DESIGN AND FIELD MEASUREMENT OF SOLENOID MAGNETS FOR THE VERTICAL INJECTION BEAM LINE OF KOLKATA SUPERCONDUCTING CYCLOTRON

Md. Zamal A.Naser, M.H.Rashid, P.K.Behera, N.Ibomcha, J.Debnath, C.Nandi, S.Mishra, U. Bhunia, S. Paul, M.K.Dey, G. Pal, C.Mallik, R.K.Bhandari
Variable Energy Cyclotron Centre, 1/AF, Bidhan Nagar, Kolkata 700 064

Abstract

Vertical injection beam line requires two solenoids at different positions to provide focusing in both planes for the low energy beam produced by the ECR ion source. Both iron-yoked solenoid magnets are placed above the pole cap of cyclotron main magnet. The solenoids are designed by using POISSON computer code. The basic consideration of the design is to get desired focal length with the space available for these in the beam line. The available space is limited by the RF components of the cyclotron and also the other components of the injection beam line. After in house fabrication of these two solenoids an extensive magnetic field measurement has been carried out with the help of a three-axis hall probe and a gauss meter. The paper presents the detailed design along with the results obtained from the magnetic field measurement. The charged particle beams successfully transported into the superconducting cyclotron through these solenoids are also reported in this paper.

INTRODUCTION

In superconducting cyclotron in Kolkata, ion species of O^{6+}, Ne^{6+}, Ne^{3+}, Ar^{6+}, O^{2+}, N^{2+} are successfully injected into the acceleration chamber of the cyclotron through the low energy injection beam line. The schematic of the vertical section of the injection beam line is shown in Fig. 1. The beam is vertically bent by the bending magnet (BM41) and it is focussed by solenoid (SM51). The solenoid (SM52) is used to focus the diverged beam coming out from the buncher. Without buncher it is also used to focus the beam. The whole vertical section is exposed in a very high fringe field due to the cyclotron main magnet. Slight deflection of the ion beam creates the problem to inject the beam into the cyclotron median plane. These two solenoid magnets serve very big role in the beam injection

DESIGN STUDY

Both the solenoids are designed considering the beam optics requirement for maximum beam rigidity of 0.641 kG-m. The diameter of the magnets are fixed by the beam pipe size. The size of the magnets is governed by the coil and the iron placed outside it. Within the limited space in the beam line the coil and iron sizes are optimised to get the desired magnetic field corresponds to the required focal length of the magnets. The field data are generated by POISSON and the effective length, focal length are calculated accordingly by using Eq. 1 and Eq. 2 respectively. Magnetic flux lines are shown in Fig. 2. Conductor size and the pancakes are chosen such a way that the maximum temperature rise (.ΔTw) of the cooling water is not more than 10^{O}C. The water cooling calculations for each pancake is carried out at the available pressure difference in the water line. Rectangular copper conductors having dimension 6mm x 6mm with circular hole of 3 mm are used.

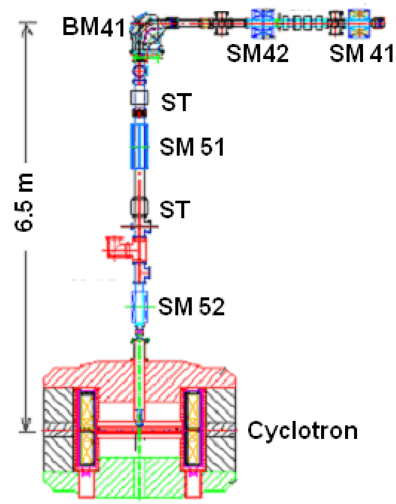

Figure 1: Schematic of vertical section of the injection beam line (SM: Solenoid magnet, ST: steering magnet)

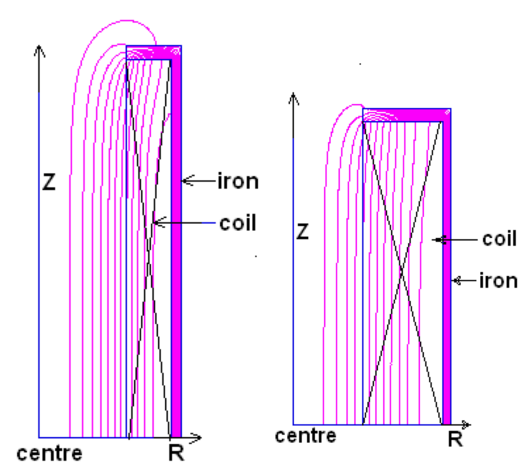

Figure 2: The field lines calculated from POISSON. a) SM51 b) SM52, Z is along the axis, R is along the radius.

