TRIUMF

Annual Financial & Administrative Report

2007-2008


EMERGENCY
VEHICLE
ENTRANCE


16th AVE (WEST)
To Marine DR
Wesbrook Mall (SOUTH)
Wesbrook Mall (NORTH)
To TRIUMF
To UBC

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 from the Government of Canada through the National Research Council of Canada.

The Province of British Columbia provides capital funding for the construction of buildings for the TRIUMF laboratory.

Cover Photo:
The copper prototype of the "high beta" cavity for the Phase II installation of the ISAC-II superconducting LINAC. Twenty cavities made from highly refined niobium are being produced at PAVAC Industries Inc., Richmond BC, and represent the first superconducting RF cavities produced in Canada.

Editor: Shirley Reeve
Editoral Assistance: Ewart Blackmore, Barry Davids, Gordon Ball, Kim Chow, Eileen Conning, Greg Hackman, Jamie Ives, Gerald Morris
Design/Primary Photos: Mindy Hapke

Contents

TRIUMF: Always a success story

When I first visited TRIUMF, I was struck by the physical beauty of the area. TRIUMF's 11-acre site sits on UBC's south campus, surrounded by Pacific Spirit Regional Park. Large trees stretch skyward, the smell of the Pacific Ocean is in the air, and snow-covered mountains rise in the distance. Images of skiing and kayaking crossed my mind.

TRIUMF Director
Nigel Lockyer

I first thought "This is why people like working at TRIUMF. This is Vancouver; this is BC; this is the west coast." As I delved deeper into the work at TRIUMF, however, I soon discovered that there is another important reason.

First impressions

Shortly after I began my term as Director, I came to understand that the individuals who make up TRIUMF possess a passion for success unparalleled in any institution with which I have been associated. It is this motivation that has earned TRIUMF world-wide respect and recognition.

The operation and management of a world-class accelerator laboratory requires a special mix of people. The TRIUMF team is diverse, and outstanding. The team includes physicists, chemists, engineers, technicians, journeymen, students, and a range of talented and skilful support staff. Like good scientists everywhere, researchers at TRIUMF have a strong curiosity. This is particularly important in particle and nuclear physics where scientists study problems of particular interest and develop new techniques, often in partnership with industry.

It pleases me to write that TRIUMF is a fine example of the benefits of stretching the mind and the boundaries of technology. Our work has helped to power the innovation economy of Canada and to assist those around the world realize success in these areas. TRIUMF's reputation for excellence is such that scientists from across the country, as well as international researchers, come here to perform cutting-edge experiments. We strive to meet their goals and demands and share in the dedicated labour and success.

When the passion began

Since its first days of operation in 1968, TRIUMF has recognized the importance of attracting and retaining exceptional and highly talented people, many of whom began the scientific programs for which TRIUMF is now internationally known. This tradition of excellence was begun by our first directors, J.B. Warren, Reg Richardson, and Jack Sample.

In the 1980s, TRIUMF's international reputation blossomed under the leadership of Erich Vogt, and TRIUMF's reputation for attracting the best to do the best was launched. Director Alan Astbury's commitment to a vital and active laboratory carried TRIUMF into new pre-eminence in nuclear physics with ISAC. At this time, TRIUMF and Canada were successfully launched onto the scientific world stage with significant contributions to ATLAS and the Large Hadron Collider (LHC) at CERN in Switzerland.

Director Alan Shotter expanded the laboratory's nuclear physics program and continued the laboratory's significant involvement in particle physics in CERN, Japan, and the USA. Again, the hiring of dedicated and passionate individuals enabled the next generation to continue TRIUMF's success story.

TRIUMF spirit

The TRIUMF spirit couples our passion for success with ingenuity and hard work. It combines the ability to marry sophisticated technical machines with the dexterity and skilful touch of the human hand to make new discoveries.

I am also proud of the spirited way in which TRIUMF's team of specialists are able to continually develop innovative tools and techniques that allow us to apply the science of particle and nuclear physics in new and different ways.

As you know, TRIUMF is a multidisciplinary laboratory that uses accelerators to perform a diverse range of experiments. In their work, researchers have found that electromagnetic radiation images of an exploding star and positron emission tomography (PET) scanner images of the human body show remarkable similarities. TRIUMF scientists have built upon these discoveries and learned how to apply many of the techniques used to study exploding stars to Parkinson's disease and cancer. Curiosity in one field drives application in another field; this is how unique and diverse innovations and inventions are made.

A further note of interest regarding our PET scanners and exploding stars. When stellar material flows from the surface of a hydrogen-rich star to a neutron star in a binary star system, the accompanying explosion is known as a nova. These explosions produce copious amounts of ^{18}F, a rare isotope of the element fluorine. Recently, TRIUMF has produced the most intense ^{18}F beams in the world for researchers to study. And this isotope is also one of the key isotopes used for medical purposes in PET scans! New discoveries are what we do at TRIUMF. Each day when I arrive for work, I wonder what's next.

A passionate vision of the future

I am excited about the opportunities that lay before us, as I think we all are. In the months ahead, look to TRIUMF to achieve the following:

a.) make significant contributions to the world-wide efforts to develop the next generation of linear accelerators
b.) lead a nuclear-medicine revolution in Canada and around the globe
c.) develop new facilities in Canada that offer access to Nobel-prize-winning science experiments involving tests of fundamental symmetries

These are ambitious goals, but I am confident that we will meet them and many others besides. As I have noted throughout this report, my assuredness for the future stems from my belief in the wisdom of the men and women who came before me and in the ability of those that currently work at TRIUMF.

In short, TRIUMF's vision for the next five years is strong because of the passion and dedication of our team and our willingness to invest our skills and strengths with those of businesses and industry.

Our work in nuclear medicine illustrates this case well. Our noted achievements in this area came about by TRIUMF's desire to start working with UBC on a PET scanner program many years ago. An added example is our medical-isotope partnership with MDS Nordion, which was launched 30 years ago.

Looking beyond our borders, Canada's entry as a world leader in superconducting radio-frequency technology is largely due to TRIUMF's ISAC-II project and the scientific opportunities presented by this facility. Finally, Canada's stake in the LHC global science project at CERN, Switzerland, is the result of TRIUMF's collaborative effort with Canadian scientists and their universities, the National Research Council Canada, the Natural Sciences and Engineering Research Council of Canada, the Canada Foundation for Innovation, and the Province of British Columbia.

In the preparation of its next five-year plan and vision for the future, TRIUMF will ride the spirit of discovery to deliver on what promises to be an exciting and rewarding time for us all.

The future is happening now at TRIUMF.

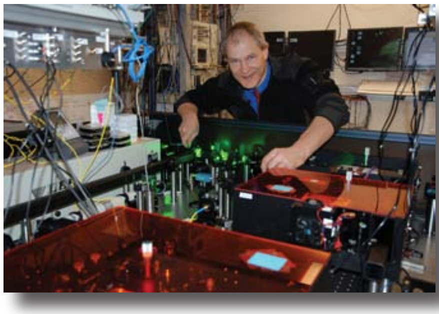
TRIUMF is an Amalgam of its People

by Nigel Lockyer

THE POWER OF PEOPLE

Shortly after I began my term as Director, I came to understand that the individuals who make up TRIUMF possess a passion for success. It is this motivation that has earned TRIUMF world-wide respect and recognition. As an international laboratory, TRIUMF competes with the best because of its people and their teamwork. The TRIUMF team is diverse and outstanding. The team includes physicists, chemists, engineers, technicians, journeymen, students, and a range of talented and skilful support staff. Although I would very much like to introduce all of the remarkable individuals who make up TRIUMF, it simply is not possible within just a few pages. Instead, I have asked a small group of employees and one TRIUMF contractor to tell their stories. In reading their words we think you will witness some of the spirit that makes TRIUMF unique.

Jens Lassen
Laser Ion Source Spectroscopist



As an optical and atomic physicist, "the chance to work with laser spectroscopy and contribute to nuclear physics is marvelous," says Jens Lassen. "Moreover, TRIUMF has a great work environment because everyone knows each other by name, rather than by title or division." As TRIUMF is one of only a handful of laboratories where cutting-edge laser ion source technology is studied, Jens' expertise and passion for precision laser spectroscopy and resonant laser ionization of short-lived isotopes is ably applied to TRIUMF's experiments. In his study of exotic isotopes, lasers are used to perform ionization of specific elements resulting in exotic-isotope beams of unprecedented intensity and purity. Jens' reputation as one the world's laser spectroscopy experts attracts graduate students from Canada and around the globe, particularly from his home country, Germany. These students come to Canada to work with one of the best laser spectroscopy physicists in the world.

Anne Trudel
Manager, Office of Environment, Health and Safety

Anne Trudel's extensive experience with radiation protection and low- and high-energy physics led to her current managerial position. As a mother and physicist, Anne appreciates TRIUMF's flexibility to allow her to fulfill both demanding roles: "I have always found TRIUMF to be a very supportive environment for managing family responsibilities and pursuing my career," says Anne. Anne fills a large and very important role at TRIUMF. She is the liaison for TRIUMF with the Canadian Nuclear Safety Commission, which monitors and audits every aspect of TRIUMF's many activities. In addition she is responsible to WorkSafe BC for the health, safety and welfare of the TRIUMF staff. Anne and her team ensure both industrial and radiation safety for employees, while maintaining environmental protection requirements and providing technical expertise to the TRIUMF scientists.

Kyla Sanderson
Undergraduate Co-op Student

TRIUMF provides employment and training opportunities for 30 undergraduate Co-op students each year. Kyla Sanderson is one of these Co-op students. As a student in the undergraduate Mechanical Engineering program at the University of Waterloo, Kyla is working at TRIUMF during the summer for her co-op program. In TRIUMF's Design Office, Kyla has a hands-on opportunity to design and model conceptual sketches using 3D computer-modeling programs. The designs then go to the Machine Shop and are constructed for experiments. "I am working in the intermediary step between theory and reality," says Kyla, "and that's a unique experience for me. My time at TRIUMF is an amazing opportunity and I want to gain as much experience as I can."

TRIUMF is an Amalgam of its People

by Nigel Lockyer

Ian Allison
Post-doctoral Research Assistant

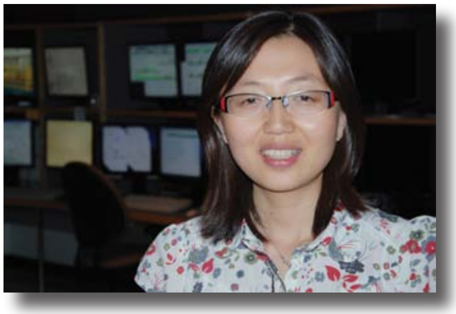
After completing a PhD in high-energy physics at the University of Glasgow, Ian Allison specifically came to Canada to join the TRIUMF theory group. "Theory researchers at TRIUMF are working on the type of physics that greatly interests me," says Ian. "At this laboratory, I am very fortunate to be able to access a wealth of valuable expert knowledge that remarkably enhances my work here." In his calculations, Ian seeks to illustrate the cutting-edge physics, science that has not yet been tested in a laboratory. In particular, his work at TRIUMF seeks to understand the details of so-called *strong interaction*s and extract fundamental parameters of nature, such as the masses of the *charm* and *strange* quarks.

Marik Dombsky
ISAC Target Scientist

Marik Dombsky is a world expert in high-temperature chemistry, a key to understanding and developing target materials. In his work, Marik develops new target materials for rare-isotope ion beam production, producing new beams of short-lived isotopes, and increasing beam intensity. "ISAC, as a facility, has the potential to do science that no one else can and that's the big attraction here," comments Marik Dombsky. After working at TRIUMF for his PhD, Marik stayed at TRIUMF to use the unique skills he gained with his work on the TISOL (TRIUMF Isotope Separator On-Line) project. Marik played a key role in developing the ISAC-I facility.

Sophia Yan
PhD Student

TRIUMF's exceptional and unique programs attract graduate and postgraduate students from around the world. Sophia is from the China Institute of Atomic Energy and is working at TRIUMF on her PhD. Her field of study is e-linac optimization under the supervision of Bob Laxdal. Sophia took her university supervisor's advice to go abroad to study. Her decision to come to TRIUMF was based on an enthusiastic recommendation. "A student in my home laboratory who had worked at TRIUMF spoke a great deal about his experiences and the unique educational opportunities at TRIUMF in the field of accelerators," Sophia says. "Now that I am here, I'm learning lots about physics and accelerators and everyone at TRIUMF offers their help." She is glad she took this opportunity to study at TRIUMF and has enjoyed her time in Vancouver since arriving in December 2007.



Sharon Tomei
Proprietor of Hot Spot Café

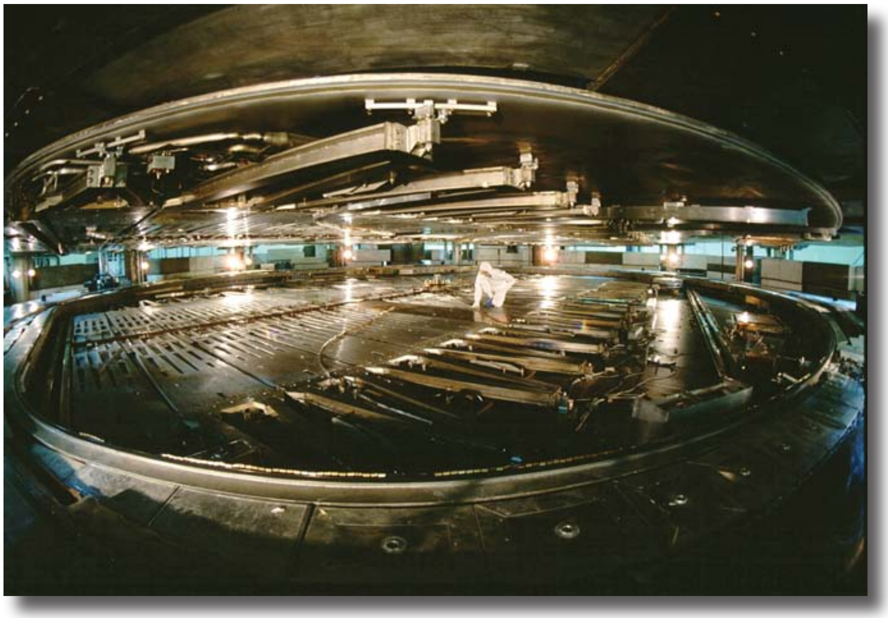
TRIUMF is located on the University of British Columbia campus, but relatively far from local coffee shops and restaurants. TRIUMF staff and the many visitors to the laboratory need a food service on site so they don't have to leave the laboratory. TRIUMF's Hot Spot Café meets that need. Dedicated to welcoming guests with fresh meals and ensuring the TRIUMF regulars are well fed and taken care of, Sharon is a cornerstone at TRIUMF and her cafeteria is a meeting place for staff and visitors. Sharon gets to know her customers and says, "I don't just recognize a face, but I know their names, their families, and their lives." Feeding about 200-300 regulars each day, Sharon and the café staff provide a full-food service to TRIUMF, including catering for conferences, meetings, and special events. "They don't even tell me what to prepare anymore," says Sharon. "They trust me to be creative and serve them something interesting and different. But they sure like their coffee, and lots of it!" Sharon has owned and operated TRIUMF's Hot Spot Café since 1999.

