

# Nuclear Theory in Canada

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# Briefs received



## *B/SM*

- 1) Sandapen-Ahmady theory (Acadia/Mount Allison)
- 2) Nuclear matter under extreme conditions (Regina/McGill)
- 3) Lewis theory (York)
- 4) BSM physics at the precision frontier (Memorial)

## *Nuclear astro*

- 5) Caballero theory (Guelph)
- 6) Vassh theory (TRIUMF)

## *Nuclear structure*

- 7) Nuclear many-body theory (Guelph)
- 8) Ab initio atomic and nuclear theory for nuclear structure/astrophysics, fundamental symmetries, and new physics searches (TRIUMF)
- 9) Ab initio nuclear theory for applications in astrophysics and tests of fundamental symmetries (TRIUMF)

# Sandapen-Ahmady theory



## Acadia/Mount Allison

- Systematic improvement of light-front holography
- Phenomenology, of relevance to experiments at Jlab, CERN, and the EIC

2027-2034: Pion Parton Distribution Functions and Distribution Amplitude, ditto for kaons, and eventually heavier mesons

2034-2041: “aim to become a particle physics hub”

## Vujanovic, Gale, Jeon (Regina/McGill)--dedicated talk

- Studies of the quark-gluon plasma, of relevance to RHIC, FAIR, the LHC, and the EIC
- i) spacetime evolution using effective kinetic theory and fluid dynamics
- ii) tomographic probes (jets and electromagnetic radiation)

2027-2034: dynamical evolution of flavors in nuclear matter; phase diagram of QCD at finite chemical potential/temperature; interpolation between high- and low-virtuality regimes

2034-2041: since quarks carry charges (leading to electromagnetic fields), necessary to develop reliable magnetohydrodynamics equations; tomographic probes for saturation regime of QCD

# Lewis theory



## York

- Lattice gauge theory for exotic hadrons (e.g., tetraquarks)
- Hamiltonian formalism on quantum computers for particle collisions as a function of time and nuclear matter at high densities

Recommendation: plan for providing remote national access to quantum computing infrastructure

## **Aleksejevs & Barkanova (Memorial)**

- Parity-violating asymmetries in electron scattering, of relevance to P2, Belle II, and MOLLER experiments
- Is the X17 anomaly SM or BSM?

Outlook: full gauge-invariant calculations aimed at key experiments, addressing kinematically rich two-loop electroweak computations

# Caballero theory



## Guelph

Nuclear astrophysics as it pertains to:

- 1) Transport properties in neutron-star crusts
- 2) Heavy element nucleosynthesis
- 3) Neutrino observables

2027-2034: role of nuclear isomers in nucleosynthesis; nuclear pasta; dark-matter impact on neutrino emission; connections between relic neutrinos and stochastic gravitational wave backgrounds; radioactive and cluster decay impact on reaction rates under extreme conditions

2034-2041: of relevance to heavy-ion collisions and RIB experiments. Data analysis framework for Hyper-Kamiokande, DUNE, LIGO, LISA, and Cosmic Explorer

