

Nuclear Structure & Nuclear Astrophysics Program

Office of Nuclear Physics (NP)

July 1, 2024

Sharon Stephenson



U.S. DEPARTMENT OF
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<https://science.osti.gov/SW-DEI/DOE-Diversity-Equity-and-Inclusion-Policies/DOE-Policies-Prohibiting-Discrimination-and-Harassment>

Nuclear Structure & Nuclear Astrophysics Research Community

- Research Area sometimes called ‘Low Energy’ Nuclear Physics
- US ‘user’ meetings held annually in August, various locations
- 2024 Workshop Topics
 - Fission studies with rare isotope beams
 - Early Career Scientists
 - Public Engagement
- 16 2024 Working Groups



7-9 August 2024

University of Tennessee Knoxville and Oak Ridge National Laboratory



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<https://indico.frib.msu.edu/event/73/overview> 3

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Priority Research Areas in the Office of Nuclear Physics (NP)

- Medium Energy Nuclear Physics
- Heavy Ion Nuclear Physics
- Fundamental Symmetries
- *Nuclear Structure and Nuclear Astrophysics*
- Nuclear Theory
- Nuclear Data and Nuclear Theory Computing
- Accelerator Research and Development for Current and Future Nuclear Physics Facilities
- Quantum Information Science for Experimental and Computational Nuclear Physics
- Artificial Intelligence and Machine Learning for Nuclear Physics
- Advanced Detector Technology Research and Development in Nuclear Physics

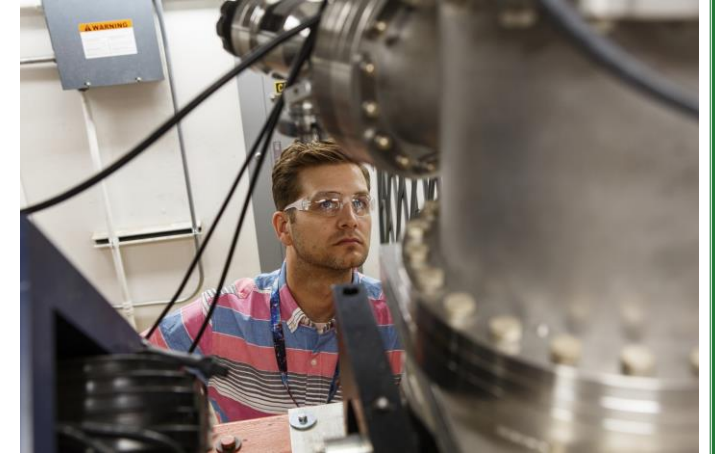


Image: Calem Hoffman, staff scientist at ANL

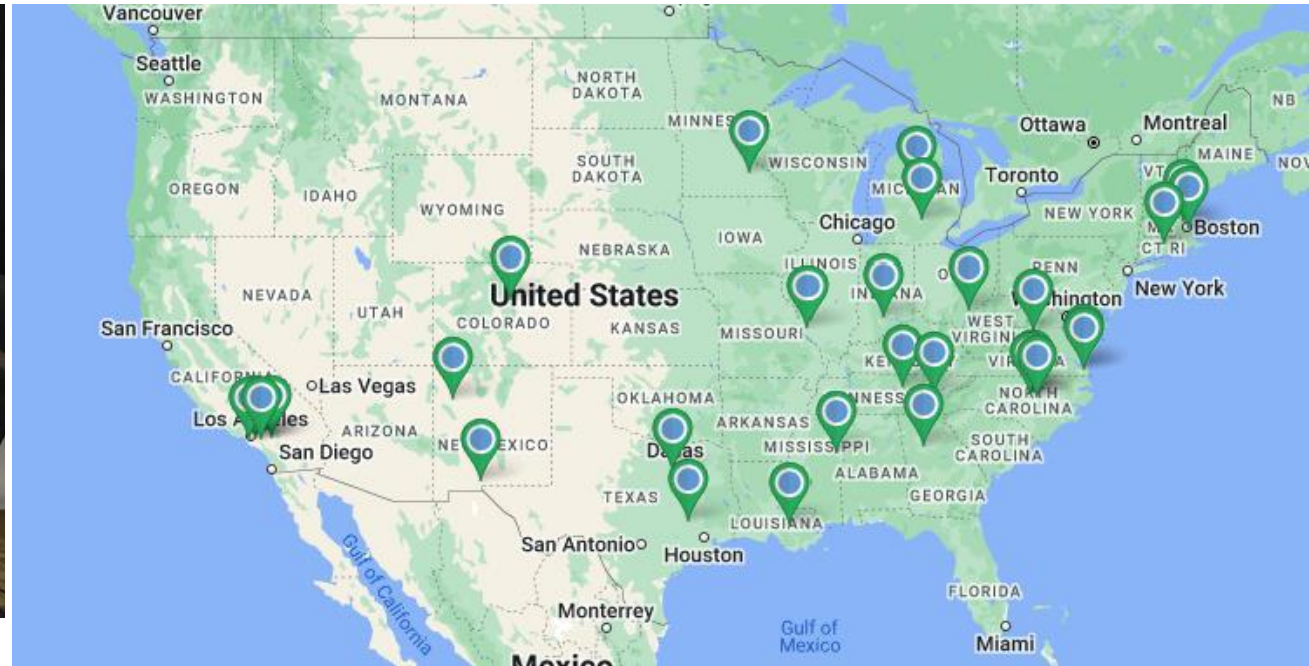
Nuclear Structure and Nuclear Astrophysics at Universities

Types of University Awards:

- ✓ Single Principal Investigator (PI)
 - ✓ Early Career Awards
- ✓ Collaborations – collaborative proposals or subawards
 - ✓ Workforce Development (RENEW, FAIR)



