TOWARDS THE COMMISSIONING OF J-PARC

T. Katoh[1], K. Furukawa[1], N. Kamikubota[1], H. Nakagawa[1], J. Odagiri[1], Y. Takeuchi[1], N. Yamamoto[1], H. Kiyomichi[2], H. Sakaki[2], H. Sako[2], G-B. Shen[2], H. Takahashi[2], H. Yoshikawa[2]
[1]*KEK, Tsukuba, Japan,* [2]*JAERI, Tokai, Japan*

ABSTRACT

J-PARC (Japan Proton Accelerator Research Complex) accelerator complex is under construction as a joint project of Japan Atomic Energy Research Institute and KEK. The accelerator complex consists of a proton linac, a Rapid Cycling Synchrotron (RCS) and a Main Ring synchrotron (MR). Accelerator buildings for the linac and RCS were completed and installation of accelerator components has started and the construction of the control system for these accelerators has also started while the MR tunnel is still under construction. The commissioning of the linac is scheduled in September, 2006 and that of RCS is in May 2007. Part of the tunnel for MR has already been constructed and installation has been started but the rest of it will be completed in next year.

The first part of the linac, Ion Source (IS), Radio Frequency Quadrupole (RFQ) linac and Drift-Tube Linac (DTL) were once installed in KEK and tested there with the control system based on EPICS. These accelerators were dismantled and transported to Japan Atomic Energy Research Institute (JAERI) Tokai site of Japan Atomic Energy Research Organization (JAERO) for installation. The set-up and test of the linac control system has just started. Software test and tuning will begin in the near future.

INTRODUCTION

J-PARC is composed of multi-stage accelerators with Material and Life sciences Facility (MLF), Hadron Physics facility (HD) and Neutrino Physics facilities (NU) that are being constructed at JAERI Tokai site as shown in Figure 1[8].

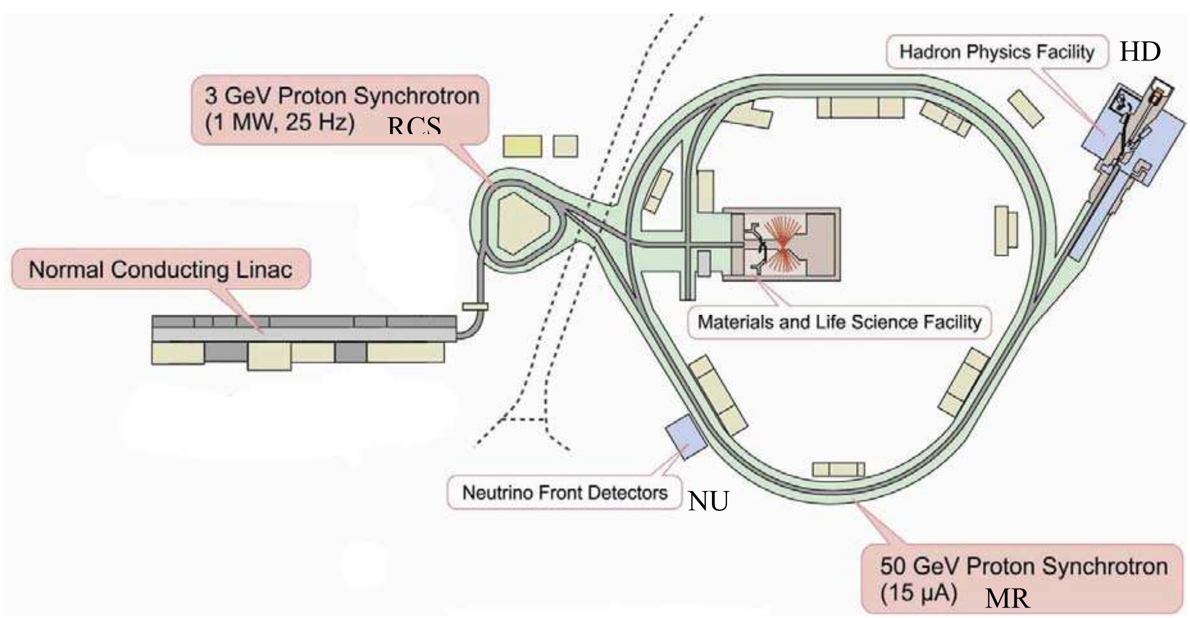

Figure 1: J-PARC Accelerators at JAERI Tokai Site.

