TRIUMF

Financial and Administrative
Annual Report 1982-1983

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DIRECTOR'S REPORT

Opposite page:
TRIUMF is Canada's meson facility, situated on the University of British Columbia campus and operated by the universities of Alberta, British Columbia, Victoria and Simon Fraser under a contribution from the National Research Council of Canada.

By any measure this year has been the first year of TRIUMF's full scientific program. The beam produced, the science accomplished and the projects completed fulfilled the promise of last year's annual report: "more than ever at TRIUMF it has been full steam ahead".

It was a year of mesons galore. The product of primary proton beam intensity and hours of operation (which is proportional to the number of mesons produced) was more than double that of any preceding year. Further, the cyclotron was operating at its design intensity (100μA) for the fraction of the year which might reasonably be hoped for. Thus half the year was allocated to high intensity operation, a quarter to polarized beam operation and a quarter to installation of new major facilities. With the split in the year about right, further increases in meson production will have to come from average beam currents above the 100μA design value.

The year of science produced many new results. In the Meson Hall the relentless search for muon conversion — events in which a muon is captured on an atomic nucleus and gives all its energy to an emitted electron with no neutrinos being created — with TRIUMF's Time Projection Chamber (TPC) continued. Such events are predicted to be very rare, occurring at most once in a thousand billion muon decays. The detection of the process of muon conversion would have profound implications for current theories of elementary particles. TRIUMF's TPC, a "camera" analyzing a million sequential events per second is a major technical achievement which was the basis of an international workshop at TRIUMF in June, 1983. Muon by muon, a million times each second, the world limit on such possible decays is being lowered with the TPC.

While the world was hailing the discovery in Europe, in early 1983, of the W and Z particles, it was in TRIUMF's Meson Hall at the same time that a definitive experiment on muon decay proved that all of the W and Z particles in nature spin in a left-handed manner.

Many other experiments use TRIUMF's pion, muon, proton and neutron beams. Even on a quick visit one gains the impression of an international mix of people and ideas at the highest levels of excellence. Some of the ideas emerging from the project are described in this report.

In TRIUMF's Applied Program, the new cyclotron for isotope production was being commissioned. In the late winter of 1983 the Queen dedicated the Positron Emission Tomograph (PET), a world-leading brain scanner built by TRIUMF and operated in the nearby campus hospital. An isotope pipeline, speeding short-lived isotopes in two minutes through a distance of two kilometres, is an umbilical connection between TRIUMF and the hospital's Imaging Centre.

The next few years promise to be very exciting for TRIUMF's science.

Right:
Erich Vogt, Director

FACILITIES

As in previous years, TRIUMF facilities during the 1982-83 period were upgraded to improve cyclotron reliability and beam quality, and provide new facilities for experimenters. The M20 channel has been revamped and there are now six simultaneously-operating experimental areas in TRIUMF's Meson Hall. In the Proton Hall experimental area, a major step in improving the resolution of the Medium Resolution Spectrometer was accomplished with the installation of a 6-quadrupole beam twister. The cyclotron's third beam line, beam line 2C, is now close to being commissioned. And the TRIUMF site has 2 new service buildings — a workshops complex and the new remote handling building.

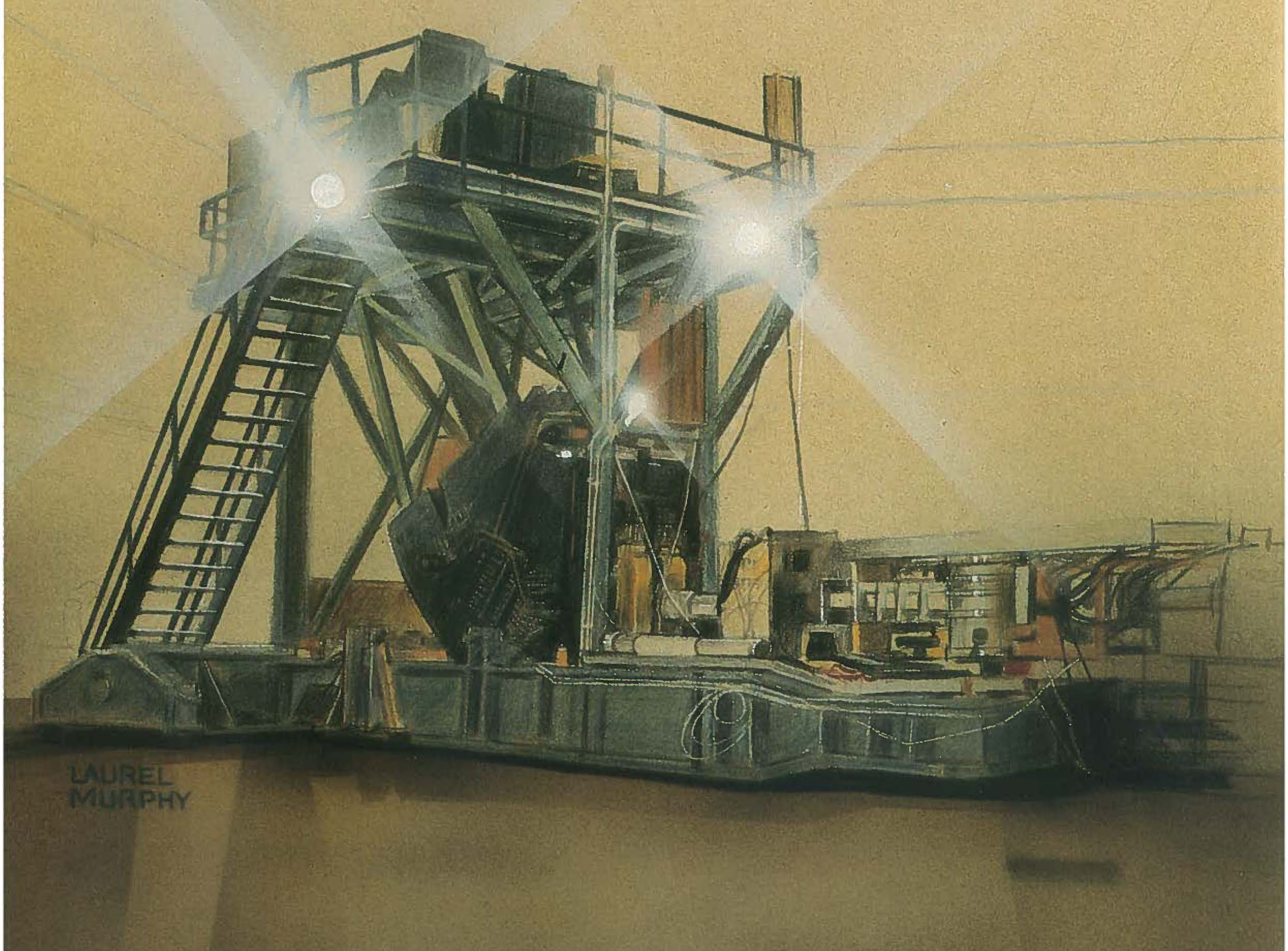
Cyclotron

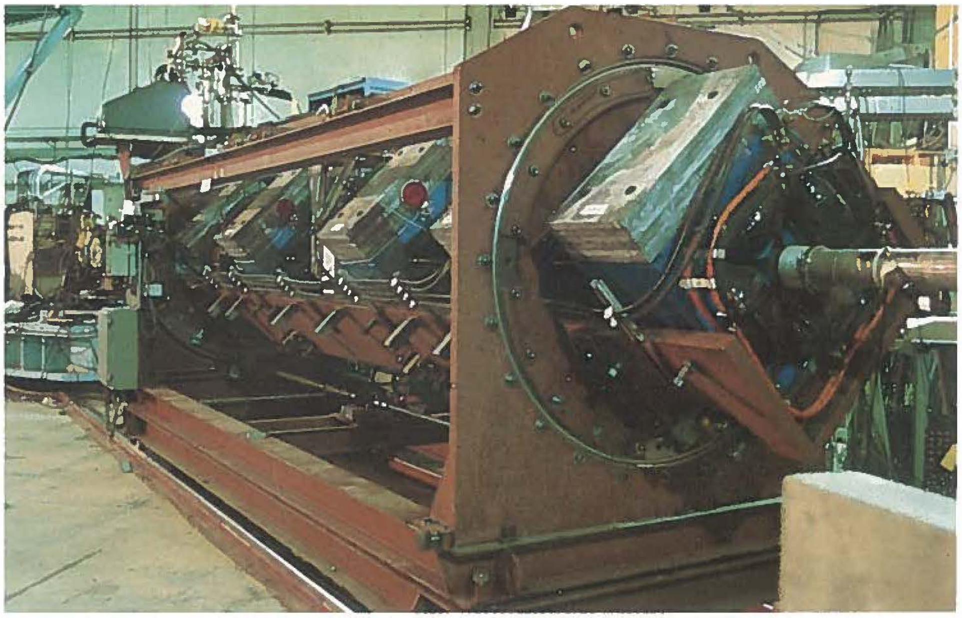
Although there were no major cyclotron facility changes during the 1982-83 year, the extremely successful year of experimentation was, in a large part, the result of greater attention to cyclotron reliability. The efforts of the Cyclotron Division towards higher reliability — both for 1983 and for the future — were given the highest project priority. The results made 1982 a year of excellent beam production, with 4650 hours of accelerated beam and 229 milliampere-hours of total extracted beam charge. This was more than twice the charge produced in any previous year. New records were also achieved for the maximum peak beam current extracted.

M20 upgrade

The design and construction of a major upgrade to the M20 secondary beam line was completed this year. Since its inception, the M20 channel has been extensively used for muon spin resonance (μSR) studies. The demands of the experimental program required higher fluxes of both "backward", "forward" and "surface" muon beams. ("Backward" muons travel at 63% of the speed of light, "forward" at 85% and "surface" at 27%.) The original beam line was removed and replaced by a much longer channel feeding two experimental areas called M20A and M20B. In one mode of operation, "backward" muons can be deliverd to one of the experimental areas while "forward" muons are concurrently sent to the second experimental area.