How Many Accelerators Have You Used Today?

by Tim Meyer and Nicole Dublanko

Accelerators make things go faster. At TRIUMF, we use accelerators to unlock the secrets of the universe and make new and beneficial discoveries. TRIUMF is a recognized world leader in the design, building and use of accelerators.

Accelerators exist in a range of shapes and sizes. There is the giant cyclotron at TRIUMF, which rockets particles down beam lines at 75% the speed of light. Another kind of accelerator is found in automobiles that zip drivers along the highway. Many accelerators are also present in homes and worksites across the country. The benefits they bring have a profound effect on the everyday lives of Canadians.



TRIUMF's cyclotron, the largest one in the world, accelerates particles to 75% of the speed of light to produce beams of unique particles for research in many scientific and medical disciplines as well as for cancer research and treatment.

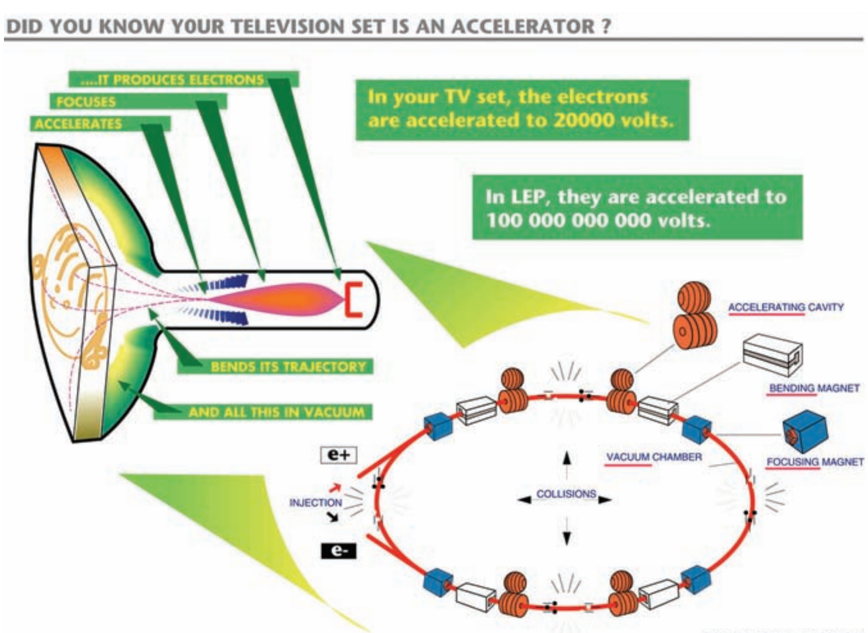
A bright idea

When we wake up in the morning, one of the first things we do is turn on a particle accelerator – the incandescent light bulb. When electricity runs through the wire in a light bulb, electrons move and radiate energy. Part of this radiated energy is released as visible light. Imagine how different everyday life would be without this marvelous invention that uses particle acceleration to create light.

A glowing invention

A few short years ago, the majority of Canadians watched TV on a set with a large tube-like monitor. These televisions are another type of particle accelerator. When the TV is turned on, electron particles are fired towards the screen on the inside of the TV's picture tube.

When an accelerated electron hits a pixel on the screen, it causes the screen to glow with a bright colour that can be seen by the viewer on the other side. Light is emitted because the pixels on the screen are covered with phosphor, a substance that releases light when it is hit with energy.



The first tube, called a cathode-ray tube, was invented in the late 1890s. At the time, scientists were struggling to understand radiation, electricity and magnetism. Nevertheless, some scientists realized the possibilities this early particle accelerator offered, and 30 years later, the TV set was born.

Food for thought: Dinner from a particle accelerator

It only takes the klystron, the scientific name for a special type of small electron particle accelerator, a matter of minutes to generate a sizzling hot meal.

How Many Accelerators Have You Used Today?

by Tim Meyer and Nicole Dublanko

The klystron, which is the key component of microwave ovens, is an important feature in the busy lives of many Canadians. The klystron produces waves of energy, which resonate with the water molecules contained in food and create heat.

Like the TV, scientists weren't thinking of preparing a hot dinner when the innovations for constructing a microwave oven came about. The klystron began in the 1940s with radar technology studies. One story says that when a chocolate bar began melting in a research scientist's pocket while working on an experiment, he discovered the potential for heating food. By the 1970s, microwave ovens became commercially available and have changed the fate of leftovers ever since. We might say the invention of the klystron is another instance of accelerated scientific thinking.

Accelerated healing

Accelerators have also made a difference in hospitals. For certain types of cancers, patients are now able to be treated with a proton accelerator. This development means patients do not require surgery.

Researchers have discovered that a focused beam of protons, moving at the right speed, can be directed to hit a cancerous tumour beneath the skin without significant damage to the surrounding cells. This type of treatment improves the chance of success in a patient's therapy and can speed up the healing process.

Equally important, researchers have learned how to direct a proton beam to target – and destroy – the DNA of cancer cells. Without DNA, cancerous cells cannot reproduce and spread through the body.

The successful treatment of a certain kind of eye cancer, choroidal melanoma, is a good example of the value of this method. With a proton accelerator, patients with this disease can be treated without having to lose their eye. This remarkable discovery has led to faster, more accurate cancer treatment without surgery.

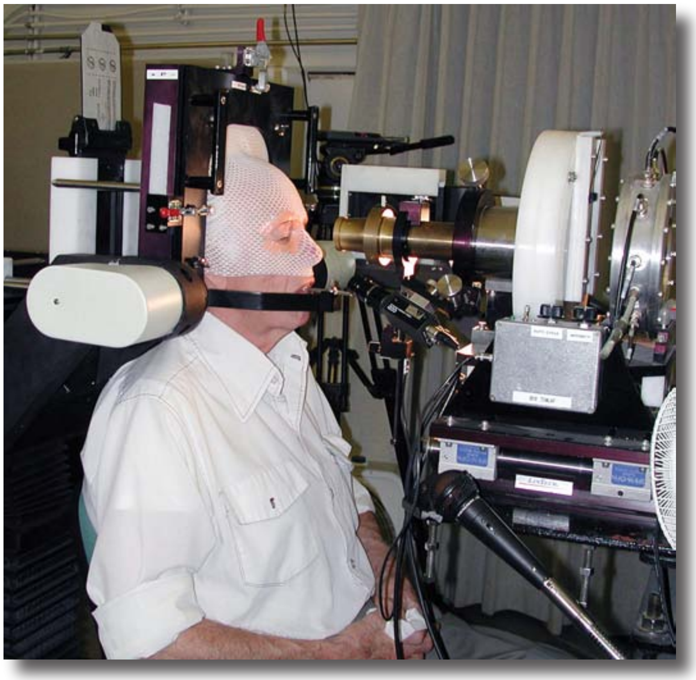
The particle accelerator is also used in cancer radiation therapies. This form of treatment is performed using X-ray radiation. To create X-rays, an accelerator increases the speed of particles to generate radiation. X-rays are separated from the other rays in the spectrum and then used for radiation treatment and analysis.

Whether providing proton beams or X-rays, accelerators offer numerous benefits to healthcare with the promise of more to come in the near future.

Electronics made easy

Just as a proton accelerator can be used to target cells beneath the surface of the skin, accelerators can deposit particles inside other materials. This technology has been employed to make computer chips.

Rather than drilling a hole through the layers of a computer chip, inserting a few particles inside, and covering it up, particles are accelerated and directed at a precise location in the material. They penetrate the surface material and come to rest at predetermined locations, such as in the middle of multiple layers. Cell phones, personal computers, and other advanced electronic equipment used regularly by Canadians were constructed with the assistance of particle accelerators.



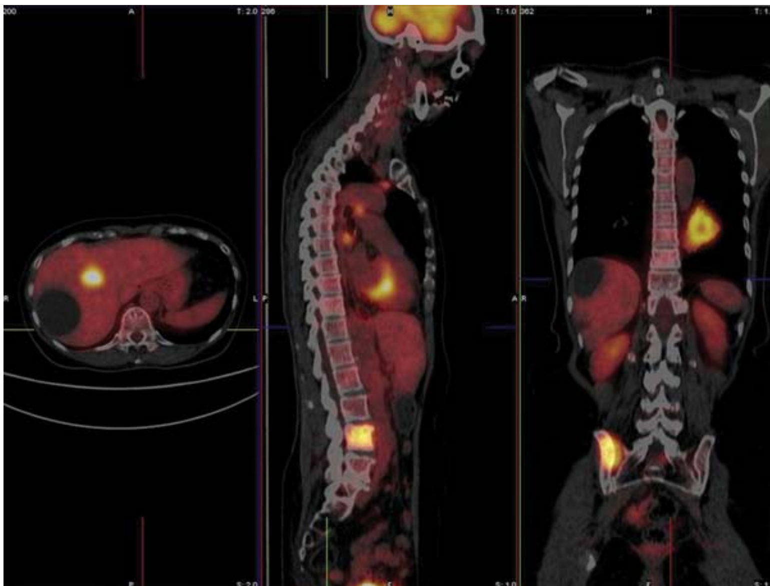
Using an accelerated beam of protons, TRIUMF treats patients with choroidal melanoma, a form of eye cancer.

How Many Accelerators Have You Used Today?

by Tim Meyer and Nicole Dublanko

TRIUMF: accelerated solutions

TRIUMF engineers and scientists work with the world's largest cyclotron, a particle accelerator that speeds particles in an expanding spiral. This particle accelerator delivers beams of charged particles for research, steered with magnetic fields and alternating electric voltage. Because protons and electrons are so small they cannot ordinarily be seen, sensitive detection equipment is required. The experiments use the beams for numerous tests, such as measuring the mass of exotic isotopes (short-lived particles) and observing isotope decay rates (how fast a particle disintegrates).



This image shows the combination of PET and CT imaging: physiology and metabolism both become visible. Physicians can then pin point the exact location, size and shape of the diseased tissue or tumor.

TRIUMF's small TR13 cyclotron produces the isotope FDG for the BC Cancer Agency, enough to treat more than 3,300 patients each year.

Though scientific research and laboratory experiments may, at first glance, appear unrelated to our daily lives, the work of TRIUMF scientists has led to effective new treatments in the field of medicine, the development of new electronic materials, and new discoveries regarding the composition and structure of elements and stars.

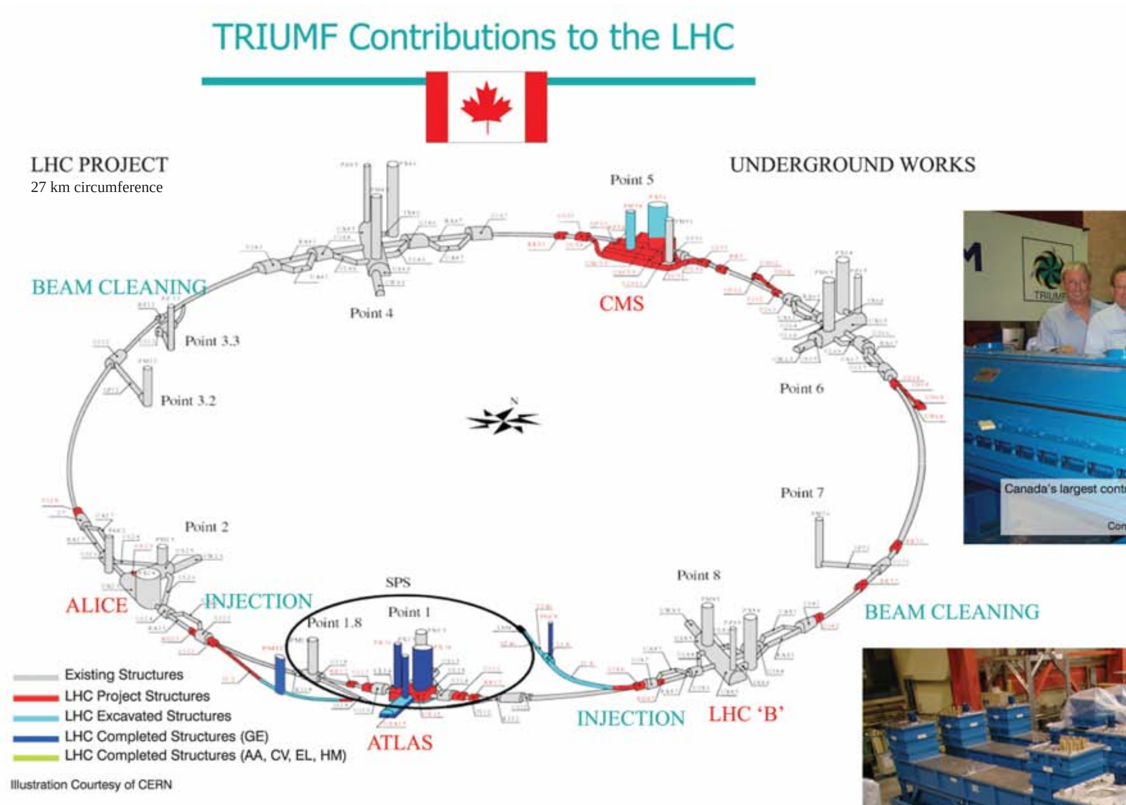
For example, when patients are tested for cancer, doctors give them a substance that will show areas inside the body that may have cancerous cells. The substance uses biochemistry to locate the cancerous cells and then uses a medical isotope to signal to external equipment where the cancer is located.

