Event System and Embedded IOCs at KEK

Recent Activities at KEK
MRF Event System for 50Hz Beam Switching
F3RP61, PLC-Embedded IOCs, etc
ATCA/μTCA for LLRF

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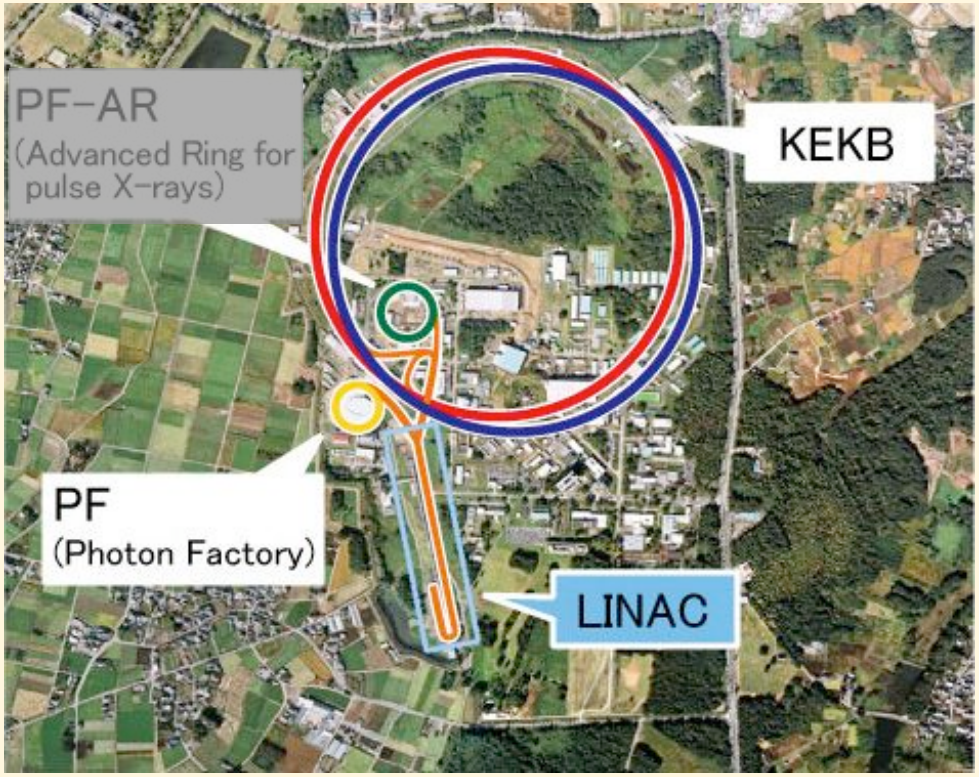
For KEKB and Linac Control Groups

May.1.2009.

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)**

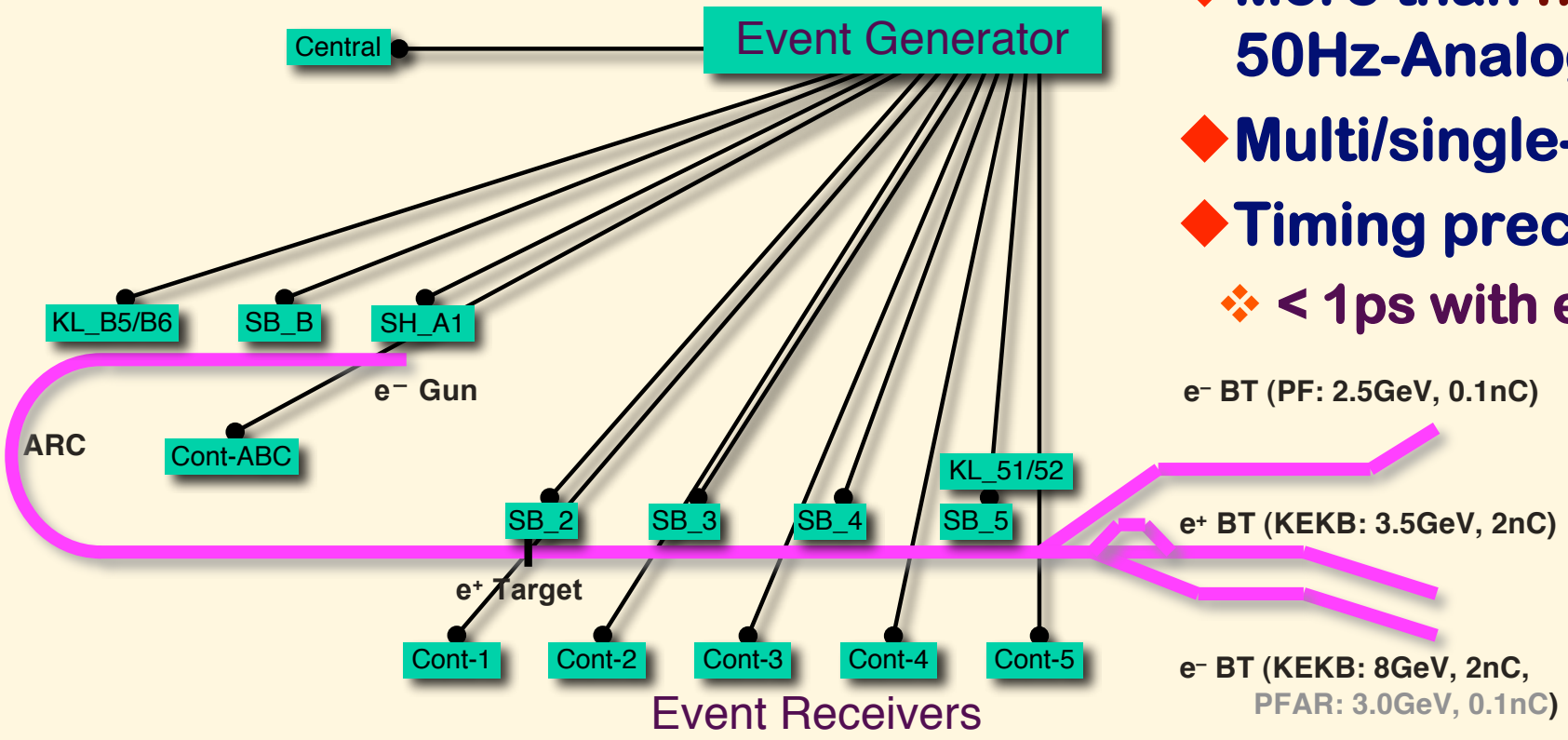


- **At first simultaneous top-up injections to three rings at KEKB and PF**
  - **Switching beams at 50Hz**
  - **For stable operation and higher quality exp. results**

