

Control system report

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Injection loss monitor

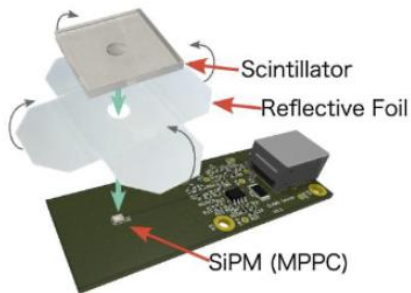
The injection loss monitors are installed by the Belle II and control groups in the MDI framework.

This collaboration started for upgrading the abort response (see p.6).

We noticed that our abort sensor (CLAWS) is sensitive to the injection beam.

We started to install injection monitor since 2024.

Sensor and electronics (Belle II)



Plastic scintillator
+
Photo sensor (SiPM)

EPICS-based DAQ system (control)

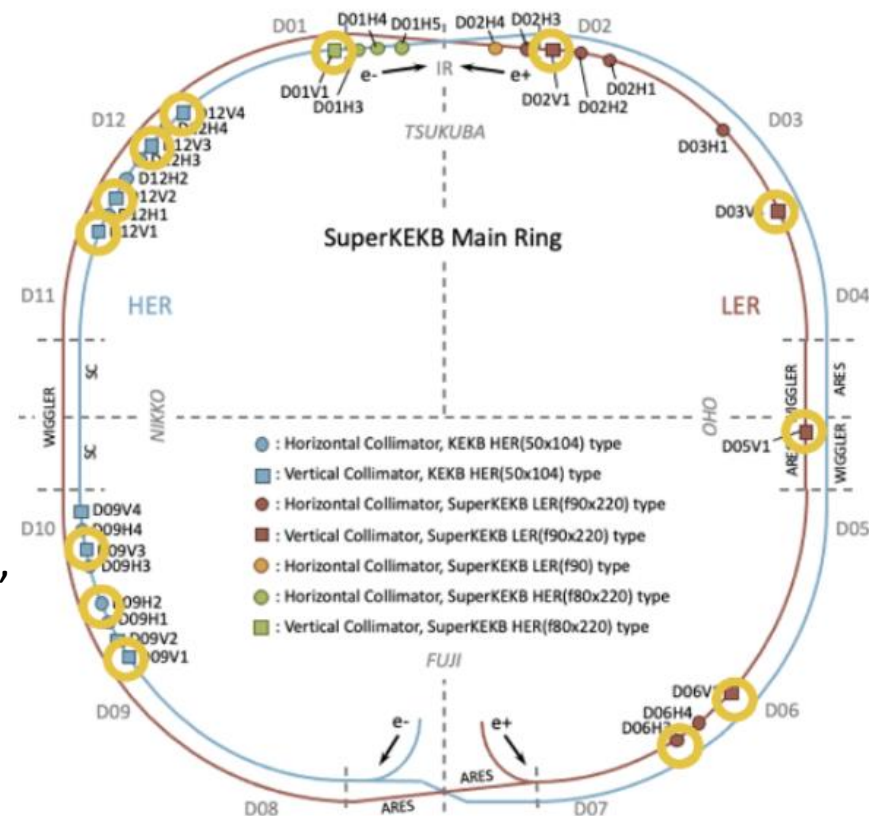
Installation and maintenance (both)

Offline analysis (both)

With discussions and the indication from simulation, we decided to install CLAWS to

- all vertical collimators
- horizontal collimators at Tsukuba straight section.

They will be operated since the 2027 run.



DAQ system of Injection Loss Monitor

The CLAWS signal is read out with a USB oscilloscope and a PC.

EPICS is running on a PC.

All necessary information is available for everyone in both online and offline.

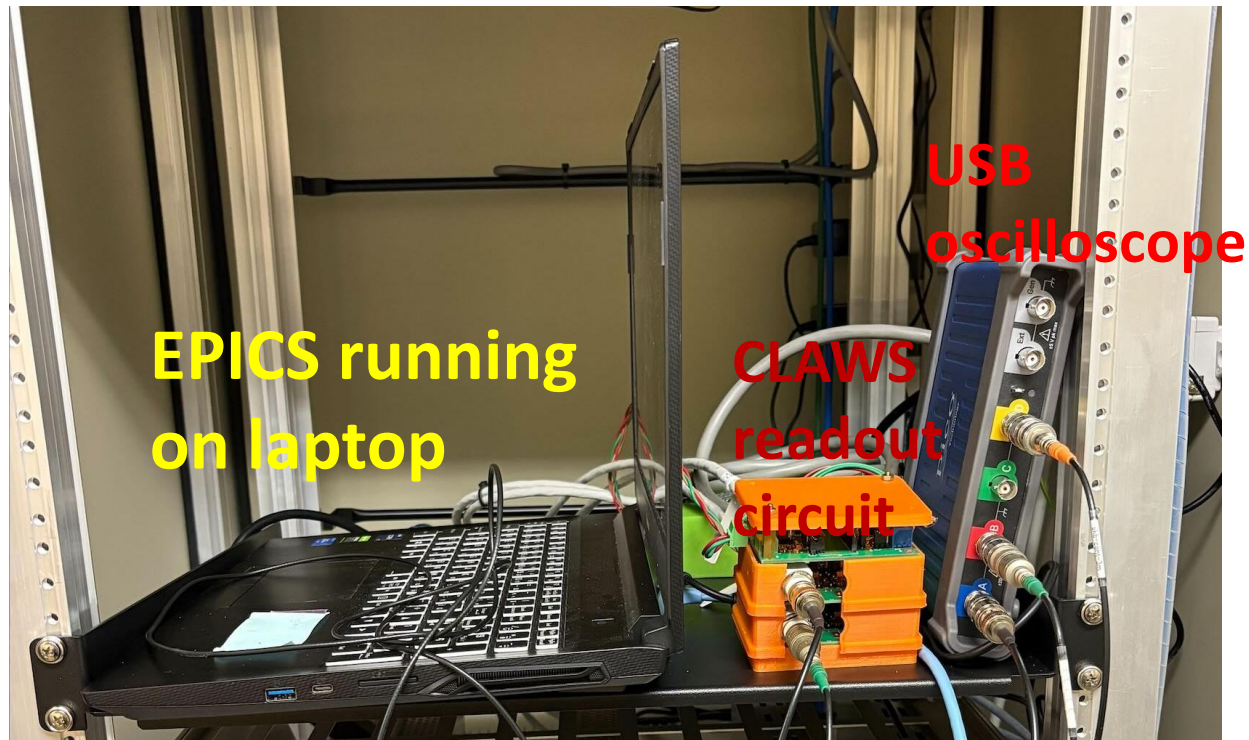
- “total” and “turn-by-turn” beam loss
- frequency domain information