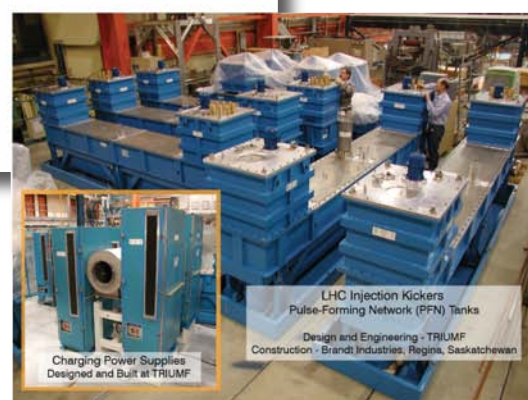
TRIUMF, in partnership with MDS Nordion Inc., produces these medical isotopes with an accelerator and delivers them to patients all over the world. This partnership exemplifies TRIUMF's ability to transfer laboratory studies to tangible applications used in daily life. Partnerships, like this one, attest to the real economic benefit provided through advanced experimental laboratories.

Accelerated construction

TRIUMF is an acknowledged leader in particle accelerators. Its specialized skills are known around the world. The expert knowledge of TRIUMF scientists is often sought by other laboratories for the development of experiments or equipment. For instance, the famous CERN laboratory in Europe requested TRIUMF's assistance in magnet design while building the Large Hadron Collider (LHC). On the other side of the world, Japan researchers sought TRIUMF's assistance in the design of a sophisticated part for their neutrino beams and detectors.

by Tim Meyer and Nicole Dublanko





TRIUMF is one of the world's experts in accelerator technology and its assistance is sought by laboratories in Canada and internationally. Its contributions to international projects such as the ATLAS experiment and LHC at CERN ensure Canada is a welcome and respected partner wherever Canadian scientists choose to carry out their research.

A powerful tool

Whether used in our homes or in a science lab, accelerators are powerful tools. Their skilful application at TRIUMF has generated new medical treatments and innovative electronic and industrial devices. Equally important, new experiments at TRIUMF continue to build and improve on these discoveries.

The successful use of accelerators in physics research has made them primary tools in the modern quest to understand the nature of the world and the universe. Long live the accelerator!

Tim Meyer is the head of Strategic Planning and Communications
Nicole Dublanko is a Communications Assistant

The Magic of Star Dust - Exploring Exotic Nuclei

by Rituparna Kanungo

Seeking clues to the origin of our existence

Our universe is made up of planets, galaxies, and stars. Seeking the clues to the origin of our existence, we look back at how the creation and evolution of the universe occurred. Our present understanding is the universe started with a big bang that created a soup of objects, among which were the massive ones called nucleons. The soup contained both positively charged nucleons called 'protons' and electrically neutral ones called 'neutrons'. As the universe cooled and expanded the hadrons coalesced together to form more complex objects, that we refer to as nuclei. Nuclei form the core of all matter around us and constitute more than 99% of the weight of any object. They are the driving fuel for the stars. The stars, including our sun shine due to the energy released by nuclear reactions.

Only a small handful of all the nuclei found in our universe exist on earth. Most of these are known as 'stable nuclei' because they are not radioactive. Ever since the discovery of the nucleus by Ernst Rutherford in 1911, the popular picture of the atom has been compared to the solar system, where electrons orbit a nucleus in the same way planets orbit the Sun. Since then we have learned that the nucleons in nuclei, also travel in "orbits". The difference is that, rather than orbiting around a massive central point like planets around the Sun, the nucleons orbit amongst each other. Also, the nuclei of atoms are small enough that their behaviour is governed by an underlying wave function, as postulated by quantum mechanics. We can never know where a nucleon is at any given time, only where it is likely to be. (The same is true for electrons in atoms.) Finally, there is not a sharp edge to a nucleus; the density is mostly constant, but as one moves out from the nucleus, it decreases smoothly to zero. However, this transition region is typically smaller than a nucleon itself.

Magic numbers

Scientists have also learned that the electrons in atoms and the nucleons in nuclei occupy different orbits (or shells), where the lowest energy orbits are filled first. For both atoms and nuclei a special set of numbers have been found, called 'magic numbers', where the electrons in atoms and nucleons in nuclei completely fill certain groups of orbits (see Fig 1). It is interesting to note that while magic numbers in atoms are 2,10,18,36,54, and 86, those in nuclei are slightly different: 2,8,16,20,28,50,82, and 126. Elements with magic atomic numbers tend to be chemically inert and undergo few if any chemical reactions. On the other hand, elements with magic nucleon numbers have extra strong binding and are often highly abundant. E.g., species like oxygen (*with proton number 8*), and calcium (*with proton number 20*) needed for our survival are abundant in nature and have the ability to react, a feature exploited by life. Since their discovery, the magic numbers have formed the basic pillars of nuclear science and were believed to be immutable. This belief was based on studying nuclei that are found naturally on earth. Today it appears this gave us a restricted view of the nucleus.

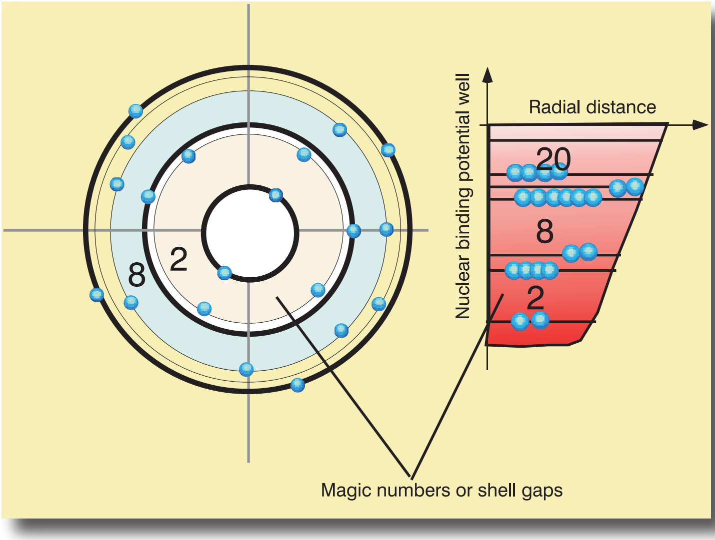


Fig.1: Schematic view of the planetary model of the nucleus. The blue balls are the nucleons (i.e. neutrons or protons). Each nucleon resides in a specific orbit that is shown on the left hand side by the black circles. The sketch on the right hand side shows the energies of the different orbits are energetically places inside the potential well that binds all these nucleons to form the nucleus. The innner most orbit (L.H.S.) is the same as the lowest orbit (R.H.S.). It is the most strongly bound orbit. The magic numbers appear as large energy gaps between clusters of orbits. They are shown in the figure as 2, 8, and 20.

TRIUMF's ISAC: exploring nuclei not found on earth

At TRIUMF, Canada's National Laboratory for subatomic physics in Vancouver, B.C., we are now capable of producing and studying the nuclei that exist in various environments in the universe but not on earth. This opens the possibility to go beyond the nuclei on earth and look into what exists in a supernova explosion, or in other cosmic objects like novae and X-ray bursters. These nuclei, called unstable nuclei (because they decay naturally), have ratios of protons and neutrons different from stable nuclei. The creation of the majority of elements on earth took place in such explosive

by Rituparna Kanungo

stellar environments, involving the unstable nuclei. Exploring and understanding unstable nuclei is a quest to unravel the variation of nature's principles and forces that bind the nucleons together to form the large variety of nuclei in our universe.

The nuclear halo: an unexpected and exotic nucleus

An unexpected exotic type of nucleus was discovered in 1985 by Isao Tanihata and his colleagues at Lawrence Berkeley National Laboratory when experiments revealed that the most neutron-rich unstable isotope of lithium, with only 11 nucleons, has an unusually large size similar to a very heavy nucleus like gold, with 197 nucleons. This remarkable deviation from the previous finding that the radius of a nucleus depends only on the total number of nucleons clearly showed a phenomenon beyond the conventional concept. ^{11}Li has two extremely weakly bound neutrons that have a large probability of being located at distances very far from the rest of the nucleus, called the 'core', thereby forming a thin neutron halo around the core. A schematic visualization of this is shown in Fig 2.

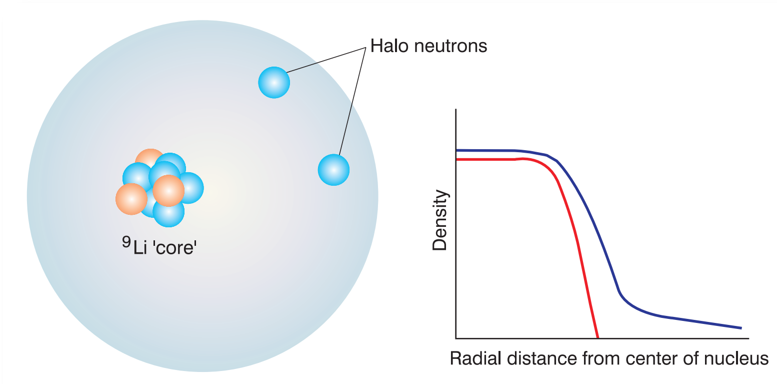


Fig.2: Schematic view of a two-neutron halo, e.g.^{11}Li. The two halo neutrons are located vary far away from the rest of the nucleus called the 'core' which is ^{9}Li in this case. A normal stable nucleus looks like ^{9}Li. The right hand side figure shows a view on the distribution of protons (red) and neutrons (blue) in such a nucleus.

An important question is how these two neutrons are arranged relative to the core and with respect to each other. It is also possible that the interaction felt by these two neutrons may differ from the general interaction between nucleons, because these two neutrons are much further away from the charged protons in the core nucleus.

ISAC-II's first experiment: a first in the world

The first experiment at the newly launched ISAC-II facility at TRIUMF, in December 2006, was also the first one in the world to investigate these halo neutron correlations through the most sensitive reaction probe. In this reaction of an ^{11}Li radioactive beam with a proton (*p*) target, two halo neutrons were transferred from ^{11}Li to the proton target. The resultant nuclei ^{9}Li(=^{11}Li-2*n*) and triton(=*p*+2*n*) were scattered in different directions. The probability distribution of this process to occur for different scattering angles carries information on the correlation between the two halo neutrons. This experiment was led by two visiting scientists Isao Tanihata and Herve Savajols using an active target detector system called 'MAYA' (Fig 3) which was brought from the French laboratory GANIL [see Davids, *ISAC-II Science with MAYA and EMMA,* Annual Financial Report 2006-07 for details].

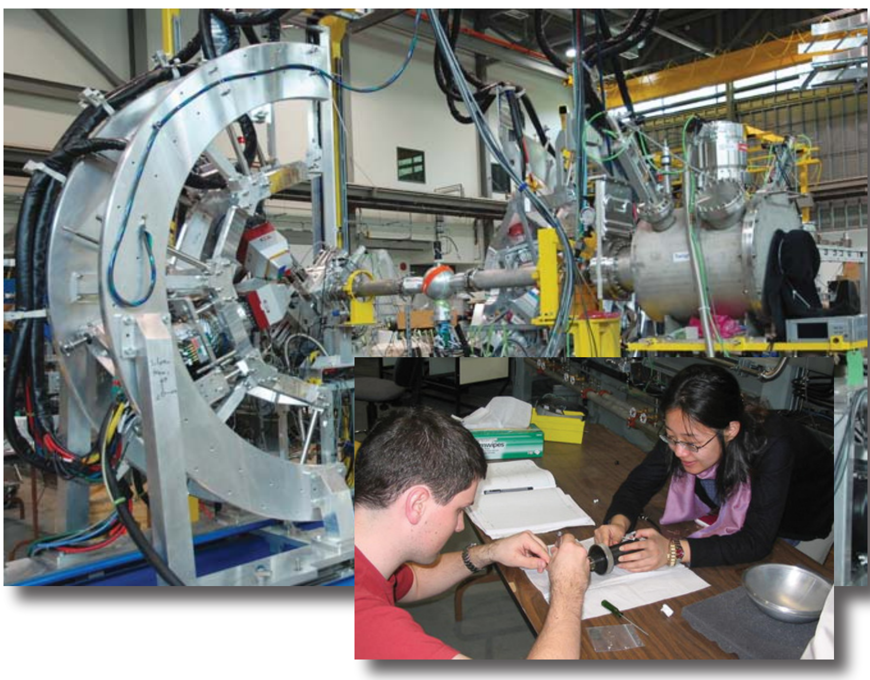


Fig.3: The TIGRESS facility where the ^{11}Be(d,p)^{12}Be reaction was performed. The inset shows students from Saint Mary's University setting up the target ladder for the experiment.

