Radiochemical measurements of neutron capture and isomeric data at the NIF

P(ND)^2-2 – Second International Workshop on Perspectives on Nuclear Data for the Next Decade

Bruyères-le-Châtel, France

October 17, 2014

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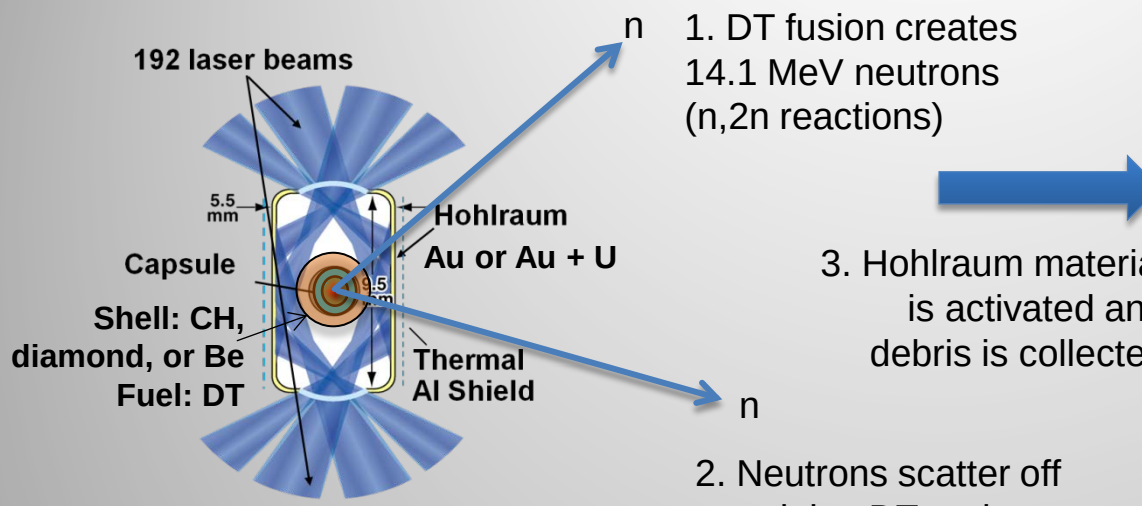
LLNL-PRES-662204

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

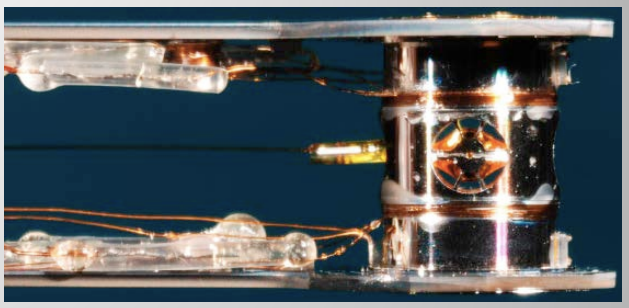
Radiochemistry on NIF is used for both capsule diagnostics and measuring nuclear data



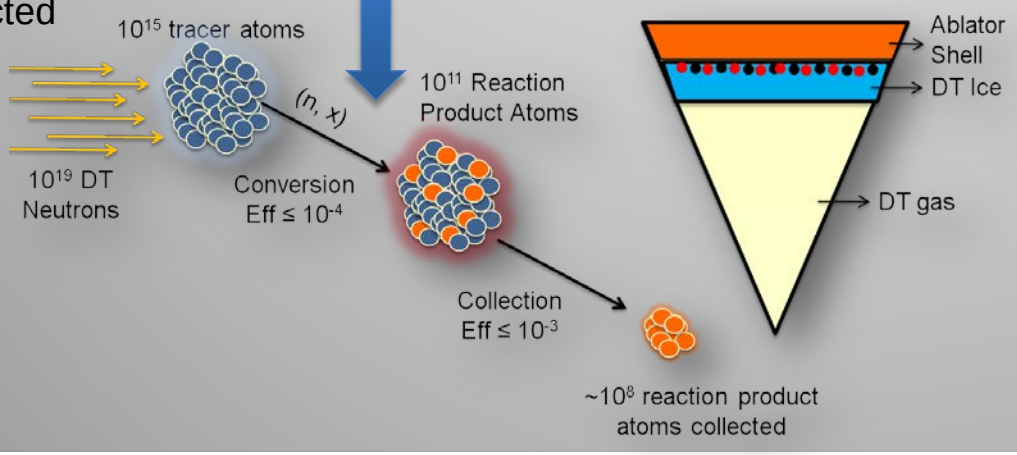
1. DT fusion creates 14.1 MeV neutrons (n,2n reactions)

