

TRIUMF **STRATEGIC** **PLAN** **2020-2025**

ACKNOWLEDGEMENTS

TRIUMF's activities are supported through a combination of public funds, revenues generated from commercial activities, and contributions received through scholarships, awards, and philanthropic donations. Our discoveries and innovations wouldn't be possible without the contributions made by our global network, which includes member universities, partner laboratories, our user community, private sector partners, and community organizations. We are deeply grateful to all those who help us push the frontiers of knowledge and harness its power for the benefit of all. Together, we're unlocking a universe of possibilities for Canada and the world.

TRIUMF Five-Year Plan 2020–2025

Copyright © 2018 TRIUMF

All rights reserved.

Learn more about our plan at <https://fiveyearplan.triumf.ca>

Front cover photo credit: M. Enriquez

CONTENTS

2	EXECUTIVE SUMMARY
4	STRATEGIC PLAN AT A GLANCE
6	MESSAGE FROM THE DIRECTOR
7	MESSAGE FROM THE BOARD CHAIR
8	A NATIONAL RESOURCE FOR THE 21st CENTURY
10	WHAT DRIVES US
12	HOW WE CREATE VALUE
13	Scientific Knowledge
16	National and International Collaboration
20	Innovation and the Economy
24	Education and Outreach
28	OPPORTUNITIES IN THE ARIEL ERA
34	OUR PLAN FOR THE NEXT FIVE YEARS
36	Science and Technology: Seizing Opportunities, Expanding Frontiers
42	People and Skills: Developing Talent, Increasing Access and Equity
48	Innovation and Collaboration: Connecting Science to Society and Canada to the World
55	FINANCING OUR PLAN
56	MEASURING SUCCESS

EXECUTIVE SUMMARY

For 50 years, TRIUMF has advanced fundamental, applied, and interdisciplinary research for science, medicine, and business. Today, as Canada's particle accelerator centre, TRIUMF is poised to enter the most exciting and transformative era in our history. With unmatched scientific opportunities across all our fields of endeavour, and the completion of two new world-class facilities—ARIEL and IAMI—we are charting a course to lead the revolution in isotope science and innovation.

As we approach 2020, we are launching a new Strategic Plan, the result of extensive community consultation. Our plan required hard choices to be made, but the final result is ambitious and fully achievable. It leverages past investments by government and builds on the laboratory's strong brand and global network to deliver a new level of top-tier science, training, and innovation to Canada for decades to come.

2

TRIUMF contributes to national prosperity in a myriad of ways. Fundamentally, we enable Canada to compete at scale in the global science and innovation enterprise. Our plan is designed to maximize our value across three key dimensions. For each dimension, we have established two primary goals, along with a set of strategies that will help us fulfil our vision and increase our impact:



SCIENCE AND TECHNOLOGY

TRIUMF's multidisciplinary expertise and state-of-the-art infrastructure enable the Canadian science and technology community to carry out internationally recognized cutting-edge research in a range of disciplines, from nuclear and particle physics to the life and materials sciences. Our ground-breaking discoveries drive Canada's contributions to extending the frontiers of knowledge.



PEOPLE AND SKILLS

TRIUMF offers a unique training ground for the next generation of science and innovation leaders. We educate students at all levels, providing them with the skills needed to drive and adapt to change, and to succeed in the knowledge economy. We broaden and deepen Canada's talent pool, with a strong focus on strengthening the STEM pipeline and increasing access for our diverse population.



INNOVATION AND COLLABORATION

TRIUMF connects science to society and Canada to the world. As a hub for discovery and collaboration, we connect leading universities and research centres across the country and act as Canada's gateway to international big science projects. Through TRIUMF Innovations, we apply science to produce technology and innovations that improve the lives of Canadians.

The outlook for TRIUMF for the next five years and the decades beyond is remarkably bright. The stars are aligned: our science is rich with opportunity, our people are first-rate, and our large-scale research infrastructure is unique and at the leading edge. With the completion of ARIEL and IAMI, we will be positioned to propel Canadian science and innovation in ways that we have only been able to imagine. However, we must act with haste. Global competition is intensifying, and the landscape is constantly changing. For Canada to strengthen its competitiveness and accelerate its economic growth, we must seize the moment. Our Strategic Plan lays out exactly what must be done.

STRATEGIC PLAN 2020-2025 AT A GLANCE

OUR VISION

Our vision is for Canada to lead in science, discovery, and innovation, improving lives and building a better world.

OUR MISSION

Our mission is to serve as Canada's particle accelerator centre. We advance isotope science and technology, both fundamental and applied. We collaborate across communities and disciplines, from nuclear and particle physics to the life and material sciences. We discover and innovate, inspire and educate, creating knowledge and opportunity for all.

OUR MEMBERS





SCIENCE AND TECHNOLOGY

Seizing Opportunities, Expanding Frontiers

GOAL 1

Make ground-breaking discoveries across our multidisciplinary research portfolio

GOAL 2

Strengthen our position as a world-leading particle accelerator centre



PEOPLE AND SKILLS

Developing Talent, Increasing Access and Equity

GOAL 3

Become a hub for interdisciplinary education and training

GOAL 4

Inspire Canadians to discover and innovate



INNOVATION AND COLLABORATION

Connecting Science to Society and Canada to the World

GOAL 5

Translate science and technology into innovation and commercialization

GOAL 6

Drive national and international collaboration in research, technology, and innovation

PLATFORMS

ADVANCED RARE ISOTOPE LABORATORY (ARIEL)

Revolutionizing the study of isotopes for science, medicine, and business

INSTITUTE FOR ADVANCED MEDICAL ISOTOPES (IAMI)

A world-class centre for advanced isotope research and development

TRIUMF INNOVATIONS

Translating scientific discovery into commercial opportunities

OUTCOMES

- Extension of the frontiers of knowledge and global recognition of Canada's contributions to discovery research
- Increased capacity for world-class, multidisciplinary research and development in Canada
- A new generation of highly-skilled Canadians ready to compete in the knowledge and innovation economy
- Greater access to STEM opportunities for all Canadians
- New game-changing technologies that support business-led innovation and improve the lives of Canadians
- A stronger, more competitive Canada in discovery and innovation

MESSAGE FROM THE DIRECTOR

From the moment humans first gazed up at the stars, curiosity has compelled us to seek answers to big questions—questions central to who we are and to our place in the universe. Today, we are privileged to live in an era rich with possibility. Each year we understand more about the universe: its birth, how its stars burn, and where and how its elements were created. The quest is pushing scientific frontiers and unlocking innovations that will benefit us all.

As we continue to search for answers, and as new questions arise, we can see more than ever before the extraordinary opportunity that lies ahead for TRIUMF—and for Canada. That’s why I’m excited to present TRIUMF’s Strategic Plan 2020-2025. In fact, it’s more than just a plan. It’s our launchpad for the future.

For five decades, TRIUMF has delivered discovery, innovation, and impact. We have a proven track record of improving the lives of Canadians and building a better world. This plan builds on our legacy and propels us towards our future—not just for the next five years but for years and decades to come.

6

As we complete two new world-class facilities, ARIEL and IAMI, we are charting a course that will lead a revolution in isotope science and innovation. And, after 50 years in operation, we are refurbishing and refreshing our core infrastructure. With so much opportunity on the horizon, it’s a perfect time for renewal.

In our plan, we’re also harnessing the power of science to solve problems. Our revitalized commercialization arm, TRIUMF Innovations, is connecting scientific inventions and ideas—and the innovators behind them—to promising opportunities in the business world.

At the heart of all this is the very special constellation of people clustered at our lab. We draw extraordinary people into our orbit, and our diverse and multidisciplinary team is our most prized asset. Expert, dynamic, and collaborative, our team creates opportunities for tomorrow’s discoverers and innovators, just as our founders did for us. Together, we continue humanity’s pursuit of answers, expanding the frontiers of knowledge with the hope that the next generation will go even further, driven by the same spark of curiosity.

The timing couldn’t be better to build the TRIUMF of the future. I invite you to join us as we launch an era of extraordinary opportunity for all.



Jonathan A. Bagger
Director, TRIUMF

MESSAGE FROM THE BOARD CHAIR

From its founding over 50 years ago, TRIUMF has successfully carried out investigations that are too large and complex for any one university to pursue alone. Driven by humanity's quest to answer big questions, and rooted in a common vision, ambition, and desire to make an impact, TRIUMF has expanded into a strong national network of 20 universities.

Today, that network is fortified by cross-sector collaborators and partners from across Canada and around the world, driving discovery and innovation, while working to develop talent and skills across the many fields linked to the lab's core programs in particle and nuclear physics, isotope and accelerator science, nuclear medicine, and materials science. Our track record of achievement speaks to the power of collaboration: it's by working together rather than on our own that we're at the vanguard and making our mark on the world stage in numerous fields, all the while building a stronger and better society.

Collectively, we have created, and are continuing to strengthen, a diverse and inclusive hub that transcends boundaries and fosters intersections of people, ideas, perspectives, disciplines, and sectors, all collaborating in the pursuit of world-class science.

Fifty years into TRIUMF's story, I'm proud of everything we've accomplished so far and excited about the next chapter in our story. Our Strategic Plan 2020-2025 is bold, and that makes me even more eager to learn what we're capable of achieving together. As you explore it, I encourage you to think about how you can be a part of it. I'm confident the best is yet to come.



Digvir S. Jayas
Chair, TRIUMF Board of Management
Vice-President (Research and International), University of Manitoba

A NATIONAL RESOURCE FOR THE 21st CENTURY

TRIUMF is Canada's particle accelerator centre and an international hub for discovery and innovation. For 50 years, we have been advancing fundamental, applied, and interdisciplinary research for science, medicine, and business. Owned and operated by a consortium of 20 member universities from coast to coast, we are located on the campus of the University of British Columbia (UBC) in Vancouver.

8

TRIUMF contributes to national prosperity in many ways, from driving discovery and innovation to developing talent and skills. We have a history of excellence in fundamental science, supporting core programs in particle and nuclear physics, accelerator-based science, nuclear medicine and isotope science, and materials science. We also translate that science into innovations that benefit Canada, from transferring superconducting technology to local industry, to developing novel processes for the production of life-saving medical isotopes. And, over the decades, we have trained generations of discoverers and innovators, equipping them with the skills needed to keep Canada competitive in the global knowledge economy.

Today, TRIUMF is home to more than 500 staff and students, whose broad scope of knowledge and expertise provide us with the capacity to answer fundamental questions that are beyond the reach of any single Canadian institution. Our track record of excellence is a direct product of billions of dollars of investment, both provincial and federal, in the laboratory's core infrastructure. Our state-of-the-art accelerator complex—featuring the world's largest cyclotron and the most powerful superconducting electron linear accelerator—is the foundation upon which our competitive advantage rests. It is a magnet for attracting leading talent to Canada.