The measured distribution is now being compared to theoretical calculations based on different models of ^{11}Li. The data seem to suggest that the two neutrons often remain close to each other, being located on the same side of the ^{9}Li core. In the conventional picture of nuclear orbits the two halo neutrons should occupy only the *p*-orbit. The data

by Rituparna Kanungo

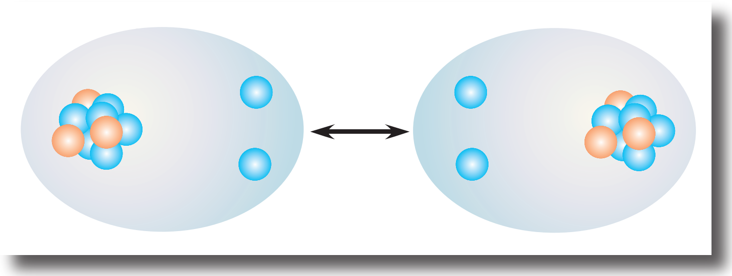


Fig.4: Schematic view of the two halo neutrons in ^{11}Li oscillating against the core to give rise to a new mode of excitation known as a 'soft dipole resonance'.

however suggests that these neutrons also occupy the *s*-orbit. Because of the weak binding and this abnormal occupation of the *s*-orbit, (which does not have a centrifugal barrier), the neutrons can extend to large distances, creating the halo.

The unusual character of the halo neutrons raises the question of whether they can affect the proton or charge distribution in ^{11}Li. Previously, a pioneering experiment led by Wilfred Nörterhäuser from Germany was carried out at ISAC to study this effect by observing the atomic transitions from the various lithium isotopes. The observations showed that the neutral halo has the effect of extending the proton distribution [see Hackman, *Experiments with ^{11}Li Beams at TRIUMF-ISAC,* Annual Financial Report 2004-2005 for details]. The proton (or charge) radius of ^{11}Li and the matter radius of ^{11}Li taken together require the halo neutrons to be located on the same side of the ^{9}Li core, consistent with the observations from the two-neutron transfer reaction.

Measuring the mass of halo nuclei with ISAC's TITAN

As mentioned earlier, the halo is strongly dictated by the weak binding of ^{11}Li. A measure of this weak binding is obtained by measuring the mass of ^{11}Li and the mass of ^{9}Li. The TITAN facility at TRIUMF has recently succeeded in measuring the mass of ^{11}Li with a precision of better than 1 part in 10 million. This measurement, part of the Ph.D. thesis of Mathew Smith, was 30 times more precise than the previous best measurements. It also showed that the energy required to knock the last two neutrons out of ^{11}Li is 20% more than previously determined.

Another interesting consequence of the halo could be a unique mode of excitation of ^{11}Li. In a pictorial view, the nucleus when perturbed could set the halo to oscillate against the core (Fig 4). This kind of oscillation can give rise to low-lying dipole resonances in the nucleus. Experiments to confirm the existence of such excitation modes are also planned at TRIUMF.

Halo features in other nuclei

^{11}Li is not the only nucleus exhibiting the halo feature. Halos can occur when nuclei tend to have very weak binding for a few nucleons located in the outermost orbits. Halos can therefore be formed with one or more nucleons. Observations so far have disclosed the existence of several one and two-nucleon halo nuclei. Most of these findings have been confined to very light nuclei. It remains an open question, whether giant multi-nucleon halos exist and how the scenario appears for heavy nuclei.

To elucidate halo features in other nuclei, and thereby aid in a complete understanding of why nuclear halos appear in nature, investigations are underway at TRIUMF of other neutron-rich nuclei such as ^{12}Be, which has the same number of neutrons as ^{11}Li but one extra proton. The presence of this extra proton seems to alter the binding of this nucleus significantly, making the neutron almost 10 times more strongly bound than that in ^{11}Li. It is interesting to determine, therefore, how the two outermost neutrons in ^{12}Be are arranged compared to ^{11}Li.

In a recent experiment led by Saint Mary's University, ^{11}Be ions from ISAC/TRILIS were accelerated through ISAC-II and reacted with deuterium atoms, whose nuclei contain one neutron and one proton. In some of the nuclear collision events, the ^{11}Be picks up the neutron from the deuterium to form ^{12}Be. In some of these events, energy from the reaction is released as a gamma ray. This experiment was performed using the TRIUMF-ISAC Gamma-Ray Escape Suppressed Spectrometer (TIGRESS) to isolate specific reaction channels. The collected data is currently under analysis.

The neutron skin: important consequences for fusion probability

A more general feature in neutron-rich nuclei is the formation of a thick layer of neutrons outside the layer of protons. This is termed as the neutron skin. The distinction between nuclear halo and nuclear skin is determined by the distribution of matter inside the nucleus. A neutron halo nucleus has a neutron distribution having a very

by Rituparna Kanungo

low-density tail, whose slope is different from the proton density at the surface. On the other hand, formation of a thick neutron skin occurs when the bulk of the neutrons push outwards compared to the protons. This gives rise to a neutron distribution whose half-density radius is larger than that of the proton distribution. Neutron skins can also give rise to low-lying dipole resonance modes. The presence of such excitation modes might have important consequences for enhancing the fusion probability in these nuclei. Interestingly, the fusion of ^{9}Li with a moderately heavy nucleus ^{70}Zn measured at ISAC by a group from Oregon State University showed an abnormally large fusion probability that is yet to be fully understood, but is conjectured to be the effect of a neutron skin. The effect of exotic structures on fusion may have a strong impact on our understanding of synthesis of heavy elements in nature. It is important to search for the existence of such resonances and investigate the fusion of heavy neutron-rich nuclei.

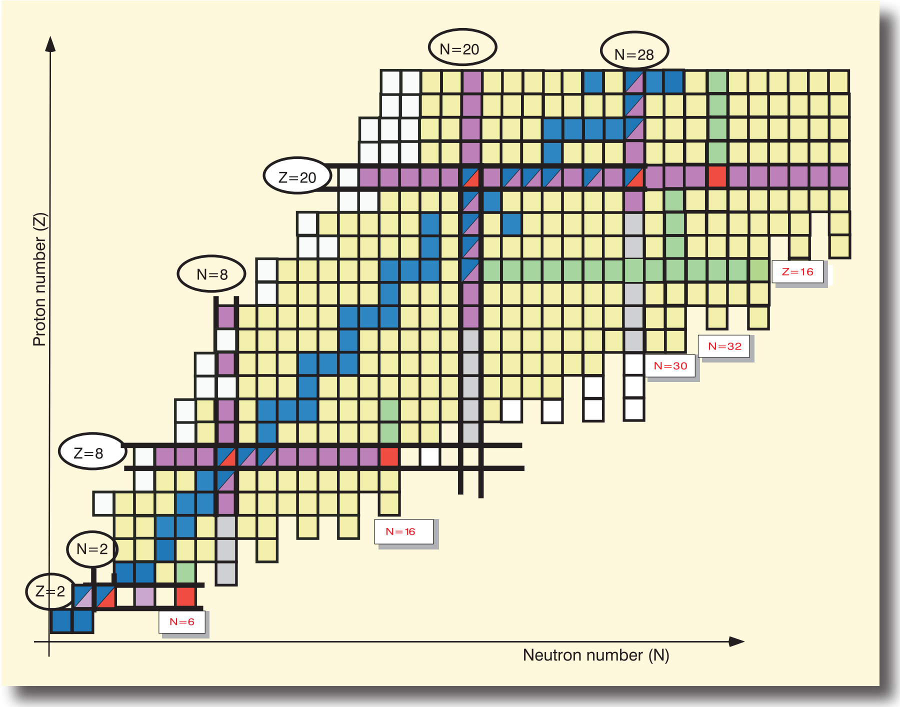


Fig.5: A section of the nuclear chart for light nuclei. The blue squares are stable nuclei. The yellow squares are unstable nuclei. The conventional magic numbers for protons and neutrons are denoted in circles and are shown by pink squares. The red filled squares are nuclei that have both magic proton and neutron numbers. These are called doubly magic. in regions of grey squares the conventional magic numbers are found to disappear in unstable nuclei. Instead, for unstable nuclei the green squares show new magic numbers appearing. They are showen in red.

New magic numbers for exotic nuclei

The golden set of numbers that formed the planetary model of the nucleus appears to undergo mutation when we are in the region of exotic nuclei that have highly unbalanced numbers of neutrons and protons. The fact that the halo neutrons in the nucleus ^{11}Li occupy the s-orbit tells us that this orbit is lowered in energy, making it possible for neutrons to reside in it. Such a change in the location of this orbit causes the conventional nucleon magic number to disappear. At some point scientists pondered whether this meant that the planetary model of the nucleus was completely washed out for exotic nuclei. It was exciting however to find the signature of new magic numbers, from recent measurements of the masses of these exotic nuclei (Fig 5). In the near future, the TITAN trap at ISAC holds excellent promise to provide clues on new magic numbers for heavier neutron-rich nuclei.

Experiments at TRIUMF, ISAC have already started to help build a detailed understanding of how and why the magic numbers change. This is associated with understanding the occupation of nucleons in different orbits. At the lowest end of the nuclear map, an experiment led by the Saint Mary's University group at the ISAC TUDA facility has shown that in very neutron-rich nuclei, the neutron number N=6 exhibits new magic number-like behavior. This is not due to the gap between orbits being further increased as we go more neutron-rich, but appears to be due to the fact that the neighboring N=8 gap disappears. Therefore, N=6 neutron-rich nuclei are more strongly bound and less prone to being deformed.

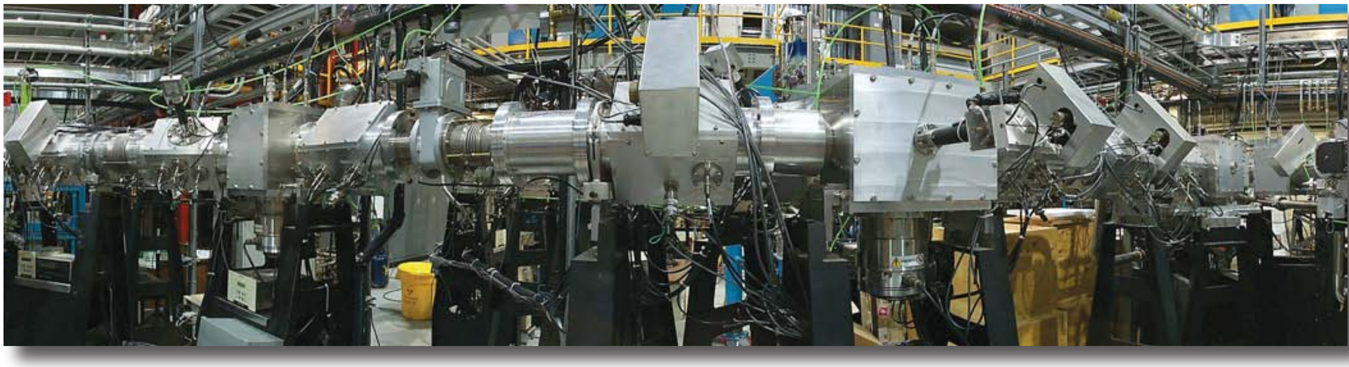
An international impact

The last few years have seen a significant growth in the amount and quality of data available on halo and neutron-skin nuclei. As evidenced by the Halo '08 International Workshop organized by Saint Mary's University and TRIUMF in March 2008, TRIUMF-ISAC beams and facilities have had a prominent and internationally recognized impact in this area of research. This leadership role is expected to continue as heavier neutron-rich isotopes produced using actinide targets will soon become available at ISAC.

Rituparna Kanungo is a Professor of Physics at Saint Mary's University, Halifax

TRIUMF Design Office

by Stuart Austen



TRIUMF's ion beam transport systems are the result of original thinking, detailed design and constant development.

Behind every great experiment

TRIUMF has a world-wide reputation for designing and building state-of-the-art accelerators, cyclotrons, and experimental equipment of all kinds. This equipment is built for use at TRIUMF, but TRIUMF also provides specially designed and built equipment to other Canadian laboratories such as the Sudbury Neutrino Observatory (SNO). In addition, TRIUMF contributes equipment and ideas to international experiments and laboratories such as ATLAS at CERN, T2K in Japan, or wherever in the world Canadian scientists have chosen to carry out their experimental programs. The ability to provide state-of-the-art equipment as well as scientific intellectual input makes Canada a welcome and respected partner on the international scientific world stage.

Behind every great experiment, there is a team of engineers, designers, and technicians that work to make the project a success. The TRIUMF Design Office, as part of the TRIUMF Engineering Division, oversees the design and development of the mechanical equipment needed for these different experiments. The Design Office also oversees the design and development of equipment for maintenance and upgrades to the main TRIUMF cyclotron and beam delivery at TRIUMF.

Working behind the scenes

When an experiment is put forward to the TRIUMF Experimental Evaluation Committee (EEC) for review and approval, engineers and designers work alongside the scientists to bring a practical approach to the development of any new equipment or technology needed to make the experiment a success.

Once an experiment is approved, a specification is generated outlining the new equipment required or the need for changes to an existing facility. Appropriate resources are assigned according to the scope of the project.

Each year the list of projects is enormous and 2007 - 2008 was no different as 92 new projects requested design and engineering assistance. The biggest challenge, and the truly creative part in the process, is pulling all the information together into a conceptual design that is both functional and practical. Although we try to *freeze* a design before proceeding with any detailed work, the enthusiasm of experimenters and designers is such that refinements to the project continually take place as new ideas and solutions arise.

Designing for the future

TRIUMF is now well into its current 2005 – 2010 Five-Year Plan, and it is over 12 years since the ISAC project was first funded. Throughout 2007 - 2008, members of the Design Office spent over 65% of their time on ISAC, divided equally between ISAC-I development and ISAC-II construction.

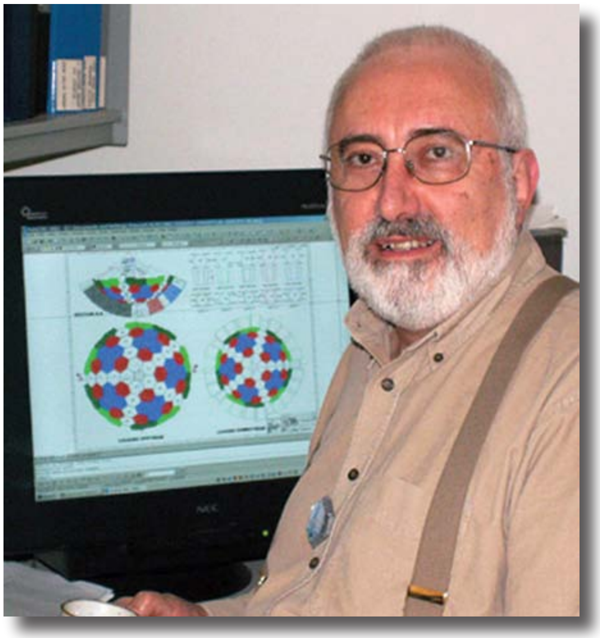
For ISAC-II, the current focus of the Design Office is the design of the high beta cryomodule section for delivering higher energy accelerated beams to experiments. The new facility uses superconducting technology, which relies on cryogenics to achieve the required accelerated beams.