Event System Configuration

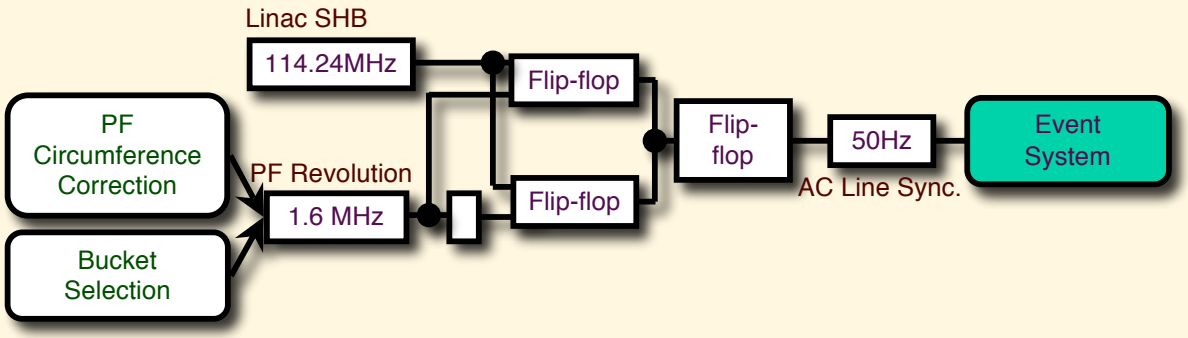
- MRF's series-230 Event Generator / Receivers.
- VME64x and VxWorks v5.5.1.
- EPICS R3.14.9 with DevSup v2.4.1.
- 13 event receivers for now.

