UPGRADE OF BEAM DIAGNOSTICS IN LEBT AND MEBT OF J-PARC LINAC

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Abstract

Front-end part (from an ion source, up to the first drift tube linac, DTL-1) of J-PARC LINAC [1] was transported to Tokai, after beam tests in Tsukuba [2]. From the coming December, commissioning with H^- beam in Tokai is scheduled. Before the commissioning, upgrade of beam diagnostics is taken; three beam current monitors (slow current transformer, SCT) and two beam phase monitors (fast current transformer, FCT) are added in the low-energy transport line (LEBT) and medium-energy transport line (MEBT). The upgrade scheme of these additional monitors is described.

UPGRADE OF BEAM DIAGNOSTICS

Before the beam commissioning at J-PARC in Tokai, we add several beam diagnostic devices in LEBT, and MEBT. In this upgrade, we add (i) three more current monitors (SCT's) to diagnose beam transmission in LEBT/MEBT, (ii) two more beam phase monitors (FCT's) to tune two bunchers. Moreover, SCT takes a role of (iii) input candidate for beam interlock system, e.g. personal protection system (PPS) and machine protection system (MPS). For the location of these additional monitors, see the figure 1 (LEBT) and figure 2 (MEBT).

RESOLUTION OF BEAM DIAGNOSTICS

FCT core is aiming for providing 0.5 deg resolution, with calibration through a dedicated test setup consisting of network analyzer [3]. SCT is aiming for providing 1 % resolution of beam current, with an interactive calibration coil wound on each inductive core. Beam position monitor (BPM) requires resolution of 0.1 mm [1]. Beam profile monitor (wire scanner, WS) is scanning the beam profile with 0.1 mm step in vertical and horizontal direction [4].

MODIFICATION OF LEBT MONITORS

Upgrade of Beam Current Monitoring

In LEBT, in order to monitor beam current after Ion Source for RFQ injection, we add a beam current monitor (SCT). There exist a movable Faraday cup and two sets of emittance monitors (double slit scanner type). One SCT is added on the same monitor head with the Faraday cup. Figure 1 shows schematic views of LEBT modification. The monitors are contained in a chamber drawn in the figure.

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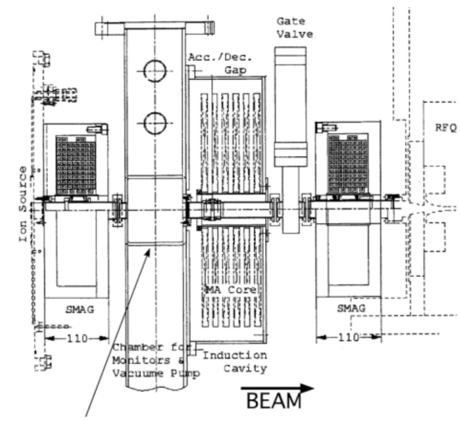

Figure 1: Schematic view of LEBT [1]. Green and red letters show existing and upgraded monitors, respectively.

MODIFICATION OF MEBT MONITORS

In MEBT, there are eight beam position monitors (BPM's) [5, 6], four beam profile monitors (wire scanner monitors, WS's) [4], and three sets of FCT/SCT (combined with each other). Figure 2 shows schematics of MEBT modification. There are several locations where monitors are positioned.

- BPM is located on each of eight Q-magnets.
- WS is located at (1), (2), (3), (4).
- SCT/FCT is located at (1),(2),(3), and by upgrade (4),(5).

(1) between RFQ and Q1
(2) between chopper and Q4
(3) between Q8 and DTL1
(4) between Q3 and chopper (= upgrade type1)
(5) between buncher2 and Q6 (= upgrade type2)

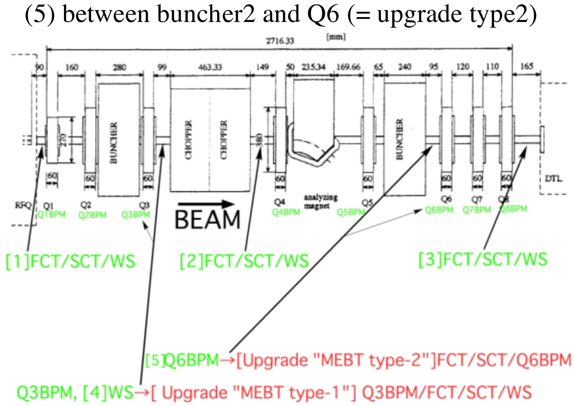

Figure 2: Schematic view of monitor location for MEBT [1]. Green and red letters show existing and upgraded monitors, respectively.

