SuperKEKB Controls

Kazuro Furukawa
For Control Group

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Contents

- Based on Presentations at the Review-2010
  - Control System
  - Simultaneous Injections to KEKB and PF
- Achievements in KEKB Controls
- Requirements to Controls
- Solutions and Developments
- Summary

KEKB Construction and Operation

- **Distributed EPICS-based Control System**
  - **2 + 1 Layers**
    - Operation programs (OPI, Channel Access Clients)
    - Equipment controls (IOC, Channel Access Servers)
    - Device hardware controllers (over Fieldbuses)
- **Operation Programs in Scripting Languages**
  - **SADscript for Beam Handling**
    - Mathematica-like language to SAD Engine
    - EPICS CA, Event-driven, List, Plot, GUI, Optimization, etc
  - **Python**
    - Object-oriented, EPICS, GUI, etc

Requirements to Controls in SuperKEKB

- **Hearing and Interviews to each Group**
  - Not much different from the present system
    - other than speed requirements
  - Mostly the same requirements to KEKB
- **However,**
  - Additional requirements may come later
    - Should be prepared for them
  - Should catch up with the current technology
    - for reasonable maintenanceability

SuperKEKB Plan

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

SuperKEKB Plan (Examples)

- **Archiving scheme and viewer**
  - Maybe existing KEKBlog and channel archivers
    - New viewer should be developed (in CSS?)
- **Alarm handler**
  - Continuation of KEKBalarm or Simulation on CSS or Python
    - Under evaluation
- **Operational Log**
  - In house, two versions with different origins
    - Postgres + (Python/Zope and Flash/Flex)
- **Scripts**
  - SADscript/Tk, Python/Tk, (decreasing Tcl/Tk)
- **Displays**
  - Edm/Medm and CSS (Control System Studio from DESY/ORNL)

Interfaces to Devices

- **VME as Device-side Computers**
  - EPICS IOC (I/O controller), CA (Channel Access) server
- **For Device Controllers**
  - CAMAC for RF, Vacuum, Beam-Transport
    - It is not impossible to maintain them, however, availability of mechanical components as well as chips
    - Hope to replace them at least at Vacuum and BT systems
  - VXI interfaces (from VME) for ring BPM
  - ARCnet (from VME) for Magnet, and other systems
    - May be replaced with Ethernet-based controllers
  - GPIB over network, etc

Embedded EPICS IOC
or
CA Everywhere

Accelerator Controls at KEKB and Linac

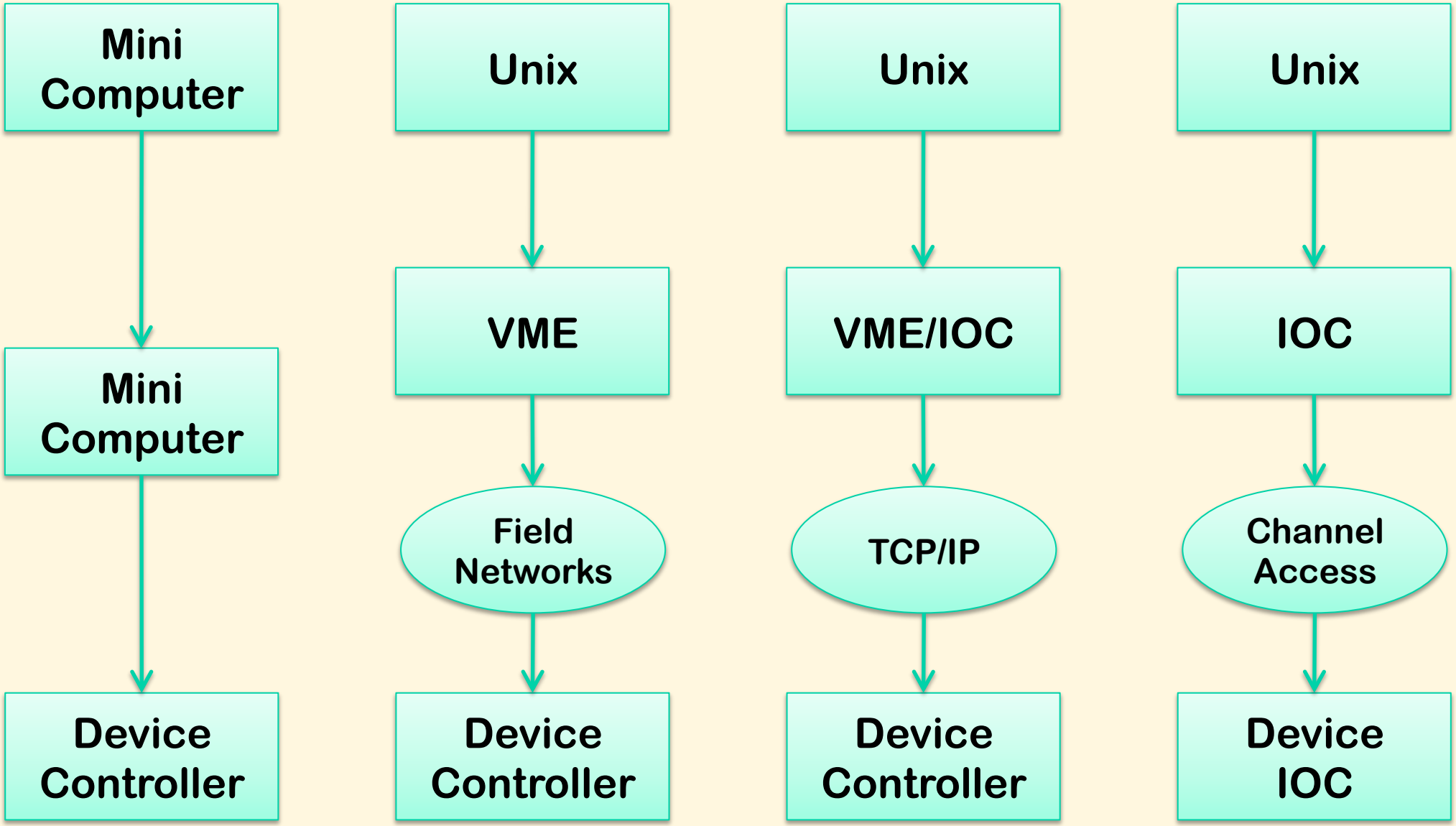
- VME + Unix (1990~)
  - Standard configuration
    - With many third layer field networks

