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Author(s): Fulton, Robert Douglas

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Nuclear and Particle Futures Pillar

Doug Fulton
Physics Division Leader

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Los Alamos is the premier laboratory in the USA for all-things nuclear

Capabilities are grounded in its LANSCE, DARHT, and Trident facilities, its leadership in critical assembly work (now in Nevada), and extensive capabilities in nuclear experiment, theory, and simulation.

The Nuclear and Particle Futures (N&PF) pillar is composed of 4 major themes* :

Nuclear Physics, Particle Physics, Astrophysics, and Cosmology (NPAC),
Applied Nuclear Science and Engineering (ANS&E),
High Energy Density Plasmas and Fluids (HEDP&F), and
Accelerators and Electrodynamics (A&E).

These four themes provide the underlying fundamental research and technological developments crucial to successfully advance:

Defense Programs weapons research,
the nuclear component of threat reduction, and
the pursuit of high priority fundamental research as identified in the strategic plans of Office of Science programs in Nuclear Physics, High Energy Physics, and Fusion Energy Sciences.

*Nuclear and Particle Futures (N&PF) Pillar LA-UR-13-28249

<http://www.lanl.gov/science-innovation/pillars/nuclear-particle-futures.php>

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Connections among the N&PF themes

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Slide 3

A&E research and facilities

- Radiography for hydrotests (DARHT)
 - Advanced cathode research
(high brightness with low emittance)
- Free Electron Lasers (AOT)
 - Naval Defense Applications
- Advanced accelerator architectures (AOT)
 - High gradient superconducting cavities
- **Advanced accelerators (Trident)**
 - **Short pulse laser driven plasmas**
 - **Neutron production for global security applications**

Accelerator and pulsed power expertise at LANL has resulted in the development of the best hydro facility in the world and will enable MaRIE.

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ANSE research and facilities

- **Proton radiography (pRad at LANSCE)**
 - Dynamic materials properties
 - High Explosives behaviors
- Isotope Production Facility
 - Isotopes for medical applications (^{82}Sr , ^{68}Ge , ^{32}Si)
- Weapons Neutron Research
 - Single Event Upset measurements
 - Fast neutron cross sections (100 keV – 800 MeV)
- Lujan
 - Cold neutron cross sections (subthermal – 500 keV)
 - Neutron radiography
- Advanced fuel cycle materials and design
- Muon Tomography for defense and global security applications
- NCERC (National Criticality Experiments Research Center) – located in the Device Assembly Facility at NNSS in Nevada
 - • Critical assembly machines plus radiation test objects

LANL combines ANSE leadership in theory, modeling, simulation, and experiment to impact stockpile stewardship, nuclear safeguards, nuclear forensics, nuclear safety, reactor design and fuel cycle, radiation therapy and medical applications, nuclear counter-terrorism, and treaty verification.

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HEDPF research and facilities

- Short pulse laser matter interactions (Trident)
 - Advanced acceleration mechanisms
 - Plasma / matter interactions
- **Inertial Confinement Fusion (Rochester and NIF)**
 - **Advanced diagnostics**
 - **Neutron Imaging**
 - Gamma Reaction History
 - Mix and burn
- High Energy Density Physics (Rochester, NIF, and Z)
 - Fundamental Turbulence research (Shock / Shear)
 - Radflow
 - Opacity
- Fluids (Shock Tube Lab at LANSCE)
 - Richtmyer-Meshkov instabilities
 - Fundamental turbulence research

LANL has excelled at developing new and unique diagnostics that are enabling a new era of high energy density physics, ignition, and fluid turbulence research.

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NPAC research and facilities

- Astrophysics research (RAPTOR)
- **Fundamental neutron research (UCN)**
 - Symmetry properties of weak interactions
 - Gamma / neutron spin correlations (np $\rightarrow$ d gamma, SNS)
 - Electron / neutron spin correlations (UCNA)
 - Anti-neutrino / neutron spin correlations (UCNB)
 - **Lifetime of the neutron (nTau)**
 - Electric dipole moment of the neutron (nEDM)
- Fundamental neutrino research (Fermilab & Sanford Underground Research Facility)
 - Is the neutrino its own anti-particle (Majorana)
 - Neutrino properties (Mini- & Micro-BooNE & LBNE)
- Heavy Ion research (RHIC / Brookhaven and Fermilab)
 - Quark Gluon Plasmas (PHENIX / FVTX)
 - Spin Physics

Expertise in medium energy nuclear physics led to pRad and muon tomography
Current work at UCN is leading to new techniques to investigate actinide sputtering

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Backup

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Record neutron-beam production with laser-driven deuterium beam @ LANL Trident laser facility*

- Operating principle:**
 - D-beam irradiates Be converter
 - D ion impact on Be nuclei → neutrons
- Neutron beam performance**
 - Adjustable with laser intensity**
 - Intense:** $\sim 5 \times 10^{10}$ n, short duration ($\sim$ ns), narrow cone ($\sim$ 1 steradian)
 - Energetic:** 5 – 150 MeV (peak @ 10-70 MeV) depending on laser intensity
- Possible applications**
 - Defense programs: $\sim$ ns probe in dynamic experiments
 - Homeland security (active interrogation): – detected shielded U238 by observing delayed fission neutrons @ Trident
 - Transient dynamics in material damage at ultrahigh fluence [$\sim 100/\mu\text{m}^2$]

Concept

Setup

*M. Roth et al., *PRL* **110**, 044802 (2013); D. Jung et al., *Phys. Plasmas* **20**, 056706 (2013); highlighted in Nature, APS, Physics World & LANL press release 6/4/2013

Proton Radiography makes high resolution, multiple frame, dynamic flash radiographic “movies”

Magnetic lenses focus pulses of high energy protons from the LANSCE accelerator to produce images.

An array of cameras collects the many (up to 43, limited only by the number of cameras) dynamic images.

Time (~1 microsecond spacing)

Multiframe flash radiography enables the investigation of time-dependent processes such as Richtmyer-Meschkov Instability growth, shown here. (W. T. Buttler)

The Neutron Imaging System at NIF provides PINEX like measurements of ICF experiments.

Neutron Imaging System at NIF

Image collection system in the NI annex at NIF

N130710 ("high-foot" experiment)

Hot Spot

Cold Fuel

14 MeV neutrons are used to form images of the hot spot region with ~ 10 micron resolution at yields of 10^{14} neutrons.

Some 14 MeV neutrons ($\sim 5\%$) scatter in the cold fuel, losing energy in the scattering process.

These low energy neutrons arrive ~ 50 ns later than the 14 MeV neutrons and provide images of the cold fuel surrounding the hot spot.

Ultracold neutrons from the LANSCE UCN Facility are used to measure the neutron lifetime

The LANSCE UCN Facility supplies neutrons to multiple user experiments including UCN τ .

Ultracold neutrons: < 300 neV, and thus trapped by material walls, magnetic fields, and gravity.

The UCN τ experiment measures the neutron lifetime by storing UCNs in a magnetic bottle, eliminating wall-related losses.

The UCN τ experiment has completed and published a demonstration run consistent with the accepted value for the neutron lifetime.