High Intensity heavy-ion Accelerator Facility

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1. Overview

The High Intensity heavy-ion Accelerator Facility (HIAF) is one of the key national scientific projects initiated during the 12th Five-Year Plan. HIAF is located in Huizhou, Guangdong province with 7-year construction period and a total budget of 2.3 billion CNY. This project is organized by the Chinese Academy of Sciences (CAS) and implemented by the Institute of Modern Physics (IMP).

Figure 1.1 Conceptional design of the HIAF project

The HIAF facility is a next-generation, world-leading high-intensity heavy-ion accelerator complex. It will be used to produce radioactive nuclides extremely far away from the beta stability line by fragmentation with primary beams. It will provide low-energy heavy ion beams with the highest peak currents. The maximum energy is up to 4.25 GeV/u. It's also equipped with a leading precision nuclear mass spectrometer, which provides a great platform for nuclides identification, weakly bound nuclear structures, reaction mechanisms, and short-lived nuclei mass measurement.

The HIAF project mainly consists of accelerators, experimental terminals, auxiliary devices, and civil constructions. The accelerator complex mainly consists of a superconducting linac (iLinac), a synchrotron booster (BRing), and a storage ring (SRing). The combination of those accelerators is optimized to provide high-energy, high-intensity, and high-quality heavy ion beams, and to produce radioactive isotopes far away from the beta stability line. Six experimental terminals will be built based on HIAF beam lines for different research areas including nuclear physics, atomic physics, nuclear astrophysics, materials, and radioactive biology.

2. Project Progress

The year 2022 was the crucial period for HIAF project. Series of research and development activities have been carried out, including the production and test of equipment, the installation and commissioning of auxiliary devices, the completion of the roof sealing and indoor decoration of buildings above ground, the sealing and backfilling of the accelerator tunnels, as well as quality control in the production and construction processes. The prototypes of key technologies have been successfully developed and tested, while 85% of conventional equipment has started mass production. Installation and commissioning of auxiliary devices such as cooling water, air conditioning and power supply distribution have been carried out. Up to now, 80% of government investment and 32% of local investment in civil construction have been completed. By the end of 2023, it is planned to complete the civil construction, the accelerator tunnel and ground buildings will be ready for accelerator system installation on site, and the equipment will be installed and commissioned gradually.

(1) Key technologies

In 2022, HIAF made significant breakthroughs in key technologies and tackled several challenges and difficulties. The first set of prototypes has been successfully developed and tested, and the project has moved on to the period of mass production and test gradually.

The manufacturing and testing of the sextupole coil for a 45 GHz ECR ion source and the high-power conventional components have been completed. The first fast-cycling pulsed current power supply with full energy storage technology has been successfully developed at the maximum non-resonant current ramping rate of 52,000 A/s. The innovative energy storage power topology has addressed the least impact of inductive loads on the power grid, and further more to reduce the power distribution level, which creates a new model for green and energy-efficient operation of large-scale scientific facilities. A pioneering solution to ultra-thin wall high vacuum chamber with a Titanium alloy liner support was developed to achieve an ultra-high vacuum condition up to 1.0E-12 mbar, which have significantly improved the magnet gap utilization and reduced the cost. The first set of dipole magnet vacuum chambers has been already developed and installed for test. A high-performance large-size MA (Magnetic Alloy)-load RF system with high-gradient fast-response and high power was developed and surpassed the state-of-art technology in the most challenging low-frequency band (100 kHz). A novel superconducting magnet with Canted-Cosine-Theta (CCT) coil technology is used for the first time in radioactive isotope separator. A large bore quadrupole magnet combined with octupole and sextupole magnets has been developed and tested, and high field gradient and good field uniformity have been demonstrated.

