

# Report from Control Group

## Hiroshi Kaji

# New delay module for Event Receiver

The delay step for EVR is, usually, 8.7ns (= One clock of FPGA).

We installed the new delay module with more precise delay setting.



**UNIV-TTLDLY**  
**(New fine delay module)**

Arbitrary delay in the 400ps step

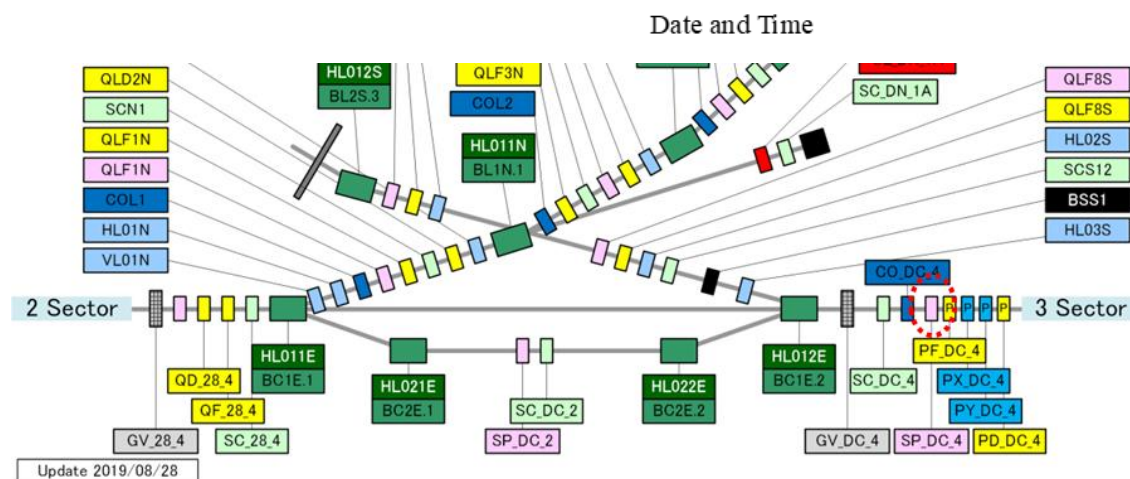
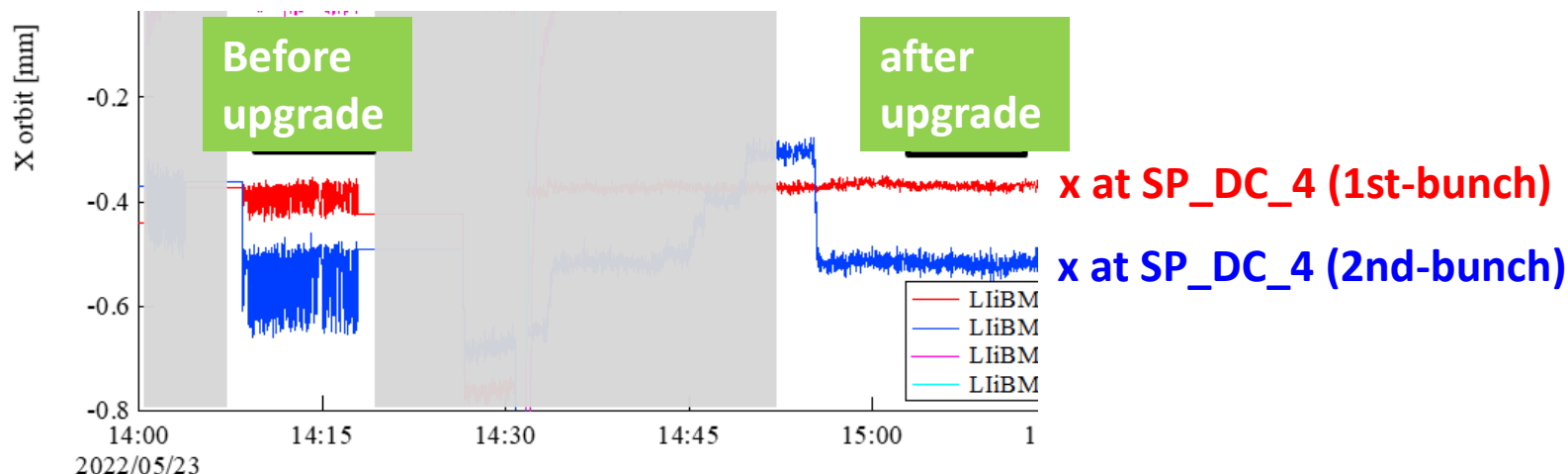
It is equipped in the universal slot.

We developed the EPICS device support for it.

# Delay control for DR extraction kicker

The Event IOC for the DR-extraction trigger was upgraded in the 2022ab run.

- A few nanosecond of the timing shift caused by the pulse-to-pulse modulation is corrected.
- **The fluctuations of the kicker angle and the x-orbit are suppressed.**



Data were taken at the first BPM after DR.

# Bunch Current unbalance in 2-bunch injection

Two-bunch injection is carried out for LER in the 2022ab run.

⇒ Sometimes, the bunch current became unbalanced.

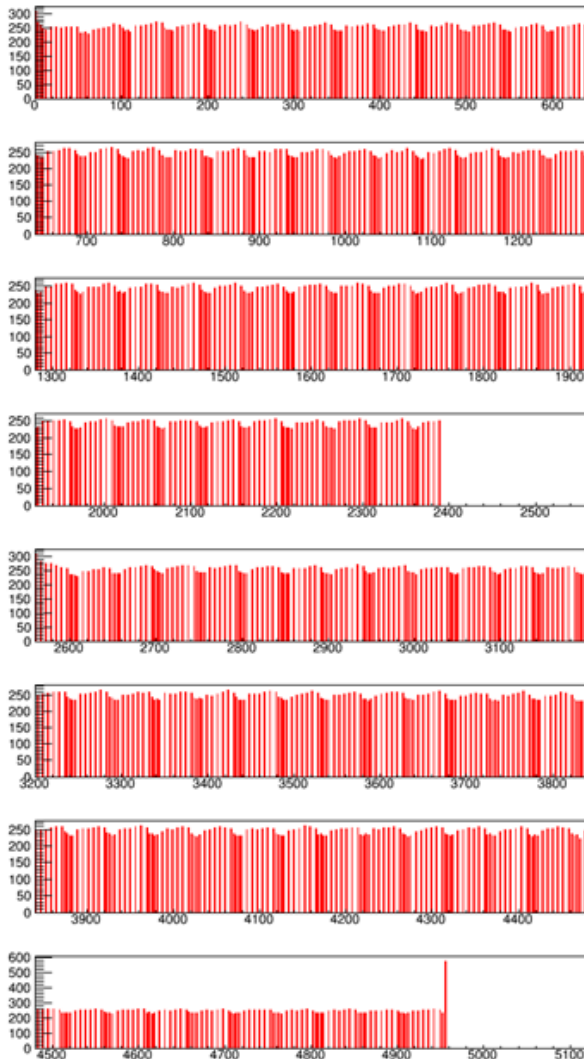


In the current Bunch selection system, Bunch Current Equalizing (BCE) is not implemented in the 2-bunch injection.

