DIAGNOSTIC CONTROLS OF IFMIF-EVEDA PROTOTYPE ACCELERATOR

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Abstract

The Linear IFMIF Prototype Accelerator (LIPAc) will accelerate a 9 MeV, 125 mA, CW deuteron beam in order to validate the technology that will be used for the future IFMIF accelerator (International Fusion Materials Irradiation Facility).

This facility will be installed in Rokkasho (Japan) and Irfu-Saclay has developed the control system for several work packages like the injector and a set of diagnostic subsystems. At Irfu-Saclay, beam tests were carried out on the injector with its diagnostics.

Diagnostic devices have been developed to characterize the high beam power (more than 1MW) along the accelerator: an Emittance Meter Unit (EMU), Ionization Profile Monitors (IPM), Secondary Electron Emission Grids (SEM-grids), Beam Loss Monitors (BLoM and µLoM), and Current Transformers (CT).

This control system relies on COTS and an EPICS software platform. A specific isolated fast acquisition subsystem running at high sampling rate (about 1 MS/s), triggered by the Machine Protection System (MPS), is dedicated to the analysis of post-mortem data produced by the BLoMs and currents transformers signals.

OVERVIEW

Irfu Control System Coordination

Irfu is in charge of the control system coordination for the European group of the LIPAc project. Therefore, Irfu provided the control system architecture [1] for the different Local Control Systems (LCS).

Diagnostics Work-package

The LIPAc includes an ion source, a Radio Frequency Quadrupole (RFQ), a Medium Energy Beam transport, the first module of a superconducting linac (SRF Linac) and a High Energy Beam Transport (HEBT) line terminated by a beam dump.

The diagnostics main goal is to provide all necessary information to accurately transport and accelerate the beam from the source to the beam dump, then to have the complete knowledge of beam characteristics. The diagnostics developed or improved at Saclay [1] and set downstream the RFQ:

- *Ionization Profile Monitors* are used for transverse beam profile measurement: the monitor is based on the ionization induced by the beam on the residual gas enclosed in the beam pipe.
- *Current Transformers* will measure the beam current all along the LIPAc accelerator: Saclay is in charge of a set of one ACCT and one FCT in the MEBT, a set of one ACCT and one DCCT in the Diagnostic plate (D-plate) of the HEBT and one ACCT located after the dipole of the HEBT. These monitors must have a high dynamic range and be able to handle duty cycle from pulsed mode to Continuous Wave (CW) mode.
- Two *Secondary Electron Emission Grid Monitors* will be installed, one in the D-plate and one in the HEBT, to measure transverse beam profile in pulsed mode. Associated with two slits, one for each axes, they will help to measure the beam emittance during commissioning tests.
- *Beam Loss Monitors* are mainly used for the machine safety and will provide an interlock signal to the Machine Protection System. They are based on LHC-type Ion Chambers (IC).
- In order to optimize the beam core and to minimize the beam halo, it was chosen to use *Micro-Loss Monitors* equipped with diamond detectors to work in the superconducting part of the accelerator (SRF Linac).

IC currents and CTs will be sampled to feed a *Post-Mortem system* data that will give useful information to

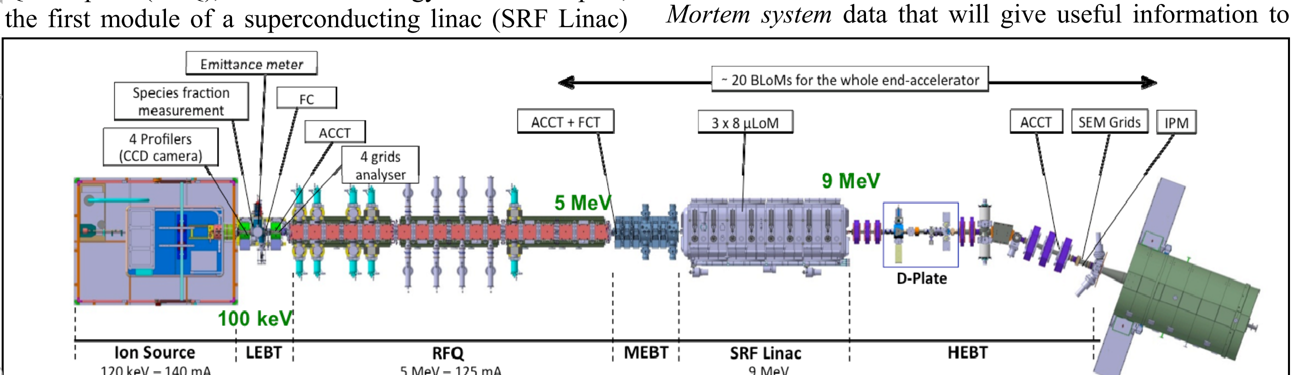

Figure 1: LIPAc Accelerator with all diagnostics provided by CEA Saclay.

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analyze the behavior of the accelerator during beam commissioning.

IFMIF EPICS PLATFORM

Software Platform

The Spiral2 platform providing a software development model, which allows having homogeneous control System [2], was agreed to suit the specifications and needs of the IMIF-EVEDA project. The software applications (Epics 3.14.12) are hosted by standard PCs running RHEL6 and CPUs running VxWorks 6.8.

