Status of Control System

28th KEKB Accelerator Review
2025-01-14
Akio Morita

Updates for Operation

- Support keyword search for the Web Shift-Report service since 2024c operation.
- Addition/Modification of abort request signal
  - Add HER D9 optical fiber loss monitor abort signal
  - Split Belle2 VxD diamond abort signal into High THR and Low THR abort.
- Update for backend database for "Abort Summary Page"
  - Upgrading database to unify "Abort Summary Page" and "SBL Verification Page". (in-progress)
    - The unified database supports the "**tag**" field for categorizing the individual abort event.
    - Database upgrade is almost finished, however, the development of Web UI software is not completed.
      - UI software WOULD be develped by MDI/Belle group.
- Abort trigger system upgrades (p.4~11)
- Timing control system upgrades (p.12~19)

Issues during Operation

- Abort timestamp slip issue at D11 station
  - PPS (pulse per second) signal over the “legacy” event distribution network is used to count up abort timestamp clock.
    - This legacy EVG/EVR system is developed for KEKB B-Factory accelerator.
  - D11 station EVR has longest optical signal path from EVG at CCB (central control building).
  - This issue is resolved by replacing the optical fan-out module with spare one.
    - +1.0 ~ +1.5dB optical signal level improvement was observed at this replacement.
- Unidentified abort request injection issue
  - In 2024 operation, the abort requests, which is not logged on the source sub-system, is observed.
    - 4 events from vacuum system, 1 event from QCS magnet power supply system
  - The abort signal line from the vacuum system WOULD be inspected to investigate this issue.
- Multiple reboots are occurred on new alma linux 9 mini PC console, which are introduced as replacement of the legacy CentOS 7 PC.
  - One broken SO-DIMM was found by memory test & it was replaced with new one. (1 PC in 5 new mini PC)
  - The kernel panic on the native alma 9 linux environment seems to occur in the Radeon kms driver,
    - As a workaround for these kms driver issue, we introduce Linux virtual machine on Windows host.
    - After this workaround, the reboot event rate seems to have reduced, however, the memory leak on Windows host & Blue-screen-of-death event is observed.
      - The relationship between the Radeon graphics driver version and the memory leak rate is investigating.

User Supports

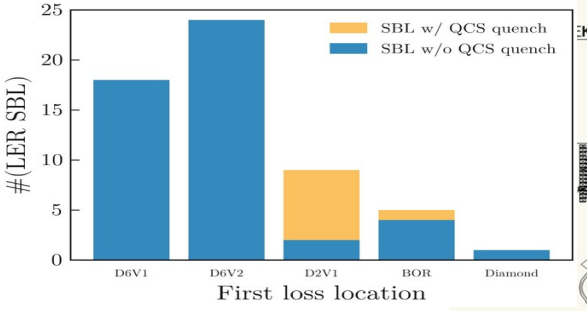
- The processor and memory resouce consumption of the user application server services exceed our expectations.
  - The heavy system loads by user application have been observed.
    - The back-end process of user introduced application (VSCode editor...) occupies a part of processor cores.
    - The parallelized data query & analysis application which don't consider total process/memory capacity.
  - The access load to SuperKEKB Archiver Appliance and KEKBLog cache server are increased too.
  - These resources were prepared to provide general data access for SuperKEKB control system, however, it is not desinged for High Performance Computing like parallel data analysis load.
  - Requesting budge for introducing new node to improve system availability, however, it would not be enough to satisfy such HPC like system load.
- Contents replication of SuperKEKB Archiver Appliance to KEKCC storage is on-going for PV analysis by Belle group.
  - Daily snapshot delta is exported into 3 tarbal gzip-ed files on the public file system: /ldata/BELLE2/AA/recent_day/.
  - Copy-out of old archive data (>>10TB) is in-progress, however, file system copy throughput is limited by a lot of small size files in the archives.

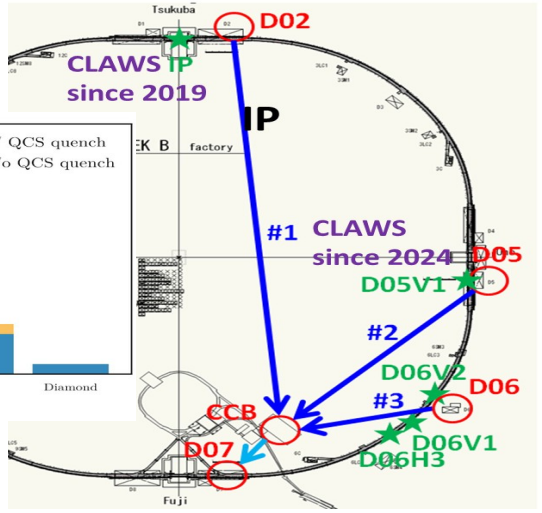
Beam Abort System upgrade

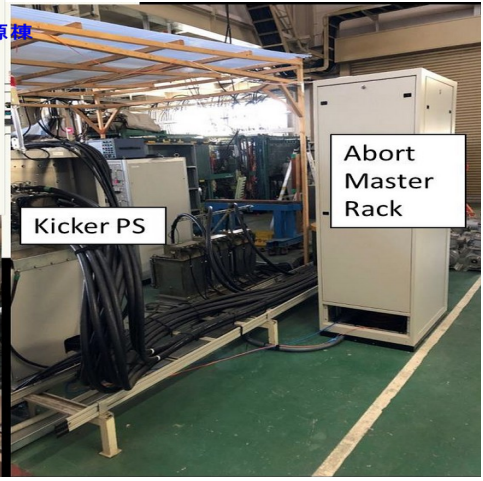
A rich program for speeding up the beam abort response is ongoing by the joint team among the SKB-BT and SKB-control, and Belle-MDI groups.
It is an essential treatment against SBL.

After the investigation of the first beam loss location in 2022,
we decided to install abort sensors at the upstream vertical collimators for the **earlier detection of SBL**.
- D05V1 since 2024 spring and D06V1 since 2024 autumn

The new master system of the LER abort trigger system is configured at D07 and directly connected with above abort sensors since 2024 autumn.
- avoid unnecessary circuitous route to CCB ⇒ **shorten the transfer time of abort signal**







LER Abort Trigger System upgrade

By comparing the abort response timing between the abort source existing in 2022 and the new D07 master,
we can know how fast the abort response becomes (It is shown as "Δt").

