INSTALLATION AND TEST PROGRESS FOR CYCIAE-100

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Abstract

The 100 MeV high intensity compact cyclotron CYCIAE-100 being built at CIAE adopts an external ion source system, accelerates H- ions up to 100 MeV and provides dual proton beams simultaneously be stripping. The ground breaking ceremony for the building was conducted in April, 2011. Then in September of 2012, the major systems for the machine, including the 435-ton main magnet, two 46.8 kAT exciting main coils, 200-ton hydraulic elevating system with a precision of 0.02 mm, high precision magnetic mapper, the 1.27 m high vacuum chamber with a diameter of 4.08 m, two 100 kW RF amplifiers, magnet power supplies with a stability better than 20 ppm in the power range between 50% and 100%, and water cooling system etc., have been in place for installation.

The paper will demonstrate the results of high precision machining and installation of large scale magnet, magnetic mapping and shimming under the condition with vacuum deformation, study on the multipacting effects under the fields in compact magnet valleys and RF conditioning. The test results for the 18 mA H- ion source and injection line as well as the 2 m long cryopanel and vacuum system will also be presented. The first beam for CYCIAE-100 is scheduled in the latter half 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 and provide dual proton beams of 75 MeV ~ 100 MeV with an intensity of 200 μA ~ 500 μA simultaneously extracted by stripping. In total 7 target stations will be built based on CYCIAE-100 for the fundamental and applied researches. Figure 1 shows the layout of BRIF.

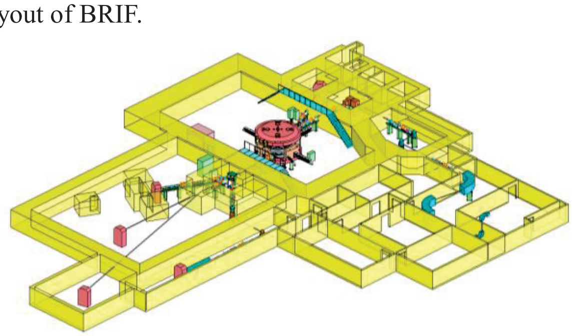

Figure 1: Layout of BRIF.

The status at different stages, including the preliminary design, technical design and construction preparation, as well as progress, has been reported at previous cyclotron conferences [1],[2],[3]. The key parts for CYCIAE-100 have been installed and tested in the main building, such as main magnet, RF cavities, RF amplifiers, main vacuum system, power supplies, etc. The main magnetic mapping and shimming on CYCIAE-100 has been finished. Most of parts testing including RF amplifiers, H- ion source, injection and extraction system, as well as main vacuum system have been finished. The beam commissioning will be started soon and scheduled to get beam in 2013.

MAIN BUILDING OF BRIF

The construction of the main building started on April 28, 2011 and the roof was sealed on January 16, 2012. The on-site installation conditions for the main devices and systems of accelerator have been ready since September 27, 2012. Figure 2 shows the main building.

Figure 2: Main building of BRIF.

MAIN INSTALLATION AND TEST PROGRESS FOR CYCIAE-100

Main Magnet System Installation, Mapping and Shimming

The main magnet of CYCIAE-100 consists of 2 top/bottom yokes, 4 return yokes, 8 poles, 16 shimming bars and 2 central plugs. It is 6160 mm in diameter and 3860 mm in height. The largest single piece weighs 169 tons. The 435-ton main magnet is installed at the cyclotron vault 4 m underground. The installation precision should be better than 0.20 mm in the direction of height and the azimuthal error is required to be no more than 0.50 mm. On the west wall of the building a horizontal hole of 7 m wide and 6 m high is reserved, through which all the parts of the main magnet will be moved into the building. Due to the 4 m height difference between the inside and outside of the building, a steel structure platform is specially made and installed at the inside of the hole with a load bearing of 200 tons. The

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heavy haul rail is installed on the platform which extends to the road outside. The targets, 12 at the two layers on the wall and 2 on the floor, are pre-set in the cyclotron vault, which are used to measure the position of large components such as the main magnet, main coil, vacuum chamber, hydraulic elevating system, and magnetic mapper.

Apart from the main magnet, the installation of other equipment, including the main coil, vacuum chamber, and the 200-ton hydraulic elevating system that realizes synchronization of 4 cylinders, are also completed. For the hydraulic system, the elevating height is 1500 mm, and the synchronization is up to 0.2 mm. The 2×46800 AT coil is Φ4206 mm in inner diameter and Φ4696 mm in outer diameter, 358 mm thick and winded by hollow copper conductor of 12×12/Φ6.5. The coil is cast by vacuum epoxy and the installation precision has reached 0.5 mm. Figure 3 shows the installed main magnet, coils, hydraulic elevating and vacuum chamber.

Figure 3: Installed main magnet.

Three hall probes have been adopted to measure the magnetic field. The measurement interval is 1.0 cm in the radial direction and 1° in the angular direction. The measurement scope is 0 ~ 360° for the angle and 0 mm ~ 2010 mm at radius respectively. Considering the obvious influence of vacuum to the magnetic field on the median plane, the first exertion of full mapping with vacuum for a large cyclotron is made. In total, 9 times of mapping and 8 times of shimming have been implemented, and based on the mapping data with vacuum and accelerating voltage (from 60 kV to 120 kV along the radius), it can be calculated that integral phase shift from the central region to the extraction is within ±20° over more than 420 turns. It also indicates that the vertical focusing force is strong enough to avoid the walkinshaw resonance from the measurement results.

