Nuclear Science Research at the LANSCE-WNR Facility

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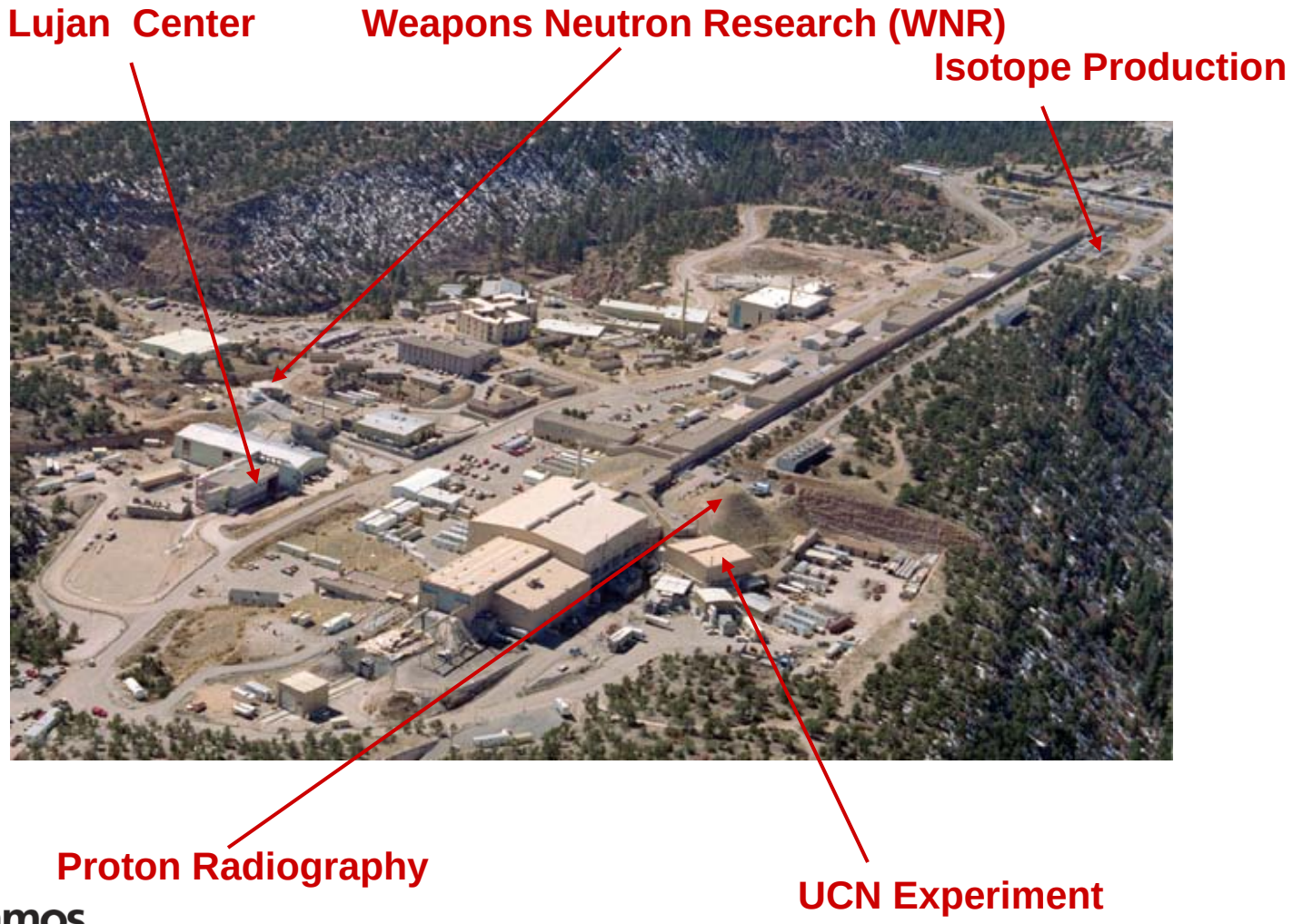
Outline

- LANSCE facility
- Sponsors and motivation
- Instrumentation
- Recent measurements
- Summary

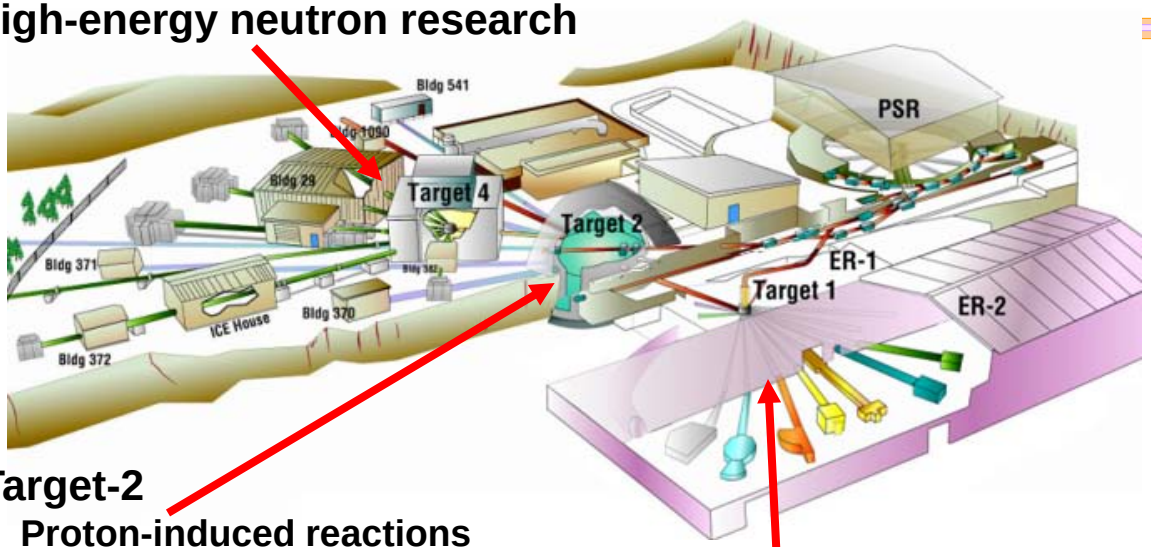
The Los Alamos Neutron Science Center (LANSCE)



