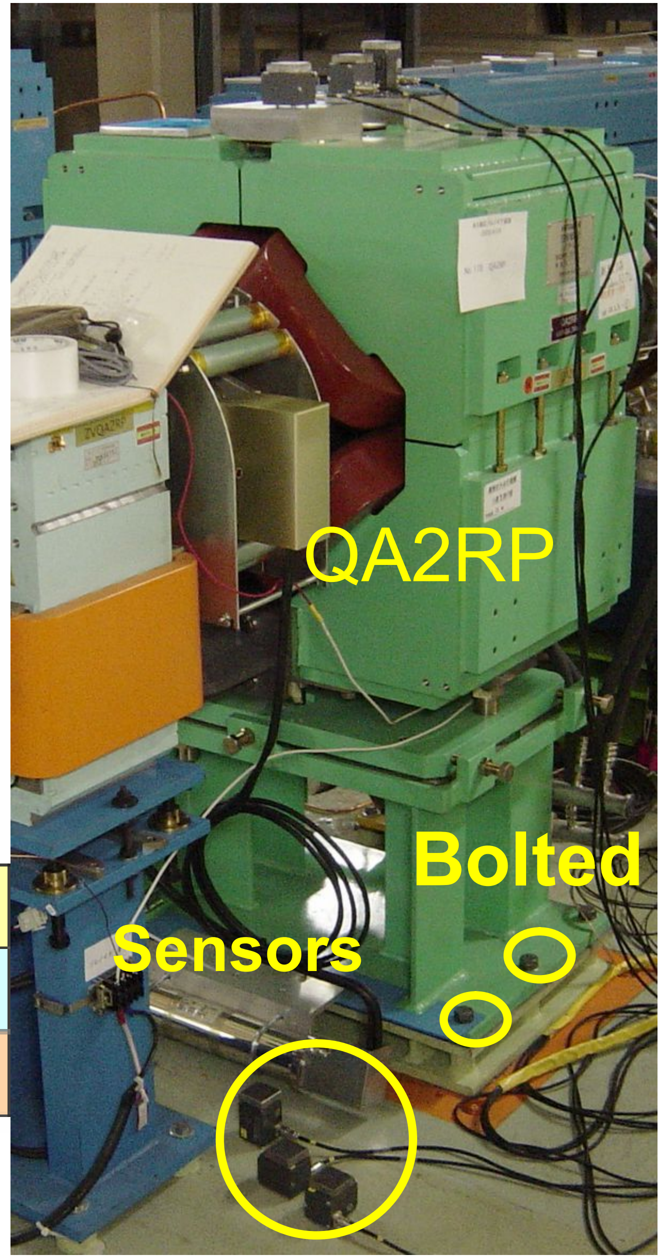


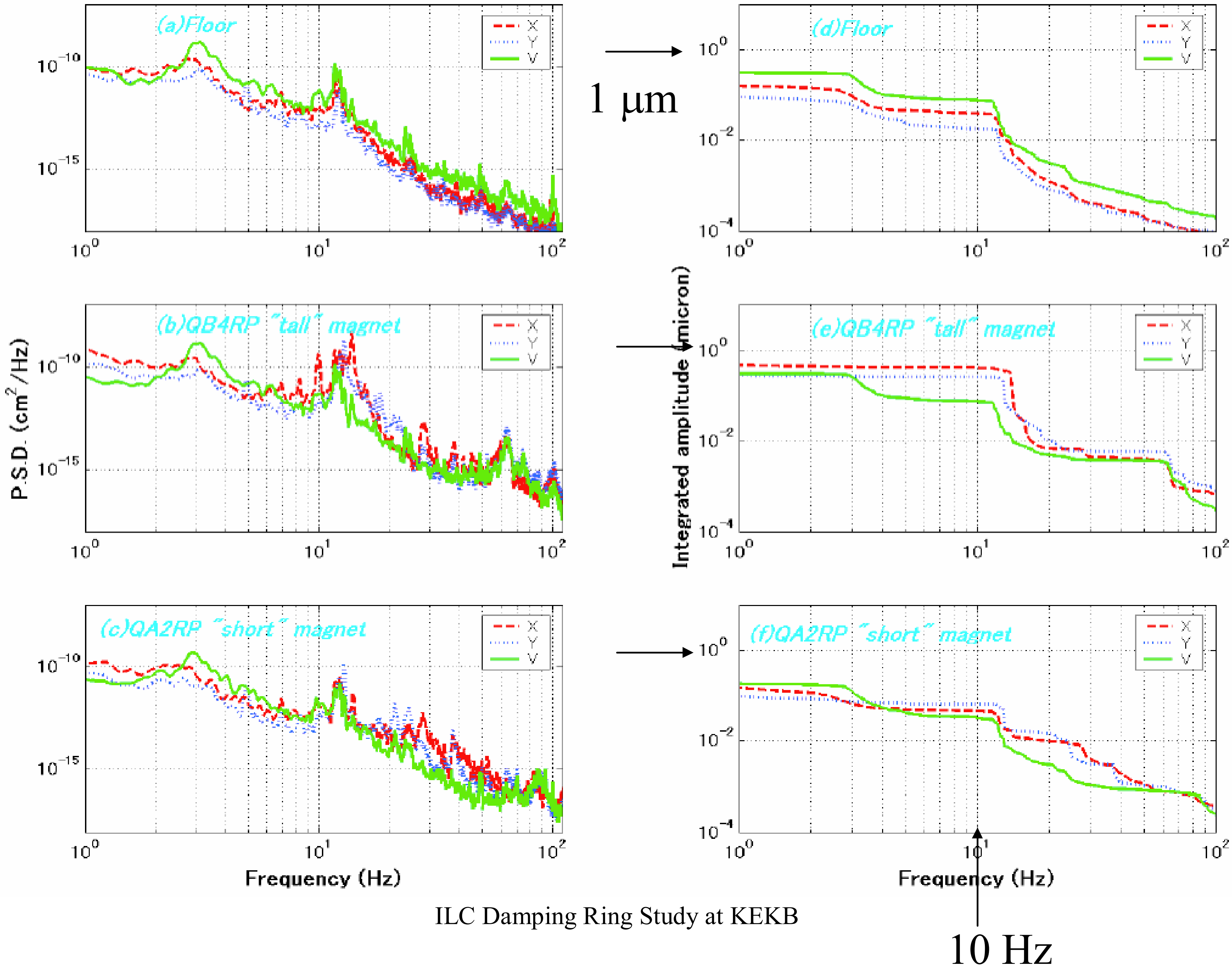
# Specifications of the acceleration sensors

