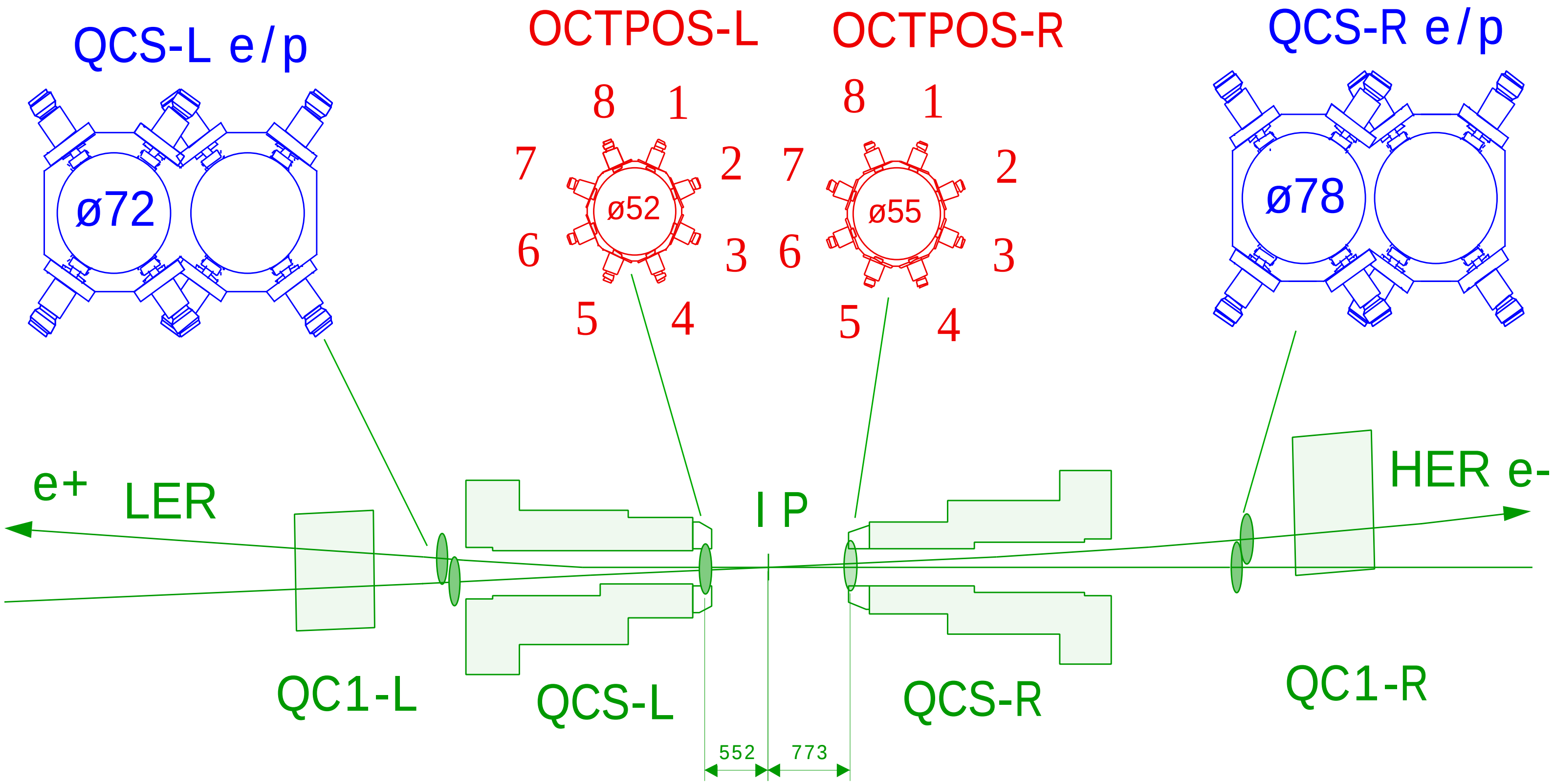
IR Beam Position Monitor for KEKB

Feb 10 2003 by M.Tejima

Introduction

- To maintain the optimum collision condition of the two beams, two special Beam Position Monitors(BPMs) with 8-button electrodes, called OCTOPOS, were installed inside the super-conducting quadrupole magnets (QCSs)
- Four normal BPMs with 4-button electrodes were incorporated outside the QCSs.
- A finite orbit separation method between the two beams was proposed to detect the beam positions of each ring with a common BPM having many electrodes.



