Design Study of the Injection System of the RIKEN Superconducting Ring Cyclotron

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Abstract

The Construction of two superconducting ring cyclotrons, SRC-4 and SRC-6 has been proposed at RIKEN as post accelerators of the existing ring cyclotron. A conceptual design of the injection system for SRC-6 is described. Structures and magnetic fields of a magnetic inflection channel and a bending magnet, which are required to be superconducting, are discussed.

1 INTRODUCTION

In the RI beam factory project,[1] two a superconducting ring cyclotrons (SRC-4 and SRC-6) is designed to boost the energy of the ion beams from the existing RIKEN ring cyclotron (RRC) up to 400 MeV/u for light ions such as carbon and 150MeV/u for very heavy ions such as uranium.

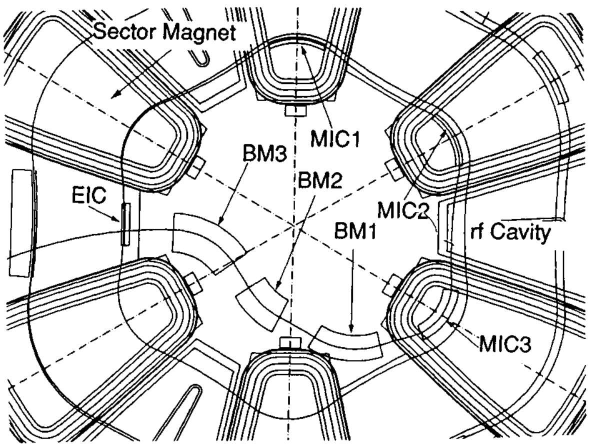

Figure 1: The Schematic layout of the SRC-6 and an example of an injection trajectory.

Figure 1 shows one of injection trajectories in SRC-6 now under consideration. A beam is injected through one of the valleys into the central region of the SRC and is radially guided to the 1st equilibrium orbit. The transport system consists of three bending magnets (BM1, BM2, BM3), three magnetic inflection channels (MIC1, MIC2, MIC3) and an electrostaitc inflection channel (EIC). The injection energies requiered to get the maximum output energies for three kinds of beams are shown in Table 1.

	Charge	E_inj (MeV/u)	E_ext (MeV/u)
^{16}O	7+	126.7	400
^{84}Kr	30+	102.1	300
^{238}U	58+	58.0	150

Table 1. The energies of injected beams to SRC-6 required for the maximum energy acceleration.

The MICs are inserted between the poles of the sector magnets to increase the bending power of the sector field locally. The EIC is placed in the position where the injection trajectory is matched finally with the 1st equilibrium orbit. Characteristics of the injection elements are summarized in Table 2. The three bending magnets and MIC3 require to use superconducting coils to achieve the required fields. The sizes of the elements must be small enough so that they can be placed within the limited available space in the SRC centeral region.

Element	ρ (m)	θ (deg)	ΔB or ΔE
EIC	17	3.4	100 (kV/cm)
MIC1	21	2.2	0.12 (T)
MIC2	1.3	51.5	0.22 (T)
MIC3	1.1	56.5	0.95 (T)
BM1	1.2	52.0	4.53 (T)
BM2	1.3	89.8	4.21 (T)
BM3	1.5	34.6	3.70 (T)

Table 2. Characteristics of the injection elements for SRC-6.

2 MIC3

Figure 2 shows a cross section of the MIC3 designed. The MIC3 consists of a main coil and a compensation coil. The coils are indirectly cooled by 4.2 K liquid helium via the coil housing made of Al alloy. This two-coil system provides the required field profile up to 0.95T in the bore of the inflection channel and with a small magntice field disturbance in the acceleration region as shown in Figure 3. Required current density of the coil for this profile is about 230A/mm2 . It is about 50% of the critical current of the superconducting wire (Cu/NbTi: 2.0). We need to analyze the beam diffusion to assure that the dissipated energy in the superconductors does not reach the quench limits. It is now in progress.

The electromagnetic force on the coils were calculated using TOSCA code. The radial forces were estimated to be 13N/mm2 (expansion) and -7.3 N/mm2 (shrink) for the main coil and the compensation coil, respectively. Finite element analysis of the MIC's structure were carried out using NASTRAN code. Deformations for the structure were calculated for two load cases: a) at room temperature with magnetic loading and b) after cooling to 4.2 K with magnetic loading as shown in Figure 4. This result showed that alminum support structure kept the coil compressive.

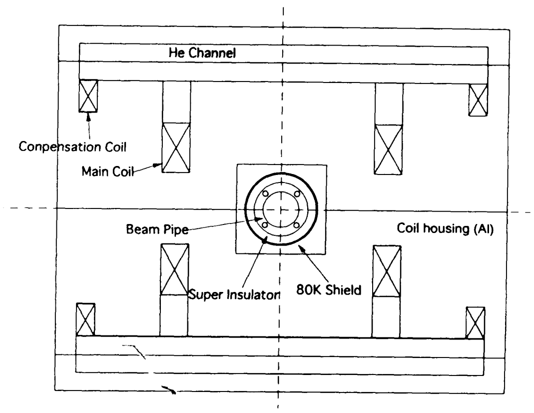

Figure 2. Cross section of MIC1.

