TRIUMF

Fundamental Physics: Atomic, Molecular & Optical (FPAMO) — Working Group

20 Year Vision Summary

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On behalf of the FPAMO Working Group:
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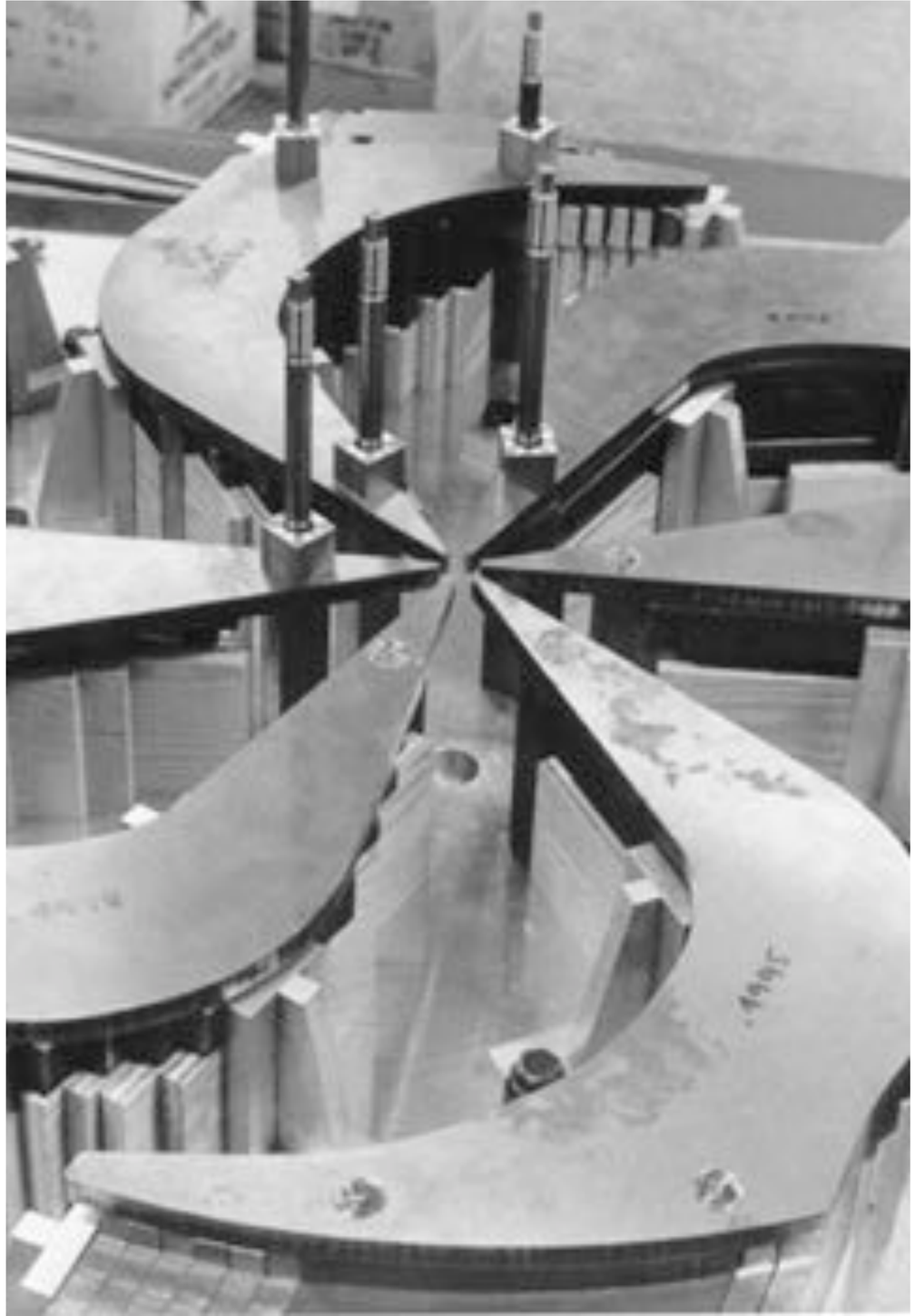
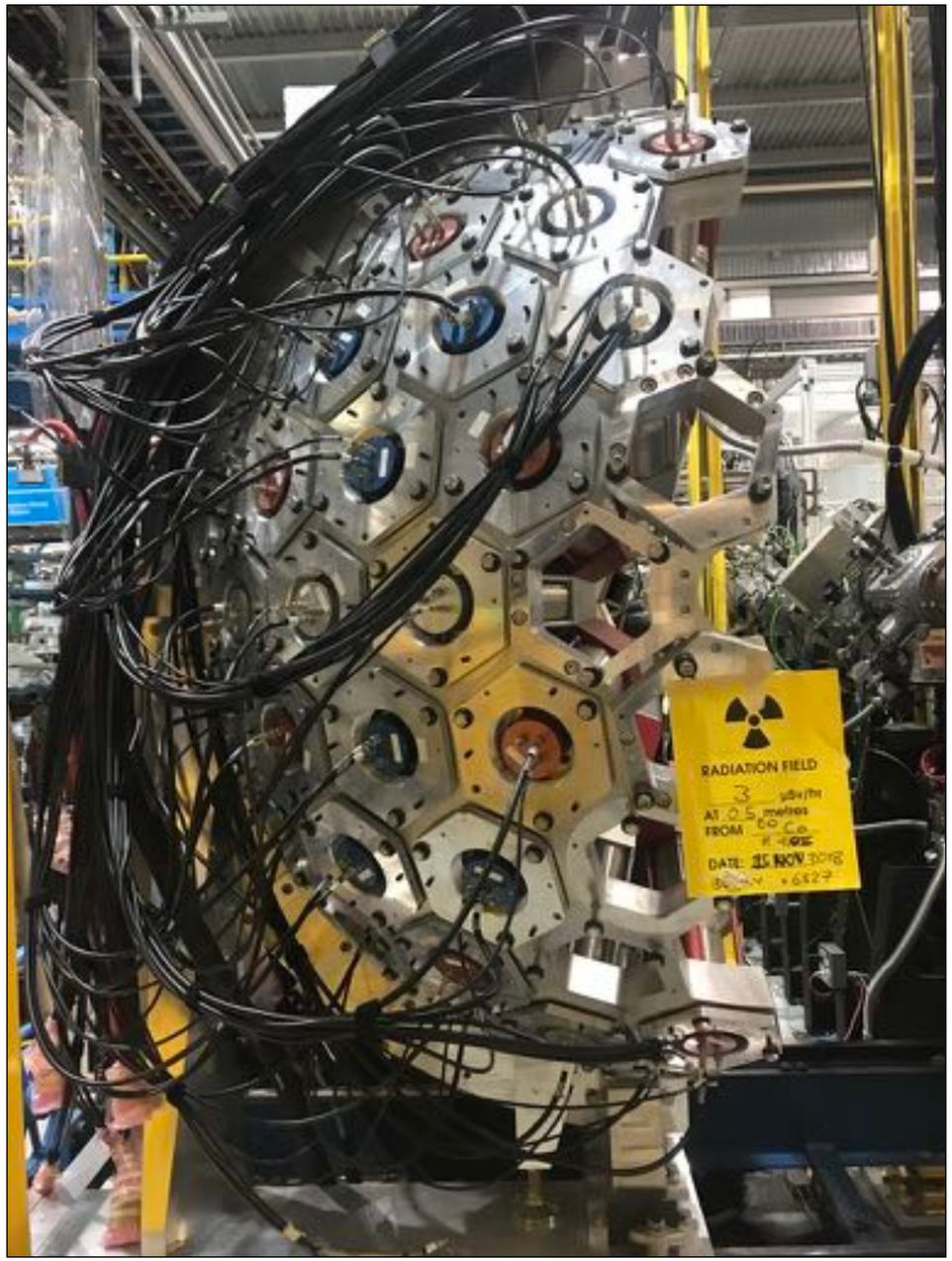
TRIUMF Science Week
Subatomic Physics Summary, Wed, Aug 18, 2021, 0840h



