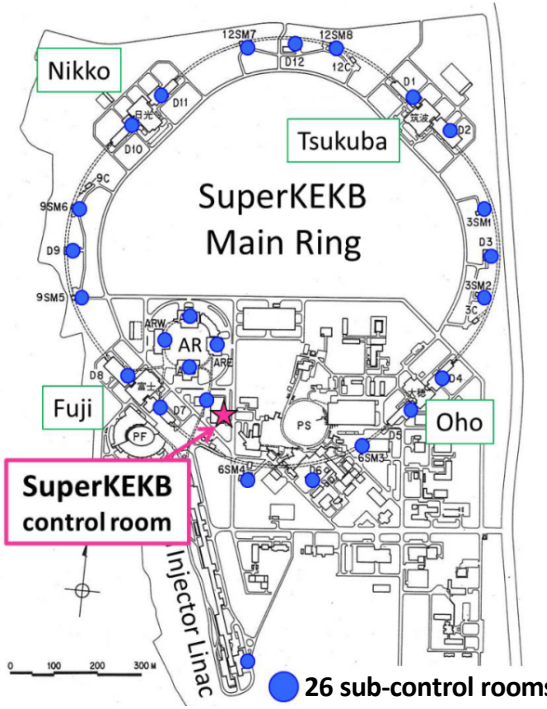
Control Group Report

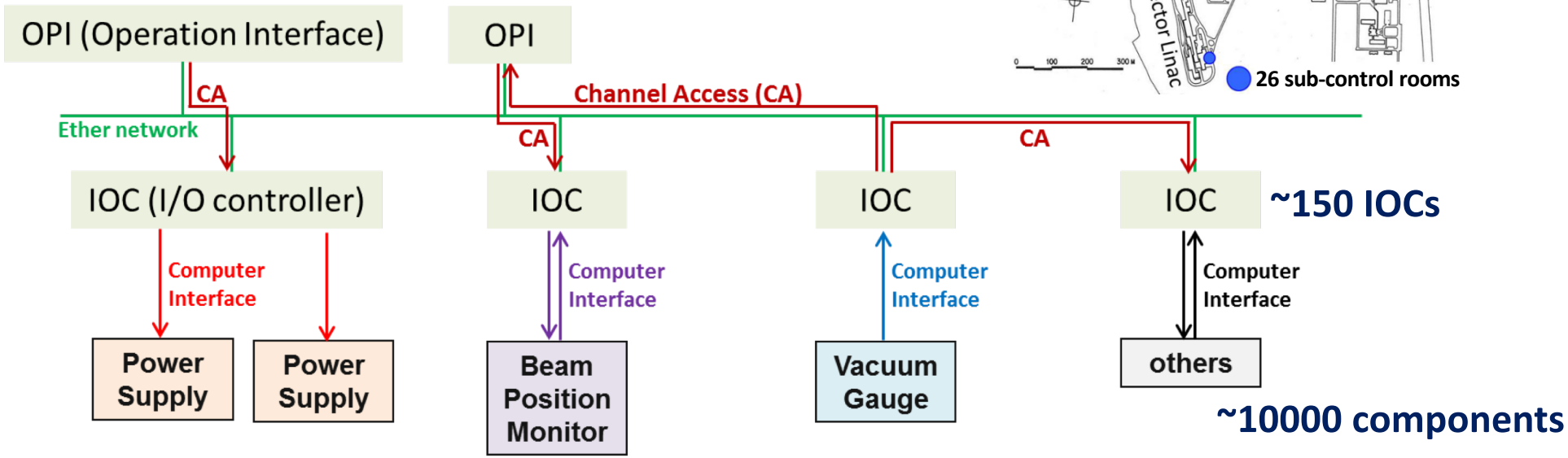
Hiroshi Kaji
on behalf of SuperKEKB Control Group

Control System Overview

The SuperKEKB control system manages the hardware belonging to ~3km beamline.

EPICS Input/Output Controller (IOC)
configured with VME, PLC, ...
Console with the Operation Interface (OPI)
based on the SAD, Python, CSS, ...
Dedicated network





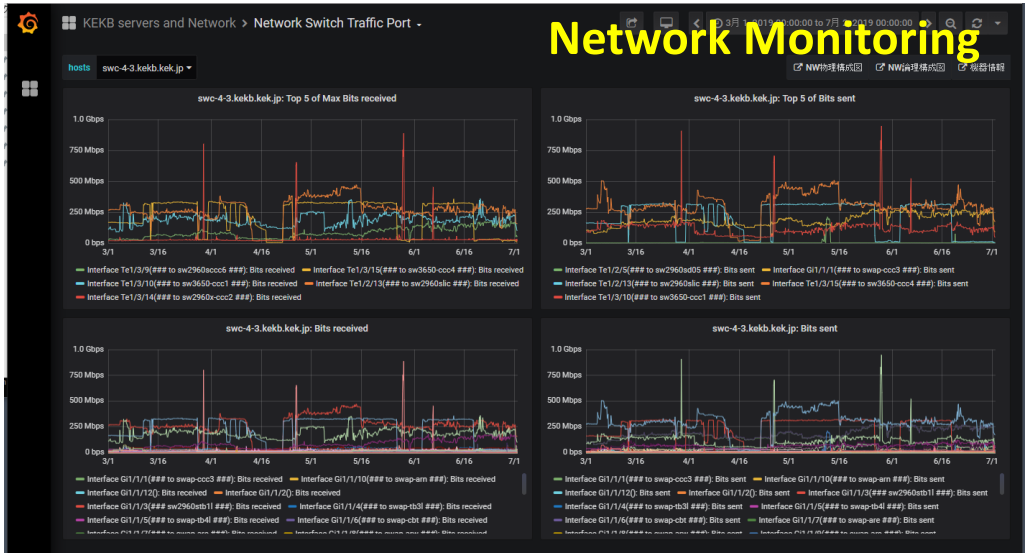
After the phase-1 operation, control group worked for the DR operation and the improvement of the SuperKEKB drivability.