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

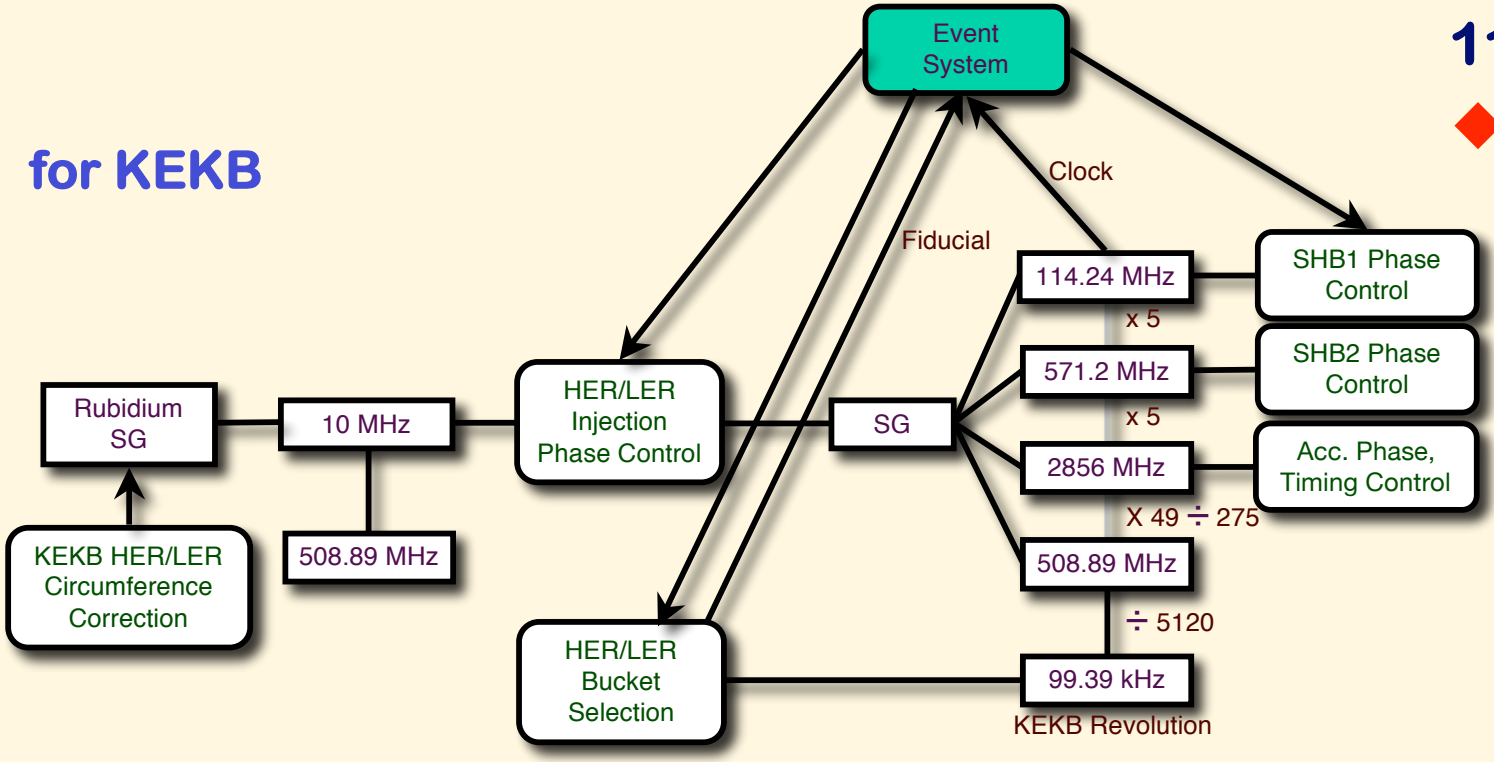


Synchronization Scheme

for PF

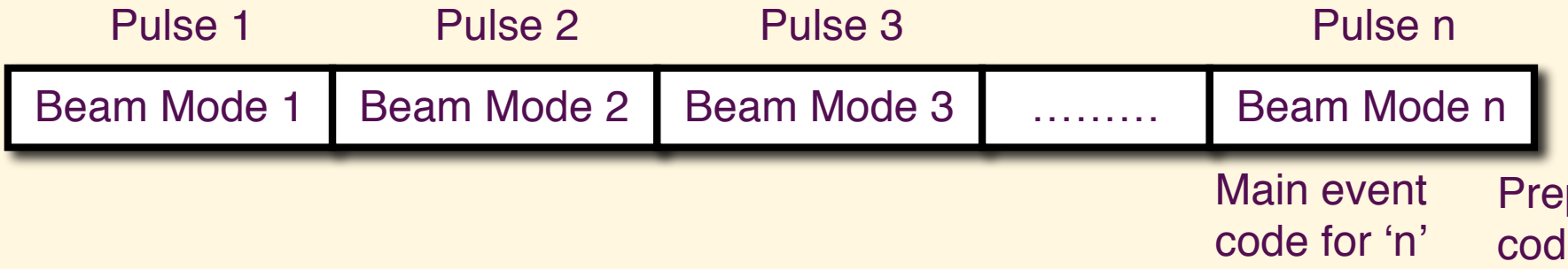


for KEKB



- **Synchronization Req.**
  - KEKB : < 30ps
  - PF : < 300~700ps
- **Linac rf is Synchronized to KEKB rf**
- **Event Clock is 114.24MHz**
- **We have to manage**
  - Circumference compensation
  - Bucket selection
  - Injection phase controls

Beam Mode Pattern Generation



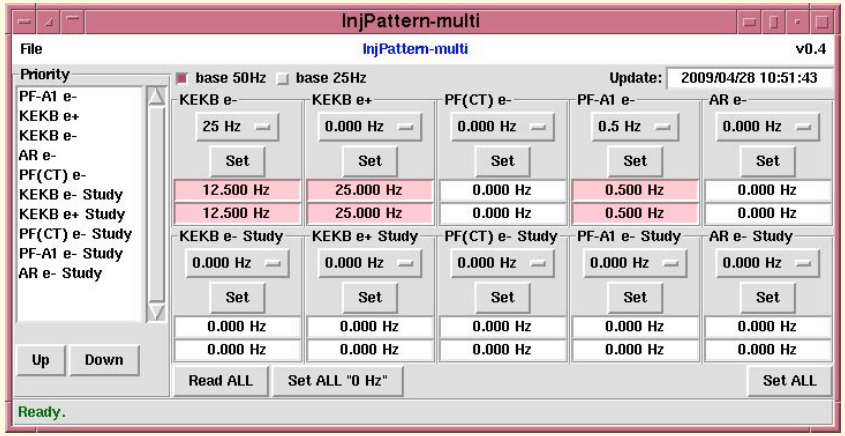
- Every pulse (every 20ms) corresponds to a beam mode.
- 10 different beam modes are defined (for KEKB e+, etc).
- One beam mode may contain many event codes.
  - At least one main code and a preparation code for the next pulse.
- Beam pattern buffer length (n) can be 2 to 500 (20ms x 500 = 10 seconds).
- A new pattern can be loaded at the end of the previous pattern.
- Otherwise, the pattern repeats forever.
- Pattern generator software arbitrates requests from downstream rings.
- There are many pattern rules due to pulse device features and limitations.
- Pattern generator software is written in scripting languages to meet daily changes during the commissioning stage.

