THE NEW FAIR ACCELERATOR COMPLEX AT GSI: PROJECT, CONTROLS CHALLENGES AND FIRST STEPS

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Abstract

An international Facility for Anti-proton and Ion Research (FAIR) has been proposed by GSI and the international community in 2001 and is currently under development. This new accelerator complex will be a significant extension to the existing GSI accelerator chain and will provide a range of particle beams from protons and anti-protons to ion beams of all elements up to uranium, as well as secondary beams of short-lived rare isotope beams. Central parts of the FAIR facility are a superconducting double-ring synchrotron and a system of storage rings.

This presentation covers status and scope of the FAIR project and its technical and organisational challenges, in particular in respect to the control system. As many parts of the new FAIR facility will be independently developed as in-kind contributions by international FAIR partner institutes, one significant point is integration and interface management. Among many other aspects, one important technical consideration is a high degree of parallel beam operation for the different research programs imposes ambitious demands on the timing and cycle management system. We will discuss first steps to a new FAIR control system.

THE FAIR PROJECT

Presently, GSI operates an in many aspects worldwide unique accelerator facility for heavy ion beams. The existing accelerator complex consists of the universal linear accelerator UNILAC, the heavy ion synchrotron SIS18, and the experimental storage ring ESR. In 2001 a major extension to the present GSI accelerator chain has been proposed by the international community that will turn GSI into an international Facility for Anti-Proton and Ion Research (FAIR) in the years to come. The layout is shown in Figure 1.

The heart and central part of the FAIR facility is a synchrotron complex consisting of two separate synchrotron accelerator rings with a maximum magnetic rigidity of 100 Tm and 300 Tm, respectively. Both machines have the same circumference and will be installed on top of each other in the same underground tunnel and be equipped with new, rapidly cycling super-conducting magnets. To achieve highest beam intensities, the SIS100 synchrotron will be operated at a repetition rate of about 1 Hz with ramp rates of up to 4 Tesla per second for the dipole magnets. The intent of the 100 Tm ring is to provide intense pulsed uranium ($q=28^+$) beams at 1 GeV/u and intense proton beams at 29 GeV. For high-intensity proton beams, required for anti-proton production, a new proton linac injecting into SIS18 is part of the project. Both heavy ion and proton beams can be compressed into 70 ns bunches required for the production, subsequent storage and efficient cooling of exotic nuclei and anti-protons, as well as for plasma physics experiment.

With the double ring facility, continuous beams with high average intensities can be provided for 1 GeV/ions of all masses, either directly from SIS100 or by transfer to, and slow extraction from the 300 Tm ring. The latter can provide high-energy ion beams with maximum energies around 35-45 GeV/u depending on the ion mass/charge ratio.

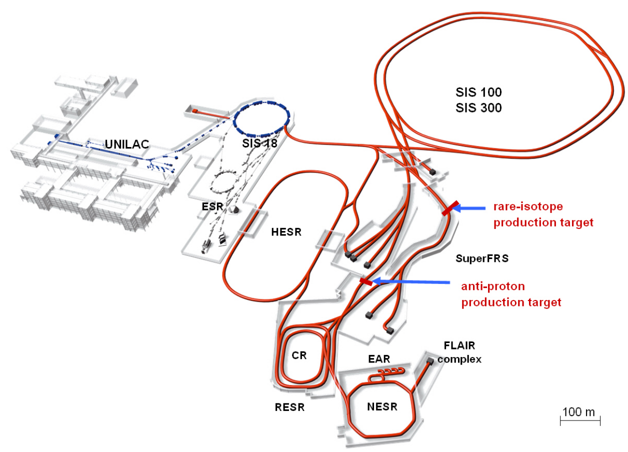

Figure 1: The layout of FAIR. The existing facility (blue) acts as injector for the new FAIR facility (red).

In addition to several fixed beam experiments target stations the facility will be complemented by a system of cooler/storage rings: A collector ring (CR) is foreseen to capture radioactive ion or anti-proton beams from the production targets and apply stochastic cooling. The RESR ring will be used for accumulation of anti-protons after pre-cooling in CR and for fast deceleration of short-lived nuclei. Anti-protons will be accumulated for long time periods up to one hour. Therefore it will be necessary to extract pilot bunches before the complete batch of anti.-protons is transferred to HESR or NESR experimental storage rings.

