DESIGN AND CONSTRUCTION OF COMBINATION MAGNET FOR CYCIAE-100

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Abstract

The high intensity compact cyclotron CYCIAE-100 being constructed at China Institute of Atomic Energy (CIAE) is designed to extract proton beam from 75MeV to 100MeV in two opposite directions by stripping foil. Two combination magnets have been designed to bend the proton beams with different energies into one common beam line. The combination magnets have been designed into the return yoke of the main magnet of CYCIAE-100 for the dynamic reason. 2 D and 3D simulation of these combination magnets have been finished, the machining of them have also been finished. The magnetic field of the combination magnets have been measured and the results shows that the measurements are very closed to the calculation, indicating these two magnets can be used in the BRIF project.

INTRODUCTION

CYCIAE-100, the high intensity compact cyclotron is being installed at CIAE [1,2]. The proton beams are extracted in two opposite directions with different energies. Two combination magnets are designed to bend beam with different energies into one common beam line, as shown in Fig. 1 [3].

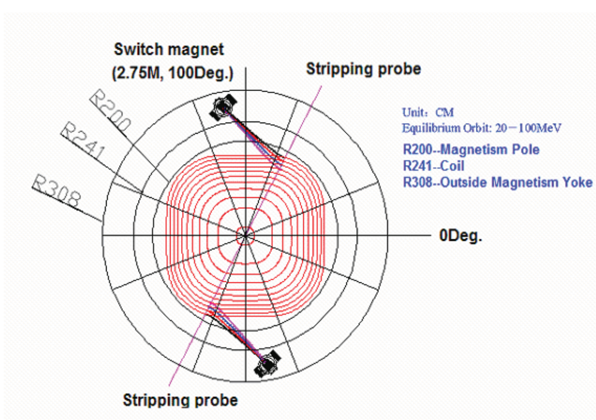

Figure 1: Layout of CYCIAE-100 and the combination magnet.

Simulation results show that the beam envelop is smaller when the combination magnet put into the return yoke of the main magnet than that put outside the return yoke, that is the reason to install the combination magnet into return yoke.

Beam from 75 MeV to 100 MeV are bending to common line through combination magnet, the maximum bending angle is 5^{o} ,detailed design will presented.

DESIGN OF THE MAGNET

Maximum bending angle of beam with energy 75 MeV to 100 MeV is 5^{o}, the magnetic rigidity of proton beam with given energy is certainly, then we can take a balance of the magnetic field and the magnet size, the main parameters are shown in Table 1.

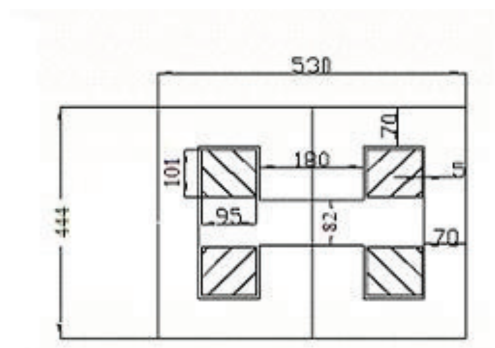

Figure 2: Layout of the magnet.

Table 1: Main Parameters

Parameter	Value
Bmax	0.53 T
Bending radius	2968 mm
Gap	82 mm
Effective length	322 mm
Ampere-turn	17500 AT
Conductor	5 mm×5 mm-Φ3 mm

Figure 2 shows the intersecting surface of the magnet, the main dimensions are also shown in this figure. Simulations based on this model have been done and shown below.

2D Field Distribution

2D simulation has been taken to ensure the main parameters of the magnet as well as to decide the size of the shimming bar that at the edge of the pole face.

POSSION [4] code is used to give the field distribution, shimming bars with height 1mm on the edge of the pole are used to increase the uniformity of the field. Different shapes of shimming bars were simulated and field uniformity were compared to get a better one.

