2012 International Particle Accelerator Conference

# PLS-II (Upgrade of PLS)Commissioning

Seunghwan Shin

for the PLS-II commissioning team

2012. 5. 22

# Project and budget @ PAL

# PAL : Chronology

## I. PLS

| | |
|---|---|
| ▪ Project started | Apr. 1 1988 |
| ▪ Ground-breaking | Apr. 1 1991 |
| ▪ 2-GeV Linac commissioning | Jun. 30 1994 |
| ▪ Storage ring commissioning | Dec. 24 1994 |
| ▪ User service started | Sep. 1 1995 |
| ▪ 1st PLS Upgrade Complete | |
| ✓ Energy ramping to 2.5 GeV | Sep. 1 2000 |
| ✓ 2.5-GeV injection | Nov. 1 2002 |

## II. 2nd Major Upgrade of the PLS (PLS-II)

| | |
|---|---|
| ▪ 3.0 GeV PLS-II Upgrade begin | Jan. 2009 |
| ▪ 3.0 GeV PLS-II Upgrade Complete | Dec. 2011 |
| ▪ User service started | Mar. 2012 |

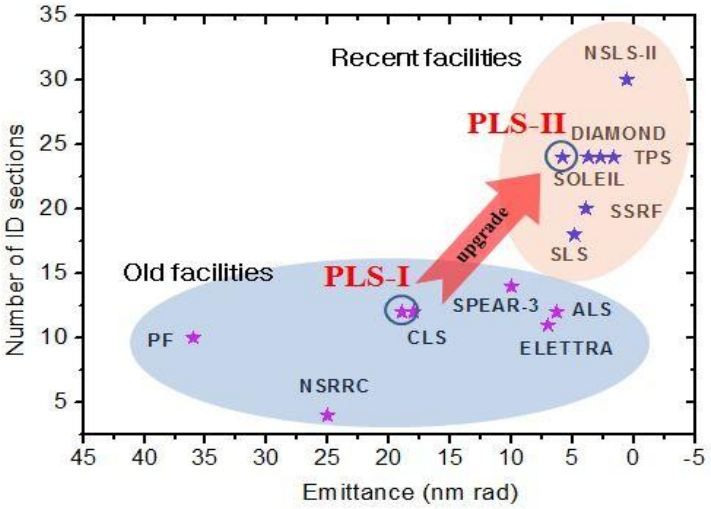
## III. PAL-XFEL Going On

▪ 10GeV Linac Based 0.1 nm x-ray FEL (2011 ~ )

# PLS-II upgrade project ('09~'11)

○ Goals
- Beam energy : 2.5 → 3.0 GeV
- Current : 200 → 400 mA
- Storage Ring Emittance : 18.9 → 5.8 nm·rad
- Top-up Operation mode
- No. of Insertion Device : 10 (24 %) → 20 (38 %)

The 3rd generation synchrotron facilities




PLS

Dismantling

DEC. '10

Re-installation

JAN. '11

PLS-II

PLS-II

# Commissioning team and contributor

## PAL

- S. Kwon
- D-T. Kim
- D-E. Kim
- M. Kim
- S-H. Kim
- S-C. Kim
- J. Kim
- C. Kim
- B. Park
- S-S. Park
- S-J. Park
- E. Park
- Y. Son
- J. Yoon
- B. Lee
- E. Lee
- J. Lee
- H. Lee
- Y. Joo
- J. Choi
- T. Ha
- W. Hwang
- I. Hwang
- J. Lee
- B. Oh
- C. Lee
- H. Lee
- J-Y. Kim

+ PAL staff

## THILAND

- H. Weidemann
- C. Somjai

## SSRF

- H. Jie
- G. Liu

## SSRL

- J. Safranek
- J. Sebek
- R. Hettel

## SOLEIL

- L. Nadolski
- N. Hurbert

## NSLS-II

- T. Shaftan
- J. Choi

## ASLS

- E. Tan

## SLS

- M. Boege

## Spring-8

- M. Takao
- T. Nakamura
- K. Kobayashi

## KEK

- J. Urakawa

## ALS

- G. Portmann
- W. Wan

## APS

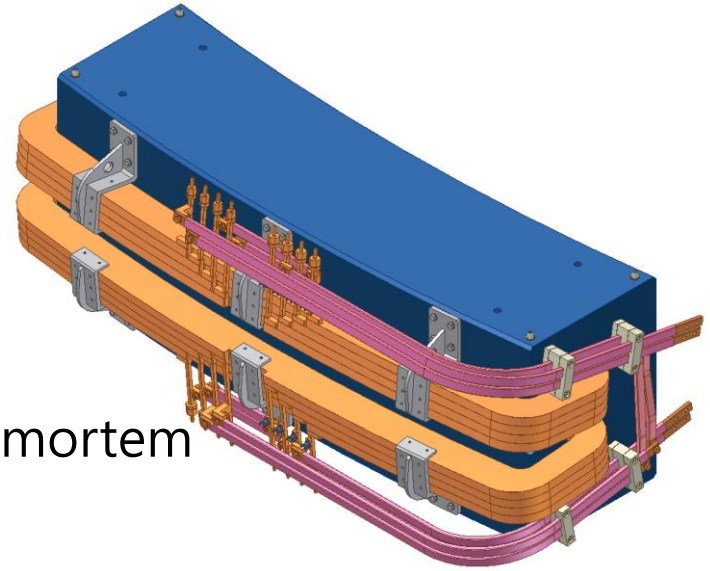
- L. Emery
- G. Decker

## TPS

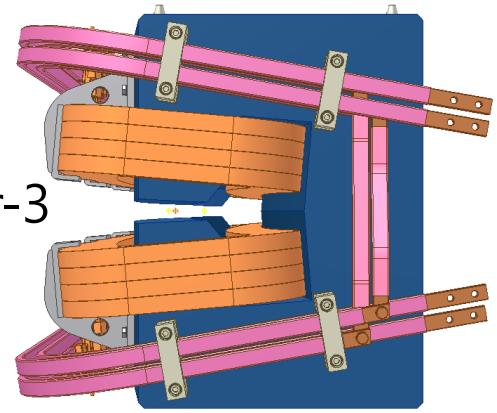
- P. Chou
- C. Kuo

# Support from accelerator society

- **Commissioning tool**
  - Matlab middle layer
  - Labca
- **Digital BPM**
  - Libera Brilliance
  - Many functions : Orbit interlock, post mortem
  - First turn, TBT, FA (10K Hz), SA (10 Hz)



- **Digital timing system**
  - Easy to control for all machine timing in control room
  - Collaboration with SSRF
- **Gradient dipole magnet**
  - Useful information from CLS, ALBA and Sprear-3
  - Collaboration with IHEP
- **Many other encouragements**



# Commissioning milestones

## ○ 2011

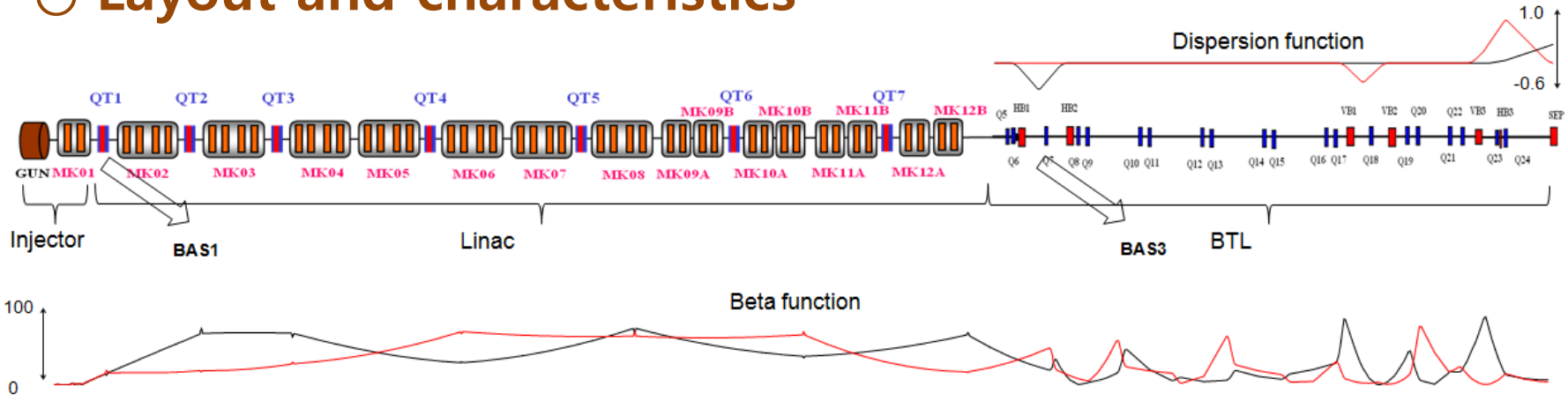
- 25 January, PLS-II installation begins
- 23 May, Linac commissioning begins
- 13 June, 3 GeV beam
- 25 June, SR installation finished and BTL commissioning begins
- 1 July, First turn
- 5 July, Kicker PS accident
- 5 August, First accumulation
- September, Shutdown for installating insertion device
- 7 October, 100 mA stored
- 24 October, First photons to beamline
- December, Shutdown for installating insertion device

## ○ 2012

- 14 February, Commissioning with users
- 21 March, Start of operations

# PLS-II Linear accelerator

## ○ Layout and characteristics

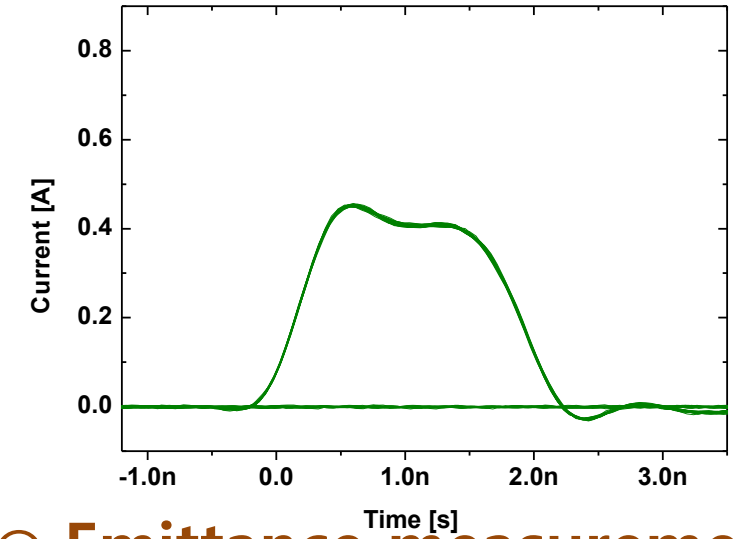


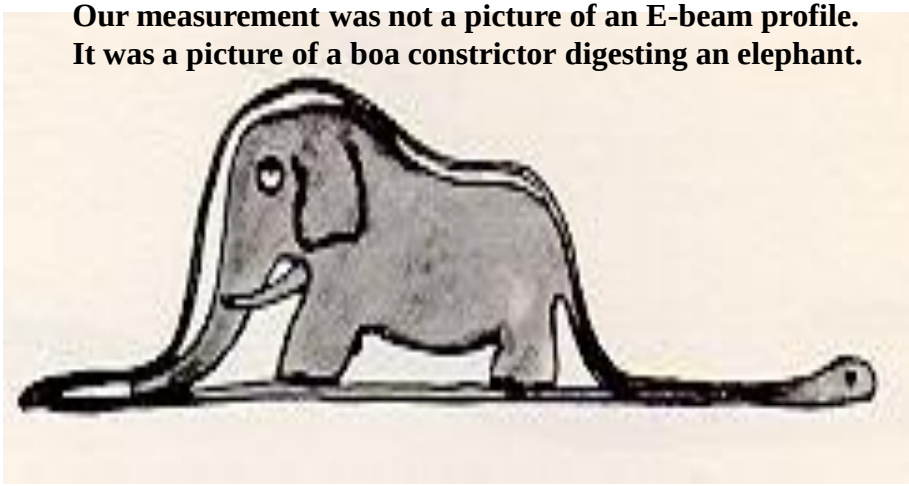

- Length = 164 m + 86 m
- 3.0GeV, full energy injection
- 2,856 MHz (S-band)
- 10Hz, 1.5 ns, 1Å pulsed beam
- Norm. emmittance 120μmrad

- Thermionic Electron Gun
- 16 Pulse Modulators (200MW, 7.5μs)
- 16 Klystrons (80 MW, 4μs)
- 15 Energy Doublers (g=1.5)
- 46 Accelerating Sections

