STATUS OF BEAM LOSS EVALUATION AT J-PARC LINAC

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Abstract

Ar-CO_2 gas proportional counters are employed for the measurement of beam loss in the current linac operation, but they are also sensitive to background noise of X-ray emitted from RF cavities. In SDTL (Separate-type Drift-tube Linac) section, protons, secondary hadrons and gamma rays would be mainly generated as a beam loss, but it is not easy to estimate real beam loss using the proportional counter. The Plastic scintillation monitors with less X-ray sensitivity and ^{3}He proportional counters with high thermal neutron sensitivity will be also employed to measure the beam loss. The combination of these detectors would bring more accurate beam loss measurements with suppression of X-ray noise. This paper reports status of beam loss evaluation using these detectors. And the signals obtained during the beam operation using the Ar-CO_2 gas proportional counter and the plastic scintillation monitors are compared to discuss the essential beam loss. Finally, a measurement of emission position and angle distributions of protons due to negative hydrogen ion (H^-) beam loss is being planed. This plan is introduced and this result would lead to clarify the source of beam loss.

INTRODUCTION

Since November, 2007, J-PARC Linac has been operated at 7.2kW beam power. During the operation, a beam loss possibly caused by the H^0 particles generated by the interaction between H^- beam and residual gas in the beam line were observed in the whole section. In the linac operation, Ar-CO_2 gas proportional counters are employed for the measurement of beam loss [1-2], but they are also sensitive to background noise of X-ray emitted from RF cavities. In the Figure 1, signals from gas proportional counters installed in SDTL section (points in dotted circle) are shown. If the RF is supplied though the beam operation is stopped, these signals still remain. In addition, protons, secondary hadrons and gamma rays would be mainly generated as a beam loss in this section, but it is not easy to estimate real beam loss only using the gas proportional counter.

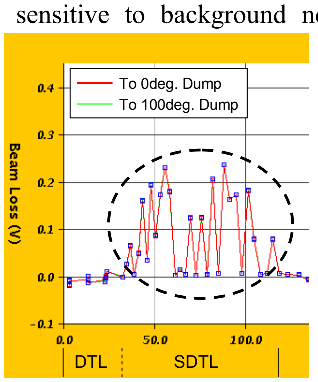

Figure 1: Beam loss in J-PARC linac at run 21 (Jan. 13., 2009).

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BEAM LOSS MONITORS IN LINAC

Totally over hundred gas proportional counters are installed in the beam line and measure the beam loss through operations since 2004.

Ar+CO_2 Gas Proportional Beam Loss Monitor

Gas proportional counter (current beam loss monitor) is a detector that makes use of the ionization effect of radioactive rays on an internal gas (Ar). Its signal can be amplified by applying a high voltage. An E6876-600's, produced by Toshiba Electron Tubes & Devices Co., Ltd., is employed for the beam loss measurement, because it is easy to make and maintain, and it has an advantage by composing with only a passive components, that is a practically key issue for the detector under the radiation surrounding [1]. Gas proportional counters are installed along the beam-line (Figure 2).

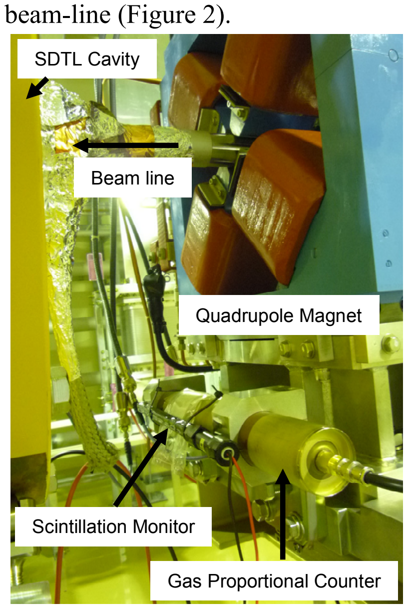

Figure 2: Installation of BLM (Gas proportional counter and plastic scintillation monitor).

Plastic Scintillation Monitor

Plastic scintillation monitors with less X-ray sensitivity are employed and installed to measure the beam loss. We used photo-multipliers of Hamamatsu H3164-10 with the gain of 1.1 x 10^6, the peak wavelength of 420 nm, and the rise time of 0.8 nsec (Figure 3). The plastic scintillator is Saint-Gobain BC-408 with the peak emission wavelength of 425 nm and rise time of 0.9 nsec, which matches the photomultiplier.

Three plastic scintillation monitors with less X-ray sensitivity are also employed and installed to measure the beam loss. One of them is installed in the SDTL section to compare the signals obtained from both gas proportional counter and plastic scintillation monitor. Others are installed in the part of A0BT and L3BT section where the high residual radioactivity is usually measured. Each monitor is set just behind the proportional counter (Figure 2).

