TRIUMF 1995–96

Annual Financial & Administrative Report

including summaries of

- *Pure Research Activities*
- *Practical Applications of Research*

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 Government of Canada through the National Research Council of Canada, including support from Western Economic Diversification.

Consortium Members
University of Alberta
University of Victoria
Simon Fraser University
University of British Columbia

Associate Members
University of Manitoba
Université de Montréal
University of Regina
University of Toronto

Our World Wide Web Home Page: http://www.triumf.ca/

TRIUMF

4004 Wesbrook Mall
Vancouver, B.C., Canada
V6T 2A3

Phone: (604) 222-1047
Telex: 04-508503
FAX: (604) 222-1074

Annual Financial & Administrative Report

1995–96

Cover Photo: Dr. Tom Pickles watches monitors in a TRIUMF control room on 21 August 1995 as, for the first time in Canada, cancer is treated with a proton beam. The patient had ocular melanoma, and the screen on the right shows a close-up video camera view of the right eye as it is being treated. The opening of this cancer treatment facility was one of the highlights of TRIUMF's year.

The 1995–96 Annual Financial & Administrative Report is prepared by the

TRIUMF Information Office

Editor: Michael La Brooy
infoff@triumf.ca 604 222-7354

We acknowledge the contributions of the following toward the preparation of presentations in this annual report:
J. Behr, E.W. Blackmore, P. Gardner, A. Gelbart, B. Jennings, T. Pickles, T. Ruth.

Contents

Board of Management
March 1996

University of British Columbia

Dr. B. Bressler
Vice-President, Research

Dr. C. Eaves
Deputy Director,
Terry Fox Laboratory, BCCRC

Dr. D.F. Measday
Department of Physics

University of Alberta

Dr. E.W. Brooker
Chairman,
EBA Engineering Consultants Ltd.

Dr. P. Kitching
Centre for Subatomic Research
University of Alberta

Dr. R. Kratochvil
Assoc. Vice-President, Research

Simon Fraser University

Dr. B.P. Clayman
Vice-President, Research

Dr. C.H.W. Jones
Dean, Faculty of Science
Board Chairman

Dr. R. Korteling
Department of Chemistry

University of Victoria

Ms. G. Gabel
President,
The Gabel Group

Dr. A. McAuley
Associate Vice-President, Research

Dr. J.T. Weaver
Dean of Science

Associate Members, Observers

University of Manitoba

Dr. T.P. Hogan
Vice-President,
Research & External Programs

Université de Montréal

Dr. M. St. Jacques
Vice-recteur à la recherche &
planification

University of Regina

Dr. K. Denford
Dean of Science

University of Toronto

Dr. R. Azuma
Dept. of Physics

Nonvoting Members

TRIUMF

Dr. A. Astbury—Director

Dr. J.-M. Poutissou—Associate Director

Mr. M. La Brooy (Board Secretary)
Head, Information Office

National Research Council of Canada

Dr. J.J. Child
Research Program Office

Prof. D.G. Stairs
Department of Physics
McGill University

"Eggs and Bacon"

I have always found the combination of eggs and bacon to be an excellent and very enjoyable breakfast. Each ingredient complements the other perfectly. Their aroma, particularly out-of-doors on a cold morning, is irresistible. I cannot claim that the combination has been my staple diet, since I am led to believe that my arteries enjoy it more than I do. However, from time to time eggs and bacon are a much anticipated breakfast treat.

Despite their close relationship, eggs and bacon retain distinct individual qualities. Eggs are the leading item in many courses, and are perhaps the most indispensable ingredient in a multitude of recipes. Bacon adds its special flavour to innumerable dishes.

In Canada today we have another pair of words which rarely appear separately: they are *science* and *technology*. We have become so familiar with their coexistence that frequently they are abbreviated to S and T. It is true that the interdependence is almost complete. There is no piece of technology which is not derived from what was once basic science, and the performance of science depends for its success on the very best of technology. But if we look carefully, in every project and proposal we can always distinguish the primary, main ingredient: it is either science *or* technology, never a "breakfast combo" of the two.

In my view this blurring of our senses is a recipe for poor decision-making. Proposals in basic science always seem to appear trimmed with dubious economic benefits. Technological projects are not judged within the harsh economy of the commercial market place, but are served garnished with indifferent science. In contrast to Michelin three-star establishments which would offer government menus rich in the exquisite tastes of science, our basic research councils are in danger of becoming greasy-spoon diners serving breakfast all day!

I would therefore like to end with a plea to all S and T task forces, advisory bodies, committees and councils: could we not plan our menu of basic science separately, with each ingredient present strictly on its merit? Meanwhile of course, I shall continue to relish my occasional round of eggs and bacon—after all, they only kill slowly, so I am told!

Alan Astbury

Experiments with TRINAT—TRIUMF's New Neutral Atom Trap

A revolution has recently occurred in atomic physics: using lasers, physicists can now cool neutral atoms to very low energies and trap them. TRIUMF is harnessing these new technologies. We are trapping radioactive atoms in a vacuum, to do precision, low-energy experiments that test the Standard Model (see Theoretical Programme, page 10).

We have already coupled our laser trap to the copious output of radioactive alkali atoms from TRIUMF's existing TISOL facility. Eventually we will use the 10-1000 times more intense ion source being built for ISAC.

The *weak* interaction between particles takes place via the exchange of very heavy bosons, the W^+, W^- and the Z. We are looking for the exchange of new bosons not now described in the Standard Model. We would not make the heavy bosons directly, as is done at high-energy colliders like LEP. Instead, we will make careful measurements of the decay products in ways that are sensitive to the spin and the "handedness" of possible new exchange bosons. In the β decay experiments, the decay is purely through the *weak* interaction, so we are automatically doing experiments at energies higher than the scale determined by the mass of the W particle, 80 GeV (about 86 proton masses).

> You will find some of the exotic physics terms mentioned in this section are described more fully in the report on the theoretical programme, page 10. How does a Zeeman optical trap work? Page 7 has a description and figure.

A Zeeman optical trap (ZOT) is the basis of TRIUMF's neutral atom trap ("TRINAT") which came into use recently.

The β/neutrino Direction Correlation: Are there Scalar Bosons?

The ZOT produces a sample of atoms, about 1 mm in size, held suspended in space by laser beams and a small magnetic field. If a radioactive atom, "A", held in such a trap undergoes β (beta) decay, the products are a "daughter nucleus", A'; a beta particle (i.e. an electron); and a neutrino, ν (the Greek "nu"):

$$A \rightarrow A' + \beta + \nu$$

All the products (including A') can freely escape the trap without contacting any nearby materials. We cannot detect the neutrino efficiently, but "conservation of momentum" provides us with a way of getting the information we need. The momenta (mass x velocity) of all the emerging particles must "balance", so by measuring the momentum of A' and of β, we can deduce the neutrino's momentum; and so we can measure the correlation of the direction of the β and the neutrino.

Imagine detectors for A' and the β particle that are back-to-back, with the trapped atoms placed between them. If the neutrino and the β are emitted in the *same* direction, then to balance their joint momentum, A' must have high momentum in the opposite direction. On the other hand, if the neutrino and β are emitted back-to-back, then their momenta will balance each other to some extent; so A' will have very low momentum, merely making up the difference between the other two particles.

How does this help us to detect a scalar boson? Consider the decay of metastable potassium-38 (^{38m}K), in which both the parent nucleus and the daughter have spin 0. That means the β and the neutrino between them must carry off a total of zero *angular* (spinning) momentum. In the Standard Model, where all the exchange bosons are vectors, it turns out that the β and neutrino have opposite helicity, i.e. the β spins along its direction of motion, but the neutrino spins opposite to its direction of motion. So, according tothe Standard Model, the neutrino and β *cannot be emitted back-to-back* (because the spins would not add up to zero); therefore A' *could not have a low momentum.* If we actually see recoils of A' with low momentum, that means a new, spin-zero, scalar boson was exchanged.

