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TRIUMF 20 Year Vision

Particle Physics Topical Group

5-page summary



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TRIUMF Twenty-Year Vision Particle Physics 5-Page Summary

The Particle Physics Topical Group engaged with the community and solicited feedback through multiple channels. These included input through the ThoughtExchange platform, a dedicated survey concentrating on Particle Physics questions, direct discussion with particle physicists at TRIUMF, and interviews with key community members including Joanne Hewett (SLAC chief research officer), Young Kee-Kim (U Chicago, chair of Snowmass process), Klaus Kirch (PSI head of particle physics section), Arthur McDonald (Nobel Laureate, Queen's U), Robert Myers (Perimeter Director), Tony Noble (Queen's U and Director McDonald Institute), Adam Ritz (UVic, IPP and LRP chair), Michael Roney (UVic and IPP Director), and Brigitte Vachon (McGill and Canadian Representative for European Particle Physics Strategy, LRP chair). This report reflects the input received through these various channels.

1. What is TRIUMF today? What are its key advantages for the future?

- TRIUMF is a leading international science laboratory and a central hub for Canada in subatomic physics. It has achieved and maintains this status by:
 - Focusing strongly on knowledge-driven fundamental research.
 - Driving new discoveries in particle physics experiment and theory.
 - Inspiring and training the next generation of intellectual leaders through its unique student programs and its collaboration with Canadian member universities and international partners.
 - Enabling Canadian participation in international collaborations through scientific advances and leadership, technical support, advanced computing, and direct in-kind contributions to accelerator and detector components.
 - Providing accelerators, facilities, and technical expertise to the Canadian community beyond the scope of what any single university can support.
 - Using this infrastructure to host experiments and theory programs on site.
 - Applying these discoveries to societal challenges.

- TRIUMF has many distinct advantages that will enable its continued leadership:
 - TRIUMF has developed unique and specialized expertise in scientific and technical areas that will be essential to future research projects.
 - The lab occupies a unique position in the Canadian physics community through its relationships and collaborations with its member universities.
 - TRIUMF plays a key role in many international collaborations and has close ties with other subatomic physics laboratories.
 - TRIUMF's mid-sized structure and relatively flat management hierarchy allows it to respond quickly to new research directions and supports a high-level of cross-fertilization across disciplines, while also being large enough to act as a Canadian hub in international projects.
 - Close working relationships between scientists, engineers, and technicians on staff at TRIUMF permit advances in detector development, electronics, data acquisition, precision assembly, scientific computing, and data science without much bureaucratic overhead.

- Expertise in accelerator physics and related technologies enables both in-kind contributions to international projects as well as world-leading contributions to particle and nuclear experiments and the local life science program.
- Relationships with member universities and other national laboratories together with local expertise and facilities allow TRIUMF to provide unique student and postdoctoral researcher development programs and to run international summer schools such as the TRIUMF Summer Institute, GRIDS, and TRISEP.

2. What trends and changes will shape TRIUMF's future?

- New discoveries in fundamental physics will guide future research directions.
- Participation in future particle colliders at the energy frontier will be subject to global decisions on which machines to pursue since the size and cost of these machines requires international collaboration. TRIUMF's experience in collider physics puts it in an excellent position to lead the Canadian contributions to any such future collider.
- Global decisions on future dark matter and neutrino experiments, and which of these projects are to be located in Canada, will impact research directions at TRIUMF.
- Advances in machine learning and quantum computing methods will lead to enhanced sensitivity in experimental analysis techniques, improved theoretical calculations, and provide new opportunities for HQP training and connections beyond academia.
- New techniques in quantum sensing and atomic measurement together with ARIEL will provide opportunities to expand the on-site program in particle physics.
- Increased understanding of equity, diversity, and inclusion will lead to a better working environment and a TRIUMF that is more representative of the people of Canada.
- Lessons learned from the pandemic will enable better off-site collaboration and international collaboration and may permit infrastructure and organizational changes.
- The [Naylor Report](#) promotes investigator-led research, training support, and facilities support, and may help TRIUMF increase its level of base funding.
- TRIUMF will be influenced by external factors, but it is ultimately up to the lab and its community to chart its future course. New trends should be examined critically to ensure that they provide increased scientific opportunities.