- Every controller on IP network (1993~ at linac)
  - Single layer in physical, two layer in logical

- EPICS (1995~)
  - Globally sharable efforts

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

Transition of Controls

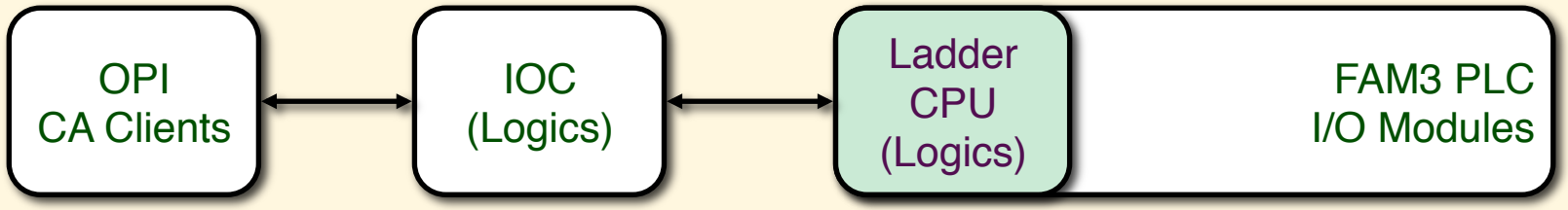


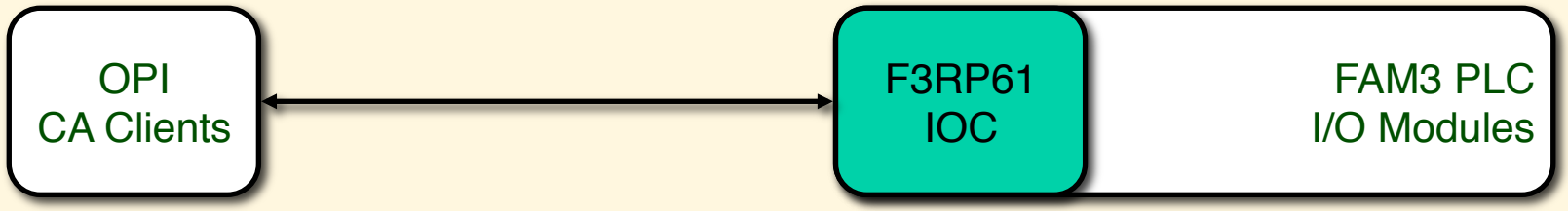
Embedded IOC in Yokogawa's PLC

- 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 CPU, 128MB RAM, 2xEthernet, USB, etc
  - Utilize realtime feature of Kernel 2.6
    - EPICS PV response time <150μsec (incl. module delay)
- Ladder sequence CPU can coexist
  - Variable sharing possible

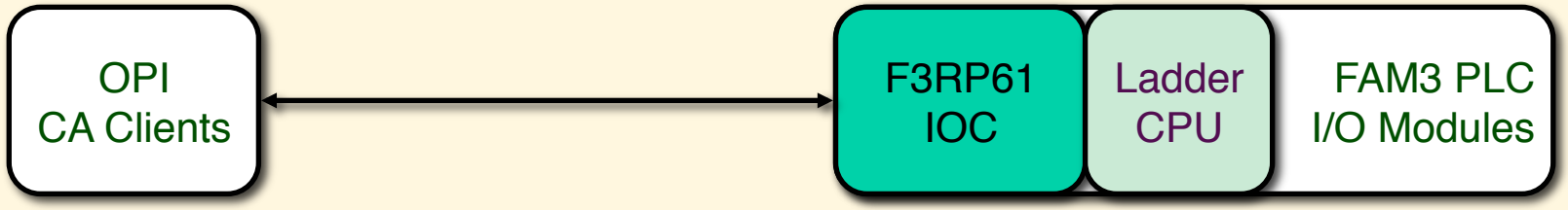
Simpler PLC Usage under EPICS

Conventional PLC usage with asynchronous access



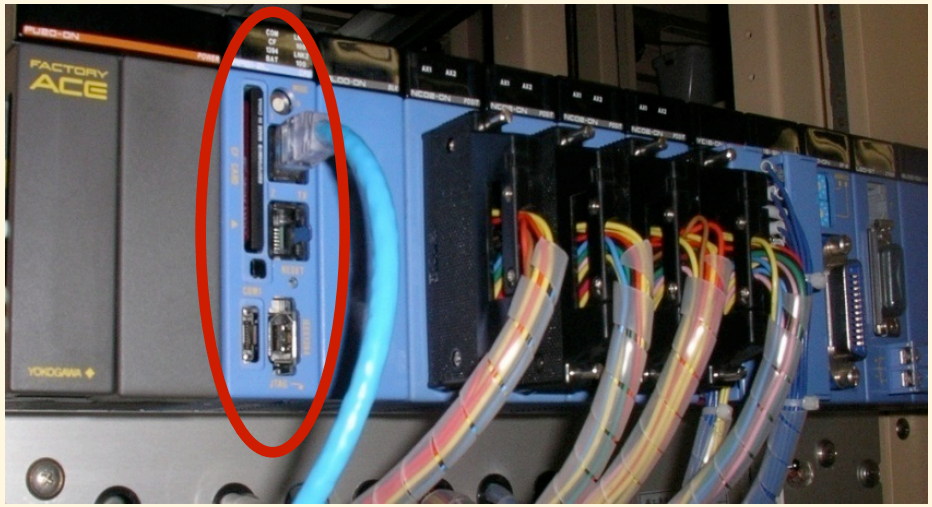


If necessary, we can combine



Logics are confined in PLC, and management is easier

- Many medium-speed controllers implemented
  - KEKB, Linac, J-PARC, PF, cERL, …, Taiwan/TLS, (and other Asian Institutes)
    - <http://www-linac.kek.jp/cont/epics/f3rp61/>