Figure 2.1 Full-sized Nb_3Sn ECR ion source cold mass

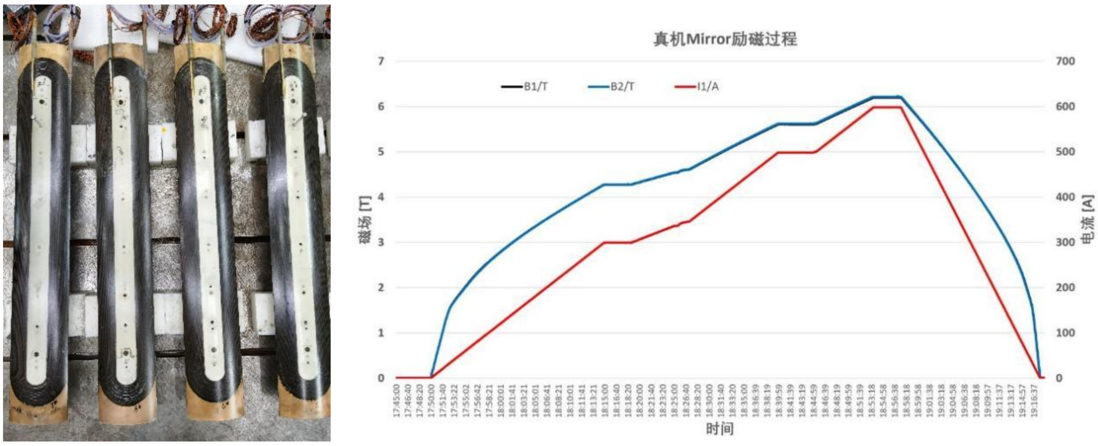

Figure 2.2 Sextupole coils (left) and its cold test result with high excitation currents

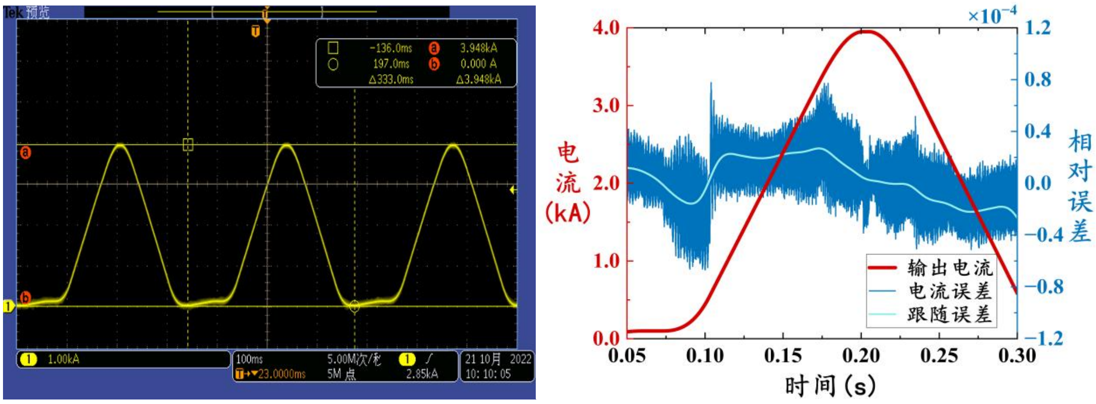

Figure 2.3 Test results of the full-energy-storage prototype with fast-cycling pulsed current power supply under actual load (3950 A/3 Hz)

Figure 2.4 The first set of the full-energy-storage and fast-cycling pulsed current power supply

Figure 2.5 The first set of the Titanium alloy lined high-vacuum chamber with ultra-thin wall

