



# LLNL Nuclear Physics Facilities – LiNuS, PRISM, NIF

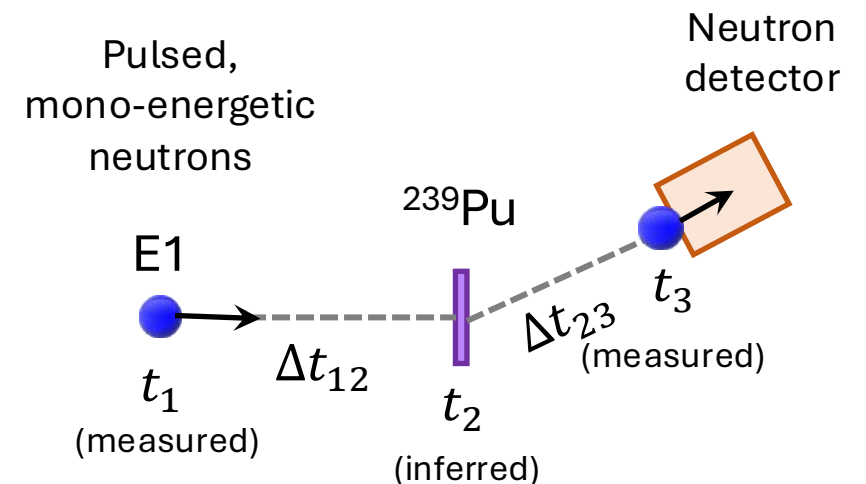
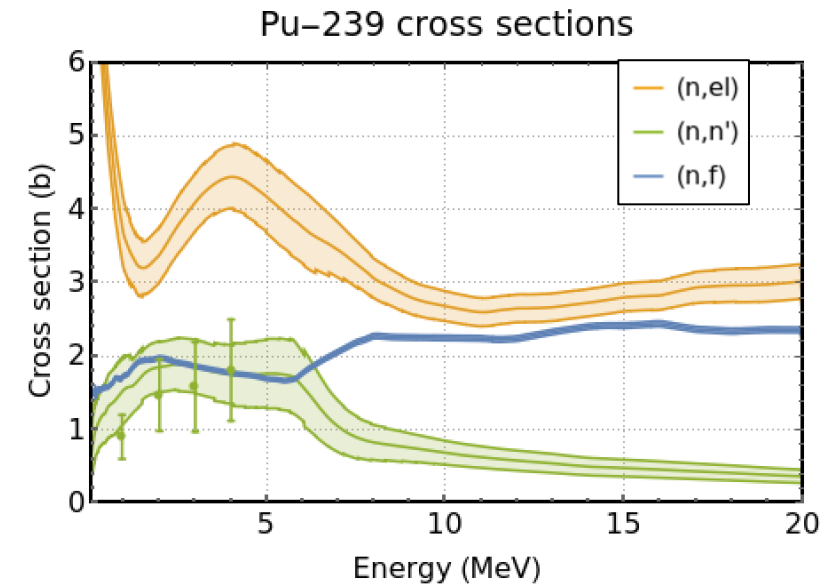
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**Robert J. Casperson**  
Lawrence Livermore National Laboratory

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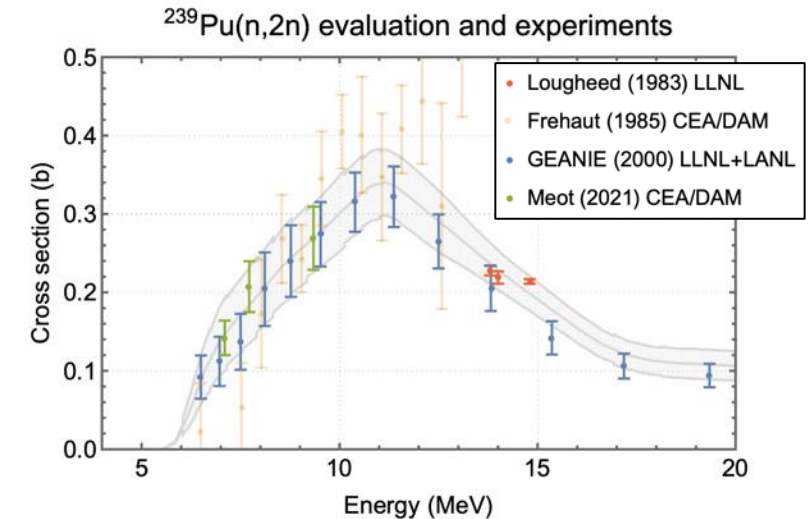
# Defense Programs Nuclear Data Needs: $^{239}\text{Pu}(n,n')$

