



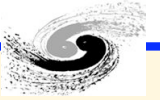
Recent Control Development at KEK

Kazuro Furukawa, KEK

KEKB and Linac Control Groups

<kazuro.furukawa@kek.jp>

Dec. 16. 2008.



- ◆ **PLC - with Embedded EPICS**
- ◆ **Event system**
- ◆ **FPGA-based system**
- ◆ **Reliability improvement**

KEKB & Linac

◆ Further Electron-Positron Collider Experiments at KEKB

- ◆ Contributed Nobel Prize to Kobayashi-Maskawa

❖ Maintenance Difficulties

- ✧ In Software and Hardware after 10-years of Operation
- ✧ Transition from CAMAC to PLC, etc.
- ✧ Transition to Newer versions of Software
 - ◆ After Stable Usage of VxWorks-5.3.1, EPICS-3.13.1.

❖ Still Intensive Use of Scripting Languages

- ✧ SAD-script, Python, Tcl.

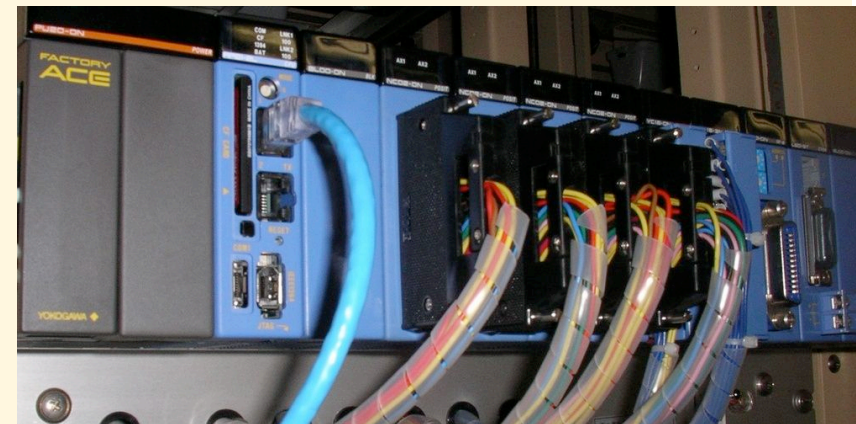
❖ Zlog operation log improvements

- ✧ Used also at RIKEN, J-PARC, and BINP

❖ Adding New Devices

- ✧ For Improved Machine Performance
- ✧ New Hardware like Linux-embedded PLC Controller (F3RP61) for Beam-mask, Pulsed-quad, etc.
 - ◆ EPICS-3.14.9, Linux-2.6 , Procserv, Pcmon, Asyn

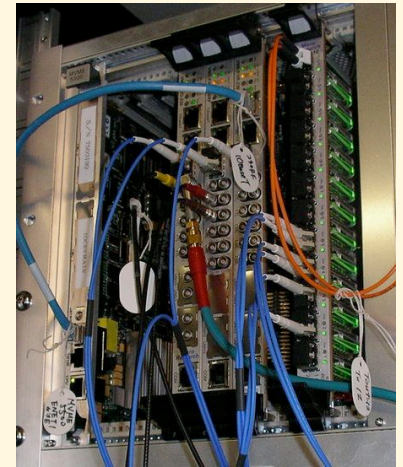
PLC with Embedded Linux/EPICS



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
- ❖ **Intruduction of Event System, EVG230-EVR230RF/EVR200**
 - ✧ 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



PLC usage

◆ At Linac

- ❖ We enforced that all the controllers should be connected over IP/Ethernet
- ❖ PLC was much cost-effective compared with VME
 - ✧ if the speed requirement allows
- ❖ Products from OMRON, Mitsubishi, Yokogawa were installed
 - ✧ Only Yokogawa (FAM3) increased, because maintenance capability over network was better
 - ◆ Ladder software downloadable over IP/Ethernet
 - ◆ (Recently Mitsubishi also added that feature)
- ❖ 150 PLCs used at Linac for RF, Magnets, Vacuum, Safety, etc

◆ At J-PARC

- ❖ Many installations with the same reason as Linac

◆ At KEKB

- ❖ Used indirectly at many devices, over serial or GPIB links



Software management

◆ Ideal at the beginning

- ❖ Separate software development at control group, at equipment group, or at industrial company
- ❖ Later, integration test IP/Ethernet

