Recent developments towards SuperKEKB controls

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for Control Group of SuperKEKB

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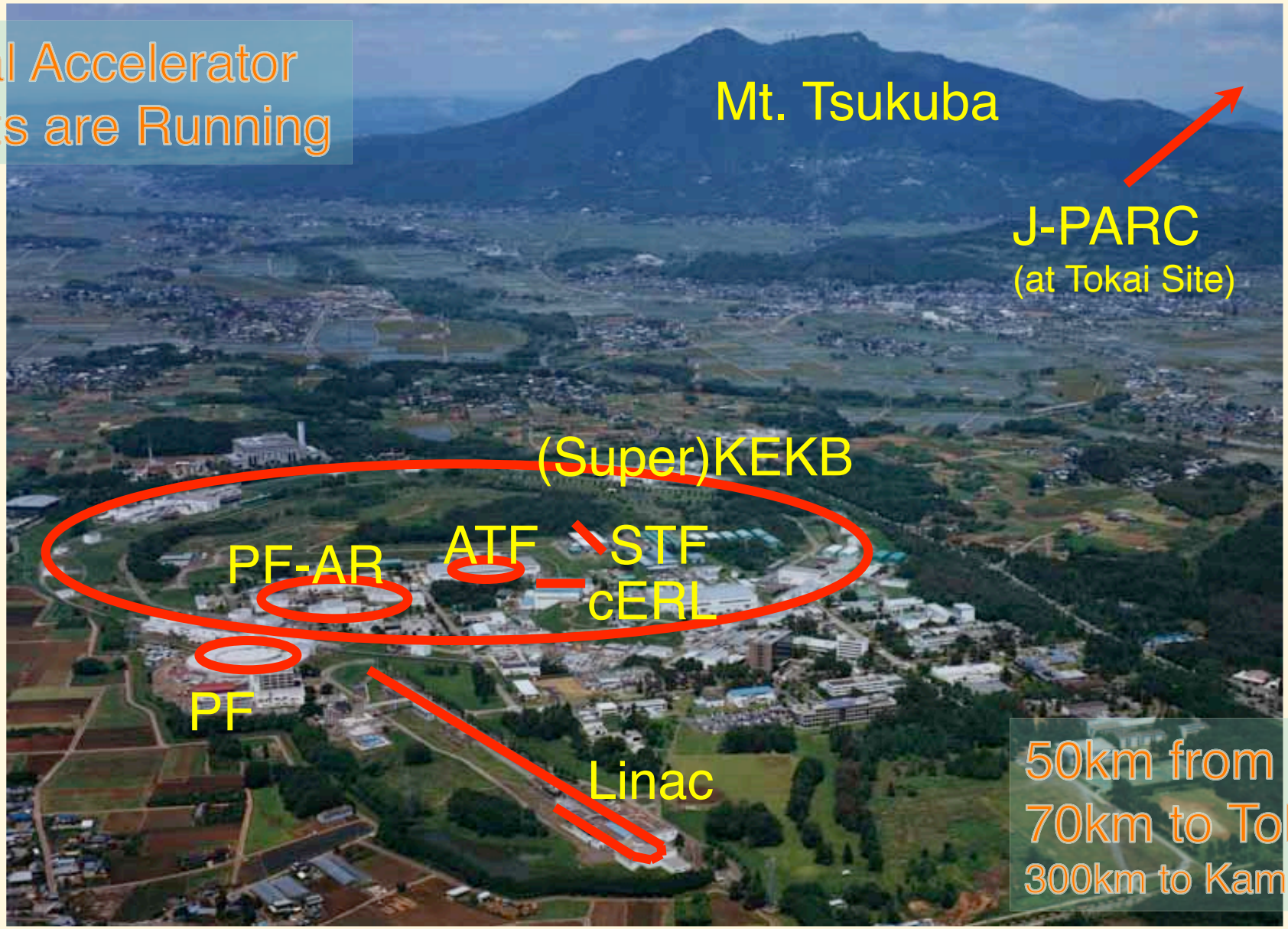
June 2011.

Accelerators at KEK

Several Accelerator Projects are Running



In this meeting

- J-PARC
  - Norihiko Kamikubota (上窪田)
  - Shuei Yamada (山田)
- PF, PF-AR, cERL
  - Takashi Obina (帯名)
- SuperKEKB, Linac
  - Masanori Satoh (佐藤)
  - Kazuro Furukawa (古川)

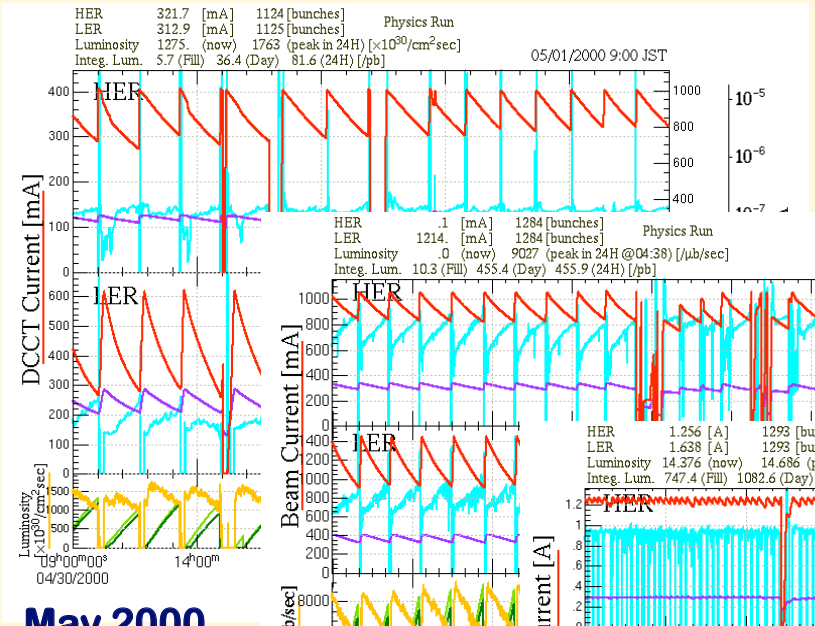
Control Systems at KEK/Tsukuba (1)

- **SuperKEKB**
  - Will inherit resources from KEKB (and TRISTAN)
    - Upgrade 2011-2014 was approved
- **Linac (electron/positron)**
  - Inject beam to (Super)KEKB, PF, PF-AR
    - Pulse-to-pulse beam modulation
- **PF (Photon Factory)**
  - Moved to EPICS environment
    - Mainly with Linux-VME
- **PF-AR (Photon Factory Advanced Ring)**
  - Mostly the same environment as KEKB
    - Many CAMAC installations

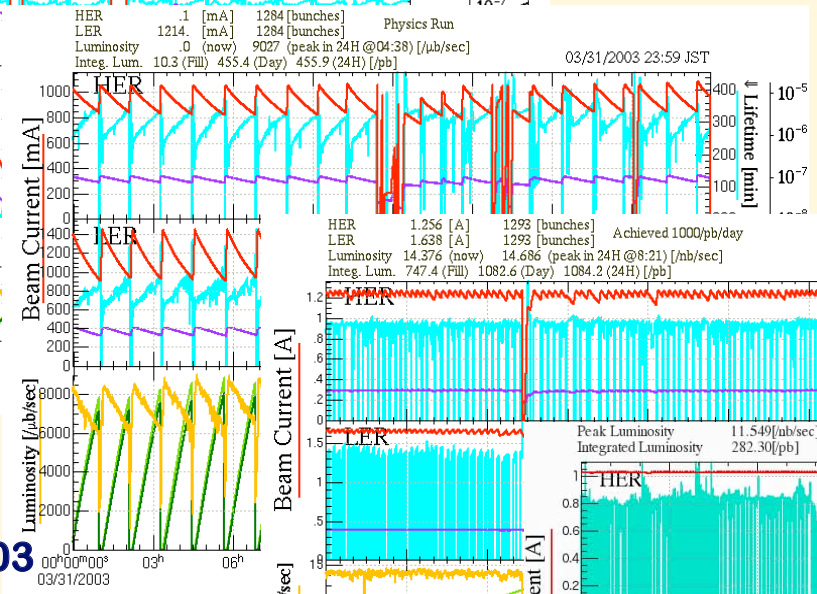
Control Systems at KEK/Tsukuba (2)

- ATF (Accelerator Test Facility)
  - Vista Controls environment with CAMAC
    - Linux and socket environment with some EPICS devices
- STF (Superconducting RF Test Facility)
  - Test facility for ILC
    - EPICS with Linux, ATCA test, PLC, …
- cERL (Compact ERL)
  - Being built for ERL development
    - May share the resources with other accelerators
- Sharing resources as much as possible

KEKB Operation Improvement (base of SuperKEKB)

