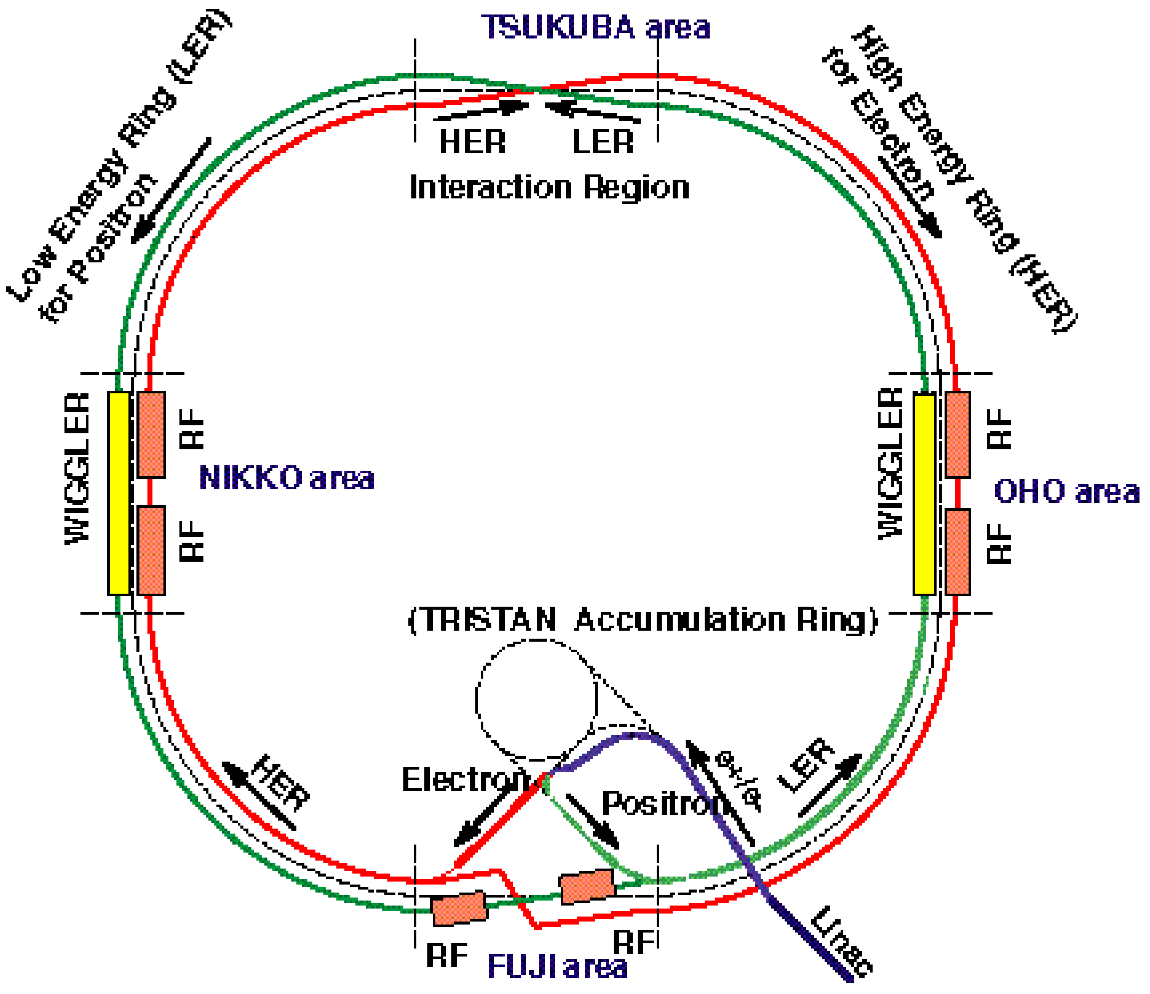
Status of Closed Orbit Correction at the KEKB

M.Tejima

KEK, Oho 1-1 Tsukuba, Ibaraki 305 JAPAN

About the KEK B-factory

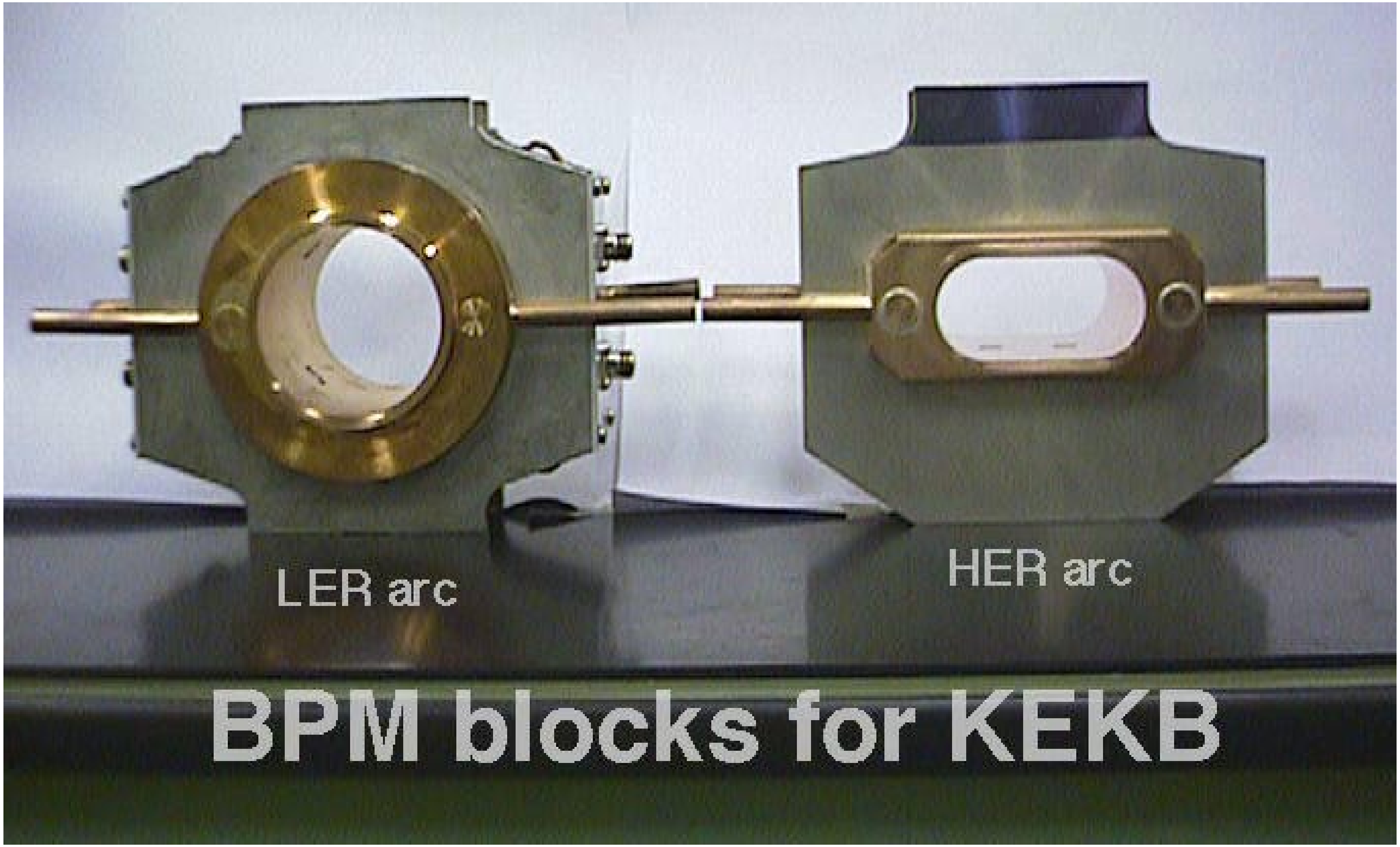


Parameters of KEKB (7/16/2001)

	LER	HER	
Horizontal Emittance	18	24	nm
Beam current	845	715	mA
Number of bunches	1153		
Bunch current	0.73	0.62	mA
Bunch spacing	2.4		m
Bunch trains	1		
Horizontal size at IP σ_x^*	103	123	μm
Vertical size at IP σ_y^*	2.3	2.3	μm
Emittance ratio $\varepsilon_y/\varepsilon_x$	4.7	3.5	%
β_x^*/β_y^*	59 / 0.65	63 / 0.65	cm
beam-beam parameters ξ_x/ξ_y	0.064 / 0.049	0.050 / 0.030	
Beam lifetime	160 @ 800 mA	300 @ 700 mA	min.
Luminosity (Belle CSI)	4.49		/nb/s
Luminosity records per day / 7 days/ month	232 / 1496 / 4788		/pb

