PROGRESS AND CHALLENGES DURING THE DEVELOPMENT OF THE SETTINGS MANAGEMENT SYSTEM FOR FAIR

H. Hüther, J. Fitzek, R. Müller, D. Ondreka, GSI, Darmstadt, Germany

Abstract

A few years into development of the new control system for FAIR (Facility for Antiproton and Ion Research), a first version of the new settings management system is available.

As a basis, the CERN LSA framework (LHC Software Architecture) is being used and enhanced in collaboration between GSI and CERN. New aspects, like flexible cycle lengths, have already been introduced while concepts for other requirements, like parallel beam operation at FAIR, are being developed.

At SIS18, LSA settings management is currently being utilized for testing new machine models and operation modes relevant for FAIR. Based upon experience with SIS18, a generic model for ring accelerators has been created that will be used throughout the new facility. It will also be deployed for commissioning and operation of CRYRING by the end of 2014.

During development, new challenges came up. To ease collaboration, the LSA code base has been split into common and institute specific modules. An equivalent solution for the database level is still to be found. Besides technical issues, a data-driven system like LSA requires high-quality data. To ensure this, organizational processes need to be put in place at GSI.

FAIR CONTROL SYSTEM REQUIREMENTS

Construction work for FAIR has been started in 2011 next to the existing GSI complex. In May 2014, the first key construction phase has been completed with the conclusion of pile-drilling work for the foundations of the facility. Once fully operational, FAIR will provide nine new accelerator installations, using the existing linac and synchrotron SIS18 as injectors [1]. See Fig. 1 for an overview of the FAIR accelerator complex.

The designated operation modes of FAIR put demanding requirements on the new control system currently in development. To optimize the number of concurrent research programs, the facility will provide up to five beams in parallel with pulse-to-pulse switching between different particle types. Additionally, great flexibility shall be provided, allowing to change the parallel operation schemes on a daily basis.

Tight resource restrictions make meeting these requirements even more challenging. After thoroughly evaluating possible options for most effectively implementing a new settings management component for the FAIR control system, enhancing CERN's existing LSA framework was identified as the most suitable approach.

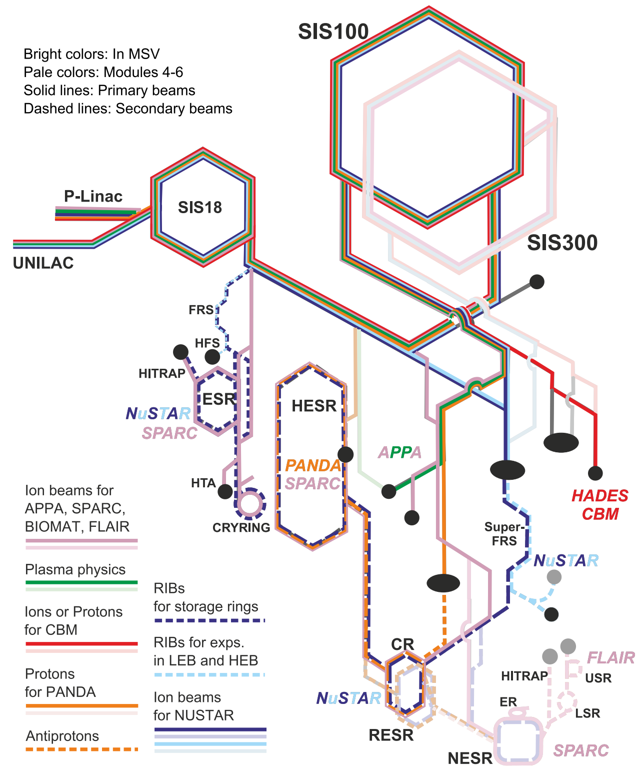

Figure 1: Overview of the FAIR accelerator complex, P. Schütt, GSI.

COLLABORATION WITH CERN

LSA is being developed at CERN since 2001. In the following years, it has constantly evolved and matured [2]. Today, CERN uses LSA to control the majority of its accelerators.

Since 2007, GSI and CERN collaborate to enhance LSA for mutual benefit and to use it as the core component for settings management within the FAIR control system.

LSA has been chosen because of its completeness regarding all important settings management aspects and also certain characteristics that are especially important for implementing enhancements towards FAIR. The framework has been designed with extensibility in mind, reflected by modular structure and separation of concerns in its design. It provides generic means of modelling different accelerators and plug-in mechanisms for adding functionality while a modern architecture ensures scalability.

As powerful as LSA already was when the collaboration started, it still requires major enhancements to support the specific requirements of FAIR. Significant steps towards this goal have been made since progress has last been reported on publicly.