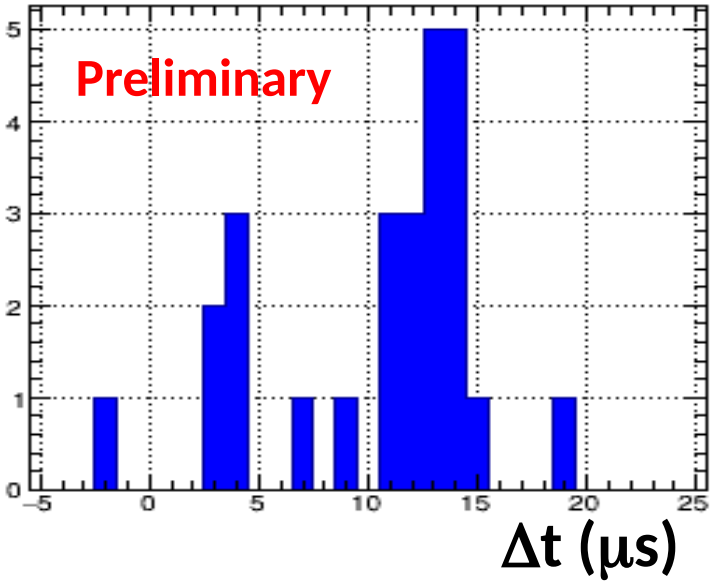
It is evaluated with the abort timestamp log.
http://kekb-co-web.kek.jp/doc/abort/timestamps_onetable.php

The D07 master launched 28 abort requests since the end of Nov. 2024.

All of them are SBL or the accidental firing of the injection kicker.

In most cases, the abort response becomes faster.

The response becomes one-turn (10μs) faster in 18 out of them.



(Note, the analysis is conducted in the abort request signal level.
The abort kicker timing is quantized in 5μs for synchronizing with the bunch-train gap.)

Our upgrade obviously mitigated the damage to the hardware from SBL.

Upgrade plan in 2025

Very promissing plan supported by **established collaborators!**

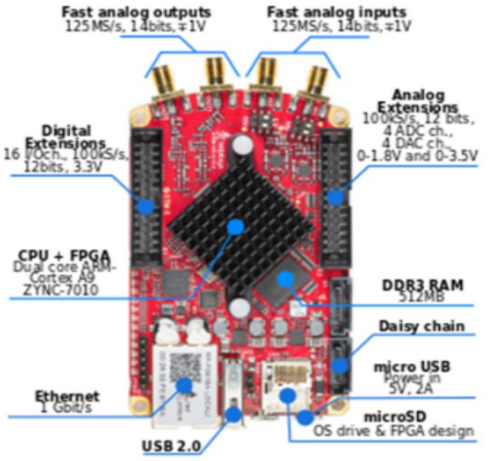
CLAWS mass production (MDI and **Nagoya Univ.**)
- 20 new sensors will be provided **in Japan**.

Abort request launcher circuit (MDI and **Nagoya Univ.**) (p.7)
- No spare any more. EoM.
- Development of new system based on Red Pitaya
  (technical support by Konstantin Popov@**ATF**).

LER upgrade plan at LER (**Nagoya Univ.** and **Tokyo Metro-Univ.**) (p.8)
- Increase of the CLAWS sensors
- Nobel Laser Abort System (partially supported by **cern**) (p.9-10)

Upgrade plan at HER (**SKB-BT group**) (p.11)
- Construction of the new abort master at D08. The location is decided.
- The sensor location should be discussed.

Abort request launcher



The timeout function of the commercial oscilloscope is employed for the abort request signal in the CLAWS system.
However, they have already been product EoL.

We develop the new abort request launcher with Red Pitaya.

The other concern is the latency of the launcher circuit since it also affects the abort response.

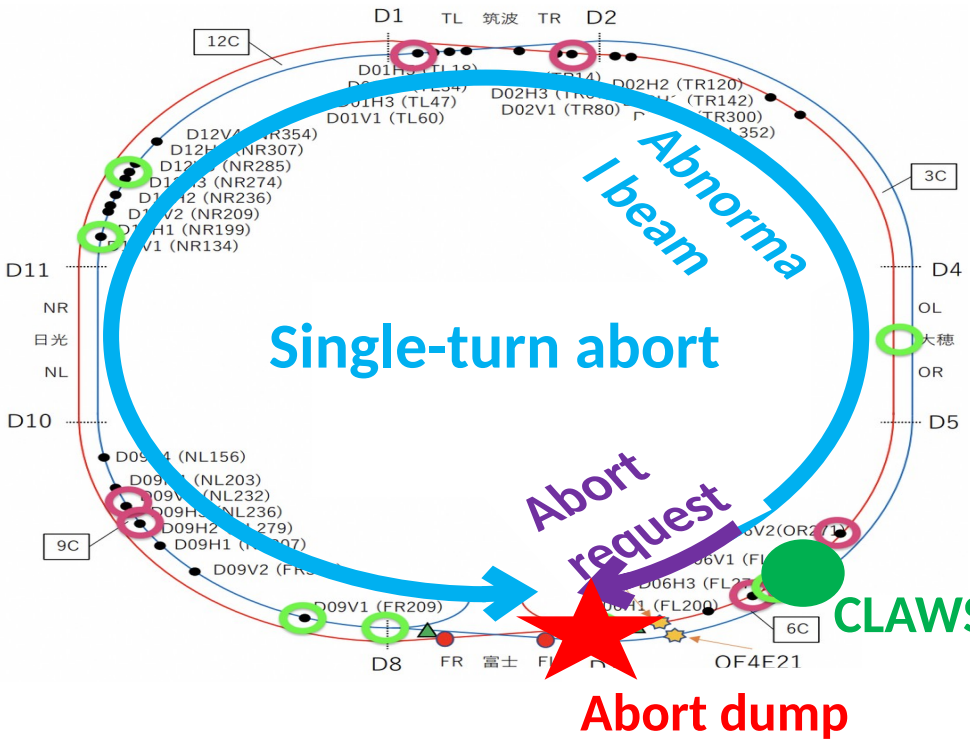
- We aim to develop the new system with the **latency < 100ns**.

