CANADA'S NATIONAL LABORATORY
FOR PARTICLE AND NUCLEAR PHYSICS

**ANNUAL ADMINISTRATIVE
AND FINANCIAL REPORT 2011 – 2012**

BEAM ON

TRIUMF

ACCELERATING SCIENCE FOR CANADA


On task, on schedule,

BEAM ON

TRIUMF is fundamentally an accelerator laboratory. Each accelerator directs a beam of particles onto a target to create exotic atoms which probe the origins of matter, to make medical isotopes, to treat cancer, or to pre-flight test aerospace components before they go into orbit.

At TRIUMF, the past year has been all about "Beam On...Target." With the ARIEL construction project in full swing, hundreds of people are working together—on point. This year's success in producing technetium-99m using cyclotrons came from a breakthrough in—target technology. TRIUMF is focused, TRIUMF is relevant, and TRIUMF's beams are...on target

on budget: **on target**

TRIUMF IS ONE OF THE WORLD'S LEADING SUBATOMIC PHYSICS LABORATORIES

TRIUMF brings together dedicated physicists and interdisciplinary talent, sophisticated technical resources, and commercial partners in a way that has established the laboratory as a global model of success.

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MESSAGE FROM THE **CHAIR OF THE BOARD**

The global economy continues to vacillate between recovery and concern about future prosperity and well-being. Nations with foresight and dedication to long-term resilience have maintained their commitments to public investment in science and technology; indeed, some of them view the "knowledge economy" as an essential part of the action plan for moving forward.

Canada is no exception. Times are tough and budgets are tight, for sure, and trade-offs have been computed, calculated, and concluded. And the commitment to TRIUMF's Five-Year Plan 2010-2015 has remained steadfast. As Canada's national laboratory for particle and nuclear physics, TRIUMF has been entrusted with a great responsibility to maximize strong investments from provincial, federal, and even foreign governments in order expand the tradition of scientific excellence and develop the next generation of breakthroughs that will ensure Canada's success in energizing and employing a workforce for a brighter economic future.

This mandate is no small feat, and I am convinced that TRIUMF will succeed. As a laboratory that pools the resources and talents of dozens of universities across the country, TRIUMF is one driver of Canada's rise as a global power in science and technology.

Regularly gracing the covers of Nature while simultaneously attracting global attention and respect for leading a pan-Canadian team to develop non-reactor-based alternatives for critical medical isotopes, TRIUMF is fulfilling on this commitment. This laboratory is bringing together the best of the best for advancement of all.

Are there challenges? Is there uncertainty? Absolutely. The Advanced Rare IsotopE Laboratory (ARIEL) advanced significantly this year and represents a major investment from the Canadian public with the hopes of enormous pay-off. The construction project is on schedule and on budget. And several Canadian companies are involved in preparing the high-tech components to constitute this world-leading discovery machine. More importantly, these companies are now securing contracts from outside of Canada for their goods and services. This is the new model for globalization: moving from intellectual partnerships to diplomatic relations to business connections and ultimately Canadian sales to foreign customers: exports.

I am proud of TRIUMF's accomplishments and committed to fulfill the next three years of this plan as we deliver real value for the Canadian taxpayer's investments. TRIUMF will continue to make you proud.

Sincerely,

R. Paul Young | Chair, TRIUMF Board of Management | Vice-President, Research, University of Toronto

VISION

[1] Lead in Science: The world sees TRIUMF as Canada's leader in probing the structure and origins of matter and in advancing isotopes for science and medicine. **[2] Leverage University Research:** The Canadian university research community views TRIUMF as a way to strengthen and expand their research programs. **[3] Connect Canada to the World:** International subatomic physics laboratories look to TRIUMF when partnering with Canada and its research community. **[4] Create Social and Economic Growth:** The global scientific community sees TRIUMF as a bridge between academia and the private sector and as a model for commercialization and social impact.

MESSAGE FROM THE **DIRECTOR**

The second year into this five-year plan is a bit like having a second child: you know what to do, but you should be prepared for surprises and to work harder than you ever thought possible!

Led by the University of Victoria, ARIEL is our flagship project for rare isotope science, and it is moving rapidly forward. There are two main components, new infrastructure (buildings) and a state-of-the-art electron linear accelerator that we call the e-linac (the electron beam travels in a straight line unlike the protons in the cyclotron that travel in an expanding spiral). The new logistics building is complete (people like the new digs I am told), and the hole in the ground is bigger and deeper than anyone expected. The e-linac team led by accelerator physicists Lia Merminga, Shane Koscielniak, and Bob Laxdal, have crossed several key technical milestones including producing beam at low energy from the "electron gun" and measured some of its properties with detectors made at the University of Victoria by Professor Dean Karlen and his students. Everyone has put in a lot of effort this year and it is the great teamwork that has made it successful.

We all have heard the saying that "It is hard to walk and chew gum at the same time" and this is precisely what TRIUMF is doing. As TRIUMF seeks to position itself as one of the leading laboratories in rare-isotope science, we must continue to be at the vanguard of the science being done now as well as complete the ARIEL project on time and budget. It is this combination that keeps TRIUMF relevant and ready to seize the opportunities that ARIEL presents. Every laboratory in the world knows it is a challenge to build a major new project like ARIEL and conduct cutting-edge science experiments at the same time. The demands on staff are huge: they have to be in two places at the same time, and weekends and evenings become one way to help get the job(s) done.

The results from year two are in, and the laboratory team has brought home the bacon once again.

This last year we had major results from our Canadian team in Japan on the T2K experiment measuring the properties of neutrinos. This result was ranked 7th most important science result of the year by Physics World. The Canadian team studying antimatter at CERN trapped it for a record 1,600 seconds and have just measured the first energy level in an anti-atom (anti-hydrogen): good enough for the journal Nature. The materials science program published a significant result in the journal Nature on an exotic composite material. The rare-isotope beam program pushed further into the neutron-rich isotopes for rubidium than ever achieved before and measured the mass of the isotopes with world's best precision. This past year ended with the expectation of a possible Higgs boson discovery, and at the time of writing the hoopla had begun.

What a great year!

Sincerely,

Nigel S. Lockyer | Director, TRIUMF

mission

[1] To make discoveries that address the most compelling questions in particle physics, nuclear physics, nuclear medicine, and materials science; **[2] To act as Canada's steward** for the advancement of particle accelerators and detection technologies; and **[3] To transfer knowledge**, train highly skilled personnel, and commercialize research for the economic, social, environmental, and health benefit of all Canadians.

values

[1] Excellence and Impact
[2] Collaboration and Teamwork
[3] Honesty and Transparency
[4] Innovation and Relevance

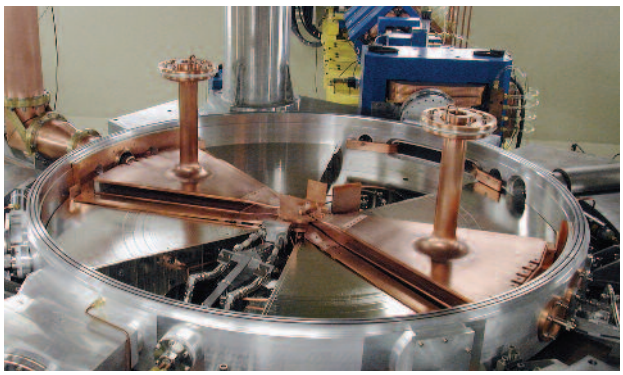
On Target: Making Key Medical Isotopes without Nuclear Reactors

by Paul Schaffer | Head, Nuclear Medicine Division

TRIUMF is committed to creating the highest impact with its research supported by the public funds that are provided by governments. To do this, we recognize that leadership is expected as individuals and also as an institution that represents Canada in the global scientific community. Making good on this notion, TRIUMF has been leading a multi-institution team across Canada, demonstrating real progress in many areas:

One of these areas is developing new alternatives to producing medical isotopes for today's healthcare system. Each year, around the world, tens of millions of medical procedures are conducted with technetium-99m (Tc-99m), an isotope used in radio-pharmaceuticals for imaging diseases of the heart and the bones and also for detecting the earliest stages of cancerous tumours elsewhere in the body. Alternative production for Tc-99m is needed as a means to pave the way for the nuclear medicine community to enter a new paradigm for isotope production – one that has long seen isotopes produced in a small number of ageing nuclear reactors around the world. One of those few reactors, the NRU reactor in Chalk River, Ontario produces just under half of the global supply and maintains a capacity to produce much more. In the past few years, the NRU as well as the other major production reactors have suffered maintenance and repair outages, threatening the global supply of medical isotopes. When these large reactors go offline in the near future, the shortage of isotope supply will be felt immediately in the medical community and ultimately by the patients that rely on their diagnostic capabilities. In addition to the supply-chain instability, producing isotopes in this conventional way involves the use of highly-enriched uranium (HEU) bringing with it a realm of socio-political issues that stretch beyond the scope of this article.

