PHYSICS FLASH

Winter 2022
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Los Alamos NATIONAL LABORATORY

Above left: Takeyasu Ito is photographed in the large magnetically shielded room used for the LANL nEDM (neutron electric dipole moment) experiment. In this case, the low magnetic field created in the room is 100,000 times smaller than the ambient magnetic field, an environment required by the nEDM experiment. The LANL nEDM experiment is one of the experiments that uses the LANL ultracold neutron source.

Takeyasu Ito elected APS Fellow

Takeyasu Ito (Nuclear and Particle Physics and Applications, P-3) has been named a 2021 American Physical Society (APS) Fellow.

The focus lead for the P-3 Neutron Team was recognized for fundamental studies that led to the development of the world's most powerful ultracold neutron source, for its commissioning, and for its application to precision measurement of the neutron and its decay.

The APS Fellowship Program recognizes APS members who may have made advances in physics through original research and publication, or made significant innovative contributions in the application of physics to science and technology. They may also have made significant contributions to the teaching of physics or service and participation in the activities of the APS.

Ito, who has a PhD in physics from the University of Tokyo, joined the Physics Division at Los Alamos as a staff scientist in 2005. His work has focused on using ultracold neutrons as a probe for studying the consistency of the Standard Model of particle physics and searching for what may lie beyond it.

Also named 2021 APS Fellows from Los Alamos were Nathan Moody (Applied Electrodynamics AOT-AE) and Eric Brown (Office of Experimental Sciences, OES).

Technical contact: Takeyasu Ito

From the seat at my desk I have had the opportunity to view the vast diversity in the Physics Division portfolio and I am truly impressed by your work. I have also seen opportunities for future development and the implementation plan includes this information. With this view I'm confident that the future of Physics Division is positive with the continued care of the division management team and the hard work of all the division members.

From Frank's desk . . .

It is mid-February as I write this, and the number of COVID-19 cases seems to be decreasing at LANL and in our community after the Omicron surge of cases. There have been many challenges in the past few months and Physics Division members continue to rise to meet each of these. Thank you for your diligence through this time.

This issue of *Physics Flash* features the recent success of our newest APS Fellow, Takeyasu Ito, and some of the new LDRD projects that are beginning this year. These projects will aid in setting the division's future direction and I look forward to learning more as these projects progress. At the same time, new and exciting projects are being proposed for start in fiscal year 2023. The innovations that are captured in these proposals are important and will power the future of Physics Division.

The LANL Agenda has been recently published both online and in PDF format (discover.lanl.gov/publications/lab-agenda/). I encourage all members of Physics Division to find the time to become familiar with this document—specifically to find where and how your work is contributing to the Laboratory mission. This agenda is structured differently from past versions, with four strategic objectives: nuclear deterrence, threat reduction, technical leadership, and trustworthy operations. Everything that is accomplished at this Laboratory touches on these different goals and the Laboratory Agenda specifies these connections. This is a very sensible organization and I have been reading with interest as we review the strategic goals within Physics Division.

We are also working to develop an implementation plan for the division strategy that was developed in previous years. This will be a plan with actionable steps toward implementation of this strategy informed by review of what has worked and what might benefit from "tweaking" in the reorganization and strategy development of the past few years. As an acting division leader my goal is to develop a draft of this implementation plan that can be provided to your next division leader.

From the seat at my desk I have had the opportunity to view the vast diversity in the Physics Division portfolio and I am truly impressed by your work. I have also seen opportunities for future development and the implementation plan includes this information. With this view I'm confident that the future of Physics Division is positive with the continued care of the division management team and the hard work of all the division members. ■

Frank Merrill, *Physics Division Leader (acting)*

Using a rare gamma ray decay to measure magnitude of nuclear fusion implosions

When studying nuclear fusion systems, the most important metric is often "how many fusions happened?" That is, what is the fusion yield of the system? Nuclear fusion systems combine deuterium and tritium, creating a ^{4}He atom and a neutron as well as extra energy. The fusion yield has been universally measured by counting the number of fusion neutrons emitted.

