Radiochemical Measurements of Neutron Reaction Products at the National Ignition Facility

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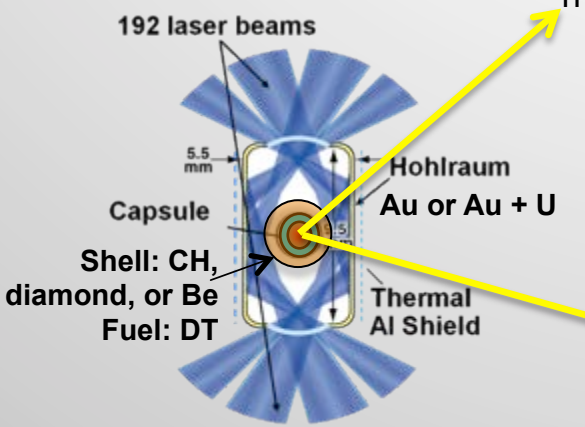
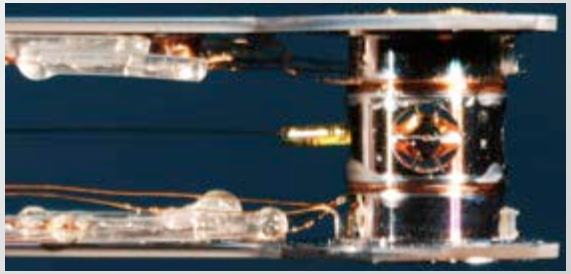
Radiochemistry at NIF can be used for both capsule diagnostics and measuring nuclear data



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

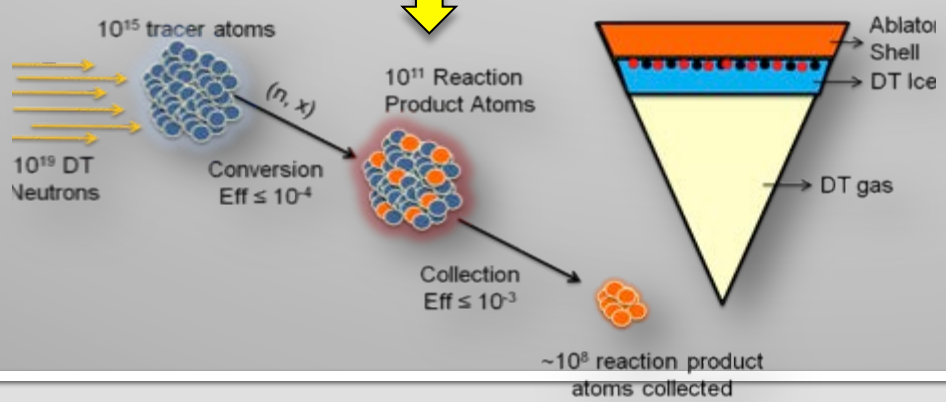
2. Neutrons scatter off remaining DT and ablator (n,γ reactions)

3. Hohlraum material is activated and debris is collected



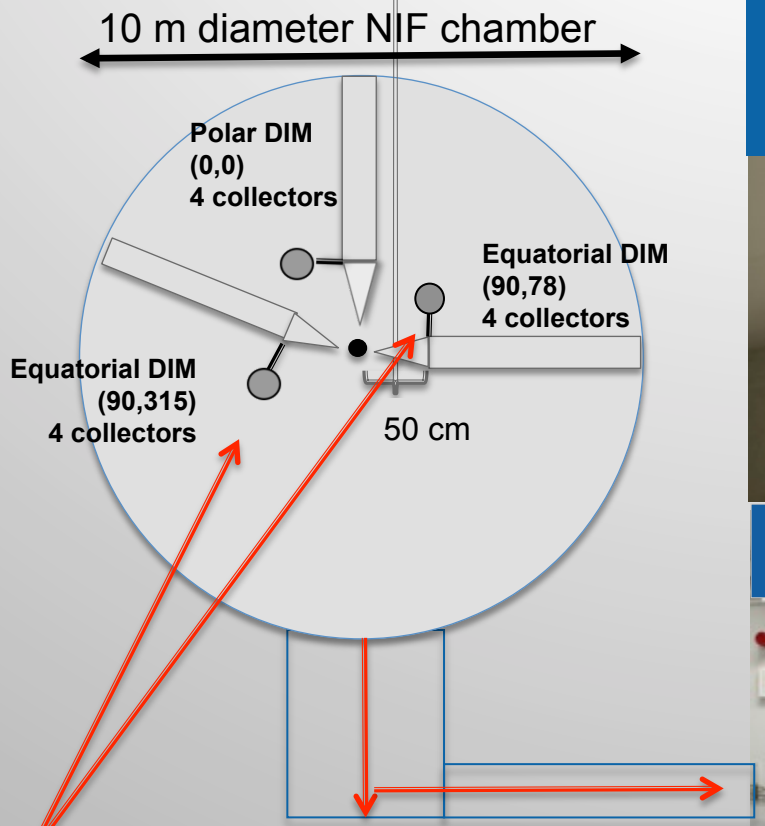
- Fuel areal density (ρR)
- Neutron capture (n,γ) cross sections (E_n<1MeV)
- Production of isotopes for various applications

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



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

Collection of solid and gaseous debris has been implemented at NIF



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

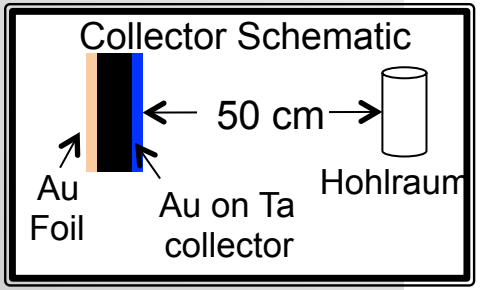
Radiochemical Analysis of Gaseous Samples (RAGS)