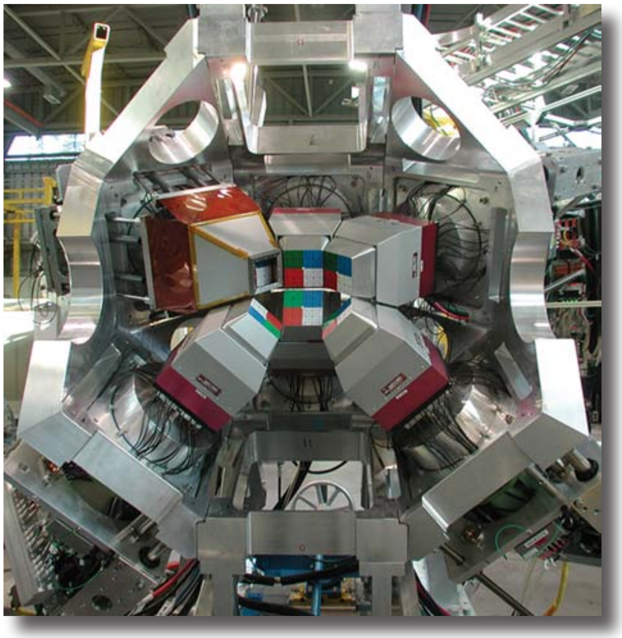
Cryogenics is the branch of physics that deals with very low temperatures, and materials have to be serviceable to below four degrees Kelvin (-269°C or -452°F). Cryogenics present new challenges in both design, and the use of new materials by Stuart Austen

and techniques for manufacture. Working with stainless steel, aluminum and copper is familiar territory; electron beam welding of niobium for a superconducting cavity is a new challenge for the designers.

Experience generates new ideas

To ensure reliable beam delivery, the infrastructure that runs the beam line and cyclotron must be constantly maintained and upgraded. This is accomplished through solid modeling and engineering analysis combined with experience from operating the various machines over time. The resulting designs optimize operations, improve performance, and enhance reliability.





Franco Cifarelli and the TIGRESS detector array; its innovative and unique support structure required forged aluminum blanks and a local manufacturer with specialized machines capable of the precision desired.

To accommodate the increasing number and special requirements of experiments, major changes are continually being planned. Despite a range of technical expertise, the answers to these changes will largely be derived from the creative minds and insights of the design team. The solutions may come from three-dimensional computer modeling or start with a clean sheet of paper and a list of ideas. Whatever the starting place, the solution will be driven by imagination and innovation. An example of this creativity is the support structure for the TIGRESS detector.

One of the preeminent components of the ISAC-II experimental program is the TIGRESS detector. The support structure for the TIGRESS detector array was created by designer Franco Cifarelli. Machined from forged aluminum, this work is indicative of the unusual challenges and intricate nature of the design work undertaken by the design team at TRIUMF. Mr. Cifarelli's work shows the application of great skill and imagination, and the ability to translate broad specifications into functional equipment, the nuts and bolts of the TRIUMF laboratory.

Supporting Canadian industry

Internationally, collaboration with laboratories such as CERN in Switzerland or J-PARC in Japan allows our designers the opportunity to participate in a broad spectrum of projects. The benefits are threefold. The work furthers the skills of our design team, allows Canada to take a respected and important role internationally in world-class physics, and provides the opportunity to introduce Canadian manufacturers and businesses to the international scientific community.

TRIUMF's Technology Transfer program transfers new and innovative technologies to Canadian industry. TRIUMF designers work with industry specialists in several fields of expertise including design, manufacturing, and sales. Equipment developed at TRIUMF has spawned new businesses such as construction and marketing of small cyclotrons for isotope production, and related support systems for diagnosis and control. TRIUMF designers have played a

TRIUMF Design Office

by Stuart Austen

Looking to Canada's next generation of designers. The ability to create new and practical designs is only begun in university. One of the strengths of TRIUMF's design team is its ability to educate talented new designers in the varying demands of operating in a specialized science facility.

critical role in the recent transfer of superconducting radio frequency technology to a local company that is now one of only five companies in the world able to supply this technology.

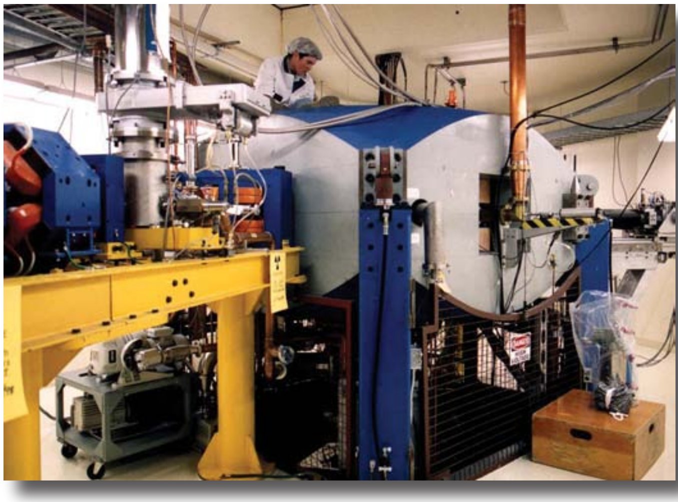
To reach Canada's young scientists, engineers, technicians, and designers of tomorrow, the Design Office provides graphics and video support for seminars, presentations, and publications. New educational software and video packages, created in collaboration between TRIUMF's scientists and graphic artists, teach the basics of physics and highlight the opportunities of a career in science and technology.

Part of the TRIUMF Design Office program includes an opportunity for engineering and physics students to work with us. Co-op students from Canadian universities and technical institutes work at TRIUMF with the Design Office for their co-op work terms, usually three or four months. This time is often a springboard to new opportunities for the students in the arena of design and engineering.

Staying strong and technically current

Since its inception in 1969, TRIUMF has been fortunate to have a team of talented designers with the ability to respond to the varying and demanding needs of each new experiment. Though technical or university education is essential, the specialized nature of the work at TRIUMF means hiring people with the prerequisite training, but also with a passion for success and the ability to learn the unique skills needed to work in a scientific facility. By pursuing designers with these attributes, the Design Group has achieved a high level of success.

The current Design Office consists of 11 designers and 1 photo-based graphic artist. Each came to TRIUMF with a variety of previous experience, training and skills, from areas such as production engineering, aerospace, submarine design and manufacture, and other research and development positions.



TR30 cyclotron for Nordion Canada. TRIUMF's licensing agreement with MDS Nordion has generated several million dollars for research.

Our team is also a good balance of youth and age. Senior designers offer experience, while junior designers bring new energy and proficiency in the latest computer-aided design and computer-aided manufacturing techniques. These computer skills are an asset for efficient merging with the latest computerized processes at the TRIUMF Machine Shop where CNC machining is currently used. We are fortunate to be able to provide a "full service" environment where all aspects of design and manufacture can be taken care of in house. The combination of senior and junior staff provides the comfort of a succession plan for the future and assurance that the TRIUMF Design Office will be behind great experiments at TRIUMF and at Canadian and international experiments and laboratories far into the future.

Stuart Austen is the Group Leader of the TRIUMF Design Office

by Igor Sekachev

Keeping TRIUMF Cool

TRIUMF has chosen low-temperature superconducting (SC) technologies for the high energy acceleration of radioactive ion beams in ISAC. The key advantages of this choice over room temperature designs are greater energy efficiency and a compact design, allowing TRIUMF to build smaller buildings to house the experimental and support facilities. These benefits allow TRIUMF to reduce its energy consumption and operational costs.

The effect of superconductivity, however, appears only at extremely low temperatures of 9K (-264^{0}C) that are not normally found on Earth. These low temperatures are achieved with cryogenic technology, which relies on helium refrigeration plants and vacuum isolated liquid nitrogen shielded distribution systems.

In 2007, TRIUMF's Vacuum and Cryogenics Group took on the tasks of planning, installing and preparing for the commissioning of Phase II of the Cryogenic Refrigeration System for ISAC-II and a new helium refrigerator for the main cyclotron. Performing the work in-house rather than contracting it out resulted in substantial cost savings for TRIUMF. The group also undertook to reduce TRIUMF's costs for liquid helium for experiments by installing a helium recovery system.

The TRIUMF Design Group were instrumental in planning and designing the ISAC cryogenic refrigeration system.

TRIUMF's use of cryogenic technologies and the resulting operational improvements and cost savings are described below.

SC LINAC powered by cryogenic technology

The construction of TRIUMF's SC facilities has been a significant milestone for TRIUMF and for SC technology in Canada. In 2006 TRIUMF's team of scientists, engineers and technical staff commissioned the first SC linear accelerator (LINAC) in Canada, using cavities made in Europe. Since then it has transferred the fabrication technology to a local company, PAVAC Industries Inc., now one of only five companies in the world, and the only Canadian company, able to produce SC equipment of this kind. The first phase consisted of 20 medium-beta superconducting cavities in five cryomodules. The Phase-II project presently underway consists of three cryomodules of a different design, containing 20 high-beta or higher velocity cavities.

TRIUMF's ISAC-II LINAC achieves its SC capabilities through the use of cryogenic technology. When in operation, a radio frequency (RF) electrical current can be transmitted through cavities made from the metal niobium without resistance or heat generation. To create the right conditions for effective operation of superconductivity in the niobium cavities, helium must be compressed and liquefied to 4.2 Kelvin (-269° C), a temperature slightly above absolute zero.

Faster, smaller, and bigger savings

A quick glance around the TRIUMF laboratory shows the ISAC-II building has a substantially different look than other buildings on site. The new building is smaller and more compact because it was specifically designed to take advantage of the smaller footprint of the refrigeration plant and associated cryogenic system. They require much less space than traditional water cooling systems. SC technology brings with it other cost benefits, in particular, lower costs for electrical power as there can be significant savings due to minimal heat losses. Equally important, TRIUMF's new cryogenic system allows TRIUMF to recover and recirculate helium used in ISAC-II and elsewhere on site. There is a world-wide shortage of liquid helium so this an important benefit in terms of conservation and cost savings.

by Igor Sekachev

Using TRIUMF's talents

To reduce capital costs, TRIUMF played a significant role in the construction of its new refrigeration facility. The scope of the contract with the manufacturer, LINDE Kryotechnik of Switzerland, was limited to the supply of major components. TRIUMF assumed responsibility for the installation of these major components, as well as the room temperature piping, a 114 cubic metre horizontal buffer tank, and a 1000 litre (one cubic metre) helium dewar. The new cold distribution system, specified by TRIUMF, was supplied by DeMaCo of the Netherlands.

The helium refrigerators installed by TRIUMF'S Vacuum and Cryogenics Group for ISAC-I and ISAC-II provide greater efficiency and cost savings.

The helium distribution system supplies liquid helium to the cryomodules which contain SC cavities and solenoids. The system is designed so that operators can cool each of the modules separately at any given time. This feature provides greater flexibility, an asset for a large research facility.

The supply trunk distributes helium flow in parallel to the cryomodules through remotely controlled supply valves. Helium returns from the cryomodules to the cold return trunk through open/close valves. The lines to and from the cryomodules are connected to the trunks through field joints. During cool-down, when temperatures are warmer than 30K, the returning gas is sent back to the suction side of the compressor through the vaporizers and room temperature return piping located outside of the building. At the end of the trunks' keep-cold sections, adjustable valves are installed to avoid potential development of thermo-acoustic oscillations.

Valves installed in the middle of the two trunk lines make it possible to run two separate refrigerators, with the linear accelerator divided into two almost-equal loads. There are also two additional helium lines between the cold trunks and the ISAC test/assembly area (clean room).

Keeping costs down

The screening of the distribution system with a liquid nitrogen shield helps to minimize liquid helium losses. As helium is significantly more expensive than nitrogen, TRIUMF engineers have designed the system to use helium only for cooling beyond the temperatures that can be achieved with liquid nitrogen.

Liquid nitrogen removes most of the heat from the cryomodules, while liquid helium cools the system down further. The liquid nitrogen distribution system supplies liquid nitrogen to the thermal shields of the helium distribution lines and the cryomodules. The nitrogen vapour is exhausted outside the building.

A phase separator in the refrigerator room accepts the two-phase (liquid and gas) nitrogen supplied from the main supply tank (34 sq metres) through a 60 metre long transfer line. The phase separator utilizes a 240 litre nitrogen Dewar, which is equipped with a pressure-differential level-monitor controlling the solenoid supply valve, a pressure switch at 69 kPa (10 pounds per sq in) controlling a vent solenoid valve, and a manual supply valve. The vent valve and the vent lines are oversized to reduce pressure fluctuations during Dewar refills.

How the system works

The Phase-II refrigerator for the high beta section of the SC LINAC was commissioned in June 2008. This refrigerator is identical to the one used in Phase-I, and the refrigerator's performance was tested with the Phase-I section of the

by Igor Sekachev

LINAC. The early addition of the new system allows for greater flexibility in constructing the Phase-II LINAC. While Phase-I is in operation, the Phase-II refrigerator will be used for Phase-II LINAC development, including the single cavity test cryostat for new cavity performance qualification and newly assembled high beta cryomodules.

