NEW OPTICS DESIGN OF INJECTION/FAST EXTRACTION/ABORT LINES OF J-PARC MAIN RING

M. Tomizawa#, A. Molodozhentsev, E. Nakamura, I. Sakai and M. Uota, KEK, Ibaraki, Japan

Abstract

The J-PARC Main Ring has three straight sections for injection, slow extraction and fast extraction. Injection line has been redesigned so as to give a higher reliability for the thin septa. The magnetic field can be reduced by adding an extra kicker. Alternative optics for the fast extraction with a larger acceptance has been proposed. In this design, the thin septa are replaced by kickers with a large aperture. Beam with an arbitrary energy can be aborted from opposite side from the fast extraction. An external abort line has been designed to deliver the beam aborted at an arbitrary energy to a dump just by using a static quadrupole doublet for the focus.

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 three 406.4 m long arc sections. The MR has an imaginary γ_t lattice in order to avoid the beam loss during transition crossing[2]. The long straight section has zero dispersion. These long straight sections are assigned for injection, extraction, collimation and RF (see Figure 1). We report a recent progress of beam optics design on the injection, fast extraction and external abort line.

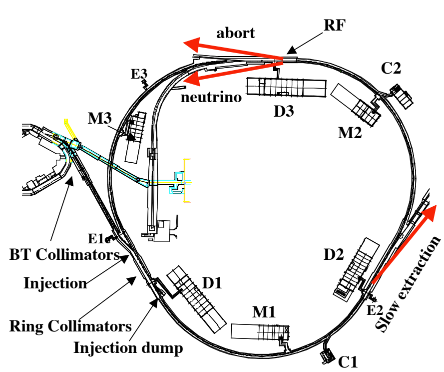

Figure 1: Layout of the MR.

#masahito.tomizawa@kek.jp

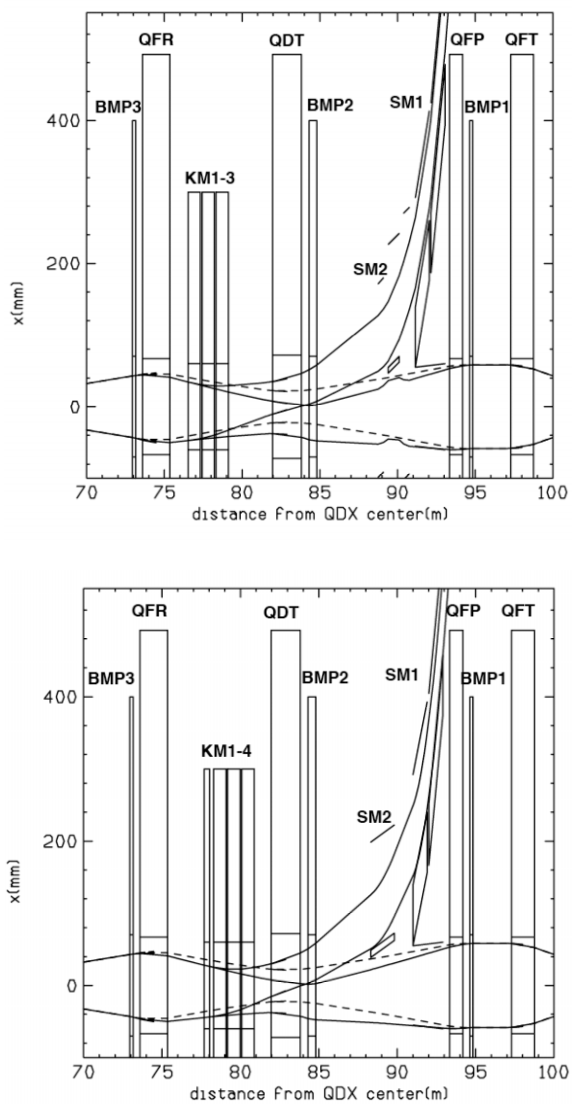

Figure 2: Injection beam orbit. Upper is from ref. [3]. Lower shows new version designed for low field of the SM2.

INJECTION

The injection device to the MR consists of the 2 magnetic septa (SM1, SM2), kickers and three bump magnets (BMP1-3). The defocusing quadrupole magnet (QDT) is located between the septa and the kickers. The slow bump orbit to opposite side from the injection to keep an enough turn separation between the injection and circulating beam envelope at the SM2 clearing the QDT

Table 1: Injection septa/kickers parameters

		unit	length (m)	angle (mrad)	Field (T)
#Inj014	SM1	1	1.8	192	1.36
	SM2 (opposite field)	1	1.4	66	0.6
	KM1-3	3	0.8	2.18	0.0348
#Inj023	SM1	1	1.8	220	1.556
	SM2 (opposite field)	1	1.4	36.6	0.334
	SM2 (eddy current)	1	1.5	36.6	0.312
	KM1-3	3	0.8	2.62	0.0418
	KM4	1	0.35	0.85	0.0310
#Inj026	SM1	1	1.8	208	1.474
	SM2 (opposite field)	1	1.4	48.2	0.439
	SM2 (eddy current)	1	1.5	48.2	0.410
	KM1-3	3	0.8	2.55	0.0407
	KM4	1	0.35	0.85	0.0310

aperture. The bump orbit can be turned off after the beam injection.