3. What will TRIUMF be? What role will it have in Canada's S&T ecosystem?

- TRIUMF will be a site hosting research, technical, experimental and user facilities, as well as being a national hub for fundamental and accelerator-based science.
- Growing and nurturing long-term expertise in these fields is difficult for universities and TRIUMF can be a national resource by creating dedicated centers which will develop a strong on-site research and development programme that can support a long-term vision and be flexible enough to develop new expertise in an evolving environment.
- We consider establishing the following R&D centres in their own right
 - A detector development center - broad with a focus on future technologies
 - An accelerator platform - broad research program for future technologies
 - A general computing facility - managed on-site for high-level computing needs across Canada
- Strong R&D centers are necessary to support fundamental research on-site, to support Canadian universities needs and to allow Canadian participation in large international

projects. Strong general R&D centers would also “naturally” foster enhanced technology transfer and provide larger immediate societal impact.

- TRIUMF will deepen connections with its member universities through joint faculty, engineering and technical positions as well as a flourishing student program.
- A transparent and well-defined process will allow member universities and users gain access to these expanded capabilities by defining quotas for external requests to be able to fulfill the universities’ needs fairly while having secured resources for pursuing the laboratory fundamental science programme. It will enable TRIUMF to have the resources and scale to imagine and develop the “next big thing” for Canada.

4. What will TRIUMF have accomplished?

- TRIUMF will have played a key role in the international energy frontier program through major analysis, hardware and operations contributions to the HL-LHC, and will be leading the Canadian scientific and accelerator efforts for the next future collider.
- TRIUMF will have led new discoveries in neutrino physics through measurements of neutrino CP violation at HyperK, tests of neutrinoless beta decay with nEXO, and measurements of astrophysical neutrinos with P-ONE.
- TRIUMF will have pioneered new precision techniques allowing for unprecedented measurements of antimatter at ALPHA and beyond, world-leading tests of the neutron electric dipole moment and lifetime with the UCN facility.
- TRIUMF will have made essential detector and analysis contributions to the search for dark matter at SNOLAB through SuperCDMS, SBC, and DEAP, and will have developed new detector technology needed to test sub-GeV dark matter as well as enable the large scale high-mass ARGO detector.
- TRIUMF will have developed new on-site particle physics experiments based on TRIUMF beams such as PIENUX, DarkLight at ARIEL and its extensions, as well as searches for new ultra-light fundamental phenomena using atomic methods.
- TRIUMF will be a premier destination for the education and training of Canadian and international particle physicists. The vibrant local environment, with experts in conversation across a variety of fields and expertise, in experiment and in theory, will be a unique environment to host workshops, conferences and meetings.
- People trained at TRIUMF will have moved throughout Canada and the world and will be leaders of the next generation of scientists and innovators.
- TRIUMF will develop programs to support its members, such as accessible housing, transportation, and daycare, allowing it to attract a diverse group of highly talented individuals that will lead the lab into the future.
- TRIUMF will inspire Canadians from all walks of life by demonstrating that science is for everyone through a vibrant outreach program.

5. What will TRIUMF be doing? What will it not be doing?

- It is essential that TRIUMF continue to focus on knowledge driven scientific research with particle physics as one of its central pillars. This research is the foundation on which the rest of the laboratories activities in science and innovation are built on and one of the highest priorities of our member universities for what TRIUMF should do.

