Sources of Slow Orbit Movement and Feedback Systems in PLS Storage Ring

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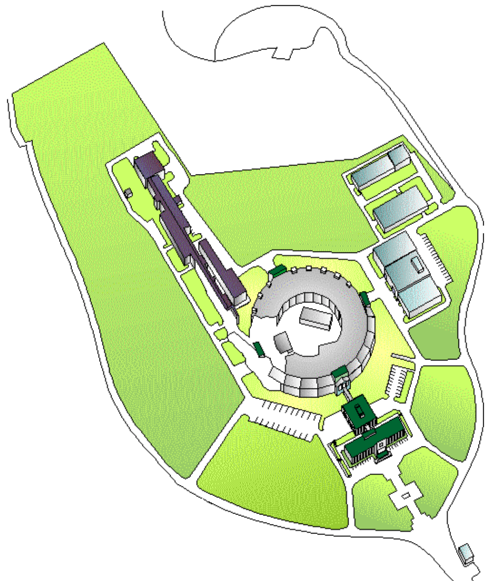
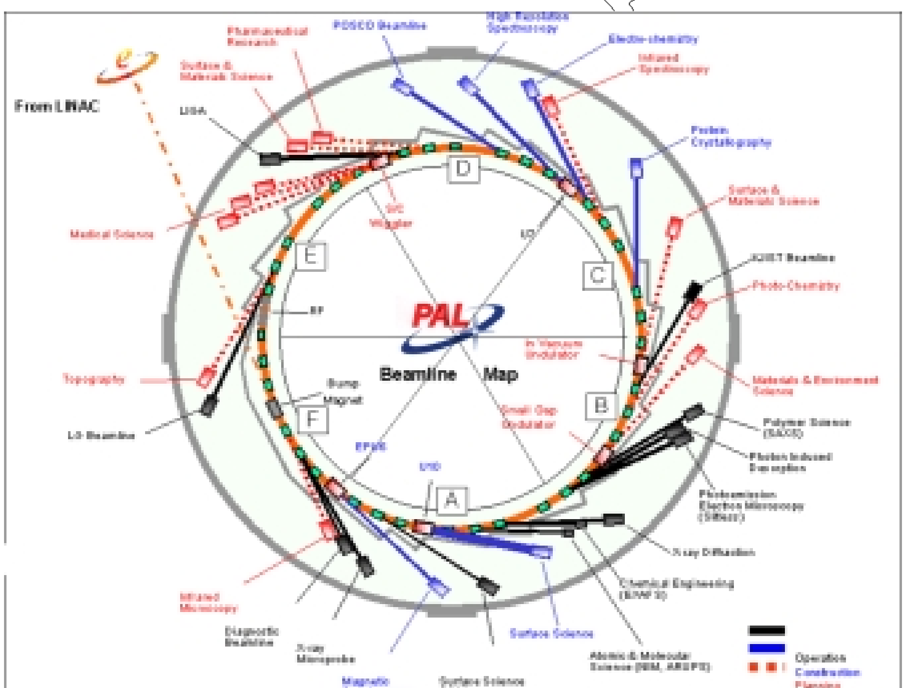
Pohang Light Sources





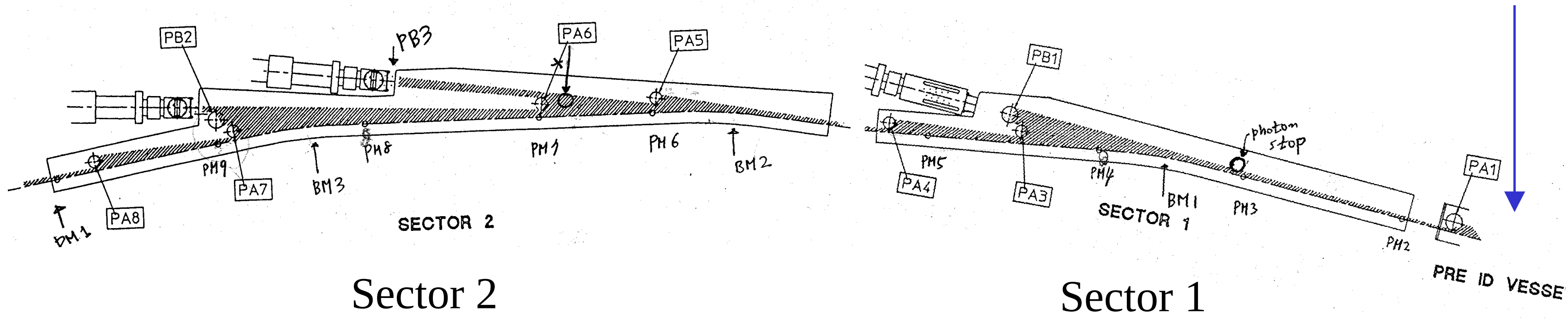
- Lattice TBA
- Superperiods 12
- Beam Energy 2.5GeV
- Beam Current 180mA
- Emittance 18.9 nm-rad
- Tune 14.28 / 8.18
- Energy spread 8.5 x 10^{-4}

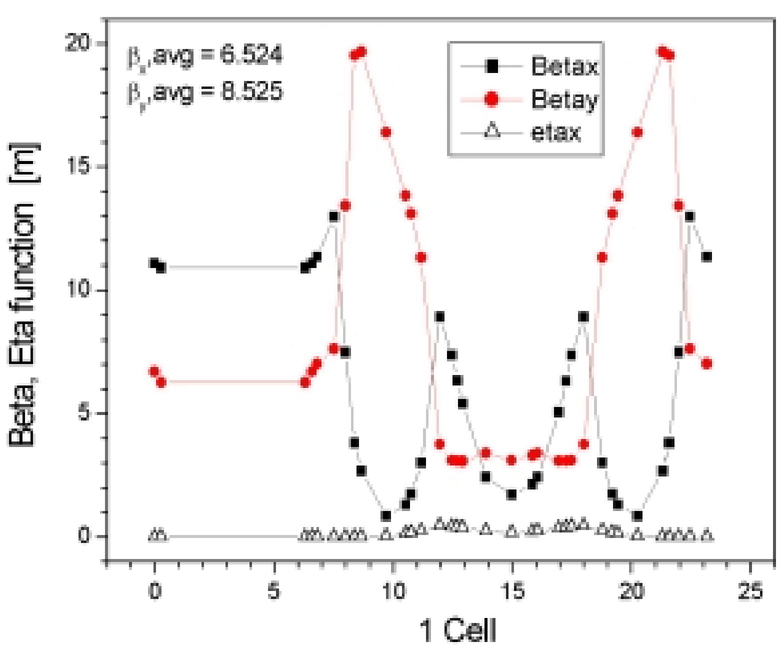
	Beta_x	Beta_y	Dispersion
Port B	1.765	3.133	0.178
Port C	1.781	1.142	0.181
Max.	11	19.7	0.4

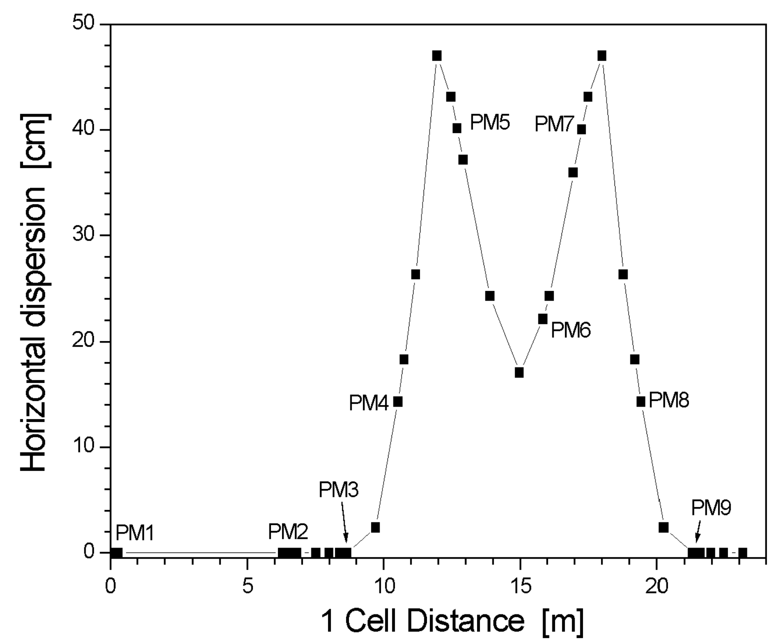
- Tunnel Air control
  - ± 0.1 °C
  - 6 control zones (A, B, C, D, E, F)
- Cooling Water control
  - ± 0.1 °C
  - single unit control

One Cell

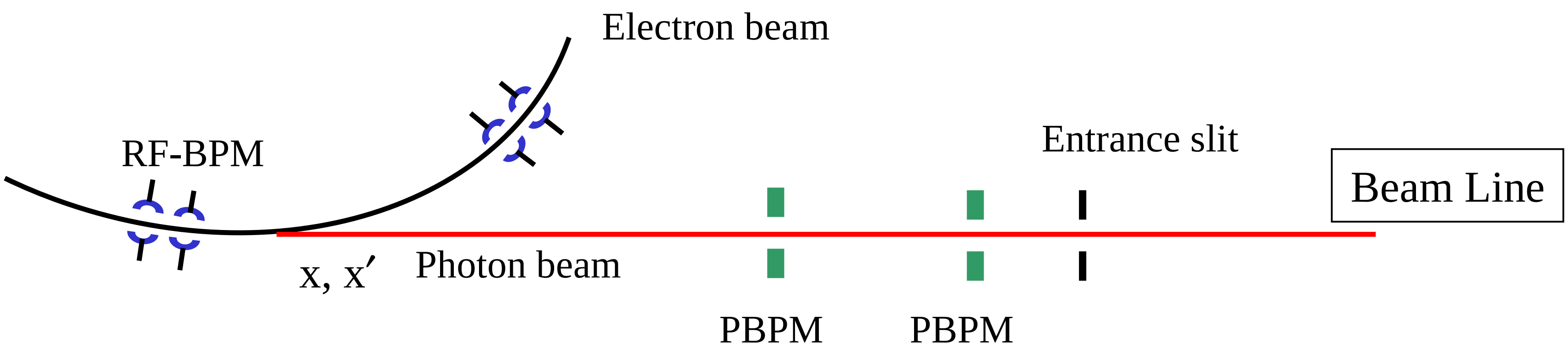
Straight Section for I.D.







