FRIB Theory Alliance
2025 LECM

Calvin W. Johnson*
San Diego State University

* Executive Board "Director" 2025

August 15, 2025

This work is supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under the FRIB Theory Alliance award DE-SC0013617

LECM, College Station, Aug 14, 2025

FRIB Theory Alliance

A coalition of scientists from universities and national laboratories.

The mission:

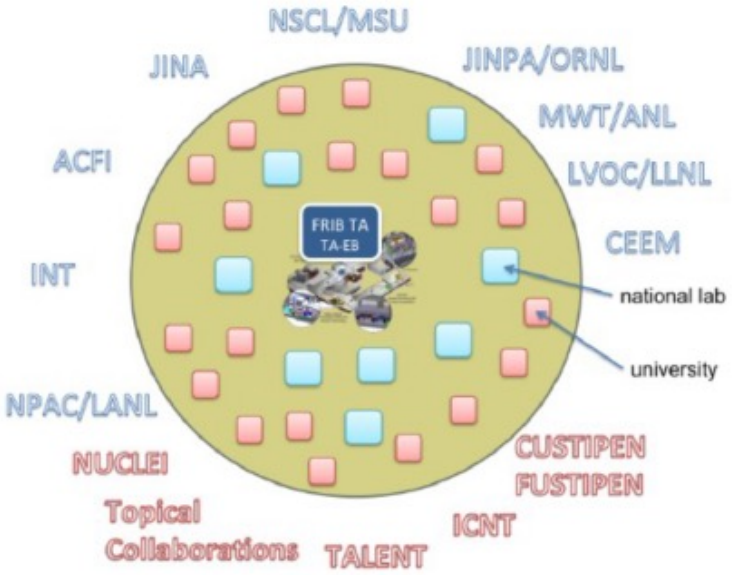
- foster advancements in FRIB-related theory
- improve coupling between theory and experiment
- create permanent theory bridge positions
- attract young talent through FRIB Theory Fellow Program
- run educational and topical programs
- foster interdisciplinary collaboration

This year

- **Topical program:** Future directions in nuclear beta decay at FRIB, Sept 2025
G. King, G. Sargsyan, A. Glick-Magid, M. Caprio, K. Leach
- **Summer school**: Emergence of Collective Motion in Atomic Nuclei, Aug 2025
M. Allmond, H. Crawford, A. Gade, T. Papenbrock, R. Stroberg
- **International Program**: EUSTIPEN travel grants to ECT*

Who we are

Total Members = 301 (196 from US)
Faculty = 135 (84 from US)
Lab staff = 45 (33 from US)
Postdocs = 56 (40 from US)
Fellows = 6 (2 from US)
Students = 59 (39 from US)



Some of our research interests

FRIB Theory Alliance

Forces
Structure
Reactions
Equation of state
Fundamental symmetries
Nucleosynthesis

And…

We can determine implications of your measurements for BSM physics, nucleosynthesis, neutron stars,…

Ab initio methods
Shell model
Continuum physics
Density Functional Theory
Weak decay
Clustering
Collective motion
Direct, knockout, transfer . . .
Optical potentials
Three-body physics
Statistical approach to reactions
Central collisions
Fission and fusion
Exotic decay

Call-A-Theorist

FRIB Theory Alliance

List of Potential Nuclear Theory Collaborators - In order to support the experimental program at FRIB right from the start, the FRIB TA Executive Board (TA-EB) has compiled a list of theorists who are willing to provide their expertise to experimental groups. Theorists can contribute to successful proposals and experiments by providing background information, suggesting experts who can address specific questions, and by collaborating directly. In turn, experimentalists can support theorists by incorporating and acknowledging the input, as well as by including them in proposals and collaborative work beyond. All users of the list are expected to use the information therein solely for the purpose of scientific discussion and collaboration. Any concerns should be reported to the Theory Alliance Executive Board.

