Status of Simultaneous Injection from LINAC

2009/2/9 @KEKB Review

N. Iida

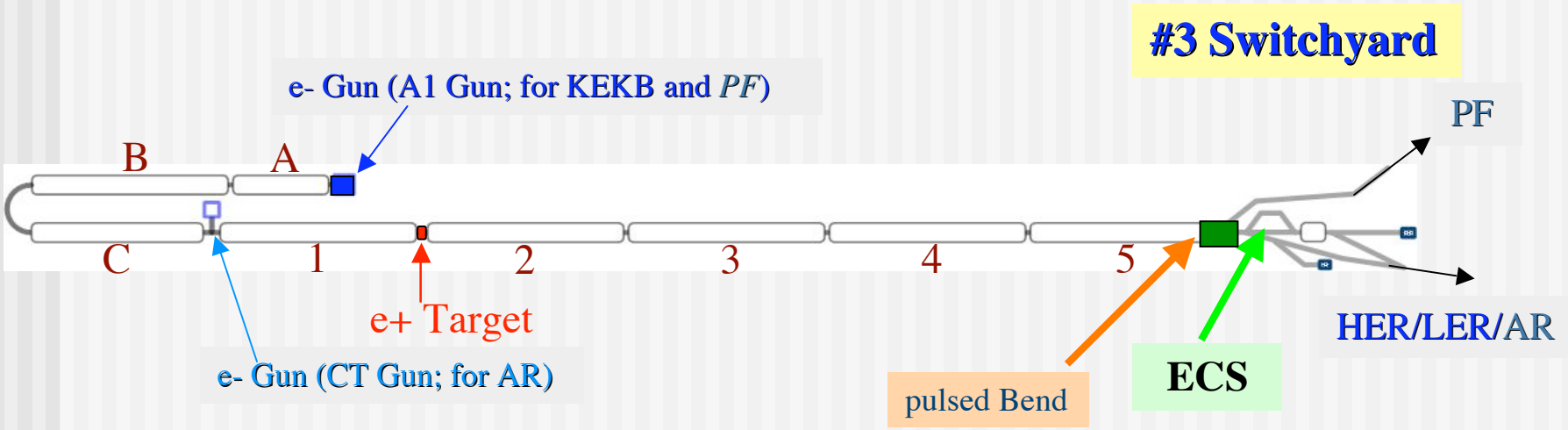
for LINAC Study group

Motivation

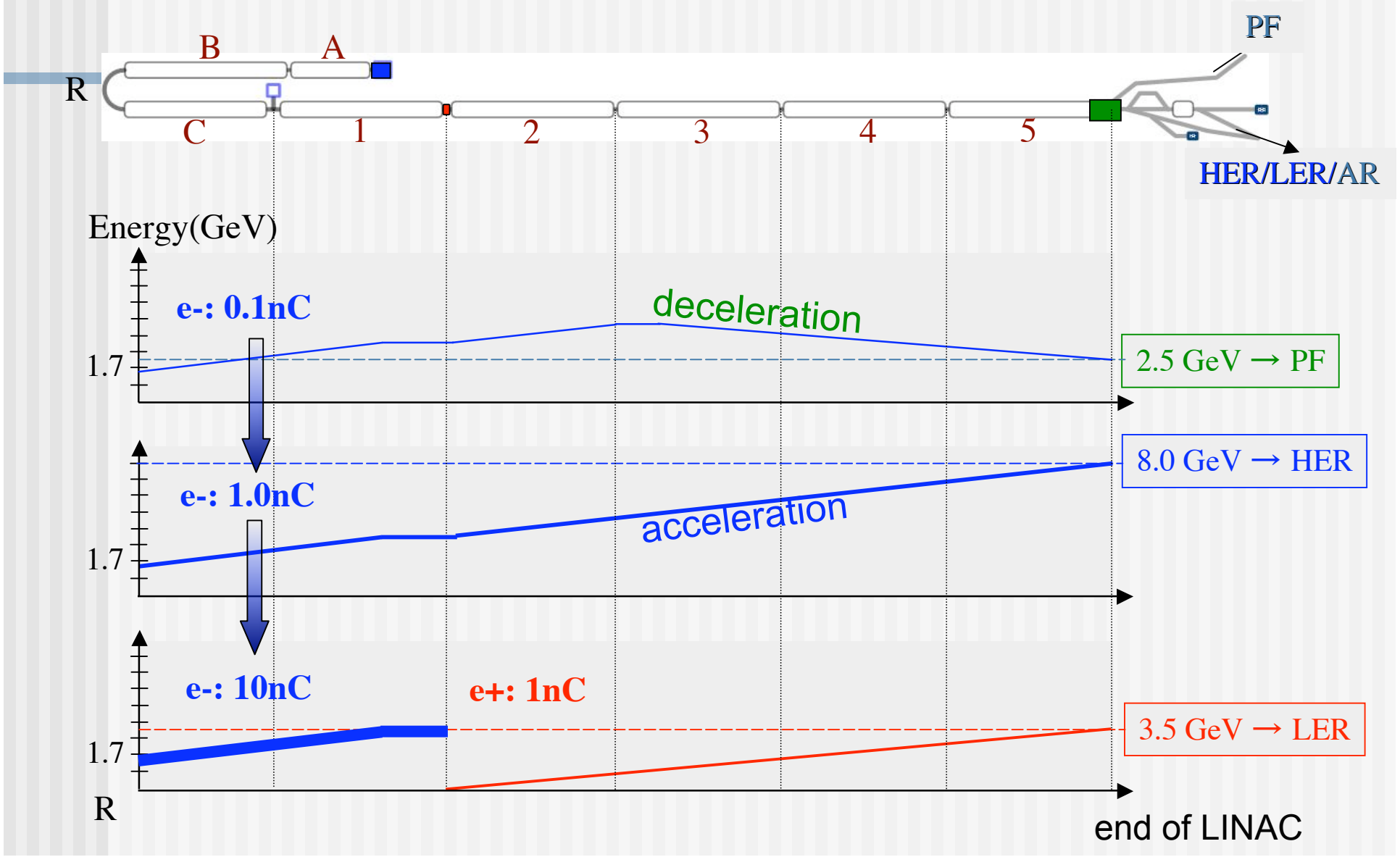
- Switching time for HER/LER injection was more than 30sec.
- Faster switching are required to improve the collision tuning with Crab cavities;
  - Luminosity tuning at constant beam currents
  - Operation at the shorter lifetimes
  - Speed up of luminosity tunings (knob scanning)
  - Prevention of current losses at the head of trains
- PF top-up operation will be started.

KEK Injector LINAC

- **Injector for 4-rings:**
  - KEKB HER (8GeV e-/ 1-nC)
  - KEKB LER (3.5GeV e+/ 1-nC)
    - CIM(Continuous Injection Mode)
  - PF (2.5GeV e-/ 0.1-nC) Twice/ day
  - PF-AR (3GeV e-/ 0.1-nC) Twice/ day



Energy profiles and Charges



Hardware Progress in 2007~2008

- Summer/2007
  - A pulse bend was installed at the branching point for PF beam.
  - PF beam has been produced by A1-GUN.
- Jun/2008
  - e- operation was done keeping the e+ target with a bypass hole inside the beam pipe.
    - Before that, for life extension of bellows used for target insertion, HER/LER injection cycle had been limited more than 5 min.
- Oct/2008
  - 10 pulse steerings were installed in LINAC.
- Nov/2008
  - Event system was introduced for timing control.

“Simultaneous Injections”

1. PF/HER injection — Achieved!
   - Fast switching beam injection
     - Switching time ~ 2 sec.
     - Used in operation (Oct./2007 ~ 10/Dec./2008)
   - Pulse-to-pulse switching
     - Conditional test injection was succeeded.
2. HER/LER injection
   - Fast alternating beam injection
     - Switching time = 2 sec.
     - Used in operation (11 ~ 25/Dec./2008)
3. HER/LER Pulse-to-pulse switching injection
   - Planned to be done in Apr./2009
4. PF/HER/LER Pulse-to-pulse switching injection
   - Planned to be done in Oct./2009

1. PF/HER
Fast switching beam injection

- Compatible optics
  - DC Magnetic field(Quad, Steering):

    Common parameter
  - Energy adjustment:

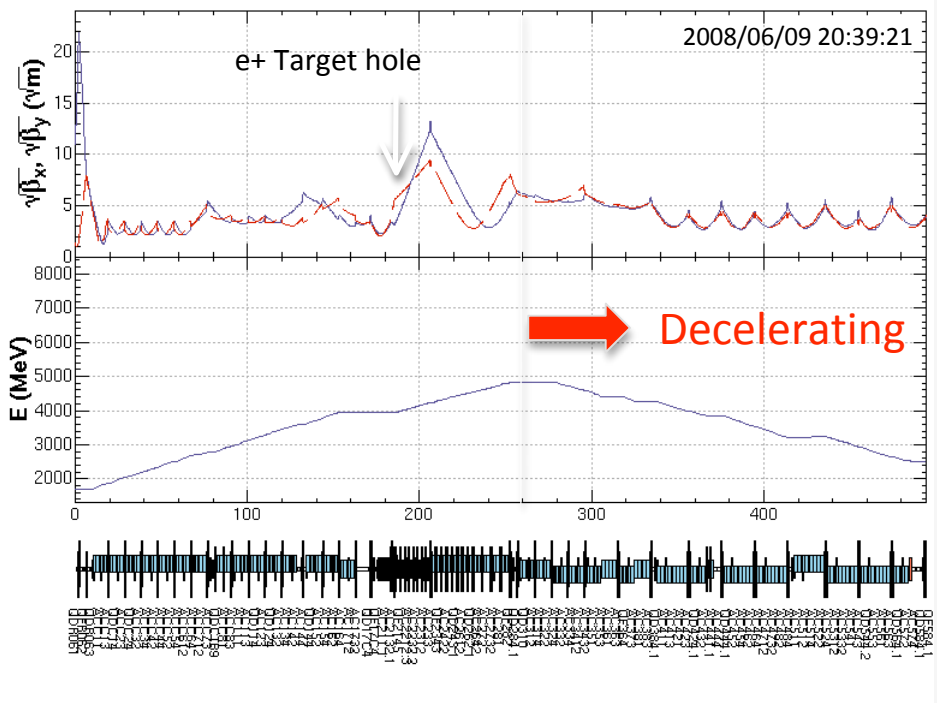
    Change Sub-Booster Klystron phase quickly
- Orbit correction

PF/HER Compatible Optics

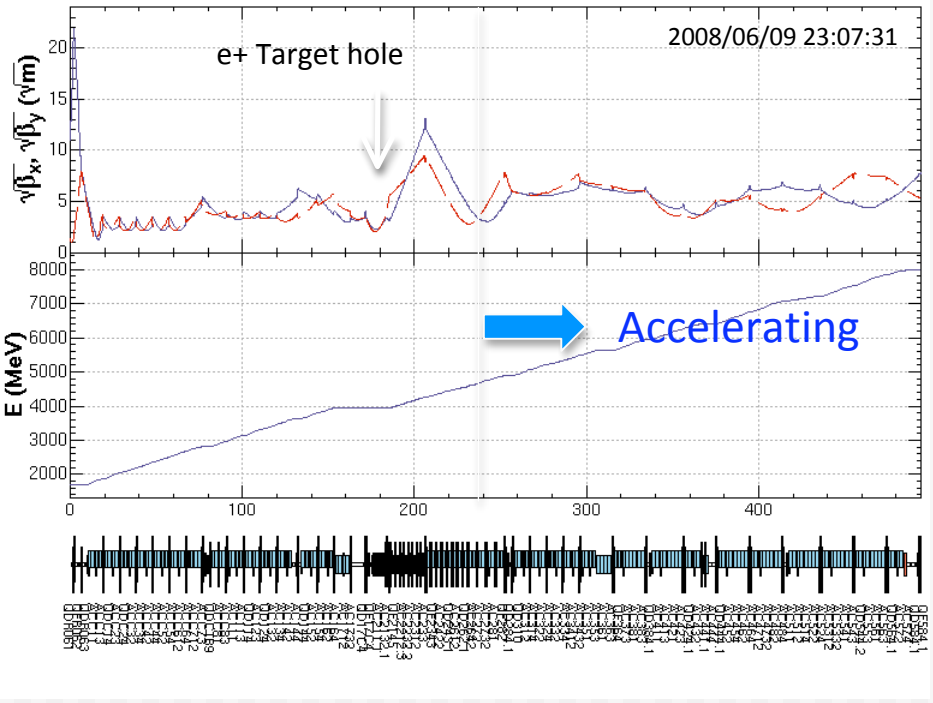
(Y.Ohnishi)

Optics from C to 5 sector is designed by based on 2.5GeV beam(PF).

2.5 GeV PF



8.0 GeV HER



Betatron phase advance
between 4 and 5 sector: 108 deg.

Betatron phase advance
between 4 and 5 sector: 30-50 deg.

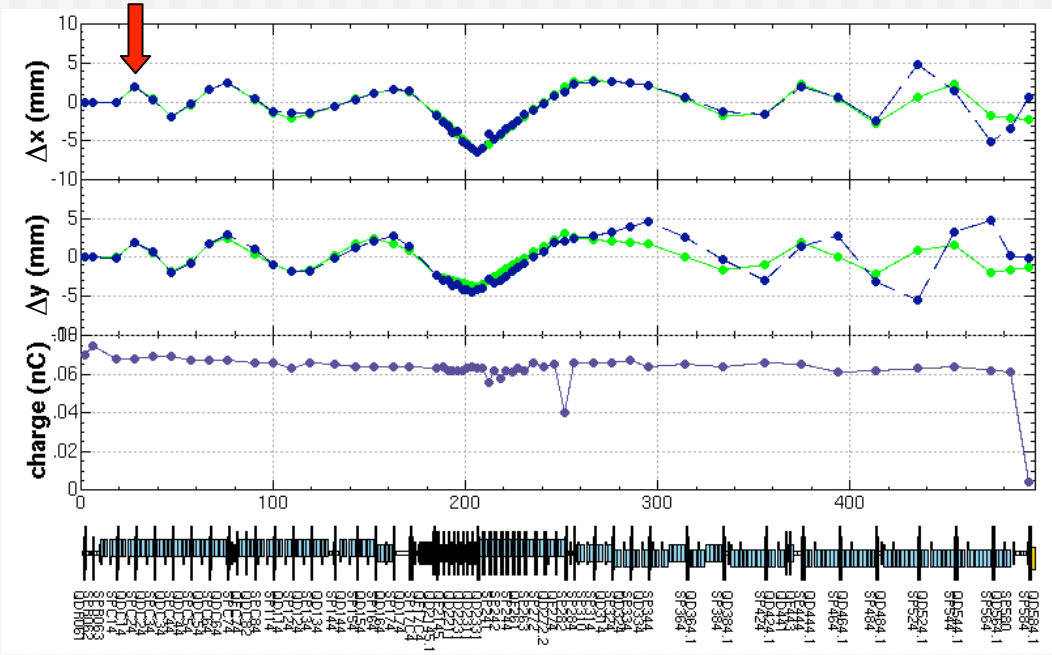
(Y.Ohnishi)

Fudge factor measurements of Q-magnets

PF Beam

Single kicks by SXC21/SYC21

Blue : Measurements
Green : Model calculations



$$\Delta x_i = x_{(+)i} - x_{(-)i}$$

$$\Delta y_i = y_{(+)i} - y_{(-)i}$$

Responses by measurements are different from model calculations.

(Y.Ohnishi)

Q fudge factor

Definition of Q fudge factors:

$$K_{PS,i} = A_{f,i} \cdot K_{\mathrm{model,i}}$$

(j)~... :
Differences of orbits between measurement and model kicked by the *j-th* steering magnet

Response matrix is calculated with SAD

Correction factors of K-values

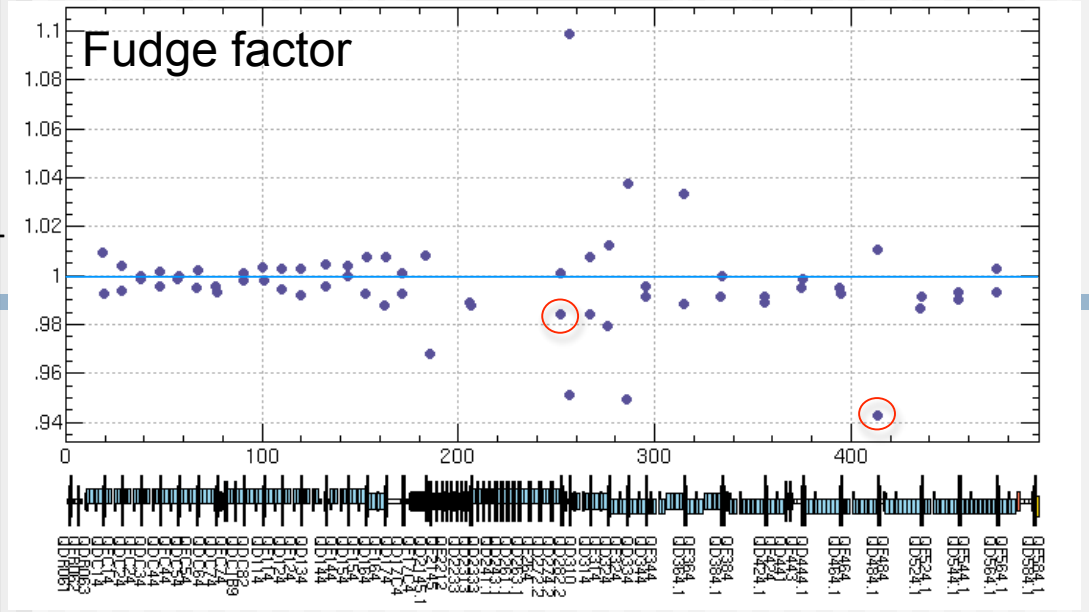
$$\begin{pmatrix} x^{(1)}_{meas,1} - x^{(1)}_{\mathrm{model,1}} \\ \vdots \\ y^{(2)}_{meas,1} - y^{(2)}_{\mathrm{model,1}} \\ \vdots \\ x^{(3)}_{meas,1} - x^{(3)}_{\mathrm{model,1}} \\ \vdots \\ y^{(4)}_{meas,1} - y^{(4)}_{\mathrm{model,1}} \\ \vdots \\ \vdots \end{pmatrix} = \begin{pmatrix} R^{(1)}_{11} & R^{(1)}_{12} & \cdots \\ R^{(1)}_{21} & \ddots \\ R^{(2)}_{11} & R^{(2)}_{12} \\ R^{(2)}_{21} & \ddots \\ \vdots \\ & & \\ & & \\ & & \\ & & \\ & & \end{pmatrix} \begin{pmatrix} \Delta K_1 \\ \Delta K_2 \\ \Delta K_3 \\ \Delta K_4 \\ \vdots \end{pmatrix}$$