Module	Location	Latency	Remark
Keysight P9242A	IP, D05	36 ns	EoL
Picoscope PS6024E	D07 master	360 ns	EoL
for fiber loss-mon.	D06, D08	400 ns	Order production
Red Pitaya	…	…	COTS

There are many Red Pitaya applications at KEK-ATF.
We received technical support from Konstantin Popov and started developing the abort launcher system with their products. (We didn't need to start from scratch.)

https://ibic12.kek.jp/mirror/www.pasj.jp/web_publish/pasj2024/proceedings/PDF/WEP0/WEP077.pdf
https://ibic12.kek.jp/mirror/www.pasj.jp/web_publish/pasj2024/proceedings/PDF/FRP0/FRP013.pdf

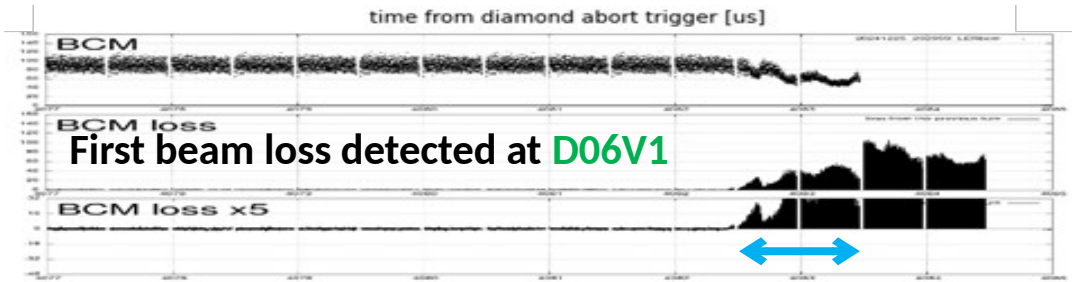
Upgrade plan at LER



After upgrade in 2024, the **single-turn abort** is realized!
- Geographically fastest response time.

Abnormal beam travels only one turn.
- the most-safe abort in the SBL accident.

12/25 20:29 SBL with QCS quench



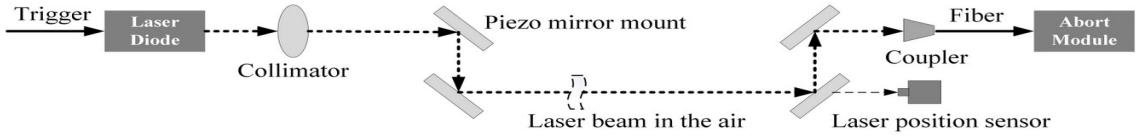
We continue upgrading the LER beam abort system to enhance **single-turn abort** capability.
- increase CLAWS sensors, for example, D06V2 and D02V1 vertical collimators.
- Novel Laser Abort System (p.9-10)

https://www.pasj.jp/web_publish/pasj2024/proceedings/PDF/WEP0/WEP023.pdf

Novel Laser Abort System

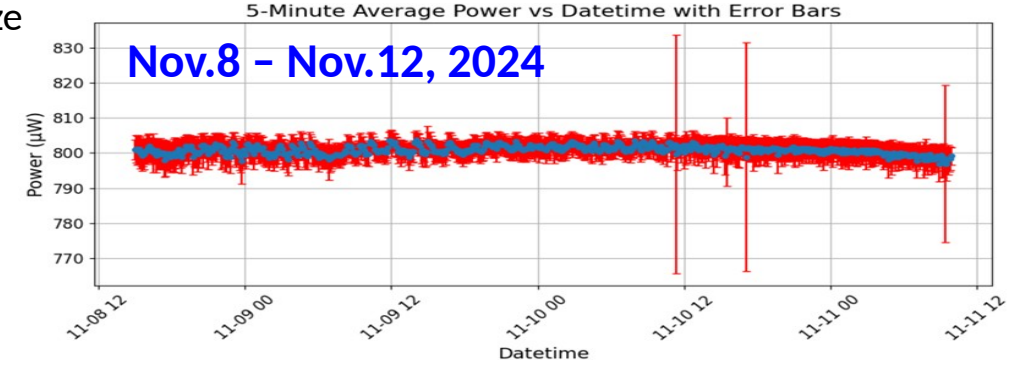
S. Kitada, H. Murakami (Nagoya),
K. Kitamura, H. Kakuno (Tokyo Metro-U),
H. Kaji, R. Zhang (KEK)

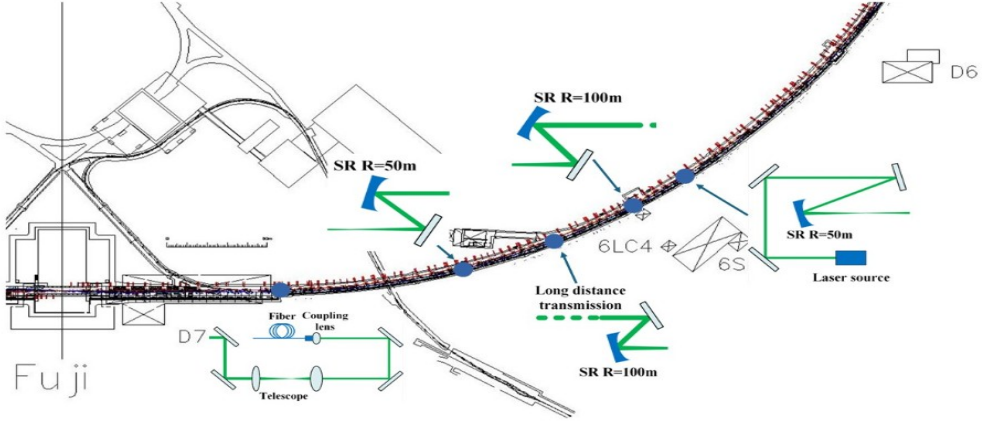
Supported by JSPS KAKENHI 24K15603



The laser light travel 1.5 times faster than the signal via the optical fiber.
⇒ **Possible to speed up the abort signal transfer.**
To employ the laser as the abort request signal, we need to stabilize the laser orbit and keep providing the power of >30uW.

The 67-hours test is carried out at the ground floor of the LINAC building.





We succeed to transfer much larger laser power (~800uW) than the requirement.
Further study is planned at the SuperKEKB tunnel.
Our target is **the stable operation for one month**.

