TRIUMF

Financial and Administrative Annual Report for 1980-1981

THE sectioned structure of the TRIUMF cyclotron is characteristic of all large, high energy cyclotrons. Einstein's theory of special relativity tells us that as the speed of a projectile increases then its mass increases likewise. A stronger magnet is therefore needed to hold the projectile in its circular path. We obtain this at TRIUMF by extending the six magnet sections more and more in the direction that the projectile is travelling. The final solution then is one in which six "magnetic arms" curve gracefully out for 30 feet. These trap the stream of protons in a tight spiral path while the cyclotron boosts their speed to 75% of the speed of light.

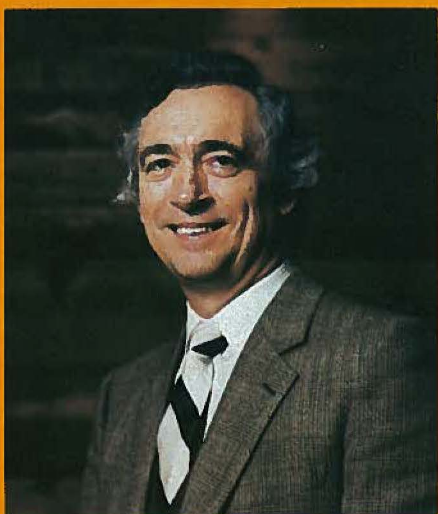
TRIUMF's logo builds on this characteristic shape by smoothing off the rough edges and sketching in three of the many possible paths that a proton beam may take as it is extracted from the grip of the cyclotron's powerful magnetic field.

Simple, informative and the symbol of TRIUMF.

In January 1972 the TRIUMF staff paused momentarily for this historic photograph on the completed lower half of the 4,000 ton cyclotron magnet. Two years later the facility was complete and the first useful proton beams were extracted from the cyclotron at the full design energy.

Management

Board of Management



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Business Manager

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The TRIUMF Annual Report Scientific Activities is available from the TRIUMF Information Office for those who wish to review the year's technical progress in detail.

WHEN you walk into TRIUMF you may notice quite a change. We've been doubling our original office space for scientific and administrative staff, doubling our workshop area and tripling the area devoted to assembling and testing equipment for experiments. And that is only the improvements in the structures housing the important steps forward TRIUMF is making scientifically!

Director's Report

The admirable expansion of TRIUMF continued during 1980/81 with an increase in NRC funding, from $9.541 M to $13.502 M, being matched by the completion of several new facilities on the main site for use in both the pure physics and applied research programs.

The cyclotron was available for 84% of the scheduled time. A 30% increase in beam production over the last year was achieved with more than 100,000 microampere hours of proton beams being delivered by the cyclotron for the first time.

Several successful improvements were made on the road to high-intensity running: one of TRIUMF's long-term goals. Some had the effect of reducing the radioactivity induced in the cyclotron and beam line components, by lowering the fraction of proton beam lost during acceleration inside the cyclotron and along the beam lines, while others improved the reliability and handling methods for equipment that is destined to become radioactive. In addition tests during the year have shown that proton beam currents of 150 microamperes can be extracted into beam line 1A, TRIUMF's high-intensity meson production-radioisotope production-pion cancer therapy line.

The Chemistry Annex redevelopment was completed this year providing in addition to the Atomic Energy of Canada Ltd.'s extensive radioisotope-handling facilities, many laboratories and offices for TRIUMF staff and an underground vault for a 42 MeV isotope production cyclotron. A ground level extension of the Proton Hall was started funded by the B.C. Provincial Government through the Universities Council of B.C. This large structure will provide an area for assembling and testing the complex equipment that goes into experiments at TRIUMF. It will be well serviced by two 50-ton cranes giving the maximum flexibility possible to researchers handling heavy apparatus. In addition the original office building has been greatly enlarged to provide a new library, a 150-seat auditorium, a centralized Business Office and many new offices for staff and visitors alike.

New facilities for pure and applied research were constructed in the main accelerator building. Inside the cyclotron vault the interim beam line 2C, for radioisotope research, was upgraded to a fully operational line. The beam line will be able to operate simultaneously with beam lines 1 and 4, generating radioisotopes for commercial and research programs. The successful operation of this beam line is a testament to the flexibility of the original cyclotron's design concepts. A new secondary channel, M11, was built in the Meson Hall to provide high flux beams of fast pions. This development brings the total number of meson channels to five.

Beam line 4C was constructed in the Proton Hall to provide the lowest intensity beam of polarized protons available at TRIUMF for a polarized proton target experiment. The beam line is expected to be used for several years in its present form.

The Applied Program has forged ahead this year with several patients being treated in the Batho Biomedical Annex as part of the B.C. Cancer Foundation's pion cancer therapy program. Only one irradiation was reduced because of a cyclotron failure.

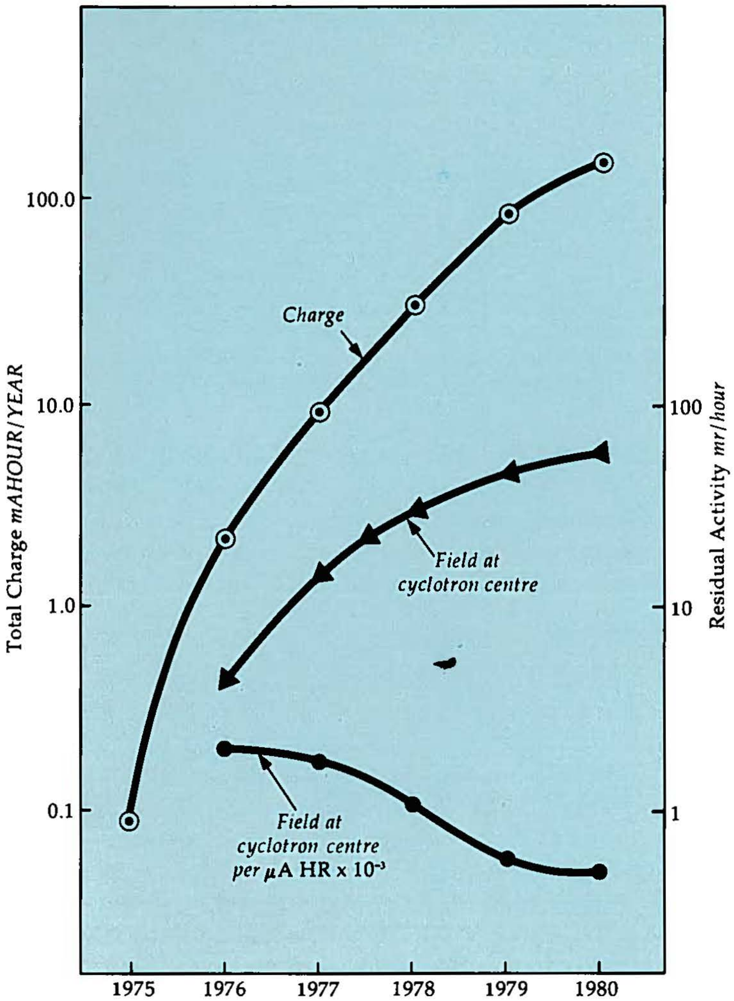
A positron emission tomograph (PET) is being constructed at TRIUMF. The project has brought together a group of people of the highest calibre in chemistry, electronics, nuclear detectors and computing. The recently ordered VAX-11/780 will be used to create meaningful scans from the raw PET data when the scanner is initially operated.

A facility was installed at the end of beam line 1A in the massive concrete shielding of the Thermal Neutron Facility (TNF) for the production of radioisotopes by

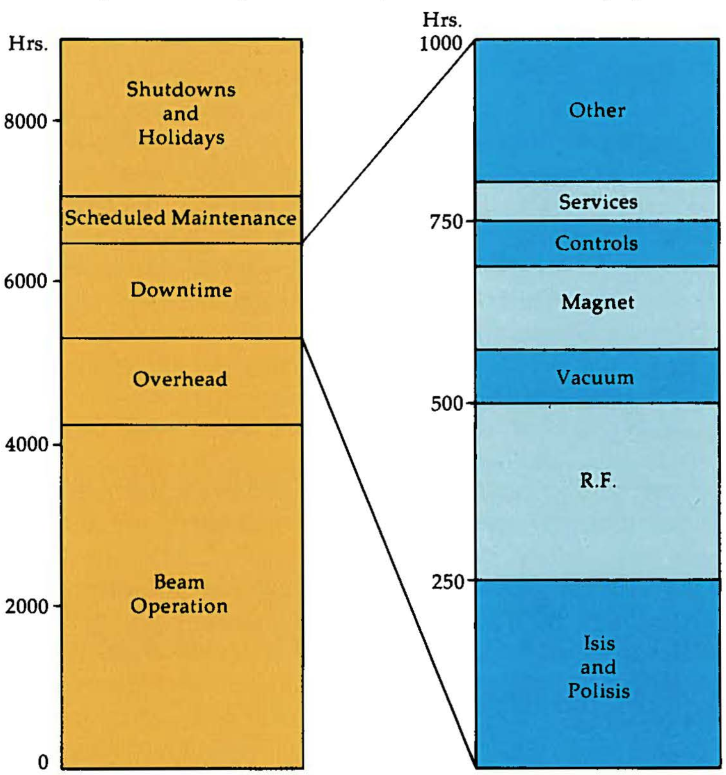
MILLIONS OF DOLLARS

	1979/80	1980/81	1981/82 (anticipated)
NRC Capital & Operating	$9.54	$13.5	$16.84
NSERC Experiments	$1.67	$ 1.85	$ 2.1
B.C. Provincial Govt. Buildings	—	$ 1.9	$ 4.9*

* $2 M is expected to be used in 1981/82.



