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TRANSVERSE H$^-$ BEAM HALO SCRAPER SYSTEM IN THE J-PARC L3BT

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Abstract

In the Japan Proton Accelerator Research Complex (J-PARC) 3-GeV rapid cycle synchrotron (RCS), transverse beam halo scraping for the injection beam is required to increase the output beam power. The transverse scraper system at the Linac-RCS beam transport line (L3BT) was utilized in a nominal beam operation because the area of the scraper section was contaminated when the scrapers were working. In the summer-autumn period of 2013, we installed the new beam-halo scrapers which had optimized scraper heads for mitigation of the radiation around the scraper system. In this paper, we report a preliminary result for a halo scraper at the L3BT.

INTRODUCTION

The J-PARC is a high intensity proton accelerator facility aiming to realize 1 MW class beam power [1]. A negative hydrogen ion beam from the linac is injected into the RCS through stripping to a proton beam by a charge stripper foil placed in the RCS injection point. In 2013 summer-autumn period, the injection beam energy has been increased to 400 MeV with the upgrade of the linac [2]. After that, the RCS will aim at final goal of the 1 MW output.

In the high power proton accelerator as a J-PARC, even small ratio of the beam loss such a beam halo cause serious radiation dose. In the RCS, radio-activation around injection section is especially serious. In order to provide such a high intensity beam for routine user program, it is required to improve the quality of the injection beam from the linac. The beam halo is one of most important behaviour of space charge dominated high intensity beam such as injection beam for the RCS. The key issue to evaluate the high intensity beam quality is the suppression of the transverse beam halo.

The L3BT beam transport line between the linac and 3GeV RCS has a transverse scraper system to eliminate a transverse beam tail or halo [3]. In 2013 summer-autumn period, we have installed new beam halo scraper system which was optimized scraper heads for mitigation of radiation around the scraper system. In this paper, we report about the new transverse scraper system in the L3BT. Hardware details and beam study results for the new scraper system will be appeared.

TRANSVERSE SCRAPER SYSTEM IN THE L3BT

The transverse scraper system in the L3BT is located downstream in the J-PARC linac institute (Fig. 1). The scraper system consists of four horizontal and four vertical scrapers [4]. Each scraper is placed with a fixed interval in the scraper section and the betatron phase advance between same direction scrapers is set to 45 deg. The tail or halo portion of the beam is charge-exchanged from a negative hydrogen ion to a proton by using thin carbon scraper heads in each scraper.

These charge-exchanged particles are led to a dedicated dump named 100deg dump about 40 m downstream from the scraper section. On the other hands, the main beam (negative hydrogen ions) is injected into the RCS. The capacity for the 100-deg dump is 2 kW, respectively.

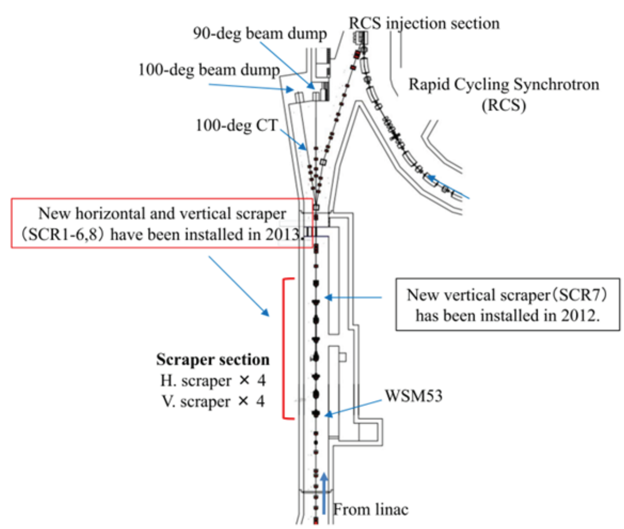

Figure 1: Schematic layout of the L3BT scraper section and the 100-deg dump.

To enable the simultaneous transport of the charge exchange protons with tolerable beam losses, a large aperture radius of the beam duct is secured in this section. Thus, in principle, radiation contamination is not so extensive around the scraper section.

However, the transverse scraper system is utilized in a nominal beam operation until 2012, because the area of the scraper section was contaminated if scrapers were working. The course of this radiation contamination is that large angle scattered proton particles by the scraper foils. Each scraper has two scraper heads which are independently movable with the stepping motors. The scraper head was adopted a carbon plate with the thickness of 100μm which is determined for the long-term durability.

In order to mitigate the multiple scattering by the scraper foil, we converted the scraper foil thickness to

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2.5µm (500µg/cm^2). Figure 2 shows the new scraper head with the thin charge stripping carbon foil. This thickness of carbon foil is the same one as second and third charge exchange carbon foil for RCS injection. The material of the new scraper foil is the Hybrid type thick Boron-doped Carbon (HBC) foil, which was developed by Sugai group in KEK [5]. The charge exchange efficiency of converted carbon foil is over 99.99 % and it is enough to use as the scraper.

