BEAM INJECTION AND EXTRACTION SYSTEM OF RIKEN RING CYCLOTRON

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Summary

From September to December 1985, we carried out comprehensive magnetic field measurements, installing the beam injection and extraction elements at each due position. The magnetic field maps inside the elements as well as those in the sector magnets were measured. The magetic field distributions inside the elements were obtained nearly as expected. On the basis of these data, small modifications were made for some of the elements to improve the distributions. The magnetic field perturbations in the sector magnets could be corrected by the trim coils.

At present, October 1986, the whole systems of the RIKEN Ring Cyclotron have been completely assembled and are on standby for commissioning.

Layout of the beam injection and extraction system and functions of its each element are described together with some of the measured data.

Introduction

The RIKEN Ring Cyclotron has two types of injectors: the RILAC and the K70 AVF cyclotron. A beam accelerated by one of these injectors is led to the Ring Cyclotron through an injection beam transport line, which is positioned 4 m above the median plane of the Ring Cyclotron. In the north-west valley of this Cyclotron, a beam is levelled down to the median plane at a slope of 45 degrees by a "canted injection system". It consists of a couple of 45-degree vertical bending magnets, a couple of quadrupole doublets, a quadrupole singlet, steering magnets and beam diagnostic devices. This system makes achromatic beam transport in vertical direction possible. The quadrupole magnets, steering magnets and the drift spaces between them are screened from the leakage magnetic flux from the sector magnets.

Figure 1 shows a layout of the beam injection and extraction system and Table 1 lists its characteristics. In the central region of the Cyclotron, a beam is put onto the median plane by BM2, one of the vertical bending magnets mentioned above, and is guided radially to the first acceleration orbit by following elements: a bending magnet, BM1, a couple of magnetic inflection channels, MIC2 and MIC1, and an electrostatic inflection channel, EIC.

The beam accelerated up to the outermost radius is peeled off by an electrostatic deflection channel, EDC, and is extracted out of the Cyclotron through a couple of magnetic deflection channels, MDC1 and MDC2. A couple of bending magnets, EBM1 and EBM2, lead the extracted beam to the beam handling system.

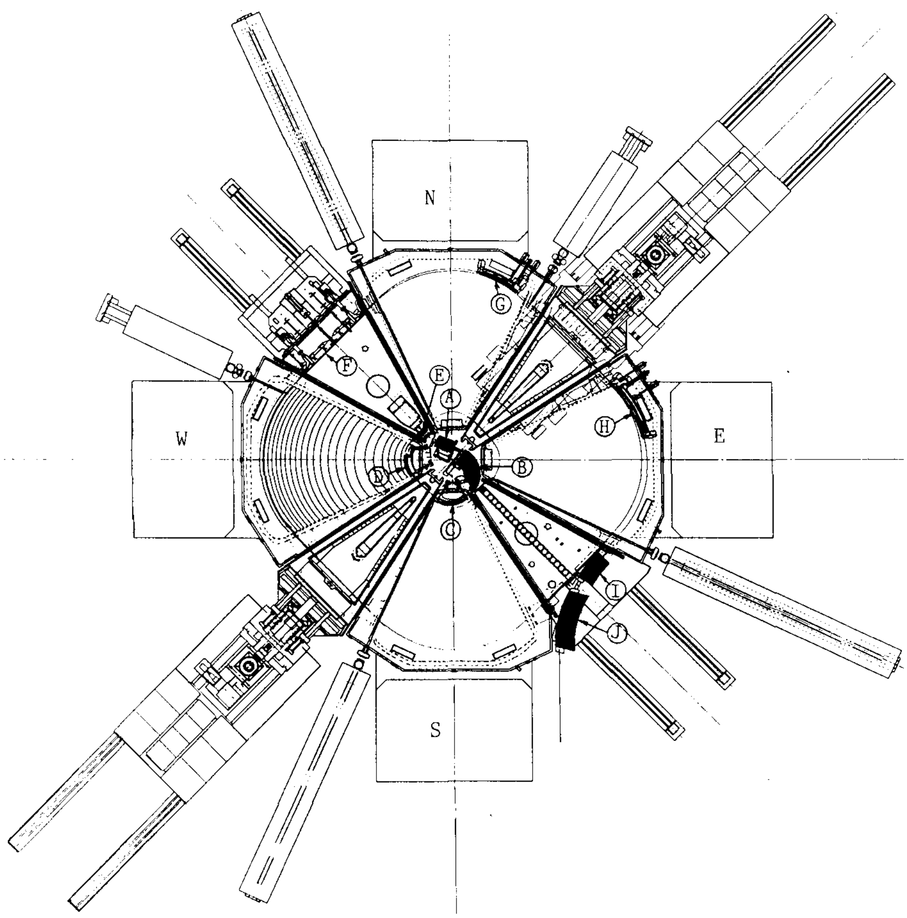

Fig. 1 Layout of beam injection and extraction system.

