# TRIUMF 1990–91
# Annual Financial & Administrative Report

*Including summaries of*

*Pure Research Activities and*

*Practical Applications of Research*

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TRIUMF is Canada's national meson facility, managed as a joint venture by a consortium of Canadian universities. It is operated under a contribution from the National Research Council of Canada.

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COVER PHOTO

*Laser system used in development of TRIUMF's new polarized ion source.*

The blue-green lines are argon laser beams powering four dye lasers. They, in turn, produce yellow laser light tuned to an absorption resonance in sodium vapour. The dye laser beams are reflected into the ion source by a system of mirrors (some visible at the top). Bright tubes left of the dye lasers are catcher tubes for recirculating dye solution. Dye laser light produces polarized sodium vapour within the source by "optical pumping". The sodium polarization is eventually transferred to a beam of protons injected into the TRIUMF cyclotron.

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The 1990–91 Financial & Administrative Annual Report is prepared by the

TRIUMF Information Office

Editor: Michael La Brooy

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## March 1991

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# Director's Report

In a short annual report, adorned with numbers and organization charts, one can at best provide touchstones to capture the essence of a large, complex national laboratory such as TRIUMF.

The driving force is pure science—the age-old questions: What's it all about? How does our universe work? What lies at the heart of matter? In its search for answers TRIUMF is fortunate to play a role at a time when there has been a wonderful quantum jump forward in our understanding of nature's basic building blocks and fundamental forces. TRIUMF provides many different tools or probes for such work.

TRIUMF's muons are one such probe. The muon is one of the basic building blocks and is related to the familiar electron. Who ordered the muon? Whoever did would be now pleased to learn that the muon elucidates for us the basic properties of the radioactive decay force, as described in what follows. But there is much more. The muon is a marvelous new probe for the structure of materials and even for fusion reactions of the kind which fuels our sun. Muon research of all kinds prospers at TRIUMF.

Although muons are the focus in this annual report, the new facilities under development, as described here, pertain to new opportunities with pions and also some exciting new astrophysics with proton beams.

The engine of pure science also drives a variety of applied programmes which produce useful (and profitable!) ideas and things. The fundamental relationship which governs such spin-offs from fundamental science is that world-class economic impact results from world-class scientists and world-class science. It is that effective combination which is so powerful for this purpose at TRIUMF.

Only a few spin-offs are highlighted in this annual report. They pertain mostly to medical applications, but TRIUMF's technology transfer activities cover a very broad range of technology and the production of royalties is growing very rapidly.

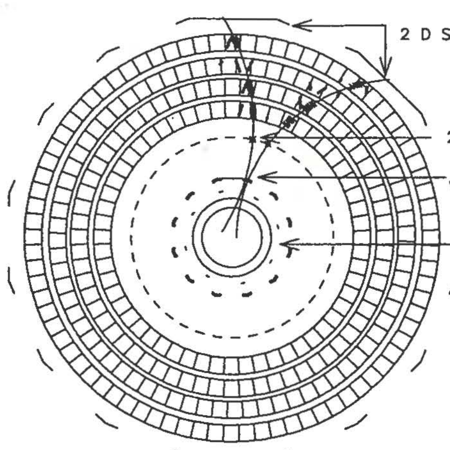
*Erich Vogt*

We acknowledge the contributions of Dr. M. Hasinoff (radiative muon capture) and Dr. G. Marshall (muon-catalysed fusion experiment) in the preparation of this report.

# The Far Side of the Muon

Of the four kinds of particles available as intense beams at TRIUMF, the muons must undoubtedly feel different from the rest. Protons, neutrons and pions are all composite particles made of quarks, but the muon is a fundamental particle itself, one of the six **leptons**. Its lighter sister, the electron, is well known to us all, though its rare, heavy brother, the tau particle, probably is not. These are the three charged leptons; each has an uncharged partner called a neutrino — the most unreactive, secretive creatures in the particle zoo.

One thing distinguishing the leptons from other particles is that none of them responds to the *strong* force, sometimes called the nuclear force, which binds together the quarks and their composites. Instead, the *weak* force and (for the three charged ones) the *electromagnetic* force are the guiding influences in the social life and liaisons of the leptons.
Despite its singular status, the muon is certainly not an outcast at TRIUMF! Indeed, it is admired as an amazingly versatile and cooperative actor in a wide range of experiments, some of them essentially pure research, others having very important and practical applications in view. In our revolving annual presentation of TRIUMF 's star performing particles, this year we bring you these two stories from the far side of the muon.




## Rare Interactions of Muons — The Radiative Muon Capture Experiment

During the past 15 years, the work of Weinberg, Glashow and Salam has changed the old perception that there were four basic forces in nature. These researchers combined the mathematics of two forces (the *electromagnetic* and the *weak*) into a single "Standard Electroweak Model." Their theory is spectacularly successful in explaining most of the experimental results where particle interactions involve leptons only.

The next step toward a single, unified model embracing all particles, requires that interactions involving the *strong* force be brought into the scheme, to create a "Grand Unified Theory". However, attempts in this direction have been much less successful: we are still somewhat uncertain about the basic details of our theory of the *strong* interaction — Quantum Chromodynamics.

Hadrons are a class of composite particles (including the proton, neutron and pion) made up of quarks bound together by the *strong* force. If one looks beyond the basic *weak* interactions of leptons into a slightly more complicated system, such as one involving a lepton and a hadron, then the excellent basic description of the Standard Electroweak Model must be modified by extra mathematical terms due to the presence of the strongly interacting hadron. How can we get experimental information about these terms?

*A large international collaboration*

Canada, together with the USA, Australia, Switzerland and China, has constructed a new particle detector at TRIUMF, to be used in an experiment to study the lepton-hadron interaction. This instrument is called a large-volume pair spectrometer (i.e. it can measure the paths and energies of pairs of particles created in a relatively large space). Such measurements will provide information on these additional terms in the "electroweak semi-leptonic model" with an accuracy of 10% or better. The basic reaction here involves a slow-moving, negatively charged muon interacting with a proton in a target of liquid hydrogen. (The hydrogen is contained in a thin-walled cylinder made of pure gold. This ensures that if any incoming muons do stop in the target walls, they will be captured quickly compared to the capture time in liquid hydrogen.)

> Frigid Fusion?
>
> Muon-catalysed hydrogen fusion has been described as "cold", to distinguish it from "hot" fusion, as in plasma confinement devices (tokamaks) or in stars like our sun. Recently the term "cold fusion" has gained notoriety after its association with results obtained in electrolytic cells at room temperature.
> Muon-catalysed fusion is well established, and should not be confused with this fusion in electrolytic cells. In fact, the TRIUMF experiment is performed at a temperature colder than any other fusion research. Perhaps we should refer to it as "Frigid Fusion"!

As the muon and proton interact, their electric charges cancel each other: the proton changes into a neutron, while the muon's mass initially is converted into a neutrino plus a high-energy gamma ray. This is the first stage. The second involves letting this gamma ray pass through a 1-mm layer of lead, where the ray's energy "congeals" into a small speck of matter plus its corresponding bit of antimatter — an electron plus a positron — inside the new detector. The detector sits in a strong magnetic field; any charged particle moving in a magnetic field is forced to travel a circular path. Thus, whenever a moving, electron-positron pair is formed, these non-identical twins immediately separate, curving in opposite directions within the detector because of their opposite charges.

But how does the detector track these leptons? Any fast-moving particle passing through a gas knocks electrons off the atoms it meets. As it moves, it leaves a long trail of charged atoms (ions) and electrons behind it, rather like a vapour trail behind a high-flying aircraft, but in miniature. The detector contains many layers of precisely positioned, incredibly fine, sensor wires throughout its volume. These pick up electric charge from any drifting electrons formed near them, and send messages to a computer. The exact timing, path and curvature of the original particles can later be reconstructed by the computer. The figure shows a typical, reconstructed, "gamma pair".

The radiative muon capture process is extremely rare, so we see only about five events per day, even at the full TRIUMF beam intensity. Thus, collecting sufficient data for this experiment takes several weeks.

