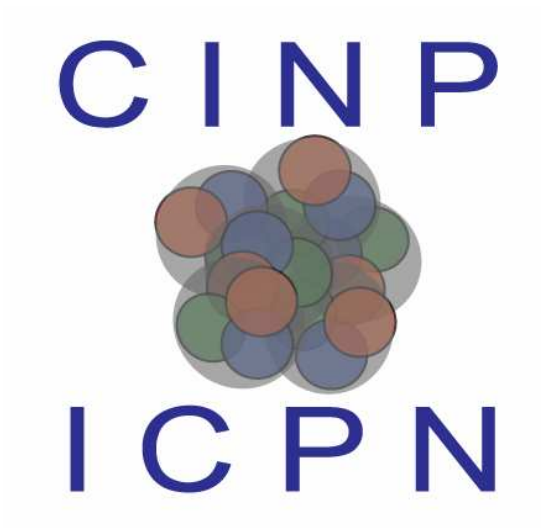


Canadian Institute of Nuclear Physics

Institut canadien de physique nucléaire

NSERC Subatomic Physics Context Session
December 17, 2021

What is the CINP?

- The CINP is a formal organization of the Canadian nuclear physics research community to promote excellence in nuclear research and education, and to advocate the interests and goals of the community both domestically and abroad
  - Federally incorporated under the Canada Not–for–profit Corporations Act
- Represents researchers covering all aspects of experimental and theoretical nuclear physics. Co–ordinates planning on a national scale and exchanges information within and between the various sub–fields of nuclear physics
- Leads initiatives to strengthen the level and quality of nuclear physics research in Canada, including fellowships, undergraduate research scholarships, student travel awards, and targeted conference support

CINP Governance

Memorial joined in 2021

Institutional Members
McGill University
Memorial University of Nfld
Mount Allison University
Saint Mary's University
Simon Fraser University
TRIUMF
University of Guelph
University of Manitoba
University of Northern B.C.
University of Regina
University of Winnipeg

Pay Annual Dues and Elect Board

Board of Directors
Rituparna Kanungo *President*
Michael Gericke
Gwen Grinyer
Sangyong Jeon
Jeff Martin
Chris Ruiz

Executive Director
Garth Huber

Treasurer
Greg Hackman

Scientific Working Groups

SWGs facilitate collaboration among researchers with common interests, and to enhance the profile of a specific research area within Canada

- **Provide input to CINP external scientific briefs**
- **Hold topical workshops or other initiatives**
- **Encourage new collaborative efforts**

- **Individual Members may belong to one or more SWGs**
- **Nuclear Theory SWG was created in 2021 in follow up to Long Range Planning consultations**

SWG	Chair	Institution
Nuclear Structure	Adam Garnsworthy	TRIUMF
Nuclear Astrophysics	Iris Dillmann	TRIUMF
Fundamental Symmetries	Gerald Gwinner	University of Manitoba
Hadron Structure/QCD	Svetlana Barkanova	Memorial University of Newfoundland
Nuclear Theory	Alexandros Gezerlis	University of Guelph
Nuclear Physics Education and Training	Juliette Mammei	University of Manitoba

CINP Individual Membership

CINP Membership December 15, 2021	
Total Membership	142
Faculty (Full) Members	85
Associate Members (Grad Students, PDFs, Professor Emeriti)	57
Experimentalists	107
Theorists	34

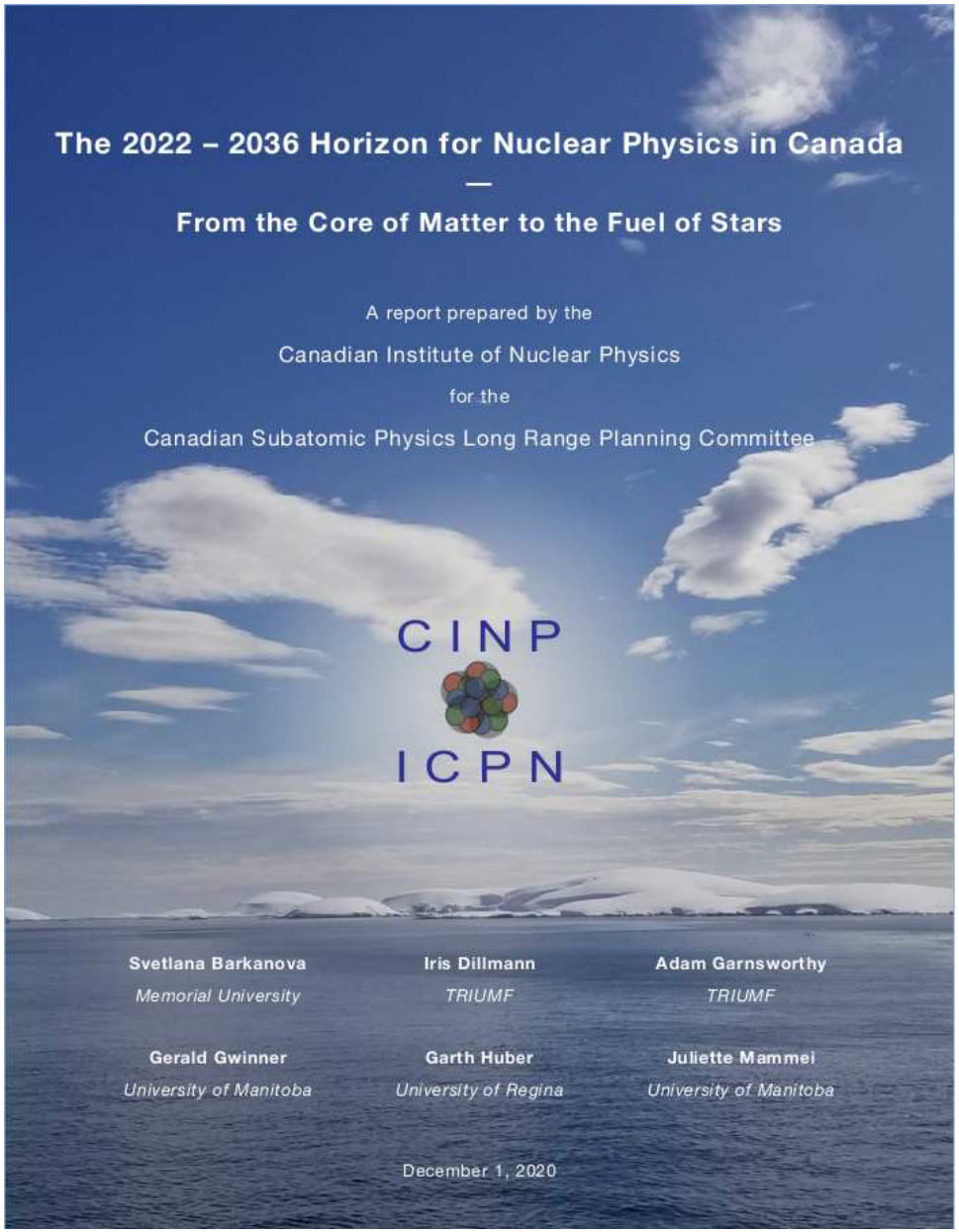
SWG Membership	
Nuclear Astrophysics	**55**
Nuclear Structure	**56**
Fundamental Symmetries	**62**
Hadrons/QCD	**49**
Nuclear Theory	**17**
Nuclear Physics Education & Training	**41**

CINP 2021 Accomplishments

- **Nuclear Physics Representation**
  - **The CINP has been vital in giving the nuclear physics community a coherent and strong voice**
  - Suggests new members to SAPES, provides input to NSERC, CFI, ISED on matters of importance to NP
  - NP Community Representative at Advisory Committee on TRIUMF (ACOT), April and October annually
  - NP input to Pan–Canadian MRS Resource Planning Board ~6 meetings/yr
  - Joint letter with IPP to Ontario, Federal and local governments protesting the closure of the Laurentian University physics program
  - Letter of support to USA for nEXO at SNOLAB
  - Formal observer to NuPECC (Nuclear Physics European Collaboration Committee)

CINP role in 2022–26 Long Range Plan

- **CINP is one of three commissioning bodies** (with NSERC, IPP) **of Canadian Subatomic Physics Long Range Plan**
- CINP Exec Dir is an Ex-Officio member on LRPC, CINP leaders Rituparna Kanungo, Jeff Martin, Juliette Mammei are voting members
- **CINP undertook broad consultation with the Canadian Nuclear Physics Research community**
- Produced a substantial White Paper: 187 pages that fed into the LRP. Available from cinp.ca



CINP Undergraduate Research Scholarships (URS)

- **Allows gifted undergraduates to work with supervisor on nuclear physics research for 16 weeks in summer**
- **A supervisor can nominate only their best student for the award. Process is competitive, with only top ~50% nominees selected.**
- **Award:**
  - $5k student stipend which must be matched by supervisor to at least $9k
  - $1300 travel supplement available if the supervisor intends to send the student to a laboratory or to work with a second collaborator for an extended period

– **CINP URS is complementary to NSERC USRA in several key aspects:**

1) Gifted international students studying in Canada are eligible to apply for the CINP URS, but not the NSERC USRA.
2) An important element of the URS is the optional Travel Award, which allows the supervisor to send student to a lab or work with second collaborator for an extended period. This can have a significant impact on the quality of the research experience for some undergrads. NSERC USRA has no such component.

