IMPROVEMENTS AND APPLICATIONS AT NIRS CYCLOTRON FACILITY

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Abstract

The NIRS-930 isochronous cyclotron has been used for various kinds of radiological and medical studies, such as development of new radiopharmaceuticals, basic research of radiobiological experiments, and study of particle detector for space. An ECR-IS has been installed in the axial injection system for extension of the research fields. New internal ion-source having two-slit geometry has been developed and successfully used in daily operation. A simple method of beam-energy measurement device was developed consisting of two capacitive-probes. A brief review of the developments and typical application of latest experiments in the various fields are described.

INTRODUCTION

The NIRS cyclotron facility [1] constitutes of AVF930 cyclotron (NIRS-930), a small cyclotron(HM-18), and nine experimental beam lines. The NIRS-930 has been used for development of new short-lived radionuclides, research of biophysics, development of particle detectors for space application and so on. The clinical trail of eye melanoma, which had been performed for almost eighteen years, came to an end in December 2003. Table 1 shows the statistics of beam time distributions among the research fields in 2003. In those studies the beam has been provided by internal ion-source. The small HM-18 has been operating routinely to product short-lived radio-pharmaceuticals for PET in conjunction with a heavy ion therapy in HIMAC [2] (Heavy Ion Medical Accelerator in Chiba). Operation of those two cyclotrons has been scheduled in the daytime from Monday afternoon to Friday except the regular maintenance time during two weeks of March and August annually.

Recently a compact ECR-IS has been equipped. Following this, some improvements has been made for an injection line. Fig.1 shows a photo of the reformed injection line for the horizontal line.

Table 1. Beam time among research field.

1. Clinical trial of eye melanoma	;	24.5 h	(1.6 %)
2. Short-lived R.I. production	;	627.3 h	(40.7 %)
3. Studies of particle detectors and radiation dosimetry	;	264.8 h	(17.2 %)
4. Basic research of radiological	;	218.8 h	(14.2 %)
5. Pay Beam for industrial use ;	;	48.0 h	(3.1 %)
6. Preparing beam and development	;	358.8 h	(23.3 %)
Total	;	1542.2 h	

IMPROVEMENTS

In the past three years some improvements for the NIRS-930 such as applying a “deceleration system” in the external injection line, development a new configuration for the central region, and install a beam energy measurement equipment in the beam line, have been performed as following.

Decelerator

A simple method for ion deceleration system has been designed and installed in the external beam-injection line. An advantage of the method utilizing the decelerator is to allow high-current ion beam extracted from an ECR-ion source due to perform a high potential difference between the source and extractor in a specified injection voltage. The decelerator is operate by DC-voltage consists of appropriate electrode assembly. In Fig.2 schematic layout

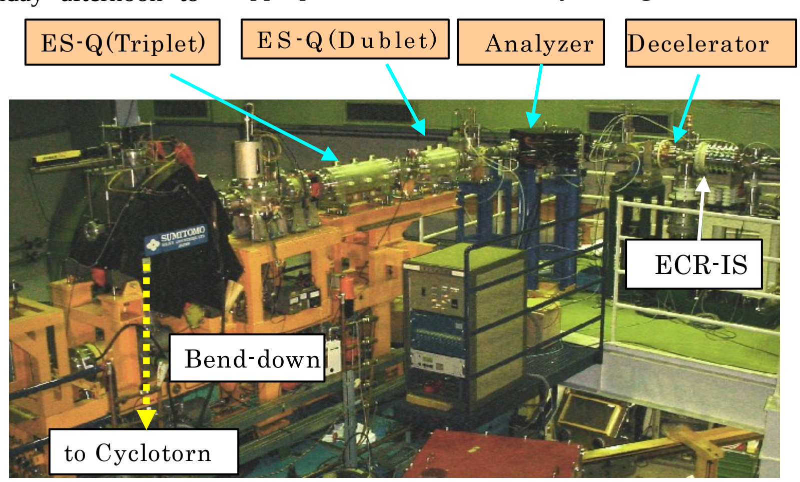

Fig.1. External injection line at NIRS-930 cyclotron.

of the system and potential distribution is shown. Electric field in the decelerator is carefully designed with the aid of 3D-field simulation code. The system works more effective to increase the beam intensity under the condition that a low injection voltage is required to match the cyclotron. In the present, about five times current increase for $^{12}C^{4+}$ beam has been obtained at the extraction of the cyclotron, where the injection voltage: 8kV with additional decelerator voltage of –10kV.