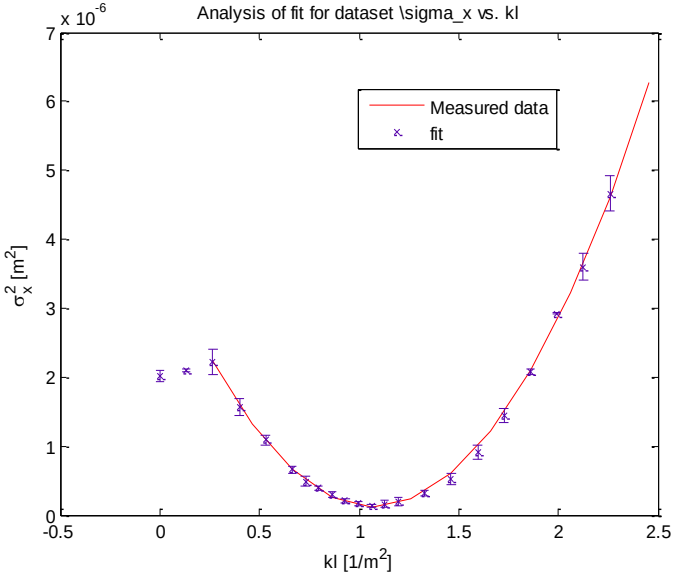
# Linac & BTL commissioning

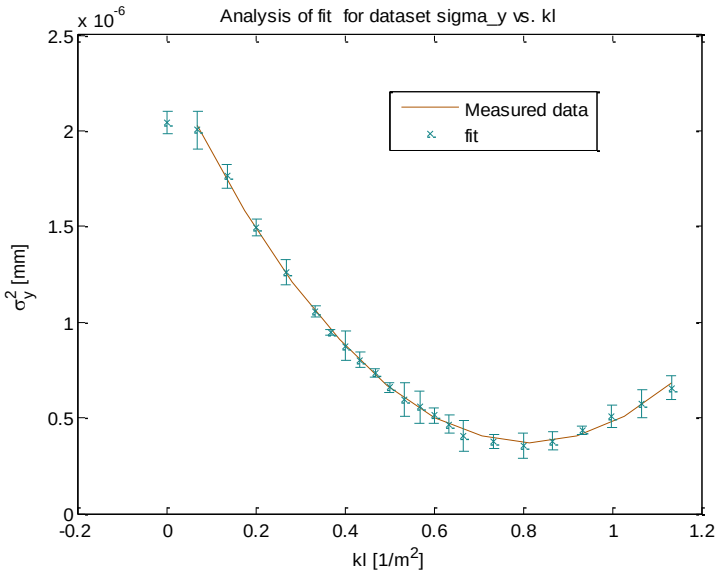
## ○ First beam from gun (23 May)



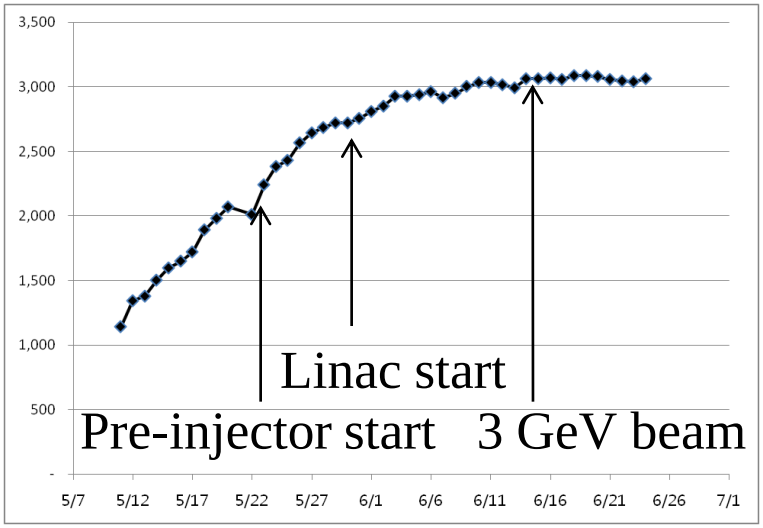

## ○ Emittance measurement (H/V: 600/800 nm @ 100 MeV)



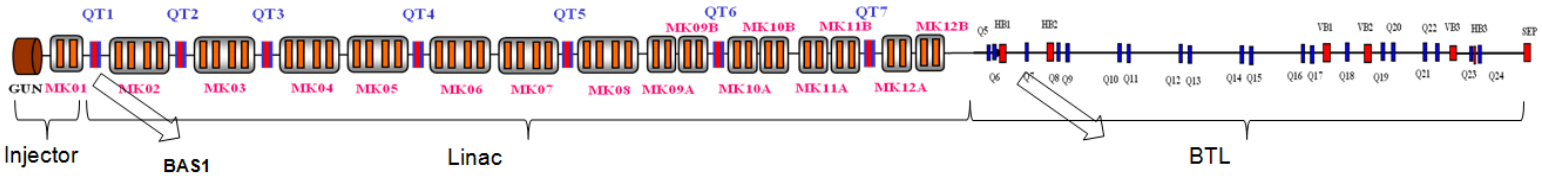
# Linac & BTL commissioning

## ○ 3 GeV beam (13 June)



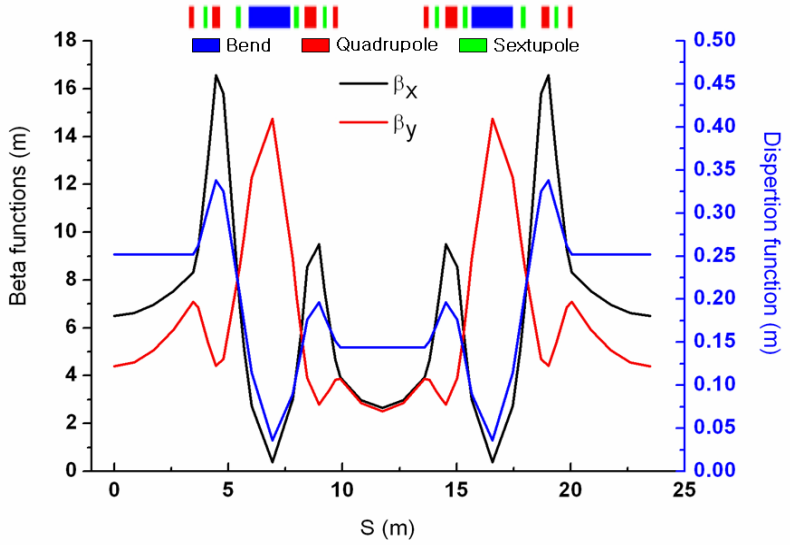

## ○ Beam at injection (29 June)

## ○ Summary

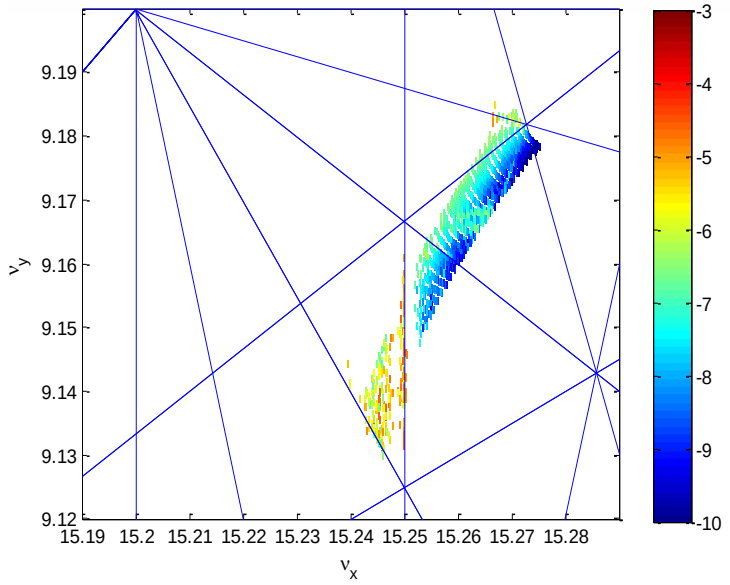


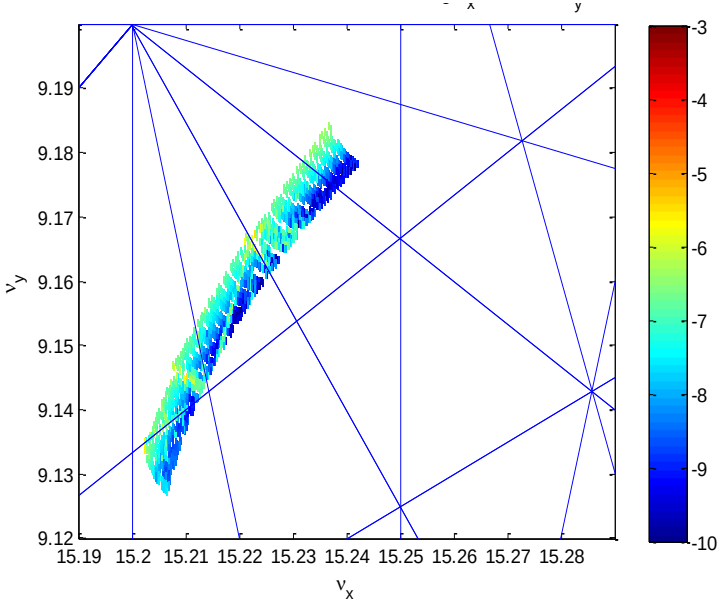

| | | | | |
|---|---|---|---|---|
| **Charge** | 0.8 nC | 0.4 nC | 0.3 nC | 0.2 nC |
| **Emittance** | 800 nm | | | 30 nm |
| **Energy jitter** | | | 0.12 % | |

# PLS-II Storage Ring



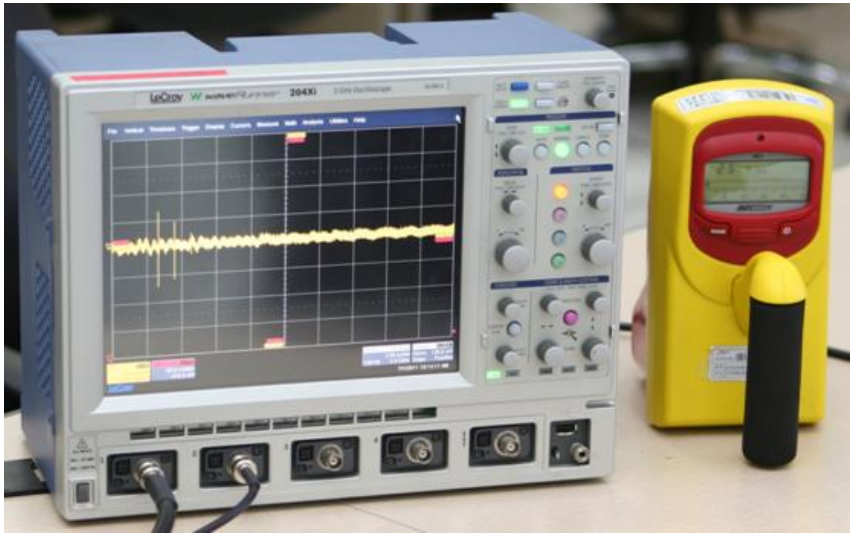

- Beam Energy 3.0GeV
- Beam Current 400mA
- Lattice DBA
- Superperiods 12
- Emittance 5.8 nm·rad
- Tune 15.245 / 9.18
- RF Frequency 499.97 MHz
- Energy spread 0.1%



# First turn & Kicker fire

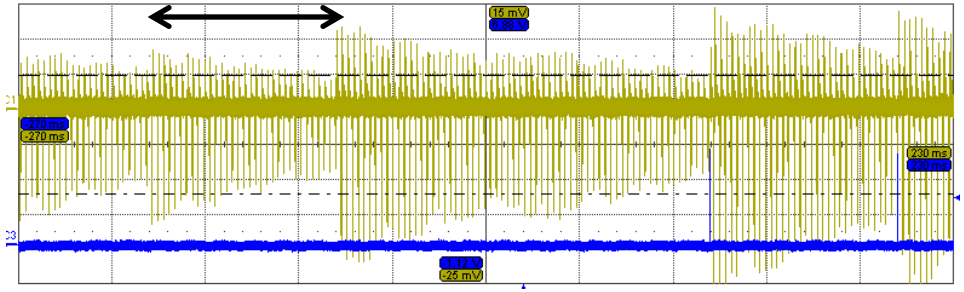
## ○ First turn (1 July)