Name	Email address	Website	Areas of current interest	Resources (formal, computational, theory networks/collaboration) available	Other areas of expertise	Wish list for experimental data
Alex Brown	brown@nscl.msu.edu	https://people.nscl.msu.edu/~brown/	Structure of sd shell nuclei (Structure includes beta and gamma decay, moments, One and two nucleon spectroscopic factors) Structure in the region of 42Si Structure of pf shell nuclei Structure for Z=28-50 up to N=56 Structure in the regions of 132Sn and 208Pb Rms radii and neutron skins connected to the neutron equation of state Rapid-proton capture rates Level densities from the shell model Structure aspects of double Di-proton decay	Shell-model codes Oxbash and NuShellX		Structure data for the regions of 42Si, 60Ca, and 78Ni Rms charge radii of proton-rich nuclei
			Indirect methods for determining nuclear reaction cross sections for astrophysics and other applications Interplay of statistical and direct reactions, formation, and decay of compound nuclei			
Daniel Phillips	phillid1@ohio.edu	https://www.ohio.edu/cas/phillid1	Halo nuclei and quantum universality Bayesian inference Astrophysical reactions for light nuclei; R-matrix theory Neutron-neutron interactions	BAND collaboration (https://bandframework.github.io/) BUQEYE collaboration (https://buqeye.github.io/) Collaboration with several physicists at TU Darmstadt	Electron & photon scattering from light nuclei Effective Field Theory Three-body dynamics Parity violation	Neutron-neutron correlations in the final state Energies, radii, B(E1) strengths of weakly bound s-wave & p-wave states near the driplines
Jorge Piekarewicz	jpiekarewicz@fsu.edu	http://web2.physics.fsu.edu/~piekarewicz/	Neutron-rich matter on heaven and earth; Neutron stars, neutron skins, giant resonances; Covariant density functional theory; Bayesian statistics	Calibration and implementation of unified covariant density functional codes to describe ground-state properties of finite nuclei, their linear (RPA) response, and properties of neutron stars.		Masses of exotic neutron-rich nuclei of relevance to the neutron star crust; Neutron densities and neutron skins of very neutron-rich nuclei to constrain EOS; Electric dipole polarizability along isotopic chains; Charge radii of mirror and exotic nuclei; constraints on the EOS at twice saturation density from heavy-ion collisions of highly asymmetric nuclei
Kevin Fossez	kfossez@fsu.edu	https://kevinfossez.github.io/	Nuclear structure including the continuum (ab initio, shell model); Halo structures, two-neutron/proton decay, many-body resonances. Collective motion.	NUCLEI collaboration; (Ab initio) Gamow shell model (GSM), density matrix renormalization group (DMRG) method, In-medium similarity renormalization group (IMSRG), particle-plus-rotor model.	High-performance computing. Shell model interactions. Radiative capture reactions, alpha clustering.	Energies and spin-parity at the drip lines in the sdfp region. Decay widths and decay channels. Beta-decay spectroscopy of proton-rich nuclei.
Filomena Nunes	nunes@frib.msu.edu	https://fimmnunes.wixsite.com/mysite	direct nuclear reactions, few-body methods for reactions, optical potential, uncertainty quantification in reactions		Halo nuclei and few-body models for halos	systematic study of elastic on several isotopic chains. simultaneous measurement of breakup and elastic. transfer measurements on neutron rich heavy nuclei
Dean Lee	leed@frib.msu.edu	https://leedeanj.wixsite.com/leegroup	nuclear clustering, forces, structure, thermodynamics, liquid-gas transition, equation of state, superfluid pairing, microscopic calculations	NUCLEI collaboration Nuclear Lattice EFT Collaboration	Quantum computing Machine learning	Cluster states, nuclear correlations, multifragmentation distributions
Jon Engel	engelj@physics.unc.edu https://physics.unc.edu/engelj/	http://www.physics.unc.edu/~engelj/	Fundamental symmetries in nuclei: double-beta decay, atomic electric dipole moments. Nuclear astrophysics: weak interactions in nucleosynthesis, r process. Nuclear structure: density-functional theory, in-medium generator-coordinate method.	DBD Topical Theory Collaboration NUCLEI collaboration	Group theoory in nuclear physics	Beta-decay spectroscopy Strength distributions for forbidden/retarded operators
Amy Lovell	lovell@lanl.gov		Uncertainty quantification for reaction theory Correlations in prompt and delayed fission observables Optical potential Machine learning to supplement data/theory	CSEWG CGMF (Monte Carlo correlated fission code)	few-body models direct reactions	correlated prompt fission observables systematic study of scattering on isotopic chains
Kristina Launey	klauney@lsu.edu	https://www.lsu.edu/physics/people/faculty/launey.php	Structure of nuclei (ab initio up to about mass 50):energy spectra, rms radii, B(E2) with no effective charge, moments, densities, sum rules; collectivity and clustering; shapes, shape co-existence Decays: beta, gamma, GT transitions, charge-exchange densities, decay widths Reactions: cross sections for proton and neutron scattering, p capture, n capture, alpha capture, spectroscopic factors Nuclear astrophysics: narrow resonance reaction rates and alpha widths	Symmetry-adapted codes with SU(3) and symplectic bases (LSU3shell: https://sourceforge.net/projects/lsu3shell/)	Optical potentials from first principles	Binding energies, energy spectra, and B(E2) for proton-rich and neutron-rich nuclei, including Ne, Mg, Ca isotopes
Chloë Hebborn	hebborn@frib.msu.edu		Coulomb and nuclear-dominated breakup reactions one-neutron knockout reactions Ab initio NCSM/RGM and NCSMC calculations		halo nuclei	Neutron knockout of halo nuclei Coulomb breakup of halo nuclei
Saori Pastore	saori@wustl.edu		electroweak properties of nuclei, electromagnetic and weak decays, electron and neutrino scattering, nuclear structure, many-body electroweak currents, neutrinoless doble beta decay, BSM with beta decay, BSM with nuclei	variational and green's function Monte Carlo methods		
Christian Drischler	drischler@ohio.edu		nuclear-matter equation of state neutron stars chiral effective field theory many-body perturbation theory Bayesian methods for uncertainty quantification,	BUQEYE collaboration N3AS collaboration	High-performance computing	Masses and neutron skins of neutron-rich nuclei High-density constraints on the nuclear EOS

A list of theorists who can support/interpret your experiment.
Go to fribtheoryalliance.org

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How to Call-A-Theorist

At least 15 different theorists involved in previous PAC proposals

To recruit a theorist collaborator, start by consulting list of theorists at fribtheoryalliance.org.

