Control System Achievement at KEKB and Upgrade Design for SuperKEKB

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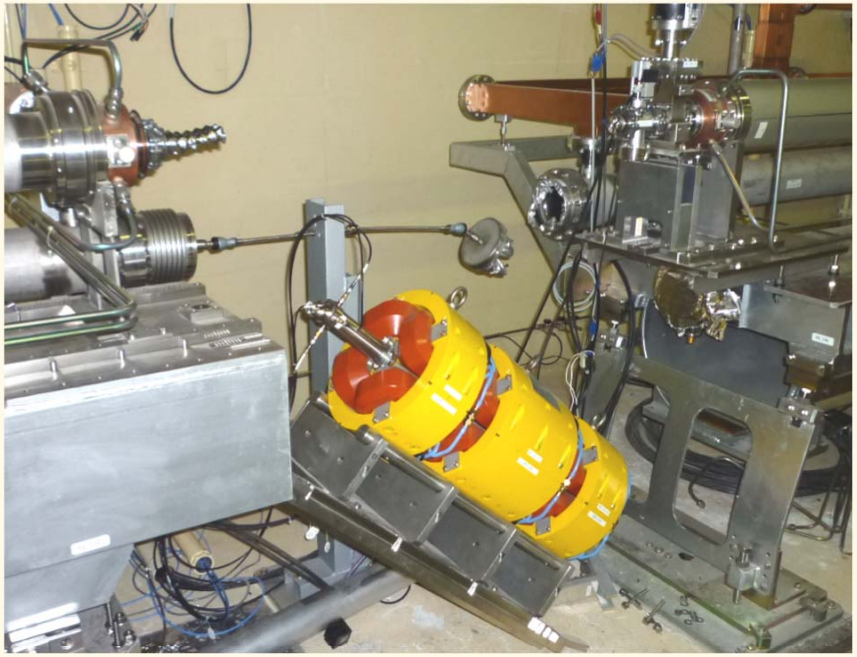
(Control Group, SuperKEKB Ring/Linac)

October 2011.

Earthquake in March – Thanks

- Thank you so much for your warm messages from all over the world.



- Operation will be normal soon.

KEKB Controls 1998 - 2010

EPICS as Main control Software Toolkit

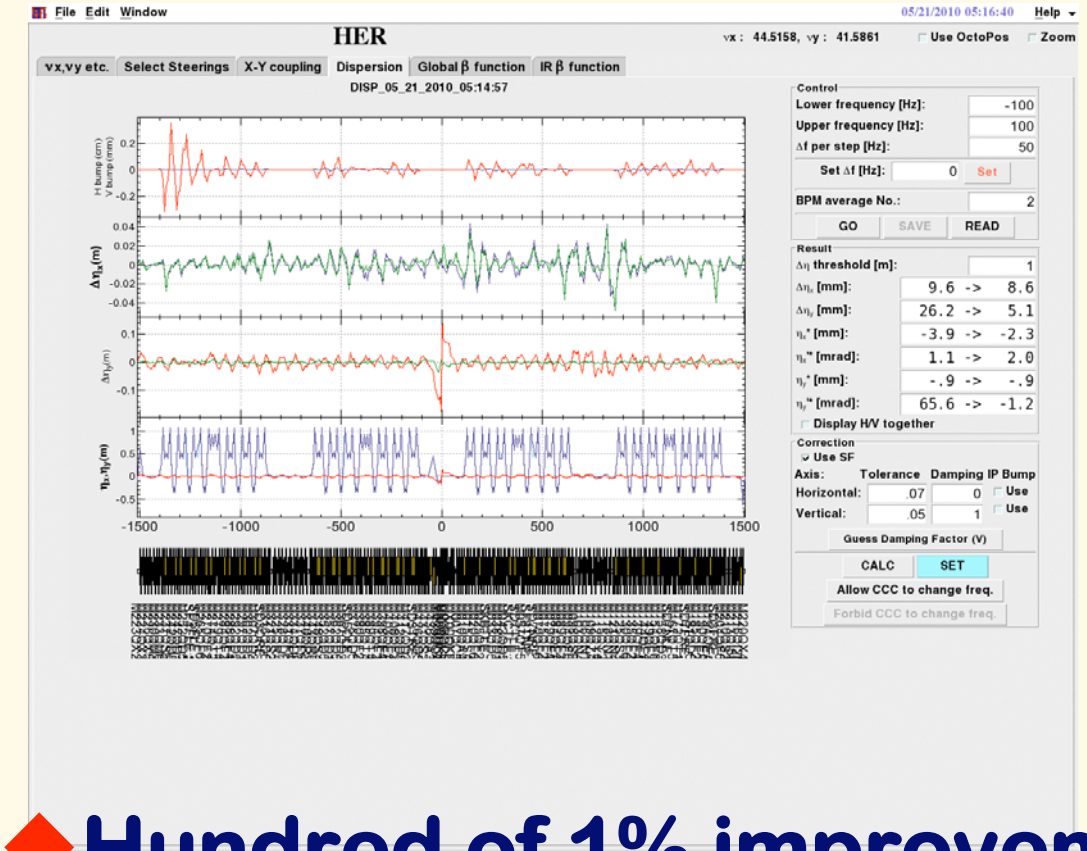
- Became one of de-facto standard at 1995
- Several fieldbuses were incorporated
  - VME, VXI, CAMAC, ArcNet, GPIB, etc
- Reduced software design efforts much

