Effective Use of Accelerators

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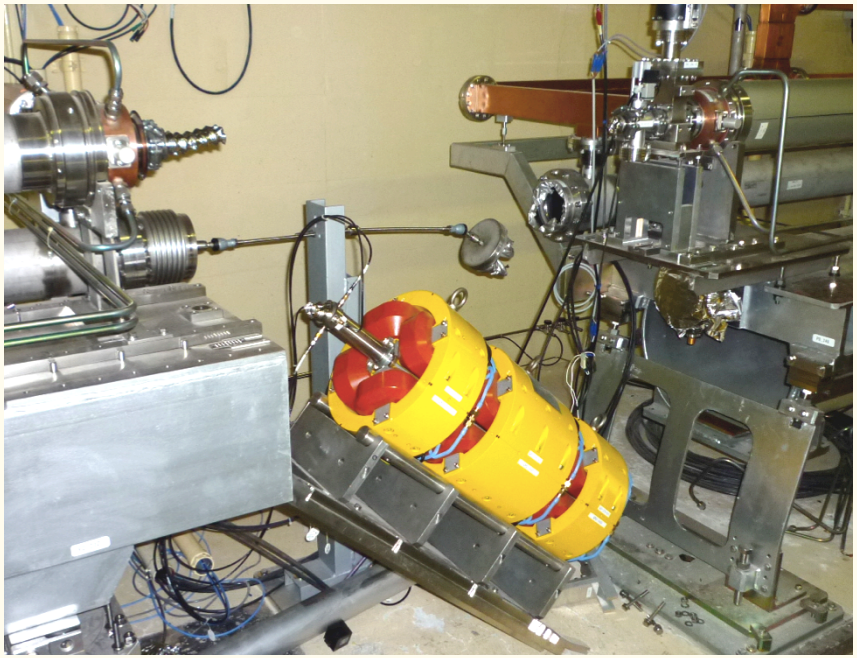
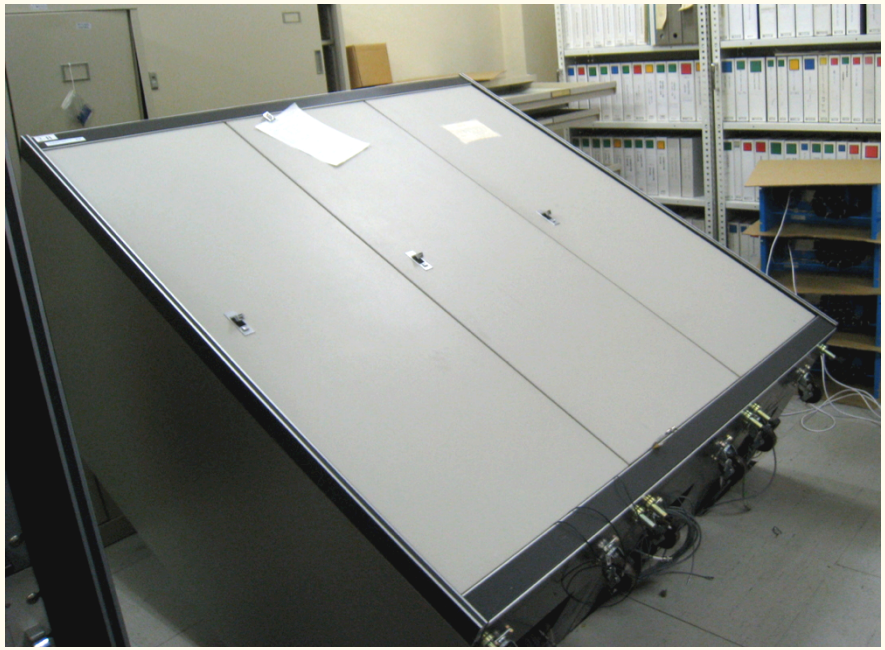
Experience and plan at KEK's electron / positron complex

- Disaster
- Overview of SuperKEKB and complex
  - KEKB 1998 ~ 2010
  - SuperKEKB 2015 ~ (We don't delay the project even with disaster)
- Effective use of accelerators
  - Based on well-designed devices and controls