The two 114 square metre helium buffer tanks are treated independently for Phase-I and Phase-II inventory because the development section has a higher probability of contaminating the helium inventory with impurities. Phase-I and Phase-II have a single helium recovery compressor, which is capable of looking after the helium gas load of the complete system. The compressor was installed and commissioned with the Phase-I refrigerator.

In case of emergencies (i.e. total power outage) the control valve system will ensure the helium recovery from both systems, guiding the flow to the Phase-I buffer tank first, and then, when the pressure reaches 800kPa, to the Phase-II buffer tank.

Cyclotron
A solution to costly maintenance

TRIUMF's new helium refrigerator for the main cyclotron cryogenic pumping system replaces a thirty-year old refrigerator previously used on the cyclotron. In addition to increased reliability, the new refrigerator is capable of liquefying helium gas.

The old system was becoming unreliable, and a factory reconditioning of the old unit or replacement with a new cryogenerator of the same type would not significantly improve performance. The Cryogenics Group proposed to replacing the old system with a new LINDE-1630 helium refrigerator.

Commissioning the LINDE-1630 helium refrigerator.

Installation goes smoothly

The new refrigerator system, including the helium buffer tank, compressor, room temperature piping, helium transfer lines, and the refrigerator were installed and commissioned. This system has successfully maintained the vacuum for beam production since September 2007.

The new system possesses numerous technical and cost-saving advantages. For example, the new system is able to produce liquefied helium and send it through the cryopanels inside the cyclotron. This feature boosts the performance of the cryopanels and improves pumping speed by lowering temperature.

A world-wide shortage of helium

A world-wide shortage of liquid helium is putting a strain on physics laboratories, manufacturers, and other businesses that depend on a secure and constant supply of liquid helium. The demand for liquid helium is fueled by growing high-tech manufacturing in China, Japan, Taiwan, and South Korea. The gravity of the situation has led the National Research Council (US) to establish a committee to study and make recommendations on the likely effects of the helium shortage. Igor Sekachev, TRIUMF's Vacuum and Cryogenics Group Leader, has been asked by the US Government to sit as a member of this committee.

Helium liquefaction at TRIUMF

TRIUMF uses about 30,000 litres of liquid helium per year for experiments. Liquid helium users at the nearby University of British Columbia require another 10,000 litres of liquid helium each year.

Despite a pricing agreement with its main supplier of liquid helium, TRIUMF is feeling the effects of shortages and rising prices. Due to the loss of two major crude helium sources, the supplier is able to provide TRIUMF with only 60% of its normal supply, and further interruptions in the supply of liquid helium can be expected, along with price increases.

Keeping TRIUMF Cool Cryogenic Systems at TRIUMF

by Igor Sekachev

TRIUMF'S two helium tanks each hold 30,000 US gallons of the increasingly rare and expensive gas.

The issue of helium retention and recycling has become a critical issue for TRIUMF.

Plans made by the Vacuum and Cryogenics Group to address the helium supply problem include maintaining TRIUMF's liquid helium and helium gas suppliers, but with the ability to substitute these suppliers if required. During the short term, from September 2007 to March 2008, an existing helium recovery system, which had been decommissioned, was restored to capture and recycle the helium gas exhaust from experiments.

For the intermediate term, April 2008 to January 2010, TRIUMF will use the new Linde TCF50 helium liquefier in ISAC-II Phase-II. In the long term, after January 2010, a helium liquefier of about 100 liquid litres per hour, similar to the Linde L140, will be purchased, installed and commissioned and is expected to meet TRIUMF's needs for the foreseeable future.

Seeking new and innovative solutions

The goal of the TRIUMF Vacuum and Cryogenics Group is to seek new and innovative solutions to improve the support provided to Canadian and international scientific experimental groups, increase the overall efficiency of TRIUMF's operation, reduce operating costs, and reduce dependence on outside suppliers of liquid helium.

The Group continues to meet its goals by developing and implementing innovative ways to address each problem encounted. This combination of science, engineering, and attention to costs are examples of the responsible practices that have made TRIUMF one of the leading laboratories in the field of cryogenics and superconducting technologies.

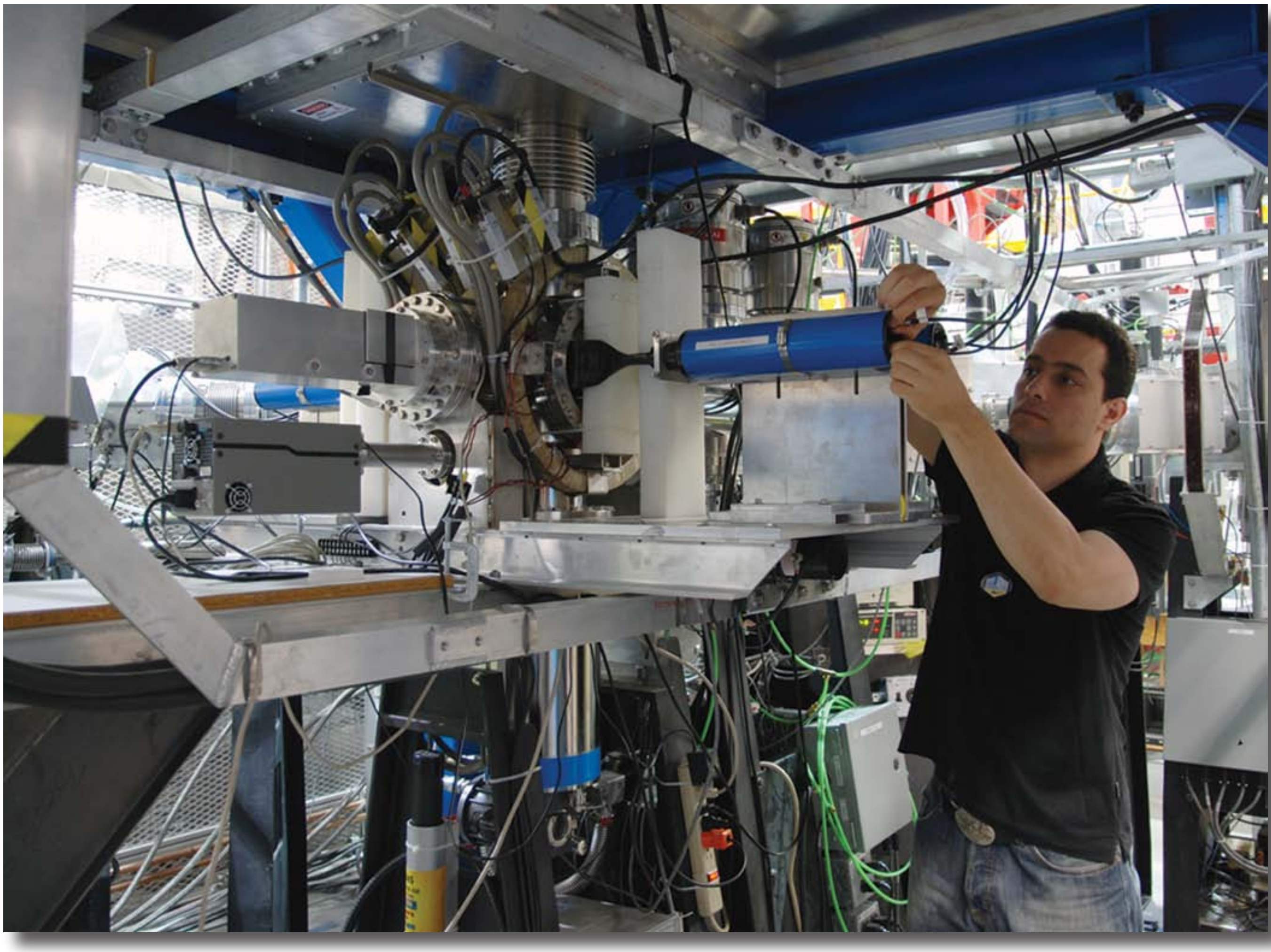
Igor Sekachev is the Group Leader of TRIUMF's Vacuum and Cryogenics Group

by Andrew MacFarlane

βNMR -- a New Tool for Investigating the Science of Materials

Materials scientists investigate the properties of solid matter in all forms, from the atomic or molecular scale to the macroscopic (visible to the naked eye). Hence Materials Science is an interdisciplinary field that includes elements of physics and chemistry, as well as engineering.

With the trend towards miniaturization in technology, interface and surface effects are becoming increasingly important, and understanding them in detail is critical since the design and construction of devices always involve interfaces between different materials. These materials are bound together into a *heterostructure*, a layered structure composed of different materials with interfaces between different material layers, called hetero-interfaces. Furthermore, as devices get



Ph.D. student Hassan Saadaoui connects a beta ray detector in the beta-NQR spectrometer. The sample in a controlled ultra-high vacuum environment is introduced into the end of the beam line from the platform above.

smaller and smaller, all parts of the device become close to some interface. It is thus critical to understand and control material properties in the vicinity of interfaces.

Unfortunately, there are very few methods for detecting variations in the properties of a solid material as a function of depth within nanometres of a free surface or a hetero-interface.

Throughout the past year, researchers from the University of British Columbia, the University of Alberta, and TRIUMF have been pioneering efforts to use beams of low energy short-lived radioactive ions, available at TRIUMF's ISAC facility, as highly sensitive probes to explore surface and interface effects in materials for advanced technologies. This technique, known as Beta Nuclear Magnetic Resonance (βNMR), enables materials scientists to minutely examine

Beta Nuclear Magnetic Resonance

by Andrew MacFarlane

A gold foil test sample mounted for the experiment in a nearby cleanroom facility. The low energy ISAC beam is focussed to a mm size spot on the sample. The implantation energy can be varied to control the depth probed by the implanted ions.

– within nanometers - the interface between two different materials. Therefore βNMR can provide information on important solid materials such as metals, semiconductors, and novel magnetic materials, and in particular how local electronic and magnetic properties near an interface of new materials differ from the main body of the material. This information cannot be obtained using any other method in the world, and can ultimately help to improve the performance of devices used in medicine, security, high performance computers and wireless communication.

How does βNMR work?

βNMR is a novel tool that combines the sensitivity of radiotracers with the power of nuclear magnetic resonance:

- *Radiotracer* techniques use radioactively unstable isotopes as marker atoms. These unstable isotopes essentially behave identically to their non-radioactive counterparts but are easily detected through the high-energy release of alpha, beta, or gamma rays when they decay. Radiotracer techniques are widely used to follow atomic and molecular processes in a diverse range of fields including medicine, biology, atmospheric science, geology, chemistry, and materials science. The radiotracers produced at ISAC are, however, very short-lived in comparison to conventional radiotracers. For example, the half-life of the isotope used in βNMR is only about 1 second.

- *Nuclear Magnetic Resonance* (NMR) finds wide usage in medicine, chemistry, and physics. It is the basis of Magnetic Resonance Imaging (MRI), a diagnostic tool used in hospitals to assess patient health. It works by detecting the weak magnetic fields due to the atoms inside a material, and can yield an immense wealth of information about the location of the atoms , their environment (what atoms they are bound to) and what these atoms are doing over time.

In βNMR, an appropriate radiotracer ion is implanted at low energies into the material of interest. The implantation energy can be varied in order to stop the ion at well-determined depths (on the order of nanometers) inside the material. The radioactive ion also has some unique properties that make it a suitable NMR probe. When this radiotracer ion decays, the direction of the decay products depends on the magnetic field within the atom, allowing scientists to reconstruct the nature of the local electromagnetic environment of the atom within the material. The result is a method of detection that is about 10 orders of magnitude more sensitive than a conventional NMR experiment, and hence very suitable for investigating the magnetic properties of ultra-thin films, nanostructures, and interfaces.

Currently, βNMR at TRIUMF is carried out with the isotope ^{8}Lithium (^{8}Li) as the radiotracer. Researchers use a pair of sophisticated spectrometers at the end of the ISAC polarized beamline to monitor the decay products and control the energy and path of the radiotracer. The samples are located in an extremely high vacuum environment (about one trillionth of atmospheric pressure) and studied as a function of depth, temperature, and applied magnetic fields.