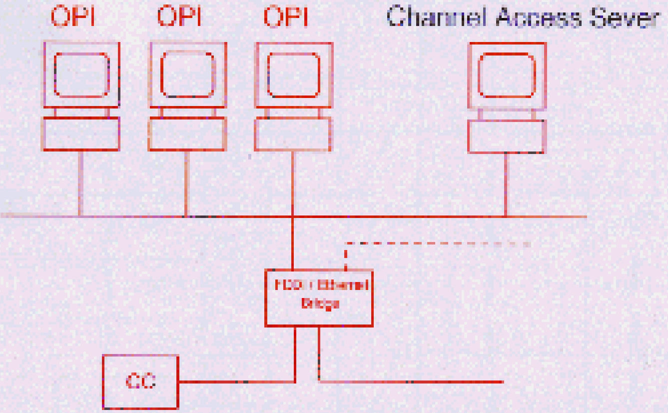
Beam Position Monitor System

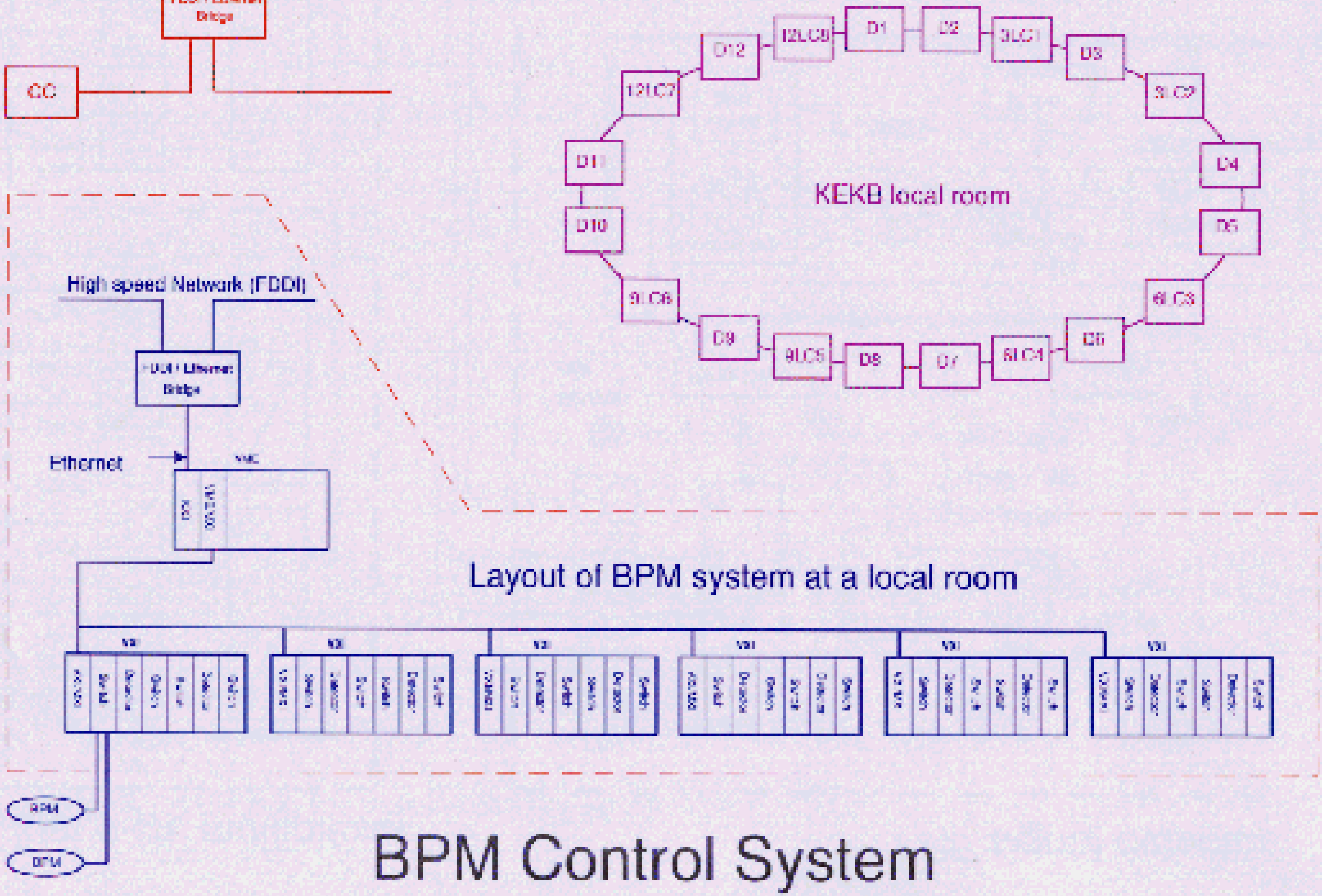
- N-type connector was adopted to transfer the beam power safely through a tough feed-through with sufficient mechanical strength and power capacity.
- Two stainless steel flames were brazed on Copper block to minimize mechanical deformation of the head.


LER arc
HER arc
BPM blocks for KEKB

Support of BPM

ÅEHER:443 bpms, LER 454 bpms
ÅE240 detectors and 480 RF switches
distributed in Local Control Buildings

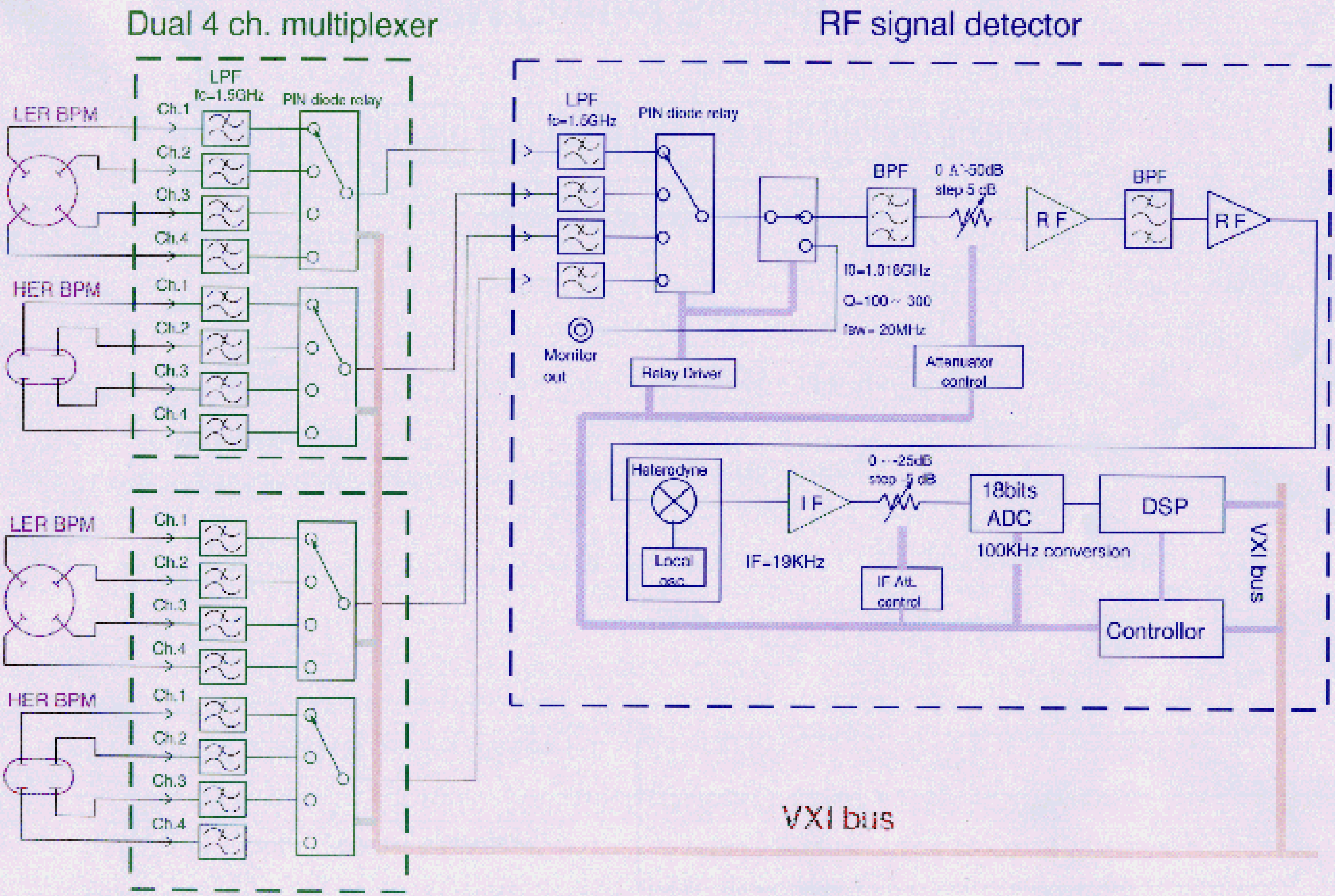




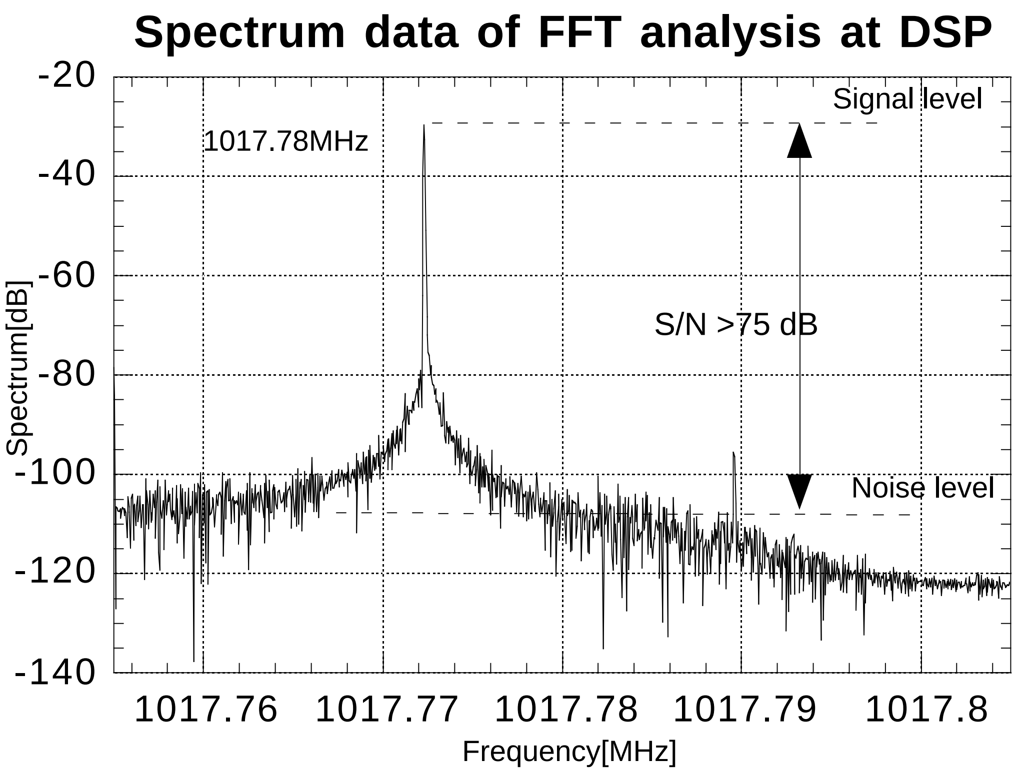
BPM Control System

To realize good accuracy and reliability of the measurement of beam position,
the BPM electronics have features as follows:

- The principle of detecting a higher harmonic component of beam signal. (1018 MHz)
- Signal process by a common detector with relays to switch four signals (PIN diode switch)

