Event System at KEK

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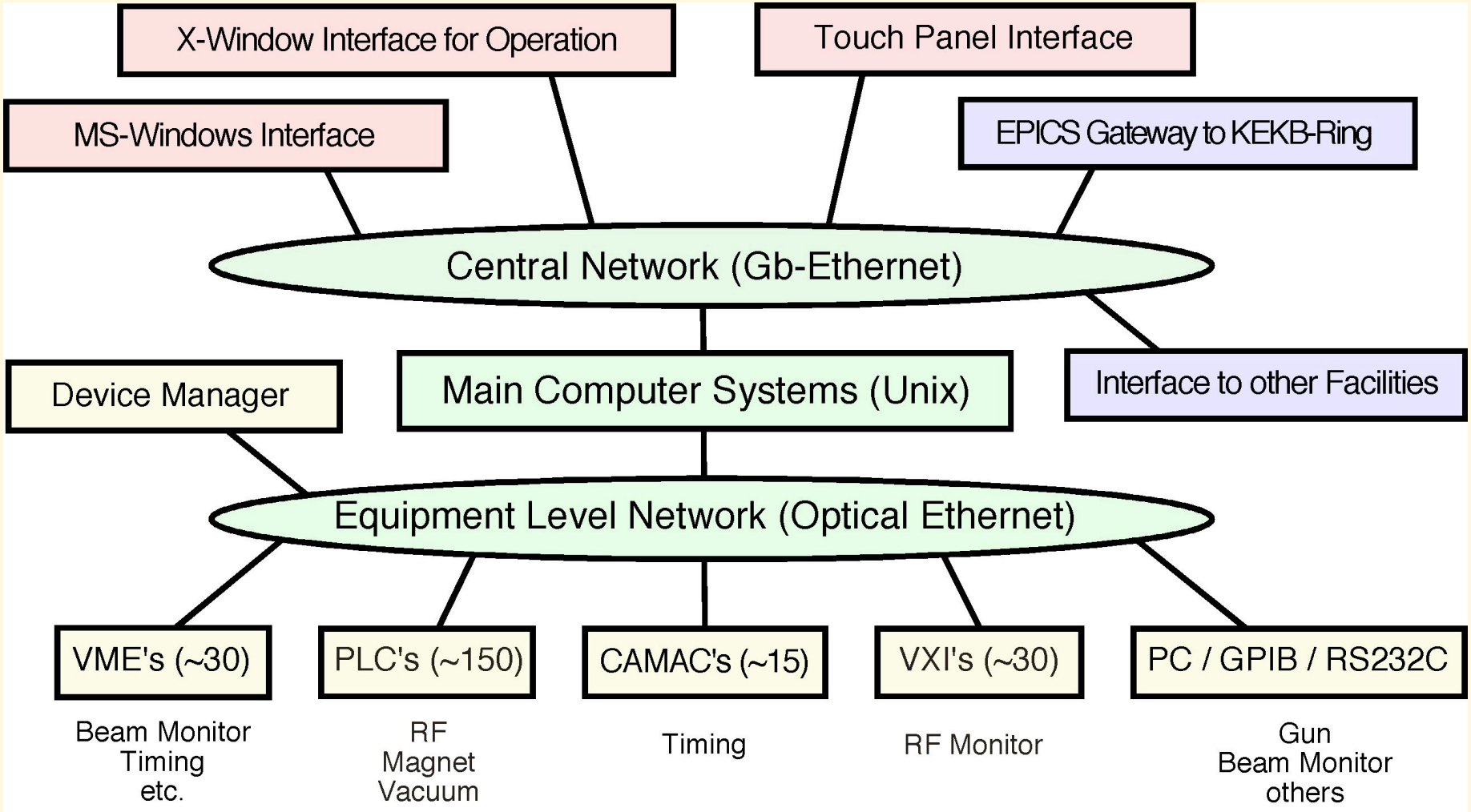
Linac; Original Physical Structure

