LASSIE: THE LARGE ANALOGUE SIGNAL AND SCALING INFORMATION ENVIRONMENT FOR FAIR

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Abstract

At FAIR, the Facility for Antiproton and Ion Research, several new accelerators and storage rings such as the SIS 100, HESR, CR, the inter-connecting HEBT beam lines, S-FRS and experiments will be built. All of these installations are equipped with beam diagnostic devices and other components, which deliver time-resolved analogue signals to show status, quality and performance of the accelerators. These signals can originate from particle detectors such as ionization chambers and plastic scintillators, but also from adapted output signals of transformers, collimators, magnet functions, rf cavities and others. To visualize and precisely correlate the time axis of all input signals a dedicated FESA based data acquisition and analysis system named LASSIE, the Large Analogue Signal and Scaling Information Environment, is currently being developed. The main operation mode of LASSIE is currently pulse counting with latching VME scaler boards. Later enhancements for ADC, QDC, or TDC digitization in the future are foreseen. The concept, features and challenges of this large distributed DAQ system will be presented.

INTRODUCTION

At all particle accelerators analogue signals are derived from detectors, rf cavities, function generators, transformers and other sources. A common way to observe these signals in order to understand, trim and operate the accelerator is the readout and signal presentation by oscilloscopes. With an increasing amount of signals at large facilities like GSI or FAIR, this solution gets expensive. Furthermore, it can not be easily integrated into a common accelerator control system, which must provide safe remote operation including data recording, storage and time-correlated presentation.

There are already solutions for analogue signal acquisition and presentation such as OASIS [1] at CERN and ABLASS [2] at GSI. With respect to the high costs of switching matrices and powerful front-end digitizers, the concept of OASIS was rejected as a solution for FAIR. However, long term experience with the low cost ABLASS system has already been obtained at GSI and the reduced performance in resolution compared with oscilloscopes was accepted for most of the signals. The principle of ABLASS is based on the conversion of analogue signals into frequencies, which are then counted in a modular VME system. To provide time-correlated signals acquired over the complete FAIR complex for the future digital control room, the concept of ABLASS will not only be ported to the new control system environment. In contrast to ABLASS the new DAQ system, which is called LASSIE ('Large Analogue Signal and Scaling Information Environment') is designed from the start as a distributed system. As such, LASSIE will be used at all FAIR [3] accelerators, which are part of the modularized FAIR start version: SIS100, HESR, CR, S-FRS, HEBT and pLinac.

GENERAL CONCEPT

LASSIE will be the data acquisition environment for a wide range of beam diagnostic systems. Most diagnostic systems consist of particle detectors like ionization chambers, scintillators, secondary electron monitors or beam loss monitors. Other signals handled by LASSIE include the output of current transformers or direct current measurement from cups and collimators.

However, the concept is not restricted to signals from beam diagnostic detectors. Other arbitrary signals like magnet ramps or accelerator rf-signals can be added for correlation purposes.

The acquisition, analysis and presentation of time correlated signals will provide essential information for beam setup, optimization, control and experiments. This is essential for beam transmission measurement, spill structure analysis and beam loss monitoring.

The system itself will not change or set accelerator hardware i.e. react on beam like feedback systems would do.

For normal operating tasks, it is sufficient to sample the signals with a frequency in the order of 1 kHz. For dedicated beam experiments higher sampling rates (currently up to 1 MHz) will be supported.

LASSIE is based on the Front-End Software Architecture (FESA) [4]. Originally developed at CERN, FESA is now advanced in a collaborative effort between CERN and GSI, allowing for GSI specific modifications. The use of the FESA framework results in a clear separation between the data acquisition part and the graphical user interface part. LASSIE includes both these parts: the data acquisition using FESA and Java based analysis and display tools. In addition, the FESA part will strictly implement the currently emerging guidelines for FESA development at GSI. This will allow the seamless integration of the LASSIE system into the new FAIR control system.

DATA ACQUISITION

LASSIE currently implements one FESA class: the LArge Scaler Array (LASA). This FESA class reads and stores the data of one or more latching scalers as a function of time over one accelerator cycle. With respect to the high amount of expected channels and the availability of high-performance acquisition modules the VME standard was chosen. All analogue signals not directly suitable for counting are converted into frequencies using I/f or U/f converters. These frequency pulses are counted in VME scaler modules like the Struck SIS3820, a 32 bit and 32-channel multi-scaler. For the time being, a GSI-built timing module decodes the accelerator timing and provides a list of machine events with their corresponding time within the accelerator cycle. This correlates the machine events with the time dependent scaler data.

