PhysicsFlash

March 2019
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INSIDE

Los Alamos NATIONAL LABORATORY EST. 1943

Physics Deputy Division Leader Eric Pitcher (left) and Ralph Massarczyk (Neutron Science and Technology, P-23) examine lead bricks that help shield a neutrino detector from background signals. Smelted in the 1800s for the Boston sewer system, this lead is a better buffer than newly smelted lead because it has already given off most of the decay products that the detector could register. The germanium-based detector, located underground to block out interference from solar radiation, is expected to run for approximately 10 years in order to detect a single neutrino event. Photo by Carlos Trujillo, XIT-TSS

Eric Pitcher

Engineering a strong, vibrant future for Physics Division

By Madeline Bolding, ALDPS Communications

> *"So far it's really been an eye-opening experience. After 36 years, I'm just going to some of these (experimental) sites for the first time."*

Eric Pitcher has a long and varied history with Los Alamos National Laboratory, having been everything from a student to, just recently, a Physics Division group leader. But it's stepping out of his focus on spallation neutron sources to engage with the broader Physics community that has him excited about his new role as deputy division leader.

"So far it's really been an eye-opening experience. After 36 years, I'm just going to some of these (experimental) sites for the first time," he said, listing off the wide-ranging facilities he has visited as part of getting to know the division staff and their work.

Pitcher considers himself a New Mexico "almost-native," having spent much of his childhood in Albuquerque and

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"If you know of a meeting that you think would be beneficial for me to attend, please let me know. I won't be able to go to everything, but will get to as many as I can."

David

From David's desk . . .

We are having a real winter for the first time since I moved to Los Alamos: my wife and I have been enjoying snowshoeing. Of course, winter brings its challenges, including dangerous walking and driving conditions. Please take it slowly and carefully and be aware of your surroundings. And as Mel Borrego (LANSCE Weapons Physics P-27) would say, "Heads up, devices down." It was Mel who suggested the P-WSST project, in collaboration with the TA-53 WSST, to have reminders of just that painted at crosswalks across TA-53.

In my previous job, I typically traveled 2-3 times per month. While I travel less now, there are still times that is it important that I do. My job is to support the work of Physics Division and the Laboratory. For example, I was in Washington D.C. attending the DOE High Energy Physics (HEP) Budget Review in February. This is where LANL presents its recent HEP accomplishments and its plans for the future. We discuss the impact of budget options that DOE has provided us and overtarget requests. If time permits, I meet with some of the DOE program managers, in part, to make sure that we are delivering what they need. I will be at Lawrence Livermore National Laboratory this month as a member of the National Ignition Facility (NIF) Peer Review Panel. The panel provides feedback on inertial confinement fusion/high-energy-density experiments that are proposed for upcoming shots, including those proposed by LANL.

The other reason that I travel is that the division does a lot of offsite work. It is important to me to visit the places where we work and understand what we are doing there. Over time, I expect to visit most of our domestic sites. It is a little harder to justify overseas visits to just understand what we do, but if I can do them as part of some other travel, I will. I plan to visit our team stationed at NIF this month and hope to spend a day at Fermilab in May. I will also go back to the Nevada Nuclear Security Site when we are setting up for the Red Sage/Nightshade experiments—I may also try to be there on shot day. I attend, as I am able, collaboration meetings and conferences where we have significant attendance. If you know of a meeting that you think would be beneficial for me to attend, please let me know. I won't be able to go to everything, but will get to as many as I can.

The division is all about its people. In the last *Physics Flash* I talked about appointing Eric Pitcher as my deputy. In this issue you can read a little more about him (page 1). Our latest award winner is Young Jin Kim (Applied Modern Physics, P-21), who has been selected as the recipient of the 2019 Outstanding Young Research Award by the Association of Korean Physicists in America (page 3). Congratulations! Finally, I congratulate Eric Larson (P-27) for 35 years of service at LANL. It is remarkable. I was glad to be able to find his out-of-the-way office to congratulate him in person.

Physics Division Leader David Meyerhofer

Pitcher cont.

falling in love with the state's climate, expansive views, and outdoor activities. He joined the Laboratory as a student and returned as a University of Michigan graduate student to perform research at the Los Alamos Neutron Science Center (LANSCE). He has been a staff scientist designing spallation sources at the Lujan Center, a deputy group leader in Theoretical Division, and was project manager for the Materials Test Station at LANSCE. Following four years at the European Spallation Source in Sweden, Pitcher returned in 2017 to become LANSCE Weapons Physics (P-27) group leader. In October Physics Division Leader David Meyerhofer named him his deputy.

Pitcher admitted that his background as a nuclear engineer is a bit unusual for the position. Historically the deputy division leader has been someone with training as a physicist. But he said he thinks his experience in a gamut of positions at the Lab will help him help Physics staff in all stages of their careers. "Having been through many of these positions I think gives me a perspective on the struggles at each level, but also the opportunities," he said. "I hope I can empathize with their challenges, support them in their goals, and give guidance when necessary."

