THE J-PARC L3BT MONITOR SYSTEM FOR RCS INJECTION

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Abstract

The J-PARC linac-3GeV rapid cycling synchrotron (RCS) beam transport line (L3BT) monitor system have been installed to tune the intensity of 5mA-50mA linac beam. The monitor system will play an essential role for the beam commissioning and the radiation control in transport line and RCS injection. In this paper, beam position monitor, profile monitor, current transformer and momentum spread measurement for J-PARC linac is described. The monitor system of RCS injection area and commissioning procedure are also discussed.

INTRODUCTION

The beam commissioning of J-PARC linac has been scheduled to start in December 2006 [1]. The negative hydrogen beam is accelerated up to the design energy of 181MeV in separated-type DTL (SDTL), and transported to RCS injection point. In order to correct the beam orbit, transverse matching, momentum jitter and the momentum spread, the diagnostics system of L3BT and RCS injection area are used systematically [2]. The L3BT monitor system is composed of 45 BPMs, 19 wire profile scanners (WS), 12 slow and 6 fast current transformer (SCT/FCT), and 38 beam loss monitors (BLM) [3, 4]. FCTs are used to measure time-of-flight (TOF) of beam bunch, and evaluate the momentum jitter. The momentum spread of RCS injection beam is also measured by non-destructive 4-stripline pickups (BPM) placed in downstream of L3BT. The spatial resolution of less than 0.3mm for BPMs and momentum spread of less than 0.1% is required for RCS injection to avoid uncontrolled beam losses. The beam emittance and position have to be investigated at injection area.

J-PARC L3BT MONITORS

The BPMs of 4-stripline electrodes with one end shorted by 50 ohm terminations have be constructed and installed in L3BT quadrupole magnets. The BPM electronics of log-ratio method was also developed successfully. Applications and database for beam based calibration (BBC) of BPMs have been examined now [5, 6]. The attenuation of 324MHz signal power level during the transmission in RF cable is also surveyed to correct the signal balance. The thin carbon wires (diameter of 7~100 μm) are equipped for WSs, and have already be installed on linac and L3BT beam line [7, 8]. An application of transverse beam matching correction has been constructed, and motor driver system for position control with long length cable is examined now. The proportional counter type BLMs were also prepared for L3BT beam line, and installed after other apparatus (cable tray and/or water cooling pipe) had be mounted. These monitor system will be an indispensable tool for linac commissioning of first phase (from December 2006 to June 2007). In this stage, low current operation of peak current 5mA, pulse width 0.05msec, and repetition rate 5Hz is planed. After the 181MeV acceleration is established, the chopper tuning, which includes single shot operation, is carried out for the various operation modes of RCS commissioning. Then the transverse matching, orbit collection, and high current operation of peak current 30mA, pulse width 0.05msec, and repetition rate 1Hz will also be examined. The commissioning items for the second phase (from September 2007) are RF set point tuning for debuncher cavities, transverse collimator tuning, and RCS injection tuning. However, the collimator tuning becomes important mainly for high intensity RCS operation, and requires lots of machine time for precise transverse matching in upstream. Then the investigation of collimator matching will be performs in later commissioning phase.

BEAM COMMISSIONING FOR L3BT

Two debuncher cavities are operated to reduce the momentum jitter and the momentum spread at the RCS injection. In order to determine the accurate RF set point of phase/amplitude, the energy gain by debuncher cavities should be measured with the accuracy of about 100keV [9]. The TOF measurement system has be prepared to satisfy this commissioning requirement. The FCT arrangement of A0BT and L3BT is shown in Fig.1.

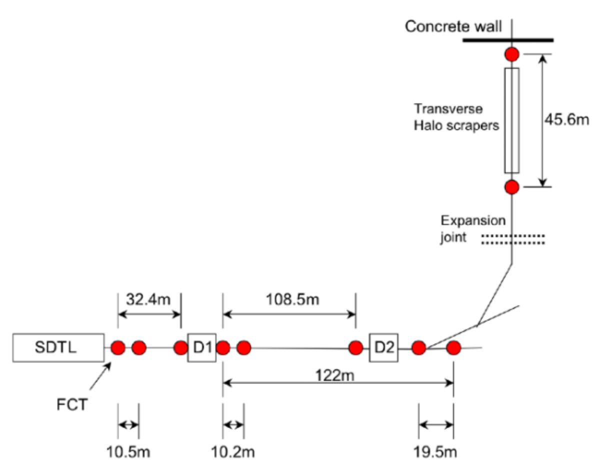

Figure 1: Schematic layout of FCTs in J-PARC L3BT.

