Beam Diagnostics

The 20th KEKB Accelerator Review

2015/2/24

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- Beam Position Monitor System（BPM）
- Photon Monitor System
- Others
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- Summary

Instrumentation at SuperKEKB

System	Quantity		
	HER	LER	DR
Beam position monitor (BPM)	466	444	83
Displacement sensor	110	108	0
Transverse bunch feedback system	2	2	1
Longitudinal bunch feedback system	0(1)	1	0
Visible SR size monitor	1	1	1
X-ray size monitor	1	1	0
Beamstrahlung monitor	1	1	0
Betatron tune monitor	2	2	1
Beam loss monitor	207		34
DCCT	1	1	1
CT	1	1	0
Bunch current monitor	1	1	1

BPM

CABLES

TBT MONITOR

LIBERA

DISPLACEMENT SENSORS

VERTICAL COLLISION FEEDBACK

BPM system at Phase 1

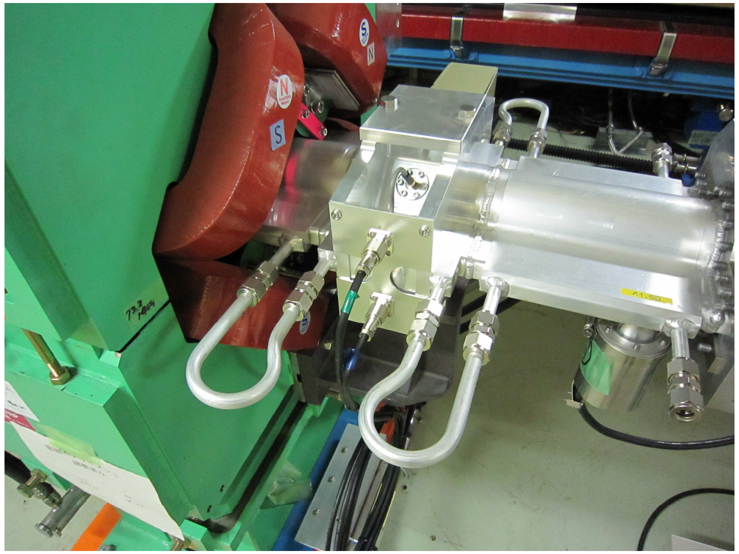
Type	Function	Resolution	Repetition	Number of units
Narrow-band system from KEKB	Closed orbit correction, CCC, optics measurement	3mm	0.25Hz	109 (already have.)
New narrow-band with 509MHz detection	As above	2 to 3 mm	0.25Hz	133
Gated turn by turn	Injection tuning, optics measurement	50 - 100mm	100kHz	116
Medium-band	Measurement of orbit variation	< 2 to 3 mm	10〜100kHz	4

One narrowband detector covers four BPMs.

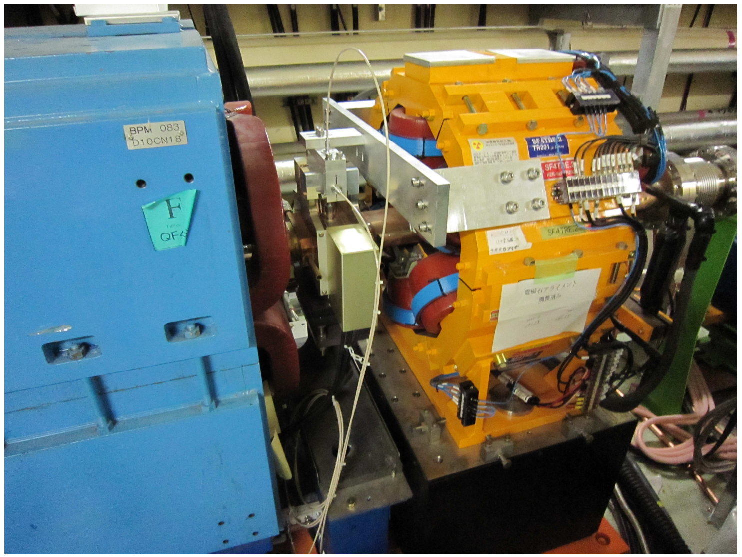
H.Fukuma

Installation of BPM cables and displacement sensors

- Installation of BPM cables will be finished by the end of March, except for seven in the arc section near Tsukuba.
- 131 displacement sensors have been installed. 68 will be installed after the alignment of sextupoles, so as not to interfere with the alignment.



Cabling at a BPM head.



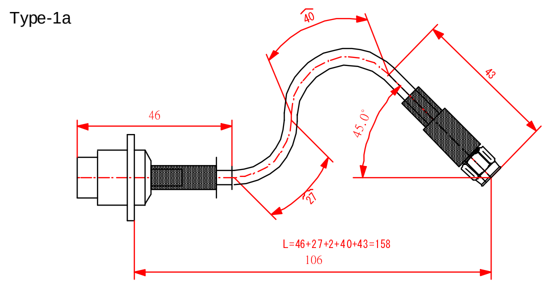
Restored displacement sensor.

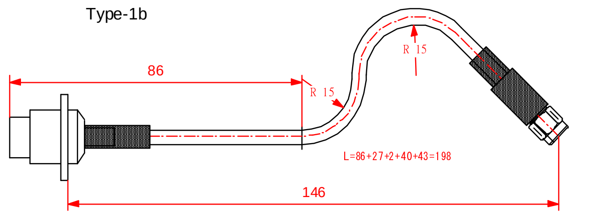
Cable rack detouring the Belle detector.

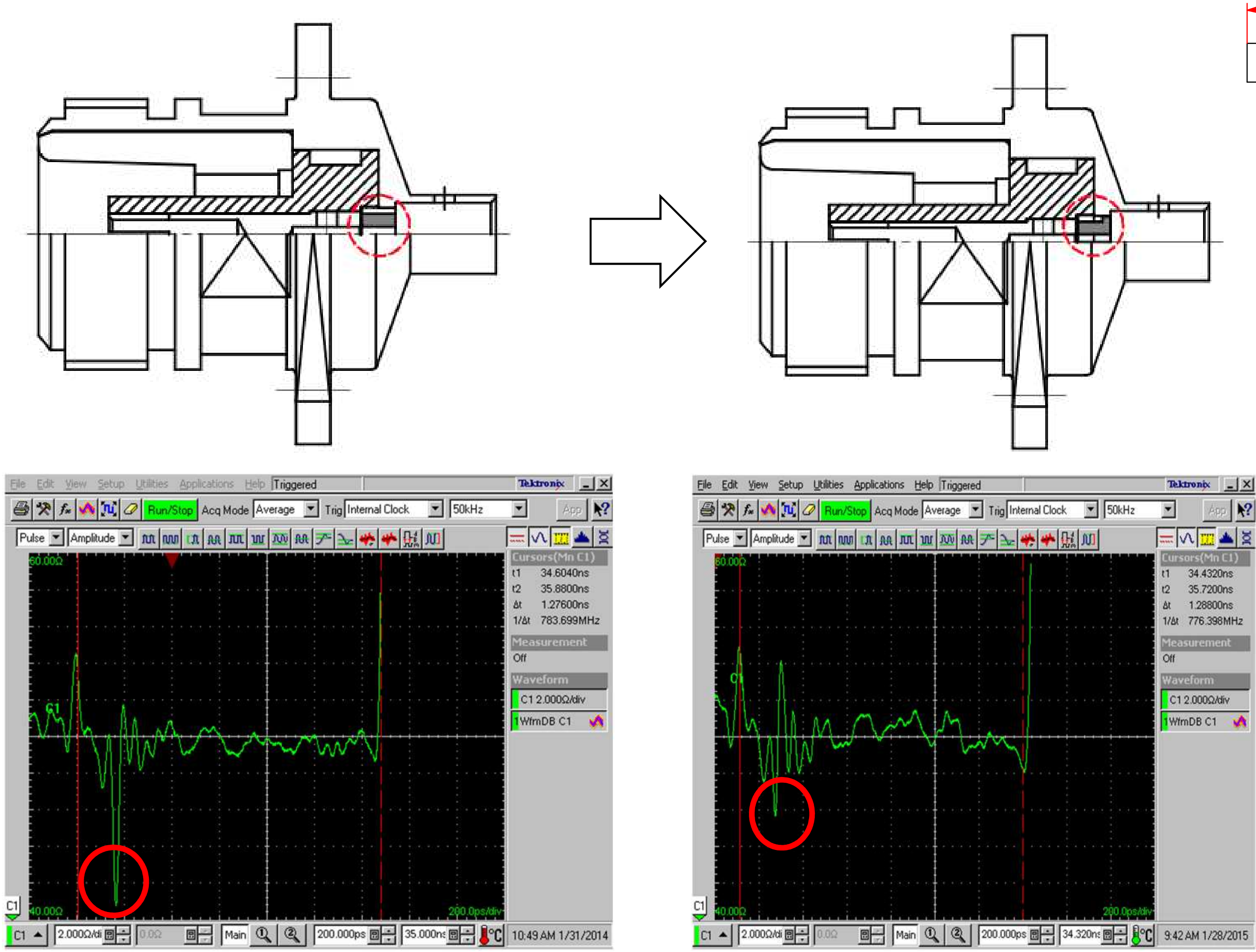
M.Tejima

BPM 3DPKFLX Cable

- Shape of the insulator was changed to more securely attach the insulation of the outside conductor of the connector and the inner conductor.
- The impedance at the terminal part was improved.



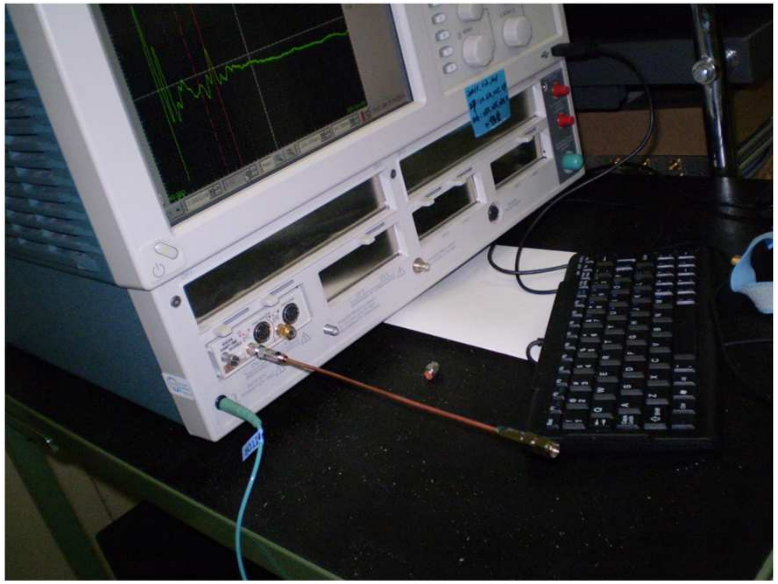




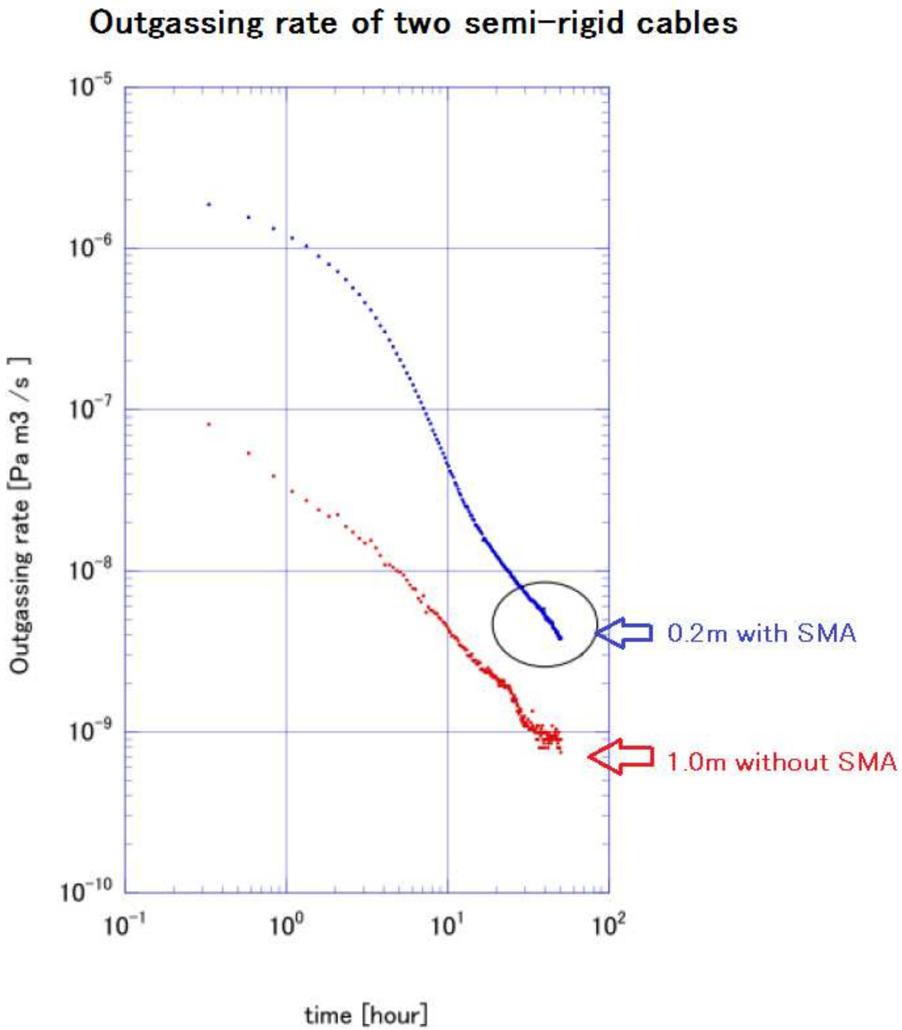
Waveform of TDR

M.Tejima

1.5D semi-rigid cable



Waveform of TDR



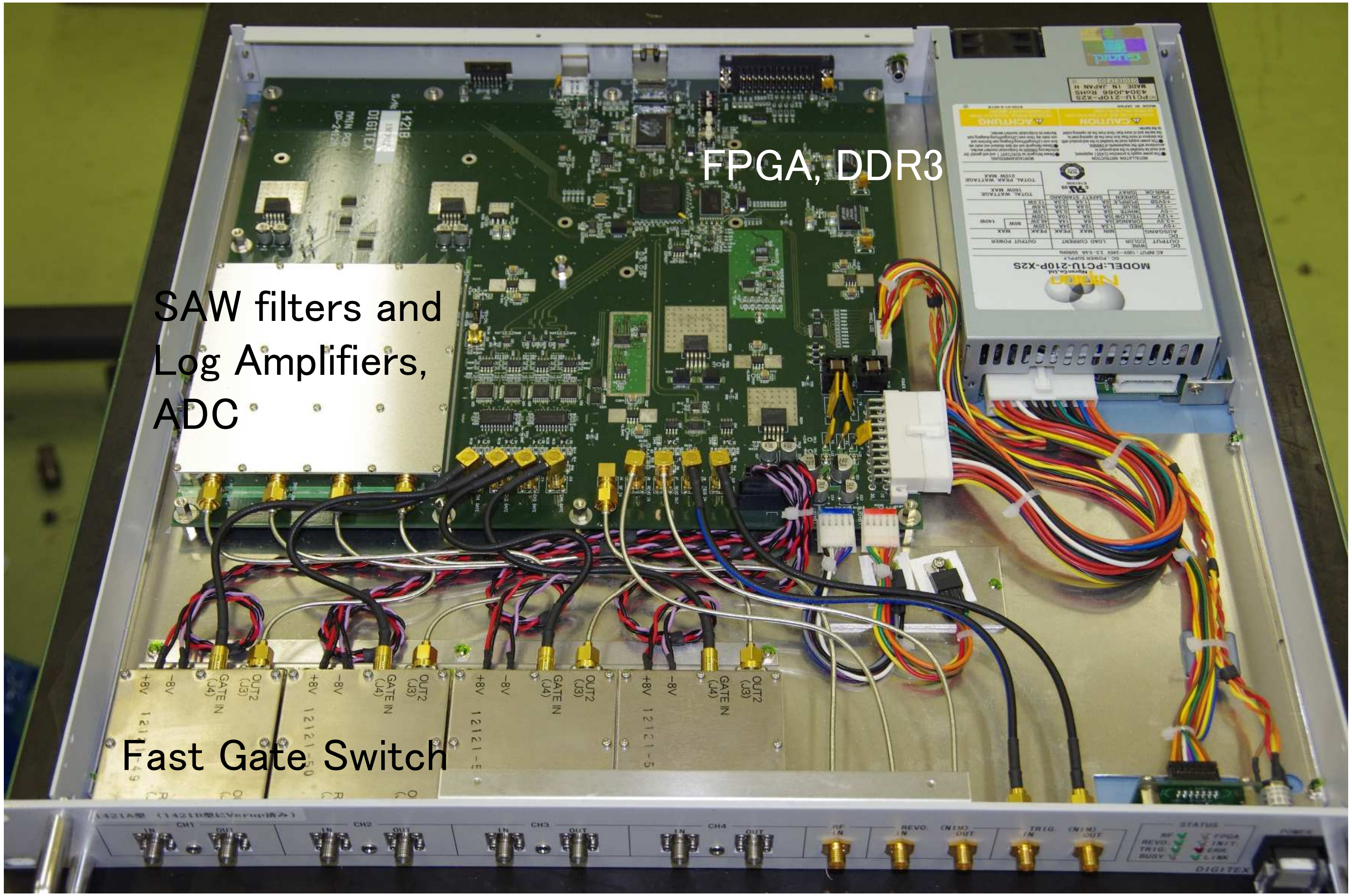
There is more outgassing with the 0.2 m cable with SMA connectors (blue) than there is with the 1 m cable with no SMA (red). We can use the cable in the cryostat.

Gated turn-by-turn monitors

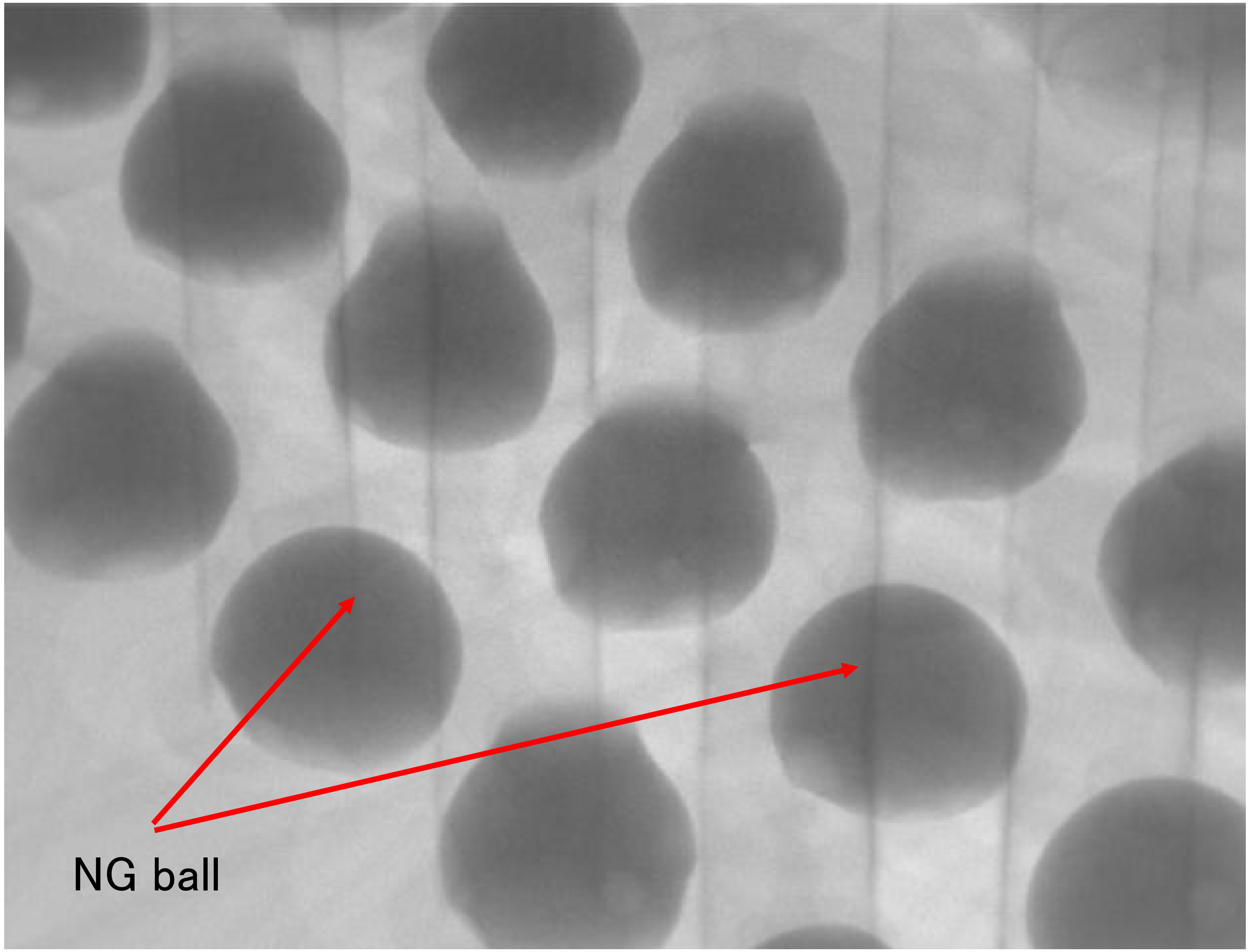
- Found soldering problems at BGA chips (FPGA and DDR3 memory).
  - Re-heat and re-work around BGA patterns for all units.
  - Installed DDR3 memory check code in FPGA FW.
- 509MHz CW calibration for all units.
  - Convert ADC counts to power (dBm).
  - Beam position conversion from power.
- Starting installation to local control rooms.
  - L2 SW-HUBs and 1U servers are ready.
  - 116 units will be installed (HER 58, LER 58).