CINP 2021 Accomplishments

2021 CINP Undergraduate Research Scholarships

Student	Supervisor	Project Title
Kiera Augusto (Winnipeg)	Jeff Martin (Winnipeg)	Fiber optic magnetometer for TUCAN EDM experiment
Gabriel Desmarais (Saint Mary's)	Greg Christian (Saint Mary's)	Spectroscopic factors of excited states in ^{22}Na and their relevance for the ^{23}Mg(p,γ)^{24}Al reaction in classical novae and X-ray bursts
Monica Figueroa (Alberta)	Andrzej Czarnecki (Alberta)	Decays of pionic atoms resulting in muonic atom
Emma Klemets (McGill)	Thomas Brunner (McGill)	Optimization of the nEXO muon veto
Colby O'Keefe (Saint Mary's)	Rituparna Kanungo (Saint Mary's)	Investigation of structure of neutron-rich nuclei
Hrishikesh Patel (UBC)	Jason Holt (TRIUMF)	Ab-initio calculations of atomic systems for major problems in nuclear physics

2020 MRS grant renewal allowed CINP to increase URS program from 5 to 6 scholarships in 2021

10 applications were received.
Selection Committee: Juliette Mammei (Manitoba), Chris Ruiz (TRIUMF), Garth Huber (Regina)

CINP Graduate Fellowship (GF)

- **A new initiative, proposed in CINP's 2020 MRS grant application**
- **Intended to attract or retain very gifted Ph.D. candidates to conduct nuclear physics research in Canada**
- **Award:** $12,000 scholarship to PhD student of high merit
  - Awardee's supervisor or home institution must agree to supplement the GF from institutional or research funds to a value of not less than $32,000
  - During fellowship period, the awardee is eligible to access conference travel funds by application to CINP Junior Scientist Travel program
- **Criteria:** In addition to academic and scientific criteria, application has EDI component
  - applicants wrote 1 page description of what role a PhD student and CINP Graduate Fellow can plan in promoting and advancing EDI in our community
- **2021 competition was for a single fellowship**
- 14 applications were received so competition was very tight. High uptake confirms strong need for such a fellowship

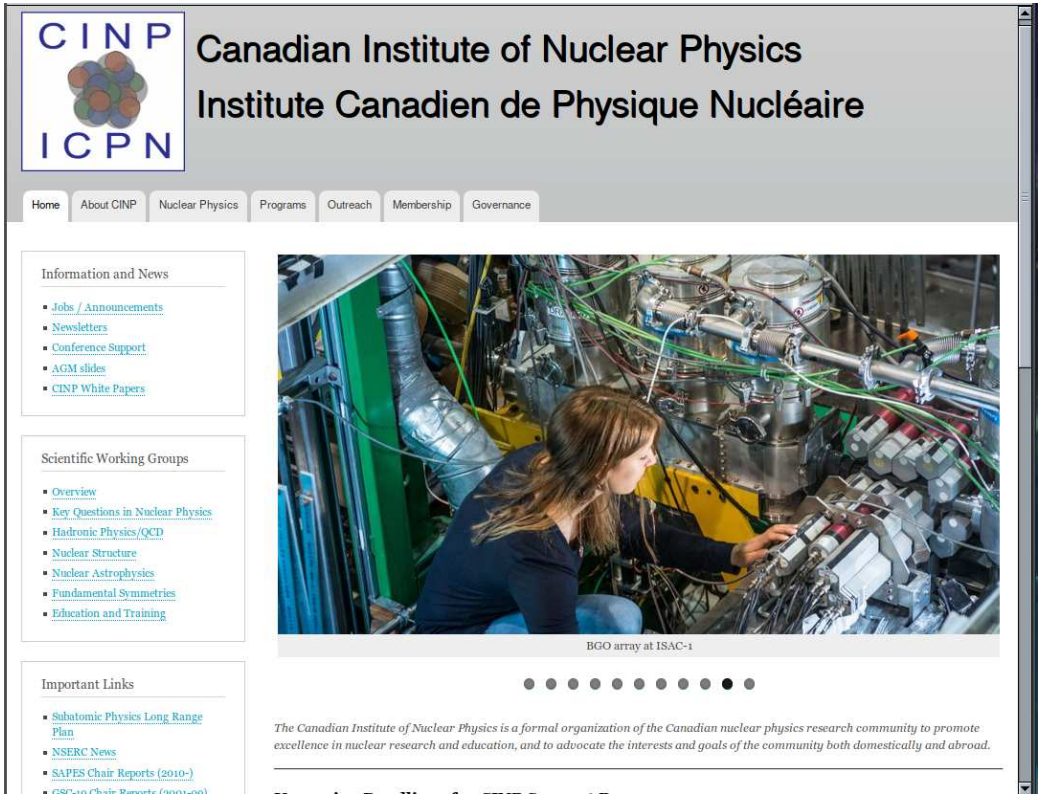
CINP 2021 Accomplishments

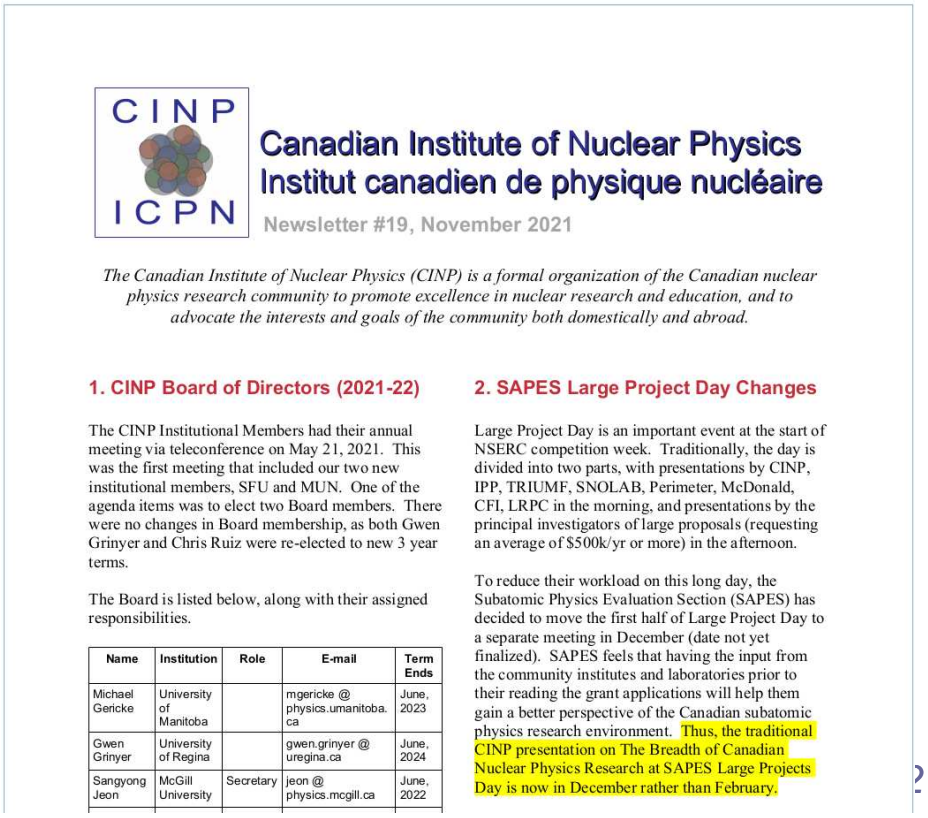
2021 CINP Graduate Fellowship

- **Recipient: Jessica Churchill (McGill)**
  - Graduated Magna Cum Laude BSc Honours Physics from Saint Mary's in 2016
  - Completed MSc in Theoretical Nuclear Physics at McGill in 2018 "*Photons and Dileptons as Probes of Early–Time Dynamics in Relativistic Heavy–Ion Collisions*"
  - Fellowship will allow this work to be extended, under supervision of Charles Gale (McGill)
- Reviewed by: Svetlana Barkanova (Memorial), Gwen Grinyer (Regina), David Hornidge (Mt. Allison)
- **CINP anticipates being able to expand the program to two fellowships in future years. Based on high quality of applications, we could have awarded at least 7!**

CINP 2021 Accomplishments

- **Community Outreach:**
  - **CINP facilitates new connections and allows the disparate Canadian nuclear physics community to develop a common identity**
  - CINP website http://cinp.ca/ updated regularly
  - 2 Newsletters, May and November annually





COVID–19 Impacts

- **Many CINP Programs impacted, as conferences and workshops delayed on moved to virtual format**
- **Conference Support Program:**
  - Approved budget for delayed events carried forward to whenever they can be held in person
  - First new conference application for summer 2022 approved
    CSQCD IX: From RHIC to Astrophysics, probing the quark-gluon plasma
- **Junior Scientist Support Program:**
  - First new JSci application for December 2021 travel approved
    Accelerator Physics workshop @ CERN
- **Canadian Undergraduate Physics Conference (CUPC 2021):**
  - Instead of travel awards to assist undergraduates presenting NP research, sponsored CINP Prize for best research presentation in nuclear physics
  - Awarded to: Emily Love (TRIUMF) *"Selecting Orbitals in Ab–Initio Nuclear Theory"*
- **Winter Nuclear and Particle Physics Conference (WNPPC 2022):**
  - Instead of a Graduate Student Travel Award Program, CINP will sponsor prizes to the best presentations by students supervised by a CINP member