PI Ronald Garcia-Ruiz and students, May 2024



NP National Laboratory Network

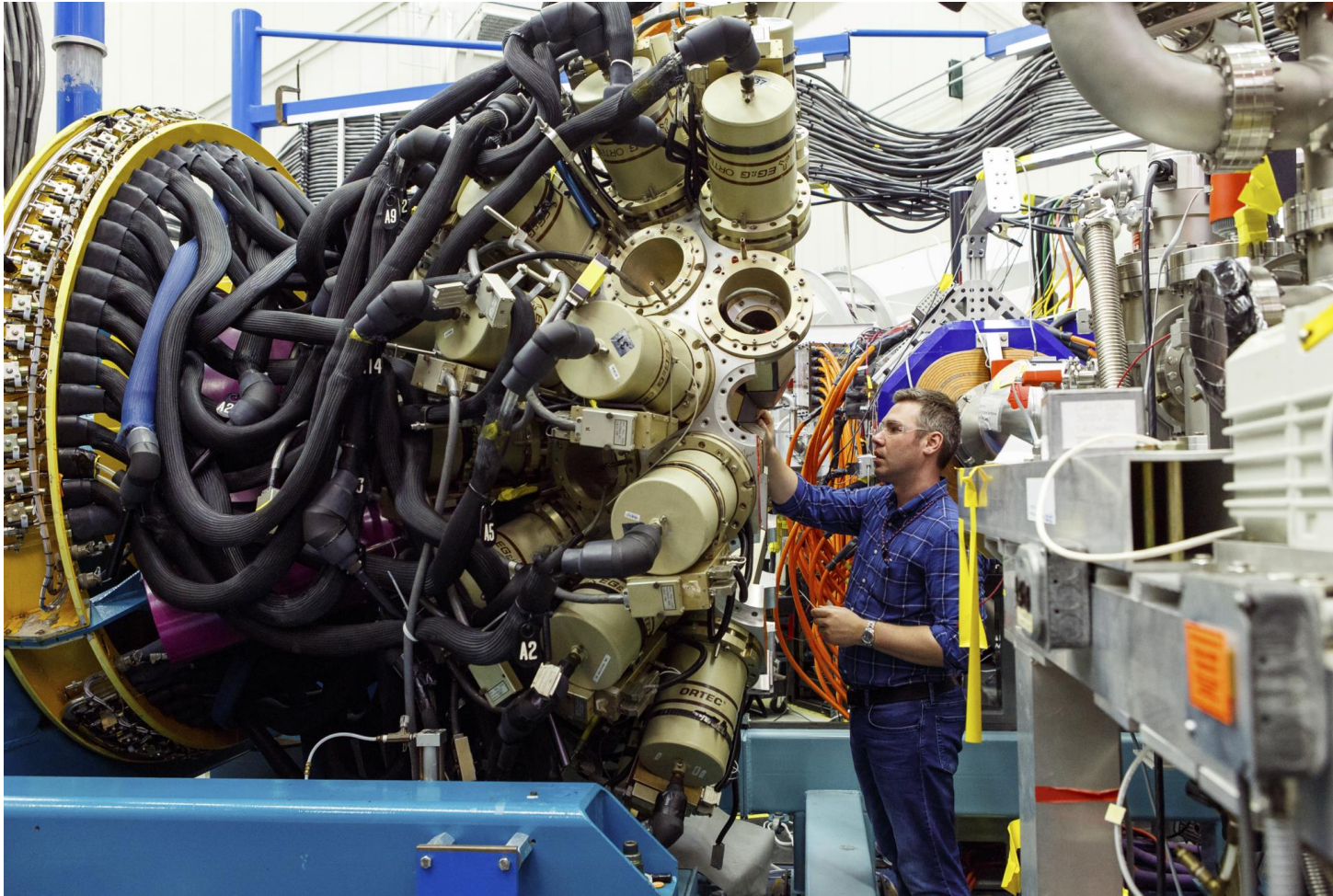


Image: Ben Kay, staff scientist at ANL

Ames Laboratory

Argonne National Laboratory

Brookhaven National Laboratory

Fermi National Accelerator Laboratory

Lawrence Berkeley National Laboratory

Oak Ridge National Laboratory

Pacific Northwest National Laboratory

Princeton Plasma Physics Laboratory

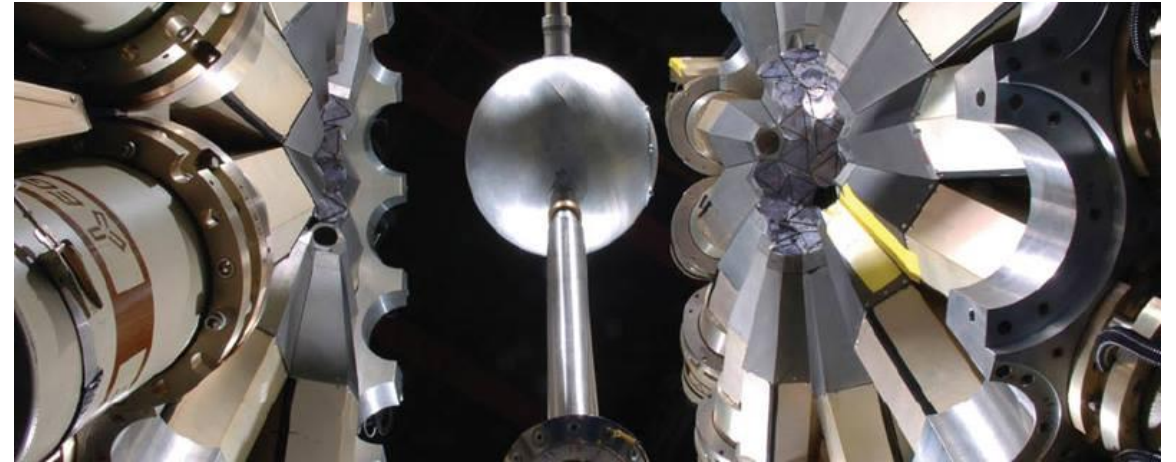
SLAC National Accelerator Laboratory

Thomas Jefferson National Accelerator
Facility

Argonne Tandem Linac Accelerator System (ATLAS)

ATLAS is a leading facility for nuclear structure research in the United States providing a wide range of beams for nuclear reaction and structure research to a large community of users from the US and abroad.