The error of TOF diagnostics is determined by the accuracy of distance between a FCT pair and the phase measurement. For the measurement of separation distance, a laser tracker (Leica LT600) and a total station (Leica TDA5005) were prepared, and the accuracy of less than 0.5mm could be realized. The error terms for the bunch phase measurement are determined by 0.5 degree for FCT head, 0.25 degree for pickup cable (for the cable length of about 100m), 0.5 degree for reference line, 2.0 degree for phase detector (E8753A), 0.25 degree for 12bit ADC resolution, and totally about 2.5 degree in average for an assumption of temperature drift of 5 degrees centigrade. Consequentry, the momentum measurement with the accuracy of 15~57keV will be expected for the present FCT layout. In order to realize more accuracy measurement, the direct reference method will be examined. As shown in Fig.2, error terms of phase detector and reference line could be canceled out, then the accuracy of TOF measurement will also be reduced to about 6~23keV.

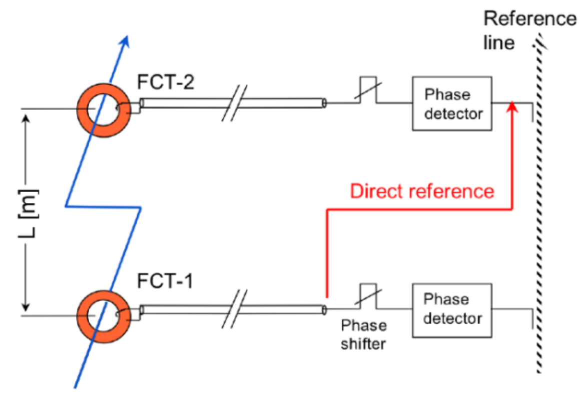

Figure 2: Reference line for TOF measurement.

Stripline pickups of BPMs can also be used as a quadrupole moment monitors to measure the beam size, from which the momentum spread is obtained. A non-destructive measurement using BPMs has been expected to tune the momentum spread of RCS injection beam. The momentum spread of less than 0.1% is required to avoid uncontrolled beam losses. The quadrupole mode should be observed on a downstream of L3BT beam line, where the large dispersion position compares to the difference of horizontal and vertical emittance-beta function products. The momentum spread is represented by:

$$\frac{\Delta P}{P} = \frac{1}{\eta}\sqrt{m - (\varepsilon_x \beta_x - \varepsilon_y \beta_y)} \quad (1)$$

where,

$$m = \sigma_x^2 - \sigma_y^2 \quad (2)$$

The practical measurement of the beam size term m is obtained as:

$$Q = \frac{(V_1 + V_3) - (V_2 + V_4)}{V_1 + V_2 + V_3 + V_4} = \frac{C}{R^2}(\sigma_x^2 - \sigma_y^2 + x_0^2 - y_0^2) \quad (3)$$

where, V show the detected signal of BPM pickups. The error term of m value can be evaluated as δm~$2.8x_0\delta x$ (or~$2.8y_0\delta y$) mm^2 in average. The transverse beam displacement x_0 (or y_0) and observation error δx (or δy) will be adjusted within 3mm and 0.1mm respectively. Consequently, the error term of m value can also be expected less than δm~1mm^2 in typical beam operation. The stabilities of δm<0.5mm^2 for the measurement have also be confirmed in the previous KEK MEBT1 experiment [10]. Figure 3 shows the m values for various $\delta P/P$ for a BPM position in downstream of L3BT (172m).

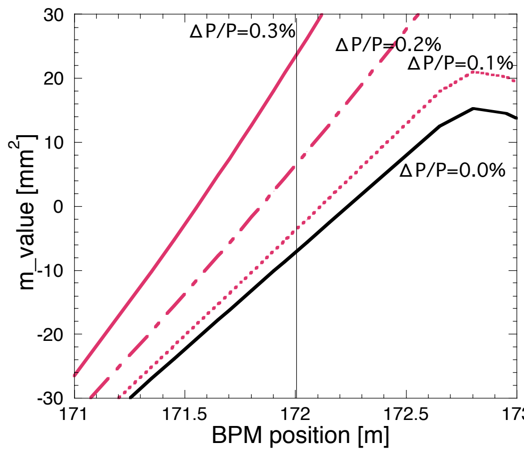

Figure 3: An m value dependence for momentum spread.

The shift of m value is about 4mm^2, then the accuracy of less than 0.025% can be expected for the dP/P=0.1% measurement. The sufficient accuracy and stability have be confirmed in the investigation. Furthermore, in order to correct the shift of the emittance-beta function product due to the space-charge-effect, another BPM will be used for a dispersion free region in L3BT.

MONITORS FOR RCS INJECTION

The chopped beam of maximum pulse length of 0.5msec is injected into RCS. The peak current of 5mA, pulse length of 0.05msec, and repetition rate of 1Hz beam will be performed in early commissioning phase. The tuning of the injection septum and the shift bump magnets will be examined. As shown in Fig.1, many magnets with large aperture and charge-exchange foil system are installed in tight space. It was difficult to mount the BPM for such area, the multi wire scanner monitor (MWPM) are mainly used at RCS injection.