Schematic view of the KEKB IR for BPMs

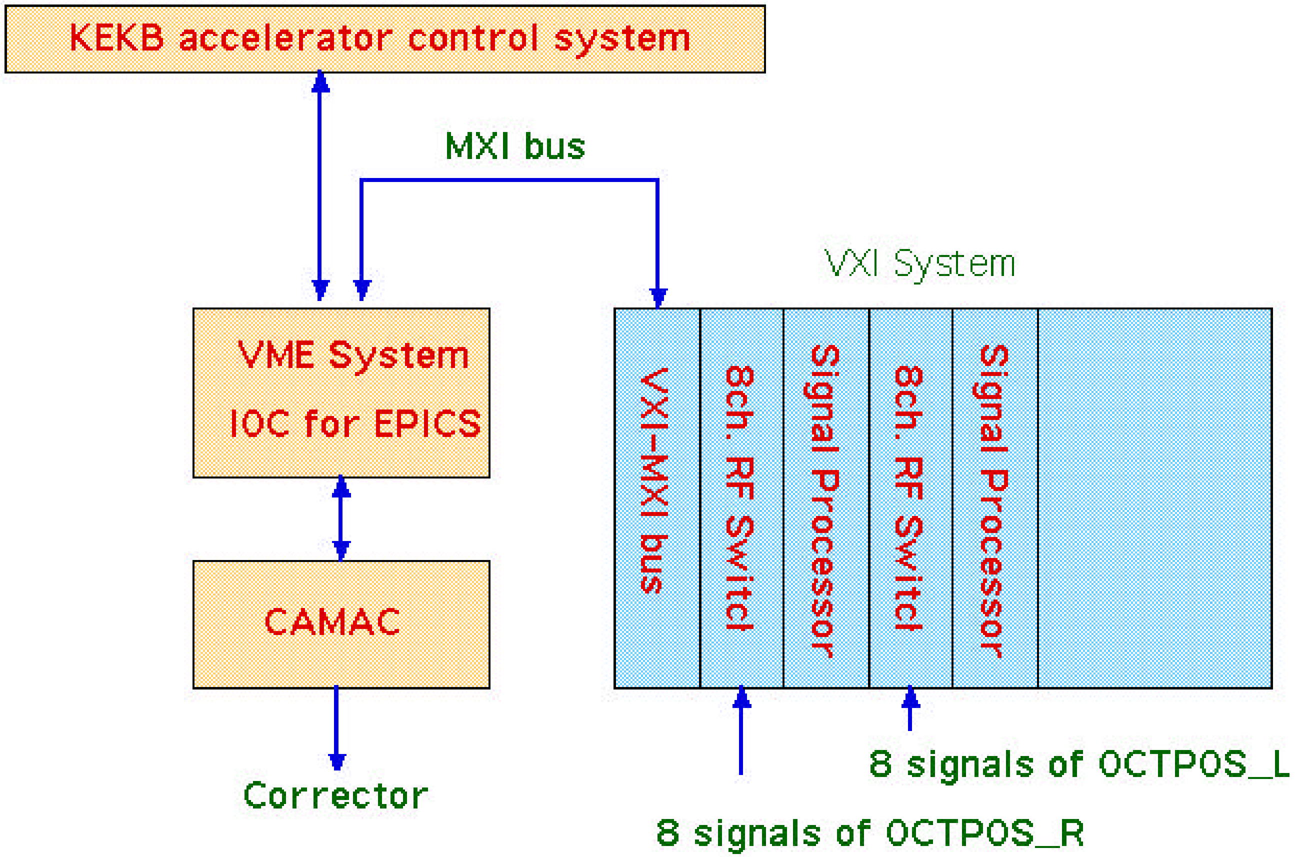
OCTOPOS

- Near the IP, the orbit separation is so small that both beams pass through a common chamber.
- Due to space problems inside the QCSs, we could not adopt directional couplers to measure the positions of the two beams separately
- We elected to install two special BPM heads each having eight button electrodes at the front end of the QCSs around the IP.
- Since the OCTOPOS is placed inside the inner bore of the QCS cryostat, the button electrode adopted was an SMA-type connector.

Signal measurement of OCTOPOS

- The output signal was detected with a narrow band detector, the same electronics employed for measuring the closed orbit at KEKB

- The signal processor detects the combined output signal of both beams, and the pickup frequency is 1019MHz .



