ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPRI016

PULSE BASED DATA ARCHIVE SYSTEM AND ANALYSIS FOR CURRENT AND BEAM LOSS MONITORS IN THE J-PARC RCS

N. Hayashi*, S. Hatakeyama, K. Yamamoto, JAEA/J-PARC, Tokai, Ibaraki, Japan

Abstract

The data archive system in the J-PARC 25-Hz Rapid-Cycling Synchrotron (RCS) records the beam intensity and the beam loss monitor (BLM) pattern for all pulses. The system is based on the common memory and utilizes the timing system of the J-PARC. Although its time resolution is limited, it is useful to detect rare events or phenomena appearing with only higher accelerator repetition. Using these data, the stability of the beam intensity, particularly an ion source can be examined. The relation between BLM patterns and its causes can be studied pulse-by-pulse basis and it would make use of future improvements.

INTRODUCTION

The J-PARC (Japan Proton Accelerators for Research Complex) is a multi purpose facility. The second accelerator, 3-GeV rapid-cycling synchrotron (RCS), is used for the muon and the neutron production target of the MLF (Material and Life Science Facility). It is also used as a booster for the MR (Main Ring) proton synchrotron. The MR provides high intensity beams to two experimental facilities, Hadron and Neutrino. In the beginning of 2014, the first accelerator Linac energy has been upgraded from 181 to 400 MeV, by adding ACS (Annular-Ring Coupled Structure) cavities [1]. Namely, H^- injection energy of the RCS has been increased and the commissioning performed well [2,3]. It is required to reduce the space charge effect towards high intensity, 8.3×10^{13} ppp (protons per pulse), and 1 MW beam power with 25 Hz repetition.

Normally, a machine tuning or beam study are performed with one shot or low repetition. It is good practice to avoid un-necessary beam loss and it is good enough for reproduced events in the most of cases. Because high sampling rate digitizer or read-out system are not able to handle for all pulses of 25 Hz without dead time. An averaging method or sampling scheme works for many cases. However, it is not suitable for rare events or phenomena only appear with 25 Hz mode, for example something related vacuum condition. Thus, pulse-by-pulse (shot-by-shot) data recording system is necessary.

DATA ARCHIVING SYSTEM

The beam instrumentation are described in refs. [4–6]. The raw output of DCCT is divided by revolution frequency to monitor the numbers of particle (beam intensity). The DCCT data resolution is about 5×10^{10} ppp with current range. All pulses of the DCCT data are recorded in to the shared memory space, although limited sampling rate, every 10 ms (100 Hz), in other words three times during one 20-ms long pulse. In the present configuration, 600 pulses data can be stored. It corresponds to maximum time duration of 24 seconds. “beam tag” is attached as serial number for each pulse to identify. Every five seconds, the data is archived onto a hard-disk for permanent use.

There are 90 proportional chamber type Beam Loss Monitors (PBLMs) around the ring. Integrated BLM signal data are also stored as the same manner as that of the DCCT. There are some oscilloscopes for DCCT and some of PBLMs with higher sampling rate (250kHz). They are used mainly for study and monitoring.

The harmonics of the RCS is $h = 2$ and there are two bunches in the ring. The beam from the Linac is chopped beam to match the RF bucket. Injection duration of the RCS is 500 μs, and it is called as “macro pulse”. Thus, the beam is present in the Linac for 0.5 ms within 40 ms (1.25 % duty). In the RCS, on-beam period is 20.25 ms out of 40 ms, almost 50 % duty. One period of the MR cycles can be varied. For the neutrino experiment, the period is 2.48 s presently and it corresponds to 62 RCS pulses.

A pulse bend-magnet at the extracted beam transport line deflects the beam to the MR every MR cycles. Otherwise the beam goes to the neutron target at the MLF. Four consecutive batches, namely eight bunches of the RCS, go to the MR. In order to avoid any residual field effect of the pulse-bend magnet, a few more empty batches follow presently. Seven empty batches continue for the neutron target.