M.Tobiyama

1421B Gated turn-by-turn monitor

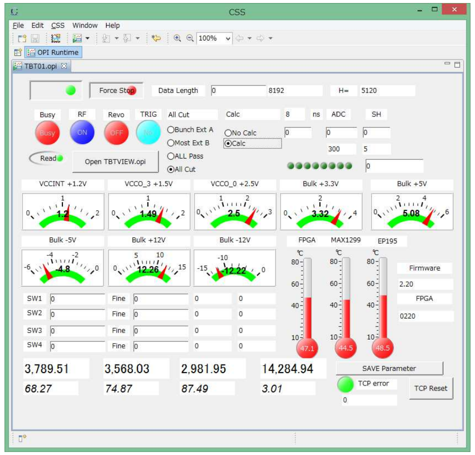


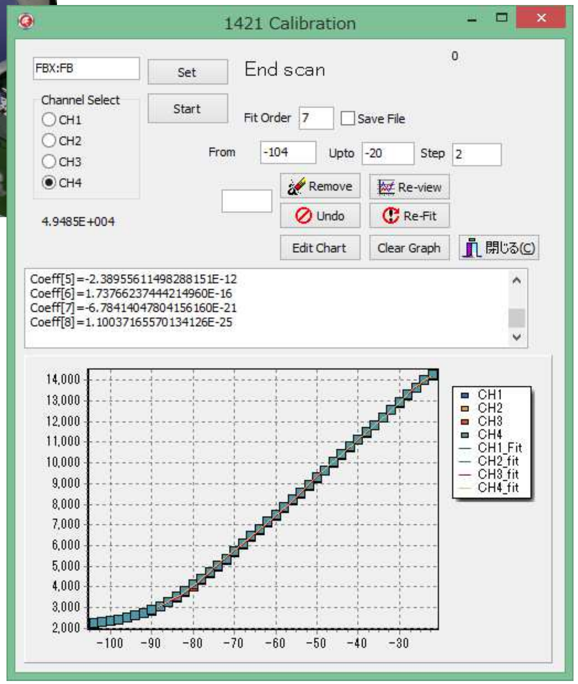
X-ray image of BGA soldering

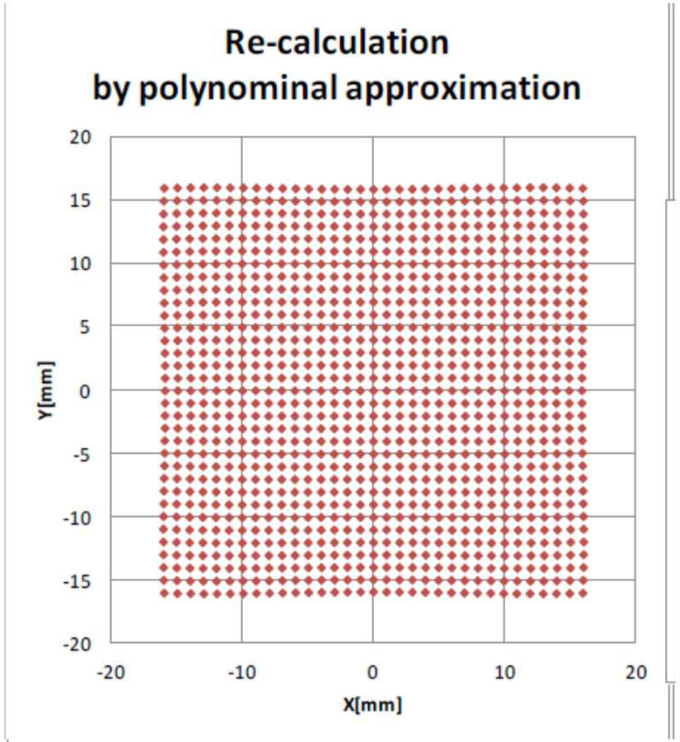


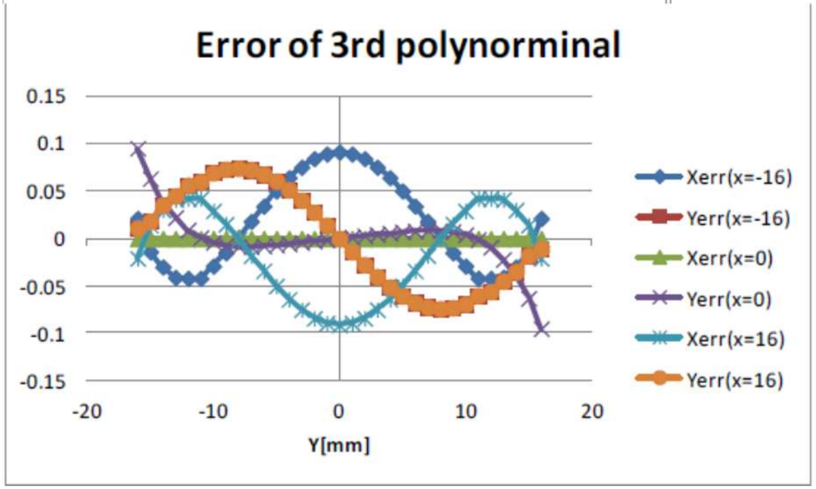
M.Tobiyama

Calibration, position re-calculation

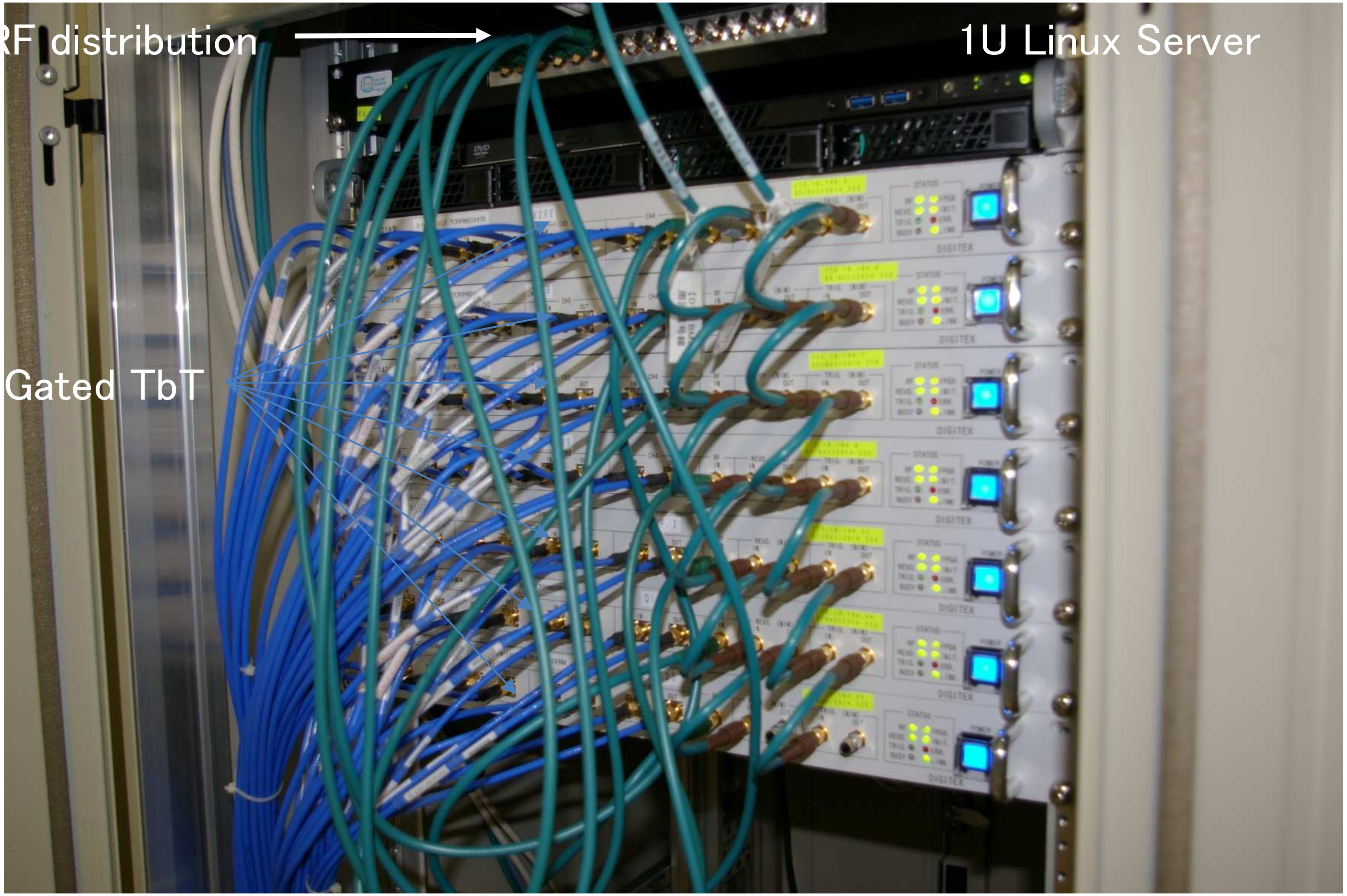








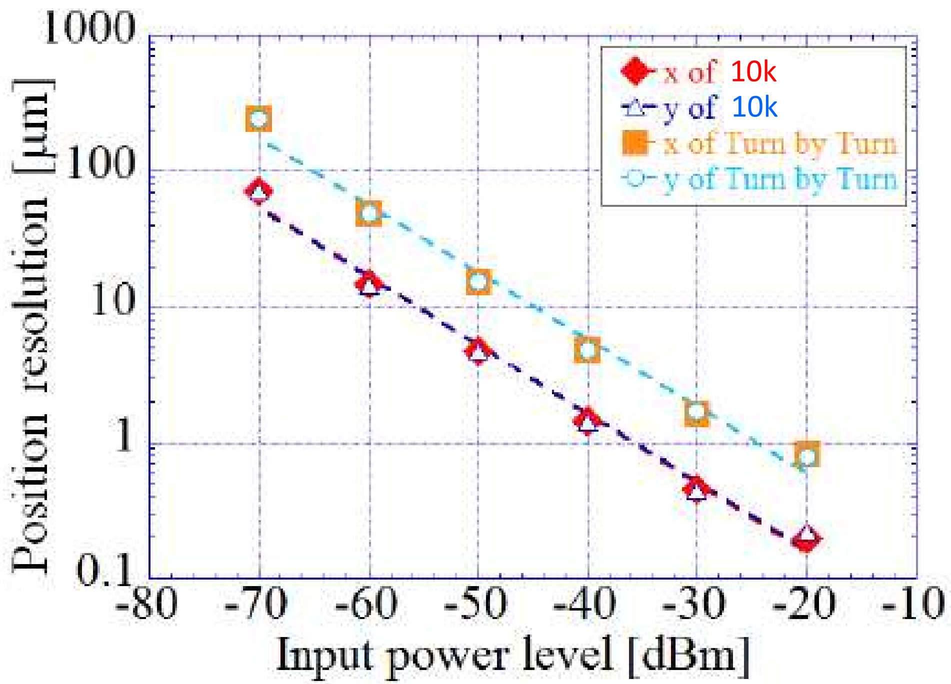
- 7th polynomial fit for ADC.
- 3rd polynomial fit for position calculation.

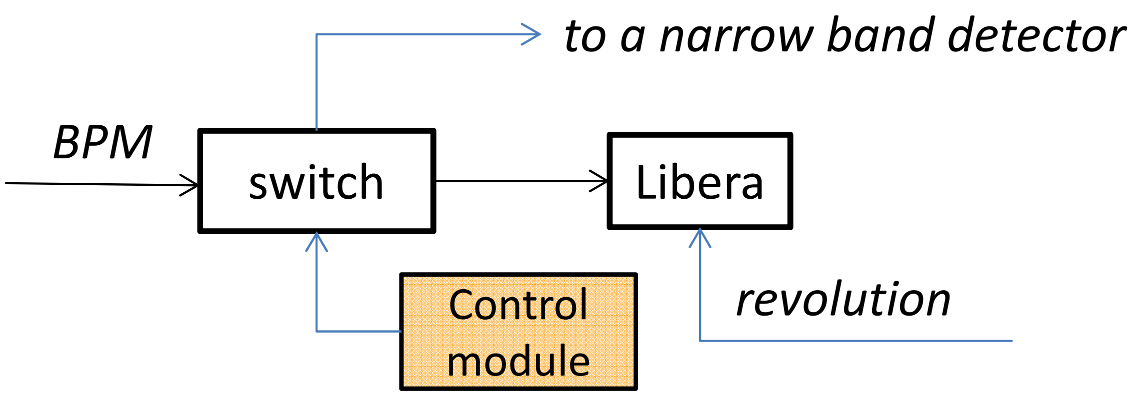

RF distribution
1U Linux Server
Gated TbT
DIGITEX

Medium band monitor

S.Kanaeda

- We use 4 Libera Brillinace+.
- These monitors measure the beam orbit:
  - To estimate vertical oscillation at IP,
  - To estimate vertical emittance growth due to sextuple magnets.





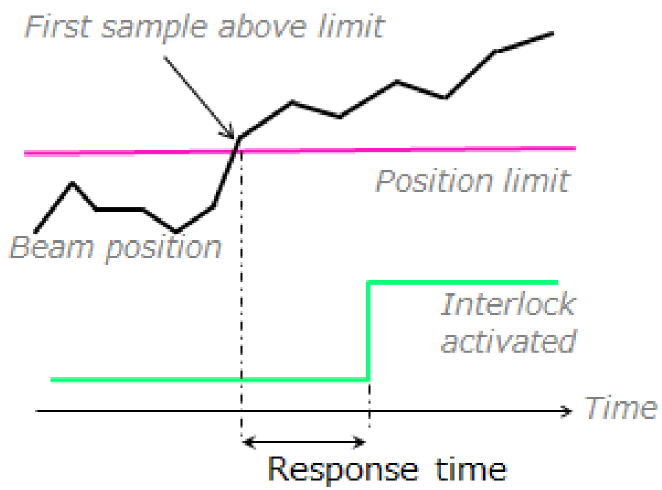
Required specification

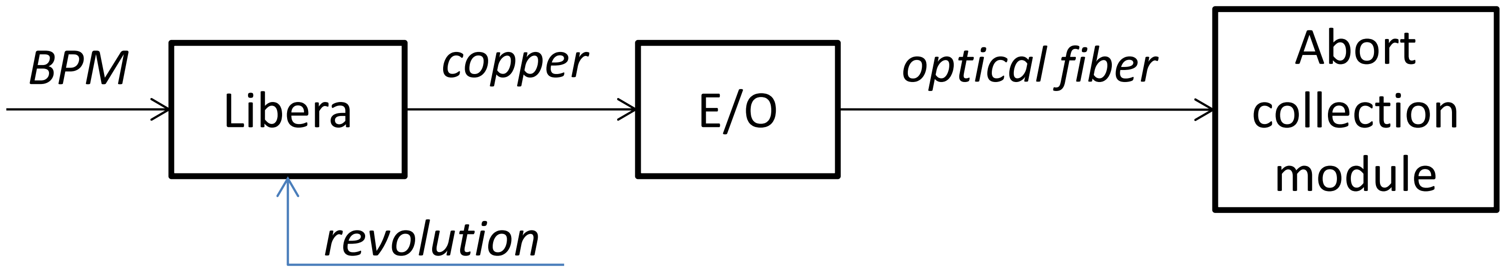
Repetition[Hz]	10k to 100k(TbT)
Resolution[μm]	< 5

S.Kanaeda

Orbit interlock monitor

- We use re-modeled Libera brilliance+ by Instrumentation Technologies.
  - Evaluated latency < 4truns (threshold ±10mm)
- 2 in HER will be installed in Phase 1.
- 2 in LER are to be installed in Phase 2 because a new abort window will be installed at this moment.
- These monitors will be used exclusively for the orbit interlock.
- A TTL abort signal from Libera is converted from electric to optical signal, then sent to an abort collection module.

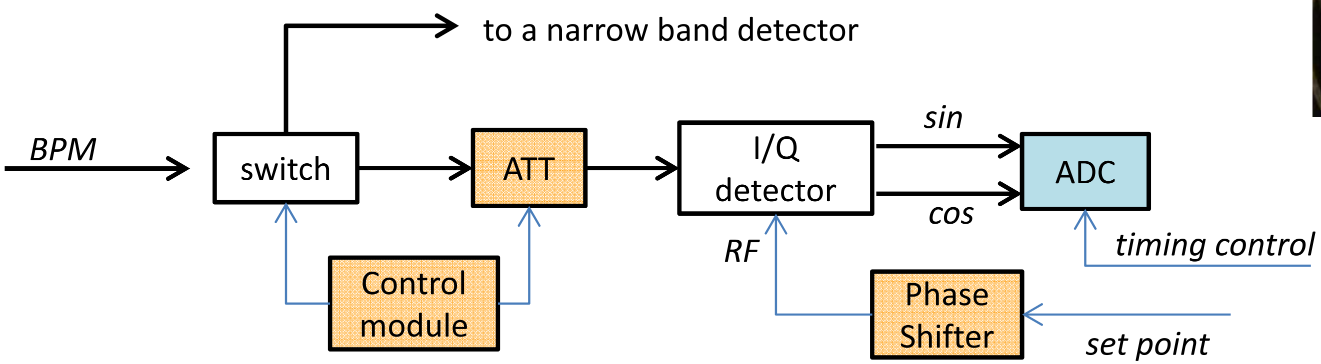


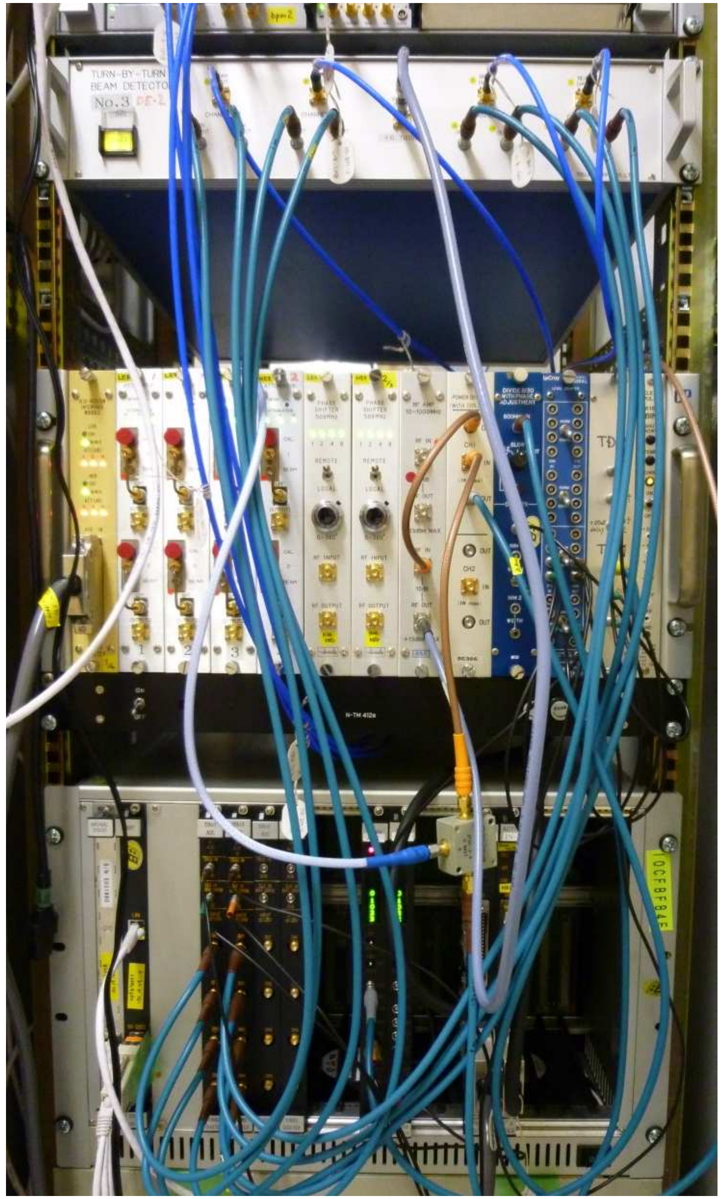


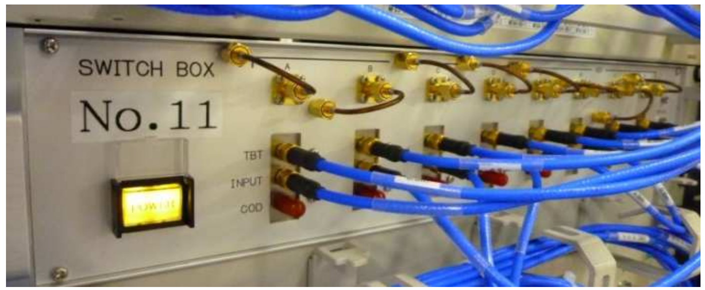
S.Kanaeda

Synchrotron oscillation monitor

- The monitors will work at Phase 1.
- Re-use 508MHz IQ detectors, switches, VME –based ADCs, timing modules, NIM-based attenuators, phase shifters.
- A new NIM module which controls the switch and attenuators was produced last year.
- All the components have been checked.
- Read out of ADC data through EPICS has been checked.







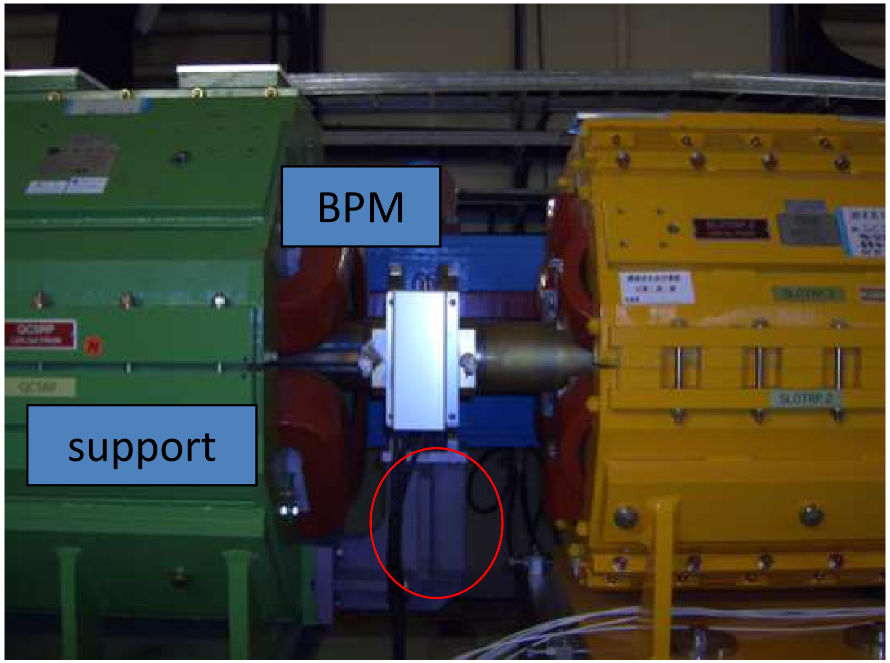
H.Fukuma

BPM displacement sensor

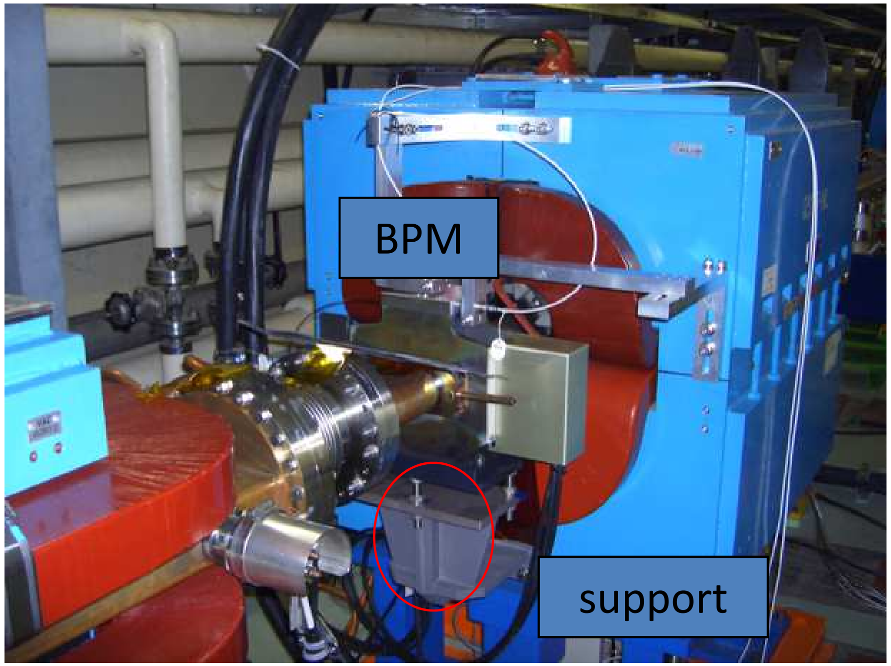
(A talk requested in the ARC2014 report)

- The movement of beam position monitors (BPMs) due to the thermal stress on vacuum chambers has been observed in KEKB, even though they are fixed to quadrupoles.
- In order to correct the BPM data, displacement sensors were introduced at all the BPMs near sextupoles, because orbit change at the sextupoles causes vertical emittance growth and tune change.