KEKB accelerator control system

MXI bus

VME System

IOC for EPICS

CAMAC

Corrector

VXI System

VXI-MXI bus

8ch. RF Switcl

Signal Processor

8ch. RF Switcl

Signal Processor

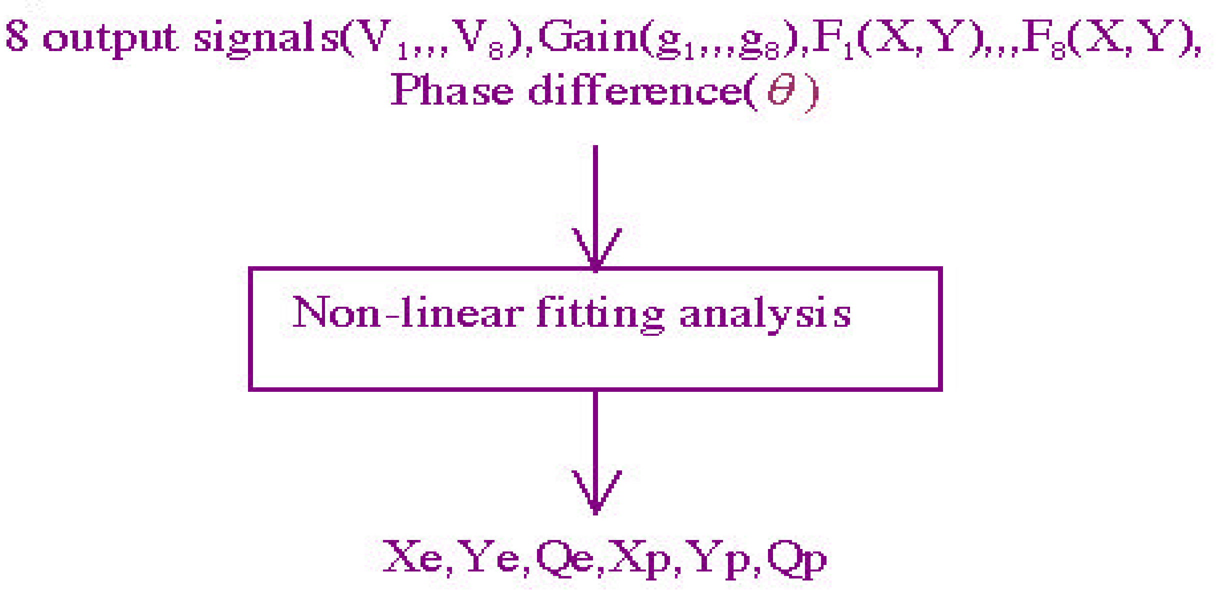
8 signals of OCTPOS_L

8 signals of OCTPOS_R

Schematic layout of control system for the Octopos

Proccessing method

- The data process is done by non linear fitting analysis based on finite orbit separation method.
- The position response function used a simple BPM model having very small electrodes.



Equation for the non-linear fitting

- The output signal can be represented with a phaser, and the peak value (Vi) of the phaser is measured by the detector, as follow

$$V_i = g_i\sqrt{\left(Q_e F_i\left(X_e,Y_e\right)\right)^2 + \left(Q_p F_i\left(X_p,Y_p\right)\right)^2 + 2Q_e Q_p F_i\left(X_e,Y_e\right)F_i\left(X_p,Y_p\right)\cos\theta}$$

where *g, F(X,Y)* and θ are the gain, the response function of the i-th electrode and the phase difference between two beams.

(Qe, Xe, Ye), (Qp, Xp, Yp) are the charge and position for positron and electron beams.

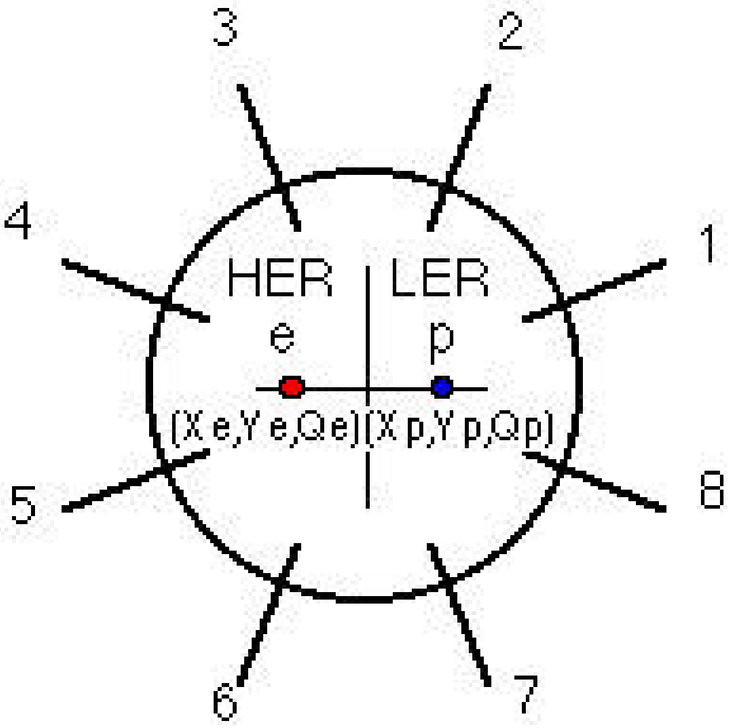
Assumption for the non-linear fitting analysis

