Los Alamos National Laboratory Facility Review

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P-27 & LANSCE

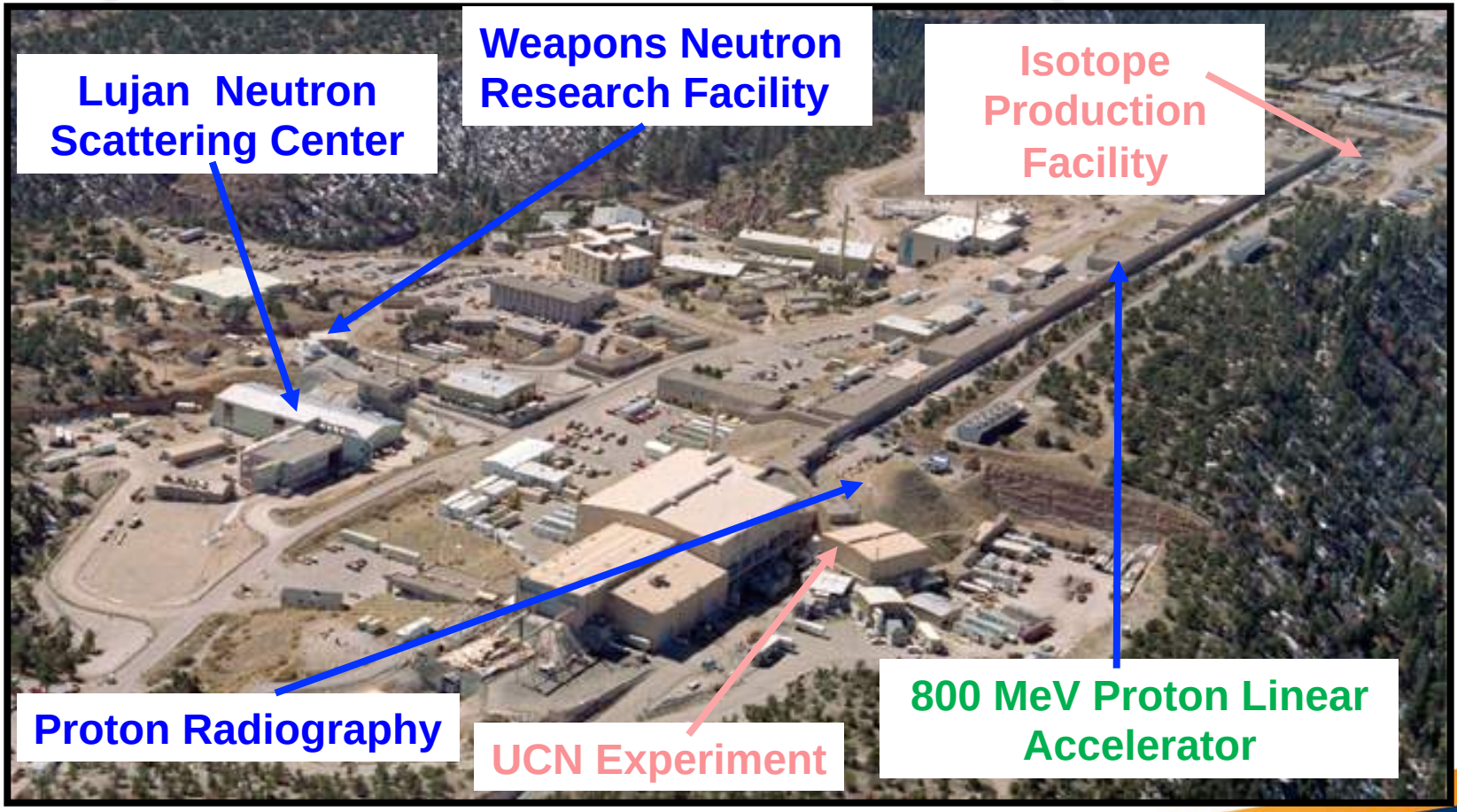
Neutron Data Needs & Capabilities for Applications
LBNL
27 May 2015

Los Alamos Neutron Science Center User Facilities

- Los Alamos Neutron Science Center (LANSCE)
  - Driver – 800 MeV proton linac
  - Beams – multiple (H^+, H^-)
    - Protons: 200 to 800 MeV
      - pRad, Blue Room, Area A (planned)
    - Moderated Neutrons: cold to 1 MeV
      - Lujan Center – 15 flight paths (3 nuclear science)
    - Unmoderated Neutrons: 0.1 to 600 MeV
      - WNR facility – 6 flight paths
  - Not included – Isotope Production Facility, Ultra Cold Neutrons (collaboration)

LANSCE is a Unique Multidisciplinary Facility for Science and Technology - User Facility Areas

Website http://lansce.lanl.gov/



Beam structure

- WNR Target 4
  - 100 Hz, 625 μs maco pulse, 1.8 μs spacing typical, of sub-ns (FWHM) proton pulses
- Lujan Center Target 1
  - 20 Hz, ~130 ns (FWHM), proton pulses from the proton storage ring (PSR)
- Blue Room Target 2
  - From a single proton pulse to pulse trains of 80 nA avg current, or PSR pulses