Discovery, accelerated

Today

- **What is FPAMO.**
- **What's happening at TRIUMF (briefly).**
- **Summary of FPAMO Working Group 20 Year Vision Document:**
  - *What is TRIUMF today?*
  - *What trends/changes will shape TRIUMF's future?*
  - *What will TRIUMF be?*
  - *What will TRIUMF have accomplished?*
  - *What will TRIUMF be doing / not doing anymore?*
  - *What will TRIUMF look like?*



What is FPAMO:

- "Tabletop"-scale **atomic**, **molecular** & **optical** precision measurements, tests of fundamental symmetries, searches for dark matter, new physics with radioactive molecules.

  ➜ eEDM's, nuclear Schiff moments, octupole deformations in radioactive molecules.
  — ***highly sensitive probes of possible CP violation.***

- New techniques in lasers, trapping, coherent light-matter interactions, atomic clocks.

  ➜ Laser-cooled polyatomic molecules, i.e. YbOH, RaF, others…
  — ***laser-cooled assembly of super-weird interesting molecules, i.e. ^{223}FrAg.***

  ➜ Quantum logic spectroscopy with ion traps, i.e. $RaOH^+$, ThF^+, others…
  — ***Many narrow frequency transitions with molecules that change with isotopes.***
  — ***possible new systems to look for BSM long-range interactions.***

- AMO physics = ***complimentary to colliders***.
  — *increasingly more & more essential to cover the parameter space for BSM physics.*

FPAMO @ TRIUMF:

- Experiments include neutron EDM, TRINAT, Francium parity violation, HAICU.

- Very active theory group:
  — **Devising new ways to test SM** physics and **find BSM** physics.

- New methods to **advance the production and study** of rare exotic molecules.

  ➜ ***FRIB*** (Michigan) seems to, for now, be concentrating on ***longer-lived*** harvested isotopes.

  ➜ Opportunities for ***shorter-lived (online-produced) isotopes*** @ ***TRIUMF-ARIEL/ISAC*** and @ ***CERN-ISOLDE***.

  ➜ New ways to make **wide varieties of molecules** (ask me later!).

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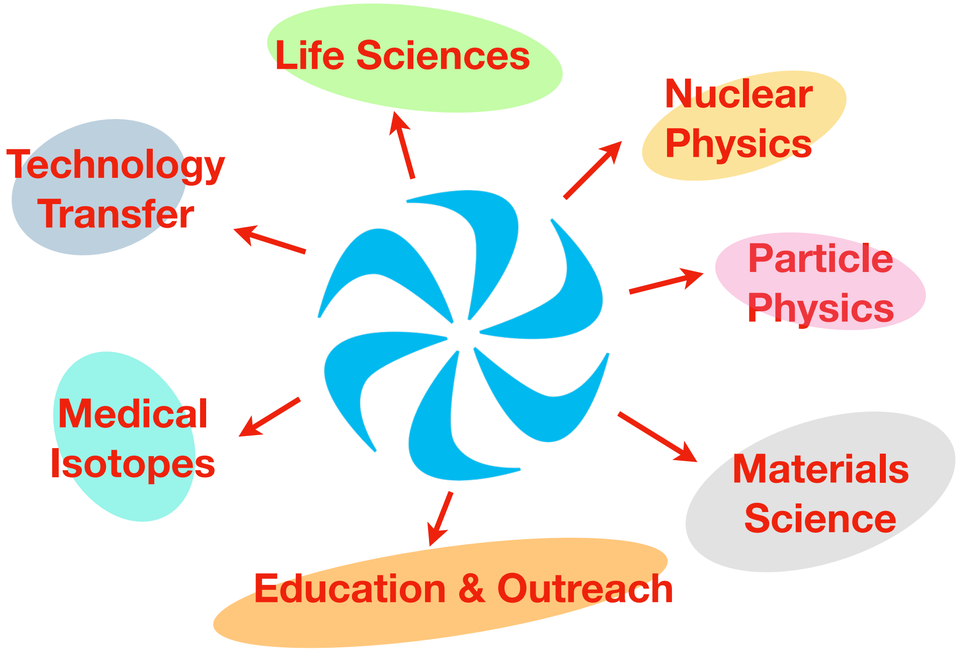
1. What is TRIUMF today?

(a) What does it do?

- World-leading laboratory for accelerator-based research.
- **Canada's** premier National research facility, hosting leading programs in:



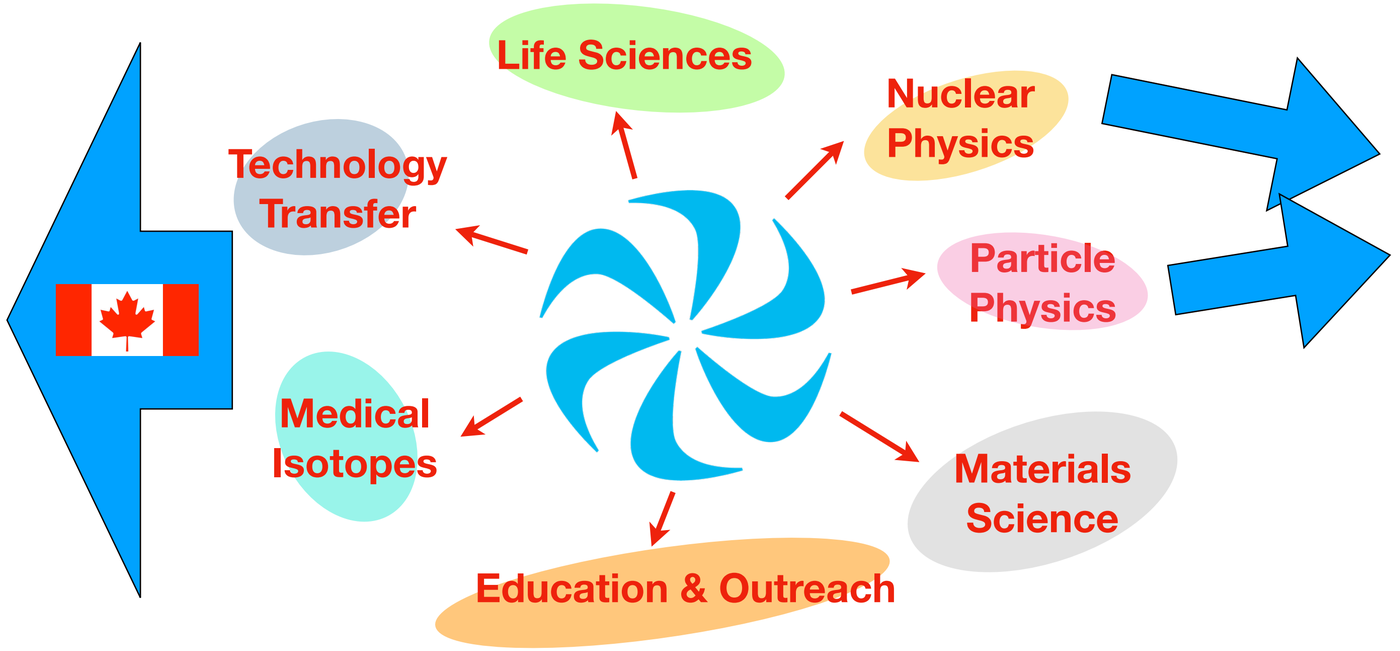
1. What is TRIUMF today?

