WHARTON 40

OF EQUAL PLACE: ISOTOPES IN MOTION

STUDY GUIDE

MICHIGAN STATE UNIVERSITY
WHARTON CENTER
FOR PERFORMING ARTS

WHARTON CENTER INSTITUTE
FOR ARTS & CREATIVITY
SUPPORTED BY MSU FEDERAL CREDIT UNION

THANK YOU FOR SUPPORTING *OF EQUAL PLACE: ISOTOPES IN MOTION*

Underwritten by Michigan State University's Facility for Rare Isotope Beams[1] with additional support by University Outreach and Engagement; Science and Society at State; and the Office of the Senior Vice President for Research and Innovation.

FRIB

DANCE EXCHANGE
GATHERING | MOVING | MAKING

MICHIGAN STATE UNIVERSITY

[1] FRIB is supported by the Office of Nuclear Physics in the U.S. Department of Energy Office of Science

TABLE OF CONTENTS

A NOTE FROM THOSE WHO BROUGHT YOU *OF EQUAL PLACE: ISOTOPES IN MOTION*

CO-DIRECTORS, *OF EQUAL PLACE: ISOTOPES IN MOTION*, KEITH THOMPSON AND AMI DOWNDEN-FANT

Welcome to *Of Equal Place: Isotopes in Motion*, a 50-minute multi-media performance commissioned by the Facility for Rare Isotope Beams (FRIB). This work has grown out of a long term partnership between Dance Exchange, Wharton Center, FRIB, Happendance and WaMPS (Women and Minorities in the Physical Sciences). On-stage and on video you will see professional dancers from Dance Exchange and Happendance, scientists, and community youth performers. This dance work delves into some of the research being done at FRIB while exploring themes that resonate in both nuclear physics and dance: stability and instability, measurement, acceleration, fragmentation, and navigating mystery. Additionally, the performance investigates the contributions of women and people of color in science through a cast diverse in age, race, and cultural backgrounds. We hope this work will engage audiences who might be new to watching dance and/or new to thinking about physics. As you watch, resist the temptation to feel like you are not "getting it." Watching a dance is a creative process, much like the creative process of scientific research. You set up an experiment. You observe. From those observations, you collect data. Then, there's the key process of interpreting the data in a way that makes sense to you. Notice what you connect to, what meaning you are making, and let your own discoveries unfold. Then repeat this process. We invite you to revel in your own discoveries, to lean into curiosities. We hope the resources in this guide and the opportunities on this campus will serve to launch you further into your understanding and curiosity of new areas for future research and creativity.

THOMAS GLASMACHER, DIRECTOR, FRIB LABORATORY

As we operate what will be the world's most powerful heavy-ion accelerator right here at Michigan State University, we are excited to share with our community how FRIB works and how the research conducted with it will positively impact our lives. The Dance Exchange performance and this Wharton Center study guide provide us with a unique opportunity to showcase the scientific work and expand our connection with science, the arts, and our local community.

MIKE BRAND, RETIRED EXECUTIVE DIRECTOR, WHARTON CENTER

Wharton Center and its Institute for Arts & Creativity are proud and excited to facilitate this special and unique collaboration with FRIB. This is a powerful demonstration of the connections between the performing arts and the STEM group, dance and physics, and its application to the education and inspiration of our young people.

ZACH CONSTAN, OUTREACH COORDINATOR, FRIB

Every day, researchers at FRIB are doing amazing work to explore the unknown. Our laboratory couldn't be more excited to share those discoveries with our neighbors in the community! We are committed to sharing through tours, public talks, open houses, summer programs, the MSU Science Festival, the Isotopolis video game, and recently the *SMASH: A Nuclear Adventure* exhibit at Impression 5 Science Center. This dance performance and exploratory event is a brand-new opportunity for you to discover cutting edge nuclear science at MSU. We can't wait to show you. Many thanks to all of our partners!

ARTEMIS SPYROU, PROFESSOR OF PHYSICS AND FACULTY ADVISOR, FRIB OUTREACH

As a scientist, I have the unique opportunity to perform my research at a world-leading facility like FRIB. Together with more than 1000 other nuclear scientists from around the world, we design and run experiments that test the fundamental laws of nature and help us understand how the Universe works. As an educator, I'm passionate about finding ways to share these amazing discoveries with everyone in our community. As we all come from different backgrounds, and with diverse experiences, the way we learn is also different. It is for this reason that at FRIB we always look for new ways to share our excitement about the scientific discoveries with all of you. This project, *Of Equal Place: Isotopes in Motion*, will introduce you to the world of nuclear science through an unusual carrier: dance. We are very excited to share this unique experience with all of you, and hope that you will enjoy it as much as we do.

BERT GOLDSTEIN, DIRECTOR, WHARTON CENTER INSTITUTE FOR ARTS & CREATIVITY

It is really about vision. How do you successfully combine the complexities of dance and physics to extoll the virtues of both as an avenue for exploration and learning? It's a big concept and that's why it has taken us four years to reach this moment. It comes back to vision and the creative energies of Wharton Center, FRIB, Dance Exchange, Happendance and all the artists and scientists who have spent hours together to achieve what will be seen on the stage and experienced after the curtain comes down. As in both arts and science, this fascinating collaboration reminds us that with the right vision, anything is possible.

CASSIE MEADOR, EXECUTIVE ARTISTIC DIRECTOR,
DANCE EXCHANGE

It has been thrilling to witness and support the creative team and partners on *Of Equal Place: Isotopes in Motion* to create a fully-immersive and embodied experience for students and educators to learn about and engage with physics and dance. At Dance Exchange, we harness the power of creativity and inquiry through dance to connect communities and to foster a more embodied, resilient, and just world. Through this project we are invested in helping to create new pathways and inspiration for students to engage with and contribute to the fields of physics and dance. As you explore resources shared in this study guide, and during workshops following the performance, you will experience kinesthetic approaches to learning that increase retention of science content for your students, deepen their personal connection to and investment in science learning, and which can be applied to different subjects and aspects of your students' lives for years to come. We are grateful for your partnership in bringing this experience to your students!

MISSY LILJE, DIRECTOR OF DEVELOPMENT AND EDUCATION SERVICES,
HAPPENDANCE INC

Did you ever gaze up at the stars and feel small? Or, maybe you've turned your gaze inward and felt a connection to the universe somehow? There are so many mysteries in our understanding of how our world came to be, it can be overwhelming to consider. And, where do we fit in? Consider this: human creativity is the bridge between darkness of not knowing and the light of discovery. *Of Equal Place: Isotopes in Motion* is a project that seeks to shine that light with dance as the medium: time, space, force, human bodies in motion, and abstract concepts coming to life in movement. The dancers give a face and structure to ideas that cannot be seen. There is a creative drive that wills us to explore new questions, be brave enough to utter new ideas, and breathe life into new discoveries. Perhaps you can embrace questions that come to mind through witnessing this project, allowing those questions to lead you into creative thought and new conversations. And, maybe you'll find a new light shining on some discoveries of your own.

ACKNOWLEDGMENTS

Portions of this study guide borrow content initially produced for *SMASH: A Nuclear Adventure*, an FRIB-inspired exhibit at Impression 5 Science Center in Lansing, Michigan.