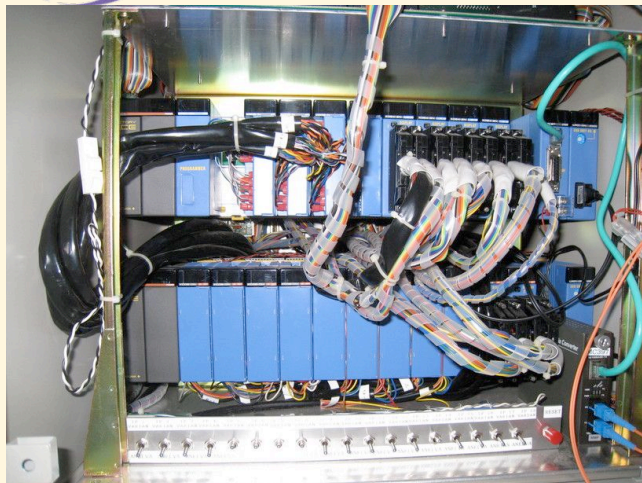
◆ Logic management

- ❖ Same logics could be placed at ladder software, in EPICS database/squencer (or in high-level applications)

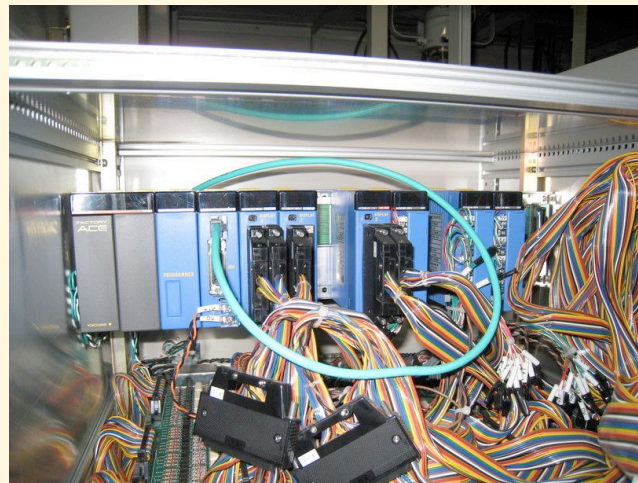
◆ Speed requirement

- ❖ Closed loop over Ethernet was slow, sometimes un-reliable
- ❖ Socket-based interrupts were possible, but complicated

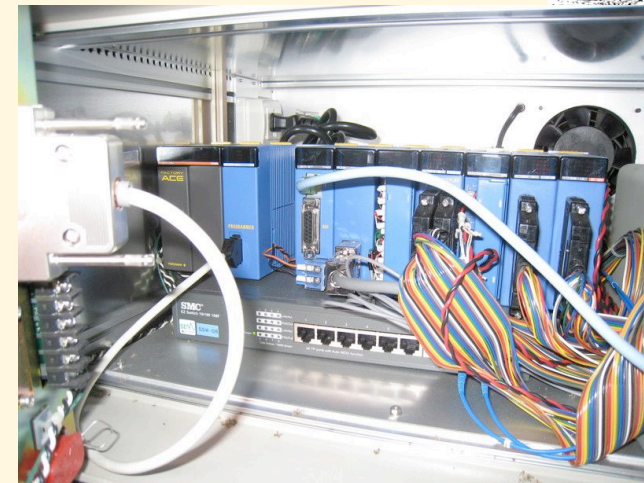
◆ Hoped to run EPICS on PLC



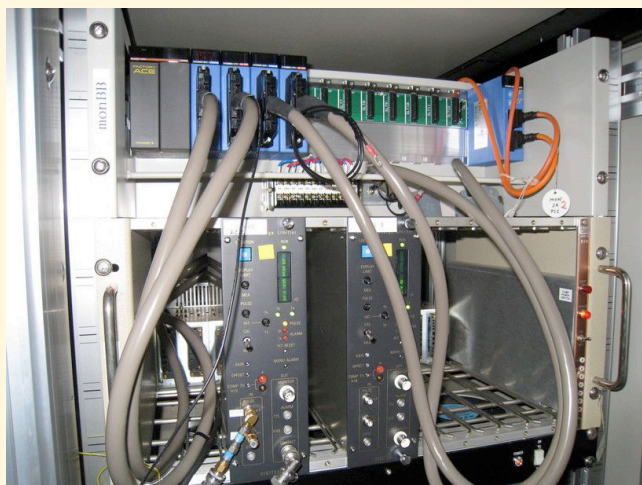
Vacuum Controller Internal



Magnet Controller Internal



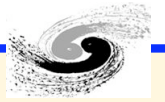
RF Controller Internal



Safety Controller



Touch Panel Display for RF



EPICS on PLC

- ◆ **VxWorks was available on PLC (Yokogawa, Mitsubishi)**
 - ❖ We use VME for realtime performance with VxWorks
 - ❖ License management of vxWorks ...
- ◆ **Yokogawa starts to provide Linux (2.6) on PLC CPU**
 - ❖ Brave enough to choose open source environment
 - ✧ We negotiate with Yokogawa to remove any license issues
 - ❖ Odagiri/KEK, Uchiyama/SHI, Yamada/Tokyo-u made much effort to realize the implementation
 - ❖ Takuya-Nakamura/MSK tailored the environment for KEKB
 - ✧ Procservice, pmon, NFS, ...
- ◆ **Three of them are used in KEKB operation**
 - ❖ Beam mask controller and Pulsed-quad controller
 - ❖ It run 57-days before software upgrade without troubles