Orbit Stability Requirement (1)

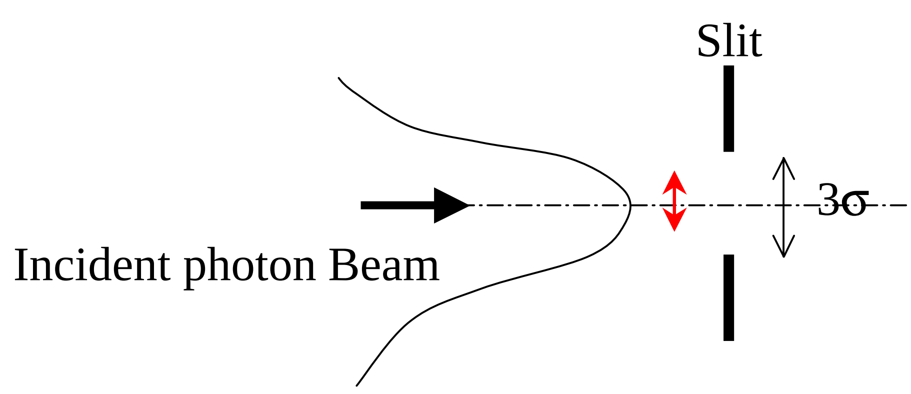


Orbit stability requirement

: for **0.1%** photon intensity fluctuation at the beam line

when the slit aperture size is 3σ of photon beam

- position displacement: less than **10% of the beam size at the source**
- Angular motion: less than **10% of the beam divergence**



Orbit Stability Requirement (2)

For **0.1%** photon intensity fluctuation

<2.5GeV, 2% x-y coupling>

	Beam Size		Orbit Stability	
	Horizontal	Vertical	Horizontal	Vertical
Bending Magnet (B & C port)	245 μm	36 μm	**24.5 μm**	**3.6 μm**
Insertion Devices	450 μm	48 μm	45 μm	4.8 μm

Angular Stability: < 1 μrad

- Actual vertical beam size (1σ) is much larger than 50μm due to vertical emittance increase.
- For U7, the slit aperture is **20 μm** and the magnification is 7:1, which corresponds to the aperture size of **140 μm** that is smaller than 3σ of beam.
  → Requirement is more stringent than 4.8 **μm**

Slow Orbit Movement

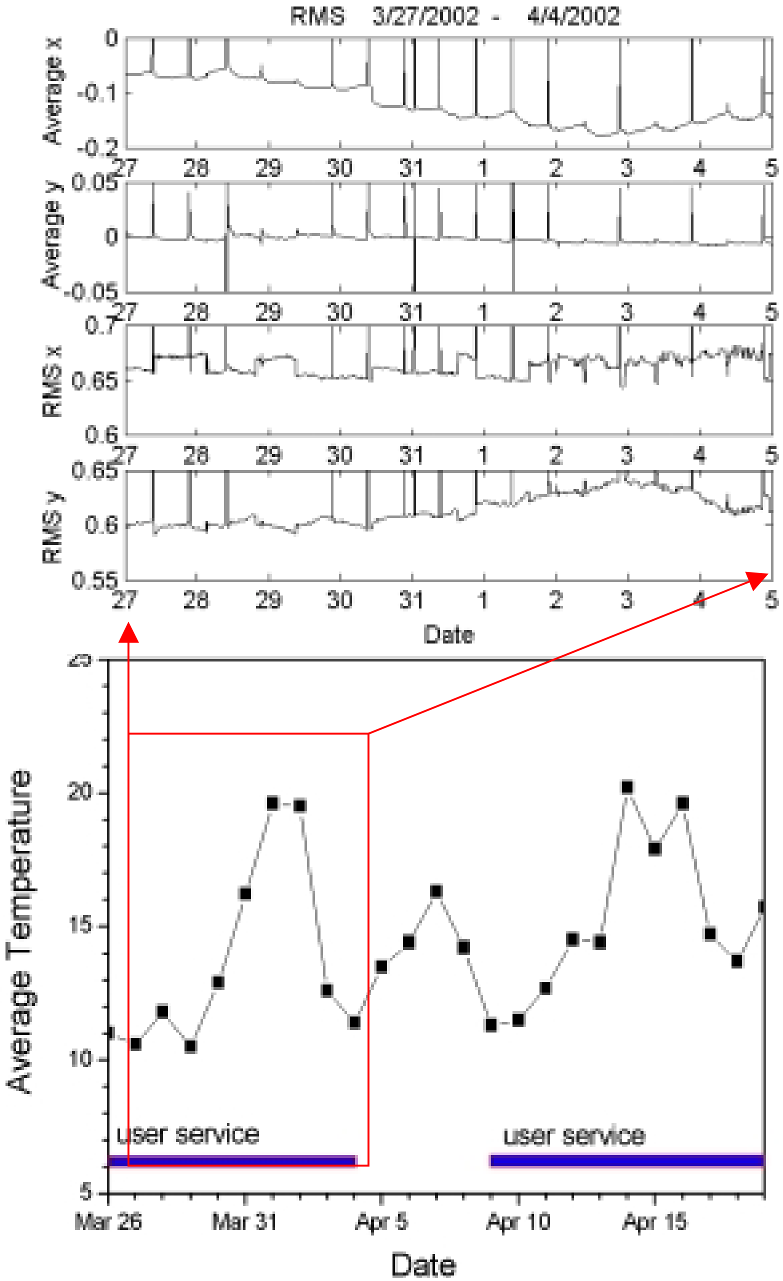
- Slow orbit movement: < 0.1 Hz
- Fast orbit movement: 0.1 ~ 500 Hz

- The magnitude of the slow orbit movement is much larger than that of the fast one
  - Correlated with weather conditions
  - Clear during the rainy winter months and the change of season

- Simultaneous movement in both Horizontal and Vertical planes
  - Average change: horizontal plane
  - rms change: vertical plane
  - Outside Temperature (+ ambient temperature of the storage ring tunnel)
  - LCW temperature
  - **Tunnel Floor motion**

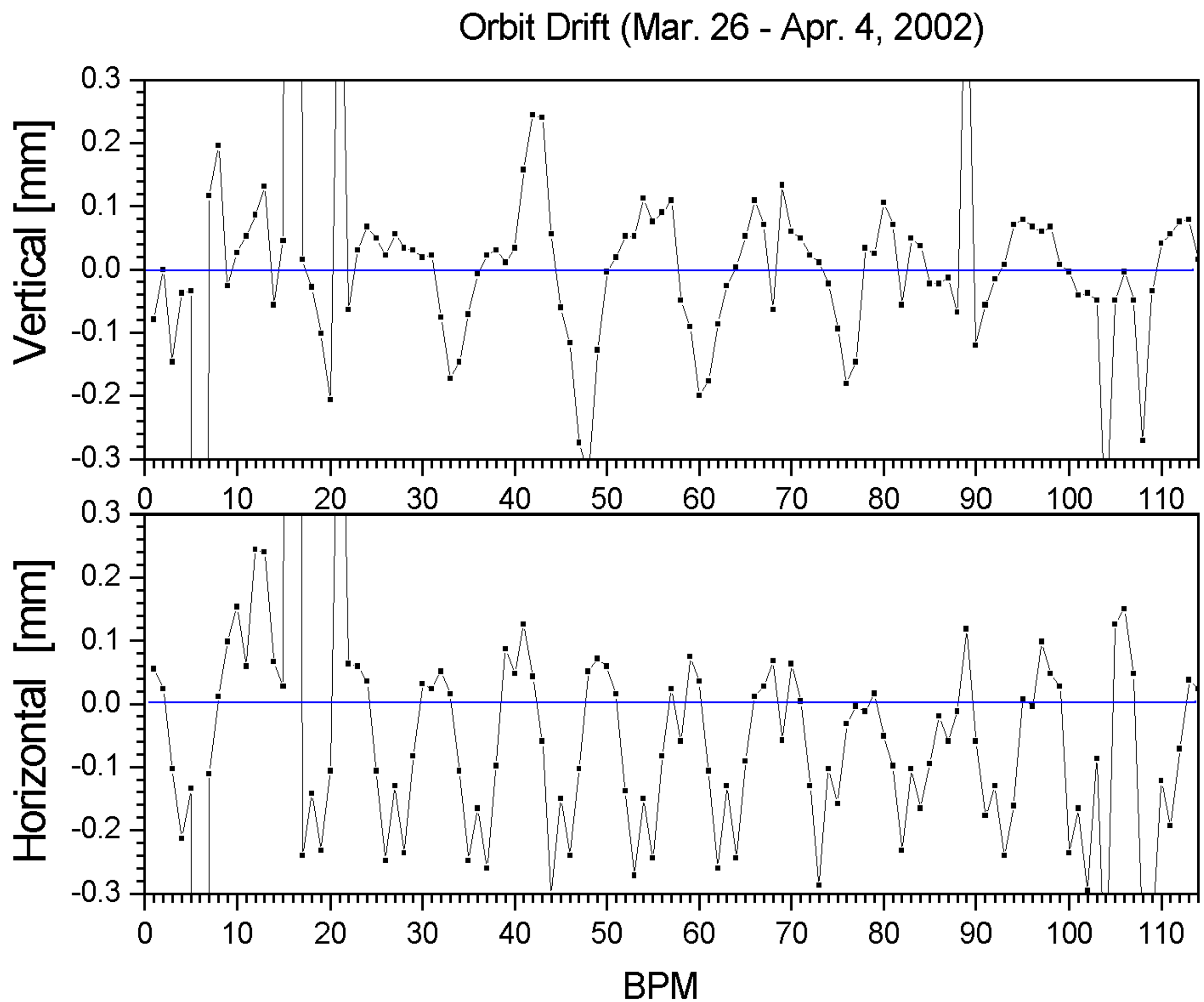
- Movement in the Vertical plane (Un-coupled to Horizontal plane)
  - rainfall
  - ambient temperature of the storage ring tunnel
  - **Localized deformation of the ring tunnel**

Outside Temperature Effect (1)



- The average in the horizontal orbit changes as much as 100 μm when the daily average of outside temperature changes 10°C.
- The r.m.s. in the vertical orbit changes about 40 μm.
- The change of the r.m.s. of the horizontal orbit is due to the insertion device operation.