Machine Protection System (MPS) is an interlock to protect mainly hardware. The system stops the beam quickly. The trigger source of MPS is usually machine failure and it also includes the BLM signal if it exceeds predefined threshold. If the MPS triggers during off-beam period, there is no associated BLM signal. On the other hand, when the MPS is triggered during on-beam period, the beam may be affected and its parameter becomes wrong region, in terms of momentums (RF failure), or orbit (magnet failure). Resultant the beam gets lost and associated BLM signal appears with the machine MPS event.

DATA ANALYSIS

Ion Source Stability

At first, we discuss solely DCCT data. If the MPS event occurs, the beam stops, and then the intensity gets zero immediately. Excluding such MPS events, one can evaluate an ion source stability. Figure 1 is a typical one day DCCT data. Most of zero intensity corresponds to Linac RF MPS events. But a few cases are no associated MPS events. Lower plot of Fig. 1 is an example. The intensity drops suddenly for single macro pulse and recovers almost in the next pulse.

* naoki.hayashi@j-parc.jp

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPRI016

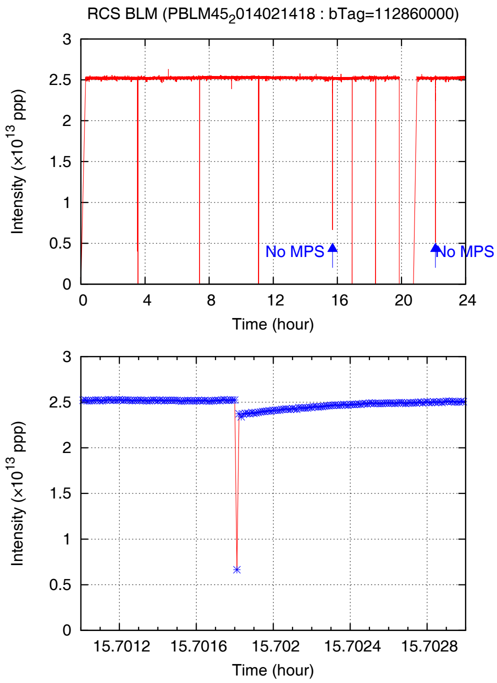

Figure 1: Typical DCCT data of one day, 24 hours, (upper) and just one pulse drop within 72 s duration (lower).

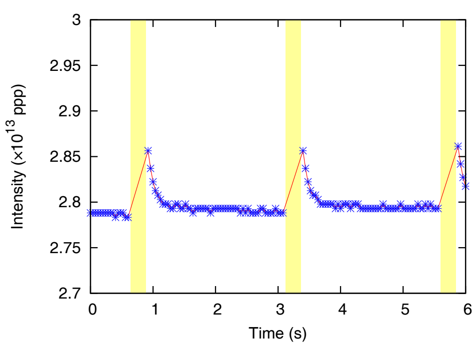

Figure 2: An example of the intensity variation during 6 s. Timing structure of 2.48 s MR cycles. There are 7 batches gap out of 62 pulses (yellow hatched region).

As we explained about timing structure, there are empty batches right after the MR batch. If the MR operation is off, seven consecutive batches are off consequently. After the gap, the intensity gets about 2% higher as shown in Fig. 2.

PBLM Pattern

A typical PBLM pattern with normal mode (No MPS) shown in Fig. 3. The horizontal axis is PBLM indexes. The RCS is three-folds symmetry lattice and there are three straight sections, injection-collimator, extraction, the RF and three arc sections in between. Vertical axis is integrated signal (arbitrary unit) from each PBLM [7]. A red line indicates the pre-defined threshold, if it exceeds the interlock MPS is triggered. There are three time range, 0, 10, and 20 ms are plotted on one figure.

