PRESENT STATUS OF THE RCNP CYCLOTRON FACILITY

Kichiji Hatanaka*, Mitsuhiro Fukuda, Keita Kamakura, Shunpei Morinobu, Takane Saito, Hitoshi Tamura, Hiroshi Ueda, Yuusuke Yasuda, Tetsuhiko Yorita, Research Center for Nuclear Physics, Osaka University, 10-1 Mihogaoka, Ibaraki, Osaka, 567-0047, Japan

Abstract

The Research Center for Nuclear Physics (RCNP) cyclotron cascade system has been operated to provide high quality beams for various experiments in nuclear and fundamental physics and applications. Three ion sources are in operation; atomic beam type polarized ion source, 10 GHz ECR source NEOMAFIOS and 18-GHz Superconducting ECR source. A 2.45 GHz proton source is under development to provide high brightness proton beams. There have been increasing demands for heavy ion beams. A supplementary budget was approved for the restoration of aging facility. Several equipments are under fabrication and the installation will be performed during January and March in 2014.

OPERATION OF THE FACILITY

The RCNP cyclotron facility consists of an accelerator cascade and sophisticated experimental apparatuses. Research programs cover both pure science and applications. Demands for industrial applications have been growing more and more. A schematic layout of the RCNP cyclotron facility is shown in Fig. 1. The accelerator cascade consists of an injector Azimuthally Varying Field (AVF) cyclotron (K=140) and a ring cyclotron (K=400). The maximum energy of protons and heavy ions are 400 and 100 MeV/u, respectively. Figure 2

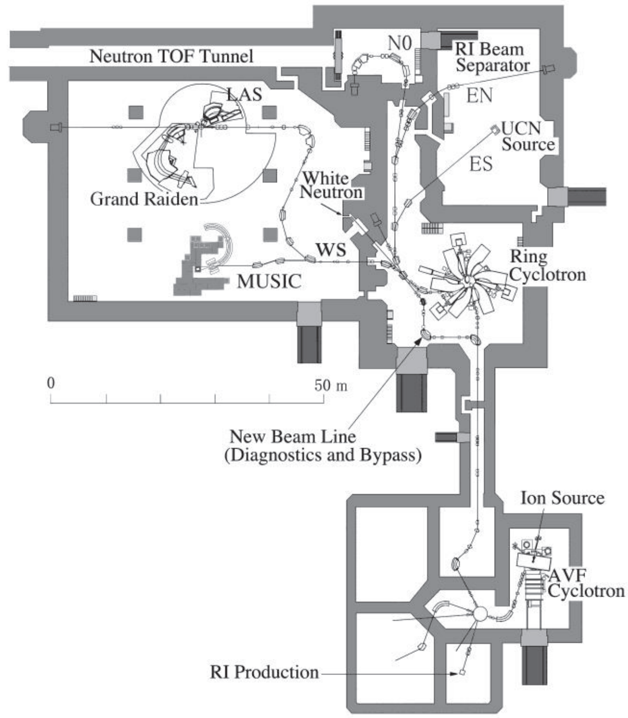

Figure 1: Layout of the RCNP cyclotron facility.