Like this exciting performance at Wharton Center, *SMASH* is the result of many committed partners working together to develop unique programming that inspires science and creative exploration. We thank our Impression 5 Science Center partners for their support of *Of Equal Place: Isotopes in Motion*, and encourage you to visit *SMASH* to continue exploring nuclear science in an engaging and hands-on way.

Dance Exchange extends a special thanks to Liz Lerman and the creative team and collaborators on *The Matter of Origins,* Dance Exchange staff and board of directors; Chris Morgan and Dance Place; Women and Minorities in the Physical Sciences; Bert Goldstein and Wharton Center, Clara Martinez; Missy Lije; Rachel Miller; Happendance; and Zach Constan, Artemis Spyrou, and the Facility for Rare Isotope Beams. Dance Exchange is grateful for the support from the National Endowment for the Arts for *Of Equal Place: Isotopes in Motion*. Additional major funders that support Dance Exchange's programming include the Montgomery County Government and the Arts & Humanities Council of Montgomery County; Maryland State Arts Council; The Morris and Gwendolyn Cafritz Foundation; The Chesapeake Bay Trust; The Dallas Morse Coors Foundation for the Performing Arts; The City of Takoma Park; The USDA Forest Service; and the National Park Service.

For their support of this collaborative project, we are deeply grateful to:

FRIB
Brad Sherrill, FRIB Scientific Director
Stefan Schwarz, Senior Research Physicist
Jorge Pereira Conca, Research Staff Physicist
Laura Popielarski, SRF and Superconducting Magnet Department Deputy Manager
Guillaume Machicoane, Accelerator Operations Department Manager
Alex Brown, Professor of Physics
Paul Gueye, Associate Professor of Physics
Jaideep Singh, Associate Professor of Physics
Kyle Brown, Assistant Professor of Chemistry
Wolfgang Mittig, Hannah Professor of Physics
Filomena Nunes, Theory Alliance Director
Karen King, Communications
Will Whelton, Communications
Mandy Zlotek, Communications
Rahul Jain, Graduate Assistant
Eric Britt, Graduate Assistant
Chelsie Boodoo, Graduate Assistant
Daniel Puentes, Graduate Assistant
Letrell Harris, Graduate Assistant
Pablo Giuliani, Research Associate
Erin Good, Research Associate
Andrea Richard, Research Associate
Mallory Smith, Beam Physicist

Wharton Center
Sandy Thomley, Senior Production Manager
Steve Heinrich, Production Manager
Laurie Briseño, Institute Operations Manager
Hope Still, Wharton Center Intern, Study Guide Coordination

OF EQUAL PLACE: ISOTOPES IN MOTION

Dance Exchange
Liz Lerman, Founder
Dance Exchange Board and staff
Clara Martinez, Everett High School for the Visual & Performing Arts
Chadorea Robinson, Dwight Rich School of the Arts
Christopher Morgan, Dance Place
All the families of those involved in the production

MSU Center for Community & Economic Development, Outreach & Engagement Partnerships
John Melcher
John Schweitzer

MSU Office of Senior Associate VP for Research and Graduate Studies
Shobha Ramanand

Women and Minorities in Physical Science

Of Equal Place: Isotope in Motion is a Dance Exchange project inspired by Liz Lerman's *The Matter of Origins*

Direction by Keith Thompson: Creative Director and Ami-Dowden Fant Director of Creative Engagement

Choreography by Keith Thompson, Ami-Dowden Fant, and Elizabeth Johnson Levine, in collaboration with performers

Sam Horning, Project Management
Cassie Meador, Creative and Partnership Advisement
Dante Fields, Stage Management
Kelly Colburn, Original Projection/Media Design
Devin Kinch, Projection/Media Design
Channing Tucker, Costume Design
Jeanette Christenson, Original Costume
Design Peter Leibold, Lighting Design
Matthew Nielson, Sound Design
Darron L. West, Original Sound Design for Marie Curie and Genesis sections

Creative Engagement Partners: Rachel Miller, Executive Director at Happendance, INC
Missy Lilje, Director of Development and Education at Happendance, INC
Clara Martinez, Dance Director of Everett High School

*The creative team would like to acknowledge Elizabeth Johnson Levine contributions as a co-creative director on the project 2015-2020 and her stewardship of the project partnerships in her past roles as Director of Partnerships and Associate Artistic Director at Dance Exchange.

*The creative team would also like to acknowledge the contributions of Juliana Ponguta in her role as a performer, collaborator, and Dance Exchange Partnering Artist during the project's development from 2015-2020.

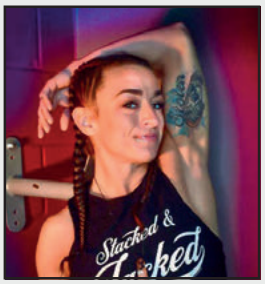
PERFORMERS

Clarence Brooks
Dance Exchange Partnering Artist

Esther Geiger
Dance Exchange Partnering Artist

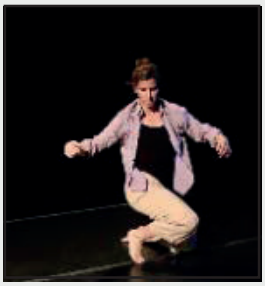
Shawn Brush
Dance Exchange Partnering Artist

Chloe Gonzales
Happendance



Jennah Quinn Gray
Happendance

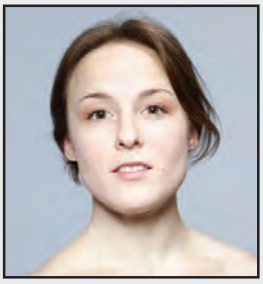
Ami Dowden-Fant
Dance Exchange Partnering Artist



Brit Falcon
Dance Exchange Partnering Artist

Lena Granger
Happendance

Linda Reiff
Happendance



Liv Schaffer
Dance Exchange Partnering Artist

Liam Shaffer
Happendance

Laura Spitzfaden
Happendance

Bridget VanderHoff
Happendance

FRIB site plan from above, on the campus of Michigan State University

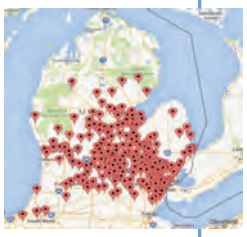
2008
MSU Wins FRIB
The U.S. Department of Energy Office of Science selects Michigan State University to design and establish the Facility for Rare Isotope Beams following a competitive process.

2008 to 2014 Planning and Design
These were intense planning years. FRIB team members developed budgets, schedules, and detailed construction plans. Through a series of reviews, these plans convinced the U.S. Department of Energy Office of Science that construction could begin.

MARCH 2014
Groundbreaking and Start of Civil Construction
FRIB groundbreaking launches civil construction. Civil construction includes building FRIB's accelerator tunnel and the buildings that will support operations. More than 1,000 participants gather to reflect on MSU's journey to selection by the U.S. Department of Energy Office of Science

MARCH 2015
FRIB civil construction continues one year after groundbreaking.

JANUARY 2016
FRIB civil construction reaches 50-percent completion.

