

## FESA AT FAIR - THE FRONT-END SOFTWARE ARCHITECTURE

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### Abstract

One of the main challenges of the planned Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt is to handle its complex parallel and multiplexed beam operation. In addition, the size of the FAIR project demands for tailor-made but yet extendible solutions with respect to all technical subsystems, especially for the control system. In order to operate and maintain the large amount of front-end equipment, standardized solutions are an absolute must. Moreover, facility-wide standards have to be defined to give guidelines and interface specifications to the international collaborators and external partners for so-called "in-kind contributions". For this reason, GSI decided to use the Front-end Software Architecture (FESA) at the lowest level of the control system. FESA was developed by CERN and is already operational at LHC and its injectors. This report presents a framework overview and summarizes the status of the FESA test installation at GSI. Additionally, first experiences with the SIS18 BPM system controlled via FESA are presented.

### INTRODUCTION

The Facility for Antiproton and Ion Research FAIR will be built at GSI in Darmstadt. The FAIR project comprises nine new accelerator-installations such as a p-linac, two synchrotrons, four storage rings, the Super-Fragment Separator and FLAIR (see Fig. 1). The existing machines UNILAC and SIS18 will serve as injectors for these new accelerators. A detailed description of FAIR can be found in [1] and [2]. Like in the past at GSI, the new FAIR facility will also be operated in a multiplexed mode, which means that several different experiments will be

supplied with several different ion types, energies, and intensities simultaneously. Due to this requirement, FAIR is going to be one of the most complex accelerator facilities worldwide.

An important consequence for the accelerator division is the installation of an additional new control system. The existing control system (CS) is well adapted for the needs of the present accelerators at GSI. Nevertheless, the installation of the FAIR machines demands for state-of-the-art technologies, regarding scalability, high performance of data acquisition systems and modern hardware solutions. Thus, the implementation of a new CS for FAIR is planned, with the prospect to upgrade the existing CS to the new one in the future.

### DEMANDS ON A NEW CONTROL SYSTEM

Due to the intricate operational scenarios for FAIR the requirements for the new CS, including industrial controls, field bus systems, distributed timing, etc., are very demanding. A detailed requirements specification for the new CS is being worked out at the moment and is far beyond the focus of this contribution. Instead, the implementation of beam instrumentation and diagnostics will be discussed exemplarily.

Approximately thousand diagnostic devices such as viewing screens, profile grids, beam loss monitors and many more have to be controlled and read out. Therefore the new CS should be optimized not only for process control but also for data acquisition performance. At this point, the high data flux and real time acquisition has to be taken into account. In addition, the correlation of locally distributed signals as a function of time must be possible which requires a sophisticated timing system. To serve many different users with measured data in parallel, a powerful middleware, as a mediator in between, is mandatory.

A standardized framework is required to implement such a large amount of different devices, including also hardware from external partners, so-called "in-kind contributions". Since it is the aim to avoid frequent costs due to software licence fees "Open Source" is preferred. The CS should be based on the highly accepted operating system Linux, widespread programming languages such as C/C++ or Java, and should support most common hardware technologies, such as VME, cPCI/PXI, PCI/PCIe, and possibly  $\mu$ TCA, based on Intel and PowerPC processors.

The most critical and sophisticated demand is the acquisition, control, and handling of data generated by parallel and multiplexed beam operation.

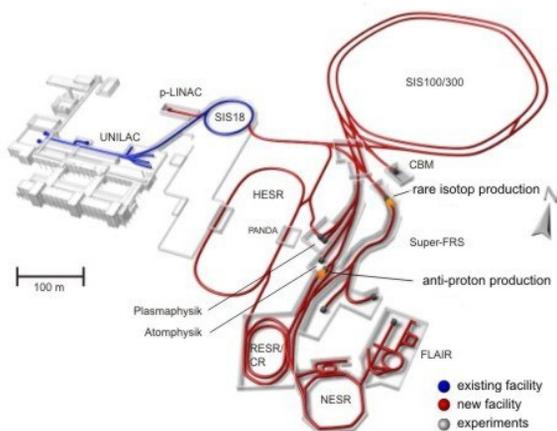


Figure 1: Layout of the FAIR facility including the existing accelerators UNILAC and SIS18.

