Overview of the status of the FAIR project

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The remarkable progress in the FAIR project reached its preliminary highlight on July 4th, 2017, when the ground breaking ceremony for the Area North took place with a wide internal and external audience (Figure 1). Immediately after the ceremony the site works for the excavation of the tunnel 110 have started. All preparatory works for the Area North (SIS100 tunnel and CBM cave) are on target schedule.

Parallel to the work on the FAIR civil construction, all connection tasks between the GSI premises and the FAIR site (Gebäude Anbindung FAIR, GAF), as well as the enhancement of the SIS18 shielding and the construction of the main transformer stations North and South were under execution by end of 2017.

The rework of the project planning was finished late 2016 resulting in an integrated master time schedule with all three areas, Accelerator, Civil construction and Experiments integrated. The progress of the project is continuously monitored against this newly defined baseline. In addition, a new risk management was established, which will be common for GSI and FAIR.

The status of the accelerator and experiment projects is detailed in the following sections. Progress on accelerator design and procurement is described first, followed by short reports on civil construction works for the FAIR project and on the major experimental projects.

FAIR accelerator subprojects

The status of the subprojects SIS18,SIS100, Super Fragment, Separator, Proton-Linac and p-bar Target, Collector Ring, High Energy Storage Ring and the cross functional topic Commons is descried in the following overview.

SIS18

The goal of this subproject is enabling the existing synchrotron SIS18 to function as injector of the FAIR accelerators, which requires a major upgrade of SIS18 and civil construction measures to connect the GSI facilities with the future FAIR buildings, GAF.

The completion of the latter is an important precondition for SIS18 recommissioning and operation in 2018. The major part of the construction works serve the purpose to enhance the shielding of the SIS18 tunnel. For this purpose a table construction over SIS 18 has been designed, which finally will carry the additional shielding material. The table pillars are installed, and the outer

Figure 1 : From the left: Paula Eerola (Finland), Catarina Sahlberg (Sweden), Albin Kralj (Slovenia), Fanny Farget (France), Pascal Debu (France), Beatrix Vierkorn-Rudolph (Germany), Viacheslav Pershukov (Russia), Dr. Georg Schütte (Federal Ministry of Research, Germany), Rakesh Bhandari (India), Zbigniew Majka (Poland), Ionel Andrei (Romania), Eric Seng (Hessian Ministry of Science), Sibaji Raha, Chairman of the FAIR Joint Scientific Council, Professor Sebastian Schmidt (Management Board member of Forschungszentrum Jülich), Ursula Weyrich, Paolo Giubellino, Jörg Blaurock (all: FAIR Management Board)

Figure 2: Construction works for the interface of the Proton Linac building

reinforcement wall, supporting the mound on the Northern side next to the public walkway „Prinzenschneise“ are completed.

The original scope of the GAF project was extended during the start-up phase in order to include the construction of the SIS18 interface to the FAIR Proton Linac building. A cost effective solution was developed which facilitated the earlier construction. Therefore, the SIS18 ground works have been extended to the UNILAC-SIS18 transfer tunnel. Until March 2018 the Proton Linac beam dump on the eastern side of the transfer tunnel and the modification of its western wall to allow for the tunnel into the FAIR Proton Linac building (Figure 2) will be finalized.

The power converters which will provide the power grid and power supplies of SIS18 are placed on "Freifläche Nord". It is essential that the new transformer station is completed before the start of the re-commissioning of SIS18. The manufacturing of the big new pulse transformers, which will be installed in this area, is finalized and the transformers have been delivered end of 2017. The site preparation and the groundworks for the transformer station are progressing well. The set-up of the underground cable duct between the new transformer station and the GSI campus, guiding the new 20kV cables has been completed.

On the Eastern side of the GSI campus the interface to the new FAIR accelerator complex has been set-up. The outer concrete wall of the experimental hall has been opened and the link to the FAIR tunnel 101, which will contain the extraction beam line out of SIS18 towards SIS100, has been built (Figure 3).

Figure 3: Construction works for the interface to the FAIR tunnel 101.

It is expected that all activities within the GAF project and the FAIR construction relevant for SIS18 operation in 2018 will be finished in time for the planned beam time. In parallel to the civil construction activities, the upgrade of the SIS18 accelerator has been continued. Major new components are in the final phase of manufacturing. The new large bipolar dipole magnet, deflecting the SIS18 beam towards the FAIR tunnel 101, has been manufactured by the company Danfysik and was delivered. The production of the dipole magnet chamber has just been awarded and the IPM (ionization beam profile monitor) magnet system was built and approved by a factory acceptance tests (FAT), before being delivered.

Due to the building displacements generated by the ongoing construction, the accelerator facility needs to be re-aligned beginning of 2018. Already in 2017, first dry runs with the new control and timing system has been performed.

SIS100

The series production of the SIS100 superconducting dipole magnets has started (Figure 4). The first of series magnet was delivered in September/October 2017. First acceptance tests, especially addressing the precision of the geometry of the internal magnet aperture, indicate a very high manufacturing accuracy which lies within the specified limits. The preparatory works for the series testing at the Series Test Facility (STF) at GSI are continuing. In collaboration with CERN, the set-up of a cold rotating field probe has been completed. All high temperature super-conducting current leads for the Series Test Facility have been delivered and accepted. While carrying out the site acceptance tests, three dipole magnets will be tested in parallel. The cold testing process for each dipole will last four weeks.

Figure 4: Yoke manufacturing for the series dipole magnets

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Figure 5: First-of-Series radiofrequency accelerator cavity at external company site.

The first two FOS (First-of-Series) quadrupole doublet units, comprising two superconducting quadrupole magnets, a superconducting steerer- and a sextupole magnet have been tested successfully at JINR Russia.

A dedicated test facility for superconducting magnets of FAIR and NICA has been set-up at JINR and was taken into operation with an official ceremony in November 2016.

One of the largest procurements of the subproject SIS100/SIS18 is the integration of the quadrupole modules, which comprises the design and production of the cryostat system. A producer was found and the contract is signed.

The major design initiative for the quadrupole modules and the so-called missing dipole modules (MDP) is almost finalized. The design of these modules has been performed by an industrial partner. There are still changes in the design of some subcomponents; therefore, the overall set of manufacturing drawings for the modules will be finalized in the GSI design office.

A First-of-Series acceleration radiofrequency (RF) cavity has been manufactured and commissioned. The cavity has reached the specified gap voltage over the complete frequency range. The formal factory acceptance tests are in preparation.

The production of the series of bunch compression cavities could be launched. A delay at the company, which produces the power converters for the cavities, could be mitigated. It has been agreed that the First-of-Series power converters will be directly installed and commissioned on site of the provider of the cavities. The installation of the first power converter is scheduled for January 2018.

One still unresolved technical issue is the insulation of the cooling pipes of the cryogenic vacuum chambers. To investigate the cooling properties achieved by using different bonding technologies, a number of model chambers have been manufactured by a company. The chambers have been installed in the First-of-Series dipole magnet, where temperature and pressure measurements have been conducted. The temperature measurements have shown that the desired surface temperatures below 15 K can be reached. However, the ceramics insulation still cracks after the thermal cycle. Therefore, new tests are planned with cooling pipes equipped with an enamel coating.

The procurement and production of several other components of the SIS100 UHV system is progressing well. Among others, the order for the cryogenics adsorption pumps has been placed and after successful First-of-Series production, the series production has been launched.

Design and tests of beam instrumentation components are converging. Several items of the beam instrumentation system could be ordered and have been delivered already, e.g. the ring cores for the beam transformers, beam loss monitors and other items. The tendering process for the cryogenic beam position monitors has been completed and the contract was awarded.

The components of the local cryogenic system of SIS100 which will distribute liquid helium to the different accelerator components, are designed in WrUST (Wrozlaw University of Science and Technology), Poland. The cryogenic system contains one of the most critical parts with respect to engineering demands: the cryogenic bypass line. A first part of the bypass line, containing the He transfer system and the superconducting bus bar system, has been manufactured and delivered to GSI. In a site acceptance test, which has been conducted at the Series Test Facility, this First-of-Series device was verified (Figure 6). In parallel, the design of the current lead box has been developed up to a full 3D model.

Figure 6: First-of-Series cryogenic bypass line of the local cryogenic system of SIS100 installed at the GSI Series Test Facility

Super Fragment Separator

In 2017 the Production Readiness for the short superconducting multiplets (July 2017) as well as for the long SC multiplets (December 2017) was achieved. The production of the First-of-Series (FoS) short SC multiplet was started. All major subcomponents are produced. The Factory Acceptance Test (FAT) of this multiplet is foreseen before summer 2018. Afterwards the multiplet will be shipped to the test facility at CERN.

