



LANSCCE Modernization: A Proposal to Update an Essential Department of Energy (DOE) Facility

John P. Tapia, Director
Accelerator Strategy Office
Los Alamos National Laboratory

May 21, 2024

Outline



- **Strategic Context for Accelerator Stewardship**
- **LANSCE Facility Overview**
- **LANSCE Modernization Project (LAMP)**
 - Brief Overview
 - Pre-conceptual Studies
 - Risks and Opportunities
- **Key Takeaways**

New missions, new challenges, new opportunities require capabilities that can deliver exciting new science!

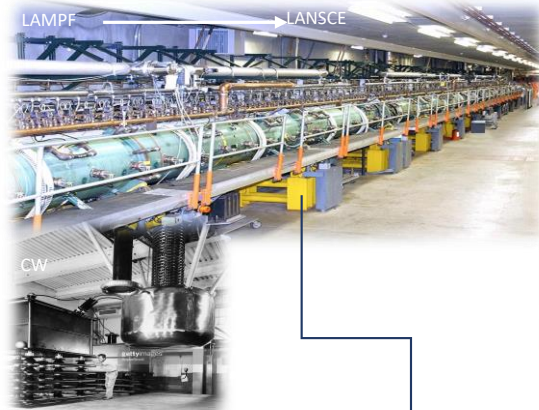
Strategic Context for LANL Accelerator Stewardship



- **Los Alamos' most visible responsibilities are its current and future large accelerators**
 - LANSCE – 800-MeV proton accelerator
 - DARHT – ~20-MeV single-pulse (chopped) linear induction accelerators
 - ECSE/ASD-Scorpius (2028) – ~20-MeV multi-pulse linear induction accelerator to be located at NNS
 - *DMMSC/MaRIE (late 2030s) – 12-GeV electron accelerator feeding a 42-keV x-ray free-electron laser to be co-located with LANSCE*
- **We have a clear sense of our strategic priorities for the next generation of stockpile stewardship**
 - We must steward people, facilities, and research
- **Accelerator capability stewardship (physics, engineering, execution/operations) is a shared responsibility**
- **Strengthening partnerships between facilities and projects can be mutually beneficial**



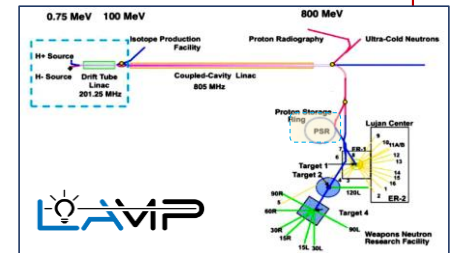
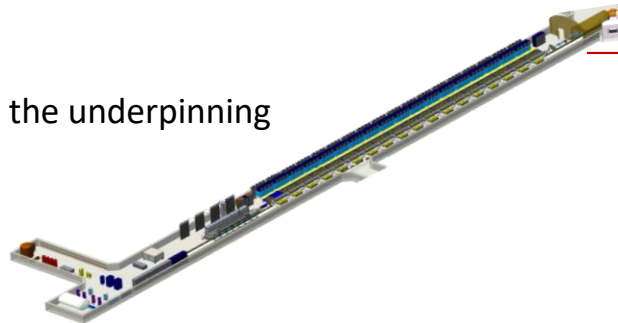
Accelerators have been, and will continue to be, essential to LANL's mission



■ Accelerator technology is a backbone of our deterrent in the absence of nuclear testing.

➤ Experiments at LANL's accelerators provide the underpinning data needed by DOE and NNSA.

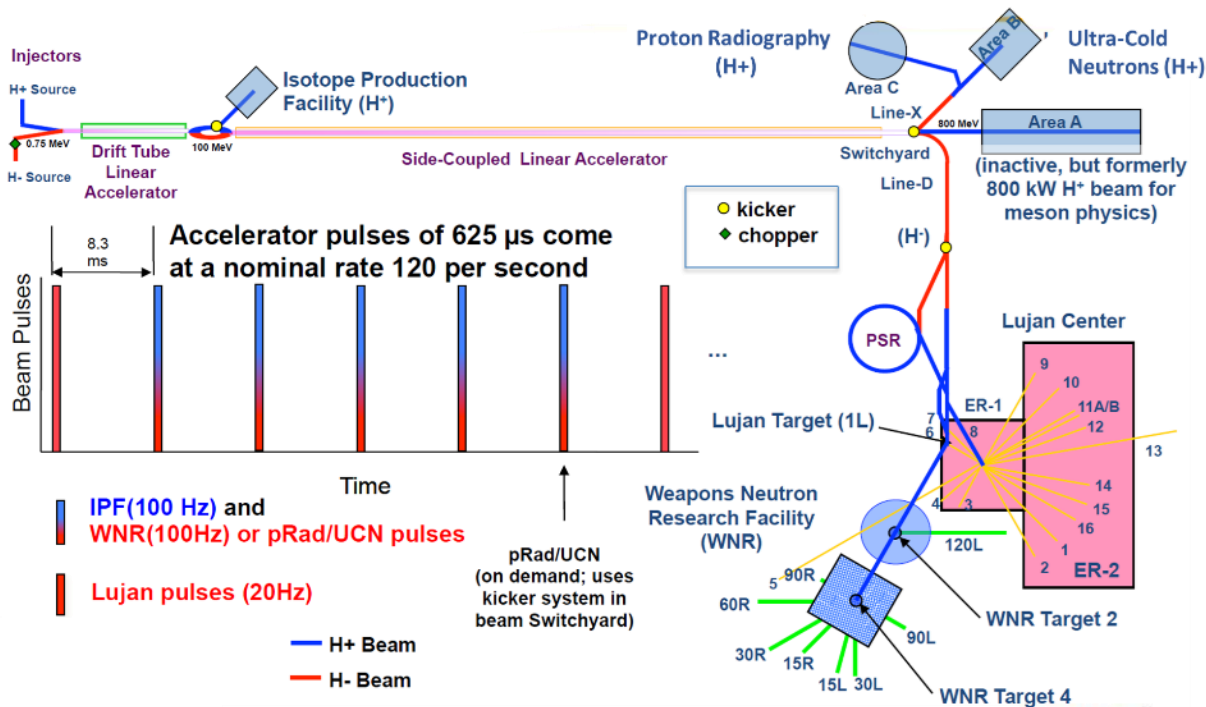
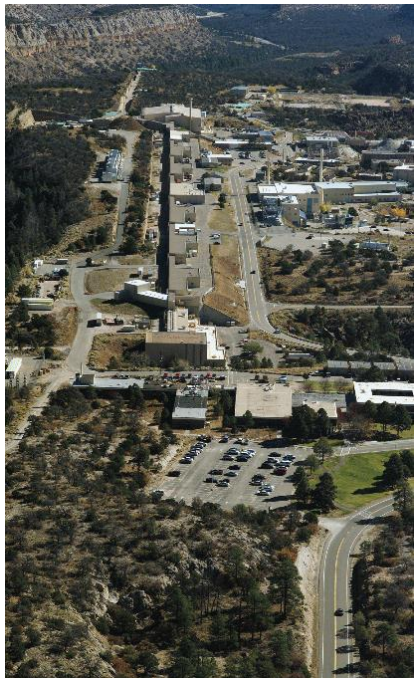
➤ LANL must continue to steward this vital technology for NNSA.



