TRANSVERSE TUNING SCHEME FOR J-PARC LINAC

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Abstract

A transverse matching scheme has been planned for the J-PARC linac beam commissioning with use of wire scanners. The beam diagnosis layout has been determined to realize the planned matching scheme. Continuous monitoring of the matching with beam position monitors is also discussed.

INTRODUCTION

In J-PARC linac [1], it is essentially important to realize precise transverse matching to suppress beam halo generation and resulting uncontrolled beam loss in the linac and the following RCS (Rapid Cycling Synchrotron). To realize precise transverse matching, we are planning to install a number of wire scanners [2] and four-strip-line BPM's (Beam Position Monitors) [3] in linac and L3BT (Linac to 3-GeV RCS Beam Transport). Planned tuning scheme for the transverse matching and the relevant beam diagnosis layout are presented in this paper.

TRANSVERSE MATCHING

Two Matching Schemes

We have set the goal of transverse tuning, or the tolerance for the rms beam size mismatch, to 10 % in order to suppress transverse halo generation. To achieve this goal, we are considering the following two schemes for the transverse matching;

- Scheme-I: Four or more wire scanners are placed periodically. Then, quadrupole magnets, which are located before the wire scanners, are tuned to have the same beam widths at wire scanner locations.
- Scheme-II: Four or more wire scanners are placed arbitrarily in the matching section. Emittance and Twiss parameters are calculated from the measured beam widths. Then, the quadrupole strengths are determined based on the calculated emittance and Twiss parameters.

Although three wire scanners are sufficient for both schemes in principle, redundant wire scanners are prepared to improve the tuning accuracy statistically.

Scheme-I is basically the same with the procedure proposed in the reference [4]. In our case, four or more wire scanners are installed in series (as densely as possible) in the vicinity of the matching point, and we plan to leave them there for swift re-commissioning. Adjusting the strengths of four quadrupole magnets, the adequate set of parameters is searched through a trial and error method. This procedure is supposed to be performed automatically to shorten the tuning time, while the detailed algorithm has not been decided yet. The starting point will be determined with Trace3D [5].

It is obviously preferable to adopt Scheme-I, because it only needs relative accuracy of the beam width measurement. In Scheme-II, we need the absolute beam sizes. Furthermore, we need information or a assumption on the longitudinal beam profile in the matching section in Scheme-II, because space-charge coupling between the transverse and longitudinal directions is not negligible. Then, we decided to adopt Scheme-I as far as possible. To adopt Scheme-I, the lattice should be periodic, and the longitudinal profile around the matching section should be reasonably regular.

As shown in Fig. 1, we have seven transverse matching points in linac and L3BT. We plan to adopt Scheme-I in five of these matching points. However, we can not adopt Scheme-I in the remaining two, because the lattice itself has no periodicity.

Matching with Scheme-I

Figure 2 illustrates a typical matching section where we assume tuning with Scheme-I. This matching section locates at the joint between DTL (Drift Tube Linac) and SDTL (Separate-type DTL) sections, where the lattice structure changes from FODO to doublet. Four wire scanners are placed in the periodic section after the transition. All the doublet quadrupoles in the SDTL section are set to their nominal strengths to secure the periodic nature of the envelope evolution. Four of the last six DTQ's (Drift Tube Quadrupole magnets) are utilized as tuning knobs to make the transverse matching. Three other DTQ's are weakened from the nominal value or simply turned off from the beginning to ensure smooth matching. They are not supposed to be subject to the beam-based adjustment. In short, only four quadrupole magnets are tuned to perform the transverse matching in this section. Needless to say, it is important to limit the number of tuning knobs to shorten tuning time and accompanying beam losses. It is required to find an adequate set of tuning knobs and their starting points in advance to reduce the number of tuning knobs retaining both sufficient smoothness of the matched solution and wide tuning range. We have tried to find the adequate sets of starting conditions with Trace3D, and we