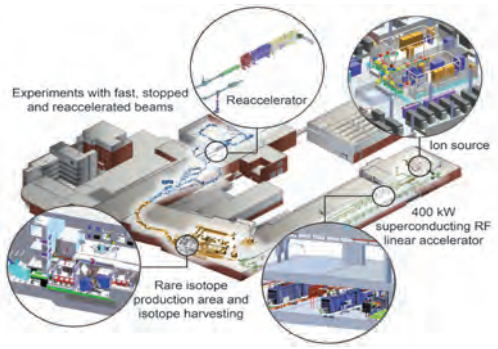


Michigan construction workers built FRIB from tunnel up! Map points represent home cities of employees who supported FRIB civil construction.

2014 to 2017 Civil Construction
Civil construction includes building FRIB's accelerator tunnel and the buildings that will support operations.

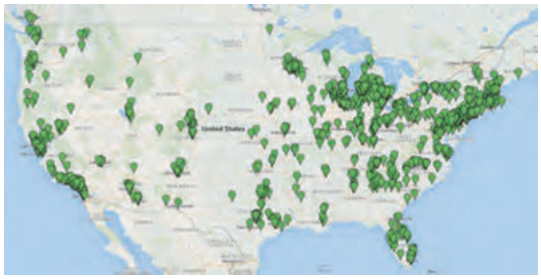
2014 to 2021 Technical Construction
Technical construction is the construction of the equipment and infrastructure needed to make the beam and conduct experiments.

2008 2014 2015 2016

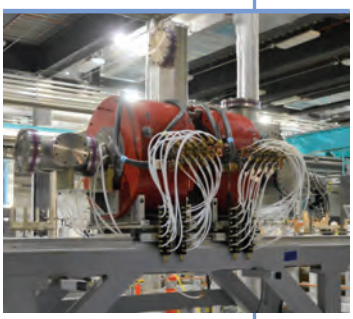


Layout of FRIB linear accelerator and experimental areas

In preparation for construction, equipment and components had to be designed and made. Many components were custom-fabricated for FRIB, from United States suppliers. Map points on the U.S. map represent domestic procurements. Notice how covered Michigan is. Many Michigan companies manufactured FRIB equipment and components.



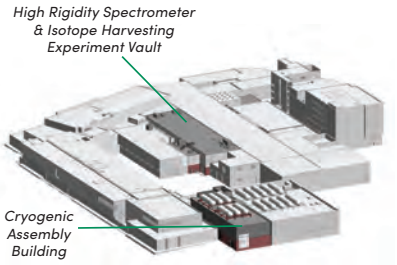
APRIL 2016
FRIB's first accelerator component, an ion source, is installed. Ion sources create the beams that will be injected into FRIB's linear accelerator. Ion sources heat the element to be studied, knock off electrons, and push the ionized atoms around with electric and magnetic fields to create beams.



AUGUST 2016
The 100,000-pound vertical cryogenic cold box arrives at FRIB. The cold box was built in Oklahoma and arrived to Michigan by way of the Lake Michigan car ferry, SS Badger! Two cold boxes cool helium to an extremely low temperature, which will make the cavities within FRIB's beam-accelerating cryomodules superconducting. When the cavities are superconducting, there is no electrical resistance, so there will be virtually no heat loss with an electrical current. That will make FRIB more energy-efficient as it accelerates rare isotope beams.

SEPTEMBER 2016
The first completed and tested beam-accelerating cryomodule is moved into FRIB's linear-accelerator tunnel. The cryomodule weighs about 26,000 pounds and is about 20 feet long. Forty-six cryomodules will accelerate a heavy-ion beam to a target, where rare isotopes will be produced.

MARCH 2017
Civil construction achieves beneficial occupancy. This is the stage of construction in which the facility can be used for its intended purpose before final completion.



APRIL 2018
Construction on two MSU-funded building additions is underway and scheduled for completion in 2019. The buildings will provide additional research and maintenance space.

SEPTEMBER 2020
The U.S. Department of Energy designates FRIB as a U.S. Department of Energy Office of Science user facility at an outdoor ceremony at MSU.

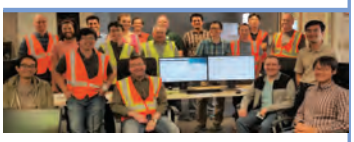
FEBRUARY 2021
FRIB scientific users worldwide submit 82 experiment proposals and 6 letters of intent in response to FRIB's first call for proposals, representing 597 scientists.

MAY 2022
FRIB Begins Operations!
The U.S. Department of Energy officially opens FRIB with a ribbon-cutting ceremony. Scientific user experiments commence.

Rendering of FRIB looking northwest

Photograph of FRIB looking northwest

2017 | 2018 | 2019 | 2022 ... and beyond



JULY 2018
First Beams Accelerated!
FRIB accelerates beams of argon and krypton in the first three beam-accelerating superconducting cryomodules. This demonstrates FRIB's major systems work well together and can accelerate beams of atomic particles.

FEBRUARY 2019
FRIB accelerates beams through the first 15 (of 46 total) cryomodules to 10 percent of FRIB's final beam energy. FRIB is on track to becoming the world's most powerful superconducting heavy-ion linear accelerator.

... AND BEYOND
Discovery and Innovation

FRIB opens new frontiers of knowledge and understanding of the universe. At FRIB, scientists explore unknown parts of the atomic realm. The discoveries will be numerous and exciting.

DECEMBER 2017
FRIB cryogenic plant is completed, and makes its first liquid helium at 4.5 Kelvin, or 4.5 degrees above absolute zero. Liquid helium makes FRIB's accelerator cavities superconducting so there is no electrical resistance and virtually no heat loss with an electrical current, making FRIB's beam-acceleration process more energy-efficient.

DECEMBER 2018
The 2 Kelvin cold box in the FRIB cryogenic plant produces liquid helium at 2 Kelvin for FRIB's first linear accelerator segment. FRIB is the first superconducting heavy-ion linear accelerator to operate at 2 Kelvin, or 2 degrees above absolute zero.

U.S. DEPARTMENT OF ENERGY | Office of Science

MICHIGAN STATE UNIVERSITY

FRIB

SO … WHAT IS THE FACILITY FOR RARE ISOTOPE BEAMS (FRIB)?

Michigan State University (MSU) operates FRIB, the Facility for Rare Isotope Beams, as a user facility for the U.S. Department of Energy Office of Science (DOE-SC), supporting the mission of the DOE-SC Office of Nuclear Physics. FRIB enables scientists to discover and study rare isotopes; i.e., versions of the elements that are typically not found on Earth. Rare isotopes help us understand the structure of matter, how stars work, and how the elements are made in the universe. FRIB's discoveries will have societal applications to improve our lives.

The establishment of FRIB was funded by DOE-SC, MSU, and the State of Michigan, and user facility operation is supported by the DOE-SC Office of Nuclear Physics. FRIB will be used by approximately 1,600 scientists from around the world who are excited to conduct their research in the new laboratory.

At FRIB, powerful electric fields, changing polarity more than 80 million times per second, accelerate particles through a 1,700-foot-long pipe up to half the speed of light, thereby creating a particle beam. Superconducting magnets are used to guide the beam around the curves to a target. When the beam strikes the target, many new isotopes are created. The isotopes of interest are selected in sensitive fragment separators. Once purified, the beam of isotopes is delivered to experimental instruments where researchers can study their properties or how the rare isotopes react with other atoms. Nuclear mass, shape, decay, and energy states are some of the basic properties of exotic isotopes that scientists will be able to explore for the first time at FRIB.