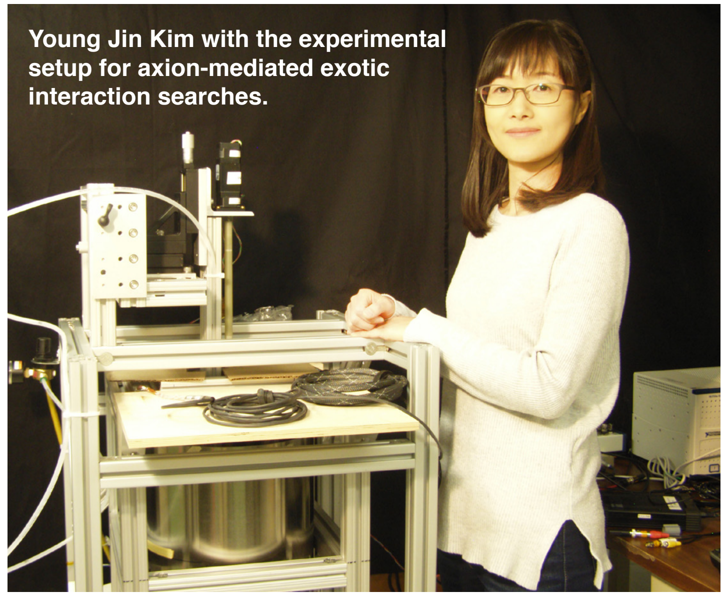
"Eric's broad background complements my own," Meyerhofer said. "I am looking forward to working with Eric to continue to keep Physics Division a scientific leader at Los Alamos and in the broader community."

In his deputy division leader role, Pitcher is helping to bring new capabilities to the Lab—a job for which he's well prepared. At the European Spallation Source, he served as head of the Target Division, managing a team working on the design, construction, and commissioning of a 160M€ target station aimed at being the world's most powerful neutron source. As project manager for the effort to build the Materials Test Station at LANSCE, he led work to construct a facility designed to aid nuclear fuel recycling and support materials science capabilities.

Pitcher's sights are now set on helping define the MaRIE end-stations and equipment that will deliver the mesoscale materials science needed to support the Lab's national security mission. MaRIE is the Lab's proposed experimental facility concept for studying matter-radiation interactions in extremes and fulfilling the capability gap identified by DOE/NNSA for a dynamic mesoscale materials science capability (DMMSC). It will include an electron accelerator that creates coherent x-rays with experimental areas to probe materials at the spatial scale beyond the atomic, molecular, and nanoscale, where a material's structure strongly influences its macroscopic behaviors and properties.

Pitcher said he is hoping to help maintain and strengthen Physics programs that are already thriving at the Lab. Proton radiography (pRad) is an essential element of the Lab's research capabilities, he said, with the complementary nature of pRad and the Dual-Axis Radiographic Hydrodynamic Test Facility making Los Alamos a dynamic materials research powerhouse. To further these capabilities, he said he's looking forward to pRad restarting high-explosives-driven plutonium shots. He is also eager to gain a better understanding of how Physics Division can further support the weapons program.

Physics Division's expertise and capabilities already underpin the Lab's national security mission; Pitcher wants to reinforce that foundation.



Young Jin Kim with the experimental setup for axion-mediated exotic interaction searches.

Young Jin Kim to receive 2019 young researcher award

Young Jin Kim (Applied Modern Physics, P-21) has been selected for a 2019 Outstanding Young Researcher Award by the Association of Korean Physicists in America (AKPA). The award, presented annually since 1994, recognizes excellence in research by outstanding young ethnic Korean physicists in North America. Recipients are chosen for their scientific excellence and potential to become leaders in the scientific community through contributions to the field.
Kim was recognized for her efforts in precision magnetic measurements for fundamental and applied sciences based on highly sensitive state-of-the-art detectors, including superconducting quantum interference devices (SQUIDs), atomic magnetometers, and high-resolution conventional systems.

In P-21 Kim is in charge of two projects as principal investigator. One is the development and testing of a novel high-sensitivity 16-channel atomic magnetometer. The device

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Kim cont.

demonstrated field sensitivity comparable to that of state-of-the-art commercial atomic magnetometers, but with anticipated 10-fold cost reduction, which can lead to revolutionary applications in magneto-encephalography. The other project is the new investigation of axion-mediated exotic spin-dependent interactions with atomic magnetometers. Her recent paper reported a first-ever experimental limit on a spin- and velocity-dependent axion-mediated interaction (*Phys. Rev. Lett.*, 121, 091802 [2018]).

She received her PhD in physics in 2011 from Indiana University at Bloomington and joined Los Alamos as a postdoctoral researcher in 2012 working on projects focused on the detection of ultra-small magnetic signals, including searching for the neutron electric dipole moment, detecting solid explosives using a nuclear quadrupole resonance, and developing an ultra-sensitive magnetic microscope.