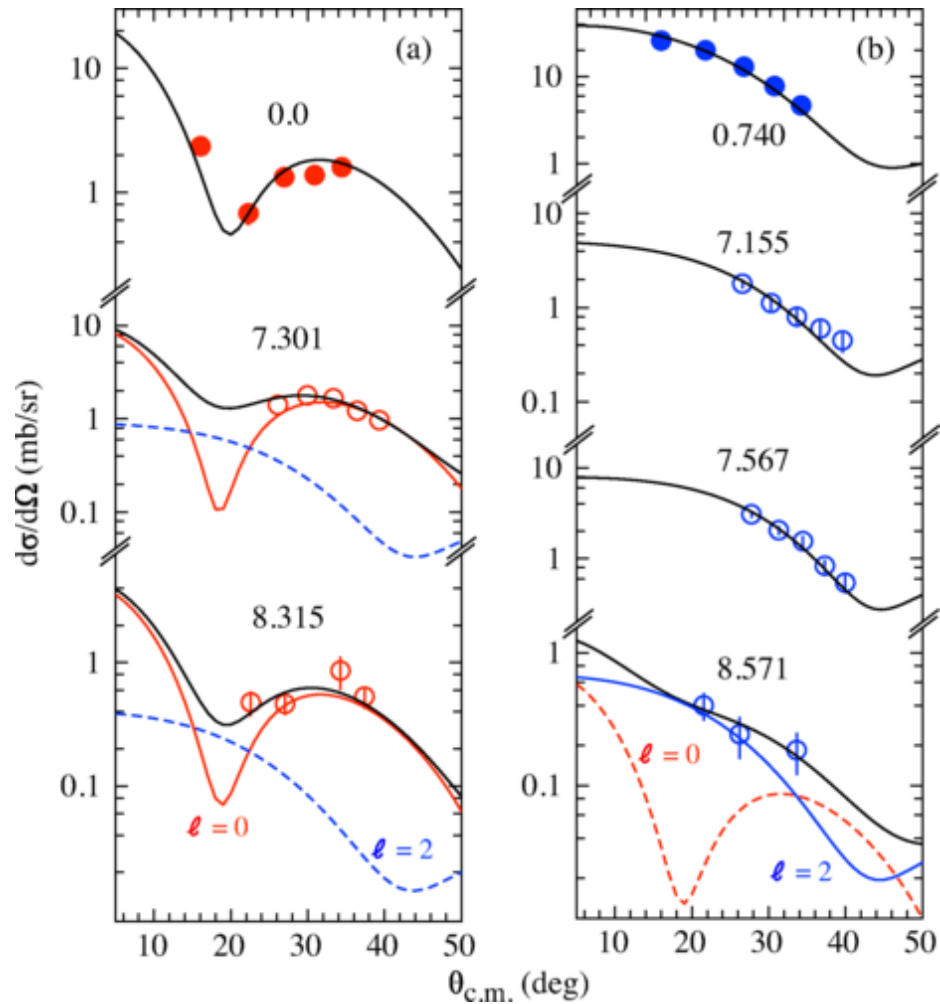
- ATLAS, located at Argonne National Laboratory, is a premier superconducting linear accelerator for studies of nuclear structure and nuclear astrophysics in the vicinity of the Coulomb barrier – the energy barrier between two nuclei due to electrostatic repulsion of their positive charge that must be overcome for them to undergo a nuclear reaction.
- The scientific focus at ATLAS is to provide experimental observations of important properties for key nuclei to underpin the development and testing of a comprehensive theory of nuclei and their interactions that has predictive power and quantified uncertainties. These efforts will answer some of the deepest questions about the evolution of the cosmos and the structure of matter.



LOCATION: Argonne, Illinois
START OF OPERATIONS: 1985
NUMBER OF USERS: 299 (FY 2023)



HELIOS @ ATLAS



Ben Kay



PHYSICAL REVIEW LETTERS

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Quenching of Single-Particle Strength in $A = 15$ Nuclei

B. P. Kay, T. L. Tang, I. A. Tolstukhin, G. B. Roderick, A. J. Mitchell, Y. Ayyad, S. A. Bennett, J. Chen, K. A. Chipps, H. L. Crawford, S. J. Freeman, K. Garrett, M. D. Gott, M. R. Hall, C. R. Hoffman, H. Jayatissa, A. O. Macchiavelli, P. T. MacGregor, D. K. Sharp, and G. L. Wilson
 Phys. Rev. Lett. **129**, 152501 – Published 3 October 2022

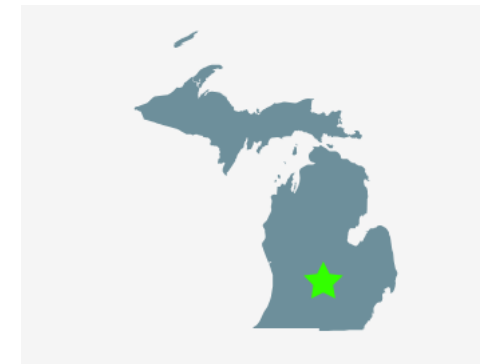
Facility for Rare Isotope Beams (FRIB)

FRIB, a nuclear structure and nuclear astrophysics accelerator, enables scientists to make discoveries about the properties of rare isotopes, nuclear astrophysics, fundamental interactions, and applications for society.