New 2.5 MW RF driver amplifiers are being installed on the drift-tube linac

Figure 3: Dual FPAs with Diacrodes® installed

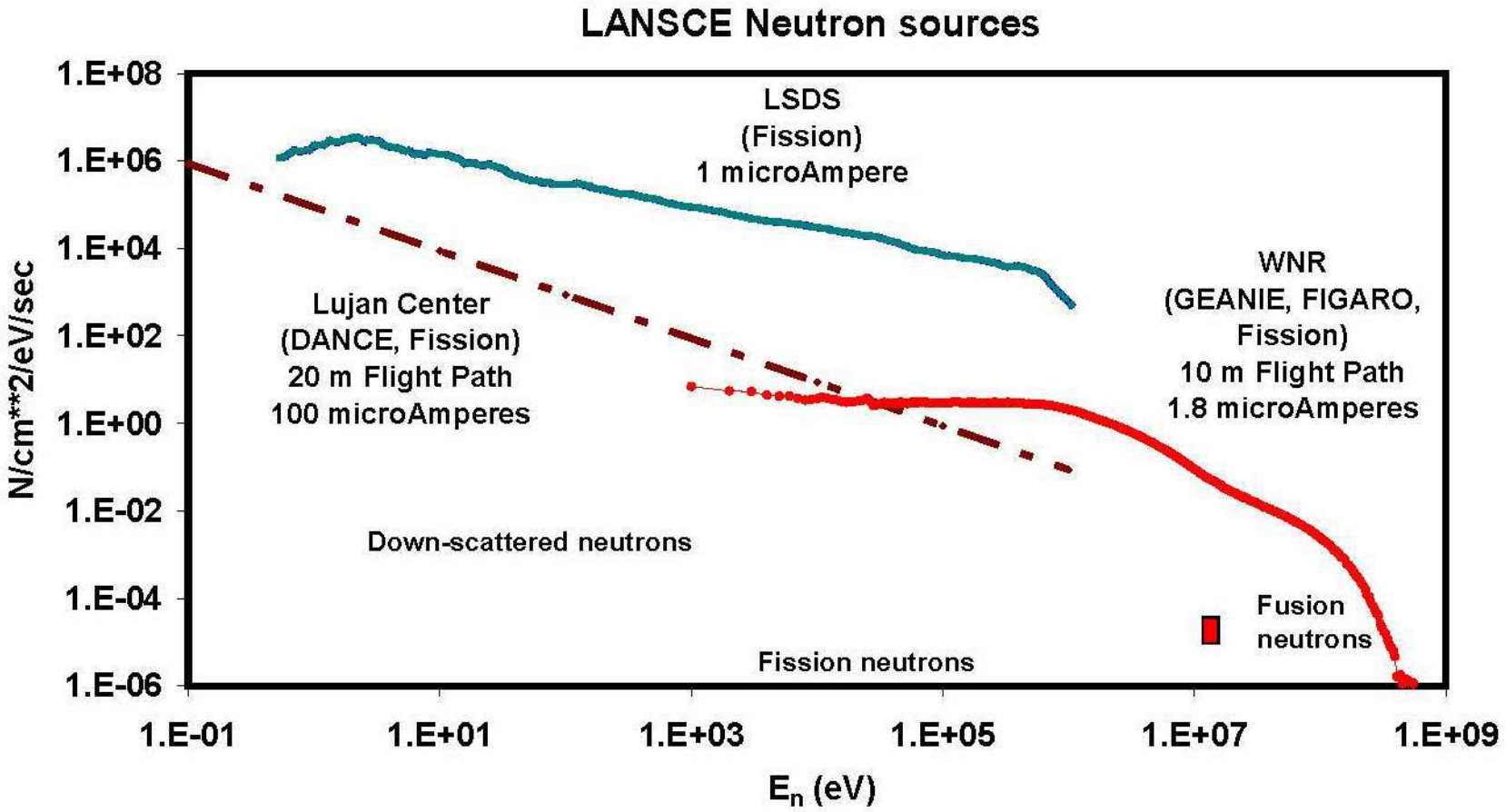
Figure 2: Coaxial feeders from PAs to branch hybrid

J. Lyles, et al. Los Alamos report LA-UR-14-26667 (2014)

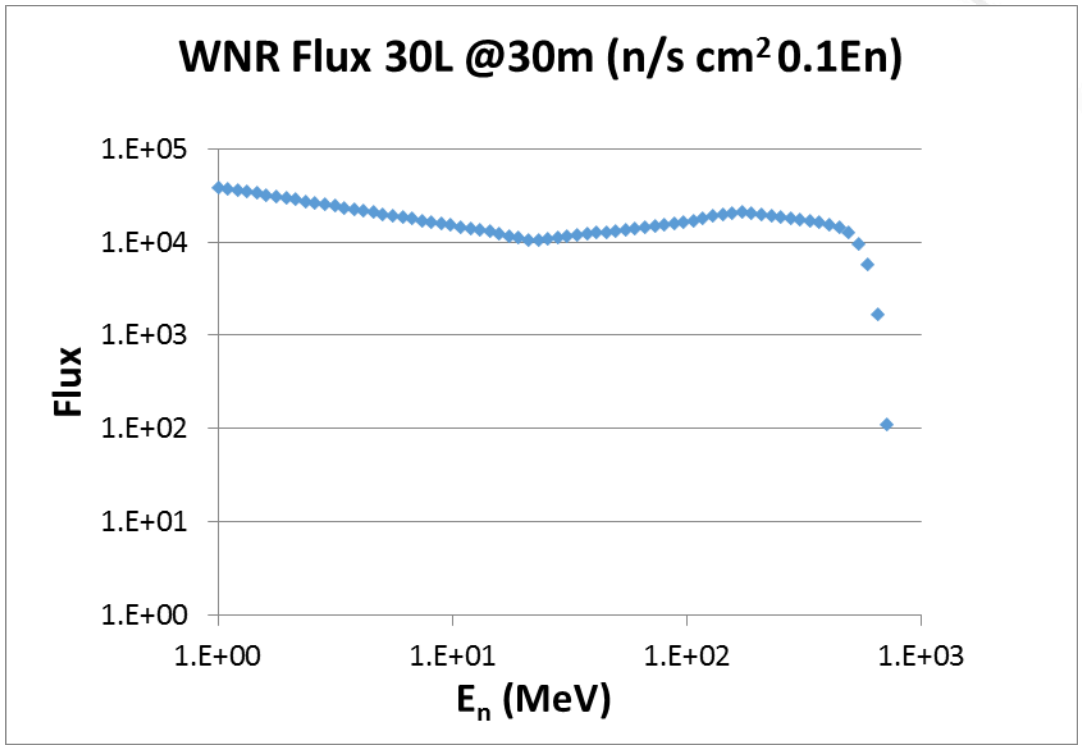
Two main neutron production targets are used

- **WNR Target 4** – high energy spallation neutrons
  - Bare W cylinder – water cooled
  - Operates at 4 μA typical, 34k/s sub-ns pulses for 1.8 μs spacing (variable)
  - 6 Neutron flight paths (from ~8 up to 90 m)
- **Lujan Center Target 1** – moderated source
  - Flux trap design typ. ~100 μA
  - Cold (LH_2) and water moderators
  - 20 Hz repetition rate, 130 ns pulse (FWHM)

LANSCE neutron energy range covers most applications



WNR 30L flux in 10% neutron energy bins at a flight path of 30 m



The flux is relatively flat in 10% energy bins to the high energy cutoff

Flux depends on proton beam parameters, collimation, distance!

