ROOM TEMPERATURE CONTROL FOR ULTRA STABLE MAGNETIC FIELD OF THE RCNP AVF CYCLOTRON

S. Ninomiya, T. Saito, H. Tamura, K. Sato
Research Center for Nuclear Physics, Ibaraki, Osaka 567-0047, Japan

High-quality beams in momentum spread have been strongly required and successfully produced in the RCNP cyclotron complex. Table 1 shows a summary of beam quality for light ions with different kinetic energies. The best results of the ratios of the energy spread to the beam energy (DE/E) in FWHM were achieved as less than $4x10^{-4}$ for all cases. The second best results were also shown in table 1. All values of DE/E were less than $5x10^{-4}$. Especially, for ^3He ions, reproducibility is quite good, even though the DE/E values themselves were not sufficient compared with those of proton cases.

Table 1: A summary of beam quality statistics

	Best energy width (DE/E)	Second best energy width (DE/E)
Proton 300MeV	55 keV ($1.8 x 10^{-4}$)	72 keV ($2.4 x 10^{-4}$)
Proton 392MeV	62 keV ($1.6 x 10^{-4}$)	100 keV ($2.6 x 10^{-4}$)
3He 420MeV	*89 keV ($2.1 x 10^{-4}$)	*90 keV ($2.1 x 10^{-4}$)
3He 450MeV	*150 keV ($3.3 x 10^{-4}$)	*165 keV ($3.7 x 10^{-4}$)
4He 400MeV	*108 keV ($2.7 x 10^{-4}$)	150 keV ($4.4 x 10^{-4}$)

*achieved in 2002

For ultra-precise beams, severe controls of the magnetic and electric fields to ion beam are needed. Especially, stability of the magnetic fields B of the injector cyclotron, the RCNP AVF cyclotron, were found to be much important for such beams[1]. For example, for 392 MeV proton beam, when the AVF magnetic field increased with a rate of DB/B » $4x10^{-6}$, the energy spread DE/E was observed to increase roughly twice[2]. At that time, DB/B increased with a rate of about $1.2x10^{-5}$ per day without any operation.

Magnetic fields in a cyclotron depend not only on a coil current, but also on form (length, width and so on) of iron core and magnetic permeability. It should be noted that it is necessary to keep the magnetic fields at all points in the AVF cyclotron constant in order to obtain and retain ultra-precise beams. Therefore, coil-current feedback with measuring a magnetic filed at one point in the cyclotron is not sufficient. All parameters for the magnetic field should be kept constant.

Since a power supply for the main coil can be controlled with the order of 10^{-6}, which is small enough comparing observed increasing rate of the magnetic field($1.2x10^{-5}$/day), the other parameters, form of iron core and magnetic permeability, should change. Both of them have hidden parameters, temperature T. The temperature coefficients of the magnetic permeability and coefficient of linear expansion for iron are roughly on the order of 10^{-4} and 10^{-5}, respectively, Therefore, temperature of the iron core should be controlled on the order of 0.01 degree, supposing drift of the magnetic field due to temperature effect becomes comparable to that from the stability of the power supply. We had already reported that the magnetic field of the AVF cyclotron kept the level within – $2.5x10^{-6}$ during over 60 hours without any adjustments of the cyclotron parameters, when the temperature stayed within −0.06 degree[1]. At that time, the energy spread of the beam, ΔE/E, retained within $4x10^{-4}$ during about one-day beam time without any adjustments.

The iron temperature is determined from balance of heat transfer from coils and to the outer circumstance, i.e., the AVF cyclotron room. A cooling system for the coils in the AVF cyclotron was improved in 2000[3] and cooling water temperature was normally controlled by the order of 0.1 degree. In summer period, however, a cooling water temperature was observed to increase a little bit, which depended on coil current. Cooling power for the main coils was slightly increased by rearrangement of the AVF water cooling system in 2002 and the effect will be checked in 2003.

To stabilize the iron core temperature, the room temperature of the AVF cyclotron is also necessary to keep constant. Figure 1 shows the room temperatures at 2:00 and at 14:00 in every day in 2001(open circle). The temperature was roughly constant, 27 degree, before the beginning of the June except the end period of the April. The reason why the temperatures decreased in this period is unknown. Then the room temperatures increased from the beginning of the June. Finally, the temperatures got to 30 degree by lack of cooling power of the air conditioner system.

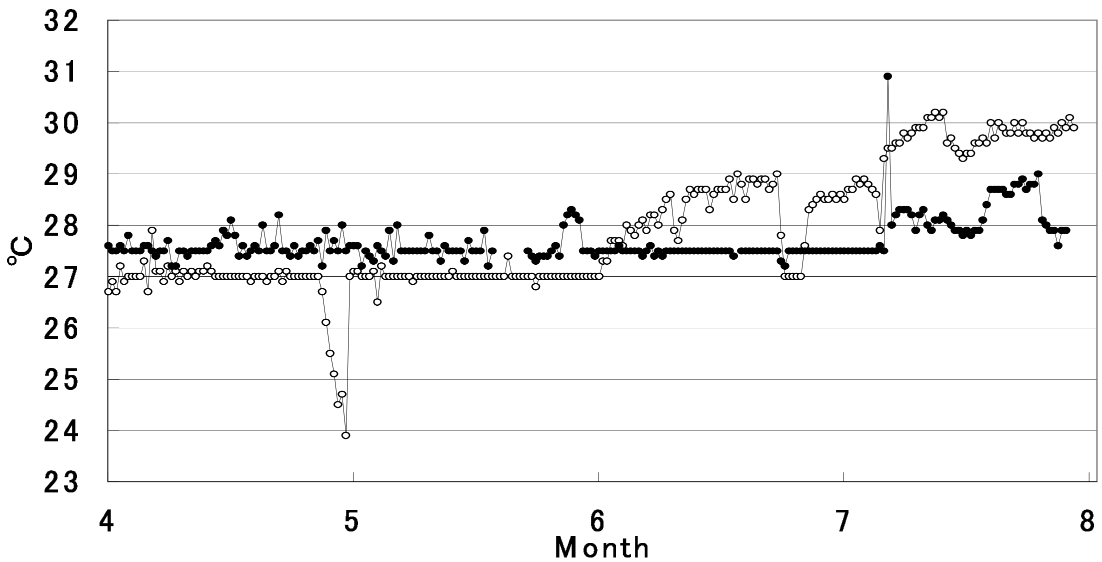

Figure 1: Temperature of the AVF cyclotron room in 2001(open circle) and in 2002(closed circle).

In the spring of 2002, we added a new air conditioner to the old system, the total power of which became stronger by about 10 %. The new air conditioner has some special features, one of which is 60 m cooling-medium line, for effective heat transfer from the radiation control area to outside. The room temperature in 2002 also shown in fig.1(closed circle), even though some data were missing. The target temperature was changed to 27.5 degree. The room temperatures were kept roughly constant until the beginning of the July. Small deviation at the beginning of the June came from trouble of the new air conditioner. In summer period, we loss temperature controls. The maximum deviation was, however, about 1.5 degree, which was obviously smaller than that in 2001.

References

[1] S. Ninomiya et. al., RCNP Annual Report 2001 p.148.

[2] S. Ninomiya et. al., RCNP Annual Report 2000 p.102.

[3] S. Ninomiya et. al., RCNP Annual Report 2000 p.99.