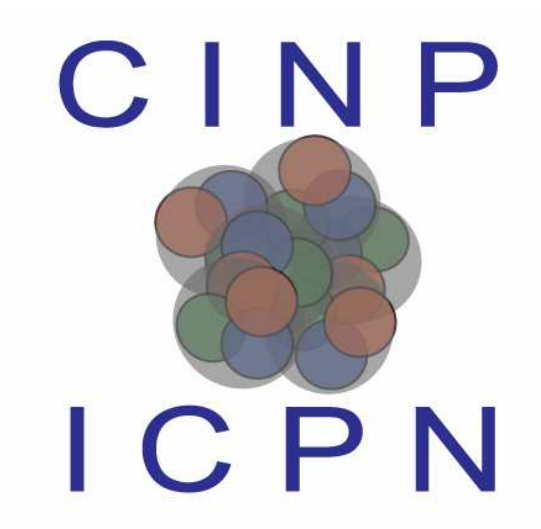


Canadian Institute of Nuclear Physics

Institut canadien de physique nucléaire

NSERC Subatomic Physics Large Project Day
Ottawa, February 21, 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

Institutional Members
McGill University
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

SFU joined in 2021

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.**
- **SWG leadership was renewed in 2019, in preparation for 2020 Long Range Planning efforts.**

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 Physics Education and Training	Juliette Mammei	University of Manitoba

CINP Individual Membership

CINP Membership February 21, 2021	
Total Membership	133
Faculty (Full) Members	86
Associate Members (Grad Students, PDFs, Professor Emeriti)	47
Experimentalists	103
Theorists	29

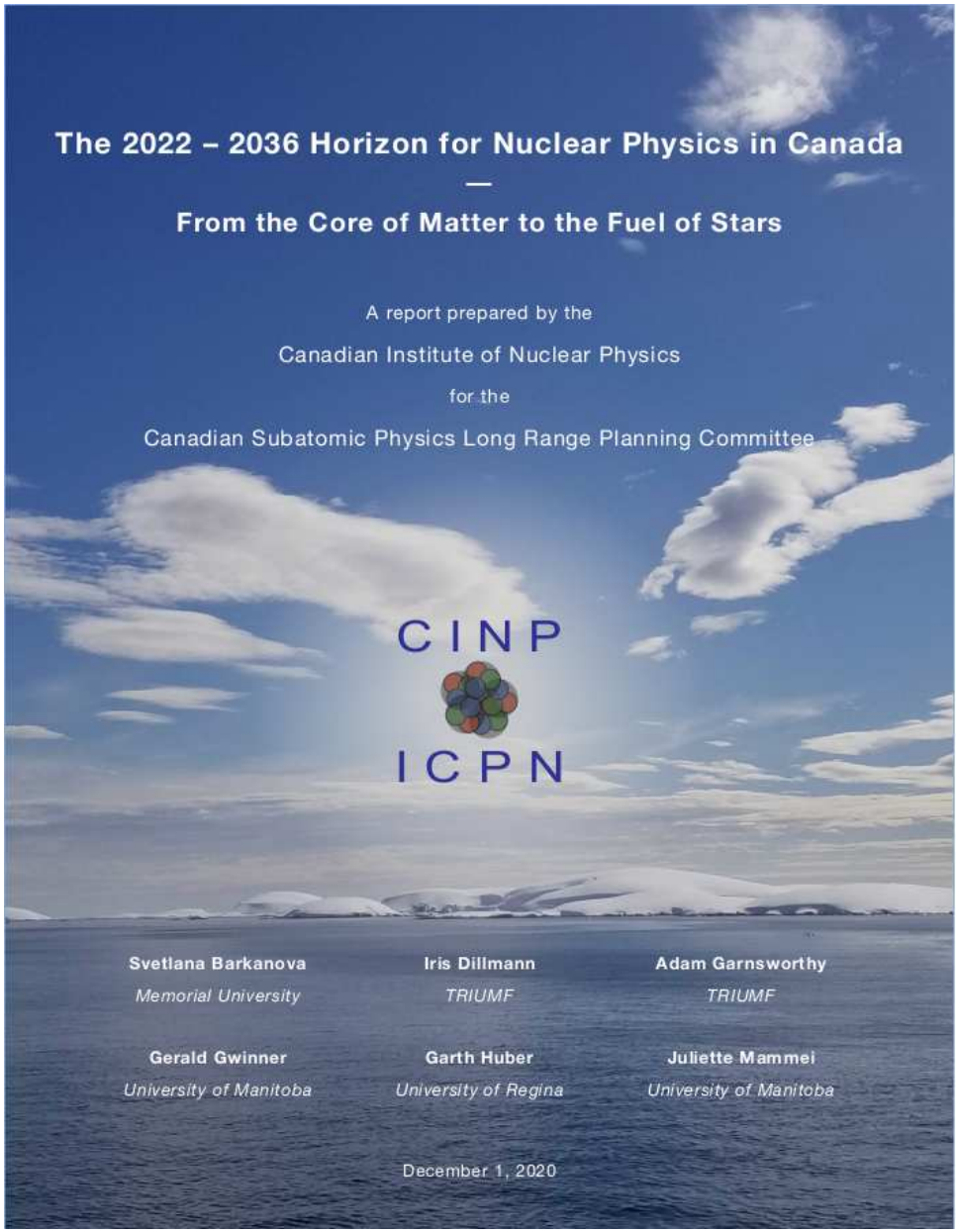
SWG Membership	
Nuclear Astrophysics	**49**
Nuclear Structure	**55**
Fundamental Symmetries	**56**
Hadrons/QCD	**45**
Nuclear Physics Education & Training	**38**

CINP 2020–21 Accomplishments

- **Nuclear Physics Representation**
  - **The CINP has been vital in giving the nuclear physics community a coherent and strong voice**
  - Meetings with NSERC, CFI, Innovation Science and Economic Development Canada (ISED) on issues of importance to the nuclear physics community
  - Joint CINP+IPP "Context Document" for SAPES Fall Policy Meeting
  - CINP+IPP submission to NDRIO on *Canada's Future DRI Ecosystem*
  - NP Community Representative at Advisory Committee on TRIUMF (ACOT), spring and fall annually
  - Astroparticle Community Planning Steering Committee
  - Formal observer to NuPECC (Nuclear Physics European Collaboration Committee)

CINP role in 2022–26 Long Range Plan

- **Broad consultation with the Canadian Nuclear Physics Research community.**
- 33 written briefs received, up from 28 in 2015
- Virtual Town Hall meetings:
  - June 22–23
  - October 26
- **CINP White Paper is substantial: 187 pages**
- Writing committee consisted of the five SWG Chairs with the Executive Director as lead editor.



CINP 2020–21 Accomplishments

- **CINP Undergraduate Research Scholarships (URS)**
  - A supervisor can nominate only their best student for the award. The selection is competitive, with only the top 42% nominees selected.
  - $5k student stipend which must be matched by supervisor to at least $9k (2020 competition figures).
  - $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 the 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. The NSERC USRA has no such component.

CINP 2020–21 Accomplishments

2020 CINP Undergraduate Research Scholarships

Student	Supervisor	Project Title
Kiera Augusto (Winnipeg)	Jeff Martin (Winnipeg)	Cryogenics of a new neutron source
Trang Bui (Manitoba)	Wouter Deconinck (Manitoba)	Simulation of trapped protons from neutron beta decay for the BL3 neutron lifetime measurement at NIST
Spencer Keller (Mt Allison)	Mohammad Ahmady (Mt Allison)	Proper light meson spin structure in light–front holography QCD
Kaitlyn Liang (Toronto)	Makoto Fujiwara (TRIUMF)	Commissioning of ALPHA–g Radial TPC
Emily Rettich (Fraser Valley)	Derek Hammett (Fraser Valley)	Decay rates of the lightest 1^{-+} hybrid from QCD Sum Rules

9 applications were received. Selection Committee: Alexandros Gezerlis (Guelph), Garth Huber (Regina), Chris Ruiz (TRIUMF).