### Hydrogen Fusion: Muons for Energy!

Although the muon interacts with other particles only by *weak* or *electromagnetic* processes, it can be a "spectator" in the *strong* interactions of nearby hadrons. In these situations, however, the muon will not sit idly by — it wants to give new meaning to the term "audience participation"! The fusion of nuclei of hydrogen isotopes is a *strong* force reaction of particular practical interest to us, and here the muon can actually catalyse a reaction which otherwise would take place only at extremely high temperatures and pressures. Why is this reaction so interesting? Because this is how the sun and stars produce all the radiation they pour down on us. It is the same reaction that releases the tremendous destructive power of the hydrogen bomb. If only we could control the process and make it proceed at precisely the speed we desire, the energy released could, in principle, provide most of our planet's energy needs for millennia, and at a very low cost.

At present we can see daunting obstacles to our use of muon-catalysed fusion for energy production. But research is providing clues to the nature of the process and how its limitations might be overcome or avoided. Some of this research is in progress at TRIUMF.

The nucleus of every hydrogen atom has a single positive charge, contributed by its single proton. However, nature does occasionally permit this lonely creature some company, in the form of neutrons: the hydrogen nucleus can have either no neutrons, or one, or two. Each of these variations is called an "isotope" of hydrogen. The physical properties (such as density) of the isotopes vary, but their chemistry remains much the same. A proton with no neutrons (p) is the most abundant hydrogen nucleus on earth. Next comes the deuteron (d, with one neutron) — only about 150 of them out of every million hydrogen atoms in sea water. The third isotope, tritium (t), has two neutrons, and is radioactive: the nucleus, apparently, cannot tolerate the two-to-one neutron ratio, so in time, one of the neutrons changes into a proton while throwing out an electron (to keep the total electric charge balanced). This process is called "*weak* beta decay", and tritium has a half-life of about 12 years.

Inside the nucleus the *strong* force binds neutrons to protons, and from that point of view these individual hydrogen nuclei are stable — that is to say, they do not undergo spontaneous rearrangement. However, if two hydrogen nuclei can be brought close together, and at least one of them contains a neutron (d or t), **then a *strong*-force nuclear rearrangement can occur**. The products can vary — some combination of free neutrons, hydrogen isotopes and helium isotopes. The greater total binding energy of the products is balanced by energy released in the form of kinetic energy (i.e. energy of motion), which is quickly converted to heat. This is the energy available through the hydrogen fusion reaction, a potentially clean and safe source of power.

Normally it is difficult to push two hydrogen nuclei together: the *electromagnetic* force makes two positive charges repel each other more and more forcefully as the distance between them shrinks.

This is where the muon comes in. A negatively charged muon can combine with a (positively charged) hydrogen nucleus to form an unusual, miniature atom called muonic hydrogen. (Physics shorthand for a muon is the Greek letter μ (mu), so these would be μp or μd.) Muonic hydrogen is a neutral system where the muon takes the place of the single electron found in a normal hydrogen atom. Being about two hundred times heavier than an electron, a muon is bound to the nucleus by a correspondingly greater energy; that is, its orbit is much closer to the nucleus than an electron's would be. In fact, a muonic hydrogen atom is about two hundred times smaller than normal hydrogen. With these properties a muonic hydrogen atom, like a small, neutral bullet, penetrates normal hydrogen or other heavier atoms.

In the next step, several unique phenomena may occur. The muon may skip to another hydrogen nucleus or to a heavier atom. And under certain conditions, another process takes place which can lead to fusion: the formation of an **exotic molecule** containing a muon. A molecule, of course, is a group of atoms joined together. Two separate atoms form a molecule when their nuclei "share" electrons; that is, one or more electrons move into orbits that surround **both** nuclei. If a muon were to replace one of these bonding electrons in any hydrogen molecule ($H_2$), this special system is called a **muonic molecule**. The hydrogen nuclei may be identical (pμp, dμd, and tμt), or different (pμd, pμt, and dμt).

The hydrogen nuclei in these molecules are **much** closer than in normal molecular hydrogen. If the nuclei are a deuteron and a triton (dμt), fusion occurs within a million-millionth of a second, releasing energy as well as liberating the muon, which can go on to provide an astonishing example of re-use and recycling: it may catalyse hundreds of such fusions before it eventually decays, after two millionths of a second, to an electron and neutrinos!

### *The Gateway*

What limits a typical fusion cycle (figure 2) is the rate at which muonic molecules are formed, since all other parts of the cycle are comparatively fast under suitable conditions. Normally this rate allows no more than a few fusions in the muon's lifetime. However, under certain circumstances a "gateway" exists called a resonance, whereby the normal molecule (with two hydrogen atoms) plus the muonic hydrogen atom can form an intermediate excited state involving all the particles — nuclei, electrons, and muon. From this state, muon-catalysed fusion occurs thousands of times faster than muon decay. The resonance conditions can be met only at certain temperatures and pressures, depending on the particular isotopes of hydrogen involved. This high rate is essential (although by itself not sufficient) for practical energy production.

Recently an experiment has been proposed at TRIUMF which will study the strength and behaviour of the resonances in the most interesting case, that of deuteron-triton (dt) fusion. We have developed a technique using small targets of solid hydrogen isotopes, and a collaboration from TRIUMF, the universities of Victoria and British Columbia, and other institutions in the USA and Europe, will build and use state-of-the-art cryogenic, vacuum, and detection systems to observe fusion. Measurements have already been made with pure, frozen deuterium targets at 2.5°K (i.e. 2.5° above absolute zero), marking the first time that fusion has been observed at so cold a temperature.

Surprisingly, the rate of fusion was comparable to the rate at higher temperatures, although theory predicted that the resonance condition would not be satisfied under the conditions of the TRIUMF measurement. This has sparked significant interest by world experts in catalysed fusion, and may indicate a previously unobserved mechanism of resonance. It marks one of a continuing series of TRIUMF results which are helping us

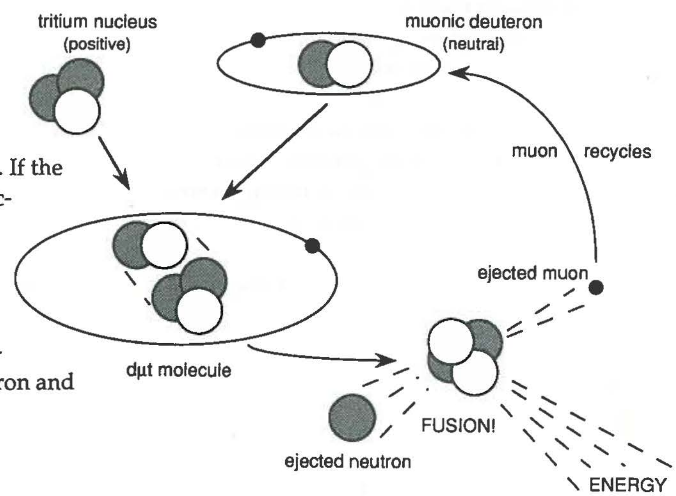



Figure 2. A simplified picture, showing a muon's part in catalysing the fusion of two hydrogen nuclei, in this case a deuteron and a triton. The products of the fusion are an alpha particle (which is a helium-4 nucleus), a free neutron, and energy.

This year TRIUMF reached a milestone in its development, with the establishing of the TRIUMF KAON Ventures Office. TKVO concentrates on finding the industrial partners and financial support that will turn the technology of TRIUMF's applied programme into actual products in the marketplace. The activities of this Office are described on pages 10–11. The items below deal with some important aspects of the current applied programme.

### PET

Positron Emission Tomography (PET) is a technique for getting unusual, computer-generated, slice images (Greek, *tome* = a cutting or slice) of a part of the human body. The images are obtained after the patient has been treated with a positron-emitting isotope that accumulates in the organ being studied. As the isotope decays, the emitted positrons are annihilated when they meet electrons in the body. This creates gamma rays, picked up by very sensitive detectors surrounding the organ. From this data, the computer can reconstruct the activity pattern of that organ.

TRIUMF was intimately involved in building the first PET scanner at the University of British Columbia hospital, and now TRIUMF scientists continue to pursue this interest further.