- **Multi-tier, Multi-hardware, Multi-client, …**



Linac; Original Software Architecture

- **Base control software structure for Multi-platform**
  - any Unix, OS9, LynxOS (Realtime), VMS, DOS, Windows, MacOS
  - TCP - UDP General Communication Library
  - Shared-Memory, Semaphore Library
  - Simple Home-grown RPC (Remote Procedure Call) Library
  - Memory-resident Hash Database Library
- **Control Server software**
  - Lower-layer servers (UDP-RPC) for control hardware
  - Upper-layer server (TCP-RPC) for accelerator equipment
  - Read-only Information on Distributed Shared Memory
  - Works redundantly on multiple servers
- **Client Applications**
  - Established applications in C language with RPC
  - Many of the beam operation software in scripting language,
    - Tcl/Tk
    - SADscript/Tk

Network with only IP/Ethernet

- The policy chosen when we upgrade Linac in 1993
  - Make network management simpler
    - Faster switches, routing, network-booting, etc.
  - Avoid Hardware failure and analysis effort with old field network
    - Home-grown field networks need much dedicated man-power
  - Cost for optical Ethernet went down at around 1995
    - Linac has high-power modulator stations, noise source
  - Nowadays many facilities have this policy with GbE
    - J-PARC controls basically followed this
  - More and more intelligent network devices
    - ex. Oscilloscopes with Windows/3GHz-Pentium built-in
    - Even EPICS IOC, MATLAB, or others can be embedded
  - Network components can be replaced one-by-one
  - Security consideration will be more and more important

Communication Network at Linac

- **Fiber-optic Networks (1982~)**
  - Because of High-power modulators for rf systems
  - ~30 Loops to connect many equipment controllers
  - However, the fiber-optic Technology was not mature enough yet
    - Often Failed and Loop Topology made it difficult to identify the trouble
- **All IP network (1993~)**
  - Still all Fiber-optic
    - (Faster Ethernet enables shorter packets and less failures)
  - Inherited at J-PARC Controls as well
- **Gradual Transition of Technologies**
  - From FDDI + 10Base-FL to 1000Base-LX + 100Base-Fx
- **Redundancy (1996~)**
  - At more than 40 Ethernet links
  - Helped continuous operation in spite of a failure at night
    - Redundant Transceivers, then Rapid Spanning-tree and HSRP/VRRP

Equipment Controllers at Linac

- 1982~(1997) (1st generation)
  - 300 microprocessor-based controllers
    - Linked together with home-grown fiber-optic network
- 1993~now (upgrade of controls)
  - 150 PLCs (programmable logic controller)
    - Linked via only Fiber-optic Ethernet/IP
      - Control communication with servers and program development
- 1995~now (upgrade for KEKB)
    - Direct Fiber-optic Ethernet/IP to each Controllers
  - 30 VXI for rf measurement
  - 7 VME / 10 CAMAC for Timing (will retire soon)
  - 20 VME for Beam monitors (will retire soon)
- 2007~ (upgrade for 50Hz beam switching)
  - 13 (increasing) VME for “event” handling, timing, llrf controls, etc.
  - 24 Oscilloscopes with WindowsXP IOC for 100 BPMs
    - 10Gs/s, 50Hz acquisition, local processing with 20 calibration parameter/BPM

EPICS Transition at Linac

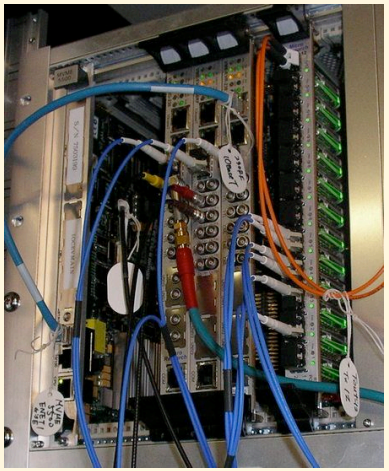
- Home-grown RPC at Linac (1990~/1993~)
  - Bad timing but no choice because of end of old mini-computer support
- No real transition to EPICS yet at Linac
  - There are middleware and applications
- LynxOS Transition was developed (1994~1996)
  - To cover both RPC and EPICS with pthread, posix
    - Mostly working, Failed to get funding for Hardware/Software upgrade
- Gateways to EPICS in several ways
  - Software-only IOC and Gateway (Clients to both RPC/CA)
  - Portable Channel Access Server of EPICS-3.12 (1995~)
  - Soft-IOC with device support to Linac RPC (2002~)
- Real IOCs are increasing
  - PLC(rf,vacuum,magnet) and Linux, Oscilloscope(bpm) with Windows, VME(llrf and timing)
  - RPC servers read EPICS IOCs, EPICS gateways read RPC servers

