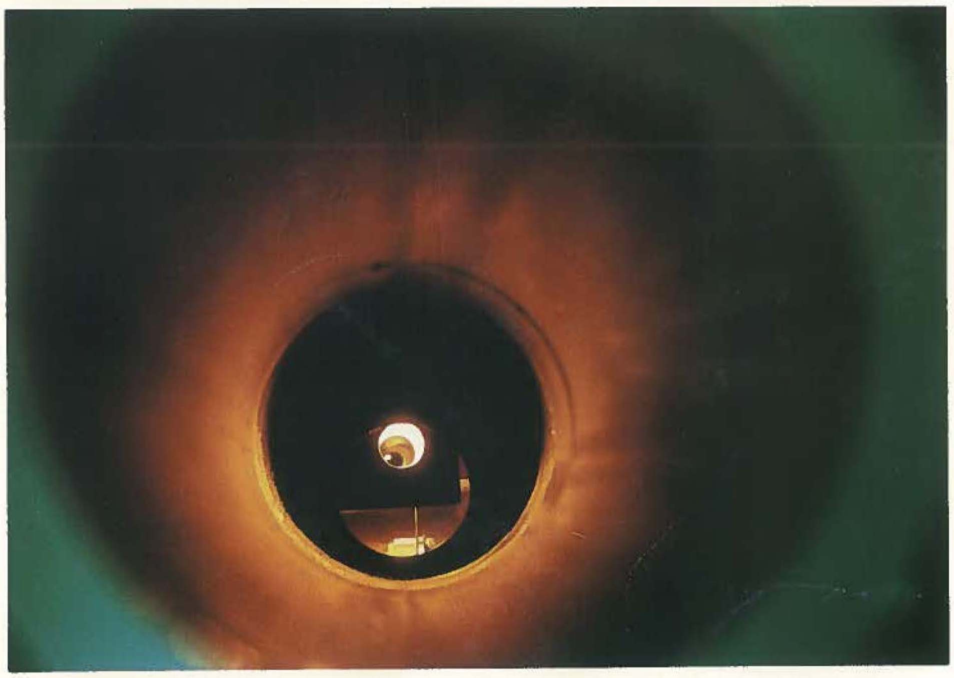
TRIUMF

1993–94

Annual Financial & Administrative Report



including summaries of Pure Research Activities & 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.

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University of Victoria	Université de Montréal
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TRIUMF

FRONT COVER

The "Eye" in TISOL

The photo shows a tantalum target oven under vacuum, glowing at a temperature of about 2000° C. In many cases such a temperature is required to release the produced radioactive species from the on-line irradiated target, and to start it on its way through the TISOL facility (see Pure Research section, page 4).

Photo by Mindy Hapke
TRIUMF Design Office

Contents

The 1993–94 Financial & Administrative Annual Report is prepared by the

TRIUMF Information Office

Editor: Michael La Brooy

We acknowledge the contributions of the following toward the preparation of this annual report: A. Gelbart (organization chart illustration), P. Gardner (TVO), J. D'Auria (Pure Research), H. Fearing (Theoretical Programme), T. Pickles (Cancer Therapy Applications), M. Hapke (photos).

Recycled Paper

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March 1993

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Director's Report

Probing more deeply into matter unfolds our history.

The various primary and secondary beams of the TRIUMF cyclotron facility produce fundamental science and economic spin-offs. The primary goal is to search for what lies at the heart of matter—for the building blocks of nature and the fundamental forces. The knowledge thus gained helps us to understand how our universe has unfolded from its earliest moments, when all matter was very hot and dense, to the present, when we—the products of that unfolding—contemplate the whole process.

The natural history of our universe is the richest, strangest, most complex and most compelling story to emerge from this century of science. All around us we see how stars are born, how they evolve and how they die. Combining these observations with laboratory experiments—at TRIUMF and elsewhere—we can understand how the various elements are created during the life cycle of a star. As described in this report some recent TRIUMF work has provided crucial links needed to understand how carbon and oxygen are created when a red-giant star suddenly goes "off-scale" in its expansion. Such dramatic explosions and the relevant nuclear reactions revealed by the TRIUMF experiments are typical of the way in which nature has fine-tuned the basic building blocks and forces in order to fumble through toward the creation of all the elements necessary for our existence. Or so it seems. As an added benediction, nature has endowed us with that very human sense of wonder evoked when we discover new pieces of the full story.

The TRIUMF enterprise is driven by wonder, plus federal and provincial funds. Each year, in this annual report, we focus on only a small slice of the science and spin-offs emerging from TRIUMF. This year, in addition to the astrophysics we give some hints as to how theory guides modern science at TRIUMF. No one know why that special language, mathematics, should be so extraordinarily effective in our efforts to describe nature. (Perhaps the puzzle is related to how our brains have evolved.) Typically, forays into new areas of science are made with quite complex mathematics. As the knowledge consolidates it usually can be simplified into mathematical forms which are more readily understood and then regarded as scientific verities. The basic verities of science always rest on experiment, and in the end almost only experiment remains. In the course of the drama of science the theorists are often the "rude mechanicals in the rustic play."

It is hoped that the readers of this report, wherever they be found, will derive some satisfaction from cash flows which balanced, from cyclotrons and facilities which operated, from applications which improved our health and our comfort, from technology which leaped into the marketplace and from new ideas in science which justified the year's work.

Erich W. Vogt

The ISAC-1 Project at TRIUMF

The universe, though composed mostly of hydrogen and helium, also contains heavy elements. These are formed in stars, through the gradual accretion of alpha particles to form increasingly massive nuclei, or by the rapid, multiple capture of protons, neutrons, etc. by more medium-sized nuclei—quite often, unstable, radioactive ones. These kinds of interactions are of increasing interest to astrophysicists. How can we study these radioactive larger nuclei? Some of them have half-lives of less than one second!

During the past ten years, a group at TRIUMF has built a facility that can create and isolate many of these interesting, short-lived nuclei of intermediate mass. The equipment is called TISOL (TRIUMF Isotope Separator On-Line).

