Los Alamos
NATIONAL LABORATORY

Neutron Facility Overview for Fusion Neutronics Nuclear Data Measurements

Keegan J. Kelly (Presenting), with thanks to:

Lee Bernstein (LBNL)

Yaron Danon, Adam Daskalaskis (RPI)

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Andy Rogers, Partha Chowdhury (UMass Lowell)

Sean Finch (TUNL)

Jeff Vanhoy (UKy)

Carl Brune (OU)

WANDA 2024 - Fusion Neutronics Session

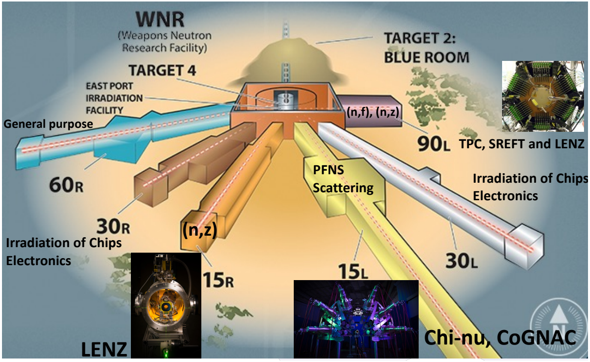
NNSA National Nuclear Security Administration

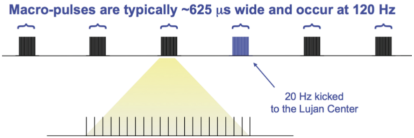
LA-UR-24-21722

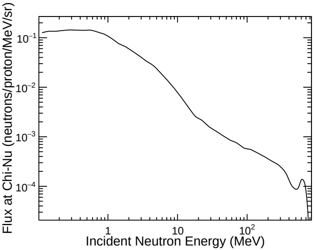
Outline

- LANL - WNR Facility and Lujan Center
- LBNL - 88” Cyclotron
- RPI - Gaerttner LINAC
- TUNL - 10 MV Van de Graaff
- UMass Lowell - Mono-E and Research Reactor
- OU - Edwards Accelerator Laboratory
- UKy Accelerator Labs

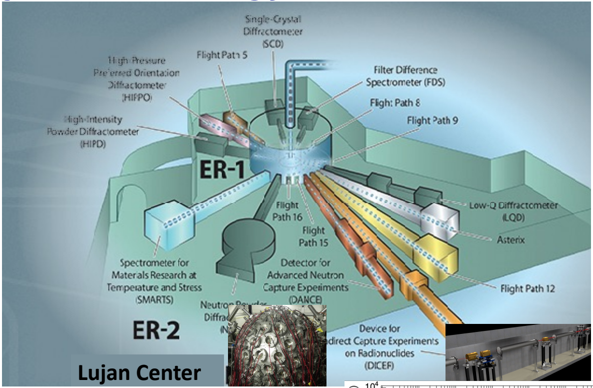
LANL WNR High-Energy White Neutron Source



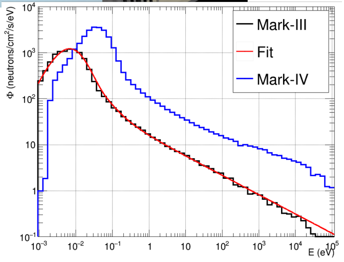




LANL Lujan Low-Energy White Neutron Source



- Recent target upgrade improved flux magnitude, range, and resolution



LBNL White Neutron Source

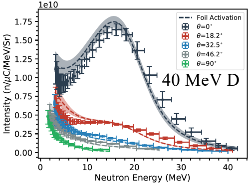
Variable energy, intense neutron beams[1] are available at two locations at the 88-Inch cyclotron[2]

Cave 0
(L.A. Bernstein's talk)

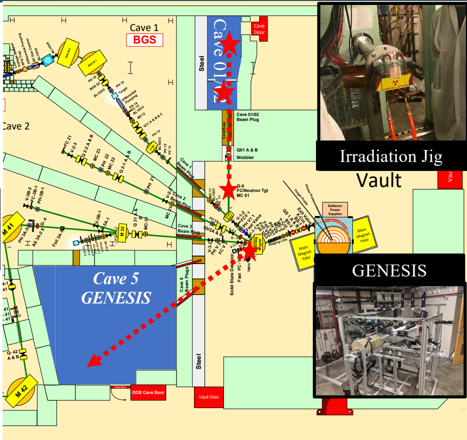
- High-level cave capable of running up to1 .5 kW of beam power.