Recent Improvements

- PLCs with Embedded EPICS (Linux)
  - from Ethernet-only to Channel-Access-only
- Event system introduction
  - Single fiber to distribute synchronized, 10ps timing, 50Hz interrupts, data, etc
- EPICS-embedded Oscilloscopes (Windows)
- FPGA-based EPICS-embedded controllers (Linux)
- Zlog operation log improvements
  - Used also at J-PARC, RIKEN, and BINP
- Reliability improvement studies
  - Redundant IOC, ATCA and EPICS, Test systems

Linac & PF & KEKB

- **Simultaneous Continuous Injection to PF, KEKB-HER and KEKB-LER**
  - **50Hz Beam Pulses are Shared between 3 Rings**
    - With very different Beam Properties, in Energy, Charge, etc.
  - **50Hz Beam Instrumentation (Beam Position Monitor)**
    - Only Passive Components other than Oscilloscope (Tek-DPO7104)
      - Windows-embedded (3GHz Intel), EPICS-3.14.9, VC++
    - One Oscilloscope reads 2-5 BPMs, 24 Oscilloscopes Installed
      - Synchronized 100-BPM Read-out
  - **Introduction of Event System, EVG230-EVR230RF from MRF**
    - 10 EVR's Installed, 1/3 of Old Timing Stations Replaced
      - VxWorks-5.5.1, EPICS-3.14.9, (Gave-up with RTEMS)
    - Event drives Low-level RF in VME, BPM Oscilloscopes over Network
    - Gun Parameters, Pulsed Magnets, Kickers, etc are Controlled 50Hz
    - Beam Pattern Rules on Client Script, can be Downloaded every second
  - **More Development Needed**
    - Flavoured Beam Feedback Systems
    - Event System Integrity Monitor



EVG & Timing

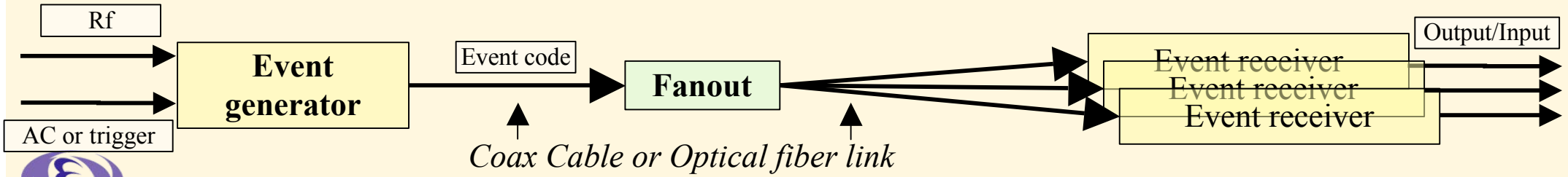
EVR & LLRF

Event System

- **Quasi-simultaneous Injection**
  - to KEKB-HER, KEKB-LER, and PF
  - 2.5GeV to 8GeV, 0.1nC to 10nC
- **Stable stored beam current at three rings**
  - Should improve collision tuning with Crab cavities
  - Should improve the quality of experimental data at PF
- **Fast switching of many device parameters**
  - In 20ms / 50Hz
  - Should be reliable because beam power is much different
- **MRF Series 230 Event Generator / Receiver**
  - VxWorks 5.5.1, MVME5500, (Originally with RTEMS but…)
  - Timing precision less than 10ps (TD4 provides 3ps)
  - Multi-mode fiber and single-mode fiber for longer distance