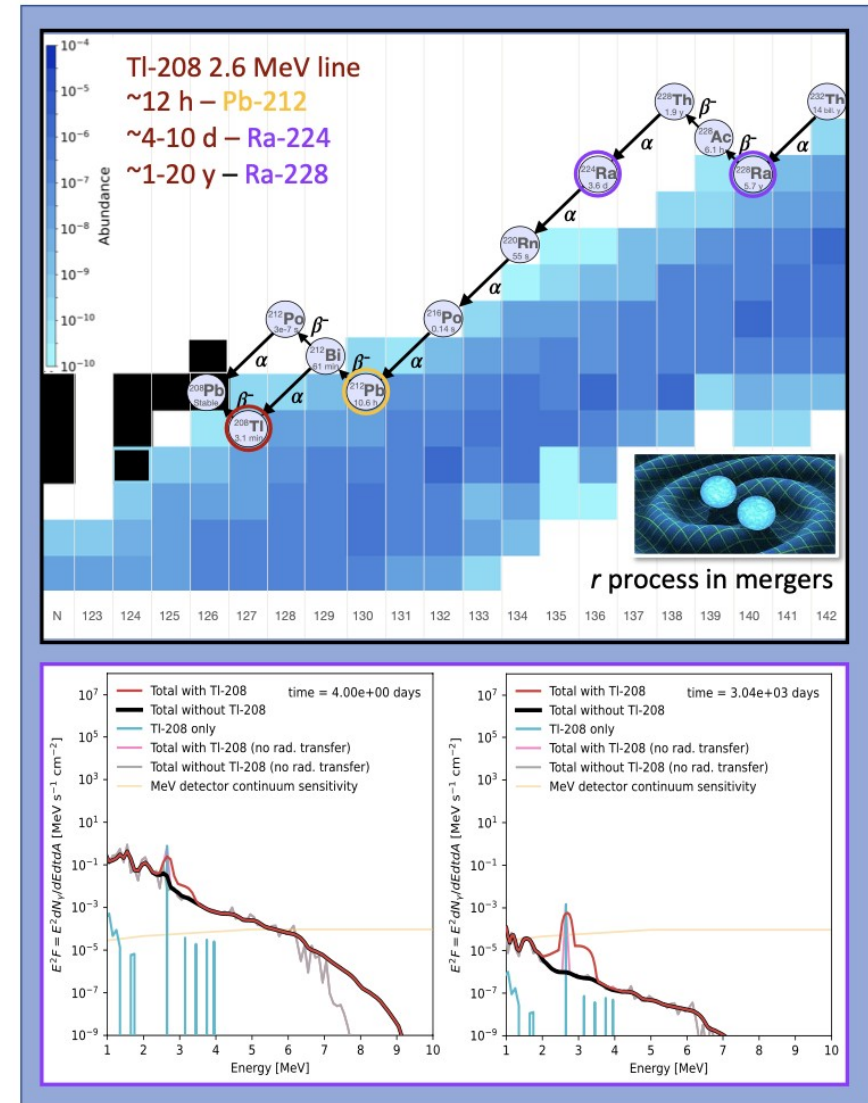
# Vassh theory

## TRIUMF

Nuclear astrophysics studies of heavy-element nucleosynthesis, comparing with stellar and solar abundances, taking inputs from both experiment and theory.

2027-2034: emphasis on ARIEL impact on reactions, decays, etc, as well as FRIB, ANL, and GSI relevance; graph theory in networks and use of Bayesian techniques

2034-2041: MeV gamma-ray sky from COSI; compact binary merger rates from LIGO; machine learning on abundance patterns of distinct nucleosynthesis processes



# Nuclear many-body theory



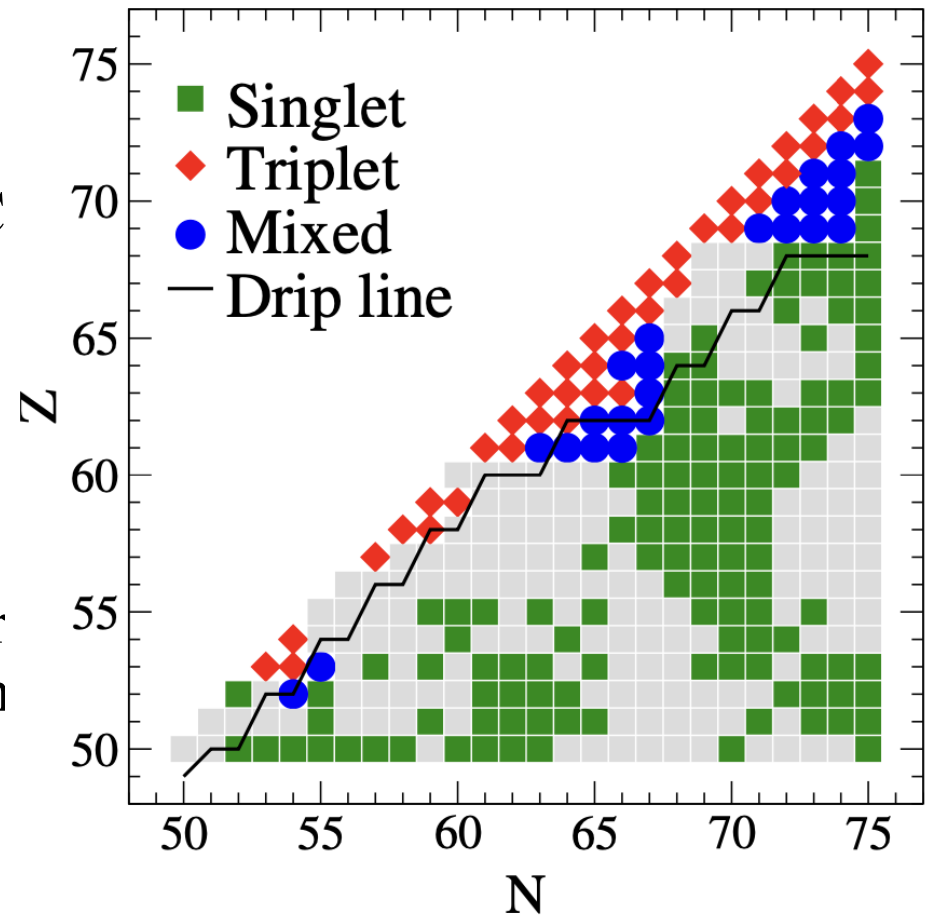
## Gezerlis (Guelph)

Use both ab initio and phenomenology to study nuclear structure and astrophysics, e.g.