Our network brings together a diverse set of stakeholders, including Canada's top research universities, funding agencies, and large research facilities, including the

National Research Council (NRC), Perimeter Institute, and SNOLAB, all united by a shared commitment to excellence. We are also a central conduit for integrating Canada with the global scientific community through participation in game-changing big science projects.

Our plan for the next five years—and our vision for the future sustainability of TRIUMF for many decades to come—is firmly grounded in the launch and convergence of three new platforms:

THE ADVANCED RARE ISOTOPE LABORATORY (ARIEL)

will make us the world’s first purpose-built, multi-user rare isotope facility, tripling isotope production and enabling more science, more training, and more commercial activity. It will drive a full-scale multidisciplinary research program that will have impact across science, medicine, and business.

THE INSTITUTE FOR ADVANCED MEDICAL ISOTOPES (IAMI),

a world-class radiopharmaceutical research facility, will support public and private sector isotope research, development, and production—both academic and commercial—ensuring that TRIUMF and our partners can capitalize on fast-moving advances in personalized nuclear medicine.

TRIUMF INNOVATIONS will spearhead all of our commercial activities, from growing companies to selling services, all the while training and empowering a new and diverse generation of Canadian innovators. Together, these platforms will transform TRIUMF into a global multidisciplinary hub, anchored by world-leading isotope science and Nobel-calibre physics and ignited by the creative and innovative spirits of talented Canadians.

“

You are at the very forefront of the frontier of knowledge. And yet, you are very practical and very applied because you are solving problems that help people every day.

”

HER EXCELLENCY THE RIGHT HONOURABLE JULIE PAYETTE, GOVERNOR GENERAL OF CANADA

TRIUMF

By the Numbers

> 50 years of discovery and innovation

Close to 600 staff and students on campus

20 member universities

WHAT DRIVES US

OUR VISION

Our vision is for Canada to lead in science, discovery, and innovation, improving lives and building a better world.

OUR MISSION

Our mission is to serve as Canada's particle accelerator centre. We advance isotope science and technology, both fundamental and applied. We collaborate across communities and disciplines, from nuclear and particle physics to the life and material sciences. We discover and innovate, inspire and educate, creating knowledge and opportunity for all.

OUR VALUES

EXCELLENCE & INTEGRITY

- We have a passion for excellence in all that we do.
- We are decisive, bold, courageous, and compassionate.
- We take responsibility for our actions, our commitments, and our contributions to the larger community.

SAFETY & ACCOUNTABILITY

- We respect the health and safety of our workers, our visitors, and our neighbours.
- We build quality into our processes and seek continual improvement in all of our systems.
- We embrace transparency and authenticity, and hold ourselves and each other accountable.

EQUITY & INCLUSION

- We empower our workforce and foster an inclusive work environment, enriching our science and our community.
- We value teamwork and open communication to ensure that everyone belongs and all voices are heard.
- We respect each other, take care of each other, and support the success of all.





HOW WE CREATE VALUE

From the abstract to the applied, TRIUMF solves problems and delivers impact. We drive compelling research and create ideas and innovations that benefit humanity. We also broaden and deepen the national talent pool by developing the skills that Canadians need to thrive in the knowledge economy and strengthen the science, technology, engineering, and mathematics (STEM) pipeline.

This section highlights the main impacts and benefits of TRIUMF's activities in four areas: scientific knowledge, national and international collaboration, innovation and the economy, and education and outreach.

SCIENTIFIC KNOWLEDGE

TRIUMF's multidisciplinary expertise and state-of-the-art infrastructure enable the Canadian science and technology community to carry out internationally recognized cutting-edge research.

As a world-leading research centre for particle and nuclear physics and accelerator-based science, much of our impact comes from the scientific discoveries and technological breakthroughs we make. Since our founding in 1968, we have transformed the understanding of fundamental physics and contributed to Canada's global reputation for scientific excellence.

Our multidisciplinary research teams have investigated and answered some of the biggest questions in science today related to the evolution of the universe, the structure of matter, the interaction of particles and nuclei, the origin of the elements, the working of our brains, and the functionality of quantum materials. Among our many achievements, we have:

- Advanced our understanding of the nuclear forces, through experimental and theoretical work, from the first days of the 520 MeV cyclotron to the rare isotope beams of ISAC (Isotope Separator and Accelerator) today.
- Set precise limits on the existence of new particles and forces through precision measurements of the electroweak decays of mesons, muons, and rare isotopes.
- Made leading contributions to discovering neutrino oscillations and determining essential neutrino properties with the Sudbury Neutrino Observatory (SNO) and T2K in Japan.
- Helped discover the Higgs boson with ATLAS at the Large Hadron Collider (LHC) at CERN, while pushing the discovery limits for new physics to unprecedented energies.
- Spearheaded efforts to trap and precisely measure the properties of anti-hydrogen with ALPHA.
- Led the world in measuring the critical nuclear reaction rates for hydrogen and helium burning in stars and star explosions.
- Mapped the phase diagram of unconventional superconductors with muons.
- Advanced our understanding of brain health, and developed radiopharmaceuticals for imaging and treating disease.

“

This TRIUMF Five-Year Plan, and the associated strategic goals, will continue to strengthen the ability of TRIUMF to support and spearhead the nuclear and particle physics community in Canada, forge new connections nationally and internationally, and maintain Canadian research leadership on a global stage.

”

**DR. NIGEL SMITH,
DIRECTOR, SNOLAB**

The quality, breadth, and excellence of our research are reflected in the more than 1,500 publications authored by TRIUMF researchers in peer-reviewed journals during the last five-years (2013-2017). Our publications had an impact well above the global average in nuclear physics, particle physics, accelerator science, and nuclear medicine, a notable feat given Canada’s relatively low specialization in these fields compared to other countries. From 2001-2008 to 2009-2016, our impact also increased. According to bibliometric analysis, “...in nuclear physics, particle physics and accelerator physics, as well as in nuclear medicine, the citation impact of research conducted at TRIUMF increased notably.” [Bibliometric analysis on TRIUMF’s research performance 2001–2016, Analytical report, Science-Metrix, July 2018.]

Today, we are recognized as an international brand for excellence in developing, designing, and constructing state-of-the-art accelerator and detector systems, as well as developing new technologies. This expertise lies at the heart of the Canadian experimental subatomic physics program. From 2013-2017, our 520 MeV cyclotron delivered over 25,000 beam hours, with overall reliability of 92%, and over 52,000 hours of secondary beam experiments with isotopes, muons, and—for the first time in Canada—ultracold neutrons.

TRIUMF accelerators enable world-leading on-site research in nuclear physics. We use isotopes and isotope technologies to understand the forces that hold protons and neutrons within the atomic nucleus and unveil the mechanisms by which stardust forms through nuclear reactions in stars and star explosions. Our new ARIEL facility, slated for completion in 2023, will transform TRIUMF into the most powerful multi-user beam facility in the world for production of rare isotopes.

TRIUMF is also a world-class testing ground for the quantum materials of tomorrow. Through explorations of materials at the nanoscale, we have discovered new emerging phenomena that may prove pivotal in creating the next generation of superconductors and devices for computing, communications, or sensors. At the same time, our new medical isotope facility, IAMI, will drive advances in nuclear medicine and capitalize on applications for imaging and treating disease. And, when complete, our world-leading facility will address fundamental questions in our understanding of the universe. TRIUMF’s impact extends far beyond the laboratory itself. We make significant contributions to off-site national and international projects, including the

Scientific Knowledge By the Numbers

**In the last 5 years TRIUMF
has delivered:**

- > 1,500 publications
- > 25,000 hours of proton beam (92% reliability)
- > 52,000 hours of muon and rare isotope beams
- 1st Canadian ultracold neutrons
- 77% involvement in NSERC subatomic physics funding

83% success for 2017 CFI projects

Sudbury Neutrino Observatory (SNO) experiment in Sudbury, Ontario, the ATLAS experiment at CERN, and the T2K (Tokai to Kamioka) experiment in Japan. Our contributions to the discovery of the Higgs particle by ATLAS and to the detection of neutrino oscillations at SNO—both Nobel Prize-winning achievements—illustrate the critical role we play in advancing fundamental science, in Canada and overseas. Canadian researchers in the SNO and T2K collaborations were also awarded the 2016 Breakthrough Prize in Fundamental Physics for the discovery and exploration of neutrino oscillations. TRIUMF's Jean-Michel Poutissou won the 2018 Medal for Lifetime Achievement of the Canadian Association of Physicists for his work in particle physics, in particular, precision experiments with mesons, muons, and neutrinos.

Another award-winning effort is TRIUMF's leading role in the ALPHA collaboration at CERN. ALPHA-Canada won the 2013 Natural Sciences and Engineering Research Council (NSERC) Polanyi award for capturing antimatter atoms in a magnetic bottle and developing methods that led to the first measurement of the properties of atomic antimatter. TRIUMF is the central hub for the Canadian contribution to ALPHA, a potentially game-changing program to help explain how the universe was able to form after the Big Bang.

