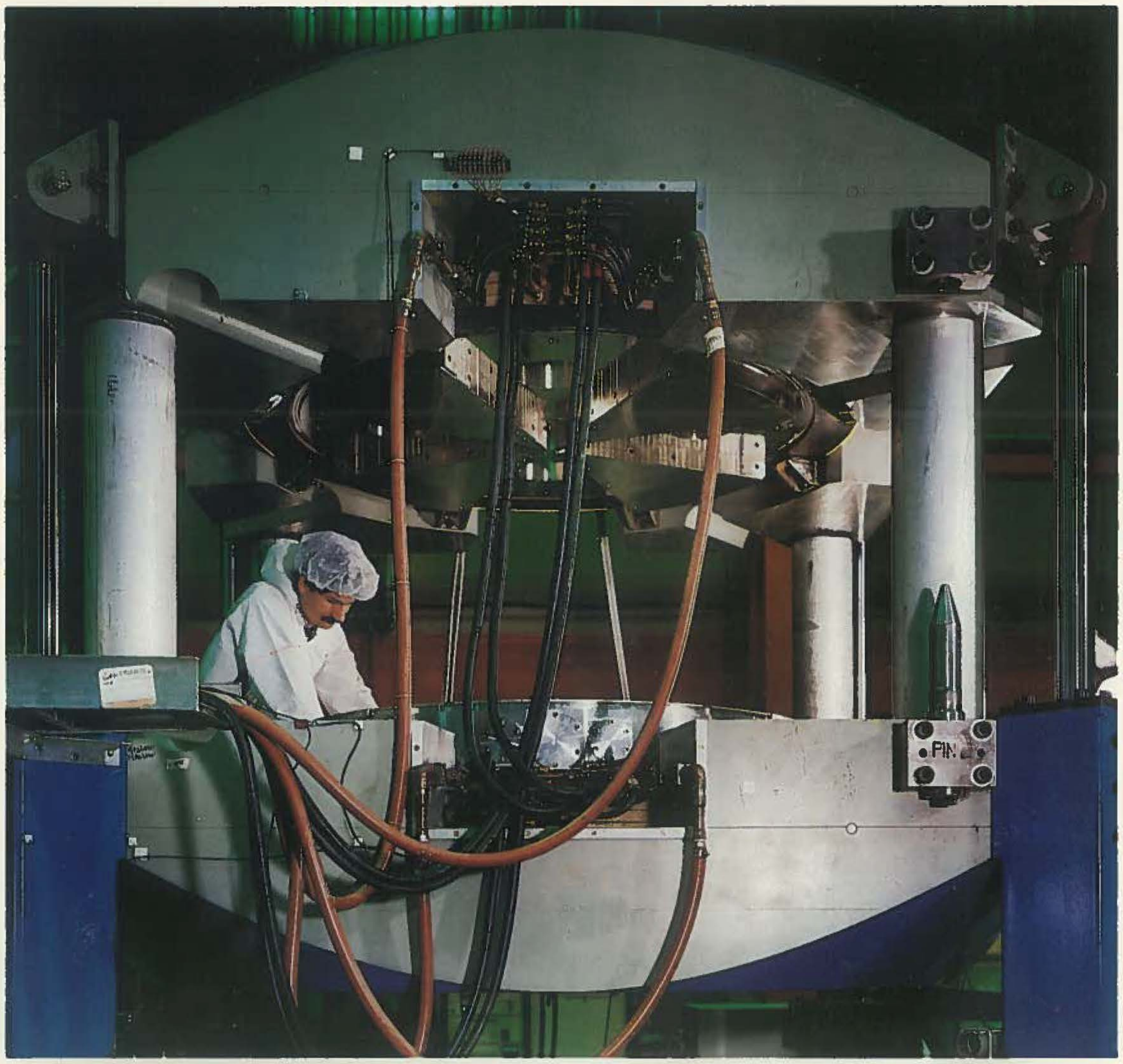
TRIUMF 1989–90

Annual Financial & Administrative Report



Including summaries of

Pure Research Activities *and* Practical Applications of Research

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

Consortium Members	*Associate Members*
University of Alberta	University of Manitoba
University of Victoria	Université de Montréal
Simon Fraser University	University of Regina
University of British Columbia	University of Toronto

COVER PHOTO

The prototype of the TR30 cyclotron, a new, low-energy accelerator designed by TRIUMF for the efficient production of radioisotopes, undergoes testing in the meson hall. Producing two very intense beams of protons simultaneously, the TR30 allows very few of these particles to stray, thus assuring a safer working environment *(see p. 7).* *Photo courtesy of EBCO Industries Ltd., who constructed the machine.*

Back Cover: *A computer plot of the magnetic field inside the TR30 looks almost good enough to eat!*

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TRIUMF Information Office

Editor: Michael La Brooy

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March 1990

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Director's Report

TRIUMF means many things to many people. Even researchers working at the laboratory may be completely engrossed in only one of the diverse range of unique research tools that TRIUMF offers.

The origin of each of the many different kinds of beams which TRIUMF produces can be traced to TRIUMF's cyclotron — the world's largest — whose function is to produce very intense beams of protons at three quarters of the speed of light. Some of TRIUMF's researchers use the proton beam directly. Their work was featured in last year's annual report (1988–89). But there is much more.

In the TRIUMF meson hall, the proton beam traverses two targets. The resulting collisions of protons with target atoms produce short-lived bundles of energy called pions. The pions belong to a family of composite particles called mesons, each of which is made by combining a quark with an antiquark. In turn, the quarks are nature's basic building blocks, and they come in six different kinds: *up*, *down*, *charmed*, *strange*, *top* and *bottom*.

Taking all the different combinations of these six with their antiparticles, one finds a large variety of different mesons. The pion is the lightest and most important member of this meson family. It breaks up spontaneously, with an average lifetime of only 26 billionths of a second. That is long enough to use it in experiments, and even for the treatment of cancer patients.

This annual report features a festival of pion research. The little guys are collected with magnets, and analysed with systems of magnets like the new CHAOS spectrometer featured in these pages.

But there is still more. The break-up of the pion produces a long-lived particle (it lasts two millionths of a second!) called the muon, whose research uses are entirely different. And still more. TRIUMF has intense neutron beams, and also many applied programmes which are direct offshoots of its work with protons, pions, muons and neutrons. And more to come. The future holds new physics opportunities for the kaon, the second member of the meson family, which will provide the *strange* quark for research.

By focusing in these reports each year on only one aspect of TRIUMF research, our succession of annual reports constitutes a roundelay of research, with pions certainly being an important refrain. Curiously, though, Nature doesn't allow us to short-change the other tools. When TRIUMF was first planned, two decades ago, it was the potential for physics with mesons (pions) that dominated the thinking and even crept into TRIUMF's name. However, the first round of research turned out to be won by the muons, which remain very important. With CHAOS, perhaps the next round will belong to the pions. No one knows for sure.

Erich Vogt

Quark + Antiquark: Pursuing the Pion at TRIUMF

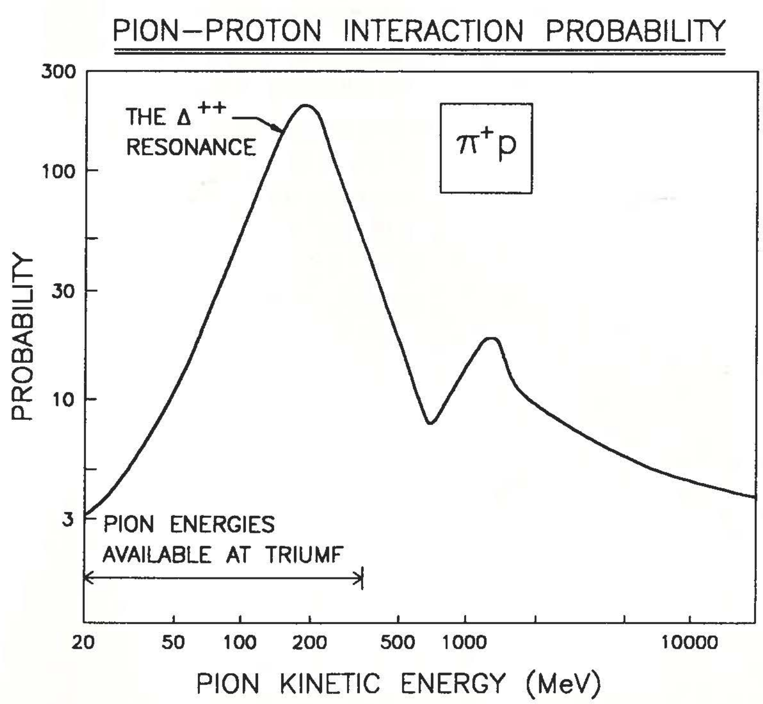
Why does TRIUMF create billions of pions each second? Why is it so important to study pion interactions with nuclei? We can best grasp the answers to such questions by viewing a historical perspective.

