Nuclear Physics: 20 Year Vision - Summary -

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aka. "The Magnificent Nuclear Seven"

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TRIUMF is the ISOL facility of choice for worldwide Nuclear Physics research

A complete toolkit of state-of-the-art facilities allows to perform experiments that define the field, exploring the wonders of the quantum world

TRIUMF is a trusted and valued resource for the public education of nuclear physics

We are a hub for the Canadian public to inform and communicate about nuclear physics in daily life, like solar fusion, nuclear medicine, energy...

The unique capabilities of TRIUMF's expanded Nuclear Physics Portfolio ensures research at the cutting edge

Additional personnel and new/ upgraded research infrastructure and techniques allow full exploitation of opportunities

What is TRIUMF today?

TRIUMF Experimental Nuclear Physics program today

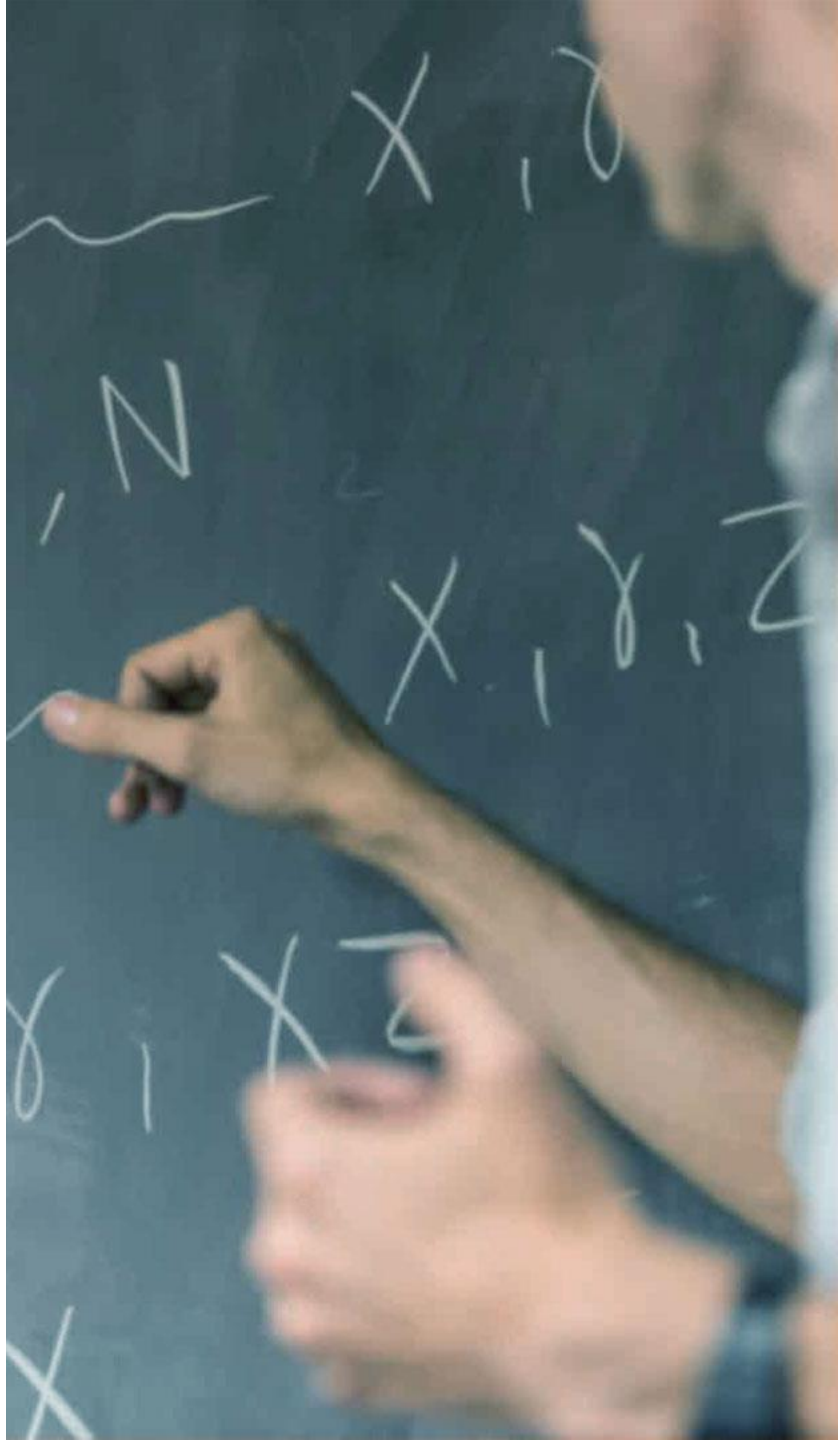
- ISAC: The **ISOL** RIB facility **in North America** since **more than 20 years**
- Fully **complementary to FRIB** (“isospin frontier”)
- Exploring the **precision frontier and performing pioneering experiments**
- **Competitive sister** of CERN-ISOLDE (despite smaller community and smaller funding)
- **2400h** of beamtime for Nuclear Physics per year for **13 permanent setups** at ISAC
- **Targeted offshore research** at RIKEN in Japan, NSCL/FRIB in USA, GSI/FAIR in Germany

