THE DEVELOPMENT OF RADIAL PROBE FOR CYCIAE-100

FengPing Guan, HuaiDong Xie, LiPeng Wen, TianJue Zhang, ZhenGuo Li, ZhiGuo Yin, Chuan Wang, CIAE, Beijing, China

Abstract

In the design of CYCIAE-100 beam diagnostics system, three radial probe targets distribute on three directions above magnetic pole and in the valley on the median plane of cyclotron. These radial probe targets can be used for beam center measurement. By blocking beam on five fingers and one stopping block, the radial probe target can measure the radial and axial distribution of H^- beam at the same time. During beam commissioning, the radial probe targets can also be used for beam intensity measurement. The changeable target tip design makes it possible to replace the damaged part and optimization of the structure. The mechanical and control part of radial probe target system is finished, assembly and prime test of the whole system will be carried out in September.

DESIGN OF RADIAL PPROBE

The project of Beijing Radioactivity Ion-beam Facility (BRIF) is being constructed at China Institute of Atomic Energy (CIAE). As a major part of the BRIF project, a 100MeV compact cyclotron (CYCIAE-100) will provide proton beam with an intensity of 200μA～500μA [1].

CYCIAE-100 is a compact isochronous cyclotron. The radius of magnetic pole is 2000 mm, yoke is 3080 mm, air gap between 46-60 mm. Large radius with small axial space plus high requirement of isochronous magnetic field, all these factors lead to the following design of radial probe target: 4580 mm long, placed on the median plane of CYCIAE-100 cyclotron, above the surface of magnetic pole, bellows with compression ratio as high as 0.234 is chosen for vacuum seal. The moving range of radial probe target is 2020 mm to assure the radial probe measurement range near the centre of CYCIAE-100 [2]. When not measuring, radial probe target is blocked off from main vacuum chamber by a gate valve. The position of three radial probe targets on CYCIAE-100 is shown in Fig. 1.

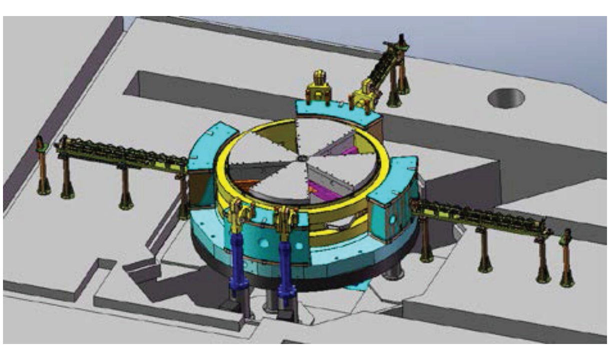

Figure 1: Radial probe targets on CYCIAE-100.

For the purpose of beam center measurement, three radial probe targets will be installed on three directions above magnetic pole and in the valley on the median plane of CYCIAE-100 cyclotron. Meanwhile, at low energy, radial probe target with water cooling can get real time beam intensity which is important parameter for prime beam commissioning. The main functions of radial probe target are as follows:

Get Beam Distribution on Axial and Radial Directions at the Same Time

The radial probe target tip, making up by five fingers and one stopping block in front, get the beam distribution on axial and radial directions by blocking the beam. Radial probe target tip is made by copper. The five fingers' positions are decided according to the calculated axial beam distribution. The five cuboid fingers with 0.5mm cuneate tip outside the stopping block can satisfy the radial resolution requirement. The five fingers are symmetrical to the median plane of CYCIAE-100, as shown in Table 1.

Table 1: The Size of Five Fingers

Finger No.	Position	Size
1	Top	9mm
2	Upper	6mm
3	Middle	4mm
4	Lower	6mm
5	Bottom	9mm

Between the five fingers and the stopping block is a layer of heat conducting ceramic, this can enhance the effect of water cooling. The structure of radial probe target tip 1 are shown in Fig. 2.

Figure 2: Structure of radial probe target tip 1.