The improvements on this channel provide six times the intensity of "backward" muons at the experimental targets than previously available. The new channel also has a 3 metre DC separator installed on the M20B leg which provides clean "surface" muon beams and the possibility of a 90° rotation of the muon spin direction. As a whole, M20 is now ideal for conducting the myriad μSR studies scheduled at TRIUMF (see page 8).





Medium Resolution Spectrometer

Some of the most promising physics experiments will take place in the Proton Hall experimental area beginning next year. Substantial improvements have been made to the Medium Resolution Spectrometer (MRS) to increase its resolution toward 70 kilovolts or better.

Much of what is known about atomic nuclei has been learned with beams of low energy protons scattered from targets. There is a "window" spanning TRIUMF's energy range in which protons penetrate far more deeply into atomic nuclei than at energies above or below. With further improvements and additions to the MRS, TRIUMF will be the only facility in the world spanning this interesting energy regime capable of carrying out experiments with a resolution of 70 kilovolts.

As part of the improvements in resolving power of the MRS, a beam twister was installed on beam line 4B, before the spectrometer. The twister incorporates 6 quadrupole electromagnets which compensate for the effect of the cyclotron energy spread on the energy resolution of the spectrometer. Also designed and fabricated during 1982 was a massive rotating carriage which holds the quadrupoles in position and rotates them to the desired angle. The carriage is required to correct for the effect of introducing a superconducting solenoid during polarized beam experiments. Mounted on rails below the beam line, the twister carriage can be rolled up or downstream to maximize the working space available at whichever target station (the MRS or the 4BT1 target station) is in use.

Beam line 2C

The construction of beam line 2C places TRIUMF on the verge of another world-wide first. When beam line 2C is commissioned, TRIUMF will be the only accelerator in the world with the capability to simultaneously extract three proton beams with different energies. Although most of the beam line's construction was completed last year, work was necessary this year to complete the control system, develop targets and test the facility using low intensity beams.

Located in the cyclotron vault, 2C is a 70 to 100 MeV high current facility for the production of radioisotopes. Five separate target facilities (one in use at a time) will be available:

- a metallic cesium heat pipe to produce xenon-127,
- a sodium iodide generator for radioiodine production,
- water-cooled beryllium for fast neutron production,
- a radiobromide generator (in the design stages), and
- a general purpose solid target rabbit system.

Radioisotope production in the 70 to 100 MeV range with the new beam line promises to reduce the "contamination" from unwanted isotopes by a factor of ten in the production of iodine-123.

With beam line 2C close to being commissioned, the TRIUMF Radioisotopes for Medicine (TRIM) group has moved the emphasis of their program to this new facility (see Applied Programs, page 6).

Building program

To provide for quicker and more efficient construction and maintenance of equipment, two new service buildings were constructed on the TRIUMF site during 1982-83.

A new remote handling building was completed in November, 1982, with offices and maintenance shops for developing and testing the robotic handling of accelerator and beam line components. The new building is located north of the vault section of the main accelerator building. The below ground levels of the building offer direct access to the cyclotron vault as well as 400 square feet of vault equipment set-up space, electronic assembly and test areas and a full-scale partial mock-up of the cyclotron's vacuum tank.

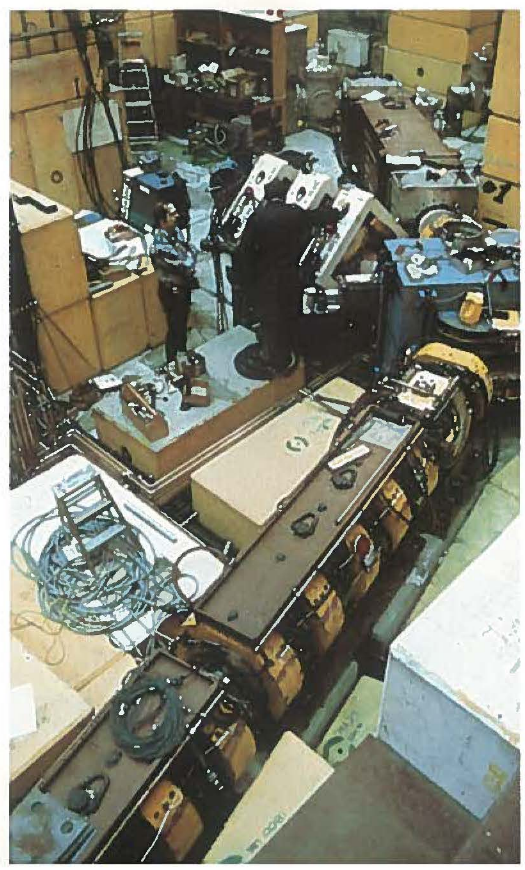
Construction was also completed in the spring of 1983 (begun August, 1982) of a new 10,000 square foot workshop building in support of cyclotron and beam line operation. The facility is located on land immediately south of the main TRIUMF site. (The land was, during 1982, obtained from the University of British Columbia.)

Opposite page:
The Medium Resolution Spectrometer (MRS) is TRIUMF's largest detector.

Above:
The 6 quadrupole twister in the Proton Hall — one step in improving the resolution of the MRS.

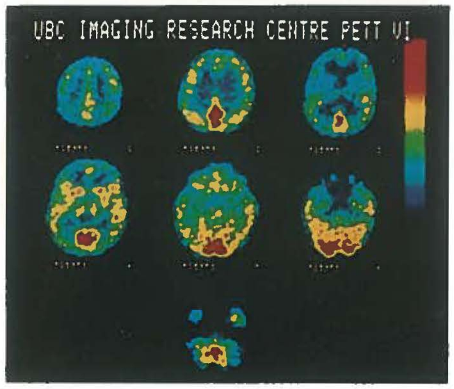
Left:
New workshops building, south of the main site.

Below:
Major improvements on the secondary beam line M20 now allow for 6 simultaneously operating experiments in the Meson Hall.



TRIUMF's progress in science is epitomized by the accomplishments of the Applied Programs. During the 1982-83 period, the TRIUMF-designed and constructed Positron Emission Tomograph (PET) brain scanner was installed in the University of British Columbia Health Sciences Hospital and an isotope transport pipeline linking TRIUMF and the hospital was constructed. In pion cancer therapy the first sixteen patients with deep-seated tumours were treated; there now appears to be no impediment to major clinical trials using this new therapy tool. A year ago, it looked as though pion cancer therapy could not proceed at TRIUMF without building a costly new experimental channel. But with some minor improvements and the smooth, high intensity cyclotron operation over the past year, pion therapy's intended goals have become possible.

Accomplishments in Applied Programs have also included major developments in PET radiopharmaceuticals, a move of radioisotope research to the new 70 MeV cyclotron beam line and the installation of AECL's 42 MeV cyclotron for radioisotope production.



