PRESENT STATUS OF THE L3BT FOR J-PARC

T. Ohkawa#, JAERI, Ibaraki, Japan,
M. Ikegami, KEK, Ibaraki, Japan, J. Qiang, LBNL, Berkeley, USA

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). The construction of the L3BT has been almost finished. The beam commissioning of the L3BT will be started soon. On the other hand we have performed 3D particle simulations with PARMILA and IMPACT to evaluate the performance of the halo scraping, momentum compaction and beam diagnostics. In this paper, results of the beam simulation of the L3BT are presented. The construction status of the L3BT is also presented in brief.

INTRODUCTION

The accelerators for J-PARC consist of a 180-MeV linac, a 3-GeV RCS, 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 <±0.2% (100%, including jitter) and

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

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 [2].

BEAM SIMULATION

Precondition

PARMILA and IMPACT codes are used for the beam simulation [3][4]. In IMPACT code we used, J-PARC Charge-Exchange Collimator Routine is added by Ikegami, which is developed based on a Stripper Routine (MstripF_BPM) originally developed as the stripping model in LANA code [5]. In a transverse scraper, halo particles are charge-exchanged by stripper foils, and then, led to a dedicated beam dump. The quadrupole 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 [6].

Calculation Results

The simulations from the MEBT to the RCS injection point are performed with PARMILA and IMPACT. Assumed peak current is 30 mA and a 3D space-charge routine is adopted. 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 [7]. Initial parameters are shown in Table 1. The calculation results of the beam parameters at the RCS injection point are shown in Table 2.

Table 1: 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

Table 2: Beam parameters at the RCS injection point

	Unit	PARMILA	IMPACT
E	MeV	181.037	181.034
αx		-1.519	-1.690
βx	m	10.376	11.913
εx_rms	πmm*mrad	0.257	0.256
εx	πmm*mrad	3.780	3.445
αy		-0.217	-0.362
βy	m	11.653	11.369
εy_rms	πmm*mrad	0.256	0.248
εy	πmm*mrad	3.614	3.653
αz		1.286	1.266
βz	deg*MeV	1479.4	1701.8
εz_rms	πMeV*deg	0.297	0.225
εz	πMeV*deg	3.573	3.610
Δp/p	%	0.024	0.022

In Table 2, E is the energy at the injection point of the RCS. ε_rms and ε denote rms and 99.5% normalized emittance, respectively. Δp/p is the momentum spread at the injection point which is calculated by using 99.5% emittance and βz. Almost the same results are obtained by using PARMILA and IMPACT codes except for εz_rms and βz. Emittance in this paper is used all normalized emittance.

#tomohiro.ohkawa@j-parc.jp

Transverse Scraper

The scraper section is composed of simple four FODO cells. The phase advance of one FODO cell is set to about 45 degrees. Transverse scraper consists of the adjustable carbon stripping foils and it is installed after each Q-magnet to remove a transverse beam halo. We evaluate the performance of the halo scraping in the scraper section. In PARMILA simulations, we adopted a model where all the particles hitting the foils are eliminated at the scraper position, but in reality the particles are charge-exchanged to H+ and then transported together with the H- beam. In the scraper model developed for IMPACT, we follow the evolution of H+ particles generated at the charge-exchange scrapers not assuming the immediate elimination of collimated particles. So we use IMPACT code to evaluate the performance of the halo scraping.

The simulations from the MEBT to the RCS injection point are performed with IMPACT. A peak beam current is 30 mA and space charge effect is calculated with three dimensions. The same beam distribution shown in Table 1 is used as initial beam distribution at the entrance of the MEBT. It is assumed that the stripper foils in each charge-exchange scraper are set to the position of 0.85 m downstream from the center of the each quadrupole magnets and the vertical or horizontal displacements of the stripper foils are calculated by using 99 % emittance and β. The calculation results of normalized 99.5% emittance at the injection point of the RCS with or without scraper are shown in Table 3. The beam distributions at the injection point of the RCS are shown in Figure 1 and 2.

Table 3: Simulated results of normalized 99.5% emittance

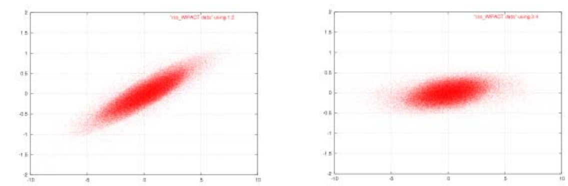
	Unit	without scraper	with scraper
εx	πmm*mrad	3.445	2.588
εy	πmm*mrad	3.653	2.647
εz	πMeV*deg	3.610	3.389
Δp/p	%	± 0.022	± 0.021

In Table 3, εx and εy, εz denote 99.5% transverse and longitudinal normalized emittance, respectively. Δp/p is the momentum spread at the injection point which is calculated by using 99.5% emittance and βz. Table 3 shows that all the particles blown up over 4π mm*mrad are eliminated in scraper section and normalized 99.5% emittance at the injection point of the RCS meets the specification of less than 4π mm*mrad. The number of collimated particles at each scraper is evaluated. The obtained results are shown in Table 4.