It is upgrade plan for LS-1.

# Possibility of BCE in the 2-bunch injection

No. of injections



BktNo

**It is the upgrade plan of Bucket Selection.**

The difference in the total # of injections in 8-hours comes from the difference in the lifetime.

It depends on the bucket spacing.

The cyclic behavior in the 49 RF-buckets is seen on the left figure.

[H. Kaji, et al., Proc. of the 18th Annual Meeting of PASJ, TUOB01, August 9 - 12, 2021, QST-Takasaki Online, Japan](#)

=> It is good condition for the two-bunch BCE.  
(Note, the bucket spacing of injection bunches is 49.)

In the two bunch injections,  
The first- and second-bunches should have similar lifetime.

The two bunch BCE is effective in such condition.

**It will be prepared during LS-1.**

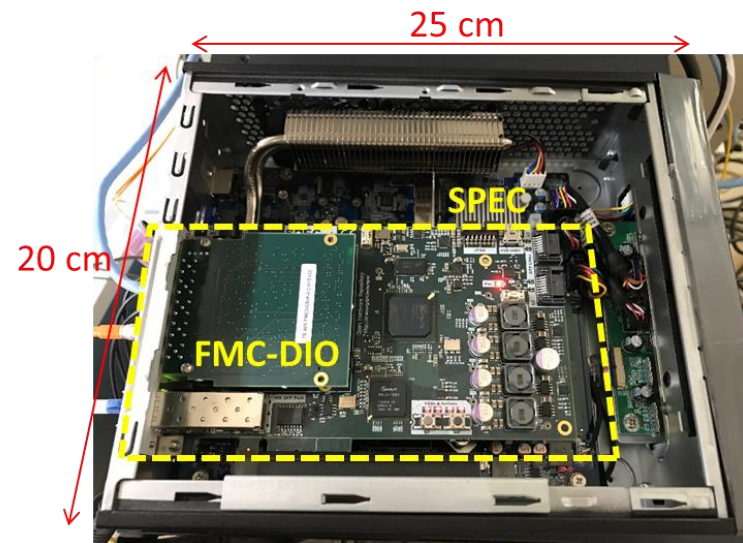
# Application of White Rabbit

**Event Timing System** is traditionally utilized for the accelerator operation.

- It realized the simultaneous top-up filling operation for colliders and light sources (4 rings).
- The new-type investigation systems for injection and abort have been developed with the timestamp synchronization.
- The sophisticated DR operation is realized with the distributed bus bit.

**White Rabbit** is utilized to improve the second and third functions.

- The distributed TDC system is operated to investigate the source of the Sudden Beam Loss accident. More TDCs will be installed during/after LS-1.
- More precise abort request timestamp will be installed during LS-1.
- Beam Gate will be partially upgraded during LS-1.
- We developed the PCIe-express-type EPICS IOC and are working for the VME IOC.

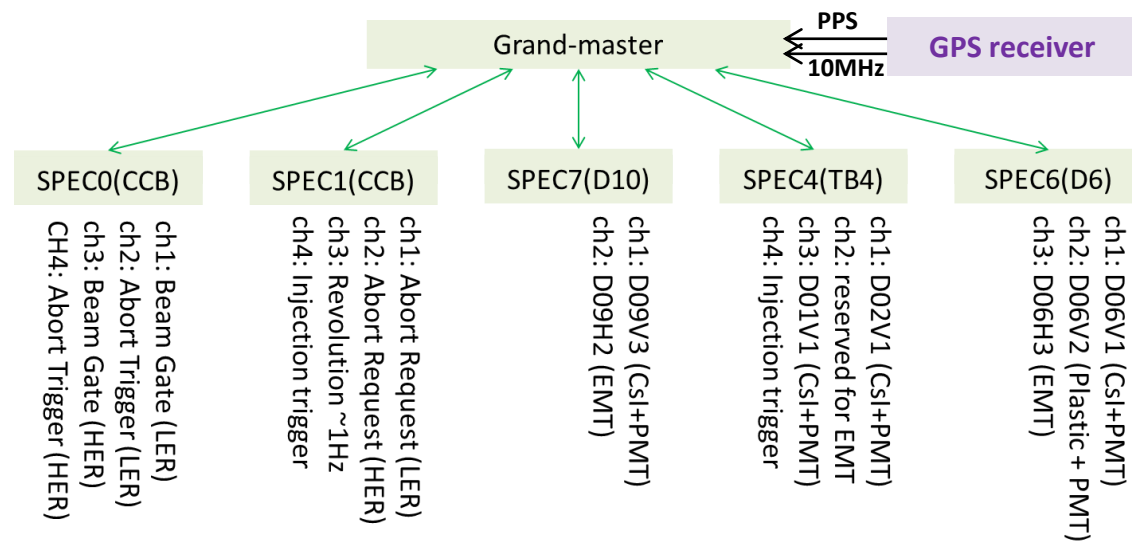
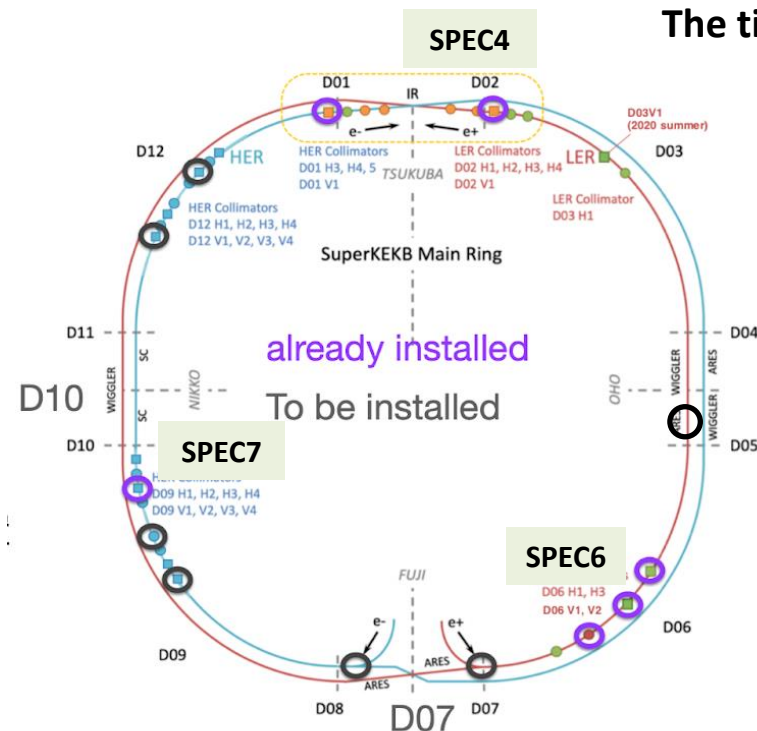


# Distributed TDC system@SuperKEKB

Distributed TDC system collects the signal from the beam loss monitors.

- ⇒ determine the duration of the injection background.
- ⇒ determine the beam bunch that causes the beam loss.
- ⇒ determine the first loss position in the Sudden Beam Loss accident.