Synchronous data taking among 6 oscilloscopes in 3km beamlines

⇒ We can combine the beam loss data from a same injection shot.

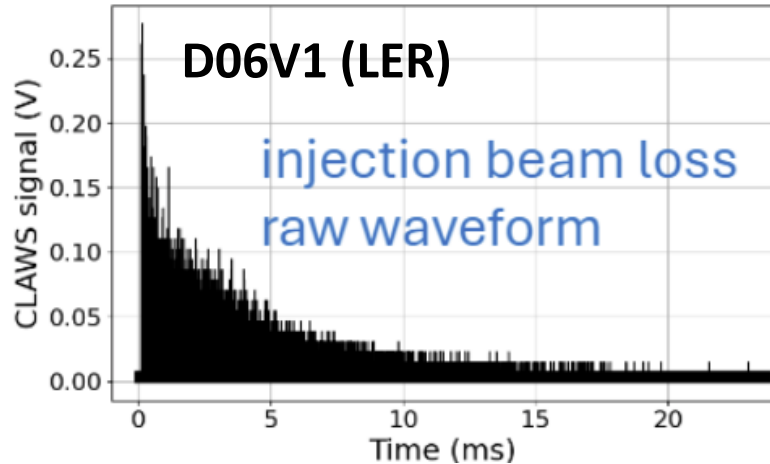
The DAQ system has been installed at D05, D07, D09, D10, D12 control buildings and Tsukuba hall.

There is capability to expand elsewhere.

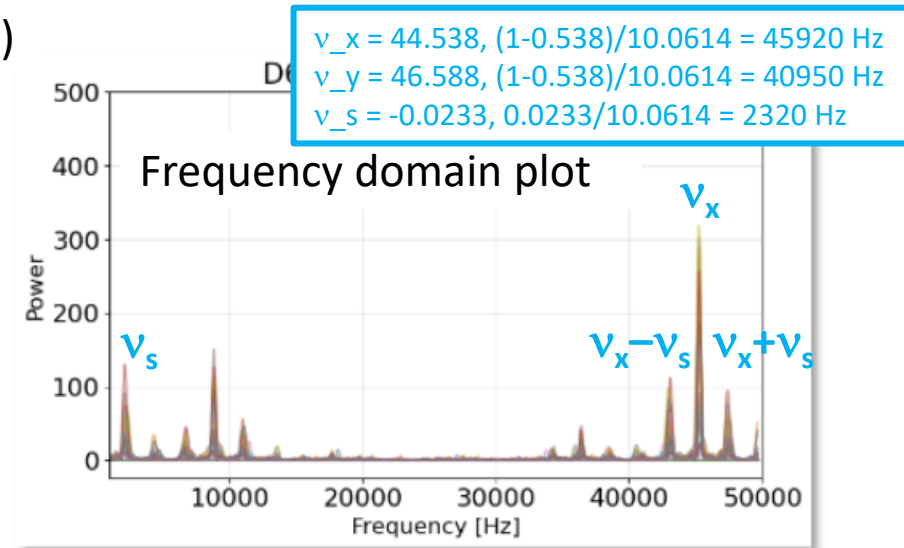
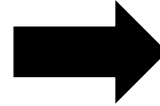


Software IOC for further reconstruction

Time domain plot (raw signal in oscilloscope)

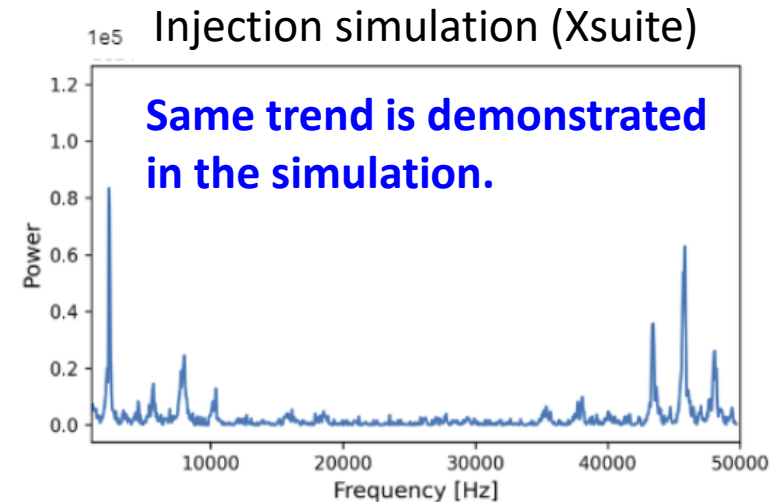


FFT



The “total” and “turn-by-turn” beam loss is reconstructed at local EPICS IOC.

In addition, its frequency domain result is stored in the other waveform by implementing FFT in the software IOC.



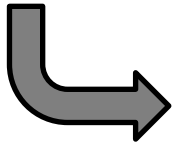
We believe this information helps understanding the mechanism of the injection beam loss and decrease of the injection efficiency.

