IMPROVEMENT OF THE DESIGN OF ACTIVE MAGNETIC CHANNEL FOR THE EXTRACTION SYSTEM OF K500 SUPERCONDUCTING CYCLOTRON IN VECC, KOLKATA

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Abstract

The extraction system of the K500 Superconducting Cyclotron [1] under construction in Variable Energy Cyclotron Center, Kolkata comprises of two electro-static deflectors and nine magnetic channels. These magnetic channels play very important role in providing adequate horizontal focusing along the extraction path through strong fringing magnetic field. Moreover the active ninth magnetic channel is used for alignment of various extracted ion species to match the central high-energy external beam transport line. This channel provides both dipole and quadruple field by means of coil current and specially shaped iron. We have improved the design of the ninth active magnetic channel to increase field quality and more control over the beam with the help of more coil current. We changed the shape of the iron and coil. Instead of a single coil it has the shape of a step coil. The field analysis shows a comparative reduction in the sextupole component and larger number of turns contributes to the larger coil field, which means more control over the beam. Phase space ellipse tracking through shows no distortion in the final phase space ellipse.

INTRODUCTION

The K500 Superconducting cyclotron is under construction at the Variable Energy Cyclotron Centre, Kolkata. The Cyclotron will accelerate ions with energies 5 to 80 MeV/n and heavy ions with energies 5 to 50 MeV/n. The extraction system of the K500 Superconducting Cyclotron comprises of two electro-static deflectors and nine magnetic channels. These magnetic channels play very important role in providing adequate horizontal focusing along the extraction path through strong fringing magnetic field. They also serve the vital purpose of deflecting the beam through the extraction region. Moreover the outermost magnetic channel M9, before injection to the external beam line is made active unlike others, which are all passive. The passive magnetic channels however present a set of problems, because the magnetic fields due to them do not scale with excitation as the channel iron is already saturated.

Hence different particles in the operating region with different charge to mass ratio and energy have different trajectories along the extraction path. At VECC simulation work has been carried out using extraction codes to evaluate this problem and suggest some reasonable solutions to them. The characteristics of the problem is that the beams get over focused at 30 KG field excitation and under focused at 47 KG field excitation. The beams after traversing through 8 passive magnetic channels reach the Ninth channel at different locations and variable inclination of the central trajectory.

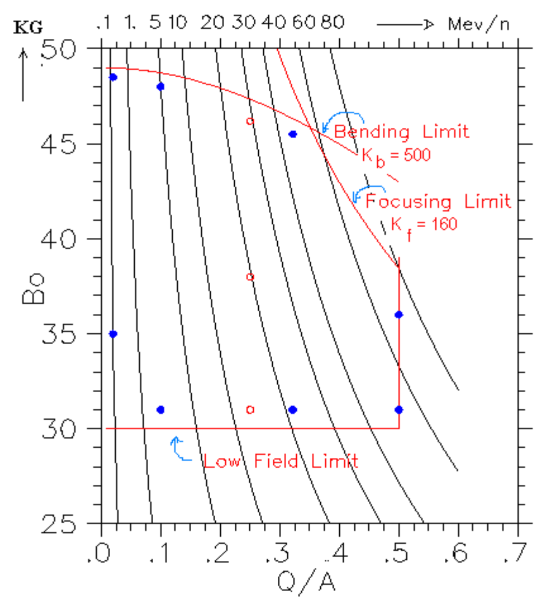

Figure 1: Operating region of K500 Superconducting cyclotron, VECC, Kolkata

The choice of Ninth channel as a passive channel would create problems related to bringing the central trajectory of different beams in alignment with central axis of the external beam line. Different solutions that have been incorporated in other superconducting cyclotrons or are possible are

(i) The channel could be passive and have strong steering magnets at the exit of the cyclotron
(ii) The channel could be active (coil and iron field) and strong enough for bending the beam so that it is aligned with the axis of the beam line.

It is the second approach that we have investigated.

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DESIGN FEATURES

The active magnetic channel M9 provides both dipole and quadruple field by means of coil current and specially shaped iron. It will be situated in the centre ring of the iron yoke and the space available to install it, is limited. Therefore, a compact design is required. Since it is in the yoke penetration a special magnet has been modelled to simulate the stray magnetic field in the yoke penetration, as shown in fig. (1a). Due to the symmetry of the magnetic median plane, only one half is shown in the figure.

