BEAM TUNING OF INJECTION AND FAST EXTRACTION OF J-PARC MR

G.H. WEI[1], T. KOSEKI[1], S. IGARASHI[1], M. TOMIZAWA[1], K. ISHII[1], A. ANDO[1], M. UOTA, M. SHIRAKATA[1], J. TAKANO[1], K. SATOU, Y. HASHIMOTO[1], K. FAN[1], N. HATAKEYAMA[1], N. KAMIKUBOTA[1], T. NAKADAIRA[1], H. HARADA[2], P.K. SAHA[2], J.Y. TANG[3]

1 KEK, 2 JAEA, 3 IHEP

Abstract

The beam commissioning of J-PARC MR was started from May 2008 and is in progress. As usual, injection is in the very first stage and strongly related to other parts of MR commissioning including fast extraction to neutrino beam line, where extracted beams finally reflect the overall commissioning result.

INTRODUCTION

Aiming to attain 30 GeV proton beam for neutrino line and hadron line, the MR beam commissioning has been done [1] including injection and fast extraction items.

TUNING OF MR INJECTION

Injection design schemes for commissioning

MR injection system can be seen in Figure 1. For single-turn injection function, two Septa, three kickers and three bumps are installed. Septa and kickers act on injection beam only, while three bumps act on circulating beam and last two bumps act on injection beam also.

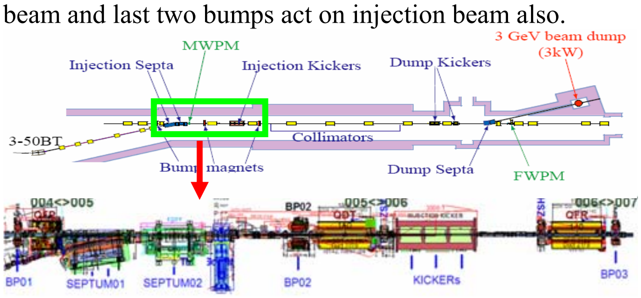

Figure 1: The layout of MR Injection section

For the MR commissioning, especially for beam tuning to neutrino beam line with an operation tune of (22.15, 20.75), two injection schemes are designed which are shown in Figure 2 and 3. The scheme in Figure 2 is simple for commissioning because three bumps are not used. Also based on this, name of "Without bump scheme" is given. Meanwhile the other one in Figure 3 is named "With bump scheme". "With bump scheme" has an advantage of larger acceptance for circulating beam than former, which can be seen from the relationship between circulating beam and septum II in Figure 2 and 3. Under current situation of injection beam with full emittance of 15 π mm-mrad in initial stage of beam commissioning, both schemes can be used.

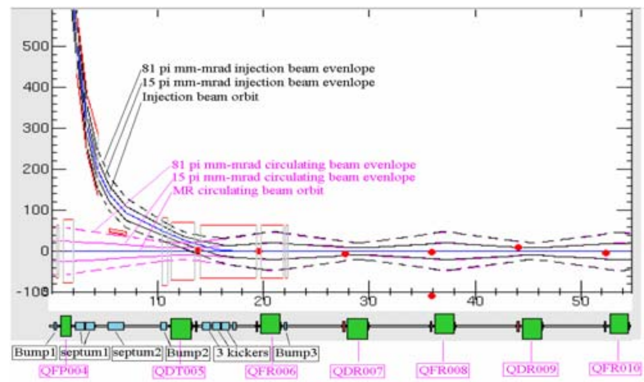

Figure 2: "Without bump scheme" of MR injection

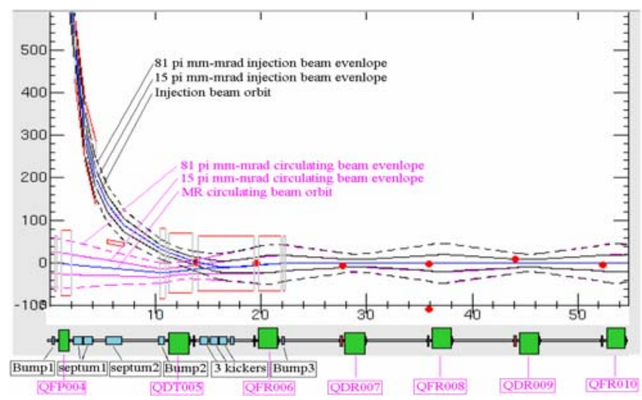

Figure 3: "With bump scheme" of MR injection

Injection orbit tuning of without bump scheme

Firstly, injection orbit was tuned before COD correction of the MR. In this step, beam positions at BPM in injection section in injection first turn were tuned to be same as design. Especially, Beam positions at MR BPM #6, #7, #8, and #9 which are located just left side of QDT005, QFR006, QDR007, and QFR008 were tuned to less than ± 1 mm.