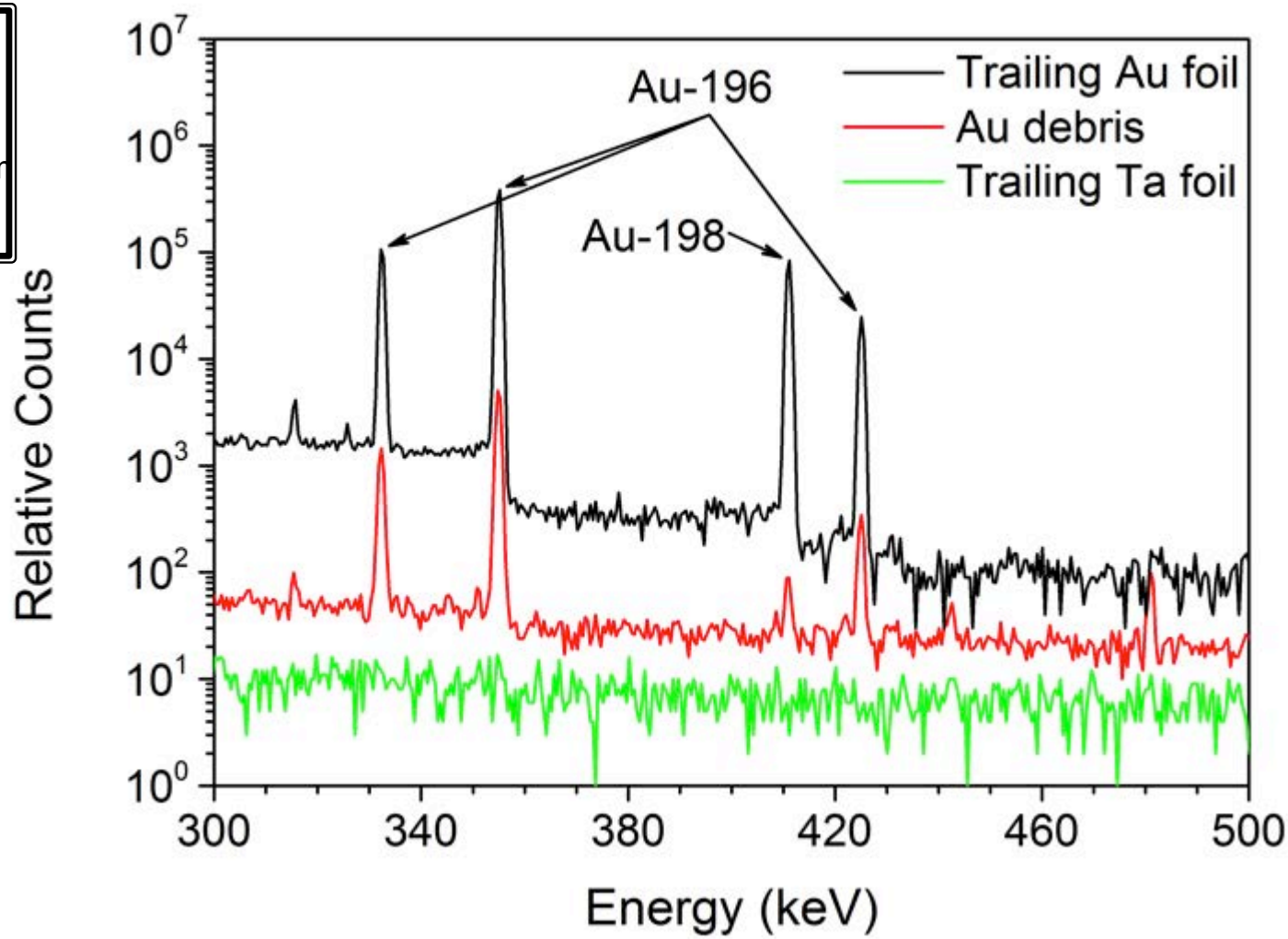
- Gas load from the chamber is collected with RAGS

- Solid RadioChemistry (SRC) detectors (2”-diameter metal or graphite foil disks)
- Up to 4 can be fielded on 3 DIMs (total of 12 collectors)