If that fails, consult Scott Bogner (bogner@frib.msu.edu), or me (cjohnson@sdsu.edu).

We know a large fraction of the FRIB-TA membership and love to connect theorists with experiment.

The earlier you contact us, the more we'll be able to help.

FRIB-TA Bridge Faculty

There will be a new call for bridge partners in September

Proposals due in mid-March

Questions? Contact Bridge Chair Sebastian König (skoenig@ncsu.edu) or Scott Bogner (bogner@frib.msu.edu)

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Sebastian Koenig, NCSU

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EFT for few-body scattering/reactions, emulators

As bridge faculty

21 papers published + 1 under submission + 4 in preparation

3 long-term graduate students + two rotation grad students + 4 undergrads

NSF CAREER AWARD

DOE QIS grant (co-PI)

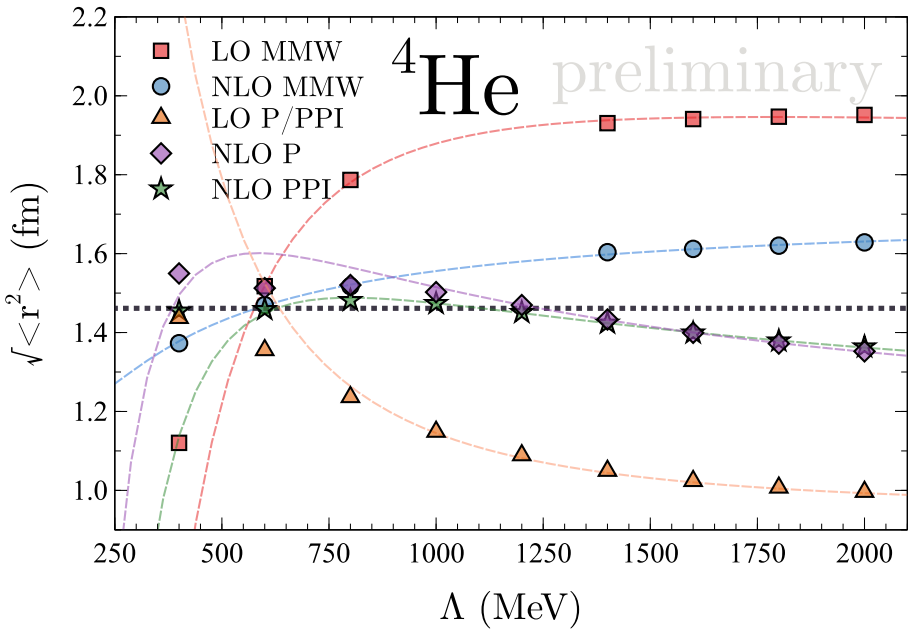
DOE AI/ML grant (co-PI)

NCSU Goodnight Early Career Innovator Award

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^{4}He radius at NLO

- **range corrections + four-nucleon force included to calculate radius at NLO**



Remarks

- calculations not quite converged above deep triton threshold
- dashes lines fit a polynomial in $1/\Lambda$
  - however: four-boson results suggest this may be problematic
- **marginal effect from pions compared to standard pionless EFT!**

Kevin Fossez, FSU

FRIB Theory Alliance



exotic nuclei, open quantum systems

As bridge faculty

8 publications (including Ann. Rev. Nucl. Part. Sci.)

3 grants – **NSF CAREER** +

Co-PI STREAMLINE (renewed)