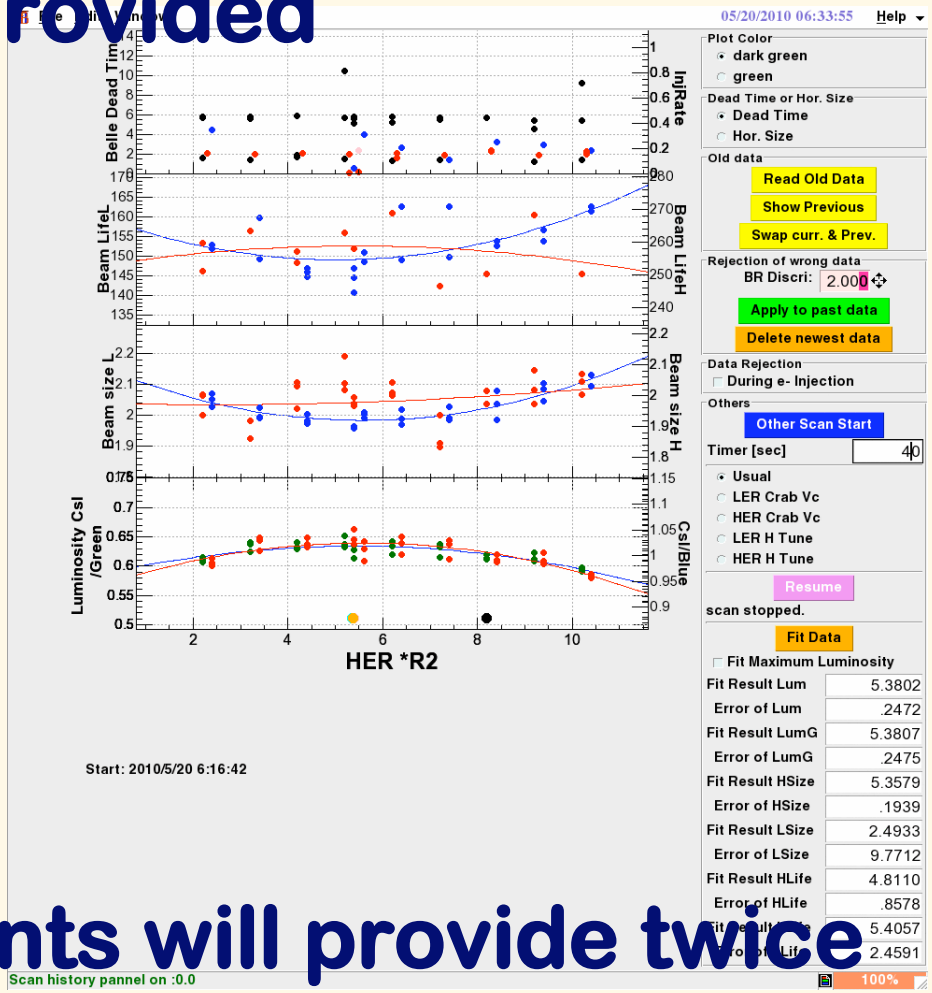
Scripting Languages for Operational Software

- 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

SADscripts/Tk

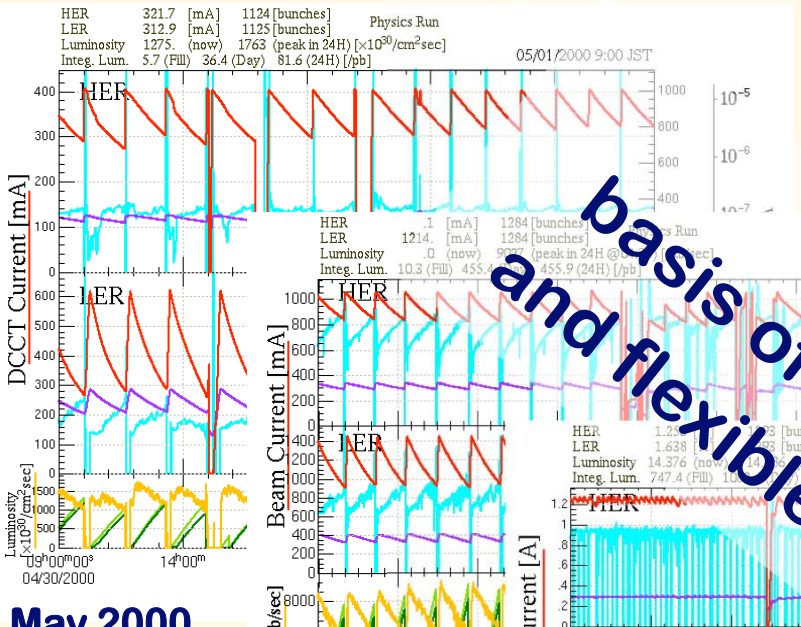
- Many machine diagnostic and correction/ feedback tools should be provided



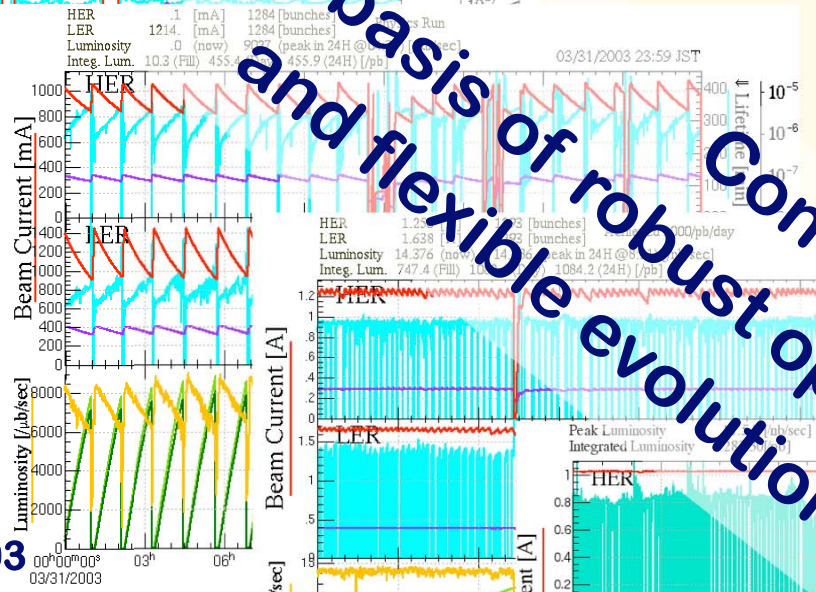


- Hundred of 1% improvements will provide twice better performance, rapidness is important