STABILITY VS. INSTABILITY AT FRIB

One of the themes explored in *Of Equal Place: Isotopes in Motion* deals with concepts of stability and instability. The rare isotopes studied at FRIB will all be "unstable"; i.e., after some amount of time they will spontaneously transform into a different isotope. The more exotic an isotope, the more unstable it is, and its transformation happens faster. While the scientific focus of FRIB is the production and study of unstable isotopes, stable isotopes are a critical part of the science and operation. For example, the starting point of producing rare isotopes is always a stable nucleus that gets accelerated to speeds up to 50% of the speed of light. The world we see around us is built with (mainly) stable isotopes. Therefore, in the quest to understand the matter that this world is made of, and where it came from, the concepts of stability and instability are intertwined at FRIB.

THE SCIENCE OF FRIB

FRIB enables discoveries in the four areas that are represented in its logo. The overlapping circles symbolize protons and neutrons that make up an atomic nucleus. The white circle on top represents the facility itself, and the squares in the diamond represent the buildings (existing and planned that will merge into FRIB.

NUCLEAR STRUCTURE (green circle: Nuclei come in different shapes and sizes. An important goal of the field is to devise models that can accurately describe all nuclei. At FRIB, researchers discover new isotopes and study their properties. Experiment and theory work together to better explain the structure of matter.

NUCLEAR ASTROPHYSICS (blue circle): The energy produced by stars, like our sun, is created by nuclear reactions. Studying these reactions in the laboratory helps us better understand how stars work and, in the process, how they synthesize the elements we see around us. FRIB will, for the first time, give access to the exotic isotopes that are responsible for these stellar processes. With FRIB, we will finally be able to understand how heavy elements are formed in the universe.

ISOTOPES FOR SOCIETY (yellow circle): FRIB enables scientists to make discoveries that help people be healthier, safer, and more productive. Many innovative technologies will be made possible *(see page 12)* by new rare isotopes and the technical ability to produce them at FRIB.

LAWS OF NATURE (sage circle): FRIB's rare isotopes let scientists test ideas about the fundamental building blocks and rules of nature. The Standard Model of particle physics attempts to explain the elementary particles and reactions that make up the visible universe. FRIB allows scientists to make precise measurements that can confirm or challenge the model.

FRIB



HOW CAN FRIB CHANGE OUR LIVES?

Nuclear science is all around you, from the technology in your smoke detector to affordable heating for your home. Advancements in nuclear science have done, and will continue to do, amazing things in our everyday lives.

HEALTH AND MEDICINE

- Each year in the United States, around twenty million nuclear medicine procedures are carried out to diagnose and treat cancers, cardiovascular disease, and certain neurological disorders.
- Nuclear science enables medical technology, like magnetic resonance imaging (MRI) and positron emission tomography (PET) scanning.
- In your home, nuclear science helps keep your family safe. Rare isotopes are used in smoke detectors.

ENERGY AND ENVIRONMENT

- Nuclear science helps reduce hunger and food shortages around the globe. Rare isotopes are used to study how plants grow, fight insects, and react to extreme temperatures. Rare isotopes can help increase yields.
- Carbon dating and other radioisotope dating allows geologists, anthropologists, and archaeologists to determine the age of rocks and other findings.
- Nuclear science research is used in modern oil and gas exploration, and in nuclear energy.

NATIONAL SECURITY

- Nuclear science is used in radiation detectors at airports and in cargo scanners.

Continued on next page.

LOCAL ECONOMY

- From construction through operation, FRIB is expected to add $4.4 billion to Michigan's economy, according to a study by the MSU Center for Economic Analysis.
- Studies have shown that FRIB created up to 1,500 Michigan jobs at the height of the construction phase, and will create hundreds of permanent jobs during operations.

RESEARCH AND EDUCATION

- MSU's graduate program in nuclear science is ranked No. 1 by *U.S. News & World Report*.
- Each year, about 10 percent of the nation's nuclear science PhD holders are educated at MSU.
- FRIB helps train the next-generation accelerator science and engineering workforce, critical to U.S. economic competitiveness, energy security, nuclear security, and nonproliferation efforts.
- About 400 to 500 scientists from around the world will visit Michigan annually. They will stay in the area and spend money in the local economy. Some might decide to move here permanently.

WHAT IS DANCE EXCHANGE?

Fueled by generosity and curiosity, Dance Exchange expands who gets to dance, where dance happens, what dance is about, and why dance matters.

Dance Exchange collaborates across generations, disciplines, and communities to channel the power of dancemaking as a means for dialogue, a source of critical reflection, and a creative engine for thought and action.

Founded in 1976 by Liz Lerman and under the artistic leadership of Cassie Meador since 2011, Dance Exchange is a non-profit dance organization based in Takoma Park, Maryland.

Much of Dance Exchange's work across our 46-year history has focused on the intersection of art and science–leading to collaborations with scientists and educators in the fields of biology, physics, ecology, genetics, and more. In addition to FRIB, we've partnered with leading science organizations such as NASA, National Park Service, the US Forest Service, the European Council for Nuclear Research (CERN), and more. By cultivating a sense of wonder, inquiry, and discovery in the dances we make and the workshops we lead, we celebrate the important role of both dance and science in moving us toward a deeper understanding of our world.

What inspires and fuels our work at Dance Exchange? Connecting across generations and communities. Making art at the intersection of social relevance and community participation. Deepening our relationships with scientists, educators, farmers, forestry specialists, creative aging experts, nonprofit and municipal leaders, independent artists, and families. Growing partnerships with schools, universities, cultural institutions, traditional and non-traditional performing venues, and members of the philanthropic community.

Our work at the intersection of art and science offers an invitation to move as a way to notice our world, and to notice as a way to move our world. Discover ways you and your students can move with us at danceexchange.org.

WHAT IS HAPPENDANCE?

Our mission: To stimulate support for the art of dance through performances and educational programs. To broaden the accessibility of dance to a diverse community and promote dance for lifelong physical and mental fitness.

Known throughout Michigan and beyond for its long history of artistic excellence and exceptional community service, Happendance boasts three focus areas: performance, education, and engagement.

Founded in 1976, Happendance dancers and choreographers are known for their excellence in performance and service, evidenced by their commitment to education, mentorship of emerging artists, community leadership, and outreach and engagement. Happendance professionals bring modern dance to area schools with Happendance Education Exchange. Performing work that enhances academic curriculum, Happendance Education Exchange visits over thirty area schools and serves 6,000 children each year bringing professional, high-quality dance to mid-Michigan schools.

Learn more at happendance.org.

HOW DO YOU INCORPORATE PHYSICS AND DANCE?

Dance Exchange has been making dances about science in classrooms, on stages, in labs, and in museums for the past 15 years. So ... how do we make a dance about physics?

