RECENT PROGRESS IN HIGH RESOLUTION BEAM OPERATION OF THE RCNP CYCLOTRON SYSTEM

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Abstract

The RCNP accelerator system consists of a K400,6 sector ring cyclotron and a K140 AVF cyclotron. Many improvements and efforts have been dedicated especially for the high resolution beam operation. It enables us to deliver a 420MeV He ^{3} beam of less than 15keV resolution in the dispersion matching mode and 90keV resolution in the achromatic transportation mode at a target point.

Optimization of flat topping in the ring cyclotron, fine tuning of the AVF cyclotron beam with a phase slit system and the highly stabilized magnet system monitored with NMR probes are the main contributors.

1 INTRODUCTION

The accelerator system of Research Center for Nuclear Physics (RCNP), Osaka University consists of a K400, 6 sector ring cyclotron and a K 140 AVF cyclotron. Usually the AVF cyclotron is operated as an injector for the ring cyclotron. The system runs for about eight months in a year. Remaining four months, about two months each in summer and winter, are dedicated for maintenance and improvement work. SHI Accelerator Service Ltd. (SAS) is entrusted for the operation under the supervision of the RCNP stuff. Currently there are nine resident operators working on the operation twenty-four hours a day, seven days a week with two people in each team (working twelve hours a day). The operators are also involved in the maintenance and improvement work.

As has been well known, high resolution nuclear reaction experiments are being conducted in the RCNP. Many progresses have been observed in the last three years in delivering high resolution beams. Figure 1 shows evolution of the beam energy width, measured by a magnetic spectrometer Grand Raiden through scattering experiment with an achromatic beam transport mode.

It is seen in the figure that noticeable improvements were made around the year 2000. The SAS operators contributed in many ways for these improvements, which are summarized as follows;

A. Optimizing flat topping condition in the ring cyclotron.
B. Fine tuning the AVF cyclotron in injection and extraction,
C. Stabilizing the magnetic field, monitored by improved NMR system of eight digits .

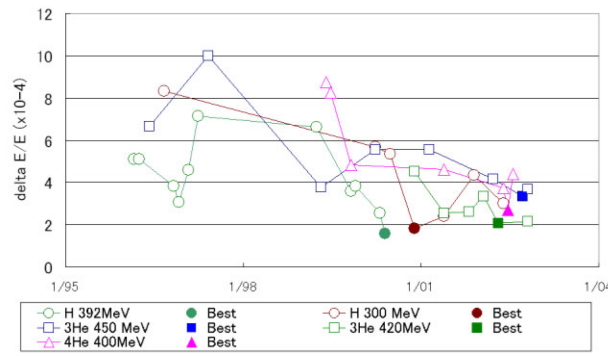

Figure 1. Energy width of Ring Cyclotron Beam

2 OPTIMIZING OF THE FLAT TOPPING CONDITION

An RF cavity of the third harmonic frequency is equipped in the ring cyclotron for flat topping (FT) of the acceleration voltage wave form.

It was difficult to tune the FT system in phase and voltage, because;

a. There is no way to observe the synthetic voltage wave form,
b. It is difficult to measure the FT voltage accurately.
c. Voltage distribution is different between the main cavity and the FT cavity. Local voltage matching is meaningless.

A voltage correction factor of 1.3 had been used for a long time in the setting of the FT voltage.

One day in 2000, there was an opportunity to operate the system just after recovery of an FT trouble. A high resolution beam was obtained unexpectedly. An inspection revealed the correction factor was accidentally set to be 1.75. The new correction factor has also made phase adjustment much easier.

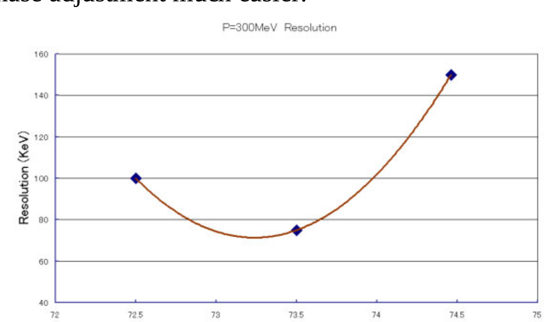

Figure 2. FT voltage and beam energy width (Proton 300 MeV)

Then fine tuning of the FT voltage after the phase adjustment has been recognized to be very effective to the final ultimate resolution. Figure 2 shows an example of the voltage tuning.

3 FINE TUNING IN THE AVF CYCLOTRON

Figure 3 shows a beam pattern in the outer region of the AVF cyclotron measured by a deflector entrance probe. Accelerated particle is He^3 to inject to the ring cyclotron for the final 450MeV beam. It is seen in the figure that the turns are almost separated especially in the outermost region.

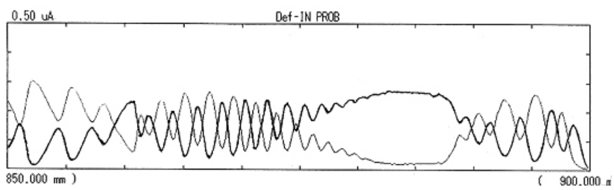

Figure 3. Beam pattern in the outer region measured by deflector entrance probe
(thick line: differential probe thin line: integral probe)

Main points in tuning for separated turns are as follows;

a. Optimizing DEE side phase slit position and buncher condition. Cutting peripheral beam by an ordinary phase slit.
b. Precise setting of the AVF cyclotron magnetic field under isochronous field established .
c. Fine tuning of valley coils in the outermost region.

