PRESENT STATUS OF THE L3BT FOR J-PARC

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Abstract

L3BT is a beam transport line from J-PARC (Japan Proton Accelerator Research Complex) linac to the succeeding 3-GeV RCS (Rapid Cycling Synchrotron). Recently, the positions of the debunchers in L3BT are revised to optimize the momentum spread at the RCS injection. In this paper, results of the beam simulation of the L3BT with the new debuncher locations are presented. The construction status of the L3BT is also presented in brief.

1 INTRODUCTION

The accelerators for J-PARC consist of a 180-MeV linac, a 3-GeV RCS (Rapid Cycling Synchrotron), and a 50-GeV MR (Main Ring) [1]. These three accelerators are connected with beam transport lines with their own peculiar functionality. L3BT is one of them which connects the linac and RCS.

To meet the requirement for the beam loss minimization, the L3BT does not only connect the linac to the 3GeV RCS, but also modifies the linac beam to be acceptable for the RCS. The required beam parameters at the injection point of the RCS are

Momentum spread <±0.1% (100%, including jitter) and

Transverse emittance < 4π mm*mrad (100%).

To achieve these beam qualities, the L3BT should have following functions: momentum compaction, transverse halo scraping and beam diagnosis.

The L3BT consists of a straight section, an achromatic arc section, a scraper section and an injection section. Two debunchers are set up in the L3BT. The debunchers are used to obtain the momentum spread of less than ± 0.1 % at the injection point of the RCS. Another effect of the debunchers is the energy centroid correction when the beam energy is shifted from the design value due to RF errors in the DTL (Drift Tube Linac) and SDTL (Separate-type DTL) sections. The vertical bump magnet for the vertical painting injection is placed at a position of π phase difference from the injection point.

2 BEAM SIMULATION

2.1Precondition

PARMILA code is used for the beam simulation. The quadruple focusing strengths are determined by using TRACE3D. TRACE3D is the envelope analysis code including the space-charge effect and it has the parameter matching function [2].

In the previous arrangement of L3BT, the distance from the exit of the last SDTL to the first debuncher was 53.126 m, from the first debuncher to the second debuncher 167.831 m, and from the second debuncher to the RCS injection point 100.204 m. The above distances are measured from the center of debuncher cavities. The second debuncher was located after the achromatic arc section.

If the beam energy at the exit of SDTL deviates from the design value due to RF errors in the DTL and SDTL section, the energy deviation is translated into large phase deviation at the debuncher location because of the long drift length between them. The longer the distance between two debunchers is, the larger the phase deviation at the second debuncher is.

The previous layout was optimized to have small momentum spread at RCS injection keeping the momentum spread at the debuncher locations below a certain value. However, recent studies have shown that the phase error due to energy deviation overwhelms the effect of phase spread. Then, we have decided to review the debuncher layout from the viewpoint of minimizing the effect of energy deviation. The available location for the second debuncher is limited to avoid the arc section. Then, we have tried the location just before the arc section for the second debuncher. On the other hand, we have some flexibility for the first debuncher location. Then, we have tried four locations (Case 1 to 4 in Table 1) for the first debuncher, and compared the momentum spread at the RCS injection.

2.2Calculation results

The envelope analyses of the L3BT are performed with TRACE3D for above four cases. The calculation results are shown in Table 1.

Table 1: Calculation result with TRACE3D

		Case1	Case2	Case3	Case4
L1	m	48.1	43.2	38.5	33.8
L2	m	108.3	113.2	117.9	122.6
ΔΦ1	deg	36.3	31.8	27.5	23.3
V1	MV	0.87	0.98	1.13	1.35
Φ1	deg	-90	-90	-90	-90
ΔΦ2	deg	60.9	60.2	60.1	60.1
V2	MV	0.37	0.39	0.42	0.45
Φ2	deg	-90	-90	-90	-90
Δp/p	%	±0.0081	±0.0091	±0.0093	±0.0093
ΔΦ	deg	38.2	39.5	39.1	38.9

In Table 1, L1 is the distance between exit of the SDTL and center of the first debuncher and L2 is the distance between center of two debunchers. V1(V2), Φ1(Φ2) and ΔΦ1(ΔΦ2) denote the voltage and phase of the first(second) debuncher and the phase spread at the first(second) debuncher, respectively. ΔΦ is the phase

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spread and $\Delta p/p$ is the momentum spread at the injection point of the RCS, respectively.

