BEAM INJECTION TUNING OF THE J-PARC MAIN RING*

G.H. Wei[2#], T. Koseki[1], S. Igarashi[1], M. Tomizawa[1], J. Takano[1], K. Ishii[1], M. Shirakata[1], K. Fan[1], N. Hatakeyama[1], M. Uota[1], K. Satou[1], Y. Hashimoto[1], A. Ando[1], H. Harada[2], P.K. Saha[2],
[1]KEK/J-PARC, Tokai, Japan; [2]JAEA/J-PARC, Tokai, Japan

Abstract

The beam commissioning of J-PARC (Japan Proton Accelerator Research Complex) MR (Main Ring) was started from May 2008 and is in progress. As usual, injection tuning is in the first stage and strongly related to other tuning items. Starting with design schemes, making adjustment due to leakage field influence from injection septum, doing envelope matching considering dilution of beam profile in Main Ring are reported in this paper.

INTRODUCTION

3 GeV beam from J-PARC RCS (Rapid Cycling Synch-rotron) is tuned to inject into MR with a maximum 1.2×10^{13} protons per pulse at a repetition rate of 25 Hz[1].

TUNING OF MR INJECTION

Injection Design Schemes for Commissioning

MR injection system can be seen in Figure 1. It is located after 3-50BT, beam transport line between the RCS and the MR. For single-turn injection, two Septa, three kickers and three bumps are installed, while the second septum is an eddy current type.

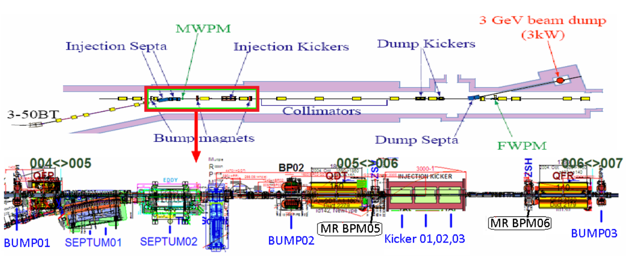

Figure 1: The layout of MR Injection section.

For the MR commissioning, 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 the former, which can be seen from the relationship between circulating beam and septum 02 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.

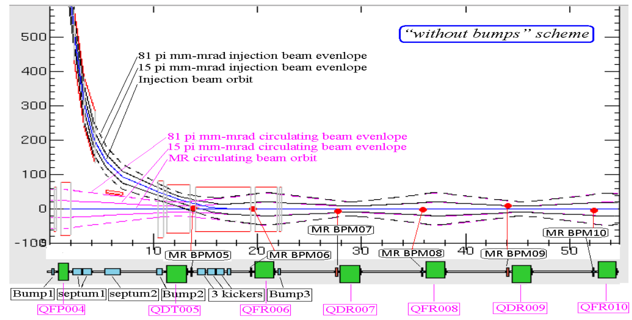

Figure 2: "Without bump scheme" of MR injection.

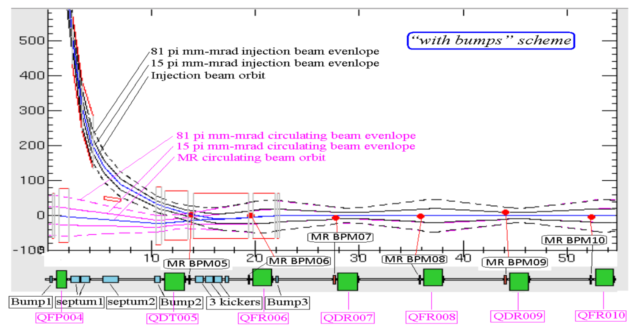

Figure 3: "With bump scheme" of MR injection.

Injection Orbit Tuning of Without Bump Scheme

At beginning, injection orbit was tuned follow the designed "Without bump scheme". Beam positions at BPM in injection section in first turn were tuned to be same as design. Especially, Beam positions at MR BPM 06, 07, 08, and 09 which are located just upstream of QDT006, QFR007, QDR008, and QFR009 were tuned to be less than ± 1 mm, which can be seen in Figure 4.

Figure 4: Orbit tuning due to "Without bump scheme".

*Work supported by KEK
#weigh@post.j-parc.jp

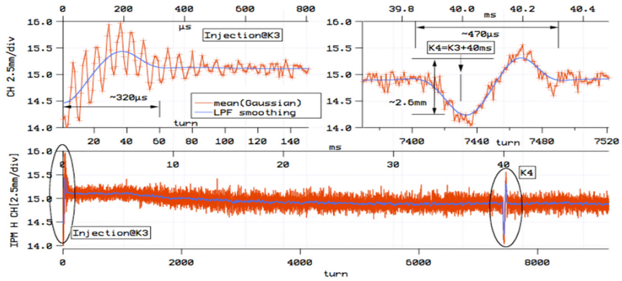

Figure 5: Analysis of MR horizontal beam position data at IPM (1st black circle: at injection timing; 2nd black circle: at latter fired timing of the injection septum 02).