In 1935, physicists were attempting to provide explanations for the picture of the atomic nucleus, a picture which had emerged in its present form only a few years earlier. This picture described a nucleus in which neutrons and protons were confined to a very small volume, on the order of a few fermis (one fermi is 10^{-15} metre). In order to confine the nucleons to this volume and overcome the mutual electrostatic repulsion of the positively charged protons, a very strong force must be at work. On the other hand, this strong (nuclear) force must be limited to an equally short range to explain observed phenomena.

By analogy with the other known forces, the nuclear force was postulated to arise from fields set up by the mutually interacting nucleons (field theory). According to quantum mechanics, this field must be quantized into discrete bundles of energy. The mutual exchange of these "field quanta" gives rise to the nuclear force.

Based on the Heisenberg uncertainty principle, Hideki Yukawa argued in 1935 that the exchange particles responsible for the nuclear force must have a mass of around 200 MeV. (Physicists usually express the mass of subatomic particles in terms of the equivalent amount of energy. On this basis, the proton has a mass of 938 MeV.) Yukawa also predicted other properties the exchange particle should have, such as its possible charge states, and its spin. Since his prediction of this particle's mass placed it between the electrons, which are very light, and the more massive protons, the particle was dubbed the **pi meson** (π), from the Greek *mesos* for "middle". It was not until 1947 that experimental evidence finally established conclusively the existence of Yukawa's pi meson (or "pion", as it is referred to nowadays).

Thus we see that the pion is the glue that holds atomic nuclei together. The nuclear force arises from the exchange of (virtual) pions between nucleons. The study of pion physics is therefore extremely fundamental, because it involves the study of the interaction of the nuclear field particles (the pions) with nucleons and with the nucleus as a whole.



The properties of the pion make it unique. It may have an electric charge of +1, 0 or –1. It is the lightest of all mesons, the charged ones having a mass of 140 MeV (about 1/7 that of a nucleon). Because it has no intrinsic spin it can be completely absorbed in a nucleus, all its rest mass becoming converted into kinetic energy of the absorbing nucleons. Finally, the charged pions live for only 26 billionths of a second.

One of the pion's other features (which had a direct influence on the design of the TRIUMF cyclotron) is its propensity to fuse with nucleons at certain energies. We call this kind of phenomenon a resonance. Pions and nucleons are most likely to form a resonance (a new particle called the *delta*) when the pion kinetic energy is about equal to its mass energy, 140 MeV, as shown in the figure. With this much energy, pions are far more likely to interact with nucleons. It is precisely to take advantage of this feature of pion-nucleon interactions that TRIUMF was designed to accelerate proton beams to 500 MeV. Such a proton beam can produce secondary pion beams of considerable energy, completely spanning the energy range defining the delta resonance.

If we look at the proton and π+ in terms of their quark composition, the formation of a delta from them can be easily understood. The accepted quark composition of the proton is a combination of two *up* and one *down* quarks: **uud**. The π+ is believed to consist of an *up* quark plus a *down* antiquark: **u**<u>**d**</u>. (Note: Antiquark initials are underlined.) When the pion and proton come together, the *down* antiquark in the pion annihilates the *down* quark in the proton, leaving behind a system composed of three *up* quarks, called the delta ++.

Pion-Proton Scattering

As an example of a typical pion experiment at TRIUMF and what we learn from such efforts, let's look at one of the simplest reactions. In particular, let's describe a recent TRIUMF experiment which examined the elastic scattering of pions from hydrogen. The scientific goal of the experiment was to help identify the basic building blocks of the proton. Specifically, the question was whether the so-called *strange* quarks are present in the proton, or whether the proton is composed entirely of the more ordinary and less massive *up* and *down* quarks, in accordance with the standard picture.

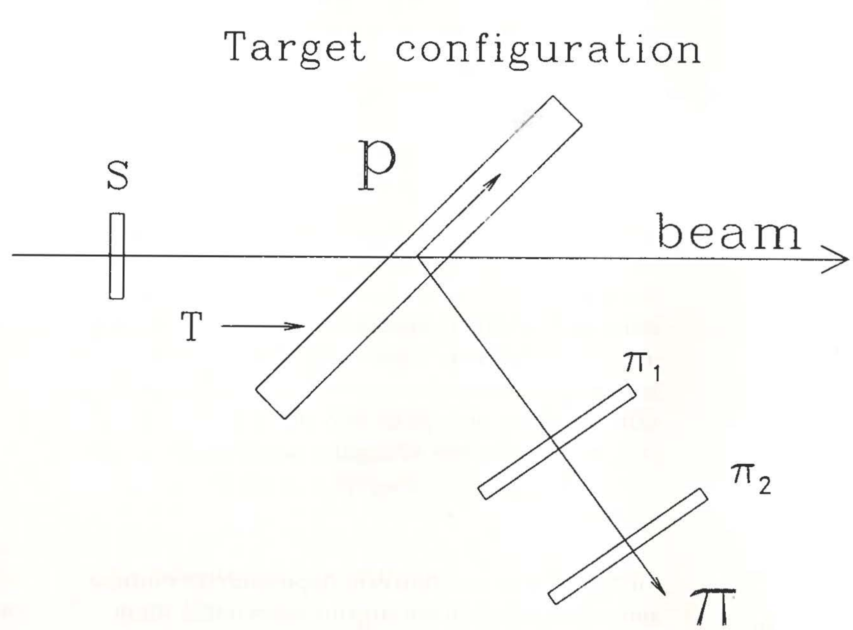
In this case, a beam of low-energy pions was allowed to strike a target consisting of polyethylene (a special plastic). The target contained carbon nuclei (C) in addition to hydrogen nuclei (H), so the experimenters had to be able to distinguish pion scattering on hydrogen from pion scattering on carbon.

One might visualize the experiment by thinking of a pool game where you shoot a cue ball (pion) on a table containing a 12-ball (carbon nucleus) and a 1-ball (hydrogen nucleus). Here we've picked out the 12-ball for the carbon nucleus because carbon consists of 12 nucleons (six protons and six neutrons). The hydrogen nucleus consists of a single nucleon, the proton. You can't see the numbers on the balls to start with, as in the actual pion scattering experiment. If you make your shot and then observe only the cue ball, it would be quite difficult to tell whether you had struck the 1-ball or the 12-ball. If, on the other hand, you could look at both the cue ball **and** the recoiling ball that was struck, you could tell what had happened.

This basic scenario is the one played out in the pion-proton scattering experiment at TRIUMF. If the incoming pion came close enough to a nucleus in the target to feel the influence of the (short-range) nuclear force, then both the scattered pion and the recoiling nucleus were detected and observed. By examining **both** reaction products, therefore, it is possible to identify clearly all pions scattering from protons.

The technique used to accomplish this feat was to employ a plastic scintillation detector as the target, as shown below. (These detectors are slices of crystal-clear plastic, treated with a chemical that emits a flash of light when an energetic particle passes through.) Thus, this target was "active", producing and detecting its own signals.

In general, the magnitude of these signals is proportional to the amount of energy deposited by the particles in the scintillator. If we orient the target so that its plane lies in the same direction as that expected for the



<u>Figure</u>
A pion in the beam passes from left to right through a detector, S, then strikes and displaces a proton, P, inside the target scintillator. The pion recoils down to the right, seen by detectors $\pi 1$ and $\pi 2$. Information from all four detectors is correlated by a computer.

recoil nuclei, then the entire path of these nuclei could lie within the target (as in the figure), i.e. they would deposit **all** of their kinetic energy **within the target**, giving a large signal.

