Control and Timing System

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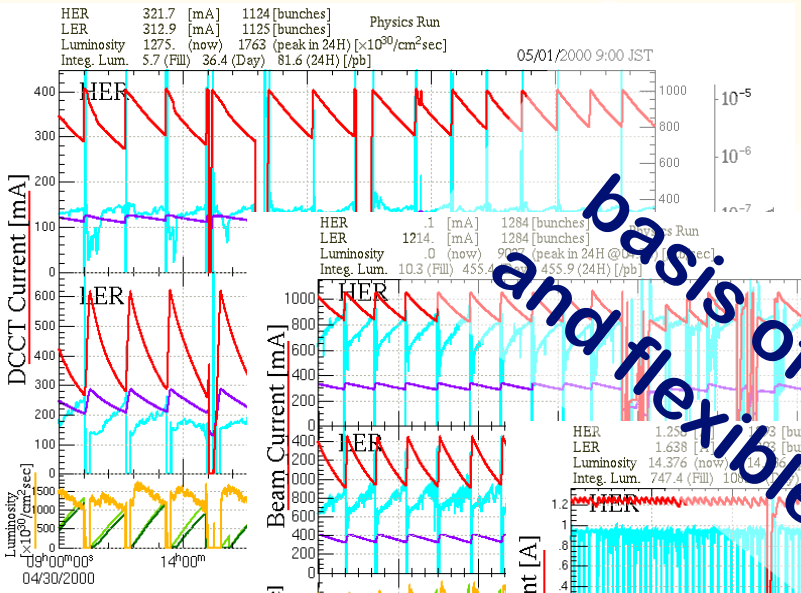
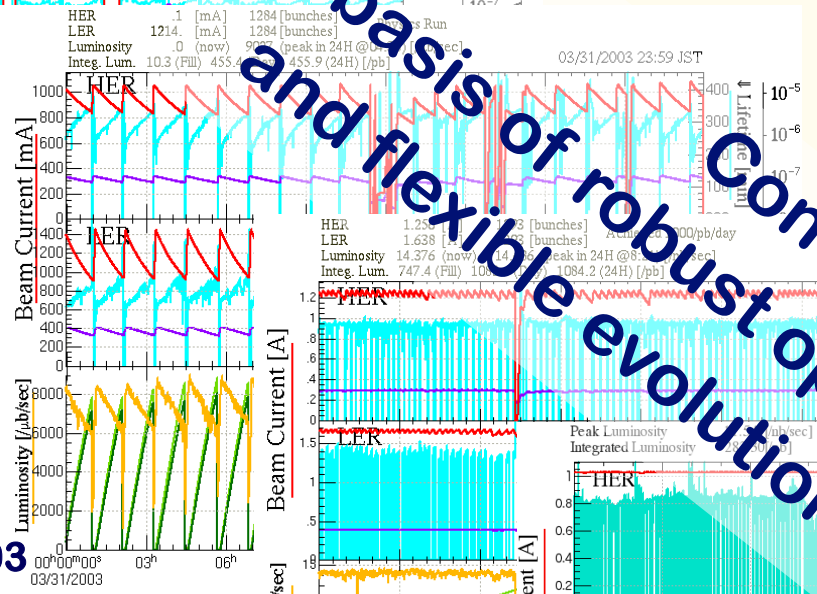
Main features of controls at KEKB

- **EPICS as Main control Software Toolkit**
  - Provided a robust basis of equipment controls
  - Reduced software design efforts much
- **Scripting Languages for Operational Software**
  - SADscript/Tk, Python/Tk, Tcl/Tk used much
    - Especially, SADscript as a bridge btw. Accelerator simulation, Numeric manipulation, Graphic interface and EPICS controls
  - Bright new idea in the morning meeting could make the operation much advanced in the evening
    - Great tool to optimize the operation