1. Response function (Fi(X,Y)) was calculated from the BPM geometry as following figure.

$$F_i(X,Y) = 1 + \sum_{k=1}^{4} R^k \left(a_i(k) \cos k\varphi + b_i(k) \sin k\varphi \right)$$

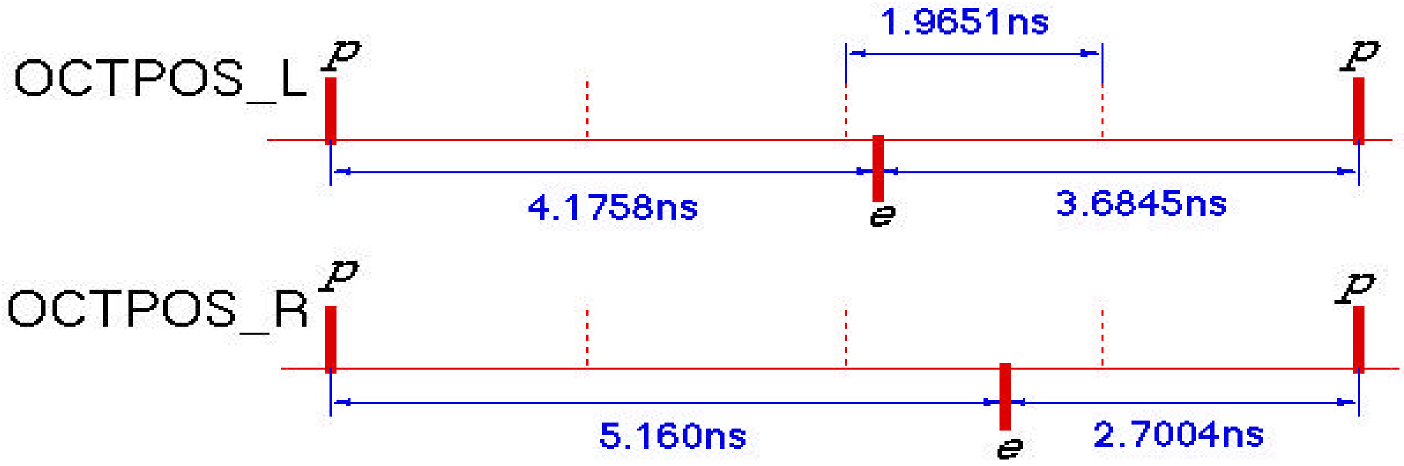
$$\text{where} \quad X = R\cos\varphi,\ Y = R\sin\varphi$$

$$a_i(k) = 2\cos\left(k(2i-1)\frac{\pi}{8} \right), \qquad b_i(k) = 2\sin\left(k(2i-1)\frac{\pi}{8} \right)$$



Assumption for the non-linear fitting analysis

2. The phase difference (θ) was defined to be constant and can be calculated from the distance between the OCTOPOS and the IP.



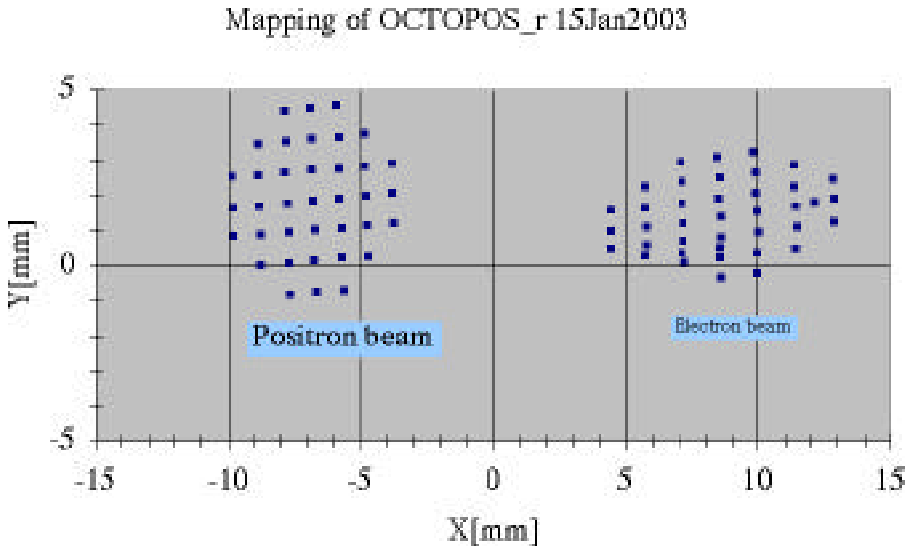
Lside π/4 @508Mhz, π/2 @1019MHz
Rside π/4 @508Mhz, π/2 @1019MHz

Correction for the non-linear fitting analysis

3. Gain coefficients (gi) for each electrode were calibrated with beam based position mapping data under the condition of single-beam operation.

