TRIUMF

Annual Financial & Administrative Report

2009-2010

Contents

The Nuclear Medicine team proudly showing off the newly renovated GMP radiochemistry laboratory. (left to right) Wade English, Ken Buckley, Christine Takhar, Jean-Michel Poutissou, Valia Barreras-Fernandez, Kathleen Genge, Jianming Lu, Mike Adam, Salma Jivan, Tom Ruth, Conny Hoehr, Paul Schaffer (missing Linda Graham, James Inkster, Tom Morley)

Cover Photo: Dr. Paul Schaffer (far right on front cover and back cover inset) and the TRIUMF Nuclear medicine group combine physics and chemistry expertise to address, along with their collaborators, some of the toughest questions in medical, biological and earth sciences. For more information on TRIUMF's Nuclear Medicine programs please visit our website at www.triumf.ca.

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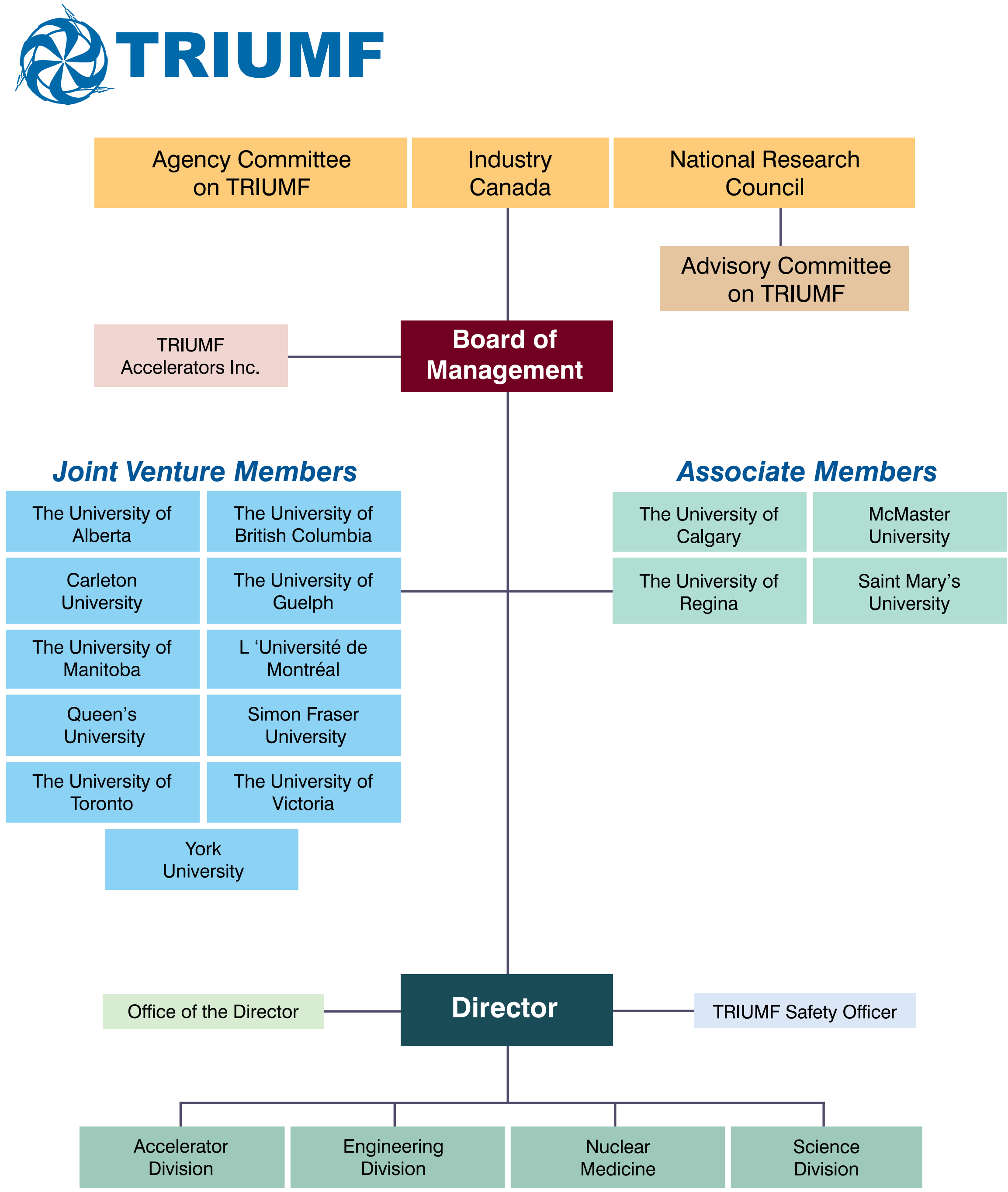


Hello, and welcome to the TRIUMF Annual Financial & Administrative Report 2009–2010. The big news from 2009 is that the Government of Canada will be supporting the next five years of TRIUMF's core operations through their support for the Five-Year Plan 2010–2015 at the level of $222.3 million. At a time when worldwide science funding is being curtailed, and even dramatically cut in some countries with traditionally strong basic science programs, we have done well with a support level that will allow us to make some long-range plans that will benefit the world in general, and Canada in particular. Let me highlight just a few of these plans.

All science at TRIUMF begins with accelerators, and our five-year funding will fund both accelerator operations and associated scientific research. In particular, this support will allow the expansion of nuclear medicine research at TRIUMF, including medical isotope related research and support for the Large Hadron Collider particle physics research program at CERN in Geneva, Switzerland. Funding includes operation and modest upgrades for TRIUMF's cyclotron, the world's largest cyclotron, which facilitates producing intense rare isotope beams for basic research, with medical applications. The program is being enhanced with a $1M grant from Western Economic Diversification for a new nuclear medicine laboratory.

In June 2009, the Canada Foundation for Innovation (CFI) approved a $17.8 million contribution toward the e-linac project led by the University of Victoria and a consortium of partners. The e-linac is a proposed high-power, electron linear accelerator using superconducting radio-frequency technology. With support from CFI, a university consortium of 13 partners, the Government of British Columbia, and TRIUMF (including support from both the National Research Council and the Ministry of Industry), this program finalized its funding and launched in June 2010. TRIUMF's flagship initiative will be the Advanced Rare IsotopE Laboratory (ARIEL), which includes the e-linac and provides an upgrade path for additional beam lines, target stations, and novel development of the accelerator itself.

As a showcase for Canadian prowess in next-generation accelerator technology, and as a platform for Canadian leadership in rare isotope beam physics, ARIEL and its e-linac represents a profound opportunity for the laboratory and the broader community. The ARIEL facility along with the high-intensity proton beams from the cyclotron will place TRIUMF firmly as a world leader in rare isotope beam research and its resulting technical and medical advances.

Nigel Lockyer
TRIUMF Director

One other component of TRIUMF's mission is finding and answering commercial opportunities. TRIUMF continues to seek out private sector partners and develop new opportunities through our spin-off company and Centre of Excellence, Advanced Applied Physics Solutions (AAPS). A number of exciting projects in their early stages show great potential in the areas of accelerator production of medical isotopes, purification techniques, radiochemistry, and new search techniques in the mining industry. Stay tuned for news on this front!

In addition to our 2009 Auditor's Report, I invite you to read all the articles in this report. One article celebrates the first decade of rare isotope science at ISAC. Another focuses on the work of Dr. Otto Häusser, who was one of the proponents of, and chief motivator behind the 8π detector proposal. To this day, 8π remains one of the best spectroscopic instruments for nuclear physics research, including those ISAC experiments using rare isotope beams. In honour of Dr. Häusser's work, TRIUMF has established a new fellowship in his name.

Two other articles in this report talk about the future of two areas of support for TRIUMF science: communications and computing.

Finally, we'd like to introduce you to some new members of our TRIUMF family.

In closing, I'd like to thank all TRIUMF staff for their efforts, because it is only through their dedication and hard work that TRIUMF is a success.

Each year TRIUMF's Annual Financial and Administrative Report provides an article, or even part of an article, that strikes me as significant or that captures my imagination. This year it was the realization that TRIUMF has turned 40. How did the years go by so fast!

I wasn't at TRIUMF in 1969 when that first shovel of dirt was dug. I didn't arrive until fifteen years later, but I know many of the men and women who created TRIUMF from cement, steel and their imaginations. Their dream of what could be became a reality, perhaps far beyond what they originally imagined. Did they know that a small laboratory on the west coast of Canada would become Canada's National Laboratory for Particle and Nuclear Physics? Did they know the laboratory would become known worldwide for its abilities and contributions to particle and nuclear physics, nuclear medicine, materials science and accelerator technologies? I suspect they did.

When that first generation eventually retired, their vision of a laboratory for Canada was carried on by a new generation, who took what that first generation had created and amplified it further, bringing reality to their own expanded vision for TRIUMF. The article "*The First Decade of Rare Isotope Science at ISAC*" will tell you about one part of that vision.

TRIUMF's second generation of scientists, engineers and technicians is now preparing to retire, but their expanded vision of TRIUMF is being carried on and expanded further by a third generation, some of whom we introduce to you in the article "*A New Generation for the 'Mother of All Science'.*" As I read about their vision for their science and for TRIUMF, it is clear that TRIUMF's future is in very good hands. The "*Director's Report*" will tell you about how TRIUMF will implement some of these plans over the next five years.

TRIUMF is excited about our science, our people and our accomplishments. The article "*Communication in Science*" will tell you about TRIUMF's efforts to share with you our excitement, our accomplishments and those of our colleagues around the world. We have so much to tell you about!

Shirley Reeve
Chief Financial Officer

TRIUMF's scientists could not implement their vision without talented and imaginative support staff, which includes engineers, technicians, and in an organization as sophisticated as TRIUMF, computing and IT specialists. The article "*Computing at TRIUMF*" will tell you a little bit of the history of computing at TRIUMF and the challenges of "directing and organizing 500 rowboats on a pond".

Students, whether they are co-op students, undergraduates, graduate students or Post Doctoral Fellows, are an important part of TRIUMF's vision. They bring an energy and curiosity to the laboratory that continually challenges us and provides TRIUMF the opportunity to nurture and develop the diverse talents students bring us. The article "*The Otto Häusser Fellowship*" will tell you about the post-doctoral fellowship we have created and something about Otto, the TRIUMF scientist and Simon Fraser University professor for whom the Fellowship is named.

And there is the science. There is so much science done at TRIUMF it takes an 800 page document to tell you about it! For this small report, the article "*It's All About Shape and Size*" will tell you about some very innovative techniques developed by TRIUMF to measure the fundamental properties of nuclei.

TRIUMF turned 40 in 2009. When people turn 40 they often ask themselves "Am I living up to my potential?"; "Am I making a difference?" TRIUMF has asked those questions every year of its existence and has continually pushed itself to ensure the answer to these questions is "Yes!"

Happy Birthday TRIUMF! May there be many many more.

by Tim Meyer

Science Communication: What is it and How Good is it?

When I was growing up, a communicator was the device that Captain Kirk used to radio instructions to Chief Engineer Scott: "Beam me up, Scotty," he'd say, and then he'd turn into silver twinkles and that was that. Times have changed. Not only are there two Spocks in the same movie at the same time, there is an emerging class of professional individuals known as "communicators" who are cropping up at major science laboratories all around the world.

The International Linear Collider has communicators (one from each region); laboratories and universities have dedicated science communications teams; and the world-wide InterAction Collaboration was formed to bring the communications leaders of the world's leading subatomic physics laboratories together twice a year. But, just what is science communications and what is its role in the world of research?

TRIUMF is a member of the global science communications network InterActions. The collaboration met in Vancouver in October 2008

By definition, science communications means communication activities that share information about science and technology. Scientists talk to one another about their research through journal papers, professional conferences, and yes, even by e-mail. This level of "communicating about science" is typically not included in science communications work although such "communication with the broader research community" is often quite crucial for the success of research. And, of course, by science, we usually mean "science, technology, engineering, and medicine" (STEM).

