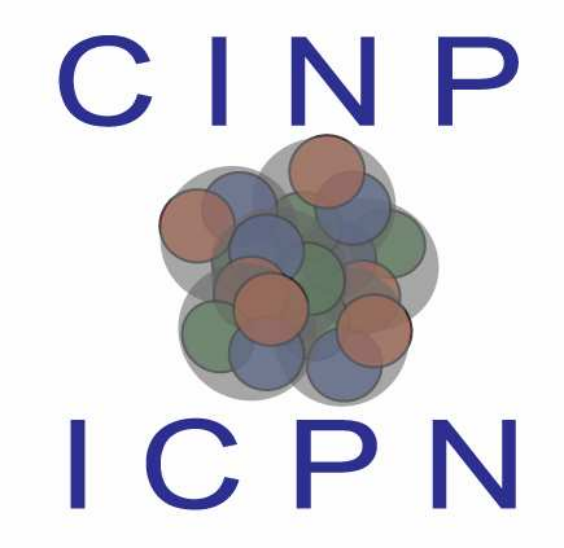


Canadian Institute of Nuclear Physics

Institut canadien de physique nucléaire

TRIUMF 5 Year Plan Discussion
July 24, 2024

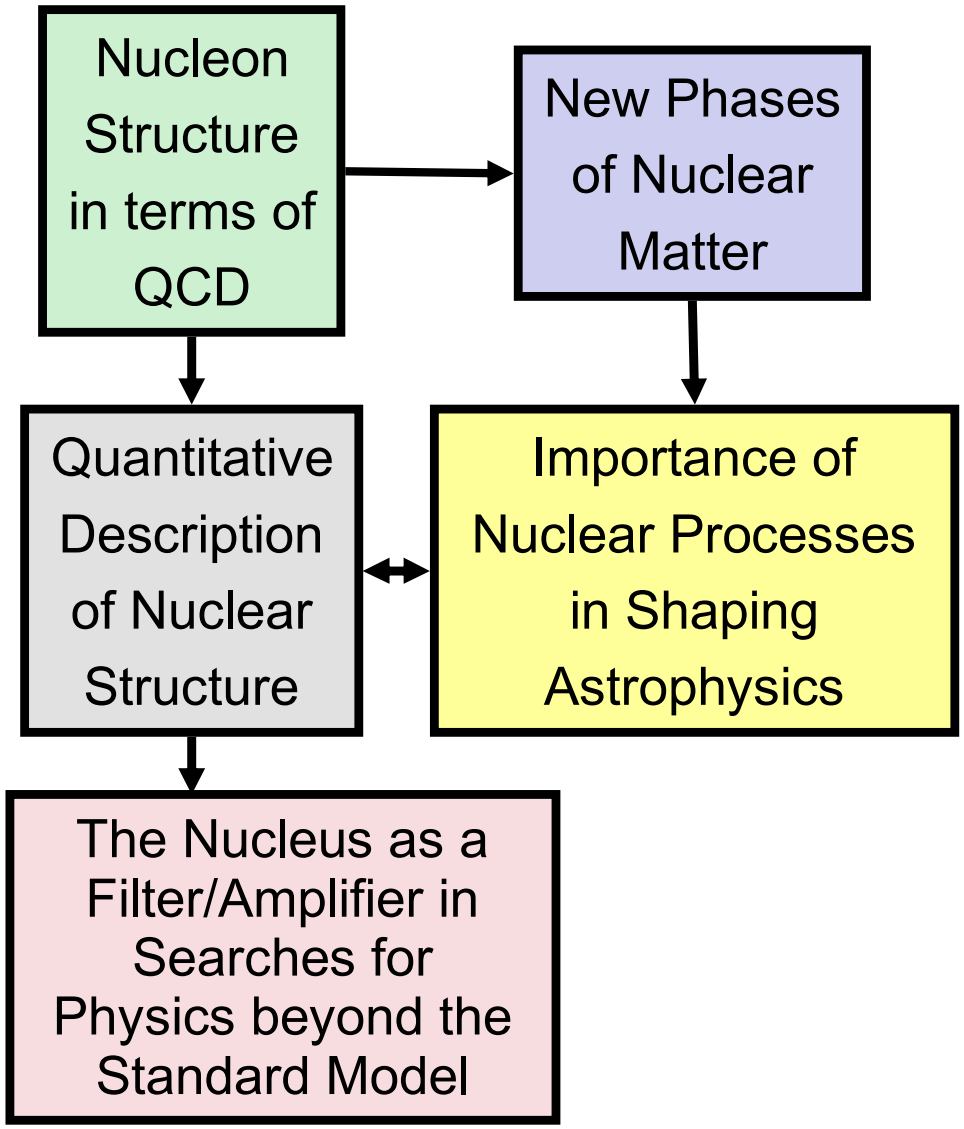
***Presented by*:**
Thomas Brunner
CINP Board Member