One measure of success for any year is the total charge delivered by the cyclotron for research. Every milliampere-hour (mA hour) delivered is equivalent to 3.6 coulombs of electrical charge or 2.25 x 10^{19} protons or 36 millionths of a gram.



1980 Beam Operation Bar Chart.

irradiating sealed targets in the 500 MeV proton beam. Unfortunately the targets cause sufficient scattering and energy loss to the proton beam to seriously reduce the thermal neutron flux in the TNF, with obvious negative effects on the neutron activation analysis program.

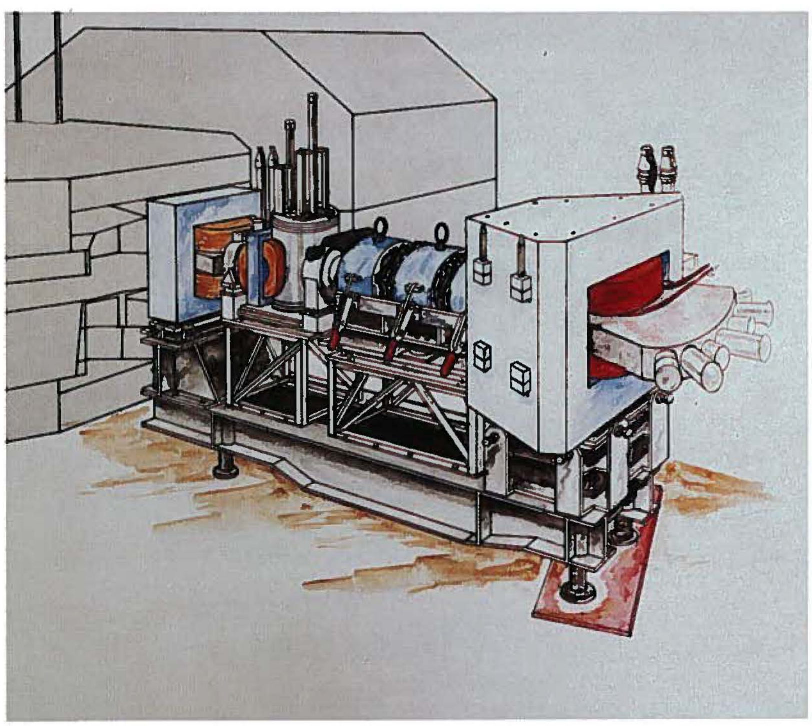
The vitality of the pure research program continued unabated. Polarized proton beams were again in great demand for experiments running simultaneously in two separate Halls. The advent of the time projection chamber and the beginning of two experiments to measure the parameters of muon decay with greater precision, and the continuation of a precision determination of the pion decay branching ratio marked a swing to particle physics on many of the secondary channels.

Facilities

Cyclotron and Beam Lines

For the first time, during 1980, over 100,000 microampere hours of proton beams were delivered by the cyclotron for use in the pure and applied research programs. Although only 10,000 microampere hours short of the scheduled quantity, the 110,000 microampere hours actually delivered represent a 30% increase in beam production over a very successful 1979. One quarter of the 4,250 hours running time were devoted to supplying polarized beams of protons simultaneously to experiments in both the Proton and Meson Halls. For the year the cyclotron availability dropped by a few percent to 84% from last year's record 88%. This slight decrease, however, was more than offset for researchers by the corresponding increased output of proton beam.

The need for more scheduled maintenance and a greater emphasis on the program to develop components with improved reliability has been recognized and a departure from the historically exponential growth of delivered beam was planned in 1980 to allow time for developments in remote handling and component reliability.



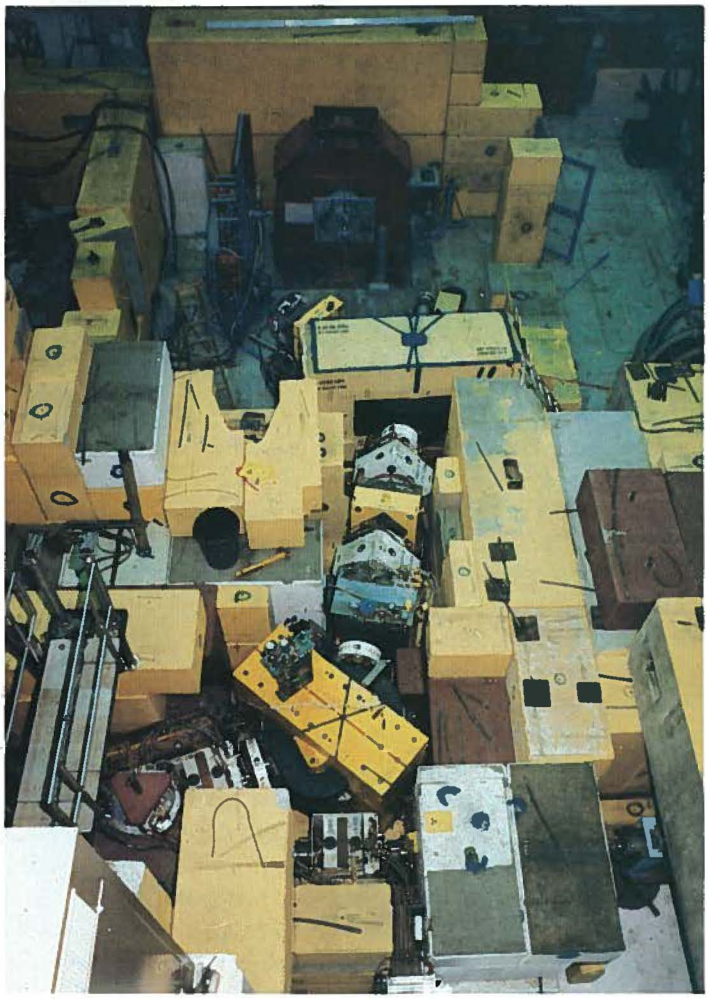
With the installation of beam line 2C, the extraction of 3 beams from the cyclotron has now been shown to be a routine mode of operation. Each beam line can operate at an independent energy and proton beam intensity allowing experiments requiring pion beams to proceed when low-intensity proton beams are in use for nuclear physics research, and low-energy proton beams are being utilized for radioisotope research. The interest in an even greater flexibility in extracting beams of protons from the cyclotron continues and, in tests using beam line 1A, it has been possible to extract two beams of 500 MeV protons into the same beam line but physically separated by 1 centimetre several metres from the cyclotron. If fully utilized, this development could allow one of the beams to be independently directed into a new dedicated beam line feeding a Piotron, a second-generation pion cancer therapy device that would produce a 15-times-more-intense pion beam than the present cancer therapy channel for 1/5 of the present maximum proton beam intensity.

Experimental Facilities

The experimental facilities available to research nuclear physicists were bolstered by the addition of three major new beam lines this year. The first, wholly contained within the substantial concrete shielding of the cyclotron vault, is called beam line 2C. The first successful extraction of a proton beam into a short prototype version of beam line 2C was announced last year. This year a complete beam line was installed to transport proton beams of between 60 and 100 MeV from the cyclotron to radioisotope-producing targets. The line is constructed in "one piece" to allow the possibility for its complete and rapid removal at a later date. The final magnet is used to direct the beam into any one of the seven channels selected by researchers. This will allow several targets to remain in position at any time, ready for use.

The second facility completed was the high flux, high resolution, high energy secondary channel for pions known as M11. The novel design of this channel, in which a quadrupole and a septum electromagnet are positioned immediately downstream of the first meson

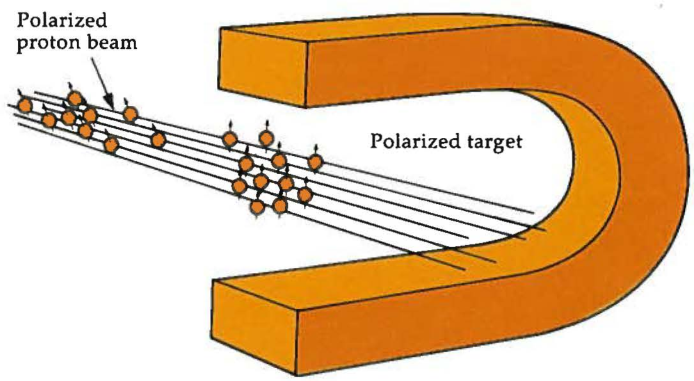
Beam line 2C will transport intense beams of 70 MeV protons to radioisotope-producing targets, in the cyclotron vault. Provisions have been made for several targets to be ready to receive beam, but only one will be irradiated at a time.



The new M11 high-energy pion channel nears completion in the Meson Hall. Nuclear physicists will soon be able to regularly use this high flux "instrument" to probe the properties of nuclei and the forces between pions, protons and neutrons. The pion production target which "feeds" the channel is at the bottom left. Pions travel down the channel (up the photo) and emerge into an area where experiments are performed.

production target in the Meson Hall, makes it possible to collect the copious number of pions produced at zero degrees from the target without disturbing the path of the primary proton beam along beam line 1A. The channel was installed in stages spanning 1980/81 and, despite problems with the operation of the septum magnet which had to be removed for repair, has started commissioning tests in preparation for use in the experimental program during 1982. The channel can be tuned to produce beams of positive or negatively charged pions from 50 to 350 MeV into a large, shielded experimental area. The performance of the channel has met the full expectations of its designers.