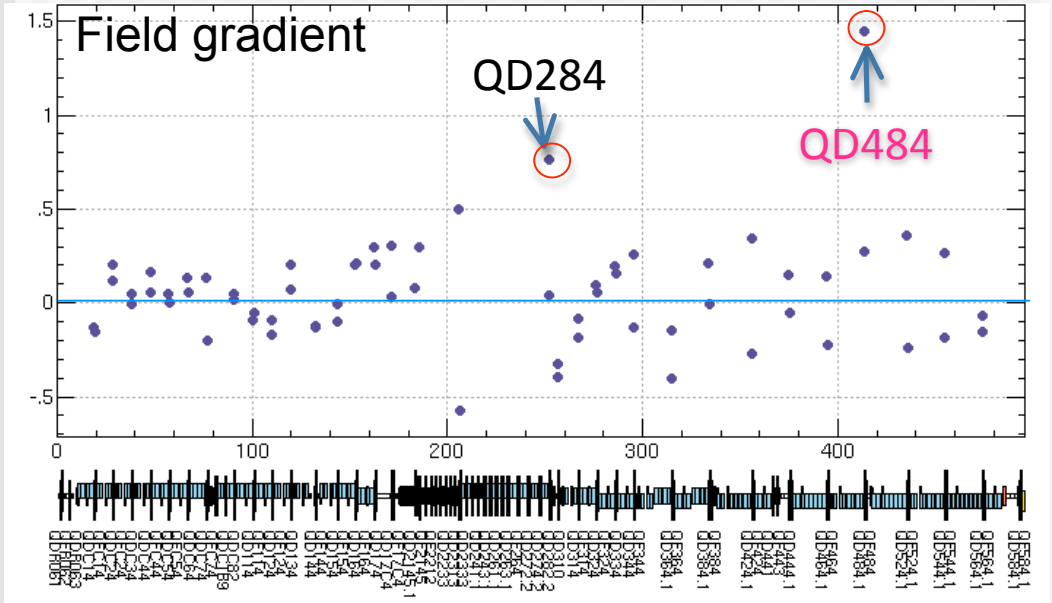
Solved with SVD

$$A^{-1}_{f,i} = 1 + \frac{\Delta K_i}{K_i}$$

1. PF/HER PF Beam

(Y.Ohnishi)





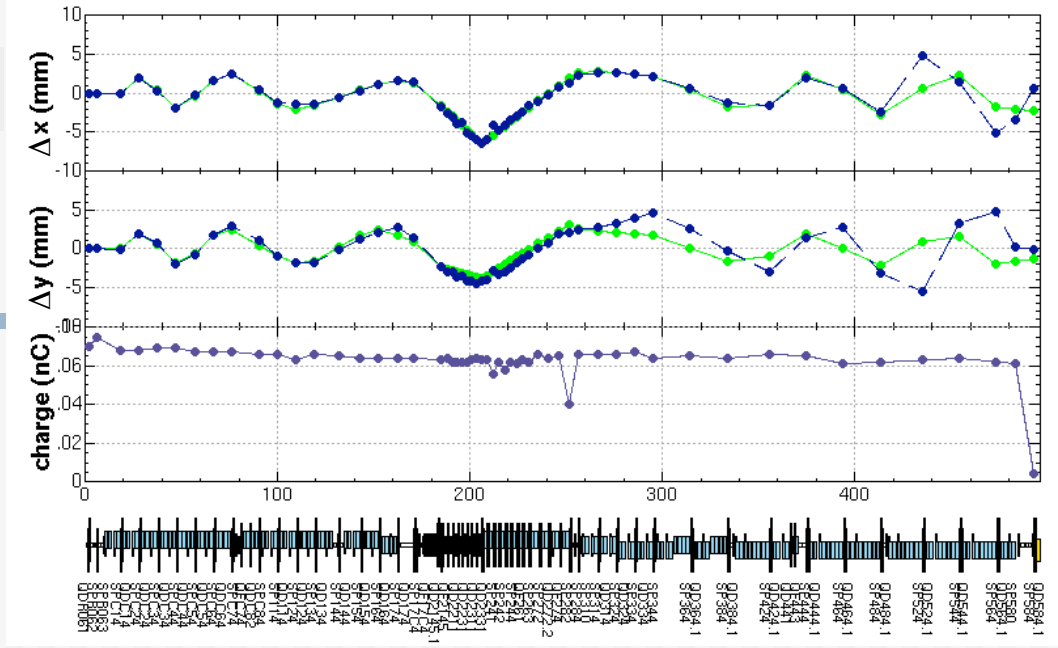
From AF and ΔB' values of QD484, the magnet is suspected to have something wrong.

Miswiring on a power supply of QD484 was discovered!

1. PF/HER

PF Beam

(Y.Ohnishi)

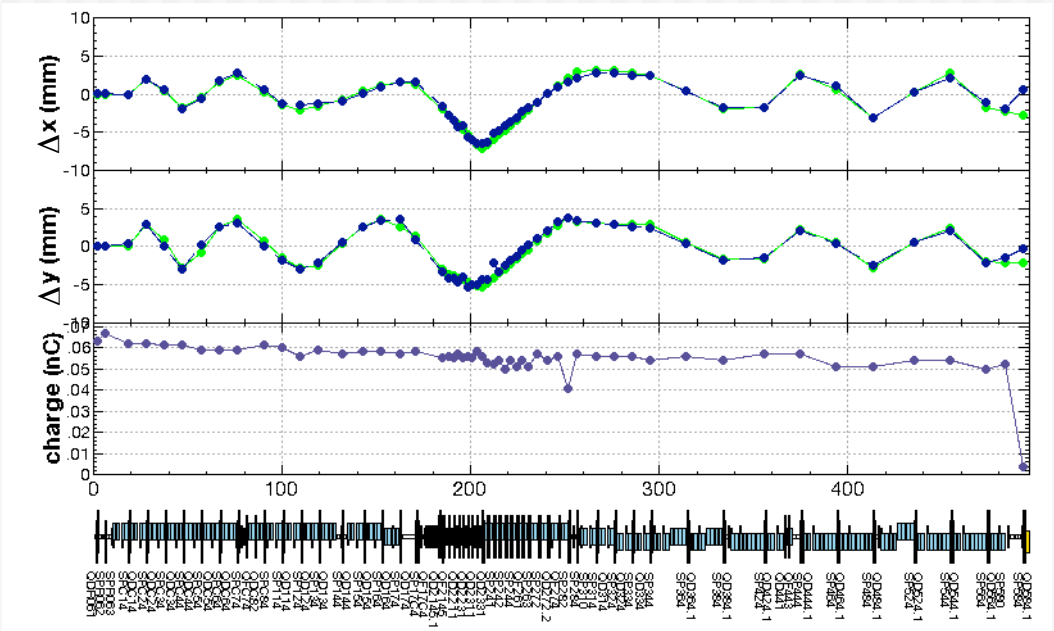


Single kicks by SXC21/SYC21

$$\Delta x_i = x_{(+)i} - x_{(-)i}$$

$$\Delta y_i = y_{(+)i} - y_{(-)i}$$

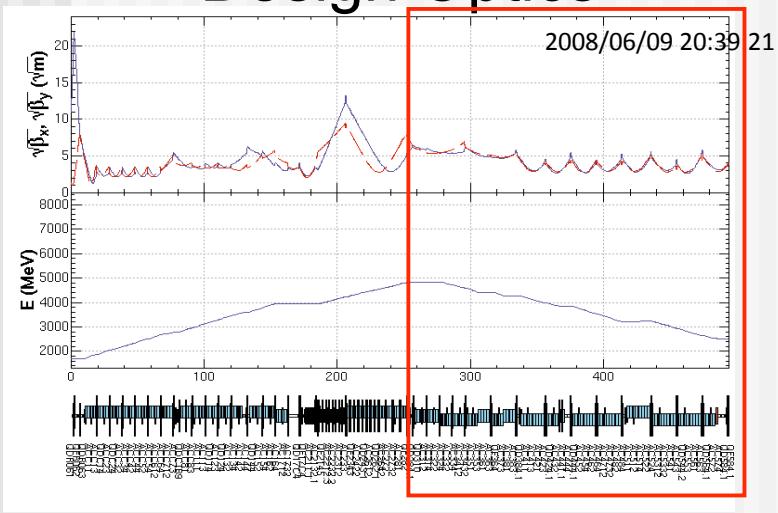
Blue : Measurements
Green : Model calculations