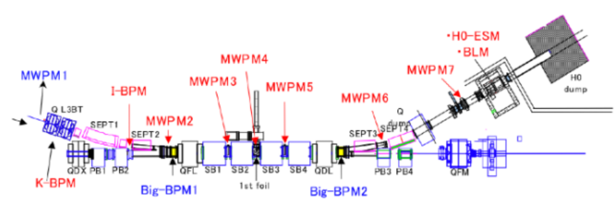

Figure 4: Schematic layout of injection monitors.

The expected rms beam size is about 1.5~2.0mm in assuming the rms emittance of 6pi.mm.mrad for linac beam, then the spatial resolution of ~0.1mm is required. The observation area of 100~250mm will also be necessary for various injection commissioning mode, namely the center injection, painting injection, and tune survey. In order to satisfy the beam position and profile measurements for the commissioning scenario, sensor wires are tilted to the direction of motor drive. To optimize the observable range, detector channel number, and scanning period, tilt angle of about 17 degree was designed. An expected physical process between thin wire and H^- beam is a dissociation of electrons, then the positive bias voltage will be an essential for MWPM1~5 to suppress the secondary electrons. The design study has been carried out based on an investigation of single wire scanner in linac. The possible interaction mechanism with charge-exchanged H^+ beam is a secondary electron emission by passing through ion beams. Since the signal level of MWPM6 and MWPM7 is supposed as about 1% for negative hydrogen beam, the wide area of ~1mm Ti sensors are required.

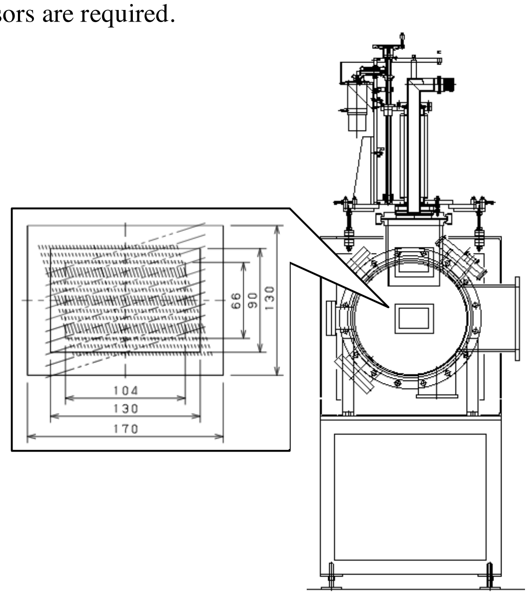

Figure 5: Schematic of MWPM4 and wire sensor.

One of the main sources of expected beam loss is caused by the H^- stripping with the injection carbon foil. About 0.4% (145W) loss for 181MeV beam comes from the excited H^0 states by the interaction with carbon foil [11]. As shown in Fig. 6, these loss components have to be ionized to H^+ beam by the second and the third foils to guide into the RCS injection dump.

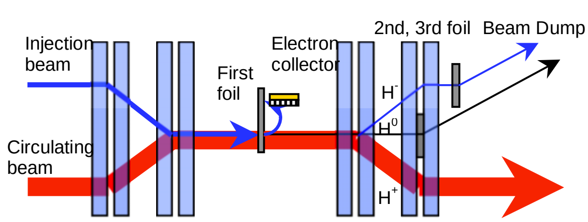

Figure 6: The H^- and H^+ beam line of RCS injection.

In order to confirm the beam intensity of dump line, high sensitivity and fast response monitor should be prepared. An induced electrostatic monitor (ESM) has been developed to observe the intensity of 0.02-0.2mA beam. The stripped electrons should also be captured and measured by electron collector to prevent the damage of electron flux, which is gyro motioned by stray field of shift bump magnets. The surface of electron collector is made with a carbon plate, and mounted on water cooling cupper block. The temperature and obtained electrons will be monitored to investigate the efficiency of electron collection, and confirm the heat flux in practical operation.

SUMMARY

The beam commissioning of linac is planed to start in December 2006. The tuning for downstream of L3BT and RCS injection will also be started in September 2007. The beam monitor system is expected as an essential tool for the beam orbit and the transverse matching correction. The debuncher tuning of momentum jitter and momentum spread are main commissioning item for L3BT beam line. The TOF measurement with FCTs and quadrupole mode measurement of 4-stripline BPMs will be performed in the early phase of L3BT commissioning. These monitors have already been installed on the beam line, and applications for beam commissioning are developed. The RCS injection has to be controlled precisely to suppress the beam losses for the high intensity operations. The injection beam monitor system has also been developed, and will be installed in January 2007.

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