Co-organizer 2 meetings + 1 summer school

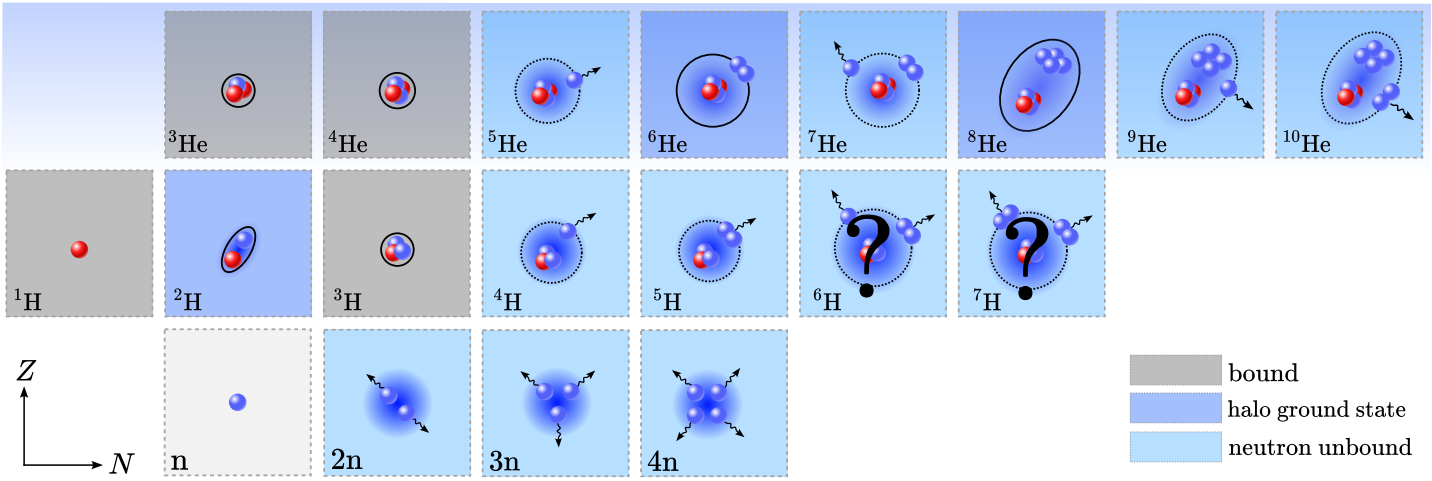
Kevin Fossez, FSU

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Ab initio description of $^{4-7}$H (work in progress)

Work lead by
A. Sehovic (FSU)

Long-term goal: Testing nuclear forces in extreme N/Z conditions where quasi-exact calculations are feasible.



Challenge: Obtain the first *ab initio* description of the H chain and determine the nature of ^{7}H g.s. ($4n$ decay).

Christian Drischler, OU

FRIB Theory Alliance

EOS from chiral EFT, UQ/emulator development



As bridge faculty

10 papers published, 3 under submission

mentored 2 grad students, 1 summer grad student, 1 MS student, 1 undergrad

Three grants, including **NSF CAREER award**

Christian Drischler, OU

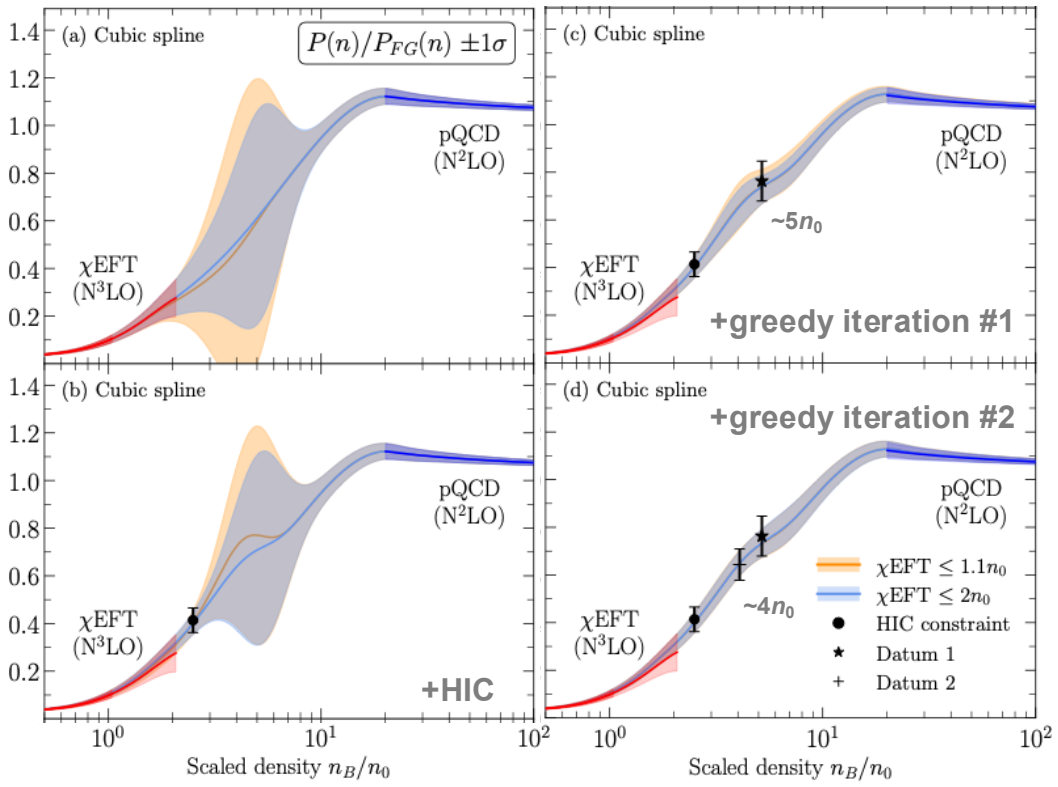
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Greedy data assimilation