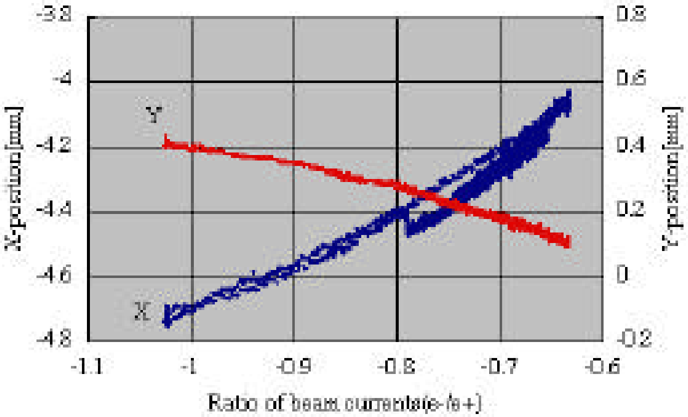
2003.1.15

Electrode#	OCTOPOS-L	OCTOPOS-R
1	1.0000	1.0000
2	1.0447	0.9710
3	1.0629	1.0143
4	0.9770	0.9080
5	1.0433	1.0096
6	1.0786	1.0523
7	0.9967	0.9605
8	0.9515	0.9626

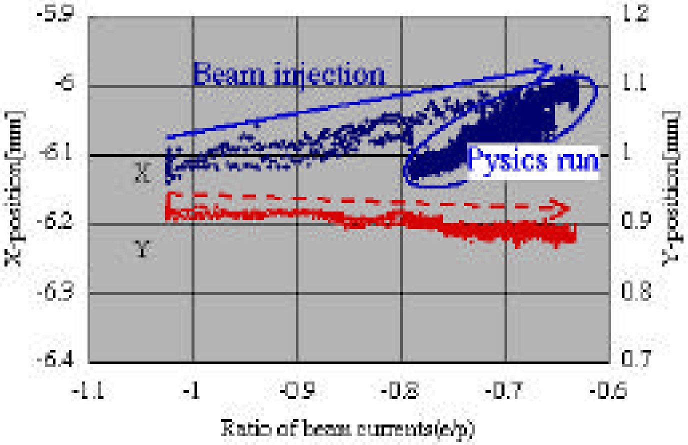


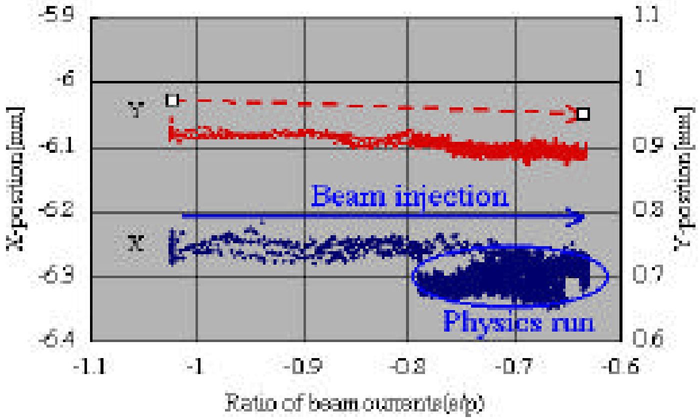
Improvement by g and θ correction

a



b





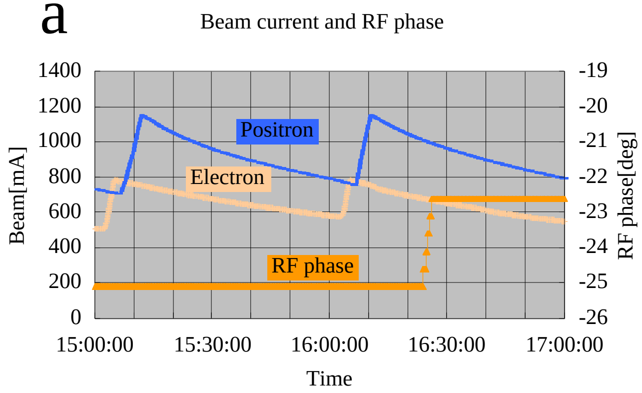
a. Variation of electron beam positions without gain correction at OCTOPOS-L

b. Variation of electron beam positions after correction of gain at OCTOPOS-L

c. Variation of electron beam positions after correction of gains and phase difference between electron and positron bunch at OCTOPOS-L.

