PRELIMINARY OPERATION OF THE BEAM LOSS MONITORING SYSTEM AT THE 100-MeV PROTON LINAC*

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Abstract

A 100-MeV proton linac has been developed as the 1st phase of KOMAC (Korea Multi-purpose Accelerator Complex) under the project name of PEFP (Proton Engineering Frontier Project). The accelerator operation has to be carried out with the objective of limiting beam losses to less than 1 W/m. When the un-intended excessive beam loss occur, the BLM(Beam Loss Monitor) inform this beam loss to operator and transmit the signal to the MPS (Machine Protection System) for the rapid shut-off of the machine. The scintillation detector and proportional counter were selected as the BLM detector because of their fast response time and high sensitivity. At the beam commissioning stage, 20 BLMs will be prepared for the beam loss monitoring. This paper will report preliminary operation results of beam loss monitoring system.

INTRODUCTION

A 100-MeV proton linac of the 1st phase of KOMAC (Korea Multi-purpose Accelerator Complex) has to be operated with the objective of limiting beam losses to less than 1 W/m during normal operation of linear accelerator. This limitation is a generally accepted figure which should keep the induced radioactivity in the vicinity of machine at a level sufficiently low to permit hands-on-maintenance during shutdown periods [1, 2].

The beam loss can be classified into regular beam loss and accidental beam loss. Regular beam loss is considered inevitable during normal operations of a linear accelerator that comes from the various sources such as beam halo due to the space charge effects, nonlinearities and so on. Because the acceleration process is not always efficient, the accelerated particles are lost before reaching the maximum energy and interact with accelerator devices. Therefore, it is acceptable as long as they do not exceed the design loss rate. Accidental beam loss is unintended loss of the entire proton beam at a single point is considered unlikely event. These beam losses have to be prevented and minimized because they can be cause excessive dose equivalent to radiation workers or the public in the accelerator facility and non-tolerable activation of accelerator components by nuclear reactions.

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To prevent accidental beam loss, the beam loss monitor systems will be designed to minimize unintended accidental beam loss by providing data for tuning the accelerator and by inhibiting the beam when excessive losses occur [3]. Thus, these beam loss monitor system must have sufficient sensitivity to detect excessive beam loss and coverage in all section of the linear accelerator.

DESIGN CRITERIA

- Slow and low level beam loss for monitoring

The long-term, low level beam loss (<1 W/m) will be averaged over 10 seconds in the IOC and compared against a 1 W/m reference. If it is exceeded the reference level, warnings will be sent to the operator.

- Fast loss for the Machine protection system

A inhibit signal will be generated if the fast and high level beam loss occur compare to 10 times higher than a 1 W/m reference level.

ESTIMATION OF RADIATION DOSE

To determine the dynamic range of the beam loss monitor, we have tried to calculate the radiation field distribution induced by beam loss by Monte Carlo Method.

Figure 1 shows that 2 dimensional neutron dose distribution calculated by MCNPX during the normal operation of linear accelerator. As shown in figure 1, Neutron dose increase gradually according to longitudinal direction because the energy of proton increase along to the length of the accelerating structure and the probability of neutron production increase according to proton energy increasing.

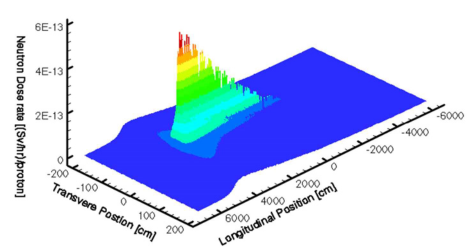

Figure 1: The neutron dose distribution during 1 W/m beam loss.

Figure 2 indicate that the absorbed dose distribution induced by neutron and photon along to the longitudinal direction at 34 cm apart from beam axis laterally The longitudinal distribution of neutron and photon shows

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same tendency but they have different intensity each other. These calculated results were utilized to determine the dynamic range of the beam loss monitor design.

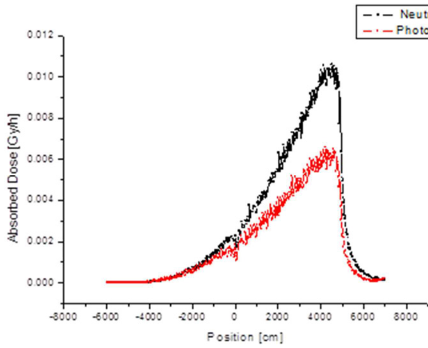


Figure 2: The expected absorbed dose rate at the linac.

CONSTRUCTION OF BLM

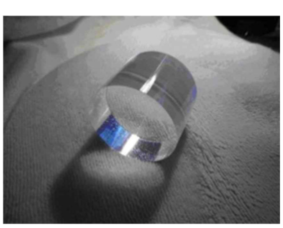
The beam loss monitor was consisted of the several parts as belows.

- Radiation detector
- Signal processing unit
- ADC (Analog to digital converter)
- MPS (Machine Protection system)

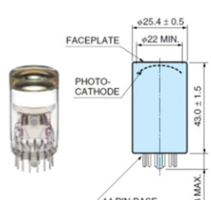
Detector Preparation

The ion chambers are widely utilized at the most of the accelerator facilities due to their high dynamic range, radiation hardness and easy calibration. But ion chamber is not sensitive at the low energy section of the accelerator and have the slow response time due to the slow ion mobility in the gas. Therefore, the proportional counter and the scintillation are selected as a detector of beam loss monitoring due to their fast response time and high sensitivity.