The limits on scalar bosons from particle physics are quite weak. If we can show that a scalar boson is exchanged less than 1% of the time, that will complement other experiments; and measurements to 0.1% would be unique.

β Asymmetry: Is Nature Left-Handed?

Another powerful tool that atom traps give us is the ability to polarize nuclei to a very high degree. (Polarized particles all have their spin axes parallel, and they spin in the same direction.) For example, the magnetic TOP trap used at Boulder to make the Bose-Einstein condensate has the fringe benefit of polarizing the nuclei, and

Boulder notified us (and our friendly competitors at Berkeley) upon its invention, suggesting we use this for β decay studies. A simpler method would be simply to turn off the trap and let the atoms fall, and align their spin in one direction by shining a weak beam of circularly polarized light on them. We can use these methods to study parity violation.

Parity is the transformation produced by reflecting the universe in a mirror. Under this transformation your left hand, not being symmetrical, changes into your right hand. Similarly, we can give a "handedness" to a nucleus by polarizing it; if the βs have a preference for coming out of a decay in a direction correlated with the spin, then parity is violated. It was believed that parity was a good symmetry until 1957, when Madame Wu at Columbia showed that parity is maximally violated in β decay, i.e. the βs come out fully correlated with the nuclear spin. We say now that the weak interaction is "left-handed", that β decay is mediated by the exchange of a left-handed W boson. This is incorporated in the Standard Model.

So why are we still interested? Because there is no fundamental reason that Nature should be completely left-handed. This has been put arbitrarily into the Standard Model merely to match experiment. The goal now is to measure precisely (to about 0.1% is interesting, and 0.01% would be complementary to high-energy colliders) to what extent parity is maximally violated, i.e. is there a "right-handed" W boson? There are theories ("left-right symmetric theories") that predict both right- and left-handed W's. The W's interact with the same strength at very high energy, but with different strengths at energies accessible to experiment. The world average of β decay experiments currently suggests that a right-handed W exists, but this is based largely on one experiment and must be carefully checked.

This result in β decay suggests a different right-handed W mass than measurements from muon decay—results which are in better agreement with the Standard Model. (The best muon experiments have been done at TRIUMF: a new experiment commenced in the fall of 1996.) The results, if both are correct, can be reconciled in some modifications of left-right symmetric theories that make the right-handed W more difficult to see in muon decay, e.g. if the right-handed muon neutrino is massive.

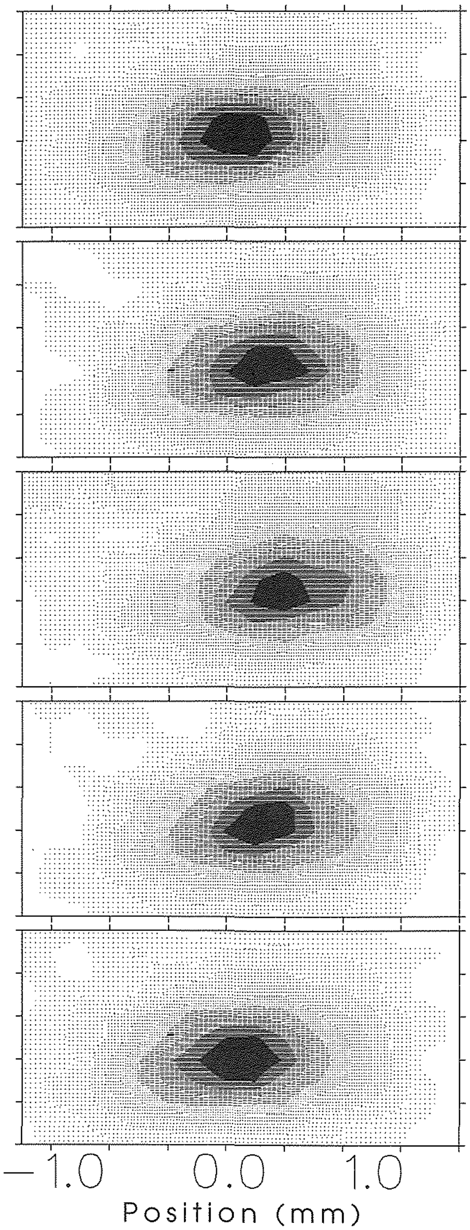
Atomic Physics of Radioactives

The cold, confined atoms in the traps are very useful for laser spectroscopy experiments on small numbers of atoms, making traps ideal for atomic experiments on radioactives. An atom caught in a trap can be "interrogated" by laser light as long as it lives, at a rate of about 100,000 photons per second. Among the possible experiments are measurements of parity violation in atoms. The main interaction between electrons and a nucleus is, of course, the *electromagnetic* interaction, which can be thought of as the exchange of virtual photons. Because the *weak* and *electromagnetic* interactions are now combined in a unified set of equations, it is also true that virtual Z bosons are exchanged in the atoms; although this Z exchange happens 10^{11} times less often, it can be distinguished because it violates parity. This effect has been measured to an accuracy of 2% in cesium, the heaviest, stable, alkali element atom. Such atoms have a simple electronic structure — a single electron outside a closed core — which makes the experiments feasible and the atomic many-body theory (necessary to interpret the experiments) tractable. The heaviest alkali element is francium, where the effect is expected to be 20 times bigger. We believe the new ISAC ion sources will be able to make ten times more francium than any other facility, and having this intensity will greatly assist these measurements.

Experimental Progress

Until now, we have coupled our trap to the output of TISOL ("TRIUMF Isotope Separator On-Line"). In TISOL, the 520 MeV proton beam from the main TRIUMF cyclotron strikes a production target (in our case, calcium oxide), creating the desired alkali metal isotopes. The target, heated to 1200°C, lets alkali atoms diffuse quickly through the material. As it is coupled to a cylinder of refractory metal with a high work function, alkali atoms are ionized upon contacting the cylinder, and then extracted as a beam of ions. The ion beam is now mass-separated (into streams of different isotopes) by a large magnet, and the particular isotope we want

These CCD camera pictures show 3000 trapped potassium-38m atoms being displaced by a laser beam (shining from the left) at five different frequencies. Centre frame shows the greatest displacement. Each frame covers approximately 3 mm across the centre of the trap.

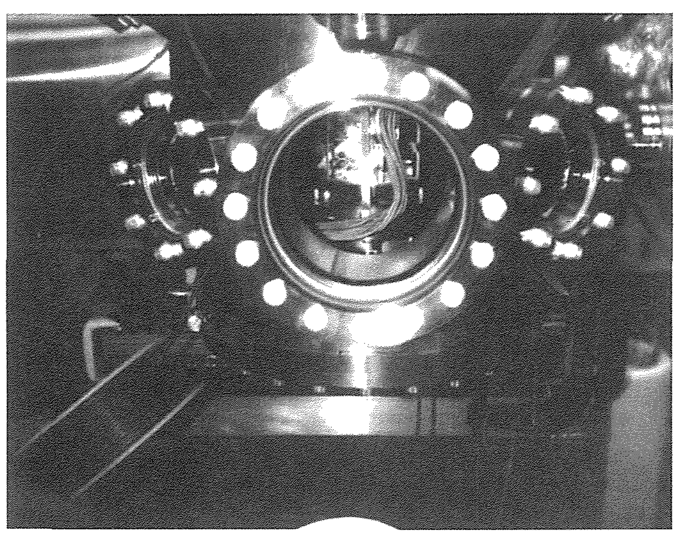


is selected and transported by standard "electrostatic optics" through an all-metal, ultra-high-vacuum beam line to the remote clean room where the TRINAT lasers and the experiment are housed (see photo). That enables us to shield our equipment from radiation produced by the main proton beam, as well as to separate it from the relatively poor vacuum (1×10^{-9} atmospheres) near the hot target to that of the final beam line at 5×10^{-13} atmospheres necessary for the trap. We stop the ion beam in another hot foil, and the atoms diffuse out and are injected into the trap region.