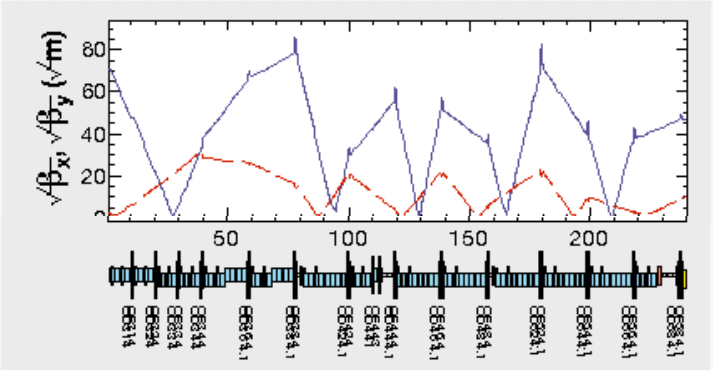


After
- QD484 mis-wiring fixed
- A_F's are innovated

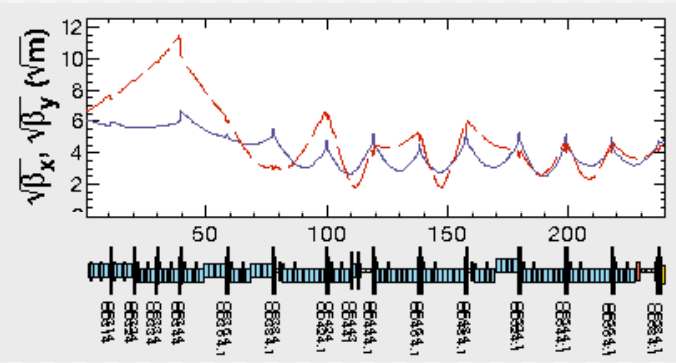
Measurements are in good agreement with model calculations

Optics measurements with wire scanners



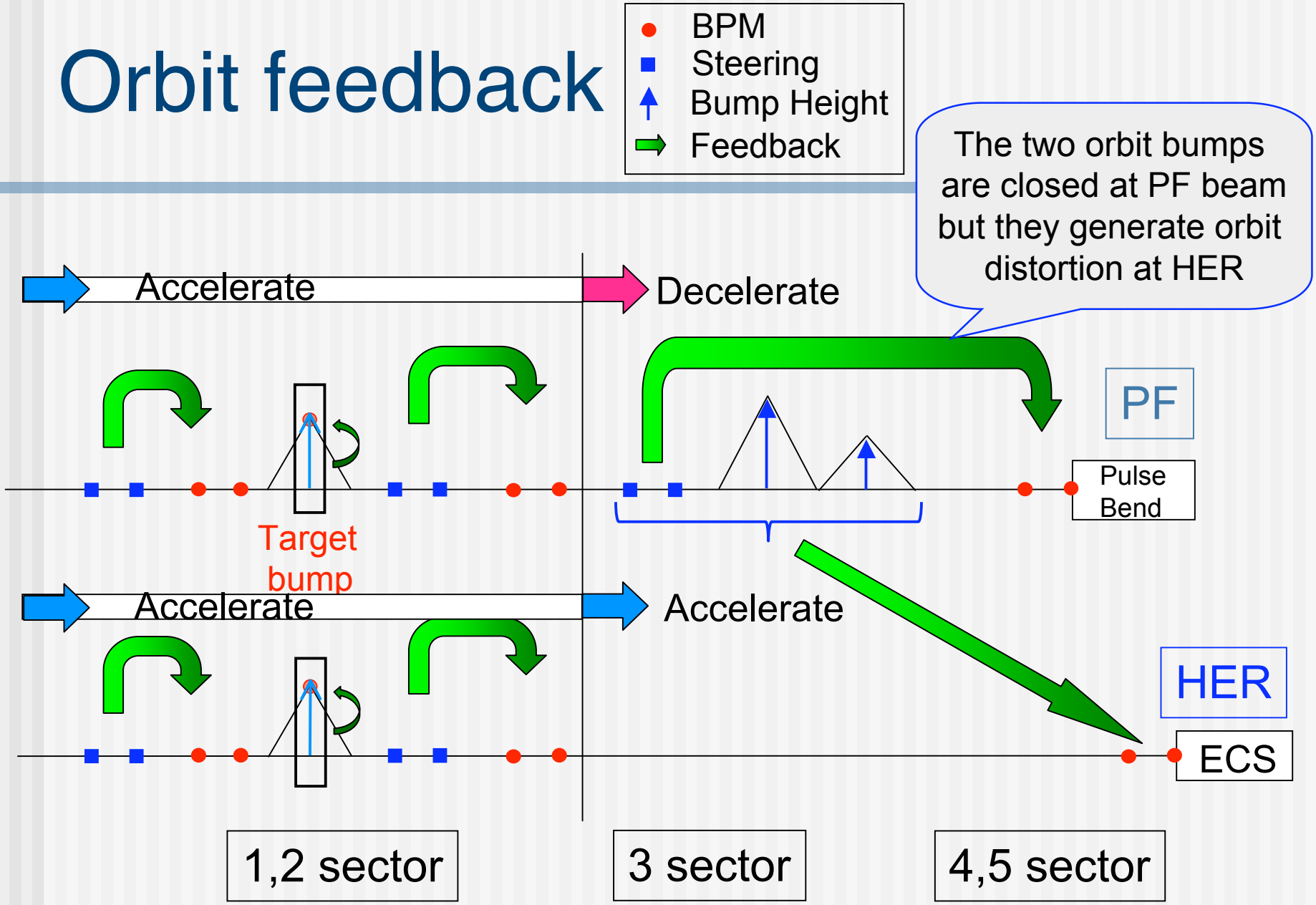


After QD484 fixed and AF's innovation



(Y.Ohnishi and K.Furukawa)

Orbit feedback

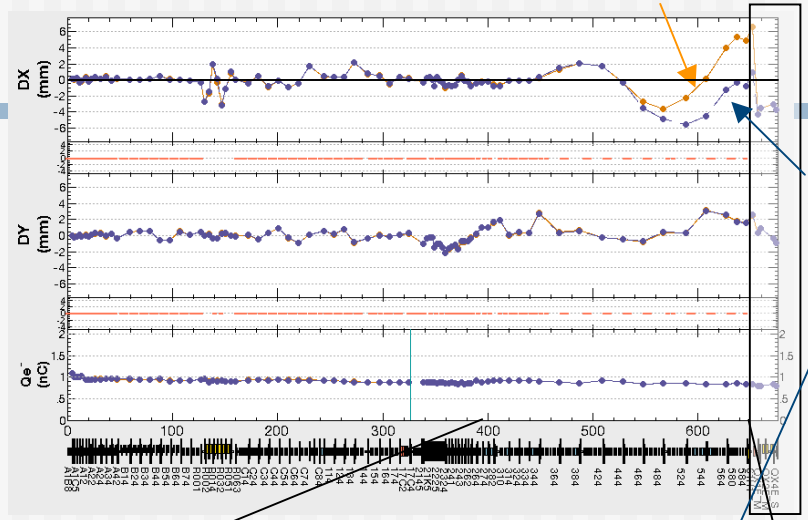


1. PF/HER

(Y.Ohnishi)

