Theory Alliance
FACILITY FOR RARE ISOTOPE BEAMS

U.S. DEPARTMENT OF ENERGY | Office of Science

FRIB Theory Alliance

Filomena Nunes
FRIB-TA managing director
Michigan State University

theory needs for rare isotope science

Topic	Theory development needed
T1: Forces	Effective field theory (EFT) constants from LQCD; Improved optimization of chiral forces, with and without Δ; Consistent operators and power counting for chiral EFT.
T2: Nuclear structure	Connect realistic nuclear forces to shell model and DFT; Microscopic optical potential that incorporates many-body correlations.
T3: Medium-mass nuclei	Properties of nuclei with validated ab-initio techniques; Shell-model effective interactions and operators derived and/or constrained from microscopic interactions, with controlled uncertainties; Unified treatment of structure and reactions.
T4: Heavy nuclei	DFT constrained by rare isotope data and ab-initio theory; Beyond-DFT treatment of open shell systems; calculations of Schiff and anapole moments. Improved DFT-based adiabatic models of the large-amplitude collective motion; Implementation of TDDFT and multi-reference DFT approaches; Effective field theory for collective nuclear phenomena based on powerful existing phenomenology. Implementation of proton-neutron, symmetry-projected multi-reference DFT and large-scale shell model to compute nuclear matrix elements for double-beta decay. Masses and beta-decay rates, calculated from DFTs and combined with experiment.
T5: Neutron stars	Controlled calculations of the nuclear equation of state for all relevant densities including extrapolations to high densities with known uncertainties; Improve constraints on nuclear EOS by identifying observables most sensitive to the high-density behavior of the nuclear symmetry energy; Calculate structure in the neutron star crust at various densities (ground state and response functions).
T6: Reactions	Ab-initio reaction theory, consistent with nuclear structure, with quantified uncertainties, adequate for many domains of experimental interest, including radiative capture, transfer, charge-exchange, breakup of dripline nuclei and superheavy synthesis to estimate production of nuclei at and beyond the dripline and to extract structural information. Microscopic theory of spontaneous and neutron-induced fission; Ab-initio theory for light-ion fusion. Reaction theory for compound nucleus formation consistent with structure. Reliable transport theory with quantified errors, including a quantum formulation with correlations, for heavy-ion reactions from low to intermediate energies.
T7: Astrophysics	Advanced simulations of compact objects; supernova, binary neutron star mergers and related explosive phenomena; Nucleosynthesis and chemical evolution simulations with up-to-date nuclear input; Neutrino interactions with nuclei in hot and dense nuclear matter, including neutrino oscillations; Hydrodynamics and neutrino transport in stars; Screening in stellar plasma consistent with reaction theory.

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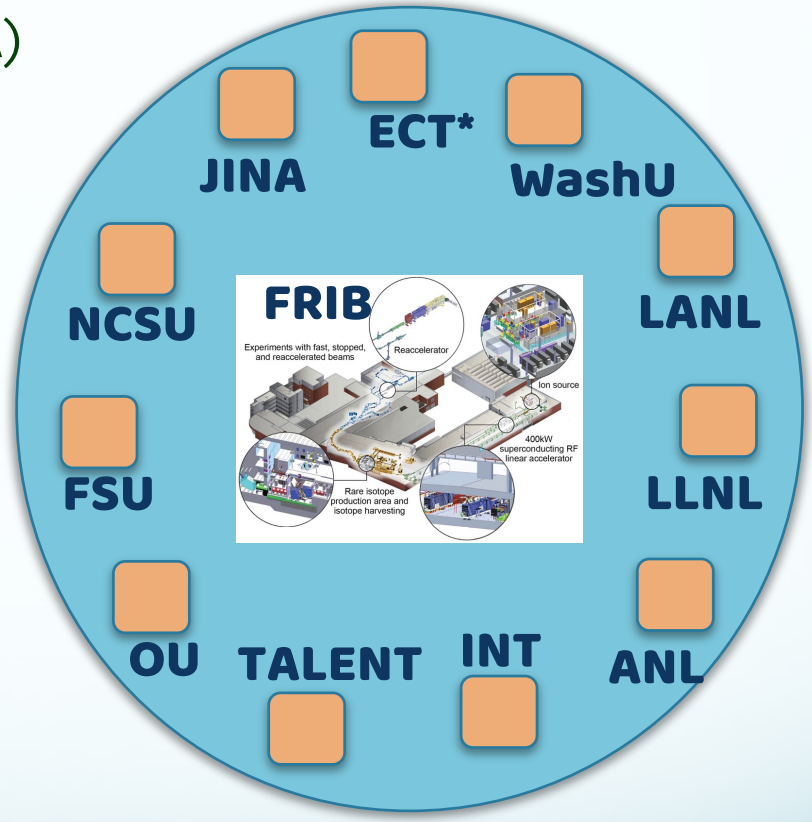
Total Members = 279 (188 from USA)
Faculty = 120 (75 from USA)
Lab staff = 38 (31 from USA)
Postdocs = 55 (39 from USA)
Fellows = 5
Students = 61 (40 from USA)



ECT*: European Center for Theory
JINA: Joint Institute for Nuclear Astrophysics
WashU: Washington Univ. St. Louis
NCSU: North Carolina State University
FSU: Florida State University
OU: Ohio University
TALENT: Training in Advanced Low Energy Nucl. Physics
INT: Institute for Nuclear Theory
LLNL: Lawrence Livermore National Laboratory
ANL: Argonne National Laboratory
LANL: Los Alamos National Laboratory

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goals

- to deliver excellent research in theory relevant to FRIB
- to serve as a focal point for stimulating and continuous interactions between theory and experiment, drawing theory activity toward those problems relevant for the science at FRIB;
- to rejuvenate the field by creating permanent positions in FRIB theory across the country;
- to attract young talent through the national FRIB Theory Fellow program;
- to strengthen theory in areas of most need;
- to foster interdisciplinary collaborations and build scientific bridges to wider theory communities;
- to coordinate a sustainable educational program in advanced low-energy nuclear theory;
- to coordinate international initiatives in the theory of rare isotopes.