- Many of the facility capabilities mentioned in this talk are discussed in terms of Defense Programs needs.  $^{239}\text{Pu}(n,n')$  was identified in the 2018 Multi-Lab L1 milestone.
- We are targeting very small uncertainties for  $^{239}\text{Pu}(n,n')$ :
  - **5% from 1-5 MeV** for non-quasi-elastic cross section.
  - We are interested in the **outgoing neutron spectrum**.
- nToF with pulsed, mono-energetic source requires the fewest corrections to determine this cross-section and outgoing neutron spectrum.
- High neutron flux would enable thinner plutonium target, and background mitigation via longer distances and collimation.
- Precise undertakings like  $^{239}\text{Pu}(n,n')$  benefit from multiple measurement approaches.



# An Additional Defense Programs Need: $^{239}\text{Pu}(n,2n)$

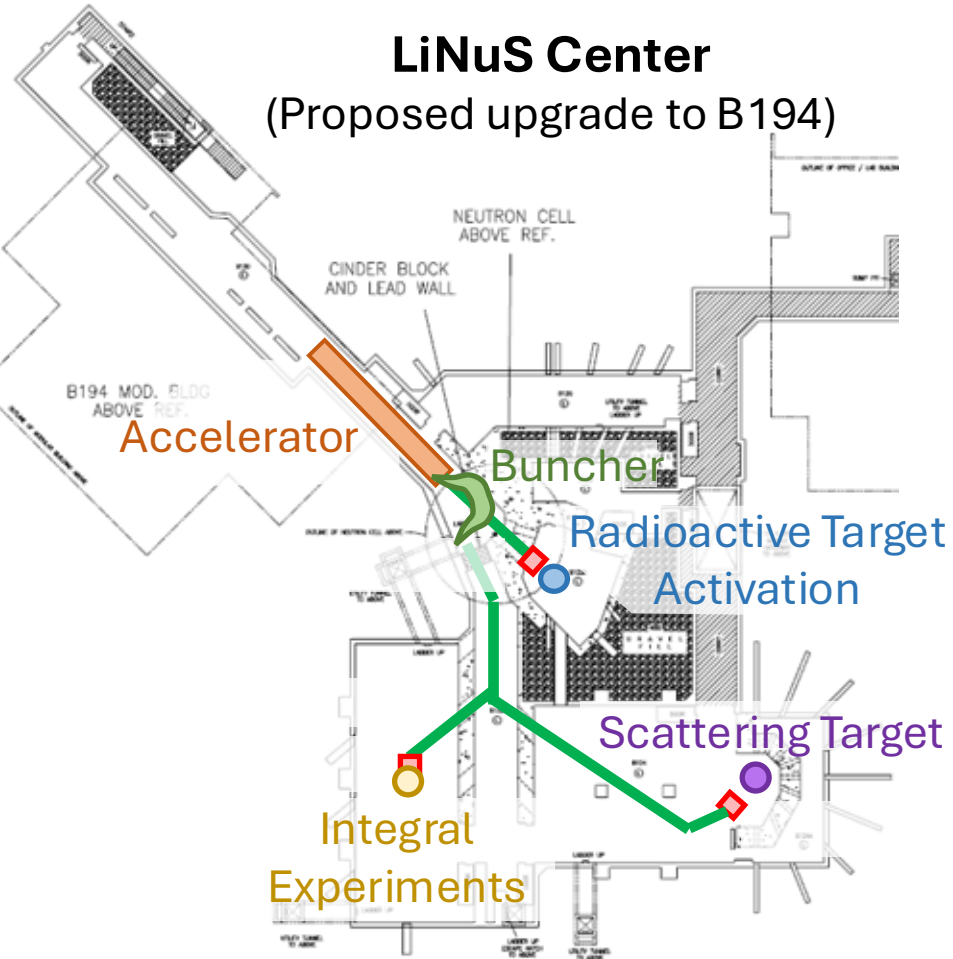
- In the 2025 Multi-Lab L1 milestone, the  $^{239}\text{Pu}(n,n')$  need was confirmed and  $^{239}\text{Pu}(n,2n)$  was additionally identified.
- We are also targeting very small uncertainties for  $^{239}\text{Pu}(n,2n)$ :
  - **2% from 14-15 MeV** (Neutrons from DT reaction)
  - **4% for 7-12 MeV** (Neutrons from DD reaction)
- Past measurement by Loughheed used Rotating Target Neutron Source-1 and alpha counting of  $^{238}\text{Pu}/^{239}\text{Pu}$  ratio for an entire year.
- The Center for Accelerator Mass Spectrometry is a modern, faster, and more precise approach for measuring this ratio.
- We currently consider activation to be the only approach that can achieve our target uncertainties, but it requires ultra-pure  $^{239}\text{Pu}$  which we fortunately have.