However, 1 in every 20,000 fusion reactions ($4.2x10^{-5}$) creates a high energy gamma ray instead of the high energy fusion neutron. Using Los Alamos's Cherenkov gamma ray detector, these rare fusion gamma rays have been measured as an alternative metric of nuclear fusion yield for inertial confinement fusion implosions at the National Ignition Facility (NIF).

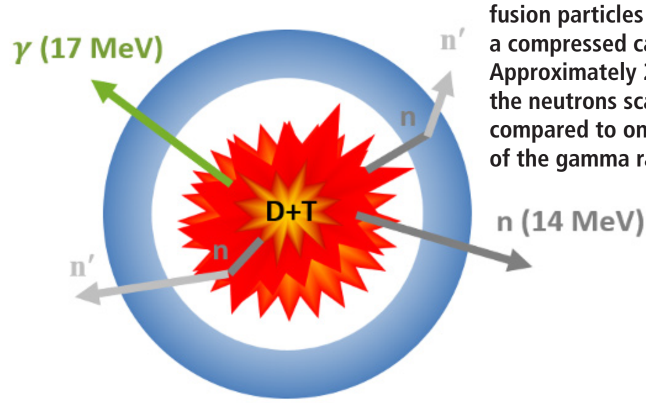
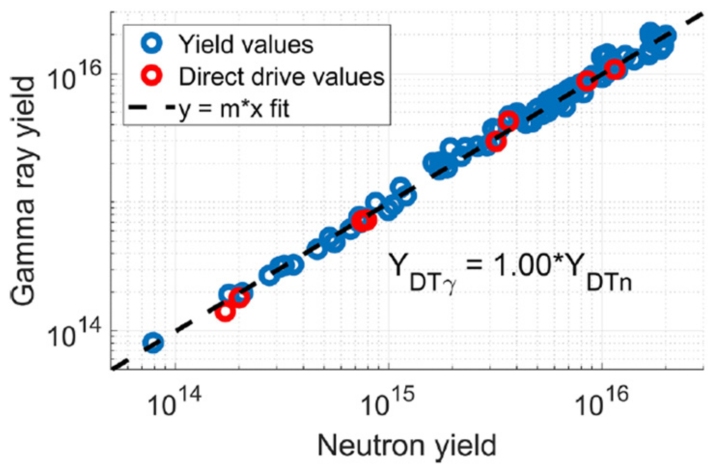


Illustration of emitted fusion particles from a compressed capsule. Approximately 20% of the neutrons scatter compared to only ~3% of the gamma rays.

Using gamma rays side steps a range of complications inherent in measuring yield in ICF implosions. The measurements, performed by a team of Los Alamos and Lawrence Livermore researchers, are reported in *Physics of Plasmas*.

Accounting for neutron scattering

"In inertial confinement fusion experiments, small pellets of deuterium-tritium are compressed with high powered lasers to extremely high densities and temperatures," said Kevin Meaney (Thermonuclear Plasma Physics, P-4), the paper's lead author. "This causes some complications for accurately measuring the total yield. The compressed capsules are so dense that ~20% of the fusion neutrons scatter on their way out of the capsule." Furthermore, he explained, because of asymmetries in the compression, the shell is thicker or thinner depending on the angle measured, causing the amount of scatter to differ. Additionally, the compressed capsules have plasma flows that further shift the energy of the fusion neutrons depending on the direction. Many detectors at many various locations on the NIF are used to measure both the unscattered and the scattered neutrons and are corrected for the energy shift from the plasma flows in order to get a confident total yield measurement.



Comparison of gamma ray and neutron measured fusion yield across 91 NIF implosions showing high agreement.