Nuclear Science research is performed at many experimental areas at LANSCE

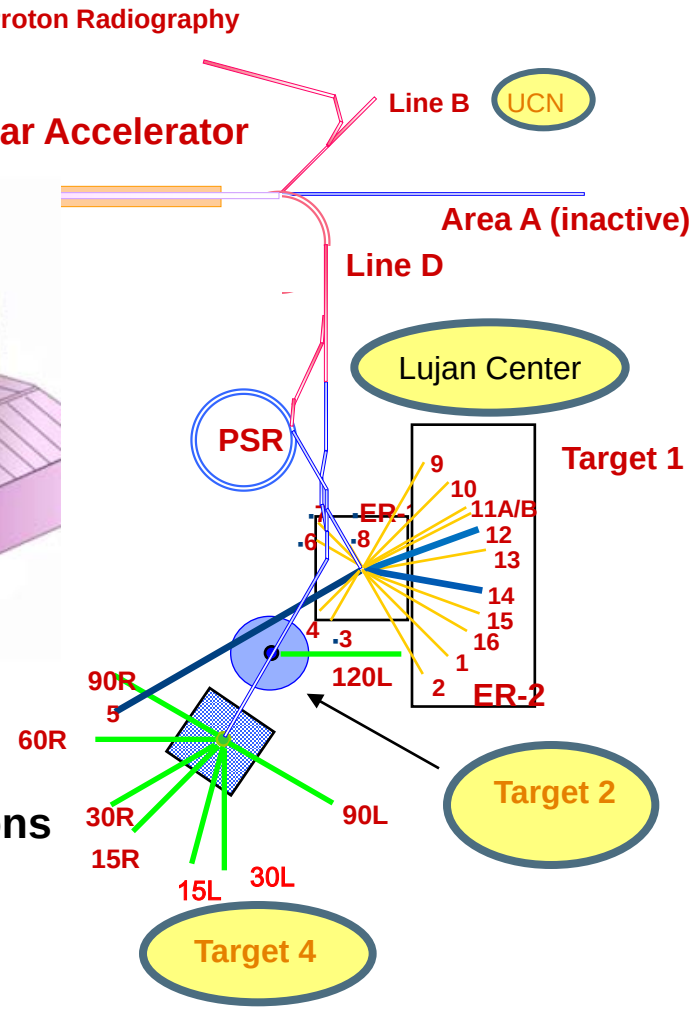
Weapons Neutron Research Facility

Target-4
High-energy neutron research



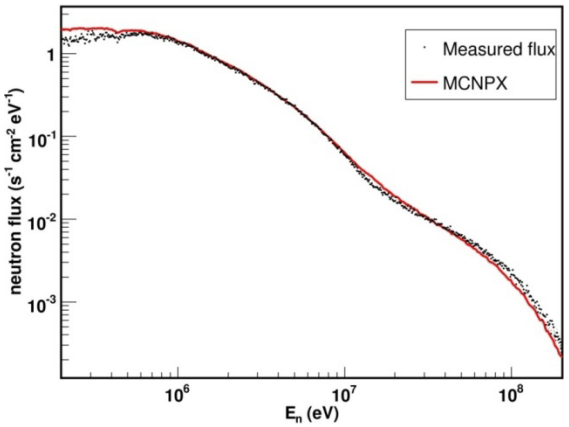
Target-2
- Proton-induced reactions
- Single-pulse experiments (Sandia)
- Lead Slowing-Down Spectrometer
- SNS target testing
- Isotope production testing

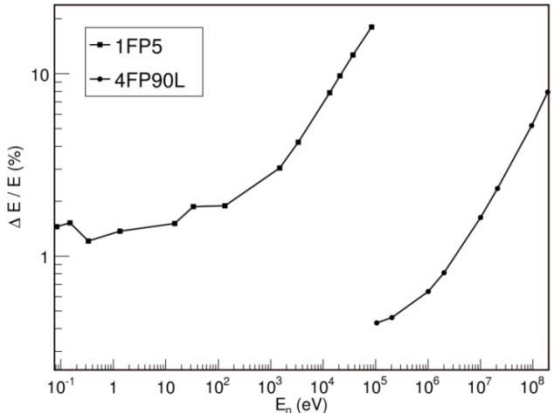
Lujan Center
Low-energy neutrons
- Material science
- Nuclear science