P-27: Nuclear and Materials Research Facilities

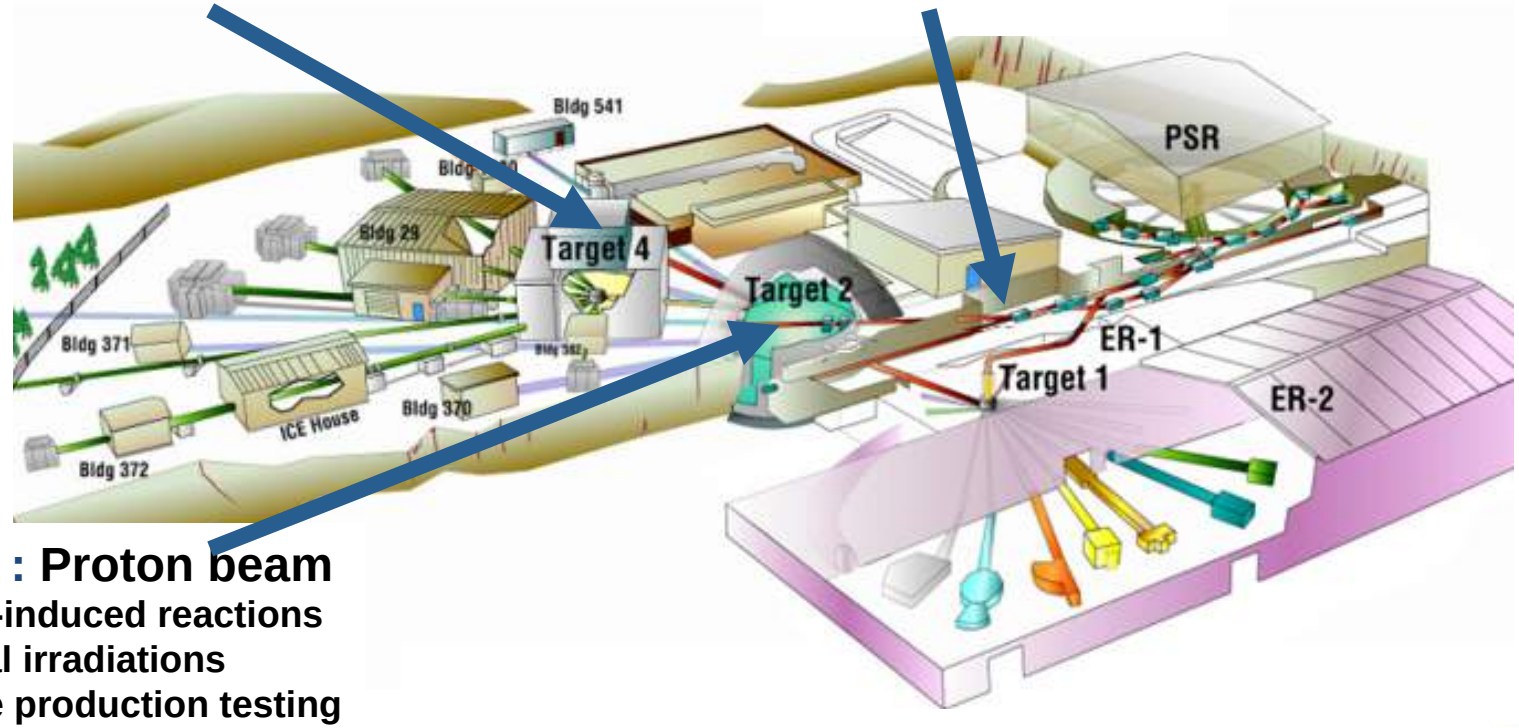
"Delivering on a robust, sustainable and enduring neutron science program with operational excellence"

Target-4 : High-energy neutrons

- Nuclear Physics
- Neutron Radiography
- Electronic device irradiation/testing
- Neutron irradiations

Target 1: Cold-Thermal-1-MeV neutrons

- Neutron Radiography
- Nuclear science
- Material science
- Electronic device irradiation/testing



Target-2 : Proton beam

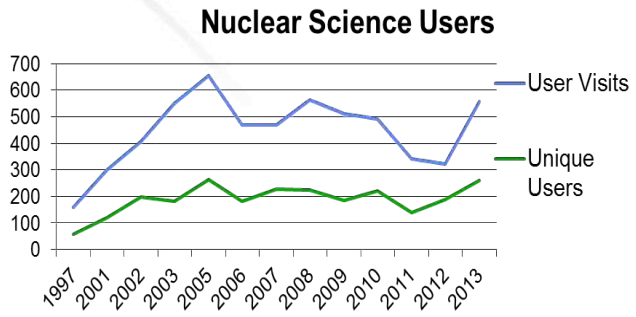
- Proton-induced reactions
- Material irradiations
- Isotope production testing
- LSDS

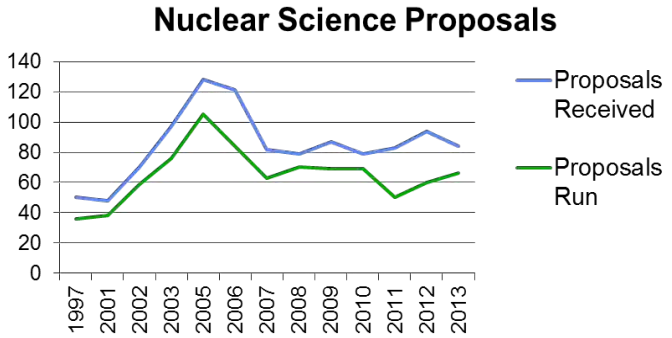
Access – Proposal Submission

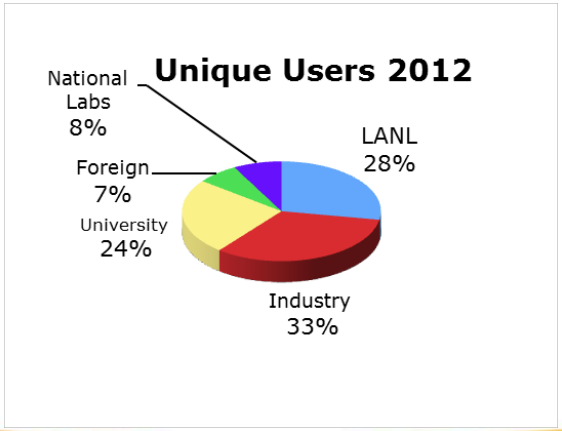
- DOE NNSA User Facilities
- Proposals are rated by a program advisory committee for merit
- Open research proposals – beam time is free for target 4, under review for Lujan, pRad
- Proprietary proposals – “full cost recovery”
- Beam time is awarded based on proposal PAC ratings and facility availability
- Fast access proposals are accepted