(a) What does it do?

- World-leading laboratory for accelerator-based research.
- **Canada's** premier National research facility, hosting leading programs in:

UNIQUE ROLES:

- Achieves a **critical mass of Canadian physicists** to compete with the rest of the world.
- Hosts **mid-to-large scale experiments** impossible to operate at universities.
- Allows Canadian scientists to **scale-up** their efforts to **international levels.**



Current projects in nuclear/particle physics with international stature

- **ISAC**
- **ARIEL**
- **ALPHA**
- **T2K**
- **ATLAS**
- **UCN**
- **TITAN** **others…**

1. What is TRIUMF today?

(b) What might be its differentiators (“unfair advantages”) in the future?

Differentiators or Unfair Advantages	Explanation	Envisioned Outcomes for TRIUMF
Technical		
Strategic		

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Differentiators or Unfair Advantages	Explanation	Envisioned Outcomes for TRIUMF
Technical	Production of high-intensity exotic RIB from one of the highest p^+ driver beams in the world + new AMO techniques for molecule production.	**Will enable** unique + unprecedented nuclear, particle and AMO research.
	3 independent RIB beam lines (ARIEL era + ISAC).	• **We must develop** specialized AMO expertise / staff. • TRIUMF **can have the ability to lead** precision measurements with short-lived rare molecules & isotopes.
	Technical support groups + long history of technical innovation.	Provides unique and very strong **local** technical experts for upcoming precision nuclear, particle and AMO experiments.
	Theory Department.	**Integrates** closely with on-site AMO experiments and new capabilities.
Strategic		

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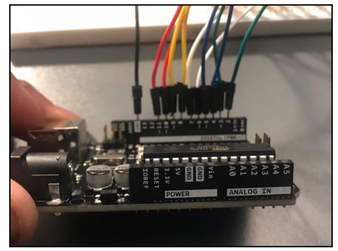
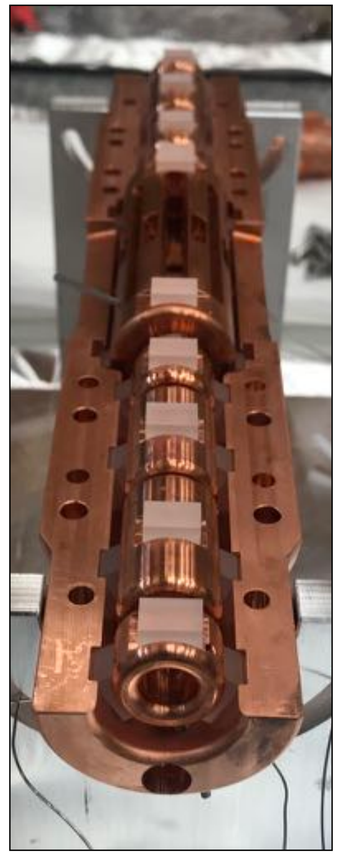
	Theory Department.	**Integrates** closely with on-site AMO experiments and new capabilities.
Strategic	Ability to operate at medium-scale (about 20-50 scientists).	• **Unique size + setup for Canada** for AMO experiments that are infeasible at universities.
	High profile hub for science in Canada.	• TRIUMF is small yet large enough for people from different fields to **interact and find serendipitous opportunities** without being separated into isolated sub-organizations.
	Strong focus on fundamental science.	Unique in Canada & supported by **highly skilled staff** and **wide array of users/visitors**. This support must be encouraged and continued.

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

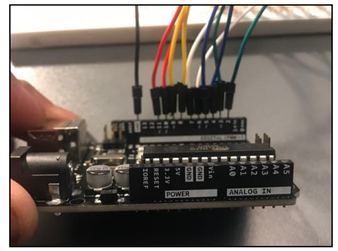
Trend/Change	Explanation	Envisioned Outcomes for TRIUMF
Technical Developments		
Operational Factors		

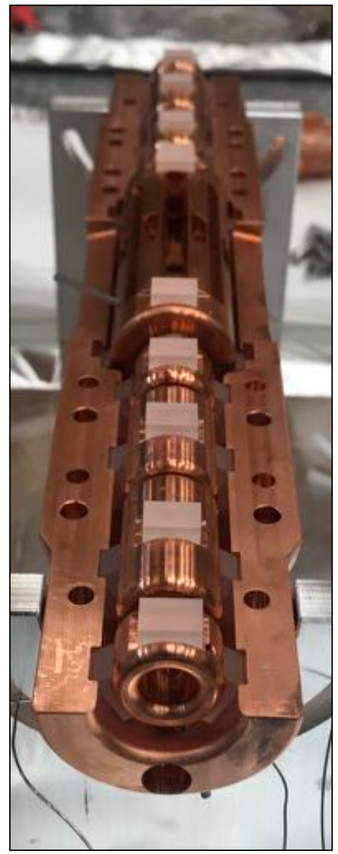




2. What trends/changes will shape TRIUMF's future?

Trend/Change	Explanation	Envisioned Outcomes for TRIUMF
Technical Developments	(1) More experiment + accelerator **automation**.	(1) Will increase remote **participation**.
	(2) More **interdisciplinary links** between "traditional" AMO to other fields.	(2) Astrophysics, cosmochemistry, other isotope sciences.
	(3) **Smaller-scale** AMO experiment focus.	(3) Achieve **quicker more creative experiments**.
	(4) Expansion of Theory Group.	(4) i.e. **quantum/theoretical chemistry**.
Operational Factors		