Sextupole on / Bending 3.00 -> 3.04 GeV

## ○ Kicker fire (5 July)

0.1 s

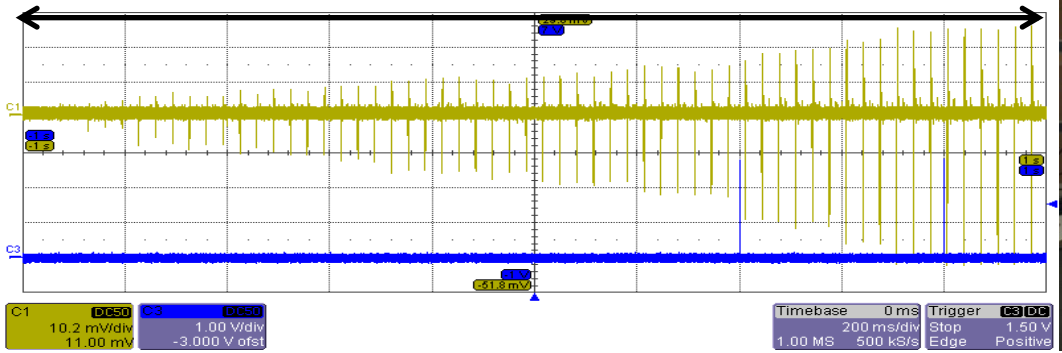


# Beam storage

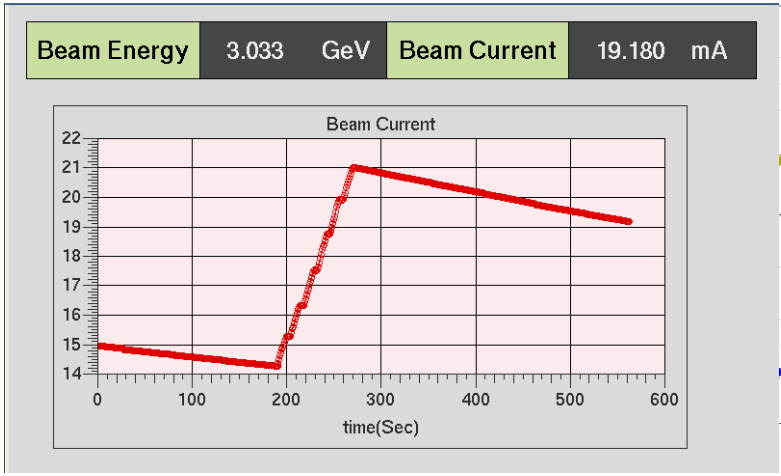
## ○ Beam storage

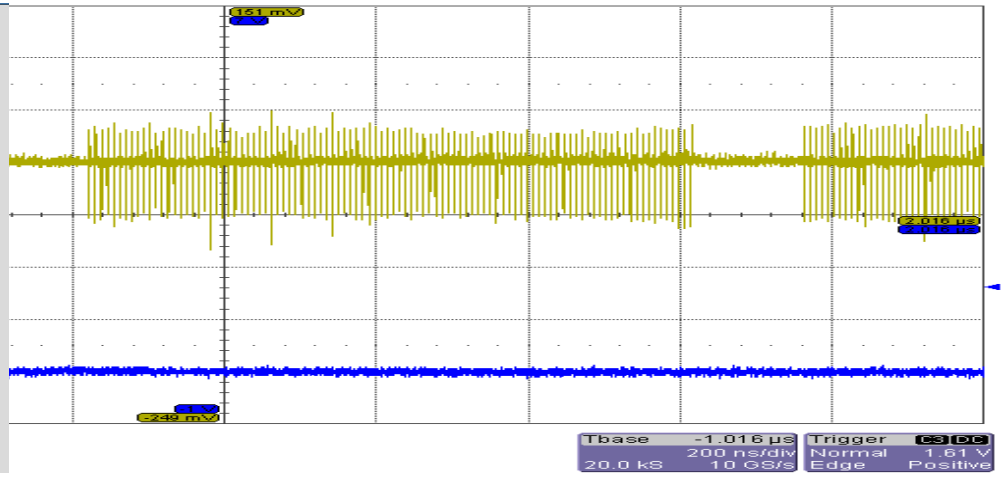
- First beam storage : 5 August
  (Kicker voltage : 13 kV -> 10 kV)
- 20 mA beam storage : 9 August