- FRIB, located at Michigan State University, is a superconducting linear accelerator which can accelerate nuclei from elements across the periodic table, up to those as heavy as uranium, to 200 MeV per nucleon or over half the speed of light. FRIB is the most powerful accelerator in the world for exploring the most exotic nuclei, many of which have never been observed.
- The science goals at FRIB are to understand how neutrons and protons combine to form isotopes, how the structure of isotopes changes as the number of neutrons gets unusually large, and the processes that populate the table of the elements. Over the last century ~2000 isotopes have been studied worldwide, using methods and equipment that scale with technology. FRIB will increase the number of isotopes available for study to ~5000.

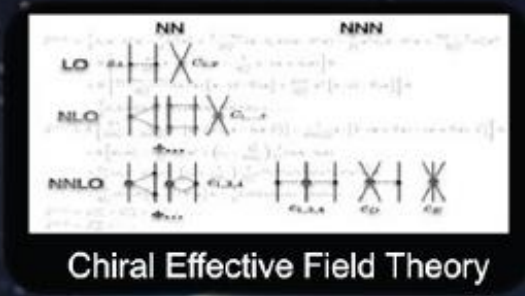
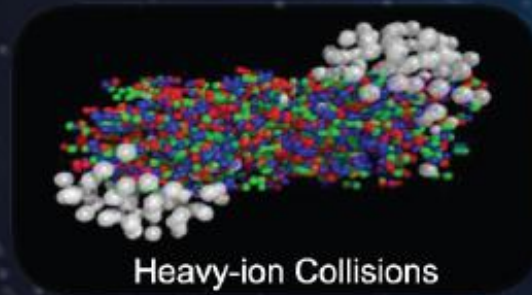
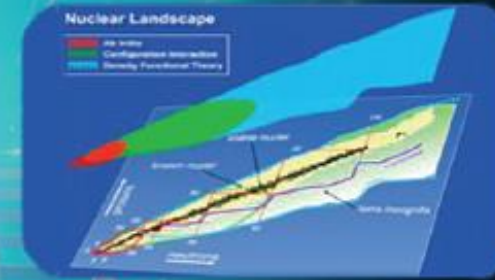


LOCATION: East Lansing, Michigan
START OF OPERATIONS: 2022
NUMBER OF USERS: 902 (FY 2023)

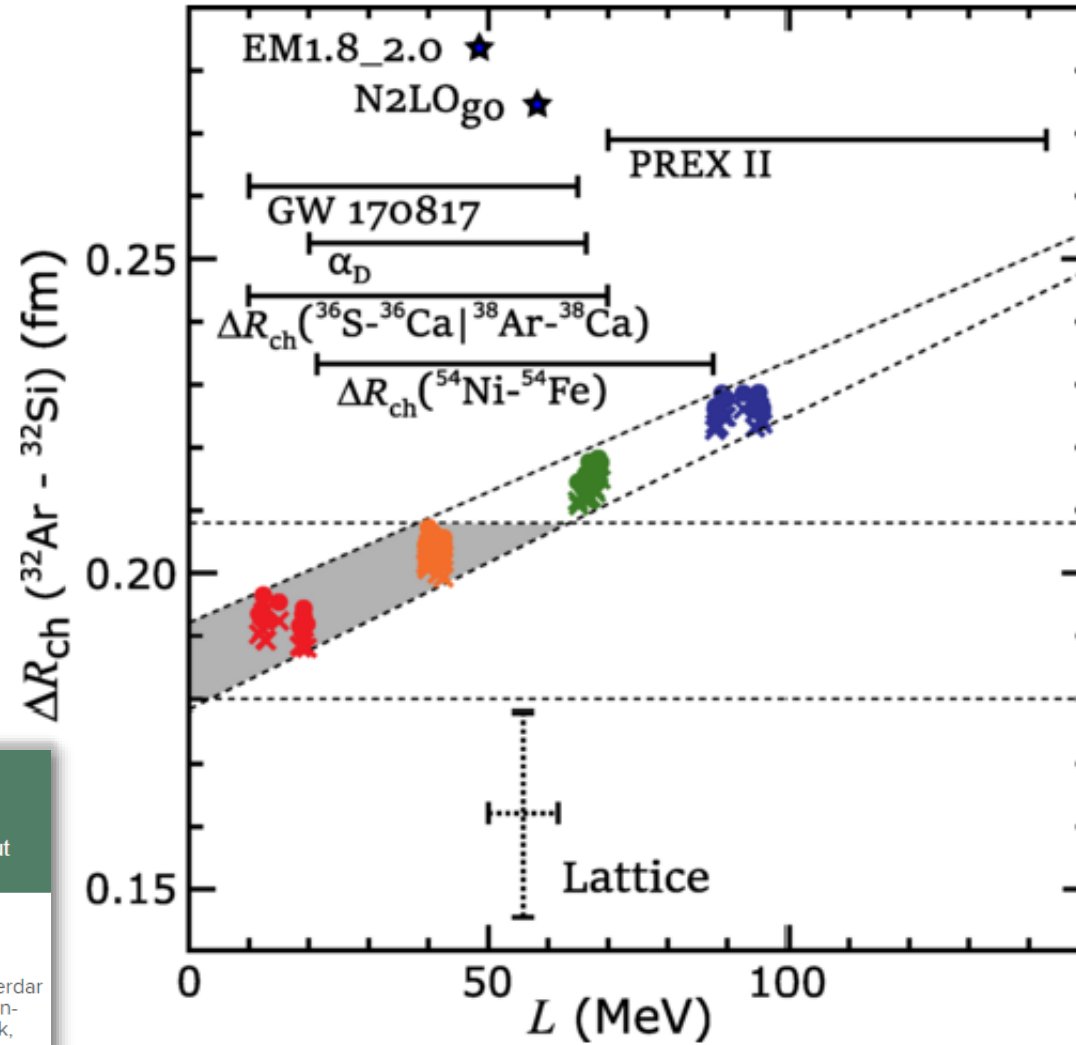
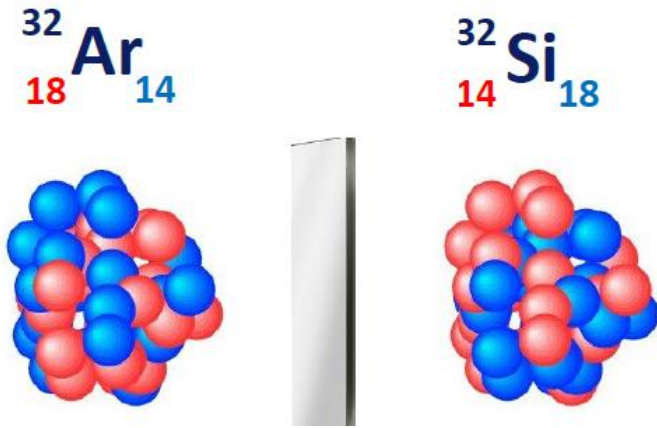