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programs

- **national FRIB theory fellow program** enhances the visibility of the field and attracts the brightest young people
- **FRIB-TA bridge program** emphasizes the importance of low-energy nuclear theory: enhances the opportunity to create permanent positions in nuclear theory
- **FRIB-TA topical programs** establish a stronger connection to experiment and foster interdisciplinary collaborations
- **FRIB-TA summer schools** engage graduate by exploring the intersections of FRIB theory with other areas
- **EUSTIPEN**: enhances collaborations between Europe and the United States on FRIB science.

Webpage contains all details: fribtheoryalliance.org

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executive board

Sonia Bacca (University of Mainz, Germany, 2021-2024, international)

Jon Engel (University of North Carolina, 2020-2023)

Jutta Escher (**Past Director**, LLNL, 2019-Dec2022)

Kevin Fossez (Florida State University 2022-2025)

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

Gaute Hagen (ORNL, 2022-2025)

Elena Litvinova (Western Michigan University, 2022-2025)

Kate Jones (University of Tennessee, 2020-2023)

Amy Lovell (LANL, 2020-2023)

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

Saori Pastore (**Director-elect**, WashU, 2021-Dec2024)

Daniel Phillips (**Director**, Ohio University, 2020-Dec2023)

Nicole Vassh (TRIUMF, 2022-2025)

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committees

- **Organization Committee** (chair: Kate Jones)
- **Theory fellow search committee** (chair: Saori Pastore and co-chair Calvin Johnson)
- **Bridge committee** (chair: Daniel Phillips and co-chair Amy Lovell)
- **Broader impacts committee** (chair: Gaute Hagen)
- **Education and topical programs committee** (chair: Jon Engel)
- **International links committee** (chair: Sonia Bacca)
- **Webpage committee** (chair: Kevin Fossez)
- **Diversity, equity and inclusion** (chair: Amy Lovell)

Webpage contains all details: fribtheoryalliance.org

fellow program

- Christian Drischler (Hosting Institution: MSU, 2020 - 2022)
- Chloe Hebborn (Hosting Institution: LLNL, 2020 - 2023)
- Xilin Zhang (Hosting Institution: MSU, 2021 -)
- Chieh-Yeah Seng (Hosting Institution: UW, 2022 -)
- Anna McCoy (Hosting Institution: WashU, 2022 -)

Previous fellows all have permanent positions:

- Diego Lonardoni (fellow hosted by LANL, now staff at LANL)
- Gregory Potel (fellow hosted by MSU, now staff at LLNL)
- Kevin Fossez (fellow hosted by ANL, now faculty at FSU)

New search to take place Fall 2022 – to hire two fellows
One to be located at MSU and another to be located at LANL

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bridge program

- Saori Pastore
  (Institution: Wash U; start year 2018-2022, tenured)
- Maria Piarulli
  (Institution: Wash U; start year 2018)
- Sebastian Konig
  (Institution: NCSU; start year 2020)
- Kevin Fossez
  (Institution: FSU; start year 2021)
- Christian Drischler
  (Institution: OU; start year 2022)

New call to come out later 2022!

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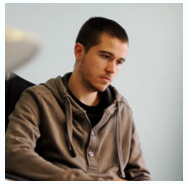
theory needs for rare isotope science

T1: Forces

T2: Nuclear structure

T3: Medium mass nuclei



T4: Heavy nuclei

T5: Neutron stars

T6: Reactions

T7: Astrophysics

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Recent Topical programs:

- Optical potentials in Nuclear Physics (03/21/2022– 04/01/2022)
  Wim Dickhoff, Chloe Hebborn, Jeremy Holt, Filomena Nunes, Gregory Potel

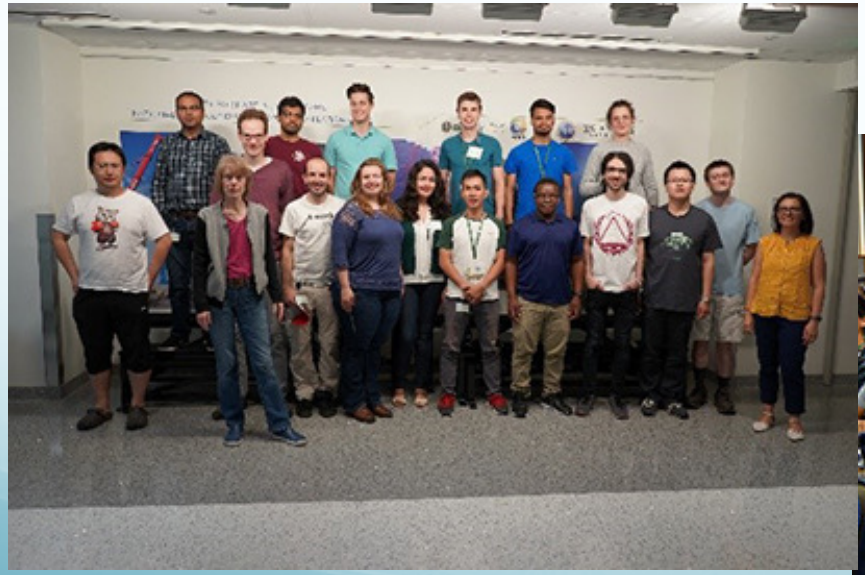
- Nuclear Isomers in the era of FRIB (05/9/2022-05/20/2022)
  Filip Kondev, G Wendell Misch, Matt Mumpower

