DESIGN OF DYNAMIC COLLIMATOR FOR J-PARC MAIN RING

M. Tomizawa#, A. Molodozhentsev and M. Shirakata, KEK, Ibaraki, Japan

Abstract

The J-PARC main ring has a beam collimator section downstream of the injection area. The allowed beam loss is about 450 W. The beam halo generated before acceleration can be scraped by a standard collimator scheme. However the beam halo can grow during the acceleration. Such a halo may cause a serious beam loss at the extracion. A collimation during acceleration (dynamic collimator) is useful to reduce the beam loss at the extraction. We propose the dynamic collimator scheme and show the performance expected from the simulations.

INTRODUCTION

The J-PARC accelerator complex comprises a 400 MeV linac, a 3 GeV rapid cycle synchrotron (RCS) and a 50 GeV main ring (MR). In the first stage of operations, the linac energy is 181 MeV, and the extraction energy for the MR is limited at 30 GeV both for the fast-extraction and the slow extraction [1].

The MR with three fold symmetry has three 116.1 m long straight sections and 406.4 m long arc sections. The long straight sections have zero dispersion. These long straight sections are assigned for injection, extraction, beam collimation and RF [2].

The extraction acceptance is determined by apertures of magnetic septa and adjacent quadrupole magnets. An accumulator ring like SNS can have the acceptance larger enough than the ring collimator aperture. This case, no loss due to the aperture limitation is expected at the extraction. In case of the synchrotron, adiabatic dumping works during acceleration. However, the emittance growth can continue during acceleration, especially at the beginning of the acceleration. The extracted beam emittance including the halo is expected to be larger than the emittance expected from the adiabatic dumping. For the J-PARC main ring, the ring collimator aperture is chosen to be 54π mm·mrad. On the other hand, the fast extraction acceptance is 19.5π mm·mrad [3,4]. We have designed the dynamic collimator scheme, which can scrape the beam halo generated during acceleration in order to avoid the beam loss at the extraction.

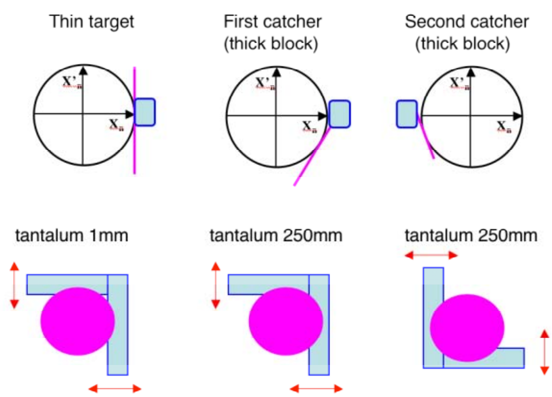

Figure 1: Principle of three-stage beam collimation and the target and catcher jaws.

DESIGN PRINCIPLE

As shown in figure 1, we utilize three-stage collimation concept, which comprises a thin target, first catcher and second catcher with thick blocks. In the present design, the target and the following catcher jaws have L-shape. Therefore, the horizontal and vertical collimations are done at the same place. The L-shape jaws for the target and the first catcher are set at the same side and opposite for the second catcher. The design principle of the dynamic collimator is as followed;

- The collimation is done up to energy where halo generation due to the space charge force becomes negligible. We chose such energy at 9 GeV in the present design.
- The jaws are set at the position corresponding to

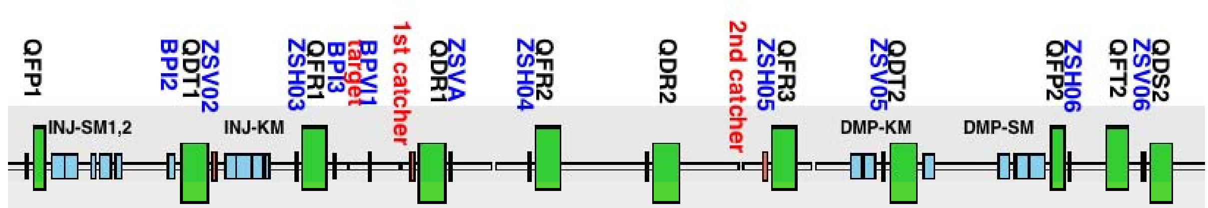

Figure 2: Layout of proposed dynamic collimator system

#masahito.tomizawa@kek.jp

54π mm·mrad at the injection energy and not moved during acceleration. During acceleration, horizontal and vertical bump orbits are made so as to optimize the collimation at the catchers as well as scraping at the target. We utilize the injection bump magnets and the steering magnets for the COD correction as many as possible. The steering strength for the COD correction is kept during excitation of the bump orbit.