Center for Accelerator Mass Spectrometry (LLNL)

# Livermore Nuclear Science (LiNuS) Center will expand experimental capabilities, supporting nuclear data and integral measurements

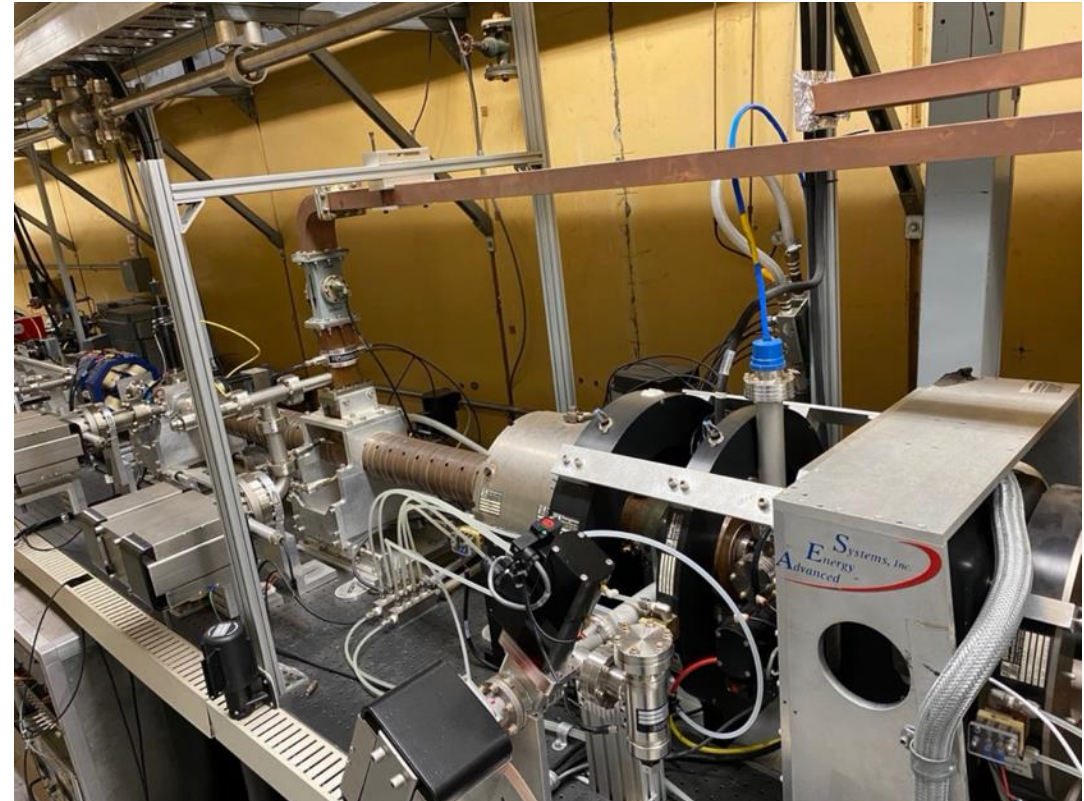
**LiNuS Center**  
(Proposed upgrade to B194)



- LiNuS will provide **high-flux, pulsed, tunable monoenergetic neutrons at a range of energies**
- Complementary to LANSCE broad energy spectrum
- Facility will provide high-priority Defense Program needs identified in multiple L1 Milestones:
  - $^{239}\text{Pu}(n,n')$  – nToF provides outgoing neutron spectrum
  - $^{239}\text{Pu}(n,2n)$  – High-flux activation with mass spectrometry
- Facility can also be used for integrated measurements such as pulsed spheres providing nuclear data constraints for reducing uncertainties
- LLNL has made LDRD investments to reduce risk on the accelerator design and target technology