Secondly, injection orbit was tuned follow MR closed orbit after COD correction of the MR. Because of leakage field of injection septa and other magnets, the MR closed orbit was not 0 on injection timing. Injection orbit should be tuned follow MR closed orbit which was shown in Figure 4. In commissioning, the MR closed orbit at certain BPM on injection timing was found by phase space plot with beam position data in starting several turns. In Figure 4 case, beam positions at BPM#6 and #8

#weigh@post.j-parc.jp

are fitted to sinusoidal curves. Beam closed orbits at BPM#6 and #8 are just the offsets of their sinusoidal curves. And due to the transport matrix from BPM#6 to #8, phase ellipse space with first 6 turn's data can be plotted as show in Figure 4 for BPM#6 and entrance of injection septum II. After correction, the amplitude of sinusoidal curves and area of phase ellipse spaces would become small as shown in Figure 4.

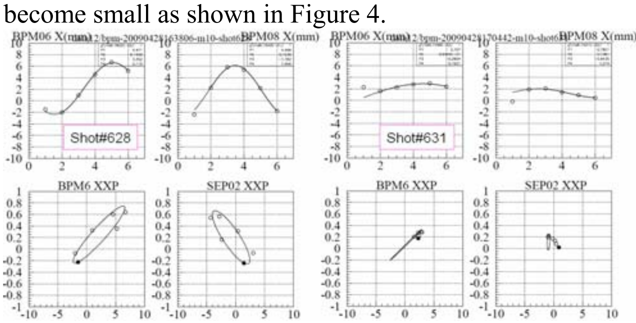

Figure 4: MR injection tuning after MR COD correction (left: before correction; right: after correction)

Injection orbit tuning of with bump scheme

For power increase in the future, "With bump scheme" was also tuned. Firstly, injection bump orbit was built in main ring. Due to real machine, a little different from design, bump orbit had also influence as distortion to MR closed orbit outside injection section. This distortion can be corrected by tuning injection by Micado method.

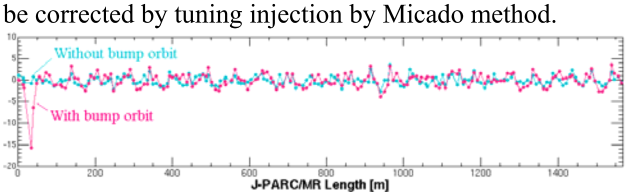

Figure 5: Show of the MR orbit with injection bump

Secondly, injection beam orbit was tuned follow the MR closed orbit again which was shown in Figure 6. This figure show that the MR closed orbit finding at certain BPM in injection timing was better done by 10 turns closed orbit fit than by only 6 turns closed orbit fit which shown in Figure 4.

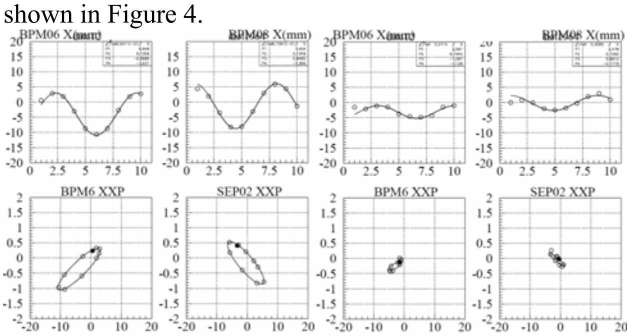

Figure 6 MR injection tuning after building bump orbit

Vertical orbit was also tuned. In real commissioning, this was tuned by measured response matrix between the last two vertical steering magnets in 3-50 BT and main ring BPM#5 and BPM#6.

