CONTROL SYSTEM FOR J-PARC HADRON EXPERIMENTAL FACILITY

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Abstract

J-PARC Hadron Experimental Facility is a multi-purpose facility for a variety of particle and nuclear physics experiments, using secondary particle beams (kaons, pions, and so on.) produced with 50GeV-15μA proton beams. Construction of Hadron Experimental Facility has been completed in Jan. 2009, and the first beam from 50GeV proton synchrotron has been successfully extracted and transported to the beam dump in Hadron Experimental Hall (HD-hall) on Jan. 27th, 2009.

The control systems of Hadron Experimental Facility cover beam line magnets, beam monitors, vacuum system, the production target, and interlock systems for radiation safety control. All components are controlled via the EPICS tools, widely used in the J-PARC accelerator control systems. In the present paper, we report the status of J-PARC Hadron Experimental Facility in detail.

INTRODUCTION

J-PARC (Japan Proton Accelerator Research Complex) [1] has three research facilities of Material and Life Science Facility (MLF) that produces pulsed neutron beams, Hadron Experimental Facility that produces intense secondary beams (~10^7 particle/s for kaons, ~10^9 particle/s for pions) for particle and nuclear physics experiments, and Neutrino Facility for the long-baseline neutrino experiment.

Figure 1 shows an overview of the Hadron Experimental Facility. The 50GeV proton beams (currently limited up to 30 GeV) accelerated in 50GeV Proton Synchrotron are extracted to the slow-extraction beam line for the duration of 0.7 second in every 6 second of the accelerator operation cycle. The extracted beams are transported to HD-hall through the beam-switching yard.

In the beam switching yard (SY), there are 33 beam line magnets in 250 m tunnel. For future extension, the magnetic septum can be installed at SM1 that allows up to 2% beam loss, and high momentum primary and secondary beams can be transported to HD-hall. At the T0 split point, the thin target that allows up to 0.1% beam loss can be installed and the test beam line can be constructed outside the SY tunnel.

In the HD-hall, the primary beams are irradiated to the production target (T1) and 30% of primary beams are consumed to produce secondary particles. The primary beams are transported to the beam dump and absorbed safely. There are 6 magnets in the primary beam line.

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Currently, three secondary beam lines are constructed in HD-hall. The K1.8 beam line can transport charged particle beams up to 1.8 GeV/c, and is mainly used for strangeness nuclear physics. The K1.8BR beam line, a branch line of the K1.8 beam line, can transport charged particle up to 1.1 GeV/c, and is used for exotic atoms and nuclei with stopped kaons. The KL beam line can transport neutral kaons and is used to search for rare neutral kaon decay mode ($K^0_L \rightarrow \nu\nu$bar).

MAGNET CONTROL

Most of the magnet power supplies in the primary and secondary beam lines are the ones originally used in the experimental facilities at KEK 12GeV Proton Synchrotron. The existing magnet control system is based on Windows-LabView, and recently modified to use MySQL server to handle magnet status settings [2]. The users can easily communicate to the magnet control system via common database tools provided by MySQL. Currently, the GUI display is built with Python-Tkinter. We have also developed the special EPICS record to handle the magnet status table on MySQL (Magnet Record) [3], but currently it is not implemented yet.

BEAM MONITOR CONTROL

As shown in Figure 2, several kinds of beam monitors have been installed in the SY and HD-hall. In the upstream part of the SY primary beam line, three Optical Transition Radiation (OTR) monitors [4] to measure 2-D profile. In the downstream of the optical matching point (MP), 14 residual gas ionization profile monitors (RGIPM) [5] to measure 1-D (horizontal and vertical) profile. Along the primary beam line, 40 air-ionization beam loss monitors (BLM) have been installed to measure secondary particles produced by accidental beam loss. At the first beam extraction from the accelerator, 9 screen monitors using tube camera to detect fluorescence light from ceramic plates had been installed in the primary beam line, but currently only 2 screen monitors remain in the beam line. A secondary emission electron monitor [6] has been installed to measure beam intensity. The T1 target monitor to measure number of secondary charged particle emitted from the T1 target has been installed outside the shielding enclosure of the primary beam line.