F3RP61

Linux 2.6.24

PPC 533MHz

128Mbyte RAM

100BaseTx x 2

USB

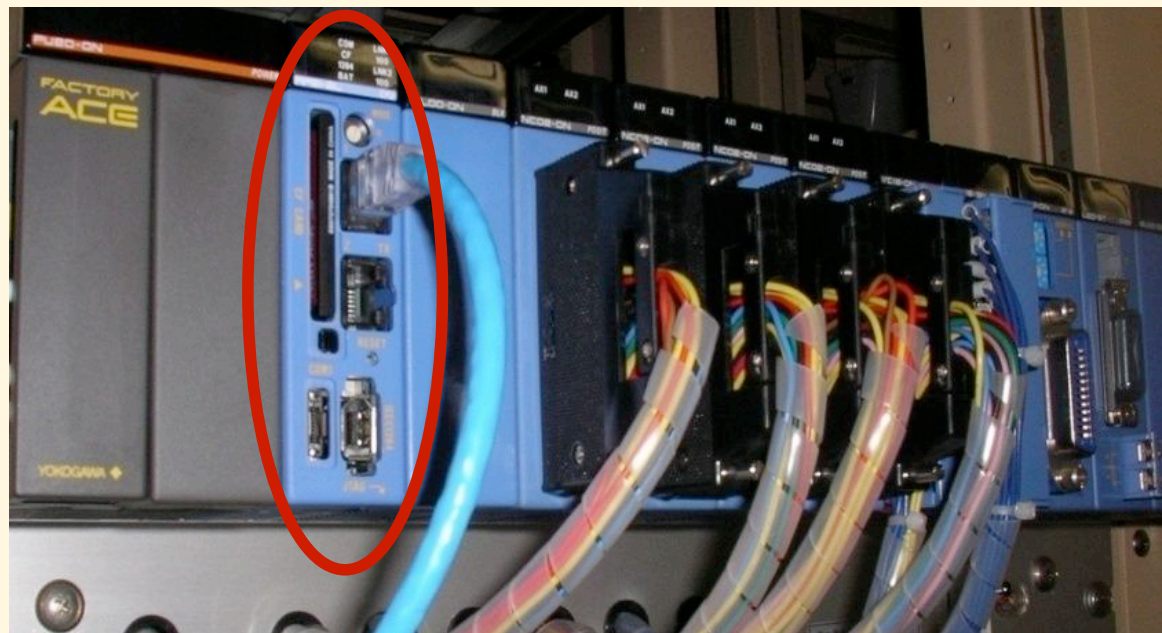
IEEE1394

Serial

PCI

I/O Bus for FAM3 Module Interface

Software development environment



Beam mask controller





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

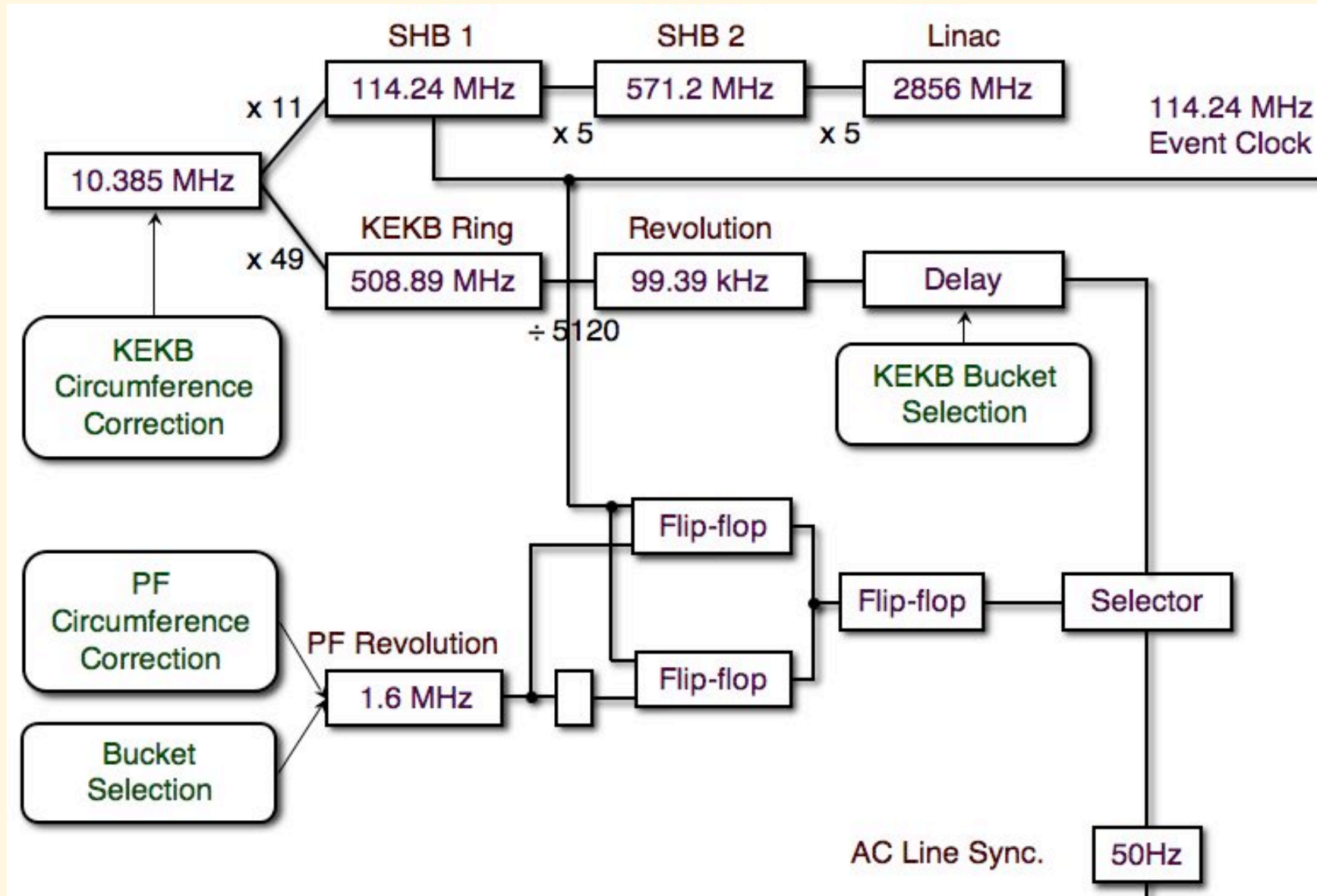
◆ Fast switching of many device parameters

