COMMISSIONING STRATEGIES FOR J-PARC LINAC AND L3BT

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Abstract

We will start beam commissioning of J-PARC linac in December 2006. The commissioning plan and the priorities of commissioning procedures are described together with some characteristic features of the commissioning procedures.

INTRODUCTION

We will start beam commissioning for J-PARC linac [1] in December 2006 with the reduced beam energy of 181 MeV [2]. In the 181-MeV operation, the negative hydrogen ions generated from a 50-keV ion source are accelerated with a 3-MeV RFQ (Radio Frequency Quadrupole linac), 50-MeV DTL (Drift Tube Linac), 181-MeV SDTL (Separate-type DTL), and led to the succeeding beam transport line called L3BT (Linac-to-3-GeV-Synchrotron Beam Transport) (See Fig. 1). The front-end part of the linac up to DTL1 was beam commissioned at KEK Tsukuba campus until 2004 [3, 4, 5, 6, 7]. In the beam test, the transverse emittance after DTL1 was measured, and a phase/amplitude scan method was demonstrated to tune the RF set-point for DTL1. The front-end part has been moved to the J-PARC site in JAEA Tokai campus and installed into the accelerator tunnel. The plan for the coming beam commissioning has been built upon the experience from the MEBT beam commissioning in KEK.

Among the major commissioning procedures, the tuning schemes for the RF set-points of DTL and SDTL are described in the references [8, 9], and the transverse matching scheme is also described in the reference [10]. Then, we do not repeat to describe these tuning procedures in this paper. Instead, we describe the commissioning plan and the priorities of the commissioning procedures in some detail. The outlines of the tuning procedures for debuncher system and transverse collimator are also presented as characteristic features for the J-PARC linac commissioning.

COMMISSIONING PLAN

As described in the reference [2], the beam commissioning for the linac and L3BT is divided into two phases, namely; from December 2006 to June 2007, and from September 2007. The second phase is followed by the beam commissioning for the succeeding RCS (Rapid Cycling Synchrotron). In the first phase, only two of four beam dumps in L3BT are available, which are 0-deg dump and 30-deg dump in Fig. 1. Furthermore, the capacity of 30-deg dump is limited to 0.1 kW. Then, the maximum beam power in the first phase is limited to the 0-deg dump capacity of 0.6 kW. In the second phase, the remaining two dumps (90-deg dump and 100-deg dump) become available and the capacity for 30-deg dump is increased to 5.4 kW. Table. 1 summarizes the dump availability. We are unable to inject the beam into the collimator section and the injection line until the second phase. Then, the collimator tuning and the injection line tuning will be the main tuning items in the second phase together with the higher duty operation. In the first phase, we will deal with the other commissioning items according to their priorities. It should be noted that most of the commissioning procedures can be performed with the limited beam power in the first phase. Typical beam parameters for the beam commissioning are summarized in Table. 2, and their beam power in Table. 3. In Table. 3, the chopping ratio of 50 % is assumed.

Table 1: Beam dump availability and capacity

	0-deg	30-deg	90-deg	100-deg
1st phase	0.6 kW	0.1 kW	N/A	N/A
2nd phase	0.6 kW	5.4 kW	0.6 kW	2 kW

First Phase (from December 2006 to June 2007)

After a precise alignment in July and August, we will perform overall off-beam commissioning of the accelerator components from September to November, which includes the RF conditioning of the accelerating cavities. After the completion of the off-beam commissioning, we will start

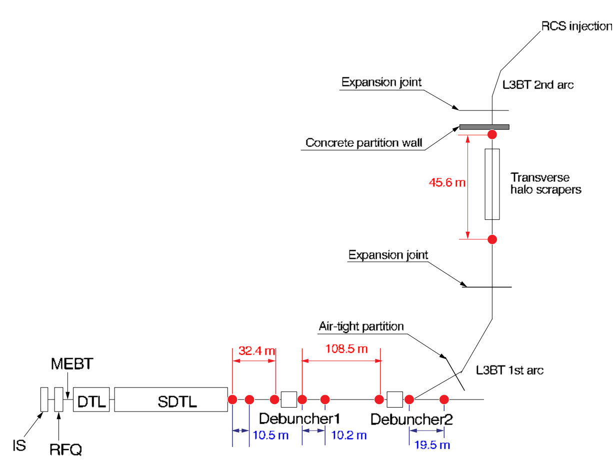

Figure 1: Schematic layout of J-PARC linac and L3BT.

