STATUS OF THE RCNP AVF CYCLOTRON

A. Shimizu, I. Miura, T. Yamazaki, K. Hosono, M. Inoue, T. Saito, T. Itahashi, N. Matsuoka, H. Sakai, K. Hatanaka, K. Nisimura*, H. Shimizu*, S. Nagamachi and M. Kondo

Research Center for Nuclear Physics, Osaka University
* Department of Physics, Kyoto University

Abstract

During the past five years, the AVF cyclotron at RCNP, open to outside users, has been operated well and used mainly for nuclear research experiments. The machine is able to deliver not only ordinary light ions but also polarized protons and deuterons and a variety of heavy ions with variable energies of wide range. Several developments have been made to increase the variety of ion species, to improve beam qualities, reliabilities and reproducibilities.

1. Operation

The details of the RCNP cyclotron is described elsewhere[1). The resonance conditions for ion acceleration by the cyclotron are shown in Fig. 1. The machine operation is scheduled of 5.5 × 24 hrs/week and regular maintenance is scheduled on every Monday. The beam time has steadily increased especially as for the polarized protons and deuterons at request of users as shown in Fig. 2. Machine developments and improvements have been made using about 5% of scheduled beam time and long period shut down time.

The setting parameters of the magnets, trim coils and RF system are given from the control computer PDP11/40 by putting a particle, charge state and energy. The internal beam can be easily tuned using just these parameters and the extraction requires a fine adjustment of Dee and deflector voltages, and a centering of the beam by valley coils. The extraction efficiency is more than 90% for protons but around 50% for high energy ^{3}He, α and heavy ions. This difficulty originates from a slight change of beam path along deflectors due to a change of main field shape at high field excitation.

2. Improvements of Beam Qualities

To get stable and excellent quality beams (energy resolution, emittances, time structures), beam diagnostics, control system and stabilities of electric and magnetic fields are essential. Phase probes and phase selection slits have been developed and improved.

A movable slit is used to select the beam at the first half turn in the central region. This accepts usually two different phases. These two beams are accelerated up to maximum radius in the isochronous field. Fig. 3 shows two peaks corresponding to the two selected beams measured by a movable phase probe. One of the two beams should be dropped out to improve the energy resolution. The magnetic field has been slightly modified from the isochronous field by changing one of the trim coils, then one of the two beams has been slipped to the decelerating region and another has remained at the acceleration region by different phase excursion during the acceleration. The extracted beam with this procedure has had small energy spread as well as small phase width.

The new slit systems (3rd and 4th) have been installed at a cyclotron radius of about 30 cm. These are effective to reduce the phase width and radial emittance. The single turn extraction would require further magnetic field and Dee voltage stabilities with these phase slits. So the stability improvement with the establishment of refined tuning method is a key to the refinement of the beam qualities.

3. Polarized Ion Acceleration

The atomic beam type polarized ion source is located on the second floor outside the cyclotron vault. The polarized beam is axially injected into cyclotron center and then inflected by 90° by an electric mirror system. The spin directions of the polarized beam is altered by RF spin transition units very quickly (0.5 to 500 Hz). No appreciable change of beam intensity is observed when the polarization states are altered by the RF transition. The beam intensities of polarized protons, vector and tensor polarized deuterons are between 20 to 50 nA on the target in the achromatic mode of the beam transport. To accelerate protons with spin in the horizontal plane, an Wien filter was installed in the course of axial injection, and the spin direction was rotated by 90°. The maximum value of the horizontal component of the proton beam polarization accelerated up to 65 MeV was measured to be about 70% of the initial value at the ion source. Details are presented to this conference by K. Hatanaka et al.[2)]

4. Heavy Ion Acceleration

The "heat insulated" cathode PIG heavy ion source has been developed and improved. Up to now, C, N, O, Ne (including small abundant ^{13}C, ^{15}N, ^{22}Ne) ions have been requested by users and Ar^{7+} ions have been tested to accelerate in the 3rd harmonic mode. The life time of the source is usually limited by either the cathode (Ta) life or the shorting out of the arc due to bridge between cathode and anode with flakes of sputtered tantalum. This difficulty is reduced by adjusting gas flow rate minutely and by keeping a larger space between anode and cathode holder. By these improvements, N and Ne beams are stably accelerated for more than 20 hrs. with moderate intensity. To accelerate C, O ions, so the arc is rather unstable compared with N_2 gas, several gas(CH_4, CO, CO_2 and O_2) and supporting gas (N_2, Ne, etc.) have been tested to improve beam intensity and life time with stable condition. These tests showed CH_4 and O_2 gases are most likely to accelerate C and O ions, respectly, in RCNP ion source. Recently, BF_3 gas was tried to accelerate B or F ions. The unstable arc behaviour revealed that some supporting gas is likely to be mixed.