LER

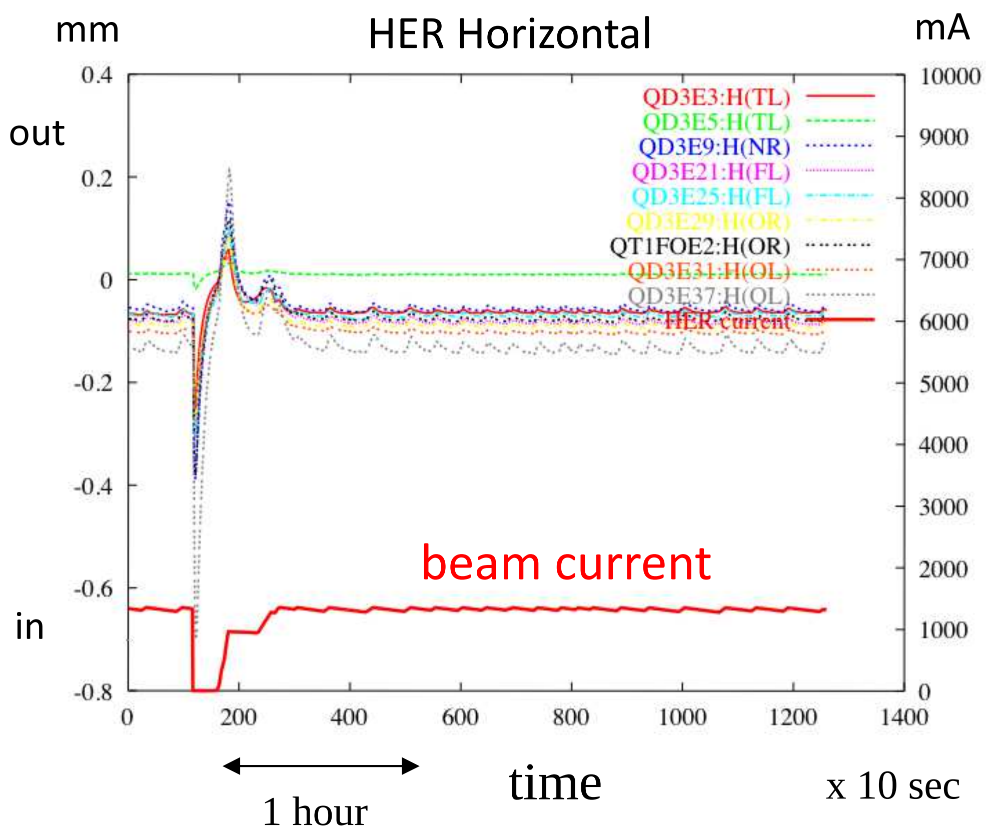


HER

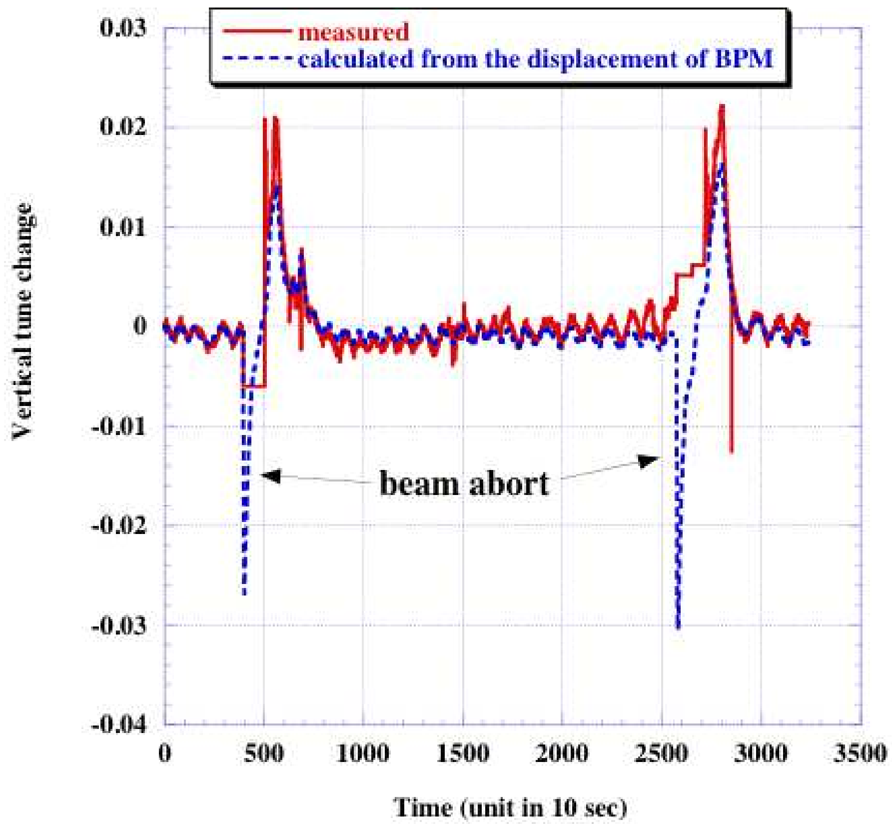


H.Fukuma

Movement of arc BPMs relative to nearby sextupoles at a beam abort in HER



Vertical tune change calculated from the movement of sextupoles



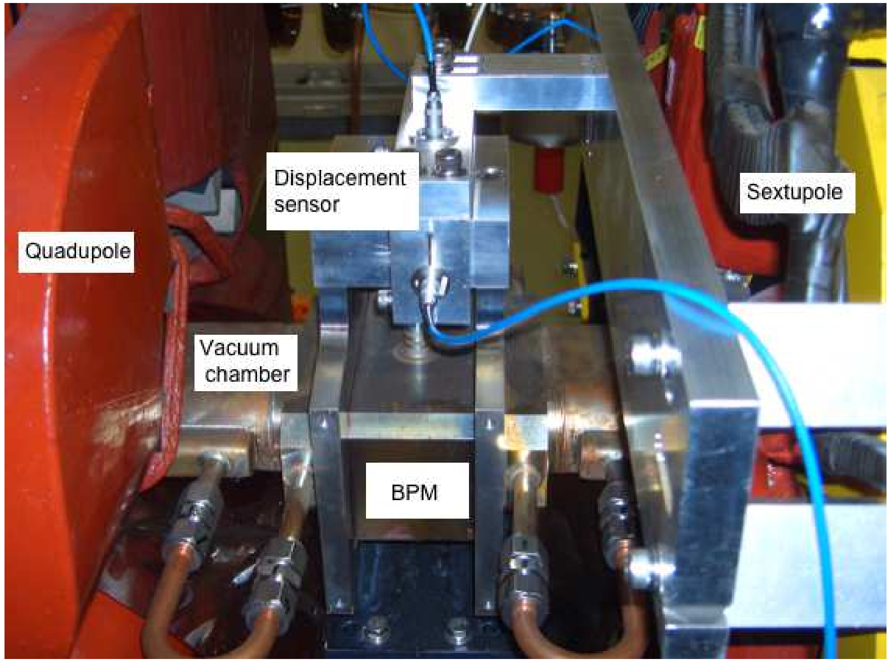
- BPMs move 0.9mm (max.) horizontally and 0.1mm (max.) vertically.
- It takes 30 to 40 min. to reach steady state after the following injection.
- Movement of the BPM depends on beam current.
- Vertical tune change is well explained by the movement of sextupoles.

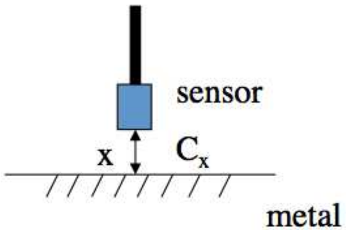
H.Fukuma

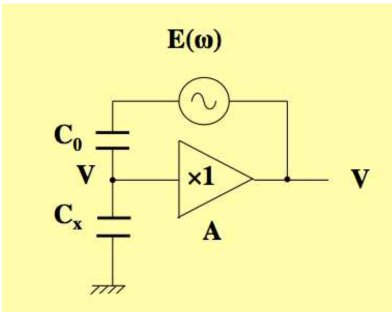
Gap detector

Specifications

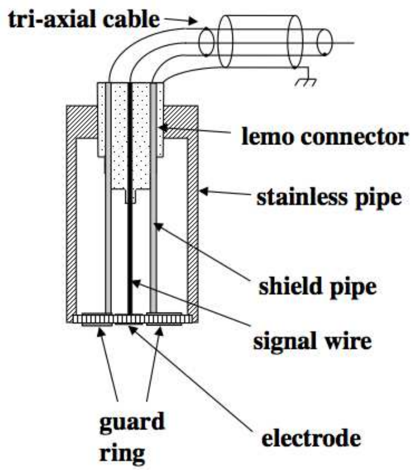
detection method	electrostatic (capacitive)
channels	2
range (mm)	0.5 - 2.5
resolution (μm)	< 0.2
nonlinearity (%)	< ±0.3
frequency response (Hz)	0 - 100
temperature coefficient (μm/deg.)	< 0.2







sensor head



H.Fukuma

Displacement sensor for rotatable sextupole at SuperKEKB LER

- In SuperKEKB, the displacement sensors used in KEKB will be re-installed at the BPMs near the every sextupoles.
- Special sensor supports made of Metal Matrix Composites with low thermal expansion coefficient of 3 10^{-6} /K are used for the sensors near rotatable sextupoles in LER.

  The support has a long pillar because it can not be mounted on the movable sextupole.

Alignment tolerance of LER sextupole (r.m.s.) (H. Sugimoto)

Evaluated based on vertical emittance growth

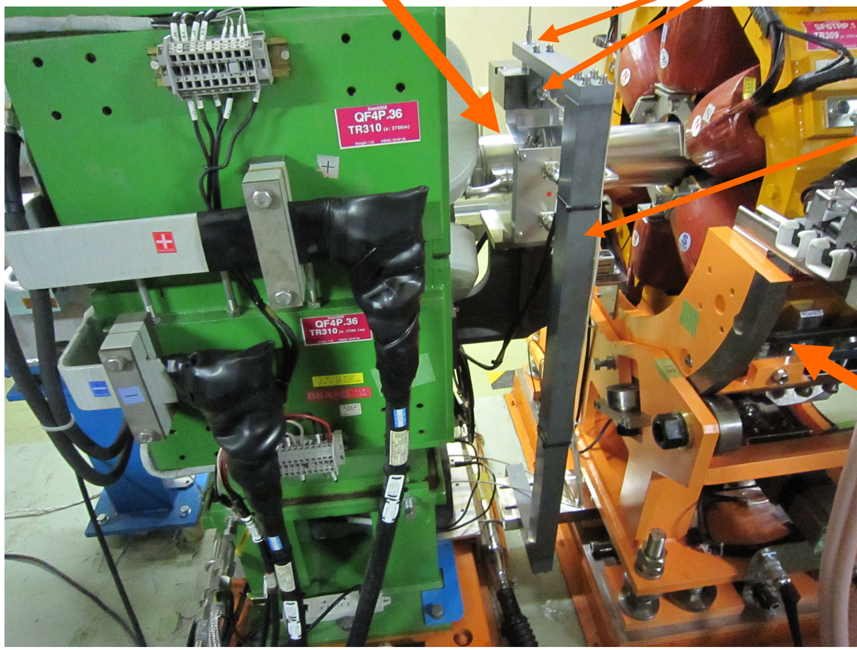
Type	DX(um)	DY(um)
SF	100	60
SD	40	30
SL	40	$\boxed{20}$

Installed rotatable sextupoles :
SL 8, SF 8, SD 8 total 24

BPM

sensors

pillar



rotatable sextupole

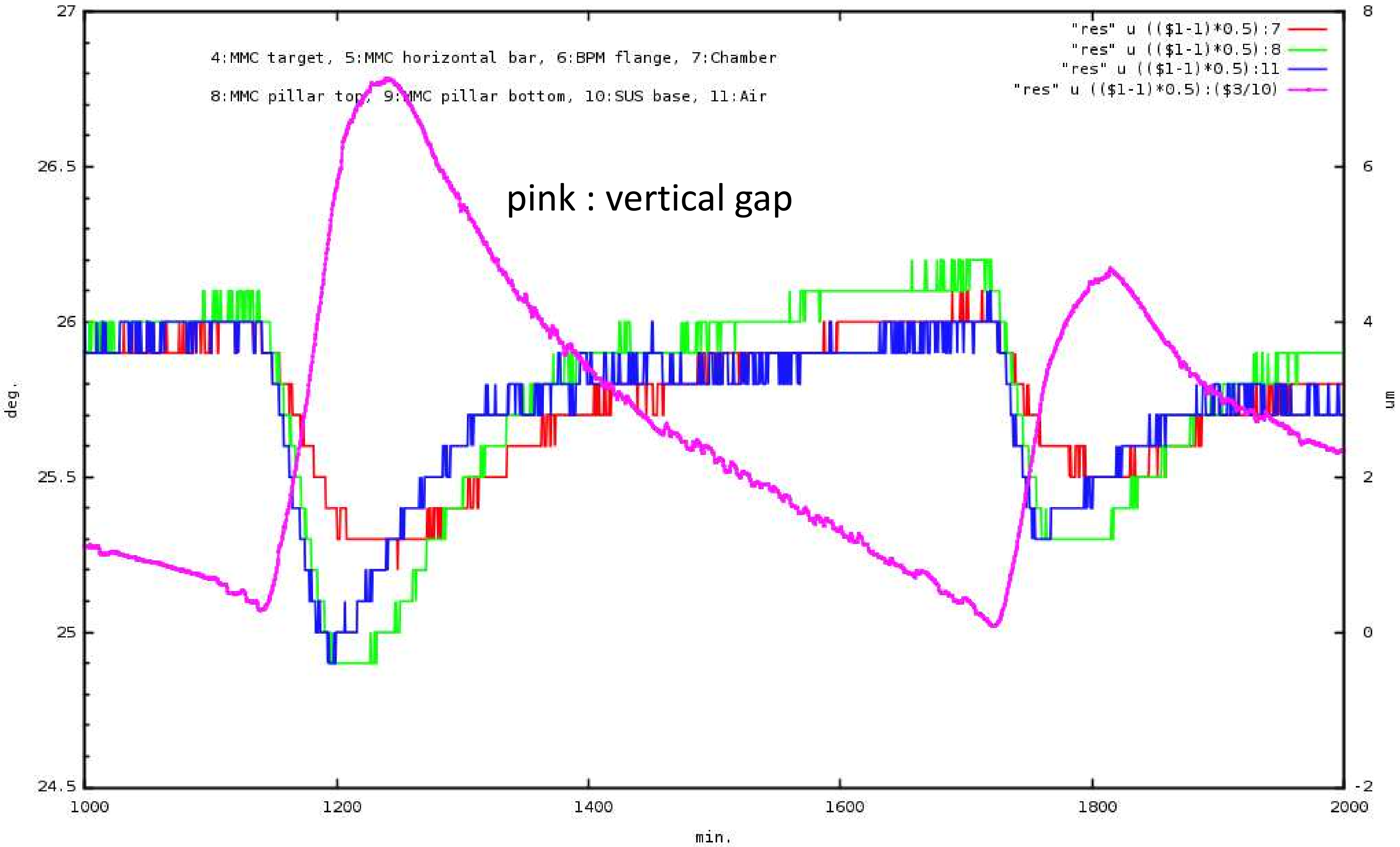
Displacement sensor near a rotatable sextpole.

Currently 15 sensors are installed.

H.Fukuma

Data of vertical displacement

red : temp. of chamber, green : MMC temp at pillar top, blue : temp. in air



H.Fukuma

Simple model

$$\text{deformation} \rightarrow \boxed{\frac{1}{1+\tau\cdot s}} \rightarrow \text{measured gap}$$

First order lag

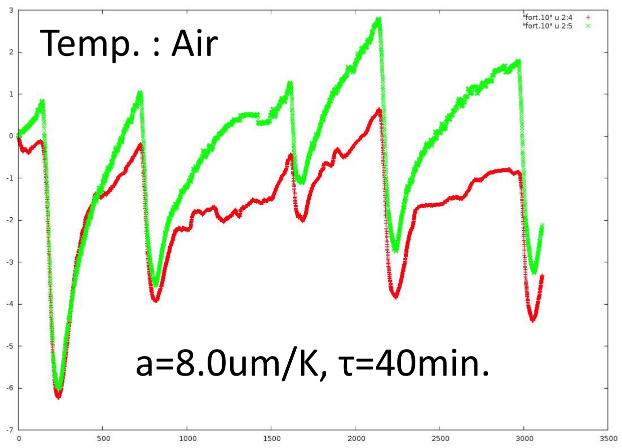
Deformation $d(t) = a(T(t) - T(0))$

T(t) : temperature
a : temperature coefficient

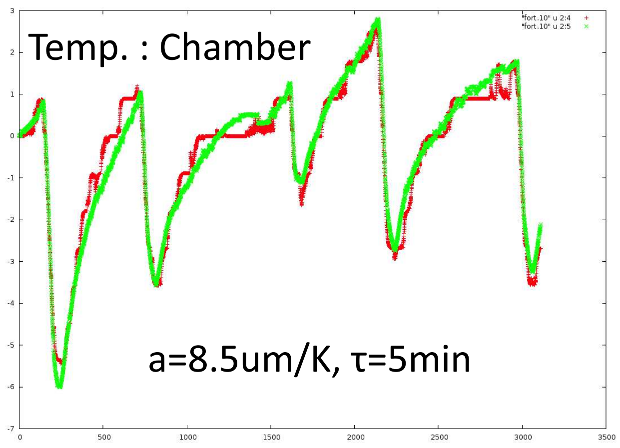
Output (measured gap)

Impulse response

$$c(t) = \int_0^t d(u)\cdot g(t-u)du = \frac{a}{\tau}\int_0^t (T(t)-T(0))\cdot e^{-\frac{t-u}{\tau}}du$$

um


min.

um


min.

red : c(t) by simulation
green : measured (sign is reversed.)

- Gap change between the sensor and the target has strong correlation with the chamber temperature. The mechanism of the deformation of a structure is not clear yet.

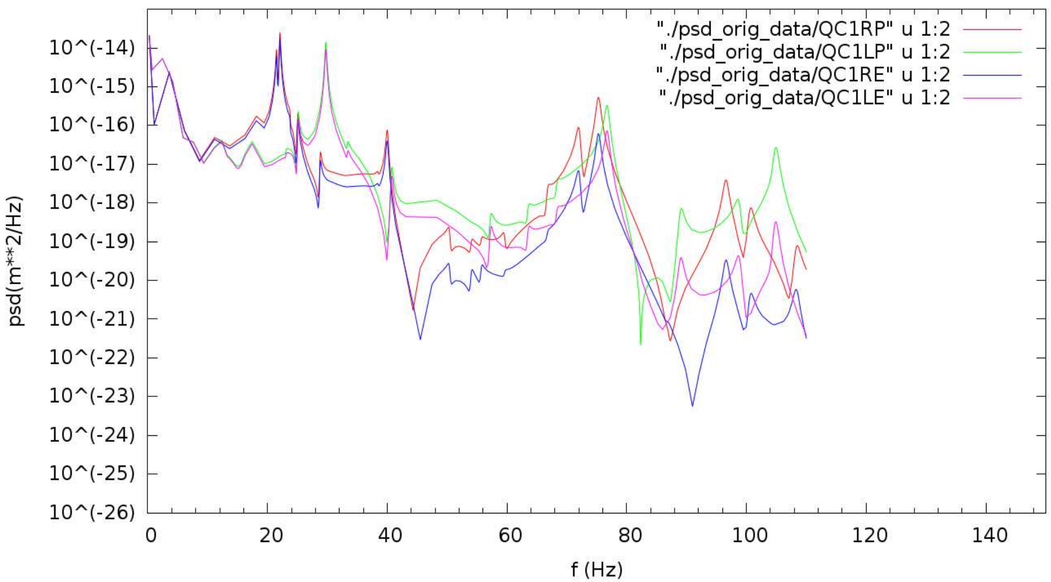
H.Fukuma

Simulation of vertical collision feedback

(Work recommended in the ARC2014 report)

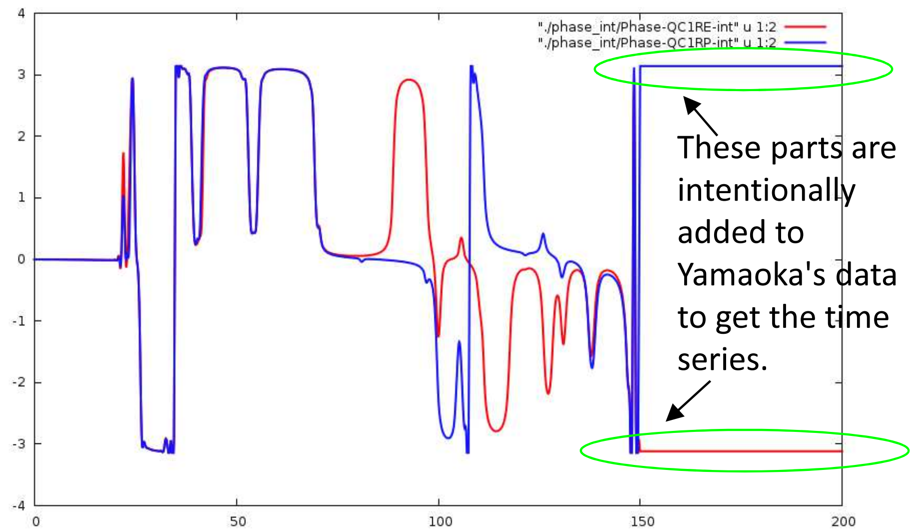
- The simulation of the vertical collision feedback was done by Simulink using time series of disturbance generated from simulated vertical oscillation of QC's.