The Los Alamos Neutron Science Center (LANSCE)



The Los Alamos Neutron Science Facility (LANSCE) has served the nation for over fifty years as a premier research facility for national security and fundamental science.



LANSCE simultaneously drives five experimental areas engaged in National Security science.

LANSCCE's unique flexibility allows it to serve a variety of DOE and NNSA missions

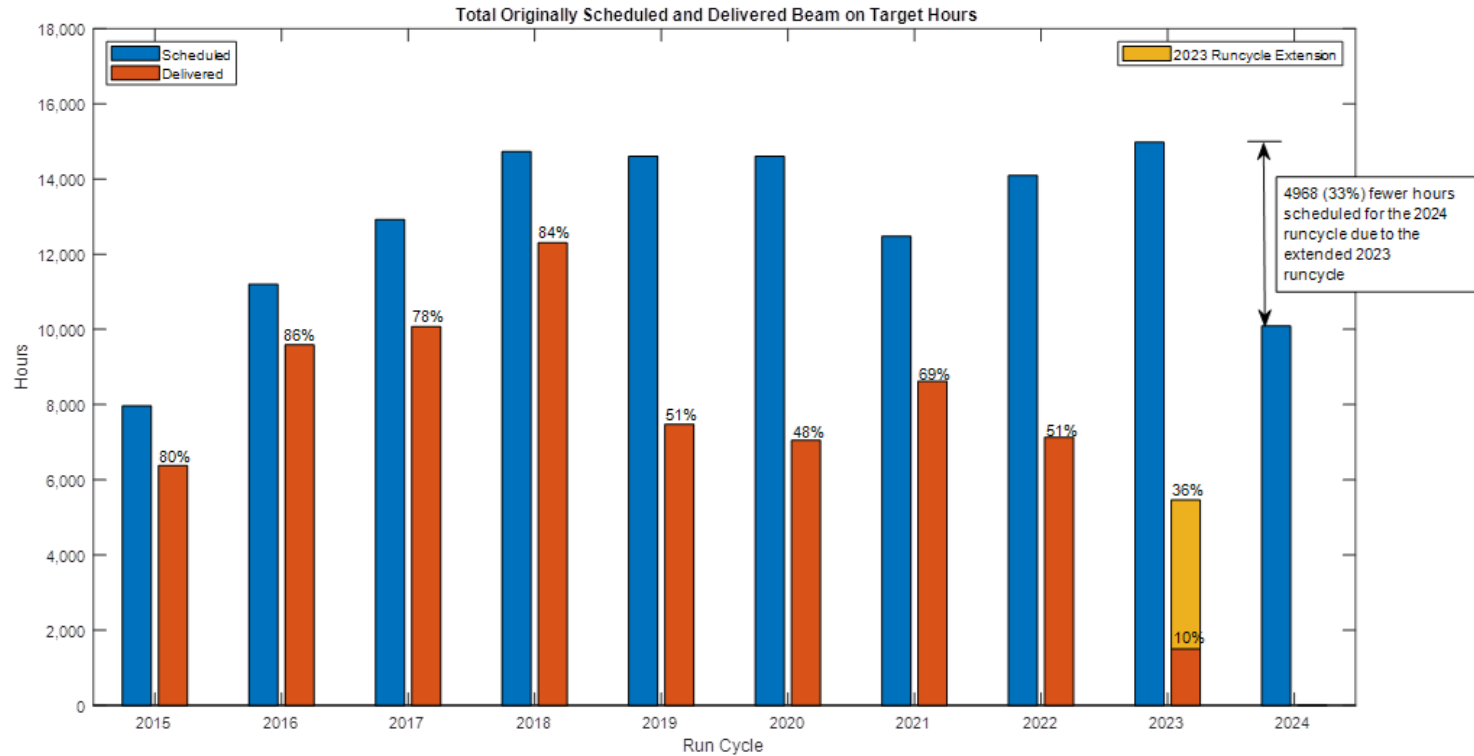


- Proton Radiography (pRad Facility)
- Lujan Neutron Scattering Center (Lujan Center)
- Weapons Neutron Research Facility (WNR)
- Isotope Production Facility (IPF)
- Ultra-Cold Neutron Facility (UCN)
- *Area A – Future experimental possibilities*



100-800 MeV proton energies
six target stations (three neutron spallation targets)
sixteen beam lines

Beam delivery is degrading and meeting user demands is becoming more challenging with each run cycle.



The LANSCE Modernization Project (LAMP) is a critical upgrade required to ensure LANSCE readiness and reliability



The timeline for LAMP is driven by three factors:

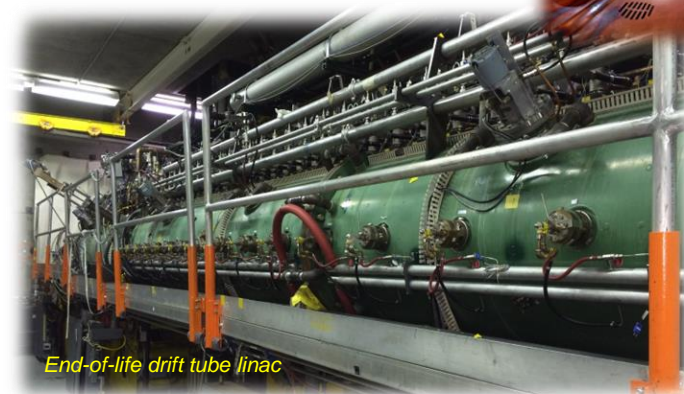
- We have already started to experience **end-of-life failures** that have reduced beam availability
- Data from LANSCE will be required to support DOE and NNSA Programs at least **through 2050**
- We have developed a **high-Technology Readiness Level (TRL) pre-conceptual upgrade design** which would take ~7 years to complete. It would replace everything from the ion sources through the drift-tube linac.