RGIPMs collect electrons produced by ionization of residual gas in the beam pipe (typically pumped in 1-10 Pa). When the primary protons of 10^{11} protons per pulse pass through the RGIPM in every 0.7 second beam extraction period, typical amount of signal collected with

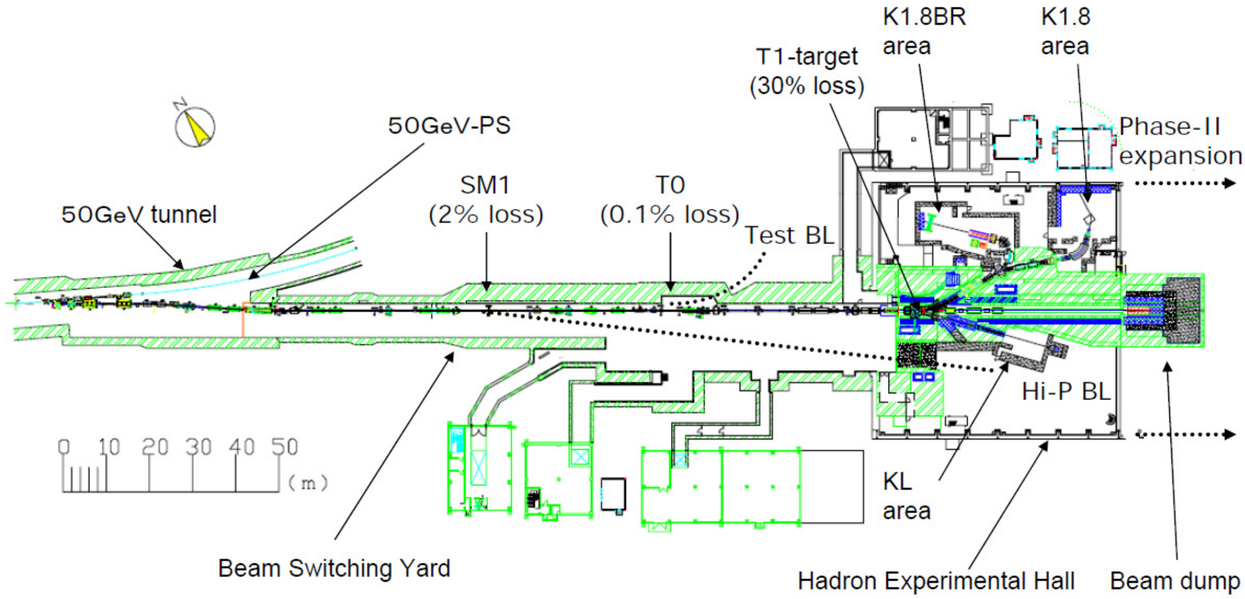

Figure 1: An overview of Hadron Experimental Facility.

RGIPM is a few nC in total 32 channel electrodes. To collect small charge in long integration period up to 1 second, a special integration module working on KEK-VME crate has been developed. This module (GNV-370) has 32 ch signal inputs and can integrate charge up to 1-4 nC in ~1 second integration time, and produce analog output up to 5 V. In the first beam extraction test, the integration time was 0.7 second.

The integrated signal for each channel is recorded with isolated A/D board (Advme-2607 advanet Inc.). Scanning of 64 channel inputs on Advme-2607 is done every after beam extraction. Data taking from Advme-2607 is done by an EPICS IOC software with the special device support module for Advme-2607, running on GE Fanuc VMIVME-7807 board. Thus the 1-D waveform records for horizontal and vertical profile distributions are available for on-line monitoring. The operators can monitor, print, and record all profile distributions on a wxpython application. The signal size from air-ionization BLM (30 cm in length) is also a few nC, and the readout electronics for BLMs are common with those for RGIPMs.