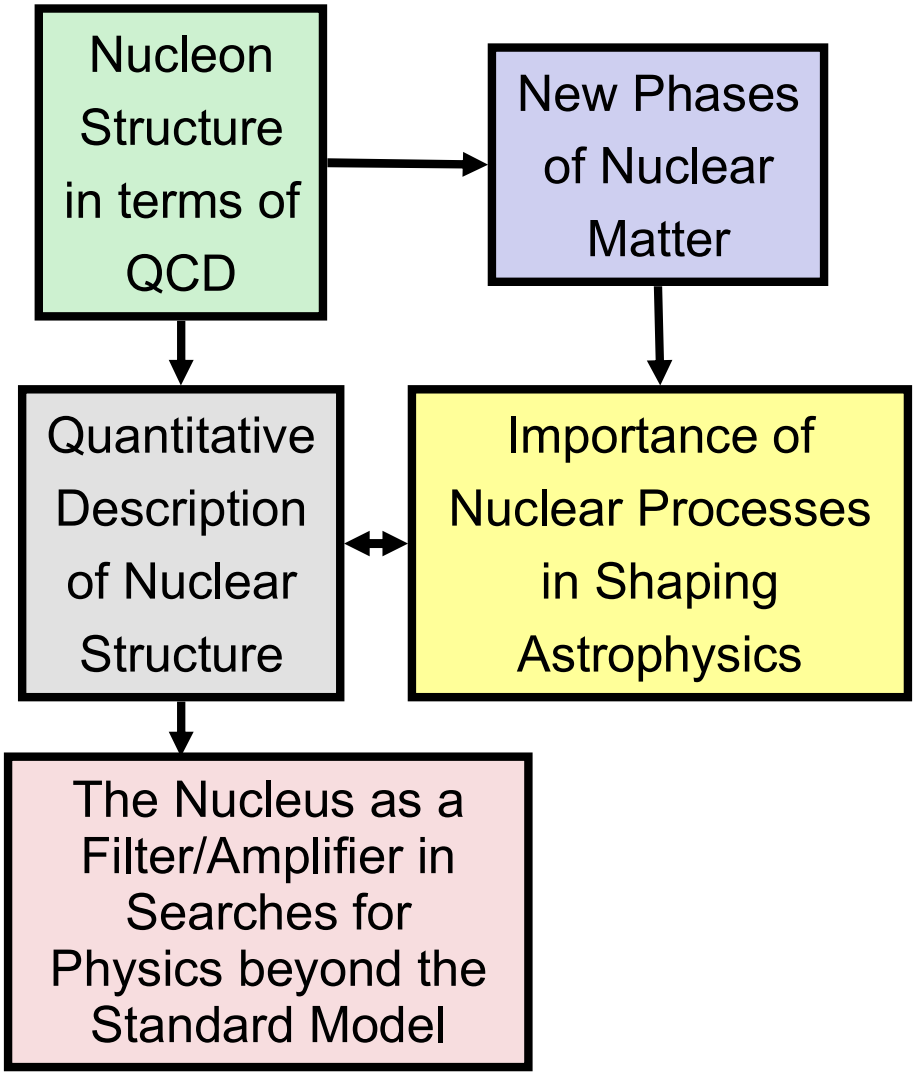
CINP Scientific Summary

A Few Slides on:

The Breadth of Canadian Nuclear Physics Research
and
Important Current and Future Priorities

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

- **Broad 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

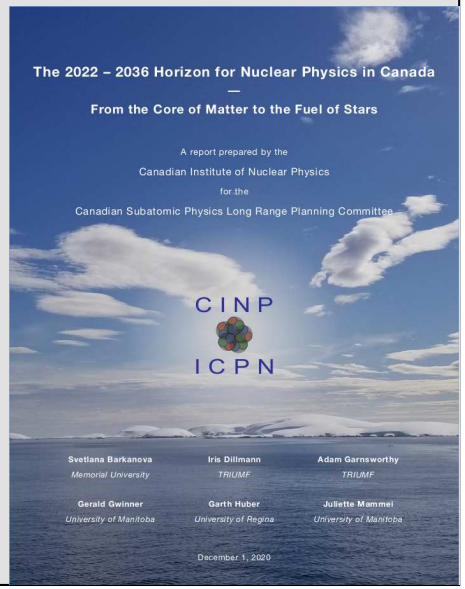
How do Quarks and Gluons give rise to the Properties and Phases of Strongly Interacting Matter?

CINP ICPN

Canadians 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 2021–26**
- **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**



2021 Research Highlights

- GlueX @ JLab: Search for Hybrid Mesons

CINP ICPN

Physics Analyses

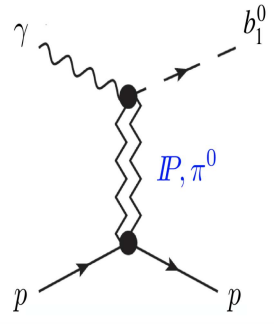
- **Physics Convenor**: Beam Asymmetry & Vector-Pseudoscalar WGs
- **πΔ/ηΔ beam asymmetry ratio:** IU/Regina-postdoc-led paper to PRC
- **$b_1\pi$ exotics doorway**: axial vector decay, LQCD predictions; xsections, angular moments and pioneering **PWA**

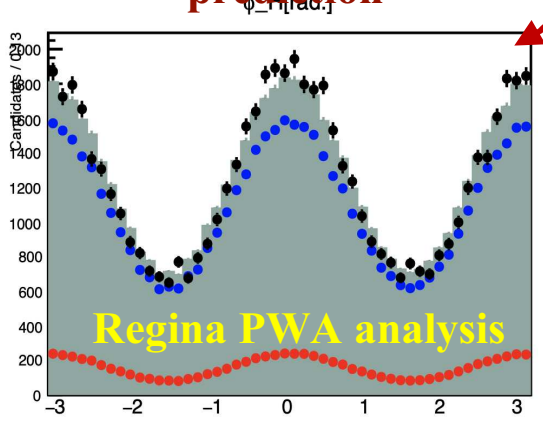
$$\gamma p \to p b_1(1235) \to p[\omega]\pi^0 \to p\pi^+\pi^-2\pi^0$$

GlueX Preliminary

Theory: $\pi_1(1564)$ exotic decays through $b_1\pi$ (and not $\eta^{(\prime)}\pi$); S/D-wave ratio prediction

Neutral b_1





PHYSICAL REVIEW C
covering nuclear physics

5th GlueX physics paper

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Letter

Access by University

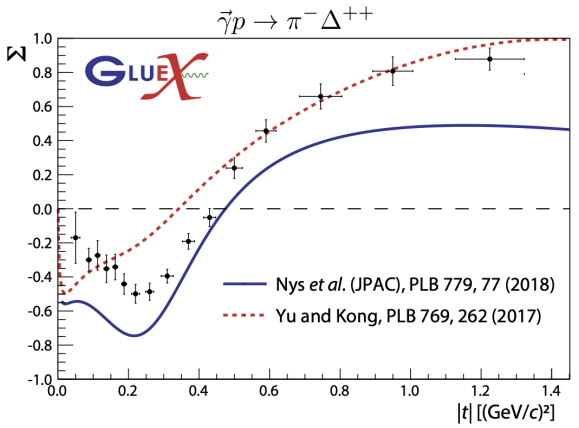
Measurement of beam asymmetry for $\pi^-\Delta^{++}$ photoproduction on the proton at $E_\gamma = 8.5$ GeV

S. Adhikari *et al.* (The GlueX Collaboration)
Phys. Rev. C **103**, L022201 – Published 22 Feb

Article References No Citing Articles

ABSTRACT

We report a measurement of the ... using data from the GlueX experi... Σ is measured as a function of fo... phenomenological models. We fi... positive at higher values of $|t|$. Th... exchange requiring pseudoscalar... charge exchange, allowing us to ... to one-pion exchange at low mor... conventional mesons may aid in ... measurement of the process at th...



t-channel particle exchange: pseudoscalar, vector, and tensor

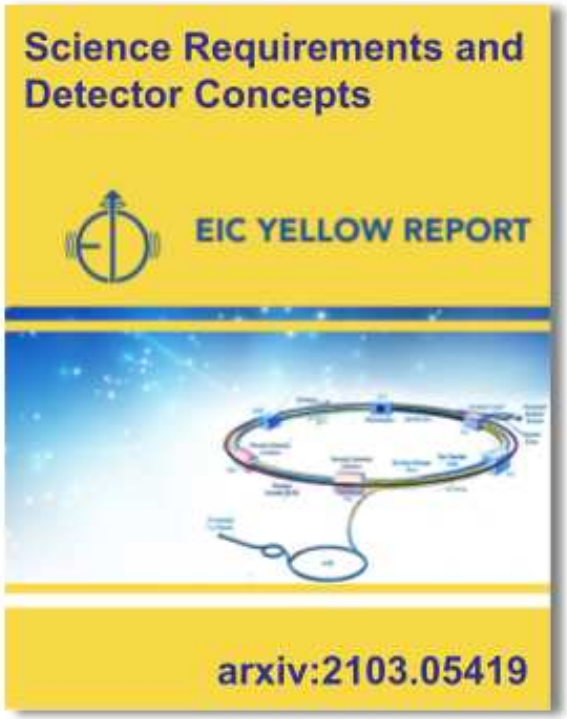
Service Contributions

- **Calorimeter Coordinator**
- **Barrel Calorimeter:** Monitoring & calibration each run period (LEDs, π^0 gain, cosmics)
- **Calorimetry upgrade**: FCAL-II for rare eta decays & SM-Dark Sector experiment (2024)
- **Machine Learning:** applied to particle ID and photon-neutron discrimination

2021 Research Highlight

Electron-Ion Collider: Two Large Collaborations

CINP ICPN



2021: From a community Yellow Report…
…**to two large collaboration detector proposals** with Canadian involvement
2022: Detector Proposal Review/Selection
2024: Construction/Installation
2030: First Beam/Operations

ATHENA: A Totally Hermetic Electron-Nucleus Apparatus

Key Characteristics:
- New 3T magnet
- Tracking: Si MAPS vertex, MicroMegas barrel, GEMs + µRWELL endcaps
- PID: hpDIRC, AC-LGAD ToF, dual radiator RICH, proximity-focused RICH
- Calo: Si-pixel imaging + SciFi hybrid barrel, PbWO + SciGlass hybrid endcaps
- Software: CERN-oriented (dd4hep, gaudi, ACTS)

EIC Canada involvement:
- U Manitoba (W. Deconinck: software WG convener)
- Mt Allison U (D. Hornidge)

Canadian resources:
- ComputeCanada full sims

EIC Comprehensive Chromodynamics Experiment

Key Characteristics:
- BaBar 1.5T magnet
- µRWell & Si tracker
- PID DIRC/mRICH/dRiCH
- Calo: Barrel, e-/Hadron endcap, Roman pots, ZDC, B0

EIC Canada involvement:
- U Regina: G. Huber (meson form factors at high Q^2); Z. Papandreou (spectroscopy of XYZ states)
- Event generators, Far forward detector studies
- Novel AI Work: Inner tracker design optimization; calo design using hierarchical density-based clustering

Canadian resources:
- JLab ifarm, Regina resources

Methods and Tools are applicable to final detector/collaboration choice

2021 Research Highlight
– Honours Received by Members

Sangyong Jeon *(McGill)*

- **Recipient of the 2021 CAP–TRIUMF Vogt Medal for Contributions to Subatomic Physics, to recognize his contributions to the theory of relativistic heavy–ion collisions and the resulting quark–gluon plasma**
- **We also note that Dr. Jeon has served as a CINP Board member since 2016**

How does the structure of nuclei emerge from nuclear forces?

