TUNE-UP SCENARIO FOR DEBUNCHER SYSTEM IN J-PARC L3BT

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Abstract

A debuncher system is installed in the beam transport line between J-PARC linac and the succeeding 3-GeV synchrotron. The purpose of the debuncher system is to reduce the momentum centroid jitter and momentum spread at the ring injection. Tuning scenario for the debuncher system is presented together with the relevant beam monitor layout. Some simulation results for the debuncher effects are also presented, based on which the tuning tolerance is determined.

INTRODUCTION

We will start beam commissioning of J-PARC linac [1] and the succeeding beam transport line in December 2006 with the reduced beam energy of 181 MeV. The beam transport line, to which we refer as L3BT, has two key functions to satisfy the requirements for the RCS (Rapid Cycling Synchrotron) injection [2, 3]. One is to reduce the momentum jitter and momentum spread, and the other is to eliminate a transverse tail or halo. To realize the former function, we have a two-cavity debuncher system in L3BT which enables longitudinal manipulation of the beam. The total of the momentum centroid jitter and the momentum spread should be smaller than 0.2 % to satisfy the requirement, and we set the tuning target to 0.1 % which corresponds to 333 keV in energy. The debuncher system consists of two debuncher cavities, and the last two 324-MHz SDTL (Separate-type DTL) tanks have been utilized for debuncher cavities in 181-MeV operation. In this paper, the planned tuning scenario for the debuncher system is presented together with some simulation results for debuncher effects.

Table 1: Main Parameters

	Previous	Current
Distance		
SDTL-debuncher #1	53.1 m	33.8 m
Debuncher #1-#2	167.8 m	122.6 m
Voltage		
Debuncher #1	1.10 MV	1.35 MV
Debuncher #2	0.45 MV	0.45 MV
Synchronous phase		
Debuncher #1	-90 deg	-90 deg
Debuncher #2	-90 deg	-90 deg

DEBUNCHER SYSTEM

The debuncher layout has recently been modified as described in the reference [3] (see Fig. 1 also), and the main parameters of the debuncher cavities for the new layout are summarized in Table 1. In short, both of debuncher #1 and #2 are moved forward to reduce the drift spaces between SDTL and debuncher #1 and between debunchers. Figure 2 illustrates the effects of debuncher effects, where 1 deg and 1 % RF dynamic errors are assumed for DTL and SDTL tanks. The errors are assumed to be uniform-randomly distributed in the above range, and 100 different sets of errors are employed in the simulation. PARMILA has been used with its 2D space-charge routine, SCHEFF, in simulations presented in this section. The dynamic errors in DTL and SDTL cause the momentum centroid jitter at the exit of SDTL, and the jitter is translated into a large phase error at the debuncher locations after a long drift space. The nonlinearity and resulting filamentation due to the large phase error have been a major concern for the debuncher system [4]. It is readily seen in Fig. 2 that the momentum centroid jitter is largely corrected by the debuncher system, and, at the same time, the momentum spread is reduced to a certain level. The total momentum spread, which includes the momentum centroid jitter and the momentum spread, satisfies the target at the RCS injection with a proper debuncher tuning.

Figure 3 shows the longitudinal phase space distribution at the RCS injection in the case with the largest momentum jitter in the 100 runs in Fig. 2, where it is seen that the filamentation is moderate even in the worst case.

We have confirmed with extensive particle simulations

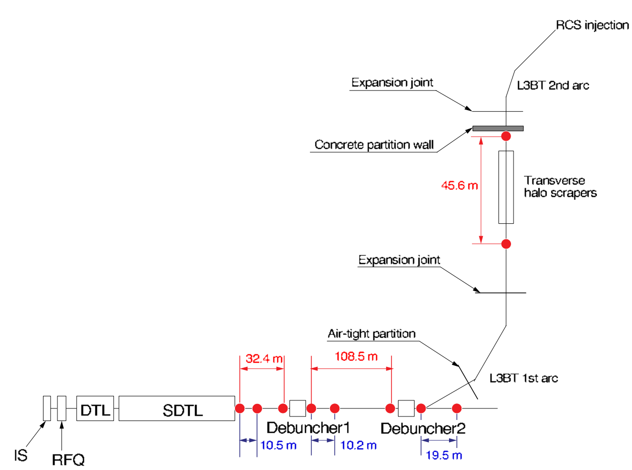

Figure 1: Debuncher and FCT layout.