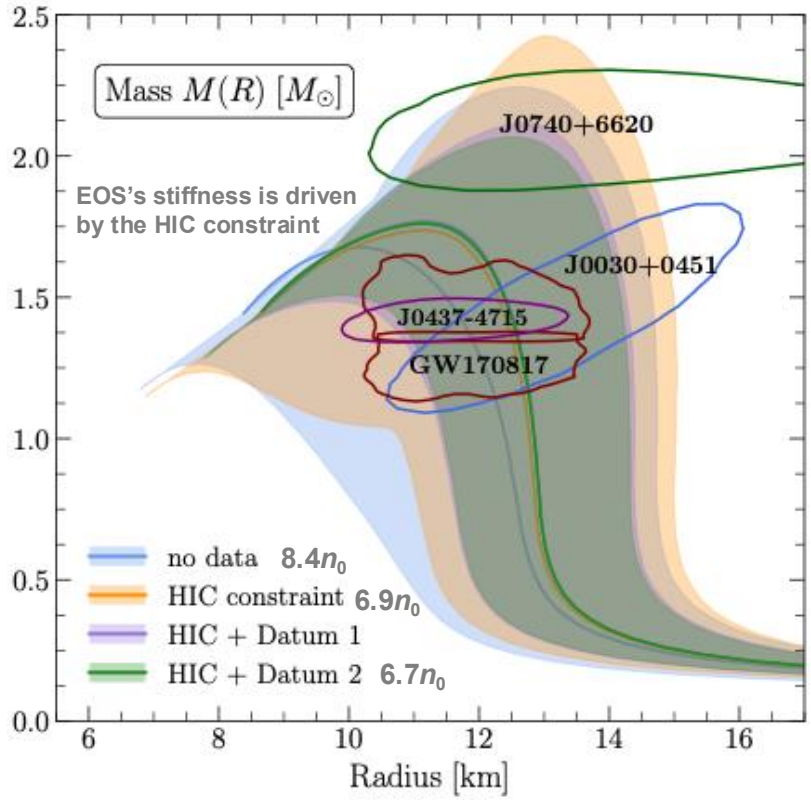
Semposki, CD, Furnstahl, Phillips, arXiv:2505.18921

OHIO UNIVERSITY

Inclusion of **exogenous data** at intermediate densities



Neutron star **mass-radius relation**



HIC: Huth *et al.*, Nature **606**, 276

insensitive to the choice of chiral EFT's upper limit if enough data are available

- Successful **University of Arizona** bridge search



Dr. Pooja Siwach: Quantum computing, neutrino physics, nuclear structure

Starts in Fall 2025

FRIB-Theory Fellows

NOTE: There will be a theory fellow search this Fall
for a position to be hosted at FRIB
with a start date of Summer/Fall 2026

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Francesa Bonaiti, ORNL

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ab-initio structure, EM properties and EOS, β-decay

As FRIB-TA fellow

5 published papers + 1 proceeding + 1 preprint
13 invited talks + 1 Summer School
2 grad students (co-supervisor) + 1 undergrad (co-supervisor)

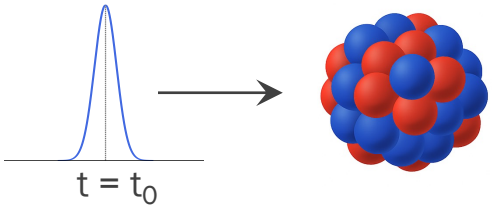
2025 APS Topical Group on Few-Body Systems Travel Award
Co-spokesperson of accepted FRIB PAC 3 expt proposal
Co-organizer of approved ECT* Workshop for May 2026
Main guest on popular-science episode of Italian podcast "A Brain Pod" (2k+ followers)

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Responses in a time-dependent approach

Goal: solving

$$i\hbar\frac{d}{dt}\left|\Psi(t)\right\rangle = \hat{H}(t)\left|\Psi(t)\right\rangle$$



with

$$\hat{H}(t) = \hat{H}_0 + \epsilon f(t)\hat{D}$$



For small ε, first-order time-dependent perturbation theory yields:

$$D(t) = \langle\Psi(t)|\hat{D}|\Psi(t)\rangle \longrightarrow \tilde{D}(\omega) \longrightarrow R(\omega) = \mathrm{Im}\left(\frac{\tilde{D}(\omega)}{\epsilon\tilde{f}(\omega)}\right)$$

Fourier transform

Grigor Sargsyan, MSU

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optical potentials from shell model, electroweak properties