- Few-body cluster in exotic nuclei (08/15/2022– 08/26/2022)
  Sebastian Konig, Kevin Fossez, Chloe Hebborn, Lucas Platter

- Theoretical Justifications and Motivations for Early High-Profile FRIB (05/16/2023 – 05/26/2023)
  Alex Brown, Alex Gade, Ragnar Stroberg

Summer schools:

- Quantum computing and nuclear few-body and many-body problems (2022)
- A practical walk-through formal scattering theory (2021)
- Dense Matter in Astrophysics (2020)
- Machine Learning applied to Nuclear Physics (2019)
- Neutron star mergers for non-experts (2018)



EIC theory workshop 2022

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how did it all happen?

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historical perspective (FRIB)

- 2008: Michigan State University is selected at FRIB site
- 2013: FRIB project baseline (CD-2), start of civil construction
- 2014: FRIB groundbreaking ceremony, March 17, 2014
- 2017: FRIB civil construction over; technical installation ramps up
- 2019: FRIB accelerated beams through the first 15 cryomodules (of 46)
- 2020 September: DOE designated FRIB as a DOE-SC User Facility
- 2021: First FRIB PAC (82 proposals requesting 9,784 hours of beam time)
- 2022 January: Technical completion of the FRIB project
- 2022 May: Ribbon cutting ceremony – inauguration of FRIB
- 2022 June: First FRIB experiment runs successfully

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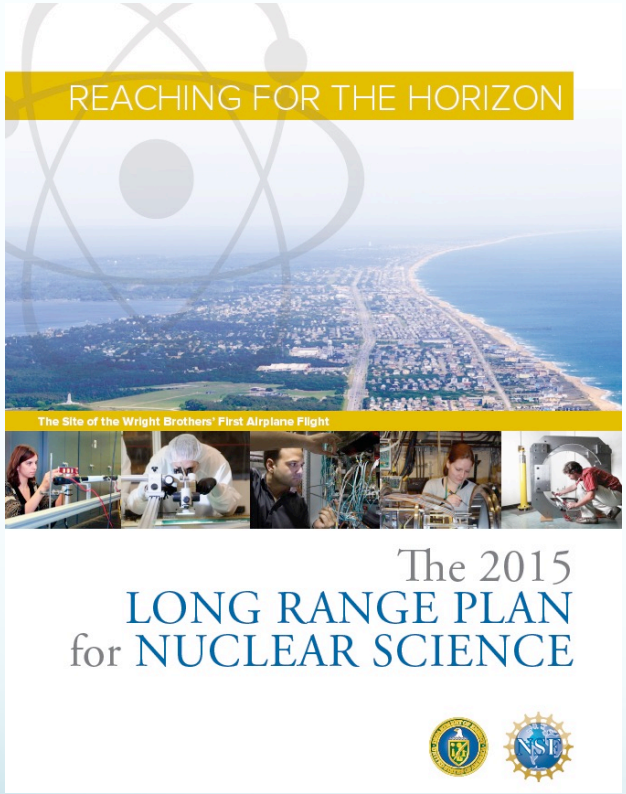
historical perspective (theory)

- 2010: Visit to DOE to discuss a possible theory center for FRIB
- 2011: Survey of the theory community
- 2013 Jan: Steering committee formed
- 2013 Spring: Comparing other models (RHIC, Jlab, INT…)
- 2013 April: Main ideas come together at Steering Committee Meeting
- 2013 December: Visit DOE to discuss the FRIB theory center
- 2014: Theory needs for FRIB and scope of FRIB theory (MPLA paper)
- 2015: Theory Alliance becomes an initiative in NP-LRP 2015
- DOE awards for the FRIB Theory Alliance
  - 1st cycle 2015-2017; 2nd cycle 2017-2020; 3rd cycle 2020-2025