Table 2: Typical beam parameters for commissioning

	Peak curr.	Pulse width	Repetition
Nominal	30 mA	0.5 msec	25 Hz
Low-current	5 mA	0.05 msec	5 Hz
High-current	30 mA	0.05 msec	1 Hz
Long-pulse	5 mA	0.5 msec	1 Hz
Single-shot	5 mA	0.05 msec	Sporadic

Table 3: Beam power for typical beam parameters

	W/o chopping	W/ chopping
Nominal	67.9 kW	33.9 kW
Low-current	0.23 kW	0.11 kW
High-current	0.27 kW	0.14 kW
Long-pulse	0.45 kW	0.23 kW

beam commissioning for RFQ and MEBT (Medium Energy Beam Transport). We believe that it is effective to take some time to make thorough trial runs in this early stage for beam diagnostics, low-level RF control system, control software, timing system and so on. MEBT is ideal for such a trial run, because it has all kinds of beam monitors installed in the linac, and it also has key components such as buncher cavities and chopper cavities. We believe that the trial runs contribute to find problems and faults in an earlier stage. In the MEBT beam test, the beam is dumped at a beam stop installed at the end of MEBT. The MEBT beam test is basically a reproduction of the beam test in KEK, but some key components were temporal ones in the KEK beam test and replaced in installing at the J-PARC site, which includes low-level RF system, timing system, and signal processing units for some of the beam monitors. In addition, a few monitors are added in MEBT to improve the beam diagnostic capability [11]. From the experience in KEK beam commissioning, the RF conditioning for DTL tanks is anticipated to take a month or so. Even if the RF conditioning for DTL tanks is extended, the above MEBT beam test can be performed in parallel with the DTL aging.

After injecting the beam into DTL, we focus on to accelerate the beam up to the design energy of 181 MeV with the minimum orbit correction and the minimum transverse matching. The minimum tunings here mean those required to avoid notable beam losses. The RF phase and amplitude are set for each klystron with a phase/amplitude scan method as described in the reference [8]. In this tuning process, we need to guide the beams with lower energy to 0-deg dump. We have confirmed with a simulation that the lower energy beams can easily be transported with a weaker quadrupole setting as long as the beam is properly accelerated in DTL1, where the field gradients are simply scaled by the magnetic rigidity of the beam [12]. The acceleration of the beam up to 181 MeV is a prerequisite to start the process to apply for the radiation control authorization for RCS. In this stage, we assume the low-current operation in Table. 2 without chopping.

After establishing the 181-MeV acceleration, the priority is given to the chopper tuning to realize the various operation modes requested from RCS commissioning, which includes so-called *single shot operation*. In the single shot operation, one macro-pulse is injected into RCS only when a request is placed, which is realized by the MEBT chopper system. The beams are totally dumped by the MEBT chopper in the idling period, and the chopper cavity is turned off only when the beam request is placed. The RF power is fed to all the cavities with 25 Hz all the time. While the chopper system itself will be commissioned in the preceding MEBT beam test, we will verify the single shot operation in this stage with a high priority.

Then, we move to the transverse matching [10], orbit collection, and high-current operation in Table. 2 as long as the time permits. Beam-based alignment of BPM's (Beam Position Monitors) is also foreseen [13].

Second Phase (from September 2007)

At first in the second phase, we perform the RF setpoint tuning for debuncher cavities [14]. We have two debuncher cavities in L3BT. While the first debuncher cavity, or dubuncher 1, can be tuned in the first phase, we need a TOF (Time Of Flight) measurement at the collimator section to tune debuncher 2. The debuncher tuning requires a long-baseline TOF measurement as discussed later.