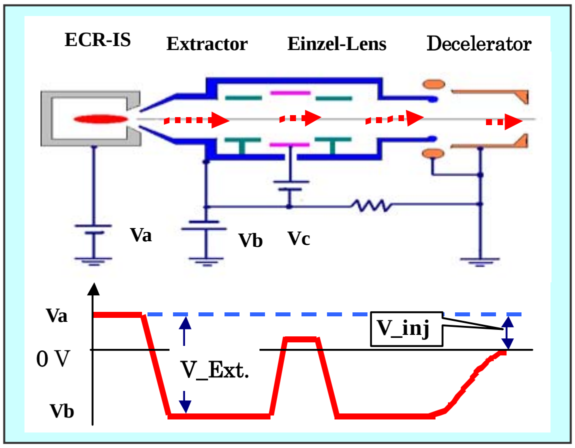

Fig.2. Ion deceleration system and typical potential distribution.

New ion-source and puller

It had been usual circumstances that, when change a beam acceleration mode, a set of ion-source and puller configuration had been also changed to adopt each deferent harmonic-modes in the NIRS-930 cyclotron. In order to perform that operation quickly, we developed a new combination with a set of modified ion-source and a puller. A schematic drawing of the configuration is shown in Fig.3. The ion-source is consisting a “two-slit” on the chimney, which having 1mm slit-width of each and separated 58.5 degrees, correspondence to deferent two-acceleration modes. Shape of the puller was formed in the beam test. In the present, the new system has been used practically in the daily operation in the cyclotron successfully.

Beam energy measurement

A beam energy measurement system applying a modified-TOF method has been developed. The system employing a set of capacitive probes, which are installed one of the straight section in the beam transport line. Detail of the measurement system and result are described in the paper [3] of this conference.

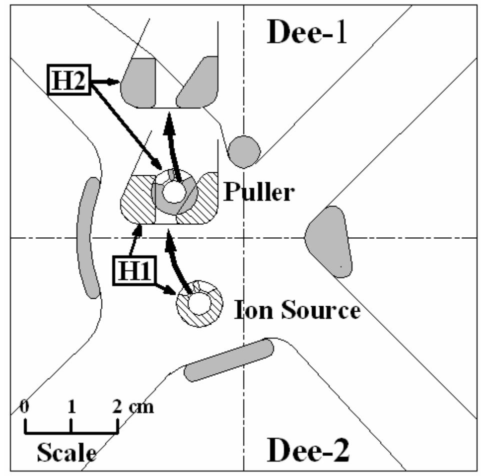

Fig.3. Schematic layout of new ion-source and puller, relation between first (H1) and second (H2) harmonics, respectively.

APPLICATIONS

Short-lived R.I. production

Short-lived isotopes such as ^{11}C, ^{15}O, and ^{18}F have been produced routinely by using three cyclotrons, i.e., AVF930, HM18 and BC2010, and labeled to biologically interesting compounds. They were mainly used in the fields of neuro-psychopharmacology, cancer diagnosis, etc., in conjunction with PET cameras. [^{11}C]methionine and [^{18}F]FDG have been routinely produced to evaluate the effectiveness of the cancer therapy by heavy ions from HIMAC. Many ^{11}C-labeled radiopharmaceuticals have been produced and used for the diagnosis of schizophrenia, depression, Alzheimer’s disease, etc. in the field of psychoneurosis. Recently, new radiopharmaceuticals, [^{11}C]DAA1106 and [^{18}F]FEtDAA1106 for imaging of peripheral benzodiazepine receptor, and [^{11}C]MP3B and [^{11}C]5R3B for the measurement of BuChE activity were developed originally and used clinically at NIRS. Production methods of ^{61}Cu by the $^{59}Co(\alpha,2n)^{61}Cu$ reaction and ^{62}Zn by the $^{nat}Cu(p,xn)^{62}Zn$ reaction have been established and applied for the synthesis of [$^{61,62}Cu$]ATSM[4] for imaging hypoxia. A new automated apparatus was developed at NIRS and commercialized. By using the developed apparatus, [^{11}C]Ro15-1788, [^{11}C]FLB457, [^{18}F]FEtDAA1106, [^{18}F]FMISO, [^{13}N]NH_3, etc. have been produced at the yields and the purities similar with those produced with the respectively exclusive apparatus.