“World-leading multi-messenger nuclear physics laboratory”

TRIUMF Nuclear Theory program today

- Hub specialized in **state-of-the-art "ab-initio" calculations** for the description of nuclei across all mass regions
- Light nuclei: quasi-exact methods have been **developed and benchmarked with experimental data from ISAC**
- Medium-mass nuclei: Converged **calculations up to ^{132}Sn** achieved, ^{208}Pb in reach
- New hire for **theoretical nuclear astrophysics** (Nicole Vassh, heavy element nucleosynthesis)

"World-leading nuclear theory hub"



What is/was hampering future success?

- Limited on radioisotope production via protons from 520 MeV cyclotron

  ⇨ **ARIEL project: Two new RIB production beamlines**

- Aging infrastructure: Various target module issues have hampered research output at ISAC in the past years

  ⇨ **Refurbishment & New target modules**

  ⇨ **ARIEL project: More beamtime, cleaner beams**

- New faculty hires missing to fully exploit synergies between ARIEL experiments + nuclear theory

  ⇨ **New faculty for theoretical nuclear astrophysics (N. Vassh) and fundamental symmetries (S. Ettenauer)**

  ⇨ **Need more "champions" for new future facilities!**

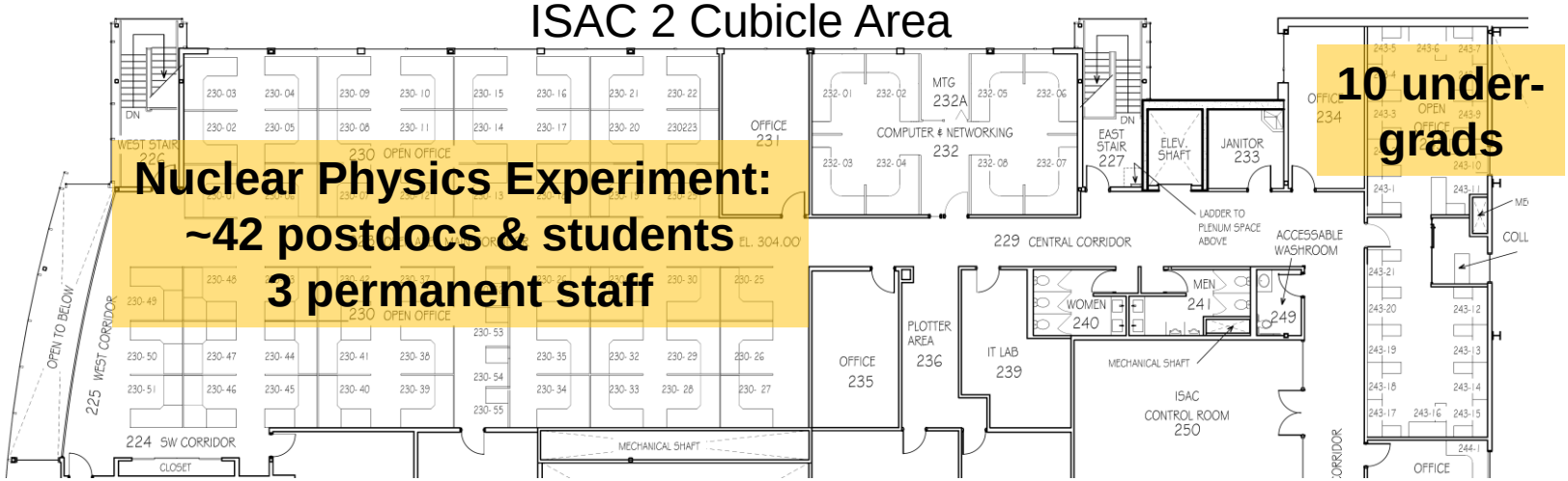
- Limited work space = limited number of students