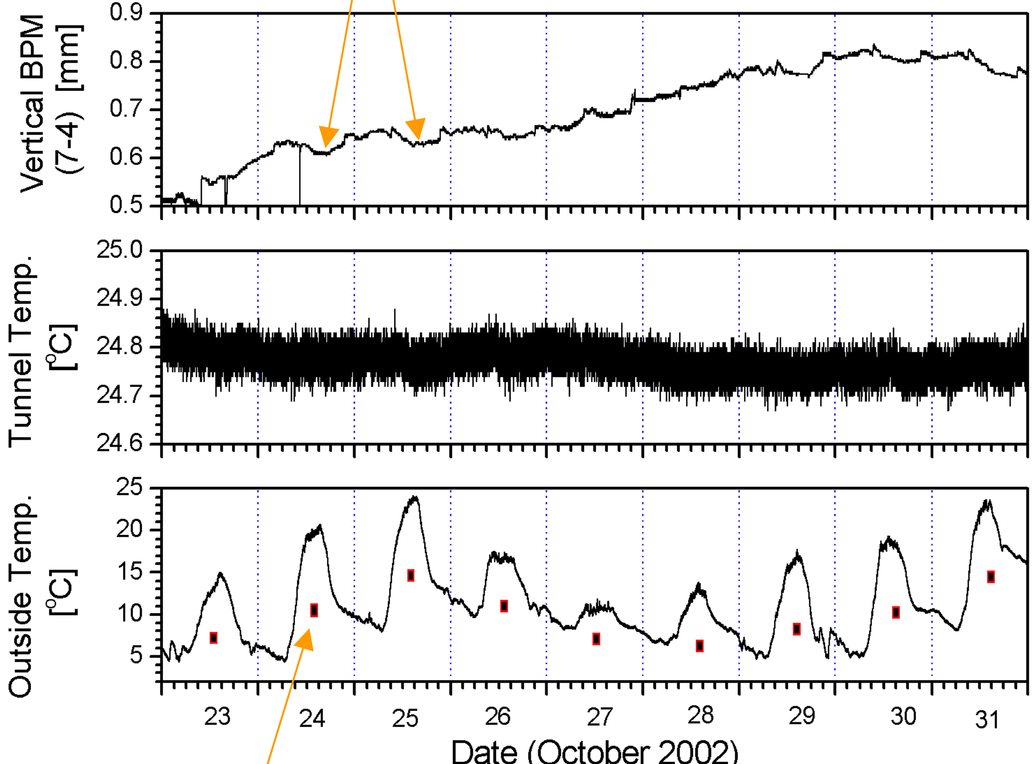
Orbit Difference

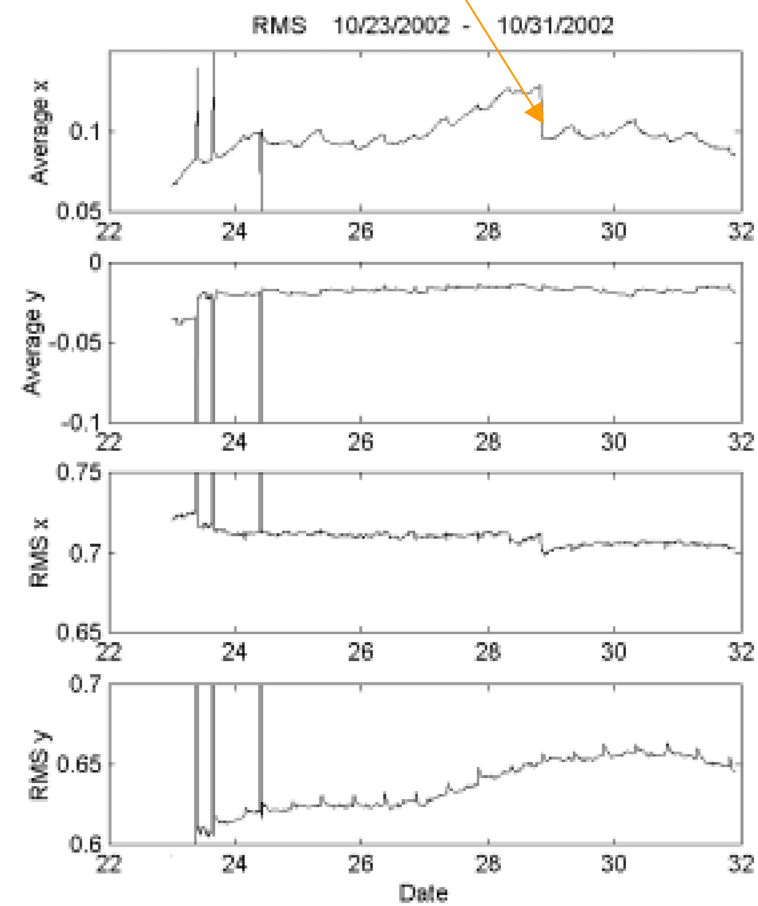


Outside Temperature Effect (2)

RF frequency change

Effect of Diurnal temperature change





Average temperature

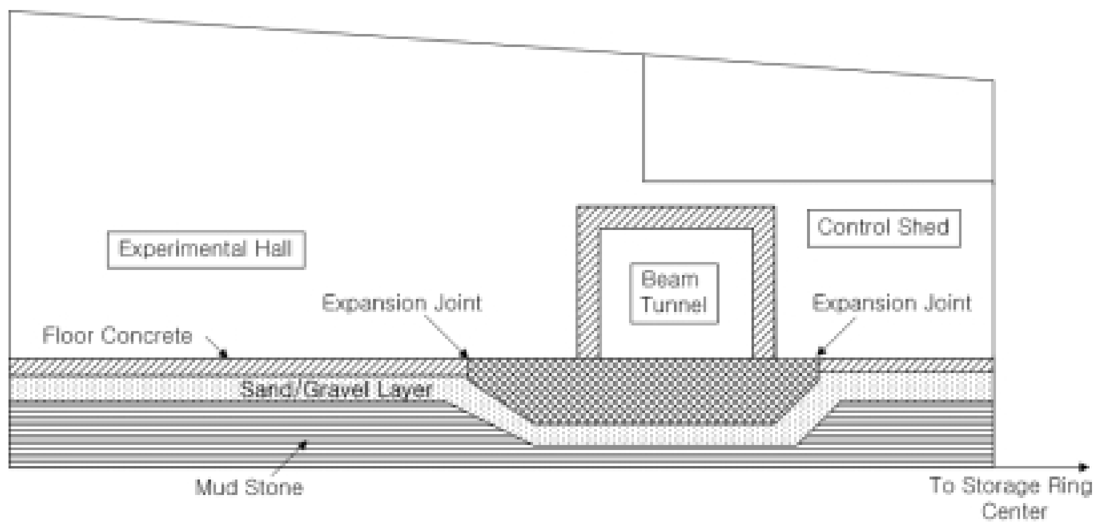
Differential Ground Settlement (1)

- Ground Motion
  - Wave dominated
  - ATL dominated
  - **Systematic motion dominated**

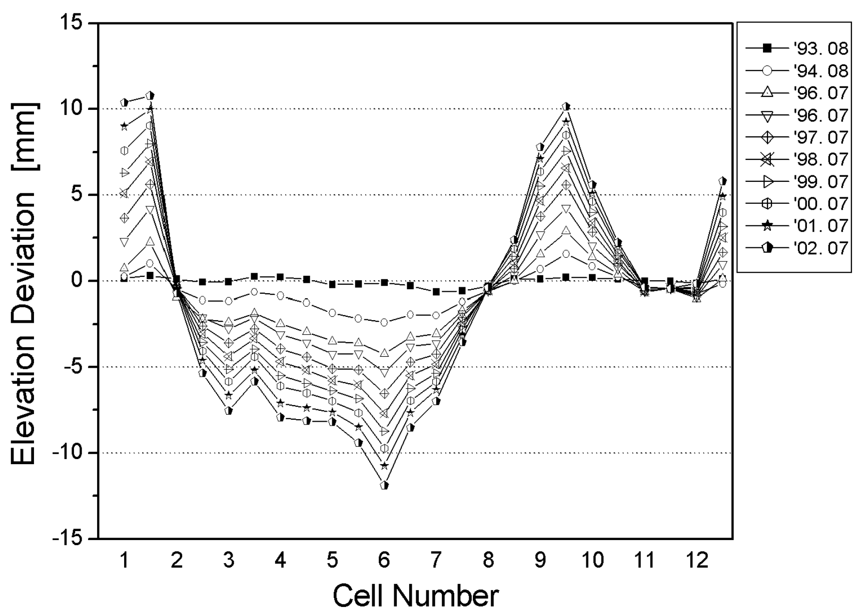
- Sources of slow ground motion
  - Atmospheric activity
  - Change of underground water
  - Temperature variation of the surface ground
  - Ocean tide

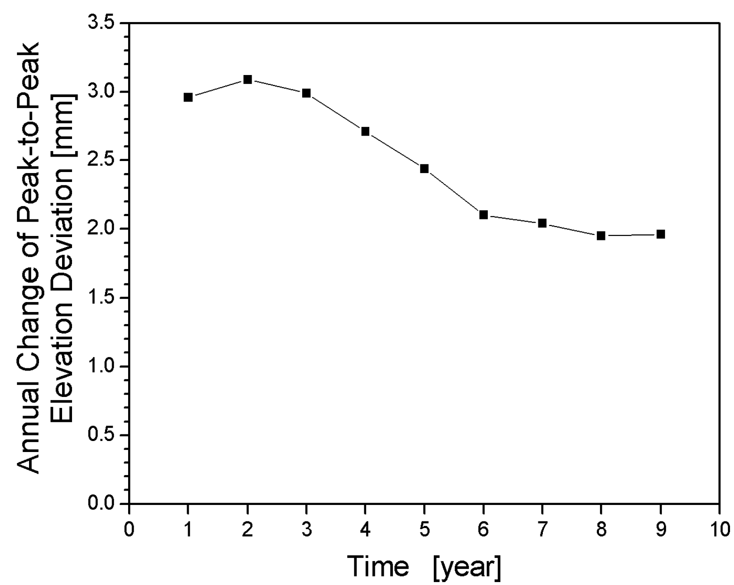
- Differential ground movement in the vertical direction
  - Load change on soft building ground during the construction
  - Concrete base plates in the ring foundation can only smooth out differential settlements over distance up to 50m

Differential Ground Settlement (2)

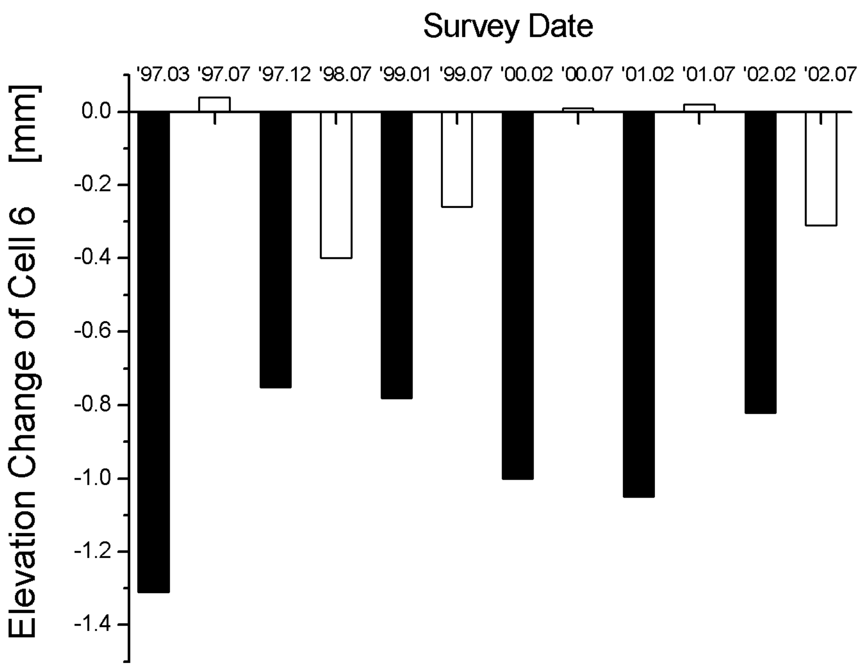


- Systematic motion dominated.
- Vertical Ground settlement does not stop and even the annual change becomes constant.