After MR COD correction, leakage magnet field influence from injection septum 02 had been found, which would give an orbit oscillation to the MR closed orbit in its firing time. As shown in Figure 5, 2.6 mm orbit oscillation in 470 µs appeared in MR closed orbit at IPM (residual gas Ionization Profile Monitor). And MR closed orbit was also oscillated in 320 µs at the beginning, about 60 turns after injection.

Thus, injection orbit should be tuned following this oscillated closed orbit. In commissioning, first 10 turns' data of MR BPM were analysed to get the MR closed orbit at the beginning of injection. For example, as shown in Figure 6, beam positions at BPM06 and BPM08 were fitted to sinusoidal curves. The centres of these two sinusoidal curves, 2.0 mm and 0.0 mm, were just MR closed orbit position at BPM06 and BPM08.

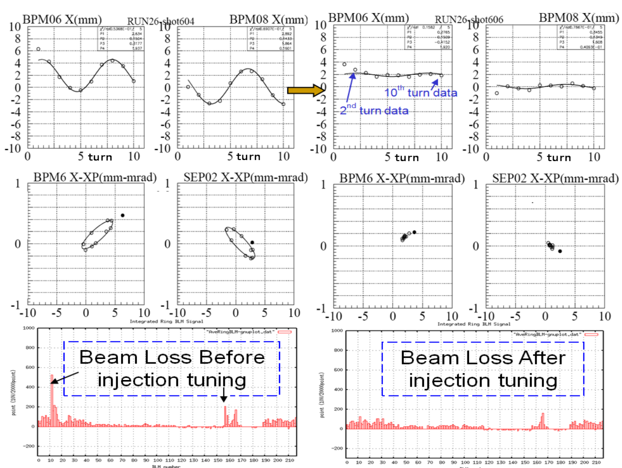

Figure 6: MR injection tuning after MR COD correction (left: before correction; right: after correction).

And considering the transport matrix from BPM06 to BPM08 and other one from injection septum 02 to BPM06, phase ellipse space at BPM06 and entrance of injection septum 02 can be calculated as shown in Figure 6. Then according to the (x, x') of phase ellipse centre and calculated (x, x') at 1st turn, adjusting displacements and angles for the injection orbit at BPM06 and injection septum 02 can be attained just by the difference of these two (x, x'). With operation interface made by codes SAD, changing value of injection magnets can be got to fit these adjustments. After correction, the amplitude of sinusoidal curves and area of phase ellipse spaces would become much smaller as shown in right side of Figure 6. And the beam loss in MR was reduced obviously too. Meanwhile, in real commissioning, data from MR BPM06 and MR BPM08 were selected for analysis also because large horizontal envelope was located at these two BPMs. Higher precision for adjustment can be got according to the jitter of BPM data, etc. Finally horizontal orbit oscillation around the closed orbit at injection time can be reduced to less than ±0.5 mm of its amplitude.

So for vertical orbit tuning of MR injection, data from MR BPM07 and MR BPM09 were selected to do analysis as shown in Figure 7. For correction, two vertical steering magnets in the most downstream part of 3-50BT were used to give adjustment. Also vertical oscillation around closed orbit at injection time can be reduced to less than ±0.5 mm in its amplitude.

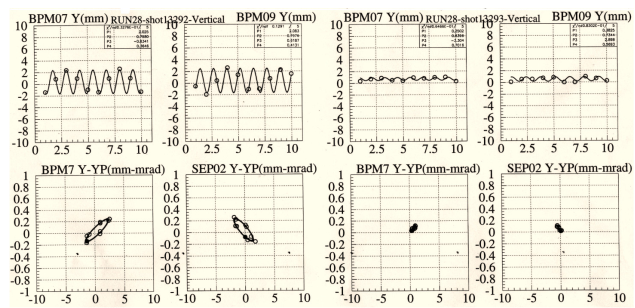

Figure 7: MR injection tuning after building bump orbit.

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 MR. Due to real machine, bump orbit building also introduced distortion to MR closed orbit outside injection section. This distortion can be corrected by the Micado method. Then about 20 mm height closed bump orbit was built in injection section whose peak was located at injection bump02. And MR closed orbit was about 15.5 mm and 6.0 mm at BPM05 and BPM06.

Secondly, injection beam orbit was tuned again following the new MR closed orbit with injection bump.

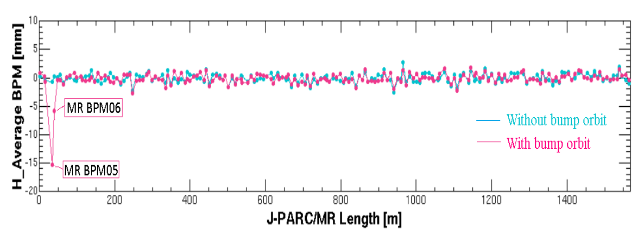

Figure 8: Show of the MR orbit with injection bump.

The success of injection orbit tuning was also verified in beam profile measurement shown in Figure 9.

