Control System of Himac Secondary Beam Course for Medical Use

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Abstruct

A new secondary-beam course for medical application is under construction at NIRS. A control system enabling automatic beam tuning was designed. In a first test of the beam tuning, the basic tuning functions were confirmed to operate effectively. Status of the development and the results in the beam tuning are summarized.

1 Introduction

A secondary-beam course is under construction in Heavy Ion Medical Accelerator in Chiba (HIMAC). An important purpose of the beam course is a study of medical application of radioactive beams. The beam course will be also used in basic sciences such as nuclear physics. A control system to provide radioactive beams easily and swiftly was designed.

The control system of the secondary-beam course satisfies the following two requirements: good reproducibility and a quick beam tuning. A control system of a secondary-beam course for medical use is required to have a good reproducibility of beam conditions including energies, intensity, sizes and purity of the secondary beams. Easy operation in beam tuning is indispensable so that operators with no special knowledge about reaction products can operate the beam course as a routine work. Use of the secondary-beam course for basic sciences is restricted to night time or the weekend so as not to interfere with the schedule of clinical trials. It is therefore important to reduce beam-tuning time for the users of the secondary-beam course.

In order to fulfill those requirements, we developed the control system which integrated the functions of data acquisition, data analysis and device control. Without assistance of operators, information from monitoring detectors is analyzed, device parameters are recalculated, and new parameters are set to devices. We finally aim to develop a control system which automatically provides new secondary-beams with pre-programmed sequences.

2 Secondary-beam course

2.1 General view

The secondary-beam course is a projectile fragment separator with two bending magnets, as shown in Fig. 1. Secondary particles produced in the target are separated by a first bending magnet in according with a ratio of the mass number and the atomic number, A/Z. The secondary particles loses some energy depending on the atomic number, Z, in an energy degrader of an aluminum plate at the focus point, F1. Finally the secondary particles are separated by A and Z numbers and are focused at a point of F2, which satisfies the double achromatic condition. The particles are transported to a focus point F3 in an experimental area[1-3].

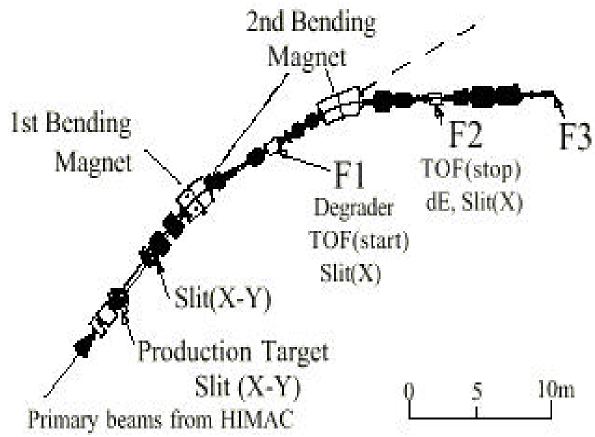

Fig. 1 The secondary-beam course in HIMAC. Closed squares on the beam line mean quadruple magnets.

2.2 Particle identification

For monitoring the secondary beams, TOF counters and a delta E counter are set on the beam line. The TOF counters are plastic scintillators with a thickness of 0.5mm. The length between the TOF start and stop counters is 10m. The delta E counter is a silicon detector with a thickness of 0.3mm. The positions of the counters are shown in Fig.1. The A and Z numbers of secondary particles are identified from information of velocity and energy loss measured by the detectors.

3 Control system

The control system consists of two computers to distribute the load of control, and is connected to the exsisting control system, High Energy Beam Transport (HEBT). Relations between these computers are schematically shown in Fig. 2.

Beam-transport devices such as the quadruple magnets, the bending magnets, the slits, the targets, and the degraders are controlled by the device control computer called High Energy Beam Transport Secondary Control Unit (HEBT-SCU). HEBT-SCU is a part of the existing control system and connected to the supervisory system.

The data acquisition computer, called Secondary Beam

Data Acquisition Unit (SB-DAU), is a complex of VME modules supporting the mtt-link. Event data from the TOF and the delta E counters taken by ADC modules are transferred on the mtt-link. The data are accumulated in the SB-DAU and are transferred with an appropriate timing. The maximum transfer rate is 10k events/sec corresponding to the maximum number of secondary particles in the secondary beam course.