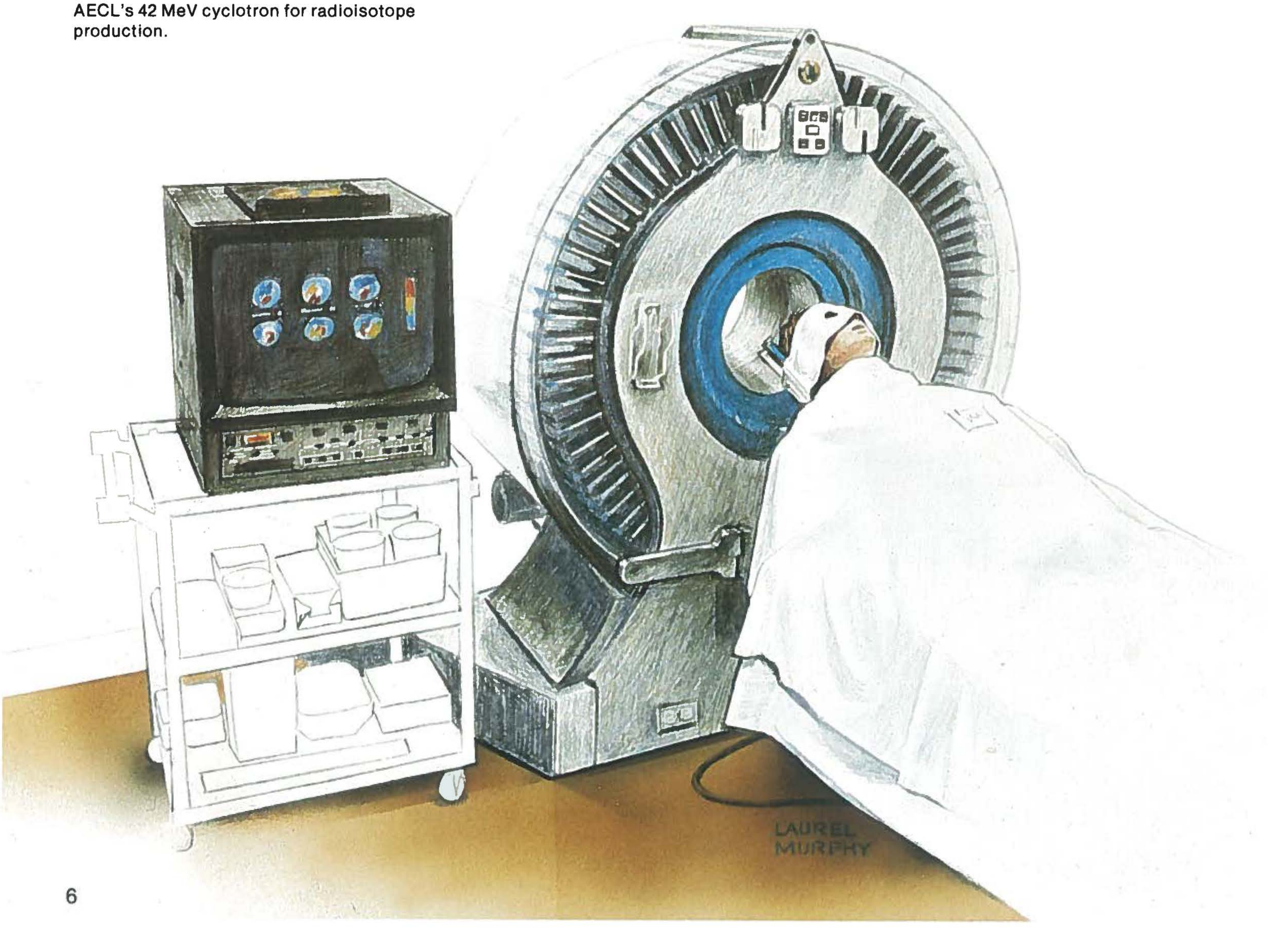
Positron Emission Tomography

Construction of TRIUMF's PET brain scanner (begun in April, 1981) was complete by July, 1982 (within one month of the scheduled date). Based on an original design by Washington University at St. Louis, Missouri, TRIUMF's PET scanner incorporated improvements in electronics and computer hardware. By November, the tomograph was disassembled and reinstalled in the PET Suite of the Acute Care Unit at the Health Sciences Centre Hospital (University of British Columbia). On February 24, 1983, PET produced its first clinical images (see photo).

To culminate a year of achievement with PET, Her Majesty Queen Elizabeth II visited the Acute Care Unit on March 3, 1983 and inspected the scanner. PET's operations were demonstrated to her by the TRIUMF/UBC PET team.

Above:
The first images from PET, February 24, 1983. Scanning agent: FDG.

Illustration:
The TRIUMF/UBC PET scanner, now installed at the University of British Columbia Health Sciences Centre.



TRIUMF's work on the production of PET scanning agents continued through 1982-83. In particular, Atomic Energy of Canada Ltd.'s new CP42 "baby" cyclotron was used to produce the radioisotopes oxygen-15 (from oxygen gas) and fluorine-18 (from neon gas). To produce the radiopharmaceuticals for use with PET, inorganic chemistry processes were established to label oxygen-15 to O_2, H_2O and CO. A new process for the production of 2-deoxy-2-fluoro-D-glucose (FDG) labelled with fluorine-18 was developed in the TRIUMF labs. FDG is used to produce PET images of glucose metabolism in the brain.

TRIUMF's program of research into the synthetic chemistry of new radio-labelled scanning agents was pursued throughout the year. Chemists particularly investigated the labelling of dopa, the substance especially suited to the treatment and study of Parkinson's Syndrome.

The new TRIUMF-developed scanning agents use short-lived radioisotopes and therefore must be used soon after they are manufactured. To accommodate this, a fast transport system was necessary to link the TRIUMF Chemistry Annex with the hospital's ACU. Earlier in the year, four 2.5 km-long pneumatic tube transport systems (called rabbit lines) were installed in a conduit 1.2 metres underground. Nine intermediate access points between TRIUMF and the ACU contain sensing equipment to locate the position of the scanning agent's rabbit capsule in transit. By year's end, the system was undergoing extensive tests.

A "baby" cyclotron

Atomic Energy of Canada Ltd.'s (AECL) new 42 MeV "baby" cyclotron was delivered to TRIUMF in early December, 1981. Designed and built by "The Cyclotron Corporation" of Berkeley, Caifornia, this H^- cyclotron operates on exactly the same principles as the TRIUMF 500 MeV machine. It is the first negative ion cyclotron the company has built and as such should be considered a prototype. Because of its small size compared to the main machine it is often called

the "baby" cyclotron. The advantages it has in common with the main machine are multiple beam extraction and simple energy variability. Initially the cyclotron will have three beam lines. On one of these the energy can be varied from 11 to 42 MeV. The machine will be used to produce commercial radioisotopes for AECL's Radio-Chemical Company and PET scanning agents.

After installation and extensive tests, the baby cyclotron accelerated its first H^+ beam to 42 MeV on May 23, 1982. Within one month, H^- beams were also accelerated and a 30 MeV beam was extracted via an exit port. By fall, various energies and percentages of extracted beam were tested on the CP42 and on October 26, AECL's first thallium test target was irradiated with protons. The first PET target received beam on December 6 and the fluorine-18 that was produced was subsequently processed into the PET scanning agent FDG.

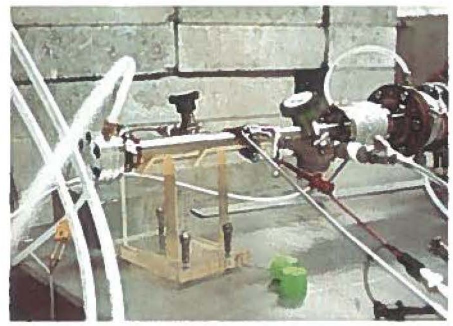
Radioisotope production

AECL also used beams from the 500 MeV TRIUMF cyclotron to produce radioisotopes for commercial shipment. Included in the 1982 shipments were copper-67, germanium-68, cadmium-109 and xenon-127.

TRIM

The TRIUMF Radio Isotopes for Medicine group marked a new phase of its radioisotope development project this year. On May 26, 1982, the group irradiated its final targets on TRIUMF beam line 4A to produce iodine-123. These final-run isotopes were used in heart imaging studies at Vancouver General Hospital and for medical radioisotope labelling studies at the University of Alberta. In Seattle, Washington, TRIM iodine-123 was used to produce liver tumour images. TRIM and Seattle's VA Hospital plan to continue study into this new method of liver imaging.

The already-successful TRIM experiments were, later in 1982, moved to a more versatile beam line area. Now stationed at beam line 2C, an experimental area constructed specifically for radioisotope research and production, TRIM will continue its research into developing improved radioisotopes for medical research and diagnostics.



Neutron activation analysis

Novatrack Analysts Limited of North Vancouver uses the slow-moving neutrons (called thermal neutrons) at TRIUMF for neutron activation analysis. The process analyses geological samples to find heavy metals such as gold and silver. The majority of users of the Novatrack facility in 1982 were industrial clients and government agencies.

Pion therapy

Improved stability and reliable operation of the TRIUMF cyclotron at high beam intensity allowed three major cancer patient treatment cycles in May, August and November, 1982. Sixteen patients were treated for brain and for pelvic tumours using the pion beam at TRIUMF. Under optimum conditions, it was found that a brain tumour treatment takes about 20 or 30 minutes while treatment of a pelvic tumour requires an hour or more.

Top:
HRH Queen Elizabeth II and Dr. B.D. Pate in the PET Suite — March 3, 1983.

Center:
Atomic Energy of Canada Ltd. hot cells used for the preparation of commercial radioisotopes.

Right:
CP42 target used to produce PET scanning agents.

PURE RESEARCH

TRIUMF's meson facility produces intense beams of pions, muons, protons and neutrons, each of which are used for a large number of experiments every year. In this annual report we focus especially on some of the recent work with muons which has emerged from TRIUMF.

The muon

Historically the muon is a maverick particle only now achieving its place in nature's hierarchy of basic building blocks and interactions. When the muon was first discovered, nearly forty years ago, it was at first, incorrectly believed to be the long sought for meson which Yukawa had predicted a decade earlier as the particle binding neutrons and protons together in nuclei. But the muon turned out to be a heavy relative of the familiar electron and its existence posed a problem for physicists for many years. More recently a comprehensive picture — called the standard model — has emerged of the basic subatomic particles and their interactions. It is a compelling picture with a few missing pieces and some important questions. TRIUMF's program with muons addresses some of the questions.

In the standard model there are two kinds of nuclear interactions — strong and weak — and correspondingly two families of basic building blocks. Each family at present consists of three pairs of particles. The strongly interacting particles are called quarks. The well known neutron and proton, and the mesons, are composite systems of quarks. The three pairs of particles which participate only in the weak interaction (which is responsible for most natural radioactivity) are called leptons. Each pair of leptons consists of a negatively charged particle and an elusive uncharged particle called a neutrino. The lightest pair of leptons are the electron and its neutrino; the next lightest are the muon and its neutrino; the other pair is the taon and its (as yet undiscovered) neutrino. The weak force, through which the leptons interact, involves the exchange of very massive (and very short-lived) particles called gauge bosons. In nature each lepton also has an antiparticle with the opposite properties (for example, the opposite electric charge).

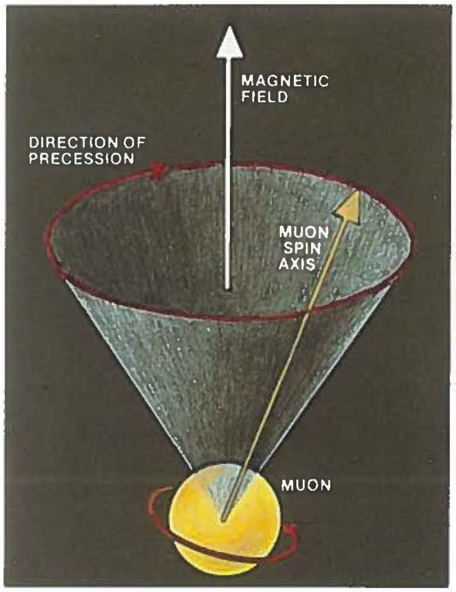
The muon is 207 times more massive than the electron. It decays spontaneously in 2 microseconds into an electron and two neutrinos. All of the experiments with muons at TRIUMF are carried out within times comparable to this 2 microsecond lifetime. TRIUMF's muons are created from the decay of pions (a meson with a lifetime of one fortieth microsecond). In turn the pions are created by the intense proton beams generated by TRIUMF's cyclotron.