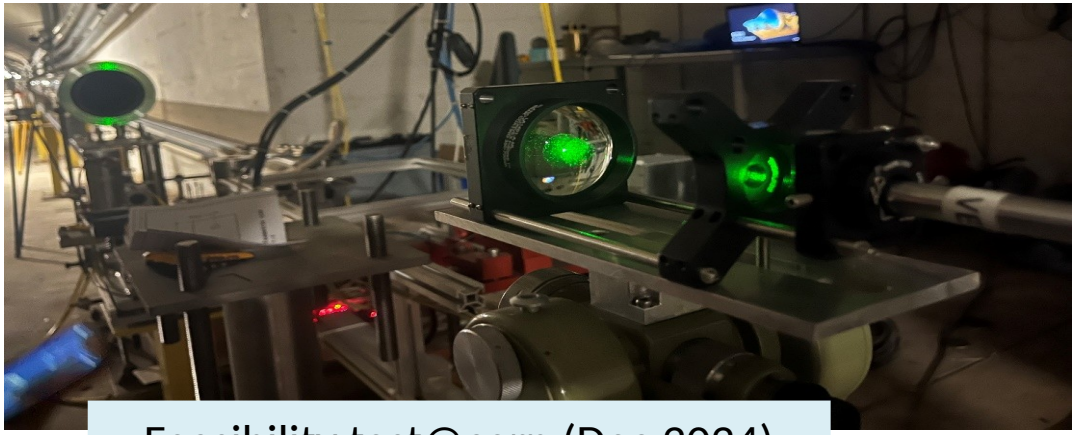
There are still a couple of technical issues to be solved.
However, the best case, we will configure the first laser abort line from D06V1 to the D07 abort master in the 2025-2026 winter run.

Structured Laser Beam option

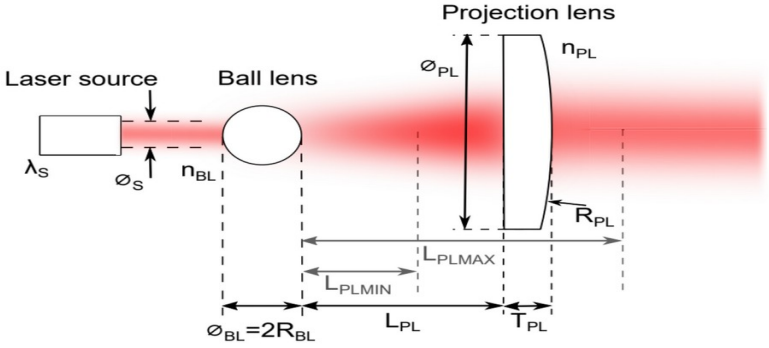
To expand the laser transfer length, for enhancing the single-turn abort capability, we plan to develop the new low-divergence laser source.

Structured Laser Beam was developed at cern.
- Ultra-low divergence of 10 μrad.
- Suitable for long distance transfer of the abort request signal.

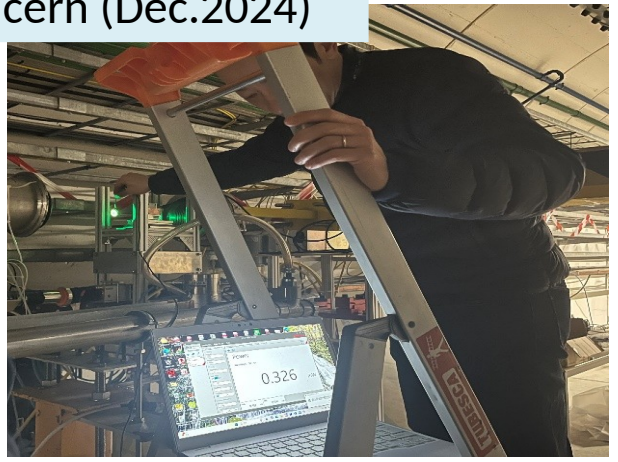
The initial feasibility test has been successfully carried out at cern.
We invite experts from cern and continue R&D at the SuperKEKB tunnel in the 2025 shutdown.
Also, considering applying for the beamline alignment (collaborative work with magnet group).



Feasibility test@cern (Dec.2024)

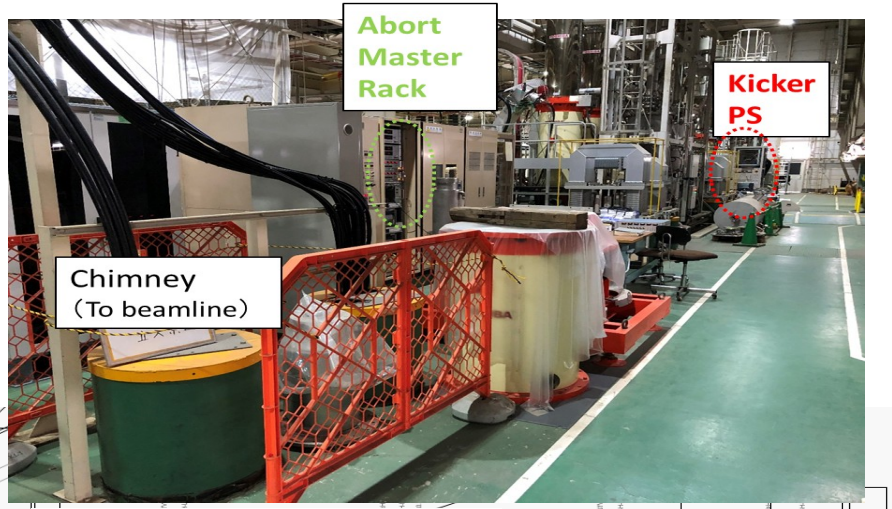


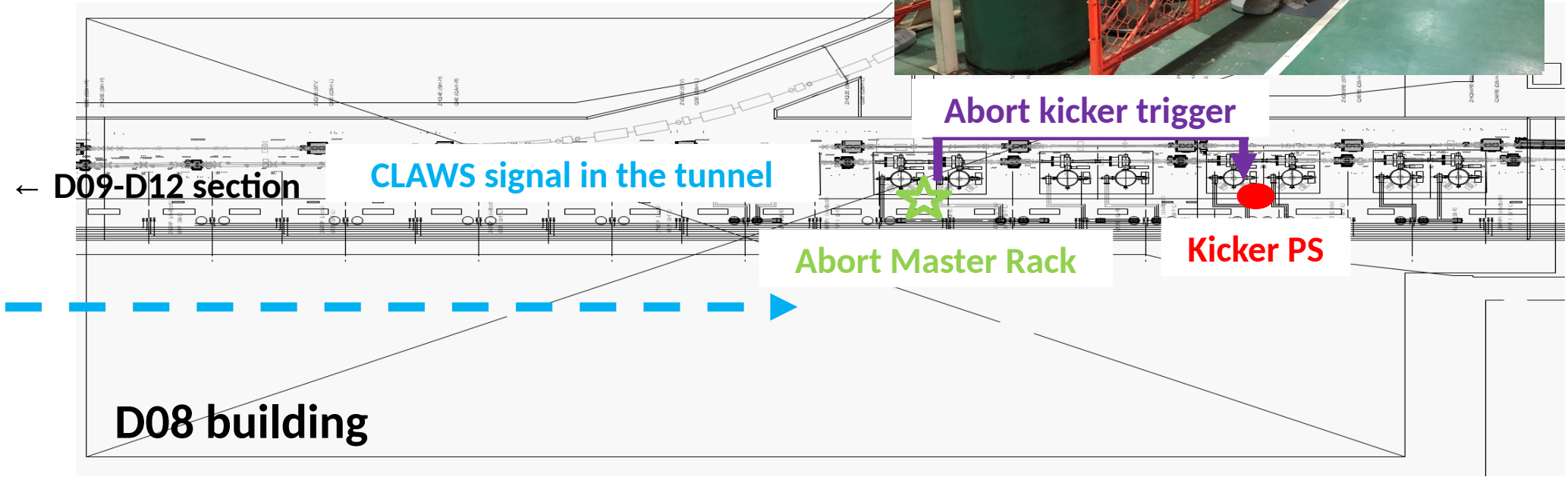
Vol. 31, No. 26 / 18 Dec 2023 / Optics Express 43312