Towards understanding of injection beam loss

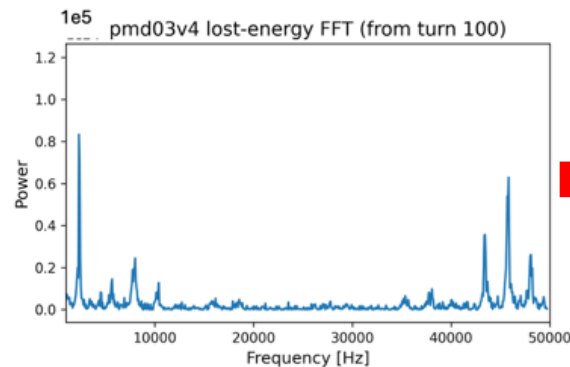
The control group contributes to the investigation of injection beam loss in the following way.

We developed the DAQ system of injection loss monitor.

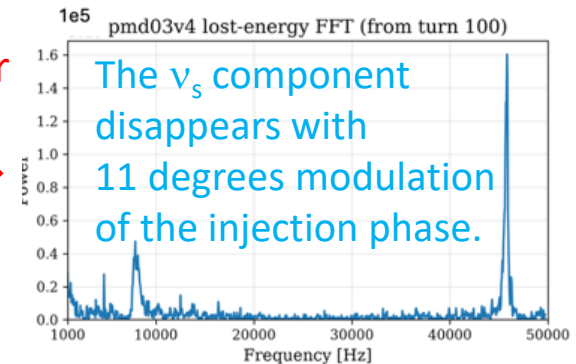
- New variables are reconstructed from raw signal.
(e.g. frequency domain information).
- It give us a new sight to understand the injection beam loss.



Simulation study to understand the new observations ongoing
(by MDI Xsuite simulation team, plots from Takahiro Nemoto)



parameter
scan



Understand underlying phenomena, search for new injection parameters.



Next step (hopefully, since next run, open task for everyone)

- Confirmation of simulation prospect
- application of new parameters in operation

The control group maintains DAQs, expand and upgrade if necessary.
All observations are recorded on our archiver. Everyone can analyze.

Abort system upgrade

The upgrade of Abort Trigger System is one of main tasks for the control group.

(conducted with help from the kicker experts.)

Speeding up the response against SBL by two improvements:

install new abort sensors for early detection.

- The new HER sensor is installed at **D09V1**, to be activated in the 2027 run.

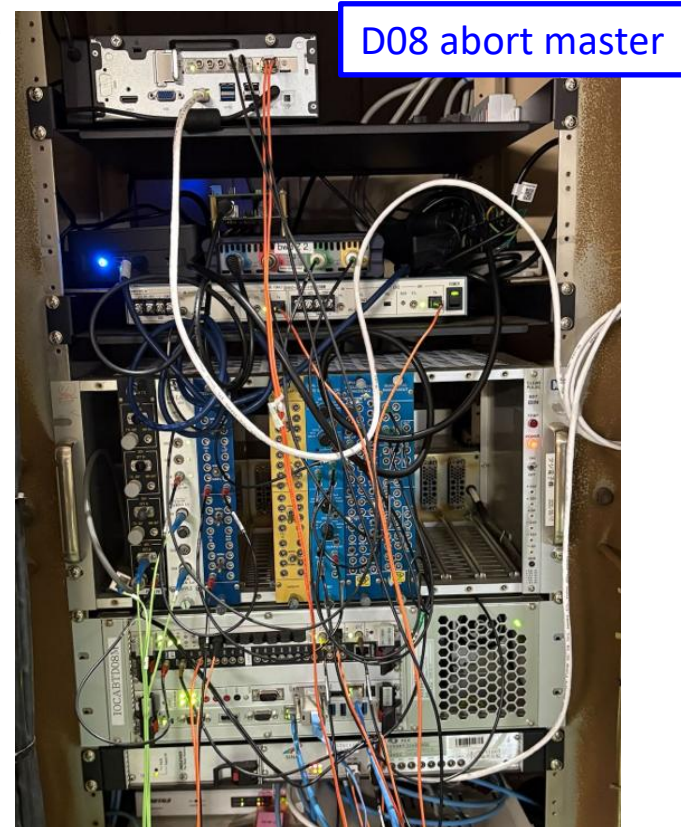
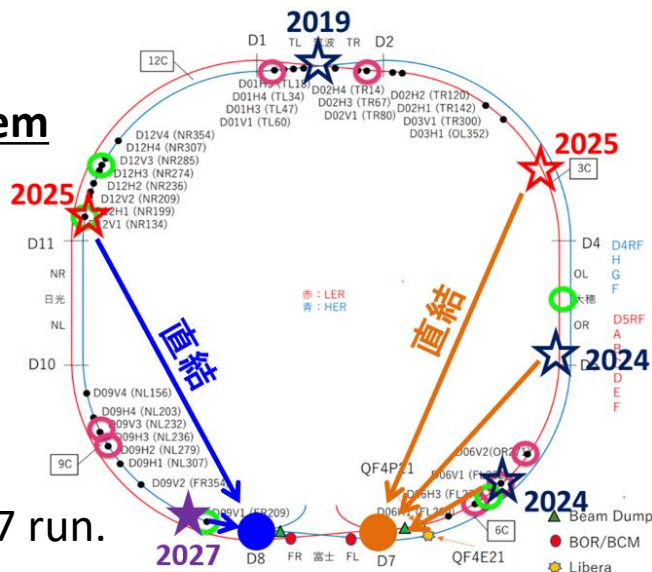
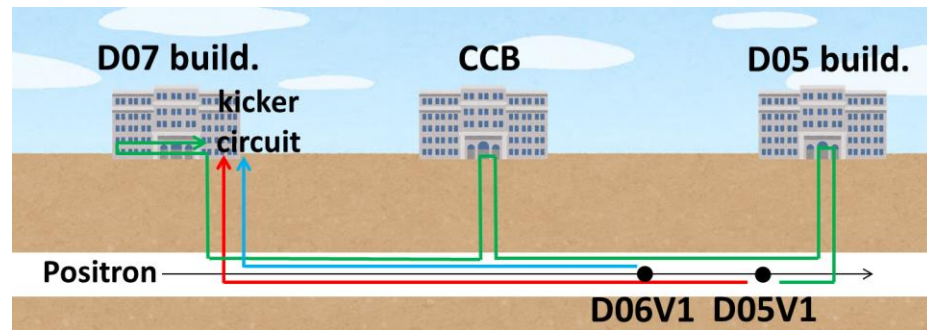
develop new master system

near the abort kicker power supply to shorten signal path.