Read below for a few helpful entry points to choreography and to explore further visit Dance Exchange's Toolbox: whartoncenter.com/toolbox

First of all, there is no one right way to make a dance about science, but there are a few things we have found helpful. In all of our dances about science, we have had the opportunity to talk to scientists. We ask them about their research and listen as choreographers. One way to listen as a choreographer is to highlight verbs. Where is the movement in what they are describing? Often science is filled with really rich actions—accelerate, collide, bind... We collect the verbs. Is the sequence of verbs important? If so, why? We ask questions. Using a creative tool we call Movement Metaphor, we investigate these verbs in the studio with dancers in the company and also through community workshops. The movement helps us learn, and when we learn often there are more questions to ask our science partners. We notice that the more we discover about the content, the more specific and rich the movement and learning becomes.

Listening as a choreographer also means watching for movement. When a scientist describes their research it's almost impossible for them to stay still. Their hands become alive as they visualize and communicate concepts. These Spontaneous Gestures, the natural body language used to communicate, are rich seeds for choreography. We collect these movements because it helps us remember and communicate information. Once there is movement there are so many creative options using theme and variation: we make the movements bigger or smaller, we make them travel, we manipulate speed and rhythm. The content helps us determine not only how to vary movement, but also how the movement is shaped in the space of the stage.

Images can also serve an important role in developing choreography. Scientific pictures, graphs, and illustrations can all be springboards for movement invention. Using a creative tool we call Detail, dancers can put the details into still positions and into movements using different body parts and have movement originate from different places. Again, the more detailed and specific investigations of the images, the more nuanced, original, and specific the movement becomes.

There are many pathways to any creative research in science or art. These are just a few ways that we have found helpful as entry points to choreography. To explore further visit: whartoncenter.com/toolbox

CAREERS AT FRIB

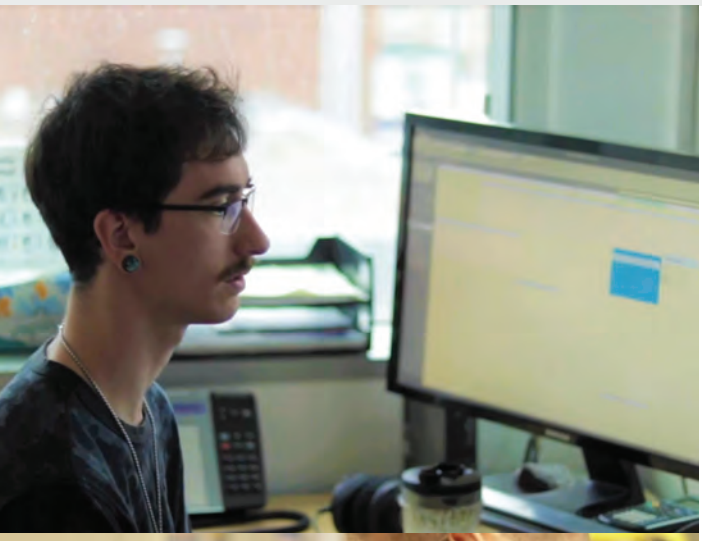
It takes a team of over 800 people to make FRIB work.

The team includes nuclear scientists, writers, accelerator physicists, welders, many different kinds of engineers, accountants, mathematicians, programmers, machinists, plumbers, and more–an incredible variety of skills, training, and backgrounds. People who have helped create FRIB started with careers in the auto industry, helicopter repair, construction, chemical engineering, farming, quality control, and other surprisingly varied fields.

Scientific research needs people who can:

- be creative
- work with others
- make things
- enjoy challenges
- keep learning
- solve problems.

What makes FRIB possible is a dedicated team who solve problems together by combining their abilities in STEM (Science, Technology, Engineering, and Math), skilled trades (welding, machining, etc.), and business (accounting, supply chain management, event organization).



CODY NORAT
Mechanical Design Engineer

"My work here at the lab primarily consists of 3-D modeling and stress-strain analysis, so we know ahead of time that something is going to be a safe installation, and there'll be no mechanical failures in the future. I've always been mechanically inclined ... I started doing brick jobs and oil changes with my father in middle school, and my mechanical love has only grown since."

MARTY MUGERIAN
Operations Accelerator Engineer

"A cyclotron operator gets to control the cyclotron as well as fix it. We have an entire tool room dedicated just for fixing the cyclotrons. I chose this career path because I've always really enjoyed science, especially as a kid ... throughout my life I always just really wanted to know: how do things work, and why do they work like that, so a career in the STEM field really seemed like the way to go."

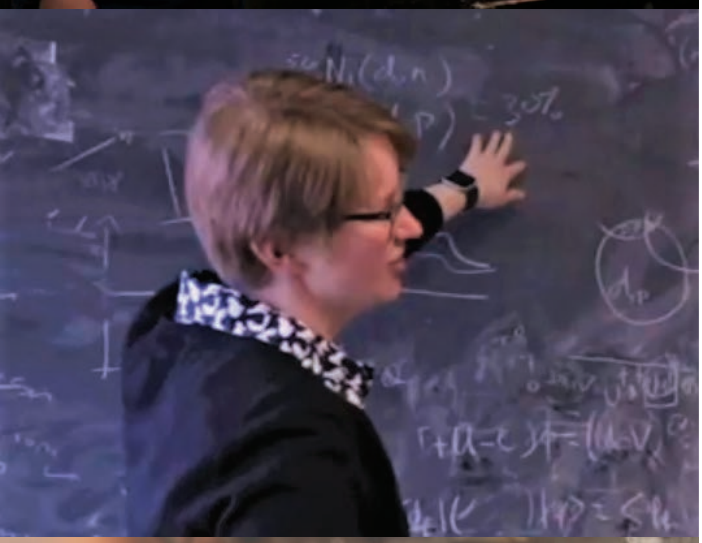
Continued on next page.

STEPHANIE LYONS
Researcher

"On a day-to-day basis, I can be analyzing data on my computer, working in the lab setting up an experiment, helping graduate students, or writing papers. I chose to study physics of how everything came into the world, how we have all the elements we have on the Earth, by continuing to just follow what I was curious about, and what I was passionate about learning."

SUSAN LECUREUX
Material and Scheduling Coordinator

"When I was growing up, I liked to work on the farm and work with all the machines and stuff. So, as my life progressed, I was always involved in making and fixing things. One of my main skill sets is the understanding of metals and seeing the possibilities of different materials that might be available to help make the science components."



TERRI POXON-PEARSON
Graduate Student

"I am a theorist. I do calculations and simulations that help the experimentalists here interpret their results. I like physics because it sort of connects to everyday life, both through applications like medical physics—used for all sorts of medical imaging and things like cancer therapies—and also even more abstract things. Like we can use some of the smallest things in the world to learn about these huge stars that are, you know, some of the largest structures in the universe."

SHANE RENTERIA
Accelerator Engineer

"I chose a physics degree in school, and I chose that because I wanted to understand the unknown. My career specifically is unique because I work with ECR (Electron Cyclotron Resonance) ion sources, and there are a handful of those in the world. Someone should choose a career in STEM if they are interested in knowing about how the world works."

Continued on next page.

PAIGE ABEL
Graduate Student

"I really enjoy seeing a problem or a potential application that science could solve, and then figuring out how to get it done. Being creative is a really big part of being in science. I think you need to really be passionate about you're doing, because it does take a lot of time to learn some of the skills that you develop in school, and putting in the time it takes to do a good experiment."