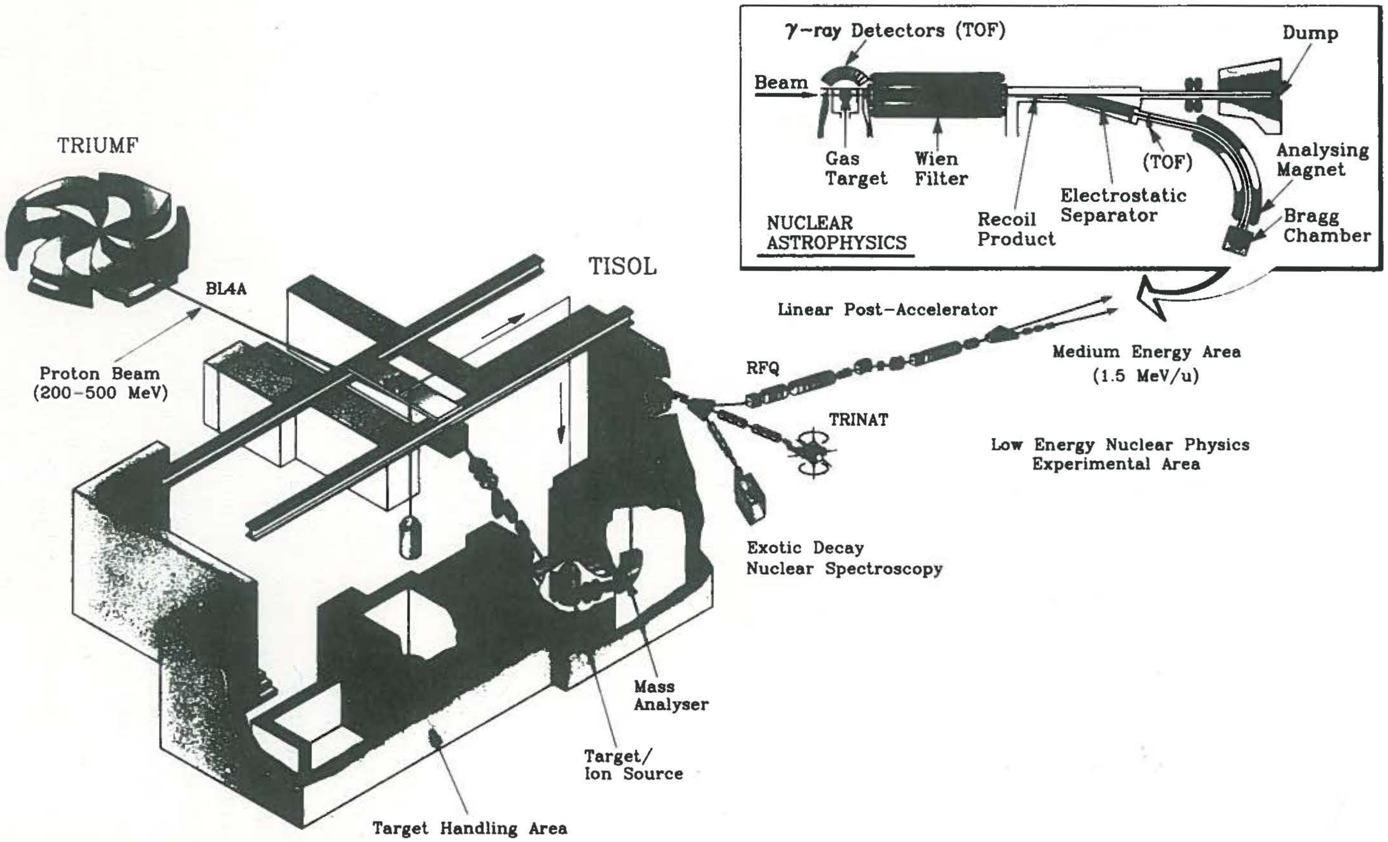
TISOL essentially creates the desired radioactive isotopes by bombarding a suitable target with energetic protons from TRIUMF's cyclotron. It then separates these radioisotopes from others that may be formed simultaneously, and provides them to experimenters as a low-speed beam of particles.

Using TISOL, TRIUMF scientists recently completed a study which helps astrophysicists estimate accurately, for the first time, the ratio of the rates of production of carbon and oxygen in the universe. The key nuclear reactions occur in developing stars; and their nova explosions lead to the release into space of both carbon and oxygen, materials crucial for life as we know it. The TRIUMF project studied the unusual decay of a beam of radioactive nitrogen-16, produced with TISOL. The nitrogen-16 decayed to an excited state of oxygen-16, which then broke down into carbon-12 and alpha particles. By studying these decays, the experimenters were able to estimate the rate of the reverse reaction, through which oxygen is normally formed throughout the universe.

TRIUMF is now poised to construct the next phase—a linear accelerator that will speed up these radioactive particle beams to much higher velocities. Named ISAC-1 (Isotope Separator/ Accelerator), the facility will allow us to simulate reactions which may be occurring when stars explode. While scientists understand the nuclear reactions occuring within many stellar environments, a clear picture of the very hot environments of novae, supernovae, or X-ray bursts has eluded them. We believe that these hot environments lead to reactions involving radioactive species. TRIUMF's ISAC-1 will enable us to simulate and study the very reactions occurring in those nova explosions.

The improvements under way now will lead to the production of very intense, radioactive beams unequalled in any other lab. TRIUMF will, in fact, become one of the world centres for the study of nuclear astrophysics and element synthesis in the universe. For example, a pressing question at present involves the intensity of the neutrinos we observe coming from the sun. The expected intensity is based upon our understanding of the reactions that occur in stars, and we use the so-called "solar model" to calculate this intensity. (This model has successfully predicted the observed distributions of the elements in the universe.) From our observations on earth, however, we find the solar neutrinos have an intensity far less than we expected. We need to know why.

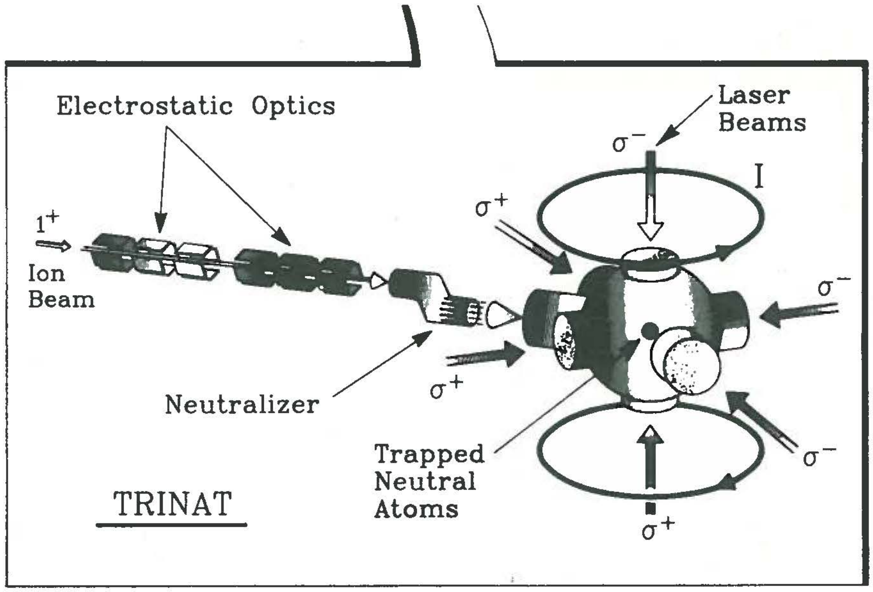
In addition to studying explosive events in the universe, scientists using ISAC-1 will also explore the mysteries of the "Standard Model" (a term used to describe the current theory covering the relationships between all the known elementary particles and forces). This model attempts to provide us with a clear picture of the ultimate basis of all matter. It describes and explains unusual entities like quarks, gluons, and kaons. Physicists at various high-energy accelerators around the world test the limitations of this model: seeking new particles, they use a "brute force" approach to shatter the nucleus and reveal its inner secrets. (A recently cancelled American project, the Superconducting Super Collider, was being built for this purpose.) However, an alternative approach is to do very sensitive, clever studies at much lower energies, in order to probe the limits of the Standard Model. A major study along these lines is in progress at TRIUMF using the existing equipment to create different types of radioactive beams. For example, by producing significant amounts of the short-lived radioactive species potassium-37, then trapping its atoms with laser light beams and lining them up in a specific direction, TRIUMF scientists can study how this potassium nucleus emits particles, and from this they can test the



ISAC-1

Pure Research

predictions of the Standard Model. In another study, intense beams of the radioactive element francium will be trapped with laser light. A study of some rare atomic transitions will reveal parameters of the Standard Model that complement (but do not duplicate) studies from high-energy accelerator labs. These rare atomic transitions are effected by the electroweak interactions and their intensity is a measure of this interaction. The figure shows this new experimental facility, called TRINAT (TRIUMF Neutral Atom Trap).



