MEASUREMENT OF BEAM LOSS TRACKS BY SCINTILLATING FIBERS AT J-PARC LINAC*

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Abstract

Highest beam loss in the J-PARC linac has been observed at the ACS (Annular-Coupled Structure linac) section. Since the observed beam loss is proportional to the residual gas pressure, the source of the beam loss is considered to be H^0 produced in an interaction of H^- beams with remnant gas. If this assumption is valid, H^0 hits the beam duct and is converted to H^+ and escapes from the beam duct. We constructed scintillating fiber hodoscopes to detect H^+'s and eventually identify the particle species as H^+. The detector system consists of 4 planes of hodoscopes which are made of 16 scintillation fibers of 64 mm long with a 4 mm x 4 mm cross section. We installed the hodoscopes at the upstream part of the ACS section and measured beam loss. The results of the measurements are presented.

BEAM LOSS IN LINAC

J-PARC linac has been operated at 7.2 kW since Nov. 2007. The maximum beam loss level has been observed at ACS, after having resolved the beam loss problem due to H^+, which originates at LEBT [1]. The beam loss at ACS is considered to be due to H^0's produced by ionization of H^- beams with residual gas in the beam ducts. The neutral H^0's generated inside the beam duct fly straight without being bent by beam line magnets. Those H^0's which are emitted along the beam line may hit the zero-degree beam duct, which were actually observed [2]. The H^0's which have larger angles will hit at the beam duct and then ionized to H^+'s. They will be emitted outside the beam duct and cause beam loss. The aim of the present work is to evaluate the absolute value of H^-'s lost inside or at the beam duct by counting the number of H^+'s. With GEANT particle simulation [4], we found the average emission angles of H^+'s are about 5 degrees with respect to the beam axis. Thus most of H^+'s will be emitted near the beam line direction. By the scintillating fiber counters, we aim at measuring these H^+'s by reconstructing their tracks.

SCINTILLATING FIBER HODOSCOPE

A hodoscope plane is shown in Fig. 1. It consists of 16 of 2 mm x 2 mm x 64 mm plastic scintillating fibers (Saint-Gobain BCF-10). Each fiber is glued to a light guide fiber of 600 mm which is optically connected to a photo-multiplier (PMT). We adopted a PMT Hamamatsu H8500C with 8 x 8 channels. We constructed 4 hodoscope planes. Two of the four planes are connected to a PMT, and the rest is connected to the other PMT. As shown in Fig. 2, we installed the hodoscopes in the ACS section. Each hodoscope plane is attached to the beam duct in perpendicular orientation to the beam direction. The fiber direction is vertical to measure horizontal positions. We name the 4 hodoscope planes from the most upstream as H0, H1, H2, and H3. The distance along the beam direction between H0 and H1 is 8.5 mm and that between H2 and H3 is 75 mm. The short distances are to reject noise signals by requiring signal timing coincidence between the pair. The distance between the two hodoscope pairs are taken to be 926.5 mm. This distance is chosen long enough to distinguish H^+ from other particles with different velocity by time-of-flight measurements. Light guide fiber does not emits scintillation light but emits Cherenkov light for particles with $\beta>0.63$, which is not possible by 181 MeV H^+ ($\beta=0.55$) but possible by electrons and positrons. In order to prevent from detecting charged particles by Cherenkov light, we changed the light guide orientation up and down between the two pairs of hodoscopes as shown in Fig. 2.