Almost the same results are obtained except for the phase spread at the first debuncher. When the first debuncher is moved upstream, larger voltage is required.

With the second debuncher before the arc section, the momentum spread at the RCS injection point is minimized at the case 1.

PARMILA simulations from the MEBT to the exit of SDTL are performed assuming RF errors in the DTL and SDTL. A peak beam current is 30 mA and space charge effect is calculated with three dimensions. The beam distribution based on the experiment and simulation result of RFQ is used as the initial beam distribution at the entrance of the MEBT [3]. Initial parameters are shown in Table 2.

The RF field amplitude and phase errors for each tank of the DTL and the SDTL are randomly generated within the range of ±1 % and ±1 deg.

Table 2: Initial parameters at the MEBT entrance

Number of particles	95322 particles
εx_0(rms)	0.212 π mm*mrad
εy_0(rms)	0.212 π mm*mrad
εz_0(rms)	0.091 π MeV*deg
εx_0(99.5%)	2.08 π mm*mrad
εy_0(99.5%)	2.05 π mm*mrad
εz_0(99.5%)	1.32 π MeV*deg

The simulation results for 100 random error cases show that the maximum energy deviation at the exit of the SDTL is ΔW=0.410 MeV (case A) and minimum is ΔW= - 0.394 MeV (case B). [4]

The phases of two debunchers with respect to the design particle are assumed to be unchanged from the design value, and we don't assume the debuncher voltage error. When the beam arrives at each debuncher, it's phase becomes the value in which the sum of the following two errors are added to the design value.

Φ_a : Phase error of SDTL output

Φ_b : Phase error due to TOF (time of flight)

Table 3 shows that the simple calculation results of phase and beam energy at two debunchers. In Table 3, W1(W2) and δΦ1(δΦ2) is the energy and phase deviation at the first (second) debuncher. δW1 (δW2) denote the energy correction by the first(second) debuncher. W is the energy at the injection point of the RCS.

If the first debuncher is moved upstream, the energy deviation at the exit of the first debuncher becomes small and hence, the phase deviation due to TOF between two debunchers becomes small. In case 4, the phase deviation and spread at the first and second debunchers can be reduced compared with those of another cases, although the momentum spread at the RCS injection point is somewhat larger according to Table 1. We shall concentrate on the case 1 and case 4.

Table 3: Calculation result

Case A	unit	Case1	Case2	Case3	Case4
W1	MeV	181.45	181.45	181.45	181.45
δΦ1	deg	-29.8	-26.8	-23.8	-20.9
δW1	MeV	-0.432	-0.441	-0.456	-0.482
W2	MeV	181.01	181.00	180.99	180.96
δΦ2	deg	-26.4	-21.6	-15.8	-7.8
δW2	MeV	-0.164	-0.144	-0.114	-0.061
W	MeV	180.85	180.86	180.87	180.90
Case B					
W1	MeV	180.64	180.64	180.64	180.64
δΦ1	deg	28.6	25.7	22.9	20.1
δW1	MeV	0.417	0.425	0.440	0.464
W2	MeV	181.06	181.07	181.08	181.10
δΦ2	deg	24.9	20.4	14.8	7.1
δW2	MeV	0.156	0.136	0.107	0.056
W	MeV	181.21	181.20	181.19	181.16

Next, the simulations from the MEBT to the RCS injection point are performed with PARMILA. Assumed peak current is 30 mA and a 3D space-charge routine is adopted. The same beam distribution shown in Table 2 is used as initial beam distribution at the entrance of the MEBT.

The RF field amplitude and phase errors for each tank of the DTL and the SDTL are randomly generated within the range of ±1 % and ±1 deg. In addition, it is assumed that there are 6 deg phase tuning errors for the debunchers. We shall concentrate on the worst case that the energy at the end of the SDTL is maximum (ΔW=0.41 MeV). The calculation results of the energy and beam parameters at the RCS injection point are shown in Table 4.

