A FACILITY FOR RADIOISOTOPE PRODUCTION AT TRIUMF WITH 70-110 MeV PROTONS

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ABSTRACT

A radioisotope production facility using protons between 70 and 110 MEV and currents in excess of 70 μA has been operating for several years at TRIUMF. This beam operates simultaneously with two other research beams from the 500 MeV cyclotron. 10 curies of ^{82}Sr were produced for commercial sales with 53.8 mAh of production in 92 days. The beamline is radiation hardened, modular and pre-aligned for ease of remote handling. Four production targets are accessible to the beam from a multiport switching magnet. These targets can also be handled remotely. The target control system uses CAMAC and a commercial, object oriented program which operates from a stored data base. Recent improvements and current applications of the production facility will be discussed.

1. INTRODUCTION

A dedicated radioisotope production facility is located adjacent to the TRIUMF 500 MeV H^- cyclotron . It consists of beamline 2C (BL2C) that can extract protons from 65 to 120 MeV with beam intensities up to 100 μA and four target stations that are mounted in the cyclotron vault wall (fig. 1). A fifth station in an adjacent area is planned for proton therapy. A switching magnet with seven ports delivers the beam to the selected branch line 2C1-7. The target station on line 2C4 is a solid target facility (STF) that is currently being used for production of ^{82}Sr and for the development of several other isotopes. Preliminary measurements for proton therapy have been made on 2C1. The lithium bromide target on 2C2, the sodium iodine target on 2C3 and the molten cesium target on 2C5 are uncommissioned. There is a Faraday cup on 2C6 for calibrations and one unused beam port, 2C7. All of the targets were designed for rapid removal into a shielded transfer flask and for repair in a remote hot cell.

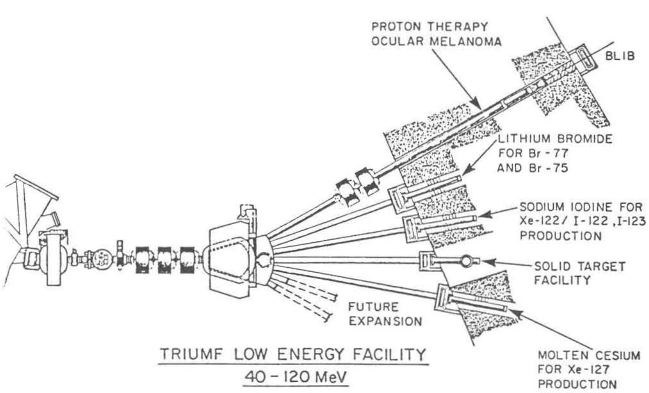

Fig.1. Beam line 2C (BL2C) and the four target stations used for radioisotope production.

The purpose of this facility is to develop isotope production technology at 65-110 MeV up to high intensity levels for medical research and future commercial exploitation. A major advantage is that isotope production on BL2C is done with almost no impact on the other beam operations at TRIUMF. Typical high circulating beam currents in the cyclotron for multiple simultaneous extractions are BL2C extracting 40 μA at 85 MeV, BL4B extracting 100 nA at 350 MeV and BL1A extracting 140 μA at 500 MeV. However, it is often necessary that the ratio of beam intensities (split ratio) in these beamlines vary by 10^4 depending on the application.

2. RECENT IMPROVEMENTS

Recent improvements in beam extraction, diagnostics and controls have resulted in regular production of ^{82}Sr for supply to North American market. A change in the target capacity of the STF was also made to increase the production rate of ^{82}Sr. The following sections describe these recent additions.