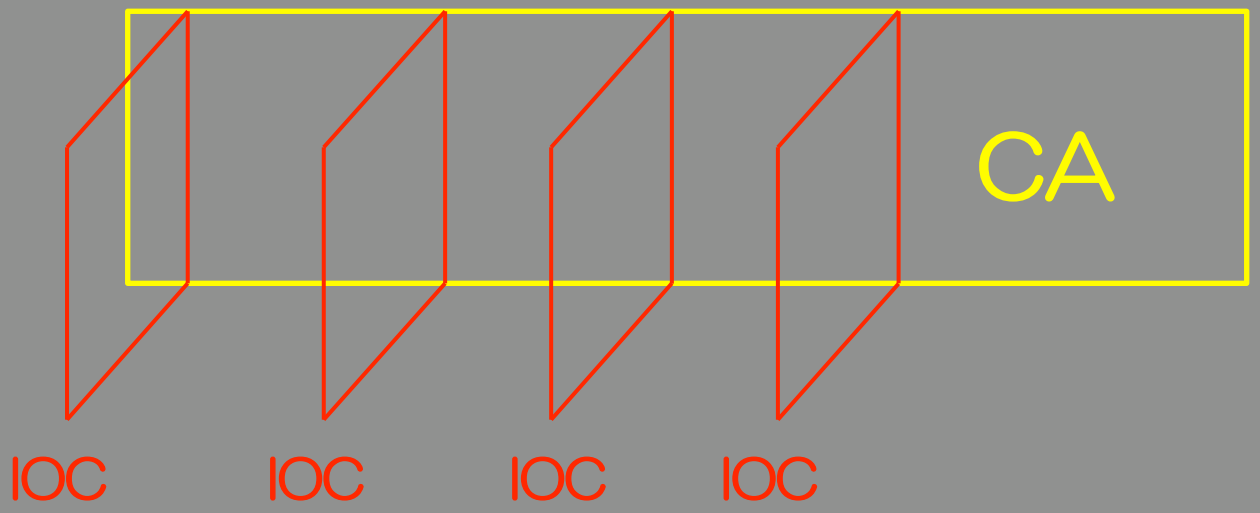
- Image processing module available as well
- Event-receiver (EVR) module being Developed by SINAP/Shanghai
  - Good example of Global Collaboration

LLRF in MicroTCA (μTCA)

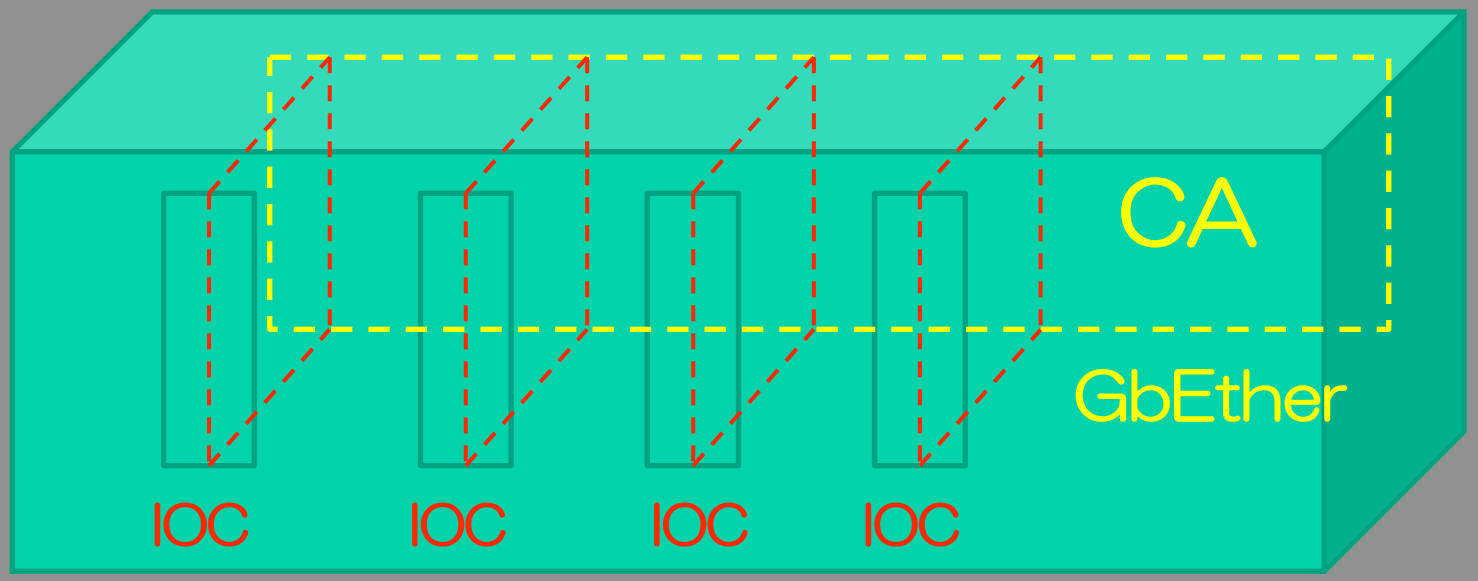
- **MicroTCA was chosen as a platform for LLRF controller**
  - Synergy between SuperKEKB, cERL, XFEL/DESY, ILC, etc
  - ATCA (2003)
    - New computing standard for telecommunication and industry
      - After CompactPCI (1993), for reliability with higher performance
    - Many serial interconnects on backplane
      - 2.5Gbps each (10Gbps in the future)
        - »One card covers all phones in a small city with a certain implementation
    - IPMI surveillance/remote-management for reliability
  - AMC (Advanced Mezzanine Card for ATCA)
    - Serial interconnects, IPMI, good part of ATCA
      - Like IP-module to VME, PMC to cPCI
  - MicroTCA (2008)
    - AMC card itself is powerful
    - Direct slot-in AMC cards in a Box
      - Commercial I/O cards for industry are available

Standard EPICS

CA as "Software bus"



Channel Access on MicroTCA Backplane



Picture by J.Odagiri

- Let's employ Channel Access on μTCA Backplane !
- Let's embed EPICS IOC on to Each μTCA/ AMC Card !