She will receive the award at two ceremonies during the joint Korean Physical Society-AKPA symposium at Harvard University and the American Physical Society Forum of International Physics reception at the Boston Convention Center this month.

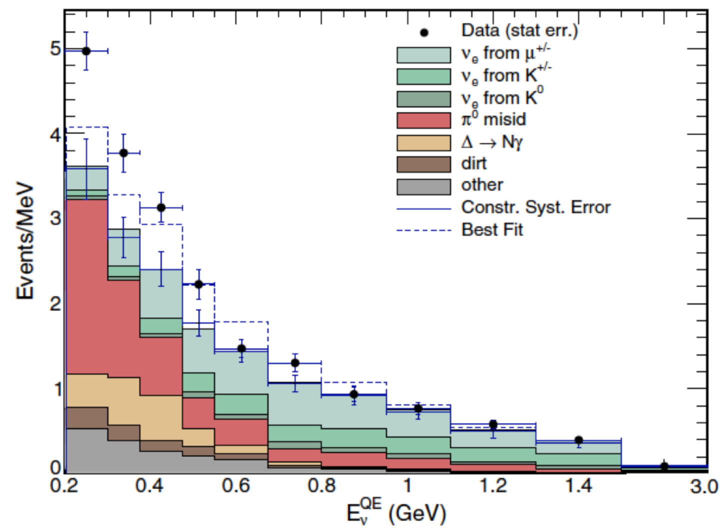
Technical contact: Young Jin Kim

MiniBooNE delivers evidence supporting "sterile" neutrinos

Recent results from the MiniBooNE experiment, an international physics collaboration that includes Los Alamos scientists, suggest that a fourth type of neutrino, a "sterile" neutrino, may exist. If found to exist, this neutrino would be a new fundamental subatomic particle of nature and would introduce new physics beyond the Standard Model.

The current Standard Model of physics states that there are three types, or "flavors," of neutrinos—electron, muon, and tau neutrinos—which convert, or oscillate, among each other. However, the new data from MiniBooNE show a significant excess of electron-flavor neutrinos and their counterpart, electron antineutrinos, that is more than simulations based on the Standard Model can explain.

MiniBooNE, an experiment located at Fermilab and designed to observe the oscillations of neutrinos, starts with a high-intensity beam of accelerated protons that are shot at a target, producing copious amounts of pions, subatomic particles that decay into muons and muon neutrinos. This beam of muon neutrinos travels until it hits the detector—a spherical tank filled with more than 800 tons of mineral oil. It has been collecting data since 2002. In the MiniBooNE setup, the researchers knew how many muon neutrinos they started with, but at low energy levels they found more electron neutrinos than they expected to find based on the Standard Model.



Researchers conducted Monte Carlo-based simulations based on the Standard Model to estimate the level of signal they would detect from a number of sources, including true signal from electron neutrinos (ν_e), misidentified neutrinos, background levels from dirt, and more. These simulation data are shown in colored bars. The data from MiniBooNE are shown as dots with error bars. Especially at lower energy levels, the signal from MiniBooNE was much higher than the simulations based on the Standard Model were able to predict.

One of the first measurements of this unexpected gap in the Standard Model came from the Liquid Scintillator Neutrino Detector (LSND) at Los Alamos in the late 1990s. Data from LSND and MiniBooNE, are consistent even though they used different experimental setups.

One theory that could explain this excess of electron-flavor neutrinos would be the existence of an unmeasurable particle that is then converted into electron neutrinos. In this scenario, at the upstream point of the experiment the new particle would be produced and would be unseen, but after traveling 540 m to the detector they would have oscillated into electron neutrinos, thus causing an "appearance" of electron neutrinos. Therefore, these data support a hypothesis of the existence of a fourth, unmeasurable flavor—a sterile neutrino, so-named because it doesn't interact with ordinary matter.

Other experiments are underway that could confirm the existence of sterile neutrinos. There are several reactor-based setups and another accelerator-based experiment under construction at Los Alamos. This experiment, known as the Coherent-Captain-Mills (CCM), takes advantage of the pions produced at the Lab's Lujan Center using the Los Alamos Neutron Science Center's linear accelerator. Like MiniBooNE, CCM will use pion decay into muon neutrinos as a source, but unlike MiniBooNE it will search for muon neutrino disappearance as a function of the distance between the source and the argon-filled detector.

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MiniBooNE cont.

