Board №2

Operation of NIRS Cyclotrons（NIRS-930 and HM-18）

Yuichi Takahashi[A)], Satoru Hojo [B)], Ken Katagiri [B)], Masao Nakao [B)], Akinori Sugiura [B)],
Takanori Okada[A)], Hiroshi Ii [A)], and Akira Noda [B)]

A) Accelerator Engineering Corporation 6-18-1-301 Konakadai, Inage-Ku, Chiba-City, Chiba, Japan 263-0043

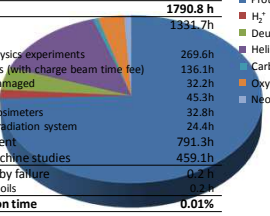
B) National Institute of Radiological Sciences 4-9-1 Anagawa, Inage-Ku, Chiba-City, Japan 263-8555

Abstract

The cyclotron facility at National Institute of Radiological Science (NIRS) consists of a NIRS-930 cyclotron (Thomson-CSF AVF-930, Kb=110 MeV and Kf=90 MeV) and a small cyclotron HM-18 (Sumitomo- Heavy- Industry HM-18).
The HM-18 has been used for production of short-lived radio-pharmaceuticals for PET.
The NIRS-930 has been used for various purposes spreading over from basic sciences to such applications as RI production and beam irradiation.
The control system of axial injection beam line was updated to the system using PLC. The beam monitors such as higher intensity viewer and phase probe were installed for operation. The operational status of the cyclotron facility is presented.

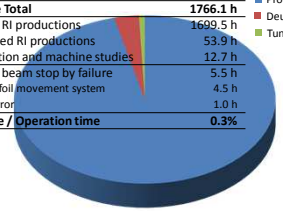
Annual Operation Time of NIRS-930

Planned time of operation	**1634.0 h**
Operation time Total	**1790.8 h**
1. Experiment	1331.7h
Experiment summary	
• Nuclear and atomic physics experiments	269.6h
• Radiation damage tests (with charge beam time fee)	136.1h
• Studies on radiation damaged	32.2h
• Biological experiments	45.3h
• Studies on radiation dosimeters	32.8h
• Studies on radiation irradiation system	24.4h
2.RI production & experiment	791.3h
3.Tuning operation and machine studies	459.1h
4.Unscheduled beam stop by failure	0.2 h
• Power supply for trim coils	0.2 h
Beam stop time / Operation time	**0.01%**



Annual Operation Time Of HM-18

Planned operation time for RI productions	**1566.0 h**
Operation time Total	**1766.1 h**
1.Protons used RI productions	1699.5 h
2.Deuterons used RI productions	53.9 h
3.Tuning operation and machine studies	12.7 h
4.Unscheduled beam stop by failure	5.5 h
• Stripping foil movement system	4.5 h
• Human error	1.0 h
Beam stop time / Operation time	**0.3%**



Unscheduled beam stop by failure

NIRS-930 Failure
(Power supply for trim coils)

Surface burning of the changeover switch
It burnt, and the output became unstable.

Disconnection of the limit switch wiring
It is a slight trouble, but we give up repair it at once because we give priority to operation of NIRS-930. It was stopped for around half a day.

HM-18 Failure
(Stripping foil movement system)

