CONSTRUCTION OF THE RCNP RING CYCLOTRON

I. Miura, T. Yamazaki, A. Shimizu, K. Hosono, T. Itahashi,
T. Saito, A. Ando, H. Ogata, I. Katayama, T. Nakatsuka, M. Kondo and H. Ikegami
Research Center for Nuclear Physics, Osaka University
Minogaoka 10-1, Ibaraki, Osaka 567, Japan
and
J. Abe
Accelerator Business Center, Techinical Department, Sumitomo Heavy Industries Ltd.
Niihama, Ehime 792, Japan

Abstract

The main components of the new facility are a six separated spiral sector cyclotron (ring cyclotron) and a beam circulation ring linked to a high precision dual magnetic spectrograph system. The injector is the RCNP AVF cyclotron. The construction of the new facility made steady progress along the four year schedule started from 1987. The main components of the ring cyclotron are fabricated and passed preliminary tests of the performance. Installation of the ring cyclotron system in the new building will be started in February 1990. The first beam is expected early in 1991.

Introduction

The plan view of the new facility is shown in Fig. 1. The main components is a ring cyclotron, a beam circulation ring linked to a high precision dual magnetic spectrograph, a neutron TOF facility, a heavy ion secondary-beam facility and a pion spectrometer[1].

The ring cyclotron is energy quadrupoler of the present RCNP AVF cyclotron. With this accelerator system, beams of p, d, ^{3}He, alpha and light-heavy ions can be accelerated up to 400, 300, 510, 400 and 400·Q^2/A MeV, respectively. Maximum energies of various ions from the ring cyclotron and several major projects are shown in Fig. 2. An emphasis is placed on the design to produce high quality beams for precise experiments in the range of intermediate energy.[2]

General description

Plan view of the ring cyclotron is shown in Fig. 3. Three single gap acceleration cavities are used in the ring cyclotron. Frequency range of the cavity is 30~52 MHz and harmonic numbers of acceleration is 6, 10, 12 and 18. An additional single gap cavity is used for flat-topping with third harmonic of acceleration frequency to get energy resolution better than 10^{-4}.

A 180°-single-dee acceleration cavity is used in the present AVF cyclotron. The frequency range of the cavity is 5.5~19.5 MHz, and fundamental and 3rd harmonic acceleration modes are used. Fig. 4 shows relation between orbital frequencies and acceleration frequencies in the present AVF cyclotron and the ring cyclotron for various ions and energies. the characteristics of the cyclotrons are given in Table 1.

For the preparation of ideal injection beams for the ring cyclotron in longitudinal phase space, a beam bancher system operated in 2nd harmonic of acceleration frequencies of the ring cyclotron is being proposed.