LANSCE has a robust user program

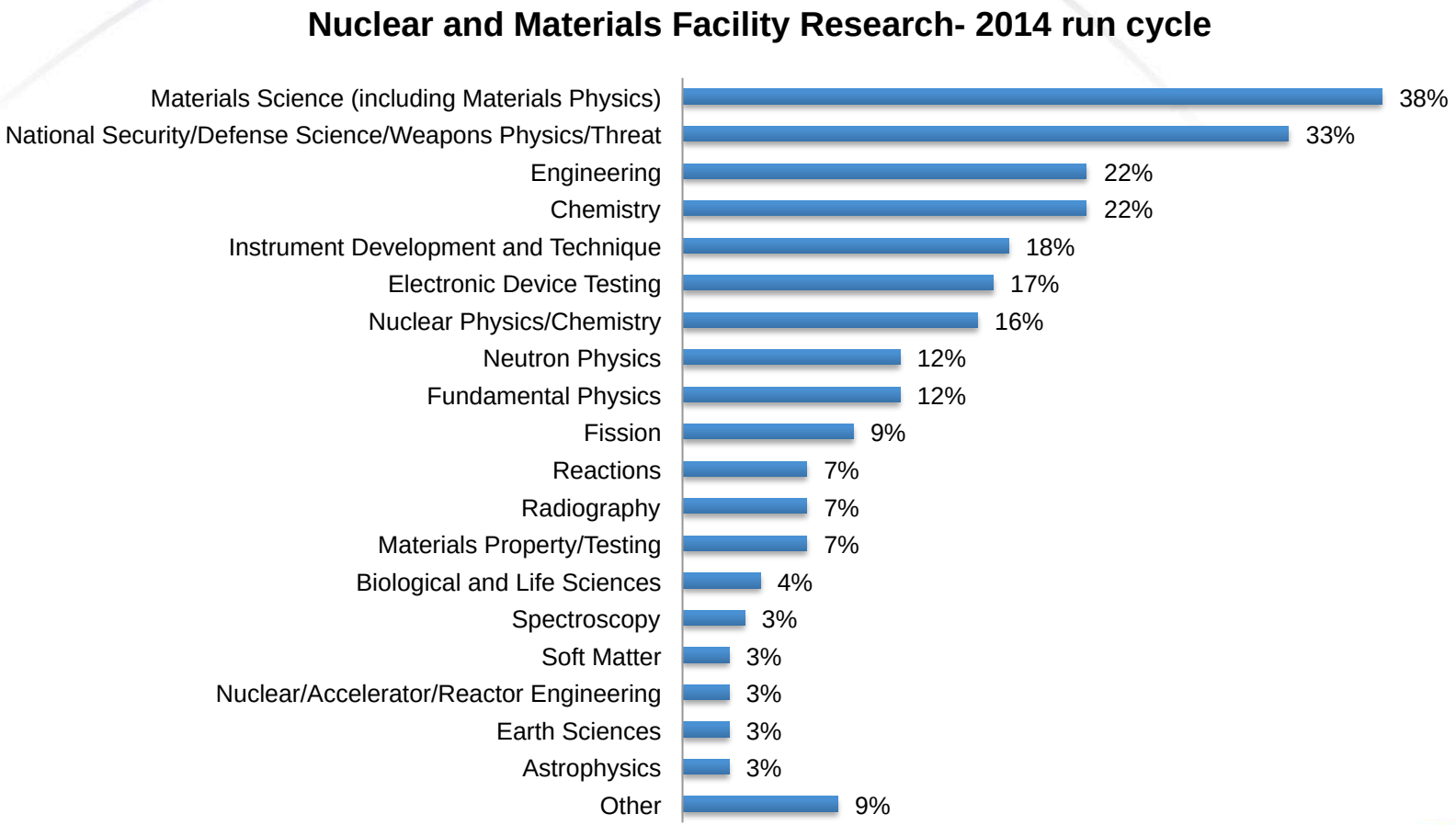
- ~200 nuclear science users per year, ~400 total visits
- Non-U.S. citizen access is routine in most cases
- Users come from universities, industry, & national laboratories







A broad spectrum of research is conducted at LANSCE



Specialized equipment and detectors at WNR Targets 4 and 2 (Blue Room)

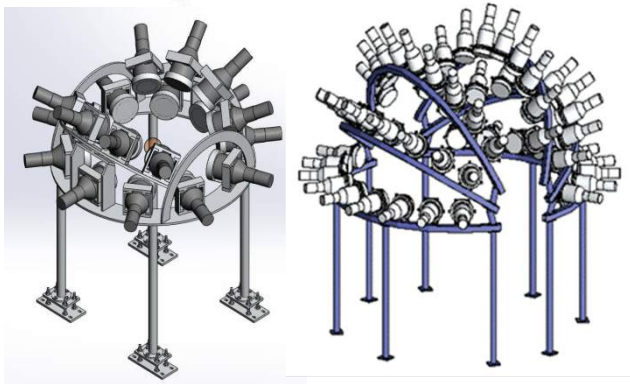
- WNR Facility
  - Chi-Nu arrays of neutron detectors for low and high energy neutrons
  - Time Projection Chamber (TPC) for fission
  - LENZ – neutron, charged particle reactions
  - SPIDER – fission fragment measurements
  - HPGe detectors – reactions and spectroscopy
  - HE Neutron Radiography - imaging
  - LSDS (lead slowing-down spectrometer) – small cross sections and radioactive samples

