Vacuum System for the Ion Cooler Ring TARN2

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Abstract

An average pressure on the order of 10^{-9} Pa has been achieved during the beam time of atomic physics experiments at the ion cooler ring TARN2. A beam life time of about 10^4 sec for 30-MeV $^4He^{2+}$ was observed by a DC Current Transformer (DCCT) under operation of the electron cooling device. Vacuum performance of the ring is presented.

1 Introduction

The ion cooler/synchrotron with an electron cooling system, TARN2, was constructed for the study of accelerator technology in 1988. Experiments on the electron cooling, the beam extraction and the beam acceleration were successfully performed[1,4].

In 1991, the first upgrade for the pump system at TARN2 was performed by newly adding titanium getter pumps and sputter ion pumps in order to promote the study of atomic physics. As a result, an average vacuum pressure on the order of 10^{-8} Pa was achieved during the beam time[2]. A further trial was made to improve the vacuum by utilizing a new type NEG pump in 1994[3]. Atomic and molecular ions such as H_2^+, H_3^+, $^3He^+$, HD^+, $^4He^{2+}$, HD_2^+, HeH^+, HeD^+, D_3^+, $^{14}N^{5+}$ and $^{14}N^{7+}$ were injected in the ring for the atomic physics experiments[4].

Whenever vacuum chambers in the ring were exposed to atmosphere about one time every year to install new equipment, baking process was again required. In 1997, an all-metal gate-valve was installed at the opposite position of the ring to the electron cooling device. As a result, futile exposure to atmosphere has been avoided.

Recently, an average vacuum pressure on the order of 10^{-9} Pa has been maintained during the beam time. Consequently, a beam life time of 10^4 sec for 30-MeV $^4He^{2+}$ was observed by a DCCT under operation of the electron cooling device. The time progress of the vacuum pressure is summarized in Fig. 1. Performance of the vacuum system at TARN2 is reported.

2 Vacuum system

The TARN2 ring has a circumference of 78 m and is hexagonal in shape with six long straight sections. The magnets of 24 dipole, 18 quadrupole and 2 bump are located in the ring. In the straight sections, two electrostatic inflectors for the ion injection (Straight section: S1), a dc current transformer, a bump magnet (S2), nondestructive profile monitors (S3), an electron cooling device (S4), a weak current measuring system using superconducting quantum interference device (SQUID), an rf knock out electrode (S5), an rf cavity and a bump magnet (S6) are located.

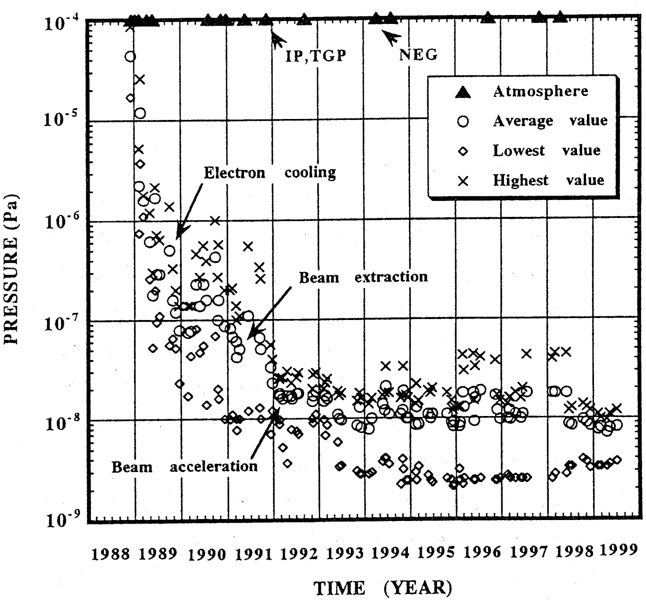
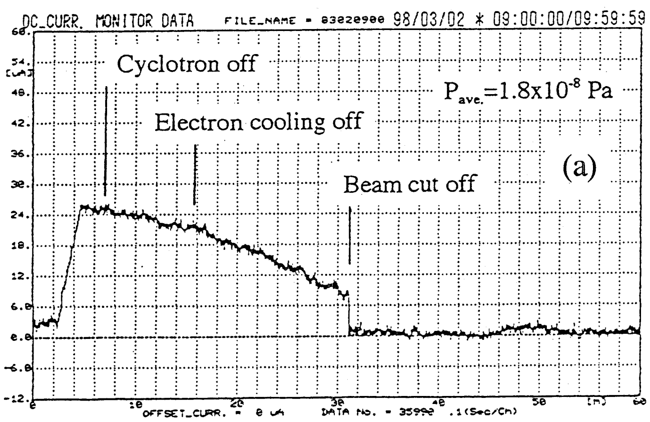


Fig. 1. Change of the vacuum pressure.