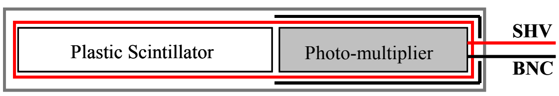

Figure 3: Plastic scintillation monitor.

BEAM LOSS MEASURMENT WITH SCINTILLATION MONITOR

We measured beam loss in the downstream part of SDTL section (SDTL13 and SDTL16), the upstream part of ACS section (ACS03), and around the first arc in L3BT section (L3BT21). We operated the photomultipliers with the high voltage at -600 ~ -700V. The raw signal is amplified by 1~10 times with a pre-amplifier (Giga G5106). We measured the counts of particles which deposit high energy loss in the scintillation monitors. We collected waveform data of macro pulses using a 12.5-GHz Tektronix oscilloscope DPO71254-R3.

As the result, only the signal from gas proportional counters is observed, even the no beam current (Figure 4).

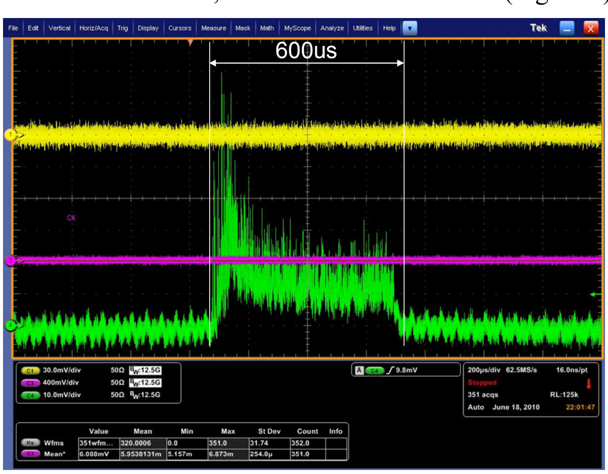

Figure 4: Signals from a gas proportional monitor (green) and plastic scintillation monitor (magenta) at SDTL13 section, during no beam operation. The beam current signal with a current transformer is also shown (yellow).

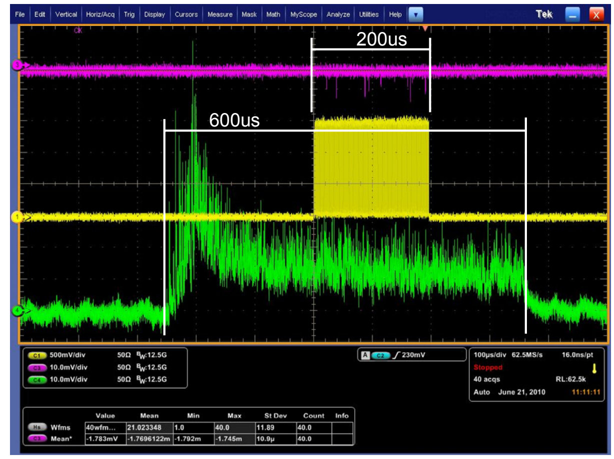

Figure 5: Signals from a gas proportional monitor (green) and plastic scintillation monitor (magenta) at SDTL13 section, during beam operation with chopped beam. The beam current signal with a current transformer is also shown (yellow).

Because the gas proportional counter recieved the high background of X-ray emitted from RF cavities, the essential beam loss cannot be detcted by the gas proportional counter. Therefore we measured beam loss with a plastic scintillation monitors. Figure 5 shows the beam loss signals obtained from a gas proportional counter and a scintillation monitor. Signals from a gas proportional counter has an RF pulse width (600us), but a signal from scintillation monitor indicates the signal with the width (200us) of real beam pulse. A good signal to noise ratio is observed for the plastic scintillation monitor (on Figure 5), with almost no sensitivity to the background X-ray.

Time resolution of the scintillation monitor is good enough to measure the beam loss caused by the chopped beam pulse (Figure 6). Width of the scintillation signal by one event is almost 40 nsec. Time delay of the scintillation signal is almost 160 nsec and this delay is corresponding to the time constant of the pre-amplifier.

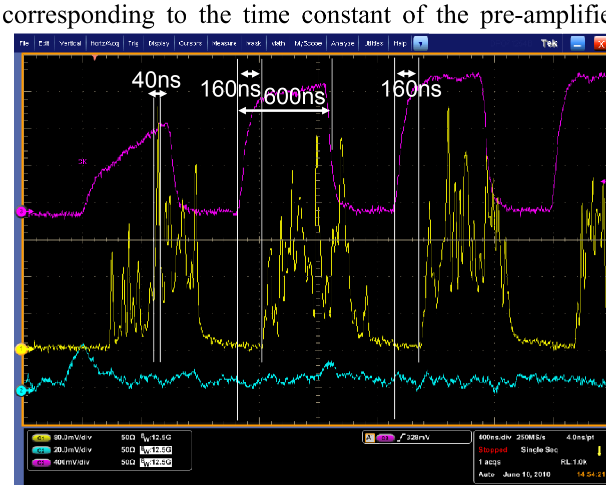

Figure 6: Signals from a gas proportional monitor (blue) and plastic scintillation monitor (yellow) at SDTL13 section, during beam operation with chopped beam. Time scale is extended to 400nsec/div. The beam current signal with a current transformer is also shown (magenta).