PSD (QC1R, L)



Phase (QC1R)

rad



These parts are intentionally added to Yamaoka's data to get the time series.

Hz

Simulated oscillation of QC by ANSYS by H. Yamaoka

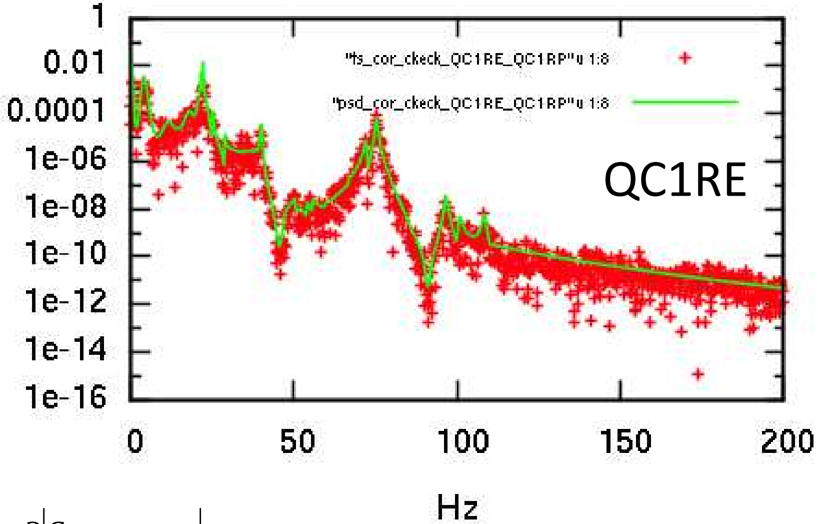
H.Fukuma

- Correlated time series are generated from the oscillation data of the quads.

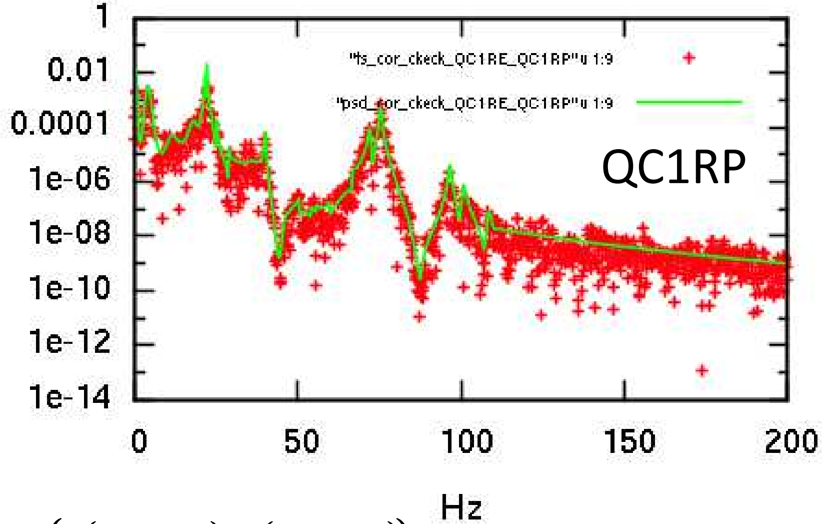
FFT of generated time series (QC1R{E,P})

red dot : FFT of generated time series
green line : data from which time series is generated.

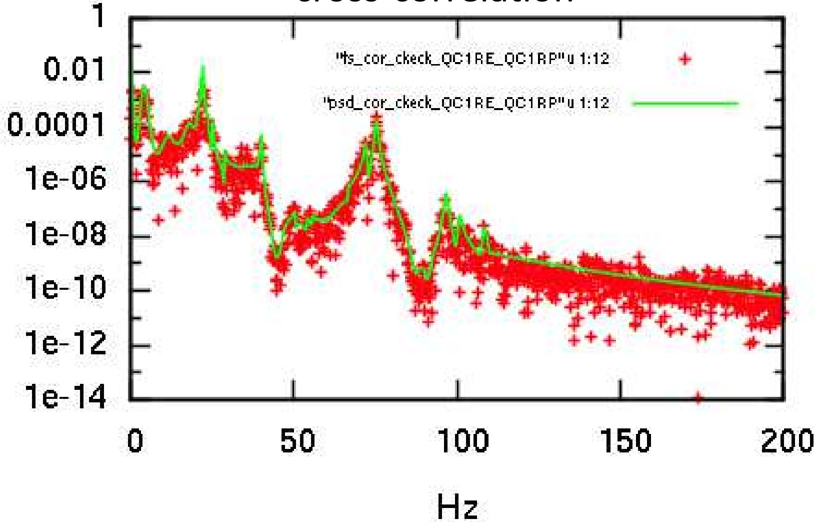
$2\left|S_{QC1RE,QC1RE}\right|$ auto-correlation



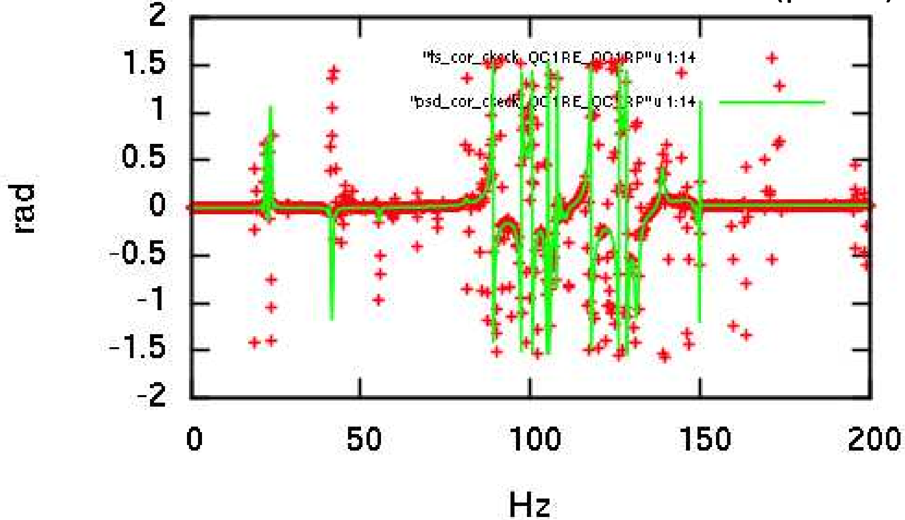
$2\left|S_{QC1RP,QC1RP}\right|$ auto-correlation



$2\left|S_{QC1RE,QC1RP}\right|$ cross-correlation



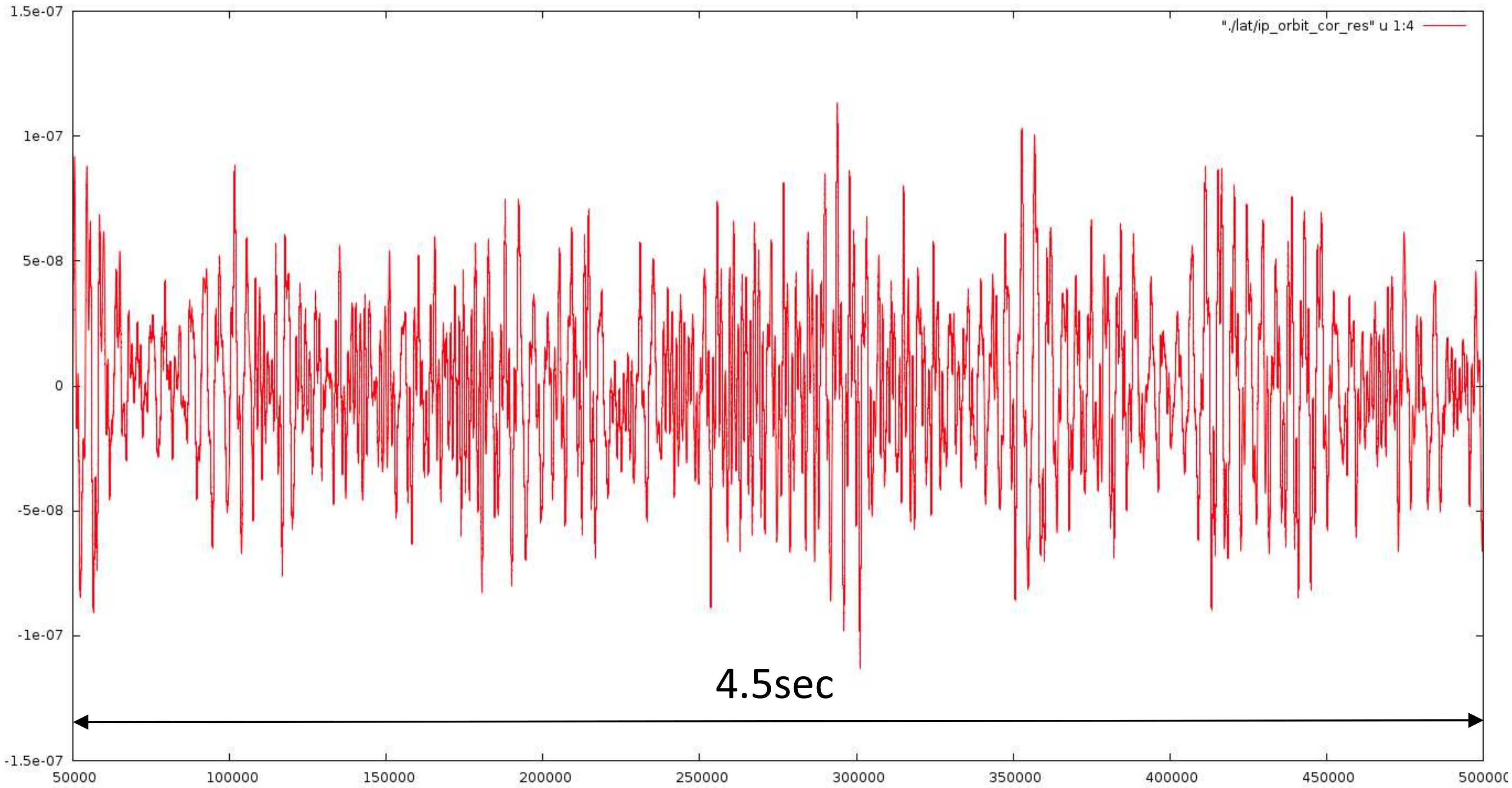
$\theta = \tan^{-1}\left(\mathrm{Im}\left(S_{QC1RE,QC1RP}\right)/\mathrm{Re}\left(S_{QC1RE,QC1RP}\right)\right)$ cross-correlation(phase)



H.Fukuma

- A macro electron and a macro positron are tracked by the 4x4 transfer matrix.
- The particle is vertically kicked at QC1's and QC2's due to their position shifts.

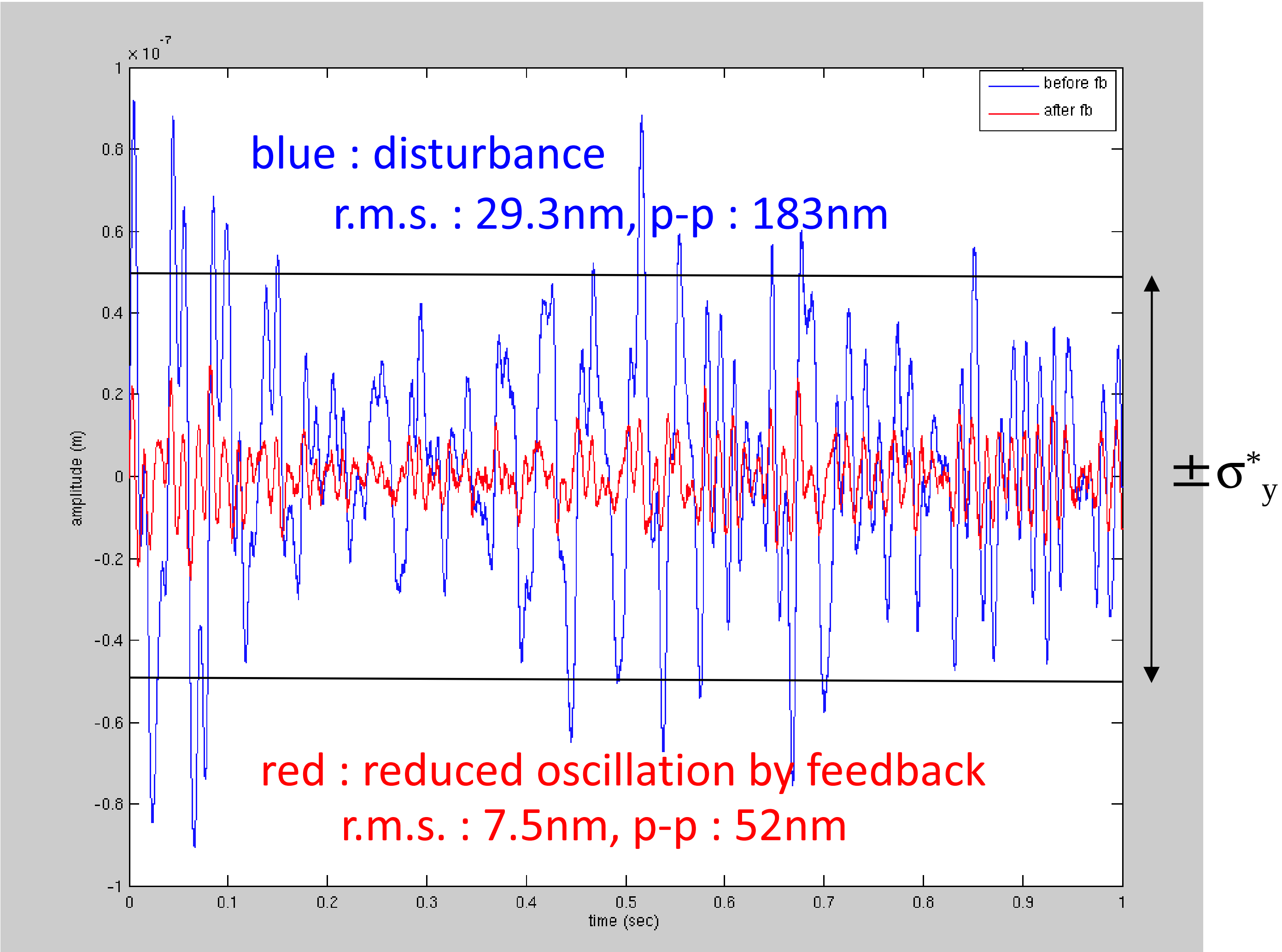
$y_p^* - y_e^*$ (m) Positron-electron orbit difference at IP



turn

- This orbit difference is put into the Simulink model as disturbance.
- A model of TAKASAGO power supply is taken into account in the Simulink model.

- Result of Simulink shows that r.m.s. amplitude is reduced to 1/4 by the feedback.



H.Fukuma

Power supply controller for IP orbit feedback

- A power supply controller for IP orbit feedback is being developed.

  It will be completed in FY2014.
- The controller has two control paths.

  -Fast control from the vertical orbit feedback controller (update rate 32kHz) for vertical feedback

  -Slow control via EPICS channel access(CA) (update rate 1Hz) for horizontal feedback, vertical and horizontal DC bump

  Fast and slow set values are added in the controller to get the set value to the power supplies.

- Functions

  -Variable gain to adjust granularity.

  -Adjustable delay for individual power supplies.

- Controller

  -Conforming to MTCA.4

  RTM(Rear Transition Module), FPGA board, DAC on FMC(FPGA Mezzanine Card)

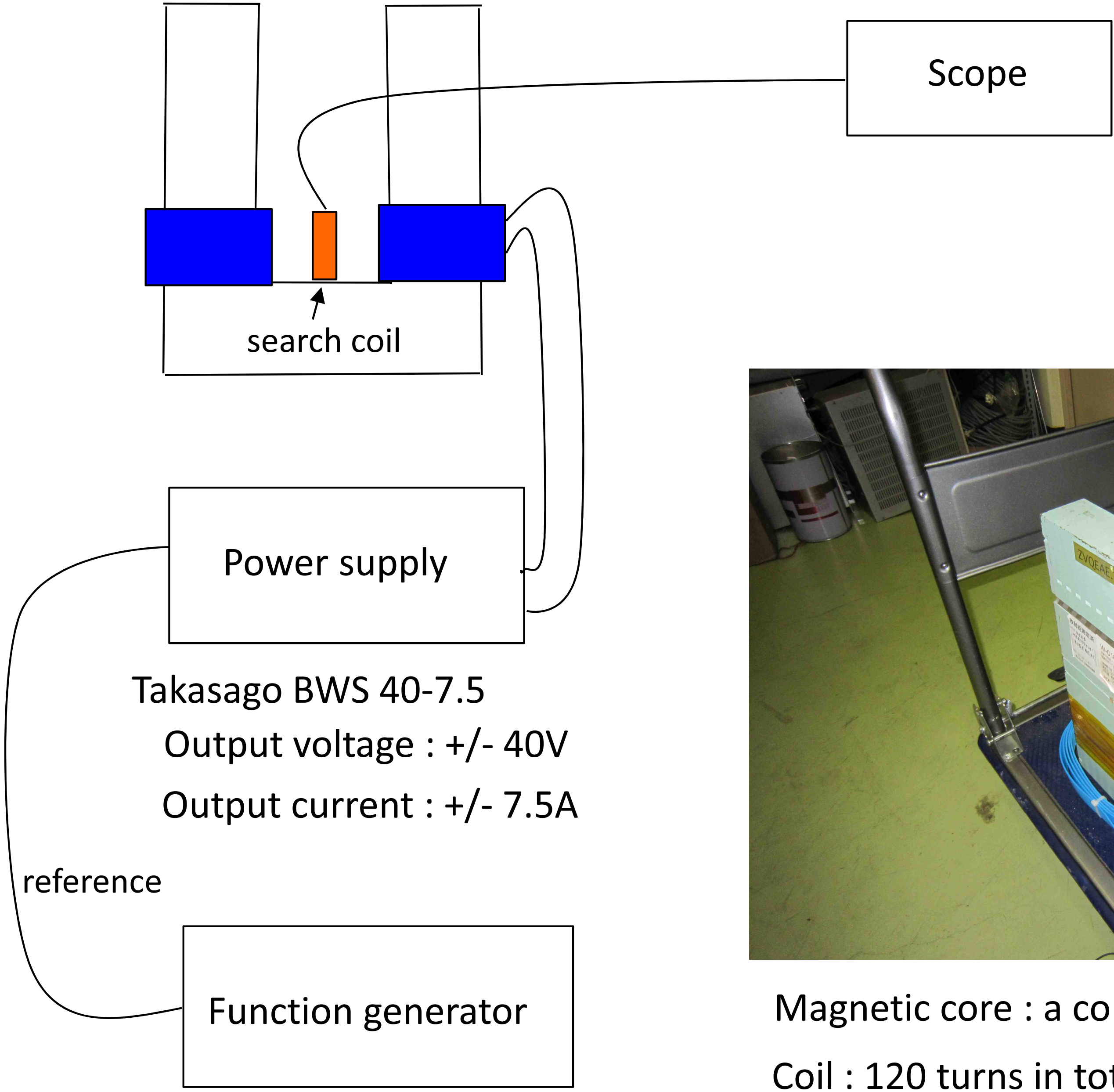
  -16bit DAC

  -EPICS IOC embedded.

  -FPGA : Xilinx Zynq SoC

H.Fukuma

- Response of a Takasago power supply was measured.



