RADIATION LEVEL IN THE J-PARC RAPID CYCLING SYNCHROTRON AFTER FIRST STUDY

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Abstract

A 3GeV Rapid-Cycling Synchrotron (RCS) in Japan Proton Accelerator Research Complex (J-PARC) has been commissioned since September 2007. The most important issue in the beam study is to reduce unnecessary beam loss and to keep the beam line clean for the sake of maintenance and upgrade of the machines. In order to achieve this purpose, we observed the beam loss monitors located around the RCS beam line. We also investigated the residual dose of accelerator components during an interval of beam study. From these results, we found that beam loss points were the injection junction point, the branch of H0 dump and extraction line, transverse collimators, and dispersion maximum points in the arcs. Especially, the entrance of the primary collimator chamber was the most radio-activated points in the RCS. To make the best use of these results for beam commissioning, we managed to minimize the beam losses and succeeded in suppressing the residual dose to a level low enough to allows us to work close to those components.

INTRODUCTION

The Japan Proton Accelerator Research Complex (J-PARC) project is a joint project of Japan Atomic Energy Agency (JAEA) and High Energy Accelerator Research Organization (KEK). The accelerator complex consists of a 181MeV (at the first stage) or 400MeV (at the second stage) linac, a 3GeV Rapid-Cycling Synchrotron (RCS), and a 50GeV synchrotron Main Ring (MR) [1]. The RCS ring accelerates a proton beam up to 3GeV and supplies it to the MR and the neutron production target. Construction of the RCS has completed and beam commissioning have been started since last year [2]. The RCS ring was designed to generate a high power proton beam of 1MW at the repetition rate of 25 Hz, but beam power is restricted at 4kW per hour in the first commissioning stage. This constraint is due to the capacity of the RCS extraction dump. Also we must reduce unnecessary beam loss and to keep the beam line clean for the sake of maintenance and upgrade of the machines. From such reasons, we reduced the repetition rate during beam study. Especially the beginning of the beam study at a new condition, we used one-shot operation in order to avoid a continuation of unnecessary beam loss. The beam condition of first study was performed by very low intensity. The peak current of the linac was 5mA (1/10 of design value), the macro pulse length was 50μsec (1/10 of design value), and one of two RF buckets was filled in the injection beam. The peak current was increased with progress of beam commissioning.

BEAM LOSS DURING COMMISSIONING

Beam loss monitor signals

We prepared three kind of beam loss monitors (BLMs) and observed these BLMs during beam study. In the early stage of the beam commissioning, the full beam loss of several shots have occurred along the ring owing to the insufficient adjustment of the beam monitors or wiring mistake of the magnet. But those problems were solved immediately and the circulating orbit during 20msec (which correspond to acceleration cycle of RCS) was established. However, the beam loss have still occurred in the following points.

(1) The junction point of L3BT injection beam and RCS circulating beam.
(2) The upstream entrance of the transverse primary collimator chamber.
(3) The branch of H0 dump line.
(4) The branch of extraction line.
(5) The transverse collimators
(6) Dispersion maximum points in the arcs

BLM signals at these points are shown in Fig. 1. A proportional ion chamber type BLM (P-BLM) signal at loss point (2) is shown in Fig. 1(a). Fig. 1(b)-(d) show the scintillator-photomultiplier type BLM (S-BLM) signals. The S-BLM of Fig. 1(b) was put at the branch of H0 dump line (point (3)), S-BLM of Fig. 1(c) was put outside of shielding wall around the first secondary collimator (point (5)), and S-BLM of Fig. 1(d) was put at a dispersion maximum point in the arc (point (6)).

The beam loss at the injection junction point (point (1)) was thought that it was caused by the pressure rise due to cracks of a ceramic duct. This ceramic duct was set in the quadrupole magnet close to injection junction. The beam loss signal was no longer detected after replacement of broken ceramic duct.

The beam loss signal at the upstream entrance of the transverse primary collimator chamber (point (2)) was distinctive. In this study, the shift bump magnets (which make a bump orbit in order to merge injection beam and circulating beam) were exited during 500μsec. The BLM signal increased since a beam injection was started (from 100μsec), and signal peak has continued till 600μsec when a bump orbit began to fall. Finally BLM signals disappeared while a bump orbit has completely fallen. From this result, it was thought that this loss was caused by multiple scattering between a charge exchange foil and circulating beam which brought close to a foil by the bump excitation (see Fig. 1(a)).

At the branch point of H0 dump line (point (3)), the beam loss was caused by the same reason above point (2).

In addition, the beam loss of this point was also affected by the circulating beam during acceleration period (see Fig. 1(b)).

The loss signal near an extraction line (point (4)) disappeared with adjustment of C.O.D. and extraction orbit.

The beam losses at transverse collimators (point (5)) were the "controlled " loss. The beam loss occurred during injection process and the middle phase of acceleration period (see Fig 1(c)).

The loss occurred near the dispersion maximum point in the arc (point (6)) when the RF bucket was filled with the beam. Since only ten of eleven sets of RF cavities are installed at present, the beam loss occurs near 10msec while requirement of cavity voltage becomes the highest.