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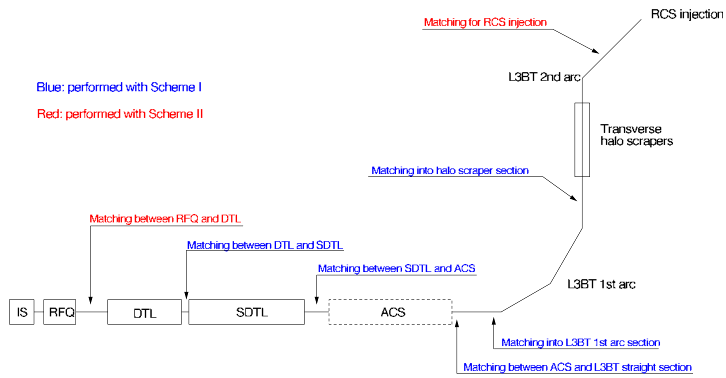

Figure 1: Quadrupole tuning points along the lianc and L3BT. Four or more wire scanners are installed at each tuning points. We plan to adopt Scheme-I in the five matching points in blue, but Scheme-II in the remaining two matching points in red.

have succeeded so far in restricting the number of tuning quadrupoles to four at all the matching sections except for the RCS injection line.

Another noteworthy example is the matching into the first arc section, which locates in the middle of L3BT. The most distinctive feature of the arc section is its three-fold symmetry as shown in Fig. 3. Taking advantage of the symmetry, we place four wire scanners at symmetric points to enable the transverse matching with Scheme-I. This setup greatly simplifies the transverse matching into the arc section. It should be noted here that these wire scanners are placed at dispersion-free regions to avoid possible influences of the dispersion.

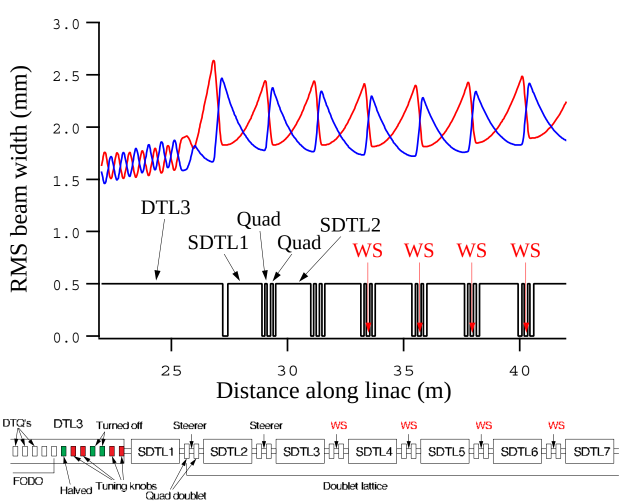

Figure 2: Quadrupole tuning at the DTL-SDTL transition. The top figure shows the beam envelope evolution around the transition and wire scanner locations (indicated as "WS"). The bottom figure shows the schematic layout of quadrupole magnets and RF cavities in this section. The four DTQ's shown as red boxes are used as the tuning knobs in this matching section.

Matching with Scheme-II

As shown in Fig. 1, the two matching sections, where Scheme-II is supposed, locate in MEBT (Medium Energy Beam Transport) and RCS injection line. Because we do not have a dedicated longitudinal emittance monitor, we need to assume some longitudinal profile along the matching section to determine the proper quadrupole strength. Then, the validity of the assumption for the longitudinal profile is anticipated to affect transverse tuning accuracy. This effect can be serious especially in MEBT, because the space-charge coupling is stronger. In addition, steep change of the longitudinal profile due to bunchers in MEBT makes the matching susceptible to the coupling. To ease this problem, we plan to perform bunch shape measurement with use of the existing RF chopper cavities [6], which is expected to provide valuable information to check the validity of the assumption on the longitudinal profile. In addition, we have a double-slit emittance monitor in the beam diagnostic line of MEBT, which is expected to be helpful for consistency check with wire scanner measurements.

While the space-charge coupling is weak, the effect of non-zero dispersion should be taken into account in the matching in the RCS injection line. Four wire scanners are placed in a dispersive region, and hence the measured horizontal beam widths can be affected by the momentum spread variation or debuncher tuning alternation. In a dispersive region, the horizontal position of a particle $\tilde{x}$ can be divided into two parts as

$$\tilde{x} = x + \eta \frac{\Delta p}{p} \tag{1}$$

with η and $\Delta p/p$ being the dispersion function and the momentum deviation, respectively. Then, the measured second moments of the beam can be written as

$$\langle \tilde{x}^2 \rangle = \langle x^2 \rangle + \eta^2 \left\langle \left(\frac{\Delta p}{p} \right)^2 \right\rangle \tag{2}$$