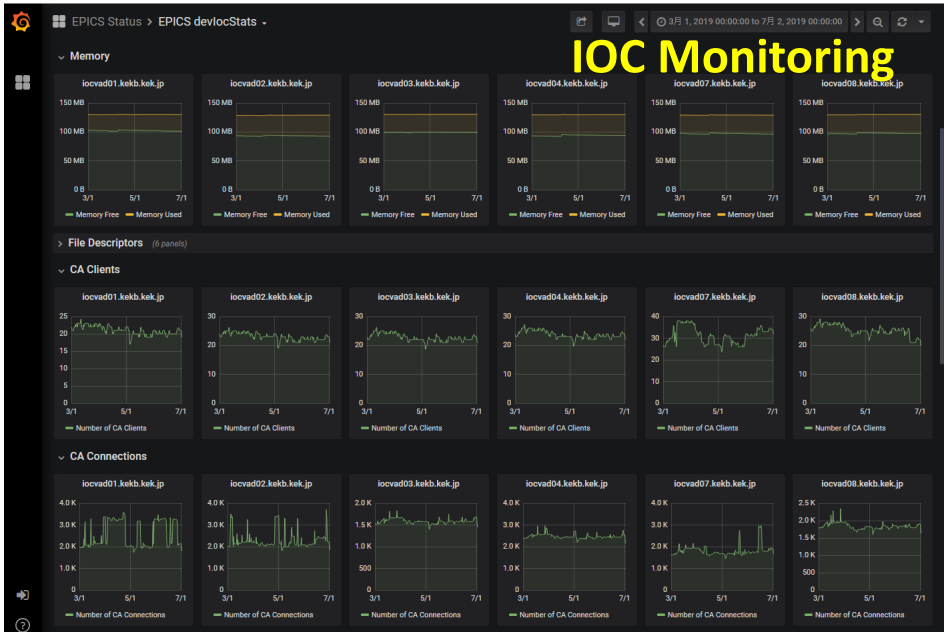
Web-based Monitoring System

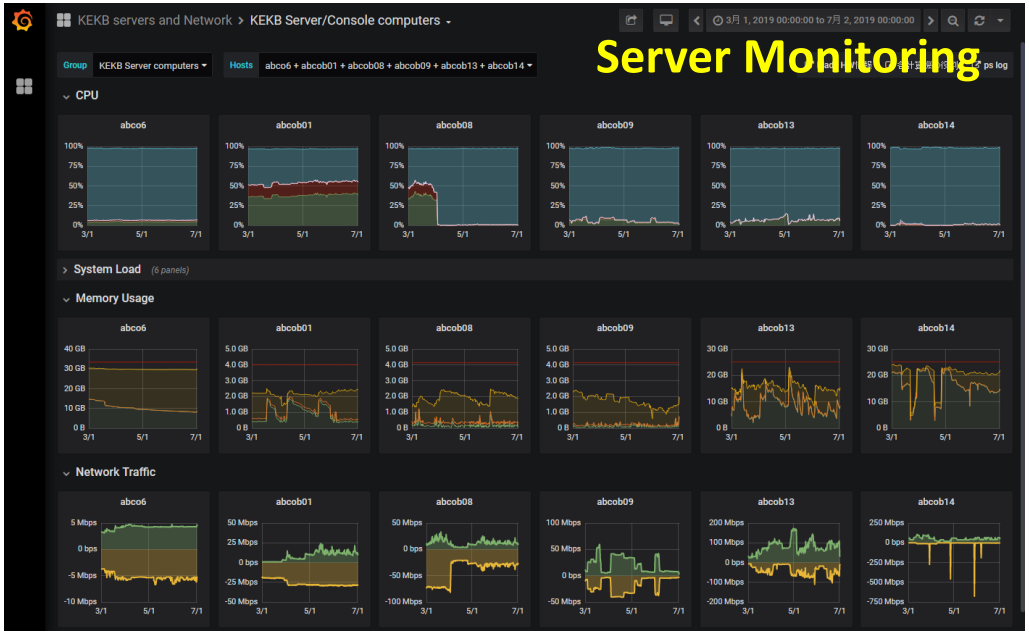
Web-based monitoring system is developed with **Grafana**. https://grafana.com

The infrastructure of control system (like server/network/IOC) is monitored.

Information is collected with **Zabbix**.
https://www.zabbix.com
https://grafana.com/plugins/alexanderzobnin-zabbix-app







Web-based Monitoring System – ctd

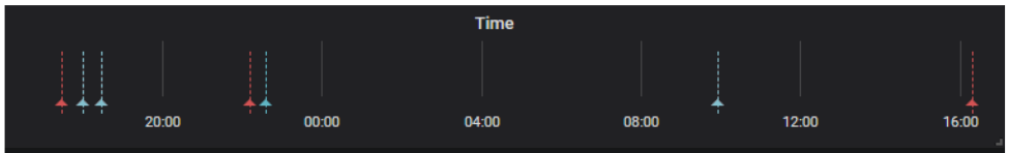
S. Sasaki, “Web-based Data Visualization Using EPICS pvAccess RPC at SuperKEKB”, in proc. of 15th annual meeting of PASJ.

In addition, we utilize the **Remote Procedure Call (RPC)** of the EPICS 7 protocol.
It enables us to collect more complicated information.
The arbitrary constructor of the EPICS PV information can be transferred.

group: MG (LER) + MG (HER)

Current Alarm

time	group	severity_id	status	message	record
2018-07-03 13:24:21.028229	MG (LER)	MINOR	LINK_ALARM	Magnet PS ESR23 NA or IL	MG_PS:ESR23:ALARM
2018-07-03 13:24:20.611562	MG (LER)	MINOR	LINK_ALARM	Magnet PS ESL_M NA or IL	MG_PS:ESL_M:ALARM
2018-07-03 13:24:20.528229	MG (HER)	MINOR	LINK_ALARM	Magnet PS QC2LE NA or IL	MGHPS:QC2LE:ALARM
2018-07-03 13:24:20.511562	MG (LER)	MINOR	LINK_ALARM	Magnet PS QC2RP NA or IL	MGLPS:QC2RP:ALARM
2018-07-03 13:24:20.511562	MG (LER)	MINOR	LINK_ALARM	Magnet PS QC1RP NA or IL	MGLPS:QC1RP:ALARM
2018-07-03 13:24:20.511562	MG (HER)	MINOR	LINK_ALARM	Magnet PS QC1LE NA or IL	MGHPS:QC1LE:ALARM
2018-07-03 13:24:20.494896	MG (LER)	MINOR	LINK_ALARM	Magnet PS QC2LP NA or IL	MGLPS:QC2LP:ALARM
2018-07-03 13:24:20.478229	MG (HER)	MINOR	LINK_ALARM	Magnet PS QC2RE NA or IL	MGHPS:QC2RE:ALARM
2018-07-03 13:24:20.461562	MG (LER)	MINOR	LINK_ALARM	Magnet PS ESR1_M NA or IL	MG_PS:ESR1_M:ALARM
2018-07-03 13:24:20.428229	MG (LER)	MINOR	LINK_ALARM	Magnet PS QC1LP NA or IL	MGLPS:QC1LP:ALARM



Abort Timestamps

Time	Title	Text	Tags
2018-07-04 16:17:45.615	Manual Abort	2018-07-04 16:17:45.615908300 Manual Abort	LER
2018-07-04 09:54:56.349	Manual Abort	2018-07-04 09:54:56.349921000 Manual Abort	LER
2018-07-04 09:54:55.646	Manual Abort	2018-07-04 09:54:55.646719600 Manual Abort 2018-07-04 09:54:55.646763600 Loss Monitor D7-3	HER
2018-07-03 22:34:24.391	Loss Monitor D10-3	2018-07-03 22:34:24.391468400 Loss Monitor D10-3 2018-07-03 22:34:24.391516500 Loss Monitor D7-3 2018-07-03 22:34:24.403163700 RF D10-C 2018-07-03 22:34:24.604765900 Soft Abort	HER
2018-07-03 22:11:06.059	Loss Monitor D1-1	2018-07-03 22:11:06.059829300 Loss Monitor D1-1 2018-07-03 22:11:06.059888600 Loss Monitor D7-1	LER
2018-07-03 18:26:24.809	Loss Monitor TSUKUBA B4	2018-07-03 18:26:24.809103600 Loss Monitor TSUKUBA B4 2018-07-03 18:26:24.809146300 Loss Monitor D7-3 2018-07-03 18:26:24.813075300 RF D10-C	HER

Alarm monitoring:
The data protocol includes the “severity” and “status” fields.

Abort signal sorting:
The data protocol includes the “time” field.