Change in Operation Modes at KEKB

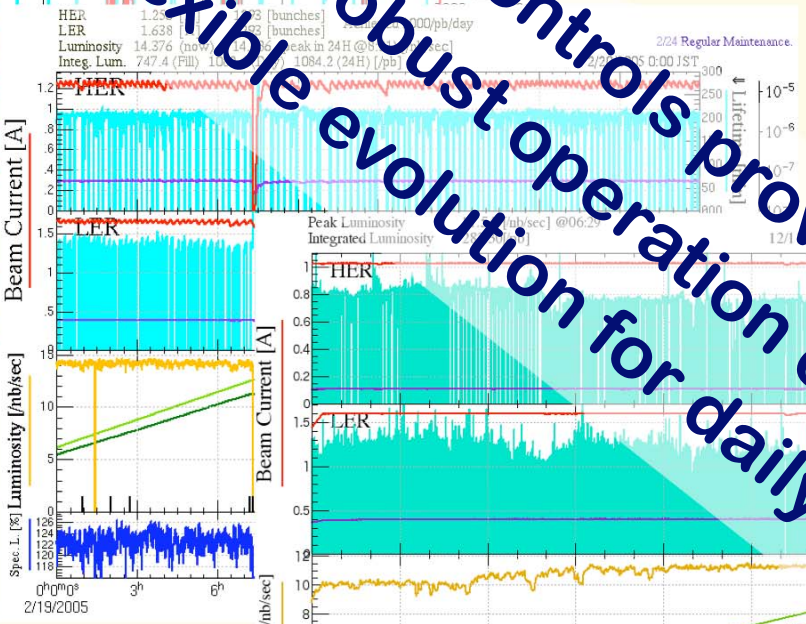


May.2000



Apr.2003

Dual Bunch e+



Feb.2005

Continuous

Injections

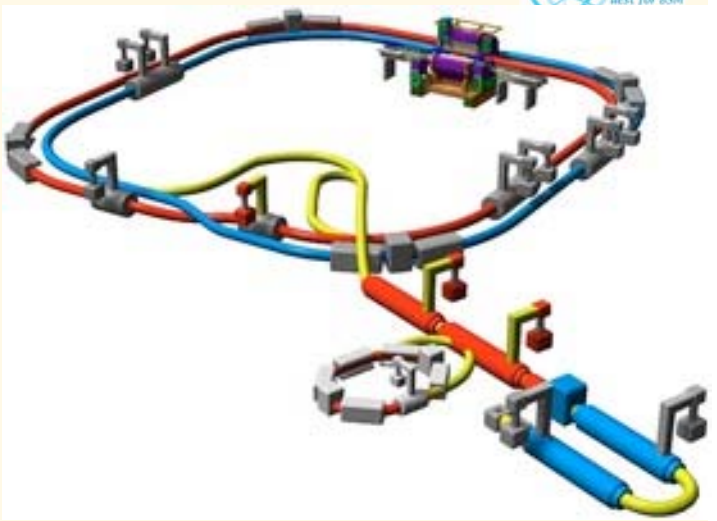
Dec.2008

Crab Cavities and

Simultaneous Injection

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

SuperKEKB



- **Electron-positron asymmetric collider**
  - Based on a decade of successful operation at KEKB
- **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

