Measurement and Data Acquisition for Accelerator Controls at KEK

(Beam Position Monitor at Linac)

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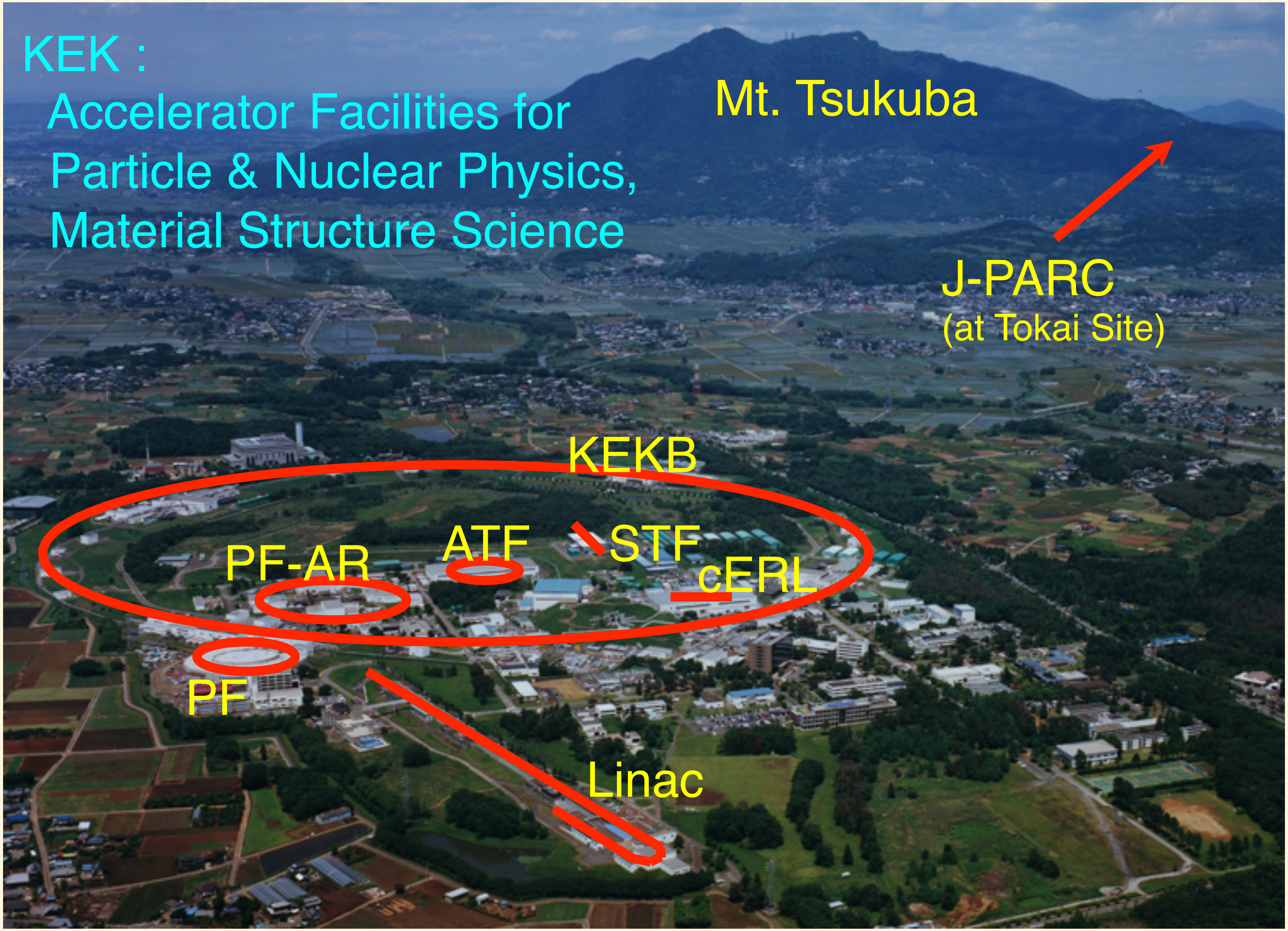
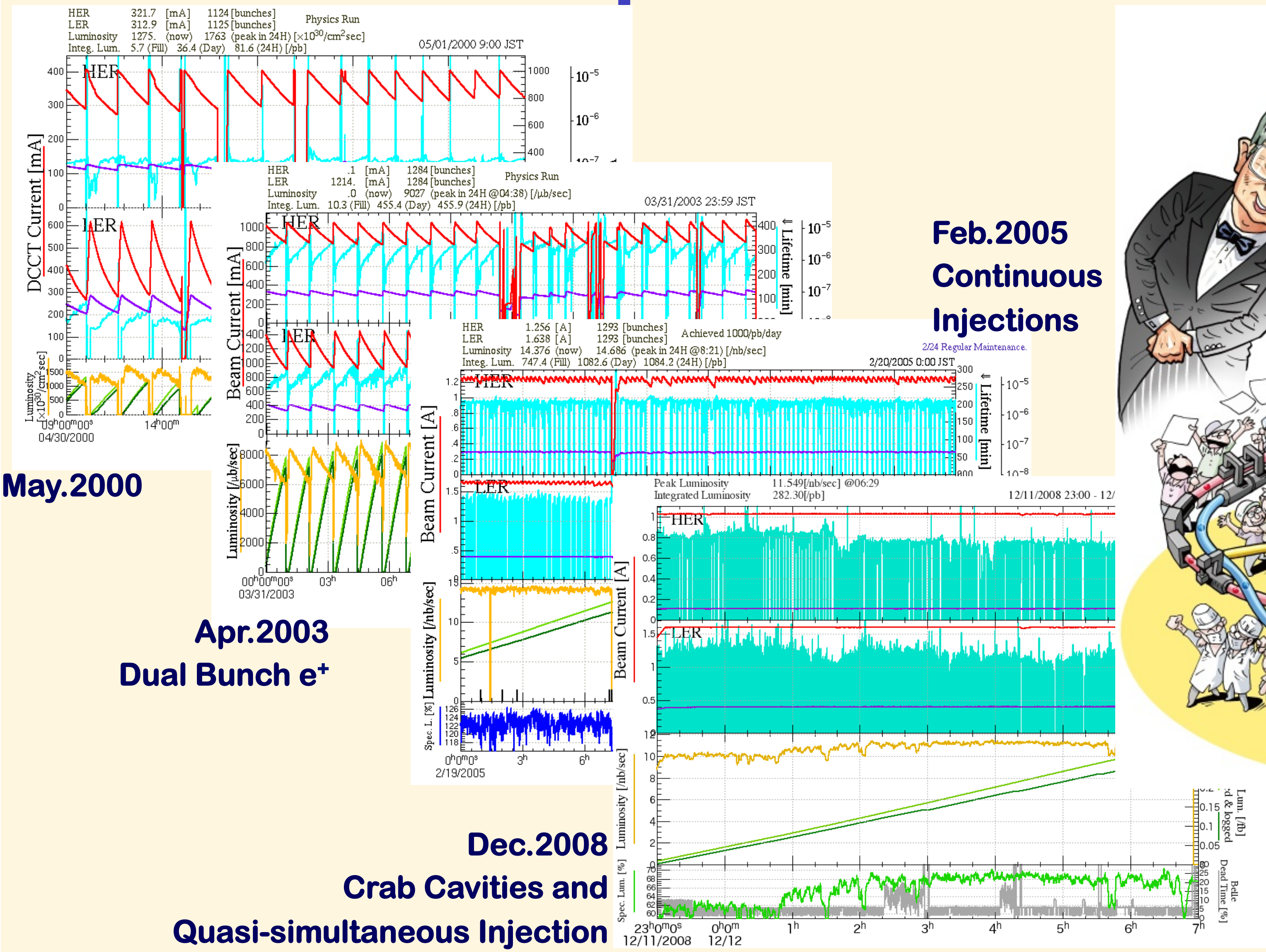
For Linac and KEKB Control Groups