With early support from NSERC and CIHR and additional funding through the Non-reactor-based Isotope Supply Contribution Program of Natural Resources Canada, the TRIUMF-led team has succeeded in developing an alternative technology for producing Tc-99m—one that makes use of existing cyclotron machines at Canadian hospitals and institutes across the country. In February 2012, at the



annual meeting of the American Association for the Advancement of Science, the team led by TRIUMF announced the successful production of Tc-99m on cyclotrons already available in Ontario and British Columbia. The team includes TRIUMF, BC Cancer Agency, Lawson Health Research Institute, and the Centre for Probe Development and Commercialization. When coupled to the work done with other teams in Canada, a pan-Canadian solution is emerging that will eliminate our dependence on isotopes from HEU and enable medical isotope production in major hospitals, where isotopes are used every day, including right now.

As head of TRIUMF's Nuclear Medicine Division and one of the team leaders, I have been privileged to guide the team in reaching this result. Producing medical isotopes in hospitals instead of nuclear reactors is a major milestone for diagnostic imaging for patients in Canada and around the world. The team took the principles of physics, chemistry, and engineering that people have known for years, and with these tools, created and then demonstrated a recipe for upgrading cyclotrons so they could be used to make Tc-99m.

The core of the technology includes preparing solid targets of molybdenum-100 and placing them in an automated system for irradiation with a cyclotron. The team developed these tools along with chemistry that isolates and purifies the technetium-99m and readies it for use in the clinic. A provisional patent has been filed for some of these core technologies.

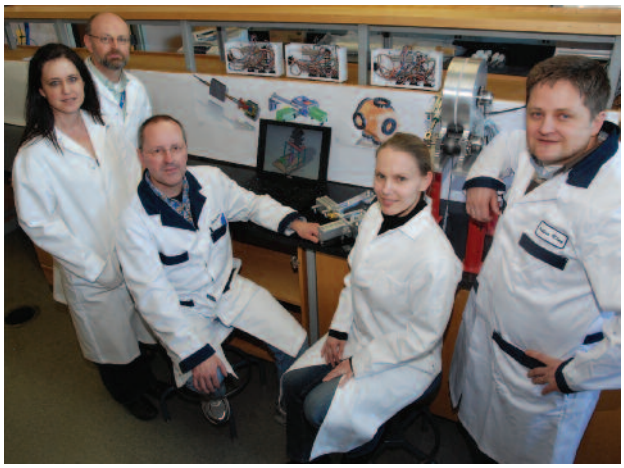
The goal of this project was to develop a technical solution that would work for many people, not just one machine or one brand of machine. TRIUMF's team has demonstrated that the existing and growing fleet of cyclotrons in Canada—which already make isotopes for other imaging protocols—can be successfully used to make high quality technetium-99m to diversify the supply of this isotope.

The technology allowed the team to achieve a global first with the production of technetium on a GE cyclotron. Almost half of the existing cyclotrons in the U.S. are GE machines which make for a potential rapid adoption of this technology in the world's biggest isotope market. This advancement will provide an easy transition from being dependent on large nuclear reactors to the cyclotrons that are already on-hand.

The impact on the isotope supply and on patients is dramatic. One of these cyclotrons can supply a metro area such as Vancouver and there are more than a dozen of these cyclotrons in hospitals across Canada. As this technology is rolled out across Canada, it will help hospitals save time and money, and reduce the wait that patients have been experiencing for critical diagnostic tests.

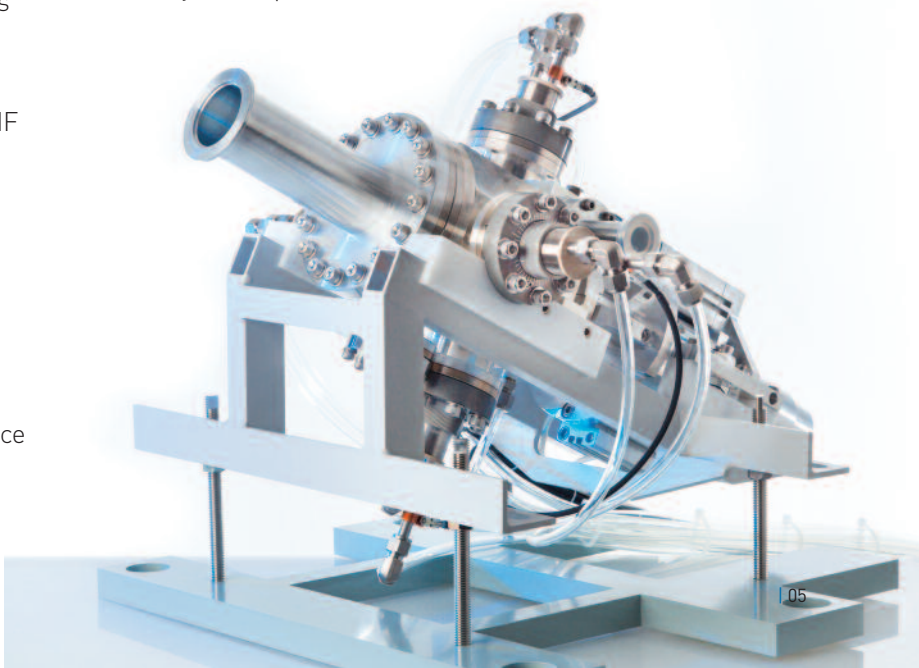
The TRIUMF-led team believes that a decentralized model for producing technetium is now possible. TRIUMF hosted an IAEA international workshop in April 2012 that examined strategies for deploying this technology in the developing world to support non-proliferation objectives.

This program has provided an opportunity for TRIUMF to showcase its expertise in cyclotron technology to Canada and the world. TRIUMF has operated the world's largest cyclotron for nearly four decades, as well as a number of smaller cyclotrons used in producing other medical isotopes for research and commercial use (often in partnership with Nordion, Inc). This technological expertise has had a direct impact on the Nuclear Medicine Division and is an example of how TRIUMF connects research excellence with business relevance.



What's next? The Government of Canada announced in Budget 2012 a second phase of the isotopes program to fully develop and deploy these alternative Tc-99m production technologies. The TRIUMF consortium expects to compete for a share of these resources to demonstrate full commercial production of Tc-99m on an ongoing basis while securing the necessary regulatory approvals to use the product regularly with human patients in clinics. The team is working with several interested commercial partners and is confident that a network of alternative isotope producers will be available when Canada's NRU reactor is scheduled to cease supplying isotopes in 2016.

This program of work has been particularly satisfying for TRIUMF because of the opportunity to demonstrate the relevance of basic research to real-world problems in a timely manner. And while perhaps the 10% genius phase is over and the next few years will be 90% perspiration, I am enormously proud of what the TRIUMF team and our partners across Canada have already accomplished.



THE 2011-2012 FISCAL YEAR WAS THE SECOND YEAR OF TRIUMF'S FIVE-YEAR PLAN 2010-2015. BASED ON THIS YEAR'S PROGRESS AND PERFORMANCE, THE LABORATORY IS ON TARGET. BELOW, THE PLANS AND PROMISES FOR THE YEAR ARE REVIEWED AND DISCUSSED, USING TRIUMF'S OVERALL MISSION STATEMENT AS A GUIDING FRAMEWORK.

ARIEL

- ☑ Install and test hardware to begin commissioning of e-linac system elements; and
- ☑ Complete and move into the new Stores Building making way for demolition and then excavation for the ARIEL isotope-production hall.

