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THE CONTROL SYSTEM FOR THE ELI-NP GAMMA BEAM DELIVERY AND DIAGNOSTICS*

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Abstract

The high brilliance Gamma Beam System (GBS) at ELI-NP is based on the Inverse Compton Scattering of laser light on relativistic electron bunches provided by a warm radio-frequency linear accelerator. The system will deliver quasi-monochromatic gamma-ray beams with a high spectral density and high degree of linear polarization. The Gamma Beam Delivery and Diagnostics (GBDD) of ELI-NP is implemented to deliver the gamma-ray beams to the experimental setups and to monitor the characteristics of the beams during the performance of the experiments. An EPICS control system is being developed for the GBDD to support the equipment for the delivery of the gamma beam and the devices for gamma beam diagnostics and monitoring. High-level software for the Gamma Beam diagnostics system is under development to complement the real-time measurements and monitoring. This paper describes the design and implementation status of the EPICS Control System for ELI-NP GBDD, including the device modular integration and the design of the high-level software.

INTRODUCTION

The High Brilliance Gamma Beam System (GBS) of Extreme Light Infrastructure - Nuclear Physics (ELI-NP) will produce intense gamma-ray beams with spectral densities of about 10^4 ¸/s/eV, a narrow bandwidth (0.5%), high degree of polarization (>95%) and tuneable energy in the range from 200 keV to 19.5 MeV [1], based on the laser Compton backscattering technique on relativistic electrons provided by a linear accelerator.

The GBS system will be delivered by the EuroGammaS Association with its own EPICS based control system framework [2] to provide the data collection and constantly monitoring for the GBS.

The GBDD System is designed and under implementation to transport the gamma output to the Gamma Experimental areas and to monitor the gamma beam features. To optimize the operation of the ELI-NP GBS and its use for experiments, it is of utmost importance to have the proper means to accurately predict the spatial, spectral and temporal characteristics of the gamma beam. The ELI-NP GBDD work package is dealing with the equipment and techniques meant to transport and optimize the gamma beam in order to make it available for user experiments within required parameters [3]. Figure 1 shows the schematic layout of the ELI-NP GBS and GBDD.

The full ELI-NP GBS system providing the beam with the design parameters is expected to be ready soon. All diagnostics and monitor systems have to be already commissioned and ready to be used.

GENERAL SYSTEM REQUIREMENTS

The GBDD system consists of the low-energy and high-energy lines that cross the ELI-Building. The line starts after the low-energy interaction point, respectively after the high-energy interaction point, and goes until the experimental area [4].

Gamma Beam Delivery

The total length of the beam transport line is approximately 100 m. The vacuum pipe for the gamma beam transport has a modular design, allowing the removal of individual segments for the placement of experimental apparatus. The pumping stations will be distributed according to their pumping power, making vacuum connections between sections of pipe where that is necessary.

For the collimation of the Gamma beam, a collimator which is operated under vacuum and the aperture of the individual slits is controlled with stepper motors.

Five small beam dumps are going to be built at the exit from each of the experimental areas to ensure safety of work in the downstream rooms. These small beam dumps can be placed in different rooms, controlled with stepper motors to move in/out of beam.

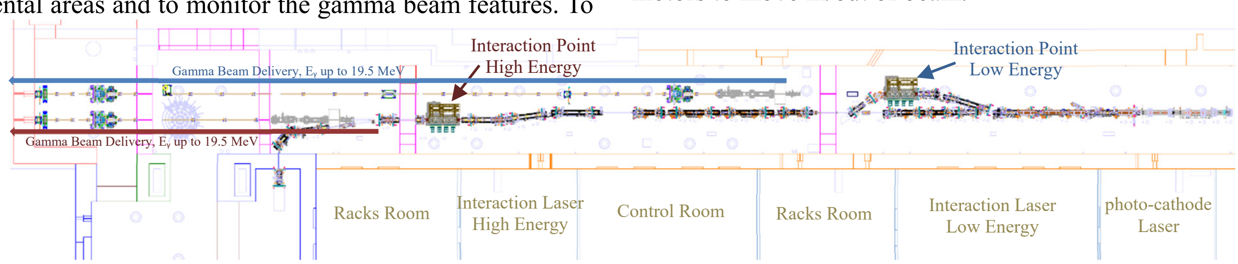

Figure 1: Schematic layout of ELI-NP GBS and GBDD.

Gamma Beam Diagnostics

The diagnostics modules of the GBDD system will provide five real-time beam monitoring systems including: energy and energy spread, flux measurement, spatial position

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monitor, time structure monitor, and beam polarization measurement.

Energy and energy spread The beam energy measuring system will use a 14-bit, 500 MS/s digitizer for the HPGe and the NaI anti-Compton shield. The attenuator and detectors will be remotely controlled using stepper motors.

Flux measurement The fission chamber for flux measurement will need a 12-bit and minimum 3.2 GS/s digitizer. One Mesytec MPR-1 preamplifier will be needed for the cathode signal.