2 s

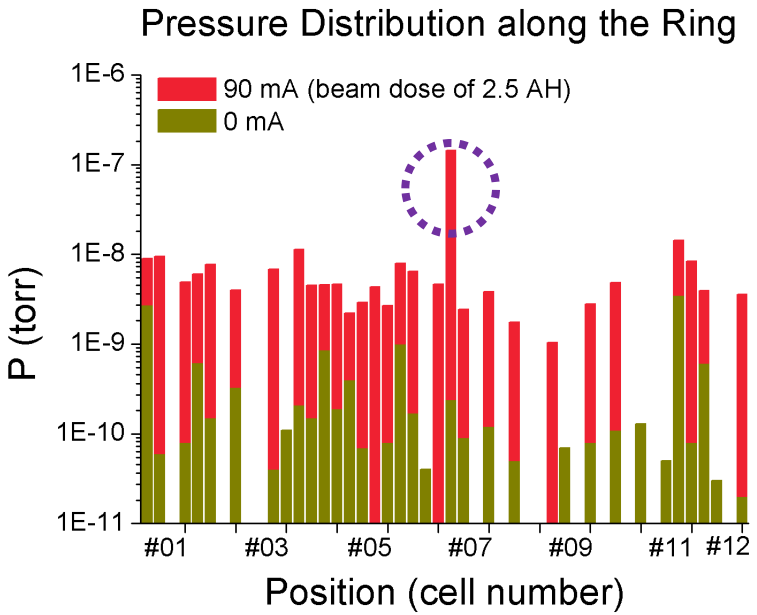


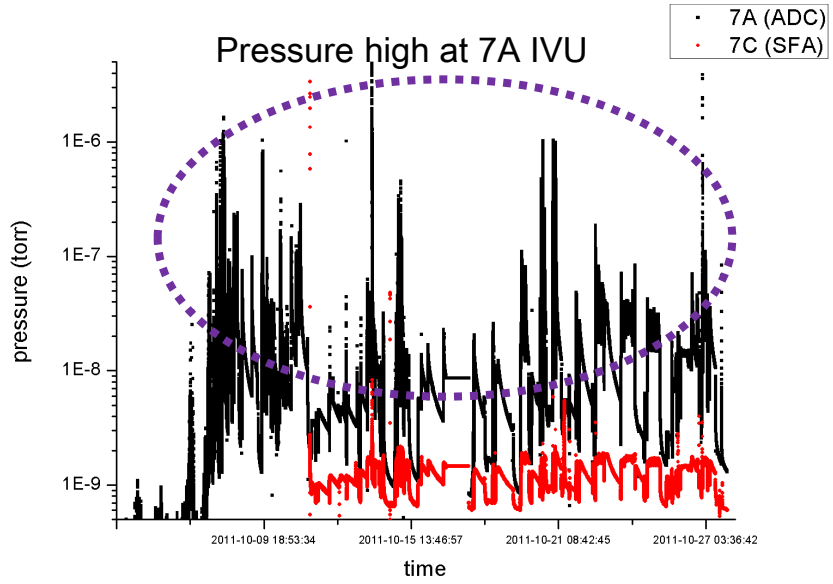


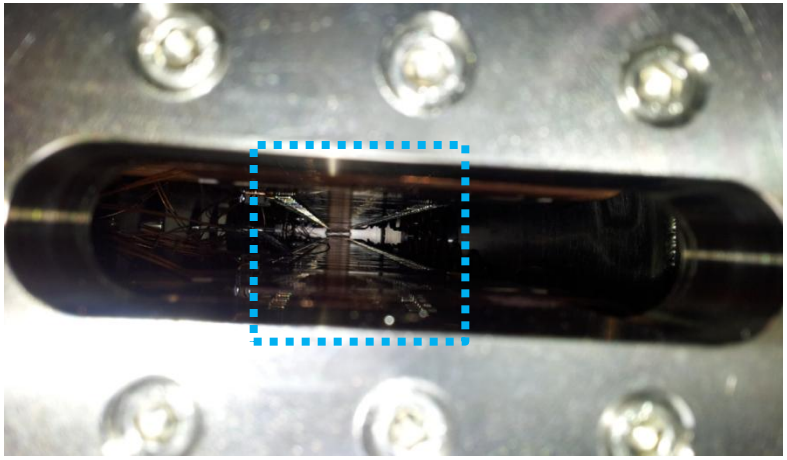


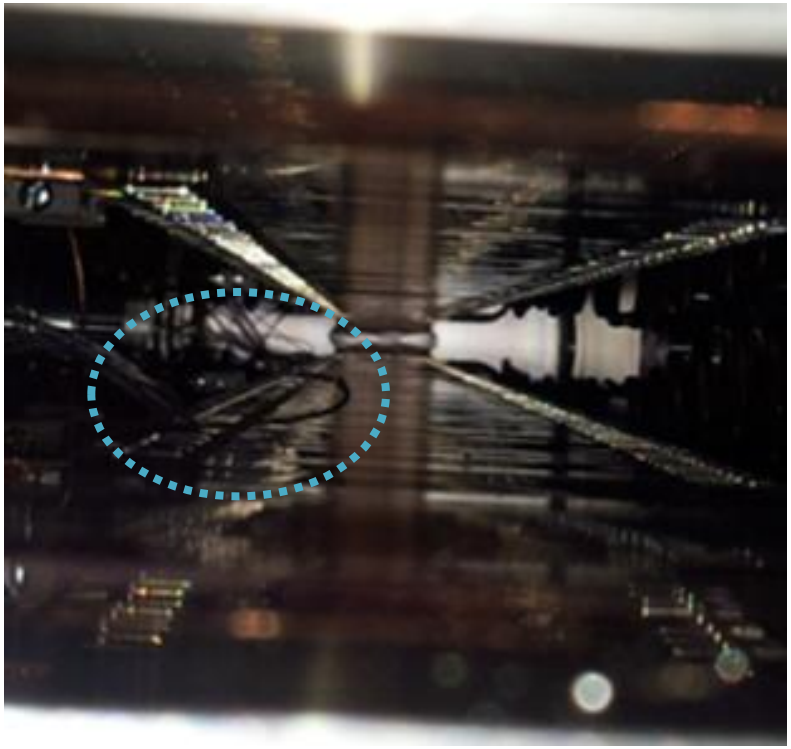



# Unexpected obstacle



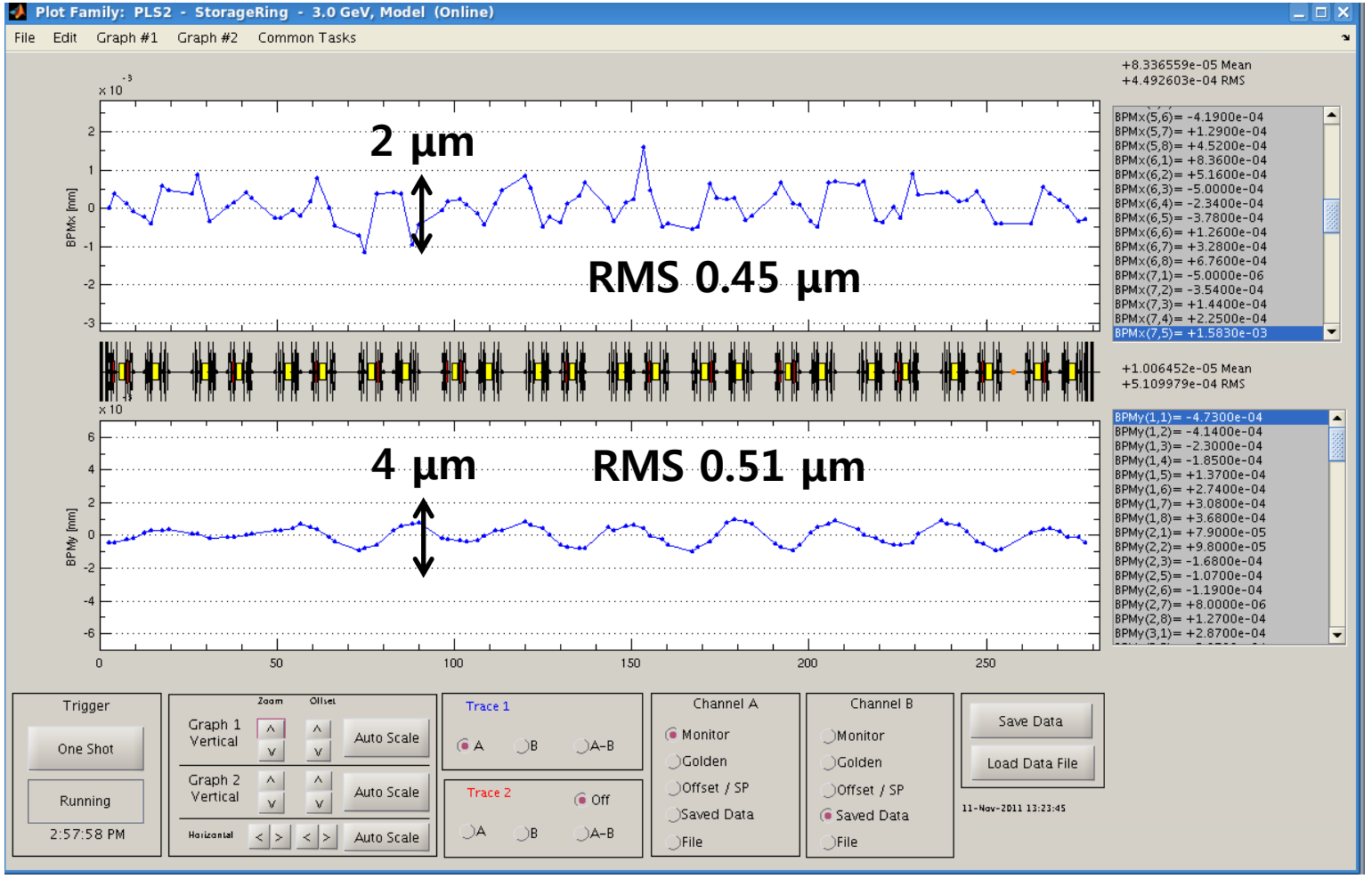





# Ring setup

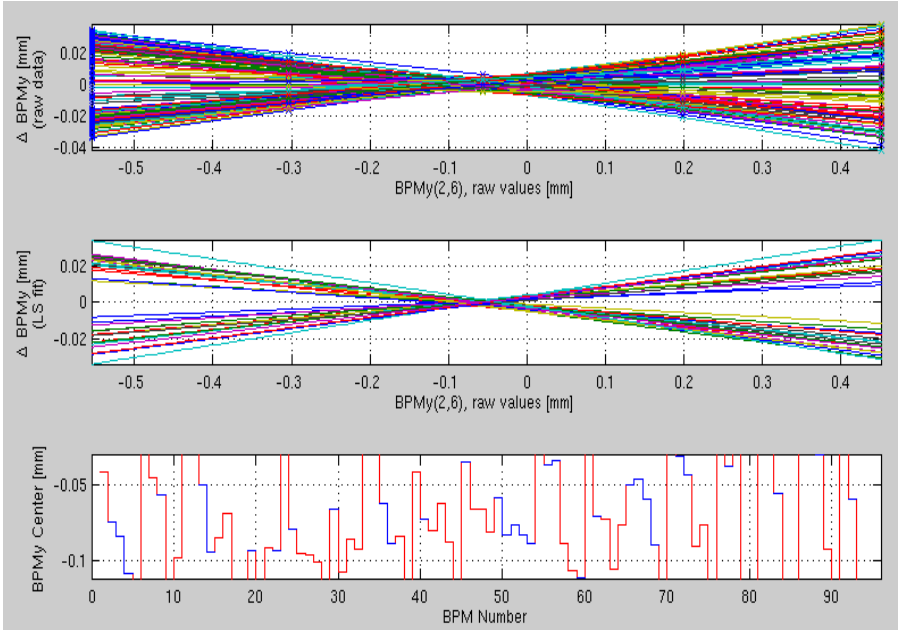
## ○ Fine orbit correction

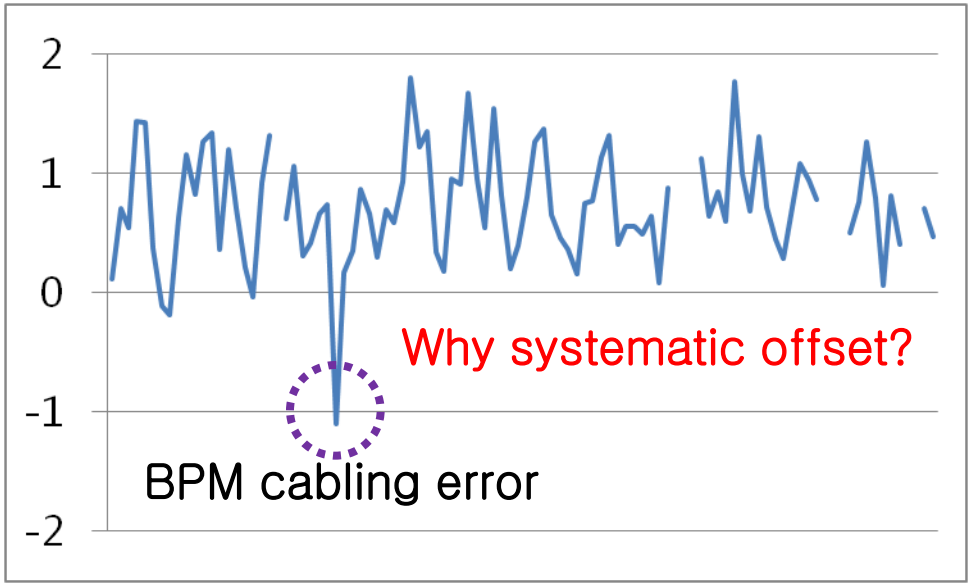
- 96 BPMs and 96 Slow correctors
- 96/93 Singular values