Cave 5
(J.A. Brown's talk)

- Breakup target in cyclotron Vault
- 7-22 m flight path
- Location of GENESIS[3]



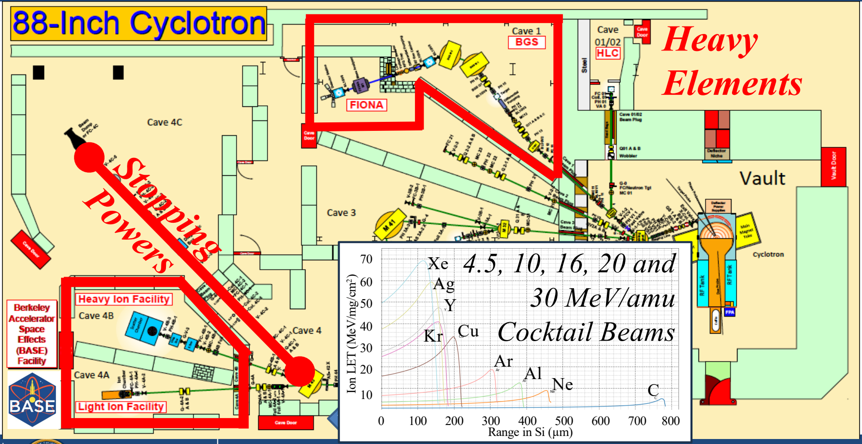
$\phi_n = 1.4\text{x}10^{11}$ /s/cm² @ 1 cm
$\phi_n = 2.0\text{x}10^{10}$ /s/cm² @ 10 cm
$\phi_n = 2.2\text{x}10^{5}$ n/s/cm² @ 10 m



[1]Secondary Neutron Production from Thick Target Deuteron Breakup. JT Morrell, AS Voyles, JC Batchelder, JA Brown and LA Bernstein. Phys. Rev. C 108, 024616 (2023). https://doi.org/10.1103/PhysRevC.108.024616
[2]The 88-Inch Cyclotron: A one-stop facility for electronics radiation and detector testing. M.Kireeff-Covo *et al.*,. Measurement, 127, (2018), p. 580-587. https://doi.org/10.1016/j.measurement.2017.10.018
[3]GENESIS: Gamma Energy Neutron Energy Spectrometer for Inelastic Scattering. J.M. Gordon *et al.,* Nuclear Instruments and Methods in Physics Research A 1061 (2024) 169120. https://doi.org/10.1016/j.nima.2024.169120

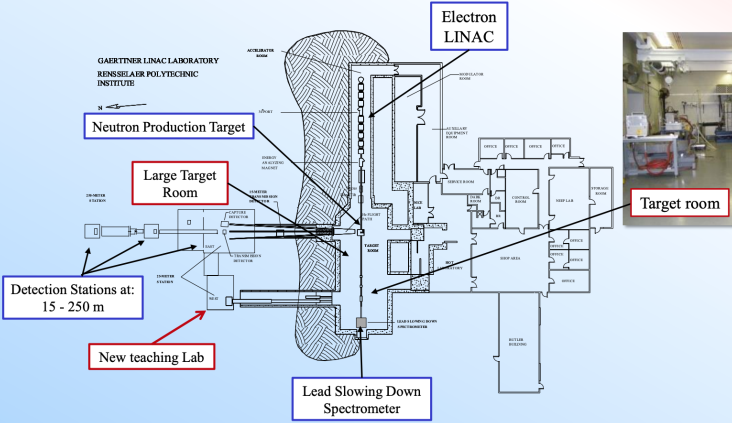
LBNL White Neutron Source

The 88-Inch also provides “cocktail” beams for electronics testing and stopping power measurements and the DOE-NP Heavy Element Program