See talk by C. Velsko for more on RAGS

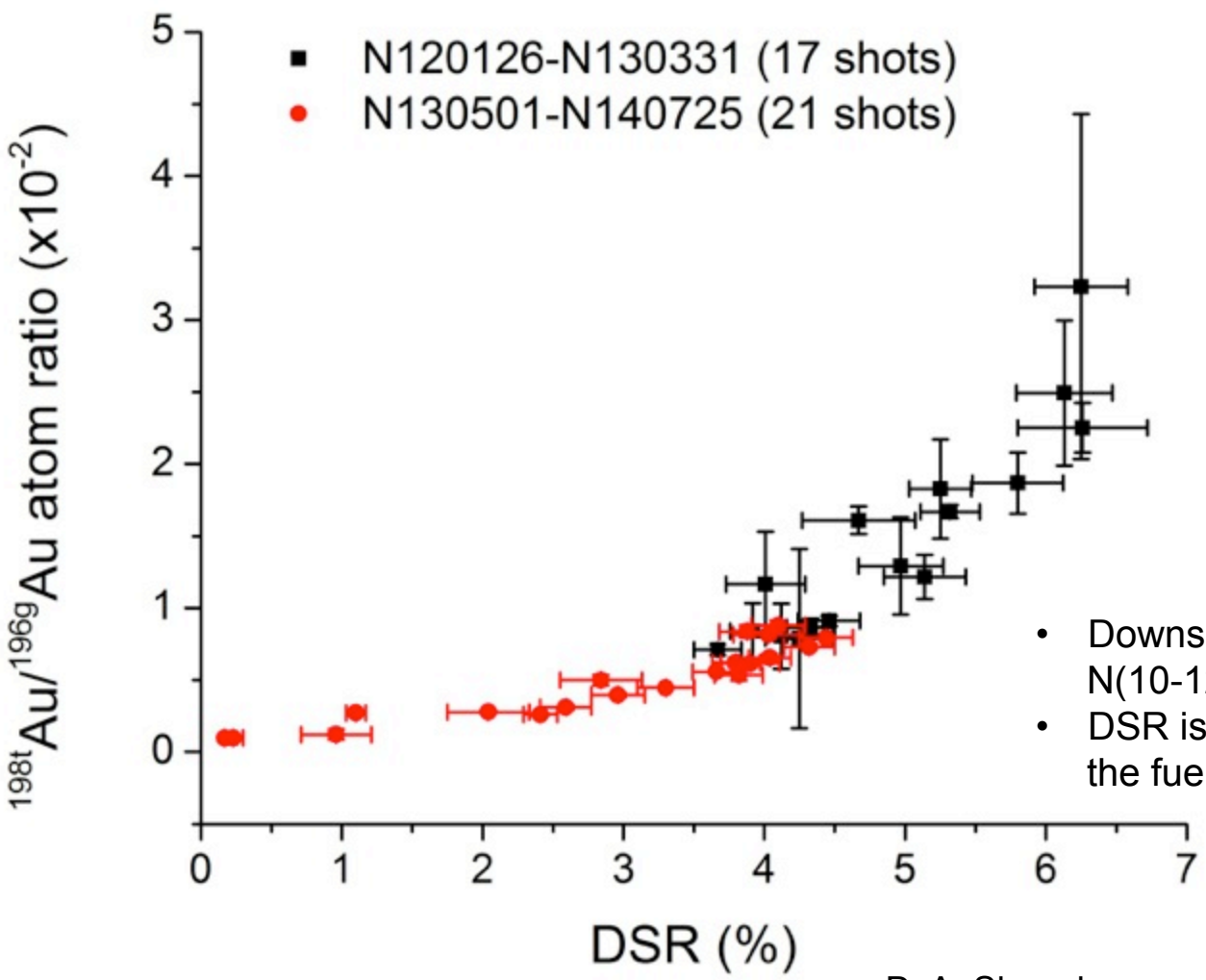
The first neutron reactions observed with the SRC were (n,γ) and (n,2n) on ^{197}Au from the gold hohlraum





Gold in the debris and backing foil had different (n,γ) signals
The debris "sees" fewer low-energy scattered neutrons

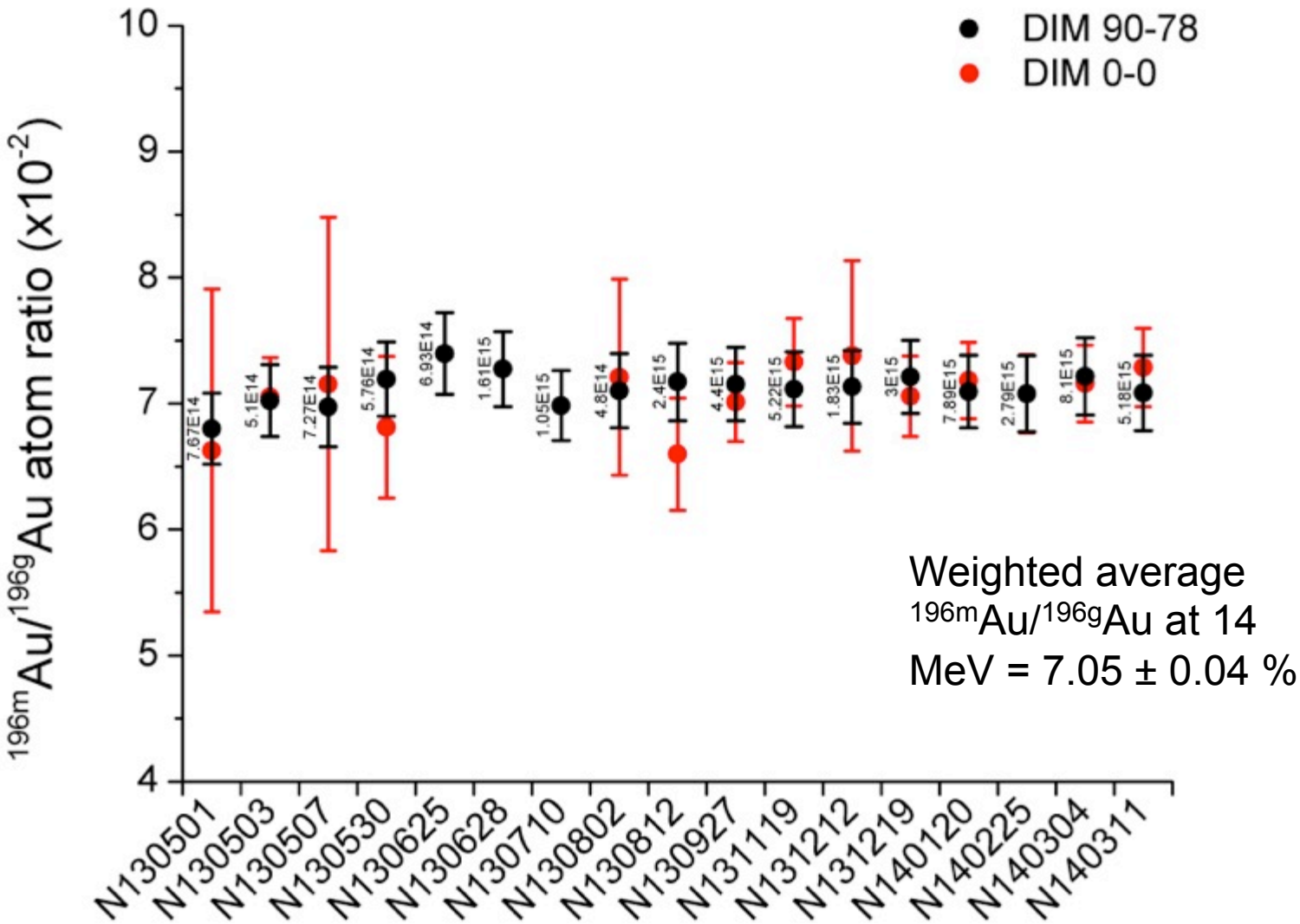
The $^{197}Au(n,\gamma)/^{197}Au(n,2n)$ ratio provides a sensitive ρR_{fuel} diagnostic