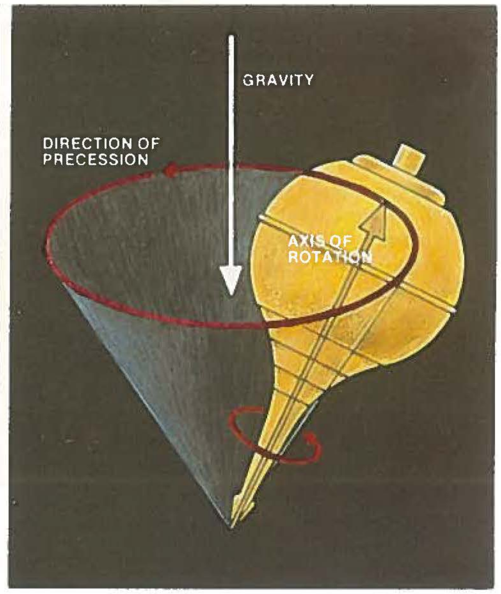
Muon spin rotation

One of the useful functions of muons lies in the fact that when they are "born" they spin like tops with their axis of rotation pointing in their direction of motion. If the spinning muon finds itself in a magnetic field, the direction of its axis starts to turn — or precess — around the direction of the magnetic field like a gyroscope set at an angle. The stronger the field the faster it precesses. This can be used as a tool for measuring the strength of magnetic fields in

Below:
Muons spin like tops. Like a top, a muon in a magnetic field has 2 motions: its spin and the turning of its axis. The turning of a magnetic field is called precession.

Opposite page:
Muons are the "daughter" particles of pions. Muons that stop in the target precess in the magnetic field and send out their "daughter" particles — electrons. Clocks time the arrival of the muons and the departure of the electrons.





the spaces between atoms as long as it is known how fast muons precess in the same strength laboratory magnetic fields. In experiments a beam of muons, each having their axes pointing in the same direction, is stopped in a sample of material. If the muon finds itself in a magnetic field, its axis starts to rotate and after a time it "dies". A set of detectors surrounding the sample is then used to measure the direction of the daughter electrons coming off the sample. The electrons come off like the beam of a lighthouse, sweeping across the face of the detectors in a regular manner. The speed at which this beam turns tells us a great deal about the strength of the magnetic field inside the sample. This technique is known as Muon Spin Rotation.

One important area of research using this technique, pioneered by a group of scientists from Tokyo, is the study of "spin-glasses". In a spin-glass the tiny atomic magnets are well ordered over short distances but this varies in time, with temperature and if the sample is placed in a magnetic field. Theoretical physicists have found the properties of these materials to be a challenge to their understanding of magnetism in general. Using these techniques an experiment can be carried in precisely controlled conditions and in zero magnetic field.

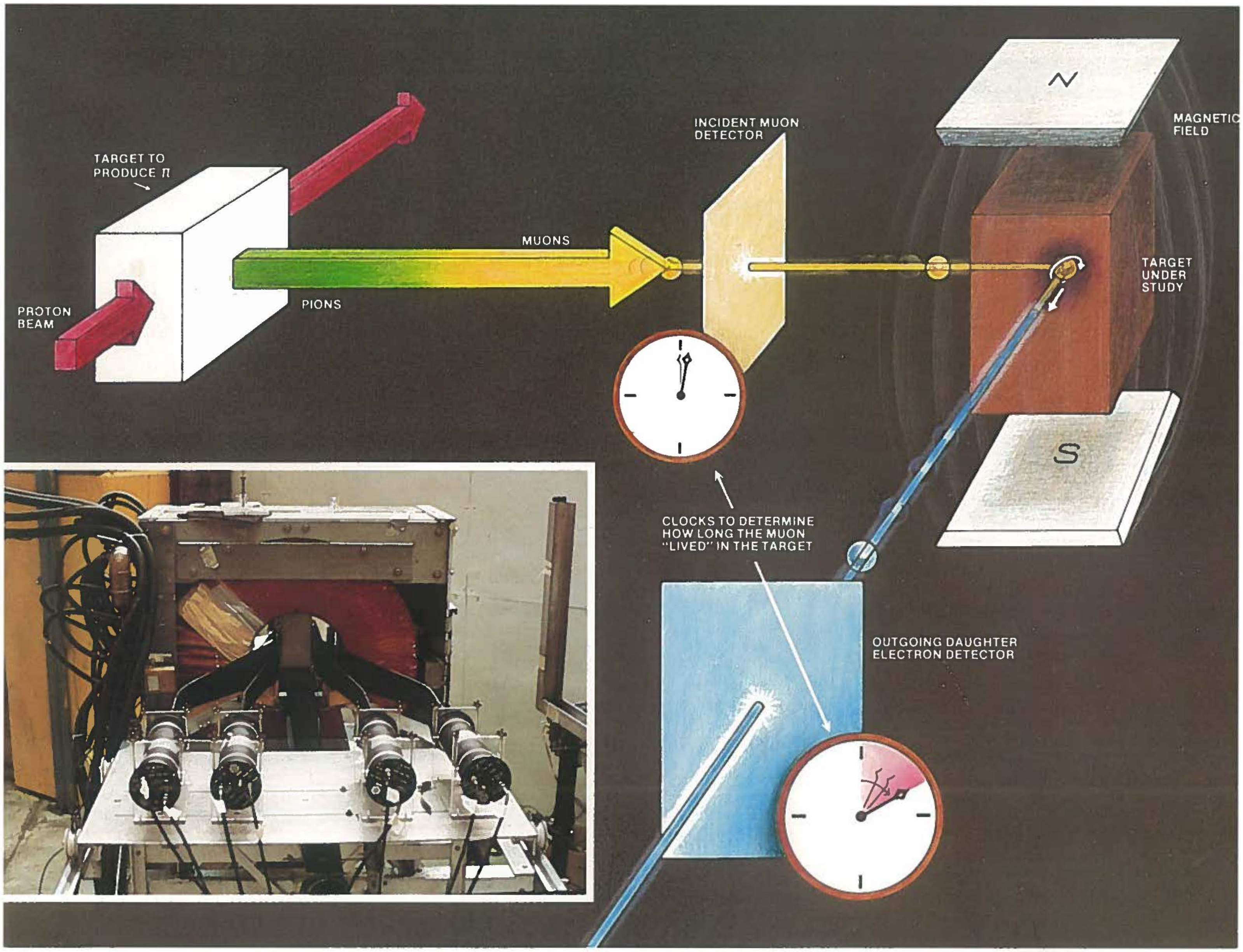
Rare decay modes

Studies of the muon itself have been invaluable in confirming the many questions raised by the standard model. The theory is able to predict how the muon disintegrates and how often.

A group from several Canadian and U.S.A. institutions have been using a very novel "camera", the Time Projection Chamber (TPC), to determine whether a muon can turn into an electron, when passing the nucleus of a heavy atom, without any neutrinos accompanying the change. This transformation is very rare, according to the standard model; billions of interactions will have to be examined to look for evidence of such neutrino-less transformations. TRIUMF's TPC has already gone well beyond previous world limits in the search for such rare decays. Their discovery would have profound implications for the standard model and for astrophysicists.

TABLE 1
Rare breakup modes of the muon

Less often than	*Physicists write*	*But say "The muon decays to..."*
190 per trillion	$\mu \rightarrow e^-\gamma$	"...an electron and a gamma ray."
2 per billion	$\rightarrow e^-e^+e^-$	"...2 electrons and a positron."
50 per billion	$\rightarrow e^-\gamma\gamma$	"...an electron and 2 gamma rays."



Above:
Muon Spin Resonance experimental equipment on the M20 secondary beam line.

Evidence for new particles

Earlier this year a most important piece was added to the standard model by the discovery in Europe of the gauge bosons — the much heralded W and Z particles. At TRIUMF this year a definitive experiment pertained to the properties of W and Z.

The W and Z gauge bosons described above all spin about their axes in a "left-handed" manner. Scientists are aware that nature is not always symmetrical in its dealing and attempt to find out the underlying causes of the difference. The question then arises: Are there any corresponding "right-handed" bosons in the world?

A group of physicists from U. California/TRIUMF have been carefully measuring what happens to muons when they disintegrate into an electron and neutrinos. The experiment was a very important step toward answering the question in that it set stringent lower limits on the possible masses of any "right-handed" members of the gauge boson family. The result showed that there is no point in searching for these particles in situations where new particles may be produced with masses lower than 7 times the known W boson mass.

Muonium in a vacuum

If positive muons stop in a very thin sample some are able to escape and on the way pick up an electron, forming muonium — the lightest atom known. Both of these particles are believed to be pointlike — that is they have no measurable size. Thus experiments using muonium allow scientists to probe the forces between positive and negative charges to far smaller distances than was previously possible using hydrogen (a proton and an electron) due to the finite size the proton.

A group from UBC/TRIUMF/Victoria has precisely measured the orbits of the electron around the muon in muonium to confirm those predicted by theory. The group was the first to observe a variety of muonium in which the electron was in a larger than normal orbit (the 2S orbit). This orbit is unstable and, as the electron spirals back into the normal orbit, gives off easily detected X-rays. An experiment deriving from this research, actually using this rare type of muonium, measured, for the first time, the Lamb shift in muonium — a small difference in the energy of two orbits in muonium (2P-2S). It is the Lamb shift which could play a crucial role in tests of the theory of electrodynamics.

Muonium chemistry

Muonium behaves chemically like a very light hydrogen atom (10% of its mass). The chemical reaction rate of muonium with ethylene has been measured at TRIUMF with ethylene in a gaseous form. Unambiguous evidence has been seen, for the first time in the gas phase, that muonium, due to its very light mass, is able to "quantum tunnel" through the barrier preventing the muonium from attaching to ethylene. Muonium reacts 20 times faster than hydrogen at — 100 °C because of this effect but behaves very much like hydrogen at 200 °C.