We can trap 3000 atoms of ^{38m}K or 1000 atoms of ^{37}K at a given time, enough to begin β decay experiments. These isotopes have half-lives of about 1 second, ten times shorter than isotopes trapped at other labs; that means we do not have to hold the atoms in the trap as long to ensure that they decay before leaving the trap.

We have also measured the precise resonant frequencies of the atoms. We do this by shining a weak probe beam in from the side and scanning the beam across the resonance, which displaces the equilibrium position of the atoms in the trap. The figure shows the displacement at different frequencies. The small (about $1/10^7$) differences in resonant frequency between different isotopes let us deduce the change in nuclear charge radius that results from adding neutrons. This is a useful bread-and-butter nuclear physics experiment. It has been done elsewhere for stable and longer-lived radioactive potassium, and the resulting trends tell us about the interaction between neutrons and protons in the nucleus.

The first β decay measurements were scheduled for the fall of 1996. Laser technologies, partly driven by the optical communications industry and partly by atomic physics basic research, are improving rapidly. We suspect that we have not yet thought of the best experiments we could do with these trapped, radioactive atoms.



A 5-cm quartz cube (the bright area visible in the 12-cm diameter window) holds the trapped atoms. The trap's laser beams enter through six of these windows.

TRINAT—TRIUMF's Neutral Atom Trap

How a Zeeman Optical Trap Works

We expect to complete TRIUMF's new ISAC project by the year 2000. One of the exciting new facilities of this project is a Zeeman Optical Trap (ZOT). This is already operating, but will become much more versatile once the full intensity of ISAC's radioactive beam source becomes available.

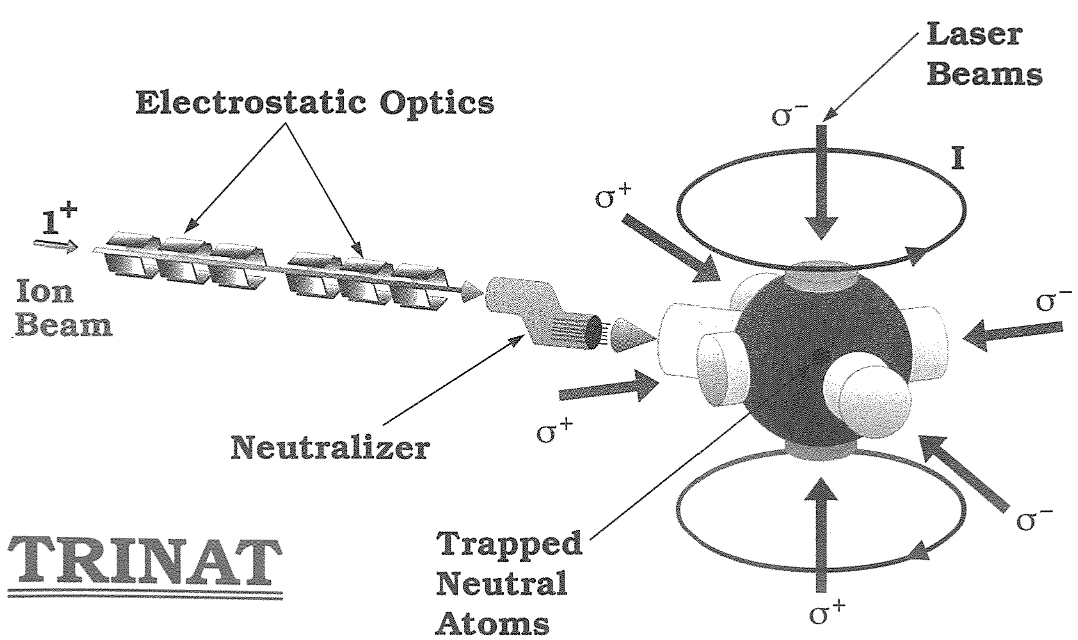
What is a ZOT? Basically, it is a means of holding a cluster of neutral atoms suspended in a very small space, in a high vacuum. It is particularly useful for studying the decay products of radioactive atoms. Held in such a trap, these atoms are not in contact with any substrate with which they could interact, so we know the products observed arise only from the radioactive decay we are studying.

To make a ZOT, we create a "damped harmonic oscillator", i.e. we not only provide a "spring" to confine the atoms, but we also slow the atoms' movements so that the spring can confine them to a small region. The slowing is produced by directing laser beams at the trapped atoms from all six directions. In general, when any atom absorbs radiation from one side, it is "pushed" in the opposite direction. The six lasers are tuned slightly to the *red* side of a resonance in the specific atoms being trapped.

Consider an atom moving up: it sees light from the downward-going beam, Doppler-shifted to the blue (i.e. *closer* to its resonance); but it sees light from the upward-going beam shifted toward the red, i.e. *farther* from its resonance. The atom absorbs more light from the beam which is *closer* to its resonance (downward-going), and is slowed.

The lasers also provide the confinement—except that we have not yet told the atoms where the centre of the trap is. To do that, we run current in opposite directions through the coils (see "I" in the figure), so as to produce a magnetic field that reverses direction at the centre. Each atom has a magnetic moment in the direction of its spin (i.e. it behaves like a tiny bar magnet). The magnetic field tries to align the spin of the atoms, just like the earth's magnetic field orienting a compass needle, while the circularly polarized light (denoted σ^+ and σ^-) also tries to change the spin of the atoms. The net effect is that atoms above centre will preferentially absorb the downward-going light.

The same principles apply to atoms moving in other directions, and the result is that all these atoms are held near the centre of the trap.



Applied Programmes
Highlights

Proton Therapy

The first patient to receive proton radiation therapy in Canada was treated at TRIUMF in August, 1995. His tumour, a choroidal melanoma, was close to critical structures of the eye and required very precise radiation treatment to avoid damage to the surrounding normal tissue.

The proton radiation therapy project is a collaborative programme between TRIUMF, the UBC Department of Ophthalmology and the B. C. Cancer Agency. During the last two years, we designed and manufactured the necessary beam line equipment, and then carried out a long process of safety checking and measurements prior to the first treatment (see cover photo).

The generosity of the Mr. and Mrs. P. A. Woodward's Foundation made all this possible. The Foundation provided a grant to cover the capital costs of the equipment; and in addition, the three organizations mentioned provided the time and services of the physicians and physicists. Following the first patient treatment in August 1995, we treated a further 12 patients up to March 1996. We hope that this programme will expand further.

For the time being, only tumours of the eye (choroidal melanomas) are suitable for treatment with the equipment available, but we are considering expansion of the facility for other tumours in the head, neck and brain regions.

Positron Emission Tomography

During 1996, the UBC/TRIUMF PET group has concentrated on implementing the projects for which we were funded recently by the Medical Research Council of Canada. These projects include the reproducibility study for the new tracers, ^{11}C-dihydrotetrabenazine, a vesicular transporter marker; ^{11}C-methylphenidate, a dopamine re-uptake transporter marker; and ^{11}C-Sch23390, an antagonist for the D1 receptors. The reproducibility study involves the scan and rescan of 10 individuals followed by complete analysis aimed at determining the level of confidence we can obtain, both for intra- and inter-subject variability. In addition, we have selected normal subjects covering the age range from the 20s to the 80s. This age range will enable us to determine the age-related changes for these receptor systems.

A second study involves the comparison of receptor concentration for two subtypes of receptors of the dopaminergic system, D1 and D2, as a function of severity of disease, in order to determine how the concentration of the receptors interplay in causing the symptoms of Parkinson's disease.

We are also developing a new radiopharmaceutical setoperone labelled with fluorine-18 which will be used to label the $5HT_2$ serotonin receptor associated with schizophrenia. We will also carry out a study to determine the effectiveness of present drug treatments for schizophrenia. We will assess this by determining the distribution of the $5HT_2$ sites before and after drug treatment in previously untreated patients.

