FOIL SCATTERING LOSS MITIGATION BY THE ADDITIONAL COLLIMATION SYSTEM OF J-PARC RCS

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Abstract

In the J-PARC RCS, the significant losses were observed at the branch of H0 dump line and the Beam Position Monitor which was put at the downstream of the H0 dump branch duct. From the beam study, we were certain that these losses were caused by the scattering of the injection and circulating beam at the charge exchange injection foil. In order to mitigate these losses, we started to develop a new collimation system in the H0 branch duct. We present latest study results and overview of this new collimation system.

INTRODUCTION

In J-PARC 3GeV synchrotron (Rapid Cycling Synchrotron, RCS), we started user operation in December 2008 with 20kW output for Material and Life science experimental facility (MLF) user [1]. We continued improvement and raised the output to 200kW in November 2010. It was continued until the shutdown caused by the earthquake disaster of east Japan. MLF user operation is usually performed successively from two to three weeks, and the commissioning/maintenance of the accelerators was sometimes inserted in this continuous operation. Typical residual dose distribution after 200kW user operation was shown in Fig 1. This result was measured in January just before the earthquake disaster. In this case, we started beam commissioning of RCS on January 13th and user operation on January 21st with 200kW output. We stopped user operation by the end of the morning of February 10th and measured the residual dose after four hours from beam stop. Measurement values are surveyed on the surface of a vacuum duct.

We found that it was not so high to prevent from accessing the accelerator components in the RCS tunnel after the present user operation. However, there were some hot points that we could not ignore around the injection area.

At first, 2.0mSv/hr dose rate was observed on the duct between the septum magnet 1 and 2 in the beam transport line from the Linac. Since the residual dose could be observed only at the opposite direction of the injection H-beam orbit, it can be thought that the source of this residual dose was H0 particles or protons which were stripped one or two electrons by some reasons (collision with the residual gas or Lorenz stripping). It was that the residual dose at this point is proportional to the beam power [2]. This result indicates that the residual dose on contact would be about 10mSv/hr after four hours with 1MW routine operation, and this value is not too high to maintain these components.

Second significant loss was observed at the branch of H0 dump line and the Beam Position Monitor (BPM) put at the downstream of the H0 dump branch. The residual doses on contact of these points were more than 5mSv/hr after four hours cooling.

There were no significant losses except above mentioned points and the ring collimators [2]. Therefore we investigated the source of the losses at the H0 dump branch duct and downstream BPM and considered counter measures on aiming at the further high output.

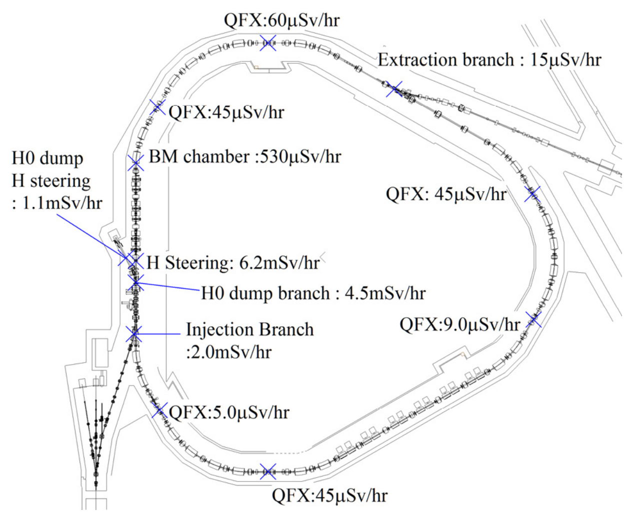

Figure 1: Residual radiation level after beam shutdown. 4 hour after 200kW 20days operation (10th Feb., 2011).

STUDY RESULTS OF THE LOSS AT INJECTION AREA

From the following beam study, we were certain that these losses were caused by the scattering of the injection and circulating beam at the charge exchange injection foil. Figure 2 shows the BLM signal dependence on the number of the foil hit at the H0 dump branch and BPM. Left figures are the integration of the loss monitor signals and right figures are integration values normalized by the number of the foil hit. It can be shown that there is a strong correlation between the BLM response and the number of the foil hit. When we used the painting injection, the number of the foil hit was reduced and BLM signal became smaller. This result indicated that it was proportional to the number of the foil hit [3]. Thus we tried to use a smaller foil in order to reduce the number of foil hit.

But when we use the smaller foil, the charge exchange efficiency became worse and increased non-exchanged fraction caused activation along the dump line.

It was found that such worse charge exchange efficiency was due to the wider Linac beam profile. We were not able to choose enough smaller foil, so we started to develop additional collimation system as the alternative way.