Science communications also usually refers to the activities of individuals who work with intention, professionalism, and partnership to pass on science achievements to non-scientists. For example, clipping a newspaper article about breakthroughs in medical imaging technology and sending it to my grandmother is a form of communicating about science. And then there's "outreach." But let's discuss that later in this article.

The Case for Science Communications

There is widespread discussion about the case for science communications. Generally speaking, it is assumed that while science is not intrinsically "good" or "bad," the advancement of science and human knowledge is important and has value. In broad terms, the arguments of the proponents can be grouped into the following categories.

- "To know is to love." If only the public understood science, they would like it more, perhaps even love it. Often called the public understanding of science school of thought, its proponents assert that when the public knows and understands the content of scientific research, they will better appreciate it. When they appreciate it, they will choose to increase public funding for science, and when they increase public funding for science, they will steer more young people into scientific careers. In this vein, science communication seeks to expand the understanding and appreciation of science. This is also sometimes called the "popularization" of science.

- "If science is for everyone, we have to share it with them—especially when they are paying for it." If public finances are one of the largest sources of funds for science, then the outcomes of scientific research should be paid back as "dividends" to the public. And since the public is composed mostly of non-scientists, science communicators must "translate" the results of science into terms that the public can digest. This line of reasoning is also connected to the "civic obligation" set of arguments.

- "Sense of civic obligation." Just as great societies support and celebrate the work of artists, musicians, and poets for their parts in advancing the human condition, the knowledge and contexts derived from scientific research offer invaluable wisdom to the public. Science communicators are then involved in the quest to share the majesty and wonder of science with the public as part of a moral commitment to the public's well being.

- "Athenian ideals." A powerful and healthy democracy relies on the education and thoughtfulness of all its citizens. As scientific research yields new understanding about how nature works and what is and is not possible, great societies need to stay apprised of these fruits of knowledge so as to properly serve their countries. In some cases, proponents of the "Athenian ideals" will also point to the role of science communications in helping a society develop reasonable societal and ethical frameworks for dealing with breakthroughs in science and technology (e.g., weapons of mass destruction, stem cell research, or human cloning).

- "Inspiring the next generation." As a calling, science is not for everyone, but it does offer inspiration and imagination to young people. Communicators focus on sharing the wonders and beauties revealed by science to inspire the next generation of leaders, scientists, and engineers.
- "Corporate affairs, corporate identity." This argument has more texture than most because it suggests that the performers of science have a responsibility to represent their skills and abilities to the public, just like a corporation, charity, or popular music band.
- "Looking good" or "spin doctoring." This rationale is more cynical than the others and simply asserts that, as an enterprise, science needs marketing and public relations to maintain public support (e.g., funding). The public would never understand the true practice and importance of science, so communicators are needed to "position" science and "make it look good."

Provincial MLA Murray Coell visited TRIUMF to learn more about its connections with the universities. Here, visiting the TIGRESS facility, he talks with Dr. Jean-Michel Poutissou.

As we see from the above list, a wide spectrum of arguments can be used to support the case for science communications. Like all arguments, there is a corresponding set of opposing opinions that either criticize specific elements like those posed above or that question the coherence and existence of science communications as an intentional, professional activity altogether. For instance, one criticism argues that science communications implies a tight ring around those who can articulate true, reliable knowledge. By defining a deficient public as recipients of knowledge, scientists get to merit their own identity as experts. Understood in this way, science communication may explicitly exist to connect scientists with the rest of society, but its very existence only acts to emphasize the distance between them: as if the scientific community only invited the public to play in order to reinforce its most powerful boundary.

As the field matures and grows stronger (there are only a handful of formal academic programs of study in science communications in North America), the scope and character of the discipline will sharpen.

Science Outreach and the General Public

Related to this existential discussion are the distinctions among science communications, education, and outreach. The distinction between science communication and science education is typically related to pedagogical activities, whose primary purpose is to achieve learning outcomes within the context of established curricula and teaching constructs established for students. Science education also includes those activities designed to improve the knowledge, skills, and abilities of teachers.

The distinction between science communications and outreach is less clear; it hinges upon a term used glibly above: the public. What is the general public? Is it a monolithic black box containing everyone who is not a scientist? In recent years, science communications practitioners and researchers have not only begun to distinguish different audiences within the public, but have also begun insisting on a two-way participatory process where scientists and communicators listen to what non-scientists have to say. This relatively new process is often called "strategic communications" in which communicators identify target audiences, key messages, and tactics to advance stated outcomes or objectives within those audiences. Loosely speaking, then, science outreach seeks (a) to popularize and communicate science to broad audiences within the general public that are already pre-disposed to like science and/or (b) to achieve general understanding, interest, and affinity for specific elements of science.

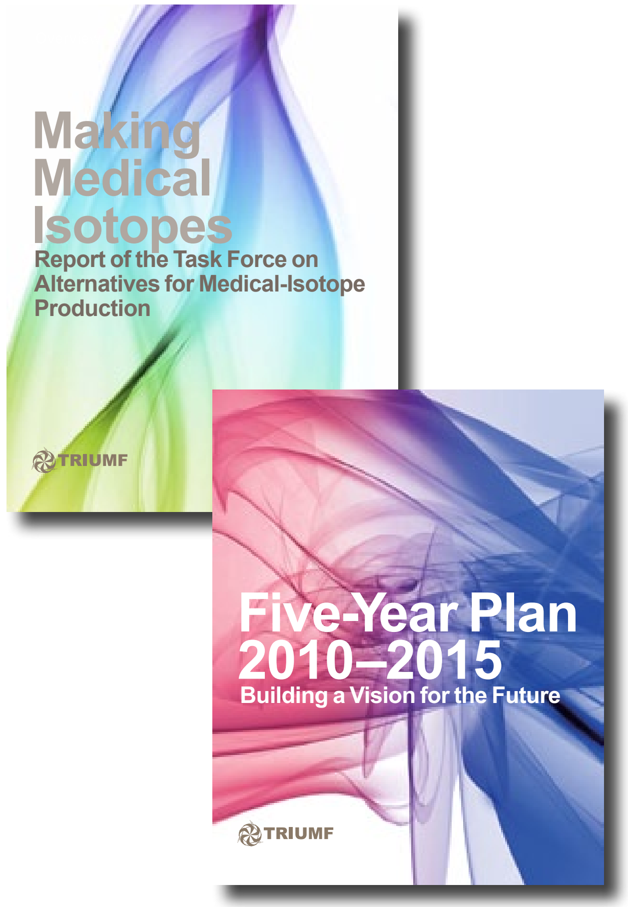
by Tim Meyer

Provincial MLA Bruce Ralson visited TRIUMF to learn more about the impact of its research. Shown here with director Nigel Lockyer, he toured the ATLAS Tier-1 data centre and spoke with Dr. Reda Tafirout.

TRIUMF's Approach

As a national laboratory with a specific publicly funded mission statement, TRIUMF has adopted an innovative approach to science communications that balances these issues in a strategic manner. Taking guidance from the adage (often associated with John D. Rockefeller) that a successful institution has "1% vision and 99% alignment," TRIUMF has positioned communications as a two-way activity that does not operate in isolation from the research or management functions of the laboratory. Rather than serving as the consistent primary spokespeople for TRIUMF, the communications team seeks to empower and enable members of the TRIUMF community to tell their own stories within a consistent, overall framework. The second key element of the TRIUMF approach is grouping together laboratory strategic planning, stakeholder relations, and communications activities. Finally, the TRIUMF strategic planning and communications team includes several individuals with Ph.D. experience in the research areas of the laboratory.

Several examples highlight features of the TRIUMF approach. When preparing its five-year business plan to request public support for core operations, TRIUMF used the combination of strategic planning and communications to develop and articulate a laboratory identity as well as a layered document that targeted different audiences (ranging from international scientists to elected officials to local business people) with different messages which, at the same time, were coherent, consistent, and connected. Here's an example.



TRIUMF's Strategic Planning and Communications office played a key role in formulating several reports.

In autumn 2008, TRIUMF convened an expert task force to analyze alternative technologies for producing medical isotopes in the face of an international supply crisis. The impact of the task force and its report was expanded and expedited by the participation and guidance of a science communicator who was familiar with the science as well as the larger public policy landscape. Similarly, TRIUMF planned and executed a

A BC student showing her science fair poster as part of the July International Nuclear Physics Conference in Vancouver.

by Tim Meyer

TRIUMF's profile in the media has steadily increased over the past 3 years, nearly doubling media mentions per year.

Community Open House on the occasion of its 40th anniversary, an event that achieved multiple outcomes in terms of increasing internal staff morale and identity, creating relations with the local neighbourhood, and raising awareness about the exciting research being conducted at TRIUMF. Building on the success of that event, TRIUMF will be prefacing an upcoming international conference in Vancouver with a special public outreach day that includes a public lecture and a joint reception for visiting world experts and for winners of regional high-school science fairs.

A Measure of Success

With respect to success, perhaps the greatest challenge in science communications is the search for definitive metrics of success and impact. In the media relations subfield, for instance, practitioners typically quote "number of readers/viewers" or "advertisement buy value" as measures of how successful a piece of coverage was. But in the real world, we find it hard to discern whether catching the attention of a body of readers or viewers actually changed anything. We are left with questions like, "Do they think differently, do they know more, and have they changed their views?" Within stakeholder relations, the most popular statistic for measuring positive impact is simply, "(1) What impressions do people have about TRIUMF after a visit or conversation? (2) Are our stakeholders investing in our future vision? (3) What do our partners and peers think of the lab?"

This lack of a definitive metric for success does, to some extent, hold back science communications. It is hard to make the case for an activity whose outcomes are diffuse and unquantifiable. And without the guidance of clear and concrete predictions of impact, it can be difficult to make the correct strategic choices about which activities to pursue next. Despite this difficulty, science communications is here to stay. Sharing scientific knowledge and success is a good and virtuous endeavour, and research institutions around the world see this sharing as a serious and necessary part of their public missions.

by Steve McDonald

In the Beginning, There Was Pong!

My computing career started with Pong! Do you remember Pong?

It was the computer game of the 1970s. Most people probably remember Pac-Man and would claim it to be the first milestone in computer gaming. But think about it? It was in colour, and the little yellow guy moved in two dimensions. Pong was the real beginning for computer games. For those of you not familiar with it, let me describe the game.

Wall-E playing the game Pong in the Disney movie Wall-E. Released in 1972, Pong was one of the earliest arcade video games. It simulates a game of table tennis using simple 2-dimensional graphics. It was my first introduction to computing.

Pong is a two-dimensional game that simulates table tennis or ping-pong. Each player controlled a dial which moved an in-game paddle by moving it vertically across the left or right side of the screen. The goal of the game was to use the paddles to ping-pong a small white dot back and forth across the screen. The only game options were the speed of the ball and the size of the paddles. Did I mention it was black and white?

If you have young children and have seen the Pixar movie *Wall-E*, you may have caught a glimpse of the game Pong in the background of one of the scenes. I have seen this movie more than a dozen times over the years—I have three children—and one night while we were watching the movie, I said, "See that game in the background that Wall-E is playing? That's the first computer game I ever played. I was thirteen."

Well, my children, ages 4, 5, and 9, looked at me in disbelief. All three were watching the movie, eating dinner, doing homework, and playing their Ninendo DS's, which probably had more raw computing power than TRIUMF's first large computer, a $150,000 VAX 11/780. They were doing all of these things simultaneously, multi-tasking the way children today do. Ever since that day, whenever we watch this movie and that Pong scene comes on, my youngest calls out: "Dad there's that game you used to play!"And then he bursts into laughter.

One Step Behind

Apart from the opportunity to share a childhood memory, what was the point of this lengthy introduction? There are two of them. The first point is the most obvious: computing has changed a lot in 30 years. The second, and I think more important point, is that our expectations have changed along with computing. I didn't use a computer until I was 15 and didn't own my first computer until I was at university. In contrast, my children have all been interacting with computers and handheld computing devices since learning to speak. Computing has become so pervasive in our lives that our expectations have changed considerably. Even the youngest of us seem to be able to recognize archaic technology and find disbelief and sometimes humour in that. But the fact is, in the computing age we will always be behind.