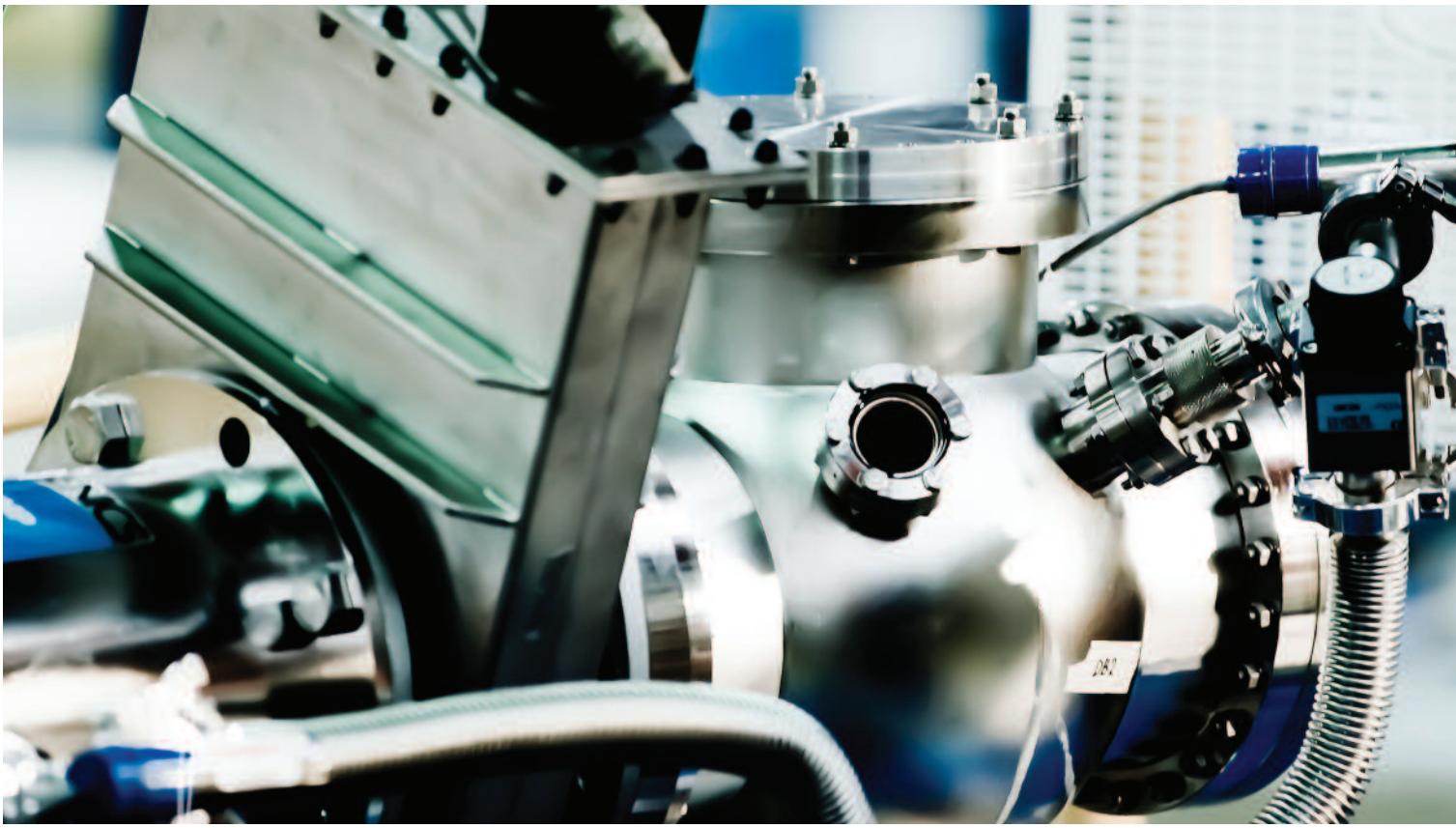
Building on the outstanding partnership with India's VECC laboratory in Kolkata, TRIUMF moved forward with design, engineering, and construction of the e-linac. A prototype electron gun (the source of electrons) was constructed in the VECC Test Area. In December 2011, electrons "arrived at TRIUMF" for the first time; that is, a beam of electrons up to 100 keV was produced and imaged at TRIUMF. Although the project is moving forward swiftly, the March 2012 milestone for assembly of the injector cryomodule and a 30 kW beam test of the electron gun was missed; the work will be complete by the end of 2012. Part of the delay was in part because of design changes to the e-linac that aim to enhance performance and better support future upgrades.

The ARIEL construction and conventional facilities project have advanced like clockwork. A new Stores Building was designed, constructed, and put into service along with a new secure Badged Portal Entry facility. The older buildings were demolished and ground-breaking for the new ARIEL facility took place November 1, 2011. The former Proton Hall was cleared out and refurbished and officially became the Electron Hall a few months later. After excavation of 1,000 truckloads of earth, the site for the ARIEL building was ready and concrete and formwork has been flowing in ever since.

The ARIEL project, including the e-linac and VECC partnership activities, regularly occupy more than 50 FTEs within TRIUMF. Quarterly and semi-annual reviews with various stakeholders measure progress consistent with the baseline schedule; some areas of scope have been revised to stay within the overall project budget.

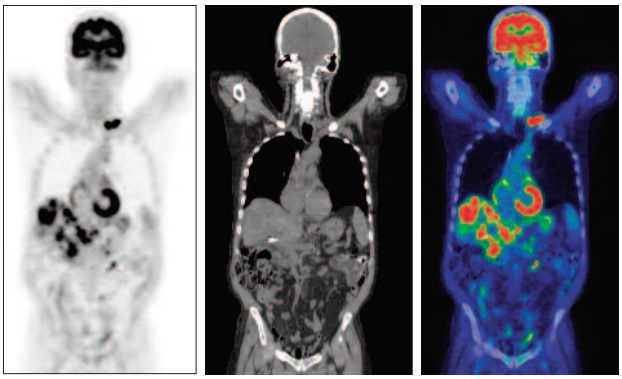
ADDRESS THE MOST COMPELLING QUESTIONS...

- ☑ Deliver unrivaled intensities of extreme neutron-rich isotopes to enable world-class research for nuclear-physics and materials-science studies;
- ☑ Expand nuclear-medicine research collaborations with Pacific Parkinson's Research Centre, BC Cancer Agency, and commercial partners;
- ☑ Achieve integrated data goals for PiENu experiment; and
- ☑ Exploit and lead science opportunities in ATLAS at CERN and T2K in Japan



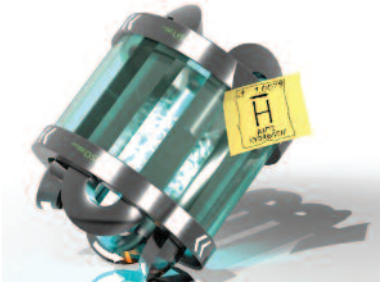
The rare-isotope beams program exceeded availability goals for 2011; among a long list of accomplishments, the ISAC facility delivered record beam power to an actinide target enabling studies of nuclei along the astrophysical r-process path. Other highlights include the investigation of three-body forces in neutron-rich calcium nuclei through sensitive mass measurements. The TITAN experiment published 14 scientific papers alone with 6 of those appearing in the prestigious Physical Review Letters journal. One of these papers featured a rare combination of experimental and theoretical prowess that compared properties of the helium-6 isotope measured in the laboratory with updated models from the blackboards and computers of theoretical nuclear physics.

In the realm of nuclear medicine, TRIUMF secured its first grant-funded research program with Genome BC under a development and knowledge-translation program. The project is showcasing TRIUMF's large molecule radiochemistry expertise by demonstrating the design and production of peptide-PNA tracers to enter, seek, bind, and allow quantification of mRNA



within cells. Early in vitro data is encouraging. Professor Yu-Shin Ding, co-director of the Yale University PET Centre, visited TRIUMF for several months as part of a collaboration agreement including the Pacific Parkinson's Research Centre. Professor Ding's expertise in novel neurological physiology combined in a potent 6 month collaboration that saw the introduction of two new tracers into TRIUMF's already large repertoire of radiopharmaceuticals. These new tracers will be used to examine the norepinephrine transporter system in the human brain in various states; work that is highly complementary to the dopamine system studies underway. TRIUMF also partnered successfully with the BC Cancer Agency and the University of Waterloo to launch a pair of projects supported by the Collaborative Health Research Program of the federal CIHR and NSERC research agencies; one is set to examine novel techniques for detecting amyloid plaques associated with Alzheimer's disease in the retina and the other explores the production of Zr-89, Ga-68, Sc-44 and Y-86 in liquid form to enable typical cyclotron centres to produce and examine these up-and-coming radiometals without substantial infrastructure or capital upgrades. TRIUMF also upgraded a portion of its underground pneumatic "rabbit line" for delivery of short-lived medical isotopes to the nearby UBC hospital and clinics.