Timestamp synchronization

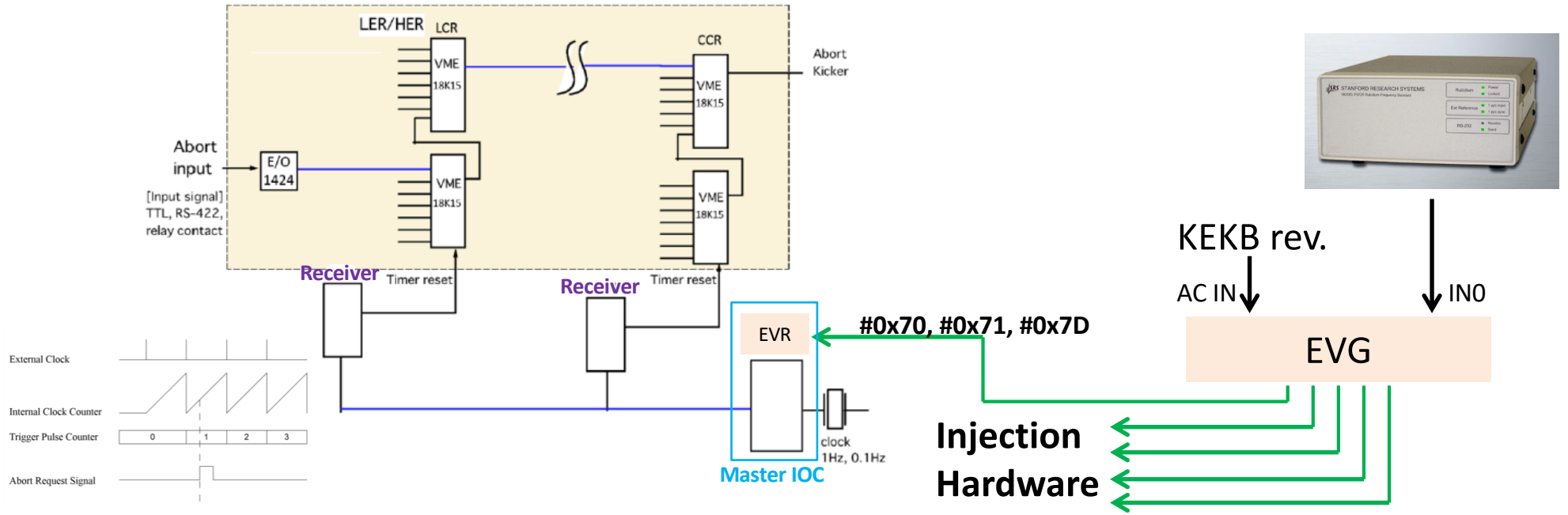
S. Sasaki, *et al*., "Upgrade of Abort Trigger System for SuperKEKB", in proc. ICALEPCS2015, Melbourne, Australia.
H. Kaji, *et al*., "Time synchronization for Distant IOCs of the SuperKEKB accelerators", in proc. IPAC2017, Copenhagen, Denmark.

Note, we discuss the timestamp (CPU clock) of the control system rather than the timing.

The CPU clocks of all Event Timing System and Abort Trigger System modules are synchronized with the accuracy of ~1μs.

- The timestamp of all Event IOCs is synchronized by the delivery of the special kind of Events.
- The common timestamp is delivered for all Abort Trigger modules.
- The EVR is installed on the master IOC of Abort Trigger System

⇒ Two systems are combined and **LINAC and MR have common timestamp**.



Abort analysis with timestamp

6/1 21:19 LER D6V2 LM abort

Seimiya-san and his team determine there is a coincidence of the abnormal LINAC pulse and the LER abort.

Abort:	**6/1 21:19:47.785007**
LINAC pulse:	**6/1 21:19:47.784**

Abnormal energy shot is observed.

-20mm@SP613(η_x=1.68 m) ⇒ ΔE = -50MeV

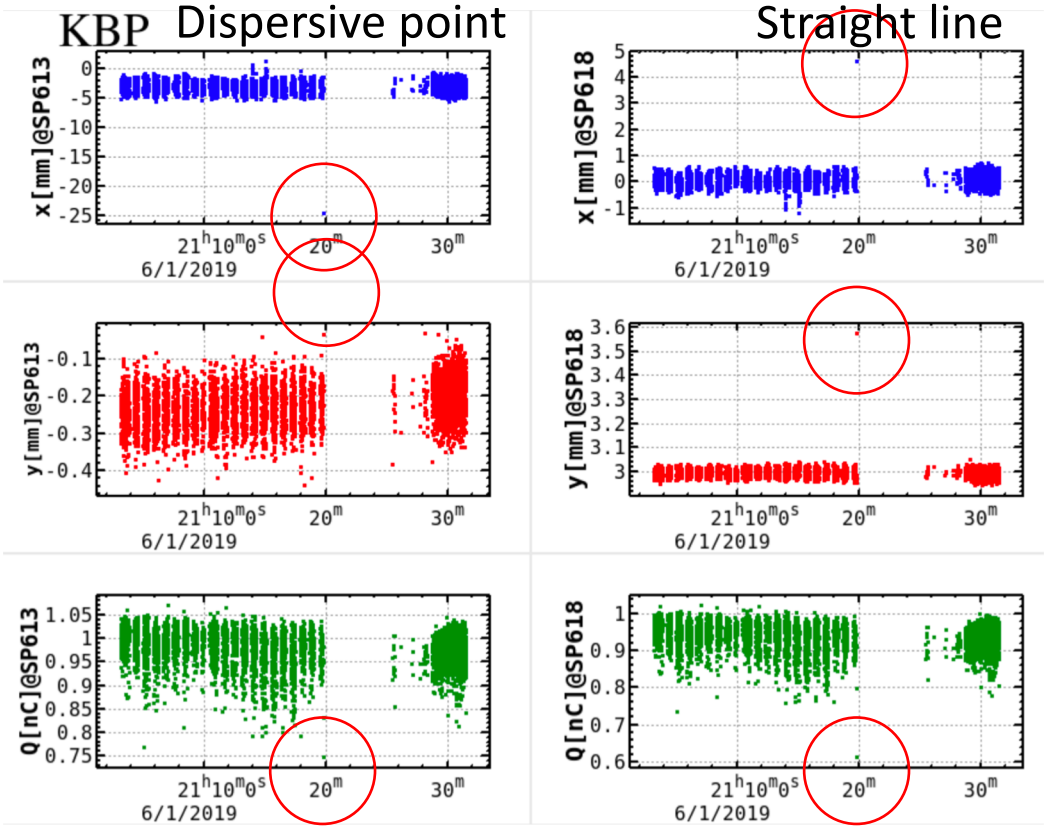
They confirmed “the klystron, KL_51, is down at this pulse”.

This low energy pulse is possible to be injected at LER.

δ ~ 1.2%

→ δ ~ 0.4% (after ECS) < BT Acceptance

We assume this pulse causes the LER abort.