Oct.2009.


KEK :
Accelerator Facilities for
Particle & Nuclear Physics,
Material Structure Science
Mt. Tsukuba
J-PARC
(at Tokai Site)
KEKB
ATF
STF
PF-AR
cERL
PF
Linac

Accelerator Improvement and Nobel Prize

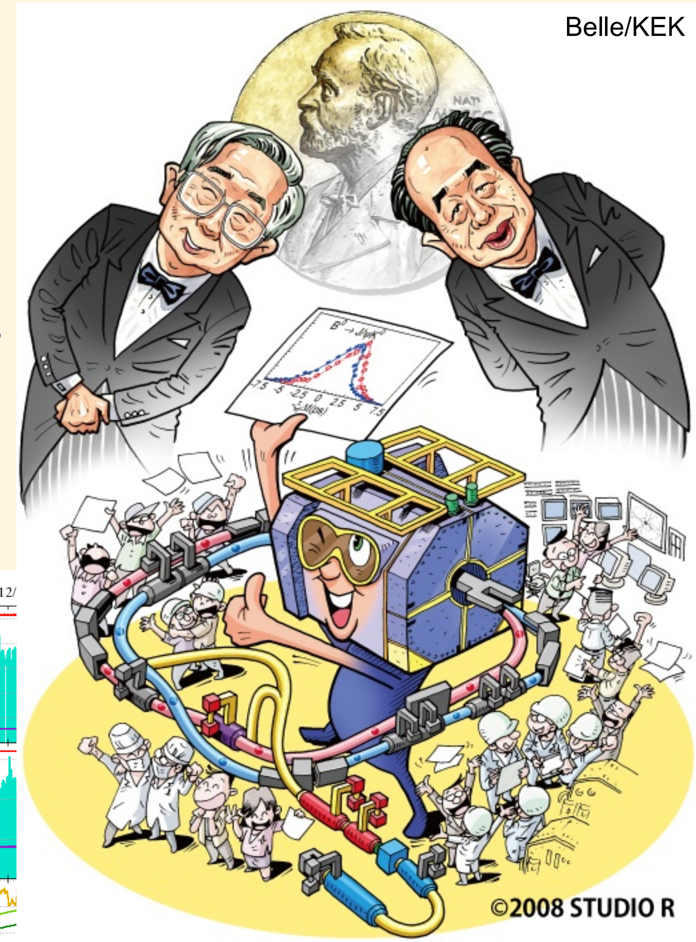


May.2000

Apr.2003
Dual Bunch e+

Feb.2005
Continuous
Injections

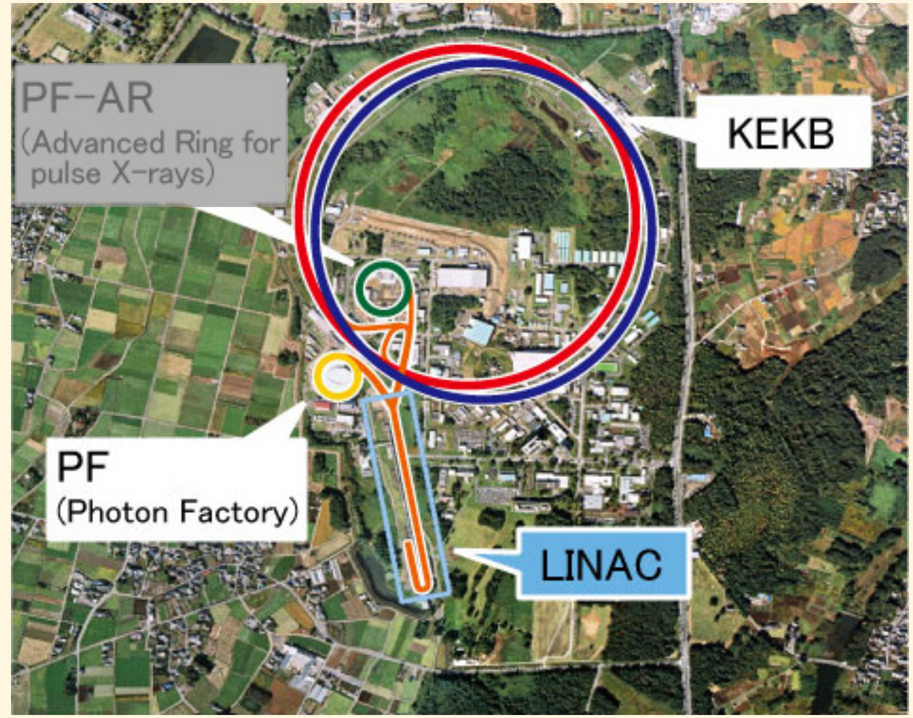
Dec.2008
Crab Cavities and
Quasi-simultaneous Injection



Flexible Upgrades for
Accelerator Operation

Simultaneous Injection Requirements

- **Linac clients**
  - **KEKB**
    - 8-GeV e– 1nC x2
    - 3.5-GeV e+ 1nC x2
    - (with 10nC primary e–)
  - **PF 2.5-GeV e– 0.1nC**
  - **(PF-AR 3-GeV e– 0.2nC)**



- **At first, simultaneous top-up injections to three rings at KEKB and PF**
  - **Switching beams at 50Hz**
  - **For stable operation and higher quality exp. results**