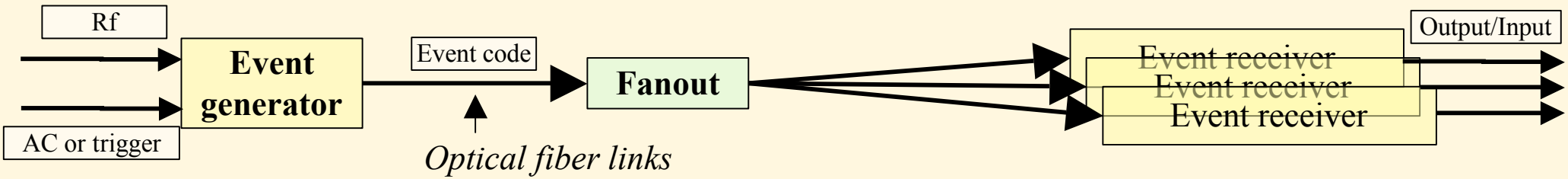
Event System

- **Many accelerator system require timing signals and accompanying information (event)**
  - **Several facilities combined and used at KEKB and Linac**
    - **Fast Timing signals are provided with delay module TD4/TD4V**
      - **Need timing trigger and rf clock**
    - **(Slow) Events are provided in another facility**
      - **Combining Hardware and Software**
  - **Event/Timing Systems which distribute the both timing and event are developed at Argonne/SLS/Diamond, and are employed at many institutes (Event Generator/Receiver)**
    - **Fast Timing, rf clock, Hardware event, Software Interrupt, can be handled in one combined system with a single fiber cable**
    - **Especially in EPICS, event can be connected EPICS Event directly, so record/database programming is possible**



Event System

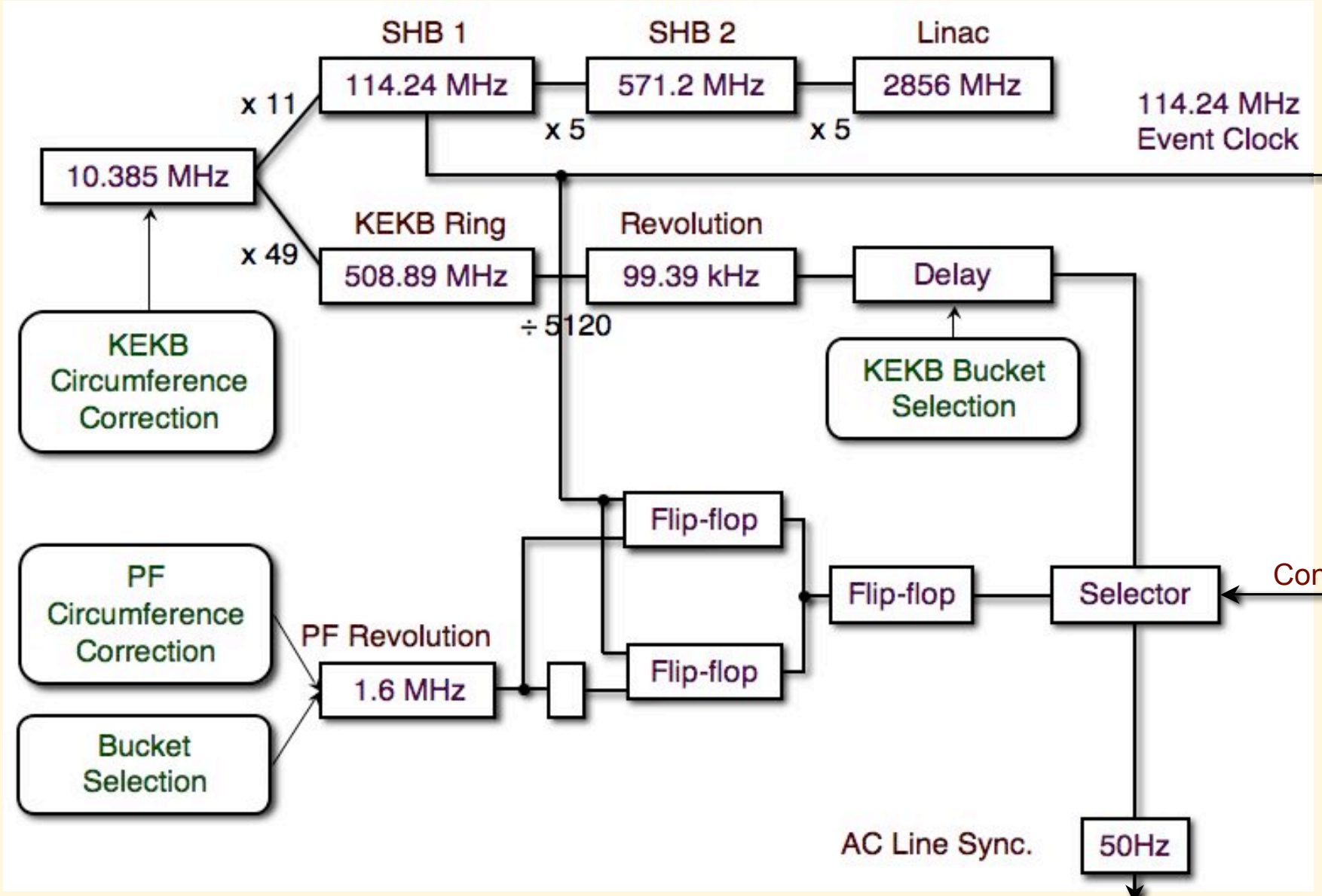
- **Distribution mechanism of timing with data/information**
- **Developed based on experiences at several accelerator institutes**
  - APS at Argonne (ANL/APS)
  - Swiss Light Source (PSI/SLS)
  - DIAMOND
  - (TRISTAN, KEKB, Linac)
  - **New Event System (EVG/EVR-200/230)**
    - Employment at many accelerator institutes
      - DIAMOND, SLS, BEPCII, LCLS, Shanghai, KEK-Linac, Australia, …
      - (SNS), (LANL), (BNL), …
    - Many functionalities
      - Bit rate up to 2.5Gbps, Event rate 50-125MHz, ~10ps precision,
      - 8bit signal, 2kbyte data buffer, EPICS support