Organizations with sophisticated and diverse Information Technology (IT) requirements often find their IT departments are reactive and seem to be one, sometimes two steps behind. TRIUMF, with its very sophisticated and diverse requirements and its limited financial and human resources, is a model that we can examine to determine why this situation is so pervasive, not just in academic environments and laboratories, but in businesses, large and small, around the world. To understand how organizations with sophisticated IT requirements, or even not so sophisticated IT requirements, got to this situation, we have to go back for some historical perspective because how things operate today is strongly coupled to the past. Let's take a look at TRIUMF's computing history.

Back in 1978, in the days of the old VAX 11/780 mentioned above, physicists and engineers did the computing at TRIUMF. This small, highly technical group was, in turn, supported by a small group of software developers. More often than not these software programmers were also physicists and engineers, and over the years they remained in the software and computing field and provided full-time support for the scientific applications that were being used at the time. These physicists and engineers eventually became TRIUMF's Computing Services Group.

Of course, back then all computing was centralized. After all, there was only one on-site computer. Only one or two people with specialized system administration skills were necessary to administer the system and the focus of the group was on scientific application support for TRIUMF staff. This focus would remain throughout the 1970s and 1980s. Eventually, additional computing groups were created to support specialized areas of computing. The Data Acquisitions Group (DAQ) was created to support the online real-time computing requirements of the experiments, and the Administrative Computing Group was created to support the financial and business requirements of running the laboratory. Computing support at TRIUMF consisted of three groups: scientific computing, real-time computing for the experiments, and administrative computing. In total, a dozen people worked in these groups.

Then came the 1990s. TRIUMF still maintained a highly centralized computing environment on several Digital Equipment Corporation (DEC)-clustered VAX systems, but physicists and their experimenters were becoming

The TRIUMF central computing centre in 2001. A small room approximately 200 sq ft consisting of a dozen or so desktop servers on storage shelves.

more demanding on computing resources. The cost of computing was also reducing at a considerable rate and it became affordable for experimental groups to purchase their own computing resources. And they did, beginning the first steps of decentralized computing.

Then, in August 1993, the world reached a pivotal moment in informational technology. The Internet became publicly accessible to everyone through Mosaic (later to become Netscape Navigator), one of the first Internet web browsers. Personal PCs started popping up everywhere and TRIUMF created the Desktop PC Support Group to accommodate the growth in these desktop systems. The result: people's expectations of computing started changing at a rapid pace.

I wasn't at TRIUMF in the late 1980s and early 1990s, as one of those troublesome experimenters forcing the decentralization of computing, but I was here during the proliferation of personal desktop systems. Looking back, I wonder how Computing Services was able to cope with such an enormous shift. My conclusion is that TRIUMF was able to cope for two reasons: (1) this type of computing was new, so the level of *expectation* for support was not what it is today; and; (2) the physicists running the experiments were happily managing their new, and empowering, decentralized computing systems on their own.

Two Steps Behind

Then, in 2000, everything changed. ISAC-I was complete and began carrying out a full experimental program; the LHC ATLAS program was taking off. Everyone at TRIUMF had at least one personal computing system but the excitement of managing one's own computing environment was wearing off. Computing systems were becoming more and more complex and many of the staff did not have the expertise to manage their computing environment by themselves. This need for assistance was forcing a change in the expectations of the computing support groups and the demands on the IT groups were growing. To get a real feel for the growth, consider that, in 1990 there were less than 100 networked computing devices on the TRIUMF IP network. Today, in 2010, there are 2,500 devices.

Over the last three decades the Computing Services Group developed a supportive culture; it helped anyone who came asking. If they didn't know the answer, and even if it was outside their general expertise, the Group would go the extra mile to find a solution. The TRIUMF community has grown to expect and appreciate this level of support but times are changing. Like other organizations and businesses world-wide, TRIUMF has limited resources and some of those resources must be focused on being proactive rather than reactive, dedicating some of its skills, time and expertise to long-term planning and assessment and implementation of innovative opportunities, while maintaining the core infrastructure so necessary to the laboratory's operations.

So how do we make this change? The majority of the literature tells us that IT must be aligned with a company's or institution's business. Looking at TRIUMF with this paradigm, i.e., to be aligned with the business of the organization, IT must be aligned with TRIUMF's scientific objectives. It must implement best practices in project management, risk management, quality management, performance management, and client or customer support engagement, all of which are well-known and well-accepted business practices and priorities. Once fragmented across divisions, TRIUMF IT is now consolidated into a single group and is represented at senior management. It is more tightly integrated and coordinated then it has ever been, but although we are making progress, we have a long way to go. We have recognized that we cannot continue to operate the way we have done in the past. This is not to say that what was done in the past was wrong. What was done then was right for the times. But the times have changed and we have to do what is right for the times now. So, there will be changes, and for some the changes will be difficult. Expectations that have been cultured over 30+ years of computing at TRIUMF will be challenged.

The TRIUMF central computing centre in 2010.

The Laws of Change

I was originally a physicist before I moved over to IT and I still often think and understand things in terms of physics analogies. One analogy that I came across recently I particularly liked since it is so relevant to this notion of change and expectations. The analogy is credited to Peter De Jager from his book *A Pocket Full of Change*. Peter is a well-known Canadian IT consultant, writer, and speaker on IT change management. He was best known for his efforts to create worldwide awareness of the year 2000 transition (Y2K) issue. According to Peter "Change is when something moves from one situation to another." Yet, he also ponders why this simple act is often so difficult. Peter's explanation is based on three laws, which closely parallel "The Three Laws of Motion" by Sir Isaac Newton.

There is another quote from Peter de Jager that goes "*People do not resist change; people resist being changed.*" The key then to affecting change is convincing people that change is necessary. Linking the change to TRIUMF's goals and plans and communicating clearly the reasons for change will increase the chances of success. Allowing TRIUMF staff to take ownership and participate in the change process will be key requirements for an effective, empowering, and strategic TRIUMF IT program.

The majority of IT projects change the behaviour of people. By definition, that means IT is about transformation and change. There will always be unpredictability. People will always find different ways to use the technology, often in ways not originally intended. With all these changes come changes in expectations. This is neither good nor bad; it just is. In large organizations, with rigid and controlled business processes, the transformation might be likened to a super-tanker trying to turn in a narrow harbour, controlled but slow. TRIUMF on the other hand, with so many creative and imaginative employees, faces a different challenge. Transformation is more like directing and co-coordinating the movements of 500 rowboats on a pond. These 500 rowboats are what make TRIUMF so successful.

	De Jager's Three laws of Change	Newton's Three Laws of Motion
Law 1	People will stay where they are, unless they have a reason to change.	An object at rest tends to stay at rest, and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
Law 2	The more people have invested in the past, the more difficult it is for them to change.	The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.
Law 3	When you try to change people, they'll resist.	For every action, there is an equal and opposite reaction.

A New Generation for Science

by Shirley Reeve

A New Generation For Science

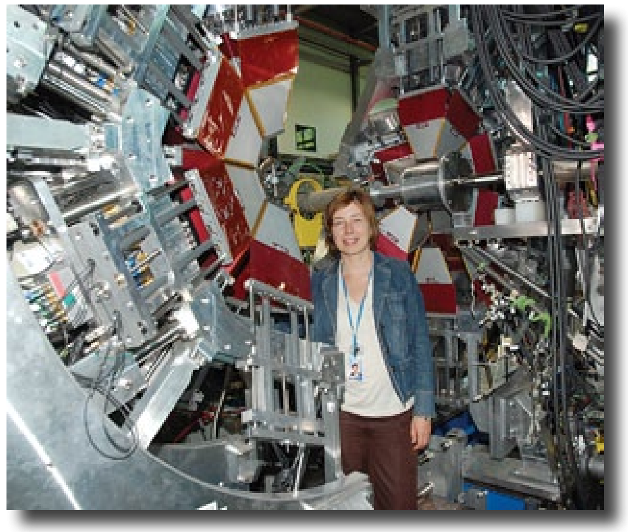
by Shirley Reeve

TRIUMF celebrated its 40th anniversary in 2009. Since its founding, TRIUMF has grown from a small regional laboratory to Canada's national laboratory for particle and nuclear physics and a major force in the international scientific community. The scientists who conceived and built TRIUMF are now retiring and a new generation of scientists is taking their place. Along with the next generation of engineers and highly specialized technical staff, these scientists will continue to build TRIUMF's reputation for excellence.

We'd like to take this opportunity to introduce you to some of the young scientists who have recently joined TRIUMF or one of our university partners. Each of these scientists will contribute to TRIUMF and to Canada through a passion for physics research and a dedication to training and educating the next generation of scientists. Although they work in different fields, these scientists have one thing in common: every one of them wanted to be a physicist at a young age.

Corina Andreoiu

Corina had decided on a career in physics by the 10th grade. Her parents and elementary school teachers encouraged her to enroll in a high-school program that focused on science. It didn't take Corina long



Corina Andreoiu, Nuclear Physicist, Simon Fraser University

to realize that physics would be her passion. After graduating with a nuclear physics degree from the University of Bucharest, Corina worked as an engineer with a company that manufactured diodes for the automobile industry. She quickly realized this career path would not be enough to satisfy her curiosity about the fundamental forces that created the universe and our world. After completing her Ph.D. at Lund University in Sweden, she received a fellowship that allowed her to work with Carl Svensson at the University of Guelph. That put her in close proximity to TRIUMF and to Argonne National Laboratory, two laboratories which would offer her the opportunity to develop a research program using stable and rare isotope beams. The program at TRIUMF eventually became her focus and, in 2005, Corina was appointed Assistant Professor of Chemistry at Simon Fraser University, one of TRIUMF's partner universities.

She looks forward to the nuclear physics research opportunities at TRIUMF both for herself and for her students. She believes that the next ten years, which will see new, rare isotope beams created and new facilities such as EMMA and ARIEL come on line to exploit the new beams, will be exciting times to be a physicist. She believes that the synergy between nuclear physics and nuclear medicine and nuclear physics and nuclear power will provide opportunities to impact our society in ways we are only beginning to understand. It is in these areas where Corina intends to expand her research.

Sonia Bacca

Sonia Bacca cannot remember when she didn't dream of being a scientist. During her last year of high school, she decided that, if it had to be science, then it had better be physics, or what she calls the

Sonia Bacca, Nuclear Physics Theorist, TRIUMF

"Mother of All Sciences." Sonia began her studies at the University of Trento, in her homeland of Italy. From there she moved to Germany and obtained her Ph.D. at Johannes of Gutenberg University of Mainz. A nuclear theorist, Sonia believes that understanding light nuclei will answer some fundamental theoretical and experimental questions, such as: "What is the nature of nuclear forces?"; "How do protons and neutrons tie together to form stable and unsable nuclei?"; and "What are the limits of existence of nuclei?" These questions, and many others, connect Sonia's area of expertise in nuclear theory to astrophysics and experimental nuclear physics in the search for the answer to the one big question "How did we, our world, and our universe come to be?"

Now a TRIUMF research scientist, Sonia's goal for the near future is advancing the predictive power of *ab-initio* (from first principles) calculations from the very light nuclei to the heavier nuclei. Sonia believes the emphasis in the study of both the structure and reaction properties, will be most valuable if focused on the neutron-rich nuclei, like those produced at TRIUMF. She also believes that TRIUMF's Theory Group is the most stimulating environment for her studies on light nuclei.