Obsolete
Cockcroft-Walton
generators



End-of-Life Magnets

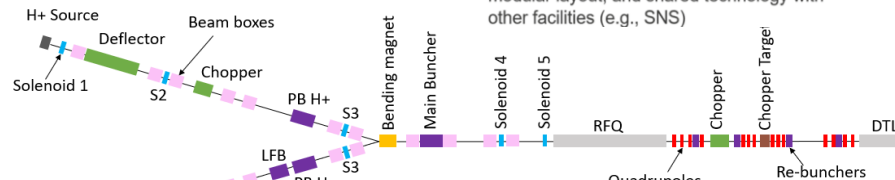


End-of-life drift tube linac

The LAMP project will modernize obsolete equipment at the front end of the accelerator



Upgrade will utilize modern design methods, modular layout, and shared technology with other facilities (e.g., SNS)



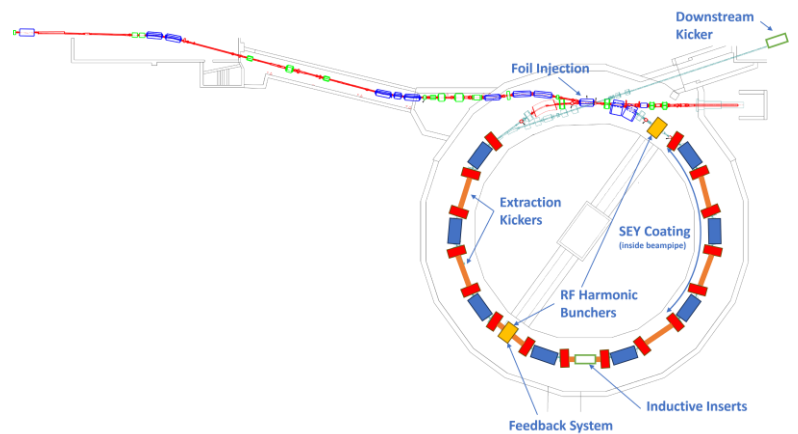
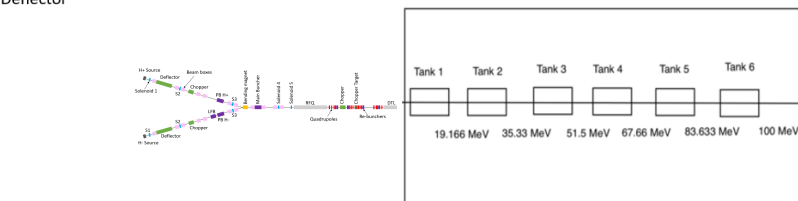
- **S2E Beam Dynamics Mod/Sim Design**

- **Upgrade of sources to end of Drift Tube Linac (DTL) at 100 MeV**

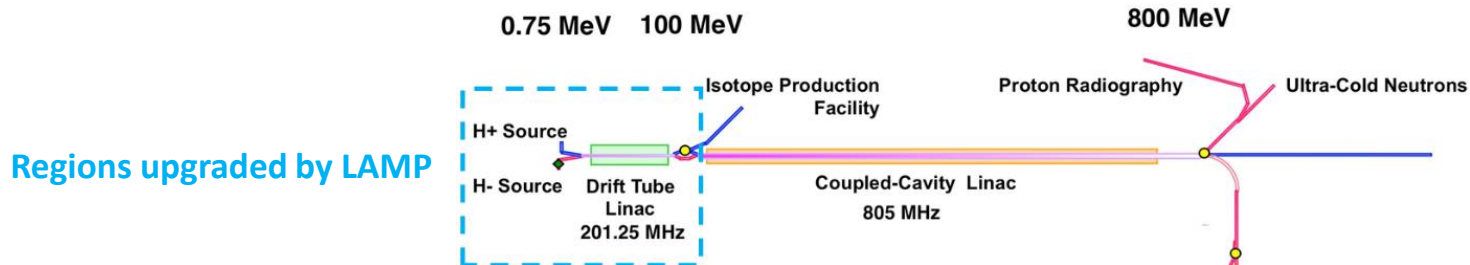
- Utilize latest advances in accelerator design (e.g., not just like-for-like replacement of components)

- **Retain/Enhance the Current Operational Features of LANSCE Facility**

- **Ensure beam matching with Proton Storage Ring**

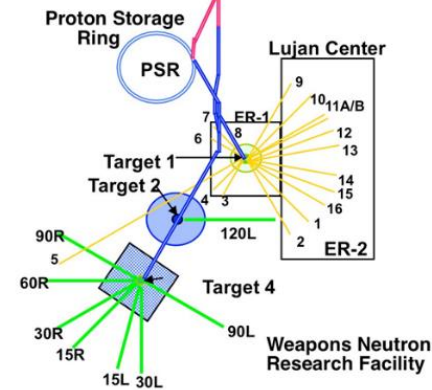


LAMP will minimize impacts to existing user facilities and off-line testing will minimize future outages