Figure 2.6 The high-performance MA-load RF system

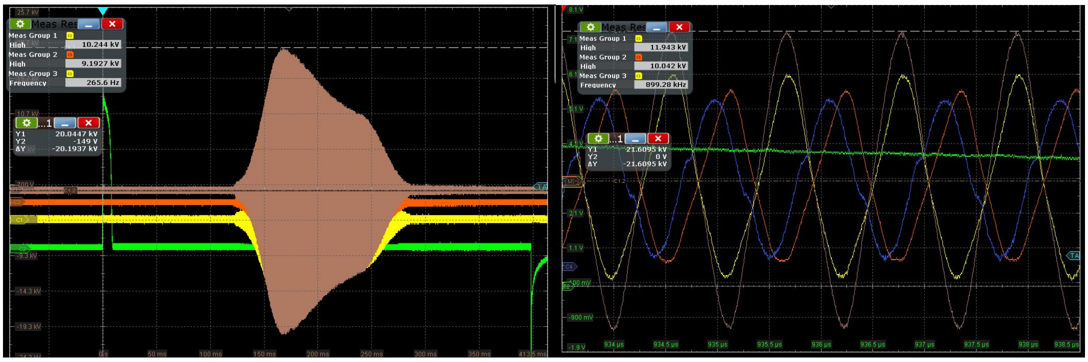

Figure 2.7 RF voltage test of the MA-load RF system

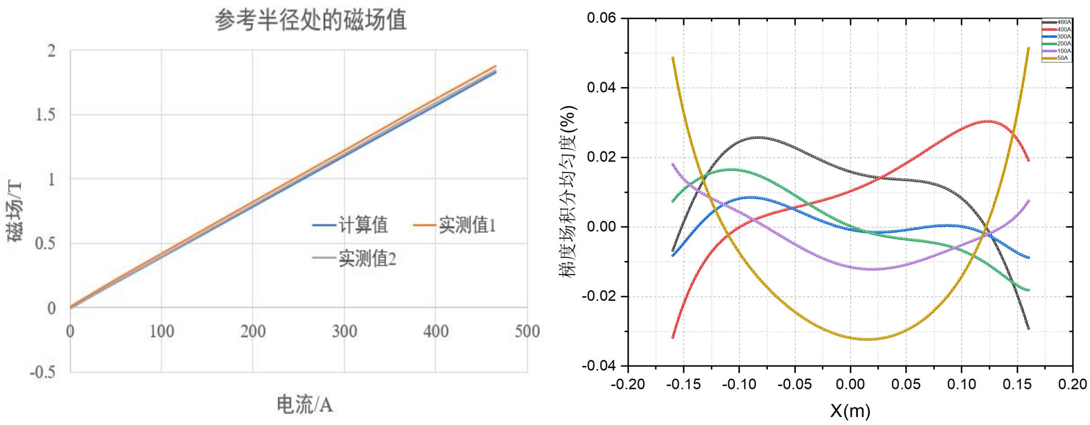

Figure 2.8 Test results of CCT coil

(2) Equipment manufacturing and testing

In 2022, based on successful results and quality control of the first set of conventional equipment, the mass production was initiated and some equipment has been tested and ready for on-site assembly.

Table 1 The status of HIAF key system mass production and test

	Mass Production Schedule					Mass Test Schedule				
	20%	40%	60%	80%	100%	20%	40%	60%	80%	100%
Beam Front end	100%					80%				
Superconducting Linac	60%					5%				
BRing	80%					20%				
HFRS	20%					5%				
SRing	60%					10%				
Beam Line Terminal	90%					5%				

At present, the mass production of equipment in the front-end system has been finished, 80% of which have been tested. For the superconducting linac, two sections of the RFQ have been completed, and the remaining are on the way. The manufacturing of two sets of cryomodules QWR007 and HWR015 was completed, including the cavities, couplers, tuners, and superconducting solenoids. For BRing, the iron cores and coils of dipole magnets have been already manufactured, and 33 sets of magnets have been integrated. Furthermore, two sets of quadrupole and sextupole magnets have also been finished. We have completed the bidding of the beam injection and extraction systems and is moving on to mass production. For HFRS, the first set of the superferric dipole magnet, DC power supply and diagnostic equipment have been finished and tested, and the other batches are ready for mass production. For SRing, the mass production of 126 magnets has begun. The vacuum equipment has been received for test. The test of the key components of the cooler system such as the cooling section coils, electron gun, and collector was completed, while other types of coils, HV system, and accelerating tubes are being processed in batch. The magnet, power supply and beam diagnostics for the beamline and experimental terminals have completed the bidding and are ready for manufacturing. The design of non-standard vacuum components has also been finished. We have completed the test of the machine protection system (MPS) and are carrying out joint tests with other systems. The first set of timing system was developed and tested, including the terminal nodes, synchronous network, and data master nodes. The development of key components such as graphite primary targets, position-sensitive detectors, energy loss detectors, time-of-flight detectors and so on for the experimental terminal systems have been also completed.