The third new facility for research was constructed in the Proton Hall and is known as beam line 4C. The beam line is an extension of the already-existing beam line 4A, through the earlier constructed neutron beam production facility, into an experimental area. The beam line was designed to transport picoamperes (billionths of amps) of polarized proton beam from the cyclotron to a recently installed 4-cubic-centimetre volume polarized proton target. This sophisticated target was loaned to TRIUMF by the University of Liverpool in the United Kingdom for use by the BASQUE group in investigating the most basic pion production mechanisms in proton-proton collisions. This marks the first use of such a target in Canada. In the target, hydrogen atoms are cooled to 0.5 kelvin, or half a degree above the absolute zero of temperature. The directions of the proton's spin (protons can be thought to spin, or rotate, about an axis much like the world) are then aligned by a strong magnetic field producing what physicists call a polarized-proton target. By appropriately orienting the strong magnetic field, it is possible to allow physicists to perform precise scattering



The force between colliding protons depends to a great extent on the directions of their spin. Sophisticated technology involving ultra-high temperatures (12,000 K) is required to produce the polarized proton beam; conversely ultra-low temperatures (0.5 K) are required to polarize protons in the target. A strong magnet keeps the spins aligned during an experiment.

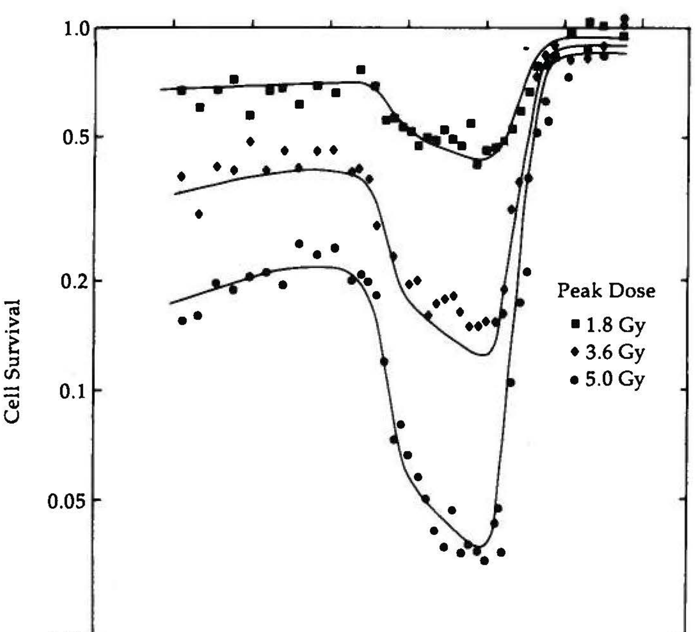
experiments wherein the direction of the target polarization is at right angles to, or aligned with, the direction of the polarized beam from the cyclotron. It is only by employing such unusual techniques and sophisticated technology that physicists will unravel the forces involved in proton-proton collisions and the mechanisms surrounding pion production. TRIUMF's links with the University of Liverpool were further strengthened this year by a joint agreement to upgrade the target to a "frozen spin" target. This will involve cooling the target to 50 millikelvin, which will allow the strong magnetic field to be considerably reduced without affecting the target polarization. Slow electrically-charged pions leaving the target during experiments will then not be trapped in the magnetic field but will escape to be detected.

Applied Program

Biomedical Program

One of the short-lived particles generated at TRIUMF is the pion. A beam of these particles is being used for cancer therapy where they have a "depth charge" effect within the tumor, while interfering very little with the healthy tissue surrounding it. For this reason the British Columbia Cancer Foundation and the Cancer Control Agency of British Columbia have been working on a project aimed at treating deep-seated cancers which are difficult to treat by conventional means.

In March, August, and November 1980, skin nodules on human patients were irradiated so that the effect of pions on human skin could be directly measured. Until this time the skin of pigs and mice was used and extrapolations made as to the expected effect on humans. In all, seven patients were treated with encouraging data being received. Very precise measurements have to be made of how pions go through bone, fat, and skin for example, in order to predict how to treat tumors most effectively. These measurements and a quantitative look at the effects of the pion beam on different tissues were initiated this past year.



Pion cancer therapy derives its usefulness from the observation that cells are preferentially killed in the region where pions came to rest. This "depth charge" effect can be used to treat localized cancers effectively while preserving nearby healthy tissue. Biophysicists are working toward a perfectly flat-bottomed survival curve which is evidently missing from this early 1977 data.

Changing the beam itself by "tuning" it differently can also alter the effectiveness (or "radiobiological effectiveness" -RBE) of the pions. A detailed series of measurements were made on the RBE values for different "tunes" on several types of tissues. In the past the area covered by the pion beam was quite large. This presented a problem because it was difficult to get the pions spread evenly over the whole treatment area. A decision was made to switch to spot scanning, in which the beam cross-section is made small and the patient moved around under the beam if a large area needs to be irradiated. To accomplish this a special computer-controlled treatment couch is being built.

Radioisotope Research

At the end of 1980 a new radiopharmaceuticals manufacturing laboratory was commissioned for the regular production of iodine radioisotopes used in imaging the heart and kidney. This special laboratory provides a controlled, safe environment for the technicians carrying out the chemistry which synthesizes the radioisotope into a chemical form that will be taken up by the organ of the body whose functioning is to be studied.

The production of medical radioisotopes, mainly Iodine-123 and Xenon-127, was well under way at TRIUMF during 1980. Twelve hospitals in British Columbia and two in Ontario received and used Iodine-123 produced at TRIUMF. As well, a small amount of Iodine-123 was distributed to the British Columbia Institute of Technology to be used in the training of medical technicians. The "no charge" distribution program is to familiarize the medical community with the advantages and problems of dealing with Iodine-123 on a regular clinical basis.

New radiopharmaceuticals for brain research are also being developed to measure changes in blood flow, glucose metabolism and other functions which result from strokes, Parkinson's disease, and other disorders. The machine that will measure the radioactive materials, a scanner called a Positron Emission Tomograph (PET for short) is currently being constructed at TRIUMF to the

PETT VI design from St. Louis. PET will give images that resemble colour CAT scan images but give the physician a three-dimensional look at the functioning of the brain by means of a set of pictures of brain "slices."

The production of positron-emitting isotopes, especially Fluorine-18, Oxygen-15 and Carbon-11, was started using a newly installed gas target on beam line 1A. Via organic chemical synthesis, 2-deoxy-2-fluoro-glucose labelled with Fluorine-18, for brain imaging, was first produced in practical quantities.

Other pharmaceuticals are being developed for future use with the PET scanner and will hopefully be useful for imaging the outer fatty covering of nerve fibres in the brain. The breakdown of this myelin sheath is involved in multiple sclerosis. Besides studying the healthy brain to better understand its normal functions, the PET scanner will be useful in the study, and hence treatment, of many disorders such as epilepsy, multiple sclerosis and some psychiatric disorders.

Radioisotope production in collaboration with AECL

The Atomic Energy of Canada Ltd. began commercial shipments from TRIUMF of Copper-67 and Cadmium-109 this past year. In addition, Sodium-22, Germanium-68, Strontium-82, and Xenon-127 were produced. A CP-42 cyclotron is expected to be delivered from the Cyclotron Corporation sometime during 1981 following a long delay in its construction. It will provide a low energy facility for the production of isotopes, to complement the present 500 MeV cyclotron. Consequently methods are being developed for the manufacturing of Gallium-67, Indium-111, Iodine-123, and Thallium-201 using the smaller accelerator's beam and facilities.

The "gas target" ready for installation in the Thermal Neutron Facility. Two radioactive gases can be manufactured at a time inside the target. The gases are piped to the Chemistry Annex where they are incorporated into pharmaceuticals for the PET program.

Neutron Activation Analysis

Neutron activation analysis is a process whereby a small sample is exposed to thermal neutrons, which in turn make the specimen radioactive. By measuring the radiation that is given off by the sample when it is removed from the irradiation facility, it is possible to tell, often to parts-per-billion sensitivity, what elements are present in the specimen.

This was the first complete year of operation for Novatrack Analysts Ltd., working in conjunction with TRIUMF. Their semi-automatic irradiation system allows for the analysis of a large number of geological and environmental samples. Many of the mining and exploration companies operating in British Columbia made use of the services provided by Novatrack during the year. The increase in the price of gold produced a dramatic rise in demand for gold analysis in geological samples. At the peak of the season twelve people were employed with more than 1000 samples a day being analyzed. In addition to gold, the other elements analyzed were arsenic, antimony, tantalum, cesium, thorium, tungsten, and molybdenum. The fact that Novatrack can accurately determine the amounts of rhenium present in molybdenum ore (something otherwise difficult to do) is of great commercial value.

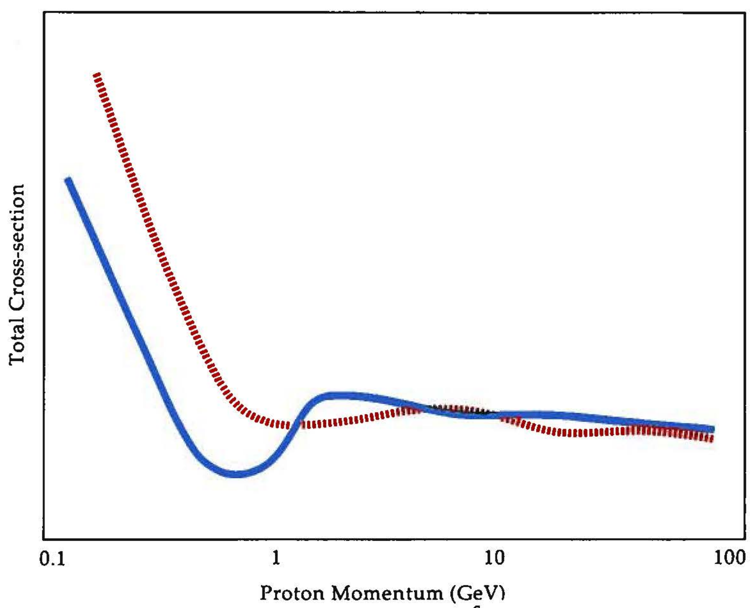
Beam line 2C nears completion in the cyclotron vault. The cyclotron (left) produces an intense proton beam which the beam line carries to the targets adjacent to the wall (right). A large (blue and red) magnet is used to select the target to be irradiated.