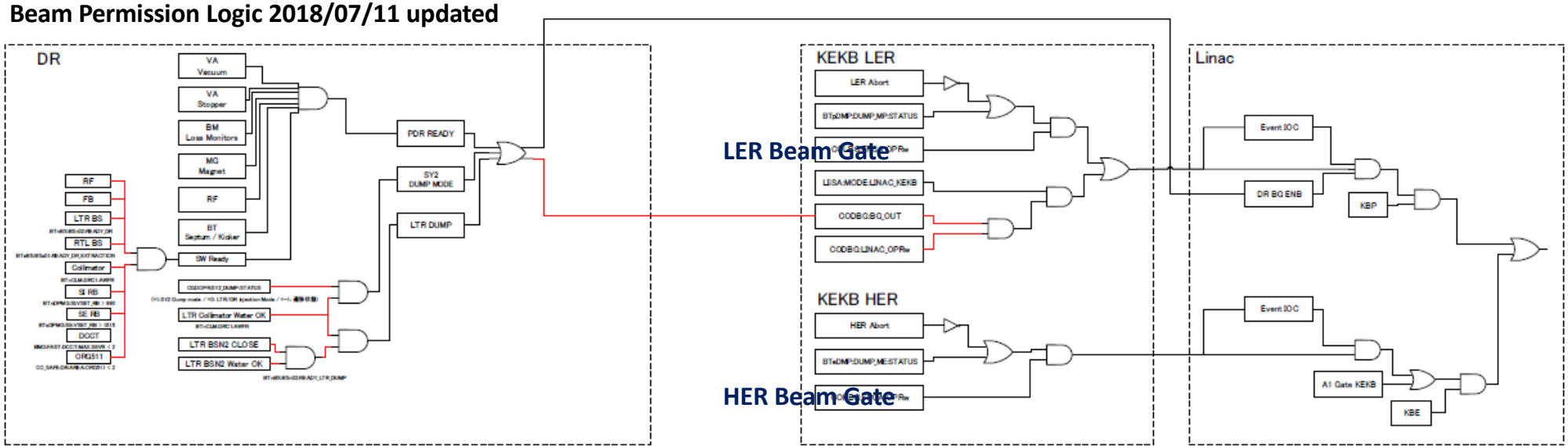
Beam Permission and Beam Gate

Upgraded for satisfying the DR operation

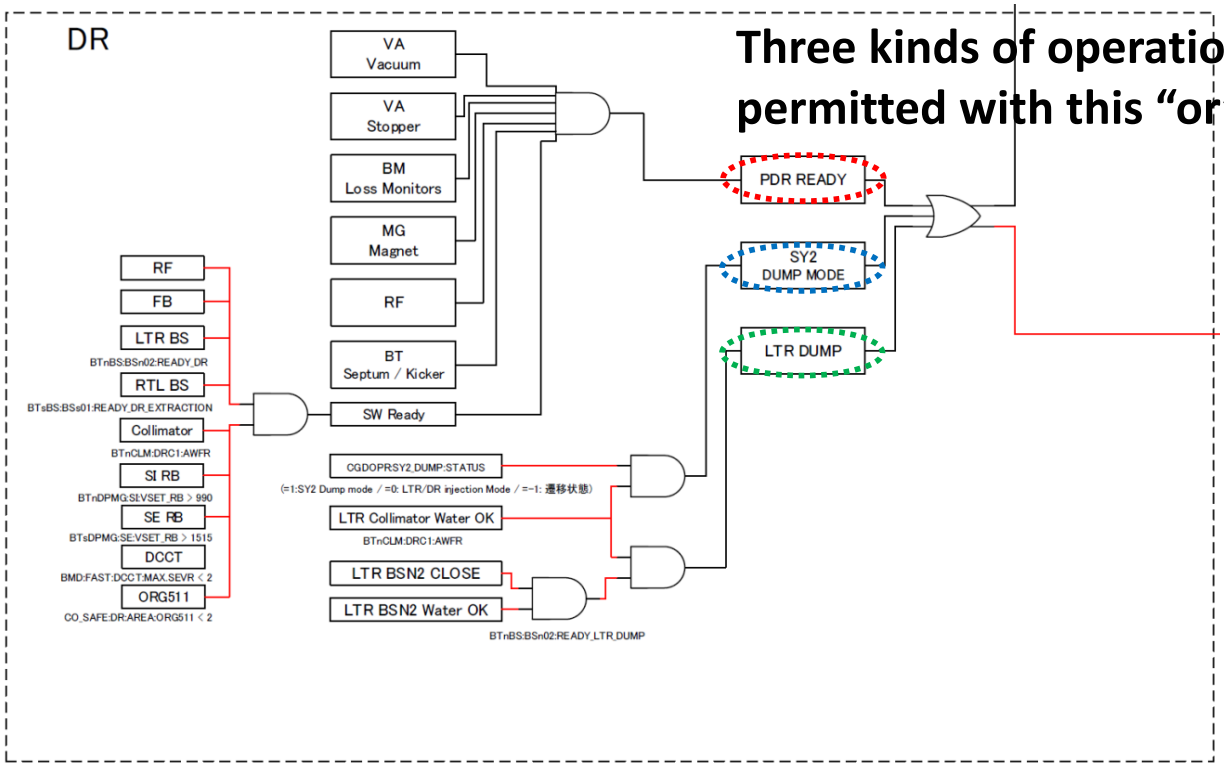
Beam Permission:
- kind of machine protection system
- Logic enables the accelerator operation when the proper condition is satisfied.
- It includes several operation modes for DR

Beam Gate:
- Switch for operators which turn on/off the LINAC operation.
- It is integrated in the Beam Permission logic.

Beam Permission Logic 2018/07/11 updated



Beam Permission for DR

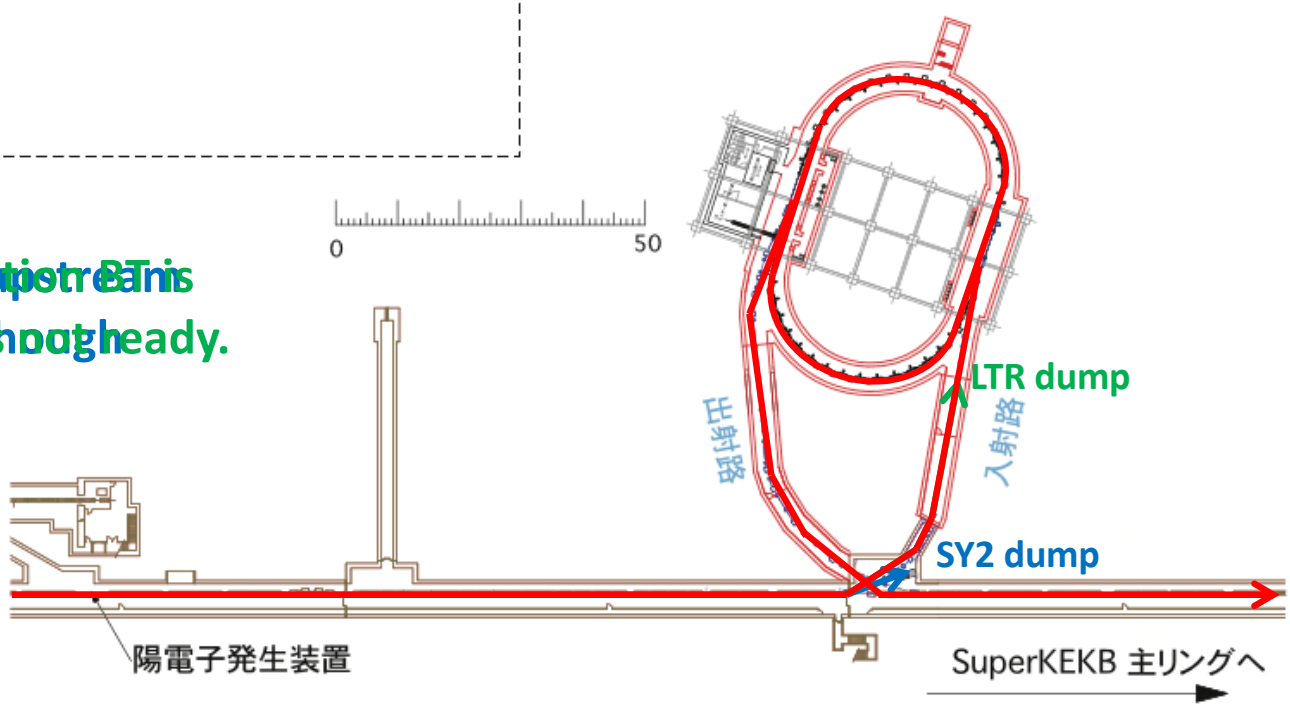


Three kinds of operations are permitted with this “or” logic.