PETTVI Retires

The PETTVI is the positron emission tomograph built by TRIUMF researchers in the early 80s for use in the UBC hospital. In the fall of this year the PETTVI had a massive and irreparable detector failure. Thus, after more than 14 years of faultless service, this machine has retired. Built under the direction of Dr. Brian Pate, the PETTVI enabled the PET group to establish the present neurological programme at UBC. Although it was not used often in recent years, its reliability is unsurpassed in modern tomographs and will be missed. All new studies and existing studies will continue on the high-resolution Siemens ECAT 953B.

Radioisotope Production

During February, UBC's TR13 cyclotron on our site was used for 400 irradiations to prepare radioisotopes, nearly as many as during all of 1995. This jump is due to the increase both in scanning protocols and in radiopharmaceutical development. All of this effort would not have been possible without the dedicated use of the TR13. Throughout the year the cyclotron has maintained a high level of performance.

Proton Irradiation Facility

We have developed a general-purpose proton irradiation facility (PIF) on beam line 1B, a 180–500 MeV, low-intensity line. This complements the proton therapy beam line, located in the same room on beam line 2C, which provides protons with energies up to 120 MeV.

We test electronic components in the PIF. High fluxes of energetic protons, electrons and heavy ions bombard spacecraft and high-altitude aircraft. Protons and heavy ions can disrupt sensitive electronics, e.g. a computer memory bit can be flipped into another state by a single particle—a "single event upset" or SEU.

As electronics devices become more sophisticated and compact, this problem has become so serious that designers need to characterize electronics components for space applications to determine which are the most reliable devices.

The TRIUMF cyclotron's proton energy range up to 500 MeV matches the proton energies found in space. During 1995 a group from the Defence Research Establishment in Ottawa (DREO) measured the SEU rates for a number of electronic devices over the full energy range of the two beam lines.

DREO, the Canadian Space Agency and TRIUMF collaborated in this work, which is intended primarily for single-event effect studies of electronic components for space applications.

Polarized Source

The development of the optically pumped polarized ion source (OPPIS) has been driven mainly by the Parity Violation experiment (Expt. 497), which received 13 weeks of beam time in 1995. One of the major advantages of this experiment is its use of an OPPIS. The OPPIS produces a high-current, primary beam of polarized H^- ions, which is later "filtered" to select the very high-quality fraction required at the parity target. The polarization direction is changed by altering the wavelength of laser light that optically pumps rubidium vapour in the source, and this has only very small secondary effects on beam energy and current. The polarization reversal is carried out frequently (40 times per second) to reduce the effects of noise on the data.

In response to TRIUMF's leadership in polarized source development, high-energy accelerator laboratories such as Fermilab, BNL and DESY have shown a great deal of interest in using an OPPIS in their polarized programmes. This is because the OPPIS can be developed to produce pulsed currents of an estimated 20 milliamperes (far higher than any other type of polarized source) and would be ideal for high-energy laboratories. We have had financial support from Fermilab, INR Moscow and DESY, visitors from KEK, INR-Moscow, BINP-Novosibirsk, and the University of Kyushu, and loans of equipment from KEK, all directed towards high-current OPPIS development.

TRIUMF holds the world record of 20 microamperes of dc polarized H^- accelerated to high energy. This suggests the feasibility of future experiments at TRIUMF with intense polarized neutron beams, and also shows that we could simultaneously operate polarized beams and the ISAC facility currently under construction.

Many Paths to Reality

Physicists describe the universe with a set of rules known as the Standard Model (SM). According to these rules, force is transmitted between objects by the exchange of particles (or "quanta") of the force. There are four known types of forces—*strong*, *electromagnetic*, *weak* and *gravitational*. (All other forces are variants of these basic four.)

Each force corresponds to the exchange of a different type of particle. The gluon generates the *strong force*, the photon (light) generates the *electromagnetic force*, the "vector bosons" (W and Z) generate the *weak force* and the graviton generates the *gravitational force*. (You may note already the physicist's predilection for peculiar names!)

These forces act on a variety of particles making up matter. The SM, then, consists of the list of exchanged quanta, a description of how they attach themselves to the matter particles (fermions), a list of the fermions, and their properties. "Field theory" takes us from the particles and exchanged quanta to phenomena seen in the laboratory.

Two problems arise: first, do we have the correct set of rules? — and second, how do we apply the rules to actually calculate a real physical process as seen in an experiment? Although the SM has been amazing in its ability to describe observed phenomena and predict new phenomena, it is certainly not the whole story. Gravitation is not described in a manner consistent with the other forces, and there are aspects of the SM that theorists consider unpalatable. It has too many free parameters that need arbitrary adjustment, and too many doors that appear to lead nowhere. Thus, there is a continuing push to refine the SM.

However, this model is exceptionally successful in describing experimental results. Because of this, theorists have little guidance as to where problems might lie, and have been free to exercise their imagination in proposing extensions to the SM. Eventually, experiments—many of them here at TRIUMF—will have to winnow out the chaff.

The Neutrino Problem

One of the few phenomena that suggest a problem in the SM, and hence that will help in the winnowing, is the deficit of neutrinos from the sun. The new Solar Neutrino Observatory being built at Sudbury, Ontario, will help determine if this deficit is due to a problem with our model of the sun or to an inadequacy of the SM in describing neutrinos. An experiment on a nuclear reaction rate, planned for TRIUMF's future ISAC facility, will play an important role in interpreting the results of the solar neutrino experiment.

Checking those Bosons

As noted above, we call the carriers of the *weak force* "vector bosons". In the arcane language of particle physics, this is because they have one unit of what is known as angular momentum. A logical possibility exists that some particles may have no angular momentum. These hypothetical particles are called "scalars" (regardless of their aptitude for scaling mountains). The existence of scalar bosons would require major modifications to the SM. This would delight the particle physics community which, contrary to the usual stereotype, loves to prove old models wrong or incomplete! Some of the first experiments to be carried out using "TRINAT"—TRIUMF's Zeeman optical trap—will test for the existence of scalar bosons.

TRINAT and Angular Momentum

The carriers of the *weak force* not only carry angular momentum themselves, but they interact in a peculiar way with the angular momentum of the particles they meet. The angular momentum of a particle must be pointed in the opposite direction to a particle's motion. Proposed experiments with the Zeeman optical trap may be able to detect interactions with particles whose angular momentum is in the direction of their motion. This would also result in a major change of the SM.

In many cases it is far from trivial to see what the SM will predict in a given situation. For example the protons and neutrons which make up the nuclei of atoms consist of quarks held together by the *strong force*. Unfortunately the *strong force* is so strong that it makes calculations difficult. One approach is to use brute force and large amounts of computational power to solve the problem numerically, using a technique known as "Lattice Quantum Chromodynamics" (QCD). We have made considerable progress in calculating the mass of particles like the proton and pion.

At higher energies, the *strong force* weakens, and hence is more amenable to calculation. "QCD sum rules" allow us to relate low-energy properties to high-energy properties, and using these may let us extrapolate correctly from one energy region to the other.

An alternative approach to the region of strong forces is to use "effective theories" having properties (symmetries) that we know the real theory must have. We might then see what relationships can be derived between physical observables. "Chiral Perturbation Theory" uses this approach to study interactions between the *strongly* interacting particles at relatively low energies. It has been particularly successful in describing the interaction of pions with nucleons.

The realistic description of nuclei usually requires models even farther removed from the fundamental rules or SM. One approach is to deal entirely with "effective" forces which are not related directly to the fundamental ones. We are, however, working toward applying our knowledge of the fundamental forces to reveal nuclear structure.

Funding for TRIUMF's Five-Year Plan

The summer of 1995 brought a turning point in TRIUMF's fortunes. Following the Government of Canada's final decision in February 1994 not to fund our proposed expansion to a "KAON factory", TRIUMF prepared a five-year plan at Ottawa's request. In June 1995, after careful evaluation of this plan, the Government announced some important decisions on TRIUMF's future.

First, the laboratory was to continue receiving government funding for its operating costs, enabling it to maintain its role as the principal subatomic research facility in Canada. Secondly, the government approved a long-term funding package covering TRIUMF's operations from April 1995 till March 2000, thus ending the annual contingency rituals performed by TRIUMF's board and management in the face of financial uncertainty each spring since the 1980s.