What shapes might a nucleus have? This question has fascinated scientists for many years. Although many nuclei are spherical, they exhibit essentially not just one shape, but different shapes ranging from doorknobs to cigars. Scientists now are exploring even more exotic shapes, e.g. banana-like (referred to as "super deformation"). Such weird objects can be found, perhaps, as we approach the point where a particular collection of neutrons and protons in the nucleus becomes unstable and can exist only briefly.

Out there, at the limits of stability, we might observe some very unusual phenomena. We already know that a few nuclei at the limits display a different distribution pattern for their neutrons and their protons. It is not entirely clear why this happens, and we need more examples and studies to explore these strange possibilities. At ISAC-1 we shall make these nuclei, at the limits of particle stability, in greater amounts than anywhere else in the world, and this abundance will allow us to probe a region hard to explore elsewhere.

Performing these world-class and significant studies will require the highest radioactive beam intensities available in the world. The new ISAC-1 will provide just that. It will utilize the very intense, intermediate-energy proton beam from the TRIUMF cyclotron to produce many species of interest. Using the knowledge gained since 1985 with TISOL, we will extract these species of interest in a new ISOL facility. Then, as needed, we will accelerate these heavy ions to the desired velocities to perform the studies.

ISAC-1 will significantly increase the types of projectiles available at TRIUMF. These species can be used for a wide range of studies over and above those mentioned earlier, and the range of applications can include material science, industrial uses, atomic physics, surface science, nuclear structure explorations of very deformed nuclei, and many more.

ISAC-1 will be available in about four years, and will involve both new and old technology. It will bring linear accelerators to TRIUMF for the first time, increasing the expertise on-site. Scientific teams are gearing up to meet the challenge of these very complex experiments, and we expect the infrastructure developed by these increased TRIUMF scientific activities to benefit planned studies at laboratories around the world.

TRIUMF's Mental Gymnasium . . .

Theoretical Programme

Any scientific endeavour like TRIUMF has always been a partnership between experimentalists and theorists. Each group brings its own particular skills and interests to bear on the problems being investigated. Experiment is the ultimate arbiter, as it tells us how things really are rather than how we wish they were, and occasionally it generates a big surprise—some new and totally unexpected phenomena.

Theory, however, usually provides the real and fundamental understanding of the way things work: theoretical models can explore details which we can never hope to verify directly by experiment. To the extent that the measurable predictions of these models check out, we can say that we have come to understand the physical phenomena being studied.

From the very beginning TRIUMF recognized this partnership between theory and experiment. The theory group, formed very early in TRIUMF's history, now has four staff members, about eight research associates and several students and visitors. They investigate a huge variety of topics. Some relate directly to experiments being done at TRIUMF, or by TRIUMF people elsewhere. Some have been stimulated by puzzling results of TRIUMF experiments. Some deal with areas of general interest to the subatomic community. We can mention only a few, to reveal a glimpse of the flavour and colour of the theorist's activities.

Ultimately, TRIUMF science aims to understand the nature of matter and the forces holding its various parts together. We now believe, with good reason, that all matter is made up of quarks—peculiar particles with fractional charges. Quarks have an overwhelming affinity for their fellows, so much so that we never see them alone. We think we also know the equations which describe this system, the so-called "Lagrangian of quantum chromodynamics" or QCD. The "quantum" and "dynamics" simply refer to the fact that one uses quantum, rather than classical, physics to describe the quark interactions. The "chromo" refers to the physicist's rather whimsical choice of colour names to describe some of the properties of the quarks.

But we have a difficulty: these equations cannot yet be solved, so we have to try various approximation schemes. "Chiral Perturbation Theory" or ChPT, is one approach which has attracted a lot of interest recently. We know the fundamental symmetries of QCD, so the idea is to write down the most general interaction which possesses these symmetries, and which thus should contain QCD. It involves a number of parameters which initially must be evaluated from experiment. Once these are known, ChPT can predict a huge number of results. To obtain such results, however, we must still make an approximation, known as a "perturbation" expansion. This means that we arrange the pieces of the calculation so that the largest and most important ones are calculated first, with subsequent pieces getting smaller and smaller, until at some point we can quit and neglect the remaining small (and hard-to-calculate) pieces. Some of the important predictions of this approach are pion-pion scattering lengths, quantities describing the low-energy scattering of pions. TRIUMF experimenters have performed a very valuable set of experiments here to measure these quantities, an excellent illustration of how experiment and theory work together.

Several people in the Theory Group are also investigating another approach to the solution of the QCD equations. It is known as "lattice gauge theory". The complete solution would hold for all points in space and time, and thus would have an infinite number of degrees of freedom—far too many for even our most powerful computers. One approach, then, to approximating this is to divide space and time into a finite lattice of points. We then try to solve the equations approximately, only for these lattice points. Ultimately, as the lattice grid becomes finer and finer, the result should approximate the true solution. Even with the fastest computers and with relatively small grids, typically 20 points on a side, this becomes a formidable task. (In fact, this area of research is one of the forces driving the development of supercomputers.) Still, we get many interesting, detailed predictions from such an approach, which can then be compared with experiment.

(Continued on page 10)

Positron Emission Tomography ("PET")

In recent years, TRIUMF's scientists have focused on software development for use with today's most advanced PET equipment. They have been working on read-out systems and analysis algorithms for the huge amount of information gathered during each PET scan.

New Small Cyclotrons

The TR13 cyclotron at TRIUMF (owned by the University of British Columbia), originally designed to provide 13 MeV protons, was shimmed to deliver beams at 19 MeV.

Taiwan had purchased a TR30/15. The machine was built and tested at TRIUMF, then commissioned and installed in Taiwan.

TRIUMF is developing a new data-acquisition system, based on VME, in collaboration with other laboratories. TRIUMF's specialists developed an analysis software package, "PHYSICA".

Cancer Therapy

This was a stimulating and demanding year. Our efforts have been directed at continuing the randomized studies with negative pions. In addition we have embarked on the development, construction, and more recently the commissioning of a proton treatment facility.

Cancer therapy with pions is an experimental treatment, in use at TRIUMF for over a decade. A beam of negatively charged, low-energy pions is focused on a tumour, usually in the brain or abdomen of the patient. Radiation generated by this process (as the pions interact with atomic nuclei within the tumour) destroys nearby cancer cells with minimal damage to more distant, healthy cells.

Pion therapy

During this year a further 47 patients were entered into our two randomized studies, which compare the effects of pions with controls treated with conventional radiation. Both these studies have now been running for several years and we hope that they will be completed by the end of 1994.