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By moving on the radial direction, the isolated five fingers get axial distribution of the beam, adding the signal from five fingers, it can get the radial distribution. The stopping block is 40 mm high, which is sufficient to block the beam on the axial direction. As shown is Fig. 2, the tip of the radial probe target is a plug in structure and can be installed on tip of the radial probe target's rod easily. The signal is connected by plug in connector. Once installed, the signal connection is finished at the same time. This structure could be easily replaced if damaged or radio-activate.

Measure the Beam Intensity at the Second Gap of the Central Region

During the prime beam commissioning, parameter setting of the ion source and axial injection line with two focus devices and two steering magnets is the key point. During this stage, without the RF voltage, the beam intensity at the second gap in the central region is measured (for 4th harmonics accelerating cyclotron, the design of the first dee gap try to increase the electrical focus effect, so not enough space for beam intensity measurement. With the right parameter setting on the injection line and deflector, beam intensity is rather high at the second dee gap even without RF voltage.).For the compact design of CYCIAE-100 cyclotron, no enough space near central region for beam intensity measurement device. At this stage, the structure of the tip 2 shown in Figure 3 is installed on tip of the radial probe target. This structure can measure the beam intensity at the second dee gap with sufficient water cooling for a long time, which is very important parameter for a compact cyclotron.

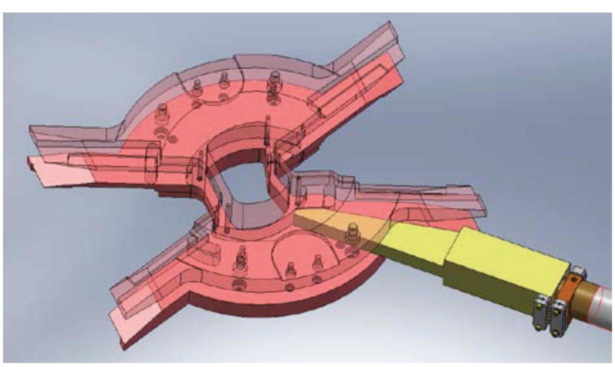

Figure 3: Structure for beam intensity at 2th gap.

Measure the Beam Intensity around 1MeV

The parameter optimization of the ion source, injection line, deflector and RF voltage is the key point of increasing beam intensity around 1 MeV. To get 500 μA beam intensity around 1 MeV energy, it is necessary to carry out beam intensity measurement by combining the signal from five fingers and the stopping block to get the total beam intensity. With water cooling, radial probe target could endure more than 500 W beam for a long time. This design already tested on 10 MeV cyclotron as shown in Fig. 4 [3].

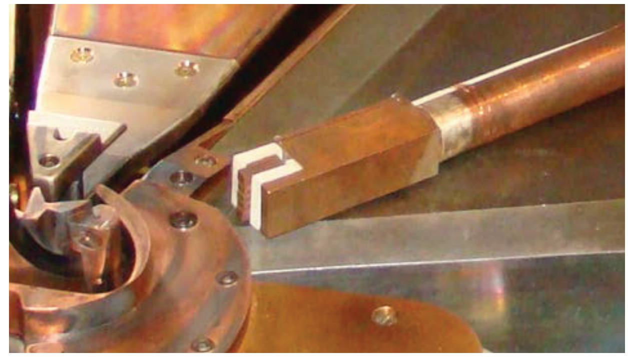

Figure 4: Radial probe target on 10 MeV cyclotron.

Beam Centre Measurement

One important function of radial probe target is beam centre measurement. During prime beam commissioning, only one set of radial probe target is produced, so compare the measurement result with calculated results to judge the centre of the turn pattern. Figure 5 shows the calculated orbit of CYCIAE-100 and orbit in the central region [4]. By calibrating the position of the five fingers, radial probe target can get beam orbit since the 3rd turn. On radial direction, the first 20 turns of the beam is the important part. Finger as small as 0.5 mm can get high resolution and decrease the errors caused by overlapping. The beam intensity signal from the stopping block can be used to judge the place of beam loss.