- LER master@D07 in operation since 2024
- HER master@D08 plan to be operated in the 2027 run.

The module update is discussed in the later slides.

- New timestamp synchronization system, p.7.
- New CPU board, p.13,14.



New scheme of timestamp synchronization

Another important role of Abort Trigger System is to provide the issue timing.

⇒ **The causal relation of abort requests helps the abort diagnosis.**

The timestamp of individual nodes is synchronized with GPS.

The old timing module (17K50 and 17K51) implements the GPS synchronization.

S. Sasaki et al., in *Proc. of 14th Annual Meeting of PASJ, TUP096*.

- They are EoL. ⇒ need alternative module.
- rough GPS synchronization, precision $> O(100\text{ns})$.

We implemented new synchronization method with White Rabbit.

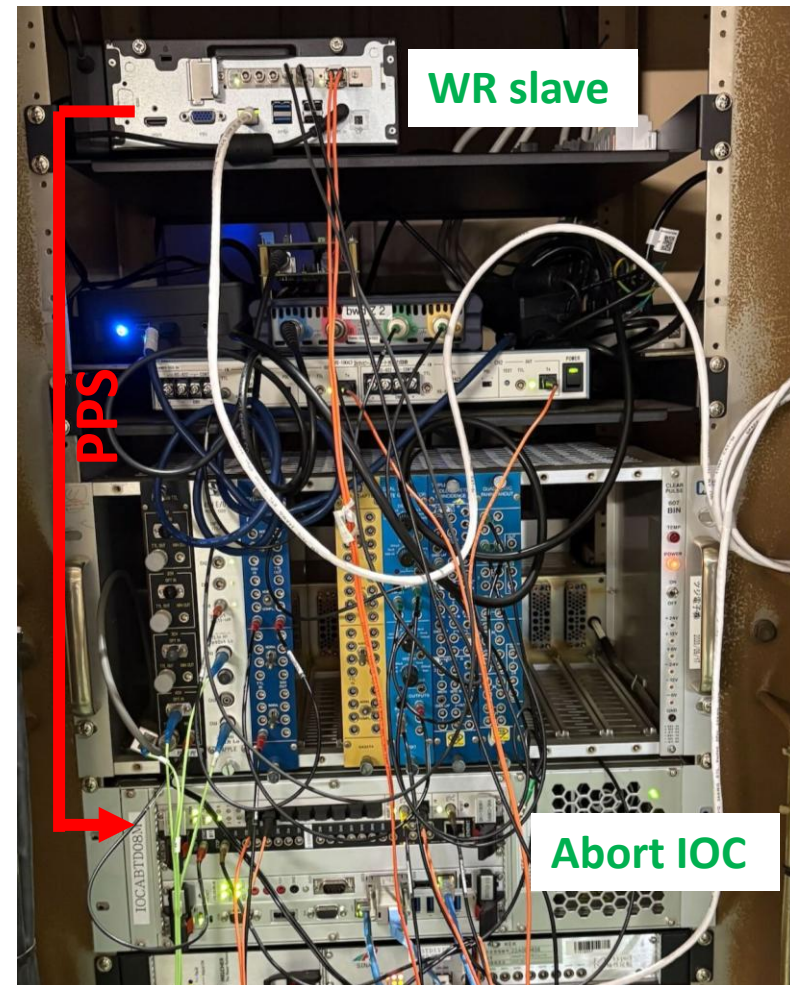
Its slave (SPEC+FMC-DIO) provides the PPS signal.

H. Kaji and Y. Iitsuka, in *Proc. of 17th Annual Meeting of PASJ, WEOT09*.

- precise GPS synchronization, precision $> O(8\text{ns})$.

It is applied to new abort masters at D07 and D08.

Hopefully, more EoL modules will be replaced in the next year.