LANSCE-WNR capabilities today

- **The lower end of the neutron spectrum at WNR is in a region of great importance to astrophysics, weapons and nuclear energy (keV to MeV)**
  - Options for proton pulse spacing (1.8, 3.6, 7.2μs) extends the neutron energy down to 30keV at WNR.
  - However, there is a trade-off between energy range, flux and resolution: longer pulse-spacing lowers the available neutron energy, but also lowers the neutron flux. Shorter flight path also lowers the energy that is accessed, but simultaneously lowers the time-of-flight resolution.
- **WNR is an intense source of fast neutrons**
  - However, an even higher flux would make it possible to perform high priority measurements that are currently not feasible.
- **WNR has an excellent energy resolution over the full spectrum, and is as low as 0.1% at 25 meters. With a 90 meter flight 0.03% could be achieved.**





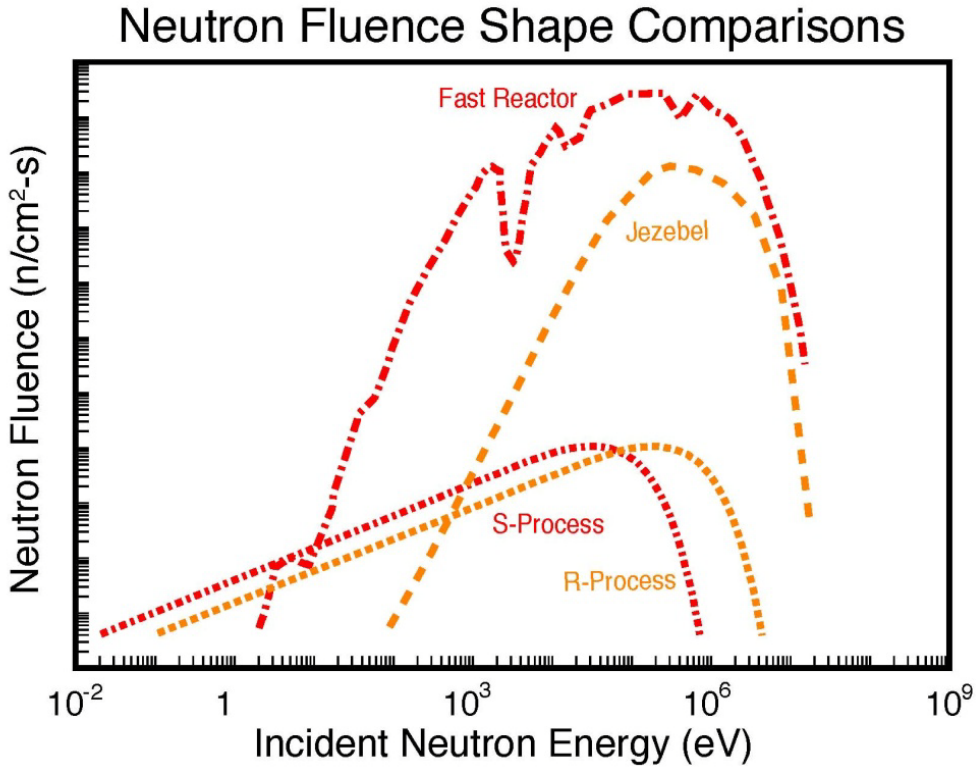
The proposed Nuclear Science Complex is an integrated capability to measure new nuclear data

- **Neutron Source**
  - Many nuclear reactions of interest pertain to short-lived isotopes created in a nuclear detonation.
  - To obtain meaningful reaction rates on small quantities of material requires an intense source of neutrons.
  - The ability to perform *Pulse Stacking* in the Proton Storage Ring (PSR) at the Los Alamos Neutron Science Center (LANSCE) will lead to orders of magnitude greater neutron fluxes on sample as well as enhanced energy resolution.
- **Neutron Detection**
  - The *Total Absorption Neutron-Gamma Observer (TANGO)* will use novel detector material (cerium-doped LaBr3) to achieve unprecedented sensitivity, energy resolution, and efficiency in detecting neutron capture reactions.
- **Target Fabrication Capability**
  - Cross section measurements generally require chemically pure target material
  - In many cases the target material is radioactive.
  - Construction of new *Radiochemistry Laboratories* at TA-48 for chemically processing small quantities of radionuclides and fabrication of targets is proposed.

Nuclear science at WNR mainly supported by DOE

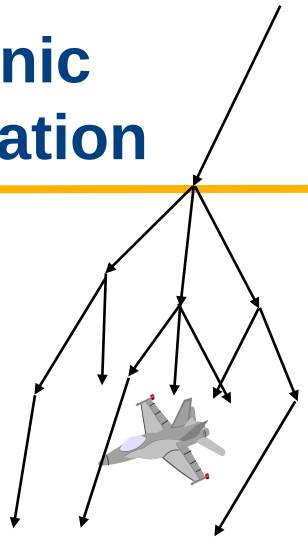
- **National Nuclear Security Administration (NNSA) support defense related research**
  - Fission and capture cross sections
  - Neutron output spectra
  - (n,2n) reaction cross sections
- **Office of Nuclear Energy supports research at LANSCE-WNR**
  - Fission and capture of actinides
  - Fission product yields
  - Detector development
- **Office of Science support basic research**
  - Astrophysics
  - Nuclear structure
  - Fission research

