ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPGW036

ARCHIVE SYSTEM OF BEAM INJECTION INFORMATION AT SuperKEKB

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Abstract

The injection archiver system is developed for the SuperKEKB collider. It records the information related to beam injection, pulse-by-pulse, so that the detailed studies of injection conditions become possible. The system is successfully operated during the phase-2 operation of SuperKEKB. The fluctuation and significant loss of injected current are observed with its new determination method. Besides, the recorded data can be utilized for studying the beam backgrounds related to the injection.

INTRODUCTION

The SuperKEKB collider [1] is a luminosity frontier machine aiming the world largest luminosity of $8 \times 10^{35}\ \mathrm{cm^{-2}s^{-1}}$. It operates the electron beam of 7 GeV and the positron beam of 4 GeV. Its phase-1 and phase-2 operations are successfully carried out in 2016 and 2018, respectively.

The next task to realize the designed luminosity is the top-up filling operation for both the electron ring (High Energy Ring, HER) and positron ring (Low Energy Ring, LER). It is necessary to keep large operation currents of 3.6 A (HER) and 2.6 A (LER) under the short beam lifetime condition. More injection tuning of injector linac (LINAC) [2] is required to realize the highly efficient and low-background injections.

We develop the injection archiver system which records information related to beam injection, pulse-by-pulse. It can be utilized for the understanding and tuning of the injection condition. This system is designed and developed during the shutdown period between the phase-1 and phase-2 operations. Then it becomes fully functioning since April, 2018.

This report briefly introduces the specification of the injection archiver system. Then some results are discussed.

INJECTION ARCHIVER SYSTEM

The details of injection archiver system are described in Ref. [3]. Here we introduce its overview and some details of the data acquisition process.

Overview

Figure 1 is the schematic view of the injection archiver system. The system consists of two computers. One is the standard database server and the other is the EPICS IOC [4] with an Event Timing System module [5]. This IOC is called "data collector".

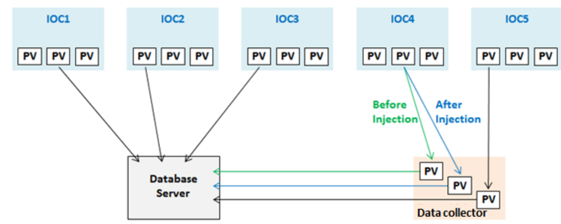

Figure 1: Schematic view of injection archiver system

All data are collected from EPICS Process Variables (PVs) and recorded on the database server. The data should be recorded, pulse-by-pulse, are once collected on the data collector with the process driven by the Event interruption.

Data Acquisition Process

The injected current recorded in the injection archiver is defined as bunch current after injection minus that before injection. Therefore, the data acquisition of the data collector is implemented twice in every injection. The first and second processes are implemented 17 ms before and 10 ms after injection, respectively.

The data collector collects the bunch current at RF-bucket to be injected beam pulse (Injection-bucket) from the bunch current monitor (BCM) PV. This process records the different channels of BCM PV in every time since the Injection-bucket is changed in every injection pulse. The Injection-bucket information is instructed via the data buffer of Event Timing System. Therefore data collector can record the data of the correct BCM channel. This determination method of injected current makes advantages as compared with the ordinary method.

The bunch currents before and after injection are recorded also for the neighboring RF-bucket (Neighbor-bucket) of Injection-bucket. Those data can be utilized for studying the effect of injection kicker magnets. Note, the storage bunches in $\pm 1\ \mu s$ interval from the Injection-bucket are kicked with the two sets of kicker magnets in the injection process.

The other advantage of the data collector is the unification of timestamps. The all pulse-by-pulse data are recorded with the CPU time of data collector. It is useful for offline analysis of injection archiver data.

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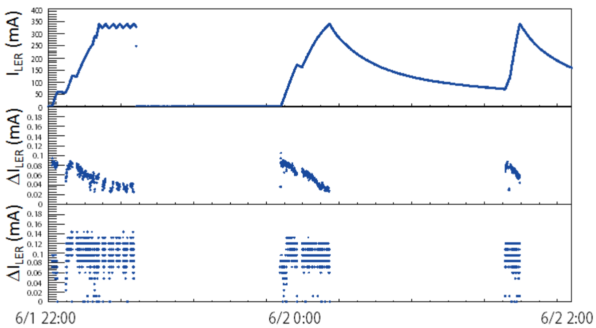

Figure 2: Time chart of operation current and injected currents at LER: The top plot shows the operation current. The middle and bottom plots are the injected currents determined with ordinary and new methods, respectively. The data from June 1st 22:00 to June 2nd 2:00 in 2018 are shown.