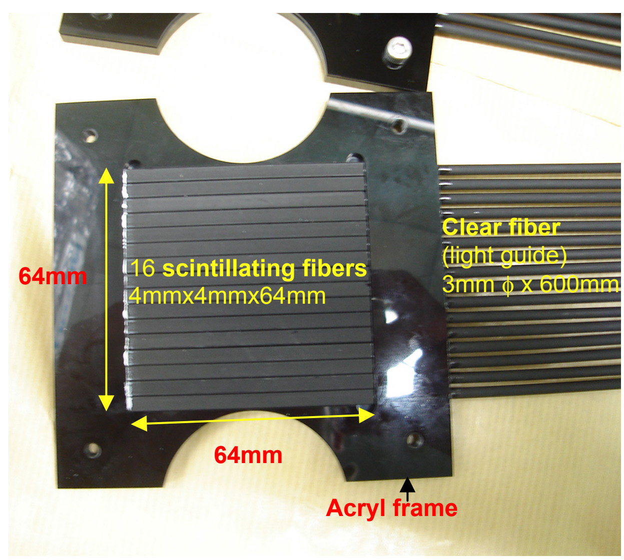

Figure 1: A scintillating fiber hodoscope.

The whole setup including readout electronics and data acquisition system is shown in Fig. 3. The hodoscopes are installed in the 20 m underground linac tunnel. Signal and high voltage cables of PMT's are connected to the electronics rack in the ground level "Klystron Gallery". A PMT signal is amplified with an amplifier and split into

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two. One signal is measured with an ADC (Analog-to-Digital Converter), and the other signal is discriminated by a discriminator circuit and the leading time of the output discriminated signal is measured with a TDC (Time-to-Digital Converter).

The ADC's and TDC's are modules in a VME crate. Their data are collected by a CPU board GEfanuc XVB601. The CPU works in RedHat Linux and data acquisition codes are implemented in C++.

The trigger is constructed based on the 25 Hz beam start signal of the J-PARC accelerator. Due to limitation of the maximum range of TDC, we adjusted the TDC common start timing to the beginning of an intermediated chopped pulse, and ADC gate timing to include the pulse, so that beam loss signals in the pulse can be measured.

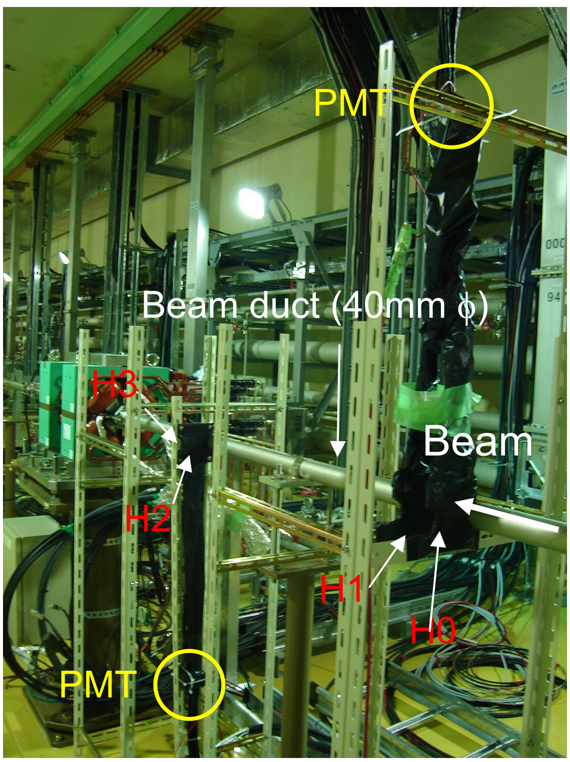

Figure 2: Experimental setup of beam loss measurements in the ACS section.

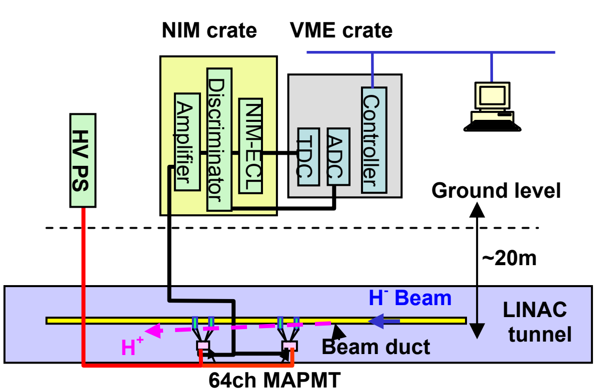

Figure 3: The whole system for beam loss measurements with scintillation fiber hodoscopes.