The energy range of interest is shared among different applications

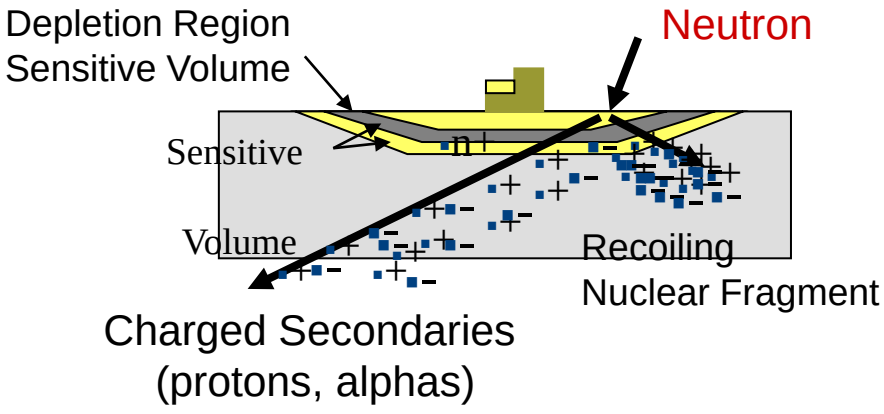


- **Fast reactors, nuclear weapons and astrophysics have similar nuclear data needs**
- **For fast spectrum applications neutron cross sections keV to MeV energies are of particular interest**

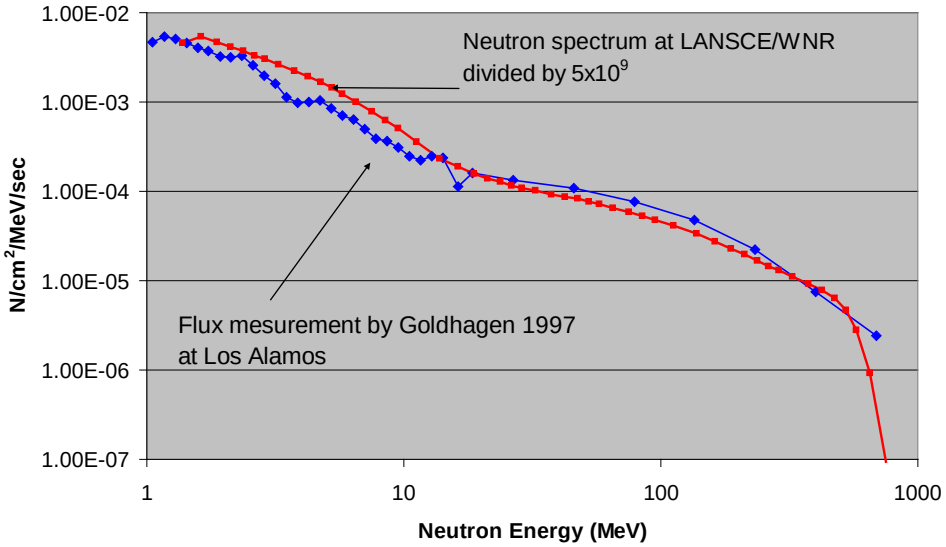
Industry users test the performance of electronic devices at LANSCE-WNR under neutron irradiation



- **Neutron Single Event Effects (SEE) are faults in electronic devices caused by neutrons**
- **Neutrons are produced by cosmic rays in the upper atmosphere , and have long mean-free paths so they penetrate to low altitudes**
- **Neutrons interact with Si and other elements in the device to produce charged particles**
- **Charged particles deposit charge in the sensitive volume which can cause the state of a node to change**



Neutron Flux at Los Alamos and LANSCE/WNR



Los Alamos NATIONAL LABORATORY EST.1943

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

NNSA

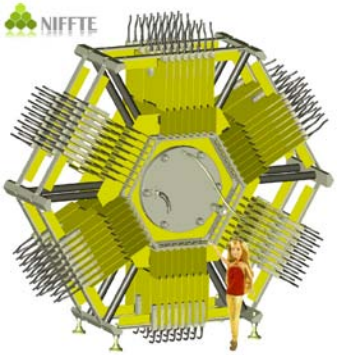
Existing instruments for nuclear science at LANSCE

DANCE (capture)

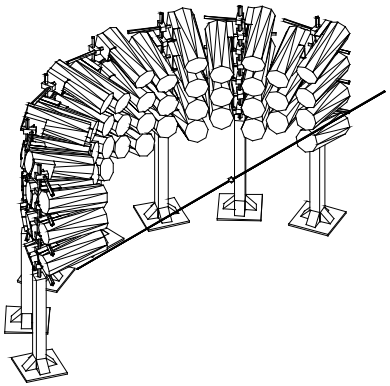
N,Z (n, charged particle)

GEANIE (n,xγ)

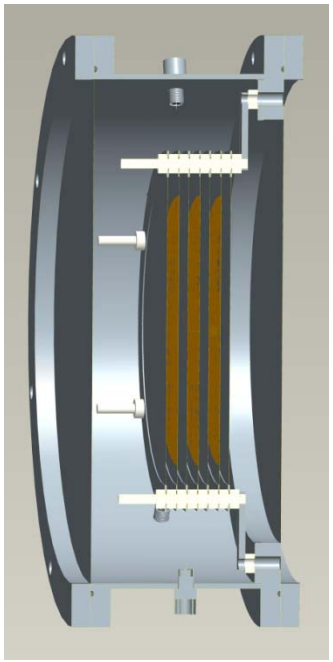
TPC, ionization chambers (fission)