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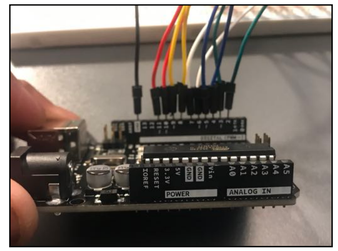
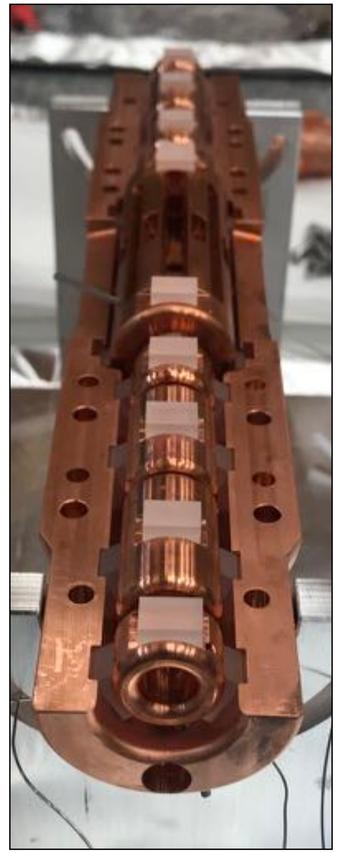
Operational Factors	(1) Evaluate scientific initiatives also on **sustainability**.	(1) Energy, natural resources, environmental impact, societal factors. — Promotion of equity, diversity, inclusion.
	(2) Less travel, **more virtual** meetings (influenced by COVID-19, but may be useful to continue in some ways).	(2) International experiments **may** use more remote shifts to optimize their run-times. However **in-person activities should still be prioritized** — create new ideas and informal close coordination.





3. What will TRIUMF be?

(a) Is TRIUMF a site, an idea, a governance model, a network hub?

(b) What role will TRIUMF play in Canada's science & technology ecosystem and why?

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Question	Detail
(a) Is TRIUMF a site, an idea, a governance model, a network hub?	• ***FPAMO envisions that TRIUMF will continue to be Canada's premier physics laboratory for accelerator-based science, and one of the world-leading facilities for rare-isotope research.*** • TRIUMF is a **site** for accelerator-based science. Also a **hub for a community of people to gather** and operate experiments.

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(b) What role will TRIUMF play in Canada's science & technology ecosystem and why?	**TRIUMF will …** (1) … be an **innovative centre** for training scientists in Canada. … continue to **complement university efforts** for training scientists. (2) … **enable university researchers** to conduct accelerator-based research. … provide **infrastructure, expertise and support** for experiments. (3) … continue to enable **knowledge transfer** from accelerator-based science to industry and society (e.g. transferring expertise in medical isotopes, other scientific/technical projects). (4) … continue to have a **premier role in R&D for interdisciplinary science**. …**build collaborations/connections** from basic physics to other disciplines.

4. What will TRIUMF have accomplished?

(a) What achievements will be proud of within Science & Technology, People & Skills, Innovation & Collaboration?

(b) What would headlines be in 10 and 20 years that you would want to see about TRIUMF?

(c) How will TRIUMF have contributed to major societal challenges?

4. What will TRIUMF have accomplished?

Question	Future Accomplishments
(a) What achievements will we be proud of within Science & Technology, People & Skills, Innovation & Collaboration?	✓ BSM discoveries thru precision AMO measurements and collaborations with particle physics, theorists.
	✓ Technological innovations, i.e. detector developments, new techniques.
	✓ Training HQP (Grad/Undergrad students); training new scientists.
	✓ New on-site AMO experiments and contributions to off-site experiments.
	✓ Advanced medical isotope and health research leading to diagnostic and therapeutic applications (^{225}Ac, NVM Ventilator, many others…).
	✓ Expanding outreach to a wider range of different community partners, e.g. Indigenous and traditionally under-represented groups (i.e. inventor labs).
	✓ Leadership in improving representation of researchers across the spectrum in FPAMO research.

4. What will TRIUMF have accomplished?

Question	Future Accomplishments
(b) What would headlines be in 10 and 20 years that you would want to see about TRIUMF?	✓ *"Rare exotic isotope and molecular beams at TRIUMF shines new light on the origin of our Solar System"*
	✓ *"New physics discovered at TRIUMF: unambiguous signs of physics beyond the Standard Model found in […]".* *[exotic molecule $X_lY_mZ_n$]*
	✓ *"Theoretical physicists at TRIUMF discover solution to the hierarchy problem"*
	✓ *"Canada celebrates TRIUMF's 75th anniversary with an unprecedented investment into fundamental research to further strengthen the laboratory's leadership in accelerator-based science"*
	✓ *"Dr. Susan Abcd, outstanding physicist and First Nations Member, appointed as next Director of TRIUMF 2030-2035"*
	✓ *"TRIUMF scientists forge the path forward in fundamental physics with rare radioactive molecules"*

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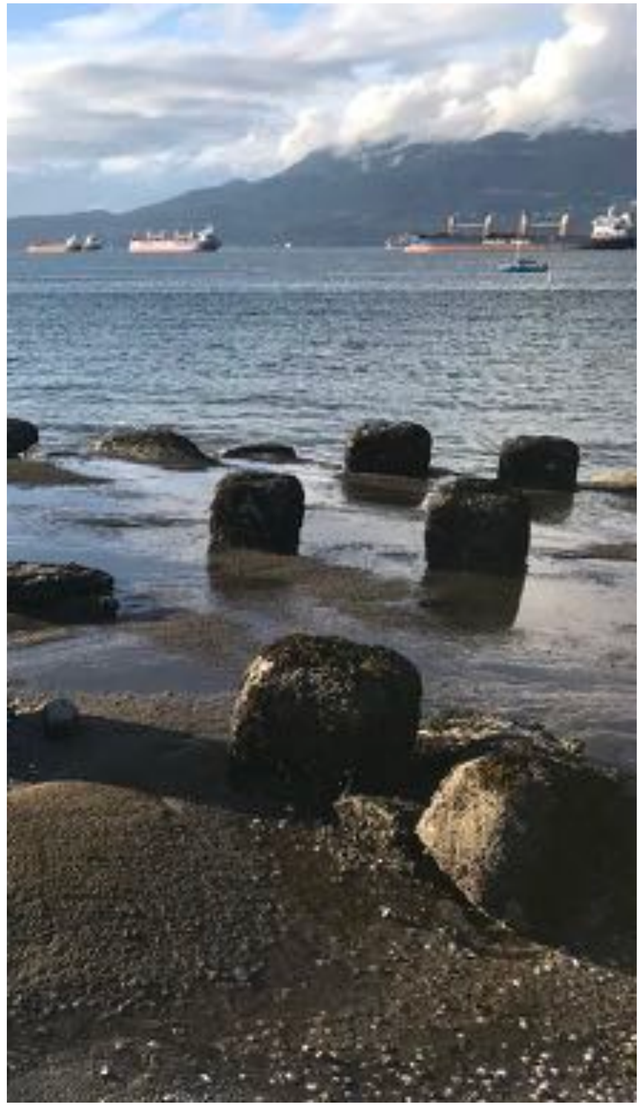
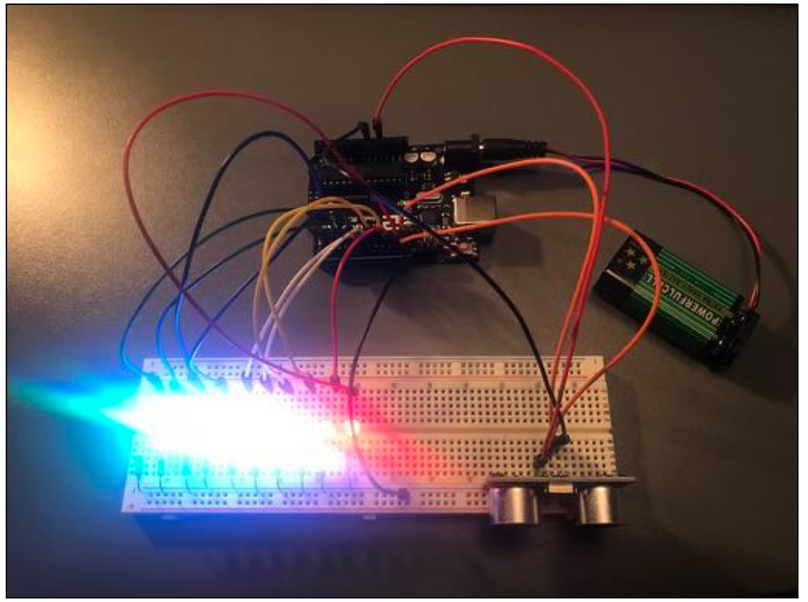
4. What will TRIUMF have accomplished?