historical perspective

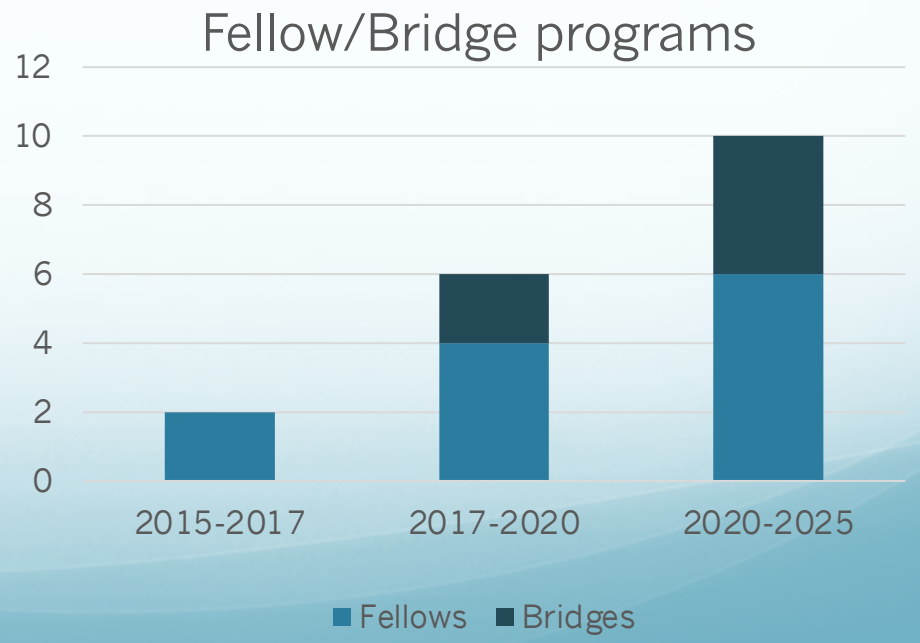


Theory initiative in LRP 2015

(…)
We recommend the establishment of a national FRIB theory alliance. This alliance will enhance the field through the national FRIB theory fellow program and tenure-track bridge positions at universities and national laboratories across the U.S.
(…)

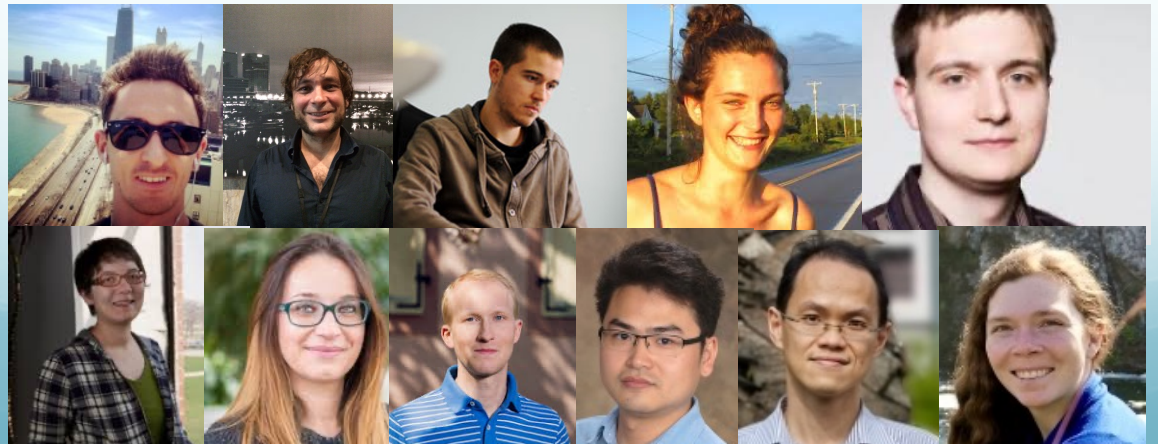
growing the effort

- Third cycle: June 2020 – May 2025
  - Fellow program: growing from 4 to 5
  - Bridge program: growing from 2 bridges to 4 bridges
  - Research administrator at 75%
  - Significant funding for topical programs and summer schools
  - Continued funding for EUSTIPEN



Future full of opportunities

- Theory is an essential ingredient in understanding rare isotopes and their impacts in astrophysics and society
- FRIB-TA captures the vast majority of the low energy nuclear theory community in the U.S. plus a significant international effort.
- The programs of the FRIB-TA have enabled important developments, for FRIB (and other rare isotope facilities worldwide)
- FRIB began operations in June 2022 and many exciting new data will start to emerge… the theory community is ready!



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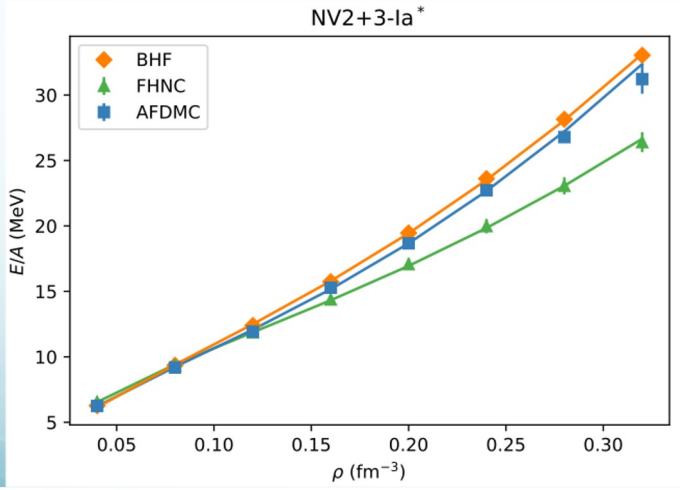
backup

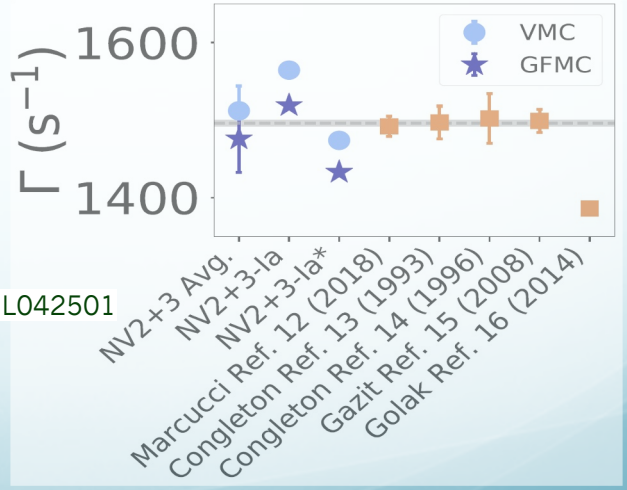
Maria Piarulli (2018 WashU) DOE Early Career Award