Benefits of gamma rays

In contrast, for the compressed capsule, only about 3% of the gamma rays are scattered. Because gamma rays move at the speed of light, plasma flows have negligible effect on the energy shift of the gamma rays. Gamma rays offer the potential of having one detector in one location giving the spatially averaged total yield, avoiding the complications of the neutron measurements. However, there are other rare neutron capture interactions that also release a similar energy gamma ray and make up about 12% of the signal that must be corrected.

Complementary combination

Using gamma rays in combination with neutrons for yield measurements offers a potential for improved precision of physics values, such as the level of compression and asymmetry. The gamma ray yield technique can be leveraged for other fusion systems such as magnetic confinement experiments. The technique was developed due to the investment in innovative nuclear diagnostics developed and used by Los Alamos National Lab and helps further understanding and diagnostic techniques for high energy density plasma systems.

The work, which supports the Lab's Nuclear Security and Energy Security missions and Nuclear and Particle Futures science pillar, was funded by the DOE Office of Experimental Science Inertial Confinement Fusion Program (LANL Program Manager John Kline).

Researchers: Kevin D. Meaney, Yong Ho Kim, Hermann Geppert-Kleinrath (P-4); Hans W. Herrmann (Dynamic Experiments, M-DO); A. S. Moore, E. P. Hartouni, D. J. Schlossberg, E. Mariscal, J. Carrera, J. A Church (Lawrence Livermore National Laboratory).

Reference: "Total fusion yield measurements using deuterium-tritium gamma rays," *Phys. Plasmas* 28, 102702 (2021).

Technical contact: Kevin Meaney

Chi-Nu uses 'quasi-differential' technique to measure neutron transport in U-235 and Pu-239

Nuclear data are crucial inputs that drive the accuracy of simulation tools used in many nuclear systems, including nuclear reactor design, operation, criticality safety, weapons physics, and nonproliferation efforts. However, such data contain many uncertain variables.

This uncertainty directly impacts how well simulations of nuclear systems represent physical observations. Neutron scattering, both elastic and inelastic, is currently a leading source of uncertainty in nuclear data libraries and has a large effect on neutron transport in fast nuclear systems.

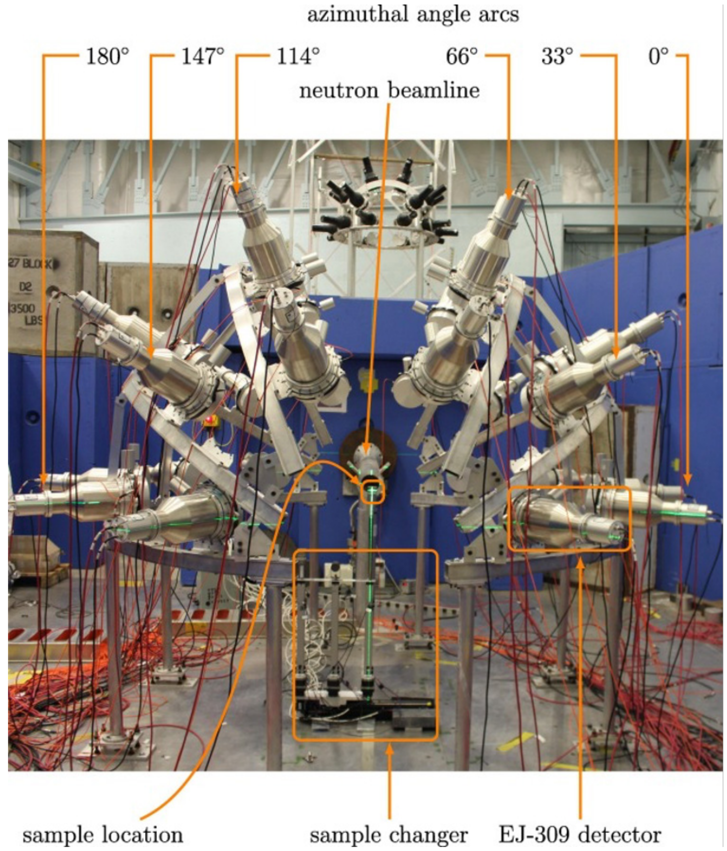
In work appearing in the *Annals of Nuclear Energy,* a team of Physics researchers and university collaborators have published a Chi-Nu measurement of neutron output spectra following neutron-induced reactions on the major fissile actinides, specifically U-235 and Pu-239. The measurements show there are a significant number of discrepancies between data library predictions of the neutron yield and physical observation.