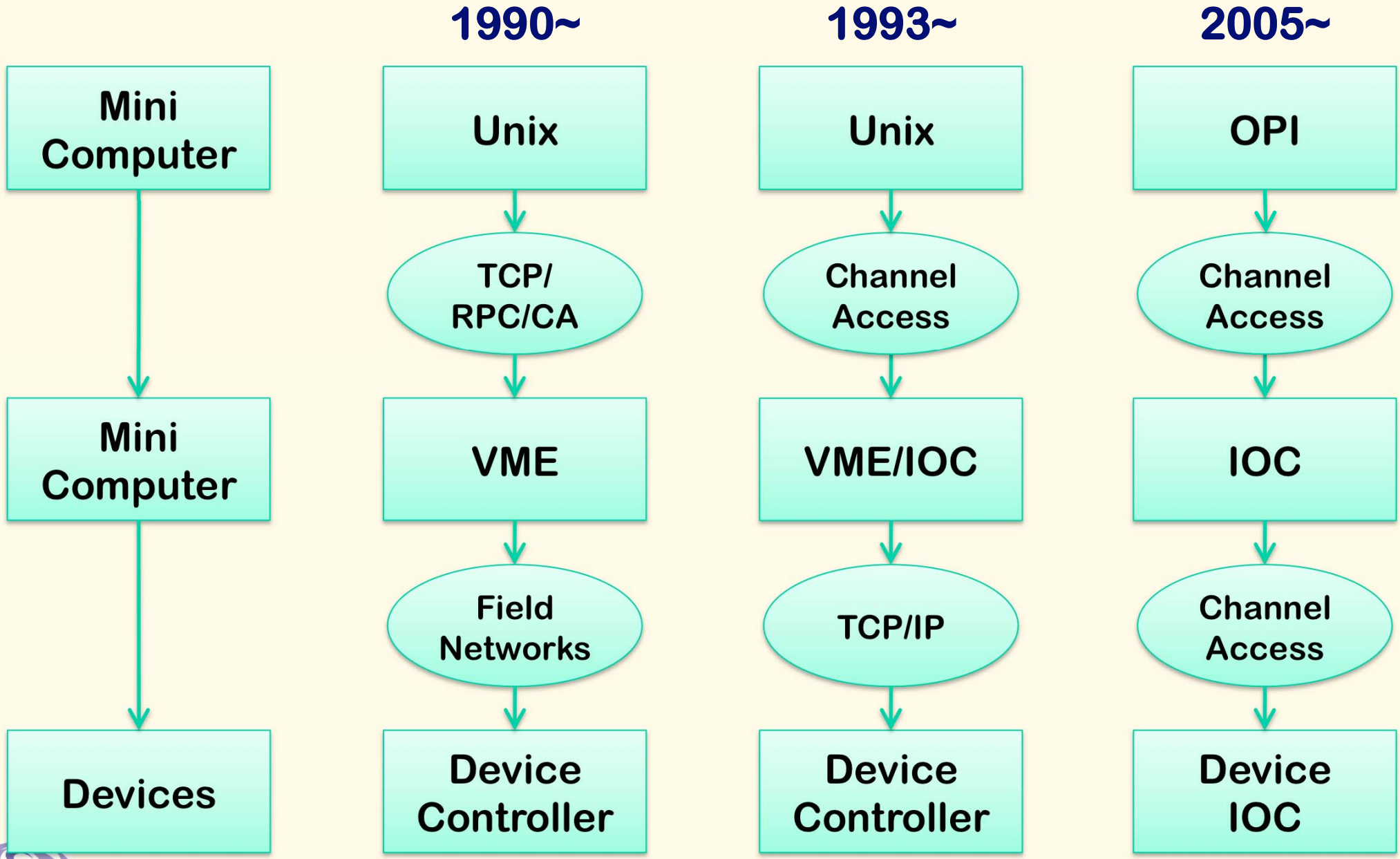
SuperKEKB Controls

- **Inherit Good part of KEKB Controls**
  - EPICS
  - Scripting languages
  - With simple rejuvenation of software/hardware
- **Two Additional Concepts**

1st: CA Everywhere

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

Transition of Architecture



Overview of controls at KEK

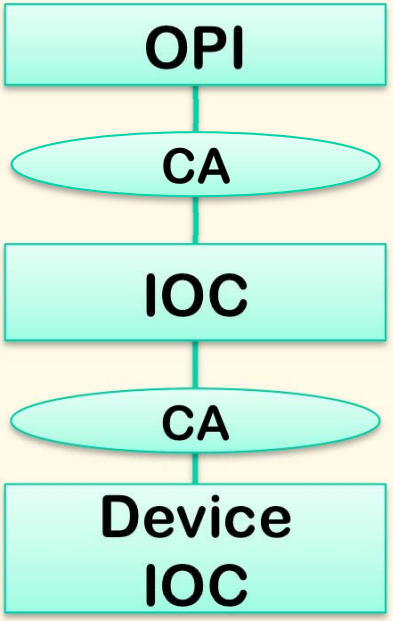
- **VME + Unix (1990~)**
  - Standard model (later EPICS) configuration
    - With several fieldbuses

- **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

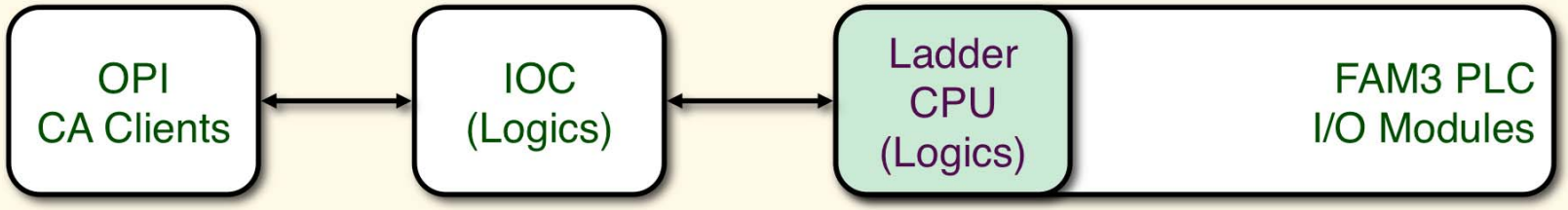
Embedded EPICS IOCs at (Super)KEKB

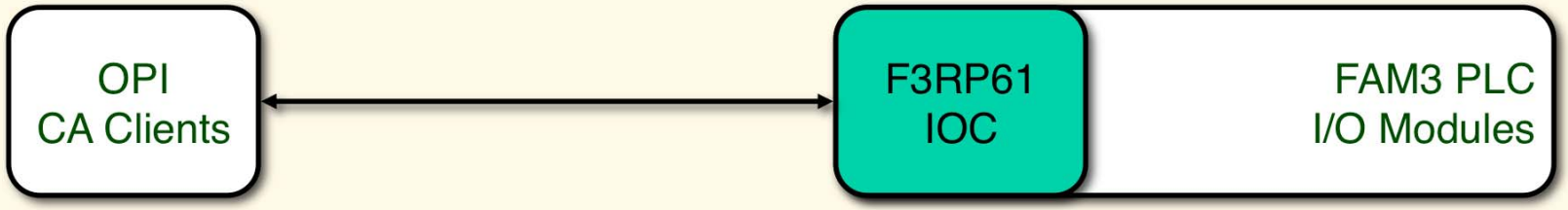
- **Not only information server, but also the same software framework on every controller**
  - Rapid development and smooth maintenance
- μTCA LLRF module: Linux/FPGA (Odagiri…) THDAULT05
- Yokogawa PLC: Linux CPU (Odagiri…)
- Oscillo. 50Hz measurement: Windows (Satoh…)
- MPS management :Linux/FPGA (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…



