DEVELOPMENT OF BEAM LOSS MONITOR SYSTEM IN THE J-PARC LINAC, 3GEV RCS AND 50GEV MR

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Abstract

The beam loss monitor system is designed to provide quantitative loss data and investigate the loss mechanism in the J-PARC linac, 3 GeV RCS and 50GeV MR. The loss monitor system is composed of scintillator, argon-methane/^{3}He gas filled proportional counter and air filled coaxial cable ionization chamber. It is necessary to measure wide dynamic range of loss intensity for various beam energies. To prevent the activation and heat load by intense beam loss, fast time response of loss signals is required. The beam loss monitors play an essential role in machine protection system (MPS). In this paper, construction and application of loss monitor system are described in detail. Preliminary result of demonstration in the KEK-PS and calibration with cobalt 60 γ -ray radiation source are also discussed.

INTRODUCTION

The J-PARC (Japan Proton Accelerator Research Complex) project aims to provide the highest beam intensity among the accelerators of such energies in the world [1]. The 3 GeV and the 50 GeV proton synchrotron ring designed to provide high intensity beams of 333μA (1MW) and 15μA (0.75MW), respectively. The potential programs at the J-PARC are high-precision frontier, such as materials and life science, and particle physics with Kaons, Muons, and Neutrinos. However, the high intensity beam accelerator complex itself requires the significant progress of design study and hardware R&D. Operational beam intensity should be limited by the beam loss and activation level of the equipment. Once the beam loss exceeds a criterion at outer environment, beam intensity has to be decreased to prevent the further activation. In order to investigate loss mechanism and suppress the beam loss, a loss monitor system is developed. The system will be essential component for beam commissioning, tuning and machine protection in high intensity beam accelerators. The loss monitor system employs the scintillator, gas filled proportional counters and coaxial cable ionization chamber, which detect γ -ray, neutron and charged particles induced by lost particle [2]. In this paper, application and preliminary results of evaluation for each loss monitors are discussed.

BEAM LOSS MONITOR SYSTEM

The distribution of loss monitors in the J-PARC linac, 3 GeV RCS and 50 GeV MR is described in Table 1. In order to optimize the condition of chopper or other equipments system, fast rise time of loss monitor is required. In addition, protection and prevention of magnet, RF cavity and other equipment against the damage by dump of the beam, should be guaranteed before thresholds are exceeded. The permitted delay time depends critically on the relation between beam energy and materials.

Table 1: Expected beam loss and designed BLM system in the JPARC linac, 3GeV RCS and 50 GeV MR. Time response is determined by requirement of beam operation and MPS.

	Required response	Expected loss level	Flux particle	Loss monitors
Linac				
~MEBT1	<1μsec <2μsec for MPS	0.8kW chopper 3W/m average	n,γ	S-BLM P-BLM (^{3}He)
~SDTL(100MeV)	<10μsec <~15μsec for MPS	0.1W/m	n,γ	S-BLM P-BLM (^{3}He)
~3GeV ring	<10μsec <~60μsec for MPS	0.1~1W/m MEBT2 1W/m average	n,γ,charged particle	P-BLM (Ar/CH_4) AIC-BLM
3GeV RCS				
injection /extraction	<10μsec	4kW	n,γ,charged particle	S-BLM P-BLM (^{3}He)
controlled loss	<10μsec	1W/m average	n,γ,charged particle	P-BLM (Ar/CH_4) AIC-BLM
uncontrolled loss	<1msec	1W/m average	n,γ,charged particle	P-BLM (Ar/CH_4) AIC-BLM
50GeV MR				
controlled loss	<100μsec	7.5kW slow ext. 1.1kW fast ext. 0.5W/m average	n,γ,charged particle	P-BLM (Ar/CH_4) AIC-BLM
uncontrolled loss	<1msec	0.5W/m average	n,γ,charged particle	AIC-BLM

The RFQ must be turned off within 2μsec for several MeV low energy beam (up to MEBT1), which contain delay time at cable and interlock modules. Thus, fast time response of less than a microsecond is required to loss monitors. Because of above requirements, scintillator and photomultiplier tube loss monitor (S-BLM) is provided at low energy region. However scintillation and photomultiplier efficiency will significantly decrease with irradiation of accelerator operation. It is necessary to correct the sensitivity with other reliable (even if slow time response) loss monitors. To calibrate the signal level of SBLM, ^{3}He gas filled proportional counter (P-BLM) is employed.