The tendering process to procure the required 21 standard superconducting dipole magnets for Super-FRS was initiated in April 2017. After a company qualifying round and two rounds of negotiations the Spanish company ELYTT was awarded with the contract. ELYTT will first verify the already existing magnet design and then produce a First-of-Series (FoS) magnet (Figure 7) which is expected to be ready in autumn next year.

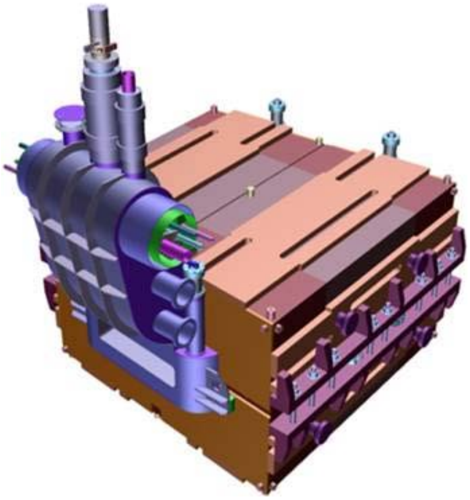

Figure 7: Design of a standard super-conducting dipole for the Super FRS by CEA Saclay as part of the documents for the tendering process

As part of technical collaboration agreement with CEA Saclay a design study for three branching super-conducting dipoles is performed. Compared to the standard dipoles these magnets require an adapted yoke and cryostat design in order to provide an additional straight beam exit to connect the different branches of Super-FRS. The kick-off for this project was in June 2017 and a preliminary design (see dedicated contribution to this report) was already presented in December 2017. It is expected that the design will be completed until summer 2018.

The specifications for the normal-conducting dipoles in the target area have been approved. Currently it is investigated whether the package can be carried out by BINP in Novosibirsk as potential in-kind. The First-of-Series prototype has been developed and built there. In parallel FAIR tendering documents are being prepared and the start of the construction of the remaining two dipoles is expected latest beginning 2019.

The conceptual design of the target chamber is ongoing together with our collaboration partner KVI-CART. The remote guidance of the up to 4.5 tons heavy plug inserts into the chamber was identified as a crucial operation. Thus a full scale mock-up of the target wheel plug was built and the operation could be successfully verified.

Late April 2017 CDR draft documents for the beam catcher, including the recommendations by the 16th MAC, have been received by CMERI Durgapur, India. This was followed by an exchange of information on the necessary remote handling methods this summer.

For the shielding flasks we aim at a combined procurement (tender and in-kind via HIP Finland) with the p-bar subproject in a common working group. The specifications for the Super-FRS transport flask are progressing. In collaboration with the Paul Scherrer Institute (PSI) in Switzerland, a potential subcontractor for HIP has been identified as KVI-CART. The specifications and documents for both packages will be finalized within 2018.

The interfaces to the hot-cell as far as construction planning for the building shell is concerned have been completed, and a study together with Siempelkamp Nukleartechnik GmbH on inserts (doors, lead window frames, crane supports, etc.) to the concrete shell has been carried out. This study will be followed up by another one specifying the details of the installations in the hot-cell.

Proton Linac

Previously, the finalization and commissioning of the p-Linac was not expected to be earlier than 2025, which might have put at risk the HESR and PANDA commissioning. Therefore, the construction of the p-Linac building was re-evaluated and subsequently rescheduled to an earlier date. The p-Linac will deliver beam already in 2023. The extended design documentation and costing has been finished in August 2017.

The proton source built at CEA is close to completion. Commissioning has been started; a current of 70 mA has been achieved, which is close to the design value of 100 mA already. The construction of the low energy beam transport (LEBT) is in progress. Additional power supplies procured by GSI are sent to CEA.

The contract with French collaborators from CNRS is signed. All seven klystrons provided by CNRS passed the Factory-Acceptance-Tests successfully and are delivered to GSI. The production of the First-of-Series modulator is in progress. This is done in-house, which has proven to be the most cost effective approach.

After the very successful power radiofrequency tests of the ladder RFQ prototype, the design of the full size RFQ, which is done at IAP Frankfurt by the group of Ratzinger, is completed and the production has started. A part of the RFQ tank has been successfully copper plated at GSI.

The layout of the CH and CCH cavities is finished. The production of the internal quadrupole triplets is ongoing.

P-bar target

Simulations for target, collimators and beam dumps (for HEBT and APPA as well) are in progress. For this purpose, an ANSYS (Multiphysics finite elements code) working group has been established in collaboration with the Technical University of Warsaw. An experiment at the HiRadMat facility at CERN is in preparation. It is planned to test the mechanical stability of different potential materials for the pbar target and to perform a benchmarking of the simulations. The work on the target station and the alignment system for the beam, a magnetic horn, is progressing.

Together with the Super-FRS team a working group for transport of the highly activated targets to hot cells has been established in order to use synergies for the construction of the shielding flasks and target handling systems.

Collector ring CR

A contract with BINP on the production of the last unassigned CR components is under preparation. Work on the remaining specifications is ongoing.

A prototype vacuum chamber will be constructed and tested at BINP' in order to check the feasibility of the technical concept for the vacuum system according to the MAC recommendations. The technical design of the prototype chamber is finished. The production started already.

Facility-Acceptance and Site-Acceptance-Tests of the First-of-Series of the CR debuncher have been successfully completed. The device fulfils the specifications and was formally accepted. The series production was started already.

The acceptance tests of the First-of-Series of the CR stochastic cooling power amplifier failed. The RF module was redesigned and a new Facility Acceptance Test has taken place, while engineering activities for the pick-up tank and RF signal processing of the stochastic cooling system are ongoing.

High Energy Storage Ring HESR

The components with the longest delivery times for the HESR, dipoles and quadrupoles were delivered completely to Jülich and were technically approved. Half of the dipole magnets were pre-assembled with vacuum chambers in Jülich and delivered to Darmstadt for interim storage.

All other essential components are in production or series production and will be delivered to Jülich by the end of 2018. After pre-assembly, these components will also be transported to Darmstadt by mid-2019.

Commons

The status report for the subproject Commons follows the major technical systems used in the other subprojects:

Magnets

After the pre-series of batch1 (51 dipole magnets) was successfully completed in February 2017 (one dipole magnet of type dip1s_0 and one of type dip13_0), the series production of the rest of the dipole magnet is under way. After having passed the Factory-Acceptance-Test (FAT) at Efremov Institute of Electrophysical Apparatus in St. Petersburg, Russia (NIIEFA) the magnets are shipped to GSI. Shipment of the series magnets started in August 2017 (Figure 8). In total 7 series magnets of type dip1f_0 and 5 series magnets of type dip13_0 underwent successful FAT at NIIEFA and were delivered to GSI until December 2017.

Figure 8: Dipole magnet type dip13_0 (S/N FAIR-023, left) and type dip1f_0 (S/N FAIR-004, right) packed for shipment to FAIR/GSI

The magnets of batch2 and 3 (22 dipole, 166 quadrupole, 92 steerer magnets) will be built by the Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia. While most of the magnet types are currently in the final design phase, production of yokes and coils of the standard 18Tm quadrupole magnet quad2 and the 100Tm steering magnet s100 has already started, see (Figure 9 and Figure 10). The FATs of the pre-series magnets of these types are re-scheduled for March 2018.

Figure 9: Yoke (left) and coil of the quadrupole magnet quad2 (right)

Figure 10: Yoke halves (left) and coils (right) of the steering magnet s100

Efremov Institute launched stamping of the laminations for dipole magnets of batch2 and 3 having identical yoke cross section like the dipole magnets of batch1 in March 2017. Initially 11400 laminations were stamped and were delivered to BINP, see Figure 11. The first magnet to be built from these laminations is the pre-series magnet of type dip15_0. Stamping of another 8000 lamination of the same type is currently in progress.

Figure 11: Lamination for dipole magnet dip15_0 at BINP

Power converters

The power converters for High Energy Beam Transport quadrupole and steering magnets will be mainly built by the Indian company ECIL (Electronics Corporation of India Limited). Up to now two contracts between FAIR, the Indian shareholder BOSE institute and the provider ECIL comprising in total 196 power converters for HEBT (152 for quadrupole and 44 for steering magnets) have been signed. The Factory Acceptance Test (FAT) for the first series of power converters is scheduled for March 2018 after solving problems in the manufacturing process.

Beam instrumentation

The day zero beam instrumentation of the HEBT lines foresees resonant transformers (RT), fast current transformers (FCT), and particle detector combinations (PDC) for intensity measurements and secondary electron emission grids (SEM-Grid), multi-wire proportional chambers (MWPC) and scintillator screens (SCR) for the determination of the transverse beam profile. After prototypes of all these instruments were tested successfully during the GSI beamtime 2016 and passed all tests, procurement, production and assembly of many components of the series were started.