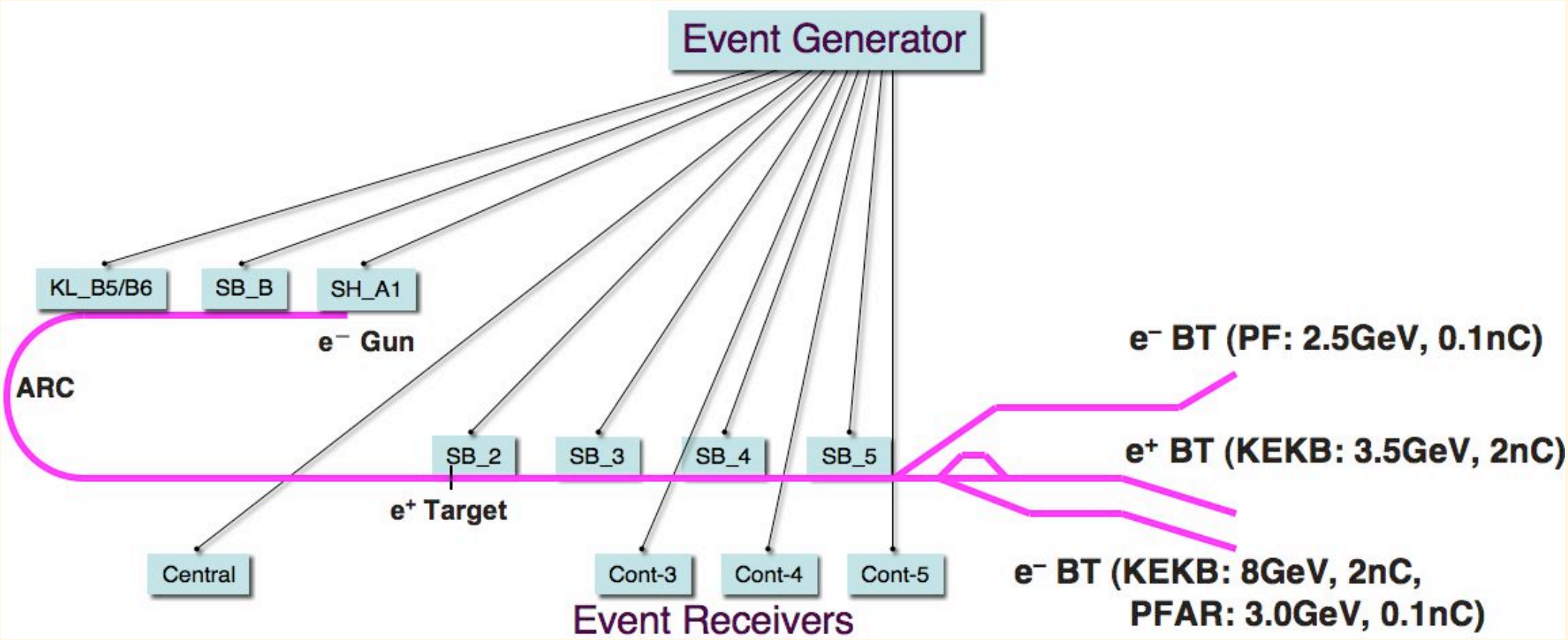
The stimulus to send an event can be:
-**pulse on a hardware input**
-**software event** (write to a register)
-an entry in an **event playback RAM**

When an event code is received the receiver can:
-**output a pulse, of specified delay and width**
-**trigger a software action (process an EPICS record)**
Each event receiver can be programmed to respond in a different way to the same event code.