Miura and Furukawa

IOC on MicroTCA

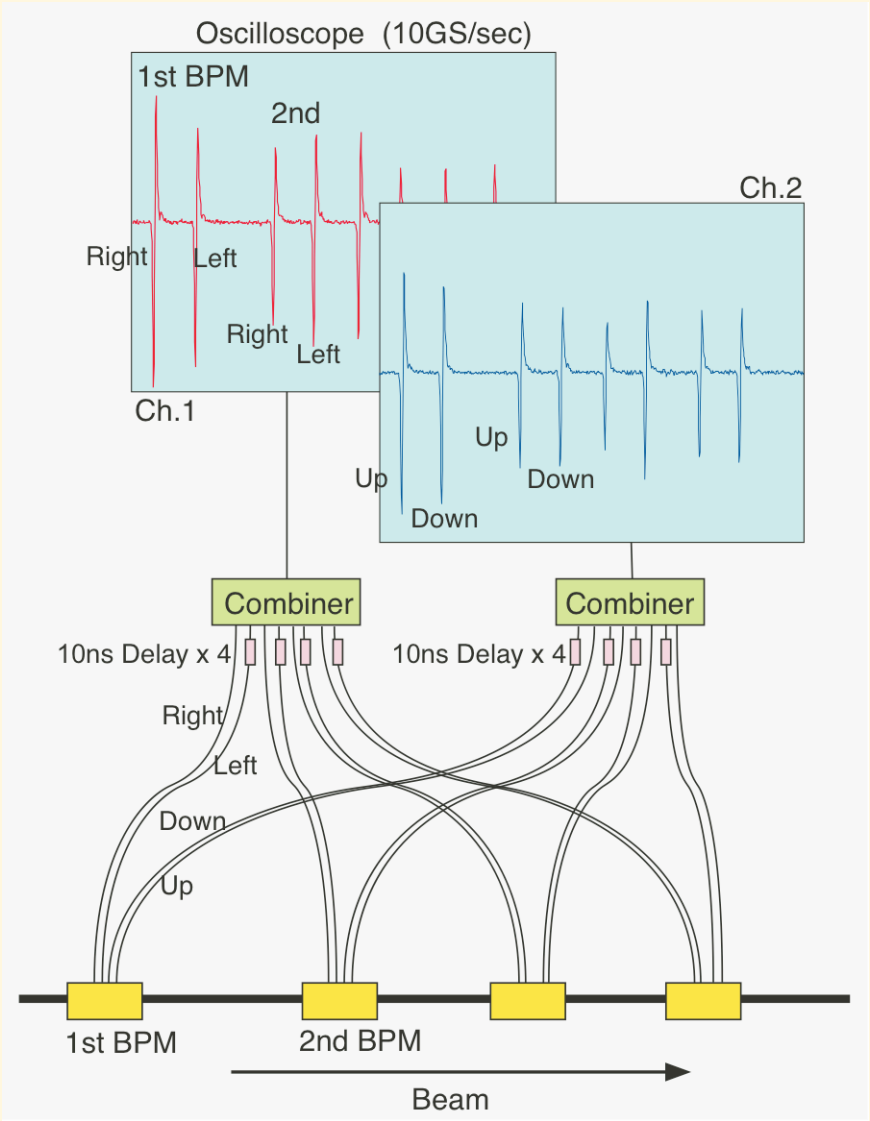
- Natural to put IOC on μTCA LLRF Controller
- Chose GbEthernet as a main media on the backplane interconnect
  - Somewhat unique
  - Some other institutes chose PCIe as the media
- Chose PowerPC core on Virtex5
  - ML507 test card from Xilinx as a good reference
- Linux on PowerPC
  - No realtime processing is necessary at Linux level
    - In the future, we may use realtime (<100μs) feature of Linux

EPICS IOC on MicroTCA LLRF Controller

- Linux 2.6 on Virtex5
  - Boot from Flash (or over network)
  - EPICS from NFS
  - Slight difficulties because …
    - Lack or experiences
  - Relatively straight forward
- EPICS 3.14.9 (for now)
  - Driver to FPGA (with mmap)
    - Scalar values directly, and waveform/arrays through ringbuffer
  - Channel access on backplane interconnect
  - Directly connected to outside at first
    - Possible to install gateway at local CPU if necessary
- Collaboration between RF group, Mitsubishi Elec. Tokki System Co. Ltd., and Control group has been going well

BPM at Linac and BT

- **BPM read-out**
  - for 0.1mm resolution
    - For KEKB/PF Injection, Not for SuperKEKB
  - Using ~30 coefficients per BPM
- **Many signals are combined into one waveform digitizer**
- **Recent Embedded IOC Solution**
- **Again reduction of resources**
  - (and much helped by Dr. Hu from Shanghai)