HEAVEN AND EARTH

Connecting Atomic Nuclei
to Neutron Stars –
systems that differ in size
by 18 orders of magnitude!



Neutron Skins, Mirror



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Nuclear Charge Radii of Silicon Isotopes

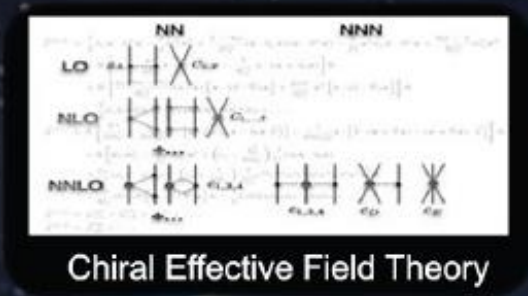
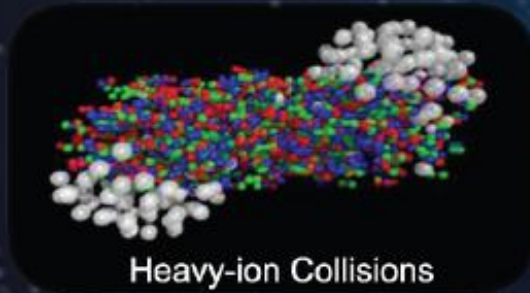
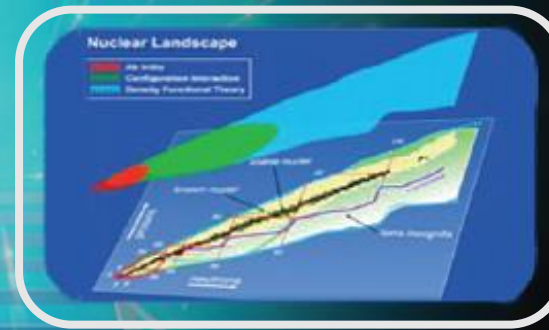
Kristian König, Julian C. Berengut, Anastasia Borschevsky, Alex Brinson, B. Alex Brown, Adam Dockery, Serdar Elhatisari, Ephraim Eliav, Ronald F. Garcia Ruiz, Jason D. Holt, Bai-Shan Hu, Jonas Karthein, Dean Lee, Yuan-Zhuo Ma, Ulf-G. Meißner, Kei Minamisono, Alexander V. Oleynichenko, Skyy V. Pineda, Sergey D. Prosnjak, Marten L. Reitsma, Leonid V. Skripnikov, Adam Vernon, and Andréi Zaitsevskii
 Phys. Rev. Lett. **132**, 162502 – Published 16 April 2024

Includes researchers from **Germany, Australia, Netherlands, Turkey, Israel, Canada, Russia,** and MIT, FRIB/MSU, ORNL, in the **U.S.**

$$L = 3\rho \left[\frac{\partial E_{\text{sym}}(\rho)}{\partial \rho} \right]_{\rho=\rho_0}$$

HEAVEN AND EARTH

Connecting Atomic Nuclei to Neutron Stars – systems that differ in size by 18 orders of magnitude!



Nuclear Landscape

- FRIB made 5 never-before-seen isotopes of the elements thulium, ytterbium, lutetium
- N=126 – ‘one to watch’