RPI - e^--Driven White Neutron Source

The RPI Gaerttner LINAC Facility



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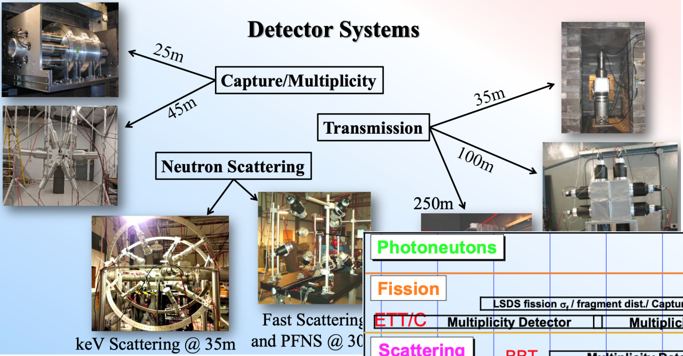
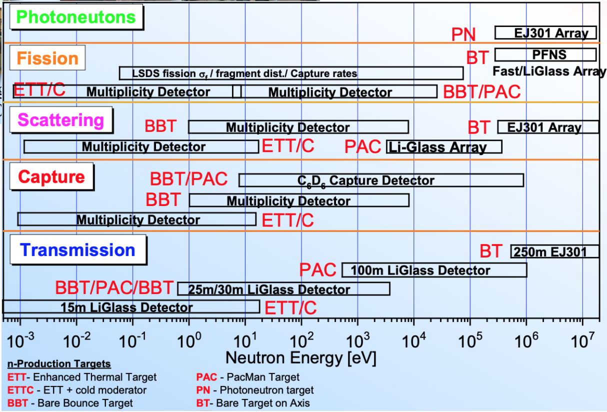
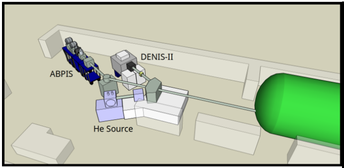
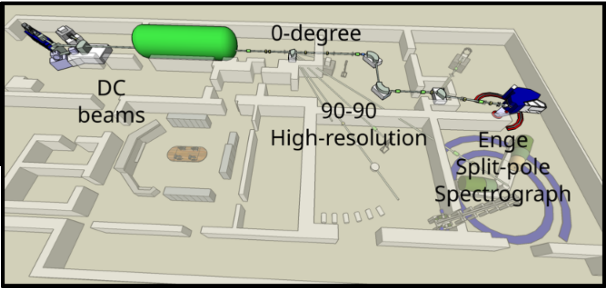
RPI - e^--Driven White Neutron Source