| 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 |

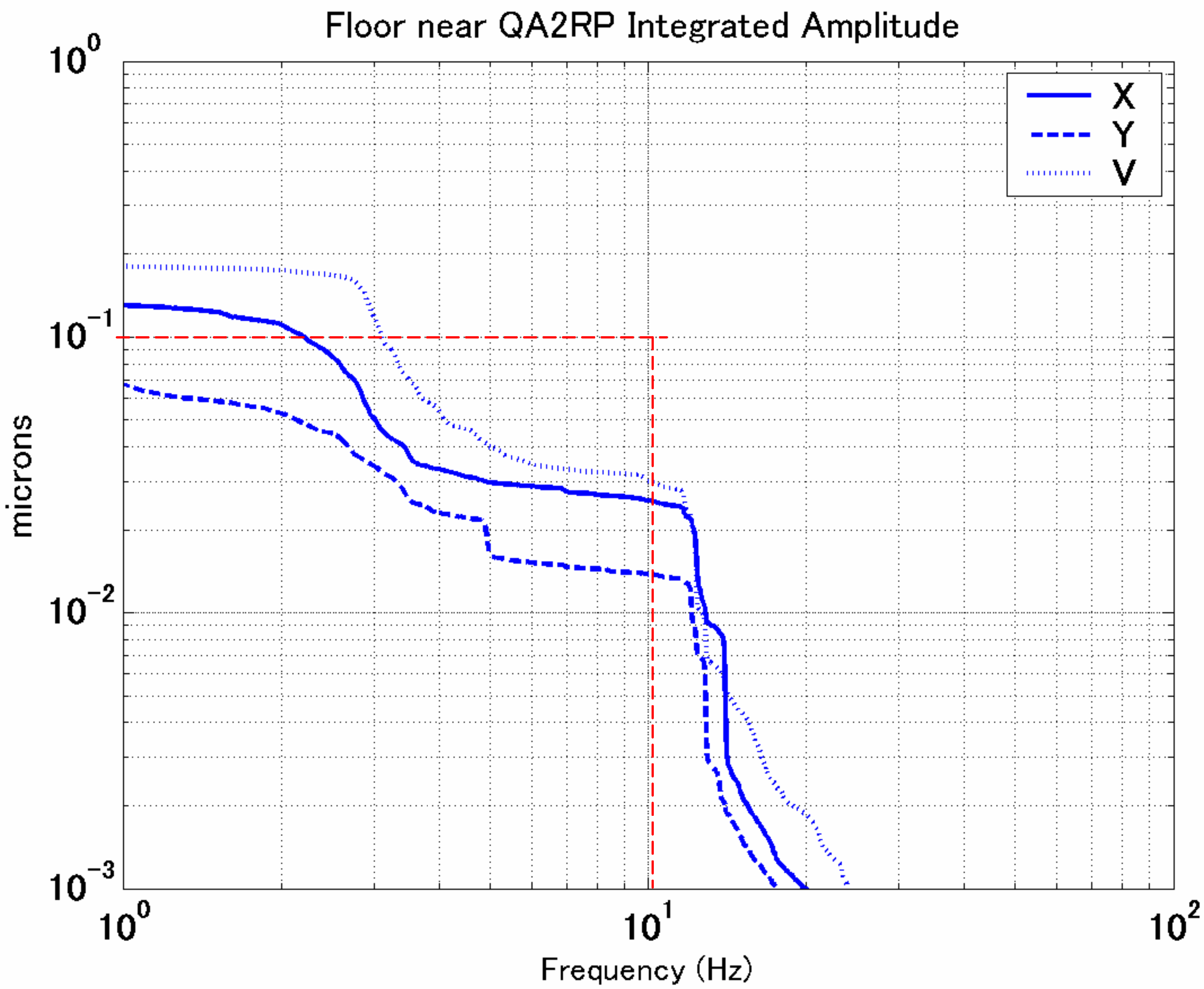
**Axis definition**

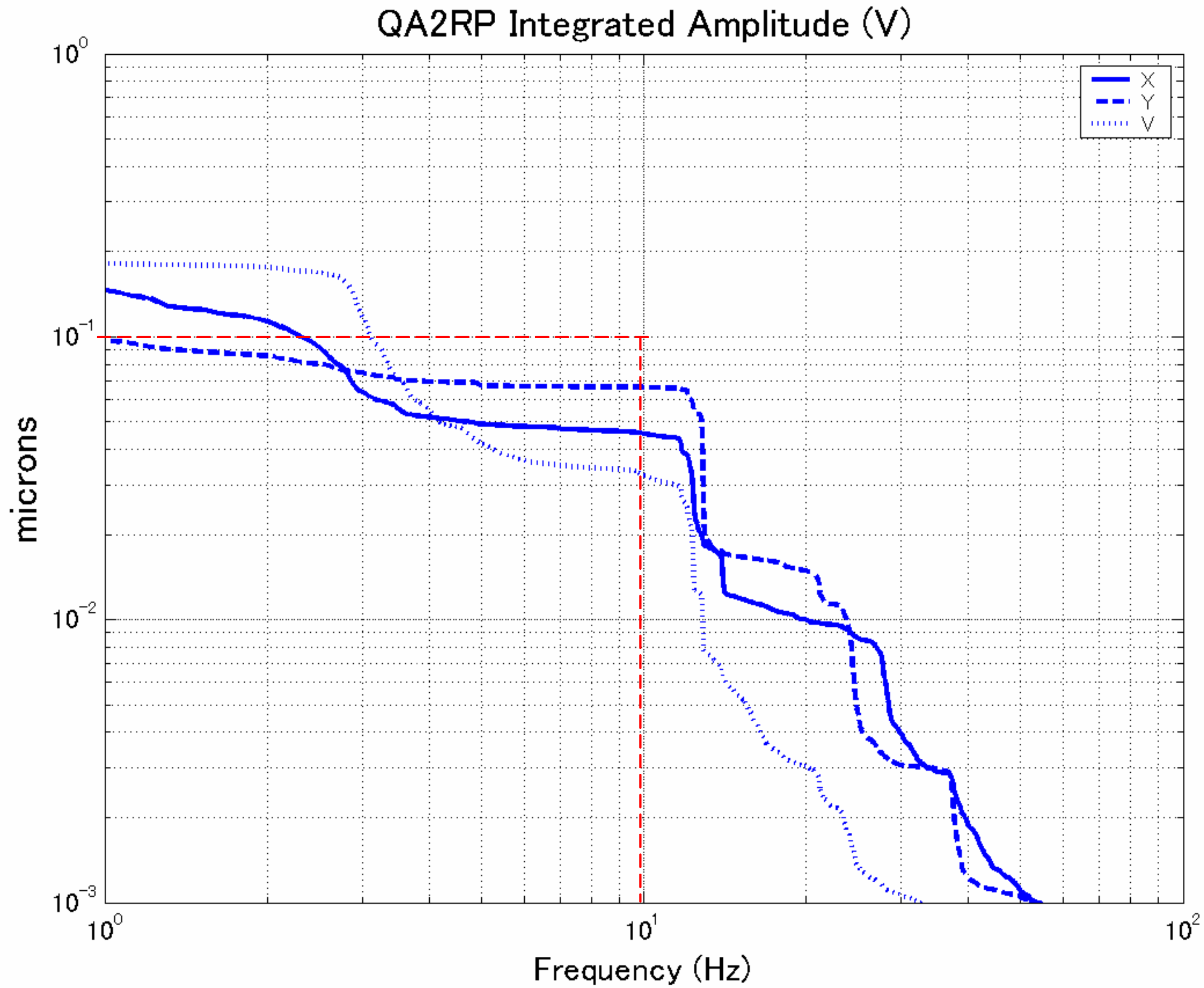
| | |
|---|---|
| x | Horizontal plane, perpendicular to beam direction |
| y | Horizontal plane, parallel to beam direction |
| v | Vertical |