MEASUREMENT

The effective length and the focal length for a solenoid magnet excited to a specified current, i is given by:

$$L_{eff}(i) = \frac{\int_{Z1}^{Z2} B_z^{\,2}(i).dz}{B_0^{\,2}(i)} \quad \text{...............................(1)}$$

$$\frac{1}{f(i)} = \frac{\int_{Z1}^{Z2} B^2(i).dz}{(2B\rho)^2} \quad \text{................................... (2)}$$

Where, B_0(i,) is the magnetic field at the centre of the magnet, Bz (i,) is the magnetic field at a distance z from the centre along the central axis, dz is the small length segment along the central axis of the magnet. Z1 and Z2 are the endpoint coordinates of the hall probe such that these points are far outside the magnet in a region where the field is negligible. Bρ is the beam rigidity.

The axial component of the magnetic field has been measured along the centre line of the magnet from a point Z1 to Z2 through the centre of the magnet stepping every 5 mm. The magnetic field has been measured for current 100A, 150A and 200A.

RESULTS AND DISCUSSIONS

Effective length and focal length are calculated for three excitations by using Eq .1 and Eq. 2 taking the data from POISSON and also from measurement. The comparison of the field profile is shown in Fig. 3 and Fig. 4. In these figures filed is plotted in one side of the magnet along the central axis from the magnet centre. Table 1 shows the comparison of the different parameters between designed and measured value. Result shows the good agreement between experiment and design. The axial magnetic field as a function of current is generated by placing the hall probe at the centre of the magnet and it is shown in Fig. 4. It is found from the measurement that focal length decreases with the magnet excitation according to Eq. 2 for the same beam rigidity.

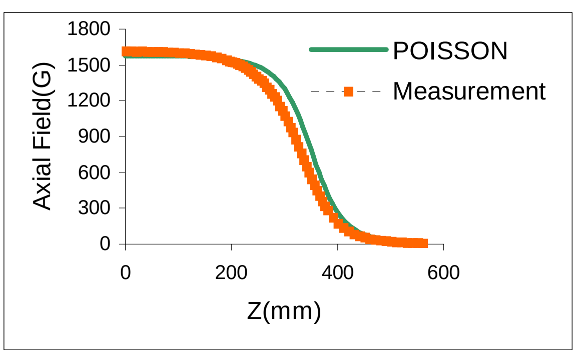

Figure 3: The field profile along the central axis of SM51

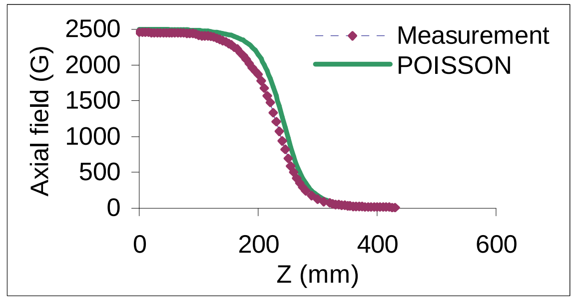

Figure 4: The field profile along the central axis of SM 52.

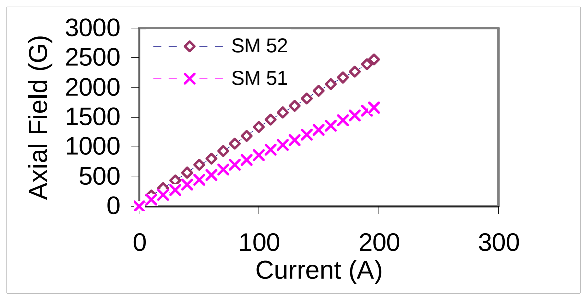

Figure 4: The excitation curve of SM 51 and SM 52.

Table 3: Comparison of designed and measured parameters at maximum operating current 200A.

Parameters	SM51		SM52	
	Designed	Measured	Designed	Measured
Overall length (mm)	720	720	500	500
L_{eff} (mm)	572	565	410	405
f (mm)	1128	1123	690	683
Current (A)	200	200	200	200
B_0 (kG)	1.57	1.62	2.5	2.46
ΔTw (^{0}C)	10	10	9	9

CONCLUSIONS

The beam dynamic calculation has been carried out in the injection beam line taking the measured parameters of the solenoids and it is good agreement with the operational settings. Maximum beam current of 30μA, with O^{6+} ion is achieved on the spiral inflector of the cyclotron.

REFERENCES

[1] M.K.Dey et al., "Beam Injection System of the Kolkata Superconducting Cyclotron", Cyclotron and their Application' Italy, October 07.