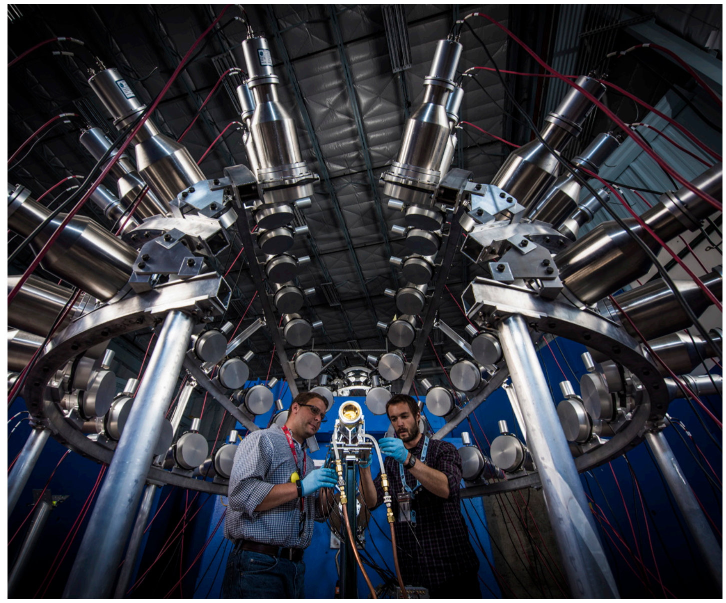
While a few alternative hypotheses could explain the results of LSND and MiniBooNE, ongoing experiments like CCM will help address these possibilities.

The MiniBooNE team includes researchers from 19 institutions. The Lab has contributed leadership to the MiniBooNE project: William Louis and Richard Van de Water (Subatomic Physics, P-25) have each served as co-spokespersons for the experiment at different times. Los Alamos contributed to building MiniBooNE: most of the phototubes and electronics are from the deconstructed LSND.

The work supports the Lab's Fundamental Science mission area and its Nuclear and Particle Futures science pillar by investigating the nature of the universe and developing the expertise and capabilities required for the Lab's national security mission. Funding came from Los Alamos Laboratory Directed Research and Development funds, Fermilab, the Department of Energy, and the National Science Foundation. Reference: "Significant excess of electron-like events in the MiniBooNE Short-Baseline Neutrino Experiment," *Phys. Rev. Letters* 121, 221801 (2018).

Researchers: A. A. Aguilar-Arevalo (Universidad Nacional Autónoma de México), B. C. Brown (Fermi National Accelerator Laboratory, Fermilab), L. Bugel (Massachusetts Institute of Technology, MIT), G. Cheng (Columbia University, Columbia), J. M. Conrad (MIT), R. L. Cooper (P-25, New Mexico State University), R. Dharmapalan (University of Alabama, UA, Argonne National Laboratory, ANL), A. Diaz (MIT), Z. Djurcic (ANL), D. A. Finley (Fermilab), R. Ford (Fermilab), F. G. Garcia (Fermilab), G. T. Garvey (P-25), J. Grange (University of Florida, UF), E.-C. Huang (P-25), W. Huelsnitz, P-25), C. Ignarra (MIT), R. A. Johnson (University of Cincinnati, UC), G. Karagiorgi (Columbia), T. Katori (MIT, Queen Mary University), T. Kobilarcik (Fermilab), W. C. Louis (P-25), C. Mariani (Virginia Tech), W. Marsh (Fermilab), G. B. Mills (LANL, deceased), J. Mirabal (Neutron Science and Technology, P-23), J. Monroe (University of London), C. D. Moore (Fermilab), J. Mousseau (University of Michigan, U-M), P. Nienaber (Saint Mary's University of Minnesota), J. Nowak (Lancaster University), B. Osmanov (UF), Z. Pavlovic (Fermilab), D. Perevalov (Fermilab), H. Ray (UF), B. P. Roe (U-M), A. D. Russell (Fermilab), M. H. Shaevitz (Columbia), J. Spitz (U-M), I. Stancu (UA), R. Tayloe (Indiana University), R. T. Thornton (P-25), M. Tzanov (University of Colorado Boulder, CU Boulder, Louisiana State University), R. G. Van de Water (P-25), D. H. White (LANL, deceased), D. A. Wickremasinghe (UC), and E. D. Zimmerman (CU Boulder).

Technical contact: W. C. Louis



The Chi-Nu project is measuring the spectra of neutrons emitted from the neutron-induced fission of plutonium and uranium with emphasis on the low-energy and high-energy portions of the spectrum.

Chi-Nu measurements obtain prompt fission neutron spectra for uranium-235 and plutonium-239

Accurate nuclear data on neutron-induced fission form the basis of criticality calculations essential for nuclear weapons and power plants. The energy spectra of neutrons produced in neutron-induced fission reactions, known as prompt fission neutron spectra (PFNS), are a significant contributor to reactivity in such systems. The NNSA supports an effort at the Los Alamos Neutron Science Center (LANSCE) to improve these experimental data. This work, called the Chi-Nu project, has been seeking data from the neutron-induced fission of both uranium-235 and plutonium-239.