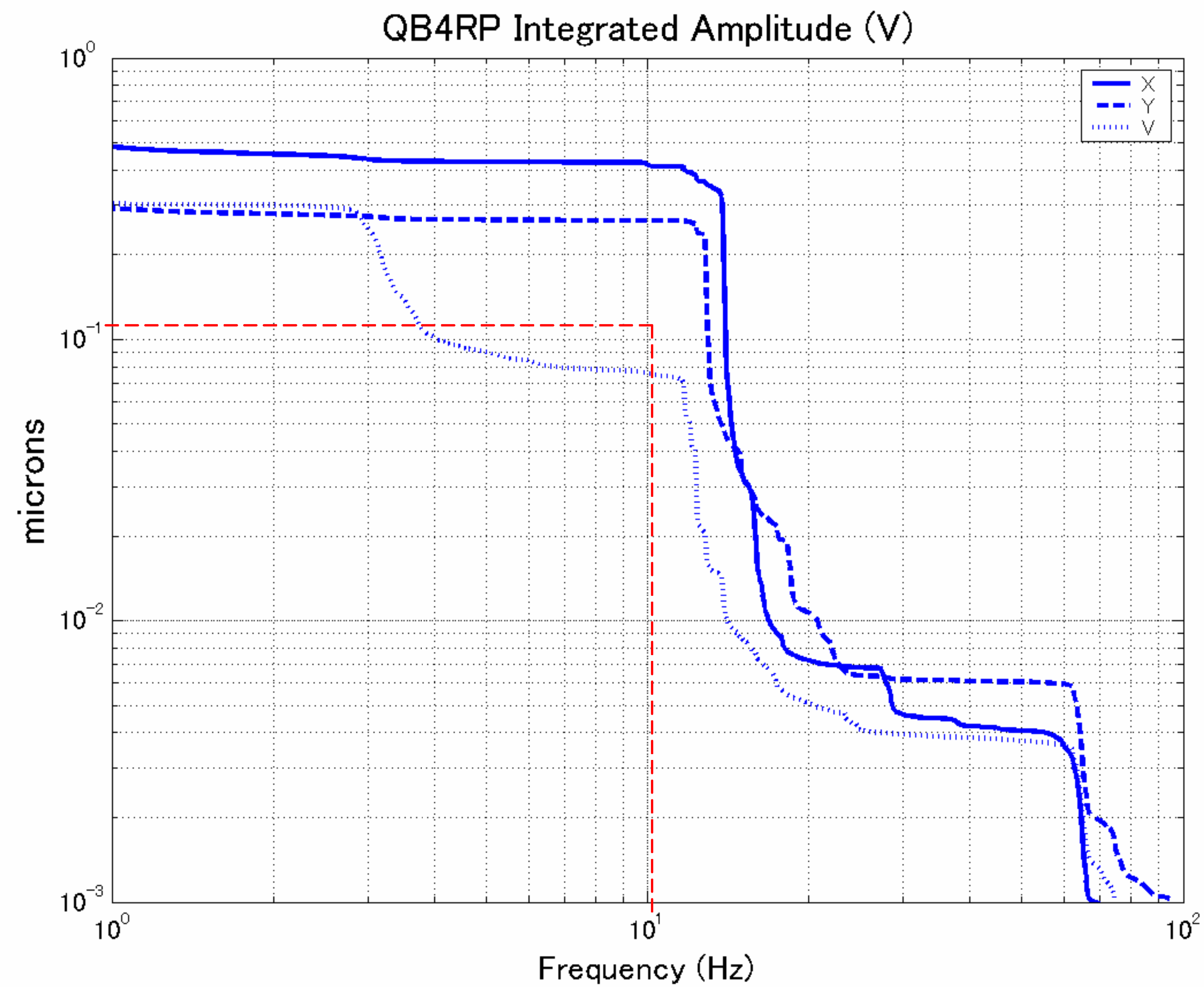



ILC Damping Ring Study at KEKB


Floor near QA2RP Integrated Amplitude
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
microns
X
Y
V
$10^0$
$10^1$