Table 4: Simulation results of the beam parameters

	unit	Case 1	Case 4
W1	MeV	181.45	181.45
V1	MV	0.87	1.35
ϕ1	deg	-124.5	-115.7
Δϕ1	deg	90.7	53.7
W2	MeV	180.97	180.87
V2	MV	0.37	0.45
ϕ2	deg	-102.1	-73.2
Δϕ2	deg	147.9	140.7
W	MeV	180.91	180.98
δW	MeV	-0.124	-0.054
Δp/p	%	-0.054 ～-0.021	-0.035 ～-0.004

In Table 4, V1(V2), Φ1(Φ2) and ΔΦ1(ΔΦ2) denote the voltage and phase of the first(second) debuncher and the phase spread at the first(second) debuncher, respectively. ΔΦ is the phase spread, δW is the energy deviation and $\Delta p/p$ is the momentum spread at the injection point of the RCS, respectively. W1(W2), W and $\Delta p/p$ denote the energy at the first (second) debuncher, the energy and the momentum spread at the injection point of the RCS.

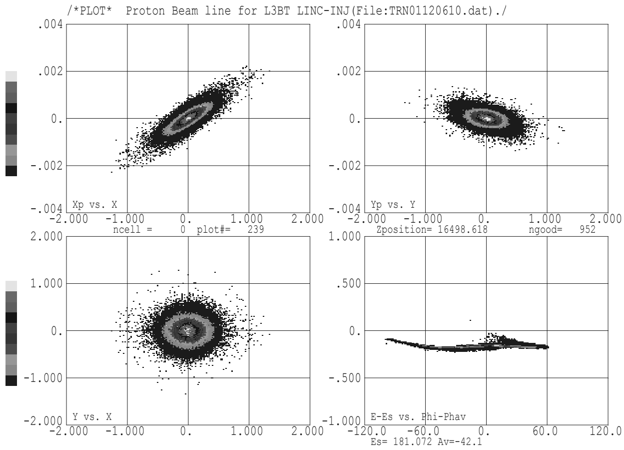

Figure 1: Beam distribution at the injection point of the RCS (case 1).

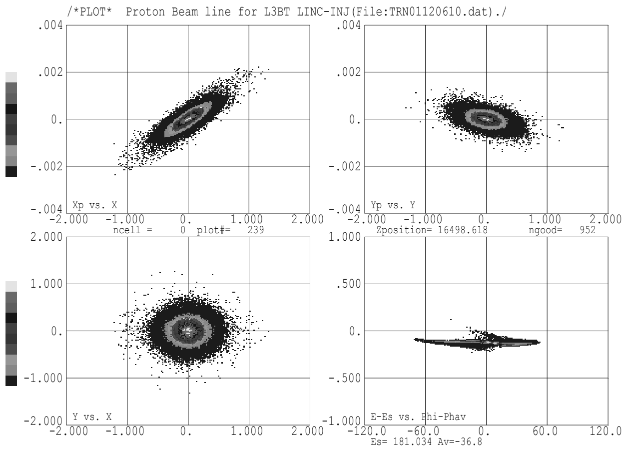

Figure 2: Beam distribution at the injection point of the RCS (case 4).

In case 4, the momentum spread at the injection point of the RCS is smaller than that of case 1. The beam distributions at the injection point of the RCS are shown in Fig. 1 and Fig. 2.

We conclude from Table 3 and 4 that case 4 (the first and second debunchers are moved to 20m, 65m upstream respectively) is more stable for RF errors than another cases. We have decided to revise the positions of the debunchers in L3BT.

3 CONSTRUCTION STATUS

Most of the components of L3BT were ordered by the end of October 2003 and will be completed by December 2005. The designs of main components (magnets, power supplies, scrapers, beam dump and so on) have been almost finished and the fabrications of them are in progress. The installation of the L3BT started in April 2005.

4 SUMMARY

The simulations from the MEBT to the injection point of the RCS are performed with PARMILA with the RF errors in the DTL, SDTL and debunchers when the first and second debunchers were moved upstream. We have decided that the first and second debunchers are removed to 20m, 65m upstream respectively from the viewpoint of minimizing the effect of energy deviation.

REFERENCES

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