- ❖ In 20ms / 50Hz
- ❖ Should be reliable because beam power is much different

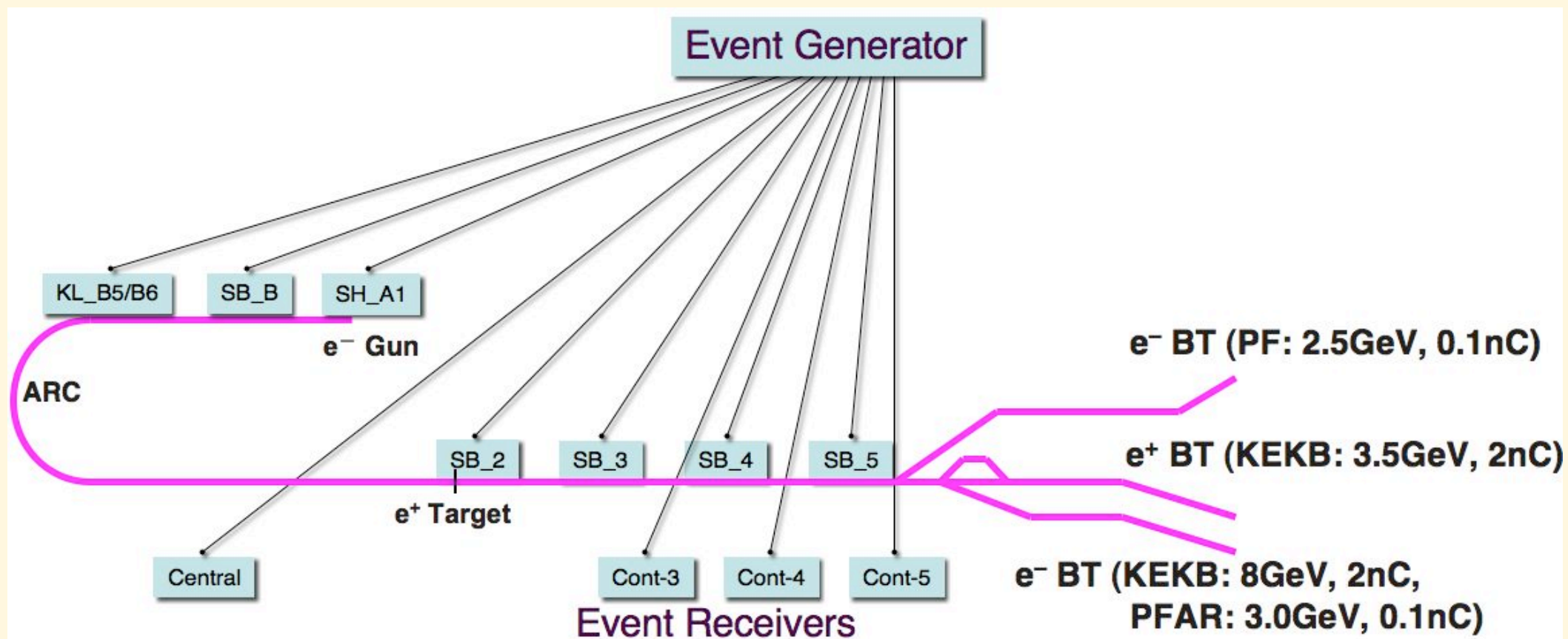
◆ MRF Series 230 Event Generator / Receiver