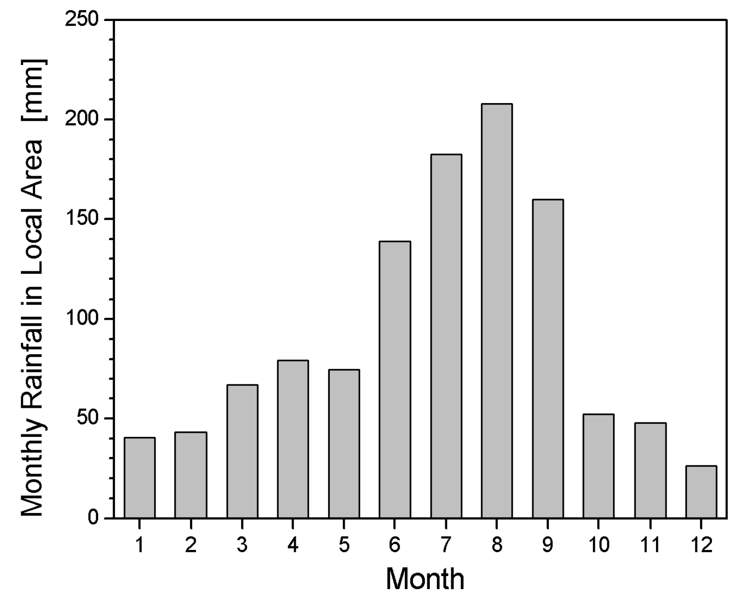




Differential Ground Settlement (3)



Rainfall Statistics in local area

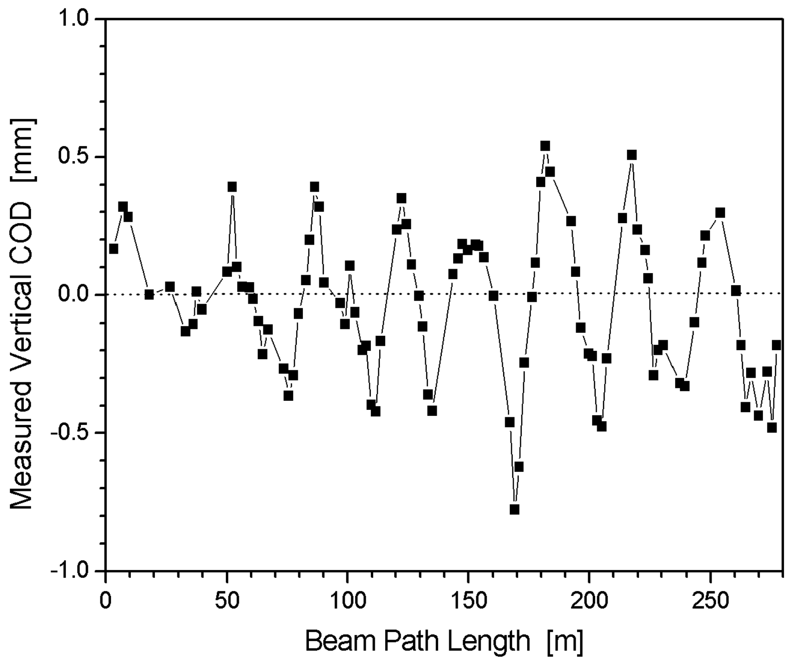


- Ground movement is not steady for one year.
  It is dominant during the second half of the year (from August to February of the next year).

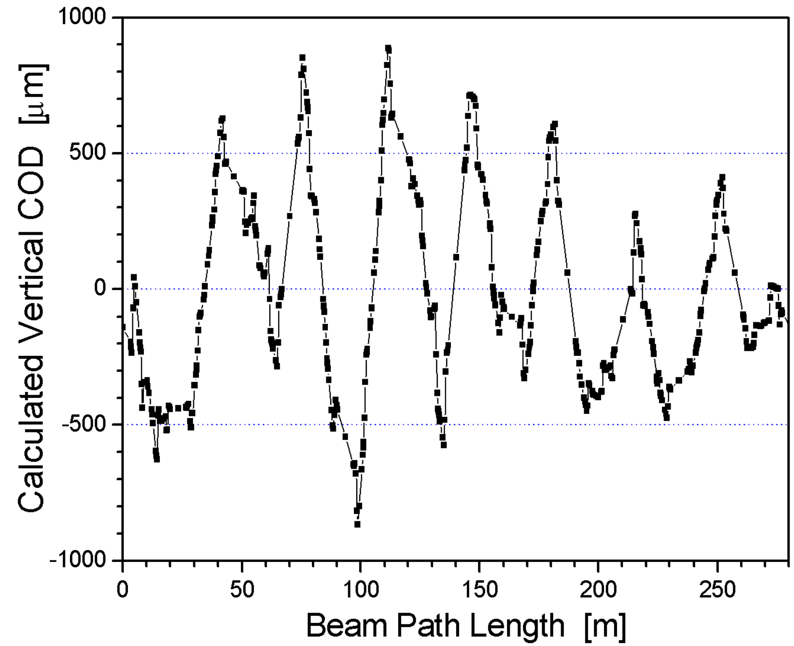
- It is expected that Ground movement is activated by cold weather in winter season followed by rainfall during the rainy season.

COD due to differential ground settlement (1)

Measurement



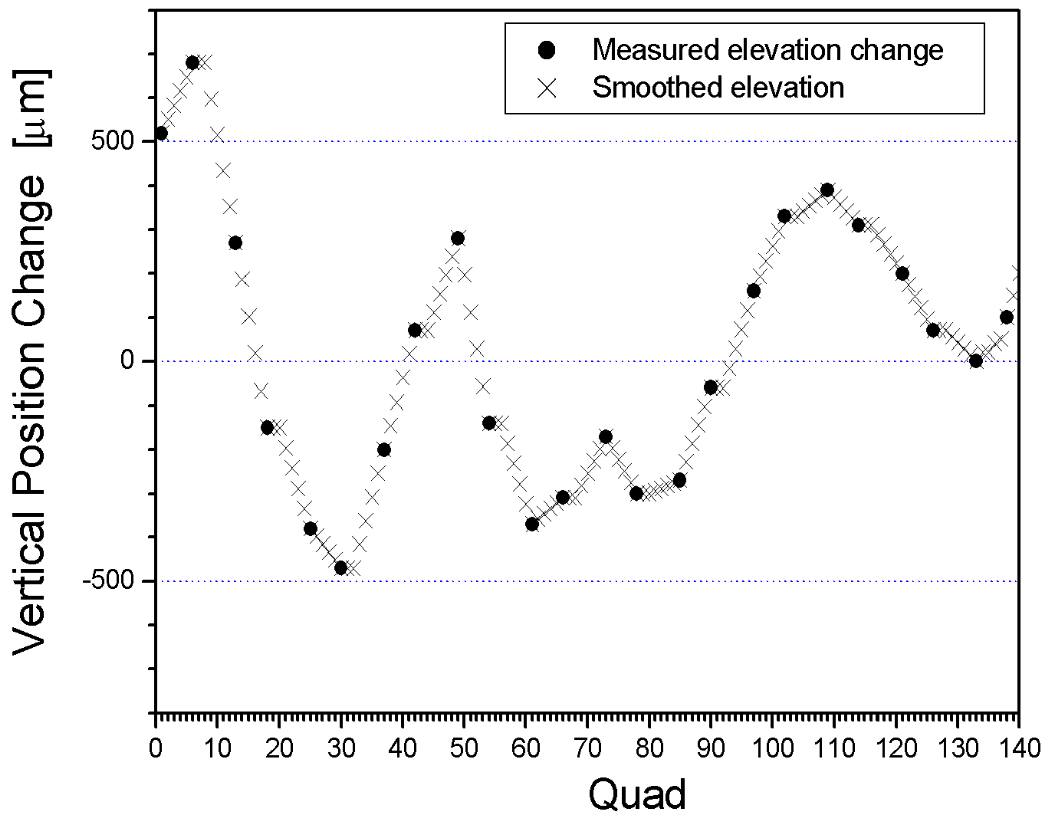
Calculation



The measured vertical orbit change **from April to July 2002**.

- COD in the vertical plane calculated by the MAD **from Feb. to July 2002**.
- using the calculated vertical displacements of quadrupole magnets with the ground elevation change data from Feb. to July 2002.

COD due to differential ground settlement (2): Quad offset

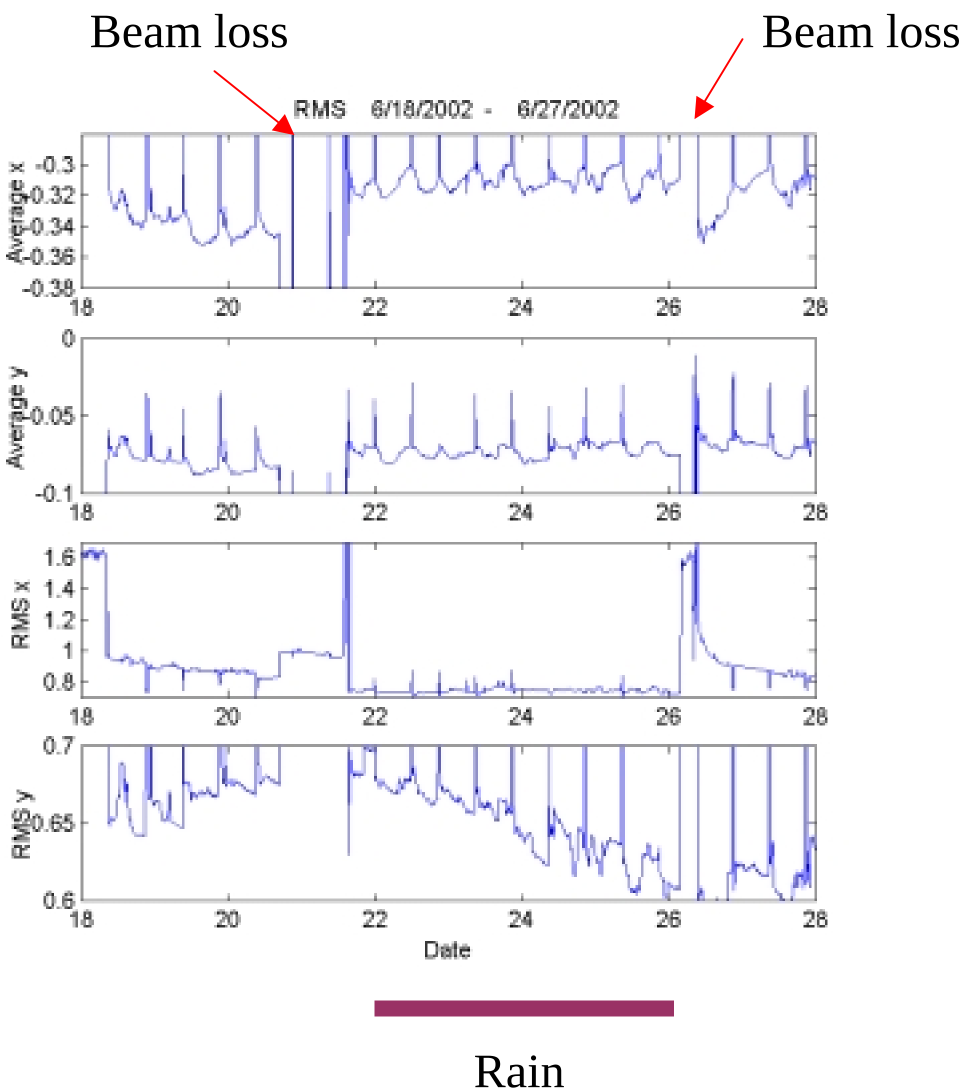


- Calculated vertical displacements of quadrupole magnets with the ground elevation change data from Feb. to July 2002.