The Tomograph Development Group at TRIUMF is a multi-disciplinary team of nine researchers supported by a strategic NSERC grant. Their mandate is to develop new apparatus and computer techniques that will improve the quality of medical images obtained using the PET technique. The group is developing several essential components for a new generation of PET cameras. Their objective: to improve both resolution and sensitivity. A new camera must take pictures of complex organs like the human brain with better detail, and with a shorter exposure time for the patient.

An important part of this quest is to develop better gamma-ray detectors — the very expensive electronic devices that register the pattern of radiation emitted by the target organ. Such detectors constitute the heart of every PET camera (and in this sense a PET detector is like the light sensor in a video camera). In collaboration with Siemens-CTI, the world's largest commercial supplier of PET cameras, the group at TRIUMF is testing and redesigning these detectors. The firm's present state-of-the-art detector contains a mosaic of 64 small crystals that register radiation to produce the 64 discrete peaks in the calibration data. The detector currently being tested contains many more detection elements; it produces much higher resolution but at almost the same material cost as the 64-element detector.

Such improved detectors will yield greatly enhanced image resolution by a PET camera. This will open a door to new types of medical research and diagnosis with the PET technique, e.g. investigating the chemical function of the many *small* structures in the human brain in greater detail than is possible at present.

### Proton Therapy

The initial tests last year confirmed the feasibility of tumour therapy using low-energy protons. This year a 24-page booklet, "Healing With Protons", was prepared by the TRIUMF Information Office with material provided by the BC Cancer Agency, and was distributed to academic, medical, and government officials. The booklet describes the treatments possible with proton beams (which are quite different from pions in their range of use), and the kind of facility envisaged here. A formal proposal for the creation of a proton treatment centre is now in its final stages of preparation.

### Pion Cancer Therapy

Pion therapy for various cancers, especially brain tumours, has been a feature of TRIUMF since the early 80s, but it has been regarded as an experimental treatment. Gaining acceptance as a standard treatment requires a "clinical trial", where patients (randomly selected) are treated with either the conventional gamma-ray irradiation or with pions. A rigorous statistical comparison of results then determines whether the new treatment is acceptable.
Currently, two such clinical trials are under way at TRIUMF. The first began in 1988, and covers "Adult, grade 3 and 4 astrocytomas." It requires the treatment of 82 patients. Just under half this number were treated by the end of this year, and though there is no interim analysis of outcome, the study shows "no evidence of unacceptable toxicity... and all the patients appear to be eligible and evaluable."

*(continued on page 11)*

## Facility tours & visitors (90–91)

With 2630 visitors to TRIUMF on 362 separate tours, our scientists were still in great demand as guides for the public. Attendance was a little lower than last year. Visitors included 891 students (34%), and 205 VIPs—mostly politicians at all levels, who came to learn more of the KAON Factory project. A 1.3 x 2-metre scale model of the KAON Factory, normally installed in our Reception area, was exhibited in various parts of Canada during the year. Included on tours were prototypes of KAON Factory equipment, built for testing at TRIUMF.

### General

Work continued on the CHAOS and the SASP projects, both of which were described in last year's report. In the proton hall, extensive modifications were made in preparation for installing the second-arm spectrometer (SASP), with its huge, 100-tonne magnet. For CHAOS, the drift chambers and other detection equipment were completed. A special target with a gold cell was prepared for the Radiative Muon Capture experiment — see the Pure Research section for details. Because of further work on the polarized ion source for the main cyclotron, TRIUMF is now well on the way to possessing a very intense polarized proton beam (see cover photo and caption on page 1). However, one of the major thrusts this year was in the TISOL facility, which produces exotic heavy ions for study, as detailed below.

### Accelerated, Radioactive, Heavy Ion Beams at TRIUMF

Physical interactions soon after the Big Bang, or in the formation of stars, involved not only the smaller, individual particles like protons and pions, but also exotic, unstable, radioactive, heavy ions. New technology now makes it possible both to create beams of such heavier particles with energies around 20 keV, and then to accelerate these projectiles up to 2 MeV/u. TRIUMF has now taken the first of these steps, and is producing a wide range of intense, radioactive beams at lower energies. This capability is opening new areas of study in such diverse fields as nuclear astrophysics, nuclear reactions involving radioactive species, production of new, very heavy nuclei, condensed matter physics, nuclear medicine, and atomic physics.

Two main approaches exist for creating such beams. The first, called the projectile fragmentation recoil method, has recently become available at other facilities — GANIL (France), GSI/SIS (Germany) and RIKEN (Japàn). Very energetic projectiles will often shatter as they pass through *thin* targets. Electromagnetic devices can capture, collect and accelerate these fragments. The resulting beams generally exhibit energies greater than 50 MeV/u and are used primarily to study the properties of the species themselves. (Note: Expressions like 50 MeV/u mean that each *nucleon* in the fragment has this much energy, e.g. a six-nucleon fragment, consisting of three protons and three neutrons, will have energy of 300 MeV.)

A second approach uses intense beams of energetic protons, such as those available at TRIUMF, to interact with *thick* targets. We can extract, ionize, and separate the reaction products (according to their mass) as radioisotope ions in a device called an ISOL facility. Properties of these exotic nuclei can then be studied at the collector of the ISOL. These species could be further accelerated in a "post-accelerator" to some desired energy (realistically, around 2 MeV/u). No major facilities of this type are yet on-line, but the cyclotron facility at Louvain-la-Neuve, in Belgium, does produce beams of nitrogen-13 by a similar principle.

Ours is an ideal location for this kind of facility, since it permits many scientists to play a role in the new approach to studies using that unique environment, the atomic nucleus. TRIUMF is considering a proposal for the installation of an accelerated radioactive beams facility of the ISOL/post-accelerator type (referred to as ISAC). The most complex part of this is the first "leg" — the ISOL device, and one such facility is already operating at TRIUMF (see drawing). It is one of only two thick-target systems in the world. TISOL is now used both for performing research and development studies related to the ISAC proposal, and for physics programmes. A wide range of beams is available from two ion sources, which include the world's only on-line ECR (electron cyclotron resonance) ion source coupled to a multi-beam ISOL device. Many experimental programmes are under way, and one study in particular is of crucial importance to our understanding of stellar element synthesis. The reaction where an α-particle reacts with a carbon-12 nucleus is considered of key importance in nuclear astrophysics, and played an important role in producing the oxygen we breathe:

$$\alpha + {}^{12}C \longrightarrow {}^{16}O$$

It is, however, difficult to measure the rate of this reaction at energies similar to those available in stars. A different approach to this system is to study it in reverse — the "beta/delayed-α emission" decay of the short-lived nitrogen-16 nucleus.

First, using TISOL, $^{16}N$ is produced and collected at an experimental station. This decays to oxygen while emitting an electron:

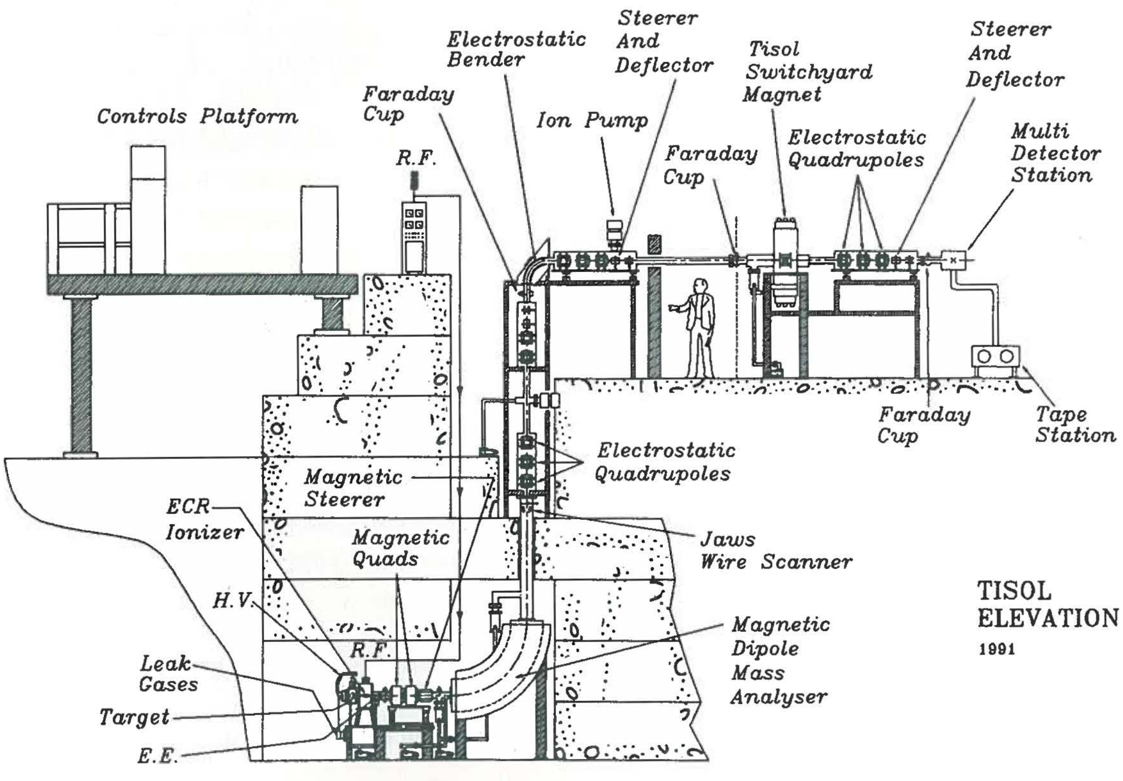
$$^{16}N \longrightarrow {}^{16}O + e^{-}$$