Prostate cancer: This study is assessing the long-term local control of locally advanced prostate cancer (stages C and D1). Conventional therapy for these patients is associated with local recurrence rates of 30–40%. The inherent resistance of these cancer cells to therapy probably causes this. We hope the biological advantages seen in the laboratory with pions will translate into a reduced recurrence rate. Of the 39 patients randomized during the year, 18 were allocated pion therapy. A total of 170 patients out of a required 210 has now been recruited to the study. We have not yet performed an interim analysis of outcome; but an analysis of the toxicity of the two forms of treatment shows no significant difference in either severity or incidence of complications between the two groups.

Astrocytomas: A parallel study is looking at the treatment of high-grade brain tumours (anaplastic astrocytoma and glioblastoma). These tumours are never cured, and conventional therapy provides only temporary benefit, so that the average survival from diagnosis is around 11 months. Once again, the main cause of treatment failure is tumour recurrence due to inherent radio-resistance. Eight further patients joined the 65 already treated, for a total of 73 to date. The first results from this study should be available by the end of 1994.

Proton Therapy

In April 1993 the Mr & Mrs P.A. Woodward Foundation provided $500,000 to construct a proton treatment facility for treating ocular melanomas. These rare tumours are usually treated by removal of the eye, or by radioactive implant. All patients treated in the first manner will lose vision, and some of those treated with implants will also do so. We hope that proton therapy will lead to some patients retaining their vision. Constructing the facility has proved to be a major undertaking, involving collaboration at all levels between TRIUMF, the BC Cancer Agency and the BC Research Centre. Over this year we progressed from the basic design of the beam-line equipment to its construction and installation.

Cyclotron Performance and Developments

• The Cyclotron Division achieved an impressive beam availability (by hours of running) for scheduled beam, both for unpolarized (89.5%) and for polarized (92.8%) running. They delivered 86% of the scheduled microampere-hours. Improved machine-and beam-line reliability may allow routine operation of the cyclotron with beam current above the present 140 microampere level.

• In the fall shutdown, the magnetic channel MC3 was tested successfully.

• Upgrading of beam line 1A continued and, with the installation of an improved rf booster in the 1994 spring shutdown, 200 microampere operation in this beam line was anticipated by the end of 1994.

• The controls system upgrade continued, with the first NOVA computer due for replacement by the end of 1993. The upgrade will be completed in another two years.

• Work continued on the design of a new rf control system and on improved beam stability and quality.

• Work was performed on ISAC design and prototyping.

• Future work will focus on the design of a new rf amplifier system and the vertical section of the ISIS transmission line.

• To support experiments in charge symmetry-breaking, the intense ion source, OPPIS (I4), was upgraded, and a frozen-spin target was completed and used successfully. (The OPPIS hydrogen ion source is the origin of the polarized beams accelerated in the cyclotron.) OPPIS delivered 5 μA extracted at 80% polarization, or 10 μA at 75%. Transition times of 1.0 ms for spin UP –> DOWN and 0.5 ms for UP/DOWN –> OFF were achieved. Current and energy resolution, and stability, are essential for the parity experiment, and are being improved.

Other Areas

• The CHAOS team commissioned the spectrometer, and began taking data in their first experiment. They had further runs early in 1994.

• The second-arm spectrometer (SASP)—the non-identical twin of the MRS spectrometer on the proton hall—had been tested, assembled and lowered into its place alongside the MRS in March 1994. This year, this spectrometer was completely installed, and commissioning plus initial data-taking began.

• The new beam line for the Parity experiment (4A2) was installed during the fall shutdown.

• An extensive polarized helium-3 programme was mounted at TRIUMF and LAMPF.

• The installation of the M9B extension (an improvement to one of the main muon beam lines in meson hall), during the spring shutdown gave a tenfold reduction of the neutral background at the experimental target. This was a joint venture with the University of Tokyo. (Experiments were performed on negative μSR, muon capture and muon-catalysed fusion.)

• TRIUMF's detector-building staff were very productive. In support of external experiments, they created a new clean room for fabricating transition radiation detectors for the HERMES experiment at DESY, in Hamburg, Germany. A new drift chamber and CCD systems were also constructed for experiment #787 at Brookhaven, USA.

TRIUMF Ventures Office

Now in its third full year of operation, the TRIUMF Ventures Office (TVO) has the mandate of pursuing all financially and technically viable opportunities to commercialize the technologies evolving from research at TRIUMF. This mandate has two aspects: to transfer TRIUMF technology to industry, and to generate income for the applied technology programme at TRIUMF.

The Provincial Government has funded the TVO. TRIUMF had been developing technology since its inception in the late 1960s, but the general funding arrangement with the federal government (which restricted the application of federal funds strictly to research and to the operation of the cyclotron) limited any possible commercialization activity. Now TVO identifies potentially commercial technologies existing within TRIUMF, and also encourages the scientists, engineers and technicians to consider the commercial aspects of their work.

Success depends on several factors: high-calibre research, industrial "demand pull" for the technology, scientific experts motivated to commercialize the technology, and available resources for commercial development. The TVO has endeavoured to fulfill the role of catalyst between the generators of scientific knowledge and the commercial demands and applications. Its strength lies in its access to the very high-calibre scientific research pursued at TRIUMF—a spectrum of technologies that includes an atypically high number of industrial opportunities with potential commercial sales of millions of dollars annually.

The following TRIUMF technologies currently attract the most interest from industry:

- isotope production
- medical scanning and imaging using advanced positron emission tomography
- medical diagnostics using innovative isotopes and techniques
- radio-frequency drying of wood products
- control systems for industrial operations
- environmental protection using cryogenics to eliminate smoke stack emissions
- nuclear techniques for detecting concealed explosives
- cyclotron production
- remotely operated vehicle

The TVO approach is to transfer viable technology into industry, using the most efficient arrangement that will recognize TRIUMF's intellectual ownership, while providing an appropriate return to that owner.

Theoretical Programme (continued from page 7)