2. Neutrons scatter off remaining DT and ablator (n,γ reactions)

3. Hohlraum material is activated and debris is collected



4. Tracer material added to the capsule is activated and collected

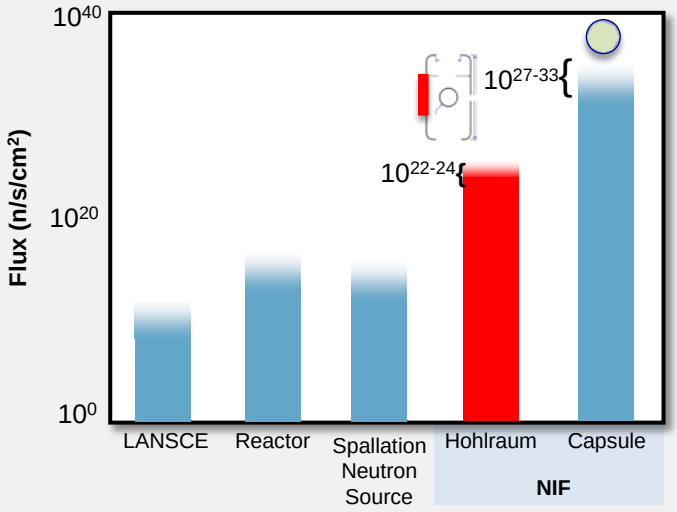


- Fuel areal density (ρR)
- Neutron capture (n,γ) cross sections (E_n<1MeV)
- Production of isotopes for various applications

- Fuel areal density (ρR)
- 1st and 2nd order (n,2n) reaction cross sections
- Excited state cross sections
- Fuel-ablator mix (charged particle reactions)

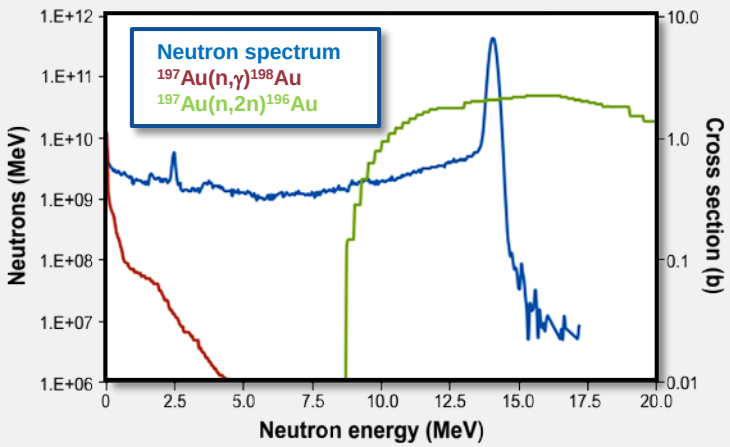
The NIF neutron spectrum creates a unique facility for performing nuclear science

Comparison of Neutron Flux



- Large neutron flux requires less target material so radioactive targets are possible
- The large flux also opens short-lived nuclear states as targets for excited state reactions