Beam Mode Pattern Generators

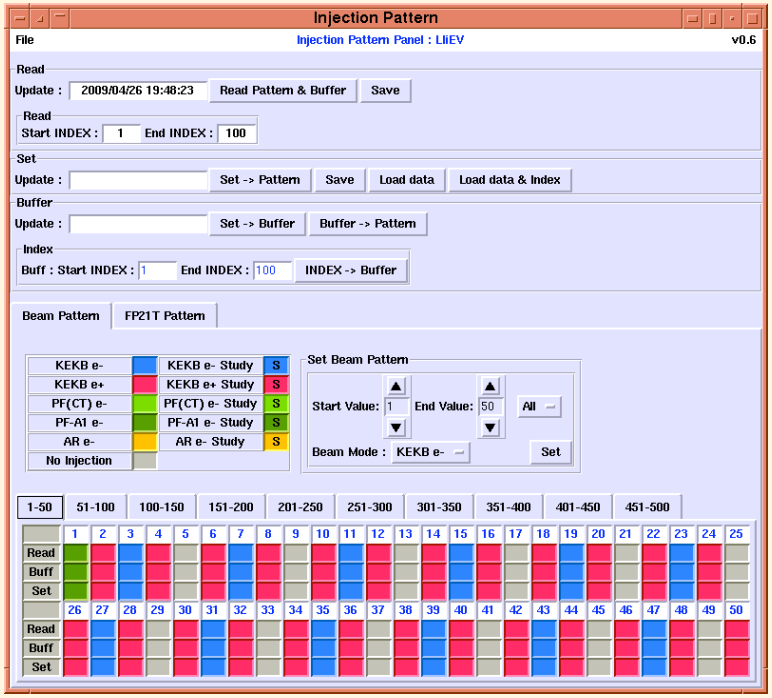
There are several versions

- 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



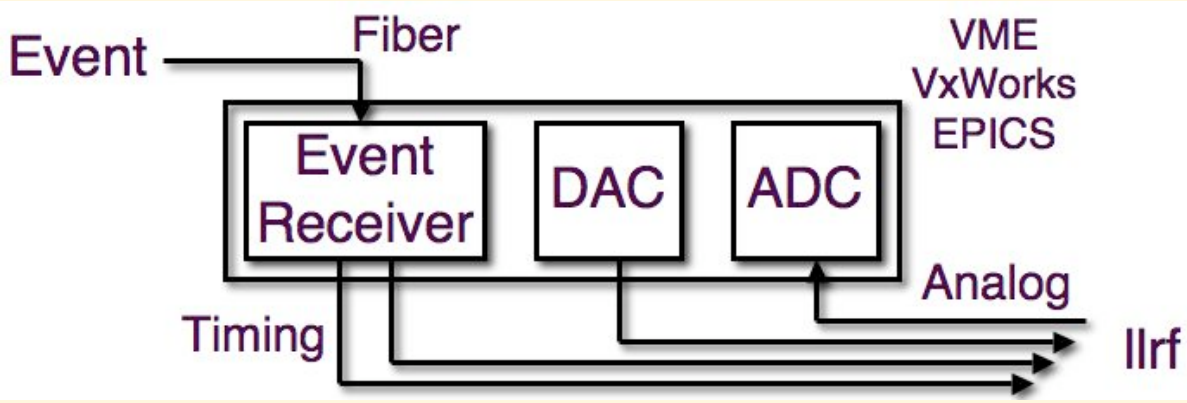
Manual pattern generator

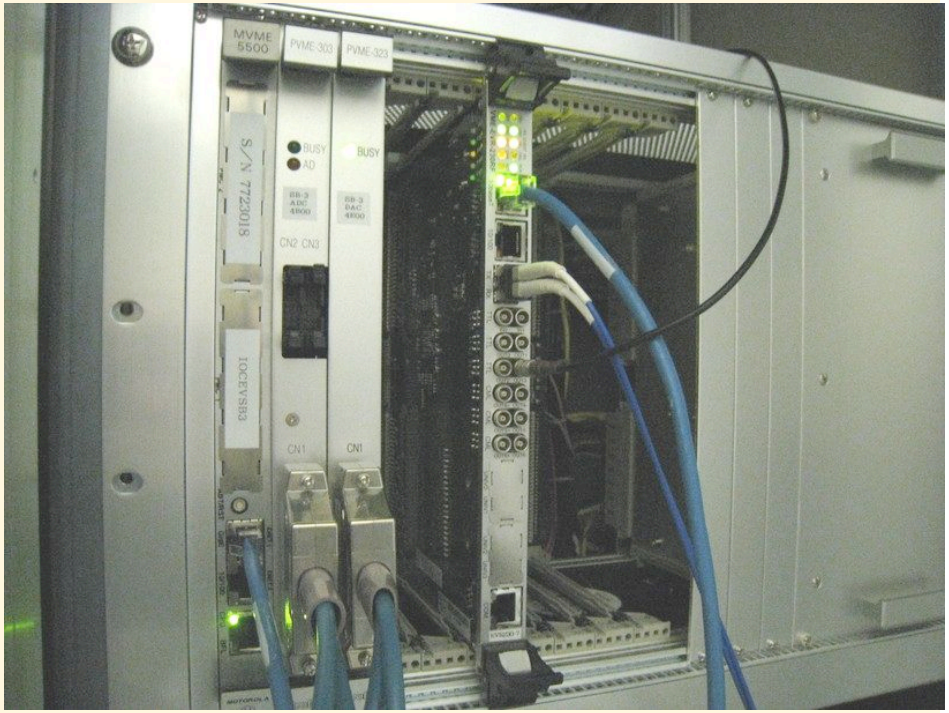


- Typical operation in Apr.2009.
  - ~25Hz for KEKB LER
  - ~12.5Hz for KEKB HER
  - ~0.5Hz for PF

LLRF

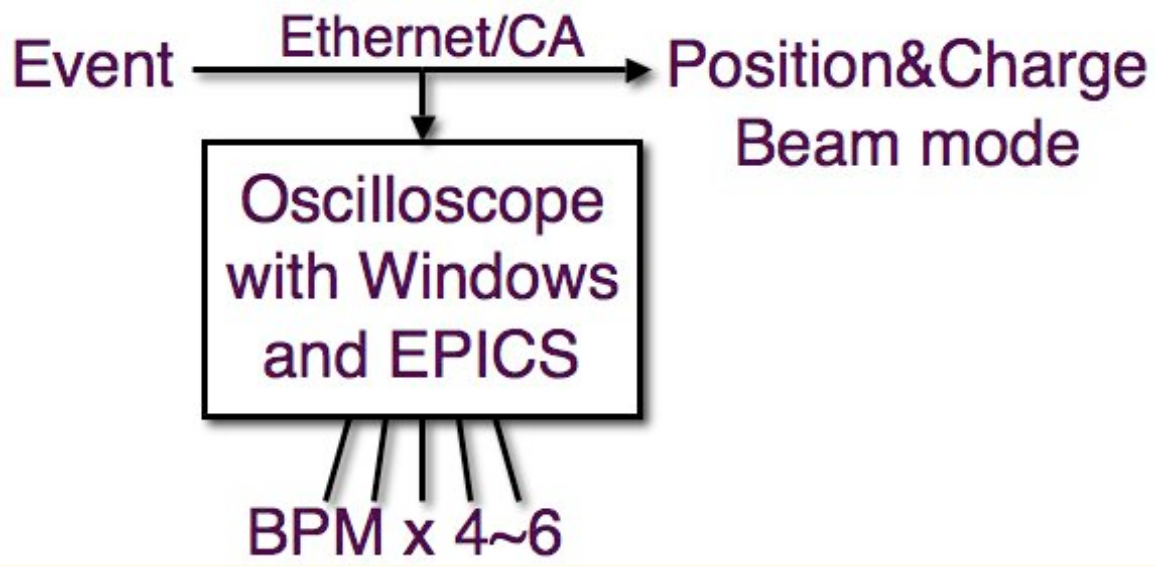
- LLRF Timing/analog signals are essential for absolute energy, energy spread, and dual-bunch energy equalization.
- Signals are switched pulse-by-pulse.
- Value changes are triggered by a preparation event.