Delay of the measured beam current is within 1 nsec.

In test measurements with plastic scintillation monitor, we successfully measured clear beam loss signals with low noise. And the time resolution of the scintillation monitor is high enough. We will employ the scintillation monitor combined with gas proportional counter in the future beam loss measurement system.

BEAM LOSS TRACKER SYSTEM

We plan to construct a beam loss tracker system which is made of hodoscopes of plastic scintillation fibers. The tracker system is used to measure systematic transverse beam loss distributions and to reconstruct particle tracks in order to identify and evaluate the absolute rates of primary protons lost from the H^- beam. The features of this system are summarized as follows [3].

1) Measurements of transverse particle distributions around a beam duct
2) Primary proton identification with particle tracking
3) Primary proton identification with the velocity measurement with the time-of-flight method
4) High-rate capability (1 MHz at maximum)

We are going to construct and install a beam loss tracker system in ACS section for beam operations from autumn of 2010. Since we had a good signal to noise ratios of beam loss measurements with plastic scintillation monitors, the tracker is based on a plastic scintillation monitor. For particle position measurement and track reconstruction, we adopt scintillation fibers of Saint-Gobain BCF-10 which has a 4 mm x 4 mm square cross section. We form a 64 mm x 64 mm hodoscope of 16 fibers as one of four squares. Four of such hodoscopes are connected to a 64-channel Multi-Anode PMT (MAPMT) Hamamatsu H8500C via optical fibers of BCF-98 with the same cross section as BCF-10. We are going to construct 4 hodocopes with two MAPMTs due to limited readout channels. The hodoscopes are installed in the linac tunnel, while the high-voltage supply of MAPMTs and signal processing, readout modules, and Data Acquisition (DAQ) system are placed in the ground level, which is about 20 m above the tunnel. We measure both energy loss and timing of a particle. The raw signals from MAPMTs are sent to a NIM crate in the ground level. For energy loss measurements, the signals are amplified with amplifiers and then sent to Analog-to-Digital Converters (ADCs) housed in a VME crate. For timing measurements, the amplified signals are converted to a rectangular pulse with discriminators and sent to Time-to-Digital Converters (TDCs) in the VME crate through NIM-to-ECL level converters. The gate signals for the ADCs and common start or stop signals for the TDCs are created with dynode signals of the MAPMTs. The ADCs and TDCs are read out with a Linux based on-board VME controller which is operated by a PC through Ethernet.

We consider the following two hodoscope configurations. For measurements of transverse particle distributions, we use the 4 hodoscopes, two of which are to measure horizontal distribution are and the rest are to measure vertical distributions are placed nearly around the beam duct at the same location along the beam line.

For track reconstruction, we arrange 4 hodoscopes along the beam line as shown in Figure 7. We may either use the combination of two horizontal hodoscopes and two vertical hodoscopes as shown in the figure, or four of horizontal hodoscopes or vertical hodoscopes. If the hit positions in the hodoscopes are aligned, they are identified as a particle track. With this configuration, if we take the distance between hodoscopes long enough (one or a few meters), we may be able to distinguish primary H^+ (proton) from other secondary low energy particles. It may also be possible to identify it with amplitudes of the signals.

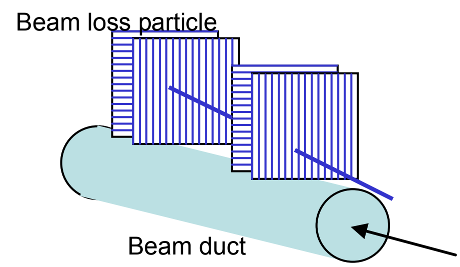

Figure 7: A hodoscope configuration for particle tracking.

SUMMARY

Because the Ar-CO_2 gas proportional counter is sensitive to background noise of X-ray emitted from RF cavities, the plastic scintillation counter with less X-ray sensitivity is employed to measure the beam loss. We successfully measured clear beam loss signals with low noise and confirmed the high time resolution. Then, a measurement of emission position and angle distributions of protons due to negative hydrogen ion (H^-) beam loss is being planed. This plan is introduced and this result would lead to clarify the source of beam loss.

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