LAMP pre-conceptual design parameters

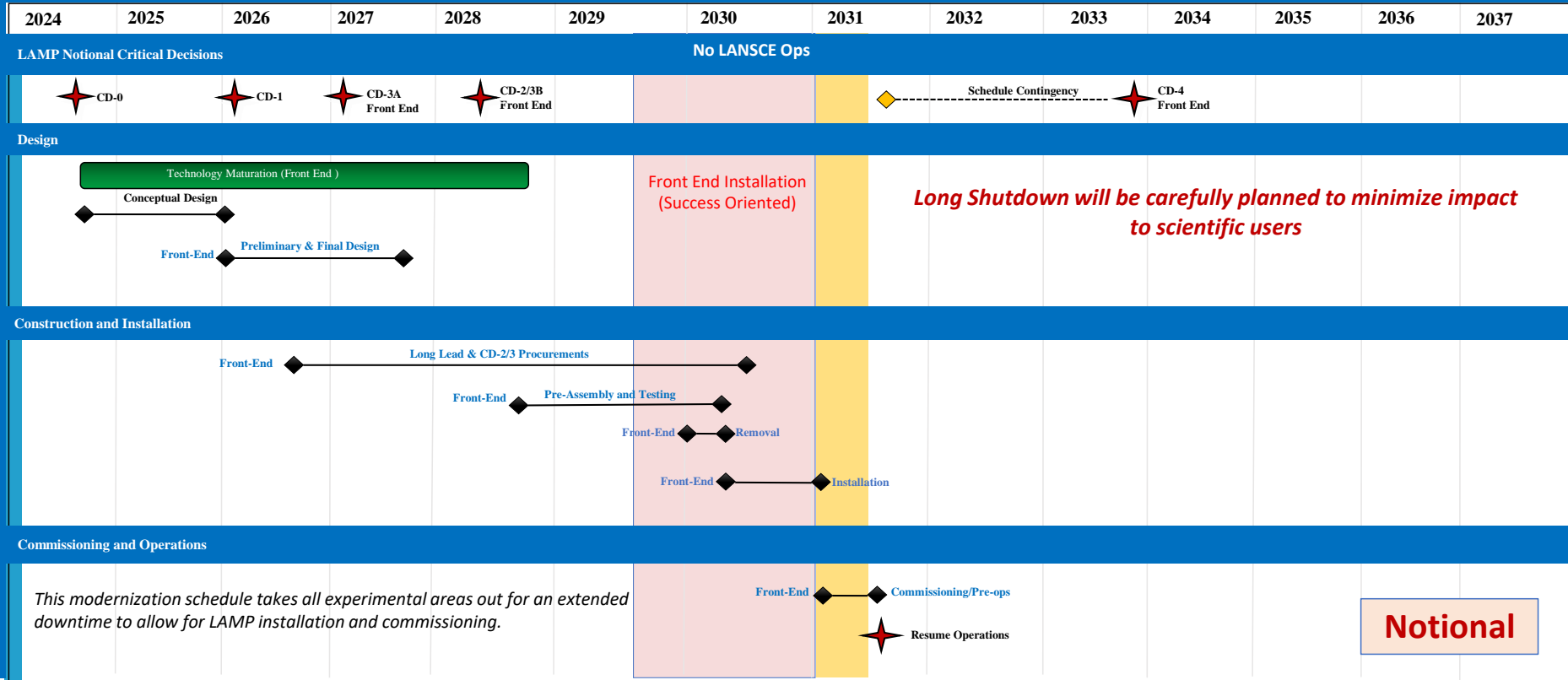
Facility	Species ⁽¹⁾	Pulses / sec	Pulse length ⁽²⁾ μs	Chopper fraction	Current /μbunch mA	Average		
						Current / pulse mA	Current, 10-sec μA	Power, 10-sec kW
Lujan/PSR	H ⁻	20	625	0.8	10	8	100	80
IPF	H ⁺	100	625	1	4	4	250	25 ⁽⁵⁾
WNR	H ⁻	100	625	2.8 · 10 ⁻³	25 ⁽³⁾	0.07	4.5	3.6
pRad	H ⁻	On demand	<625	-	10	~1 ⁽⁴⁾	<1	<1
UCN	H ⁻	10, at 0.2 Hz	625	0.8	10	8	10	8



An acquisition strategy is being developed with our sponsor



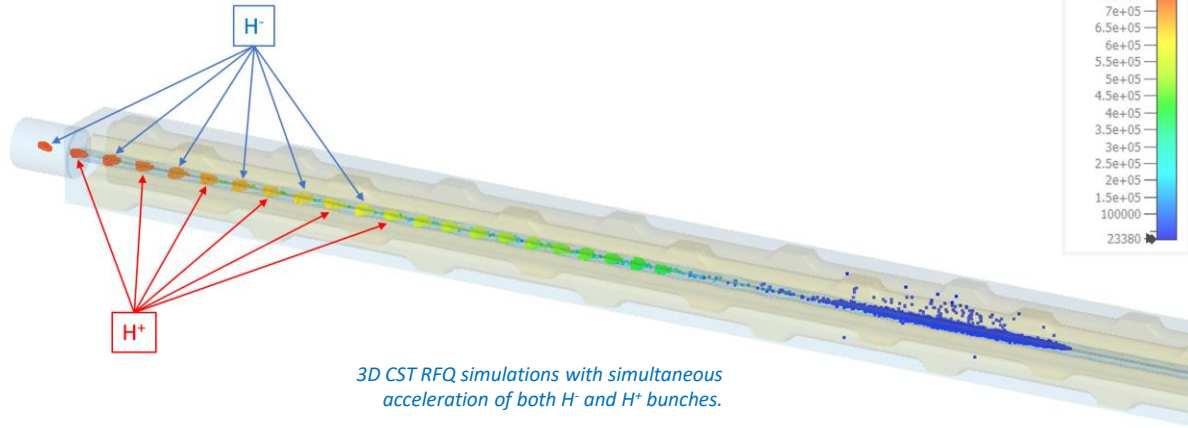
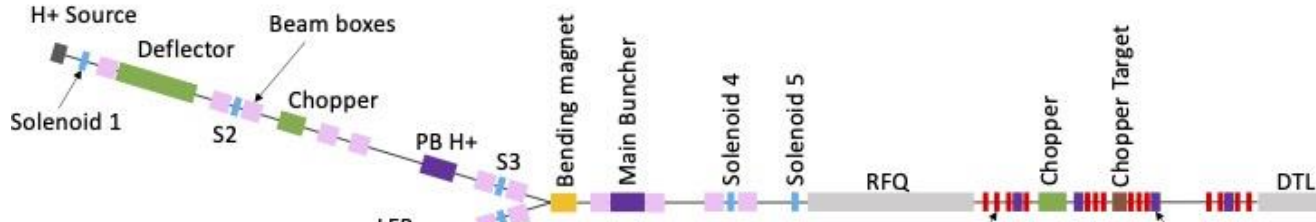
LAMP Project






Laboratory internal investments on LAMP Front End efforts in Mod/Sim show RFQ with simultaneous H⁺ & H⁻ beams



Layout of the new RFQ-based 3-MeV injector.



3D CST RFQ simulations with simultaneous acceleration of both H⁻ and H⁺ bunches.