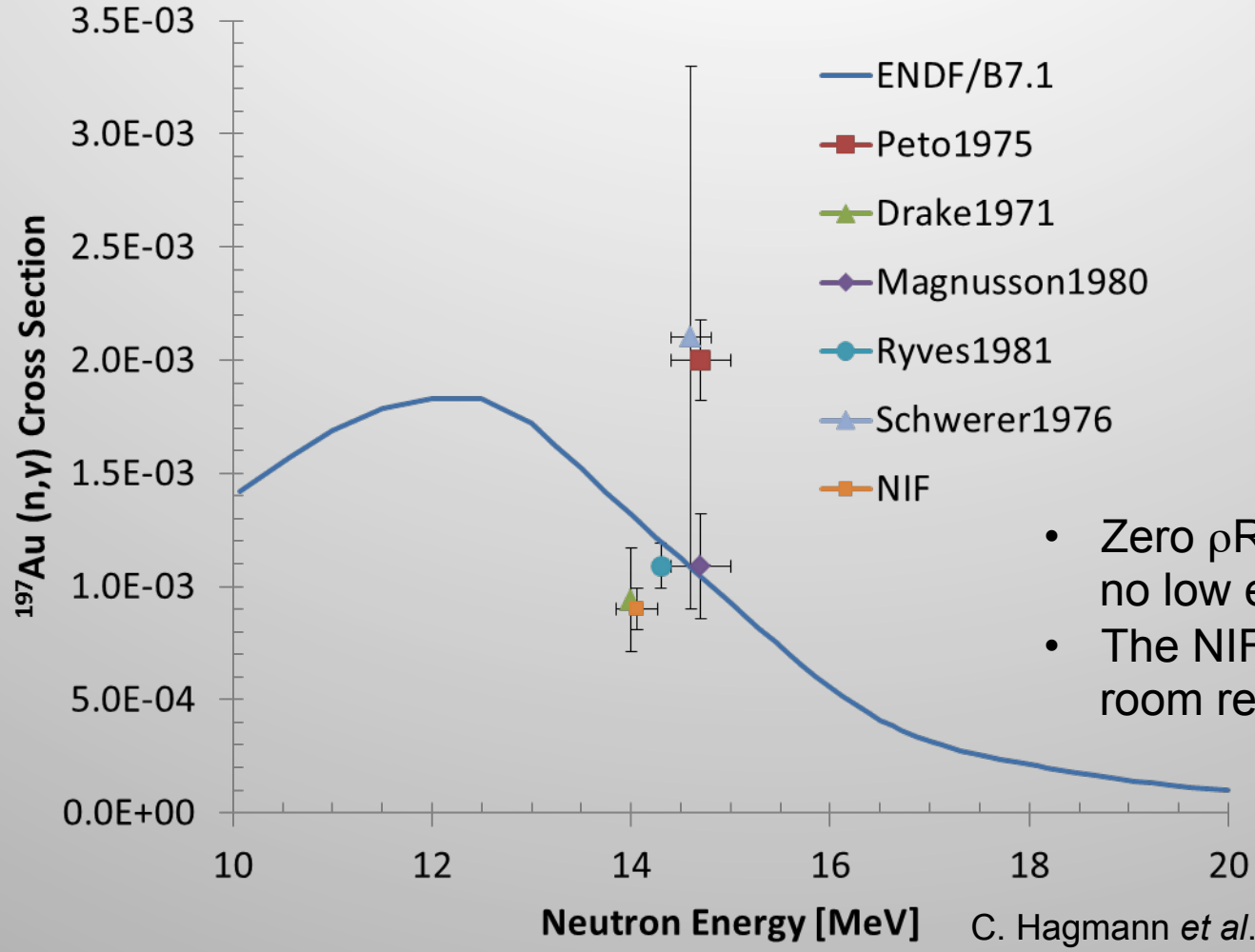
- Downscattered ratio (DSR) = N(10-12 MeV)/N(13-15 MeV)
- DSR is correlated with the ρR of the fuel

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

Production of the ^{196m}Au isomer has also been observed in the gold hohlraum debris



An indirect drive exploding pusher was used to measure the 14 MeV ^{197}Au(n,γ) cross section



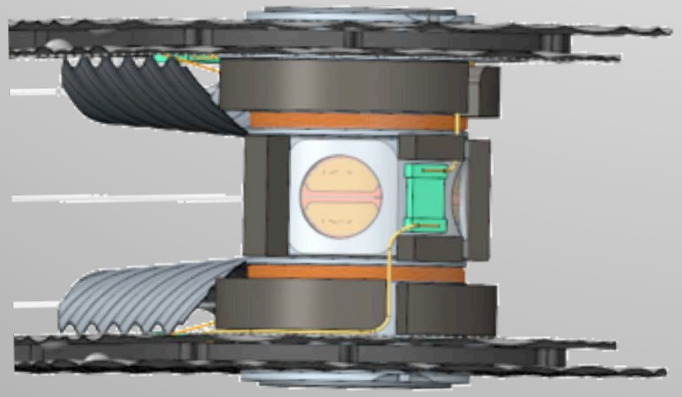
- Zero ρR capsule meant no low energy neutrons
- The NIF value is "free" of room return contributions

C. Hagmann *et al.*, POP, Submiitted (2014)

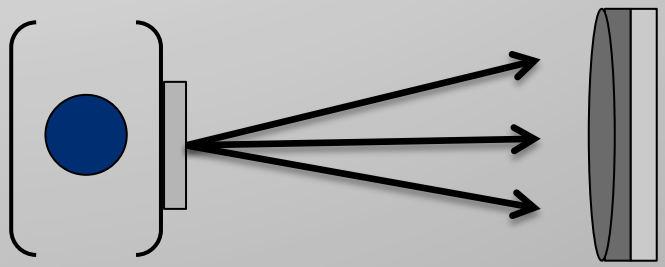
This platform is being developed for (n,γ) measurements at NIF