Earthquake in March 2011 – Thanks

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



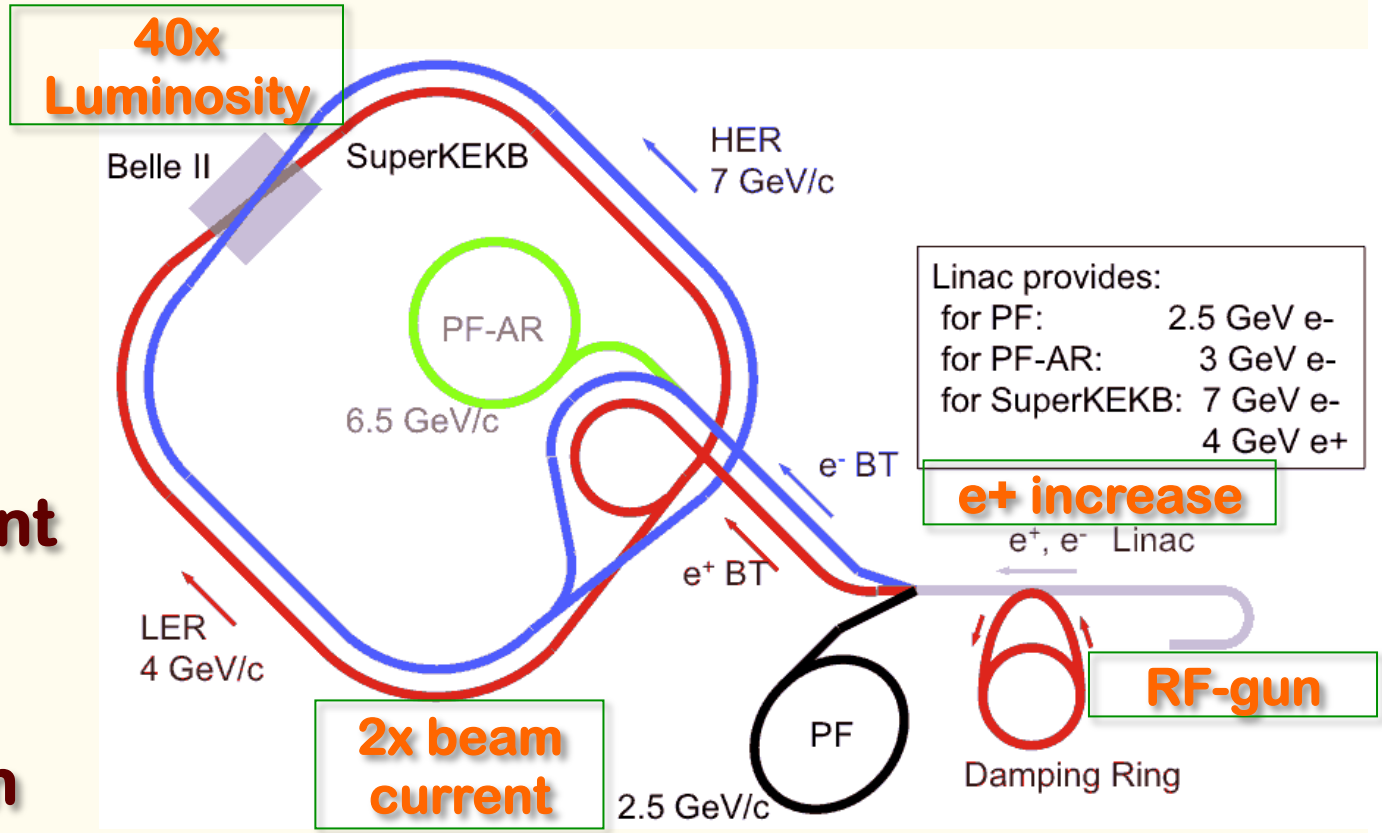


- Operation for PF, PF-AR recovered by June 2011, whole Linac recovery by March 2013, hopefully.

Linac in SuperKEKB Project

- 40-times higher Luminosity
  - Twice larger storage beam → Higher Linac beam current
  - 20-times higher collision rate with nano-beam scheme
    - → Low-emittance Linac injection beam
    - → Shorter storage lifetime → Higher Linac beam current

- Linac challenges
  - Low emittance e-
    - High-charge RF-gun
  - Low emittance e+
    - Damping ring
  - Higher e+ beam current
    - New capture section
  - Beam transport
  - Four ring manipulation