CINP 2020–21 Accomplishments

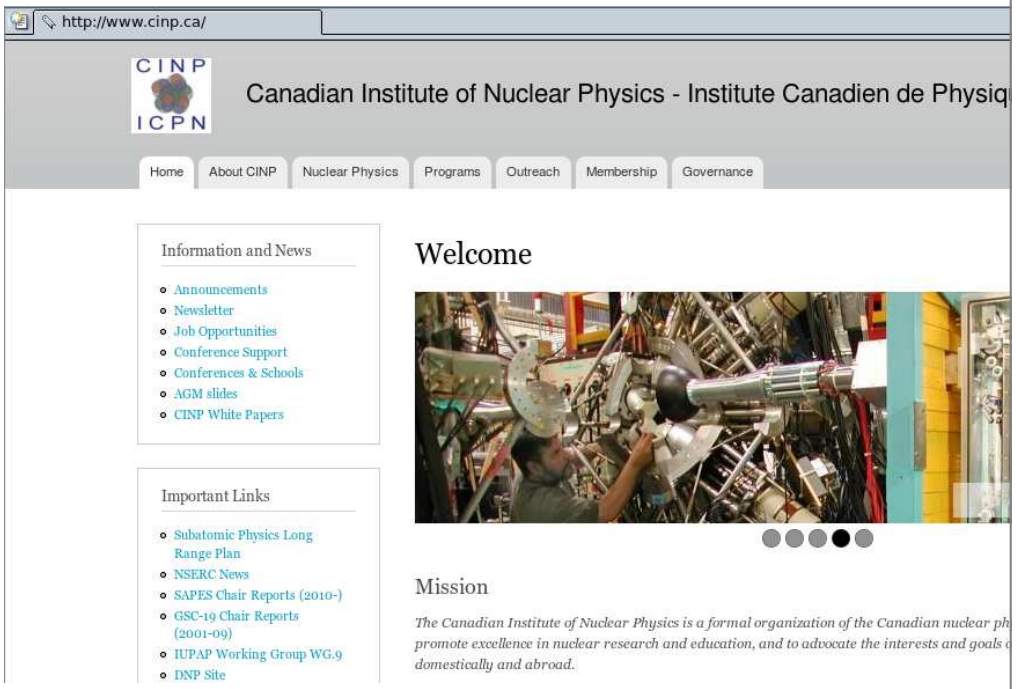
- By far the largest component of the CINP's MRS grant is devoted to HQP support. Diversity is taken into consideration in the awarding of funds.
- **One of the suggestions from the June CINP Town Hall Meeting was to explicitly incorporate an EDI component in the Education & Training SWG Terms of Reference:**
  - To promote equity, diversity and inclusion (EDI) in accord with the CINP Policy,
  - To provide information about EDI training opportunities to the CINP membership,
  - To collect and report data regarding EDI within the Canadian Nuclear Physics research community.
- Revisions approved by CINP Board: January 26, 2021

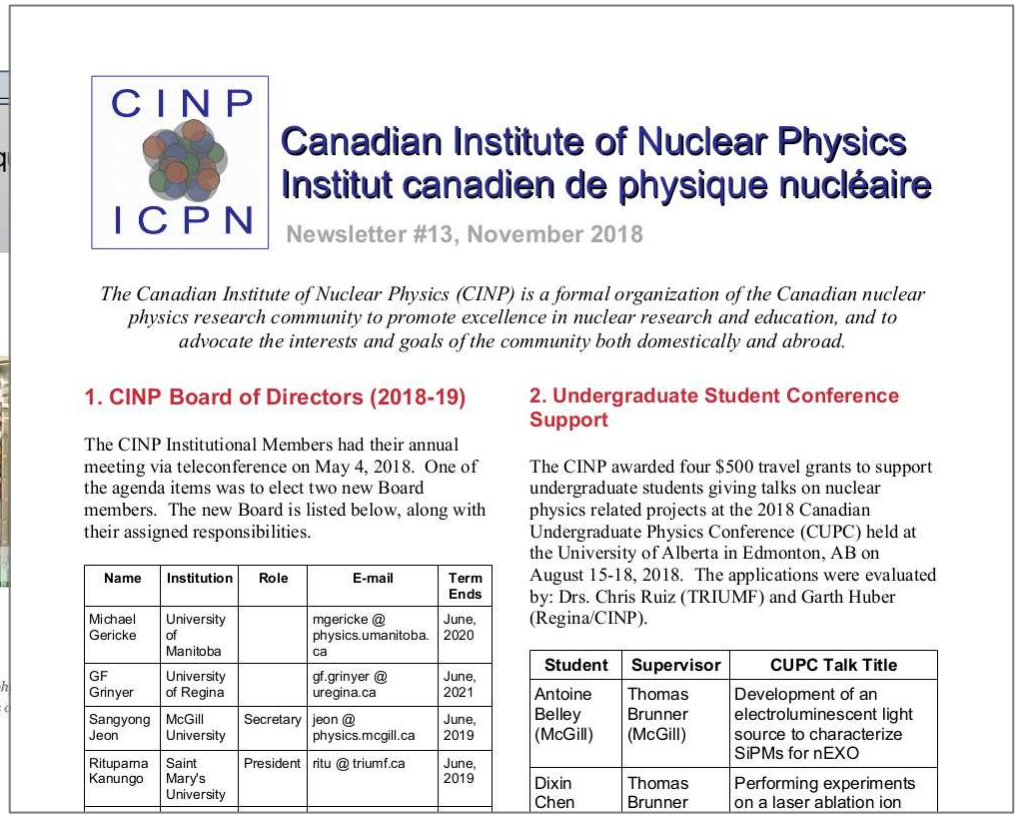
CINP Graduate Fellowship

- **Intended to attract or retain very gifted Ph.D. candidates to conduct nuclear physics research in Canada.**
- **Criteria:** Merit and quality of proposed research, utility and relevance to the LRP, academic qualifications, letters of recommendation, likelihood of accomplishment of proposed research objectives by graduation.
- **Application has an EDI Component:** Describe what EDI means to you in the context of research and education in Canada. What role could a PhD student and CINP Graduate Fellow play in promoting and advancing EDI in our community? List and describe any relevant activities that you have participated in, or organized, that were directly related to promoting and advancing EDI in any area or discipline.
- **First competition for a 1 year $12,000 Fellowship is underway. Applications due March 29, 2021.**

CINP 2020–21 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 annually.





CINP
ICPN

Canadian Institute of Nuclear Physics
Institut canadien de physique nucléaire

Newsletter #13, November 2018

The Canadian Institute of Nuclear Physics (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.

1. CINP Board of Directors (2018-19)

The CINP Institutional Members had their annual meeting via teleconference on May 4, 2018. One of the agenda items was to elect two new Board members. The new Board is listed below, along with their assigned responsibilities.