Spatial position monitor The gamma beam spatial distribution system utilizes a CCD camera to collect the light produced in a scintillator placed in the beam by means of a mirror. The system is designed to be mobile and could be moved to different experimental areas.

The camera will be placed outside vacuum in a special mount, which ensures position reproducibility and easy removal. The scintillator and the mirror will be housed in a light-tight box inside the beam transport pipe. To ensure position reproducibility of the scintillator, a motor controller will be attached to the scintillator.

Time structure monitor One 5*5-cm fast plastic scintillator or $LaBr_3$ detector will be used to monitor the time structure of the beam. One channel of 14-bit, 500 MS/s digitizer will be used.

Beam polarization measurement The NRF polarimeter measurement will be carried out using the segmented CLOVER detectors from the ELIADE array [5]. The d(γ,n)p intensity monitor and polarimeter uses three neutron detectors, either EJ-301 or Li-glass depending upon the energy of the emitted neutrons and, consequently, on the beam energy. The 14-bit, 500 MS/s digitizer is needed to record the waveforms. One channel should be reserved for recording the signal of the machine.

Requirements Summary

The detectors used for the Gamma Beam Diagnostics are different, however, the types of digitizers have been minimized to ensure a quicker implementation of acquisition software and analysis routines.

Low voltage power crates are required for the digitizer units that are connected to the detectors of ELIADE. High voltage power supplies are required for all the other detectors.

The DAQ module will deal with the waveform acquisition by the digitizers.

The GBDD Control System will provide the monitoring and control for the vacuum stations, the high voltage power supplies, the low voltage power crates, the motor controllers and the CCD camera.

Input Output Controller (IOC) servers, data storage and Operator Interfaces (OPIs) will be distributed for each system connected via Ethernet.

The High-level software for the diagnostics system will also be implemented to provide the GUI tools to accomplish the measurements.

SYSTEM DESIGN FOR GBDD CS

The CS for GBDD based on EPICS [6] is being designed and implemented to provide the machine information connection with the GBS CS, to collect data from GBDD devices, to monitor status of GBDD devices, and to provide the High-Level Software (HLS) for the Gamma Beam Diagnostics.

General Architecture Model

The architecture of the GBDD CS is structured as the standard three-tier structure:

User interface for individual controls for sub-modules and the high-level software for the Gamma Beam Diagnostics, including graphical and non-graphical user interfaces.

Central services which need to run continuously for process variables archiving and alarm monitoring.

Equipment interfaces consist of IOCs that are responsible for interaction with equipment and devices.

The gigabit Ethernet (GigE) Local Area Network (LAN) allows the communication between the IOCs and OPIs.

Software Architecture Model

The GBDD CS is based on a modular control system design that can be schematically shown as figure 2. It includes the modular design for the devices grouped by the following sub-modules:

- Vacuum system,
- High voltage Power supply module,
- Power crate module,
- Data acquisition module,
- Beam profile module,
- Motor control module,
- Interlock module.

Besides, the high-level software is being designed according to the physics requirement to carry out the measurements and monitoring for Gamma Beam Diagnostics.

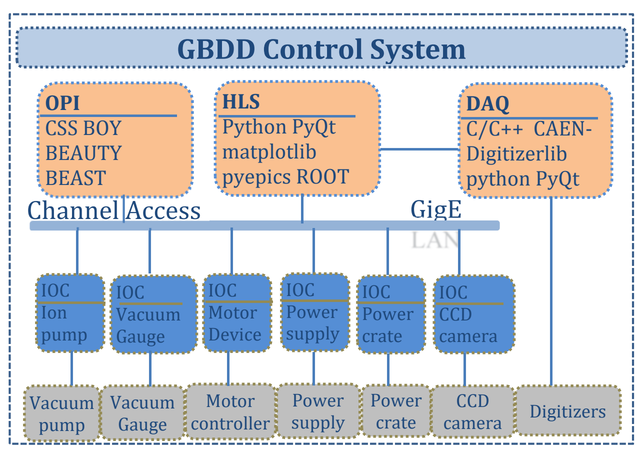

Figure 2: The software architecture for GBDD CS.

IMPLEMENTATION STATUS

The implementation for each type of devices follows the modular design that defines the common parts including the required software package framework for IOC and OPI,

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and the communication interfaces between IOC and OPI from the hardware and software perspective.

The current finished work includes the EPICS integration of the following devices: the VME crate, the high voltage power supplies, the CCD camera prototype and the digitizers. The high-level software for Gamma Beam Diagnostics has also been designed based on the physics requirement.

Integration of the Devices

Power supplies The power supplies used in the GBDD system consist of the VME power crates and the high voltage desktop power supplies.

In the GBDD system, CAEN VME8100 power crates are used for digitizers which connected to the detectors for ELIADE. To integrate the VME8100 power crates, Asyn and StreamDevice are used to configure the IOCs connected via GigE port.