SuperKEKB Injector Linac

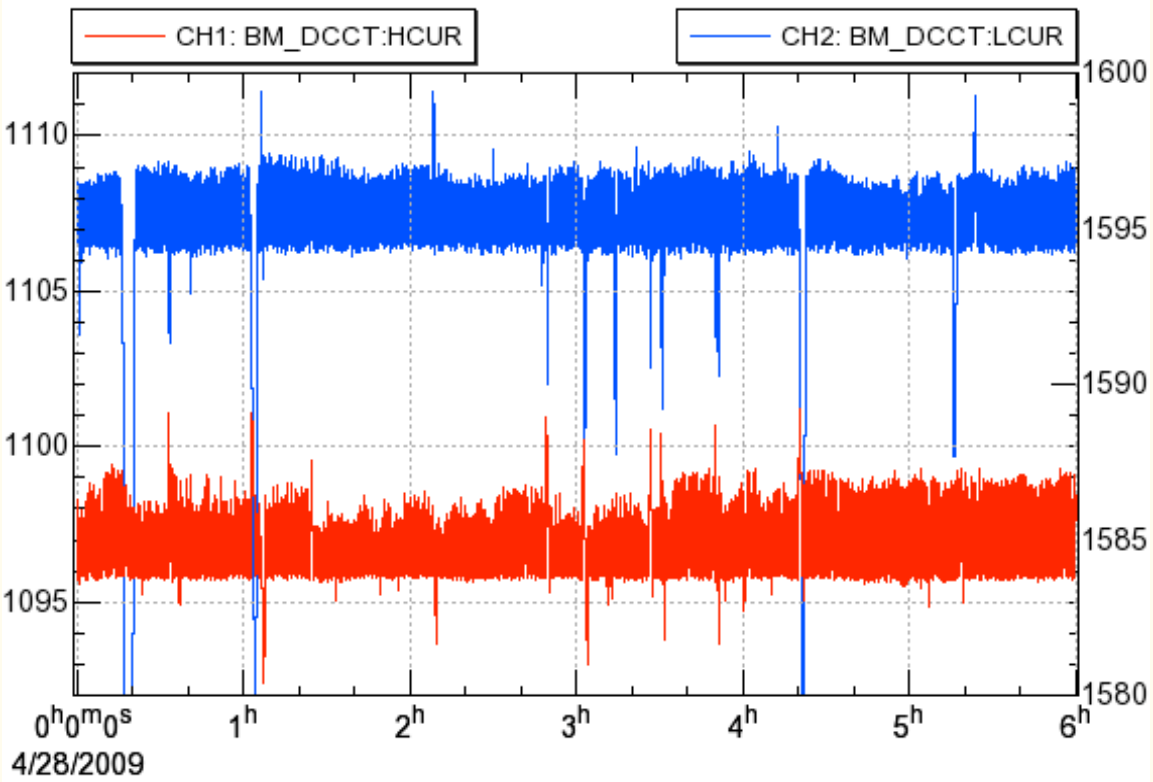
- **Higher Injection Beam Current**
  - To Meet the larger stored beam current and shorter beam lifetime in the ring
  - 4~8-times larger bunch current for electron and positron
  - Reconstruction of positron generator, etc
- **Lower-emittance Injection Beam**
  - To meet nano-beam scheme in the ring
  - Positron with a damping ring
  - Electron with a photo-cathode RF gun
  - Emittance preservation by alignment and beam instrumentation
- **Quasi-simultaneous injections into 4 storage rings**
  - SuperKEKB e^-/e^+ rings, and light sources of PF and PF-AR
  - Improvements to beam instrumentation, low-level RF, controls, timing, etc

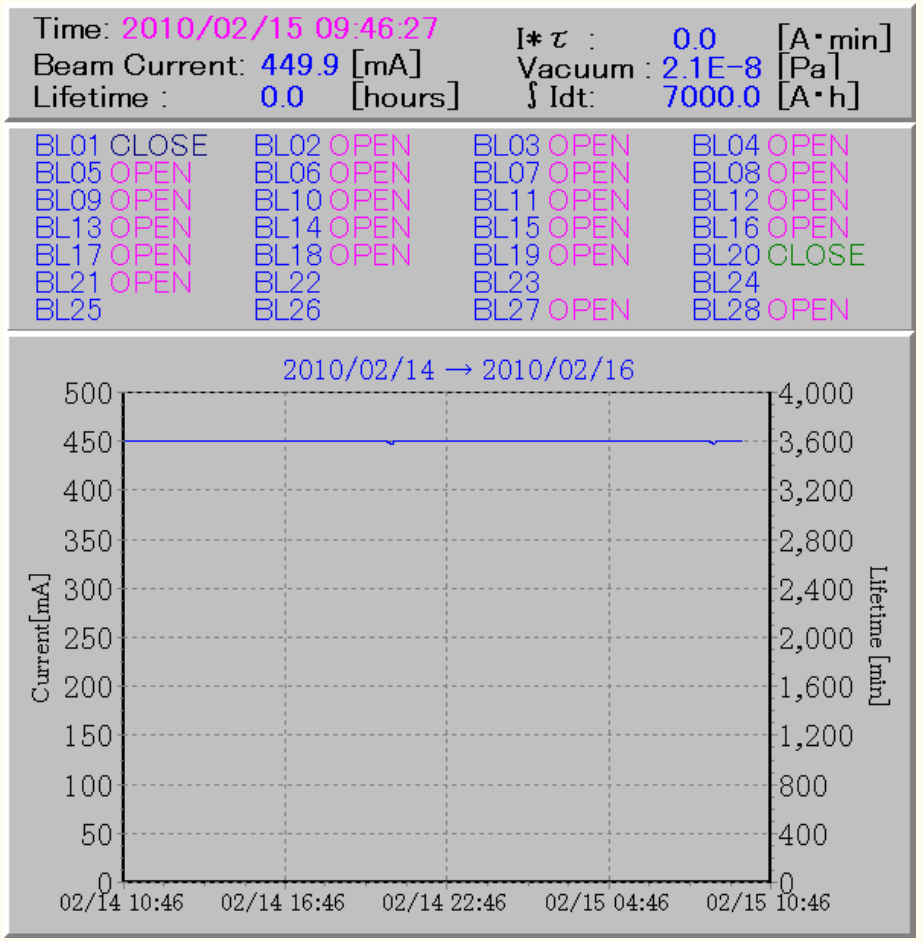
Effective Use of Linac for SuperKEKB, PF, PF-AR