The federal government has now allocated a total of $166.6 million to TRIUMF over the next five years. The multi-year nature of this commitment is important: it allows the laboratory to embark on long-term projects, so essential in this kind of science. Of this funding, $96.6 million is a continuation of the existing commitment by the National Research Council of Canada. The remaining $70 million over 5 years will be provided from a reallocation within the existing budget of Western Economic Diversification Canada (WED). With this funding, however, come certain requirements and expectations.

Canada's Contribution to CERN

First, there is the matter of a Canadian contribution to CERN, the multinational European laboratory for particle physics, in Geneva. Canadian scientists have participated in CERN experiments for decades, but Canada is not a member of this European consortium and has therefore not shared in the lab's operating expenses. TRIUMF will now use its accelerator expertise in making a significant contribution to the world's highest-energy particle accelerator (the Large Hadron Collider) to be constructed at CERN by the year 2005. By contributing technical and scientific expertise and equipment built in Canada via TRIUMF, Canada in future will be regarded as "paying its way" on the international physics scene, thereby enabling Canadian scientists to retain access to CERN experiments. The CERN Council had indicated it expected such contributions from non-member states whose physicists were heavily involved in the experimental programme at the LHC. Once a formal agreement with CERN is signed, this contribution will be worth approximately $30 million over the following five-year period.

Building a New Facility

Secondly, TRIUMF is required to construct ISAC (acronym for Isotope Separator/ACcelerator)—a new, unique research facility, costing about $38 million of the total funding package. The provincial government has also promised support for this project, and will contribute $9.7 million toward the civil construction of the facilities. ISAC will make use of the existing intense proton beam from our cyclotron to create powerful beams of exotic, short-lived, radioactive atoms. These will be accelerated in a new linear accelerator structure to be built over the next five years. When completed, ISAC will, in fact, have the world's most intense accelerated beams of radioactive nuclei. The facility will be used by an international community of astrophysicists, who will be able to simulate the formation of elements in stars and in the early universe; and by physicists studying nuclear structure and the behaviour of unusual atomic nuclei.

Infrastructure Support for Physicists

Throughout this period TRIUMF will provide infrastructure support for the national community of subatomic physicists who need to base their science on accelerator facilities outside Canada. For the most part, this support will consist of building apparatus, such as detectors. The remainder of the funding, after the payments for CERN and ISAC, will be used for this infrastructure support and for the normal operating expenses of TRIUMF.

Because the total amount of funding is significantly less than was proposed in our five-year plan, in August 1995 TRIUMF underwent a staff reduction (see page 18), in order to remain within its budget. With these changes, TRIUMF will be able to maintain its existing strong programmes in basic science, including condensed matter research and biomedical physics. Since a substantial part of the five-year funding comes from WED, TRIUMF is required to provide the government with indicators that its research is stimulating economic activity, especially for small businesses. The WED involvement also provides strong encouragement for applied science and technology transfer. Currently such work includes developing a novel type of detector for explosives or contraband hidden in luggage at airports, and the continued on-site commercial production of isotopes for medical use.

Canada, through TRIUMF, Is Helping to Construct the Large Hadron Collider at CERN

CERN, the European laboratory for particle physics research located near Geneva, operates the largest complex of particle accelerators in the world (see page 13). The laboratory has now embarked on an ambitious, new project to build a superconducting proton-proton collider in the 27-kilometre tunnel of the existing electron-positron collider (LEP). This "Large Hadron Collider" (LHC), providing collisions at 14 TeV, will be in a unique position to answer fundamental questions on the constituents of matter and their interactions. The CERN Council, representing 19 member-states contributing to the CERN budget, approved this technically and fiscally challenging project in December 1994.

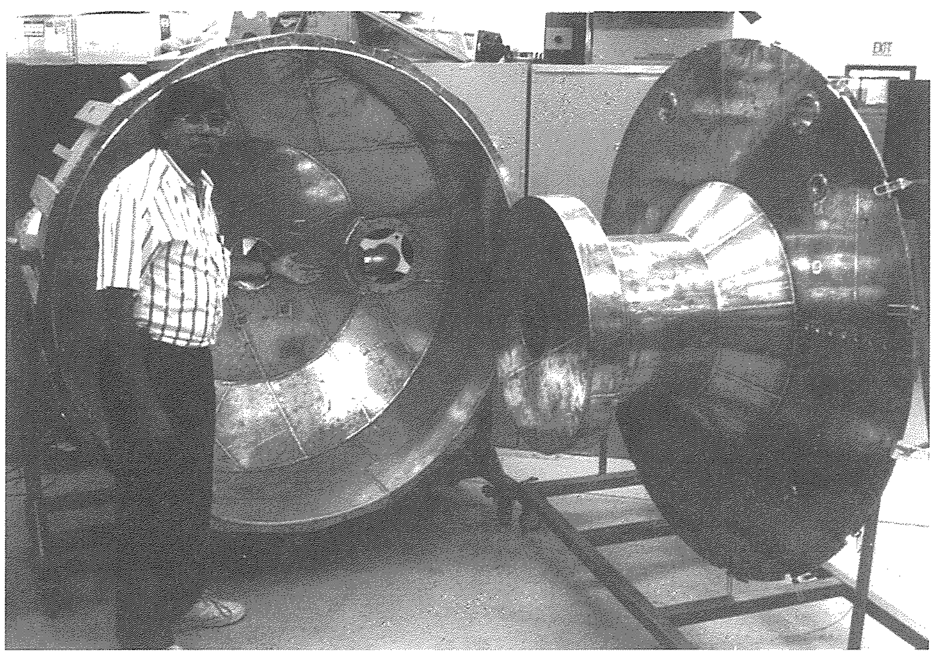
However, meeting the planned completion date (first collisions by 2005) for LHC requires that several non-member states participate, especially those whose scientists plan to be involved in the LHC experiment programme—the USA, Japan, Canada and Russia.

In June 1995 Canada announced its participation in the LHC construction. TRIUMF's five-year funding plan, approved in June 1995, includes a provision for "in-kind" Canadian contributions via TRIUMF of accelerator expertise and components, amounting to $30 million (including $11 million for TRIUMF salaries). An important aspect to this work is Canadian industry's involvement in developing and fabricating the equipment. TRIUMF and CERN accelerator personnel have identified the area most suitable for initial collaboration: the upgrading of the injector synchrotrons to optimize them for LHC injection. Through discussions they have identified about 20 tasks for TRIUMF and Canadian involvement over the next few years. By the end of 1995 about 25 TRIUMF staff were involved in these tasks, mostly on a part-time basis.

The tasks cover the full range of accelerator expertise available at TRIUMF. They include beam dynamics calculations, and simulations involving primarily intellectual contributions; the design and fabrication of large magnets and power supplies; development of controls and instrumentation; and radio frequency components. One activity—the development of a prototype 40 MHz cavity, shown below—is being carried out to study higher-order modes and how to control them and to develop methods of tuning the cavity.

A large collaboration meeting was held at CERN in the first week of October 1995, and CERN collaborators visited TRIUMF during the year. The first major contract as part of this work was awarded to Inverpower Controls in Ontario for two high-voltage power supplies for the 40 MHz cavity. In addition to the radio frequency work, the task which requires early delivery involves providing dipoles and quadrupoles for the linac and the transfer line from the Proton Synchrotron Booster to the Proton Synchrotron.