Modern accelerators have the ability to deliver different beams quasi in parallel. At GSI this is currently done using the concept of virtual accelerators of which there can be up to 16. FESA allows for multiplexed data storage, i.e. data is stored for each virtual accelerator separately. By design, memory allocation within the FESA framework is quite static, although the upcoming FESA 3.0 version allows for a slightly more dynamic memory handling. Nevertheless, as the LASA class is designed to handle 200 or more scaler channels and to store the data over full accelerator cycles of varying length of up to 15 s with selectable sampling frequencies, a more flexible memory handling is required. In addition, the required possibility of selecting sampling frequencies up to 1MHz mandates the ability to disable almost all of the scaler channels but the few ones of interest. This is caused not only by the memory required but also by the bandwidth of the VME backplane, which restricts the data rate. Therefore, the LASA class implements a custom memory management allocating a fixed amount (typ. 50%) of the system memory and is using two memory banks. While new acquired data is stored in one bank, the data of the previous cycle can be read by clients from the other bank. The downside of this implementation is that the LASA class is not truly multiplexed. Data for every accelerator is sent to the clients and it is the client's decision whether to ignore or display it.

Often, beam physics experiments require the storage of data on disk for later offline analysis. This data storage in ASCII or binary form is handled by the FESA class either to a network file-system or to an attached local solid-state disk. The storage procedure is realized in a thread, a so-called concurrency layer, separated from the data acquisition and the full spill data is copied to a memory buffer before writing. This ensures that data acquisition is not hampered by blocking write operations.

In the FAIR control system it is expected that data acquisition classes like the LASA class will also be responsible for setting DAQ related components like amplifiers etc. The LASA class is designed for this task. However, for the time being the class can only obtain these settings from the current GSI control system.

General guidelines for designing the interface of FESA classes at GSI/FAIR are currently being prepared. According to these guidelines FESA classes should return (and accept) physically meaningful values to clients. Using device settings from the current GSI control system, the LASA class can convert the scaler data into the physical input data like currents or voltages. For many diagnostic systems these currents or voltages are proportional to the beam current, i.e. the number of particles per second passing the detector. The proportionality factor however is usually dependent on the energy loss in the detector, which in turn requires information like beam energy, charge state and isotope mass to be calculated. Although these calculations are currently implemented in the LASA class for test purposes, it is still discussed whether this is the appropriate place for such calculations. It requires, that the FESA class is informed of the beam parameters either by the FAIR control system or by the central machine timing system. Both are not available yet.

The LASA class always reads all active scaler channels and stores them in memory. Clients are usually interested only in a few channels. To facilitate easy access to single channels without the need to send all data to the clients, the LASA class uses the ability that a single FESA process running on a front-end computer can present several devices to the clients. Thus, the LASA class running on a front-end computer presents each scaler channel as a single device to the clients. Clients accessing this device can obtain the integrated data over the full accelerator cycle or between two selected events and, if desired, the time dependent spill data also between two selected events. This allows easy use of the LASA class from generic GUIs and other applications of the future control system.

EXPERT TOOLS

In addition to the LASA class, the LASSIE system consists of several expert GUI tools, which are written in Java and are based heavily on CERN libraries for communication with the FESA classes and graphical display.

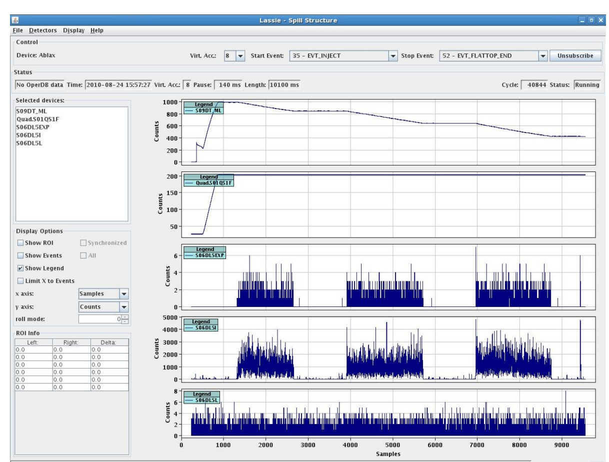

Figure 1: The Lassie spill structure tool for analysis of synchrotron signals (from top to bottom: current transformer, quadrupole ramp and beam loss monitors).