Coinciding with these signals would be those from the scattered pions, which would generally emerge from the target material. These are detected in separate plastic scintillation counters, arranged nearby. The resulting combination of signals was used to identify the occurrence of pion-proton elastic scattering events.

The experiment was carried out for a variety of incident beam energies, and measured for a variety of scattering angles at each incident energy. The resulting body of data was then analysed using a technique known as "partial-wave expansion"; and the results of this analysis were then compared to the results of theoretical calculations which had a single unknown, but were otherwise fairly reliable. The single unknown was, of course, the amount of *strange* quark present in the hydrogen nucleus (the proton). Thus, by comparing the results of a pion scattering experiment to these theoretical calculations, it was possible, within the framework of the theory, to determine the *strange* quark content of the proton.

Remember that up to this point, the proton was thought to consist entirely of three non-*strange* quarks (two *up* and one *down*, or "**uud**"). The results of the comparison described above, however, yielded the astonishing result that as much as 20% of the proton seems to be composed of matter-antimatter pairs of *strange* quarks ($\underline{s}s$)! Other laboratories have also observed this result recently, and right now this is one of the most exciting avenues of research using intermediate energy pion beams.

Pion Spin Physics

TRIUMF has played a leading role in the blossoming new field of pion spin physics. Physicists have known for many years that the nuclear force is spin-dependent. However, difficulties in polarizing the beam and/or target particles have hampered research into this fundamental aspect of the nuclear force. In fact, for pion beams, it is impossible to polarize the incident particles since pions have no intrinsic spin! However there is still an **angular momentum** associated with the incoming pions relative to the target nucleus.

This angular momentum can couple with the intrinsic spin associated with the target nucleus under study. We learn about this aspect of the nuclear force by **polarizing** the target nuclei (i.e. aligning all their axes of spin). TRIUMF is a world leader in the technology of polarizing various target nuclei for nuclear physics experiments. We polarize them by placing a sample of complex molecules containing the nuclei to be studied (along with other nuclei required to achieve polarization) in a high magnetic field and a very low temperature. The magnetic field used is 25 kilogauss, about 44,000 times greater than the earth's magnetic field in Vancouver. The temperature required is approximately 0.1° above absolute zero (i.e. –273° Celsius).

Studies have been made at TRIUMF of pion scattering from several types of polarized targets. For example, polarized proton targets have been employed to study the difference in pion scattering from protons with their spins axes pointing up, and protons with their spins pointing down. This difference arises solely from the spin-dependent part of the nuclear force. The information from such a measurement has been used to define further the partial waves associated with pion-proton scattering. This, in turn, fits into the *strange* quark issue described above.

Extensive studies have also been made of pion scattering from polarized deuteron targets. The deuteron's nucleus consists of a proton and neutron (heavy hydrogen). Polarized protons have only two possible spin orientations. Mathematically, protons are said to have a spin of 1/2, and the projection of this spin along a given axis can be either +1/2 or –1/2. Deuterons have spin of 1, and there are three possibilities: projections of +1, 0 or –1. The first measurements anywhere in the world of pion scattering from a tensor polarized deuteron target were performed at TRIUMF. Such measurements are sensitive to aspects of the nuclear force which had never been accessible previously. These studies have had a tremendous impact on our understanding of pion interactions with nuclei, partly due to the large number of (spin-dependent) observables which are accessible with a spin 1 target like the deuteron, and also because this three-body system can be calculated exactly (in principle) with sophisticated models.

More complex nuclei have been polarized recently for study with pion beams at TRIUMF. One example is carbon-13, an isotope of carbon containing one more neutron than does ordinary carbon. This extra neutron can be polarized, opening the possibility of exploring fascinating phenomena. When an incoming pion encounters the (polarized) neutron, a new but very short-lived particle, the delta, can often form as a result of their fusion. By observing pion scattering from polarized carbon-13, we can learn about the spin-orbit interaction of the delta with the remaining (core) nucleus of carbon-12, even though the delta doesn't live long enough to complete even a single orbit of the core nucleus!

A Small, New Cyclotron for the Efficient Production of Radioisotopes

A major focus of interest in the applied programmes this year was TRIUMF's collaboration with EBCO Industries to design and build the prototype TR30 cyclotron in little more than 12 months.

This is a superb example of the kind of technology transfer that occurs with a large facility pursuing pure research in several fields. Obviously TRIUMF's staff has accumulated vast experience after 15 years of running the world's largest, most complex cyclotron, and we have developed expertise in all the finer points of cyclotron operation. In particular, TRIUMF has a world-leading edge in the technology of ion sources — the equipment that initially creates the dense stream of particles that is accelerated in a cyclotron.

The TR30 is a small machine, designed to emit simultaneously two very intense beams of 30 MeV protons for the commercial production of radioisotopes. Nordion International Inc. (formerly the Radiochemical Co., a subsidiary of Atomic Energy of Canada) has for many years been producing radioisotopes at the TRIUMF site using an American-built cyclotron commissioned in 1983. With its sales soaring for several years in a row, Nordion urgently needed a second production machine. TRIUMF and EBCO collaborated in designing, building and testing the first TR30, which was due to be installed in the newly enlarged Nordion annex by the second quarter of 1990. Up to 100 of these machines could be sold internationally over the next few years.

A photo of the TR30 appears on the front cover of this report, and a colourful three-dimensional "map" of its magnetic field is reproduced on the back cover.

Pion Therapy

By the end of this year the Batho Biomedical Facility had treated a total of over 220 patients.

A randomized brain tumour treatment trial involving 83 patients was well under way. Approximately half are being treated with pions, and the rest with conventional gamma radiation. A satisfactory outcome in this trial could result in pions being accepted as conventional therapy for such patients.

A similar trial began for patients with prostate tumours, and the treatment of chordoma and adenocarcinoma patients is also new this year. One patient received a combination of gamma and pion radiation which required exceptionally careful control of the "dose profiles".

The physical facilities have been upgraded: modern computer hardware and colour monitors have replaced the old, and a massive neutron shield beside the treatment couch resembles the steel door of a bank vault with a window for pions cut into its centre (rather more impressive for visitors than the earlier stacks of small concrete blocks).

Proton Therapy

Although the characteristics of pions make their use ideal for the destruction of large tumours such as glioblastomas in the brain, there are conditions for which *proton therapy* is preferable. Low-energy proton beams have long been used elsewhere for treatment of areas requiring pin-point precision, such as flat, extended tumours on surfaces of the eye, and tumours immediately beside the spinal cord or vital brain structures.

Proton beams are now available in six other countries for this kind of therapy, but Canada has no such facility. Experiments completed this year at TRIUMF show that a low-energy proton beam from our cyclotron would indeed be suitable for this purpose, and the possibility of building a treatment centre is being explored further.

Positron Emission Tomography

A multidisciplinary group funded by the Medical Research Council has now been formed at the University of British Columbia to study degenerative diseases of the motor pathways. The PET team is playing a leading role in this endeavour, since a key hypothesis is that changes in the brain cells affecting movement can be monitored with PET technology.

Through a collaborative arrangement with the Schering Plough Pharmaceutical Co. in the USA, the PET chemistry group received two new compounds suitable for specialized brain scans. The group has now developed procedures both for labelling these substances with ^{11}C and for separating and isolating them. We will be the first to use these with PET for evaluating the loss of neurons that many neurological diseases cause in the brain.