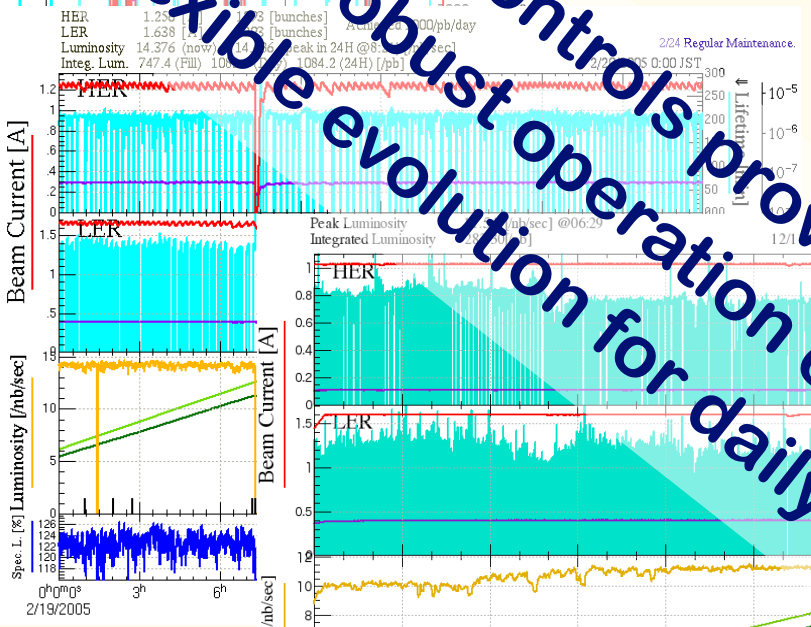
Change in Operation Modes at KEKB



May.2000



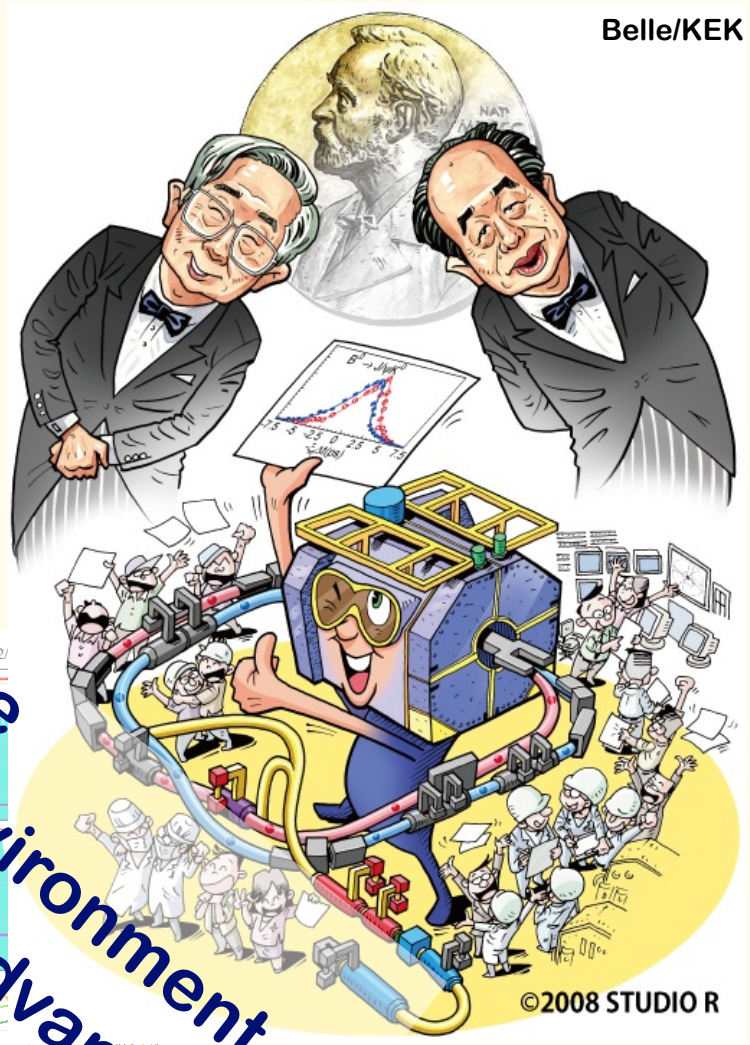
Apr.2003
Dual Bunch e+



Feb.2005
Continuous
Injections

Dec.2008
Crab Cavities and
Simultaneous Injection

basis of robust operation environment
and flexible evolution for daily advances
Controls provide



SuperKEKB Controls

- Inherit Good part of KEKB Controls
  - EPICS
  - Scripting languages
- Two Additional Concepts
  - Channel Access Everywhere
  - Dual-layer Controls
- And Other Miscellaneous Improvements
  - Rejuvenation of software / hardware

1st: CA Everywhere

- **EPICS Channel Access (CA) Everywhere**
  - Embed EPICS control software (IOC) everywhere possible
  - Reduce efforts on protocol design, testing, etc

Overview of controls at KEK

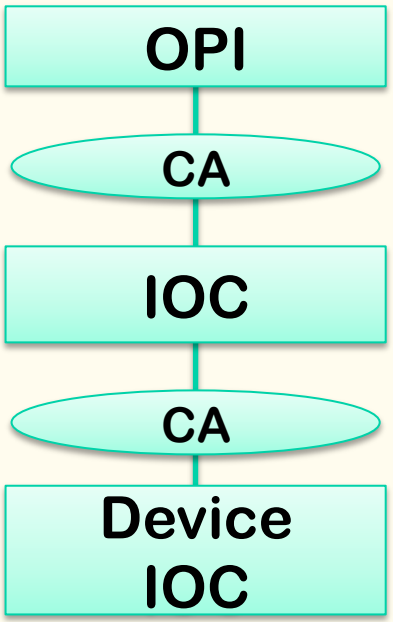
- **VME + Unix (1990~)**
  - Standard model (later EPICS) configuration
    - With several fieldbuses

- **Every controller on IP network (1993~)**
  - 2-layer physical, 3-layer in logical (Linac, J-PARC)

- **Every controller with EPICS IOC (2005~)**
  - Channel Access everywhere (CA Everywhere)
    - Good for rapid development and smooth maintenance
      - May need some consideration on network management