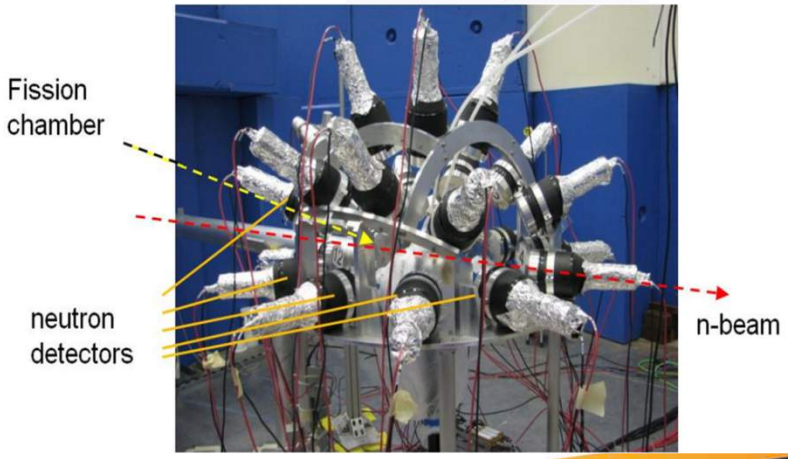
Chi-Nu has two neutron detector arrays for prompt fission neutron spectrum measurements and more

- ^{6}Li-glass low-energy neutron detectors
- Liquid scintillator high-energy neutron detectors
- Uses double time-of-flight
  - LANSCE spallation source to fission chamber → incident neutron energy
  - Fission chamber to neutron detector → fission neutron energy

