05 DEC. 1978

RECENT DEVELOPMENTS AT TRIUMF

Karl L. Erdman*

CM-P00067110

Abstract

The beam currents and their quality at TRIUMF have been steadily improved since the accelerator began operations shortly before the last Conference. The high current beam stop has now been completed and currents of over 100 μ A have been accelerated. The accelerator routinely delivers beam of 150 nA of polarized protons. The addition of new beam lines and the improvements in transmission and stability have continued in an orderly fashion to the expected full capability envisaged by the proposers of the negative ion cyclotron meson facility.

1. Introduction

At the Cyclotron Conference held in Zürich in 1975 a report on the first operation of the TRIUMF accelerator was given by J.R. Richardson¹ who was, at the time, the director of the facility. It was most gratifying for him to see his ideas for using H^- acceleration vindicated. A beam of up to 525 MeV protons was extracted from the machine by the use of thin aluminum and carbon stripping foils positioned at various radii in the vacuum tank.

Since that time the machine has been operated in a program in which two thirds of the time has been directed to beam production and one third to machine study and technical improvements and modifications. There have been two 6-week periods per year during which the machine has been shut down for modifications in the cyclotron. Modifications to the experimental areas are done during these shutdown periods.

Operating beam currents have been increased slowly from the initial 10 nA to 20 μ A during the last three years with short periods of high current operation. In July of 1977 the first beam of over 100 μ A was extracted, and since that time stability and quality of the high current beam has been steadily improved as will be reported in other papers at this conference.^{2,3}

The polarized ion source of the Lamb shift type which was put into operation shortly after the delivery

of the first beam to the experimental areas also has been steadily improved. A dc beam of 1 μ A of 70% to 80% polarized H^- ions is now regularly delivered by the ion source and a beam of 200 nA has been delivered to the experimental areas. This has made possible a variable energy neutron beam created by charge exchange in a liquid deuterium target.

The transmission through the cyclotron has also been improved until with the buncher in operation a transmission of over 30% of the beam from the ion source through the cyclotron at a beam current of 20 μ A has been obtained. A more detailed description of this achievement is given in another paper at this conference.² The total current from the ion source is routinely 600 μ A.

A study has been made of the possible improvements to energy stability and to the possibility of single turn extraction. The use of slits at the centre of the machine has allowed an impressive scan of the beam current as a function of beam radius to be made. (Fig. 2) A discussion of this will also be given in a separate paper at this conference.³

2. Facility Development

The facility presently consists of two experimental areas, one dedicated primarily to nucleon-nucleon interactions and nuclear physics and the second to pion and muon reaction studies.⁴ The layout of the experimental halls and the extracted beam lines is illustrated in Fig. 3. During the summer of 1978 two additional extraction ports were installed on the machine at the side of extraction port two. The primary purpose of these ports was to provide beams for isotope production.

A bending magnet in beam line 1 allows for a second nucleon-nucleon interaction area and the extraction of two simultaneous, independently variable energy, polarized proton beams.

A second target station has been constructed into beam line 1 for two additional secondary meson channels which are presently under construction. One of these channels is a backward-going slow pion-muon channel with an acceptance of 30 msr, and the other is a zero degree forward takeoff pion channel having high resolution.

The beam stops at the end of the nucleon-nucleon interaction area are both carbon blocks in iron shields buried outside of the building. They are capable of stopping 10 μ A and 100 nA of beam, the lower figure being for the beam stop on the line servicing the broad range spectrograph. The experimental floor is excavated 12 m below ground level.

The beam stop at the end of beam line 1 has been upgraded to take beam currents of up to 400 μ A and has been provided with a D_2O moderator and neutron ports to provide a facility for neutron experiments of various kinds.

An internal beam dump capable of handling 10 nA of beam has been installed at the end of the nucleon-nucleon channel in the meson area.

The original target BLITZ in the meson area and its three associated secondary meson channels remain unchanged.

Fig. 1. Monthly microampere-hours delivered to experimenters.

*TRIUMF, Vancouver, B.C., Canada V6T 1W5

Fig. 2. Radial scan of the circulating beam in the TRIUMF cyclotron from 143 in. to 315 in.