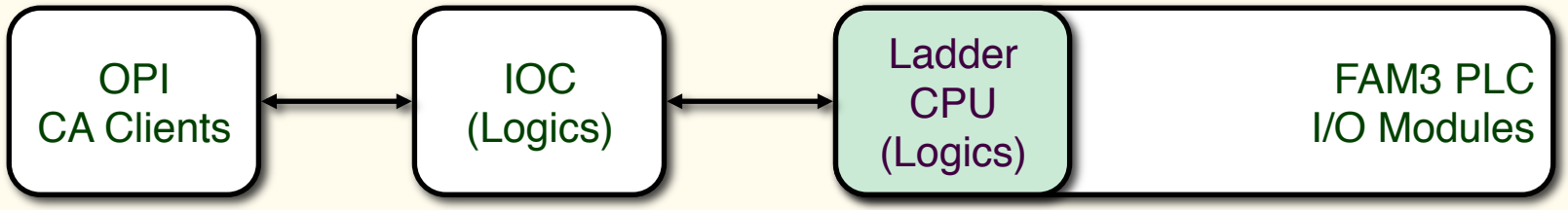
Embedded EPICS IOCs at SuperKEKB

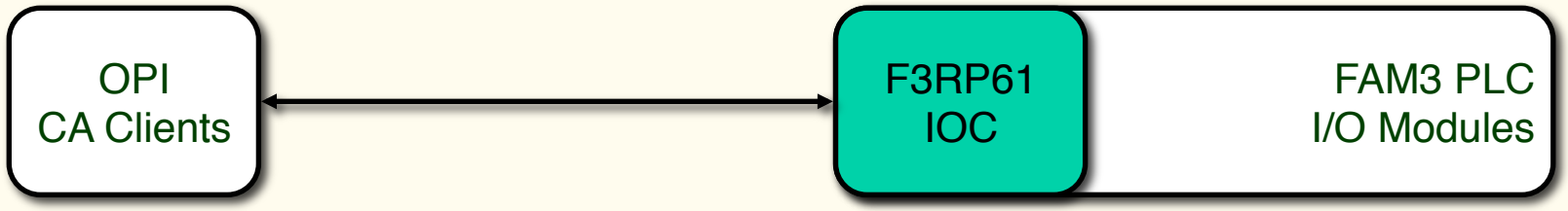
- **The same software framework on every controller**
  - Rapid development and smooth maintenance
- μTCA LLRF module: Linux/FPGA (Odagiri…)
- Yokogawa PLC: Linux CPU (Odagiri…)
- Oscillo. 50Hz measurement: Windows (Satoh…)
- MPS management :Linux/FPGA (Akiyama…)
- Timing TDC: Linux/Arm (Kusano…)
- Power modulator: Linux/FPGA (Kusano…)
- Libera BPM at 50Hz: Linux/FPGA (Satoh…)
- NI cRIO : CAS/FPGA (Odagiri…)
- Many more…



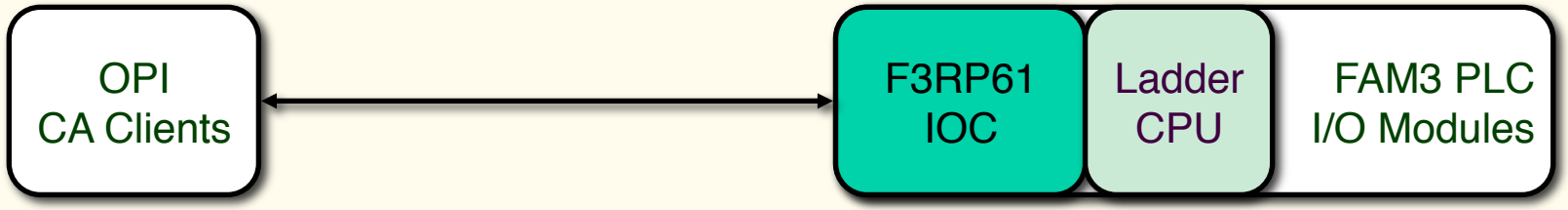
Simpler PLC Usage under EPICS

Conventional PLC usage with asynchronous access





If necessary, we can combine



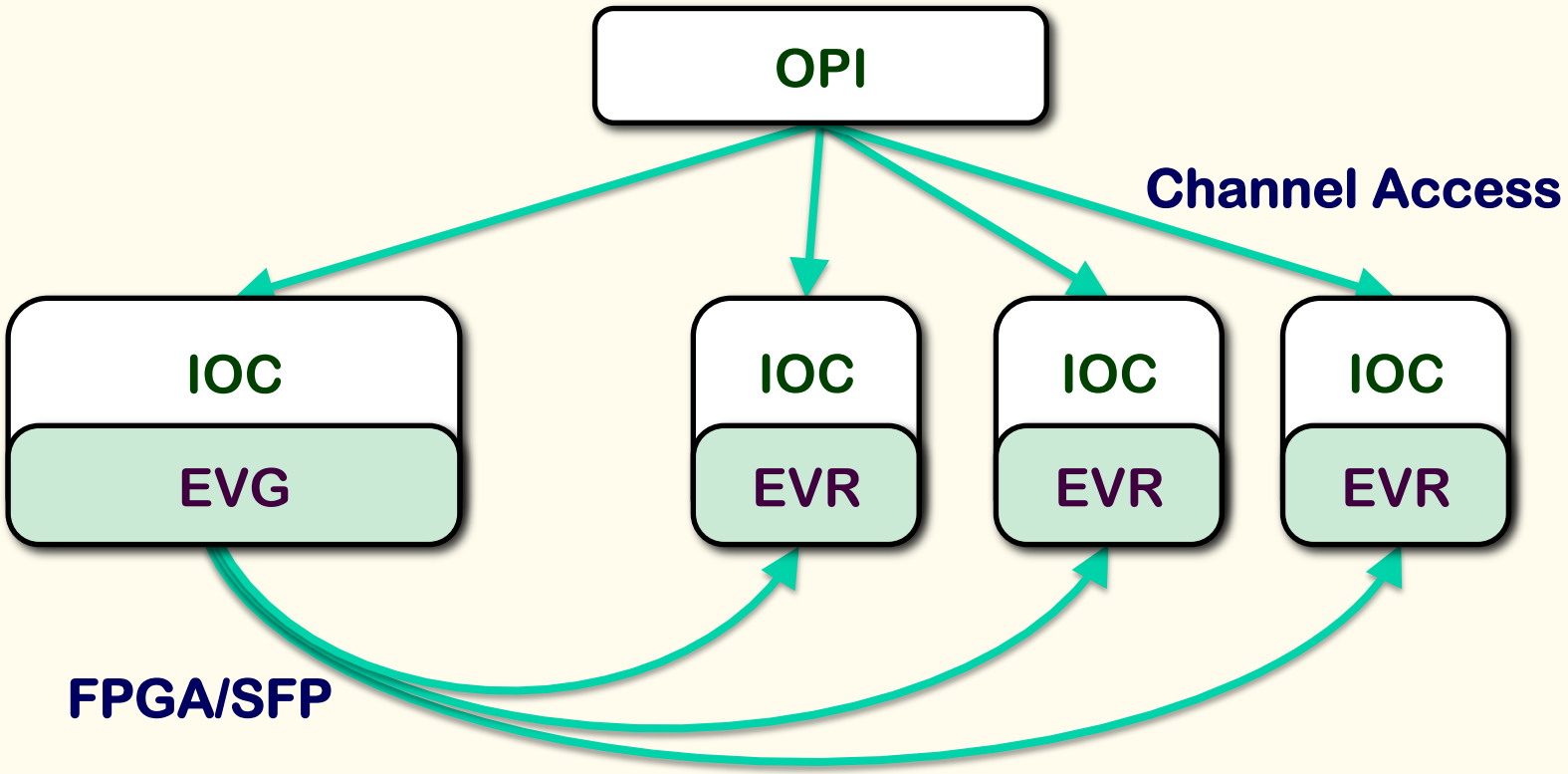
Logics are confined in PLC, and management is easier