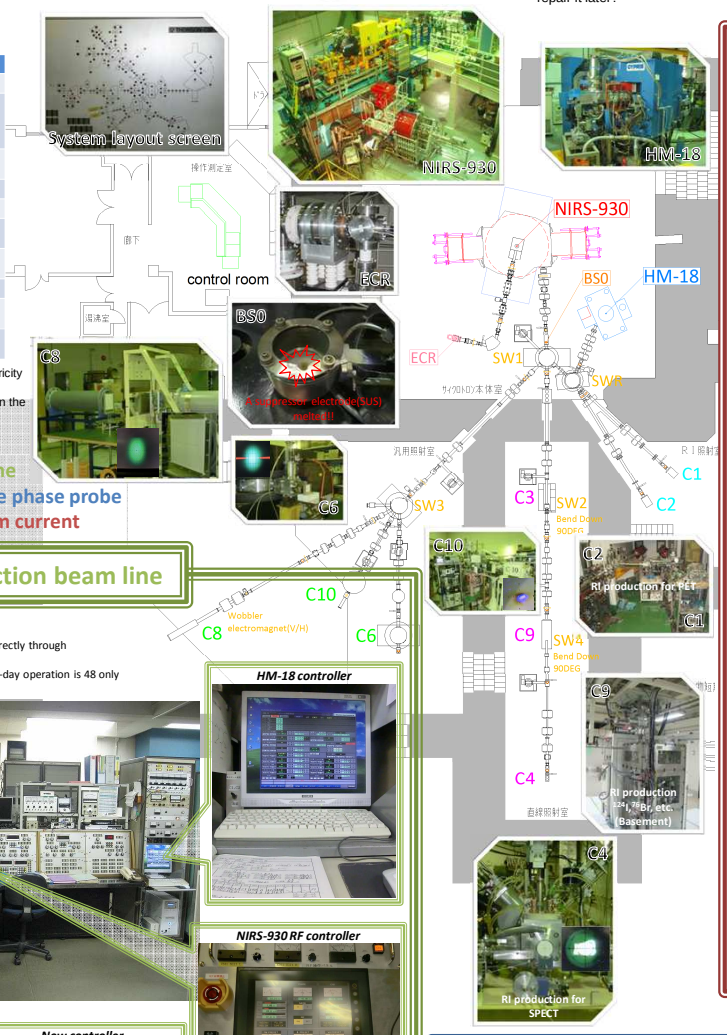
There are two cyclotrons in the same room, which affects each other's operation.
Even if we have faced with a malfunction in one, we cannot repair anymore if the other is operating.
We choose either; we stop the cyclotron operation and repair it or continue operation in trouble and repair it later?

General operation schedule

Schedule	NIRS-930	HM-18
8:30	Power supplies Turn on & Coolant circulation Start	
8:40	Main coil maximum excitation Start RF Setup Ion source Setup Beam line Setup	Main coil Setup RF Setup Ion source Setup
8:50	Main coil maximum excitation End Ion source & RF Adjustment Start	Cyclotron acceleration Adjustment Beam line Setup
9:00	Cyclotron acceleration Adjustment	Irradiation Start
9:20	Each course beam line Adjustment	
9:30	Beam spot Confirmation (In a course or the course end)	
9:40	Irradiation room preparations for user	
10:00	Irradiation Start	
15:00		Irradiation End (Only Main coil and SWR turn on)
18:00	Irradiation End Power supply Turn off & Coolant circulation Stop	

Because we do not operation the cyclotrons for 24 hours, we turn on electricity in morning and turn off at night.
we are required the first beam in about 90 minutes after power supply on in the morning. In addition, the acceleration adjustment is performed in order to answer in the demand strength from a user.
We performed the following improvements as follows.

- PLC control system of axial injection beam line
- Beam confirmation and adjustment using the phase probe
- Development of a monitor , with a high beam current



PLC control system of axial injection beam line

conditions of the console
A cyclotron control room has various control systems.
One of the kinds has control using potentiometer, which control power supplies directly through potentiometers separately.
The number is approximately 80. The minimum setting number to be used for one-day operation is 48 only for NIRS-930(The maximum numbers 58) HM-18 uses only 5.

Before controller
(axial injection beam line)

HM-18 controller

Potentiometer(most popular)

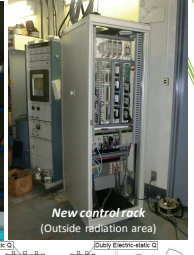
NIRS-930 RF controller

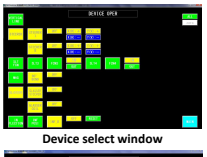
purpose
- Shorten time for apparatus setting.
- Make the reproduction of the beam better and make the stability better.

Means
- Using numeric keypad input(change control into PLC from potentiometer)
- Put a control rack outside of a radiation area.

New controller
(axial injection beam line)
& Ion source controller

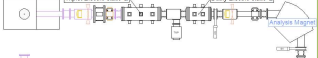
Before control rack
(Inside radiation area on NIRS-930)

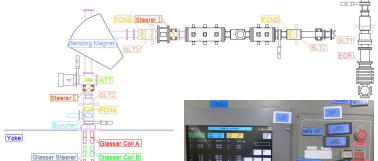




Device select window

Setting window and numeric keypad



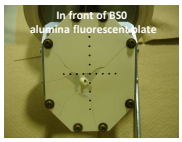


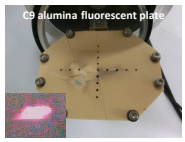
Result
- The possible misread of a setting and mistake of the set point was largely reduced by numeric keypad input.
- 16% of potentiometer controls to use by operation turned into PLC control.
- Sequence control became possible because of PLC control.
- The setting value and the output one were found to have a big difference for a Glasser coil（power supply output needs its calibration）

Consideration
We want to change an entire control system to PLC control from potentiometer control finally.
It may be hard to adjust the beam by the numeric keypad input only. Therefore we want to add the encoders.