Name	Institution	Role	E-mail	Term Ends
Michael Gericke	University of Manitoba		mgericke @ physics.umanitoba.ca	June, 2020
GF Grinyer	University of Regina		gf.grinyer @ uregina.ca	June, 2021
Sangyong Jeon	McGill University	Secretary	jeon @ physics.mcgill.ca	June, 2019
Rituparna Kanungo	Saint Mary's University	President	ritu @ triumf.ca	June, 2019

2. Undergraduate Student Conference Support

The CINP awarded four $500 travel grants to support undergraduate students giving talks on nuclear physics related projects at the 2018 Canadian Undergraduate Physics Conference (CUPC) held at the University of Alberta in Edmonton, AB on August 15-18, 2018. The applications were evaluated by: Drs. Chris Ruiz (TRIUMF) and Garth Huber (Regina/CINP).

Student	Supervisor	CUPC Talk Title
Antoine Belley (McGill)	Thomas Brunner (McGill)	Development of an electroluminescent light source to characterize SiPMs for nEXO
Dixin Chen	Thomas Brunner	Performing experiments on a laser ablation ion

COVID–19 Impacts

- **Many conferences and workshops were either delayed on moved to virtual format**
- **Many CINP Programs Impacted**
- **Conference Support Program:**
  - **Four approved events were delayed. Approved budget will be carried forward to FY21, or whenever these events are held in person.**
- **Junior Scientist Support Program:**
  - **Approved PDF travel to workshops delayed or canceled.**
- **Canadian Undergraduate Physics Conference (CUPC 2020):**
  - **Instead of a Student Travel Award Program to assist undergraduates supervised by CINP members in presenting their research at the conference, we sponsored a named CINP Prize awarded to the best research presentation in nuclear physics.**
- **Winter Nuclear and Particle Physics Conference (WNPPC 2021):**
  - **Instead of a Graduate Student Travel Award Program, CINP sponsored four $500 prizes to the best presentations by students supervised by a CINP member.**

CINP NSERC Expenditures

FY20 (projected)	
Representation Travel	0
Long Range Plan	12,166
Conference Sponsorship (approved but deferred)	10,500
Undergrad Scholarships	25,000
URS Travel Supplement	2,600
Student Conf Travel	0
Student Recruitment	2,500
Junior Sci Travel Support (approved but deferred)	3,850
Misc	852

FY21 (budgeted)	
FY21 Installment	75,000
Representation Travel	10,600
Long Range Plan	1,350
Conference Sponsorship	7,000
Undergrad Res Scholarships	30,000
URS Travel Supplement	5,600
Student Conf Travel	
CUPC 2021	2,400
WNPPC 2022	4,800
Student Recruitment	1,750
Junior Sci Travel Support	6,000
Graduate Fellowship	12,000
Misc	1,450

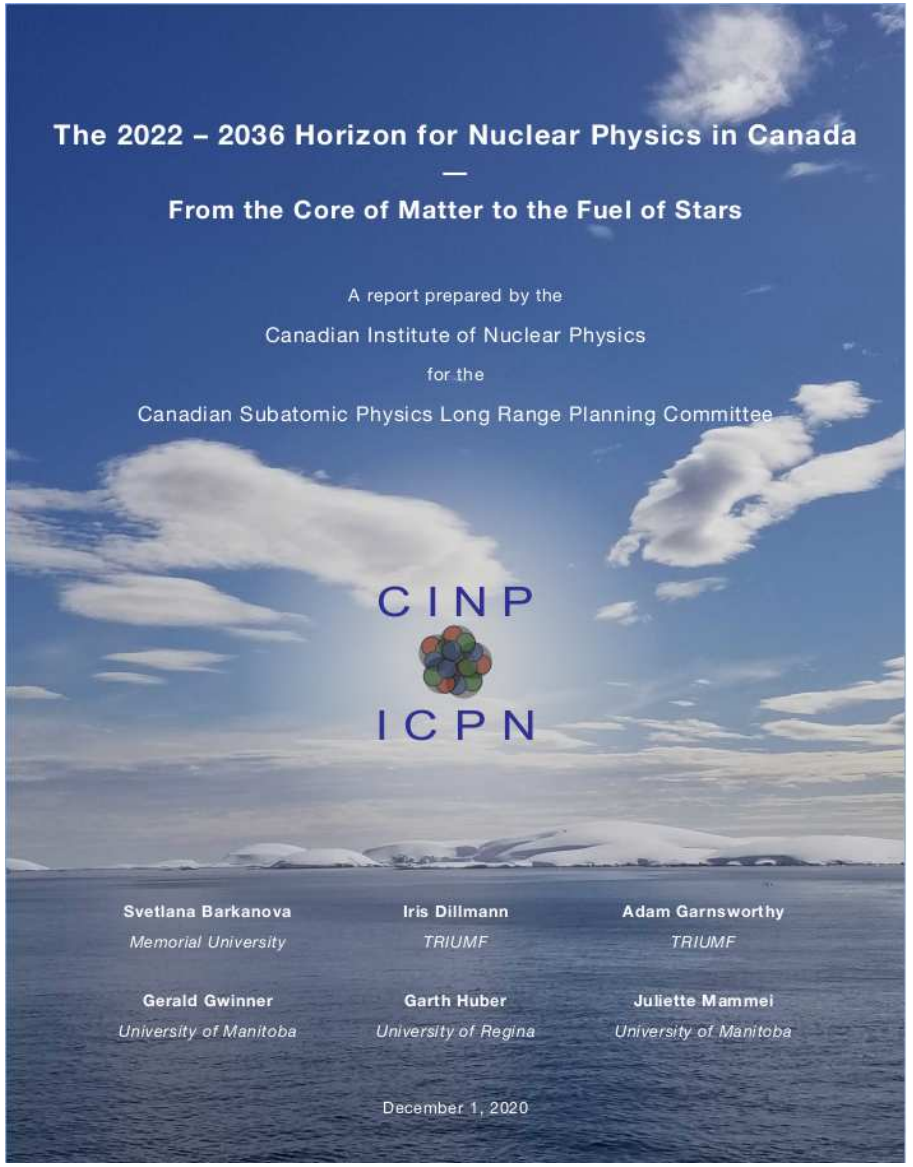
CINP Scientific Summary

A Few Slides on:

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

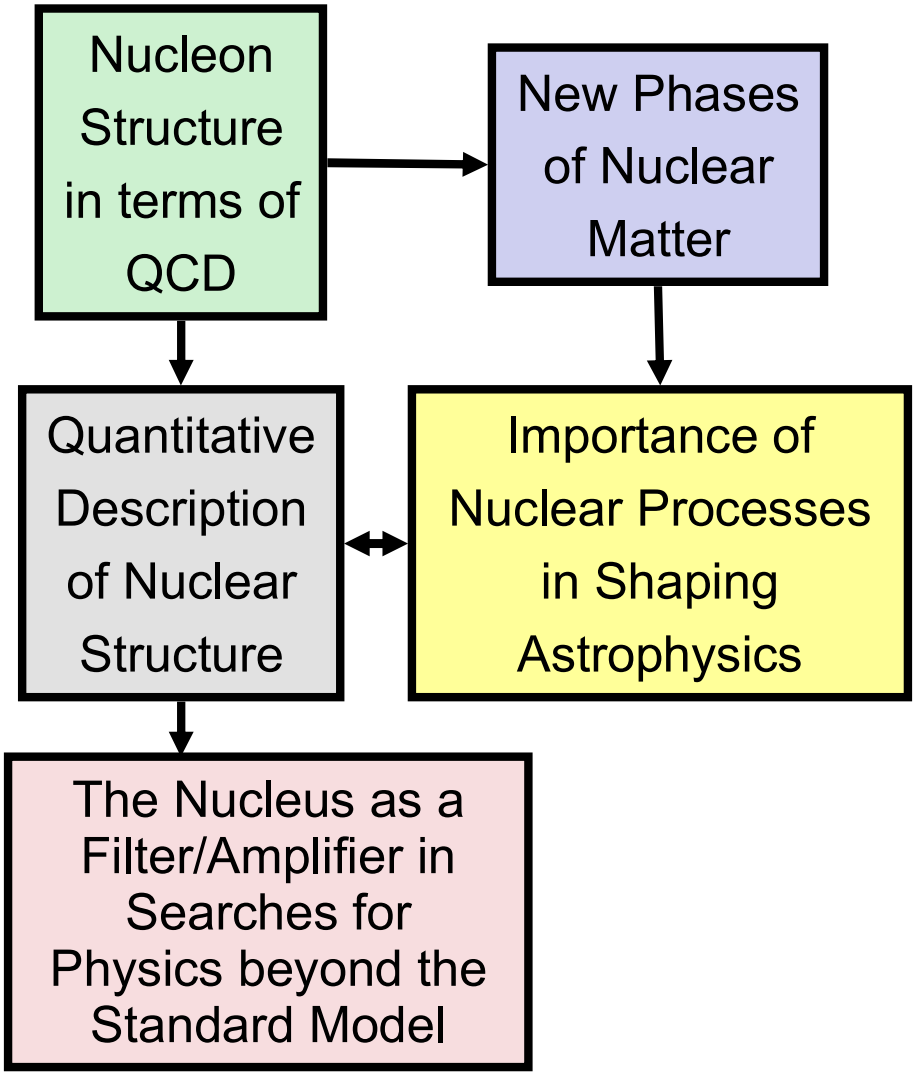
CINP 2022–26 LRP White Paper

- The Canadian nuclear physics community is pursuing a diverse set of research endeavors which address key questions of major importance to understanding the origin, evolution and structure of visible matter in the universe.
- Report available from: https://cinp.ca/



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.**

- **<u>Medium term (2022–26):</u> Canadians involved in data taking and analysis of data. JLab Eta Factory (JEF) is planned with upgraded GlueX equipment for 2021–26.**
- **<u>Longer term (2027-36):</u> 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?

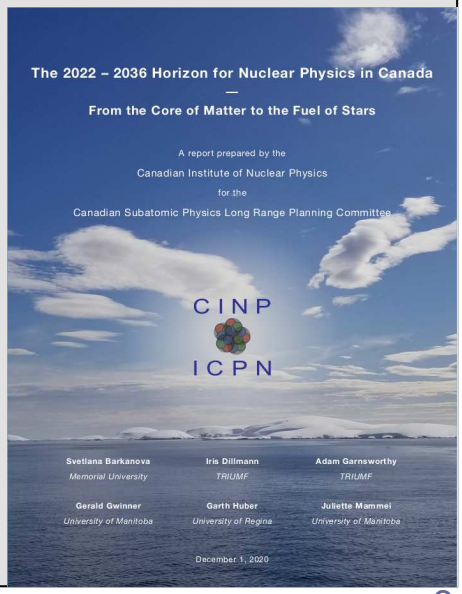
- A key goal of nuclear physics research is the development of a comprehensive, predictive theory of complex nuclei.
- This has driven the recent development of high quality radioactive beams, allowing both neutron and proton numbers to vary over a wide range.
- Areas of active inquiry include:
  - **Studies 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 0νββ 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 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.

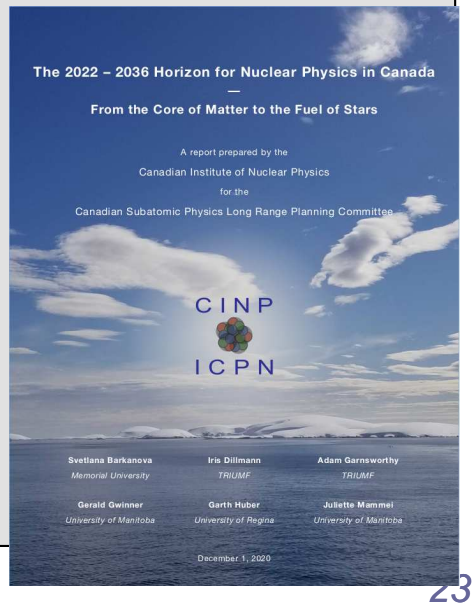
What is the role of radioactive nuclei in shaping the visible matter in the universe?

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, etc. 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?

- 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**

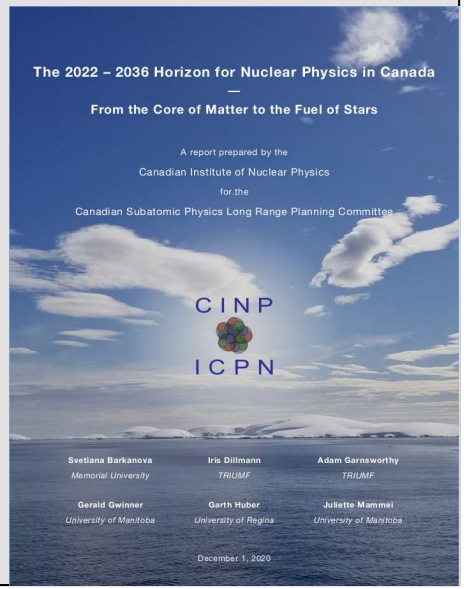
What Physics Lies Beyond the Standard Model?

Medium term (2022–26):

- Active ISAC program: Laser–trapped Francium, GRIFFIN β–decay, TRINAT, TITAN
- TUCAN and ALPHA–g CFI–funded upgrades completed
- NaB, nPDGamma, nHe3 cold neutron experiments underway
- MOLLER @ JLab will 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



2020–21 Research Highlight

- GlueX @ JLab: Search for Hybrid Mesons

CINP ICPN

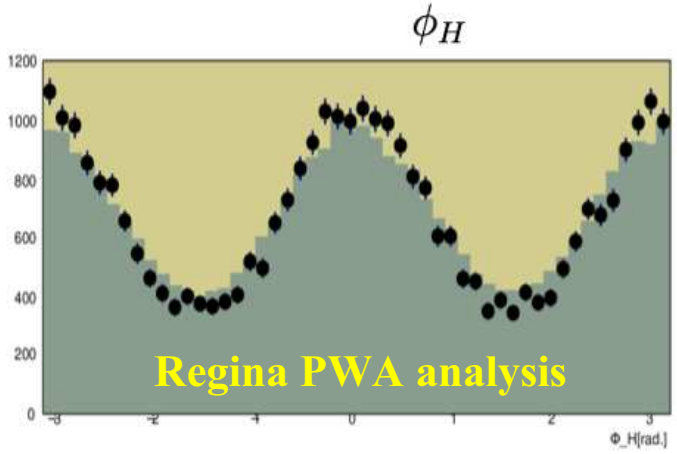
Physics Analyses

- **Physics Convenor**: Beam Asymmetry Working Group
- **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