During a visit at Bergoz Instrumentation in France on May 3rd – 5th 2017, the FAT (Factory Acceptance Test) of all current transformers for the FCTs was successfully completed (Figure 12) and all detectors were delivered to GSI on May 16th, 2017.

Figure 12: Current transformer of FCT

The order to produce 25 vacuum chambers with a ceramic gap for RT/FCT (Figure 13) was awarded to the German company FMB Feinwerk- und Meßtechnik GmbH. The First-of-Series (FoS) chamber was produced in February 2018. Production and Tests of the complete series will be completed in 2018.

Data acquisition and expert control applications were implemented, which are based on the FESA framework developed at CERN (Front-End Software Architecture). Progress was especially achieved with the integration of data acquisition modules into the White Rabbit Timing Network, resulting in precise triggers and timestamps for data acquisition and analysis. A major part of the data acquisition has already been tested in a production environment using the CRYRING accelerator.

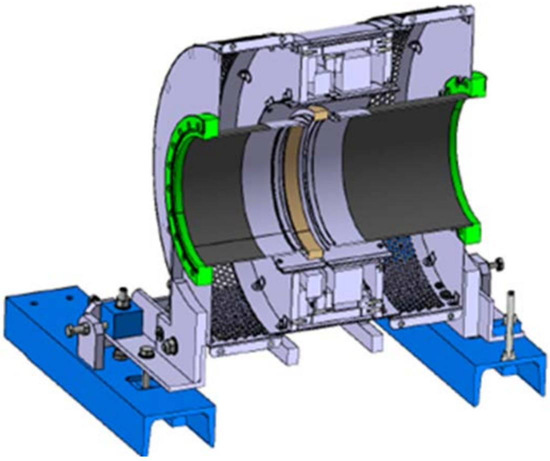

Figure 13: 3D-model of resonant transformers combined with FCT (cut view including both toroids).

Several subprojects which are carried out with the Slovenian in-kind partner Instrumentation Technologies: the DAQ for the beam position monitors BPM of the high energy beam transport system HEBT was delivered in January 2018 and the design of the BPM pre-amplifier are finished and Final Design Reviews (FDR) took place. The board layout for pre-amplifiers was approved, prototype and series were produced, and delivery to FAIR already took place.

Moreover, the Slovenian in-kind partner VacuTech will start the production of the pneumatic drives in this year.

Vaccuum chambers

The vacuum chambers for the dipole magnets of batch1 will be built by BINP. The Factory Acceptance Test (FAT) of the first two pre-series vacuum chambers took place in May 2017 (Figure 14). After giving the allowance for the delivery, the two chambers were shipped to FAIR/GSI on 7th of August 2017 for the Site Acceptance Test (SAT).

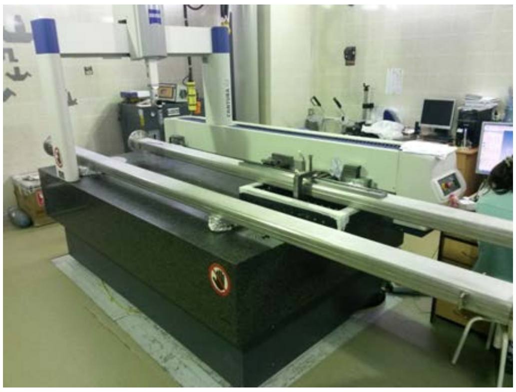

Figure 14: Geometrical inspection of pre-series chambers during FAT at BINP in May 2017

The material for all five branching chambers arrived at BINP in March 2017. In the meanwhile the production of the five chambers has started, with FAT being concluded for two already.

Power connection to FAIR

An intensive collaboration between the technical department EPS, FAIR S&B and the energy provider e-netz took place in order to design and construct new transformer station for the FAIR and GSI accelerators. The orders of four main items (buildings, transformers, high voltage cables and 20 kV switchgear) were placed in April 2017. The construction of the new FAIR transformer stations North and South are progressing within plans. Shell construction works on the FAIR transformer station North for the witch gear-building, the transformer foundations with oil pits, and the foundations for the HV-circuit breaker are completed (Figure 15).

Figure 15: FAIR transformer field North

Figure 16: New Transformer in test field

Figure 17: Transformers ready for transport

Factory-acceptance-tests of the new transformers took place successfully in Balikesir/Turkey (see Figure 16 and Figure 17). The delivery of the new transformers has started. The work on the transformer field north base started in February 2017 and has been finished beginning of 2018.

Power converters Cables and Machine cable management

The new work package (2.14.1.10) "Machine cable management" will provide the best possible cable data quality to the planners, using the cable database for the collection of this information. Later on, this information will be used for the cable routing and the procurement processes. A first complete list of cables (total numbers of cables: 43.400) was given to FAIR S&B in November 2017.

Together with FAIR Site & Buildings, the specifications for the procurement and cable-laying were developed so that a specification of services will be compiled end of 2018.

Cryogenics:

The technical department Commons Cryogenics (CRY) is responsible for the GSI and FAIR wide cryogenic helium cooling of superconducting magnets. CRY is presently operating a prototype test facility (PTF), a series test facility (STF), a helium supply unit (HeSu) and two more cryo plants for the R3B GLAD magnet testing and for the cooling of the CRYRING electron cooler solenoid. The main customers at FAIR are the SIS100 and the Super-FRS with a total helium inventory of about eight tons. Additionally CRY serves small consumers like the final focusing system of APPA and the large scale experiments CBM/HADES and Panda. Furthermore the department is responsible for the so-called local cryogenics belonging to SIS100 and Super-FRS respectively.

Helium Supply Unit (HeSu)

The HeSu is a liquefier with a decant station, a mobile Dewar parking station and a warm gas recovery system with campus wide helium return lines. The HeSu was taken into operation in 2015 and has delivered more than 49,000 l of LHe to users onside the campus so far. The

Figure 18: Helium supply unit for FAIR prototype testing

Figure 19: Universal cryostat for FAIR prototype testing

main purpose is the cryogenic testing of FAIR prototypes. It has a liquefaction capacity of approximately 25 l/h for pure helium gas and 17 l/h in purification mode. A picture of the installation is shown in Figure 18. The warm gas storage capacity was upgraded by additional 30 m³. Part of the HeSu project was a universal cryostat for the testing of FAIR components, in particular SIS100 beam pipe vacuum chambers. The universal cryostat has a more than 4 m long cold testing area with an actively cooled table. A picture of the universal cryostat is shown in Figure 19. The big side flanges can be operated by one single person crane support. Several different cooling techniques are realized: (a) LN2 shield cooling and LHe 4 K cooling with Dewars (using the HeSu), (b) LHe cooling only, with a boil-off cooling of the shield using again Dewars, or (c) connection to the universal connection box of the STF, see below in Figure 19.

Cryogenic Infrastructure for the Series Test Facility (STF)

The series test facility for SIS100 dipole serial magnet testing was taken into operation in 2015 and continuously running in 2016 and 2017 for the testing of the first of series (FoS) dipole magnet, but additionally for the test of the SIS100 main current leads, for the SIS100 local current leads, for SIS100 cryo adsorption pumps and for the site acceptance test (SAT) of the first parts of the local cryogenics for SIS100 arrived at GSI in summer 2016. The serial testing of the dipole magnets was started in 2017. The STF has an overall cooling capacity of 1.5 kW @4K equivalent and is equipped with four test benches for magnet testing and one universal connection box. Up to now the plant has about 15,000 h of operation. A picture of the STF cryogenic infrastructure is shown in Figure 20.

Figure 20: The GSI series test facility

Procurement of the FAIR Cryo Plant CRYO2:

For FAIR one central cryo plant will be installed serving a helium cooling capacity for SIS100, Super-FRS, CBM and HADES. In the first step a 19 kW @ 4 K equivalent cryo plant will be installed, including a campus wide 1.6 km long distribution system. Two industrial studies concerning the cryo plant layout were performed in 2014 and afterwards the specification was continuously adapted to future user requirements. The procurement phase is currently ongoing: After specification was approved, the budget was released and the official announcement has taken place in October 2017. According to the present time schedule the contract with the manufacturer will be signed in September 2018 and the plant installation will take place in the second half of 2021 followed by the commissioning performed until the end of 2022.

Cryogenic Infrastructure for the GLAD Magnet:

For the testing of the GSI GLAD magnet, which will be later a central component of the high energy branch of the SuperFRS, the cryogenic department has refurbished an existing cryo plant. The refurbishment comprises a complete check of the hardware, the replacement of a large number of actors and sensors, a complete new electronic cabinet and state of the art control software using the CERN industrial control software environment UNICOS in combination with Siemens WinnCC OA. The GLAD magnet was cooled down for the first time in 2017.