DR operation is possible. Injection to BT is possible even though the DR is not ready.

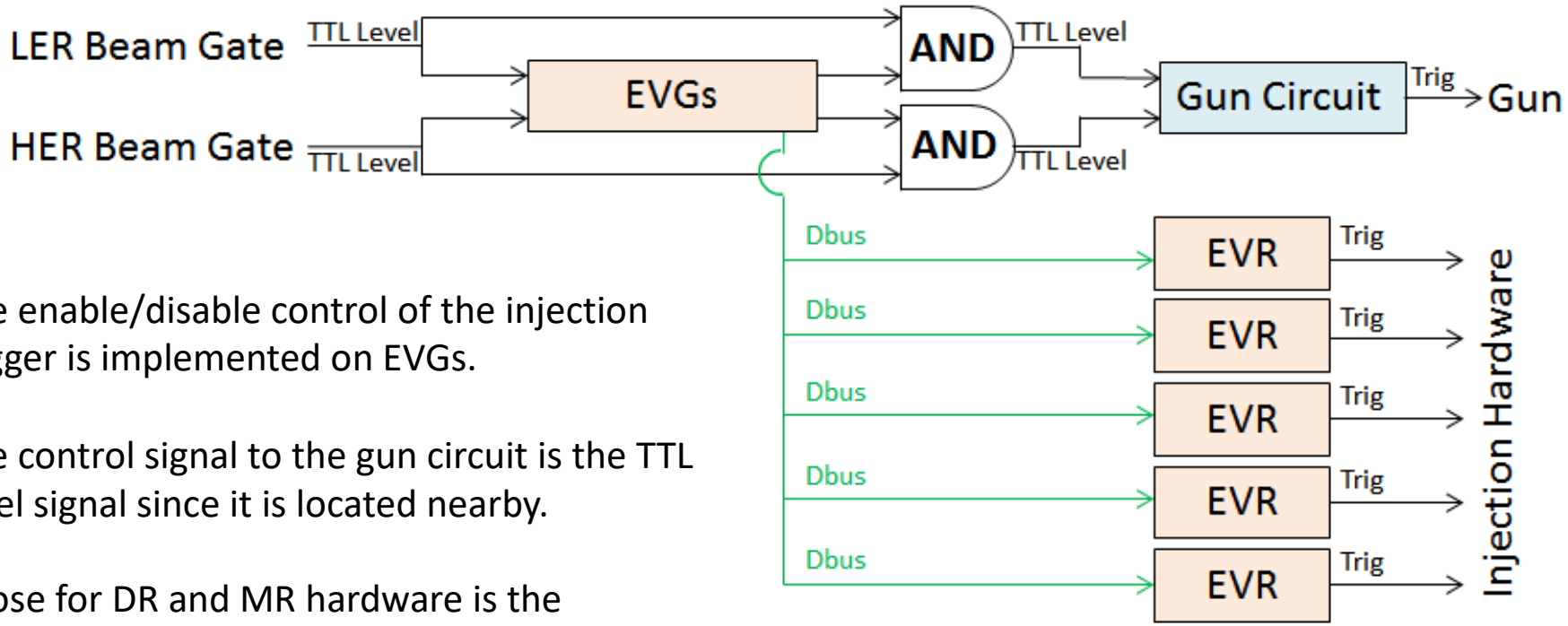
DR operation is impossible. Injection to BT is possible even though the DR is ready.

the DR and its BT is not ready.



Synchronized Control of Injection Hardware

H. Kaji, *et al.*, "Beam Gate Control System for SuperKEKB",
in proc. IPAC2018, Vancouver, Canada.



The enable/disable control of the injection trigger is implemented on EVGs.

The control signal to the gun circuit is the TTL level signal since it is located nearby.

Those for DR and MR hardware is the Distributed Bus Bit (Dbus) signals.

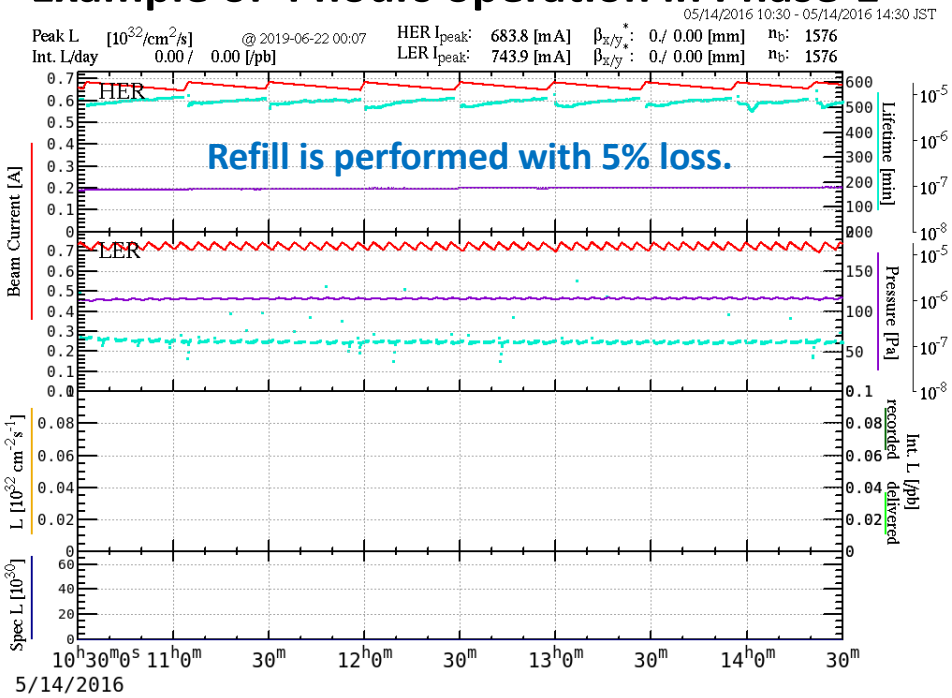
The triggers for all hardware are enabled/disabled synchronously. The DR extraction hardware is controlled with the appropriate delay (DR storage time) from the DR injection hardware.

Comparison of Top-up Injection in Phase-1 and Phase-3

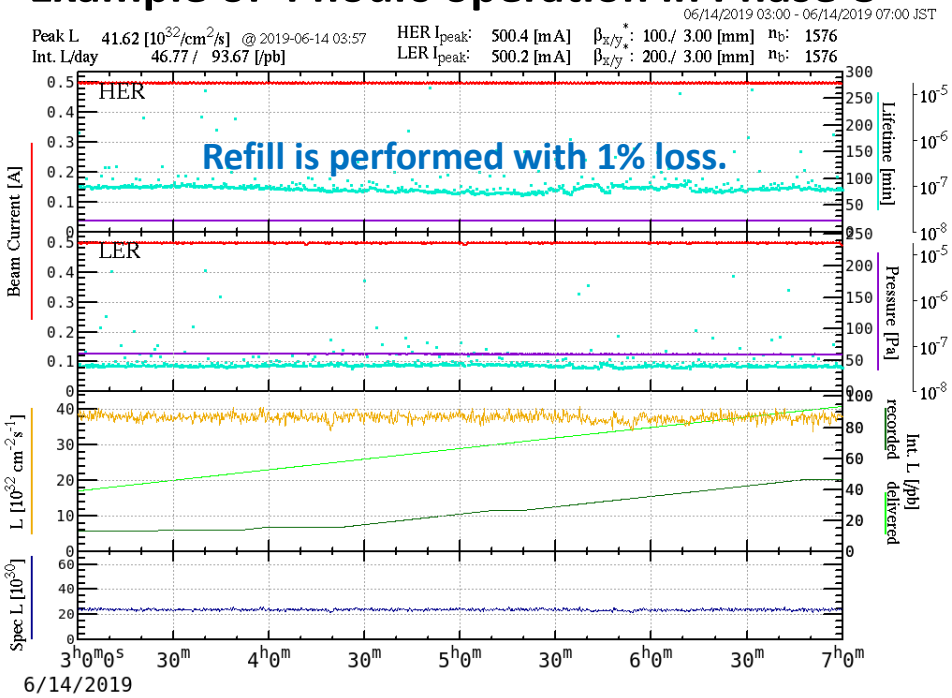
The Beam Gate signals for individual hardware are synchronized and the system becomes robust.
The frequent switching of Beam Gate becomes possible.