Facility tours & visitors

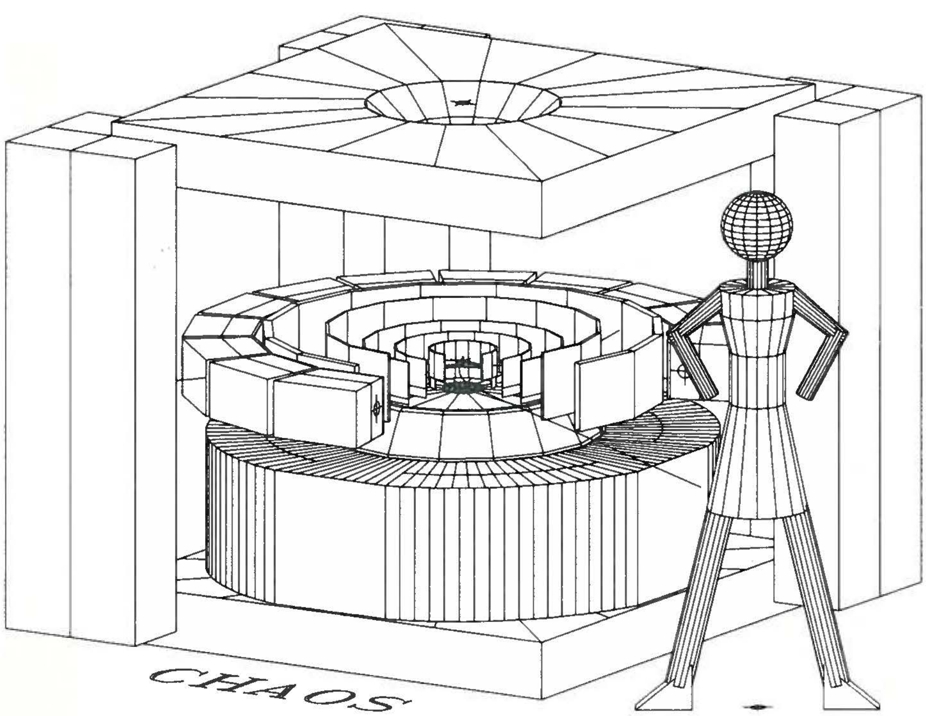
With all the publicity given to the KAON Factory campaign, TRIUMF was once again a popular attraction for the general public. We received 3167 visitors on regular tours (including 987 students), and a further 1987 during the UBC Open House in March 1990, for a total of 5154 this year. Distinguished guests included the Prime Minister of Japan, Academician Eugeny Velikhov (President Gorbachev's Science Advisor), and the Hon. Joe Clark, as well as senior Japanese and Korean financial officials.

CHAOS
A New Spectrometer Facility for Meson Hall

To exploit the advantageous time characteristics of the TRIUMF cyclotron, we are building a spectrometer that will let us extend our research to previously inaccessible domains. For the most part these involve investigating extremely rare processes, and reactions leading to more than one particle in the final state. The physics associated with these conditions has until now been difficult to explore: accumulating a meaningful number of events would take an extremely long time; and over such long periods, the large backgrounds (signals from other events) would obscure those events sought.

We have therefore begun to construct a unique spectrometer facility designed to allow simultaneous measurement of the products of pion-induced reactions over a full 360°. It is dubbed CHAOS (Canadian High Acceptance Orbit Spectrometer), and consists of a large cylindrical dipole magnet with the target located at the centre. Particles emanating from the target as the result of pion interactions curve outwards due to the influence of the magnetic field through planes of cylindrical wire chambers. The positions recorded in these wire chambers can then be used to determine the orbit described by the particles, and consequently, their momentum.

Constructing this spectrometer is a multinational effort. The wire chambers are being instrumented with funding provided by NSERC; the wire chamber construction costs are funded by the University of Colorado; the scintillation and Cerenkov detector arrays are being built and paid for by the Italian equivalent of NSERC (INFN); and the target is being built at the University of Karlsruhe. Canadian institutions involved in the project include TRIUMF, the University of British Columbia, and the University of Regina.



With such a powerful new tool soon to be at our disposal, we predict many new and interesting phenomena will be uncovered in the future with the pion beams at TRIUMF. With developments like this one, TRIUMF will secure and maintain and its international leadership in the field of pion-nuclear physics.

A New Magnetic Spectrometer for Proton Hall

As last year's annual report noted briefly, the principal innovation destined for proton hall is a large, new, magnetic spectrometer, called SASP for Second Arm SPectrometer. It will greatly enhance the experiment possibilities in that area, and will be a sort of twin for the existing Medium Resolution Spectrometer. The pair will form a dual-arm spectrometer system ("DASS") serving the main target in proton hall.

Since late 1989 the huge, 100-tonne dipole magnet for SASP (machined by EBCO, a Richmond, B.C., firm) has dominated the centre of the proton hall extension. It has drawn much comment from visitors as it is subjected to various testing procedures. (Despite their worries, it has not yet magnetically "wiped clean" any credit cards!)

What is the advantage of having TWO spectrometers serving the same target? Experimenters say this system will enable them to detect and observe two particles emerging simultaneously from a target under bombardment: they will be able to observe not only the "bulk properties" of nuclei but the individual protons *inside* the nuclei.

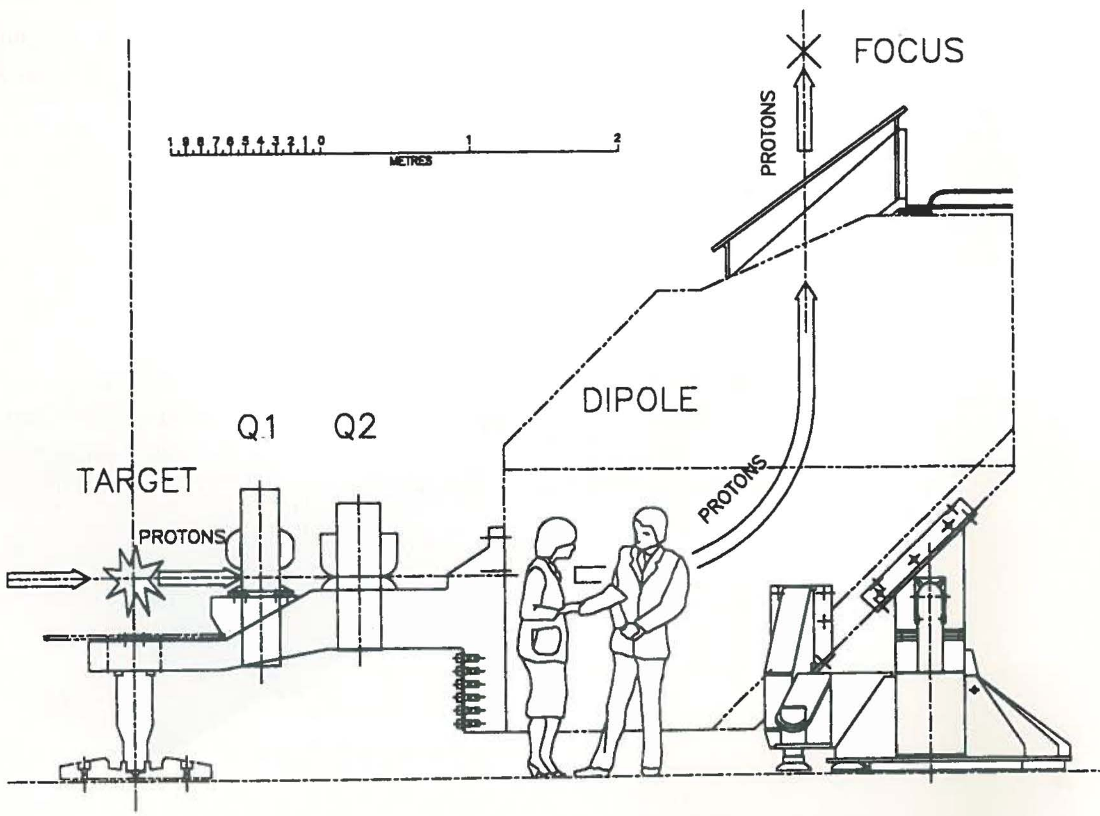
In a typical experiment, a fast-moving proton from the cyclotron beam might knock out a proton from the nucleus of a target atom, bouncing out itself at the same time. Accurate simultaneous measurement of the direction and momentum of both protons, one in each spectrometer, will reveal how strongly the nuclear proton had been bound inside the nucleus. This, in turn, shows directly the "shell" structure of the nucleus (similar to the better-known electron shell structure of atoms, studied by chemists).