- **Top-up Injections to all of Four Rings (from 2015~)**
  - SuperKEKB e^-/e^+ rings, and light source PF
    - the same as in KEKB-PF
  - Light source PF-AR should not interfere SuperKEKB rings
    - Lifetime of SuperKEKB rings are expected to be ~10minutes
- **Fast switching of beams**
  - 3.5-times different energies, 100-times different bunch charges
  - Fast controllable magnets, low-level RF, high-power RF, guns, injection systems, independent ring circumference compensations, beam instrumentations (prepared since 2006)
  - Very tricky
  - Event-based fast controls
- **Controls are the essential part of accelerator**
  - To make use of it

Typical Top-up Stored Beam Current Stabilities

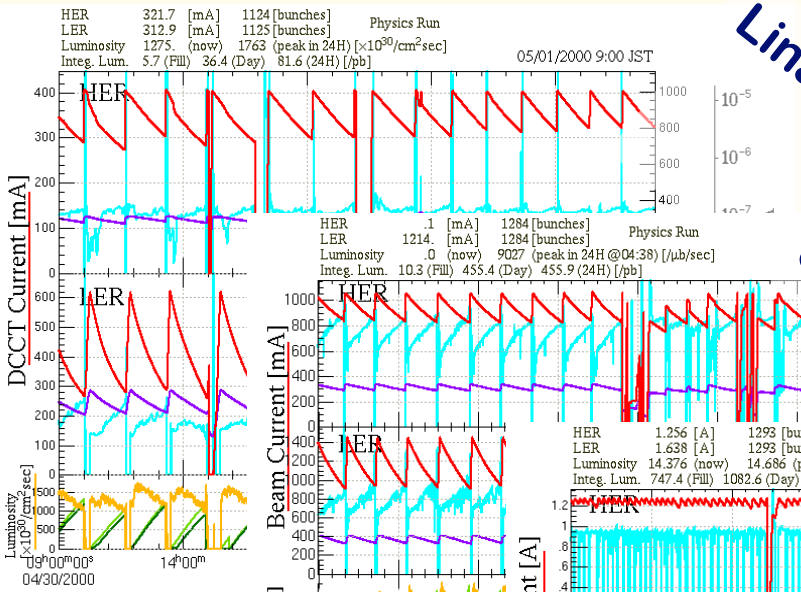
- **Beam current were kept stable (Apr.2009~Jun.2010)**
  - **Led to good physics, etc. experimental results**
  - **KEKB (~0.05%)**
    - **HER e–: 1107 ± 1mA**
    - **LER e+: 1585 ± 1mA**
  - **PF: 450 ± 0.05mA (~0.01%)**



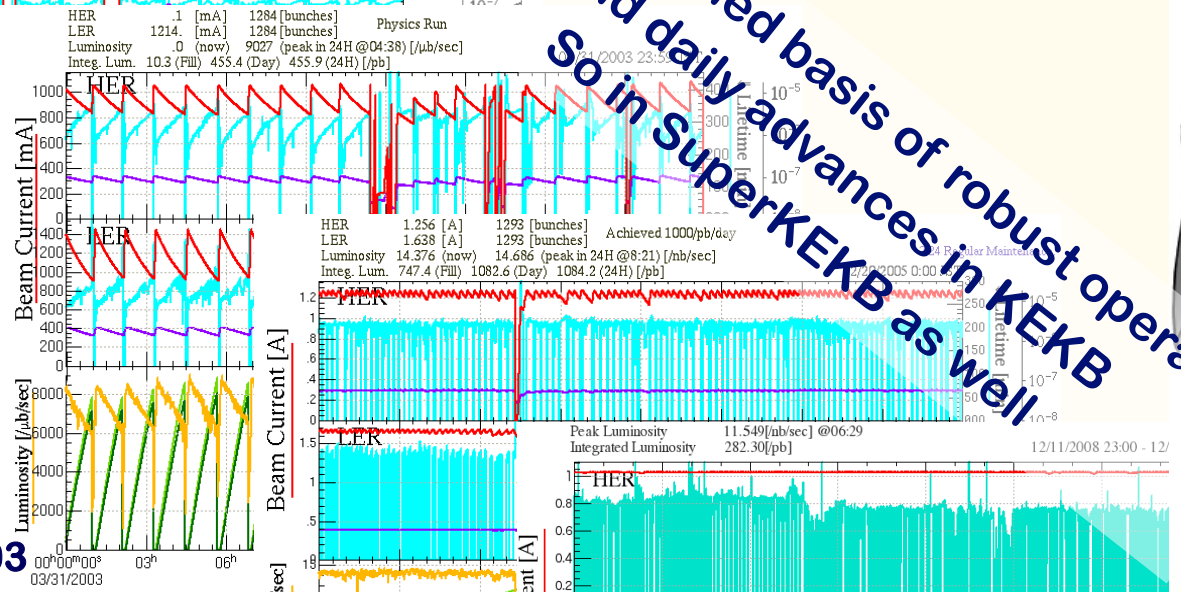


Change in Operation Modes at KEKB

Linac provided basis of robust operation and daily advances in KEKB
So in SuperKEKB as well