⇒ Top-up parameter is improved.

Example of 4 hours operation in Phase-1



Example of 4 hours operation in Phase-3



In the rough estimation with formula, $L \propto I_{LER} I_{HER}$,
It seems the loss of integrated luminosity is suppressed with new parameter.
We believe the upgrade of Beam Gate is excellent work!

Archiver Status

The control group supports the following two archivers so far.

KBLog:
- Main archiver from the KEKB project
- All necessary information for the operation is recorded.

CSS archiver:
- Sub system for the limited uses.
- The data of QCS and Belle solenoid are archived.

EPICS Archiver Appliance:
- Test operation with the small users is performed.
- The stress test is scheduled during this summer shutdown.
- We plan to release to all SuperKEKB members from the autumn run.

Injection Archiver:
- The injection data are recorded for all injector pulses.
- Two systems are operated (CSS and AA).

EPICS Archiver Appliance

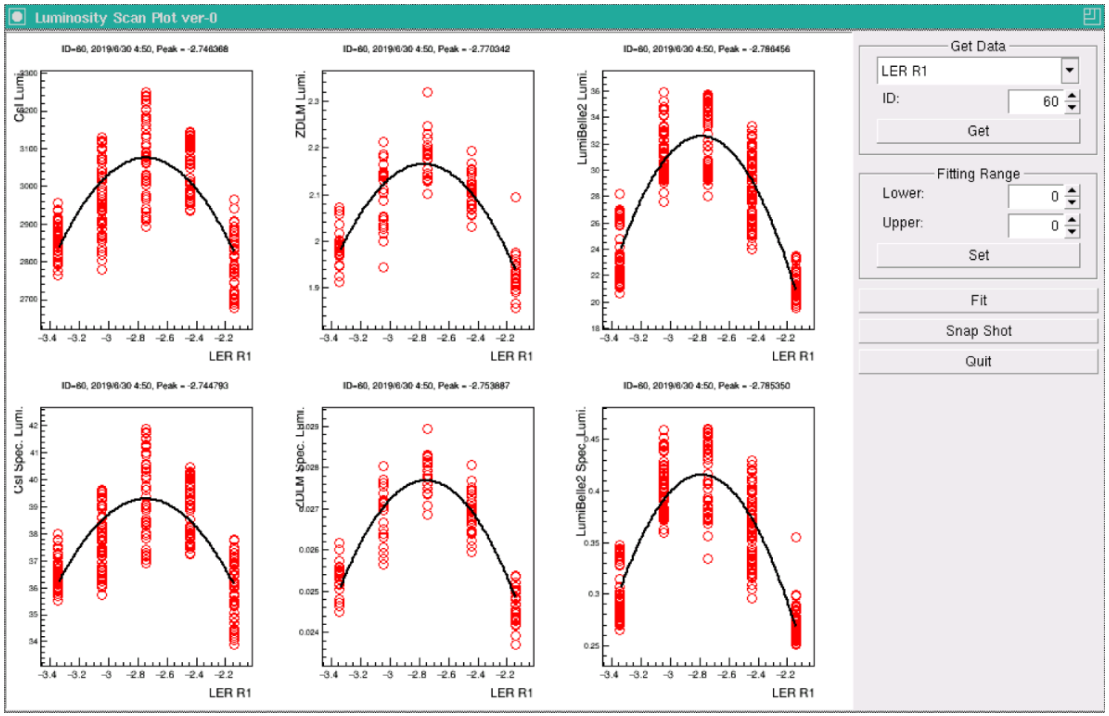
EPICS Archiver Appliance is an open source archiver developed at SLAC.
It is fully utilized in the accelerator operation at J-PARC.

The high performance is reported by the J-PARC control group.
- **1/4 data volume as compared with the CSS archiver**
- **Quite high speed retrieval**

	CSS	AA
1hour	1.236s	0.136s
24hour	24.229s	0.150s
3days	637.408s	2.408s

Retrieval time for the 1Hz processing PV data

All data of the luminosity scan in phase-2 and phase-3 are recorded. The panel for data retrieval is developed.



The test operation is performed with two servers and two clusters.

We perform the stress test during this summer shutdown.
The service will be provided for all SuperKEKB users before the next operation.

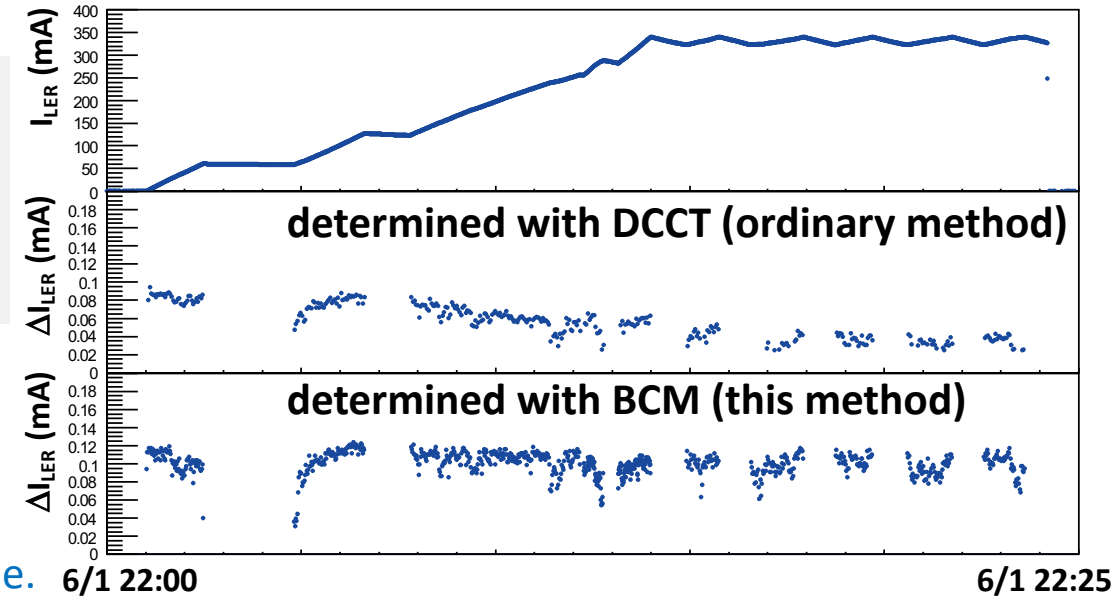
Injection Archiver

H. Kaji, et al., "Archive System of Beam Injection Information at SuperKEKB", accepted by *Journal of Physics: Conference Series*

Injected current is determined and recorded for all injector pulse.