Fig. 3. Layout of the TRIUMF experimental areas.

3. Thermal Neutron Facility

Since the stopping of the beam at the end of the beam line 1 at high currents leads to usable neutron fluxes, it was decided to design a beam stop⁵ that would allow the stopping of 400 μ A beams and optimize the neutron fluxes obtainable.

The thermal neutron facility is shown in Fig. 4. It consists of a thin-walled stainless steel flask filled with lead. The flask is connected to a vacuum system through pipes passing through an 8 m water tank in which the flask is immersed. The lower half of the flask is in a separate compartment filled with D_2O to optimize the thermal neutron flux. Various ports for rabbit systems, slow neutron channels and fast neutron channels penetrate the two-meter primary steel shield surrounding the double-walled water tank. (Fig. 5) The performance of the lead beam stop during beam-on periods is shown in Fig. 6.

The lead in the flask becomes molten to its upper surface at a beam current of 20 μA . Cooling is achieved by convection in the lead and by conduction through the steel container near the upper surface on the lead where it is molten. As the current is increased to 100 μA the temperature in the centre of the lead where the beam is being stopped increases to 500°C. At this current the bands of melted, convecting lead contacting the stainless steel flask are 2 mm wide, as could be seen in tests simulating the action of the beam. The width of the molten contact area increases with beam current.

After several runs of 100 μ A the lead flask was removed from the water vessel and inspected for distortions or indications of thermally induced stresses. No distortions of any kind were seen. It appears that the system will work as designed as a high current beam stop.

Fig. 4. The thermal neutron target, moderator and reflector assembly.

Fig. 5. The thermal neutron facility and connecting beam line. Vertical cross-section along beam line.

Fig. 6. The operating temperature in the TNF as a function of beam current.

4. Low Energy Extracted Beams

In Fig. 7 it is possible to see the position of the low energy extracted beam ports added to beam port 2 on the cyclotron tank. Beams to these ports were successfully extracted from the inner orbits of the cyclotron at 70 and 90 MeV. The beams were measured at the new extraction ports by profile monitors, and the profiles are seen in Figs. 8 and 9.

The beams were viewed on wire chambers with a 3 mm wire spacing positioned at the extraction port. The amplitude of the current on each wire is seen in the oscilloscope picture. The external beam lines for these ports have not been installed but the successful extraction has now made TRIUMF the only cyclotron that has simultaneously extracted three beams of different energy and intensity. It also allows an energy variability of the extracted beam from 70 MeV to 525 MeV in a continuous fashion in one cyclotron. The maximum stable ratio between two beams has been improved to $1:10^4$. (Fig. 10) The low intensity beam was varied while the high intensity beam was held constant in the exercise. The stability problems are discussed in another paper at this conference.³

Fig. 7. Extracted beams from TRIUMF.

Fig. 8. Beam profile of extracted 70 MeV beam. Wire spacing 3 mm.

Fig. 9. Beam profile of extracted 90 MeV beam. Wire spacing 3 mm.

Fig. 10. Variation of the split ratio of extracted beam at a level of $1:10^4$.

5. 5:1 Pulser

Two pulsers have been inserted into the injection line of the TRIUMF ion source and injection system. The first one is in the ion source (micropulser) and it operates at a rate of 1 kHz. It has a duty factor which varies from 1% to 99%. It is used to change the beam intensity in achieving a 100 μ A tune, and the gap in the beam current at the 99% duty factor is seen by toroidal magnetic pickups and cylindrical capacitive pickups. This feature is used in various tuning, current measuring and stabilization procedures as described in other papers in this conference.³

The micropulser operates on the beam microstructure and is capable of passing one pulse in five in the RF cycle. Since the rotation frequency is one fifth of the RF frequency, instead of 5 spokes in the rotating charge cloud there is only one. The beam suppression during the operation of this pulser is seen in Fig. 11 which shows both the capacitive pickup signal with and without the micropulser in operation. The suppression factor was measured in the experimental

Fig. 11. Capacitive pickup signal on the extracted beam in beam line 1.

area on the M9 channel, and Fig. 12 shows the appearance of the secondary beam in the 5:1 mode of operation. The suppression factor is better than 2×10^{-7} , the limit of sensitivity of the measurement.