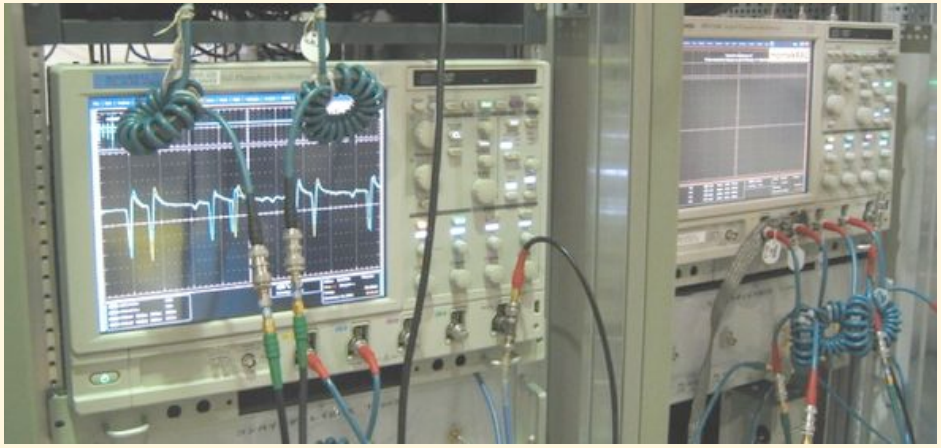




BPM

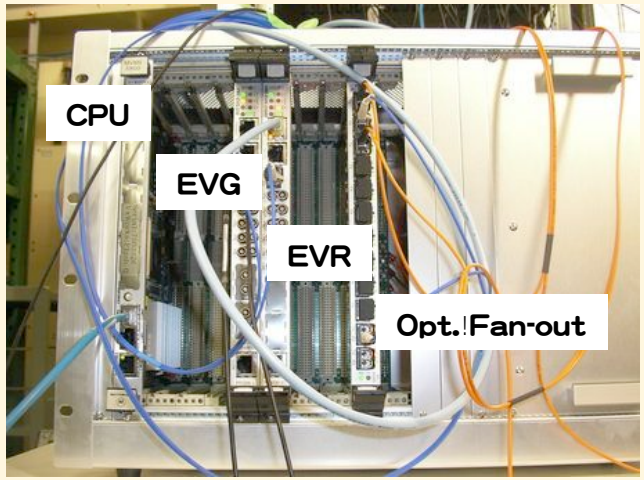
- Tektronix DPO7104 can acquire data at 50Hz.
  - With embedded EPICS
- Beam modes are recognized by events through CA network.
- Clients can monitor data of an interested beam mode.
- 26 oscilloscopes are installed.
- 100 BPMs are synchronized. (100 BPMs at BT as well soon)

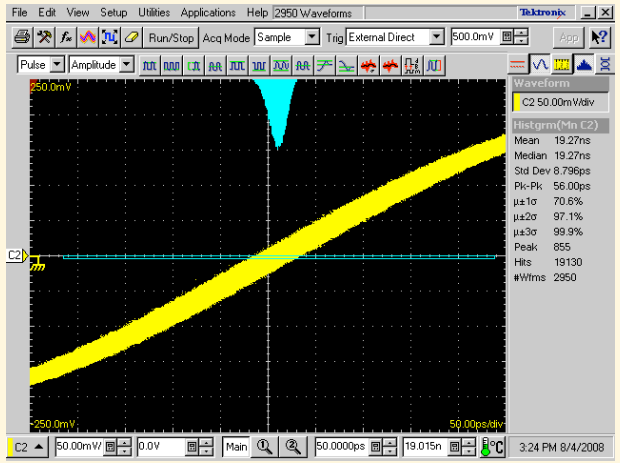




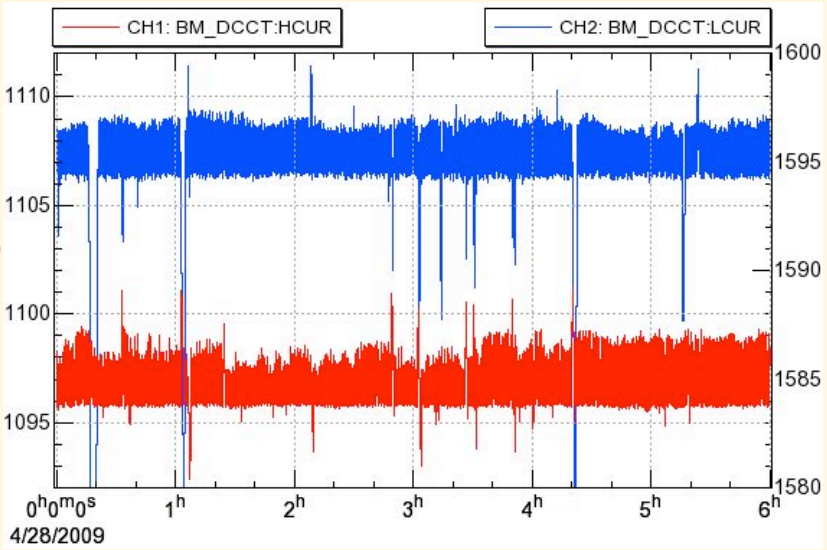
Linac Event System

- **Satisfies the requirements**
  - Event rate : 114.24MHz
  - Fiducial rate : 50Hz
  - Timing jitter (Short term) : ~8ps
  - No. of defined events : ~50
  - No. of receiver stations (now) : 13
  - No. of Fast parameters (now) : ~120

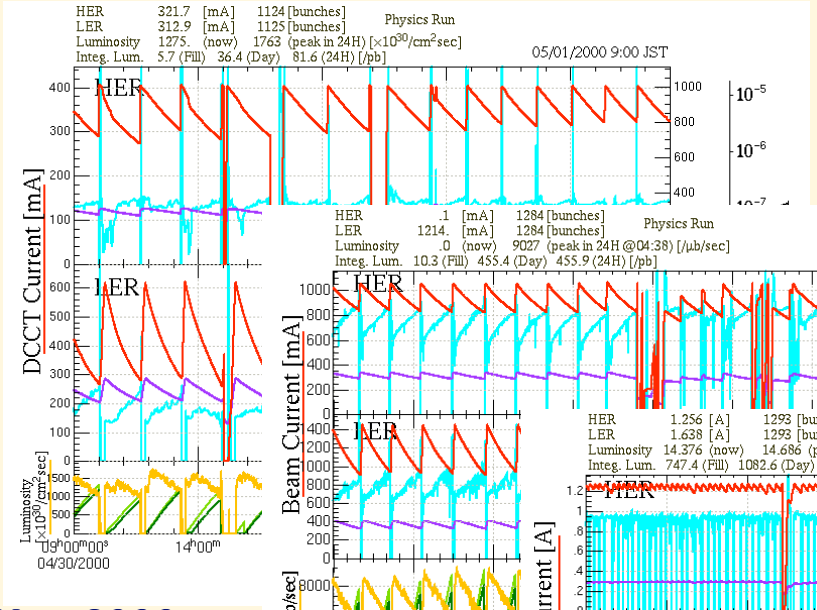




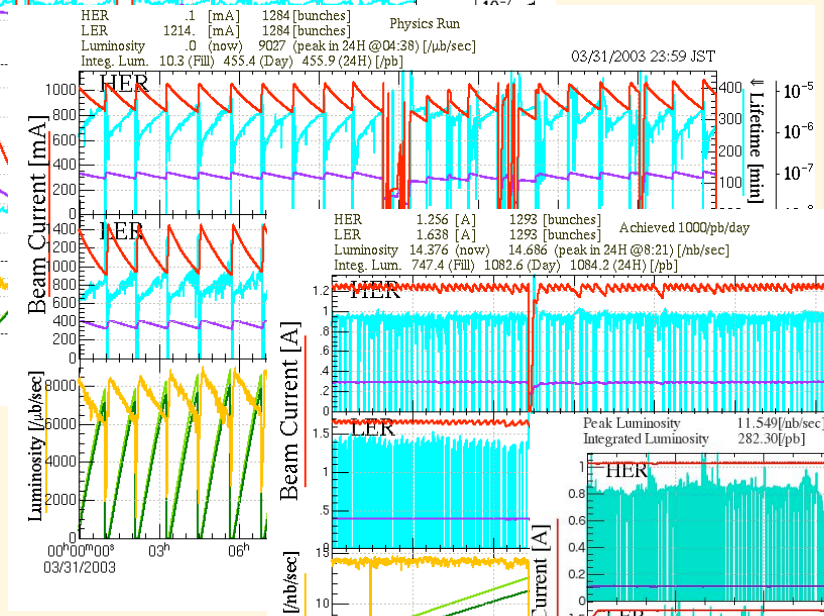
- **Beam currents are kept within**
  - KEK 2mA (improving)
  - PF 0.1mA (in 450mA)