Beam Instrumentations at Linac

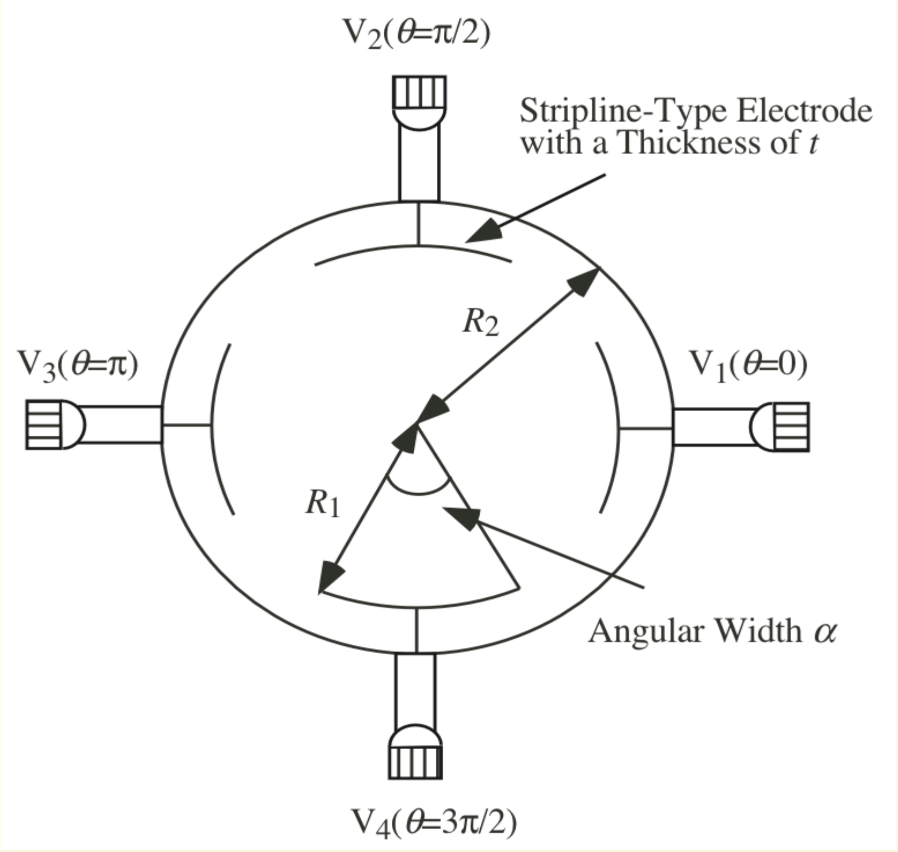
- **Diagnosis for High-stability (for high luminosity at KEKB ring)**
  - Wider dynamic range (0.1nC ~ 12nC)
  - Reasonable resolution
- **Transverse wake-fileld suppression**
  - Beam position torrelance (0.1mm ~ 0.3mm) against center of quads, otherwise leads to emittance growth
- **Beam monitors**
  - Beam position monitor (Stripline): ~100
  - Streak camera: 2
  - Wire scanner: 14
  - Compact Screen monitor: ~100
  - Wall-current monitor: (~50)

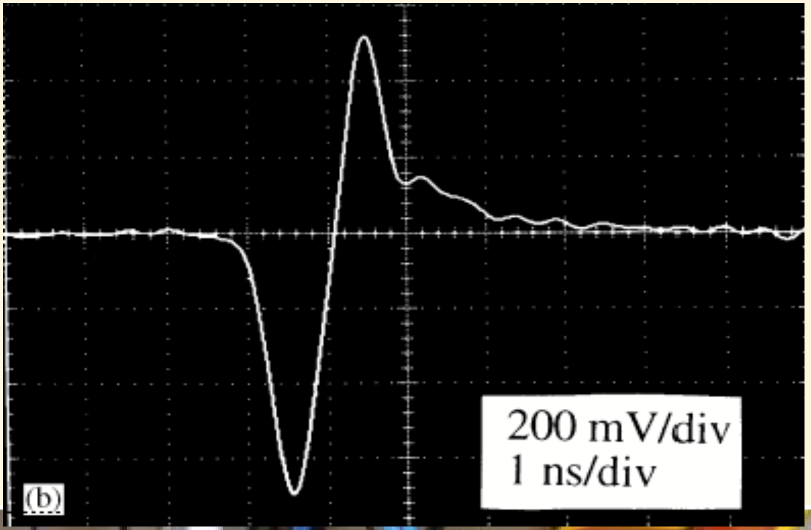
BPM, one of most important Beam Instrumentation

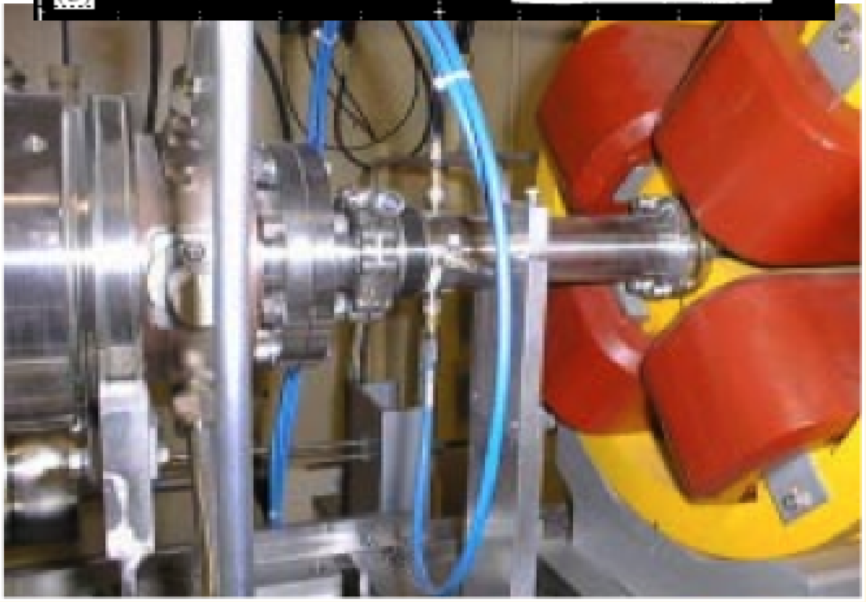
- ~100 monitors (~100 more at beam transport line)
- Resolution down to ~100μm
- Simultaneous orbit acquisition along the 600m linac
- Simultaneous dual-bunch measurement in a pulse (96ns apart)
- Dynamic range of 0.1nC~12.5nC
- Repetition of 50Hz
- Limited electrode length, fast signal of 10ps - 1ns
- Limited budget
- Limited construction/maintenance man-power