# PRISM Accelerator at LLNL/B194

- S-band (2.998 GHz) linac developed by AES/Raytheon for a previous project
  - 40 keV DC thermionic gun + sub-harmonic buncher
  - Standing-wave linac section powered by 10 MW Thales klystrons/ScandiNova modulators.
  - System produces up to 100 mA macro-bunch current @ 25 MeV and 110 Hz rep. rate
- Experiments with PRISM use electrons and bremsstrahlung photons for nuclear physics and radiation effects research



# PRISM is being used to examine photonuclear data and perform diagnostic tests

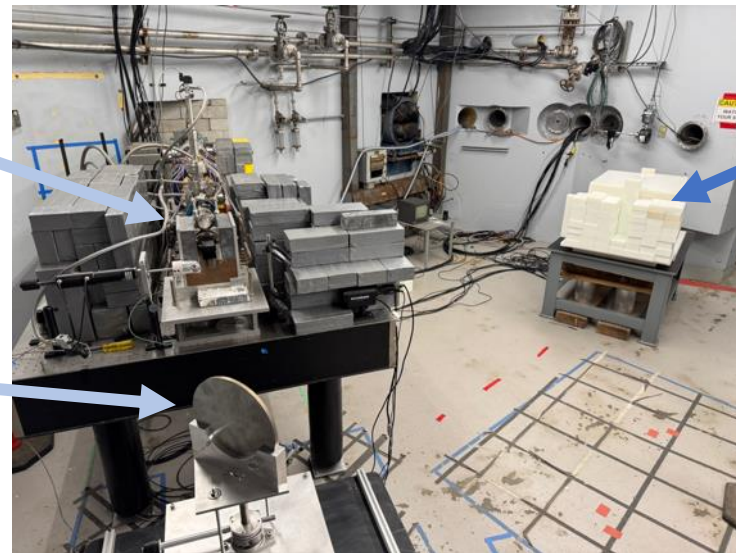
- Photonuclear effects can become important with high energy radiography -- PRISM spectrum matches NNSA Scorpius planned for PULSE, but much lower intensity
- PRISM is being used to test nuclear data (integrated measurements), shielding, and detectors



Electron accelerator

Conversion target

Material target



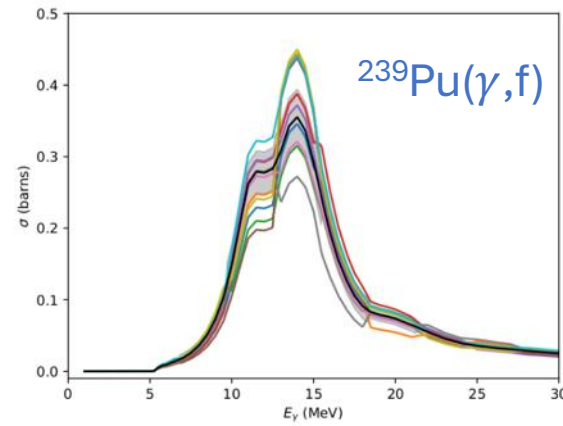
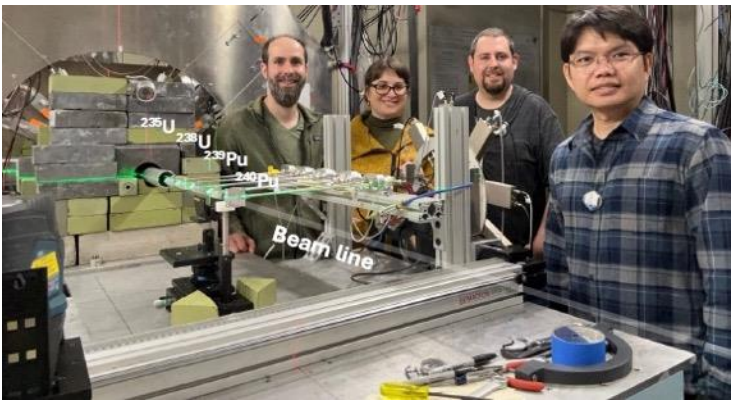
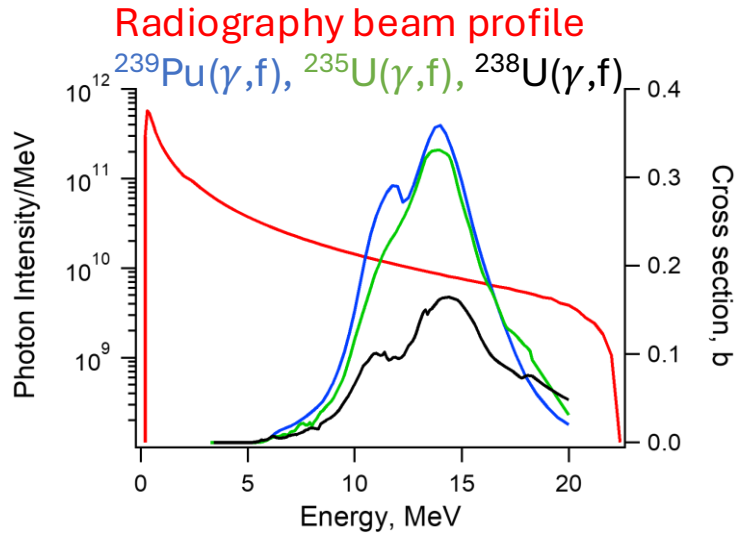
Detector + shielding