Tektronix TDS350P
200MHz, 1GS/s

Takasago BWS 40-7.5
Output voltage : +/- 40V
Output current : +/- 7.5A

Tektronix AFG320

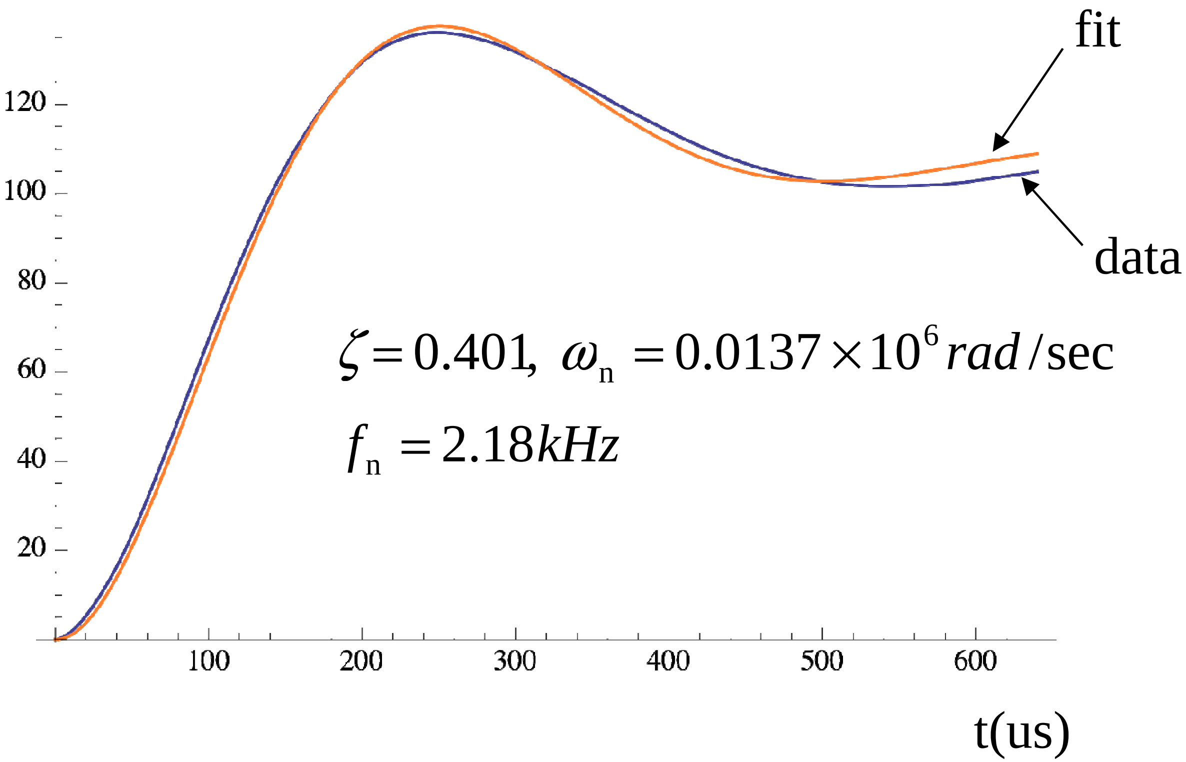
Magnetic core : a corrector of KEKB

Coil : 120 turns in total

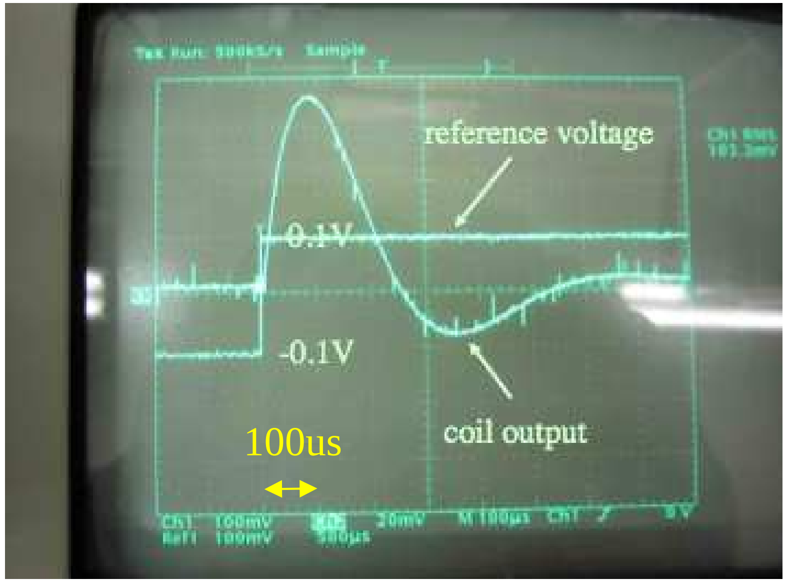
- Step response of magnetic field excited by the power supply can be approximated to 2nd order lag.
- The system is under-damped system.

$$T(s)=\frac{K\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$$

$$V(t)=K\left(1-\frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}}\sin\left(\sqrt{1-\zeta^2}\,\omega_n t+ArcTan\left(\frac{\sqrt{1-\zeta^2}}{\zeta}\right)\right)\right)$$

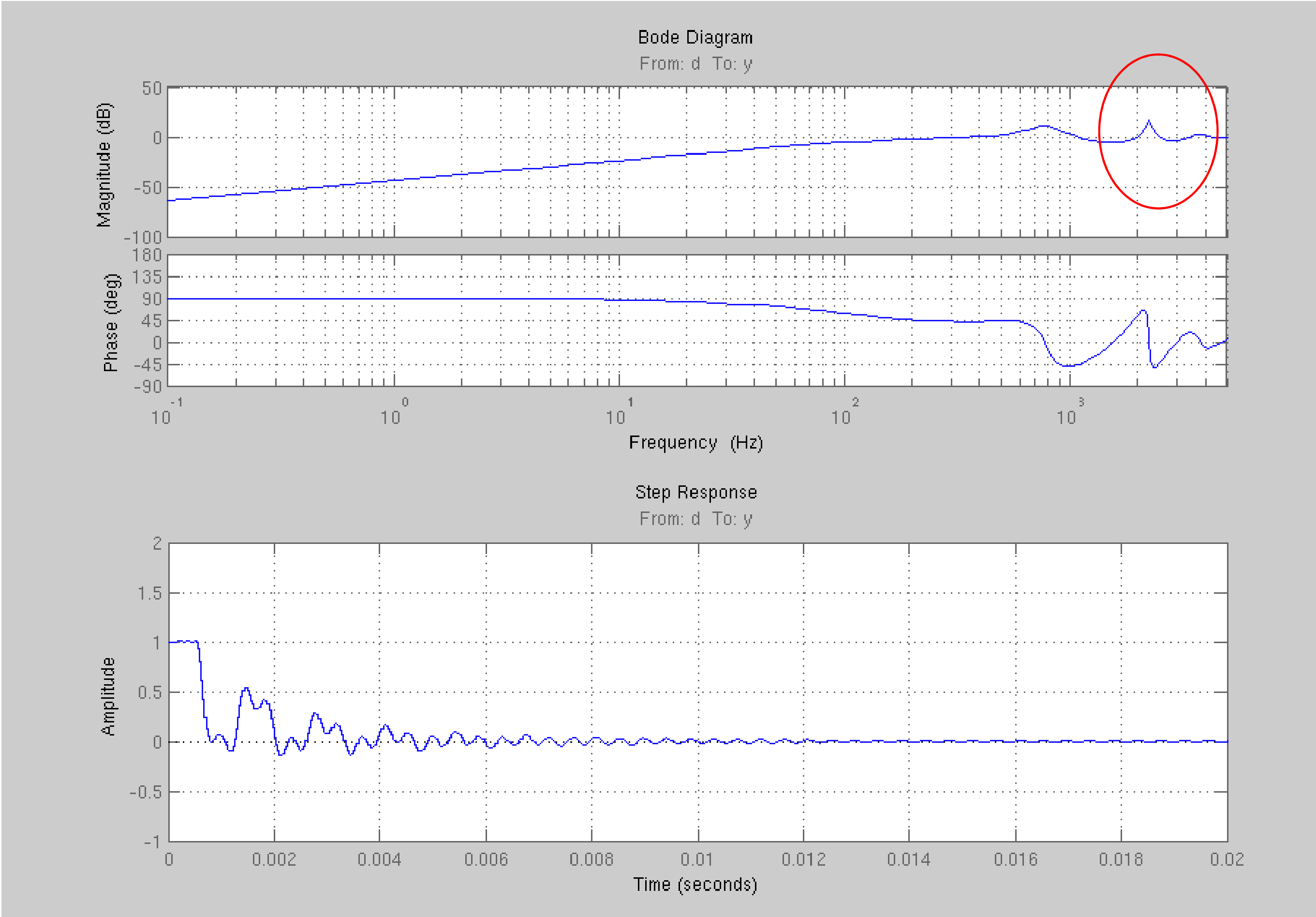


Raw data



Coil output was integrated to get the magnetic field.

- Disturbance rejection using the transfer function of 2nd order lag for the power supply was calculated by Simulink.



The result below100Hz is almost same as that for the 1st order lag.
A resonance-like peak near 2kHz is enhanced.

This peak almost disappears if a transfer function of critical damping is used for the power supply.

PHOTON MONITORS

SRM

XRM

LABM

Photon Monitors

J.Flanagan

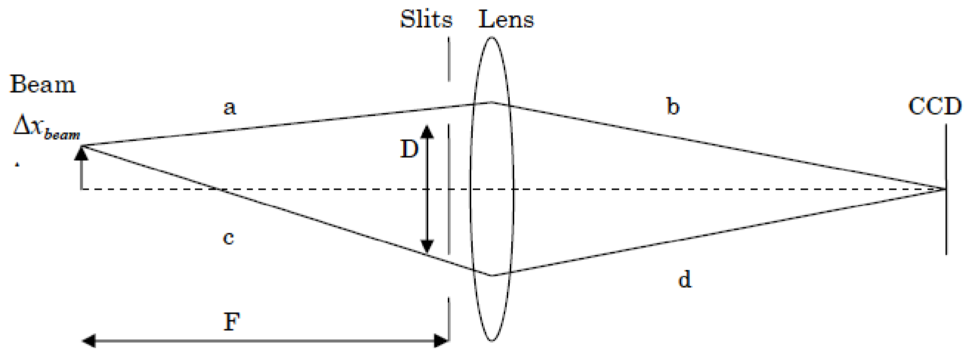
- SRM: Synchrotron Radiation Monitor
  - Visible light monitor. Interferometer, streak, gated camera, etc.
  - σ_z, σ_x (σ_y)
- XRM: X-ray Monitor
  - Pinhole, Coded Aperture mask, etc.
  - σ_y (σ_x)
- LABM: Large Angle Beamstrahlung Monitor (IR)
  - SR-like radiation from interaction point (~300-600 nm)
  - Can measure size ratios and relative offsets at collision point.

J.Flanagan

SRM: Interferometers

SR Source Bend Parameter	S-LER1 (BSWFRP)	S-HER (BSWOLE)	Units
ε_x	3.20E-09	4.54E-09	m
κ	0.27%	0.25%	
ε_y	8.64E-12	1.14E-11	m
β_x	8.86	10.17	m
β_y	30.71	26.92	m
σ_x	168.4	214.9	μm
σ_y	16.3	17.5	μm
Beam Energy	4	7	GeV
Bend effective length	0.89	2.90	m
Bend angle	5.04	5.00	mrad
Bend radius ρ	179.0	580.0	m
Observation wavelength λ	4.00E-07	4.00E-07	m
SR Opening angle θ_c (λ)	1.0	0.7	mrad
Slits opening angle D/F (H)	0.2	0.2	mrad
Slits opening angle D/F (V)	0.8	0.9	mrad
Max. Visibility (H) γ_{max}	90%	90%	
Max. Visibility (V) γ_{max}	98%	98%	
Min. measurable beam size $\sigma_{x\,min}$	164.1	157.4	μm
Min. measurable beam size $\sigma_{y\,min}$	15.7	15.0	μm

- Resolution fundamentally limited by measurement wavelength and opening angle between slits from beam (D/F).
- Max. slit separation determined by beam spread and mechanical considerations.

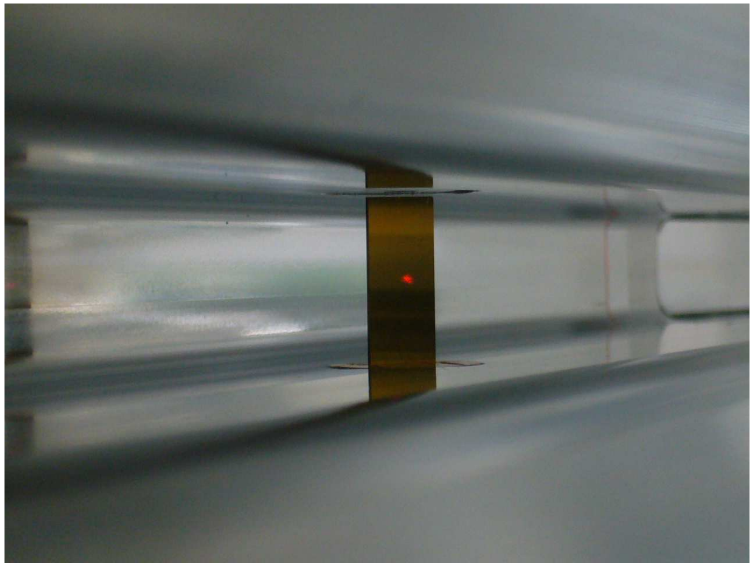


- Will primarily use for horizontal beam size measurements
- Vertical beam size measurement is possible with interferometers, though is near the limit of the interferometer resolution, and single-shot measurement is not possible.
- But can be useful for cross-calibration purposes at larger beam sizes.
- To minimize deformation due to heat load, will use gold-coated diamond mirrors.

SRM: Extraction mirrors and chambers

J.Flanagan

Diamond extraction mirror for visible light beam size monitor in holder



Mirror mounted in extraction chamber.

Extraction chamber installed in tunnel.
(Vac. Group)

- Diamond mirrors for visible light monitors have been installed in extraction chambers and aligned.

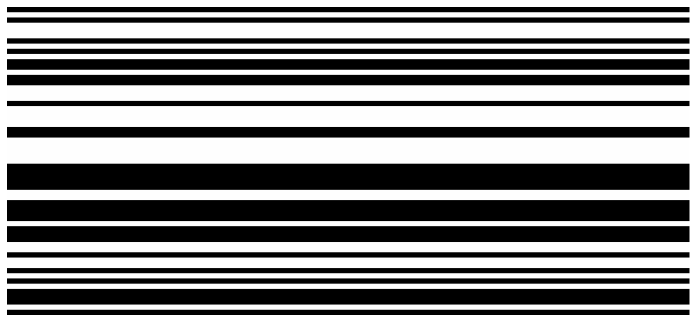
SRM: 2015 Plans

- Optical transport lines from tunnel to surface to be installed Summer 2015.
  - Largely re-using KEKB components, with some modifications to reach new chamber location.
- Above-ground optical components to be reconstructed by Phase 1 turn-on.
- From Phase 1 turn-on:
  - Commissioning of SRM.

XRM: X-Ray Monitor

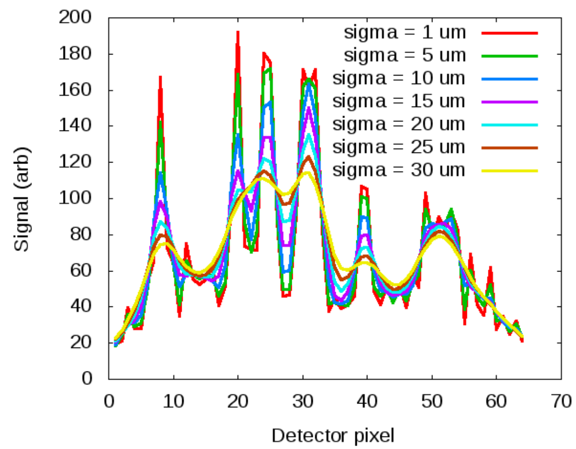
J.Flanagan

Xray Source Bend Par.	S-LER (BS2FRP.1)	S-HER (BS2E.82)	Units
ε_x	3.20E-09	4.60E-09	m
κ	0.27%	0.24%	
ε_y	8.64E-12	1.10E-11	m
β_y	50.0	11.5	m
σ_y	20.8	11.3	μm
Beam Energy	4	7	GeV
Effective length	0.89	5.9	m
Bend angle	28.0	55.7	mrad
ρ	31.7	105.9	m
Critical Energy	4.4	7.1	keV



59-element Uniformly Redundant Array mask pattern

- Coded Aperture Mask:
  - In-hand :
    - High-power, 59-element, 10 μm/element URA
    - 10 μm Au mask on 625 μm Si substrate
  - Under development:
    - 20 μm Au mask on 500 μm CVD diamond (monocrystalline) substrate
      - Substrates manufactured.
      - New pattern being designed for improved resolution (E. Mulyani)
- Detector:
  - 64-pixel (Phase 1), later 128-pixel, 50 μm pitch linear array
  - InGaAs detectors in hand (same type as used at CesrTA)
  - Deep Si detectors in development for better detection efficiency at high energy (SLAC)



Simulated detector response for various beam sizes at SuperKEKB LER

XRM: Hardware

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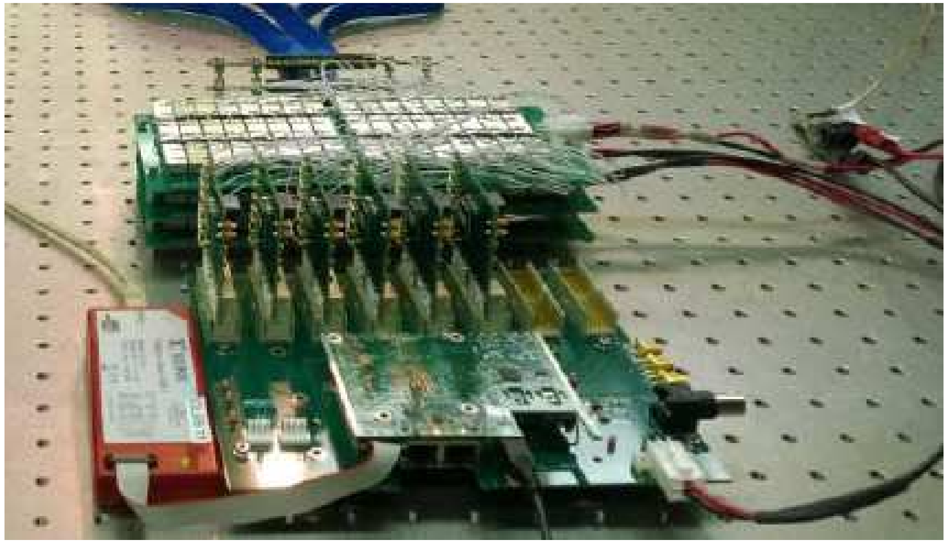
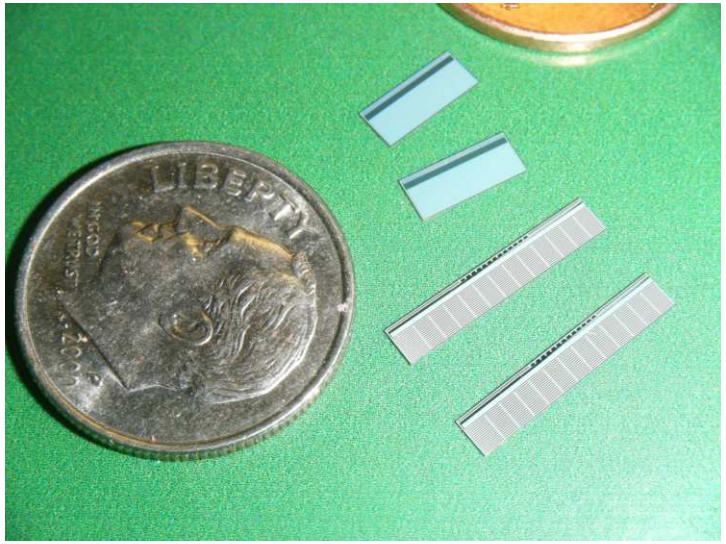
- All vacuum components (beam pipes, optics box, Be filters and windows, beam stopper and gate valve, etc.) have been delivered or ordered, except for screen monitors for beam-based alignment.
- 64-channel prototype high-speed readout system and detector mount made (U. Hawaii). Firmware under development.
- High-energy detector wafers processed and diced, and detector and spectrometer chips undergoing leakage testing. (SLAC)
  - Chips from first wafer show high leakage currents. Second wafer chips being tested.
  - Need for second wafer run to be evaluated based on yield.
  - Heat-sinking and mounting design of detector to follow.



High-speed readout electronics for the X-ray monitor, being developed by U of Hawaii.



Deep Si pixel detector and spectrometer chips for the X-ray monitor, being developed at SLAC.

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XRM: 2015 Plans

- Finalize firmware and fabricate 2 production model 64-channel high-speed readout systems. (UH)
- Production of final detector and spectrometer chips, and mount and heat-sink detectors. (SLAC)
- Install and align x-ray beam lines at SuperKEKB (May-July), integrate detectors and readout systems (Fall).
- Initial commissioning with first beam at SuperKEKB.

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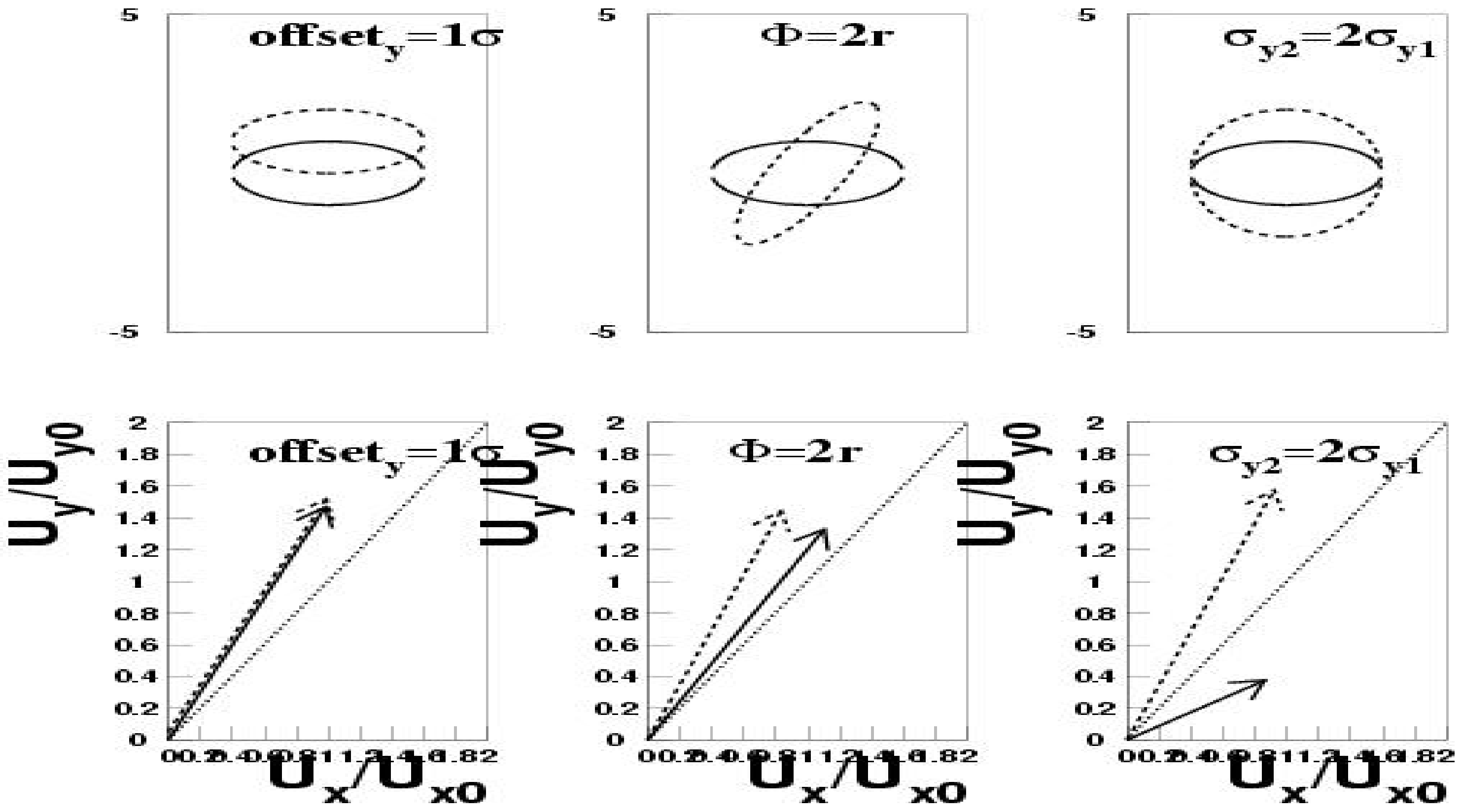
LABM: Large Angle Beamstrahlung Monitor

- The radiation of the particles of one beam due to the bending force of the EM field of the other beam.
- Beamstrahlung POLARIZATION at specific azimuthal points provides information about the beam-beam geometry.