Figure 2.9 Some equipment of the front-end system

Figure 2.10 Superconducting RF cavities of iLinac

Figure 2.11 Cryomodule of iLinac

Figure 2.12 Dipole magnets of BRing

Figure 2.13 Quadrupole and sextupole magnets of BRing

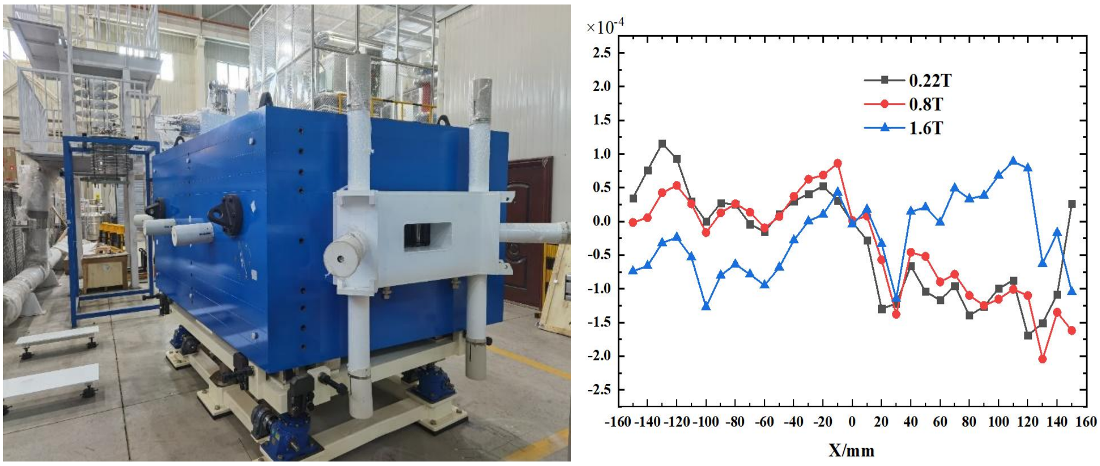

Figure 2.14 Superferric dipole magnet of HFRS and its field uniformity

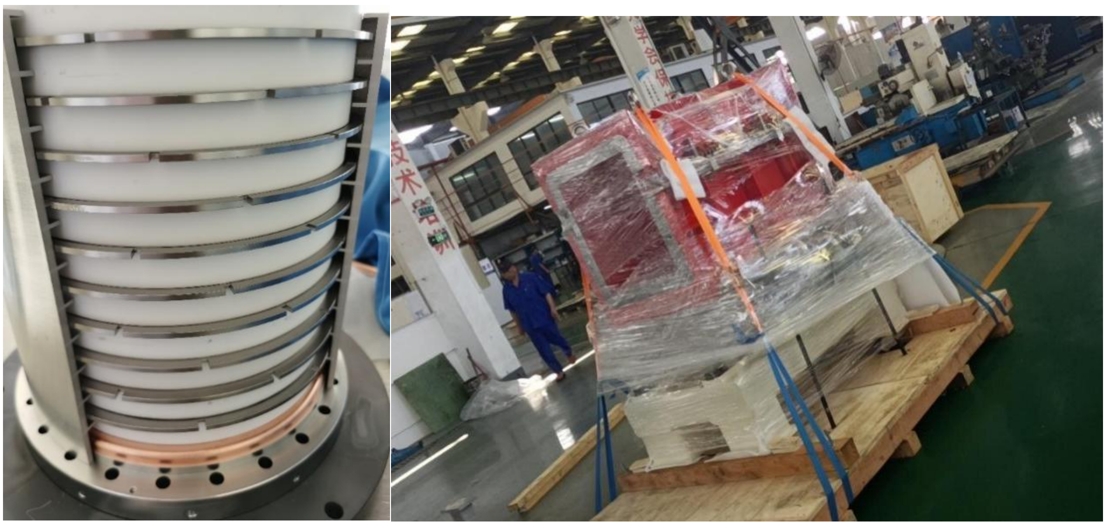

Figure 2.15 Acceleration tube and magnetic yoke of the electron cooler in SRing

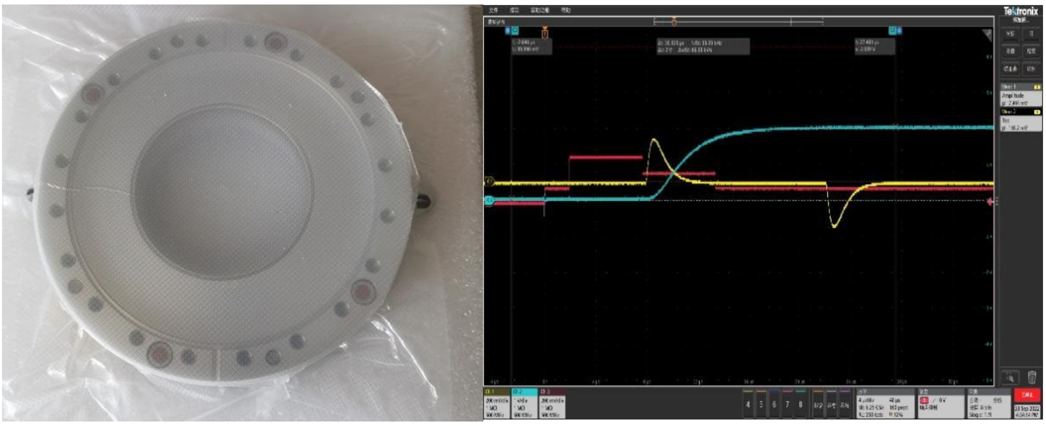

Figure 2.16 The ICT device and its test result in the beamline

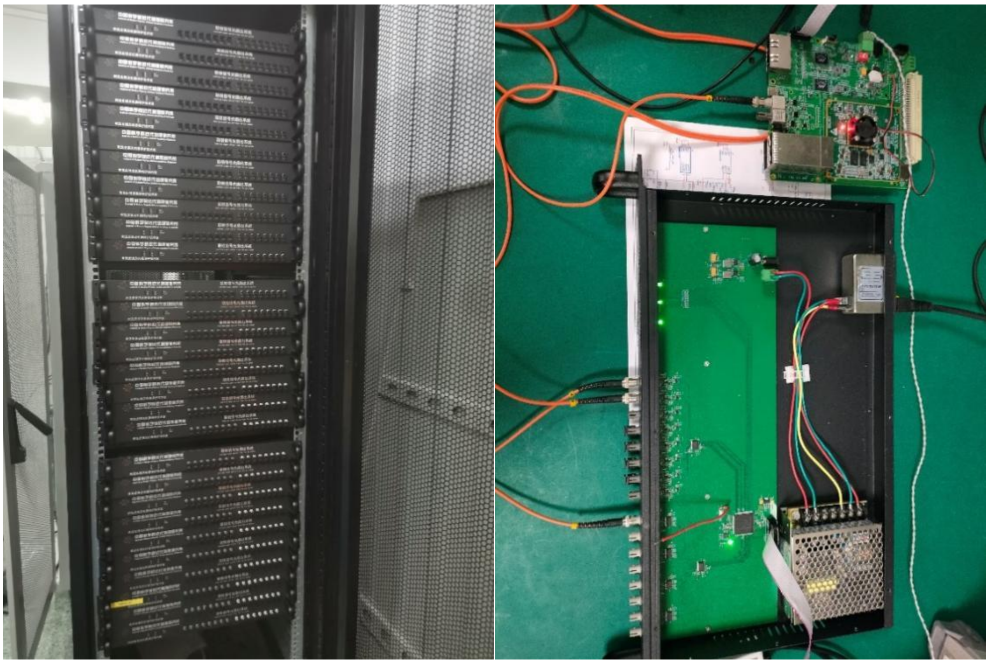

Figure 2.17   MPS equipment and joint test setup

