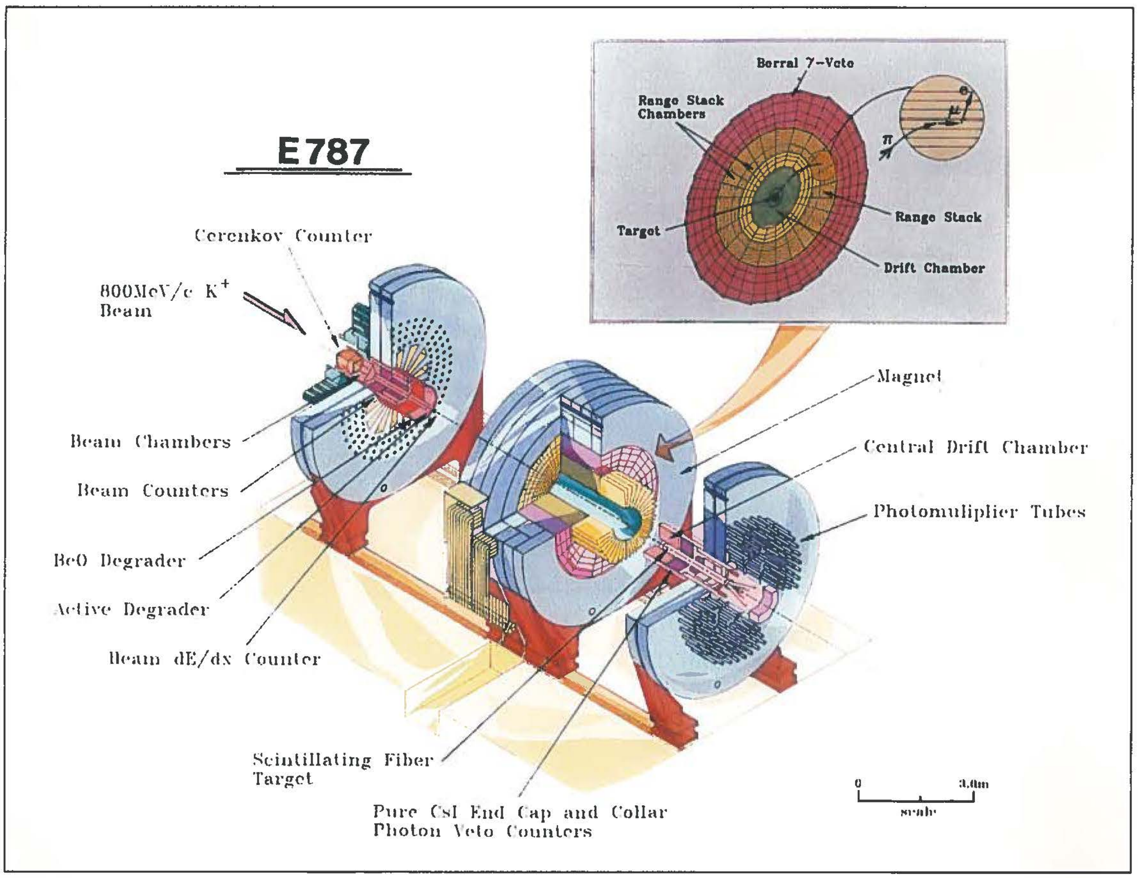
TRIUMF

1994–95

Annual Financial & Administrative Report



including summaries of

Pure Research Activities

and Practical Applications

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.

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

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Cover Photo: Part of the complex detector for Experiment 787 at Brookhaven—see the "Pure Research" section on page 4.

The 1994–95 Financial & Administrative Annual Report is prepared by the

TRIUMF Information Office

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We acknowledge the contributions of the following toward the preparation of presentations in this annual report: E. Blackmore, D. Bryman, P. Gardner, P. Jackson, J. Ng, T. Pickles, M. Vetterli

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International Relations

A little over a year has passed since the negative decision on the KAON proposal by the Federal Government. In May 1994 the management of TRIUMF was requested to present a five-year plan for the future of the laboratory. This exercise was completed by June and presented verbally in Ottawa in July to an assembly of senior bureaucrats and deputy ministers. The proposal was well received; however March 1995 has passed with no clear decision on the laboratory's future, which hangs, rather too delicately for comfort, in the balance.

So far, the exercise of trying to assure a bright scientific future has proved to be both educational and confusing. TRIUMF, since its creation in the late 1960s, has pursued a basic research programme in subatomic physics. Over the years the programme has come to embrace medical treatment, materials research and work in the life sciences, but the central, driving force has been curiosity-driven experimentation into what are the basic building blocks of matter, and what are the rules governing the forces of nature which act between these constituents. The success has been gauged internationally and support for the science has been determined by peer review of its excellence.

In order to perform this science TRIUMF staff must employ technology which is state-of-the-art. This technology has to be invented or taken from wherever it can be found in the world. The process has produced in the TRIUMF scientists and engineers a pool of talent and knowledge which is probably unique in Canada. It represents a resource which can have immeasurable value to the so-called "high tech" industries, and in an effort to realize some of this capital, TRIUMF runs an office for technology transfer. However, we should never lose sight of the fact that the technological resource exists only because of the demands of the basic science. Why then should government give TRIUMF a future? Herein lies the confusion. For some, excellence in basic science reigns supreme. After all, every piece of modern technology was once a piece of curiosity-driven research; to say nothing of the vital training of the young people involved, a role traditionally fulfilled by basic research. Others insist that in these days of straitened finances, priorities must shift. The overwhelming priority for TRIUMF is the transfer of its technology; and the promise of a detailed accounting of jobs created, companies enhanced, and new technologies spawned is the only way of assuring a rosy future.

If we are successful in our quest for funding it is already clear that the management of TRIUMF will find itself in the uncomfortable position of trying to satisfy these dual requirements. Whether this is possible, only time will tell, and one has a great deal of sympathy with the views expressed by the Duke of Wellington in the following letter attributed to him, and sent by him to the British Foreign Office in 1812 during the Napoleonic wars in Europe.

"Gentlemen:

Whilst marching to Portugal to a position which commands the approach to Madrid and the French forces, my officers have been diligently complying with your requests which have been sent by H.M. ship from London to Lisbon and then by dispatch rider to our headquarters.

We have enumerated our saddles, bridles, tents and tent poles, and all manner of sundry items for which His Majesty's Government holds me accountable. I have dispatched reports on the character, wit and spleen of every officer. Each item and every farthing has been accounted for, with two regrettable exceptions for which I beg your indulgence.

Unfortunately the sum of one shilling and ninepence remains unaccounted for in one infantry battalion's petty cash and there has been a hideous confusion as to the number of jars of raspberry jam issued to one cavalry regiment during a sandstorm in western Spain. This reprehensive carelessness may be related to the pressure of circumstance since we are at war with France, a fact which may come as a bit of a surprise to you gentlemen in Whitehall.