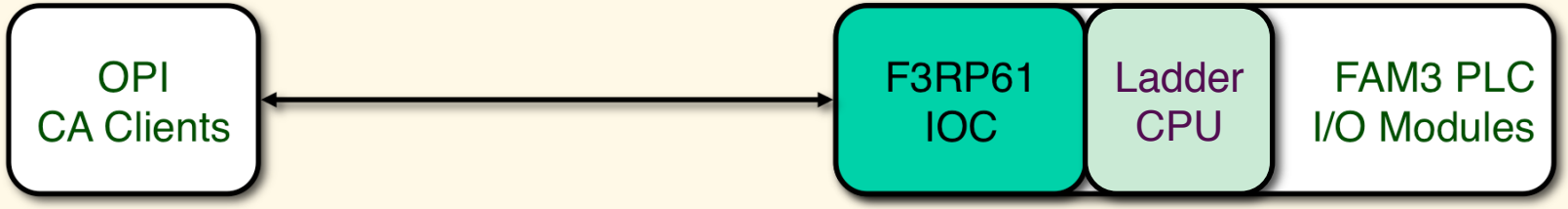
Simpler PLC Usage under EPICS

Conventional PLC usage with asynchronous access





If necessary, we can combine



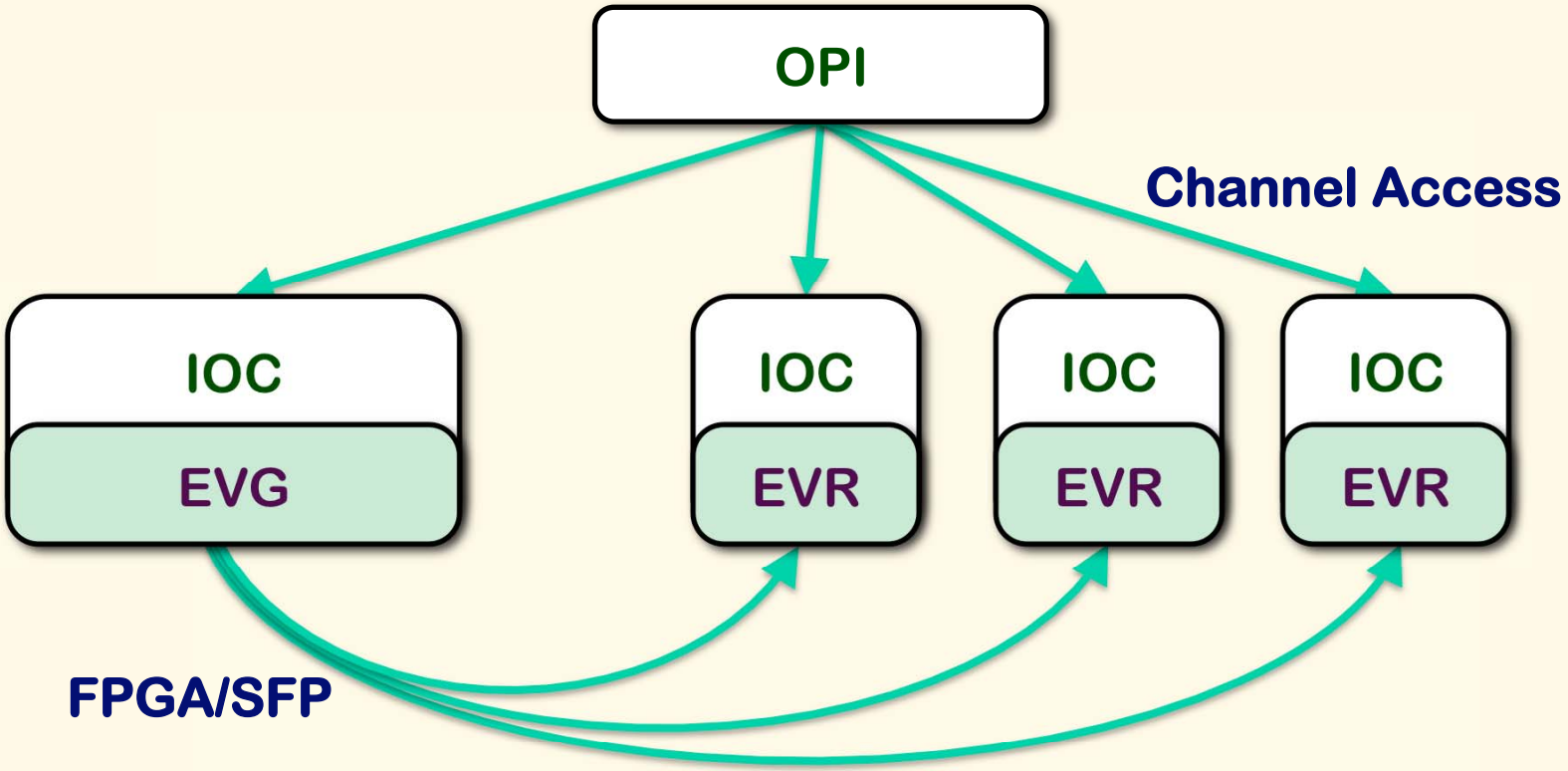
Logics are confined in PLC, and management is easier

