UPGRADE PLAN OF BLM SYSTEM OF J-PARC MR

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Abstract

To meet new requirements of the J-PARC MR BLM system for future high power beam operation, an upgrade plan have been studying. After descriptions of present performances of the BLM system, the overview of a new system is presented.

INTRODUCTION

The J-PARC Main Ring synchrotron (MR) accelerates the high intensity 3GeV proton beam from Rapid Cycling Synchrotron (RCS) through 3-50 beam transport line (350BT) up to the 30GeV. The extraction has two modes, Fast and Slow Extraction (FX and SX).

As for the Fast Extraction (FX), the bunched beams have been delivered to the neutrino target. The designed beam intensity is 4E13 per bunch; in total 300T proton/pulse for 8 bunch operation. On 11th April, 2012, the 190kW beam operation has been achieved, where the intensity was 100T proton/pulse and the repetition was 2.56s. The maximum peak current was 100A.

The designed beam intensity for SX operation is 100kW. The high power DC beam is delivered to hadron experimental hall. In Feb. 2012, 3.2kW (4T proton/pulse), 6s interval operation was established. The maximum accumulated DC beam was 0.13A.

The beam diagnostics need wide dynamic range to measure wide variety of beam loss intensity due to the 2 different extraction modes. Some of them are required to measure DC signal components to tune SX. The data-taking systems including signal amplifier have been installed in the power supply buildings outside of the accelerator tunnel to avoid high level radiation exposure. The 100~300m long coaxial cables are used for an analog signal transmission. The input capacitance of the amplifier is thus 10~30nF.

PERFORMANCE OF THE PRESENT BLM SYSTEM

Design Concepts

The present BLM system had been designed based upon the required performances listed below.

1) The system is required to measure beam loss at the primary beam commissioning stage using 1/100 beam intensity.

2) The signal rise time is less than 10μs to meet the alarm signal criterion of Machine Protection System (MPS).

3) The MR's acceptable beam loss intensity is 0.5W/m based upon the maintenance scenario, and thus the system is required to measure its beam loss in good accuracy.

P-BLM System

We have adopted the proportional counter type BLMs (P-BLMs) to cover wide range of beam intensity of two mode operations. Figure 1 shows gas gain curve. It can be seen that the maximum gain is 2E4 when the bias is set to 2kV.

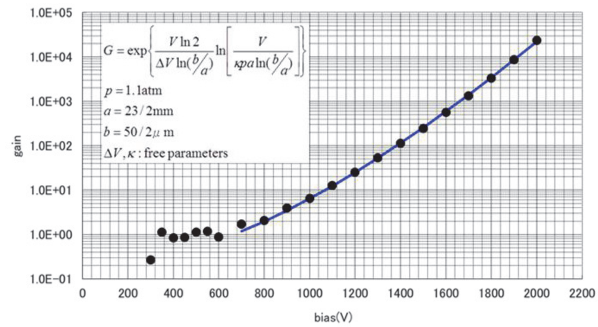

Figure 1: The gain curve of the P-BLM mounted at QM#199. The solid blue line is the fitting result.

The total number of P-BLM is 216 for MR and 38 for 350BT which is mounted on each quadrupole magnet (QM). Changing the gas gain, the P-BLM has a flexibility to adapt to a drastic change of the beam operation, that is, changes from FX to SX or changes from low power beam commissioning to high power normal operation.

On the other hand, it has a gain reduction problem originating from a slow mobility of positive ions compared to that of the electrons [1]. The higher the output current, the thicker the positive charge sheath are generated around anode wire of the detector. The positive charge sheath decreases the electrostatic field around the wire. The deterioration of the electrostatic filed cause the gain reduction. Therefore the delicate bias tuning is required as the beam loss power changes. The theoretical estimations show that the 1 μ A DC output current causes about 10% gain reduction. This means that the system underestimates a loss power for an unexpected high level fast beam loss (for example injection and extraction beam loss).

It is advantageous to monitor low level slow loss (slow loss). As described in ref. [2], by using the gas gain ability, the design requirements have been achieved in early beam commissioning stage. However the total dynamic range is about 2E3 for a gas gain setting.

Long-AIC System

Long Air Ion Chamber using coaxial cable (long-AIC) has been installed to measure a high level fast beam loss (fast loss). In total, 3 long-AICs and 19 long-AICs have been installed along 350BT and MR tunnel, respectively. The averaged length is 84m long. These completely

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cover the whole area, although it loose position resolution.

At the 350BT collimator area where 12 collimator units are used to cut the beam tail outside the emittance of 54π mm mrad for horizontal and 60π mm mrad for vertical, one 43m long-AIC which is completely covers the collimator area is used for beam halo/tail monitoring. We have checked the output charge linearity by using intentional beam losses. As can be seen in the Fig. 2, it shows good linearity up to the 8.4E11/batch which is corresponds to the 1% loss of the designed one. The error bar was estimated taking into account the shot by shot fluctuations and the ±2% error due to beam hit position on each collimator. The overall error was estimated to be ±7%.