Upgrade plan at HER

The construction of the HER abort master at the D08 hall is planned in the 2025 shutdown.
- **Master location has been decided.**
- **All material except for Red Pitaya are delivered.**





Also, the installation of the CLAWS sensors to the HER beamline is needed.

Timing system and Injection control

Bunch Current Equalizing (BCE) in the 2-bunch injection is released since the 2024 spring run. (p.13)
- the rate of 1-bunch BCE (potential degradation of the injection power) can be reduced.

Two evaluations for the BCM injection efficiency is released since the 2024 spring run. (p.14-16)
- We proposed the new “1 pulse after” version to be the online efficiency.

“Shot-by-shot” data acquisition trigger synchronizing followings is developed. (p.17-18)
- TbT monitors
- three directional kickers (inj. kicker, vertical kicker, RF kicker)
- fast beam loss monitors
- Belle II

White Rabbit related R&D is continued. (p.19 & p.21-22)

Two-bunch BCE

Even though the two-bunch injection is implemented, there has been no two-bunch bunch current equalizing (BCE) mode in both SuperKEKB before LS-1 and the KEKB era.

Therefore, we had accumulated the stored beam by a mixture of the “two-bunch unplanned” and “one-bunch BCE” injections.
It is the potential degradation of the injection power.

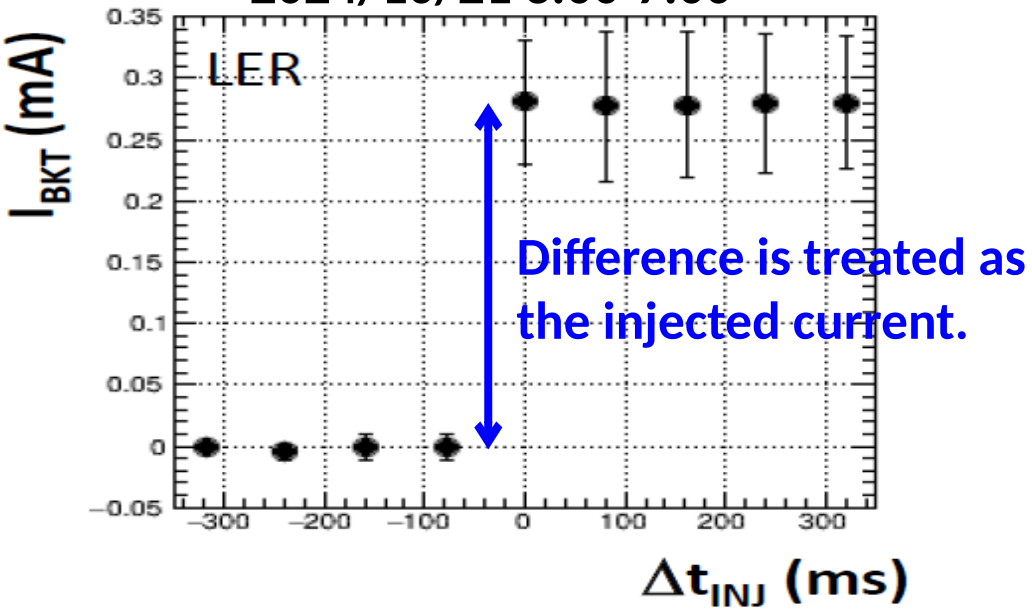
We developed the two-bunch BCE mode in LS-1.
It is activated since the 2022 spring run.

First activation on Apr. 3, 2024.

Injection efficiency

We can evaluate the **injection efficiency** with bunch current difference before and after injection since we can know which RF-bucket LINAC injects the next beam with the **Bucket Selection** system.
Note, the injection efficiency evaluated from difference of the total current (DCCT measurement) is affected by the lifetime effect.

2024/10/21 3:00-7:00

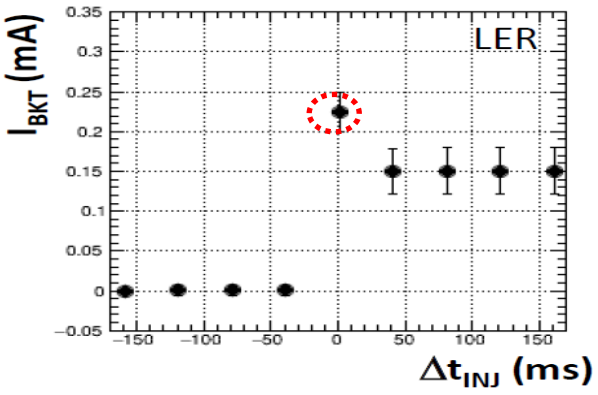


The BCM measurement is issued 1ms after every injection.

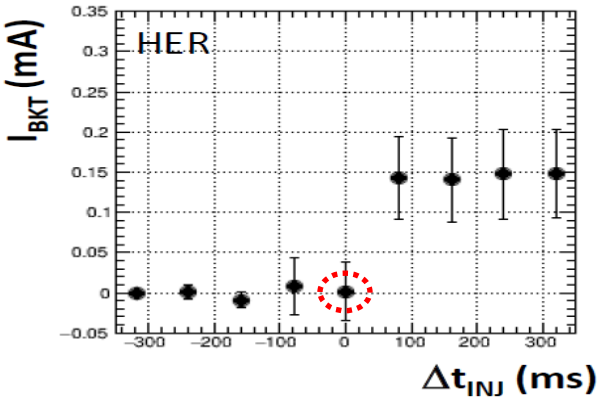
We evaluate the injection efficiency by divided it by the BT-end current.

