SETTING GENERATION FOR FAIR

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Abstract

The experimental program envisaged for the Facility for Antiproton and Ion Research (FAIR) requires complex operation schemes of its accelerators and beamlines including parallel operation of several experiments. Thus, there is a strong need to develop an appropriate setting generation system, which shall supply consistent settings for all devices across the facility to support the planned parallel operation modes. This system should also provide standard tools for modifying and accessing the settings. These requirements will be met by using LSA, a generic accelerator modeling framework developed at CERN, as basis for the setting generation system. We will report on the status of the setting generation system for FAIR, covering both the implementation of the physics model as well as the extensions to the LSA framework realized within a collaboration with CERN. Results of the first test runs with the existing GSI synchrotron SIS18 will be presented.

INTRODUCTION

The FAIR facility, soon to be constructed close to the site of the existing GSI facility, will serve experiments from fields such as hadron, nuclear, atomic, and plasma physics as well as biology and material sciences with heavy ion beams composed of a large variety of isotopes at unprecedentedly high intensities [1].

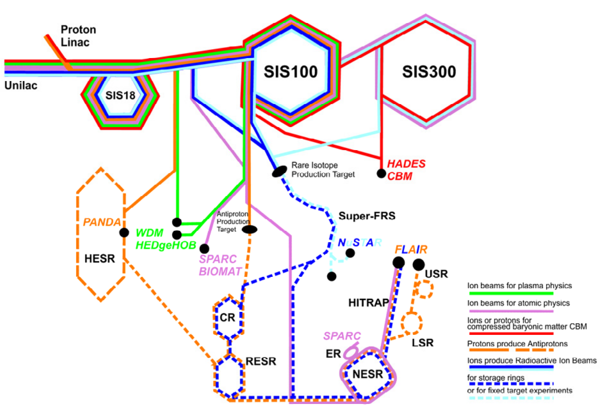

Figure 1: The accelerators and beamlines of the GSI/FAIR accelerator complex.

To maximize the duty cycle of the facility, it is foreseen to run several experiments in parallel, with pulse-to-pulse switching of all beam parameters including ion species. Moreover, a high degree of flexibility for changing the parallel operation schemes on a daily basis is requested by the experiments. Figure 2 gives an example of a typical parallel operation mode in the modularized start version of FAIR.

Due to its tight resource constraints, parallel operation poses a big challenge to the FAIR control system, which is presently being developed at GSI [2]. An important aspect of the control system concerns the generation and management of consistent settings supporting the planned parallel operation modes. After careful evaluation, it was decided to use the existing LSA framework from CERN [3] for setting generation within the FAIR control system. A collaboration with CERN was set up to extend LSA according to the needs of CERN and FAIR, sharing the development effort among both institutes.

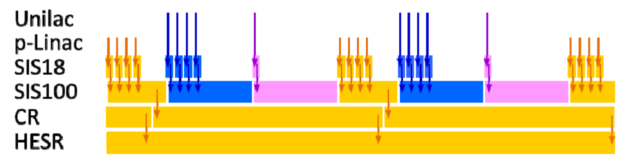

Figure 2: Periodic pattern and dependency of accelerators for parallel operation of anti-proton production (orange), RIB production (blue), and atomic physics (pink).

THE LSA FRAMEWORK

LSA, the LHC Software Architecture, was developed at CERN starting in 2001 and is the core controls software component for settings management within the CERN control system [3]. It is presently used to control LHC, SPS, and LEIR, but more accelerators will follow [4].

LSA is designed as a generic framework for accelerator modeling. Its architecture provides clear separation between data model, business logic and applications. Its modular structure allows plugging in institute specific implementations.

The LSA framework covers all important aspects of settings management: the data describing the accelerator (geometry, optics) and its devices (hardware limits, calibrations, properties); the generation and modification (trim) of set values; and exploitation (equipment control, measurements). All data, static or dynamic, is persisted in a database and can be accessed through standard interfaces. For settings, a history is available.

LSA Concepts for Accelerator Modeling

An accelerator within LSA is modeled by defining its parameter hierarchy, from top level physics down to hardware parameters. Intermediate parameters provide access to further derived quantities. Associated with each relation is a rule for calculating the value of the dependent parameter from its parents. Thus, changes to the physics parameters can be propagated consistently down to the hardware parameters, resulting in a consistent change of the set values of many devices at the same time.