Control Systems (CO)

The activities of the accelerator Controls Department is fully focused on the development and implementation of the accelerator control system for FAIR.

During the past months significant progress has been made in all control system subprojects. The design of the standard equipment controllers (SCU) for FAIR power converters and many other systems, of which more than 1200 units will be needed, has been successfully completed and production and assembly of the first batch (100 units) has been completed. Several components of the newly developed White Rabbit protocol-based high-precision time and event distribution system, backbone of real-time control in the control system for the full facility, has been further developed and is already installed and under production test for the CRYRING machine.

Electronic timing receiver boards (FTRN) in several form factors (PCe, VME, PMC, uTCA), both GSI in-house developments as well as Slovenian in-kind contribution projects are under development. Schematics design and board layout has been checked and prototypes have been produced or are presently under evaluation. Significant progress has also been made in development of the fundamental underlying control system software frameworks for accelerator equipment control (FESA), communication middleware, databases, physics modelling of the machines and beam lines (LSA) as well on user interfaces graphical control room applications. Development on the accelerator measurement and data archive system has started; an early prototype version is presently being evaluated in the controls lab to confirm the technologies and products. On the industrial controls side, vacuum control with the industrial control SCADA-based UNICOS framework has been developed, installed, commissioned and is presently under testing as a collaboration project of GSI and a Slovenian in-kind provider at the CRYRING. The vacuum bake-out control of all sections of the CRYRING has been already successfully implemented and tested, shortcomings and problems have already being identified and are presently being addressed. In respect of cryogenic controls, several cryogenic sensors and actuators have been tested as a sound base for the cryogenic controls system design. Technical and functional specification documents for the control system of the upcoming tendering of the FAIR central cryo-plant have been worked out and are formally approved.

Following the agreed project strategy of the control system subproject, the full control system architecture was implemented at the CRYRING machine, being used as test-bench for FAIR. During the last months numerous tests have been performed in order to identify bugs and limits and apply. Finally the control system was already used for commissioning the CRYRING local injector and ring with beam. Presently a new release of the control system stack is being prepared for beam operation in August/September. In parallel, the control system team is fully engaged in providing the FAIR control system already for the upcoming beam time of the existing GSI machines in 2018 and 2019. These two applications to existing machines will greatly reduce the time and risk during commissioning of the FAIR machines

Transport and Installation

Numerous workshops on the topic of accelerator installation have been carried out since 2016, resulting in the creation of dedicated additional work packages and corresponding detailed installation plans.

An overall concept for the intermediate storage of FAIR components is currently in progress.

Measures have been taken to use existing Campus Facilities according to increasing requests for adequate component testing and storage. The overall need for intermediate storage leads to leasing of external storehouse areas. Presently the storage of HESR components delivered by Forschungszentrum Jülich (FZJ) is ongoing (see Figure 21 and Figure 22).

Figure 21: Unloading of one of the HESR dipole magnets

Engineering /Mechanical Integration

For visualization of beam lines, buildings and technical building services and for facilitation of coordination tasks and test processes in a web-based tool, the Kisters 3D viewer, was implemented. This tool allows work package leaders, subproject leaders and management to receive a general overview. Independently of CAD tools the configuration of the beam lines will be shown together with their position in the buildings. This view can be used on any web-connected unit like computers or mobiles independently of any license structure. The content will be updated regularly once in a month by the person in charge of DMU group.

Figure 22: Remote positioning of an HESR dipole magnet

Figure 23 shows the screenshot of the Kisters 3D viewer with the detail of the HEBT beam lines and buildings.

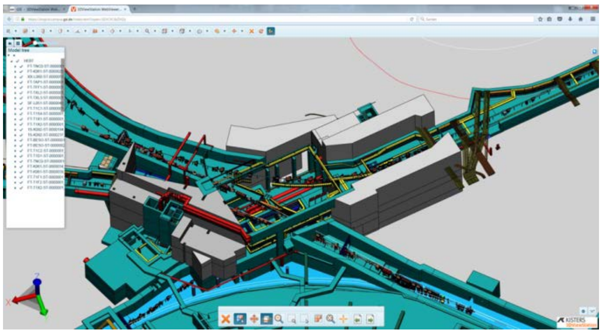

Figure 23: Screen shot of Kisters 3D viewer with HEBT

FAIR Site & Buildings

The approval for the tendering and awarding of civil works for the construction area North by the BMBF is given mid-September 2016. The reorganization of the FSB department was completed in 2017. The development of a staffing plan of FSB department is also finalized.

The civil works execution plan for the FAIR project is divided into construction area North and construction area South. The contractual schedules with the civil design companies will be adapted accordingly. Detailed scheduling of civil work packages is currently progressing in cooperation with the civil designers.

An overall time schedule including defined periods for installation of machine components was developed as part of the integrated project master time schedule.

The ZBAU reapplication, which is required by German law for building measures financed by the federal government, was submitted to the Landesbetrieb Bau und Immobilien Hessen, LBIH, on time in December 2016.

The tenders for groundwater lowering, trench sheeting and excavation in the construction area North was contracted on schedule in Mai 2017. Official ground breaking ceremony has been performed on July 4th, 2017. Site works have been started in July 2017 and are progressing as planned.

The overall project civil construction permission is issued since 2014 for the entire facility. Some construction permissions for the buildings have to be revised as part of the design process (e.g. for the north and south electrical substations). The revised applications are scheduled in line with the civil construction schedule.

FAIR Experimental Areas

Major developments for the experimental areas of CBM, APPA, NUSTAR & PANDA are described in the following chapters.

APPA

Work on design and construction of the experiment components proceeds as planned. Special efforts have been made to complete the installation and continue the commissioning of the CRYRING. In May 2017, a new test with beam has been performed, which served as a test of the FAIR control system. With this new FAIR-like control system, the operation status as of 2016 could be re-achieved. Also tests of the beam diagnosis elements (PBMs) and the first training for the operators' team to get used to the new control system were done. For these activities, we acknowledge the strong support from the on-site specialist as well as from our collaboration members from the Jagiellonian University, in Krakow, Poland.

With high enthusiasm, the completion of components which will be used in the FAIR Phase-0 for experiments was pushed ahead. The APPA collaborations submitted over 70 experiment proposals for the FAIR Phase-0 program, and currently prepare the new equipment needed for carrying them out.

In July 2017, the Expert Committee ECE recommended two TDRs for key components of the APPA plasma physics to be accepted. A third one is still in the evaluation process and three new ones are in preparation.

The Plasma workshop organized in July at GSI concluded the reorganization process and program update of the HEDgeHOB/WDM collaboration. The new collaboration, HED@FAIR (High Energy Density physics at FAIR) strengthened the scientific goals of the plasma physics program at FAIR and gained new collaboration members interested in contributing to the realization of the experiments.

CBM

CBM experiment: The CBM magnet has been contracted to BINP, the review of the planning status was completed in April 2017; the magnet is currently in the conceptual design phase. The silicon tracker (STS), RICH, time-of-flight (TOF), and muon (MUCH) detector systems have approved TDRs, are in the engineering design phase, and full-sized pre-series chambers are verified in test beam campaigns. The STS, as most complex detector project, will structure the production readiness reviews in three parts (sensor, electronics, integration) planned for 2017 and 2018. A co-operation has been established with JINR, which builds 4 silicon tracker planes using the same technology as CBM to augment the BM@N tracking system, the fixed target experiment at the Nuclotron in Dubna. The photon detector of the Ring Imaging Cherenkov Detector, RICH, is in an advanced stage, all of the photo multipliers are tested.

The RICH readout is a joint CBM, HADES, and PANDA development. The RICH photon detector component has a modular design and is planned to be used in the context of the HADES experiment at SIS-18 starting 2018. The production readiness review for the first batch of Time-of-Flight ToF chambers was completed in March 2017, the production has started. The Projectile Spectator Detector, PSD, also has an approved TDR; all modules have been produced and will be tested at CERN and JINR. The STS, RICH, TOF, and PSD activities at BM@N/JINR, STAR/RHIC and HADES/SIS-18 constitute the CBM FAIR Phase-0 activities which will produce early operational experience for these detector systems and generate valuable physics data. The feasibility of the whole data-acquisition chain with high rates is proposed to be demonstrated using mini-CBM within Phase-0.

In total 7 out of 12 planned TDRs are approved, they describe in terms of financial volume about 80% of the components which require a TDR and are mandatory for the day-1 setup. One of the remaining TDRs was submitted in 2017 and the last ones in 2018. The final TDR describing the Online/Offline Software including the online event selection will be prepared in close coordination with the FAIR Computing TDR.