Based on these results, the researchers recommend a new evaluation using these results for U-235 and Pu-239. Such an improved evaluation would increase the accuracy and reliability of fast neutron transport calculations in systems using fissile U-235 or Pu-239, such as critical assemblies, fast nuclear reactors, and past nuclear weapons tests.

The measurements were performed at the Los Alamos Neutron Science Center (LANSCE) using a "quasi-differential" method previously developed at Rensselaer Polytechnic Institute (RPI). Leveraging the Weapons Neutron Research Facility's continuous energy neutron beam, the experiment measured all of the outgoing neutrons as functions of neutron time-of-flight and outgoing neutron angle.

These measurements were then compared to predictions based on nuclear data libraries though Monte Carlo N-particle simulations, pointing to specific energies and scattering angles at which current nuclear data libraries do not match the measured data. While similar measurements on iron and U-238 had been done previously at RPI, the need for higher neutron flux and access to large samples of fissile material required that these new measurements be performed at LANSCE.

> The measurements were performed at the Los Alamos Neutron Science Center using a 'quasi-differential' method previously developed at Rensselaer Polytechnic Institute. Leveraging the Weapons Neutron Research Facility's continuous-energy neutron beam, the experiment measured all of the outgoing neutrons as functions of neutron time-of-flight and outgoing neutron angle.



In this photograph, the experimental setup is annotated to mark the sample location, sample changer, an EJ-309 liquid scintillation detector, and the azimuthal angles. The detectors are oriented such that their liquid cell is closest to and perpendicular to the sample.

This work was done in collaboration with RPI and formed most of the PhD thesis of Kumar Mohindroo, a former LANL student now at Oak Ridge National Laboratory. Other RPI staff involved were Prof. Yaron Danon and Dr. Ezekiel Blain.

LANL staff involved were Matt Devlin and Keegan Kelly (Nuclear and Particle Physics and Applications, P-3) and John O'Donnell (Applied and Fundamental Physics, P-2).

The work was funded by the Office of Experimental Sciences (NA-113)/Primary Assessment Technologies and supports the Lab's National Security mission and Nuclear and Particle Futures science pillar.

Technical contact: Matt Devlin

LDRD new starts represent tech excitement and mission opportunity

Physics Division staff play key roles in six projects selected for funding

The Laboratory's Directed Research and Development Program is essential for the technical vitality of the Lab and builds capabilities for future mission challenges. At its core is high-risk, high-reward research. Funded with less than 6% of the Laboratory's operating budget, the program makes it possible for Lab scientists and engineers to pursue cutting-edge R&D and solve the nation's most difficult challenges.

The Directed Research (DR) component makes long-range investments in multidisciplinary projects vital to LDRD's long-term ability to enable the Laboratory to execute its missions. Exploratory Research (ER) projects focus on a single discipline or capability that explore highly innovative ideas, often fundamental, in science and technology that underpin Laboratory programs.

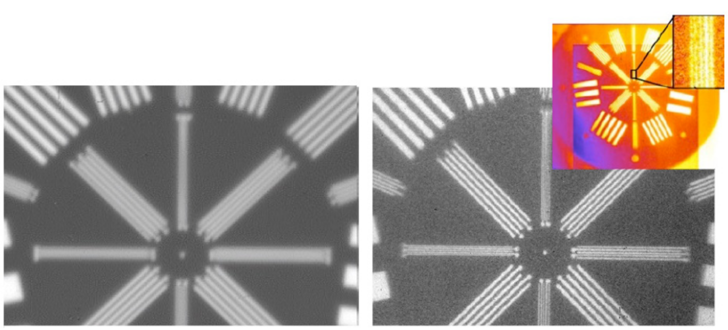
Many strong proposals were received in the recent FY22 DR and ER proposal competition. Those funded represent a small fraction of the ideas put forth by the talented technical staff at this Laboratory. Physics Division staff are playing key roles in the following projects.