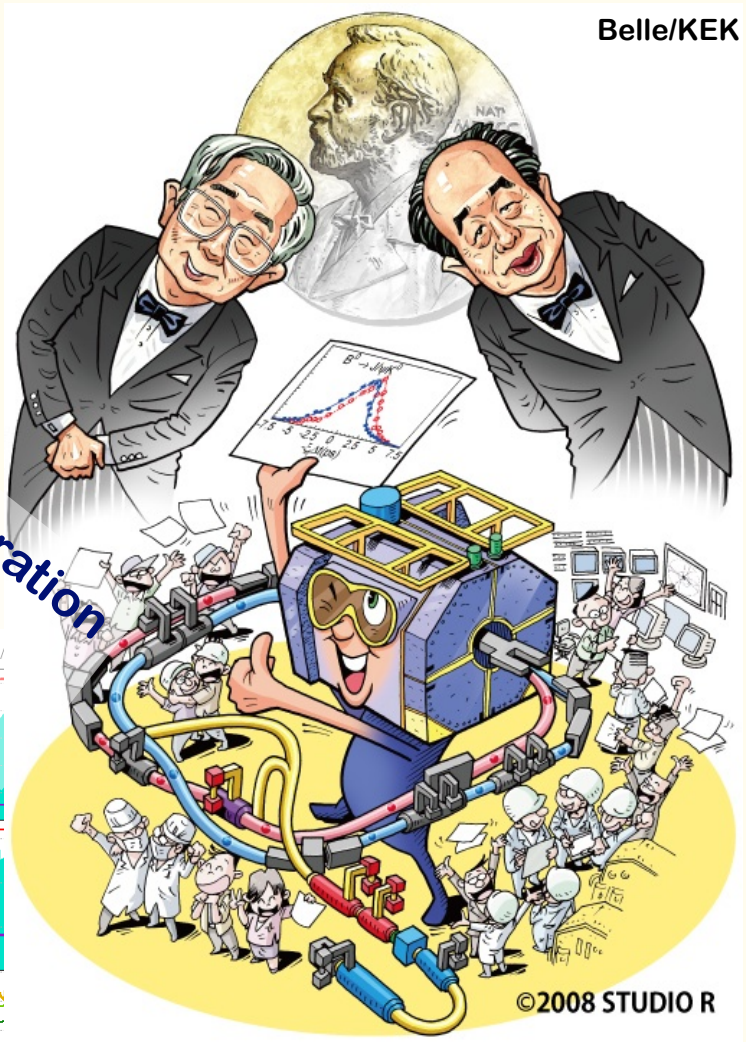
May.2000



Apr.2003
Dual Bunch e+

Feb.2005
Continuous
Injections

Dec.2008
Crab Cavities and
Simultaneous Injection



SuperKEKB Controls/Operations

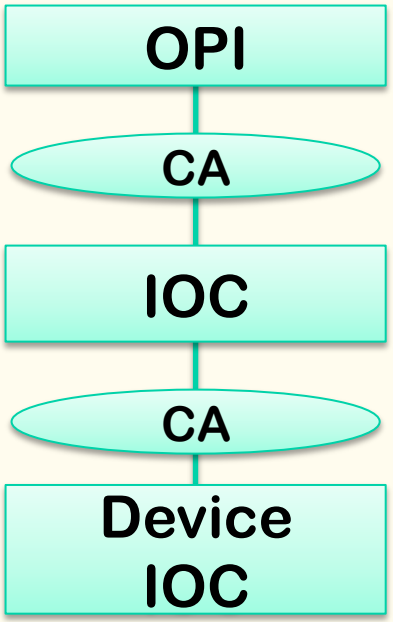
- **Inherit Good part of KEKB Controls**
  - EPICS
  - Scripting languages
- **Two Additional Concepts**
  - Channel Access Everywhere
  - Dual-layer Controls (EPICS and Event-based controls)