In-beam physics experiments with ions and anti-protons will be accomplished in the New Experimental Storage Ring (NESR). It will be equipped with stochastic and electron cooling systems as well as with a variety of experimental devices, including a high precision mass spectrometer, internal target experiments and an electron-nucleus scattering facility. NESR can be used to decelerate ions and anti-protons and to extract them for FLAIR low energy experiments.

Experiments with anti-protons of up to 14 GeV can be performed in the High-Energy Storage Ring (HESR). This ring will feature an internal target and associated detectors. It will be equipped with a high-energy electron cooler and a stochastic cooling system to compensate beam degradation due to target interaction and intra-beam scattering.

FAIR PROJECT STATUS

Right from the initial proposal, the FAIR project has been positively evaluated by all technical and political committees and has been recommended for realization by the German science council. In April 2006 the final FAIR baseline technical report was presented to the international steering committee (ISC) which as has been accepted the project for realization in the years 2007 to 2015.

The total construction costs of the project, scrutinized by several cost review committees, have been assessed to almost 1200 M€ and were also accepted by the ISC. The German government has committed funding of 75% of the construction costs; 25% of the costs are required to come from non-German partners, turning the FAIR project into an international project. As of now 13 nations have expressed their interest in participating in the FAIR project, some having made already financial commitments. Contributions to the FAIR project can be either in cash on in-kind. A large number of working packages have been defined that partners could take over. Yet, no final decision on working packages has been taken so far. It is important to note that working package takers will be fully responsible for implementation, delivery and commissioning.

Schedule

Recently the German government has decided to officially start the FAIR project together with those partners that have their interest and have given a financial commitment. The official project kick-off event will happen on November 7th, 2007.

Building activities are expected to start in late 2008 or early 2009. FAIR will be realized in a staged concept. The first experiments with the superconducting fragment separator (SFRS) are expected already for the year 2012. Completion of the full FAIR complex is aimed for the year 2015.

TECHNICAL CHALLENGES TO THE CONTROL SYSTEM

The performance parameters of the FAIR facility require new thinking in regards to control system design. Technical challenges include the following points:

Parallel Operation and Timing

An important consideration in the design of the FAIR facility is to support a high degree of truly parallel operation of the different research programs. Parallel operation provides maximum integrated beam time or integrated luminosity for each of the different programs operated in parallel. This implies that the facility operates for the different programs more or less like a dedicated facility.

Figure 2 shows an example of a parallel beam production pattern throughout the accelerator chain for production of anti-protons for HESR, a fixed beam high energy experiment (compressed baryonic matter) after SIS300, high atomic physics after SIS100 and in-beam experiments with anti-protons in HESR in parallel.

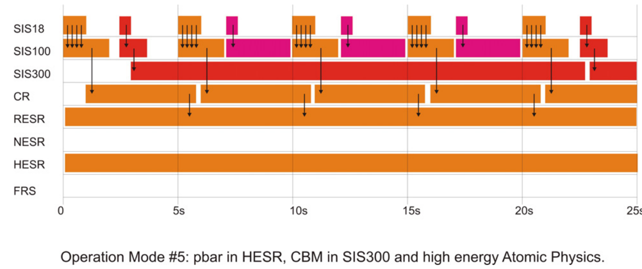

Figure 2: Parallel operation of FAIR accelerators

A tool for setting up an operation mode is needed in order to edit the individual machine cycles in the accelerator chain, assisting the user to find the optimal sequence. Constraints from the cryogenic plant and from the power grid (energy load must be kept within certain limits, dangerous resonances have to be avoided) have to be taken into account.

The interplay and timing synchronization of the different accelerators together with the great number of combinations of individual cycles and beam patterns require a dedicated sequence and cycle management. At run-time a central and individual event sequencers will orchestrate the accelerator chain. In an emergency case, running cycles must be interrupted at any time and the beam safely dumped.