New Science, New Discoveries and New Applications

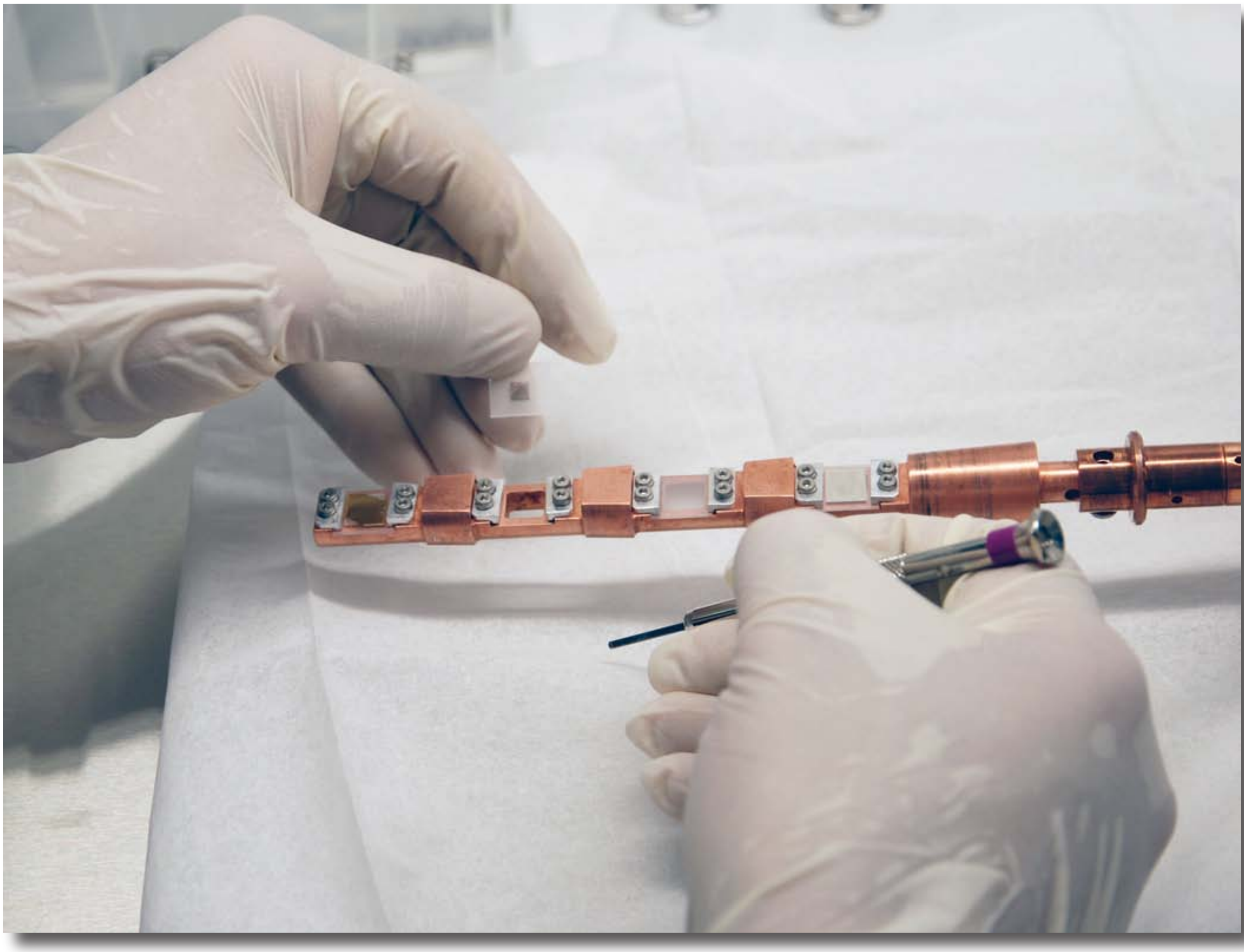
There are many remarkable scientific phenomena that can depend on depth in heterostructures. The novel βNMR technique can make important contributions to understanding these systems. Here, some select applications of βNMR are reviewed.

by Andrew MacFarlane

Magnetic Proximity Effects & Spintronics

A magnetic layer, such as iron, can induce magnetism in an adjacent metallic layer – this is called the magnetic *Proximity Effect*. It is the basis for a property of magnetic/nonmagnetic multilayer structures called "giant magnetoresistance" (GMR), where the electrical resistance of the structure depends strongly on an external magnetic field. The discovery of this effect by A. Fert and P. Grünberg forms the basis of current state-of-the-art magnetic recording technology in computer hard disks, for example, and was awarded the 2007 Nobel Prize in Physics. There is still much to understand about magnetic proximity effects in these and similar structures that will form the basis of an emerging new technology called *Spintronics*. Spintronics is a new type of electronics that combines the electrical charge used in conventional electronics with the electron's intrinsic magnetism (spin) to make new devices for the storage, transmission, and processing of information. As an understanding of the depth dependence is key to the advancement of this work, βNMR is ideally suited to make major contributions to this important stream of materials research.

For example, recently βNMR scientists have studied magnetic proximity effects in metallic magnetic multilayer structures and monolayers of magnetic molecules, which may one day provide the smallest possible unit of magnetic storage. In this latter work, the researchers implanted ^8Li probes into a crystalline silicon substrate, coated with a single layer of magnetic Manganese$_{12}$ (Mn_{12}) molecules. The βNMR team were able to detect the magnetic effects due to this incredibly small amount of material and found significant differences in the properties of Mn_{12} in monolayer form compared to bulk crystals. This is an important discovery for future applications of such systems since they will undoubtedly require such molecular magnets to be fabricated in the form of monolayers on surfaces.



Samples for beta-NQR are mounted on a ladder to facilitate quick sample changes to make maximal use of the highly sought after ISAC beam.

by Andrew MacFarlane

The βNMR scientists are now pursuing problems in magnetic *semiconductors* which will be instrumental in the implementation of spintronics and allow integration of spintronic devices into conventional semiconductor technology. The βNMR team collaborates with scientists throughout the world to obtain high-quality samples for their experiments.

Superconductors

When cooled below their transition temperature, superconductors are able to carry an electrical current with zero electrical resistance, making them appealing candidates for power transmission applications. Superconductors also exhibit many exotic *quantum mechanical* properties that are normally found only in much smaller structures such as single atoms. This property is used in devices such as the ultrasensitive magnetometer known as the Superconducting Quantum Interference Device (SQUID), that are used in applications as diverse as functional imaging of the brain and geosensing. Here, the fascinating fact that particles like electrons can, under certain conditions, behave as waves is actually the basis of the operation of the device.

Recently, there has been much interest in employing the wave-like quantum mechanical properties of matter in devices such as quantum computers, where the information is not simply coded and processed as bits, but instead as the state of a quantum mechanical state. The evolution of this state with time can then be used in radically new computational algorithms that will dramatically increase computing power.

An important phenomenon in this regard is the superconducting proximity effect. In this case, a superconducting layer causes an adjacent metallic layer to act as a superconductor over a range of depths near the interface.

The βNMR scientists have investigated several types of heterostructures involving a superconducting layer. The advantage of depth resolution in this case is to study over what distance from the interface are the properties of the normal metallic layer changed and how are these properties changed. These are key issues in devices designed to use the quantum properties of superconductors.

Looking Ahead

The development and continued refinement of βNMR at TRIUMF's ISAC I facility has allowed scientists and engineers to obtain information on novel materials that cannot be obtained using other techniques. This knowledge can be useful in improving current devices, and for developing materials for future applications.

In addition to the experiments on spintronic materials and superconductors mentioned above, the βNMR scientists are also investigating many novel systems, including those with applications in energy storage, surface catalysis, and thin plastic electronics. Furthermore, the TRIUMF materials science team is also developing other isotope beams that have properties complementary to those of the easily produced ^{8}Li. One example is ^{11}Beryllium (^{11}Be). Unlike ^{8}Li, it is a pure magnetic probe, insensitive to electrical effects in the host material.

Clearly, there are great prospects for dramatically advancing materials science using βNMR at TRIUMF. In fact, there is so much interest in using this powerful technique that demand far outstrips available beamtime. Even with this demand, βNMR is one of the heaviest users of the highly oversubscribed ISAC facility. Thus the team is looking forward to plans currently being considered by TRIUMF to dramatically increase beam production in several major initiatives in its coming five year plan.

W. Andrew MacFarlane is an Assistant Professor of Chemistry at the University of British Columbia, Vancouver

AUDITORS' REPORT

To the Joint Venturers of TRIUMF

We have audited the statement of financial position of TRIUMF as at March 31, 2008 and the statements of combined funding/income and expenditures and changes in fund balances for the year then ended. These financial statements have been prepared to comply with section 11b of the TRIUMF joint venture agreement and the contribution agreement with the National Research Council of Canada. These financial statements are the responsibility of TRIUMF's management. Our responsibility is to express an opinion on these financial statements based on our audit.

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

In our opinion, these financial statements present fairly, in all material respects, the financial position of TRIUMF as at March 31, 2008 and the results of its operations and the changes in its fund balances for the year then ended in accordance with the basis of accounting described in note 2 to the financial statements.

These financial statements, which have not been, and were not intended to be, prepared in accordance with Canadian generally accepted accounting principles, are intended for the information and use of the Joint Venturers and the National Research Council of Canada and may not be appropriate for any other use.

PricewaterhouseCoopers LLP

Chartered Accountants
Vancouver, B.C.
June 20, 2008

TRIUMF

Statement of Combined Funding/Income and Expenditures

As at March 31, 2008

	2008 $	2007 $
Assets		
Cash and cash equivalents	7,749,517	7,451,031
Restricted cash	7,615,683	401,074
Due from Joint Venturers	335,644	410,884
Funding receivable	905,750	868,968
	16,606,594	9,131,957
Liabilities		
Accounts payable	1,060,687	1,127,071
Funds received in advance	2,788,881	2,864,306
Decommissioning Fund	7,615,683	401,074
Bank loan	-	906,658
	11,465,251	5,299,109
Fund Balances		
Restricted		
Natural Sciences and Engineering Research Council Fund	3,540,315	2,773,941
MDS NORDION Inc. Fund	100,000	100,000
Canada Foundation for Innovation	(269,252)	(241,404)
	3,371,063	2,632,537
Other		
Commercial Revenue Fund	1,145	1,084,788
General Fund	57,572	31,512
TRIUMF House Building Fund	(628,795)	(1,328,298)
Intramural Accounts Fund	2,340,358	1,412,309
	1,770,280	1,200,311
	5,141,343	3,832,848
Total liabilities and fund balances	16,606,594	9,131,957

TRIUMF
Statement of Financial Position
As at March 31, 2008

	2008 $	2007 $
Funding/income		
National Research Council Fund	51,500,000	45,500,000
Natural Sciences and Engineering Research Council Fund	6,374,929	5,266,630
MDS NORDION Inc. Fund	3,938,506	3,771,760
Canada Foundation for Innovation	1,867,939	2,406,137
Affiliated Institutions Fund	1,815,124	1,084,050
Commercial Revenue Fund	1,711,706	1,486,266
General Fund	461,169	417,161
	67,669,373	59,932,004
Expenditures		
Buildings and improvements	505,470	586,523
Communications	144,872	157,995
Computer	1,022,417	1,435,878
Facility conformity costs	7,200,000	400,000
Equipment	6,834,656	6,428,809
Power	1,905,098	2,192,484
Salaries and benefits	35,794,712	34,138,291
Supplies and other expenses	12,953,653	13,052,245
	66,360,878	58,392,225
Surplus (deficit) of funding over expenditures for the year	1,308,495	1,539,779
Fund balances - Beginning of year	3,832,848	2,293,069
Fund balances - End of year	5,141,343	3,832,848

TRIUMF
Notes to Financial Statements

1 Nature of operations

TRIUMF is Canada's national laboratory for particle and nuclear physics, owned and operated as a joint venture by the University of Alberta, Carleton University, the University of Victoria, Simon Fraser University, the University of British Columbia and the University of Toronto, under a contribution from the National Research Council of Canada. As a registered charity, TRIUMF is not subject to income tax.

At March 31, 2008, each university owned an undivided 16.7% interest in all the assets and was responsible for 16.7% of all liabilities and obligations of TRIUMF, except for the land and buildings occupied by TRIUMF, which are owned by the University of British Columbia. On April 1, 2008, L'Universite de Montréal became a joint venture; each venturer's interest is now 14.3%.

These financial statements include only the assets, liabilities, funding and expenditures of the activities carried on under the control of TRIUMF and do not include the other assets, liabilities, revenues and expenditures of the individual joint venturers.

Sources of funding include grants and contributions from the National Research Council of Canada, the Natural Sciences and Engineering Research Council, and governments; advances and reimbursements from other sources; royalty income; 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.

MDS NORDION Inc. Fund
Advances and reimbursements from MDS NORDIAN Inc. for expenditures undertaken at its TRIUMF site.

Canada Foundation for Innovation (CFI)
Funding to grantees for capital projects related to TRIUMF activities. These funds are administered by TRIUMF on behalf of the grantees.

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

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

General Fund
Investment income for discretionary expenditures incurred by TRIUMF.

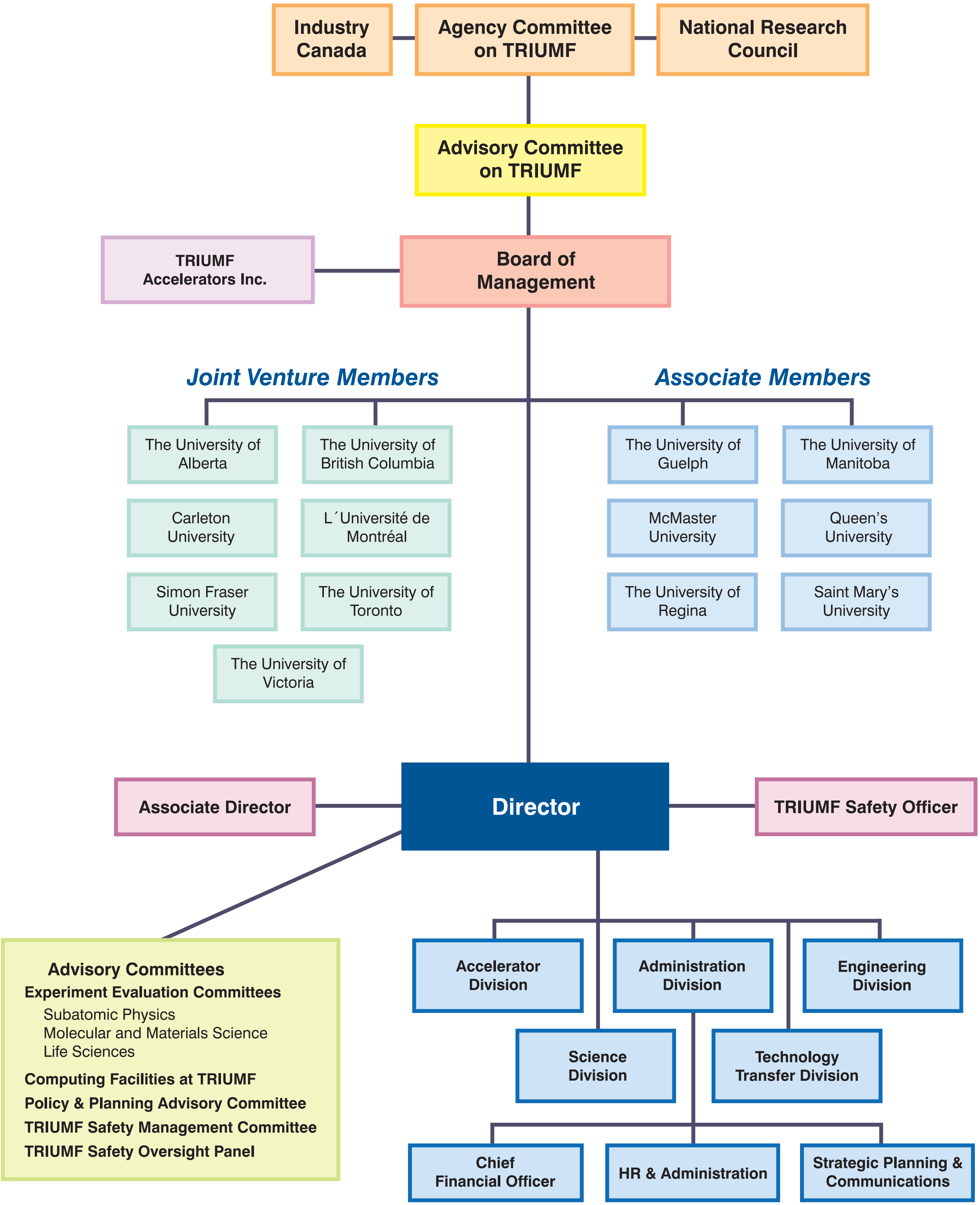
TRIUMF House Building Fund
Contributions from unrestricted funds and expenditures for the construction of TRIUMF House.