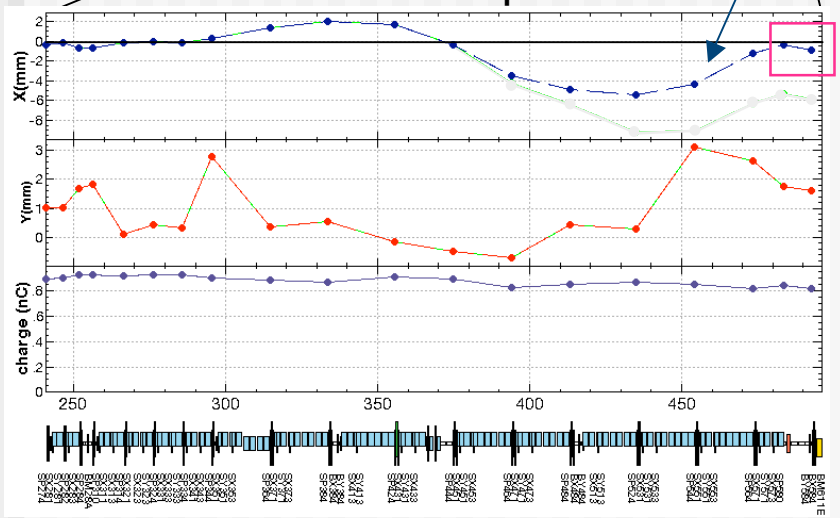
HER Orbit correction ⟺ PF Orbit

Before orbit correction



After orbit correction

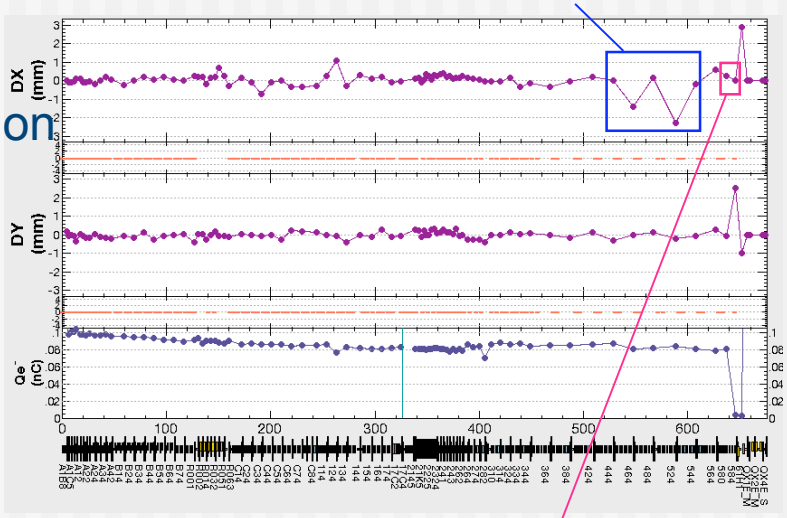
Close up



The horizontal positions can be set to 0 mm at the entrance of ECS

The difference of PF beam orbit between before HER orbit correction and after that.

2 bumps can be seen



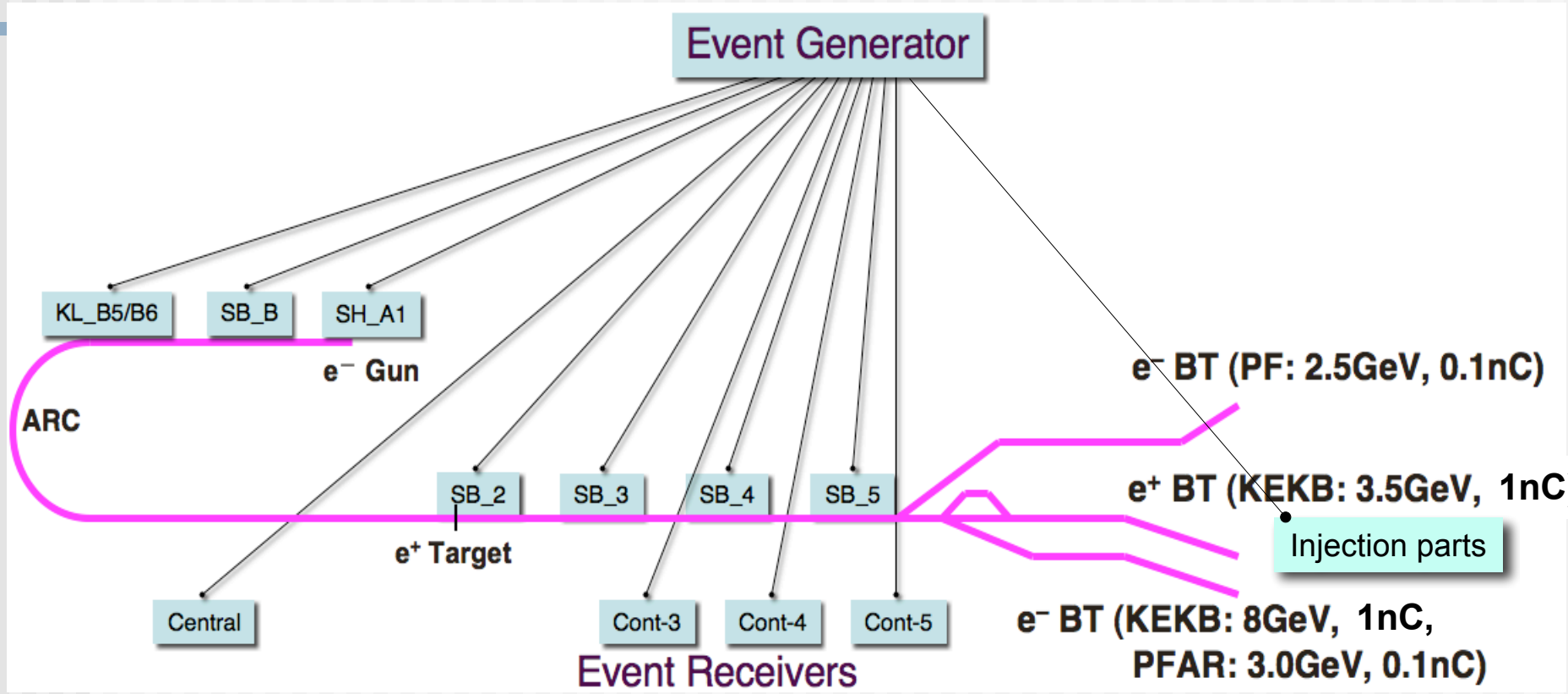
The orbits are not affected at the entrance of pulsed bend.

Pulse-to-pulse Switching

- Event system
- PF/HER injection

K. Furukawa

Event system configuration



Event system

- Fast switching of many device parameters
  - In 20ms / 50Hz
- MRF Series 230 Event Generator / Receiver
  - VxWorks 5.5.1, MVME5500
  - Timing precision less than 10ps

◆Event Receivers

Phase switching of SHB and SB
: Event system controls SHB and SB phases instead of PLC.

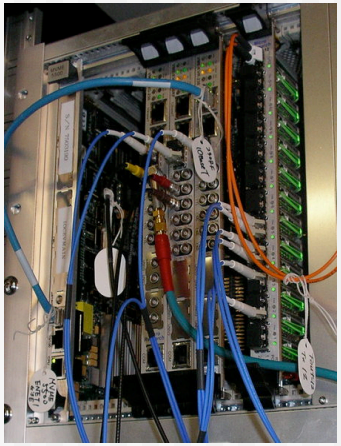
ACC/STB switching of SB

GUN
: GUN bias
: High voltage
: GUN delay

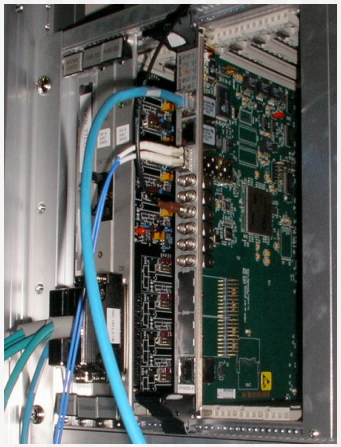
Pulse magnet
: Pulse steering
: Pulse bend
: Pulse coil
: Septum, kicker