G. Bonvicini

J.Flanagan

LABM: Vacuum and Optical Components

- Construction of optics boxes completed. (Wayne)
- Optics boxes, optical components, and optical beam line components shipped to KEK from Wayne State. (Wayne)
- Extraction chambers fabricated, and test-fitting of extraction mirror and window carried out. (KEK)
- Extraction chambers installed at the IP. (KEK)

Inside view of LABM extraction mirror inside HOM-protection slot in IR beam pipe.

Test fit of LABM extraction mirror (left) and extraction window (right) on IR beam pipe.

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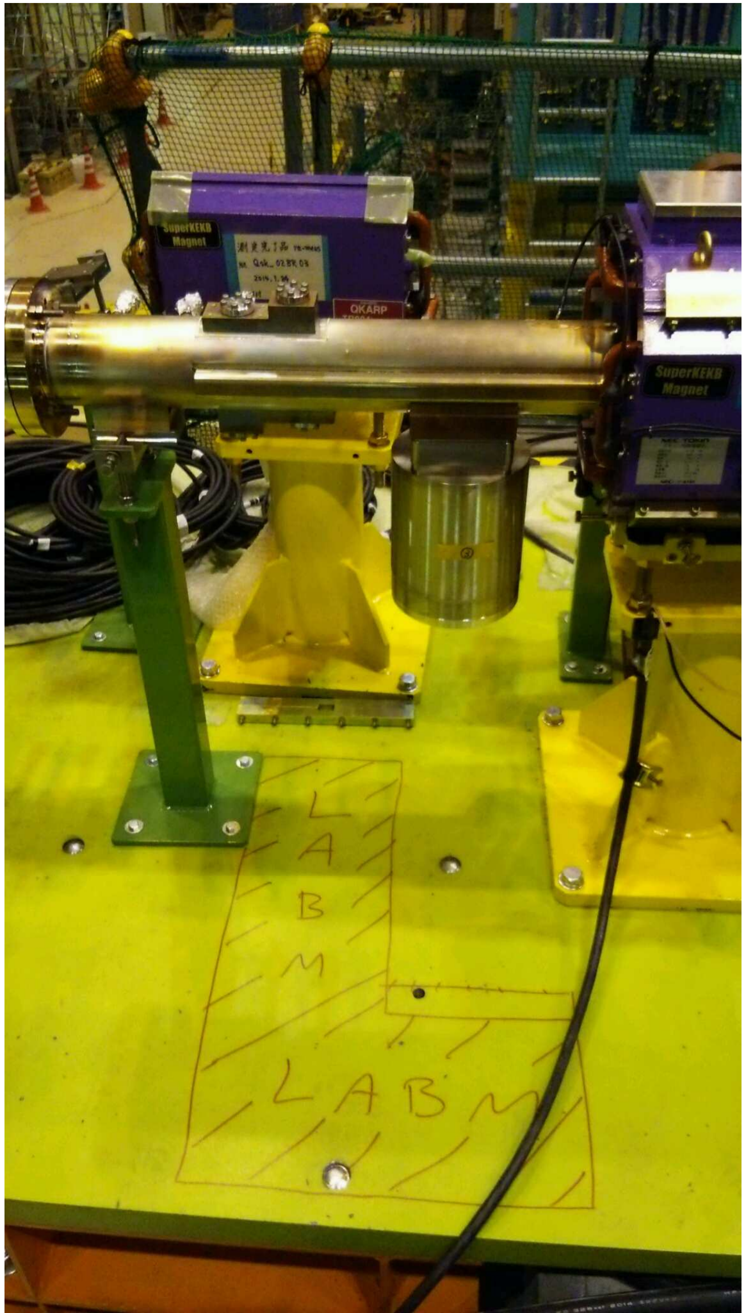
LABM: 2015 Plans



- Install LABM beam lines, optics boxes and electronics around IP. (Wayne State, KEK)
- Calibrate system. (Wayne State)
- Systematics checks with first beam at SuperKEKB.

LABM extraction chamber at IP, with planned locations of optical beam line supports marked on floor.

OTHERS

FB

BUNCH CURRENT MONITOR

LOSS MONITOR

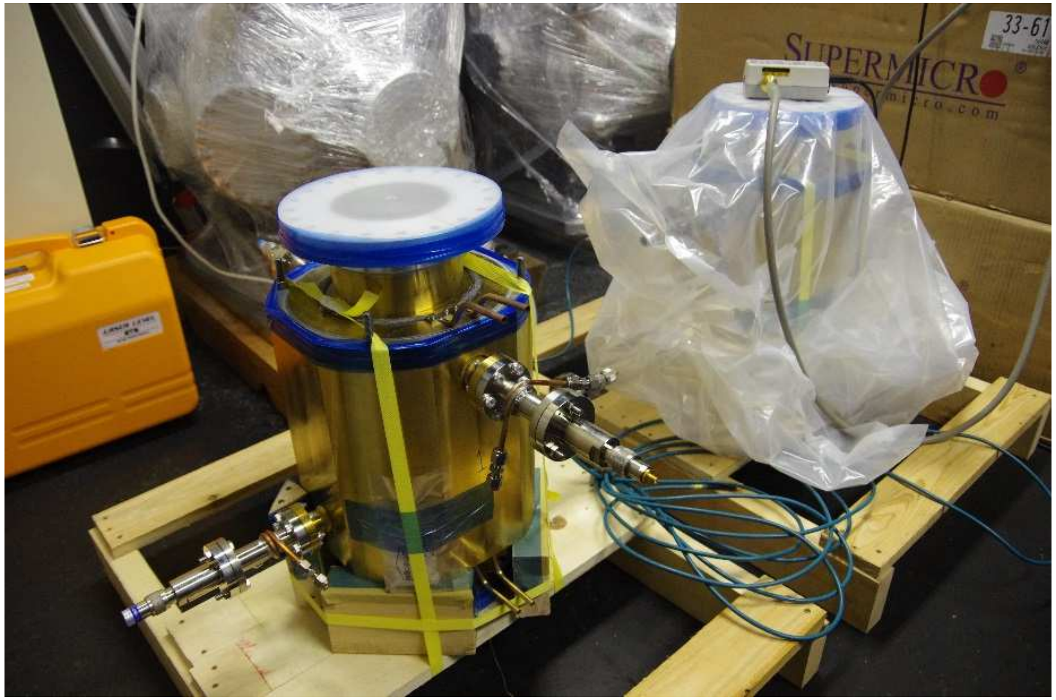
FAST BEAM DECAY MEASUREMENT (DCCT)

CLEARING ELECTRODES

DR

Bunch feedback system

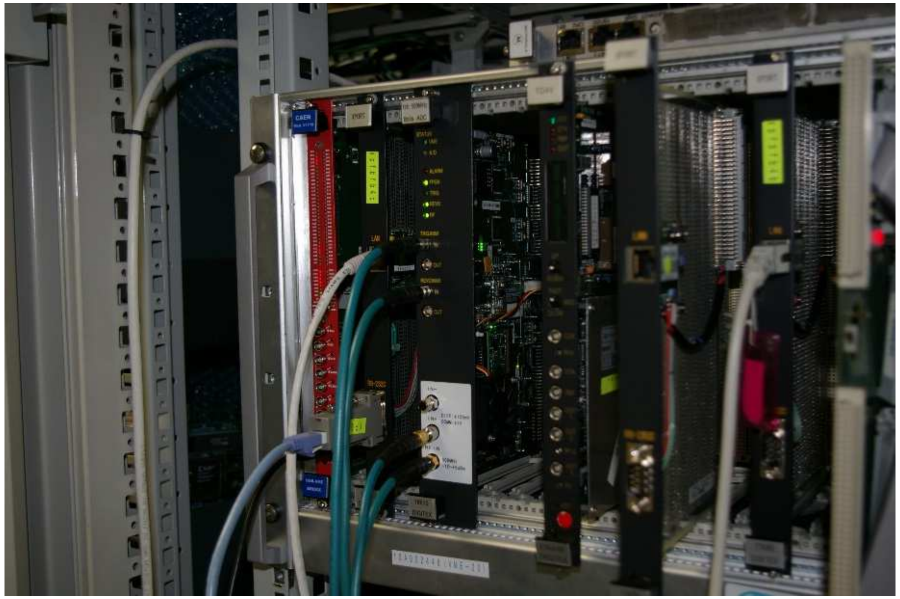
- Installed most of the vacuum components (except L-Kickers).
- Re-arrangement of the low level components in the FB local control room
  - Network cables
  - Replacement of NIM power supplies.
  - Removal of old two-tap FIR filters, installed new components such as new detectors.



Longitudinal kicker

Bunch current monitor/Memory

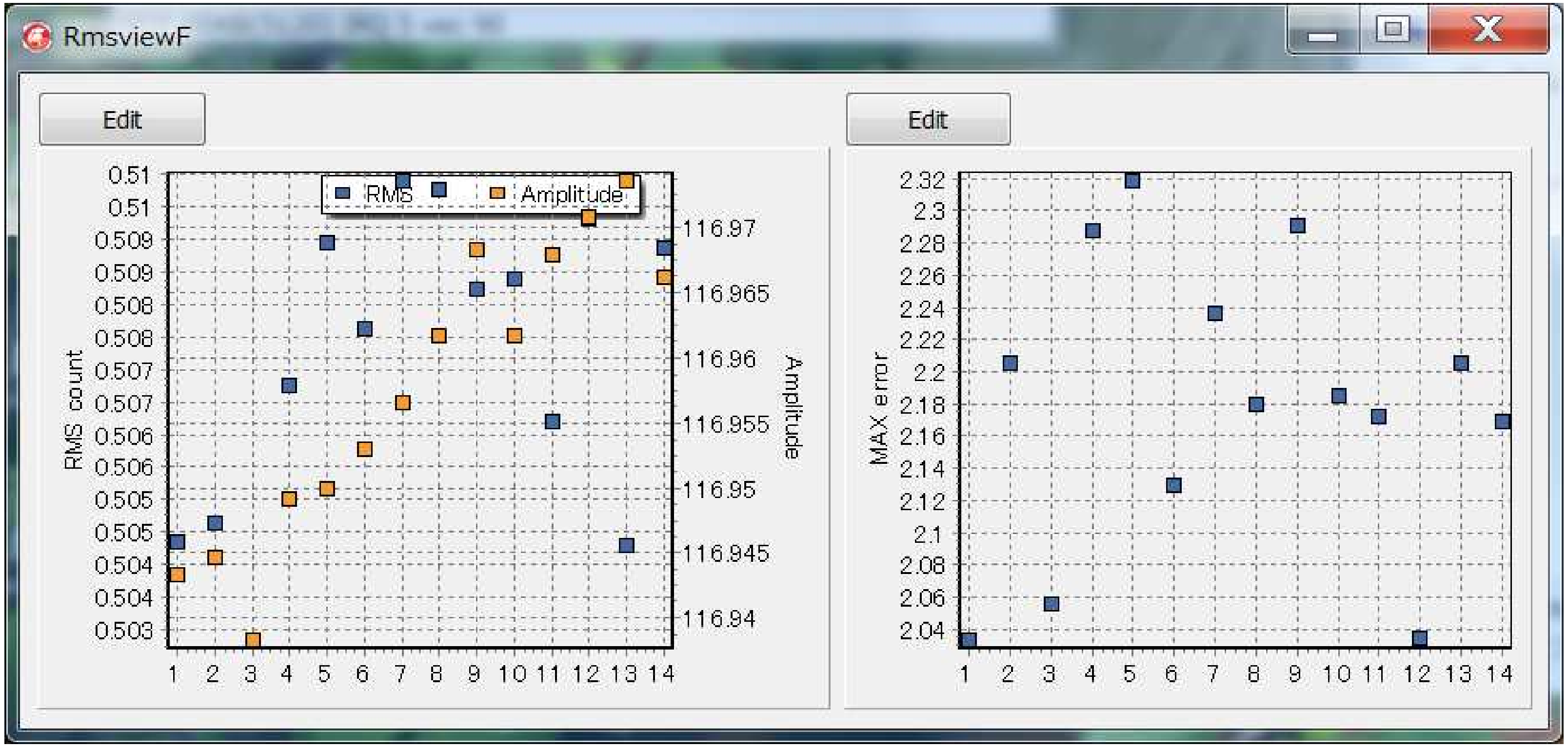
- 8-bit ADC(MAX108)
- Spartan6 FPGA on SO-DIMM daughter card (Mars MX1)
- 128MB DDR2 memory
- BCM : Block RAM
- BOR : DDR2 memory
  - 4k, 8k, 16k x 5120
  - 20M, 40M, 80M
- 1.1ms to transfer 5k data to IOC (BCM)



KEKB(H=5120), PF(H=312), AR(H=640), DR(H=230) supported
EPICS Device support ready

M.Tobiyama

Sine wave fit

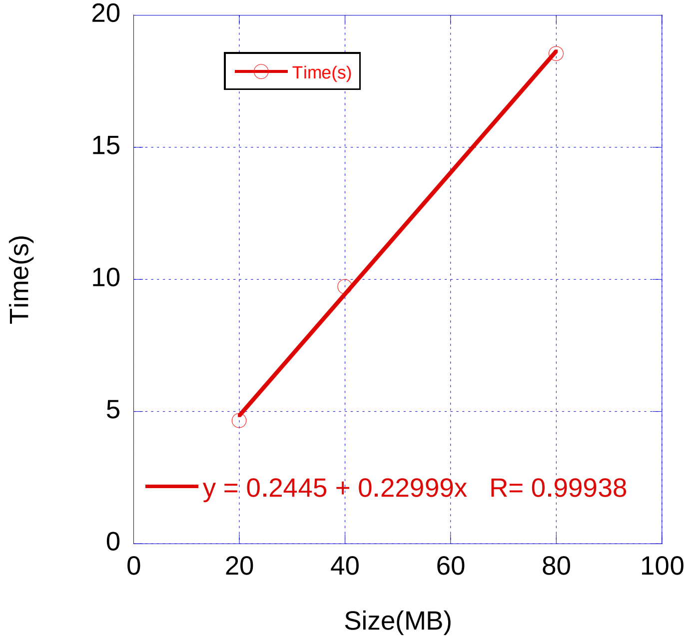


RMS 0.5 counts, MAX error 2.2 counts

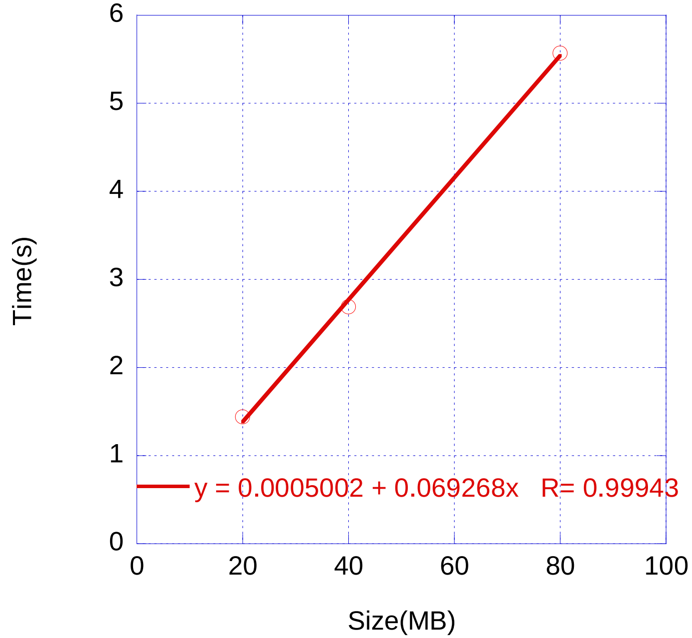
M.Tobiyama

Large data transfer

- BLT (D32 block transfer) supported.



BOR to IOC ~4MB/s

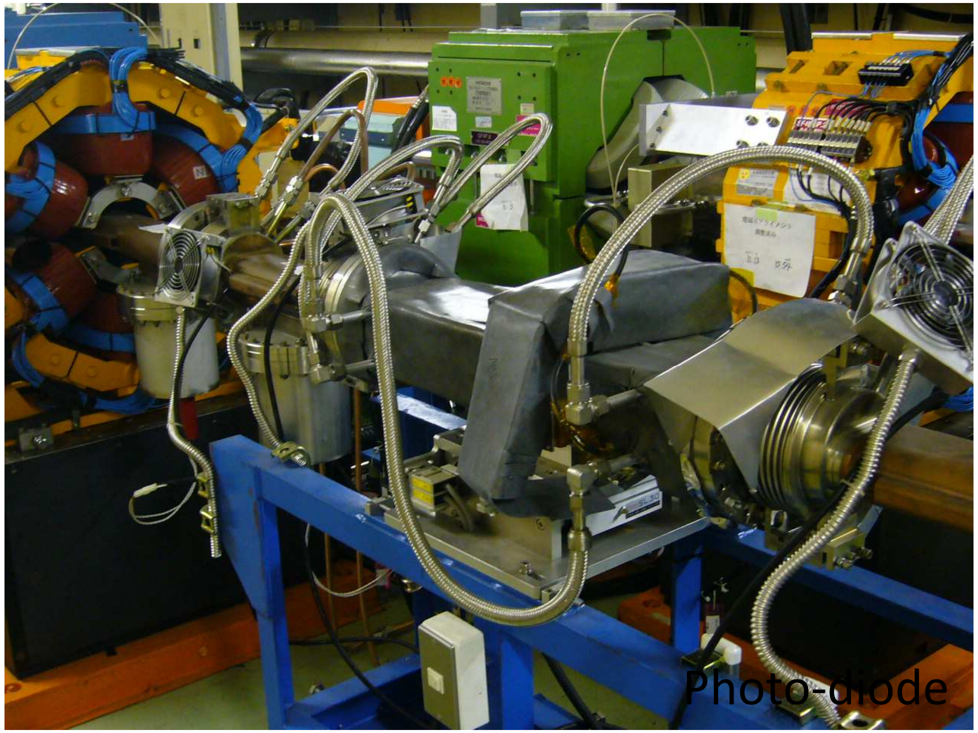


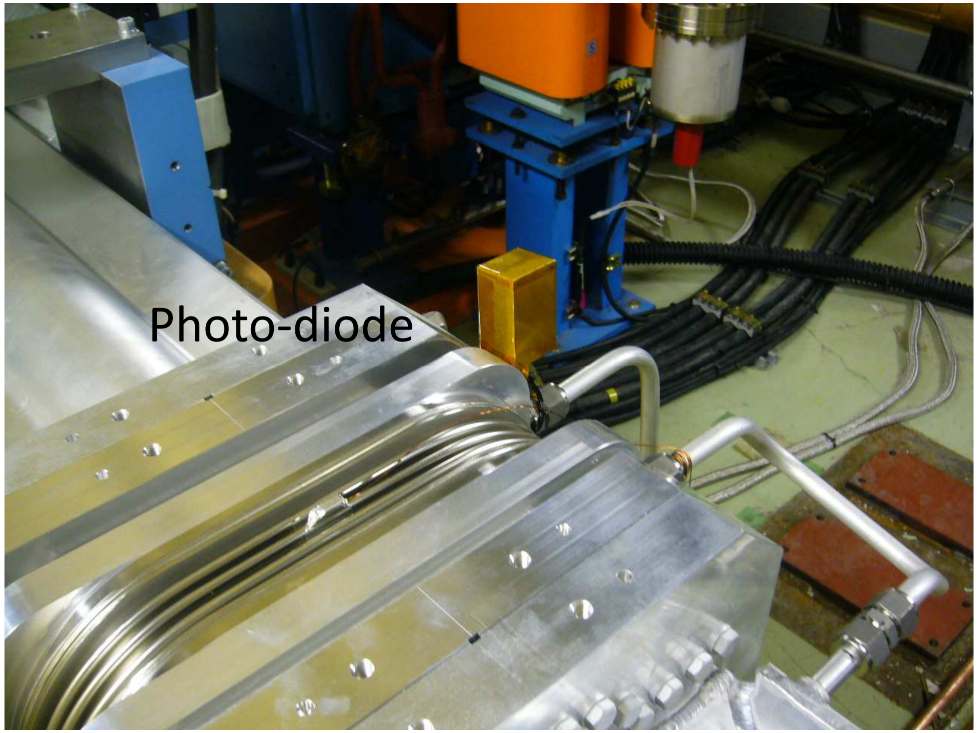
IOC to NAS (GbE+10GbE) ~14MKB/s

7s for 20MB data transfer (vs. 5 min. with old BOR).

Loss Monitor

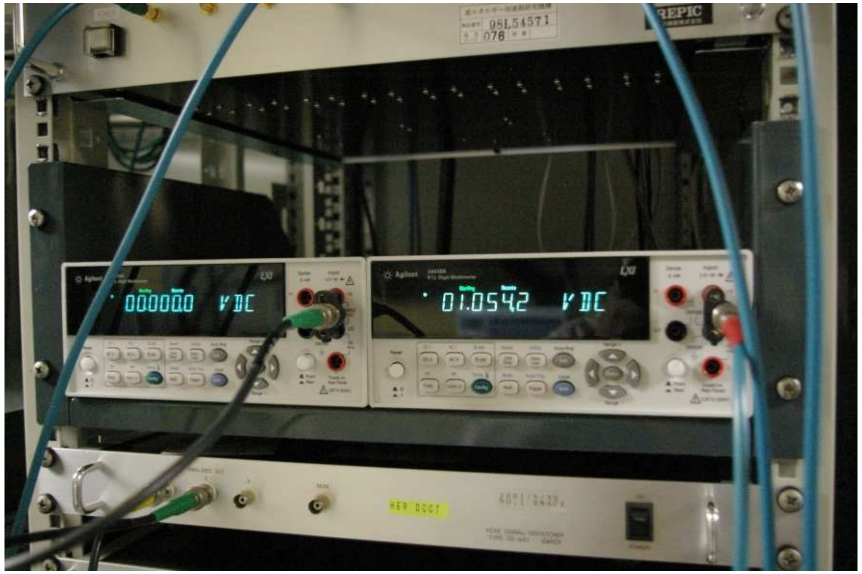
- Installation of LM cables and sensors has finished except for IR region.
- Read-out modules (integrator + interlock module, ADC) are prepared and cabling in control room will be done soon.