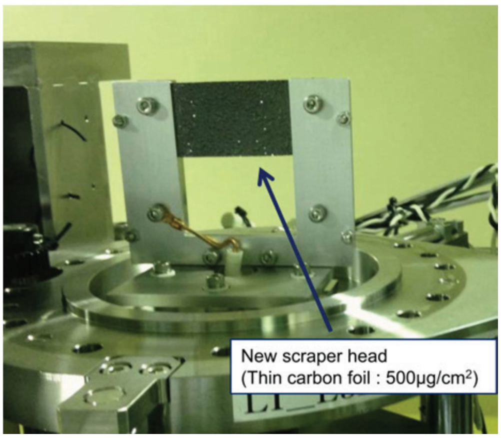

Figure 2: Picture of the new scraper head with the thin carbon foil. The carbon foil is mounted by the metal foil folder.

Because this thin carbon scraper foils is easily fragile, some shatterproof method for radioactive fragment of the carbon foil is required for the new scraper system. If the thin carbon foil is broken, both gate valves are closed, and the fragment of foil is taken away with closed chamber from the L3BT.

In 2012 summer period, we developed a new vertical scraper system with thin carbon scraper, and replaced a most downstream vertical scraper (scraper-7) with new one [6]. From the results of the test study for a new vertical scraper, we had positive result about new scraper system. Based on these results, we had replaced all transverse beam scrapers in L3BT in the summer 2013.

BEAM EXPERIMENTS FOR THE NEW SCRAPERS

Scraped Beam Profile

All scrapers are accommodated with the Wire Scanner Monitor (WSM) in its vicinity for scraper edge position tuning. The wire scanner monitor (WSM) is a very useful and powerful tool for the beam profile diagnostics at the L3BT. Figure 3 shows the transverse beam profiles which were measured by the WSM53 in the scraper section. The WSM53 is placed nearby first vertical scraper (Fig. 1). In this figure, the injection beam for the RCS had quite a lot of beam tail and halo portion at the scraper section. These halo parts of the injection beam is source of beam losses and it cause radiation contamination in the RCS [7].

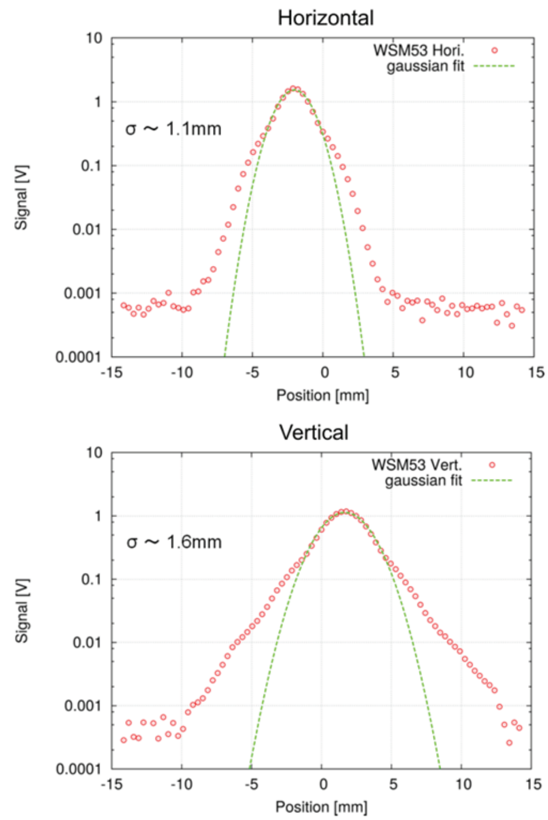

Figure 3: Transverse beam profile at the WSM in the L3BT scraper section. The red dots are the measurement results by the WSM and green lines are gaussian fitting results.

In order to purge the beam halo parts, we have to set adequate position of the scraper-edge. However the scraper foils are so thin, it is difficult to improve the precision of the foil edge position in advance. All scrapers are accommodated with the WSM in its vicinity for position tuning of scraper-edge.

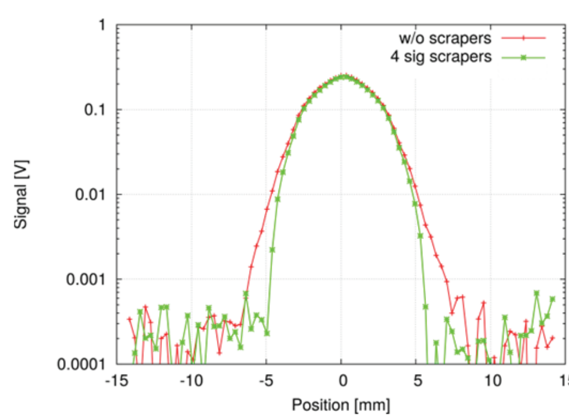

Figure 4: Scraped beam profile in the vertical direction. Red lines are vertical beam profile without setting scrapers, green lines are beam profile with setting scrapers.