Bad examples

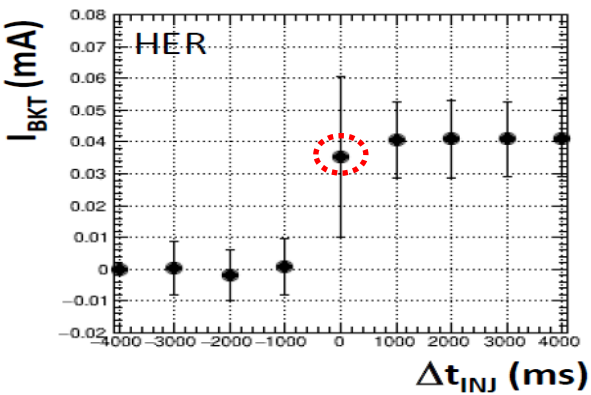
2024/6/5 12:40-13:40
(2024 spring)



2024/10/21 3:00-7:00
β_y*: detuned



10/22 1:00-9:00
β_y* = 1mm



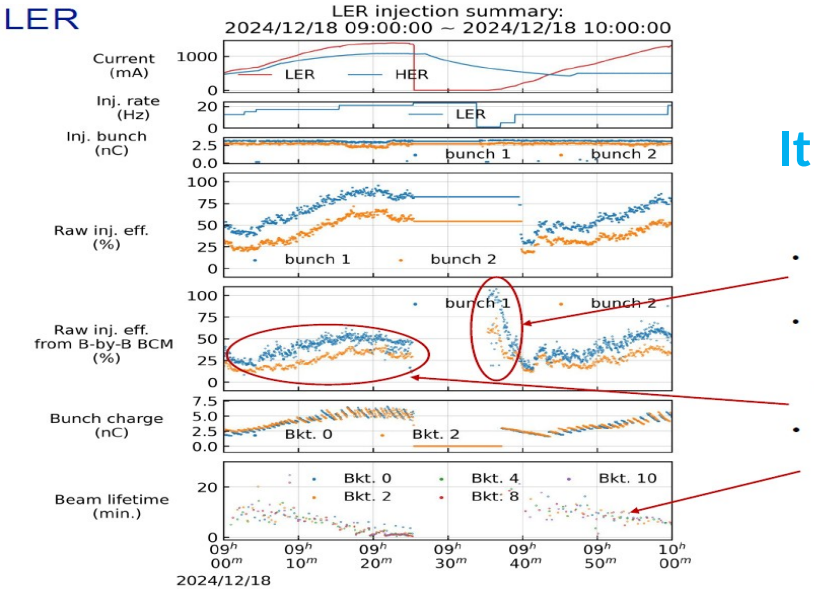
We can not measure the bunch current just 1ms after the injection.
Sometimes (not always), the bunch current is **incorrect**.
The resultant injection efficiency becomes unreliable.
The measurement at one pulse later should be used as "**bunch current after injection**".

Two evaluations with BCM

Since the 2024 spring run, we provided injection efficiency with both "1ms after injection" and "1 pulse after injection".

Still "1ms after" version of efficiency is utilized as the online monitor.
However, the experts already been using the "1 pulse after" version.
(eq. the injection tuning by the machine learning)

We propose to change the online monitoring efficiency to be the "1 pulse after" version.



It is also proposed by the ITF team.

- LER injection efficiency is better at low currents, due to the TbT orbit FB.
- Bunch-by-Bunch LER injection efficiency is not consistent with PV data: "TM_EVR0:LER:INJ_EFF:BCM1", and "TM_EVR0:LER:INJ_EFF:BCM2".
- Beam lifetime can be calculated with charge decay data in a bunch.

Slide from T. Yoshimoto (LINAC)

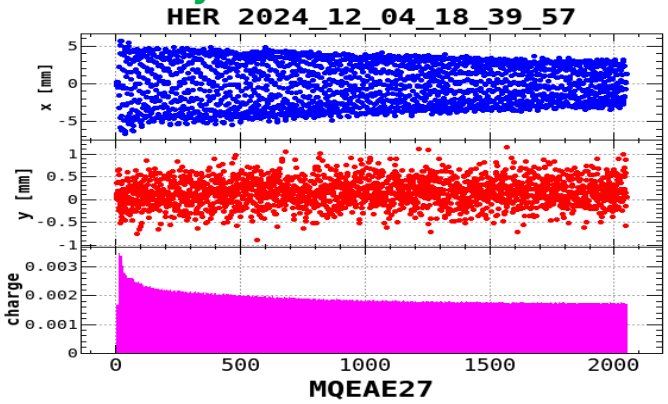
New data acquisition trigger

We developed the new data acquisition trigger that synchronizes the valuable data.
- Note, it was called “software trigger” and synchronized only the TbT BPM.
- HER and LER were not separated.

Two measurement modes are established
- injection beam mode
- stored beam mode with the kickers in three directions.

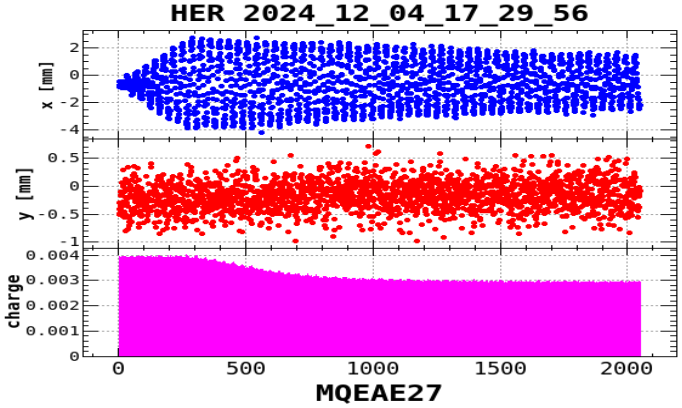
Followings are synchronized!
- kickers in three directions (inj. and vertical kickers, RF kick)
- BT orbit
- TbT BPM
- injection efficiency
- Fast injection loss monitor at HER vertical collimators
- ECL trigger for Belle II (can be added other sub-detectors)
- CLAWS, We utilize it also for injection beam studies.
  First one has been installed at D01V1.