The unique feature of DASS will be its ability to look at these nuclear knockout reactions with a *polarized* beam, i.e. where all the beam protons are spinning in the same direction. This will induce asymmetries in the knockout collisions, rather like the asymmetric collisions of a fast-spinning cue ball on a billiard table. We already know what asymmetry we would see when a beam proton is scattered from a *free* proton (i.e. one not bound inside a nucleus). The question is, How will the environment inside a nucleus modify this? Any changes we observe will tell us about the original local environment of the emerging proton.

The ability to observe these effects is what will make our new facility unique in the world.

Other Facility Improvements

- A major extension of the "Chemistry Annex" (mostly housing the Nordion facilities) took place this year, in order to accommodate the vault and target caves for the new TR30 production cyclotron.
- The high-intensity polarized source for the main cyclotron was developed further.
- The last of the old PDP-11 data acquisition computers was replaced with a VAX.



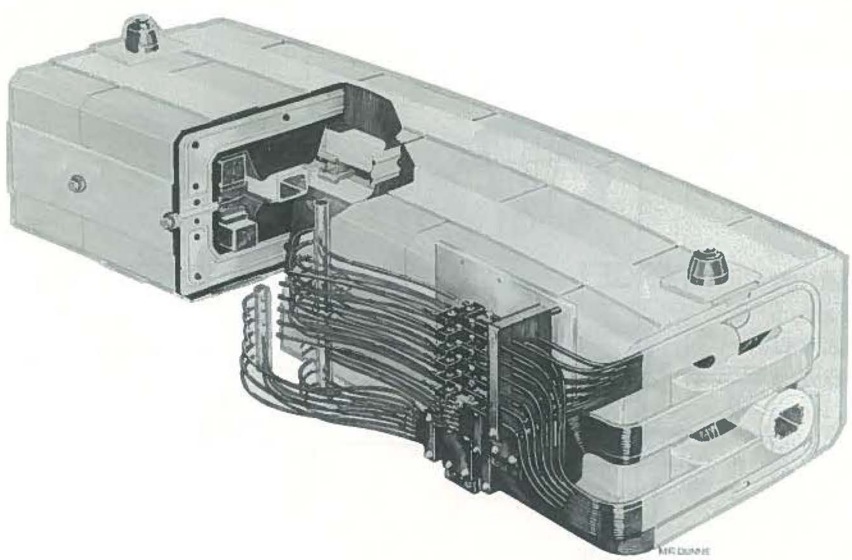
KAON Factory Project Definition Study

The $11-million Engineering Design and Impact Study for the KAON Factory, jointly funded by the governments of Canada and British Columbia and popularly known as the Project Definition Study (PDS), was officially completed on 28 February, when the reports prepared by TRIUMF and the various consulting companies were submitted to the two governments.

Although the reports were not publicly released until May it seems appropriate to summarize the general findings of the Study by reproducing the "highlights" of the report of the federal-provincial Steering Committee here (see opposite page). For a committee whose mandate was to collect facts rather than make recommendations the tone of their report was gratifyingly positive.

We should also mention some highlights of the work done by TRIUMF staff, who:

- arranged eight workshops on different aspects of the science programme, four in Canada, two in Japan and one each in Germany and Italy
- reconfigured the experimental area and beam lines in light of the new science priorities
- successfully carried out tests on two designs of rotating, cooled, production targets
- confirmed racetrack lattices for the main rings while retaining a circular lattice for the Booster, and redesigned all the transfer lines for the new site
- have nearly completed the prototype Booster dipole magnet
- took delivery of the dipole magnet power supply, and designed dc bypass chokes
- successfully operated a kicker magnet with 40-kV pulses 50 times per second
- supervised the construction of a four-metre-long ceramic vacuum chamber, complete with radiofrequency shield
- completely rebuilt the perpendicularly biased ferrite tuner for ac operation of the Los Alamos radiofrequency cavity, and carried out the first tests
- detailed the logical structure of the control system
- built a prototype magnetic channel for extracting negative hydrogen ions from the cyclotron



Report of the Steering Committee — Highlights

• The science opportunity for Canada provided by the KAON Factory has been strongly reaffirmed by the world science community. KAON would be a unique, world-class accelerator facility in the major new effort, around the globe, to probe what lies at the heart of matter.

• The refined KAON Factory design has been reviewed by a prestigious, international panel of accelerator experts who unanimously pronounced the project to be technically mature and urged that construction funding be secured with the utmost urgency.

• On the basis of extensive international consultations, it is reasonable to expect that the total foreign participation which can be negotiated could be close to the $200 million target. Substantive responses, far more than expressions of interest, were received. In the absence of a funding commitment from Canada, this constitutes considerable success. The international consultations confirmed the desirability of an early decision on KAON construction.

• The cost, in 1989 dollars, for construction of the KAON Factory is estimated at $693 million over a five-year period. The international panel of accelerator experts considers these costs to be on a firm footing. Annual operating costs are estimated to be $98 million (1989 dollars), or $68 million in new funds beyond the current $30 million for TRIUMF.

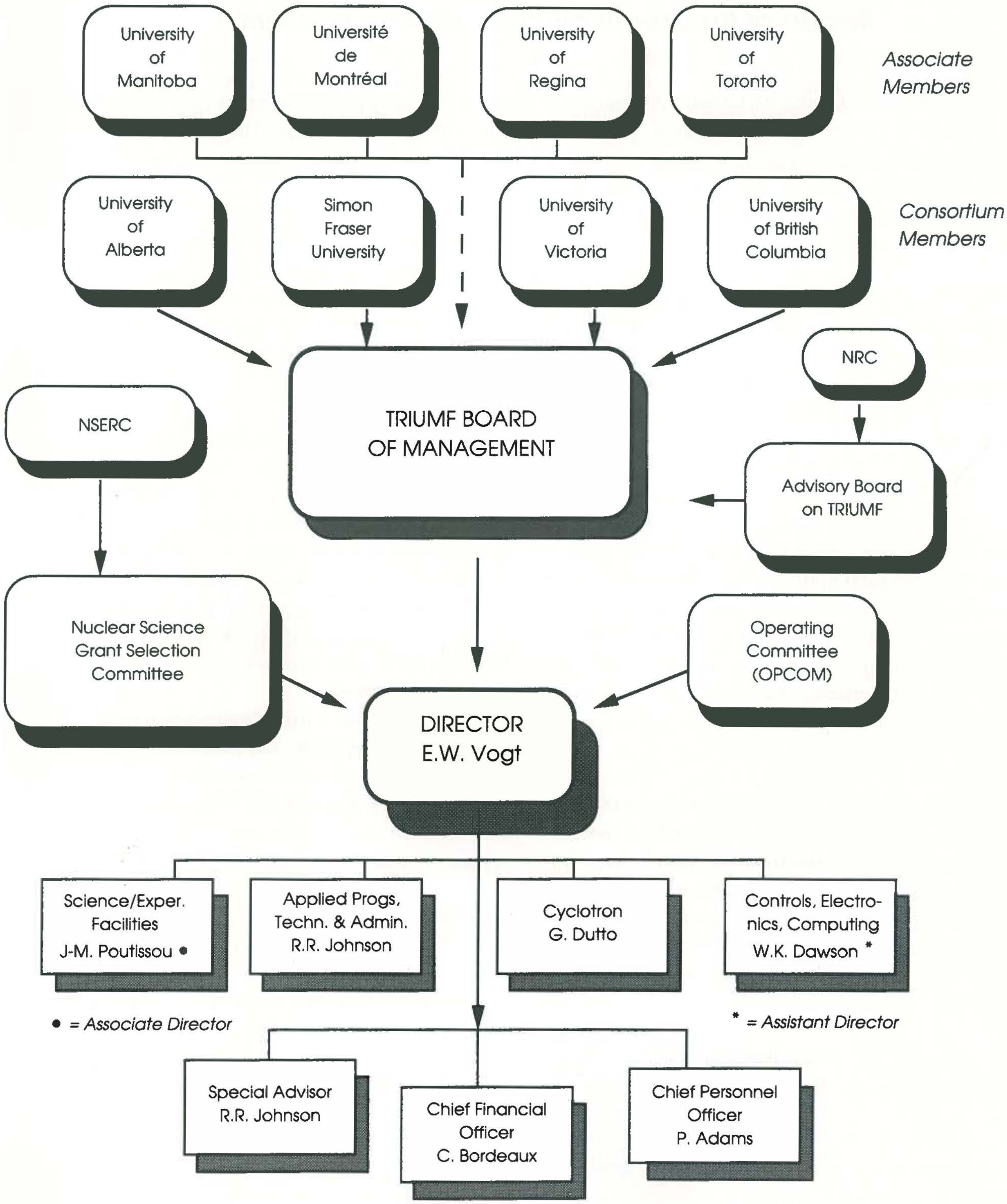
• A full initial environmental assessment, including two public meetings, found little environmental risk and received considerable positive public comment and approbation. There is no apparent impediment to a construction decision.