Featured in Physics

Editors' Suggestion

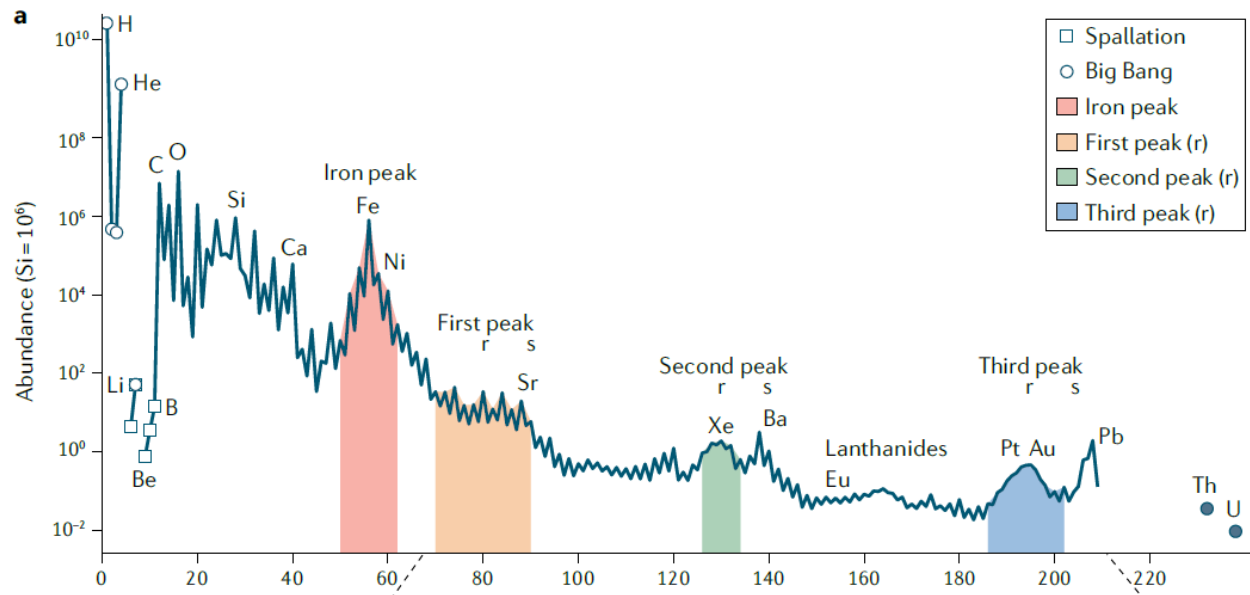
Observation of New Isotopes in the Fragmentation of ^{198}Pt at FRIB

O. B. Tarasov, A. Gade, K. Fukushima, M. Hausmann, E. Kwan, M. Portillo, M. Smith, D. S. Ahn, D. Bazin, R. Chyzh, S. Giraud, K. Haak, T. Kubo, D. J. Morrissey, P. N. Ostroumov, I. Richardson, B. M. Sherrill, A. Stolz, S. Watters, D. Weisshaar, and T. Zhang
 Phys. Rev. Lett. **132**, 072501 (2024) – Published 15 February 2024

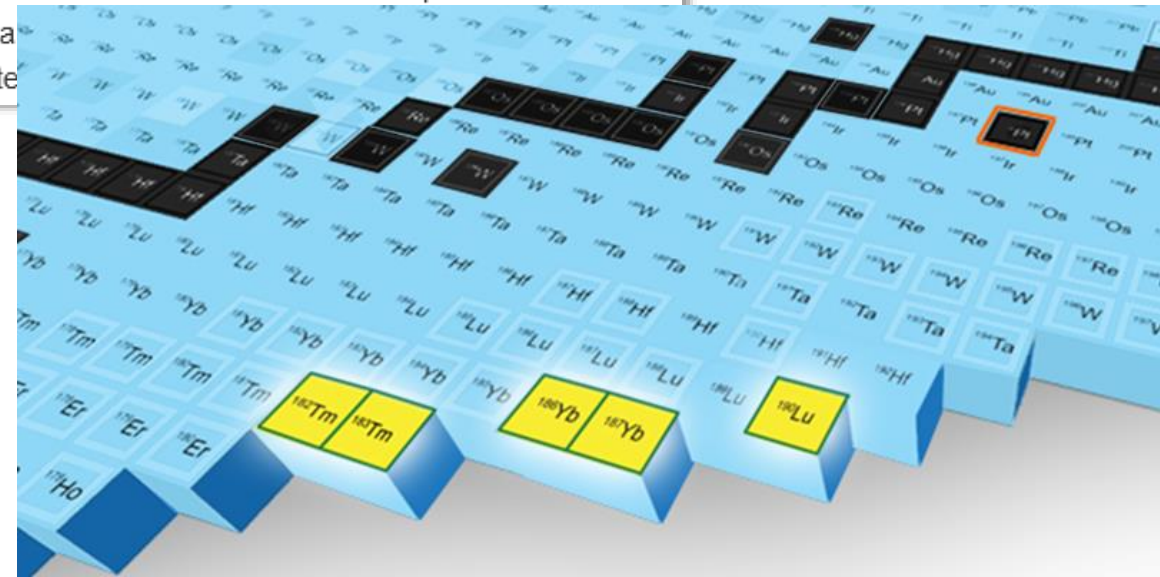
Physics: Five New Isotopes Is Just the Beginning



Oleg Tarasov



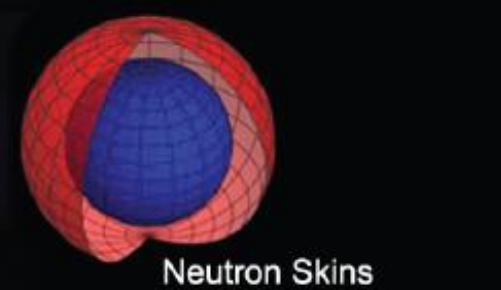
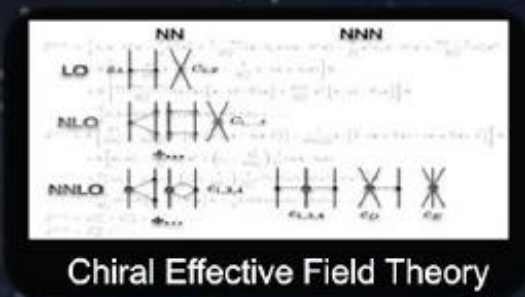
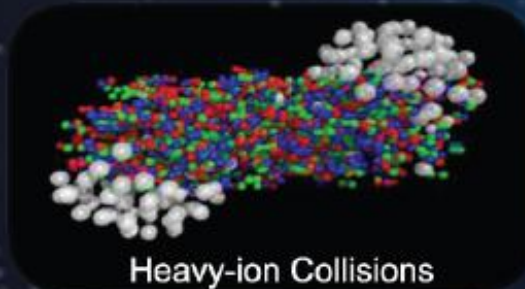
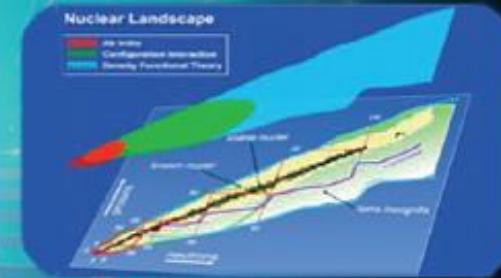
In a year after its opening, the Facility for Rare Isotope Production, a highly potent



Includes researchers from RIKEN in Japan, IBS in South Korea, and MSU in the U.S.