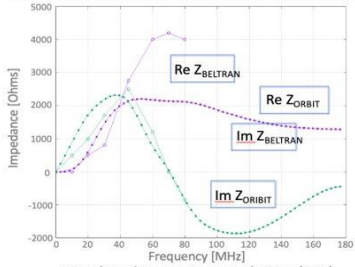

Start-to-end simulation for LAMP front-end scoping studies
 S. Sosa, D. Gorelov, S. Kurennoy,
 J. Upadhyay, E. Henestroza
 LA-UR-24-21709
 February 14th, 2024



position monitor 1	
Output	Energy
Sample	406/475
Time	405 ns
Particles	186715
Maximum (Sample)	787920 eV
Maximum (Global)	802079 eV

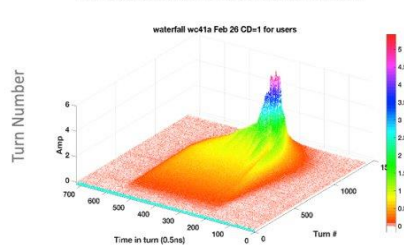


Laboratory internal investments on preconceptual evaluation for the LANSCE Proton Storage Ring future upgrade

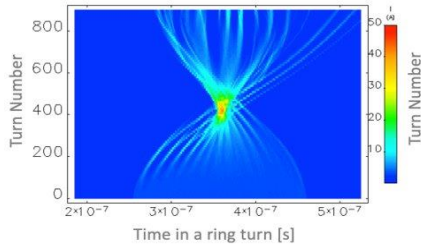
The Input Parameters for Ferrite Permeability



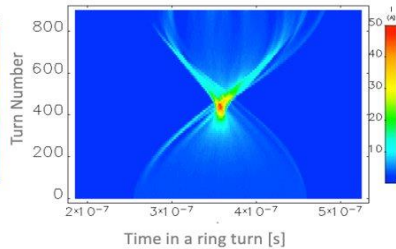
Measured Beam Accumulation (163°)



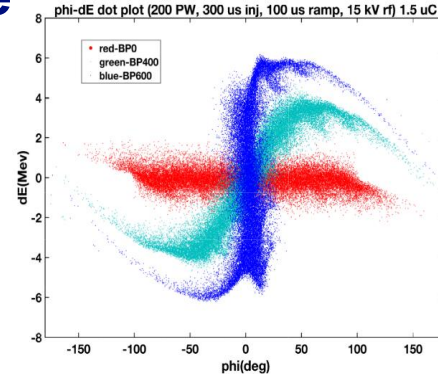
Simulated Beam Accumulation (25°)



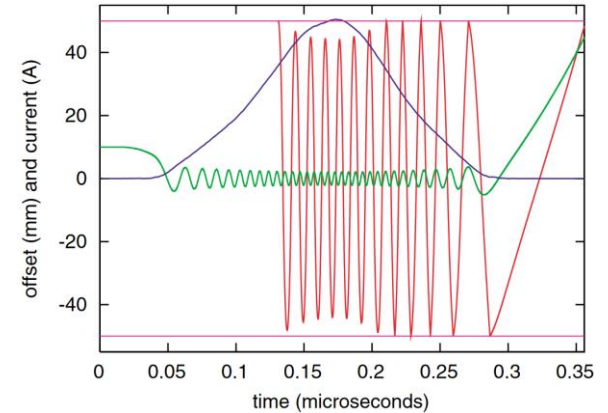
Simulated Beam Accumulation (125°)



Modeling impedance-driven instability in the ring, and mitigation via ferrite inserts



Snap-rotation options for beam extraction



Multipacting calculations (another driver of beam instabilities)

LAMP Risks and Opportunities



- LANSCE has unique experimental capabilities that need to continue during execution of LAMP.
- Obsolete technology is increasing the likelihood of single-point failure, risking the loss of all LANSCE experimental capabilities.
- The laboratory must also execute on multiple simultaneous and high-profile projects with workforce limitations.
- LAMP is also exploring partnerships to mitigate any potential staffing challenges.
- To deliver the agreed upon technical, cost, and schedule baselines, project will:
 - Use commercially available technologies using pre-qualified, proven companies.
- **LANL is looking for people to join our LAMP Team!**

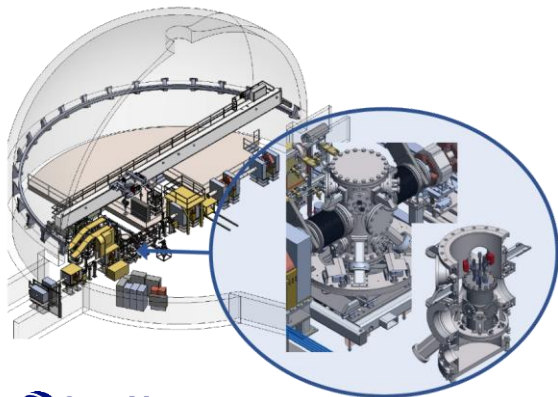


Experimental enhancements spanning the major science areas at LANSCE under consideration



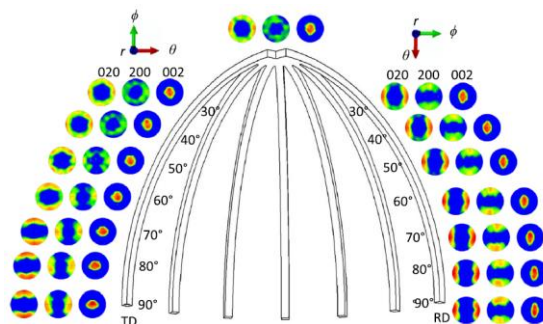
Dynamic Imaging

- Multi-pulse x-ray source for pRad
- Additional proton radiography beamline in LANSCE Area A
- Additional drivers and diagnostics
- pRad energy upgrade



Materials Characterization

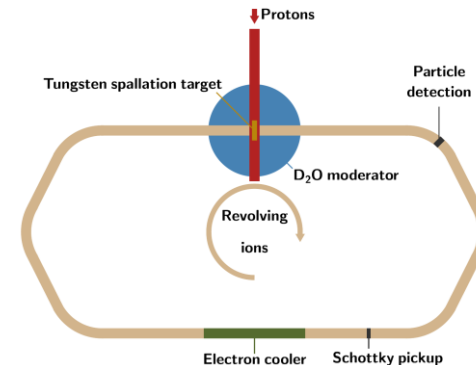
- Dedicated beam line for classified experiments
- New multi-probe flight path for imaging and bulk characterization
- Compact x-ray source for small scale, hazardous, classified experiments.



Spatially resolved texture measurement uranium using HIPPO.