The injected current, ΔI, is determined from bunch current monitor as follows:

$$\Delta I = I_{bunch}(after) - I_{bunch}(before)$$

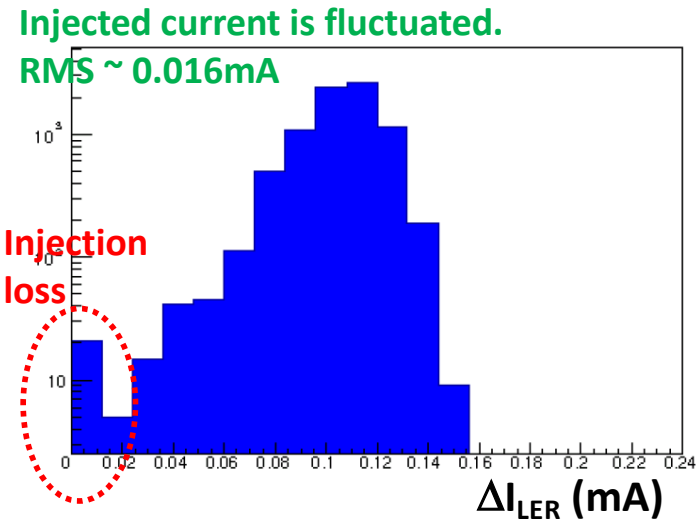


Note, injection RF-bucket is changed in every injector pulse. However, we can know it from Bucket Selection or Event Timing System.
The measured RF-bucket is changed in every time.

Two systems are operated.

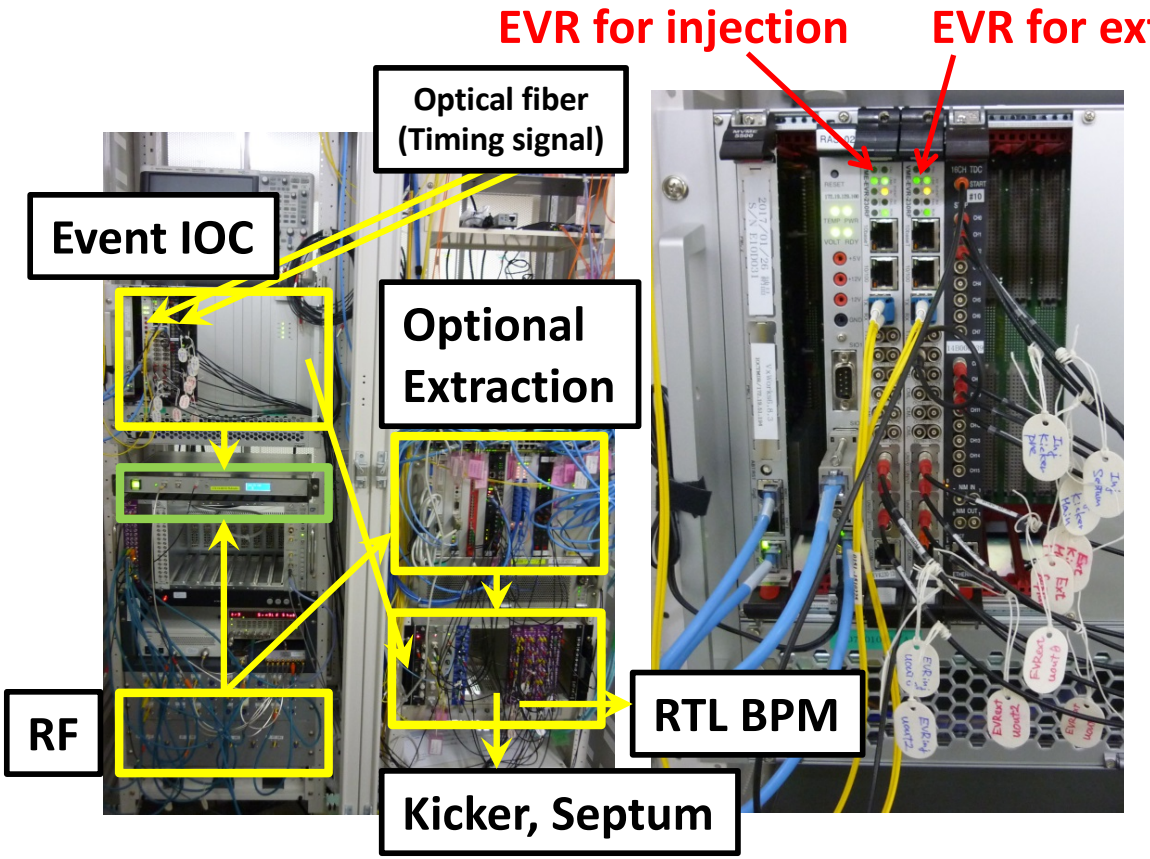
Event Timing System and CSS archiver
- operated from phase-2,
- packet loss ~0.2%
- cannot be operated in the injection rate >25Hz

Bucket Selection and Archiver Appliance
- operated from phase-3,
- Almost perfect, but still a little packet losses are found.
- possible to record all injection pulse in 50Hz



Damping Ring Sub-timing Station

H. Sugimura et al., “Synchronized Timing and Control System Construction of SuperKEKB Positron Damping Ring”, in proc. ICALEPCS2017, Barcelona, Spain



Two EVRs generate the injection and extraction triggers, respectively.

The enable/disable of triggers for the kicker and septum magnets from EVGs via the Distributed Bus Bit.

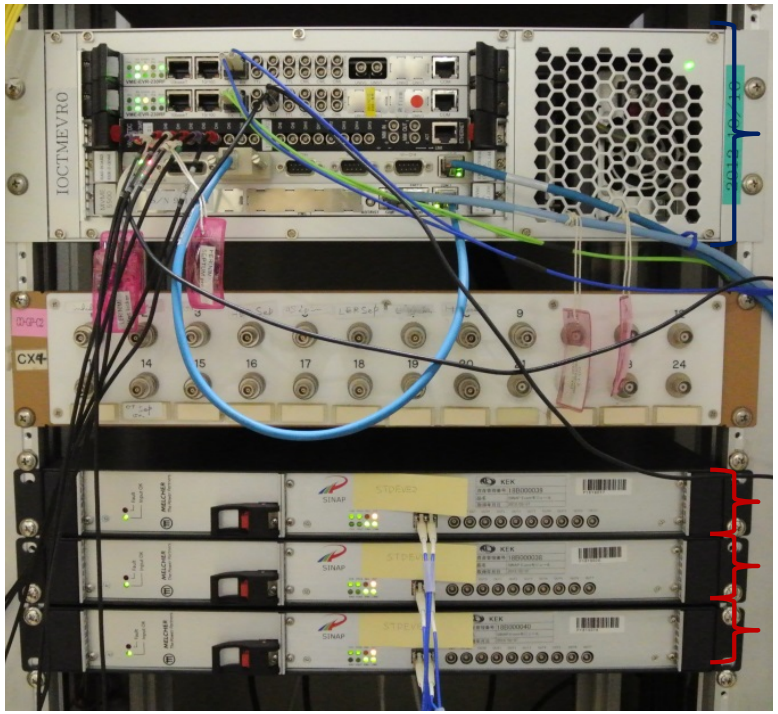
⇒ **realize sophisticated DR operations**

Optional beam extraction system
- Trigger is generated with the DR revolution
- Possible to extract storage beam no matter what the LINAC/DR conditions

Note, the timing trigger for the BPMs is generated by the beam diagnostic group. We skip it.

Standalone Event Receiver (STD-EVE)

Developed by the collaboration of the KEK and SINAP control groups.