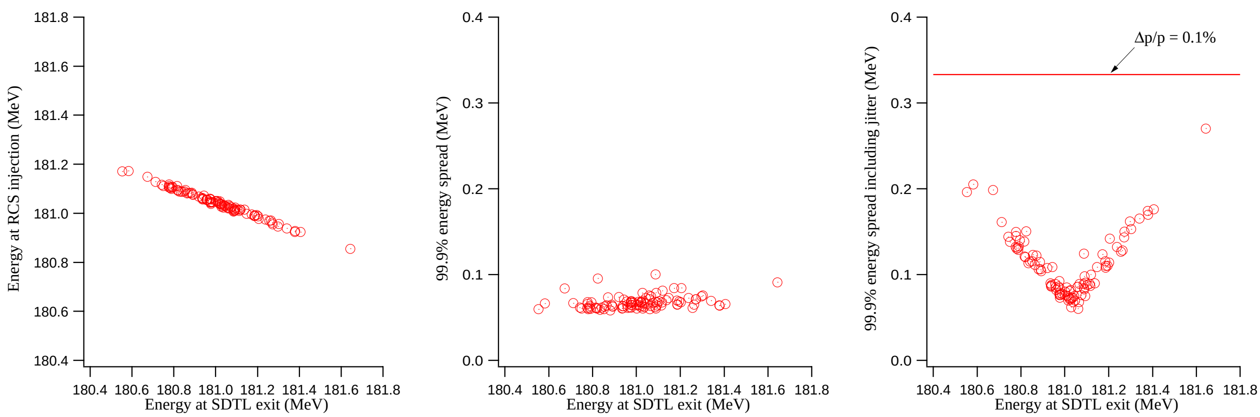

Figure 2: Simulation results for debuncher effects without debuncher set-point errors. Left: energy centroid jitter, middle: energy spread, and right: total of energy jitter and spread.

that the error tolerances for debuncher cavities are significantly increased by the layout modification, where the drift space between SDTL and debuncher #1 is substantially reduced. The error sensitivity of the debuncher cavities is demonstrated in Fig. 4 where the voltage for the debuncher #2 is reduced by half but the target for the momentum spread is still nearly satisfied. After carefully examining the error sensitivities, the tuning goals are set to 7 deg and 7 % for debuncher #1 and 20 deg and 20 % for debuncher #2 securing an enough margin.

To be noted here is that the phase set-point error has the following three effects; Firstly, it causes an offset of the centroid momentum. Secondly, it causes an deviation of logitudinal focusing forces. Finally, it reduces the tolerance to the momentum jitter of the output beam from SDTL. The first effect is practically harmless as long as it is static, and the second effect is equivalent with the amplitude error to which the beam quality is not so sensitive as shown above. The third effect needs some attention, because it may cause serious filamentation due to sinusoidal nature of the RF force with a certain momentum jitter. However, we have confirmed in particle simlations that the phase errors of the level assumed above cause no visible effect at the RCS injection (results not shown), which is attributed to the enough tolerances for the phase errors of the debuncher system. Especially, the error tolerances of debuncher #2 is significantly large in our layout, and it is essentially important to realize a reasonable tuning considering that an accurate tuning of a small amplitude cavity often involves practical difficulties.

TUNING SCENARIO

We plan to perform phase/amplitude scan to tune the phase and amplitude of the RF power sources for debuncher cavities. Because the phase-scan curve is nearly sinusoidal due to a small number of cells and hence a small phase slip in a debuncher cavity, the measurement of the absolute beam energy with TOF (Time Of Flight) method is

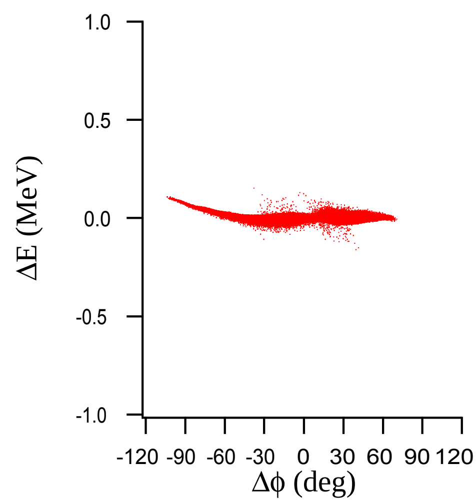

Figure 3: The longitudinal phase space distribution at the RCS injection in the worst case in the 100 runs in Fig. 2.

indispensable for the tuning. In the phase/amplitude scan, the field voltage is determined from the maximum energy gain during the RF phase scanning of 360 degree, and the optimum RF phase is determined by minimizing the energy gain. To satisfy the tuning goal, the energy gain of each debuncher cavity should be measured with the accuracy of around 100 keV. Then, a high accuracy of several tens of keV is required for the individual TOF measurement.