Chi-Nu (n,xn+γ)

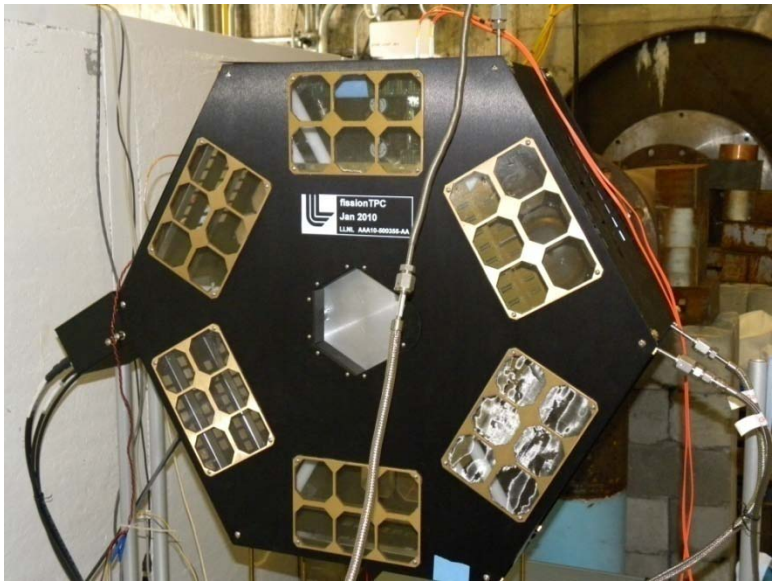


Fission detectors



Ionization chambers

- Used since the ’40s
- Reliable, fast, insensitive to radiation damage
- Limited event information

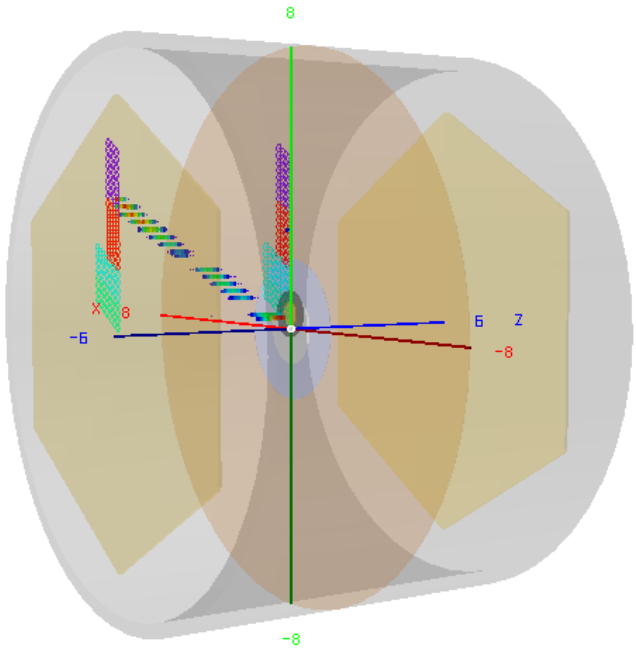


Time Projection Chambers (TPC)

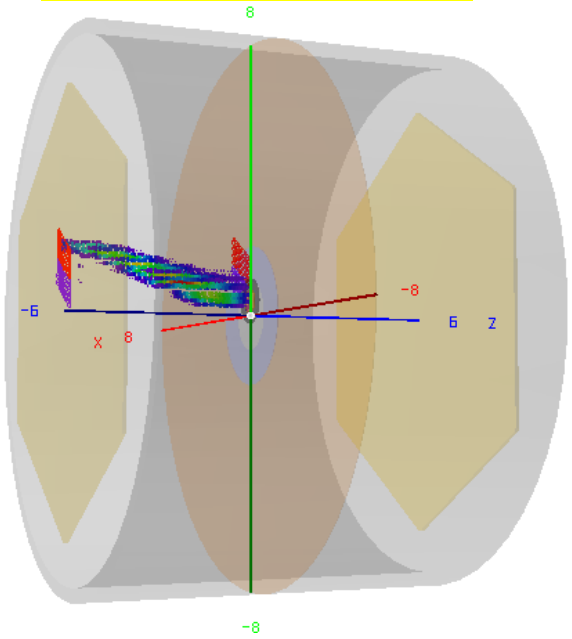
- Provide 3D representation of particle tracks
- Invented in the late 1970’s for particle physics
- The NIFFTE TPC is being commissioned for fission studies