HEAVEN AND EARTH

Connecting Atomic Nuclei to Neutron Stars – systems that differ in size by 18 orders of magnitude!



X-ray Binaries

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First Direct Measurement Constraining the $^{34}\text{Ar}(\alpha, p)^{37}\text{K}$ Reaction Cross Section for Mixed Hydrogen and Helium Burning in Accreting Neutron Stars

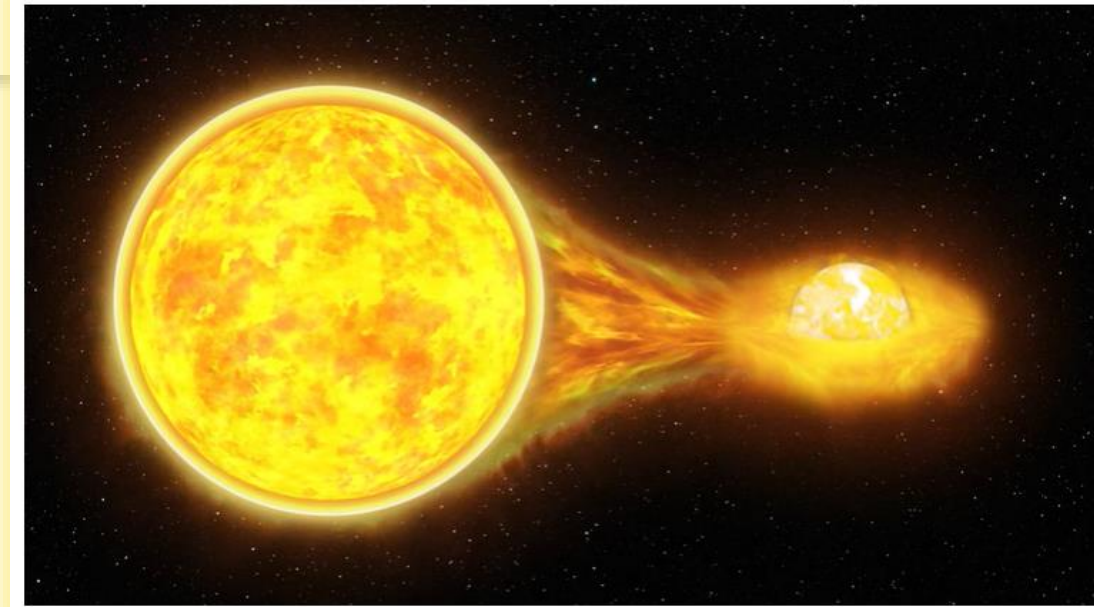
J. Browne *et al.* (JENSA Collaboration)
Phys. Rev. Lett. **130**, 212701 – Published 22 May 2023



Kelly Chipps

PHYS.ORG

Element creation in the lab deepens understanding of surface explosions on neutron stars



Includes researchers from **South Korea, Germany**, and ORNL, LSU, Mines, FRIB/MSU, UTK, Rutgers in the **U.S.**

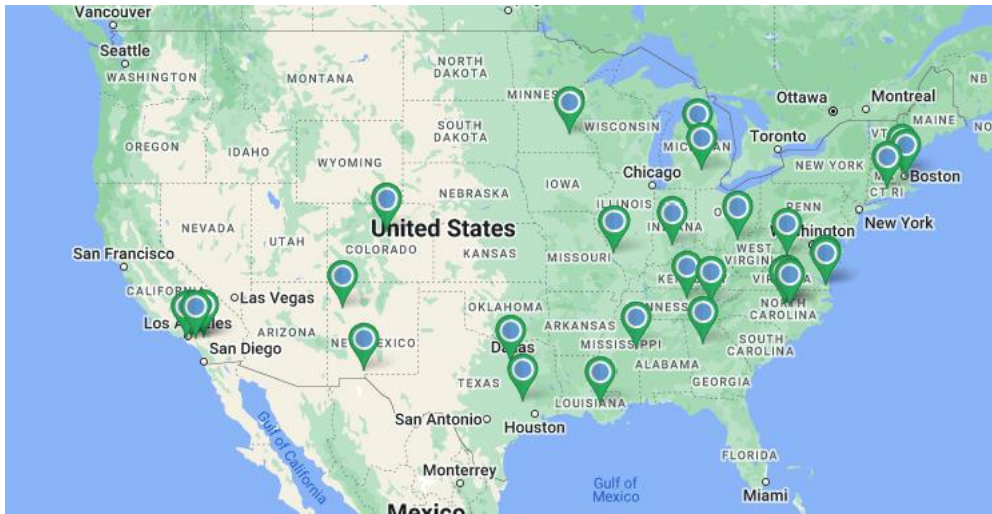
Workforce Development



<https://www.youtube.com/watch?v=vTwT3fG5RBY>

Leveraging Expertise from Universities

- *Nuclear Structure and Nuclear Astrophysics*
- *Nuclear Theory*
- *Nuclear Data and Nuclear Theory Computing*
- *Accelerator Research and Development for Current and Future Nuclear Physics Facilities*
- *Artificial Intelligence and Machine Learning for Nuclear Physics*
- *Advanced Detector Technology Research and Development in Nuclear Physics*