HER injection beam



HER stored beam (RF kick)

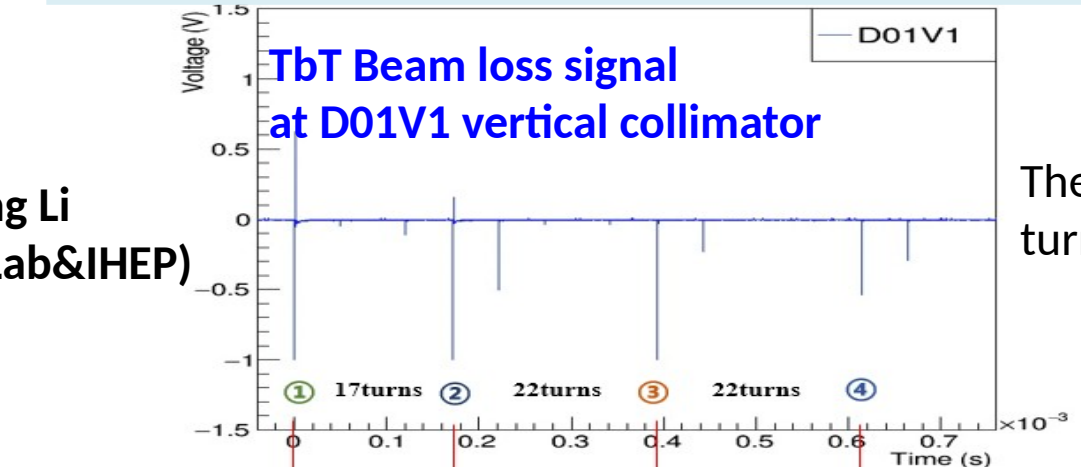
Note, data is taken
at the dispersive point.



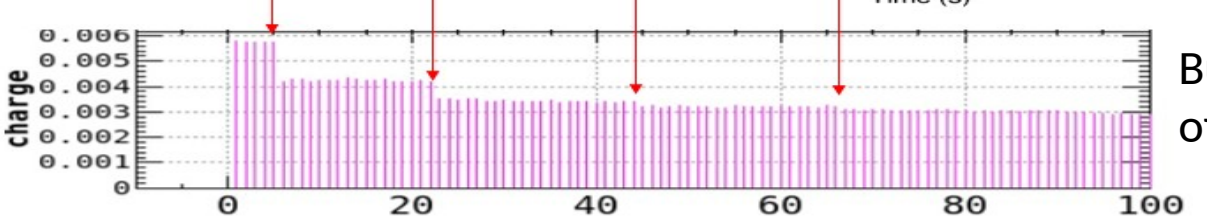
Synchronization with fast loss monitor

This data is taken when we kick the HER stored bunch by the vertical kicker.
In this mode, the TbT-BPM, TbT loss monitor (CsI scintillator+PMT), and vertical kicker pulse magnet is triggered by the same timing signal.

Meng Li
(IJCLab&IHEP)



The fast loss monitor measured the turn-by-turn beam loss.

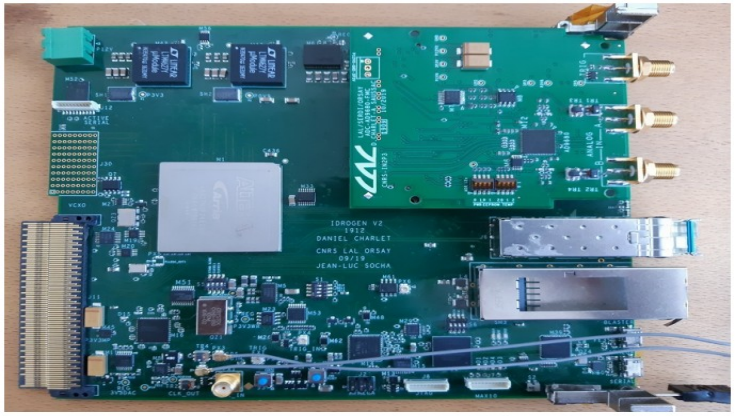


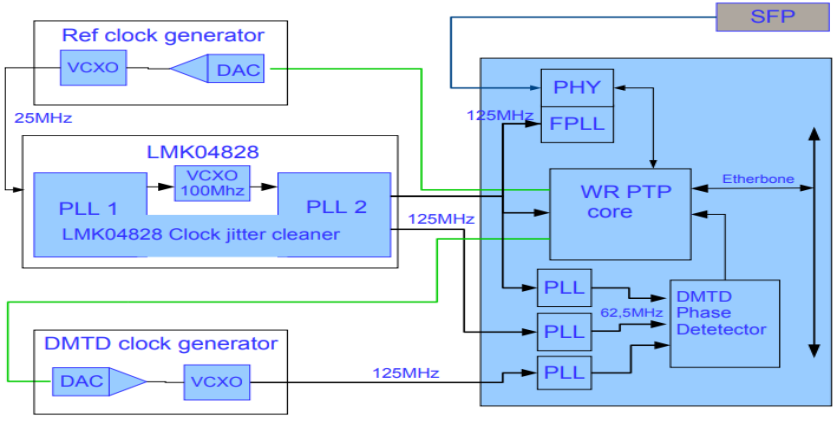
Bunch charge information from one of the TbT monitors.

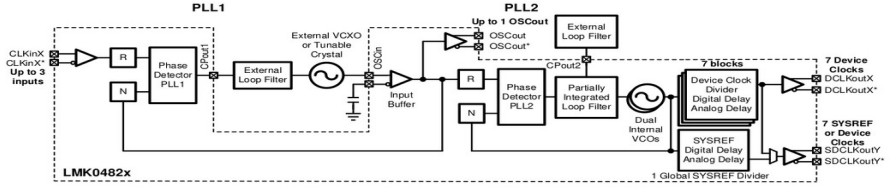
It is a strong tool to understand the aperture and the injection beam loss.
We took extremely valuable data.
However, the analysis is not ready for this meeting. Please wait IPAC!

White Rabbit R&D

H. Kaji, T. Kobayashi, T. Yamaguchi (KEK)
A. BACK, D. Charlet, A. Martens (IJCLab)







The IDROGEN board is developed at IJCLab.
- μTCA.4 type board
- standalone mode, available
- Intel Arria10 FPGA board with SFP and QSFP.

The White Rabbit system is configured.

A few telescopes selected as its timestamp synchronization.
The test stand for superconducting spoke cavity at IJCLab.

