THE CONSTRUCTION PROGRESS OF BEIJING RADIOACTIVE ION-BEAM FACILITY

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Abstract

The Beijing Radioactive Ion-Beam Facility (BRIF) being constructed at CIAE consists of a 100 MeV high intensity cyclotron CYCIAE-100, an isotope separator on line (ISOL) system with a mass resolution of 20000, and a superconducting booster (SCB). The construction of the main building started on April 28, 2011 and the roof was sealed on Jan. 16, 2012. The on-site installation conditions have been ready since Sept. 27, 2012. Up to now, the fabrication of all major components for CYCIAE-100 have been completed, including the main magnet system, the RF system, ion source and injection, main vacuum, etc. For the ISOL system, the equipment fabrication has been completed and magnetic mapping and shimming is being performed on the large-scale analysis magnet. The fabrication of the major components for the SCB system has been accomplished as well, and the work on copper-niobium sputtering is under way. At present, the installation and assembly is in full swing and the beam commissioning is predicted to be finished in mid 2013. The first beams of CYCIAE-100 are expected by the end of 2013.

INTRODUCTION

The Beijing Radioactive Ion-Beam Facility (BRIF) will be mainly used for productions of intense proton and radioactive ion beam (RIB) in fundamental and applied research, e.g., neutron physics, nuclear structure, material and life sciences and medical isotope production. For this project, a 100 MeV H- cyclotron (CYCIAE-100) with external ion source is selected as the driving accelerator, which will accelerate H- ions up to 100 MeV and provide dual proton beams simultaneously extracted by stripping. In total 7 target stations will be built based on CYCIAE-100 for the fundamental and applied researches. A two-stage isotope separator on line system (ISOL) with mass Resolution of 20000 will be positioned between the cyclotron and existing tandem. A superconducting Linac booster (SCB) after the tandem functions to increase the energy of heavy ion from tandem by 2MeV/q. The ISOL system is installed in a new building west of the tandem and SCB is installed in the existing hall of the tandem. Two proton beams will be provided simultaneously by the cyclotron to south for applications of proton beam directly and to north for RIB generation. More than 40 proton-rich beams and 80 neutron-rich beams with beam intensity higher than 106 pps will be provided by this facility. Figure 1 shows the layout of BRIF and Figure 2 shows the main building.

The fabrications of all major components for CYCIAE-100 have been completed, and the major systems of the machine, including the 435-ton main magnet, two 46.8 kAT exciting main coils, 200-ton hydraulic elevating system with a precision of 0.02mm, high precision magnetic mapper, the 1.27m high vacuum chamber with a diameter of 4.08m, two 100kW RF amplifiers, magnet power supplies with a stability better than 20ppm in the power range between 50% and 100%, and water cooling system etc., have been ready for installation. Meanwhile, the main magnetic mapping and shimming on CYCIAE-100 being performed in the building will be finished in the beginning of this May. The tests for the 18mA H- ion source and injection line as well as the 2m long cryopanel and vacuum system have been performed and the first beam is scheduled in the latter half of this year. The equipment fabrication for the ISOL and SCB systems has been completed as well. The magnetic mapping and shimming for the ISOL system is being performed on the large-scale analysis magnet, and the work on copper-niobium sputtering is under way.

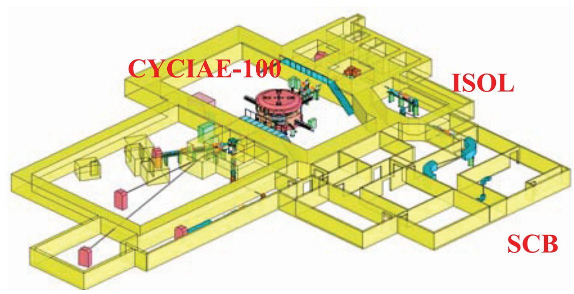

Figure 1: Layout of BRIF.

Figure 2: Main building of BRIF.