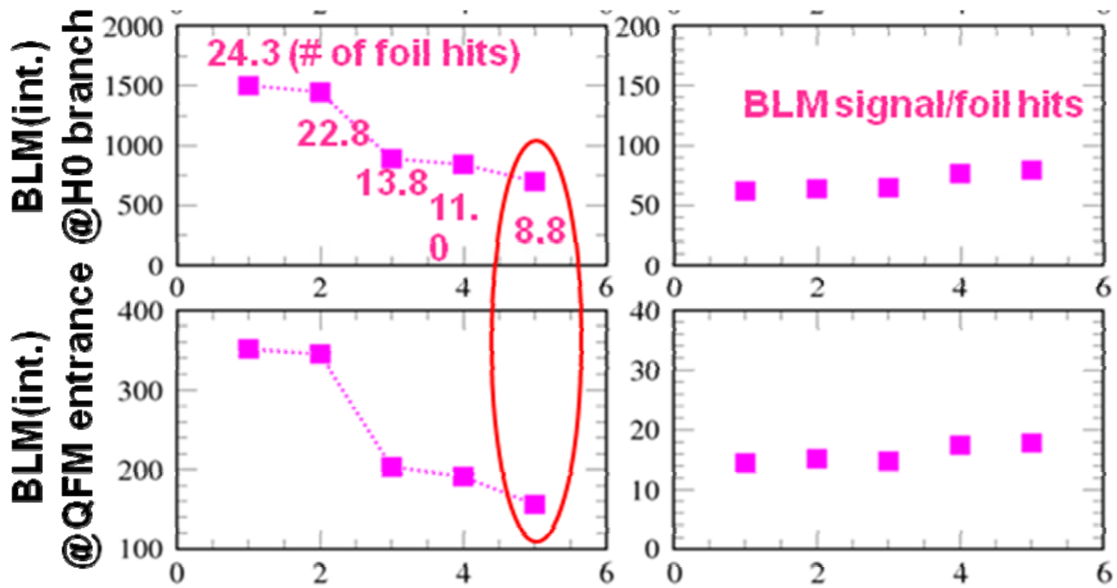

Figure 2: BLM signal dependence on the number of foil hit.

ADDITIONAL COLLIMATION SYSTEM

Simulation of the Scattered Particles

In order to optimize the additional collimator design, we investigated the orbits of lost particles around the loss point by the SAD code. Figure 3 shows the calculation orbits of scattered particles.

In this calculation, we assumed that scattered particle was kicked from +30mrad. to –30mrad by the foil, and calculated the trajectory of those scattered particles with the magnetic field of the quadrupole and the injection bump magnets. As a result, the particles with very large scattered angle were localized on the branch duct of H0 dump. Moreover, when we inserted a collimator in the downstream of the branch and set it at a position that corresponds to 486πmm-mrad aperture, The BPM loss was reduced and those lost particles were localized on this new collimator. More detailed simulations were performed by using the SAD and GEANT4 codes [4].

Hardware Design

The new collimator was designed to add to existing vacuum chamber of the H0 dump branch. Present location of the existing vacuum chamber of the H0 dump branch is shown in Fig. 4. This new collimation system consists of two horizontal blocks (right and left). These collimator blocks are made of copper, with their thickness set to be 200mm. This value is set so that protons of hundreds of MeV are stopped adequately.

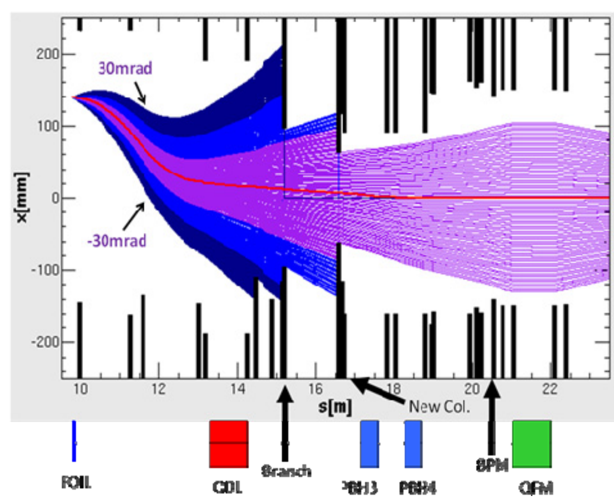

Figure 3: Orbit of the scattered particles by the foil. The scattering angle was varied ±30mrad and large scattered particles are well localized on the branch and new collimator.

The collimator needs to adjust the angle along the beam axis and its position by operating conditions. Because of the existence of the septum magnet, all mechanisms for position and angle adjustment must be installed on the opposite side of the septum magnet. Figure 5 shows the cross section of the collimator chamber. The collimator movable part has two bellows, one is for position adjustment and another is for angle adjustment. Movable range is from 50mm to 95mm and it is enough to choose all operating conditions($6.0<\nu_x$, $\nu_y<7.0$). The adjustable range of the angle is from -1degree to +1 degree.