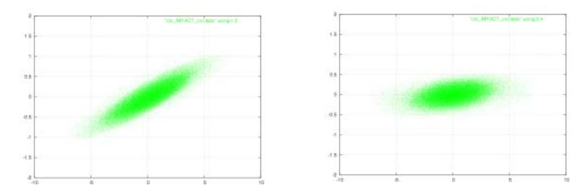
Table 4: Number of collimated particles

Initial number of particles	95322 particles
N_{H+}	1380 particles
Scraper load	1.448 %

In Table 4, N_{H+} is the total number of collimated particles in the scraper section. Scraper load denotes the ratio of the collimated particles to initial particles at the MEBT entrance. The H+ halo particles which are charge-exchanged by stripper foils run with the core (H-) beam along the beam line, and they are split at the first dipole magnet after stripping. The H+ halo particles are transported to the beam dump. The quadruple focusing strengths in the beam dump line are determined by TRACE3D with the calculation results of the beam parameters at the exit of this dipole magnet. About 1% of H+ halo particles are lost in the scraper section and beam dump line after hitting the beam duct.



(a) horizontal phase space (b) vertical phase space
Figure 1: Beam distributions at the injection point of the RCS (without scraper)



(a) horizontal phase space (b) vertical phase space
Figure 2: Beam distributions at the injection point of the RCS (with scraper)

Scraper Gap Width Errors

We consider the effect of the gap width errors of the stripper foils in each scraper. The simulations from the MEBT to the RCS injection point are performed with gap width errors systematically generated in the vertical or horizontal displacement of the stripper foils. We evaluate the difference of scraper load at each scraper. It is assumed that the vertical or horizontal displacements of the stripper foils are calculated by using 99 % emittance and β. As for the gap width errors, three cases (-0.1 mm, -0.2 mm, and -0.3 mm) are considered. In each case, the same amount of gap width errors is applied to all the stripper foils. The number of collimated particles at each scraper is evaluated. The obtained results are shown in Table 5.

Table 5: Number of collimated beam

	Unit	case1	case2	case3
Δx/Δy	mm	-0.1	-0.2	-0.3
N_{H+}		1500	1623	1774
Scraper load	%	1.574	1.703	1.861

In Table 5, Δx/Δy denote the stripping foils misalignment for horizontal/vertical displacements. When the transverse displacements within the range of –0.3mm are systematically caused in the stripper foils, the number of collimated particles at each scraper becomes large in proportion to the amount of the displacements of the stripper foils. When the gap width errors of the stripper foils in each scraper become –0.3mm, the amount of the fraction of collimation at the scrapers increases about 30%. Table 6 shows the simulation result of normalized 99.5% emittance at RCS injection point.

Table 6 shows that the larger the gap width errors of the stripper foils in each scraper become, the smaller normalized 99.5% emittance at the injection point of the RCS becomes.

Table 6: Simulated results of normalized 99.5% emittance

	Unit	case1	case2	case3
Δx/ Δy	mm	-0.1	-0.2	-0.3
εx	πmm*mrad	2.546	2.498	2.449
εy	πmm*mrad	2.603	2.559	2.500
εz	πMeV*deg	3.386	3.388	3.385
Δp/p	%	± 0.021	± 0.021	± 0.021

Quadrupole Gradient Errors

Next, we consider the change of the beam parameters in the scraper section when systematic magnetic field errors are caused for four quadrupole magnets in matching section to the scraper section (assuming the matching errors in the transverse direction). The simulations from the MEBT to the RCS injection point of the RCS are performed with magnetic field errors systematically generated in above magnets. We evaluate the difference of scraper load caused by the change of the beam size at each scraper. It is assumed that the vertical or horizontal displacements of the stripper foils are not changed from the reference position.

As for the quadruple magnetic field errors, three cases (0.5%, 1.0%, and 3.0%) are considered. These values corresponds 0.25%, 0.52%, and 1.75% respectively, when the quadruple magnetic field errors are converted into the mismatch factors. In each case, the same amount of gradient error is applied to all the quadrupoles. The number of collimated particles at each scraper is evaluated. The obtained results are shown in Table 7.

Table 7: Number of collimated beam

	Unit	case1	case2	case3
ΔG/G	%	0.5	1.0	3.0
N_{H+}		1355	1399	1426
Scraper load	%	1.422	1.468	1.496

In Table 7, ΔG/G denote the quadruple magnetic field errors. When the magnetic field errors within the range of 1.0% are systematically caused in four quadrupole magnets in matching section, the number of collimated particles at each scraper is slightly fluctuating. It can be confirmed that the fraction of collimation at the scrapers is insensitive to the systematic gradient errors. When the magnetic field error becomes 3.0%, the amount of the fraction of collimation at the scrapers increases about 3%. Table 8 shows the simulation result of normalized 99.5% emittance at RCS injection point.

Table 8: Simulated results of normalized 99.5% emittance

	Unit	case1	case2	case3
ΔG/G	%	0.5	1.0	3.0
εx	πmm*mrad	2.608	2.588	2.590
εy	πmm*mrad	2.648	2.620	2.642
εz	πMeV*deg	3.396	3.401	3.396
Δp/p	%	± 0.021	± 0.021	± 0.021

Table 8 shows that normalized 99.5% emittance at the injection point of the RCS meets the specification of less than 4π mm*mrad in all cases.

CONSTRUCTION STATUS

Most of the components of L3BT were ordered by the end of October 2003. The designs and the fabrications of main components (magnets, power supplies, scrapers, beam dump and so on) have been finished by December 2005 and the installation of the L3BT will be finished in June 2006. The beam commissioning to one third of the first arc of the L3BT will be started in December 2006 and after that it will be started in September 2007.

SUMMARY

The simulations from the MEBT to the injection point of the RCS are performed with PARMILA and IMPACT to evaluate the performance of the halo scraping. Systematic quadrupole gradient errors are also considered assuming the matching errors in the transverse direction. The fraction of collimation at the scrapers is insensitive to the systematic gradient errors. It can be confirmed that the required beam parameters at the injection point of the RCS are satisfied in all cases.

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