Cornelia (Conny) Hoehr

Conny Hoehr obtained her physics degrees in Germany: a M.Sc. degree at Albert Ludwigs University of Freiburg, and a Ph.D. at Max-Planck Institute for Nuclear Physics and Ruprecht Karl University of Heidelberg. Growing up, Conny planned to be an archeologist, but during her last year in high school she was inspired by a

Conny Hoehr , Nuclear Physicist, Accelerator Operations, TRIUMF

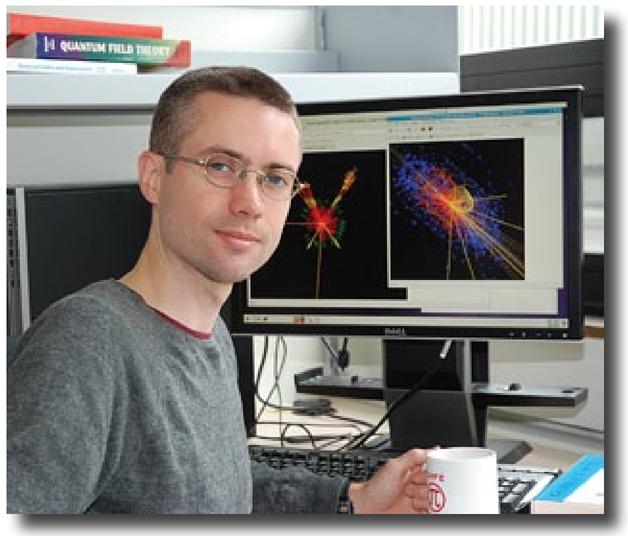
physics teacher who thought Conny would make an excellent physicist.

Inspiring teachers have been a theme in the development of Conny's intellectual appetite for physics. In her third year of university, a professor told her that a formula can be written for a collision of two particles, but not for collisions with more than two particles. Conny knew that real-life particle collisions always have more than two particles, and she became intrigued by the uncertainty of what happens during those collisions. In her fourth year of study, another professor introduced her to proton and heavy ion bombardment in the treatment of cancer. Conny was hooked! After graduation Conny did her postdoctoral studies at Argonne National Laboratory, but was attracted to TRIUMF because of its status as a world-class designer, builder, and operator of different types of accelerators.

As a physicist with an interest in accelerator physics Conny's goals fit with TRIUMF's investigations into better, faster, and more economical ways of producing medical isotopes. Currently, Conny works on producing medical isotopes for cancer diagnostics for the BC Cancer Agency and for research in Parkinson's and Alzheimer's diseases at the University of British Columbia. Conny has plans to begin researching ways to expand TRIUMF's unique Proton Therapy Program for other cancer treatments besides those currently being done for ocular melanoma. Conny hopes that her research will allow her and TRIUMF to "give back" to Canada in a very direct way.

David Morrissey

As a young boy, David Morrissey always wanted to understand how things worked, so it is understandable that he chose science as a career. His love for the beauty of a simple mathematical formula to describe



David Morrissey, Particle Physics Theorist, TRIUMF

a complicated physics system took him to McGill, where he obtained his B.Sc. and then to the University of Chicago for his Ph.D. Post-doctoral positions at the University of Michigan and Harvard University rounded out the education that would ultimately lead him to the TRIUMF Theory Group.

Today, David concentrates his research on elementary particle physics in order to discover and understand the underlying particles and forces that make up everything in our world and universe. He is particularly by Shirley Reeve

interested in electroweak symmetry breaking, a process which plays a central role in the theory of elementary particles, the Standard Model (SM).

Theoretical analyses and models suggest many more fundamental particles and forces exist than those described by the SM, and David is actively looking for those missing particles and forces by using data from the Large Hadron Collider (LHC) in CERN. David's theoretical investigations assist members of the ATLAS Collaboration to look more efficiently and effectively at the data streaming into TRIUMF's Tier-1 Centre hoping to find signs of the new physics that will challenge the SM.

David also believes that an important part of his work is in training undergraduate, graduate, and post-graduate students to pass on the skills and education needed to move his area of research forward through the 21st century.

Bernd Stelzer

From an early age, space exploration fascinated Bernd Stelzer. Along with his twin brother Oliver, Bernd followed the space shuttle missions, particularly those which carried German astronauts. Like his brother, he planned to have a career in space as either an astronaut or an astrophysicist. When Bernd and Oliver investigated the academic credentials they would need to become astronauts, they discovered that most German astronauts had degrees in physics. Astronaut or astrophysicist, Bernd would need a degree in physics.

Bernd obtained his M.Sc. at the University of Heidelberg with one year at the University of Cape Town, South Africa, and then began work on his Ph.D. at the University of Toronto. Bernd accepted a Humboldt Fellowship to work at the University of California, Los Angeles (UCLA) before going to work at Fermilab. The offer of a faculty position at Simon Fraser University provided Bernd and his wife the opportunity to move to Vancouver, his wife's hometown, and the chance to work on the ATLAS experiment.

Bernd's area of research is top quark physics and the search for the Higgs boson. Newton was able to describe the properties of particles with mass but could not discover the origin of mass, or why the different building blocks of nature, the fundamental particles, have very different masses. The top quark is particularly interesting to Bernd because it has enormous mass and couples most strongly to whatever mechanism is governing the generation of mass, currently believed to be the Higgs boson, the particle that ATLAS is determined to find at the LHC.

Bernd believes the research he and his colleagues, including his twin brother Oliver, are carrying out at ATLAS will solve some of the universe's big mysteries like the origin of mass, the nature of dark matter, and the possibility of extra dimensions and will solve them within the next decade.

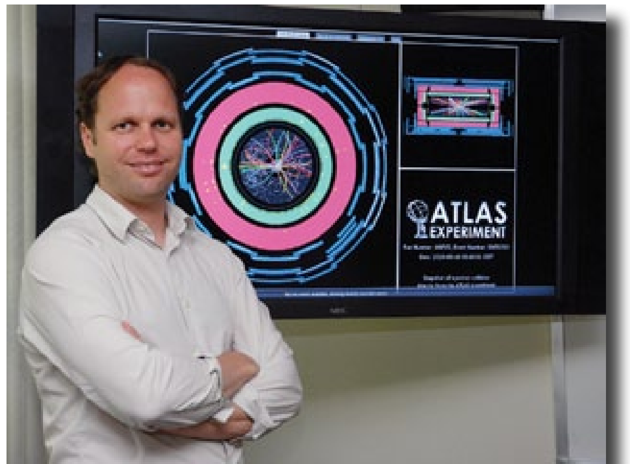
Oliver Stelzer-Chilton

Like his twin brother Bernd and many other boys of the late 20th century, Oliver Stelzer-Chilton wanted to be an astronaut. When Oliver looked up the CVs of the astronauts of his homeland of Germany, he discovered that most of them were physicists. So, Oliver decided he would be a physicist too.

While obtaining his M.Sc. at the University of Heidelberg, he studied for a year at the University of Cape Town, South Africa. After completing his M.Sc. at Heidelberg, Oliver followed his girlfriend (now his wife) to Canada and began work on his Ph.D. at the University of Toronto. After graduation, he won a Marie Curie Fellowship from the European Union and went to work for Oxford University at Fermilab.

TRIUMF seems to be the natural career choice for Oliver. TRIUMF and Canada's investment in, and long-term commitment to, the construction and the research being done at ATLAS and at the LHC provide Oliver with unique opportunities to pursue his goal of probing the fundamental laws of nature. With TRIUMF hosting one of the world's ten Tier-1 Centres, Oliver has immediate access to the research data streaming from the ATLAS experiment. He believes that these data holds the promise of groundbreaking new discoveries in physics beyond the Standard Model.

Although Oliver has abandoned his childhood dream of becoming an astronaut, he feels his present dream of finding new particles like the Higgs boson, new symmetries, or force carriers, is much more exciting, and when discovered, is certain to change the world.



Bernd Stelzer, Particle Physicist, Simon Fraser University

Oliver Stelzer-Chilton, Particle Physicist, TRIUMF

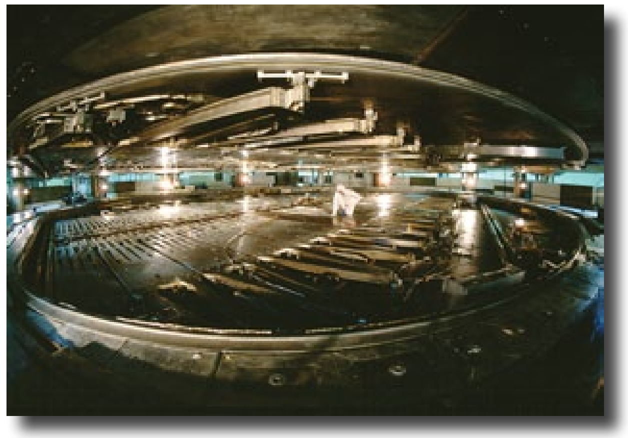
by Shirley Reeve

The 1st Decade of ISAC Rare Isotope Science at TRIUMF

by Marcello Pavan

TRIUMF marked several milestones in 2009: the 40th anniversary of its official commemoration; the 35th anniversary of main cyclotron operation; the 14th anniversary of the ISAC facility; and the 10th anniversary of accelerated rare-isotope beams.

For over 25 years, TRIUMF's on-site physics program was based on high-energy protons and pion and muon beams produced by these protons from the main cyclotron accelerator.



Interior view of the TRIUMF cyclotron accelerator, the main driver behind the lab's exotic rare isotope program.

Its transformation into a premiere rare-isotope beam facility began in Mont Gabriel, Quebec in 1984 when workshop participants saw the need for a next-generation facility at TRIUMF, one which could produce rare-isotope beams using the ISOL (isotope separation online) technique. The participants recommended building a test facility and in 1985 a second workshop in Parksville, B.C. reinforced this recommendation. The result was the "TRIUMF ISOL Facility" proposal, which was presented to the TRIUMF Board of Management in June 1985.

The TISOL (TRIUMF ISOL) test facility was built, and by 1987, it had produced a rare-isotope beam of potassium-37. Successful TISOL experiments over the next decade convinced scientists of the need for a larger rare-isotope facility, and so the ISAC (isotope separator and accelerator) project was conceived along the lines of the 1985 ISOL facility proposal. Work on ISAC began in June 1995 after the federal government approved $18.1 million CDN in funding, with the provincial government contributing an additional $9.7 million for civil construction.

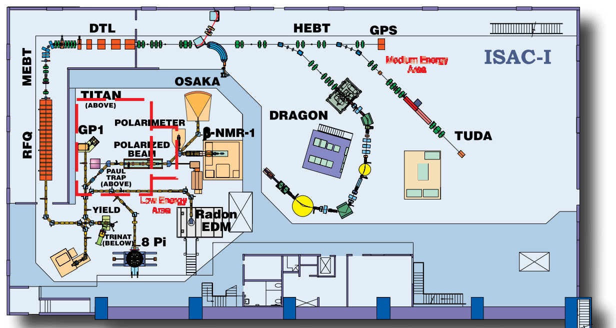
The first low-power proton beam on the ISOL production target was delivered in May 1998 and was followed by the delivery of the first rare-isotope beam (potassium-38m) on November 28th. Full-power target operation commenced in December 1999, and the first accelerated rare-isotope beam (sodium-21) was delivered to experiments in the spring of 2001.

Meanwhile, in the late 1990s, a second experimental hall and a third beam-acceleration stage was proposed. This upgrade, which would become ISAC-II, would use SRF (superconducting radio-frequency) technology to increase the final beam energy by a factor of 10 and would broaden the physics reach beyond astrophysics to studies of nuclear structure itself.

With federal and provincial funding, construction of the ISAC-II building and the first of five SRF accelerator modules began in 2001. In April 2006, a stable (i.e., "normal") beam was accelerated through both the ISAC-I and the ISAC-II linear accelerators to two-thirds of the final design energy. The ISAC-II era began when the first rare isotope beam (lithium-11) was delivered to an experiment in the ISAC-II experimental hall on January 5, 2007.