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A. Bracco, H.P. Gubler, D.K. Hasell, W.-P. Lee, W.T.H. van Oers, University of Manitoba
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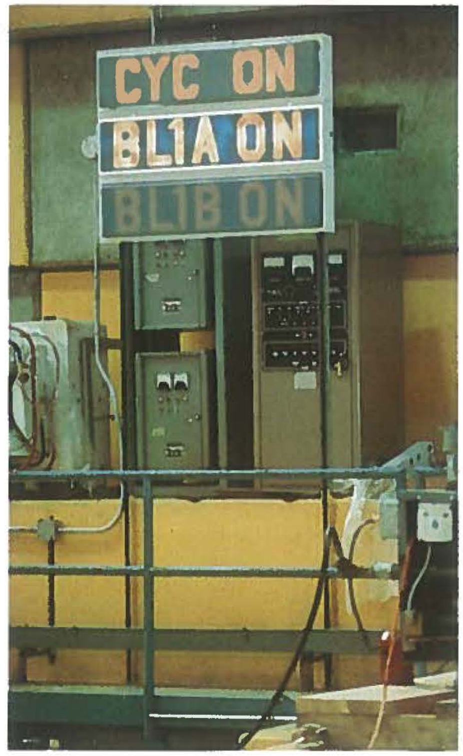

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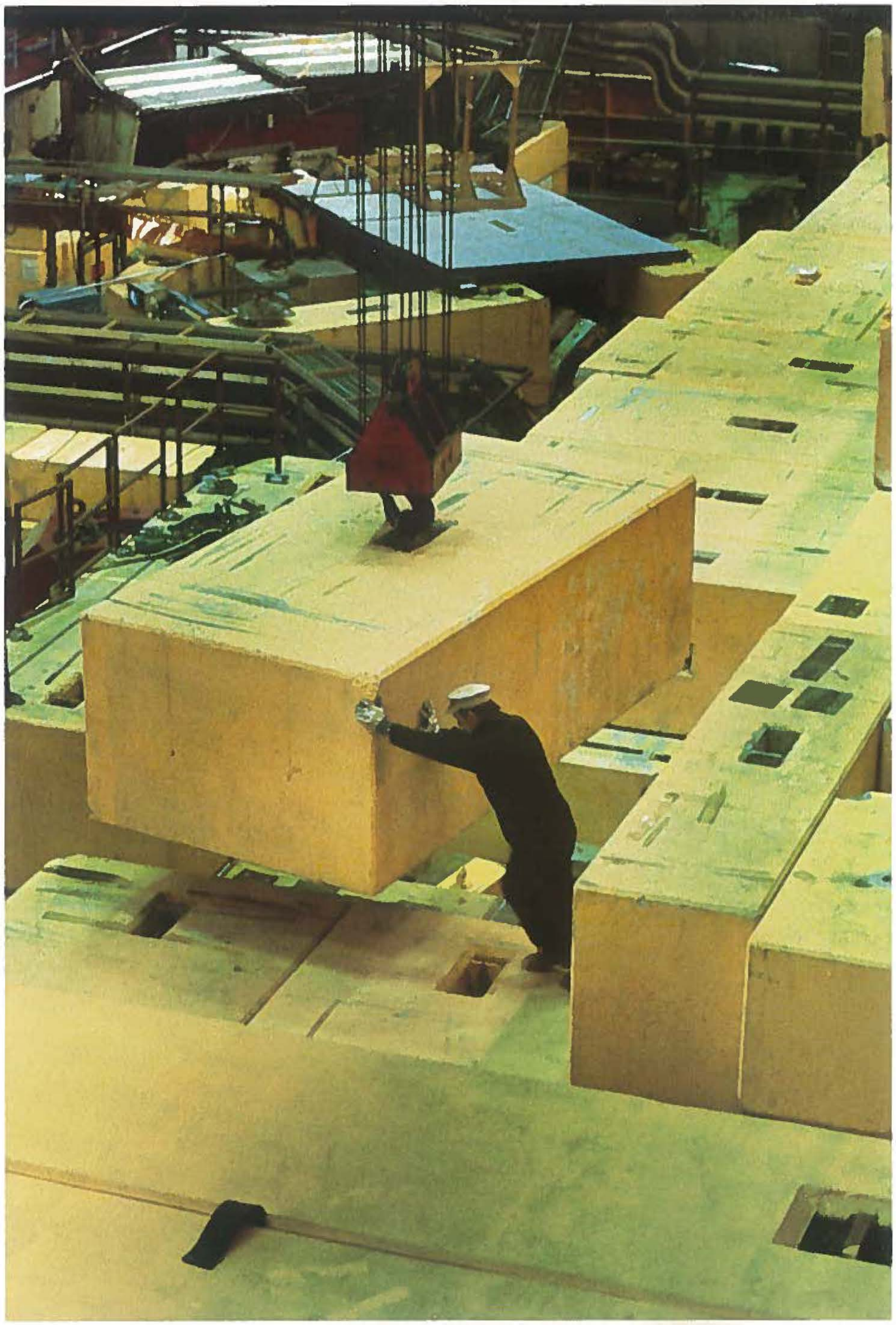
C.Y. Kim, S. Rowlands, University of Calgary
A.L. Carter, Carleton University
O.F. Häusser, F.C. Khanna, H.C. Lee, Chalk River Nuclear Laboratories
J.W. Scrimger, S.R. Usiskin, Cross Cancer Institute, Edmonton
B.S. Bhakar, N.E. Davison, W. Falk, J. Jovanovich, R. McCamis, J.P. Svenne, University of Manitoba
S.D. Hanham, MacMillan Bloedel Research
B. Margolis, S.K. Mark, McGill University
P. Depommier, Université de Montréal
M.S. Dixit, C.K. Hargrove, National Research Council
H. Blok, Novatrack Analysts Limited
G.T. Ewan, B.C. Robertson, Queen's University
J.T. Sample, Research Secretariat of B.C.
M. Krell, Université de Sherbrooke
T.E. Drake, University of Toronto
R.T. Morrison, Vancouver General Hospital
W.P. Alford, University of Western Ontario

Overseas
D.V. Bugg, R. Gibson, Queen Mary College, London
N.M. Stewart, Bedford College, London
A.S. Clough, University of Surrey
A.N. James, University of Liverpool
C. Amsler, A. Astbury, R. Keeler, CERN
R. Engfer, R. Kiefl, Universität Zürich
J. Domingo, E.L. Mathie, SIN
L. Antonuk, Université de Neuchatel
R. Grynszpan, CNRS Vitry
S. Ahmad, Orsay
R. van Dantzig, IKO Amsterdam
J. Niskanen, University of Helsinki
M. Furic, Inst. R. Boskovic
C. Cernigoi, N. Grion, R. Rui, Universitá di Trieste and INFN
J. Alster, Tel-Aviv University
B. Olaniyi, University of Ife
K. Nagamine, T. Yamazaki, University of Tokyo
K. Sakamoto, Japanese Federal Government
I.R. Afnan, Flinders University of South Australia

United States
D. Ashery, Argonne National Laboratory
K.W. Jones, Brookhaven National Laboratory
F.P. Brady, University of California, Davis
B.M.K. Nefkens, J.R. Richardson, University of California, Los Angeles
M.B. Epstein, D.J. Margaziotis, California State University
J.J. Kraushaar, T. Masterson, University of Colorado
H.S. Plendl, Florida State University
B. Blankleider, H.O. Meyer, M.E. Rickey, P. Schwandt, T. Ward, Indiana University
Y.K. Lee, Johns Hopkins University
P. Tandy, Kent State University
C. Clawson, K.M. Crowe, G. Gidal, S. Kaplan, R.H. Pehl, V. Perez-Mendez, S. Rosenblum, H. Steiner, M.W. Strovink, R. Tripp, Lawrence Berkeley Laboratory
J.W. Blue, Lewis Research Center, NASA
L.E. Agnew, H.L. Anderson, J. Clark, J.S. Fraser, C.Y. Huang, R.J. Macek, Los Alamos National Laboratory
R.P. Redwine, Massachusetts Institute of Technology
F.D. Becchetti, University of Michigan
H.B. Willard, National Science Foundation
B. Bassalleck, B. Dieterle, University of New Mexico
J.K. Chen, State University of N.Y. Geneseo
R.A. Segel, K.K. Seth, Northwestern University
F.E. Bertrand, D.J. Horen, T.P. Sjoreen, Oak Ridge National Laboratory
B.C. Clark, Ohio State University
D.K. McDaniels, University of Oregon
K.S. Krane, R. Landau, A.W. Stetz, L.W. Swenson, Oregon State University
R.F. Carlson, University of Redlands
G.S. Mutchler, Rice University
R. Dubois, Standord Linear Accelerator Center
R. Bryan, Texas A & M University
V.G. Lind, R.E. McAdams, O.H. Otteson, Utah State University
M. Blecher, K. Gotow, D. Jenkins, Virginia Polytechnic Institute and State University
J.P. Geraci, I. Halpern, E.M. Henley, University of Washington
A.S. Rupaal, Western Washington University
W.C. Sperry, Central Washington University
C.F. Perdrisat, M. Eckhause, R.T. Siegel, College of William and Mary
H. Bichsel
T.C. Sharma