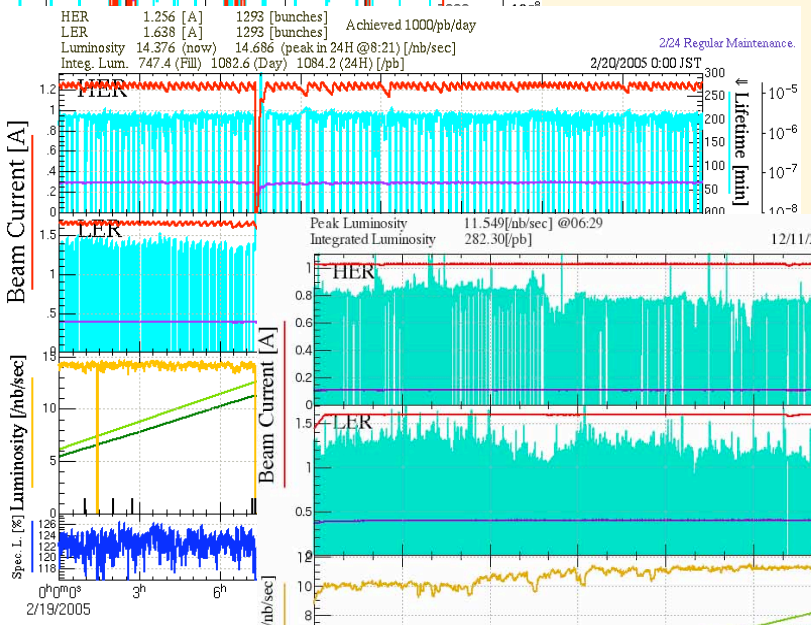


May.2000



Apr.2003

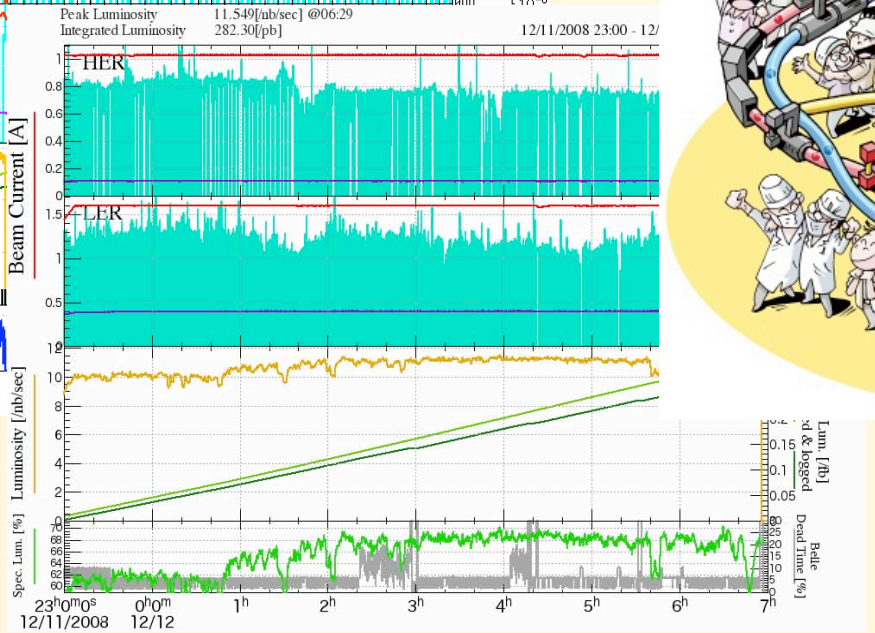
Dual Bunch e+



Feb.2005

Continuous

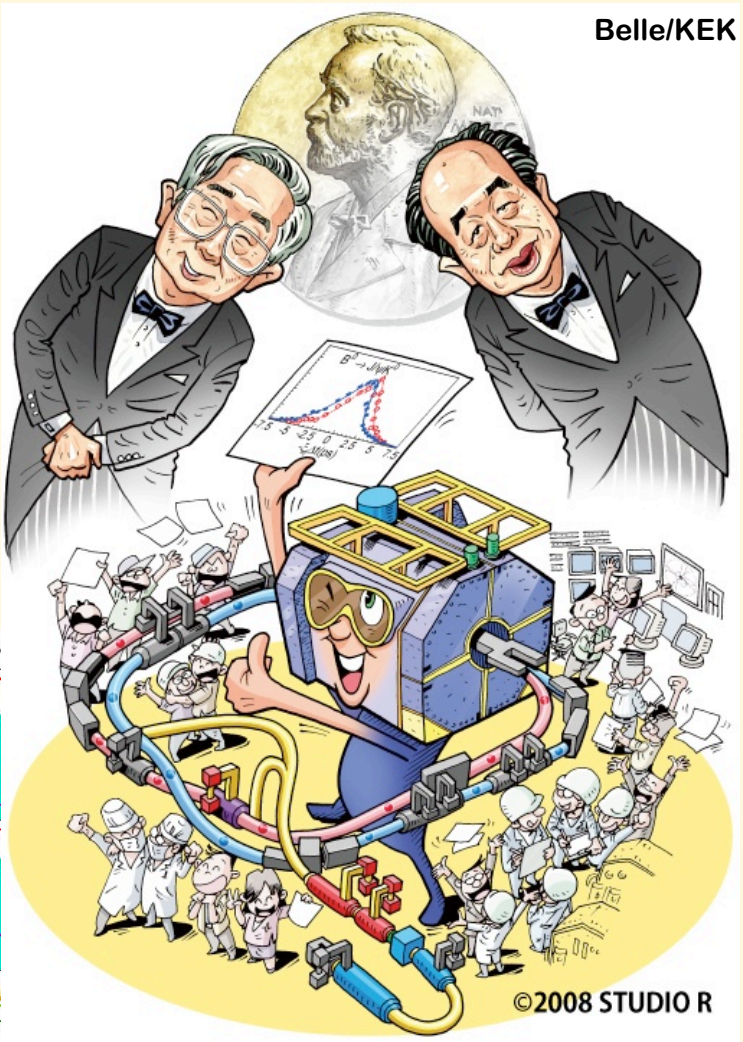
Injections



Dec.2008

Crab Cavities and

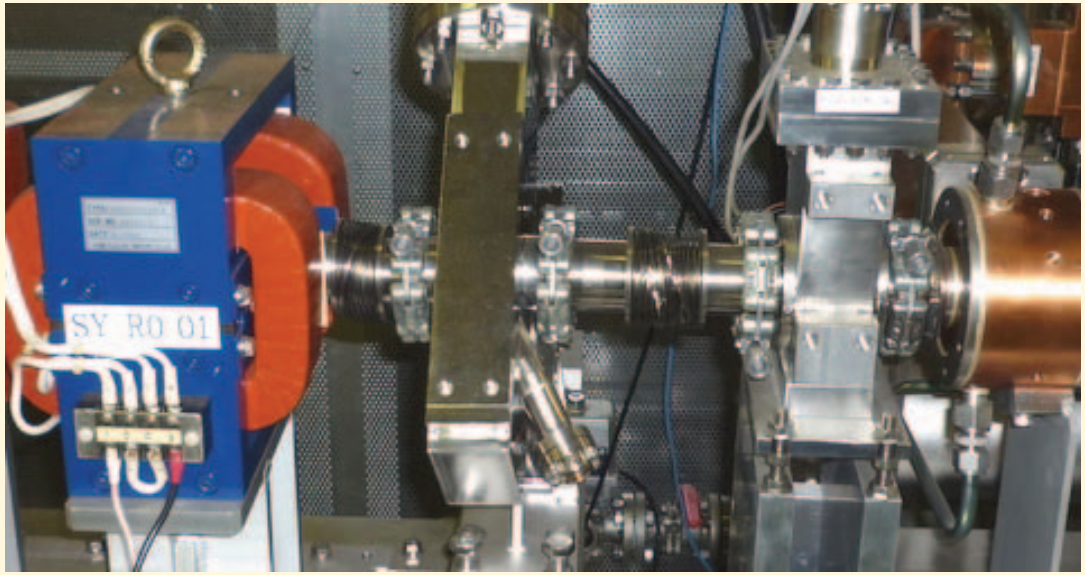
Simultaneous Injection

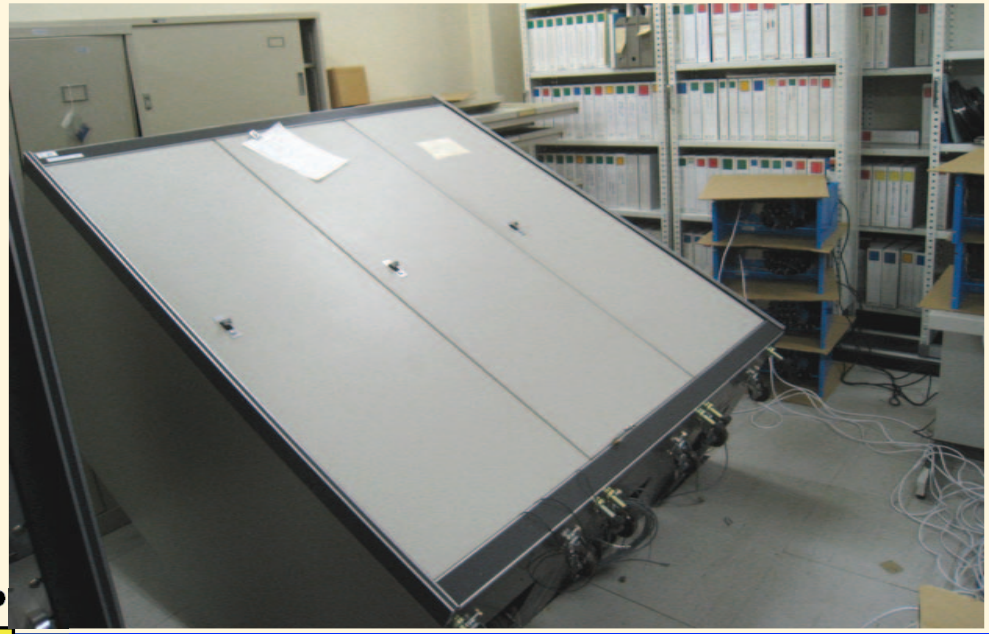


SuperKEKB

- Electron-positron asymmetric collider
  - Based on a decade of successful operation at KEKB
- (Most part of) the budget was approved
  - Have to start the operation in 2014
  - Have to recover the damages by earthquake
- Aims at 40-times higher luminosity
  - $8 \times 10^{35} cm^{-2} s^{-1}$ for further flavor physics studies
  - 7GeV / 2.6A electron, 4GeV / 3.6A positron
  - $\beta_y^* \sim 0.3mm$, $\varepsilon_x / \varepsilon_y \sim 4nm/9pm$, $\sigma_y \sim 50nm$, $\sigma_z \sim 6mm$
  - Ante chamber, longer bend, damping ring, rf gun,etc

Damages at electron Linac (as example)





Movie at Linac Tunnel (Soft-structure part)

Thank you

- Thanks to your concern and kind words from around the world
  - ex. on TV program
    Yesterday,
    “cheer up, Japan”
    in Chinese
    and in Japanese

KEKB Controls

- Large contribution to the success of KEKB
- EPICS as basic enviroment
  - Standard software configuration as of 1997
  - Several field networks, CAMAC, ArcNet, etc
- Scripting languages for operational tools
  - SADscript, Python/Tk, Tcl/Tk
  - Rapid modifications based on daily meetings
  - Any operators should be able to manipulate complicated feedback, and so on