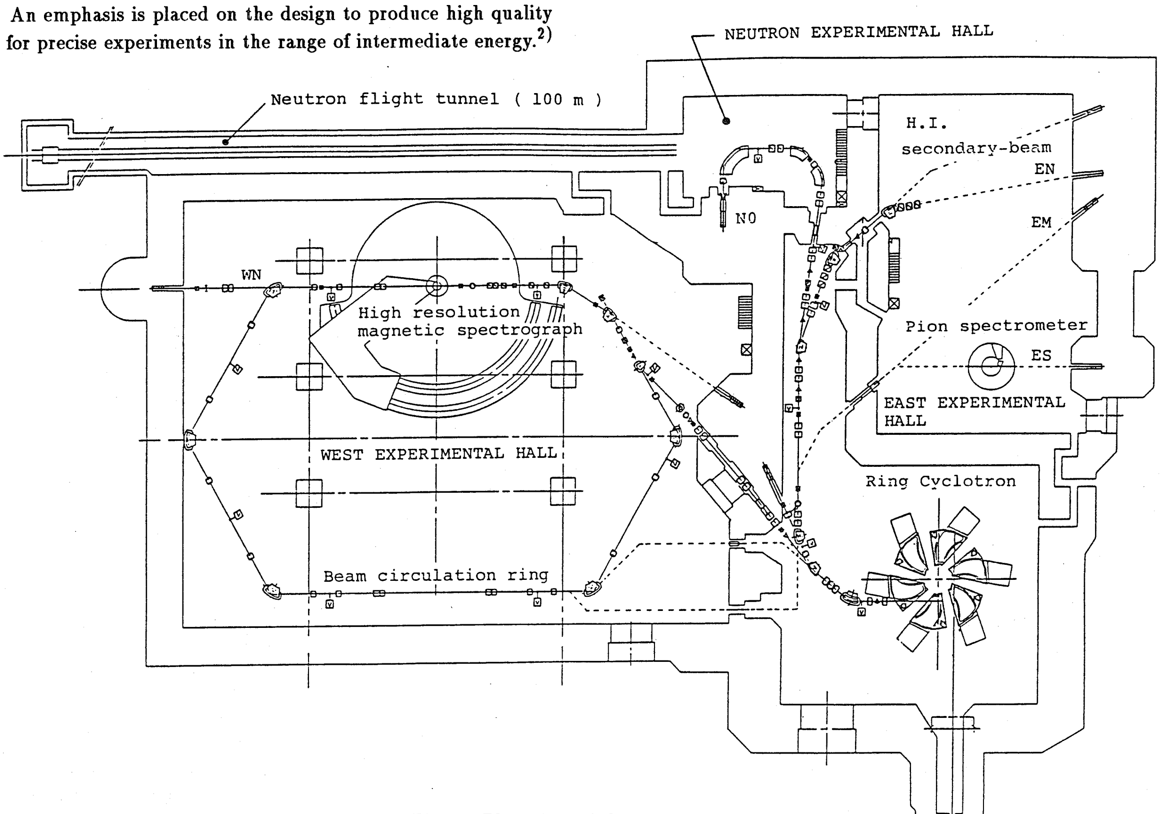

Fig. 1. Plan view of the new facility.

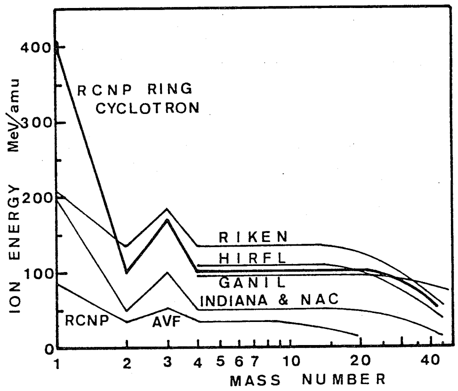

Fig. 2. Expected maximum energies of various ions for the RCNP ring cyclotron and several major projects.

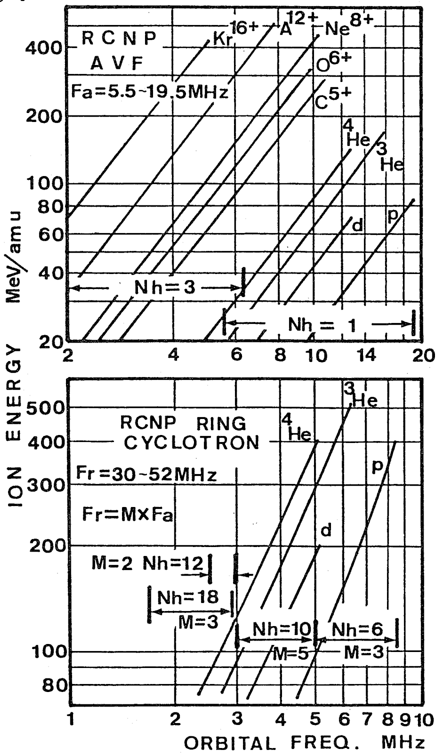

Fig. 4. Orbital frequencies, acceleration frequencies and harmonic numbers of acceleration in the present AVF cyclotron and the RCNP ring cyclotron. M is ratio of the RF frequency of the ring cyclotron to the AVF cyclotron.

Magnets of the ring

the sector magnet of the six separated sector ring cyclotron were designed by using a computer code FIGER[3] (artificial magnetic field distribution generator) and the results of model magnet study of the previous proposal.[4] A preliminary measurements of the magnetic field distribution have been performed in the factory. The results are quite satisfactory.[5] The complete field measurements are scheduled to start in August 1990.

Acceleration system

Single-gap type acceleration cavities were used to reduce RF power loss and cavity size. The size of the cavity reduced much by using capacitive tunning with a pair of rotatable plates. The radial voltage distribution of the acceleration cavity is convex shape and radially increasing.[6] This voltage distribution is suitable to get wide phase acceptance with flat-topping.