Pure Research Program

The basic research program at TRIUMF covers a broad spectrum of topics from particle and nuclear physics to chemistry and solid state physics. In last year's report some of the general aspects of research were described giving an overall picture of the experiments underway in both the Proton and Meson Halls. This year and in future issues, a portion of the program will be presented covering one area of research at a time. Nuclear physics using proton beams will be reviewed this year.

TRIUMF has a feature which makes it unique amongst the meson factories, namely the ready variability of the energy of the extracted proton beam. This possibility arises because of the original design philosophy of the cyclotron: namely to accelerate negative hydrogen ions (see "TRIUMF Profile" 1979-80 Report). Together with the polarized ion source, which can produce a world record 200 nanoamperes of polarized protons "on target," these make TRIUMF an extremely powerful "tool" for studying nuclear physics in the intermediate energy region, as well as the details of pi-meson (pion) production.

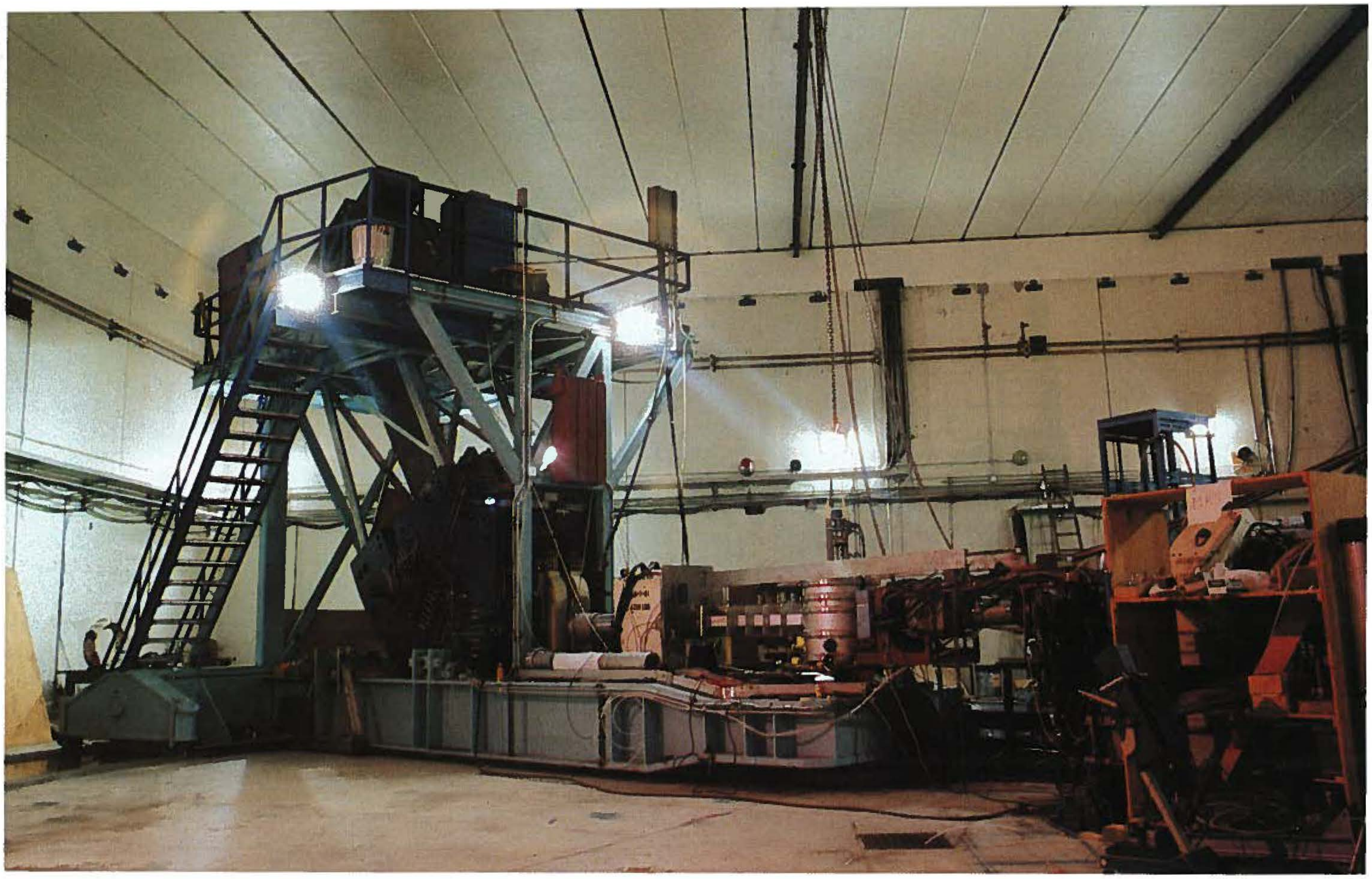
The medium energy region offers several notable advantages for carrying out nuclear physics research. The nucleus is more "transparent" to protons in this region, which is one way of saying that the protons do not interact with nuclei quite so strongly. The details of protons interacting with free nucleons (i.e. protons or neutrons) has been well established at TRIUMF by the BASQUE group and forms the starting point for all theoretical calculations of protons interacting with groups of nucleons — the stable nuclei.



The total cross-section is a measure of the probability that a beam of protons, or neutrons, will collide with a single hydrogen atom (a proton) when passing through a bath of liquid hydrogen. This probability is at a minimum in the range of energies available to scientists at TRIUMF. The nucleons are therefore able to probe deeply into nuclei at these energies and give physicists a glimpse of the core.

Of crucial importance in making the most effective use of these tools is the availability of a good detection system to analyze the energy of charged particles and in particular measure the polarization of protons scattering from nuclei. The medium resolution spectrometer (MRS) fulfills such a role and measures the energy to an accuracy of a few parts in a thousand. Polarization is a phenomenon exhibited by particles that "spin." One can imagine elementary particles, such as protons, as small spheres rotating about an axis. If we say that the direction of the "spin" is that of the proton's north pole axis then a polarized proton beam is one in which more protons have their north poles pointing up rather than down. When a polarized beam strikes a target of carbon more protons scatter to the left, if the beam is polarized up, than to the right. This phenomenon is being utilized to enable physicists to measure the polarization of protons scattering into the MRS by counting the number of protons which scatter to the left and to the right from a small carbon target installed near the detection system.

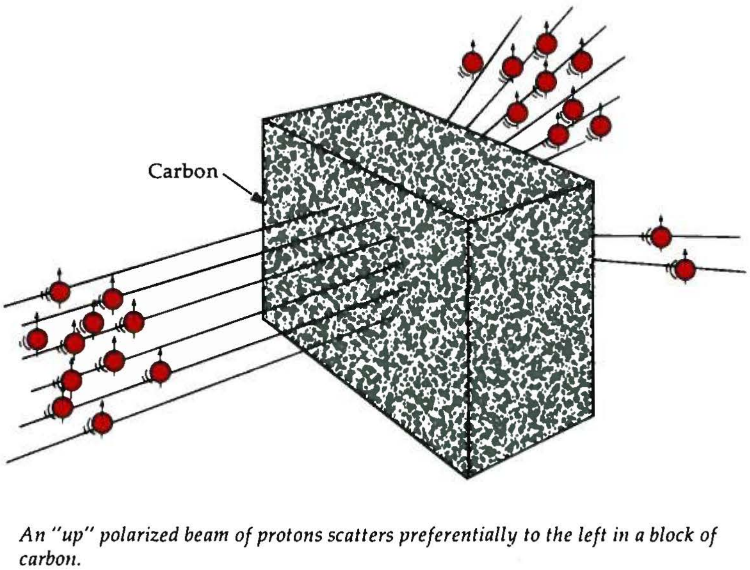
In nuclear physics research, the polarized proton beam has shown itself to be an invaluable investigative tool time and time again. The outcome of a collision between protons and/or neutrons depends both on the direction of the incident particle's spin and that of the struck particle. A U.B.C./TRIUMF/Manitoba group has been carrying out a long program of investigating the production of pions when a polarized proton beam collides with targets chosen from a variety of elements. One of the amazing discoveries was the strong left-right asymmetry in the probability for pions to be produced. For example, if a fully polarized proton beam struck nuclei in a normal carbon target forming Carbon-13 and a positive pion, at some angles more than 80% of the pions are produced moving to the left! This phenomenon has not yet been satisfactorily explained and further measurements will be made over the full



The MRS stands ready to be used in yet another experiment. The primary proton beam (moving right to left) strikes a target within the upright cylindrical chamber and scatters in all directions. Those protons moving toward the MRS are captured, deflected upward through 45° and identified by an array of sensitive detectors mounted above a 100-tonne magnet (bottom).

energy range for the TRIUMF proton beam for clues to the mechanisms involved.

By employing polarized beam and a beryllium target, a TRIUMF/Alberta group have found an unexpected result for the polarization of the protons which scattered off the target. The new data require for the first time the inclusion of a proton-nucleus tensor force, in the theory describing the collision. This force was not necessary to explain previous experiments that did not use polarized beam.