2nd: Dual-layer Controls

- Another layer in addition to EPICS/CA
  - Event system helps EPICS with another channel
  - Additional functionality, synchronization and speed

Dual-layer Controls

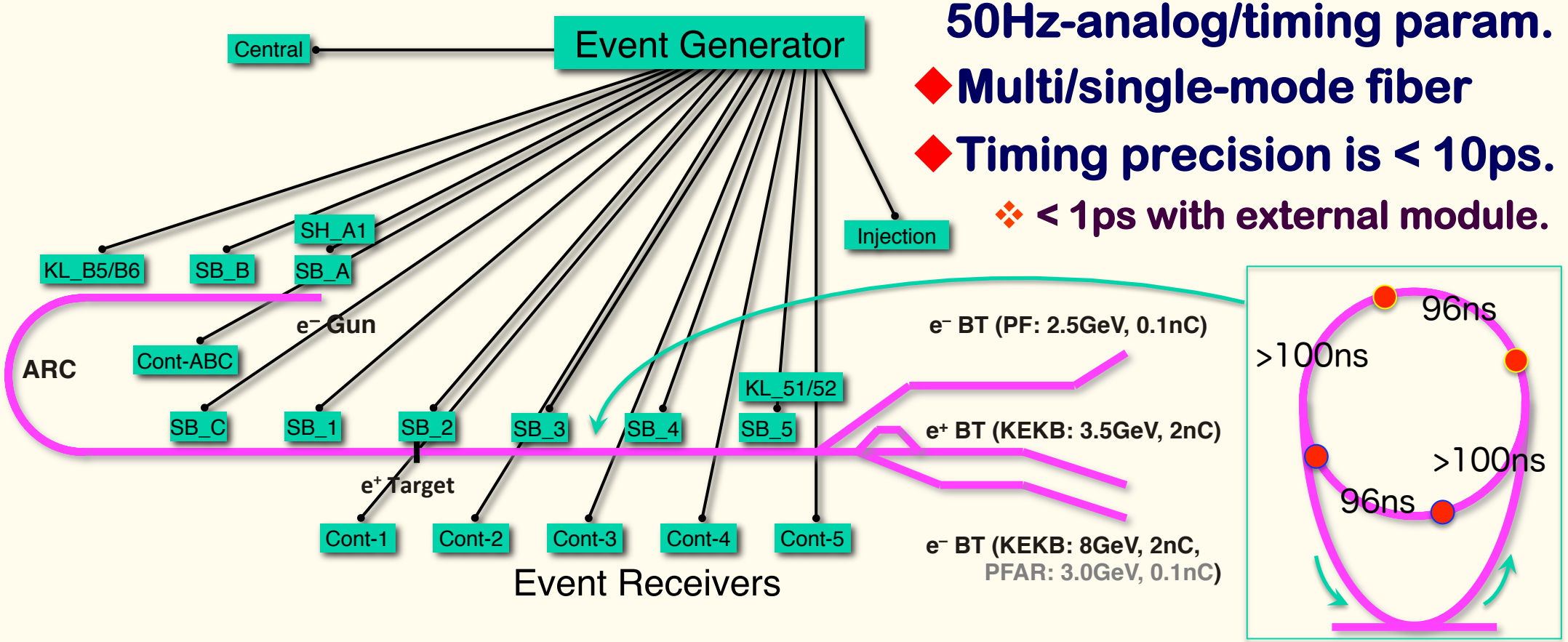
- **IOC controls via Conventional EPICS CA**
  - Above 1ms, ordered controls
- **Fast FPGA controls via SFP/Fiber**
  - 10ps ~ 100ms, 114MHz synchronous controls



Fast, Global, and Synchronous Controls

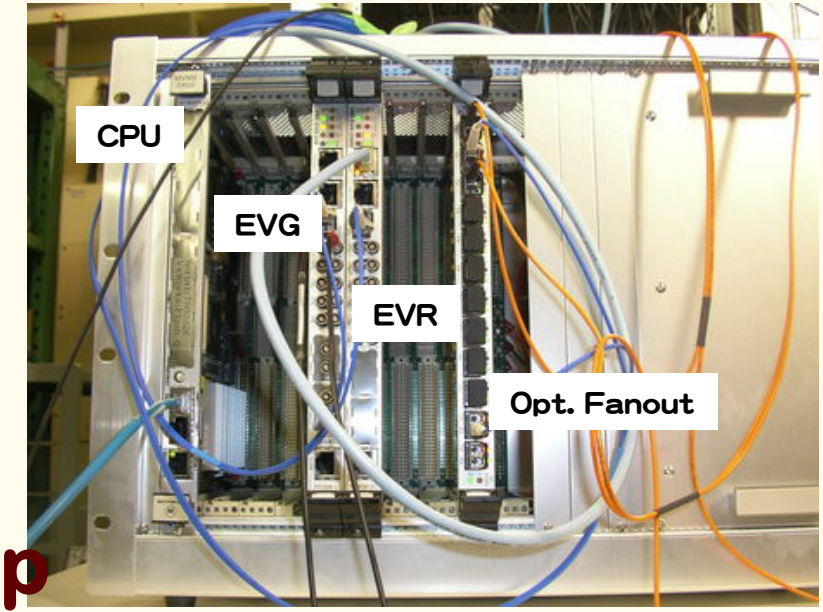
- MRF's series-230 Event Generator / Receivers
- VME64x and VxWorks v5.5.1
- EPICS R3.14.9 with DevSup v2.4.1
- 17 event receivers for now

- 114.24MHz event rate, 50Hz fiducial
- More than hundred 50Hz-analog/timing param.
- Multi/single-mode fiber
- Timing precision is < 10ps.
  - < 1ps with external module.