• Nearly 200 firms across Canada are capable of being key contractors for high-technology components of KAON valued at $316 million (in 1989 dollars). Over 85% of the high-technology content of the KAON Factory is of high priority to Canadian industry in such areas as robotics, microelectronics and software.

• The economic impact assessment indicates that during construction, the KAON project would generate up to $550 million of Gross Domestic Product, create up to 17,000 person years of employment and generate up to $1.1 billion of industrial activity. During operations, it is estimated that the project would generate over $77 million per year in industrial activity yielding up to $42 million in GDP and provide up to 1900 person years of employment.
Despite the fact that a full quantification of all benefits was not possible, the measured project benefits can fully account for nearly 80 per cent of the project costs. The residual would have to be justified on the basis of the economic, social and scientific benefits which could not be quantified.

• The Steering Committee believes that the KAON Factory Project is feasible and can be successfully accomplished within the costs and schedule presented. The Steering Committee is of the unanimous and strong opinion that the Canadian and international scientific community is ready and waiting for an early decision.

Organization Chart



Financial Review

Ongoing constraints in operating funding, while we await a decision on substantial upgrading of the facilities, would have resulted in massive layoffs had it not been for the financial relief afforded by two projects. As a result, it was possible to keep the highly trained cadre of staff intact in anticipation of a decision by the Federal Government on the proposed upgrade to a KAON Factory. Considerable financial support from abroad is virtually assured when approval for a KAON Factory is obtained.

Both projects mentioned above are of short duration. One came to an end in this fiscal year: the KAON Factory Engineering Design and Impact Study, funded jointly by the Federal Government and the British Columbia Government on a 50-50 basis. This study, referred to in the financial statements as the Federal Project Definition Study and the Provincial Project Definition Study, has a total funding of $11 million, of which $6,851,500 is allocated to TRIUMF in this fiscal year.

The other project is an agreement with EBCO Industries Ltd. of Richmond, B.C., to provide EBCO with technical assistance and the technology required to manufacture a 30 MeV cyclotron for the use of Nordion International Inc., situated on the TRIUMF site. This project will come to its completion in FY 1990-91.

The Medical Research Council of Canada continued to provide substantial support. These funds are administered elsewhere and are therefore not reported here.

The same holds true for funding by the Natural Sciences and Engineering Research Council of TRIUMF-based experiments administered elsewhere, as distinct from those administered at TRIUMF. Nordion International Inc., formerly Atomic Energy of Canada Ltd., is still the major commercial user of TRIUMF facilities. The flow of their funds through TRIUMF fluctuates because the great majority of their transactions are handled by their administration located on the TRIUMF site. Only those services required directly from TRIUMF are reported here.

The number of transactions on behalf of affiliated institutes has stabilized, with the exception of those for USSR institutions whose activities at TRIUMF are steadily increasing. The Statement of Funding and Expenditures and Changes in Fund Balance for Affiliated Institutions consists of advances and reimbursements for expenditures undertaken on behalf of various institutions from Canada and abroad, for their TRIUMF projects.

Expenditures in the Statement of Combined Funding and Expenditures are at acceptable levels. It is expected that the Federal Government will reintroduce support to TRIUMF at a level sufficient to maintain the high international recognition TRIUMF has achieved, and that this support will include the requisite upgrading of the facilities.

C. Bordeaux
Chief Financial Officer

SOURCE OF FUNDS	*1989–90*		*1988–89*	
	$ million	*%*	*$ million*	*%*
National Research Council	*26.51*	*62.19*	*26.51*	*69.17*
NSERC	*2.97*	*6.97*	*3.27*	*8.53*
Federal Project Definition Study	*3.40*	*7.98*	*1.97*	*5.14*
Provincial Project Definition Study	*3.45*	*8.10*	*1.89*	*4.94*
NORDION International Inc.	*1.41*	*3.31*	*2.39*	*6.23*
Affiliated Institutions	*2.28*	*5.35*	*1.37*	*3.57*
EBCO Industries Ltd.	*1.97*	*4.62*	*0.55*	*1.43*
Investment & Other Income	*0.63*	*1.48*	*0.38*	*0.99*
	42.62	*100%*	*38.33*	*100%*

From the Auditor

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

AUDITORS' REPORT TO
THE BOARD OF MANAGEMENT
TRIUMF

We have examined the statement of financial position of TRIUMF as at March 31, 1990 and the statements of funding and expenditures and changes in fund balances for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests and other procedures as we considered necessary in the circumstances.

In our opinion, these financial statements present fairly the financial position of TRIUMF as at March 31, 1990 and its funding and expenditures and changes in fund balances for the year then ended in accordance with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Coopers & Lybrand

Vancouver, B.C.
June 1, 1990

TRIUMF

STATEMENT OF COMBINED FUNDING AND EXPENDITURES
AND CHANGES IN FUND BALANCES
FOR THE YEAR ENDED MARCH 31, 1990

	1990	1989
FUNDING	$	$
National Research Council	26,510,000	26,510,000
Natural Sci & Eng Research Council	2,974,234	3,267,370
Federal Project Definition Study	3,400,000	1,965,000
Provincial Project Definition Study	3,451,500	1,894,500
Nordion International Inc.	1,410,790	2,392,645
Affiliated Institutions	2,279,169	1,374,226
EBCO Industries Ltd.	1,965,017	550,737
Investment and other income	628,035	381,266
	42,618,745	38,335,744
EXPENDITURES		
Building construction	96,034	394,005
Communications	324,569	374,481
Computer	2,362,415	3,549,490
Equipment	4,488,940	2,503,859
Lease payments — Nordion Intl. Inc.	—	651,800
Power	1,872,537	1,701,079
Salaries and benefits	22,158,709	20,020,954
Supplies and expenses	11,440,758	6,950,892
	42,743,962	36,146,560
EXCESS (DEFICIENCY) OF FUNDING OVER EXPENDITURES FOR THE YEAR	(125,217)	2,189,184
LESS: DEFERRED FUNDING	(15)	(57)
FUND BALANCES — BEGINNING OF YEAR	3,134,399	945,272
FUND BALANCES — END OF YEAR	3,009,167	3,134,399

TRIUMF

STATEMENT OF FINANCIAL POSITION
AS AT MARCH 31, 1990

ASSETS	1990 $	1989 $
CASH & TEMPORARY INVESTMENTS	2,777,950	1,442,824
ACCOUNTS RECEIVABLE (Note 3)	1,760,158	2,425,288
TOTAL ASSETS	4,538,108	3,868,112

LIABILITIES AND FUND BALANCES

	1990 $	1989 $
ACCOUNTS PAYABLE	1,424,989	494,000
DEFERRED FUNDING		
National Research Council	15	28
Federal Project Definition Study	—	11
Provincial Project Definition Study	—	18
	15	57
DUE (FROM) TO UNIVERSITIES		
The University of Alberta	(62,541)	(49,131)
The University of Victoria	(42,007)	2,549
The University of British Columbia	202,152	288,135
Simon Fraser University	6,333	(1,897)
	103,937	239,656
FUND BALANCES		
Natural Sciences & Eng. Research Council	1,440,207	1,273,386
Federal Project Definition Study	—	545,883
Provincial Project Definition Study	—	688,844
Nordion International Inc.	100,000	192,960
Affiliated Institutions	(50,097)	(91,813)
EBCO Industries Ltd.	21,810	(23,636)
TRIUMF	805,157	572,025
Intramural Accounts	692,090	(23,250)
	3,009,167	3,134,399
TOTAL LIABILITIES & FUND BALANCES	**4,538,108**	**3,868,112**