Question	Future Accomplishments
(c) How will TRIUMF have contributed to major societal challenges?	✓ Through **deepening our understanding of fundamental laws** that govern the universe.
	✓ Promoting **rational scientific, evidence-based world views**, and international **collaboration** as a tool for progress in society. — TRIUMF, with its focus on fundamental science, can be a unifying force in an age where many scientific questions are becoming politically polarized.
	✓ Providing Canadian society with **continuing evidence of Canadian involvement** in cutting-edge fundamental science.
	✓ **Education + training** of students who become future leaders.
	✓ **Active programs to promote equity, diversity & inclusion**, in collaboration with high-schools (local and nationally) and universities, connecting outreach activities to TRIUMF research (i.e. inventr Labs)…

inventor Labs

New Initiative at TRIUMF



- **Innovative hands-on STEAM education for kids & youth to explore natural physical phenomena.**
- **Encourage curiosity-based play, creation, discovery through collaboration, high-quality experimentation, community leadership and science happening at TRIUMF.**

✓ **New STEAM initiative for TRIUMF (not existed before).**

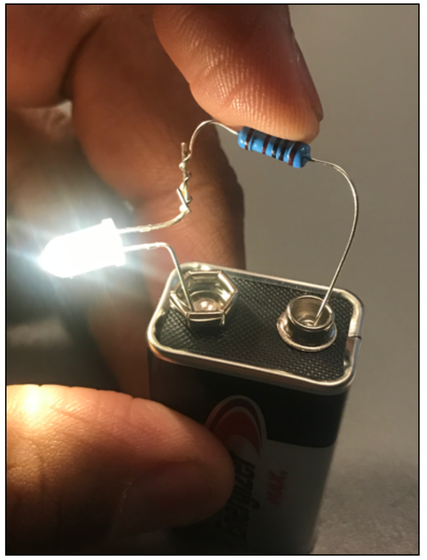
✓ Response to ***Truth & Reconciliation Calls to Action*** and to increase the reach of TRIUMF into society (to do good for society).

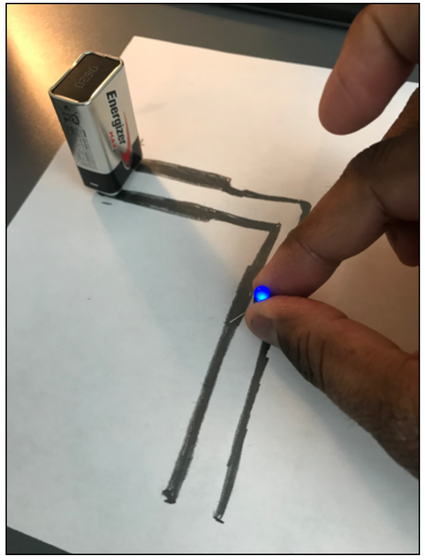
✓ ***Founded in 2020 (C. Charles)***; delayed because of COVID-19; several virtual events already happened in 2021 spring-summer with schools across Canada, grades 7-12.

✓ Collaborating with Communications Dept & TRIUMF Innovations.

✓ Aims to launch **in-person @ TRIUMF** when safe to do so (2022 ?).

✓ ***Physics & STEAM educational outreach*** to all young kids, youth… early…





inventor Labs

New Initiative at TRIUMF

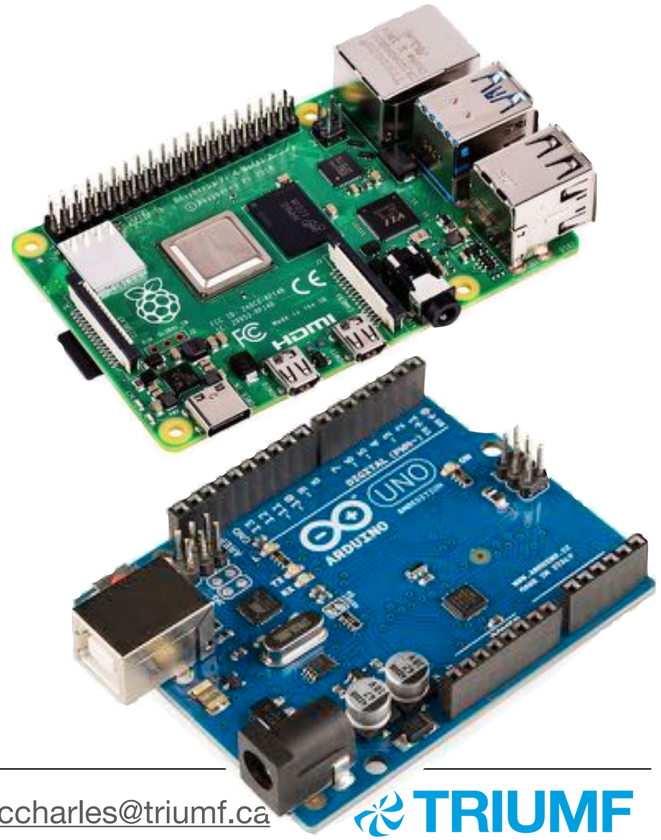
- ✓ Arduino & Raspberry-Pi based physics experimentation, data acquisition, custom experiments, sensors and electronics projects — ***accessible to kids & youth***.

- ✓ Build & strengthen **relationships** between TRIUMF, local schools and schools across Canada, UBC outreach/STEAM programs, TRIUMF member universities, youth organizations, community groups and STEAM programs and high-tech industry.

  - **Want to target** kids/youth displaced from their geographic homelands, ancestral, cultural and spiritual roots.

  - **Want to target** kids/youth potentially subject to systemic racism/discrimination in education, or lack of access to unique, advanced, creative opportunities.
    — Some groups include (but not limited to): Indigenous persons, women, persons of colour, LGBTQ, and as many kids/youth in general as possible.