Cross-discipline collaboration

# Photonuclear data are a newer emphasis

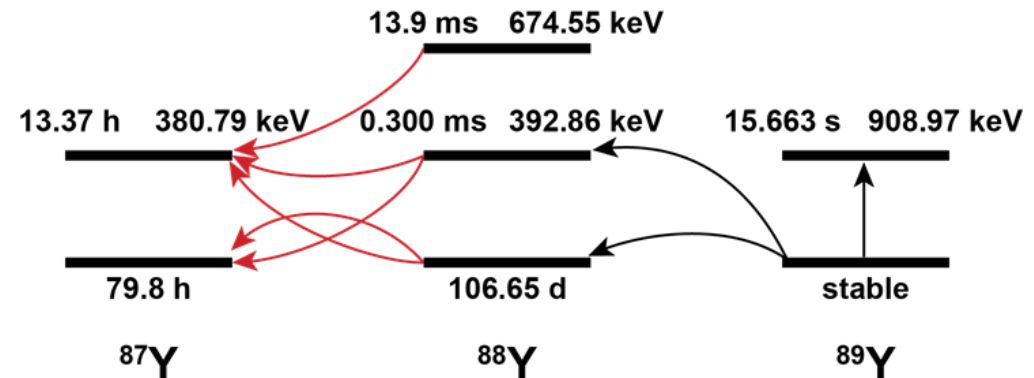
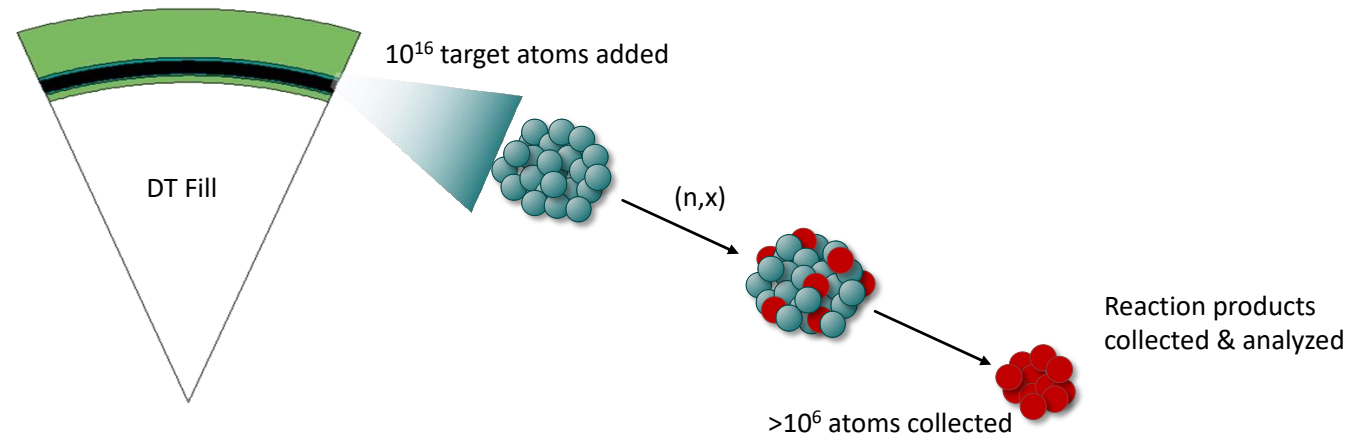
- Need high-intensity penetrating radiography for examining dense materials and challenging experimental conditions (e.g. smoke)
- Photonuclear reactions need to be considered for photon energies  $> \sim 7$  MeV
- Neutrons and gammas produced
  - reduce image quality
  - affect shielding requirements
  - damage other diagnostics
- Neutron scatter also plays a role