  ⇨ **Need more office space for students and visitors!**

Major Issue: Desk Space

- Desk space is rare → Growth of groups is hampered
- Hiring of CoOp undergrads limited by available space, not by available projects
- No dedicated visitor/ off-shift experimentator spaces available

ISAC 2 Cubicle Area



ISAC 1 Counting Rooms

Off-Shift & Discussion Area

On-Shift Area

Theory:
8 grad students +
4 CoOp students
for 6 desks…

Public perception of Nuclear Physics

Blinky, the three-eyed fish

“Nuclear = Bad”

“Nuclear = Bomb”

“Nuclear = Fukushima”

“Rare isotopes”
(instead of radioactive isotopes)

“Atomic energy”

IAEA
International Atomic Energy Agency
Atoms For Peace

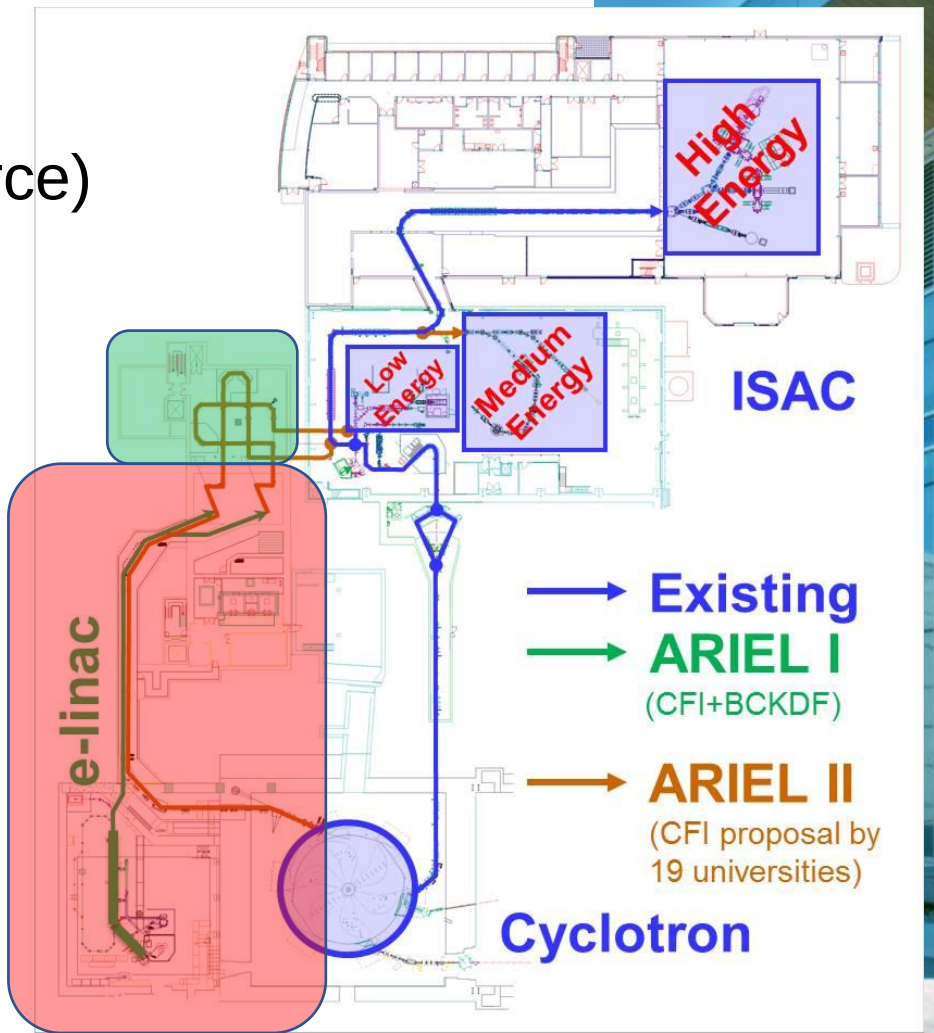
https://www.slps.org/Page/46499

What trends and changes will shape TRIUMF's future?