PETER MANWILLER
Particle Accelerator Alignment Engineer

"My job is to make sure that all of the magnets that accelerate, focus, or steer those particles are all in exactly the right spot. We use laser trackers to measure distances and angles very accurately. We align hundreds of these devises ranging in dimensions from the size of a pencil to something like a magnet the size of a truck, and putting them all in the right positions to within the width of a piece of paper."

MALLORY SMITH
Physicist

"...we take really high-energy beams and smash them into a target, and those reactions produce a lot of different, smaller nuclei. Then we filter out to a subset of a small number of nuclei that the experimentalists want to measure ... it's a field where you can do the computational, you can work with your hands, you can work on theory, you can work on data analysis, and big data and, those kinds of things."

LUKE ROBERTS
Assistant Professor

"I study how neutron stars are born and how neutron stars die, and how they can make some of the heaviest elements in the universe in this process. Mostly the tools I use are pencil and paper or my laptop ... I always enjoyed math and I always enjoyed computer programming, so I taught myself to program computers when I was pretty young."

INTERVIEW WITH A DANCER: LENA GRANGER

Missy Lilje, Education Director of Happendance, sat down with professional dancer Lena Granger.

Missy: How did you get into dance?

Lena: At age 5, I was enrolled in dance and gymnastics, but going forward I had to choose one or the other. I chose gymnastics and ended up doing that for seven years. I really loved gymnastics and my favorite events were the balance beam and floor exercise. I wasn't the best on the team by any means, but I appreciated being a part of something bigger than myself. Unfortunately, I got injured during practice on the balance beam and that injury ended my journey with gymnastics. Seven years after I had last taken dance, I decided to give dance another try. I enrolled at a local studio, and I was hooked. I became passionate about dance. For the first time, I felt like I actually understood my body and how to express myself through movement. It was truly liberating. It boosted my self-confidence; I knew this was something I could be good at.

Missy: Where did you study dance?

Lena: My preliminary training began at Fusion Dance Center. In high school, I became more serious about my dance training; I began dancing at Happendance and with the Children's Ballet Theater. I realized that dance could be more than just a high school activity, it was something that I could major in at college. I looked at other majors (accounting, graphic design, architecture) but none of them appealed to me. I was accepted into the Maggie Allesee Department of Theatre and Dance at Wayne State University and graduated with my BFA in Dance. My college dance experience was incredible. One can learn almost anything by picking up a book or searching the internet; dance is a movement practice that is hands on. You must be diligent in showing up every day, being present, and doing the work. I appreciated that opportunity to be in my body every day and to understand the endless possibilities of what the body can do.

Missy: What would your life be like without dance?

Lena: I would be without my community! I am grateful that dance has brought passionate, hard-working, caring, and creative people into my life. Each of them has been a source of inspiration and support to me. The dance community is small and tightly knit: we can move to different places and do different things yet still find ways to support each other, and sometimes even dance together again! I also wouldn't have had opportunities to travel and learn from the well-known, wise, and wonderful artists I met. Each one furthered my dance training as well as my identity as an artist. The scholarships that I sought out in the dance department and academically through the University made it possible for me to graduate from college debt-free! In another field of study, I'm not sure that I would've had that same opportunity.

Continued on next page.

Missy: Are there any risks that come with being a dancer?

Lena: So many risks! But I think dance also gives you the resources to live with those risks. There are financial risks: jobs in dance are very competitive, and they aren't always as consistent or reliable as a typical 9-5 office job. Being a physical practice, there's always the risk of injury in dance. Fortunately, there are great resources out there for injury prevention and recovery. In my college course on dance kinesiology and movement analysis, I learned about forms of cross-training (Pilates, yoga, biking, swimming) to keep my body strong and healthy during dance training, as well as techniques for recovery (massage, salt baths, rest).

Probably the hardest risk to manage is the risk of presenting yourself before an audience and not being liked or accepted. Here, there aren't active measures you can take to minimize the risk. Whether in a piece as a performer or presenting a piece as a choreographer, there's the risk that people won't understand or appreciate the work you present. While we do keep our audience in mind as we create, we don't make work so that everyone will understand and appreciate it. We make work to get audiences thinking, to start conversations, to share ourselves in hopes of relating to and encouraging maybe one person out there. That one person, that conversation, is enough to keep us creating.

Missy: Why are you interested in this particular project, working with Dance Exchange and FRIB?

Lena: While at college, I participated in a workshop led by Dance Exchange. Their philosophy and approach to dance was extremely informational and enjoyable. When offered this opportunity, I was thrilled to work with them again in this new context of performance and collaboration. This project is also very personal to me: my brother is the Cryomodule Cold Mass and Cryogenics Design Team leader at FRIB. I have seen and learned about his work for the past 10 years, as he has seen and supported me through my dance journey. Through this project, my world of dance and his world of engineering are able to come together and be a part of the same conversation.

CAREERS IN DANCE

ARTS ADMINISTRATOR

KELLY STUIBLE-CLARK

Musical Theatre Programs Manager,
Wharton Center Institute for Arts & Creativity

What I love about my work as an arts administrator is that it's always changing, and I'm learning new things daily.I also work in education, so I'm proud that I'm able to both teach the next generation of artists, as well as support others doing the work. Part program management, part event planning, I'm also able to connect with creatives across the region to provide exciting and innovative opportunities for all ages!

PUBLIC SCHOOL TEACHER

CLARA MARTINEZ

Dance Director, Everett High School for the Visual & Performing Arts

Teaching Dance full-time in a public high school is fun, challenging, exciting, and one of the greatest joys of my career! To do a job like this one, you have to be open to trying new things and working with lots of different kinds of people. I love getting to know many different students, developing relationships with them, and learning more about life and the world through the expression of dance. I earned my BFA in Dance from The Ohio State University, danced professionally and also started teaching in local dance studios where I lived. I eventually went on to become a teaching artist (someone who teaches their medium of art in different schools). I loved that job so much that when the opportunity to work full-time in a school as a dance teacher and director became available, I applied right away!

PHYSICAL THERAPIST

LINDA REIFF

PTA, Willows of Okemos; Pilates instructor, Michigan Athletic Club

Being a Physical Therapist Assistant allows me to use my dance experience to understand the body on a physical level and use that knowledge in rehabilitation of patients. A PTA works in outpatient and inpatient settings, as well as in long-term care facilities. An associate degree is necessary to become a licensed PTA, and it involves an understanding of science, with courses in Anatomy, Kinesiology, and courses in therapeutic exercise and manual therapy.

Continued on next page.

DANCE PROFESSIONAL
AMI DOWDEN-FANT

Professional Performer, Choreographer, Speaker, Dance Educator, & Owner/ Director of River City Dance & Performing Arts. Earning my BFA from Virginia Commonwealth University launched me into the professional dance world, dancing, traveling, performing in a variety of venues, and developing professional relationships. Together these furthered my artistry and choreographic knowledge, creating dance projects, teaching, and choreographing musicals for a variety of establishments. Maintaining these professional relationships furthered opportunities to speak about my professional dance experiences. While continuing to further my current dance endeavors, I started a business. As the director/ owner of a dance studio (RiverCityArts.Studio)I run the day to day operations of a business, along with teaching dance to ages 3 to Adults. This challenging and equally rewarding adventure has provided avenues to help mentor and brighten lives through the art of dance. I'm highly fortunate to have had the opportunity to develop a career from my talent. It's a true accomplishment, which I'm grateful for everyday.