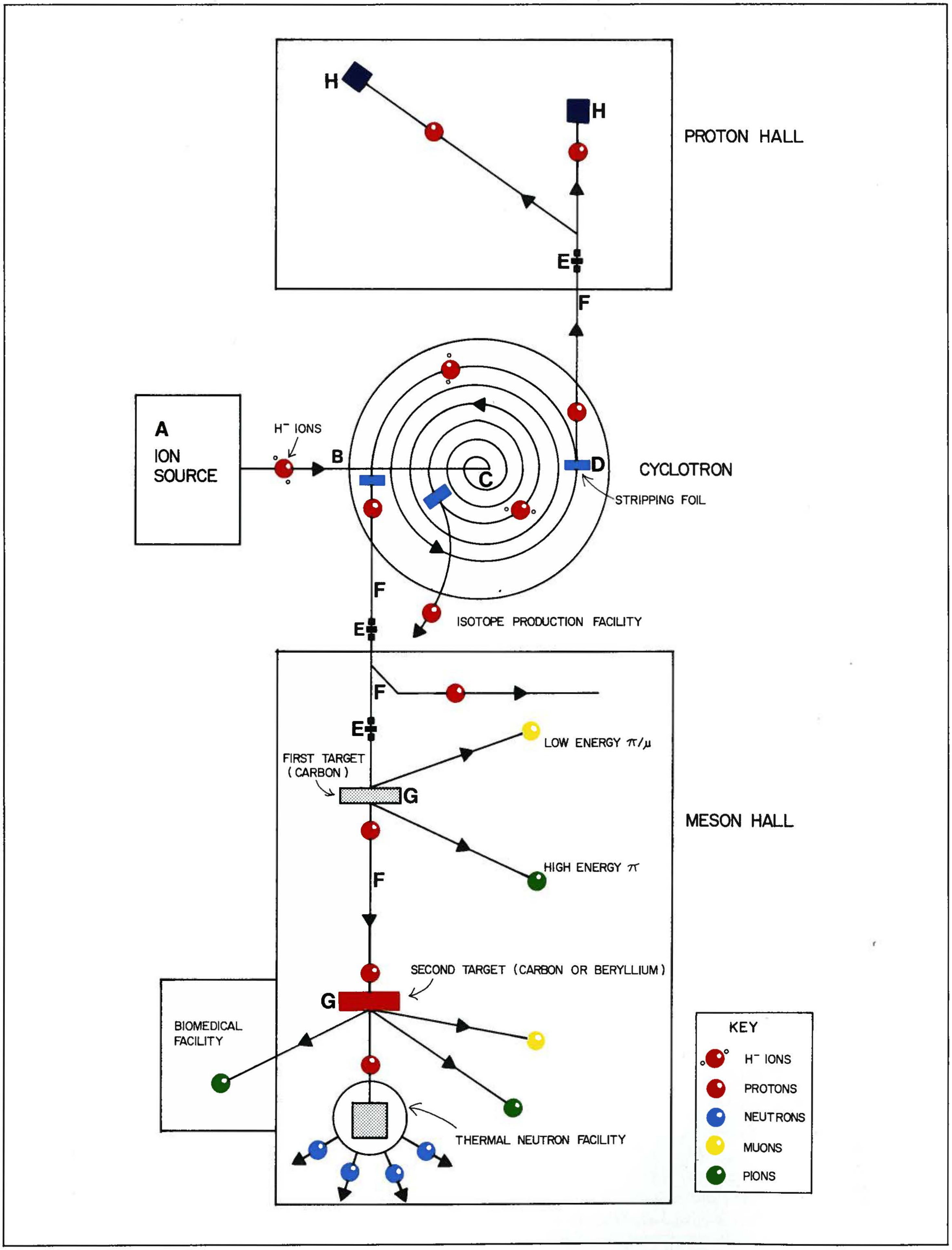


An "up" polarized beam of protons scatters preferentially to the left in a block of carbon.

Several other experiments benefitted from polarized beam during the year. Of note are the studies of (p,d) on Helium-4, Carbon-12, Carbon-13, Oxygen-16 and Calcium-40, and measurements of $^3He(\vec{p},p)^3He$. While the differential cross-section for all of these reactions can usually be well explained by theory, the same cannot be said for the left-right asymmetry in the scattered proton flux, especially to excited states of the residual nucleus. In addition a study of the high momentum-transfer reaction $^2H(p,\gamma)^3He$ hopes to understand the basic reaction mechanism in the absence of complications that arise in the analogous pion production reaction.

Many nuclear physics experiments are also underway which do not employ polarized beam. A TRIUMF/Alberta/Oregon group have been using the MRS to determine the distribution of neutrons in calcium and lead, as an alternative to those experiments mentioned last year using slow pions. The Simon Fraser University group are involved in a variety of complex measurements. In one experiment the flux of fragments is measured after protons collide with a thin silver target. It is a supreme test of our understanding of the nucleus to be able to predict its behavior under such "atom smashing" conditions. In another experiment, nuclear chemistry techniques are being used to measure the total probability for Polonium-210 to be produced from Bismuth-209 by proton bombardment and by then emitting either a gamma ray or a neutral pion.

While these experiments are described by one of the many models of the nucleus they all add to our wealth of knowledge of this infinitesimally small and enigmatic object which still defies our complete understanding after half a century of intense study.


PROTON HALL
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C
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CYCLOTRON
STRIPPING FOIL
F
E
ISOTOPE PRODUCTION FACILITY
F
E
FIRST TARGET (CARBON)
G
LOW ENERGY π/μ
HIGH ENERGY π
MESON HALL
F
SECOND TARGET (CARBON OR BERYLLIUM)
G
BIOMEDICAL FACILITY
THERMAL NEUTRON FACILITY
KEY
H⁻ IONS
PROTONS
NEUTRONS
MUONS
PIONS

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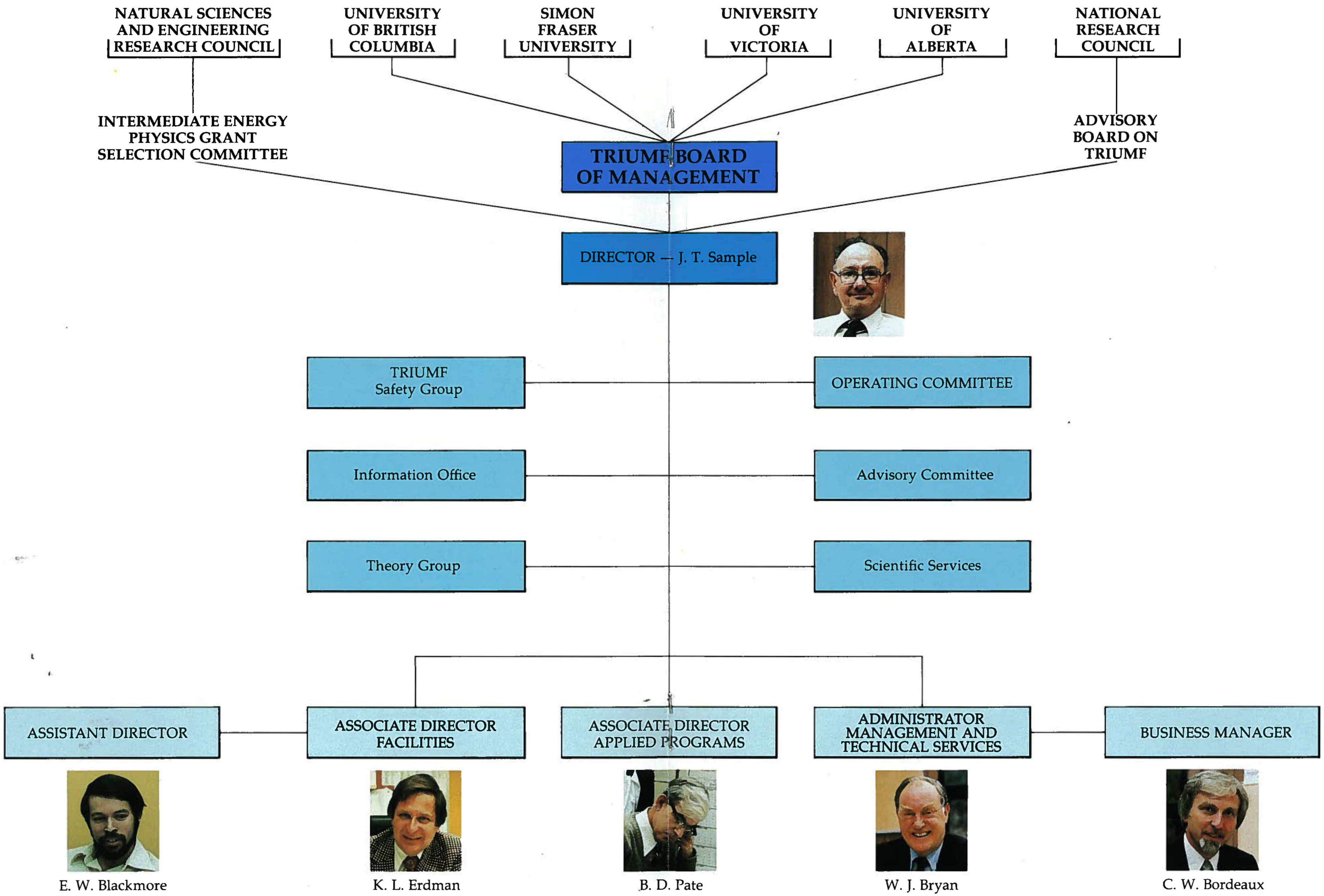
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Financial Review

