PARTICLE DISTRIBUTIONS AT THE EXIT OF THE J-PARC RFQ

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Abstract

A 3.115m long, 324MHz, 3MeV radio-frequency quadrupole (RFQ) linac is used as the first RF accelerator of the J-PARC linac. We have performed RFQ simulations to provide a particle distribution for an end-to-end (from the RFQ entrance to the injection point of the rapid cycling synchrotron (RCS)) simulation of the J-PARC linac. Two simulation codes, PARMTEQM and TOUTATIS are used for the RFQ simulations. The simulated emittances show good agreements with the ones measured at the exit of the medium energy beam transport (MEBT).

INTRODUCTION

Beam characteristics of the J-PARC linac are being discussed in detail by performing the end-to-end simulation, as described in separate papers [1][2][3]. The results of the simulation strongly depend on the initial particle distribution, therefore, "realistic" distribution should be adopted. The commissioning of the front-end part (from an ion source(IS) to the MEBT) of the J-PARC linac was done at KEK by February 2003 [4][5]. In this paper, we perform the RFQ simulations using a distribution based on measurement at the low energy beam transport (LEBT). Obtained distributions at the RFQ exit are transported to the MEBT exit. Simulation results are compared with the measurement at the MEBT exit to confirm the validity as an initial distribution for the J-PARC-linac end-to-end simulation.

PARTICLE DISTRIBUTION AT THE RFQ ENTRANCE

We assume following particle distribution at the RFQ entrance; A Gaussian distribution in the x-x' and y-y' planes (truncated at 4σ), the energy is 50keV with no spread and the phase is uniform. The width of the Gaussian is decided based on the measured distribution obtained with emittance monitors at the LEBT. Figure1 shows the measured distribution at the LEBT and the distribution used for the RFQ simulations. Since the LEBT emittance monitors are located between two solenoid magnets of the LEBT, neutral particles, such as H^0, are included in the measurement. Therefore, we regard the tails of the measured emittances as a background. The injection beam parameters used for the RFQ simulations are summarized in Table 1. The beam current is a measured value at the LEBT.

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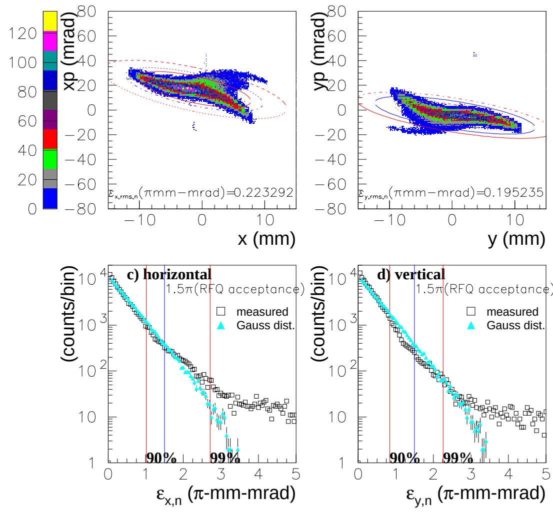

Figure 1: Measured emittances of the LEBT. The left-top and right-top show the phase space plots in the x-x' and y-y' planes, respectively. The ellipses are 90%, 1.5π mm·mrad (design acceptance of the RFQ) and 99% emittances. The bottom figures represent the beam current in the slices of the ellipses. The beam current is normalized to 100000. Open squares show the experimental result and closed triangles represent the distribution used for the simulation.

Table 1: Injection beam parameters used for the RFQ simulations

Parameters	values
Beam current	32 mA
Number of particles	100000
α_t	2.23
β_t	0.112 mm/mrad
ϵ_t(rms, normalized)	0.217π mm·mrad
Distribution(x-x', y-y')	Gaussian (truncated at 4 σ)
(phase)	Uniform
(energy)	50keV, no spread

SIMULATION RESULTS AT THE RFQ EXIT

We use two simulation codes, PARMTEQM[6] and TOUTATIS[7] for the RFQ simulations. Table 2 shows emittances and Twiss parameters at the RFQ exit obtained with use of the distribution described in the previous section. The rms emittances are not significantly different be-

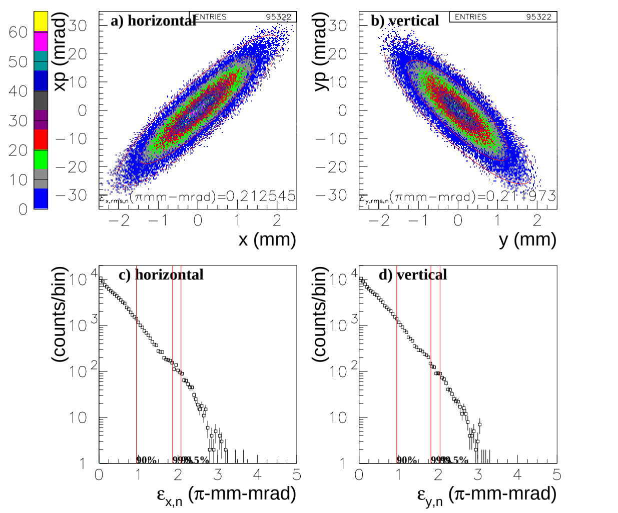

Figure 2: Particle distribution at the exit of the RFQ obtained with PARMTEQM.