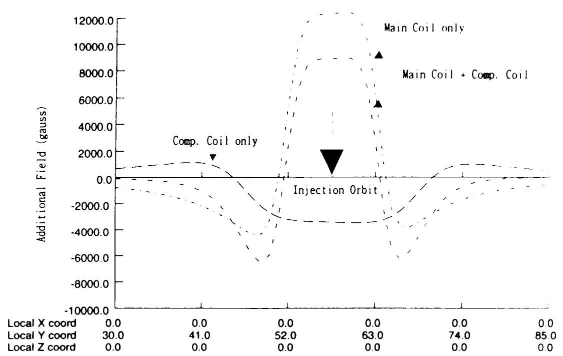

Figure 3. Field profile of MIC3

3 BM1

There are two main dificulties in the design of BM1. One is that we can not use iron yoke because of the fringing field from the sector magnet. The other is that there is limited space to install BM1. The allowed distance between the injection trajectory and the end of the cryostat of BM1 is about 20cm. A cross section of BM1 preliminary designed is shown in Figure 5. Two type of coils, iron pole and iron shim are used to generate required fields. Figure 6 shows a field profile calculated using POISSON. Analysis for the mechanical and cryogenical stability is in investigation.

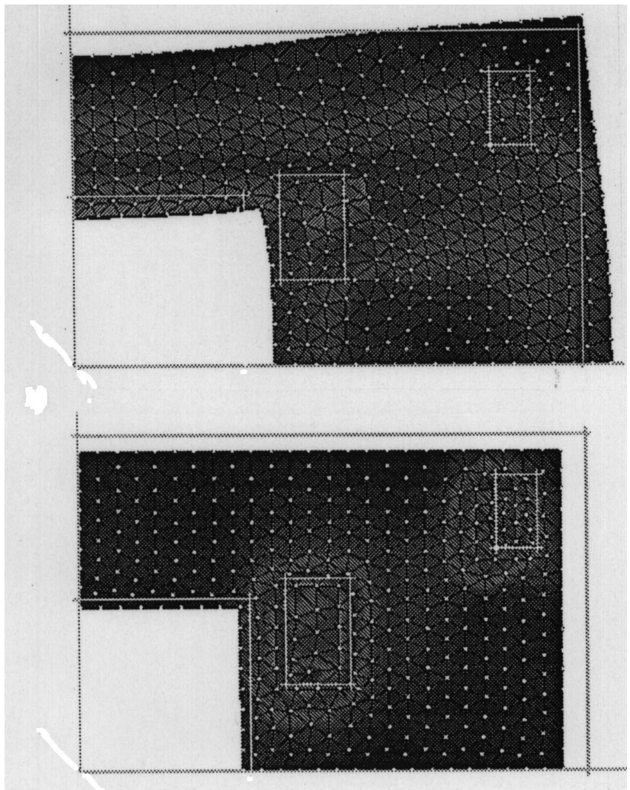

Figure 4. Deformations from structure analysis: a) at room temperature with excitation, b) after cooling to 4.2K.

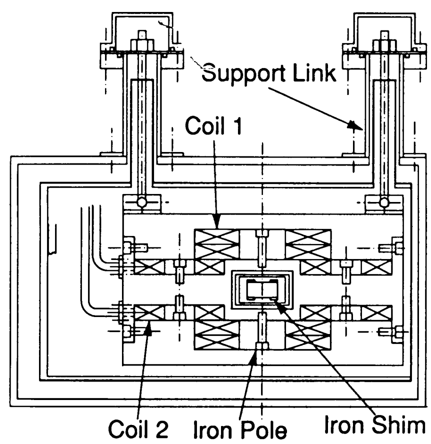

Figure 5. Cross section of BM1.

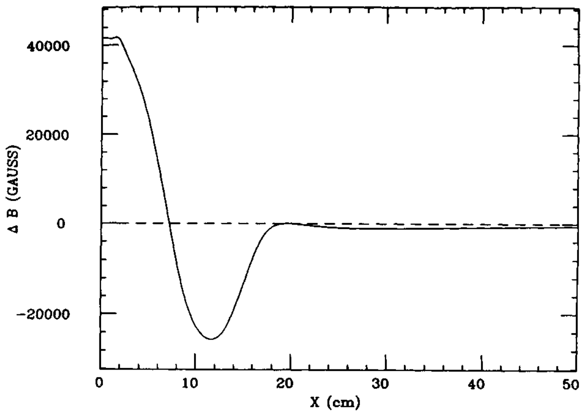

Figure 6. Field profile of BM1 calculated using POISSON code.

REFERENCES

[1] Y. Yano, et al.: 'RIKEN RI Beam Factory Project' These proceedings p. ???.