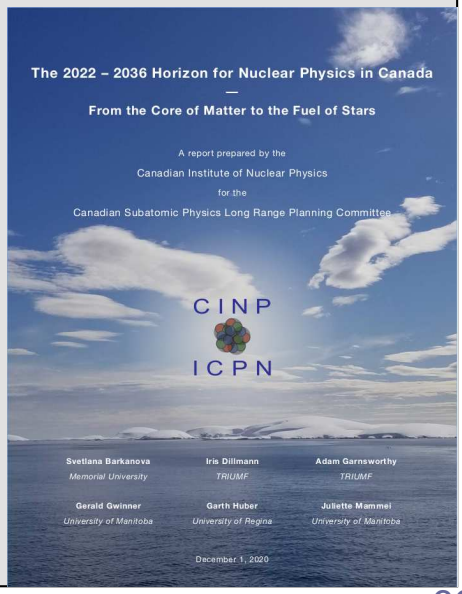
- **A key goal of nuclear physics research is the development of a comprehensive, predictive theory of complex nuclei**
- This has driven the recent development of high quality radioactive beams, allowing both neutron and proton numbers to vary over a wide range
- Areas of active inquiry include:
  - 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?

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

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

- High quality work off–shore at GSI, RIKEN, FRIB, JLab & Interactional involvement @ ISAC
- 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

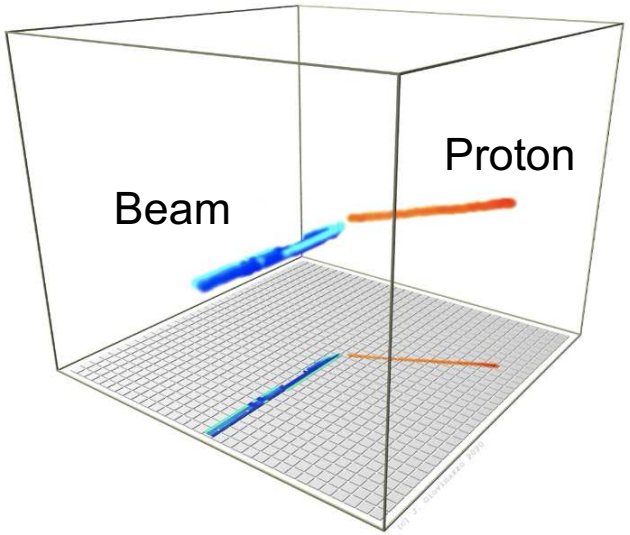


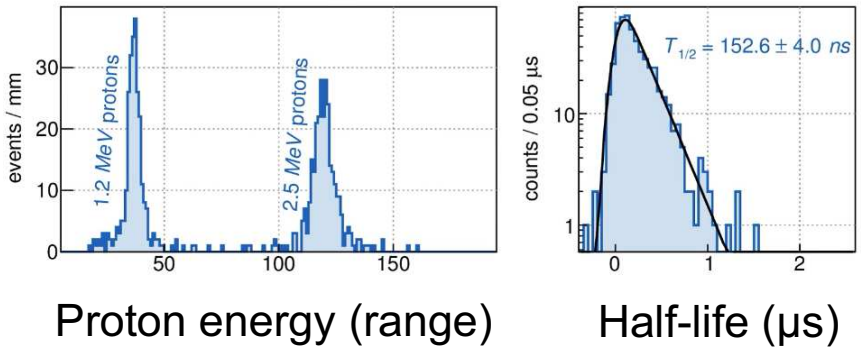
2021 Research Highlight

- 4D imaging of dripline radioactivity in a TPC

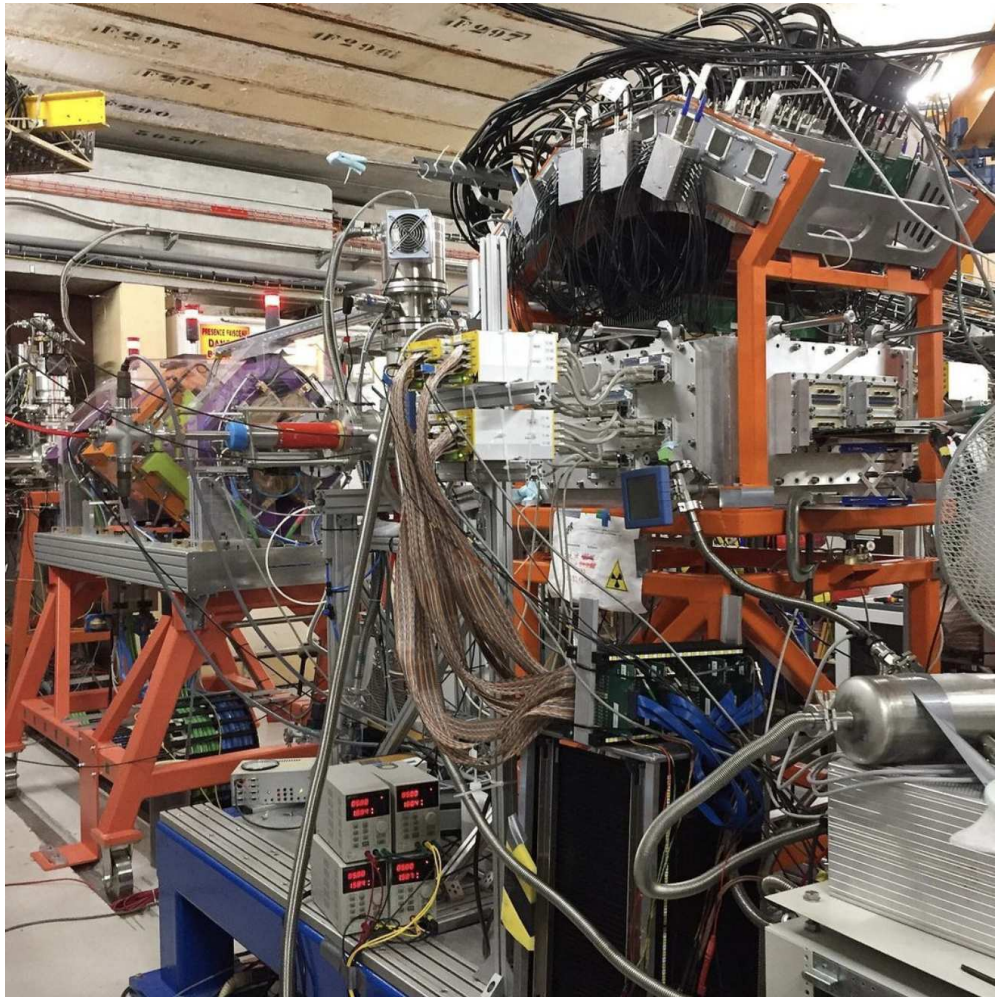
- Proton emission from a 155 ns isomer in ^{54}Ni observed for the first time in a TPC
  - *Nature communications* **12**, 4805 (2021)

ACTAR TPC: Regina, Bordeaux, GANIL Santiago, KU Leuven, Lund, NSCL





Proton energy (range) Half-life (µs)



2021 Research Highlight

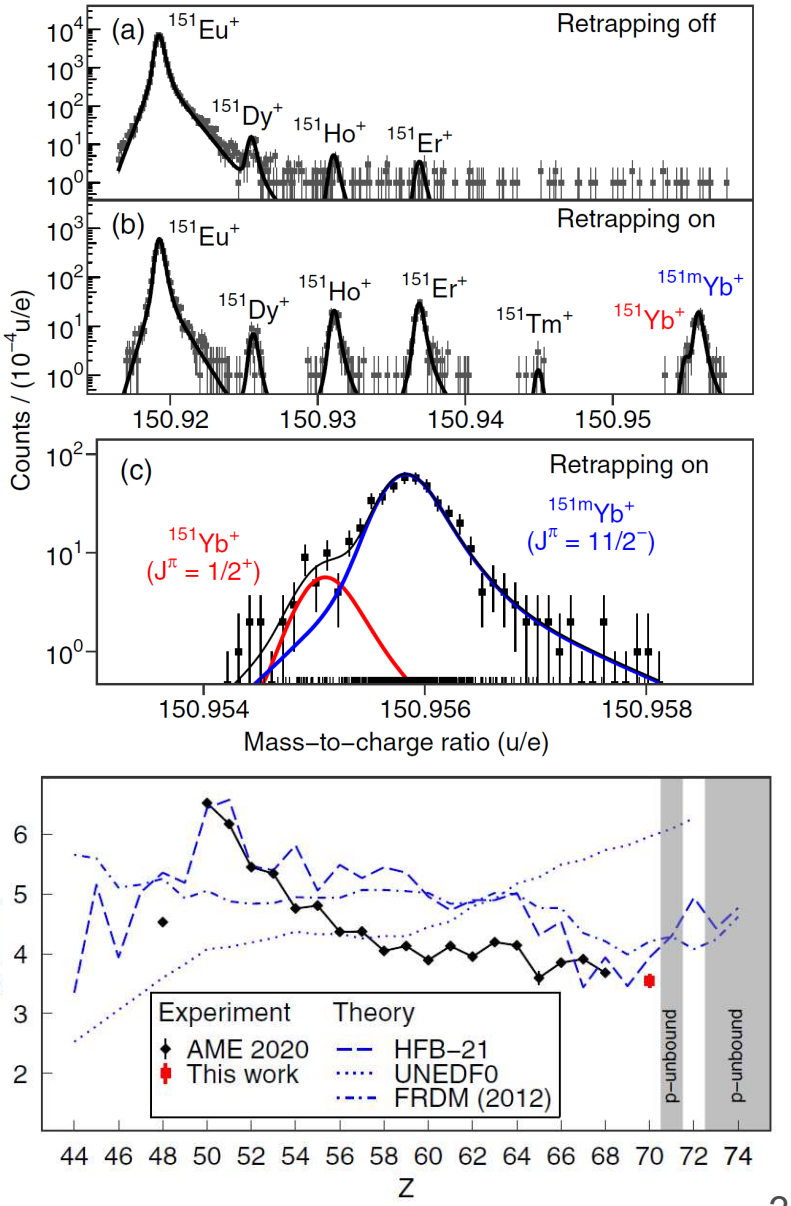
- TITAN-TRIUMF probes the proton dripline

Mass measurements of neutron-deficient Yb isotopes were used to predict the proton dripline and compared to theory.