- Future progress in many areas of particle physics will rely on new developments in detector and accelerator technology. TRIUMF has important resources and experience in these fields and should expand its capabilities further.
- The activities of TRIUMF in particle physics should be driven by the pursuit of answering the big open questions in our field. This means continuing our strong pursuit in international collaborations but also expanding our local program in particle physics. TRIUMF should be both bold and flexible and ready to adapt its program in the event of a major new discovery and emerging new research directions.
- International programs:
 - TRIUMF's involvement at the LHC will transition to a new energy-frontier collider such as the International Linear or a Future Circular Collider.
 - The current involvement on T2K will transition to HyperK and beyond.
 - Precision and intensity-based experiments such as ALPHA and NA62 will evolve into new programs at CERN and elsewhere.
 - TRIUMF will continue to support these programs with local infrastructure through detector and accelerator development and construction as well as advances in theoretical, analysis, and computational methods.
- National programs:
 - Dark matter searches at SNOLAB such as SuperCDMS and DEAP will wrap up, and TRIUMF will continue on new experiments searching for low mass dark matter with novel detector technologies as well as higher masses with ARGONIE.
 - Searches for neutrinoless double beta decay will continue at SNOLAB supported by TRIUMF scientific leadership and technical contributions.
 - TRIUMF will continue to collaborate with the Perimeter Institute and SNOLAB on scientific programs and exchanges as well as on the training of HQP.
 - Detector R&D at TRIUMF will create new tools for discovery.
 - Accelerator research and development at TRIUMF will be essential to future research at the energy and intensity frontiers.
- Local programs:
 - TRIUMF will expand its local particle physics program.
 - In the near/intermediate term, TRIUMF will develop and support a UCN user facility and explore new programs such as DarkLight at ARIEL, PIENUX, and P-ONE.
 - Over the longer term, the lab could expand into a range of quantum sensing experiments such as atomic interferometry (example Fermilab's MAGIS), the use of cavities to detect dark matter (example UW's ADMX), and other possibilities studied in the Developing New Directions program that could include non-accelerator-based approaches if the science case is strong and supported by the community. A successful example of a laboratory expansion in this direction is the DESY Dark Sector program (ALPS, IAXO, MADMAX).
- TRIUMF will continue and expand its training of HQP by making full use of the unique facilities and connections that have developed from its scientific pursuits.
- TRIUMF will expand its engagement activities and share its scientific pursuits with Canada and the world:
 - Research that seeks to uncover and understand the fundamental building blocks of the universe is extremely appealing to the general public because of its potential to

answer deep questions about the ultimate nature of the cosmos and reality, as well as the cutting-edge technology required by this work.

- Research projects that take place in Canada are particularly enticing to Canadians for their potential to answer big questions right in our own backyard.
- The Perimeter Institute has done an excellent job at connecting with the general public through its promotion and outreach based on its fundamental (theoretical) research. TRIUMF should expand its collaboration with Science World and other science museums in the country.

6. What will TRIUMF look like? Will there be more than one site? What will its organization and community look like?

- TRIUMF needs to modernize its campus and use its limited space more efficiently
 - Larger, modern multi-story buildings will alleviate laboratory, office and meeting space crunch and provide a stimulating and creative research environment with engaging meeting and outreach components
- TRIUMF can evolve into a facility with national laboratory status, removing the classification as a “sunset lab” with a limited timeline. The national facilities that can be hosted by TRIUMF include a detector development center, an accelerator platform for research and beam delivery (including beams for medical radiation therapy) and a national computing and data science center.
- Additionally, a new site would allow further expansion and if it were in the Eastern part of Canada this would alleviate the perception that TRIUMF is a Western-only laboratory. This new site could be located at a university in Eastern Canada with traditional large infrastructure capabilities.
- A possible scenario that could be an outcome of a carefully evaluated restructuring of Big Science in Canada could see SNOLAB and TRIUMF joining together.
- Establishing a joint venture between TRIUMF and SNOLAB could provide two centers for large experimental facilities in Canada and would strengthen collaborations and transfer of expertise between Canadian universities. It would allow pooling resources and administration and provide a common vision for experimental physics in Canada.
 - The two centers of particle physics research would however have different foci based on their historical set of expertise:
 - EAST: can host a dark matter-neutrino / quantum valley
 - WEST: can host a fundamental science / isotope valley
 - This would fundamentally broaden the mandate of TRIUMF as a national lab.
- TRIUMF will have a more diverse community of staff, users, and visitors that reflects the country and be an EDI champion through the establishment of concrete measures to foster diversity in the lab and publicly advocating for a diverse workforce
- Having established at TRIUMF an internationally renowned workshop and conference program will make it a global focal point for discussion and reflection of the field.
- An expanded academic program with online courses and summer schools on specialized topics will enhance the training of students in Canada and abroad.