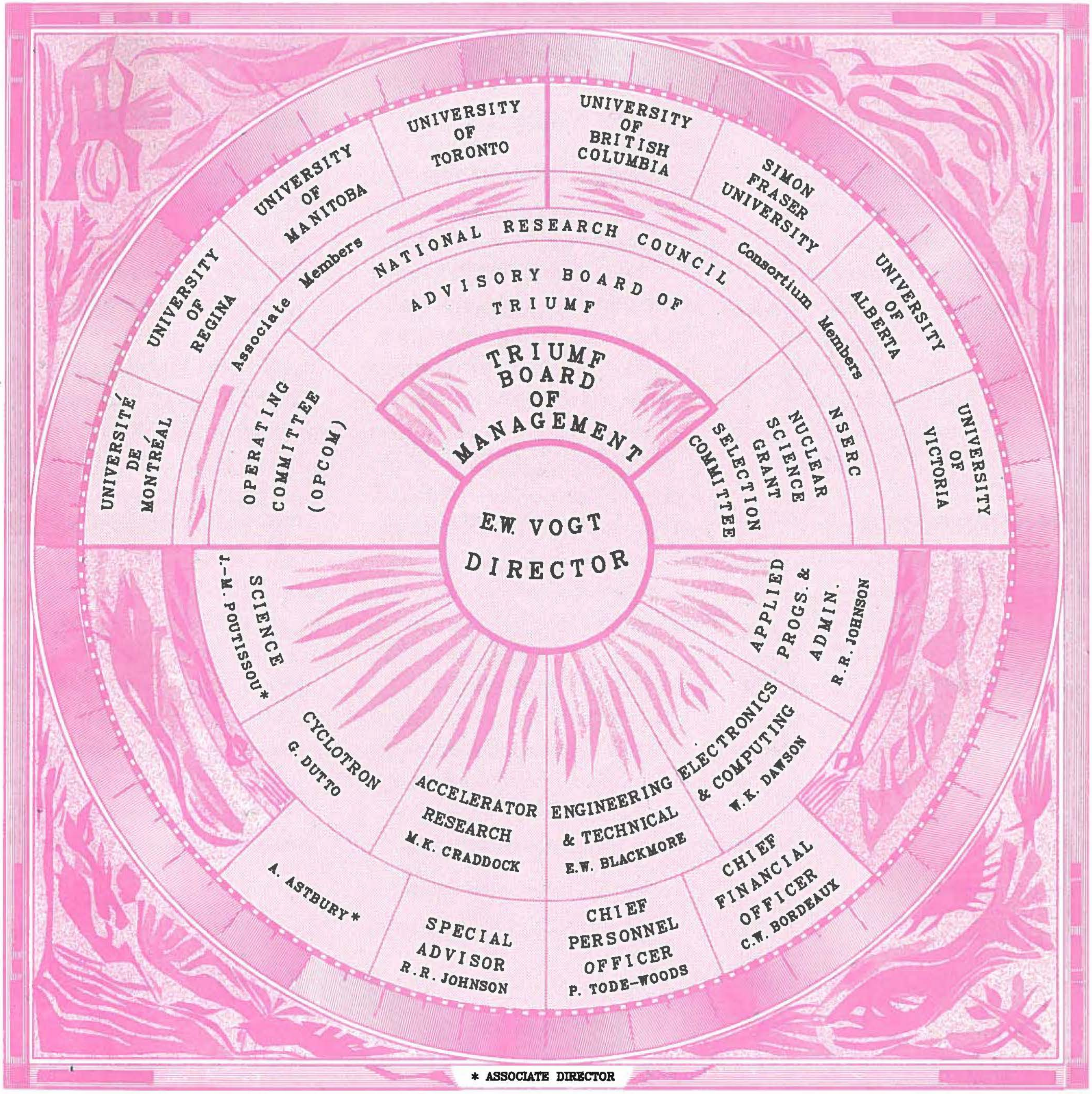
These are only two of the many areas of interest to members of the Theory Group. We also study pion-nucleon and nucleon-nucleon processes, hypernuclei (those nuclei containing particles such as the lambda or sigma hyperon), rare decays of kaons and other particles, symmetry principles, reactions of few-body systems, and some of the properties of condensed matter which can be explored with muons. Interested readers can find more detailed summaries of many of these projects in the TRIUMF Annual Scientific Report, and see how the theorists work in partnership with their experimental colleagues to help us all understand the very interesting science of the TRIUMF programme.

SUMMARY OF CURRENT TRIUMF TECHNOLOGY TRANSFER PROJECTS, 1993–94

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. Contraband detection system	USA	Development contract	1994	>$1 M
3. Magnet technology research	BC	Under negotiation	—	—
4. PET calibrating isotopes	BC	Development contract	1995*	>$100,000
5. Radio frequency	BC	Under negotiation	1994	n/a
6. Control systems	BC	Development	—	n/a
7. Smoke stack emission removal	BC	Licence signed	1996*	—
8. Compact commercial cyclotron components	Germany	Purchase order	1993–94	$66,000
9. Pion cancer therapy research	BC Cancer Institute		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. Magnet technology for mining industry	Alberta	Lease & assistance	1992	>$1,000
13. Medical isotopes	Ontario	Licence signed	1988	>$15 M
14. Strontium-rubidium isotope production	Ontario	Licence signed	1991	>$1 M
15. Isotope target systems	Ontario	Licence signed	1992	>$100,000
16. Power supply	Ontario	Discussions	1993	—
17. Muon analysis	Japan & Russia	Agreement signed	—	—
18. Remote operating vehicle	BC	Letter of Intent signed	—	—
19. Strontium production	Russia	Under negotiation	—	—
20. Isotope Research	Russia	Joint research	—	—
21. Automated Blood Sample	USA	Discussions	—	—
22. Proton cancer therapy research	BC Cancer Institute		1995	
23. Radiation Monitors	USA	Sale	1993	$20,000
24. Compact commercial cyclotron components	UK	Purchase order	1995	$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



Financial Review

We received $8,875,000 from the Department of Industry Science & Technology, through the National Research Council, as a supplement to the base budget of $21,447,000. This allowed staff levels to remain constant and enabled the science programme to remain stable.

Funding of experiments via the TRIUMF Common Grant from the Natural Sciences and Engineering Research Council decreased by $706,125 (15.5 %). This reduced funding contributed to a lower-than-normal fund balance at year-end. NSERC awards additional funds for experiments at TRIUMF to grantees at member or affiliated universities, but those amounts are not known to us as the appropriate universities account for them.

The Medical Research Council (MRC) continues to award grants for TRIUMF-related experiments, but channels those through universities only. Again, we are not informed of the amounts granted. The major experiment related to the MRC is the Positron Emission Tomography project under the leadership of Dr. Tom Ruth.

The number of institutes, both national and international, using TRIUMF's facilities remained relatively constant. Expenditures undertaken on their account fell by approximately 24%, but this does not affect TRIUMF's finances.

Nordion International Inc.'s use of the TRIUMF facility was comparable with the previous year. Ebco Industries Ltd.'s use of TRIUMF services decreased because no new sales occurred, and this reduced our royalty revenue. Both Nordion and Ebco have technology transfer licences from TRIUMF, resulting in $400,486 in royalty income.

Negotiations are ongoing with both the federal and the provincial governments about the future direction of TRIUMF. The prolongation of these discussions has necessitated annual supplements to TRIUMF's operating budget for several years. We expect that solutions to this ad hoc financing will be forthcoming, and that long-range planning can be restored eventually.

C.W. Bordeaux
Chief Financial Officer

SOURCE OF FUNDS	*1993–94*		*1992–93*	
	$ million	*%*	*$ million*	*%*
National Research Council	30.3	77.7	31.2	73.1
NSERC	3.9	9.9	4.6	10.7
NORDION International Inc.	1.7	4.2	1.9	4.6
Affiliated Institutions	2.2	5.7	2.9	6.8
EBCO Industries Ltd.	0.4	1.1	1.1	2.5
Royalty Fund	0.4	1.0	0.8	1.8
Investment & Other Income	0.1	0.4	0.2	0.5
	39.0	100%	42.7	100%

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, 1994 and the statements of funding and expenditures and changes in fund balances for the year then ended. These financial statements are the responsibility of TRIUMF's management. Our responsibility is to express an opinion on these financial statements based on our audit.