The timestamp of all TDC nodes are precisely synchronized with GPS.

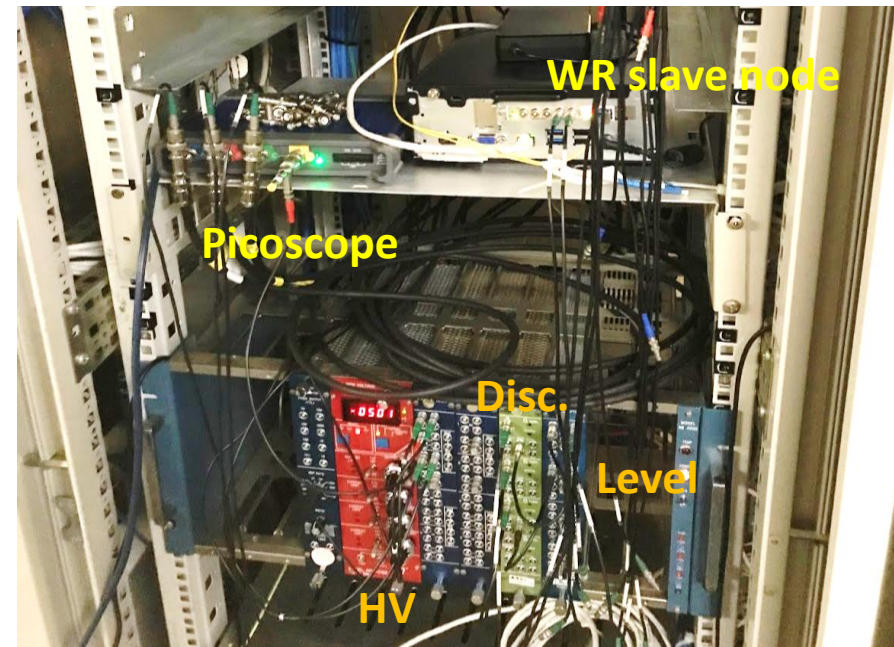
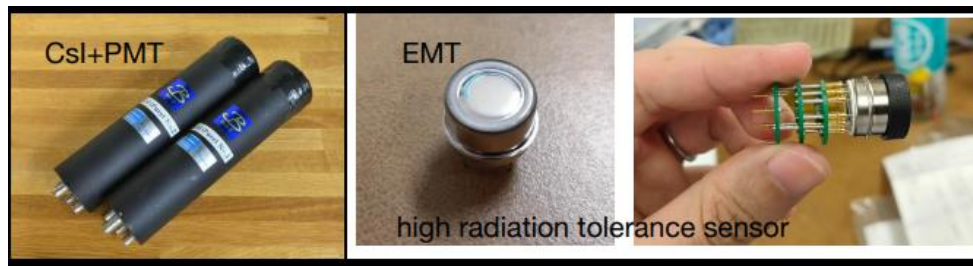


We collect all information via EPICS PV and record on Archiver Appliance.



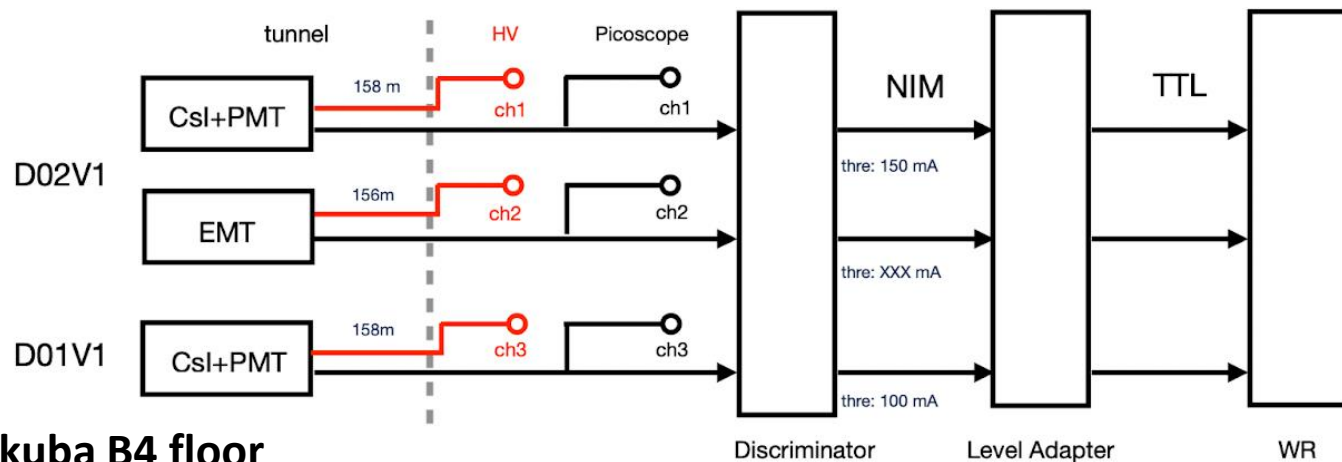
# Loss Monitor Station

Loss monitors with precise time resolution are installed by Belle II group.