2.1. BL2C extraction mechanism

It is necessary to select the optimum incident and exit proton energies for production targets to maximize the yield of desired isotope species while minimizing the yields of undesired species. This requires that beam can be extracted over the complete energy range of the production facility. Furthermore, it is necessary to have a selection of foils available in the extraction mechanism for remote replacement when damaged by intense beams and also to alter the split ratio as mentioned above. The original 2C extraction mechanism used four single foil mechanisms positioned for discrete energies. Another undesirable feature of this mechanism was that the stripping foils were rotated into the beam which caused unnecessary beam steering as a function of the intensity split ratio. The new extraction probe described here corrects this problem and satisfies all of the requirements noted above. It was installed in the fall of 1990 after extensive testing in the laboratory. It has three orthogonal foil positioning mechanisms which are accurate to 0.1 mm. This allows continuous operation over the energy range of 65 to 120 MeV. The energy spread is 0.5 MeV due to overlapping orbits in the cyclotron. The beam intensity can be varied over a range of 10^4. Six different, reusable graphite foils (pyrolytic) are available from a carousel attached to the probe positioning mechanism, (figure 2). The carousel is designed for quick replacement. During normal operating periods, 8-12 weeks, 30 mAh of beam charge is extracted with intensities up to 45 μA. In this period two or three of the foils, 2.5-4.0 mm wide, are typically damaged. A range of foil widths from 0.1 mm to 8.0 mm is required to obtain the split ratio variation noted above. The stripper mechanism employs three DC motors with absolute shaft encoders for positioning and it is controlled by a microprocessor that communicates with cyclotron control system via the CAMAC highway. The entire mechanism is mounted on a frame which is attached to the tank lid and can be installed or removed by standard, in-tank remote handling equipment.

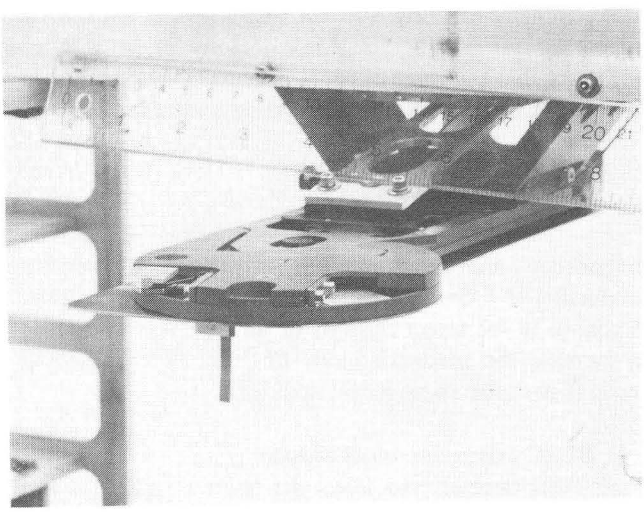

Fig. 2 . An extraction foil deployed from the foil carousel.

2.2. Diagnostics

For successful operation of the facility it is necessary to monitor beam loss to less than 0.1 μA out of 50 μA, to maximize isotope production and to minimize beamline activation. This is achieved by accurate total current measurement, by accurate beam profile measurement and by target protection. The original nonintercepting total current monitor had been sync6hronized with the time of flight signal so that whenever the extraction energy was changed the electronics required retuning. The electronics were changed to incorporate a 1 KHz digital comb filter that is synchronized to the RF fundamental frequency. On the STF, a prototype scanning wire monitor has been installed and the target protect monitor has been redesigned. The scanning wire monitor is a pneumatically driven, single stroke cross which passes through the beam at 45°. The cross is made of molybdenum strips which are 0.05 mm wide and 3 mm deep with respect to the beam. The monitor gives good beam profiles from 50 nA-50 μA without causing significant beam losses. It was installed in the 90 fall shutdown. The redesigned halo monitor was installed in June, 91 following the beam destruction of the original which inaccurately measured beam losses. The target protect monitor measures the beam halo using secondary emission foils. The new monitor incorporates a thermocouple in a graphite shielding ring upstream of the monitor and the halo foils have been moved away from the high intensity beam but out of the beam shadow of the graphite ring. This improved halo monitor design is being used in the other 2C lines.

2.3. Controls

The 2C targets control system must monitor all of the targets parameters and take the necessary actions. Space restrictions in cyclotron control console meant the 2C targets must be controlled through a single terminal that could be configured to an individual operator's needs with multiple, responsive displays. The 2C control system that ran on a PDP11 was replaced in 1990 with VISTA™, a current value database programme using a graphical, user interface that runs in a microVAX II. This programme allows icon displays and mouse control as well as on-line editing on sections of the 2C controls. VISTA recently underwent several upgrades along with terminal improvements in the main control console so that multiple displays with 1 sec. response are available and programme crashes are less frequent. Initially the displays would only control a single action such as starting a pump or opening a valve and would read back monitoring devices such as thermocouples, flow meters and pressure transducers. In the STF, targets are lowered into the beam by a water system that is isolated from the target cooling water. To insert, remove, or cool a target, a sequence must be followed that depends on various conditions in the STF. To automate these operations and reduce the chance of operator error, process controls have been developed for the STF using VISTA and will be used in the other target controls[1]. Figure 3 show a typical terminal screen with a display indicating the state of the individual components including the halo monitor, a display for setting the process and several icon displays. The STF has been set to *TUNE* which means the cooling water system is running to act as a beam dump but the target is not inserted.