Neutron capture measurements program at NIF will begin in 2015

- Materials can be added to the outside of the TMP
- First two shots will have rare earth foils (Nd, Tm, Gd)
- Indirect drive exploding pushers will be used to measure 14 MeV neutron reactions



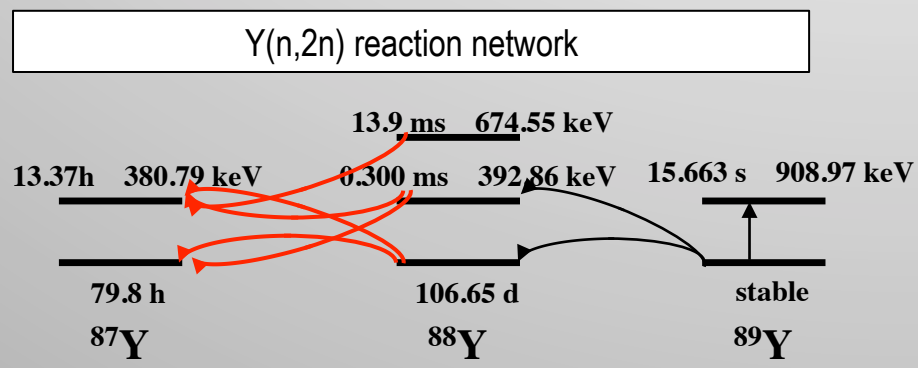
- Neutron capture at < 1MeV can be done with capsules with non-zero ρR
- A “known” and “unknown” are co-loaded in the capsule ablator
- Neutron spectrum is inferred from materials on the hohlraum and behind the collector



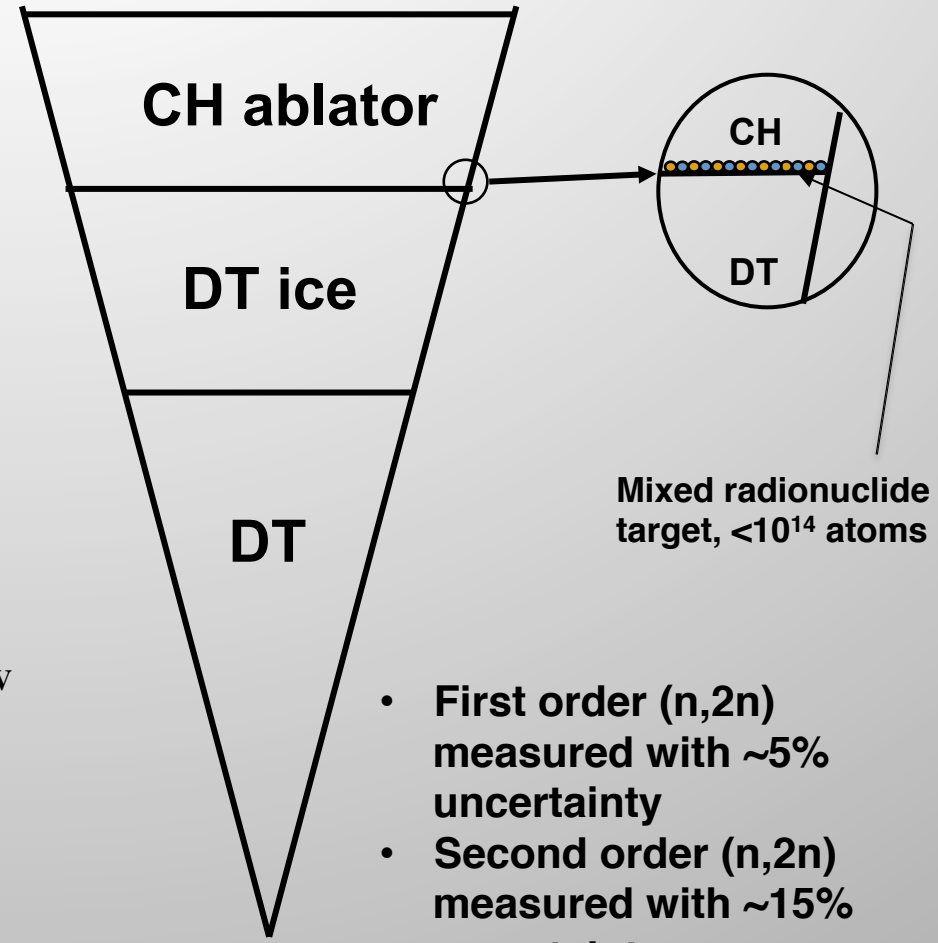
Capsule doping is currently under development

The ability to measure second order neutron reactions becomes possible with higher neutron yields

- Activation cross sections from excited nuclear states are mostly based on model calculations
- These experiments are difficult at an accelerator because the targets are highly radioactive
- Using a NIF capsule means we only need a small number of radioactive atoms