Users Executive Committee

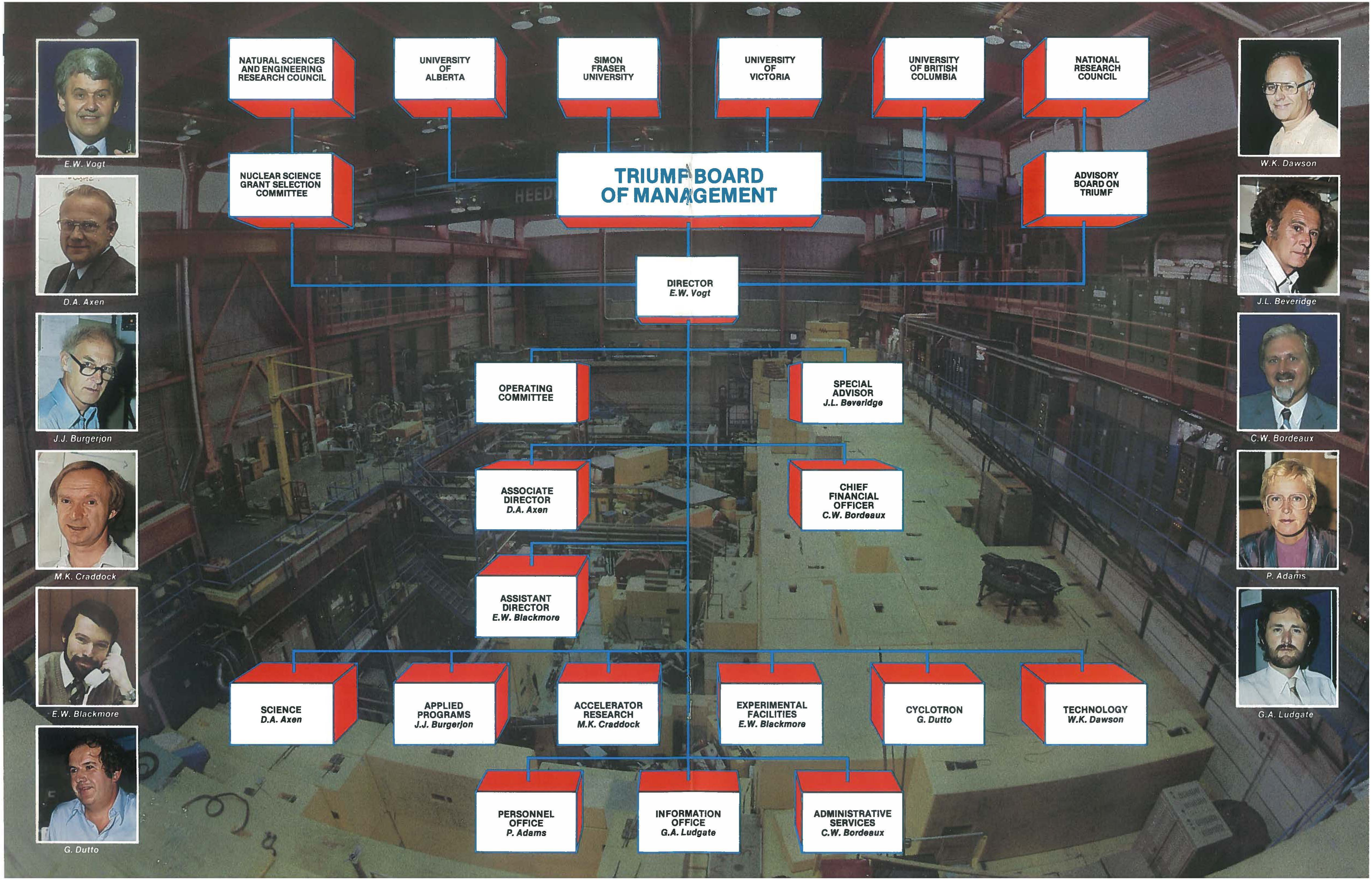
Preceding the Users Annual General Meeting December 1, the following members of the Executive Committee were elected:

D. Garner, *Chairman*	University of British Columbia
R. Abegg, *Associate Chairman*	University of Alberta
G.K.Y. Lam	B.C. Cancer Control Agency
R. Helmer	Simon Fraser University
D.K. McDaniels	University of Oregon

G.A. Ludgate, *TRIUMF Liason Officer*

Long Range Planning Committee

D.F. Measday, *Chairman*	University of British Columbia
J.-M. Poutissou, *Secretary*	University of British Columbia
D.A. Axen	TRIUMF
E.W. Blackmore	TRIUMF
K.M. Crowe	Lawrence Berkeley Laboratory
D.A. Hutcheon	University of Alberta
J.R. Richardson	University of California, Los Angeles
A.W. Stetz	Oregon State University
R. Woloshyn	TRIUMF


NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL
UNIVERSITY OF ALBERTA
SIMON FRASER UNIVERSITY
UNIVERSITY OF VICTORIA
UNIVERSITY OF BRITISH COLUMBIA
NATIONAL RESEARCH COUNCIL
NUCLEAR SCIENCE GRANT SELECTION COMMITTEE
TRIUMF BOARD OF MANAGEMENT
ADVISORY BOARD ON TRIUMF
DIRECTOR E.W. Vogt
OPERATING COMMITTEE
SPECIAL ADVISOR J.L. Beveridge
ASSOCIATE DIRECTOR D.A. Axen
CHIEF FINANCIAL OFFICER C.W. Bordeaux
ASSISTANT DIRECTOR E.W. Blackmore
SCIENCE D.A. Axen
APPLIED PROGRAMS J.J. Burgerjon
ACCELERATOR RESEARCH M.K. Craddock
EXPERIMENTAL FACILITIES E.W. Blackmore
CYCLOTRON G. Dutto
TECHNOLOGY W.K. Dawson
PERSONNEL OFFICE P. Adams
INFORMATION OFFICE G.A. Ludgate
ADMINISTRATIVE SERVICES C.W. Bordeaux
E.W. Vogt
D.A. Axen
J.J. Burgerjon
M.K. Craddock
E.W. Blackmore
G. Dutto
W.K. Dawson
J.L. Beveridge
C.W. Bordeaux
P. Adams
G.A. Ludgate

FINANCIAL REVIEW

The Financial Review for 1982-83 shows that, unlike last year, some decreases in receipts occurred (Fig. 1). The major cause of the 17.03% decrease in Sponsoring Organizations' receipts is the completion of the Positron Emission Tomograph in fiscal 1982. All other organizations in this group kept their funding at about historical levels. The drop in receipts of 9.27% from the Province of British Columbia is due to the building program nearing completion. The Province of British Columbia, through the Universities Council of British Columbia, approved a building program to keep pace with expansion as reflected in the TRIUMF Five Year Plan (next page). The total approved amount to date is $7,475,000. The decrease in our investment income was due entirely to the drop in interest rates.

Figure 1

% changes in receipts over previous year

NRC	+ 23.93%
NSERC	+ 19.28%
AECL	+ 19.81%
Province of B.C.	− 9.27%
Sponsoring Organizations	− 17.03%
Investment Income	− 1.20%
Total Receipts	+ 18.78%

The continued enthusiastic support received from the National Research Council (NRC) made it possible to again have a 24% increase in funding over last year. NRC funds all of TRIUMF's operations, maintenance, development and capital expansion. The contribution is $20,893,000 for fiscal 1983. The receipts amount to $20,867,950 because $16,243 was received the previous year.

The sole financial support for experiments performed under the aegis of TRIUMF is provided by the Natural Sciences and Engineering Research Council (NSERC). The funding increased by 19.28% over last year when the increase was 16.77% over the previous year. With more experimental facilities becoming available each year, there is a continued need to expand the financial support to experimenters.

The Atomic Energy of Canada Limited (AECL) receipts still show an increase of 19.81% due to their capital program at TRIUMF continuing. It is expected to come to an end next year, causing the funding to be reduced considerably. The purchase of the 42 MeV Cyclotron (CP42) from The Cyclotron Corporation (TCC) in California has run into some problems. TCC was granted the rejection of the executory contract, related to this CP42, by the Bankruptcy Court of the Northern District of California, U.S.A., under the terms of Chapter 11. Negotiations are underway to arrive at an acceptable settlement. The costs and consequences of these actions are the responsibility of AECL.

The expenditures in the Statement of Combined Receipts and Expenditures (page 17), are within budget and fully recoverable. The general increase in activities, in line with the 5-Year Plan projections, led to the hiring of additional staff which is reflected in increased salary expenditures. Salary expenses for operation and expansion of the facilities increased by 22.37% which is slightly less than the increase of 23.93% in NRC funding for these purposes.

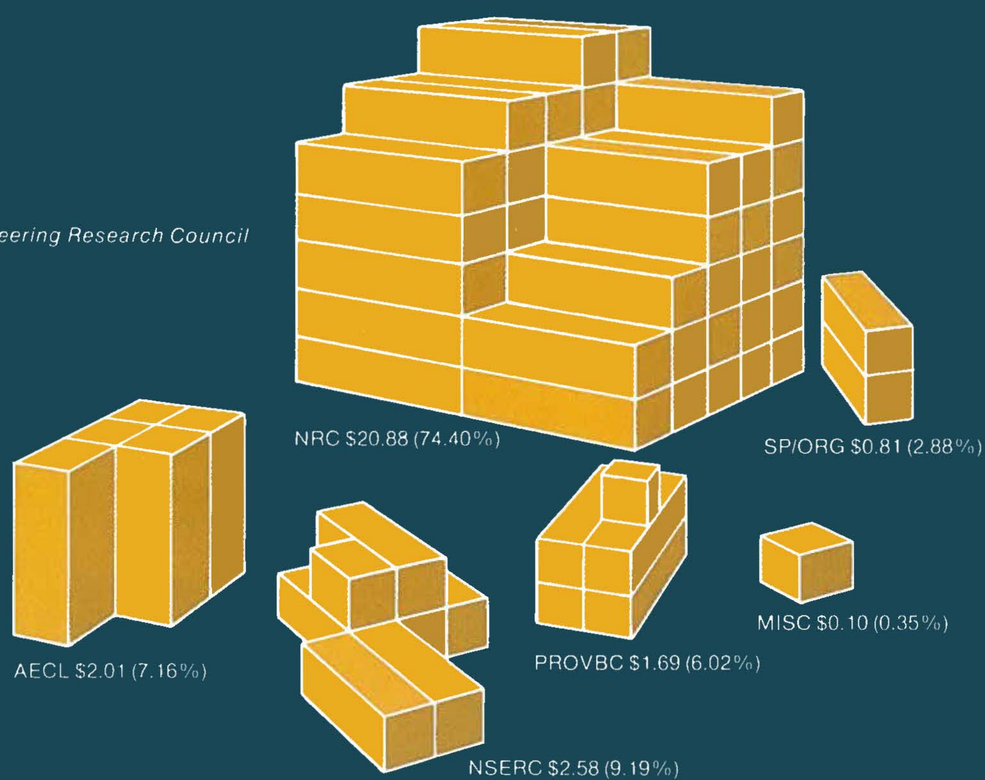
A successful year was experienced in that all major obligations were met and expenses were at acceptable levels. The forecast for next year, fiscal 1984, is continued real growth in receipts from NRC and NSERC, a continuation of the building programs funded by the Province of British Columbia and the usual support from all institutions using the TRIUMF facilities.