Orbit Perturbation Sources

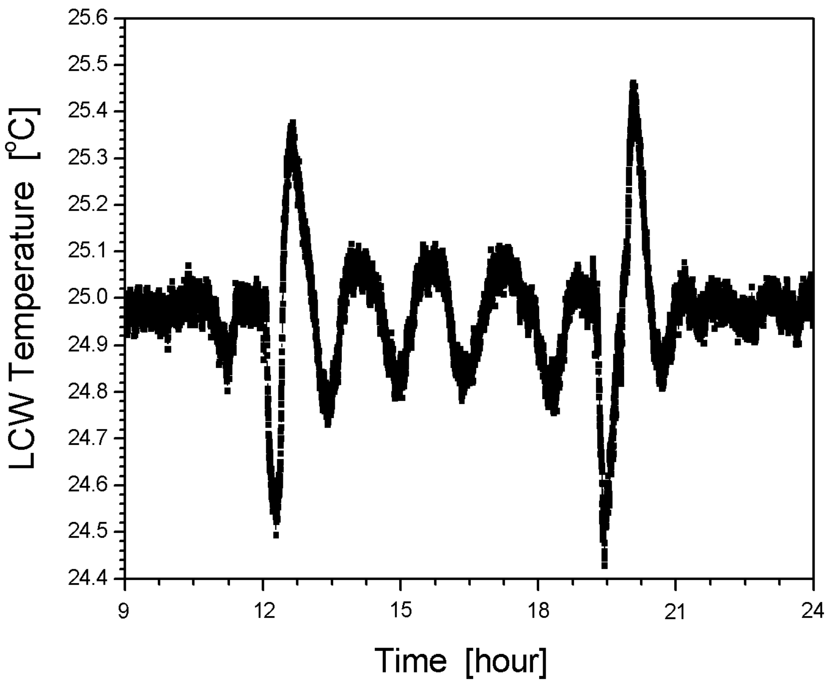
- Localized
  - Localized ground settlement
  - Localized change of ring tunnel temperature
  - Insertion Devices Operation
- Distributed
  - LCW Temperature change

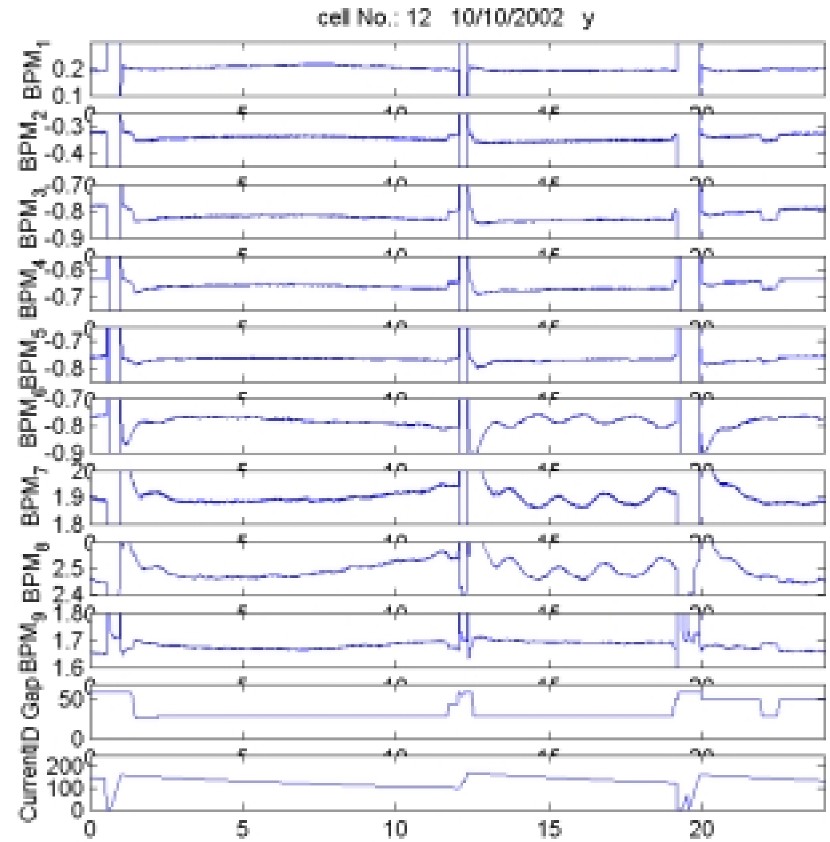
Rainfall Effect



- Rainfall causes a vertical beam motion.
- Differential Ground movement due to the change of underground water

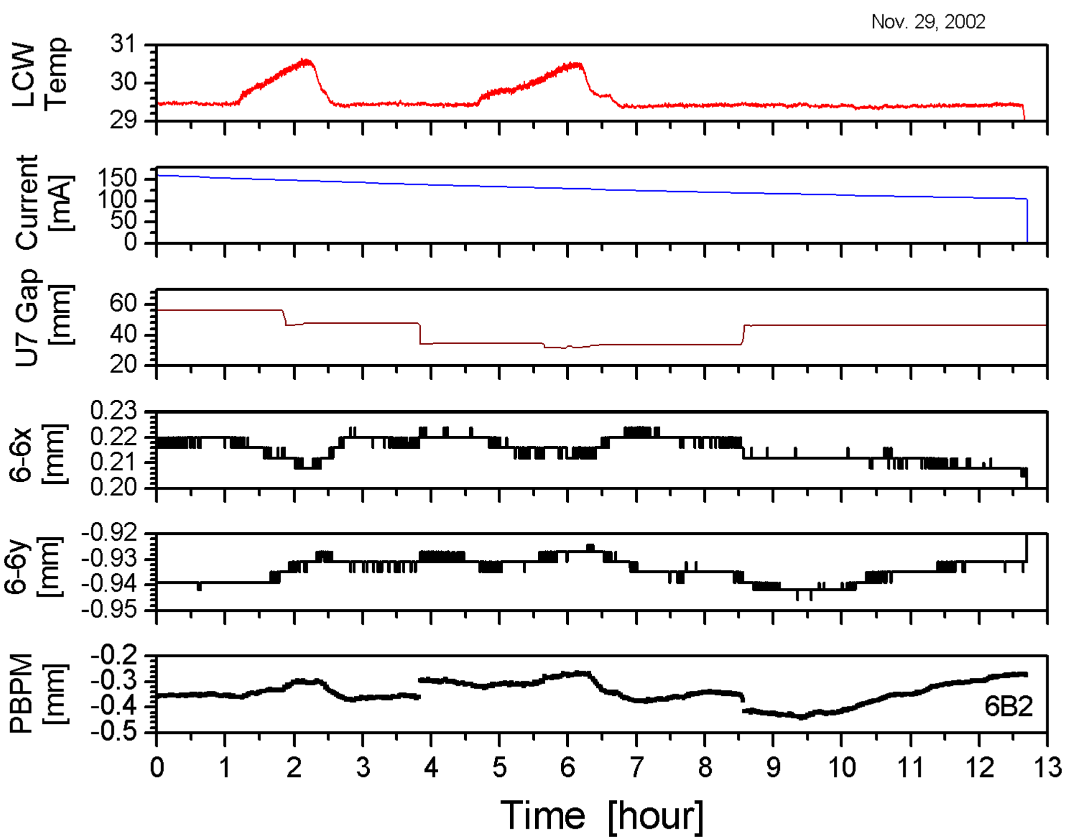
LCW (Distributed)

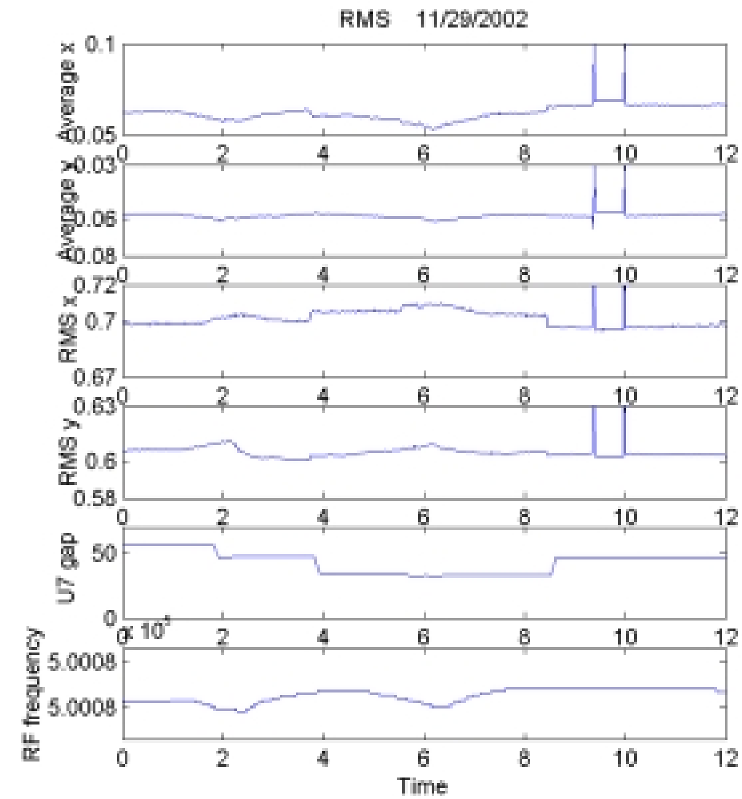




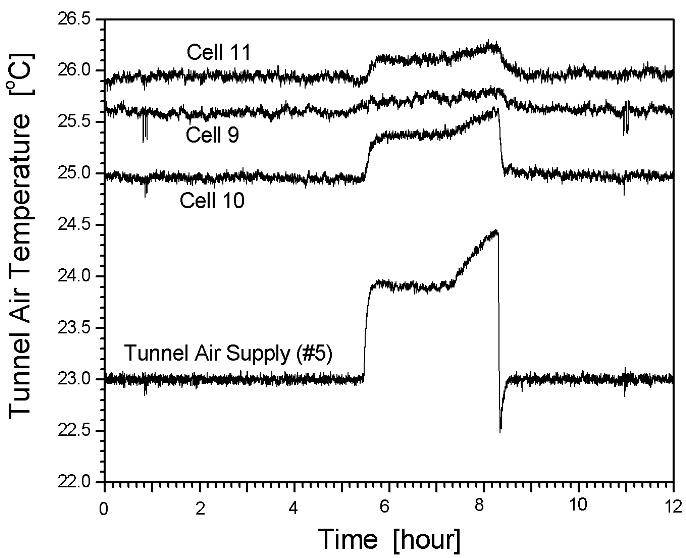
- Horizontal Orbit: a small dependence on LCW temperature
  - Cooling change in Bending Magnet
- Vertical orbit does not show a dependence on LCW Temperature.
  - Parasitic movement only appears in Sector **2 chamber** of Cell **1, 2, 4, 12**
  - due to BPM intensity dependence due to TE mode in antechamber