PROGRESS ON CYCIAE-100

The status of CYCIAE-100 at different stages, including the preliminary design[2], technical design and construction preparation[3], as well as progress[4], has been reported at previous cyclotron conferences. The construction of CYCIAE-100 takes the advantages of both the high precision, typical of AVF cyclotrons and

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strong focusing of separated-sector cyclotrons. The major systems, including the 435-ton main magnet, two 46.8 kAT exciting main coils, 200-ton hydraulic elevating system with a precision of 0.02mm, high precision magnetic mapper, the 1.27m high vacuum chamber with a diameter of 4.08m, two 100kW RF amplifiers, magnet power supplies with a stability better than 20ppm in the power range between 50% and 100%, and water cooling system etc., have been in place for installation in the main building. Currently the main magnetic mapping and shimming on CYCIAE-100 is coming to an end. . For the RF system, two RF cavities and their frequency and Q value measured coincide well with the numerically calculated[5]. Following the installation of two 100kW RF power supplies and transmission lines in the building, the test with full output power has been finished.

Figure 3: Installed CYCIAE-100.

The 410-ton main magnet of CYCIAE-100 is 6160mm in diameter and 3860mm in height. The largest single piece weighs is 169 tons. The installation precision should be better than 0.20mm in the direction of height and the azimuthal error is required to be no more than 0.50mm. The main magnet is installed in the building that is 4 meters under the ground. On the west wall of the building a horizontal hole of 7m wide and 6m high is reserved, through which. all the parts of the main magnet will be moved into the building. Due to the 4m difference in height, the parts could not be transported directly to the building for installation. A detailed installation plan has been worked out and evaluated in advance that ensures the successful implementation later on for the main magnet and coils, hydraulic elevating system, and magnetic mapper. The installation precision has reached up to 0.10mm in height and 0.20mm in the azimuthal direction, both above the design parameters. Figure 3 shows the installed main magnet, coils, hydraulic elevating and vacuum chamber.

After 4 times of mapping and 3 times of shimming, the phase shift within the radius of 90cm has been reduced by 80%. Figure 4 shows the measured variation of the vertical free oscillation frequency, which represents the vertical focusing force. It can be seen from the figure that after the third time shimming, it is well over at the extraction region, indicating the vertical focusing force is strong enough to avoid the walkinshaw resonance.

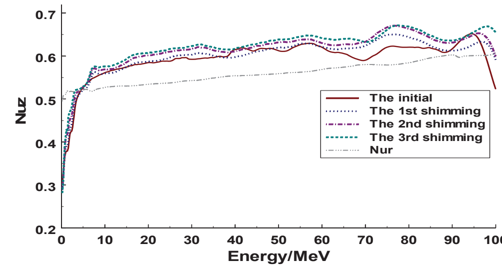

Figure 4: The variation curve of vertical free oscillation frequency v_z over the 4 times of mapping.

Two RF cavities were installed and tested in the temporary building. The frequency and Q value measured (9300 under the frequency of 45.8 MHz) coincide well with the numerically calculated one (~10300). The 100kW RF power system is consisting of RF dummy load, intermediate solid state amplifier, and electronic tube final stage power amplifier. These devices are large in dimension and heavy in weight and meanwhile contain many electrical elements of high precision, posing critical challenge to transportation and installation. After finishing the RF shielding, the two 100 kW RF amplifiers are in place for the onsite power commissioning. Figure 5 shows the installed RF cavities and RF power system in the shielding room.

Figure 5: RF cavity (left) and RF power system in the shielding room (right).

Other systems for CYCIAE-100 are proceeding as scheduled. Two cryopanel devices to be installed in the compact cyclotron with large pumping speed of 6000L/S per set will be fabricated by June of 2013. The test of 15mA H- ion source has been finished[6]. The injection line and dual extraction system were installed in the temporary building and the debugging is in smooth progress. Figure 6 shows the ion source, injection and extraction system. The water cooling, pneumatic system, power supply systems are ready now. The PLC device and the procurement for the safety interlock system have been completed. The joint debugging of the neutron detector and VME acquisition has been carried out, as well as the debugging of the upper computer software.

In general, significant progress on CYCIAE-100 has been achieved, especially in the aspects of equipment fabrication, installation and commissioning. It has paved the way for the follow-up installation, system debugging, as well as the upcoming beam commissioning.