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Rules are selected by matching parameter types rather than parameters only. This allows generic modeling: the same rules can be applied for any accelerator. In Figure 3, a part of the generic hierarchy for circular accelerators in FAIR is shown.

The modular design of the LSA framework enables physicists to implement the machine model themselves in a structured and simple way, without having to cope with the complexities of the underlying software techniques.

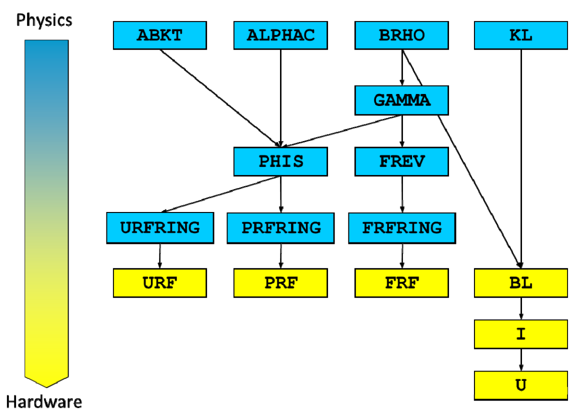

Figure 3: Generic parameter hierarchy.

To describe the time dependency of set values, LSA uses the concept of cycles and super cycles. These are subdivided into beam processes, usually describing an action the accelerator performs (e.g. injection, ramp, extraction). A setting contains the value of a parameter in a certain beam process. This value consists of two additive contributions, target and correction. Typically, the former is set to a theory value (e.g. created from the optics information contained in the LSA database) while the latter is used to trim the machine. For time dependent settings, the values are represented by discretized functions.

Realized LSA Extension for FAIR

Some extensions to the LSA framework for its application in the FAIR setting generation system have already been realized by the LSA collaboration. The most important extension concerns the possibility to let rules change the length of cycles during trims. This feature shall be used heavily at GSI and FAIR, where e.g. the beam energy is routinely and frequently trimmed upon request by experimenters. To optimize the duty cycle, the cycle length is then changed, keeping the ramping speed fixed. This feature had not been included in the LSA system from the beginning due to the rather static timing of the CERN accelerators controlled by LSA.

Future LSA Extensions for FAIR

So far, the LSA framework is tailored to modeling single accelerators. Consequently, it is presently lacking structures for representing the interdependencies of accelerators in a large facility. This may come as a surprise, considering that LSA was developed at CERN. But in fact, at CERN the coupling of the accelerators is not done on the setting generation level, but rather at the level of the timing system, completely bypassing LSA.

For the FAIR setting generation system, the inclusion of concepts to model the parallel operation schemes is essential. Otherwise, given the high degree of flexibility demanded by the FAIR users, the operational complexity when changing a parallel operation scheme becomes simply unmanageable. Therefore, an extension to the LSA framework is proposed including the following concepts:

- A *pattern* object, holding the information about the sequence of accelerators and the settings required to execute a particular parallel operation mode;
- A *chain* object, representing the accelerators and settings required to produce beam for a single experiment from source to target;
- An extension of the existing *super cycle* object to represent the settings of a single accelerator during the execution of a particular parallel operation mode.

With these definitions, chains and super cycles are essentially orthogonal views on the contents of a pattern. While super cycles do exist in the present LSA system, they are currently only a grouping method for cycles and need to be enhanced to reflect the sense of a super cycle described here. Figure 4 illustrates these concepts.

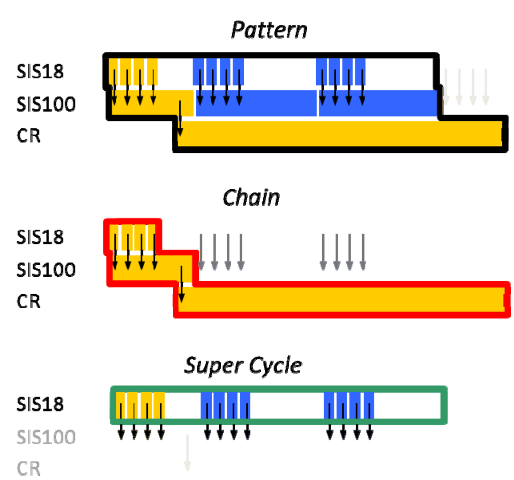

Figure 4: Pattern, chain, and super cycle, illustrated for the parallel operation of anti-proton production (orange) and RIB production (blue). The injector linacs as well as the HESR accumulating the anti-protons are omitted.