Research Focus

- Quantum Monte Carlo calculations of many-body systems
- Many-body interactions from Chiral Effective Field Theory
- Bayesian Methods and UQ



PRC 105 (2022) 055808



PRC 105 (2022), L042501

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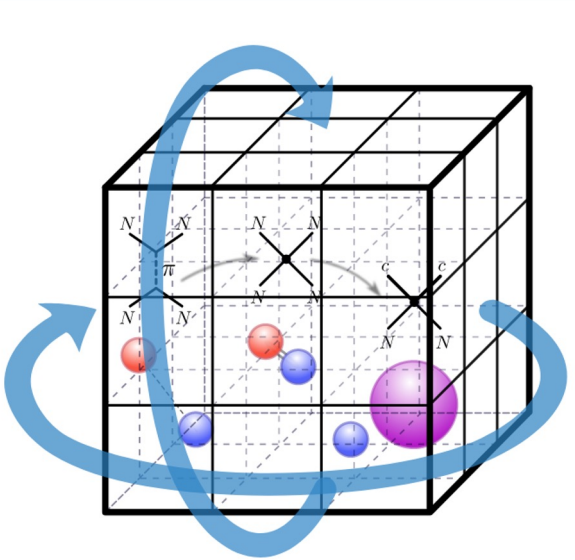
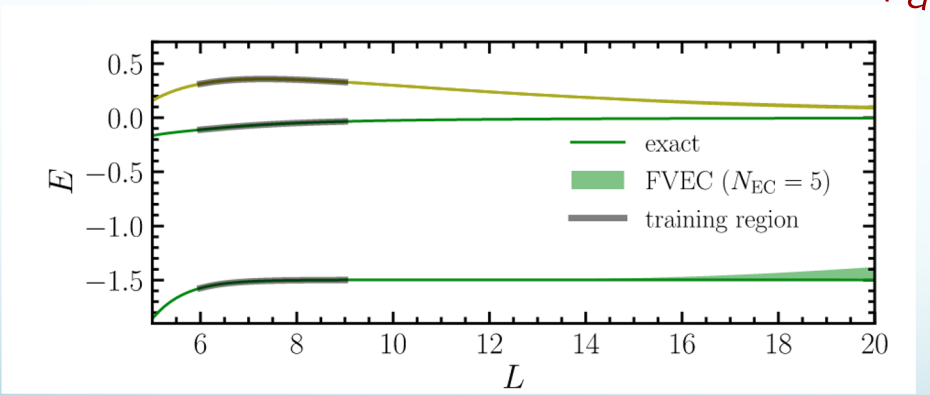
Sebastian König (2020 NCSU) NSF Early Career Award

Research Focus

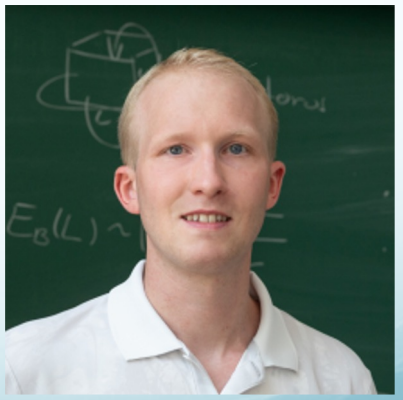
- Nuclear Effective Field Theories
- Few-body systems in finite volume
- Emulators and extrapolations





Organizer of FRIB summer school and topical program

PRC 106 014309 (2022); relevant for searches of resonances, e.g., 4-nucleon resonant state



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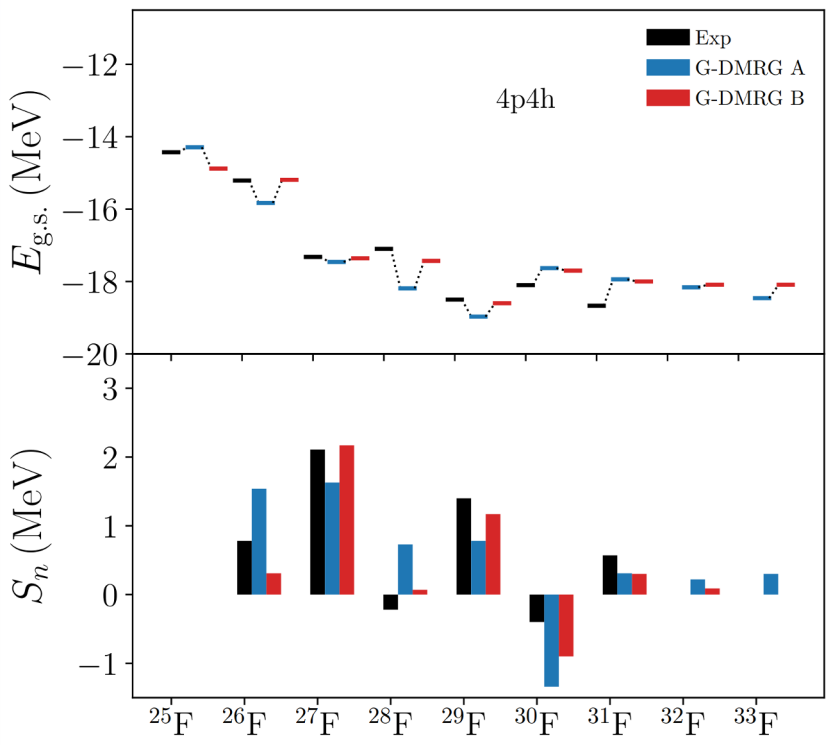
Kevin Fossez (2021 FSU)