Materials Characterization

- Expanded WNR capabilities for radioactive targets
- Partnering with Isotope Production Facility for improved targetry
- A neutron target facility to measure short-lived isotopes



Neutron target conceptual rendering for long-term radionuclide measurements



Key Takeaways

- *The protons and neutrons from LANSCE will be needed through 2050*
- *To extend the lifetime of LANSCE, increase its reliability, and maximize its throughput, we are partnering with DOE-NNSA to implement the LAMP Project*
- *We are also exploring options for redeveloping unused experimental areas to deliver more scientific data in the future*

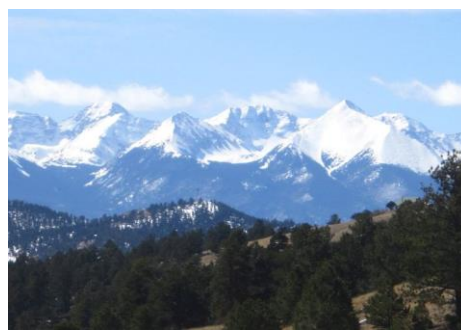


Accelerator Strategy Office



Thank You

LANL is in a culturally and environmentally rich location





Back Up Slides

LANSCCE material and nuclear data are critical for stockpile assessment and certification



The LANSCCE accelerator complex is a **unique NNSA resource** that acquires an enormous range of **physics and engineering data** required by the Los Alamos, Livermore, and Sandia weapons programs

- Authorization basis to **perform classified experiments with special nuclear material** using protons and neutrons
- Unique capability to measure a breadth of nuclear data** needed for initial conditions for boost, neutron reactivity, nuclear forensics, and criticality safety
- Provides qualification and characterization** of new and aged materials, components, and high explosives **for Significant Finding Investigations (SFIs), Life Extension Programs (LEPs), Alterations, and Modifications**, as well as to qualify **new manufacturing methods**

Mission space available at various US accelerators

	LANSCCE	Brookhaven	FermiLab	SNS
Proton Radiography	●	●	●	●
High Explosive Drive	●	●	●	●
Classified Experiments	●	●	●	●
Dynamic Plutonium Capability	●	●	●	●
Low-Energy Nuclear Physics	●	●	●	●
Isotope Production	●	●	●	●
Neutron Diffraction	●	●	●	●
Static Plutonium	●	●	●	●
Neutron Radiography	●	●	●	●
Energy-Resolved Tomography	●	●	●	●
Neutron Irradiation for Defense and Civilian Applications	●	●	●	●

LANSCÉ's experimental areas support all parts of NNSA's mission space



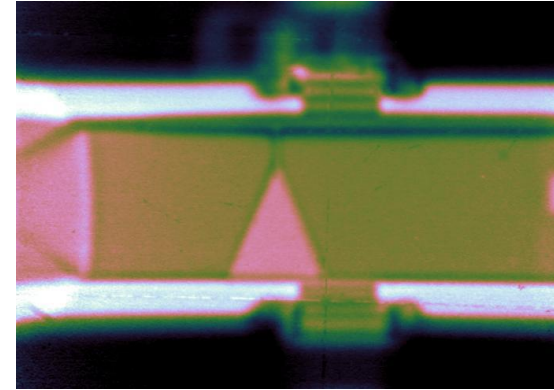
Mission/Area	Dynamic radiography (pRad)	Neutron scattering (Lujan)	Nuclear physics (Lujan/WNR)	Neutron radiography (Lujan/WNR)
Stockpile Sustainment	Significant findings; hydrodynamic experiment interpretation; <i>plutonium aging studies</i>	Plutonium aging studies; secondary and high explosive material properties	Underground nuclear test analysis; key nuclear data for neutron reactivity metrics	Component surveillance/inspection
Future Deterrent	Explosive and subsystem characterization/ design (e.g., detonators); subcritical experiment interpretation; <i>safety/surety</i>	Advanced model development; scintillator development for hydrodynamic and subcritical experiments	2018 Level 1 pegpost; subcritical experiment interpretation	Advanced inspection technique development
Modern Materials and Manufacturing	New explosive characterization /formulation; <i>plutonium manufacturing</i>	Direct cast uranium; advanced manufacturing (e.g., plutonium alloys and secondary components)	Criticality assessments for safety and efficiency; effects quantification	Component inspection
Threat Mitigation (NA-20/80)	Render safe design; foreign materials	Scintillator and sensor development for nonproliferation	Nuclear data for foreign threats and nonproliferation; effects quantification	<i>Foreign components</i>

Italics show planned future capabilities
Bold shows global security applications

The pRad Facility provides a unique capability for dynamic radiography



- **pRad is able to take dynamic movies of shock and detonation events, with a unique ability to image high explosive detonation.** Data have been crucial to LEPs, ALTs, MODs, SFIs, and manufacturing
- pRad drivers include **high explosives, a powder gun, and pulsed power**
- **Data acquired at pRad:**
 - 21 radiographs of areal density
 - Up to 16 channels of velocimetry
 - Multiple custom diagnostics, including visible imaging, x-rays, pins, etc.
- **Future plans include Pu@pRad experiments**
- **pRad is oversubscribed**, with most users granted less beam time than they request



AWE experiment of a high explosive burn front past a plastic wedge



LANL experiment on material properties of copper

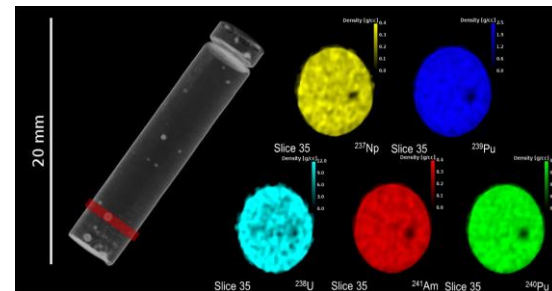
The Lujan Center characterizes NNSA materials for qualification



- Neutron scattering uses the **unique properties of neutrons** to provide **experimental microstructural characterization** used to **advance models for manufacturing and performance**
- **Unique mandate and ability to study classified, toxic, explosive, and/or radioactive materials under extreme conditions**
 - Weapon components
 - Nuclear fuels
- Recent highlights:
 - **Plutonium aging**
 - **Isotope-specific imaging**
 - Characterization of **additively manufactured LANL/LLNL/SNL/KCNSC components**
- **Beam time constraints mean that only ~2/3 of proposals receive time in a given run cycle**



Lujan Center experimental hall

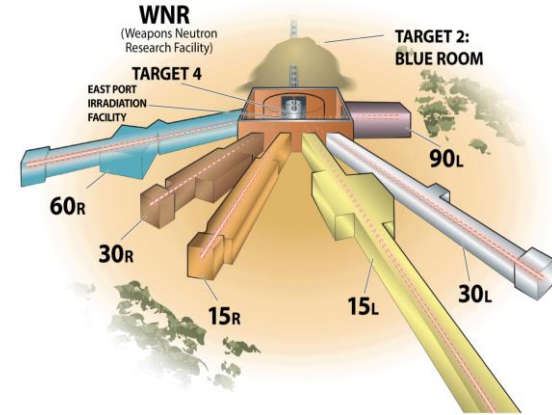


Nuclear fuel elemental distributions

The Weapons Neutron Research Facility is NNSA's center of excellence for nuclear physics