This brings me to my present purpose, which is to request elucidation of my instructions from His Majesty's Government, so that I may better understand why I am dragging an army over these barren plains. I construe that perforce it must be one of two alternative duties, as given below. I shall pursue either one with the best of my ability but I cannot do both:

1. *To train an army of uniformed British clerks in Spain for the benefit of the accountant and copy boys in London or, perchance,*
2. *To see to it that the forces of Napoleon are driven out of Spain."*

Alan Astbury

Particle Physics

Refinement Through Rarities

Particle physics is in one of the most interesting and perplexing phases ever encountered in modern science. On the one hand we know of four basic forces in nature, and we have the "standard model" of subatomic physics (SM), providing a consistent theoretical picture of how nature's basic building blocks interact with each other via the *weak*, the *electromagnetic* and the *strong* forces. (Gravity is not yet included in the SM.) The building blocks are the quarks—*up* and *down* (u, d), *charm* and *strange* (c, s), and *top* and *bottom* (t, b); and the leptons (the negatively charged electron, muon, and tau particle—referred to as e^-, μ^-, τ^-—and their related neutrinos (ν_e, ν_μ and ν_τ), which are electrically neutral. One can see, therefore, that each of these groups, the quarks and the leptons, comes in three related pairs, referred to as "generations". Remarkably, all confirmed measurements agree with the predictions of the SM.

On the other hand, we strongly suspect there must be more to the story: the SM contains a large number of unspecified parameters, and it does not explain some crucial problems, like the generation puzzle. (Why do fundamental particles come specifically in three generations?) Nor does it explain the variation in the strengths of the basic forces. All over the world, physicists are directing much of their current experimental effort to addressing questions of this sort, in attempts to probe the SM in ever greater detail, and to search for new directions.

Rare Decays

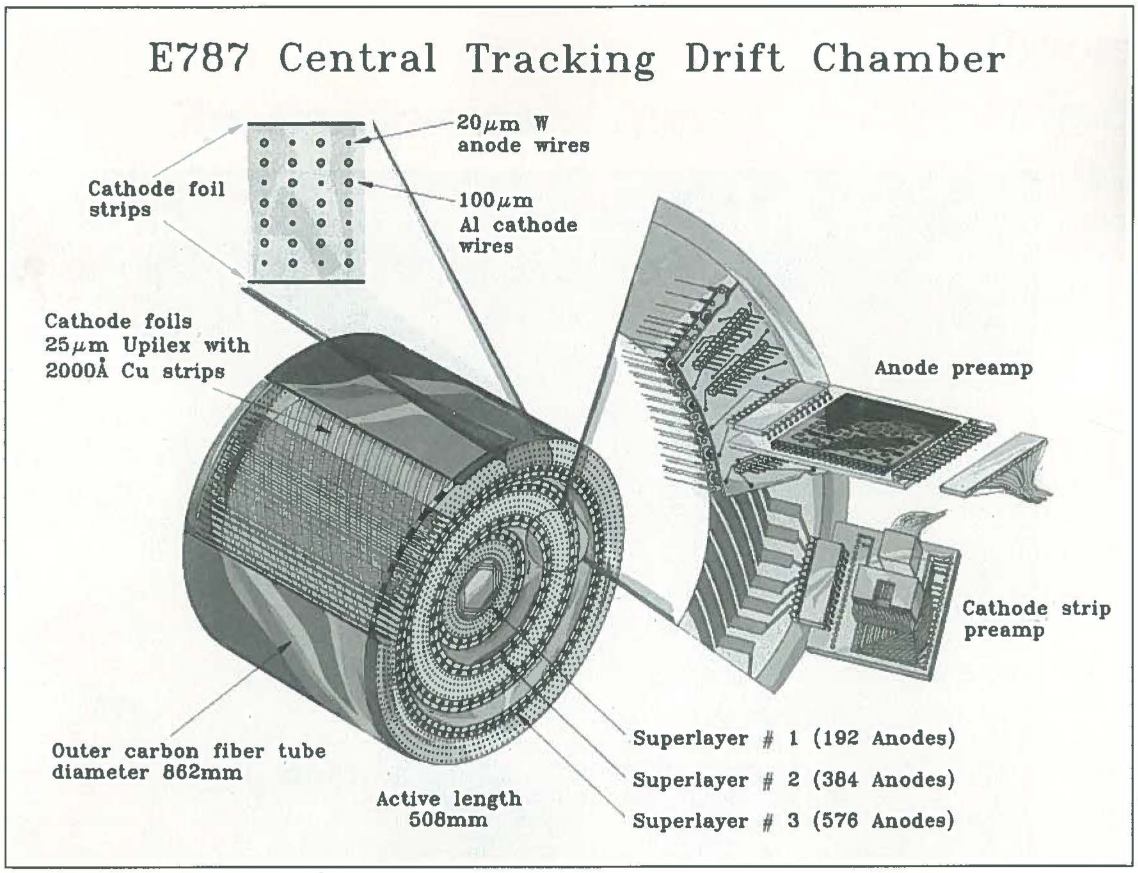
Many elementary particles, including muons, pions and kaons, decay into light particles (e.g. electrons, neutrinos) through the action of the *weak* force. Theory predicts that some of these (which we call "rare decays") will occur at extremely low rates. Observing them could lead to a greater level of understanding of the SM, or even to entirely unexpected, new insights.

In many diverse fields of science, rare phenomena provide an effective route by which we can isolate underlying principles of general importance.

If we could carefully measure the frequency of some special rare decays of mesons and leptons, we could challenge the SM by comparing our results to its detailed predictions. The simplest reactions, like muon decay — a muon decaying to e^- and $\bar{\nu}_e$ (an antineutrino) and ν_μ — involve only leptons; and leptons don't "feel" the *strong* force. This simplifies any high-precision SM calculations we have to make for comparison with experiment results. Studies with muons at TRIUMF and elsewhere have been very important in establishing the validity of many aspects of the SM and in confronting the predictions of alternative theories. However, when hadrons, like pions and kaons, are involved (hadrons are particles that can also interact through the *strong* force, and are made up of quarks and/or antiquarks), the range of possibilities for testing hypotheses is enriched but reliable calculations are difficult, if not impossible. *Weak* and *electromagnetic* processes can generally be computed to high accuracy (using "perturbation theory"), but the *strong* interaction, particularly at low energy, requires a different (non-perturbative) approach for which, usually, we cannot obtain reliable theoretical results.