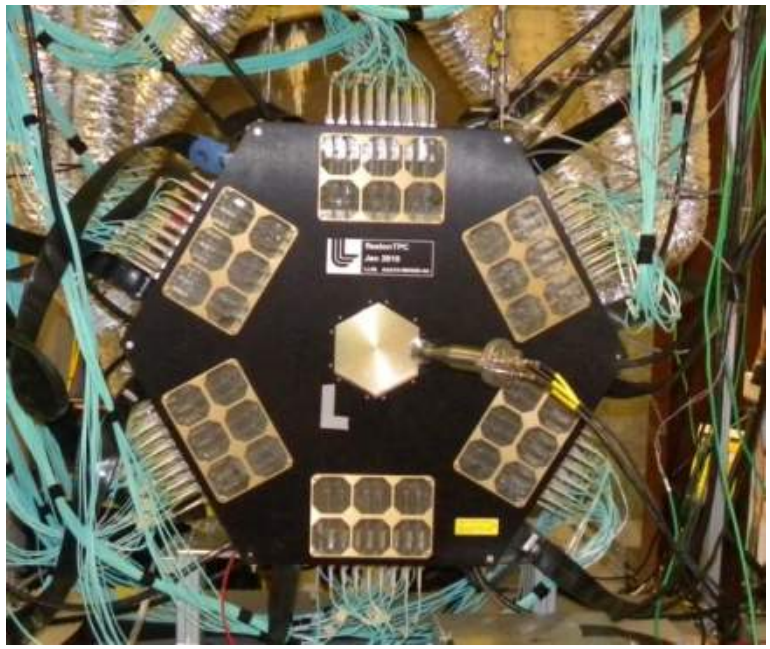
LLNL fission chamber

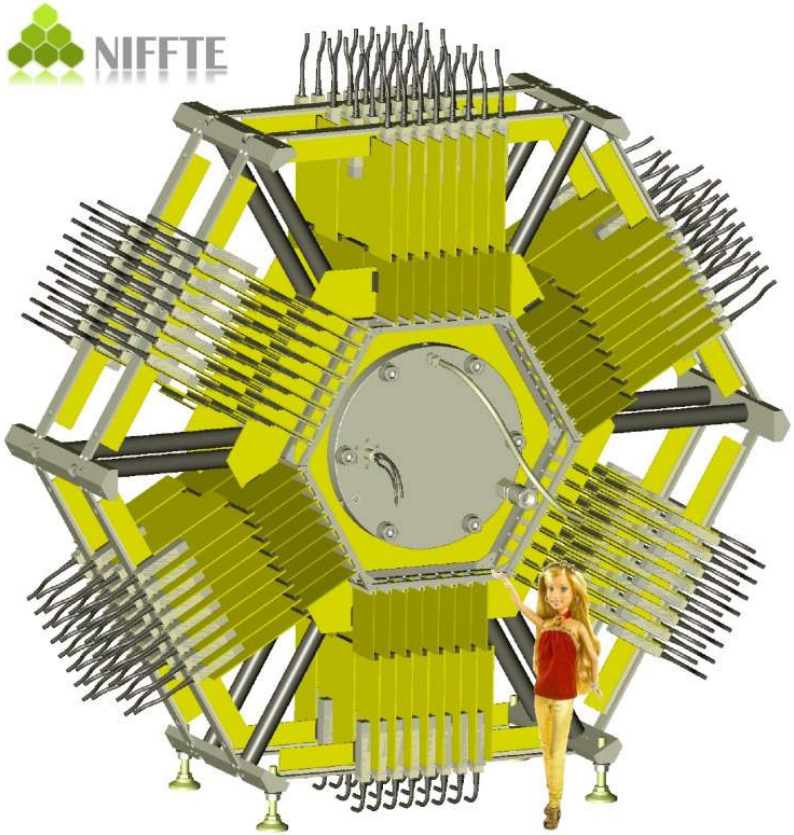
Two LANL neutron detector arrays





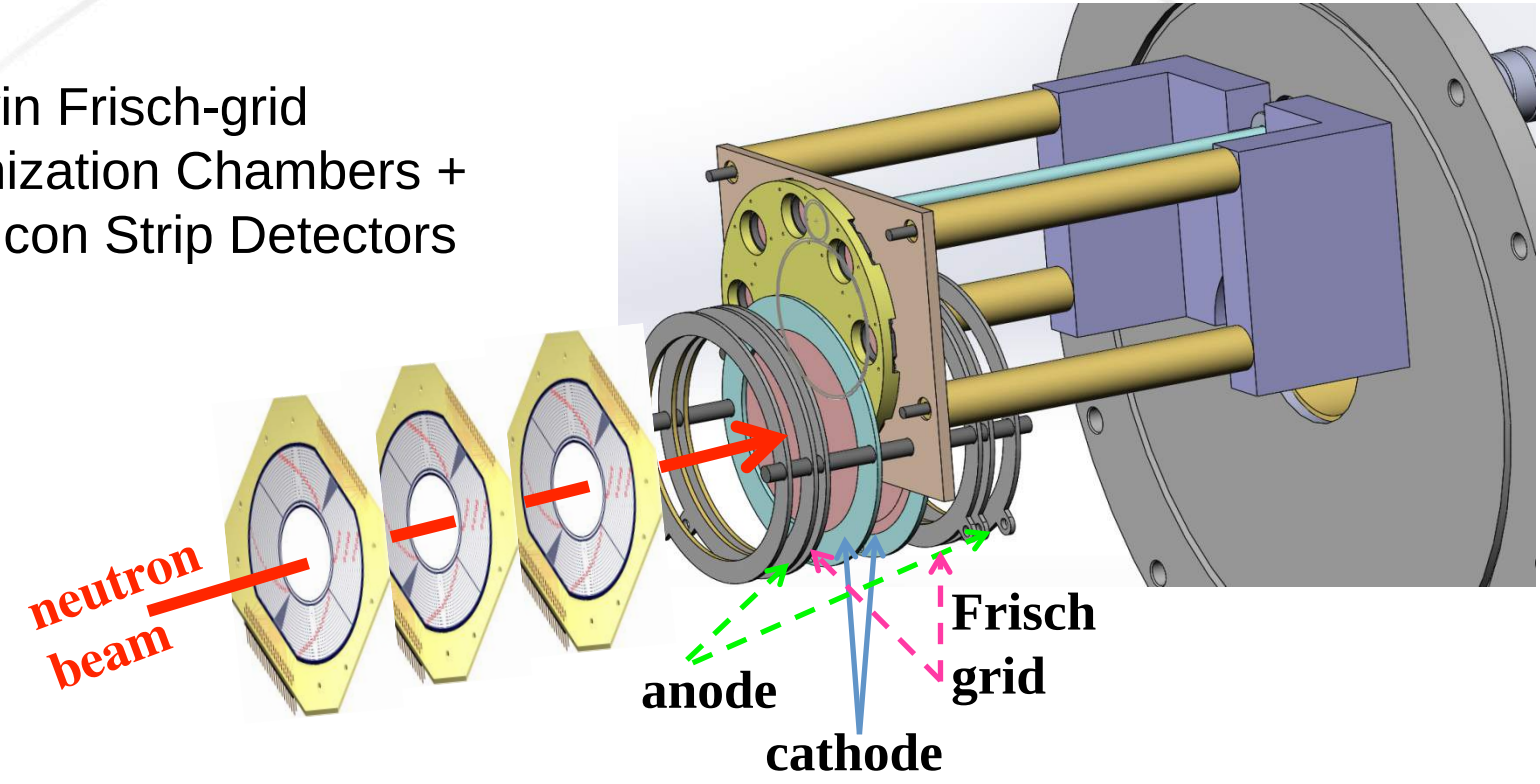
The Time Projection Chamber is measuring precision fission cross section data



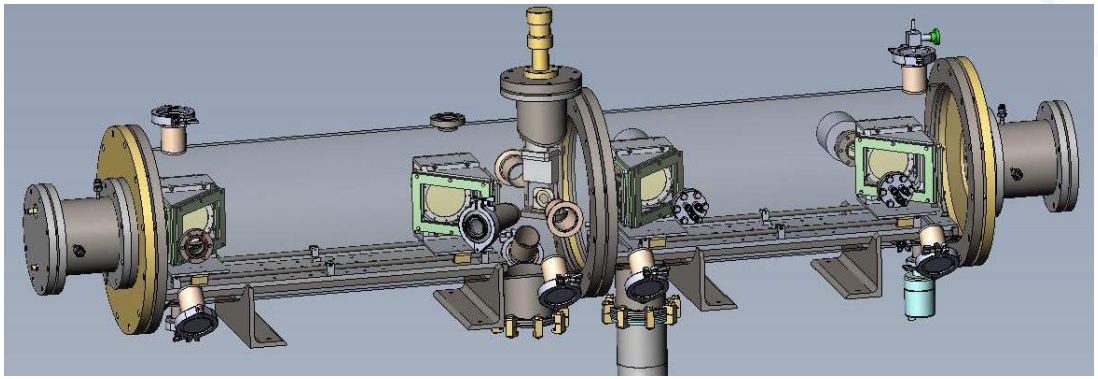


LENZ - low-energy neutron-induced charged particle reaction setup

Twin Frisch-grid
Ionization Chambers +
Silicon Strip Detectors



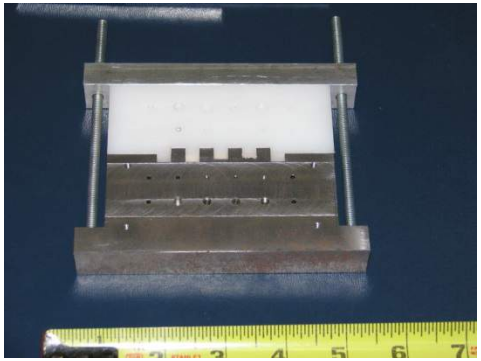
SPIDER is designed to measure fission fragment mass and charge with a goal of 1 mass unit resolution



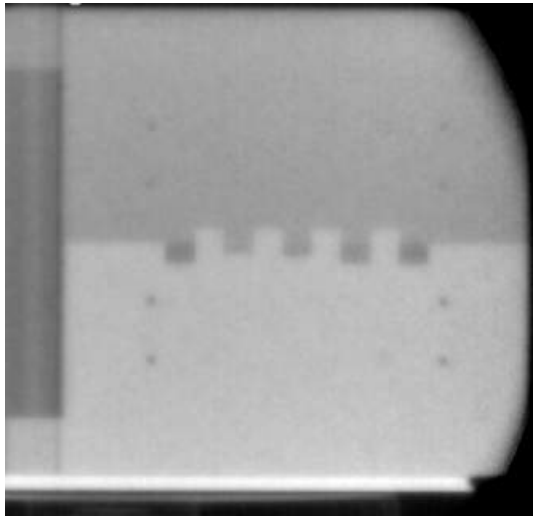
- The 2E-2v method can provide 1 amu resolution for light fragments
  - Demonstrated with Cosi-fan-Tutti at ILL
- SPIDER uses ionization chambers for energy measurement
  - 1% energy resolution for α-particles, 0.5% for fission fragments
  - Thin entrance window (Mylar or SiN)
- Fast, position sensitive TOF detectors
  - Micro-channel plates

High-energy neutron imaging can penetrate very thick dense objects

Image Panel, CT stage and uranium plates + test assembly in a WNR high-energy neutron flight path (15R).



n-Radiography Test Assembly from LLNL (above) and radiograph taken with the high energy system (right).