HADES experiment: HADES is a running experiment which will be moved from its current place in the SIS-18 experimental hall to the CBM cave. The work structure is therefore very different from the one of the CBM experiment and consists of the construction of an ECAL, a major upgrade of the RICH, the addition of tracking and time-of-flight detectors covering the very forward hemisphere, and several other upgrades. The HADES ECAL mainframe was delivered and installed in the current HADES cave by end of August 2017. It is largely funded by Polish contributions. The RICH upgrade is done in collaboration with CBM, using identical photon detector technology and actually sharing high cost components. Both ECAL and RICH will be ready in mid-2018 in time for the FAIR Phase-0 program at SIS-18. The forward tracking stations are based on PANDA straw technology and the geometry of the PANDA forward tracker.

NUSTAR

For all experimental set-ups of the NUSTAR pillar, the list of components and associated Work Breakdown Structure code (PSP Code) was refined and re-confirmed. An intense activity was devoted to the improvement of the time scheduling of the planned NUSTAR experiments, which was matched to the Integrated Master Schedule of the FAIR project. For each experiment, the milestone defining the completeness of each component necessary for the installation of the experimental set-up was mirrored in an overview plan. This allowed also the creation of an installation plan. The time range available for installation is established in the plan of the Civil Construction.

Two time windows define the time range available for the assembly of components. The allocated time slot for the installation of NUSTAR experiments is in some cases too early with respect to the foreseen beam availability. The beam availability is scheduled in only one plan (Commissioning plan) for the whole FAIR project. For this reason, it is foreseen to reschedule the experiment installation starting backwards from the Commissioning plan. This would be advantageous for some of the experimental groups which could profit from experimental activities at the upgraded GSI facility and other laboratories.

Work has continued on the detailed technical specifications for several In-Kind and Collaboration Contracts. Three previously submitted TDRs have been accepted by ECE.

Work on NUSTAR detection systems, electronics, data acquisition is proceeding according to the internal planning. Focus is on readiness for FAIR Phase-0 experiments from 2018 onwards. In total 39 Phase-0 proposals have been submitted to the GSI PAC. The CDR for the LEB magnets has been reworked and has very recently been accepted.

PANDA

Electromagnetic Calorimeter (EMC): The first-of-series of 16 modules of the Target Spectrometer Barrel EMC is under construction at University of Gießen (D) in collaboration with IHEP Protvino (RU). All sub-modules have been assembled with crystals and APDs. But the final assembly of the module planned for summer 2017 is further postponed due to the much delayed delivery of the PCBs needed for the mounting of readout chips, reducing the margin on the schedule by half a year. The delivery of the high-purity PWO base material funded by Russia was completed in May 2017. The samples showed very good quality and are stored for further processing. The crystal producer CRYTUR in Czech Republic has by now produced 75 crystals of a pilot series, which show very good quality. The mass production should resume as soon as possible preventing delays. The Forward Endcap EMC is currently under construction in Bonn and Bochum and will be fully assembled at FZ Jülich until mid-2018. The module design of the Backward Endcap EMC has been revised and is complete now. A full readout chain was tested successfully with beam.

Superconducting Solenoid Magnet: The PANDA solenoid magnet was assigned to BINP Novosibirsk (RU) and a collaboration contract for the construction of the complete magnet was signed in March 2017. It is planned to perform technical follow-up of the contract with help from CERN. Work has started and a plan review was performed in summer 2017. The yoke production was subcontracted in November 2017 and the yoke FDR was started.

Barrel DIRC: The TDR of the Barrel DIRC, a German in-kind contribution to FAIR, was submitted in September 2016 and updated in May 2017 with results from a test- beam in fall 2016. The TDR has meanwhile been approved by FAIR ECE.

Luminosity Detector: The Luminosity Detector TDR was submitted in March 2017 and is currently under review by FAIR ECE.

Time-of-Flight (ToF) Detectors: The technical design of the Barrel ToF Detector is based on Silicon Photomultipliers and thin scintillator tiles. Its TDR – submitted in April 2017 - will be approved beginning of 2018 by FAIR ECE. The Forward ToF consists of more conventional large area scintillator bars read out by photomultiplier tubes. This TDR was revised and will be submitted to FAIR.

Forward Tracker: The technical design of the forward tracking detectors was completed with the missing piece of the required simulation of track pattern recognition and was reviewed internally. It is currently revised for submission to FAIR ECE.

Endcap Disc DIRC: After a first technical report in 2014 a review team had recommended a list of studies and improvements, which were completed by the beginning of 2017. A TDR for a full-size prototype was compiled on the basis of these experiences.

Infrastructure: The planning of electrical supplies for the experiment was coordinated with the electrical planning of the building to save cost in the infrastructure of the experiment.

Further service planning for cooling and routing of experiment cables and supplies is ongoing.

The technical service planning of the hall led to a revision of the architecture of rooms and dimensions requiring a re-planning of parts of the layout of the experiment infrastructure.

The FAIR Sequencer
Semi-automation in view of accelerator commissioning and operation

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Abstract

FAIR extends and supersedes GSI's existing accelerator infrastructure both in complexity as well as in number of devices that required to safely inject, accelerate, and extract particle beams to the experiments.

In order to perform the initial accelerator hardware- and beam-commissioning, quality assurance, as well as subsequent system re-validation tests in a most efficient and reliable fashion with the limited resources at hand, a high-level Java-based sequencer frame-work has been developed as a core part of the control system to aid the semi-automated testing, validation of the devices' system responses, and control of the accelerator facility (e.g. processing of SAT check-lists, generation of QA documentation. 'as-good-as-new' machine protection tests, etc.).

Introduction

For many sub-systems the number of involved devices increases ten-fold with respect to what exists in the present facility (notably power-converters, magnets, RF systems, beam instrumentation, cryo- and quench protection systems). At the same time, a much higher level of detail and more stringent testing of the system function and accelerator setup is required at FAIR to provide a safe and reliably accelerator control, necessary while operating at the highest beam intensities and energies.

Thus, the validation of the systems' function is not only required during the initial Site-Acceptance-Tests (SAT) but also as part of an 'as-good-as-new' testing policy during regular routine operation in view of validating the machine protection and ALARA (ie. As-Low-As-Reasonably-Achievable) loss minimisation targets, as well as for an early detection and identification of non-conformities and faults. The gathered information can be used to schedule planned preventative maintenance during routine day-to-day operation before these non-conformities become beam-inhibiting faults.

Architecture and Design

The FAIR Sequencer is based on earlier concepts, developments, and experience at CERN [1]. It is conceptually divided into three parts: the middle-tier 'sequencer' service, i.e. the software system capable of running the sequences, the 'sequences' themselves, and a graphical user interface that provides a more ergonomic and user-friendly interaction with these test procedures.

Each sequence consists of a subset of tasks that contain the individual testing steps (ie. SAT checklist items) as described, for example, by the individual device SAT criteria, commissioning or test procedures outlined in [2].

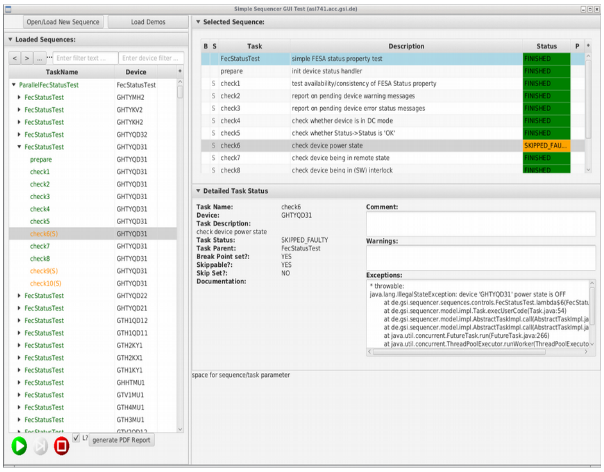
Sequences are typically defined per device, can be further nested, executed in parallel for a group of devices with the possibility to 'start', 'stop', 'pause', 'step', or 'repeat' individual tasks as required.

At the same time, the execution result of each task ('pass', 'failure', 'warning', 'skipped', etc.) is documented alongside the applicable detailed testing meta information in the FAIR Archiving System out of which an automatic PDF-based test report can be generated.

While keeping the same user-level functionality, it was decided, to re-implement the Sequencer core due to the obsolescence of some of the used software library components, unavailability of the required controls infrastructure services at GSI, and also to deploy more modern Java development concepts that since became available [3].

The Sequencer interacts with all FAIR sub-systems, controls interfaces and databases, and provides a generic abstraction interface that moves large parts of the complexity of interacting with the accelerator control system towards the frame-work itself rather than the user-level testing code that can be kept simple, short and functional.

The Sequencer is being tested and already used during the early Dry-Runs in 2017, and equipment specialists, operation and others are encouraged to consider using it if semi-automated testing and/or other procedures interacting with the FAIR control system are required that are not covered by the other available tools.