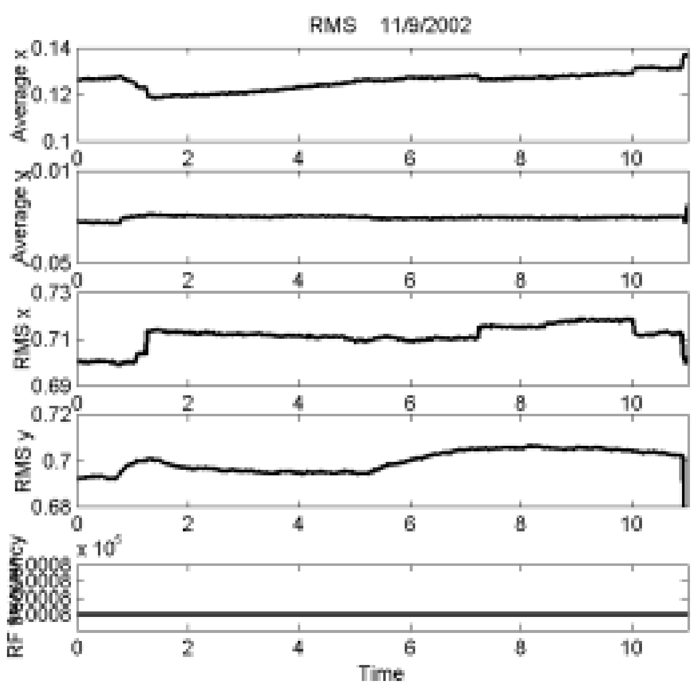
LCW (Distributed)

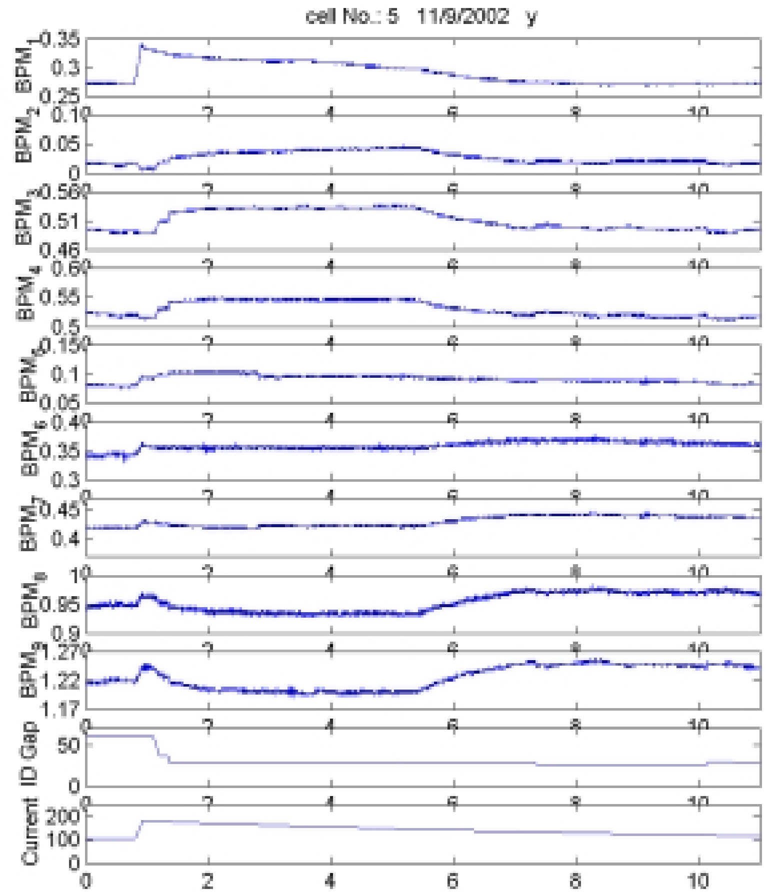




Tunnel Air Temperature (Localized)

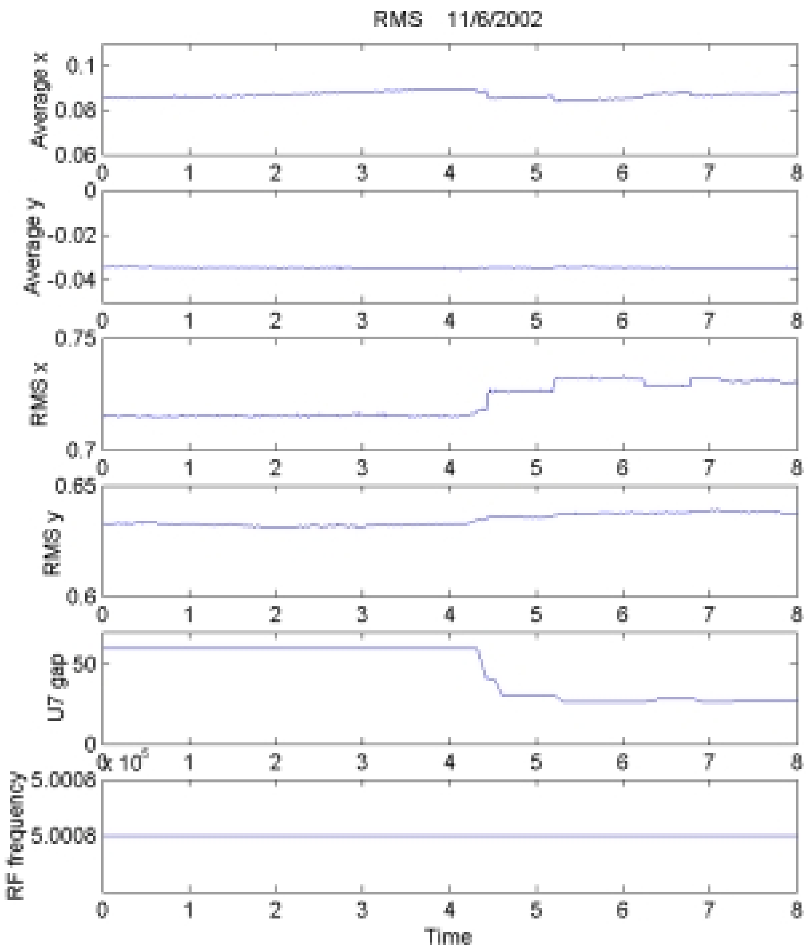


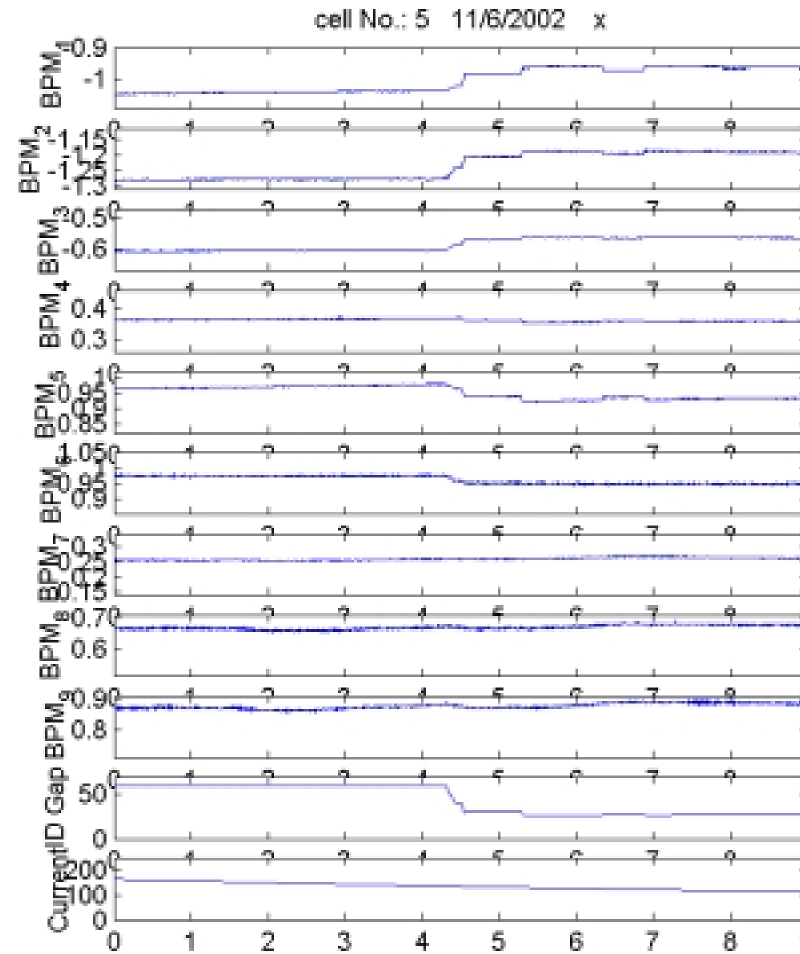




- Tunnel Air control for **zone E** is out of control.
- Tunnel air temperatures in Cell 10 and 11 change too much.
- r.m.s. change in the vertical plane: 12μm
- no change in the horizontal plane

Effect of ID Gap on Orbit





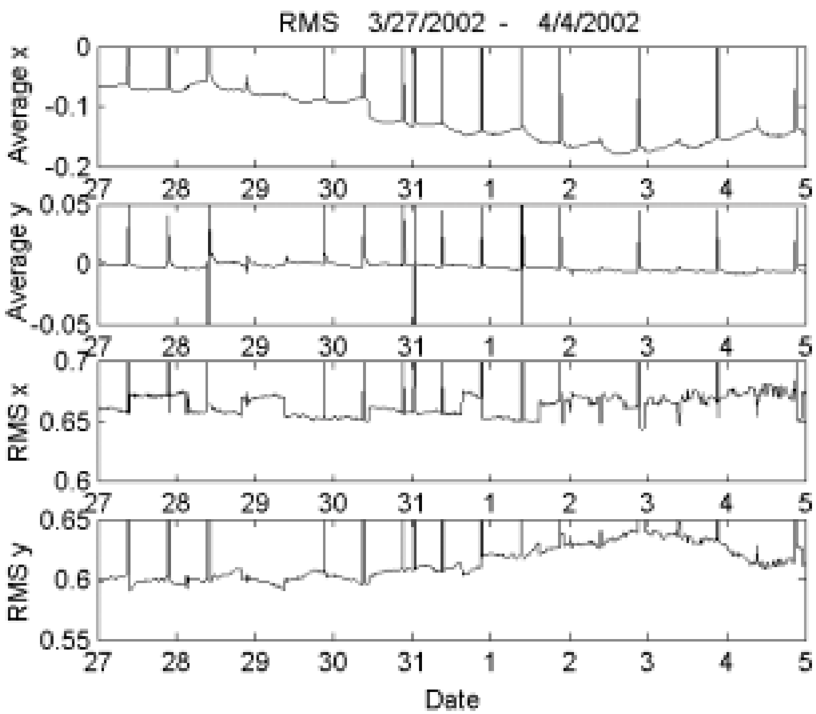
- **Vertical orbit change: ~ 6 μm**
- **Horizontal orbit change: ~ 17 μm**

How to reduce the slow orbit movement?