The DEE side phase slit[1)] is a supplemental phase slit equipped inside the DEE electrode of the AVF cyclotron.

While the slit was installed in 1997, it was not used effectively for a long time.

Recently it has been realized that the slit can be very effective, based on the progress of beam turn monitoring and beam injecting condition with a buncher. Using the DEE side phase slit and the ordinary phase silt simultaneously, beam length is shortened very effectively. Conceptual structure is shown in the Figure 4. Electrode 3 is the DEE side phase slit. Number 4

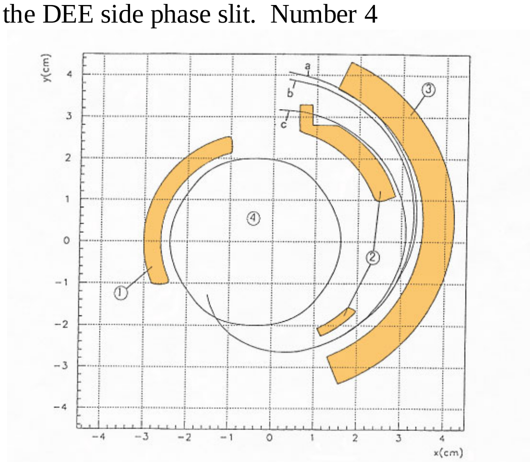

Figure 4. DEE side phase slit and incidence beam orbit

There are two functions of the DEE side phase slit. One is to shape the beam in radial direction, the other is to deflect the beam orbit by the electric field penetrating from an opening of the electrode 2. The effect of the opening is shown in the figure 4. The line b indicates a beam orbit at a timing of the peak accelerating voltage, line a indicates it at ten degrees earlier than the peak and line c indicates ten degrees later. The orbit of the line a is shifted over the line b. It enables us to cut line a component by the ordinary phase slit, and to select the best part of the injecting beam.

With this adjustment, beam time length is shortened and then turns are separated.

4 NMR FIELD MONITOR IN THE AVF CYCLOTRON (TO THE EIGHT DIGITS)

Recently it became clear that the beam quality improves at highly stabilized magnetic field through stabilizing the temperature of the cyclotron magnets. It is required to monitor the magnetic field stability with the accuracy of 1ppm.

Although an NMR instrument can measure field in the precision, it was difficult to apply to the AVF cyclotron. Figure 5 shows the magnetic field distribution, where flat part of the magnetic field is very little. To perform the required measurement of the accuracy, it must be ensured that the NMR probed head is small enough, field gradient over the probe is properly corrected[2)] and a controller has 8 digit capability.

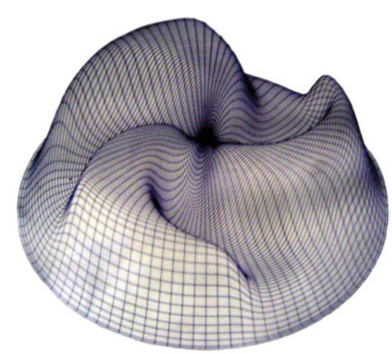

Figure 5. Magnetic field distribution in the AVF cyclotron.

Figure 6. show the improved probe head and a correcting coil set. Increasing turn number of the modulation coil, the modulation amplitude is increased to10mT from conventional 1-2mT.

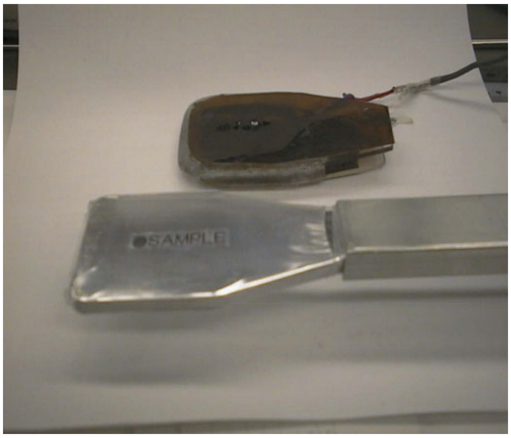

Figure 6. NMR probe head and correcting coil set

Figure 7 shows the correcting coils. The correcting coils are thin and do not disturb the isochronous field.
Conventional NMR controller was of 7 digits. The 8 digits capability is necessary to monitor the field in the 0.1ppm accuracy and the controller has been developed.
By detecting a very little field change, it has become possible to recover the beam fluctuation.

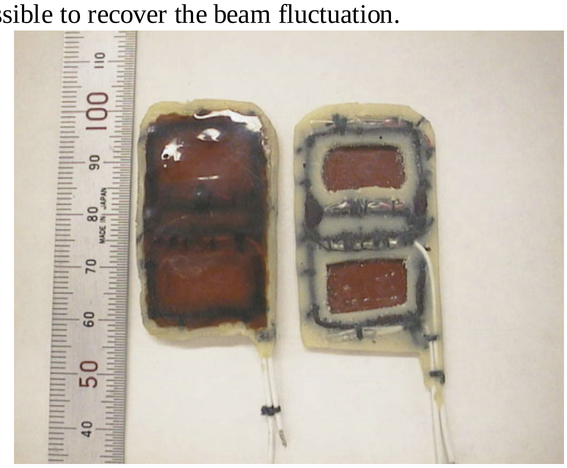

Figure 7. Correcting coils

The achievements described above are the result of every day work of the following members taking part in sustaining operation of the RCNP cyclotron system.

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5 REFERENCES

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[2] M. Kibayashi, Proc. of the 12th Symposium on Accelerator Science and Technology, Wako(1999) 319-321