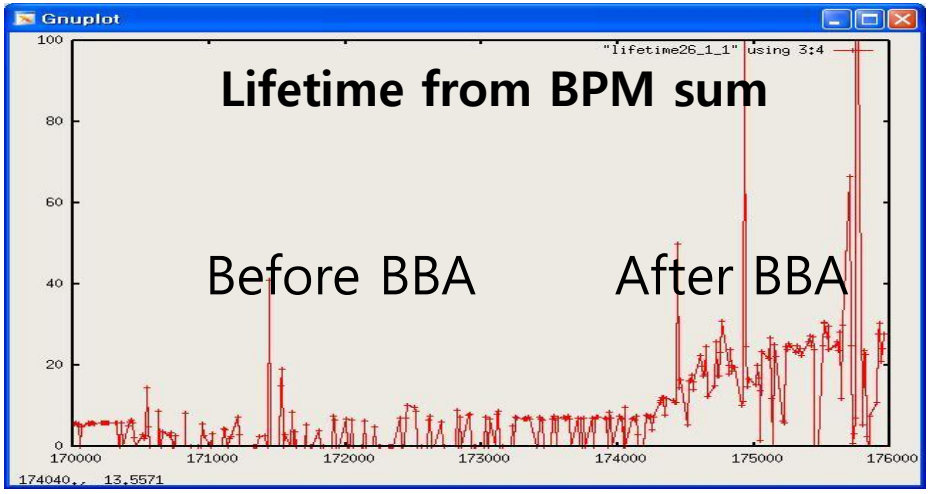


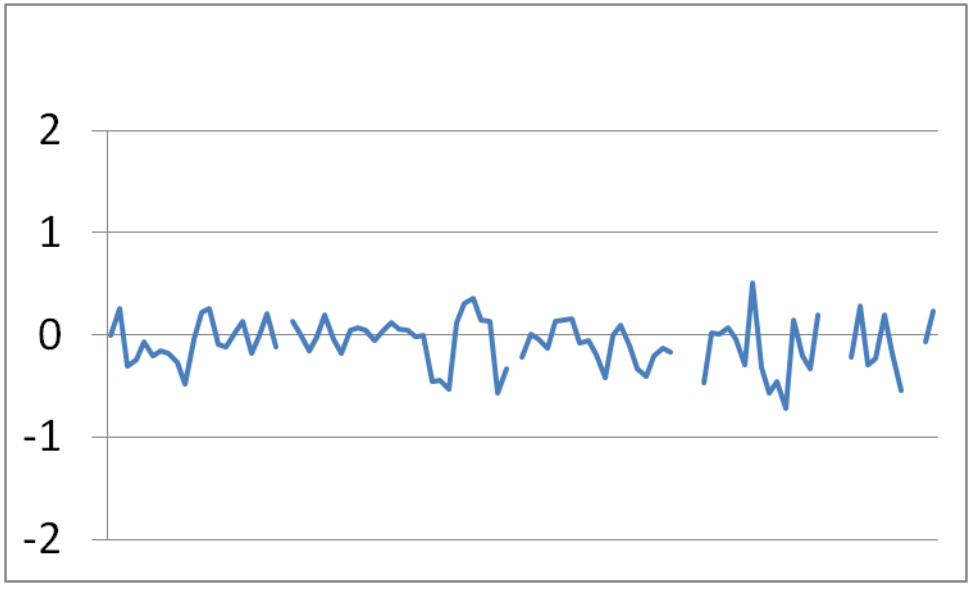
# Ring setup

## ○ Beam based alignment



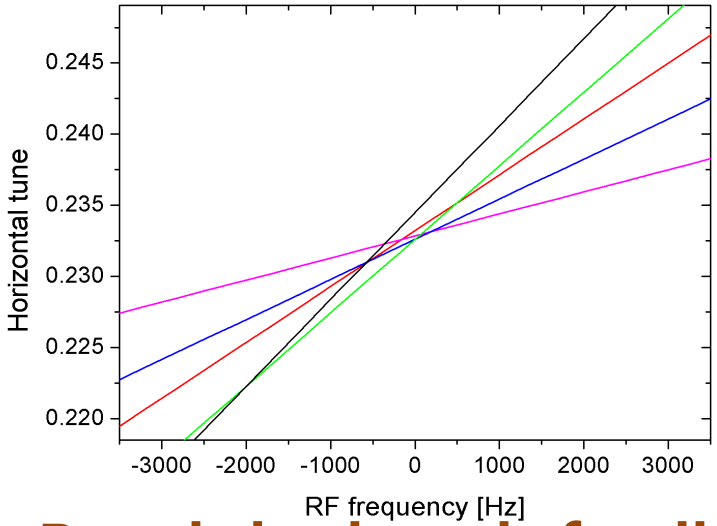



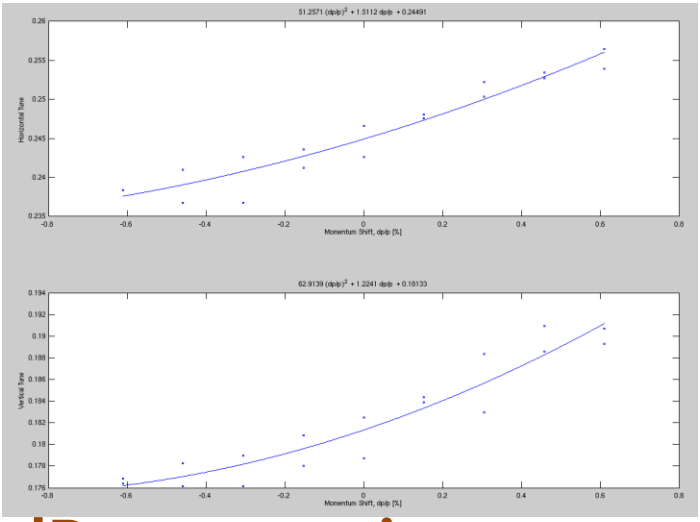



# Ring setup

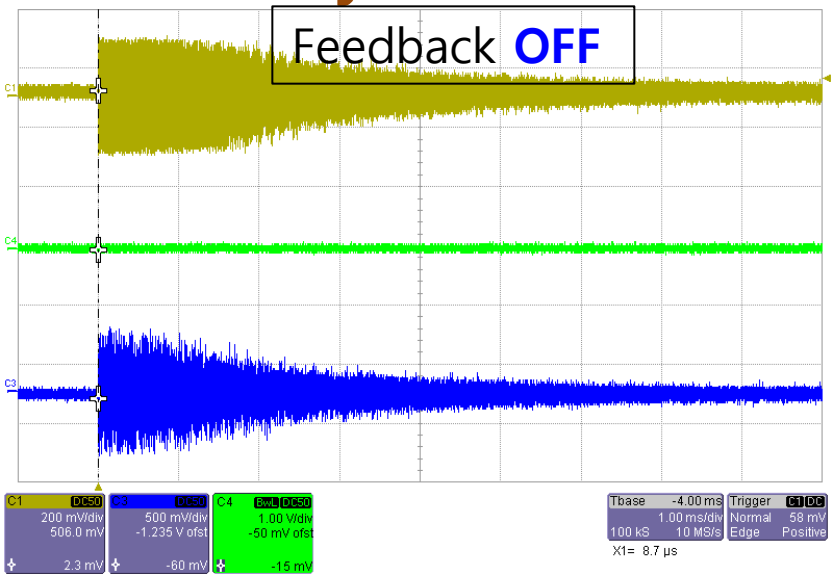
## ○ RF frequency optimization

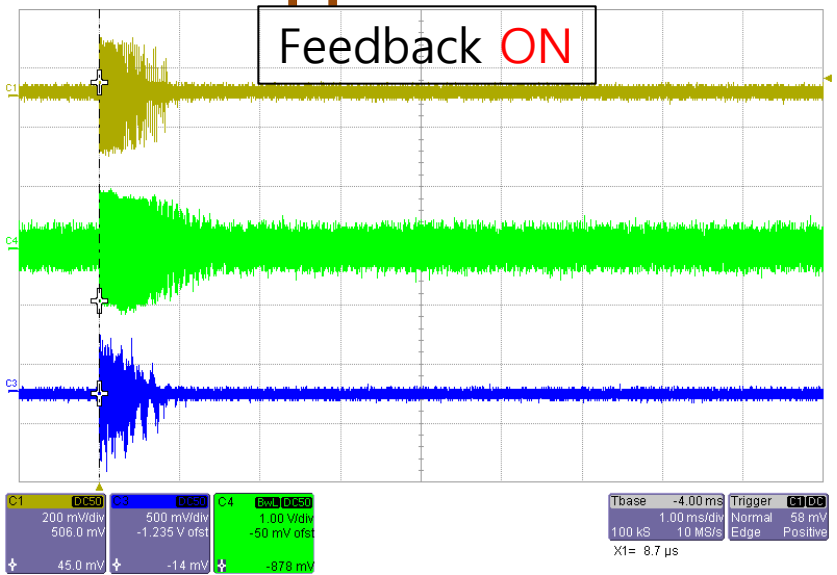



## ○ Chromaticity ; 1~2



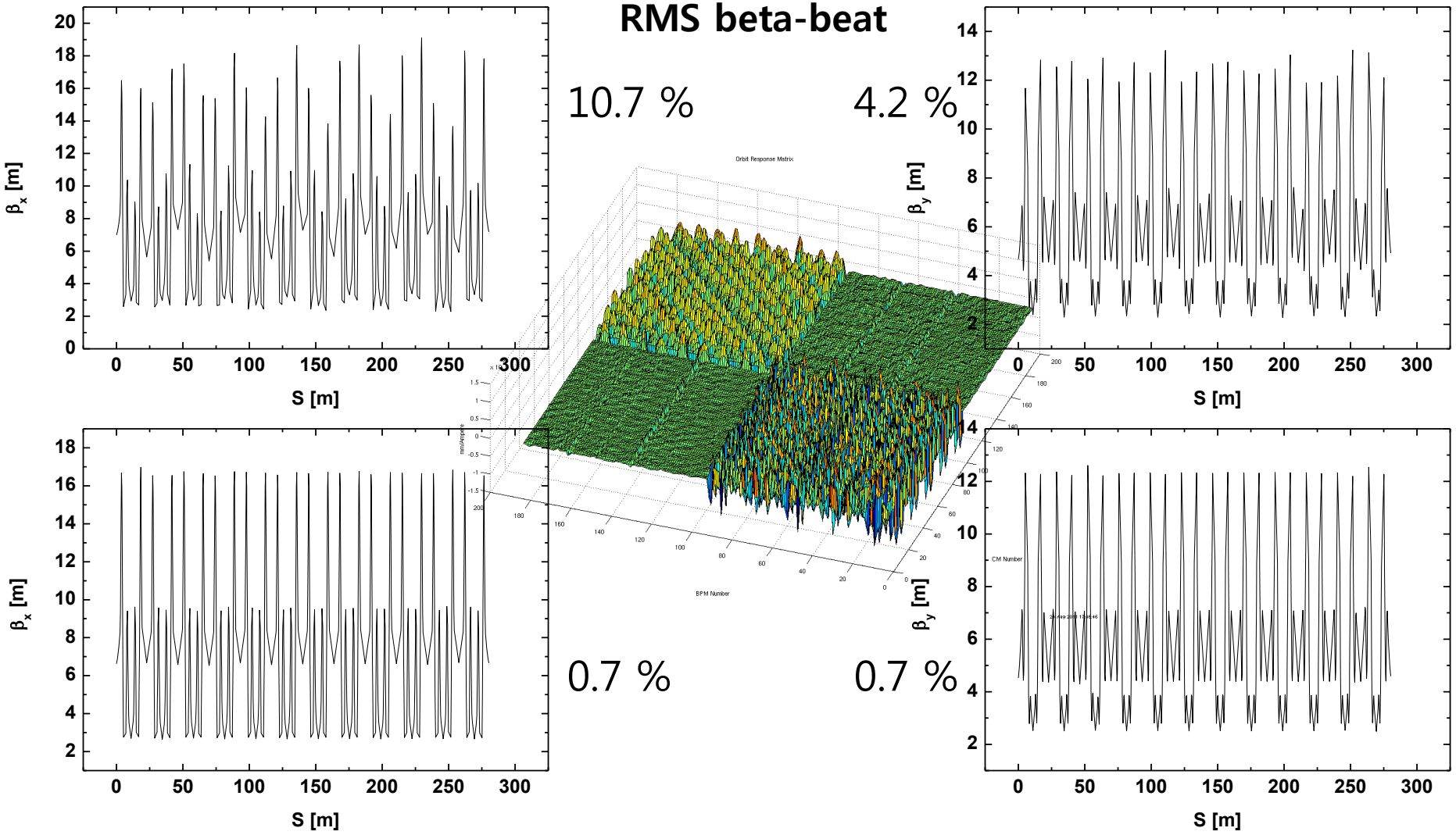
## ○ Bunch by bunch feedback; 20 dB suppression



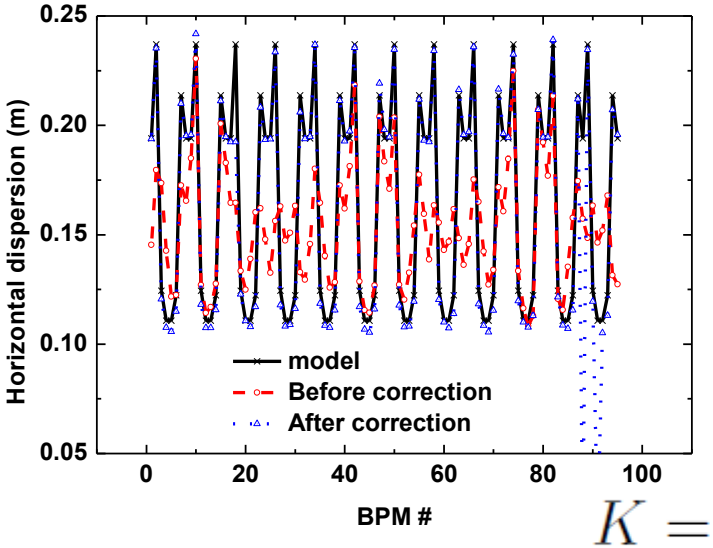
# Ring setup

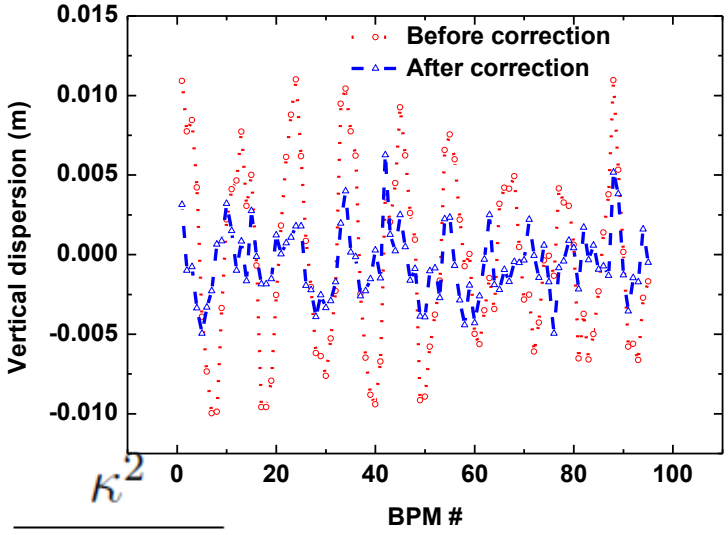
## ○ LOCO application; Beta correction



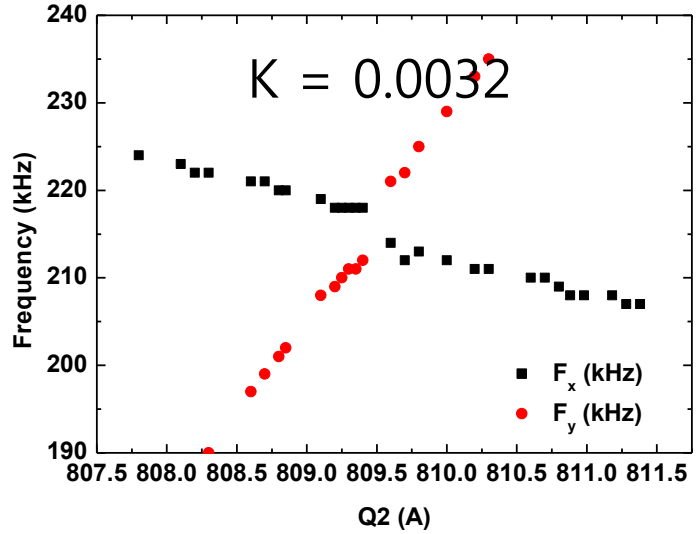
# Ring setup

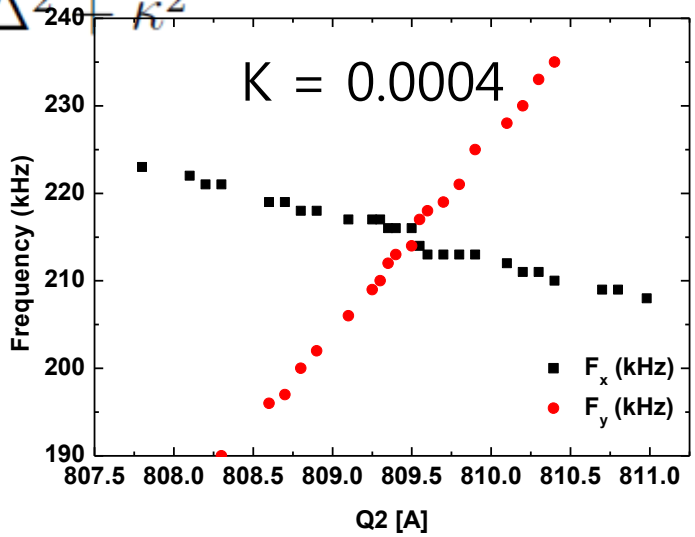
## ○ LOCO application; Dispersion and coupling correction




$$K = \frac{\epsilon_y}{\epsilon_x} = \frac{\kappa^2}{\Delta^2 + \kappa^2}$$



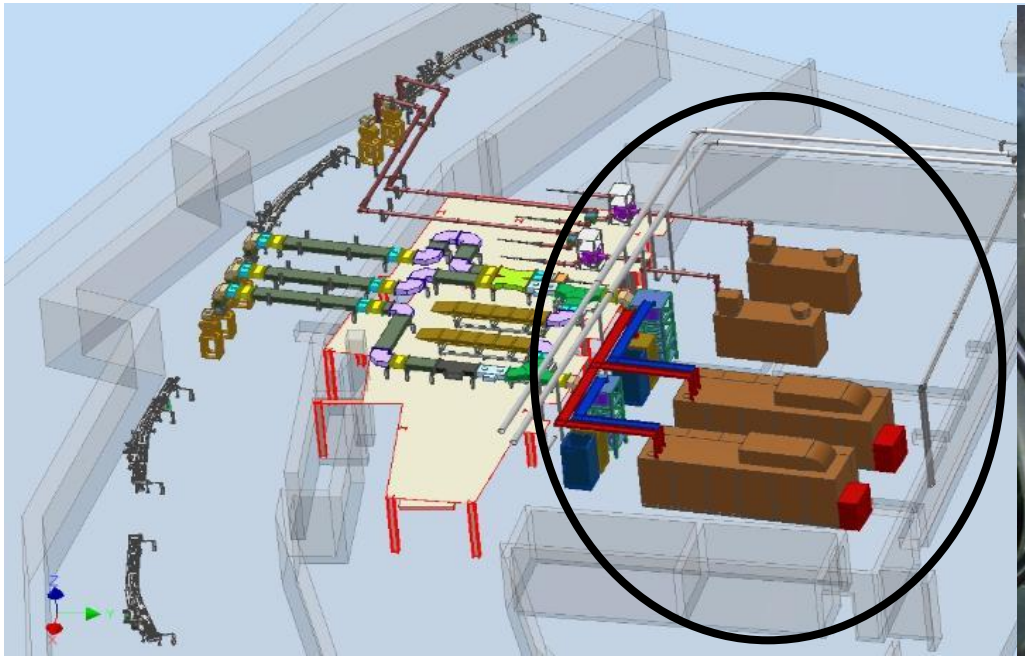



# RF cavities system

## ○ PLS-II RF chracteristics

- 1.85 MV gap voltage
- 4 cavities
- RMS 0.1 % amplitude
- RMS 0.1 degree
- High power RF
- Digital field control

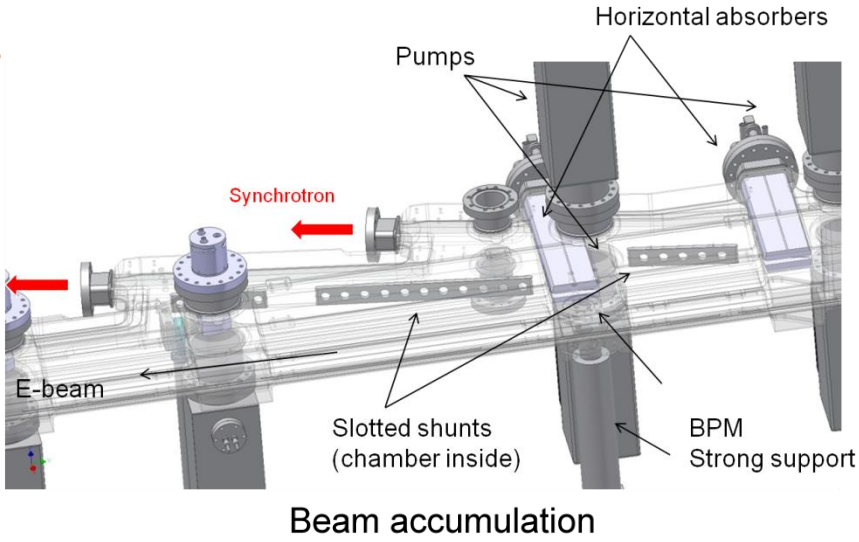
| Specification | Phase-I(~2012) | Phase-II(2013~) |
|---|---|---|
| Energy/Current | 3.0GeV/100mA | 3.0GeV/200mA |
| Losses with IDs | 1,242keV | 1,242keV |
| Beam Power | 124kW | 248kW |
| RF Cavities (Q'ty) | NC x 5 | SC x 2 |
| RF Power Sources | (75x2)+300kWx2 | 300kWx2 |
| Cryomodule | installing | ~1.8MV/each |
| Cryogenic | commissioning | ~700W |