High beam current monitor

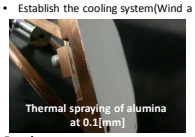
conditions of the viewer
The existing beam monitor in use does not have cooling mechanism.
And it will be broken if we put the beam on the alumina fluorescent plate without weakening its strength.
Therefore we weaken strength to ～0.1 [μA] at axial injection beam line(before inflector) in order to observe the extracted profile beam when we confirm a spot.
However, the beam profile will be changed by lowering its strength.

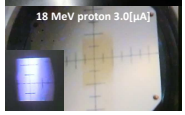




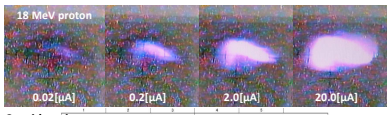
Purpose
Make the beam monitor which can be used for the confirmation of the spot with a high beam current.
The specifications required acceptance of the beam spot of 20.0 [μA] of Proton 30[MeV]

Means
- Reduce the heating rate（thin alumina fluorescent plate)
- Increase cooling efficiency
  (Connection of a base and the alumina fluorescent plate)
- Establish the cooling system(Wind a cooling pipe around a base)

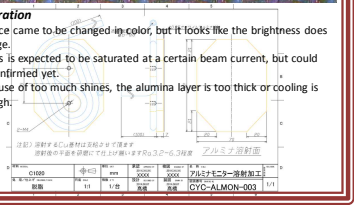




Result
- We could confirm the beam spot by a high current than before.
- After spot confirmation, the surface changed color (burnt?)
- Shining of the beam spot seems too much.



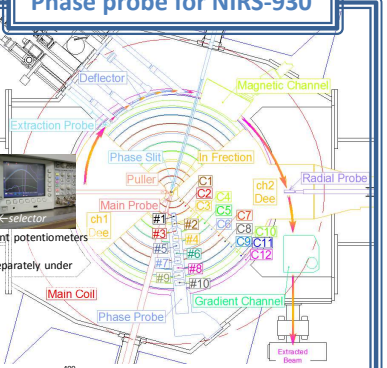
Consideration
The surface came to be changed in color, but it looks like the brightness does not change.
Brightness is expected to be saturated at a certain beam current, but could not be confirmed yet.
As the cause of too much shines, the alumina layer is too thick or cooling is not enough.



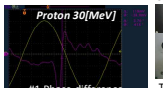
Phase probe for NIRS-930

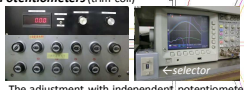
purpose
- Adjust ideal acceleration phase and increase of the beam current.

Means
1. Install a phase probe and measure the beam phase relative to the Dee voltage at each position.
2. Adjust ideal phase with a trim coil at each position.
3. Adjust an axial injection beam line to match the phase condition.



Potentiometers (trim coil)





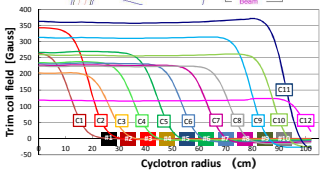
The adjustment with independent potentiometers is considerably difficult.
The phases can be monitored separately under each position selection.

Adjustment result

Nuclide	Energy	Goal	Attend
proton	30[MeV]	20.0[μA]	26.0[μA]
Proton	60[MeV]	10.0[μA]	9.3[μA]
deuteron	20[MeV]	12.0[μA]	20.0[μA]

We obtained the reproducible good parameters.

Consideration
Reproduction confirmation of the acceleration phase came to be made quickly.
When acceleration and extraction cannot be reproduced, we can reproduce matching phase with the use of a phase probe.
When we cannot reproduce the axial injection beam line, phase slips off totally(When the adjustment of the buncher in particular cannot be reproduced)
We want to simplify the reproduction confirmation of axial injection beam line.



WAO 2014 26-31 October 2014 WORKSHOP ON ACCELERATOR OPERATIONS Mainz, Germany