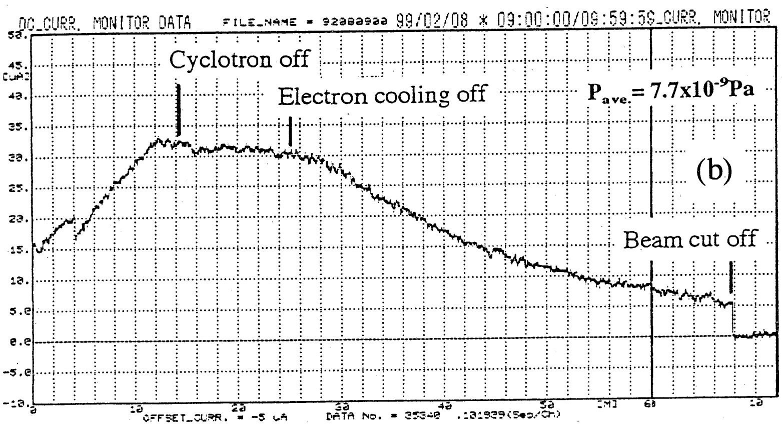


Fig.2. Beam current measured by the DCCT .

The vacuum chamber at the electron cooling section is isolated by a pair of all-metal gate valves from other region of the ring.

The pump system consists of Titanium Getter Pump (TGP), Ion pump (IP), Non Evaporable Getter pump (NEG) and Turbo-Molecular Pump (TMP). The TGP, IP and NEG were installed at the chambers of straight sections and dipole magnets. Total pump speed of TGP, IP and NEG after the upgrade in 1994 was 42000 l/s[4]. The turbo-molecular pumps with a pumping speed of 500 l/s are installed at the straight sections of S1, S3 and S5. Roots pumps located at S3 and S5 are used only at the time of pumping down from the atmospheric pressure in order to quickly evacuate in the intermediate flow region.

The pressures of eight positions in the ring are measured by B-A gauges. The information is transferred to TARN2 control room through optical fiber and is saved in floppy disc. Quadrupole mass filter was used for the residual-gas analysis. In 1997, ring was exposed to atmosphere in order to install an induction accelerator for the measurements of cooling force [5] and at the same time an all-metal gate valve was installed at the opposite side of the electron cooler. In 1998, a cryogenic current measuring device using a superconducting quantum interference device (SQUID) was installed in straight section (S5)[6].

3 Beam life time

We measured beam life time for 40-MeV,$^4He^{2+}$ beam with the DCCT. Measured beam current at a vacuum pressure of 1.8x10^{-8}Pa in 1998 is shown in Fig.2(a). At first, beam intensity increased during cool-stacking up to 25 micro-ampere. After the cool-stacking, injection beam from the cyclotron was stopped by closing a shutter. Then, electron cooling was stopped after 9 minutes from the cyclotron beam off and finally the ion beam was cut off by a beam shutter in the ring after 15 min. Similar data obtained at a vacuum pressure of 7.7x10^{-9} Pa for an energy of 30-MeV in 1999 is shown in Fig.2(b). Table 1 shows the life time obtained from the figures.

The life time of the cooled beam is estimated by an extrapolation from the figure.

Data in 1993 are values without electron cooling after injection.

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Table 1. Beam life time T(1/e) of $^4He^{2+}$ ion.

Energy (MeV)	Pressure (Pa)	cooled (s)	not cooled (s)	Calendar year
30	7.7x10-9	11000	8500	1999
40	1.8x10-8	2300	1100	1998
40	1.7x10-8	-	400	1993

4 Pressure at beam time

Before the beam time, titanium getter pumps were sublimated about 20 min by a mode of 30 sec power on and 60 sec power off. The titanium sublimation is effective for the insufficient part of baking process.