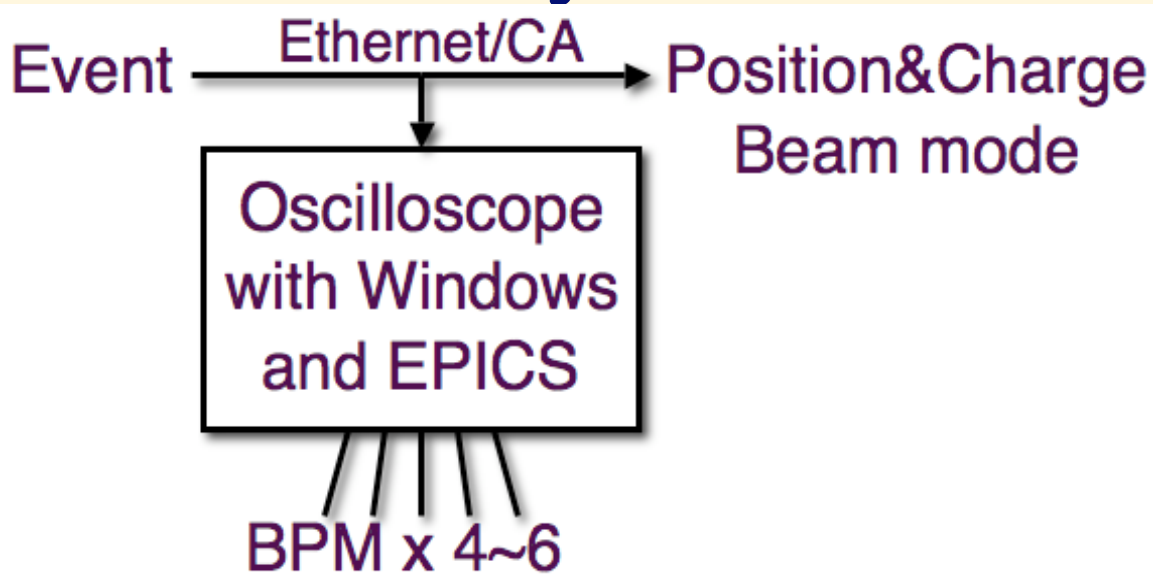
100 BPMs — 24 x DPO7104 — Clients

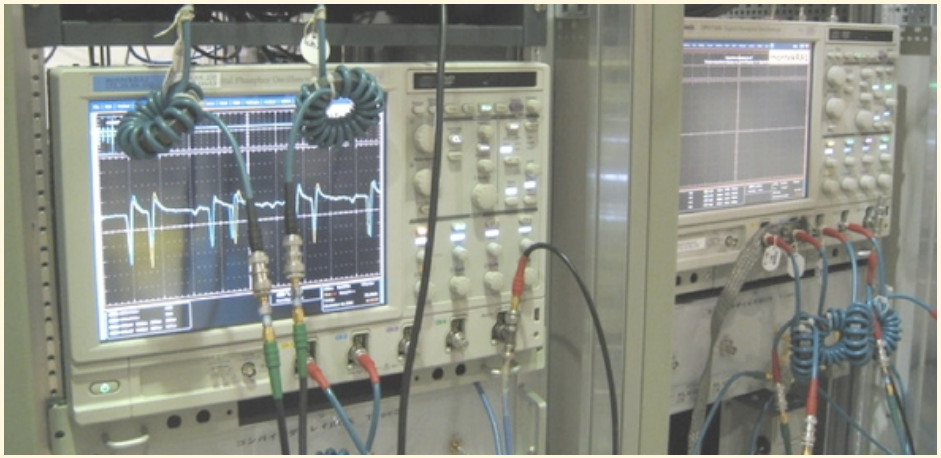
- **Old configuration**

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.





Several other Embedded IOC

- Other oscilloscope-based IOCs
  - 8-electrode and other monitors (M. Satoh et al)
- TDC with Linux/ARM (Armadillo)
  - Timing consistency surveillance (S. Kusano et al)
- Magnet PS with Linux/ARM(or FPGA)
  - Two prototypes for SuperKEKB (T. Nakamura et al)

Event-based Controls and Timing

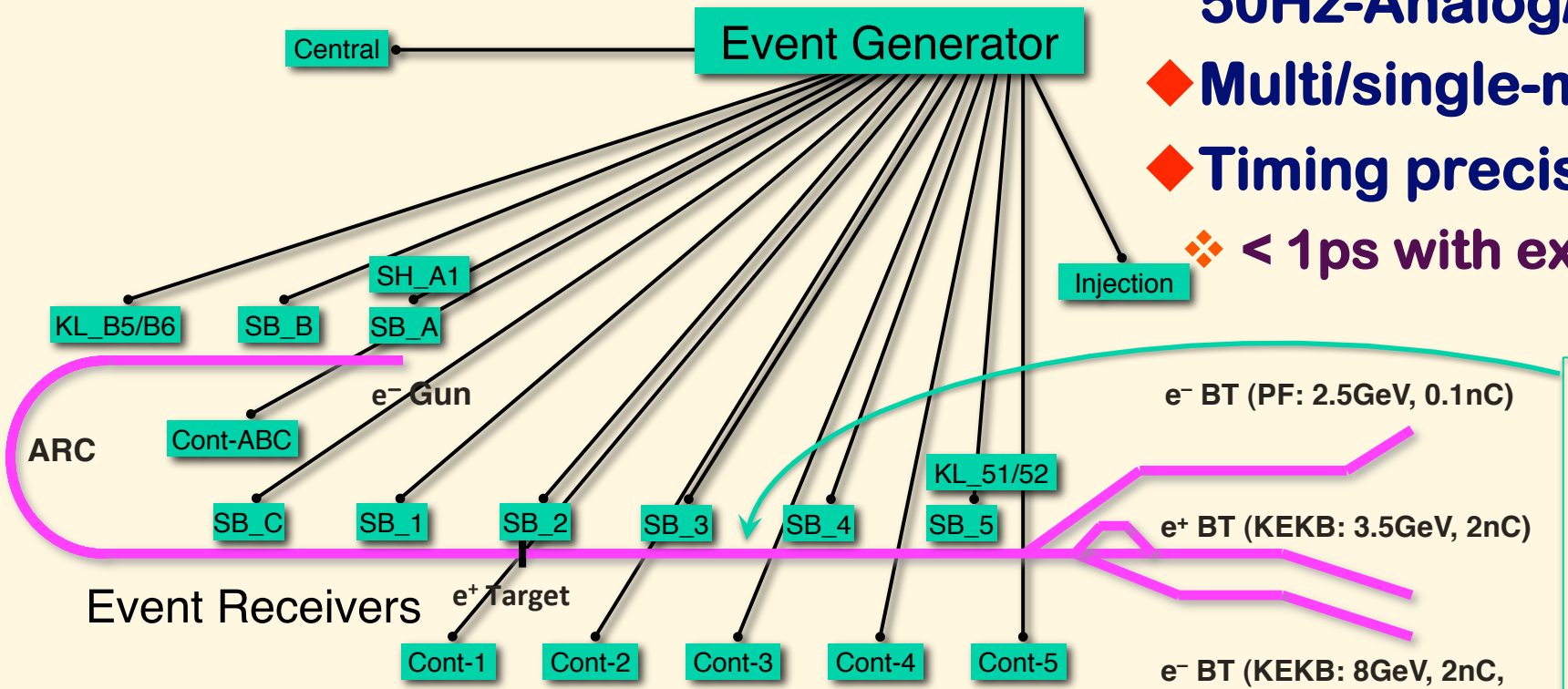
Simultaneous Injection

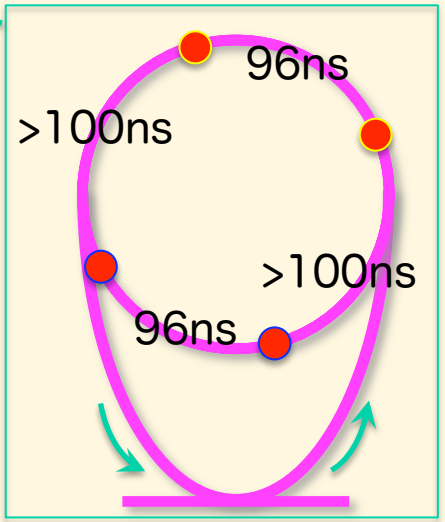
- SuperKEKB HER/LER injections under shorter lifetimes
- PF top-up injection for higher quality experiments
  - Simultaneous (non-topup) injection to PF-AR not to disturb SuperKEKB operation
- Achievement in KEKB complex
  - Reduced the Beam Switch Time from 10-120 seconds to 20ms
  - Beam currents are kept within 1mA (~0.05% for KEKB), 0.05mA (~0.01%, PF)
- Much more complicated with bucket selections at damping ring and main ring
- Should add PF-AR as well not to disturb SuperKEKB operation
  - Through damping ring
- 4rings! with different beams
- Beam Juggling

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.