New measurements, new evaluations, and covariance data being delivered

# NIF Platform Development for Measuring (n,2n) Cross Sections on Radioactive Species

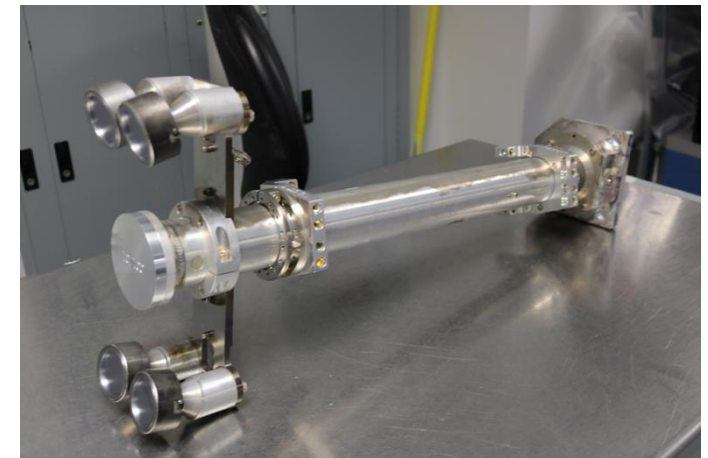
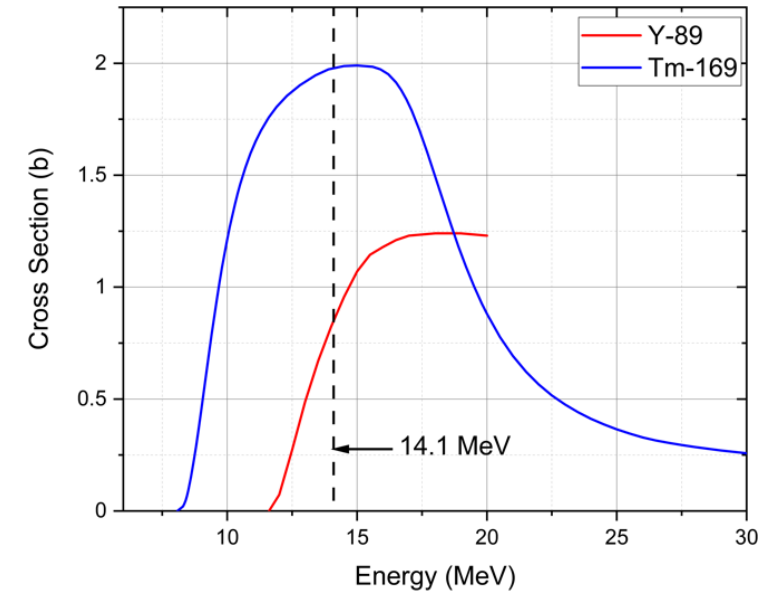
- High neutron yield and small burn volumes result in neutron fluxes much larger than traditional neutron sources
- Large neutron flux requires fewer target atoms to make a measurement ( $10^{13}$  atoms vs 100 times more material for an accelerator measurement)
- Short burn time ( $\sim 100$  ps) means that short-lived, excited states are accessible at higher neutron yields



# Known reference reactions are used to determine unknown cross sections

- Target materials and associated collection tracers are added to NIF capsules and dried to a thin layer on the inner surface of the capsule
- Reaction products are collected using Solid Radiochemistry (SRC) diagnostic at NIF and analyzed in the Nuclear Counting Facility (NCF)
- Two target nuclides with a “known” and “unknown” cross section are co-loaded together