In particle physics, the PiENu experiment seeks to measure a rare decay iwith high precision. The experiment is wrapping up shortly with a complete set of data that will allow it to achieve the highest sensitivity on this measurement. Internationally, TRIUMF led Canadian involvement in both the ATLAS experiment at CERN and the T2K experiment at KEK in Japan. The ATLAS experiment announced tantalizing traces of the long-sought Higgs boson in December 2011 (the discovery of a new particle consistent with the Higgs boson was later announced in July 2012); Canadians were widely recognized for their role in the 3,000 person effort. Under co-leadership of TRIUMF scientists the ATLAS collaboration set constraints on the existence of supersymmetric and other exotic particles over a wide mass range. TRIUMF scientist and SFU professor Michel Vetterli was elected as ATLAS Collaboration publications chair, a role that starts after a year serving as deputy. In July 2011 the T2K collaboration, which shoots a neutrino beam 295 km across Japan, announced first results clearly indicating that the third neutrino mixing angle is non-zero and large. These results were confirmed in the spring of 2012 by several reactor based experiments. The ALPHA experiment at CERN was able to perform the first ever microwave spectroscopy of atomic transition in antihydrogen and published the result in Nature; TRIUMF scientist Makoto Fujiwara was awarded the American Physical Society's John Dawson Prize for this work.



ADVANCE PARTICLE ACCELERATOR AND DETECTION TECHNOLOGIES...

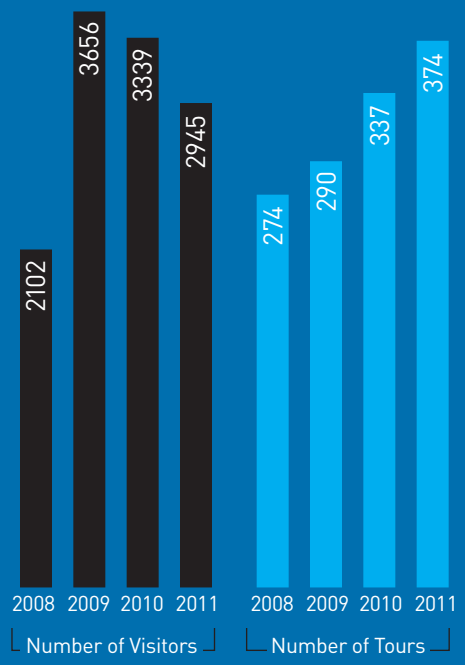
- ☑ Enhance isotope production capacity at ISAC facility by installing and commissioning expanded target handling and testing facilities;
- ☑ Create and deliver heavy, rare isotopes using 10 μA from main cyclotron on an actinide target—a global first;
- ☑ Complete and test new muon beam-line facilities at M-9A and M-20 to serve a growing user community; and
- ☑ Within the CycloTech99 framework, demonstrate capabilities for commercial-scale production of Tc-99m using existing medical cyclotrons;

BY THE NUMBERS:

EXCELLENCE WITH IMPACT

In the 2011–2012 fiscal year, TRIUMF:

Shared the laboratory with **2,945** people for public tours including nearly **850** students



Hosted **16** VIP visits including the His Excellency the Right Honourable David Johnston, the Governor General of Canada

Provided educational and/or research work experiences for **6** high-school, **75** undergraduate, and **76** graduate students

Hosted more than **416** external visiting scientists

Supported **30** scientific experiments at ISAC in nuclear physics, **19** experiments at CMMS in molecular and materials science, and **11** experimental programs for life sciences and nuclear medicine

Delivered **2,432** hours of radioactive-isotope beams and **1,883** hours of stable-isotope beams to scientific experiments in its ISAC facility

Achieved **99%** availability for the Canadian ATLAS Tier-1 Data Centre and increased CPU capacity to **4,160** cores with **7.2** Petabytes of disk storage and **5.5** Petabytes of tape storage to process **14** billion events from the ATLAS detector in **4** million distinct computing-grid jobs

Authored or co-authored **251** scientific peer-reviewed publications including two Nature Physics cover stories

Treated **9** cancer patients using proton therapy in cooperation with the BC Cancer Agency (BCCA)

Used its TR13 cyclotron to produce **671** runs of medical isotopes delivered to hospitals for research, **72** runs for medical isotopes to BCCA for the diagnosis of cancer patients, and **204** runs for isotope-production research and development

Produced up to **1,800,000** patient doses (in partnership with Nordion, Inc.) of medical isotopes for commercial sale

Generated **$1,441,927** of commercial revenue; when averaged over several years, TRIUMF's ratio of generated revenues compare to annual operating budget is about 3%—equal to the same metric for the Massachusetts Institute of Technology

Operated the main cyclotron for **5,159** hours or just more than **94%** of scheduled performance

Had **406,390** visits to its website and was followed by **1,616** people across social-media platforms (Twitter, Facebook, etc.)

Attracted new talent to Canada from **11** different countries

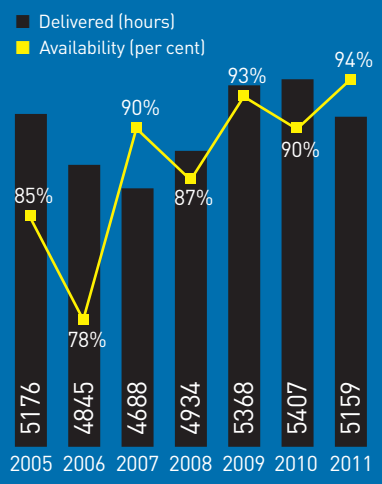
Received high recognition for its staff: SNM Michael J. Welch Award for Thomas J. Ruth, APS John Dawson Award for Makoto Fujiwara, Business in Vancouver Top 40 Under 40 for T.I. Meyer, and the CAP-TRIUMF Vogt Medal for David Sinclair

Assisted in hosting the record-breaking annual meeting of the American Association for the Advancement of Science in Canada for the first time in **30** years, including fostering the participation of **200** B.C. high-school science students

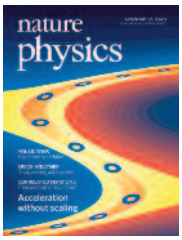
Nationality of scientific users coming to TRIUMF

United States 29.0%	Israel 0.9%
Canada 25.2%	Argentina 0.2%
Japan 18.4%	Italy 0.2%
France 8.3%	Denmark 0.2%
United Kingdom 6.6%	Sweden 0.2%
Switzerland 3.1%	Russia 0.2%
Germany 3.1%	Spain 0.2%
China 1.4%	Brazil 0.2%
India 1.4%	

Cyclotron Performance



The main cyclotron at TRIUMF received a national award for engineering excellence; in February 2012, the Engineering Institute of Canada recognized the TRIUMF cyclotron alongside five other engineering marvels in Canada (e.g., CN Tower, Confederation Bridge, Canadarm, and so on) on the occasion of the organization's 125th anniversary. Elsewhere, a trio of Canadian scientists from TRIUMF collaborated with an international effort to develop fixed-field alternating gradient accelerators; the results were featured as a cover story in Nature Physics.



TRIUMF is continuing to develop an accelerator science research and education program. Components of the program include teaching graduate courses at UBC and University of Victoria, supporting graduate thesis research at TRIUMF under TRIUMF staff mentorship.

TRIUMF's ISAC facilities are the centerpiece for advancing isotopes for science. Beams of protons from the main cyclotron are directed to two underground target stations where the rare, exotic isotopes are formed. The isotopes are then extracted and delivered in the form of a beam to science experiments in the ISAC experimental halls. Upgraded facilities for reliable, conditioning and testing of the ISAC target modules were designed and installed. Designs and

In December 2011, TRIUMF set a new world record for highest total beam power directed onto an actinide target.

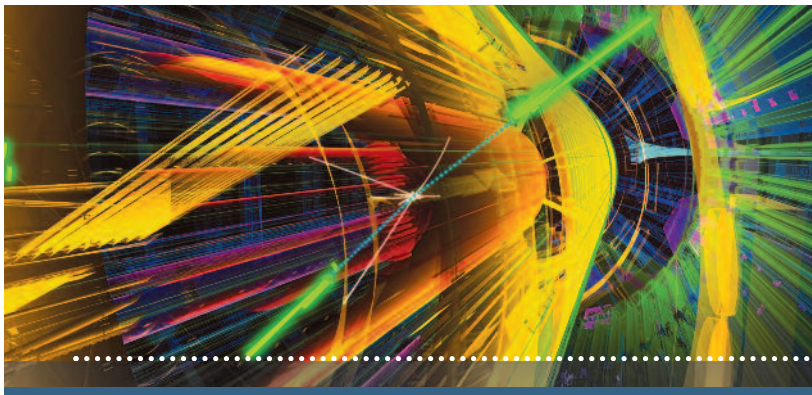
engineering of the enhanced "quick-disconnect" interface was advanced, and the efficiency of the isotope-yield station was doubled.