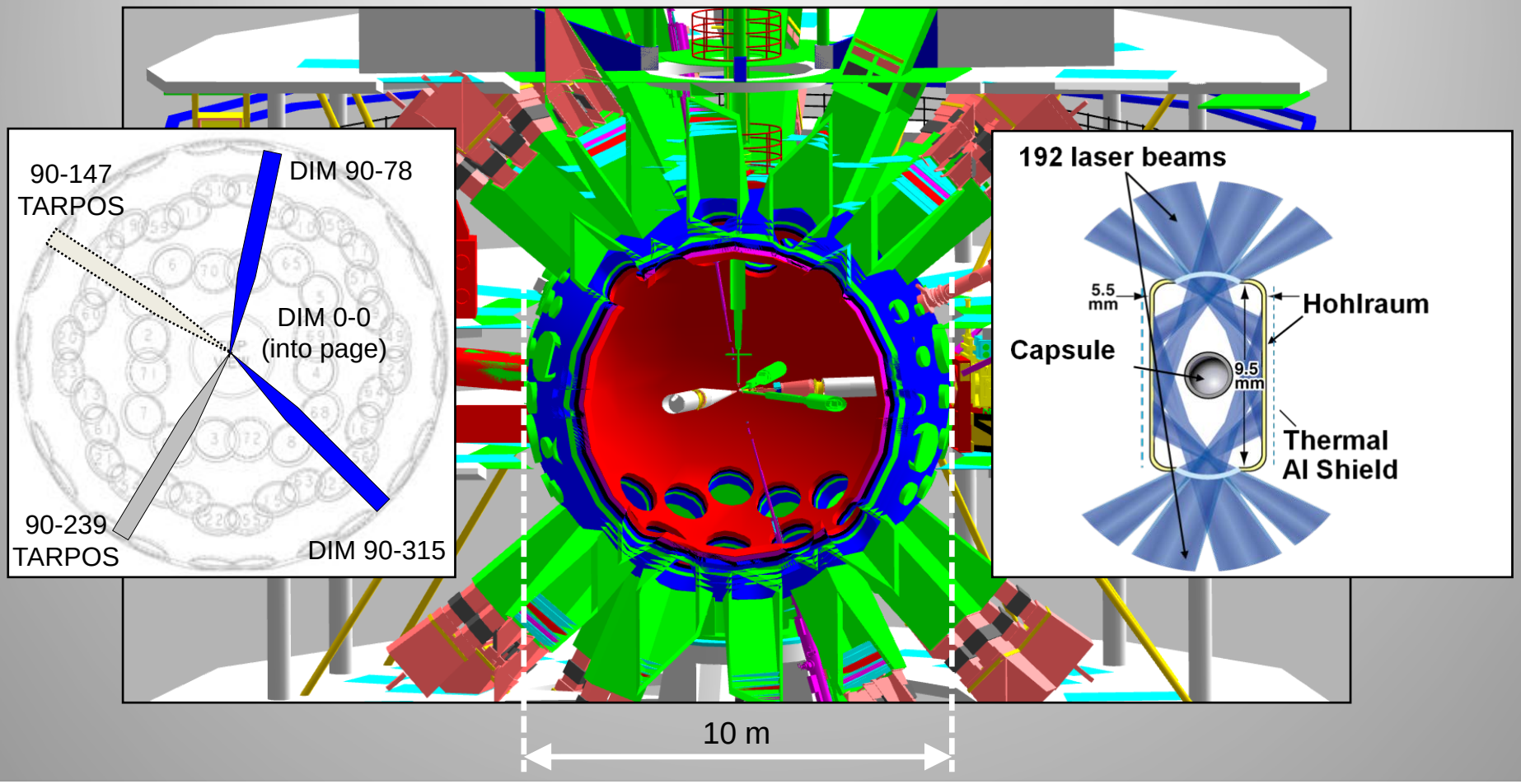
N111103 Post-shot Simulated Neutron Spectrum



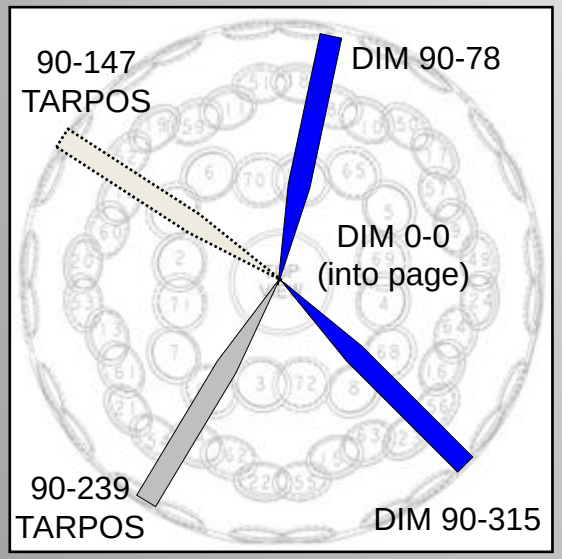
- 14 MeV and downscattered neutrons are produced
- Simulations show 65% of neutron captures in the hohlraum are from <1 MeV neutrons

NIF explores regimes that cannot be reached with traditional accelerators

Collection of debris is complicated due to size difference: capsule/hohlraum vs chamber