Correction of RF phase change

a

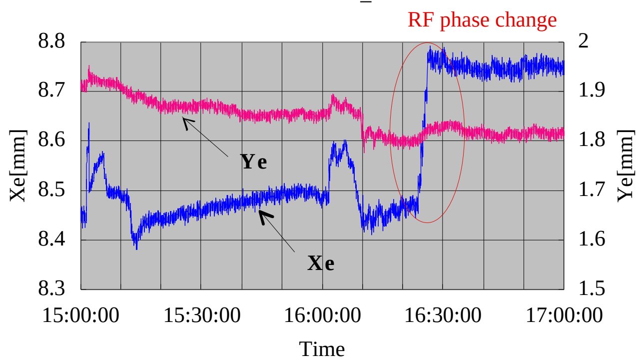


a. Example of RF phase change to adjust collision point

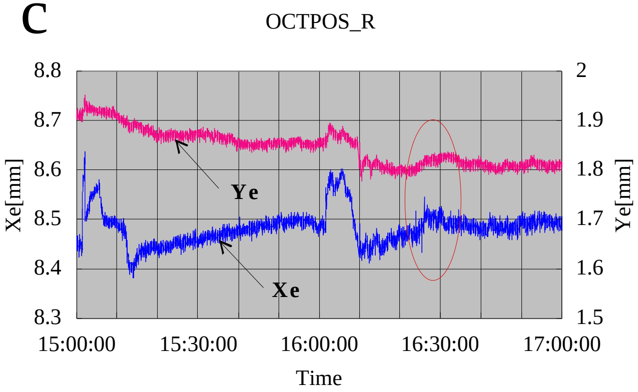
b. Xe of OCTOPOS_r stepped up.

c. The phase difference(θ) was corrected in response to 2xRF phase.