Linac beam of 8.3×10^{13} particles is injected into the rapid cycle synchrotron (RCS) during 500μsec. In order to confirm the efficiency of injection process, time resolution of less than several microseconds is required, which can survey the beam loss behaviour in each revolution period. Ar/CH_4 (90/10%) gas mixture P-BLM is prepared for 3GeV RSC and 50GeV MR by reason of time response, lifetime, and feasibility of maintenance. Although damage threshold is not so serious in RCS, high time resolution is also required to avoid the activation at injection. In addition, injected beam has to be aborted in the 50 GeV MR, when anomalous loss is observed. However, the degradation in gain of Ar/CH_4 gas filled P-BLM due to the deposit of polymerized material on wire was reported [3]. So that the air ionization chamber (AIC-BLM) is distributed in linac, 3GeV RCS and 50GeV MR to correct the signal level of PBLM (Ar/CH_4). It is also used to observe the uncontrolled beam losses around the 50 GeV MR.

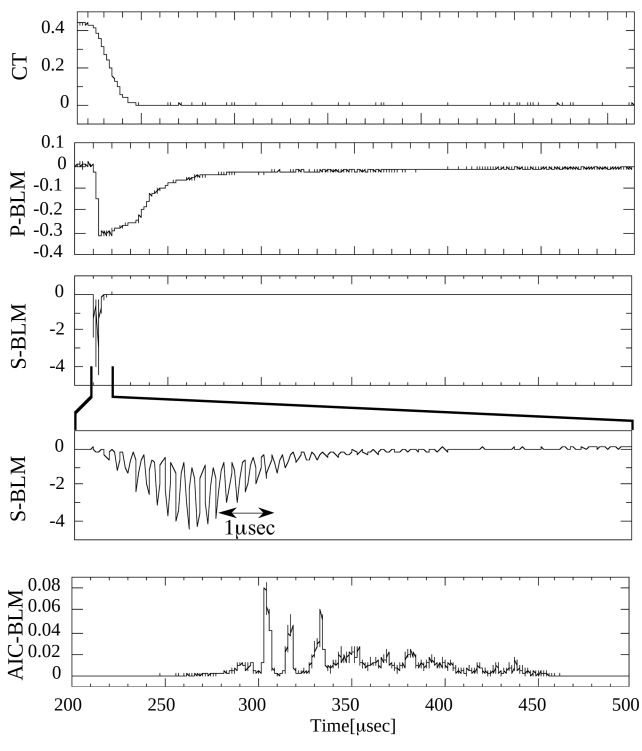

Figure 1: Current transformer and loss monitor signals of the KEK booster extraction. In this study, extraction bump magnet was excited to scatter beam paticles. In CT signal, the delay time of 15 μsec is corrected

EXPERIMENTAL RESULTS

S-BLM will be used to optimize the commissioning and tuning in the linac and is monitored during the injection/extraction in RCS. Figure 1 shows an S-BLM loss signal of KEK-PS booster extraction. As can be seen in the Fig. 1, S-BLM could observe the extraction loss oscillation with revolution frequency of about 6MHz. PBLM also shows the rise time of several microseconds for input impedance of 10 kΩ [1,4]. It can not be used to MPS at upper stream of linac. In addition, low energy loss beam principally induces neutron and γ -ray [5,6]. So that the ^{3}He gas filled P-BLM is applied to calibrate the scintillator efficiency of S-BLM. To satisfy the MPS requirement of high energy beam, the Ar/CH_4 (90/10%) gas filled P-BLM is used at down stream of linac. Sufficient signal level and time response could be expected for high energy region.

Figure 2 shows that the preliminary results of P-BLM calibration with cobalt 60 γ -ray radiation source. It was confirmed that about 25% decreasing of sensitivity were observed for accumulated charge of 3.0 C. In order to calibrate the signal level of Ar/CH_4 gas filled P-BLM, dual check system is performed. Air ionization chamber is distributed to confirm the signal level. Furthermore, detected signal of P-BLM during the all machine operation should be recorded.