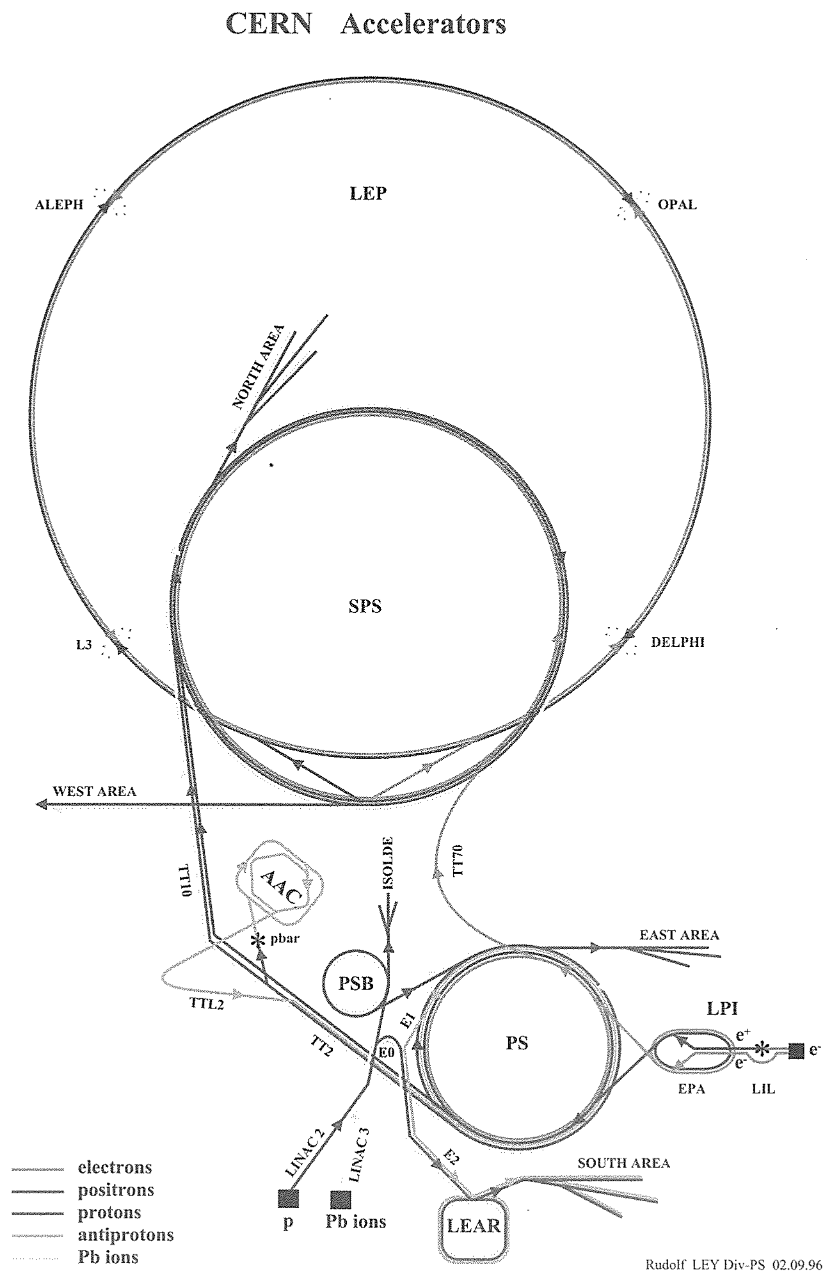
In parallel with their accelerator participation, Canadian scientists are collaborating in the design of the ATLAS detector, one of the two large detectors approved for the LHC. TRIUMF physicists and engineers will design and construct some of the components for this detector, and are already developing prototypes.



Full scale model of a new 40 megahertz radio frequency cavity for CERN, built and now being tested at TRIUMF

The Complex of Accelerators at CERN

The large (LEP) ring is 27 km in circumference. The equipment contributed through TRIUMF will be used at several locations on the site.



LEP: Large Electron Positron Collider
SPS: Super Proton Synchrotron
AAC: Antiproton Accumulator Complex
ISOLDE: Isotope Separator Online Device
PSB: Proton Synchrotron Booster

LPI: Lep Pre-Injector
EPA: Electron Positron Accumulator
LIL: Lep Injector Linac
LINAC: Linear Accelerator
LEAR: Low Energy Antiproton Ring

TRIUMF's Technology Transfer Programme

The TRIUMF Ventures Office (TVO) mandate is to pursue all technically and financially viable opportunities for commercializing technologies evolving from research at TRIUMF that will enhance the Canadian economy. The objectives of the TVO are twofold: to transfer TRIUMF technology to the Canadian economy; and to generate income for the applied technology programme at TRIUMF.

The TVO acts as a catalyst in bringing together scientific knowledge with commercial demand and application. The TVO identifies TRIUMF technologies with commercial potential and encourages those involved to consider the commercial aspects of their work. A researcher must decide between pursuing academic recognition through publication, and the longer-term possibilities and uncertainties of commercialization. Some of our technologies currently attracting the most interest from industry are:

- isotope production for medical applications
- medical imaging using advanced positron emission tomography
- radio-frequency drying of agricultural products
- environmental protection using cryogenics to eliminate smoke stack emissions
- nuclear techniques for detecting concealed contraband
- cyclotron production

From its inception, TRIUMF has had a long history of interaction with Canadian businesses—small, medium and large—to enhance their manufacturing capabilities through technologies and techniques that have evolved or been acquired at TRIUMF. Since 1990, TRIUMF has operated a programme, funded by the BC provincial government, to commercialize the technology and scientific knowledge generated at TRIUMF.

The approach used at TRIUMF is to transfer viable technology into industry, using the most efficient arrangement that recognizes TRIUMF's intellectual ownership and provides an appropriate return to the laboratory. TRIUMF encourages and actively participates in efforts to diffuse any viable scientific or technological knowledge into the Canadian economy through the most prudent and appropriate vehicle(s), among the following approaches:

a) direct sale to industry;
b) licence to industry;
c) gift or donation to appropriate organizations;
d) training of industrial collaborators;
e) contract development work for industry;
f) employee secondments from TRIUMF;
g) employee secondments to TRIUMF;
h) start-up companies by TRIUMF staff;
i) student training and employment;
j) joint ventures with industry or other organizations.

TRIUMF has a large economic impact on Canada in general, and on the four western provinces in particular. The current TRIUMF staff complement of about 300 persons is composed of experimental physicists, together with some theoreticians, plus scientists from associated disciplines, supported by technicians, engineers, facilities operators and an administrative group. In addition, there are about 20 research associates (RAs) and 25 students employed by TRIUMF on a fixed-term basis, ranging from four months for students to two years for RAs. Grants and other external funding provide employment for a further 80 or so persons at TRIUMF for the period of tenure of that particular funding. In total, TRIUMF generates about 430 full-time equivalent positions of employment.

During the five-year period from 1990 through 1995, TRIUMF's cumulative expenditures in BC, Alberta, Saskatchewan and Manitoba totalled about $170 million. For fiscal 1995–96, the total annual funds that were administered by and through the facility reached $41 million. This comprised the aggregate of the core funding that supports operations, improvements and development, expansion of facilities, plus the NSERC, MRC and funding from foreign agencies which provide general support for experiments.