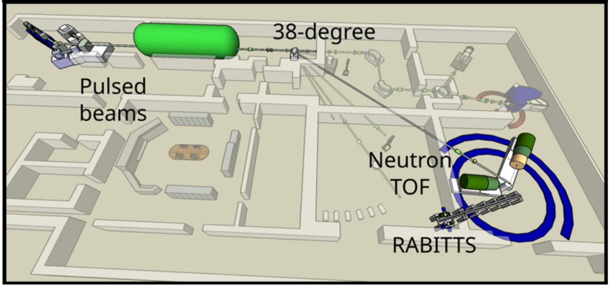




TUNL - Monoenergetic Neutron Source

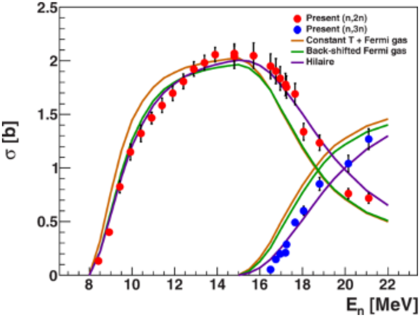


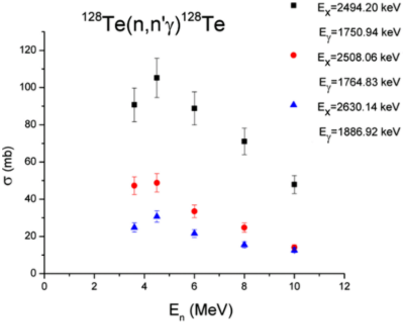


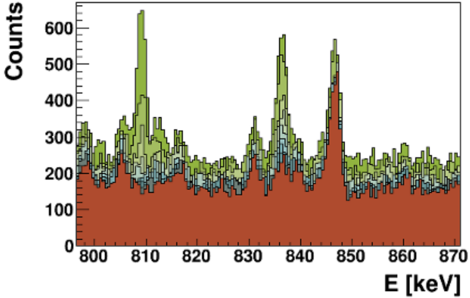


- E_n = 60 keV, 560 keV
  - ^{7}Li(p,n)^{7}Be
- E_n = 1.0 - 4 MeV
  - ^{3}H(p,n)^{3}He
- E_n = 4.5 - 13 MeV
  - ^{2}H(d,n)^{3}He
- E_n $>$14.0 MeV
  - ^{3}H(d,n)^{4}He

TUNL - Monoenergetic Neutron Source





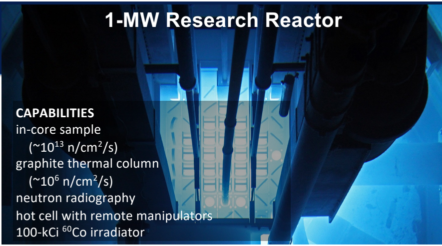


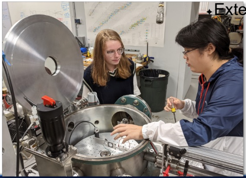
UML Radiation Laboratory

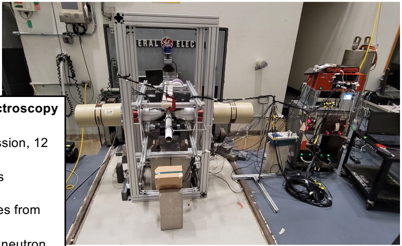
UMass Lowell Radiation Laboratory

CAPABILITIES

- *p*, *d*, He, … ions
- Up to 50-μA DC beam
- ***Sub-ns pulsing***
- Mono-energetic pulsed neutrons via ^{7}Li(*p*,*n*) reaction
- Fast-neutron beamline (goniometer, neutron scattering, ToF)
- Ion microprobe
- General purpose scattering chamber
- External beams



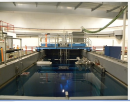




High-resolution coincidence gamma-ray spectroscopy

- MIXED ARRAY OF DETECTORS (MAD) with HPGe/BGO assemblies and Compton suppression, 12 Stilbene
- Modern digital DAQ, acquisition of 32 channels asynchronous
- Ability to measure gamma-gamma coincidences from thermal neutron capture reactions.
- Ability to tag on neutron emitted follow prompt neutron induced fission and examine coincident gamma-rays in the fission fragments.

UML Radiation Laboratory



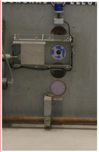
UML RESEARCH REACTOR

1 MW thermal power, open-pool, demineralized water, MTR flat plate fuel design, NRC licensed

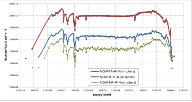
https://www.uml.edu/research/radlab/neutron-facilities.aspx

Contact: L. Bobek, T. Regan, M. Jandel (marian_jandel@uml.edu)

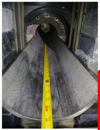
- **THERMAL NEUTRON BEAM**
- Pneumatic shutter
- 6-inch diameter beam – can be collimated
- Total thermal flux: **~6 x 10^5 n/cm^2/s**
- Easy access, low gamma contamination, parallel beam
- **Recently updated, new funded programs (DOE, NSF)**