As FRIB-TA fellow

9 papers published + 4 under submission

mentored 1 undergrad

primary co-organizer of a summer school and a topical program

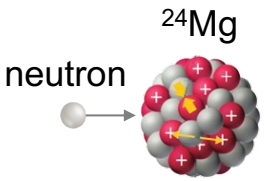
LLNL director's institutional award 2024

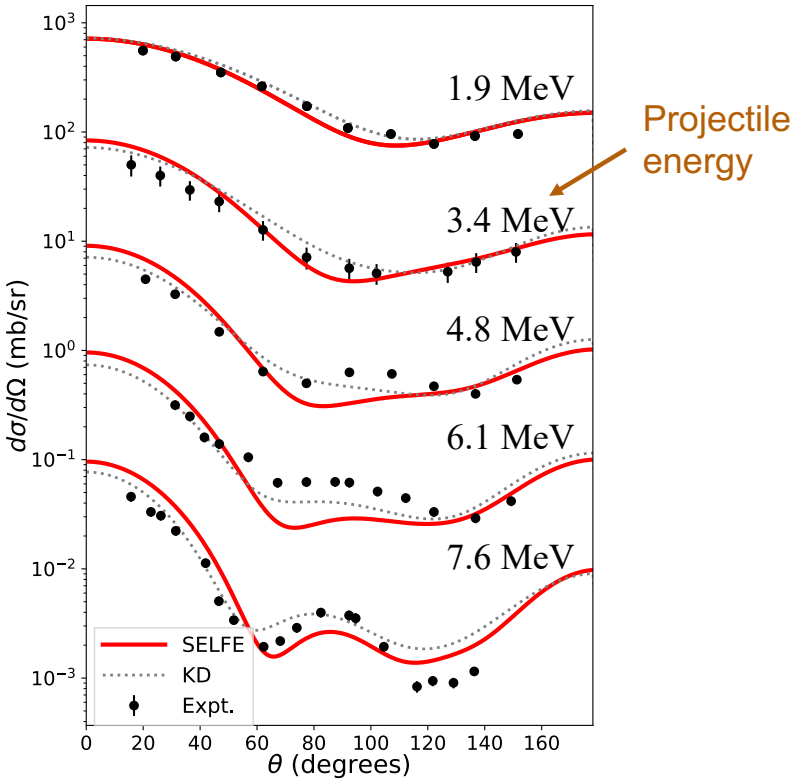
100,000 node-hours on FRONTERA, 25,000 node-hours on NERSC

Grigor Sargsyan, MSU

FRIB Theory Alliance

Accurate prediction without parameters fitted to experimental scattering data!





Sargsyan, *et al.*, arXiv:2410.21714

Linda Hlophe, LANL

few-body models for capture, transfer, breakup



As FRIB-TA Fellow:

1 paper published, 1 submitted

Mentored summer student

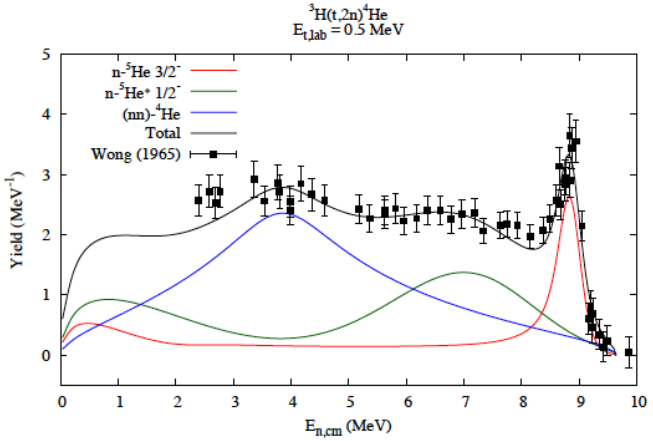
Organized FRIB-TA summer school 2024

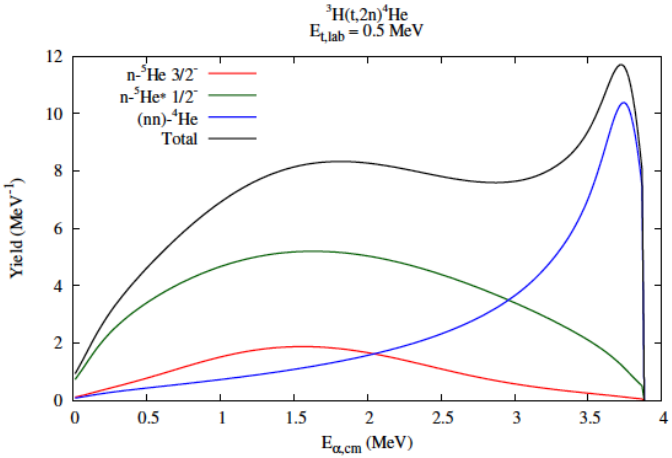
Linda Hlophe, LANL

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Breakup spectra

$^3H(t,2n)^4He$





- Preliminary results w/ SPECT code
  - model captures essential physics
- Full 3-body code under development
  - Fortran2023 compliant
  - Python interface