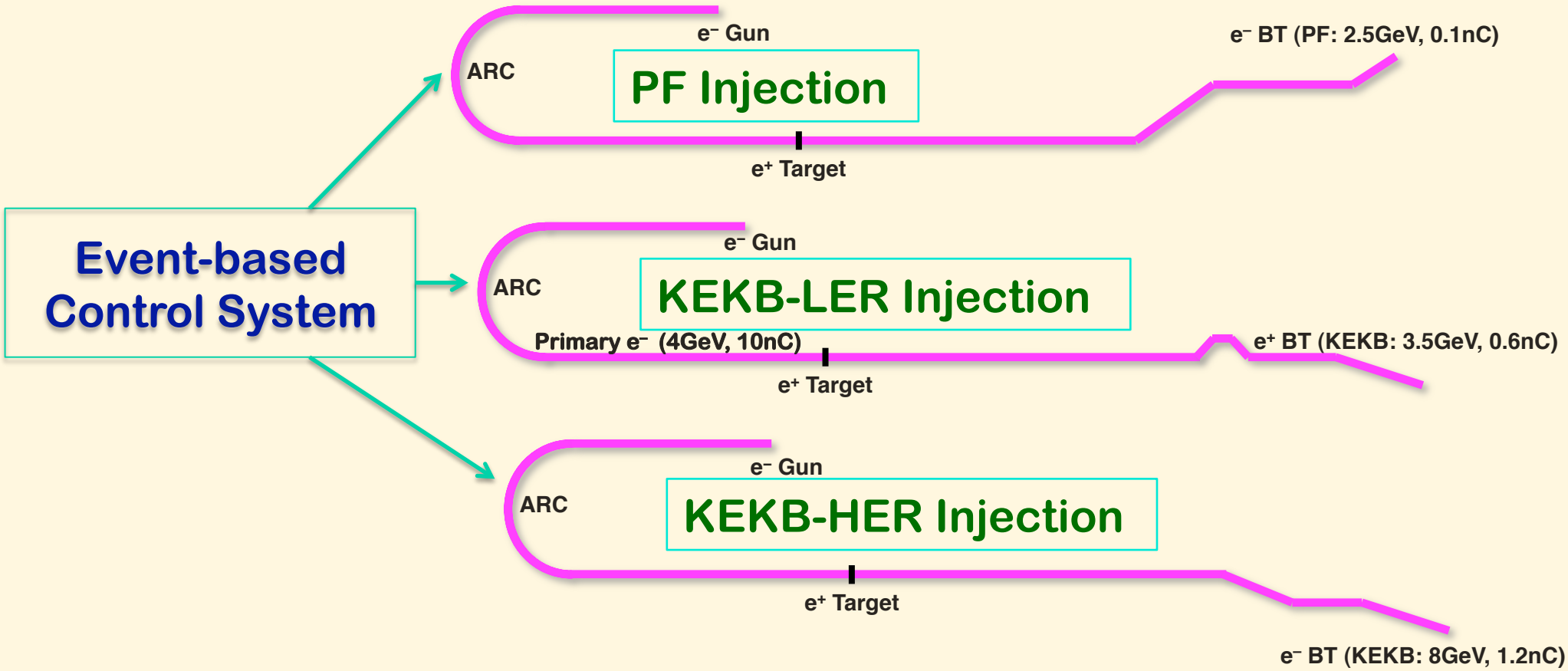
Energies will be changed and DR will be added

Fast Parameters

- **Parameters switched via event system**
  - Each parameter has at least 4 flavors (HER,LER,PF,PF-AR and maybe stealth study modes)
  - **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
  - **KEKB injection RF phase, timing, bucket selection : 2x3**
  - **BPM : ~100x3**
- **Damping ring injection should be added**
- **Integrity monitors soon**
- **Some of the modules will be developed with SINAP/Shanghai**