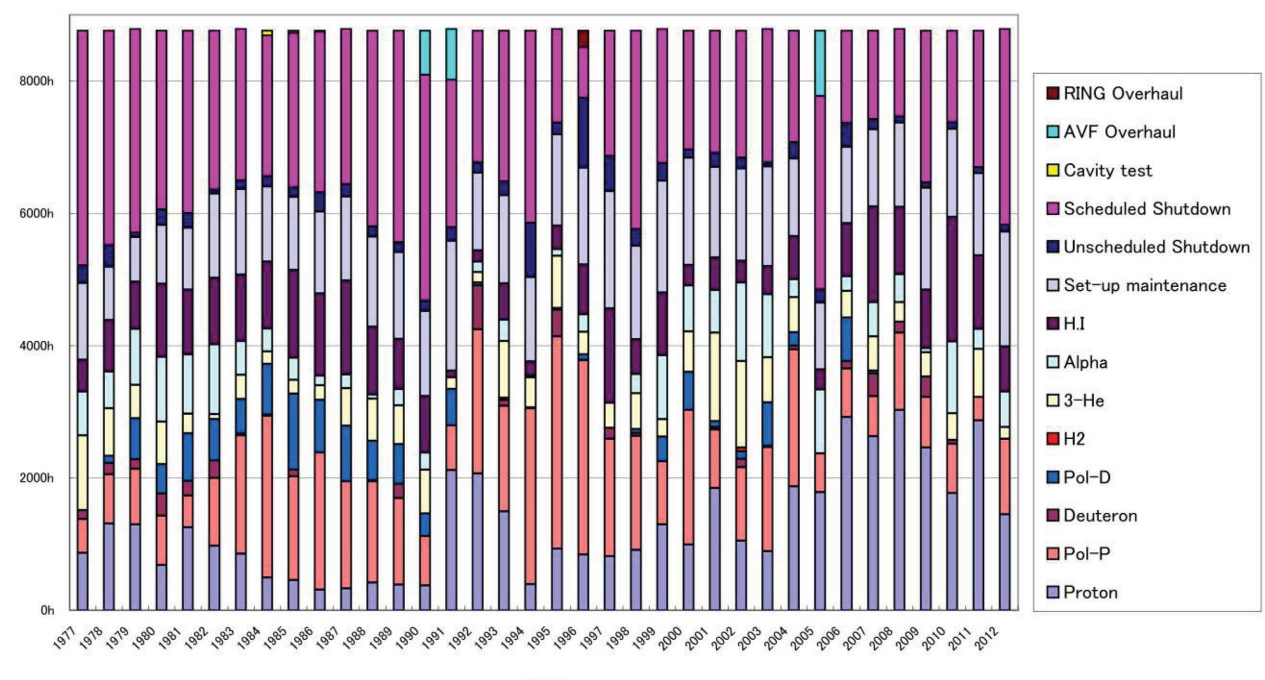

Figure 2: Operating statistics of the RCNP cyclotron facility..

*hatanaka@rcnp.osaka-u.ac.jp

ISBN 978-3-95450-128-1

shows the operating statistics. It provides ultra-high-quality beams and moderately high-intensity beams for a wide range of researches in nuclear physics, fundamental physics, applications, and interdisciplinary fields. Sophisticated experimental apparatuses are equipped like a pair spectrometer, a neutron time-of-flight facility with a 100-m-long tunnel, a radioactive nuclei separator, a super-thermal ultra cold neutron (UCN) source, a white neutron source, and a RI production system for nuclear chemistry and medicine. A pion capture beam line is installed to provide low energy DC muons. Such ultra-high-resolution measurements as $\Delta E/E=5x10^{-5}$ are routinely performed with the Grand-Raiden spectrometer by utilizing the dispersion matching technique. The UCN density was observed to be 26 UCN/cm^3 at the experimental port with a beam power of 400 W [1]. The white neutron spectrum was calibrated and the flux was estimated to be 70 % of that obtained at Los Alamos Neutron Science Center (LANSCE) in the USA. Neutrons are used for the radiation effect studies on integrated circuits and so on. The production efficiency was demonstrated to be 3 x 10^8 μ^+/s and 1.7 x 10^8 μ^-/s with 1μA, 400 MeV protons.

DEVELOPMENTS

Figure 3 shows ion species accelerated in 2011. Almost a half of experiments are performed with protons. However there have been increasing demands for heavy ions. Recently we accelerated $^{129,\,132}$Xe beams by the AVF cyclotron. To meet demands intensive developments are ongoing. Recent results are presented in this meeting [2]. Light ions up to $^{6,7}Li^{2+,\,3+}$ ions are provided by the 10-GHz NEOMAFIOS. Polarized protons and deuterons are generated by the atomic beam type polarized ion source [3]. Recently we suffer from the short life time of the dissociator. Quarts tubes are damaged by the plasma and white powders accumulate on the nozzle surface cooled down to around 30 K. Hydrogen atoms are recombined there to molecules and are not polarized. We analyzed the material by X-ray and it is SiO^2. We have not understood yet why the life of the tube becomes shorter than before It is a few days now although it was longer than two weeks.

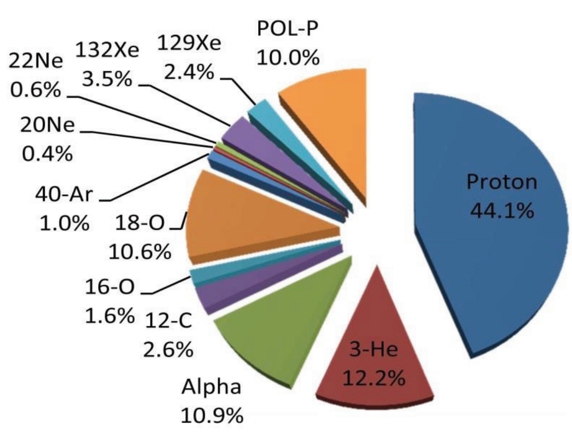

Figure 3: Distribution of ions accelerated in 2011.

A 2.45 GHz ECR source was built to increase proton currents [3]. High intensity is strongly requested for UCN and muon production. Figure 4 shows a photograph of the source. Three ring permanent magnets generate magnetic field which does not have a mirror shape. The maximum RF power is 2 kW. BN plates are put both ends of the plasma chamber. 0.8 mA proton was observed at the extraction voltage of 15 kV. Developments are ongoing to achieve higher intensity than 1 mA [2].