- ❖ 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

Basic synchronization outside of EVG



Event system configuration, autumn 2008

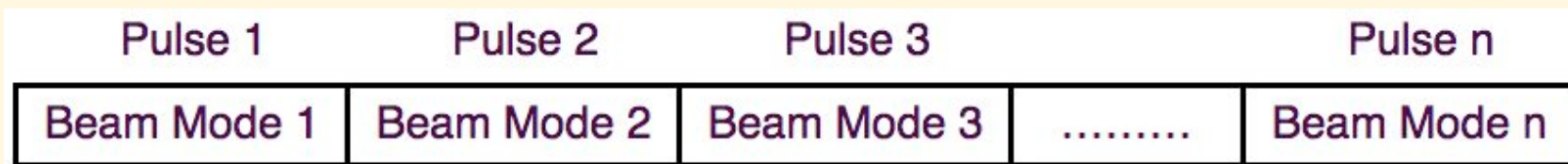




Beam mode pattern generation

- ◆ 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



File Injection Pattern Panel: LMEV v0.5

Read
Update: 2008/12/08 20:31:39 Read Pattern & Buffer Save

Read
Start INDEX: 1 End INDEX: 100

Set
Update: Set -> Pattern Save Load data Load data & Index

Buffer
Update: 2008/12/08 19:19:37 Set -> Buffer Buffer -> Pattern

Index
Buff: Start INDEX: 1 End INDEX: 100 INDEX -> Buffer

Beam Pattern FP21T Pattern

Set Beam Pattern
Start Value: End Value: 100 Even Number

Beam Mode: No Injection

1-50	51-100	100-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Read																								
Buff																								
Set																								
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Read																								
Buff																								
Set																								

File InjPattern-multi v0.1

Update: 2008/12/15 07:38:45

Priority	KEKB e-	KEKB e+	PF(CT) e-	PF-A1 e-	AR e-
PF-A1 e-	0 Hz	0 Hz	0 Hz	0 Hz	0 Hz
KEKB e-	0 Hz	0 Hz	0 Hz	0 Hz	0 Hz
KEKB e+	12.5 Hz	0.0 Hz	0.0 Hz	0.0 Hz	0.0 Hz
AR e-	12.5 Hz	0.0 Hz	0.0 Hz	0.0 Hz	0.0 Hz
PF(CT) e-	0 Hz	0.0 Hz	0.0 Hz	0.0 Hz	0.0 Hz
KEKB e- Study	0 Hz	0 Hz	0 Hz	0 Hz	0 Hz
KEKB e+ Study	0 Hz	0 Hz	0 Hz	0 Hz	0 Hz
PF(CT) e- Study	0 Hz	0 Hz	0 Hz	0 Hz	0 Hz
PF-A1 e- Study	0 Hz	0 Hz	0 Hz	0 Hz	0 Hz
AR e- Study	0 Hz	0 Hz	0 Hz	0 Hz	0 Hz