To enable the accurate beam energy measurement, we plan to perform long-baseline TOF measurements before and after each debuncher cavity. Figure 1 shows the FCT (Fast Current Transformer) layout for these long-baseline TOF measurements. The lengths of the baselines are 32.4 m, 108.5 m, and 45.6 m for before debuncher #1, after debuncher #1, and after debuncher #2, respectively. An additional FCT pair is prepared for each long-baseline TOF pair to cross-check the TOF measurement with shorter baseline measurement. The long-baseline TOF measurement has

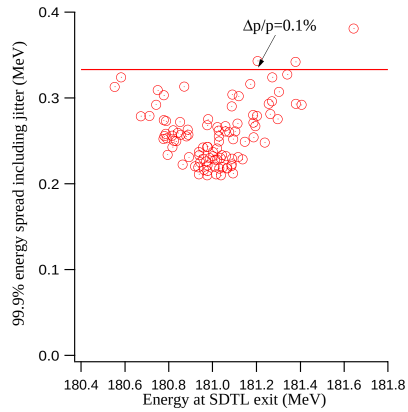

Figure 4: Simulation results for debuncher effects with half debuncher #2 amplitude (total energy spread).

the following two prerequisites; One is the precise measurement of the distance between two FCT's, and the other is the precise measurement of beam phase difference between the FCT pair.

To enable the precise distance measurement, the FCT's are accommodated with reference bases for a 1.5-inch CCR (Corner Cube Reflector). The CCR is utilized for the distance measurement both with a total station (Leica TDA5005) and a laser tracker (Leica LT600). The specification of TDA5005 for the distance measurement accuracy is 0.2 mm for the length shorter than 120 m, and the accuracy is expected to be around this value if two FCT's are directly visible. Because it is difficult to have direct visibility for a FCT pair, we plan to measure the distance between nearby quadrupole magnets with TDA5005. Then, the distance between the nearby quadrupole magnet and the FCT is measured with LT600. The total distance accuracy, which includes the relative position error between the reference base and the toroidal core, is expected to be better than 0.5 mm.

On the other hand, the overall measurement accuracy for the phase difference is estimated to be around 2.5 deg, where the error is mainly attributed to the accuracy of the phase detector and the calibration error for FCT heads [5]. The estimated accuracies for TOF measurements are summarized in Table 2. Accordingly, the accuracies for energy gain measurements are estimated to be 55 keV and 40 keV for debuncher #1 and #2, respectively, which satisfy the requirement for the debuncher tuning with a reasonable margin.

It should be noted that a few alternative tuning procedures for the RF phase are foreseen, which includes the beam-loading minimization.

CONTINUOUS MONITORING

Once the debuncher tuning is established, continuous monitoring of the tuning becomes important. Basically, the beam centroid momentum can be monitored with the long-

Table 2: Estimated Long-baseline TOF Accuracy

Error Source	Phase	Distance	Total
After SDTL	52 keV	7 keV	52 keV
After Debuncher #1	15 keV	2 keV	15 keV
After Debuncher #2	37 keV	5 keV	37 keV

baseline TOF measurement during the nominal operation. However, the measurement after debuncher #2 is anticipated to be affected by the operation of transverse collimators [6]. Then, an additional TOF measurement is planned around the first arc section utilizing two BPM's (Beam Position Monitors) as a backup. While these BPM's do not have reference bases for a CCR, they are usable for monitoring the relative change of the beam momentum. We expect that the baseline of around 40 m can be secured for the BPM pair, and the expected resolution is around 42 keV, which is expected to be useful in monitoring the relative deviation from the original tuning. The deviation of the path length in the arc section is negligible because of the small momentum compaction factor of 1.5×10^{-3}.

Slow feedback of the monitored centroid momentum to RF phase and amplitude for the last SDTL module or debuncher cavities is foreseen to minimize the effects of slow drift of RF parameters. Continuous monitoring of the momentum spread is also proposed using a few BPM's in the injection line [5].

SUMMARY

A planned tuning scenario for the debuncher system in J-PARC L3BT is described. The tuning goals for the RF set-points are determined to 7 deg and 7 % for debuncher #1 and 20 deg and 20 % for debuncher #2 based on particle simulations. The RF set-point is to be determined with a phase/amplitude scan with absolute energy measurement by long-baseline TOF measurements. The accuracy of the long-baseline TOF measurements is estimated to be sufficient for the debuncher tuning.

REFERENCES

[1] Y. Yamazaki ed., "Accelerator Technical Design Report for J-PARC", KEK-Report 2002-13.

[2] T. Ohkawa et. al., "Beam Dynamics Design of the L3BT for J-PARC", PAC'05, May 2005, Knoxville, p. 3091.

[3] T. Ohkawa et. al., "Present Status of the L3BT for J-PARC", 2nd Aunnal Meeting of Particle Accelerator Society of Japan, July 2005, Tosu, p. 251.

[4] M. Ikegami et. al., "A Simulation Study on Error Effects in J-PARC Linac", LINAC'04, August 2004, Luebeck, p. 345.

[5] S. Lee et. al., "The J-PARC L3BT Monitor System for RCS Injection", in these proceedings.

[6] M. Ikegami et. al., "Tuning Strategies for Transverse Collimator in J-PARC L3BT", in these proceedings.