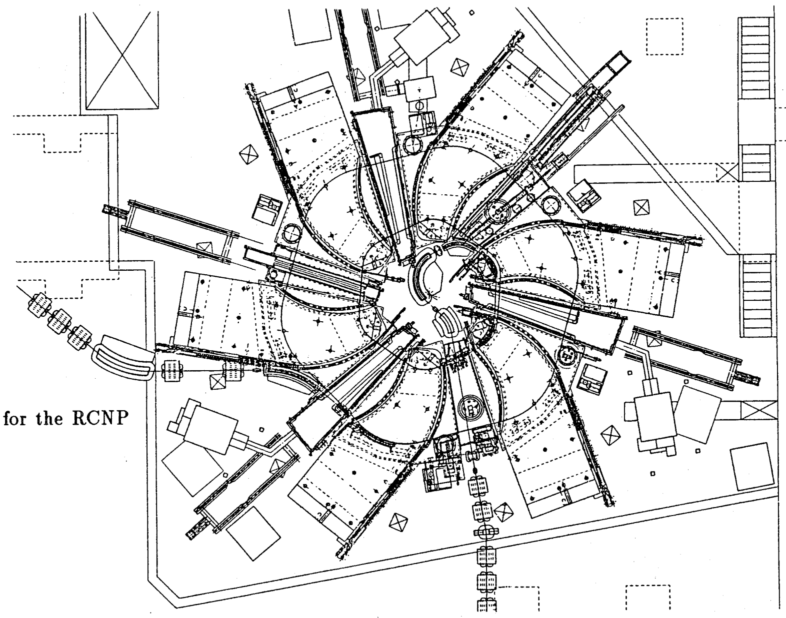

Fig. 3. Plan view of the ring cyclotron.

A single gap cavity is used for flat-topping. The upper and lower walls of the cavity can be slid as inductive-tunner-plates. A very much similar radial voltage distribution as that of the acceleration cavity was realized for the flat-topping cavity.

Three RF power amplifiers for the acceleration cavities were fablicated. The amplifiers generated 250 kW RF power on a dummy load. Preliminary measurements on the shunt impedance of the cavities and matching condition of the coupling loops have been done.[7]

RF power test with non-evacuated cavities will be started also in August 1990.

Table 1

Characteristic of cyclotrons

	Injector Cyclotron	Ring Cyclotron
No. of sector magnets	3	6
Sector angle	max 52°	22~ 27.5°
Injection radius (cm)		200
Extraction radius (cm)	100	404
Magnet gap (cm)	20.7 min	6.0
Max. Magnetic field (kG)	19.5	17.5
Proton max. energy (MeV)	84	400
Alpha particle energy (MeV)	130	400
^{3}He energy (MeV)	160	510
Weight of magnet (ton)	400	2100
Main coil magnet (kW)	450	440
No. of trim coils	16	36
Trim coil power (kW)	265	350
No. of cavities	1	3(Acc.) 1(FT)
RF frequency (MHz)	5.5~19.5	30~52 90~155
RF power (kW)	120	250×3 45

Injection and extraction

The injection and extraction systems of the ring cyclotron[8] satisfy the central-position phase matching condition (dispersion matching). A variable dispersion system follows the extraction system of the ring cyclotron to cancel the velocity dependent momentum dispersion ($D=R_{ex}(1-\beta^2)$) of a relativistic isochronous cyclotron at extraction radius (R_{ex}).

Orbit analyses for accelerated beams

The orbital properties of the accelerated beams in the ring cyclotron were studied in simulated magnetic field distribution.

The sine wave acceleration voltage in the ring cyclotron produce energy broadening of 700 keV for 400 MeV proton beams having RF phase width 7°. this energy broadening can be canceled perfectly with only one flat-topping cavity, without evident radial-longitudinal coupling effect. If the RF phase errors between the cavities are less than $\pm 0.1°$, the energy width of the 400 MeV protons is less than 10^{-4}.

The orbit properties of the beam along the injection and extraction elements in the ring cyclotron also studied. The turn separations at injection and extraction points are 10mm and 3mm, respectively.

The wide phase acceptance for single turn extraction mode with flat-topping is desirable to get high intensity beams. The phase acceptance depend much for the radial distribution of the acceleration voltage.