The project reached an NNSA level two milestone when researchers at Los Alamos and Lawrence Livermore National Laboratory made clear observations of two neutron spectral features from nuclear fission. These features—multi-chance fission and pre-equilibrium, pre-fission neutron emission—were either poorly understood or were never before observed in the fission neutron spectrum.

Multi-chance fission implies that one or more neutrons were emitted after equilibrating with the target nucleus but prior to nuclear fission, thereby altering the identity of the nucleus undergoing fission as well as the energy spectrum of neutrons associated with the fission event. Significant differences in the probability of different multi-chance fission modes were observed between the uranium-235 and plutonium-239 systems, which were contrary to fission model predictions in

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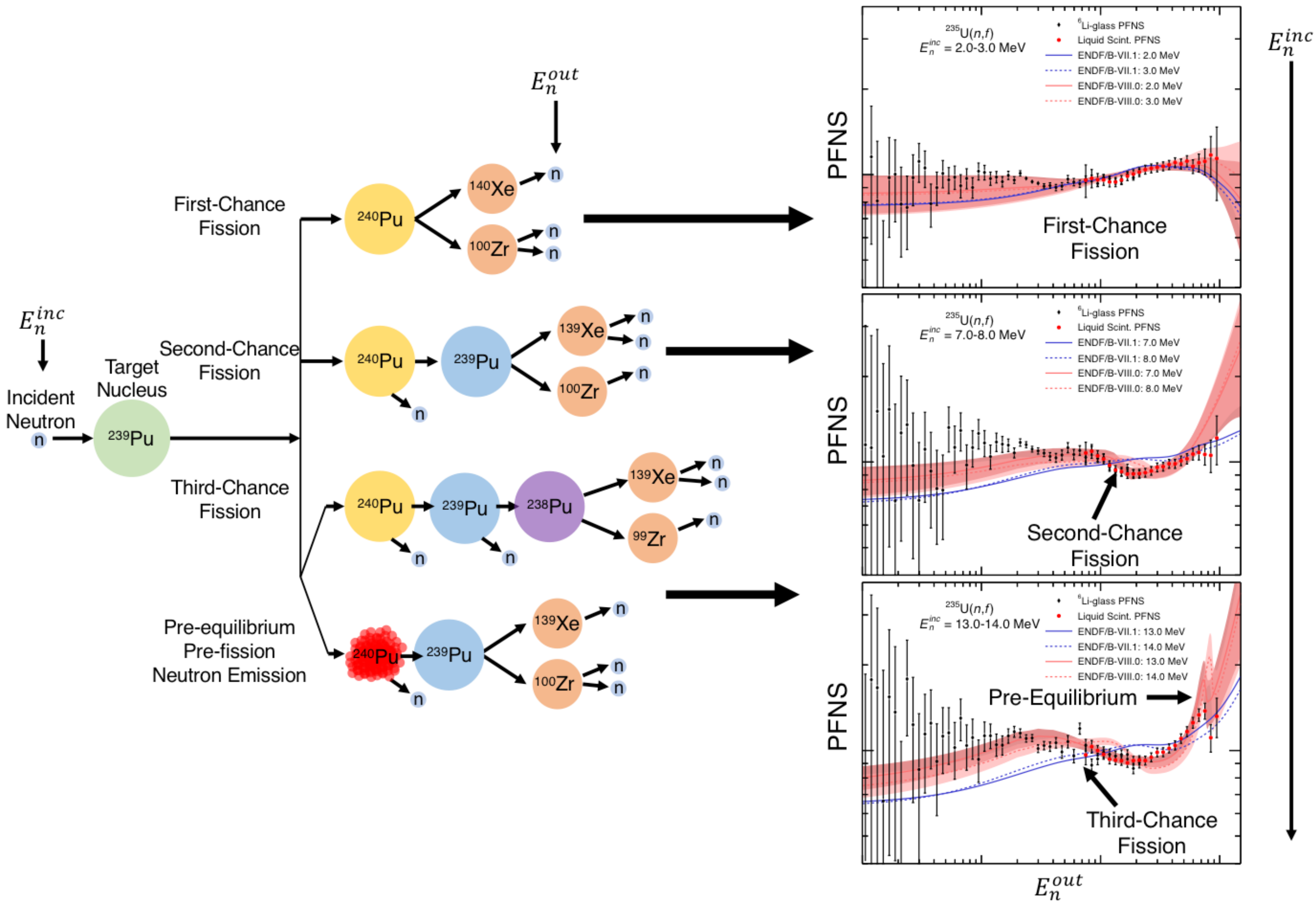
Chi-Nu cont.



some cases. Pre-equilibrium, pre-fission neutron emission occurs in more energetic systems and changes the emitted neutron spectrum from fission as a function of detection angle. Neither this process nor its angle dependence had been observed for the neutron-induced fission of plutonium-239 and there were sparse data on this feature for uranium-235 before Chi-Nu.