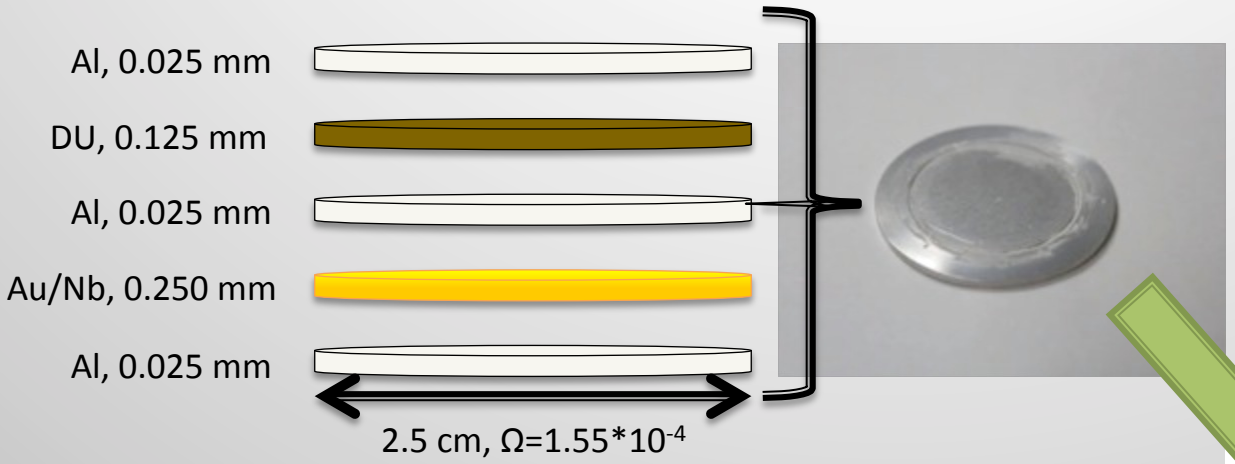


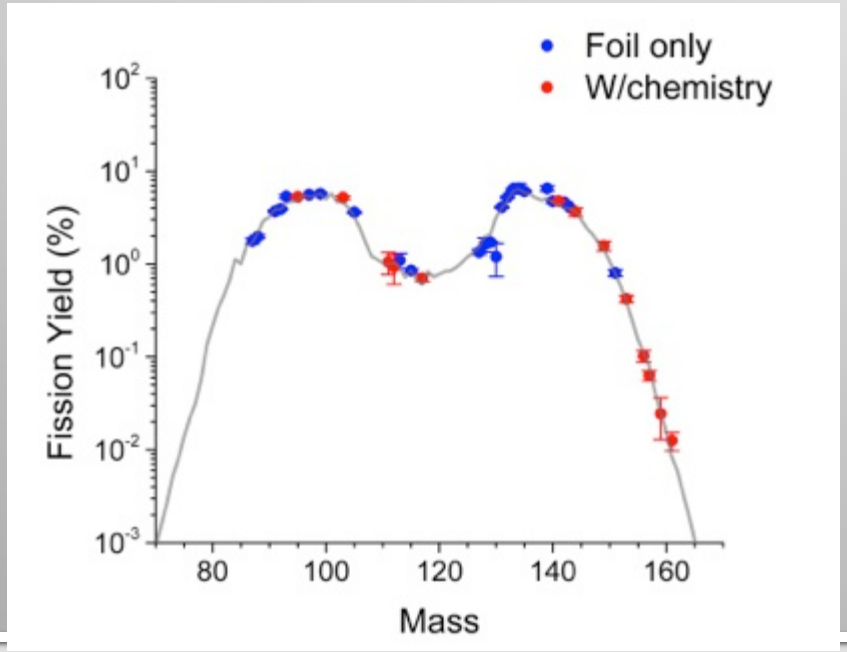
Field two capsules – one with Y-89, the other with Y-88 – the difference can be attributed to contributions from excited states

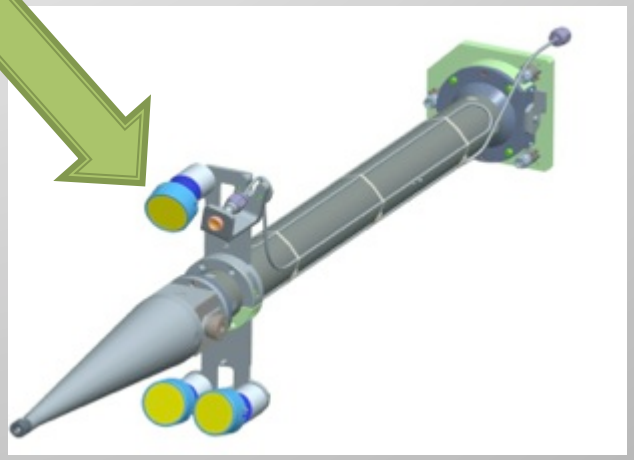


- **First order (n,2n) measured with ~5% uncertainty**
- **Second order (n,2n) measured with ~15% uncertainty**

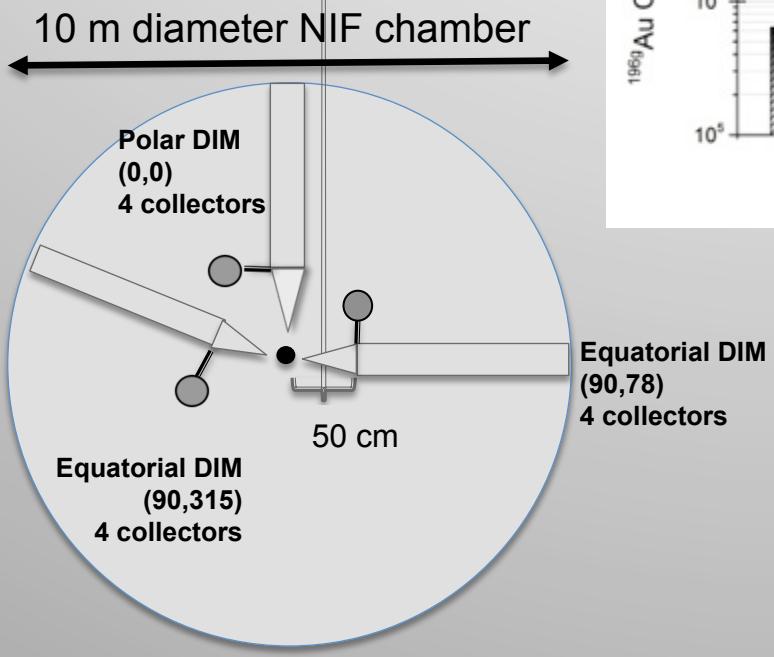
TOAD sample holder is fielded behind the SRC collector at 50 cm