The FAIR timing system must at least provide μs precision, for high precision synchronization, e.g. for beam transfer between accelerator stages (bunch-to-bucket transfer), a bunch synchronous timing system will have to be provided, to achieve a deviation of no more than 100 ps between any two receivers in the facility.

Operation

For an efficient exploitation of the potential of FAIR at high beam intensities (e.g. $4x10^{13}$ ions/cycle in SIS100) or in anti-proton mode, a high degree of automation is needed. This includes sophisticated modelling of the beam manipulation along the accelerator chains to calculate good initial settings and efficient tuning and trimming procedures. Effects on the beam such as persistent fields, magnetic history, machine-to-machine cross-talk, etc. have to be taken into account and compensated. Fault detection and out-of-band monitoring is essential to operate the machines. A complete beam operational history is needed to build up a long term understanding of accelerator performance. In case of malfunction all necessary data for post-mortem analysis has to be available.

PROJECT MANAGEMENT ISSUES

Due to the central and integrating nature of the accelerator control system as well as taking into account a constant evolvement in the future the FAIR management as well as the in-kind advisory board (IKAB) decided that the development of the system must be geographically based at the FAIR home institute. A strong team of core developers and a team of integrators are needed on-site in order to coordinate all development, equipment and system commissioning activities.

Significant parts of the FAIR facility will not be developed on-site at GSI, but will be in-kind contributions from FAIR partner institutes. These working-packages could range from a complete accelerator (e.g. HESR) to technical subsystems. Considering this situation with having a multitude of technical contributions, a strict policy of standardization is absolutely necessary in the project. Moreover, central deployment and procurement of interface electronics and systems should be implemented to achieve a maximum of standardization.

Interface definitions must be worked out and defined, in co-operation with partners, as soon as possible after the project start Once defined, interfaces must be obligatory and well enforced within the project such that all developments must comply with the set of standards defined. The controls group must have full authority over collaboration partners to impose technical controls frameworks as solutions. It is important that the management follows this line, even if short-sighted technical solutions of a given collaboration partner look as if they would represent an economy. Conflicts must be resolved in an early stage to avoid undesirable developments and re-designs.

GENERAL STRATEGY TOWARDS A FAIR CONTROL SYSTEM

The expected full functionality of the FAIR facilities, using the existing GSI accelerators as injector machines, demands a substantial revision of the present GSI accelerator control system. The performance for FAIR controls has to be pushed beyond the capacity of the existing system. New functions needed shall not be retrofitted to the present control system. Instead, a new system shall be designed and implemented that respects the new functionality needed from the beginning on. The new system can substantially build on proven principles and solutions of the existing control system. All software and equipment development has to comply with the standards defined right from the beginning.

The present control system cannot be completely replaced as it is a substantial investment in hardware and software. Therefore, the existing system will be modernized and obsolete technology will be replaced in order to allow integration into the new FAIR control system. This is already an ongoing activity during the FAIR preparatory phase.

The FAIR control system will be designed as a decentralized distributed system. It will be based on a strictly modular design with well defined interfaces which will allow breaking down the project in interconnected work packages that can be implemented independently.

In the design of the FAIR control system, industrial and widely available commercial components shall be used as much as possible. In addition, proven solutions and complete building blocks of other control systems (e.g. front-end architecture, timing, etc.) are being evaluated and shall be used in order to reduce the development effort.

On the technical level, the control system is not well defined yet. Detailed functional and technical specification need to be defined first before a dedicated design of the system can be made. Such activities are presently ongoing. A dedicated specification analysis and design study is being carried out and a first preliminary architectural design will be completed by end of 2007 or early 2008.

The GSI controls group aims at learning from the experience of other installations. Proven solutions as well as areas of collaboration with other groups in the community shall be identified and evaluated. Adequate implementations should be used wherever possible for reducing the development effort; the development should then be concentrated on integration of missing functionality. In addition, interface definitions for devices and system must be worked out early in the project for compiling specification documents.

In order to avoid commissioning of a new control system and a new accelerator it is intended to test the new system already with the existing machine.

REFERENCES

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