Monitor
: BPM
: Wire scanner
: RF

Injection parts
: Injection phase
: Bucket selection



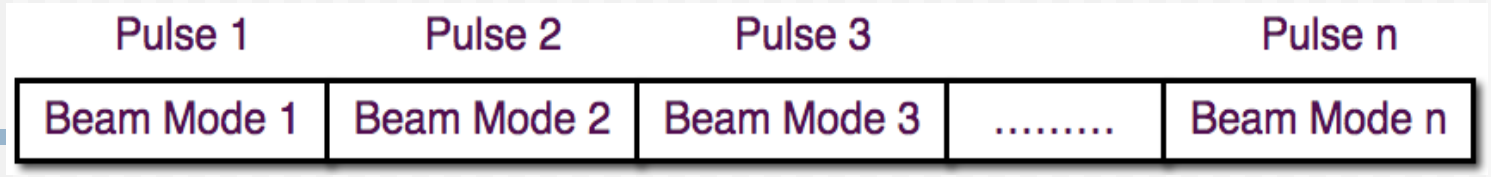
EVG & Timing



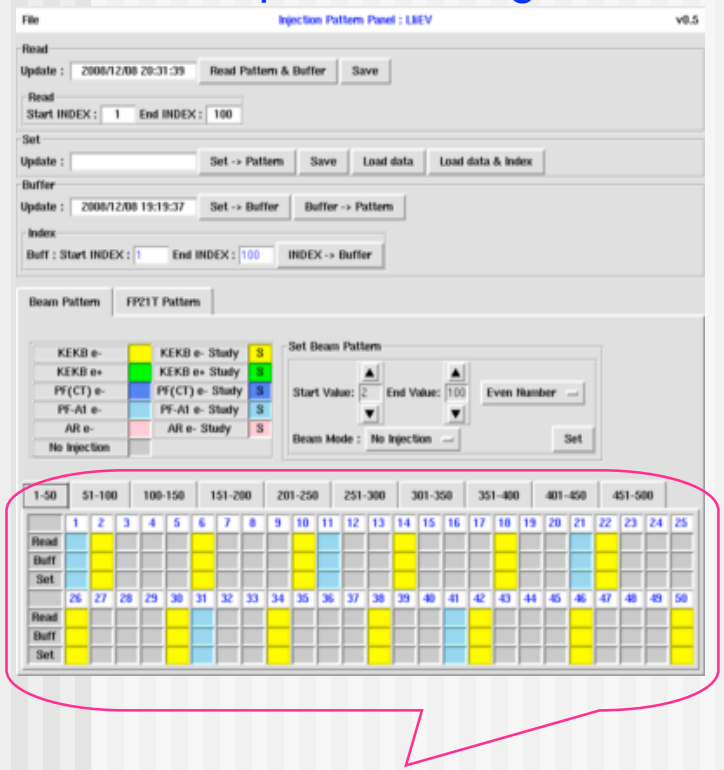
EVR & LLRF

K. Furukawa

Beam mode pattern generation

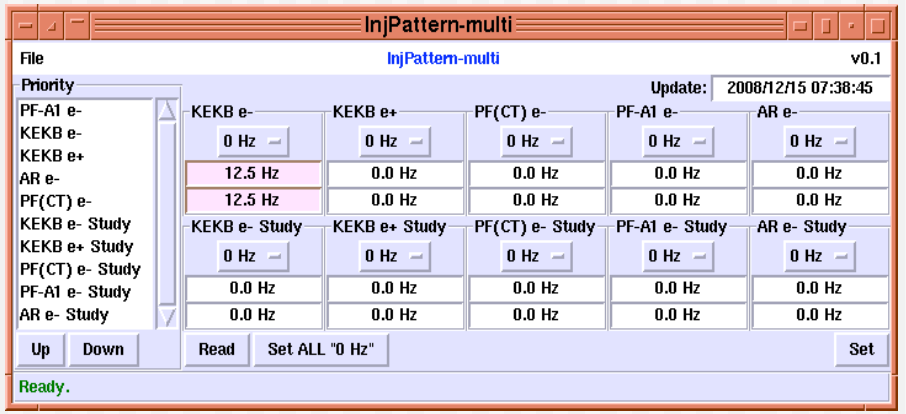


Manual pattern designer



Beam mode pattern

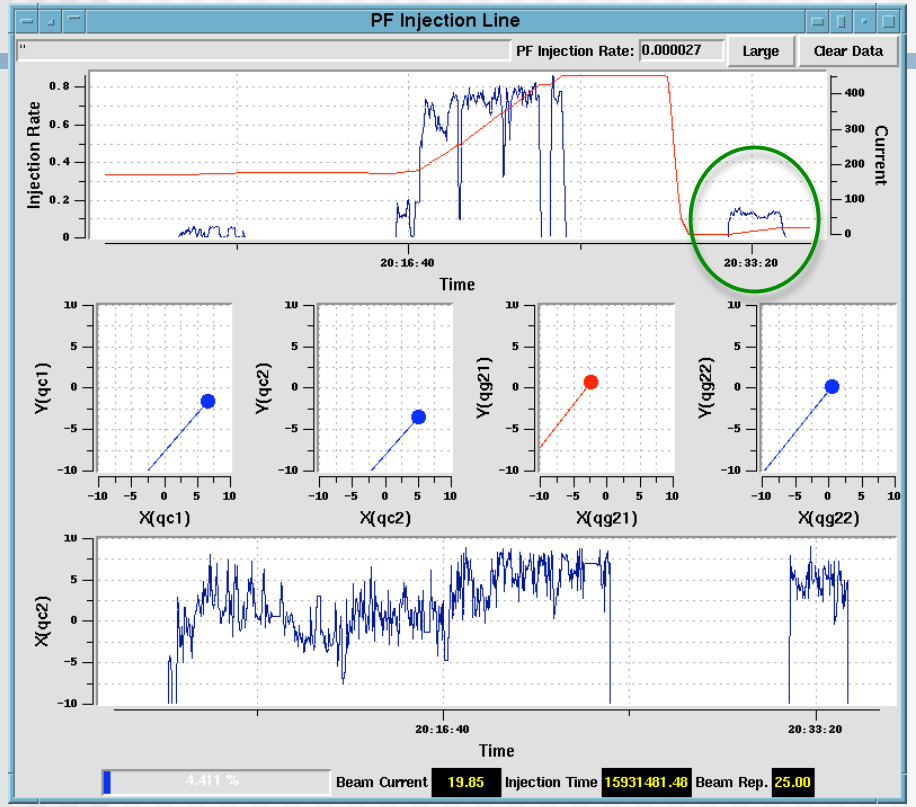
A version for current operation



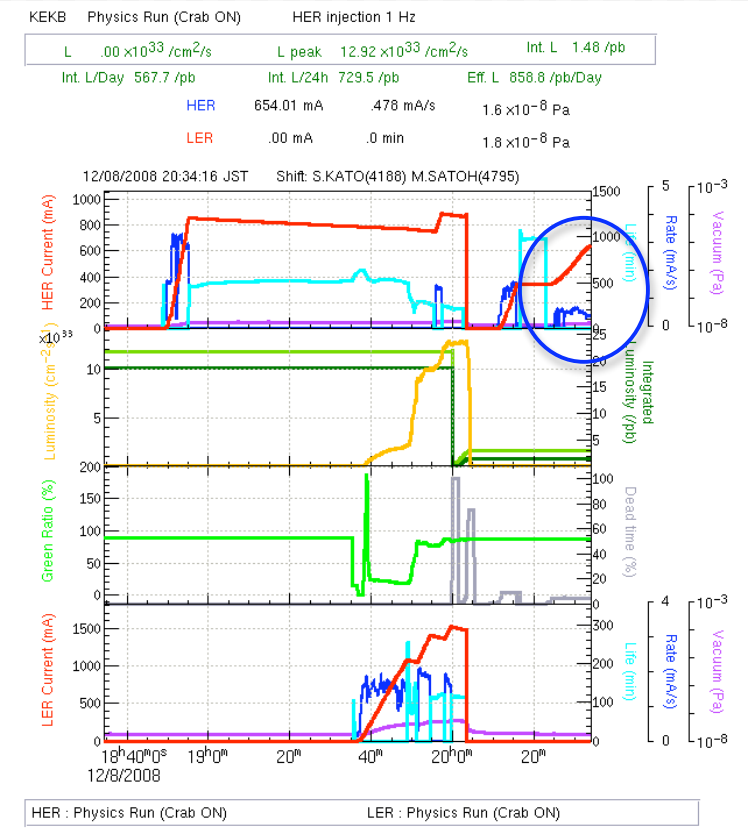
- 10 different beam modes are defined (for LER, etc).
- Using a graphic interface, arbitrary pattern can be set.
- We can switch beam mode every 20ms pulse.
- Beam mode pattern specifies how to change beam modes for 1 second.
- A new pattern is loaded at the end of the previous pattern.
- Otherwise, the pattern repeats forever.
- There are many pattern rules due to pulse device features and limitations.