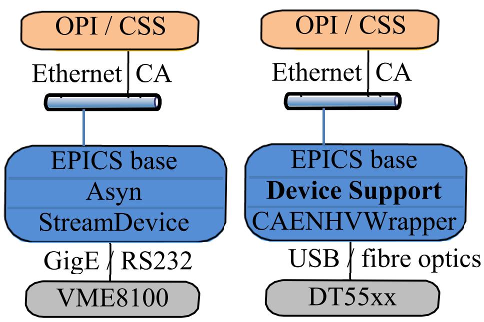

Figure 3: Modular design for power supplies.

High voltage power supplies CAEN DT5533N and CAEN DT5521M are used for the detectors. To integrate the DT55xx power supplies into EPICS, the device support has been developed based on the CAENHVWrapper lib to connect the power supplies via fibre optics or USB 2.0 port. The modular design for the integration of power crates and power supplies can be shown as figure 3.

The GUI showed in figure 4 has been designed to provide the monitoring and control of the power supplies using CSS BOY [7].

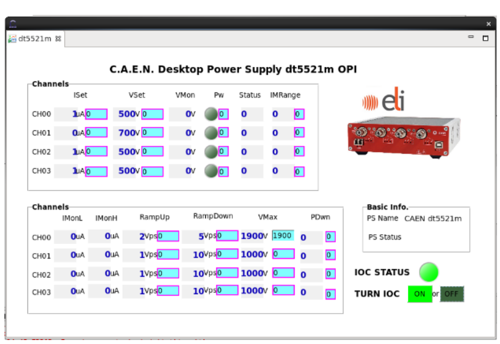

Figure 4: Snapshot of CAEN dt55xx OPI.

CCD camera A prototype of CCD camera integration has been implemented based on Basler acA1600-20gm. Aravis is used as the EPICS camera driver wrapper and areaDetector is used as the EPICS device support module and EPICS databases. The areaDetector plugins are used to save images and to provide arrays used for displaying images acquired by the camera. A CSS BOY GUI is designed to provide an intuitive way to use the cameras.

Digitizers the DAQ module for GBS experiment is under development, digitizers for the Gamma Beam Diagnostics will also be integrated into the DAQ [4]. The control system and high-level software will make connection with the DAQ module. Soft IOC will be implemented if necessary. The GUI has been developed for testing the digitizers, using python, PyQt and matplotlib, which can be seen in figure 5.

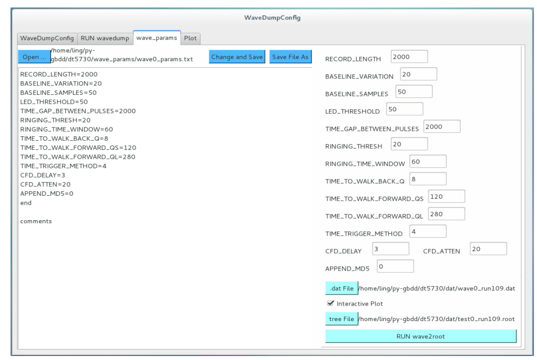

Figure 5: GUI for digitizers.

High-level Software Design for Gamma Beam Diagnostics

The HLS for Gamma Beam Diagnostics has been designed to carry out the measurements for gamma beam energy and energy spread, gamma beam flux, the spatial position, the time structure and the beam polarization.

The HLS collects waveform data from digitizers via the DAQ module, analyses the data and then presents the results. ROOT [8] has been adopted to carry out the data analysis. Python and PyQt are used for the script programming and GUI design. Pyepics is used as the interface to EPICS channel access and matplotlib is used to perform the result plotting.

The main data flow diagram for the HLS of Gamma Beam Diagnostics is shown in figure 6:

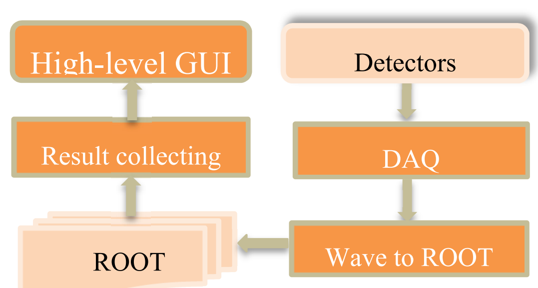

Figure 6: Data flow diagram for HLS for Diagnostics.

CONCLUSION

The full ELI-NP GBS system providing the beam with the design parameters is expected to be ready soon. All diagnostics and monitor systems have to be already commissioned and ready to be used.

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The system design for the EPICS based control system of GBDD has been finished. The implementation for the device integration has been carried out modularly for the power supplies, CCD prototype and digitizers. The HLS has been designed and it is presently under development to accomplish the online measurements for gamma beam energy and energy spread, gamma beam flux, the spatial position, the time structure and the beam polarization.

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[7] CSS, `http://www.aps.anl.gov/epics/eclipse/`

[8] ROOT, `https://root.cern.ch/`