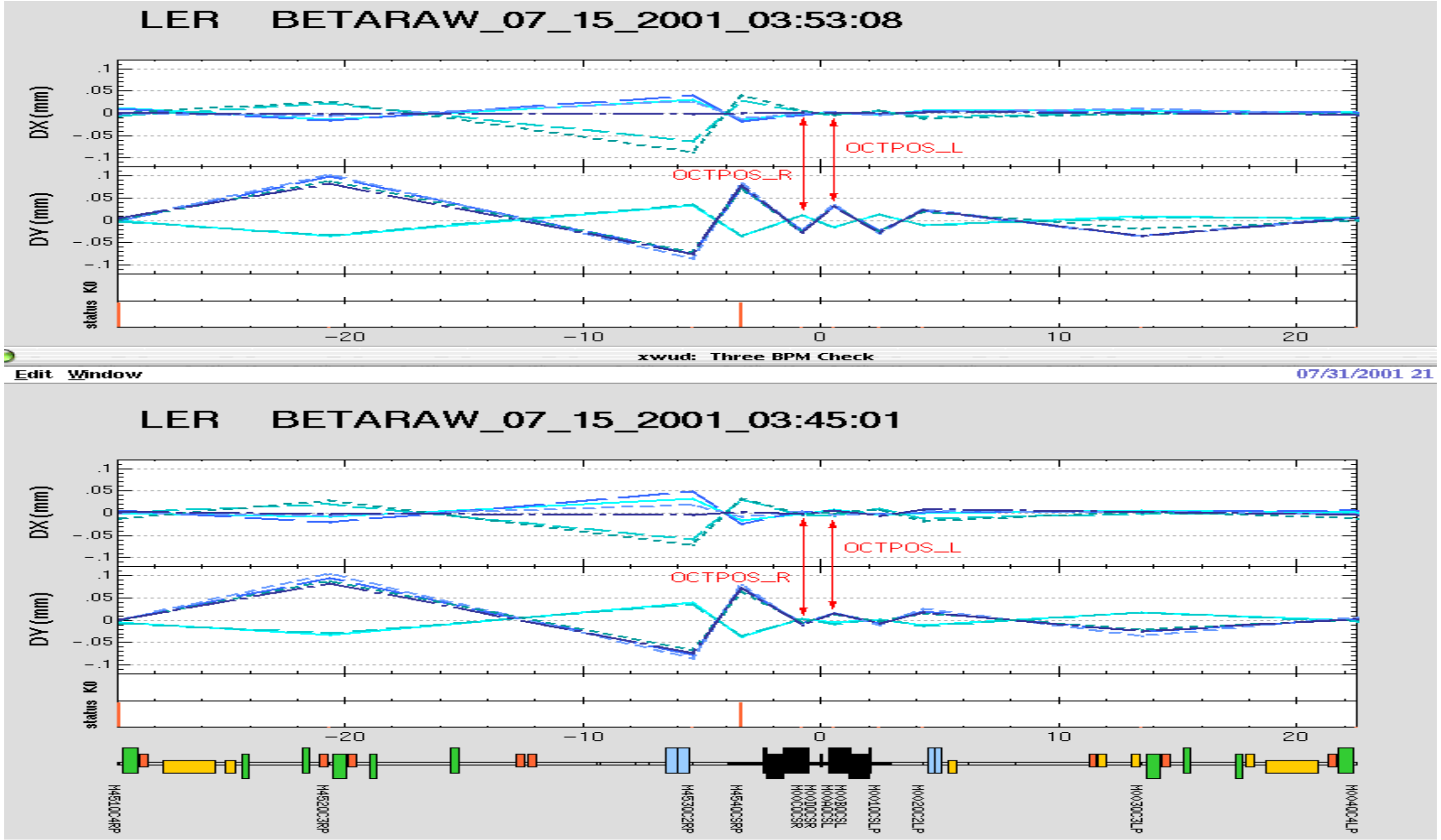
b



c



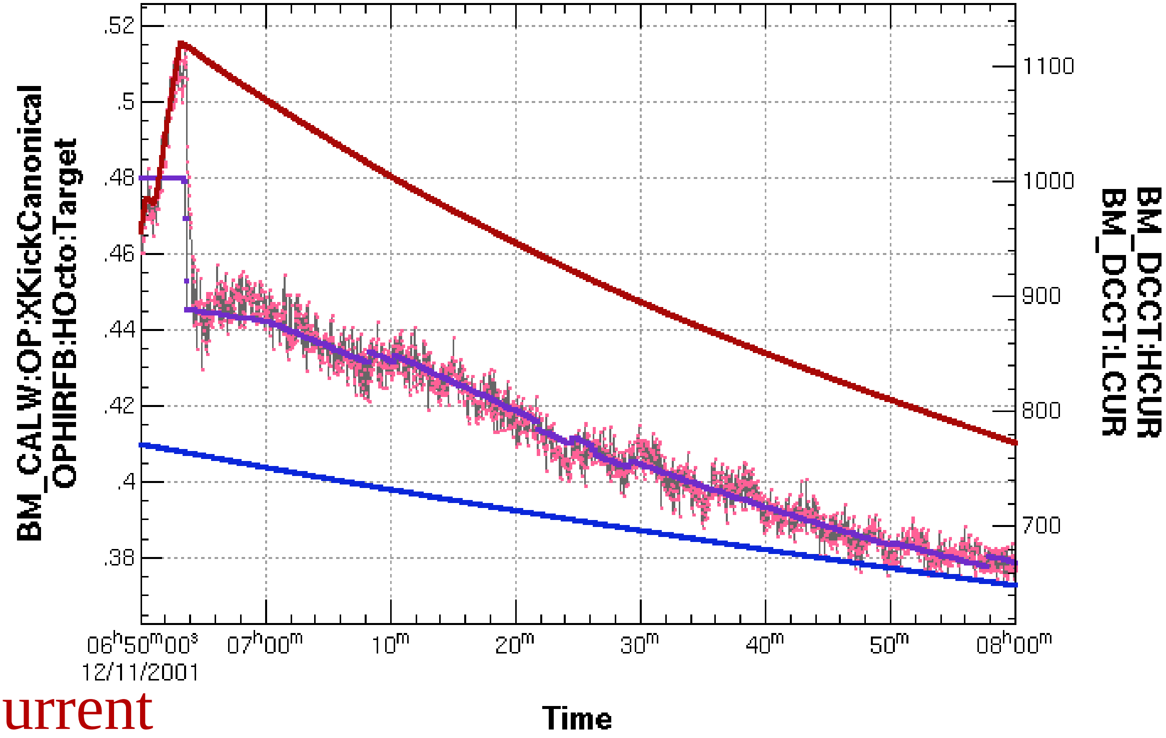
Performance @ KEKB optics correction



Correlation error at IR was calculated from the difference in the single-kick orbits in HER by the three- BPM correlation method (upper: electron beam; lower: both beams)