Fig. 12. Secondary beam production during operation of the 5:1 pulser.

6. Cryopumping

The cyclotron has been operating with a cryopumping system consisting of 80°K and 20°K cryopanel. During the pumpdown cycle the tank is heated to 70°C by circulating hot water for 12 h at which time the base pressure reaches 2×10^{-7} Torr and the cyclotron can be put into operation. After continuous operation for a month the base pressure reaches 2×10^{-8} Torr. Since the activation by gas stripping is comparable to that by electromagnetic stripping at high gas pressures, and the activation of the cyclotron tank poses a serious problem, it was decided to install liquid helium cooled cryopumps into the cyclotron to reduce the base pressure much more quickly by pumping off the hydrogen produced through the dissociation of the absorbed water in the tank. A prototype pump consisting of a cylindrical container for liquid helium, having a diameter of 1 m and a height of 10 cm with a chevron baffle cooled to 80°K in front of the pumping surface, was installed in the tank during the spring shutdown in 1978. This system has now been tested. The base pressure rapidly reaches 2×10^{-8} Torr after the bakeout is finished. The boil-off rate for the liquid helium is between 1 to 5 l per day.

7. Energy Resolution

The turn pattern obtained in the cyclotron by the use of slits is seen in Fig. 2. The single turn structure is clearly seen to 200 MeV, and the separation is quite good to full energy. A spectrum taken of a target with the broad range spectrograph is displayed in Fig. 13.

Fig. 13. MRS energy resolution using energy slits in the cyclotron.

The resolution at 200 MeV was 650 keV of which most was due to the instrumental resolution and not the energy resolution of the cyclotron. Since the acceleration voltage of the machine is now 160 keV per revolution, single turn extraction has been achieved at that energy. The figure indicates that further tuning will be necessary before it is achieved at full extraction energy.

8. Applied Program

The installation of the 70 and 90 MeV extracted beams and the isotope production targets at the TNF and at the end of beam line 4 marked the beginning of the applied program at TRIUMF. Isotopes will be produced at the cyclotron and will be marketed by the AECL Commercial Products Division. TRIUMF has entered into an arrangement with AECL-CP in which a new, small, isotope production cyclotron will be installed at the facility to back up periods when the main machine is shut down for maintenance. This 200 μ A, 42 MeV, negative ion machine will be purchased from the Cyclotron Corporation.

A neutron activation analysis group has been set up to do commercial analyses using the rabbit system of the thermal neutron facility.

Neutron beams will also be produced with the 42 MeV machine for the purposes of cancer therapy, and the necessary additions of laboratory space and treatment rooms for these purposes has been authorized.

9. Conclusions

The major objectives listed in the conclusions at the end of the summary paper on TRIUMF¹ have been achieved. The running at full intensity requires the completion of remote handling equipment for the cyclotron. Although the 3rd harmonic system has been tested at low power it has not yet been put into operation. These are the two remaining machine developments necessary to bring the cyclotron up to the capabilities initially envisaged for it. The increase of the beam current to 400 μ A awaits the development of an improved ion source.

References

1. J.R. Richardson, The status of TRIUMF, Proc. 7th International Conference on Cyclotrons and Their Applications (Birkhäuser, Basel, 1975), p.41
2. M.K. Craddock, K.L. Erdman and J.T. Sample, Basic and applied research at the TRIUMF meson factory, Nature 270, 671-676, December (1977).
3. E.W. Blackmore, P. Bosman, R. Burge, G. Dutto, D. Gill, G.H. Mackenzie and P.W. Schmor, Achievement and control of the 100 μ A beam at TRIUMF, this conference.
4. E.W. Blackmore, M.K. Craddock, G. Dutto, C.J. Kost, G.H. Mackenzie and P.W. Schmor, Measurements and corrections to the beam properties in the TRIUMF cyclotron, this conference.
5. A.S. Arrott, R.E. Blaby, J.J. Burgerjon, T.A. Hodges, R.R. Langstaff, T.L. Templeton and I.M. Thorson, The TRIUMF thermal neutron facility, TRIUMF report TRI-77-1 (1977).