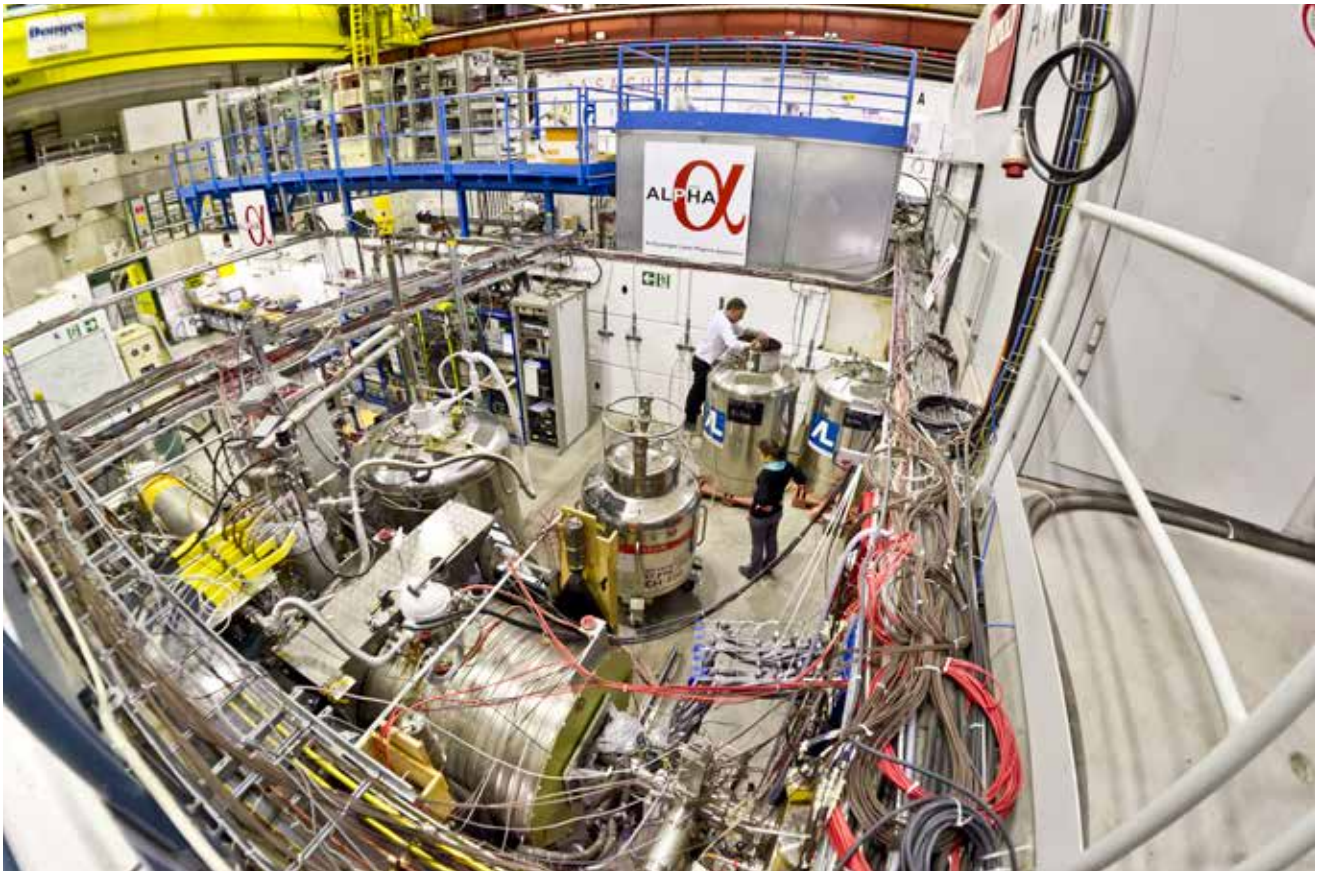


Photo credit: CERN

NATIONAL AND INTERNATIONAL COLLABORATION

TRIUMF connects leading Canadian universities with each other, and with national and international facilities around the world.

Our large-scale research facilities provide centralized infrastructure, resources, tools, and expertise in pursuit of compelling science. As the only laboratory operating at this scope and scale in Canada, TRIUMF tackles problems too large and complex for any single researcher or institution. Collaborative efforts with our member universities and partners such as SNOLAB and the Perimeter Institute have spurred transformative advances in nuclear and particle physics in particular, and enhanced Canada's strong research reputation, in general. Our support for university capital requests to the Canada Foundation for Innovation (CFI) has resulted in an 83% success rate for funding—more than double the national average—a strong indicator of our excellence and relevance to Canada.

16

As a central hub for discovery and collaboration, TRIUMF is Canada's gateway to the world. We enable Canada to compete on a global scale in research and innovation, connecting Canadian scientists and universities with our sister laboratories abroad, and making leading contributions to international big science projects, both at home and around the globe.

In 2017, TRIUMF hosted nearly 900 users and scientific visitors (more than double the number in 2012), from a total user-base that spans 39 countries.. At home, our international collaborations focus on conducting advanced rare isotope experiments and developing the world's highest-intensity UCN facility. In November 2017, we produced Canada's first ultracold neutrons. Over the next five years we will launch the world's most sensitive neutron electric dipole moment experiment.

TRIUMF has more than 60 active agreements with various centres and facilities around the world. In 2013-2017, we enabled more than 200 Canadian scientists to participate in international big science projects. Here are some examples of the critical contributions we made—and are continuing to make—on behalf of the Canadian community:

- TRIUMF is deeply engaged with ATLAS at the CERN LHC, both in the science and the technology. We managed Canada's original contribution to the LHC accelerator and built critical parts of the ATLAS detector, and we are currently constructing detector upgrades. We are leading Canada's next accelerator contribution—five crab-cavity cryomodules, for which \$10 million funding was announced in June 2018. We continue to operate 1 of the 10 global Tier-1 data centres to process the

raw data produced by the experiment. Our lab-to-lab collaboration with CERN extends over several research topics, from particle physics to nuclear physics to accelerator science.

- We continue to play a leading role in the ALPHA anti-hydrogen experiment at CERN; Canadians make up one-third of the collaboration. We made a major contribution to the current experimental apparatus and, in 2018, we completed the key detector for a new gravity experiment.
- TRIUMF led the Canadian contribution to the T2K long-baseline neutrino experiment in Japan, collaborating closely with KEK (Japan's High-Energy Accelerator Research Organization), among others. We invented the off-axis beam method for the T2K experiment—a technique that is now used around the world. We were also instrumental in building the neutrino target at J-PARC (Japan Proton Accelerator Research Complex). In support of this activity, we established a TRIUMF office at KEK with space and support for Canadian researchers.
- We continue our key involvement in a range of experiments at SNOLAB, which are poised to search for dark matter particles, such as Dark Matter Experiment using Argon Pulse-shape discrimination (DEAP) and SuperCryogenic Dark Matter Search Experiment (SuperCDMS), and to discover the nature of neutrinos, such as Sudbury Neutrino Observatory (SNO+) and next-generation Enriched Xenon Observatory (nEXO).
- Our connections with national labs in the United States have enabled Canadian contributions to some of their major experiments. For example, we support the Q-weak physics experiment at Jefferson Lab, which seeks to make the most precise measurement of the weak charge of the proton. We also collaborate on accelerator R&D with Fermilab, and on rare isotope science projects with Michigan State University, which is constructing the \$1 billion Facility for Rare Isotope Beams (FRIB).

Finally, by enabling dialogue and the exchange of ideas, TRIUMF—alongside its global network of similar facilities

“

The long-standing, fruitful collaboration between TRIUMF and CERN is based on shared values and common goals, such as those that are stated in TRIUMF's Five-Year Plan 2020-2025. CERN is committed to continuing and strengthening its partnership with TRIUMF in the years to come, and to working together to push back the frontiers of knowledge, develop new technologies, train the young generations and promote worldwide collaboration.

”

DR. FABIOLA GIANOTTI,
DIRECTOR-GENERAL, CERN

National and International Collaboration

By the Numbers

875 users in 2017 (+100% since 2012)

Users from 39 countries (2013-2017)

> 60 international partnerships

> 200 Canadian scientists in international projects via TRIUMF

ADVANCED RARE ISOTOPE LABORATORY (ARIEL)

ARIEL is the only purpose-built multi-user rare isotope facility in the world, as well as the world's most powerful Isotope Separation Online (ISOL) complex.

ARIEL will enable world-class research on the nature of atomic nuclei, the origin of the heavy chemical elements, quantum materials and biomolecules, as well as medical isotopes for the imaging and treatment of disease. It will massively expand our rare isotope program by providing more exotic isotope species with very high intensities and by adding two production targets in parallel to the existing ISAC target station. Together, the three isotope production stations will allow us to fully exploit the numerous existing experimental facilities at ISAC.

At the heart of ARIEL is a built-in-Canada superconducting electron accelerator (e-linac) for isotope production via photo-production and photo-fission as well as a second proton beam line from TRIUMF's cyclotron for isotope production via proton-induced spallation, fragmentation, and fission.

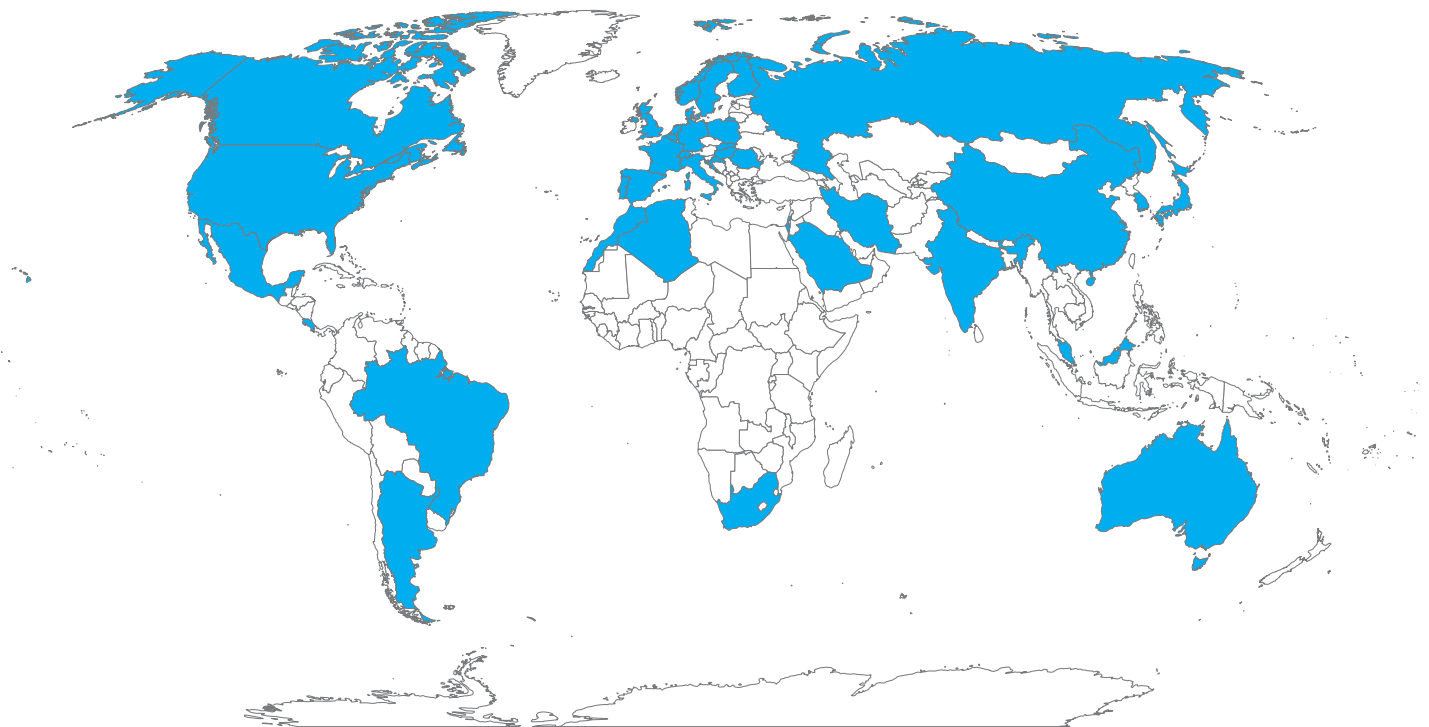
18

Funded by CFI, as well as five provinces, with backing from 21 universities, construction of ARIEL is occurring in two stages. The first stage (2010-2014) included the construction of the ARIEL building as well as development of the e-linac, which produced its first accelerated beam in 2014. The second stage (2017-2023) involves the construction of the two target stations, associated laboratory and hot-cell infrastructure, as well as the rare isotope beam transport beamlines, mass-separator, and an electron-beam ion source for charge breeding.



around the world—offers a natural platform for international engagement. Birthed in the dynamics of the Cold War, nuclear and particle physics have a long history of bridging political divisions to realize the diplomatic potential of scientific collaboration. Boasting decades of collaboration with partners across Europe, the Middle East, Asia, and the Americas, TRIUMF is one of Canada’s most respected and versatile avenues for bilateral and multilateral cooperation. As the world faces a period of growing uncertainty, TRIUMF will be able to play an increasingly important role in maintaining open channels for peaceful global cooperation.