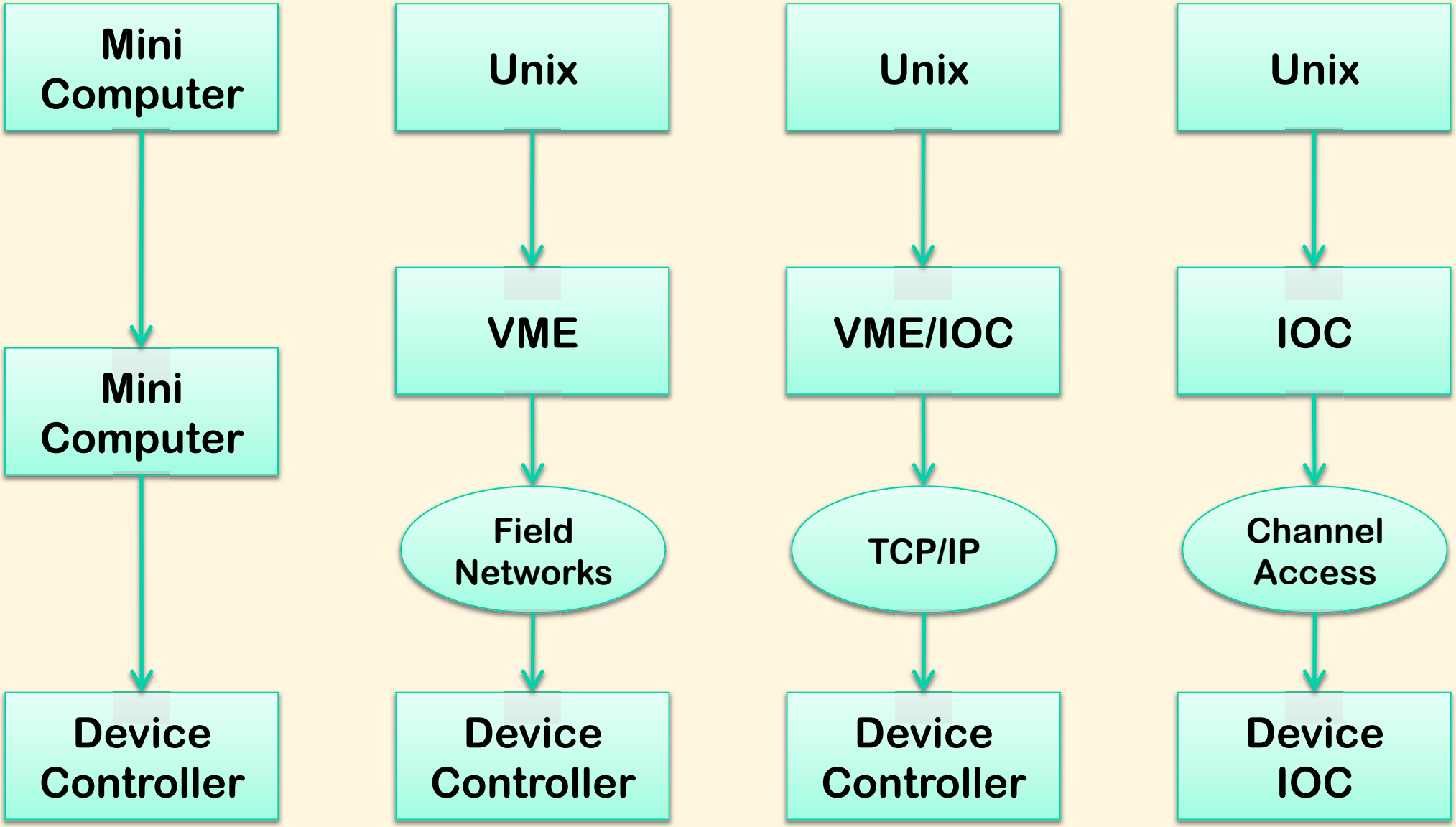
Controls at KEK

- VME + Unix (1990~)
  - Standard EPICS configuration
    - With many third layer field networks

- Every controller on network (1995~)
  - Single layer in physical, two/three layers logical

- Every controller with EPICS IOC (2005~)
  - Channel Access everywhere (CA Everywhere)
    - For longer term maintenance

Transition of Controls



IOC on MicroTCA

- Decided to put IOC on μTCA LLRF Controller
  - Natural after generations of LLRF Controllers
  - Shared among STF, cERL, and SuperKEKB
- Chose GbEthernet as a main media on the backplane interconnect
  - Somewhat unique
  - Some other institutes chose PCIe as the media
- Chose PowerPC core on Virtex5
  - ML507 of Xilinx as a good reference
- Linux on PowerPC (Windriver Linux)
  - No realtime processing is necessary for now
  - Later, we may use realtime PREEMPT_RT (<100μs) of Linux