(A) 45-degree vertical bending magnet (BM2)
(B) Radial bending magnet (BM1)
(C) Magnetic inflection channel (MIC2)
(D) Magnetic inflection channel (MIC1)
(E) Electrostatic inflection channel (EIC)
(F) Electrostatic deflection channel (EDC)
(G) Magnetic deflection channel (MDC1)
(H) Magnetic deflection channel (MDC2)
(I) Extraction bending magnet (EBM1)
(J) Extraction bending magnet (EBM2)

Bending Magnets

The bending magnets are of a modified window-frame type. We adopted this type of magnets to produce a uniform field distribution and to reduce a current density in the coils. They are placed in the atmosphere and fixed in position.

Table 1 Characteristics of the beam injection and extraction system.

Element	Radius of Curvature	Bend Angle	Maximum Field	Gap Width	Entrance/Exit Face Angle
BM2	46.0 cm	45.0 deg.	1.66 T	42.0 mm	45.0/0.0 deg.
BM1	45.7	102.75	1.67	42.0	15.0/-13.5
MIC2	41.5	78.69	1.87		
MIC1	49.8	39.7	1.59		
EIC	364.5	3.62	50.0 kV/cm	18.0	
EDC	straight	1.08	50.0	18.0	
MDC1	212.6	17.79	1.62 T		
MDC2	229.9	24.66	1.51		
EBM1	229.5	15.0	1.51	42.0	
EBM2	215.0	30.2	1.61	42.0	15.0/15.0

There is no element between BM2 and the steering magnet, the downstream element of the canted injection system, which is placed above the main coils of the north sector magnet. The beam pipe between them is doubly screened from the strong leakage field from the sector magnet by square cross section of soft-iron shieldings. A dummy shielding of the same shape is placed symmetrically with respect to the median plane of the Cyclotron. On the beam-entrance side of BM2, a magnetic field clump is mounted which has a symmetric shape with respect to the above plane. This field clump absorbs the leakage magnetic flux from BM2, which is harmful to the accelerated beam because it sweeps out the beam vertically. We observed that there is no field component which sweeps the accelerated beam vertically and steers the injected beam radially inside BM2 when the sector magnets are energized. The entrance face angle of BM2 (45 degrees) was determined to keep enough space for installing BM2 in the narrow central region. The adjustment of vertical bending of the beam is made by the combination of BM2 and the steering magnet mentioned above. To facilitate this adjustment, a four-needle probe is set between BM2 and BM1.

Eight turns of twenty-four turn coils of BM1 are divided into two portions: a beam entrance and an exit sides as shown in Fig. 2. Different magnetic field strengths can be set in each portion with two power supplies. This enables BM1 to have a function of steering the beam radially both in its position and direction. The exit face angle of BM1 was determined to make the dispersion matching in the first approximation possible.

BM2 is a H-shape magnet and the other three bending magnets are C-shaped. These magnets have the same pole profile. Figure 3 shows this pole profile and coil windings configuration together with the

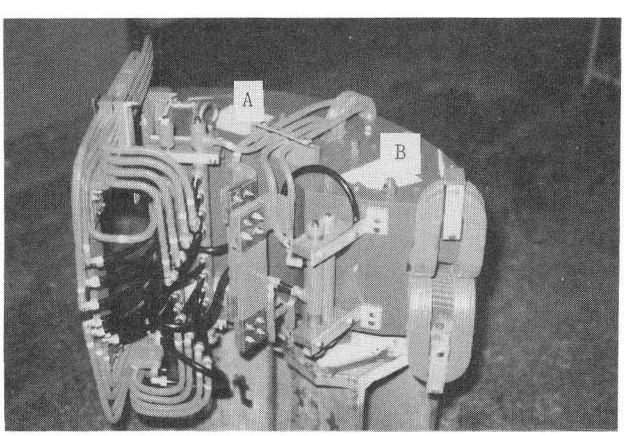

Fig. 2 Photograph of BM1. (A): Beam entrance side (B): Beam exit side. The end profile of pole is approximated by Rogowski's curve.

measured radial field distributions of BM1. EBM2 has additional coil windings surrounding the outer coils indicated in Fig. 3.