IP loss monitor station

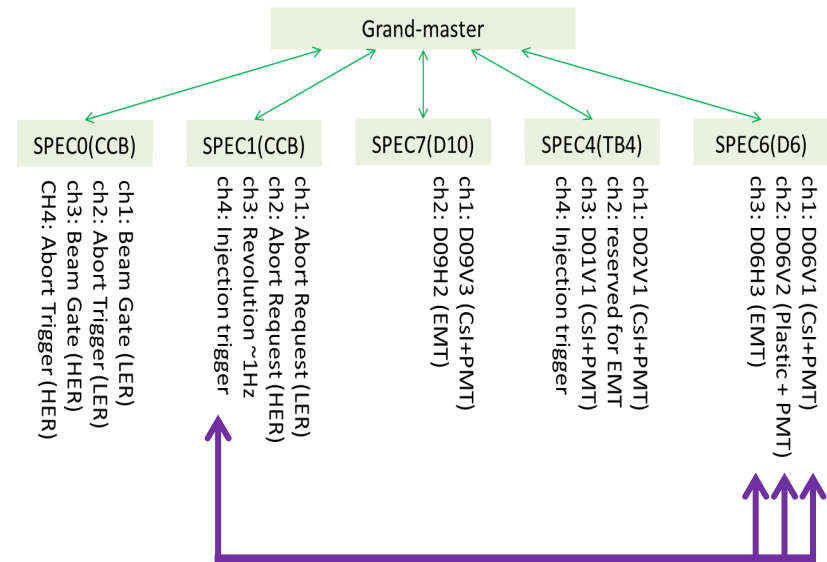
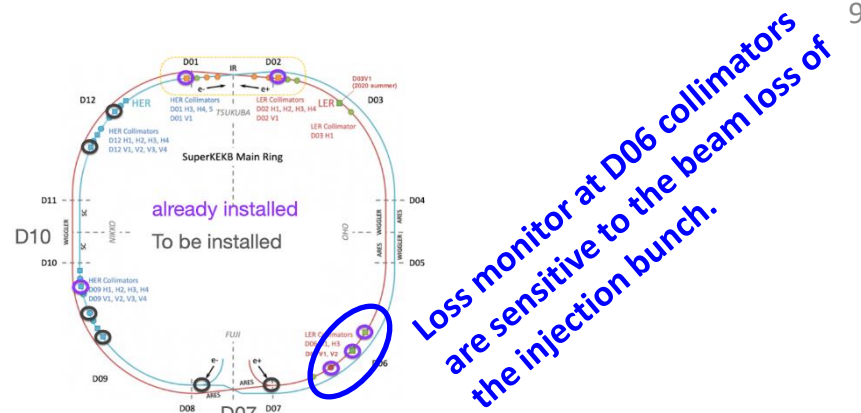
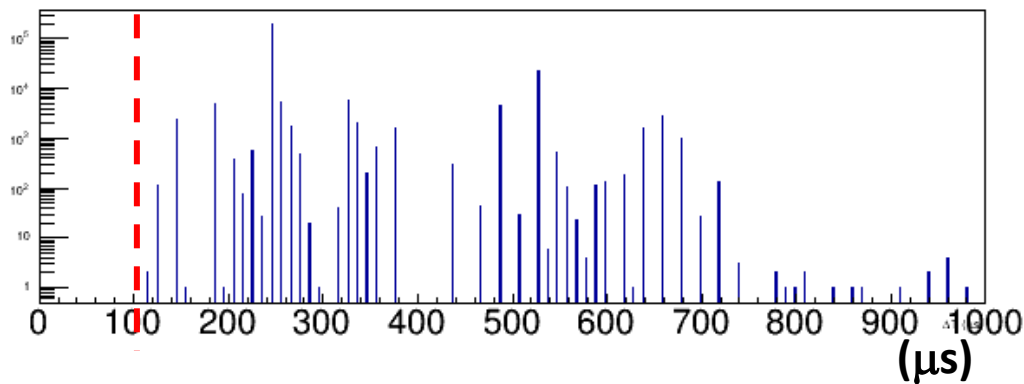
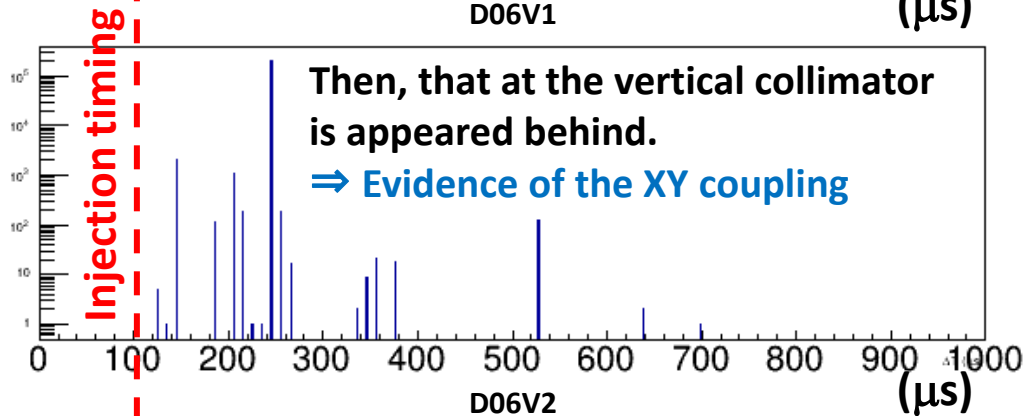
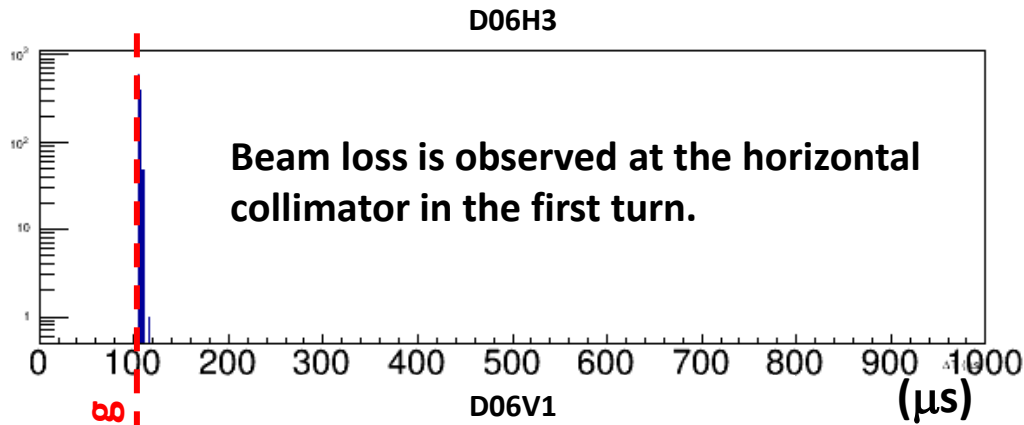
- The signal from loss monitor is divided in two.
- One put into the oscilloscope to record waveform.
- The other put into White Rabbit to know the precise timestamp.



Node at Tsukuba B4 floor



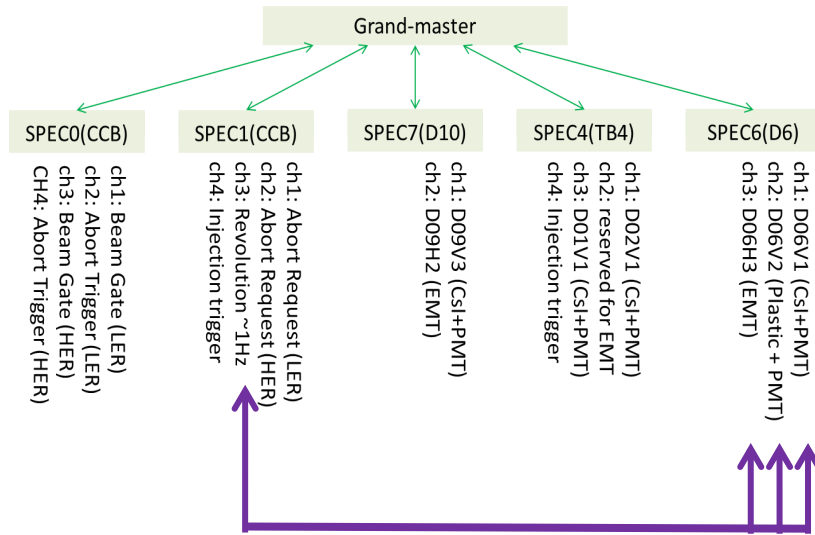
# Injection background



Input timing is compared between the injection trigger and the signals from the D06 loss monitor.

Data will be utilized to understand the injection condition.