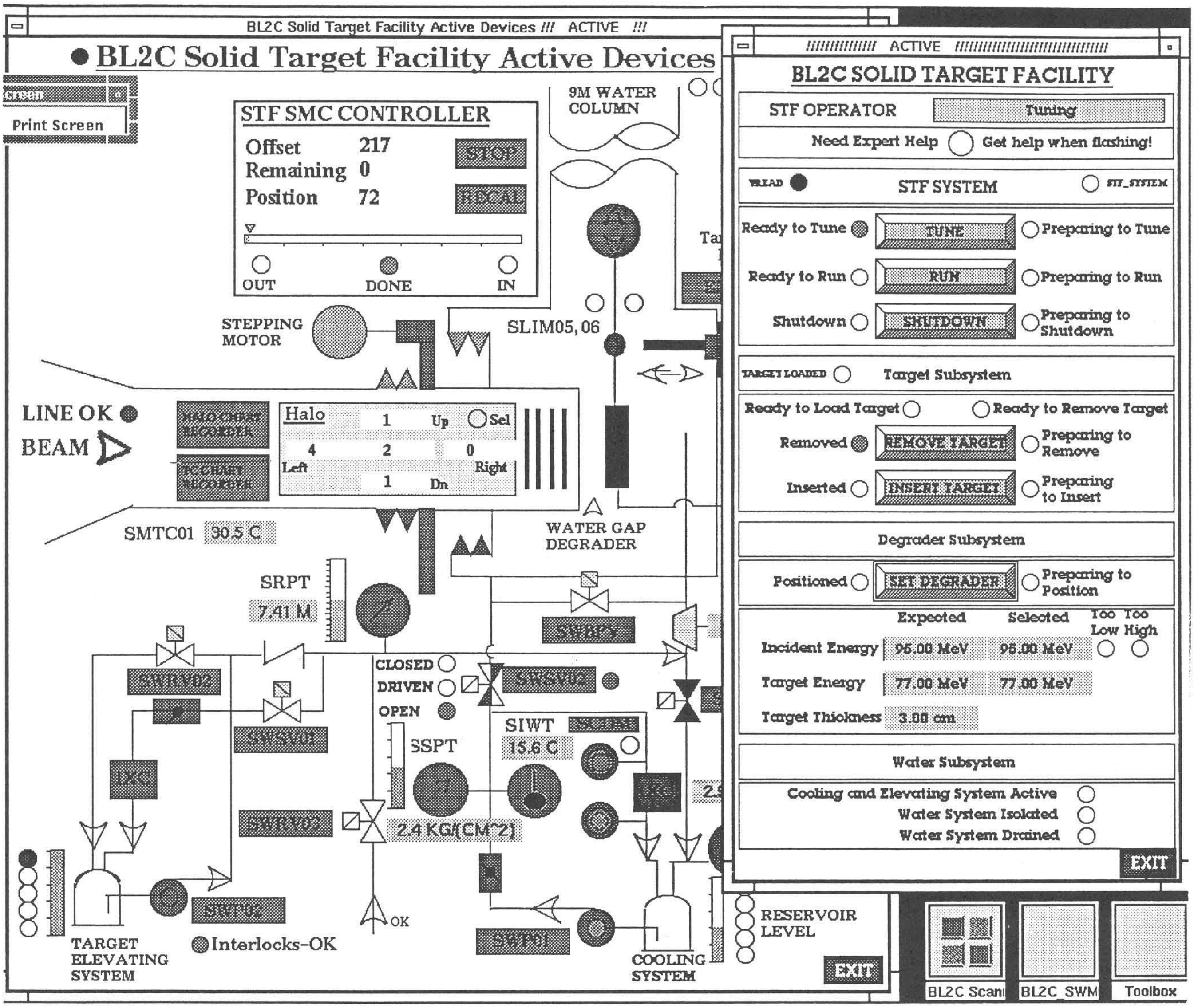

Fig. 3. A typical terminal screen with two displays and several display icons.