ENCUMBRANCES AND COMMITMENTS
(Note 4)

NATIONAL RESEARCH COUNCIL
STATEMENT OF FUNDING AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1990

	1990 $	1989 $
DEFERRED FUNDING—BEGINNING OF YEAR	28	216
FUNDING		
Contributions	26,509,972	26,509,784
TOTAL APPROVED CONTRIBUTION	26,510,000	26,510,000
EXPENDITURES BY ACTIVITY AREA		
Salaries	19,084,480	17,265,523
Power	1,872,535	1,701,079
Administrative and overhead	1,438,498	1,527,613
Cyclotron and facilities operation	2,538,322	2,451,503
Site services	821,074	827,906
Support services	1,631,356	1,664,502
Major projects	1,626,298	2,200,164
Minor projects and development	325,630	352,826
	29,338,193	27,991,116
Funds recovered — salaries and cost centres	(2,828,208)	(1,481,144)
TOTAL EXPENDITURES	26,509,985	26,509,972
DEFERRED FUNDING — END OF YEAR	15	28
EXPENDITURES BY OBJECT		
Buildings	(31,756)	271,440
Communications	232,546	273,786
Computer	2,362,285	2,026,137
Equipment	1,884,514	1,757,125
Power	1,872,535	1,701,079
Salaries and benefits	19,071,866	17,359,275
Supplies and services	3,170,453	4,301,470
Salary expenditure recovered	(2,052,458)	(1,180,340)
	26,509,985	26,509,972

FEDERAL PROJECT DEFINITION STUDY

STATEMENT OF FUNDING AND EXPENDITURES AND CHANGES IN FUND BALANCE
FOR THE YEAR ENDED MARCH 31, 1990

	1990	Outstanding commitments, 31/03/1989	Total Allocated Project Funding & Expenditures 1990
FUNDING	$	Less: $	$
Contributions	3,400,000	–	3,400,000
EXPENDITURES			
Buildings	4,086	(4,086)	–
Computer	86,466	(40,368)	46,098
Equipment	1,673,991	(413,573)	1,260,418
Salaries & benefits	710,518	–	710,518
Supplies & services	1,470,833	(87,856)	1,382,977
	3,945,894	(545,883)	3,400,011
EXCESS (DEFICIENCY) OF FUNDING OVER EXPENDITURES FOR THE YEAR	(545,894)	545,883	(11)
DEFERRED FUNDING	11	–	11
COMMITMENTS	–	(545,883)	(545,883)
FUND BALANCE, BEGINNING OF YEAR	545,883	–	545,883
FUND BALANCE, END OF YEAR	–	–	–

	1989	Add:	1989
	$	$	$
FUNDING			
Contributions	1,965,000	–	1,965,000
EXPENDITURES			
Buildings	–	4,086	4,086
Computer	360,246	40,368	400,614
Equipment	221,494	413,573	635,067
Salaries & benefits	472,573	–	472,573
Supplies & services	364,793	87,856	452,649
	1,419,106	545,883	1,964,989
EXCESS (DEFICIENCY) OF FUNDING OVER EXPENDITURES FOR THE YEAR	545,894	(545,883)	11
LESS: DEFERRED FUNDING	(11)	–	(11)
COMMITMENTS	–	545,883	545,883
FUND BALANCE, END OF YEAR	545,883	–	545,883

PROVINCIAL PROJECT DEFINITION STUDY
STATEMENT OF FUNDING AND EXPENDITURES
FOR THE YEAR ENDED MARCH 31, 1990

	1990	Less: Outstanding commitments, 31/03/1989	Total Allocated Project Funding & Expenditures 1990
FUNDING	$	$	$
Contributions	3,451,500	–	3,451,500
EXPENDITURES			
Buildings	–	–	–
Computer	35,080	(480)	34,600
Equipment	209,306	(152,317)	56,989
Salaries & benefits	645,313	–	645,313
Supplies & services	3,250,663	(536,047)	2,714,616
	4,140,362	(688,844)	3,451,518
EXCESS (DEFICIENCY) OF FUNDING OVER EXPENDITURES FOR THE YEAR	(688,862)	688,844	18
DEFERRED FUNDING	18	–	18
COMMITMENTS	–	(688,844)	(688,844)
FUND BALANCE, BEGINNING OF YEAR	688,844	–	688,844
FUND BALANCE, END OF YEAR	–	–	–

	1989	Add:	1989
	$	$	$
FUNDING			
Contributions	1,894,500	–	1,894,500
EXPENDITURES			
Buildings	120,000	–	120,000
Computer	292,953	480	293,433
Equipment	24,745	152,317	177,062
Salaries & benefits	428,033	–	428,033
Supplies & services	339,907	536,047	875,954
	1,205,638	688,844	1,894,482
EXCESS (DEFICIENCY) OF FUNDING OVER EXPENDITURES FOR THE YEAR	688,862	(688,844)	18
LESS: DEFERRED FUNDING	(18)	–	(18)
COMMITMENTS	–	688,844	688,844
FUND BALANCE, END OF YEAR	688,844	–	688,844

TRIUMF
NOTES TO FINANCIAL STATEMENTS
FOR THE YEAR ENDED MARCH 31, 1990

1. JOINT VENTURE OPERATIONS

TRIUMF is a joint venture established by the University of Alberta, the University of Victoria, Simon Fraser University and the University of British Columbia, having as its goal the establishment and continuance of a national facility for research in intermediate energy science under a contribution from the National Research Council of Canada.

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

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

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

(c) Federal Project Definition Study
Funding provided by the federal government to research and define the financial and scientific requirements of the proposed KAON Factory.

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

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

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

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

(h) TRIUMF
Investment for discretionary expenditures incurred by TRIUMF.

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

2. SIGNIFICANT ACCOUNTING POLICIES

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

TRIUMF
NOTES TO FINANCIAL STATEMENTS
FOR THE YEAR ENDED MARCH 31, 1990 (CONTINUED)

3. **FUNDING RECEIVABLE**

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

	1990 $	1989 $
NSERC	438,464	601,149
Federal Project Definition Study	264,149	829,733
Provincial Project Definition Study	—	398,500
NORDION International Inc.	286,677	243,881
Affiliated Institutions	(261,537)	(73,861)
EBCO Industries Ltd.	1,032,405	425,886
	1,760,158	2,425,288

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 as at the fiscal year end, comprise:

	1990 $	1989 $
National Research Council	350,000	636,000
Natural Sciences and Engineering Research Council	169,000	86,000
Federal Project Definition Study	—	546,000
Provincial Project Definition Study	—	689,000
NORDION International Inc.	36,000	9,000
Affiliated Institutions	12,000	47,000
EBCO Industries Ltd.	22,000	15,000
	589,000	2,028,000

5. **NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL — FUND BALANCE**

Funding unexpended	1,747,126	1,519,722
Grant accounts overexpended	(306,919)	(246,336)
Fund balance — end of year	1,440,207	1,273,386
Number of grants awarded during year	49	49
Number of grants administered throughout year	92	88

6. AFFILIATED INSTITUTIONS — FUND BALANCE

The fund balance at the fiscal year end comprises:

Funding received in advance		
Expenditures recoverable	411,434	404,427
Fund balance — end of year	(461,531)	(496,240)
	(50,097)	(91,813)

7. PENSION PLANS

The employees of TRIUMF are members of the pension plan administered by the university that sponsors their employment. TRIUMF records the pension expense as cash contributions to the plan based on a prescribed percentage of employee earnings. The pension expense for the year was $1,204,227 (1989 $1,094,998).

1990 TUEC
(TRIUMF Users' Executive Committee)
Chairman: D.R. Gill
Associate Chairman: G. Greeniaus
Members: C. Davis, N. Stevenson, M. Vetterli
Liaison Officer: M. La Brooy

TRIUMF Users' Group

(March 1990)

TRIUMF

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

CONSORTIUM MEMBERS

U. of Alberta

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

Simon Fraser U.