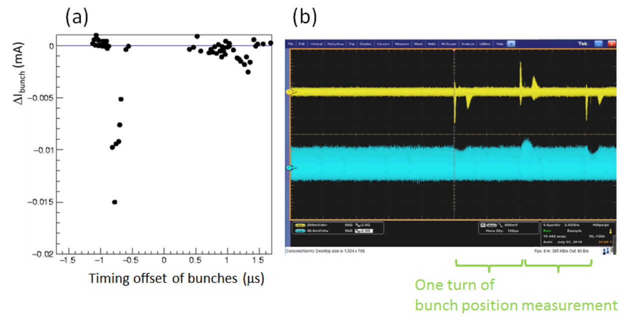

Figure 3: Bunch current difference between before and after injection (a) and bunch position measurement with one turn BPM (b): in the plot (a), the horizontal axis is the timing offset of each bunch from the Injection-bucket and the vertical axis is the bunch current difference. The result of only bunches around rising and falling edges of the injection kicker pulse is shown. In the oscilloscope picture (b), the yellow indicates the horizontal position of each bunch. One turn of measurement in the 10 µs period is shown a few times.

RESULTS IN THE PHASE-2 OPERATION

The injection archiver system is successfully operated in the phase-2 of SuperKEKB which is carried out in 2018. In this section, we discuss some results from the recorded data.

Injected Current

The injected current recorded in the injection archiver is superior to the ordinary method utilized at KEKB [6]. In the ordinary method, the injected current is determined as the total beam current after injection minus that before injection. And the total beam current is measured by the DCCT with large uncertainty. The one second average of measured values is utilized for the injected current determination.

Figure 2 is an example of LER injection data. The time chart of operation current and injected currents are shown. The injected currents determined with both ordinary and new methods are shown together.

The injected current determined from total beam current needlessly includes the current difference of non-injected storage bunches. The information of those bunches does not contribute to the determination of injected current, on the contrary, impede. There is the effect of current decrease which is caused by the natural beam decay. The injected current determined with the ordinary method is strongly affected by the current decrease of non-injected bunches. Consequently, the injected current cannot be determined correctly when the operation current is large and the beam lifetime is short.

The injected current on injection archiver avoids the influence of natural beam decay since it utilizes the information of only Injection-bucket. The measured values keep the same level in all operation time while those in the ordinary method gradually decrease with the operation current increase. This is benefited from the new determination method utilizing the Event Timing System process.

The other advantage is the pulse-by-pulse recording. There is a fluctuation of the injected current caused by the unstable operation of LINAC hardware. This fluctuation is correctly recorded on the injection archiver. Besides, the beam losses caused by the failure of LINAC hardware are observed in the data period. They show a very low value of injected current. They cannot be observed in the ordinary method since the pulse-by-pulse information is lost in the time-averaging process.

Background Study

The data on the injection archiver can be utilized for understanding the injection-related beam backgrounds. In addition to keeping large beam currents, the precise understanding and suppression of beam backgrounds at the interaction point (IP) are important for the fruitful physics results at SuperKEKB[1].

The injection process imposes the bad influences on the storage beams so that they are instable after injection during a few milliseconds. Some of the beam particles in the storage bunches are lost with radiating photons. This process becomes one of the considerable backgrounds in the collision data recorded with the Belle-II detector [8].

The effect of injection kicker magnets can be studied with the data of Neighbor-bucket. We observe the beam current loss caused by the kicker magnetic field in the HER injection. The bunch currents around rise-time and fall-time of the kicker pulse are decreased as shown in Figure 3 (a). It is made in the following process. The timing of the kicker pulse is drifted since the latency of its amplifier circuit is changed with depending on the room temperature. The drifts independently happen for two sets of kicker components that are installed on the upstream and downstream of the injection point. The magnitudes of magnetic fields become inequivalent around the rising and falling edges of the pulse.

[1] For example, the search for the physics phenomena with the low multiplicity, like the dark photon and lepton flavor violation [7], needs the precise understanding of beam backgrounds.

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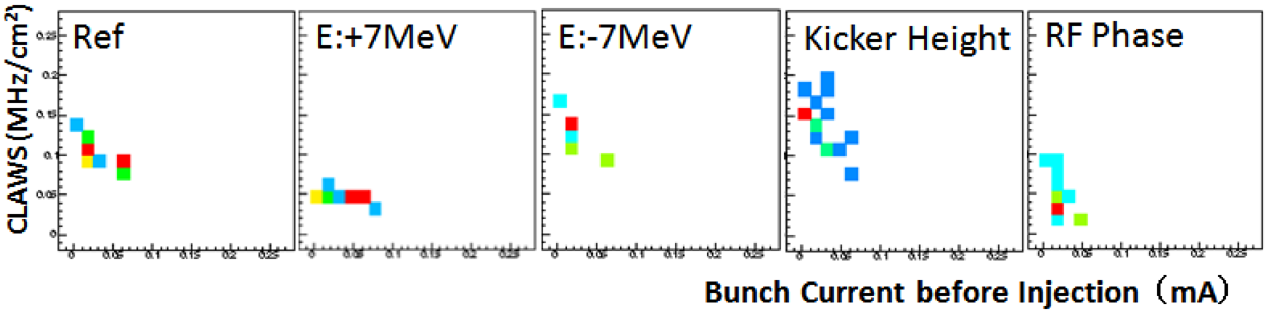