BEAM LOSS MEASUREMENTS

In order to calibrate timing of each fiber, we performed the following methods.

1. Adjust relative timing between adjacent fibers using charged particles which pass through the two fibers.
2. Adjust timing between a fiber pair on H0 and H1, or H2 and H3 since they are close to each other.
3. Adjust timing of fibers in the 4 planes at the same time by cosmic rays, in the configuration of 4 hodoscope planes attached face-by-face to each other and placed in the horizontal direction as shown in Fig. 4.

We adopted Method 3, since it can calibrate all the fibers in the 4 hodoscopes simultaneously. Figure 5 shows the time correlation between H2 and H3 due to the cosmic rays. A clear single peak at each fiber is observed. The time difference at each fiber is adjusted to 0 by subtracting a time-offset from TDC measured at each fiber.

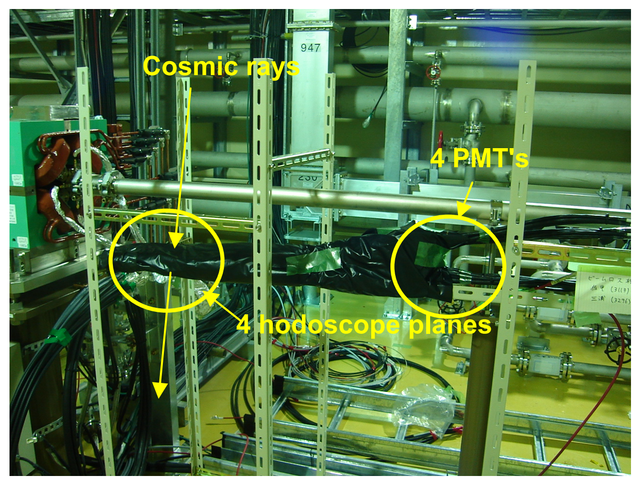

Figure 4: A setup for cosmic ray measurements.

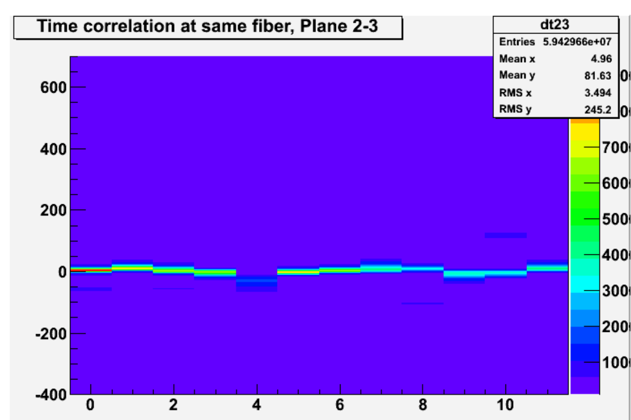

Figure 5: TDC difference (bin) between fiber pairs in H2 and H3 as a function of the fiber number. Fiber 0 is closest to the beam axis. One TDC channel corresponds to 0.2 nsec.

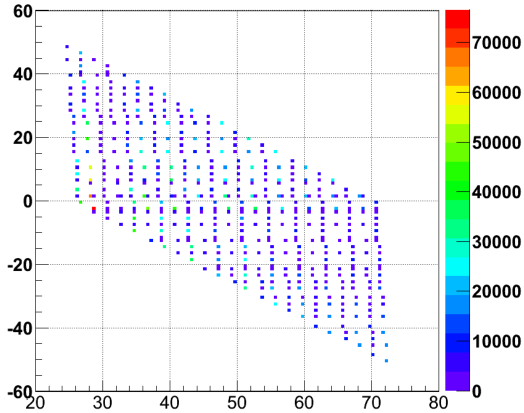

Figure 6: Horizontal positions at H0 (x-axis) (mm) (the origin is at the beam axis) and track angles with respect to the beam axis (mrad) for tracks with hits in all 4 hodoscope planes.