Prototype TPC beam testing at LANSCE

Light ion event

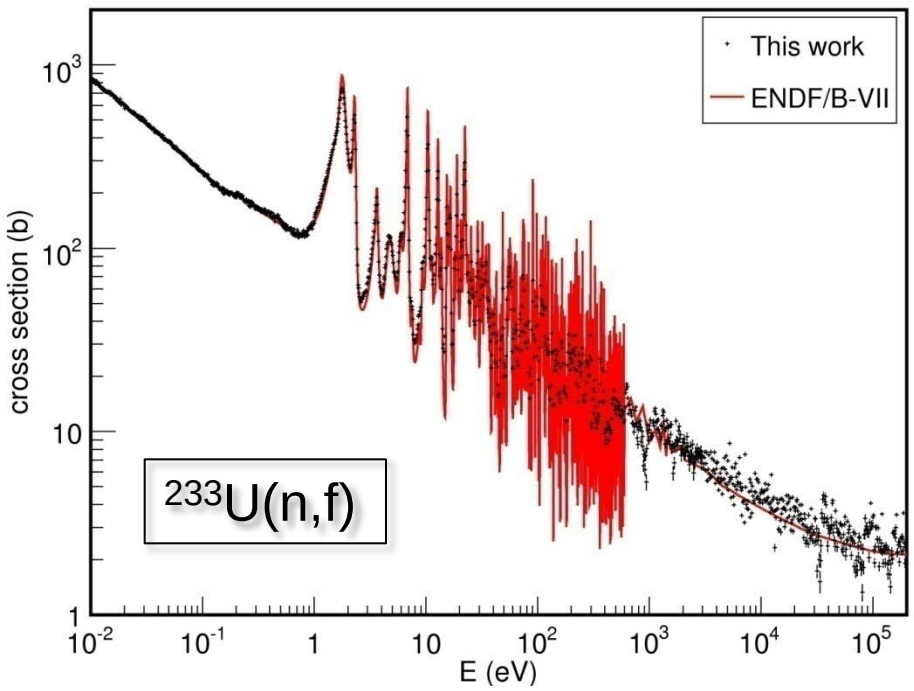


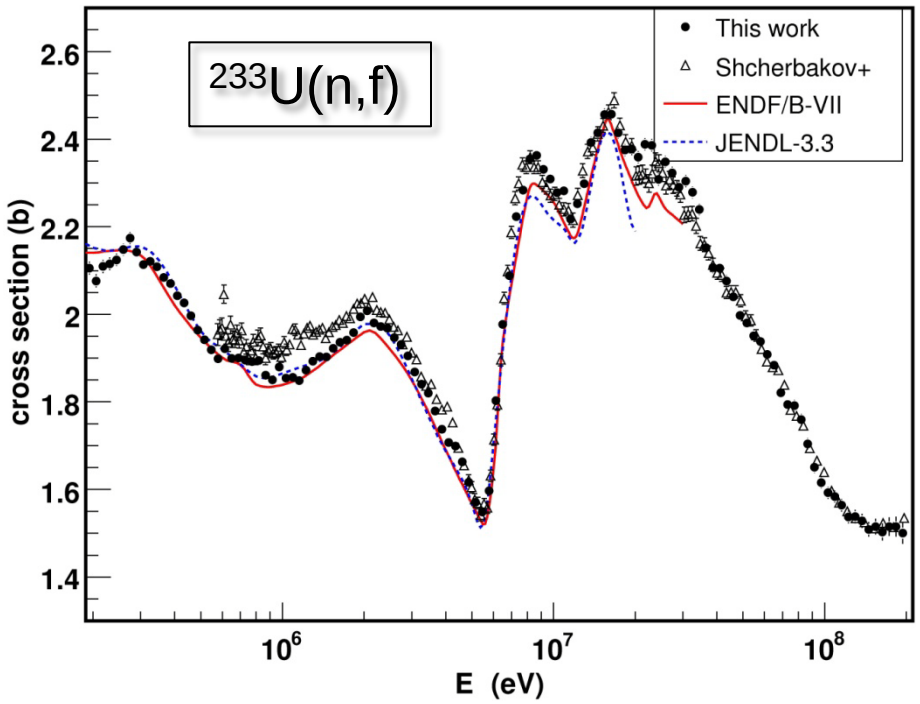
Fission fragment



- A prototype prepared at LLNL was received at LANL in July 2010
- First beam tests with blank target in August
- Beam data with U-238 sample collected in October-December

Recent fission work: The U-233(n,f) cross section





- **The neutron energies below 200 keV are measured at Lujan Center. Structures in the unresolved resonance region observed, missing from the evaluation.**
- **The data set extends to 200 MeV. The only other measurement extending beyond 20 MeV is from PNPI (Shcherbakov et al.)**

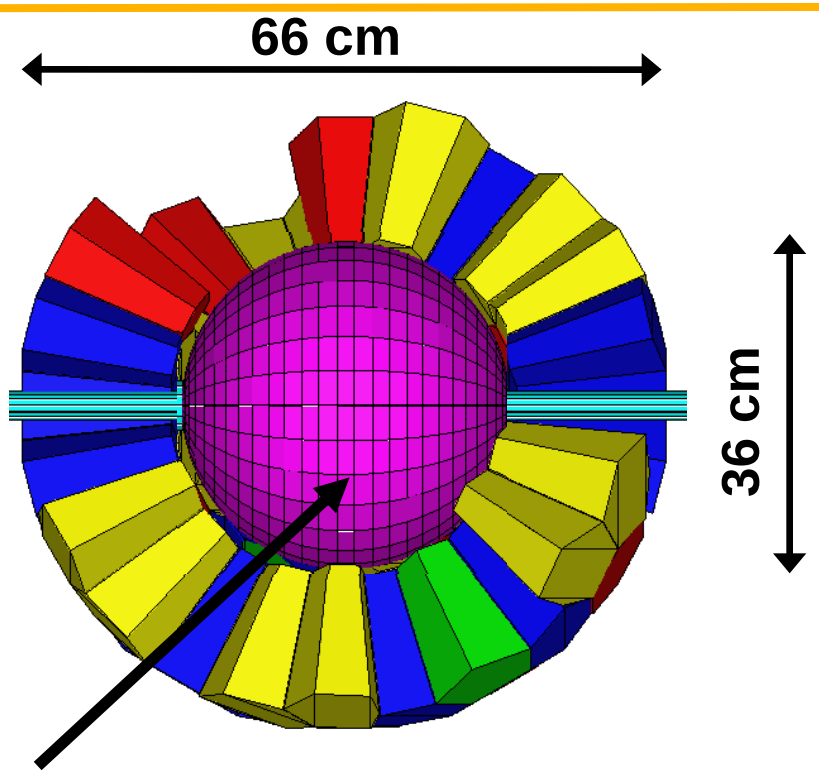
Detector for Advanced Neutron Capture Experiments (DANCE)