Summer Reading....Long Range Plan & White Papers

- 2023 [A New Era of Discovery: The 2023 Long Range Plan for Nuclear Science](#)
- 2023 [White Paper on Nuclear Structure, Reactions, and Astrophysics](#) from November 2022 town hall meeting
- 2023 [Opportunities with Neutron Induced Reactions](#) (executive summary, white paper in preparation)
- 2023 [update of the 2019 FRIB 400 MeV/u Upgrade White Paper](#)
- 2023 [White Paper on Dense Nuclear Matter Equation of State from Heavy-Ion Collisions](#)
- 2023 [White Paper on Advancing Target Science: Targetry for the Low Energy Nuclear Physics Community in the FRIB Era and Beyond](#)
- 2022 [White Paper on the TUNL Nuclear Astrophysics Program](#)
- 2022 [The Status and Ambitions of the US Heavy Element Program](#)
- 2022 [ARUNA: Advancing Science, Education Scientists, Delivering for Society](#)
- 2022 [Perspectives on few-body cluster structures in exotic nuclei](#)
- 2022 [Horizons: Nuclear Astrophysics in the 2020s and Beyond](#)
- 2022 [White Paper on Optical Potentials for the Rare-Isotope Beam Era](#)



LECM
LOW ENERGY COMMUNITY MEETING

Low Energy Community
Meeting 2024

7-9 August 2024

University of Tennessee Knoxville and Oak Ridge National Laboratory



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<https://indico.frib.msu.edu/event/73/page/778-white-papers>

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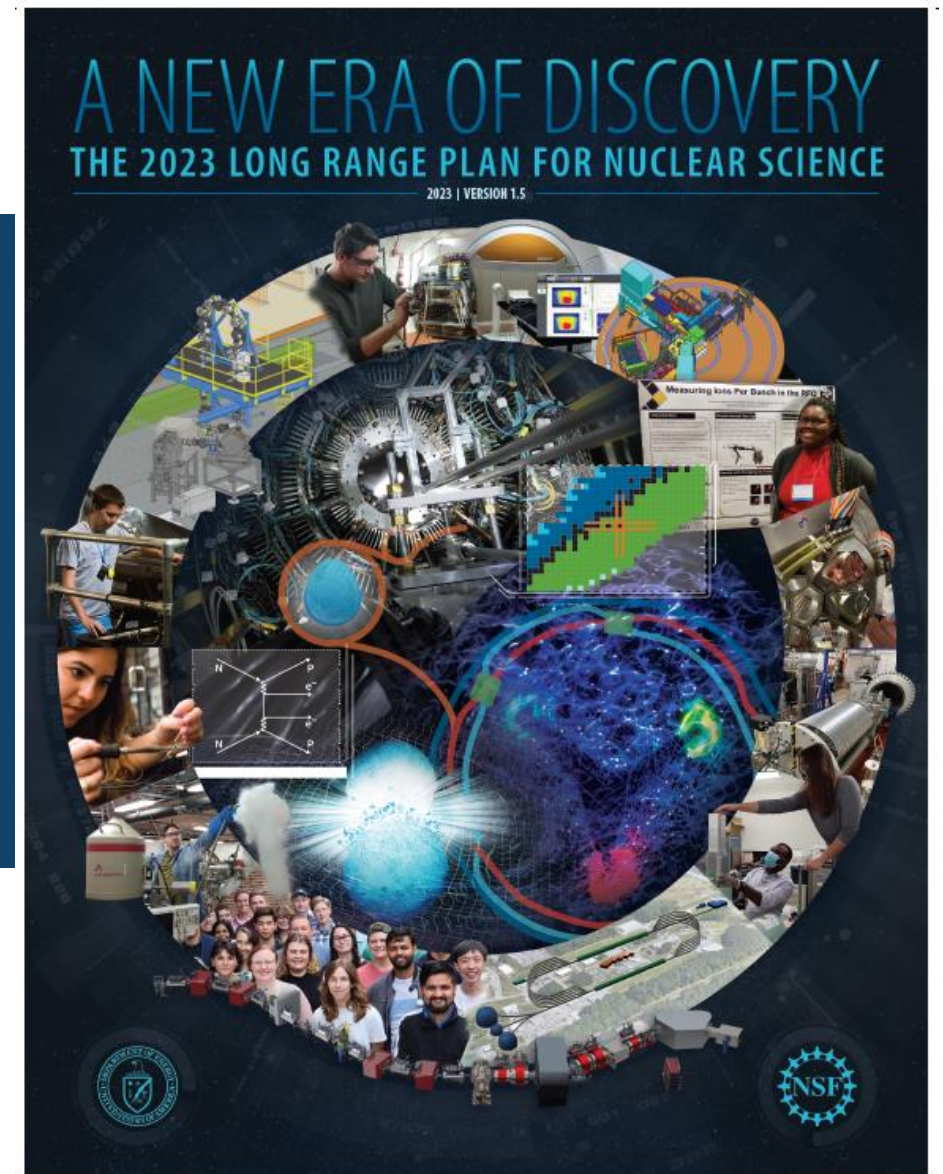
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Summary

- Universities and DOE labs are the talent hubs the NS&NA program.
- Experimental scope with investments in areas of need to the research community, including workforce development.
- All federal agency contributions to the scope of work are valued and leveraged.
- Annual Community Meeting is an excellent event to start.

Sharon Stephenson: Sharon.Stephenson@science.doe.gov

Ken Hicks: Kenneth.Hicks@science.doe.gov



Upcoming NP Office Hour

- Monday, August 5: Nuclear Data Program
- For more information:
 - <https://science.osti.gov/np/officehours>