Experiment 787

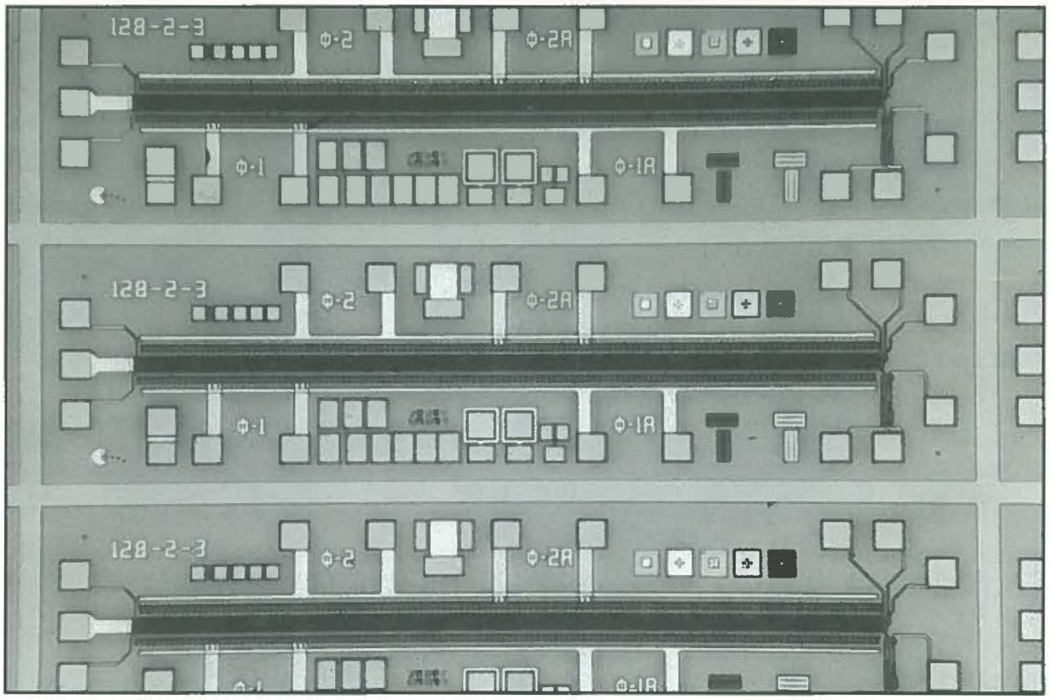
There are, however, a few exceptional *weak*-force processes involving hadrons which, due to symmetries or special circumstances, have decay rates which can be calculated with high precision and these lead to important tests of the SM. Pion decays (studied extensively at TRIUMF) generally require the exchange of only one boson (the *weak* force carrier) between interacting particles. However, the SM predicts the "suppression" of decays of kaons through the *weak* force be-



cause they can occur only with a *two-step* exchange of bosons, which is more complicated. These "higher-order" processes are potentially fertile testing grounds for the SM because the entire spectrum of quarks, leptons, and bosons is involved. A few higher-order *weak* interactions have been observed. But the ultra-rare decay of a kaon (K^+) to a positive pion (π^+) and two neutrinos may be the only one that is both observable in an experiment with current facilities *and* subject to precise calculation. The price for this arrangement is a very low rate of decay: we expect this to occur in only about two out of 10^{10} kaon decays. The most interesting unknown in the SM calculation is the interaction strength between the recently discovered t quark and the d quark. Thus, by studying this ultra-rare kaon decay, we may obtain one of the most detailed tests of basic assumptions in the SM, as well as insight into aspects of the model which are least understood.

The Experiment

A group of physicists at Brookhaven National Laboratory (BNL) in Upton, New York, is now performing an experiment (A1) aimed at observing whether this decay to $\pi\nu\nu$ occurs within the predicted range of decay rates. The project, Experiment 787, is a decade-long effort of physicists and engineers from BNL, Princeton University and TRIUMF, recently joined by two Japanese groups. It employs a kaon beam produced by the upgraded 30 GeV alternating-gradient synchrotron. The apparatus (see front cover of this report) is located inside a solenoidal magnet with a diameter of about 3 metres, and with a field of approximately 1 tesla. TRIUMF and BNL scientists specially designed the beam line to reduce the fraction of contaminating particles (primarily pions) to less than 25% of the total, which is ten times better purity than previously achieved anywhere. A unique, gas-filled tracking chamber built at TRIUMF (see figure above) analyses the momenta of the charg-



TRIUMF's gallium arsenide microchip—about 2 mm x 1 mm

ed particles from the K^+ decays. These particles are subsequently stopped in a stack of scintillation detectors used to measure their range (average length of passage in material) and energy.

An electron- and photon-detection calorimeter (a device to measure the total energy of particles) radially surrounds these scintillation detectors, and also covers both ends of the detector. It consists of many thin layers, alternating lead with plastic scintillator, and employs an "advanced material" provided by the BNL and Japanese groups—a pure cesium iodide crystal array. These detectors contribute to an elaborate scheme to suppress backgrounds from processes which, although similar to the rare kaon decay being sought, occur up to 10^9 times more often!

Results and Future Prospects

Prior to this work, physicists had searched for

$$K^+ \rightarrow \pi^+ + \nu + \bar{\nu}$$

in a series of experiments. These led to the calculation of a maximum possible rate for this particular decay (relative to all K decays) of less than 2 out of 10 million; thus, at least three thousand times greater precision was required to reach the SM prediction. Experiment 787 has so far acquired data with sensitivity (approximately 10^{-9}) to explore the "window" above the SM range for exotic processes like $K^+ \rightarrow \pi^+ + x$ (x represents any unobserved particles, including neutrinos). But, alas, no signal has appeared yet.

These "null" results have strong consequences for non-standard theoretical models in which exotic new particles like "lepto-quarks" occur. (These are exotic, hypothetical objects which have quantum numbers of both leptons and quarks.)

The experiment is continuing to increase the power to observe the decay $K^+ \rightarrow \pi^+ + \nu + \bar{\nu}$ through the development of novel techniques, and instrumentation like the TRIUMF high-speed gallium arsenide CCD digitizers. (These are microchips developed at TRIUMF — see photo above — that can temporarily handle information from detectors, and pass it on to computers, in a way that far surpasses the performance of the old silicon microchips.) We anticipate that we will achieve sufficient sensitivity, during the next few years, in the SM range of predictions, while exploring a thousand times beyond the limits of previous experiments for signs of physics *not* covered by the SM!

(See also HERMES Expt on page 24)

The Significance of Spin

We know that quarks are the basic constituents of both protons and neutrons; and that these, together with electrons, are the building blocks of all atoms. All these particles interact with each other via nature's forces. Formerly, physicists believed that there were only four basic forces in nature—the *gravitational*, the *electromagnetic*, the *weak*, and the *strong* forces (the last two perceptible only at at the level of atoms and their components).

Electromagnetic force arises from the exchange of photons (the quanta of light) between electrons or quarks. The *weak* force is carried between interacting particles by very heavy quanta known as W and Z bosons, roughly 80 to 90 times the mass of the proton.

In the 1980s, particle physicists, through experiments at CERN and Fermilab, firmly established the validity of the standard *"electroweak"* theory. This theory is based on the realization that the *electromagnetic* force, responsible for powering light bulbs and computers in our homes and offices, and the *weak* radioactive decay force, an important component in the power budget of the sun and other stars, are one and the same, and can be described by the same mathematics.

Success in mathematically "unifying" two of these four forces has prompted theorists to consider a still greater possibility—a mathematical grand unification of this *electroweak* force with the *strong* force that holds the quarks permanently inside a proton or neutron. Eventually, this unification should also include the *gravitational* force, but we believe that this will require the concept of "supersymmetry".