Collection of solid debris has been implemented at NIF

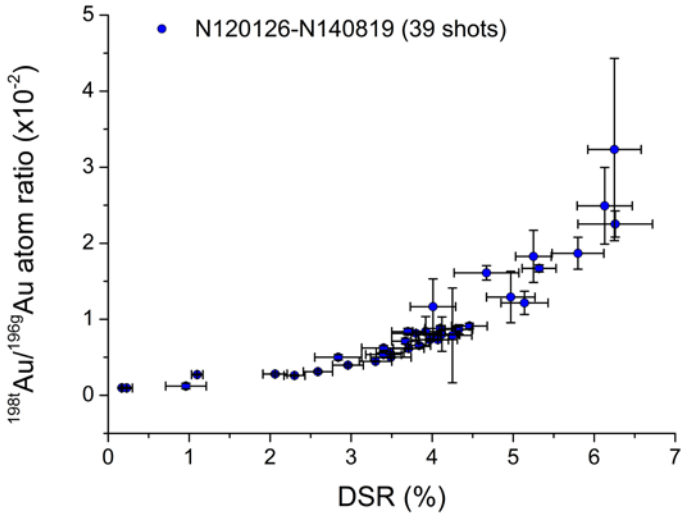


Diagnostic Insertion Manipulator (DIM) with Solid RadioChemistry (SRC) collectors

- Collectors (metal foil or graphite) are removed post-shot & gamma counted
- Time required for delivery of SRC samples is currently ≥ 3 hrs. post shot
- We are working with NIF RSO and Engineering to shorten this time

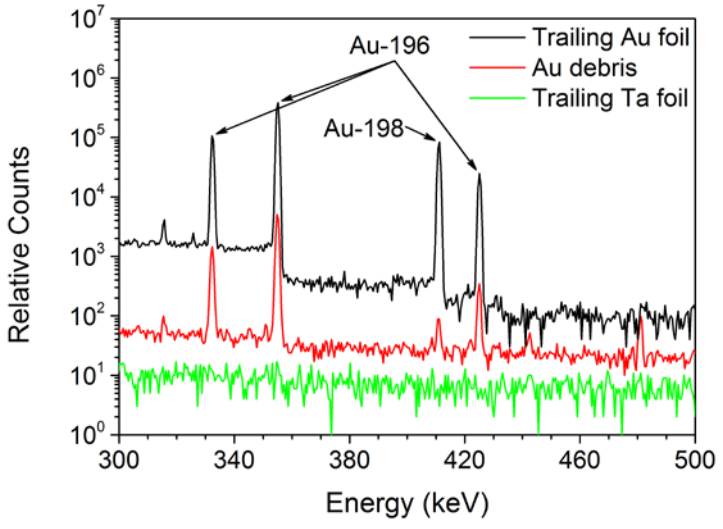
The feasibility of nuclear science at NIF was established during the NIC campaign – SRC

D. Shaughnessy *et al*.,
Rev. Sci. Instrum. **85,** 063508 (2014)



- Activation of the gold hohlraum is measured with the Solid Radiochemistry (SRC) diagnostic
- The (n,γ) to (n,2n) ratio of the gold is highly correlated with fuel areal density (ρr)

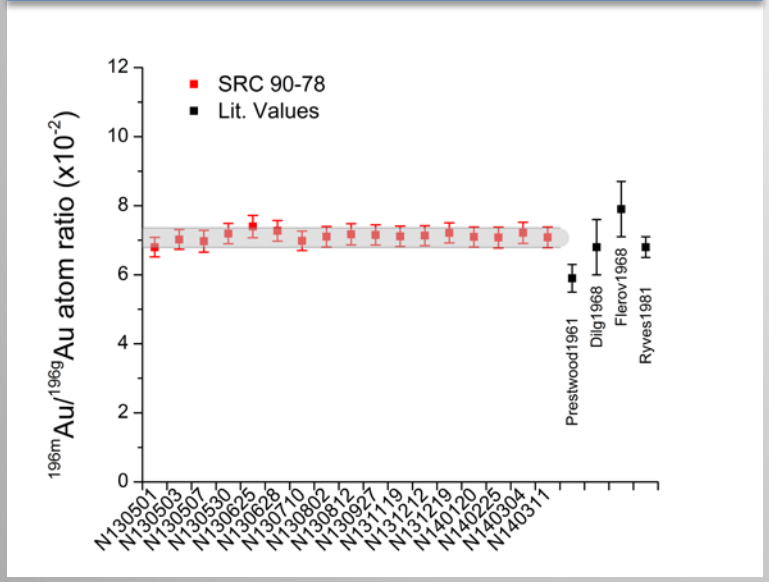
Gamma-ray spectra of hohlraum debris and backing foils