Basic synchronization outside of EVG



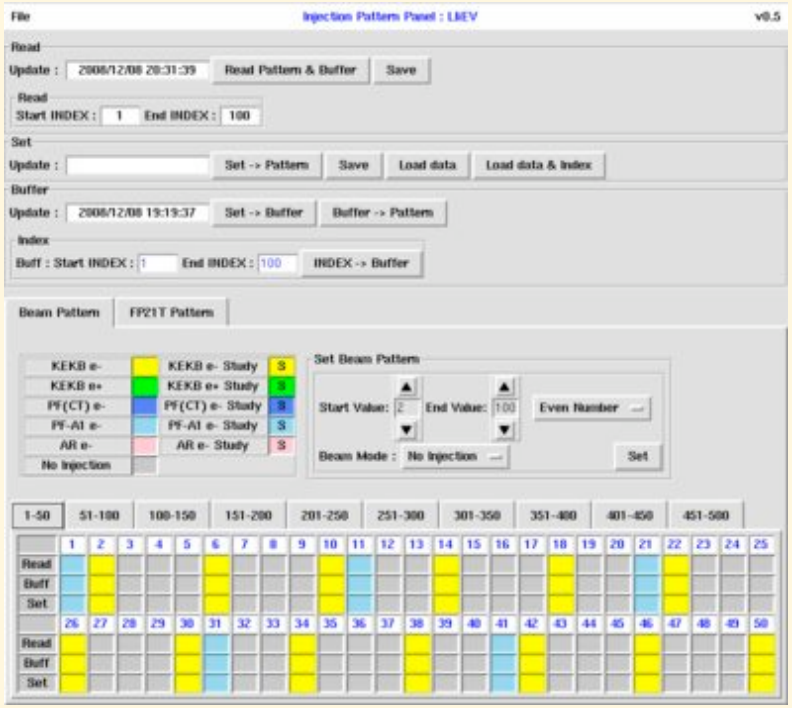
Event system configuration, autumn 2008

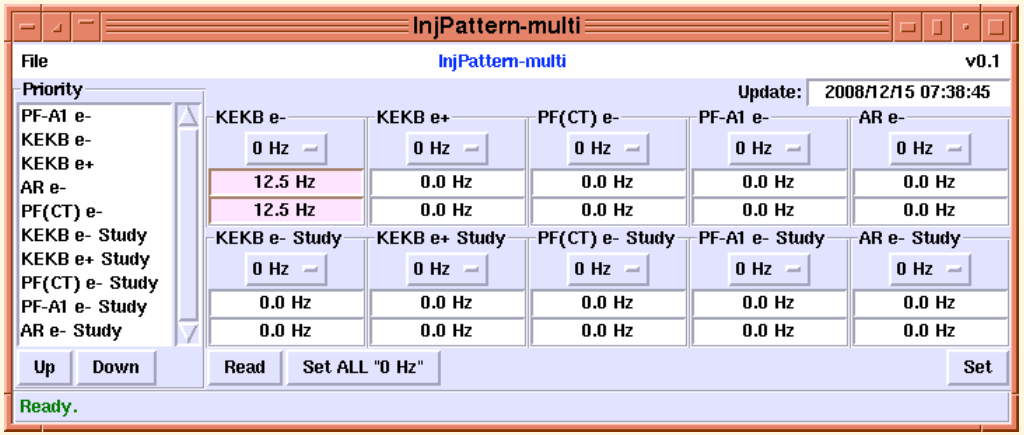


Beam mode pattern generation

- 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.
- About 50 event codes are defined.
- Some events correspond to many functions, and others to specific devices.
- Beam pattern buffer length (n) can be 2 to 500 (20ms x 500 = 10 seconds).
- A new pattern is 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.