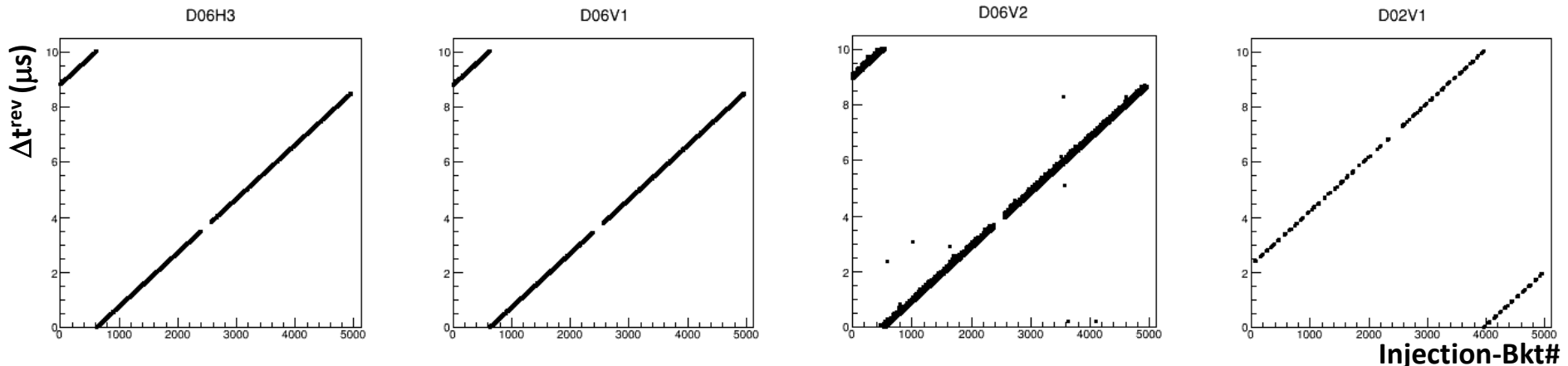
# Bunch number detection



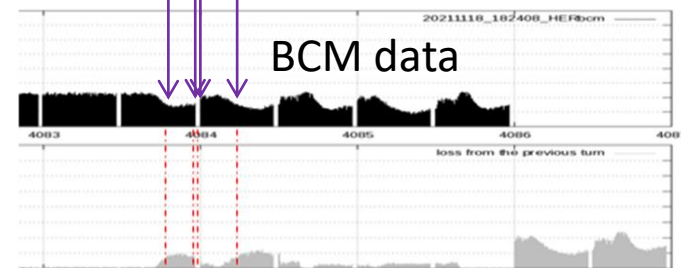
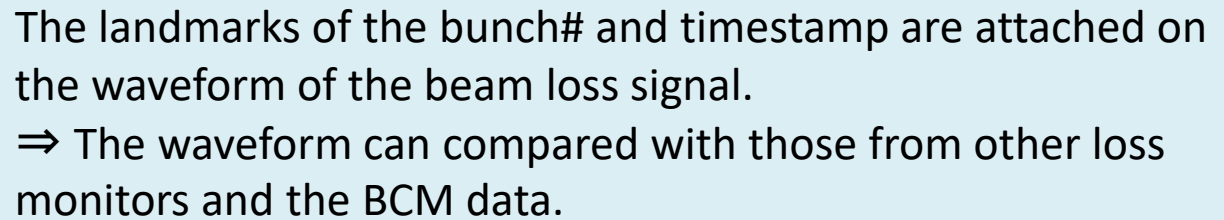
The ID of bunch that causes the beam loss can be evaluated by the time relation between the revolution and the signal from the loss monitors. Injection background give us the good calibration of the timing relation.

$\Delta t^{\text{rev}}$  timing offset for the #0-bucket

- D06H3: +8.842  $\mu\text{s}$
- D06V1: +8.817  $\mu\text{s}$
- D06V2: +8.972  $\mu\text{s}$
- D02V1: +2.263  $\mu\text{s}$

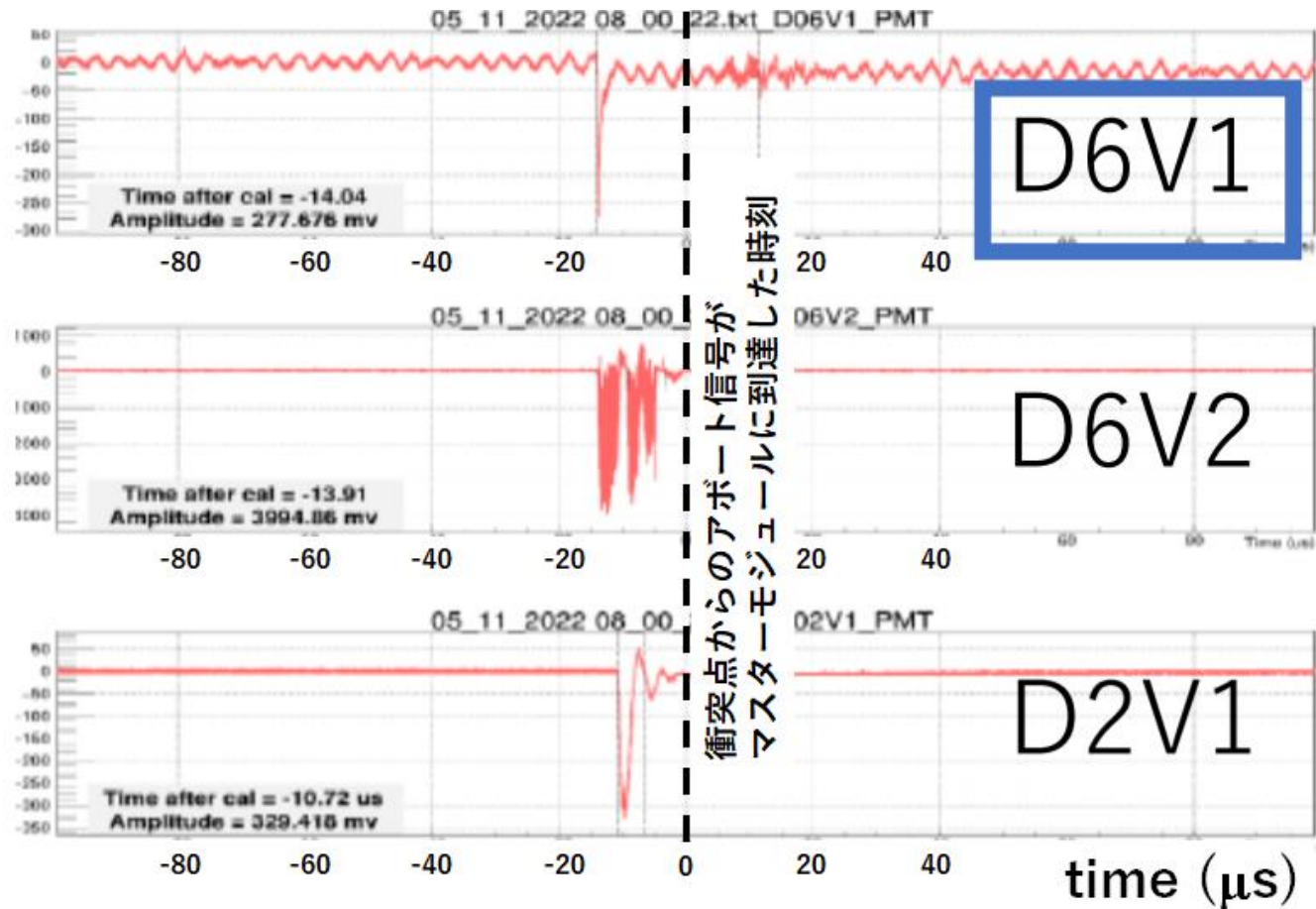


**Note, this relation is valid also for the stored bunches.**



# Direct comparison of loss monitor signals

The raw signal from the loss monitors can be compared directly with the White Rabbit timestamp.