Fig. 5 shows result of calculation on the properties of the accelerated beam in radial and longitudinal phase space. The simulated magnetic field distribution and the measured radial voltage distributions of the cavities are used for the calculation. Phase acceptance more than 20° in width can be expected for the acceleration frequency.

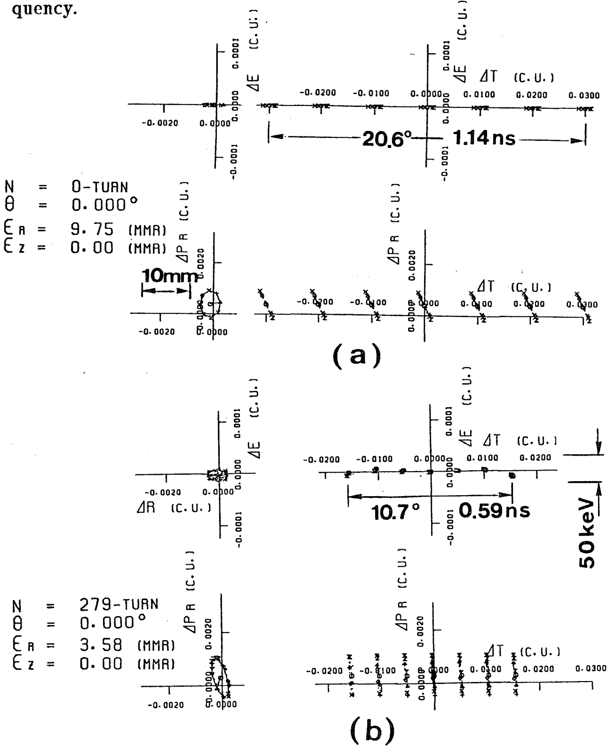

Fig. 5. Beam profiles projected in radial and longitudinal subspace and its coupled space.
(a): before acceleration (63.7 MeV protons).
(b): after acceleration (400 MeV protons) with flat-topping.

Vacuum system

The vacuum chamber of the ring cyclotron consists of six magnet chambers, three acceleration cavity chambers, a flat-topping cavity chamber and two valley chambers as shown in Fig. 3. The gaps between these chambers are sealed by puneumatic expansion seals. The reliability of the seals was verified with a prototype of the seal.[9]

Evacuation tests of perfectly assembled magnet chambers and cavity chambers were done. The results were better than designed values. After 10 hours of evacuation, the acceleration chamber can be pumped down to 2×10^{-7} Torr.

Beam diagnostic system

Layout of the beam diagnostic system, design of the diagnostic elements and the format of graphic display for the diagnostic data has been determined.[10]

Control system

The present control system of the AVF cyclotron will be used without any modification. For the ring cyclotron, new computer control system are developed.[11]

The control system of the ring cyclotron and the beam transport system consists of a system control computer (micro VAX 3500), four group control units (one micro VAXII and three RTVAX) and many universal device controllers.

A twin operator console of the ring cyclotron will be installed near by the present operator console of the AVF cyclotron and connected directly to the system controller.

Each group control computer is connected to the system control computer through a computer network Ethernet. Each group control computer is also connected to universal device controllers through optical fiber serial lines. The setup sequence of the ring cyclotron operation can be described by language OPELA and controlled by the group control computer.

References

1) S. Morinobu et al., Construction of Experimental Apparatuses and Beam Line, RCNP Annual Report 1987.

2) H. Ikegami, Proc. 12th Int. Conf. on Cyclotrons and their Applications, Berlin (1989),
I. Miura et al., RCNP Annual Report 1986, Proc. Third Japan-China Joint Symposium on Acc. RIKEN (Japan) 1987.

3) I. Miura et al., A Computer Code FIGER, Proc. of the 4th Symposium on Acc. Science and Technology, RIKEN (Japan), 1982.

4) K. Hosono et al., Spiral Sector Magnet of RCNP Ring Cyclotron Project, RCNP Annual Report 1984.

5) K. Hosono et al., presented at this symposium.

6) T. Saito et al., Proc. 12th Int. Conf. on Cyclotron and their Applications, Berlin (1989).

7) I. Miura et al., presented at this symposium.

8) A. Ando et al., Proc. 12th Int. Conf. on Cyclotron and their Applications, Berlin (1989).

9) A. Shimizu et al., presented at this symposium.

10) T. Itahashi et al., presented at this symposium.

11) T. Yamazaki et al., presented at this symposium.