CINP Perspectives for the 5YP

- **The CINP represents researchers in all areas of contemporary Nuclear Physics**
  - CINP's Scientific Working Groups:
    - QCD/Hadrons – *Chair: Svetlana Barkanova (Memorial)*
    - Nuclear Astrophysics – *Chair: Nicole Vassh (TRIUMF)*
    - Nuclear Structure – *Chair: Paul Garrett (Guelph)*
    - Fundamental Symmetries – *Chair: Jeff Martin (Winnipeg)*
    - Nuclear Theory – *Chair: Alexandros Gezerlis (Guelph)*
    - Nuclear Physics Education & Training– *Chair: Ruben Sandapen (Acadia)*
- **Many CINP researchers use the rare–isotope beams TRIUMF provides, while others use TRIUMF's infrastructure support (e.g. detector and electronics fabrication, test beam, etc.)**
- **Both are crucial to the continuing health of nuclear physics research in Canada**
- **The community priorities are enumerated in the CINP White Paper and the Canadian Subatomic Physics Long Range Plan**

Nuclear Physics is driven by fundamental investigations of the origin, evolution and structure of strongly interacting matter

- **CINP in alignment with international consensus on the key questions of significance to the broader community**
- **Driven by the criteria of research excellence and critical mass of effort, Canadian nuclear physicists have *self–selected* their efforts to make substantive contributions to these "big questions"**



How do Quarks and Gluons give rise to the Properties and Phases of Strongly Interacting Matter?

CINP ICPN

- **Although much is known about QCD in the perturbative regime, one of the central problems of modern physics is the connection of observed hadron properties to QCD**
- This is a major research effort internationally, and the Canadian experimental efforts are concentrated off shore
- Canadian theory contributions in Lattice QCD, Radiative Corrections, and other areas
- Exotic nuclear matter existed during the first moments after the Big Bang, and can be recreated in relativistic nuclear collisions at RHIC and LHC
- There are some very active Canadian theorists contributing to our understanding of the phase diagram of nuclear matter using intensive high performance computing techniques

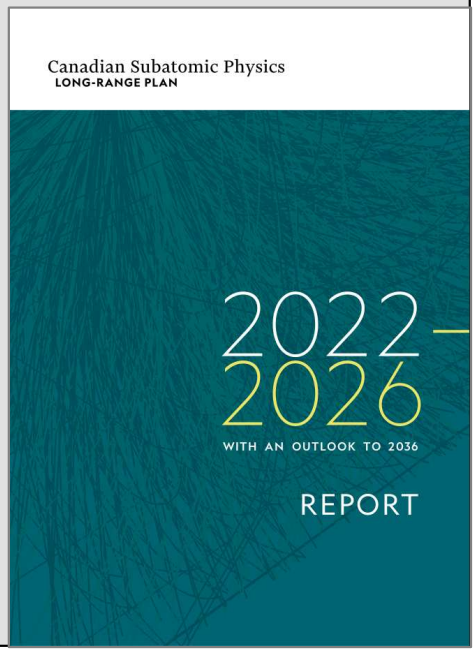
How do Quarks and Gluons give rise to the Properties and Phases of Strongly Interacting Matter?

CINP ICPN

Canadian groups have made substantive detector contributions to the JLab 12 GeV Upgrade, and have moved to data collection and analysis mode

- GlueX (exotic hybrid mesons) Hall D
- Pion and Kaon Form Factors Hall C

- **Medium term (2022–26):** Canadians involved in data taking and analysis of data. JLab Eta Factory (JEF) is planned with upgraded GlueX equipment for 2024–26
- **Longer term (2027–36):** SoLID experiment at JLab
- **Canadian participation at Electron–Ion Collider will uniquely address profound questions about nucleons, including the origin of hadronic mass, the origin of nucleon spin, and the emergent properties of dense systems of gluons**



How does the structure of nuclei emerge from nuclear forces?