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

U. of Victoria

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

U. of British Columbia

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

ASSOCIATE MEMBERS OF THE TRIUMF CONSORTIUM

U. of Manitoba

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

U. of Regina

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

U. de Montréal

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

U. of Toronto

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

TRIUMF Users' Group—Other Institutions

Canada

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

Outside Canada

Australia
U. of Adelaide — A.W. Thomas
Flinders U. of South Australia — I.R. Afnan
U. of Melbourne — S. Koutsoliotias, S.A. Long, S. McDonald, K.J.Raywood, G.G. Shute, B.M. Spicer, G.N. Taylor
Belgium
Université Catholique de Louvain — J. Deutsch
Bulgaria
Sofia U. — I. Enchevich
China
Academia Sinica — X-D. Jiang, Y.P. Zhang
Inst. Atom. Energy — Yong-Shun Wu
IHEP, Beijing — Chaoquing Chan, Z.H. Ding, J. Lu, N.S. Zhang
Peking U. — Y. Ye
Czechoslovakia
NPIC — J. Zolka
Egypt
Ain Shams U. — K.E.A. Negm
Finland
U. of Helsinki — J. Niskanen
France
CEN Saclay — P. Couvert, B. Mayer
ESRF — F. Loyer
NM–CRNS — R. Grynszpan
Saturne — F. Meot, J. Yonnet
Germany
Bayer — R.P. Trelle
U. of Bonn — P.K.A. David, D. Theis
Karlsruhe — E.T. Boschitz, M. Metzler
KFA Julich — S. Martin
Max Planck Institut — C. Wiedner
Inst. f. Strahlen-und-Kernphysik — J. Ernst
Erlangen U. — H.M. Hofmann
TH Darmstadt — H. Wortche
Tech. Inst. Munich — T. von Egidy
Tubingen U. — G. Wagner
Greece
Patras U. — D.S. Tsatis
Hungary
Cent. Research Inst. for Physics, Budapest — D. Horvath
Israel
Hebrew U. — E. Friedman, A. Goldring, N. Kaplan
Soreq Nucl. Resrch. Ctr. — A. Altman
Soroka Med. Ctr. — M.R. Quastel
Tel-Aviv U. — J. Aclander, J. Alster, D. Ashery, J.M. Eisenberg, H. Hahn, I. Kelson, M.A. Moinester, E. Piazetsky, A. Rahav, R. Ram, A. Stern, A.I. Yavin, A. Zidon, M. Zilka
Italy
Inst. di Fisica, Trieste — C. Cernigoi, R. Rui
INFN, Bari — N. Grion, V. Paticchio
Universita di Milano — A. Bracco, L. Rossi
Japan
Aoyama-Gakuin U. — J. Akimitsu
KEK — J. Imazato
Kyoto U. — H. Sakaguchi
Meson Sci. Lab., Tokyo — R. Kadono
Nat. Lab. for H.E. Phys. — C. Yamaguchi
Nat. Res. Inst. Police Science — K. Kuroki
Osaka U. — F. Fujimoto, N. Matsuoka, T. Noro, H. Sakai
RIKEN — K. Katsumata
Tohoku U. Hosp. — Y. Hosoi, K. Sakamoto, R. Sujita
Tokyo Inst. of Technology — H. Miyatake, N. Nishida
Tokyo Metropol. Inst. — H. Toki, M. Toki
U. of Tokyo — M. Iwasaki, I. Masahiko, T. Nagae, K. Nagamine, S. Nakamura, H. Outa, S. Sakamoto, T. Yamazaki, Y. Yamazaki, H. Yasuoko
Korea
Soeul Nat. U. — J.C. Kim
Yonsei U. — K.S. Chung, J.M. Lee
Netherlands
IKO — R. van Dantzig
Technische Hogeschool Delft — H. Postma
Technische Hogeschool Eindhoven — J.I.M. Botman
Tech. U. — W. Kleeven
Utrecht U. — Z. Papandreou
Nigeria
U. of Ife — B. Olaniyi
Poland
Inst of Nucl. Stud. — S. Burzynski
Warsaw U. — J. Miszczak, A. Sliwinski
Saudi Arabia
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Spain
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Arizona State U. — J. Comfort, R.F. Marzke, J.R. Tinsley
AT&T Bell Labs — D. Harshman
BNL — S.U. Chung, R. Sawafta, T.E. Ward
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California Institute of Technology — K.H. Chang, A. Gonzales
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U. of California, Los Angeles — B.M.K. Nefkens, J.R. Richardson
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CEBAF — D.J. Mack, S.A. Wood
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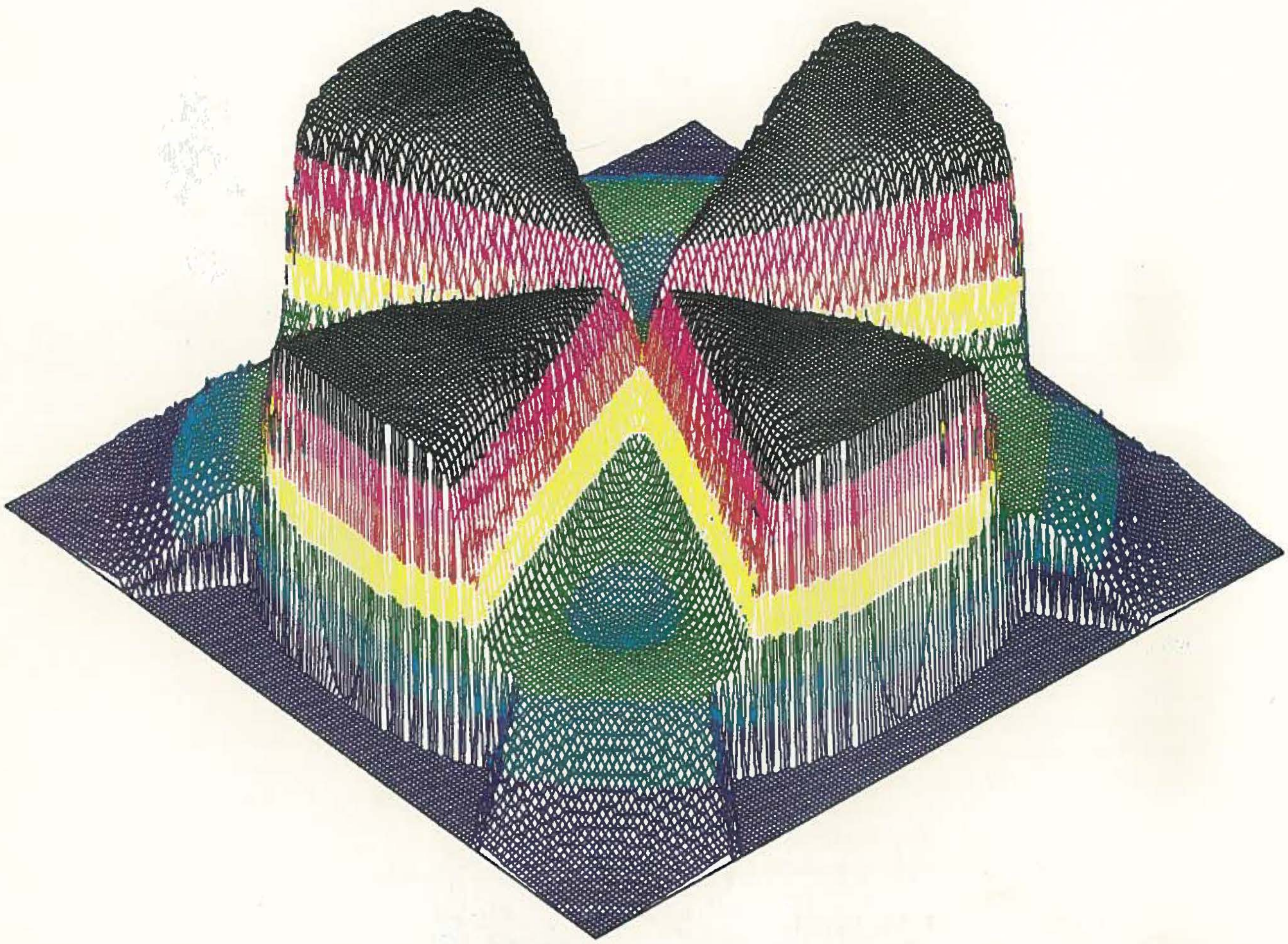

Measured TR30 Magnetic Field