Figure 6 shows acceptance in the horizontal position and the angle of the tracks passing through the 4 hodoscope planes. Here, a track is defined as a straight line in a 3-dimensional (z, x, t) space, where z is the coordinate along the beam line, x is the horizontal coordinate, and t is the time-of-flight. Fig. 7 shows residuals of hits in x and t on H1 and H2 with respect to the tracks. Clear peaks are observed in both plots, which indicate evidence for charged particle tracks.

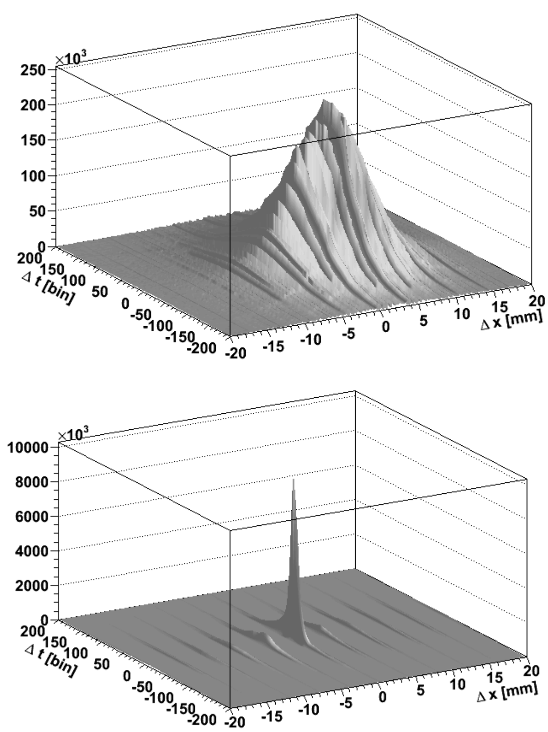

Figure 7: Hit residuals in horizontal position (mm) and TDC bin on H1 with respect to a track connection hits between H0 and H3 (top). Hit residuals on H2 (bottom).

Figure 8 shows the very preliminary distribution of time-of-flight (in TDC bin) between H1 and H2. The distance between H1 and H2 is 843 mm. The polar angle with respect to the beam axis is 0.01-0.05 mrad. Tracks are required to have the hits on the 4 planes. The χ^2 / *dof* in z-x plane and z-t plane is less than 5 and 20, respectively. Due to a large number of combinatorial background tracks, it is still hard to see the signal of H^+. Unfortunately, our measurements forced be stopped due to Tohoku Region Pacific Coast Earthquake on Mar 11, 2011, which destroyed the J-PARC accelerator complex. However, by rapid recovery by the J-PARC collaborators, we are going to resume our measurement on Dec. 2011.

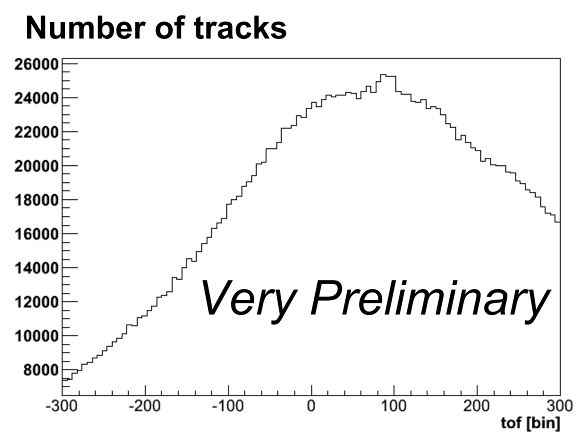

Figure 8: Preliminary time-of-flight measurements.

CONCLUSION AND OUTLOOK

We observed charged particle tracks with angles close to the beam axis. However, we need to improve signal-to-noise ratio to observe H^+ signals in time-of-flight measurement. In a new experiment from Dec. 2011, we are going to use new coaxial signal cables with better signal transmission, and measure charge of individual signal by using a fast dynode signal of PMT's. We are also going to move the hodoscope positions farther from the beam axis, in order to decrease the signal rates to reduce background level.

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