- Thickness of the target and the catchers is optimized by considering the effective collimation from 3 up to 9 GeV.

DYMAMIC COLLIMATOR DESIGN

The collimator section is located downstream from the injection region in the long straight section. This secton consists of a regular FODO lattice with phase advance of 90 deg per one cell for both horizontal and vertical planes. This phase advance is constant even if the tunes in the ring are changed.

Location of the primary target, the first and second catchers is shown in Figure 2. Table 1 shows relative phase relation between the target and the catchers, which is carefully chosen to obtain a high collimation efficiency.

Table 1: Relative phase relation between the target and the catchers.

	$\Delta\Phi$x(deg)	$\Delta\Phi$y(deg)
Target	0	0
First catcher	17	15
Second catcher	160	114

Target and catcher material is tantalum, which is same as that for the transport line collimators. Thickness of the target is 1 mm, which is chosen to give a suitable angular spread so as to collimate at the catchers. Thickness of the catchers is 250 mm, which is chosen to stop particles scattered by the target in the range from 3 GeV to 9 GeV.

The horizontal bump orbit is made by four horizontal steering magnets for the COD correction (ZSH03, ZSH04, ZSH05, ZSH06) and two injection bump magnets to make bump orbit for the injection (BPI2, BPI3). The vertical bump orbit is made by 4 vertical steering magnets (ZSV02, ZSVA, ZSV05, ZSV06) and an additional magnet (BPVI1). The ZSVA is moved from upstream to downstream of the QDR quadrupole.

BEAM COLLIMATION PERFORMANCE

The STRUCT code[5] was used to simulate an interaction process with the jaws and the related beam tracking. All elements in the STRUCT input are converted from output of the SAD code through a filter program made for this purpose. Realistic aperture shapes of vacuum ducts in the lattice magnets are given in the STRUCT input.

First we simulated the collimation at 3 GeV energy. The bump orbit is not made at this energy. Figure 3 shows transverse phase space and momentum distributions at the exit of the target. Initial beam emittance for both planes is 54π mm·mrad, and momentum spread $\Delta p/p=\pm0.63\%$. The target jaw position was determined so as to hit the beam edge slightly. The middle of Figure 3 shows the distributions at the exit of the second catcher. Particles

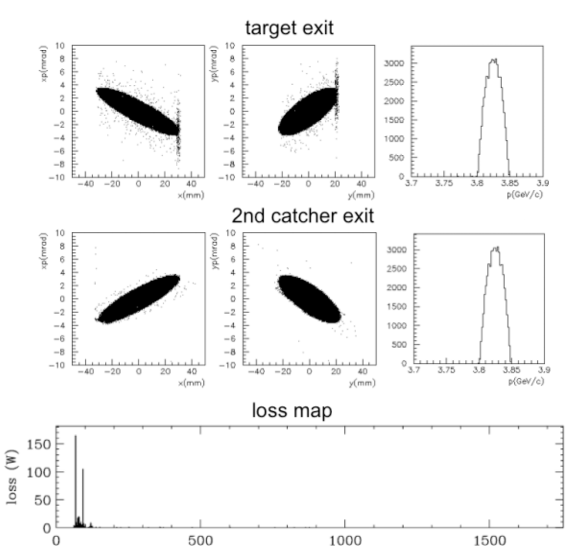

Figure 3: 3GeV Beam distributions at the exit of the target, the 2nd catcher and the beam loss map.

Table 2: Parameters of the magnets used to make bump orbit for the dynamic collimation.

L(m)	B(T)	name
0.5	−0.077	BPI2
0.2	−0.112	ZSV02
0.2	−0.006	ZSH03
0.2	0.030	BPI3
0.2	0.136	BPVI1
0.2	0.013	ZSVA
0.2	0.011	ZSH04
0.2	−0.020	ZSH05
0.2	0.033	ZSV05
0.2	0.077	ZSH06
0.2	0.118	ZSV06