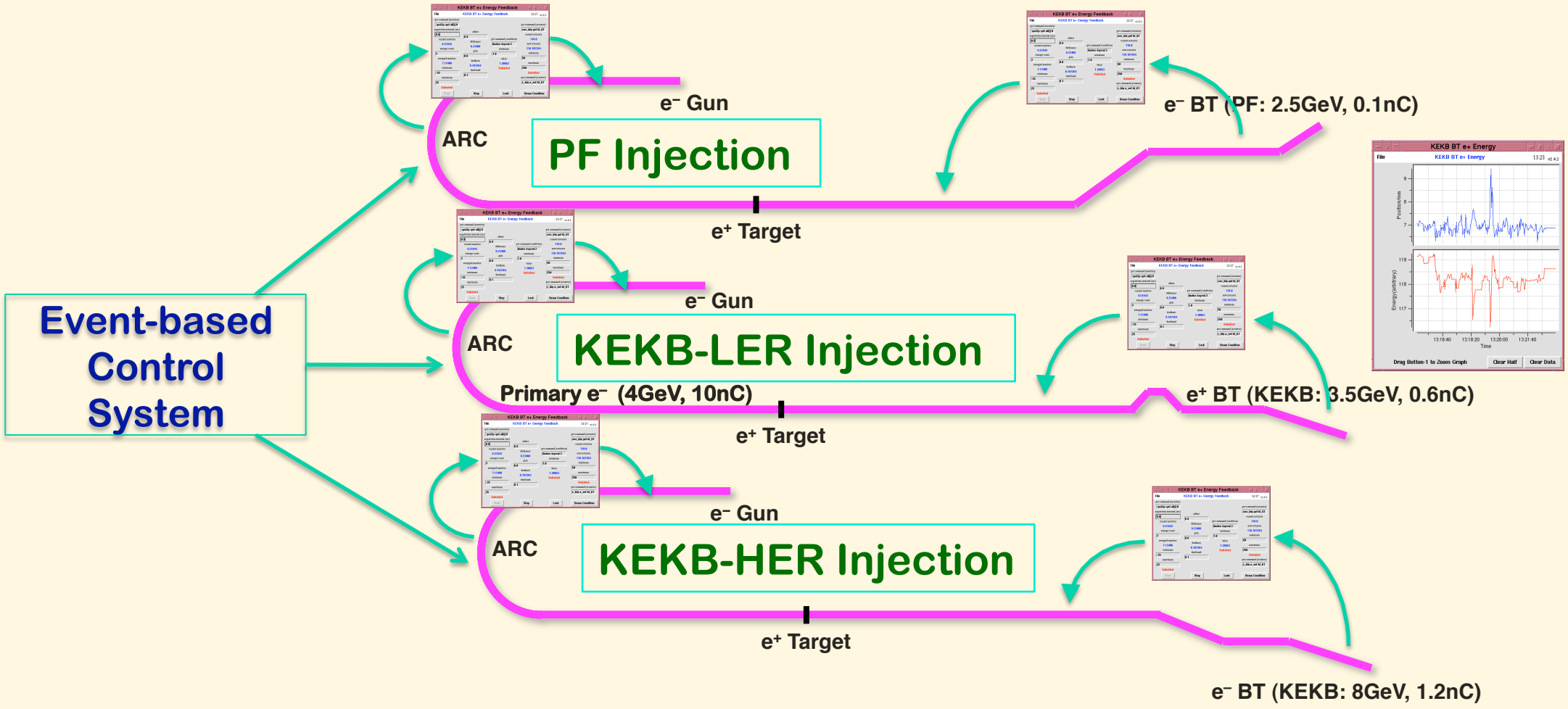
Three Virtual Accelerators

- 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**



For SuperKEKB Complex

- **Slightly More Complicated Conditions with DR**
  - Harmonic number of SuperKEKB-MR (509MHz) is 5120
  - Common frequency between Linac-MR is 10.38MHz (49 buckets, 96ns)
  - DR should have common frequency, RF chosen to be 509MHz
  - 2x2 bunches, bunch separation of 49-bucket , kicker rise/fall time of 100ns
  - Jitter (wait-time) of HP modulator (50Hz) must be <~2ms
  - Harmonic number of DR was chosen to be 230
- **In order to Select All the Buckets in SuperKEKB MR**
  - Active (Pulse-to-pulse) LLRF controls necessary at linac
    - Better LLRF monitor is required
  - Dependency between pulses increases
- **For PFAR Injection**
  - Positron have to be used to share the beam-transport
  - Independent circumference controls will interfere
    - PF can use 2.5GeV electron with accidental synchronization (<~300ps)
    - More investigation underway

Other Developments

Linac BPM

- **Resolution ~10μm required**
  - Emittance preservation with beam-based alignment
- **Conditions**
  - FTE of ~1.0
  - Two-bunch measurement apart by 96ns
  - Large dynamic range (~x100) for four rings
  - Pulse-by-pulse
- **Present evaluation**
  - Libera single-pass box, with modifications
    - Embedded EPICS IOC possible, maybe with EVR interface
  - If not applicable, modifications to other solutions

Wire-scanners at Linac and BT

- CAMAC elimination, if possible
  - VME read-out evaluation this year for new installation
- Pulse-by-pulse Read-out
  - Controlled by event system
  - Noise elimination with the same detection condition?
- For lower emittance
  - Maybe correction by surrounding BPMs needed

More Measurement Technique

- **Switching between Four Rings**
  - Challenging to improve beams during operation
- **Event-based Controls may Help More**
  - No-destructive measurements with four beams
  - Stealth (used beam-pulse) measurements
    - With beam deflector
  - Dithering pulse-by-pulse
    - If very good resolution was achieved

PPS, MPS and others

- **Personnel Protection System**
  - Will be managed by Safety group (Mimashi-san)
    - Will have Embedded EPICS to PLC system
- **Machine Protection System**
  - Continue to use KEKB Solution
    - ARCnet read-out could be replaced by Ethernet Interface
    - TTL (50ohm) and Relay signal interfaces
    - ~1μs signal transfer
- **More Device Level Developments**
  - For Vacuum, Magnet, and so on

Conclusion

- Steady Improvements/Developments
- Collaboration between Groups is Essential
- International Collaboration is also Proceeding
- Controls Have Interface to Every System
  - Controls can Enjoy Accelerators
  - With Phronesis (Greek: Ability to understand the Universal Truth)