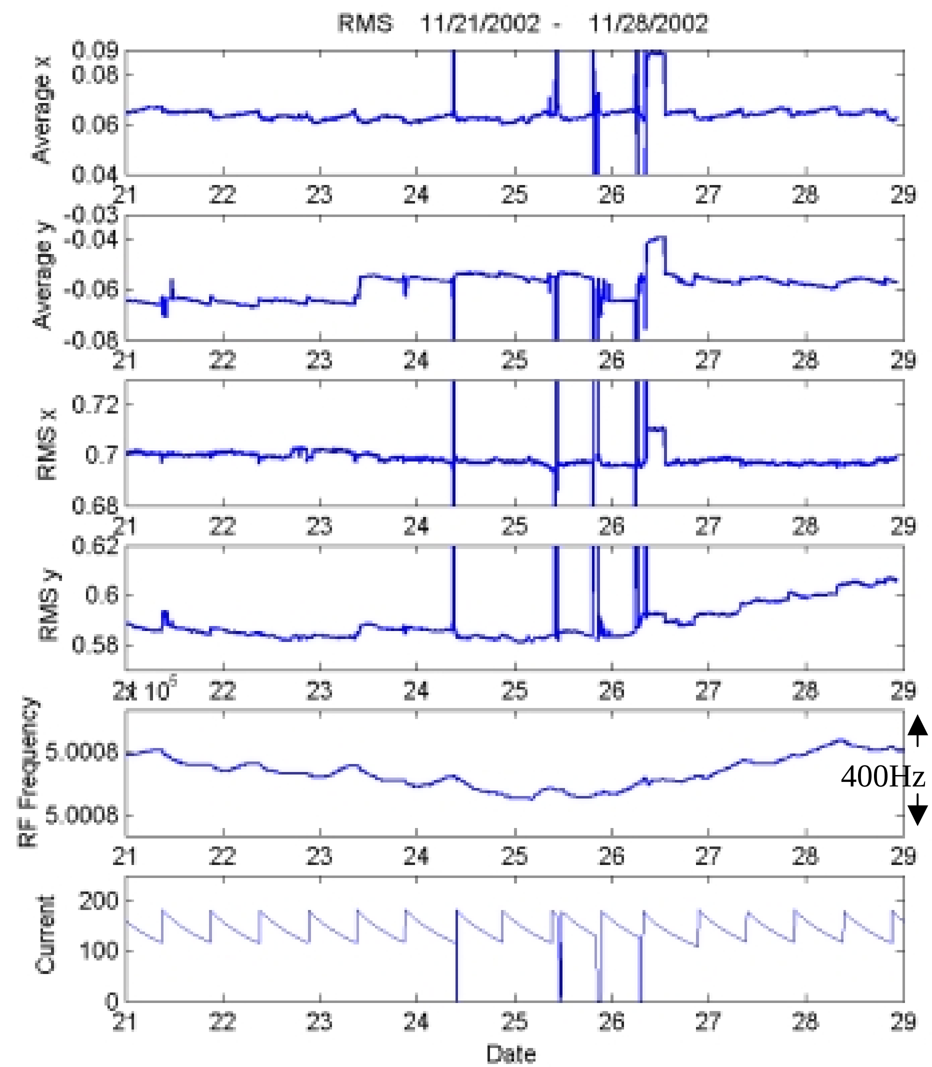
- **Orbit Feedback**
  - Global orbit feedback: under preparation
    - Bandwidth: < 0.1 Hz
  - RF frequency automatic correction: in use
  - Local orbit correction: under preparation and will be used soon.
- **HLS (Hydrostatic level system)**
  - will be installed soon to measure the ground motion during the machine run.

RF frequency correction

Without RF Frequency Correction



Without Frequency Correction (automatic)



- Uses only dispersion BPMs (5, 6, 7).
- The average of horizontal orbit is bounded within about 7 μm.
- Intensity dependence of BPM causes a small variation in the feedback.

Orbit Feedback : Performance Limitation

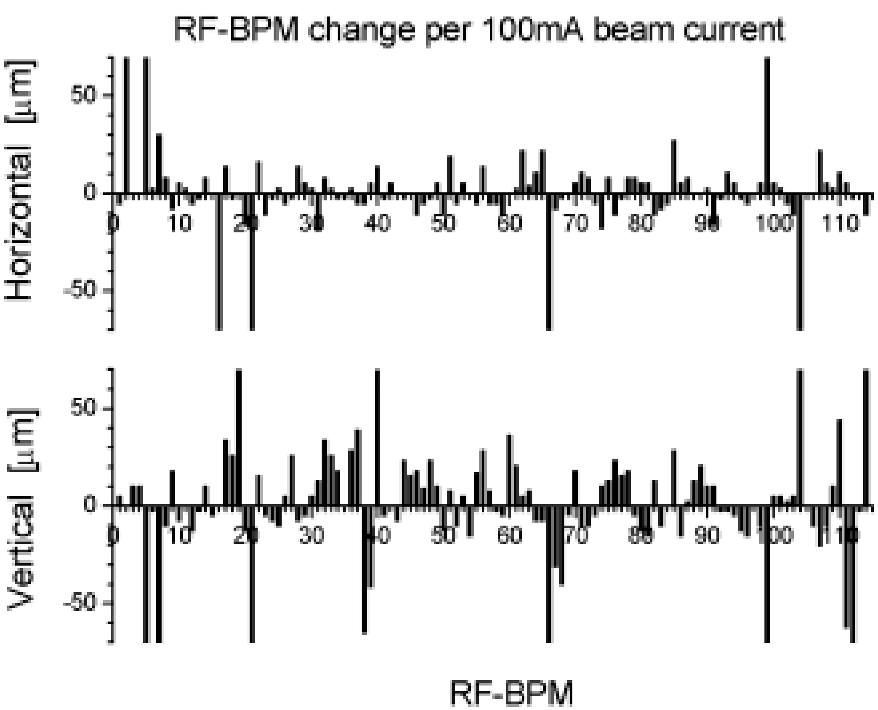
- **Orbit Perturbation detection**
  - RF BPM
    - **false beam motion**
      - **intensity dependence**
      - **Chamber motion**
    - **local position / angle calculation errors**
    - **BPM resolution**
  - **false beam motion** should be eliminated.

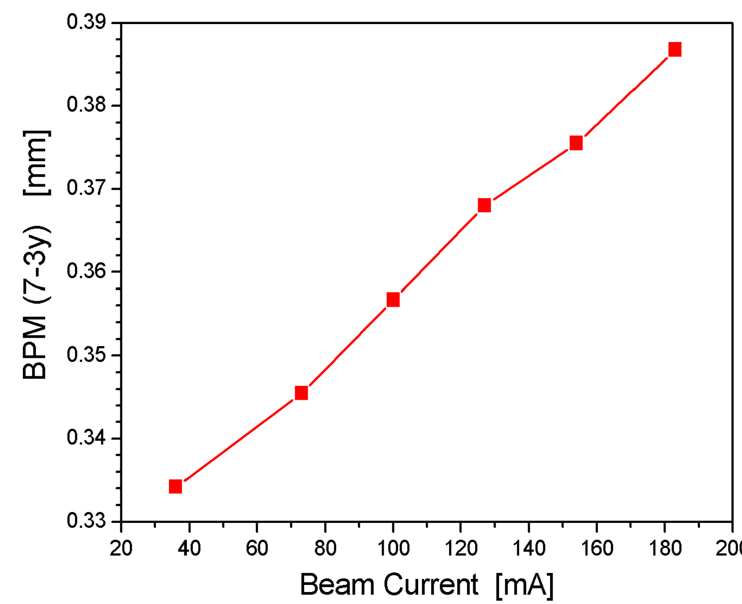
- **Orbit corrector system**
  - **Corrector resolution, quantization noise and step resolution**
  - **orbit-dependent response matrix**

Intensity Dependence of RF-BPM (1)

❑ **False beam motion is due to intensity dependence of RF-BPM**

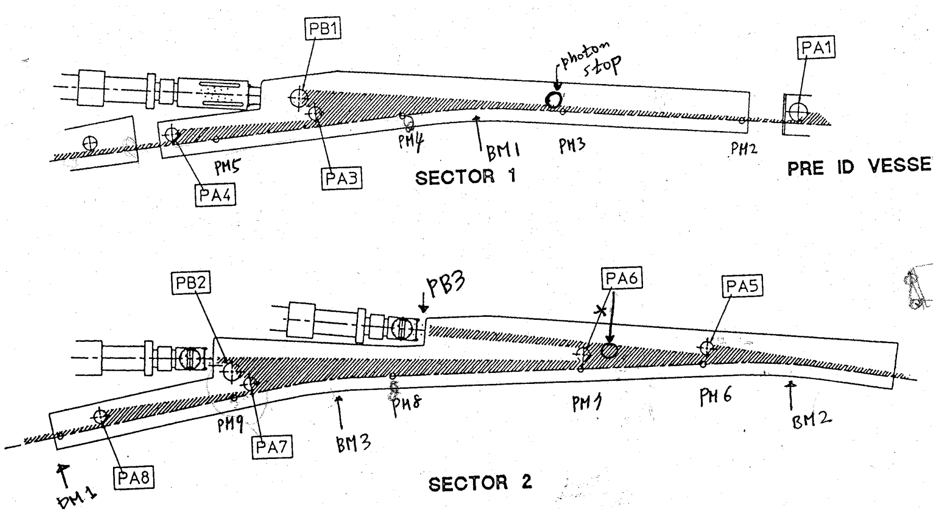
- ➢ BPM chamber movement and TE mode in antechamber
- ➢ **Sector chamber BPM (mounted on a 10 meter long huge tank) is absolutely not free from perturbations.**
- ➢ BPM electronics problem:
  - ✓ Gain drifts and non-linearities
  - ✓ More elaborate calibration work is absolutely necessary





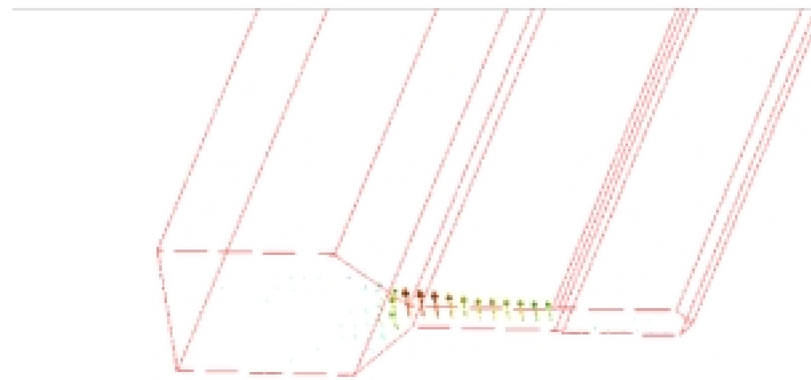
Intensity Dependence of RF-BPM (2)

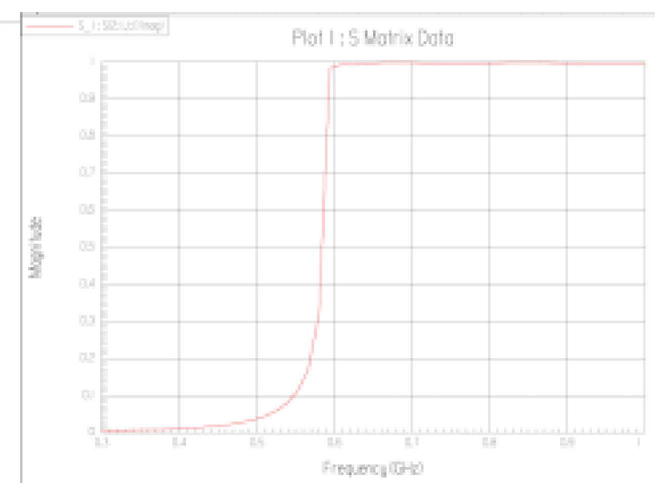
Synchrotron Radiation



- ➢ heating of the vacuum chamber from synchrotron light
- ➢ 2.5 GeV 180 mA:
  - ✓ photon power 10 kW / cell
  - ✓ photon stop: 7 kW
- ➢ **dependent on orbit**