WORLD MAP OF TRIUMF’S USERS FOR 2013-2017



**IN 2017, TRIUMF
HOSTED 875 SCIENTIFIC
VISITORS AND USERS**



- Canada 42%
- Africa and Europe 16%
- Americas 25%
- Asia and Pacific 17%

INNOVATION AND THE ECONOMY

TRIUMF has a long history of applying science to state-of-the-art technology and innovations that benefit Canada and the world, particularly in the field of medicine.

Leveraging our tremendous scientific contributions and capabilities, TRIUMF's impact extends deeply into the economic and societal spheres. Over 2012-2018, TRIUMF generated over \$600 million in economic impact in Canada. Among the community of international physics-based laboratories, TRIUMF is a leader in translating research into real and sustainable impact.

In a national ecosystem that struggles to capitalize on ideas and innovations, TRIUMF continues to bring scientific and technological breakthroughs to market. Here are some examples of our impact and achievements in technological innovation and commercialization:

20

- Our 40-year partnership with global health sciences company BWXT (formerly Nordion) on commercial production of medical isotopes has resulted in more than 50 million patient doses shipped to patients around the world, 9.5 million of them in the last five years. This represents about 15% of the isotopes that Canada exports each year.
- Our expertise in the accelerator production of isotopes enabled us to resolve a national medical crisis in the 2000s. In the face of an increasingly unreliable isotope supply from nuclear reactors, TRIUMF, with government support, assembled a team of experts from across our network to provide an innovative solution. The result enabled hospitals to produce ^{99m}Tc directly on medical cyclotrons like the ones used for PET isotope production. A sustainable option for isotope security around the world, this technology is now being implemented in several other countries. The TRIUMF-led team won the 2015 NSERC Brockhouse Prize and our spin-off company, ARTMS™ Products Inc., won a 2017 BC Technology Impact Award.
- When IAMI and ARIEL come online, we will be able to produce a greater variety and volume of isotopes that have tremendous potential for commercialization and improving the health of Canadians. For example, TRIUMF has world-leading capability for producing ^{225}Ac -based compounds for targeted alpha therapy, which could revolutionize cancer therapy. Other applications for these isotopes include improving the imaging of neurological disease, accelerating drug development, and improving environmental studies through the use of radiotracers.

TRIUMF INNOVATIONS

TRIUMF Innovations Inc. is the business interface and commercialization arm of TRIUMF, acting as a portal into TRIUMF and its network for the private sector world of industry partners, customers, and investors.

Through TRIUMF Innovations, companies can access the multi-disciplinary expertise, world-class infrastructure, and global network at TRIUMF to:

- Radiation-test new technologies for computing, communications, and aerospace electronics
- Create life-saving nuclear medicine technologies, including new diagnostics and radiotherapeutic treatments
- Commercialize particle detector technologies for use in sectors ranging from mining and security to oil and gas
- Develop and validate new technologies using TRIUMF's global network of top researchers

TRIUMF Innovations' business team brings new discoveries to market through industry partnerships, licensing, and start-up companies. TRIUMF Innovations identifies, assesses, develops, incubates, and commercializes technologies in collaboration with partners in industry, academia, and government. To date, five spinoff companies have successfully gone to market, with more in the pipeline. TRIUMF Innovations helps navigate business challenges, including intellectual property management, fundraising, and scale up.

A new Commercialization and Entrepreneurship Training Program will equip our people with the skills necessary to accelerate innovation. Through a range of courses, workshops, and individual mentoring programs, TRIUMF Innovations will provide effective, hands-on business training to Canada's research community.

In addition, TRIUMF Innovations also functions as a hub to connect private sector partners with TRIUMF's national network of top researchers and institutions. For example, we are working to make new quantum computing tools widely available across multiple sectors, and to establish new training programs to provide job-ready highly-qualified data science personnel for a wide range of industries.

Innovation and the Economy

By the Numbers

Successes of the last 5 years:

- \$15.5M in commercial revenues
- 30 patents filed
- 9.5M medical isotope doses produced
- \$8M private sector investment secured by 5 TRIUMF spin-off companies

83 irradiation services contracts in 2017 (+100% since 2013)

\$1.1B in gross economic output between 2012-2018

- As the only proton therapy facility in Canada, we work with the BC Cancer and UBC Eye Care Centre to use our accelerators to treat 10 patients per year for ocular melanomas. We have a 91% success rate for controlling the associated tumours.
- TRIUMF technology extends into other sectors, some of which might seem quite surprising. For example, spin-off company CRM GeoTomography Technologies Inc. uses TRIUMF-developed muon detectors at mining sites to search for ore using 3D images that highlight the variations in density of different ore deposits. Other applications of the technology are being explored in defense and security.

With the recent revitalization of our innovation arm, TRIUMF Innovations, we have intensified our knowledge transfer and commercialization efforts. Over 2013-2017 we generated almost \$15.5 million in commercial revenue through medical isotope production and irradiation services. This represents a 67% increase in growth compared with 2008-2012. We will use the revenues to support our commercialization efforts, as well as other value-added activities across the laboratory.

TRIUMF also creates intellectual property for technologies and spin-off companies. We filed 30 patents over the five-year period, and, in total, have successfully established five spin-off companies that have attracted a total of \$8M in private sector funding, with several already boasting international customer bases: ARTMS™ Products Inc., CRM GeoTomography Technologies Inc., Frontier Sonde Inc., Micromatter Technologies Inc., and IKOMED. As noted above, TRIUMF technologies are applied in areas as diverse as medicine, mining, environmental monitoring, and oil and gas surveying.

Over 2013-2017 we more than tripled the number of paying users of our Proton Irradiation and Neutron Irradiation Facilities (PIF & NIF)—a premier test site for space-radiation effects. Many of the proton users are Canadian space-related companies, such as MDA Corporation, while neutron use is primarily by international companies, such as The Boeing Company and Cisco Systems, Inc., for avionics, microelectronics, and communications equipment.



Photo credit: Michael Levy

EDUCATION AND OUTREACH

TRIUMF offers a unique training ground for the next generation of science leaders, educating students at all levels, and inspiring Canadians through a variety of outreach activities.

At TRIUMF, postdoctoral research fellows and graduate and undergraduate students work side by side with top scientists, engineers, technicians, and tradespeople. In the last five decades, we have welcomed thousands of students through our doors. We train them in a range of disciplines, including nuclear and particle physics, nuclear medicine, materials and molecular science, and accelerator and detector technologies. We also give them unparalleled experience working in international, multidisciplinary teams, and the skills required to operate cutting-edge technologies and tools.

We are among the largest co-op employers in Canada, hosting 126 undergraduate students in 2017, an 88% increase from 2012. The jobs reflect the broad range of work performed at TRIUMF, from our core research disciplines to engineering, computing, business, and communications.

24

TRIUMF also attracts postdocs and graduate students to Canada from around the world and provides them with exceptional opportunities for research, training, and career development. In 2017, TRIUMF hosted 71 graduate students, a 65% rise from 2013. On average, nearly 30 students graduate per year; many move beyond academia into the Canadian job market. The number of postdocs remained relatively constant at around 56 fellows per year over the same period. In cooperation with institutional partners, we also run summer schools for graduate students and postdocs in topics spanning the breadth of our research program.

To help students apply scientific knowledge to solving real-world problems and to better prepare them for future jobs, TRIUMF and UBC have established Isotopes for Science and Medicine (IsoSiM), through the NSERC CREATE program. IsoSiM provides enriched training experiences for undergraduates, graduates, and postdocs in the production, preparation, and application of isotopes for science and medicine in world-class collaborative, interdisciplinary research environments. We enhance their training with professional skills development as well as industry internships and international research experiences at leading German research laboratories.

For many years, TRIUMF's Unveiling the Universe lecture series has captured the public's imagination about the big questions that animate our investigations. Our communications and public engagement efforts connect science with society by



stimulating curiosity and inquiry about the natural world and demonstrating the broader value of science and technology.

We also engage and inspire Canadians through site visits, informal science education activities, public lectures, workshops, arts and culture programming, community events, and partnership initiatives. On average, 4,700 people, including 1,000 children, tour our facilities every year. In 2013-2017, we touched over 70,000 participants at various informal science outreach events.

In recognition of the transformative role that teachers play in growing the next generation, we support teachers through a long-standing collaboration with the British Columbia Association of Physics Teachers (BCAPT). Every two years, in partnership with BCAPT, we host a special professional development event at TRIUMF that is attended by around 60 teachers and teacher candidates.

Education and Outreach

By the Numbers

211 students and postdocs hosted in 2017 (+40% since 2012)

28 graduate students via UBC/ TRIUMF IsoSiM CREATE program

141 students graduated in last 5 years

Connected with > 23,000 members of the public in 2017



Digital communications enable us to share TRIUMF's story and the wonder of science far and wide, making TRIUMF and high-quality STEM content and resources more accessible than ever before. In recent years, we added another social media platform, Instagram, to our other channels, which include Facebook, Flickr, and Twitter. Our Instagram platform enjoyed an audience growth rate of 105% in 2017 and has proved to be an effective tool for compelling campaigns that showcase role models in STEM, in particular #Coopcovers, a series featuring TRIUMF co-op students.

“
I was interested in working for TRIUMF when I read their Vision Statement. I loved this idea of inclusiveness and openness, but also working for the betterment of the country, the people, and science in general.
”

**NADÈGE PULGAR-VIDAL,
FORMER TRIUMF CO-OP STUDENT**



OPPORTUNITIES IN THE ARIEL ERA

With the completion of ARIEL and IAMI, we are poised to enter the most exciting and transformative era in TRIUMF's 50-year history. Our new facilities will allow us to boldly lead the revolution in isotope science, seek to capture new opportunities, and claim our rightful place at the forefront of the global scientific and innovation enterprise.

The outlook for TRIUMF for the next five years and the decades beyond is remarkably bright. The stars are aligned: our science is rich with opportunity, our people are first-rate, and our large-scale research infrastructure is unique and at the leading edge. With the completion of ARIEL and IAMI, TRIUMF will be positioned to propel Canadian science and innovation in ways that we have only been able to imagine.

28

Enabled by ARIEL and IAMI, we are charting a course to be the global leader in isotope science in all its many facets. We will combine our enhanced isotope capabilities and technologies with our Nobel-calibre multidisciplinary research program in nuclear and particle physics, nuclear medicine, and quantum materials.