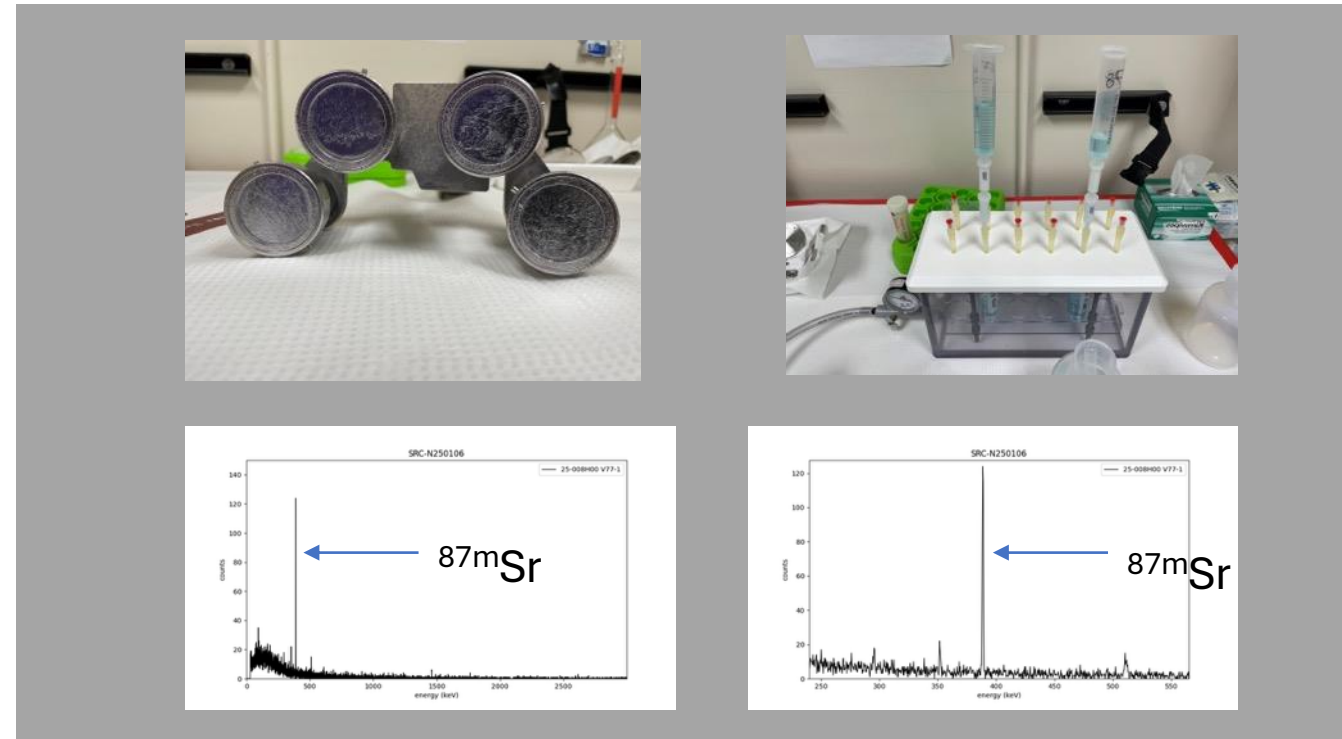
$$\sigma_{\text{unknown}} = \sigma_{\text{known}} (n^0_{\text{known}}/n^0_{\text{unknown}})(N_{\text{unknown}}/N_{\text{known}})$$



Platform developed for  $^{88}\text{Y}(n,2n)^{87}\text{Y}$  measurement at 14 MeV at NIF

# Successful Post-Shot Chemistry and Detection of $^{87}\text{Y}$ from N250106 $^{88}\text{Y}(n,2n)^{87}\text{Y}$ shot

- Following the successful N250106 NIF shot solid radiochemistry collectors (SRC) from 90-315 were recovered and chemically processed
- Reaction products ( $^{87}\text{Y}$  and  $^{168}\text{Tm}$ ) and fission products were leached from the surface of SRCs and all fission product and vanadium activation products were removed from the Y and Tm
- A generator was set up to milk  $^{87\text{m}}\text{Sr}$  from  $^{87}\text{Y}$  (since  $^{87}\text{Y}$  could not be detected with the  $^{88}\text{Y}$  background)
- This was milked for 10 days to determine how much  $^{87}\text{Y}$  was produced in the shot



(Top) SRCs in 90-315 bracket post shot and initial radiochemical processing  
(Bottom) Gamma spectrum of eluted generator showing clean  $^{87\text{m}}\text{Sr}$  peak, indicating presence of  $^{87}\text{Y}$