1st: CA Everywhere

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

Embedded EPICS IOCs at SuperKEKB

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

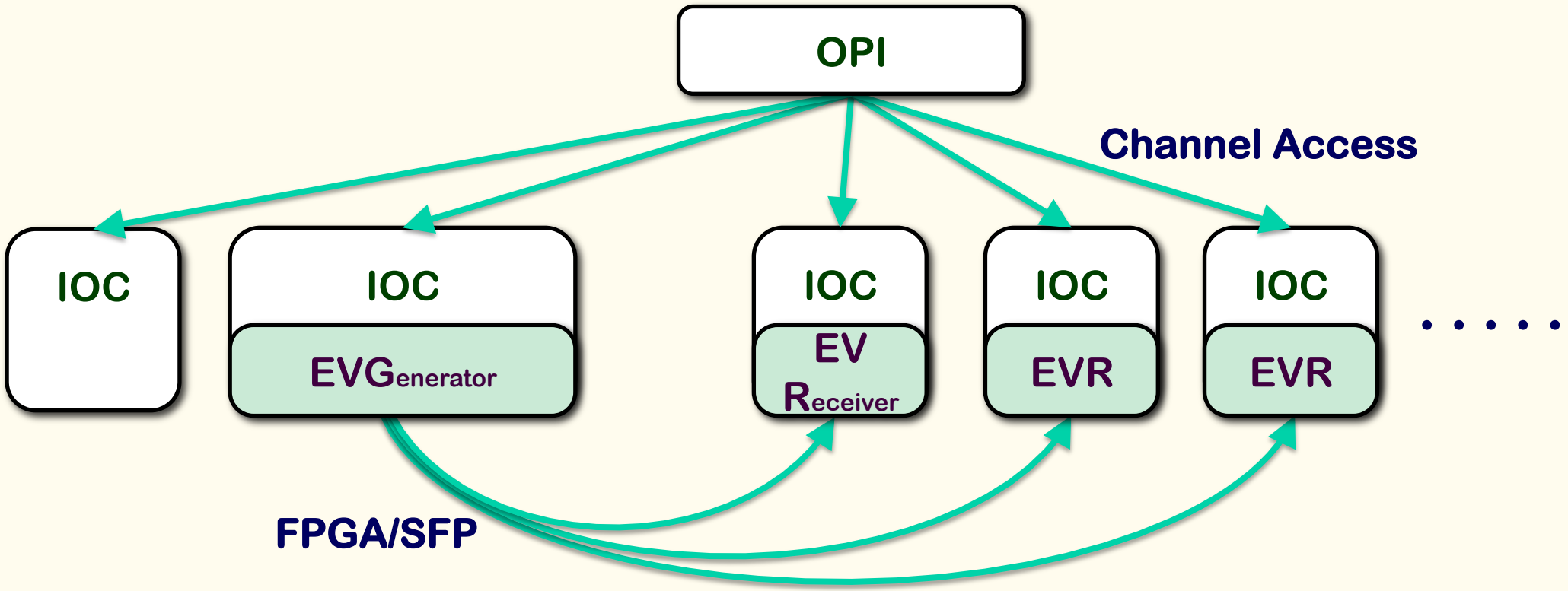


2nd: Dual-layer Controls

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

Dual-layer Controls

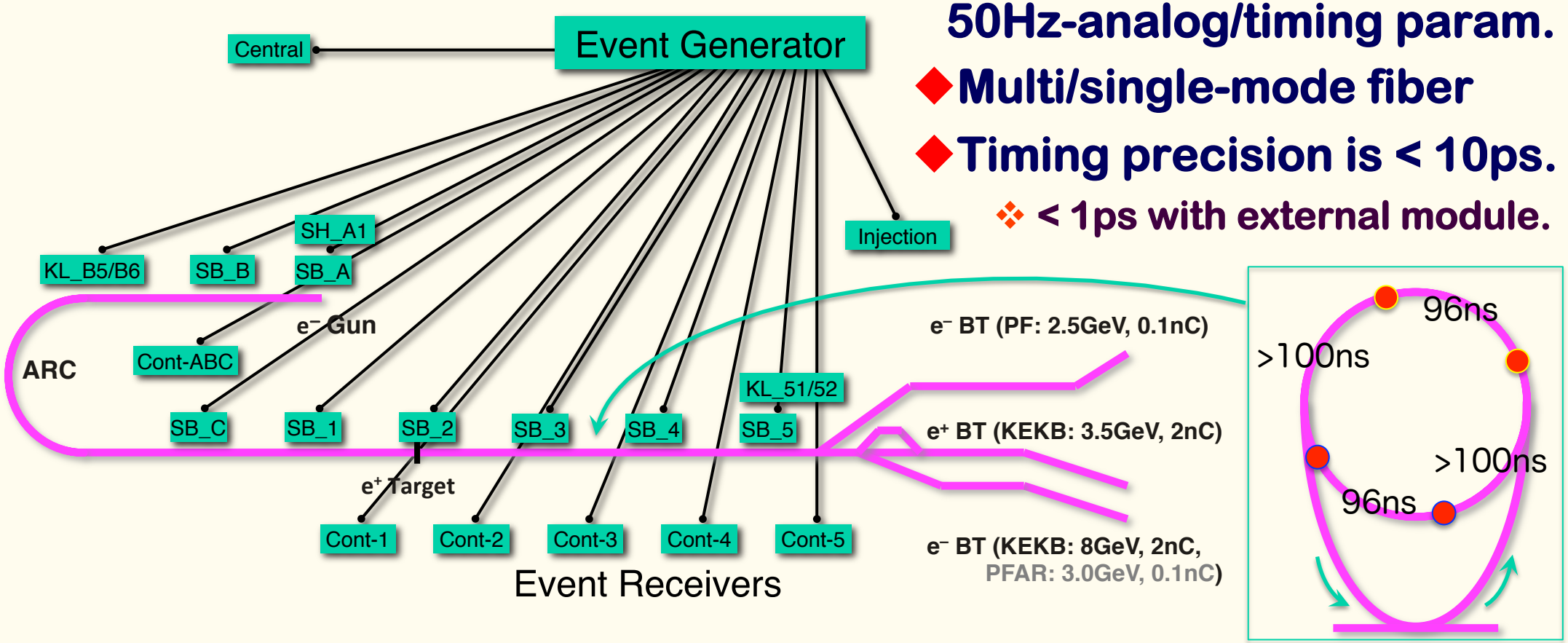
- **IOC controls via Conventional EPICS CA**
  - Above 1ms, ordered controls
- **Fast FPGA controls via SFP/Fiber**
  - 10ps ~ 100ms, 114MHz synchronous controls