Recently, an average vacuum pressure of 10^{-9} Pa has usually been maintained during beam time. For example, pressures recorded during a beam time for experiment of 4 days for 7Me-V,HD^+ ion is shown in Fig.3.

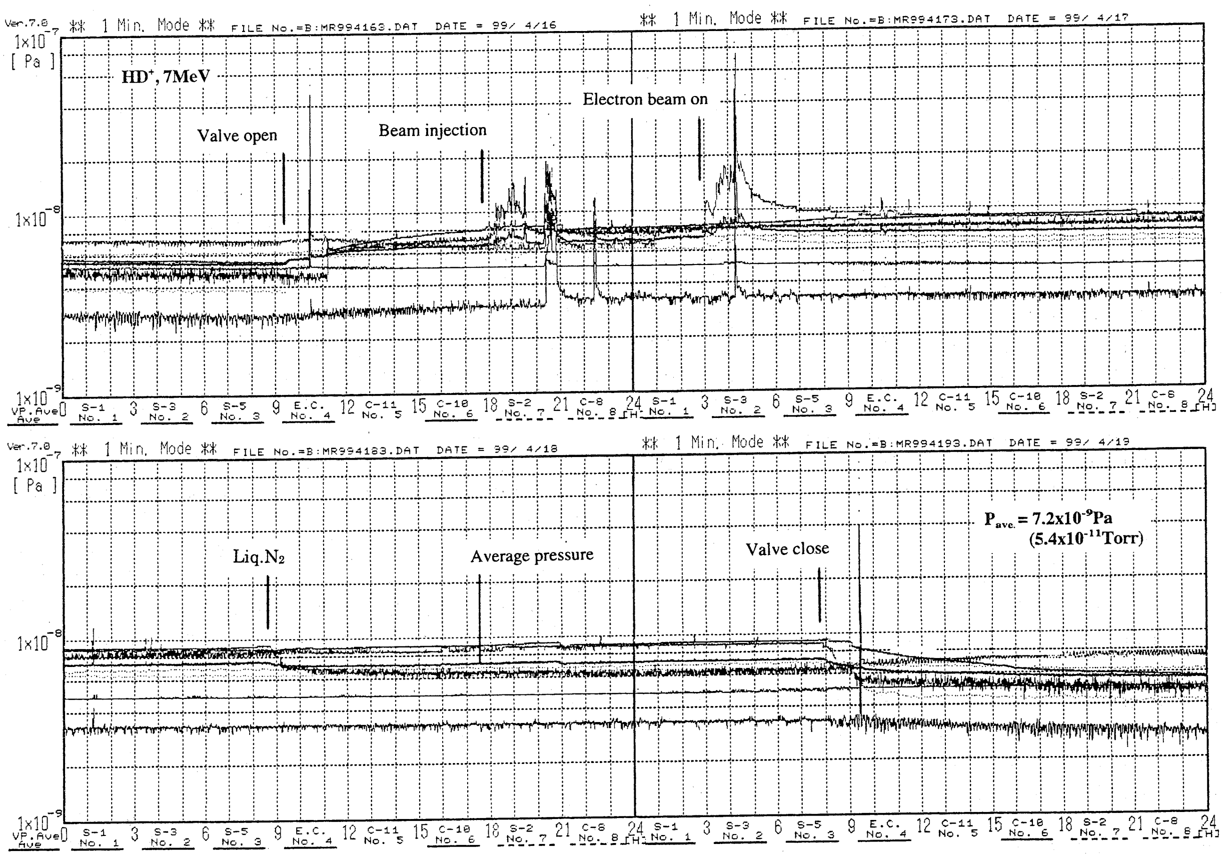

Fig.3. An example of vacuum pressure as a function of time which were measured at eight positions of a ring during the beam time. Liq.N_2 means that liq N_2 was filled up into the titanium getter chamber with liquid nitrogen trap in upstream transport line of inflector chamber.

5 Summary

Recently, an average vacuum pressure on the order of 10^{-9} Pa has been maintained during the beam time.

Beam life time of 10^4 sec was observed for 30-MeV, $^4He^{2+}$ ion at a vacuum pressure of 7.7×10^{-9} Pa with electron cooling.

Acknowledgment

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