BPM Design

- Strip-line, 50ohm, attached to a quad

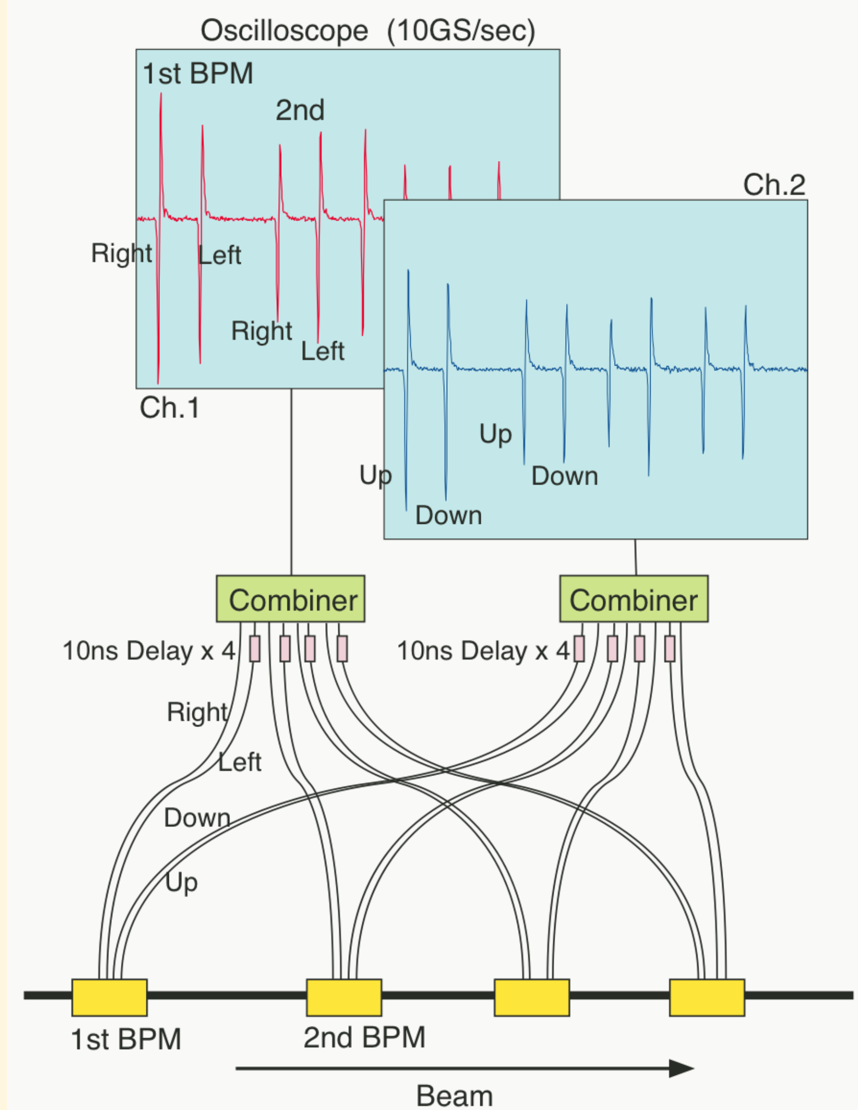






Measurement and Data Acquisition

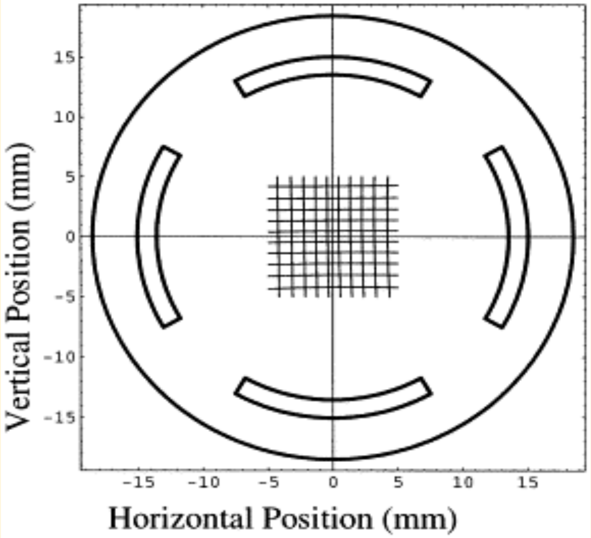
- **Originally much efforts to develop detectors, shaping amplifiers**
  - **No budget for all BPMs**
- **Switched to direct waveform acquisition**
  - **Minimized active components, then minimized calibration tasks, maintenance**
  - **Equal-length cables**
  - **One oscilloscope covers about 5 BPMs, or combined 20 (or 40) waveforms**
  - **5 - 10Gs/s (with additional interpolation)**
  - **Possible to measure dual bunches**
  - **Solved many issues at once!**
  - **Extract each signal, apply calibration factors, send to upper layer at 50Hz**



Database and Calibration Factors

- Pulse timing value for each electrode, each monitor, each of four beam modes
- Dynamic range (voltage) for each beam mode
- Mapping information up to 3rd order polynomial
- Cable loss for each electrode, combiner loss, charge conversions for single/multi-bunch beams
- About 40 coefficients for each BPM
- Processed on one of 24 DPO7104s in the framework of EPICS software then served directly to clients at 50Hz

100 BPMs — 24 x DPO7104 — Clients

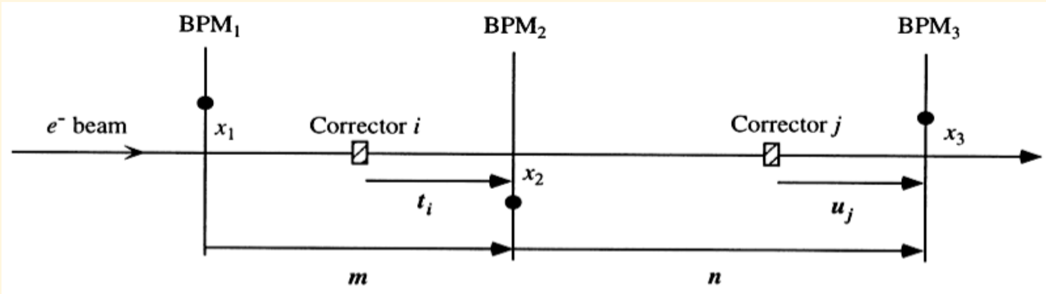


- Old system served at 1Hz

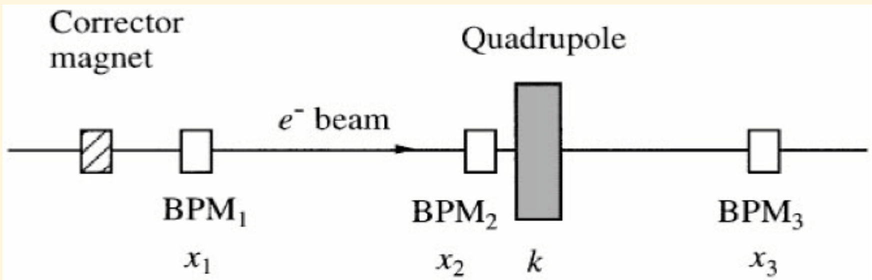
100 BPMs — 19 x TDS680B — 19 VMEs — ~5 Unix — Clients

Evaluation

- Linear position relation between 3 BPMs on changing correctors –> deviation ~0.1mm