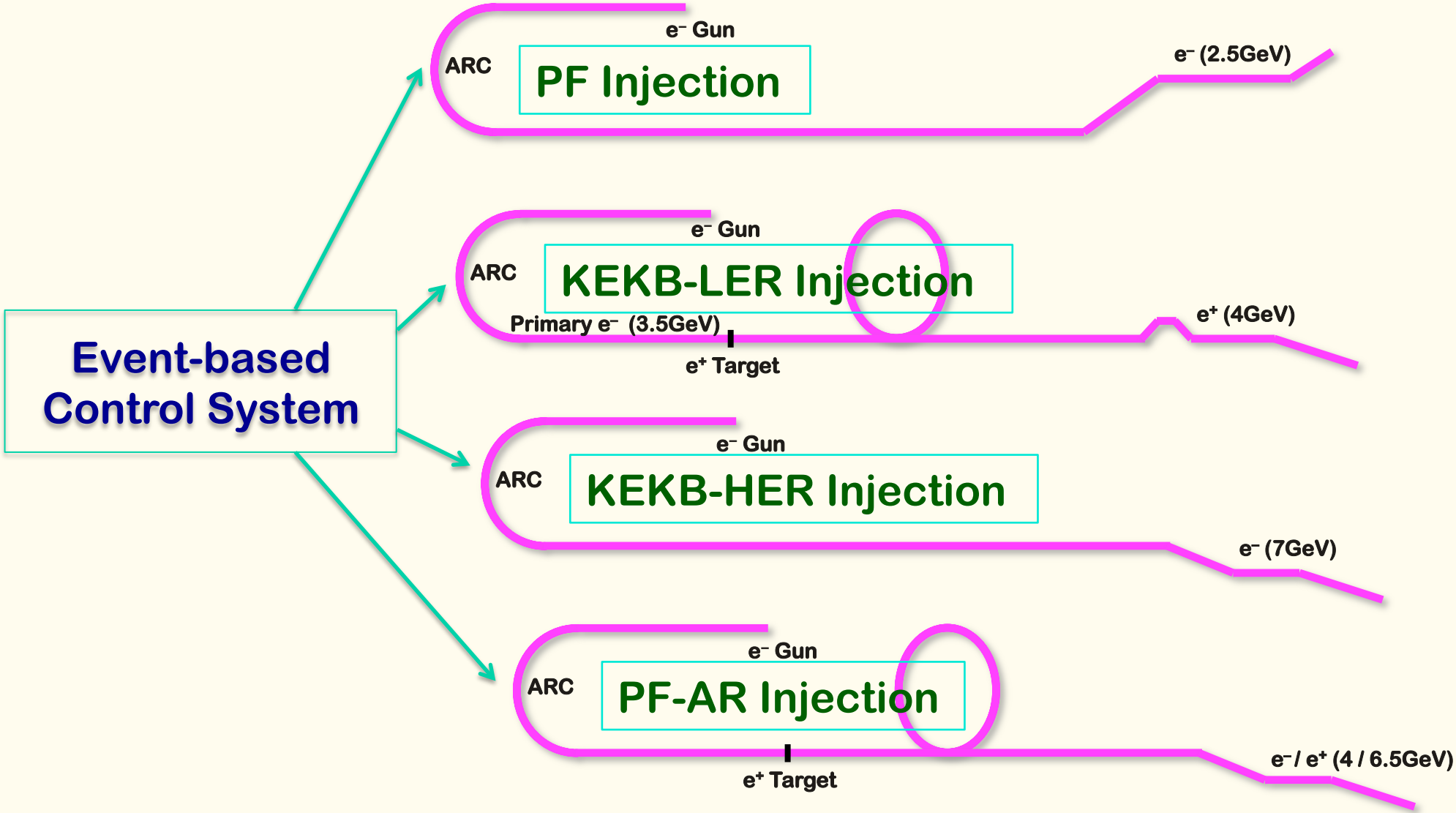
Event System Upgrade

- More event receivers required
  - Mostly VMEs, and some PLCs
    - PLC module under development at SINAP/Shanghai
- Should have more modern software
  - OS, EPICS driver, FPGA firmware
    - Collaboration in EPICS community
- Timing monitors
  - TDC were developed
- LLRF monitors
  - Under development by RF group