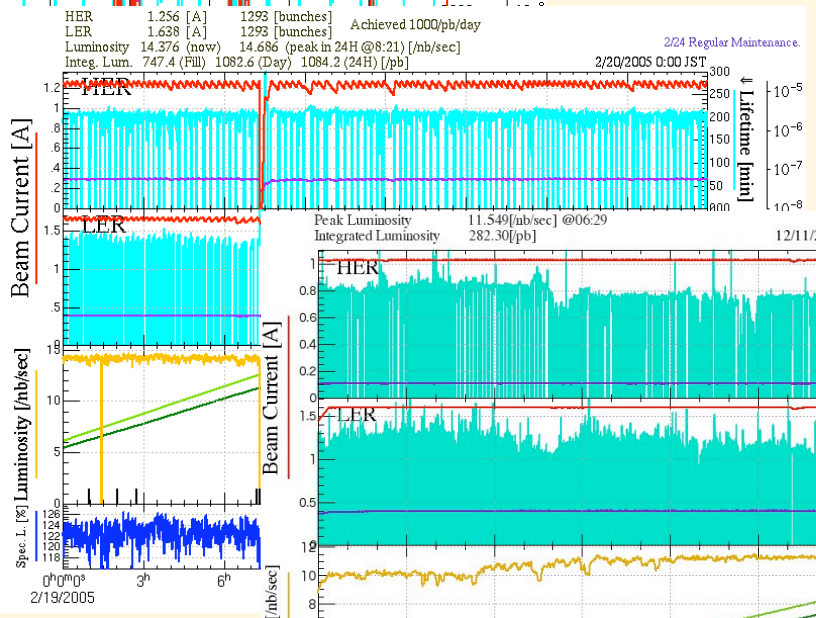
KEKB Operation Improvement



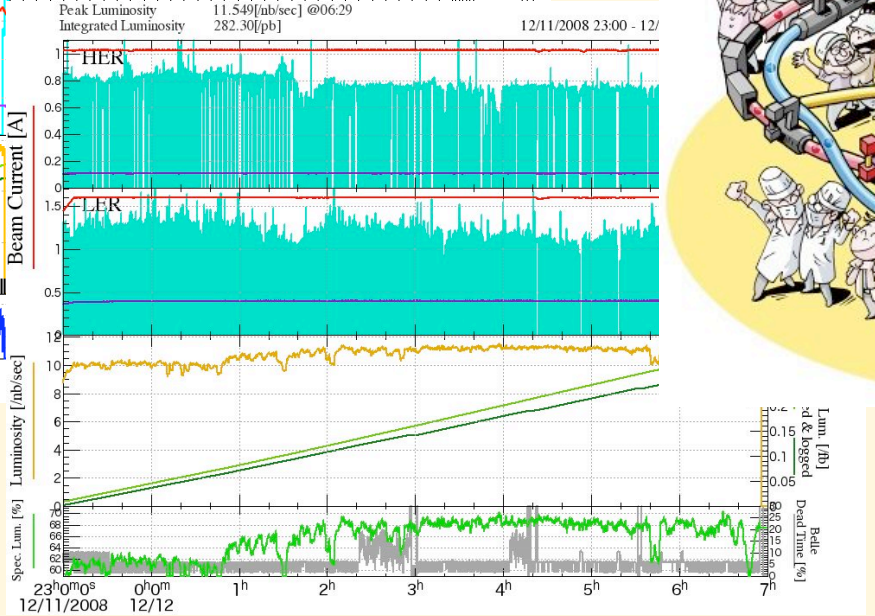
May.2000



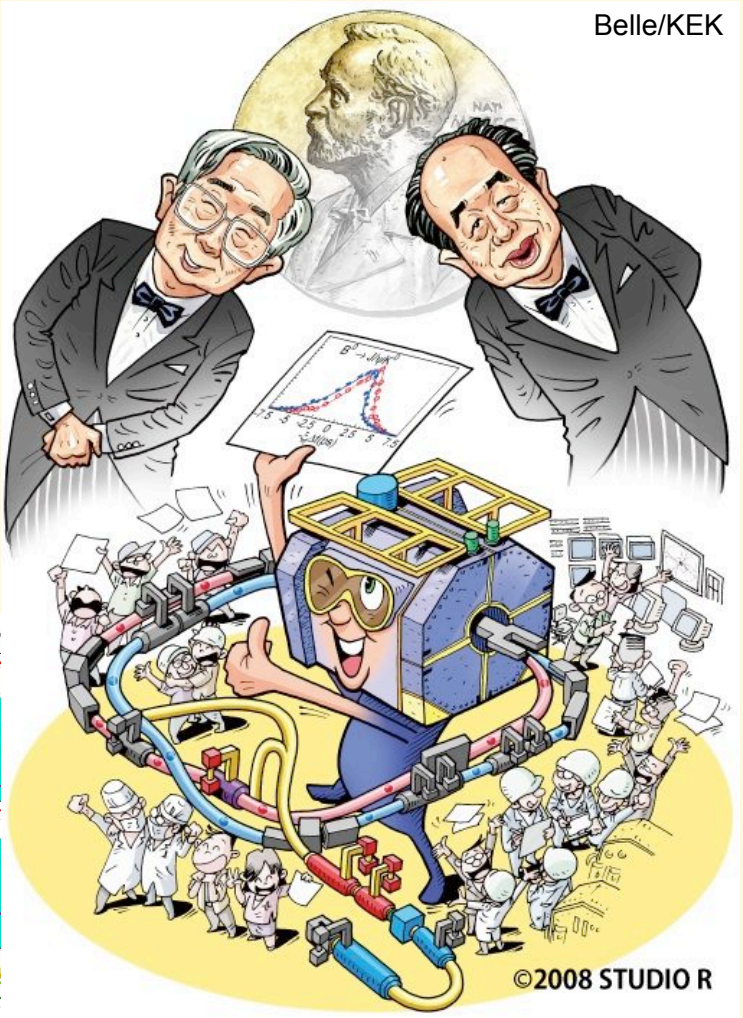
Feb.2005
Continuous
Injections



Apr.2003
Dual Bunch e+



Dec.2008
Crab Cavities and
Quasi-simultaneous Injection



(Initial) PLC usage at KEK

- At e–/e+ Linac
  - We enforced that all the new controllers should be connected over IP/Ethernet since 1993 (instead of other field networks)
  - PLC was much cost-effective compared with VME
    - if the speed requirement allows
  - Products from OMRON, Mitsubishi, Yokogawa, etc. were installed
    - Only Yokogawa (FAM3) remained and others were removed, because maintenance capability over network was better
      - Ladder software downloadable over IP/Ethernet, etc.
      - (Recently Mitsubishi also added that feature)
  - 170 PLCs (with Ethernet) used for RF, Magnets, Vacuum, (Safety), etc
- At J-PARC
  - Many installations with the same reasons as e-Linac
- At KEKB
  - Used indirectly at many devices, over serial or GPIB links
- Even custom hardware modules can be designed (I/O Open)

Software management with PLCs

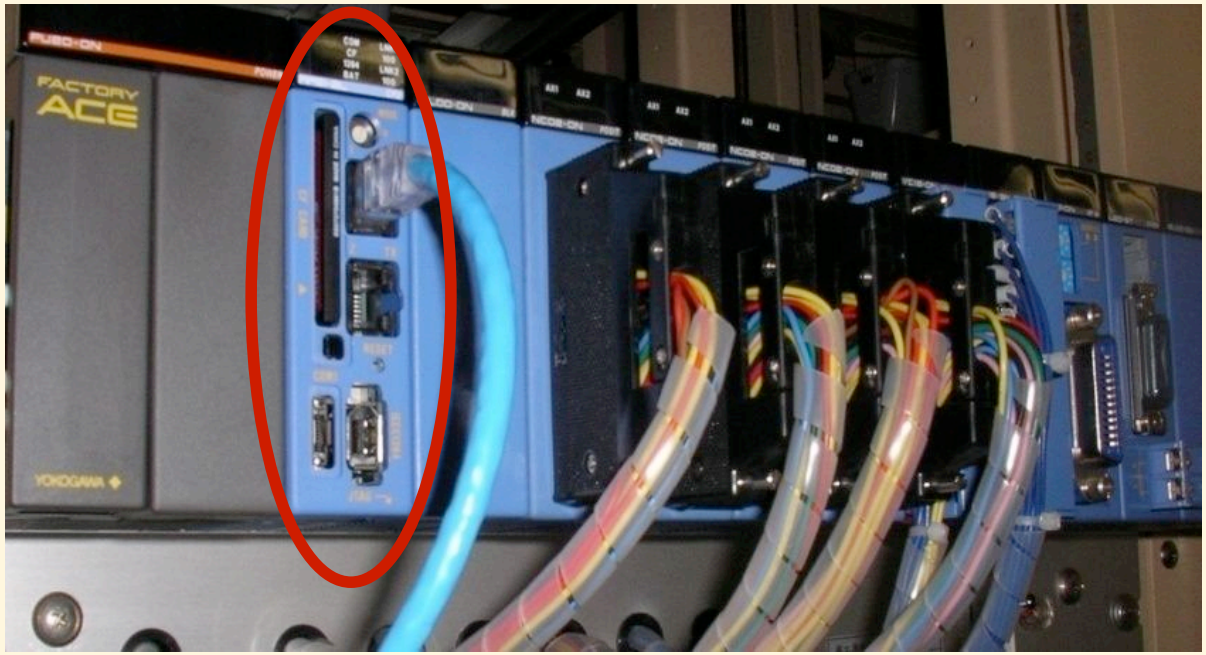
- **Ideal at the beginning**
  - Separate software development at control group, at equipment group, or at industrial company
  - Later, integration test with IP/Ethernet
- **Logic management, however**