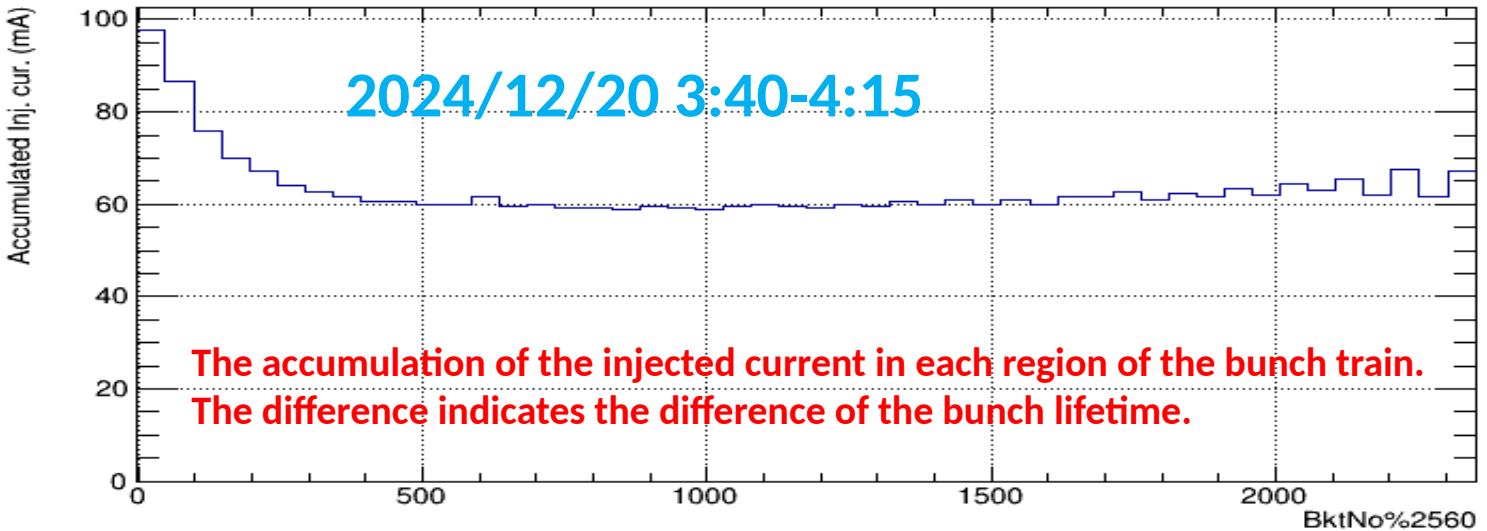
KEK participates:
- performance test
- development of the EPICS device support

We aim for its application to
- Luminosity measurement synchronized with the environmental change.
- DAQ for the beam diagnose system

Backup Slides

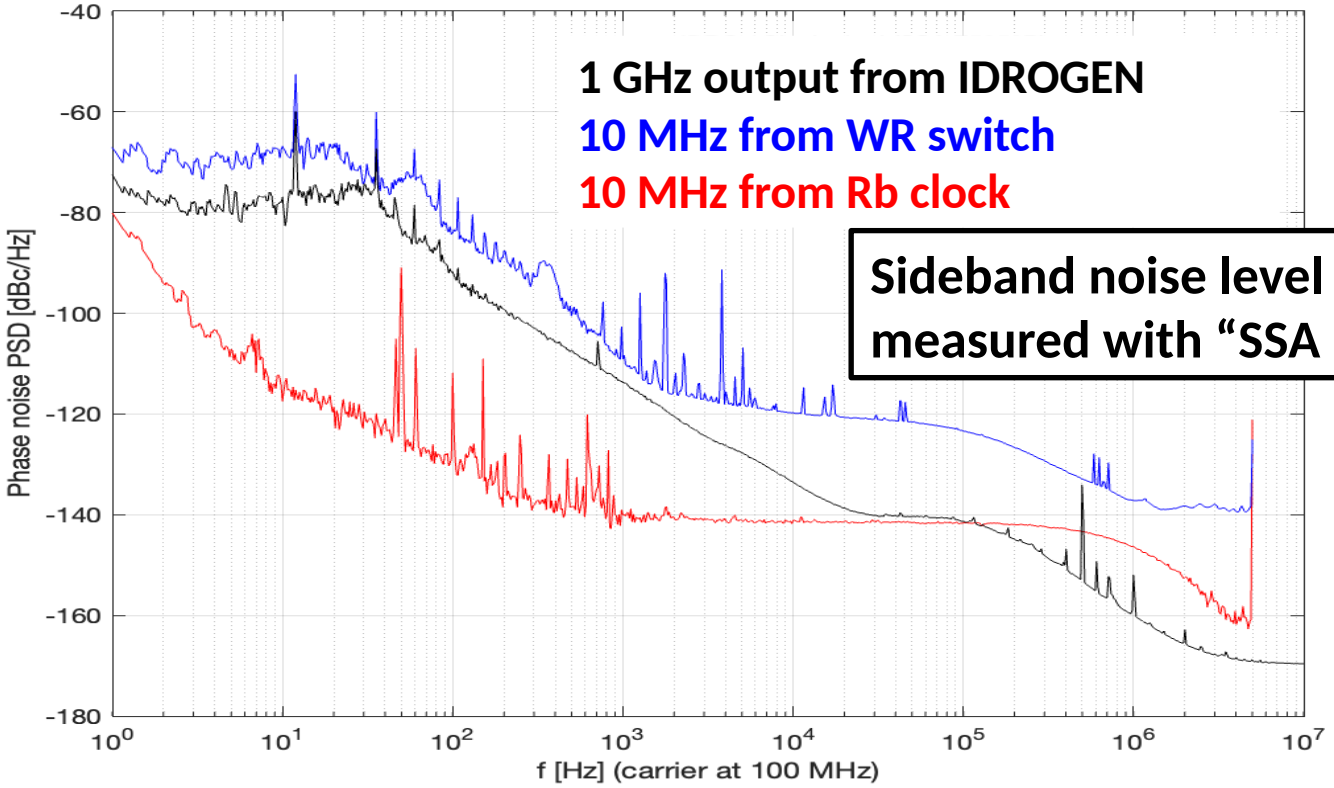
Lifetime ratio among bunches

Since we carried out the top-up filling operation in the BCE mode,
We often inject the LINAC beam into the short lifetime bunch.
Therefore, we can evaluate the relative difference in the bunch lifetime.
It is also informed by Bucket Selection and recorded on Archiver Appliance.



Note, the bunch lifetime depends also on the bucket spacing.
See **Journal of Physics: CS 2687(2) 022009-022009**

Sideband noise level



Sideband noise level of 1GHz reference clock is measured with “SSA E5052B”.

Jitter

494 fs (100Hz-10MHz)
1747 fs (30Hz-10MHz)
2801 fs (1Hz-10MHz)

It is enough performance for the timing trigger usage.

Relative phase jitter