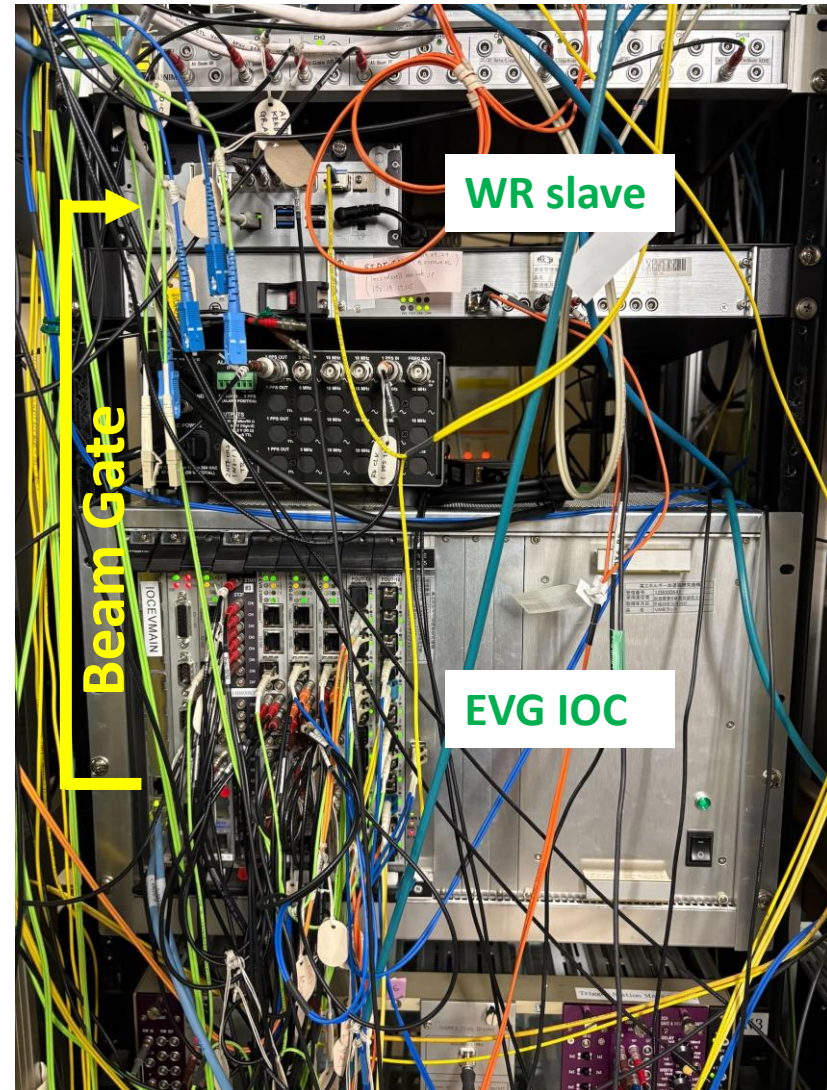
Beam Gate update

The Beam Gate system turns on/off the timing trigger delivery.
That should be synchronously controlled among the gun and pulse power supplies.
Otherwise, fake-firing or misfiring occurs.

New logic is developed on the White Rabbit modules (same module as timestamp sync.).

- The Beam Gate signal is transferred from slave node to slave node in the White Rabbit network.
- The precise timestamp of on/off state transition recorded provided via EPICS.

LINAC Main Timing Station



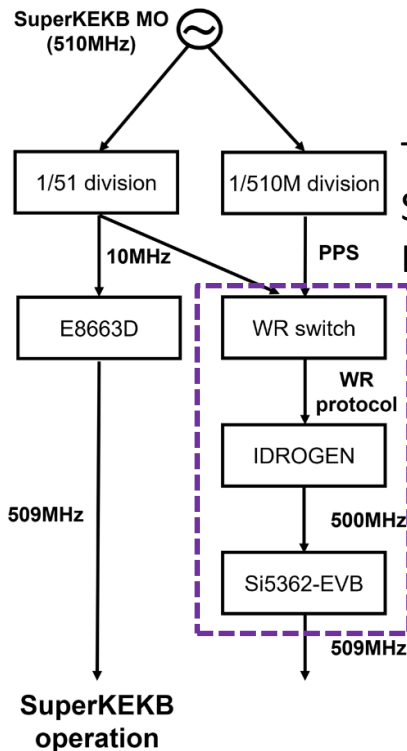
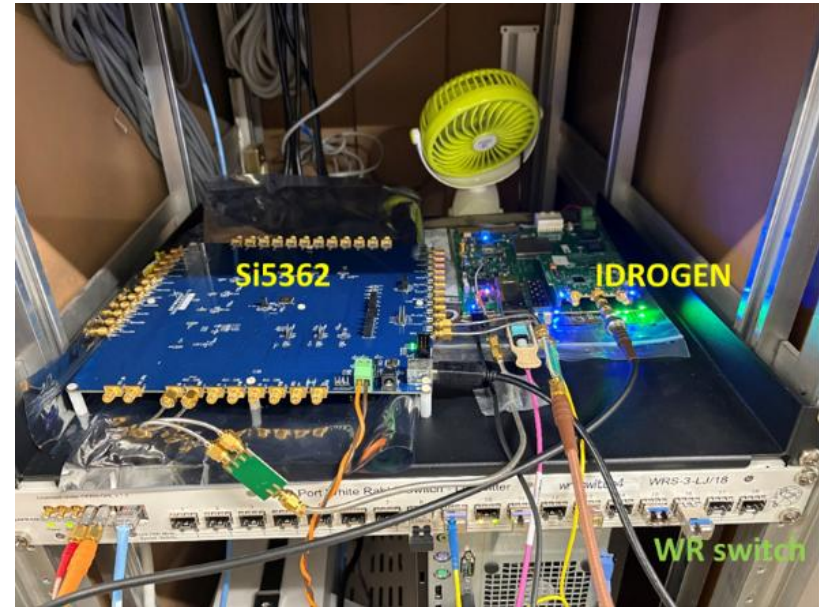
R&D of new RF clock delivery system

The RF clock generator based on White Rabbit is developing with IJCLab group of Belle II and LLRF.

- μ TCA type slave node (IDROGEN) developed by IJCLab
- We succeeded to introduce circumference correction.
- short-term jitter, 2.12ps
- confirmed long-term stability for >3 months in the SuperKEKB operation.