The results, which were made possible after the team developed new tools to properly interpret the measured neutron spectra reduce uncertainties in calculations of fast nuclear systems, help guide future evaluations of prompt fission neutron spectrum data, and shed light on some poorly-understood features of nuclear fission.

The Chi-Nu team collected data using a two-arm time-of-flight technique. Fission events were detected with a parallel-plate avalanche counter, and the time difference between fission and incoming neutron creation times yielded the incoming neutron energy. Neutrons were detected in either a lithium-6 glass or liquid scintillator detector to measure low- and high-energy neutrons. The time difference between neutron detection and fission times yielded the outgoing fission neutron energy.

Despite the differences in behavior and detection mechanism of these two detectors, the Chi-Nu team was able to combine data from each detector type to form a single measurement of the prompt fission neutron spectra from uranium-235 and plutonium-239 spanning the largest outgoing neutron energy range ever measured in a single experiment.

This research was funded by the Primary Assessment Technologies science campaign. It supports the Lab's Nuclear Deterrence mission area and the Nuclear and Particle Futures science pillar by reducing the uncertainties of key data used to predict nuclear performance. Ultimately, the research will provide a firm foundation of prompt fission neutron data to better certify the stockpile.

Researchers: M. Devlin, K. J. Kelly, J. A. Gomez, R. C. Haight, J. M. O'Donnell, and T. N. Taddeucci (LANSCE Weapons Physics, P-27); D. Neudecker, M. C. White (Materials and Physical Data, XCP-5); C. Y. Wu, J. Henderson, R. A. Henderson, M. Q. Buckner, B. Bucher (LLNL).

Technical contact: Matt Devlin

First comprehensive experimental study of ion heating in collisional plasma shocks and plasma flows

Data will test improved astrophysical plasma, HED, and ICF models

Shocks are a fundamental feature of supersonic plasma flows, affecting the energy balance and dynamical evolution of physical systems in which the shocks are embedded.

Understanding the physics in such phenomena is essential for studies of astrophysical systems or in high-energy-density (HED) and inertial confinement fusion (ICF) experiments. Plasma shocks are complex as they feature multiple interactions of particles, magnetic fields, and other physics phenomena.

In *Physical Review Letters* and in an invited talk at the 60th annual meeting of the American Physical Society Division of Plasma Physics, Plasma Physics (P-24) researchers and external collaborators presented the first detailed study of the time evolution of ion temperature and ion heating due to unmagnetized collisional plasma shocks and interpenetrating supersonic plasma flows.

Using the Plasma Liner Experiment (PLX) at Los Alamos National Laboratory, the researchers obtained detailed data enabling comparison with theory and simulation across a range of regimes. These new fundamental data are valuable for validating and improving first-principles modeling of these phenomena and represent a crucial advance for modeling HED and ICF experiments and a range of astrophysical plasmas.

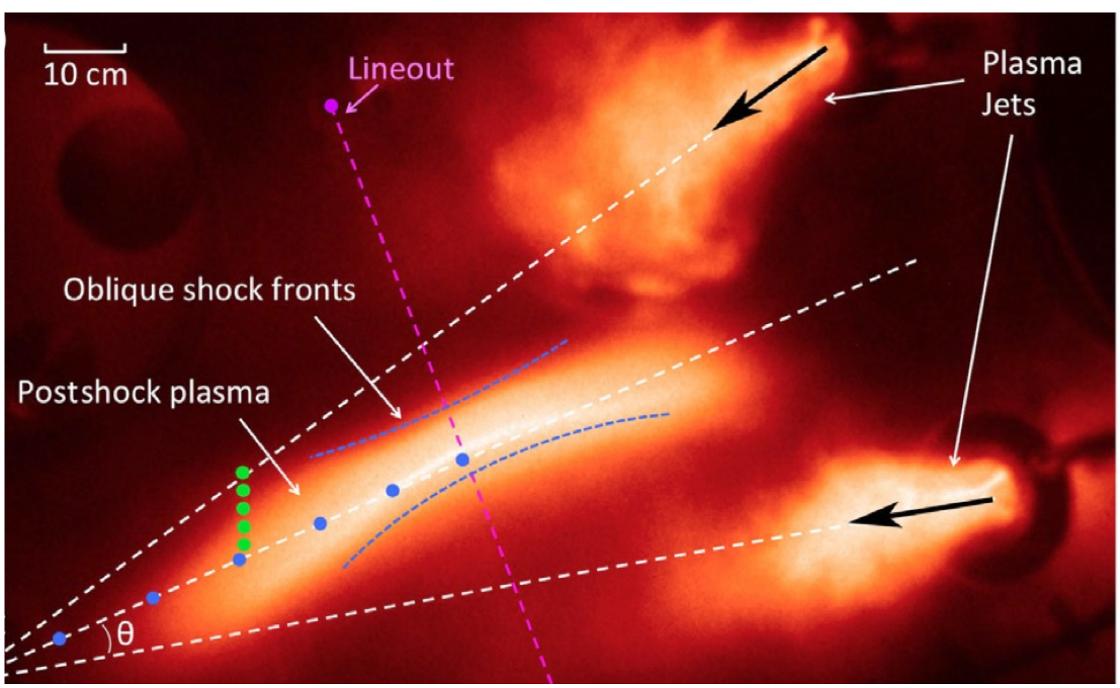
Using the PLX, where six coaxial plasma guns are mounted on a spherical vacuum chamber, the researchers fired two guns at a given time to obliquely merge and form collisional plasma shocks and interpenetrating supersonic plasma flows.