In December 2011, TRIUMF set a new world record for highest total beam power directed onto an actinide target for the production of exotic, heavy isotopes. The record was achieved on Saturday, December 3, when the scientific team confirmed that 9.8 microamps of 500 MeV proton beam current (about 60 trillion protons per second) were striking the actinide target material. Before then, the record was held by CERN's ISOLDE facility with a record of about 2 microamps reached several years ago. The U.S. HRIBF facility at Oak Ridge has the overall record with highest current and power density; the TRIUMF team surpassed them in the area of total power. After obtaining full approval from the CNSC regulator based on an earlier pilot run, TRIUMF used the actinide target as the source of isotopes for ground-breaking science experiments.

TRIUMF has been steadily advancing two projects (called M-9A and M-20) to substantially upgrade and expand its materials-science facilities using muon beams. These facilities use proton beams from the main cyclotron along a beam line called Beam Line 1A.

The aging infrastructure of the beamline failed in several key areas during the year, creating an urgent crisis as well as an interruption of the original installation plans. Detailed, precision repairs took place and the two materials-science facilities will be coming online in 2012. A more substantive overhaul of the core beam line is being developed.

As featured in this report, TRIUMF led a national team of four institutions (TRIUMF, BC Cancer Agency, Lawson Health Research Institute, and the Centre for Probe Development and Commercialization) to develop cyclotron-based production of technetium-99m, the world's most commonly used medical isotope. The team announced successful production of the isotope using existing cyclotrons in Ontario and British Columbia at the February 2012 American Association for the Advancement of Science meeting in Vancouver. A broadly defined provisional patent on the core technologies has been filed.



THIS CHANGES EVERYTHING

Some things are too exciting to wait a year to share: on the morning of July 4, 2012, the ATLAS and CMS collaborations at CERN's Large Hadron Collider announced definitive observation of a new particle consistent with the long-sought Higgs boson. Each team includes 3,000 scientists and the ATLAS team included 150 Canadians. Celebrations and congratulations crisscrossed the country. TRIUMF has been the bridge for Canada's involvement in this global effort. The new particle is thought to be a single excitation of the pervasive Higgs field that is hypothesized to span all of space and that acts like a molasses to slow particles down, creating the experience of mass. The hunt has spanned many decades and, as some say, this breakthrough finishes one chapter in particle physics and starts the next. The next big questions include: What are the complete properties of the Higgs? Is it just as predicted? What other particles are hidden in the stacks of data pouring in from the experiments?

FOR THE BENEFIT OF ALL CANADIANS...

- ☑ Complete on-site MHESA nuclear-medicine laboratory where TRIUMF and Nordion, Inc. scientists will work alongside one another to develop medical isotopes of the future;
- ☑ Successfully renew core operating license from Canadian Nuclear Safety Commission;
- ☑ Complete design, install, and transition to new enterprise-resource planning system;
- ☑ Expand international science partnership and investment;
- ☑ Drive multiple successes for Advanced Applied Physics Solutions, Inc.; and
- ☑ Develop a strategic partnership with an external science outreach and education organization.

The new nuclear-medicine laboratories in the MHESA building are not yet complete. Hand-over of the lab space for commissioning was delayed (but is now underway), primarily due to redirecting talent and resources to the ARIEL and Tc-99m projects for several months. Nordion, Inc. and TRIUMF are preparing a second phase of the Cooperative Research and Development grant from NSERC for the study of novel chelates for the incorporation of promising new radiometals. TRIUMF collaborated with its commercialization partner AAPS, Inc., to release a commissioned, independent report in February 2012 that surveyed the deployment of PET imaging technologies for clinical care of cancer across Canadian provinces. The report found that Canada is behind its international peers in the utilization of PET imaging technologies.

Working through a sequence of reviews, inspections, and quality-management analyses, TRIUMF successfully applied to the Canadian Nuclear Safety Commission for a renewal of its operating license. For the first time in its existence, the laboratory was awarded a ten-year operating license, effective July 1, 2012.

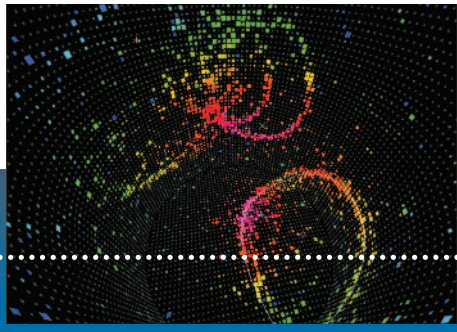
As part of a renewal of business practices and tools, TRIUMF launched an overhaul of its enterprise-resource planning (ERP) system. The initial project scope included a tight integration of many aspects of the finance, supply chain, human resources and payroll, and business-management functions. As design and implementation work proceeded in 2011/2012, it became clear that the implementation of a brand new system and its complexities would require additional time in order to ensure all functionalities are properly addressed. The new system is expected to be commissioned and in use by the end of 2012, later than originally planned.

By the end of March 2012, TRIUMF completed aligning its program of work, its funding envelope, and stakeholder expectations. Redistributing and redirecting staff, selected hires, and managing succession were key strategies.

For the first time in its existence, the laboratory was awarded a ten-year operating license.

One of TRIUMF's greatest assets is its employees. In that regard, initiatives this past year focused on enhancing recruiting. This included the development of a new web portal focused on careers at TRIUMF, as well as the introduction of a comprehensive interactive online orientation tool to enhance the on-boarding process for new employees. In support of the on-boarding process, a New Employee Reference Handbook was developed, and a 90-day survey introduced to gain valuable feedback from new employees.

Committed to connecting Canada to the world, TRIUMF seeks strategic opportunities for international partnership and investment. During the past year, TRIUMF worked with the VECC laboratory in India to develop a third phase of partnership in accelerator science and technology. This third phase is valued at $10.4 million and has been approved by India's Department of Atomic Energy; the formal signing ceremony is expected to take place in November 2012.



THE ELUSIVE NEUTRINO

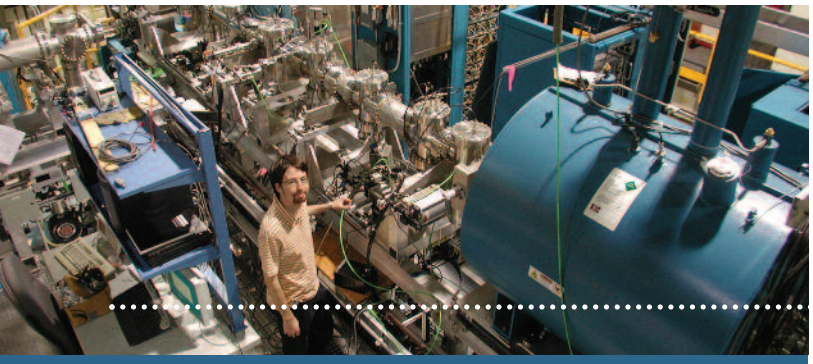
Neutrinos are some of the most mysterious particles in the Standard Model. They have been used to image the earth and detect far-away supernovae, and for a few months, they appeared to be capable of travelling faster than light speed (this has since been disproved). Canadians via TRIUMF have been participating in a Japan-based neutrino experiment called T2K. The collaboration's measurement of the non-zero mixing property of the neutrinos ranked 7th in the Top 10 Physics Breakthroughs of the Year as reported by the UK's Physics World.

U.S. researchers secured funding from the U.S. Department of Energy to construct a laser facility at TRIUMF for upcoming research with francium isotopes in ISAC. TRIUMF is also exploring a science-policy internship program with Korea.

TRIUMF has taken key actions to support the success of Advanced Applied Physics Solutions (AAPS), Inc., a federally funded Centre of Excellence for Commercialization and Research launched in 2008. Building on an investment by Western Economic Diversification to develop cosmic-ray muon geotomography technology for detecting buried ore

deposits, AAPS has formed a spin-off company that has secured $500,000 of funding from first-round customers who will help deploy and benchmark the technology. TRIUMF's detector and electronics teams have been closely involved. AAPS has also formed a second spin-out company IKOMED, Inc., that is developing radiation-reducing technology for x-ray fluoroscopy machines. IKOMED has secured substantial private investment in its first round and its prototype product is undergoing evaluation by an OEM manufacturer.

In autumn 2011, TRIUMF joined forces with Science World British Columbia as a founding "Partner in Innovation." The new five-year agreement will allow both organizations to deliver optimal programming and support for science-interested students and the public from "K through grey." TRIUMF's high-school fellowship programs will be connected with Science World's Future Science Leader program. Together, TRIUMF and Science World are organizing a public science lecture from CERN Director-General Rolf Heuer in early June 2012 in downtown Vancouver at the Telus World of Science. In summer 2011, TRIUMF hosted its second aboriginal high-school summer student who learned research skills in the lab and prepared a series of weekly blogs about his experience.