The injection orbit tuning result can be also verified in the MR IPM show which can be seen in Figure 7.

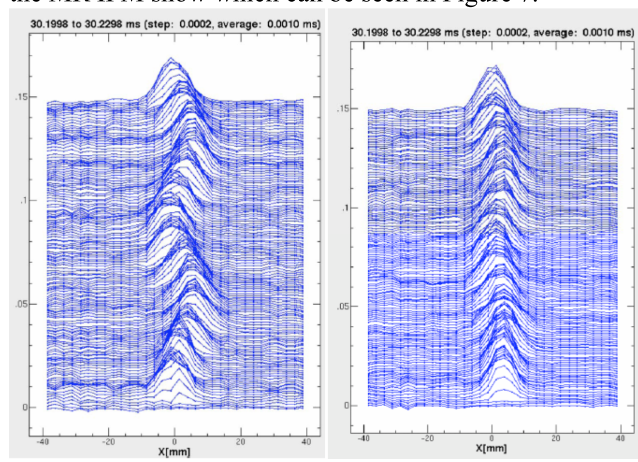

Figure 7: MR IPM record of injection orbit tuning (left: before correction; right: after correction)

Injection Optics matching

Besides injection orbit tuning, injection optics matching had been well done also. In commissioning, new excitation curve of 3-50 BT magnets, beam size data from last two profile monitor and injection profile monitor were used for urgent calculation. After using new excitation curve and changing of one quadrupole magnet which was shown in Figure 8 [2], injection optics matching had been well done which can be seen from picture 1 to picture 4 in Figure 8 of beam profiles at the MR IPM on injection timing. And beam loss in the MR was also improved too.

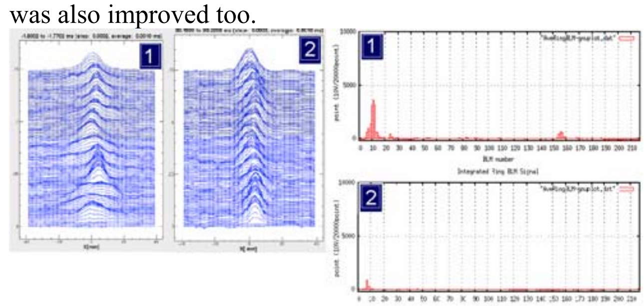

Figure 8: MR injection optics matching and corresponding beam loss (1: mismatched; 2: matched)

The MR circulating beam profiles were also attained by FWPM in The MR before and after optics matching. Distribution of these two profiles can be explained by injection dilution theory [3] which can be seen in Figure 9. The ratio of dilution beam size and non-dilution beam size can be calculated by follow equation.

$$\eta = \frac{b}{a} = \frac{\varepsilon_3}{\varepsilon_1} = \xi + \sqrt{\xi^2 - 1} \quad (1)$$

Where,

$$\xi = \frac{1}{2}\left(\frac{\beta_1}{\beta_2} + \frac{\beta_2}{\beta_1} + \frac{\beta_1}{\beta_2}\left(\alpha_2 - \frac{\beta_2}{\beta_1}\alpha_1\right)\right) \qquad (2)$$

Here, β_1 α_1 means mismatched twiss parameter while β_2 α_2 means matched ones. For the MR injection case, $\beta_1 = 13.6$ m, $\alpha_1 = -0.32$, $\beta_2 = 15.6$ m, $\alpha_2 = -1.56$ at exit of injection kickers, so The ratio of dilution beam size and non-dilution beam size is about 3, which coincided with measured beam profiles in the MR commissioning.

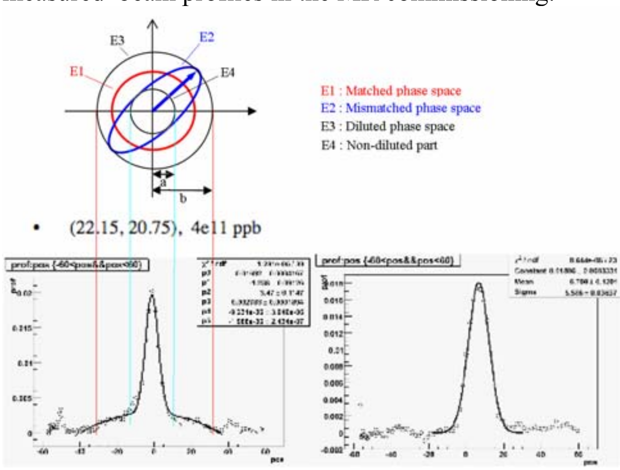

Figure 9: Explanation of MR injection optics matching (left: mismatched; right: matched)

TUNING OF MR FAST EXTRACTION

Tuning of Beam to Neutrino Beam Line

The MR third straight section is assigned for the fast extraction shown in Figure 10. 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 five kicker magnets and twelve septa which give a bipolar kick to both sides.