  - Same logics could be placed at ladder software, in EPICS database/squencer (or in high-level applications)
- **Speed requirement**
  - Closed loop over Ethernet was slow, sometimes un-reliable
  - Interrupts were possible, but slow and complicated
- **Thus, hoped to run EPICS on PLC**

EPICS on PLC

- VxWorks CPU was available on PLC (Yokogawa, Mitsubishi)
  - Besides normal sequence / ladder CPU
  - However, license management of vxWorks …
- Yokogawa starts to provide Linux (2.6) on PLC CPU (F3RP61)
  - Brave enough to choose open source environment
    - We negotiate with Yokogawa to remove any license issues
  - Odagiri/KEK, Uchiyama/SHI-RIKEN, Yamada/KEK made much effort to realize the implementation, (but no need for asynchronous records)
  - Takuya-Nakamura/MSC-KEK tailored the environment for KEKB
    - Procserv, pcmon, NFS, …
- Three new IOCs are used in KEKB operation
  - Since September 2008, and another later, four in total
  - Beam mask controllers and Pulsed-quad controllers
  - No trouble at all, they run more than 6 months
- ~20 new IOCs are also used in J-PARC operation now

F3RP61 (e-RT3 2.0)

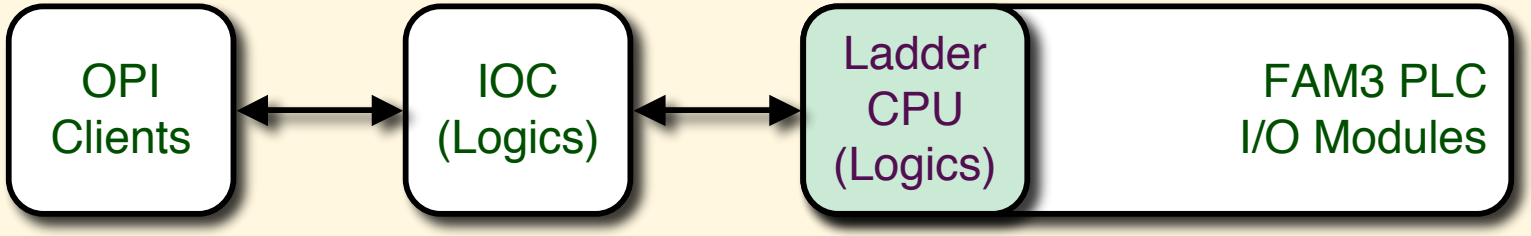
Linux 2.6.24
PPC 533MHz
128Mbyte RAM
100BaseTx x 2
USB
IEEE1394
Serial
PCI
I/O Bus for FAM3 Module Interface
can access to mature FAM3 I/O Modules
Can be combined with conventional ladder CPU
Software development environment (ELDK)