Figure 2

SOURCE OF FUNDS

(in millions of dollars)

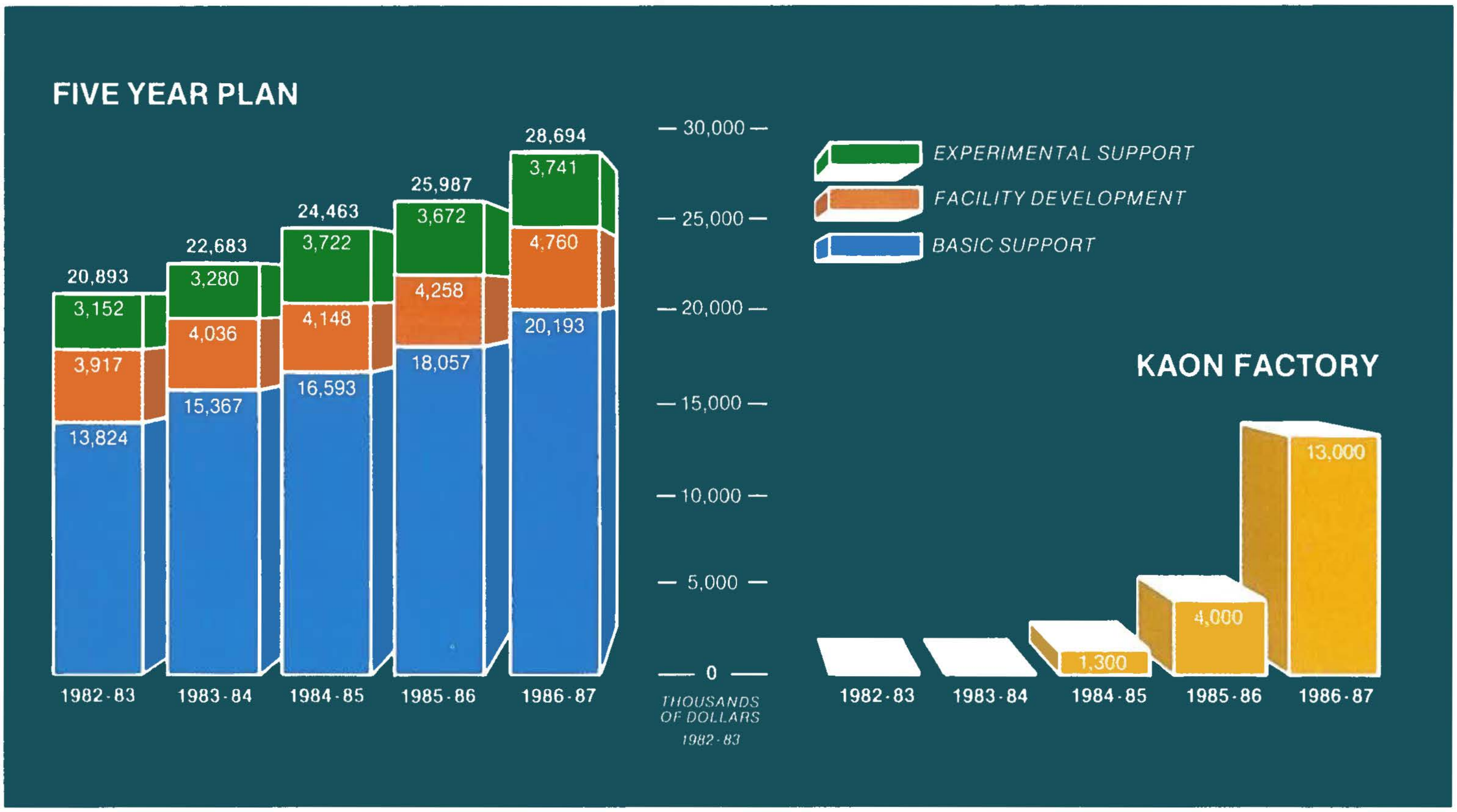
NRC: *National Research Council*
NSERC: *Natural Sciences and Engineering Research Council*
AECL: *Atomic Energy of Canada Ltd.*
SP/ORG: *Sponsoring Organizations*
MISC: *Miscellaneous*



FIVE YEAR PLAN

TRIUMF's Five Year Plan is submitted to the NRC Advisory Board on TRIUMF each fall. It is a rolling plan intended to forecast TRIUMF's future intentions and the associated financial requirements. Within the plan three broad areas of expenditure are identified, namely: the basic support and operation of the existing facility, the development of new facilities which enhance TRIUMF's capabilities, and the support of experiments to be performed at TRIUMF. Forecasts of requirements in each of these areas are centred about the development of major facilities and are based on a model to guide the extension of the Five Year Plan. This model identifies additional financial requirements associated with the general increase in TRIUMF's scope and capabilities implied by the completion of major facilities.

A proposed major new addition to TRIUMF, the Kaon Factory, is dealt with as a separate line item within this plan. The feasability of this exciting new possibility at TRIUMF is being actively pursued, however the indicated funding requirements have not been approved.



TRIUMF 5 YEAR PLAN
(Thousands of 1982-83 dollars)

	1982-83	1983-84	1984-85	1985-86	1986-87
Basic Support	13,824	15,367	16,593	18,057	20,193
Facility Development (excl. Kaon Factory)	3,917	4,036	4,148	4,258	4,760
Experimental Support	3,152	3,280	3,722	3,672	3,741
Subtotal	20,893	22,683	24,463	25,987	28,694
Kaon Factory	—	—	1,300	4,000	13,000
Total	20,893	22,683	25,763	29,987	41,694

AUDITORS' REPORT

Board of Management
TRIUMF

We have examined the statement of working capital position of TRIUMF as at March 31, 1983, together with the statement of combined receipts and expenditures and the statement of National Research Council fund transactions for the year then ended. 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 statements present fairly the working capital position of TRIUMF as at March 31, 1983, its combined receipts and expenditures and the disbursement of National Research Council funds received for the year then ended in accordance with the accounting policies set out in Note 1, applied on a basis consistent with that of the preceding year.

MacGillivray & Co.

MacGillivray & Co.
Chartered Accountants

Vancouver, Canada
July 12, 1983

FINANCIAL STATEMENTS

TRIUMF
STATEMENT OF COMBINED RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1983

	1983	1982
RECEIPTS		
National Research Council Funds	$20,876,757	$16,845,000
Natural Sciences and Engineering Research Council Grant	2,583,124	2,165,420
Atomic Energy of Canada Limited Funds	2,005,435	1,673,770
Province of British Columbia Grant	1,688,446	1,861,128
Sponsoring Organizations	814,379	981,539
Investment Income	104,556	105,826
	28,072,697	23,632,683
EXPENDITURES		
Building Construction	1,625,644	1,801,580
Communication	142,569	171,165
Computer	180,408	176,156
Cyclotron Costs-Atomic Energy of Canada Limited	554,108	473,442
Equipment	2,709,189	2,333,604
Equipment and Facility Components-Atomic Energy of Canada Limited	22,599	13,998
Facilities in Progress	1,704,731	1,202,609
Insurance	45,235	37,637
Interest	3,887	48,203
Loan Interest & Principal. Atomic Energy of Canada Limited	758,037	704,459
Minor Construction	62,865	67,687
Miscellaneous	8,924	4,644
Power	1,086,410	676,825
Salaries and Benefits	12,478,400	10,391,489
Sessional and Occasional Staff Costs	1,038,085	470,059
Supplies and Expenses	5,514,056	4,326,304
	27,935,147	22,899,861
EXCESS OF RECEIPTS OVER EXPENDITURES	137,550	732,822
ADD FUNDS BALANCE beginning of year (Note 2)	225,155	(450,044)
	362,705	282,778
LESS FUNDS BALANCE end of year	292,819	225,155
DECREASE IN DEFICIT for the year	69,886	57,623
SURPLUS (DEFICIT) beginning of year	(160,051)	(217,674)
SURPLUS (DEFICIT) end of year	$ (90,165)	$ (160,051)

COMMITMENTS (Note 3)

TRIUMF
STATEMENT OF WORKING CAPITAL POSITION
FOR THE YEAR ENDED MARCH 31, 1983

	1983	1982
ASSETS		
CASH ON HAND	**$200,000**	$ —
FUNDS RECOVERABLE		
Natural Sciences and Engineering Research Council Grants Overexpended	**105,553**	65,400
Atomic Energy of Canada Limited	**—**	234,038
Other Administered Funds Overexpended	**126,283**	151,085
	231,836	450,523
DUE FROM UNIVERSITIES		
The University of British Columbia	**149,758**	271,289
Simon Fraser University	**—**	12,891
The University of Alberta	**26,623**	—
	176,381	284,180
TOTAL ASSETS	**608,217**	734,703
LIABILITIES		
DUE TO NATIONAL RESEARCH COUNCIL	**25,050**	16,243
DUE TO UNIVERSITIES		
The University of Victoria	**45,416**	30,064
The University of Alberta	**—**	12,337
Simon Fraser University	**23,992**	—
	69,408	42,401
ACCOUNTS PAYABLE	**104,319**	176,675
	173,727	219,076
UNEXPENDED BALANCES		
Natural Sciences and Engineering Research Council Grants Unexpended	**384,813**	547,060
Other Administered Funds Unexpended	**55,740**	112,375
Atomic Energy of Canada Limited	**59,052**	—
	499,605	659,435
TOTAL LIABILITIES	**698,382**	894,754
WORKING CAPITAL — UNALLOCATED FUNDS	**($ 90,165)**	($160,051)

TRIUMF
NOTES TO THE STATEMENTS OF COMBINED RECEIPTS AND EXPENDITURES, AND WORKING CAPITAL POSITION
FOR THE YEAR ENDED MARCH 31, 1983

NOTE 1: ACCOUNTING POLICIES

The following are the significant accounting policies:

a) Basis of Accounting
All transactions are recorded on an accrual basis. Expenditures on capital assets and inventories are expensed as incurred.

b) Atomic Energy of Canada Limited
These statements do not reflect transactions that Atomic Energy of Canada Limited may have entered into directly.