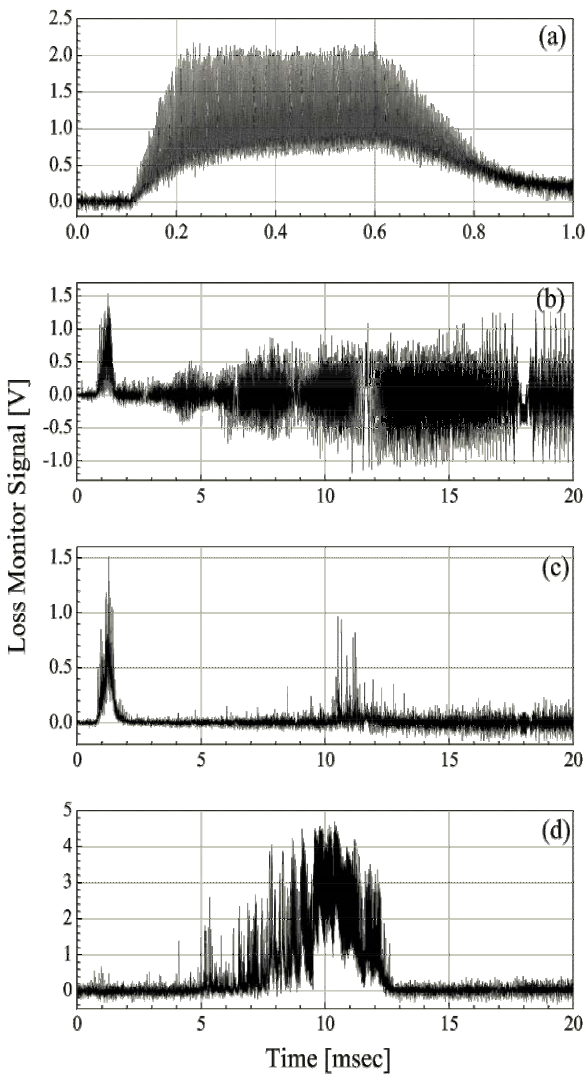

Figure 1: BLM signals. Vertical axis means the voltage from BLM. Input impedance of preamp is 50Ω, HV bias voltage is -1550V (P-BLM) and -600V(S-BLM). Each signal was 100 multiplied by the preamp which was located at sub-tunnel. Horizontal axis is measurement time from injection. Fig. 1 (a) is a signal during 1msec of injection period. Fig. 1 (b)-(d) are signals during acceleration period.

Beam Current monitors

The number of particles measured by Wall current monitor and DC Current Transformer is shown in Fig. 2. This measurement was performed during the beam study being done at present (June 2008). The number of particles correspond to about 100kW per bunch (4.3×10^{12}) was accelerated. The painting bump did not use and all injection beam have entered into the ring center orbit in piles. In this study, the loss during the acceleration period was 3.4%. It has occurred during 2 msec after injection start, and most of lost particles were absorbed with the collimators.

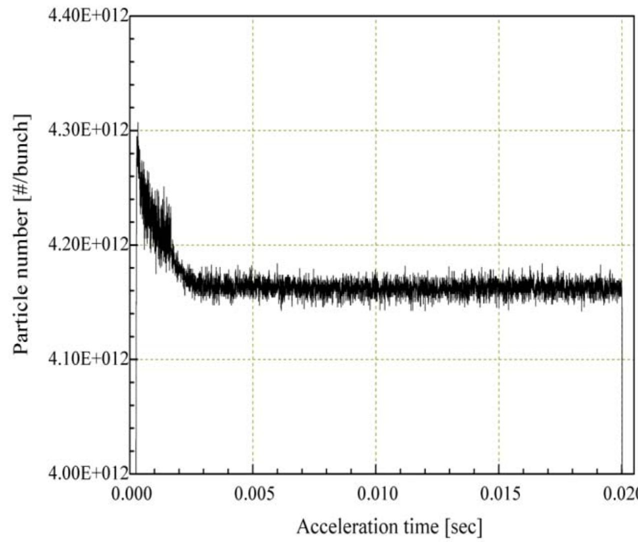

Figure 2: Particle number during acceleration.

Residual dose rate after beam study

The amount of residual dose is shown in Fig. 3. These values were immediately measured after the end of beam study on February. The beam condition was that the repetition rate was 25Hz and the number of particles was corresponding to 100kW. Beam operation was performed about 5 minutes at 12:00 on 24 February, and acceleration efficiency was about 94% at this time. Since the beam study was performed by hundreds of shots of one-shot or 1Hz operation except this operation, it is thought that the residual dose was mostly generated during this 25Hz operation.

From this residual dose result, the above-mentioned loss of point (2) and point (6) should be especially taken care. The residual doses of 3.5-12μSv/hr have been generated by the loss of point (6) and 120μSv/hr has been generated by the loss of point (2). However, acceleration efficiency was improved in the latest study and the influence of residual dose may be small. The residual dose due to present study will be measured at the first week of July again.