The collimator tuning may be a major commissioning item for the second phase. However, we should fully optimize the transverse matching upstream before using the transverse collimator, and the transverse matching in the upstream section might not be sufficient depending on the progress in the first phase of the beam commissioning. Above all, the transverse collimator becomes important in the phase where we increase the beam power of RCS, but not in the early stages of the RCS commissioning. Considering the above situations, we may leave the elaborated collimator tuning [15] until later, and proceed to the injection line tuning.

The tuning of the injection line is performed injecting the beam into a beam dump to which we refer as the RCS injection dump. Nominally, the neutral hydrogen atoms generated in the charge-exchange injection or the negative hydrogen ions which miss the charge-exchange foil are dumped at the injection dump [16]. In the injection line tuning, the beam is deliberately injected into the injection dump extracting the first charge-exchange foil. (For the purpose of the second and third foils, refer to the reference [16].) The tuning subjects here are the beam position, angle, and transverse Twiss parameters at the foil location. The beam position and the angle are measured with three MWPM's (Multi-Wire Profile Monitors) in the vicinity of the foil [17]. The Twiss parameters are evaluated with these three MWPM's and other six profile monitors (two MWPM's and four wire scanners) in the L3BT injection line.

CHARACTERISTIC COMMISSIONING PROCEDURES

Some of characteristic tuning procedures for J-PARC linac are briefly described in this section, while the detailed descriptions will appear in the references [14] and [15].

Debuncher Tuning

We have two debuncher cavities in L3BT to reduce the momentum jitter and the momentum spread at the RCS injection. We plan to perform a phase/amplitude scan to determine the RF set-point for debuncher cavities. However, an absolute energy measurement with high precision is required for the RF set-point tuning because of the small voltage for the debuncher cavities. The voltages for debuncher cavities are 1.35 MV and 0.45 MV for debuncher 1 and debuncher 2, respectively. To realize the RF set-point tuning with sufficient accuracy, the energy gain by the debuncher cavities should be measured with the accuracy of around 100 keV. We perform long-baseline TOF measurements before and after each debuncher cavities to meet this requirement. The FCT (Fast Current Transformer) layout for the long-baseline TOF measurements is shown in Fig. 1. The length for the baseline ranges from 32.4 m to 108.5 m. In the long-baseline TOF measurements, it is indispensable to measure the distance between a FCT pair with a high accuracy. To enable the accurate distance measurement, we equipped the FCT with a reference base for a 1.5-inch CCR (Corner Cube Reflector) which is compatible with a laser tracker (Leica LT600) and a total station (Leica TDA5005). In combination of LT600 and TDA5005, we can measure the distance with the accuracy of better than 0.5 mm including the positioning error between the reference base and the toroidal core. As a result, the beam energy is supposed to be measured with the accuracy of 15-57 keV in the long-baseline TOF measurements, assuming the phase measurement error of 2.5 deg.

Collimator Tuning

We have four horizontal and four vertical collimators in L3BT to eliminate the transverse tail or halo. The collimator section has eight quadrupole magnets placed with the fixed interval of 4 m. The tail particles are charge-exchanged to protons at the collimators and transported to 100-deg dump about 40 m downstream from the end of the arc section. In determining the collimator edge location, it is important to adjust the collimator gap center to the beam centroid. To enable the tuning, a WS (Wire Scanner) is installed after each collimator.A WS is selected because of the relatively easy calibration between the wire position and the collimator edge location. A BPM is also installed in the vicinity of the collimator to monitor the beam position drift during the operation. In narrowing the collimator gap, we need to monitor the dumped beam power for 100-deg dump. As the peak intensity of the dumped beam is weak, we plan to measure the dumped beam power by measuring the temperature rise of the beam window instead of using the conventional SCT (Slow Current Transformer). The calibration of the dumped power measurement is also an important commissioning item, where the calibration is performed with an SCT. In the calibration, the weak beam power is simulated by reducing the duty factor.

SUMMARY

The beam commissioning of J-PARC linac will be started in December 2006. The commissioning plan and procedures have been established.

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