A Decade of Physics Highlights

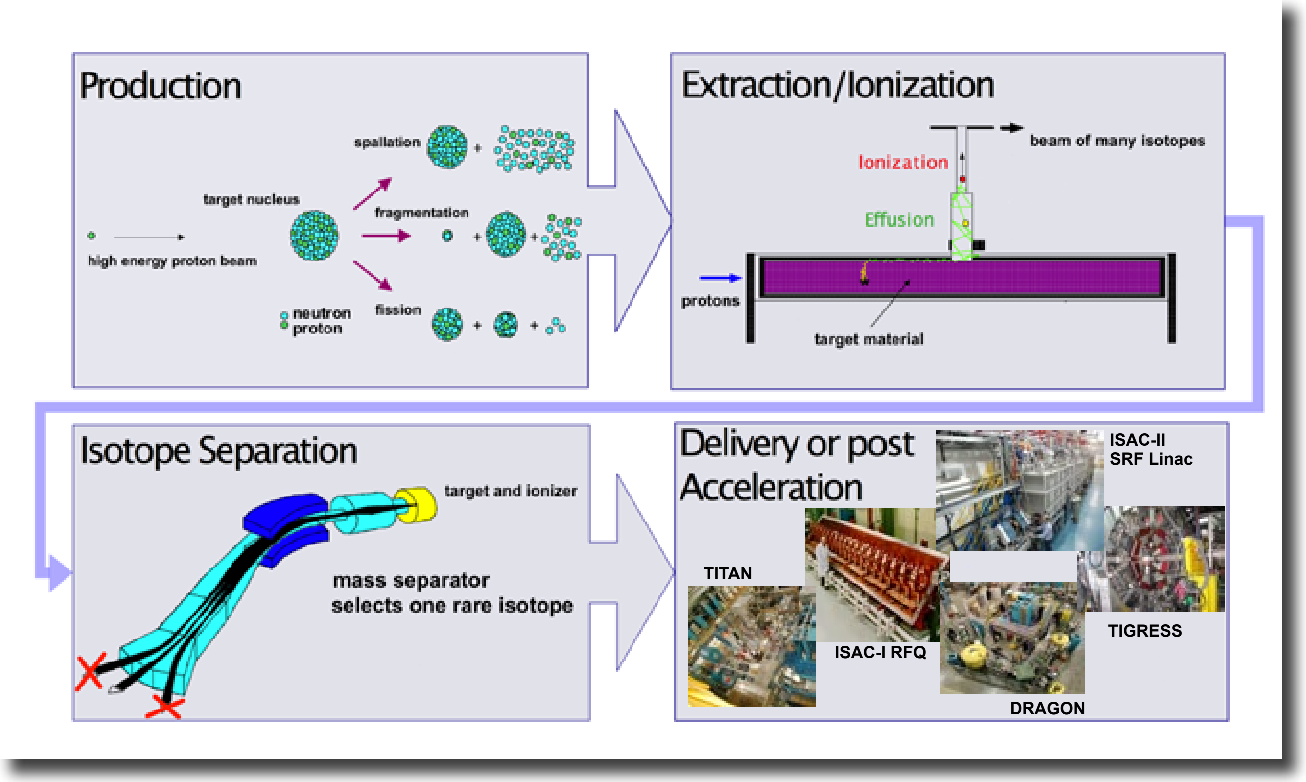
Rare-isotope beam intensities at ISAC are the highest in the world for many isotopes, without which many important experiments could not be performed. Basically, rare isotopes are created by shattering a large, stable nucleus with a high-energy beam. At ISAC, an intense beam of 500 MeV protons from the TRIUMF cyclotron is directed onto the rare-isotope production target. In the ISOL method, the beam both shatters the target nuclei and heats up the target which allows



Schematic plan view of the ISAC-I experimental area, home of the fundamental symmetries and nuclear astrophysics program.

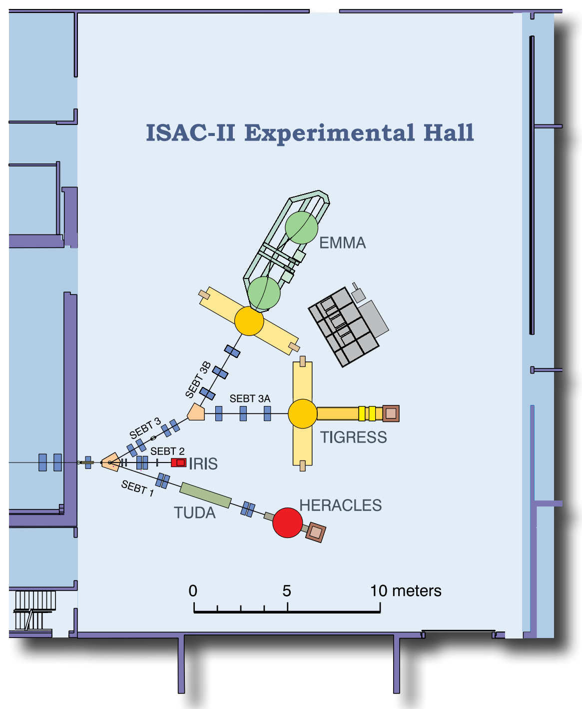
the nuclear fragments to escape the target volume through so-called thermal diffusion and effusion. The effused nuclear fragments are promptly ionized to permit manipulation by electric and magnetic fields. The ionized nuclear fragments are then filtered at the so-called front end with a combination of electric and magnetic fields (mass separation) to yield a beam of a single rare isotope.

The filtered rare-isotope beams are delivered to one of three experimental areas: the low- and medium-energy areas in ISAC-I and the high-energy area in ISAC-II. The



A schematic representation of how exotic rare isotopes are created at ISAC.

low-energy area takes unaccelerated beam directly from the front end, while the medium-energy area receives accelerated beams of variable energy from the two ISAC-I linear accelerators—the radiofrequency quadrupole (or RFQ) and the subsequent drift tube linac (DTL). After exiting the DTL, the beam can also



Schematic plan view of the high-energy ISAC-II experimental area, primary home of the nuclear structure program.

be diverted to the superconducting linear accelerators for acceleration and delivery to the ISAC-II high-energy area. In 2010, new superconducting accelerator modules will be installed to accelerate ions up to the final design energy.

The unique coupling of ISAC's superb isotope production and post-acceleration capabilities results in yields of many rare isotopes over a broad energy range. With a variety of facilities able to exploit these capabilities, many world-class experiments have been conducted over the past decade in three key areas: fundamental symmetries, nuclear astrophysics, and nuclear structure.

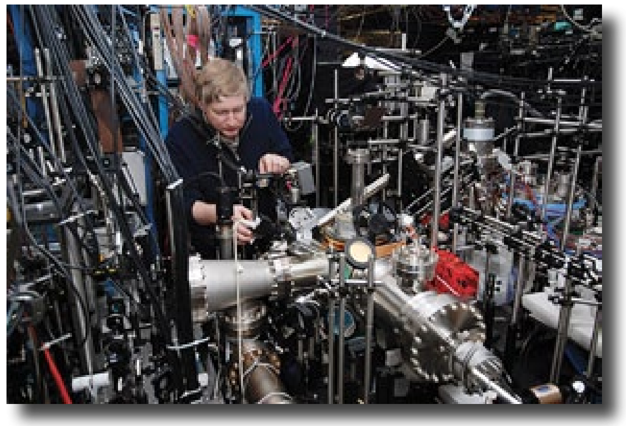
Fundamental Symmetries

Tests of fundamental symmetries involve conducting measurements to search for deviations from the Standard Model (SM) of particle physics, a model which describes the interactions of the fundamental constituents of matter (e.g., quarks). Usually the purview of high-energy physics, in which accelerators of much higher energy than the TRIUMF cyclotron are used, much can be learned about the fundamental interactions from precision studies of certain types of rare isotopes. As such, TRIUMF can make important contributions to our understanding of the fundamental basis for the existence of the universe that are complimentary to those from the giant particle physics facilities around the world.

by Marcello Pavan

by Marcello Pavan

For example, the TRINAT (TRIUMF Neutral Atom Trap) facility uses a combination of lasers and magnetic fields ("double magneto-optical trap") to trap rare isotopes "in mid-air" within a vacuum chamber. TRINAT is able to provide a complete description of the angles and energies of rare-isotope decay, giving us the ability to search for new exotic particles or interactions outside the SM. A measurement of the nuclear beta-decay of the rare isotope potassium-38m was a milestone result for TRINAT and set the best limit on



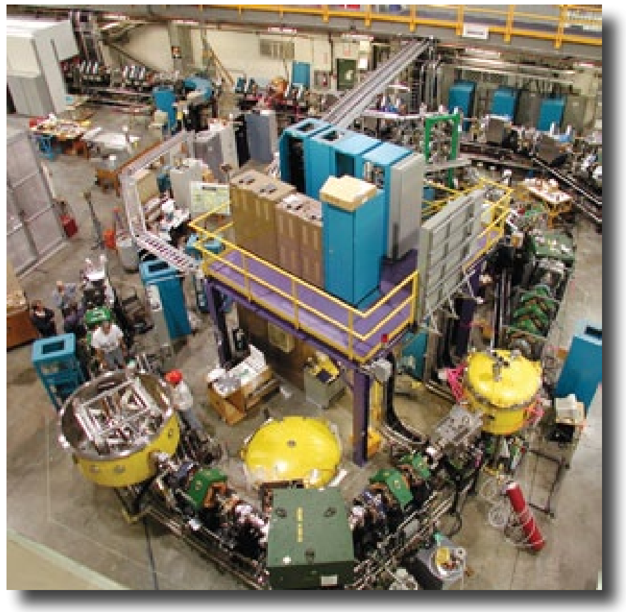
TRIUMF scientist Dr. John Behr working on the TRIUMF Neutral Atom Trap (TRINAT), a cornerstone of the fundamental symmetries program. TRINAT is able to trap exotic rare isotopes in mid-air for precision decay studies.

the existence of a particular exotic interaction. More recently, TRINAT measurements of the rubidium-80 decay constrained another non-standard interaction. Other measurements have searched directly for exotic particles. Future upgrades will allow us to continue to search for physics beyond the Standard Model and explain the matter around us.

Nuclear Astrophysics

Nuclear astrophysics studies the nuclear processes that take place within stellar objects (e.g., stars and supernovae) or took place during the Big Bang, processes that created the elements that make up our universe.

ISAC's DRAGON (Detector of Recoils and Gammas Of Nuclear Reactions) facility directly measures key reactions between rare isotopes and either hydrogen or helium (which together make up 98% of the universe) within exploding stellar objects like supernovae. Combined with the unique low-velocity RFQ accelerator, DRAGON probes interaction energies mimicking those stellar phenomena. DRAGON's critical nuclear astrophysics experiments have shed light on the production of rare isotopes such as titanium-44 in supernovae explosions and aluminum-26g and sodium-22 in stellar novae. DRAGON's first



Overhead view of the DRAGON facility, at the heart of TRIUMF's nuclear astrophysics program. DRAGON can recreate reactions occuring inside stars and supernovae.

measurement of the production of magnesium-22 from sodium-21 and hydrogen is a milestone experiment in nuclear astrophysics. The nearby TUDA (TRIUMF-UK Detector Array) experiment looks at different aspects of the similar reactions, adding important information to our understanding of nuclear synthesis within explosive stellar environments.

Nuclear Structure
ISAC

Nuclear structure experiments study various properties of atomic nuclei, including their mass and the mechanisms that bind neutrons and protons together. The study of nuclear structure is presently enjoying a renaissance, where the holy grail of a complete description of atomic nuclei from "first principles" seems tantalizing within reach. The rare isotopes produced by ISAC offer a stringent testing ground for

View looking west of the ISAC-I area.

modern nuclear structure theories. In particular, ISAC's very high beam intensities have made it the best place to study so-called "halo nuclei," which are very exotic nuclei with a compact core and one or more neutrons orbiting far away.

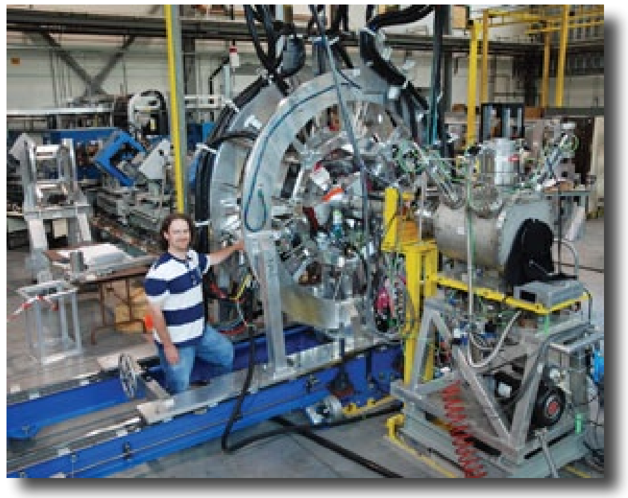
A collaboration led by a group from Darmstadt, Germany carried out a precision measurement of the charge radius of the lithium-11 halo nucleus. Recently TITAN (TRIUMF's Ion Trap for Atomic and Nuclear Science) carried out a precision measurement of the lithium-11 mass, despite the fact that the nucleus survives for only 8.6 milliseconds on average before decaying. This measurement provided the most precise determination of the energy required to remove the two far-away neutrons from the nucleus, a key property of halo nuclei. The mere existence of halo nuclei pose a major challenge to modern theories of nuclear structure, and TRIUMF's work on these ultra-exotic nuclei is giving theorists the data they need to confront this challenge. (See It's All About Shape and Size on Page 20 of this report.)