LOOKING FOR MAGIC IN CALCIUM

Calcium, an important element in biological systems, is of great interest in nuclear physics. The most abundant isotope, calcium-40 or Ca-40, which has 20 protons and 20 neutrons, is the heaviest stable element that has an equal number of protons and neutrons. Another peculiar feature of calcium isotopes is that it is the only element that contains two, nearly stable, doubly-"magic" nuclei: Ca-40 and Ca-48. Calcium-40 is stable while the half-life of 48Ca is over a billion times longer than the age of the universe and hence can be considered stable as well. A magic number in nuclear physics occurs when a certain number of nucleons (either protons or neutrons) arrange themselves into shells, much like atomic orbitals for electrons. The nuclear established magic numbers are 2, 8, 20, 28, 50, 82, and 126. Recently, physicists have been trying to develop theories based on quantum chromodynamics to predict aspects of nuclear physics. The new tools allowed the calculation of so-called "three-body" forces, where three nucleons interact simultaneously. (In previous theories, it was assumed that nucleons would only interact with each other one at a time.) Theorists now begin to calculate properties of the neutron-rich calcium isotopes and compare them to experiment. Enter TITAN, TRIUMF's premier mass-measuring experiment. The result? TITAN's mass measurements have sufficient precision to show that the calcium isotopes match the enhanced theoretical calculations more accurately than ever before.

ARIEL

- ☐ **Steady** progress on the ARIEL project on schedule and on budget with substantive completion of the ARIEL building construction and services ready for staged use.
- ☐ **Maintain** e-linac schedule and funding profile.
- ☐ **Authorize** and launch third phase of partnership with India's VECC laboratory to jointly explore and develop target-module technologies for ARIEL in Canada and ANURIB in India.

ADDRESS THE MOST COMPELLING QUESTIONS...

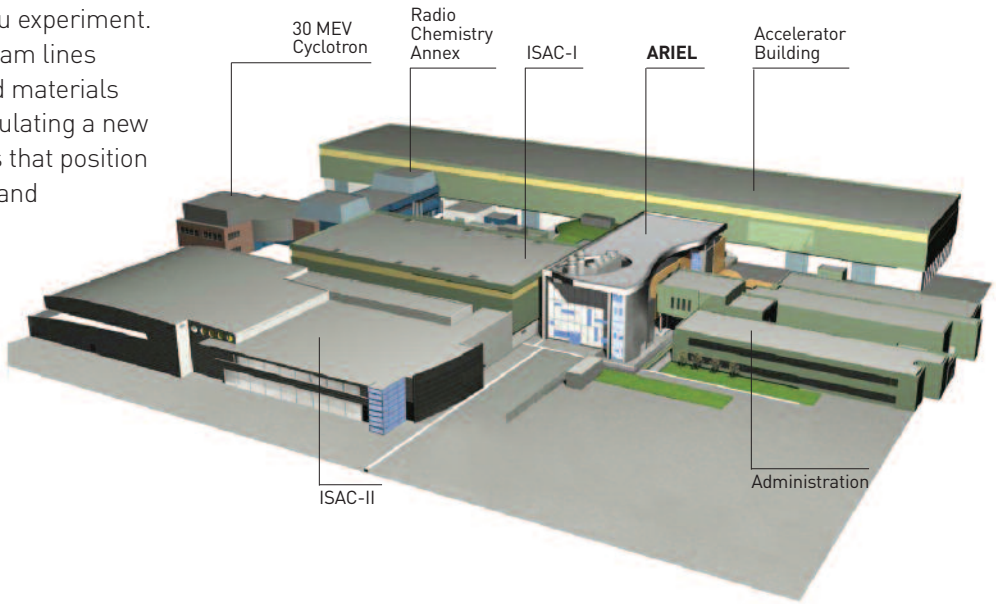
- ☐ **Advance** breakthroughs in particle and nuclear physics to generate at least one science-journal cover story featuring TRIUMF and Canadian scientific contributions.
- ☐ **Complete** data-taking and move into final data-analysis for ground-breaking PiENu experiment.
- ☐ **Complete** and commission new beam lines (M-9A and M-20) for molecular and materials science while simultaneously formulating a new strategic plan for these capabilities that position Canada among the world leaders; and
- ☐ **Pursue** the Higgs boson and other new physics beyond the Standard Model with the ATLAS experiment at CERN and the T2K experiment in Japan.

ADVANCE PARTICLE ACCELERATOR AND DETECTION TECHNOLOGIES...

- ☐ **Complete** upgrades to isotope-production target module infrastructure.
- ☐ **Assess** and develop management plan for ageing Beam Line 1A.
- ☐ **Examine** and begin structured approach to reducing and reusing liquid-helium through a planned future helium-liquefier plant.
- ☐ **Develop** preliminary elements of e-linac to begin accelerator research and development program.

FOR THE BENEFIT OF ALL CANADIANS...

- ☐ **Advance** neighbourhood district-energy system project with local UBC community including technical engineering feasibility study.
- ☐ **Provide** proton-therapy treatment for ocular melanomas and serve as secondary supplier for BC Cancer Agency's medical-isotope needs.
- ☐ **Identify** and advance major knowledge- transfer project with AAPS, Inc., and third-party commercial partner.
- ☐ **Map out** and launch national community-based plan to develop and deploy Tc-99m production capacity using existing medical cyclotrons across Canada.
- ☐ **Demonstrate** performance of safety, assurance, quality-management, and other systems to secure renewed operating license from Canadian Nuclear Safety Commission.
- ☐ **Provide** cultural activities for local community that advance appreciation of science, technology, and art.



FINANCIAL POSITION

Fiscal year ending March 31, 2012 represented Year Two of TRIUMF's current Five Year Plan. Building on the momentum created in 2011, TRIUMF marched forward and executed its plan in accordance with the established budgets and schedules.

TRIUMF's operating costs, funded by a contribution from the National Research Council, totalled $44.0M and represented a $1.0M (or 2.2%) reduction from the previous year.

The Advanced Rare IsotopE Laboratory (ARIEL) moved into full swing as resources were deployed to transition the project from its design phase to the start of construction. This $63M investment, funded via the University of Victoria from contributions made by Canada Foundation for Innovation, British Columbia Knowledge Development Fund, and TRIUMF in-kind contributions, demonstrates TRIUMF's ability to plan and execute large-scale projects. The end result will bring great value to the Canadian public.

Several other projects were started, progressed, or completed in the year in accordance with established commitments, while the laboratory maintained its normal operating levels in support of our core science and research programs.

Based on an external review of TRIUMF's core computing facilities including its Management Information System, a team was assembled to design and implement a new financial and administrative system (Enterprise Resource Planning System – ERP). The review stated that TRIUMF requires a flexible and responsive information system to comply with changing and increasingly stringent regulatory demands, and to provide reliable management reporting. Significant efforts and progress were made during the year and it is anticipated that the cutover to the new system will occur by the 4th quarter of 2012. In conjunction with modifications to TRIUMF's planning and reporting methods, the new system will continue to assist management in maintaining a fiscally healthy laboratory.

Looking forward, TRIUMF is positioned to carry out and meet its commitments in a financially sustainable manner. Our fiscal prudence and disciplined adherence to our financial policies serve to position TRIUMF for continued success and provide ongoing value for stakeholders.

Henry Chen | Chief Financial Officer

INDEPENDENT AUDITOR'S REPORT

To the Joint Venturers of TRIUMF

The accompanying summary financial statements, which comprise the summary statement of financial position as at March 31, 2012 and the summary statement of combined funding/income and expenditures and changes in fund balances for the year then ended, and related notes, are derived from the audited financial statements of TRIUMF for the year ended March 31, 2012. We expressed an unmodified audit opinion on those financial statements in our report dated July 18, 2012. Those financial statements, and the summary financial statements, do not reflect the effects of events that occurred subsequent to the date of our report on those financial statements.

The summary financial statements do not contain all the disclosures required by section 11b of the TRIUMF joint venture agreement and the contribution agreement with the National Research Council of Canada, and are prepared using the basis of accounting referred to in note 2 of the accompanying summary financial statements. Reading the summary financial statements, therefore, is not a substitute for reading the audited financial statements of TRIUMF.

Management's responsibility for the summary financial statements

Management is responsible for the preparation of a summary of the audited financial statements in accordance with the basis of accounting described in note 2 of the summary financial statements.

Auditor's responsibility

Our responsibility is to express an opinion on the summary financial statements based on our procedures, which were conducted in accordance with Canadian Auditing Standard (CAS) 810, "Engagements to Report on Summary Financial Statements."

Opinion

In our opinion, the summary financial statements derived from the audited financial statements of TRIUMF for the year ended March 31, 2012 are a fair summary of those financial statements, in accordance with the basis of accounting described in note 2 of the summary financial statements.