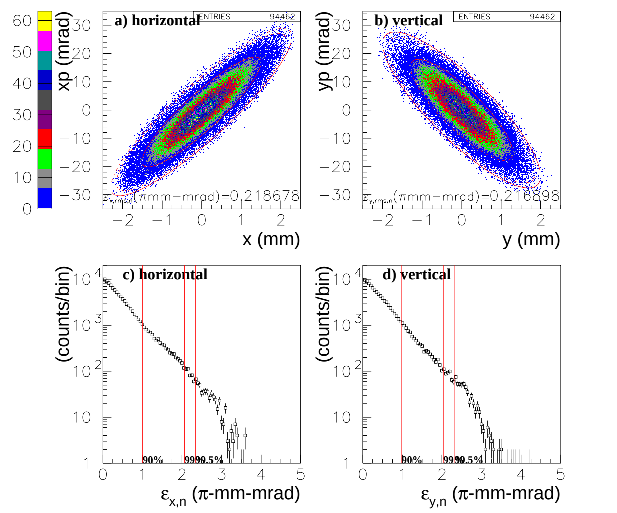

Figure 3: Particle distribution at the exit of the RFQ obtained with TOUTATIS.

tween the results of the two codes, but the 99.5% emittances of the TOUTATIS results are larger than those of the PARMTEQM results. Figures 2 and 3 are transverse distributions obtained with PARMTEQM and TOUTATIS, respectively.

Table 2: Simulation results at the RFQ exit. PQM and TTS mean PARMTEQM and TOUTATIS, respectively

Parameters	PQM	TTS
Transmission (%)	95.3	94.5
α_x	-2.11	-2.09
β_x (mm/mrad)	0.180	0.179
ϵ_x (π mm·mrad, rms, n)	0.213	0.219
ϵ_x (π mm·mrad, 99.5%, n)	2.08	2.33
α_y	1.63	1.60
β_y (mm/mrad)	0.138	0.136
ϵ_y (π mm·mrad, rms, n)	0.212	0.217
ϵ_y (π mm·mrad, 99.5%, n)	2.05	2.33
α_z	-0.123	0.0755
β_z (deg/MeV)	751	668
ϵ_z (π deg·MeV, rms)	0.0914	0.0957

Figure 4 represents the vane voltage dependence of the transmission of the RFQ. Both the simulation results and measured values are shown. Closed circles in the Figure 4 represent the experimental data of the measurement II in reference[4], and closed squares are the experimental data after the pre-chopper cavity installation into the LEBT, this decreased the transmission of the RFQ. This figure shows that the TOUTATIS result is closer to the measurement than PARMTEQM result, but the difference is not significant.

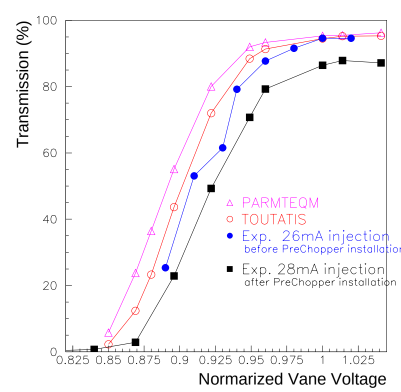

Figure 4: Measured and simulated transmission of the RFQ as functions of the vane voltage.

COMPARISON WITH THE EXPERIMENTAL RESULTS AT THE MEBT EXIT

With the simulated distributions obtained in the previous section, we compare the MEBT simulation results with the experimental data at the MEBT exit. For the MEBT simulation, we use PARMILA[8] with 2-D space charge, and took the fringing fields of the Q-magnets into account by the method described in [5]. In Table 3, the results using the distributions at the RFQ exit obtained with PARMTEQM and TOUTATIS are shown. The experimental data are also presented. The experimental data are results of the measurement I in [4]. The beam current was 29mA. Figures 5, 6 and 7 are measured distribution and simulated ones using PARMTEQM and TOUTATIS, respectively. Both the simulation results reasonably agree with the experimental data in the rms and 90% emittances.

