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CURRENT STATUS OF THE RCNP RING CYCLOTRON

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Abstract

Experimental studies with the RCNP Ring Cyclotron were started from 1992. Energy resolution of 25keV was obtained with high resolution spectrograph Grand Raiden for 300MeV proton beam of 80keV energy width by using dispersion matching. A very short polarized proton beam pulse of 150ps was achieved for neutron TOF experiment. A new high intensity polarized proton and deuteron ion source, a new axial injection system and injection beam line for polarized ion source and Neomafios were installed in August 1994. The old RCNP AVF cyclotron has been used as injector cyclotron without any modification. On this scheduled summer shutdown, the control system and the main magnet power supply of the AVF cyclotron were replaced by a new one. Many improvement on the stability and the controllability of the AVF cyclotron can be expected. On January 17th, 1995,the Ring Cyclotron was displaced about 5mm by the earthquake. The realignment of the system had been made and experimental studies are started in May.

I. Introduction

The construction of the RCNP ring cyclotron was started in 1987. The first extracted beam was obtained in 1991[1]. The ring cyclotron is energy quadrupler of the RCNP AVF cyclotron. Proton and alpha particles can be accelerate up to 400MeV. The K value for light-heavy ions acceleration is 400. Table 1 shows the accelerated ions and the energies by the ring-cyclotron[2]. For 400Mev proton beam acceleration, 30-50% of accelerated beam was lost by axial oscillation driven with median plane error near ν_z=1 resonance for unproper setting of the trim coil currents[3]. However no beam loss was observed for smooth surface current density distribution of the trim coil[4].

Plan view of the ring cyclotron is shown in Fig.1. Three single gap acceleration cavities are used in the ring cyclotron. Frequency range of the cavity is 30-52 MHz. An additional single gap cavity is used for flat-topping with 3rd harmonic of acceleration frequency to get good energy resolution and wide phase acceptance for single turn extraction mode[1].

The phase acceptance is 20° for energy deviation with flat-topping within 10^{-4}. A 180°-single-dee acceleration cavity is used in the injector cyclotron. The frequency range of the cavity is 5.5-19.5MHz. The phase acceptance of the injector cyclotron is 7° and 4°, since the ratio of acceleration frequency of the ring cyclotron to the injector cyclotron is 3 and 5 for proton and alpha, respectively. In order to get high quality injection beam for the ring cyclotron, the six dimensional phase space volume of the injection beam is limited by various slits between the ion source and the ring cyclotron. The beam intensity reduction about 10^{-2} with these slits is very serious for polarized beam and heavy ion beam. The beam intensity upgrade project had been done in 1994[5,6,7]. Many efforts are being continued to improve beam quality, stability and intensity of the ring cyclotron. Injection beam instabilities caused by main coil and trim coil power supply of the injector cyclotron was serious problem. The beam stability upgrade project of the injector cyclotron was done in this summer[8,9,10].

Table 1 Accelerated Ions and the energies

Proton	100,200,250,300,350,365,380, 390,400 MeV
Deuteron	150,170,200 MeV
^{3}He	450 MeV
Alpha	300,400 MeV
$^{14}N^{7+}$	560,980 MeV

II. BEAM INTENSITY UPGRADE PROJECT

1. New axial injection system

Old axial injection line with electrostatic quadrupole lenses was replaced by new system with Glaser lenses, sawtooth buncher and spiral inflector to get a high-transmission and stable operation. Fig.2 shows layout of the injection line. The direction of magnetic field in the Glaser lenses is excited alternately to cancel the depolarization effect of the lens. The obtained injection efficiency for 65MeV proton is 14%[5,7].

2. High intensity polarized ion source

A new atomic beam type polarized proton and deuteron source with cold(30K) nozzle, NEOMAX sextuple magnets and ECR ionizer. A maximum proton current of 8μ A was obtained for 65MeV. The polarization is about 0.75. The polarized ion source is horizontal type and easy for maintenance. The polarized protons and deuterons are deflected upward by 6.7 and 15 degrees respectively with electrostatic deflector and deflected downward by 96.7 and 105 degrees with a following dipole magnet to get longitudinally polarized beam in the vertical beam line[5,7].

3. NEOMAFIONS

A 10GHz ECR ion source NEOMAFIOS is used as external ion source of the injector cyclotron from last September. Table 2, shows the beams accelerated for experimental studies[6,7].

III. BEAM STABILITY UPGRADE PROJECT

1. Control system of the injector cyclotron

It became difficult to maintain the old control system of AVF cyclotron. A new control system was needful to install a new high resolution high stability reference voltage for every power supplies of the AVF cyclotron. The main computer of the ring cyclotron control system was upgraded from micro VAX 4000/200 to micro VAX 4000/500. The control and monitor functions of the AVF cyclotron were concentrated to the ring cyclotron control system[8].

2. DC power supplies for the injector

The achieved long-term current stability of the new main magnet power supply is 4×10^{-6}. The long-term current stability better than 10^{-5} was obtained for the trim coil power supply by using HOLEC-DCCT-TOPACC. The remained old DCCT of the trim coil power supplies will be replaced soon by the new DCCT[9].