Typical VME-type EVR IOC

Standalone EVR (STD-EVE)
- **1U height box on the 19inch rack**
- **embedded CPU with EPICS**
- **16 output channels with fine delay function**

The easy way for install and maintain EVR

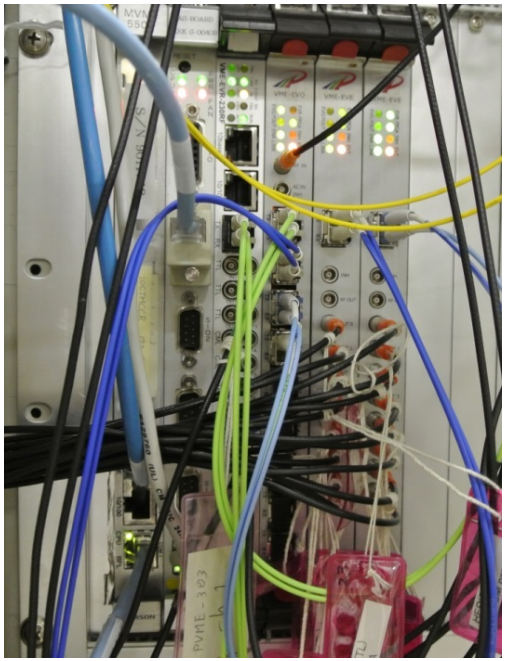
If someone want to have a new injection-trigger, he/she can set-up and use one output channel of STD-EVE by themselves.
- **Timing-expert does not need to do anything.**
- Non-timing-expert of control group can work instead of them.

If someone want to install a new STD-EVE,
- **Timing-expert advises, but in principle, does not work anything.**
- Non-timing-expert of control group can install a new STD-EVE.

They are employed also at PF-AR and ATF.

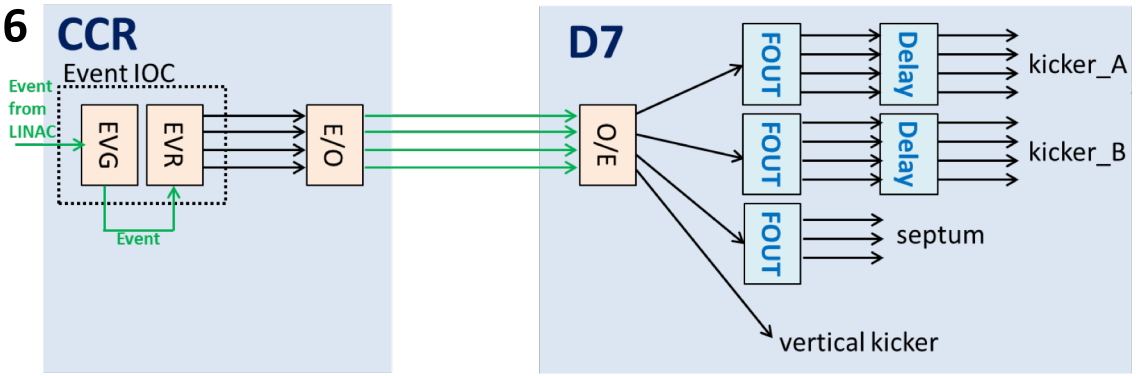
MR Sub-timing Station

Year2016

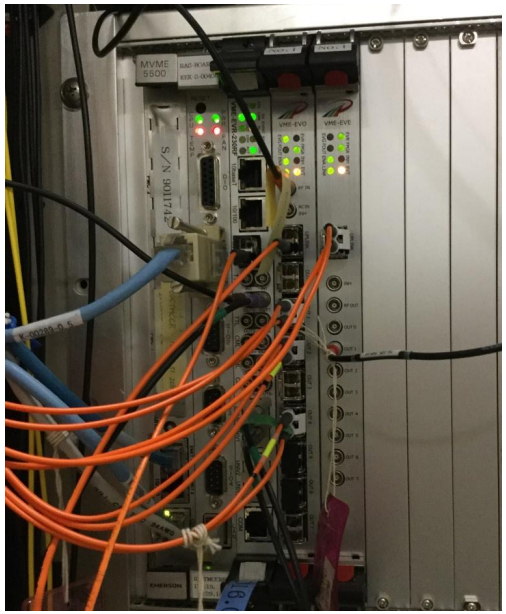


The STD-EVEs are installed at the D7 and D8 sub-control rooms.

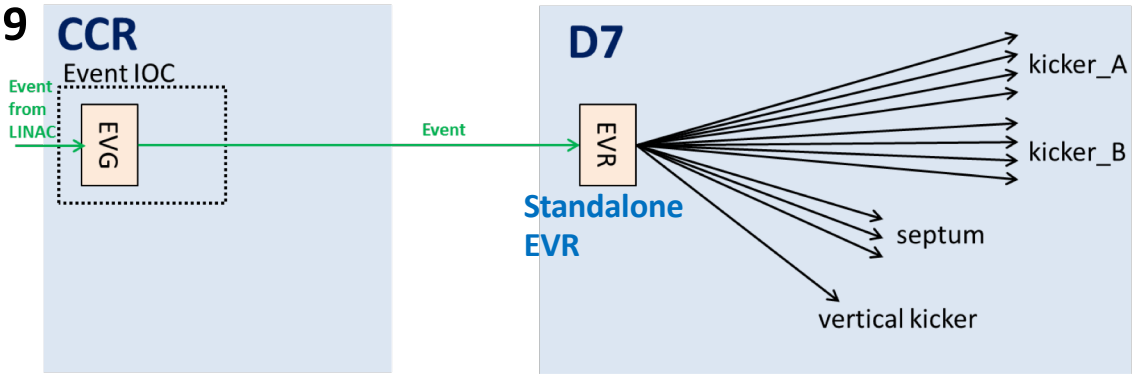
Year2016



Year2019



Year2019



The signal lines become simple and maintenance free.

- **Cables are reduced.**
- **Many modules are removed.**

Summary

DR operation

DR Sub-timing System is developed.

- Two EVRs provide the injection and extraction timing triggers, respectively.
- It includes optional beam extraction system which works independent from the Event Timing System.

Beam Permission Logic and Beam Gate are upgraded.

- Three DR operation modes are included.
- The control of the injection and extraction components are realized with the delayed synchronization.
- More frequent ON/OFF switching of Beam Gate is realized.

Improvement of accelerator drivability

Web-based monitoring system is developed.

- The infrastructure of control system is monitored.
- The system is expanded to adapt the RPC protocol of EPICS 7.

Standalone Event Receiver is developed and installed at MR.

- This system relieves the efforts of the timing experts.

New archiver systems are developed.

- EPICS Archiver Appliance is tested and seems excellent so far.
- All injection pulse data are recorded on the injection archiver.

Upcoming Presentations

PASJ

H. Sugimura, et al., “Control system for SuperKEKB accelerator”
H. Sugimura, “Development of event receiver on Zynq evaluation board”
N. Yoshifuji, et al., “Vacuum control system based on F3RP71 for SuperKEKB”
H. Kaji, et al., “Application of EPICS Archiver Appliance at SuperKEKB”
S. Sasaki, et al., “Monitoring system with Zabbix at SuperKEKB”
T.T. Nakamura, “Application of the device configuration notation TXDB to the SuperKEKB control system”
T. Nakamura, et al., “Deployment of Archiver Appliance at PF-AR accelerator”

ICALEPCS

H. Kaji, et al., “Control System of SuperKEKB”
S. Sasaki, et al., Monitoring System for IT Infrastructure and EPICS Control System at SuperKEKB”
T.T. Nakamura, et al., “The Upgrade Status of the SuperKEKB Magnet Control System”
H. Sugimura, “Development of Event Receiver on Zynq7000 Evaluation Board”