# Vacuum system

## ○ PLS-II Vaccum chracteristics

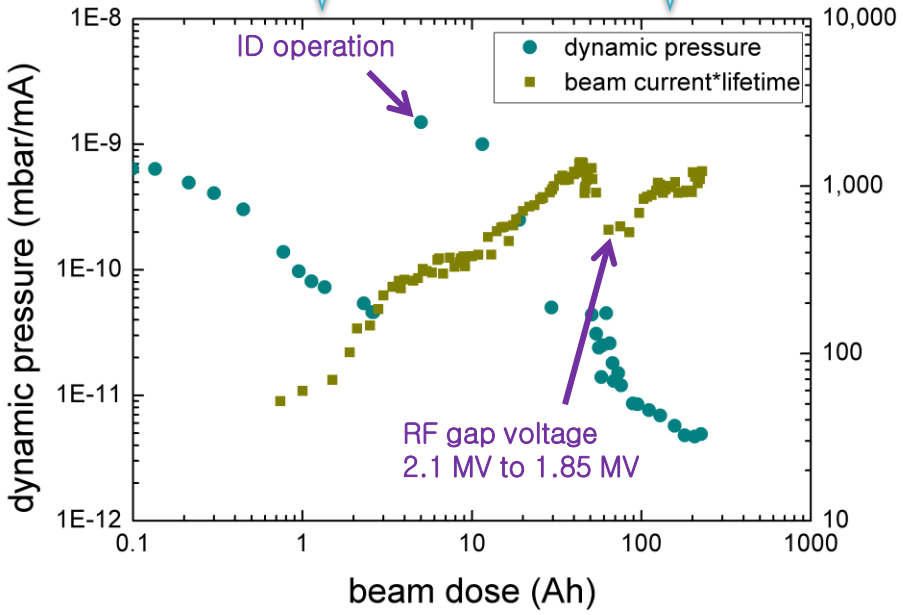
- Aluminium vacuum chambers
- Combination pumps (NEG+SIP) as main pumping

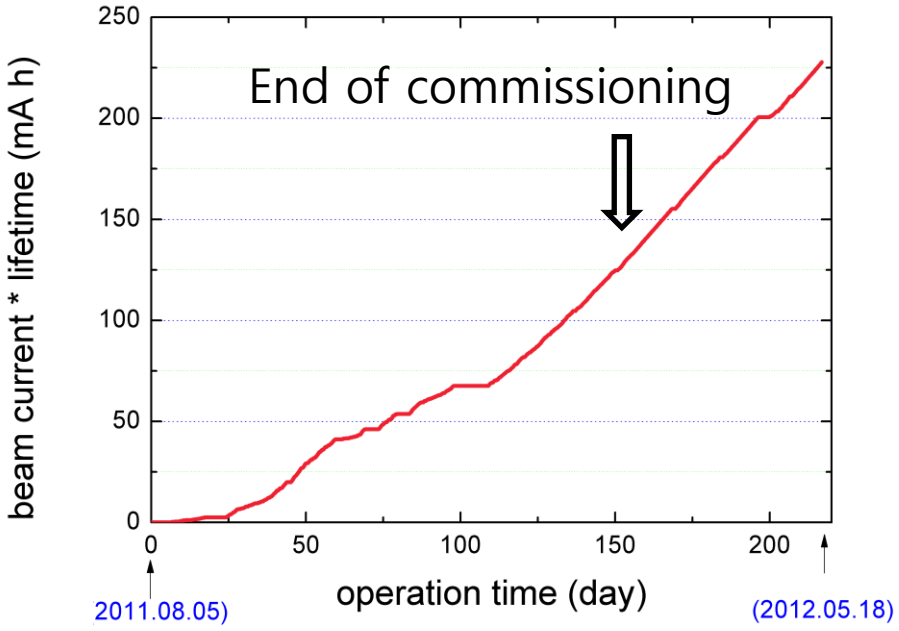



Beam accumulation

Lifetime is limited by vacuum.

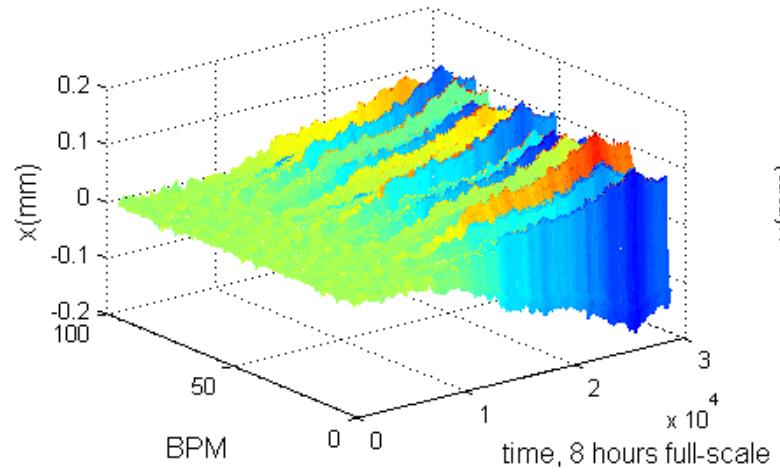
Lifetime is limited by Tousheck effect.

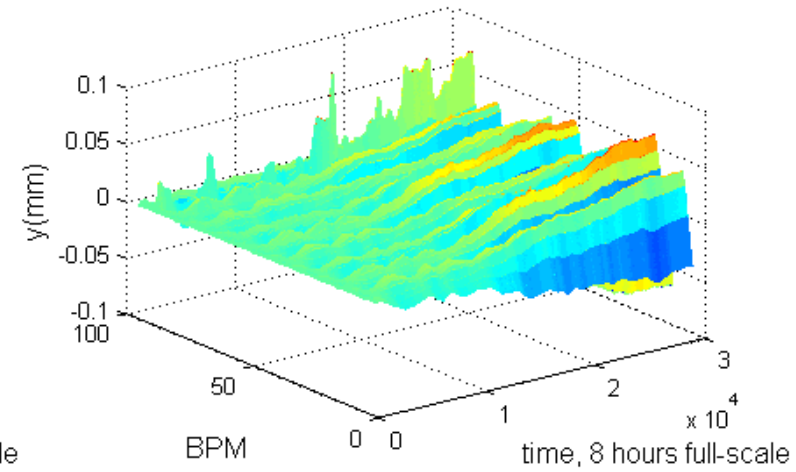


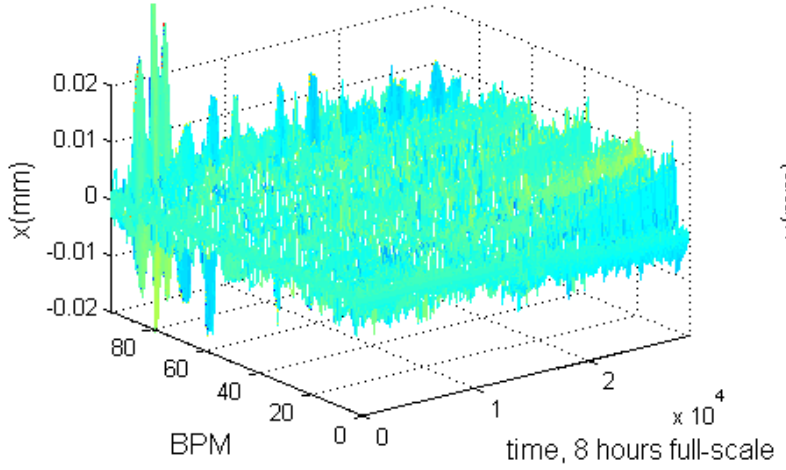
# Orbit stability

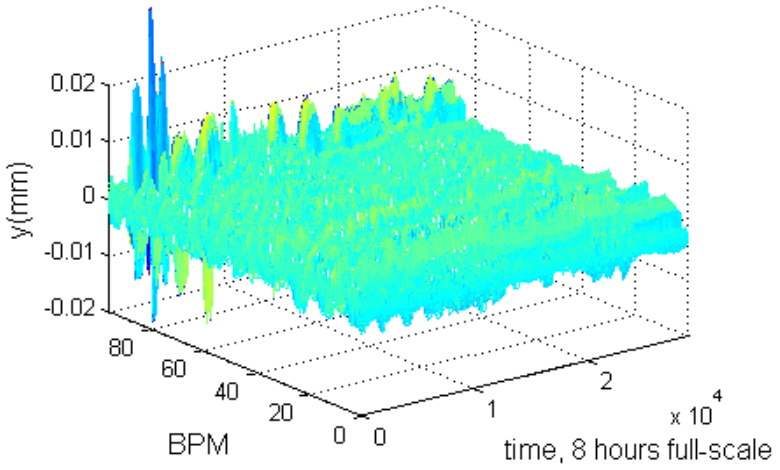
Orbit drift with no feedback (2012.02.12 08:00 ~ )



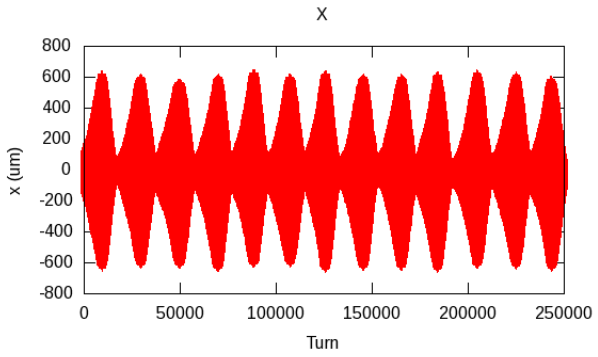

Orbit drift with feedback (2012.02.13 00:00 ~ )

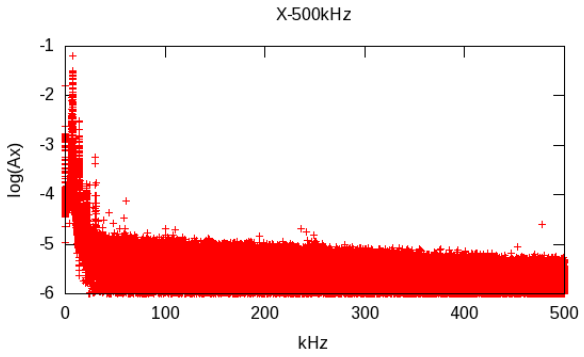


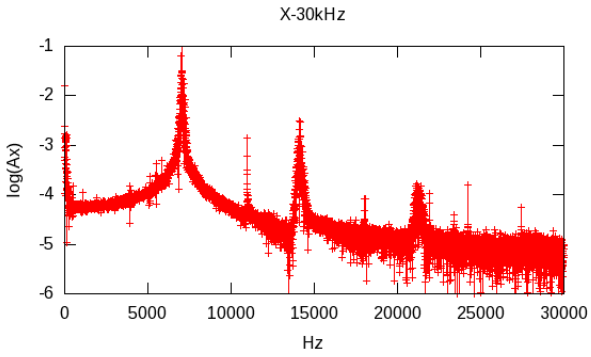



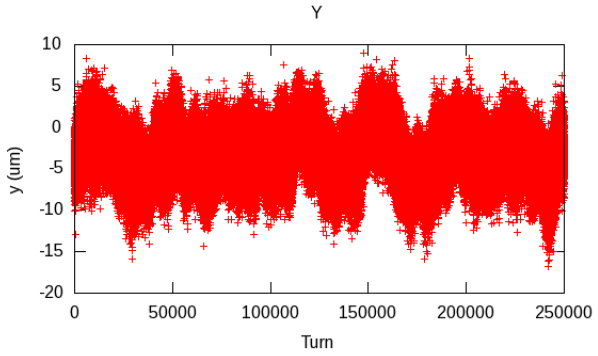
# Instability

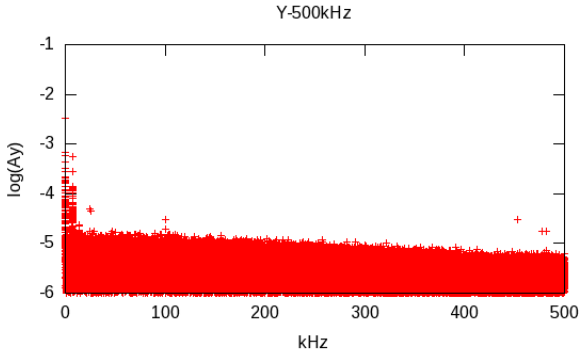
## ○ LCBI by RF HOM ; X, Sum spectrum @ 7kHz