To understand supersymmetry better, we must know that particles such as electrons and quarks differ from the force-carrying particles, such as the photon, by a property called *spin*, which is the intrinsic angular momentum carried by a particle. Basically, this is similar to the spin of Earth about its axis, but with an important difference: the spin property is measured in units that allow only for whole numbers or halves ("integer" or "half-integer" spin, in the physics jargon).

So electrons and quarks have half-integer spin and are called fermions; whereas the W and Z particles and photons have integer spin (1) and are called bosons. The unifying principle of supersymmetry theory dictates that the electrons and quarks will also have partners that have spin 0. Similarly, the photon, for example, will have a half-integer spin partner. A large part of the effort at the Large Hadron Collider (LHC), the new accelerator complex being built at CERN, will be to discover these particles.

The theory group at TRIUMF is involved in calculations that quantify the effects of these new hypothetical particles in the rare decay modes of the kaon*, now being investigated in Experiment 787. If the supersymmetric particles mentioned here *do* exist, and are exchanged *in addition to* the exchange of the usual W and Z bosons in the kaon's expected decay into a pion (π^+) and a pair of neutrinos, this additional contribution would *change the expected decay rate.*

This is what makes Experiment 787 such an important one: should its measurements confirm this theoretically calculated decay rate, it will be a signal of new physics, and will have a profound impact on our fundamental understanding of the structure of matter.

* See "Pure Research" section, page 4

TRIUMF Ventures Office

(continued from page 10)

of scientific discovery it cannot be relied on as a long-term shield from competitive alternatives.

The TVO has established a network of contacts with many commercialisation offices throughout North America, and constantly utilizes those contacts in its own activities.

New technology such as that emanating from TRIUMF is, by definition, a high-risk venture. Although projects may appear to have promising potential, from experience it can be predicted that not all of them will actually fulfil expectations. The TVO always takes a conservative approach in projecting current opportunities into future commercial activities.

Applied Programmes

Highlights

Pion Therapy Ends

During the early 1980s, TRIUMF began to investigate a novel form of cancer therapy utilizing the powerful pion beams available here. The basic idea was originally suggested in a paper published in 1963 by Oxford's Professor Don Perkins: the known behaviour of pions as they came to the end of their brief, 26-nanosecond average lifetime, suggested that they could be used to destroy deep-seated tumours, with minimal effects on the surrounding tissue.

TRIUMF's early experiments clarified the ideal dose and frequency of treatments. Two clinical trials began, one concerned with treating brain tumours (glioblastoma) and the other with prostate cancers.

Volunteer patients in both trials were randomly assigned by computer to be treated either with conventional (gamma ray) therapy or with pions. Both trials were completed in 1994, and the results were made known in 1995.

Essentially, although the pion treatments were comparable in many ways to conventional therapy in effectiveness, they had insufficient advantage to warrant continuing the programme. It was felt that some of the resources (of the BC Cancer Agency and other funding sources) used for investigating pion therapy could be turned to another innovation: proton therapy for eye tumours.

The pion cancer therapy programme, therefore, has come to a halt this year, and the beam line has been used in other pion physics experiments. It may, at some time in the future, return to providing prostate cancer treatments.

Since the mid-1980s, TRIUMF was one of only two facilities in the world investigating the treatment of cancer with pions—the only one during the final two years. It treated over 300 patients with this unique form of therapy.

Coming: Proton Therapy for Eye Tumours

The TRIUMF accelerator not only provides an intense beam of protons travelling at 3/4 the speed of light, but also makes it possible for users to tap into the accelerating beam and draw off some of the protons at lower speeds. Protons moving at about one tenth of TRIUMF's maximum velocity are ideal for use in a form of cancer therapy hitherto unavailable in Canada.

Recently, following an agreement between the Mr. & Mrs. P.A. Woodward's Foundation and TRIUMF, the BC Cancer Agency, and the University of British Columbia's Eye Care Centre, we began to construct a proton therapy facility at TRIUMF. The Foundation is funding much of the cost for installing a treatment chair and proton beam line to treat ocular melanomas. Installation is progressing, and we anticipate that the first patient will be treated during the summer of 1995. This will be the only proton cancer therapy centre in Canada.

Positron Emission Tomography ("PET")

During the years, TRIUMF's scientists have focused on developing software, especially in conjunction with the state-of-the-art ECAT 953-B31 PET scanner installed three years ago at the UBC hospital. The earlier model there, built by TRIUMF scientists more than a decade ago, is also still useable.

A New, Contraband Detection System (CDS)

TRIUMF has signed an agreement with the Northrop Grumman Corporation to develop a novel type of contraband detector, useable at airports, docks, post offices, etc. This system would utilize three entirely different areas of TRIUMF technology.

Unlike many current detection systems which rely on X-rays to find drugs or explosives, the TRIUMF system makes use of the fact that these substances contain nitrogen; and nitrogen nuclei strongly absorb gamma rays at a specific wavelength. By scanning a rotating pile of luggage with suitable gamma rays and noting where there is strong absorption, a computer can create a 3-D image of the possible drugs or explosives. To do this, the computer uses software of the kind developed by TRIUMF for creating high-resolution images from PET scans.

TRIUMF is probably the only site in Canada where all these three technologies — proton accelerators (leading to the creation of the needed gamma rays), radiation detection systems, and tomography software—are all in use in different areas, leading to the idea of developing a "combination product".

The TR 30 Cyclotron

The TR 30 is a small, production cyclotron, accelerating protons to 30 MeV. It was designed by TRIUMF staff, built by EBCO Technologies (Richmond, BC), and is owned by NORDION International Inc., whose facilities occupy part of the TRIUMF site.

The TR 30 produces radioisotopes that have applications in medicine and industry. The original design goal for beam current was 350 μA. (Beam current is the electric current actually carried by the stream of protons emerging from the cyclotron, normally measured in microamperes — μA — which are millionths of an ampere.) Since it began operating in 1990, the TR 30 has exceeded by far its design goal, routinely running at 500 μA during this year. This makes it one of the most productive commercial cyclotrons in the world.

This year TRIUMF embarked on an upgrade programme to raise the power of this system even further. To achieve this goal, several component systems had to be developed. Two particular areas receiving attention were the radio frequency system (which provides the power to the "dees" for accelerating the beam), and the hydrogen-ion source and injection system (which insert into the cyclotron's centre its "raw material" — the ions to be accelerated).

We have made excellent progress, and we expect to complete this upgrading by the end of 1995. At that point, we anticipate that the TR 30 will be able to supply 1000 μA (1 milliampere) of beam current, making it an unusually powerful cyclotron system for manufacturing radioisotopes.

The TR-13 Cyclotron

Meanwhile the first model of the TR 13, a small, new, TRIUMF-designed production cyclotron, was commissioned this year. This machine yields a proton beam at 13 MeV, suitable for producing most of the positron-emitting isotopes needed for PET scans. In tests, it provided more than 60 μA of beam current simultaneously to each of two targets, exceeding its design parameters. The first of these machines is owned by the University of British Columbia and will remain at the TRIUMF site, providing radioisotopes for the UBC hospital's imaging centre.