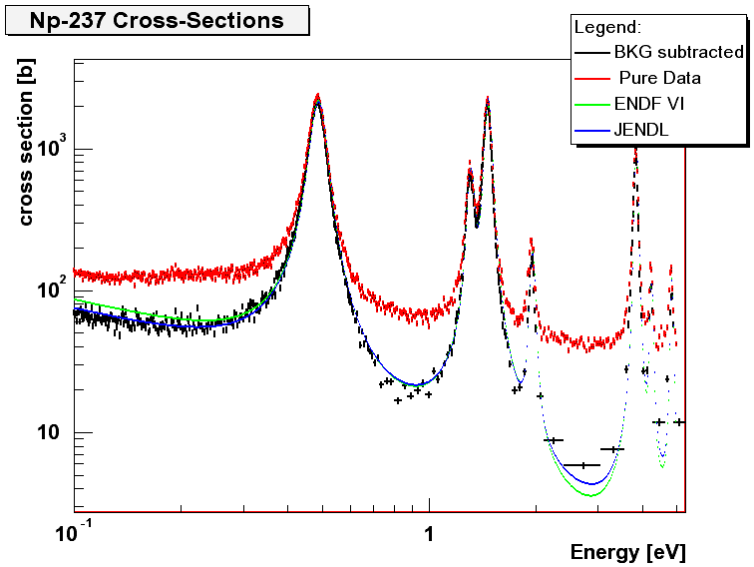
Lujan Center special instruments for nuclear science

- Device for Advanced Neutron Capture Experiments (DANCE) – neutron capture and fission studies
- Neutron radiography MCP – energy-resolved neutron imaging and computed tomography
- One “general purpose” flight path (FP-12)
- Plans to expand to other Lujan Center flight paths

DANCE – for neutron capture and fission measurements (Target 1)

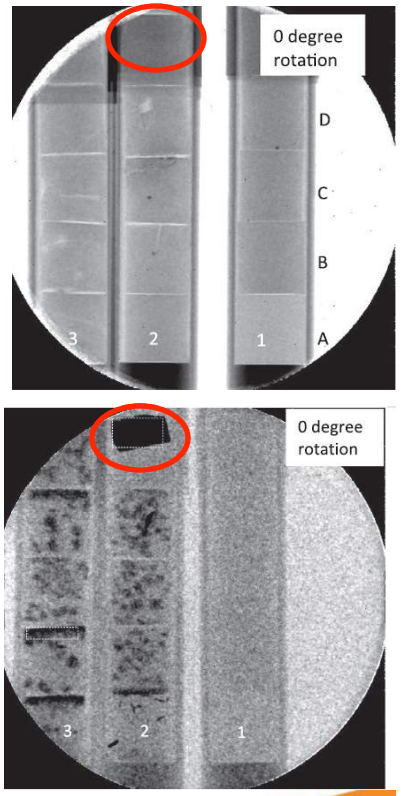
***D**etector for **A**dvanced **N**eutron **C**apture **E**xperiments*

- 160 BaF_2 crystals
- 4 different shapes
- 7 cm ^6LiH ball
- $\varepsilon_\gamma \approx 90\ \%$
- $\varepsilon_{casc} \approx 98\ \%$

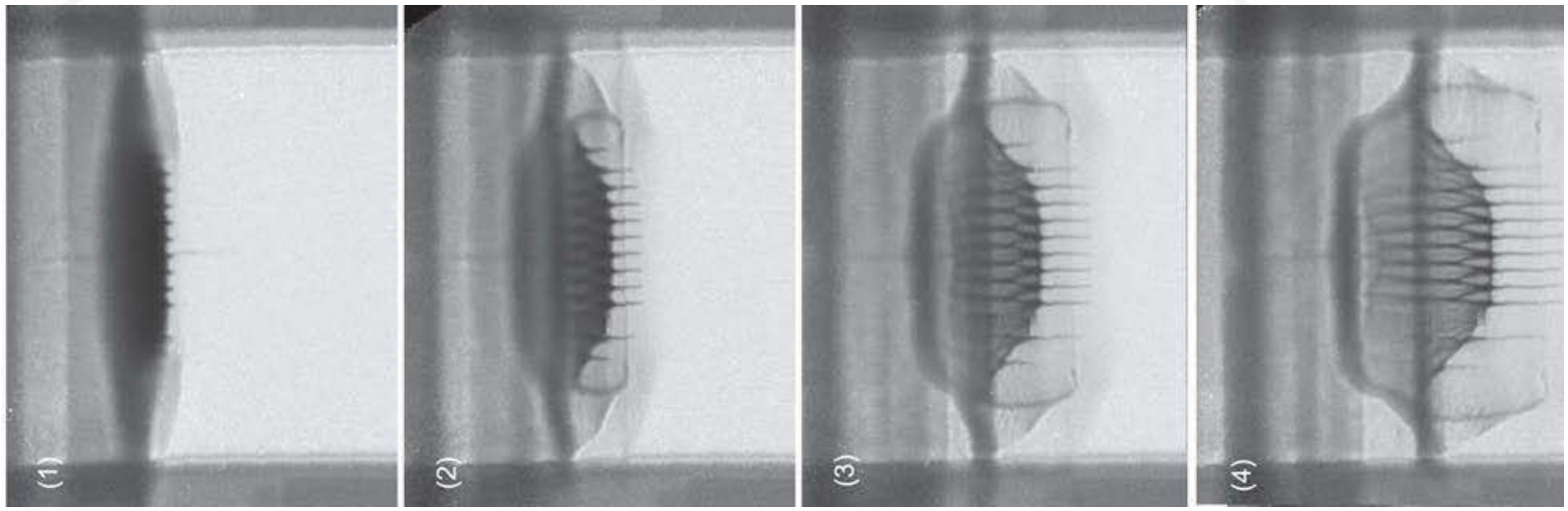


Low-energy neutron imaging has a variety of applications (Target 1)