There are three stages of cascade accelerators and each accelerator has its special characteristics. The linac will be operated with 25 Hz repetition rate with the RCS in the phase 1 of J-PARC. In the phase 2 of this project, the linac will be extended to 600 MeV by adding super-conducting linac and will be operated with 50 Hz and half of the linac pulses will be supplied to Transmutation Experimental Facility (TEF) for the development of Accelerator-Driven technology (ADS). The RCS will accelerate protons up to 3 GeV and will supply them to Materials and Life-sciences Facility

(MLF) where neutron and meson physics experiments will be performed. The MR will be operated every 3.64 seconds typically. The beam pulses from the linac will be shared by the RCS and the ADS in Phase 2 of J-PARC project. The RCS accelerates half number of pulses from the linac and the other half will be delivered to the ADS. The MR accepts only 4 cycles of RCS pulses during its operation cycle (4 out of 91 pulses) and the rest are sent to MLF where neutron and muon experiments will be performed. The main parameters are shown in Table 1.

Accelerator	Energy	Beam Current	Repetition Rate
Linac	181 MeV [600 MeV]	50 mA (peak)	25 Hz [50 Hz]
RCS	3 GeV	333 uA	25 Hz
MR	40 GeV [50 GeV]	15 uA	1/3.64 sec. (typically.)

[ ] indicates the parameters after construction phase 2.

Table 1: The main parameters of the J-PARC accelerators.

CONTROL SYSTEM ARCHITECTURE

There are three different types of accelerators and they have different requirement for the control system. The linac is operating with 25 Hz or 50 Hz repetition rate, the RCS is 25 Hz and MR is every 3.64 seconds typically. Each accelerator has its own control system as shown in Figure 3. These subsystems can be operated separately from the CCR because that the commissioning date is different.

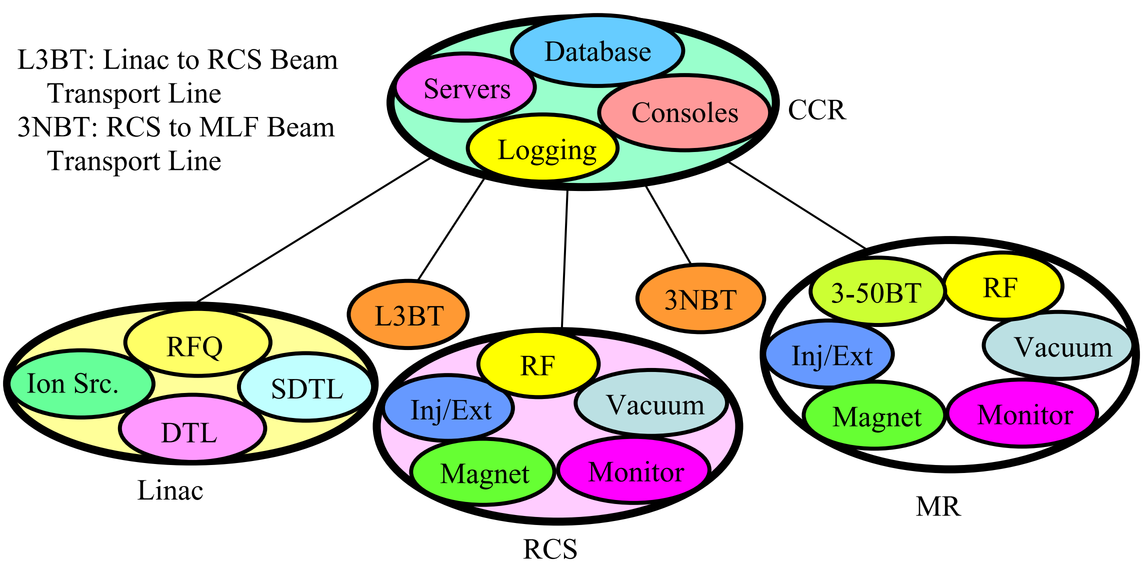

Figure 3: Configuration of the J-PARC control system.