ISAC-II

The high-energy beams of rare isotopes at ISAC-II allow scientists to probe the structure of a wide variety of nuclei using the so-called "Coulomb excitation" technique. This technique probes the shape and volume of collective modes of motion in the nucleus, as well as the role of single particles, with the aim to develop better models of nuclear structure and the nuclear force. ISAC-II's program uses TIGRESS (TRIUMF-ISAC Gamma-Ray Escape Suppressed Spectrometer) as the main tool for a comprehensive Coulomb excitation program. TIGRESS consists of an array of up to 16 High-Purity Germanium HPGe clover detectors. Each clover detector has 4 HPGe crystals to detect the gamma rays emitted from the nuclear reactions.

The first TIGRESS experiment probed the evolution of the structure of exotic sodium isotopes containing many more neutrons than normal. A measurement

Overhead view of the ISAC-II area.



Front view of the TIGRESS facility in the ISAC-II area. TIGRESS is at the core of the lab's nuclear structure program.

using sodium-29 yielded the first result for an important reaction parameter, which turned out to be in good agreement with a leading theoretical calculation.

TIGRESS is only at the beginning of its nuclear structure studies at ISAC-II. Its full compliment of detectors is expected in 2010, and new particle detection systems for use in conjunction with TIGRESS are under development. TIGRESS will provide a treasure trove of valuable information for scientists eager to disentangle the mystery of isotopes, from those used in medicine to those created inside exploding stars.

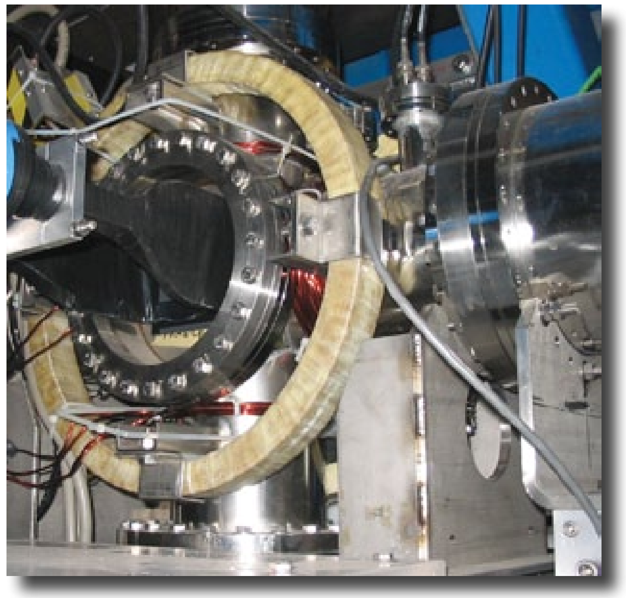
Summary

In the decades to come, TRIUMF's ISAC facilities await a cornucopia of physics riches. The newly upgraded ISAC-II accelerator soon will be delivering higher beam energies to new facilities, bringing a whole new dimension to nuclear structure studies at ISAC. Fundamental symmetry studies will enter a new phase with many new low-energy beam experiments. Two experiments will seek new sources of time-reversal symmetry violation which is key to the excess of matter over antimatter seen in the universe. Finally, the development of new rare-isotope beams means that ISAC will continue to be a world leader in nuclear structure and astrophysics studies for years to come.

It's All About Shape and Size

by Matthew Pearson

There are very few physical properties more fundamental than shape and size. This is as relevant to atomic nuclei as it is to the everyday objects and people that we see. One of the challenges of nuclear physics is to be able to correctly predict these properties for all possible nuclei. In order to have confidence in theoretical models of these properties, they must be compared to experimental results, not only using the 300 or so nuclei that are found in nature but in as many different types as possible. At the ISAC facility at TRIUMF, we can produce exotic, very short-lived nuclei that are at the extremes of matter that can be created. By combining state-of-the-art measuring techniques with these intense beams of exotic nuclei, not only can theoretical models be tested but new insight into how nuclear matter is arranged can be gleaned.



Photograph of the β Nuclear Quadrapole Resonance (βNQR) apparatus.

So how do you look at the shape and size of a nucleus? This is an interesting question. Due to their incredibly small size you cannot simply use a large magnifying glass or microscope - the light that they use is far too crude a measure. In order to see the shapes and sizes of objects this small, we instead look at how they interact with the environment around them. For simple atoms created and observed within a vacuum, their environment is as simple as the electrons that surround them. Whereas, for any nucleus that has been deposited within a solid, the interaction with the adjacent, local atoms provides the most sensitive probes to the intruder's structure. Over the past year at TRIUMF, we have started programmes to utilise both of these phenomena to investigate two very different extremes of nuclear structure.

Ground state moments of ^{11}Li

Lithium (Li) is one of the lightest elements in the periodic table. It's nucleus is made up of three

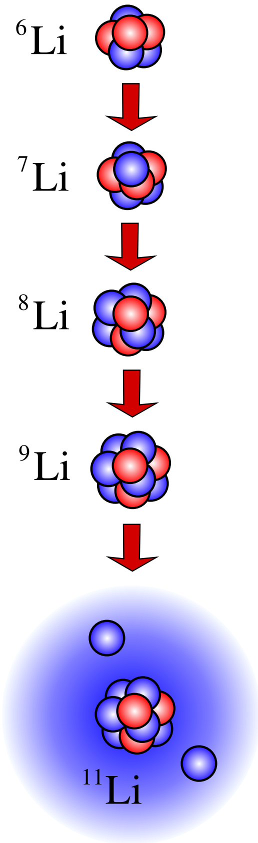


Figure 1: A sketch of the full chain of Li isotopes, including the Halo nucleus ^{11}Li.

protons, defining it as Lithium, and between three and eight neutrons depending upon the isotope. (An isotope is a species of atom that has the same number of protons, hence nearly identical chemistry, but a different number of neutrons giving it different nuclear properties.) Two of these isotopes, Lithium-6 and Lithium-7 (^{6}Li and ^{7}Li) are stable to decay, meaning that they will not spontaneously undergo any form of nuclear decay and change into another species. These two isotopes are commonly found in nature and used in everyday life, for example, in batteries. Of the other three isotopes that it is possible to create artificially, ^{11}Li is a very special case. Unlike the classical, textbook picture of a nucleus consisting of an almost spherical lump containing all of the neutrons and protons that make up that particular nucleus, it has been shown that the final two neutrons in ^{11}Li spend the vast majority of their time well outside the traditional core, that in this case, resembles ^{9}Li as shown in figure 1.

It's All About Shape and Size

by Matthew Pearson

When this was first discovered by Isao Tanihata and colleagues at Berkeley in the early 1980s, the term Halo nuclei was coined, and it was assumed that the extra neutrons had very little influence on the inner core. However, experiments carried out several years later at TRIUMF showed that this was not the case, and that in fact, the inner core of this large nucleus appears significantly larger than expected. This does not mean that it is actually a lot larger, just that it appears to be. One theory that we set out to investigate at TRIUMF is that the nucleus is a different shape, in this case slightly squashed, which when looked at with a nucleus spinning fast gives an appearance of a slightly fuzzy but larger size.

In order to measure this change precisely, several established techniques have been brought together and used in a new, innovative way to produce a novel experimental technique. For many years the material science group has been using the longest-lived, unstable lithium isotope (^{8}Li) in order to investigate novel properties of new materials. This is possible as the shape and size of ^{8}Li is well known. This new approach uses the ^{8}Li to probe a single crystal of a particular material to discover its properties. Using the information from the crystal gained with one isotope, it is then possible to use this crystal to look at the properties of other isotopes of the same element as long as they are implanted within the crystal in a similar way.

The technique used at TRIUMF relies upon the fact that the nuclei of interest naturally spin. This means that they have an axis, or direction, about which they spin. Also, when they undergo radioactive decay,

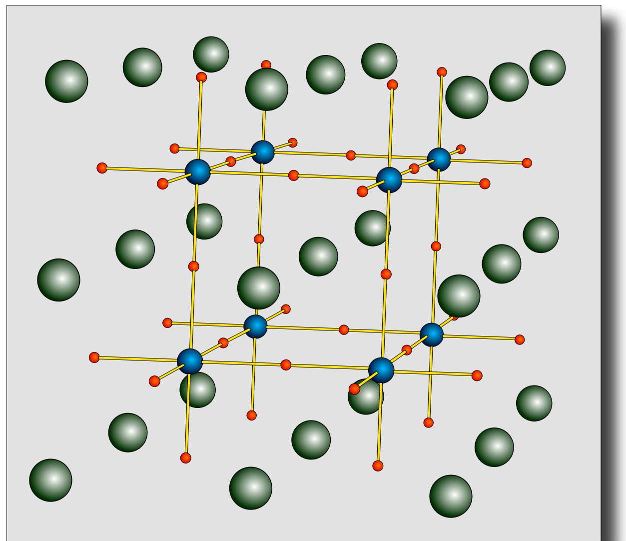


Figure 2: Cartoon of a Strontium Titanate crystal. The large white spheres represent Strontium, the blue one Titanium and the red Oxygen atoms.

nuclei emit particles in a direction that is determined by the orientation of the initial spin. Therefore, in order to observe the interaction between the isotope of choice and the host crystal, the implanted nuclei are all initially oriented using laser techniques to make them all spin in the same direction. In this case the crystal of choice was Strontium Titanate, an insulating crystal with a well known structure, shown in figure 2.

The way that the interaction with the crystal is measured is by attempting to destroy the order of the spins that have been created. This is done by exposing the system to an oscillating magnetic field. When this field matches a characteristic resonant frequency of the isotope–crystal system, the order created by the laser system is destroyed. It is the change in this frequency between the different Lithium isotopes that

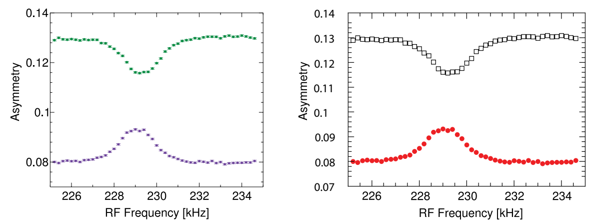


Figure 3: Experimental signatures for ^{8}Li (left side) and ^{9}Li (right side).

allows us to determine the different shapes. Typical spectra are shown in figure 3.
From this initial experiment using 2 Lithium isotopes (^{8}Li and ^{9}Li), we have been able to deduce that not only is this technique working incredibly well, allowing the most precise determination yet of the shape of ^{9}Li to be determined, but that we are ready to go ahead and will be in a position to see any form of change in the nuclear shape when we attempt to measure ^{11}Li in the upcoming year.