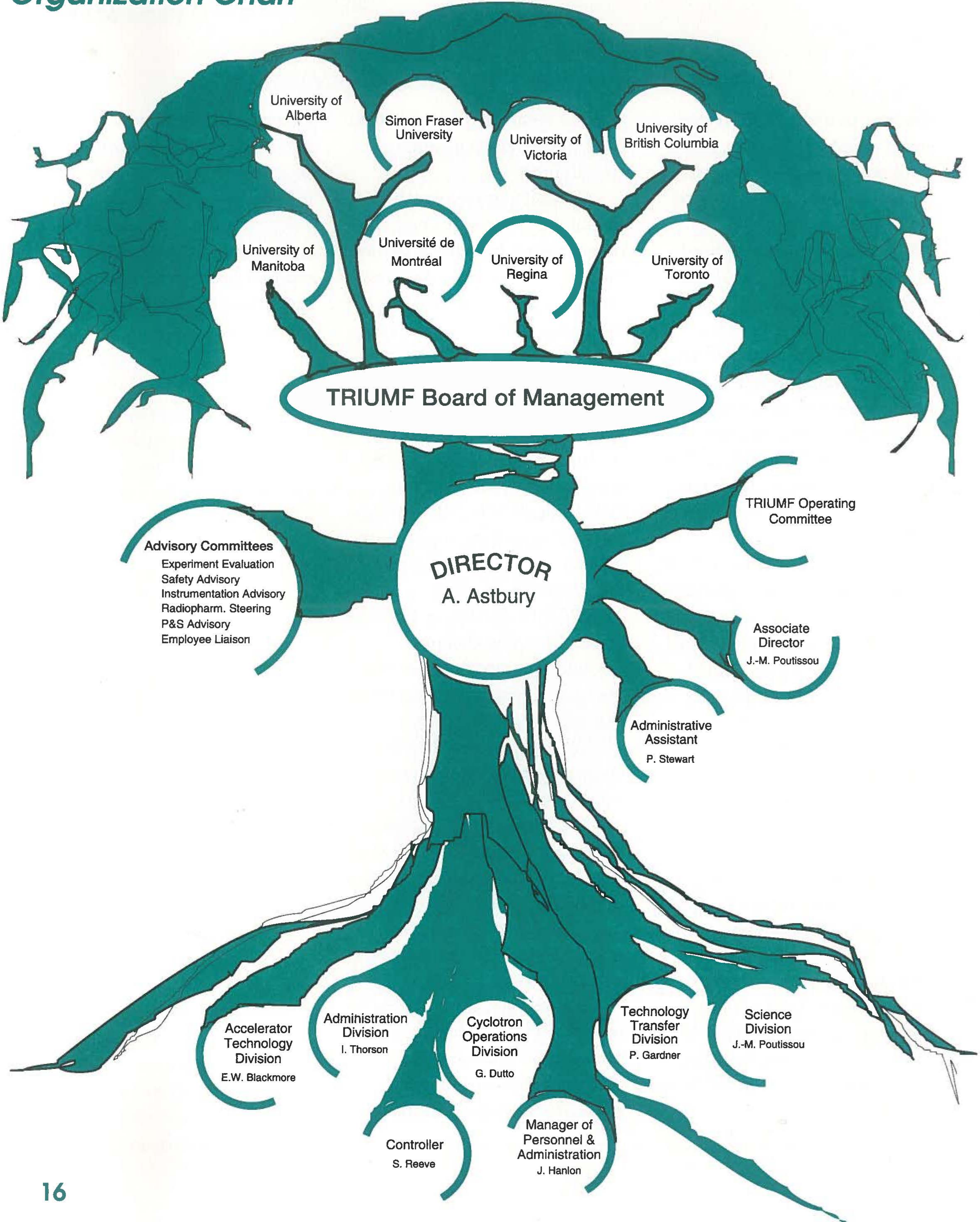
Western Canadian companies have generated revenues and commercial sales as a result of technologies developed at TRIUMF. These technologies have been transferred to commercial recipients, generally in the form of a licence. Total cumulated revenues which have accrued to commercial companies from the development and sale of TRIUMF technology have exceeded $100 million to date. This number is a conservative estimate since it reflects only known direct sales by TRIUMF licensees. In special cases that demonstrate specific social benefit, such as the B.C. Cancer Agency, technological assistance has been provided through a contribution.

TRIUMF receives royalties, consulting revenues or other consideration from the activities that are pursued for defined ancillary purposes unrelated to fundamental research. The revenues received from these commercial activities have been used to fund applied research and development projects, including such essential TRIUMF expenses as patenting. From 1990 through 1995, TRIUMF has received aggregate revenues of over $4 million from royalties and corporate funding.

TRIUMF also has an impact on the Canadian economy through the steady flow of visiting researchers to the area, both to participate in research at TRIUMF and to attend conferences and seminars related to subatomic physics. These visitors are attracted to Vancouver by the presence of TRIUMF. Annual local conferences organized by TRIUMF attract over 800 delegates and result in approximately $1.4 million in delegate expenditures.

In summary, the scientific research at TRIUMF has generated a substantial economic impact on the Canadian economy, and particularly on the western provinces. In future years, this economic contribution will continue to strengthen and grow, as TRIUMF continues to work with industrial partners to develop and commercialize technologies, and to transfer its skills and knowledge to Canadian businesses.

Organization Chart



TRIUMF Users' Group

1996 TRIUMF Users' Executive Committee (TUEC)	
Chairman:	G. Roy
Chairman Elect:	M. Hasinoff
Members:	J. D'Auria, E. Korkmaz, E.L. Mathie, A. Trudel
Past Chairman:	J.D. King
Liaison Officer:	M. La Brooy

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

(a) to provide a formal means for exchange of information relating to the development and use of the facility;

(b) to advise members of the entire TRIUMF organization of projects and facilities available;

(c) to provide an entity responsive to the representations of its members for offering advice and counsel to the TRIUMF management on operating policy and facilities.

Membership of the TRIUMF Users' Group is open to all scientists and engineers interested in the TRIUMF programme. As of March 1996, there were 717 members from 233 institutions in 34 countries.

Government Committees Reporting on TRIUMF

NRC Advisory Committee on TRIUMF (ACOT)

Dr. D. Stairs	McGill University *(Chairman)*
Dr. N. Sherman	NRC *(Secretary)*
Dr. P.-G. Hansen	Michigan State U.
Dr. J.C. Hardy	AECL
Dr. J.G. Martel	NRC
Dr. D. Perkins	Oxford U.
Dr. B. Peters	
Prof. V. Soergel	Physikalisches Inst.
Prof. M. Stott	Queen's U.
Dr. R. Taylor	SLAC
Ex officio	
Prof. R. Carnegie	Carleton U.
Dr. C.H. Jones	Simon Fraser U.
Dr. S. Page	U. of Manitoba

Agency Committee on TRIUMF (ACT)

Dr. A.J. Carty	President	NRC *(Chairman)*
Dr. T. Brzustowski	President	NSERC
Mr. K. Lynch	Dep. Minister	Industry Canada
Mr. J. McLure	Dep. Minister	Western Economic Diversification
Dr. N. Sherman		NRC *(Secretary)*

Financial Review

In June 1995 the Government of Canada approved a Five Year Plan for TRIUMF which provides $166.6 million, $70 million of which is provided by Western Economic Diversification, to fund TRIUMF operations and new initiatives through to the year 2000. At the same time, the Provincial Government of British Columbia announced building funds for TRIUMF in the amount of $9.7 million.

The approval of the Five Year Plan provides a change of focus for TRIUMF, away from the holding pattern of the last number of years and towards the CERN collaboration and ISAC project. The National Research Council contribution agreement also provides a mandate for increased efforts on behalf of small business development, infrastructure support for the Canadian physics community, life sciences and technology transfer activities. The TRIUMF Business Office will be working with the Director, division heads and TRIUMF Ventures Office in developing methods and procedures to maximize and quantify our success in fulfilling our commitments to our funding agencies and the Canadian physics community.

One of the first steps toward meeting the financial obligations defined in the NRC contribution agreement was taken during the summer of 1995. TRIUMF underwent a restructuring of the laboratory which resulted in the voluntary and involuntary termination of 49 of our colleagues, approximately 15% of our NRC employee base. The full cost of this restructuring is reflected in the 1995–96 financial statements.

Approval of the Five Year Plan also meant that NSERC grantees and affiliated institution scientists could proceed with their experiments and activities, here in Canada and abroad, with the assurance that TRIUMF would continue to provide facilities, staff and administrative assistance for them. Their activities at TRIUMF were unavoidably slowed while awaiting the Federal Government's approval and during the subsequent downsizing and restructuring.

We are all looking forward to a very positive and successful future for TRIUMF!

S.L. Reeve, C.G.A.
Controller

	1994–95		1993–94	
SOURCE OF FUNDS	*$ million*	*%*	*$ million*	*%*
National Research Council	33.318	75.3	33.250	75.4
NSERC	3.438	7.8	3.772	8.6
NORDION International Inc	1.675	3.8	2.167	4.9
Province of British Columbia	1.144	2.6	0.0	0.0
Affiliated Institutions	3.449	7.8	3.551	8.1
Commercial Revenue	1.003	2.3	1.148	2.6
Investment & Other Income	0.240	0.4	0.161	0.4
	44.267	100.0	44.049	100.0

Coopers
&Lybrand

chartered accountants

AUDITORS' REPORT

To the Board of Management of TRIUMF

We have audited the statement of financial position of TRIUMF as at March 31, 1996 and the statements of funding, income 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, 1996 and the results of its operations and the changes in its fund balances for the year then ended in accordance with generally accepted accounting principles.