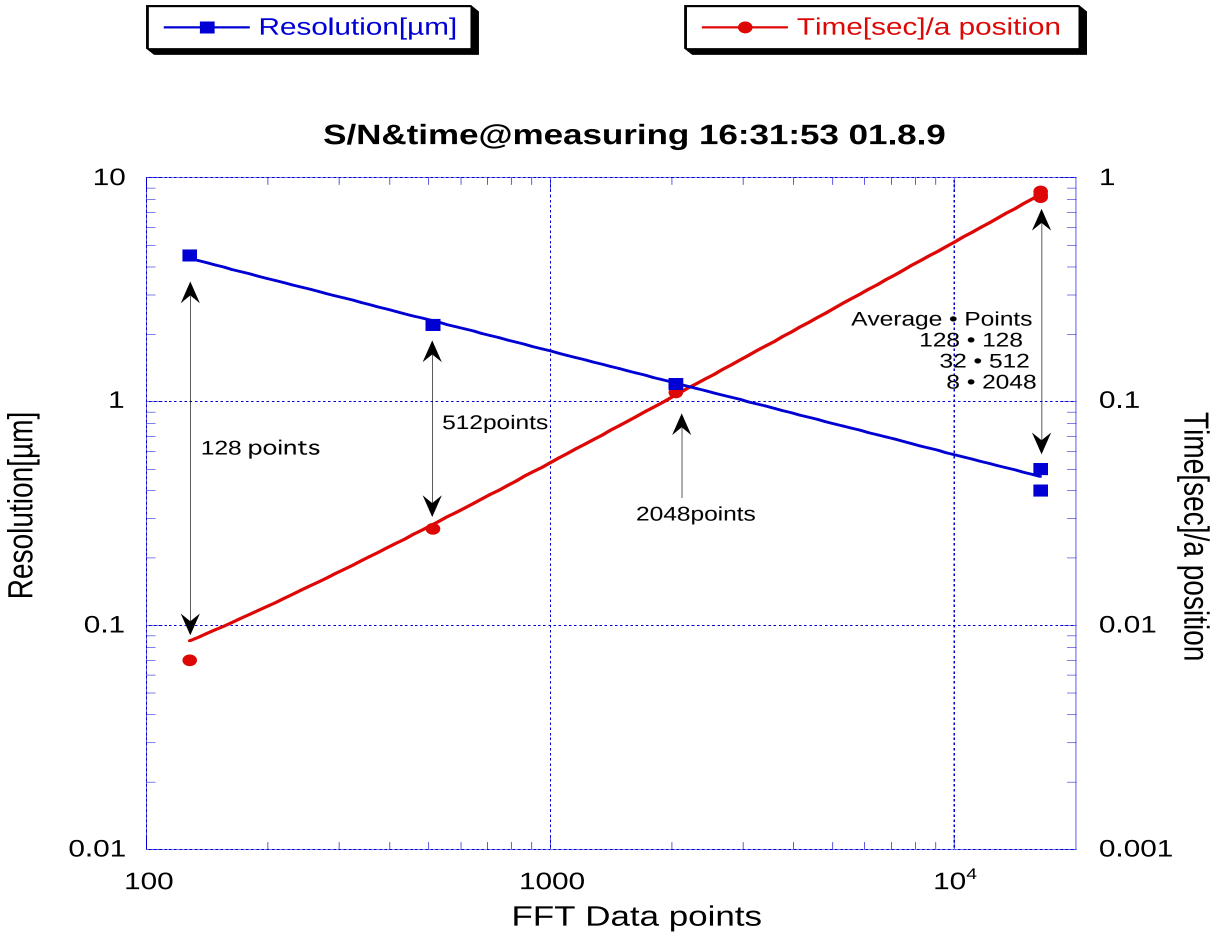

Dual 4 ch. multiplexer
RF signal detector
LER BPM
HER BPM
Ch.1
Ch.2
Ch.3
Ch.4
LPF
fc=1.5GHz
PIN diode relay
BPF
0 ~ -50dB
step 5 dB
RF
f0=1.018GHz
Q=100 ~ 300
fbw= 20MHz
Monitor out
Relay Driver
Attenuator control
Heterodyne
Local osc
IF
IF=19KHz
0 ~ -25dB
step 5 dB
IF Att. control
18bits ADC
100KHz conversion
DSP
Controller
VXI bus
VXI bus

Spectrum data of FFT process at DSP



The S/N ratio (75dB) is an equivalent to a position resolution of 2.9 µm. In practical operation, the BPM system gives about 1.5µm by 4-fold averaging.

Position resolution and Measurement-speed vs. FFT points



Performance of BPM

Content	Requirement	Performance
Relative accuracy	≤ 10 μm	≤ 3 μm
Absolute accuracy	≤ 100 μm	≤ 66 μm
Speed [1)]	≤ 1 sec / a ring	≤ 3 sec / both ring[2)]
Dynamic range	10 mA ~ 2.6 A	10 mA ~ 2.6 A

1) The speed is about 10msec/ a BPM when the sampling data is set 64 points for the FFT analysis.

2) Four time averaging at the FFT analysis of 2048 sampling data.


File Edit Measurement Correction Steering Orbit Window
10/12/2001 10:20:53 Help
HER Orbit Correction
19.875 mA
Correction Off.
dp/p0 -0.3906D-05
measured 10/12/2001 10:20:50
DX (mm)
DY (mm)
-1500 -1000 -500 0 500 1000 1500
CCC running: GOLD_10_12_2001_09:03:55*
range DX Auto Fix (1.5) DY Auto Fix (1.5) Replot
Ring -T- T-N -N- N-F -F- F-O -O- O-T @BPMx @BPMy
mea sta ref m-r s-r cal gold m-g
mea-> ref gold Save mea ref m-r gold Clear Stat. Standard Size
Correction Panel
Conditions
mea mea-ref mea-gold
Horizontal Vertical
SVD MICADO
Tolerance (H) .01
Tolerance (V) .01
normal fast
44.50110 44.51682 44.51940
41.61467 41.61751 41.60500
Correction
Calculate
Set Correctors
Damping Factor (H) .5
Damping Factor (V) .5
Damp Fact. (Adj K) .1
Damp Fact. (Mom C) .5
Start CCC
Stop CCC
Correction
Display Results
Orbit
Measure
BPM NG: 020 30
Use NG BPMs
Recall ->
mea ref gold
Factor 1
Read iBump Files
Forget Old Bumps
Option
IP kick
Weight(H) 10
Weight(V) 30
Set QCS
Synch Set
Adjust Kick
Momentum Correction
Size Feedback
Show uncorr. iBump
CCC Interval 4
I thres. mA .1
iBump Damper
Damping Rate 0
(current value 0)
Set
IP Position
Fix IP Position
Weight 100
Clear Size FB Records
Clear Inhibit Flags
Hard Copy

CALIBRATIONS OF THE BPM

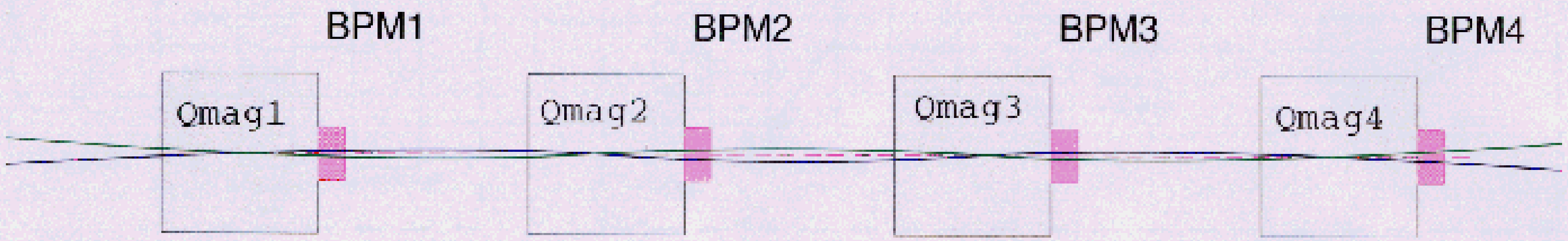
(1) Calibration before the commissioning

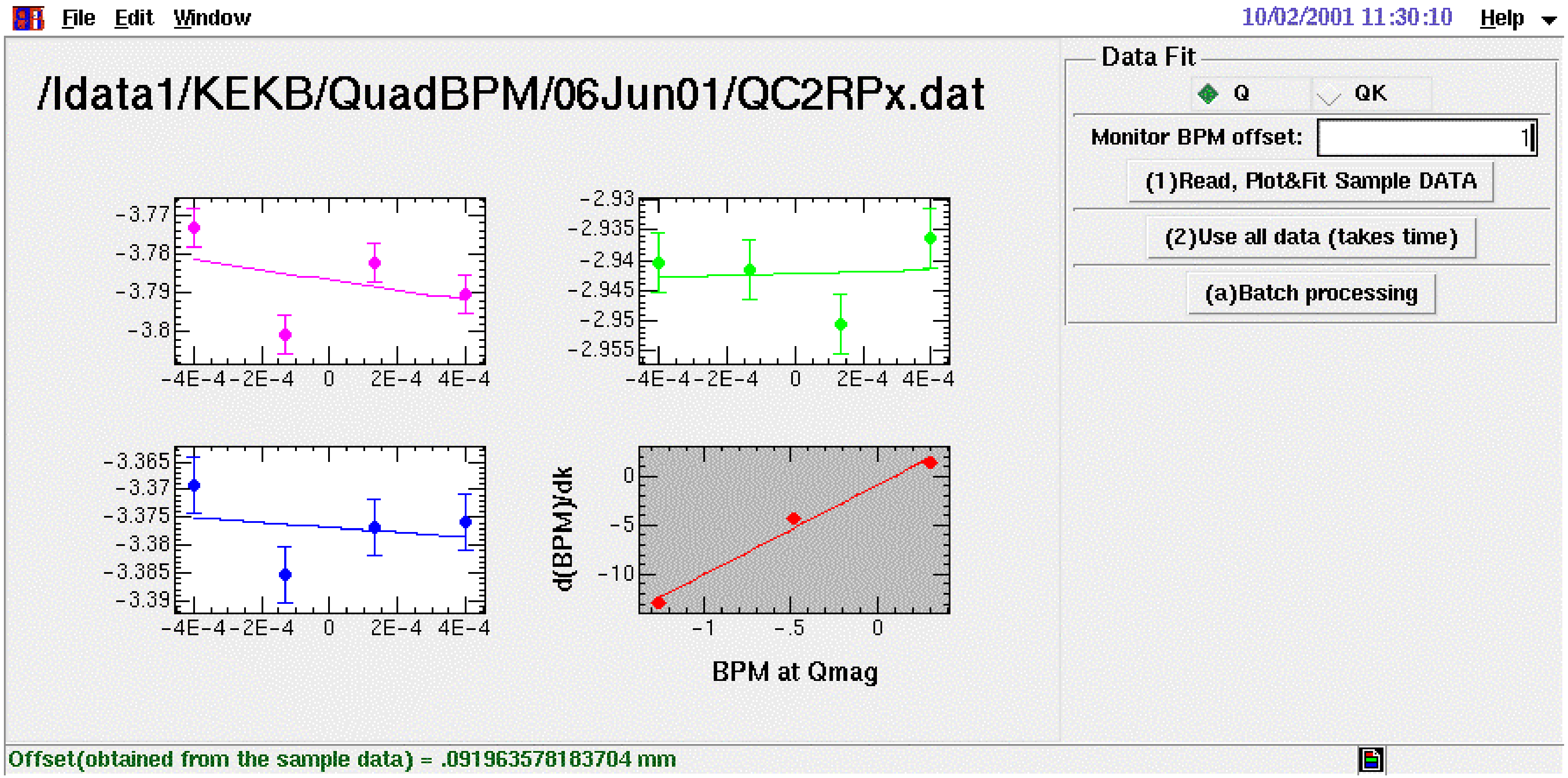
Content	Accuracy of calibration
Mapping measurement	≤ 20 μm
Alignment of BPM heads	≤ 38 μm(hor.), ≤ 16 μm
Attenuation of cables	≤ 50 μm
Total	≤ 66 μm