## SITUATION

Besides the set-up of a new control system for FAIR the main task is to assure the proper operation of the existing accelerators. This leads to a reduction of capacities for R&D work within the technical groups in charge at GSI. It is obvious that equipment experts have to be integrated into the software development to meet the FAIR demands and to compensate the lack of manpower. Furthermore the start-up of a CS-collaboration with a partner institute seems to be a promising approach. A powerful partner is CERN with its recently developed CS for LHC. CERN and its CS are close to the FAIR requirements producing heavy ion beams in a multiplexed operation. CERN had to build a new CS for LHC and already started a software upgrade program for the injectors, such as the Linacs and the proton synchrotron PS. This situation is similar to what will be for FAIR. One important part of the CERN CS which has been evaluated for usage at FAIR is the front-end and data acquisition architecture. This part is called *Front-End Software Architecture (FESA)* and was developed for LHC and its injectors by a cooperation of CERN controls and beam instrumentation group. The evaluation of FESA at GSI was started in October 2006 and ended in March 2008 leading to the decision to adapt FESA for FAIR.

## FESA

The real-time front-end software architecture FESA is a framework used to fully integrate equipment such as power supplies, PLCs or beam diagnostic devices at the front-end level into the CS. The output product of this framework is a so-called equipment class. FESA provides JAVA based graphical user interfaces (GUI) [Fig. 2] to design, deploy, instantiate and test the equipment classes.

The XML based output of the design phase is used to generate C++ source code via XSLT processing. This code has to be adapted to the device-specific readout and control methods based on non-generic drivers and libraries. The subsequent compilation of the code leads to a platform-dependent executable file. This has to be associated with the corresponding front-end CPU (VME, PCI, etc.) by using the Deployment-Tool. Then, this executable file can either be started manually or on reboot of the front-end system. It handles the whole real-time data acquisition and communication with the middleware. The proper functioning of the DAQ can be tested with the Navigator-Tool. A basic approach to FESA, especially from the user's point of view, is described in [3].

## ADVANTAGES OF FESA FOR FAIR

The evaluation phase of FESA at GSI had shown that the system is capable for the use at FAIR from a technical point of view. Of course other data acquisition systems do exist and also a GSI-built system could perform similarly. The main reason to choose FESA is the high level of maturity and its immediate availability to set the surrounding conditions and to start education and usage with the existing staff and possible in-kind contributors.

FESA is not only a control but also data acquisition system and therefore allows the integration of demanding applications such as video imaging or high resolution bunch to bunch beam position monitoring. The framework addresses also non-CS-department equipment experts such as beam diagnostic department members to integrate complex devices into the CS. So, partially, the lack of manpower can be compensated. The decision for FESA leads to a high standardization of supported environment. It is intended to minimize the multiplicity of used hard- and software, in order to maximize the maintainability of the DAQ. The actual FESA version is 2.10 and includes beneath many other features timing-simulation, RT priority settings, run-time diagnostics, and monitoring tools [4]. For the time being the version 3.0 with participation of GSI staff is under development at CERN.

## CONSEQUENCES

It is obvious that a complete FESA environment installation at GSI is a challenging task on its own. There are fundamental dependencies between FESA and the CERN environment, which have to be resolved for the usage at GSI. The CERN timing system is an example. Within FESA, the scheduling of all actions is designed by