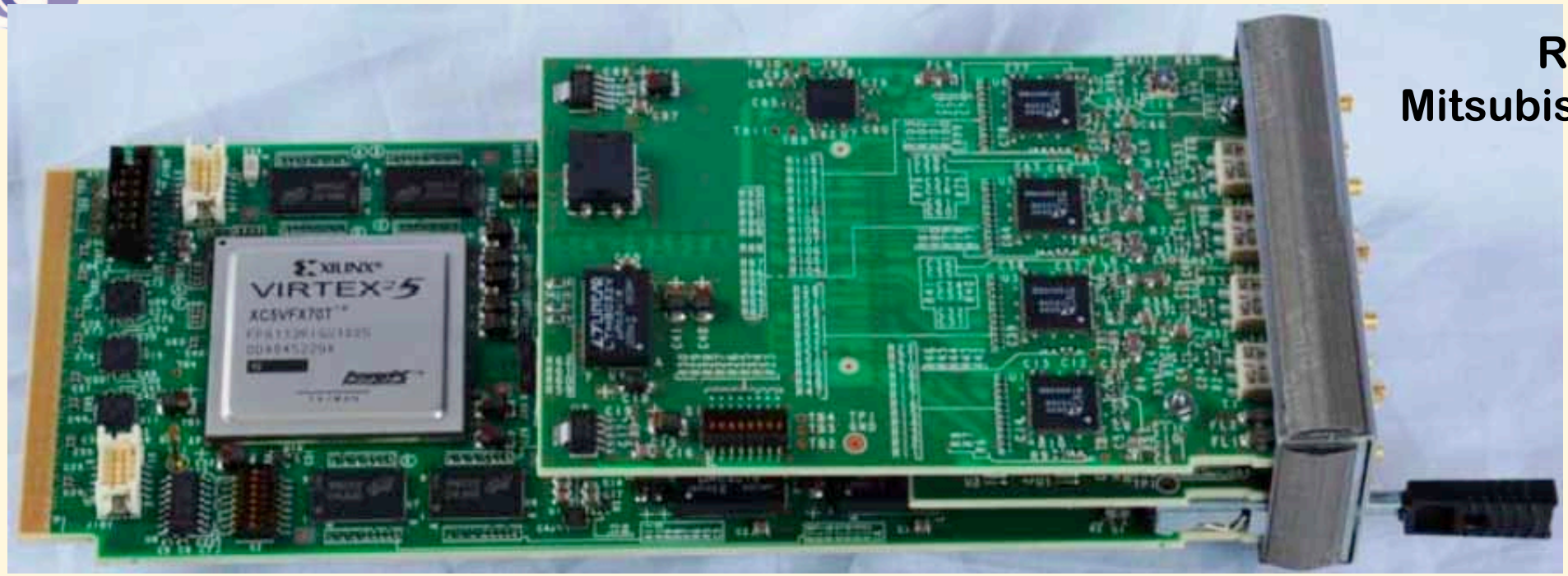
RF Group

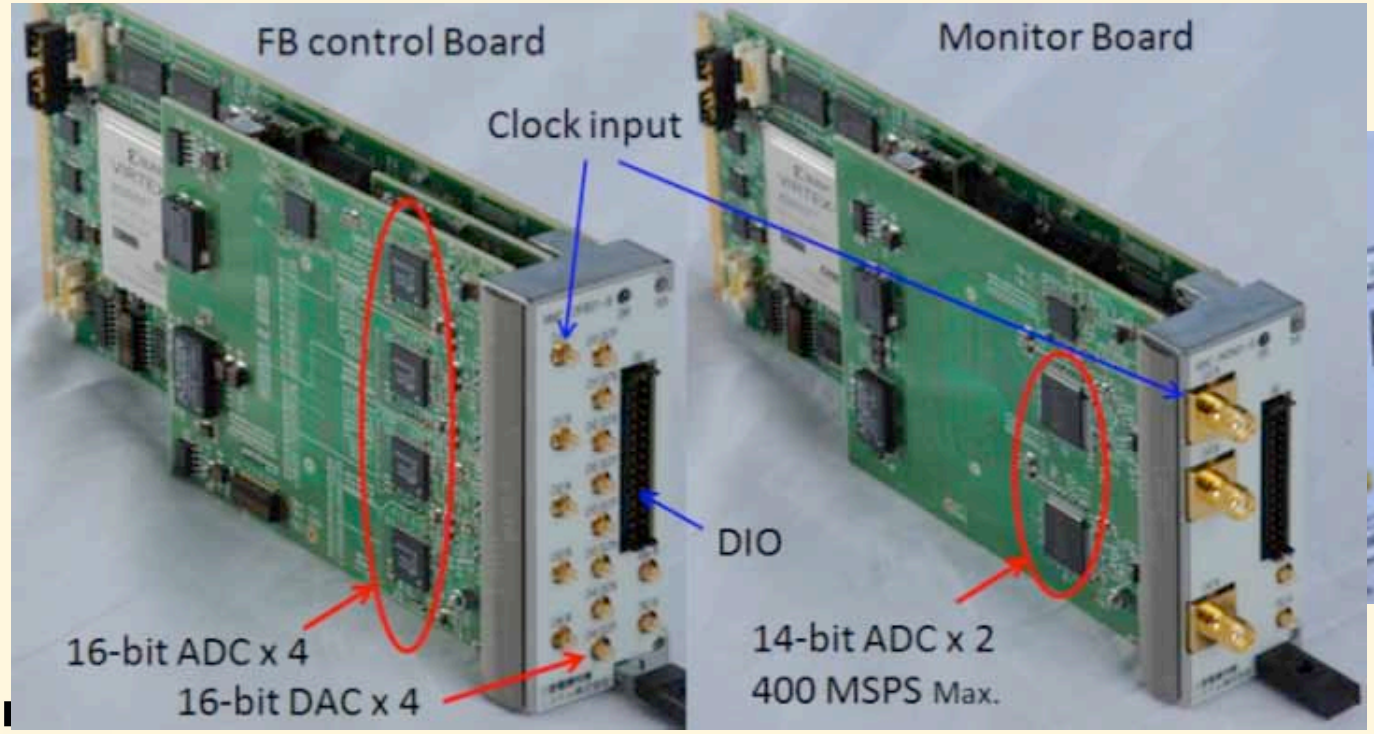
MicroTCA based LLRF Controller

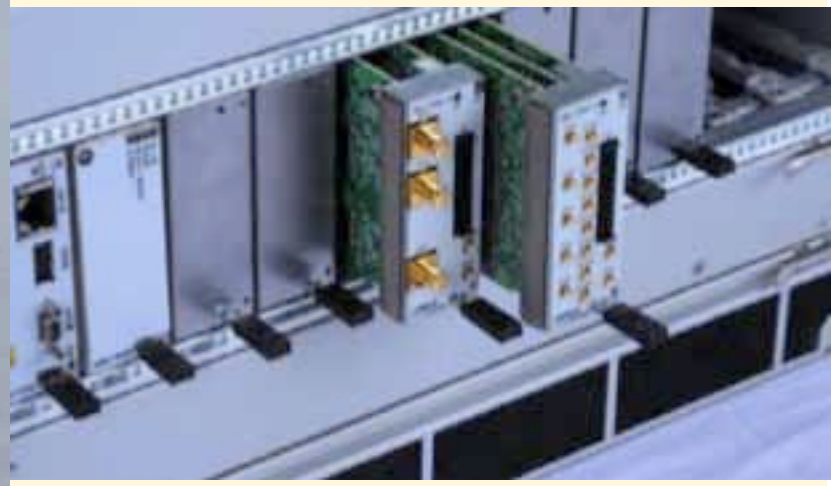
- Single-width full-height module
- Without physics experiment extension (we started earlier)
  - Front-panel connectors (rather busy)
- Digital part and Analog part are separate
  - ADC 16bit, 130Msps, x4
  - DAC 16bit, 500Msps, x4
  - Virtex5 with PPC440
  - RAM 640MB, Flash 64MB
  - Also monitor card with the same digital part
    - ADC 14bit, 400Msps, 1.4GHz, x2
- Fabrication subcontracted
  - Mitsubishi Electric Tokki System

<http://www-linac.kek.jp/cont/epics/mtca/>

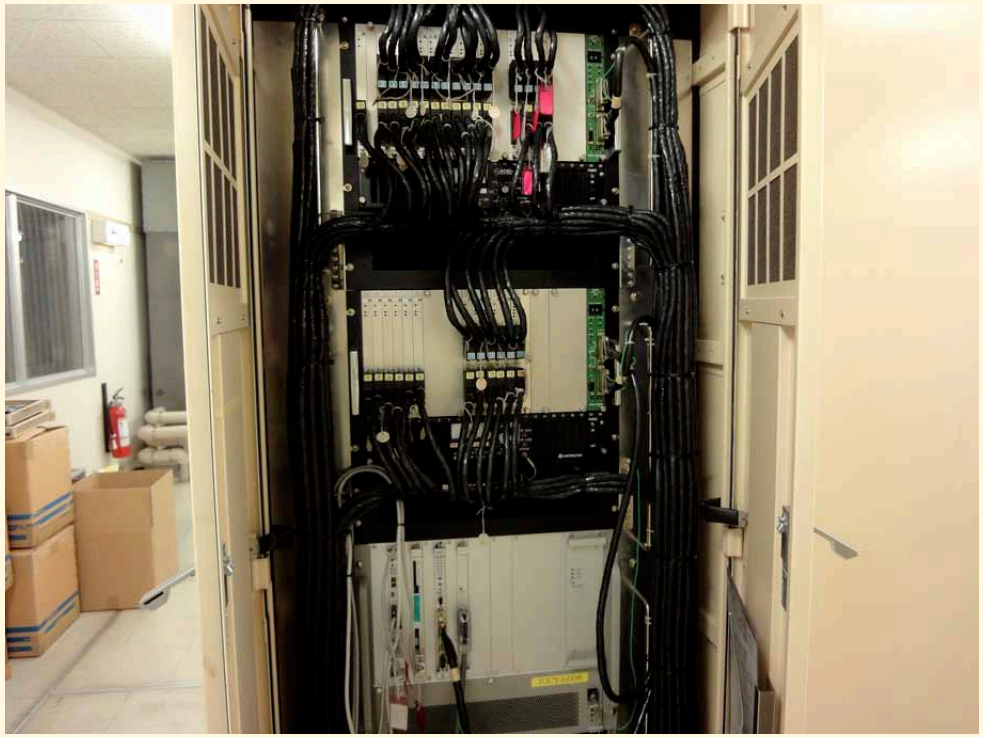
RF Group
Mitsubishi Tokki

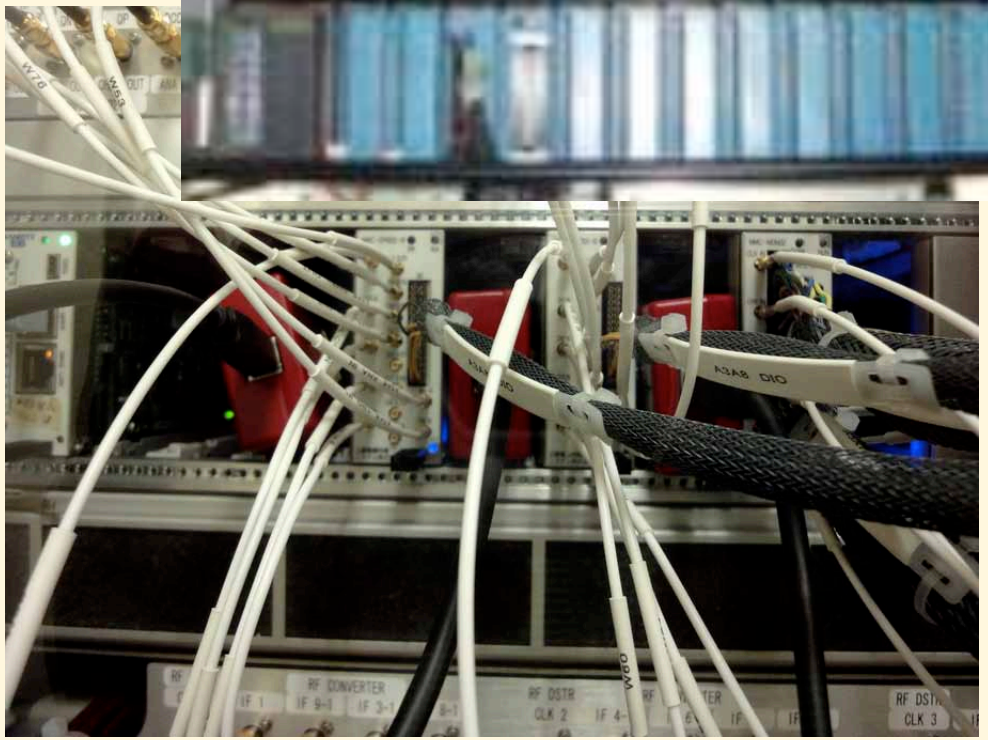






RF Controls





CAMAC and NIM modules

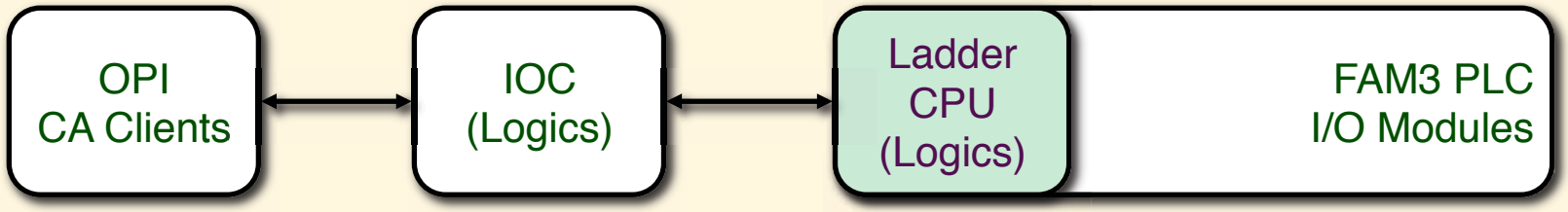
MicroTCA and PLC

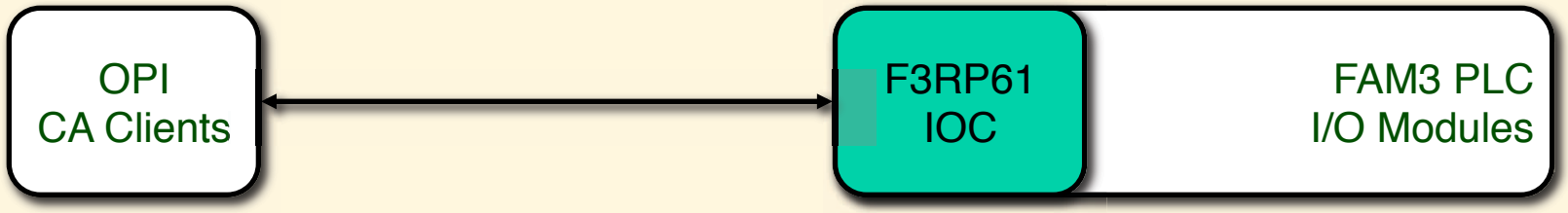
Embedded IOC in Yokogawa's PLC

- More than 150 PLCs were employed at Linac
  - All through TCP/IP network since 1993
    - Successful to reduce resource consumption
- Now Linux CPU is available (2008~)
  - 533MHz PPC, 128MB RAM, 2xEthernet, USB
  - Utilize realtime feature of Kernel 2.6 (J. Odagiri et al)
    - EPICS PV response time <150μsec (incl. module delay)
- Ladder sequence CPU can coexist
  - Register variables can be shared