Finally,

$$^{16}O \longrightarrow {}^{12}C + \alpha$$

The beam of $^{16}N^{+}$ ions has a higher intensity than is available anywhere else. This study began in 1991, and will take about three years to complete.

With this facility now operating, it is correct to say that the TRIUMF programme has expanded significantly. It includes not only a wide selection of exotic, light, secondary particles used in beams, like muons and pions, but essentially any heavy ion, stable or radioactive. It provides another important tool for Man as he explores the mysteries of the nucleus and the universe.




TISOL
ELEVATION VIEW
1991

# TRIUMF KAON Ventures Office

In June 1990, the Government of British Columbia provided funds to establish and operate the TRIUMF KAON Ventures Office (TKVO). Its mandate: To pursue vigorously all financially and technically viable opportunities for commercializing the technologies evolving from activities at TRIUMF, and at the future KAON Factory. Such offices have become increasingly common at research institutions around the world. They provide a useful commercial benefit to the home country without in any way diluting the institution's original research goals.

The new office has two objectives as it works toward commercializing both the novel technology and the skills developed at TRIUMF and at KAON: First, to use these innovations to increase and strengthen technical capability in Canadian industry and the Canadian labour force. (But if Canadian firms seem unable to handle a specific technology, then TKVO will look for opportunities outside Canada.) Secondly, TKVO will generate revenue through its activities.

During recent years, TRIUMF has worked with its funding agencies to develop policies and procedures for operating the TKVO. Discussions have covered the splitting of any revenues, so as to make the Office financially self-sufficient within five years. This may seem somewhat ambitious, to judge by the experience of most other commercialization offices in North America. However, the TKVO's first 18 months have been remarkably successful, and current projections suggest that it could become self-sufficient by the end of its *second* year. Containing the costs of operation seems to be the key to reaching this goal.

With the TKVO acting as a lens to focus the new, strong, commercialization thrust at TRIUMF, the indications are that its activities will not only continue, but will greatly increase in the KAON era. By the end of its second year of operation, the TKVO will have negotiated at least five new licences with industrial partners; five new consulting agreements; three staff secondments; one spin-off company with TRIUMF staff; patents for four or five other technologies, each with strong commercial potential.

### The Money-Makers

The five activities likely to provide most of the revenue from commercialization:

1) Consulting for industry
2) Expert staff secondment, both to and from industry
3) Licence agreements with industry
4) Joint ventures with industry
5) Start-up companies spun off by TRIUMF or KAON staff

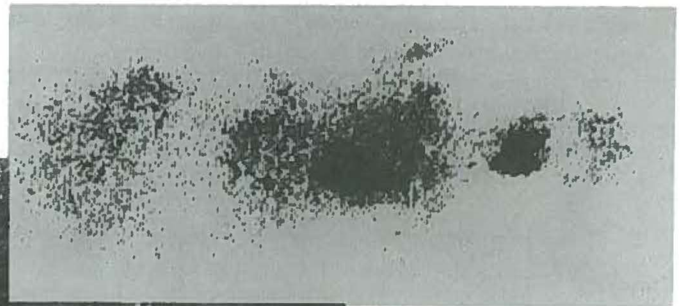
In addition to these, it still has about 15 projects at various stages of negotiation with potential industry partners.

Currently attracting the most interest for commercialization of TRIUMF knowledge are:

- medical scanning and imaging
- medical diagnostics (developing isotope-producing equipment as well as new radioisotopes)
- medical treatments
- high-speed gallium arsenide microelectronics
- environmental protection processes
- software
- unique industrial processes
- detection of specific elements
- radiofrequency applications
- cancer therapy

Because these were identified by "demand pull" from industry, we may reasonably assume they will continue to be of interest.

The TKVO has already established a network of contacts, including many commercialization offices throughout North America, and constantly uses these contacts in its own activities.



In the TRIM lab (left), Tammy Lutz and Hayes Dougan examine the scintiphoto (above) of a rabbit heart, labelled using a radiopharmaceutical containing iodine-123. A radioisotope like this one can be chemically bonded to many different kinds of molecules, thus yielding diagnostic scans of different body systems when administered to a patient.

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## Applied Programmes

(continued from page 7)

The other trial is for "Stage C and D prostate tumours." This began in June 1990, and is progressing well. So far, 51 patients have been treated out of the needed 208.

A total of 293 patients has now been treated with pions at TRIUMF, which is one of only two locations in the world offering this novel therapy. This programme remains a focus of intense interest for all our visitors.