S- and D-waves in MC describe b_1 amplitude



arXiv.org > nucl-ex > arXiv:2009.07326

5th GlueX physics paper accepted by PRC

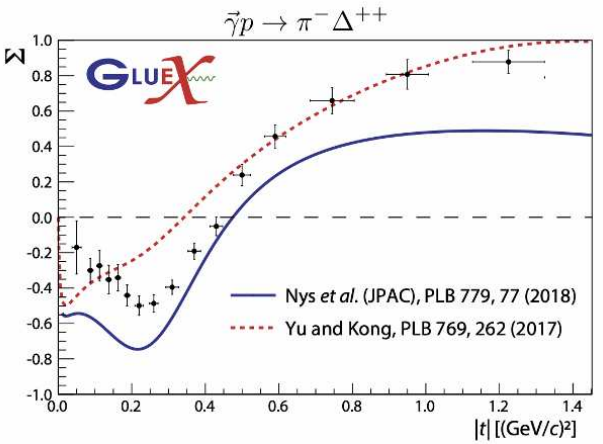
Nuclear Experiment

[Submitted on 15 Sep 2020 (v1), last revised 8 Jan 2021 (this version, v2)]

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

GlueX Collaboration: S. Adhikari, C. S. Akondi, A. Ali, M. Amaryan, A. Asaturyan, A. Austregesilo, Z. Baldwin, F. Barbosa, J. Barlow, E. Barriga, R. Barsotti, T. D. Beattie, ... E. Chudakov, S. Cole, O. Cortes, V. Crede, M. M. D ... I. Egiyan, T. Erbora, A. Ernst, P. Eugenio, C. Fane ... K. Goetzen, V. S. Goryachev, L. Guo, H. Ha ... T. Jones, V. Kakoyan, G. Kalicy, M. Kamel, V. Khac ... D. I. Lersch, H. Li, W. B. Li, B. Liu, K. Livingston, G. J. ... McCracken, W. McGinley, C. A. Meyer, R. Miskimen, R ... C. Paudel, P. Pauli, R. Pedroni, L. Pentchev, K. J ... ors not shown)

We report a measurement ... X experiment in the photon beam energy rang ... and compared to phenomenological model ... |. The reaction can be described theoretically by ... this reaction requires charge exchange, allowin ... t low momentum transfer. Constraining pro ... esons. This is the first measurement of the proc ...



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

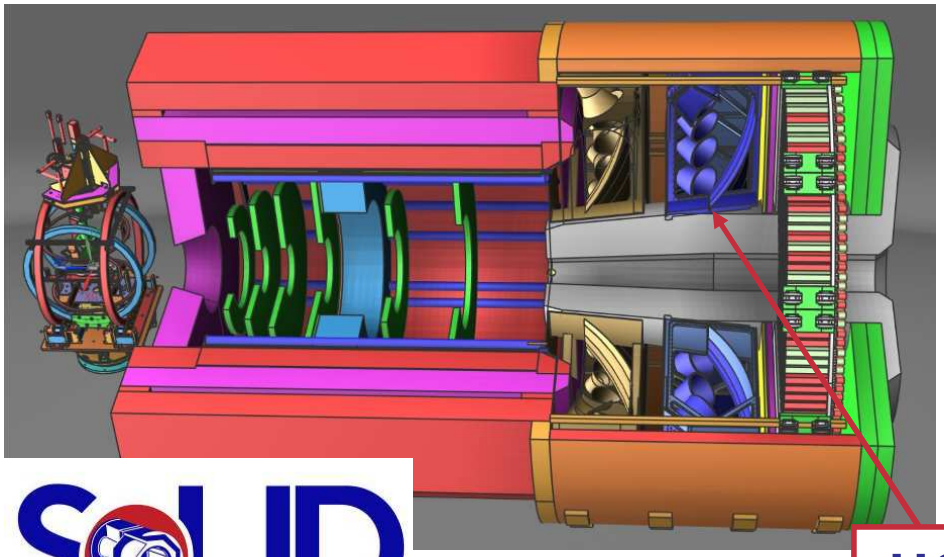
Service Contributions

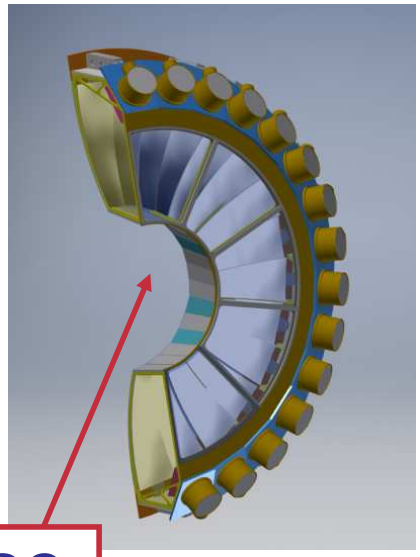
- **Calorimeter Coordinator**
- **Barrel Calorimeter:** Calibration each run period (cosmics, LED, π^0s)
- **Calorimetry upgrade**: FCAL-II for rare eta decays & BSM experiment (2024)
- **Machine Learning:** applied to particle ID and photon-neutron discrimination

2020–21 New Research Capabilities

- Solenoidal Large Intensity Detector (SoLID) Prototyping

- SoLID @ JLab will use latest detector and readout technology to enable ~10x increase in luminosity compared to existing detectors.
- U.Regina & Duke U. are responsible for Heavy Gas Cherenkov (HGC), needed for π/e separation.
- Prototype HGC module construction advancing well with funds from CFI, Fedoruk Centre, NSERC, U.Regina.





2020–21 Research Highlight

Electron–Ion Collider: 800+ page Yellow Report

Table of Contents:
- Executive Summary
- Volume 1: Physics
- Volume 2: Detectors

Canadian contributions:
1. Multi-Dimensional Imaging
2. Hadronization
3. Connections with Other Fields
4. Detailed Detector Aspects

Canadian leadership:
- EIC Steering Committee
- EIC Canada Collaboration

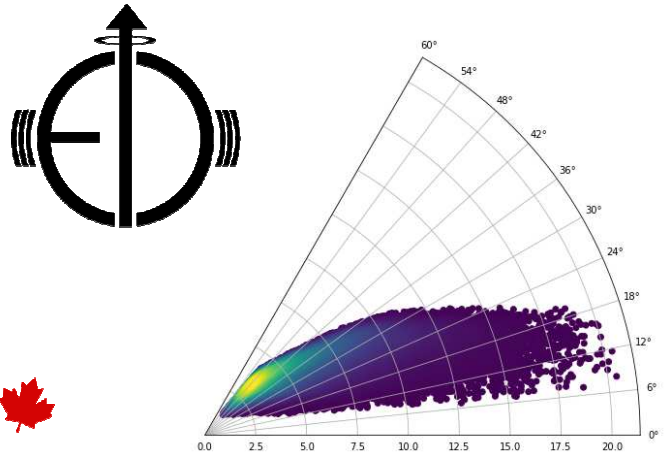
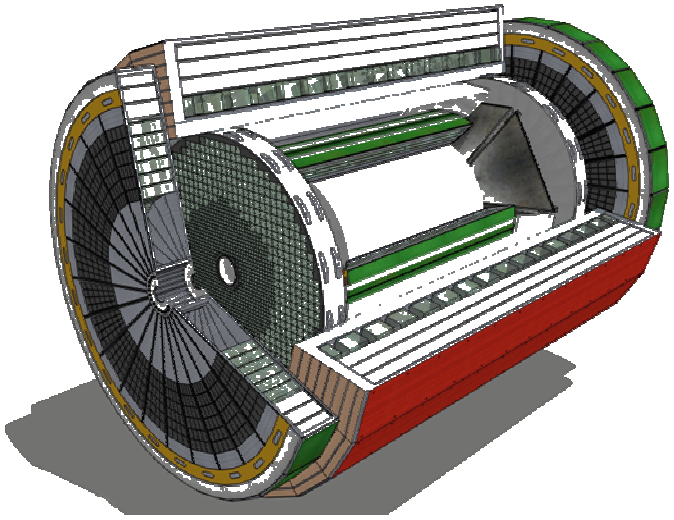