$10^2$
Frequency (Hz)



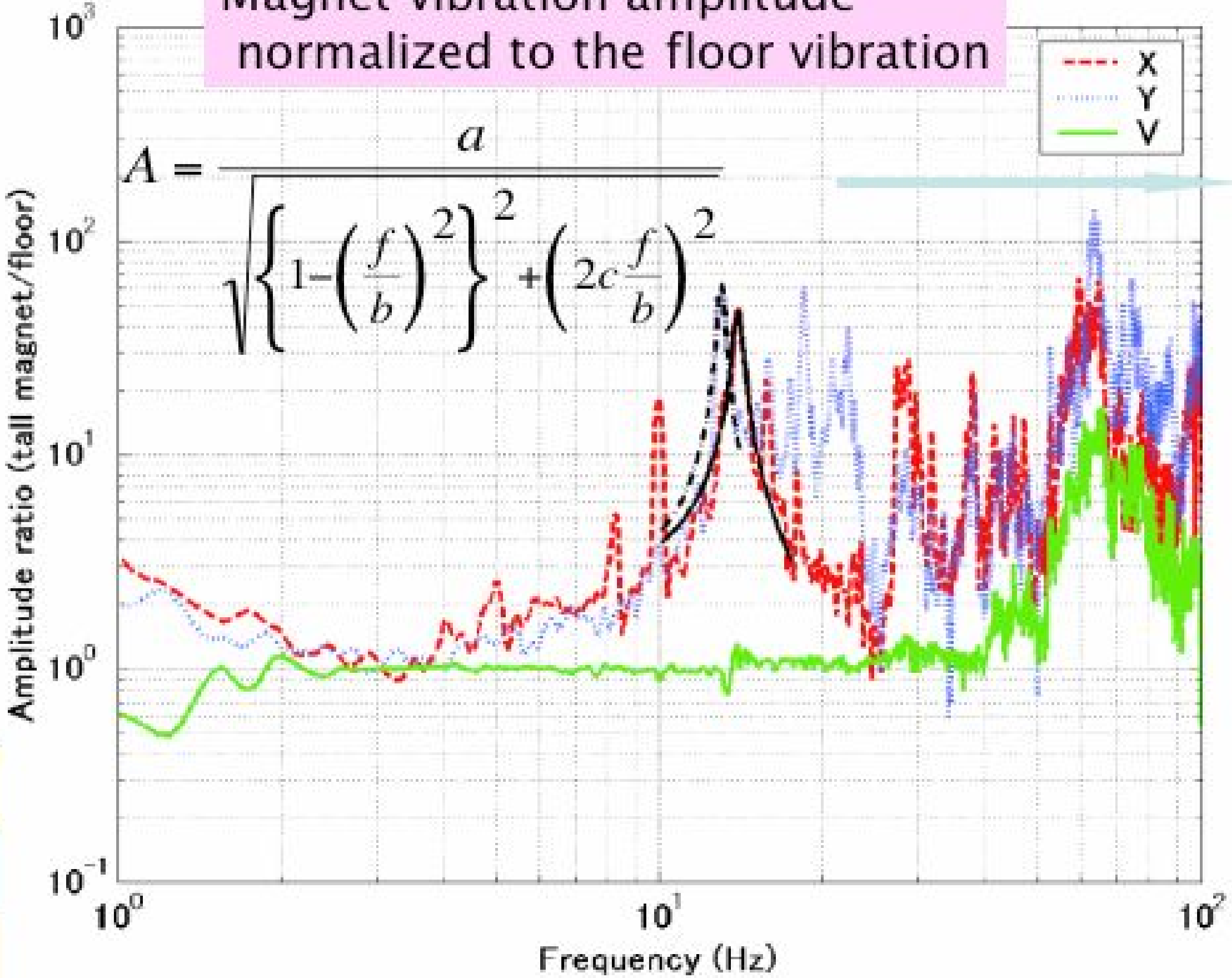
QA2RP Integrated Amplitude (V)
X
Y
V
microns
Frequency (Hz)
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^1$
$10^2$