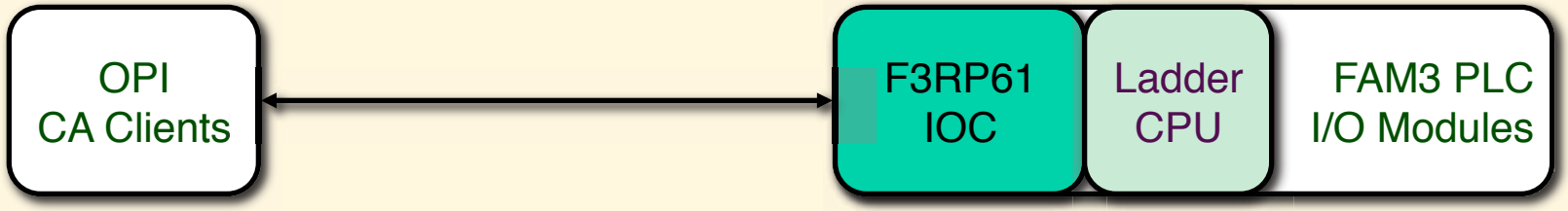
Simpler PLC Usage under EPICS

Conventional PLC usage with asynchronous access



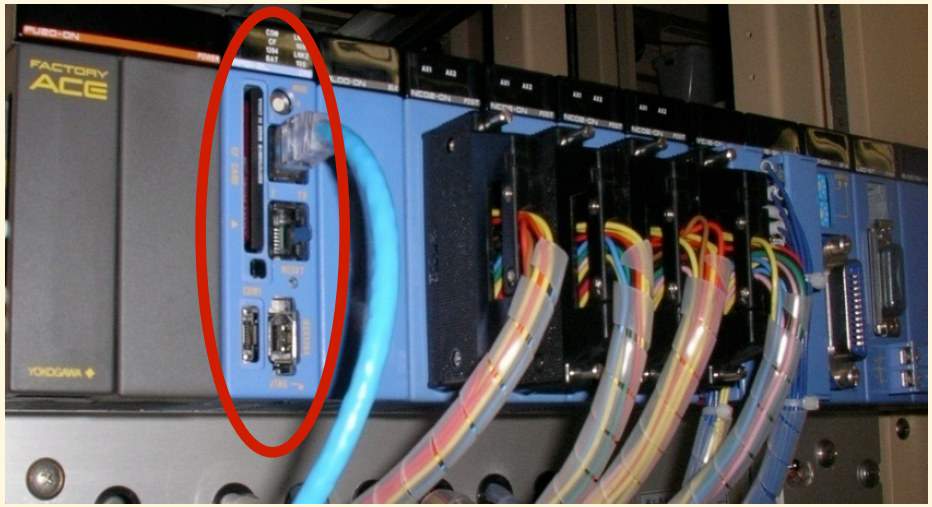


If necessary, we can combine



Logics are confined in PLC, and management is easier

- Many medium-speed controllers implemented
  - KEKB, Linac, J-PARC, PF, cERL, RIKEN, NSRRC, (Korea/PAL, Beijing/IHEP)

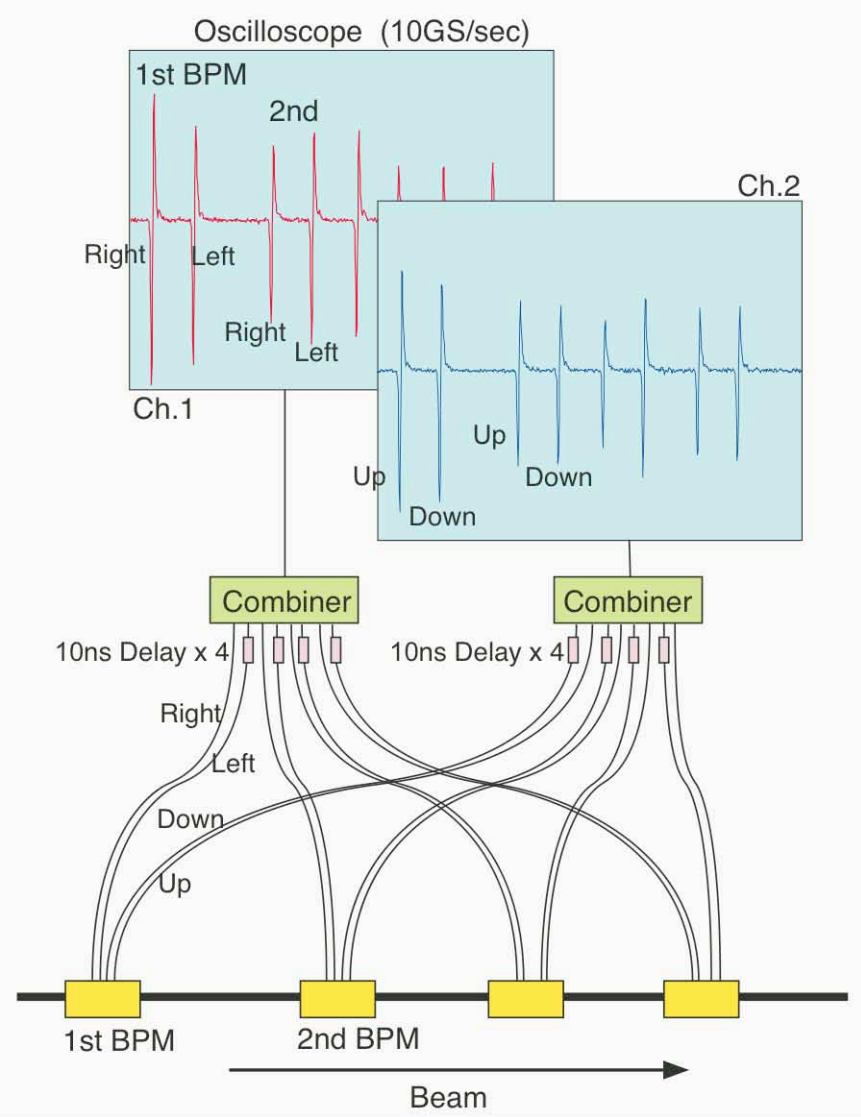


- Image processing module available
- Discussing on EVR module production with SINAP/Shanghai

<http://www-linac.kek.jp/cont/epics/f3rp61/>

BPM at Linac and BT

- BPM need only 0.1mm resolution
  - Using ~30 coefficients per BPM
- Many signals are combined into one waveform digitizer
- Again reduction of resources
- Recent Embedded IOC Solution
  - Much helped by Dr. Yong Hu



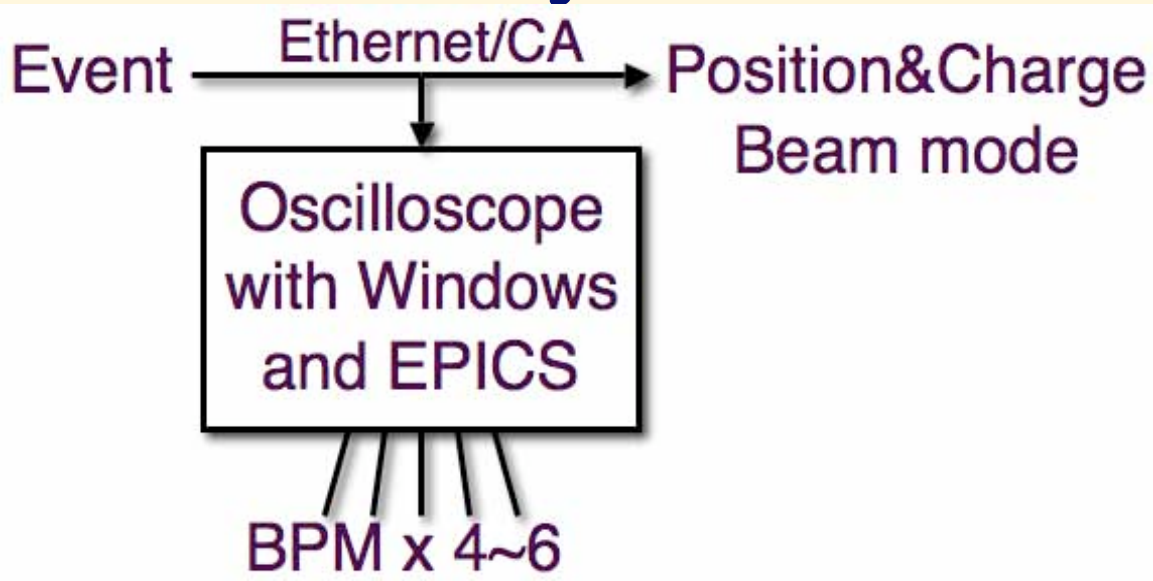
100 BPMs — 24 x DPO7104 — Clients

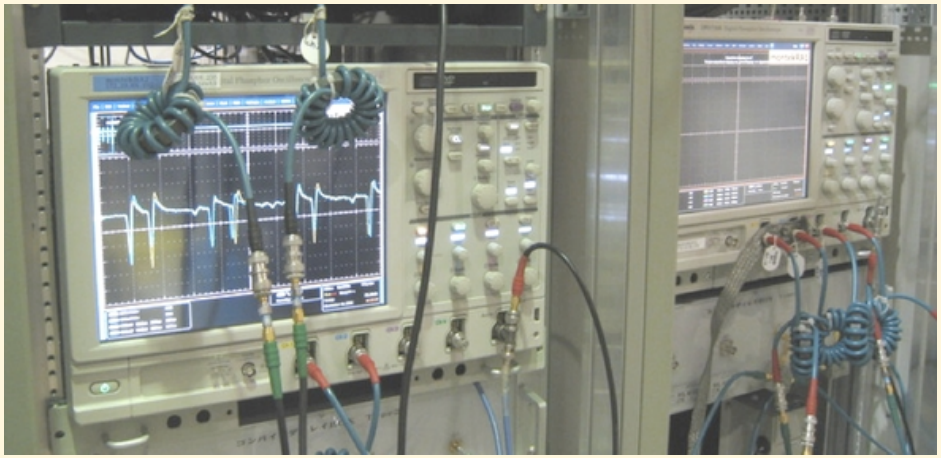
- Old configuration

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

BPM DAQ

- Tektronix DPO7104 can acquire data at >50Hz.
  - With embedded EPICS, under pulse-to-pulse beam modulation
- Beam modes are recognized by events through CA network.
  - Missed less than once in million times
- Clients can monitor data of an interested beam mode.
- 24 oscilloscopes are installed for Linac, and 4 for BT.
- 200 BPMs are synchronized for Linac and BT.