ISBN 978-3-95450-146-5

PROGRESS SINCE 2010

The LSA framework is now feature-complete for SIS18. Although the machine model for this accelerator has not been fully completed and not all of its operation modes are covered yet, the system allowed for operating SIS18 to carry out machine development work already targeted at the future FAIR facility. Two examples certainly worth mentioning include resonance compensation experiments using tune variations at injection and extraction plateaus as well as commissioning of the new H=2 cavity.

These advances show that the teams keep their focus on the requirements for the new facility, with the test installation of the CRYRING storage ring to be commissioned in the coming months. Some of the fundamental concepts targeted at FAIR's flexible operation modes have already been implemented and shall be tested with CRYRING. Two of them, being most distinguished from a settings management perspective, shall be described in more detail.

GENERIC MODEL FOR RING ACCELERATORS

The fact that the structure of LSA adheres to the principle of separation of concerns shows its benefits, amongst others, in decoupling work packages between physicists and computer scientists. While the framework itself is responsible for executing algorithms according to the machine model and supplying settings to devices, development of the machine model itself is done using tools that supply the machine model to the framework database with physics algorithms being implemented in a plug-in style.

Modelling accelerators in LSA works by defining a hierarchy that describes parameters for accelerator control from top-level physics parameters (e.g. particle type, energy) via parameters that represent intermediate calculation results (e.g. revolution frequency) down to hardware parameters (e.g. power converter currents) and the relations between them. Associated with each relation is an algorithm component (called "rule" within in LSA) that calculates a dependent parameter from its parents [3].

For FAIR, the fact that several new accelerators are being built concurrently calls for an approach that maximizes reuse of modelling artefacts and optimizes resource usage. Instead of creating different models for each accelerator from scratch, machine physicists at GSI decided to create a generic model for ring accelerators that shall be the basis for all synchrotrons and storage rings within FAIR. This model was being used to operate SIS18 and will subsequently be used for CRYRING.

All rings within FAIR will be equipped with a uniform controls interface, making it possible to take advantage of great similarities on the level of physics modelling including input parameters, relations between them and rules responsible for their calculation. Also on the technical level, advantages of a consistent implementation are being leveraged, including handling of timing and RF.

Using this generic approach, similarities can be expressed using a single rule for calculations in multiple accelerators and a generic hierarchy that is part of each accelerator's model. Distinctive features of certain accelerators are added to the model while keeping the generic structure, similarly to the concept of abstract and concrete classes in software engineering. Figure 2 shows an excerpt of the SIS18 parameter hierarchy as an example.

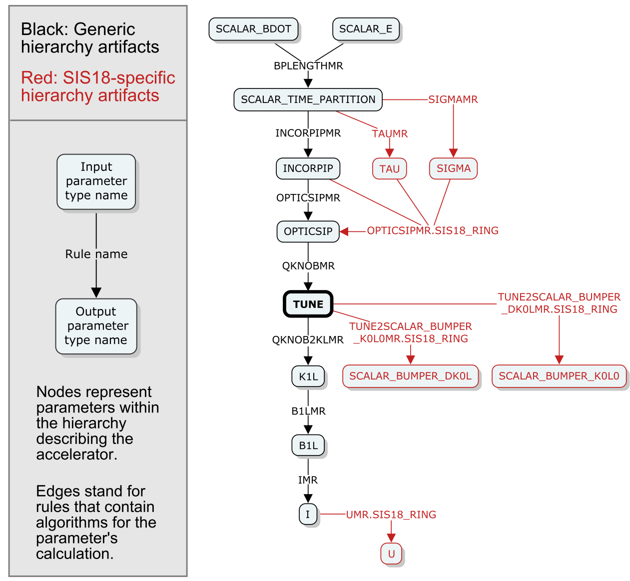

Figure 2: Hierarchy for inputs and outputs of the tune parameter type, showing how distinctive features of SIS18 are added while keeping the generic ring accelerator model structure intact.

There are two main advantages to the described approach. It reduces duplication, which results in less effort for modelling all additional rings and also increases consistency, which makes machine models and operation processes easier to understand. Consequently, the effectiveness of training and maintenance measures is also expected to benefit from this generic modelling approach.

BEAM PRODUCTION CHAINS AND PATTERNS

Beam production chains and patterns are the central technical concept which shall allow for highly flexible operation planning across the whole FAIR facility. They will be tested for the first time during commissioning and test-operation of CRYRING.

Representing a major change in perspective, beam production chains establish a beam-oriented view on the facility compared to the accelerator-oriented view towards settings management dominant in LSA up to this point.

However, beam processes, which are the most central building blocks within LSA for describing settings within a time span, will continue to be used. Beam processes represent a specific procedure on the beam within one accelerator (e.g. injection, ramp, extraction). Rather than being con-

ISBN 978-3-95450-146-5

tained in higher-level cycles and super cycles, which are also accelerator-specific, they will now be part of beam production chains, which allow for scheduling a beam across accelerators. To be able to coordinate multiple beams traversing the facility in parallel, beam production chains will be grouped into patterns. An example of typical parallel operation for the modularized start version of FAIR is given in Fig. 3.