Their data indicate that regardless of the amount of interpenetration (small or large), the ion temperature is much greater than the electron temperature; indicating that the predominant heating goes to the ions. The experiment validates theoretical predictions in conditions of small interpenetration between jets. When interpenetration between jets is significant, shocks do not apparently form, and the observed ion temperature peak is lower than predicted by collisional plasma shock theory. Additional physics such as multi-fluid or kinetic plasma physics must be included, and the data will be particularly valuable for testing and validating those models. An important example where this situation arises is in the laser-ablated plasma streams within the hohlraum of inertial fusion targets.

Reference: “Experimental measurements of ion heating in collisional plasma shocks and interpenetrating supersonic plasma flows,” *Phys. Rev. Lett.,* 121, 185001 (2018). Participants are Samuel Langendorf (P-24), Kevin Yates (University of New Mexico, UNM, and P-24), Scott Hsu (P-24), Carsten Thoma (Voss Scientific), and Mark Gilmore (UNM).

The work, which supports the Laboratory’s Energy Security mission and Nuclear and Particle Futures science pillar, was funded by the DOE Office of Fusion Energy Sciences and the Advanced Research Projects Agency–Energy.

Technical contact Samuel J. Langendorf



Fast-camera, visible-light image of two merging argon plasma jets, showing the formation of oblique, collisional plasma shocks.

All mixed up: a review of Los Alamos's capabilities to study variable-density mixing

Many natural and manmade systems have materials of different densities that mix with each other: atmospheres, oceans, stars, industrial processes, and one example pertinent to energy security—inertial confinement fusion systems. A recent invited review article by Kathy Prestridge (Neutron Science and Technology, P-23) published in *Physical Review Fluids* highlights Laboratory research studying variable-density mixing in a wide range of flow regimes.

"Experimental adventures in variable-density mixing" surveyed experiments conducted at Los Alamos National Laboratory focusing on understanding mixing in difficult environments, including shock-driven mixing, subsonic mixing, and high-energy-density (HED) plasma mixing. These laboratory-based experiments are designed to simplify some of the complex multiphysics that occurs in stars, such as chemical and thermonuclear reactions, turbulent mixing, and HED plasma physics. By designing experiments that are scaled down from the complex problems, experimentalists are able to make more precise measurements of the particular flow they are studying.

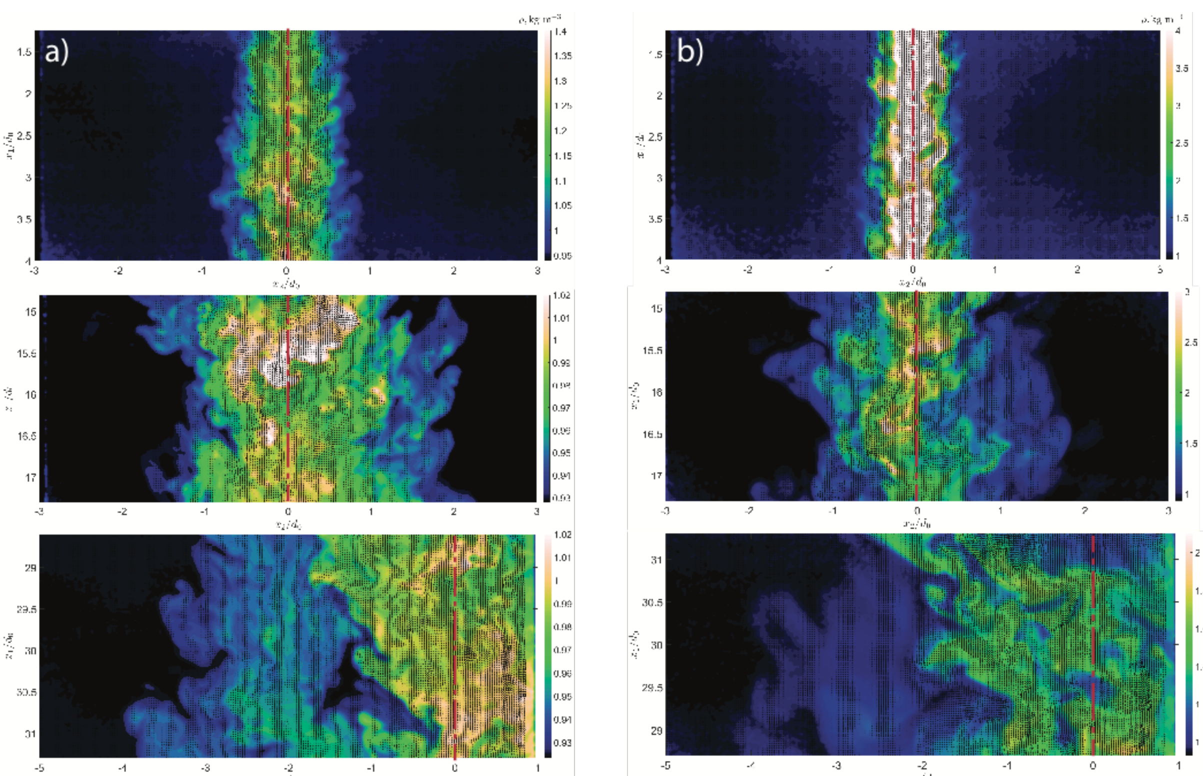
Precise measurements inform physics models of flows with large density differences between the mixing materials. Large density differences (non-Boussinesq) mean that the materials behave differently than canonical mixing approximations, based upon small density differences, would suggest. In the experiments, the density ratios between the mixing fluids are at least two, making them well outside regimes covered by the Boussinesq approximation. In these mixtures, Los Alamos researchers have found time-dependent mixing phenomena, asymmetries in mixing and distribution of turbulent kinetic energy, and interscale energy transfer driven by the mean flow that moves energy from small to large scales via eddy stretching.