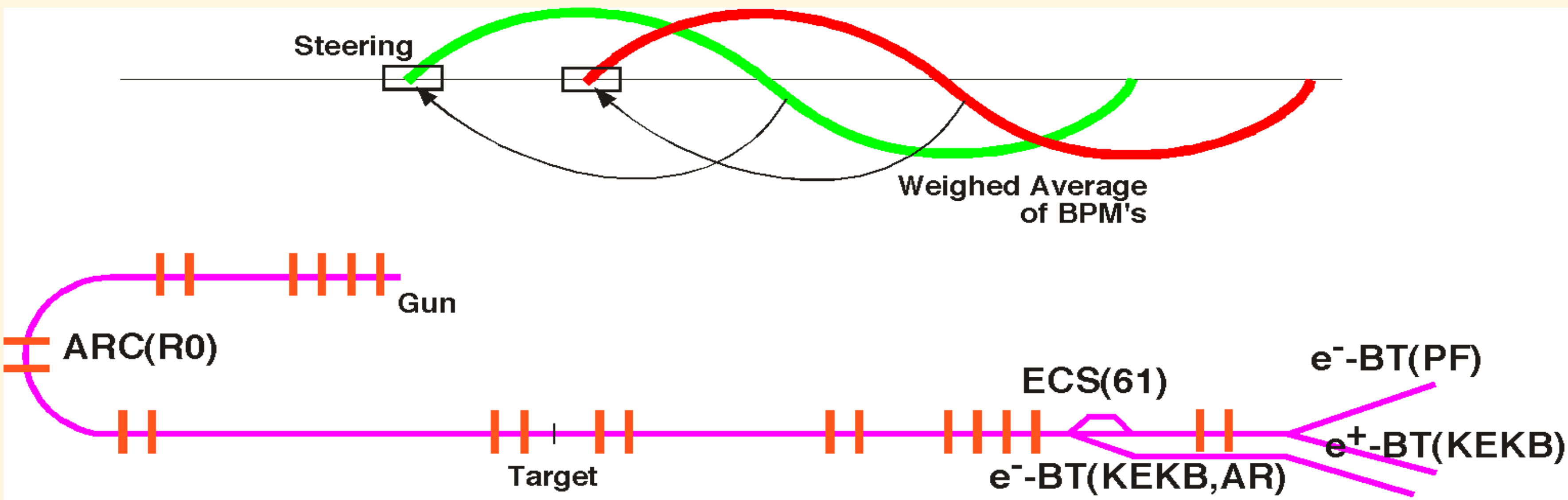
- Alignment against accompanying quad, changing corrector/quad – offset measurement – every BPM



- Beam based recalibration of BPMs with many measurements (use of fourth information other than x, y, charge)
- Charge calibration was carried with Faraday cup (energy at ~250MeV)

Orbit Stabilization

- **Simple orbit feedback**
  - **Monitor**
    - Type 1: Two BPM (~90 degree phase apart)
    - Type 2: Weighed average of BPMs over a betatron wave length
  - **Actuator: Two steerings**