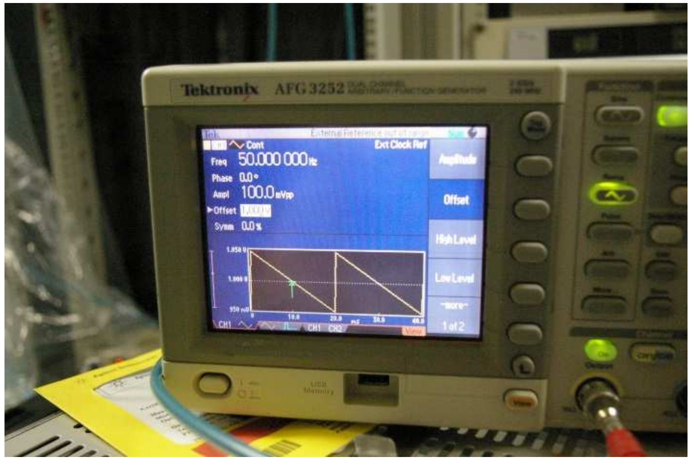




Fast beam decay measurement system

- Keysight 34410A DVM
  - Can transfer ~5ksps data to the host without data gap.
- Calculate using EPICS sequencer
  - Mean, Injection rate, Decay rate, Injection counts.
  - 1st order fit to get decay slope.
- Good agreement with the input signal.





H.Fukuma/M.Tobiyama

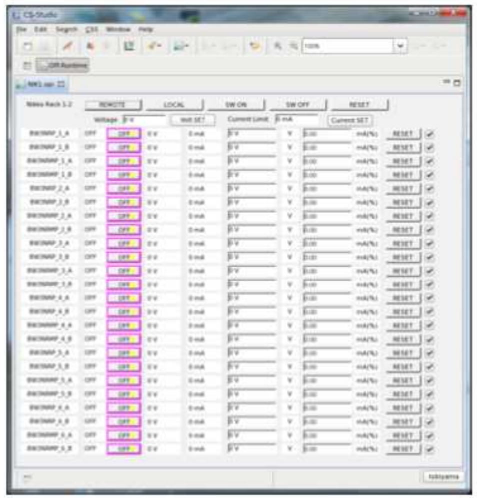
Power supply system of clearing electrodes for electron cloud mitigation

- Clearing electrodes are installed in Oho and Nikko straight sections to mitigate the electron cloud effect. The number is 52 in Oho and 60 in Nikko.
- Each electrode is powered by individual power supply.
- Cabling and installation have almost completed.
- Development of control software has finished (EPICS device support, CSS operation panel, Batch generation of database).
- Application of voltage will be tried in this spring.

Specification of power supply

DC voltage	1kV(bipolar by manual switch)
Current	100mA
Voltage stability	<0.01%
Voltage ripple	<0.01%(r.m.s)
Control	optical link controlled via Ethernet

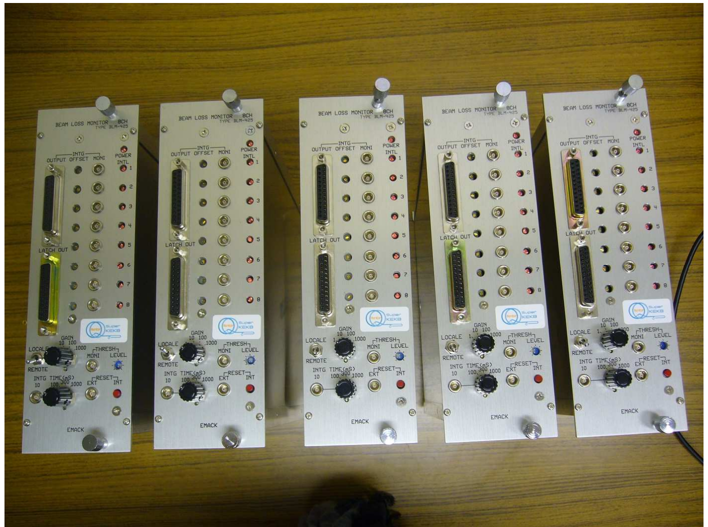
Power supply system for clearing electrodes in Nikko B4.

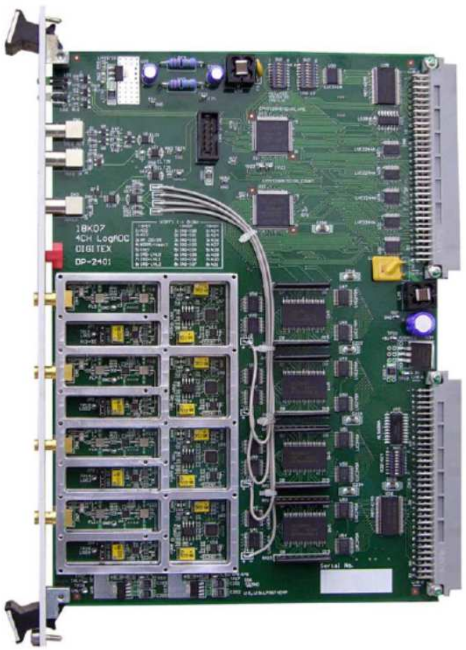


Operation panel

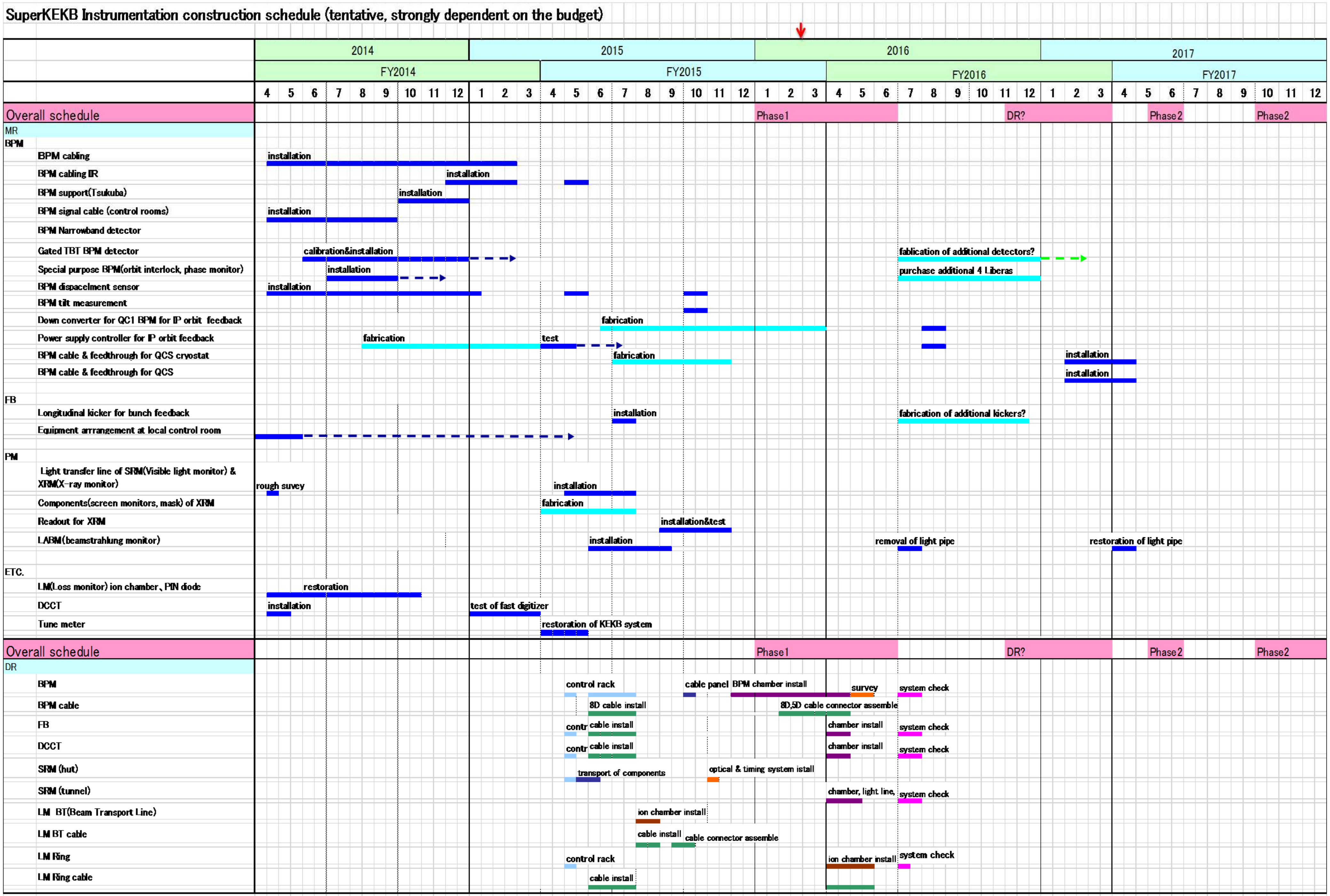
DR

- Most of sensors, electronics and cables are ready for BPM,FB,SRM,LM and DCCT.
- Cabling between ground floor and tunnel will be done in 2015.
- Chamber installation of each monitor will be done in 2015 or 2016.
- Preparation of special monitor (bunch current monitor, tune meter, synchrotron phase monitor etc…) starts in 2015.





Schedule



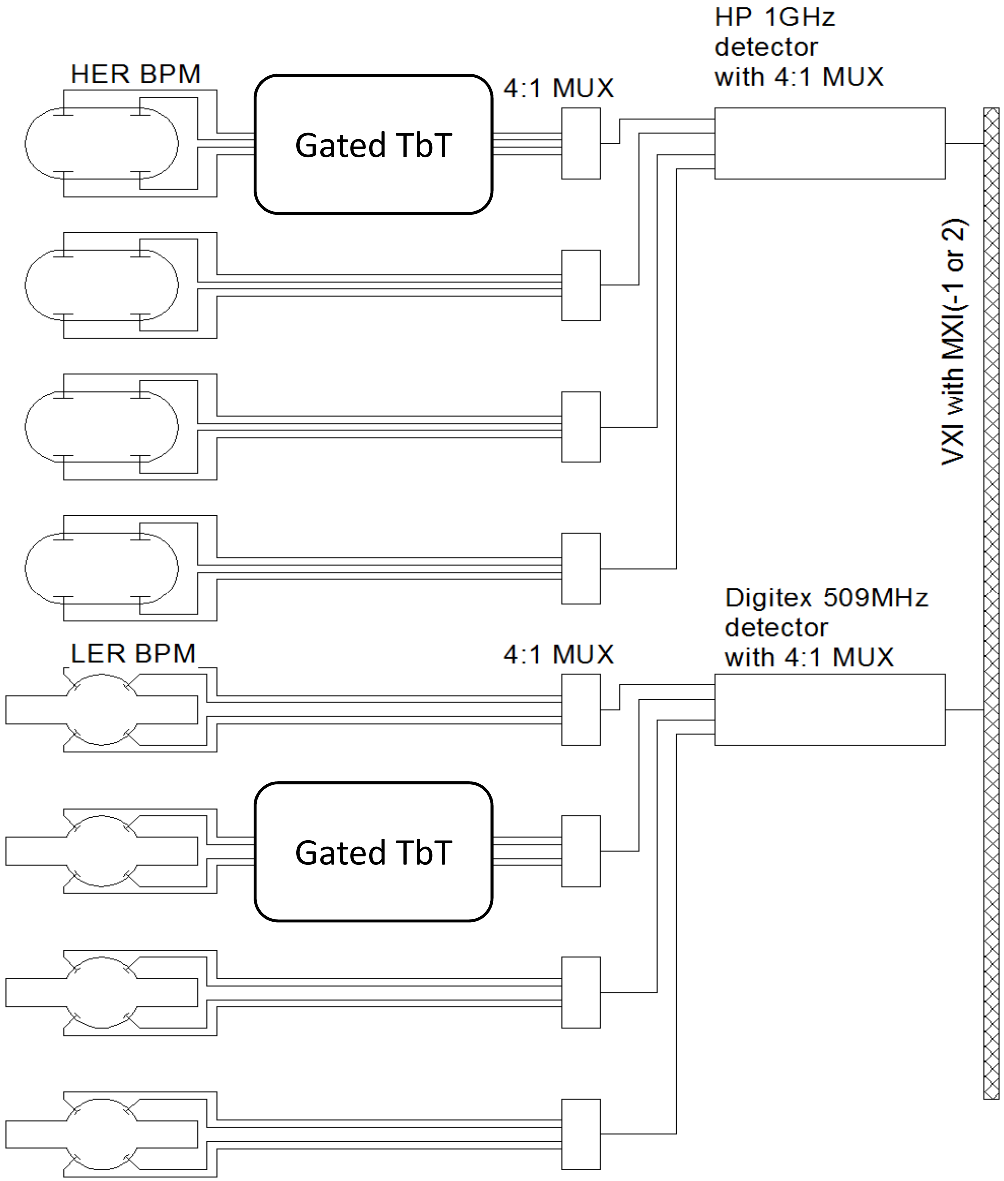
SuperKEKB Instrumentation construction schedule (tentative, strongly dependent on the budget)
2014
2015
2016
2017
FY2014
FY2015
FY2016
FY2017
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
Overall schedule
Phase1
DR?
Phase2
Phase2
MR
BPM
BPM cabling
installation
BPM cabling IR
installation
BPM support(Tsukuba)
installation
BPM signal cable (control rooms)
installation
BPM Narrowband detector
Gated TBT BPM detector
calibration&installation
fablication of additional detectors?
Special purpose BPM(orbit interlock, phase monitor)
installation
purchase additional 4 Liberas
BPM dispacelment sensor
installation
BPM tilt measurement
Down converter for QC1 BPM for IP orbit feedback
fabrication
Power supply controller for IP orbit feedback
fabrication
test
BPM cable & feedthrough for QCS cryostat
fabrication
installation
BPM cable & feedthrough for QCS
installation
FB
Longitudinal kicker for bunch feedback
installation
fabrication of additional kickers?
Equipment arrangement at local control room
PM
Light transfer line of SRM(Visible light monitor) & XRM(X-ray monitor)
rough suvey
installation
Components(screen monitors, mask) of XRM
fabrication
Readout for XRM
installation&test
LABM(beamstrahlung monitor)
installation
removal of light pipe
restoration of light pipe
ETC.
LM(Loss monitor) ion chamber、PIN diode
restoration
DCCT
installation
test of fast digitizer
Tune meter
restoration of KEKB system
Overall schedule
Phase1
DR?
Phase2
Phase2
DR
BPM
control rack
cable panel
BPM chamber install
survey
system check
BPM cable
8D cable install
8D,5D cable connector assemble
FB
contr
cable install
chamber install
system check
DCCT
contr
cable install
chamber install
system check
SRM (hut)
transport of components
optical & timing system install
SRM (tunnel)
chamber, light line,
system check
LM BT(Beam Transport Line)
ion chamber install
LM BT cable
cable install
cable connector assemble
LM Ring
control rack
ion chamber install
system check
LM Ring cable
cable install

Summary

- The installation of MR beam diagnostics system is advancing smoothly.
- DR schedule depends on components of other groups.

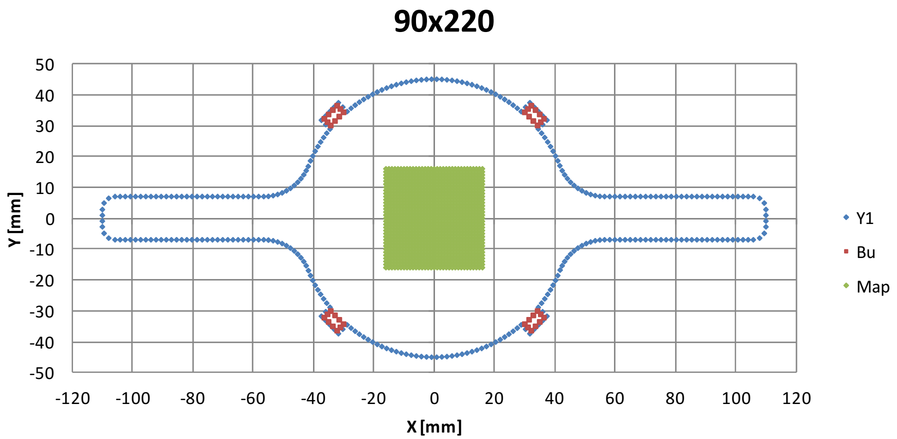
backup

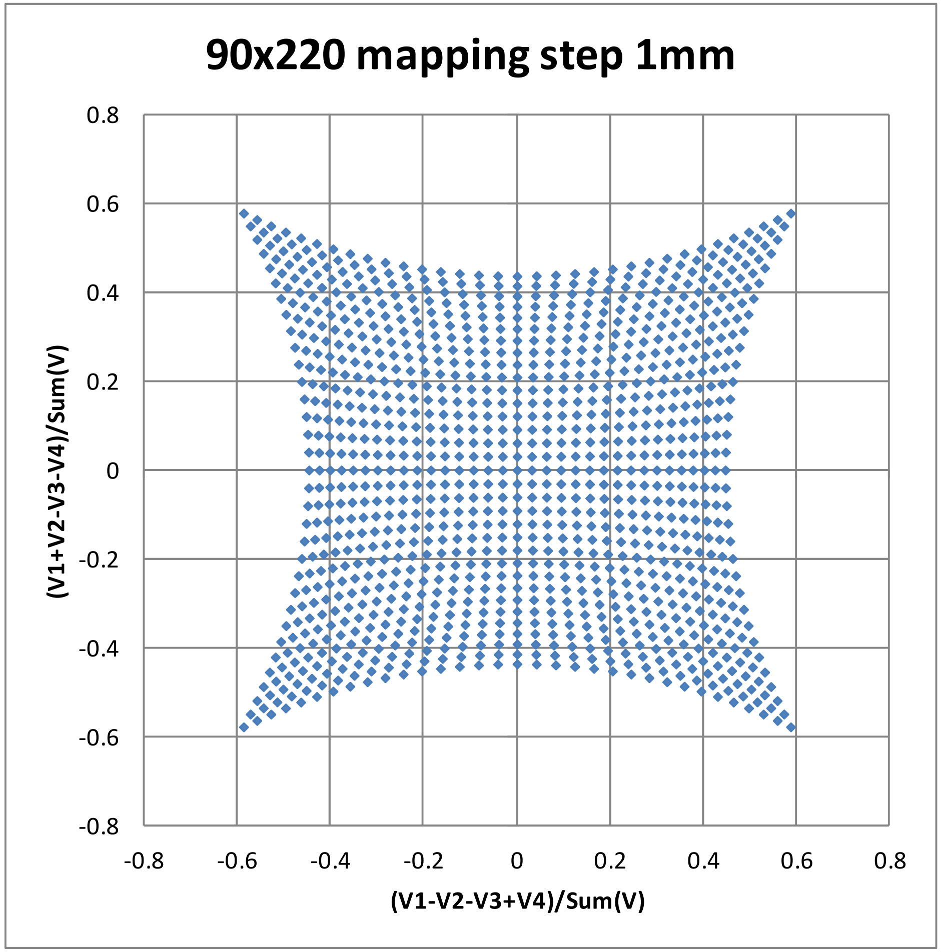
Configuration of main BPM system



- Super-heterodyne detectors in KEKB BPM system are also main detectors in SuperKEKB.
- Detection frequency in LER is lowered to 509 MHz due to the chamber cutoff frequency of 989 MHz.
- Selected 270 BPMs have *gated* turn-by-turn monitoring function.