NOTE 2: SUMMARY OF END-OF-YEAR FUNDS BALANCE

	1983	1982
Funds Unexpended		
National Research Council	$ 25,050	$ 16,243
Natural Sciences and Engineering Research Council	279,260	481,660
Atomic Energy of Canada Limited	59,052	—
	363,362	497,903
Funds Overexpended		
Atomic Energy of Canada Limited	—	234,038
Other Administered	70,543	38,710
	70,543	272,748
Funds Balance	$ 292,819	$ 225,155

NOTE 3: COMMITMENTS

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

	1983	1982
National Research Council	$1,159,000	$1,533,000
Natural Sciences and Engineering Research Council	241,000	172,000
Atomic Energy of Canada Ltd.	179,000	755,000
Building Construction Project	249,000	834,000
Other Administered	31,000	14,000
TOTAL	$1,859,000	$3,308,000

TRIUMF
NATIONAL RESEARCH COUNCIL FUNDS
STATEMENT OF RECEIPTS AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1983

	1983	1982
RECEIPTS		
Contribution	**$20,876,757**	$16,845,000
EXPENDITURES		
Administration	**2,453,547**	1,749,410
Cyclotron services	**6,939,505**	5,013,893
General services	**5,547,011**	4,324,456
Commissioned facilities	**1,225,808**	1,217,512
Minor Projects	**257,996**	101,194
Major projects	**3,722,359**	3,143,048
Experimental support	**913,073**	793,072
Unallocated	**(191,349)**	205,393
Sub total Expenditures	**20,867,950**	16,547,978
EXCESS OF RECEIPTS OVER EXPENDITURES	**8,807**	297,022
FUNDS UNEXPENDED (OVEREXPENDED) beginning of year	**16,243**	(280,779)
FUNDS UNEXPENDED (OVEREXPENDED) end of year	**25,050**	16,243

	1983	1982
EXPENDITURE BREAKDOWN BY PROGRAM ELEMENT		
Basic support	**13,978,472**	10,655,204
Facility development	**3,790,107**	3,142,001
Experimental support	**3,099,371**	2,750,773
	20,867,950	16,547,978

	1983	1982
EXPENDITURE BREAKDOWN BY OBJECT		
Communications	**120,309**	151,212
Computer	**125,442**	126,729
Equipment	**2,220,109**	2,073,929
Facilities in progress	**1,704,731**	1,202,609
Insurance	**45,235**	37,637
Minor construction	**62,865**	67,687
Power	**1,086,410**	676,825
Salaries and benefits	**10,945,865**	9,140,479
Sessional and occasional staff costs	**645,247**	330,662
Supplies and expenses	**3,911,737**	2,740,209
	$20,867,950	$16,547,978

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Journal publications:

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C.E. Picciotto and M.S. Zahir, Neutrinoless double-beta decay in left-right symmetric models, Phys. Rev. D **26**, 2320 (1982). [TRI-PP-82-30]

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R.K. Keeler, R. Dubois, E.G. Auld, D.A. Axen, M. Comyn, G.A. Ludgate, L.P. Robertson, J.R. Richardson, D.V. Bugg, J.A. Edgington, W.R. Gibson, A.S. Clough, N.M. Stewart and B. Dieterle, Neutron-proton scattering cross sections between 200 and 500 MeV, Nucl. Phys. **A377**, 529 (1982). [TRI-PP-81-72]

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G.J. Lolos, P.L. Walden, E.L. Mathie, G. Jones, E.G. Auld, W.R. Falk and R.B. Taylor, Energy dependence of the analysing power for the $^{12}C(\vec{p}, \pi^+)^{13}C$ reaction with polarized protons of 200 to 250 MeV, Phys. Rev. C **25**, 1086 (1982). [TRI-PP-81-21]

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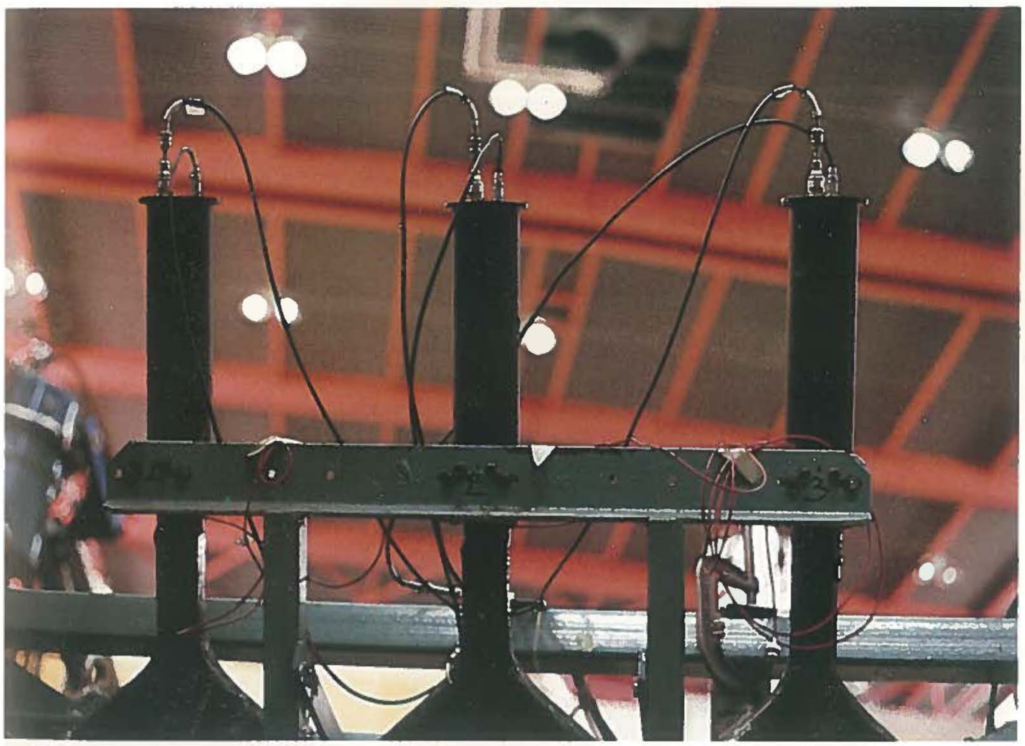

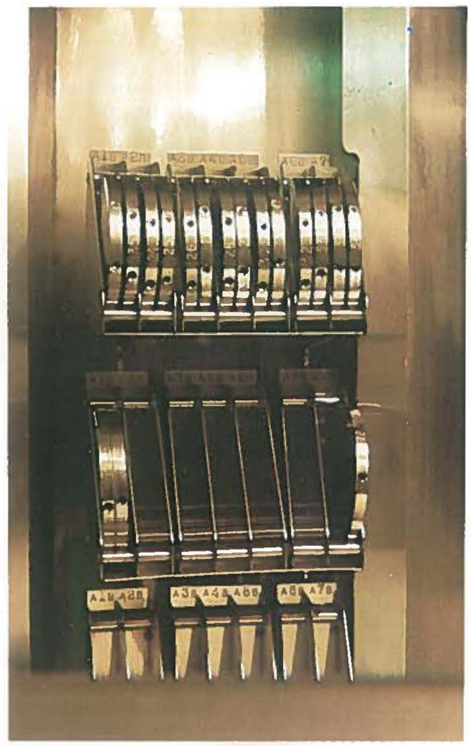

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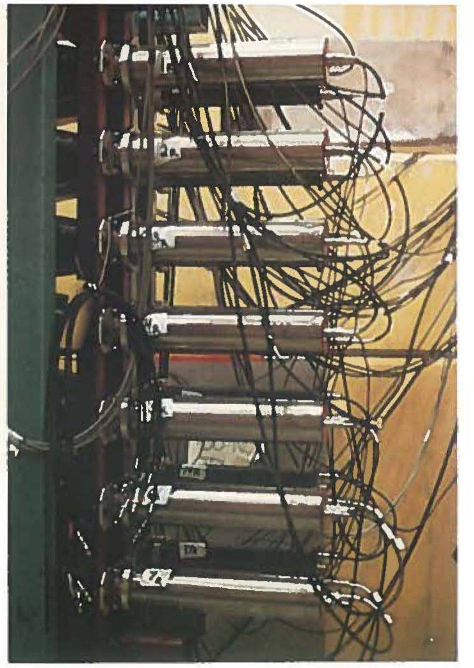

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Scientists who are currently (or have been) involved with experiments at TRIUMF represent 6 Canadian provinces, 21 U.S. states and 16 other nations.

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