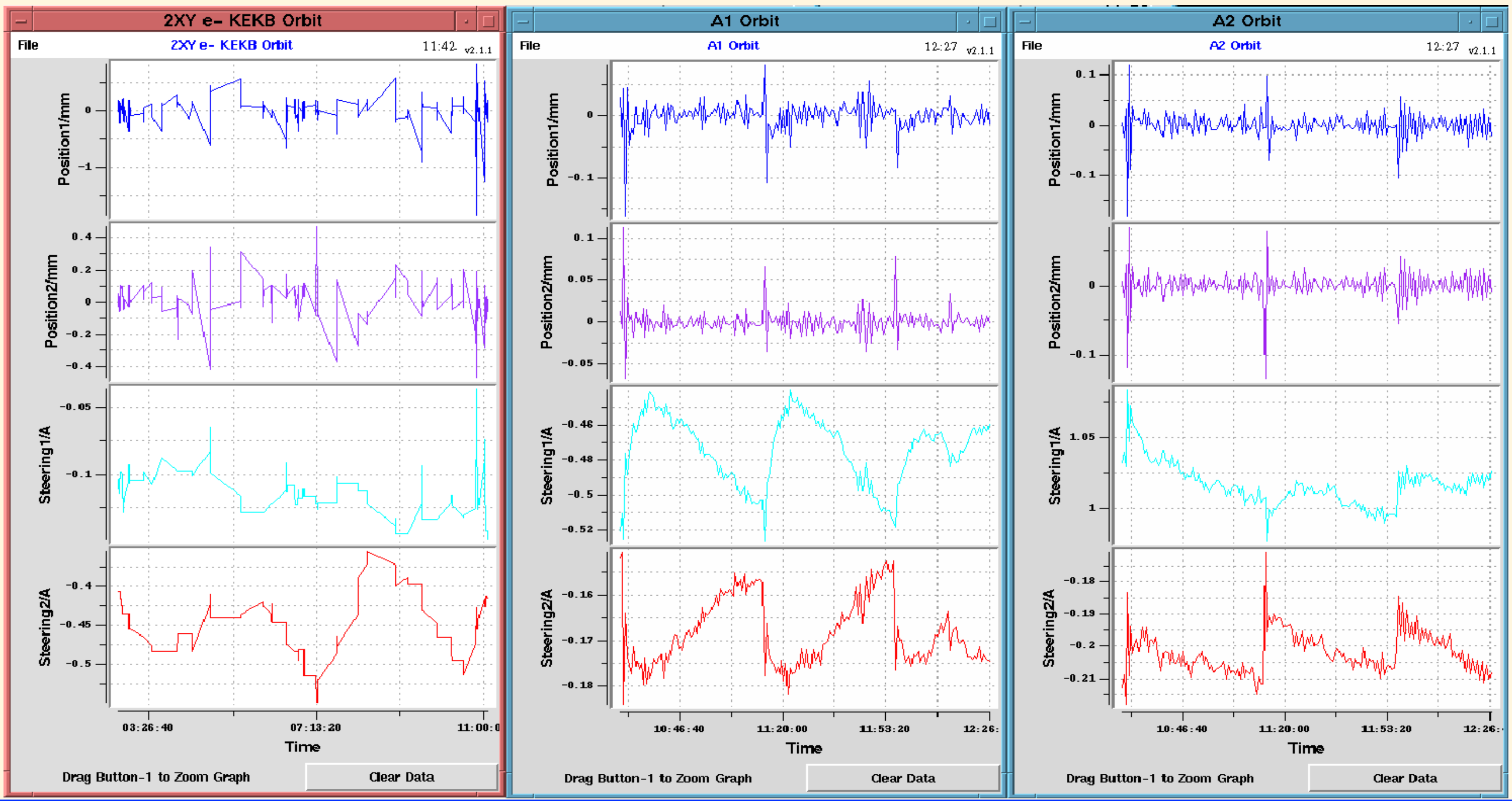


Orbit Fluctuations and Stabilizations

- **At the beginning of the commissioning, both stabilized well**

Daily change, peak at 6 O'clock, caused by SB_C

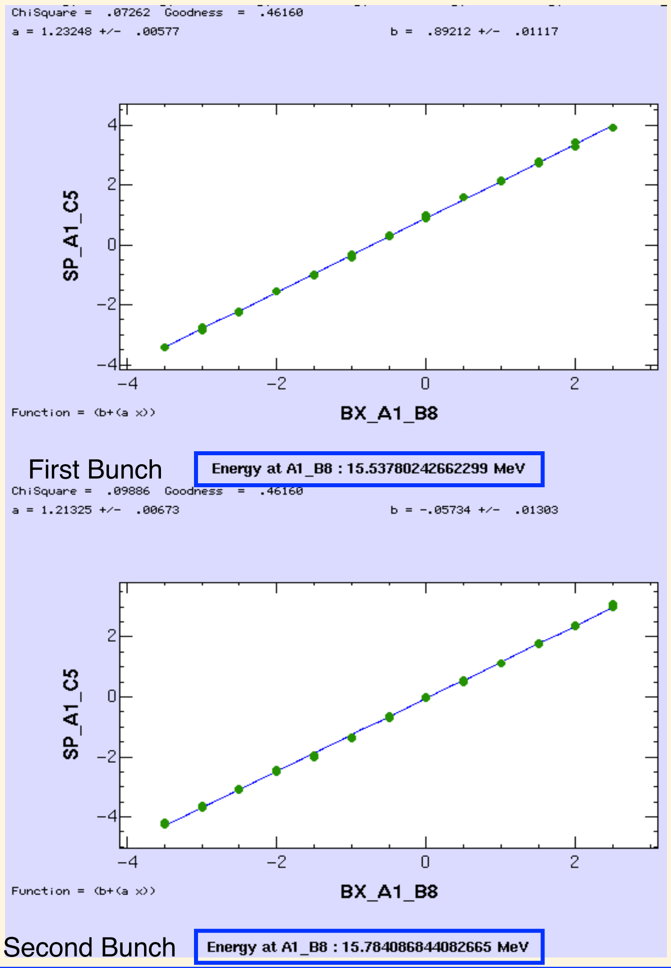
40-minute changes in A sector Later attributed to SHB

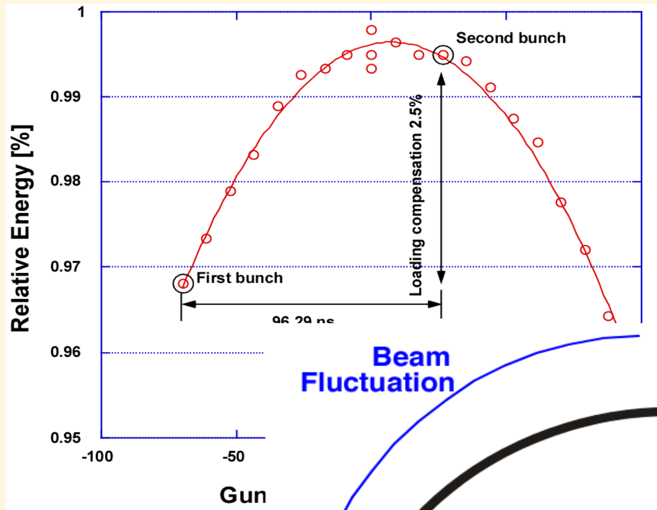


Dual-bunch Energy Equalize, and Feedback

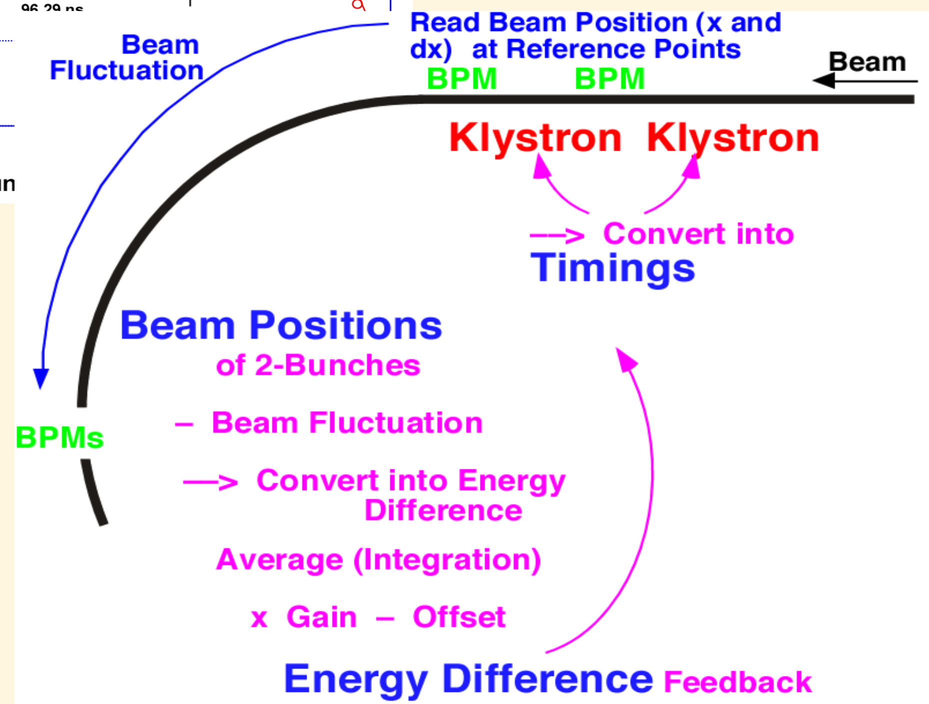
◆Energy equalization is important for stable operation