TE Mode in antechamber





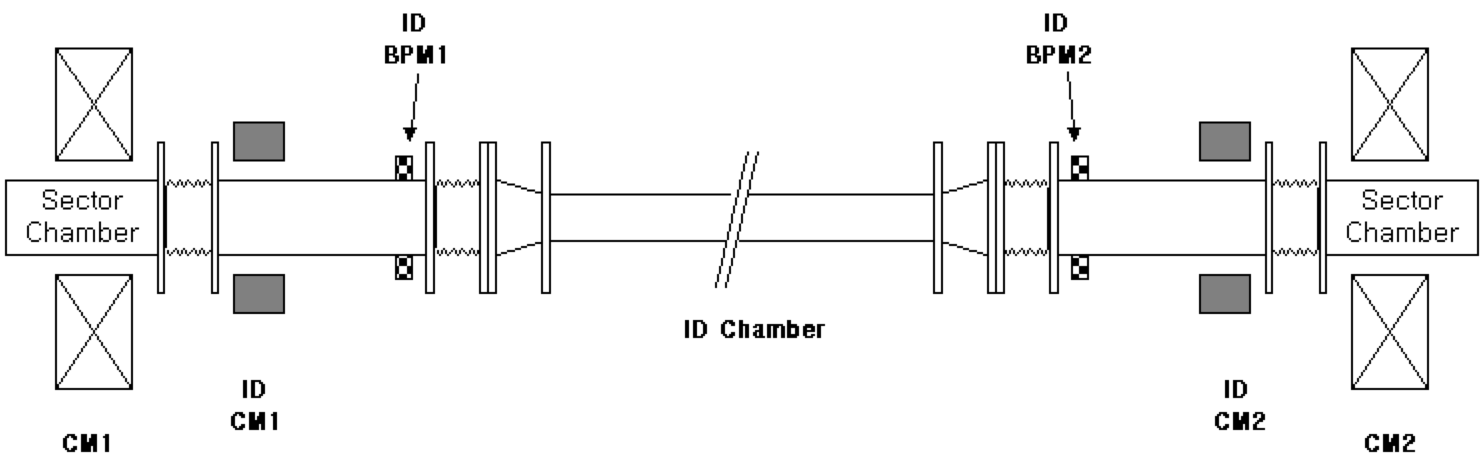
➢ Many Transverse Electric Modes around 500 MHz exist !

➢ Weak to chamber deformation

Local Orbit Correction / Feedback for Insertion Devices

Local orbit Correction and Feedback

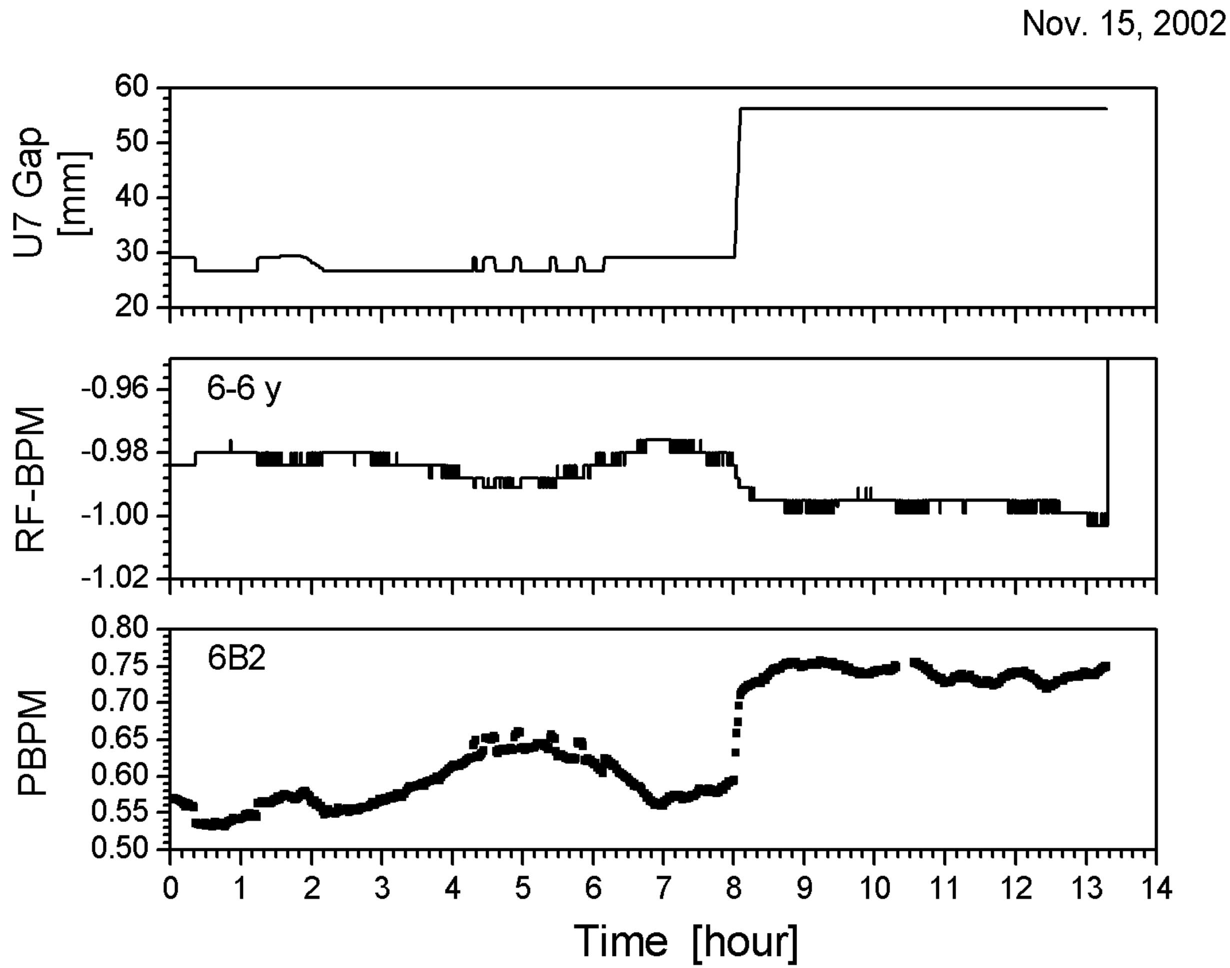
- 4-magnet bump structure
- Feedforward orbit correction



❑ Sector chamber BPM is absolutely not free from false motion.

- Search for Good BPM → ID BPM is a best choice
- we can modify easily the structure ID BPM and add a temperature stable support.

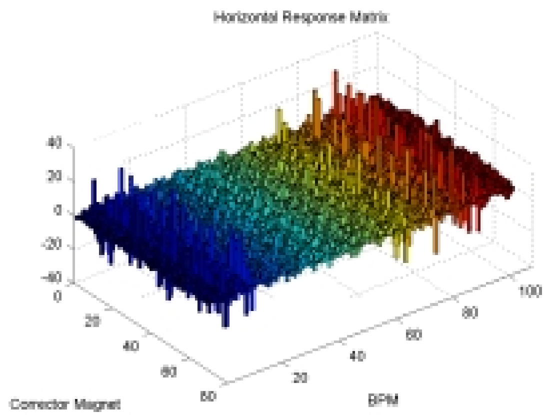
Sensitivity to Orbit Perturbation

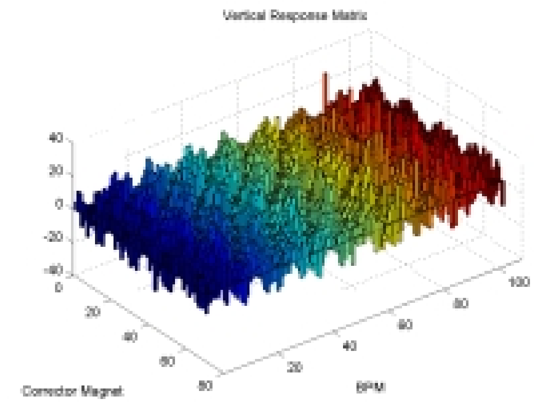


- In above figure, RF-BPM and PBPM measure the same source.
- RF-BPM measures the 20μm change, but PBPM the 150 μm change.
- Thus, angular stability at the source point is very important.
- PBPM shows better sensitivity on orbit perturbation than RF-BPM.

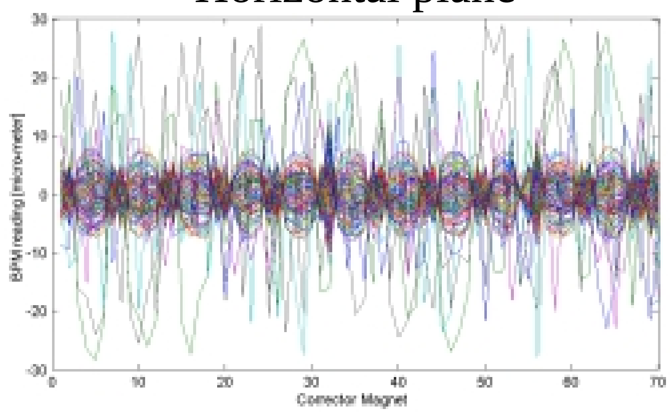
Corrector Power Supply

Orbit change from 1 bit change of power supply

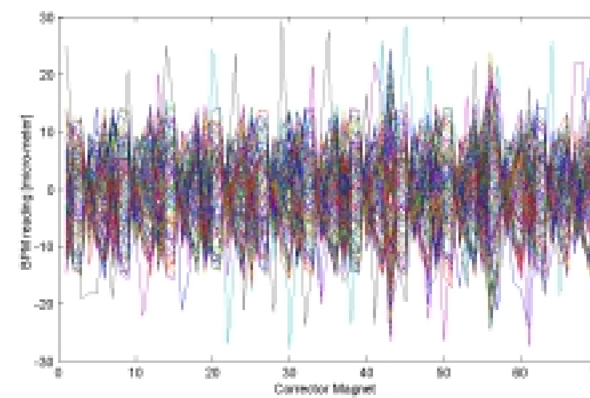




Horizontal plane



Vertical plane



- RMS Orbit motion due to orbit feedback using 30 corrector power supplies with 12 bit DAC is estimated: y_{rms} = 6.3 micro-meter
- Upgrade to 18 bit DAC is required.

Global Orbit Feedback: Scheme

- **Perturbation detection**
  - uses both RF-BPM and PBPM for each cell
    1) two RF-BPMs
    2) Or, two RF-BPMs and one PBPM
    3) Or, one RF-BPM and two PBPMs for divergence control in beam line
- **Algorithm**
  - choose the scheme to alleviate the effect of intensity dependence RF-BPM
  - Harmonic correction or SVD
  - Effect of Insertion device operation: feedforward local orbit correction

Summary

- Facts and causes of slow orbit movement are identified;
  the outside weather condition, the tunnel floor elevation,
  the ambient temperature of the storage ring tunnel, and the LCW temperature.

- Each factor causes an orbit movement with different pattern and magnitude in the horizontal and/or vertical planes.

- RF Frequency automatic correction can reduce the horizontal orbit movement due to the environment temperature change.

- Requirements and scheme for the global orbit feedback are reviewed
  - **Sensitivity to Orbit Perturbation**
  - Feedforward local orbit correction
  - HLS