LDRD-Directed Research projects

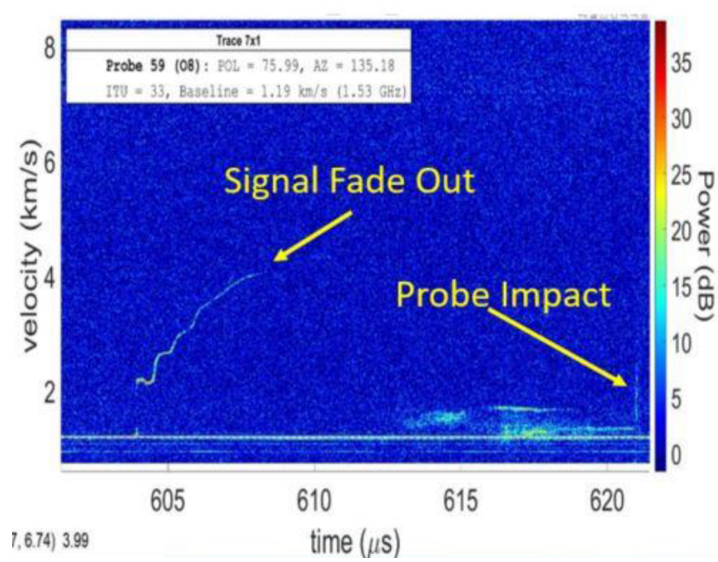
Laser-based x-ray radiographic imaging for weapons science and applications

Principal investigator: Brian Albright (XTD Primary Physics, XTD-PRI); Co-principal investigators: Sasikumar Palaniyappan (Thermonuclear Plasma Physics, P-4) and James Hunter (Non-destructive Testing and Evaluation, E-6)

This project seeks to develop novel x-ray sources based on high-power short-pulse lasers with unique advantages, including small spot size, flexible configuration, and tailorable spectra. This will allow the Lab to deploy flexible, compact x-ray sources for static tomographic radiography and dynamic multi-axis radiography at its firing sites and facilities such as the Proton Radiography Facility and the Nevada National Security Site's U1a complex. The higher resolution, shorter pulse duration, and tunability of its proposed sources will enable new applications in the weapons program and broader scientific community. This effort applies unique LANL expertise and capability in high-power laser-plasma interaction science, radiography, numerical modeling, and target fabrication. The work supports the Weapon Systems and Nuclear and Particle Futures science pillars.



Radiography of test object from Microtron beam (left) and Trident laser-based x-ray sources (right), showing the improved resolution possible with a laser-based source, with its much smaller x-ray spot size (<100μm).



Determining the causes of multiplexed photonic Doppler velocimetry signal loss during a dynamic experiment

Principal investigator: Gregg Sullivan (DARHT Experiments and Diagnostics, J-4); Co-principal investigators: Phillip Miller (Focused Experiments, M-3) and Patrick Younk (Dynamic Imaging and Radiography, P-1)

In this project, the researchers are investigating the mechanisms of data loss in certain weapon experiments. The image above is an example of data loss relevant to the problem. The team will pursue several lines of investigation to better understand the data loss phenomenon and how best to mitigate its effects. While the proposed ideas are at a low technical readiness level, they may have significant impact on how weapon systems are experimentally underwritten in the future. The work supports the Weapon Systems science pillar.

continued on next page

LDRD new starts cont.