Proton Therapy Facility

As reported under "Applied Programmes", TRIUMF received funding from a private foundation to construct a new facility for treating eye tumours (ocular melanoma) with a proton beam—the first such facility in Canada. This work involves adapting one of the existing beam lines to provide protons in the relatively low energy range required; constructing a treatment room and a control room; developing software for controlling the proton beam; constructing a special treatment chair; and designing and installing various beam control mechanisms along the final few metres of the proton beam's path.

We expect that this work will be completed and the facility in use during the next fiscal year.

A More Powerful Polarized Beam

An optically pumped, polarized ion source ("OPPIS") was tested in TRIUMF's main cyclotron early this year. Normally, when the cyclotron produces a *polarized* beam of protons, the beam current is only a small fraction of that for an unpolarized beam.

OPPIS is intended to increase the beam current substantially, while maintaining a high level of polarization. Early results were 120 μA of current at 78% polarization, and 56 μA at 85%.

ISAC & TRINAT

Despite uncertainty about its future, TRIUMF began the design and construction of facilities required to deliver intense, radioactive ion beams from TISOL to a new location suitable for the TRIUMF neutral atom trap, TRINAT. These facilities include a beam line designed to achieve ultra-high vacuum in the region of the trap, and a temperature-controlled, dust-free room for the system of frequency-stabilized lasers and associated optics used in the trap. March saw the beam line design completed, and a preliminary structural design of the room. We have a detailed schedule with an ambitious objective of demonstrating the trapping of short-lived potassium isotopes by the fall of 1995.

TRIUMF Ventures Office

The TRIUMF Ventures Office (TVO) mandate is the pursuit of all financially and technically viable opportunities for commercializing the technologies evolving from research at TRIUMF, in any appropriate manner that will enhance the Canadian economy. The provincial government provides funding for the TVO.

The objectives of TVO are twofold: to transfer TRIUMF technology to Canadian economy; and to generate income for the applied technology programme at TRIUMF.

The TVO's approach is to identify potentially commercial technologies within TRIUMF, and to encourage those involved to consider the commercial aspects of their work. The researcher must decide between pursuing academic recognition through publication, or the longer-term possibilities and uncertainties of commercialisation.

Success is never guaranteed. It is a "body contact" activity requiring the presence of several factors:

i) high calibre research
ii) industrial "demand pull" for the technology
iii) scientific experts motivated to commercialize the technology
iv) available resources for commercial development.

The TVO is a catalyst in bringing together scientific knowledge and the commercial demand and application. Though TRIUMF's annual operating budget is only about $33 million, its spectrum of research technologies tends to include an atypically high number of industrial opportunities with potential commercial sales of millions of dollars per year. Our technologies currently attracting the most interest from industry are:

- isotope production
- medical imaging using advanced positron emission tomography
- radio frequency drying of agricultural products
- control systems for industrial operations
- environmental protection using cryogenics to eliminate smoke stack emissions
- nuclear techniques for detecting concealed contraband
- cyclotron production
- remote operating vehicle

Our approach is to transfer viable technology into industry, using the most efficient arrangement that recognizes TRIUMF's intellectual ownership, while providing an appropriate return to the laboratory. Five main activities generate such revenue:

a. Consulting services for industry: TRIUMF staff are hired under contract by industrial companies to assist in developing commercial products and processes in which TRIUMF has significant expertise. The objective: to develop products that will ultimately return royalties.

b. Expert staff secondment to and from industry: At industry's request, TRIUMF staff members are placed in companies, and industrial representatives are placed in TRIUMF so that technological know-how can be transferred from TRIUMF to industry, and vice versa.

c. Licence agreements with industry: TRIUMF licenses suitable companies to produce goods or processes developed at TRIUMF. Cumulative sales by TRIUMF's industrial licensees in recent years have totalled close to $100 M.

d. Joint ventures with industry: Where warranted, TRIUMF participates in joint ventures with partners to commercialise TRIUMF technologies. Such arrangements are, however, infrequent because of the downside risk.

e. Start-up companies from TRIUMF staff: When the developers of a new technology or application are interested in starting up their own company to commercialise the TRIUMF technology, this is encouraged under some form of licence arrangement between the parties.

A broad spectrum of technologies evolve at TRIUMF, each with its own window of opportunity for commercialisation. Any technology advance not properly exploited can become stale, and surpassed either technically or economically in the marketplace. Our role at TRIUMF must be the *timely* identification of the technologies followed by appropriate commercialisation that optimises the opportunity.

TRIUMF's strength lies in the unique aspects of the facilities, combined with the scientific excellence of the staff and the research conducted here. Patent protection can be important in identifying a novel technology, but at this level

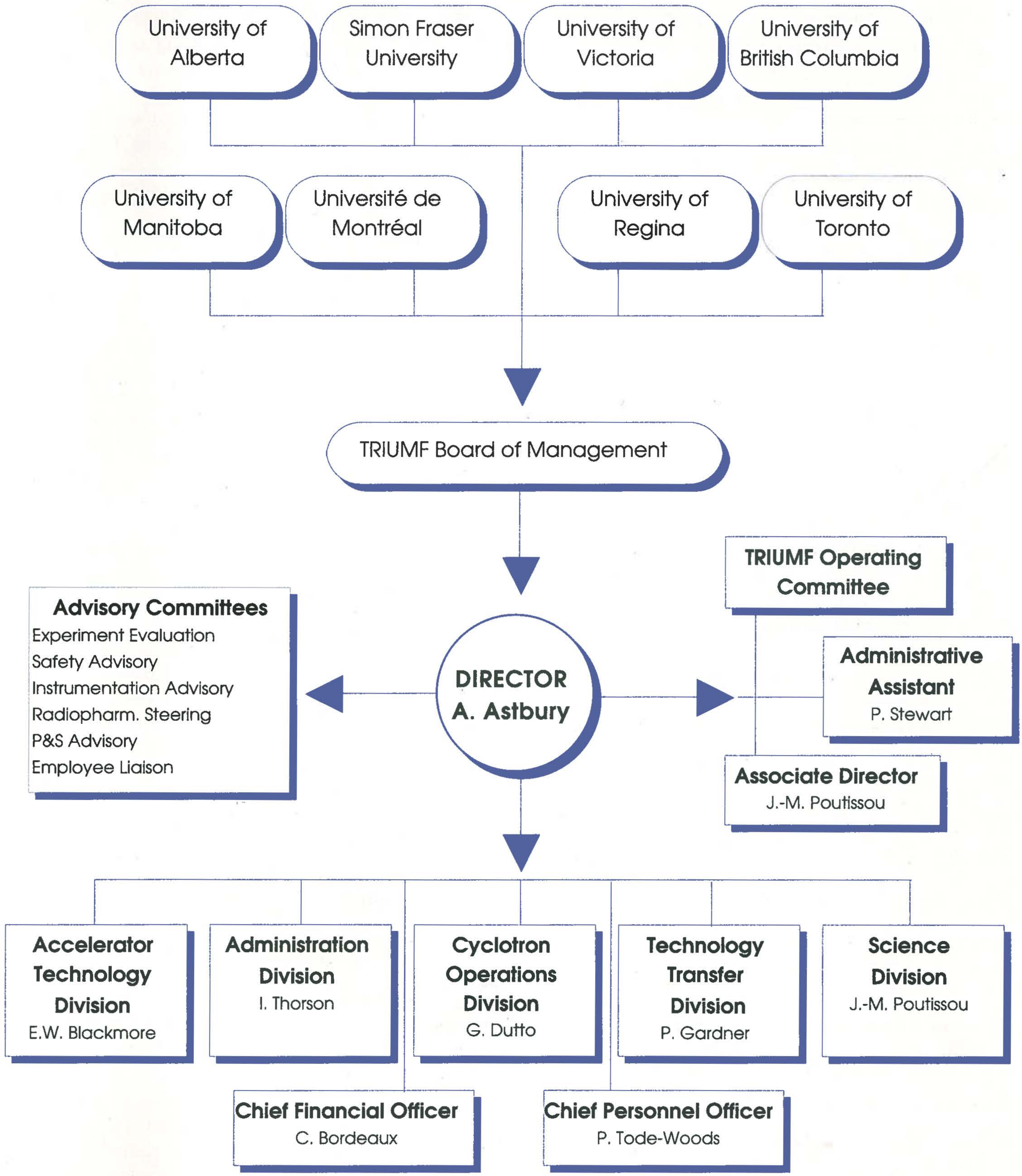
(Continued on page 7)