Values were also used to explore the evolution of nuclear shell structure at N=82.

New “retrapping” technique isobarically purifies beam. It has since permitted other mass-measurement studies:

- Tests of isospin symmetry with ^{60}Ga S.F. Paul, *et al.*, PRC accepted
- The emergence of a shell closure of N=34 in Sc isotopes E. Leistenschnedier, PRL 126, 042501 (2021)
- Pathways of r-process nucleosynthesis with ^{134}In C. Izzo *et al.*, PRC **103**, 025811 (2021)



S. Beck *et al.*, PRL127, 112501 (2021)

2021 Research Highlight

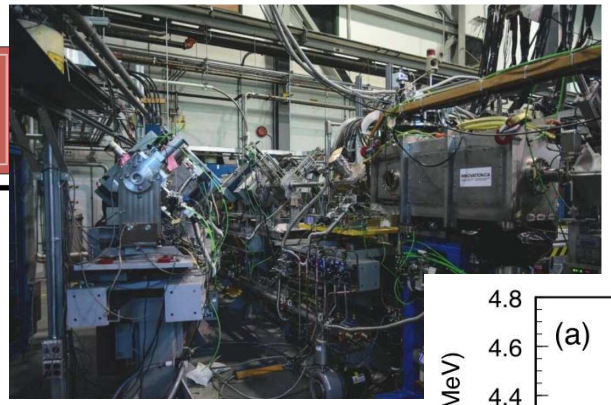
– IRIS @ TRIUMF finds deformation in doubly magic ^{8}He

Physics Letters B 822 (2021) 136710

Contents lists available at ScienceDirect

Physics Letters B

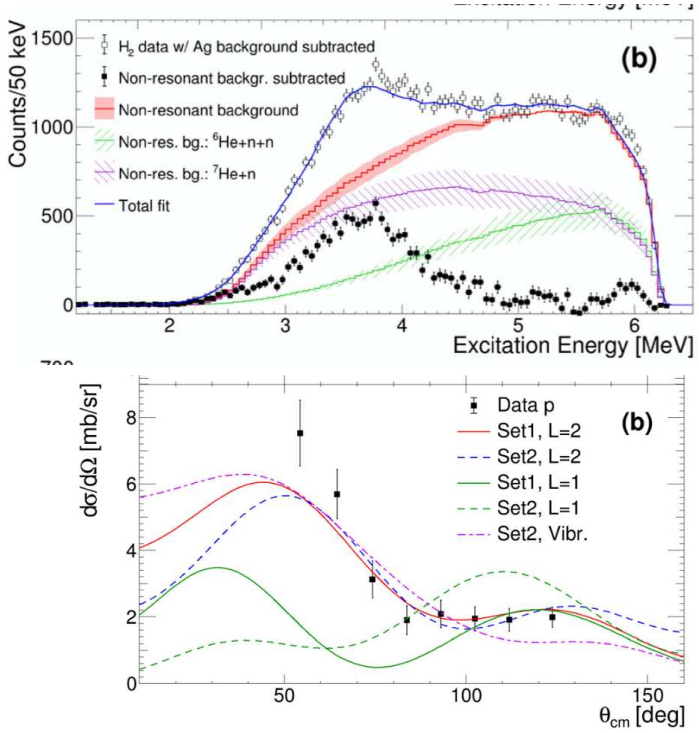
www.elsevier.com/locate/physletb



Proton inelastic scattering reveals deformation in ^{8}He

M. Holl [a,b], R. Kanungo [a,b,*], Z.H. Sun [c,d], G. Hagen [c,d], J.A. Lay [e,f], A.M. Moro [e,f], P. Navrátil [b], T. Papenbrock [c,d], M. Alcorta [b], D. Connolly [b], B. Davids [b], A. Diaz Varela [g], M. Gennari [b], G. Hackman [b], J. Henderson [b], S. Ishimoto [h], A.I. Kilic [g], R. Krücken [b], A. Lennarz [b,i], J. Liang [i], J. Measures [j], W. Mittig [k,l], O. Paetkau [b], A. Psaltis [i], S. Quaglioni [m], J.S. Randhawa [a], J. Smallcombe [b], I.J. Thompson [m], M. Vorabbi [b,n], M. Williams [b,o]

High statistics ^{8}He(p,p') @ IRIS

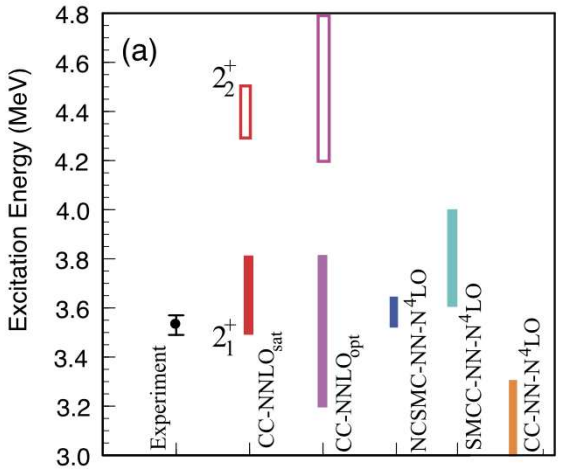


^{8}He double magic
(Z= 2, N = 6 sub shell closure)

Yet shows large deformation in 2^{+} state !

$$V_{l}(R) = -\frac{\delta_{l}}{\sqrt{4\pi}}\frac{dU(R)}{dR}$$

$$\beta_2 = 0.4(3)$$



NCSM :
^{8}He : **Qn = 6.15 efm^2**, Qp = 0.60 efm^2
^{12}C: Qn = Qp = 6 efm^2

Neutrons line rugby-ball, Protons spherical

Media coverage

PHYS.ORG
NOVEMBER 17, 2021
A glimpse of deformation in helium-8

Apple news
SCIENMAG: Latest Science and Health News
TRIUMF's IRIS provides a glimpse of deformation in helium-8

2021 Research Highlight

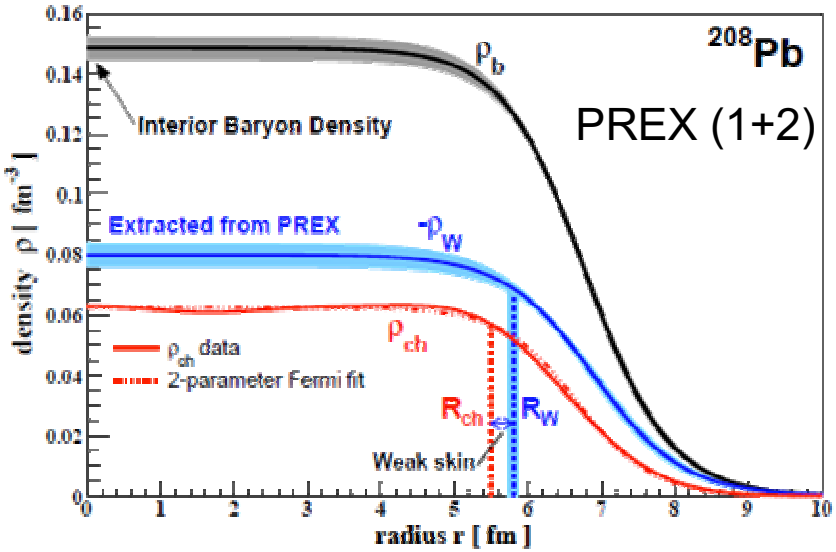
– neutron skins of heavy nuclei – neutron matter EOS

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \propto Q^2 \frac{F_W}{F_{ch}}$$

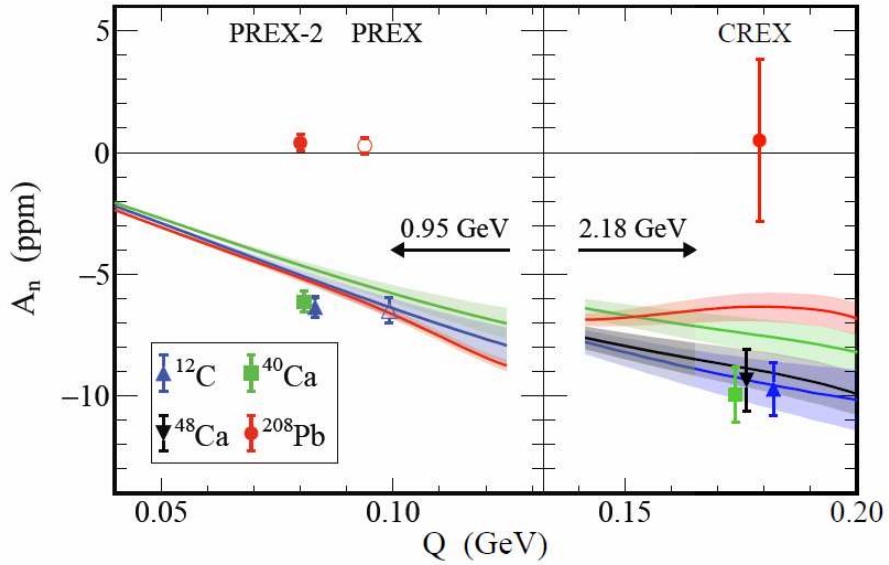
$$A_{PV} = 550 \pm 16(\text{stat}) \pm 8\ (\text{syst})\text{ppb}$$