LDRD-Exploratory Research projects

Time-resolved ion temperature of burning plasmas with multi-puck array

Principal investigator: Kevin Meaney (P-4); Co-principal investigators: Yongho Kim (P-4) and Nels Hoffman (Plasma Theory and Applications, XCP-6)

A burning plasma driven by inertial confinement fusion offers a laboratory-made thermonuclear condition for the first time where the alpha particles created by the deuterium-tritium (DT) fusion reactions are the primary source of heating in the plasma. Achieving a burning plasma condition is necessary toward self-sustaining fusion energy. Thermal ion temperature is highly sensitive to the energy deposition of the alpha particles. The researchers propose to extract the time-resolved ion temperature by differentiating temporal reaction histories of two DT fusion products: 14-MeV neutrons and 16-MeV gamma rays. The way in which the ion temperature evolves affects the energy distribution of fusion neutrons, which broaden due to the thermal-Doppler effect. The broadening of neutron energy at various detection locations allows inference of how the ion temperature changes through the fusion burn. A new concept will be tested by coupling P-4's existing gamma ray diagnostics with an additional array of multiple neutron-to-gamma converters (i.e., pucks). With successful fielding of the multi-puck array diagnostic, specific physics-focused experiments investigating the effect on burning plasma cooling due to the mix of high Z material will be performed at the OMEGA laser facility. Time-resolved information of the ion temperature could provide a unique and constraining observable to be used for deeper understanding of burning plasma and benchmarking Los Alamos's numerical simulations. The work is part the LDRD "High energy density, plasma, fluids, and beams" technical category, which concentrates on understanding the physics and applications of high-energy-density matter, plasma, warm dense matter, accelerators and particle beams, and fluids.

The decay of nature's rarest isotope

Principal investigator: Ralph Massarczyk (P-1); Co-principal investigator: Samuel Meijer (P-1)

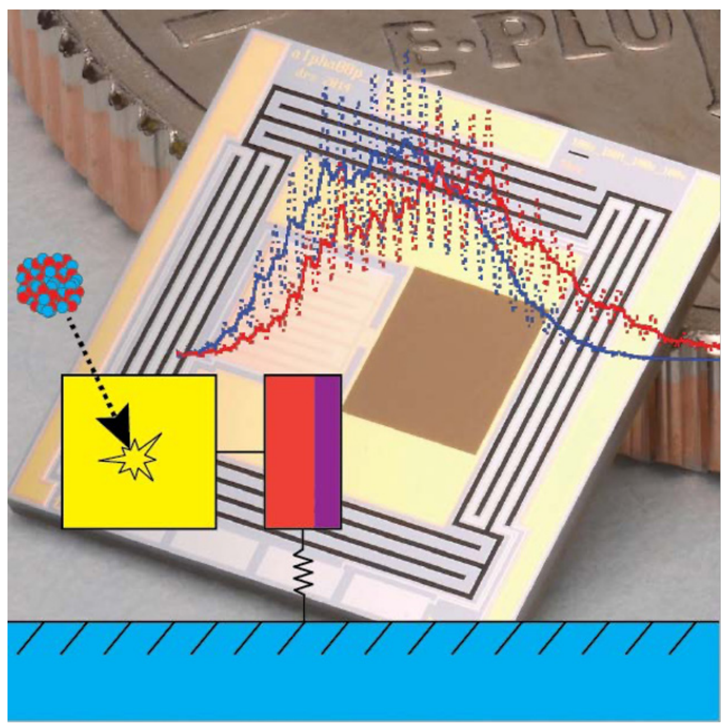
In this project the researchers plan to measure the decay of one tantalum isotope—specifically, the decay of its isomeric state 180mTa. The challenge is tantalum is one of the rarer elements—and the isotope 180 is found only in traces in naturally occurring isotopes. The decay is not yet observed. It is the only known unobserved metastable transition and has attracted attention for decades. Needed to measure this decay are not only a significant amount of material but also expertise and possibilities in ultralow background counting. With LDRD's help, the researchers used the unique opportunity to install samples in one of the cleanest experiments worldwide previously used for double-beta decay research. An observation will demonstrate the limits for the ability to make ultralow background radioassay measurements as well as provide an interesting measurement of a nuclear extreme.