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

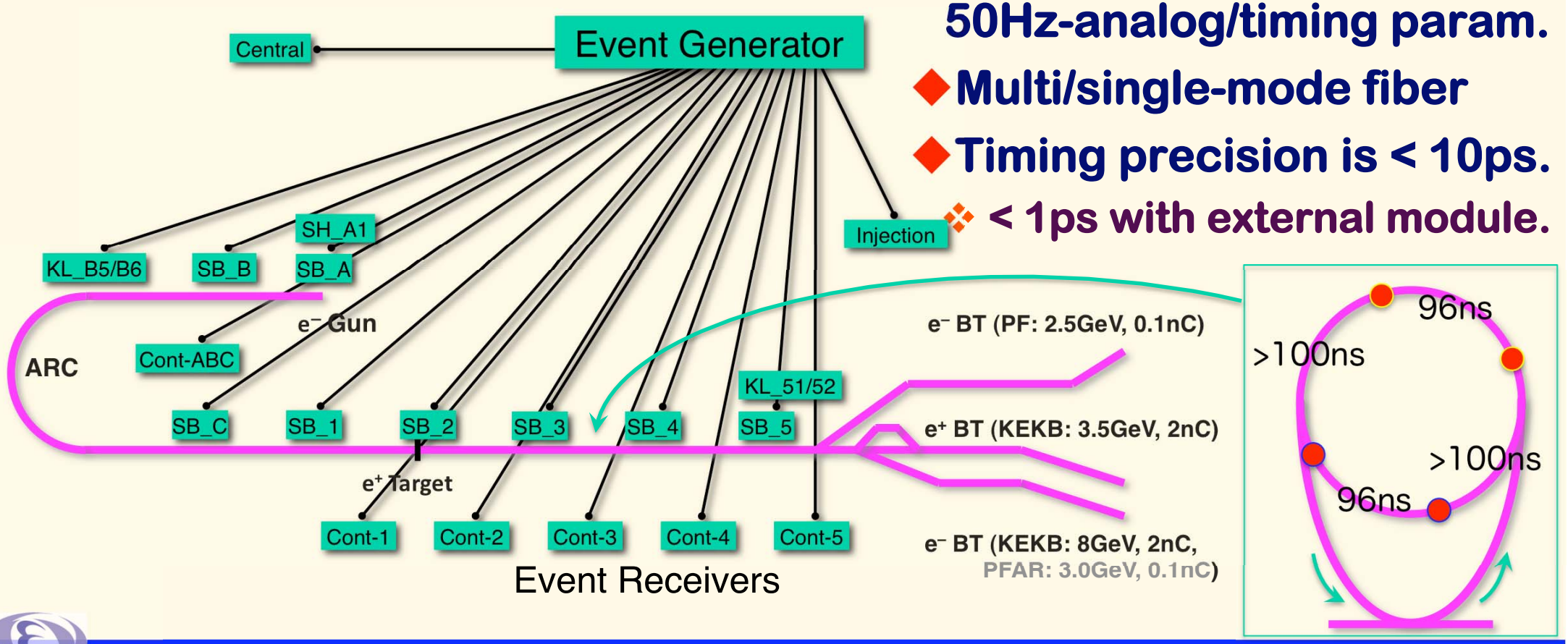
- **IOC controls via Conventional EPICS CA**
  - Above 1ms, ordered controls
- **Fast FPGA controls via SFP/Fiber**
  - 10ps ~ 100ms, 114MHz synchronous controls



Fast Global 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 up to now

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



Event Manipulation

Human Operator

Injection Programs

Flexible with script and reliable/fast with FPGA.