ARIEL

- Two additional beamlines will provide two more radioisotope beams
- CANREB (CANadian Rare isotope facility with Electron Beam ion source) will provide cleaner beams

The ARIEL project will drive and shape the local nuclear physics science program for the next 20 years!



Remote participation and automatization of processes

- Pandemic has forced to develop tools and procedures for partial remote participation
  → **very good experiences**
- Complete remote control not possible: some setups too complex, quick hands-on interaction needed
- Unchanged: Large number of on-site staff still needed for setup and maintenance
- Time difference allows night shifts to be co-supervised by colleagues in Europe or Asia
- Better automatization of processes saves valuable beamtime and allows staff to focus on other important things

What can TRIUMF do against climate change?

- Need to ramp up efforts to help to reduce CO_2 emissions, e.g.
  - by **local adjustments to operational aspects** to use less and/ or greener power
  - by intellectual efforts: consider **new faculty hire**

- Construction of “Small Modular Reactors” as fully independent “green” energy source *highly unlikely in BC*
- TRIUMF could make a dedicated hire for **“Green energy and nuclear transmutation”** → using TRIUMF facilities e.g. for material testing in radiation environments, measuring critical nuclear reaction or decay data, transmutation of long-lived nuclei with nuclear reactions, development of new accelerator techniques…

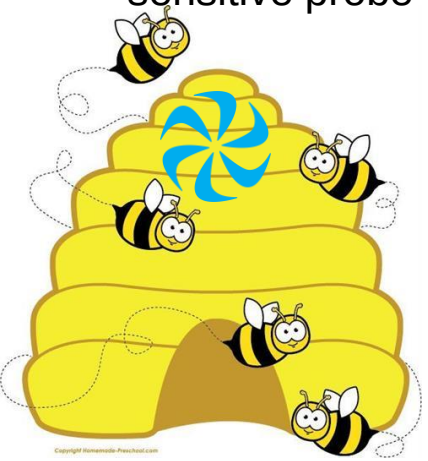
What will TRIUMF be without funding constraints?

TRIUMF 2030: Busy as a beehive

- ARIEL is in full swing: **3 radioisotope beams in parallel** (9000h beamtime per year)
- **Dedicated cubicle space for 15 visitors and experimentators**
- **2 new joint positions** at Canadian partner universities

New major facilities envisioned for operation at ISAC

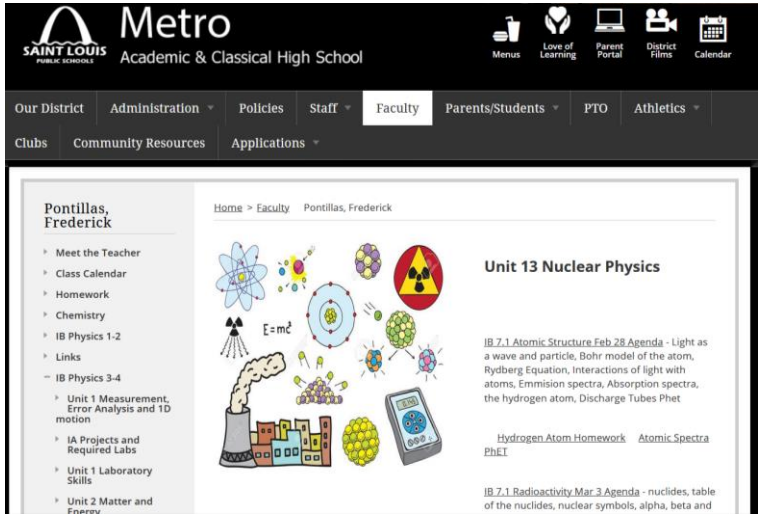
- 2 additional dedicated **Multi-Reflection Time-Of-Flight Spectrometers** with M/ΔM > 20000 provide additional isobaric beam purification
- **Radioactive Molecules for Fundamental Physics (RaMs)**: Enhancement of the eEDM sensitivity in heavy radioactive molecules as sensitive probe to detect a permanent electric dipole moment