System Architecture

The J-PARC accelerator control system is based on EPICS tool-kit and operated with client-server model [1], [2], [8]. The hardware configuration is three-layer model. The highest layer is the presentation layer, which includes network, operators' consoles, server computer, logging computer, archiving computer, and database computer. The next layer is the equipment control layer that includes I/O controllers (IOC) on which EPICS Channel Access (CA) server software runs. The lowest layer is the hardware interface layer with VMEbus modules, GPIB equipment, Programmable Logic Controllers (PLCs) and other instruments that are connected through the field-bus. For the J-PARC control system, we decided to use Ethernet as the field-bus. The general configuration is shown in Figure 4.

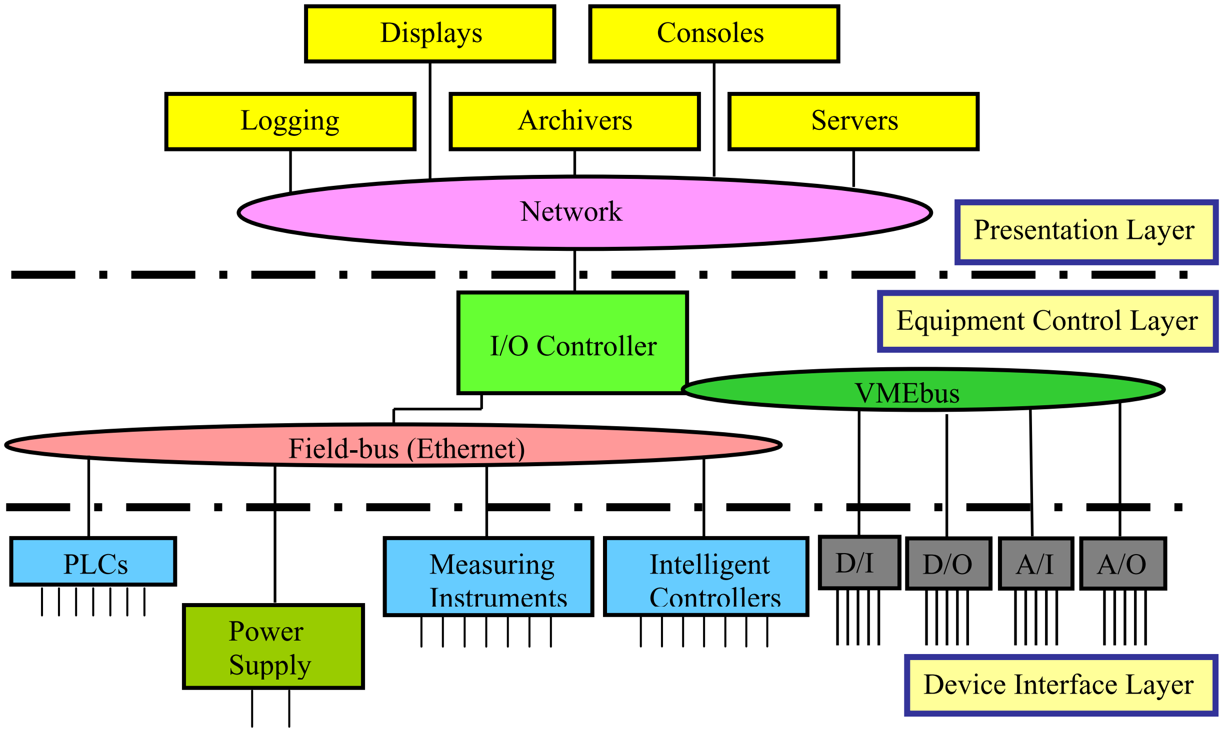

Figure 4: 3-Layer model of J-PARC control system.

COMMON ENVIRONMENT

In this section we describe the common environment such as the network system, timing system, operators' consoles, Machine Protection System (MPS), Personnel Protection System (PPS), etc.

Network System

And each control system is connected to common network as a sub-system as shown in Figure 5 and accelerators will be controlled from the Central Control Room (CCR) by the unified operation team. The backbone network is Giga-bit Ethernet (GbE). For each subsystem redundant network paths are provided and some network switches are redundantly connected. The network for accelerator control is separated from the laboratory network by a "Fire-Wall" gateway.

The central part of the network system has been installed and being tested. The connection between the central node and linac and RCS nodes will be completed soon.

Timing System

The timing control system generates three fundamental signals, 12 MHz standard clock signal, 50 Hz signal, and the MR cycle start signal. The timing system distributes these 3 signals through optic fibre cables to the local control rooms [3]. The timing signal receiver modules are installed in the VME IOCs and delayed timing signal outputs are used to control and synchronise equipment.