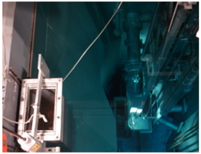
- **FAST NEUTRON BEAM**
- Shielded bunker, interlock, continuous monitoring.
- 6-inch diameter beam – can be collimated
- External access to switch samples (mobile tray/station – can be automated)
- Broad Group Fluxes (n/cm^2-sec)
- Accessible neutron fluxes
- Total: **~1 x 10^{12} n/cm^2/s**
- Additional shielding/moderation possible

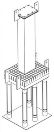


MCNP neutron flux at three locations along the fast beam port



- **FAST NEUTRON IRRADIATOR**
- 1 MeV equivalent flux: **~10^{11} n/cm^2/s**
- Supports samples as large as 30cm x 30cm x 15cm
- 1 MeV-equivalent fast neutron flux:
  - ~10^{11}n/cm^2/s
- Greater than 4000:1 fast-to-thermal flux ratio
- Neutron/Gamma ratio of 7x10^9 n/cm^2 per rad





- **IN-CORE IRRADIATIONS**
- Radiation “baskets” are open aluminum sample holders within the reactor core. Three located in the front of the core. One located in the core center.
- Maximum neutron flux in the core front:
- **1.3 x 10^{13} n/cm^2/s** thermal , **8.2 x 10^{12} n/cm^2/s** fast
- Maximum neutron flux available in the core center:
- **2.5 x 10^{13} n/cm^2/s** thermal , **1.6 x 10^{13} n/cm^2/s** fast

- **PNEUMATIC SAMPLE SYSTEM**
- The pneumatic sample system allows for the rapid movement of small experimental samples through a transport tube to a location external to the reactor core.
- A timer system permits automatic return of samples for irradiations from 2 seconds to 20 minutes.
- HPGe counting (low background) station can be placed at the exit
- Maximum dimensions 4-cm I.D. x 12-cm long and mass less than 300g. Samples typically placed in polyethylene vial 2.5-cm I.D. x 7.5-cm long.Vial is then placed into a polyethylene “rabbit”
- Maximum neutron flux: **~5.3x 10^{12} n/cm^2/s** thermal **~2.5 x 10^{12} n/cm^2/s** (fast)
- **Recent Collabborative Projects – BNL, LANL sample iirradiatioins**

OU - Edwards Acc. Mono-E and White Sources

Edwards Accelerator Laboratory at Ohio University

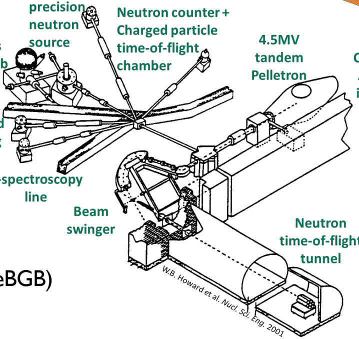
Research Areas:
Nuclear Astrophysics, Applications, Structure, Surface Science

Senior Researchers:
Carl Brune, Steve Grimes, David Ingram, Tom Massey, Andrea Richard, Alexander Voinov

Technical Staff:
Don Carter, Greg Leblanc

Neutron Beam Capabilities:
0.1-25 MeV
mono-energetic and white sources

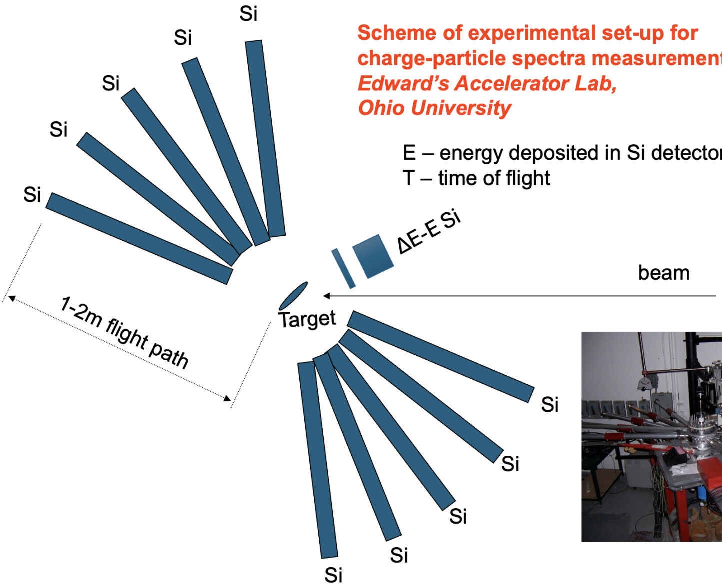
Neutron Detection Capabilities:
30-m time-of-flight tunnel
various scintillators
polyethylene moderator with ^{3}He and BF3 (HeBGB)