Research Focus

- Gamov Shell Model
- Density matrix renormalization group
- In-medium similarity renormalization group

Organizer of FRIB summer school and FRIB-TA topical program

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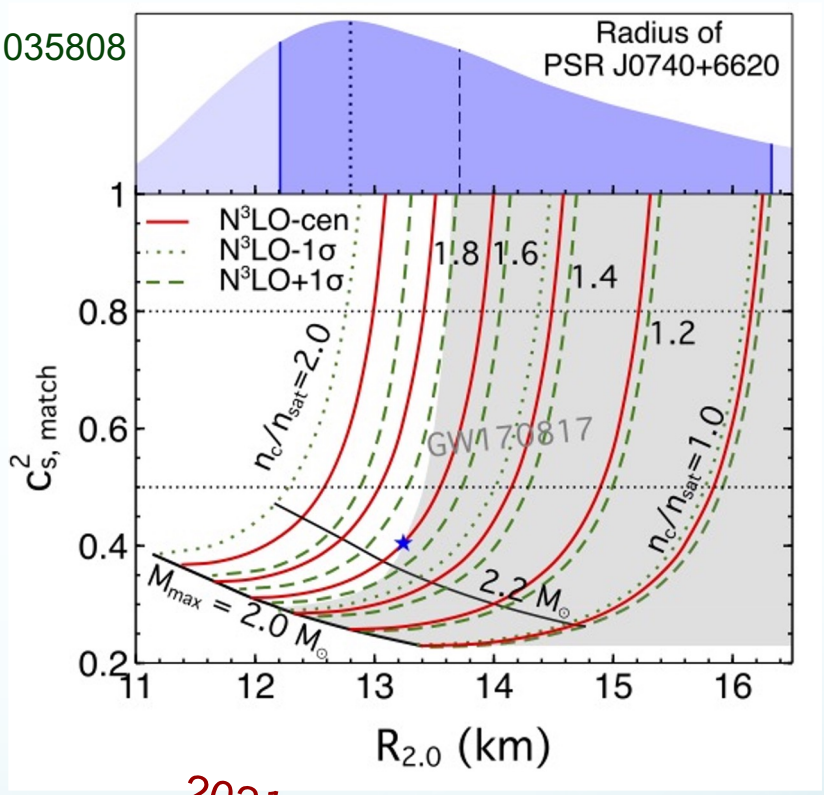
Christian Drischler (2020 MSU | 2022 OU Bridge Faculty)

Research Focus

- Neutron Stars and EoS
- Nuclear Emulators
- Bayesian Methods
- Nuclear effective field theories

PRC 105, 035808



2021 FRIB Achievement Award for Early Career Researchers - Theory

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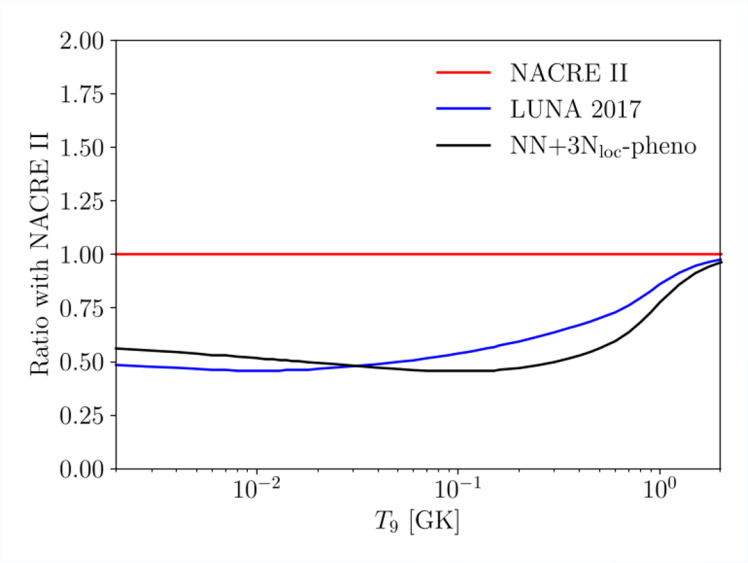
Chloe Hebborn (2020 LLNL | 2023 FRIB Assistant Prof)

2021 PhD Solvay Award



PRL 129 (2022) 4

Research Focus

- Knockout reactions
- Ab initio description of reactions
- Integrated structure and reaction theories for accurate predictions