TaskName	Device
ParallelFecStatusTest	FecStatusTest
FecStatusTest	GHTYMH2
FecStatusTest	GHTYKV2
FecStatusTest	GHTYKH2
FecStatusTest	GHTYQD32
FecStatusTest	GHTYQD31
prepare	GHTYQD31
check1	GHTYQD31
check2	GHTYQD31
check3	GHTYQD31
check4	GHTYQD31
check5	GHTYQD31
check6(S)	GHTYQD31
check7	GHTYQD31
check8	GHTYQD31
check9(S)	GHTYQD31
check10(S)	GHTYQD31
FecStatusTest	GHTYQD22
FecStatusTest	GHTYQD21
FecStatusTest	GTH1QD12
FecStatusTest	GTH1QD11
FecStatusTest	GTH2KY1
FecStatusTest	GTH2KX1
FecStatusTest	GTH1KY1
FecStatusTest	GHHTMU1
FecStatusTest	GTV1MU1
FecStatusTest	GTH4MU1
FecStatusTest	GTH3MU1

B	S	Task	Description	Status	P
		FecStatusTest	simple FESA status property test	FINISHED	
		prepare	init device status handler	FINISHED	
	S	check1	test availability/consistency of FESA Status property	FINISHED	
	S	check2	report on pending device warning messages	FINISHED	
	S	check3	report on pending device error status messages	FINISHED	
	S	check4	check whether device is in DC mode	FINISHED	
	S	check5	check whether Status->Status is 'OK'	FINISHED	
	S	check6	check device power state	SKIPPED_FAU...	
	S	check7	check device being in remote state	FINISHED	
	S	check8	check device being in (SW) interlock	FINISHED	

Task Name: check6
Device: GHTYQD31
Task Description:
check device power state
Task Status: SKIPPED_FAULTY
Task Parent: FecStatusTest
Break Point set?: YES
Skippable?: YES
Skip Set?: NO
Documentation:

Comment:

Warnings:

Exceptions:

```
* throwable:
java.lang.IllegalStateException: device 'GHTYQD31' power state is OFF
        at de.gsi.sequencer.sequences.controls.FecStatusTest.lambda$6(FecStatu
        at de.gsi.sequencer.model.impl.Task.execUserCode(Task.java:54)
        at de.gsi.sequencer.model.impl.AbstractTaskImpl.call(AbstractTaskImpl.ja
        at de.gsi.sequencer.model.impl.AbstractTaskImpl.call(AbstractTaskImpl.ja
        at java.util.concurrent.FutureTask.run(FutureTask.java:266)
        at java.util.concurrent.ThreadPoolExecutor.runWorker(ThreadPoolExecuto
```

space for sequence/task parameter

☑ L?

Figure 1: Sequencer GUI impression.

Acknowledgements

The valuable contributions, advice and recommendations that guided the re-implementation of the new FAIR Sequencer from our CERN colleagues V. Baggiolini and R. Gorbonosov are greatly acknowledged.

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Accelerator infrastructure: UNILAC / SIS18 / ESR / FRS / CRYRING / pbar-Separator / SIS100 / p-Linac / CR / Super-FRS / HEBT / HEST / CERN-LHC
PSP codes: 2.14.17, 2.14.10.1
Strategic co-operation with: CERN

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Development of optical beam profile monitors

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Optical beam diagnostics is planned for intense ion beams which would destroy conventional beam diagnostic devices. The concept is to measure beam-induced light emission from a gas target, space-resolved, and to deduce beam profiles from these data. A more detailed description of the concept is given in Ref. [1] and references therein. More results are also presented in the annual report of the plasma physics group at GSI for the year 2017.

An important issue is to study, if the concept can be used at the low pressure conditions within the beam-lines. Model experiments at the Munich Tandem accelerator using a DC-beam of 87 MeV ^{32}S ions (2.72 MeV/u) exciting various gases over a wide pressure range were performed in 2017. Both spectroscopic studies and preliminary profile measurements have been performed. The spectroscopic studies are used to identify appropriate optical transitions. Based on the results transmission filters were used to take pictures of the beam in various wavelength regions. Differential pumping was installed at the beam entrance for pressures below 1mbar. A f=30cm vacuum monochromator (McPherson 218) was used to record beam induced spectra of Ne, Ar, Kr, Xe, and N$_2$. An example is given in Fig. 1. It shows mainly lines (and in the case of nitrogen molecular bands) of neutral and singly ionized target species.

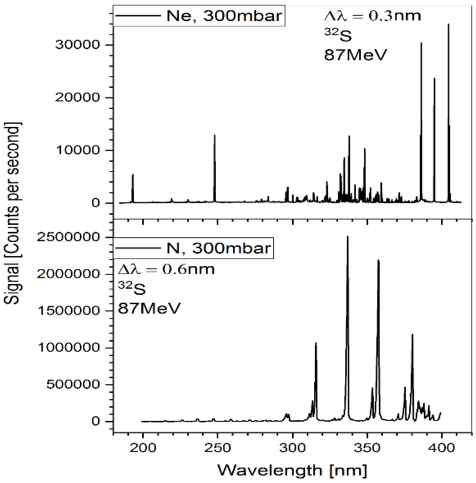

Figure 1: Overview spectra for neon and nitrogen recorded at an elevated target gas pressure of 300mbar.

Beam profile measurements were performed with a sensitive, cooled CCD camera (ATIK 383L+) combined with a f=60mm broadband (315 to 1100nm) apochromatic lens. Appropriate bandpass filters were used to select various emission regions for the emission from neutral and ionized species. The ion beam was sent through a 1mm diameter aperture into the target gas. A general result is that secondary electrons can strongly excite neutral species, which leads to pronounced wings in the beam profiles for target densities around 1mbar (see Ref. [1]).

At low pressure, the range of the secondary electrons is so large that they do not lead to the formation of visible "wings" and rather hit the walls of the cell (Fig. 2). In Fig. 3 it is shown that the beam profile is well represented for both low pressure and high pressure. At high pressure it is due to the fact that the range of the secondary electrons is short compared to the diameter of the ion beam.

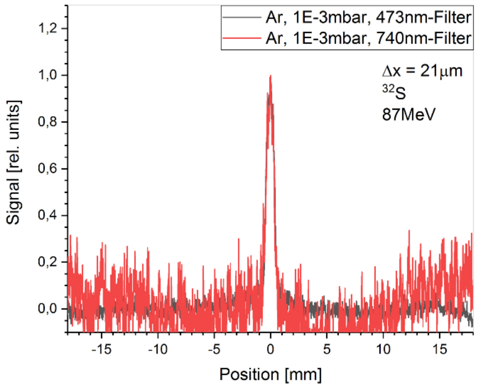

Figure 2: Example of a beam profile measurement at relatively low pressure. The "wings" which appear for measurements using neutral lines (red) are not pronounced under these conditions.

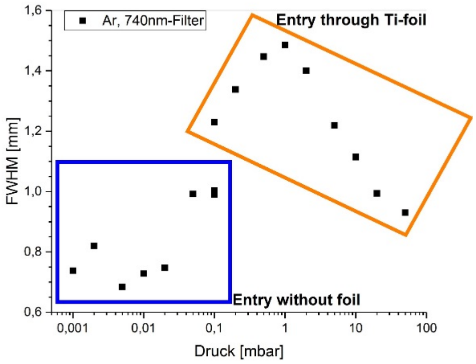

Figure 3: Beam diameters (FWHM) measured for a wide range of target gas pressures using the emission from an atomic line.

Acknowledgements

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Prototype development of a Multipurpose Hardware Unit for deterministic bunch-to-bucket transfers between synchrotrons

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Introduction

In the context of the FAIR project, a new concept for a fully-deterministic bunch-to-bucket transfer (B2B) between sending and receiving synchrotrons (e.g. SIS18 and SIS100) is currently under development. Developing dedicated electronic solutions for each technological task represents an invest in terms of costs and time. Hence, it is intended to develop a new multipurpose hardware unit (MHU) to minimize this invest. The MHU has to fit in a large spectrum of current and future applications with sufficient performance. As a result, it has to be at least compatible with all kinds of signal formats currently being used in the low-level radio frequency (LLRF) environment at GSI.

MHU Application Areas

The MHU is based on a programmable unit which covers the actual application concerning the most general functions on parallel input signal conversion and processing. An FPGA-based solution is planned. Several currently defined functional blocks, e.g. Phase Advance Prediction or Phase Shift Module, are foreseen and based on the requirements document [1].