2.4 Enlarged target capacity of the solid target facility

The original solid target facility had been designed for targets thinner than 8 mm and densities greater than 3 g/cm^3. However, in the case of metallic rubidium the density is only 1.5 g/cm^3 and improved yields of ^{82}Sr can be obtained by increasing target thickness and incident beam energy in correlation. In the spring of this year, it was decided to remove the solid target facility and rebuild the target receiver to accommodate 30 mm steel cassettes, 4 g/cm^2. To accomplish this activity, it was necessary to remove the bottom section of the facility to a hot cell where it was remotely disassembled and the new receiver was installed. In more than five years operation, this was the first instance where the remote handling devices and special facility design for remote service has been exercised. Radiation fields of about 10 R/h were measured inside the STF target cave. The activity was satisfactorily completed in 30 man days with an accumulated dose of 0.6 man-rem distributed among 4 persons. The improved performance is described in the following section.

3. RECENT OPERATIONS AND APPLICATIONS

During the last year, 1991 and the first half of 1992, about half of the available operating time has been devoted to high level production of ^{82}Sr and the improvement of production and processing technologies developed earlier. Metallic rubidium targets, 1.8 g/cm^2, have been bombarded with 62 MeV protons as shown in the following table. The average beam current noted includes an average of 1.2 days per week where there was no beam due to cyclotron maintenance activities. The beam is normally 30 to 45 μA during bombardment and one target was run at 70 μA for a test of the cooling system. The short run ^{82}Sr production rate, i.e. neglecting decay, is 0.22 mCi/μAh. Currently, 4 g/cm^2, rubidium metal targets are being tested with 76 MeV protons up to 100 μA in a effort to shorten the batch production time from three weeks to one.

RADIOISOTOPE PRODUCTION ON BEAMLINE 2C, 1991
All rubidium targets, 1.8 g/cm^2
61 MeV incedent proton energy

TARGET #	mAh	Ci@EOB
A3	7437	1.40
A6	6230	1.70
A5	5880	1.30
A10	4531	0.93
A12	4400	0.92
A17	1599	0.37
A16	8140	1.60
A15	15603	2.60
TOTAL	53880	10.3

The new BL2C stripper allowed operation of the cyclotron at high currents when the primary high current beamline, BL1A, was unable to accept beam because of target problems. 30 μA, 95% of the circulating beam, was extracted by 2C for the irradiation of target A16 with the remainder of the beam passing on to the beamline 4 stripper. This operating mode eliminates the irradiation caused by electromagnetic stripping since most of the beam is extracted at 85 MeV and is an acceptable alternative to production with shared beam when minimum activation of the cyclotron is desired before a cyclotron maintenance. A full 100 μA test is planned in the near future but regular operation at this level waits for an improvement in the ion source and injection system.

4. FUTURE DEVELOPMENT

Other beamline activities center on the search for production schemes of possible therapeutic isotopes, ^{97}Ru, ^{178}W and ^{188}Pt. There are several production schemes for these species and cross sections have been measured for rhodium, tantalum and iridium targets respectively, but the overall viability depends also on the development of efficient and easy radiochemical procedures for separating the desired species from its production target. These procedures are now being investigated. Also there has been a request for ^{122}Xe which is used as a generator of ^{122}I for PET. This requires commissioning of the molten sodium iodide on branch line 2C3. No radio-chemistry is required here as the xenon parent is easily trapped on most surfaces at 77 °K. This target can supply one Curie of ^{122}Xe or ^{123}I in a few hours at 20 μA of 86 or 70 MeV protons. In the next year, beam time will be shared with developments in the external beam area (1B) for proton therapy.

5. CONCLUSION

The radioisotope facility at TRIUMF has successfully demonstrated new techniques for commercial isotope production at high intensities. The recent improvements have allowed the facility to operate smoothly with almost no impact on other TRIUMF operations. Through careful planning and design, the upgrades and operation of the facility have had a minimal impact on the dose budget at TRIUMF.

6. REFERENCES

[1] Wilkinson, N.A. and Ludgate, G.A., "Application of Object Oriented Techniques in the TRIUMF Beam Line 2C Control System". p. 681 of this proceedings.