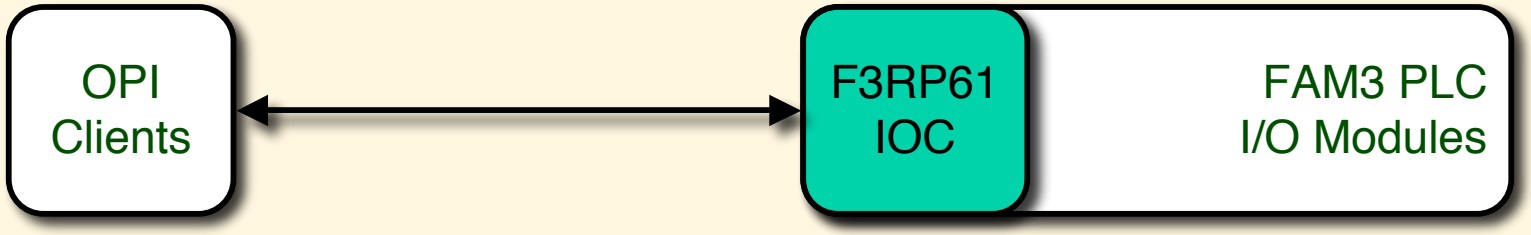
KEKB Beam mask controller

Simple Usage under EPICS

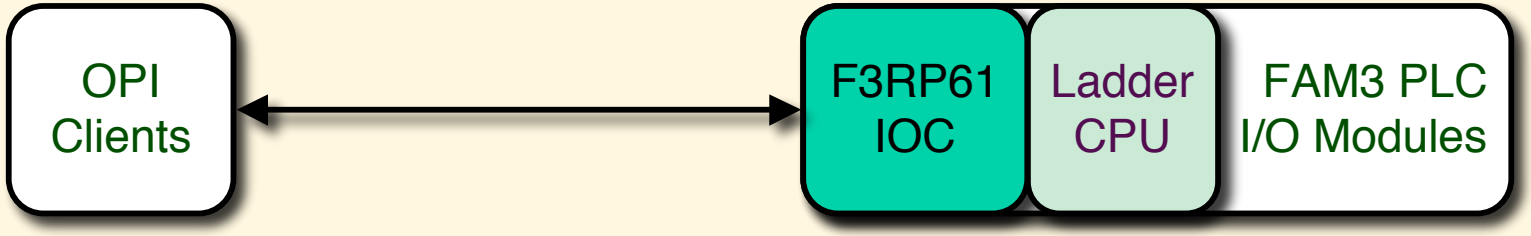
Conventional PLC usage with asynchronous access



PLC usage with F3RP61 with only synchronous access and maybe with sequencer



If necessary, we can combine



Device Support

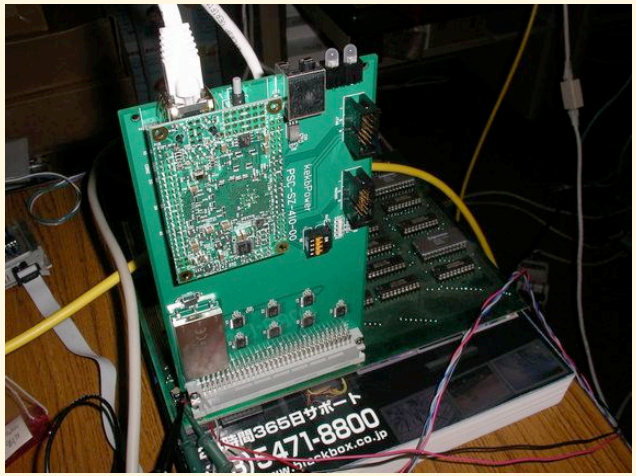
- No need for asynchronous access
  - Direct access to all I/O modules
- Can access to registers on ladder CPU
  - If necessary
- Interrupts also possible
- Logics can be database links or sequencers
- Did extend the number of EPICS developers

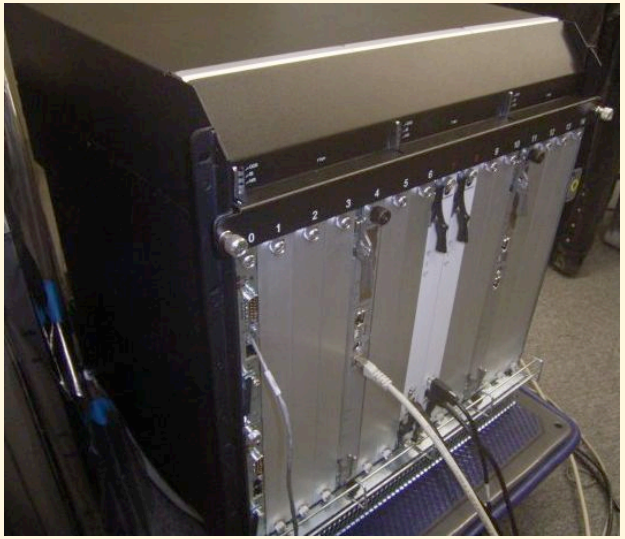
- Source code and documents
  - http://www-linac.kek.jp/cont/epics/f3rp61/

  - Local development, PREEMPT_RT realtime (Yamada, et al)

Other Developments at KEK

- By A. Akiyama, et al
  - Embedded IOC on FPGA controller
- By M. Satoh, et al
  - Embedded IOC on oscilloscopes
- By A. Kazakov, et al
  - Redundant IOC (RIOC with OSI supports)
  - Redundant Gateway
  - ATCA IOC with HPI/SAF support for RIOC
    - ATCA for STF/ILC-LLRF and μTCA for ERL-LLRF
  - Automatic test system environment
- By Klemen Zagar, et al
  - Wireshark protocol analyzer for CA



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