Figure 2 shows injected and circulated beam envelopes for the 81π mm·mrad + COD 1mm. Upper in Figure 2 shows beam envelopes for the original design (#inj014) [3]. The SM2 is, an "opposite field" type, which comprises three magnets [4]. This design requires 0.6 T for the opposite field septum operated at a short pulse excitation. We have redesigned the beam optics according to a request to secure a higher reliability for the SM2. In this new design (#inj023), the kickers are moved to upstream than #inj014 and one more kicker is added to keep enough turn separation at the exit of the SM2. As a result, the field required for the SM2 decreases to roughly half. This design enables us to use eddy current type without current sheet for the SM2. However, the acceptance/emittance ratio is reduced from 2 to 1.5. This may cause a serious beam loss around injection area. We also have proposed a compromise version (#inj026) between #inj014 and #inj023. The parameters of #inj014, 023 and 026 are listed in Table 1. At present, the #inj023 scheme with the eddy current type has the first priority for the first beam commissioning. This injection scheme may be again modified when the beam intensity increased and beam loss at the injection region become serious.

FAST EXTRACTION

The third long straight section is assigned for the fast extraction. A beam line for the neutrino oscillation experiment goes inside from the ring, on the other hand, a beam abort line goes outside. The fast extraction system comprises 5 kicker magnets and 14 magnetic septa which give a bipolar kick to both sides [5]. Parameters of the kickers and the magnetic septa for this reference design are listed in Table 2. Figure 3 (upper) shows envelops for extracted beam together with the injected beam with 81π mm·mrad+1mm(COD). The emittance of extracted beam envelope is 10π mm·mrad, which is 1.5 times larger than the adiabatic dumping value to 30 GeV extraction energy for 54π mm·mrad at 3 GeV injection energy. The

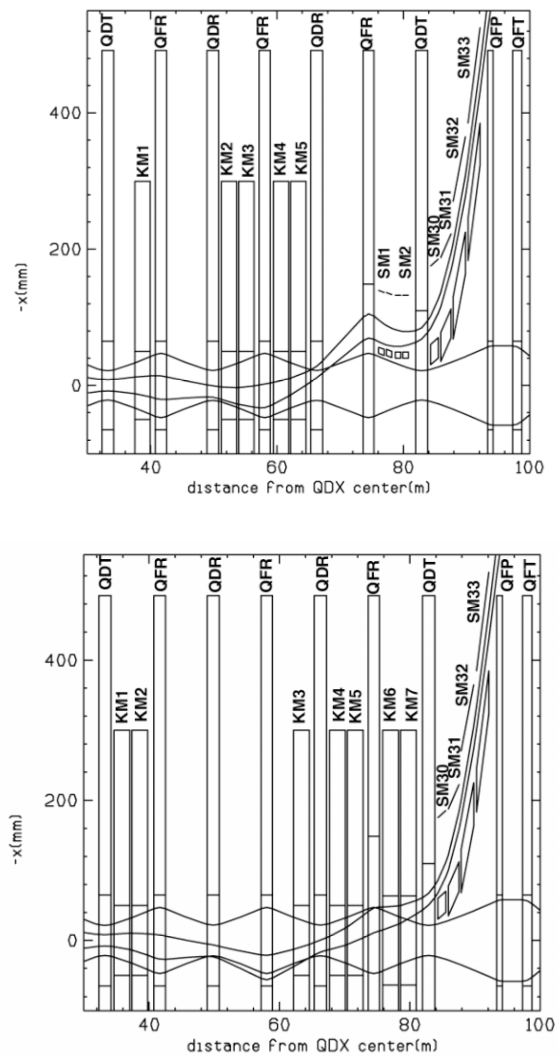

Figure 3: Fast extraction beam orbit. Upper is reference design. Lower shows alternative design.

acceptance of this extraction line is 19.5π mm·mrad, which is limited by the QFR and SM1 apertures.

Table 2: Parameters of fast extraction

		unit	length (m)	angle (mrad)	Field (T)
reference design	KM1-5	5	2.43	1.18	0.0501
	SM1-2	4	0.875	2.364	0.279
	SM30	1	1.225	9.69	0.816
	SM31	1	1.66	16.01	1.01
	SM32	1	1.9	18.23	1.01
	SM33	1	1.9	18.23	1.01
alternative design	KM1-2	2	2.43	1.12	0.0475
	KM3	1	2.43	0.744	0.0316
	KM4-5	2	2.43	1.55	0.0658
	KM6-7	2	2.43	2.07	0.0879
	SM30	1	1.225	11.95	1.01
	SM31	1	1.66	20.1	1.25
	SM32	1	1.9	15.49	0.841
	SM33	1	1.9	15.49	0.841

On the other hand, we have proposed an alternative extraction scheme. In this scheme, the thin septa are replaced by two additional large aperture kickers. The present five kickers can be utilized just by arranging the location (see lower in Figure 3). Since this scheme has a large acceptance of 38π mm·mrad, the beam loss at the extraction is expected to be reduced. However this scheme needs a new large aperture kicker and limit the extraction energy around 30 GeV, since it needs large kick angles for some of the kickers as shown in Table 2.