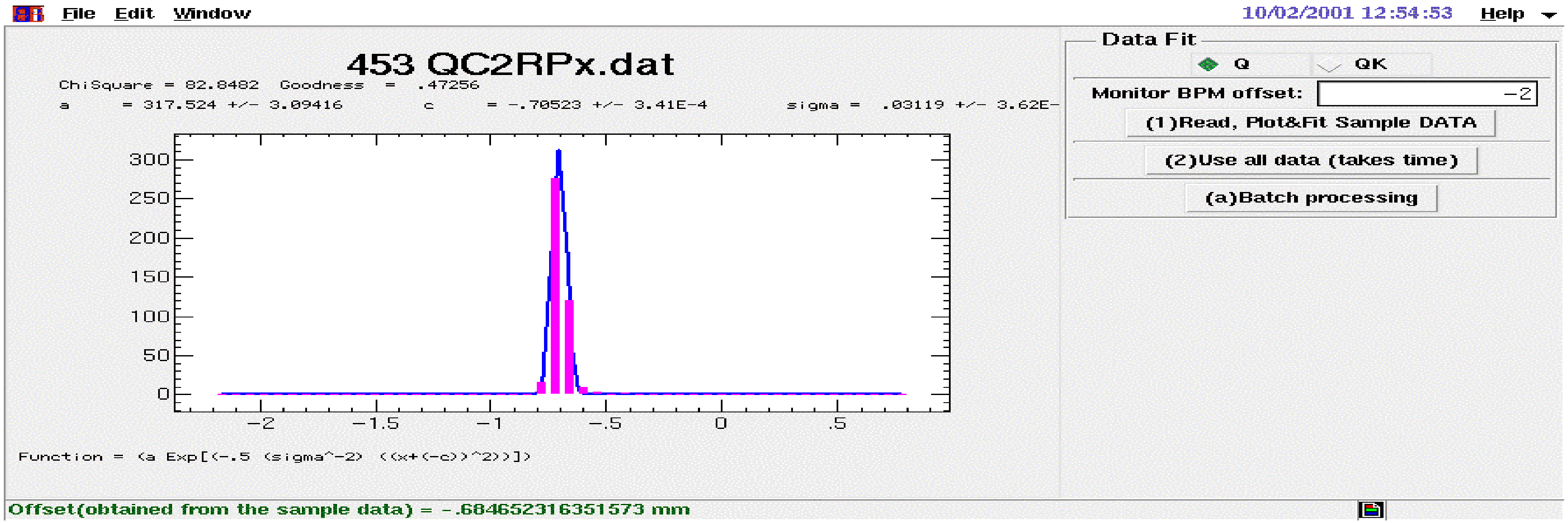
(2) Beam based alignment for the BPM

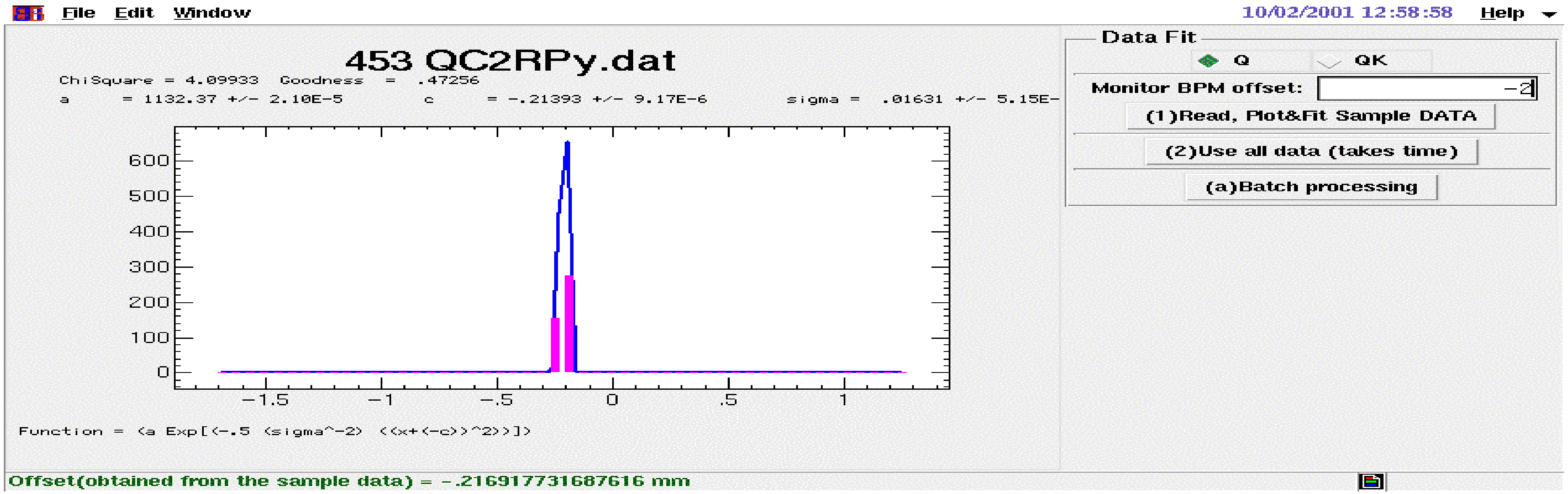
BPM offset from the magnetic field center of a Quadrupole magnet according to the Quad-BPM method.

- The COD is changed 3 times using a couple of Hor. And Ver. steering mag.
- The adjacent Q-mag' strength(k) is changed also 4times.
- The dx/dk is measured by whole BPM.

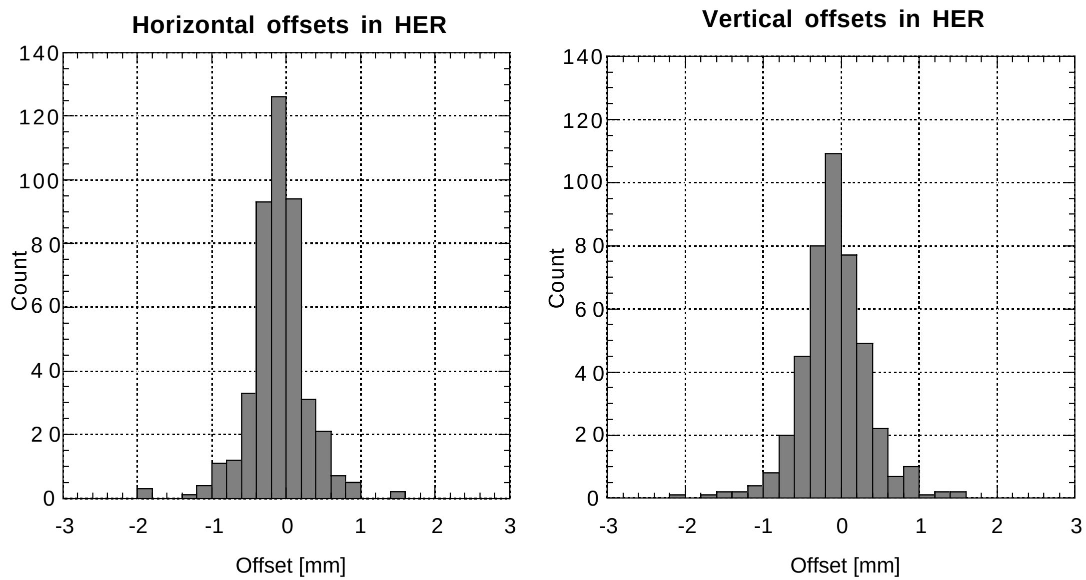



File Edit Window
10/02/2001 11:30:10 Help
/ldata1/KEKB/QuadBPM/06Jun01/QC2RPx.dat
Data Fit
Q
QK
Monitor BPM offset:
1
(1)Read, Plot&Fit Sample DATA
(2)Use all data (takes time)
(a)Batch processing
-3.77
-3.78
-3.79
-3.8
-4E-4 -2E-4 0 2E-4 4E-4
-2.93
-2.935
-2.94
-2.945
-2.95
-2.955
-4E-4 -2E-4 0 2E-4 4E-4
-3.365
-3.37
-3.375
-3.38
-3.385
-3.39
-4E-4 -2E-4 0 2E-4 4E-4
d(BPM)/dk
0
-5
-10
-1 -.5 0
BPM at Qmag
Offset(obtained from the sample data) = .091963578183704 mm

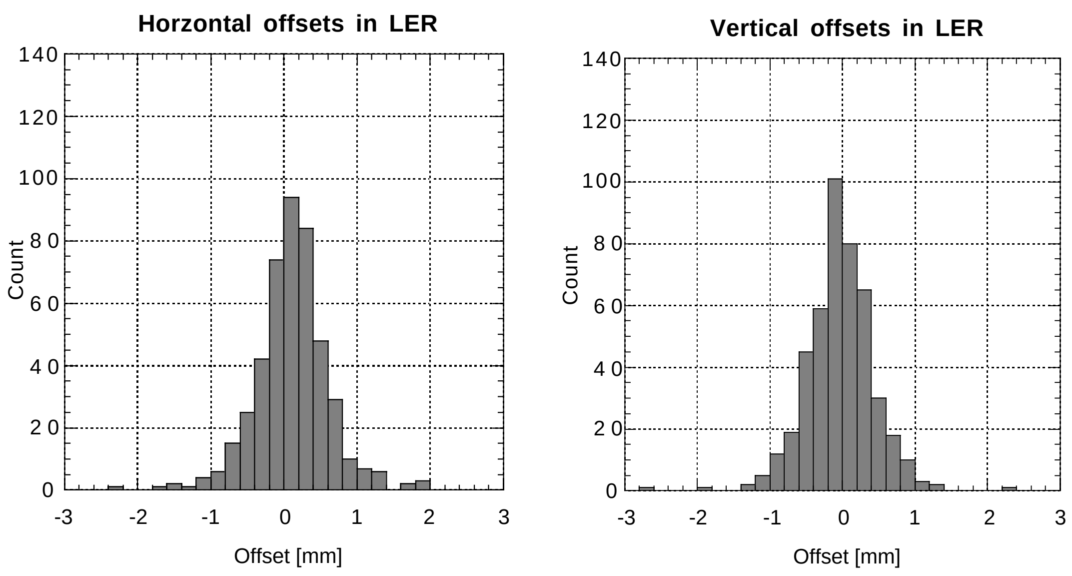

File Edit Window
10/02/2001 12:54:53
Help
453 QC2RPx.dat
ChiSquare = 82.8482 Goodness = .47256
a = 317.524 +/- 3.09416 c = -.70523 +/- 3.41E-4 sigma = .03119 +/- 3.62E-
300
250
200
150
100
50
0
-2
-1.5
-1
-.5
0
.5
Function = (a Exp[(-.5 (sigma^-2) ((x+(-c))^2))])
Data Fit
Q
QK
Monitor BPM offset:
-2
(1)Read, Plot&Fit Sample DATA
(2)Use all data (takes time)
(a)Batch processing
Offset(obtained from the sample data) = -.684652316351573 mm



File Edit Window
10/02/2001 12:58:58 Help
453 QC2RPy.dat
ChiSquare = 4.09933 Goodness = .47256
a = 1132.37 +/- 2.10E-5 c = -.21393 +/- 9.17E-6 sigma = .01631 +/- 5.15E-
600
500
400
300
200
100
0
-1.5 -1 -.5 0 .5 1
Function = (a Exp[(-.5 (sigma^-2) ((x+(-c))^2))])
Data Fit
Q
QK
Monitor BPM offset:
-2
(1)Read, Plot&Fit Sample DATA
(2)Use all data (takes time)
(a)Batch processing
Offset(obtained from the sample data) = -.216917731687616 mm