Using patterns, it shall be possible to create a model for the whole FAIR accelerator complex, keeping track of resources and providing settings for all devices. The patterns will be executed by the central timing system of FAIR. Several patterns may be prepared in advance, making fast switching between different parallel operation modes possible.

SETTING GENERATION FOR FAIR

The LSA framework provides a suitable platform for the realization of the setting generation system for FAIR. However, it comes without any physical contents. To implement a working setting generation system, the LSA system must be supplied with the data and rules describing the accelerators to be modeled. To this end, a project team was established at GSI in 2008.

It was decided to use the existing GSI synchrotron SIS18 as a prototype, since this opened up the possibility to actually test the setting generation system with a real machine long before the FAIR accelerators would be ready. Moreover, SIS18 will serve as an injector to the SIS100 and therefore become an integral part of the FAIR accelerator complex anyway.

SIS18 as Prototype

An empty LSA test system had been set up at GSI by the beginning of 2009. The implementation of the physics model for SIS18 then consisted of two separate tasks. On the one hand, the static data describing the layout of SIS18 (geometry and optics) and the properties of its devices (interface, calibration curves, devices limits, etc.) had to be collected and imported into the LSA database. On the other hand, a parameter hierarchy had to be defined and algorithms had to be devised (and implemented as rules) to calculate the set values for all devices from the high-level physics parameters. After completion of these tasks, the LSA system was ready to calculate SIS18 cycles and super cycles. An example is given in Figure 5.

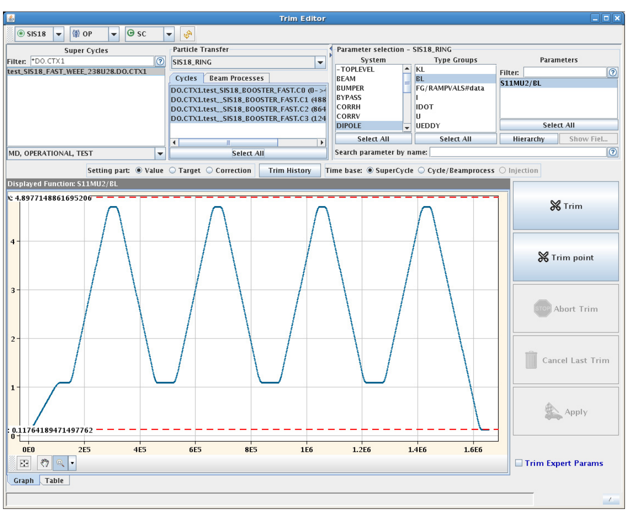

Figure 5: LSA application showing the main dipole field for a SIS18 super cycle in the FAIR injector mode.

Apart from the implementation of the physics model, considerable effort was taken to support the data format of the ramped devices in SIS18 so as to be able to run the accelerator with the data calculated by the LSA system. As a result, by March 2010 LSA was successfully used in a test run of SIS18 with beam.

A Generic Ring Model

Based on the experience with the SIS18, a generic model for all synchrotrons and storage rings of FAIR and GSI is now being developed. In this respect, it is of advantage that all rings of FAIR are designed at the same time, such that they can be equipped with a uniform controls interface. Moreover, the operational schemes of the FAIR synchrotrons and storage rings turn out to be similar to those of the existing machines SIS18 and ESR, respectively. Here, the LSA feature of matching rules by parameter type leads to a big reduction of the effort for implementation and maintenance: The same rules can be used for all accelerators as long as identical relations are used to model identical physics.

Presently, the generic model allows the calculation of reference synchrotron cycles for SIS18 and SIS100 as well as some representative beamlines. It will soon be extended to include the existing storage ring ESR.

CONCLUSIONS

A setting generation system for the FAIR accelerator complex is being developed at GSI, based on the CERN LSA framework. A generic synchrotron model has been implemented, allowing the operation of SIS18 as well as the calculation of reference set values for SIS100. As a result of the collaboration with CERN, the LSA system now provides functionality for changing the length of cycles caused by trims.

Concerning the physics model, the next steps will include a completion of algorithms for synchrotrons as well as the implementation of a generic model for the storage rings of FAIR, with the existing storage ring ESR as prototype. The LSA framework itself shall be extended to provide the concepts for modeling the parallel operation schemes of FAIR.

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