- Scattered room return neutrons are a small contribution to neutron reactions on the hohlraum
- MCNP simulations support that neutron capture is from downscattered capsule neutrons

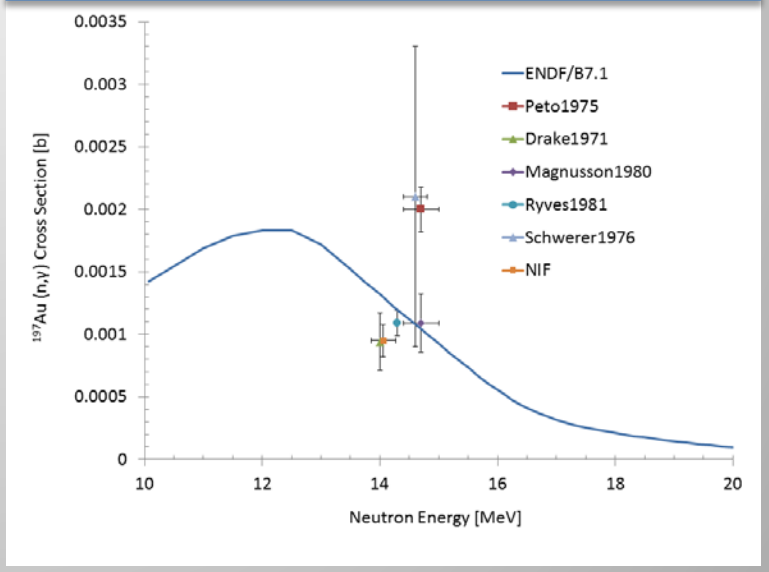
Measurement of gold reaction cross sections at 14-MeV from hohlraum debris

$^{197}Au(n,2n) \rightarrow \sigma(^{196m}Au)/\sigma(^{196g}Au)$



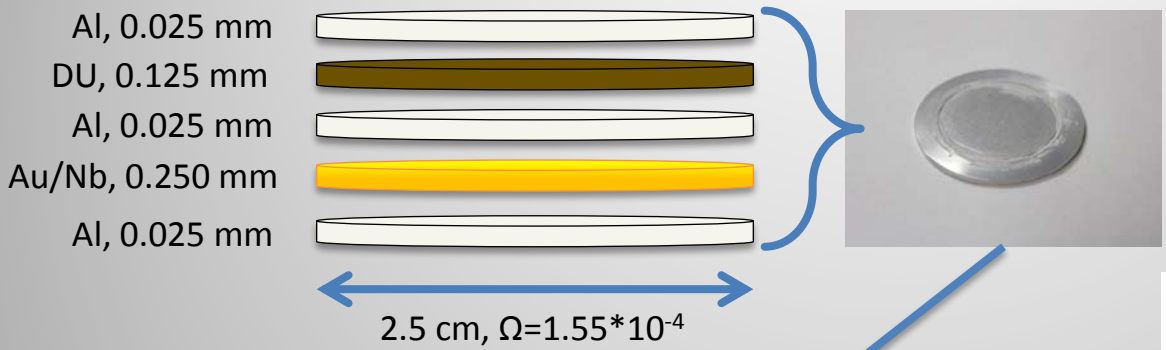
D. Shaughnessy *et al*., *Rev. Sci. Instrum.* **85,** 063508 (2014)

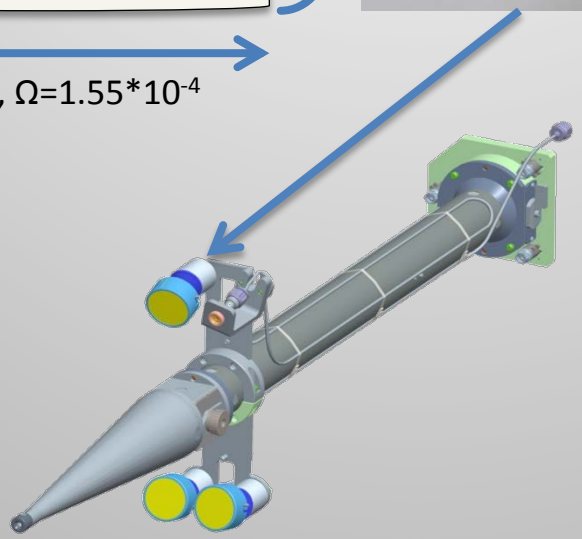
$^{197}Au(n,\gamma)^{198}Au$



C.A. Hagmann *et al*., *Phys. Plasma,* submitted (2014)