The work is part of the LDRD "Quark to the cosmos" technical area. This area explores underlying physics that governs the behavior and properties of the universe, from the smallest-scale constituents of matter and their interactions to the largest physical systems in the universe, attacking problems at the forefront of nuclear physics, particle physics, astrophysics, and cosmology, and the application of knowledge gained through these disciplines to broad-ranging challenges in fundamental and applied science.

Fission fragment spectroscopy beyond the 1 atomic mass unit

Principal investigator: Matthew Carpenter (Safeguards Science and Technology, NEN-1); Co-principal investigator: Jack Winkelbauer (Nuclear and Particle Physics and Applications, P-3)

Making precise measurements of the neutron-induced fission process is challenging and high-quality data are scarce, despite being critical to LANL's stockpile stewardship mission. This project will apply state-of-the-art microcalorimeter detector technology to directly probe fission observables for the first time. The objective is to develop a windowless fission fragment detector system, potentially capable of <0.1% energy resolution. LANL is a world leader in microcalorimeter detector technology and fission science. Leveraging this expertise the team aims to combine these fields to create a pioneering nuclear data measurement capability. The work supports the LDRD "Quark to the cosmos" technical area.



A illustration depicting the concept behind a windowless fission fragment detector system, a novel device that will revolutionize the collection of neutron-induced fission measurements.

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LDRD new starts cont.

High depth-of-field proton radiography

Principal investigator: Fesseha Mariam (P-1); Co-principal investigators: Joshua Tybo and Matthew Freeman (both P-1)

This project will develop a new achromatic lens imaging system that aims to dramatically increase the range of energy losses over which a high-resolution set of dynamic images can be created using proton radiography. This will effectively allow for imaging not only objects that are much thicker but also with greatly varied areal densities, unlocking a new class of experiments that expands that range of mid-scale experiments to more closely approach those of the Dual-Axis Radiography Hydrodynamic Test Facility and filling a gap in the capability that presently exists in mid-scale experimental work. This work will be done, at scale, using 30-MeV electrons at the Idaho Accelerator Center, providing a blueprint and set of expectations for lens performance using 800-MeV protons at the Los Alamos Neutron Science Center, and ultimately providing a set of tools more capable of validating the enhanced simulations powering new weapons designs. The work supports the LDRD "Quark to the cosmos" technical area. ■

Inclusivity tip

Take a minute to update your email signature to include your personal pronouns. This is a simple and easy way to make everyone feel comfortable and included. For the template and updates, visit the Lab's template downloads page.

Celebrating service

Congratulations to the following Physics Division employees that recently celebrated service anniversaries:

Christopher Morris, P-1	45 years
Hanna Makaruk, P-2	25 years
Michael Mocko, P-2	15 years
Matt Durham, P-3	10 years
Elena Guardincerri, P-3	10 years
Kun Liu, P-3	10 years
Shea Mosby, P-3	10 years
Thomas Weber, P-4	10 years
Andrew Chavez, P-2	5 years
Christopher O'Shaughnessy, P-3	5 years
Christopher Prokop, P-3	5 years
Alexander Rasmus, P-2	5 years
Benjamin Tobias, P-2	5 years

HeadsUP!

Returning administrative keys

A worker must return all administrative (Level IV with a LANL series number) keys to the appropriate lock and key custodian when he or she no longer requires use of the key (e.g., when transferring to a new organization or a new office, retirement).

When an administrative key is returned to the appropriate lock and key custodian, its status will change from issued to received and an email receipt will be sent to the individual returning the key.

Another option is to return the key to the lock and key office, located in TA-3, Building 0495. After a team member receives the key, he or she will contact the appropriate custodian for the key "series." The key will remain assigned to the individual until the custodian physically receives it and updates the status from issued to received.

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For past issues, see www.lanl.gov/org/ddste/aldps/physics/physics-flash-archive.php.

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