Preliminary results  
by Liu@SOKENDAI

The first beam loss position in the Sudden Beam Loss accident can be determined.

# Measurement of abort request timing

One of the advantages of SuperKEKB against KEKB is the abort timestamp.  
The abort timestamp helps the abort study.

S. Sasaki, et al., in Proc. ICALEPCS2015, MOPGF141, Melbourne, Australia

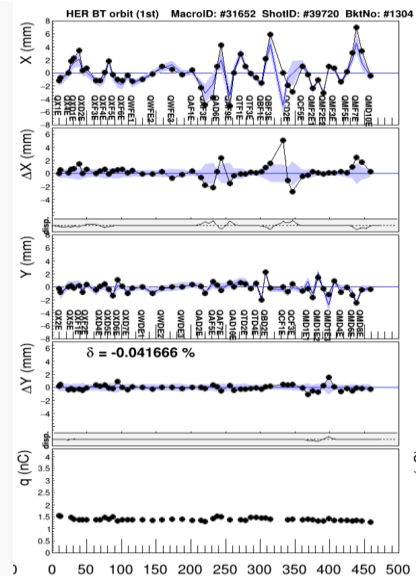
H. Kaji, et al., in Proc. IPAC17, THPAB113, Copenhagen, Denmark

To advance the abort study, we put distributed TDC node for all Abort Trigger modules so that the synchronization timestamp becomes accurate to be 8ns.

We can know

- more precise detection of the first beam loss position.
- how many turns the injection bunch traveled before abort.

RING	MESSAGE	DATE	DELTA
LER	Belle2 CLAWS	2022-06-22 08:39:42.652924900	0.000 000 000
HER	Belle2 CLAWS	2022-06-22 08:39:42.652925300	0.000 000 400
LER	RF D5-F	2022-06-22 08:39:42.652928600	0.000 003 700
LER	RF D5-E	2022-06-22 08:39:42.652928900	0.000 004 000
LER	COLSAFE:CCC:ABORT:CCC-7	2022-06-22 08:39:42.652929300	0.000 004 400
LER	RF D5-D	2022-06-22 08:39:42.652929300	0.000 004 400
LER	Loss Monitor D6 (Optical Fiber)	2022-06-22 08:39:42.652929800	0.000 004 900
LER	COLSAFE:CCC:ABORT:CCC-6	2022-06-22 08:39:42.652930200	0.000 005 300
LER	Loss Monitor D4-3	2022-06-22 08:39:42.652930300	0.000 005 400
LER	Belle2 VXD diamond	2022-06-22 08:39:42.652932100	0.000 007 200
LER	RF D5-C	2022-06-22 08:39:42.652932300	0.000 007 400
HER	Belle2 VXD diamond	2022-06-22 08:39:42.652932500	0.000 007 600
LER	Loss Monitor D1-1	2022-06-22 08:39:42.652932500	0.000 007 600
LER	RF D5-B	2022-06-22 08:39:42.652933900	0.000 009 000
LER	Loss Monitor D4-1	2022-06-22 08:39:42.652934400	0.000 009 500
LER	COLSAFE:CCC:ABORT:D5	2022-06-22 08:39:42.652934600	0.000 009 700
LER	COLSAFE:CCC:ABORT:D2	2022-06-22 08:39:42.652935200	0.000 010 300
LER	COLSAFE:CCC:ABORT:D4	2022-06-22 08:39:42.652935600	0.000 010 700



	Syn. accu.
Inter-module	100ns – 1μs
Injection	<40μs

# Beam Gate upgrade with White Rabbit

The enable/disable control of the pulse components is implemented by Beam Gate. It is for the starting/stopping the beam injection.

There are difficulties for the synchronized control between the gun and the injection kickers.

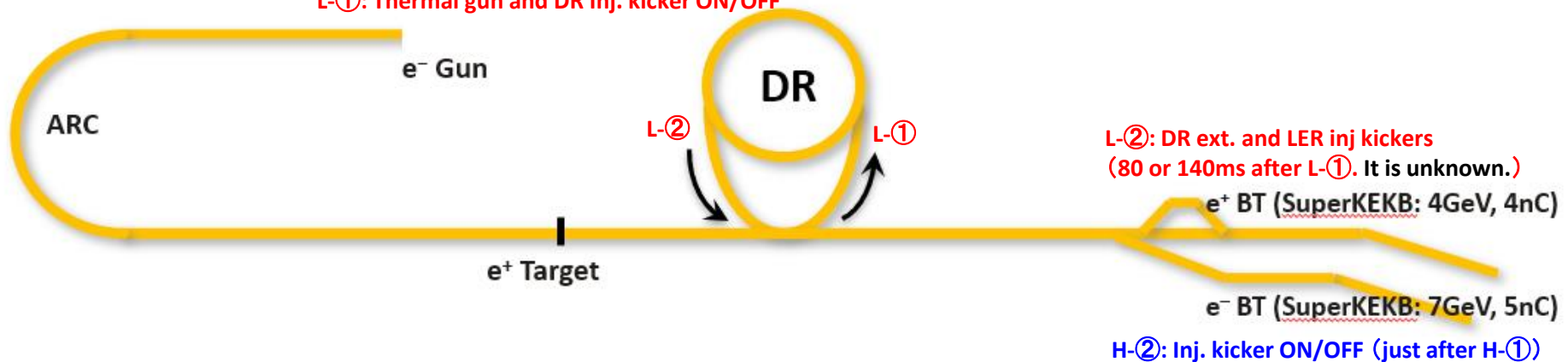
- LER: Injections with unequal interval makes the unequal DR storage time (i.e. 23Hz).
- HER: The latency in the RF gun control from Beam Gate is always fluctuated.

All logics are installed on the master IOC of the Event Timing System.

- It is difficult to revise during the operation period. The system is vital for our project.
- The only developer can revise the system. It needs the special knowledge.

H-①: RF gun ON/OFF (After 0-80ms from Beam Gate. It is not stable.)