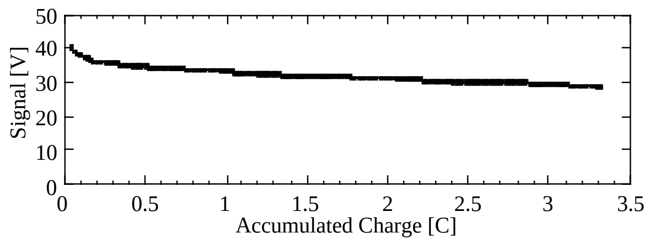

Figure 2: Gain degradation in argon-methane P-BLM under cobalt 60 irradiation. The anode wire diameter and length were 60 μm and 850mm.

The AIC-BLM is made of coaxial cable, with the inner conductor supported by spiral polyethylene insulator. About 500 V high tension is applied to the outer electrode as the bias voltage for the chamber. One end of the coaxial cable is used to pick up the signal, where the BNC signal pin is connected to the detector inner conductor. The other end is for the high tension terminal, where the HV-N connecter is attached to the outer conductor. Figure 3 shows the relation between the AIC-BLM signal and the loss intensity. Section I and II represent integral loss signal of injection and extraction area of the KEK-PS main ring. Although the accumulation of beam loss is significantly different, sensitivity of AIC-BLMs are similar to each other. On the other hand, an ionized electron from an atom is easily captured by oxygen, and creates O^{2+} and O^{2-} ions [7]. Ion mobility and high tension determine the delay time of AICBLM (about 0.1 msec). Although AIC-BLM can not provide MPS interlock signal due to slow time response, performs the sufficient reliability during twenty years operations.

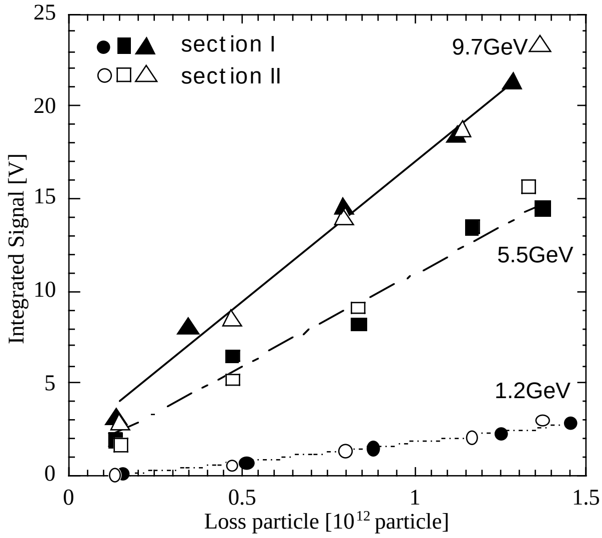

Figure 3: AIC-BLM integrated loss signals of the KEK-PS main ring. In this study, steering magnet was excited to scatter beam particles at injection (I) and extraction (II) area.

SUMMARY AND DISCUSSION

The beam losses with wide dynamic range of intensity and energy are expected in the J-PARC linac, RCS and 50 GeV MR. In order to pursue various phenomenon concerning with high intensity beam loss, a diagnostic system has been developed. S-BLM distributes along the upper stream of the linac and injection/extraction area of RCS. ^{3}He gas and Ar/CH_4 (90/10%) gas mixture P-BLM are installed in linac.

Argon-methane P-BLM are also employed to tune and investigate the loss mechanism around the RCS and 50 GeV MR, which provide alarm signal for abort system when anomalous loss is observed. Coaxial cable AIC-BLM are placed at down stream of linac and RCS to correct the sensitivity of Ar/CH_4 (90/10%) gas mixture P-BLM. AICBLM also distributes in the 50 GeV MR to observe the uncontrolled beam losses. The development of loss monitor system will support the MPS and contribute a great deal to experiment and operation.

In order to evaluate the absolute sensitivity of each loss monitors, further experimental studies are required in future. Efficiency, lifetime and other performance of ^{3}He gas filled P-BLM and various scintillators should also be examined in the KEK-PS and cobalt 60 γ -ray irradiation facilities. Especially, the correlation of loss monitor signals and actual beam loss position have to be found to investigate the loss mechanism and realize the MPS. Further investigation both experimental and numerical are indispensable to develop the BLM system in the J-PARC linac, 3 GeV RCS and 50 GeV MR.

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