DANCE PROFESSIONAL
CLARENCE L. BROOKS JR.

Having danced with 75+ dance companies, my career in dance was happenstance; I was studying mathematics to become a math teacher. On a whim, I attended a free day of dance at another college; later that day they offered me a full scholarship to transfer. While a dance major, I was hired as a salaried apprentice in a ballet company and received summer scholarships to study and perform at festivals around the nation. After two decades of touring the USA, Europe, and Asia and two serious injuries, I matriculated in grad school to get an MFA in dance to teach in universities. I am a tenured professor now.

DANCE PROFESSIONAL
KEITH A. THOMPSON

My career in dance began when I was in college, then performing jazz dance in Minneapolis, over 35 years ago. Now, I am not only the director of dance at Arizona State University, but I choreograph my own work in New York, Europe, and Asia; I have been fortunate to work with brilliant women like Trisha Brown and Liz Lerman, among many others. It hasn´t always been a direct path, nor has it often been easy; but with hard work and focus, my life in dance has always been a rewarding one.

ADDITIONAL DANCE-RELATED CAREERS

CHOREOGRAPHER/DIRECTOR
Choreographers create original dances, put together moves in sequence for a dance routine and develop new interpretations of existing dances. Directors control the artistic and dramatic aspects and visualizes the script while guiding the technical crew and actors/dancers in the fulfillment of that vision.

PROFESSOR
A teacher with the highest rank in a college or university.

MASSAGE THERAPY
Massage therapists help relieve pain, heal injuries, improve circulation, relieve stress, increase relaxation, and aid in the general wellness of their clients by using touch to manipulate their muscles and soft tissue.

COACH/PERSONAL TRAINER
Coaches and Personal Trainers instruct and assist people in reaching their personal health and fitness goals.

COSTUME DESIGNER
Designs costumes for film, stage, or television.






WHAT TO EXPECT AT THE *ISOTOPES IN MOTION* EVENTS

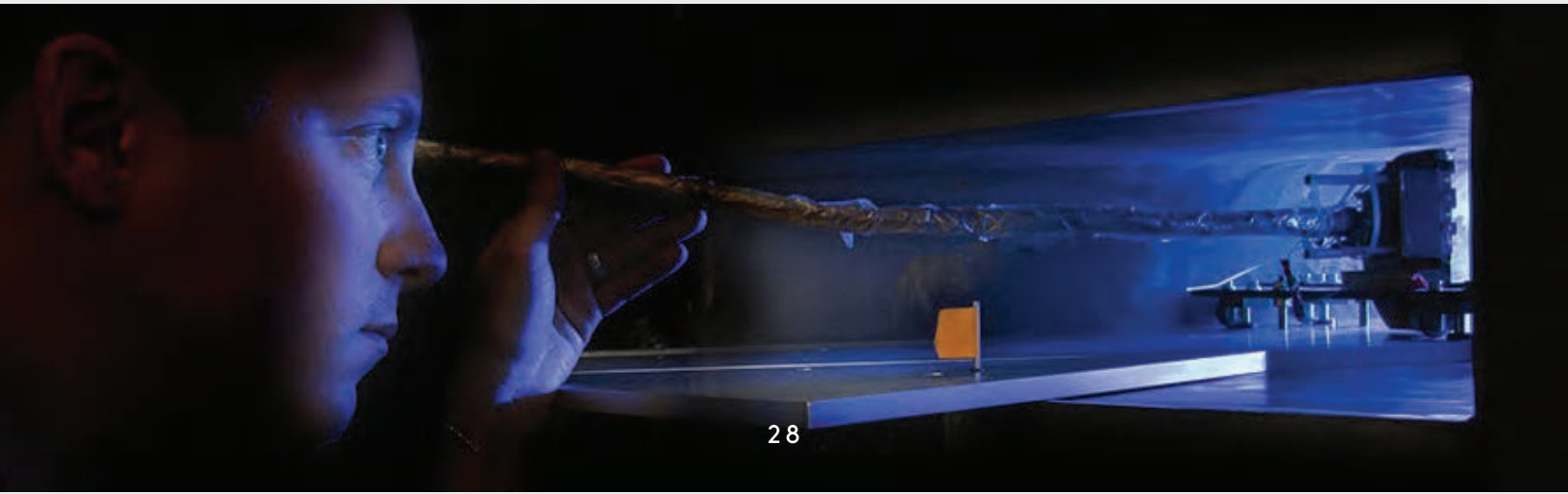
A performance by Dance Exchange and Happendance on the Pasant Theatre stage at Wharton Center. After the performance, you are invited to a variety of activities where you will learn more about FRIB, nuclear science, dance, and more. Please come explore:

- Hands-on nuclear science workshop: Build models of rare radioactive isotopes
- Interactive exploration of the science and dance concepts from the performance
- The FRIB Laboratory: Tour the actual research vaults where rare isotopes are measured
- Careers in science and performance: Find out what it takes to develop a career in which you can discover something new about the universe
- Demonstration area: An array of demonstrations and activities where you can be a scientist
- Movement Workshop: Physics on Your Feet with Dance Exchange: Get moving! Learn some movements from the performance, and collaborate with dancers and scientists to discover why movement matters. No experience necessary. Just dress comfortably to move!

QUESTIONS FOR DISCUSSION

Questions for discussion. Prior to attending the performance, explore any of the questions below with your students and identify questions you may want to ask scientists and dancers following the performance.

- What do scientists do?
- Why is it hard to learn about the nucleus?
- Who works at the Facility for Rare Isotope Beams (FRIB)? What skills do they need?
- How do we measure what we can't see?
- How are we made of stars?
- Why do we invest in big research facilities like FRIB? How does it benefit us?



QUESTIONS FOR REFLECTION

After experiencing the performance, discuss any of the questions below with your students and gather questions they may have to explore further.

- What was your favorite moment in the performance and why?
- Where did you see or experience stability and instability in the dance?
- Can you talk about the role of video in the performance? What projections stuck with you and why?
- What is a question you would have for one of the performers?
- What was something you learned or relearned through the performance?
- How did the dance communicate principles of science and physics?
- How are people and stars connected?
- What is something you can measure? Something you can't?
- Has the performance changed your thoughts on who a scientist is? Who is a dancer? If so, why?

A creative prompt and activity to explore with your students following the performance.

- In this activity called Perpetual Prompt you will offer a verbal prompt and your students will write a series of sentences, each beginning with the prompt phrase and then completed with something different each time.
- Start by having your students reflect on something they are wondering about. Then have them reflect on additional things they wonder about by completing the prompt "I wonder..."
- You can set a fixed time (three to five minutes is plenty) for your students to complete the prompt as many times as they can. Tell them to keep writing their prompt followed by whatever comes to mind, keeping pen to paper for the entire time. If they draw a momentary blank they can write "I don't know what to write" until the next idea comes to them.
- After the time is up, have them read for themselves first, and then with a partner or the class, some of their writing responses. You can emphasize that they are in charge of their story and the writing they choose to share with the group.
- To learn more about Perpetual Prompt and explore this activity further, visit: www.d-lab.org/toolbox/view/-Perpetual-Prompt

TERMS TO KNOW

ALPHA PARTICLE: A helium nucleus (2 protons and 2 neutrons). Can only travel a short distance in air. Does not penetrate through matter very well. A thin piece of paper will stop them.