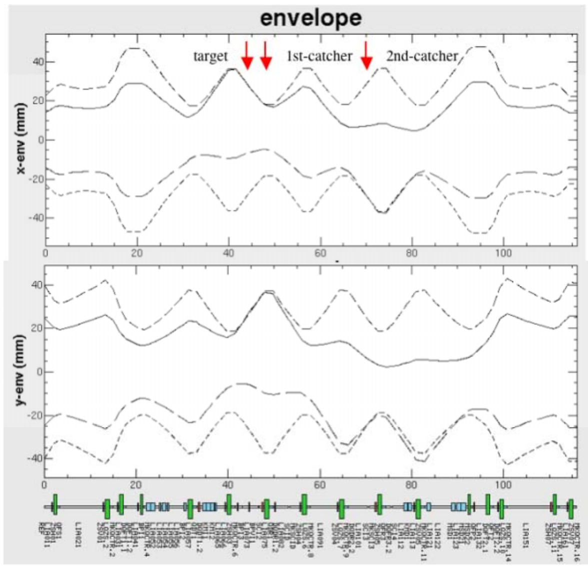

Figure 4: Beam envelopes at 9 GeV (inside lines) and 3 GeV (outside lines).

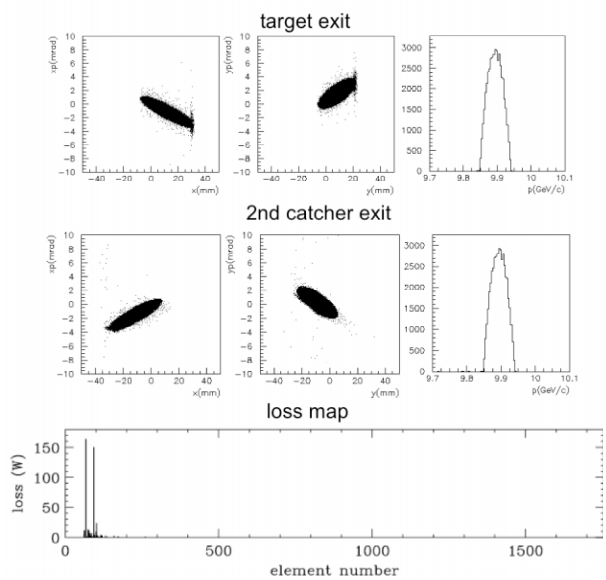

Figure 5: 3GeV Beam distributions at the exits of the target, the 2nd catcher and the beam loss map.

scattered by the target is well collimated by the first and second catchers. Lower in Figure 3 shows the beam loss map in the whole ring. The loss area is well localized around the collimator section. High collimation efficiency is obtained for this condition.

Next we examined the collimation performance at 9 GeV energy. Beam emittance for both planes is 20.9π mm·mrad, and momentum spread $\Delta p/p$=±0.47%. In this case, the bump orbit is excited so as to scrape and collimate particles with the emittance larger than 20.9π mm·mrad (see Figure 4). Parameters of the magnets to make the bump orbit are listed in Table 2. The steering magnets have enough margin to correct the COD at this energy. Figure 5 shows transverse phase space and momentum distributions at the exit of the primary target and the second catcher. Particles scattered by the target is well collimated by the first and second catchers also at this energy. Lower in Figure 4 shows the beam loss map in the whole ring. The loss area is localized around the collimator region. Therefore high collimation efficiency is attained also at this energy.

CONCLUSIONS

We have designed the three-stage dynamic collimation scheme for the J-PARC main ring. In the present study, beam halo up to 9 GeV energy can be well scraped and collimated by making the bump orbit around the collimator section. The beam simulation shows the good collimation performance for both 3 GeV and 9 GeV. We believe the dynamic collimation scheme proposed in this paper would greatly contribute to reduce the beam loss at the extraction.

REFERENCES

[1] M. Tomizawa, "Machine Status of J-PARC", Nuclear Physics B (Proc. Suppl.) 154 (2006)123-128

[2] Accelerator Group JAERI/KEK Joint Project Team, "Accelerator Technical Design Report for J-PARC", KEK Report 2002-13, March 2003.

[3] M. Tomizawa, Y. Kamiya, H. Kobayashi, I. Sakai, Y. Shirakabe, "Injection and Extraction Orbit of the J-PARC Main Ring", Proc. of EPAC06, p1987-1989.

[4] M. Tomizawa, A. Molodozhentsev, E. Nakamura, I. Sakai and M. Uota, "New Optics Design of Injection/Extraction/Abort Line of the J-PARC Main Ring", these proceedings.

[5] A. Drozhdin and N. Mokhov, "The STRUCT Program: Users Reference Manual", Sep. 17, 1999.