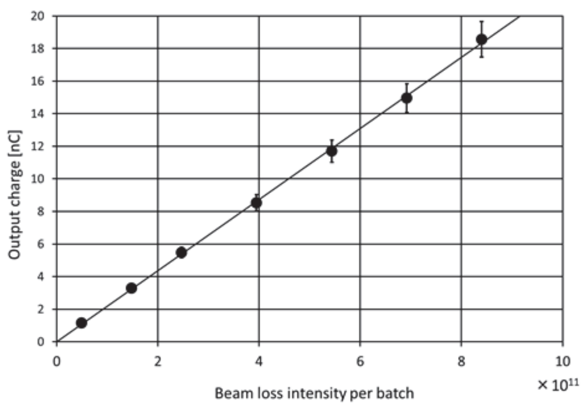

Figure 2: Calibration result of 350BT long-AIC for beam halo/tail monitoring by using intentional beam loss.

OVERVIEW OF THE NEW BLM SYSTEM

Concepts of the New BLM System

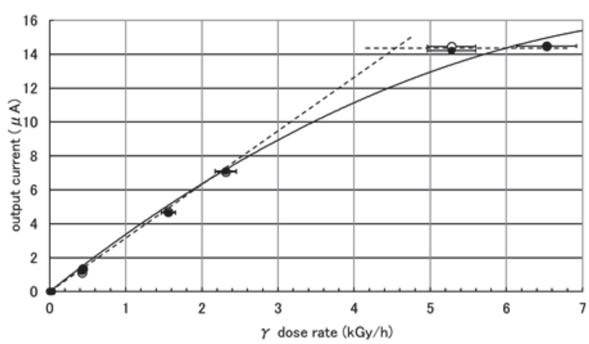

Figure 3: The calibration results of the short-AIC using Co60 γ source. The solid circles shows the data of negative biasing to collect negative charged ions and the open circles shows that of positive. The dashed lines are to guide the eyes and the solid line is a fitting result.

We have been studying a new BLM system. The new system has new requirements listed below in addition to the old ones.

4) The residual dose measurements after beam stop in addition to the conventional beam loss measurements.

5) The required dynamic range is higher than 1E6 to cover 1kW fast beam loss at collimator area to residual dose measurements.

6) The needed frequency band is from DC up to about 200kHz which is correspond to revolution frequency.

7) More higher frequency band is needed to study intra bunch oscillation.

Improvement of the Dynamic Range by Short-AIC + P-BLM System

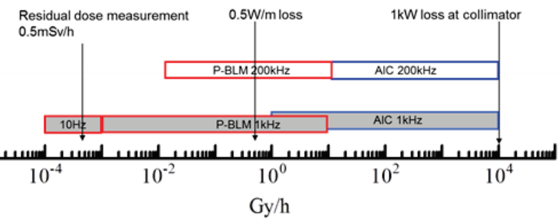

Figure 4: The dynamic range using the both P-BLM and short-AIC. Gas gain of P-BLM is set as 1E3. Open boxes show the dynamic range of the raw signal and the gray boxes show that of integrated signal. The frequency bands of the data are also shown.

To meet the requirement 5), a 1m long AIC (short-AIC) will be operated with the existing each P-BLM. We have checked output charge linearity by using Co60 γ rays (see Fig. 3). The data shows linearity up to 10μA which is corresponds to 3.2kGy/h within an uncertainty of about 10%. By choosing the gas gain setting of P-BLM, the dynamic range of the system will be improved. For example, when we set the gas gain as 1E3, the net dynamic range will be 1E8 as shown in Fig. 4.

Fast Beam Loss Measurements by S-BLM

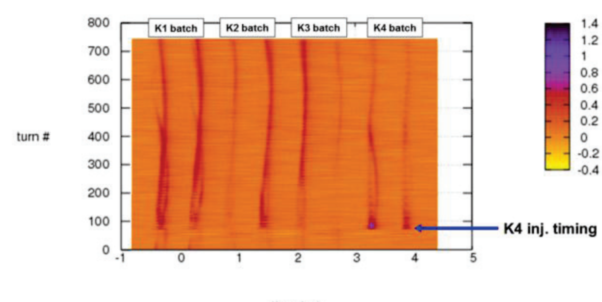

Figure 5: The two dimensional intra-bunch beam loss distribution. A batch is injected from K1 to K4 at intervals of 40ms.