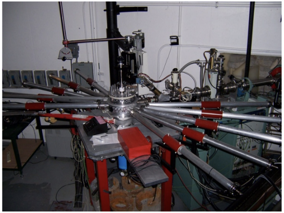


OU - Edwards Acc. Charged Particle Capabilities

Scheme of experimental set-up for charge-particle spectra measurements
Edward's Accelerator Lab,
Ohio University

E – energy deposited in Si detectors
T – time of flight

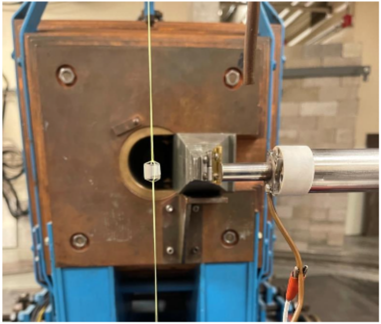




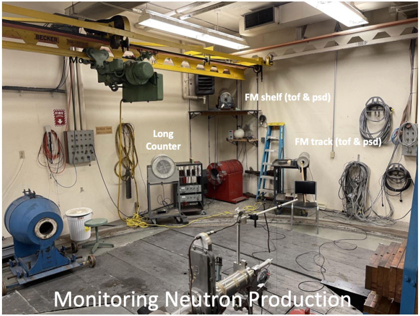
UKy - Monoenergetic Source

- **Accelerator**
  - HVEC Model CN: 7 MV
  - rf source
  - p, d, ^{3}He, α, … ions
  - Authorized for ^{3}H gas targets
  - measure exit neutron energy
  - 1 ns pulse widths every 533 ns
- **Basic Nuclear Science**
  - Nuclear Structure via (n,n'γ)
    - Level Schemes & Transitions
    - Spectroscopic Information
    - DSAM Lifetimes
  - (^{3}He,nγ)
- **Applied Nuclear Science**
  - Differential (n,n') Cross Sections
    - ^{12,13}C, ^{7}Li, ^{19}F , ^{54,56}Fe , ^{23}Na , ^{28}Si
  - Detector Development
    - Univ Guelph / TRIUMF

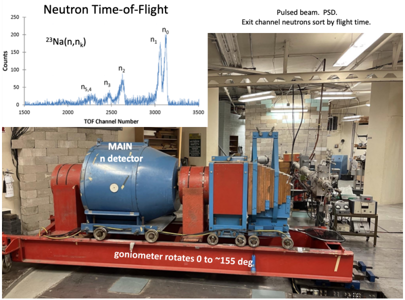
Quick reminders about the University of Kentucky Accelerator Lab programs

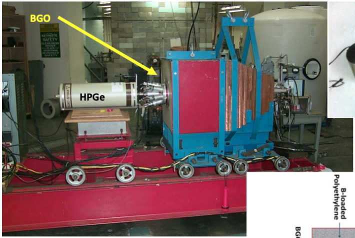


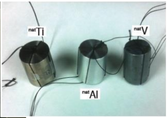
UKy - Monoenergetic Source

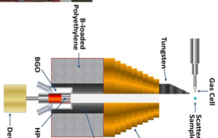


Pulsed beam. PSD.
Exit channel neutrons sort by flight time.









γ-Ray Detection

We have a wide variety of US-based neutron facilities ready to perform fusion-relevant measurements!

Thanks to everyone for submitting content for this talk!