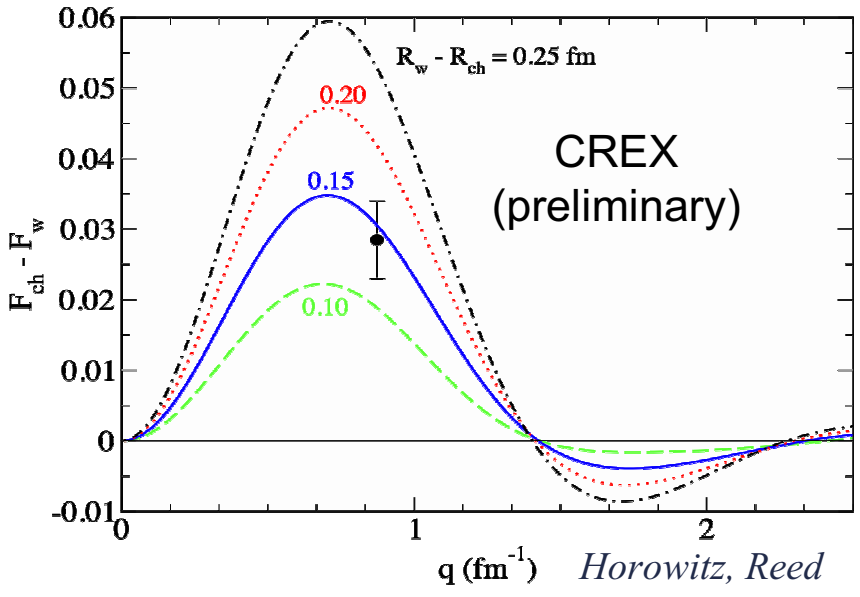
$$R_n - R_p \equiv 0.283 \pm 0.071\ \text{fm}$$

Future neutron skin measurements at Mainz



Beam-normal single-spin asymmetries





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 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

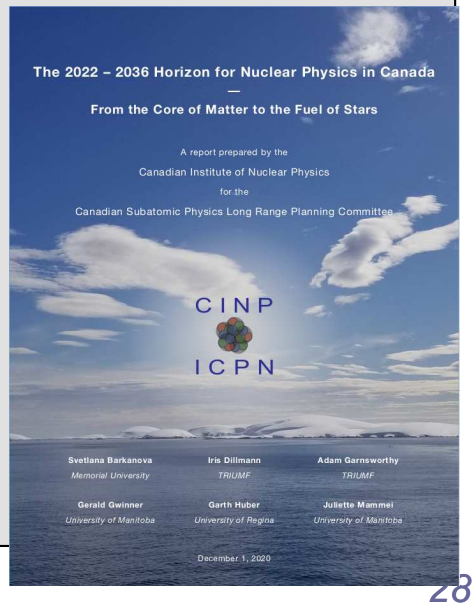
What is the role of radioactive nuclei in shaping the visible matter in the universe?

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



2021 Research Highlight

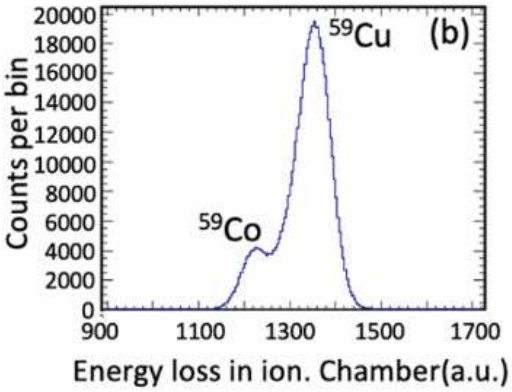
– IRIS @ TRIUMF - First direct measurement of ^{59}Cu(p,α)^{56}Ni rate

PHYSICAL REVIEW C **104**, L042801 (2021)

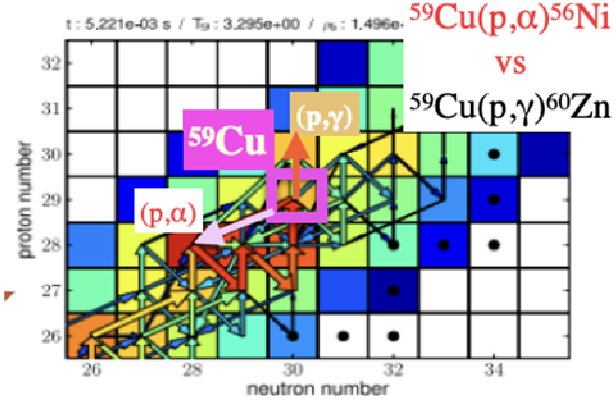
Letter

First direct measurement of ^{59}Cu(p, α) ^{56}Ni: A step towards constraining the Ni-Cu cycle in the cosmos

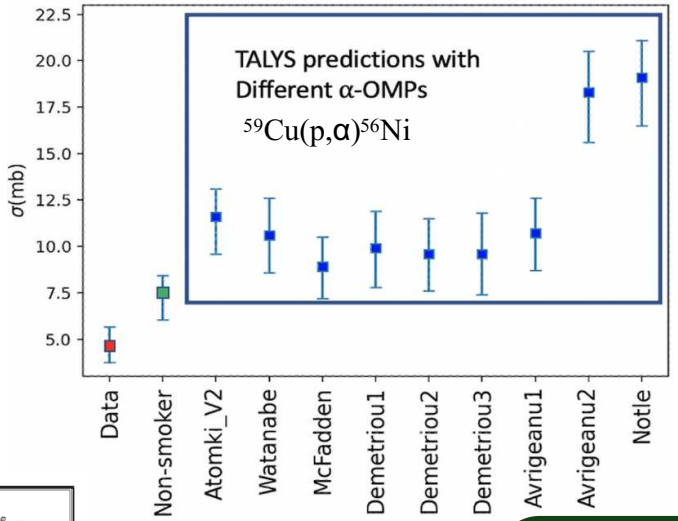
J. S. Randhawa,[1,*] R. Kanungo,[2,3,†] J. Refsgaard,[2,3] P. Mohr,[4] T. Ahn,[1] M. Alcorta,[3] C. Andreoiu,[5] S. S. Bhattacharjee,[2,3,6] B. Davids,[3,7] G. Christian,[2] A. A. Chen,[8] R. Coleman,[9] P. E. Garrett,[9] G. F. Grinyer,[10] E. Gyabeng Fuakye,[10] G. Hackman,[3] J. Hollett,[2] R. Jain,[11] K. Kapoor,[10] R. Krücken,[3,12] A. Laffoley,[9] A. Lennarz,[3,8] J. Liang,[8] Z. Meisel,[13] B. Nikhil,[2] A. Psaltis,[14] A. Radich,[9] M. Rocchini,[9] N. Saei,[10] M. Saxena,[13] M. Singh,[2] C. Svensson,[9] P. Subramaniam,[2] A. Talebitaher,[10] S. Upadhyayula,[3] C. Waterfield,[2] J. Williams,[3] and M. Williams[3]

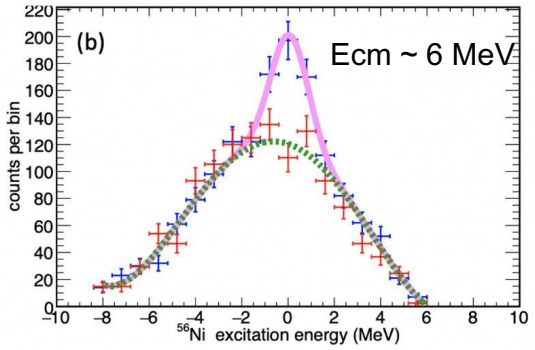


Important for νp process and X-ray bursts light curve

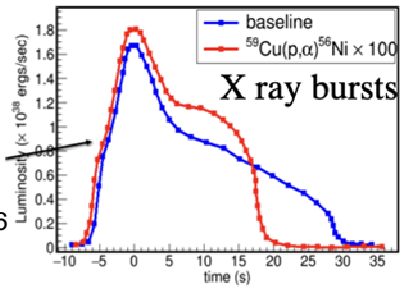


A. Arcones et al. ApJ 2012





Lower Ecm measurement under analysis



R. Cyburt et al. ApJ 2016

- ^{56}Ni in ground state
- Cross section lower than Non-SMOKER predictions
- Ni-Cu cycle may not hinder heavy element synthesis.

What Physics Lies Beyond the Standard Model?

- **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; Fr-EDM, Radioactive Molecules @ ISAC**
- **Neutral Current Weak Interactions**
  - **MOLLER PV e^- Scattering @ JLab; Atomic Parity Violation @ ISAC**
- **Majorana 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**

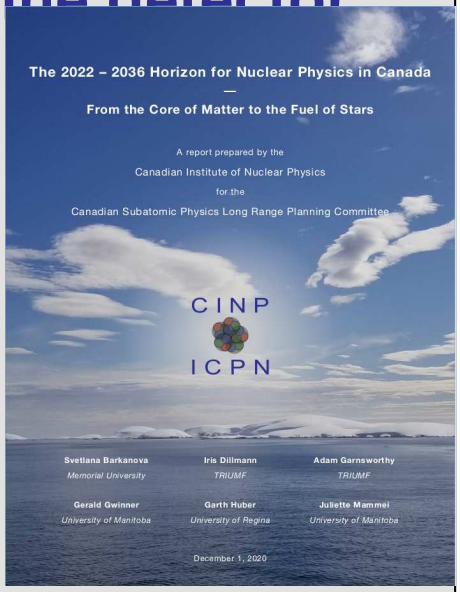
What Physics Lies Beyond the Standard Model?