- **POLARIS:** Nuclear-spin polarizer beamline, used by Material Sciences, Nuclear Physics, and Life Sciences
- **TRIUMF Storage Ring (TRISR):** Low-energy storage ring for the direct measurement of astrophysically-relevant radioactive neutron capture cross sections

Change the public perception of Nuclear Physics

- Make TRIUMF a **hub for a "Canadian Center for the Public Understanding of Science"**
- More **focus on common nuclear physics phenomena**: Element creation in stars, natural radioactivity, solar fusion, radiopharmacy, …
- **Invest in nuclear physics outreach tools**, e.g. LEGO Binding Blocks outreach project (Christian Diget, U York/ UK), dedicated Nuclear Physics lectures for high schools, permanent exhibitions at Science World, "Geek Shop" at TRIUMF …



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8m-long representation of the Nuclide Chart, built using over 25,000 LEGO® bricks.

LEGO Binding Blocks (U York/ UK)
https://www.york.ac.uk/physics/public-and-schools/secondary/binding-blocks/about/

What will TRIUMF have accomplished?

What will TRIUMF have accomplished? (I)

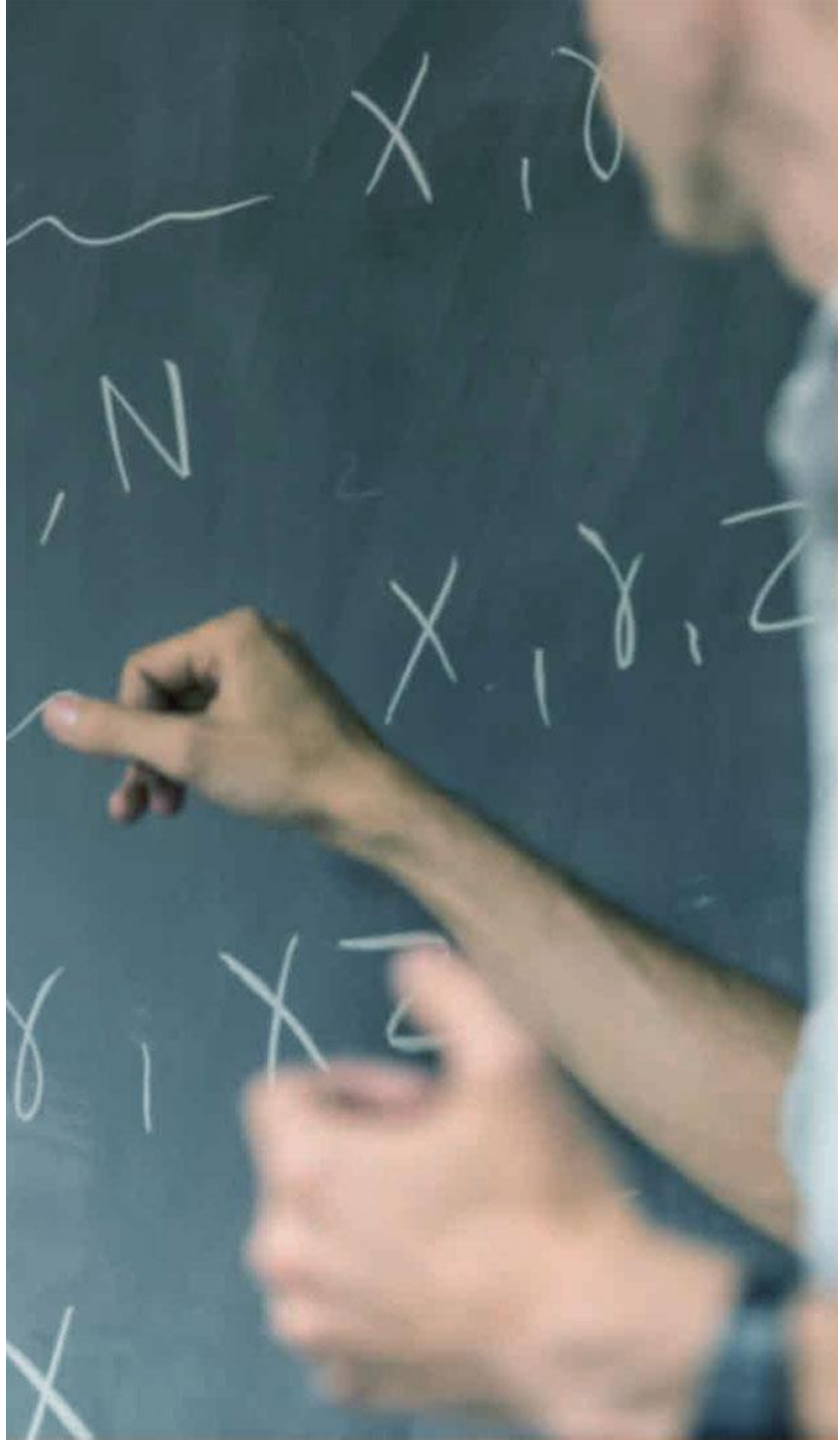
- **Parallel beam operation** at ISAC as well as the availability of **beam almost year around** has allowed to **multiply the science output**.
  The **time between proposal and experiment is on average 6-12 months**, which allows spokespersons to better plan the research of their students and postdocs.