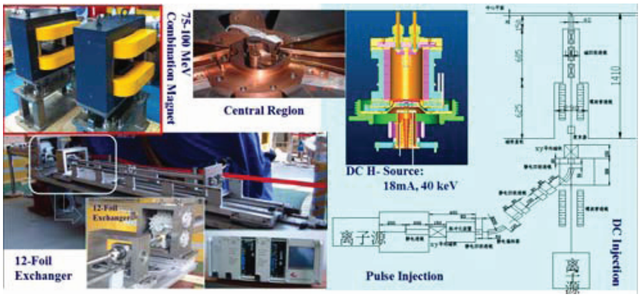

Figure 5: Ion Source, Injection and Extraction System.

PROGRESS ON ISOL

The ISOL system is to generate short life radioactive ion beam on-line and its designed mass resolution power is 20000 to separate required isobar from adjacent species. It consist of target ion source, analyzing magnets, electrostatic quadruples, electrostatic steers, beam diagnostics units and beam indentify units, vacuum system and control system. The target ion source has been installed and its commissioning is been carried out on a test bench in laboratory. A Li beam has been produced from the target ion source. The magnetic field measurements for 7 magnets are being carried out. All the power supplies including 300kV HV power supply for magnets, lens, steers are ready. The electrostatic quadruple and steer, beam diagnostics units have been manufactured and its assembling is under way in laboratory. Figure 6 shows the ISOL system.

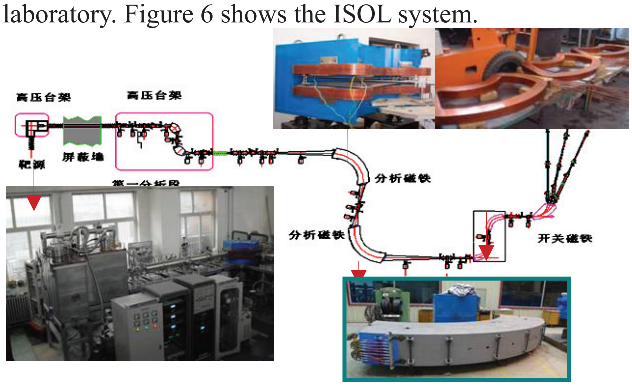

Figure 6: ISOL system.

PROGRESS ON SCB

The SCB system includes one cryomodule with 4 Nb sputtered QWRs (=0.11) inside and final energy gain of 2MeV/q, will be installed downstream of the existing tandem (Figure 6). In the cryostat, the container and QWRs have common vacuum, QWRs are surrounded by a shield which is cooled by liquid nitrogen, a helium reservoir is installed as a buffer for QWRs. The reservoir and QWRs will be pre-cooled by liquid nitrogen before liquid-helium cooling. Seamless copper bases of QWRs are fabricated by machining and sputtered in a tri-magnetrons sputtering system.

To match longitudinal acceleration, a DC beam pulsed system, which includes a travelling wave chopper, a double drift buncher and a phase pickup, will be installed. The buncher works with fundament frequency of 6MHz and efficiency of 50%, drifting distances could be changed by switching among electrodes to match ions with different velocities. Up to now, the cryostat has been manufactured and the improvement to reduce thermal loss will be finished at the end of May. 4 QWRs have been sputtered and the tests at 4.5K are in progress.

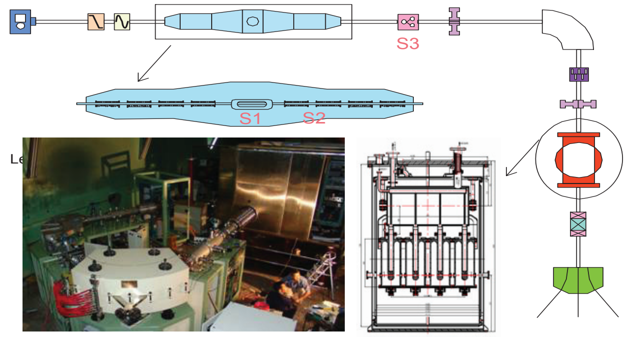

Figure 7: SCB system.

SUMMARY

Up to now significant progress has been achieved in the building construction, main accelerators manufacture, installation and assembly of BRIF. The ground breaking ceremony for the building was conducted in April, 2011, followed by the roof sealing in Jan, 2012. The on-site installation, including the field mapping & shimming, RF power test, etc. of CYCIAE-100, ISOL and SCB systems has started since September of 2012. The beam commissioning for CYCIAE-100 is about to start and the first beams are expected by the end of 2013

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