Organizer of two FRIB-TA topical programs

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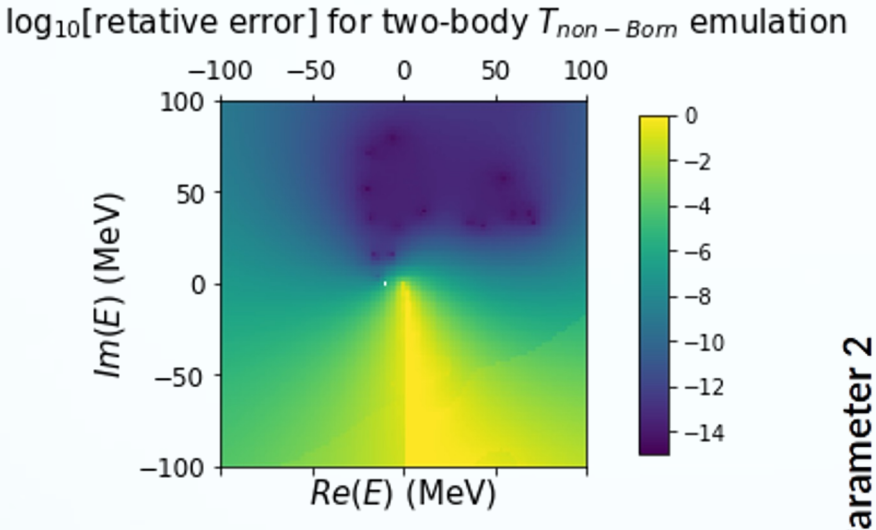
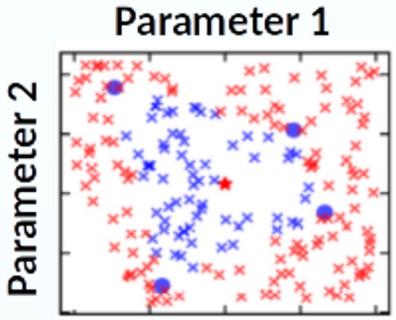
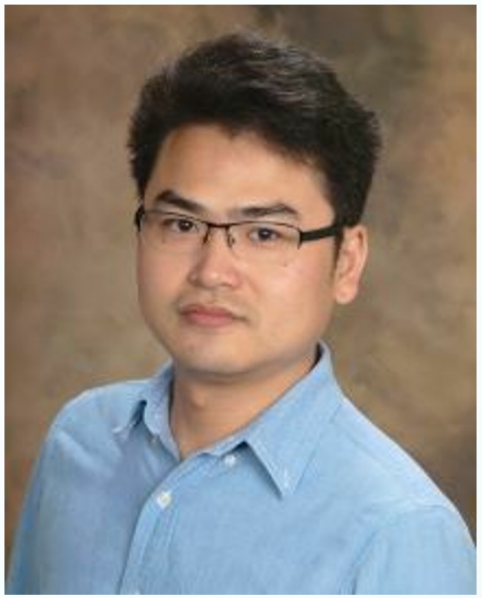
Xilin Zhang (2021 MSU)





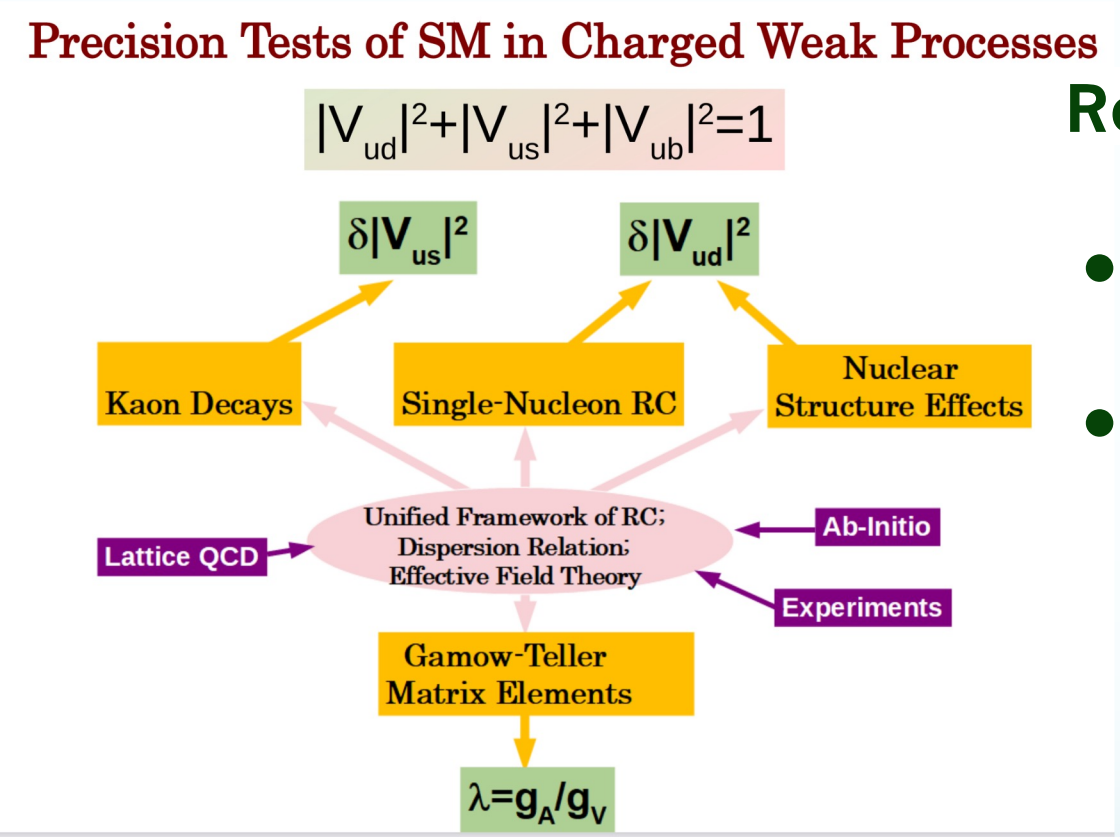


Research Focus

PRC 105 (2022)