Charge radius of ^{74}Rb

Whereas ^{11}Li is as neutron rich as it is possible to get (it has as many neutrons per proton as is possible), Rubidium-74 (^{74}Rb) is at the far proton rich side of the nuclear landscape. Once again it lives for a very short time, 65ms (.065 second), and is hard to produce in quantities larger than a few thousand per second even at facilities such as TRIUMF. From the point of view of nuclear physics ^{74}Rb is also very interesting. It has exactly the same number of protons as neutrons (37). Also, despite being made up of an odd number of both protons and neutrons, the total spin of the nucleus is zero. This suggests that within the nucleus everything appears to pair-up and create an interesting symmetric order that crosses the bounds between the two different particles. This also means that the technique used to study the Lithium isotopes will not work here.

by Matthew Pearson

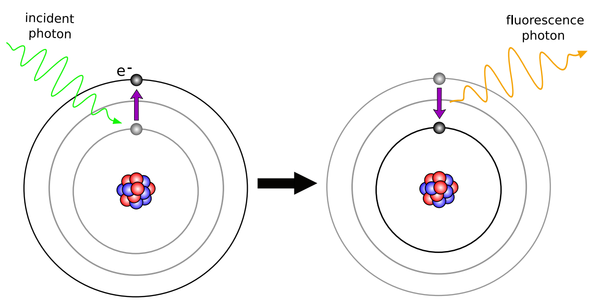
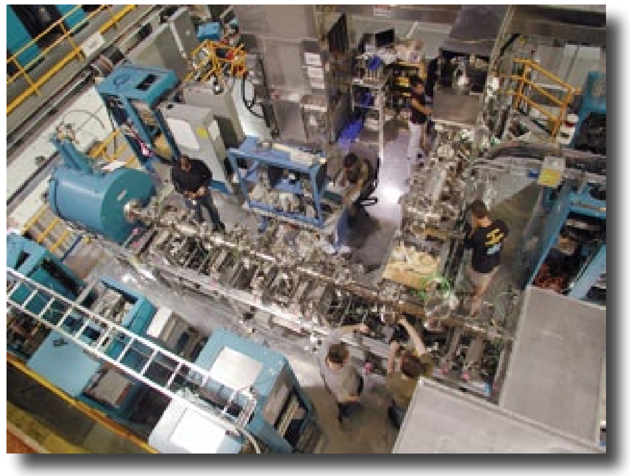


Figure 4: Electron energy levels, absorbing and emitting a photon.

One of the best probes of the size of the nucleus is to look at its effect on the electrons that orbit around it. The classical, high school picture of an isolated atom with a small nucleus and electrons spinning around it like planets around the sun is not exactly accurate. While not totally wrong, the electrons not only go around the nucleus in circles but can also go across the circle in a motion that could take them directly through the nucleus. This is not as strange as it first appears as when viewed on the scale of the electron, the nucleus is not a solid lump of stuff, more a loosely packed assortment of particles. It is not surprising then that a small change in the size of the nucleus can significantly affect the electrons that spend some of their time passing through it.

Although the paths of the electrons can be quite complicated as they both rotate around the nucleus and fly through it, the energy that they have is very well defined. Also, in order to change an electron from one form of motion to another requires that the electron be provided with exactly the right amount of energy to make the change. Too little or too much and it simply will not get there. This energy can be given to the electron using a laser and the technique is called laser spectroscopy. The advantage of a laser is that it produces small packets of energy, called photons or particles of light, that have a very well defined energy. Crudely speaking the different energies correspond to different colours of light, with blue light having more energy than red. While most lasers that you find in everyday life, such as laser pointers as well as those in CD and DVD drives, can only operate at one colour, there are some lasers where this can be changed and controlled with great precision. Once an atomic electron has absorbed the correct amount of energy in order to undergo a change in motion it will stay in this state for a short time (10^{-9}s or 0.000000001 seconds) before emitting the photon again in order to drop back to a less excited state. As with everything else in nature, it will always default back to the least energetic state possible. By observing the photons that are emitted, we can see when they have been absorbed – as it is not possible to give up energy that has not first been gained.

This might sound easy enough, but the numbers of atoms that are produced are only a few thousand per second and they only live for a few tens of milliseconds. Therefore even at the most powerful production facility in the world, we only have a few hundred of them at any one time. Each one can only emit one photon at a time, but there are literally more photons around from other sources than anyone can imagine. (This is still true even in so called dark rooms used for film processing.) Therefore, any photon detector will not be able to distinguish between those that we want to see and those that we do not unless something special is done. This is where TRIUMF once again is pioneering new techniques in order to be able to look at fewer and fewer atoms to probe more and more exotic nuclei. First, techniques that have been around for many years are used. Obviously the experiment is performed with the atoms totally enclosed within a light-tight container, without even air inside. However, as the laser beam has to be there, there are still far too many photons around for these few atoms to be seen. To get around this we collect the atoms within a dedicated buncher which is part of the TITAN experimental set-up. This effectively allows us to stockpile the Rb atoms then release them in a very quick pulse. In fact we can release the bunch of atoms so quickly that they fly past the detectors in a microsecond (0.000001 seconds). As it is therefore known where the atoms are at any time and they are all together, it is possible to count only the photons detected when the atoms are present. This makes the technique over a thousand times more sensitive than conventional methods. The difference can be seen in figure 5.



TITAN uses a bunching technique to release Rb atoms in very quick pulses.

It's All About Shape and Size

by Matthew Pearson

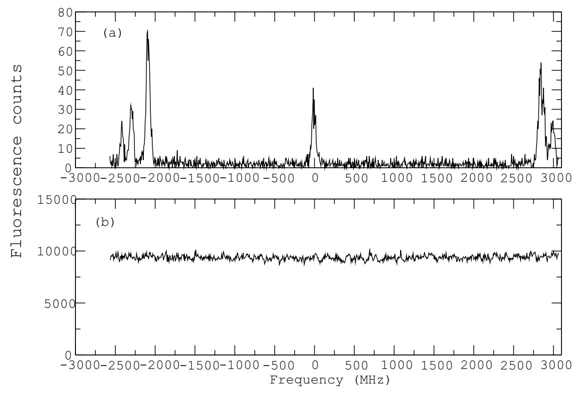
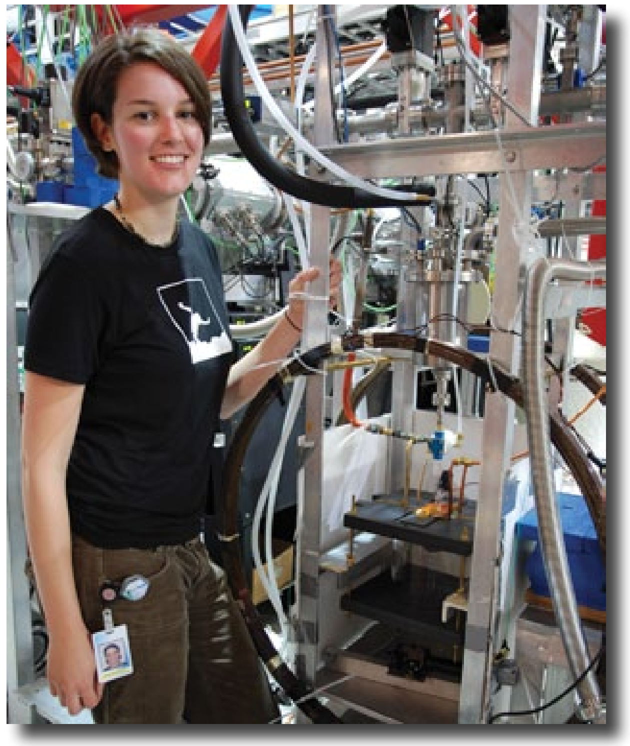


Figure 5: Photons observed both continuously (lower plot) and only when Rb atoms are expected to be there (upper plot).

Here the lower plot shows what the photon detector sees if it counts all the photons that it sees, whereas the upper plot only shows those photons seen when we expect to see them from the bunch of atoms flying past. As you can see in figure 5, one is a flat line showing no interesting structure while the other is far more interesting.

This experiment was first tried with a heavier isotope of Rubidium, ^{78}Rb, that is produced in greater quantities so that the technique can be perfected prior to attempting the more challenging ^{74}Rb. From the observed spectra you can see many peaks. This is due to two different isotopes of Rb being present at the same time. One peak comes from ^{78m}Rb and the other from ^{78}Rb. From this it can be seen that we have the sensitivity and ability to go forward and attempt to measure the more interesting Rubidium-74.



Carolyn Kierans, a Simon Fraser University undergraduate student, studies fundamental symmetries with nuclei.

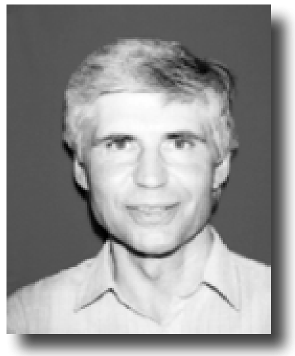
Conclusion

Over the past year a couple of programmes have started at the TRIUMF ISAC facility in order to study both the shapes and sizes of the ground state of atomic nuclei. Both encompass tried and tested methods of investigation while using innovative ways of extracting nuclear information from the affect that the nucleus has on its immediate surroundings. These experiments are performed by a fully international group of physicists from as far away as the United Kingdom and Germany, as well as all across Canada, and much closer to home here in Vancouver.

The Otto Häusser Fellowship

by Jean-Michel Poutissou

So who was this famous physicist after whom we've named TRIUMF's newest, and most prestigious fellowship to date? Otto, for those of us who had a chance to know him.

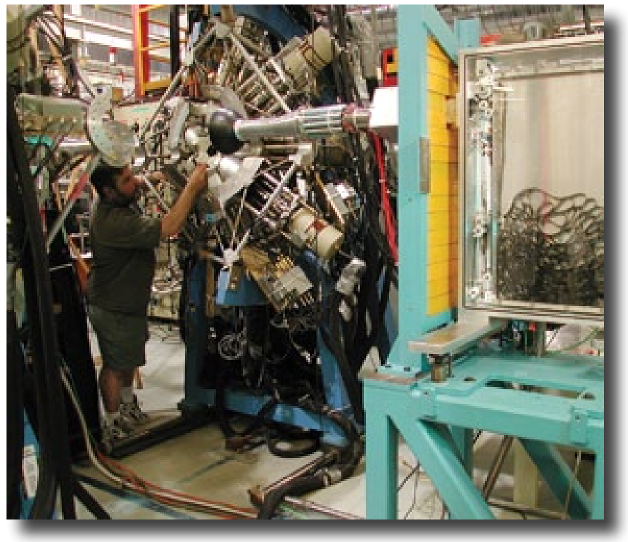


Dr. Otto Häusser

Professor Otto Friedrich Häusser was born in Germany in 1937. He graduated from the University of Erlangen and after a two-year post-doctoral stay at Oxford, he came to the Chalk River Laboratories. That was in 1966, and back then Chalk River was one of the most advanced nuclear research establishments in the world. It had one of the highest energy tandem accelerators and a superb spectroscopy team. In addition, the germanium detector, the tool of choice for best energy resolution work, was first developed there.

At Chalk River, Otto established a comprehensive program to test the limits of validity of the shell model by measuring nuclear moments and seeking evidence for mesonic effects in nuclei. Some superb publications resulted from his collaboration with D. Ward and I. Towner.

Always pushing the limits of experimentation, Otto was one of the proponents of the 8π detector proposal. Funded by NSERC and AECL in 1984, the 8π gamma-ray spectrometer to this day, remains one of the best spectroscopic instruments for nuclear physics, including those experiments in ISAC using rare isotope beams.



8π Gamma-ray Spectrometer - The name 8π was coined by Otto Häusser (1937-1998) and comes from the structure and functionality of the device.

By 1983, Otto became a TRIUMF/SFU senior joint research scientist at Simon Fraser University. He was attracted to TRIUMF and specifically to the scientific potential of the variable energy, high quality, polarized and unpolarized proton beams from the cyclotron. At TRIUMF, he quickly realized the importance of using polarization observables to disentangle the various spin and isospin components of the nucleon nucleus interaction.

When Otto found a problem worth tackling, he would plunge into the new area and seek the best possible instruments to carry on his work. In this way, he went on to develop and install a brand new polarimeter package on the Medium Resolution Spectrometer (MRS) and develop a ^{3}He polarized target that was based on the best available lasers of the time. Otto's scientific drive would also compel him to move to whatever facility was the most suitable for his research. After realizing that his ^{3}He polarized target was the best approximation to a pure polarized neutron target, Otto then conducted experiments in TRIUMF's Meson Hall before taking his target "on the road" to Los Alamos. Later, he would develop a similar target for the Hermes experiment in Hamburg.