- **TUCAN** (ultra-cold neutrons) and the **Radioactive Molecules** experiments will have **provided the world's most sensitive search for a permanent electric dipole moment (EDM)** of the neutron ($\delta d_n < 1 \cdot 10^{-27}$ e·cm) and electron ($\delta d_e < 1 \cdot 10^{-29}$ e·cm), respectively.
  One or both of these experiments will either **observe an EDM orders of magnitude larger than predicted by the standard model, or rule out numerous theories** of physics beyond the standard model.

What will TRIUMF have accomplished? (II)

- Construction of the worldwide **first storage ring coupled to an ISOL facility** (TRISR)
  Thanks to the intense and clean beams from the ISAC+ARIEL+CANREB facility and a high-intensity neutron generator target, for the **first time the measurement of direct neutron capture cross sections on short-lived nuclei** with half-lives shorter than 1d can be performed.

- **Computational and theoretical advances** in Nuclear Theory for ab-initio many-body methods have allowed the **first consistent treatment of structure and reactions** for virtually all existing nuclei
  Provided **exact inputs for beyond-standard-model searches, e.g. neutrinoless double-beta decay ($0\beta\nu\nu$), WIMP-nucleus scattering, and fundamental symmetry violations**. Atomic nuclei can now be described with a precision and accuracy akin to what is possible for quantum chemistry.



Summary

Better education
Better communication
Better outreach

Public

People

More office space
New faculty
More students

Science

New ideas
More cutting-edge research
Exploring the precision frontier
More recognition

Thank you!

Merci!

www.triumf.ca

Follow us **@TRIUMFLab**

Discovery, accelerated

Links

Canadian Institute of Nuclear Physics: 5-Year Plan Input Document for Subatomic LRP:

https://cinp.ca/subatomic-physics-long-range-plan

Canadian Subatomic LRP (2022-27):