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.

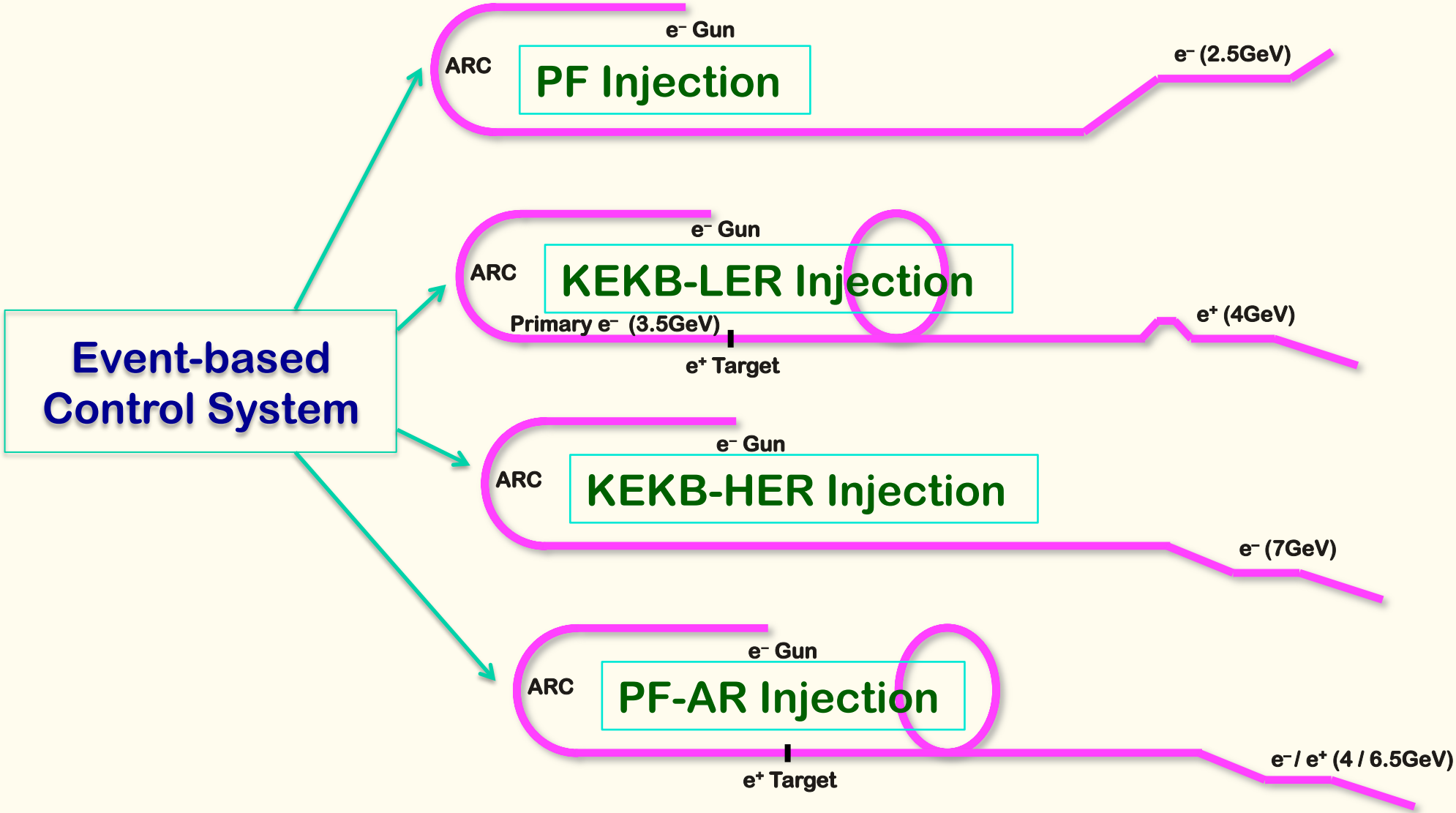


Event-based Control Components

- Great combination of commodity devices
  - FPGA (field-programmable gate array) and SFP (small form-factor pluggable)
- In SuperKEKB we will utilize
  - MRF's VME modules (cPCI, PMC, etc possible)
  - SINAP's VME and PLC modules
  - FPGA-SFP-based controllers
  - Event delivery even over Ethernet
    - Error rate over Ethernet < 10^{-7}
- ~200 analog/binary control points every 20ms and many more sync. measurements