  - **Want to target** systemic social inequalities: *how science is done and by whom…*
    How can physics contribute to being a more inclusive science?



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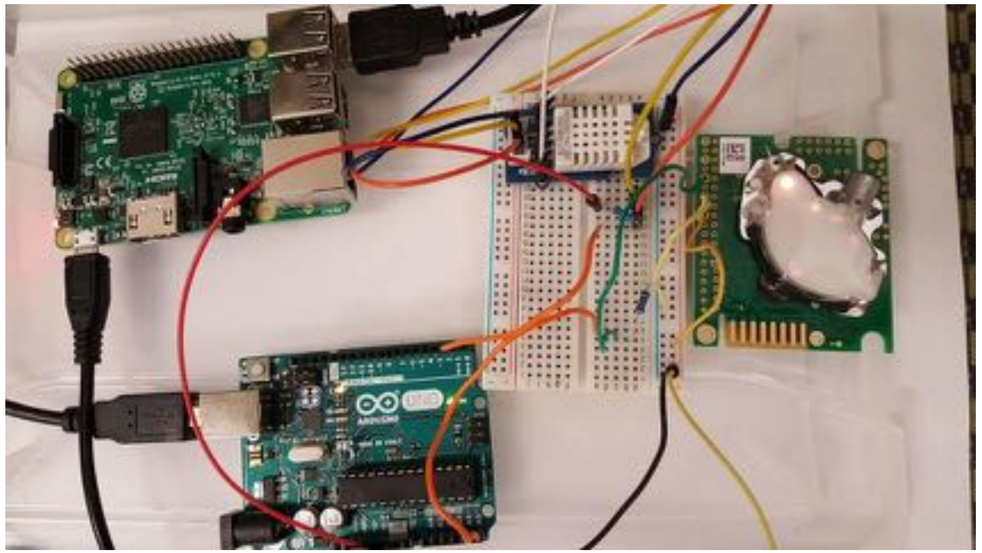

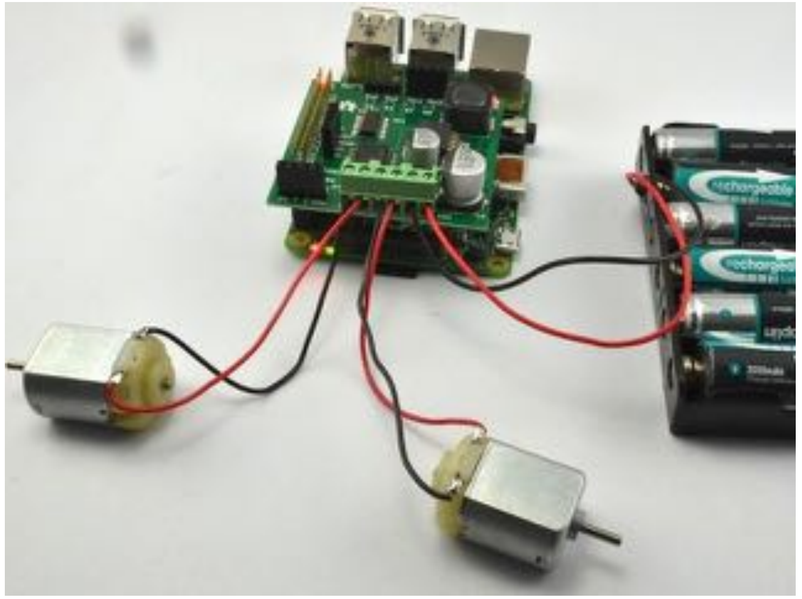

More Info or to get involved: C. Charles
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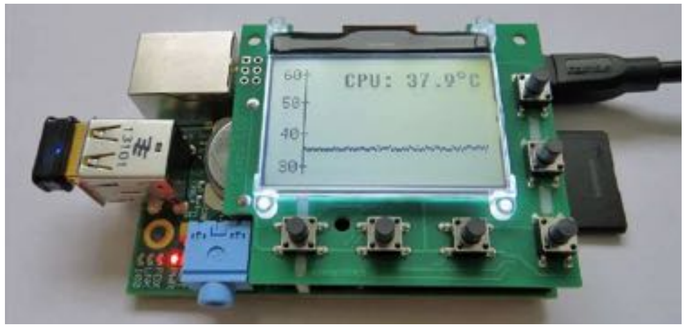

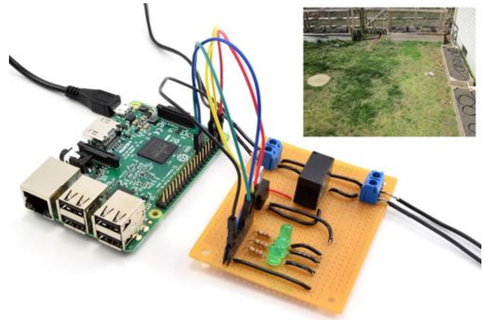

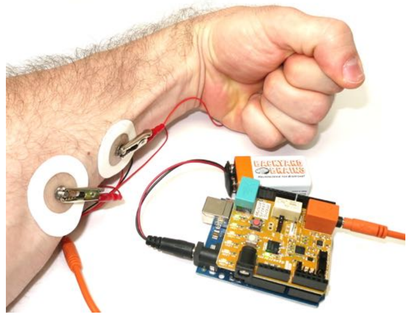

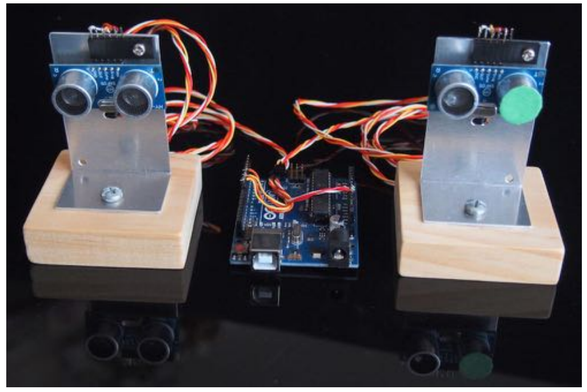

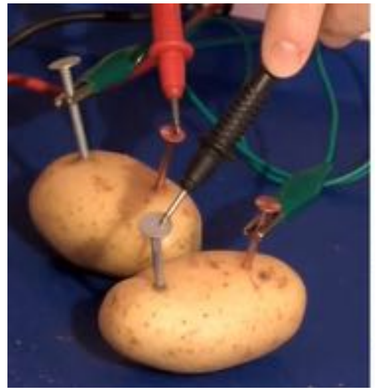

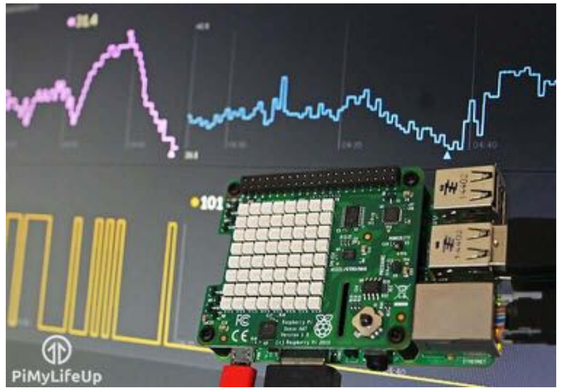

5. What will TRIUMF be doing / not doing anymore?

(a) What will TRIUMF be doing if there were no funding constraints?