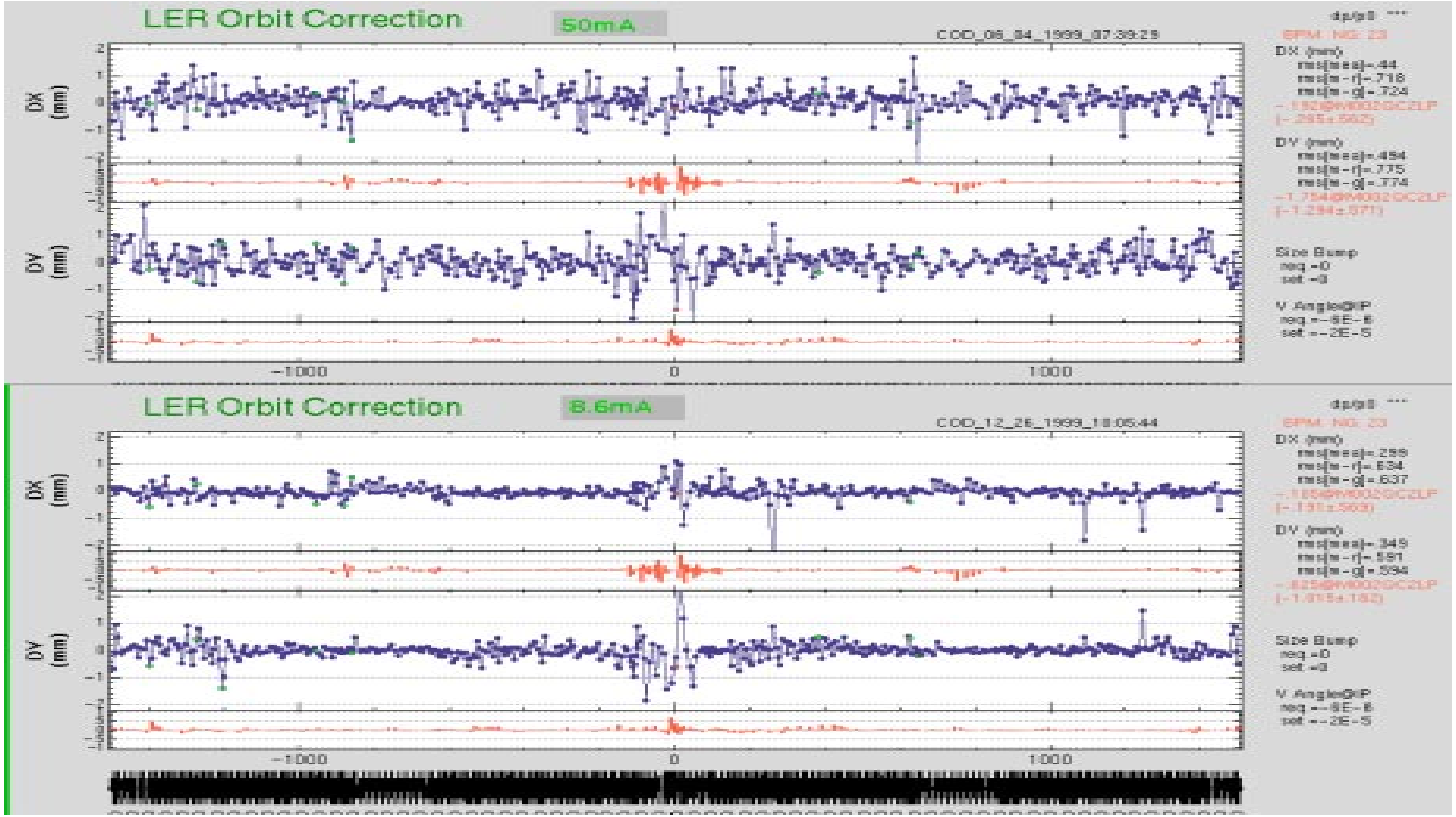


Histogram of offset measured by beam based alignment in HER



Histogram of offset measured by beam based alignment in LER

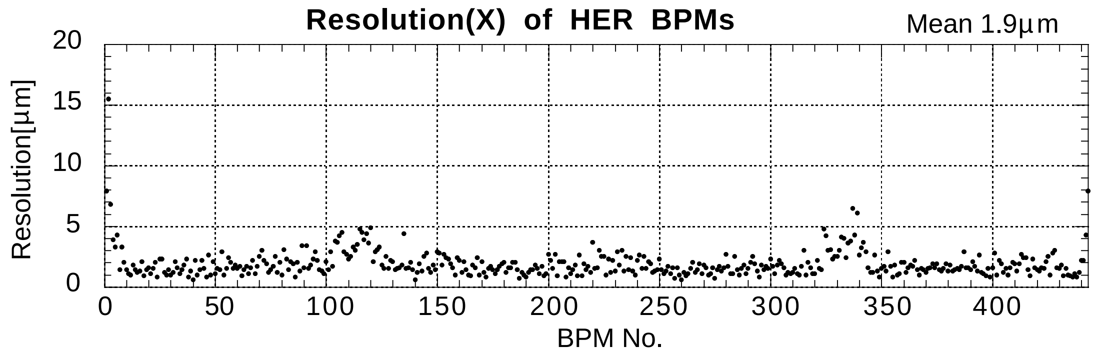
Improvement of closed orbits

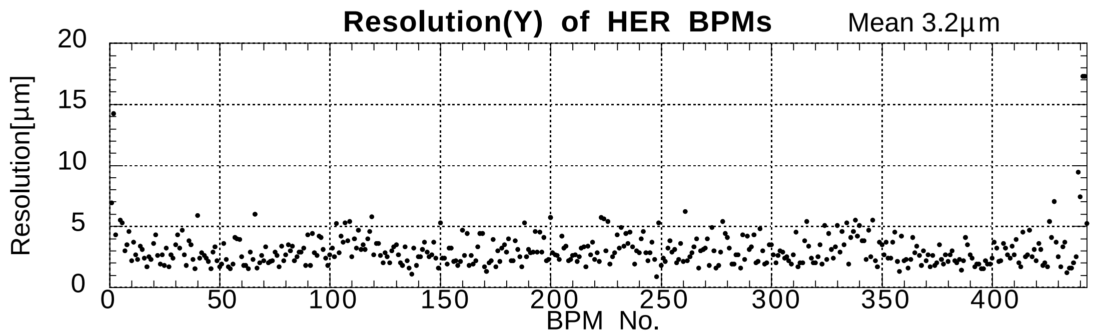


LER closed orbit before offset correction

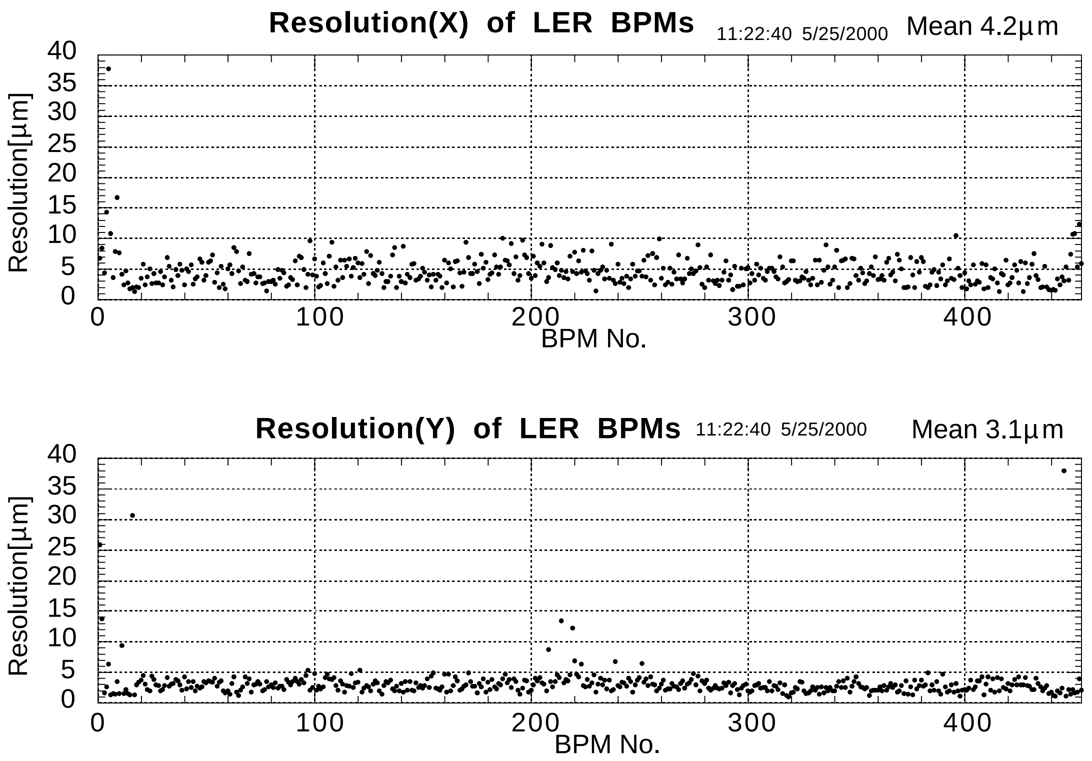
Measurement of position resolution

Three-BPM method





Distribution of all BPM resolutions in HER



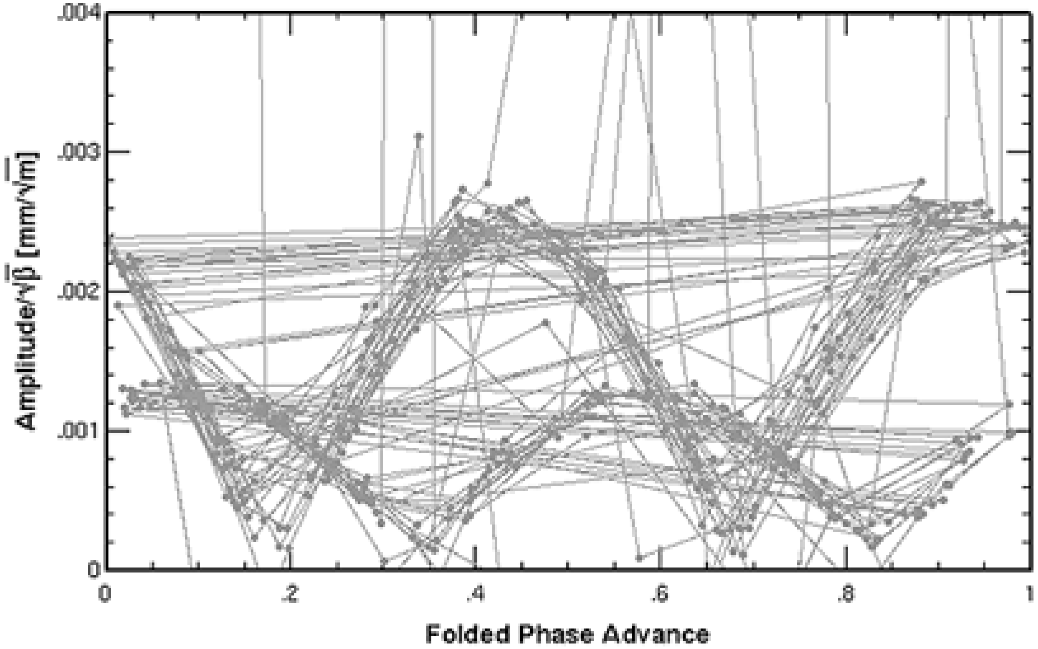
Distribution of all BPM resolutions in LER