Scintillator and photomultiplier tube type BLM (S-BLM) will be installed. A typical signal rise time is a few nano-seconds. The Fig. 5 shows 2-dimensional turn by turn intra-bunch beam loss distribution measured from just before the K4 injection timing. When the K4 batch is injected, strong beam loss occurred for K1 batch and K2 rear bunch in addition to the K4 injection loss, as a result of the reflected wave of the kicker magnet.

Measurement of the Residual Dose

For a long turn and a high power beam operation, estimates of the residual dose rate of the accelerator components of a maintenance time is likely to be more important considerations rather than the beam loss power estimates itself. Measurements of a residual dose rate by using P-BLM will demonstrate how serious a beam operation for a component's activation. Fig. 6 shows residual dose rate after beam stop. The gas gain was 2E4. The figure shows the contribution of short lived unstable nuclei Fe53 whose half-life is 8.51min. Assuming that the ratio α of the number of the generated nuclei with a long half-life of a few months (longer than the MR operation running time) to that of the generated Fe53 is always stable, the simple equation,

$D_f < \alpha D_{Fe53}\Delta T + D_i$,

gives a dose rate of a maintenance time to some extent. Here, the D_f means the dose rate after some cooling time after beam stop. The first element of the right hand side of the equation means the dose rate from the long lived nuclei. It is proportional to the dose rate from Fe53 (D_{Fe53}) and beam operation time (ΔT). The D_{Fe53} is directly proportional to the beam loss power. The second element D_i means the initial dose rate at the time of beam operation start.

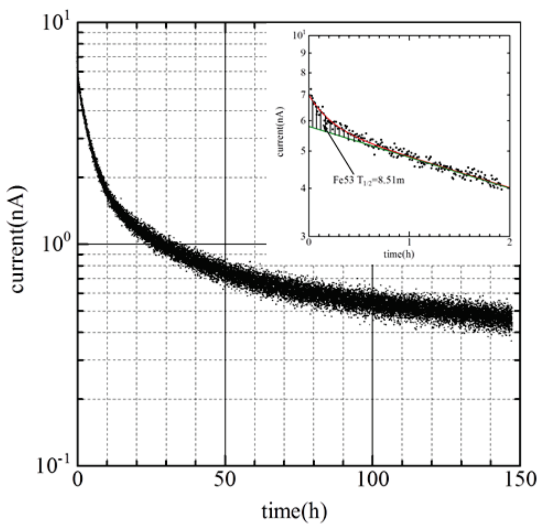

Figure 6: The residual dose measurement using P-BLM after beam stop. The vertical axis shows output current. The enlarged figure is also shown. 1nA output corresponds to 160μSv/h.

New Data-Taking System

Figure 7 shows a diagram of a new data taking system for P-BLM and short-AIC system. The current signal of each monitor head is fed into I-V converter. The analog signal is digitized by the 24bit ADC through isolation amplifier and anti-aliasing LPF. To compensate ground level offset due to temperature drift of the amplifier, leakage current of the monitor and effect of the residual dose, the FPGA averages the offset data before the time of beam injection and makes the offset correction. The digitized raw data is divided into two. One is used as 1MS/s waveform data and the other is used as 1kS/s integrated waveform data. The two waveforms are compared with MPS alarm level stored in the Random Access Memory (RAM) to make MPS alarm. The digital waveforms are transferred via VME backplane bus line to an upper system.

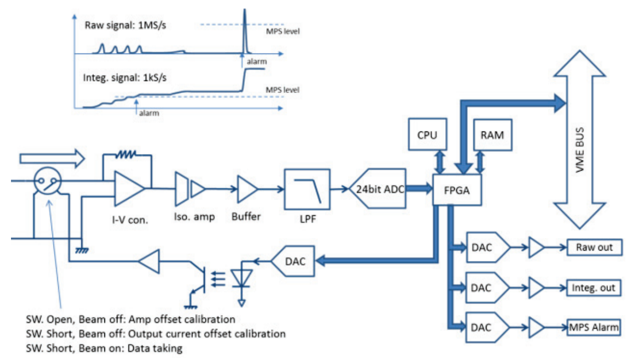

Figure 7: Block diagram of the new data taking system for P-BLM and short-AIC.

SUMMARY

To measure the residual dose and intra-bunch beam loss phenomena, the BLM system is required to be upgrade. The essences of the upgrade plan are to extensively enhance the dynamic range and higher frequency band. The double monitor system, P-BLM and short-AIC, will improve the dynamic range up to 1E8. And, the introduction of the S-BLM makes it possible to study more complicated loss mechanism.

A part of the system will be replaced with the new one in this long summer shut down.

REFERENCES

[1] R. W. Hendricks, Rev. Sci. Instrum. 40 (1969) 1216.
[2] T. Toyama et. al., Proc. of HB2008 (2008) P. 450.

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