https://subatomicphysics.ca/

TRIUMF 20-year Vision Development Plan

https://www.triumf.ca/node/39223

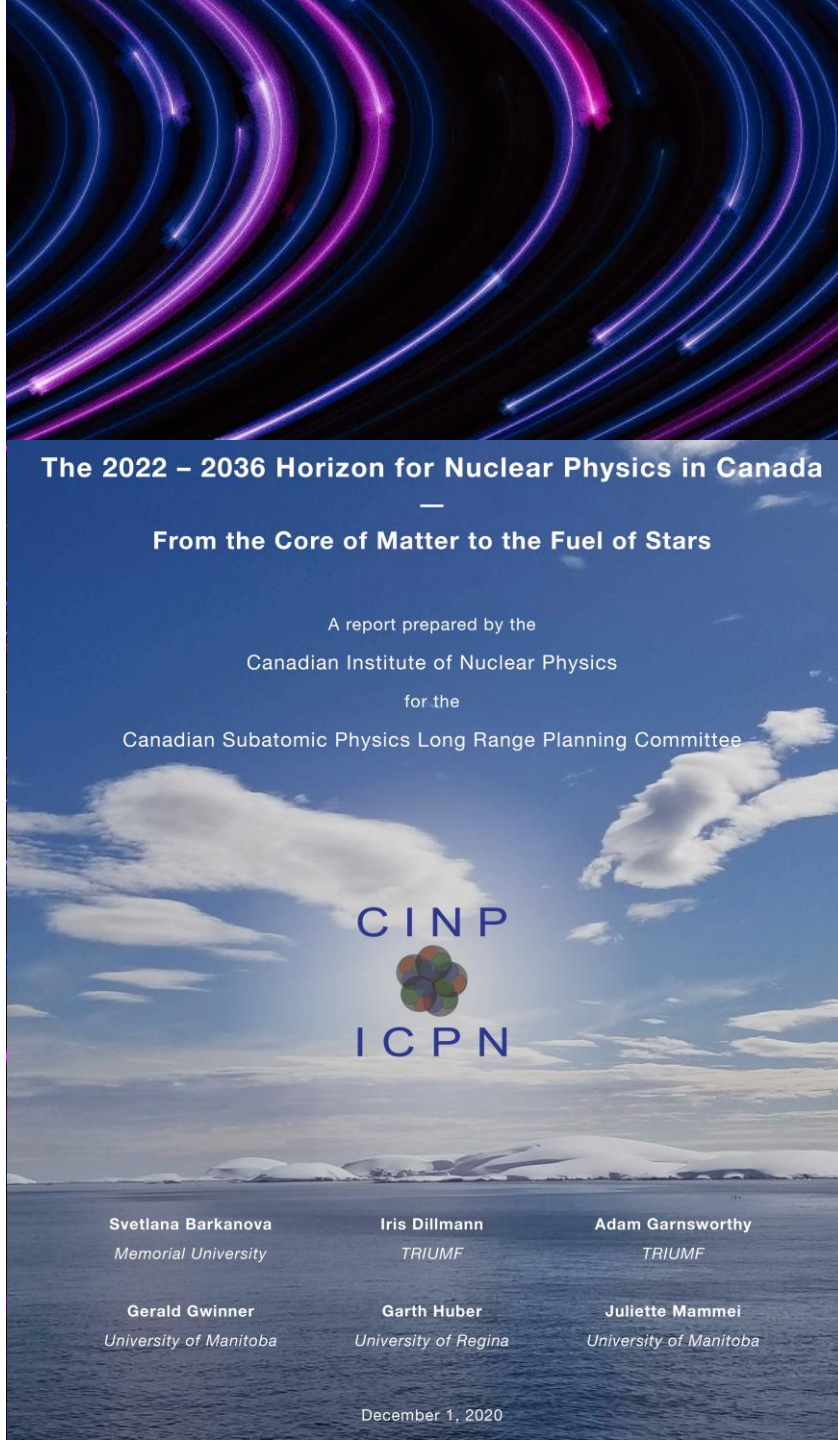
https://meetings.triumf.ca/event/238/attachments/2340/2649/AllTopicalGroupSummaries.pdf

Big Science Questions for Nuclear Physics in Canada 2022-26 (-2036)

CINP Report 2020: Research covered by TRIUMF NP

- How does the structure of nuclei emerge from nuclear forces?
- What is the role of radioactive nuclei in shaping the visible matter in the universe?
- What physics lies beyond the Standard Model?

https://cinp.ca/subatomic-physics-long-range-plan



Science Recommendations Subatomic Physics Long Range Plan in Canada 2022-26 (I)

Draft (August 2021):

Science Recommendation: High priority Canadian Infrastructure

We recommend fully capitalizing upon the unique science opportunities provided by the SNOLAB and TRIUMF infrastructure, and by the Perimeter Institute, in the pursuit of the science drivers.