Medium term (2022–26):

- Active ISAC program: Laser–trapped Francium, GRIFFIN β–decay, TRINAT, TITAN
- TUCAN and ALPHA–g CFI–funded upgrades completed
- NaB cold neutron experiment underway
- MOLLER @ JLab CFI–IF finalized. Detector construction begun, to be commissioned ~2025, run to ~2030
- Positive funding decision awaited on nEXO 5 tonne detector

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



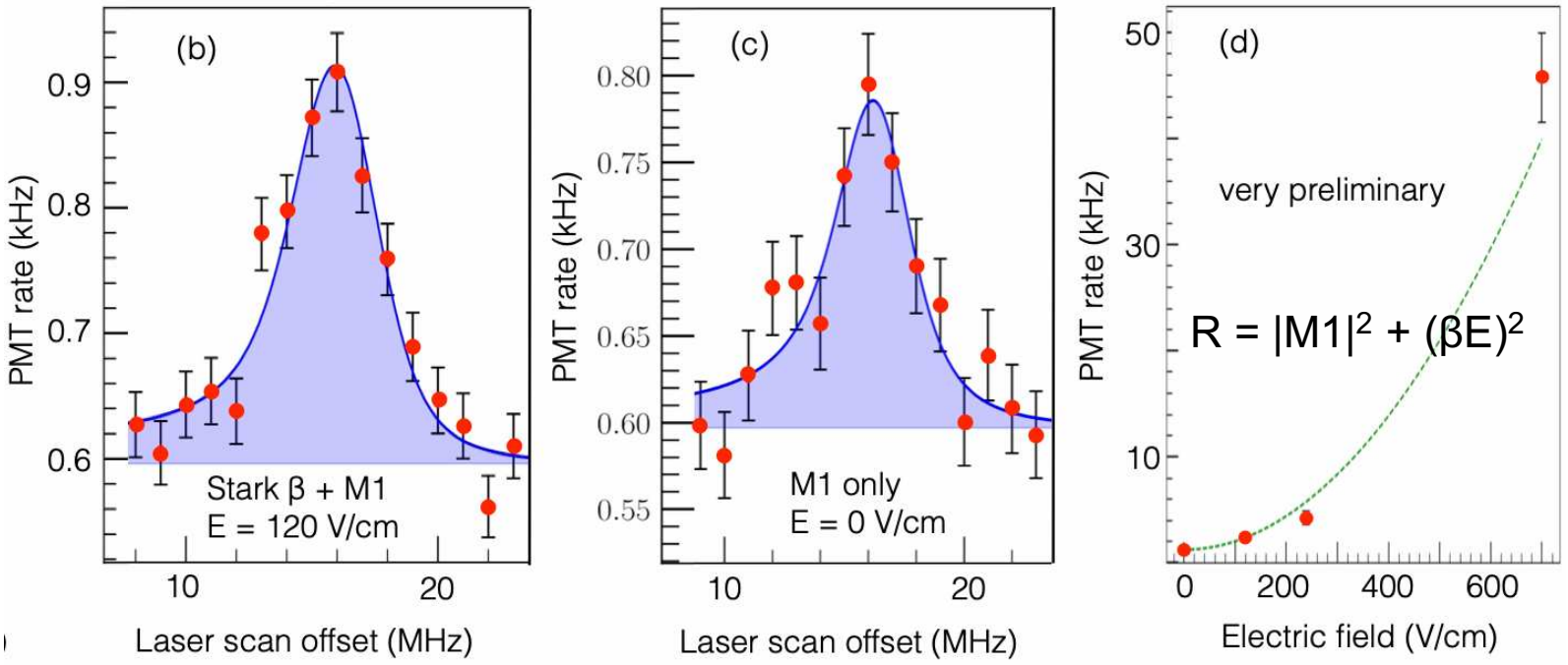
2021 Research Highlight

- Towards atomic parity violation in francium

CINP ICPN

Fall 2021 breakthrough

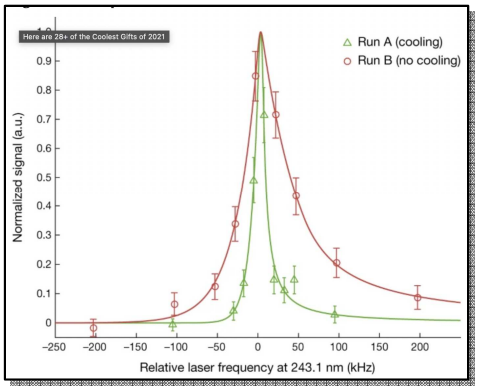
- Observed 7s - 8s β-E_{stark} + M1 trans.
- ≈ 10^{13} × weaker than allowed atomic transition!
- this is the resonance for APV studies (≈ by late 2024)
- critical to determine β and M1 strengths to interpret APV

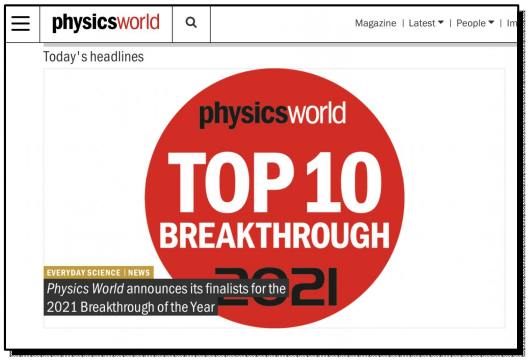


2021 Research Highlight

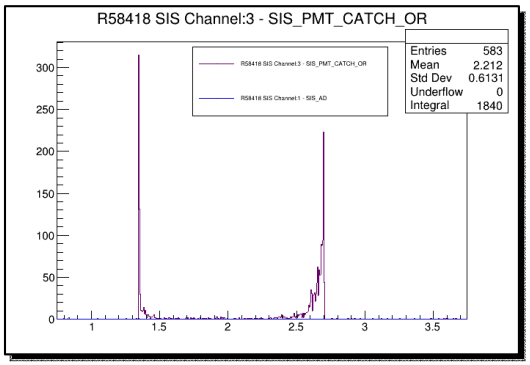
- Laser Cooling of Antihydrogen: ALPHA

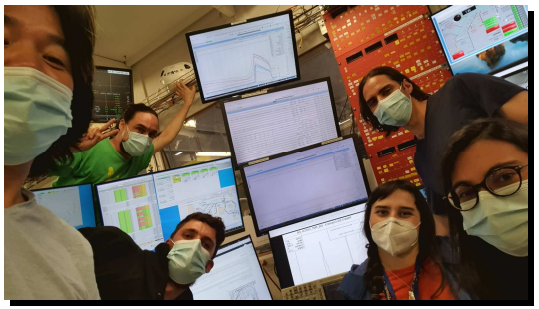
April 2021: Canadian-led breakthrough published in *Nature* cover. Dec 2021: This was selected among Top 10 Breakthroughs of 2021 by *Physics World* (UK Institute of Physics)





Aug 2021: First antiprotons captured from new ELENA decelerator ring at CERN





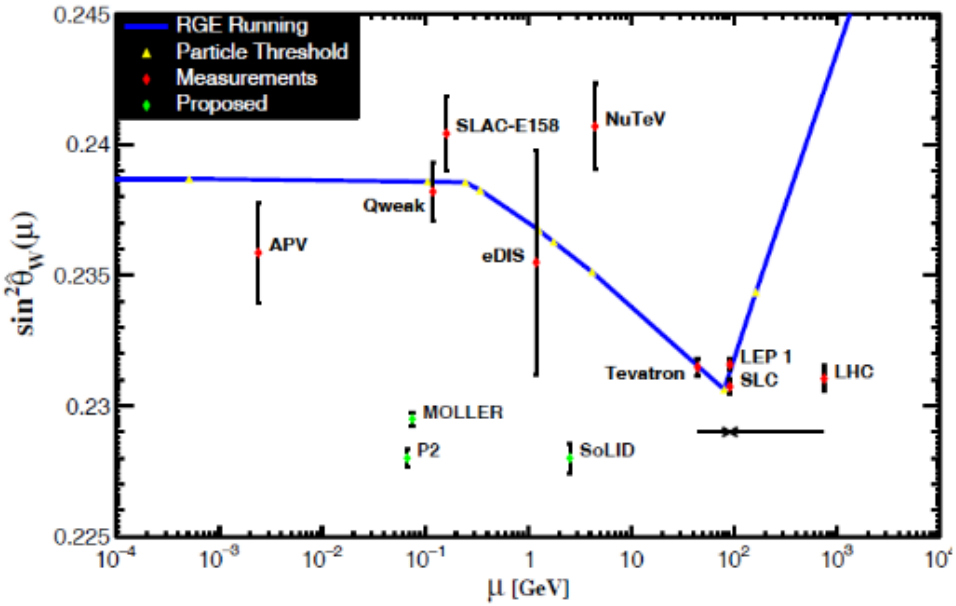
April 1st, 2021 *Nature* Cover

2021 Research Highlight

- MOLLER Experiment Update

CINP ICPN

High precision measurement of the Weak mixing angle at low momentum transfer, using electron-electron scattering at 11 GeV.