Fig 8.115: π^+ in $p(e,e'\pi^+n)$ at 5 x 41 GeV (event generator developed in Canada)

EIC Project Schedule:
- ✓January 2020: CD-0
- ✓February 2021: CD-1
- …
- 2024: Construction and Installation
- 2030: First beam: Start of Operations



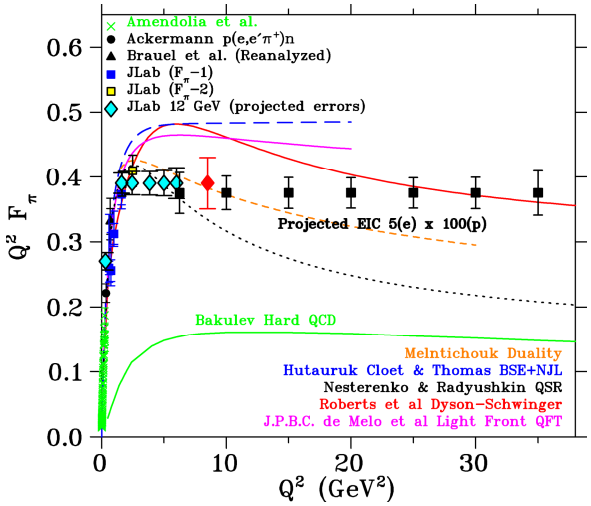


Fig 7.40: Pion form factors (U. Regina)

2020–21 Research Highlight

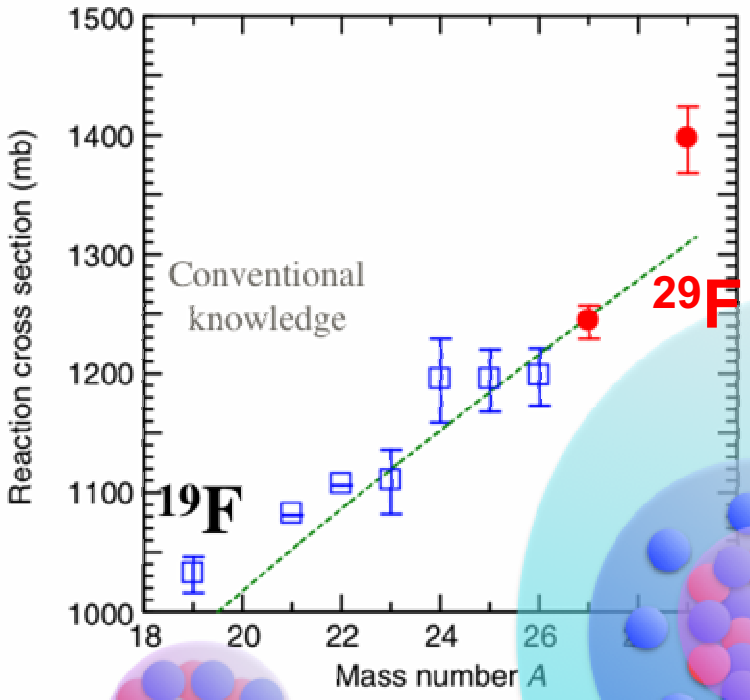
- Heaviest two-neutron halo discovered in ^{29}F@RIKEN

CINP ICPN

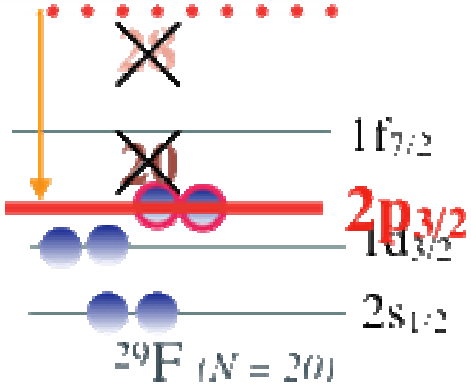
PHYSICAL REVIEW LETTERS 124, 222504 (2020)

S. Bagchi*, R. Kanungo*, Y. Tanaka et al.

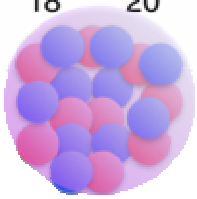
Two-Neutron Halo is Unveiled in ^{29}F



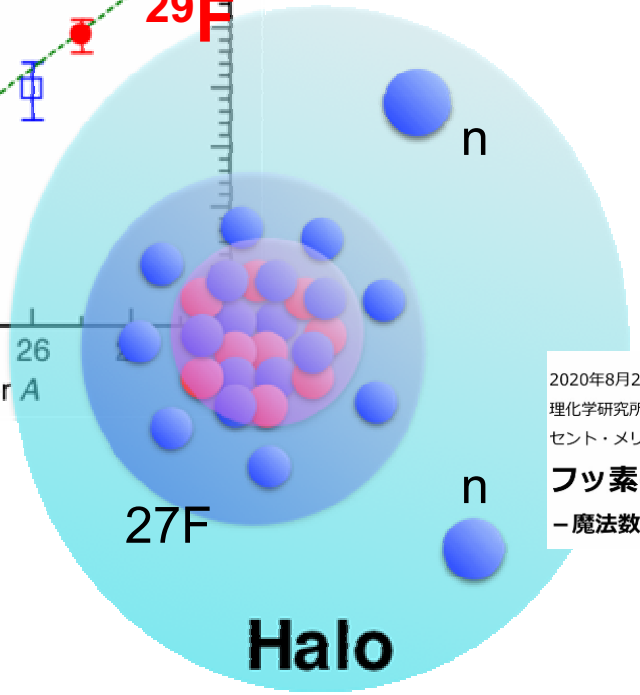
29F Large increase in σR —> matter radius