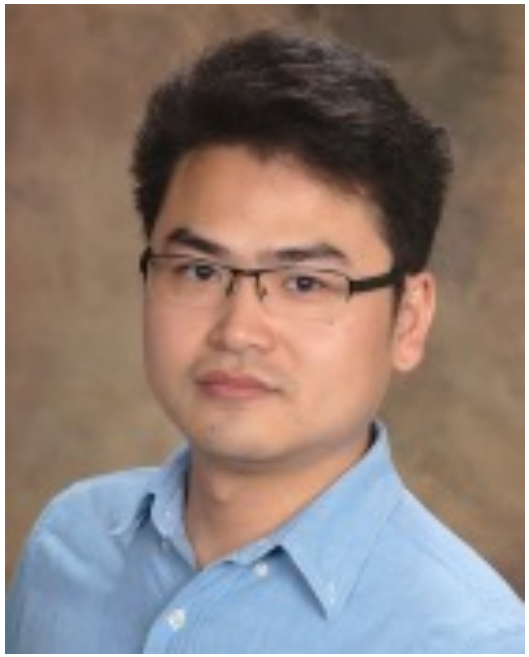
Submitted in collaboration with Mark Paris and Gerald Hale (LANL)

Facility for Rare Isotope Beams
U.S. Department of Energy Office of Science | Michigan State University
640 South Shaw Lane • East Lansing, MI 48824, USA
frib.msu.edu

Xilin Zhang, MSU

FRIB Theory Alliance

scattering/reactions, AI/ML techniques



As FRIB-TA fellow

10 published papers, 4 undersubmission

mentored 1 postdoc, 1 grad student, 3 undergraduates

Member of STREAMLINE collaboration

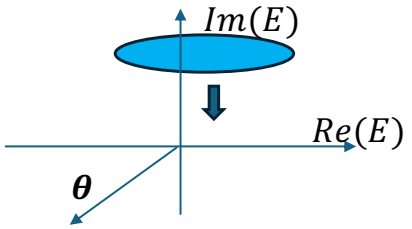
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Xilin Zhang, MSU

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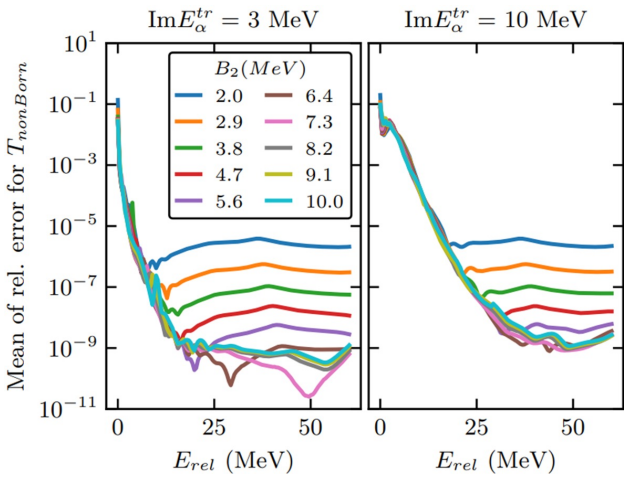
Unifying Continuum Methods with Complex-Energy Emulators

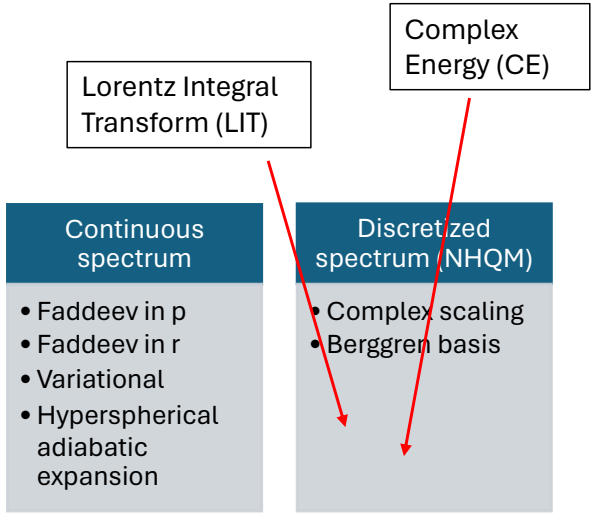
- Using bound-state solvers to extract continuum physics for larger systems
- Its $\boldsymbol{\theta}$-emulation → easy access
- XZ, 2411.06712, accepted by PRC
- XZ, 2408.03309, under review



- A single author, multi-year project: possible bc of the **TA support and granted research independence**
- Collaborations welcome!