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

2 Significant accounting policies

Basis of presentation
These 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 follow Canadian generally accepted accounting principles 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.


Industry Canada
Agency Committee on TRIUMF
National Research Council
Advisory Committee on TRIUMF
TRIUMF Accelerators Inc.
Board of Management
Joint Venture Members
The University of Alberta
The University of British Columbia
Carleton University
L´Université de Montréal
Simon Fraser University
The University of Toronto
The University of Victoria
Associate Members
The University of Guelph
The University of Manitoba
McMaster University
Queen's University
The University of Regina
Saint Mary's University
Associate Director
Director
TRIUMF Safety Officer
Advisory Committees
Experiment Evaluation Committees
Subatomic Physics
Molecular and Materials Science
Life Sciences
Computing Facilities at TRIUMF
Policy & Planning Advisory Committee
TRIUMF Safety Management Committee
TRIUMF Safety Oversight Panel
Accelerator Division
Administration Division
Engineering Division
Science Division
Technology Transfer Division
Chief Financial Officer
HR & Administration
Strategic Planning & Communications

One Thing Leads to Another

by Shirley Reeve

When I read Nigel Lockyer's impressions of TRIUMF after his first year as Director, I realized how much I take TRIUMF and its extraordinary accomplishments for granted. How did this small Canadian laboratory become such a highly respected laboratory on the world stage? How did it develop the technical expertise in so many areas that it has become a sought after partner by universities and laboratories in Canada and around the world?

Like many of you, I take it for granted that TRIUMF will excel. I fail to recognize what an amazing place TRIUMF is and how the pieces have come together over the last 40 years to make TRIUMF unique. The pieces are simple; the people and their passion for the science and for TRIUMF. The synergy that has developed between these pieces has made so many things at TRIUMF possible.

Installing the super conducting cryomodules in the ISAC-II accelerator hall.

The synergy: it began with accelerators

The synergy between TRIUMF's scientists, engineering and technical staff began in the very early 1970s when together they built the world's largest cyclotron. In TRIUMF fashion they took it one step farther: TRIUMF developed an expertise in accelerator technologies that is recognized world-wide. TRIUMF's expertise in designing and building accelerators led to the design and development of small cyclotrons used to produce medical isotopes in a dozen countries around the world and TRIUMF has plans for even smaller cyclotrons, not much bigger than an espresso machine that will allow hospitals to produce medical isotopes on demand.

The latest achievement of the TRIUMF accelerator group is the construction of a superconducting accelerator for ISAC-II and the transfer of the superconducting technology to a local company, one of only five companies in the world and the only Canadian company able to use superconducting technology. TRIUMF's Five-Year Plan for 2010 – 2015 proposes the construction of Canada's first e-LINAC, an electron accelerator, which will provide new capabilities for TRIUMF's rare isotope beam facility ISAC and open possibilities for the production of new and different medical isotopes.

TRIUMF's accelerator group is in demand by laboratories around the world that are looking to build cutting edge accelerators. TRIUMF is a sought after partner, ensuring Canadian researchers are welcome collaborators at the world's laboratories.

Accelerator expertise leads to more than accelerators

TRIUMF's skill at designing, building and operating accelerators led MDS Nordion Inc. to partner with TRIUMF in the production of medical isotopes. This very successful collaboration provides Canada and the world 2.5 million patient doses of medical isotopes for the diagnosis and treatment of disease each year.

One thing leads to another. TRIUMF's skill at producing medical isotopes provided an opportunity in the early 1980s for the TRIUMF staff to build the University of British Columbia's (UBC) first PET scanner, a machine that relies on isotopes to perform the scans and uses techniques to "look" inside the body similar to those used by physicists use to "look" inside the atom. That fledgling TRIUMF/UBC PET program, whose Director is a TRIUMF scientist and which relies heavily on TRIUMF engineering and technical staff, has become one of the two top research programs of its kind in the world, investigating the causes and possible cures for Parkinson's disease and other neurological and psychiatric disorders. TRIUMF provides its considerable expertise in PET technology and radiopharmaceutical production to PET Centres across Canada.

TRIUMF has recently entered into an agreement with the BC Cancer Agency to produce medical isotopes for the diagnosis and treatment of cancer until their new building and small cyclotron, a TRIUMF cyclotron manufactured by by Shirley Reeve

a local company, is complete. TRIUMF produces about 275 patient doses a month of the isotope FDG for the BC Cancer Agency. TRIUMF also operates a Proton Therapy facility to treat ocular melanoma, the only one of its kind in Canada. Over 130 patients have been successfully treated at TRIUMF.

A Proton Irradiation facility, along with a sister facility using neutrons, tests the effects of cosmic radiation on sensitive electronics. Companies such as MDA, the Canadian Space Agency, Boeing and Cisco Systems regularly use TRIUMF's facilities to test and radiation harden electronics used in airplanes, in equipment sent into space and even sophisticated systems used at ground level.

Pioneering in materials science

A small group of TRIUMF staff pioneered the study of high temperature superconductors using muon spin resonance (μSR), a technique using muons to investigate the properties of materials. TRIUMF was the first and currently one of only three laboratories in the world capable of exploiting this technique in the study of superconducting materials. In typical TRIUMF fashion, one innovative technique led to another. The unique capabilities of TRIUMF's ISAC facilities led to the pioneering of a second technique, βNMR, a technique used to study the properties of thin films, so critically important to the development of smaller and smaller electronic components. The technique of βNMR is discussed in the article *Beta Nuclear Magnetic Resonance* in this report. TRIUMF is currently the only facility in the world using the βNMR technique to study thin films, but rare isotope production facilities similar to TRIUMF's ISAC facilities are planned in the US and Europe.

TRIUMF's passion: particle and nuclear physics

TRIUMF's contributions to Canada and the world in accelerator technology, medical isotopes, Life Sciences and Material Sciences is a product of TRIUMF's passion: the science of particle and nuclear physics. The TRIUMF staff excels at building cutting edge accelerators, research facilities, particle detectors and related instrumentation because they are needed to do the science: to find the answers to the question of how our universe and world came to be. Answering these questions, along with building TRIUMF's reputation as one of the best in the world at what we do, are important to the TRIUMF staff. TRIUMF works as a team from the design stage, through the engineering, construction and commissioning of the facilities and equipment. It is this team work, generating innovative ideas and techniques, that produce facilities such as ISAC-I and ISAC-II, unique experimental equipment such as TITAN and TIGRESS, and our many contributions to experimental facilities abroad that allows TRIUMF and Canada to have an impact far beyond what the small size of the laboratory would suggest.

The TRIUMF passion for excellence extends to everything it does, both at home and abroad. When the LHC at CERN, the world's largest physics laboratory "turns on" in late 2008, Canada can proudly take its place front and centre because of the quality of the contributions of equipment and expertise TRIUMF made to the LHC on behalf of Canada. TRIUMF made similar contributions to the LHC's ATLAS detector, ensuring Canada's physics researchers a prominent and respected position in the ATLAS experiment. As always at TRIUMF, one success leads to another. The ATLAS Tier 1 Centre at TRIUMF, which is one of only 11 centres around the world, will manage petabytes of data from the ATLAS experiment and by 2011 will be Canada's largest academic computing network. The contributions to CERN are the largest TRIUMF has made but by no means the only contributions. Laboratories in Japan, Europe and the USA, where Canadian researchers have mounted experiments, have benefited from TRIUMF's contributions of equipment and expertise.

TRIUMF contributed one of the two hadronic endcaps for the ATLAS detector at CERN.

One Thing Leads to Another

by Shirley Reeve

The people who make it happen

A successful laboratory, like a successful business, relies on the skill and passion of its people to make it successful. There is a brief article early in this report that introduces you to a very small group of the TRIUMF staff we think are representative of the whole. What that article cannot begin to tell you is how diverse and talented our people are, how passionate they are about their work, and how so many of them have chosen TRIUMF as the laboratory where they want do their work.

Young scientists from Canada and from countries such as France, Russia, Germany, Japan, Italy, England, India, China, Korea, the USA and many others, have chosen to come to TRIUMF because they see their future here doing the research they love, research that would be difficult or impossible anywhere else in the world, with equipment and a skill set that is difficult to find elsewhere. Young Canadian researchers have returned from universities and laboratories abroad to take positions in our universities because Canada can provide them and their students with unique and diverse research opportunities at TRIUMF and with TRIUMF's scientific collaborators abroad.

And it is not just scientists. In previous *Financial and Administrative Annual Reports* we have introduced you to some of the engineering, computing and technical groups at TRIUMF. It is these groups who provide the specialized expertise necessary to build and operate the unique and complicated equipment needed for research either at TRIUMF, at other Canadian laboratories or laboratories abroad where Canadian physicists have chosen to carry out their research. Working side-by-side with the scientists, they design, invent, build, program and operate our complicated equipment and operating systems. They, too, are passionate about what they do. It is not unusual to come to work early in the morning and find groups of scientists, engineers and technical staff who have worked through the night to solve a problem, to complete a project, or to meet a deadline. That is just business as usual at TRIUMF.


Indulge your sense of wonder and curiosity with a visit to TRIUMF, Canada's national laboratory for particle and nuclear physics.

The next generation

TRIUMF reaches out to students; they are our next generation of scientists, engineers and technical experts and will keep Canada and TRIUMF strong and competitive on the world stage. Science is curiosity driven and the students' enthusiasm, curiosity, and wonder remind us all that these traits cannot be taught, only nurtured wherever we find them. TRIUMF's student programs, whether for high school students, undergraduates, Co-op placements, or graduate students, provide intellectual challenge and nurture that sense of curiosity and wonder in the young men and women who will become the leaders of tomorrow. TRIUMF student positions and are highly prized and sought after by students across Canada and some of these students return to TRIUMF for advanced degrees. In the last five years, students working at TRIUMF have earned 104 PhDs and 223 MScs.

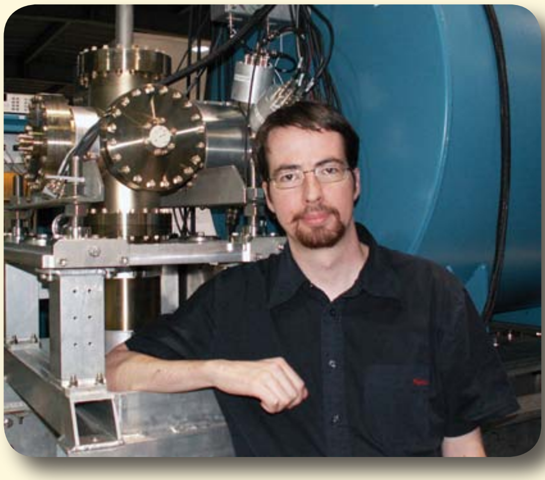
Come and see your national laboratory for particle and nuclear physics

TRIUMF welcomes over 2,000 non-scientific visitors a year on tours of the laboratory that run twice daily in the summer and twice weekly during the winter months. Special tours can be arranged on request. We would love to have you visit us. For more information on TRIUMF and its facilities, please visit www.triumf.ca. If you would like to read more about the science and the groups at TRIUMF who make the science happen, please visit www.triumf.info/public/about/annual_report.

Shirley Reeve is TRIUMF's Chief Financial Officer

Jess Brewer, the University of British Columbia, wins the CAP/DCMMP Brockhouse Medal for his outstanding experimental contributions to Condensed Matter and Materials Physics. Jess has performed almost all of his experimental work at TRIUMF.

TRIUMF wins its second NSERC Synergy Award for Innovation in four years. The 2007 award was made to TRIUMF and D-Pace, Inc for their partnership in the development of products and services for cyclotrons and other particle accelerators.



Maxime Brodeur, TRIUMF, wins the Carl Westcott Fellowship for his exceptional work on TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN) project.

Carl Svensson, the University of Guelph, wins the NSERC Staecie Memorial Fellowship and the CAP Herzberg Medal. His recent work is as the leader of TIGRESS, the TRIUMF-ISAC Gamma-Ray Escape Suppressed Spectrometer.

TRIUMF was one of only eleven winners in the national competition of the Centres of Excellence for Commercialization and Research (CECR) Program. The award has resulted in the creation of the not-for-profit company Advanced Applied Physics Solutions (AAPS).

TRIUMF

Canada's National Laboratory for Particle and Nuclear Physics

Stephen J. Toope, President of UBC, toured TRIUMF with Director Nigel Lockyer and Science Division Head Jean-Michel Poutissou.

BC Health Minister, George Abbott, and the BC Minister of Technology, Trade and Economic Development, Ida Chong, visited TRIUMF.

TRIUMF hosted the international Halo Workshop.

The experimental research team of Professor Shimoda from Osaka University, Japan, successfully completed their polarized beam β-decay studies of sodium-28.

The search for Strange Quarks: The International G-Zero Collaboration held their annual meeting at TRIUMF.

TRIUMF
4004 Wesbrook Mall
Vancouver, B.C.
V6T 2A3 Canada
Tel: 604 222-1047
Fax: 604 222-1074
www.triumf.ca