Beam mode pattern generation



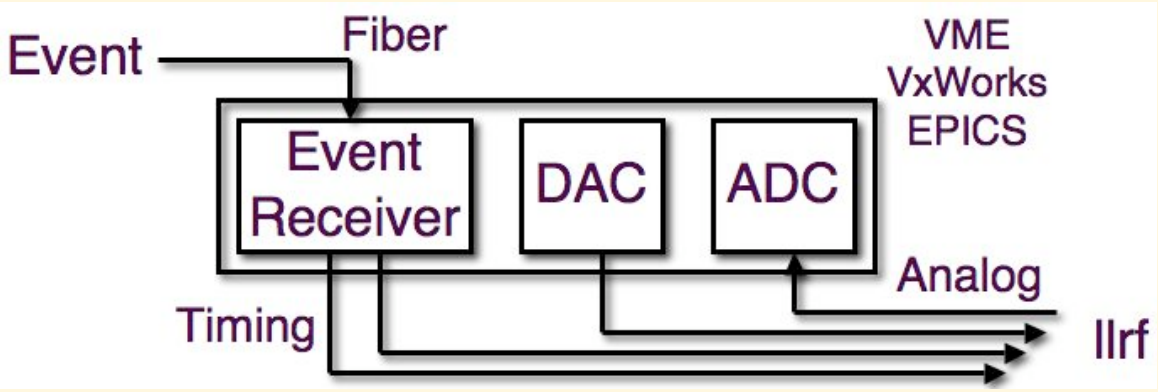


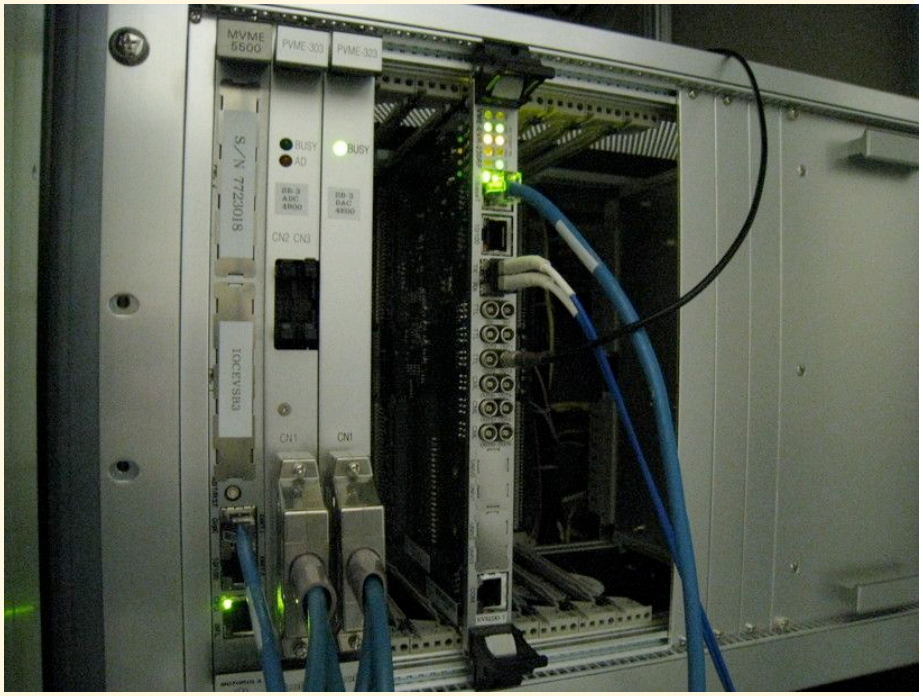
Manual pattern designer

A version for current operation

LLRF

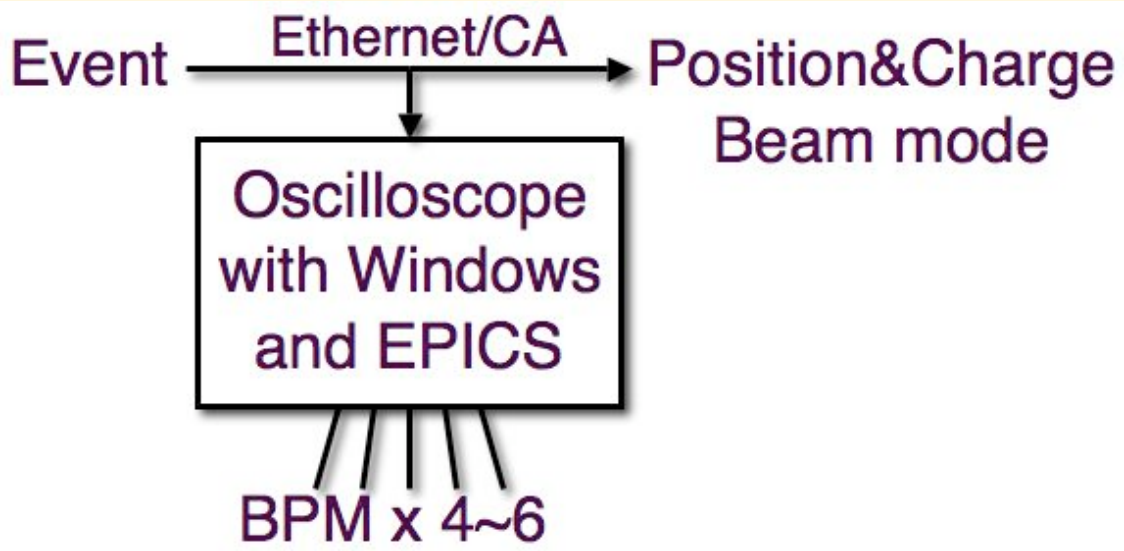
- Timing and analog signals are essential for absolute energy, energy spread, and dual-bunch energy equalization.
- Signals can be switched pulse-by-pulse.
- Driver klystrons (SB), energy tuner klystron (KL), and sub-harmonic bunchers (SH) are managed by the event system.

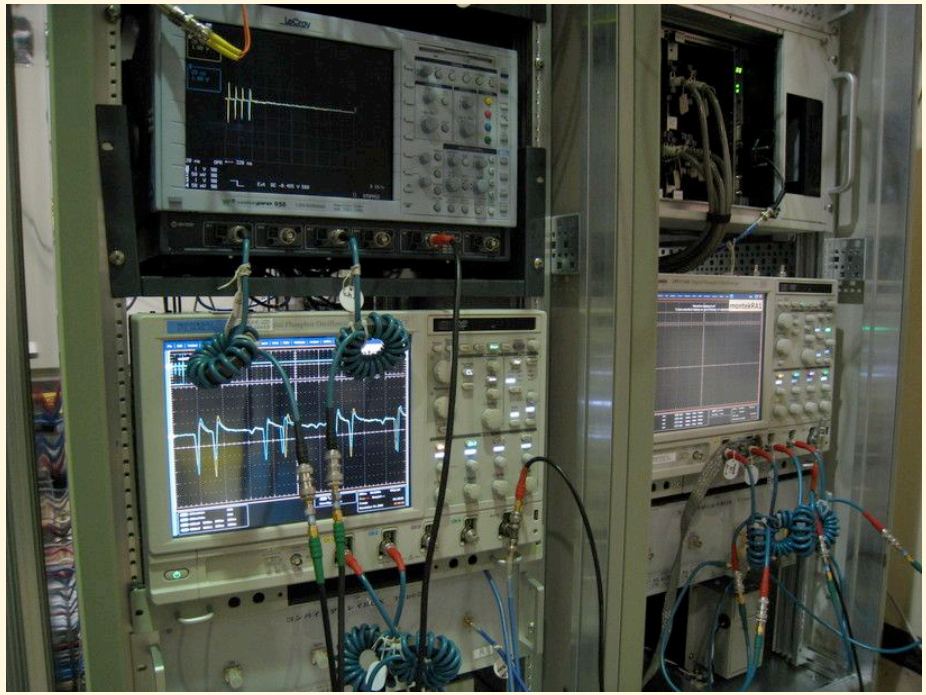




BPM

- DPO7104 can acquire data in 50Hz .
- Beam modes are recognized by events through network.
- Clients can monitor data of an interested beam mode.
- 100 BPMs are synchronized.





Parameters

- Parameters switching via Event system
  - RF Timing x~35
  - LLRF x~11
  - Gun voltages, fast delays, x4
  - Pulsed magnets x~12
  - Injection system x~4
  - BPM over channel access x~100
- Basically sufficient for fast beam mode switching
- More parameters next year
- Integrity monitors
- Improved slow beam feedback, fast feedback, etc.

Thank you

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