Figure 4: Two-dimensional plots for bunch current of Injection-bucket before injection and beam background rate at IP: the data in the injection conditions of normal parameters, injection bunch energy +7 MeV and −7 MeV, injection kicker height −0.75 mm, and RF phase at HER +4 degrees are shown. The number of entries in each bin is illustrated with colors. The red indicates large entries while the blue indicates a few entries.

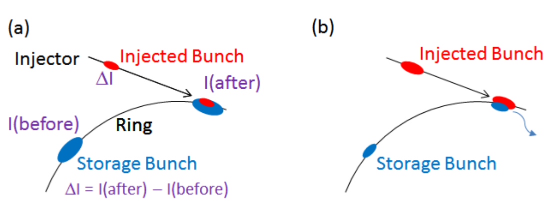

Figure 5: Illustrations of the relation between the injected bunch and storage bunch (a) and their beam-beam kick (b): the injected current, ΔI, is determined as the bunch current after injection, I(after), minus that before injection, I(before). The injection archiver system records I(before), I(after), and ΔI.

Consequently, the storage bunches in those regions cannot be back to the stable orbit. They are oscillated and lost with radiations.

This oscillation is observed with one turn bunch position monitor (BPM) as shown in Figure 3 (b). The position of storage bunches around rise-time and fall-time of the kicker pulse is obviously shifted from stable orbit after injection and they are changed in every turn.

The interesting behavior of the rate of injection beam background is observed in the detailed offline analysis. There is a correlation between the bunch current of Injection-bucket before injection and the beam background rate at IP in the HER injection as shown in Figure 4. The background rate is measured with the CLAWS sub-detector of Belle [9]. These data are taken during the injection background study run in July 2018. The correlation is observed only when the bunch current before the injection is smaller than the injected current and its magnitude depends on the injection parameters.

One of the assumptions explaining this behavior is the beam-beam kick between the injected bunch and the storage bunch. The bunch current before the injection is actually the bunch current which has already stored at Injection-bucket before injection as illustrated in Figure 5 (a). It seems the storage bunch is kicked by the injected bunch as shown in Figure 5 (b). Then it is oscillated and decayed with emitting the beam backgrounds. The effect is strong when the storage bunch current is small and it becomes weaker when the bunch current becomes larger.

The beam background related to injection will be studied and considered more in phase-3 which is carried out in 2019. Their understanding is very much important since the background rate is one of the concerns to realize the top-up filling operation. It must be at least a few factors smaller.

CONCLUSION

The injection archiver system is developed for the SuperKEKB collider. It records the injection-related data, pulse-by-pulse.

The determination of injected current in the injection archiver is free from the influence of natural beam decay. The detailed understanding of the injection condition is possible with the pulse-by-pulse data. The fluctuation and significant loss of injected current can be studied with the LINAC parameters.

It is suggested the recorded data can be utilized also for understanding the beam background related to the injection. Their detailed understanding will be carried out in the phase-3 operation with the injection archiver system.

The top-up operation has not been implemented yet because of large beam background conditions during injections. We hope the injection archiver system supports the understanding of beam backgrounds.

REFERENCES

[1] Y. Ohnishi, *et al.*, "Accelerator Design at SuperKEKB", *Prog. Theor. Exp. Phys.*, vol. 2013, no. 3, p. 03A011, 2013.

[2] M. Akemoto, *et al.*, "The KEKB Injector Linac", *Prog. Theor. Exp. Phys.*, vol 2013, no. 3, p. 03A002, 2013.

[3] H. Kaji, *et al.*, "Archive System for Injection Current at SuperKEKB", in *Proc. of 15th Annual Meeting of PASJ*, Nagaoka, Japan, 2018.

[4] EPICS website: `https://epics.anl.gov/index.php`

[5] Event Timing System website: `http://www.mrf.fi`

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[6] S. Kurokawa, *et al.*, "Overview of the KEKB accelerator", *Nucl. Instrum. Meth. A*, vol. 499, pp.1-7, 2003.

[7] B2TiP website: https://confluence.desy.de/display/BI/B2TiP+WebHome

[8] The Belle-II collaboration website: https://www.belle2.org

[9] P.M. Lewis, *et al.*, "First Measurements of Beam Backgrounds at SuperKEKB", *Nucl. Instrum. Meth. A*, vol. 914, pp.69-144, 2019.