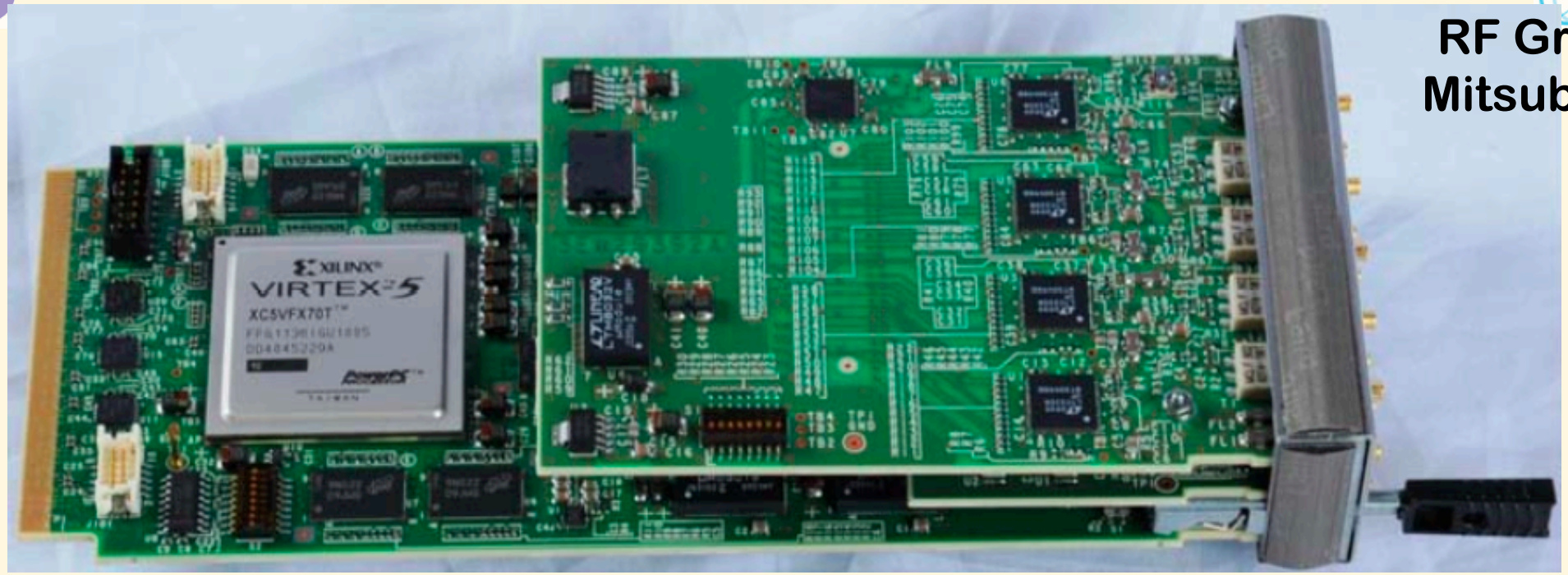
Thank you for your patience

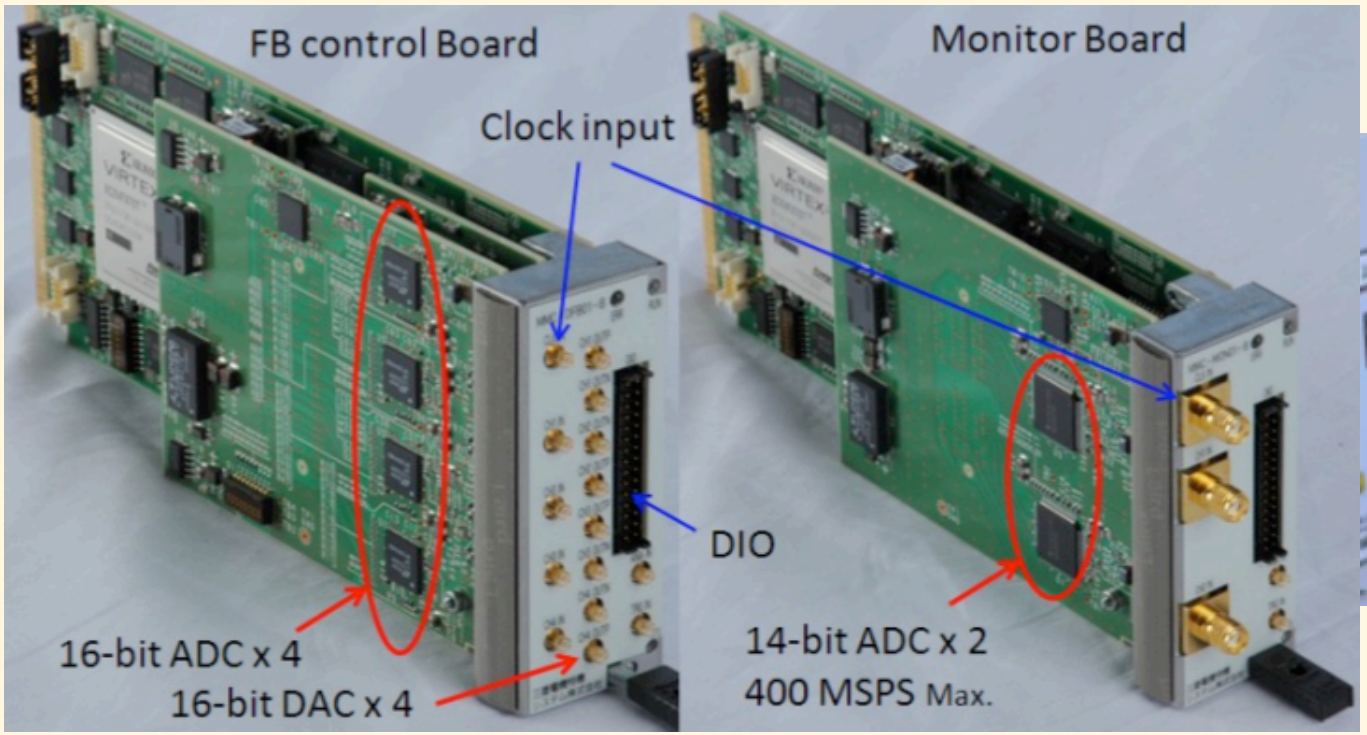
RF Group

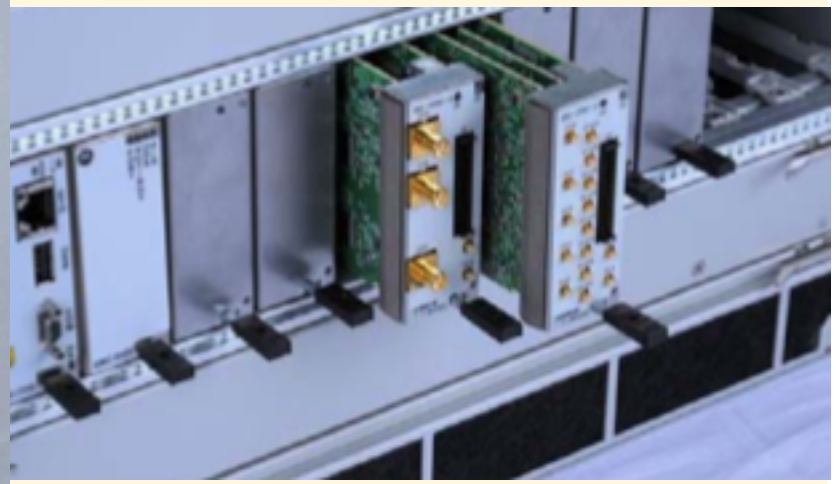
MicroTCA based LLRF Controller

- 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
  - Windriver Linux (ML507 is supported)

RF Group
Mitsubishi







More development

- FPGA controller is ready (Sep.2010)
- EPICS IOC and local display application
  - With EDM under development
- μTCA management capabilities over IPMI
- Commissioning in 2011 for STF and cERL
  - Slightly later for SuperKEKB
- Future
  - Comparison to ATCA
  - Move out of Windriver Linux (?)
  - Redundant System (?)
  - …