Operators' Consoles

The J-PARC accelerators will be operated by the operators and accelerator physicists sitting in the CCR. There will be tens of Personal Computers (PCs) or powerful servers in the computer room next to the CCR. For each operator, several display monitors will be provided with a set of a keyboard and a pointing device. There will be no noisy equipment and only quiet PCs, keyboards, display monitors, and mice will be set in the CCR for the ergonomic reasons. It is desirable to keep the CCR quiet enough for the operators. The large screen monitors equipped with Digital Light Processing (DLP) devices or Liquid Crystal Display (LCD) will be used for displaying general information. The console desk will be designed as flexible as possible for later modifications as that of KEKB accelerator operators' consoles [10].

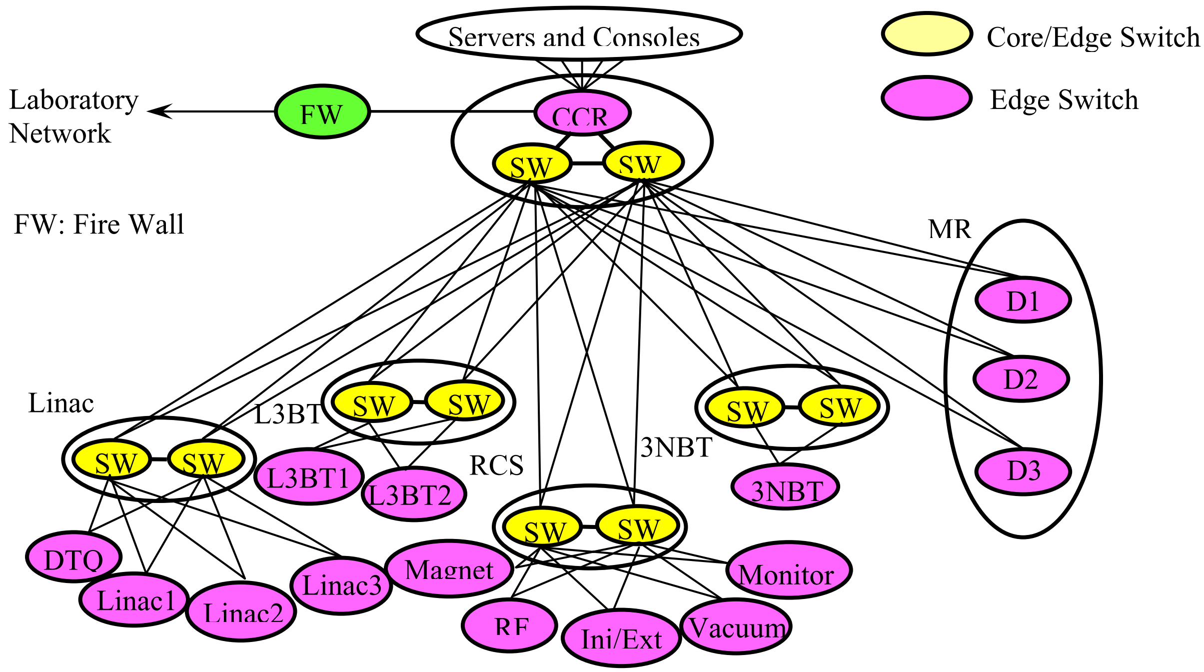

Figure 4: The J-PARC accelerator control network.

Machine Protection System (MPS)

Since the J-PARC accelerators will be operated with very high beam intensities, we must operate them very carefully to keep the beam not hitting the accelerator components. Therefore, an MPS is introduced to stop the beam as quick as possible, i.e. within about 50 micro-seconds, while the normal beam pulse width is about 500 micro-seconds. Beam losses along the linac, beam transport lines are detected by fast radiation monitors and if the beam loss exceeds certain limit, the alarm signal will be transmitted to the beam control circuit at the upper stream of the linac.

The MPS modules have been developed and tested. The MPS for the linac is now being installed.

Personnel Protection System (PPS)

Personnel protection from radiation or other dangerous situation is also a job of J-PARC control group [9]. Every radiation controlled area is monitored by the PPS to keep personnel out of the area. The system is controlled by using redundant PLCs.