Bio-physics study

We measured the energy and angular distributions (7 eV-10 keV and 20˚-160˚) of secondary electrons produced in the collision of 6.0 MeV/u He^{2+} ions with water vapor. Binary-encounter collision peaks were clearly observed at the calculated energies at angles of <90°, as well as the K-LL Auger peak of oxygen at about

500 eV for all angles. From these measurements, the doubly differential cross sections (DDCS) of electron emissions were deduced with an estimated uncertainty of ±13%. The energy distribution (SDCS) was also obtained by integrating the DDCS values with respect to the ejected angles, and compared with the empirical model of Rudd and the original Rutherford cross section (Fig.3). The energy spectrum (SDCS) showed good agreement with the model of Rudd in the energy range of secondary electrons of <100 eV. However, in the 100-1000 eV energy range, the experimental spectrum shows small discrepancies by -30%, and is nearly twice greater in the region >3keV[5].

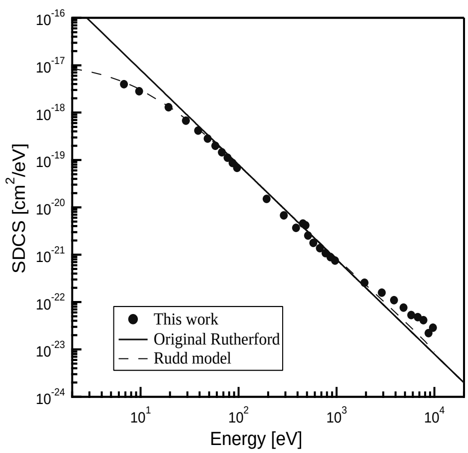

Fig.4. Comparison of the obtained energy spectrum with Rudd model and the original Rutherford cross section.

Performance of the phoswich neutron detector for aircraft measurement

To measure neutron energy spectra from a few MeV to over 100 MeV at the cruising heights for radioprotection of aircrews, the phoswich neutron detector was developed, but the detector configuration was improved to bring it into aircrafts easily[6]. The detector is consisted of a biodegradable liquid scintillator (EJ-399-06) with 127 mm diameter and 127 mm length covered with a 15 mm thick slow plastic scintillator (EJ-299-13). Particles are discriminated by applying the difference of pulse shapes depending on detected particles. To improve the particle discrimination between neutrons and protons, pulse shapes from the detector are acquired directly with high resolution. Characteristics of particle discrimination were measured by irradiating 70 MeV proton beams into the detector directly. Neutron and proton pulse shapes were acquired using the digital storage oscilloscope to optimize the data acquisition board, as shown in Fig.5. Both signals show different shapes at signal tail, 100 - 400 nsec.

Calibration of space radiation instruments

Radiation monitor instruments for astronauts or aircrews have been calibrated[7] using proton or light ion beams. In space and high altitude environment, these radiations are dominant and the instruments should be calibrated with high-energy beams. For example, Liulin-4J portable silicon spectrometers which have a 10 mm x 20 mm x 0.3 mm silicon detector and operated for 5 days with a secondary battery were irradiated proton and alpha beams and recorded ADC distribution. Comparing calculation results of GEANT4 simulation package, response functions of the spectrometers were estimated (Fig. 6).

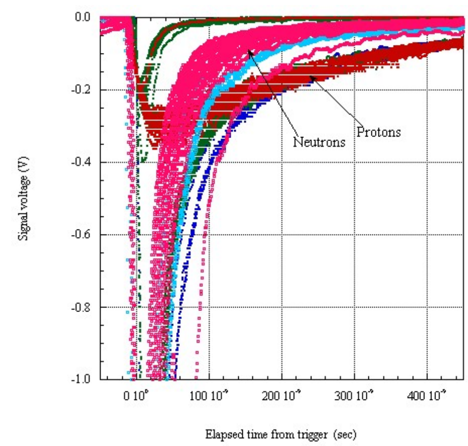

Fig.5. Neutron and proton pulse shapes acquired using a digital storage oscilloscope. At 100-400 nsec after trigger times, signal differences are clearly observed.

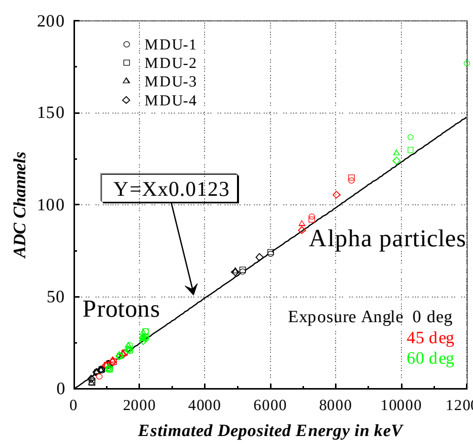

Fig.6. Response function of a Liulin-4J silicon spectrometer. Deposit energies in a silicon detector were estimated using GEANT4 simulation package.

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