Up Down Read Set ALL "0 Hz" Set

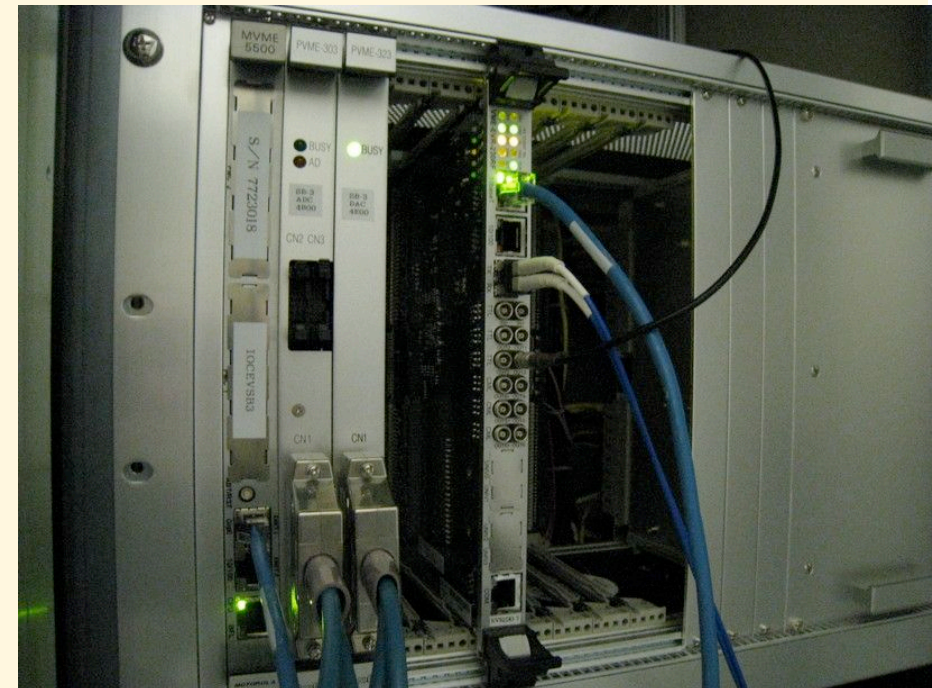
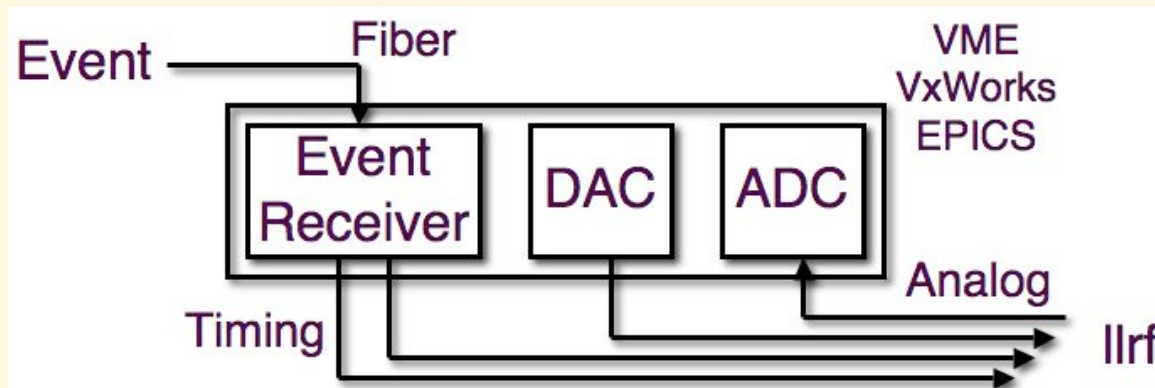
Ready.

Manual pattern designer

A version for current operation

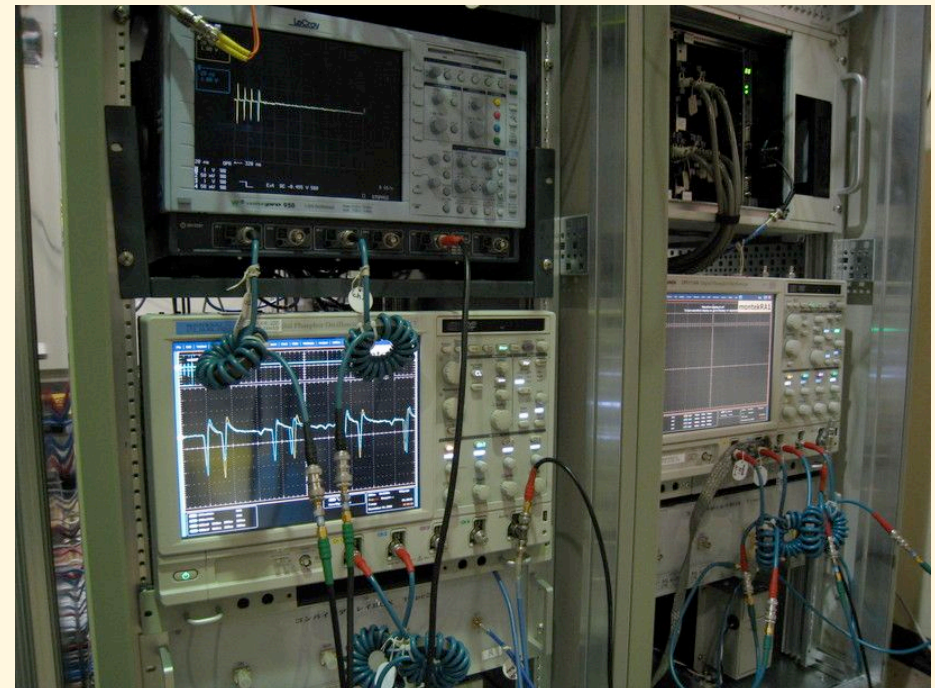
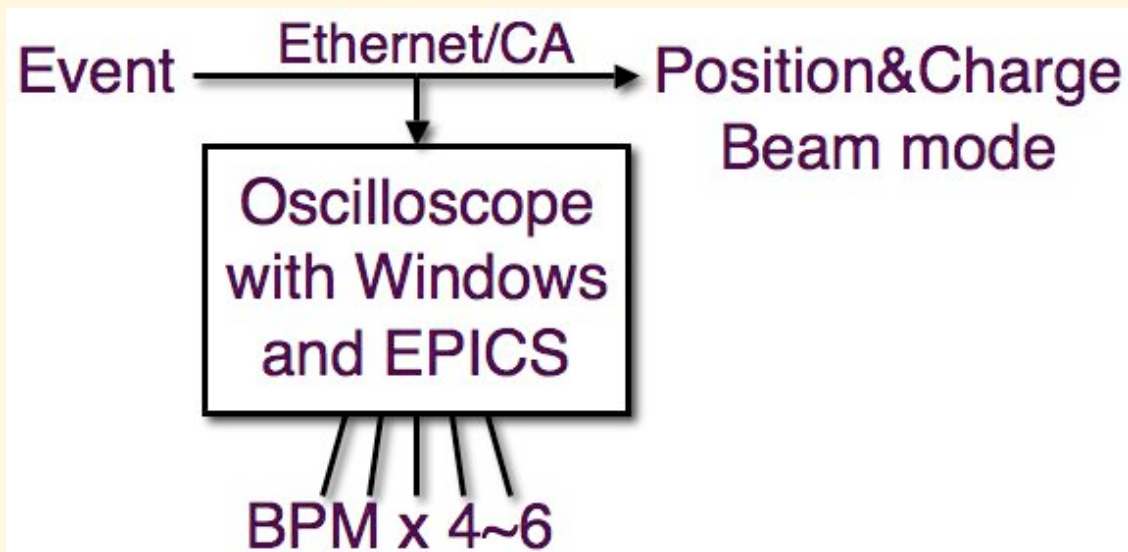
LLRF