Many other Embedded IOC

- Other oscilloscope-based IOCs
  - For pulsed device monitors (M. Satoh et al)
- TDC/Linac with Linux/ARM (Armadillo)
  - Timing consistency surveillance (S. Kusano et al)
- MPS manager with Linux/FPGA (Suzaku)
  - For J-PARC and cERL, etc (A. Akiyama et al)
- Magnet PS with Linux/ARM(or FPGA)
  - One of Two prototypes for SuperKEKB (T. Nakamura et al)
- Possible Libera BPM readout (?)
  - with modifications for simultaneous injections
- Vacuum measurement with cRIO (?)
  - with Channel Access enabled

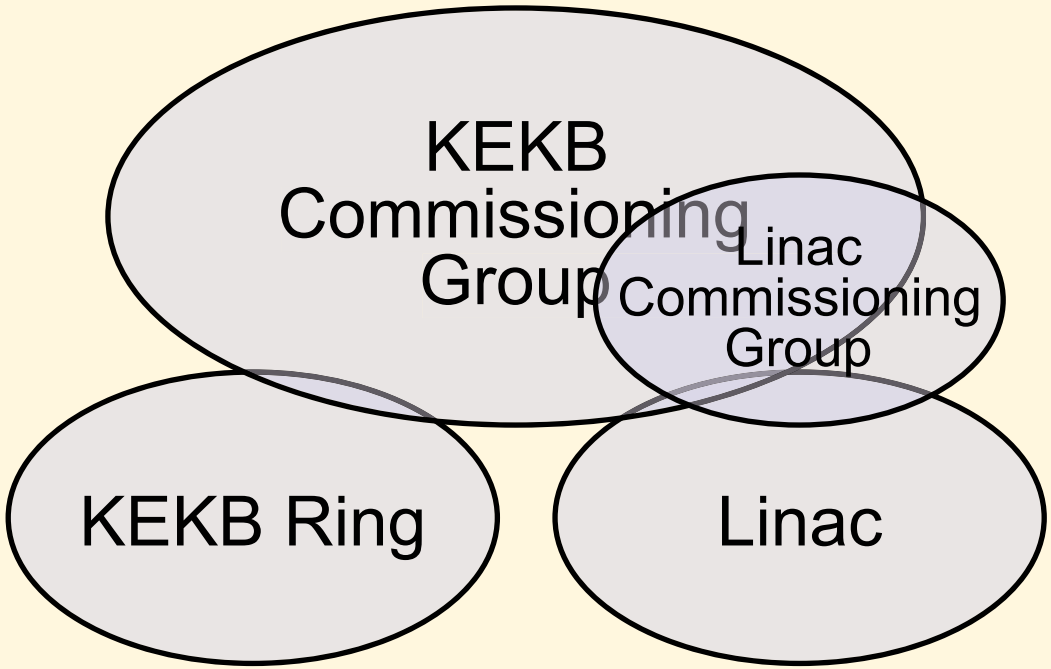
KEKB Commissioning Groups

Formation of Commissioning Group (KCG)

- Linac Commissioning (LCG)
  - 7 from Linac
  - ~10 from Ring
- KEKB Ring Commissioning Group (KCG)
  - All LCG
  - ~20 from Ring
  - Several from Detector (BCG)
- Commissioning software

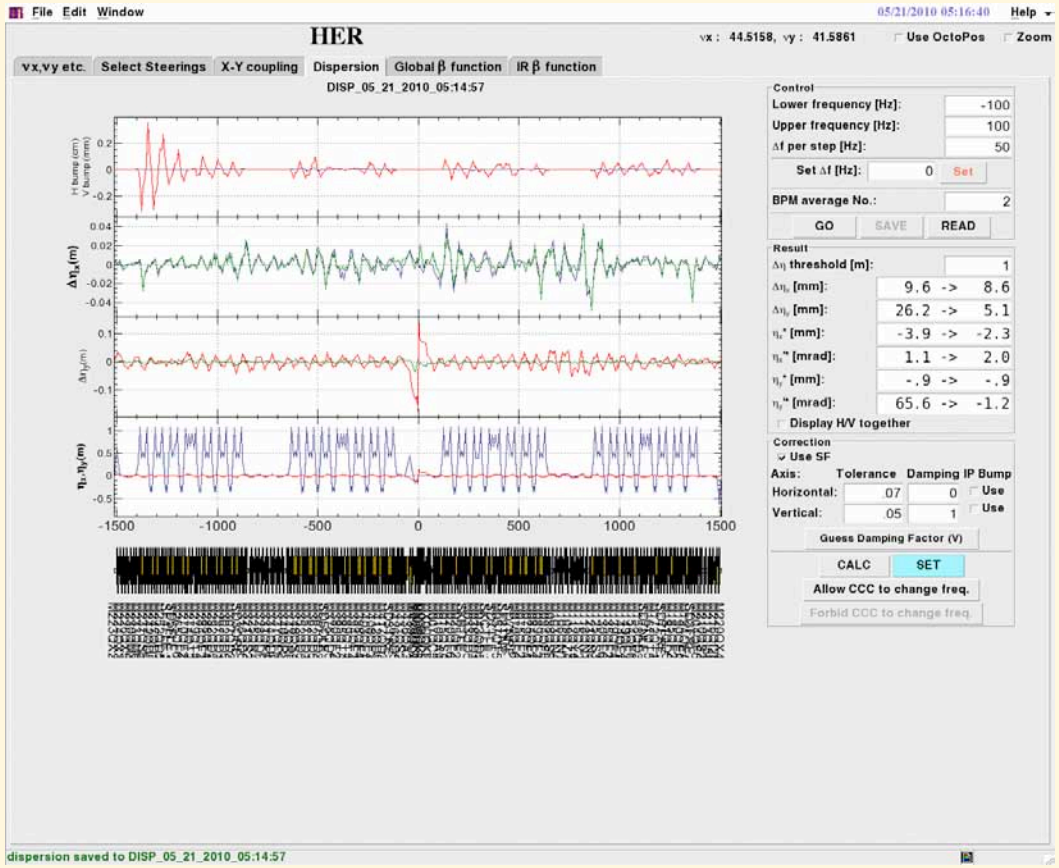
base was formed during
Linac Commissioning
(1997~)