Upgrade of Beam Current Monitoring

In MEBT, in order to monitor beam current after each of two bunchers, two SCT's are added. One SCT is for beam current after buncher-1 (SCT-type1, hereafter). The other SCT is for beam current after buncher-2 (SCT-type2, hereafter). SCT-type2 gives complemental measurement of chopped beam current.

Upgrade of Beam Energy (time-of-flight) Monitoring, for Tuning of Two Bunchers

In order to tune two bunchers in MEBT, beam energy after each of the bunchers need to be monitored continuously. We add two beam phase monitors (FCT's). One is FCT-type1, which is located after the buncher1 (between Q3 and chopper). The other is FCT-type2, which is located after buncher-2 (between buncher-2 and Q6). For beam energy monitoring, following pairs of FCT's are used to measure time of flight (TOF, which is a function of beam energy). For energy after buncher-1, time of flight between FCT(2) and FCT-type1 is used. For energy after buncher-2, time of flight between FCT-type2 and FCT(3) is used. Namely,

$$TOF\ (after\ buncher1) = FCT(2) - FCT(type1)$$
$$TOF\ (after\ buncher2) = FCT(3) - FCT(type2)$$

Upgrade of Beam Interlock System

It is required to monitor integrated number of accelerated beam for each running mode. This is because each beam dump has its own capacitance for deposited power. When the accelerated beam exceeds the threshold, beam interlock needs to be functioned [7].

SCT provides time-to-time number of accelerated beam (= beam current), and an analog-integrating circuit integrates for each period of macro bunch (~500 micro-seconds). Then the analog integrated signal is transmitted to digitizer, and integrated for certain period (typically 1 hour) to compare with an interlock limit. Monitors and readout electronics (analog integrator, digitizer, digital integrator, comparator, etc) are required to be redundant. Figure 3 shows schematics of the interlock system for total number of accelerated particles.

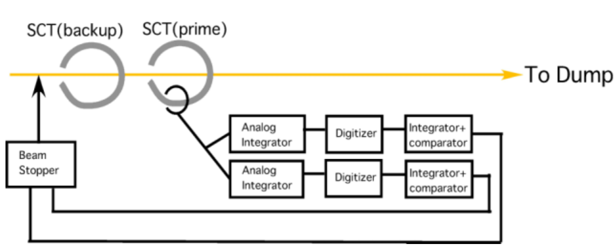

Figure 3: Schematics of the interlock system for total number of accelerated particles. SCT provides elementary information for the system.

The SCT-type2 (located between buncher-2 and Q6) can provide an input signal for the interlock system, cooperating with PPS (personal protection system) and MPS (machine protection system). Depending on the noise condition during machine operation, some of the following candidates are chosen as a prime input and as a backup input.

Candidates for input to interlock system
(i) SCT between Q8 and DTL-1
(ii) SCT between DTL-1 and DTL-2
(iii) SCT between DTL-2 and DTL-3
(iv) SCT between buncher-2 and Q6 (= SCTtype2)

MECHANICAL STRUCTURE

The mechanical structure is following. Each set of CT is explained separately.

Additional SCT in LEBT

In order to save space, a SCT is attached on the same monitor head with Faraday cup. The SCT has ϕ 34 mm in diameter. To avoid the out gas from the inductive core of SCT, the SCT is isolated from the vacuum of beam duct (the SCT core is contained in a space occupied by 1 atm. of air, then the space is isolated in the beam duct vacuum). RF signal is transmitted through a ceramic spacer (see figure 4), which is covered by a metal plate against secondary electron production. SCT has 50 turns (for signal) and 1 turn (for calibration input) of coils around inductive core.

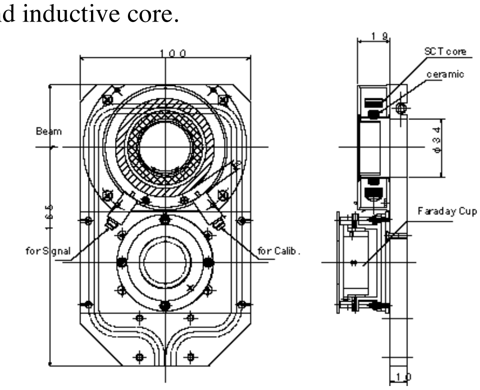

Figure 4: SCT monitor in LEBT. A faraday cup detector is also mounted on the same detector head. Depending on the functionality, either the SCT or the Faraday cup is on the beam line (mechanically moved by a stepping motor).