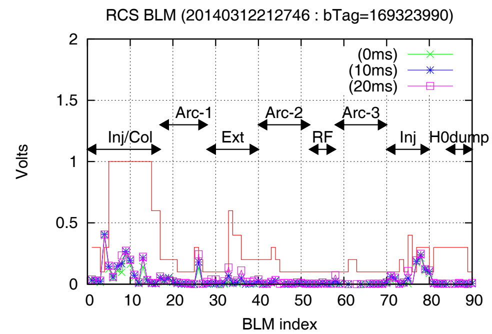

Figure 3: Normal BLM pattern without MPS interlock.

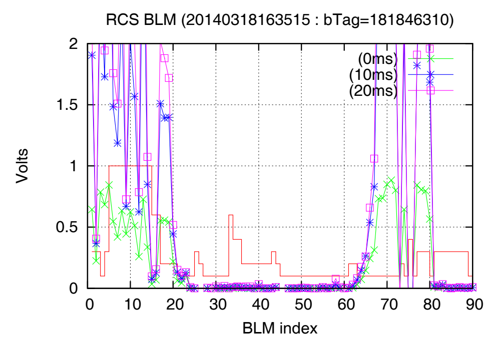

Figure 4: PBLM pattern with Shift bump magnet PS MPS.

Figure 4 shows in case of Shift Bump magnet power supply is off, which makes bump orbit during the injection period. So all beam smash around the injection area. In case of the kicker magnet power supply failure, the beam loss are distributed all around the ring as shown in Fig. 5. Since there is no loss before 10 ms, it seems that the interlock was triggered between 10 to 20 ms. After the event, the BLM gives undershoot signal due to large loss. Figure 6 is MPS event during Linac ACS16 became very unstable. Sometime only RCS-PBLM MPS events were also observed but similar pattern. It seems the same cause, but ACS16 did not trigger the MPS by some reason. An interesting event to be investigated is only BLM MPS. It could be imaged that anything hardware or instruments failure, but the present MPS system can not detect. Only beam gets affected. It is some sign of small trouble which may become serious

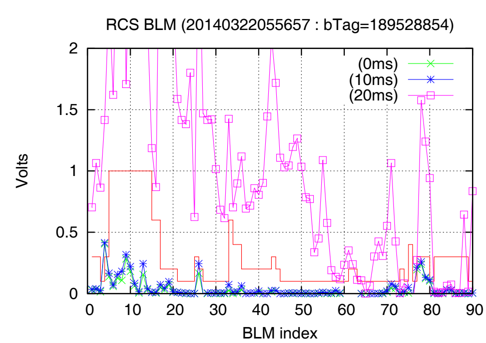

Figure 5: PBLM pattern with kicker magnet PS failure.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-THPRI016

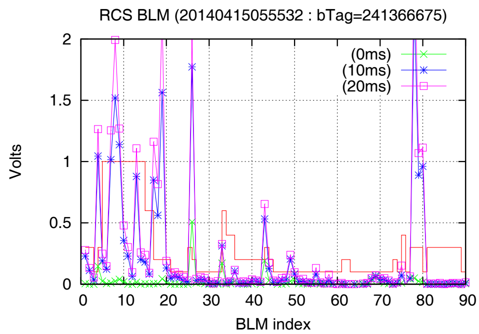

Figure 6: PBLM pattern with Linac ACS16 MPS.

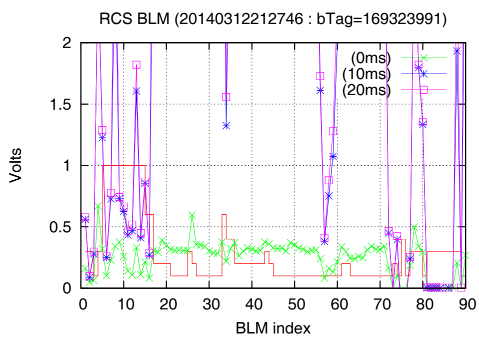

Figure 7: An example of PBLM only MPS event.

in later. Figure 7 is such an event. One possible candidate might be missing paint bump trigger. Because beam loss already started at 0 ms all over the ring. According to the DCCT data, almost full beam (2.5×10^{13} ppp) was injected, but 30 % beam were lost by 10 ms.