Mapping of 90x220 ante-BPM

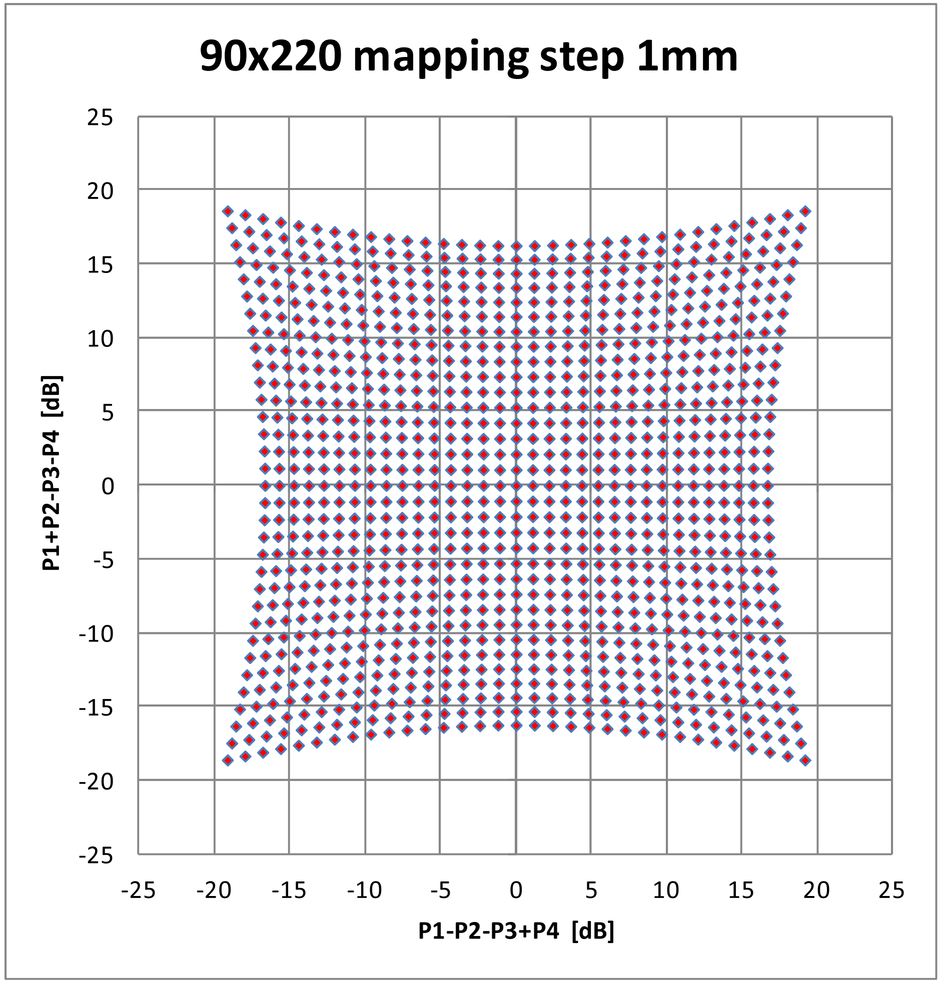




M.Tejima

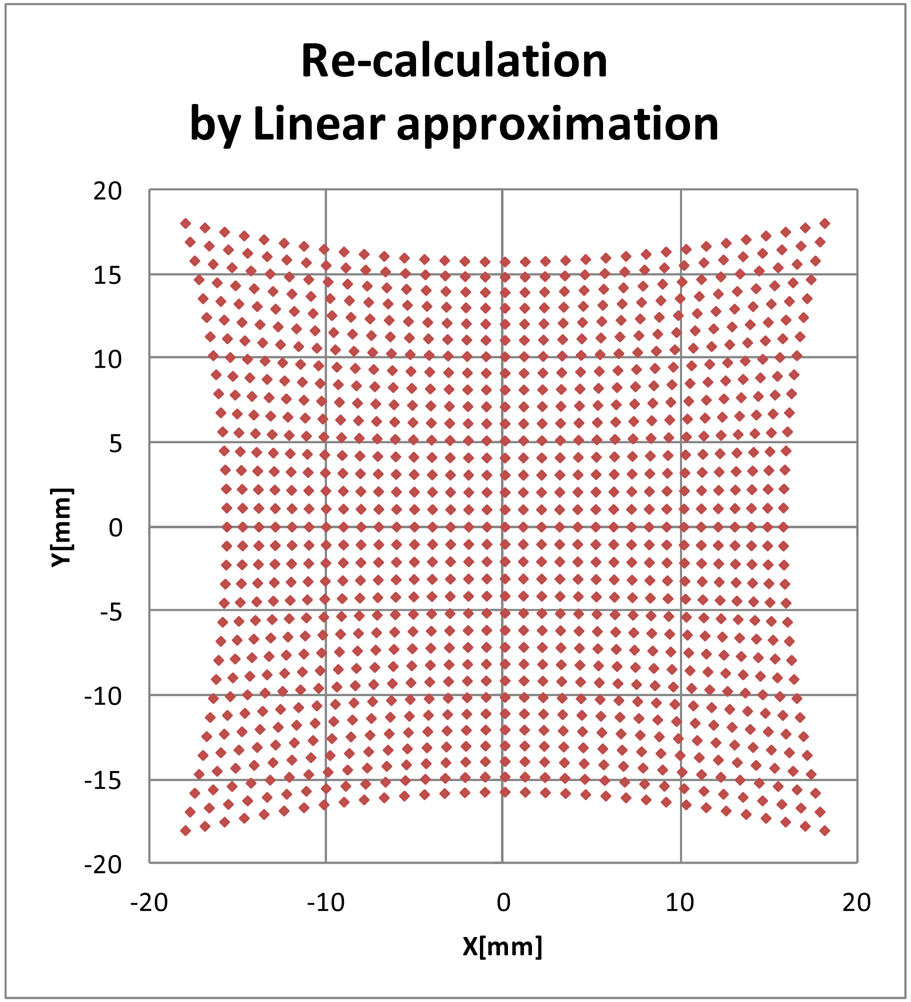
LR detection

- 電極の出力電圧
  V1, V2, V3, V4
- LR回路の出力
  P1=20Log(V1)
  P2=20Log(V2)
  P3=20Log(V3)
  P4=20Log(V4)
- ノーマライズ
  H=P1-P2-P3+P4
  V=P1+P2-P3-P4

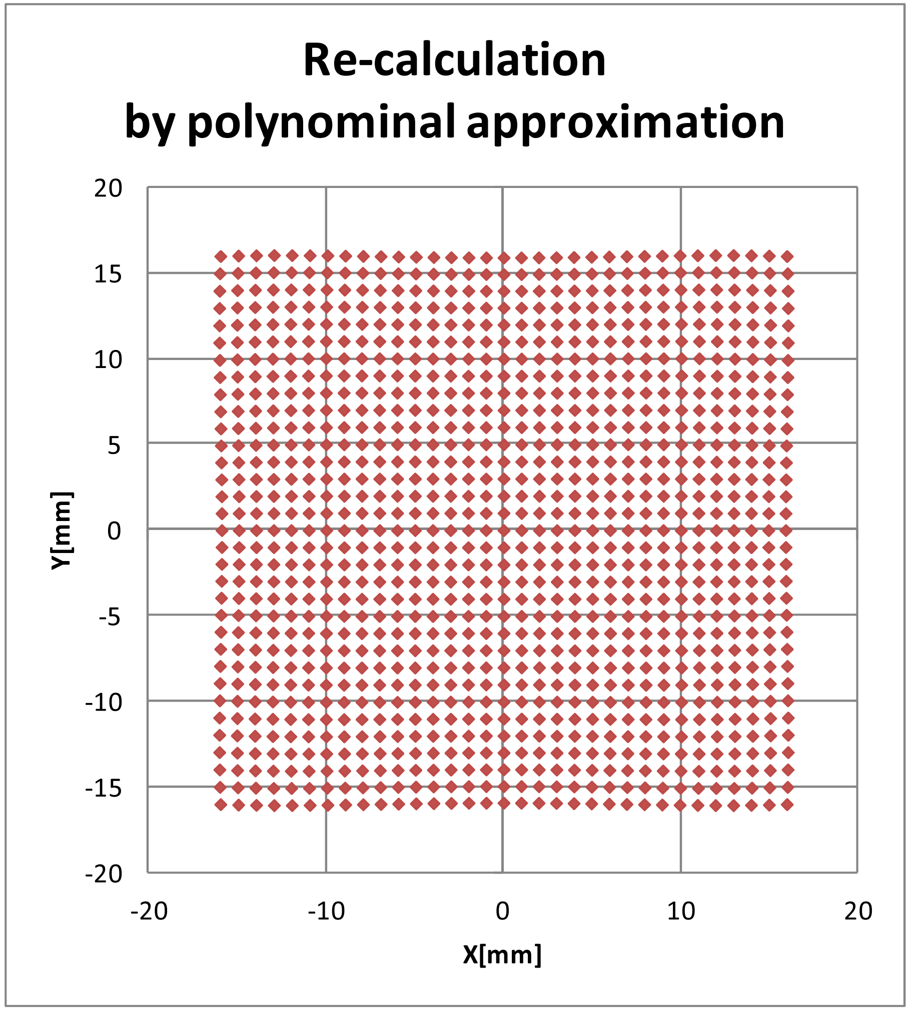


M.Tejima

Re-calculation for beam positions



$$\begin{cases} X = 0.943 \cdot H \\ Y = 0.970 \cdot V \end{cases}$$

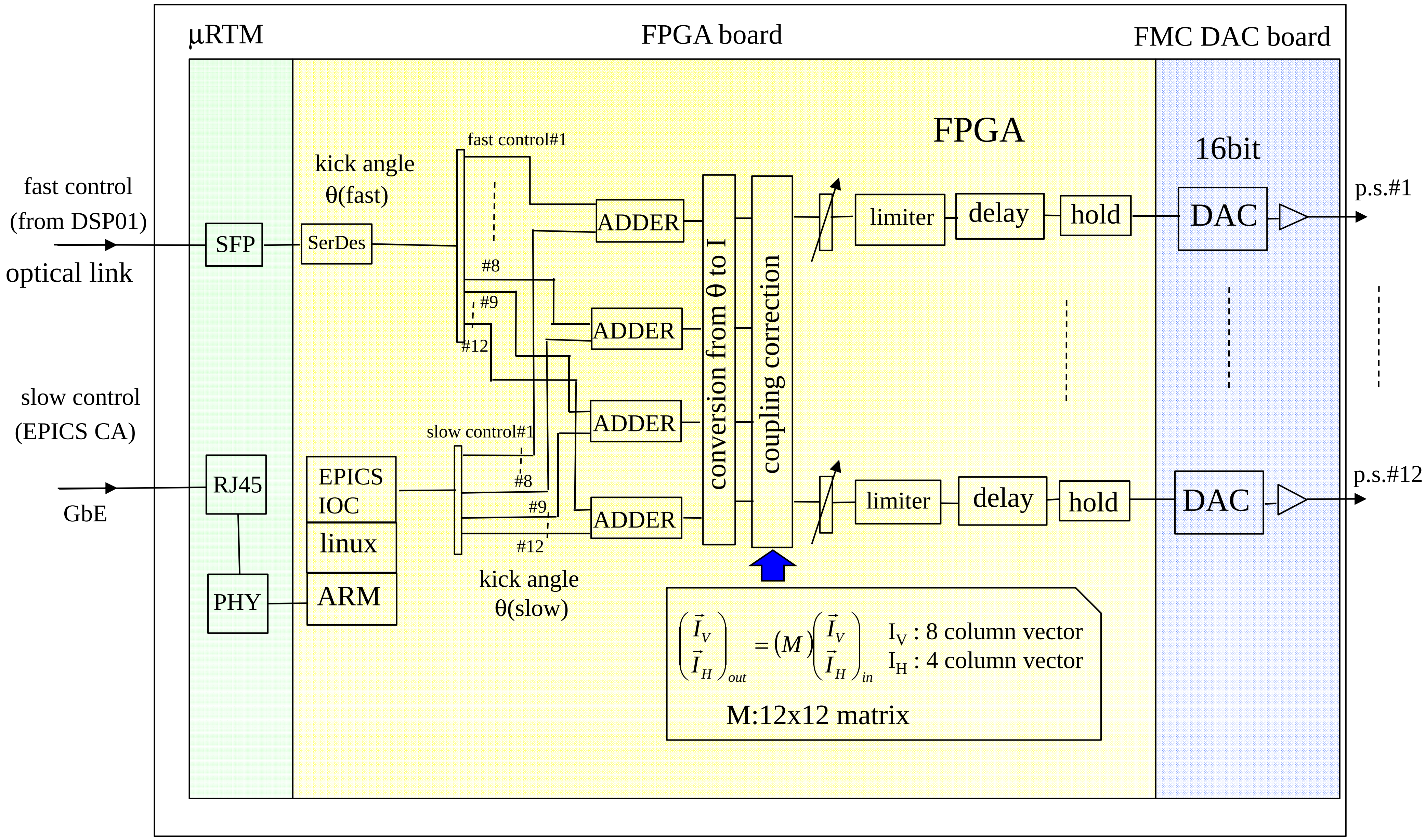


$$\begin{cases} X = 0.917 \cdot H + 0.00013 \cdot H^3 - 0.00038 \cdot H \cdot V^2 \\ Y = 0.945 \cdot V + 0.00013 \cdot V^3 - 0.00036 \cdot H^2 \cdot V \end{cases}$$

境界要素法で得たマッピングデータを使って、最小二乗近似で係数を求めた

H.Fukuma

Power supply controller board (conforming to MTCA.4)



RTM : Rear Transition Module

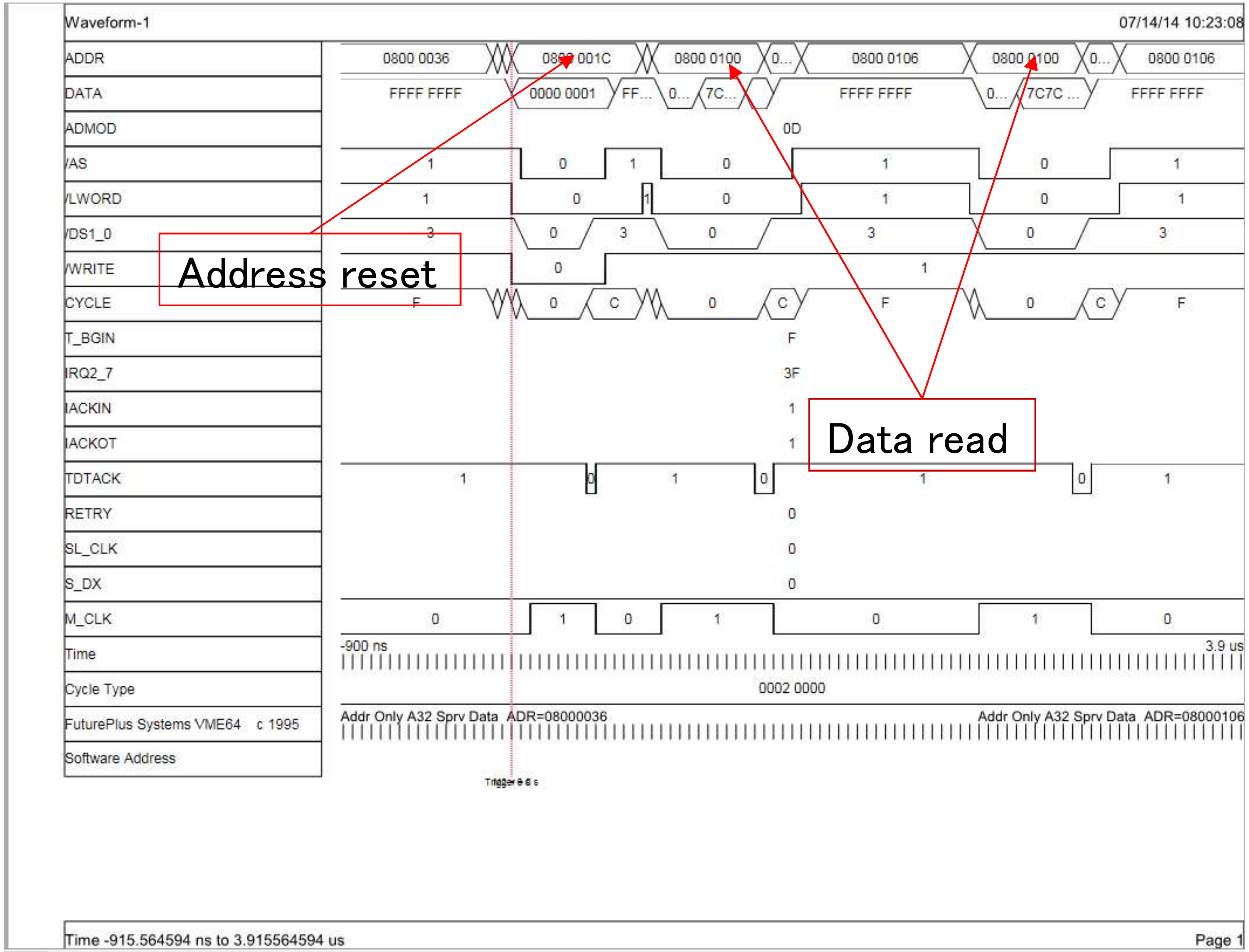
FMC : FPGA Mezzanine Card

p.s. : power supply

EPICS device support related difficulties

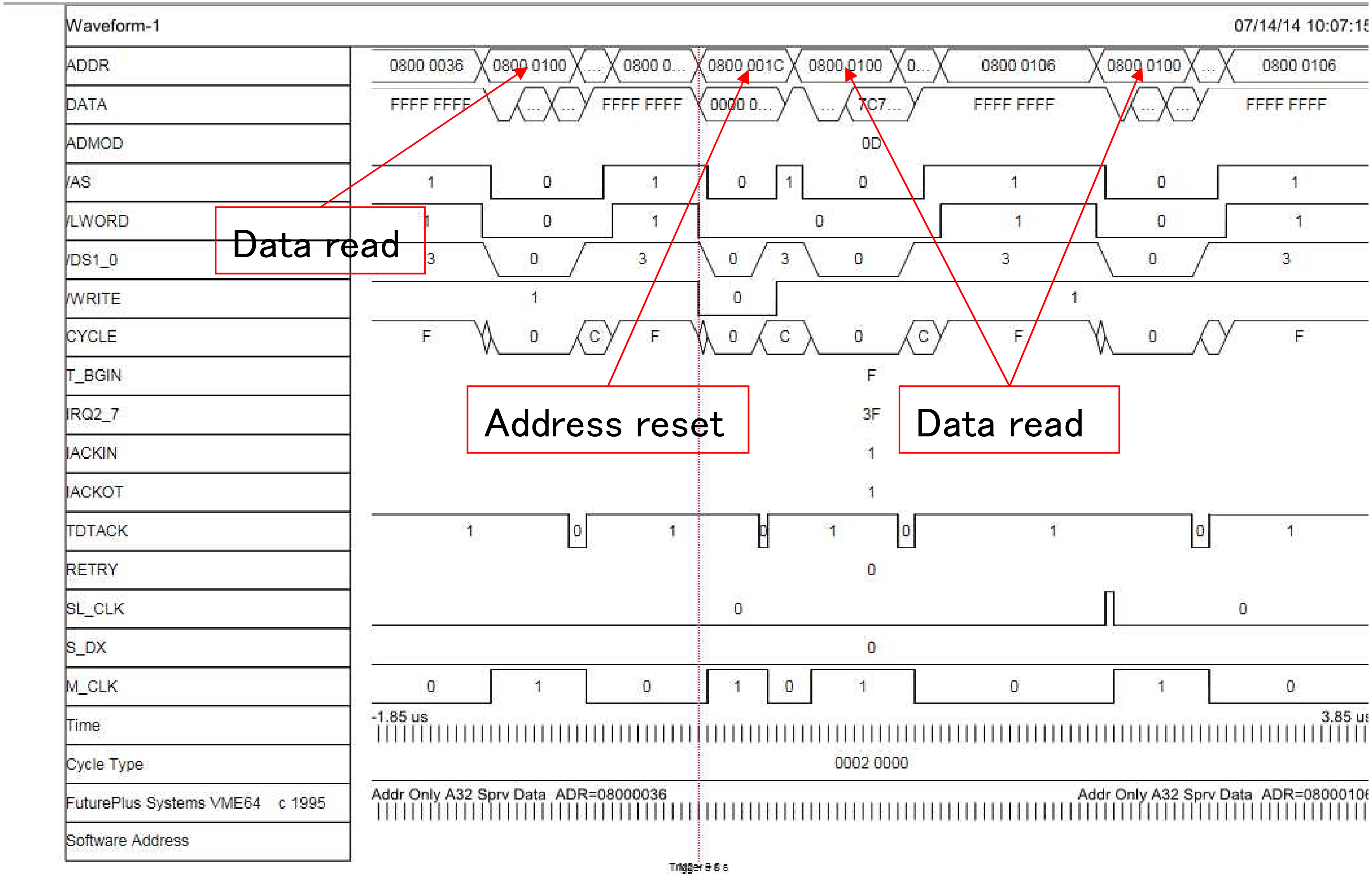
- We've found the command order (read and write) on the VMEbus changed during the debugging process of the EPICS device support of BCM board, which destroyed the data order.
  - Out-of-order operation of CPU (PPC5500).
  - Rather rare event (about 10^{-3}): fairly difficult to find.
- Needed to insert special command to guarantee the operation order.
  - There should be command to suppress such nasty "optimization" for the whole bus operation– no such command has been prepared on (current?) VxWork 6.8.3.
  - I'm not confident whether other device supports are OK or not.

Bus access as written by code



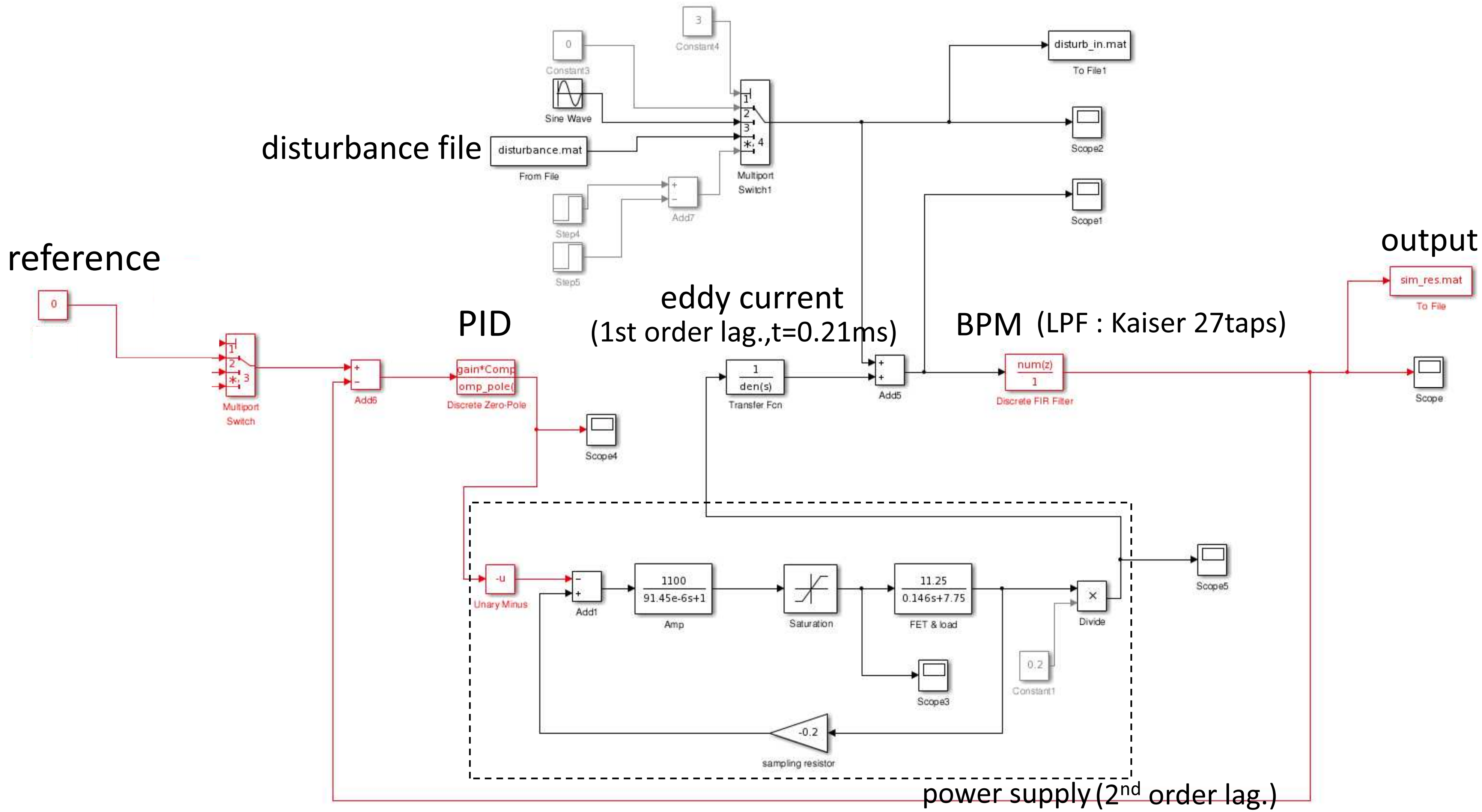
M.Tobiyama

Wrong order



H.Fukuma

Simulink model



A model of the TAKASAGO power supply is taken into account.