PF/HER Pulse-to-pulse switching

PF / 5Hz



HER / 12.5Hz



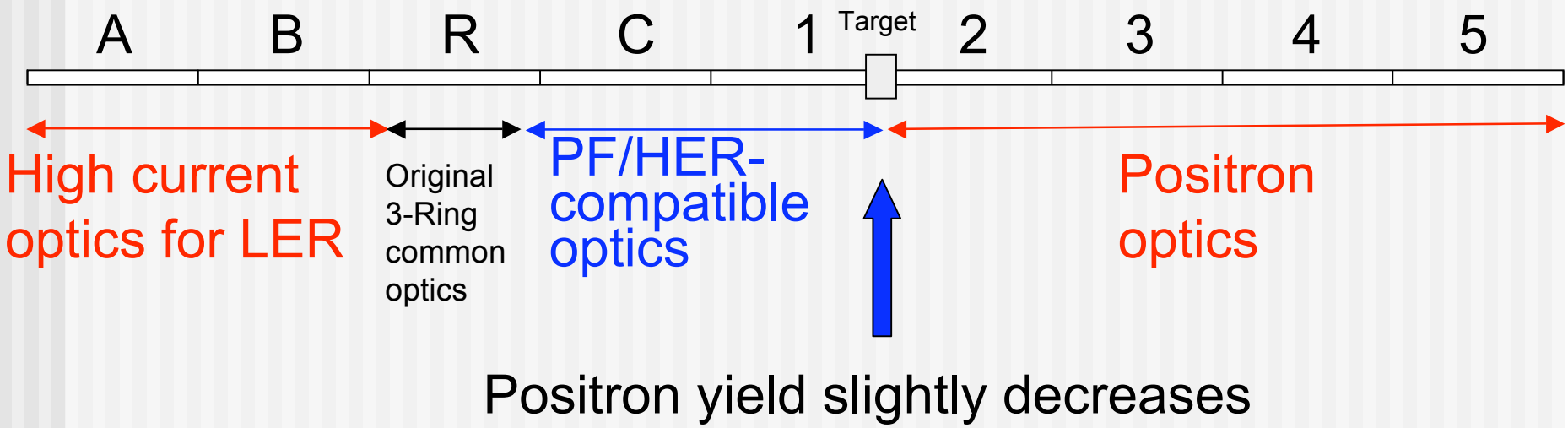
- In 8/Dec/2008, we could injected beams to both of PF and HER with pulse-to-pulse.
- But the 25 Hz injection to PF mode, HER injection ratio was worse and the noise level of Belle detector was also too bad.
- **Now this problem is resolved.**

2. HER/LER Switching

- Compatible optics
- Orbit correction

HER/LER Compatible optics

Setting of Quads

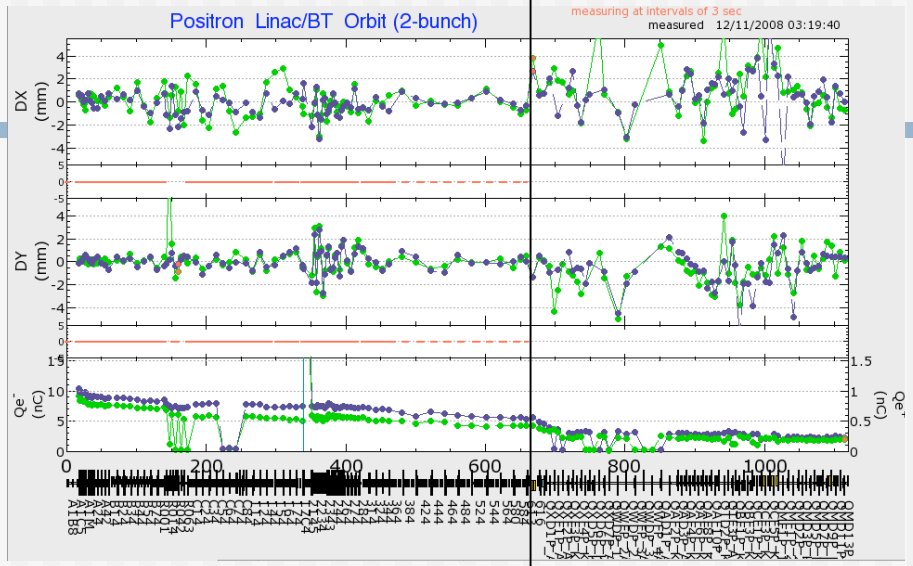


Positron yield slightly decreases

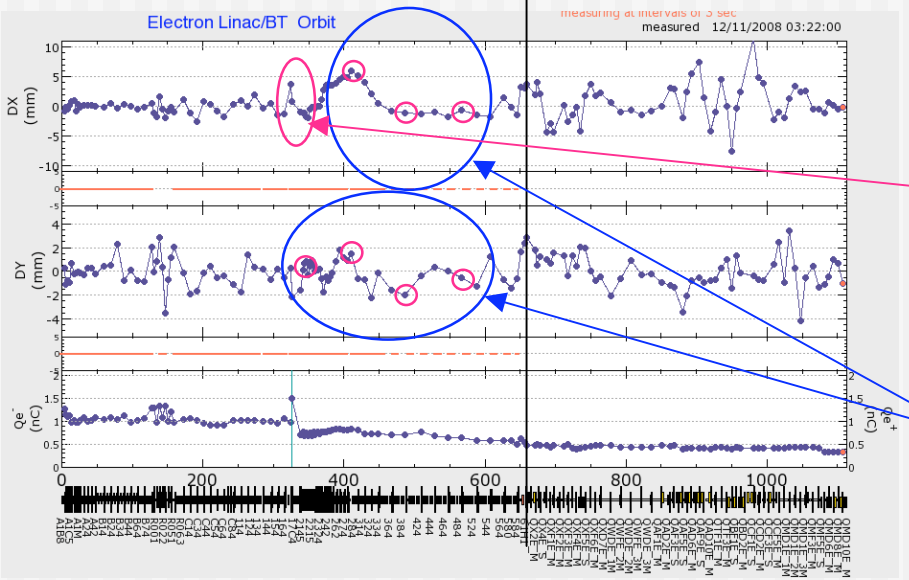
HER/LER Orbit correction

LINAC BT

LER



HER



LER orbit correction

We corrected orbit so that LER orbit becomes flat with only DC steerings.

Pulse steerings

Target bump

For HER, electron beam passes through the target hole by making a bump with pulse steerings.

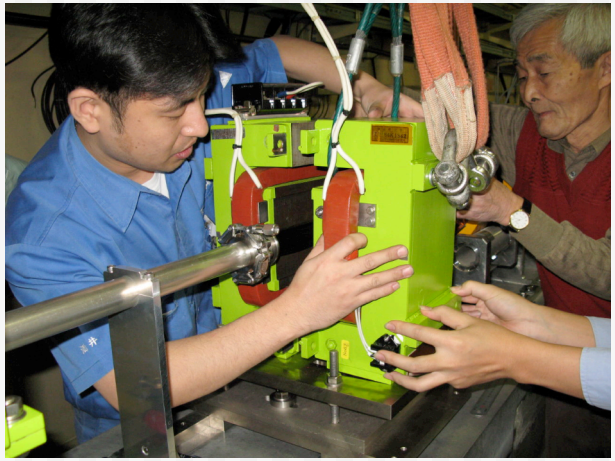
HER orbit correction

Pulse steerings can correct HER beam.

T.Kamitani, K.Yokoyama, M.Kikuchi, et.al.