ARIEL will help us compete in the race to answer foundational questions about the nature of atomic nuclei and the origin of the heavy chemical elements. With ARIEL and IAMI, we will be capable of producing a diverse and reliable long-term supply of exotic isotopes for science, medicine, and business, while developing a host of new applications downstream. At the same time, we will continue to be an essential partner and ambassador for Canada in the global particle and nuclear physics endeavour.

However, we must act with haste. Global competition is intensifying, and many opportunities are time-sensitive. For Canada to strengthen its competitiveness and benefit from the substantial investments in ARIEL and IAMI, we must act now to seize our advantage.

Here are some of the most promising opportunities that we have identified—and are pursuing.

CRITICAL ROLE OF NUCLEAR PHYSICS IN MULTI-MESSENGER ASTRONOMY

How were the heavy elements formed? Multi-messenger astronomy promises to hold the answer, drawing upon nuclear physics, astrophysics, and astronomy as never before. Just last year the discovery and observation of neutron star merger GW170817, in both gravitational and electromagnetic waves, offered a clue: the first direct observation of heavy element production via the rapid neutron-capture process (“r-process”).

Are neutron star mergers the dominant site for heavy element production? Nuclear physics input, delivered by next-generation rare isotope facilities such as ARIEL, will be critical to determining the answer. With international competitors like the Facility for Rare Isotope Beams (FRIB) in the United States coming online on a similar timeline, TRIUMF must push ahead with the completion and ramp-up of ARIEL to be the first in the world to produce the key measurements.

INCREASING COMPETITION AT THE FRONTIERS OF PARTICLE PHYSICS

With the discovery of the Higgs boson and confirmation of the Standard Model by the LHC experiments, particle physics is entering uncharted territory. We know that dark matter and neutrino mass both require new physics beyond the Standard Model. But what is it? A world-wide multi-pronged effort is underway to find the answer.

No matter the path, TRIUMF is well established as an important player in this international endeavour. We currently work across a spectrum of activities, ranging from data analysis to accelerator and detector development for experiments in Canada and abroad. In particular, we will contribute to the High-Luminosity LHC and ATLAS upgrades, continue our long-baseline neutrino efforts with T2K and HyperK in Japan, and support a suite of experiments at SNOLAB. We will also carry out precision experiments at low energies, such as the neutron EDM and rare isotope experiments at TRIUMF, as well as anti-hydrogen investigations with ALPHA at CERN.

GROWING DEMAND FOR NEW MEDICAL ISOTOPES AND RADIOPHARMACEUTICALS

Nuclear medicine is currently experiencing a renaissance with new radiopharmaceuticals. These include ones that personalize

“
TRIUMF is a scientific jewel in the crown of Canada, giving our country an important place at the table in the global network of discovery and innovation.

”
**MS. KARIMAH ES SABAR,
CEO AND PARTNER,
QUARK VENTURE INC.**

“

The 40-year partnership with TRIUMF has been rewarding in providing medical isotopes for the health and well-being of humankind. The products produced by the partnership touch the lives of millions of people. We look forward to many more years of the successful relationship.

”

**JERRY PORTER,
GENERAL MANAGER (CANADA)
BWXT (FORMERLY NORDION INC.)**

medicine, combining specific targeted therapies in response to targeted diagnostic tests. With IAMI starting operation in 2020, TRIUMF will have the capacity and capability to help meet the growing demand for new medical isotopes for new radiopharmaceuticals—from laboratory development through preclinical studies all the way to human trials. IAMI will do more than simply reinforce our current nuclear medicine program, which focuses on imaging of neurological disease and cancer. It will transform it into a national and international hub for radioisotope technologies and applications, and establish TRIUMF as a leader in all things isotope.

IAMI will foster innovation in a wide range of fields, including radiopharmaceutical development, accelerator research, and advanced isotope development. These developments will open new opportunities for targeted cancer therapy using alpha and Auger emitters as well as imaging techniques for the acceleration of drug development.

IAMI is primed to produce and develop isotopes with life-saving applications and the potential to dramatically advance life sciences and health research. As a result, TRIUMF, the Province of British Columbia, and Canada will remain at the leading edge of research and development of isotopes applied to life sciences and nuclear medicine.

RACE TO DEVELOP NEXT-GENERATION QUANTUM MATERIALS

Quantum materials and technologies are key elements in emerging global trends in communication, security, sensing, and computing. They are the essential building blocks for next-generation superconductors, spintronics, sensors, transducers for quantum communication, and quantum computers with almost unlimited application potential.

TRIUMF's facilities—unique in North America—are used to understand underlying material structures and emerging quantum phenomena, knowledge that is essential to developing new functional materials and applications. Our facilities are also used to study next-generation battery materials, the role of trace metals in biomolecules, and the chemistry in advanced nuclear reactors.

As a leader in advanced characterization techniques, TRIUMF's Centre for Molecular and Materials Science (CMMS) is poised to play an important role in the development of next-generation quantum materials, enhanced through a new partnership with the Canada First Research Excellence Fund (CFREF)-supported Stewart Blusson Quantum Matter Institute at UBC. We are also part of a nationwide proposal to coordinate the use of complementary capabilities and competencies at the quantum-oriented CFREF centres at UBC, Université de Sherbrooke, and University of Waterloo, as well as at the NRC, CLS, and TRIUMF.

The completion of ARIEL, and the planned renewal of the driver beamline for our muon-based CMMS program, will dramatically increase our capabilities for making major discoveries and for driving innovation in all things quantum.

IMPERATIVE TO EXPLOIT ADVANCES IN DATA SCIENCE AND COMPUTING

Scientific computing is a critical component of much of the work that takes place at TRIUMF and our partner facilities around the world, particularly in high-energy physics experiments. In recent years, the amount of data produced has increased exponentially at research facilities and private businesses alike. Rapid advances in large-scale computing, big data, machine learning, and quantum computing are starting to have serious implications for how we do our work; it is imperative that we remain at the forefront of this fast-changing field. Using our experience in advanced high-performance computing and the application of machine learning algorithms gained through our work on CERN's ATLAS experiment, we can play a critical role in advancing data science capabilities and techniques across disciplines, while at the same time teasing out new discoveries.

Recent advances in theoretical methods and in computing power, in particular supercomputers, have enabled nuclear physicists to confront theory with data and calculate, from first principles properties of heavy nuclei once thought impossible to reach. This has enriched both theory and experiment at facilities such as ISAC and ARIEL. The emergence of usable quantum computers has the potential to take these calculations to a new level with quantum computer-based nuclear science.

This is but one example of how a deeper exposure to quantum computing could enrich our science program, given the extensive national and international networks we have established. We recently signed a cooperative agreement with Germany's Helmholtz Association, along with Canadian companies D-Wave Systems Inc. and 1QBit, to jointly establish Canadian and German quantum computing and machine learning networks. Our aim is to facilitate national and international collaboration in the use of applied quantum computing and machine learning tools to enhance research across our fields of endeavour. The Canadian quantum computing network is one of the initiatives related to our involvement in Canada's Digital Technology Supercluster.

INSTITUTE FOR ADVANCED MEDICAL ISOTOPES (IAMI)

IAMI is a state-of-the-art facility for research into next-generation, life-saving medical isotopes and radiopharmaceuticals. Located on TRIUMF's campus, it will comprise an integrated series of labs and a TR-24 medical cyclotron, one of the most technologically advanced commercial cyclotrons in the world. IAMI will significantly increase British Columbia's and Canada's capacity for the sustainable and reliable production and distribution of medical isotopes currently critical for Canadian health research and clinical use, including ^{99m}Tc and ^{18}F .

The new institute will also enhance radioisotope and radiopharmaceutical research by bringing together TRIUMF faculty and students with partners from academia, not-for-profits, government, and industry. Similarly, it will synergize the Vancouver region's diverse nuclear medicine sector, acting as a research hub and centrally managing the production of radioisotopes and radiotracers for commerce and clinical research. It will give TRIUMF, UBC, BC Cancer, and others, efficient access to leading-edge expertise, infrastructure, and oversight of accelerator-based isotope research and applications. As a conduit for isotopes using our other accelerators, IAMI will foster innovation in a wide range of fields, including radiopharmaceutical development, accelerator research, and advanced isotope development.

IAMI will secure British Columbia's supply of critical medical isotopes, such as ^{99m}Tc , and act as a back-up producer and supplier of ^{18}F to the BC Cancer. This additional production capacity will accommodate future expansion of its PET camera infrastructure.



OUR PLAN FOR THE NEXT FIVE YEARS

To build on our existing strengths and capitalize on emerging opportunities, our plan for 2020-2025 invests in three critical dimensions:



SCIENCE AND TECHNOLOGY



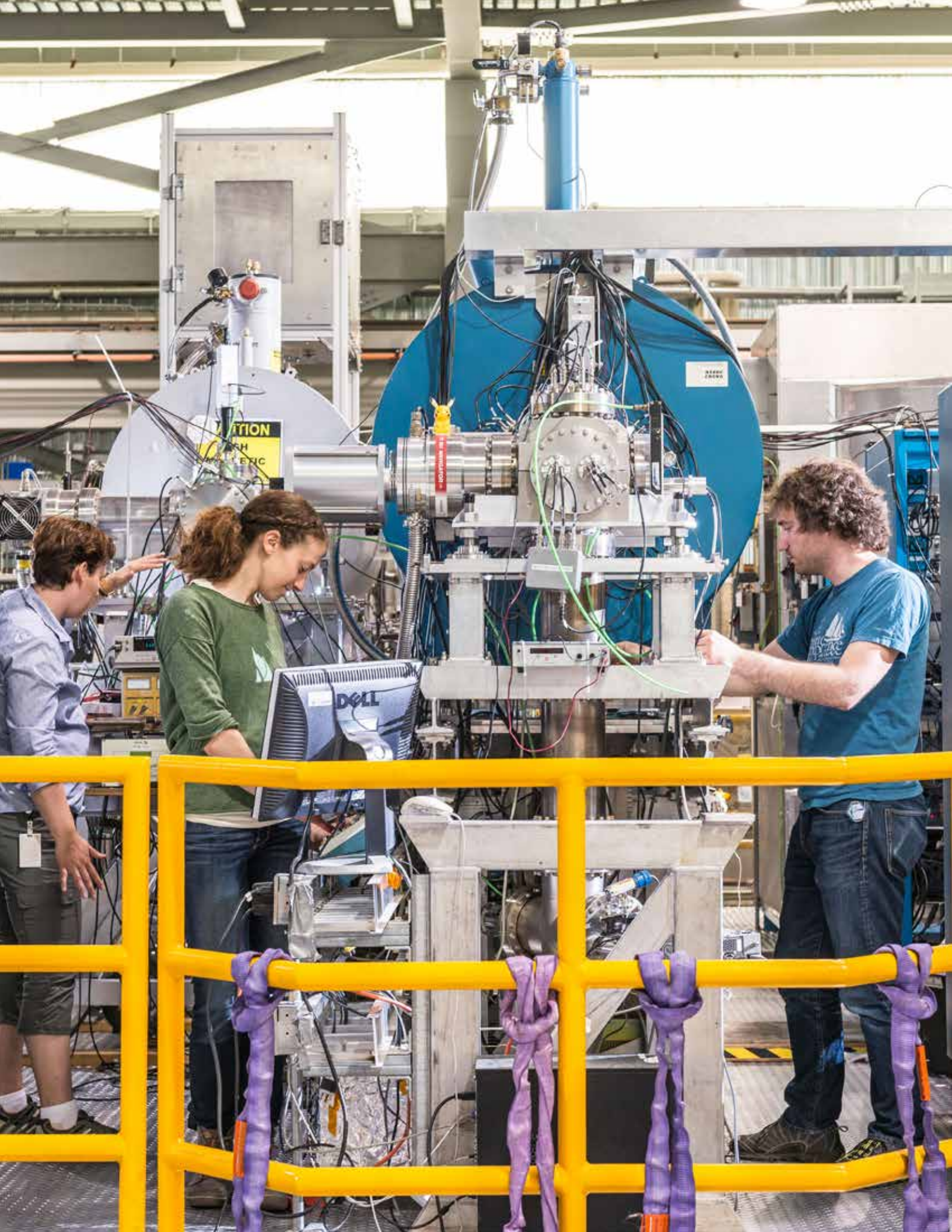
PEOPLE AND SKILLS



INNOVATION AND COLLABORATION

For each dimension, we have established two primary goals, along with a set of strategies that will help us fulfil our vision and increase our impact. Our plan leverages past investments by government and builds on the laboratory's strong brand and global network to deliver a new level of top-tier science, training, and innovation to Canada. The plan also supports our efforts to build a laboratory with a diverse, welcoming, science community and a demonstrated commitment to equity, diversity, and inclusion.

The plan is the result of extensive community consultation. It required hard choices to be made, but the final result is ambitious, achievable, and fully consistent with TRIUMF's vision, mission, and values. It permits full exploitation of our three platforms—ARIEL, IAMI, and TRIUMF Innovations—and will enable us to maximize the value and benefits we deliver to Canada and Canadians over the five-year period and for decades to come.





SCIENCE AND TECHNOLOGY: SEIZING OPPORTUNITY AND EXPANDING FRONTIERS

GOAL 1 Make ground-breaking discoveries across our multidisciplinary research portfolio

OUTCOME Extension of the frontiers of knowledge and global recognition of Canada's contributions to discovery research

Extending the frontiers of knowledge through science is a uniquely human activity, and one that has transformed our world for the better. According to Canada's 2017 Fundamental Science Review, "if there is one lesson that we can confidently take from history, it is that science and inquiry are the foundations of progress in almost every human endeavour."

Canada has a strong reputation for producing breakthrough discovery research, particularly in advancing our understanding of the fundamental particles and forces that have shaped our universe. For more than 50 years, TRIUMF has been a key contributor to Canada's successes on the world stage—driving global advancements in physics through its world-class facilities, talent, and expertise in leading technologies, including accelerators.

In the ever-changing world of science, transformative discoveries often happen at the interface between disciplines. That's why TRIUMF is continuing to build a diverse multidisciplinary science portfolio that provides opportunities for cross-fertilization and collaboration. As an incubator for creative ideas and technologies, we are committed to pursuing discoveries across a range of disciplines, from nuclear and particle physics to the life and materials sciences.

We will achieve this goal by:

- **DISCOVERING HOW STARDUST IS MADE** All life in the visible universe, including us, is made of stardust. Through our world-leading nuclear physics program, we will determine where and how the heavy chemical elements—from iron to uranium—are produced in cataclysmic stellar processes. We will do so by advancing our understanding of atomic nuclei and their role in the evolution of the stars. TRIUMF's Isotope Separator and Accelerator (ISAC) is one of only a few facilities in the world that is capable of such studies. Our results will inform supercomputer simulations of neutron star mergers and star explosions, and enable the interpretation of multi-messenger astronomical observations. The launch of our rare isotope facility, ARIEL, will keep Canada at the forefront of this scientific quest.
- **UNDERSTANDING THE ORIGINS AND EVOLUTION OF THE UNIVERSE** Canada contributes to breakthroughs in understanding the particles and forces that have shaped our universe through TRIUMF's work in global projects. We will harness our expertise and international network to search for physics beyond the Standard

Model through a number of initiatives. For example, we will deliver on Canadian contributions to the ATLAS detector upgrades for the High-Luminosity Large Hadron Collider (HL-LHC) at CERN. We will also seek to discover the nature of dark matter and probe the properties of the elusive particles known as neutrinos. Finally, we will explore the relation between matter and antimatter by playing a leading role in CERN's ALPHA anti-hydrogen experiment and by pushing precision measurements with ultracold neutrons and rare isotopes at TRIUMF.

- **DEVELOPING NEW RADIOPHARMACEUTICALS TO DIAGNOSE AND TREAT DISEASE** Exciting new developments in nuclear medicine hold promise for radically improving the health of Canadians. With the launch of IAMI, our state-of-the-art research facility, we will capitalize on our unique capabilities in the research and development of accelerator-based medical isotopes. These isotopes support imaging and treatment of neurological disease and cancer while illuminating biological processes at the cellular level.
- **DRIVING THE REVOLUTION IN QUANTUM MATERIALS** Our Centre for Molecular and Materials Sciences is one of only a few facilities in the world that use particle beams of muons and rare isotopes to characterize the electronic and magnetic properties of advanced quantum materials under a range of conditions. And, when ARIEL is online, our rare isotope capabilities will be unparalleled. We will renew and enhance our facilities and use them to find new quantum materials to build better batteries, electronic devices, and quantum computers.
- **LEVERAGING OUR STRENGTH IN ACCELERATOR SCIENCE AND DETECTOR TECHNOLOGY** Expanding our capabilities—and Canada's expertise—in our core disciplines requires that we leverage and enhance our competencies in accelerator science and detector technologies. We will secure Canada's leading contributions for next-generation accelerator facilities and large-scale detector systems. Through TRIUMF, Canada will play a key role in HL-LHC at CERN and other major international science projects.
- **APPLYING DATA SCIENCE AND MACHINE LEARNING ACROSS OUR PORTFOLIO** Through our contributions to ATLAS, we have gained experience in high-performance computing and advanced analysis techniques. We will translate this expertise to our work in nuclear physics, accelerator science, and nuclear medicine—enabling new discoveries and innovations. We will enable researchers in our network to run classical and quantum machine learning systems for cutting-edge science applications.

TRIUMF'S RESEARCH ACTIVITIES

Macro to micro: Accelerating discovery and innovation by connecting the study of the vast with the study of the very, very small

Inner Space

Cosmology & Dark Matter

Nuclear Astrophysics

Particle Physics

Electronics & Radiation Testing

Nuclear Physics

Accelerators, Detectors, and Data Sciences

Nuclear Medicine

Molecular & Materials Science

Outer Space



GOAL 2 Strengthen our position as a world-leading particle accelerator centre

OUTCOME Increased capacity for world-class, multidisciplinary research and development in Canada

State-of-the-art infrastructure is the bedrock of cutting-edge research and technology development. It enhances our capacity to perform at world-class levels, and acts as a catalyst for dynamic interactions between disciplines. Improving Canada's performance requires access to leading facilities and infrastructure.

As Canada's particle accelerator centre and a global leader in accelerator science and technology, TRIUMF attracts scientists and users from across Canada and around the world. We excel in building and operating high-performing, unique accelerator systems featuring a wide variety of particle beams—from protons and electrons to rare isotopes and muons. These systems drive multidisciplinary science programs, from nuclear and particle physics and quantum materials to applications in nuclear medicine, telecommunications, and aerospace.

40

The launch of two new platforms will increase our capacity to make breakthrough discoveries and deliver innovative solutions. ARIEL and IAMI will make Canada a destination of choice for international scientists and a hub for exciting new multidisciplinary programs and experiments. Refurbishment of the Meson Hall beamline will ensure sustainable and reliable performance, as well as open up new opportunities in our materials science program. Our state-of-the-art infrastructure will be underpinned by a refreshed governance model and an inclusive organizational culture.

We will achieve this goal by:

- **UNLEASHING THE FULL POWER OF OUR ACCELERATOR COMPLEX** Our accelerator systems are already among the most advanced in the world. With the launch of ARIEL, we will become the world's most powerful multi-user rare isotope beam facility and one of the top facilities for accelerator science. Showcasing a made-in-Canada ultra-high-power superconducting electron linear accelerator and leveraging TRIUMF's original cyclotron—the largest of its kind in the world—ARIEL will triple our rare isotope beam capacity. This means we will produce more exotic isotopes for science, medicine, and business. Increased production will boost access and support for a variety of projects in particle and nuclear physics, life sciences, and quantum materials—projects that will expand our horizon of knowledge.

■ **ESTABLISHING TRIUMF AS A GLOBAL CENTRE FOR NUCLEAR MEDICINE**

Building on our expertise in developing and producing accelerator-based isotopes, we will launch IAMI with two regional partners: UBC and the BC Cancer. The state-of-the-art facility will be a global hub for developing, producing, and commercializing life-saving medical isotopes, as well as new radiopharmaceuticals for imaging and treating diseases. This new centre will place Canada at the leading edge of research and development in nuclear medicine while, at the same time, improving the health of Canadians and securing the nation's isotope supply.

- **INVESTING IN STATE-OF-THE-ART LABORATORY INFRASTRUCTURE** To fully harness the enhanced capabilities that ARIEL and IAMI can deliver, we will maintain and upgrade our laboratory infrastructure and accelerator facility. We will optimize safety, reliability, and effectiveness using the latest technologies, practices, and processes. Refurbishing the Meson Hall proton beamline using robotic technologies will strengthen our materials science program, advance the Ultracold Neutron Facility, and increase commercial use of our high-energy protons for irradiation services and the production of therapeutic isotopes. Finally, we will seek funding for new buildings to expand our office and laboratory space, including space to welcome the scientific community and engage the general public.

■ **ATTRACTING THE BEST SCIENTISTS TO OUR WORLD-CLASS FACILITIES**

Improving our facilities and adding new infrastructure will help make TRIUMF a preferred destination for the world's best scientists and commercial users. We will attract and engage them by ensuring our accelerators are reliable, involving them in developing new capabilities, and providing technical and scientific support for non-experts. By bringing people together from a wide range of disciplines, we will create an even more intellectually stimulating environment, which, in turn, will generate world-leading discoveries and innovations.

- **BUILDING A MODERN AND INCLUSIVE ORGANIZATION** With inclusion and diversity explicitly called out in our values, we will continue to weave them into the very fabric of our laboratory. As members of a diverse, innovative science community, we will challenge one another to become thoughtful, engaged citizens and leaders. To better achieve our goals, we will deploy a flexible organizational structure to develop and manage our facilities and people efficiently, with clarity and purpose, and guided by opportunity and risk analysis. A continuous improvement culture will transform TRIUMF into a learning organization with a mature safety culture and highly engaged people focused on finding creative solutions to problems. TRIUMF will be fit for the future with modern, inclusive business practices and a new governance model that features a refreshed corporate structure with an effective skills-based board.