Particle-dimer scattering





NHQM: non-Hermitian Quantum Mechanics

Executive board

FRIB Theory Alliance

Mark Caprio (University of Notre Dame, 2025-2028)

Maria Colonna (INFN-LNS, Catania, Italy, international rep., 2024-2027)

Christian Drischler (Ohio University, 2024-2027)

Jon Engel (**Past Director**, University of North Carolina, 2020-Dec2025)

Alexandra Gade (FRIB users relations, MSU, 2022-2025)

Kyle Godbey (MSU, 2025-2028)

Chloe Hebborn (IJCLab, Orsay, France, 2025-2028)

Ben Kay (ANL, experimental rep., 2023-2026)

Calvin Johnson (**Director,** San Diego State University, 2021-2024)

Sebastian Koenig (**Director-Elect,** NC State, 2023-2027)

Gregory Potel (LLNL, 2023-2026)

Ingo Tews (LANL, 2025-2028)

Nicole Vassh (TRIUMF, 2022-2026)

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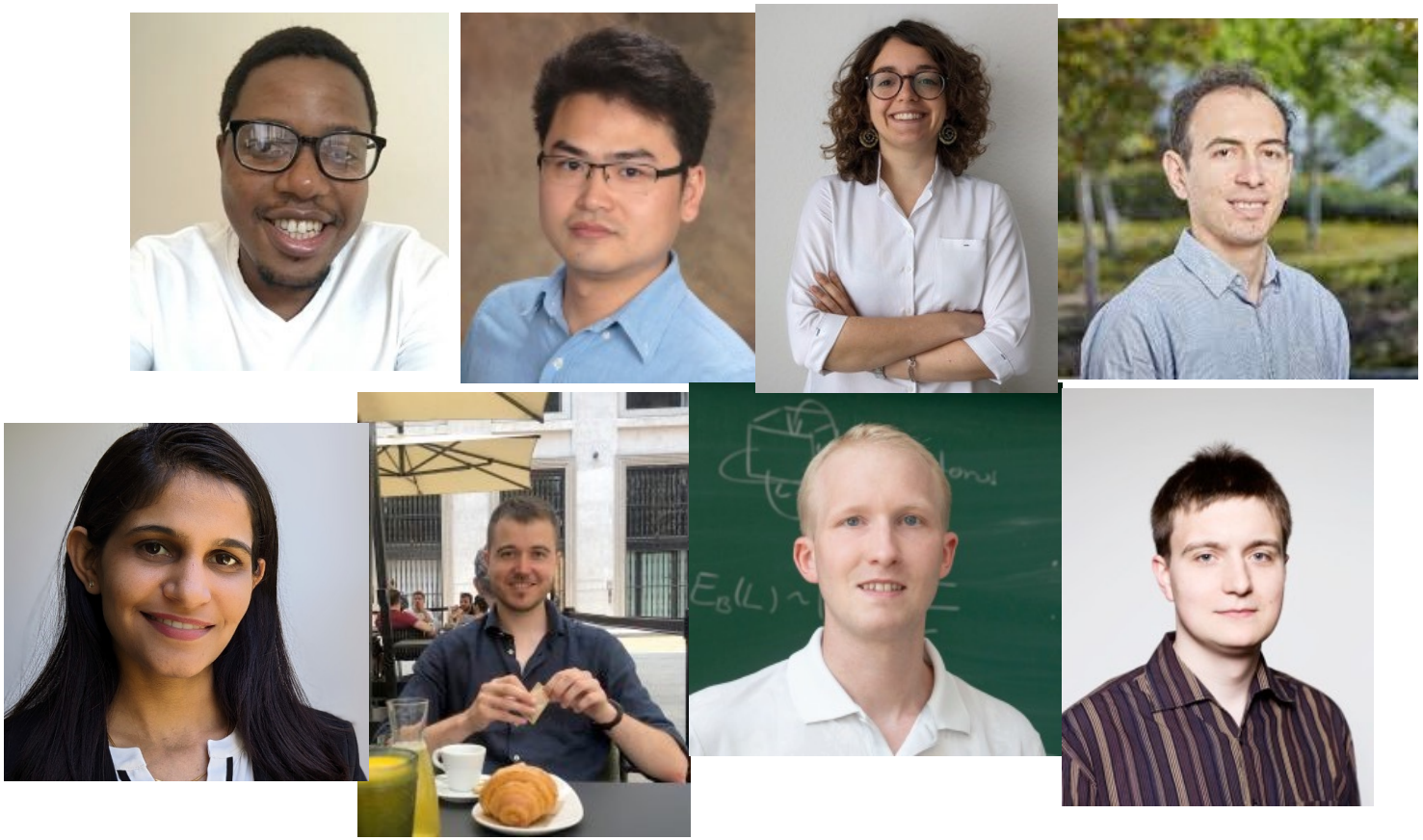
Nicole Vassh (TRIUMF, 2022-2026)

Outgoing board members:

Jon Engel
Kevin Fossez
Gaute Hagen
Elena Litvinova

Scott Bogner (NSCL, MSU) [Managing Director]
Gillian Olson (MSU) [Administrative Support]

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