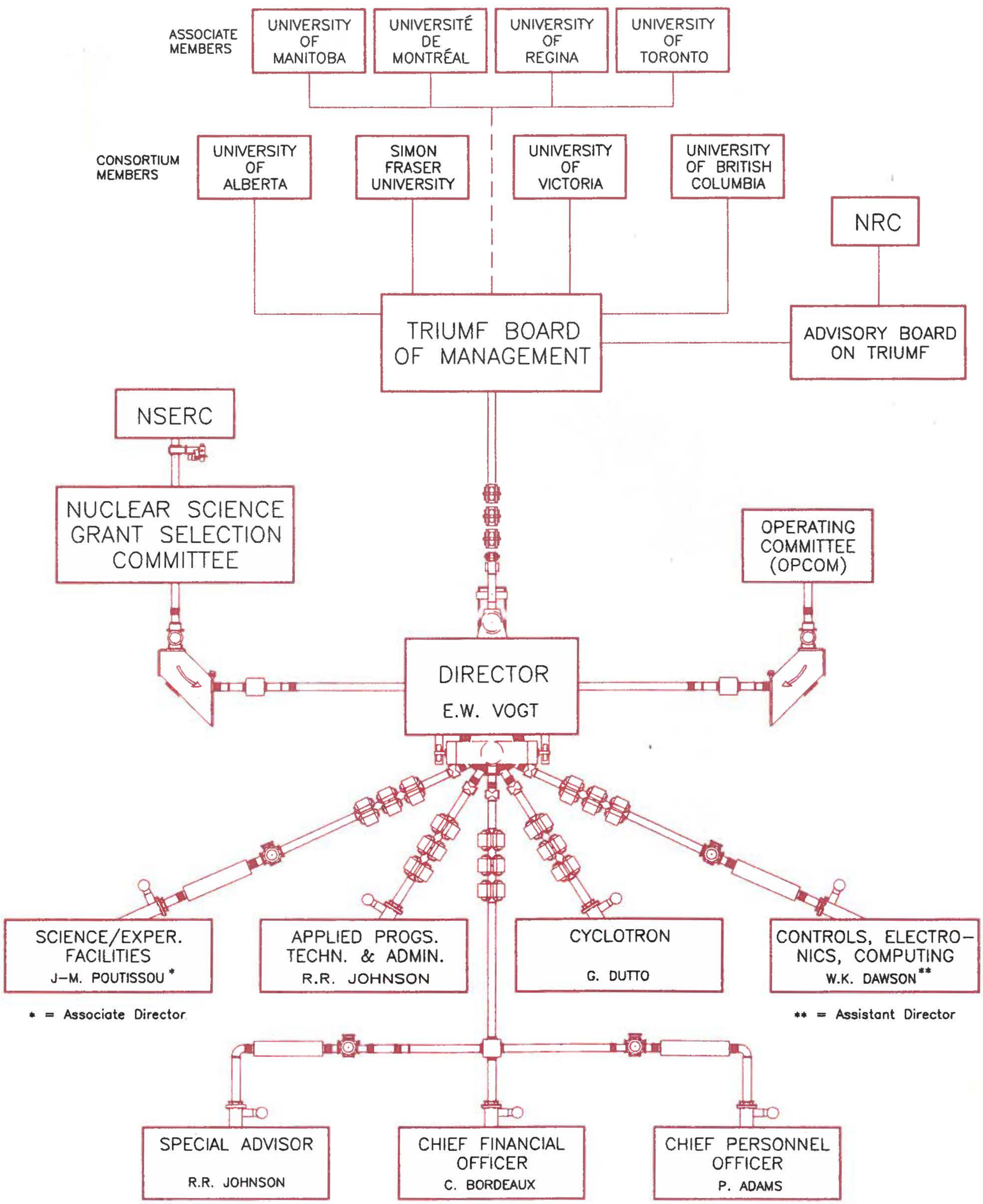
### TRIM

TRIUMF Radioisotopes for Medicine (TRIM) seeks to develop practical applications of new radioisotopes for use in health care, medical research and the industries that serve these fields.

The TRIM group has been functioning for about 16 years. In the late 1970s they introduced large amounts of the radioisotope iodine-123 to about 20 clinics across Canada. In the 1980s they designed and built a third beam line at TRIUMF, dedicated to producing radioisotopes by using protons between 40 and 110 MeV. This high-level facility produces medically interesting species outside the normal range of small, commercial cyclotrons.

R&D by TRIM is made available to industry through the open literature. Most recently this group has improved the technology for production of positron-emitting nuclide generators, strontium/rubidium-82 and barium/cesium-128. These devices, together with their PET equipment, promise to be a leading myocardial (heart) diagnostic in the next decade. Cooperative research continues between TRIM and several institutions in the USA and the USSR.

# Organization Chart



# Financial Review

TRIUMF continues to labour under severe financial constraints aggravated by uncertainties about its funding. Only continuing activities in the applied sciences and additional support received from the Government of British Columbia enabled TRIUMF to keep its staff intact in anticipation of a positive decision by the Federal Government on the proposed upgrade to a KAON Factory.

The main decrease in overall funding, shown in the Statement of Combined Funding and Expenditures and Changes in Fund Balances, is due to the combined Federal/Provincial KAON project definition study having come to an end in the previous year. This $7 M drop in funding is slightly offset by a $1 M extension to this study and a $0.5 M KAON promotion grant, both by the B.C. Government.

The decrease in funding from EBCO Industries Ltd. of Richmond, B.C., is due to the completion of a 30 MeV cyclotron built with TRIUMF assistance, for the use of NORDION International Inc., situated on the TRIUMF site. The latter activity explains the increase in NORDION International Inc. funding. TRIUMF does operate and maintain NORDION's cyclotrons on this site.

A separate line item was created showing the Royalty Fund. It is expected that these funds will increase substantially, mainly because a Ventures Office has been created at TRIUMF with the financial assistance of the B.C. Government, under the able direction of Mr. Philip L. Gardner. Several technology transfer licences are being negotiated at this time.

The Medical Research Council of Canada continued to provide substantial support. These funds are administered elsewhere and are therefore not reported here. The same holds true for funding by the Natural Sciences and Engineering Research Council of TRIUMF-based experiments administered elsewhere, as distinct from those administered at TRIUMF.

Activities on behalf of affiliated institutes are increasing, particularly in regard to participation by U.S.S.R. scientists. Funding from affiliated institutes consists of advances and reimbursements for expenditures undertaken on behalf of various institutes from Canada and abroad for their TRIUMF projects.

Expenditures in the Statement of Combined Funding and Expenditures and Changes in Fund Balances are at acceptable levels. The high percentage of salary and benefit costs is unavoidable under the present circumstances, where highly trained and adequately experienced staff has to be kept on hand, as agreed to by the Federal Government, to allow the expansion to a KAON Factory to go ahead when decided on.

It is expected that the Federal Government will reintroduce financial support to TRIUMF at a level sufficient to maintain the enviable international recognition TRIUMF has achieved, and that this support will include the requisite upgrading of the facilities.

*C.W. Bordeaux*
*Chief Financial Officer*

| *SOURCE OF FUNDS* | *1990–91* | | *1989–90* | |
|---|---|---|---|---|
| | *$ million* | *%* | *$ million* | *%* |
| National Research Council | 26.51 | 72.59 | 26.51 | 61.98 |
| NSERC | 2.93 | 8.02 | 2.97 | 6.94 |
| Federal Project Defn. Study | -- | -- | 3.40 | 7.95 |
| Prov. Project Defn. Study | -- | -- | 3.45 | 8.07 |
| Prov. Project Defn. Study Extension | 0.94 | 2.57 | -- | -- |
| NORDION International Inc. | 2.00 | 5.48 | 1.41 | 3.30 |
| Affiliated Institutions | 2.90 | 7.94 | 2.28 | 5.33 |
| EBCO Industries Ltd. | 0.69 | 1.89 | 1.97 | 4.61 |
| Royalty Fund | 0.15 | 0.41 | 0.15 | 0.35 |
| Investment & Other Income | 0.40 | 1.10 | 0.63 | 1.47 |
| | 36.52 | 100% | 42.77 | 100% |

# From the Auditor

Coopers & Lybrand | chartered accountants | a member firm of Coopers & Lybrand (International)

**AUDITORS' REPORT TO**
**THE BOARD OF MANAGEMENT**
**TRIUMF**

We have audited the statement of financial position of TRIUMF as at March 31, 1991 and the statements of funding and expenditures and changes in fund balances for the year then ended. These financial statements are the responsibility of TRIUMF's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with generally accepted auditing standards. Those standards require that we plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In our opinion, these financial statements present fairly, in all material respects, the financial position of TRIUMF as at March 31, 1991 and its results of operations and changes in fund balances for the year then ended in accordance with generally accepted accounting principles.

Coopers & Lybrand

Vancouver, B.C.
June 5, 1991

NOTE: The excerpts from the Auditor's Report in the following pages are prepared by the TRIUMF Information Office, which takes responsibility for any inadvertent errors or deviations. Copies of the entire Auditor's Report to the TRIUMF Board of Management are available from the TRIUMF Business Office. [Editor]

TRIUMF

**STATEMENT OF COMBINED FUNDING AND EXPENDITURES**

AND CHANGES IN FUND BALANCES

FOR THE YEAR ENDED MARCH 31, 1991

| **FUNDING** | 1991 | 1990 |
|---|---|---|
| | $ | $ |
| National Research Council (Schedule 1) | 26,510,000 | 26,510,000 |
| Natural Sci & Eng Research Council | 2,925,064 | 2,974,234 |
| Federal Project Def. Study | – | 3,400,000 |
| Prov. Project Def. Study | – | 3,451,500 |
| Prov. Project Def. Study Extension (Schedule 2) | 942,000 | – |
| Nordion International Inc. | 1,992,500 | 1,410,790 |
| Affiliated institutions | 2,904,804 | 2,279,169 |
| EBCO Industries Ltd. | 686,328 | 1,965,017 |
| Royalty Fund | 150,000 | 150,000 |
| General Fund | 407,624 | 628,035 |
| | 36,518,320 | 42,768,745 |

| **EXPENDITURES** | | |
|---|---|---|
| Building construction | 3,474 | 96,034 |
| Communications | 320,340 | 324,569 |
| Computer | 1,756,426 | 2,362,415 |
| Equipment | 1,706,602 | 4,488,940 |
| Power | 1,909,320 | 1,872,537 |
| Salaries and benefits | 23,282,269 | 22,158,709 |
| Supplies and expenses | 8,780,350 | 11,590,758 |
| | 37,758,781 | 42,893,962 |

| | | |
|---|---|---|
| DEFICIENCY OF FUNDING OVER EXPENDITURES FOR THE YEAR | (1,240,461) | (125,217) |
| LESS: DEFERRED FUNDING | – | (15) |
| FUND BALANCES — BEGINNING OF YEAR | 3,009,167 | 3,134,399 |
| **FUND BALANCES — END OF YEAR** | 1,768,706 | 3,009,167 |