PEOPLE AND SKILLS: DEVELOPING TALENT, INCREASING ACCESS AND EQUITY

GOAL 3 Become a hub for interdisciplinary education and training

OUTCOME A new generation of highly-skilled Canadians ready to compete in the knowledge and innovation economy

To thrive and grow in the new knowledge economy, Canada must continue to develop and attract a well-educated, highly-skilled, and flexible workforce. Solving society's most challenging problems requires the work of diverse and multidisciplinary teams of scientists, engineers, technicians, tradespeople, and other workers with broad sets of skills. Global competitiveness and national prosperity also depend on giving all Canadians a fair chance to succeed. Canada is a nation rich in diversity; the Inclusive Innovation Agenda places inclusion and diversity front and centre of government programs and policies.

At TRIUMF, we recognize that equity, diversity and inclusion are integral to excellence and enhance our ability to accomplish our mission. They are ingrained in everything we do. Going forward, we are committed to increasing our efforts to broaden and deepen Canada's talent pool, with a strong focus on strengthening the STEM pipeline and increasing access for our diverse population. Our world-class, multidisciplinary research programs provide people with the specialized, and real-life, skills needed to drive and adapt to change—and to succeed in the knowledge economy. We target early-career researchers in particular to promote diversity in the workforce of the future. We complement their post-secondary education with unique training opportunities in research, technologies, entrepreneurship, and commercialization.

We will achieve this goal by:

- **FOSTERING A CULTURE THAT EMBRACES EQUITY, DIVERSITY, AND INCLUSION** Research shows that successful science and innovation requires the collaborative efforts of diverse individuals with diverse skills. Therefore, we will seek to build a TRIUMF with as many types of talented people as possible, working together in a supportive, collaborative environment. We will make diversity and inclusion a priority in our organization, from our hiring and operating practices to our training programs to our governance. Our focus will be on women, indigenous people, and other under-represented groups in STEM. We will set targets and review them regularly, to keep us on track, accountable—and equitable.
- **INCREASING EARLY-CAREER RESEARCH OPPORTUNITIES** We already attract some of the best young researchers from around the world and train them for future careers in research. We give them experience working on cutting-edge science in international, multidisciplinary teams. We equip them with the skills they need to use the latest technologies and tools. Going forward, we will prepare them for careers in the private sector as well as in research, by offering additional training in

entrepreneurship and commercialization, communications, project management, and data science. We will expand our work experience program to welcome more undergraduate co-op students from colleges, polytechnics, and universities, offer more places for international students, and increase the number of inter- and multi-disciplinary opportunities, including engineering, communications, and business. We will expand our formal Ph.D. program in accelerator science with the University of Victoria to support young researchers interested in advancing accelerator technologies. We will also create strategic postdoctoral fellowships for women and other under-represented groups in partnership with like-minded institutions.

- **EXPANDING PROFESSIONAL DEVELOPMENT TRAINING** We recognize that people are our most valuable asset. That's why we are committed to increasing and improving professional development efforts, ranging from science and engineering to the trades and business. A new training program will offer professional development options and personalized plans for all of our graduate students and post-doctoral fellows. For our staff, we will create individual development plans with career paths in mind, including external training opportunities. We will also launch new programs that will build staff diversity through formal apprenticeships in a variety of Red Seal trades as well as Engineers-in-Training.

- **TRAINING STUDENTS ACROSS OUR NETWORK** We will develop a range of training options for university, college, and polytechnic students at all levels across our network in our core scientific disciplines. Our new training platform will combine distance-learning opportunities that are accessible to everyone with hands-on laboratory experiences on-site at TRIUMF. For example, we will offer lectures, summer courses and schools, workshops, international guest lectures, and intensive practical training in detector and instrumentation technologies.





GOAL 4 Inspire Canadians to discover and innovate

OUTCOME Greater access to STEM opportunities for all Canadians

Canada's economic future depends on a myriad of brilliant, curious minds trained in the science, technology, engineering, and mathematics (STEM) disciplines. This means we must inspire, engage, and empower young Canadians—individuals from all backgrounds and communities—today!

The imperative to create knowledge and opportunity for all is embedded in TRIUMF's mission: discover and innovate, inspire and educate, creating knowledge and opportunity for all. Through public engagement, outreach, and storytelling, we connect with people across the country. We stimulate curiosity about the natural world and the power of technology, fostering creativity, inquiry, and scientific literacy. In this way, we can help prepare the next generation of problem-solvers, critical thinkers, discoverers, and innovators.

We will achieve this goal by:

■ EXTENDING PUBLIC ENGAGEMENT TO COMMUNITIES ACROSS CANADA

To encourage more Canadians, especially young people from under-represented groups and remote communities, to be excited about science, and eager to learn STEM skills, we must increase and diversify our efforts to reach them. TRIUMF will provide professional development opportunities for teachers, educators, journalists, and science communicators. We will collaborate with our network to gather, develop, and share innovative resources and bring outreach programs to communities across the country. We will also leverage the latest tools and technologies to share the wonders of STEM through virtual experiences, especially for schoolchildren. We will offer everyone in our organization the chance to develop their public engagement and outreach skills, for example, through the TRIUMF Ambassador Program. We will reinvigorate our arts and culture program to connect more people with STEM, particularly those who do not think of themselves as science enthusiasts.

■ COMMUNICATING THE VALUE OF SCIENCE, TECHNOLOGY, AND INNOVATION

TRIUMF has an exciting story to tell and a desire to inspire Canadians. We will show how our ground-breaking discoveries help answer some of the most fascinating scientific questions, and how our applications and innovations contribute to Canada's progress and prosperity. Through collaborations with our member universities, the NRC, granting councils, CFI, international partners, and industry, we will amplify our voices to tell powerful Canadian stories in science, technology, and innovation. Together, we will promote and celebrate our shared successes through common digital communications resources and tools, and deliver effective communications, public relations, and social media campaigns.



INNOVATION AND COLLABORATION: CONNECTING SCIENCE TO SOCIETY AND CANADA TO THE WORLD

GOAL 5 Translate science and technology into innovation

OUTCOME New game-changing technologies that support business-led innovation and improve the lives of Canadians

Canada's high standard of living is increasingly dependent upon the knowledge economy. At TRIUMF we are increasing our efforts to drive and support innovation and commercialization. In particular, TRIUMF Innovations will translate our world-leading discoveries into new technologies and applications—applications that will help solve issues of national importance and generate social and economic benefits for Canadians as quickly as possible.

We recognize that successful commercialization can take many forms. Our flexible model and extensive network will allow us to work with a range of partners across the country. Together, we will explore creative ways to identify game-changing technologies across multiple verticals, transform them into innovative products, and bring them to market. Our long-term goal is to grow TRIUMF Innovations into a national commercialization centre.

We will achieve this goal by:

- **COMMERCIALIZING TECHNOLOGIES DEVELOPED AT TRIUMF** We will collaborate with industry partners to bring new technologies to market, such as new cancer therapies with pharmaceutical companies or new green technologies with mining companies. We will create intellectual property for promising technologies and license it to companies in return for milestone payments, royalties, or equity. Where appropriate, we will create new start-up companies to commercialize technologies that have a sustainable competitive advantage or need significant investment to bring to market. Ultimately, our dream is to create a large-scale, high-impact Innovation Park to drive the development and commercialization of disruptive technologies that cross a number of disciplines. We will work with partners in academia, industry, and government to explore concepts for planning and building such a facility.
- **HARNESSING OUR TECHNOLOGIES TO SOLVE REAL-WORLD PROBLEMS** We target and address real-world challenges in a number of ways, from enabling industry to "de-risk" technologies on the path to commercialization to helping the government tackle national issues, such as the medical isotope crisis. Going forward, we will explore new opportunities and expand current industrial partnerships, particularly in radiation testing at our irradiation facility and in the production of medical isotopes at our new IAMI facility. We will also establish new partnerships in priority areas, such as using PET medical isotope technologies to improve efficiency in mining, clean energy, pulp and paper, and food

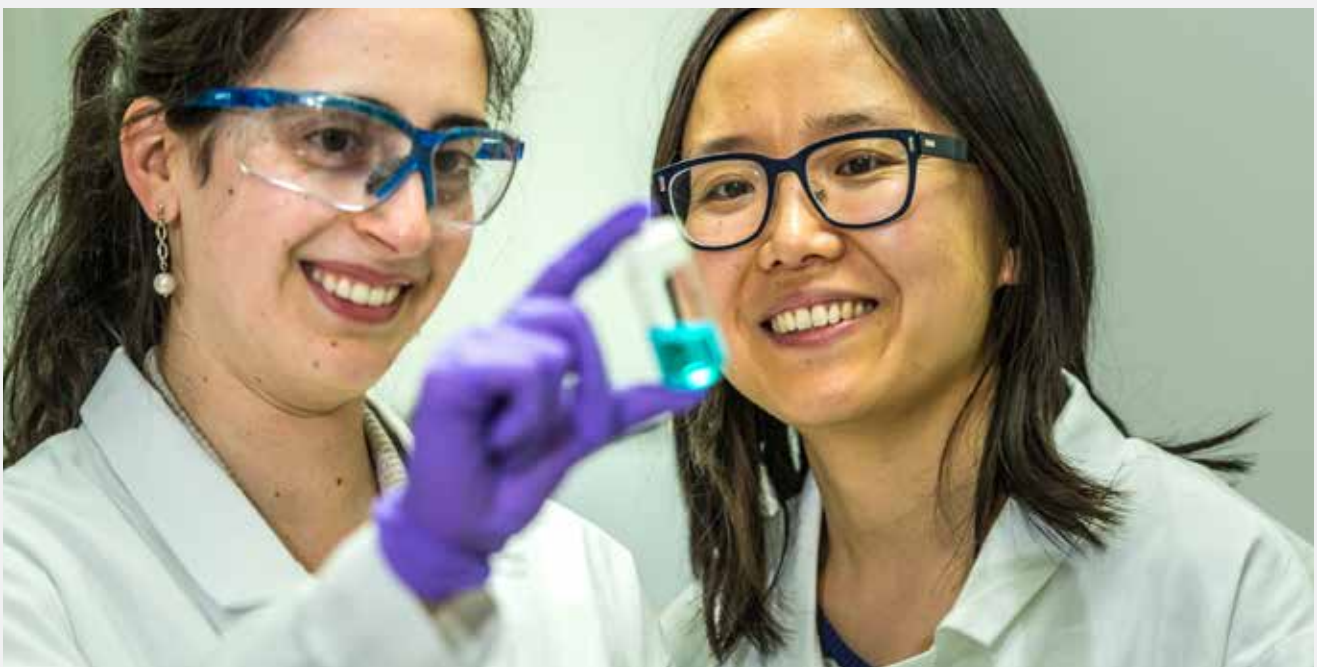
manufacturing. The revenue generated will provide long-term sustainability for TRIUMF and TRIUMF Innovations.