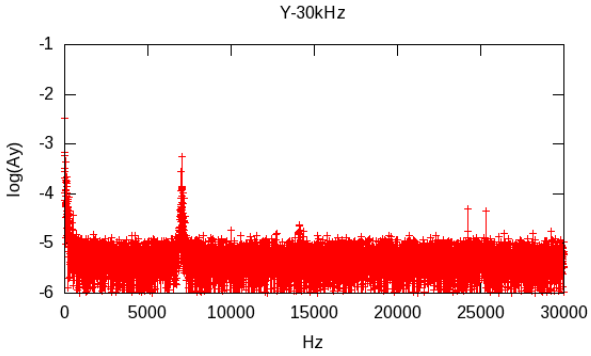


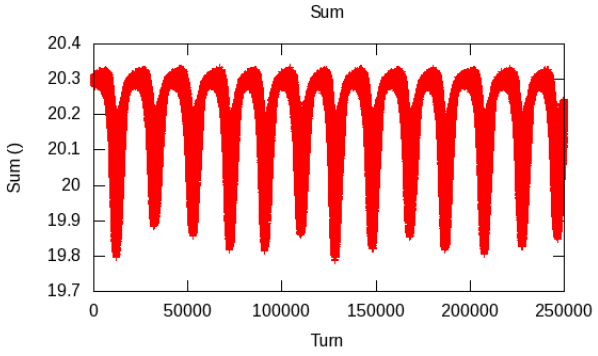



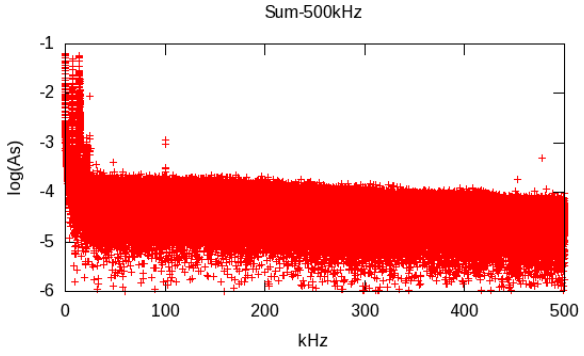



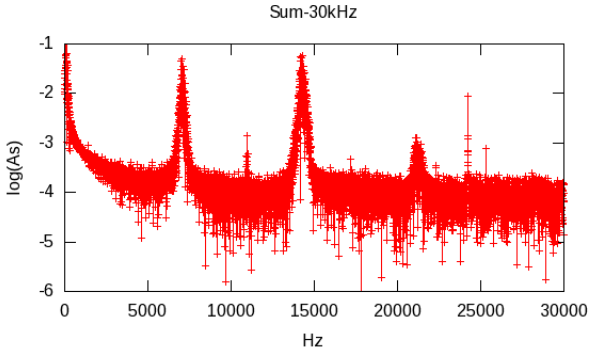



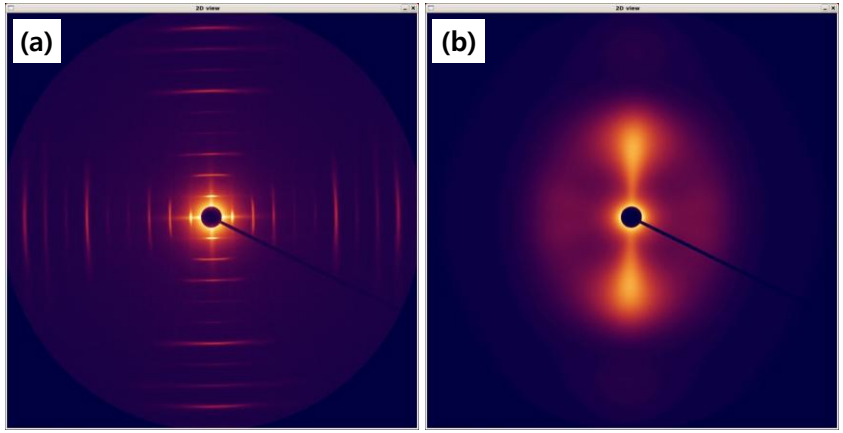



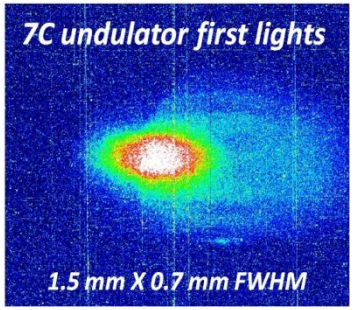



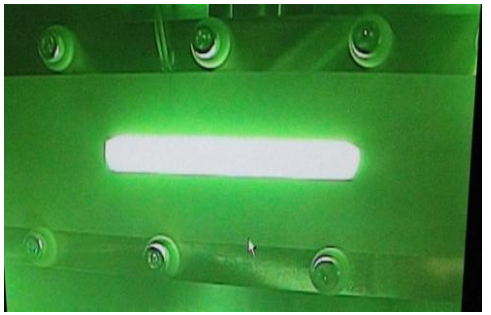



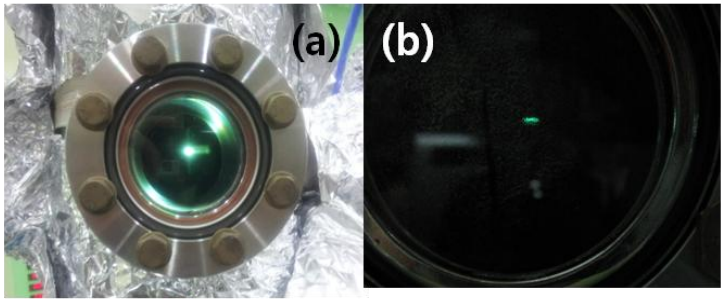
# Beam line commissioning

## ○ 30 Beam line including 14 IDs (10 IVUs)

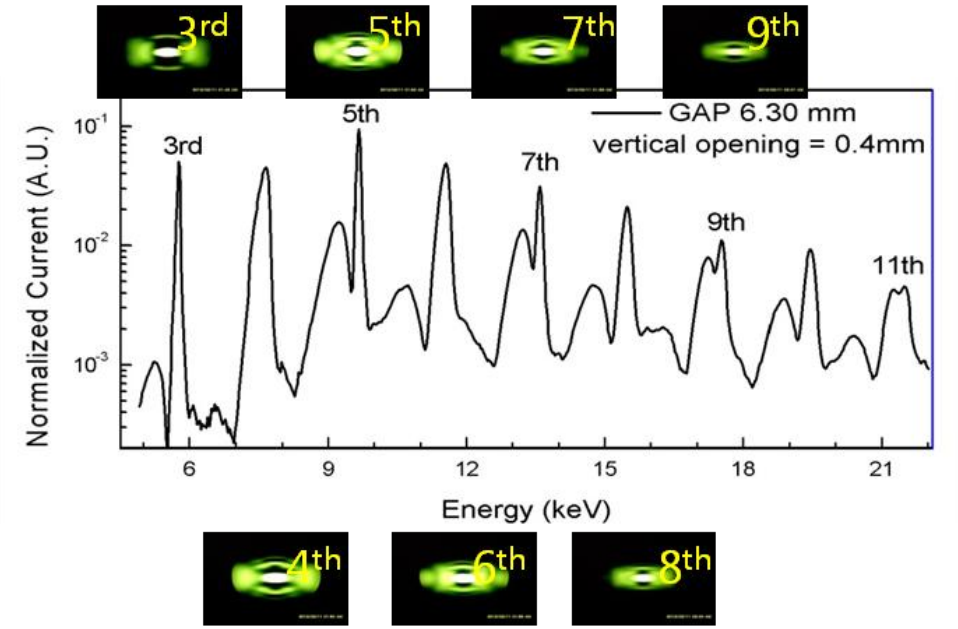


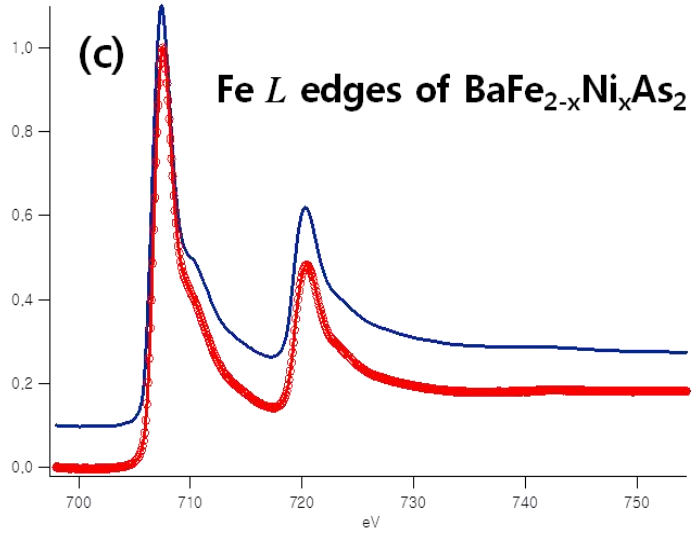





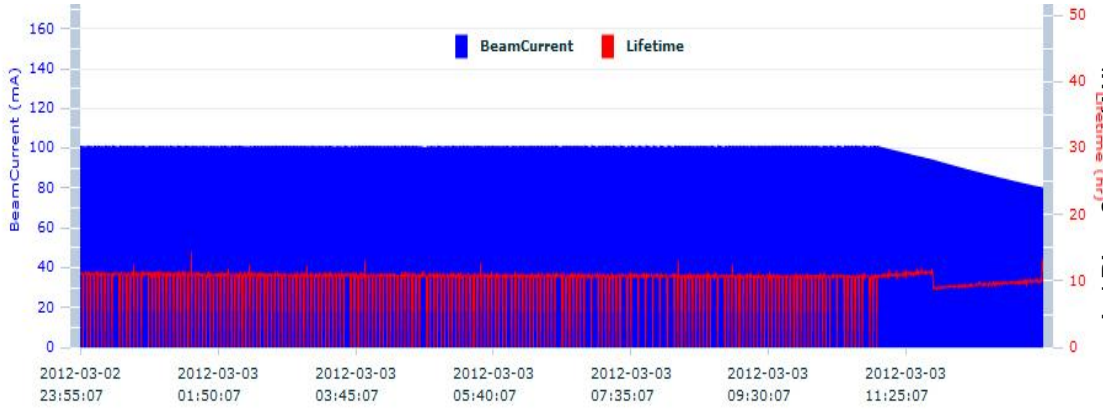

## ○ Spectrum from SFA IVU

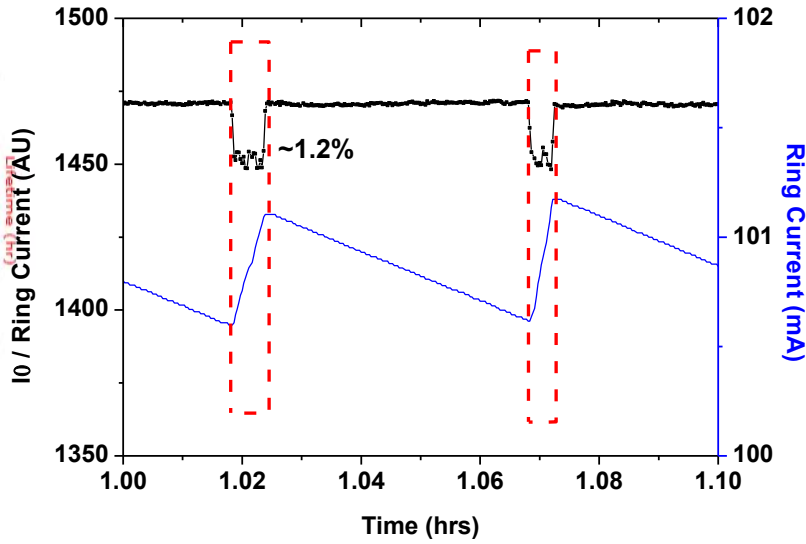


# Top-up commissioning

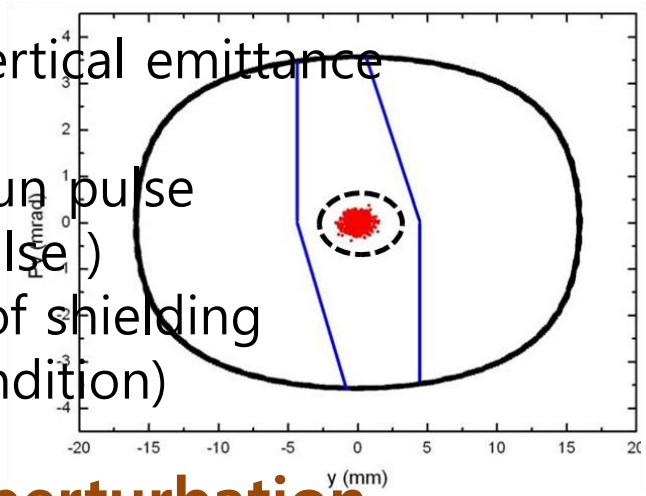
## ○ On test stage

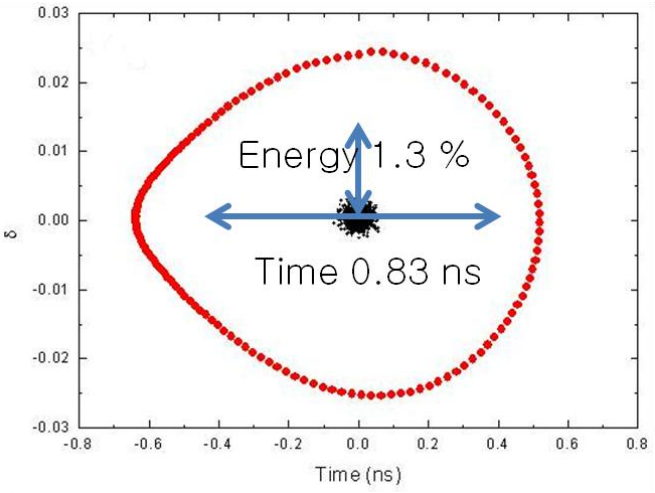



## ○ Radiation safety issue

- Reduction of vertical emittance (Slit before SR)
- Reduction of gun pulse (Current 2ns pulse )
- Enforecement of shielding (Keep same condition)