To accelerate metal ions, sputtering electrode installed in the anode is now under development. Pulsed power supply (0.3 ∿ 10 kHz) to get higher charge states is also now under conditioning.

References

1) M. Kondo et al., Proceedings of the 7th Int. Conf. on Cyclotrons and their Applications, p. 95
M. Kondo, RCNP Annual Report (1976) p. 1
2) K. Hatanaka et al., Contribution to this conference.

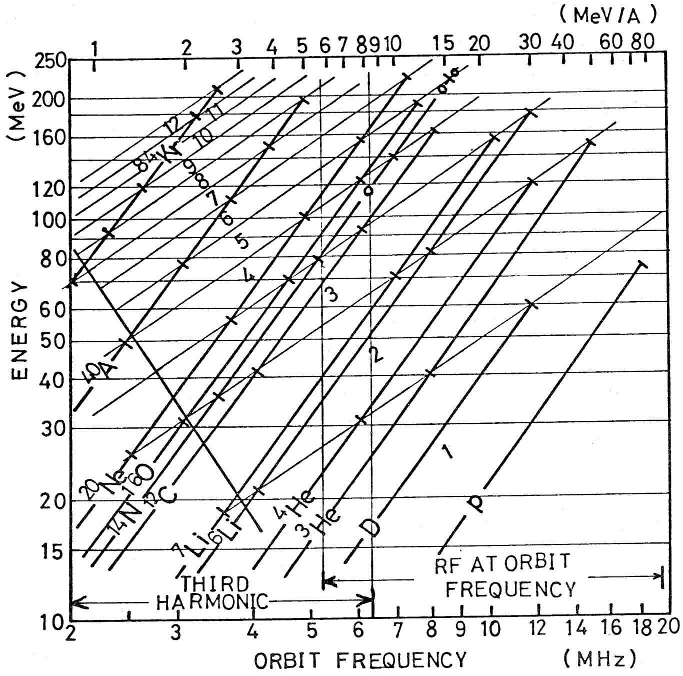

Fig. 1. Resonance condition of RCNP cyclotron.

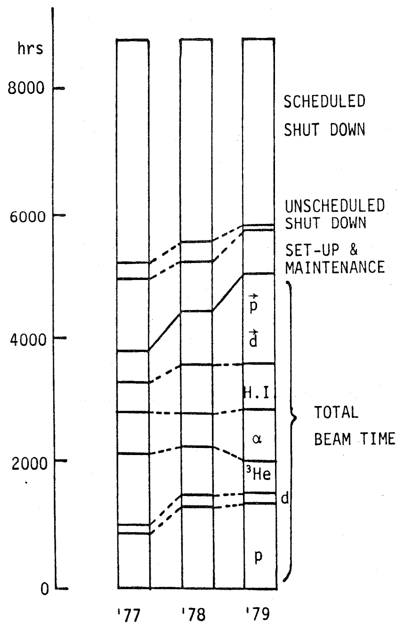

Fig. 2. Development of time distribution of RCNP cyclotron.

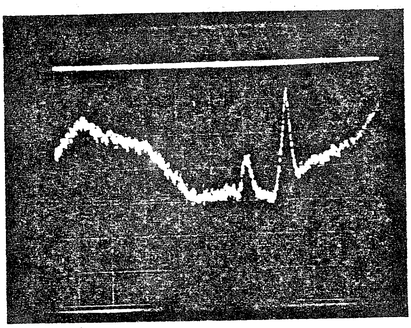

Fig. 3a. The phase probe signal. Two phases are separated.

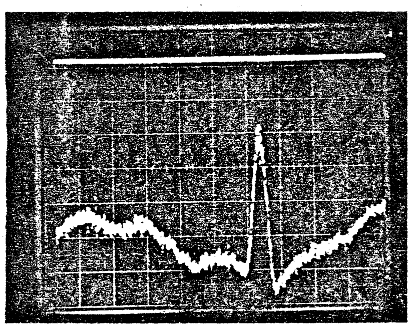

Fig. 3b. One of the two beams was dropped by modified field.