Feedback Performance

Horizontal feedback



red: LER current

blue: HER current

purple: H target

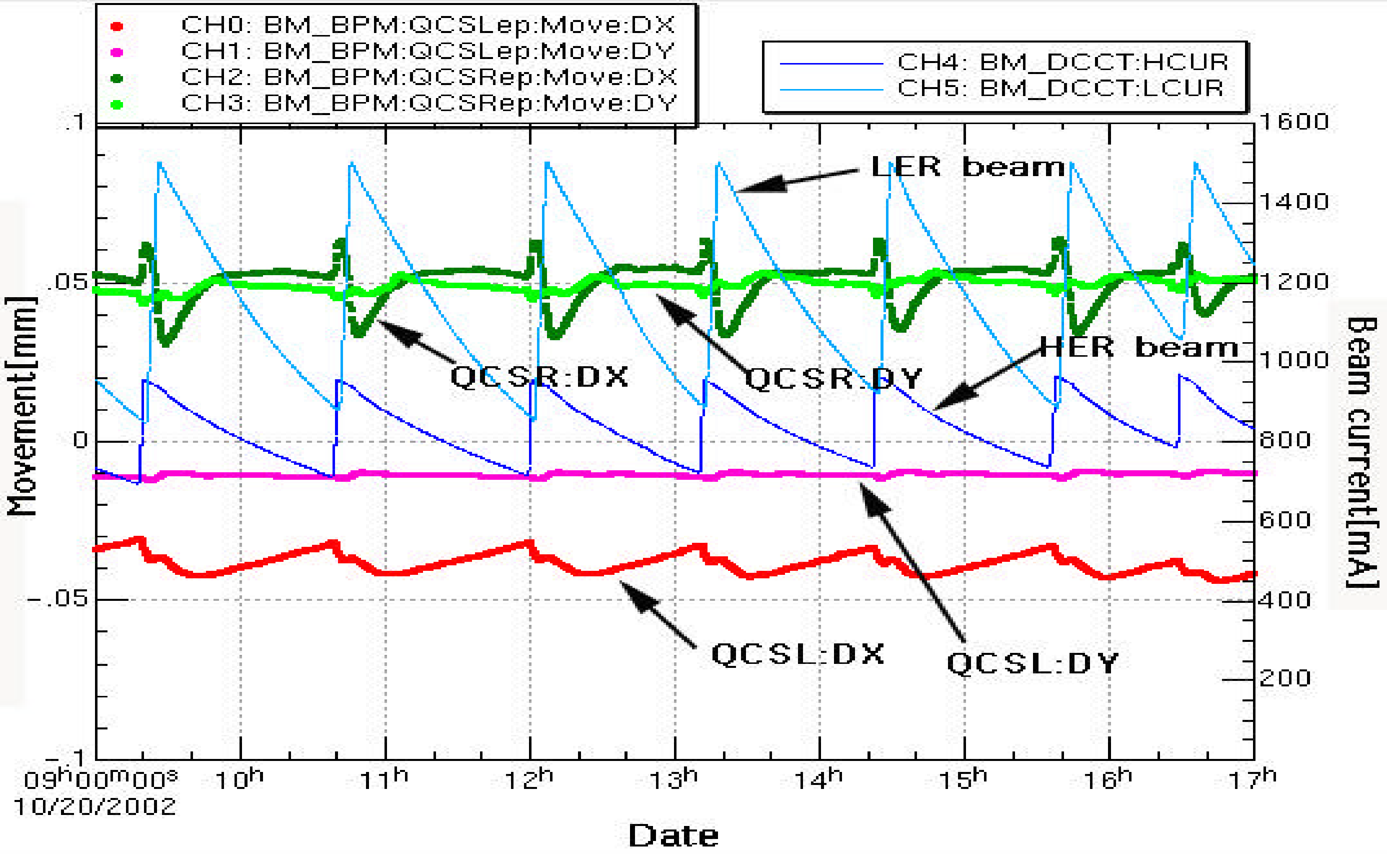
pink: measured H canonical kick

Normal BPMs for IR

- Four normal BPMs with 4 electrodes at the exit of the QCS were also incorporated into this IR BPM system as a back-up to the OCTOPOS BPMs.

- These BPMs are not supported firmly at the end of a magnet; as a result, heating of the vacuum chamber causes mechanical movement of the BPMs.

- These movements are measured by two displacement meters, and are compensated in the beam position data by these displacement measurements.



Movement of the Normal BPM chamber due to heat up by beam intensity

Position Resolution of OCTOPOS and QCS bpms

OCTOPOS_R [mm]

	xp_r	yp_r	xe_r	ye_r
STDEV.(10)	0.003	0.005	0.006	0.004

OCTOPOS_L [mm]

	xp_l	yp_l	xe_l	ye_l
STDEV.(10)	0.007	0.002	0.008	0.004

QCS BPMs_R [mm]

	QCSLE:X	QCSLE:Y	QCSRE:X	QCSRE:Y
STDEV	0.002	0.005	0.003	0.007

QCS BPMs_L [mm]

	QCSLP:X	QCSLP:Y	QCSRP:X	QCSRP:Y
STDEV	0.002	0.005	0.002	0.009

(Actual measurement data)

Summary

- The OCTOPOS system for the IR has been used for the first time to optimize the collisions under two-beam operation for physics experiments since 2001 November.
- There was a disagreement in the results of the measurement between the OCTOPOS BPM and the four normal BPMs during two-beam operation in the case of high-current beam.
- The reliability of positions measured by OCTOPOS has been improved after corrections for gains and phase difference.