Table 3: Measured and simulated results at the MEBT exit

Parameters	Exp.	PQM	TTS
α_x	-3.13	-3.70	-3.67
β_x (mm/mrad)	1.79	2.70	2.71
ϵ_x (π mm·mrad, rms, n)	0.252	0.244	0.259
ϵ_x (π mm·mrad, 90%, n)	1.17	1.10	1.20
α_y	-1.72	-1.40	-1.31
β_y (mm/mrad)	1.00	1.20	1.14
ϵ_y (π mm·mrad, rms, n)	0.214	0.234	0.250
ϵ_y (π mm·mrad, 90%, n)	0.971	1.04	1.09

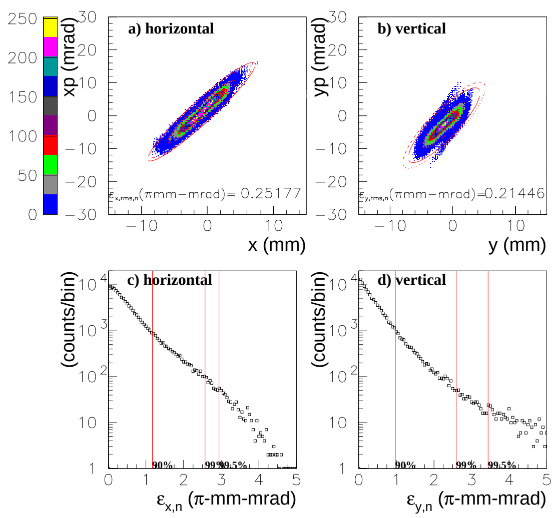

Figure 5: Measured emittances at the MEBT exit.

CONCLUSION

Starting with the distribution based on the measured distribution at the LEBT, we have performed the RFQ and MEBT simulations. For the RFQ simulations, PARMTEQM and TOUTATIS are used. In the rms emittances, there is no significant discrepancy between the results of the two codes, however, the tails of the emittances of the TOUTATIS result are about 10% larger than those of the PARMTEQM results. The MEBT simulation with these distributions well reproduce the experimental results at the MEBT exit in rms and 90% emittances. This shows that the simulated distributions at the RFQ exit are realistic enough to use the simulation of the J-PARC linac.

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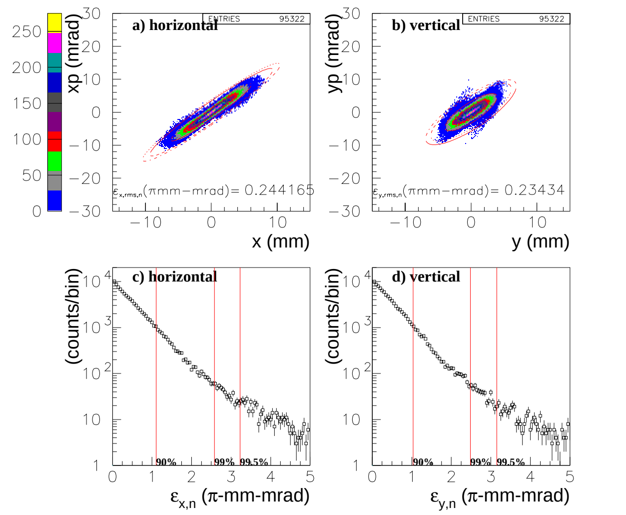

Figure 6: Simulation result at the MEBT exit using with the distribution obtained with PARMTEQM.

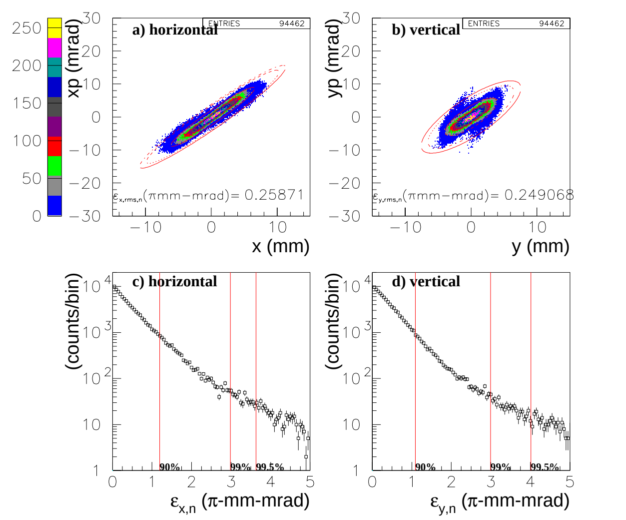

Figure 7: Simulation result at the MEBT exit using with the distribution obtained with TOUTATIS.

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