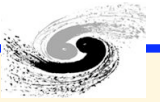
- ◆ Timing and analog signals are essential for absolute energy, energy spread, and dual-bunch energy equalization.
- ◆ Signals can be switched pulse-by-pulse.
- ◆ Driver klystrons (SB), energy tuner klystron (KL), and sub-harmonic bunchers (SH) are managed by the event system.



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.

Embedded EPICS with FPGA

◆ Suzaku/atmark-techno

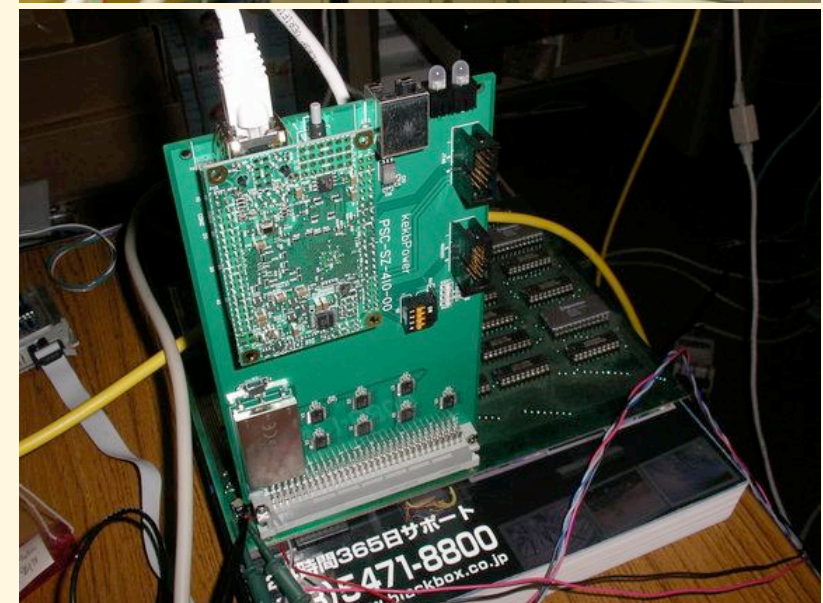
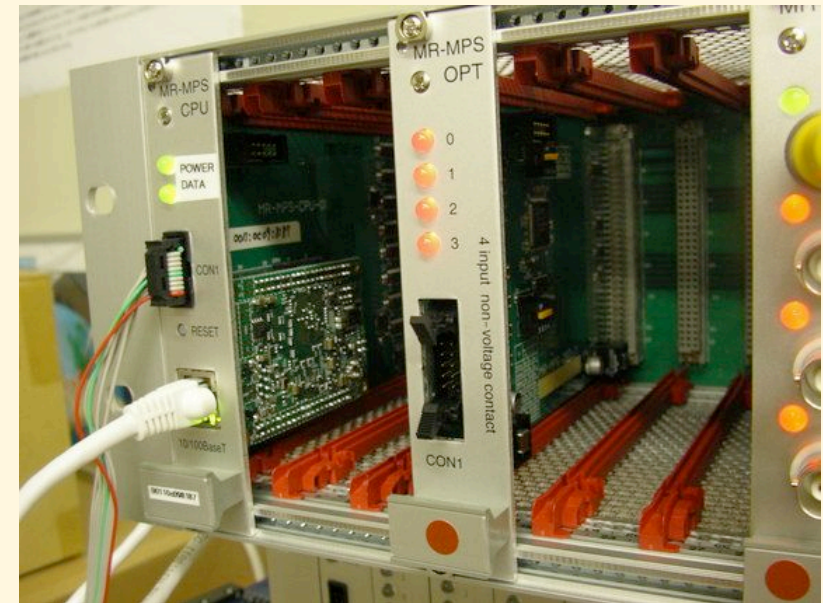
- ❖ FPGA Vertex-4
- ❖ PPC Linux-2.6
- ❖ EPICS 3.14