Figure 2.18 Data master node and the synchronous network of the timing system

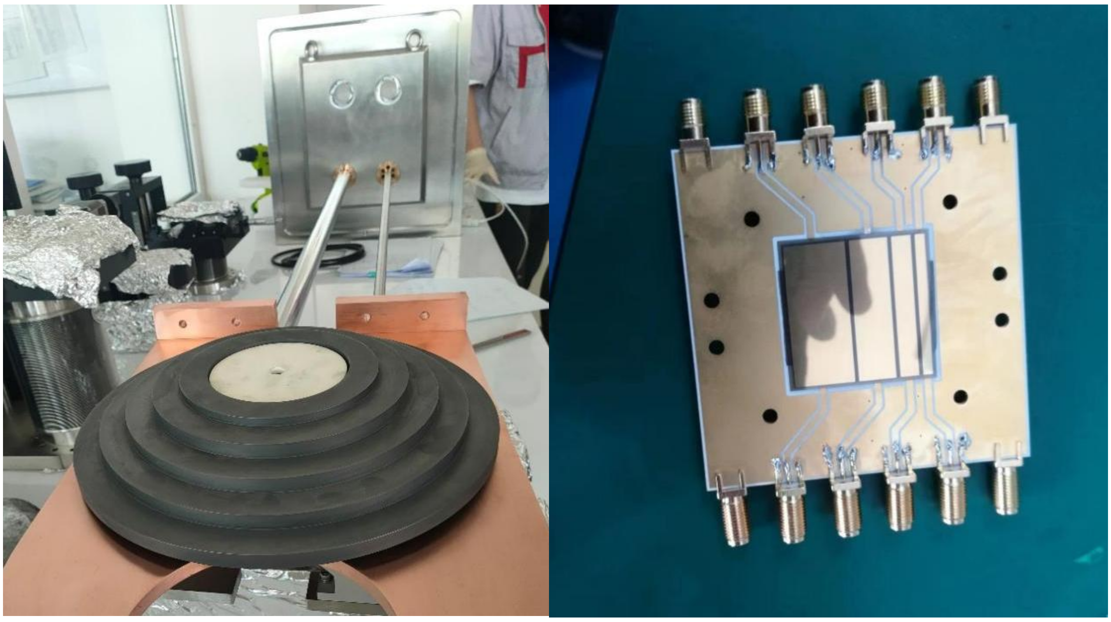

Figure 2.19 The graphite primary target and position-sensitive detector in terminal

(3) Accelerator sectional mockup

In 2022, accelerator sectional mockup was installed and tested to improve the construction quality and efficiency in the accelerator tunnel. It will verify the interface of equipment, the installation processes and the reliability of joint operation.

HIAF sectional mockups include the BRing arc section and HFRS superconducting section, which are installed at the test halls in Tianshui and Lanzhou respectively. The BRing arc section mainly contains magnets, power supplies, vacuum and diagnostic equipment. There are four dipole magnets, two quadrupole magnets, two sextupole magnets and one corrector magnet. In addition, the corresponding vacuum chambers, power supplies, a beam position monitor (BPM), a collimator, and the required vacuum pumps and chambers are also included. The HFRS superconducting section mainly consists of a superferric dipole magnet, a cryomodule combined with multipole magnets, as well as the vacuum pipe and chamber. Up to now, the BRing arc section has been installed, while the HFRS sample section was 50% completed. It is planned to complete the test and verification in 2023.