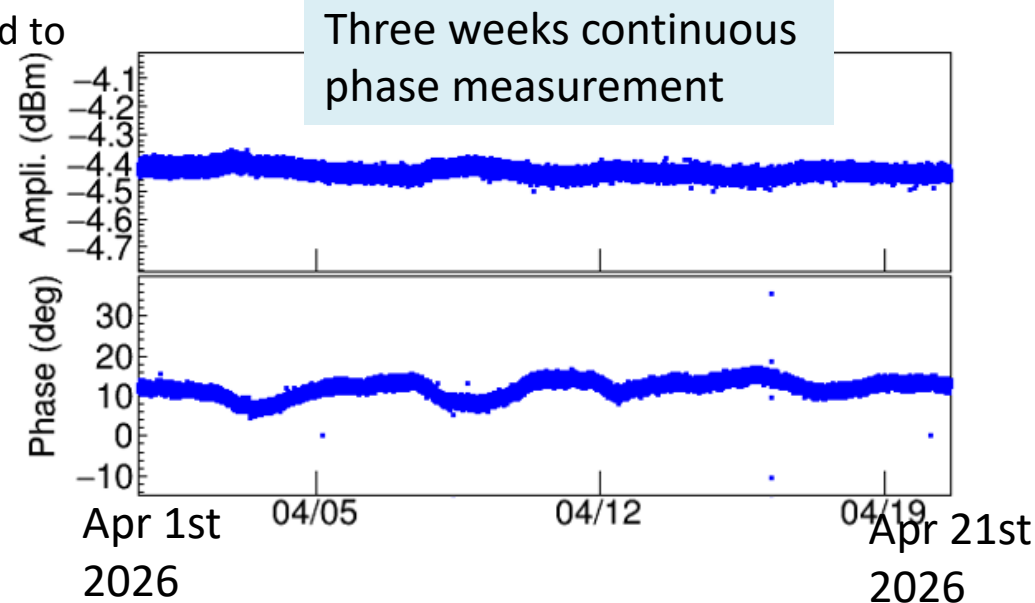
Submitted to IEEE Transactions on Nuclear Science.

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The reference signal from SuperKEKB MO is provided to IDROGEN test bench.

**IDROGEN
test bench**



Event module update

The update of old Event Timing modules is a big issue for LINAC.

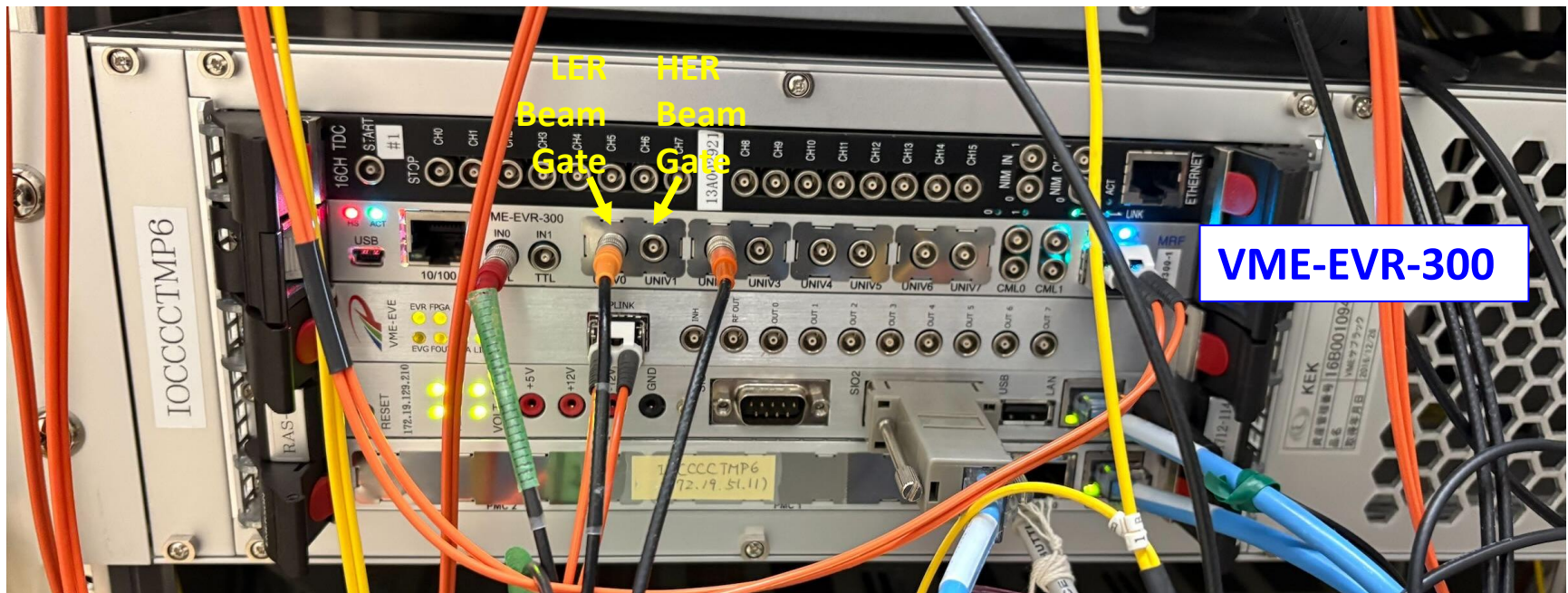
- The “MRF’s 230 series” Event module is EoL.
- We have spares, but is not enough for later 2030’s.

The “later series” module is introduced for the delivery of BT-BPM trigger.

- The VME-EVR230RF is replaced with **VME-EVR-300**.
- It will be in operation in the LINAC-BT run, December 2026.

The new Beam Gate signal (p.8) is introduced.

⇒ **The fake-firing will be eliminated.**



Renewal of CPU modules

The control system of the large-scale accelerator is built with hundreds of CPU modules connected via the dedicated network (accelerator control network).

To simplify the maintenance, most of the EPICS IOCs at SuperKEKB are developed with only two kinds of CPU modules.