The installation of PPS for the linac and the RCS area is underway and will be completed by the end of this year.

Integrated Beam Control System

In order to keep the beam loss low and to avoid unnecessary irradiation from the beam, we must be careful in operating J-PARC accelerators. We must check all the conditions before operating accelerators with certain parameter set. We are designing a software system that checks parameters whether their combination is reasonable or not. The system is being designed now.

Fieldbus

As described above, we decided to use Ethernet as the fieldbus and we have developed both hardware and software for controlling equipment through Ethernet. One of them is the EMB-LAN controller module for controlling power supplies in standardised interfaces [4], [5]. By using this module, a power supply is connected directly to the network. Another example is the Beam Position Monitor Controller (BPMC). This is an intelligent controller that handles a beam position monitor set with 4 electrodes. It can store a continuous series of position signals or sample continual series of data. We use a network-based measuring instruments system called WE7000 made by Yokogawa Electric Co. Ltd. There are varieties of data acquisition modules; from low-speed to high-speed, from low-cost to high precision, depending on the cost. We have already tested in the DTL commissioning at KEK Tsukuba site [4], [6], [11].

Programmable Logic Controllers (PLCs)

Many PLCs are used in the power supply systems, RF systems, vacuum systems, cooling systems, etc. We have developed a common EPICS device driver supports for PLCs models manufactured by several companies, e.g. Yokogawa Electric, Mitsubishi Electric, and OMRON [5].

ACCELERATOR SPECIFIC CONTROL SYSTEMS

The characteristics of each control sub-system are shown in Table 2. In the table, number of IOCs, used operating system name, and input/output interfaces are shown. The linac and RCS control sub-systems mainly use VxWorks operating system and Linux operating system is used auxiliary while MR control sub-systems mainly use Linux and VxWorks auxiliary. All sub-systems use PLCs and Embedded Local Area Network interface (EMB-LAN) modules for power supplies. The linac and MR control sub-systems use WE7000 measuring instruments. BPMC is the Beam Position Monitor Controller for MR and it is equipped with micro-processor and real-time Linux operating system.

Accelerator	IOC Hardware	IOC Operating System	Input/Output Interfaces
Linac	~65 VMEs	VxWorks, Linux	VME Modules, PLC, EMB-LAN, WE7000
RCS	~25 VMEs	VxWorks, Linux	VME Modules, PLC, EMB-LAN
MR	~50 VMEs	Linux, VxWorks	PLC, BPMC, WE7000, EMB-LAN

Table 2: IOCs for the control sub-systems.

Linac Control System

Linac is composed of the ion-source, Radio Frequency Quadrupole (RFQ) linac, three Drift-Tube Linac (DTL) tanks, and 32 Separated-type Drift-Tube Linac (SDTL) tanks. There are about 50 sets of klystron power stations and each of them drives 4 accelerating cavities and has a set of a DC power supply, a Vacuum, RF driver, and monitoring systems mounted in 12 racks. Two IOCs for the linac control are mounted in a row of racks, one for MPS and the other for PLCs and beam monitors.

RCS Control System

RCS is operated with about 25 Hz repetition frequency which is not synchronized with the AC power line frequency 50 Hz. The standard frequency signal is generated by the precise frequency synthesizer and divided to get 25 Hz signal. The accelerator components of the RCS are controlled by PLCs or directly by VME IOCs [7].

MR Control System

Control system for MR is composed of several sub-systems, e.g. magnet control, RF control, vacuum control, beam injection/extraction and beam monitoring sub-systems. These sub-systems are connected to the J-PARC accelerator control system at three local control rooms D1, D2 and D3 through the J-PARC backbone network as shown in Figure 4. For the beam position measurement, intelligent BPMCs are used

MR Beam Abort System

In order to reduce the radiation caused by the beam losses in the MR tunnel, the Beam Abort System will be provided. When the beam loss higher than certain limit is detected or a failure of the MR component happens, the beam coasting around the ring will be forced to be extracted to the beam dump by using the fast extraction system in reverse polarity.

SCHEDULE

The construction schedule of accelerators is shown in Figure 6. Construction of the linac and RCS buildings has been completed and the installation of linac and RCS components is in progress. The software for linac and RCS installation and test is now under development. The construction of all accelerators will be completed in the early 2008 and operation will start in mid 2008.