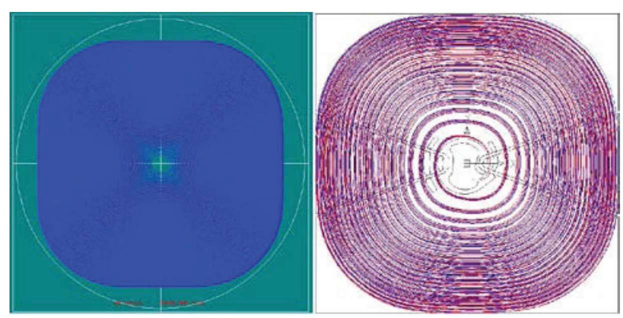

Figure 5: Calculated orbit of CYCIAE-100 and orbit in the central region.

MECHANICAL DESIGN

As the beam measuring range has a span of 2020mm from the main vacuum chamber wall to the center of the accelerator, the most challenging part for the design is that the cantilever is too long for the radial probe target's rod. In the design, it adopts a structure that a support sleeve is installed at the front-end of the device, and the front-end support of the rod is installed in the sleeve. By doing this, the length of cantilever changes from 3150 mm to 2150 mm.

The radial probe target's rod is divided in two stages, the front part's diameter is 40 mm, the back part's diameter is 48 mm, this design reduce the weight of the rod, thus reduce the droop of the target tip greatly.

Outside the main vacuum chamber, a mechanical pump and a turbo pump keep the radial probe target in high vacuum, this helps to keep the 10^{-8} pa vacuum in the main vacuum chamber during the radial probe target measurement. If not measuring, the radial probe target is blocked off by gate valve from the main vacuum chamber.

CONTROL AND DATA ACQUISITION OF THE RADIAL PROBE TARGET SYSTEM

The position of radial probe target is measured by a novotechnik TLH-2250 linear potentiometer and precious +10V reference voltage. The control and data acquisition system is shown in Fig. 6. The NI-PCI-7334 stepping motor control card control the stepping motor then the radial probe target movement; the current signal from the five fingers and the stopping block is amplified by I-V converter then sent the output voltage signal to NI-PCI-6259 data acquisition card.

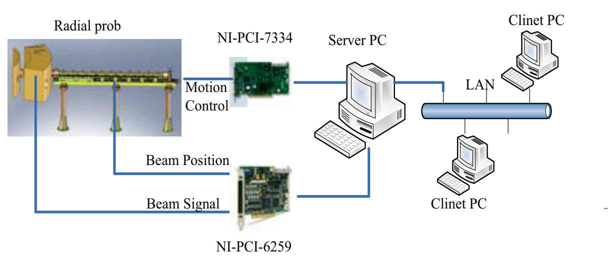

Figure 6: Layout of radial probe target system.

The I-V converter can achieve the same high transimpedance gain as the shunt ammeter but with much higher SNR and smaller input impedance. This is very important for the small current signal from the fingers of radial probe target. The cable from the radial probe target tip to the vacuum feed through is hidden in the rod of radial probe target. This can reduce the noise caused by RF leakage greatly. I-V converter is prone to oscillate if the applied capacitance is bigger than a critical value determinate by the regulation loop and the voltage noise gain is also sensitive to the input capacitance, so instead of the coaxial cable with large parallel capacitance, we chose shield twist pair to connect radial probe target and the data acquisition part inside the CYCIAE-100 control room.

The NI-PCI-6259 works under multi channel scanning mode. By analyzing the beam intensity and position one can get the beam distribution inside the cyclotron. Labview is chosen for the related software. With the client software on a computer, the data from the radial probe target system can be checked on any computer inside the LAN.

IMPLEMENTATION AND TESTING

By now, the mechanical part of radial probe target is finished and the assembling under going. The off line assembly and test should be finished after September. By October this radial probe target will be installed on the north direction on the median plane of CYCIAE-100. During the prime test, target tip 2 will be installed to measure the beam intensity at the second gap.

The control software has been finished, including the data acquisition and the data processing etc. A preliminary test for the I-V converter and data acquisition has been performed, and a good result was obtained in the procedure.

CONCLUSION

In the design of CYCIAE-100, three radial probe targets distribute on three directions above magnetic pole and in the valley on the median plane. The structure of radial probe target tip makes it very easy to replace. The radial probe target can get the beam distribution on radial and axial directions; it can also be used to measure the beam intensity at the second gap and at low energy region. Radial probe will play an important role in the beam commissioning of CYCIAE-100.

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