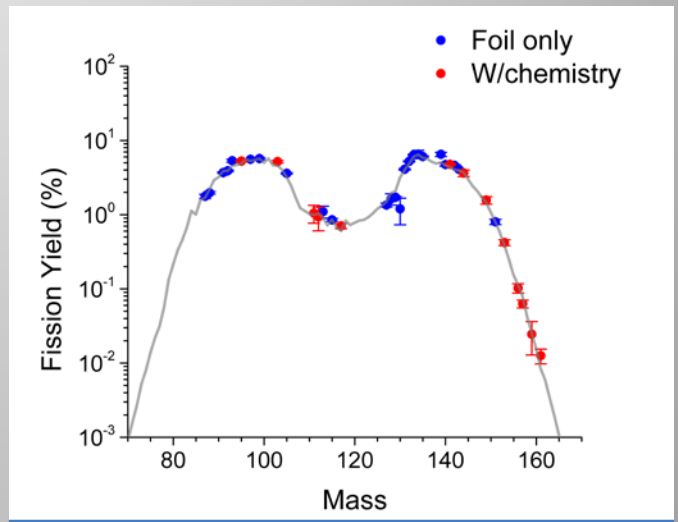
Target Option Activation Device (TOAD) is fielded behind SRC collectors for activation measurements





TOAD was developed for performing nuclear reactions on NIF

*England, T.R., Rider, B.F., LA-SUB--94-170 (1995)



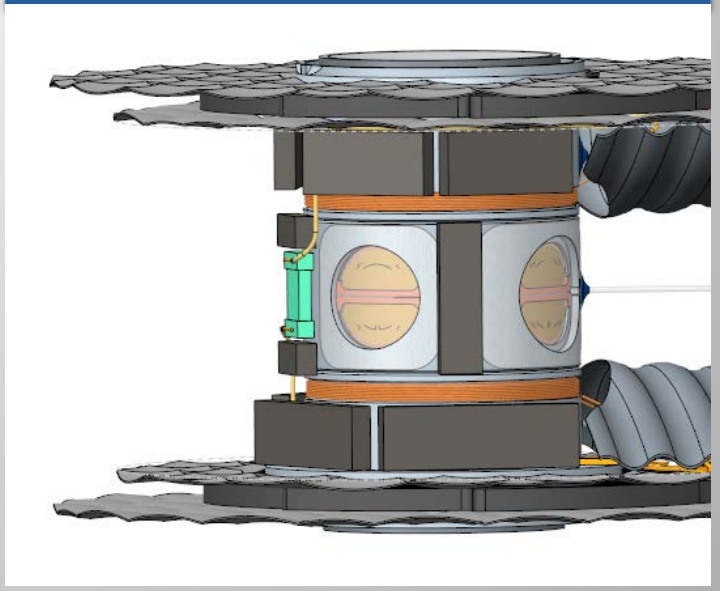
Fission Yield Measurements of U-238 (N. Gharibyan *et al.*, *J. Radioanal. Nucl. Chem., available online* (2014)

Incorporate target material inside the capsule/ablator and target material added to the hohlraum

Method in development for adding dopant on the inner surface of capsule

- ≤1x10^{16} atoms coated in the inner surface of the capsule
- Vacuum fill system coupled with a roto-vap drying procedure