Correction of ORBIT OSCILLATIONS

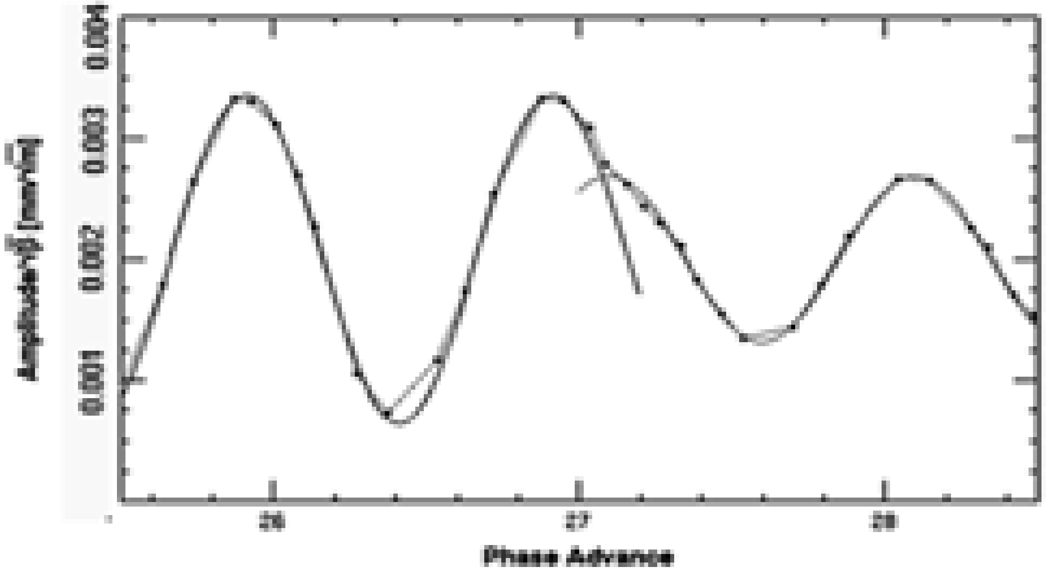
Measurement by EPIICS "waveform" record

- High-speed measurement: 2~120 positions/sec
- Record length: 512 points
- Start timing: Event code

The Oscillation source is magnetic field of the proton synchrotron of 0.47Hz



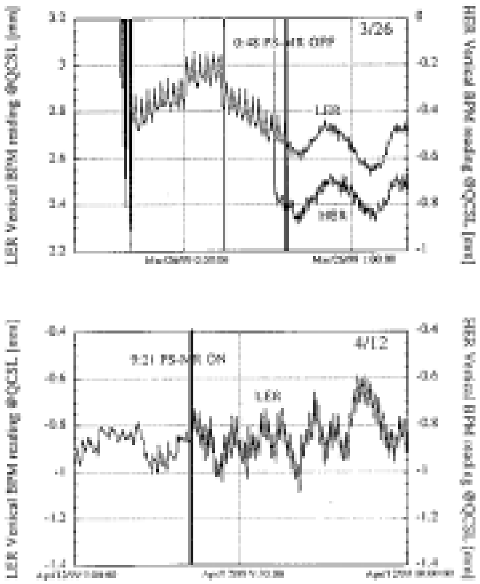
Overlapping of the amplitude of 0.47 Hz component on the folded phase advance of optical function in the LER



Trace of the amplitude of 0.47 Hz components over the phase advance of the optics function.

KEKB COD Oscillation and PS-MR

Apr/30/1999 N Akasaka

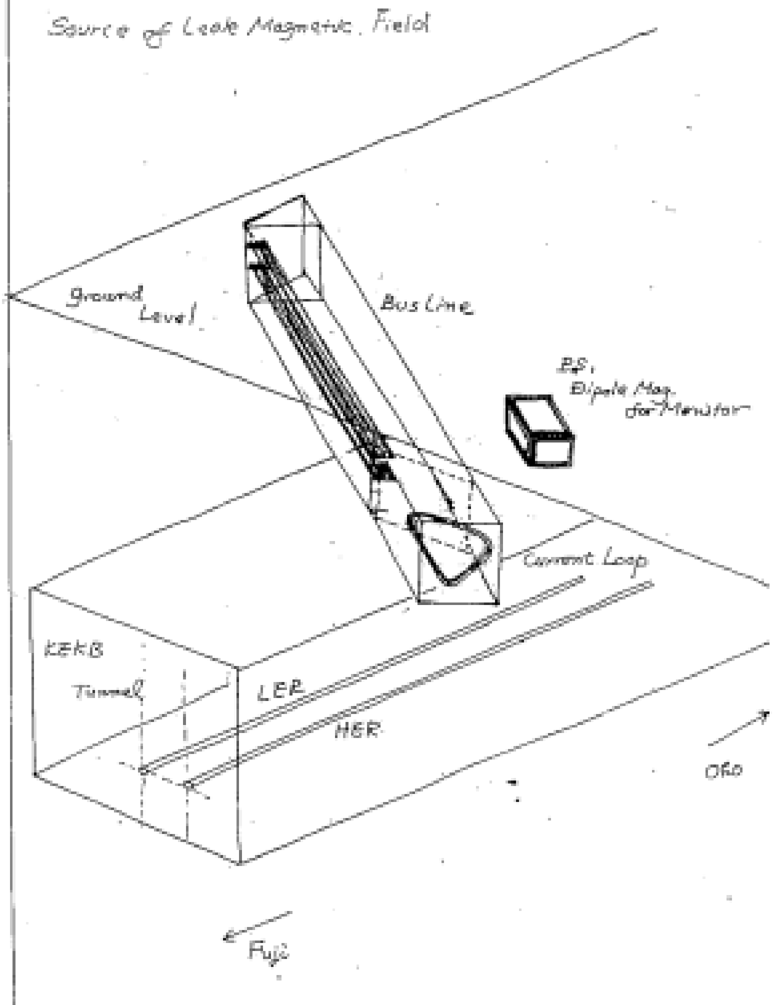


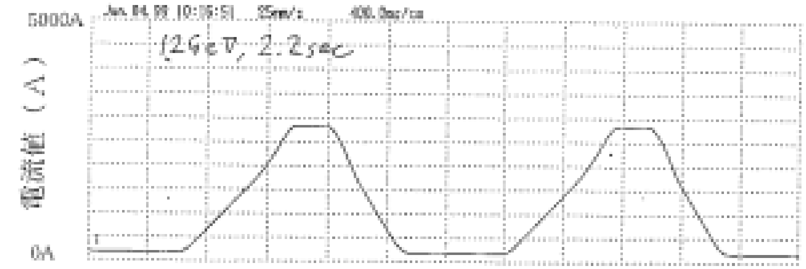
PAGE 1

KEK ENGINEERING NOTE

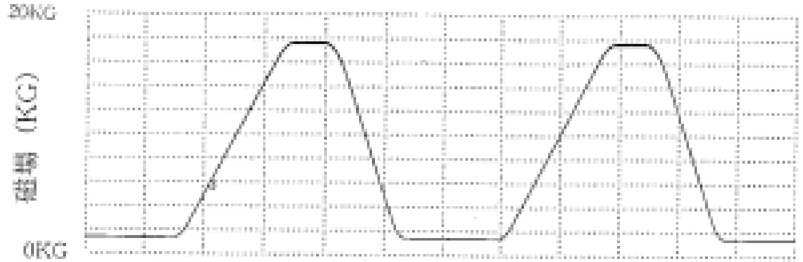
CODE: DATE:

NAME:

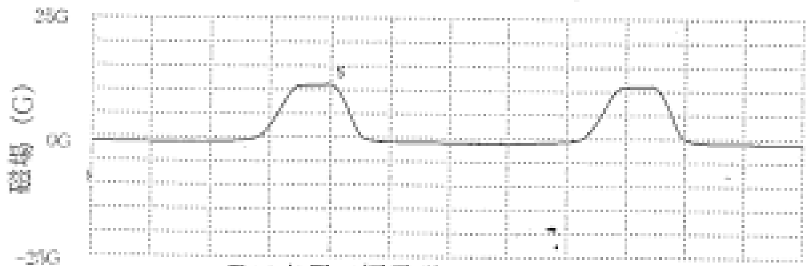




PS主リング二極電磁石の電流(A)



二極電磁石の磁場 (KG)



モニタ用二極電磁石の漏れ磁場
(電磁石より約７０cmの場所で測定)

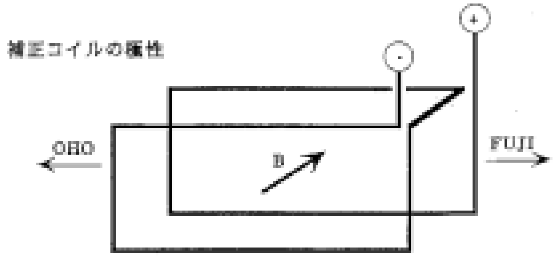


図１４－Ａ

補正コイルの長さ

COIL ID	Length
#1-1	462 mm
#1-2	906 mm
#2-1	626 mm
#2-2	450 mm
#2-3	625 mm
#3-1	466 mm
#3-2	594 mm
#3-3	464 mm
#4	546 mm
#5	1476 mm