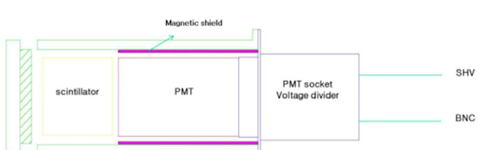
- The scintillation detector



(a) Plastic scintillator



(b) PM-tube



(c) fabrication of detector

Figure 3: The fabrication of scintillation detector.

The scintillation detector will be consisted of plastic scintillator (BC-408, Saint-Gobain) [3] and Photo-multiplier tube (R1924A, Hamamatsu), magnetic shield, optical coupling, light reflector and metal casing for noise shielding (Fig. 2). The specification of the scintillator and PM-tube is summarized in Table 2 and Table 3.

Table 1: Specification of Plastic Scintillator

Model	BC-408
Manufacturer	Saint-Gobain
Density	1.032 g/cm3
Refractive index	1.58
Rise time	0.9 ns
Max. emission wavelength	425 nm

Table 2: Specification of PM-tube

Model	R1924A
Size	25 mm (1”)
Spectral response	425-650 nm
Dynode structure	L/10
Typical gain	2E+6
Rise time	1.5 ns

- The Proportional counter

The proportional counters are manufactured by Toshiba for beam loss monitor, which is installed and operated at the J-parc successfully. [4]

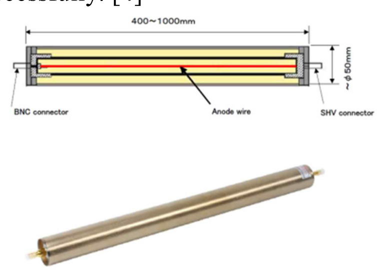


Figure 4: Proportional counter (E6876-600).

Table 3: Specification of Proportional Counter

Model	E6876-600
Manufacturer	Toshiba (Japan)
Gas	Ar + Co_2
Response time	0.1 usec
Typical gain	1000 (at 2000 V)

Signal Processing Unit

The scintillation detector and the proportional counter are typical current source. Therefore, the current pre-amplifier is required, to transform the voltage analog signal which can process the signal at the ADC (Analog to digital convertor) for the beam loss monitoring. And also, the signal processing unit can produce the inhibit signal and transfer to the MPS for the rapid beam shut-off. Figure 4 shows the design of the signal processing unit.

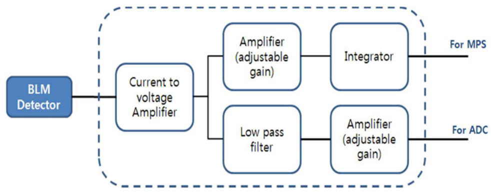


Figure 5: Block diagram of signal processing unit.

Installation of Beam Loss Monitor

The 8 of scintillation detectors will be installed at the middle of each DTL section . the 4 proportiona counter detector will be installed at the 45 degree bending magnets in the 20 MeV, 100 MeV beam line. The total 12 beam loss monitors will be installed at the at the beam commissioning stage.

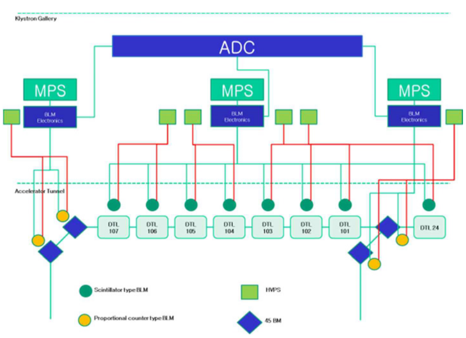


Figure 6: The installation plan of beam loss monitoring system.

Preliminary Test of the Detector

To measure the radiation sensitivity of detector, the preliminary test for the fabricated scintillation detector and proportional counter were performed by the standard radiation source. The scintillation detector was irradiated by Cf-252 neutron source with 1327 μSv/h dose rate and they show the good linearity as the neutron dose rate (figure 7). But they shows unit to unit variance.

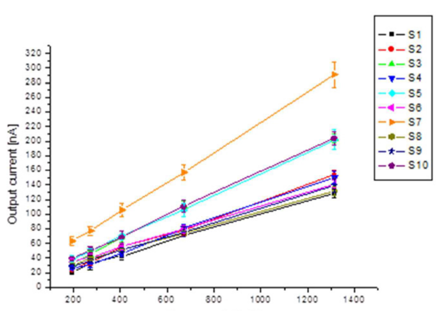


Figure 7: Sensitivity of scintillation detector as a function of the neutron dose rate.

For the proportional counter, the detectors were irradiated by Cs-137 standard gamma source. They show identical sensitivity each other.

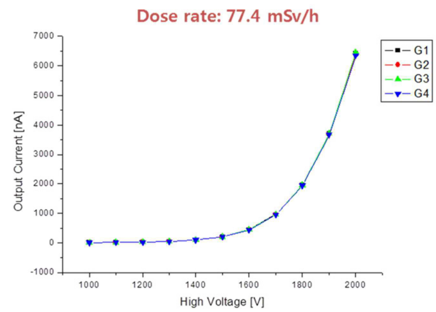


Figure 8: Sensitivity of proportional counter as a function of the high voltage.

CONCLUSION

At the beam commissioning stage, the total 12 beam loss monitors were prepared for the beam loss monitoring. The scintillation detector and the proportional counter are selected as a beam loss monitor. Their radiation sensitivity were measured by using the standard radiation source. Through the signal processing unit, the status of beam loss at the linac monitored by ADC, A inhibit signal will be generated and transferred to MPS when the un-intended excessive beam loss occur.

ACKNOWLEDGMENT

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