MHU Prototype Realization

A wide range of the required hardware components can be based on commercial-off-the-shelf (COTS) devices, but for special interface requirements of GSI there is a need for the development of new modular interface modules. The Achilles Arria 10 System on Module (SoM) constitutes the processing unit of the MHU which enables high modularity and interchangeability in case of future designs. A carrier board is connected to the SoM and a customized backplane, which enables the interfacing of modular extension boards and GSI inherent boards like the DIOB (Digital Input Output Board) [2] and MMD (Maintenance Module for External Devices) [3] module connected to the SCU backplane [4]. Regarding current Use Cases described in [5] several customized interface boards shown in figure 1 have to be developed. They are depicted as an optical interface board for ODL (Optical Direct Link) and OTR (Optical Token Ring), a PC interface board providing debugging and access points via Ethernet, or UART and a peripheral interface Board providing BuTiS clock reference, analog TTL based IOs and status LEDs. As depicted in figure 1, one of the carrier board FMC ports is connected to the customized backplane, the other one is foreseen as modular FMC interface for the extension with standardized COTS FMC daughter boards; e.g. ADC/DAC daughter board.

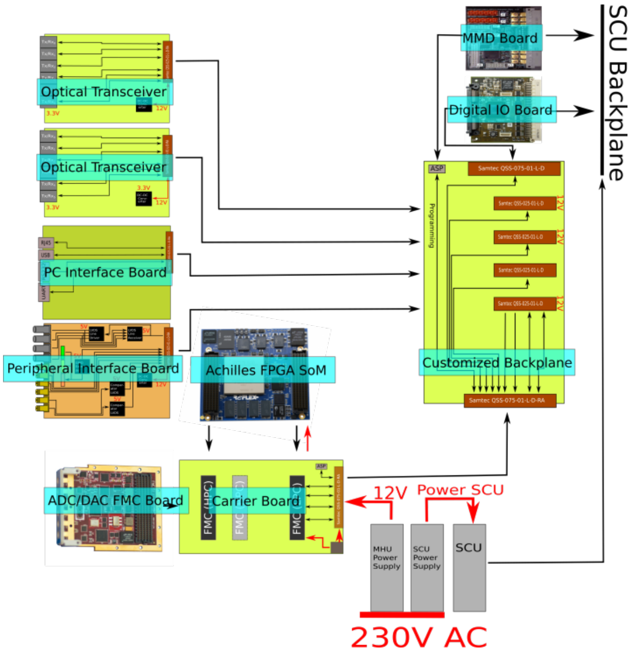

Figure 1: MHU Design based on Achilles SoM with carrier board, customized extension boards, customized backplane and GSI system interfaces.

Outlook

The first prototype designs have been started with the availability of the SoM, the ADC/DAC FMC daughter board, the DIOB, MMD, SCU-Backplane and the development of the ODL interface board, that was successfully tested. Further prototype development will be necessary to implement the entire MHU, which concerns the development of the carrier board, the customized backplane, the peripheral interface board and the PC interface board.

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Characterization of the Cryogenic Current Comparator for FAIR*

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The design of the Cryogenic Current Comparator (CCC) has been adapted to offer an optimal performance when it is used for nA beam current measurements in the FAIR facilities. Following this preparation, in 2017 the FAIR prototype, also called CCC-eXtended-Dimension (CCC-XD), was manufactured from niobium and assembled into an optimized superconducting shielding geometry, surrounding an enhanced flux-concentrating core made from NANOPERM© material [1]. Extended tests on the new system have been performed, which showed that the transition to the large FAIR beamline diameter was a success [1, 2].

Performance of the CCC-XD

The primary challenge of the new design for the CCC at FAIR was to increase the radius to accommodate for the beamline diameter of 150 mm while maintaining the performance of the predecessors. After its assembly the CCC-XD (shown in fig. 1) was characterized in a controlled environment inside a wide-neck cryostat. A magnetically shielded room is available at Friedrich-Schiller-University Jena to exclude external magnetic influences. With this setup a white noise level of <3 pA/Sqrt(Hz) [2] can be achieved which is regarded as an improvement compared to earlier values of 11 pA/Sqrt(Hz), measured in the accelerator environment [3].

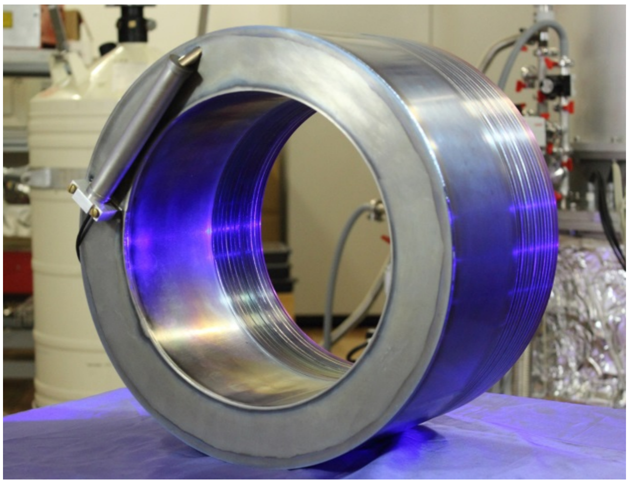

Figure 1: The FAIR prototype CCC-XD. The cartridge holding the SQUID electronics is mounted to the front. In the back the welding of the meander structure is visible.

In order to determine the current resolution, a calibration wire passes through the CCC and allows to apply a test current to simulate an ion beam. Figure 2 shows the response of the CCC-XD (red) to a 1.65 nA current pulse (green). In the laboratory, these intensities can easily be detected without any additional data processing.

The sensitivity of the SQUID can be tuned by adjusting the coupling of the pick-up coil around the flux concentrator to the sensing coil of the SQUID. Here the signal gain and the frequency bandwidth can be balanced depending on the requirements. The present configuration achieves a slew rate of 0.16 µA/µs using the full bandwidth of 200 kHz [2]. For some applications in which time resolution is less important (e.g. in storage rings) a 10 kHz low-pass filter is used to suppress high frequency noise which limits the slew rate at the same time (fig. 2).

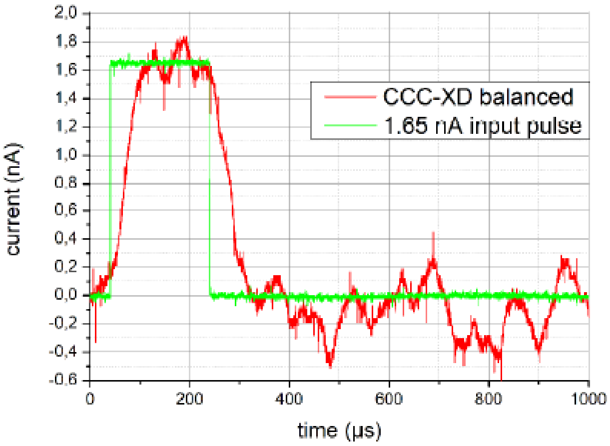

Figure 2: Response of the CCC-XD (red) to a 1.65 nA (200 µs) current pulse (green), measured with a 10 kHz low pass filter [4].

Specification of the CCC cryostat for FAIR

The specification for the FAIR beamline cryostat was finalized and the construction is finished until the end of 2018. The mechanical design has been supported by ANSYS calculations in the frame of the collaboration with TU Darmstadt. Throughout the measurement campaigns it has become apparent that mechanical oscillations of the cryostat are a source of noise for the sensitive SQUID system. Thus the cryostat is designed in a way to avoid mechanical resonances and to provide sufficient damping of external vibrations. Further tests on noise sources and alternative shielding geometries are ongoing [1]. With the CCC-XD tested and ready to measure currents, the focus is currently on the preparation for the setup in CRYRING.

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Bunch Shape Measurements at the GSI cw-Linac prototype

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The existing GSI accelerator will become the injector for FAIR. To preserve and enhance the current experimental program at UNILAC, a dedicated new Linac is under development, which shall run in parallel to the FAIR injector, providing cw-beams of ions at energies from 3.5 – 7.3 MeV/u.

For this cw-Linac a superconducting prototype cavity (demonstrator) has been developed and was first operated with beam in summer 2017 [1]. The resonator is a Crossbar H-structure (CH) of 0.7 m length, with a resonant frequency of 216.8 MHz. It has been installed behind the GSI High Charge State Injector (HLI), which provided 108 MHz bunches of 1.4 MeV/u Ar6+/9+/11+ ions at a duty cycle of 25%. Due to the frequency jump and small longitudinal acceptance of the CH, proper matching of the HLI beam to the prototype was required. The bunch properties of the injected beam as well as the effect of different phase- and amplitude-settings of the cavity were measured in detail with a bunch shape monitor (BSM) fabricated at INR, Moscow, while the mean energy was analyzed by time of flight method. Figure 1 shows the experimental setup at the cw-Linac test stand.