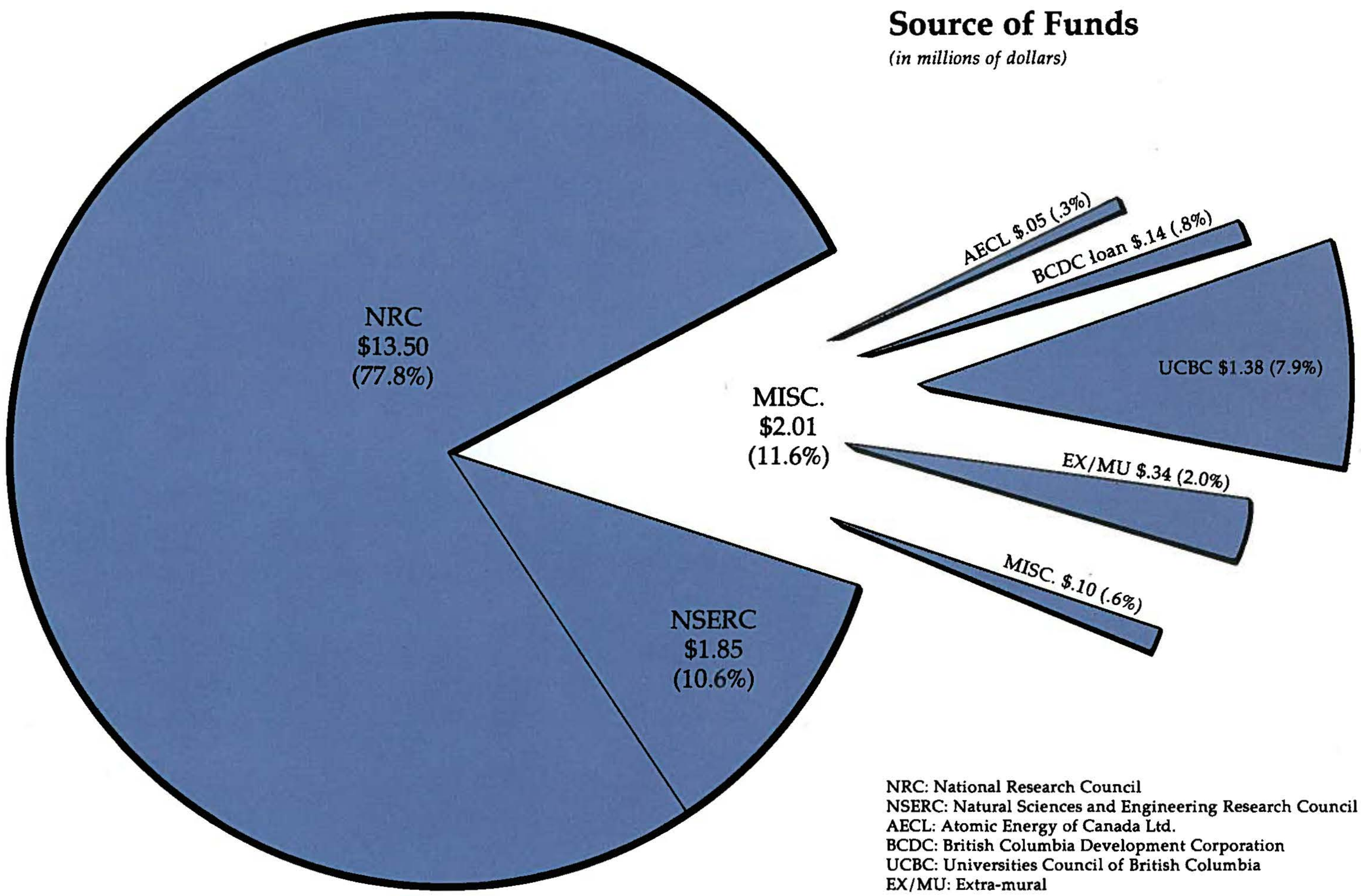
A successful year was experienced in the overall funding of the operating, capital and general experimental support costs. The funding for this, by the National Research Council, increased by 41.5%. In contrast, the support received for specific experiments from the Natural Sciences and Engineering Research Council was disappointingly low in that the increase did not cover the inflation as experienced at TRIUMF. It is hoped that, in the near future, grants to experimenters will more closely match the growth in facilities.

The Province of British Columbia, through the Universities Council of British Columbia, has approved Phase I of a building programme designed to keep pace with expansion as reflected in the TRIUMF 5-Year Plan. Phase I was nearly completed at year-end.

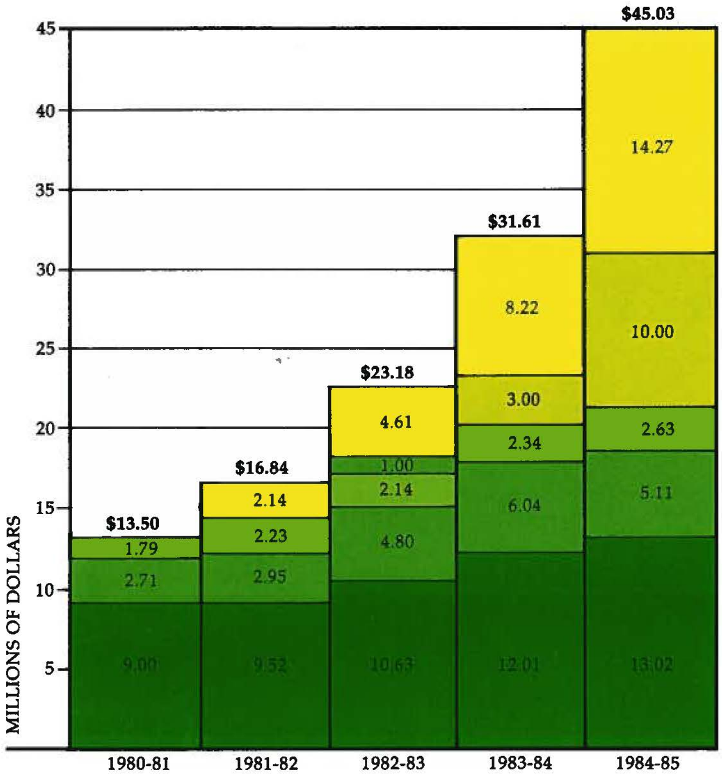
Funds received from other sources have continued to grow with the exception of those received from Atomic Energy of Canada Limited - Commercial Products as their building phase was completed last year and the installation of the 42 MeV cyclotron was delayed until next year. A continued growth of funds received from user institutions is expected.

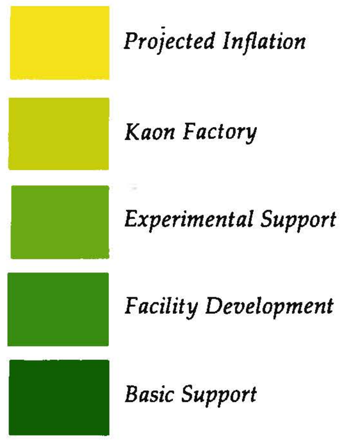
Source of Funds

(in millions of dollars)



NRC: National Research Council
NSERC: Natural Sciences and Engineering Research Council
AECL: Atomic Energy of Canada Ltd.
BCDC: British Columbia Development Corporation
UCBC: Universities Council of British Columbia
EX/MU: Extra-mural





TRIUMF's 5 Year Plan was submitted to the National Research Council for the first time in December 1980. Due to our late publication date last year and because of the intense interest generated in the plan it was included in our first report to consolidate the view of TRIUMF's fiscal future. The 5 Year Plan was accepted in principle by the National Research Council and will be updated each fall as a rolling forecast of TRIUMF's future intentions.

TRIUMF 5 YEAR PLAN
(in millions of 1980 dollars)

	1980-81	1981-82	1982-83	1983-84	1984-85
Basic Support	$ 9.00	$ 9.52	$10.63	$12.01	$13.02
Facility Development	2.71	2.95	4.80	6.04	5.11
Experimental Support	1.79	2.23	2.14	2.34	2.63
Subtotal	$13.50	$14.70	$17.57	$20.39	$20.76
Kaon Factory	—	—	1.00	3.00	10.00
Total	$13.50	$14.70	$18.57	$23.39	$30.76
Projected Inflation	—	2.14	4.61	8.22	14.27
Total (current dollars)	$13.50	$16.84	$23.18	$31.61	$45.03

Auditors' Report

To the Board of Management,
TRIUMF:

We have examined the statements of fund transactions of TRIUMF for the year ended March 31, 1981. Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests and other procedures as we considered necessary in the circumstances.

In our opinion these financial statements present fairly the results of fund transactions of TRIUMF for the year ended March 31, 1981 in accordance with the accounting policies set out in Note 1 of TRIUMF's SUMMARY OF COMBINED RECEIPTS AND EXPENDITURES, applied on a basis consistent with that of the preceding year.

MacGillivray, Johnson, Richard & Co

Vancouver, Canada — CHARTERED ACCOUNTANTS
July 22, 1981

Financial Statement

TRIUMF
SUMMARY OF COMBINED RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1981

	1981	1980
RECEIPTS		
National Research Council Funds	$13,502,000	$9,541,000
Natural Sciences and Engineering Research Council Grants	1,854,340	1,667,040
Atomic Energy of Canada Ltd. Funds	53,792	—
British Columbia Development Corporation — loan proceeds	140,000	2,610,000
Province of British Columbia Grant	1,376,488	10,810
Sponsoring Organizations	334,893	183,589
Investment Income	100,384	142,001
	17,361,897	14,154,440
EXPENDITURES		
Building Construction	1,390,893	1,108,813
Communication	72,111	65,705
Computer	222,773	185,644
Cyclotron Costs-Atomic Energy of Canada Ltd.	—	576,860
Equipment > $10,000	762,094	849,271
Equipment < $10,000	747,519	740,817
Equipment and Facility Components-Atomic Energy of Canada Ltd.	217,317	357,993
Facilities in Progress	603,661	451,345
Insurance	11,968	55,734
Interest Expense	484,930	326,049
Minor Construction	116,364	114,126
Miscellaneous	30,067	17,228
Rentals (Note 2)	—	—
Salaries and Benefits	7,964,389	5,965,450
Sessional and Occasional Staff Costs	505,959	398,127
Supplies and Expenses	5,248,520	3,554,810
	18,378,565	14,767,972
EXCESS OF EXPENDITURES OVER RECEIPTS	1,016,668	613,532
FUNDS UNEXPENDED beginning of year	602,010	1,297,928
	414,658	(684,396)
FUNDS RECEIVABLE (UNEXPENDED) end of year (Note 3)	450,044	(602,010)
DECREASE IN DEFICIT FOR THE YEAR	35,386	82,386
SURPLUS (DEFICIT) beginning of year	(253,060)	(335,446)
DEFICIT end of year	$217,674	$253,060

TRIUMF
NOTES TO THE SUMMARY OF COMBINED RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1981

NOTE 1: ACCOUNTING POLICIES

a) National Research Council
By Treasury Board directive, the accounting policy is an accrual basis. Expenditures shown for the year ended March 31, 1981 include all payables as of March 31, 1981 in respect of goods and services received on or before March 31, 1981. The closing balance is carried forward to operations of the subsequent year.

b) Atomic Energy of Canada Ltd.
All transactions are recorded on a cash basis and include only those transactions recorded by TRIUMF and do not include any transactions recorded by AECL.

c) Other Funds
All transactions are recorded on a cash basis.