Science Recommendation: Theory

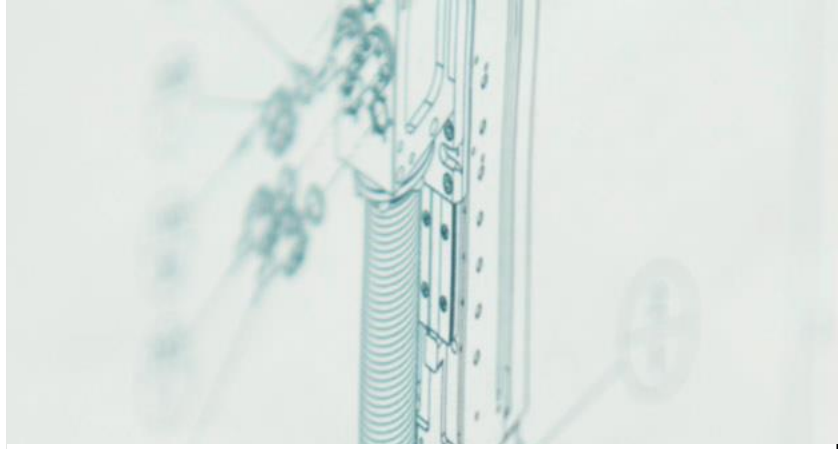
Critical mass and research breadth are vital for the theory community in Canada, to maximize the future impact of subatomic physics research.

We recommend maintaining strong support to ensure the vibrancy of the theory community over the next decade, both to explore new directions and to support the synergistic interaction between subatomic theory and experiment.

Science Recommendation: Enabling R&D

We recommend the support of enabling R&D activities for the future development of accelerators and detector technology, and the development and use of emerging technologies including novel computational and analysis tools.

https://subatomicphysics.ca/



Canadian Subatomic Physics
LONG RANGE PLAN

2022-26

Draft v1

Prepared by the Subatomic Physics LRP Committee

Science Recommendations Subatomic Physics Long Range Plan in Canada 2022-26 (II)

Draft (August 2021):

Science Recommendation: High priority experimental programs

We recommend pursuit of the following scientific program, which is identified as essential to address the science drivers.

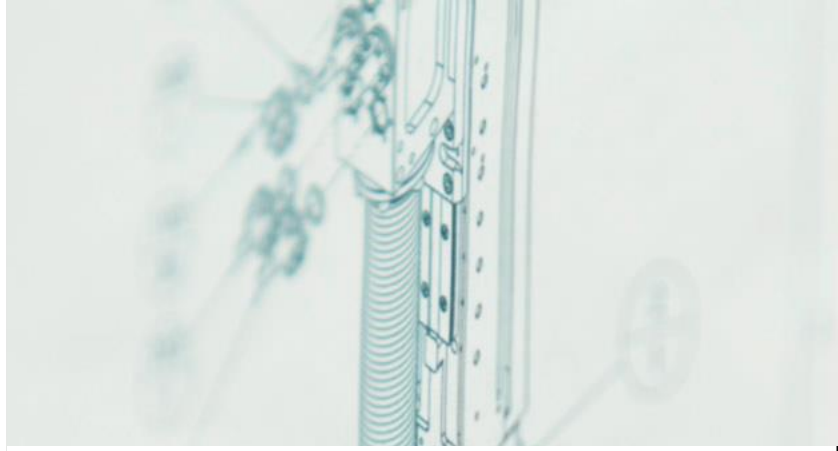
- From quarks and gluons to nuclei:
  - Explore the structure of hadrons and nuclei using rare isotope and accelerator-based facilities.

This scientific program is currently implemented through Canadian leadership in a set of flagship projects identified based on their potential scientific payoff, Canadian core expertise, the level of community engagement, opportunities for the scientific and technological training of the next generation, and Canadian investments to date:

- Flagship projects with broad physics outcomes
  - From quarks and gluons to nuclei: TRIUMF ARIEL-ISAC experiments, EIC.

To maximize Canada's future scientific impact, we recommend the support of projects and initiatives within the scientific program (above) that are under development or may be developed in the future, with the potential for high impact.

- From quarks and gluons to nuclei:
  - The future program should include the full exploitation of TRIUMF and offshore RIB facilities, as well as JLab programs.



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