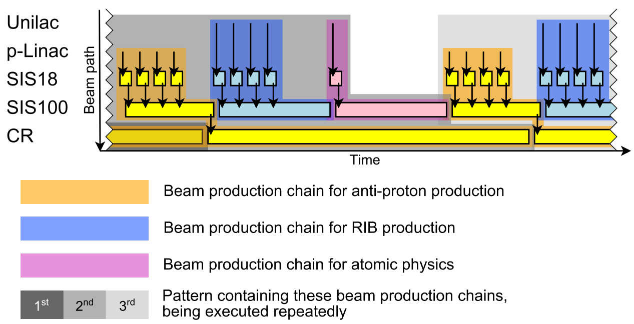

Figure 3: Example for parallel beam operation showing aggregation of beam process chains into patterns. HESR accumulating the anti-protons is omitted.

Relying on the existing beam process concept of LSA, beam production chains will not contradict the framework's principles, but become an additional modelling element, complementary to existing cycles and super cycles, leaving it to the framework's user to decide which one to use, based on the requirements.

Some modifications to LSA were necessary as prerequisites to the implementation of the described concept. All of them were carried out in close cooperation and with most valuable support from CERN, including flexible beam process lengths and optics definitions which are now relative regarding time [4]. Most recently, flexible assignment of timing information to different levels of contexts has been realized.

REMAINING DIFFICULTIES

Within the years past, the collaboration between CERN and GSI continued to thrive and mature, even allowing for a constructive retrospect and good practices to be extracted [5]. Still, on a technical level, some difficulties remain.

The LSA core module is being built separately at both institutes, making completely controlling the process possible for each of them. Other CERN libraries however, which are not included in the collaboration agreement, have to be treated as third party libraries by GSI. They cannot be built at GSI, but in the future, being able to apply bug fixes to them might be necessary to ensure operability of the FAIR facility.

For historical reasons that have proved difficult to overcome, CERN and GSI continue to use different build systems to prepare their LSA releases, repeatedly causing version inconsistencies in deployed packages. A new build system currently being developed at CERN is expected to resolve this issue once the transition has been completed.

A joint effort to divide the LSA code base into common and institute specific modules has proved most beneficial. On the database level, an equivalent solution is still being investigated. This missing separation on the database level leads to tables for certain features of LSA not used at GSI being empty or reported missing by CERN database queries. Both cases are a potential source of issues. Also, it has proved to be problematic to synchronize the state of code and database changes between institutes. While a manual interim solution is in place, a properly tool-supported, permanent solution is still to be found.

OUTLOOK

The commissioning of CRYRING during the coming months will be the next major milestone for the usage of LSA at GSI and FAIR. Having been contributed by the Manne Siegbahn Laboratory of Sweden, the machine itself and necessary infrastructure is currently being set up. CRYRING consists of a small ion storage ring with electron cooling, an RFQ linear accelerator and two injectors for different types of ions. It will be operated solely through the new control system utilizing LSA for settings management. It will also be the first machine to be operated using the new beam production chain and pattern concept.

Building on this, the next logical step is to make operations applications adhere to the beam-focused perspective represented by beam production chains and patterns as well. As all former applications were accelerator-focused, this will be a major change for users and operators.

Apart from purely technical advances, GSI will have to further refine its business processes. As LSA is a data driven system, high-quality data is crucial to its operation. Defined and well-established processes are needed for introducing, verifying and maintaining data including device representations, calibration curves and accelerator master data. Establishing these processes and thus ensuring data quality represents an important step towards operating the new FAIR facility.

REFERENCES

[1] R. Bär et al., "Development of a new Control System for the FAIR Accelerator Complex at GSI", ICALEPCS'09, Kobe, Japan, TUP107.

[2] G. Kruk et al., "LHC Software Architecture (LSA) - Evolution toward LHC Beam Commissioning", ICALEPCS'07, Knoxville, Tennessee, USA, WOPA03.

[3] D. Ondreka et al., "Setting Generation for FAIR", IPAC'12, New Orleans, Louisiana, USA, THPPR001.

[4] J. Fitzek et al., "Settings Management within the FAIR Control System based on the CERN LSA Framework", PCaPAC'10, Saskatoon, Saskatchewan, Canada, WEPL008.

[5] R. Müller et al., "Benefits, Drawbacks and Challenges during a collaborative Development of a Settings Management System for CERN and GSI", PCaPAC'14, Karlsruhe, Germany, TCO101.

ISBN 978-3-95450-146-5