■ **CONNECTING OUR NETWORK WITH OPPORTUNITIES IN THE PRIVATE SECTOR**

We have a long history of working effectively with both academic and industry partners. Going forward, we will leverage our network to exploit strategic opportunities with the private sector. For example, we will seek to host a new Canadian quantum computing network to give researchers across the country access to world-leading tools. And we will create a national data science training program to help people in our network find jobs in industry. We will also connect researchers at our member universities to potential investors and development partners to accelerate the path from technology development to commercialization.

■ **TRAINING THE NEXT GENERATION OF SCIENTIST-ENTREPRENEURS**

Founders of successful, science-based start-up companies understand technology and are passionate about how it can be used. They possess skills and expertise in business and commercialization and can access experienced mentors who bring advice and a network of investors and partners. To encourage entrepreneurship in our R&D community, we will launch a commercialization/entrepreneurship training program in partnership with the UBC Sauder School of Business. The program will match entrepreneurs-in-training with industry-based mentors. We will also establish an Entrepreneurs-in-Residence program to help us identify strategic commercialization opportunities, and work with our researchers and other partners to build companies around those technologies.





GOAL 6 Drive national and international collaboration in research, technology, and innovation

OUTCOME A stronger, more competitive Canada in discovery and innovation

Partnerships and collaboration are catalysts for scientific discovery and technological innovation. In fact, as science becomes more complex, true progress requires the combined talents and resources of multiple actors. To compete effectively on a global scale in discovery research and innovation, Canada must consolidate its expertise, facilities, and resources to build critical mass in strategic fields.

Since innovation can occur anywhere, deriving social and economic benefit from scientific breakthroughs depends on swift action and deep understanding. This can only be achieved if Canada is an integrated and valuable partner in international science collaborations. Building bridges of collaboration and cooperation is key to mobilizing knowledge and enhancing competitiveness.

52

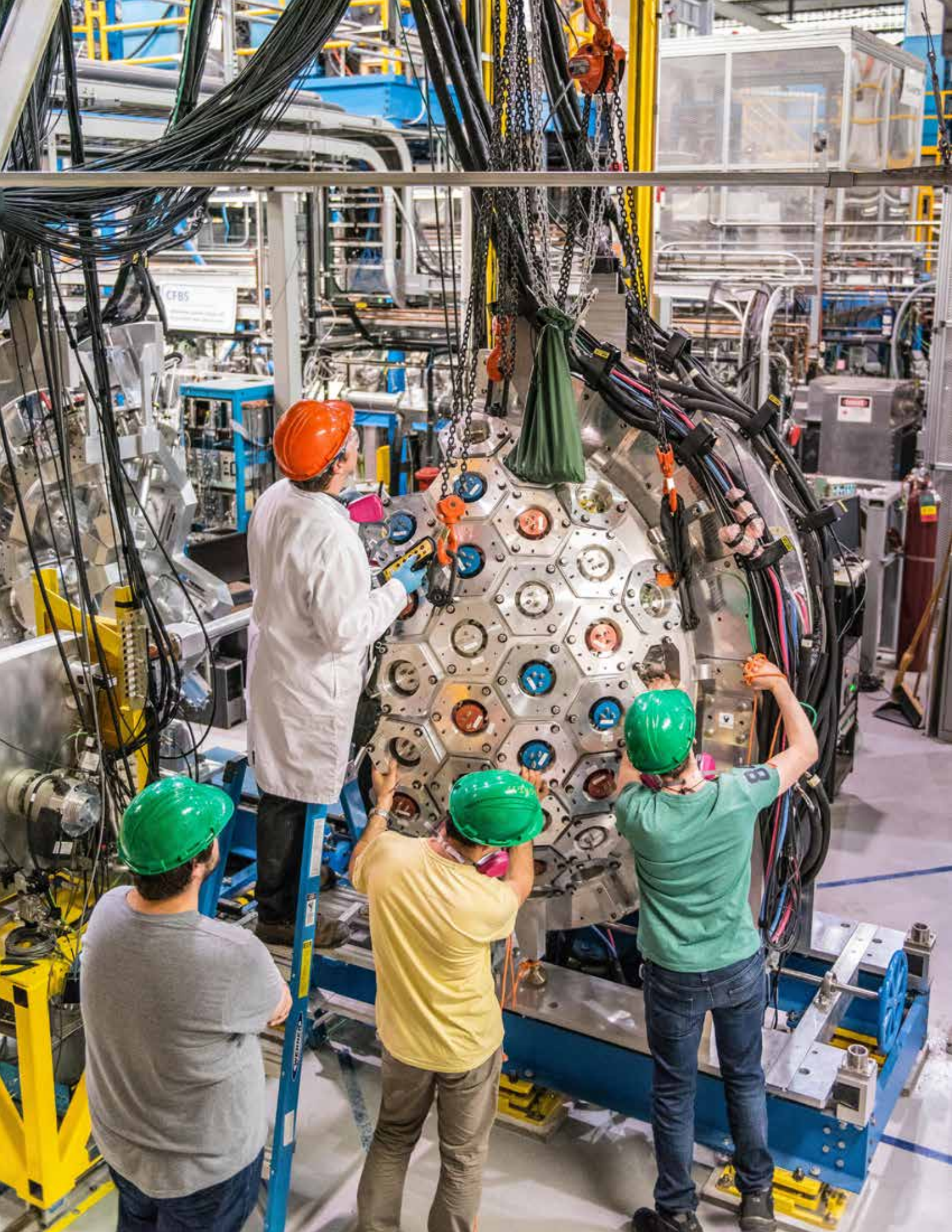
TRIUMF operates in an ever-expanding network of academic, government, and industry partners across the country and around the world. As an internationally recognized brand for excellence, we are committed to harnessing the power of our connectivity to drive Canadian growth and prosperity.

We will achieve this goal by:

■ **LEVERAGING OUR NETWORK TO CREATE NEW COLLABORATION OPPORTUNITIES**

We recognize that the strength and breadth of our network, both in Canada and abroad, provides fertile ground for cooperation and collaboration, in research, innovation, commercialization, and training. Building on our successes in nuclear and particle physics, we will launch collaborative research initiatives in detector technologies, life sciences, materials science, and engineering. Together with our member universities and other partners, including NRC, SNOLAB, Perimeter Institute, and industry, we will focus our efforts in areas of Canadian strength aligned with our mission. For example, we will join with others to advance research in quantum materials and technologies through Canada First Research Excellence Fund (CFREF) initiatives.

- #### ■ **PROVIDING A GATEWAY TO INTERNATIONAL BIG SCIENCE PROJECTS**
- Our cutting-edge expertise and infrastructure have made us a conduit for Canadian cooperation in international science, creating exceptional leadership opportunities for our members in game-changing research. At home, we will continue to work with international partners at our Ultracold Neutron Facility and to advance dark matter and neutrino experiments at SNOLAB. Internationally, we will continue our leading



efforts in CERN projects such as ATLAS at the HL-LHC and ALPHA, and make key contributions to next-generation, long-baseline neutrino projects. We will also pursue new collaborations on future cutting-edge experiments and accelerator facilities, at home and abroad.

- **ADVANCING INTERNATIONAL COOPERATION IN SCIENCE AND RESEARCH** As a trusted ambassador for Canada, TRIUMF's many international cooperation agreements have elevated the national profile and reputation in science and research. We will strengthen existing alliances through new initiatives, such as high-power targets for isotope production at CERN and the Canadian contribution to the HL-LHC. We will also formalize cooperation agreements with new international partners, similar to our most recent agreement with the Helmholtz Association in Germany, in quantum computing and big data. In addition, we will fortify our network by recruiting more Canadian universities as full members of TRIUMF, and by welcoming our first international associate members.





FINANCING OUR PLAN

The comprehensive plan outlined here covers our entire science program, as well as development of our infrastructure, our organization, and our skills training and outreach programs. To deliver on this ambitious plan, we require \$320 million in support over five years for our core operations from the Government of Canada through our contribution agreement with the National Research Council Canada (NRC). We assume that, together with our partners, we will continue to be successful in obtaining funding from the Canada Foundation for Innovation (CFI) and provincial agencies for capital investments into infrastructure, as well as funding from the Tri-Council agencies for research support. The commercial revenue we generate will provide essential additional support for our program, as well as all the commercialization and technology transfer activities of TRIUMF Innovations. We will also pursue philanthropic and other support for a new main building.

MEASURING SUCCESS

OUTCOME

SAMPLE PERFORMANCE MEASURES

Extension of the frontiers of knowledge and global recognition of Canada's leading contributions to discovery research

- Major scientific results
- High-impact publications
- New radiopharmaceuticals
- Awards for TRIUMF research
- Canadian contributions to international projects
- Demand for TRIUMF beams and technical services

Increased capacity for world-class, multidisciplinary research and development in Canada

- Hours of ARIEL isotope beams in 2025
- Accelerator performance
- Quantity and variety of medical isotopes produced
- Number of scientific visitors and commercial users
- Equity, diversity, and inclusion metrics
- Employee and user satisfaction
- Operational savings through process improvements

A new generation of highly skilled Canadians ready to compete in the knowledge and innovation economy

- Numbers of students trained
- Career outcomes tracked
- Undergraduate program expanded
- Interdisciplinary programs developed
- Apprenticeship and Engineers-in-Training programs established
- Professional development programs established
- Student satisfaction and EDI metrics for each program

OUTCOME

SAMPLE PERFORMANCE MEASURES

Greater access to STEM opportunities for all Canadians

- Public engagement and outreach programming delivered outside Vancouver
- Public engagement and outreach programming delivered to under-represented communities
- Partnerships and collaborations that create more pathways to access STEM opportunities
- Professional development programs for educators, journalists and communicators
- Metrics to measure strength of TRIUMF's, our partners', and Canada's brand

New game-changing technologies that support business-led innovation and improve the lives of Canadians

- Start-up companies created
- Licensing deals, invention disclosures, and patents filed
- Annual commercial revenue from services, milestones, licenses, equity in start-ups
- Private sector investments/funding in spin-off companies and TRIUMF
- Number of industry partnerships
- Number of trainees in science-based entrepreneurship and commercialization program

A stronger, more competitive Canada in discovery and innovation

- Size of member network
- Collaborations with domestic and international partners
- Canadian participation enabled by TRIUMF in international projects
- International investments into TRIUMF's science program
- Size of user network



4004 Wesbrook Mall
Vancouver BC V6T 2A3 Canada
t 604.222.1047

Learn more about
our Five-Year Plan 2020-2025

<https://fiveyearplan.triumf.ca>

www.triumf.ca
[@TRIUMFLab](https://twitter.com/TRIUMFLab)



**Discovery,
accelerated**