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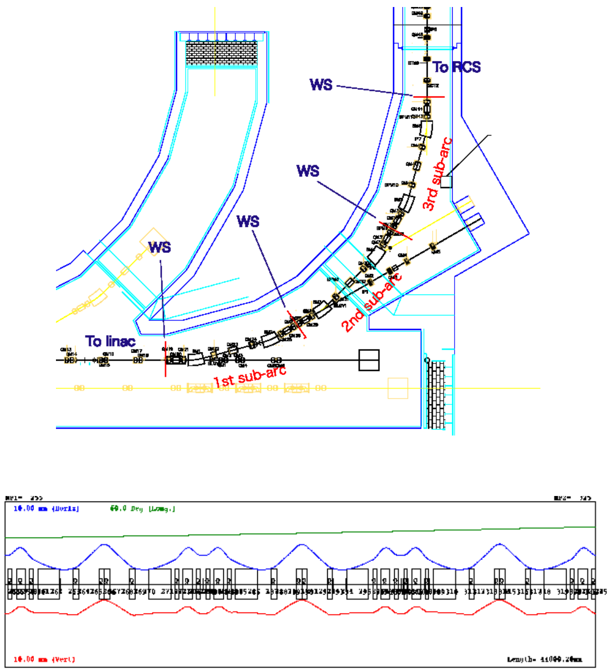

Figure 3: Transverse matching into the first arc section of L3BT. The top figure shows the layout of the arc section, and four wire scanners are placed at symmetrical points (indicated as "WS"). The bottom figure shows the envelope evolution in the arc section. The blue line shows the horizontal beam width, and red vertical.

where $\langle X \rangle$ denotes the ensemble average of X. Then, the measured rms beam width $\sqrt{\langle \tilde{x}^2 \rangle}$ is broadened due to the dispersion effect. This variation can provide us with valuable information on debuncher tuning, but, at the same time, it may make the transverse matching procedure intricate. The beam width broadening due to space-charge effects are, however, expected to be typically less than a few % with proper debuncher tuning in our case. Then, we expect that the dispersion effects can be neglected in the transverse tuning, while reasonably adequate debuncher tuning is a premise for it. The debunchers are planned to be tuned by time-of-flight measurements with FCT's (Fast Current Transformers) independently.

NON-DESTRUCTIVE MONITORING

After the initial transverse tuning is established, continuous monitoring of the matching becomes important. Because the measurement with wire scanners are partially destructive, the frequency of the measurement is anticipated to be limited. Then, we are planing to use BPM's for continuous monitoring of the transverse matching. Combining the signals from its four pickups in a proper way, we can obtain a value which is proportional to the difference between the horizontal and vertical second moments, $\langle x^2 \rangle - \langle y^2 \rangle$ [3, 7]. As it is anticipated to be difficult to perform absolute beam width measurement with BPM's, we

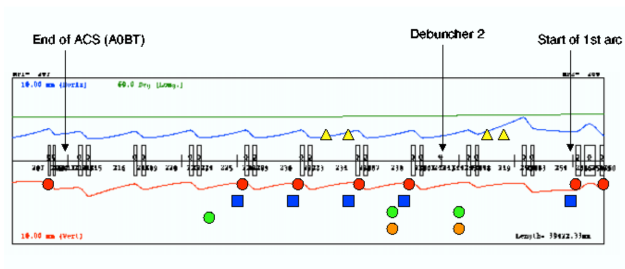

Figure 4: Schematic beam monitor layout for the L3BT straight line before the first arc section. Blue squares indicate wire scanner locations, red circles BPM locations. Thin rectangulars aligned in the middle represent quadrupole magnet.

are planning to monitor the time variations of the second moments to detect deterioration of the matching. In order to make the monitoring effective, we plan to install a BPM in the vicinity of each wire scanner as illustrated in Fig. 4.

SUMMARY

A transverse tuning scenario has been established for J-PARC linac which utilizes wire scanners. The wire scanner locations has been determined to realize the planned tuning scheme. In the tuning scenario, the emphasis has been put on avoiding absolute measurements as far as possible. We are also emphasizes the importance of swift re-commissioning and continuous monitoring of the matching. To realize the continuous monitoring, we plan to use four-strip-line BPM's and install them in the vicinity of the wire scanners.

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