ISBN 978-3-95450-128-1

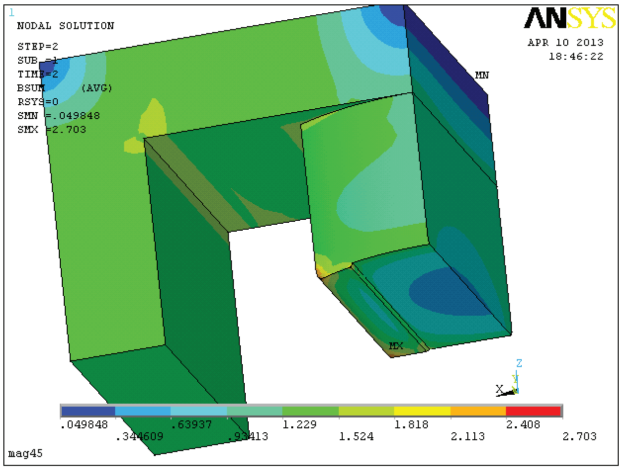

Figure 3: 3D simulation.

Trapezoid shimming bars with bottom width 35 mm and top width 30 mm have been adopted, the height of each shimming bar is 1 mm to enhance the magnet gap is big enough for beam.

3D Field Distribution

ANSYS code is used to do the 3D simulation of this magnet. A 3D model is built as shown in Fig. 3, in this figure ,the field distribution of the magnet is also shown, which is more accurate to describe the field.

Entrance of the magnet is straight that beam fly into combination magnet will be almost upright to pole edge and is also easy to do the machining, exit of magnet is arc with radius 123 mm, which is also to make beam upright to pole edge.

Fringe field can also be get from 3D calculation, both mechanical length of the magnet and beam trajectory can be get by using 3D field distribution.

Coil And Power Supply

Copper conductor with inner hole was used for coil of combination magnet, water cooling is used because of the high current.

To avoid high current and low voltage, the conductor 5 mm ×5 mm with inner hole Φ3 mm is adopted. Then the rated current of the magnet is almost 73 A, and the power is 3 kW. The calculated temperature raise of the coil is less than 20℃, which is fit for magnet running.

MEASUREMENT RESULTS

Measurements of these two magnets have been done by using Hall probe. A 3D magnetometer was used to do the measurement, the positioning accuracy of magnetometer is 0.04 mm, and can measure the magnetic field automatically.

As shown in Fig. 4, the left figure is the magnet under measuring, right figure is the field distribution on the mid-plane, which one can see the fringe field clearly.

The uniformity of the field from measurement is 1.28E-3 in ±40 mm along x direction.

Charged beam in the magnetic field of combination magnet will bending a small angle, integral beam motion equation in the field, we can get the beam trajectory, as shown in Fig. 5, the solid line is the 100 MeV proton beam trajectory in the magnet, the bending angle is about 3^{o}, which shows that this magnet can bend the beam into a common beam line.

Figure 6 is the particles distribution in the phase space, left one is the horizontal space and the right one is the vertical space. Uniform distribution of the particles is used, the figure shows that the changes in phase space is very small because of the small bending angle.