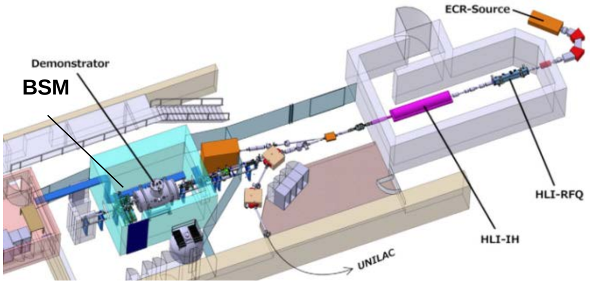

Figure 1: Setup for cw-Linac test measurements at the HLI beamline.

Figure 2 shows the basic principle of the BSM. The device was developed at by A. Feschenko at the INR Moscow and is therefore often referred to as “Feschenko Monitor” [2]. The beam is longitudinally scanned with a tungsten wire, placed at the beam axis on negative potential (–10 kV). By interaction of the ions with the metal surface secondary electrons are generated, which are extracted towards ground potential. The electrons pass through an rf-deflector (operating at the frequency of the accelerating cavity) and are swept over a vertical slit before they get deflected by magnetic field for energy separation. The counts at the SEM detector are plotted as a function of rf-phase. In this way, the spatial information of the particle distribution inside the bunch is transformed into phase information, relative to the rf-period of the accelerator (deflector field). It is obvious that the BSM can - as a matter of principle - not be considered as non-destructive. Besides reduction of intensity, slight deviations in particle position and energy have been observed. However, with a phase accuracy of ~1°, high stability, reproducibility and good handling, the device was found to be an excellent tool for Linac commissioning.

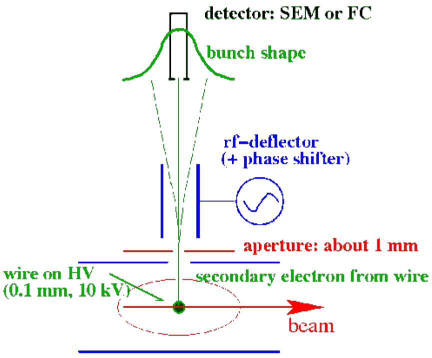

Figure 2: Principle of the BSM.

After optimization of the buncher settings for injection, the injection parameters and rf-power and phase in the demonstrator were varied to check the effect on output current, bunch structure, particle energy and transverse emittance. In this way, the characteristics and design values of the prototype could be verified in very detail. Representative for the numerous measurements, which have been carried out, figure 3 shows a scan of the bunch width as a function of the demonstrator rf-phase. The resolution of the system, basically dependent on the aperture shown in fig. 2, is better than 1°.

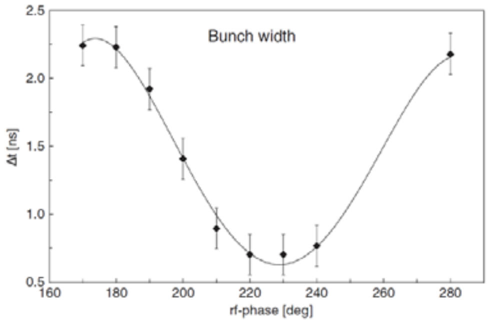

Figure 3: Phase scan of the output bunch length.

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RADHARD: a program for radiation damage to materials for FAIR

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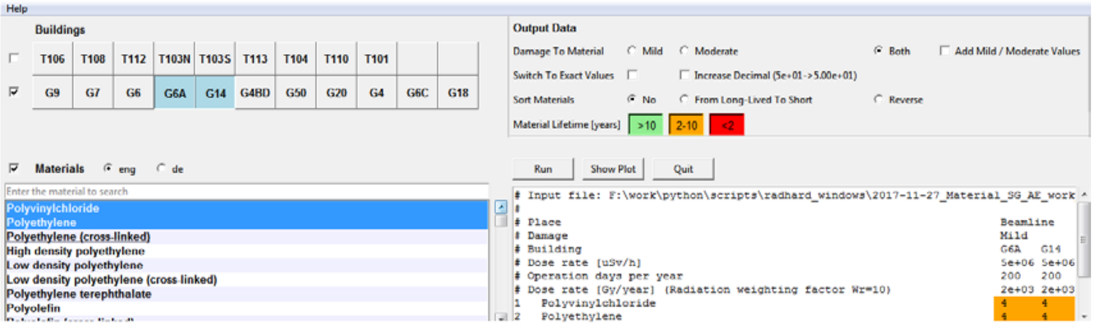
Introduction

FAIR will consists of at least 20 radiation protection areas at the accelerators and connected beam lines where a lot of different complex devices will be exposed to high neutron radiation fields in quasi-continuous operation. It is crucial to maintain a stable operation of all devices and mechanisms in in these areas. To achieve this one key aspect is to take into account the radiation hardness of materials. The radiation hardness of a material depends on its type; e.g. metals in comparison to most polymers can stay longer under irradiation until certain damage occurs. More details can be found in the work previously done at GSI [1].

Description

In order to obtain an estimate of the lifetime of materials located in high radiation field areas of FAIR the RADHARD program was created at GSI. The program uses a collection of data which has been taken mostly from CERN radiation damage test data [2].

This program is written in Python programming language [3] and a remote access to the program is available under Linux at GSI (/u/aevdokim/codes/radhard), access under Windows is still under development.



☐ T106 T108 T112 T103N T103S T113 T104 T110 T101

☑ G9 G7 G6 G6A G14 G4BD G50 G20 G4 G6C G18

☑ Materials ● eng ○ de

Polyvinylchloride
Polyethylene
Polyethylene (cross-linked)
High density polyethylene
Low density polyethylene
Low density polyethylene (cross-linked)
Polyethylene terephthalate
Polyolefin

Damage To Material ○ Mild ○ Moderate ● Both ☐ Add Mild / Moderate Values
Switch To Exact Values ☐ ☐ Increase Decimal (5e+01->5.00e+01)
Sort Materials ● No ○ From Long-Lived To Short ○ Reverse
Material Lifetime [years] 🟩 >10 🟧 2-10 🟥 <2

```
# Input file: F:\work\python\scripts\radhard_windows\2017-11-27_Material_SG_AE_work
#
# Place                                                     Beamline
# Damage                                                    Mild
# Building                                                  G6A    G14
# Dose rate [uSv/h]                                         5e+06  5e+06
# Operation days per year                                   200    200
# Dose rate [Gy/year] (Radiation weighting factor Wr=10)    2e+03  2e+03
1   Polyvinylchloride                                       4      4
2   Polyethylene                                            4      4
```

Figure 1: Example of the graphical user interface of the program. On the left side is input; on the right side are toolbar (up) and output data (down).

Purpose of the program was to have a convenient and user-friendly possibility to get a quick result on the lower limit of the expected lifetime of materials of interest for selected buildings for a broad spectrum of users at GSI and FAIR, e.g. architects, planners, scientists etc.

The program includes data on radiation damage for more than 70 materials (polymers, metals, ceramics etc.).

Features

The user interface of the program is divided into three sections: input, output, toolbar (see Fig. 1).

The Input section includes a selection of FAIR buildings and materials, the possibility of switching between English and German names for materials, and a search for materials by pattern. The Output section includes a window for displaying data.

The Toolbar section allows to fine-tune the output with the following options: sort materials by their lifetime, highlighting lifetime of selected materials and show their exact values, show result of Mild/Moderate/Both damage to materials and add the column with their values respectively.

The program allows the user to automatically create a bar plot with data on relative radiation effects for selected materials (see Fig. 2).

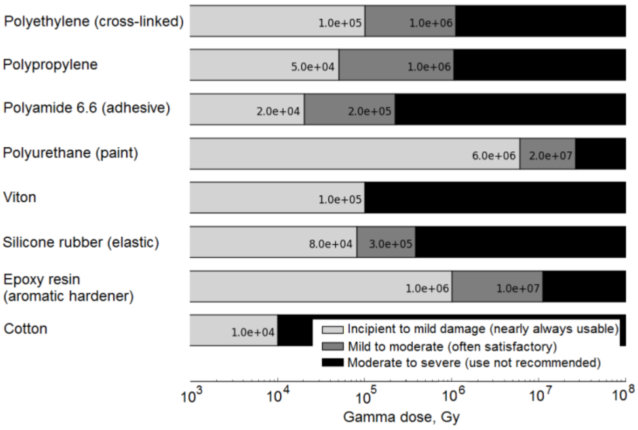


Figure 2: Plot example of general relative radiation effects for selected materials. The scale shows how much radiation in Gy each material can resist keeping its functionality.

Development

The work to improve the program continues, and in future some other features as well as new materials will be included as follows: group materials by class (thermoplastic and thermosetting polymers, natural polymers, metals and alloys, ceramics, oils etc.), add flexibility to work with input and output data. We encourage all GSI and FAIR Users to submit requests for new materials to evaluate and include into this Database.

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