QB4RP Integrated Amplitude (V)
X
Y
V
microns
Frequency (Hz)
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^0$
$10^1$
$10^2$

Magnet vibration amplitude normalized to the floor vibration

$$A = \frac{a}{\sqrt{\left\{1-\left(\frac{f}{b}\right)^2\right\}^2+\left(2c\frac{f}{b}\right)^2}}$$




Fitting Results

| Axis | *b*(Hz) | c (%) |
|---|---|---|
| X | 14 | 1.9 |
| Y | 13 | 1.4 |

Natural frequency

Damping factor

Typical number for damping factor

| | |
|---|---|
| Reinforced concrete | 5% |
| Bolt (rivet) | 2% |
| Welding | 1 % |

IWAA2004, CERN, Geneva, 4-7 October 2004

**VIBRATION MEASUREMENTS IN THE KEKB TUNNEL**

*Mika Masuzawa, Yasunobu Ohsawa, Ryuhei Sugahara and Hiroshi Yamaoka*

1. Motions of the QA2RP/QB4RP magnet (non-IR magnets) were measured along with the floor motion near by.
   - A clear vibration peak at ~13 Hz was observed.
   - When normalized to the floor motion the vertical peak disappeared.
   - Horizontal peaks were fitted to obtain damping factors and natural (resonant) freq. of the system.
   - The damping factor of the magnet system was found to be ~2%. This agrees with the typical damping factor of bolt (rivet) structures.
   - The integrated amplitude is ~0.4μm for freq.>1 Hz.

2. Motions of the IR magnets were measured. The floor motion near the IP was also measured.
   - The IR magnet PSD curves have more complicated structures than those of the non-IR magnets.
   - The vibration amplitude is largest in the x direction in all IR magnets, ~0.35μm for QCS.
   - The IR magnets (and the supporting table) has a peak ~ 8 Hz.
   - The vibration amplitude of the IR magnets are much smaller than the size of the colliding beams (~2μm vertically and ~100μm horizontally).

**Vertical vibration amplitude is less than 0.1 μm for for freq. >10Hz**

**Vibration depends on location, time of the day, day of the week and so on (I will skip the details here).**

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