TRIUMF

**STATEMENT OF FINANCIAL POSITION**

AS AT MARCH 31, 1991

| | 1991 | 1990 |
|---|---|---|
| **ASSETS** | $ | $ |
| CASH & TEMPORARY INVESTMENTS | 2,290,234 | 2,777,950 |
| FUNDING RECEIVABLE (note 3) | 730,792 | 1,760,158 |
| TOTAL ASSETS | 3,021,026 | 4,538,108 |

**LIABILITIES AND FUND BALANCES**

| | 1991 | 1990 |
|---|---|---|
| ACCOUNTS PAYABLE | 494,567 | 1,424,989 |
| DEFERRED FUNDING | | |
| National Research Council (Schedule 1) | – | 15 |
| DUE TO (FROM) JOINT VENTURERS | | |
| The University of Alberta | 32,527 | (62,541) |
| The University of Victoria | (26,952) | (42,007) |
| The University of British Columbia | 751,609 | 202,152 |
| Simon Fraser University | 569 | 6,333 |
| | 757,753 | 103,952 |
| FUND BALANCES | | |
| Natural Sciences & Engineering Research Council | 904,191 | 1,440,207 |
| Prov. Project Definition Study Extension (Schedule 2) | (318,893) | (54,753) |
| NORDION International Inc. | 100,000 | 100,000 |
| Affiliated Institutions | (138,183) | (50,097) |
| EBCO Industries Ltd. | 1,013 | 21,810 |
| Royalty Fund | 95,368 | 104,616 |
| General Fund | 956,202 | 805,157 |
| Intramural Accounts | 169,008 | 642,227 |
| | 1,768,706 | 3,009,167 |
| **TOTAL LIABILITIES & FUND BALANCES** | 3,021,026 | 4,538,108 |

ENCUMBRANCES AND COMMITMENTS (note 4)

Schedule 1

# TRIUMF
## STATEMENT OF FUNDING AND EXPENDITURES
## NATIONAL RESEARCH COUNCIL
FOR THE YEAR ENDED MARCH 31, 1991

| | 1991 $ | 1990 $ |
|---|---|---|
| DEFERRED FUNDING—BEGINNING OF YEAR | 15 | 28 |
| **FUNDING** | | |
| Contributions | 26,509,985 | 26,509,972 |
| **TOTAL APPROVED CONTRIBUTION** | 26,510,000 | 26,510,000 |
| **EXPENDITURES BY ACTIVITY AREA** | | |
| Salaries | 19,973,830 | 19,084,480 |
| Power | 1,909,320 | 1,872,535 |
| Administrative and overhead | 1,693,122 | 1,438,498 |
| Cyclotron and facilities operation | 2,427,609 | 2,538,322 |
| Site services | 570,323 | 821,074 |
| Support services | 1,172,299 | 1,631,356 |
| Major projects | 260,450 | 1,626,298 |
| Minor projects and development | 438,152 | 325,630 |
| | 28,445,105 | 29,338,193 |
| Funds recovered — salaries and cost centres | (1,206,576) | (2,828,208) |
| | 27,238,529 | 26,509,985 |
| Contribution from other funds | (728,529) | - |
| **TOTAL EXPENDITURES** | 26,510,000 | 26,509,985 |
| **DEFERRED FUNDING — END OF YEAR** | Nil | 15 |
| **EXPENDITURES BY OBJECT** | | |
| Buildings | - | (31,756) |
| Communications | 273,076 | 232,546 |
| Computer | 1,175,197 | 2,362,285 |
| Equipment | 844,180 | 1,884,514 |
| Power | 1,909,320 | 1,872,535 |
| Salaries and benefits | 19,975,787 | 19,071,866 |
| Supplies and expenses | 3,860,089 | 3,170,453 |
| Salary expenditure recovered | (799,120) | (2,052,458) |
| Contributions from other funds | (728,529) | - |
| | 26,510,000 | 26,509,985 |

Schedule 2

TRIUMF

# STATEMENT OF FUNDING AND EXPENDITURES AND CHANGES IN FUND BALANCE

## PROVINCIAL PROJECT DEFINITION STUDY EXTENSION

FOR THE YEAR ENDED MARCH 31, 1991

| | 1991<br>$ | 1990<br>$ |
|---|---|---|
| **FUNDING** | | |
| Contributions | 942,000 | – |
| **EXPENDITURES** | | |
| Communications | 6,469 | – |
| Computer | 64,318 | 11,668 |
| Equipment | 143,857 | – |
| Salaries & benefits | 473,067 | – |
| Supplies & services | 518,429 | 43,085 |
| | 1,206,140 | 54,753 |
| DEFICIENCY OF FUNDING OVER EXPENDITURES FOR THE YEAR | (264,140) | (54,753) |
| FUND BALANCE — BEGINNING OF YEAR | (54,753) | – |
| **FUND BALANCE — END OF YEAR** | (318,893) | (54,753) |

# TRIUMF
## NOTES TO FINANCIAL STATEMENTS
## FOR THE YEAR ENDED MARCH 31, 1991

1. JOINT VENTURE OPERATIONS

TRIUMF is a joint venture established by the University of Alberta, the University of Victoria, Simon Fraser University and the University of British Columbia, having as its goal the establishment and continuance of a national facility for research in intermediate energy science under a contribution from the National Research Council of Canada. As a registered charity, TRIUMF is not subject to income tax.

Each university owns an undivided 25% interest in all the assets, and is responsible for 25% of all liabilities and obligations of TRIUMF, except for the land and buildings occupied rent-free by TRIUMF, which are owned by the University of British Columbia.

These financial statements include only the statement of fund transactions of TRIUMF and do not include the assets, liabilities, revenues and expenditures of the individual joint venturers. The sources of funding include grants and contributions from NRC, NSERC and governments, advances and reimbursements from other sources, and investment income. The sources and purposes of these funds are:

(a) National Research Council (NRC)
Funding of operations, improvements and development; expansion of facilities (buildings excluded); and general support for experiments.

(b) Natural Sciences and Engineering Research Council (NSERC)
Funding to grantees for experiments related to TRIUMF activities. These funds are administered by TRIUMF on behalf of the grantees.

(c) Provincial Project Definition Study Extension
Funding provided by the provincial government to continue to research and define the financial and scientific requirements of the proposed KAON Factory.

(d) NORDION International Inc.
Advances and reimbursements for expenditures undertaken on its TRIUMF project.

(e) Affiliated Institutions
Advances and reimbursements for expenditures undertaken on behalf of various institutions from Canada and abroad, for their TRIUMF projects.

(f) EBCO Industries Ltd.
Advances and reimbursements for expenditures undertaken on the 30 MeV cyclotron project.

(g) Royalty Fund
Royalties from technology transfer agreements.

(h) General Fund
Investment income for discretionary expenditures incurred by TRIUMF.

(i) Intramural Accounts
Expenditures and recoveries for internal projects and services. The recoveries of expenditures are charged to the appropriate TRIUMF funding source by Intramural Accounts.

2. SIGNIFICANT ACCOUNTING POLICIES

TRIUMF follows generally accepted accounting principles for non-profit organizations as referred to in the CICA Handbook. Expenditures on capital assets and supplies are expensed as incurred.