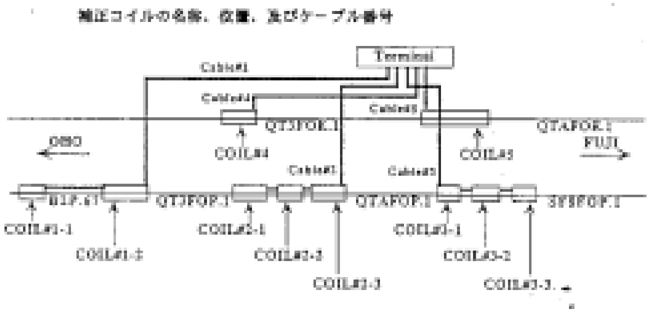


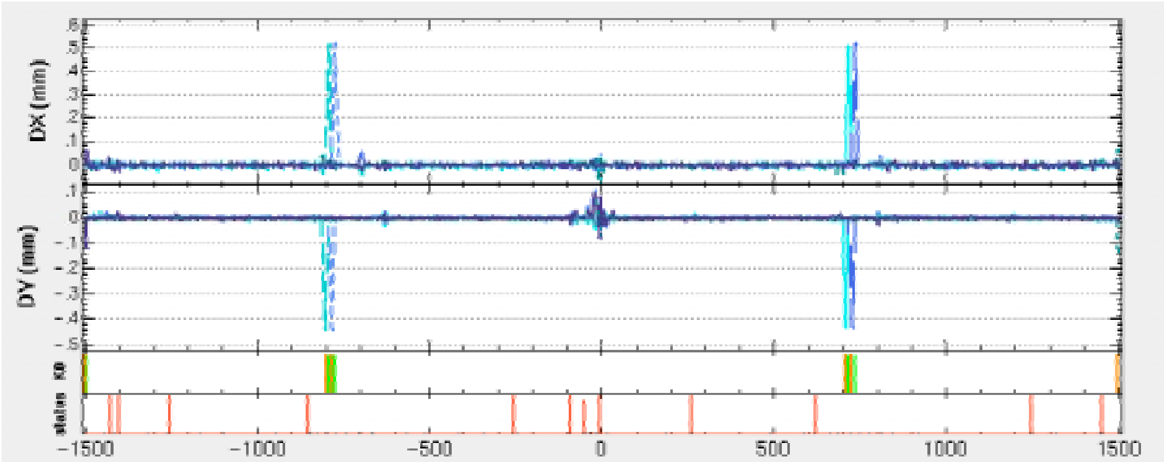
図１４－Ｂ

The 3-BPM Correlation Analysis Based
On the Lattice Model

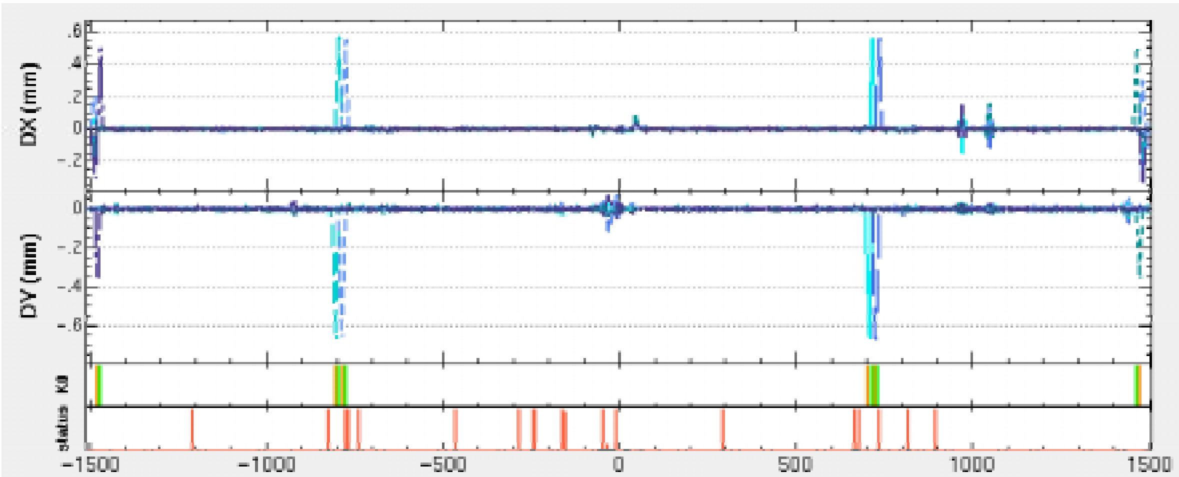
Between analyzed beam position and measured position,

the difference is about 10 μm.

Consistency between 3 Adjacent BPMs



HER



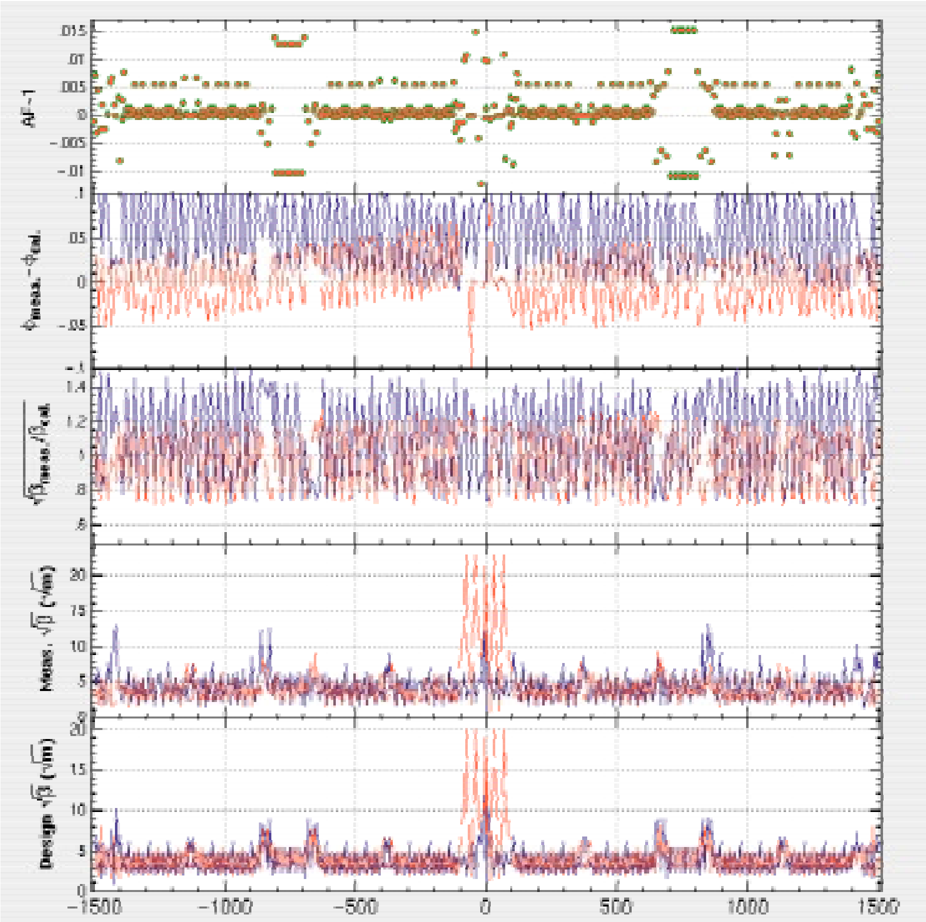
LER

$$\begin{pmatrix} x_3 \\ P_{x3} \end{pmatrix} \xleftarrow{n} \begin{pmatrix} x_2 \\ P_{x2} \end{pmatrix} \xleftarrow{m} \begin{pmatrix} x_1 \\ P_{x1} \end{pmatrix}$$

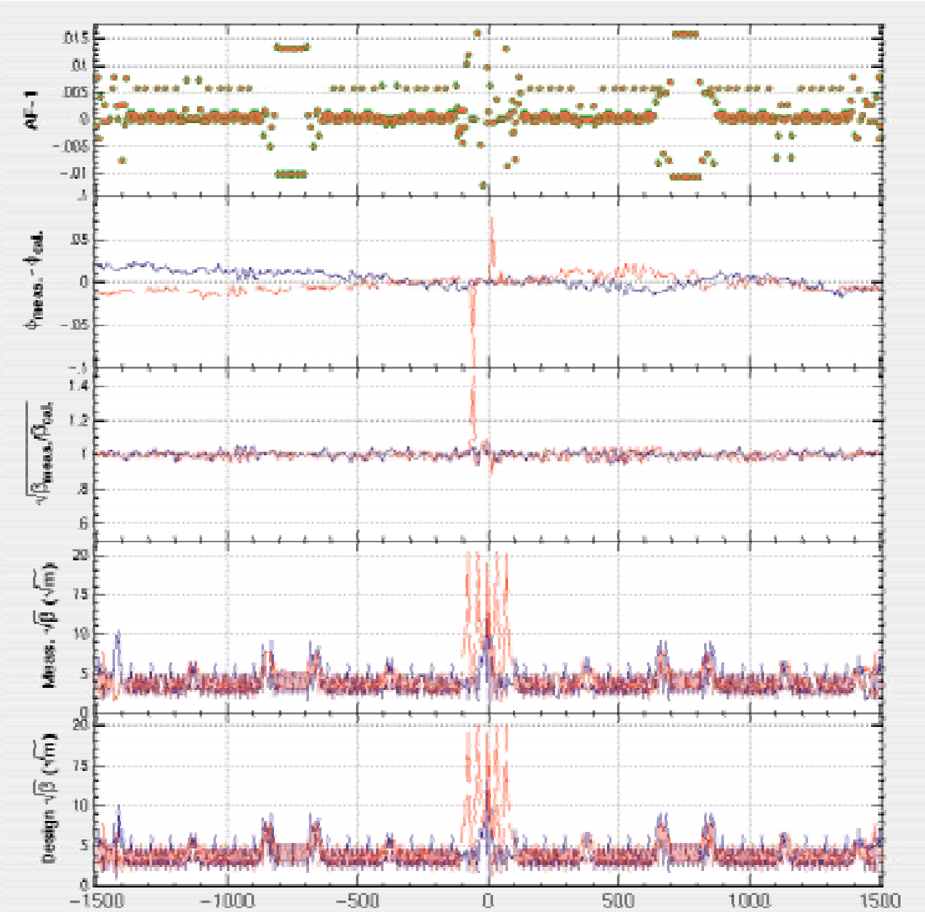
$$M \equiv nm, \; x_2 = \frac{n_{12}x_1 + m_{12}x_3}{M_{12}}$$

Global Beta Correction(LER)

before correction



after correction



$\Delta\beta x/\beta x$ (before -> after) 0.291 -> 0.042 $\Delta\beta y/\beta y$ (before -> after) 0.321 -> 0.043

Fitting method to obtain β functions at BPMs from single-kick orbits

(by N. Akasaka)

A kick * at * produces the displacement * at the i-th BPM as

$$x_{ia} = \frac{\sqrt{\beta_i \beta_a}}{2\sin\pi\nu}\cos\left(\pi\nu - |\varphi_i - \varphi_a|\right)\cdot\theta_a$$

$$= f_a\sqrt{\beta_i}\cos\left(\pi\nu - |\varphi_i - \varphi_a|\right)$$

$$f_a \equiv \frac{\sqrt{\beta_a}}{2\sin\pi\nu}\theta_a$$

$$x_{ia} \equiv F_{ia}\left(i,\beta_i,\varphi_i,f_a,\varphi_a\right)$$

$$= \sqrt{\beta_i}\cos\varphi_i\cdot f_a\cos\left(\pi\nu\pm\varphi_a\right)\mp\sqrt{\beta_i}\sin\varphi_i\cdot f_a\sin\left(\pi\nu\pm\varphi_a\right)$$ ...... (1) for $\sqrt{\beta_i}\cos\varphi_i$ and $f_a\sin\varphi_a$

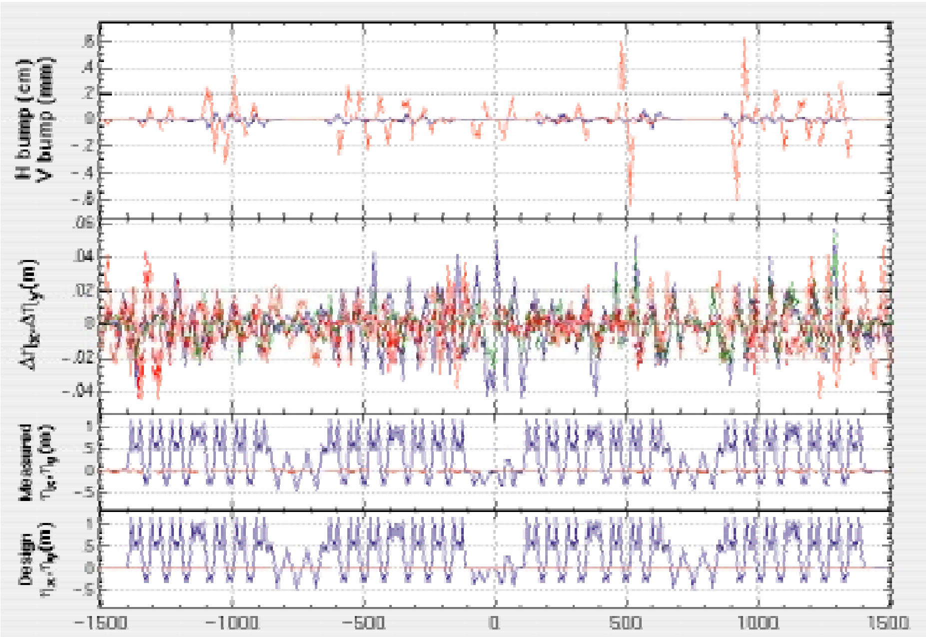
$$= f_a\cos\varphi_a\cdot\sqrt{\beta_i}\cos\left(\pi\nu\pm\varphi_i\right)\pm f_a\sin\varphi_a\cdot\sqrt{\beta_i}\sin\left(\pi\nu\pm\varphi_i\right)$$ ...... (2) for $f_a\cos\varphi_a$ and $f_a\sin\varphi_a$