N = 20 shell vanishes with the appearance of the neutron halo



Stable



2020年8月21日
理化学研究所
セント・メリーズ大学

フッ素-29が「2中性子ハロー原子核」であることを発見
－魔法数20の消失と中性子ハロー構造の出現－

RIKEN Press Release

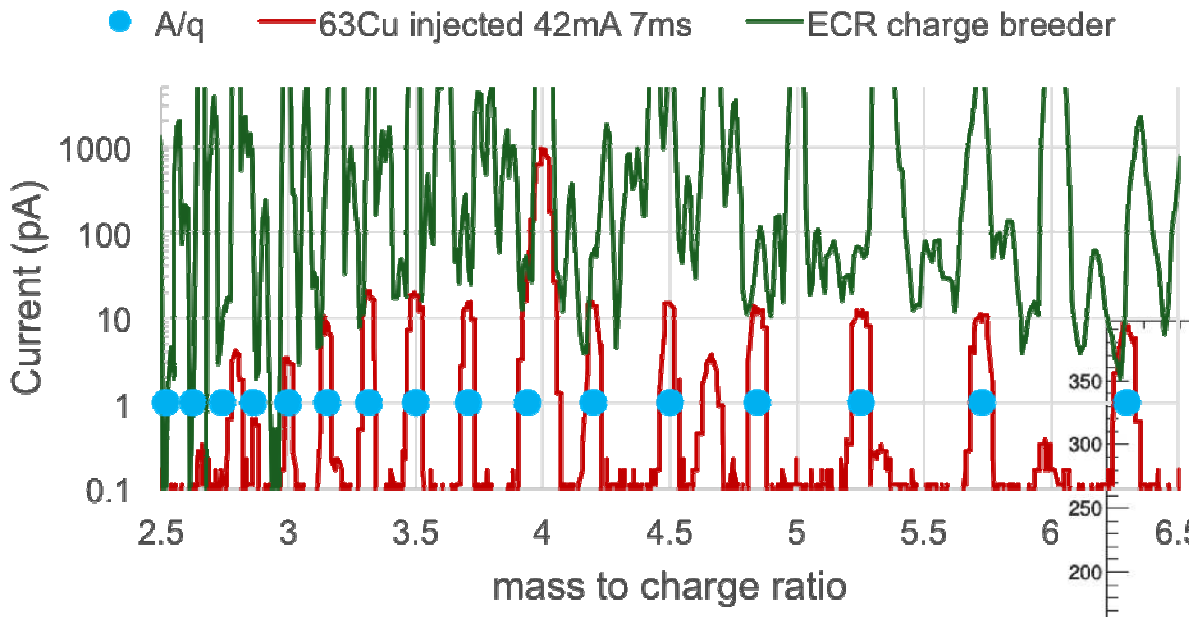
* Supervised HQP

2020–21 New Research Capabilities

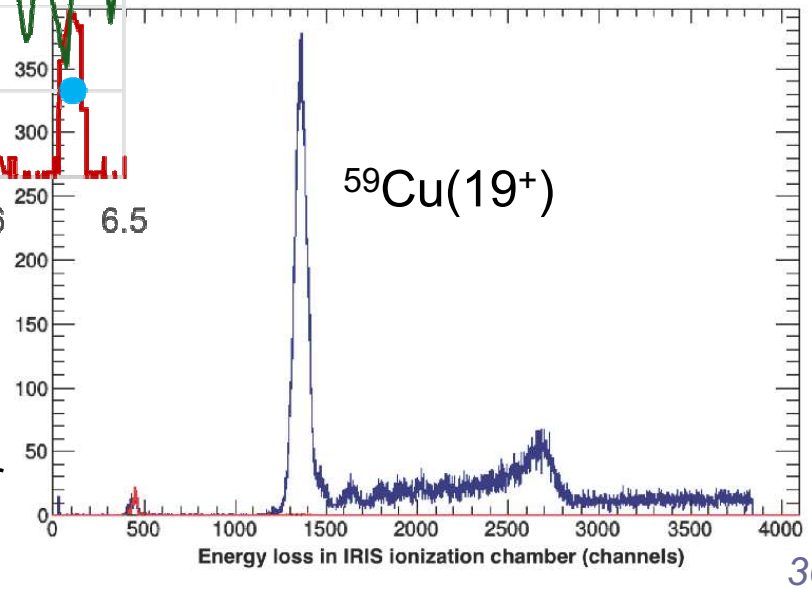
- CANREB – first RI beam accelerated

- **December 6, 2020 CANREB successfully accelerated a beam of $^{59}Cu^{19+}$ from the CANREB EBIS and delivered to the IRIS facility at 9 MeV/u**

- $^{63}Cu^{1+}$ beam from ISAC target station (~100 pA in front of EBIS)
- EBIS parameters: B = 1 T, e-beam = 42 mA, charge breeding time = 7 ms



CANREB charge breeding shows very clean Cu beam



Energy loss measured in IRIS ionization chamber

2020–21 Research Highlight

- Standard Model loops explaining “ATOMKI” anomaly

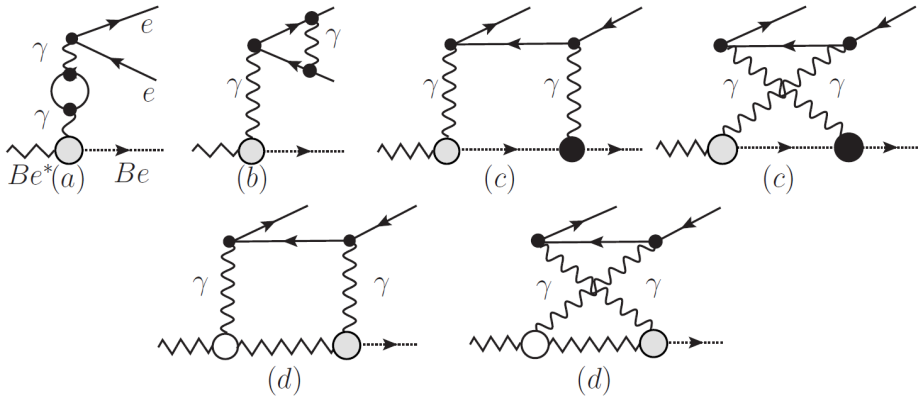
CINP ICPN

As previously proven for MOLLER and other precision measurements, the higher-order SM contributions can play a significant role.

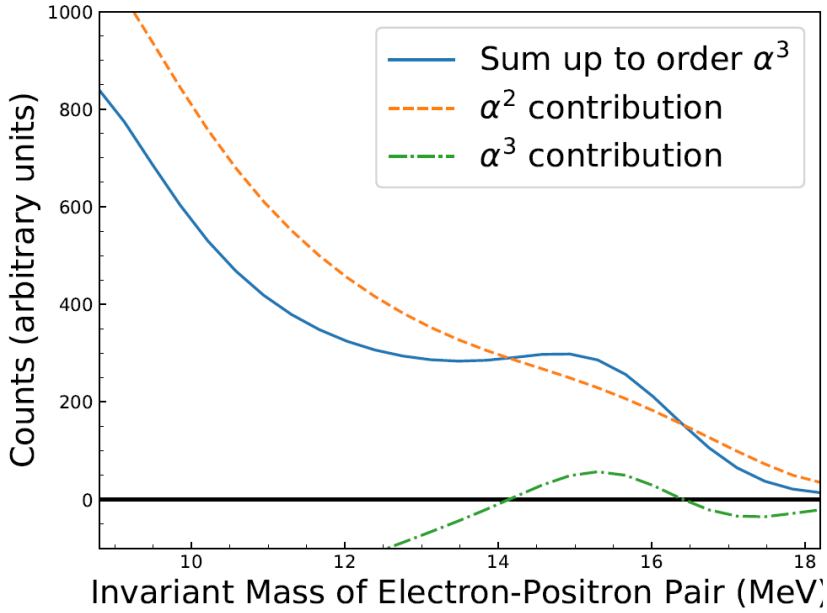
The massive calculations requiring new dispersive methodology (10.1103/PhysRevD.98.036021) are being addressed by a theory group at Memorial University of Newfoundland.

In arXiv:2102.01127, Aleksejevs et al show that the experimental structure observed by ATOMKI team can be reproduced within the Standard Model by adding the full set of second-order corrections and the interference terms to the Born-level decay amplitudes.

The paper implements a detailed model of the ATOMKI detector, and also shows how experimental selection and acceptance bias exacerbate the apparent difference between the experimental data and the Born-level prediction.



Higher order QED contributions in decay of $^8Be^*$

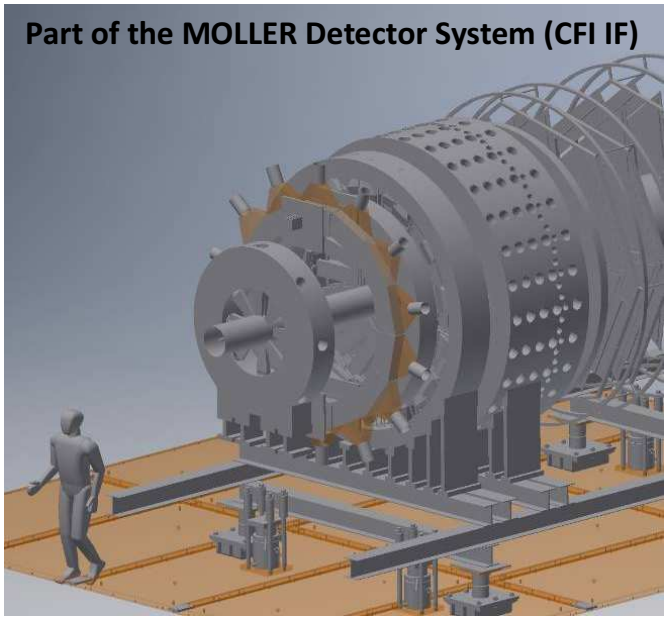


A peak in of electron-positron pair creation arising from interference between loop and tree-level effects.