CINP ICPN

- **A key goal of nuclear physics research is the development of a comprehensive, predictive theory of complex nuclei**
- This has driven the recent development of high quality radioactive beams, allowing both neutron and proton numbers to vary over a wide range
- **Areas of active inquiry include:**
  - Studies of neutron halos and skins
  - Tests of *ab-initio* theories in light and medium mass systems
  - Evolution of nuclear shell structure as a function of the neutron-proton asymmetry proton and neutron number
  - Studies of nuclear collectivity, shape coexistence, and nuclear shape transition

How does the structure of nuclei emerge from nuclear forces?

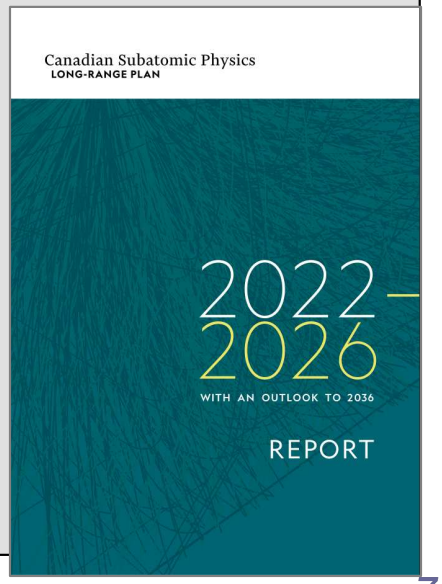
CINP ICPN

Medium term (2022–26): **Highest priority is to capitalize on the recent investments in new world–class detector infrastructure at ISAC. New detector systems, such as EXACT-TPC and RCMP, will begin physics prgrams at ISAC**

- **High quality work off–shore at GSI, RIKEN, FRIB, JLab. Increasing interational users @ ISAC**

Longer term (2027–36): **ARIEL will be a next generation rare–isotope beam facility, new beam species, higher intensities, cleaner beams, longer beam periods**

- **Global ab–initio calculations of all nuclei may become possible in next 5–15 years, making statistical analyses of properties and limits of nuclei from first principles a reality**
- **Nuclear structure investigations relevant to 0vββ may become a future direction**



What is the role of radioactive nuclei in shaping the visible matter in the universe?

CINP ICPN

- Nuclear astrophysics addresses many fundamental questions including: the origin of the elements, the connection of observed solar abundances and nuclear structure phenomena, the structure of neutron stars, the equation of state for asymmetric nuclear matter, etc.
- Interdisciplinary: New era in nuclear astrophysics has opened with the use of radioactive beam facilities, improved astronomical observation and modeling
- Multi–messenger nuclear astrophysics is already being carried out, with the aim to better understand various aspects of the creation of nuclei in stellar events, e.g. observation of GW170817 and follow up observations gave much new informationabout the rapid neutron capture process

What is the role of radioactive nuclei in shaping the visible matter in the universe?

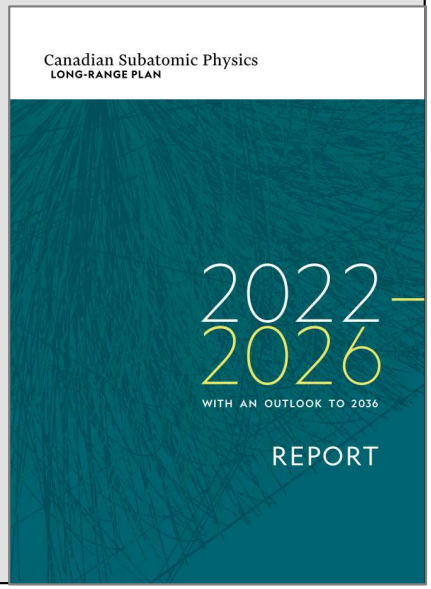
CINP ICPN

Medium term (2022–26): **Majority of domestic program is carried out at ISAC, complemented with off-shore activities at GSI (Germany), RIKEN (Japan), FRIB (USA), GANIL (France)**

- The flexibility of several ISAC detectors to be combined allows a wide coverage of experiments that are not easily possible elsewhere, e.g. EMMA + TIGRESS, GRIFFIN + DESCANT, TITAN EBIT + 8π, DRAGON + GRIFFIN, detectors.