The bending magnets perturb the sector field. We found that such perturbations can be corrected by the trim coils.

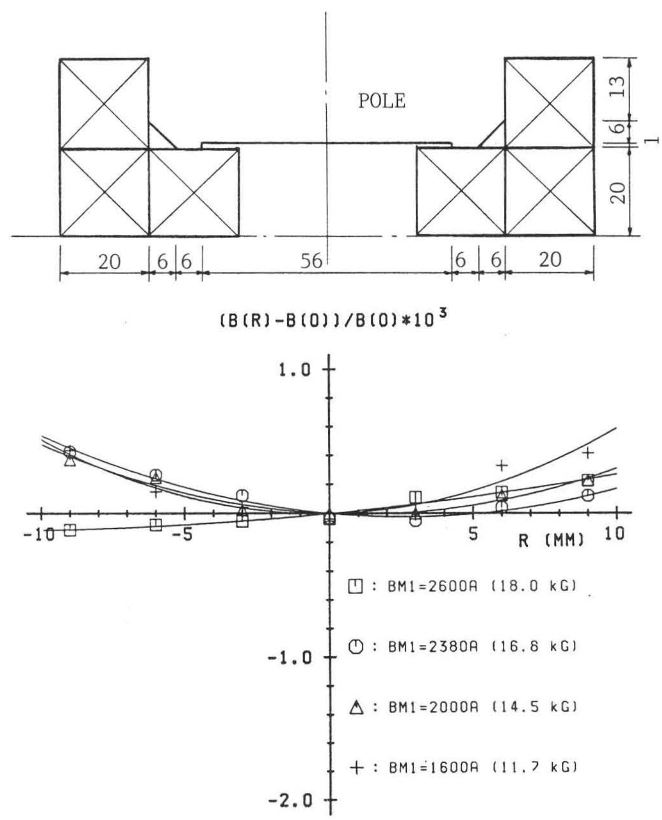

Fig. 3 Top: Pole profile of the bending magnets.
Bottom: Measured radial field distributions of BM1.

Magnetic Channels

The magnetic channels are inserted between pole gaps of the sector magnets (the effective gap space for installing them is 52 mm wide). They are fixed in position, but their positions can be adjusted manually from outside the vacuum chamber. MIC1 and MIC2 consist of floating iron shims and coils, while MDC1 and MDC2 consist of coils only. The configurations of the iron shims and coils or the coils were designed so that uniform magnetic fields of a sextupole component better than $1\text{x}10^{-3}$/cm can be produced inside the channels. Every magnetic channel except MIC2 is equipped with the other coils wound by the side of the above coils. Such coils are called "compensation coils" and are used to reduce the magnetic field perturbations brought about by the magnetic channels in the sector fields outside them. These compensation coils and the coils for adjusting the beam trajectory are connected in series. MIC2 has no compensation coils because of the lack of space. The iron shims and coils are mounted on a stainless-steel frame; these are contained with a vacuum tight case of 3 mm thick stainless steel plates. The beam passage is provided by a stainless-steel pipe of 24 mm ϕ in aperture. The inside of this vacuum-tight case is filled with epoxy resin.

Figure 4 and 5 shows the configuration of the iron shim and coils and the measured radial field distributions of MIC2 and MDC1, respectively. As for the magnetic channels having the compensation coils we observed that the sector field does not change when a current is fed to the coils. The perturbed field in the sector magnet by MIC2 can be corrected by the trim coils.

Electrostatic Channels

The electrostatic channels are of a conventional type. Their radial positions at beam entrance and exit can be remotely adjusted by 10 mm and 40 mm in full range for EIC and EDC, respectively. The maximum dc voltage of 90 kV could be successfully applied to the 18 mm wide gap between the anode and the cathode.

Figure 6 shows EDC installed inside the valley vacuum chmaber.