PricewaterhouseCoopers LLP

Chartered Accountants | Vancouver, B.C. | July 30, 2012

STATEMENT OF FINANCIAL POSITION

As at March 31, 2012

	2012	2011
	$	$
Assets		
Cash and cash equivalents	10,878,148	11,634,530
Restricted cash	10,194,410	10,069,448
Due from Joint Venturers	4,748,402	2,079,449
Funding receivable	1,929,016	1,150,190
	27,749,976	24,933,617
Liabilities		
Accounts payable and accrued liabilities	4,686,553	2,780,212
Funds received in advance	3,974,310	4,085,972
Decommissioning Fund	10,194,410	10,069,448
	18,855,273	16,935,632
Fund Balances		
Restricted		
Natural Sciences and Engineering Research Council Fund	4,216,445	4,665,908
NORDION Inc. Fund	100,000	100,000
Natural Resources Canada	-	(103,326)
	4,316,445	4,662,582
Other		
Commercial Revenue Fund	2,056,579	1,434,198
General Fund	249,196	132,633
Intramural Accounts Fund	2,272,483	1,768,572
	4,578,258	3,335,403
	8,894,703	7,997,985
Total liabilities and fund balances	27,749,976	24,933,617

STATEMENT OF FUNDING AND EXPENDITURES AND CHANGES IN FUND BALANCES

For the year ended March 31, 2012

	2012	2011
	$	$
Funding/income		
National Research Council Fund	44,000,000	45,000,000
Natural Sciences and Engineering Research Council Fund	6,316,503	6,309,557
British Columbia Knowledge Development Fund	4,877,723	632,024
NORDION Inc. Fund	4,190,636	4,219,420
Advanced Applied Physics Solutions Inc. Fund	1,806,141	1,754,608
Canada Foundation for Innovation	10,196,335	5,580,147
Natural Resources Canada	1,043,988	700,238
Affiliated Institutions Fund	2,207,629	2,110,304
Commercial Revenue Fund	1,441,927	2,628,668
General Fund	200,258	98,063
Intramural Accounts Fund	1,116,365	1,275,087
	77,397,505	70,308,116
Expenditures		
Buildings and improvements	6,387,794	847,283
Communications	216,387	190,173
Computer	1,241,276	2,049,025
Consulting	3,374,520	2,390,710
Equipment	6,662,677	5,251,722
Power	2,370,483	2,608,866
Salaries and benefits	40,588,275	40,281,034
Supplies and other expenses	13,710,207	10,720,245
Travel	1,949,168	1,847,246
	76,500,787	66,186,304
Surplus of funding over expenditures for the year	896,718	4,121,812
Fund balances - Beginning of year	7,997,985	3,876,173
Fund balances - End of year	8,894,703	7,997,985

NOTES TO FINANCIAL STATEMENTS

1 | Nature of operations

TRIUMF is Canada's national laboratory for particle and nuclear physics. It is owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council of Canada. As a registered charity, TRIUMF is not subject to income tax.

The members of the joint venture are the University of Alberta, Carleton University, the University of Guelph, Queen's University, the University of Manitoba, the University of Victoria, Simon Fraser University, the University of British Columbia, l'Université de Montréal, the University of Toronto and York University. There were no changes to the membership during fiscal 2012.

At March 31, 2012, each university owned an undivided 9.09% interest in all the assets and liabilities of TRIUMF, except for the land and buildings occupied 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 assets, liabilities, revenues and expenditures of the individual joint venture members.

Sources of funding include grants and contributions from the National Research Council of Canada, the Natural Sciences and Engineering Research Council, other government funding; advances and reimbursements from other sources; commercial revenues; and investment income. TRIUMF has established a number of separate funds to account for the various funding sources. The sources and purposes of these funds are:

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

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

British Columbia Knowledge Development Fund
Funding provided for the civil construction of buildings. These funds are provided by the Province of British Columbia through the university members of the TRIUMF joint venture.

NORDION Inc. Fund
Advances and reimbursements from NORDION Inc. for expenditures incurred at TRIUMF.

Advanced Applied Physics Solutions Inc. (AAPS)
Advances and reimbursements from AAPS for expenditures incurred at TRIUMF.

Natural Resources Canada (NRCan)
Funding for capital projects related to TRIUMF activities, specifically for proof-in-principle that specific medical isotopes currently produced by nuclear reactors can be produced by cyclotrons.

Canada Foundation for Innovation (CFI)
Funding to Canadian universities for capital projects related to TRIUMF activities. These funds are administered by the universities and TRIUMF is reimbursed for expenditures undertaken in accordance with the terms of the grant.

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

Commercial Revenue Fund
Royalties, revenues and expenditures relating to commercial activities and technology transfer.

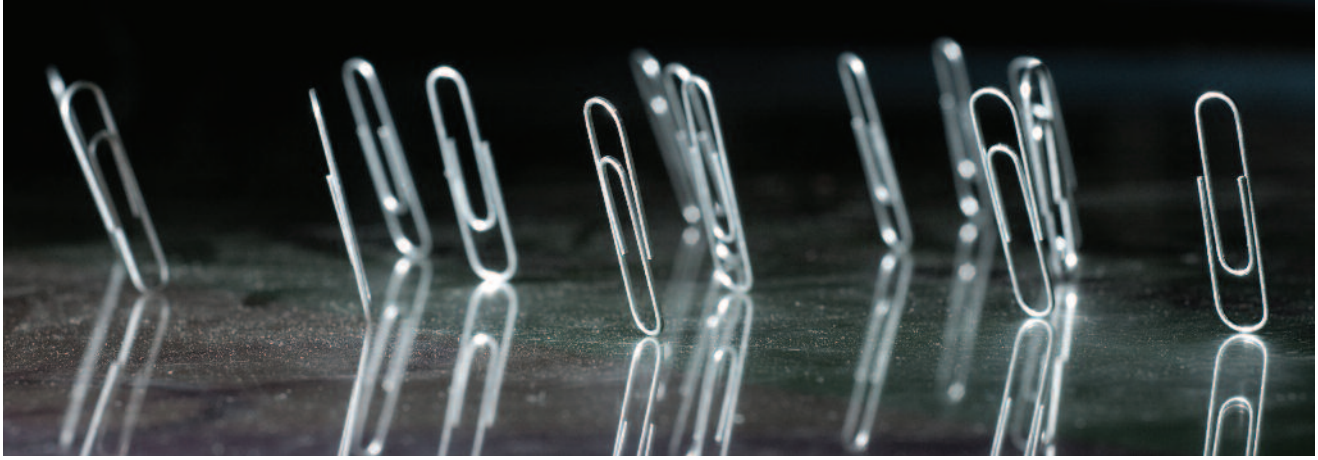
General Fund
Interest income generated is used for non-qualifying discretionary expenditures incurred by TRIUMF.

Intramural Accounts Fund
Net recoveries generated by internal projects and services. The recoveries of expenditures are charged to the appropriate TRIUMF funding source by Intramural Accounts.