# TRIUMF
## NOTES TO FINANCIAL STATEMENTS (CONTINUED)

3. FUNDING RECEIVABLE

Funding receivable comprises amounts billed or receivable from (payable to):

| | 1991 | 1990 |
|---|---|---|
| Natural Sciences and Engineering Research Council | 450,596 | 438,464 |
| Federal Project Definition Study | – | 264,149 |
| Provincial Project Definition Study Extension | 242,000 | – |
| NORDION International Inc. | 236,280 | 286,677 |
| Affiliated Institutions | (294,322) | (261,537) |
| EBCO Industries Ltd. | 96,238 | 1,032,405 |
| | 730,792 | 1,760,158 |

4. ENCUMBRANCES AND COMMITMENTS

In addition to the accounts payable reflected on the statement of financial position, outstanding encumbrances and commitments, representing the estimated costs of unfilled purchase orders and contracts placed at the fiscal year end, comprise:

| | 1991<br>$ | 1990<br>$ |
|---|---|---|
| National Research Council | 230,000 | 350,000 |
| Natural Sciences and Engineering Research Council | 129,000 | 169,000 |
| Provincial Project Definition Study Extension | 60,000 | – |
| NORDION International Inc. | 35,000 | 36,000 |
| Affiliated Institutions | 80,000 | 12,000 |
| EBCO Industries Ltd. | 1,000 | 22,000 |
| Royalty Fund | 1,000 | – |
| General Fund | 170,000 | 340,000 |
| | 706,000 | 929,000 |

5. CONTINGENCY — The General Fund is restricted by the amount of the deficit of the Provincial Project Definition Study Extension Fund should additional funding not be obtained.

6. NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL — FUND BALANCE

| | 1991<br>$ | 1990<br>$ |
|---|---|---|
| Funding unexpended | 1,319,046 | 1,747,126 |
| Grant accounts overexpended | (414,855) | (306,919) |
| Fund balance — end of year | 904,191 | 1,440,207 |
| Number of grants awarded during year | 47 | 49 |
| Number of grants administered throughout year | 120 | 92 |

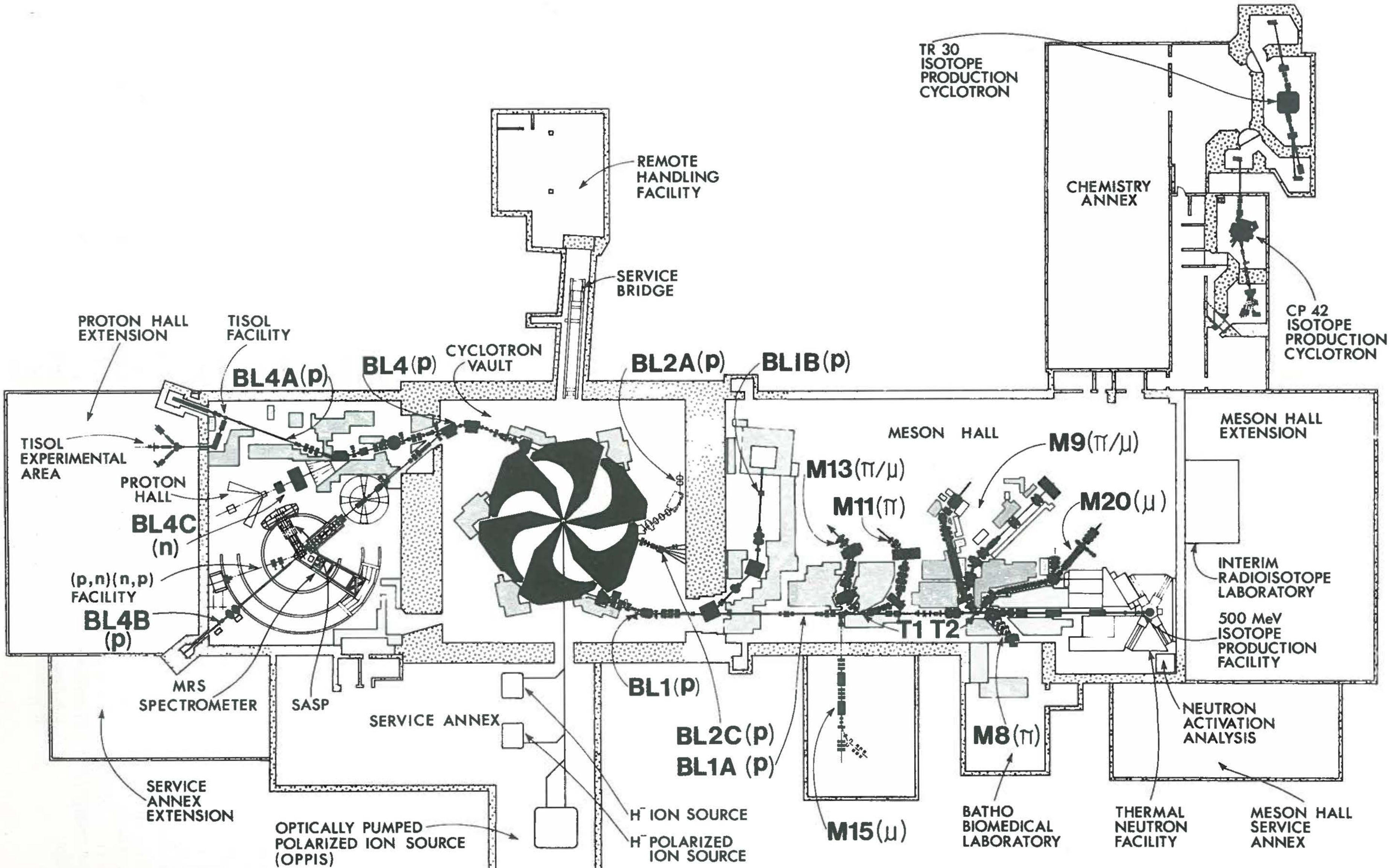
7. AFFILIATED INSTITUTIONS — FUND BALANCE

The fund balance at the fiscal year end comprises:

| | | |
|---|---|---|
| Funding received in advance | 294,135 | 411,434 |
| Expenditures recoverable | (432,318) | (461,531) |
| Fund balance — end of year | (138,183) | (50,097) |

8. PENSION PLANS

The employees of TRIUMF are members of the pension plan administered by the university that sponsors their employment. TRIUMF records the pension expense as cash contributions to the plan based on a prescribed percentage of employee earnings. The pension expense for the year was $1,288,163 (1990 — $1,204,227).




# BEAMLINES AND EXPERIMENTAL FACILITIES

——— EXISTING ------- PROPOSED

**1991 TUEC**
(TRIUMF Users' Executive Committee)
Chairman: G. Greeniaus
Associate Chairman: A. Olin
Members: T. Ruth, M. Sevior, R. Tacik
Liaison Officer: M. La Brooy

# TRIUMF Users' Group

435 Members — 183 Institutions — 30 Countries

## TRIUMF

P-A. Amaudruz
F. Bach
M.J. Barnes
C. Bennhold
J.L. Beveridge
E.W. Blackmore
C.W. Bordeaux
J. Brack
M. Butler
J. Carey
C. Chen
L. Chen
M. Comyn
M.K. Craddock
D.C. Cunningham
P. Delheij
Z.H. Ding
D.A. Dohan
J. Doornbos
G. Dutto
W. Faszer
H.W. Fearing
J.S. Fraser
D. Frekers
D. Garner
C. Geng
D.R. Gill
D.P. Gurd
R. Helmer
R.S. Henderson
R. Hilton
A.C. Hurst
D.A. Hutcheon
B.K. Jennings
R.R. Johnson
R. Keitel
R. Kiefl
E.J. Kim
W. Kleeven
G. Koch
A. Konaka
S.R. Koscielniak
C.J. Kost
Y. Kuno
M. La Brooy
R. Lee
D. Leinweber
J. Lu
G.A. Ludgate
J.A. Macdonald
G.H. McKenzie
G. Marshall
O. Meirav
R.D. Merritt
C.A. Miller
B. Milton
N. Mobed
L. Moritz
J.N. Ng
S. Nozawa
T. Numao
U. Oelfke
C. Oram
A.J. Otter
D. Ottewell
B.P. Padley
B. Pearce
D. Pearce
J.B. Pearson
J.M. Poutissou
R. Poutissou
A. Ramos
W. Rawnsley
J.G. Rogers
T.J. Ruth
M. Salomon
P. Schmor
H.R. Schneider
J.W. Schneider
W. Schott
M. Senba
M. Sevior
G. Smith
N. Stevenson
I.M. Thorson
E. van Meijgaard
V.K. Verma
D. Vetterli
M. Vetterli
J.S. Vincent
E.W. Vogt
G.D. Wait
P. Walden
G. Waters
D. Webster
D.M. Whittall
U. Wienands
N. Wilkinson
R. Wittman
R. Woloshyn
J. Worden
D.H. Wright
Y.S. Wu
S. Yen
M. Zach