L-①: Thermal gun and DR Inj. kicker ON/OFF



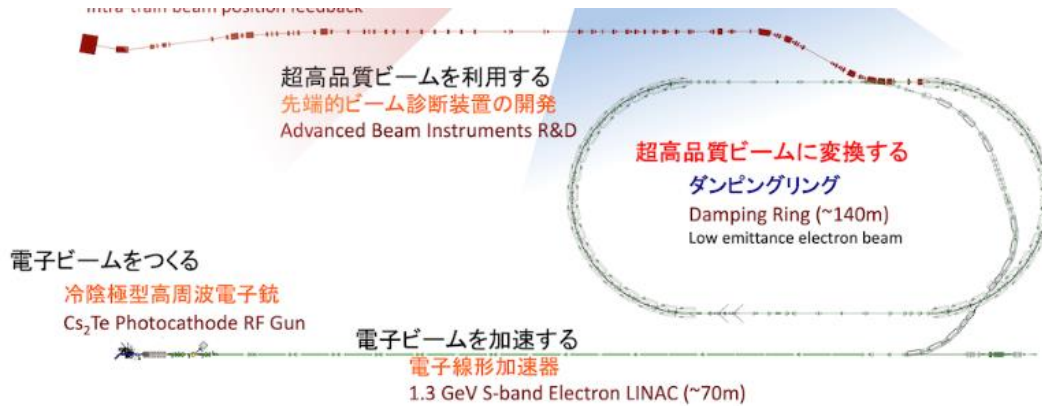
White Rabbit will be utilized for transferring the Beam Gate signal with arbitrary delay.

⇒ Test has been done at ATF. See next slide.



# New Beam Gate signal with White Rabbit

<https://atf.kek.jp/atfbin/view/Main/PublicILCandATF>



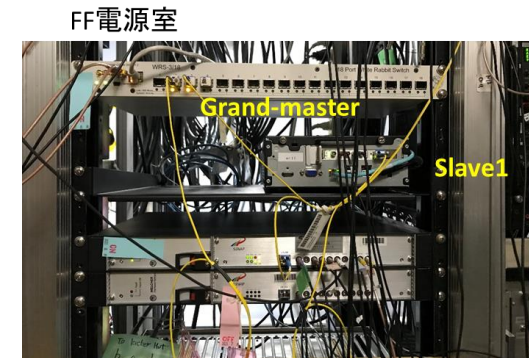
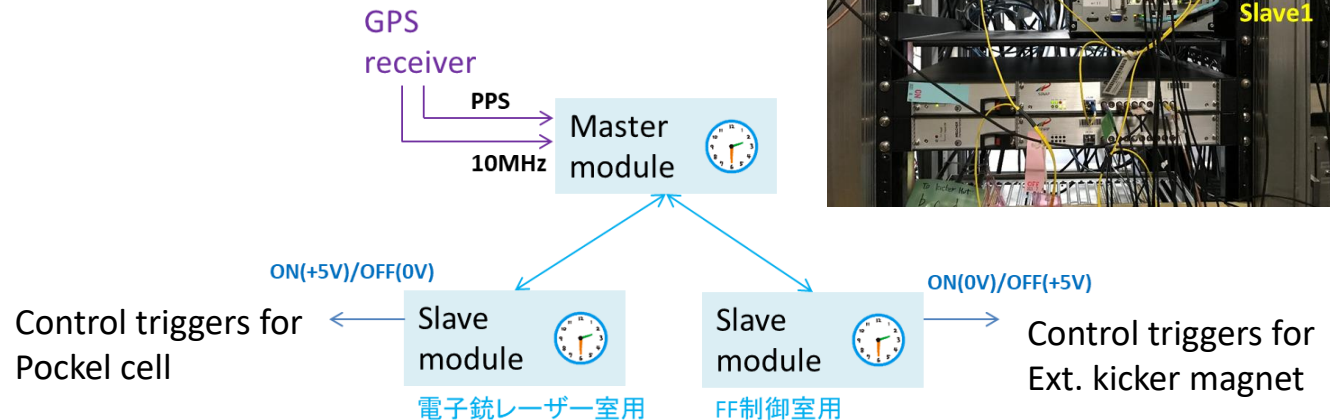
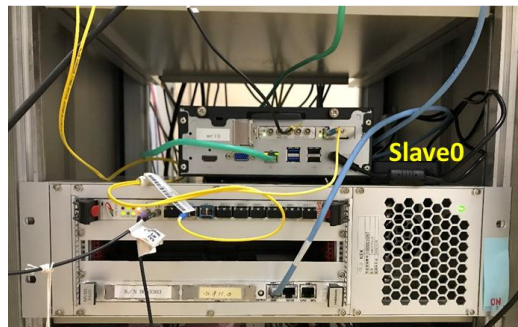
	SuperKEKB	ATF
Operation Interval	20ms	160ms
DR storage time	At least 40ms	220m

ATF (Accelerator Test Facility) has the similar specification.

- The DR storage time is longer than the linac operation interval.
- It is good condition for the study of our Beam Gate system.

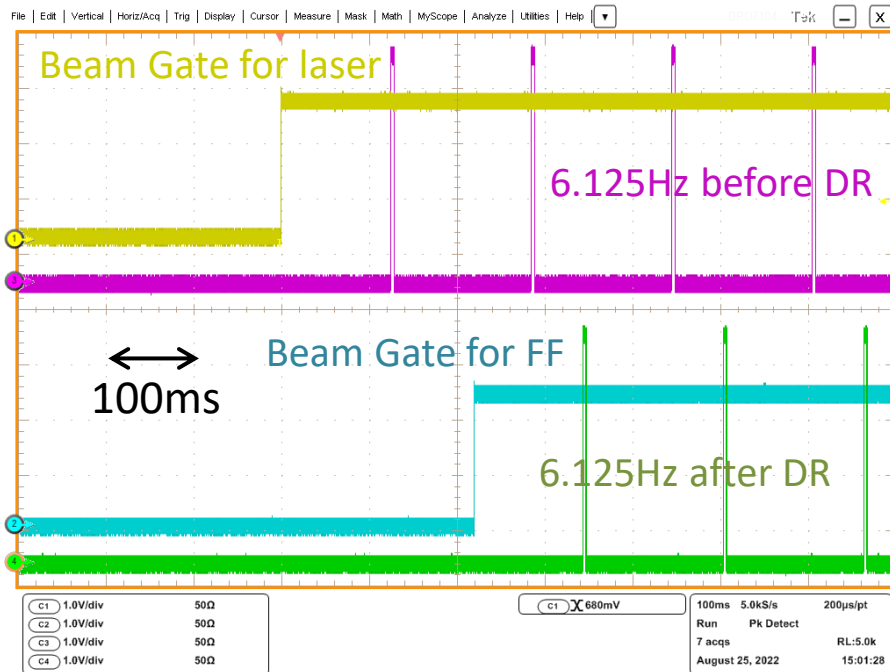
And they will be operated from 2022 Autumn to 2023 Autumn.