Measurement at Bunching section
after equalization





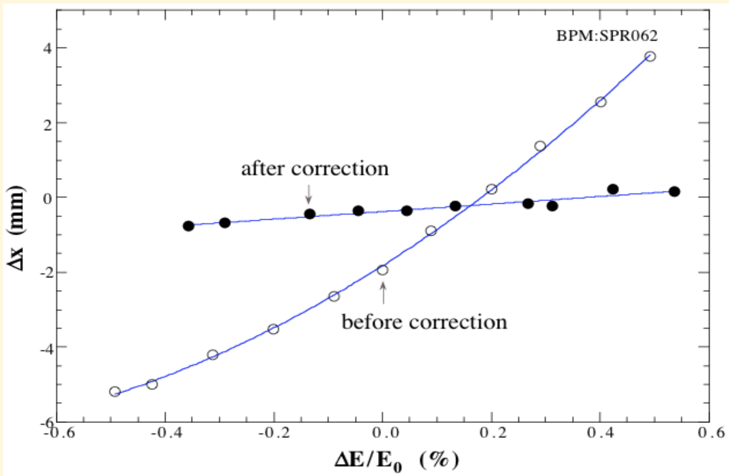
Stabilization at R0 Arc



Achromatic and Isochronous Arc

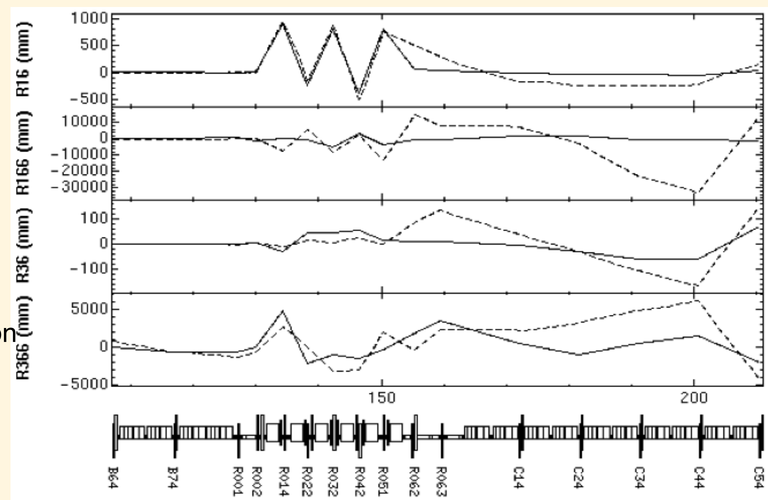
◆**Optics correction by quadrupoles and sextupoles using BPM and streak camera**

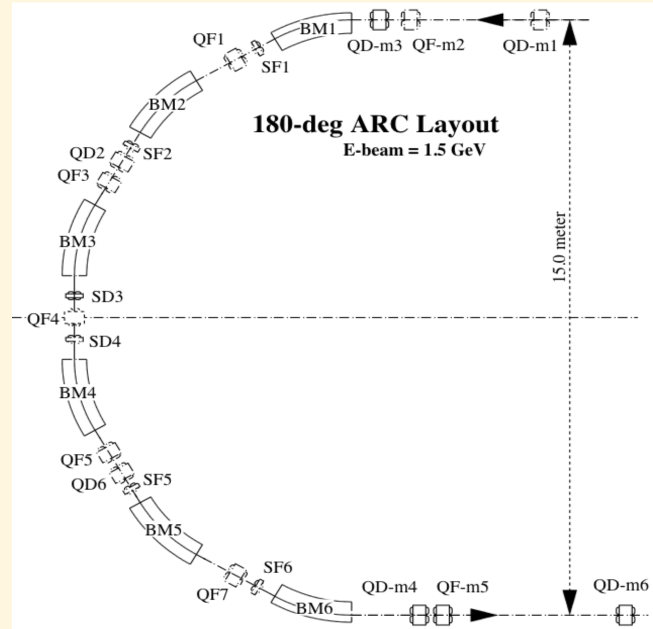
R16



First & Second Orders

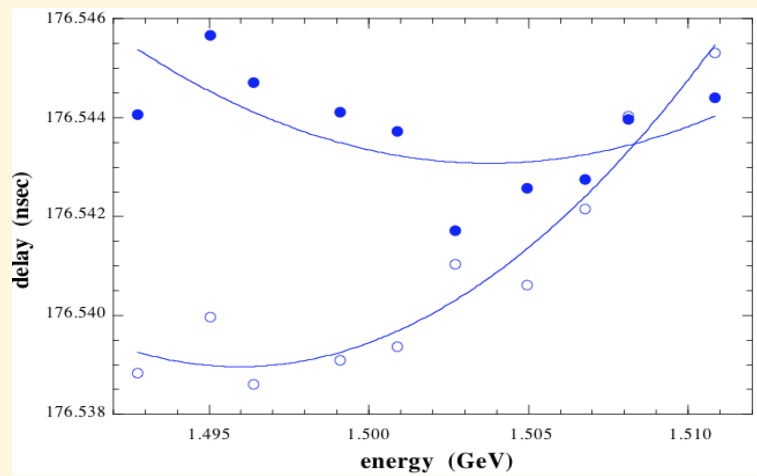
Solid lines: after correction





R56

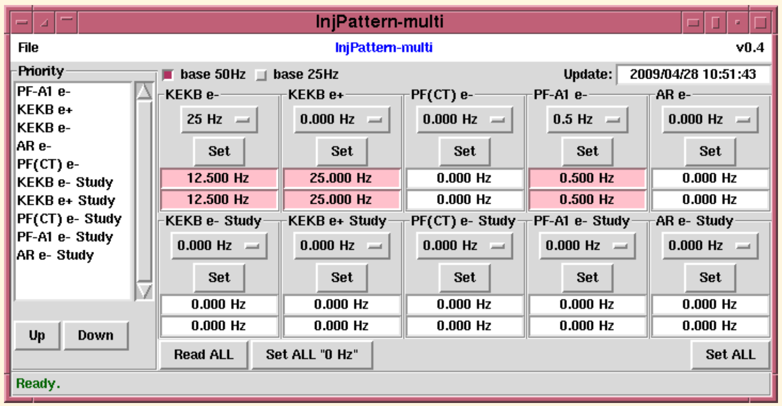
blue: after correction



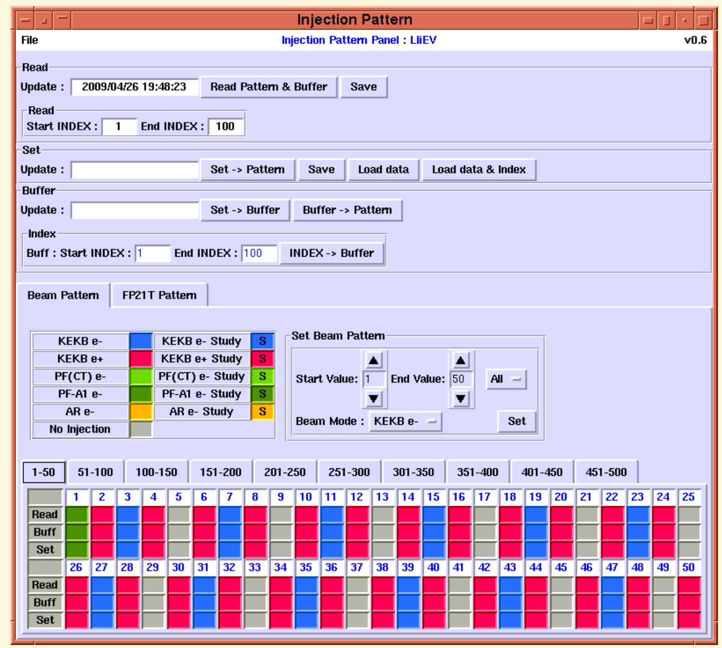
Beam Mode Pattern Generators

- **There are several versions**
  - **Because we were commissioning new pulsed hardware equipment, the beam optics schemes, event system itself, etc, since autumn 2008**
  - **One of them is mostly used, remote or human controllable, automatic- prioritized arbitrated, etc**