- The WNR Facility produces neutron beams for seven stations conducting a range of experiments **from fundamental measurements of the nuclear properties of materials to applied measurements acquiring radiographic and radiation effects data**
 - predicts the performance of **nuclear weapons primaries**; recent work made the **first credible uncertainty estimate of a key primary performance metric**
 - provides **technology validation** for high-performance computing systems, avionics components, space satellite sensing systems, and other systems
 - **radiography** complements x-rays and protons to 'see' low-density, low-Z features obscured by high-density, high-Z material
- New Mark IV 1L target in 2022 will **increase flux for some nuclear physics experiments by 50-100x**
- **WNR is oversubscribed by 2-4x**



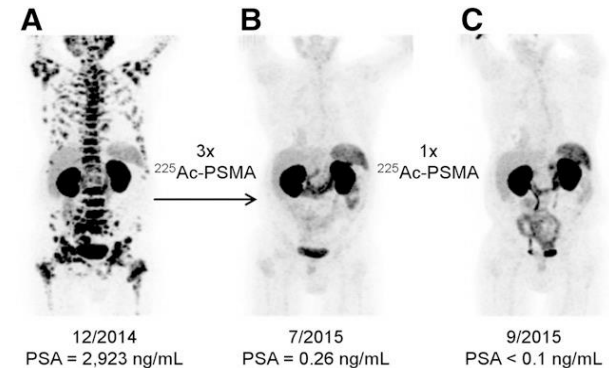
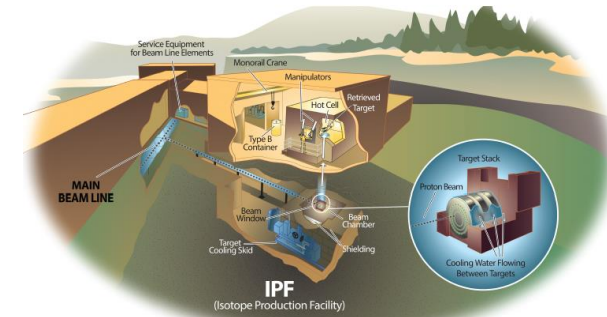
Neutron radiography enables imaging that is impossible with x-rays



The Isotope Production Facility delivers time-sensitive medical isotopes for patients around the nation



- The Isotope Production Facility (IPF) is designed to produce **large quantities of isotopes for medical, industrial and research users**
 - The IPF does not compete with commercial suppliers, but instead uses our unique capabilities to supply isotopes that are more challenging to produce or for which market demand is still emerging
 - The IPF, along with the BLIP at BNL, ensures a steady supply of essential short-lived isotopes throughout the year
 - Isotopes for targeted alpha therapy (^{225}Ac) are future thrusts
 - Funded by the Isotope Program in the DOE Office of Science, which supports operations of the IPF beamline
- IPF has been producing **isotopes of interest to NNSA** for study at WNR – it has the unique capability to deliver the quantities and purities needed