NOTE 2: RENTALS

The charge for rentals is an internal charge to the various funding organizations and credited to National Research Council.

NOTE 3: SUMMARY OF END OF YEAR BALANCES

	1981	1980
FUNDS RECEIVABLE		
National Research Council	$280,779	$ —
Atomic Energy of Canada Ltd.	398,593	—
Other Administered Funds	—	114,937
	679,372	114,937
FUNDS UNEXPENDED		
Natural Sciences and Engineering Research Council Grants	225,227	253,537
Other Administered Funds	4,101	—
Atomic Energy of Canada Ltd.	—	326,734
National Research Council	—	136,676
	229,328	716,947
	$450,044	$(602,010)

TRIUMF
STATEMENT OF WORKING CAPITAL POSITION
FOR THE YEAR ENDED MARCH 31, 1981

	1981	1980
ASSETS		
FUNDS RECEIVABLE		
Natural Sciences and Engineering Research Council Overexpended Grants	$138,090	$68,844
Atomic Energy of Canada Ltd. Projects	398,593	(326,734)
Other Administered Funds	82,699	147,334
	619,382	(110,556)
NATIONAL RESEARCH COUNCIL FUNDS RECEIVABLE (UNEXPENDED)	280,779	(136,676)
TOTAL ASSETS	$900,161	$(247,232)
LIABILITIES		
DUE TO UNIVERSITIES		
University of British Columbia	$306,363	$(572,053)
University of Victoria	5,268	81,397
Simon Fraser University	70,519	12,882
University of Alberta	56,692	918
	438,842	(476,856)
ACCOUNTS PAYABLE	228,876	127,906
	667,718	(348,950)
UNEXPENDED BALANCES		
Natural Sciences and Engineering Research Council Unexpended Grants	363,317	322,381
Other Administered Funds	86,800	32,397
	450,117	354,778
TOTAL LIABILITIES	$1,117,835	$5,828
DEFICIT — BALANCE OF UNALLOCATED FUNDS	$(217,674)	$(253,060)

TRIUMF
SUMMARY AND DISPOSITION OF FUND BALANCES
FOR THE YEAR ENDED MARCH 31, 1981

	U.B.C.	U. Vic.	S.F.U.	U. of A.	Total for Year	Total 1980
BALANCES FORWARD	$444,147	$(81,397)	$(12,882)	$(918)	$348,950	$962,482
RECEIPTS	15,916,897	545,000	315,000	585,000	17,361,897	14,154,440
	16,361,044	463,603	302,118	584,082	17,710,847	15,116,922
EXPENDITURES	16,896,283	468,871	372,637	640,774	18,378,565	14,767,972
	(535,239)	(5,268)	(70,519)	(56,692)	(667,718)	348,950
LESS ACCOUNTS PAYABLE	228,876	—	—	—	228,876	127,906
BALANCES CLOSING	$(306,363)	$(5,268)	$(70,519)	$(56,692)	$(438,842)	$476,856

TRIUMF
NATIONAL RESEARCH COUNCIL FUNDS
STATEMENT OF RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1981

	1981	1980 (Restated)
RECEIPTS		
Current funding from NRC	$13,502,000	$9,541,000
EXPENDITURES		
Basic budget —Administration	1,380,250	968,002
Cyclotron services	2,647,948	1,819,452
General services	4,494,740	4,473,171
Facility		
Development — Commissioned facilities	2,103,253	716,590
Minor projects	344,904	89,905
Major projects	1,501,414	1,719,529
Experimental support	1,203,901	557,966
Unallocated	243,045	(128,162)
	13,919,455	10,216,453
EXCESS OF EXPENDITURES OVER RECEIPTS	417,455	675,453
FUNDS UNEXPENDED beginning of year as restated (Note 2)	136,676	812,129
FUNDS RECEIVABLE (UNEXPENDED) end of year	$280,779	$(136,676)

COMMITMENTS (Note 3)

A breakdown of expenditure by object is as follows:

	1981	1980
Communications	$64,785	$57,007
Computer	146,203	122,753
Equipment in excess of $10,000	639,395	737,608
Equipment under $10,000	596,886	645,660
Facilities in progress	603,661	451,345
Insurance	11,968	55,734
Minor construction	116,364	114,126
Rentals	(129,912)	(109,653)
Salaries and benefits	7,096,985	5,318,596
Sessional and occasional staff costs	322,175	216,640
Supplies and expenses	4,450,945	2,606,637
	$13,919,455	$10,216,453

TRIUMF
NOTES TO THE NATIONAL RESEARCH COUNCIL FUNDS
STATEMENT OF RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH, 31, 1981

NOTE 1: ACCOUNTING POLICY

By Treasury Board directive, the accounting policy is an accrual basis. Expenditures shown for the year ended March 31, 1981 include all payables as of March 31, 1981 in respect of goods and services received on or before March 31, 1981. The closing balance is carried forward to operations of the subsequent year.

NOTE 2: FUNDS UNEXPENDED BEGINNING OF YEAR AS RESTATED

A clarification of funding policy by NRC covering the period from April 1, 1976 to March 31, 1980 established a net surplus of $136,676. Expenditures of $335,446 from prior years has been included in Unallocated Funds (Note 1, OF UNALLOCATED FUNDS).

	1980
Funds receivable as previously reported	$198,770
Prior period adjustment	335,446
Funds unexpended as restated	$136,676

NOTE 3: COMMITMENTS

Commitments represent the estimated costs of unfilled purchase orders and contracts placed as at the fiscal year end.

1981	1980
$1,758,506	$1,075,627

NOTE 4: RESTATEMENTS

The comparative figures have been restated to reflect reclassifications of accounts.

TRIUMF
NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL GRANTS
STATEMENT OF GRANTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1981

	1981	1980
RECEIPTS		
Common grant for the year (NOTE 1)	$1,854,340	$1,663,040
Sundry grants	—	4,000
	1,854,340	1,667,040
EXPENDITURES		
Communications	4,003	5,093
Computer	74,147	54,383
Equipment in excess of $10,000	122,699	89,907
Equipment under $10,000	110,631	60,707
Rentals	126,591	106,338
Salaries and benefits	675,668	472,407
Sessional and occassional staff costs	169,674	181,487
Supplies and expenses	599,237	743,043
	1,882,650	1,713,365
EXCESS OF EXPENDITURES OVER RECEIPTS	28,310	46,325
BALANCE OF UNEXPENDED GRANTS beginning of year	253,537	299,962
BALANCE OF UNEXPENDED GRANTS end of year (NOTE 2)	$225,227	$253,537
NUMBER OF GRANTS AWARDED DURING THE YEAR	40	37

NOTES

NOTE 1: ADMINISTRATION
TRIUMF, on behalf of NSERC, receives and administers the grant funds awarded to those individuals using the TRIUMF facilities.

NOTE 2: BALANCE OF UNEXPENDED GRANTS

	1981	1980
Unexpended balances	$363,317	$322,381
Overexpended balances	(138,090)	(68,844)
UNEXPENDED GRANTS	$225,227	$253,537

TRIUMF
ATOMIC ENERGY OF CANADA LTD. FUNDS
STATEMENT OF RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1981

	1981	1980
RECEIPTS		
AECL (NOTE 1)	$53,792	$ —
British Columbia Development Corporation — loan proceeds	140,000	2,610,000
	193,792	2,610,000
EXPENDITURES		
Building construction	23,873	1,104,291
Cyclotron costs	—	576,860
Equipment and facility components	217,317	357,993
Loan interest	433,562	280,647
Miscellaneous	16,437	3,015
Salaries and Benefits	162,242	153,223
Supplies and Expenses	65,688	12,592
	919,119	2,488,621
EXCESS OF EXPENDITURES OVER RECEIPTS	725,327	(121,379)
FUNDS UNEXPENDED beginning of year	326,734	205,355
FUNDS RECEIVABLE (UNEXPENDED) end of year (NOTE 2)	$398,593	$(326,734)
Project breakdown:		
Construction Project	$366,701	$(307,054)
Other Projects	31,892	(19,680)
	$398,593	$(326,734)

NOTES

NOTE 1: ACCOUNTING POLICY
All transactions are recorded on a cash basis and include only those transactions recorded by TRIUMF and do not include any transactions recorded by AECL.

NOTE 2: OVER EXPENDITURES
By agreement with AECL the excess of expenditures over receipts is fully recoverable.

TRIUMF
BUILDING CONSTRUCTION PROJECT FUNDS
STATEMENT OF RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1981

	1981	1980	Total To Date
RECEIPTS			
Province of British Columbia (NOTE 1)	$1,376,488	$10,810	$1,387,298
EXPENDITURES			
Building construction	$1,246,019	$ —	$1,246,019
Design costs	121,001	4,522	125,523
Supplies and expenses	9,468	6,288	15,756
	$1,376,488	$10,810	$1,387,298

COMMITMENTS (Note 2)

NOTES

NOTE 1: FUNDING

These are the expenditures under Phase I of the building program endorsed by the Universities Council of British Columbia in June, 1979 and approved by the Province in October, 1979 in the amount of $2,565,000. An additional $294,600 under Phase II of the building program was approved in March, 1981.