RF System Installation and Testing

Two RF cavities with radius about 1.2 meters are being installed in the valleys after the testing in the temporary building. The frequency and Q value measured (9327 and 9690 respectively under the frequency of 45.8 MHz) coincide well with the numerically calculated one (~10300) [4]. For the compact cyclotron, the magnetic field in the valleys for the RF cavities is very high. The scheme of producing the multipacting effects in the RF cavities is very complicated for the compact cyclotron and it will increase the difficulties for the input of high power and commissioning for the RF system. The study on the multipacting effects under the fields in compact magnet valleys and RF conditioning will be given in detail in this conference. After finishing the RF shielding, the two separated 100 kW RF amplifiers are in place for the onsite power commissioning. The RF power system is consisting of RF dummy load, intermediate 3.5 kW solid state amplifier, electronic tube final stage power amplifier and low level RF control system (LLRF). The testing power has exceeded 100 kW. The phase instability is better than ±0.1° and the amplitude instability is better than 5×10^{-4} with LLRF system. 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. Figure 4 shows the RF cavities, installed RF power system in the shielding room and tested LLRF system.

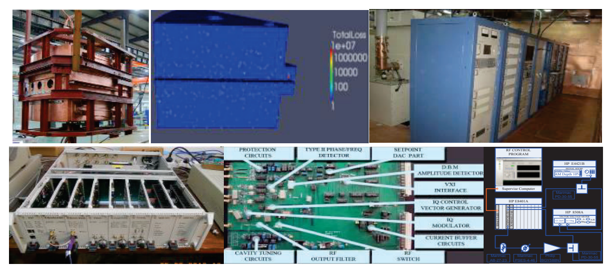

Figure 4: RF cavity, multipacting effects, RF power system in the shielding room, and LLRF system.

Main Vacuum System

The main vacuum chamber is a huge aluminum cylinder of 1.27 m in height and 4.08 m in inner diameter and the top/bottom yokes are functioning as its covers for CYCIAE-100. Considering all of the effects including the sector magnets, centering coils, beam diagnostic probes and beam extraction probes located inside the vacuum chamber, it is more difficult to obtain the required vacuum and the total pumping speed needed should be more than 140,000 L/s based on outgassing load calculation. The designed vacuum of the main vacuum chamber is better than 5×10^{-6} Pa. Figure 5 shows the installed vacuum chamber.

Figure 5: Vacuum chamber in place.

In order to obtain the required vacuum, a dry pump (56 L/s), two turbo-molecular pumps (1300 L/s for each), two cryopumps (10000 L/s for each), and two sets of plug in cryopanel system are used to CYCIAE-100 [5]. The cryopanel system, which consists of chevron baffles, a shield, the cryoarray, is cooled by Stirling refrigerator with cryo transfer line. Figure 6 shows the installed dry pump, cryopumps and the cryopanel system.

Figure 6: The installed dry pump and cryopumps (upper) and the cryopanel system (lower).

The pressure in the main vacuum chamber is up to 7×10^{-5} Pa after 24 hours with all the pumps except the cryopanel in August. The beam tuning condition for the low intensity is satisfied under the obtained main vacuum without cryopanel. It is not difficult to obtain the designed main vacuum if the cryopanel is used for CYCIAE-100.

Injection and Extraction System

The tests of 15 mA H- ion source, injection line and dual extraction system have been finished in the temporary building. The normalized H- beam emittance of ion source under 10 mA is 0.55 π-mm-mrad [6]. Two combination magnets with the maximal field of 0.55 T have been installed after finishing magnet filed measurement and the field uniform between 50 mm ~ 200 mm along the beam transfer direction is about 1.92×10^{-2}. The stripping probe system with 12-foil exchanger in the vacuum chamber has been tested and can work very well. Figure 7 shows the ion source, injection and extraction system.

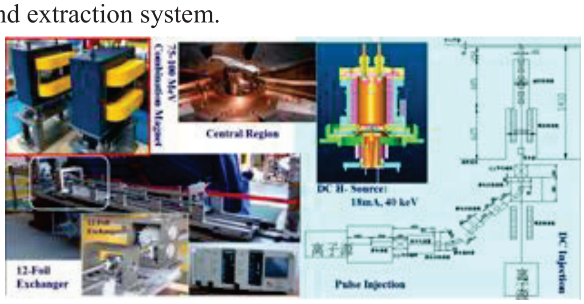

Figure 7: Ion source, injection and extraction system.

Other Systems for CYCIAE-100

The water cooling, pneumatic system, power supply systems have been installed well and tested now. The main magnet power supply with the specifications of 110 A/286 V in rated output and $\pm1\times10^{-5}$/8h in stability has been installed. 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. Figure 8 shows the main control room and control system used for CYCIAE-100.

Figure 8: Main control room, control system, power supplies and water cooling system.

CONCLUSION AND NEW SCHEDULE OF CYCIAE-100 PROJECT

Since the beginning of 2011, significant progress on CYCIAE-100 has been achieved, especially in terms of building construction, equipment installation and test. It has paved the way for the follow-up installation, system debugging, as well as the upcoming beam commissioning. 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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