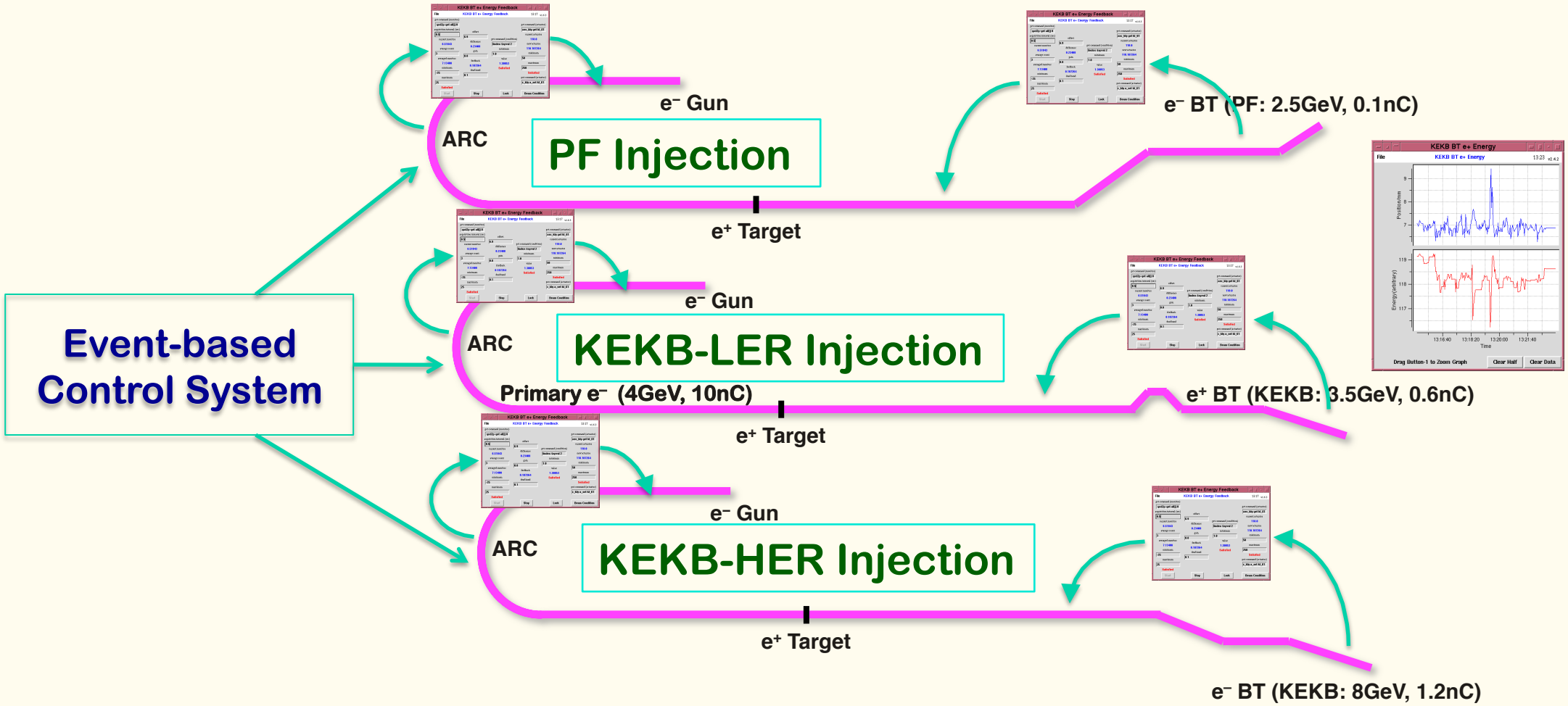
One Machine, Multiple Virtual Accelerators (VAs)

- Independent parameter set for each VA, one of VAs is active at a time



Multiple Closed Loop Controls Overlapped

- Closed loops can be installed on each VA independently
  - Tested at KEKB

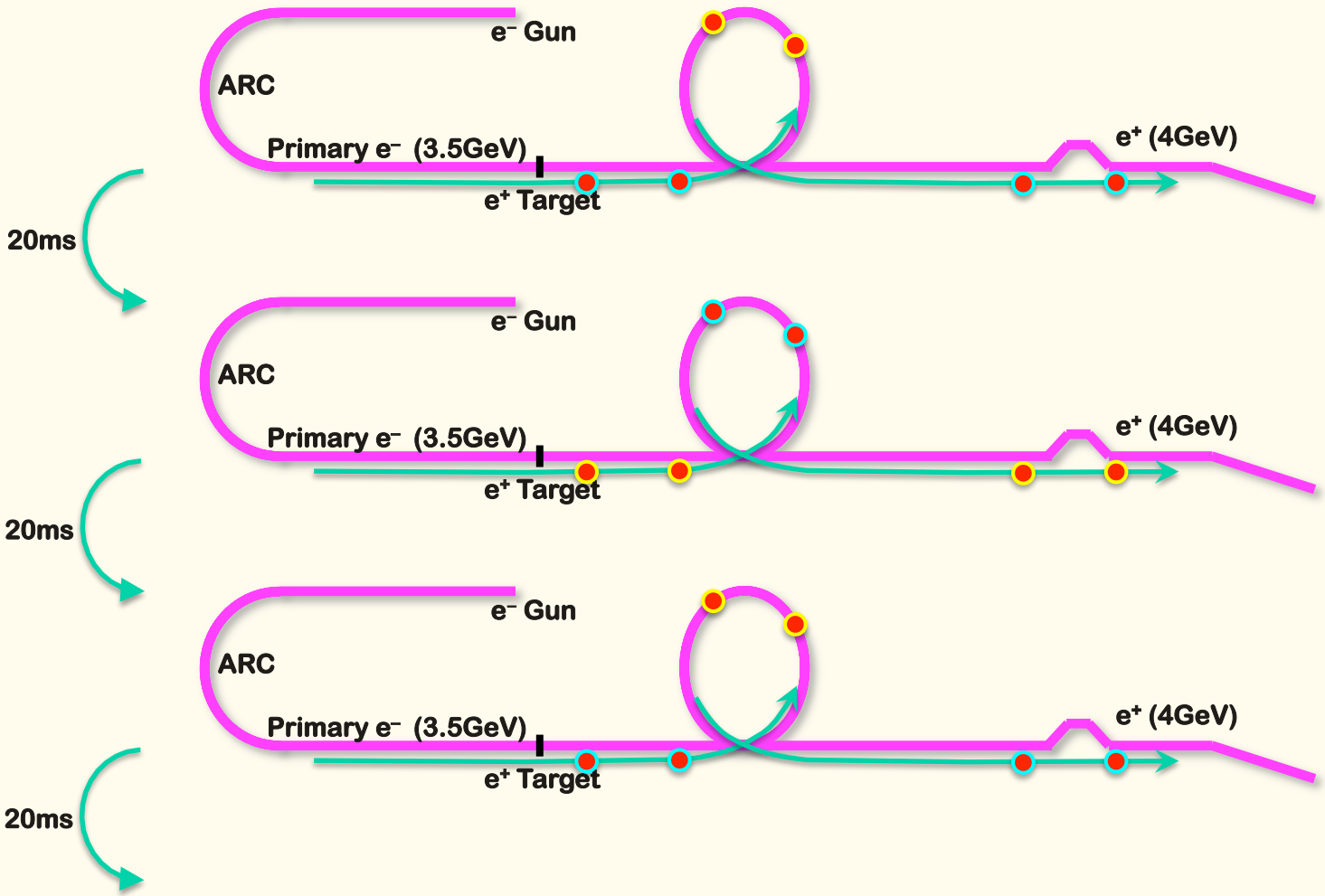


Event and Timing System

- **Beam mode should be modulated pulse by pulse**
  - **Somewhat tricky in controls and timing**