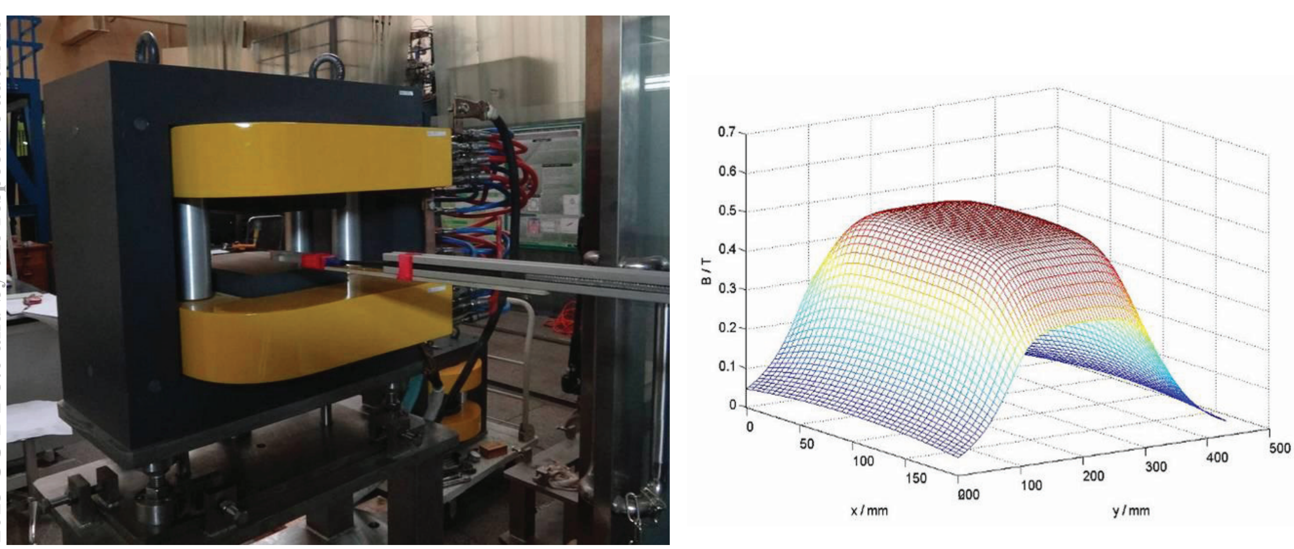

Figure 4: Measurement of combination magnet and the field distribution on the mid-plane.

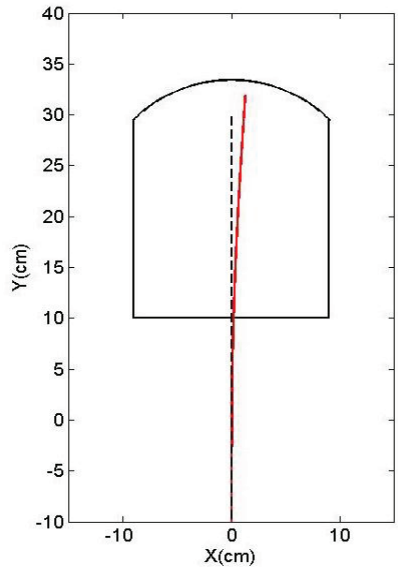

Figure 5: Beam trajectory through the magnet.

Field maps of different currents are also measured as to bend proton beam with different energy. The uniformity is almost same.

CONCLUSION

A pair of combination magnet of 100 MeV compact cyclotron under constructing at CIAE have been finished. The measurement of the field and the beam dynamic simulation shows that these magnets can bend proton beam with different energy into one common beam line. The magnets have already been installed into the return yoke of main magnet of CYCIAE-100, the beam test will be done by the end of this year.

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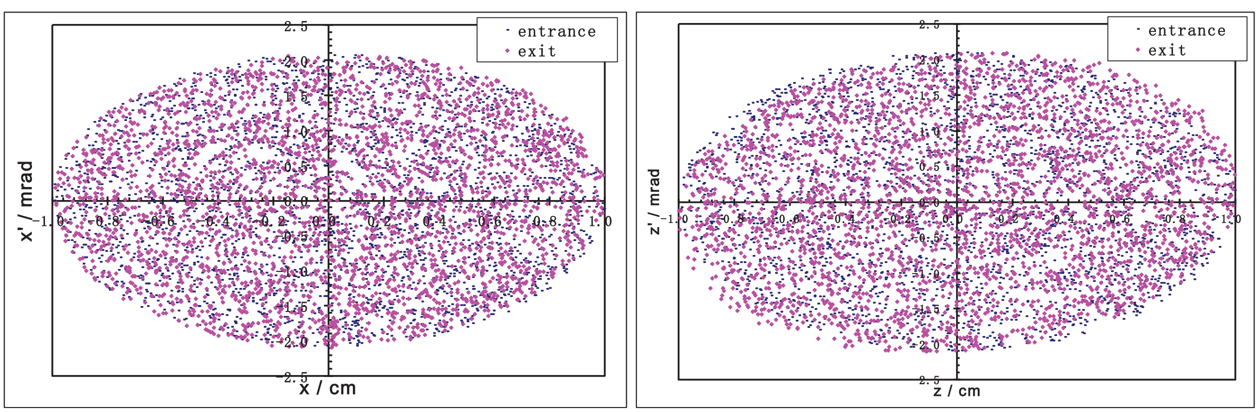

Figure 6: Phase distribution at the entrance and exit of the magnet.

ISBN 978-3-95450-128-1