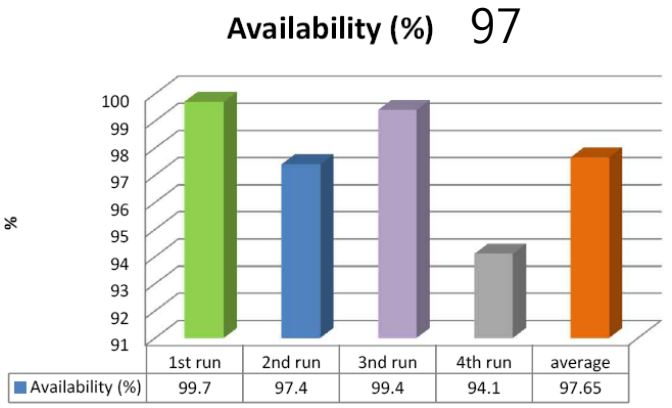



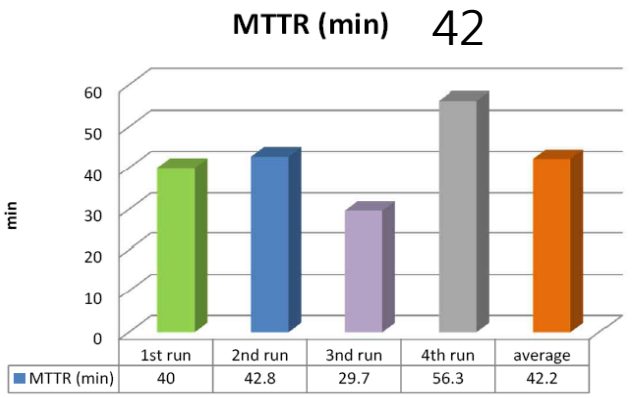

## ○ Stored beam perturbation

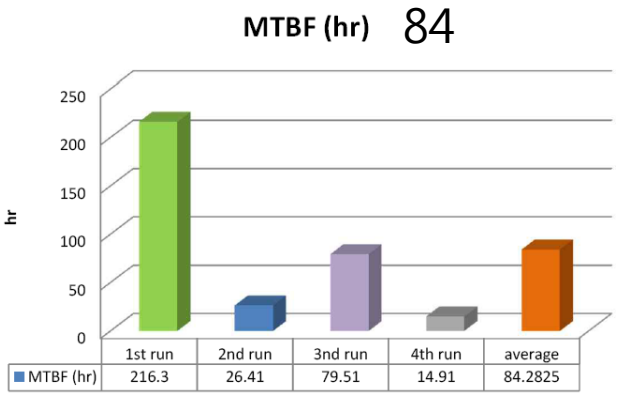
- On plan to improve injection system

# Post commissioning; User operation

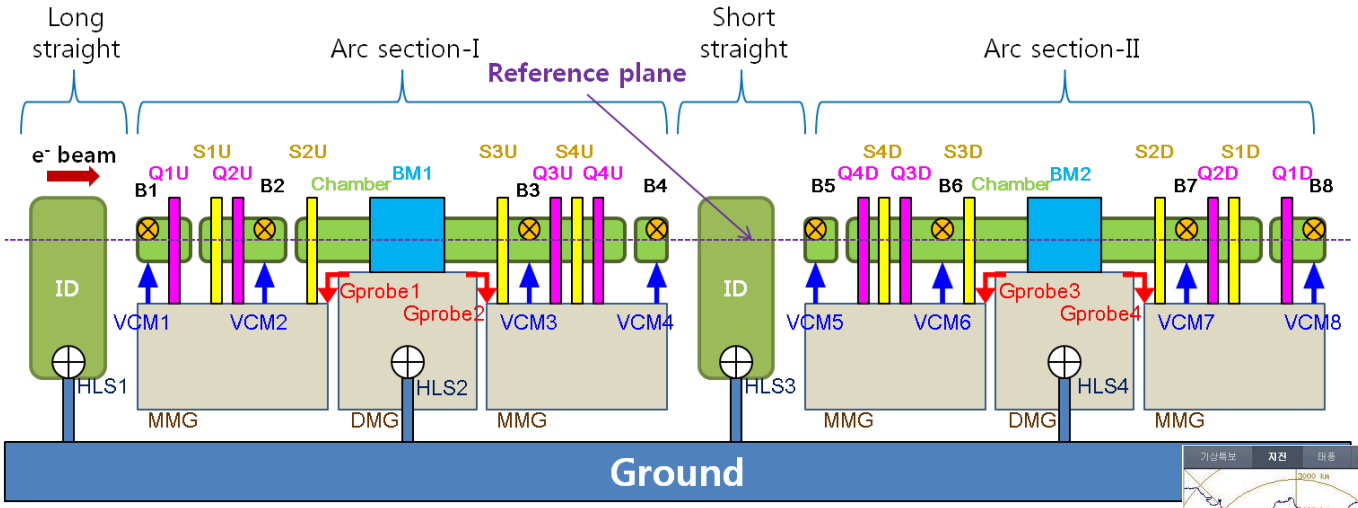
- So far, 207 experiments
- So far, 1079 people

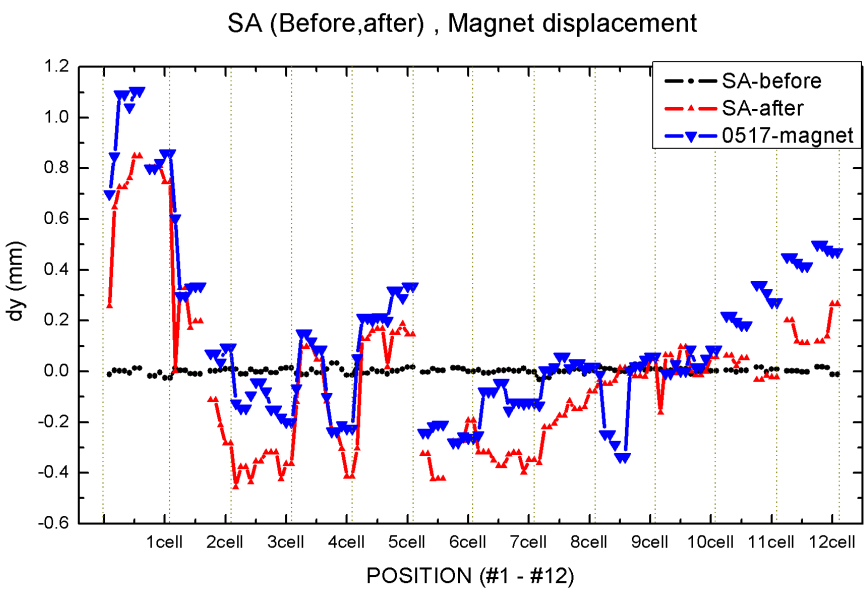



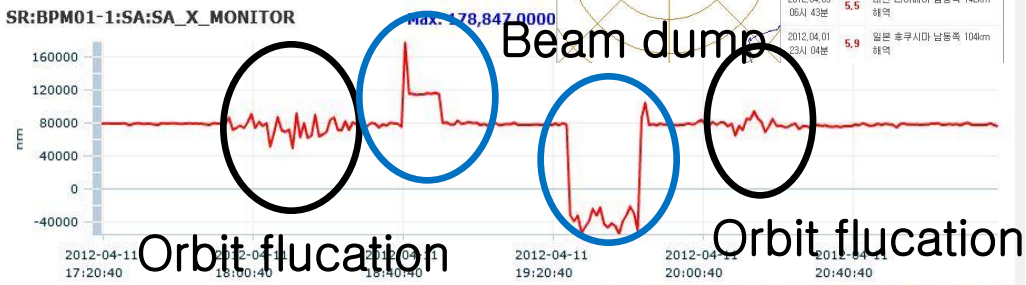
# Post commissioning; Ground motion

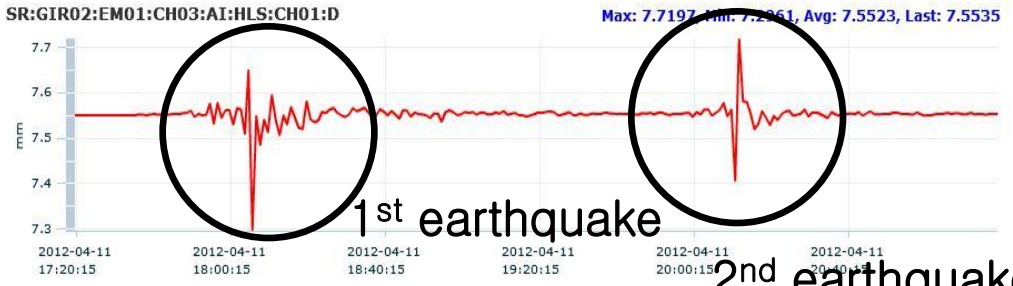




Machine check

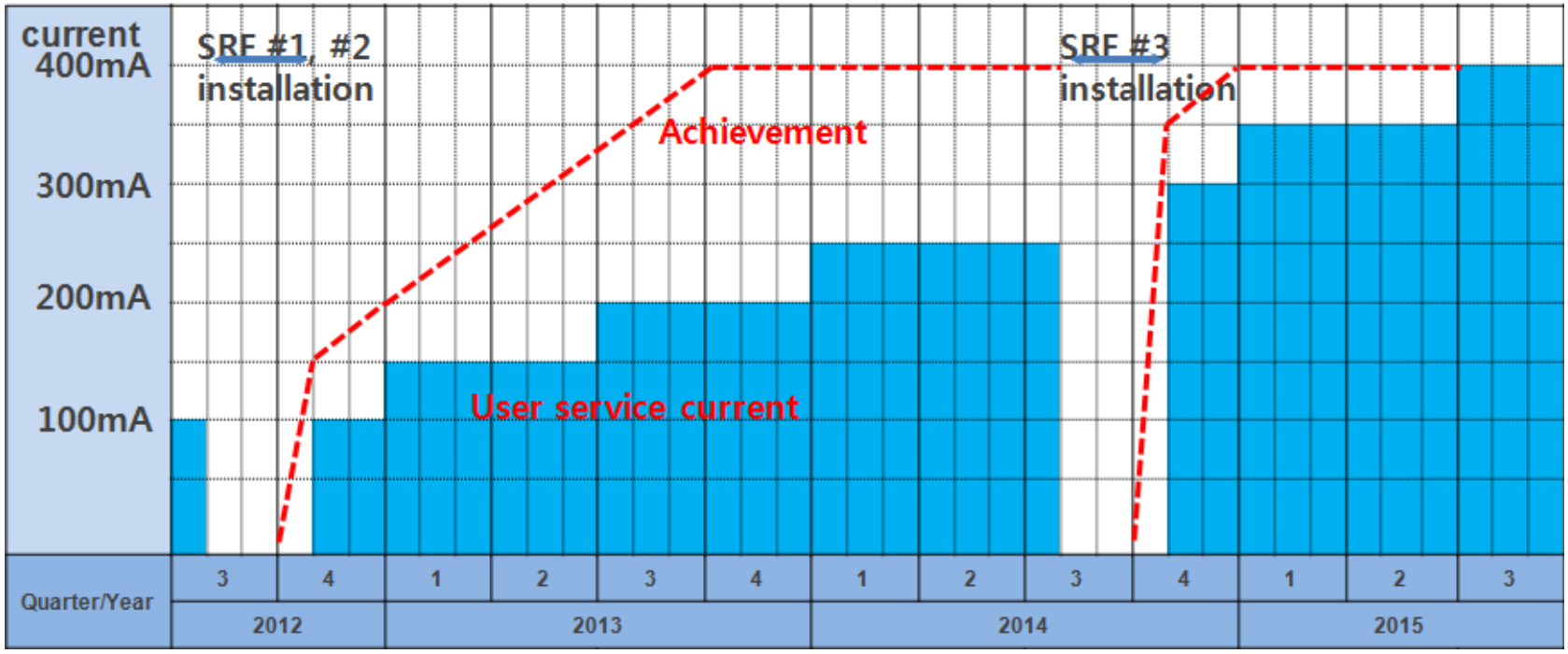


# Summary

○ Current status / Commissioning Goals / PLS-II Goals

- Beam energy : 3.0 / 3.0 / 3.0 GeV
- Current : 100 / 100 / 400 mA
- Storage Ring Emittance : 5.8 / 5.8 / 5.8 nm·rad
- Operation mode : Decay / Top-up / Top-up
- No. of Insertion Device : 14 / 14 / 20
- Orbit stability : 2 / 2 / < 1 μm



# Acknowledgements

We really would like to appreciate all efforts and helps from worldwide accelerator physicists.

PAL staffs, even skipping their vacation during PLS-II commissioning, showed much passions with expertise and energy towards the commissioning with fine work.

Thanks so much !