ABORT EXTRACTION

The beam with arbitrary energy in the range from the injection to the top can be aborted when an interlock system is fired. Since the beam size at the low energy is large, the beam edge hits on the vacuum chamber in the quadrupole magnets. But a residual activity by this beam loss can be small, since the beam abort does not frequently occurs. A mechanical damage at the vacuum chamber or the quadrupole poles due to the beam hit is also neglected, since an energy deposit per volume is small for the large beam size at the low energy.

An abort dump is located at about 71 m downstream from the last magnetic septum (SM33) exit. The beam duct in the dump has an inner diameter of $^{\phi}$738 mm. Even if any focusing element is not used in the 71 m beam line, 3 GeV beam with 54 π mm·mrad can be accepted in this duct. A quadrupole doublet can reduce the beam size at the duct end. This would give a larger margin for the kick angle error of the beam from the ring. The quadrupole doublet is located at about 10 m from the exit of the last magnetic septa (SM33). The quadrupole doublet is operated at DC mode and excited by one power supply. The quadrupole strength is chosen to minimize 3 GeV radial beam size at the dump position. The minimum radial beam size is about 100 mm for quadrupole strength of 3.04 T each. The focusing force by the quadrupole doublet reduces with increasing energy. Therefore it increases β function at the dump position. However, adiabatic dumping effect by acceleration decreases the beam emittance. As a result, aborted beam with any energy can be well delivered to the dump. Figure 4 shows aborted beam envelops at 3GeV and 30 GeV energies. The beam emittances are 54π and 10π mm·mrad, respectively. Figure 5 shows radial beam size as a function of aborted energy without any position and angular errors at the SM33 exit. The allowable position and angular errors at the exit of the SM33 are over ±30 mm and ±2 mrad at any energy.

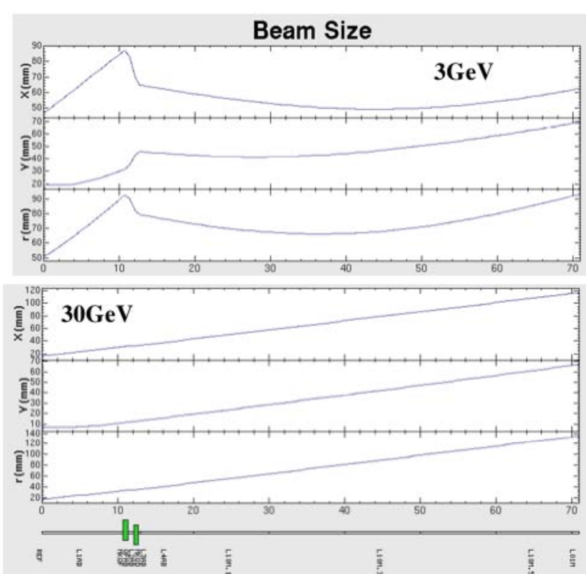

Figure 4: Abort beam envelopes.

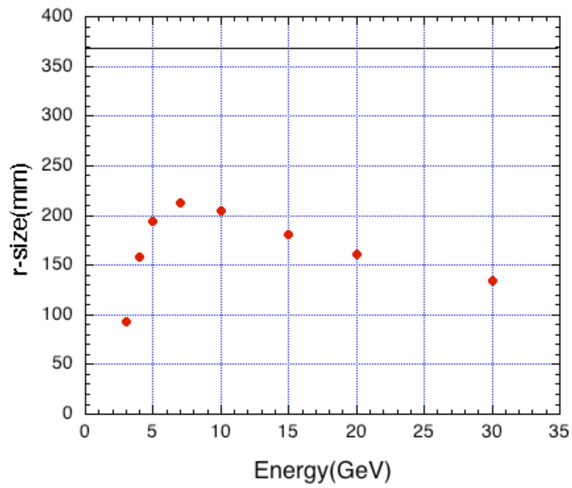

Figure 5: Radial beam size as a function of aborted energy.

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] I. Sakai, Y. Arakaki, K. Fan, M. Tomizawa, M. Uota, A.K. Kawasaki, H. Mori, A. Tokuchi, Y. Morinaga and A. Nishikawa, "Operation of the Opposite Field Septum Magnet for the J-PARC Main Ring Injection", these proceedings.

[5] Y. Shirakabe, Y. Arakaki, T. Kawakubo, Y. Mori, S. Murasugi, E. Nakamura, I. Sakai, and M. Tomizawa, "R&D Status of the Fast Extraction Kicker Magnets for the KEK/JAERI 50GeV Synchrotron", Proc. of the EPAC2004, p. 1333-1335.

 1-4244-0917-9/07/$25.00