- Fast and accurate emulators for quantum continuum states
- Interpolations/extrapolations in model parameter space
- EFTs for nuclear reactions

Chien Yeah Seng (2022 UW)



Research Focus

- Precision test of the SM
- EFTs

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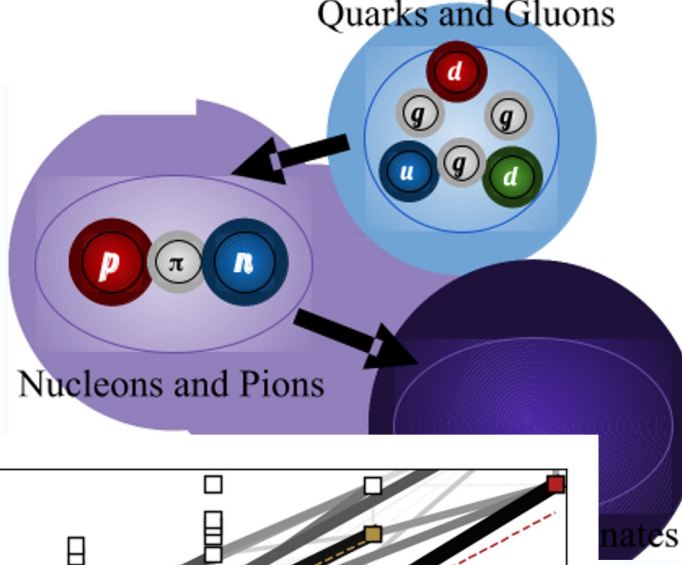
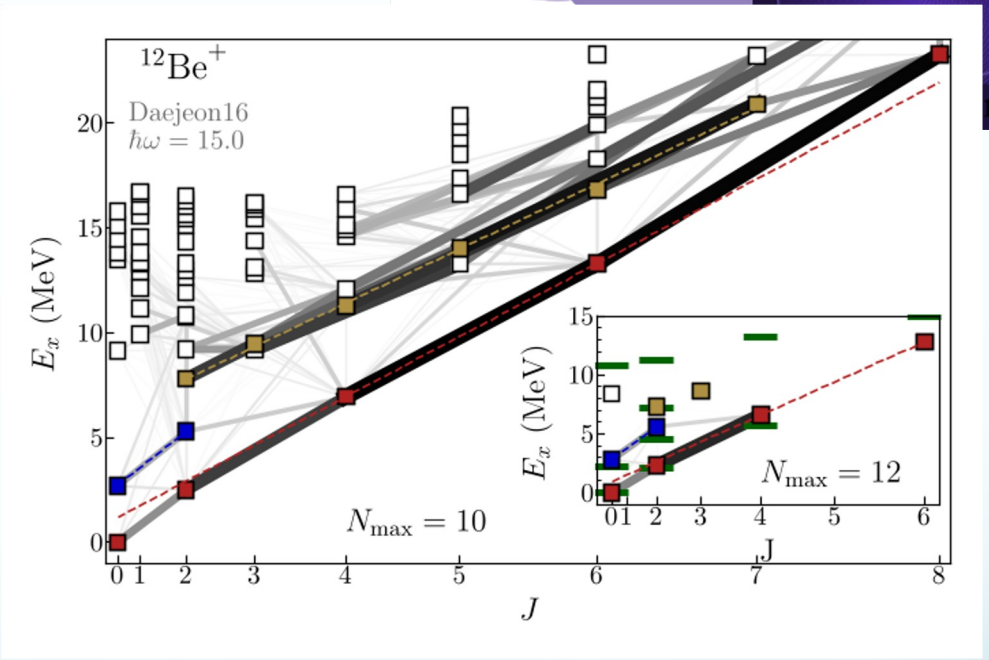
Anna McCoy (2022 WashU)





Research Focus

- Ab initio methods
- No-core shell model
- Symplectic no-core configuration interaction

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FRIB achievement award for early career researchers

- Joint FRIB-TA and FRIB UO effort
- Theory and experimental awards
- Announcement went out late April
- Deadline for applications: 7th June
- Many excellent candidates

Amy Lovell (FRIB theory board member) selected as the theory awardee this year!
Talk Plenary Session tonight 17:25 CDT

(part of activities of Education and Topical Program committee)

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Code of Conduct: The FRIB Theory Alliance is committed to fostering a safe, diverse, and equitable environment that values mutual respect and personal integrity. The diversity of people, ideas, cultures, and educational backgrounds enables the FRIB Theory Alliance's scientific research program and is an essential aspect of its mission. Members of the Theory Alliance, while participating in professional activities, are expected to behave in an ethical, professional, and respectful manner. We are committed to working with our partners to promote diverse and inclusive spaces for those affiliated with the alliance.

FRIB-TA does not tolerate harassment of any kind, including sexual harassment, bullying, intimidation, violence, threats of violence, retaliation, or other disruptive behavior. Discrimination in any guise (verbal, written or physical) based on an individual's race, color, sex, religion, disability, etc. is not acceptable. When such behavior is brought to the attention of the FRIB-TA, it will be investigated by the FRIB DEI investigator. If claims are verified, the harasser will face consequences up to and including removal from the FRIB-TA membership, at which point the harasser will not be granted permission to attend FRIB-TA events. To file a complaint please contact FRIB HR manager Teresa Vicary (vicary@frib.msu.edu) and/or the Chair of the FRIB-TA DEI committee Amy Lovell (lovell@lanl.gov).