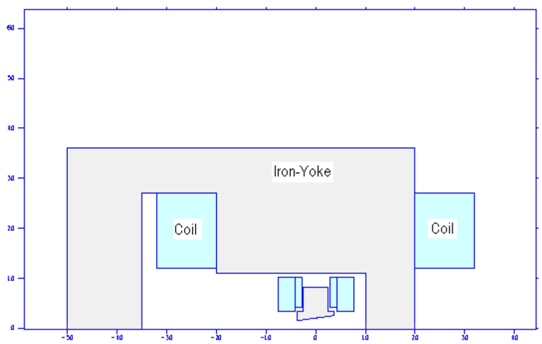

Figure 1(a): Layout of the magnet for calculating the field of the Active magnetic channel M9 with POISSON code (which is in the Yoke penetration)

The design calculations have been done using POISSON code [2]. Figure (2a) and figure (2b) show M9 with a single coil and with step-coils. The maximum coil current used in the calculation is 423 Amp. Field in the Yoke penetration, where M9 will be situated, is simulated with POISSON code using model magnet as shown in fig (1a). is shown in fig. (3) when the central field of the K500 SCC magnet is of the order of 40 KG.

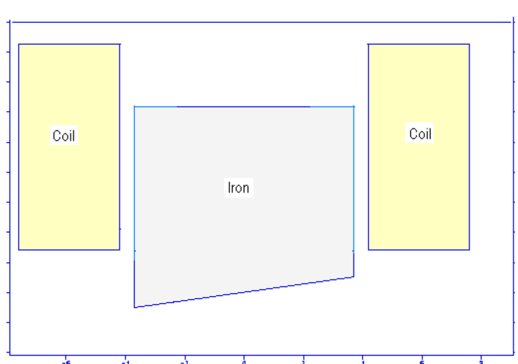

Figure 2(a): Geometry of the M9 channel used in POISSON calculation with a single coil.

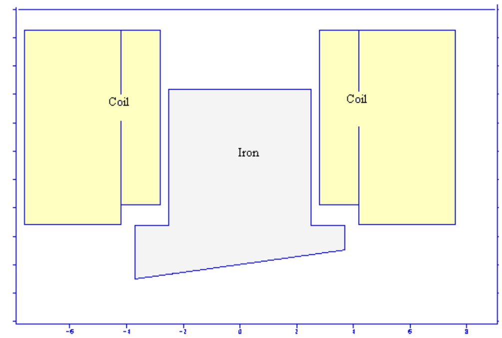

Figure 2(b): Geometry of the M9 channel with step coils used in POISSON calculation.

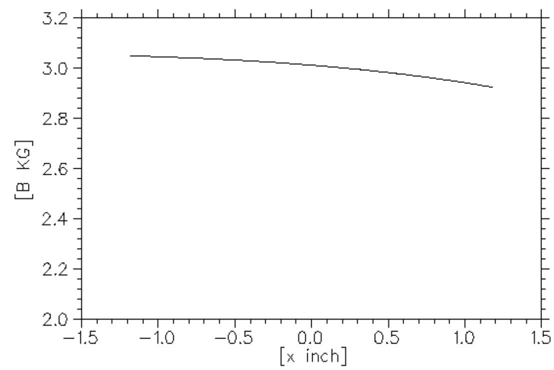

Figure 3: Field in the Yoke penetration where M9 will be situated, the central field of the K500 SCC magnet is of the order of 40 KG

Table (1a) and table (1b) show the dipole and quadrupole components present in the field in the two cases. Using step coils we obtained more coil field contribution.

Table 1(a): M9 with single coil

Current [Amp]	Magnetic field $B=B_0+B_1.x+B_2.x^2$	Dipole field B_0 [G]	Quadrupole Field B_1[G/cm]
+423	*9735 -635 x - 37 x^2*	*9735.*	*635.*
0	*6079 - 412. x - 10 x^2*	*6079*	*412.*
-423	*2455 - 161.x + 3.x^2*	*2455*	*161*

Simulations show that for different species, the central ray would make a ± 3° angle with the central line of the external high-energy beam line.