## CONSORTIUM MEMBERS

### U. of Alberta

R. Abegg
M. Boyce
E.B. Cairns
J.M. Cameron
W.C. Choi
W.K. Dawson
J.B. Elliott
P.W. Green
L.G. Greeniaus
F.C. Khanna
P. Kitching
E. Korkmaz
J. Li
W.J. McDonald
P. McNeely
G.C. Nielson
A.A. Noujaim
W.C. Olsen
J. Pasos
N. Rodning
G. Roy
H. Sherif
J. Soukup
G. Stinson
Y. Ye
N-S. Zhang
J. Zhu

### Simon Fraser U.

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S. Atkins
D. Boal
J. Brodovitch
A. Celler
J.M. D'Auria
O. Hausser
K.P. Jackson
R. Jeppesen
R.G. Korteling
B. Larson
M. Law
P.W. Percival
B. Pointon
S. Sun-Mack
A. Trudel
D. Webster

### U. of Victoria

A. Astbury
G.A. Beer
D. Britton
D. Bryman
E.T.H. Clifford
G.B. Friedmann
T.A. Hodges
R. Keeler
D.L. Livesey
D.E. Lobb
G.R. Mason
A. Olin
C.E. Picciotto
P.R. Poffenberger
P.A. Reeve
L.P. Robertson
M. Rosvick
P.R. Schenk
M. Turcotte
C.S. Wu

### U. of British Columbia

D. Armstrong
E.G. Auld
D.A. Axen
J.H. Brewer
J. Congleton
F. Duncan
T. Duty
A. Feltham
D.G. Fleming
B. Forster
P. Gumplinger
M. Hanna
M.D. Hasinoff
G. Hofman
J. Iqbal
R. Jacot-Guillarmod
G. Jones
N. Kaplan
J. Kempton
S. Kreitzman
L.C. Lew Yan Voon
P.W. Martin
J. McAllister
C.A. McDowell
D.F. Measday
Y. Miyake
B.A. Mofta
A. Noble
B.D. Pate
M. Pavan
C. Ponting
G.B. Porter
J. Roy
D. Sample
R. Schubank
V. Sossi
A. Templeman
K. Venkataswaran
D.C. Walker
C. Waltham
P. Weber
B.L. White
B. Yang
H.K. Yen

## ASSOCIATE MEMBERS OF THE TRIUMF CONSORTIUM

### U. of Manitoba

A. Amer
A. Berdoz
B.S. Bhakar
D.J. Birchall
P. Blunden
J. Campbell
C.A. Davis
N.E. Davison
W.R. Falk
K.M. Furutani
A.A. Hamian
J. Jovanovich
D. Mosscrop
S.A. Page
W.D. Ramsay
A. Sekulovich
K.S. Sharma
V. Sum
J.P. Svenne
W.T.H. van Oers
J. Zhao

### U. de Montréal

G. Azuelos
G. Belanger
P. Depommier
L. Lessard

### U. of Regina

G.J. Lolos
E.L. Mathie
S.I.H. Naqvi
V. Pafilis
R. Tacik
D.M. Yeomans

### U. of Toronto

R. Azuma
D. Bandyopadyay
C. Chan
E. Fawcett
L.R. Kilius
J.D. King

## TRIUMF Users' Group—Other Institutions

## Canada

B.C. Cancer Inst.— G.K.Y. Lam, L.D. Skarsgard
BCIT — G.A. Moss
Cancer Control Agency — H. Shirato
Carleton U. — A.L. Carter
Chalk River Nuclear Laboratories — M.S. De Jong, H.C. Lee, D. Noakes, J.A. Sawicki, I.S. Towner
Cross Cancer Institute, Edmonton — J.W. Scrimger, R.C. Urtasum, S.R. Usiskin
EBCO Industries — J.T. Sample
McGill U. — J. Crawford, J. Lee, B. Margolis, S.K. Mark, R. Moore, K. Oxorn
National Research Council — M.S. Dixit, C.K. Hargrove, W.R. Jack
Nordion Intern'l Inc. — J.K. Porter
Novatrack Analysts Limited — H. Blok, D.D. Burgess, H.L. Rosenauer
Queen's U. — G.T. Ewan, B.C. Robertson, M.J. Stott
U. of Saskatchewan — E.J Ansaldo, H.S. Caplan, N. Mobed, C. Rangacharyulu, Y.M. Shin
Saskatoon Cancer Clinic — C. Lapointe
Université de Sherbrooke — K.E. Newman
Vancouver General Hospital — R.T. Morrison
U. of W. Ontario — W.P. Alford

## Outside Canada

**Australia**
U. of Adelaide — A.W. Thomas
Flinders U. of South Australia — I.R. Afnan
U. of Melbourne — S. Koutsoliotias, S.A. Long, S. McDonald, K.J.Raywood, G.G. Shute, B.M. Spicer, G.N. Taylor

**Austria**
IMEP Vienna — H. Zmeskal

**Belgium**
Université Catholique de Louvain — J. Deutsch

**Bulgaria**
Sofia U. — I. Enchevich

**China**
Academia Sinica — X-D. Jiang, Y.P. Zhang
Inst. Atom. Energy — Yong-Shun Wu
IHEP, Beijing — Chaoquing Chan, Z.H. Ding, J. Lu, N.S. Zhang
Peking U. — Y. Ye

**Czechoslovakia**
NPIC — J. Zofka

**Egypt**
Ain Shams U. — K.E.A. Negm

**Finland**
U. of Helsinki — J. Niskanen

**France**
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ESRF — F. Loyer
NM-CRNS — R. Grynszpan
Saturne — F. Meot, J. Yonnet

**Germany**
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U. of Bonn — P.K.A. David, J. Ernst, D. Theis
Erlangen U. — H.M. Hofmann
Karlsruhe — E.T. Boschitz, M. Metzler
KFA Julich — H. Maletta, S. Martin
Max Planck Institut — C. Wiedner
Tech. Inst. Munich — T. von Egidy
TH Darmstadt — H. Wortche
Tubingen U. — G. Wagner

**Greece**
Patras U. — D.S. Tsatis

**Hungary**
Budapest Research Inst. for Physics — D. Horvath

**Israel**
Hebrew U. — E. Friedman, A. Goldring, N. Kaplan
Soreq Nucl. Resrch. Ctr. — A. Altman
Soroka Med. Ctr. — M.R. Quastel
Tel-Aviv U. — J. Aclander, J. Alster, D. Ashery, J.M. Eisenberg, H. Hahn, I. Kelson, M.A. Moinester, E. Piazetsky, A. Rahav, R. Ram, A. Stern, A.I. Yavin, A. Zidon, M. Zilka

**Italy**
Inst. di Fisica, Trieste — C. Cernigoi, N. Grion, R. Rui
INFN, Bari — V. Paticchio
Universita di Milano — A. Bracco, L. Rossi

**Japan**
Aoyama-Gakuin U. — J. Akimitsu
KEK — J. Imazato
Kyoto U. — H. Sakaguchi
Meson Sci. Lab., Tokyo — R. Kadono
Nat. Lab. for H.E. Phys. — C. Yamaguchi
Nat. Res. Inst. Police Science — K. Kuroki
Osaka U. — F. Fujimoto, N. Matsuoka, T. Noro, H. Sakai
RIKEN — K. Katsumata
Tohoku U. Hosp. — Y. Hosoi, K. Sakamoto, R. Sujita
Tokyo Inst. of Technology — H. Miyatake, N. Nishida
Tokyo Metropol. Inst. — H. Toki
U. of Tokyo — M. Iwasaki, I. Masahiko, T. Nagae, K. Nagamine, S. Nakamura, H. Outa, M. Oyaizu, S. Sakamoto, T. Yamazaki, Y. Yamazaki, H. Yasuoko

**Korea**
Seoul Nat. U. — J.C. Kim
Yonsei U. — K.S. Chung, J.M. Lee

**Netherlands**
Eindhoven U. — J.I.M. Botman, W. Kleeven
IKO — R. van Dantzig
Technische Hogeschool Delft — H. Postma
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