BETA-MINUS PARTICLE: Energetic electrons. Can easily penetrate paper but a thin aluminum plate will stop them.

BREATH: Inhalation or exhalation of air from the lungs.

CHART OF NUCLEI: The equivalent to the periodic table for nuclear physicists. Lists proton number on the vertical axis and neutron number on the horizontal axis. Each point on the plot represents a different isotope.

CORE: The central or most important part of something.

DANCE COMPONENTS: Actions that come together to engage the body in expressing emotions, ideas and observations, including:

DYNAMICS: The "loud and soft" of movement, as when transitions are sharp and rhythmic, or smooth and gently changing.

LEVEL: Position of a shape or movement relative to the ground. Example: crouching to make a low movement, rising on tiptoe with arms reaching upward, etc.

MOVEMENT: Motion in any or all parts of the body. Examples: raising eyebrows, arm and hand movements, swaying the torso, galloping with feet.

REPETITION: Performing a movement more than once, either in succession or reoccurring at different points throughout a movement phrase.

SCALE: Size and Range. Shapes and movements can be made larger or smaller, often by moving them to other parts of the body. Examples: a circle made with arms will be bigger than one made with the fingers.

SHAPE: A fixed configuration of some or all parts of the body. Examples: making a circle with the arms, spider shapes with our fingers, leaf shapes with the entire body.

TEMPO: The speed of movement: slow, moderate, or fast.

TRAVELING: Transitioning a shape or movement from one location to another.

DANCE PHRASE: A series of shapes and movements in a finite, repeatable sequence.

DISTAL: Situated away from the center of the body or from the point of attachment.

ELECTRON: Particle with far less mass than the proton, has negative electric charge, and with protons and neutrons makes up atoms.

ELEMENT: Basic building block of nature. Defined by the number of protons in the nucleus (i.e. the "atomic number" of 6 protons = carbon.)

ENERGY: The strength and vitality required for sustained physical or mental activity.

FOCUS: The center of interest or activity. Also, the direction the dancer is looking.

FRAGMENTATION: A method of changing a nucleus by smashing it into another one, thus breaking off protons and neutrons. This is a way to make rare isotopes from stable ones.

GAMMA RAY: Photons similar to light rays or x-rays except they are much higher in frequency and energy. Can penetrate most matter easily. Requires lead bricks for shielding.

GROUNDED: Well balanced and sensible.

HALF-LIFE: The time in which an unstable nucleus has a 50/50 chance of decaying. Effectively a measure of how unstable a particular nucleus is: very unstable nuclei have a short half-life.

INVENTION: The action of creating/inventing something, typically a process or device.

ISOTOPE: Variety of an element as defined by the number of neutrons in the nucleus (e.g., 6 neutrons in a carbon nucleus = carbon-12, the isotope being 12, the sum of protons and neutrons).

LINEAR ACCELERATOR: A machine that uses a line of high-voltage parts to accelerate a charged particle (like a nucleus) to high speeds. Nuclei must be accelerated to high energies for fragmentation to be successful.

NEUTRON: Particle with about the same mass as proton, but no electric charge, found in the nucleus.

NEUTRON STARS: Smallest and densest stars in the universe. Result from the explosive death of a massive star.

NUANCE: A subtle difference in shade of meaning or expression.

NUCLEUS: Core of an atom, composed of protons and neutrons.

PHRASING: The division of music into phrases in a particular way, especially in performance.

PROTON: Positively-charged particle found in atomic nuclei.

RADIATION: Small, invisible particles released by unstable atoms to become stable. Can take the form of an alpha particle, beta particle, or gamma ray.

RARE ISOTOPE: Variety of an element that is unstable and thus not normally found on Earth. Mostly found where nuclear reactions are currently making new nuclei (e.g. stars).

RELEASE: Allow something to move, act, or flow freely.

SPACE: A continuous area or expanse which is free, available, or unoccupied.

SPONTANEOUS GESTURE: The often unconscious gesture that a person will make in the acts of self-expression or describing something. Observed carefully, these can become the source of movements in a dance sequence.

STABLE NUCLEUS: A favorable (low-energy) combination of protons and neutrons that does last forever.

STANDARD MODEL: Current best understanding of what the Universe is made of and how the fundamental particles of nature interact with each other.

SUPERCONDUCTOR: A wire that, when cooled to a low enough temperature, offers no resistance to electricity. Thus, it can carry large amounts of current and waste none of that energy as heat.

TACTILE: Perceived by touch.

UNSTABLE NUCLEUS: An unfavorable (higher-energy) combination of protons and neutrons that does not last forever. In time, it will "decay" (give off radiation) and often change into a different kind of element or isotope (by altering the number of protons or neutrons, respectively).

VARIATION: A change that alters one or more elements of a movement or phrase. Changes in speed, size, or level are variations.

RESOURCES FOR FURTHER STUDY

"Opening the doors to discovery" - Discover FRIB. *msu.edu/discoverFRIB*

"A Facility for Rare Isotope Beams (FRIB) at MSU" – A 4-minute video about the laboratory. All grades. *youtu.be/EPG919lJK8s*

"Marble Nuclei Lessons" – A nuclear science lesson with activities and demonstrations. Grades 6-12. *jinaweb.org/educational-outreach/marble-nuclei-lessons*

"Isotopolis" – A game for iOS, Android and the web about rare isotope research. All grades. *gamedev.msu.edu/isotopolis/*

"The Rare Isotope Rap" – A 5-minute music video about FRIB. All grades. *youtu.be/677ZmPEFlXE*

"The Small Matter of Big Science" – A 45-minute documentary about the history of nuclear science, featuring FRIB at 38:43. Grades 7-12. *youtu.be/z-P8OSeP1hk*

Learn more about FRIB. *frib.msu.edu*

Nuclear science camps for middle/high-school students. *whartoncenter.com/spartanyouth*

Explore FRIB research and more at the annual MSU Science Festival. *sciencefestival.msu.edu*

"Hunting for Rare Isotopes: The Mysterious Radioactive Atomic Nuclei that will be in Tomorrow's Technology" - Popular Science article by Artemis Spyrou. *whartoncenter.com/rare*

"Elements from the Stars: The Unexpected Discovery that Upended Astrophysics 66 Years Ago" - Popular Science article by Artemis Spyrou and Hendrik Schatz. *whartoncenter.com/elements*

SMASH: A Nuclear Adventure, FRIB-inspired nuclear science exhibit at Impression 5 Science Center. Permanent exhibit opened in August 2019. *impression5.org/exhibits/hands-on-exhibits*

Hiking the Horizontal by Liz Lerman. *lizlerman.com/hiking-the-horizontal/*

Science Choreography – *sciencechoreography.wesleyan.edu/*

JMU DNA Dance – *youtube.com/watch?v=8c8PjPlW23Q*