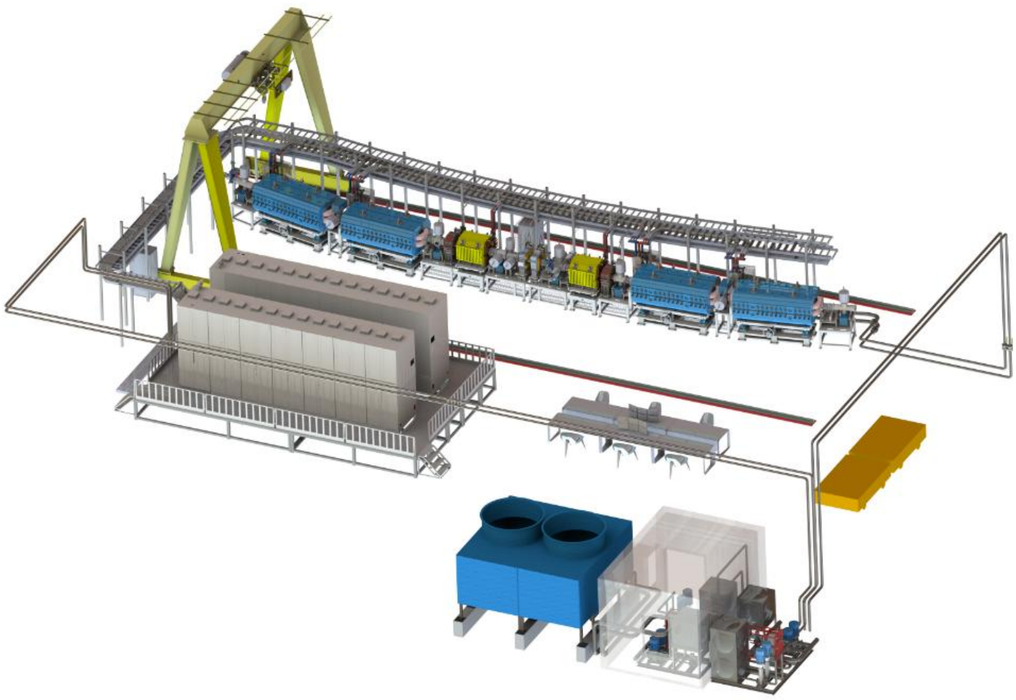

Figure 2.20 Layout of the BRing sectional mockup

Figure 2.21 Overview of BRing sectional mockup

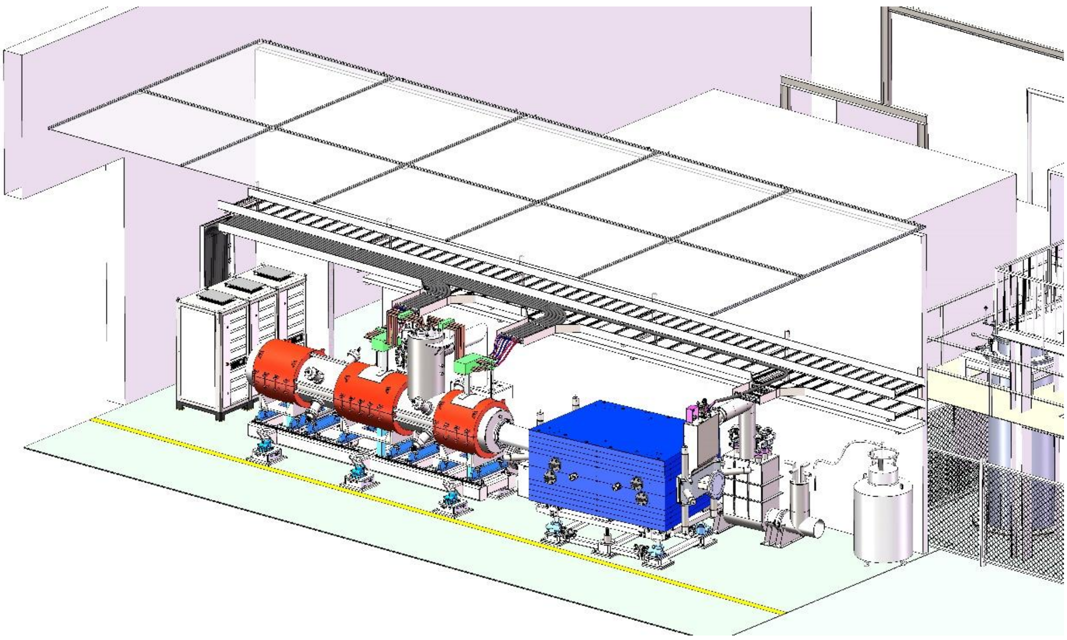

Figure 2.22 Layout of the HFRS superconducting sectional mockup

Figure 2.23 The valve box and the pipeline of HFRS sectional mockup

(4) Civil construction and utilities

Based on the accelerator design requirements, the BIM (Building Information Modeling) modeling of the utilities has been finished, including various equipment, electromechanical system and civil construction. In November, we began the installation of the cooling water and air conditioning systems. The cryogenic system and electrical equipment systems have completed the component processing and are ready for final assembly.

The main structures of BRing, HFRS, and SRing tunnels have been completed, waterproofing and backfilling of the tunnels are started. The tunnels of ion source, superconducting linac and injection line are in process smoothly. Four ground buildings, operation building, integrated station building No. 3, test hall and refrigeration center, have completed the secondary structures construction and are moving one to electromechanical installation, decoration, which are expected to be put into use gradually in March 2023.