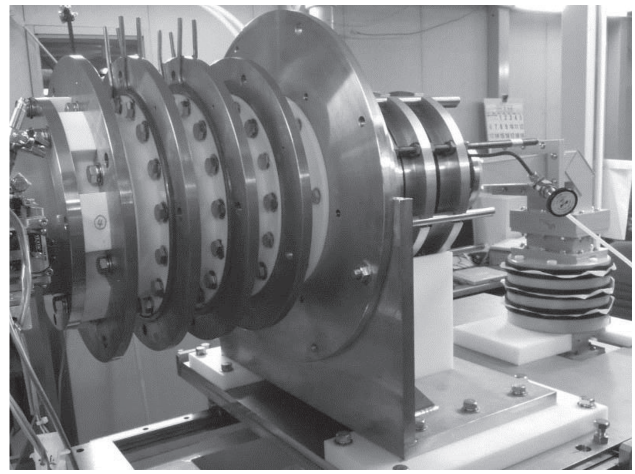

Figure 4: Photograph of the 2.45 GHz proton source.

Beam is extracted from the AVF cyclotron through two electrostatic deflectors, one magnetic channel and one passive magnetic shield and there were no focusing elements. Beam axis used to shift from the designed orbit due to the fringing field of the cyclotron magnet and spread in the horizontal plane due to the strong vertical focus. This had beams hit the wall of the beam pipe and gave residual activities. In order to correct the beam position and give a horizontal focus, a gradient corrector was constructed and installed at the exit of the cyclotron vacuum chamber [4]. It can generate both a dipole and quadrupole field by exciting two coils with different currents [4]. Figure 5 shows an effect of the gradient corrector which shows an focus action as well as steering.

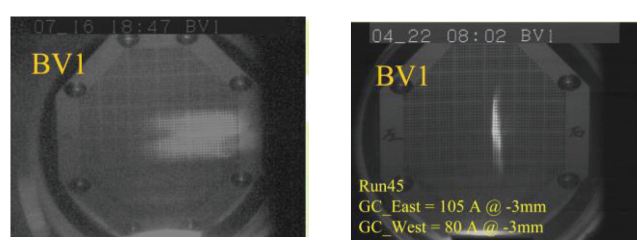

Figure 5: Beam profile observed at the screen installed at 0.5 m from the gradient corrector. Left: no excitation. Right: excitation currents ate 105 and 80 A.

During August in 2012 and March in 2013, cyclotrons were stopped due to the ant-earthquake reform of the cyclotron building. During the shutdown, the hard-wired interlock system of the AVF was replaced by a system

ISBN 978-3-95450-128-1

employing programmable logic controllers (PLC). Instrument panels were replaced by computer graphic displays. Figure 6 show the control room after the reform.

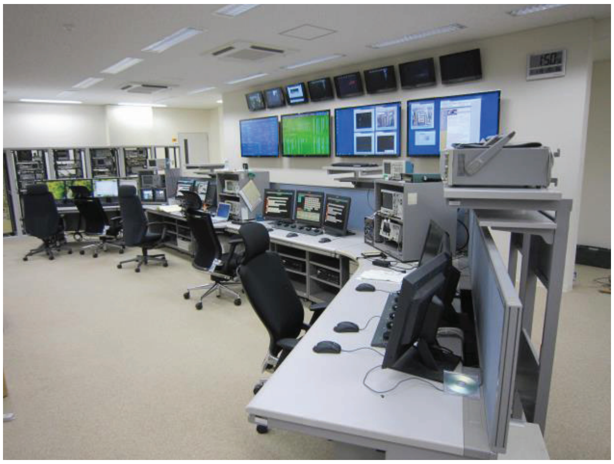

Figure 6: Control room after reform.

SUMMARY

The RCNP cyclotron facility has been stably operated in general. A supplementary budget was approved to restore aging devices and to add new ones. A discharge-type buncher and a solenoid lens are implemented in the axial injection line to the AVF. The connection between the RF resonator and the AVF dee electrode where we have water leaks in a few cooling pipes. Two electrostatic injection channels, two magnetic injection channels and two electrostatic extraction channel are replaced and two magnetic extraction channels are fabricated as spares. The fine tuning system of the ring cyclotron flat-topping cavity is improved. A switching magnet is replaced by a magnet with high temperature superconducting (HTS) wires. Time sharing operation is planned. A beam line is built to perform forward angle measurements including zero degrees at the Grand Raiden spectrometer. Another line is constructed to deliver low energy muons to the experimental port. The installation is scheduled from January to March in 2014.

REFERENCES

[1] Y. Masuda, T. Kitagaki, K. Hatanaka, M. Higuchi, S. Ishimoto, Y. Kiyanagi, K. Morimoto, S. Muto, M. Yoshimura, Phys. Rev. Lett. 89 (2002) 284801.

[2] T. Yorita et al., in these proceedings. TUPPT016.

[3] K. Hatanaka, K. Takahisa, H. Tamura, M. Sato and I. Miura, Nucl. Instr. Meth. in Physics Research A 384 (1997) 575-582.

[4] M. Fukuda et al., Cyclotrons 2013, Vancouver, Canada, TUPSH006, these proceedings.

ISBN 978-3-95450-128-1