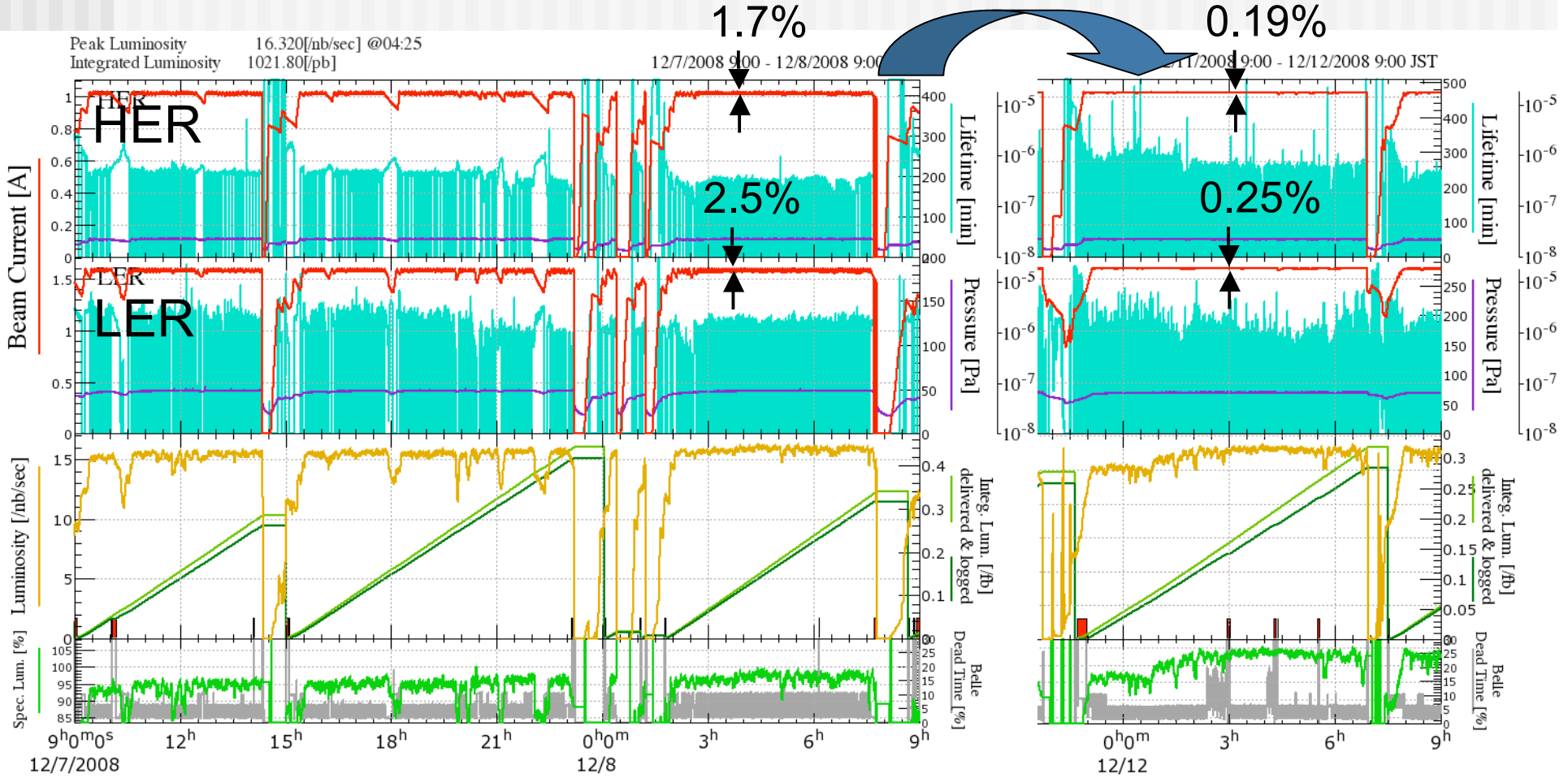
10 pulse steerings are installed

- Bend
  - Bending angle: 1mrad
  - Gap: 35 mm
  - Length: 150mm
- PS
  - Max current:10A
  - Pulse width: 19.5msec.
  - Pulse shape: 1+cos(t)
- Ceramic chamber
  - Mn-Mo coating



HER/LER Fast Alternating Beam Injection

- In 12/Nov/2008 HER/LER could be successfully switched in 2 sec.
- The injection ratio is good as usual.
- The beam current variations are one order decreased in both rings.
- Quality of luminosity tuning is much improved.
- Time for luminosity tuning cycle has speeded up.



Plans for Pulse-to-pulse Switching Injection

- 2-rings(HER/LER)
- 3-rings(PF/HER/LER)

3. Pulse-to-pulse switching injection plans for 2-rings

- HER/LER pulse-to-pulse switching injection is the next target by Apr/2009.
  - Pulse-to-pulse beams were successfully transported to both ends of BT lines.
- Injection phase of KEKB
  - The switching time for an up-down module is 2 seconds/360 degrees, which is used for changing the injection phases of HER and LER.
  - This limits the HER/LER switching time now.
  - We will replace the up-down module with two modules for HER and LER, which can be switched within 20ms.
- Bucket selection of KEKB
  - Connection from the event system to bucket selection system is under development.

3. Pulse-to-pulse switching injection plans for 2-rings (cont'd)

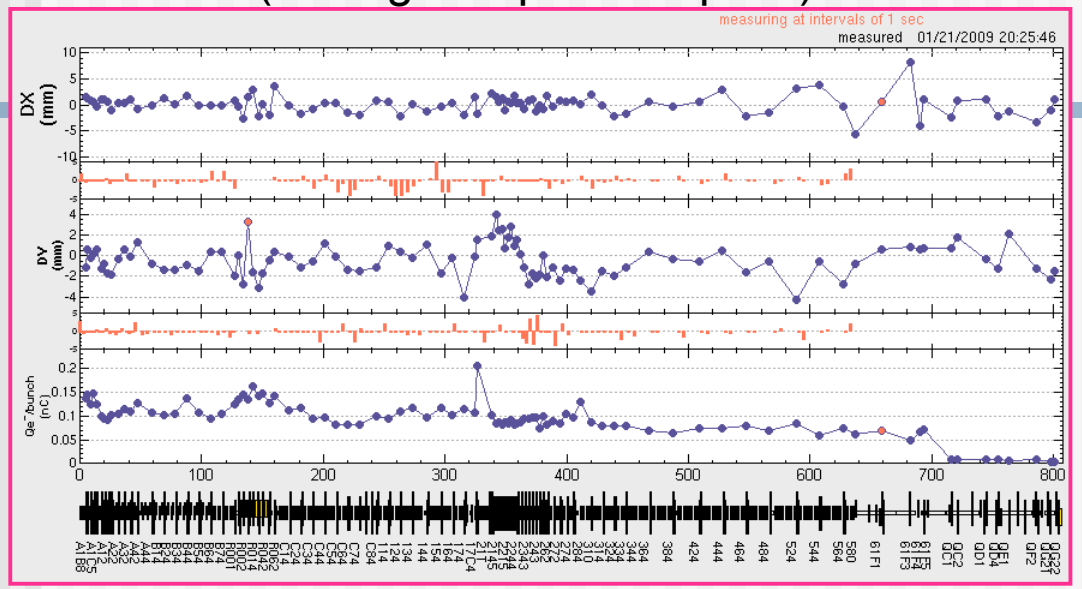
- Monitors
  - BPM's in LINAC and BT are being prepared.
  - Wire Scanner system is also under development.
- Orbit feedback and Energy feedback system
- LINAC alignment at the downstream of the target.

4. Pulse-to-pulse switching injection plans for 3-rings

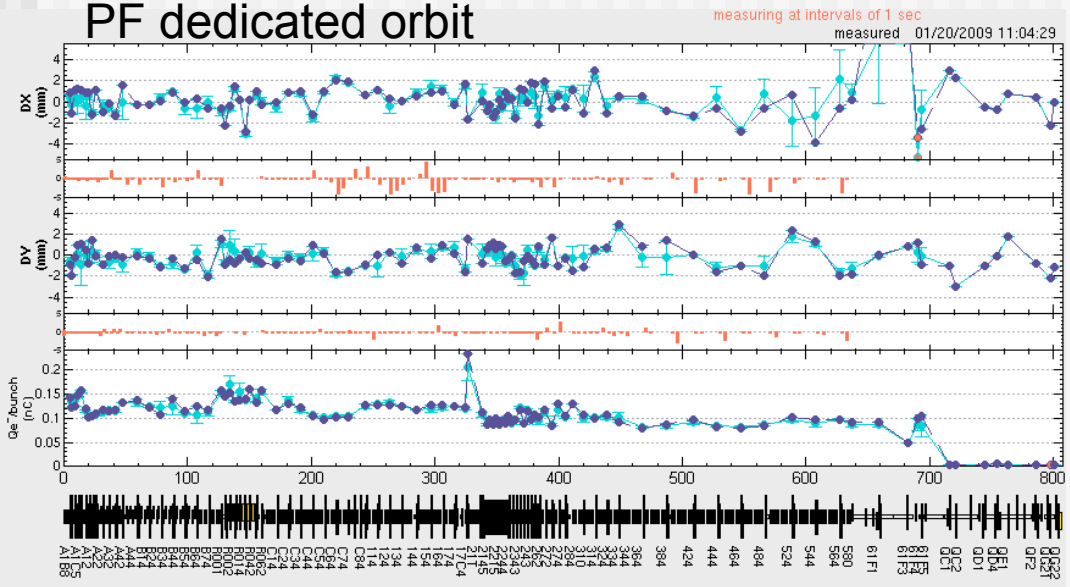
- PF operation will be top-up mode from Oct./2009.
  - We should realize the pulse-to-pulse injection for 3-rings, PF/HER/LER.
- PF/HER/LER compatible optics
  - We tried to pass PF beam with the HER/LER compatible optics, which worked well.
  - Better optics will be designed, taking the energy profiles of 3 modes into consideration.
  - Response function for the new optics should be measured.
- Pulse steering
  - Kick angle will be adjusted for each mode.
  - Additional pulse steerings are planning.

PF beam with the HER/LER compatible optics

PF orbit (3-Ring compatible optics)



PF dedicated orbit



Now progressing

- All phases of sub-booster in 2 and 3 sectors are shifted to “stand-by”.
- The orbit can be corrected only with pulse steerings.
- The charge and orbits are comparable to the PF dedicated optics

Summary

- We achieved Fast Alternating Beam Injection to HER and LER, which improved the quality of luminosity tunings.
- Pulse-to-pulse switching to HER and LER is being prepared for the operation from Apr/2009.
- We aim at the pulse-to-pulse switching to PF, HER and LER on Oct/2009.
  - PF/HER compatible optics was reproduced in design tool. The same method will be applied to the 3-ring scheme.