- A new capability under development at LANSCE exploits the short (130 ns FWHM) proton beam pulses that produce thermal & epithermal neutrons
- Detector: ^{10}B-doped Micro Channel Plate
- Resolution: < 100 μm
- Technique uses nuclear resonances that are isotope specific
- Tungsten inclusions in uranium rods have been imaged (at right) using resonance gating



Proton Radiography (pRad) captures fast transient phenomena



Tin target shocked by an explosively driven flyer plate
The action takes place over 3 microseconds

Camera shutter speeds of 60 ns

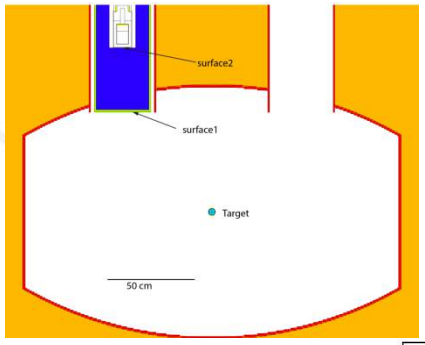
Users include: AWE, CEA, VNIIEF ARL, Harvard, Imperial College, & Technical University of Darmstadt.

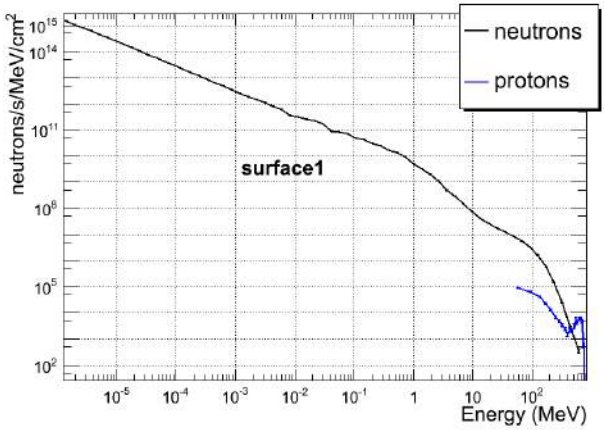
Proton irradiations are performed in the Blue Room, new facility planned

- Blue Room (Target 2) – direct proton beam
  - 800 MeV beam energy, but lower is possible
  - $\leq$ 80 nA proton beam current = 5×10^{11} p/s typ.
  - 2.5 cm diameter beam spot, typical
  - Turns off WNR Target-4 flight paths
- Planned facility at LANSCE Area A
  - Can run simultaneously with WNR Target-4
  - Large area, flexible configurations
  - Higher currents than Blue Room allowed

Neutron irradiations are performed at two locations

- Target-4 East Port (at right)
  - Near neutron production target
  - Neutron flux ~3x10^{13} n/cm^2/day for 1-100 MeV & 100-800 MeV
- Target-4 FP-60R @ 10 m
  - Peripheral beam in front of collimator
  - 3x10^{11} n/cm^2/day





Energy	Neutrons/cm^2/day
1eV-1keV	5.9E+13
1keV-1MeV	1.1E+14
1MeV-100MeV	2.5E+13
100-800MeV	2.9E+13

Summary of user program experimental capabilities at LANSCE

Summary of LANSCE User Facility Experimental Stations				
WNR Target 4 High-Energy Neutrons (~100 keV to 600 MeV)				
Flight Path or Station	**Distance**	**Flux (typ.) 10% En bin – depends on collimation!**	**Neutron Shutter**	**Attributes**
TPC - 4FP90L	7 – 15 m		Fixed circular	
ICE House - 4FP30L	~20 – 30 m	~10^5 n/cm^{2}s	Fixed circular	"Cosmic-ray flux"
40 m stn 4FP30L	40 m		Fixed circular	ICE House off
Chi-Nu - 4FP15L	22 m		Variable rectangle	Low n return pit
90 m stn - 4FP15L	90 m		Variable rectangle	Chi-Nu off
4FP15R	13 – 29 m		Variable rectangle	
ICE II - 4FP30R	~14 – 18 m	~2 x 10^5 n/cm^{2}s	Fixed circular	"Cosmic ray-flux"
4FP60R	20 m		Fixed circular	
n-irradiation - 4FP60R	~10 m	~ 10^{11} n/ cm^{2}s	Fixed circular	Simultaneous 4FP60R
Target 4 East Port	~1 – 2 m	~ 10^{13} n/ cm^{2}s	NA	Simultaneous Target 4
Lujan Center Target 1 Moderated Neutrons (meV to 1 MeV)				
Flight Path or Station	**Distance**	**Flux (typ.) depends on collimations, etc.**	**Neutron Shutter**	**Attributes - moderator**
n-imaging – 1FP5	6 – 10 m		Fixed circular	Water
1FP12	~16 m		Fixed Hg circular	LH_2, 2 choppers
DANCE - 1FP14	20 m		Fixed Hg circular	Water
Blue Room Target 2 Protons (200 – 800 MeV protons) 12 m diameter with 6 m basement & dome				
Use	**Max. current**	**Flux**	**Beam diameter**	**Attributes**
Proton irradiations	80 nA	~3x10^{13} p/cm^{2}s	~5 cm	Target 4 off, low n return design
LSDS	1 μA avg or ~10^{13} p/ pulse(PSR)	~1000x target-4 fluxes,	< 1 cm	Target 4 off, linac or proton storage ring (PSR) beam, low n-energy resolution
Proton Radiography - Area C Dome				
Use	FOV	Protons/pulse (typ.)	Time Range	Attributes
p-imaging, fast transient effects	~10 cm		ns – μs or longer	Magnetic lenses -I, 3x

- Thank You for Your Attention!