Hardware Platform

The VME standard is composed of an Emerson Motorola MVME5500 and a set of NEXEYA ADAS VME boards:

- ICV150 with 32 ADCs, 16 bits resolution, and 30K Sample/s
- ICV714 with 16 DACs, 12 bits resolution
- ICV196 with 96 binary input/output channels
- ICV108, a controller board with a 4 Mb RAM
- ICV178 with 8 ∑Δ ADCs, 16 bits, 1.2 M Samples/s

All modules are embedded in a standard VME crate. Irfu developed the EPICS drivers for all these boards.

POWER SUPPLIES

High voltage power supplies used for diagnostics are FUG, TREK, and CAEN models. FUG and TREK are controlled by ADAS VME cards and CAEN by network through the StreamDevice package.

EMITTANCE METER UNIT

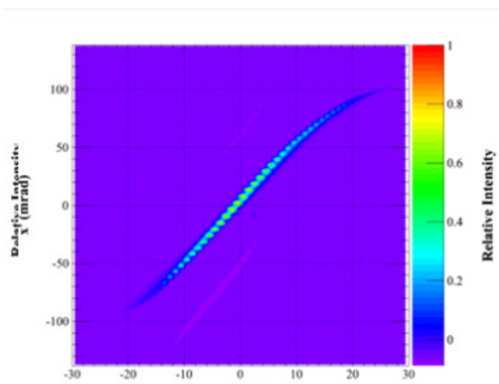

Figure 2: Emittance measurement in LEBT.

An Allison scanner is implemented to measure the transverse emittance in the LEBT. It is composed of two sets of slits, two electric deflection plates located in the space between the slits and a Faraday cup with secondary electron repeller. A servo motor drives the head to scan the distribution of the beam. At each position, deflection plates are ramped with voltages of opposite polarity to determine the angle of the beamlet passing through the entrance slit. Parameters such as position, voltage, angle and current are made available for further analysis.

The movements of the head are achieved through an OMS MAXv motion controller. Two TREK high voltage amplifiers are used to provide voltages onto the deflection plates. One FUG high voltage power supply drives the electron repeller. ADAS VME boards perform the input/output with the equipment's (ICV174/150/196). The analog signal issued from the Faraday cup is being analyzed using ADAS acquisition boards (ICV178/108).

CURRENT TRANSFORMERS

CT is a kind of monitor which allows measuring the beam current with a precision of 0.15 mA. This device is used in pulsed or continuous mode.

Six CTs are installed along the LIPAc accelerator: four ACCTs for injector, MEBT, D-plate and HEBT, one DCCT for D-Plate and one FCT in the MEBT.

The acquisition is based on both VME boards, ADAS ICV108 and ADAS ICV178. The ICV108 is a controller board with an external trigger and includes a 4 Mo RAM dedicated to measurements with possibility of DMA transfer. This card integrates also several running modes.

In this case the mode uses the whole 4Mb RAM in flip/flop single event. It integrates a pattern which determines what channels have to be saved in RAM and can be modified online. The ICV178 is an 8 channels ∑Δ board with 16-bit resolution for each ADC. The sampling frequency goes from 50kS/s up to 1.2MS/s and can also be modified online.

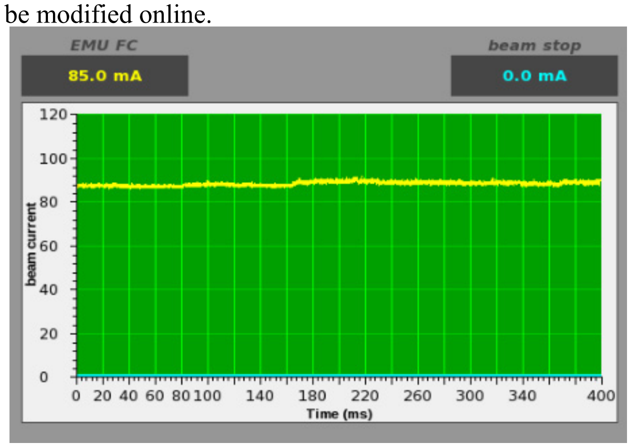

Figure 3: Acquisition LEBT beam signal.

IONIZATION PROFILE MONITORS

The goal of an IPM is to measure the transverse beam profile. Its resolution is around 1mm and the data must be acquired at a 10Hz repetition rate.

Two IPMs are located in the D-plate (2x80 channels, one horizontal and one vertical) and another one downstream to the beam dump (128 channels). The Front End Electronic (FEE) integrates the input current from the IPM and was specially designed to manage the sampling and the holding functions for all beam configurations (pulse or cw).

A trigger (rising edge of pulse) is provided to the signal conditioning module by the timing system. It can also run in continuous mode without trigger.

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Several VME Boards are used to control the hardware. The acquisition is done by ICV150 ADAS board 16-bit ADC +- 10Volts associated with two ICV110 ADAS slave boards.