Prestridge's article discussed the capabilities of several of the Laboratory's custom tools, including the Turbulent Mixing Tunnel and the Vertical Shock Tube as well as diagnostics such as particle image velocimetry and planar laser-induced fluorescence. The article discussed meaningful collaborations with colleagues studying turbulence modeling and performing validation studies. She called out challenges within the field and areas in need of further study.

This invited publication is a result Prestridge's plenary talk at the 70th annual meeting of the American Physical Society Division of Fluid Dynamics (DFD) in Denver. Prestridge's work earned her the first invited talk from either LANL or Lawrence Livermore National Laboratory at a DFD meeting, and the journal's editors selected it for inclusion in *Physical Review Fluids.*

Reference: "Experimental adventures in variable-density mixing," by K. Prestridge, *Physical Review Fluids* 3(11), 110501, 2018. Prestridge's work is supported by Science Campaign 4 (LANL Program Manager Melissa Douglas), and the HED experiments are supported by the ICF Program (LANL Program Manager John Kline).

Technical contact: Kathy Prestridge



Velocity and density fields at various downstream locations for (a) air jet and (b) SF_6 jet.

HeadsUP!

Safety campaign reminds workers to stow devices when walking

To ensure employees remain mindful of their surroundings—and not their electronic devices—while walking, workers at TA-53, the Los Alamos Neutron Science Center (LANSCE) mesa, have adopted a campaign known as "Heads Up. Devices Down."

Warnings, aimed at those walkers who have their heads down looking at their devices instead of paying attention to oncoming traffic, were painted on either ends of crosswalks around LANSCE. The goal is to remind walkers to stay safe and watch what they are doing, particularly near moving vehicles.

With thousands of reports of accidents—including fatal ones—in the United States involving people distracted by their mobile devices, Physics Division, in collaboration with the TA-53 Worker Safety and Security Team (WSST), is doing its part to try to alleviate potential incidents in that area.

Mel Borrego (LANSCE Weapons Physics, P-27) got the idea for the campaign while at the Advanced Photon Source convention in Chicago last year when he noticed a painted image on the sidewalk reminding him to pay attention to his surroundings rather than his mobile device.

"I thought it was a great idea at the time, as my head was down and I was looking at my phone," he said.

After seeing the stencil on the sidewalk, he contacted Physics Division management to see if a similar program could be set up at TA-53. Now approximately 40 "Heads Up. Devices Down" reminders are painted at LANSCE.

"We have enough distractions," said Tracy Salazar (LANSCE Facility Operations, LANSCE-FO). "Reminders are really good."

Nationally, distracted walking is a serious problem. According to the Governors Highway Safety Association, nearly 6,000 pedestrians were struck and killed by motorists in 2017. The National Safety Council suggests walkers in any setting not use their mobile devices at all. The National Safety Council's website states that many distracted walking accidents occur in the home or in one's own neighborhood.

Contact Borrego or Salazar for more information on the "Heads Up. Devices Down" campaign.

Celebrating service

Congratulations to the following Physics Division employees recently celebrating service anniversaries:

Eric Larson, P-27 .... 35 years
Raymond Newell, P-21 .... 15 years
Heather Johns, P-24 .... 5 years
Daniel Poulson, P-25 .... 5 years

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Published by the Physical Sciences Directorate.

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