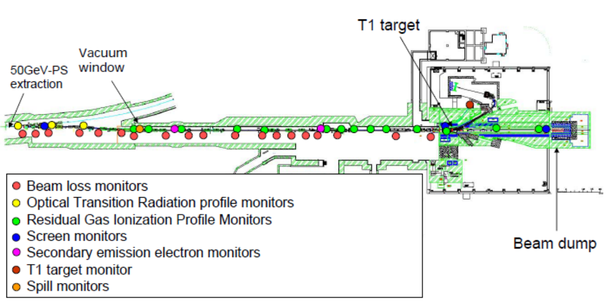

Figure 2: Beam monitors installed in Hadron Experimental Facility.

Charge from Secondary electron emission monitor is converted to TTL pulse with ORTEC-439 digital current integrator, and pulse count is recorded with REPIC RPV-120 8ch VME visual scaler. The number of pulse is converted to beam intensity and can be monitored with IOC software module running on VMIVME-7807. The number of pulse measured with the T1 target monitors , which is comprised of three scintillation counters, are also recorded by the same way.

High voltage power supplies for RGIPMs and BLMs are controlled with CAEN SY2527 and HV power supply boards. CAEN SY2527 can communicate via TCP/IP, and the OPC server is provided for remote control. The OPC device support developed in BESSY is used to control CAEN SY2527 with EPICS.

INTERLOCK SYSTEMS

As described in Ref. [8], the safety system of J-PARC accelerator is comprised of PPS (Personnel Protection System) that controls the beam permit of the primary and secondary beam lines, and MPS (Machine Protection System) that controls accidental failure of beam line equipments and beam abort.

In Hadron Experimental Facility, PPS is based on sequencer modules connected to safety equipments, such as dipole magnet power supplies, beam shutter, beam keys, and so on. PPS in each experimental area (K1.8BR/K1.8/KL) is independently controlled with sequencer modules, and the main PPS control unit is connected to the J-PARC accelerator PPS.

MPS is used to respond accidental failure on beam line equipments, such as magnet breakdown, vacuum leak, and so on, and send signals to abort and/or stop the beam extraction from 50GeV-PS ring. MPS elements in Hadron Experimental Facility are BLMs, vacuum pressure, thermal switch attached on beam line magnets and beam dump core, and the rotation motor and water pump for the T1 target.

Both PPS/MPS are controlled with ladder program running on sequence CPU modules (Yokogawa Inc. FA-M3 PLC series) in each sub-systems. In order to monitor the interlock status remotely, the IOC controller F3RP61-based IOC modules [9] are adopted to PPS/MPS PLC. Each PLC modules distributed to each experimental area are connected with optical fibers and communicate via optical FA-link. Thus, the detailed information of each experimental area can be monitored with the IOC program running on the F3RP61 module.

OTHER SLOW CONTROL

The thermo-couples attached to the beam line magnets, the beam dump core (40 copper blocks), and the output signals from vacuum pressure gauge are connected to the Agilent 34980A multi-function measurement unit. Each element is scanned every 1 second, and the unit is remotely controlled via the Agilent E5810 LAN/GPIB gateway. The GPIB device support provided as an extension of EPICS components is used to monitor each element.

To monitor and control the high voltage power supplies of the electrostatic separator and the T1 target local control unit, the F3RP61 embedded PLC modules are used. In both cases, the sequence CPU modules are running on each PLC subsystem. The additional F3RP61 modules can read and/or write to the state variables in the sequence CPUs, and can control the devices remotely.

FUTURE PLANS

On-line monitoring using EPICS for OTR profile monitors are under preparation. The PPS and MPS interlock may be extend when new secondary beam lines and experimental area are construct. The detailed control of the primary beam transportation could be automatically done by manipulating EPICS records if the beam conditions become stable. For users working in HD-hall, web interface to present the information on the Hadron Experimental Facility would be helpful.

ACKNOWLEDGEMENTS

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