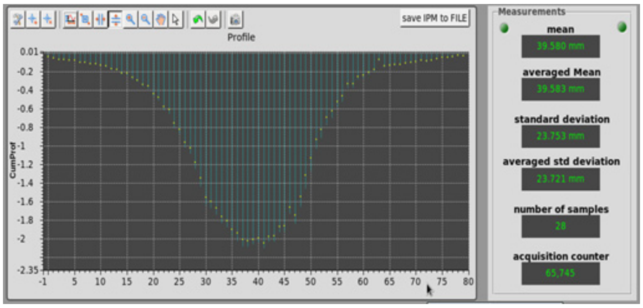

Figure 4: IPM profile tested at Saclay.

SEM GRID

The goal of a SEM-Grid is to have a beam profile measurement at low duty cycle in case of IPM measurement is not sensitive enough. Mainly used during beam commissioning, one SEM-grid is included in the D-plate and another one downstream to the beam dump. A complete integrated solution (COTS and EPICS software), provided by Ganil laboratory, will be used to manage the measurement and acquire the data. Their SEM-Grid and its control were developed for the Spiral2 project. Their requirements are to measure transverse beam profile at 5 or 9 MeV at duty cycles higher than 5 10^{-5}, with a resolution around 1 mm.

The controls and the profile data will be done by a dedicated controller through the MODBUS-TCP protocol and will be connected on the second Ethernet port of the CPU. The EPICS driver was achieved by GANIL software team.

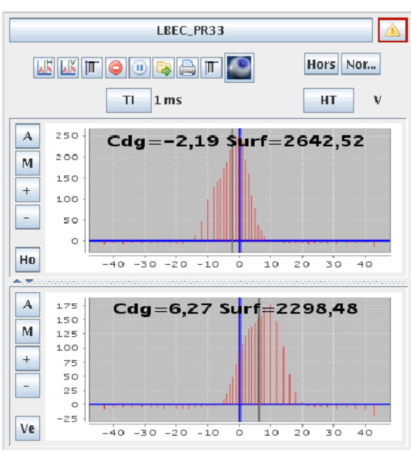

Figure 5: SEM-grid profile of Injector Spiral2.

BEAM LOSS MONITOR

The main goal of the BLoM system is to measure the particle losses to insure the machine safety. If losses are higher than the permissible threshold it must provide a fast interlock signal to the Machine Protection System (MPS) in less than 10 µs to avoid irreversible damages. It has to monitor beam losses with a very high sensitivity, about 1 W/m. This system is based on LHC-type Ion Chambers (IC).

The electronics will provide 2 signals for the MPS triggered by 2 thresholds. The integrators similar to those developed for IPMs, will be monitored at 1Hz by the same ICV150 VME module as for the IPMs (without ICV110 extension module because only twenty four channels are needed) and managed by the same ICV196, thanks to the available input/output signals not used by the IPMs.

Programs of the thresholds and gains for the discriminators will be done by the MCP4728. It's an electronic component composed of four D/A converters and must be controlled using the i2c serial protocol. A specific RS232 gateway allows using EPICS StreamDevice package.

The principle of the FEE is described above:

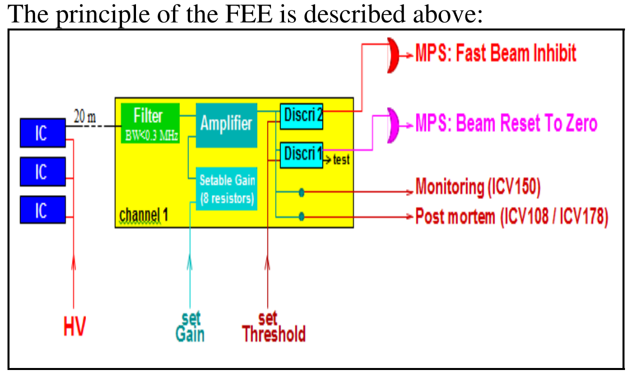

Figure 6: FEE for the BLoM system (IRFU/SEDI).

POST MORTEM

In order to understand what happened when beam shuts down a dedicated fast acquisition will be designed. Only IC currents and CTs are concerned by this topic.

For all other diagnostics it will be done automatically thanks to the circular buffer filled by the slow acquisition. ICs currents and CTs will be sampled every µs by the same kind of VME board used for the sampling of CT in nominal mode: ADAS ICV108 and ADAS ICV178 but in another running mode.

In this case the whole 4Mb RAM is used in circular buffer mode, the acquisition fill the circular buffer every µs for all ICs currents and CTs.

When a trigger from the MPS occurs, acquisition is stopped and the circular buffer gets frozen. Then the buffer can be transmitted to the motherboard in order to be analyzed. The time range surrounding the trigger depends on the number of sampled signals and the sample frequency.

Twenty ICs currents and four CTs sampled at 1 MHz ensures a 100ms range time for each signal.

REFERENCES

[1] F. Gougnaud et al., "The implementation of the injector Spiral2 control System", ICALEPCS 2011, Grenoble, France, October 2011

[2] J. Marroncle et al., "IFMIF-LIPAc Beam Instrumentation and its challenges", in IBIC 2012 proceedings, Tsukuba, Japan

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