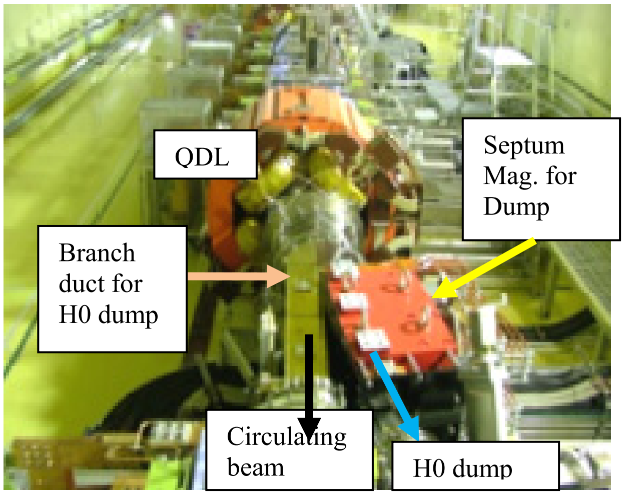

Figure 4: Location of the H0 dump branch.

The heat load at one collimator block is assumed to 100W. This value is estimated from the actual beam study and has enough margin. The collimator blocks are connected with the thermal conductors and it transmits 100W heat load to the outside from the vacuum. Cooling fins are welded on the outside of the conductor and those fins are cooled by natural air. Thus we choose the material of the collimator as copper. ANSYS calculation indicates that temperature rise of the collimator block is about 50degree with 100W heat load if the natural air is kept to 30degree.

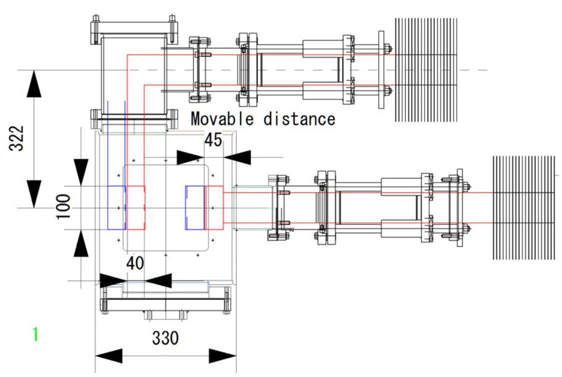

Figure 5: Cross section of movable collimator chamber.

Design of the Radiation Shielding

The radiation shield design of collimator is carried out by MARS code. In this model, the collimator vacuum chamber is covered with 450mm iron shield and beam loss was assumed to localize on just branch of the duct. The amount of the lost beam was assumed to 100W. The MARS calculation result is shown in Fig. 6.

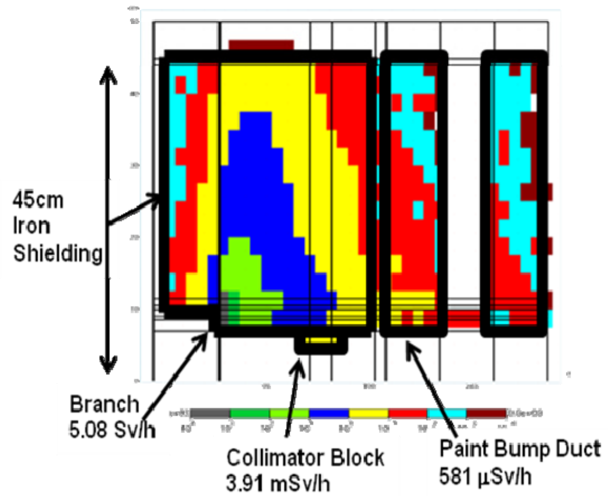

Figure 6: Residual dose estimation result.

This result expresses the residual dose distribution of the collimator and its shield after 1month operation and 1day cooling. In this result, the branch is activated over 1Sv/h, but the surface of the shielding is activated mostly under 1mSv/h and this value is almost same as the dose level of 1W/m region. The personal doses by the radioactivation level of the collimator can suppress by the shielding.

Other Development Items

We are also developing other items to establish enough performance of new collimator system: Development of SUS430 vacuum duct in order to reduce the fringe field from septum magnet and measurement of the out gas rate from SUS430 chamber [4, 5]. We continue to design the easy maintenance system as well.

CONCLUSION

We investigated the source of the losses around the injection area and considered countermeasures. As a result, we judged that new collimation system can enough reduce these losses. This new system will install in this year and will test on January 2011.

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