In the late 1980s, Otto was also attracted by the charge exchange program being developed in the TRIUMF Proton Hall. He realized the potential of using (p,n) and (n,p) reactions to study spin-changing electroweak interactions, thereby determining the strength of interactions of considerable interest for nuclear synthesis. Some of his measurements are still used as a reference for electron-capture probabilities in the simulation of supernovae explosions.

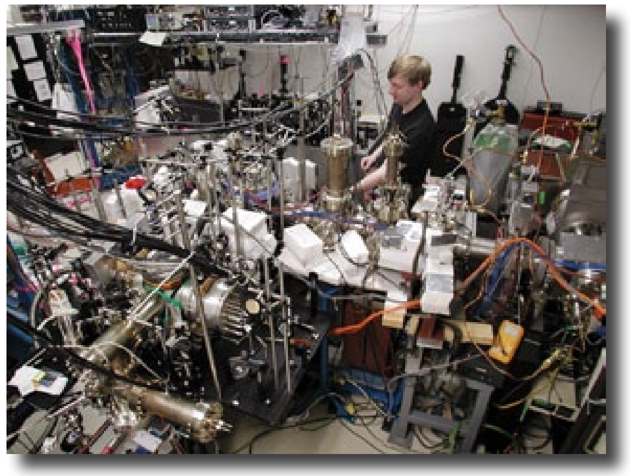
Otto's broad interests and his determination to understand all the intricacies of a field and then explain it in a clear and pedagogical way, made him the most eloquent defender of the science of KAON. That interest led him to explore more systematically how nuclear physics could contribute to the search for physics beyond the Standard Model. He was particularly attracted to the parity violation studies that Carl Wieman was conducting in cesium isotopes in Boulder and at LAMPF. Convinced that atom traps were the best instrument for these studies, he once again plunged into a new field and built the TRINAT facility in the TRIUMF Proton Hall Extension to eventually trap the best possible candidate atom, francium.

At that time TISOL was a possible source of such an actinide isotope, but soon ISAC came along, and the facility was moved to ISAC shortly before his death in 1998. With actinide targets now operational at ISAC we are on the verge of realizing his dream (Exp. 714).

Otto was very intense, very demanding of himself and his collaborators, and totally dedicated to his two passions: physics and music. (He played the cello with the same intensity and brio as he conducted his experiments.) He trained by example and pushed

The Otto Häusser Fellowship

by Jean-Michel Poutissou



An early version of the TRINAT experiment set up in the ISAC-I building.

a new generation of young scientists at TRIUMF to emulate his dedication to science.

He was an inspiration. He was a role model. He did so much in 15 years to advance the reputation of TRIUMF and of Canadian science that he was an obvious choice when we came to name a new fellowship. The first Otto Häusser fellowship has just been awarded to support an outstanding young researcher in his dream for scientific excellence and in outreach activities.

AUDITORS' REPORT

To the Joint Venturers of TRIUMF

The accompanying summarized Statement of Financial Position and Statement of Expenditures and Changes in Fund Balances are derived from the complete financial statements of TRIUMF as at March 31, 2010 and for the year then ended on which we expressed an opinion without reservation in our report dated June 18, 2010. Those financial statements were prepared to comply with section 11b of the TRIUMF joint venture agreement and the contribution agreement with the National Research Council of Canada, and are prepared using the basis of accounting referred to in note 2 of the accompanying financial statements. The fair summarization of the complete financial statements is the responsibility of management. Our responsibility, in accordance with Assurance Guideline 25 of the Canadian Institute of Chartered Accountants, is to report on the summarized financial statements.

In our opinion, the accompanying financial statements fairly summarize, in all material respects, the related complete financial statements of TRIUMF in accordance with the criteria described in the Guideline referred to above.

The summarized 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. Furthermore, the summarized financial statements do not contain all the disclosures required by Canadian generally accepted accounting principles. Readers are cautioned that these financial statements may not be appropriate for their purposes. For more information on TRIUMF's financial position, results of operations and changes in fund balances, reference should be made to the related complete financial statements.

PricewaterhouseCoopers LLP

PricewaterhouseCoopers LLP
Chartered Accountants
Vancouver, B.C.
June 20, 2010

TRIUMF

Statement of Financial Position
As at March 31, 2010

	2010 $	2009 $
Assets		
Cash and cash equivalents	6,008,792	6,517,371
Restricted cash	9,942,000	8,859,614
Due from Joint Venturers	303,969	386,104
Funding receivable	1,676,103	1,302,573
	17,930,864	17,065,662
Liabilities		
Accounts payable	1,075,720	1,664,960
Funds received in advance	3,036,971	3,180,910
Decommissioning Fund	9,942,000	8,859,614
	14,054,691	13,705,484
Fund Balances		
Restricted		
Natural Sciences and Engineering Research Council Fund	3,908,632	3,242,076
MDS NORDION Inc. Fund	100,000	100,000
Canada Foundation for Innovation	(530,740)	(203,209)
	3,477,892	3,138,867
Other		
Commercial Revenue Fund	13,450	(41,450)
General Fund	87,095	137,110
TRIUMF House Building Fund	(236,983)	(628,795)
Intramural Accounts Fund	534,719	754,446
	398,281	221,311
	3,876,173	3,360,178
Total liabilities and fund balances	17,930,864	17,065,662

TRIUMF

Statement of Expenditures and Changes in Fund Balance

For the year ended March 31, 2010

	2010 $	2009 $
Funding/income		
National Research Council Fund	44,000,000	43,500,000
Natural Sciences and Engineering Research Council Fund	6,587,586	5,970,896
MDS NORDION Inc. Fund	4,350,138	4,370,636
Advanced Applied Physics Solutions Inc. Fund	1,166,618	1,033,968
Canada Foundation for Innovation	1,946,096	1,114,884
Western Economic Diversification Fund	918,964	-
Affiliated Institutions Fund	2,191,470	2,092,220
Commercial Revenue Fund	2,338,207	1,529,721
General Fund	60,947	175,071
Intramural Accounts Fund	1,442,797	1,801,083
	65,002,823	61,588,479
Expenditures		
Buildings and improvements	334,315	1,176,123
Communications	245,542	158,169
Computer	1,203,207	903,876
Consulting	1,347,242	1,348,735
Facility conformity costs	1,000,000	1,000,000
Equipment	4,342,100	4,116,790
Power	2,551,233	2,343,671
Salaries and benefits	40,102,553	36,638,698
Supplies and other expenses	11,527,208	13,763,186
Travel	1,833,428	1,920,396
	64,486,828	63,369,644
Surplus (deficit) of funding over expenditures for the year	515,995	(1,781,165)
Fund balances - Beginning of year	3,360,178	5,141,343
Fund balances - End of year	3,876,173	3,360,178

TRIUMF

Notes to Financial Statement

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, 2010, each university owned an undivided 16.66% interest in all the assets and was responsible for 16.66% 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, 2010, the University of Guelph, the University of Manitoba, l'Université de Montréal, Queen's University and York University became joint venturers; each venturers interest is now 9.09%.

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

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 Nordion Inc for expenditures undertaken at its TRIUMF site.

Advanced Applied Physics Solutions Inc.

Advances and reimbursements from Advanced Applied Physics Solutio9ns Inc for expenditures undertaken at the TRIUMF site.

Western Economic Diversification (WED)

Funding for capital projects related to TRIUMF activities.

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

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 corporate incorporated in 2006 and controlled by TRIUMF. The only asset held by TAI is the operating license issued by the Canadian Nuclear Safety Commission (CNSC), 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.

Historical photographs from TRIUMF's first ten years.
(Photos taken by Terry Bowyer)

1967

TRIUMF's site of 12 acres is leased from the University of British Columbia

1968

UBC Physics Department faculty show a model of the cyclotron

1969


Turning sod for the Newton Apple Trees by Hon. Jean-Luc Pépin May 5, 1969

1970

TRIUMF staff and students in 1970

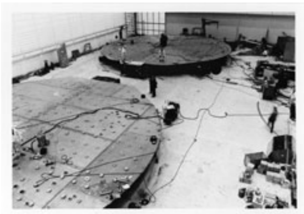

The TRIUMF Circle is visible in the upper left


The substructure of the cyclotron rapidly takes shape

1971


The substructure around the cyclotron vault is built


Lower magnet sector assembly


Vacuum tank base and lid


Beam line 1 escape stairwell (south side)


Centre region lower support structure


Centre region lower support structure


Lower magnet sectors taking shape


Cyclotron trim coil installation


Vacuum tank installation

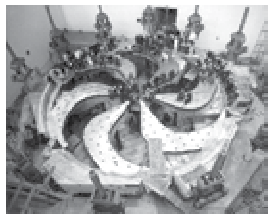

Magnet alignment at centre region

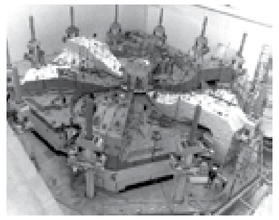

Completed magnet sectors

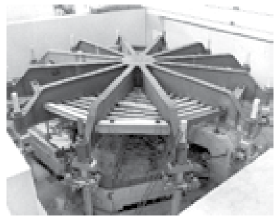

Tie-rod alignment

1972

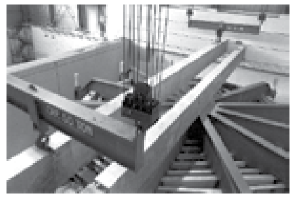

Cyclotron lid elevating structure


Staff sitting on magnet sectors


Completed upper magnet sectors


Completed cyclotron structure


Vault roof beam manufacture


Installing roof beams


Main control room


ISIS Faraday cage

1973

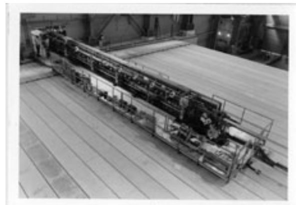

Injection beam line


Resonator assembly


Shielding blocks

1974


Beam dump (proton hall)


Vault roof injection line


Proton hall beam line installation


Early view of the meson hall


Resonators installed


T2 installation


Beam line 1A installation


Director Reg Richardson sitting at the control panel during the first beam


First beam TRIUMF control room
Don Heywood, Dave Gurd, Corrie Kost, Gerardo Dutto, Reg Richardson, George MacKenzie, Ewart Blackmore, Milos Zach (left to right)

1975

1976


M20 beam line installation

Meson hall assembly

Biomedical pion channel

February 9,1976
Prime Minister Pierre Elliott Trudeau officially opened TRIUMF.
Reg Richardson, director of TRIUMF (right).

First SASP magnet

1977


4B Beam line spectrometer

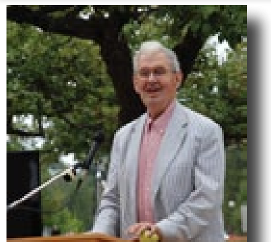
Meson hall mezzanine construction

T2 Secondary beam lines M9, M20, M8 (looking east)

TNF Thermal Neutron Facility

TNF facility tube array

TRIUMF 1969 - 2009



TRIUMF celebrated its 40th anniversary with an open house that attracted over 1,300 adults and children from around the lower mainland to celebrate the event with food, games, prizes, and lots of fun science to make the day memorable for everyone who attended. Mrs. Lorna Warren, the wife of TRIUMF's first Director, Dr. J.B. Warren, was the guest of honour and unveiled the plaque commemorating the original planting of TRIUMF's Newton's apple trees in 1969. Many of the original TRIUMF scientists were in attendance *(see facing page)* and a special set of photographs helped honour their contribution to TRIUMF's 40 years of success.

TRIUMF 40th Anniversary

Photo: C. Kost

(left to right) Ed Auld (kneeling), Joop Burgerjon, Terry Creaney, Alan Otter, Richard Lee, Lyle Robertson, Joyce Murray, Erich Vogt, David Walker, Lorna Warren, Ralph Korteling, Nigel Lockyer, Mark Halpern, John Hepburn, George MacKenzie, Jan Fialkowksi, Jack Beveridge, George Griffiths, Richard Helmer, Karl Erdman, Don Heywood, Mike Craddock (kneeling)

TRIUMF

Canada's National Laboratory for Particle and Nuclear Physics

TRIUMF 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.

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