- VME CPUs: 118 modules, **MVME5500**, fast and robust, but expensive
- PLC CPU: 196 modules, **F3RF61**, low cost and low power consumption

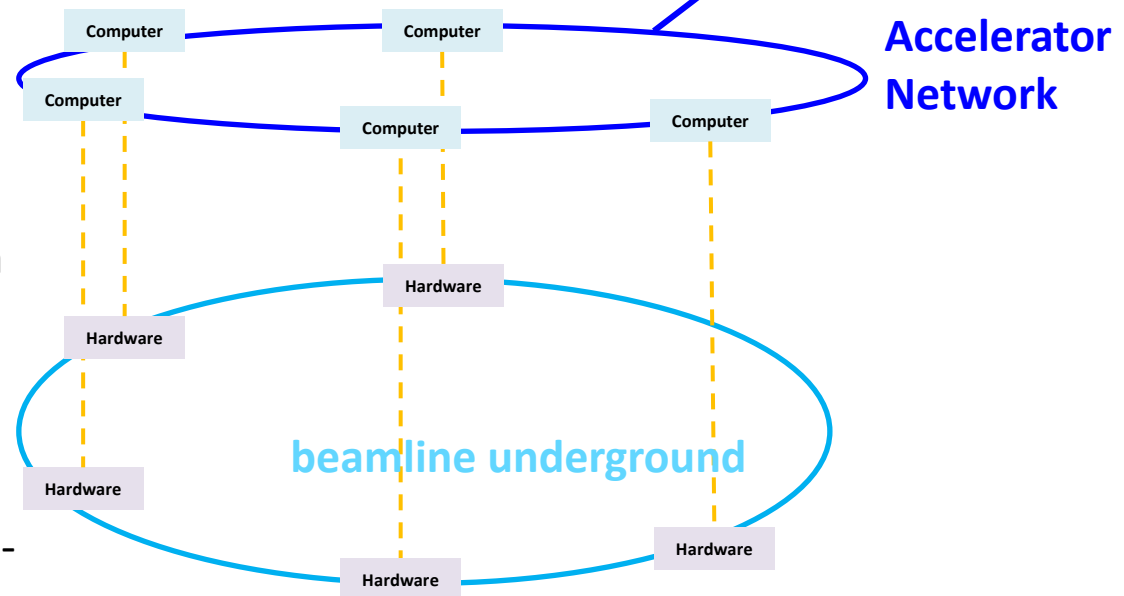
Office



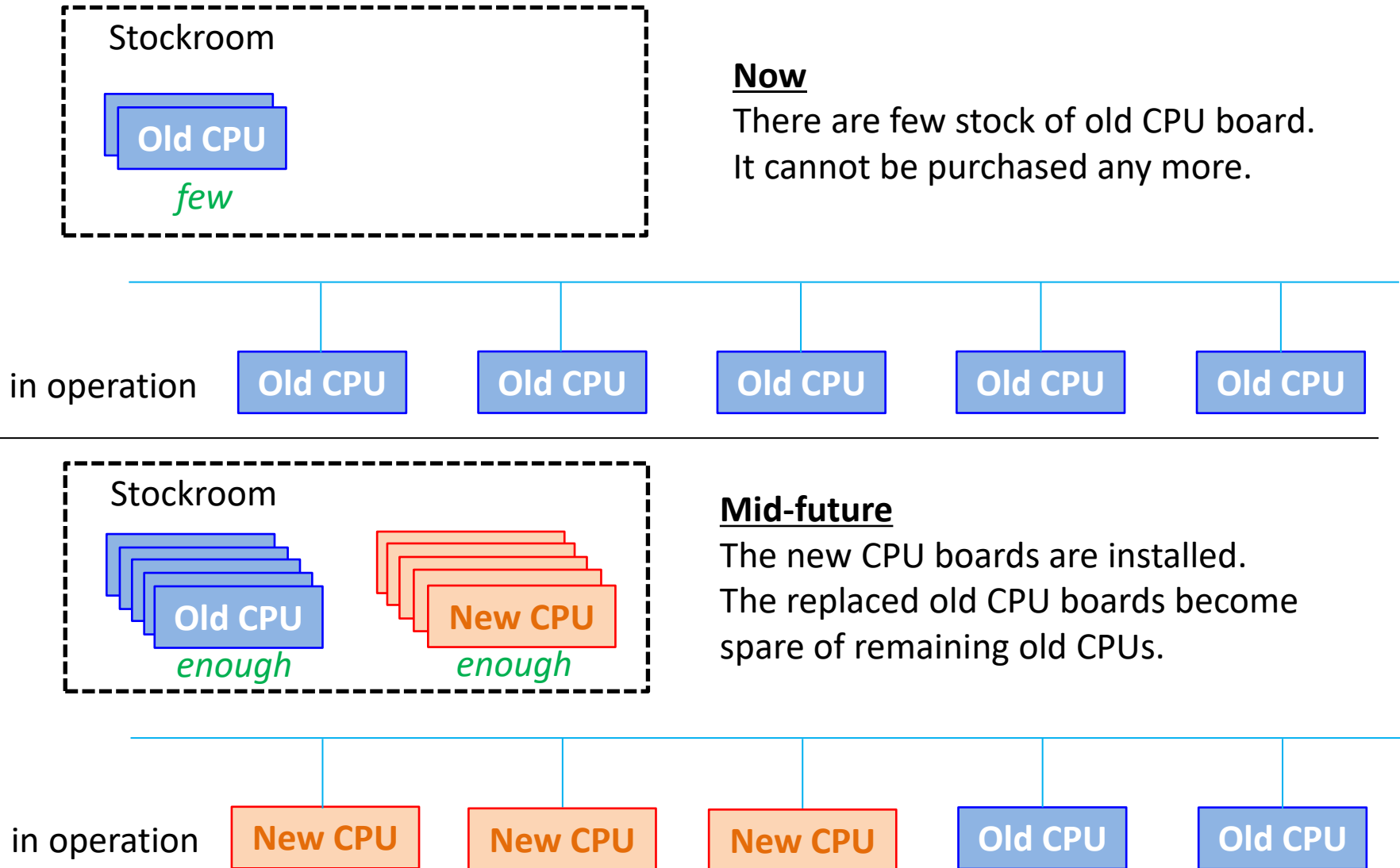
However, both modules are EoL after 10 years of the operation.

The update of the control system CPU is mandatory and ongoing.

Note, the aged control system must be renewed with the sustainability strategy in the long-term project.



Sustainability strategy



Of course, finally, all of old CPUs will be replaced with new one.