160 BaF_2 Scintillators

4 Detector Shapes each covering the same solid angle

$\varepsilon_\gamma \approx 90\ \%$

$\varepsilon_{casc} \approx 98\ \%$

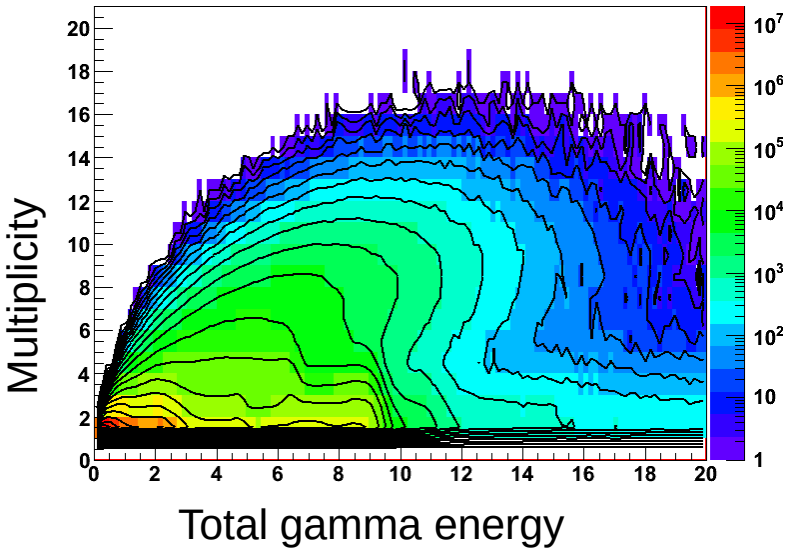


^{6}LiH Shell Surrounds Sample (6 cm)

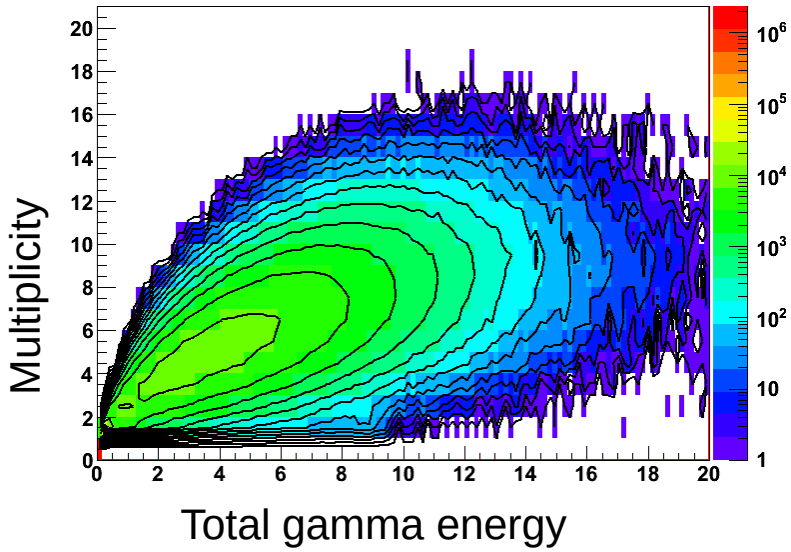
For details see: Heil *et al,* NIM A 459 (2001) 229-246

DANCE Gamma-ray Spectrum from fission can be identified with Fission Tagger

Raw DANCE gammas

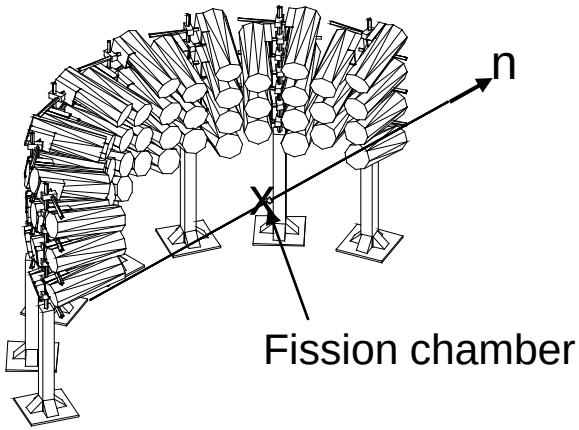


Fission-gated DANCE gammas



The Chi-Nu array is used to measure the fission neutron spectrum

Chi-Nu (n,xn+γ)