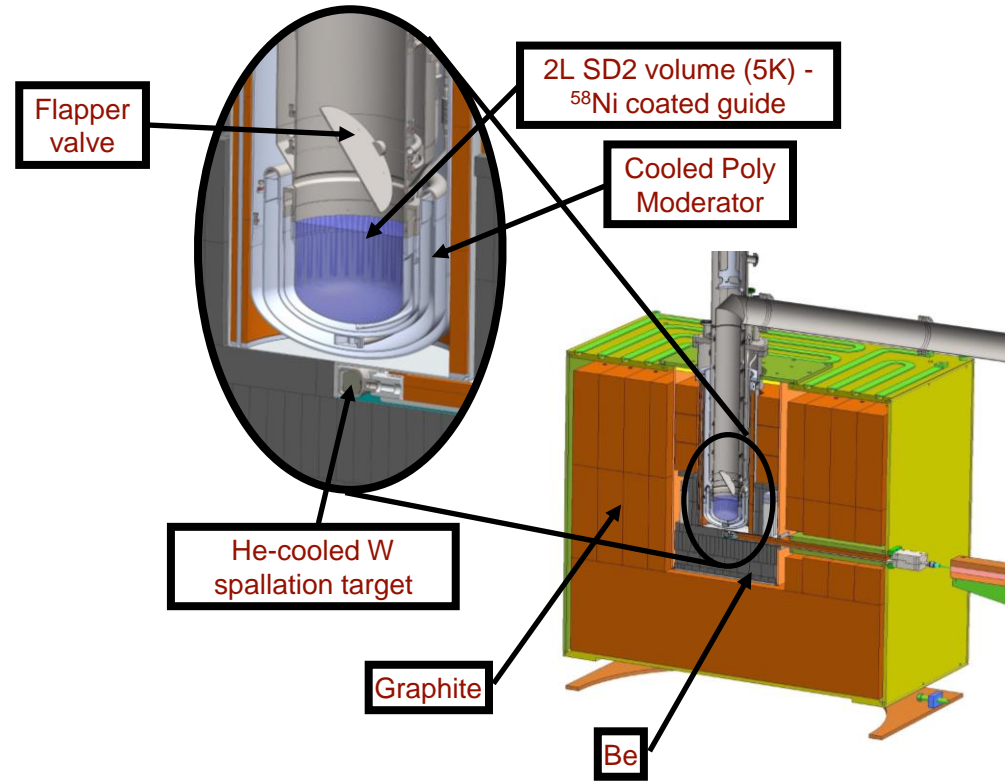


C. Kratochwil, *J. Nuc. Med* 57 2016 1971

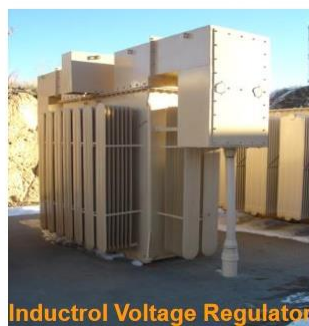
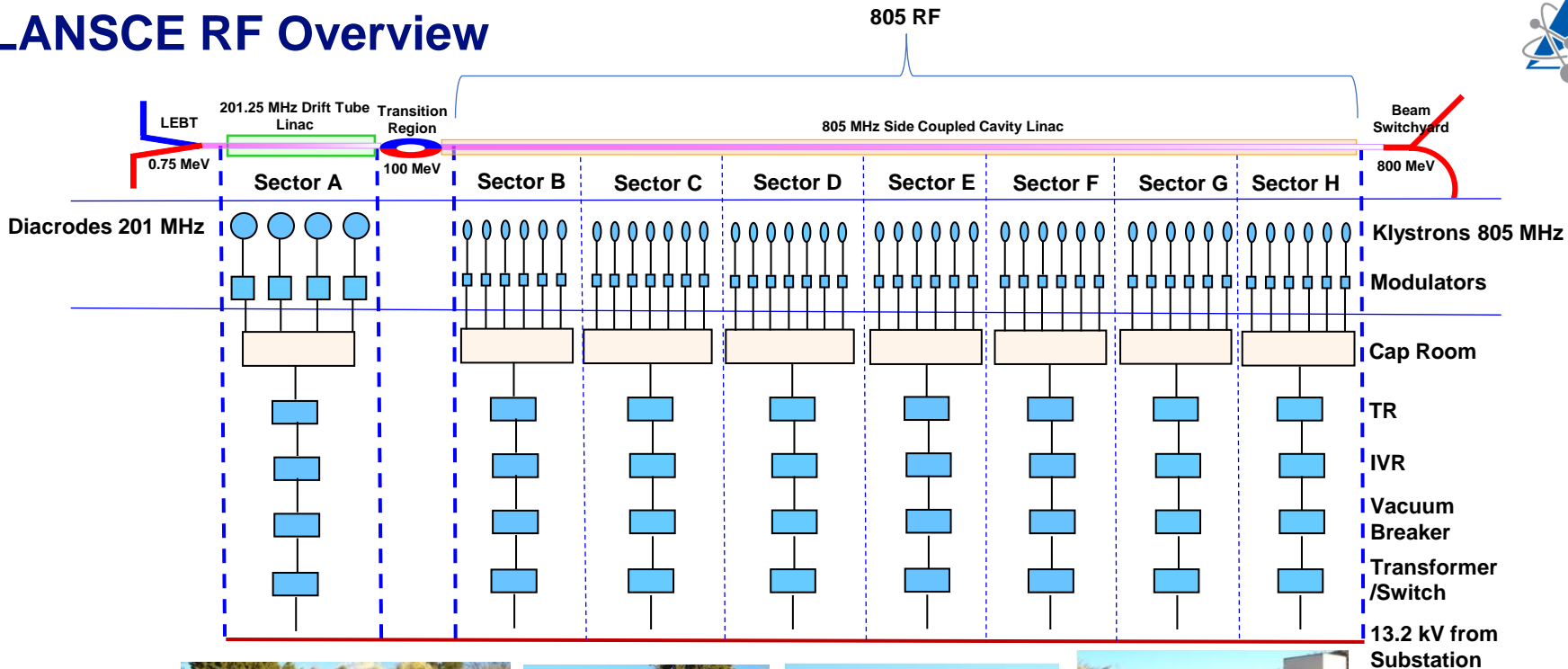


The Ultracold Neutron facility delivers nuclear data

- **World's most intense source** of ultracold neutrons, which flow like water, can be stored for minutes, and have unique interactions with materials
- **Most precise measurement** of neutron lifetime ever made is currently in press
- Studying potential applications to **fission fragment damage** and **material hydriding**



LANSCCE RF Overview

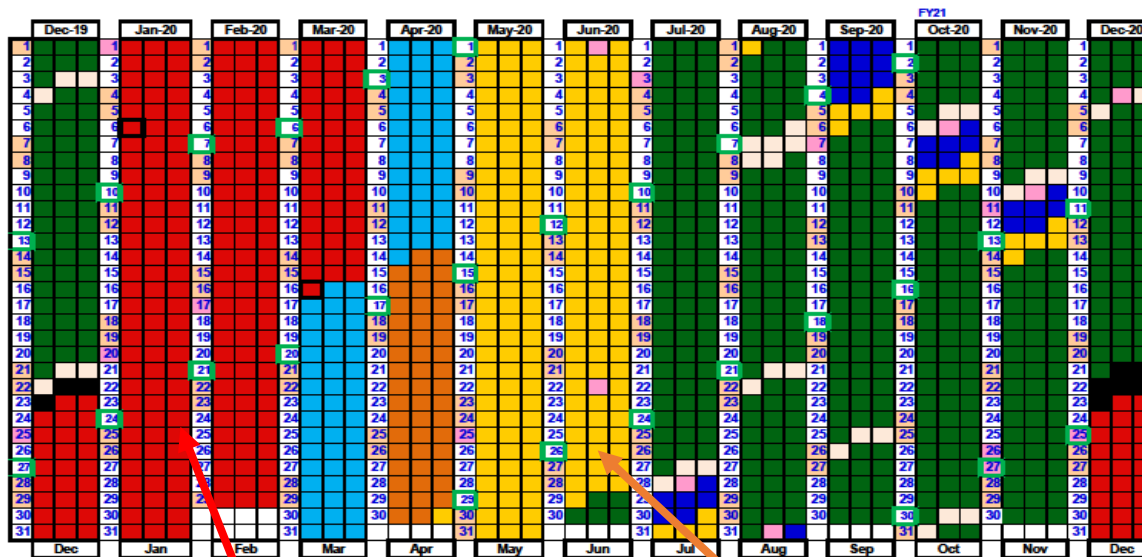


Current LANSCE beam availability lags significantly behind its peers



Approved CY 2020 LUF Operating Schedule
Version 1.0
19-Dec-19

Key:
Maintenance
Startup
Experimental operations



Beam reliability only 60-85%; industry standard 95%

Long maintenance period determined by work required and obsolete designs

Startup ~6 weeks; other accelerators ≤ 2 weeks

Modest investments in experimental areas can deliver even more impactful data [LANSCCE Enhancements (LANE) and beyond]



- Area A provides a **high-quality experimental facility**
- To deliver the **data needed to support advanced assessments needed in the 2030s**, we are examining options for Area A, including restoring (high-power) H⁺ transport. Its existing infrastructure enables the installation of several new capabilities relatively easily. **Options include:**
 - Increased energy and/or multiple-probe pRad
 - Revolutionary nuclear physics
 - Fusion material studies (for FES)
 - Enhanced effects characterization (for NNSA and industry)
 - World-leading ultracold neutrons (for NSF/DOE-NP)
 - Higher energy isotope production (for NNSA and DOE-IP)
- LANSCCE has held a series of workshops – with participation from all the current experimental areas, plus possible future users - to select and refine the most feasible and valuable options



Area A is almost ready for the installation of beam equipment – in 1970 and now