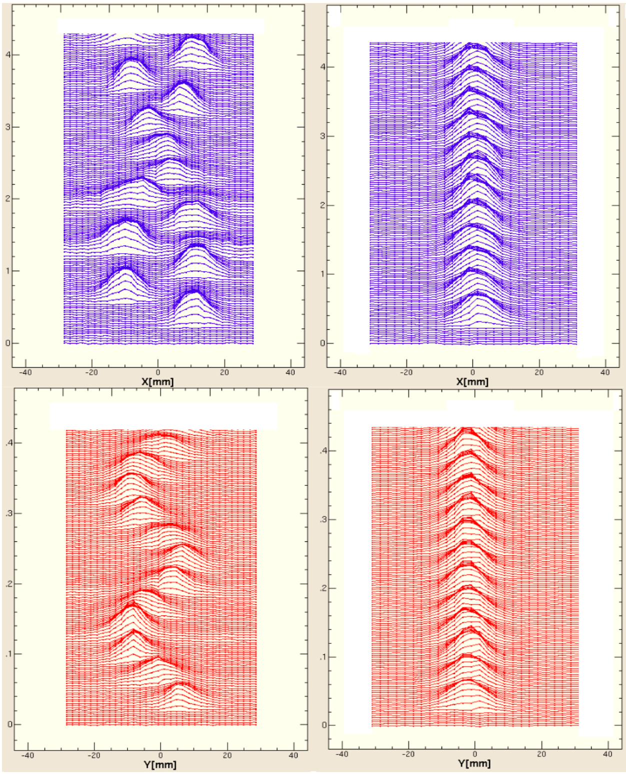

Figure 9: Horizontal (upper) and vertical (lower) beam profile mountain views for the first twelve turns measured with IPM. (Left: before injection orbit correction; Right: after injection orbit correction).

Injection envelope matching

Besides injection orbit tuning, injection optics matching had been done also. After adjusting quadrupole magnet in 3-50 BT [2], injection envelope matching had been well done which can be seen from MR beam profile mountain views and beam loss before and after matching as shown in Figure 10.

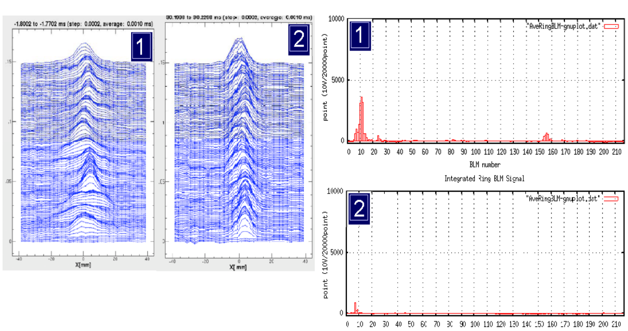

Figure 10: Beam profile mountain views at MR IPM and MR beam loss before and after injection envelope matching (1: mismatched; 2: matched).

The MR circulating beam profile distributions were also attained by MR FWPM (Flying Wire Profile Monitor) before and after envelope matching shown in Figure 11. The improvement can be explained by injection dilution theory [3]. The ratio of dilution beam size and non-dilution beam size can be calculated by follow equation.

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

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 parameters 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 was coincided with the measured beam profiles in Figure 11 .

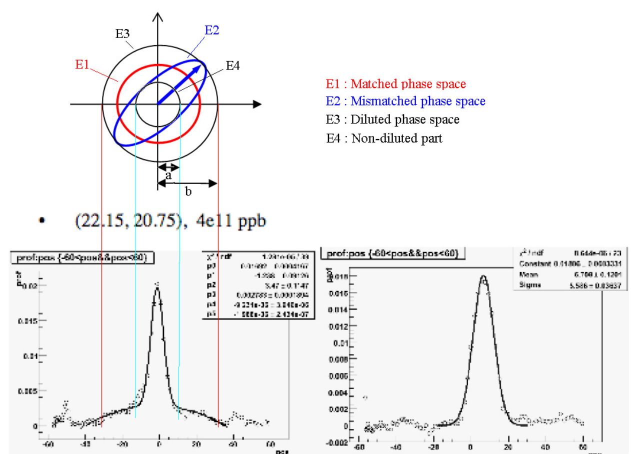

Figure 11: MR beam profiles shows by MR FWPM before (left) and after (right) envelope and its explanation (dilution beam size: b; non-dilution beam size: a; b:a=3).

SUMMARY

Beam injection tuning of the MR has been well done. Influence from leakage field of injection septum 02 and beam envelope mismatching were met and managed. Injection orbit oscillations around MR closed orbit are less than ±0.5 mm in its amplitude in both horizontal and vertical at injection time, which are enough for 70 kW operation [1].

REFERENCES

[1] T. Koseki, Challenges and Solutions for J-PARC Commissioning and Early Operation, in these proceedings.
[2] S. Igarashi, J-PARC MR Beam Commissioning, OHO09.
[3] J. Y. Tang, NIMA 595 (2008) 561.