22.7 m from
WNR source

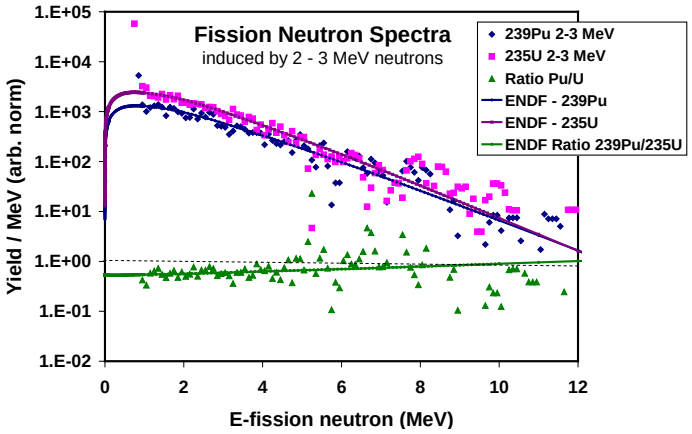
20 liquid scintillator neutron detectors

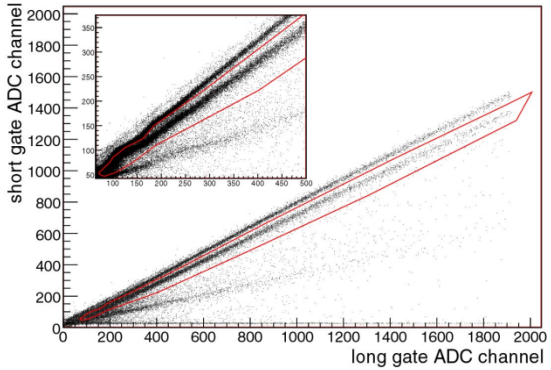
2 gamma-ray detectors

Double time-of-flight experiment

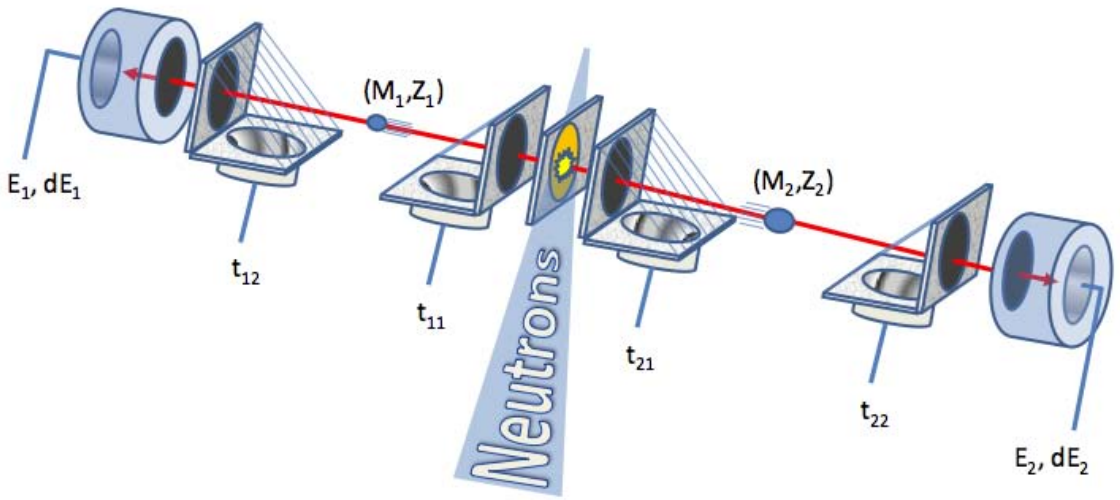
Neutron Output: improved measurements are needed at the extremes of the spectrum

- **Measure fission neutrons below 0.6 MeV**
  - ^{6}Li-glass detectors
  - Room-return is an issue - new flight path
- **Measure fission neutrons better above 8 MeV**
  - Better timing on fission chamber (LLNL-LANL collaboration)
  - More efficient neutron detectors (larger solid angle for detection)
  - Lower background
- **Neutron detector efficiency**
  - 252Cf
  - Tagged neutrons
- **Digitizer DAQ**





Spectrometer for ion detection in fission research (SPIDER)



- **We will develop a new instrument at LANSCE that measures the mass, charge and kinetic energy of fission products**
- **This will give us the needed data on fission product yields as a function of neutron energy for important actinides**

Irradiation effects on structural materials in reactors can be investigated at LANSCE

- Neutron-induced charged particle production leads to buildup of gases in the structural material of reactors
- By measuring the probability of these reactions we can calculate the gas-formation rate
- The (n,z) chamber at LANSCE uses particle telescopes to measure charged particles from iron and other structural materials

Summary

- The LANSCE-WNR facility supports a broad nuclear science program
- There is a strong focus on nuclear data for application (nuclear energy, defense)
- A proposed upgrade, the Nuclear Science Complex, would enhance the facility and provide new capabilities
- The user program at WNR has steadily grown in the last 10 years, and attracts researchers from industry, universities and national labs
- Continues investment into world class instrumentation keeps the nuclear science program competitive and provide the flexibility needed to address changing priorities for our sponsors