Example of Beam Mode Pattern : e+ 50Hz

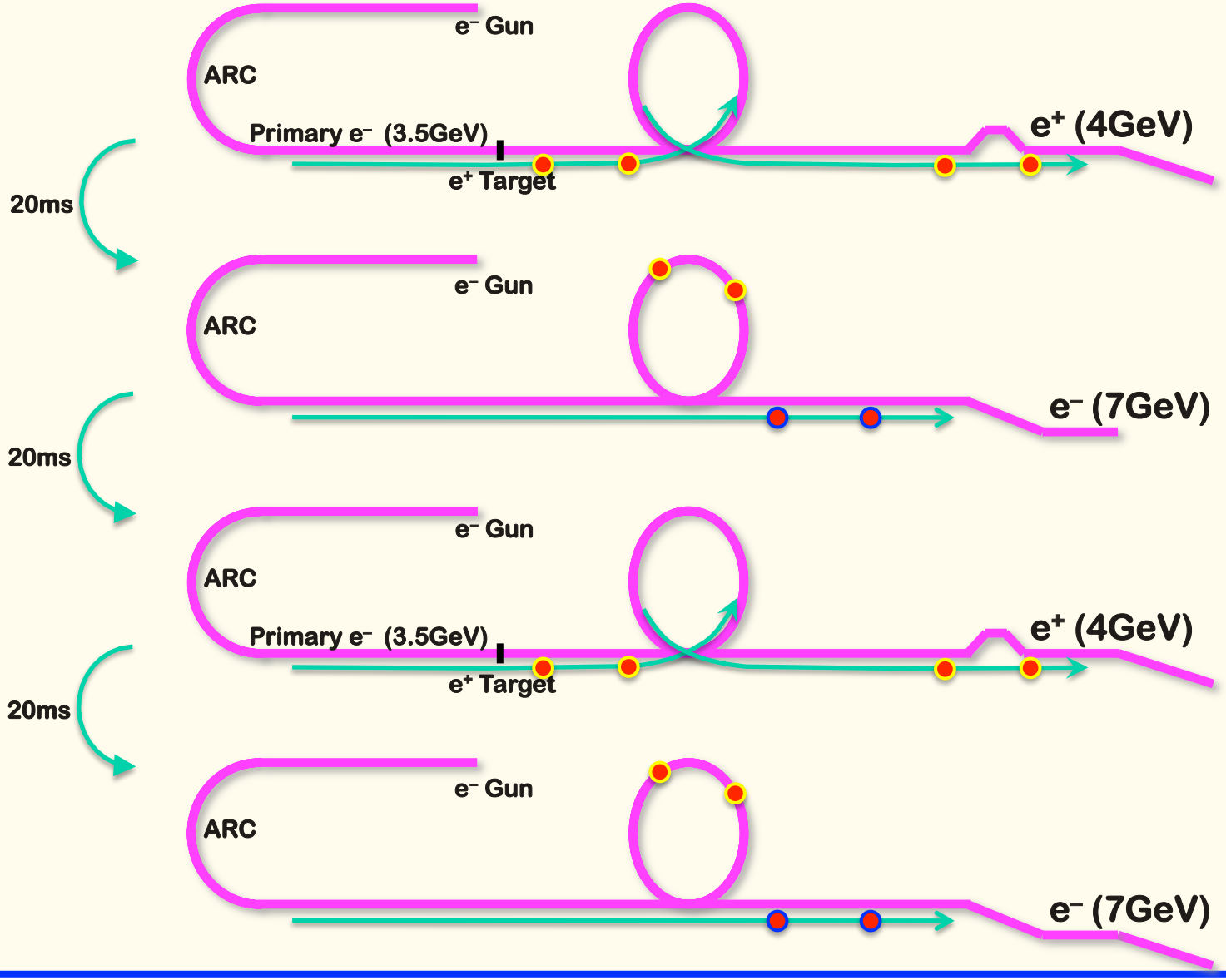
- Extract e+ (bunch selected at MR), Inject e+ (bunch selected at DR)



- Simple (?) beam juggling needed. Pulses are coupled tightly

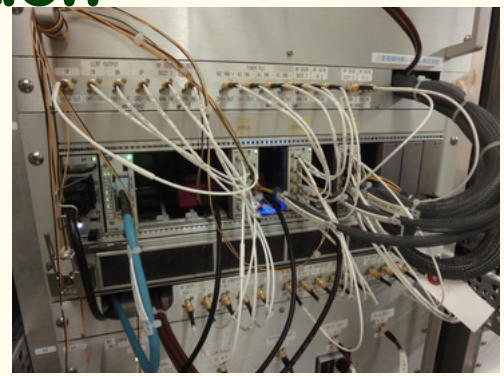
Example of Beam Mode Pattern : e+ 25Hz / e− 25Hz

- Interleaved e+ and e-, dependency between pulses mostly decoupled



Bucket Selection

- **Small challenge**
  - Bucket bunch current equalization at MR
  - Bucket spacing at DR for Inj./ext. kickers
  - At least, Linac after DR should have RF phase modulated every pulse
  - Also, DR will have RF phase modulated every pulse
    - Recommended by the last review committee
    - That relax the pulse-to-pulse coupling condition
  - More stability monitors are installed
    - Timing monitors (TDC), LLRF monitors
    - Linac long distance clock monitor tested



PF-AR Injection with e^+

- **Small challenge**
  - Common BT line between SuperKEKB and PF-AR e^+
  - Independent circumference compensation
    - RF frequency change independently
      - KEKB ~ 4×10^{-7}, PF/PF-AR ~ $4 \sim 20 \times 10^{-6}$ (depth dependent)
  - Damping ring will use SuperKEKB MR frequency
    - DR 508.9MHz vs PF-AR 508.6MHz
- **PF-AR will fix RF frequency at Injection**
  - To maintain the injection phase synchronization
  - Near future PF-AR will have direct 6.5GeV e- injection, and the situation will be relaxed

Other Upgrades (1)

- **Rejuvenation of basic control components**
  - On-going year-by-year
    - Computer / file server
    - Redundant control network
    - Console
    - Power line, power supply
    - Rack fan, filter
    - Seminars, training
    - etc.