This tool-set contains a general control and monitor tool for the LASA classes running on different front-end computers, a spill structure analysis tool [Fig. 1], a counter display tool [Fig. 2], a dose level tool [Fig. 3] and others. Using the object oriented approach of Java, the major part of the core functionality, like obtaining data from the FESA classes via suitable providers, storing and analyzing the obtained data and many GUI widgets, could be put into packages common to all tools. This makes the GUI part of the LASSIE system more like a framework and gives it a great flexibility with respect to developing new and dedicated tools. Furthermore, most of the tools are not restricted to use the LASA class. Any FESA class implementing the same interface for the devices it handles could be used. This would for example include the readout of an ADC, which in principle also represents time dependent data.

With the exception of the general control and monitor tool, the expert tools do not address a LASA class (or scaler array) but the devices presented by the running LASA classes. As such, the expert tools inherently can deal with a distributed system, which consists of FESA classes running on different front-end computers in different locations of the accelerator complex.

Of course, the possibility of missing or delayed data from one or more front-end computers must be taken into account. Currently the virtual accelerator number and the UTC timestamp of the GSI machine timing transmitted once per cycle are used to assure the correlation of the data received and to detect any errors. With a first test setup using two LASA systems approximately 300m apart, no significant error rate could be observed for typical SIS cycles of a few seconds.

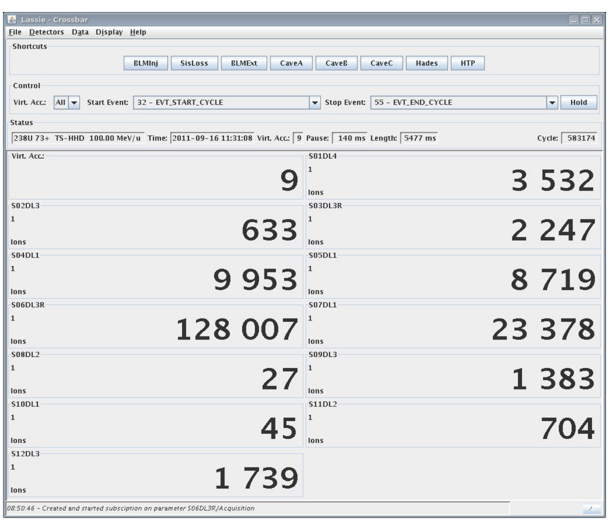

Figure 2: The counter display tool shows the total counter sum of a detector or device after each cycle.

In the FAIR control system the machine timing will be handled via the White Rabbit timing system. This new timing system is based on Synchronous Ethernet, the Precision Time Protocol (PTP), new developed hardware and a field-bus like topology [5]. It provides deterministic data with sub-ns accuracy. Thus, every VME system will be equipped with a White Rabbit timing receiver card.

As every event will be tagged with a time stamp, precise data correlation between the distant crates is assured. In the future this precise tagging may also allow data correlation throughout different timing domains of the accelerator complex.

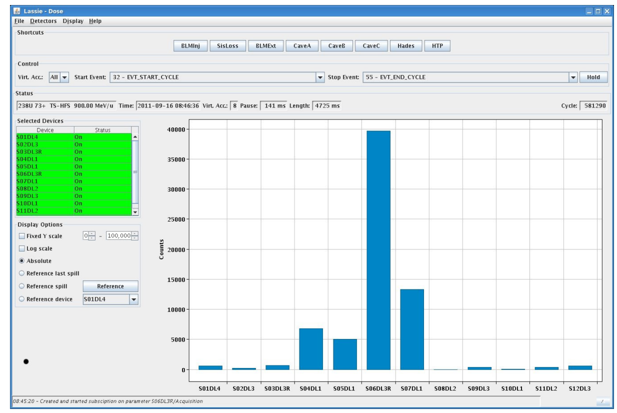

Figure 3: The dose level tool shows the total counter sum of a detector or device after each cycle and is mainly used for beam loss detection.

CONCLUSIONS

LASSIE presents the first implementation of a major beam diagnostic system using the FESA framework and Java based expert GUIs at GSI. It is extensively tested with diagnostic devices from the current SIS18 accelerator of GSI and the current machine timing system. Although many details of the FAIR infrastructure like the new White Rabbit timing system are not available right now, adaptation of the current LASSIE system is expected to be straight forward.

The possibility to extend LASSIE with other FESA classes acquiring time-dependent data e.g. DAC driven magnet power supplies, transforms it into a powerful tool. It will provide oscilloscope-like features fully integrated into the control system, making most of the expensive cables and hardware scopes in the control room obsolete.

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