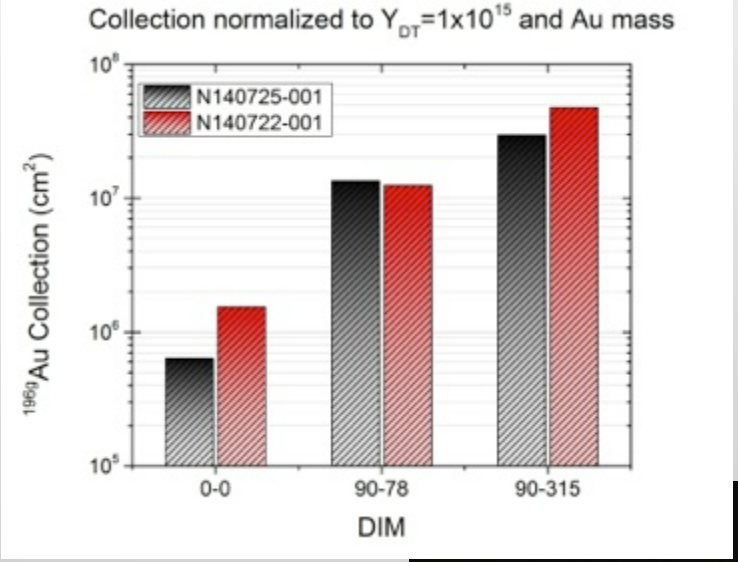


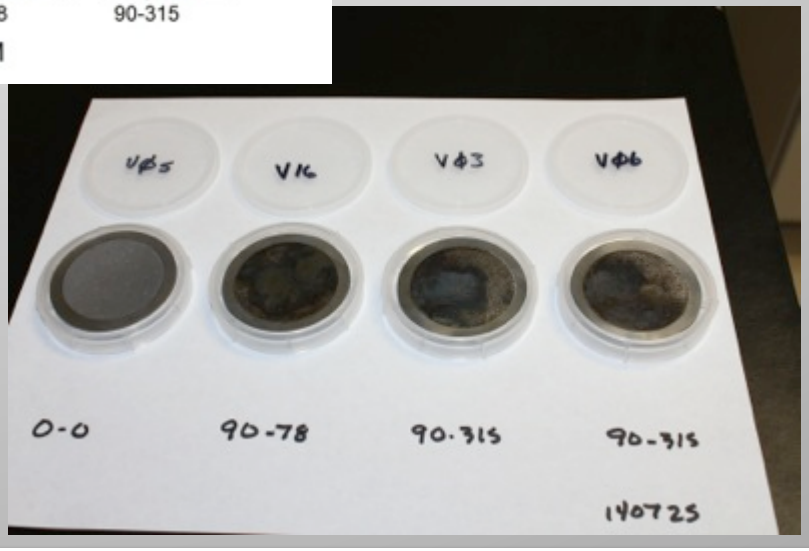




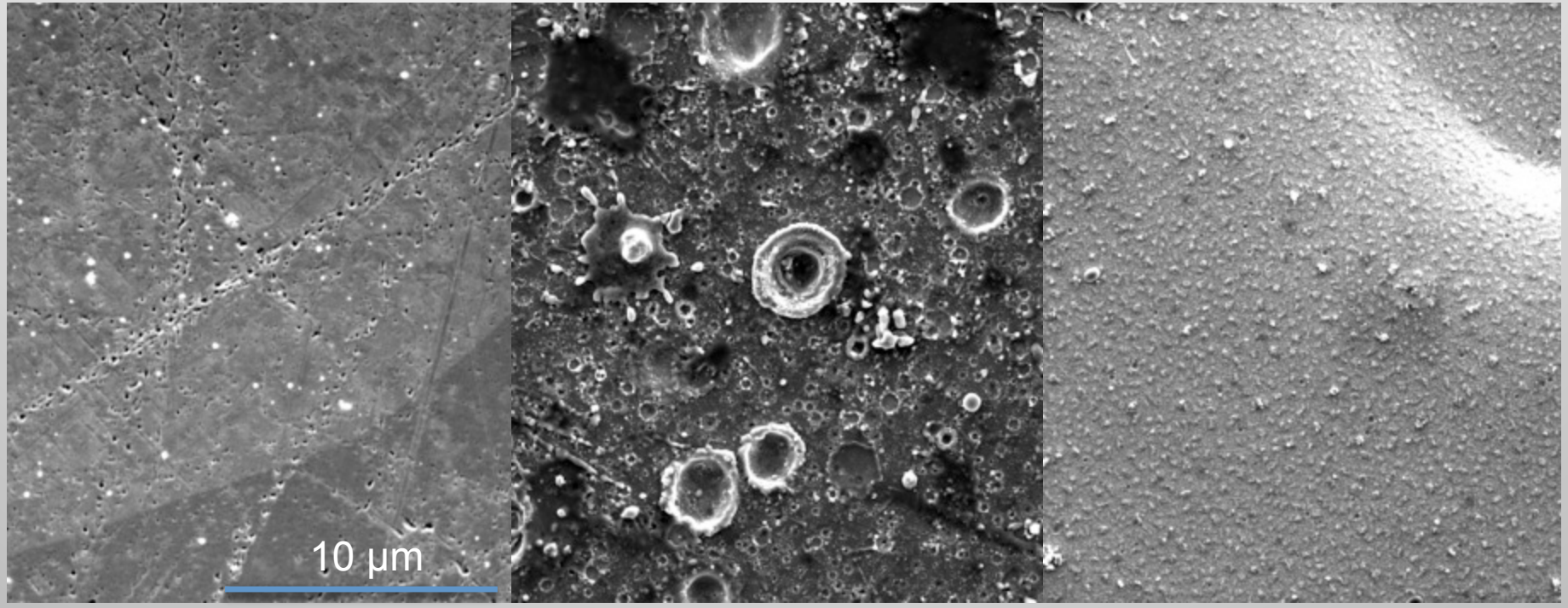
New SRC brackets on DIM 90-315 show the inhomogeneity of NIF debris