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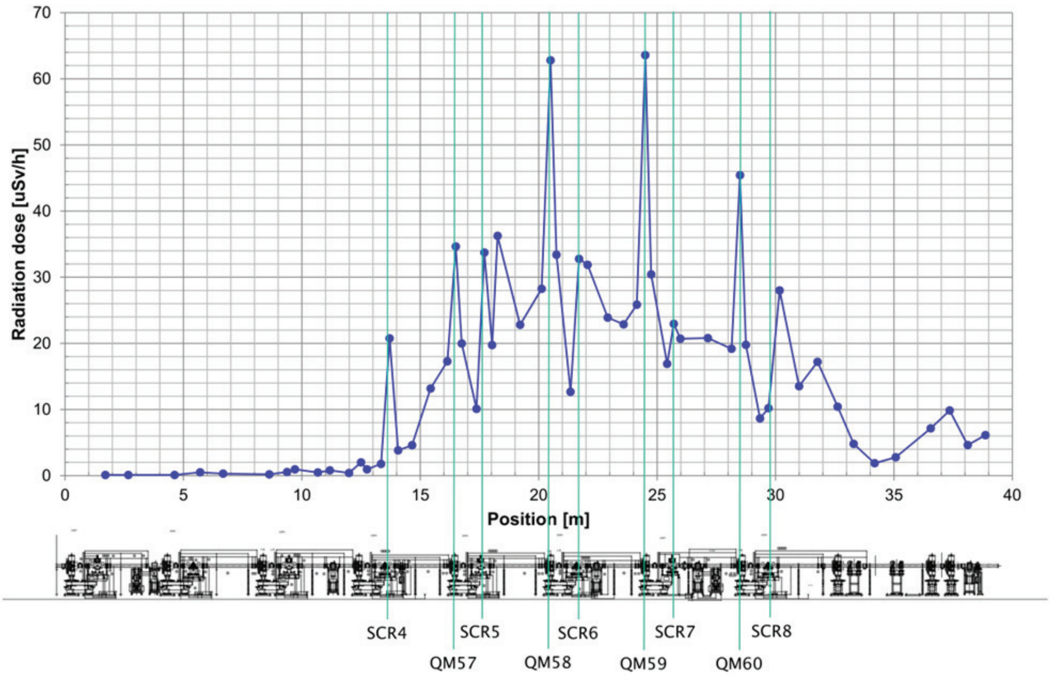

Figure 5: Figure of the radiation dose around the scraper section after 2 days user operation. Localized radio-activation was observed at the new scrapers and the quadrupole magnets.

Thus, we did a search the position of the scraper-edge by comparing the WSM measurement and scraped beam current ratio. The ratio of the scraped beam current with scraper scanning was obtained by a conventional current transformer (CT). The CT is positioned about downstream from the bending magnet which separate scraped proton beam from the H^- beam core (Fig. 1).

The scraped beam profile measured by the WSM which is placed downstream from the scraper section is shown in the Figure 4. The edge positions of all scrapers were set about 4σ of beam core from the beam centre. The parameter σ is a standard division of fitted gaussian distribution. From Fig. 4, only the halo parts of the injection beam were obviously purged by the scrapers and we confirmed that new scraper eliminate a transverse beam tail or halo.

Radiation Dose Measurement Around the Scraper Section

After two day of user operation with beam scraping, we measured radiation dose around the scraper section. Figure 5 shows distribution of radiation dose at the scraper section. Scraper edge positions were 5σ of the beam core and scraped beam ratio was 1.1 % at that time. Radiation dose level around the scraper section was higher than expected. Radio-activation became higher toward downstream in the scraper section. Because betatron amplitude is relatively large around the quadrupole magnets, high radio-activation was observed in this place. Also, locally high radiation dose at the scraper was observed.

We assume that scraped particles was scattered by the foil folders of the scraper heads and scattered particles caused unexpected radio-activation around the scraper section. We are doing numerical simulation to understand scraped particle behaviour in the scraper section and more optimized scraper head will be installed in 2014 summer period.

SUMMARY

In the J-PARC RCS, transverse beam halo scraping for the injection beam is required to increase the output beam power. In order to avoid radio-activation around the scraper section new scraper system with a thin carbon foil was installed in the L3BT. From the result of feasibility study for the new scrapers, we confirmed that new scraper eliminate a transverse beam tail or halo. After two day of user operation with beam scraping, the residual dose around the new scraper was higher than expected. We are doing numerical simulation to understand scraped particle behaviour in the scraper section and more optimized scraper head will be installed in 2014 summer period.

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