◆ J-PARC MPS

◆ KEKB Magnet

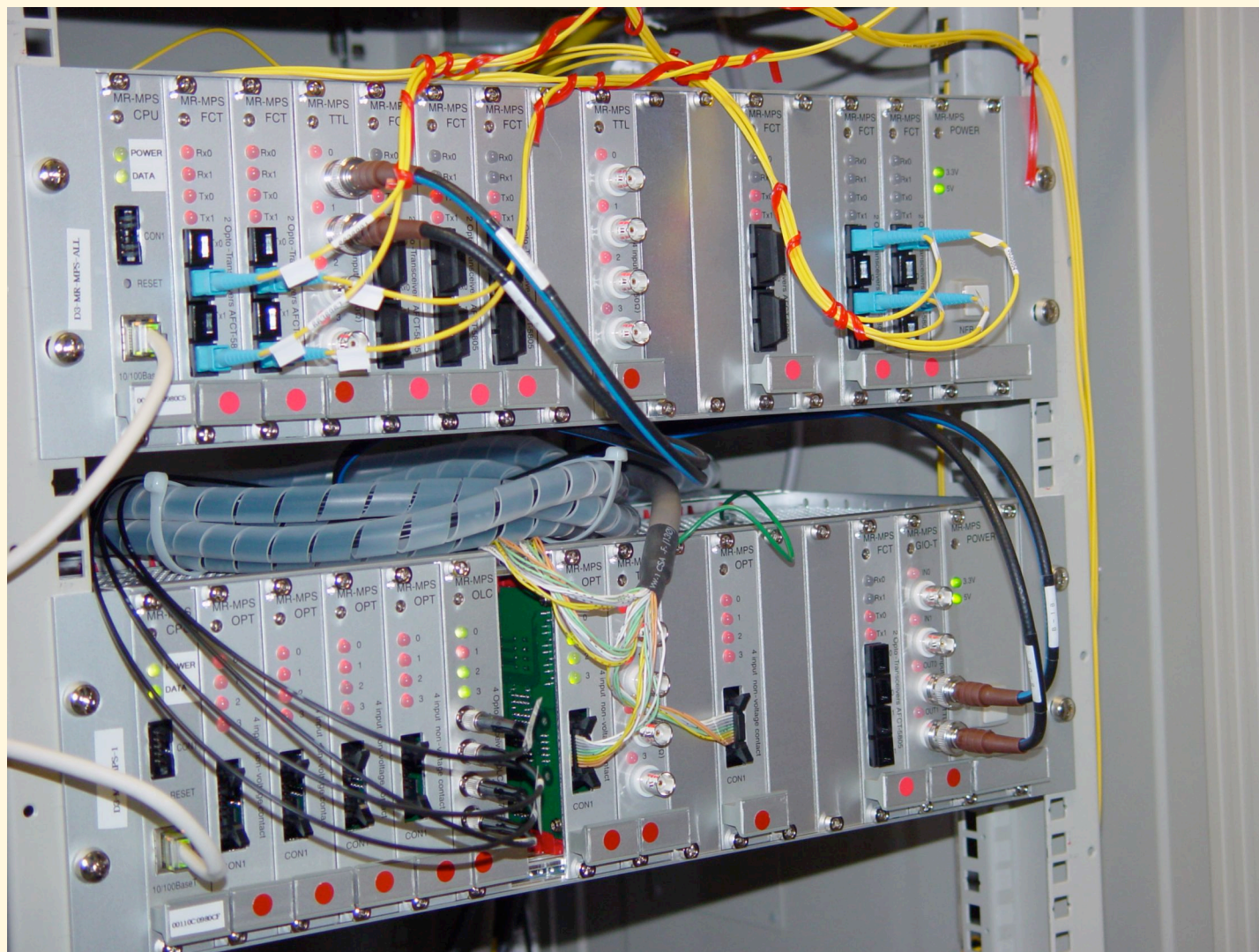
◆ Linac RF

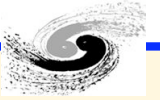


J-PARC MR MPS Operational

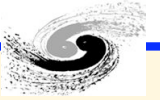
◆ Akiyama,
Nakagawa,
et al.

◆ Several
Different
Interfaces





Thank you



Thank you