SEM images of the collectors show both small debris particles and large splats

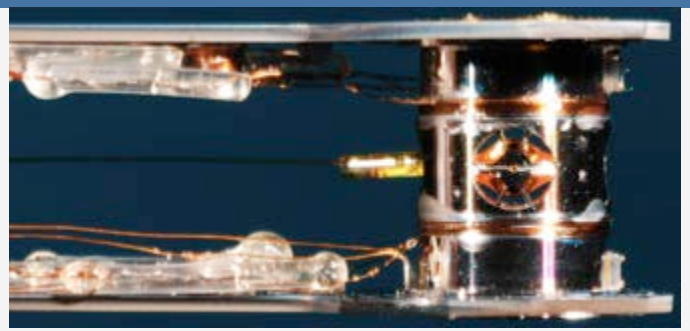


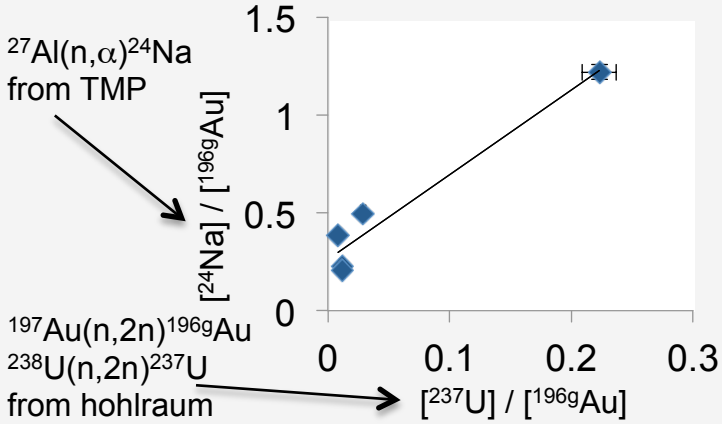
Pre-shot | Post-shot (0-0, Polar) | Post-shot (90-78, Equator)

- The polar samples have a high density of craters and large splats.
- The equatorial samples have fewer craters and less large debris splats. There is a high density of very small (< 1µm) features on the disks.

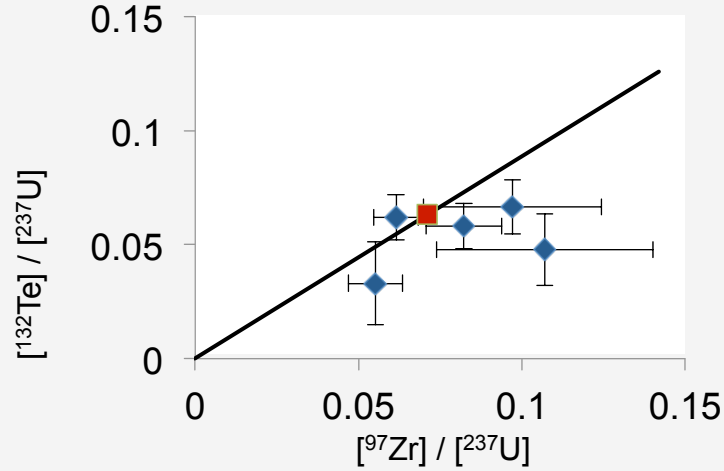
Fractionation of NIF debris must be further analyzed to optimize collection

Products produced in different parts of the hohlraum might fractionate from one another in the debris



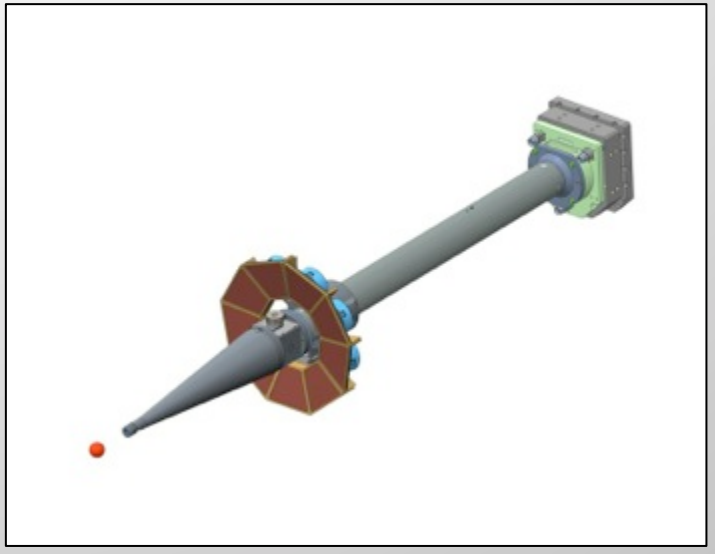


Fission products produced from DU in the hohlraum appear to fractionate based on volatility



- In order to perform measurements based on hohlraum or capsule materials, the distribution of products in the chamber must be well understood
- Collection of capsule debris needs to be demonstrated

Future experiments require larger collection area and capsule doping



- Vacuum assisted flow-through for coating capsule shells
- Ongoing work to assess material (~1E15 atoms) loading and distribution after drying

- Large area collector has 20x greater area (currently designed for DIM 90-78)
- Improved collection on the polar DIM will be required for capsule collection

A rapid sample extraction system will enable measurement of short-lived nuclides

Summary

- Radiochemical collection of solid and gaseous debris at NIF has been developed
- Neutron capture reactions on the gold hohlraum have been observed – adding materials to the hohlraum will act as the target for future measurements of unknown cross sections
- As neutron yields increase, the ability to do second-order neutron reactions increases
- While improvements in debris collection have been made, additional improvements will optimize collection of capsule debris
- Methods for doping NIF capsules with target atoms are being developed for future shots

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Colors and arrows

Summary box is now full width bleed

Collection normalized to $Y_{DT}=1x10^{15}$ and Au mass