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

In our opinion, these financial statements present fairly, in all material respects, the financial position of TRIUMF as at March 31, 1994 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.
June 3, 1994

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

TRIUMF

STATEMENT OF COMBINED FUNDING AND EXPENDITURES AND CHANGES IN FUND BALANCES

For the Year Ended March 31, 1994

FUNDING	1994	1993
National Research Council	$ 30,322,000	$ 31,260,000
Natural Sciences & Engineering Research Council	3,854,375	4,560,500
NORDION International Inc.	1,648,330	1,946,739
Affiliated institutions	2,224,973	2,909,827
EBCO Industries Ltd.	437,131	1,068,660
Royalty Fund	400,486	771,405
General Fund	133,657	222,574
	39,020,952	42,739,705
EXPENDITURES		
Buildings	143,908	80,388
Communications	347,459	289,592
Computer	1,115,750	1,843,602
Equipment	1,925,368	2,336,646
Power	1,836,048	1,754,981
Salaries and benefits	26,490,775	26,004,862
Supplies and other expenses	9,211,179	9,366,562
	41,070,487	41,676,633
Excess (Deficiency) of Funding over Expenditures for the Year	(2,049,535)	1,063,072
Fund Balances — Beginning of Year	3,743,445	2,680,373
Fund Balances — End of Year	$ 1,693,910	$ 3,743,445

TRIUMF

STATEMENT OF FINANCIAL POSITION

As at March 31, 1994

	1994	1993
ASSETS		
Cash & Temporary Investments	$ 902,309	$ 4,149,436
Funding Receivable (note 3)	1,137,097	1,736,476
Total Assets	$ 2,039,406	$ 5,885,912
LIABILITIES		
Accounts Payable	$ 154,583	$ 1,062,940
Due to (from) Joint Venturers		
The University of British Columbia	185,303	1,074,013
The University of Alberta	(4,386)	2,935
The University of Victoria	(11,975)	(709)
Simon Fraser University	21,971	3,288
	190,913	1,079,527
	345,496	2,142,467
FUND BALANCES		
Restricted		
Natural Sciences & Engineering Research Council (note 5)	553,475	1,346,111
NORDION International Inc.	100,000	100,000
Affiliated institutions	(13,532)	(18,215)
EBCO Industries Ltd.	–	(192,915)
	639,943	1,234,981
Other		
Royalty Fund	628,994	857,725
General Fund	–	817,042
Intramural accounts	424,973	833,697
	1,053,967	2,508,464
	1,693,910	3,743,445
Total Liabilities & Fund Balances	$ 2,039,406	$ 5,885,912

Encumbrances and Commitments (note 4)

TRIUMF

STATEMENT OF FUNDING AND EXPENDITURES

NATIONAL RESEARCH COUNCIL

For the Year Ended March 31, 1994

	1994	1993
FUNDING		
NRC Contributions	$ 30,322,000	$ 31,260,000
Transfer from General Fund	1,001,590	–
	31,323,590	31,260,000
EXPENDITURES BY ACTIVITY AREA		
Salaries	22,822,610	21,988,048
Administrative and overhead	1,965,040	1,954,478
Power	1,836,048	1,754,981
Cyclotron and facilities operation	1,798,852	2,256,903
Support services	1,172,532	1,698,138
Major projects	817,877	812,127
Site services	749,911	689,680
Minor projects and development	501,813	732,402
	31,664,683	31,886,757
Funds recovered — salaries and cost centres	(341,093)	(626,757)
Total Expenditures	31,323,590	31,260,000
Excess of Funding over Expenditures for Year	$ Nil	$ Nil
EXPENDITURES BY OBJECT		
Buildings	$ 103,908	$ 54,718
Communications	282,849	255,322
Computer	751,207	1,439,646
Equipment	773,714	1,298,291
Power	1,836,048	1,754,981
Salaries and benefits	22,822,610	21,988,048
Supplies and other expenses	4,925,806	4,962,681
Salary expenditure recovered	(172,552)	(493,687)
	$ 31,323,590	$ 31,260,000

TRIUMF

NOTES TO FINANCIAL STATEMENTS

For the Year Ended March 31, 1994

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

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

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

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

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

Royalty Fund
Royalties and expenditures relating to commercial activities.

General Fund
Investment income for discretionary expenditures incurred by TRIUMF.

Intramural Accounts
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**

	1994	1993
Natural Sciences and Engineering Research Council	$ 192,719	$ 266,975
NORDION International Inc.	258,000	251,836
Affiliated Institutions	322,605	468,480
EBCO Industries Ltd.	363,773	749,185
	$ 1,137,097	$ 1,736,476

Funding receivable from affiliated institutions comprises —		
Funding receivable	$ 939,785	$ 1,414,243
Less: Funding received in advance	(617,180)	(945,763)
	$ 322,605	$ 468,480

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:

	1994	1993
National Research Council	$ 541,000	$ 379,000
Natural Sciences and Engineering Research Council	415,000	65,000
NORDION International Inc.	66,000	9,000
Affiliated Institutions	193,000	58,000
EBCO Industries Ltd.	–	7,000
Royalty Fund	6,000	30,000
General Fund	5,000	5,000
Intramural Accounts	2,000	182,000
	$ 1,228,000	$ 735,000

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

	1994	1993
Funding unexpended	$ 1,008,574	$ 1,689,884
Grant accounts overexpended	(455,099)	(343,773)
Fund balance — end of year	$ 553,475	$ 1,346,111
Number of grants awarded during year	39	44
Number of grants administered throughout year	82	97

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 $1,554,000 (1993 — $1,442,000).

7. **Contingent Liability**

During the year ended March 31, 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 as a prior period adjustment, if material, against the Royalty Fund.

1994 TUEC
(TRIUMF Users' Executive Committee)
Chairman: B.K. Jennings
Chairman Elect: J.D. King
Members: R. Baartman, M. Comyn, J. Doornbos, K.P. Jackson
Past Chairman: W.T.H. van Oers
Liaison Officer: M. La Brooy

TRIUMF Users' Group

497 Members — 158 Institutions — 28 Countries

TRIUMF

M. Adam
W. Andersson
A. Altman
P.A. Amaudruz
W. Andersson
D. Axen
R. Baartman
S. Baer
M.J. Barnes
C. Bennhold
J.L. Beveridge
E.W. Blackmore
C.W. Bordeaux
J. Brack
P. Bricault
D.A. Bryman
K. Buckley
J.W. Carey
G. Chadwick
C. Chen
M. Comyn
M.K. Craddock
J. Cresswell
W. Cummings
P. Delheij
J. Doornbos
F. Duncan
G. Dutto
W. Faszer
H.W. Fearing
R.J. Garisto
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D.R. Gill
M. Gingras
P. Gumplinger
M. Hahn
O.F. Hausser
R. Helmer
R. Hilton
A. Hosaka
A.C. Hurst
D.A. Hutcheon
B.K. Jennings
R.R. Johnson
G. Jonkmans
T. Kadantseva
R. Keitel
M. Kermani
R.F. Kiefl
P. Knowles
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S.R. Koscielniak
C.J. Kost
M. La Brooy
G.K.Y. Lam
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P. Levy
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W. Lorenzon
J. Lu
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G. Marshall
S. McFarland
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B. Milton
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T. Numao
A.J. Otter
D. Ottewell
B.P. Padley
J.J. Pan
G. Poulis
J.M. Poutissou
R. Poutissou
M.A. Punyasena
A. Ramos
K.J. Raywood
G. Redlinger
J.G. Rogers
L.Root
J. Roy
T.J. Ruth
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S. Scherer
P. Schmor
H.R. Schneider
J.W. Schneider
R. Schubank
M. Senba
M. Sevior
K-S. Sim
G. Smith
J.E. Sonier
V. Sossi
N. Stevenson
G. Stinson
I.M. Thorson
H. Trottier
A Trudel
S. Veillette
E. Venczel
V.K. Verma
M. Vetterli
J.S. Vincent
E.W. Vogt
G.D. Wait
P. Walden
K. Warman
G. Waters
N. Wilkinson
R. Woloshyn
D.H. Wright
S. Yen
You Ke
M. Zach
M. Zhong