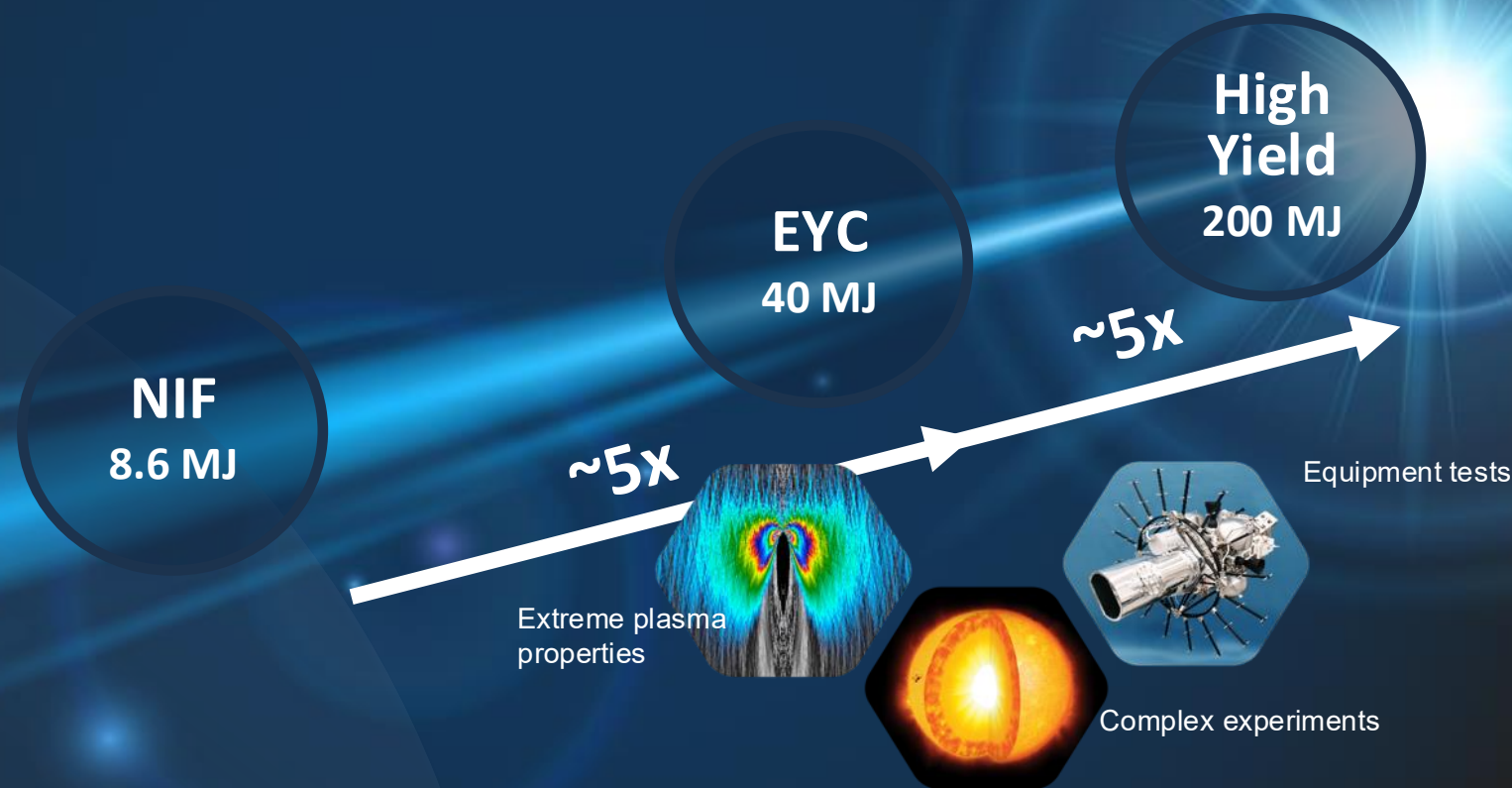
Successful Detection of  $^{87}\text{Y}$  from  $^{88}\text{Y}(n,2n)^{87}\text{Y}$  by Radiochemical Purification



# An upgrade to NIF, termed the Enhanced Yield Capability (EYC), is an intermediate way point to a High-Yield Facility

The EYC capability will

- Provide access to critical HED conditions needs to support the evolving stockpile,
- Validate code capabilities,
- Provide a better extrapolation to a high yield facility, and
- Provide essential experience with fielding multi-10 MJ yields in the laboratory towards a high-yield facility.



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