Additional SCT+FCT (type-1) in MEBT

In order to save space, a BPM mounted on Q3 magnet, the additional FCT+SCT, and Wire Scanner monitors are welded with each other (but not connected with chain cramps through flange-to-flange connections. See Fig.5). It has ϕ 37.7 mm in diameter, and total length is 179 mm. To allow position adjustment among these detectors, a bellow is welded between the BPM and the FCT, and a support structure for the WS has adjustable connection scheme with bolts in 3 directions. Fundamental functionality is implemented on each detectors, e.g. a base structure of a survey ball for FCT positioning, vacuum protection from outgas from inductive core (ceramic window for RF signal transmission), electron protection on the ceramic core. Before welding, BPM [8] and CT have already been calibrated independently at bench test setup. Figure 6 shows BPM and FCT/SCT before welding. To prevent mechanical destruction of ceramic spacer, small pieces of metallic sheets (spot-welded) are used (see figure 6) to make electrical conductivity of the core case.

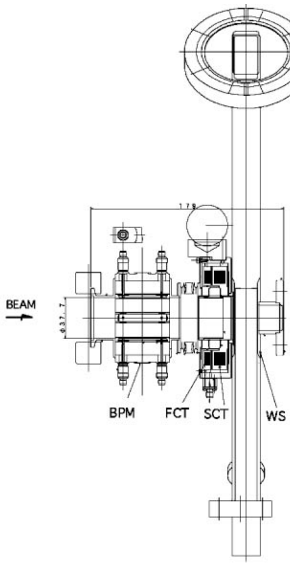

Figure 5: Mechanical design of MEBT monitor (type1). In this figure beam runs from left (BPM) to right (WS). Monitors are welded with each other.

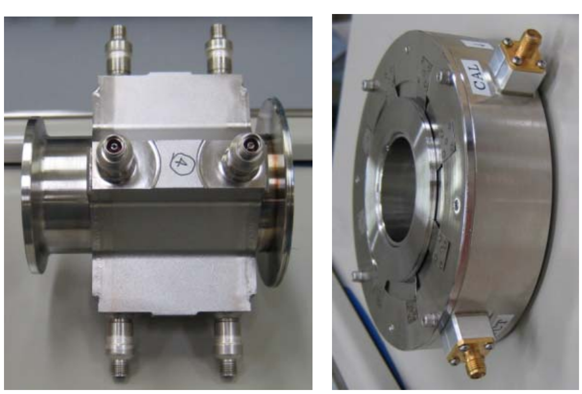

Figure 6: BPM (left) and FCT+SCT(right), before weld.

Additional SCT+FCT (type-2) in MEBT.

In order to save space, the additional FCT+SCT, and a BPM mounted on Q6 magnet are welded with each other (See Fig.7). It has ϕ 37.7 mm in diameter, and total length is 173 mm. Same cares around ceramic are taken as type-1.

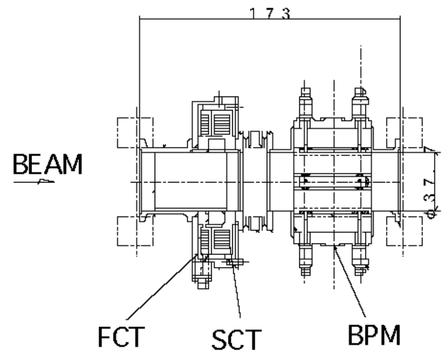

Figure 7: Mechanical design of MEBT monitor (type 2). In this figure beam runs from left (FCT) to right (BPM). Monitors are welded with each other.

INSTALLATION

Welded monitors are planned to be installed in the middle of August, 2006. Then these monitors are used for the beam commissioning from December, 2006.

SUMMARY

- One additional SCT in LEBT, and two additional set of FCT/SCT's in MEBT are designed, and fabricated, and have been calibrated. BPM's being welded on the CT's have been also calibrated.
- By the additional monitors, it becomes possible to monitor continuously beam current at LEBT, and MEBT after chopper. Also, capability is acquired to tune bunchers in MEBT with monitoring beam energy for each. Also SCT in MEBT is useful to give an input signal for beam interlock system.
- Installation is planned in August, and beam commissioning is planned in December, 2006.

REFERENCES

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