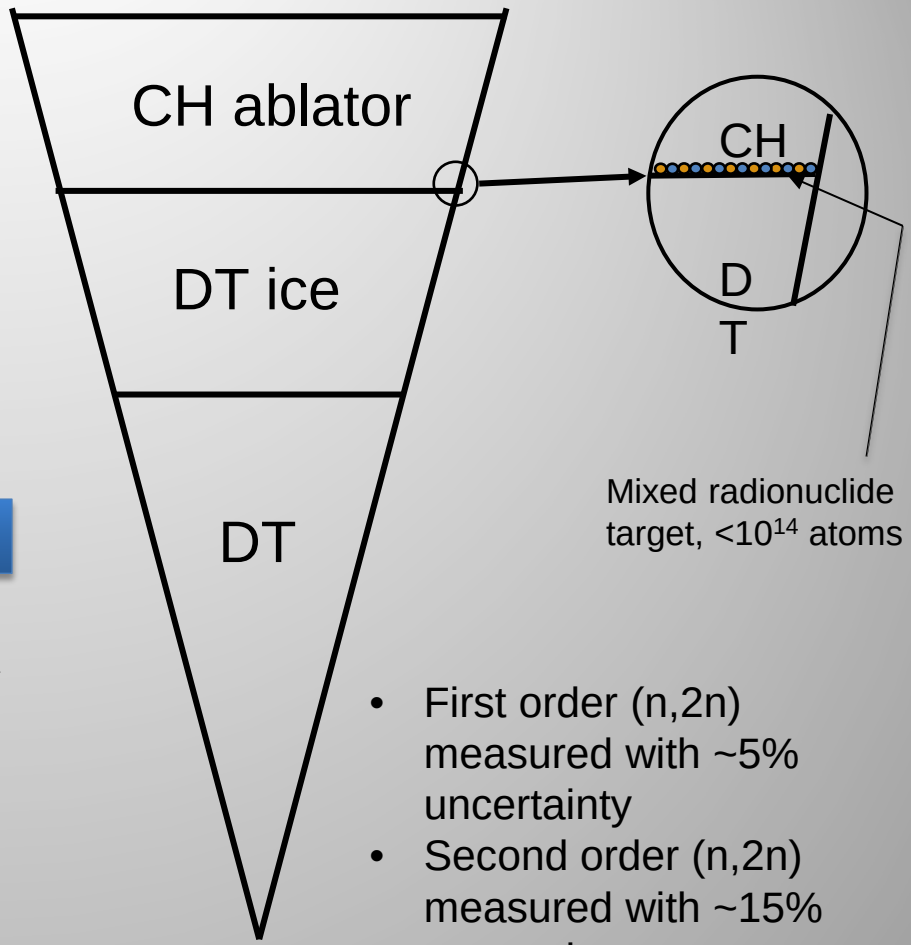
Target material is being added to the outside of hohlraum



- 0.5 mm thick foils of Tm and Nd are being added on the outside of the hohlraum
- Assess collection, geometrical fractionation and perform cross section measurements
- Dedicated shots in FY15

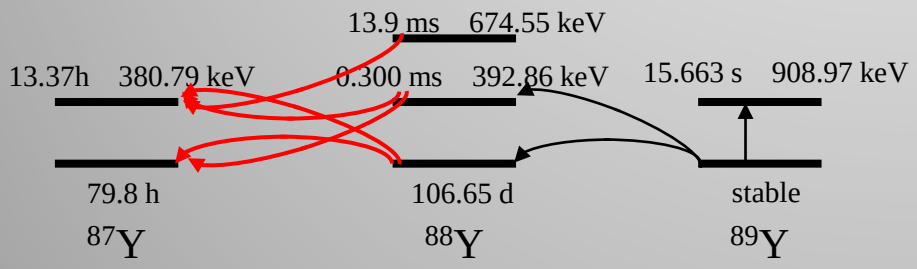
Second order processes are difficult (or impossible) to measure at traditional neutron sources

- Activation cross sections from excited nuclear states are based on models with uncertainties up to 50%
- These experiments are very difficult at an accelerator because the targets are highly radioactive
- Using a NIF capsule means we only need a small number of radioactive atoms