3. RF system of the ring cyclotron

Many efforts were made to improve stability of RF system. Typical phase excursion between acceleration and flat-topping voltages are 0.1deg/week. The voltage stabilities are 0.01% and 0.1% for the acceleration and flat-topping voltage respectively[10]. The development to improve stability of the RF system is being continued.

4. RF system of the injector cyclotron

The low-level RF system was replaced by new system very similar to the ring cyclotron RF system. Improvement on the stability is expected.

IV. DAMAGE AND IMPROVEMENT

1. Utility

Old chillers of the cooling water system and old air conditioning system for the AVF cyclotron were replaced by new one. PID temperature regulator of the cooling water was appended.

2. Repair of the cooling pipes

The Dee-electrode of the AVF cyclotron was overhauled to repair perfectly the cooling water leakage to vacuum.

3. The earthquake

The estimated maximum acceleration of the earthquake(January 17th,1995) on the RCNP is more than 300gal. About 5mm slip to north was occurred between the rest and the base-plate of the ring cyclotron. No damage of the elements was occurred. The rests and the base-plates were welded together after the realignment of the ring cyclotron system[2].

4. RF current contact of the ring cyclotron

After long exposure to the atmosphere during two months realignment of the ring cyclotron, the sliding RF current contacts (made of graphite admixed silver) failed on 300MeV proton acceleration position. The cavity wall was polished and the contacts were replace by pure silver contacts in this summer. The leaf springs of the RF current contacts of the acceleration cavity were degraded by three years operation on high temperature($\sim$ 300°C). The leaf spring is silver plated and made of Be-Cu alloy having electric conductivity about 20% IACS. The thermal conductivity of metal is nearly proportional to the electric conductivity. Cr-Zr-Cu alloy (85% IACS) leaf springs will be installed soon.

Table 2 Accelerated ions from Neomafios

	Energy AVF (MeV)	Beam current at exit (eμ A)
d	43.5	9
$^{3}H^{1+}$	32	4
$^{3}He^{2+}$	92.6	7.4
$^{4}He^{2+}$	120	3.2
$^{6}Li^{2+}$	64	0.042
$^{6}Li^{3+}$	131.1	0.088
$^{7}Li^{3+}$	114.0	0.242
$^{14}N^{4+}$	130.3	4.4
$^{14}N^{5+}$	210	2.3

Reference

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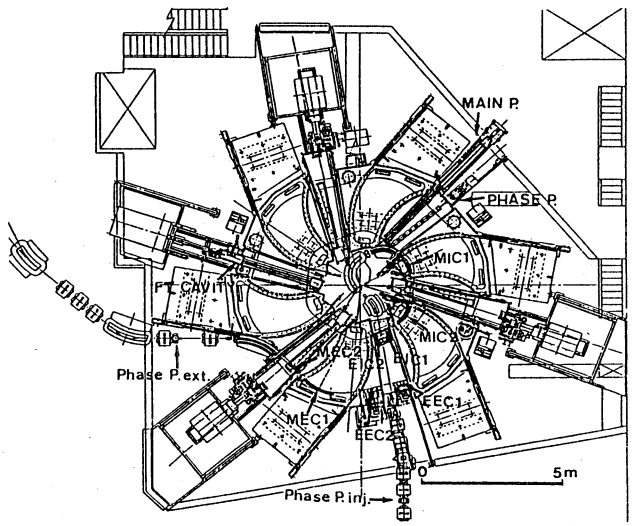

Fig.1 Plan view of the ring cyclotron.

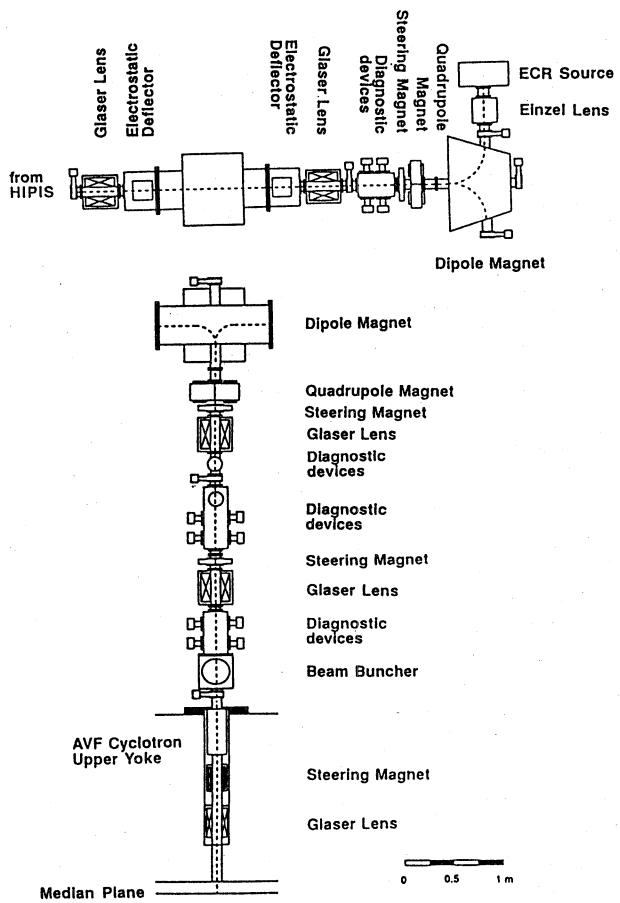

Fig.2 Layout of the injection line.