VME CPU update

MVME5500 ⇒ SVA061
started this year

The SVA061 CPU module is firstly introduced as the Beam Loss Monitor IOC at J-PARC MR.

CPU: intel Atom x7-E3950
RAM: 8GB
OS: Ubuntu/Alma Linux
(VxWorks 7.0 available)



We received three modules in March 2026.

The software for following control modules has already been developed.

- abort interlock module
- TDC module
- Event Receiver “VME-EVE”
- Event Receiver “VME-EVR-230RF”

Further development ongoing.

Some of EPICS IOCs can be updated with above device support software.

⇒ **We started updating the VME CPU.**

Update in 2026 shutdown

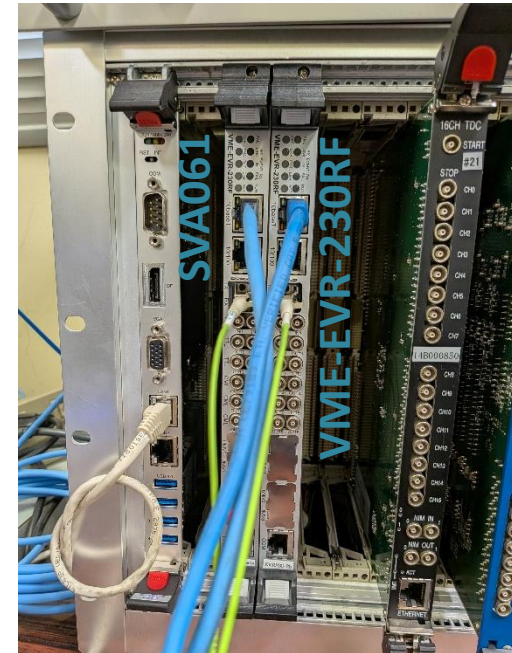
The CPU of the D07/D08 abort master IOC is replaced. It will be in operation since Jan 2027.



One of wire scanner IOCs will be updated at LINAC, maybe next month.

- EPICS device/driver is a little bit customized.

Plan to report at a workshop in the next week (Di Wang).



Soon, we will receive four more modules.

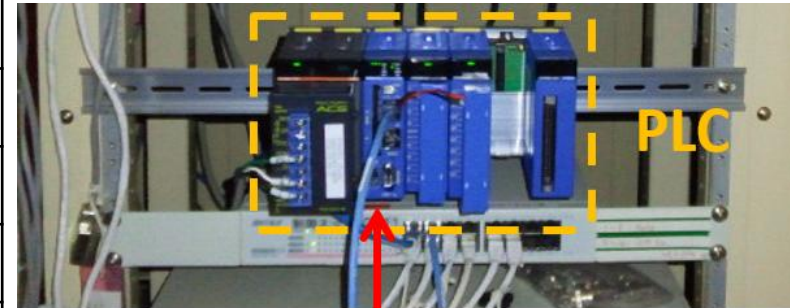
⇒ Further software development and implementation in the next year.

PLC CPU update

F3RF61 ⇒ F3RF71
since 2020

The update of the PLC CPU advances a little in comparison with VME.

	F3RP61	F3RP71
AR	19	3
Beam Monitor	7	0
Beam Transport	22	1
Control	10	2
Magnet	30	1
RF	56	6
Super conducting	8	0
Vacuum	3	28
Total	155	41
Stock	29	4



F3RP61

Most of the CPUs for the vacuum IOC have been replaced with F3RP71. It gives us the stock of F3RP61.

For further replacement, we need understanding and helps from individual hardware group.

Working list

Item	Treatment to EoL	Improvement	Schedule
Injection Loss Monitor		Provide frequency domain information contribute to injection improvement	Operation in the 2027 spring run, Further expansion possible
Abort Trigger System	Timestamp: Old Event module (17K50, 17K51) ⇒ White Rabbit	Speed up response Precise timestamp with PPS delivery from WR contribute to SBL treatment	Operation in the 2027 spring run
RF clock generator	Old optical converter ⇒ IDROGEN (WR)	Compensation of cable delay drift improve clock precision	Still in R&D phase
BT-BPM trigger	VME-EVR-230 ⇒ VME-EVR-300	Eliminate fake-firing with WR Beam Gate system contribute to injection improvement	Operation in Dec 2026
CPU update	VME: MVME5500 ⇒ SVA061 PLC: F3RF61 ⇒ F3RF71		Ongoing PLC since 2020 VME just started No exact schedule

Conclusion

The huge-scale control system has been developed for SuperKEKB.
It is one of the largest beamline accelerators in the world.
The excellent control system has supported a smooth operation since 2016.

Our outstanding knowledge of the accelerator control system *indirectly* helps increase SuperKEKB's luminosity.

- The development of the injection loss monitor DAQ system helps understanding the mechanism of the injection beam loss.
- The upgrade of abort system makes abort response faster and mitigate radiative damage from SBL.

The several control modules are EoL after 10 years of operation.

⇒ biggest issue for the SuperKEKB control system

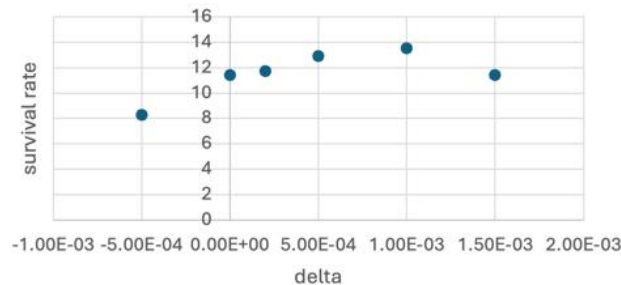
We partially updated the EoL modules.

- GPS synchronization of abort timestamp ⇒ White Rabbit
- old Event Timing module ⇒ Later products
- sustainability strategy of CPU update is ongoing.

The update of the aged control system will be conducted toward the 203x era.

Some examples from Xsuite

Energy scan (rad=mean)



FFT of energy, D03V4