❑ **USD 65M Project**

- 6M NSF (Final)
- 4M CFI (Final)
- 55M DOE (CD1 stage, first funding in 2020, CD2 in 2021)

❑ **Current People and Schedule:**

- Presently 9 faculty from U. Manitoba, U. Winnipeg, U. Memorial, UNBC
- +1 new faculty search at U. Manitoba underway
- Presently 3 postdocs and 9 students
- Construction: 2022 – 2025
- Installation: 2025 – 2026
- Running: 2026 – 2029

❑ **Ongoing Work by Canadian Group:**

- Main Detectors: Completing design and prototype testing
- Main Detectors: Completing design and prototype of electronics
- Background Detectors: Ongoing design of pion detectors
- Tracking Detectors: Ongoing prototyping of pixel detectors
- Polarimetry Detectors: Ongoing prototyping
- Simulations
- Analysis software design

Some BSM sensitivities include:

Deviations produced by

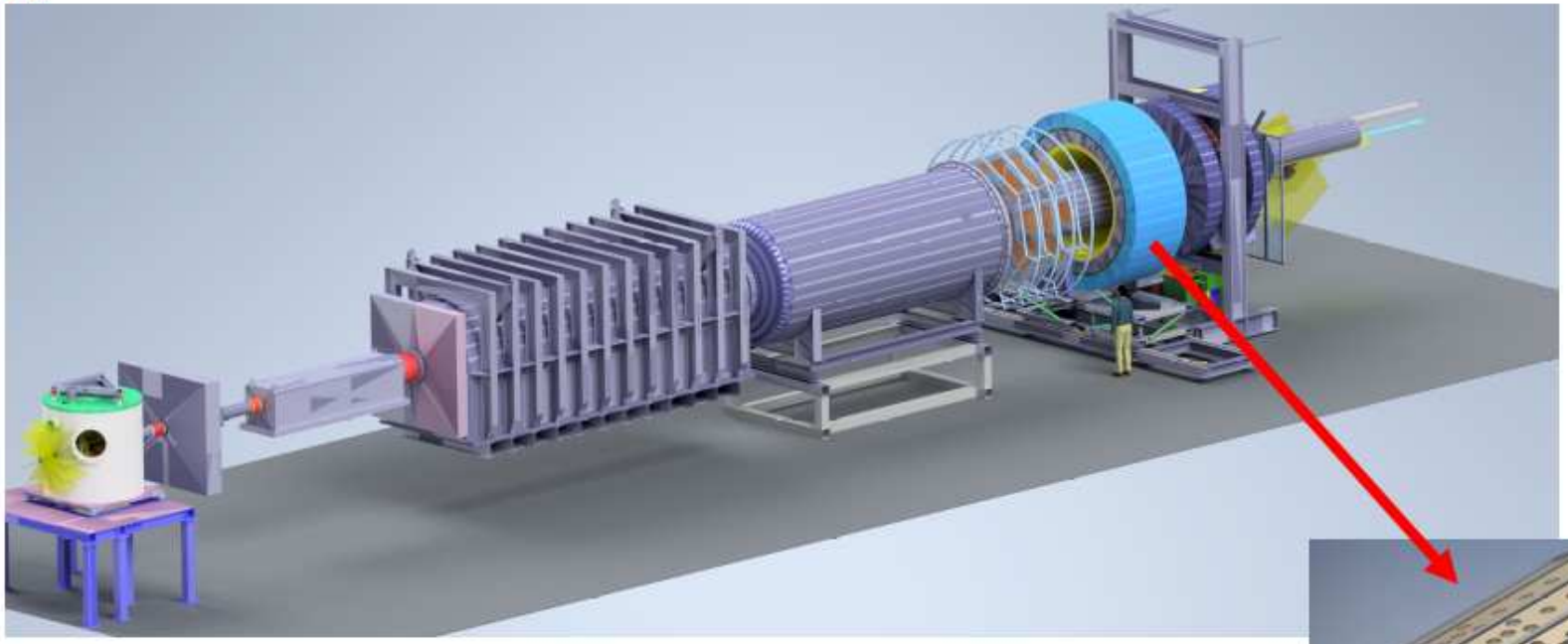
- massive boson interactions
- dark photon and level dark
- new parity-violating interactions
- lepton compositeness ()

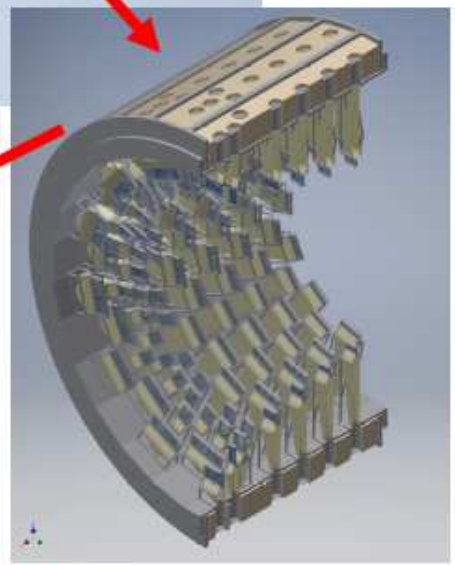
2021 Research Highlight

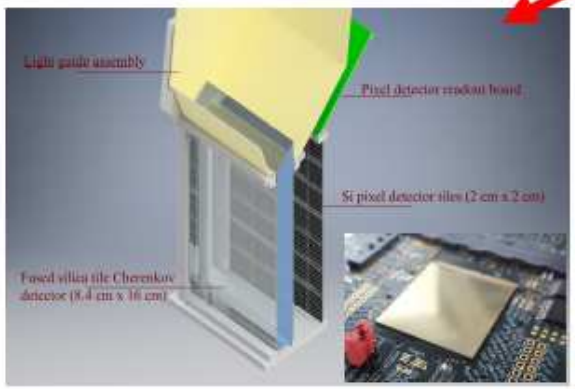
- MOLLER Experiment Update

CINP ICPN

High precision measurement of the weak mixing angle at low momentum transfer, using electron-electron scattering at 11 GeV.







- **CAD 6M CFI/IF funding approved in 2020 round:**
  - **Main detectors: 224 quartz DIRC detectors**
  - **512 Channels of electronics (preamp + ADC)**
  - **Profile mapper: 2688 2x2 cm HVMAP chips**
  - **Associated operational equipment**
  - **R&D and Testing Infrastructure**

2021 New Research Initiative
- A radioactive molecule lab for fundamental physics

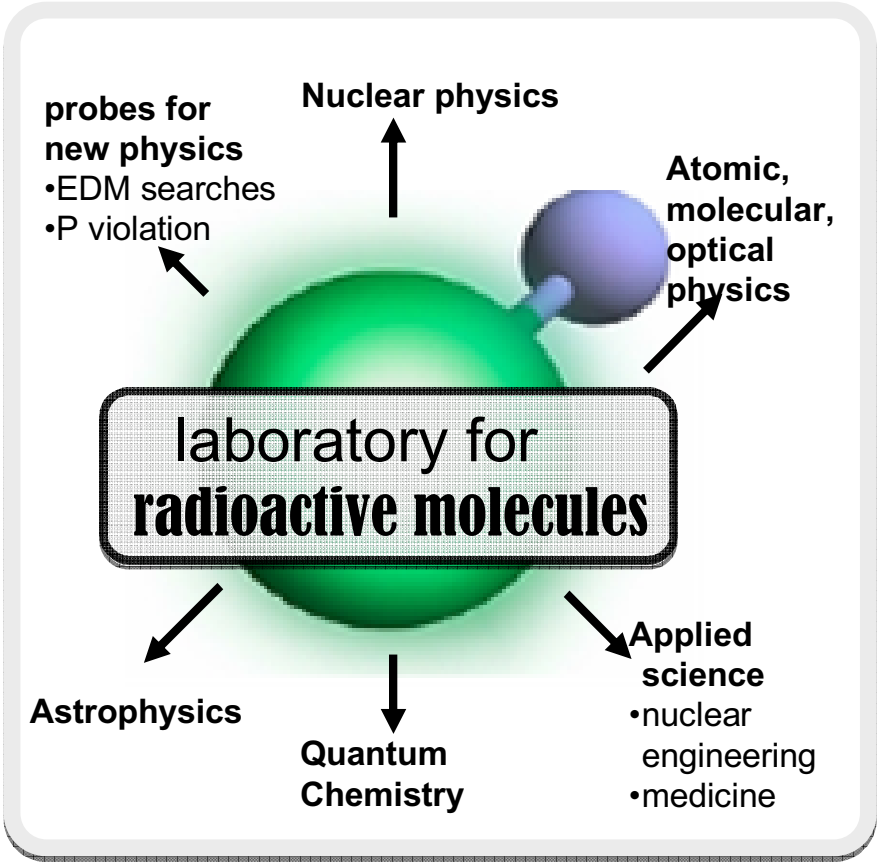
- **Radioactive molecules as novel precision probes for fundamental physics**

- Initial physics program:
  - octuple-deformed nuclei incorporated into polar molecules → unmatched sensitivity for nuclear EDMs
  - access nuclear anapole moments via diatomic molecules

- New laboratory for radioactive molecules @ TRIUMF:
  - dedicated laboratory for the study of radioactive molecules
  - to host 3-4 experimental stations
  - within existing laboratory space at TRIUMF
  - provision for expansions into other fields

- Next Steps in 2022:
  - submit CFI IF for laboratory infrastructure & experimental stations (≈20 M CAD$)
  - Prepare for laboratory construction in 2024
  - design and construct first experimental equipment
  - workshop on Radioactive Molecules at TRIUMF

- Current Canadian team: 12 faculty and staff physicists from UofToronto (lead), TRIUMF, UBC, U. Manitoba, McGill, UofOttawa



CINP Summary

- The Canadian nuclear physics community's work addresses the most important open questions as identified by broad international consensus
- In the 2022–26 time period, we are primed to leverage scientific discoveries from the investments already made into research equipment and infrastructure at TRIUMF, and at international facilities where Canadians lead high priority programs (e.g. JLab, ALPHA)
- Strong case for increased support to maximize Canadian scientific output in nuclear physics research