The table below presents the current status of TVO activities, 1994–95

TRIUMF Technology	*Location of Corporate Partner*	*Type of Commercial Agreement*	*Date of First Revenue*	*Estimated Annual Industry Revenue*
1. Compact commercial cyclotrons	BC	Licence signed	1991	>$2 M
2. Explosives detection system	USA	Development contract	1994	>$1 M
3. Magnet technology	BC	Research	—	—
4. PET calibrating isotopes	BC	Development contract	1994	>$100,000
5. Radio frequency	BC	Under negotiation	1994	n/a
6. Control systems	BC	Development	1994*	n/a
7. Smoke stack emission removal	BC	Licence signed	1994	—
8. Compact commercial cyclotron components	Germany	Purchase order	1993–94	$66,000
9. Pion cancer therapy research	BC Cancer Agency		1987	>300 patients treated
10. Positron emission tomography research	BC	Joint research with UBC Hospital	—	>1500 patients scanned
11. Electronics for lumber industry	BC	Purchase orders	1985	>$10,000
12. Calibrating isotopes	BC	Development	1995	>$100,000
13. Magnet technology for mining industry	Alberta	Lease & assistance	1992	>$1,000
14. Medical isotopes	Ontario	Licence signed	1988	>$15 M
15. Strontium-rubidium isotope production	Ontario	Licence signed	1991	>$1 M
16. Isotope target systems	Ontario	Licence signed	1992	>$100,000
17. Power supply	Ontario	Discussions	1993	—
18. Muon analysis	Japan & Russia	Agreement signed	—	—
19. Remote operating vehicle	BC	Under final negotiation	—	—
20. Strontium production	Russia	Under negotiation	—	—
21. Isotope Research	Russia	Joint research	—	—
22. Automated Blood Sample	USA	Discussions	—	—
23. Proton cancer therapy research	BC Cancer Agency		1994	
24. Radiation Monitors	USA	Sale	1993	$20,000
25. Compact commercial cyclotron components	UK	Purchase order	1994*	$80,000

Notes: 1. "Estimated Annual Commercial Revenue" is a conservative estimate for the current financial year, or projected for the first year of revenue.
2. * indicates a projection based on the best available current information.

Organization Chart



For the Year Ended March 31, 1995

Funding/Income	1995	1994
National Research Council Fund	$ 33,250,000	$ 30,322,000
Natural Sciences & Engineering Research Council Fund	3,771,530	3,854,375
NORDION International Inc. Fund	2,166,732	1,648,330
Affiliated Institutions Fund	3,551,198	2,224,973
EBCO Industries Ltd. Fund	178,680	437,131
Commercial Revenue Fund	969,351	400,486
General Fund	161,159	133,657
	44,048,650	39,020,952
Expenditures		
Buildings	41,093	143,908
Communications	583,645	347,459
Computer	1,756,368	1,115,750
Equipment	3,674,503	1,925,368
Power	1,896,524	1,836,048
Salaries and benefits	27,572,406	26,490,775
Supplies and other expenses	8,399,356	9,211,179
	43,923,895	41,070,487
Excess (Deficiency) of Funding/Income over Expenditures for the Year	124,755	(2,049,535)
Fund Balances — Beginning of Year	1,693,910	3,743,445
Fund Balances — End of Year	$ 1,818,665	$ 1,693,910

From the Auditor

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

AUDITORS' REPORT

To the Board of Management of TRIUMF

We have audited the statement of financial position of TRIUMF as at March 31, 1995 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, 1995 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, 1995
(except for notes 8 and 9
which are as of July 6, 1995)

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]

Statement of Combined Funding/Income and Expenditures and Changes in Fund Balances

The Department of Industry Science and Technology, through the National Research Council, once again provided supplemental funding to augment the National Research Council contribution of $21,686,000. The augmented budget of $33,250,000 allowed the staffing levels to remain constant and enabled the science programme and general operations of TRIUMF to remain stable while awaiting a decision on the proposed Five Year Plan.

The Natural Sciences and Engineering Research Council Common Grant Fund, used to fund experiments at TRIUMF, remained constant when compared to the previous year but the year-end fund balance continues to decrease. Government budget cuts to NSERC funding levels, combined with new NSERC granting rules which make it very difficult for grantees to carry forward any large grant balances, make it likely that future NSERC fund balances will continue to be low.

The number of national and international affiliated institutions using TRIUMF's facilities remained constant although the flow-through of recoveries and expenditures increased dramatically. These increases were due primarily to several larger projects such as HERMES being administered through TRIUMF.

NORDION International Inc. and EBCO Industries Ltd. hold technology transfer licences from TRIUMF which resulted in royalty income of $375,000 and $117,000 respectively. During the year TRIUMF entered into a project with an American aerospace company, resulting in revenues of $378,000 for the 1994–95 fiscal year.

TRIUMF continued to provide facilities, staff and administrative assistance to Canadian research projects whose grants were not administered directly by TRIUMF, such as those of the Medical Research Council, whose grants are channelled through the universities.

Negotiations are ongoing with the federal and provincial governments about the future directions of TRIUMF, and a decision on the proposed Five Year Plan is expected early in the 1995–96 fiscal year. A positive decision will put in place longer-term funding arrangements, allowing TRIUMF to plan its future beyond the end of each fiscal year.