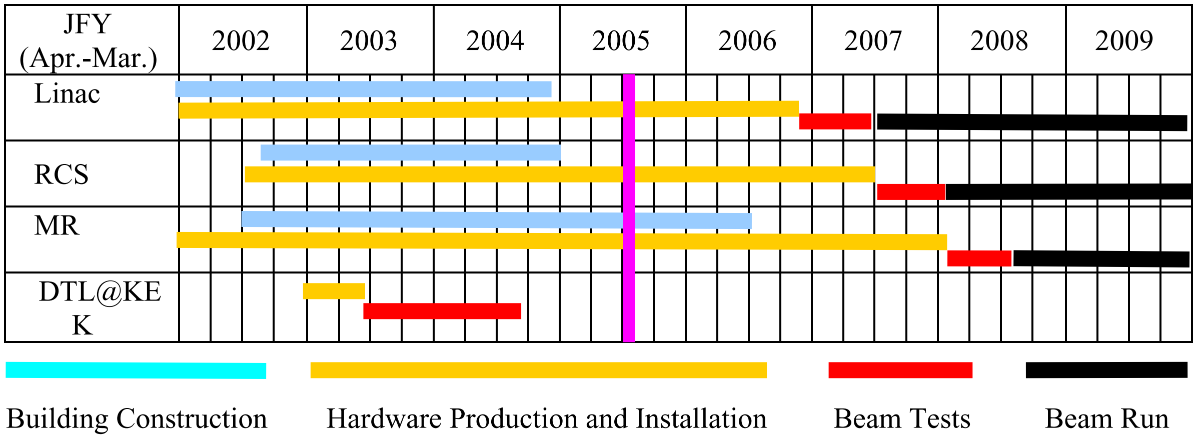

Figure 6: J-PARC construction schedule.

SUMMARY

The construction of the J-PARC control system is now partially being installed and hardware and software development is underway. The commissioning of the linac is scheduled in 2007 and construction of all the accelerator control system will be completed in 2008.

ACKNOWLEDGEMENT

We would like to thank all the people in the J-PARC accelerator groups and controls people in the experimental facility groups for their collaboration and valuable suggestions.

REFERENCES

[1] T. Katoh, et al., "PRESENT STATUS OF THE J-PARC CONTROL SYSTEM", PAC05, Knoxville, TN, USA, May 2005, ROPA003.

[2] T. Katoh, et al., "PRESENT STATUS OF THE J-PARC CONTROL SYSTEM", ICALEPCS 2003, Gyeongju, Korea, October 2003, pp.1-5.

[3] F. Tamura, et al., "J-PARC TIMING SYSTEM", ICALEPCS 2003, Gyeongju, Korea, October 2003, pp.247-249

[4] N. Kamikubota, et al., "PROTORYPE CONTROL SYSTEM OF THE 60-MEV PROTORN LINAC FOR THE J-PARC PROJECT", ICALEPCS 2003, Gyeongju, Korea, October 2003, pp.81-83.

[5] J. Odagiri, et al., "EPICS DEVICE/DRIVER SUPPORT MODULES FOR NETWORK-BASED INTELLIGENT CONTROLLERS", ICALEPCS 2003, Gyeongju, Korea, October 2003, pp.494-496.

[6] M. Takagi, et al., "NETWORK-BASED WAVEFORM MONITOR FOR THE J-PARC ACCELERATOR COMPLEX", ICALEPCS 2003, Gyeongju, Korea, October 2003, pp.497-499.

[7] H. Takahashi, et. al., "CONTROL SYSTEM OF 3 GeV RAPID CYCLING SYNCHROTRON AT J-PARC", PAC05, Knoxville, TN, USA, May 2005, FPAT047.

[8] Accelerator Technical Design Report for J-PARC, 2003, JAERI-KEK.

[9] Y. Takeuchi, "Personnel Protection System of Japan Proton Accelerator Research Complex", Proc. ICALEPCS 2003, Gyeongju, Korea, October 2003, pp. 404-406.

[10] T. Katoh, et al., "ERGONOMICS IN KEKB CONTROL SYSTEM", Proc. WAO 2001, Villar-sur-Ollon, Switzerland, January-February 2001, pp. 5-9.

[11] M. Takagi, et al., "Beam-monitor Software of the KEK Proton Linac for J-PARC", PO1.061-6 of this conference.