CONSORTIUM MEMBERS

U. of Alberta
R. Abegg
W.K. Dawson
P. Green
L.G. Greeniaus
P. Kitching
N. Kolb
E. Korkmaz
J. Li
W.J. McDonald
P. McNeely
T. Nakano
W.C. Olsen
A.K. Opper
G. Roy
F.M. Rozon
H. Sherif
J. Soukup
T. Stocki

Simon Fraser U.
B. Addison-Jones
M.S. Atkins
J. Brodovitch
J.M. D'Auria
M. Dombsky
R. Harrop
K.P. Jackson
P.W. Percival

U. of Victoria
A. Astbury
G.A. Beer
T.A. Hodges
R. Keeler
D.E. Lobb
G.R. Mason
A. Olin
C.E. Picciotto
P.R. Poffenberger
P.A. Reeve
L.P. Robertson

U. of B.C.
I. Affleck
A. Ambardar
D. Arsenau
J.H. Brewer
K. Chow
T. Duty
D.G. Fleming
S. Gil
M.D. Hasinoff
J. Hoey
P. Hoffman
S. Johnston
G. Jones
W. Keil
S. Kreitzman
W.A. MacFarlane
P.W. Martin
D.F. Measday
G.D. Morris
C. Orvig
S. Ounsiger
V. Pacradouni
M. Pavan
D. Sirota
R.J. Snooks
N. Suen
D.C. Walker
C.E. Waltham

ASSOCIATE MEMBERS

U. of Manitoba
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J. Campbell
C.A. Davis
W.R. Falk
L. Gan
M. Landry
S.A. Page
W.D. Ramsay
A. Sekulovich
K.S. Sharma
J.P. Svenne
W.T.H. van Oers
J. Zhao

U. de Montréal
G. Azuelos
P. Depommier
C. Leroy

U. of Regina
G.M. Huber
G.J. Lolos
E.L. Mathie
S.I.H. Naqvi
R. Tacik
D.M. Yeomans

U. of Toronto
R. Azuma
D. Bandyopadyay
J.D. King
J.D. Powell

TRIUMF Users' Group—Other Institutions

Canada

B.C. Cancer Agency — M.K. Dimitrov
B.C. Cancer Foundation — L.D. Skarsgard
B.C. Cancer Research Centre — D. Garner
B.C. Children's Hospital — H. Nadel
BCIT — B. Pointon
Calgary U. — C.Y. Kim
Carleton U. — M. Dixit, R. Hemingway
Chalk River Nuclear Laboratories — J.C. Hardy, I.S. Towner
EBCO Industries — J.T. Sample
Foster Radiation Lab. — J.K.P. Lee
IBC — J.C. Prior
Kwantlen Coll. — J.B. Pearson
Laurentian U. — C. Virtue
Lion's Gate Hosp. (Vanc.) — P. Cohen
McGill U. — D. Britton
Ottawa Civic Hosp. — N.G. Hartman
Queen's U. — B.C. Robertson
Saskatchewan U. — E.J Ansaldo, C. Rangacharyulu, Y.M. Shin
St. Paul's Hospital — A. Belzberg
University Hospital (UBC) —D.B. Calne, B. Kramer, L-Y. Chan, R. Morrison, B.J. Snow, I. Szaz
Vancouver Gen. Hosp. — A. Celler, S.A. Jackson, B. Lentl, R.A.L. Sutton, W. Thompson, V. Walker
W. Ontario U.— W.P. Alford

Outside Canada

Australia
Adelaide U. — B. Pearce
Flinders U. of South Australia — I.R. Afnan, B. Blankleider
U. of Melbourne — S.A. Long, B.M. Spicer

Belgium
Université Catholique de Louvain — J. Deutsch

Bulgaria
Sofia U. — I. Enchevich

China
Peking U. — Y. Ye

Croatia
Zagreb U. — M. Furic

Finland
U. of Helsinki — J. Niskanen

Germany
DESY — K.M. Furutani, W. Schott
Erlangen U. — H.M. Hofmann
IEK— W. Klug
Karlsruhe U. — H.M. Staudenmaier
KFA Jülich — S. Martin
Max Planck Institut — C. Wiedner
Muenster U. — D. Frekers
Ruhr U., Bochum — H. Freiesleben
Tubingen U. — G. Wagner

Greece
INS — X. Aslanoglou
Patras U. — D.S. Tsatis

Hungary
Budapest Research Inst. for Physics — D. Horvath

India
Hindustan Lever Ltd. — K. Venkateswaran

Israel
Ben Gurion U., Negev — S. Mordechai
Hebrew U. — E. Friedman, N. Kaplan, A. Leviatan, M. Paul
Tel-Aviv U. — J.M. Eisenberg, M. Moinester

Italy
Cons. Naz. D. Ricerche — S. Marco
Milano U. — C. Birattari
Inst. di Fisica, Trieste — N. Grion

Japan
KEK — S. Kanda, Y. Kuno, K. Nakai, K. Yoshitaka
Osaka U. — N. Matsuoka
Tokyo Inst. of Techn. — N. Nishida
Tokyo U. — P. Birrer, K. Kojima, T. Nagae, K. Nagamine, K. Nishiyama, M-H. Tanaka, T. Yamazaki

Korea
Seoul Nat. U. — J.C. Kim
Yonsei U. — J.M. Lee

Netherlands
Kernfysich Vers. Inst. — A.M. van den Berg
Tech. Hogeschool Delft — H. Postma
Utrecht U. — J. Congleton

Poland
Warsaw U. — A. Sliwinski

Russia
INR, Dubna — P. Nomokonov
INR, Moscow — K. Alexei, A.S. Belov, V.N. Bolotov, R. Djilkibaev, V. Gaidach, A. Iliev, N. Ilinsky, I. Kopeikin, A. Krasulin, V.D. Laptev, V.A. Matveev, E.A. Monich, P.N. Ostroumov, V. Paramonov, A. Pashenkov, A. Poblaguev, V.G. Polushkin, P. Reinhardt-Nikulin, J. Senichev, S. Serezhnikov, E. Shaposhnikova, N.A. Titov, A. Zelenski
INR, Novosibirsk — A.A. Bashkeev, A. Kupriyanov
Inst. Theor. & Expt. Phys. — P. Volkovitsky
ITEP — M. Katz