2 | Significant accounting policies

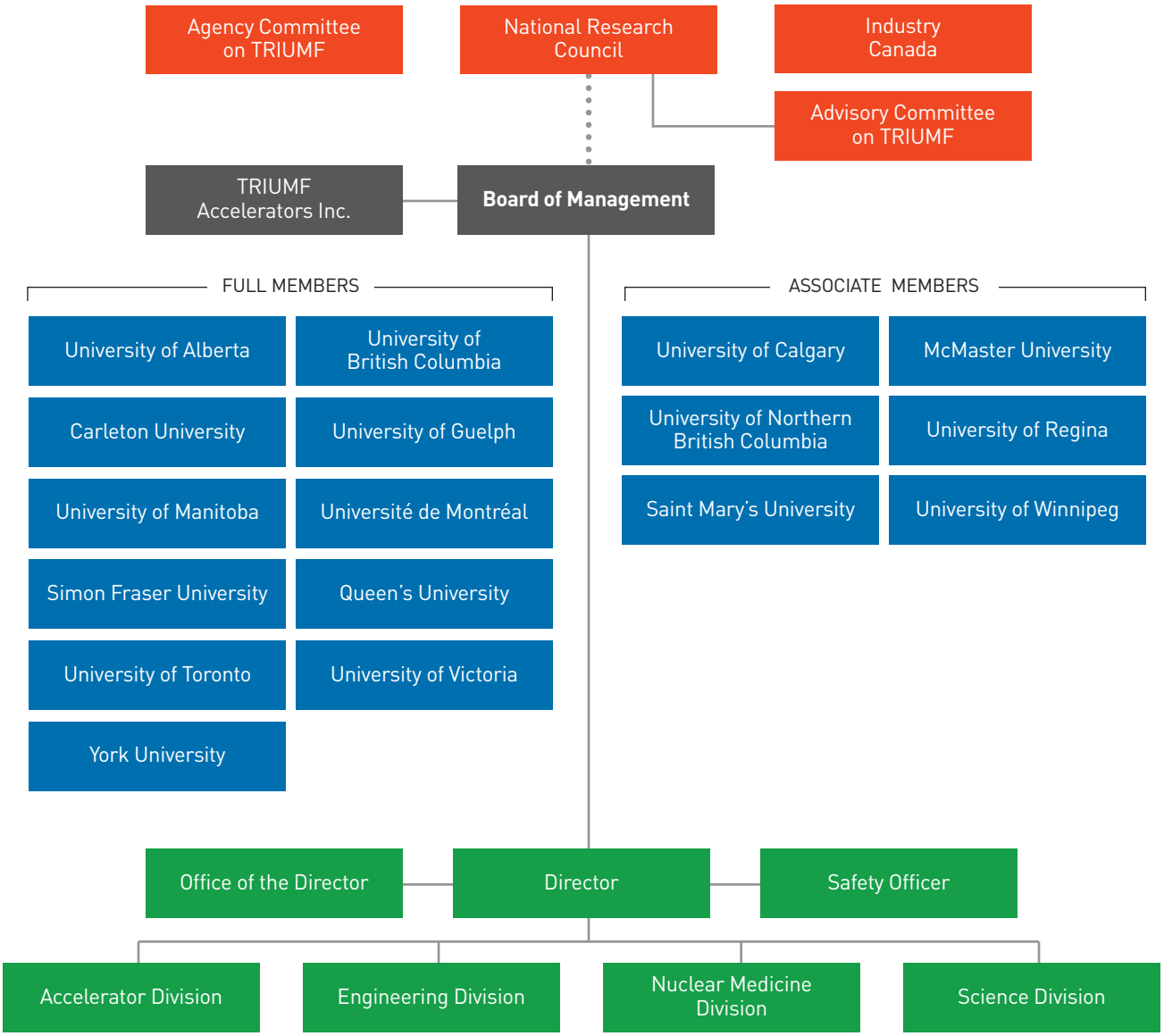
Basis of presentation
These summarized financial statements have been prepared in accordance with section 11b of the TRIUMF joint venture agreement and the contribution agreement with the National Research Council of Canada, and has elected to continue to follow Canadian generally accepted accounting principles (GAAP) for not-for-profit organizations as referred to in the Canadian Institute of Chartered Accountants (CICA) Handbook, except that all property, plant and equipment purchased or constructed for use at TRIUMF and related decommissioning costs (if any) are expensed in the period in which the costs are incurred.

These financial statements do not include the accounts of TRIUMF Accelerators Inc. (TAI), a not-for-profit federal corporation incorporated in 2006 and controlled by TRIUMF. The only asset held by TAI is the operating license issued by the Canadian Nuclear Safety Commission, which was recorded at the exchange value of $nil. Since inception TAI has not incurred any expenses or liabilities and has not recognized any revenue.



GOVERNANCE STRUCTURE

TRIUMF is Canada's national laboratory for particle and nuclear physics. It is owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council Canada with building capital funds provided by the Government of British Columbia. Situated on 12.5 acres on the south campus of UBC in Vancouver and founded more than 40 years ago, TRIUMF presently employs about 450 staff and students.



ACKNOWLEDGEMENTS

TRIUMF's activities are largely supported by contributions from the following organizations:

- Canada Foundation for Innovation
- Canadian Institutes of Health Research
- Genome BC
- Government of British Columbia
- Government of Canada
- Industry Canada
- National Research Council Canada
- Natural Resources Canada
- Natural Sciences and Engineering Research Council
- Networks of Centres of Excellence of Canada
- Western Economic Diversification Canada

SELECTED PARTNERS

TRIUMF works with many individuals, organizations, educational institutions, and private companies to fulfill its mission. These include:

Canada

Advanced Applied Physics Solutions, Inc.
Advanced Cyclotron Systems, Inc.
AECL, Inc.
BC Cancer Agency
British Columbia Innovation Council
Burnaby Board of Trade
Canadian Association of Physicists
Canadian Institute for Nuclear Physics
Canadian Light Source, Inc.
Canadian Space Agency
CANARIE
Centre for Probe Research and Development
D-Pace, Inc.
General Electric
Institute of Particle Physics
Jubilant-Draximage, Inc.
Lawson Health Research Institute
Nordion, Inc.
Ottawa Heart Institute
Pacific Parkinson's Research Centre
PAVAC Industries, Inc.
Perimeter Institute
Positron Emission Tomography Imaging at UBC
Science World British Columbia
Selkirk College
Shad Valley
SNOLAB
Vancouver Board of Trade

International

Argonne National Laboratory, Argonne, USA
Brookhaven National Laboratory, Upton, USA
China Institute of Atomic Energy, China
Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany
CERN, Geneva, Switzerland
Fermi National Accelerator Laboratory, Batavia, USA
GANIL, Caen, France
Gesellschaft für Schwerionenforschung mbH (GSI), Darmstadt, Germany
High Energy Research Organization (KEK), Tsukuba, Japan
Institut des Sciences Nucléaires (ISN), Grenoble, France
Institute for High-Energy Physics (IHEP), Beijing, China
Institute for Nuclear Research (INR), Russia
Istituto Nazionale di Fisica Nucleare (INFN), Italy
Japan Atomic Energy Agency (JAEA), Tokai, Japan
Japan Proton Accelerator Research Complex (J-PARC), Tokai, Japan
Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
Lawrence Berkeley National Laboratory (LBL), Berkeley, USA
Lawrence Livermore National Laboratory (LLNL), Livermore, USA
Los Alamos National Laboratory (LANL), Los Alamos, USA
Manhattan Isotope Technology, LLC, Lubbock, USA
Ministry of Education, Science, and Technology (MEST), Seoul, Korea
National Superconducting Cyclotron Laboratory (NSCL), East Lansing, USA
Oak Ridge National Laboratory (ORNL), Oak Ridge, USA
Paul Scherrer Institut (PSI), Switzerland
Rutherford Appleton Laboratory (RAL), UK
RIKEN Nishina Centre for Accelerator-Based Science, Wako, Japan
SLAC National Accelerator Laboratory, Menlo Park, USA
Thomas Jefferson National Accelerator Facility, Newport News, USA
Toyota Central R&D Labs, Inc.
UT-Batelle, LLC, USA
Variable Energy Cyclotron Centre, Kolkata, India

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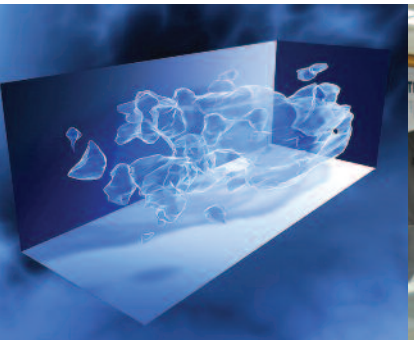
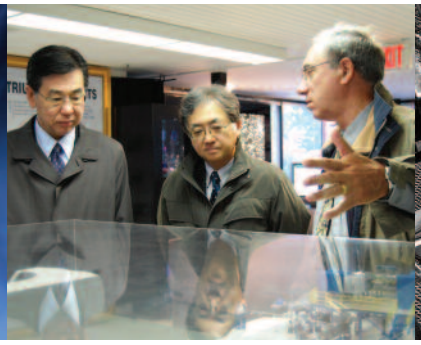
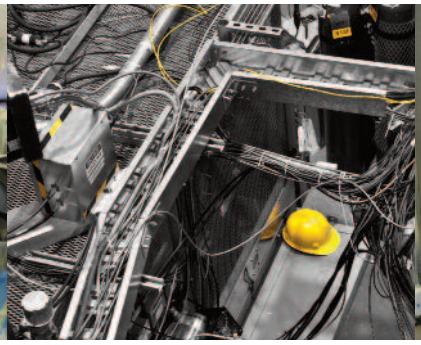
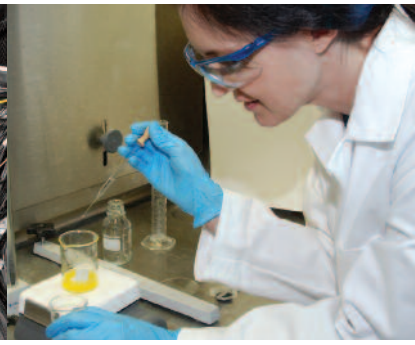
ATLAS = ATLAS Collaboration

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