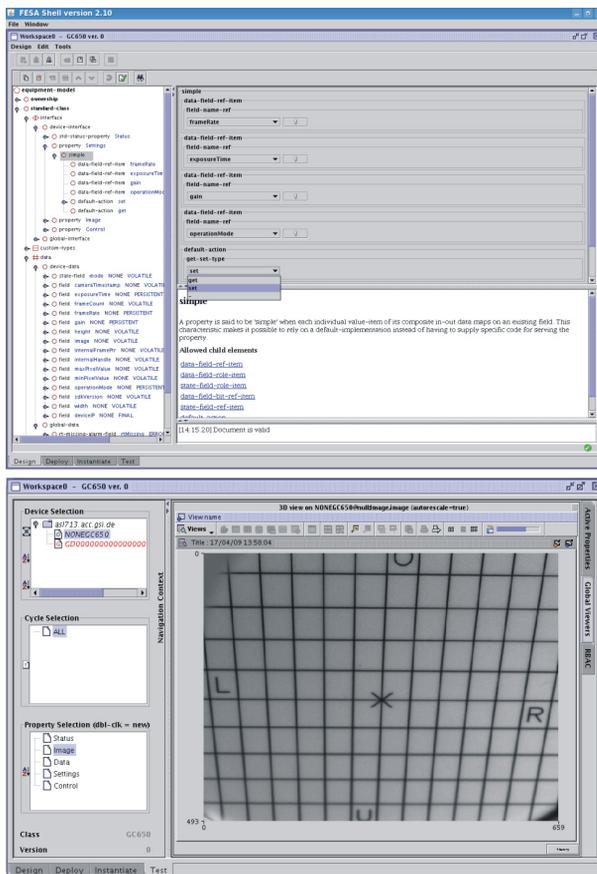


Figure 2: Example screenshots of two FESA GUIs made in Java. Top: Design-Tool. Bottom: Navigator-Tool with video data.

using the CERN timing events and domains. The existing GSI timing is very different to the CERN timing and can not be used directly with FESA. For this reason an FPGA based converter was developed. This module decodes the GSI timing information which consists of machine events and the actual virtual accelerator ID and encodes this to CERN specific telegrams and machine events, accepted by the CERN timing receiver cards.

As a medium-term solution, a new FAIR timing system is foreseen, which is also subject of an ongoing collaboration between GSI, CERN and other European institutes.

Presently, the buildup of a core team of FESA experts at GSI is mandatory. This requires full understanding, training and adaption of FESA to the GSI accelerators. Collaboration between the CERN and GSI CS groups to transfer the expertise is already established.

## TEST INSTALLATIONS

Preliminary preparations and tests were carried out to investigate the principle and technical usability of the FESA framework at GSI and FAIR. For this, equipment classes for common VME devices such as fast ADC, Multiscaler, and I/O modules were successfully designed and accessed with FESA.

Furthermore, the complete vertical hierarchy from the low-level sensor and front-end system via the Middleware (CMW) up to the JAVA based GUI in the main control room was tested to learn and demonstrate the possible control system architecture for FAIR. Therefore, a comprehensive beam position monitoring (BPM) system for the SIS 18 as a test project was launched. Due to personal and time critical issues, the commercial control system company Cosylab [5] was contracted for a feasibility study and software implementation in close collaboration with beam diagnostics and controls staff. The concept of this challenging DAQ with data rates of up to 700MB/s is described in [6]. Twelve Libera Hadron systems [7] are used to digitize the analog position signals at a rate of 4x125MSamples/s.

To access and handle all parts of the system, three FESA classes were developed. Each Libera uses an instance of the BPM class. All 12 instances are orchestrated by the BPMMaster class. In addition the AuxiliaryBPM class is used to record synchrotron signals, such as rf, intensity, etc., to be visualized on the same time scale as the BPM measurements.

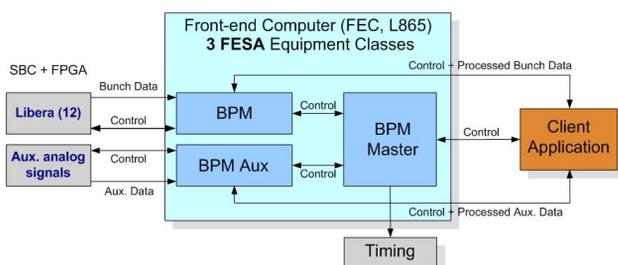


Figure 3: SIS-18 BPM system: FESA software layout.

The software layout is shown in Fig. 3. At present, the commissioning of the FESA based BPM system takes place. First promising orbit data as well as a distribution of bunch windows, based on the bunch detection algorithm, is presented in Fig. 4.



Figure 4: Java GUI showing first orbit data recorded with the new SIS-18 BPM system.

## CONCLUSION

The multiplexed beam operation at FAIR with its large set of requirements for the future control system as well as the need for a standardized framework, providing efficient device integration, confirms the decision for FESA. On the one hand that implies the set-up of a FESA competence center at GSI and on the other further adaption efforts such as the development of new timing adapters and the design of future timing concepts together with CERN. The BPM test project has shown very good performance and liability and has proven the operability of FESA at GSI. The authors would like to thank all members of the CERN control system group for the work done so far within the scope of this collaboration.

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