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

	1994–95		1993–94	
SOURCE OF FUNDS	*$ million*	*%*	*$ million*	*%*
National Research Council	33,250	75.4	30,322	77.7
NSERC	3,772	8.6	3,854	9.9
NORDION International Inc	2,167	4.9	1,648	4.2
Affiliated Institutions	3,551	8.1	2,225	5.7
EBCO Industries Ltd	179	0.4	437	1.1
Commercial Revenue	969	2.2	400	1.0
Investment & Other Income	161	0.4	134	0.4
	44,049	100.0	39,020	100.0

TRIUMF

Statement of Financial Position

As at March 31, 1995

	1995	1994
ASSETS		
Cash & Temporary Investments	$ 2,378,950	$ 902,309
Funding Receivable (note 3)	1,765,409	2,209,376
Total Assets	$ 4,144,359	$ 3,111,685
LIABILITIES		
Accounts Payable	$ 874,564	$ 154,583
Deposits from Natural Sciences & Engineering Research Council Fund (note 5)	320,046	455,099
Deposits from Affiliated Institutions	790,680	617,180
	1,985,290	1,226,862
Due to (from) Joint Venturers		
The University of British Columbia	347,634	185,303
The University of Alberta	(13,147)	(4,386)
The University of Victoria	(20,252)	(11,975)
Simon Fraser University	26,169	21,971
	340,404	190,913
	2,325,694	1,417,775
FUND BALANCES		
Restricted		
Natural Sciences & Engineering Research Council Fund (note 5)	118,475	553,475
NORDION International Inc. Fund	100,000	100,000
Affiliated Institutions Fund	16,273	(13,532)
	234,748	639,943
Other		
Commercial Revenue Fund	950,042	628,994
General Fund	(15,210)	–
Intramural Accounts Fund	649,085	424,973
	1,583,917	1,053,967
	1,818,665	1,693,910
Total Liabilities & Fund Balances	$ 4,144,359	$ 3,111,685

Encumbrances and Commitments (note 4)

TRIUMF

Statement of Funding and Expenditures

National Research Council Fund

For the Year Ended March 31, 1995

	1995	1994
National Research Council Funding	$ 33,250,000	$ 30,322,000
TRIUMF Funding		
Contributions from General Fund	–	$ 1,001,590
	$ 33,250,000	31,323,590
Expenditures by Activity Area		
Basic lab operations	5,117,890	4,477,225
Base program development	1,029,187	1,198,699
Base program support	3,920,983	2,950,342
ISAC-1	718,898	86,850
CERN collaboration	189,110	156,782
Salaries and benefits	23,068,625	22,822,610
	34,044,693	31,692,508
Expenditure recoveries	(794,693)	(368,918)
Total Expenditures	33,250,000	31,323,590
Excess of Funding over Expenditures for the Year	$ Nil	$ Nil
Expenditures by Object		
Buildings	$ 34,570	$ 103,908
Communications	533,175	282,849
Computer	1,469,979	751,207
Equipment	2,032,328	773,714
Power	1,896,524	1,836,048
Salaries and benefits	23,068,625	22,822,610
Supplies and other expenses	4,713,396	4,925,806
Salary expenditure recovered	(498,597)	(172,552)
	$ 33,250,000	$ 31,323,590

TRIUMF
NOTES TO FINANCIAL STATEMENTS
For the Year Ended March 31, 1995

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, 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.

The 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 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 on its TRIUMF project.

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

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

Commercial Revenue Fund
Royalties and expenditures relating to commercial activities.

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.

Royalty Income

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

3. **Funding Receivable**

	1995	1994
Natural Sciences and Engineering Research Council Fund	$ 508,623	$ 647,818
NORDION International Inc. Fund	325,159	258,000
Affiliated Institutions Fund	931,627	939,785
EBCO Industries Ltd. Fund	-	363,773
	$ 1,765,409	$ 2,209,376

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:

	1995	1994
National Research Council Fund	$ 610,000	$ 541,000
Natural Sciences and Engineering Research Council Fund	109,000	415,000
NORDION International Inc. Fund	49,000	66,000
Affiliated Institutions Fund	46,000	193,000
Royalty Fund	13,000	6,000
Intramural Accounts Fund	3,000	2,000
General Fund	-	5,000
	$ 830,000	$ 1,228,000

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

	1995	1994
Funding unexpended	$ 438,521	$ 1,008,574
Grant accounts overexpended	(320,046)	(455,099)
Fund balance — end of year	$ 118,475	$ 553,475
Number of grants awarded during year	42	39
Number of grants administered throughout year	91	82

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 $1,482,000 (1994 — $1,554,000).

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.

(continued on page 24)

1995 TUEC

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Members: M. Comyn, M. Hasinoff, K.P. Jackson, A. Trudel
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717 Members — 233 Institutions — 34 Countries

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W. Ontario U.— W.P. Alford

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RIKEN — T. Inamura, T. Matsuzaki, I. Tanihata
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Tokyo U. — P. Birrer, S. Kubono, T. Nagae, K. Nagamine, K. Nishiyama, F. Sakata, M-H. Tanaka, T. Yamazaki
Tokyo Metropolitan U. — H. Nakahara

Kazakhstan Republic

INP — A. Arzumanov

Korea

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Yonsei U. — J.M. Lee

Nepal

Tribhuvan U. — H.P. Risal

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Utrecht U. — D. Yeomans

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Warsaw U. — A. Golnik, A. Sliwinski

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Arkansas U. (Little Rock) — W. Braithwaite, C. Byrd
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CEBAF — D.J. Mack
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Chicago U. — J.W. Truran
Clark U. —D.S. Brenner
Colorado U. — X.Y. Chen, M.D. Holcomb, J.J. Kraushaar, R.J. Peterson, R.A. Ristinen, J. Roy, W.R. Smythe
Columbia U. — K. Kojima, G. Luke, O. Tchernyshyov, T. Uemura