Coopers & Lybrand

Vancouver, B.C.
May 31, 1996

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, Income and Expenditures and Changes in Fund Balances

For the Year Ended March 31, 1996

Funding/Income	1996	1995
National Research Council Fund	$ 33,318,000	$ 33,250,000
Natural Sciences & Engineering Research Council Fund	3,437,900	3,771,530
NORDION International Inc. Fund	1,674,713	2,166,732
Province of British Columbia Building Fund	1,144,000	–
Affiliated Institutions Fund	3,448,749	3,551,198
Commercial Revenue Fund	1,003,448	1,148,031
General Fund	240,469	161,159
	44,267,279	44,048,650

Expenditures		
Buildings	54,693	41,093
Communications	219,646	583,645
Computer	1,554,936	1,756,368
Equipment	2,403,782	3,674,503
Power	2,007,527	1,896,524
Salaries and benefits	28,228,996	27,572,406
Supplies and other expenses	7,682,487	8,399,356
	42,152,067	43,923,895
Excess of Funding, Income over Expenditures for the Year	2,115,212	124,755
Fund Balances — Beginning of Year	1,818,665	1,693,910
Fund Balances — End of Year	$ 3,933,877	$ 1,818,665

TRIUMF

Statement of Financial Position

As at March 31, 1996

	1996	1995
ASSETS		
Cash & Temporary Investments	$ 4,816,676	$ 2,378,950
Funding Receivable (note 3)	2,342,886	1,765,409
Total Assets	$ 7,159,562	$ 4,144,359
LIABILITIES		
Accounts Payable	$ 2,445,970	$ 874,564
Deposits from Natural Sciences & Engineering Research Council Fund (note 5)	230,305	320,046
Deposits from Affiliated Institutions	694,133	790,680
	3,370,408	1,985,290
Due to (from) Joint Venturers		
The University of British Columbia	(122,248)	347,634
The University of Alberta	(10,219)	(13,147)
The University of Victoria	(38,326)	(20,252)
Simon Fraser University	26,070	26,169
	(144,723)	340,404
	3,225,685	2,325,694
FUND BALANCES		
Restricted		
Natural Sciences & Engineering Research Council Fund (note 5)	377,186	118,475
NORDION International Inc. Fund	100,000	100,000
Province of British Columbia Building Fund	916,407	–
Affiliated Institutions Fund	43,500	16,273
	1,437,093	234,748
Other		
Commercial Revenue Fund	1,273,264	950,042
General Fund	197,344	(15,210)
Intramural Accounts Fund	1,026,176	649,085
	2,496,784	1,583,917
	3,933,877	1,818,665
Total Liabilities & Fund Balances	$ 7,159,562	$ 4,144,359

Encumbrances and Commitments (note 4)

TRIUMF

Statement of Funding and Expenditures

National Research Council Fund

For the Year Ended March 31, 1996

	1996	1995
National Research Council Funding	$ 33,318,000	$ 33,250,000
Expenditures by Activity Area		
Basic lab operations	4,418,973	5,117,890
Base program development	564,322	1,029,187
Base program support	3,156,388	3,920,983
ISAC-1	1,562,848	718,898
CERN collaboration	540,427	189,110
Salaries and benefits	23,912,943	23,068,625
	34,155,901	34,044,693
Expenditure recoveries	(837,901)	(794,693)
Total Expenditures	33,318,000	33,250,000
Excess of Funding over Expenditures for the Year	$ Nil	$ Nil
Expenditures by Object		
Buildings	$ –	$ 34,570
Communications	174,805	533,175
Computer	1,143,644	1,469,979
Equipment	1,456,714	2,032,328
Power	2,007,527	1,896,524
Salaries and benefits	23,912,943	23,068,625
Supplies and other expenses	4,929,716	4,713,396
Salary expenditure recovered	(307,349)	(498,597)
	$ 33,318,000	$ 33,250,000

TRIUMF
NOTES TO FINANCIAL STATEMENTS
For the Year Ended March 31, 1996

1. **Nature of 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, which has 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 assets, liabilities, funding and expenditures of the activities carried on under the control of TRIUMF and do not include the other assets, liabilities, revenues and expenditures of the individual joint venturers.

Sources of funding include grants and contributions from the National Research Council, Natural Sciences and Engineering Research Council and governments, advances and reimbursements from other sources, royalty income, and investment income. The sources and purposes of these funds are:

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

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

NORDION International Inc. Fund
Advances and reimbursements for expenditures undertaken at its TRIUMF site.

Province of British Columbia Building Fund
Funding from the Province of British Columbia for the construction of new facilities and the upgrade of existing facilities.

Affiliated Institutions Fund
Advances and reimbursements for expenditures undertaken on behalf of various institutions, from Canada and abroad, for scientific projects and experiments carried out at TRIUMF.

Commercial Revenue Fund
Royalties, revenue and expenditures relating to commercial activities. During the year ended March 31, 1996, all financial activities of the EBCO Industries Fund were included in the Commercial Revenue Fund. The prior year's financial statements have been restated to reflect this change in disclosure.

General Fund
Investment income for discretionary expenditures incurred by TRIUMF.

Intramural Accounts Fund
Net 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**

Basis of Presentation

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.
A statement of changes in financial position has not been prepared as management believes such a statement would not provide any additional useful information.

Royalty Income

TRIUMF records royalty income when notification and verification of sales are received.

3. **Funding Receivable**

	1996	1995
Commercial Revenue Fund	$ (10,576)	$ –
Natural Sciences and Engineering Research Council Fund	402,200	508,623
NORDION International Inc. Fund	197,665	325,159
Provincial Government Building Fund	894,000	–
Affiliated Institutions Fund	859,597	931,627
	$ 2,342,886	$ 1,765,409

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:

	1996	1995
National Research Council Fund	$ 570,000	$ 610,000
Natural Sciences and Engineering Research Council Fund	61,000	109,000
NORDION International Inc. Fund	84,000	49,000
Provincial Government Building Fund	1,037,000	–
Affiliated Institutions Fund	191,000	46,000
Commercial Revenue Fund	4,000	13,000
Intramural Accounts Fund	-	3,000
	$ 1,947,000	$ 830,000

5. **Natural Sciences and Engineering Research Council Fund Balance**

	1996	1995
Funding unexpended	$ 1,197,491	$ 438,521
Grant accounts overexpended	(230,305)	(320,046)
Fund balance — end of year	$ 967,186	$ 118,475
Number of grants awarded during year	37	42
Number of grants administered throughout year	72	91

6. **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 are made to the plan based on a prescribed percentage of employee earnings. The pension expense for the year was $1,516,640 (1995 — $1,482,000).

7. **Contingent Liability**

In 1994, an action was commenced against TRIUMF by a former research partner. The plaintiff is claiming that TRIUMF did not provide certain technology transfers as agreed. The outcome of this proceeding and the amount of loss, if any, is not determinable at this time, and accordingly, no provision has been made in the financial statements. Should TRIUMF lose the action, any settlement will be accounted for in the period of settlement in the Commercial Revenue Fund.

8. **Economic Dependence**

TRIUMF's operations are funded under a contribution from the Government of Canada through the National Research Council of Canada, including support from Western Economic Diversification. TRIUMF is economically dependent upon this funding source for its ongoing viability.
The Government of Canada has committed to fund $166.6 million for the operations of TRIUMF over a five year period ending March 31, 2000. The Government of British Columbia has committed to fund $9.7 million for conventional construction. Management has no reason to believe that ongoing funding from these governments will not continue into the future after the expiry of the above commitments.