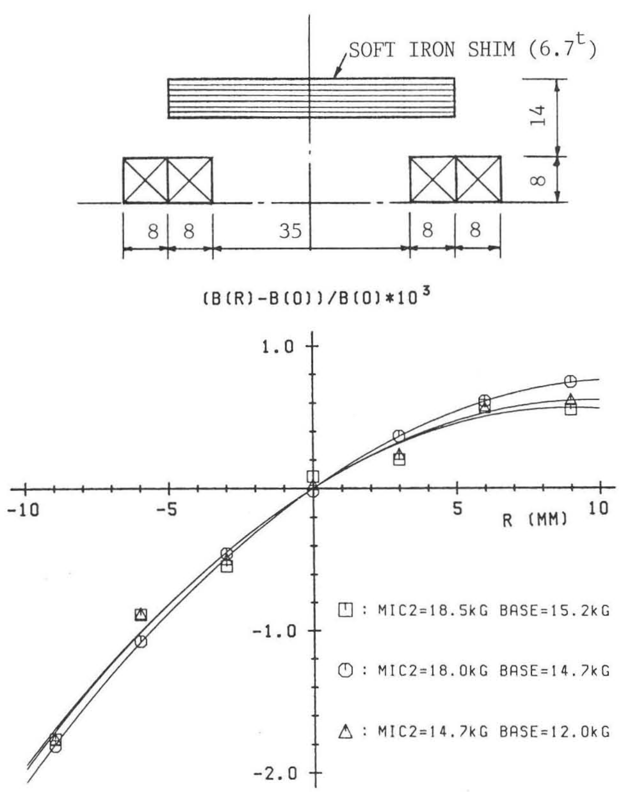

Fig. 4 Top: Configuration of iron shim and coils of MIC2.
Bottom: Measured radial field distributions.

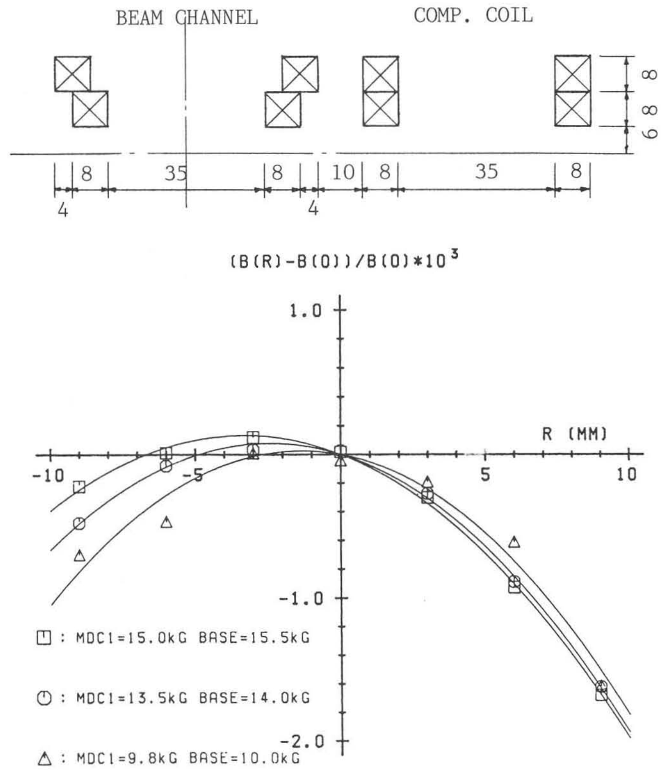

Fig. 5 Top: Configuration of coils of MDC1.
Bottom: Measured radial field distributions.

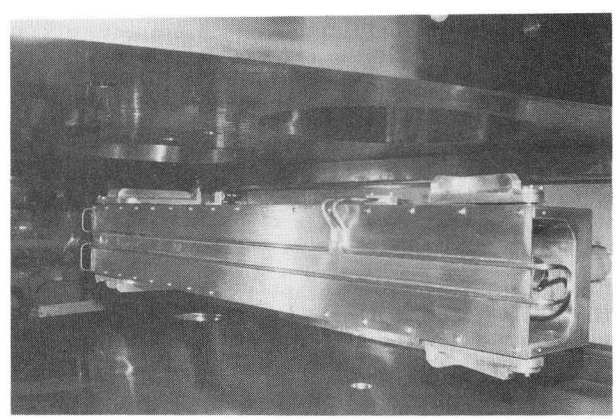

Fig. 6 Photograph of EDC.