To get a steering of the order of 3° for the maximum rigidity beam (3.34 Tesla Meter) field required is of the order of 4 KG, which can be tuned with the new M9 coil design. Also field analysis shows that the sextupole component is less or comparable in the new design. After trial and correction procedure the cross section of the M9 found is shown in figure (2b). The magnetic fields and the field gradients are shown in fig. (3a) and (3b).

Table 1(b): M9 with step-coil

Current [Amp]	Magnetic field $B=B_0+B_1. X + B_2. X^2$	Dipole field B_0 [G]	Quadrupole Field B_1[G/cm]
+423	$B = 9735. - 635. x - 37. x^2$	*9735.*	*635.*
0	$B = 6079. - 412. x - 10\, x^2$	*6079*	*412.*
-423	$B = 2455. - 161.x + 3.x^2$	*2455*	*161*

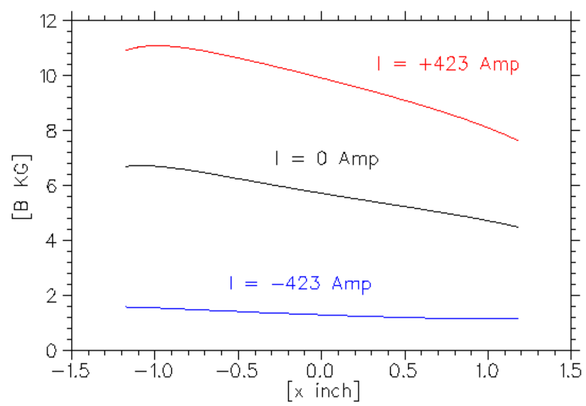

Figure 3(a): Plot of x ~ B (magnetic field across the cross-section) for the step-coil M9.

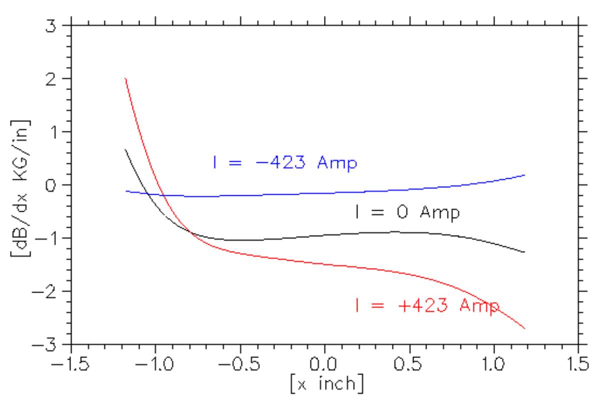

Figure 3(b): Plot of x ~ dB/dx (magnetic field gradient across the cross-section) for the step-coil M9.

Phase space ellipse tracking through the magnetic channel M9 is shown in figure (4). The area of the phase space ellipse taken in the calculation is 10 π mm-mrad. Ninety-four points have been taken in the perimeter of the ellipse and they are tracked through the magnetic channel M9 by running computer routines basically integrating the equations of motion. The output ellipses show that there is no distortion.

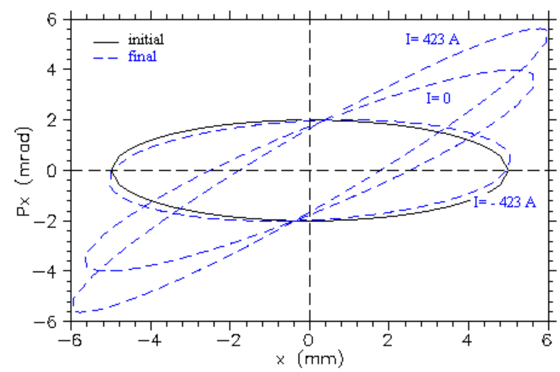

Figure 4: Shows radial phase space ellipses at the entrance and exit of the active ninth magnetic channel. Emittance = 10 π mm-mrad

NOTES

There is an option of changing the iron profile after the actual field measurement of the VECC K500 Superconducting Cyclotron, which will be done this year.

REFERENCES

[1] Bikash Sinha and Rakesh Kumar Bhandari, “Status of the Superconducting Cyclotron Project at VECC” Presented in The 3rd Asian Particle Accelerator Conference Korea, 2004.

[2] POISSON/SUPERFISH Reference Manual, Los Alamos Accelerator Code Group MS H829