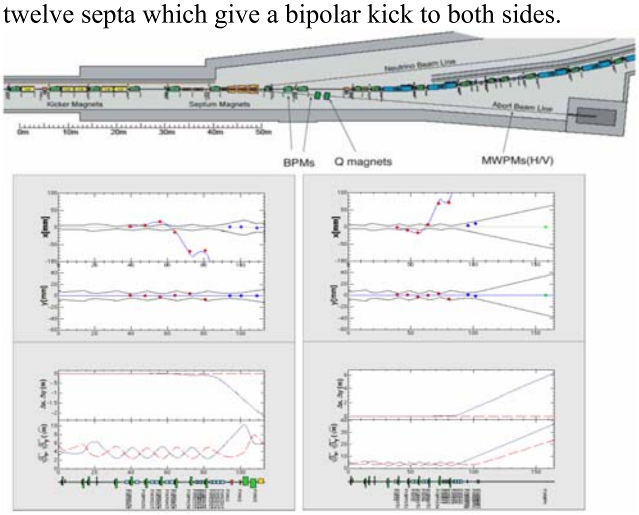

Figure 10: Layout of MR Fast Extraction (up) and extraction orbit to neutrino beam line (down-left) and to abort beam line (down-right)

Based on layout and design of The MR fast extraction in Figure 10, 30 GeV beam orbit to neutrino beam line was corrected by the SAD CODE.

Tuning of Beam to Abort Beam Line

There are two modes for beam to abort beam line, 30 GeV mode and 3 GeV mode. Show of 30 GeV mode can be seen in right-down picture in Figure 10. Based on calculation in Figure 11, 3 GeV mode was tuned too, whose beam sizes at profile monitor just before dump were same as simulation which were shown in Figure 12.

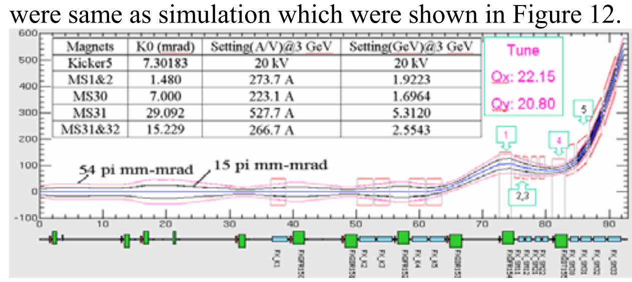

Figure 11: MR 3 GeV beam tuning to abort line

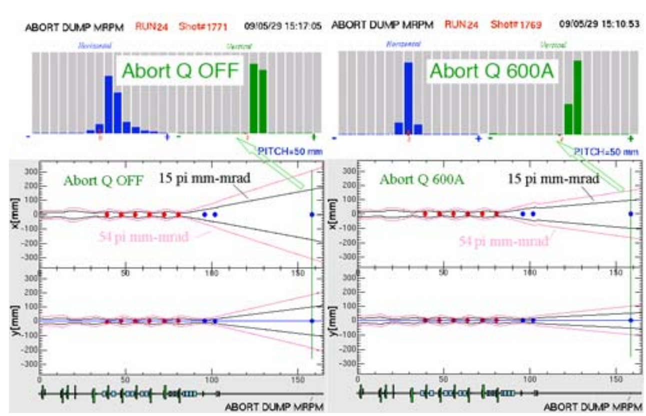

Figure 12: MR 3 GeV beam tuning to profile monitor in abort line

SUMMARY

Starting from May of last year, The MR commissioning is in good progress. The injection and extraction commissioning in initial stage of beam commissioning were done smoothly and is in full cooperation with the MR overall commissioning.

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