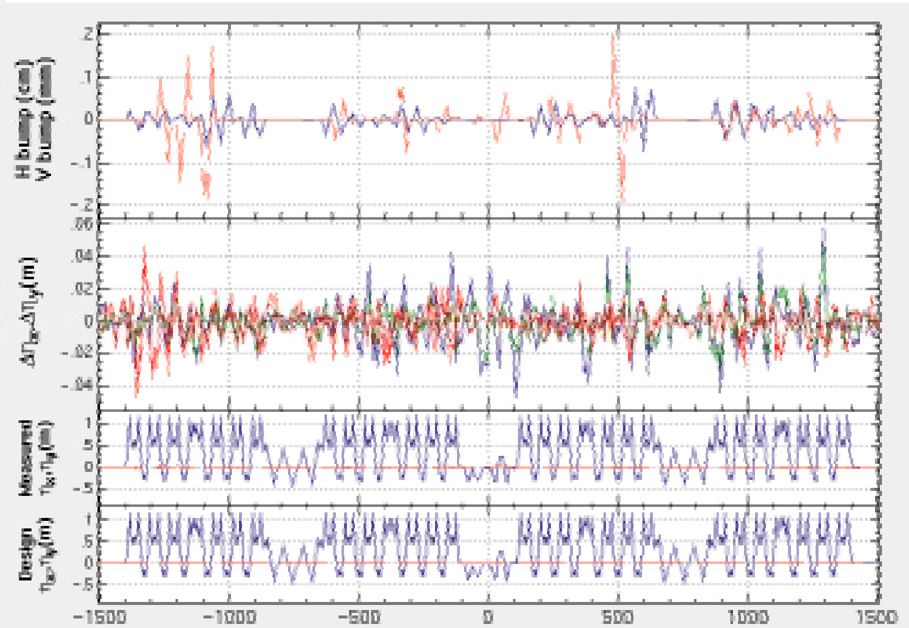
(β_i,φ_i) and (f_a,φ_a) are evaluated using (1) and (2) alternately.

Global Dispersion Correction(HER)

before correction

after correction

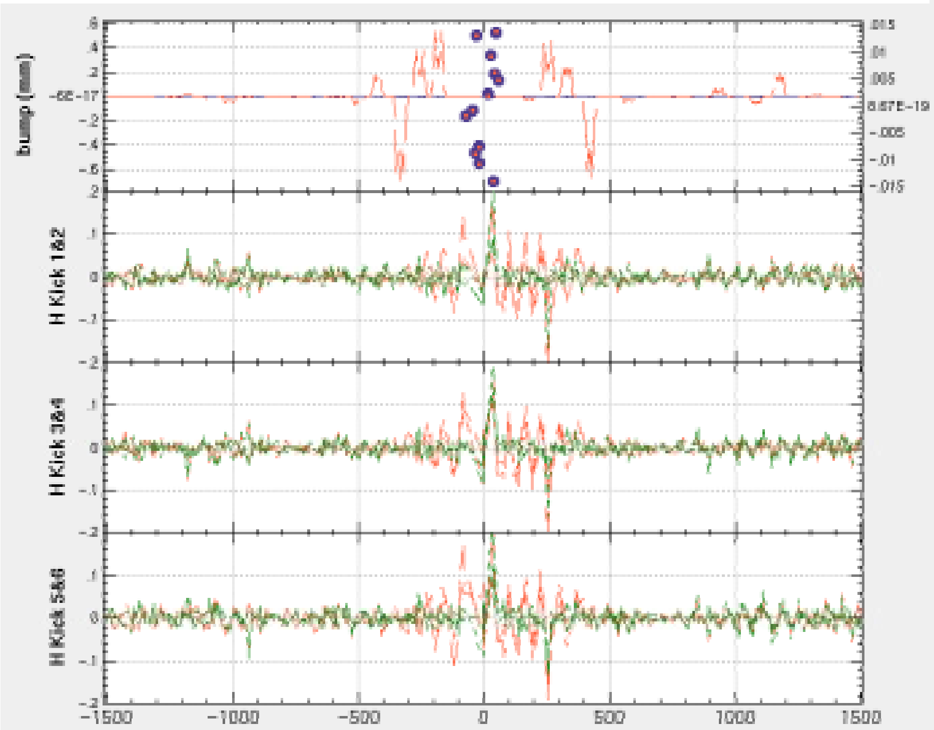




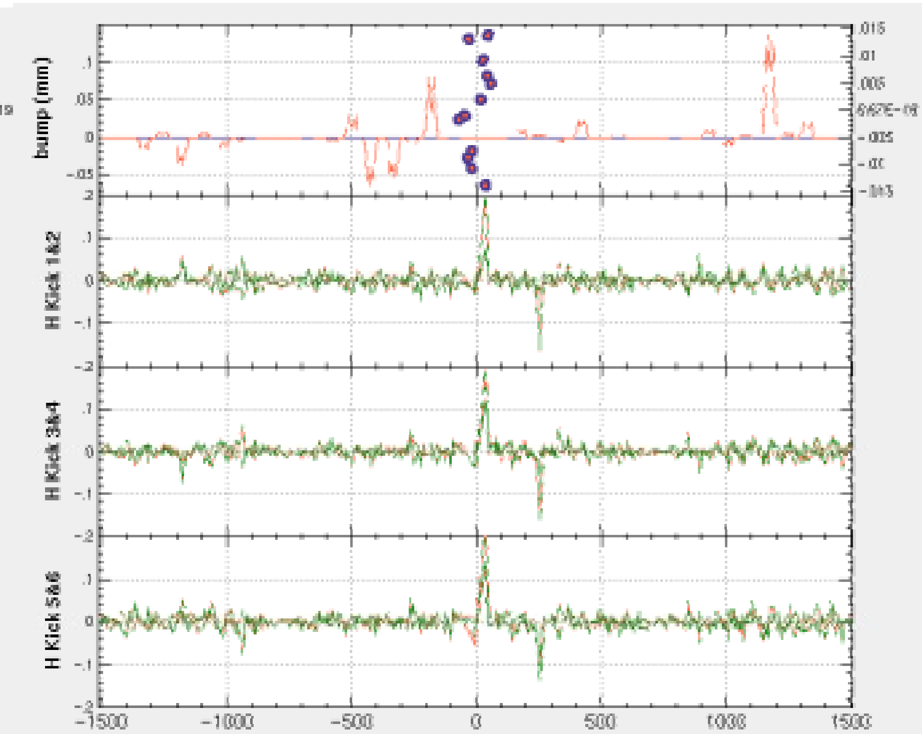
$\Delta\eta y$ (before -> after) 15.0 -> 11.1 mm

Global Coupling Correction(HER)

before correction

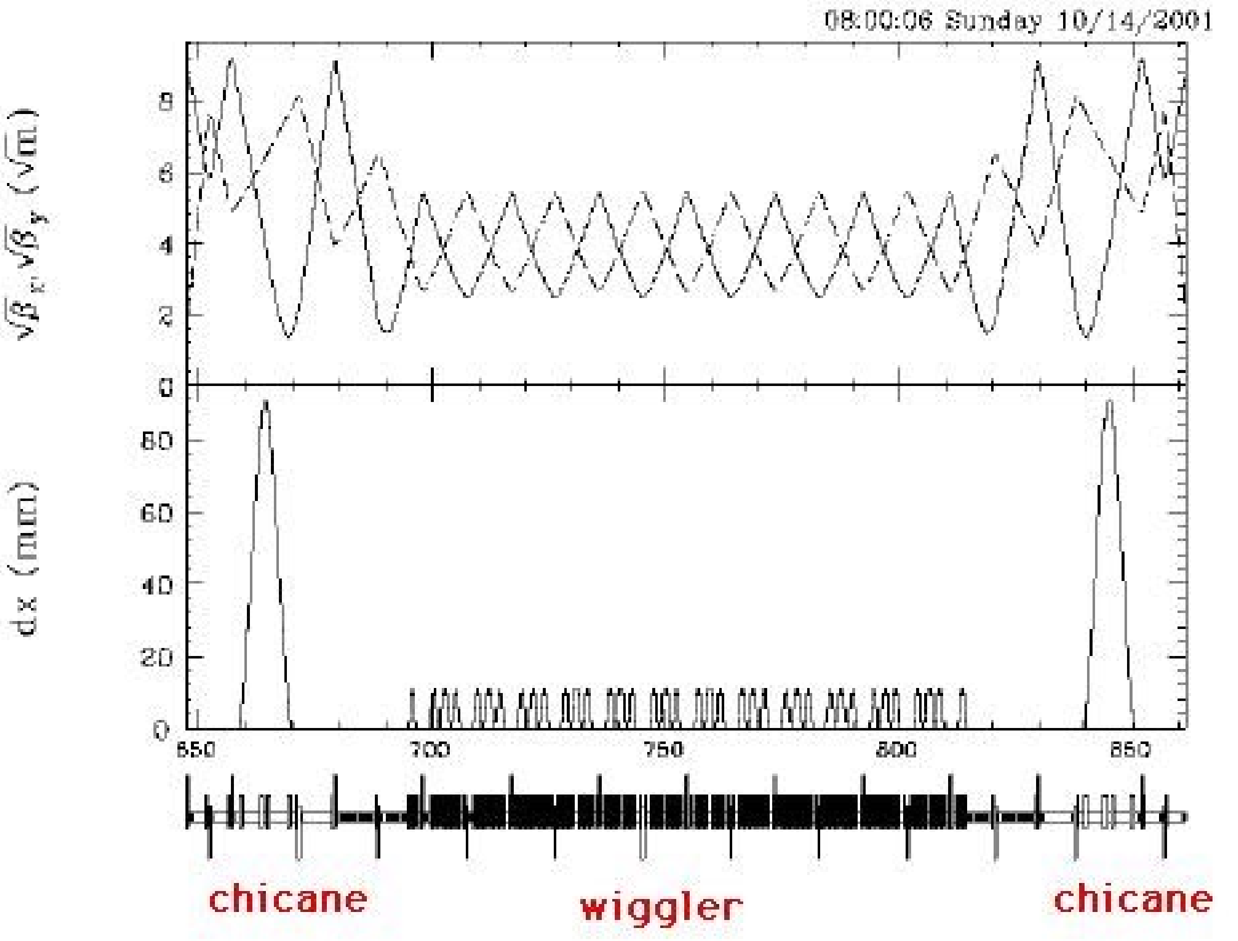


after correction



Δy (before -> after) 26.7 -> 19.4 μm

Orbit Length Correction with Chicane



The orbit length in the arc is adjusted with chicanes in LER.

$$\Delta p / p_0 = \sum_i x_i \eta_{xi} \Big/ \sum_i \eta_{xi}^2$$

x_i	*Measured position*
η_{xi}	*Desgn dispersion*

$$\Delta l = \alpha \cdot \Delta p / p_0 \cdot C_0$$

α	*Momentum compaction factor*
C_0	*Design circumference*
l	*Orbit length*

$$\Delta l \propto \Delta \theta_{chicane}$$

θ	*Kick angle at chicane*

Kick angle at chicane and Shift of RF frequency