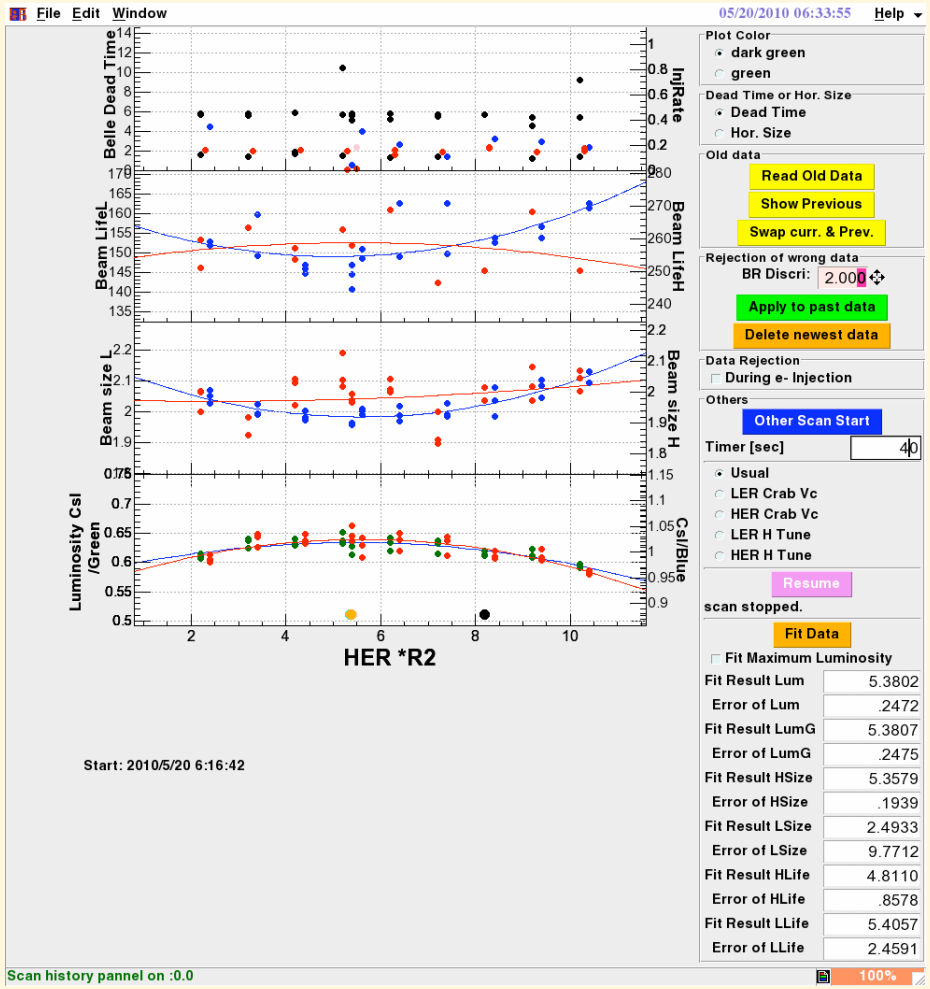
SADscript/Tk , Python/Tk



SADscripts/Tk

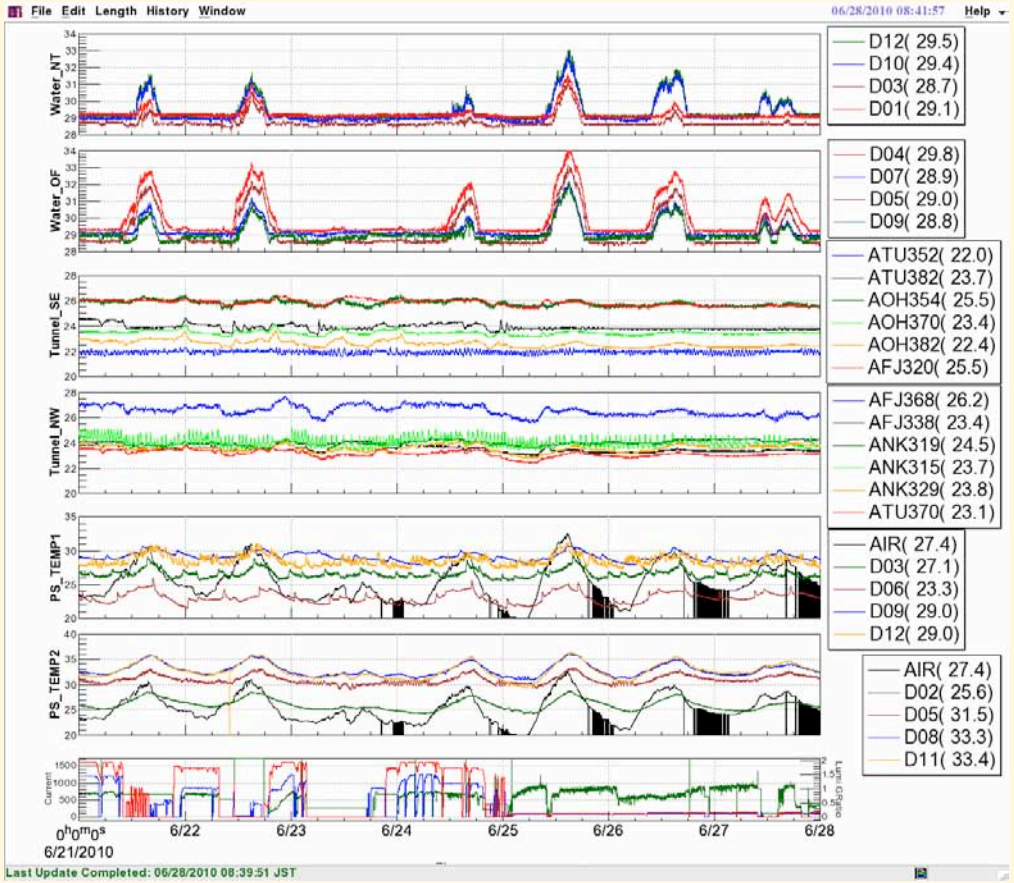
- **Many machine diagnostic and correction/ feedback tools**

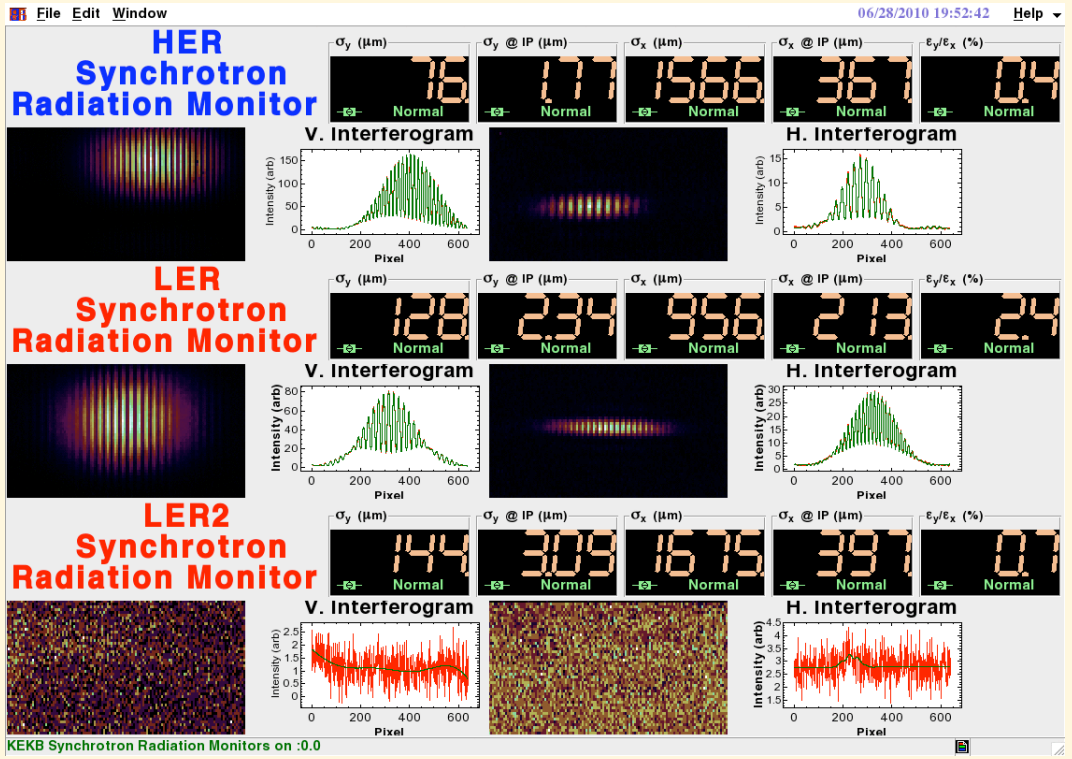




Archive viewers and Strip charts

- **Visualization is important**





SuperKEKB Plan (1)

- For nano-beam scheme with 40-times higher luminosity
  - Many new facilities should be required
- Will start based on the existent environment
  - With additional concept of CA everywhere
- Help device groups to have better global controls
  - Replacement of old installations such as CAMAC
  - Solutions not only VME but also other types of controllers, embedded EPICS if possible
- Faster networks for the groups who can build controllers by themselves
- Better connection to operational environments
  - Keeping SAD environment, etc
  - Monitoring at offices

SuperKEKB Plan (2)

- **Archiving scheme and viewer**
  - Maybe existing KEKBlog and channel archivers
    - New viewer should be developed
- **Alarm handler**
  - CSS or Python (to simulate KEKBalarm)
    - Should evaluate soon
- **Operational Log**
  - In house, two versions with different origins
    - Postgres + (Python/Zope and Flash/Flex)
- **Scripts**
  - SADscript/Tk, Python/Tk, (decreasing Tcl/Tk)
- **Displays**
  - CSS and MEDM/EDM

SuperKEKB Plan (3)

- Interviews to each device groups
  - Planning to have monthly meeting and training
    - To collect user requirements
  - Partially successful for old hardware replacements
    - Not yet effective for new functionalities
      - Whether both sides do not have experiences
- ex. Global orbit feedback
  - We don't need to stabilize the orbit other than the collision point
  - Monitor group is basically responsible for this
    - Under development with several candidates
    - But they still need some data path

Simultaneous Injection

- SuperKEKB injector need simultaneous injections to four rings, HER, LER, PF, and PF-AR, with different beam characteristics
- Event timing controls will be described some more in Timing session

Summary

- Controls Have Interface to Every System in Accelerators
  - We can Enjoy Accelerator
- There should be Room to Establish Further Controls Utilizing Beam Monitors, RF Monitors, and More
  - With Phronesis, Ability to understand the Universal Truth

Thank You

□□您□

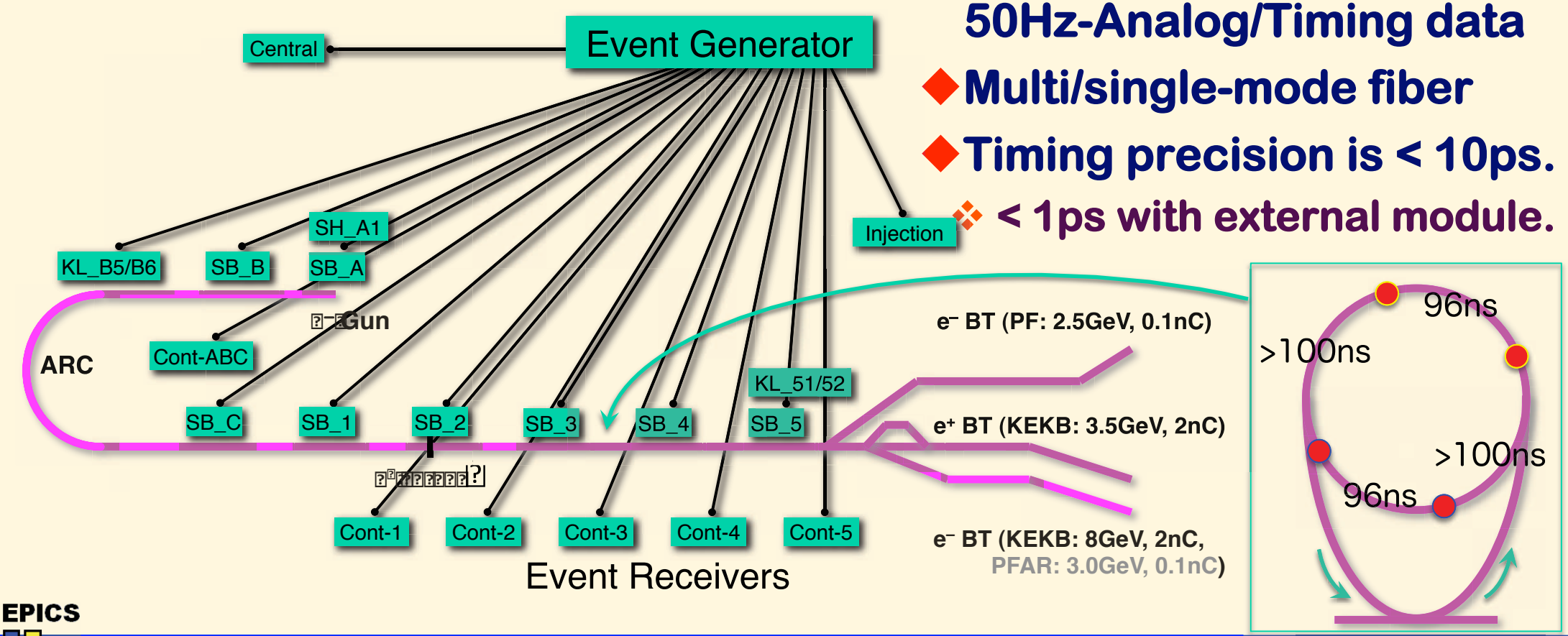
Thank you

Backup

Event System for Simultaneous Injection

- MRF's series-230 Event Generator / Receivers
- VME64x and VxWorks v5.5.1
- EPICS R3.14.9 with DevSup v2.4.1
- 17 event receivers up to now

- 114.24MHz event rate, 50Hz fiducials
- More than hundred 50Hz-Analog/Timing data
- Multi/single-mode fiber
- Timing precision is < 10ps.
  - < 1ps with external module.