Longer term (2027–36): **Canadian program will profit from full implementation of ARIEL facility at TRIUMF**

- New detectors planned to take full advantage of upcoming photofission beams and intense re–accelerated heavy nuclear beams from ARIEL, e.g. EXACT–TPC
- **TRIUMF Storage Ring (TRISR)** Proposal for a low–energy storage ring with a neutron generator at ISAC is underway



What Physics Lies Beyond the Standard Model?

CINP ICPN

- **Studies of fundamental symmetries via very precise low and intermediate energy experiments have been part of nuclear physics since its inception**
- Complementary to direct probes by high energy physics since precision lower energy experiments indirectly probe mass scales and parameter spaces not otherwise accessible

The Canadian NP program is very active, addressing:

- **Time Reversal and CP violation:**
  - **TUCAN n–EDM search; Radioactive Molecules @ ISAC**
- **Neutral Current Weak Interactions**
  - **MOLLER PV e^- Scattering @ JLab; Francium Atomic Parity Violation @ ISAC**
- **Neutrinos:**
  - **$0\nu\beta\beta$ studies @ SNOLab; BeEST search for keV–scale ν @ ISAC**
- **CPT, Lorentz and Weak Equivalence Principle violation: ALPHA @ CERN**
- **CKM Matrix Unitarity: GRIFFIN, TITAN @ ISAC**
- **Beta–Neutrino Correlations: TRINAT neutral atom trap @ ISAC**

What Physics Lies Beyond the Standard Model?

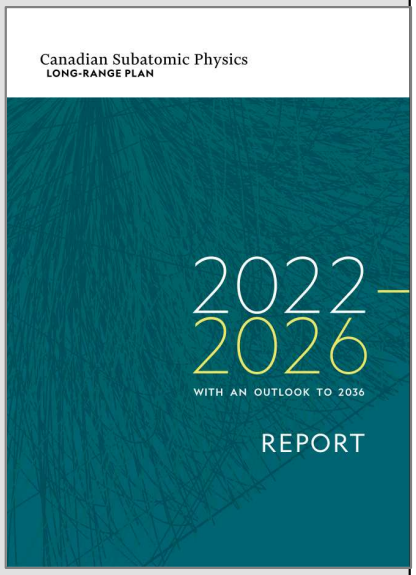
CINP ICPN

Medium term (2022–26):

- ISAC program: Laser–trapped Francium, GRIFFIN β–decay, TRINAT, TITAN
- TUCAN and ALPHA–g upgrades completed
- NaB cold neutron experiment underway
- MOLLER @ JLab construction begun, run to ~2030
- Positive funding decisions by funding agencies towards deploying nEXO @ SNOLAB