- 1) Clustering in cold gases vs nuclei w QMC
- 2) Mixed-spin pairing in  $A \sim 130$  nuclei (TITAN or AGATA)
- 3) Neural-network wave functions for light nuclei

2027-2034: clustering and pairing studies for neutron-star crusts, nuclei, and model system

2034-2041: increased contact with lattice gauge theory; novel QMC techniques using artificial intelligence



Palkanoglou, Stuck, Gezerlis,  
PRL 134, 032501 (2025)

# Holt theory



## TRIUMF

Capitalize on valence-space formulation of the in-medium similarity renormalization group. Of relevance to both TRIUMF and SNOLAB

2027-2034: explore superheavy region, looking for island of stability; neutrinoless double beta decay for dark matter searches, neutrino-nucleus scattering for all experimentally relevant nuclei; anapole moments, Schiff moments, EDM

2034-2041: provide first ab initio input (masses, beta decay, neutron capture rates) for r-process nucleosynthesis simulations

# Navratil theory

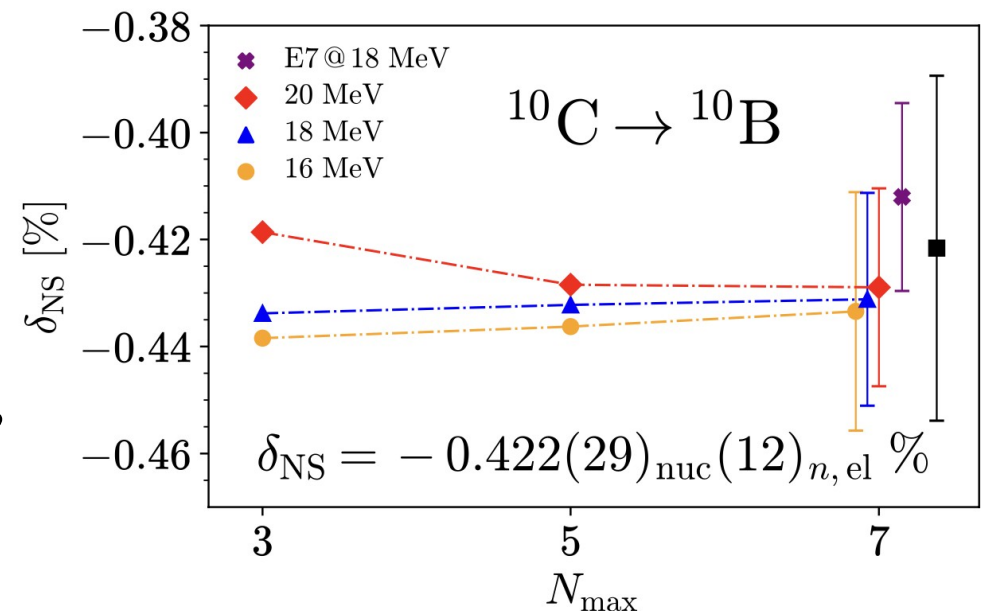


## TRIUMF

Ab initio theory of nuclear structure and nuclear reactions for light and medium-mass nuclei, needed to understand exotic nuclei probed at rare isotope facilities such as ISAC/ARIEL at TRIUMF. Both many-body Green's function and unified description of bound and unbound states.

2027-2034: determine  $v_{ud}$  in CKM matrix; searches for nuclear parity-violating moments; radiative capture reactions, transfer reactions involving alpha particles

2034-2041: compute many-body Green's functions including continuum effects; describe nuclear deformation.



# Recommendations



- Increased funding for HQP, including postdoc support where that is not currently feasible
- NSERC-RTI, CFI-JELF, Digital Alliance for high-performance computing, including an exascale computer with GPU acceleration and large-memory nodes
- National plan for remote access to quantum computers
- NSERC theory support should not disadvantage smaller/remote institutions
- Scholarships targeting individuals from underrepresented groups
- More generous travel support and explicit support for publication fees
- Funds incentivizing interdisciplinary studies
- Faculty-level positions to establish critical mass nationally
- Make exploitation of ARIEL highest priority. Support RadMol and BeEST