Remote controlled automatic pattern arbitrator



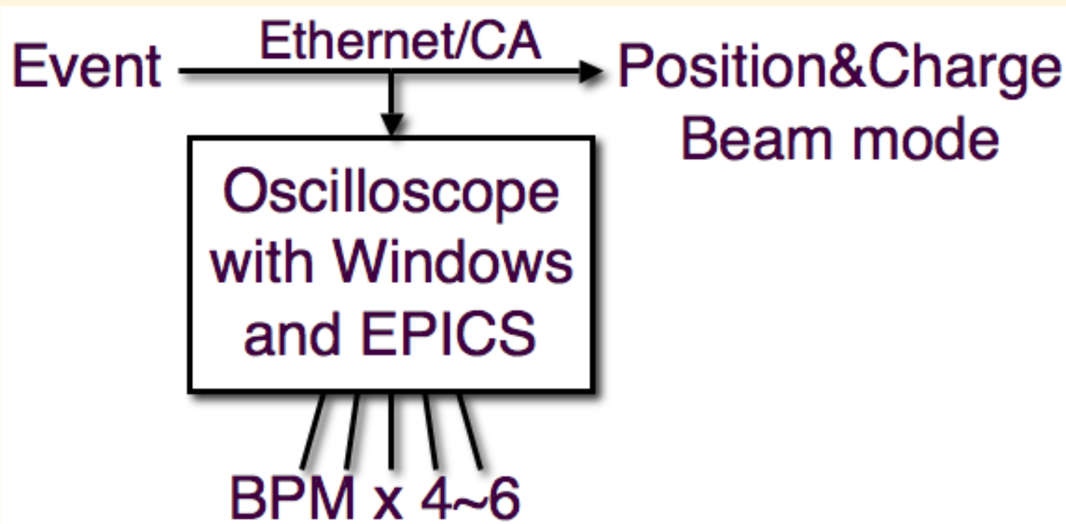
Manual pattern generator

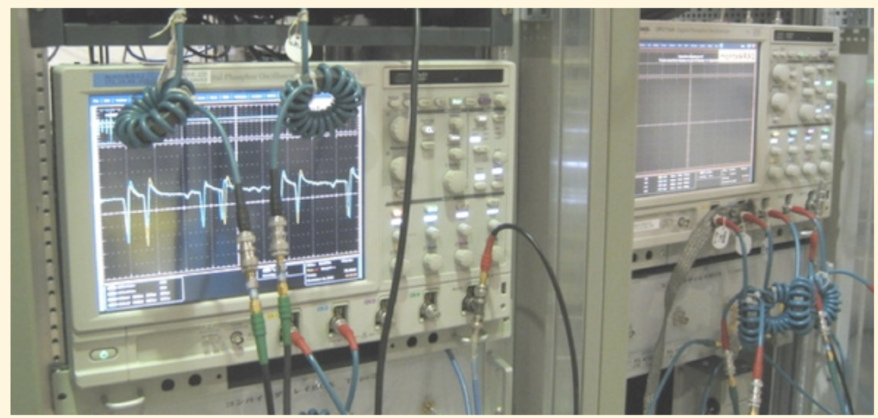


- **Typical operation in Apr.2009.**
  - **~25Hz for KEKB LER**
  - **~12.5Hz for KEKB HER**
  - **~0.5Hz for PF**

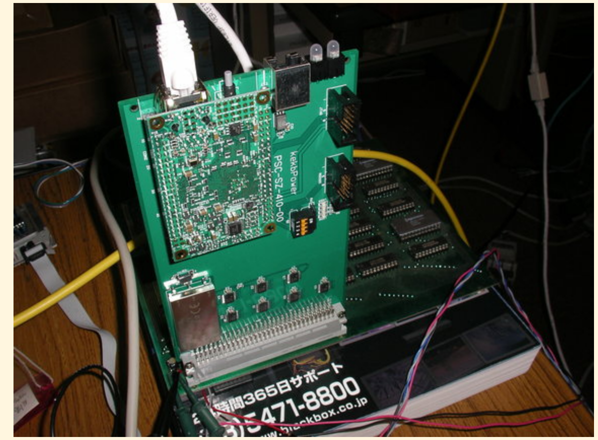
BPM DAQ

- Tektronix DPO7104 can acquire data at >50Hz.
  - With embedded EPICS
- Beam modes are recognized by events through CA network.
- Clients can monitor data of an interested beam mode.
- 26 oscilloscopes are installed.
- 100 BPMs are synchronized. (100 BPMs at BT as well soon)

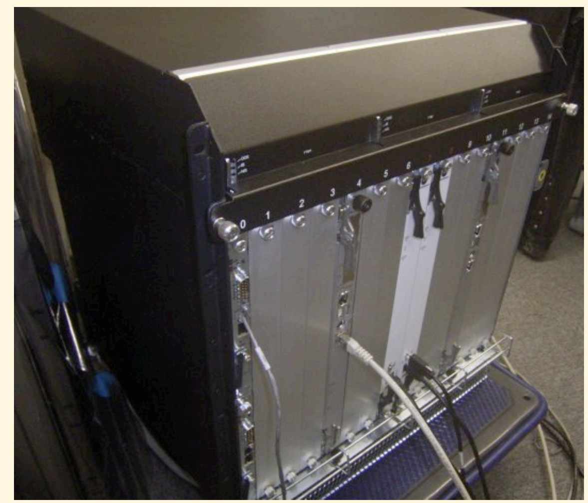




Other EPICS Development Activities at KEK



- **By A. Akiyama, et al**
  - **Embedded IOC on FPGA-based controller**
- **By M. Satoh, et al**
  - **Embedded IOC on oscilloscopes**
- **By A. Kazakov, et al**
  - **Redundant IOC (RIOC with OSI supports)**
  - **Redundant caGateway**
  - **ATCA IOC with HPI/SAF support for RIOC**
    - **ATCA for STF/ILC-LLRF and μTCA for cERL-LLRF**
  - **Automatic test system environment**
- **By K. Zagar, et al**
  - **Wireshark protocol analyzer for CA**
- **By K. Furukawa, et al**
  - **Event-based fast control system**



Summary

- **DPO7104 (firmware v1.03 2years ago) can acquire enough data at ~200Hz**
- **All of the BPM requirements (for now) are satisfied, with high availability (because of less active components)**
  - **Waveform data acquisition has much more possibility in particle accelerator applications**
- **For the future, faster and more precise processing is necessary**
  - **ERL at 1.3GHz-continuous and ILC at 10MHz-10Hz, with precision of <1micro-m**

Summary 2

Oscilloscope

- Not a simple measurement instrument
- But a data acquisition station
  - With embedded application software
    - EPICS framework in our case
- And a data processing system
  - With direct networking capability
    - Preferable with Linux, but acceptable with Windows

Thank you