2020–21 New Research Capabilities

- MOLLER Experiment Update

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



- **2020 Canadian R&D:**
  - Integrating detector development (Canadian lead)
  - Detector electronics (Canadian lead)
  - Spectrometer development (strong Canadian contr.)
  - CMOS based HVMAP detectors for electron beam Compton polarimeter (Canadian lead)

- **2020 Progress:**
  - MOLLER project received first DOE budget allocation for 2020 fiscal year
  - CD1 achieved in 2020, DOE project started (US$ 65M)
  - NSF Midscale proposal approved (US$ 7M equipment + some personnel)
  - CFI IF Proposal for integrating detectors was successful (CAD 6M total)

- **Next Steps in 2021:**
  - Expect CD2 in Fall
  - Prepare for construction in 2022-2024

On the Canadian side, this project currently involves 9 faculty, 2 postdocs, and 7 students. Institutions: U. of Manitoba (lead), U. of Winnipeg, UNBC, Memorial (new members welcome).

2020–21 Research Highlight

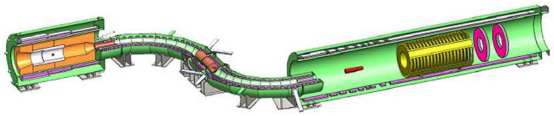
- Theory of bound muon decays

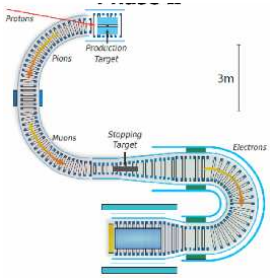
PHYSICAL REVIEW D **102,** 073001 (2020)

Decay of a bound muon into a bound electron

M. Jamil Aslam,[1,2] Andrzej Czarnecki,[1] Guangpeng Zhang,[1] and Anna Morozova[1]

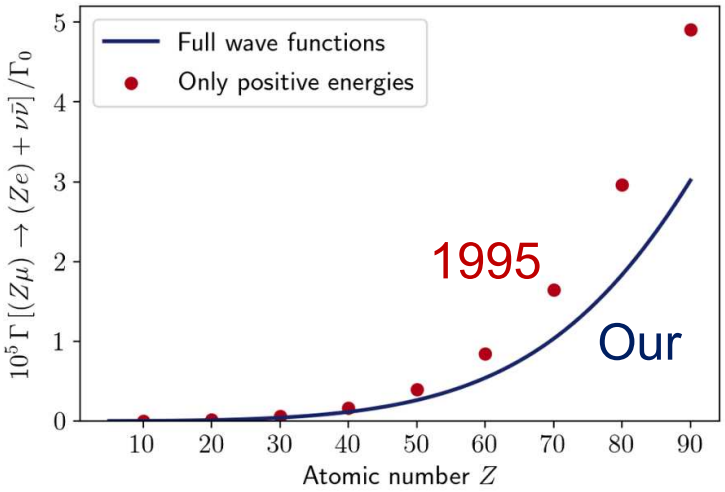
Theory of bound-muon decays: needed for muon-electron conversion searches:

Mu2e in Fermilab 

COMET in J-PARC 

Bound-muon to bound-electron: determined in Brodsky, Greub, Munger, Wyler (1995) but neglected virtual positrons in hydrogen-like atom.
In lead (Z=82) only 0.2% probability of finding e^+,
but contribute -30% to the decay rate!

Explanation: decay happens close to the nucleus, there: relative e^+ content is large.

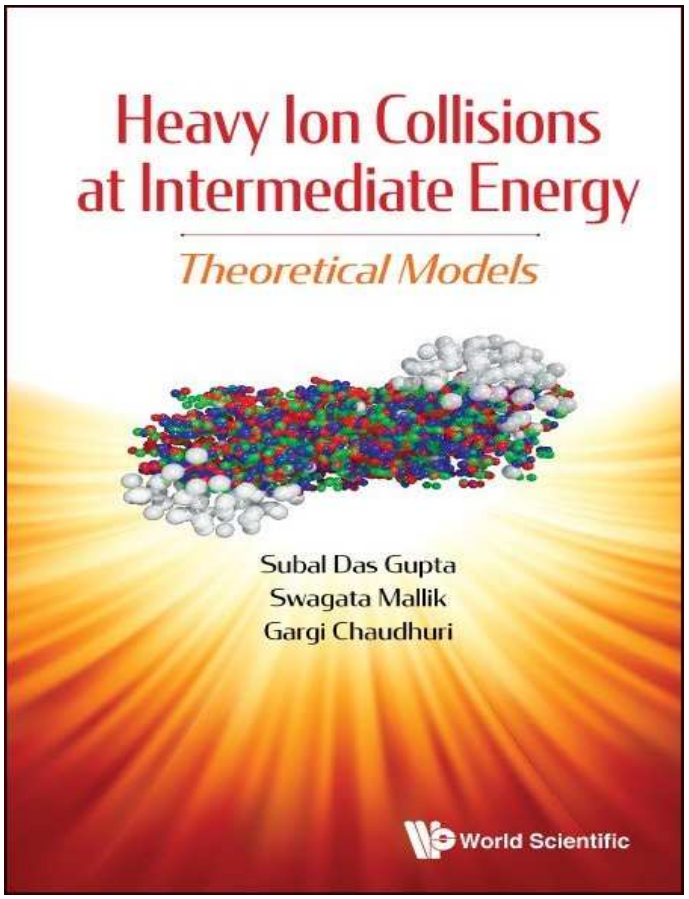


2020–21 Research Highlight
- Book Publication

➢"Heavy Ion Collisions at Intermediate Energy: Theoretical Models"
S. Das Gupta, S. Mallik and G. Chaudhuri
World Scientific Publishers (2019)

❑ The book is a graduate level book on Intermediate energy heavy ion collisions.

❑ Subal Das Gupta is an Emeritus professor at McGill University, Montreal, Canada and has spent several winters in Variable Energy Cyclotron Centre (VECC) in Kolkata, India. Swagata Mallik and Gargi Chaudhuri are Scientific Officers at VECC and also spent significant time at McGill.



2020–21 Research Highlight

- Honours Received by Members

Dr. Willem T. H. van Oers

(University of Manitoba/TRIUMF)
University Distinguished Professor (Emeritus)

(Executive) Secretary of IUPAP Working Group 9 [Nuclear Physics]

Recipient of the 2020 'Henri Abraham' Award for Distinguished Service to IUPAP (the International Union of Pure and Applied Physics)

2020–21 Research Highlight

- Honours Received by Members

- **Jens Dilling, TRIUMF**
- **Rutherford Memorial Medal in Physics, Royal Society of Canada**
- For breakthrough discoveries in experimental nuclear physics.
- He developed and built a mass spectrometer that is the fastest and most precise in the world for studies of some of the shortest-lived isotopes produced in accelerators.