Figure 2.24 Aerial view of the HIAF campus (photo on 2022/12/20)

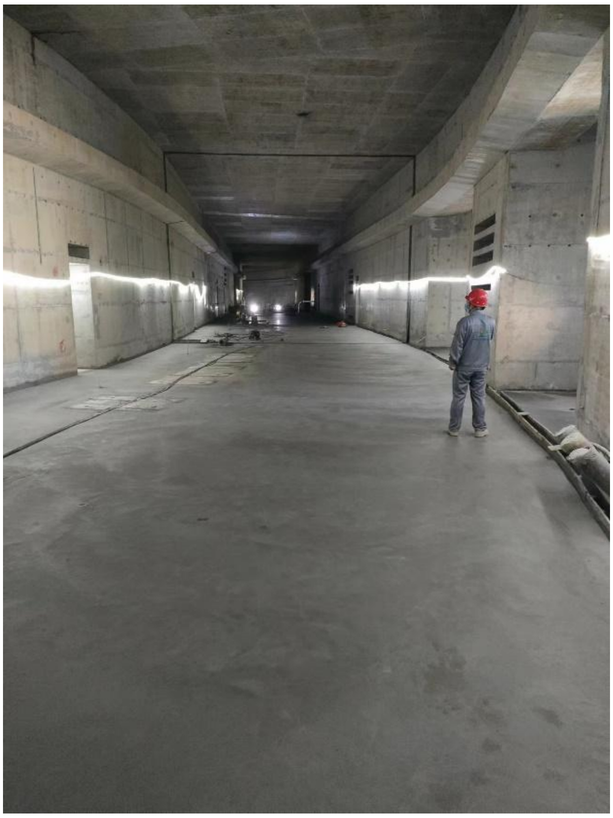

Figure 2.25 HIAF-BRing tunnel

Figure 2.26 HIAF-SRing tunnel under backfilling

Figure 2.27 Test station building No.3 ready for utility assembly

Figure 2.28 Transfer cranes in place inside the test hall

Figure 2.29 Engineers are working on the pipelines for the utilities in test hall

3. Chronicle of events

Jan.25th, the headquarter of the Huizhou research branch of IMP, and also for the HIAF and CiADS projects, was officially put into use.

Figure 3.1 Aerial view of the HIAF and CiADS headquarter

Feb.9th, WEN Jinrong, Deputy Secretary and Mayor of Huizhou Municipal Committee, visited HIAF and CiADS projects.

Figure 3.2 WEN Jinrong visited the campus of HIAF and CiADS

Mar.3rd, WANG Xiyi, Vice governor of Guangdong province and the Academician of Chinese Academy of Sciences, visited the headquarter of HIAF and CiADS.

Figure 3.3 Symposium about HIAF and CiADS projects

May.3rd, LIU Ji, Secretary of the Huizhou Municipal Party Committee and director of the Standing Committee of the Municipal People's Congress, visited the campus of HIAF and CiADS and Dongjiang Laboratory.

Figure 3.4 LIU Ji visited the campus of HIAF and CiADS