NOTE 2: COMMITMENTS

Commitments represent the estimated costs of unfilled purchase orders and contracts placed as at the fiscal year end.

1981	1980
$1,550,178	$35,500

TRIUMF
OTHER ADMINISTERED FUNDS
STATEMENT OF RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1981

	1981	1980 (Restated)
RECEIPTS FROM SPONSORING ORGANIZATIONS		
Current	$334,893	$183,589
EXPENDITURES		
Communications	3,323	3,605
Computer	2,423	8,508
Equipment in excess of $10,000	—	21,756
Equipment under $10,000	40,002	34,450
Rentals	3,321	3,315
Salaries and benefits	29,494	21,224
Sessional and occasional staff costs	14,110	—
Supplies and expenses	123,182	186,250
	215,855	279,108
EXCESS OF EXPENDITURES OVER RECEIPTS	(119,038)	95,519
FUNDS RECEIVABLE beginning of year	114,937	19,418
FUNDS RECEIVABLE (UNEXPENDED) end of year (NOTE 2)	$(4,101)	$114,937

NOTES

NOTE 1: FUNDING
This statement covers the portion of research projects carried out at TRIUMF at the request of and funded by various sponsoring organizations.

NOTE 2: FUNDS RECEIVABLE (UNEXPENDED)

	1981	1980
Funds receivable	$82,699	$147,334
Funds unexpended	(86,800)	(32,397)
	$(4,101)	$114,937

NOTE 3: RESTATEMENT
The comparative figures have been restated to exclude funds presented elsewhere in the financial statements.

TRIUMF
UNALLOCATED FUNDS
STATEMENT OF RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1981

	1981	1980 (Restated)
RECEIPTS		
Investment Income	$100,384	$142,001
EXPENDITURES		
Interest Expense	51,368	45,402
Project Costs Absorbed	24,674	—
Travel Costs Absorbed (Recovered)	(11,044)	14,213
	64,998	59,615
UNALLOCATED FUNDS for the year	35,386	82,386
DEFICIT beginning of year as restated (NOTE 1)	(253,060)	(335,446)
DEFICIT end of year	$(217,674)	$(253,060)

NOTES

NOTE 1: DEFICIT BEGINNING OF YEAR AS RESTATED
As referred to in Note 2, OF THE NATIONAL RESEARCH COUNCIL FUNDS, a clarification of National Research Council funding policy; $335,446 of expenditures is included in Unallocated Funds.

NOTE 2: RESTATEMENT
The comparative figures have been restated to reflect reclassifications of accounts.

TRIUMF Users' Group

Charter

The TRIUMF Users' Group is an organization of scientists and engineers with special interest in the use of the TRIUMF facility. Its purpose is:

a) To provide a formal means for exchange of information relating to the development and use of the facility.
b) To advise members of the entire TRIUMF organization of projects and facilities available.
c) To provide an entity responsive to the representation of its members for offering advice and counsel to the TRIUMF management on operating policy and facilities.

The Chairmen for the last four years were:

Chairman 1978 — J. M. Poutissou
Chairman 1979 — G. A. Beer
Chairman 1980 — K. P. Jackson
Chairman 1981 — J. H. Brewer

Users Group Membership

University of Alberta

E. B. Cairns
J. M. Cameron
W. K. Dawson
J. B. Elliott
L. G. Greeniaus
J. Greben
P. Kitching
G. A. Moss
G. C. Neilson
A. A. Noujaim
W. C. Olsen
G. Roy
D. M. Sheppard
H. Sherif
J. Soukup
R. C. Urtasun

University of British Columbia

D. S. Beder
C. E. Cramer
D. G. Fleming
G. Jones
R. Kiefl
J. R. Ledsome
G. Marshall
P. W. Martin
C. A. McDowell
J. M. McMillan
J. Sams
J. Trotter
D. C. Walker
B. L. White

University of Victoria:

S. Ahmad
G. A. Beer
G. B. Friedmann
T. A. Hodges
A. D. Kirk
D. E. Lobb
G. R. Mason
C. E. Picciotto
L. P. Robertson
C. S. Wu

Simon Fraser University

A. S. Arrott
D. Boal
J. M. D'Auria
B. L. Funt
R. Green
C. H. W. Jones
R. G. Korteling
P. W. Percival

TRIUMF

R. Abegg
E. G. Auld
D. Axen
G. Azuelos
R. Baartman
M. Betz
J. L. Beveridge
E. W. Blackmore
B. Blankleider
J. Blok
C. W. Bordeaux
J. Brewer
W. J. Bryan
D. A. Bryman
A. L. Carter
M. Comyn
M. K. Craddock
D. A. Dohan
J. Doornbos
R. Dubois
G. Dutto
F. Entezami
K. L. Erdman
W. Falk
H. W. Fearing
D. R. Gill
H. P. Gubler
D. P. Gurd
D. Garner
S. D. Hanham
D. K. Hasell
M. Hasinoff
D. A. Hutcheon
K. P. Jackson
C. J. Kost
G. Lam
R. Lee
G. A. Ludgate
J. A. Macdonald
G. H. Mackenzie
G. R. Mason
D. F. Measday
C. A. Miller
J. Ng
J. Niskanen
T. Numao
B. Olaniyi
A. Olin
C. Oram
D. Ottwell
R. Poutissou
P. A. Reeve
J. R. Richardson
B. D. Pate
J. M. Poutissou
J. G. Rogers
A. Rosenthal
M. Salomon
J. T. Sample
P. Schmor
O. U. Shanker
J. E. Spuller
A. W. Thomas
I. M. Thorson
J. Tinsley
V. K. Verma
J. S. Vincent
E. W. Vogt
G. D. Wait
P. Walden
C. E. Waltham
J. B. Warren
G. Waters
H. Wilson
R. Woloshyn
M. Zach

Other Canadian Institutions

C. Y. Kim, S. Rowlands, University of Calgary
T. Walton, Cariboo College
G. A. Bartholomew, J. S. Fraser, O. F. Hausser, F. C. Khanna, H. C. Lee, A. McDonald, Chalk River Nuclear Laboratories
J. W. Scrimger, S. R. Usiskin, Dr. W. W. Cross Cancer Institute, Edmonton
P. A. Egelstaff, University of Guelph
B. S. Bhakar, J. Birchall, A. Bracco, N. E. Davison, M. S. de Jong, J. Jovanovich, R. McCamis, W. T. H. van Oers, University of Manitoba
B. Margolis, S. K. Mark, L. Yaffe, McGill University
P. Depommier, J. P. Martin, Université de Montreal
C. Hargrove, M. Dixit, National Research Council
G. T. Ewan, B. C. Robertson, Queen's University
M. Krell, Université de Sherbrooke
T. E. Drake, University of Toronto
R. T. Morrison, Vancouver General Hospital
W. P. Alford, University of Western Ontario
L. Skarsgard, M. G. J. Young, B.C. Cancer Foundation
J. W. Scrimger, S. R. Usiskin, Cross Cancer Institute

Overseas

W. R. Gibson, Queen Mary College
N. M. Stewart, Bedford College, London
A. S. Clough, University of Surrey
D. Wilkinson, University of Sussex
A. N. James, University of Liverpool
R. Engfer, Universität Zürich
L. Antonuk, Université de Neuchâtel
C. Amsler, A. Aslbury, R. Keeler, CERN
R. Grynszpan, Vitry
R. van Dantzig, IKO Amsterdam
J. Alster, Tel-Aviv University
R. Hayano, K. Nagamine, K. Sakamoto, University of Tokyo
I. R. Afnan, Flinders University of South Australia
J. M. Laget, CEN Saclay
M. Furic, Institute R. Baskivic, Zagreb
B. K. Jain, Slabba Atomic Research Centre

United States

K. W. Jones, Brookhaven National Laboratory
B. M. Nefkens, University of California, Los Angeles
F. P. Brady, University of California, Davis
M. P. Epstein, D. J. Margaziotis, Calfornia State University
B. Bassalleck, Carnegie-Mellon University
H. L. Anderson, University of Chicago
G. A. Goulding, Florida A&M University
H. S. Plendl, Florida State University
M. E. Rickey, T. Ward, P. Schwardt, Indiana University
Y. K. Lee, Johns Hopkins University
P. Tandy, Kent State University
C. Clawson, K. M. Crowe, S. Kaplan, G. Gidal, R. H. Pehl, V. Perez-Mendez, S. Rosenblum, W. J. McDonald, R. Tripp, M. W. Strovink, Lawrence Berkeley Laboratory
L. E. Agnew, C. A. Goulding, R. J. Macek, H. L. Anderson, Los Alamos National Laboratory
H. B. Willard, National Science Foundation
B. Dieterle, University of New Mexico
J. K. Chen, State University of N. Y. Geneseo
K. K. Seth, Northwestern University
F. E. Bertrand, Oak Ridge National Laboratory
B. C. Clark, Ohio State Iniversity
D. K. McDaniels, University of Oregon
K. S. Krane, R. Landau, A. W. Stetz, L. W. Swenson, Oregon State University
R. P. Redwine, Mass. Inst. of Technology
R. F. Carlson, University of Redlands
G. S. Mutchler, Rice University
R. Bryan, R. B. Clark, Texas A&M University
V. G. Lind, R. E. McAdams, O. H. Otteson, Utah State University
M. Blecker, K. Gotow, D. Jenkins, Virginia Polytechnic Institute and State University
W. C. Sperry, Central Washington University
D. Ashery, Argonne National Laboratory
H. Bichsel, I. Halpern, E. M. Henley, P. Wooton, University of Washington
A. S. Rupaal, Western Washington University
C. F. Perdrisat, R. T. Siegel, College of William and Mary
J. J. Kraushaar, T. Masterson, University of Colorado
T. C. Sharma, Washington

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