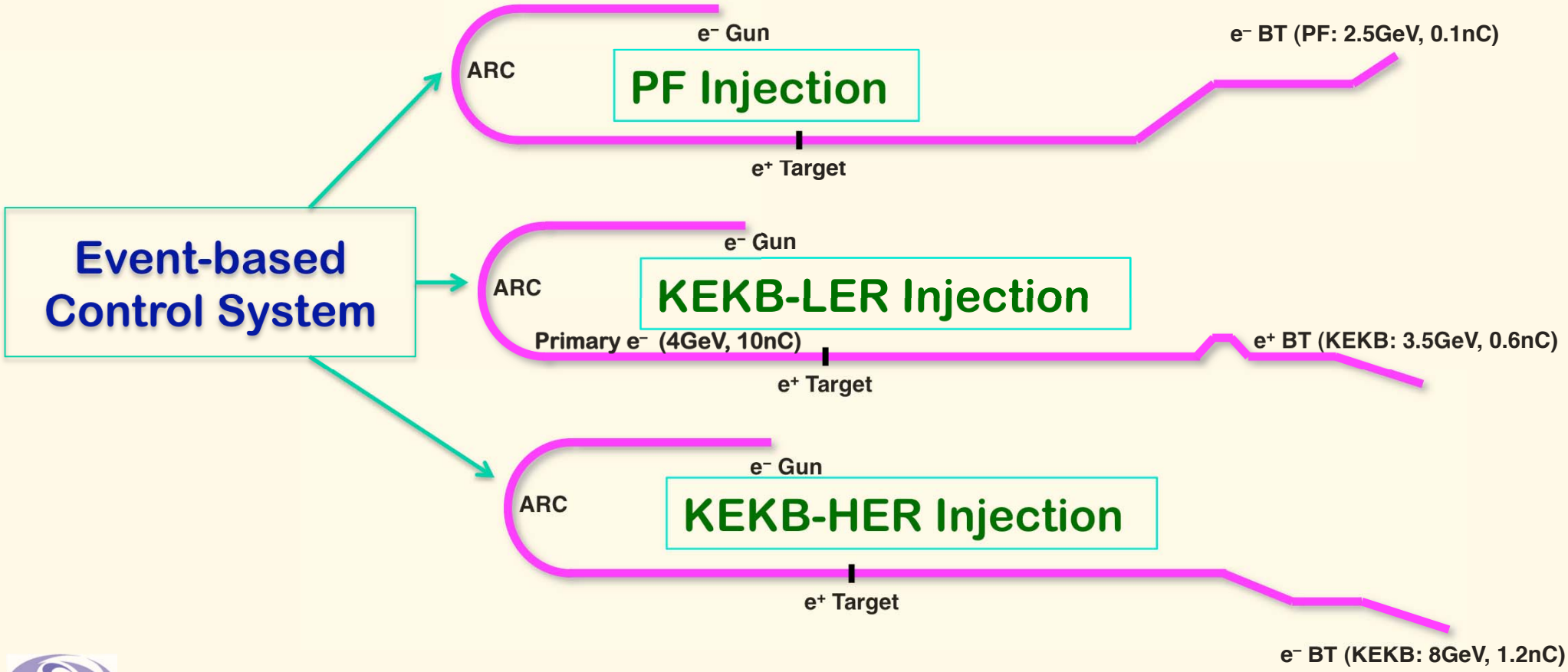
Arbitrate and Generate Beam Mode Pattern (in PythonTk)
- considering priorities of the ring accelerators
- equalizing pulsed power supply interval
- in arrays of length 2 (40ms) to 500 (10s)
- each element corresponds to a 20-ms time slot and a beam mode

Generate Events for the Next 20-ms Time Slot (in Event Generator)
- reading two consecutive elements from the beam mode pattern
- generate several events for the next pulse
- generate preparation events for the next after next

Generate Signals based on Received Events (in Event Receiver)
- generate pulsed signals as prepared in the previous time slot
- program the signals (analog value, delays, etc) for the next
- start to generate analog signals for the next

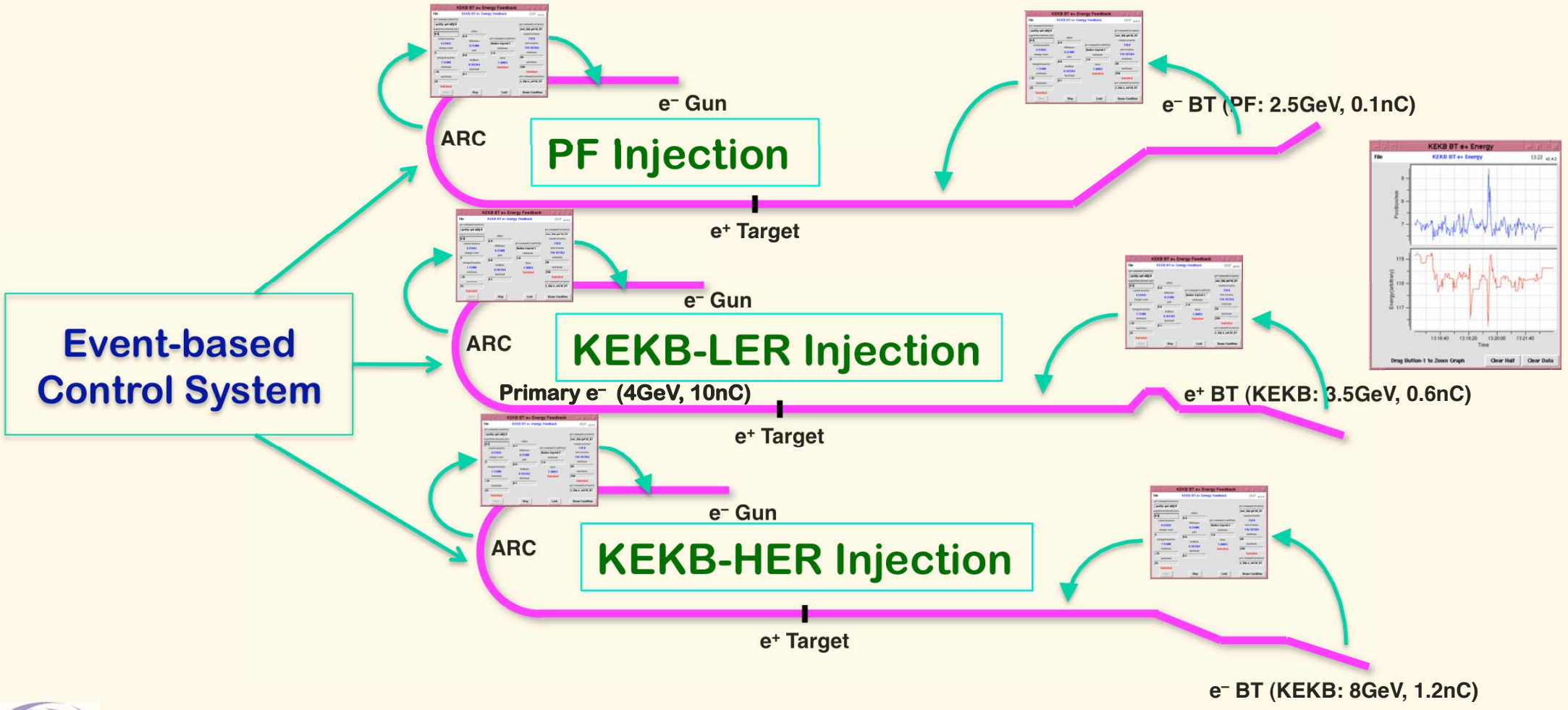
One Machine, Multiple Virtual Accelerators (VAs)