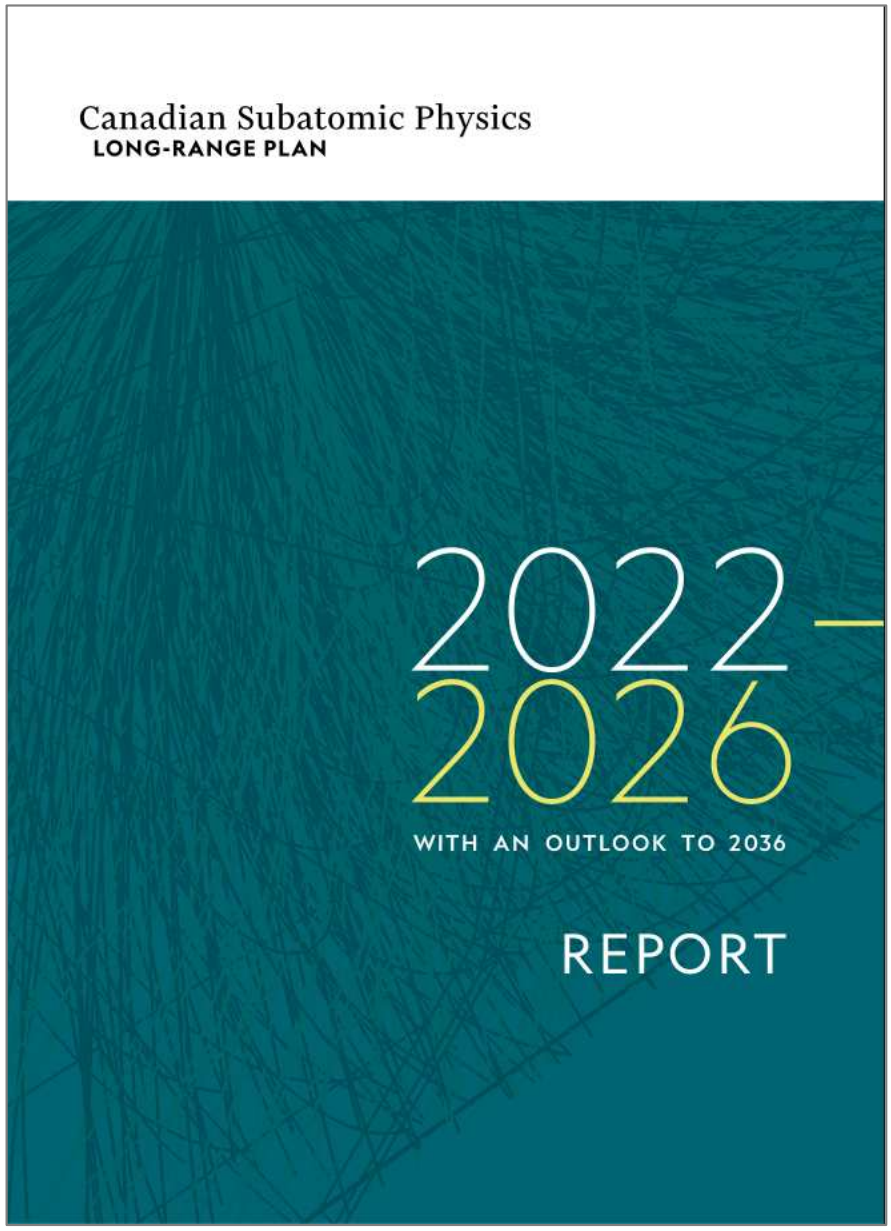
Longer term (2027–36):

- Precision spectroscopy with radioactive molecules will be major new effort @ ISAC
- FrPNC to start atomic PV run @ ISAC
  - Possible extension to cold Fr, Ag molecules
- Deployment of HAICU by ALPHA Collaboration
- Fundamental Symmetries @ EIC



Nuclear Physics High–Priority Science

- **Flagship Projects with Broad Physics Outcomes:**
  - TRIUMF ARIEL–ISAC Experiments
  - Electron–Ion Collider
- **Flagship Projects with Strategic Physics Outcomes:**
  - JLab 12 GeV Program
  - Offshore RIB Experiments
  - ALPHA/HAICU, MOLLER, TUCAN



TRIUMF's Important Roles

- **The success of TRIUMF's on site nuclear physics program is obviously a very high priority of the CINP community**
  - Completion of ARIEL project
  - Reliable delivery of RIB beam to experiments
  - TUCAN neutron EDM
- **TRIUMF is also Canada's primary support center for large domestic and international projects**
- **This impacts all areas of CINP researcher activity:**
  - nEXO @ SNOLAB
  - MOLLER @ JLab
  - Electron–Ion Collider accelerator and detector
  - ALPHA/ALPHA–g @ CERN
  - MRS Facility Coordination Support
- **The challenge of the coming 5YP will be to balance TRIUMF's activities in both areas**

Updating Community Priorities

- **It is time to start thinking as a community about what we want to accomplish in the next Canadian Subatomic Physics Long Range Plan 2027–2031**
  - Goal is for new LRP to be released in Fall 2026
  - CINP+IPP need to start planning for Terms of Reference, agency sponsors, and LRPC composition later this year
- Although there have been some encouraging announcements in the recent Federal Budget, long term funding increases for science generally, and SAP specifically, are far from certain
  - **What should we do better/differently in next LRP?**
  - **What "hard data" can we as a community gather that will better make our case for financial support?**