Mixed radionuclide target, $<10^{14}$ atoms

Y(n,2n) reaction network

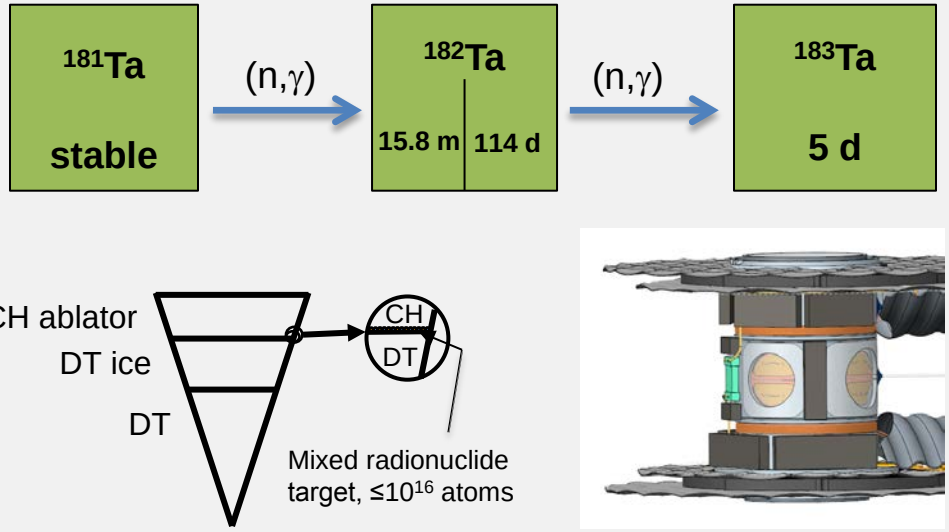


Field two capsules – one with Y-89, the other with Y-88 – the difference can be attributed to contributions from excited states

- First order (n,2n) measured with ~5% uncertainty
- Second order (n,2n) measured with ~15% uncertainty
- Almost no data exist for second order reactions

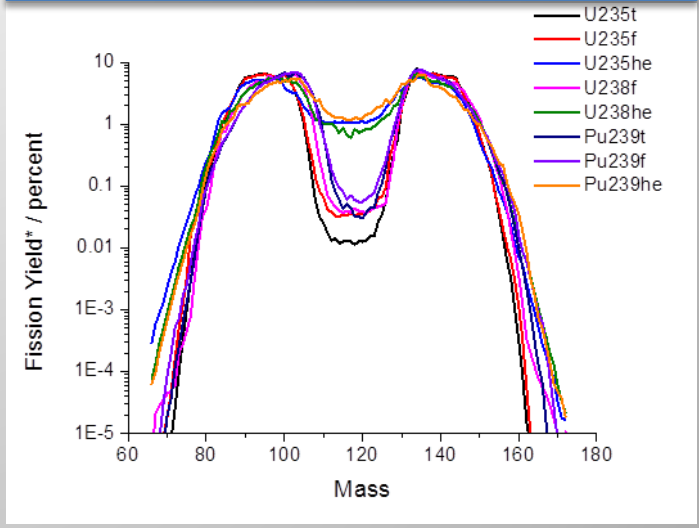
Development of capabilities allow for unique experiments in support of national security missions

Measure of capture cross sections on structural materials



- Uncertainties in cross sections on structural materials make their interpretation difficult in debris samples
- Same approach can be used for studying multiple order and excited state (n,2n) reactions
- Major funding from Global Security

Production of reference materials for development of post-det surrogate debris



- Nuclear forensics models require realistic sample analysis for validation
- Currently, exercise samples are NOT representative of what real samples may look like
- External funding for FY15-16

Summary

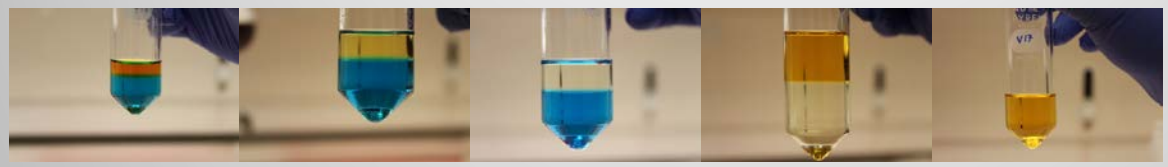
- Radiochemistry at the NIF can be used to measure nuclear data, cross sections, and isotope production

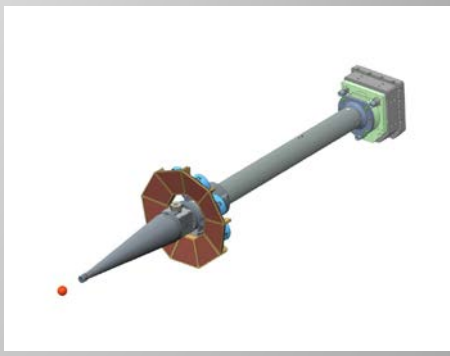
- Fielding targets in the capsule, on the hohlraum, and at the collector position expose materials to different neutron spectra
  - (n,γ), (n,2n), multiple order (n,2n), etc.

Intense, instantaneous neutron flux at NIF allows for nuclear science measurements that are not possible at traditional neutron sources

Work in progress

- Extraction of debris off collector surface





- Increase in collection solid angle
- Add target material into the capsule
- Dedicated NIF shot with added target material on hohlraum (N_NF_DTExPsh_AA - 12/7/14)