- **Control/Monitor are carried dependent on a VA**
  - Mostly independent between VAs
- **Independent parameter set for each VA, one of the VAs is controlled at a time**
  - VAs for Injections (HER (e-), LER (e+), PF, PF-AR) and Linac-only in SuperKEKB project



Multiple Closed Loop Controls Overlapped

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



Towards SuperKEKB

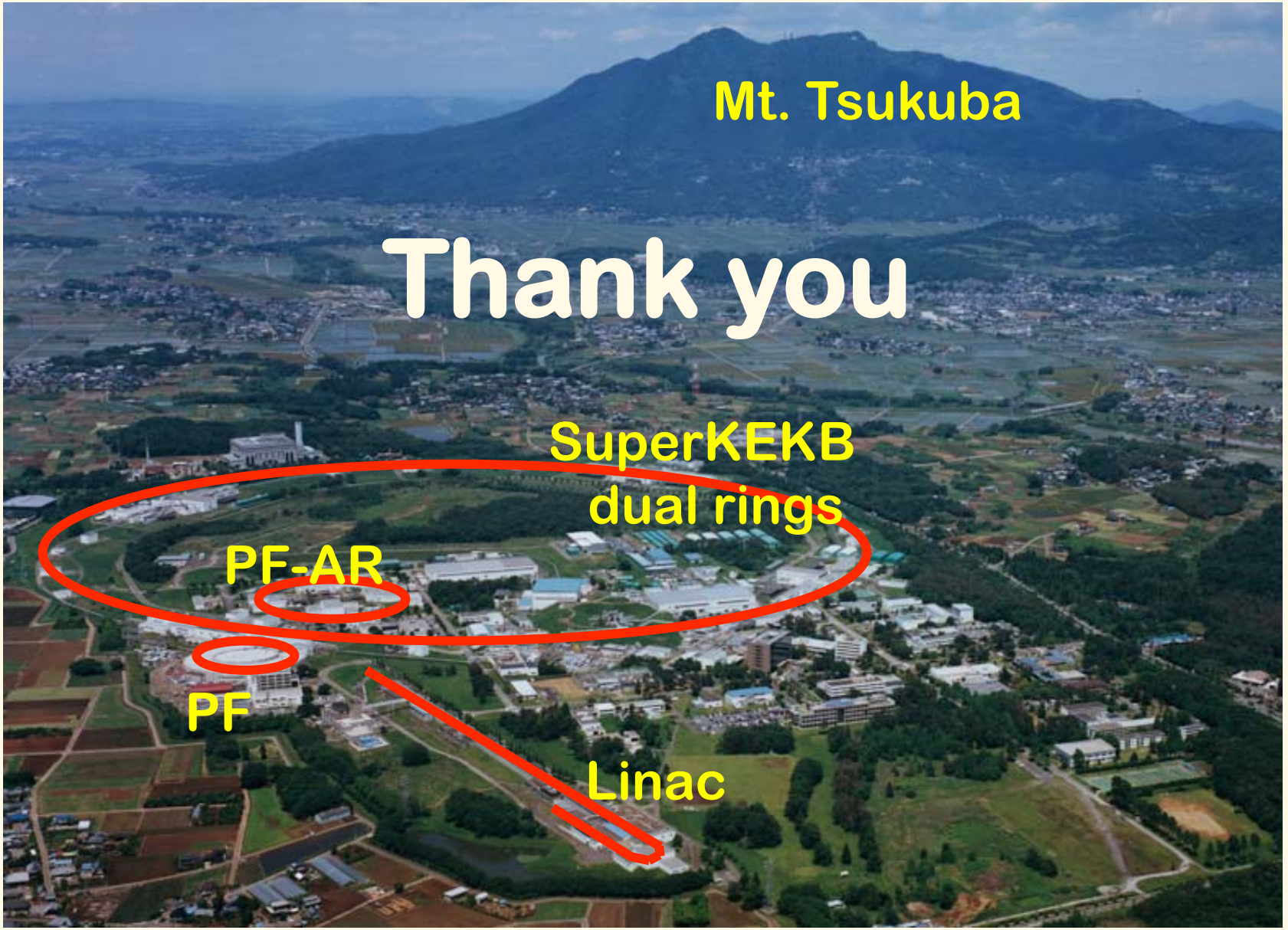
- Upgrade of controllers for each type of device
  - Discussions with device groups, for aging controllers
- Base software components, OS, EPICS, CSS, (Scripting) Languages
  - Especially EPICS Collaboration-based software
- Operational software
  - Archiver, Archive viewer, Alarm, e-Log, etc
- Information sharing to offices
  - More Web based application software
- Seminar and training
- IP Networking, Wireless LAN, Console Desk, etc

Accelerator Controls

- It's a fan to interact with all the components of the accelerator through control hardware and software
- It's a fan to interact with all the staff members of the project in order to design and improve controls
- We can contribute to the machine performance and the results even without realizing it

Conclusion

- Control efforts have contacts with all activities in the particle accelerator. We are at the privileged position to enjoy it.
- Based on existent KEKB controls, "CA Everywhere" and "Dual-layer Controls" should be enforced.
- With some Phronesis (Greek: practical wisdom, ability to understand the universal truth), we believe we can achieve the target.


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

Thank you