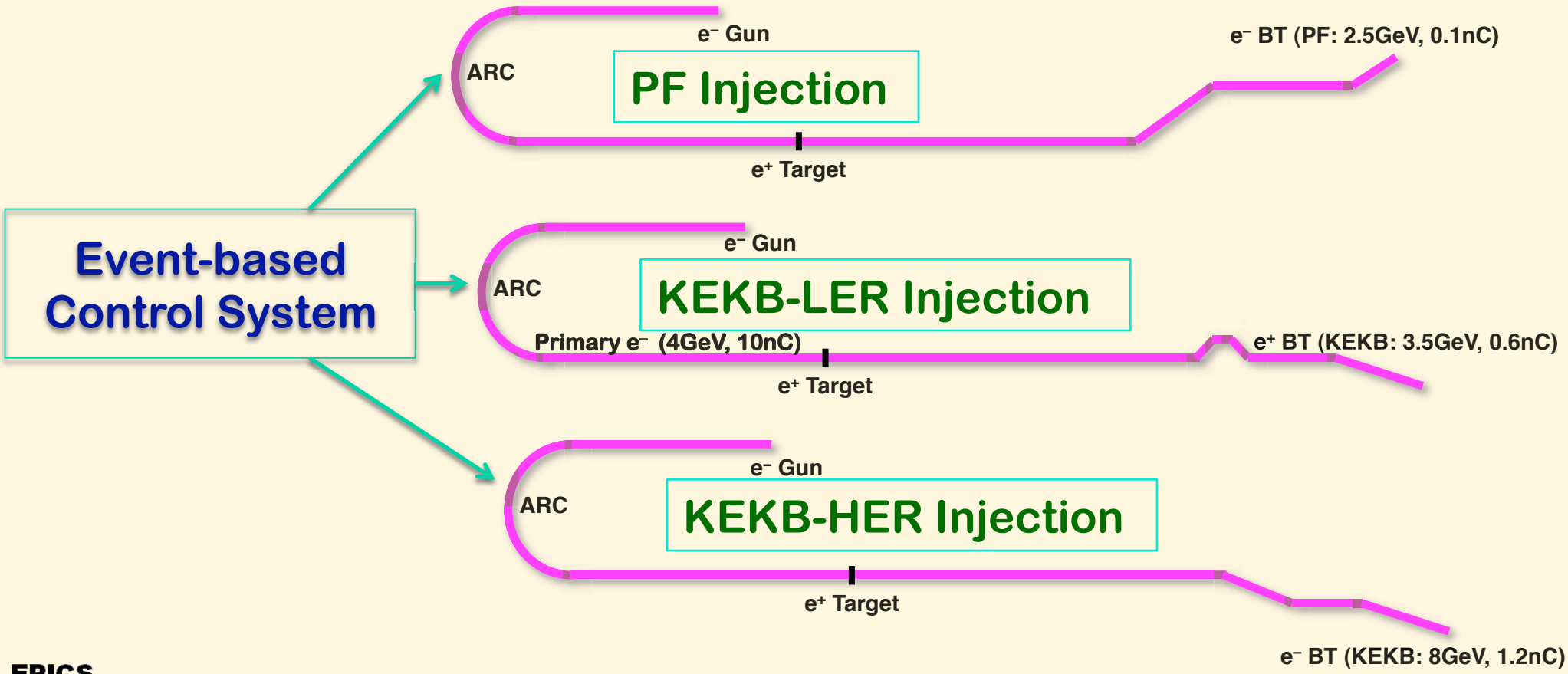


Parameters

- **Parameters switched via event system**
  - LLRF phase/timing : 14x4
    - Overall energy profile, dual-bunch energy equalization, final energy adjustment
  - HP RF timing : ~60
    - Energy profile and backup management
  - Gun voltages, picosecond delay : 4
    - Beam charge selection, dual bunch selection, bunching
  - Pulsed magnets/solenoid : 14
    - Beam transport selection, orbit controls, positron focusing
  - Injection phase interface : 2
  - Bucket selection interface : 2
  - BPM : ~100x3
- **Sufficient for fast beam mode switching**
- **Integrity monitors soon**

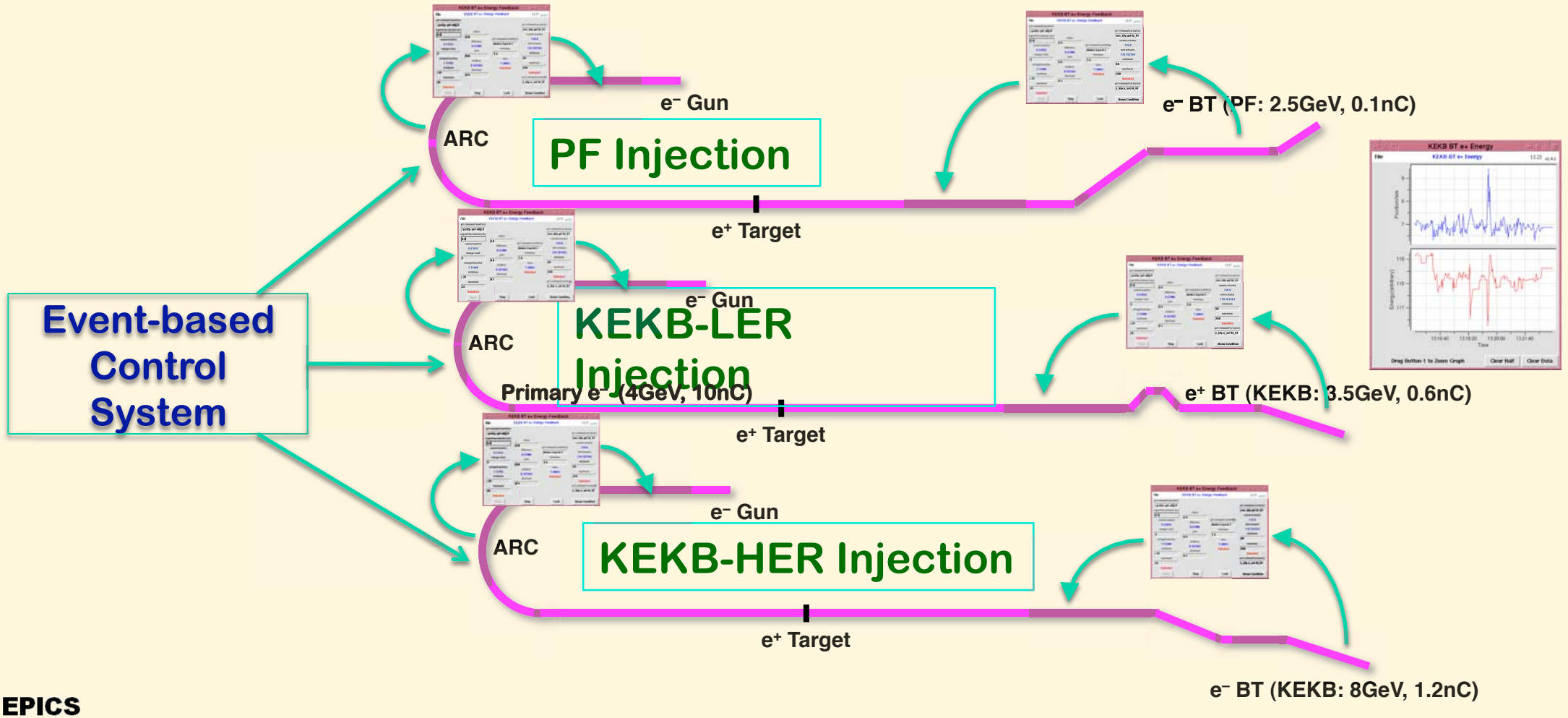
Three Virtual Accelerators

- Controls and instrumentations are essentially mode-dependent, and mutually independent
- Selecting a real machine out of three virtual machines
  - Managing three parameter sets (four under SuperKEKB environment)



Three-fold Independent Closed Loops

- **Feedback loop software act on one of three virtual machines**
  - **Managing independent parameter sets**



Event System Consideration for SuperKEKB

- Possiblly Cascaded Event Systems
  - For damping ring, main ring and other sub-systems
- New firmware with new register map
  - For newer device support software in EPICS community
    - Several local modification already, want to synchronize with other institutes
  - Several institutes in Asia may use CompactPCI as well
    - Whether PLC version can use the same envronment??
- Several fast control projects for SuperKEKB
  - Several embedded systems with PLC EVRs for RF stations
  - Bucket selection to cover both damping and main rings
    - In KEKB, separate system was used and selection signal was used as AC to EVG
  - Fast feedbacks in Linac and in main ring
- Several others