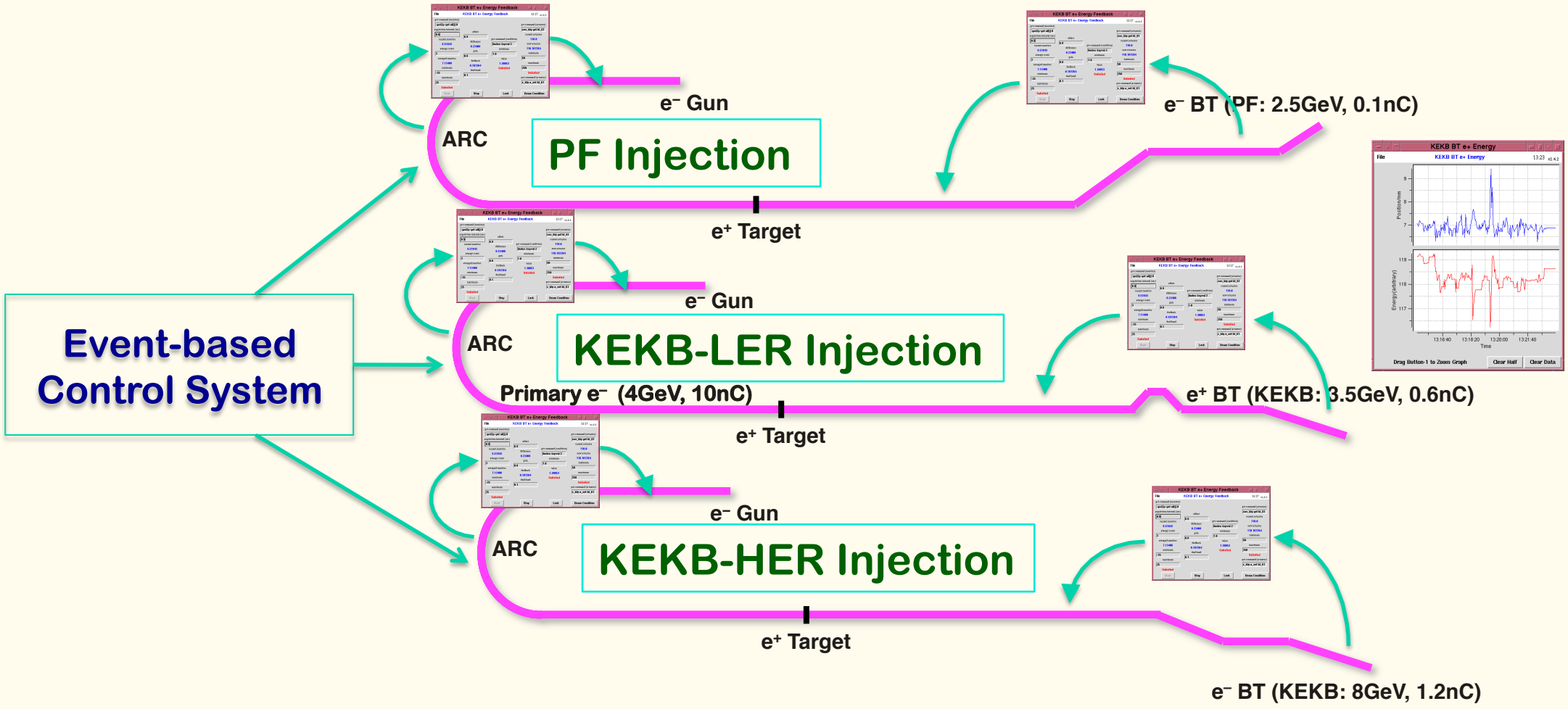
One Machine, Multiple Virtual Accelerators (VAs)

- 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



Summary

- We can make use of accelerators efficiently and effectively
- Use of event-based controls as well as (embedded-) EPICS, and scripting languages, will be essential for advanced operations


Thank You for Your Patience

Event Timing System Development

- Collaboration with SLAC, LANL, BNL, PSI, SINAP
- For PLC (F3RP61 Linux CPU) as well as VME
- Under testing
- Many more synchronous controls at a reduced cost