Moreover, we will improve the residual dose at point (2) by covering with additional shielding walls. And cure of beam loss at point (6) will be executed by progress of longitudinal beam control and installation of the 11th acceleration cavity in the maintenance period during this summer.

CONCLUSION

We succeeded in acceleration a considerable particle number correspond to 100 kW in only half a year study without painting injection.

It is remarkable that there were rarely high residual dose point (Only the L3BT dump vacuum window and above mentioned primary collimator chamber) after demonstration of the 100 kW operation even though it was limited for only 4 minutes. This was due to not only good performance of all components of RCS, but also the good quality of injection beam from the linac. The linac beam was satisfied the all requirements for RCS and very stable all the time during RCS commissioning study.

We will install the 11th RF cavity and additional shielding walls in the maintenance period during this summer in order to reduce the influence of residual dose. For these treatments, even if the repetition rate and operation time will be increased under the 100kW operation, the RCS can be kept as one of the cleanest proton synchrotron in the world.

REFERENCES

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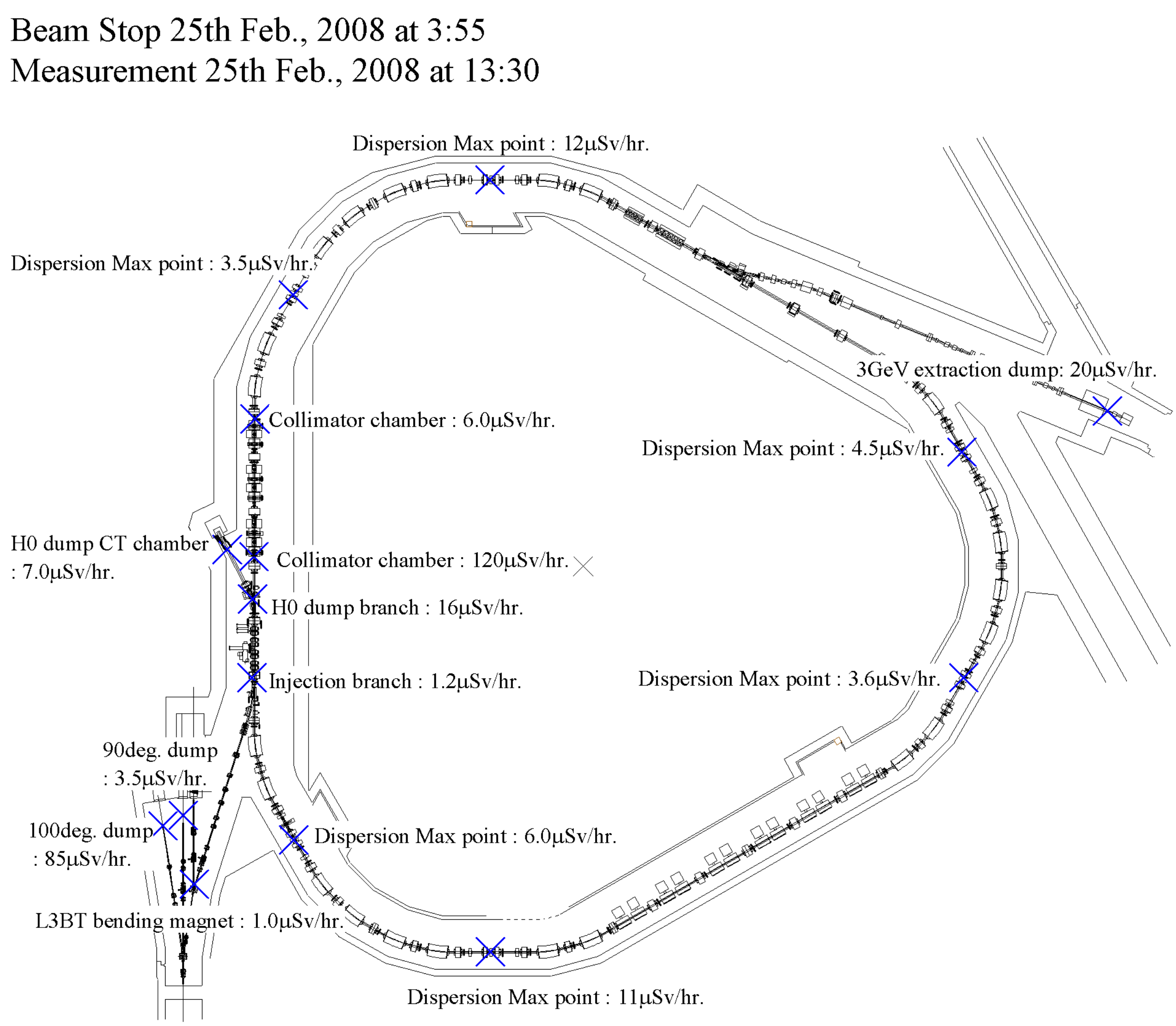

Figure 3: Residual dose rate after beam study.