TRIUMF Users' Group—Other Institutions

Duke U. — C. Laymon
Fermilab — S.A. Bogacz
Florida State U. — P. Cottle, L.M. Muga, H.S. Plendl
Georgetown U. — W.S. Rodney
George Washington U. —C. Bennhold, Z. Papandreou
Harvard U. — J. Sisterson
Harvard-Smithsonian Ctr. — P.L. Smith
Hood College — J.M. Stadlbauer
Idaho Nat'l Eng. Lab. — J. Aryaeinejad
Idaho State U. — Z.-Y. Zhou
Illinois U. — P.T. Debevec, A.M. Nathan
Indiana U. — R.D. Bent, J.M. Cameron, W.P. Jones
Johns Hopkins U. — Y.K. Lee
Kent State U. — R. Madey, P. Tandy, J.W. Watson
Kentucky U. — T. Gorringe, C. Jiang, M. Kovash, K. Lin, M.A. Pickar, S.W. Yates, J. Zhou
LAMPF — J. O'Donnell
LANL — P. Barnes, E.P. Chamberlain, W.D. Cooke, M.D. Cooper, A.J. Gancarz, R.E.L. Green, R.C. Haight, R.H. Heffner, C.M. Hoffman, G. Hogan, P.E. Koehler, G.P. Lawrence, L. Le, D.G. Madland, R. Mischke, C.L. Morris, J.R. Nix, B.K. Park, W.F. Sommer, D. Strottman, D. Swenson, W.L. Talbert, T. Talley, J. Ullman, D.J. Vieira, D.H. White
Lawrence Livermore NL — J.A. Becker, S.S. Han, G.J. Mathews, L.S. Pan, T.F. Wang
LBL — J. Batchelder, D.J. Clark, T. Collins, K.M. Crowe, P. Kammel, C.M. Lyneis, M.F. Mohar, D.M. Moltz, C. Naudet, M.J. Nitschke, G. Odyniel, T. Ognibene, T.J.M. Symons
Loma Linda U. — B. Clausen
Louisiana State U. —J.P. Draayer, E.F. Zganjar
Louisville U. — J.S. Chalmers
Marcel M. Barbier Inc. — M.M. Barbier
Maryland U. — N.S. Chant, P.G. Roos, W.B. Walters
Michigan State U. — T. Antaya, F.D. Becchetti, W. Benenson, T. Glasmacher, R.M. Ronningen, B.M. Sherrill
Minnesota U. — D. Dehnhard
Mississippi State U. — R.B. Piercey
MIT — A. Kerman, R.P. Redwine, J. Zhao
New Mexico U. — B. Bassalleck, M.D. Chapman, B. Dieterle, M.A. Frautschi
Notre Dame U. — J. Görres, M. Wiescher
NSCL — M. Hellstrom
Oak Ridge NL — Y.A. Akovali, R.L. Auble, C. Baktash, F.E. Bertrand, J.D. Garrett, D.J. Horen, N. Johnson, C.M. Jones, W. Nazarewicz, D.K. Olsen, M.S. Smith, D.W. Stracener, K.S. Toth
Ohio State U. — R.N. Boyd, K.K. Gan, H. Kagan, R.L. Malchow, S. Shao, C. White
Ohio U. — J. Rapaport
Old Dominion U. — S. Kuhn
Oregon State U. — W. Loveland, A.W. Stetz, L.W. Swenson
Pacific Northwest Labs — P.L. Reeder
Pennsylvania U. — H.T. Fortune, P. Hui, Z. Mao, M. McKinzie, A. Williams
Princeton U. — C.J. Girit, R. McPherson, S. Smith
Rice U. — S.A. Dodds, T.L. Estle
Rutgers U. — C. Glashausser, N. Koller, P. Rutt, G. Thomson
Santa Cruz U. — K. Shaughnessy
SLAC — W.B. Herrmannsfeldt, U. Wienands
SSC Lab — A. Fry, D.P. Gurd, P. Padley, M. Turcotte
Stanford U. — S.S. Hanna
SUNY — G.D. Sprouse, C.-M. Zou
Temple U. — C.J. Martoff, Y. Zhang
Tennessee U. — C. Bingham, M. Halka, L.L. Riedinger
Tennessee Tech. U. —R.L. Kozub
Texas A&M U. — R.A. Bryan, H.A. Schuessler
Texas Tech. U. — D. Lamp, R. Lichti
UCLA — B.M.K. Nefkens, P. Sandler
Utah State U. — V.G. Lind
Valparaiso U. — S. Stanislaus
Vanderbilt U. — D.J. Ernst, W. Ma
Virginia Polytechnic Institute and State U. — M. Blecher, K. Gotow, D. Jenkins
Virginia State U. — M. Blankson-Mills, D. Noakes, C. Stronach
Virginia Tech. — I. Strakovsky
Virginia U. — D.G. Crabb, E. Frlez, S. Hoibraten, Y. Tzamouranis
Washington U. — E.G. Adelberger, M. Alberg, V. Chaloupka, V. Cook, J.G. Cramer, C. Gossett, G.A. Miller, W.G. Weitkamp, W. Haxton
Westinghouse (Hanford) — E.R. Siciliano
William & Mary Coll. — M. Eckhause, W.J. Kossler, R. Pourang
Wisconsin U. — A.B. Balantekin
Yale U. — M. Gai, P. Parker

Uzbekistan

INR, Uzbek. — A. Avezov, A. Melis
NPI, Uzbek. — D. Mirkarimov
Uzbek. Acad. Sci. — A. Azimov, A. Muminov

Yugoslavia

Nucl. Sci. Inst. Vinca — K. Subotic

[Note: Because of ongoing political changes in Eastern Europe, the affiliations and countries of Users' Group members from that area may now be different from those shown. — Editor]

The HERMES Experiment

Physicists have developed a relatively simple model of matter, the so-called "descending staircase": the smallest part of a compound that retains all the properties of the compound is a molecule. Molecules are made up of atoms, which in turn are made up of electrons orbiting a nucleus. A nucleus is composed of nucleons (protons and neutrons), which are made up of even smaller particles, called quarks.

To study the substructure of nucleons, we use a process called *deep inelastic scattering*. Basically, high-energy electrons strike a target of protons and/or neutrons, and we observe the scattered particles. As the energy of a particle increases, it probes smaller and smaller distances; so that at the energy of the HERA storage ring in Hamburg, Germany (home of the HERMES experiment), the electrons can "see" the quark structure.

Of particular interest to physicists at HERMES is the property of the proton called spin. This is a form of angular momentum which appears in quantum mechanics and is a fundamental property of subatomic particles.

How is the spin of the proton related to the spin of its constituents? That is the question HERMES is attempting to answer. Studying this important quantity requires that both the electron beam and the proton target be prepared in special states: they are polarized. (In a polarized group, the particles are all spinning in the same direction, with their axes parallel.) The HERMES spectrometer detects electrons scattered from the polarized nucleon target, determining their energy and the angle through which they are deflected. By comparing the distribution of scattered electrons (in angle and energy) for different polarization states of the beam and the target, experimenters deduce information about the spin of the proton.

These high-energy collisions produce many particles other than the scattered electrons, so it is essential to identify the electrons among the emerging particles. A series of detectors does this job, one of them being a "transition radiation detector" (TRD), designed and built at TRIUMF by Canadian physicists. A TRD identifies electrons by detecting X-rays produced when a highly relativistic particle passes through a special material called a radiator. In the HERMES energy range, only electrons produce these X-rays, so their presence indicates that the associated particle is the one of interest in the scattering process. The TRD is basically a switch: whether it sees or does not see an X-ray tells us whether the particle is or is not an electron. The HERMES TRD contains 12 large (4 m x 1 m x 10 cm) "modules" which consist of a radiator followed by a gas-filled chamber to detect the X-rays. Construction of the TRD began in mid-1993, and the last modules were shipped to DESY on time, in October 1994.

The HERMES spectrometer was completely installed in the spring of 1995 and was then commissioned. Data-taking began in August 1995.

TRIUMF
NOTES TO FINANCIAL STATEMENTS
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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. On June 14, 1995, the Government of Canada announced a commitment of $166.6 million to fund TRIUMF over the next five years. At the same time, the Government of British Columbia announced its contribution of $9.7 million for conventional construction. Management has no reason to believe that ongoing funding from government will not continue into the future after the expiry of the above commitments.

9. **Subsequent Event**

Subsequent to March 31, 1995, TRIUMF has commenced restructuring plans, including a planned staff reduction. Severance costs associated with this reduction are not expected to exceed $3.1 million and will be accrued in the period approved by the Board.