(b) What are the priorities for TRIUMF activities?

(c) What activities capture the interest & imagination of the general public?

(d) Which program elements or facilities will we stop because they have been completed, or to make space for new initiatives?

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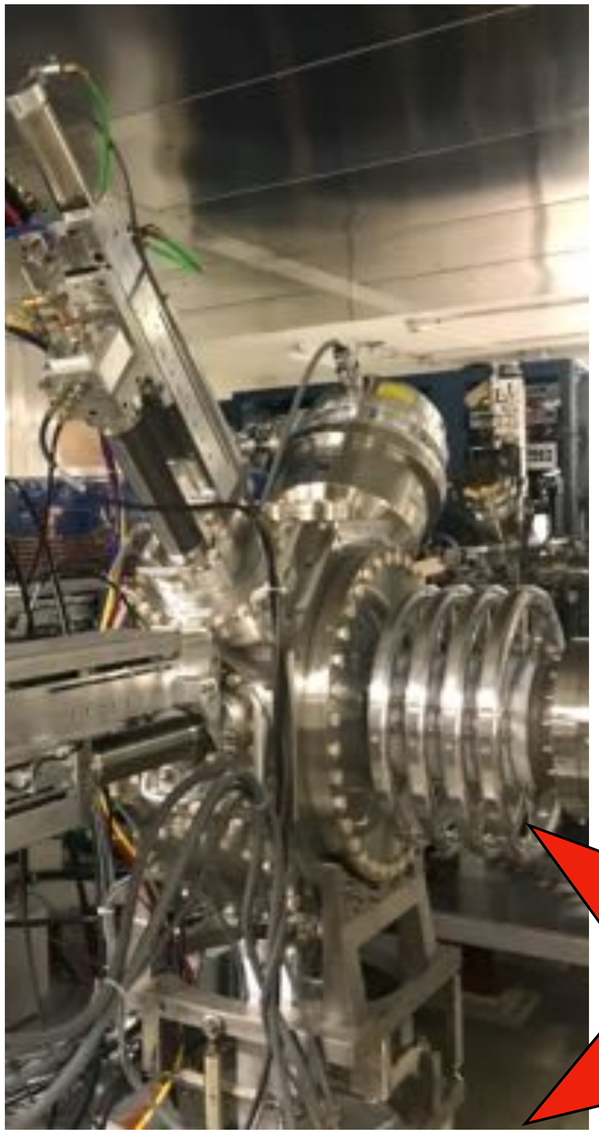

Question	Explanation	Envisioned Outcomes for TRIUMF
(a) What will TRIUMF be doing if there were no funding constraints?	Build a large AMO group/research centre.	Wide freedom to adapt high-end AMO tools into AMO research exploiting rare radionuclides. ***Try new ideas liberally***.
	Narrow the large gap between laser-cooling and spectroscopy at cutting-edge AMO labs, compared to efforts at RIB facilities like ISAC and ARIEL.	***Improved measurements*** of nuclear moments, hyperfine anomalies, isotope shifts, parity and time-reversal symmetry violation, highly-charged ion clock transitions, quantum chemistry.
	Expand our accelerator complex (buildings + infrastructure + research facilities).	Higher energy proton or muon collider facilities; anti-atom (deuterium) factory.
	Establish a national centre of excellence for a high-energy accelerator mass spectrometry (AMS) facility (6 or 9 MV) and/or (15-20 MV) machines. ***Use Inspired / societal benefits.***	Lead Canada in ultra-low level isotope ratio measurements, precision isotope ratio analyses of rare nuclides or molecules, interdisciplinary research.
	Stronger TRIUMF summer student program.	Recruit excellent students worldwide.

Research !!!

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5. What will TRIUMF be doing / not doing anymore?

Question	Envisioned Outcomes for TRIUMF
(b) What are the priorities for TRIUMF activities?	**IAMI, ARIEL** = current priorities.
	Establish an **AMO research cluster** focused on fundamental science.
	International **collaboration** & welcoming international **researchers**.
(c) What activities capture the interest and imagination of the general public?	

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	International **collaboration** & welcoming international **researchers**.
(c) What activities capture the interest and imagination of the general public?	Unique exciting STEAM outreach activities (e.g. inventr labs , others,…).
	Anything related to “**antimatter**” or “**Einstein**”.
	Radioactive beam science and its applications to **medicine (cancer)**.
	Use of accelerators with a**strophysics and cosmochemistry**.
	Annual TRIUMF open days could have a **better/stronger connection with local communities** via tours, presentations, demonstrations by scientists.

5. What will TRIUMF be doing / not doing anymore?

(d) Which program elements or facilities will we stop because they have been completed or to make space for new initiatives?

- Particle physics could be scaled back in favour of more fashionable areas…

  (depends on the lab direction…)

- <u>However</u> — it is vital to maintain a strong ***fundamental physics focus*** and presence.

6. What will TRIUMF look like?

(a) What buildings & infrastructures will be on-site?

(b) Will there be more than one site?

(c) What will TRIUMF's organization and its community look like?

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(b) Will there be more than one site? → ***No !***

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Question	Future Accomplishments
(a) What buildings & infrastructures will be on-site?	✓ New AMO experimental facility. ✓ Development of new techniques bridging AMO and nuclear physics + precision studies of rare nuclides for fundamental symmetry tests. ✓ Better and sufficient lab space for individual research programs. ✓ New main cyclotron / proton accelerator (“wish list”). ✓ New office building (!!) ✓ Reduce pressure on existing space. — Greatly helps the science effort. ✓ **Innovative workspaces in common areas to inspire creative thought and collaboration (chalkboards, “glass” chalkboards, better lounges, group discussion/study areas, etc).**