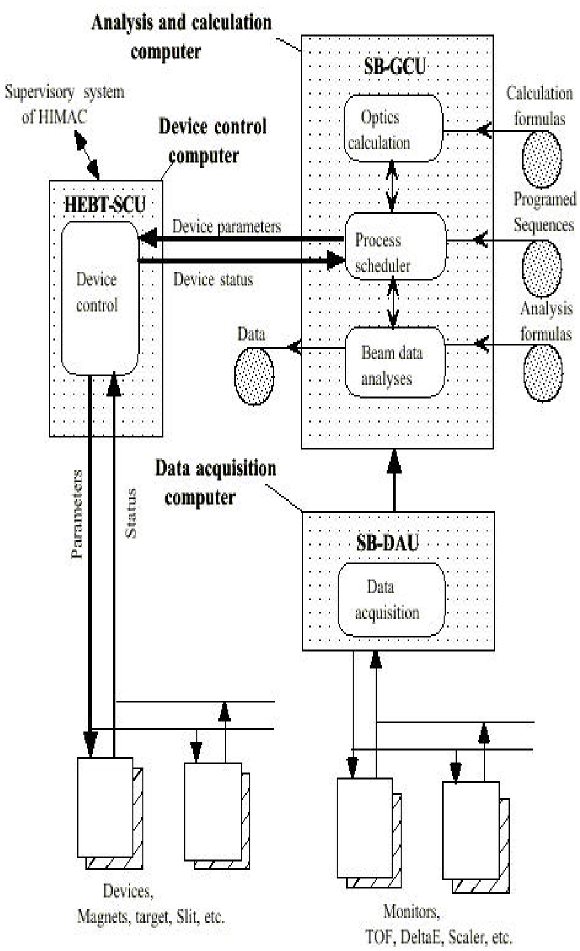

Fig 2. Control system of the secondary-beam course. The system consists of two computers of SB-DAU, SB-GCU and a part of HEBT control system named HEBT-SCU.

A UNIX work station, named Secondary Beam Course Control Unit (SB-GCU), plays a main role in the automatic-beam tuning, i.e. data analysis and parameter calculation based on the programmed sequences. SB-GCU also works as an man-machine interface, displaying the sorted data, status of the secondary-beam course and accepting operation commands.

The data transfer between SB-DAU and SB-GCU is synchronized with the timing of the beam. A schematic timing chart of the control system is shown in Fig.3. During the time of beam-off, SB-DAU transfers the data which are accumulated in memories of SB-DAU. SB-GCU carries out analysis and calculation of device control parameters for the received data and sends the results of the calculation to HEBT-SCU. HEBT-SCU controls the devices based on the parameters by the SB-GCU.

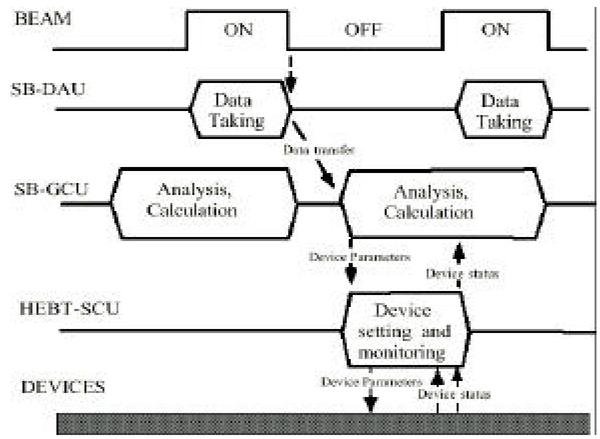

Fig. 3 Timing chart of the control system.

4 Automatic beam tuning

Automatic beam tuning is carried out by a program in SB-GCU. The program consists of three components : a data analysis, a beam-optics calculation and a process scheduler. The data-analysis program calculates counts of detected secondary particles, and evaluates the average and the dispersion of the TOF data measured by the plastic counters and energy loss in the silicon detector of the secondary particles. The beam-optics calculation program calculates field strength of the magnets according to the required conditions.

The process scheduler determines the control parameters of the devices such as magnet current or slit width by using results of the other two programs and searches the required optimum condition. The result of the calculations is transferred to HEBT-SCU, which controls the devices and checks the result of device setting.