Other Upgrades (2)

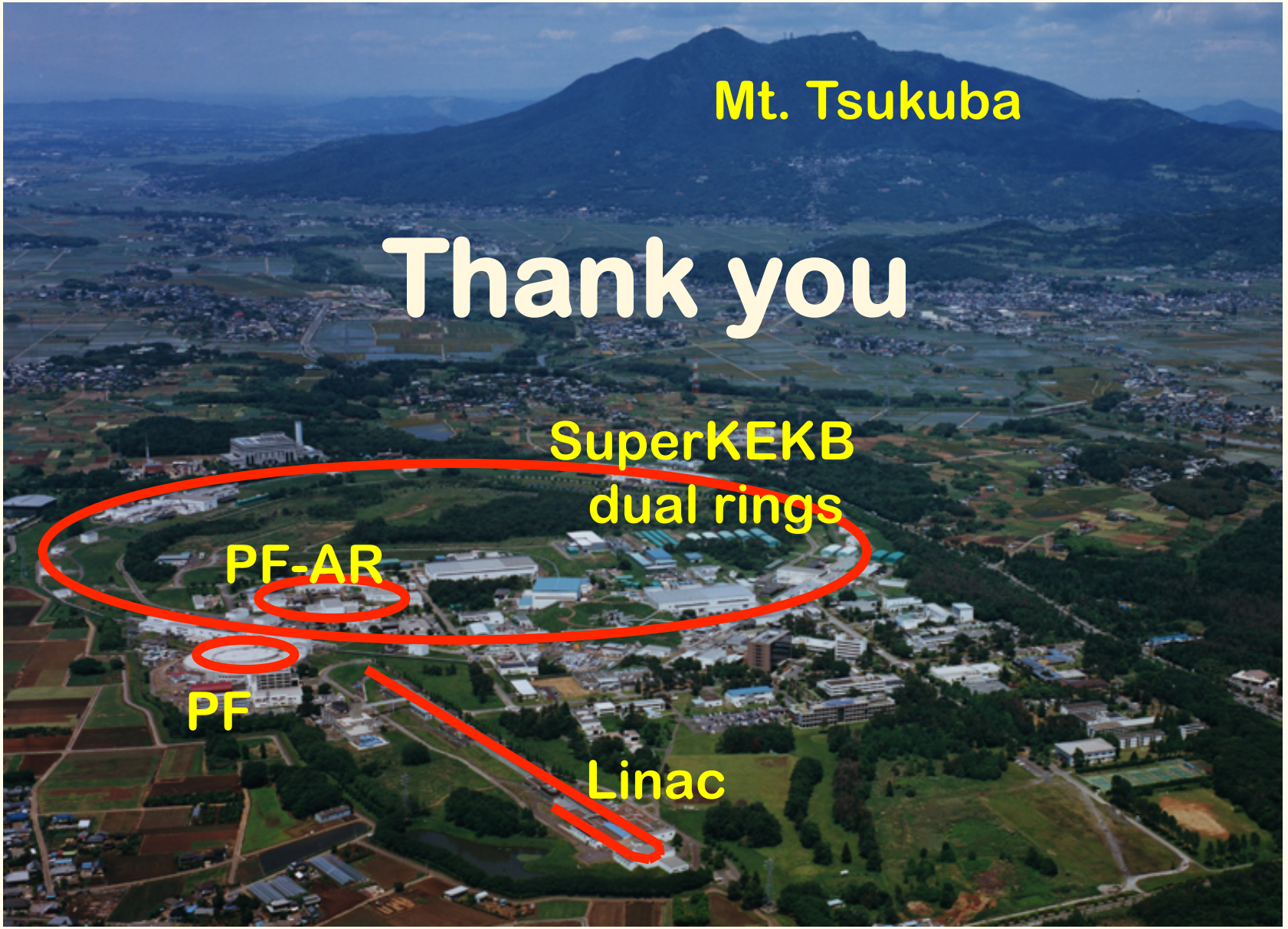
- Control System Studio (CSS)
  - In addition to scripting languages
  - More robust
  - Development and runtime environment are unified
  - Actively developed in EPICS community
  - Invited Kay Kasemir from ORNL/SNS
  - Ask Cosylab to tailor to our environment
- Several operation software under CSS are under evaluation
  - At Linac and PF-AR
  - Channel archiver, Alarm handler, Synoptic display manager, etc

Other Upgrades (3)

- **Linac Beam Position Monitors**
  - 10-micron resolution required
    - wakefield compensation
  - 50Hz pulse-to-pulse modulation
  - Two bunches in a pulse (96-ns separation)
  - Attenuator controls (~100-times)
    - Libera/i-Tech or local company
- **Linac-BT Wire Scanners**
  - 50Hz pulse-to-pulse modulation
  - Two bunches in a pulse (96-ns separation)
  - Possible correction by near-by BPMs
  - Replacing old CAMAC, etc
    - Collaboration with VECC/India

Conclusion

- **Steady Improvements/Developments are underway**
  - With additional concepts of CA everywhere (or embedded EPICS controller) and dual-layer controls (or event-based synchronous controls)
- **International Collaboration is also Proceeding**
- **With Phronesis** (Greek: Practical wisdom, Ability to understand the Universal Truth), **we believe we can achieve the goal**


Mt. Tsukuba
Thank you
SuperKEKB
dual rings
PF-AR
PF
Linac