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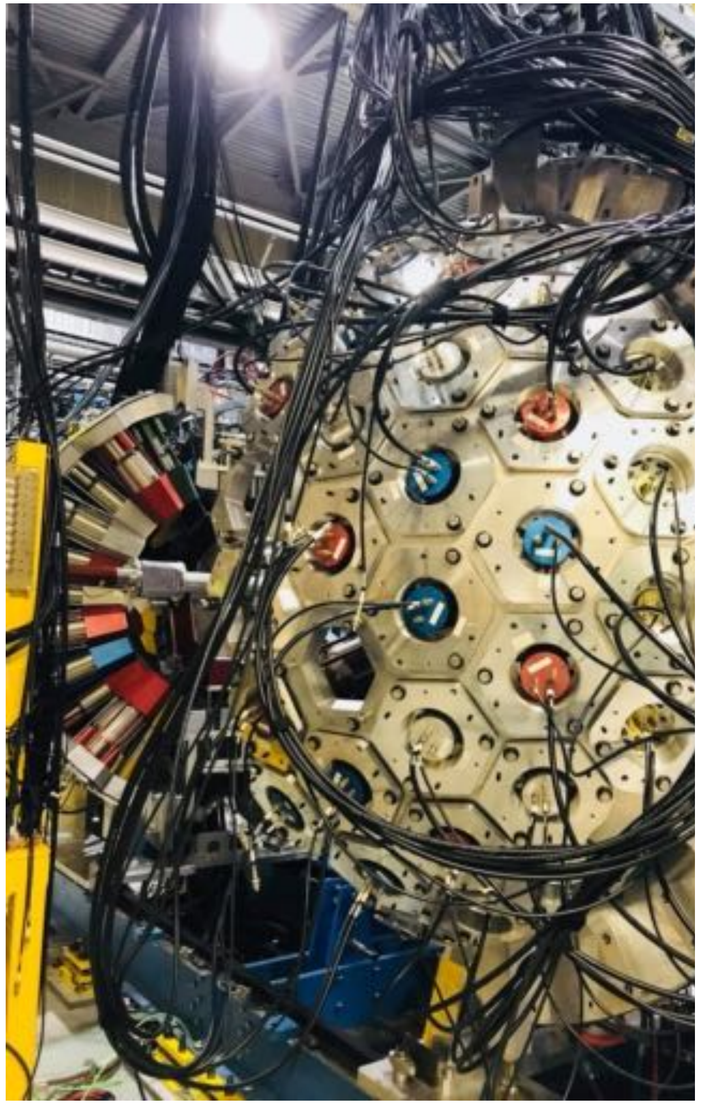

Question	Future Accomplishments
(c) What will TRIUMF's organization and its community look like?	✓ More EDI community of staff, users, visitors. ✓ Transparent and open communication between management and scientists. ✓ Better & more opportunities for free discussion between colleagues. ✓ Investment in scientific & technical staff (for the long term). ✓ Resolution of ***a general discontent*** within the scientific workforce with TRIUMF's governance model (too heavily weighted towards senior management rather than "general" scientific staff). ✓ More inclusive "bottom-up" model rather than "top-down". ✓ Resolution of sometimes opaque communications between management and scientific/technical staff. ✓ Rediscovering and encouragement of close inter-personal relationships = **ESSENTIAL** to TRIUMF's success (central asset). ✓ ***Recommendation***: open discussion with all layers of TRIUMF workforce to identify and resolve these difficult complex issues…

6. What will TRIUMF look like?

Some **current** points of concern to consider…

Explanation	Envisioned Outcomes for TRIUMF
Managerial overhead. *Increasing management structure and unnecessary rigidity* has affected TRIUMF's traditional **flexibility**, close personal **interactions**, **collegiality** and **freedom** for creative new ideas.	• Management will support researcher-led initiatives & encourage **creative research activities**. • We must **develop fair collaboration** with colleagues, open dialogue, and reinstitute a balance for opportunities with creative, flexible scientific work.
Staffing Levels. *Current staff levels may be insufficient* to operate RIB facilities and experiments, especially in the new ARIEL era.	• We need to **value & invest in our existing scientific and technical staff and hire additional excellent colleagues** to keep up with research and development. Value & appreciate everyone's role.
Slackening the focus on **fundamental science**.	Pursuing short-term applications for short-term gain will deprive Canada of a unique and globally visible institution.

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Thank you
Merci

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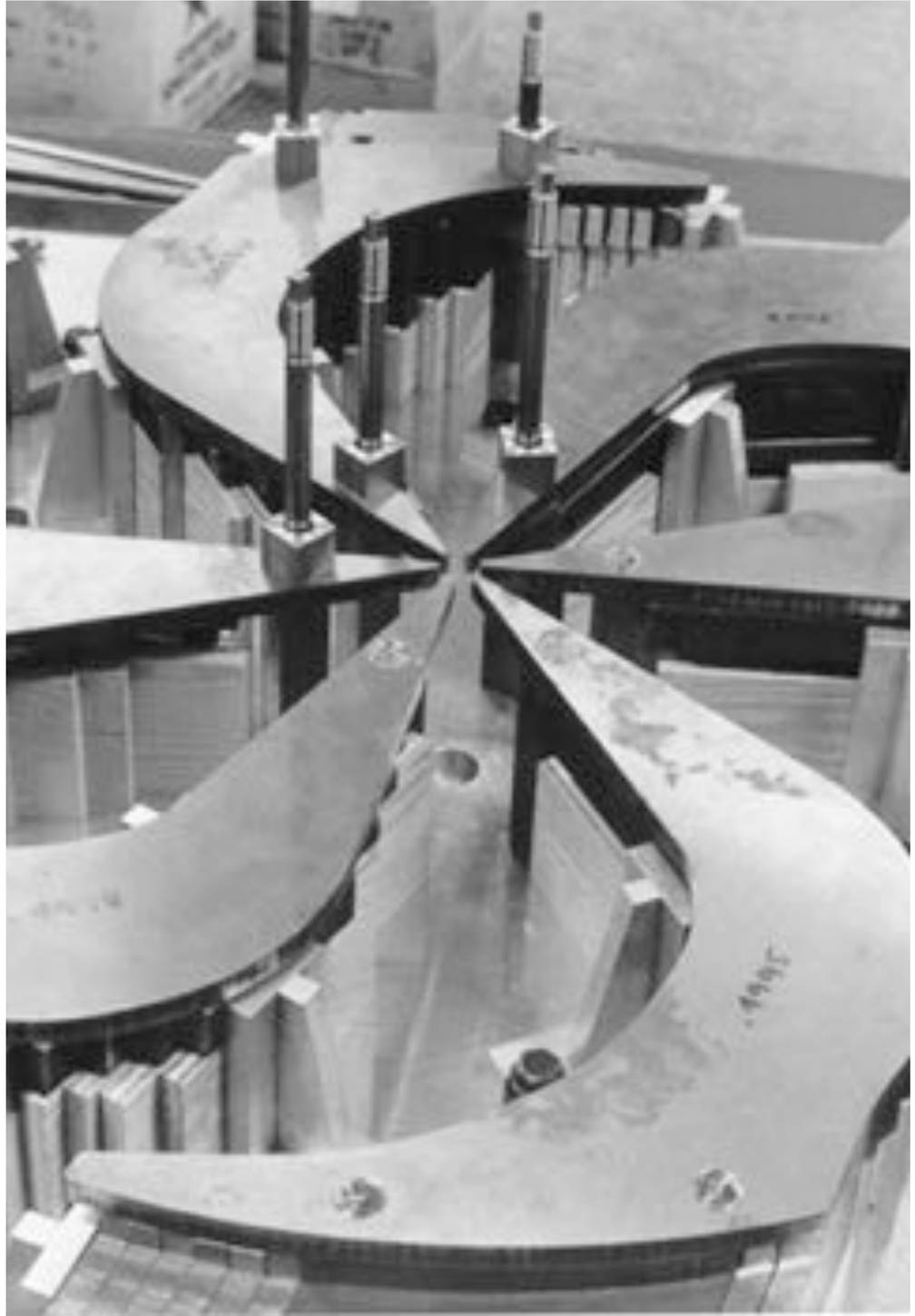

Discovery, accelerated