We explain the algorithm for automatic-beam tuning, taking ^{11}C production from ^{12}C beams as an example. The flow chart is shown in Fig. 4. The sequence of the search is as follows. (1) The magnetic field of the first bending magnet is decided using the primary ^{12}C beam. The magnetic field is swept and the TOF (start) detector counts the number of particles to determine the magnetic field giving the maximum counts. (2) The magnetic field of the second bending magnet is similarly determined using the TOF(stop) counter. (3) The device parameters of the magnets for the secondary ^{11}C beams is calculated based on the magnetic field for the ^{12}C beam. (4) As all devices are set to transport the ^{11}C beams, ^{11}C counts identified on a two dimensional map, TOF and the energy loss, are integrated and the production rate of ^{11}C is evaluated. The magnets and the slits between F1 and F2 are swept in predetermined ranges and the optimum condition is decided.

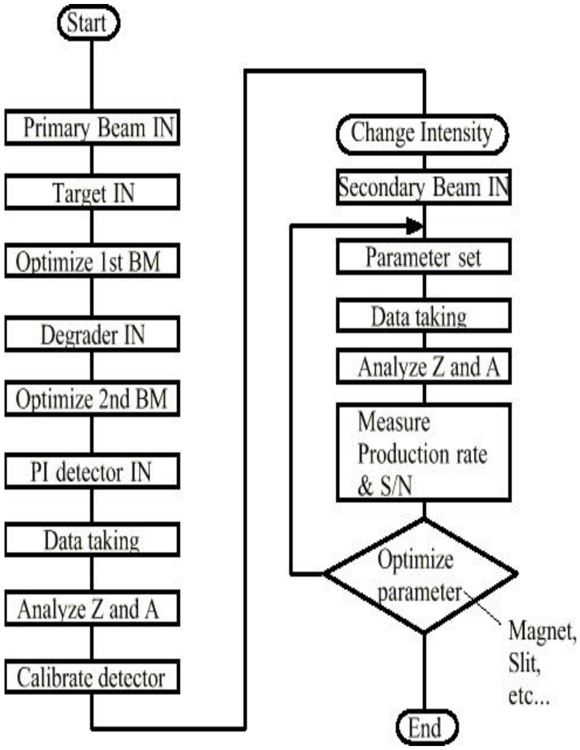

Fig. 4 Flow chart of automatic beam tuning.

5 Result of the experiment

In a first step of the beam tuning, productions of ^{11}C[4] and ^{13}O were achieved. The ^{11}C was employed because ^{11}C was a useful positron-emitter in medical applications. The production of ^{13}O was carried out as a test to produce a secondary particle which is distant from stable nuclei. The test experiment was concentrated to confirm effectiveness of the tuning algorithm. The condition in the test experiment is shown in Table 1.

Table 1 Conditions of the test experiment

Primary beam Energy (MeV/u)	^{12}C 400	^{28}Si 400
Secondary Beam	^{11}C	^{13}O
Production targets Thickness (mm)	Be 76	Be 51
Degrader Thickness (mm)	Al 7.0	Al 3.5
Beam spill rate (sec/spill)	3.3	3.3

The results of the automatic tuning for ^{11}C and ^{13}O are shown in Tables 2, 3, respectively. In the ^{11}C production, the maximum of the production rate was considered to be the optimum condition. In the ^{13}O production, both maximization of the production rate and the purity were employed to determine the optimum condtion. The production rate and the purity is almost equal to those obtained in manual tuning.

In the search of the optimum condition, the magnetic field was swept in a range of ± 0.3 % with a step of 0.05 %. Time for beam tuning was about 40 minutes. The intensity of the primary beams were measured by an ionization chamber in HEBT, while measurements of the secondary beams were halted. We are preparing a non-destructive monitor of the primary beams so that the primary and secondary beams can be measured simultaneously. When the new monitor is installed, not only reliability of the measurements will be increased but also the tuning time will be greatly reduced.

Table 2 Result of tuning test of ^{11}C.

Optimum Condition	Degrader Al (mm)	Production Rate	Purity (%)
Production Rate	7	1.9×10^{-3}	98

Table 3 Result of tuning test of ^{13}O.

Optimum Condition	Degrader Al (mm)	Production Rate	Purity (%)
Production Rate	3.5	6.5×10^{-7}	2.7
Purity	3.5	1.7×19^{-7}	6.5

6 Summary

We are constructing the secondary beam course. In the development of the control system, the first test of automatic beam tuning was carried out with satisfying results. The control system could generate the secondary ^{11}C beam with same quality as that of manual tuning.

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