Beam Loss Related to Vacuum

It was realized that beam loss occurred only with 25 Hz operation mode, before the user run started. It was examined with lower repetition or one shot mode and it was acceptable beam loss level. However, once it was switched to 25 Hz operation, heavier beam loss occurred very frequently (Fig. 8). It seems to be related vacuum condition [8]. In the last summer, the most of vacuum chambers were opened to the air for re-alignment works after large earthquake [3]. Because of bad vacuum condition, the pressure rise rather quickly and the beam loss increase at the same time. It is presumable that the RF feedback signal got wrong signal due to these loss, and it induced further heavy beam loss.

SUMMARY

The pulse based data archive system at the J-PARC RCS is presented. As their applications, several beam loss patterns by various causes and the ion source stability are discussed. The present system has a limit of sampling speed. Faster sampling archive system would be useful for detailed understanding of the machine and make them further stable.

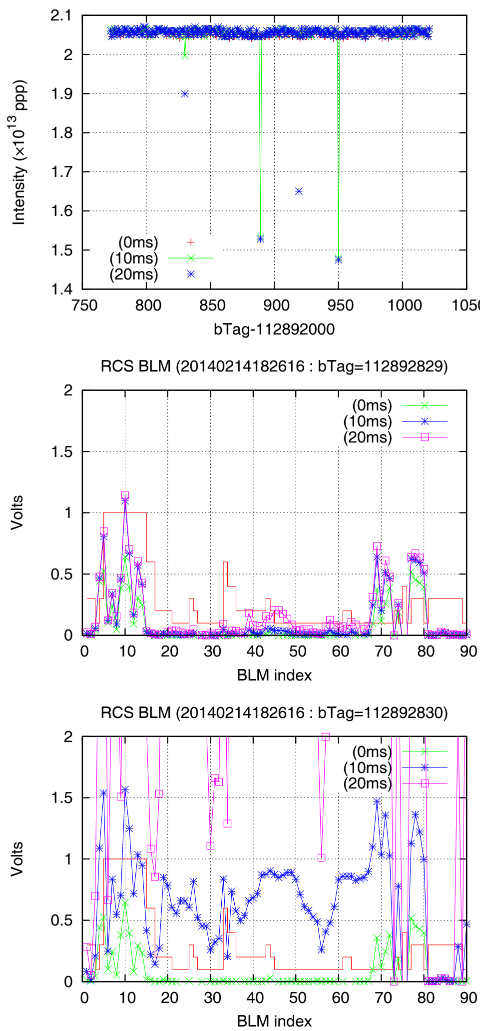

Figure 8: Intensity trend for 10 seconds (top). Large beam losses are indicated on 830, 889, 920 and 950. At that time, nominal PBLM pattern at 829 (middle) and heavy loss pattern at 830 (bottom).

REFERENCES

[1] H. Ao, et al., Phys. Rev. ST Accel. Beams 15, 051005. (2012)

[2] H. Hotchi, IPAC'14, Dresden, Germany, TUXA01, IPAC'14, Germany, June 2014.

[3] M. Kinsho, THPME064, IPAC'14, Germany, June 2014.

[4] H. Takahashi, et al., *Proceedings of EPAC 2008*, p.1553-1555., Genova, Italy (2008).

[5] N. Hayashi, et al., *Proceedings of EPAC 2008*, p.1125-1127., Genova, Italy (2008)

[6] N. Hayashi, et al., Nucl. Instr. Meth. A677, p.94-106. (2012).

[7] K. Yamamoto, et al., *Proceedings of IPAC'10*, p.2842-2844., Kyoto, Japan (2010).

[8] K. Yamamoto, et al., THPME063, IPAC'14, Germany, June 2014.