TRIUMF Users' Group—Other Institutions

I.V. Kurchatov Inst. — V. Keilin, I. Kovalev, E. Krasnoperov, E. Meilikhov, V. Selivanov, V. Storchak
LNPI, Leningrad — A. Kotov, D. Seliverstov
Moscow RTI — V.A. Konovalov
Moscow EPI — A.L. Mykaelyan
SPB State U. — A. Bolokhov

Saudi Arabia

King Fahd U. — El-Kateb

South Africa

Nat. Accelerator Centre — D.M. Whittal
Witwatersrand U. — K.P.F. Sellschop, G.C. Smallman

Spain

Valencia U. — A. Ramos, M. Vincente

Sri Lanka

P. Lumumba U. — K. Jayamanna

Switzerland

Basel U. — A. Feltham
CERN — A. Noble, C. Oram, A. Rijllart, P. Weber
Fribourg U. — F. Muelhouser, L. Schellenberg
Mittelenergiephysik — W. Gruebler
PSI — R. Abela, A. Amato, B. Blankleider, F.S.N. Gygax, P. Locher, E. Morenzoni, A. van der Schaaf, H.C. Walter
Zurich U. — R. Engfer, E. Roduner

Ukraine

INR — A. Papash

United Kingdom

Leicester U. — E.D. Davis
Rutherford Lab. — S. Cox
Sussex U. — K. Prassides

United States

Argonne N.L. — M. Barnabas
Arizona State U. — J. Comfort, R.F. Marzke
BNL — E. Kistenov, T.E. Ward, C. Woody
Boeing Def. & Space Gp. — E. Normand
Boston U. — J.P. Miller
Bowdoin Coll. — G.T. Emery
California State U. — E.F. Gibson
California U., Berkeley — M.W. Strovink
Carnegie-Mellon U. — P.D. Barnes, A. Berdoz
CEBAF — D.J. Mack
Centenary Coll. — J. Lisantti
Central Washington U. — W.C. Sperry
Colorado U. — X.Y. Chen, S. Hoibraten, M.D. Holcomb, J.J. Kraushaar, R.A. Ristinen, W.R. Smythe
Columbia U. —G. Luke, T. Uemura
Florida State U. — H.S. Plendl, A.G. Williams
George Washington U. — Z. Papandreou
Harvard U. — J. Sisterson
Hood College — J.M. Stadlbauer
Illinois U. — P.T. Debevec, A.M. Nathan
Indiana U. — R.D. Bent, J.M. Cameron, W.P. Jones
IUCF — P. Schwandt
Johns Hopkins U. — Y.K. Lee
Kent State U. — R. Madey, P. Tandy, J.W. Watson
Kentucky U. — T. Gorringe, M. Kovash, K. Lin, M.A. Pickar
Lawrence Berkeley Laboratory — D.S. Armstrong, J. Batchelder, K.M. Crowe, D.M. Moltz, C. Naudet, G. Odyniel, T. Ognibene
LLNL — S. Han, L.S. Pan
Los Alamos National Laboratory — L.E. Agnew, W.D. Cook, R.E.L. Green, R.C. Haight, C. Laymon, C.L. Morris, S. Stanislaus, W.L. Talbert, D.J. Vieira
U. of Maryland — D. Leinweber, P.G. Roos
Minnesota U. — D. Dehnard
Mississippi State U. — R.B. Piercey
MIT — R.P. Redwine
New Mexico U. — B. Bassalleck, M.D. Chapman, B. Dieterle
New York State U. — D. Gabor
Oak Ridge National Laboratory — D.J. Horen, K.S. Toth
Ohio State U. — K.K. Gan, H. Kagan, R.L. Malchow, S. Shao, C. White
Ohio U. — J. Rapaport
Old Dominion U. — S. Kuhn
Oregon State U. — A.W. Stetz, L.W. Swenson
Pacific Northwest Labs — P.L. Reeder
Pennsylvania U. — H.T. Fortune, P. Hui, M. McKinzie, A. Williams
Princeton U. — R. McPherson
Rice U. — S.A. Dodds, T.L. Estle
Rutgers U. — C. Glashausser, S.K. Kim, G. Thomson
SSC Lab — D.P. Coupal, A. Fry, D.P. Gurd, T. Pal, M. Turcotte, U. Wienands
Stanford U. — S.S. Hanna
SUNY — C-M. Zou
Temple U. — C.J. Martoff, Y. Zhang
Texas A&M U. — R.A. Bryan
Texas Tech. U. — D. Lamp, R. Lichti
UC Santa Cruz — K. O'Shaughnessy
UCLA — B.M.K. Nefkens
User Technology Assoc. — J. Kempton
Virginia Polytechnic Institute and State U. — M. Blecher, K. Gotow, D. Jenkins

TRIUMF Users' Group—Other Institutions

Virginia State U. — D. Noakes, C. Stronach

Virginia Tech. — I. Strakovsky

Virginia U. — D.G. Crabb, E. Frlez

Washington U. — V. Cook, J.G. Cramer, C. Gossett, G.A. Miller, W.G. Weitkamp

Westinghouse (Hanford) — E.R. Siciliano

William & Mary Coll. — M. Eckhause, W.J. Kossler, R. Pourang

Yale U. — M. Gai

(Unaffiliated) — M. Halka

Uzbekistan

INR, Uzbek. — A. Avezov, A. Melis

NPI, Uzbek. — D. Mirkarimov

Yugoslavia

Ruder Boskovic Inst. — I. Slaus

[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]

KAON Factory

A Closing Word

In September 1985, TRIUMF published its "KAON Factory Proposal"— a 200-page summary of a possible new, expanded facility at the TRIUMF site. With two new accelerators (synchrotrons) boosting the beam of the existing TRIUMF cyclotron, the KAON Factory would provide physicists with the world's most intense beam of protons at an energy of 30 GeV, instead of TRIUMF's present 520 MeV. This beam would be used to create secondary beams of kaons, antiprotons, other hadrons, and neutrinos (hence the acronym KAON), all at intensities unapproached in any other laboratory in the world.

The following nine years saw intense debate on the merits of such a megaproject. The scientific case was good, and the KAON Factory received strong support internationally; the obstacle was the cost, and this led to a great effort to raise part of the funding from sources other than Ottawa. The Government of British Columbia, convinced that such a facility could help to bring a new era of high-tech development to the province, offered to contribute—initially about one sixth of the capital cost. It later raised its offer to one third of the cost.

Other countries also showed great interest, with the governments of the USA, Japan, Germany and Italy tentatively indicating about $200 million support, should the Government of Canada decide to go ahead with the proposal.

The governments of Canada and British Columbia jointly funded a further $11 million Project Definition Study to refine the concepts and verify the support from the international physics community, and this PDS report was produced in 1990. In September 1991 the Canadian government announced it would contribute $236 million toward the project (i.e. one third of the PDS study's construction cost estimate of $708 million in 1989 dollars).

However, during the following two years, with the changes of governments in both Ottawa and Victoria, with cost estimates rising, and with increasing public concern over government deficits, the drive for the KAON Factory seemed to slow down. Finally, the federal budget of February 1994 indicated that the project would not receive federal funding, ending the dream of a decade.

The KAON chapter in TRIUMF's history is over. Now TRIUMF scientists are turning their attention to other possible innovations to keep the search for new knowledge in Canadian subatomic physics as exciting and challenging as ever.