電子銃レーザー室

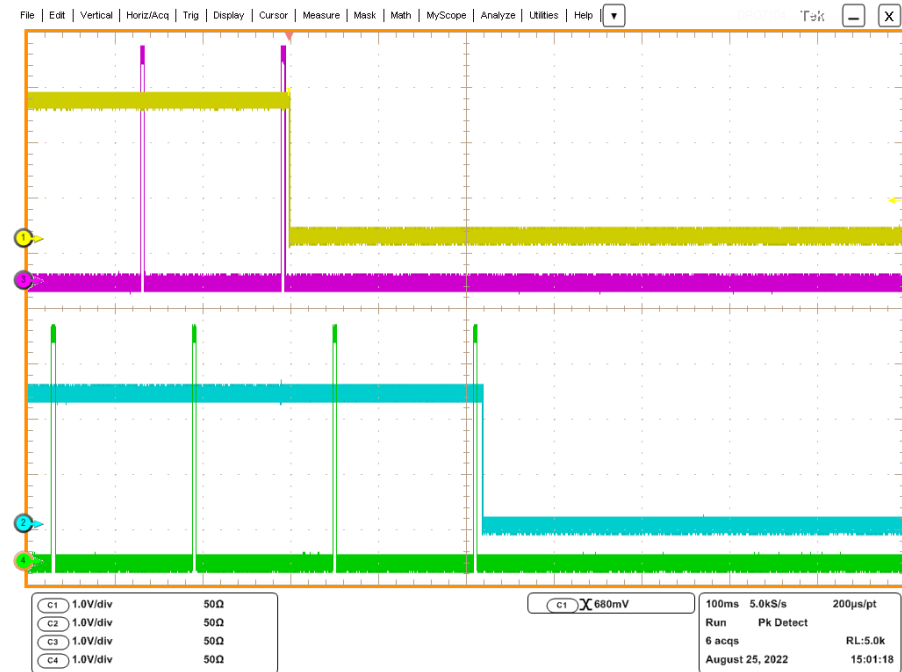


# Beam Gate test at ATF

## Beam Gate ON



## Beam Gate OFF



**This system is employed since October 2022.**  
**More studies are on-going.**

- We plan to install for HER (LINAC and D08) during LS-1.
- Then, the LER installation will be followed.

# Software release

The EPICS device support is developed and released on the White Rabbit official site

- SPEC + FMC-DIO

<https://ohwr.org/project/fmc-tdc/wikis/how-to-set-up-the-spec-and-fmc-dio-with-epics>

- SPEC + FMC-TDC

<https://ohwr.org/project/fmc-tdc/wikis/how-to-set-up-the-spec-and-fmc-tdc-with-epics>



# Networking and Computing

## **Networking**

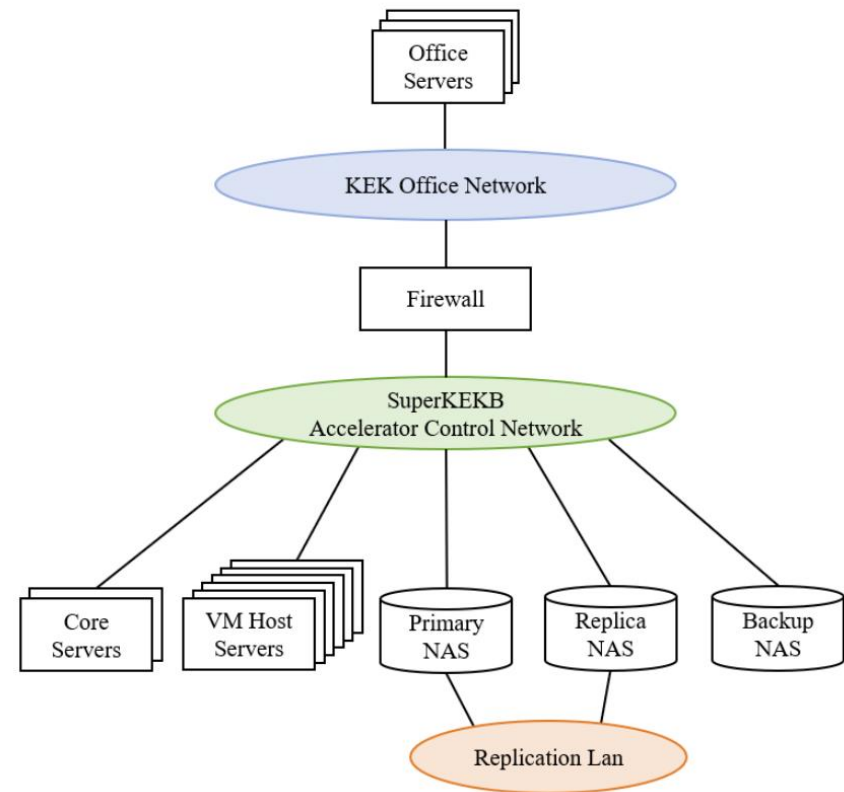
SuperKEKB accelerator control network is separated from the Office Network by a firewall.

Most of the instruments connect to the SuperKEKB network, and a few server connect office network.

All main servers and storages are changed to 10GBASE-T connection from this summer.

## **Computing**

The blade server has been used from KEKB era, but due to the end of maintenance, server and storage are updated.



# Update Server and Storage

## Server

We adopted rack mount type servers, and operates using virtual machines in the server.

## Storage

We adopted “zfs” file system and the storage is equipped with SSDs with a capacity of 20TB.

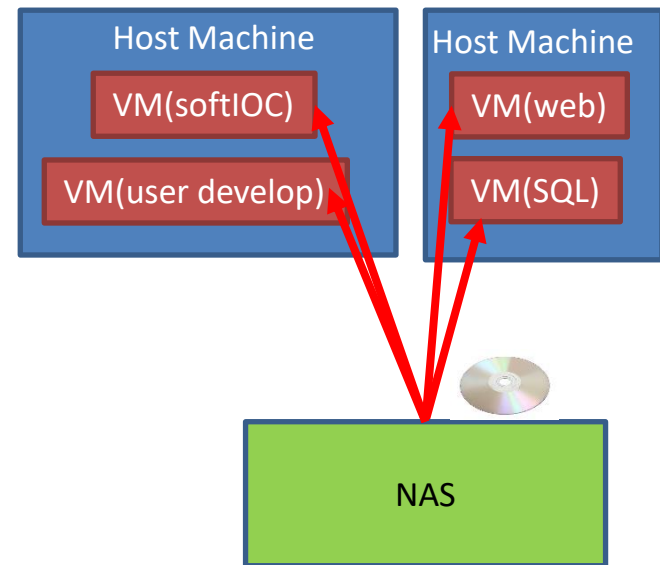
By making various devices redundant, we enhanced fault tolerance.

- RAIDZ2 (double parity)
- Two Power Supplies
- Two Controller for fail over and one backup node.
- backup every 15 minutes
- UPS



# Virtual Machine Management

- We adopted virtualization technology with “KVM” to isolate the execution environment for each application.
- It is also sustainable so that environment can be maintained even if the hardware is replaced.
- The virtual machines are running on six rack servers to keep the load balance.
- We are planning to locate the image of VMs at NAS to enable live migration (currently stored locally).





# Summary

The Event IOC for the DR-extraction trigger was upgraded.

- Small timing shift caused by Pulse-to-pulse modulation is corrected.

The BCE in the two bunch injection will be performed after LS-1.

The application of White Rabbit is enhanced.

- The distributed TDC system is utilized for the loss monitors with the precise time resolution.
- Beam Gate will be upgraded. The test operation of the prototype is ongoing at ATF.
- The precise abort timestamp will be provided.

The EPICS device support for the above upgrade was developed and released.

The workstation and storage servers were upgraded.

- They have already been available for users.
- All services are running on the virtual machine. It give us flexibility in maintenance.