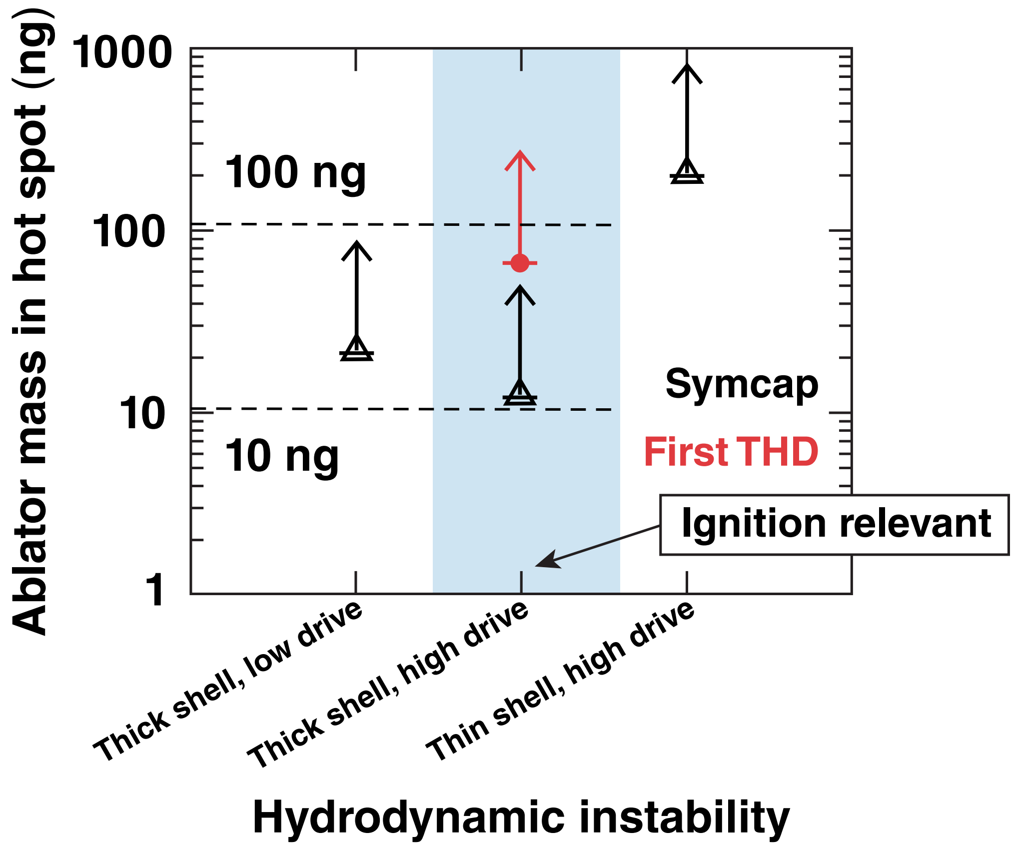
Spectroscopic Observations of Ablator Mass Mixed into the Hot Spot of a NIF Implosion



S. P. Regan
University of Rochester
Laboratory for Laser Energetics

52nd Annual Meeting of the
American Physical Society
Division of Plasma Physics
Chicago, IL
8–12 November 2010

Summary

Mix in MJ indirect-drive implosions at the National Ignition Facility (NIF) are diagnosed with Ge K-shell spectroscopy

UR LLE

NIC

- Hydrodynamic instabilities and jets seeded by isolated shell-surface mass modulations and the gas fill tube are predicted to mix ablator mass deep into the hot spot at ignition time (deep mix)*
- Estimates of "deep mix" using measured spectroscopic signatures are presented
  - lower bound of mix mass for ignition-relevant implosions ranges from 10 to 100 ng
- The mix mass depends on the hydrodynamic stability of implosion

Controlling the amount of mix mass (<100 ng) is crucial for ignition.

*B. A. Hammel *et al*., High Energy Density Phys. 6, 171 (2010).

Related talks: B. A. Hammel (B12.00006).
S. Haan (B12.00001).

The Mix Working Group is a part of the National Ignition Campaign (NIC)

R. Epstein, F. J. Marshall, T. C. Sangster, and D. D. Meyerhofer

University of Rochester
Laboratory for Laser Energetics

B. A. Hammel, H. A. Scott, D. K. Bradley, D. Callahan, M. J. Edwards, M. J. Eckart, S. H. Glenzer, J. D. Kilkenny, O. L. Landen, N. B. Meezan, R. Prasad, V. A. Smalyuk, and L. J. Suter

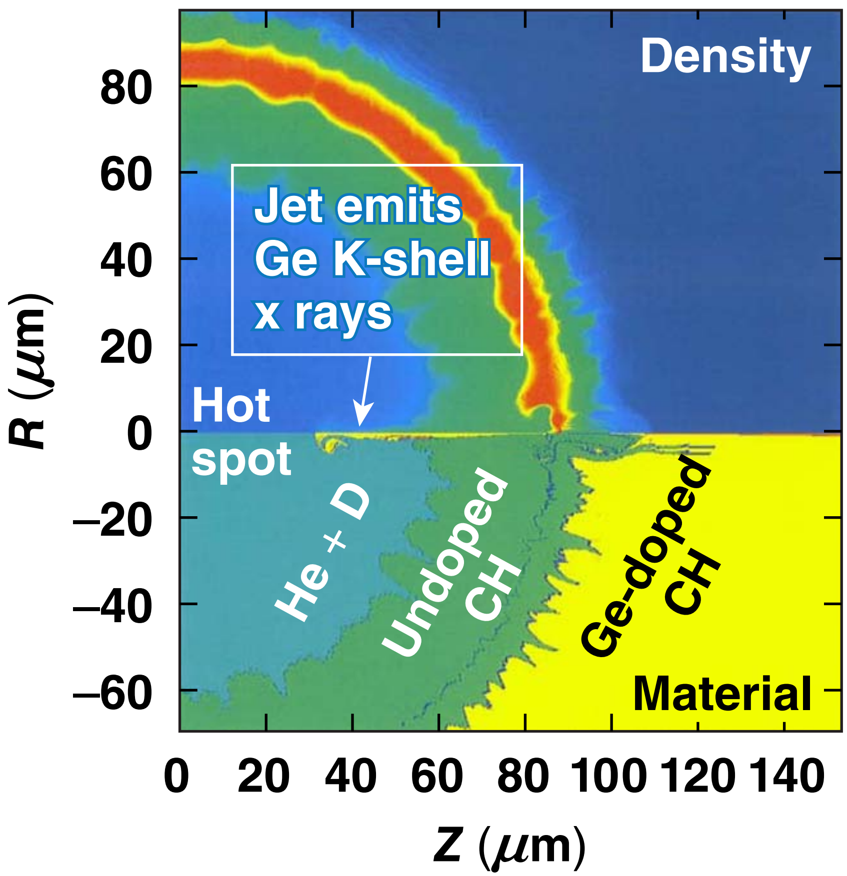
Lawrence Livermore National Laboratory

R. C. Mancini

University of Nevada–Reno

The NIF mix requirement, set by rad-hydro simulations, is that <100 ng of ablator be mixed into the hot spot at ignition time

HYDRA* 2-D simulation



- **High ℓ-mode perturbations (50 to 200) cause deep mix.**

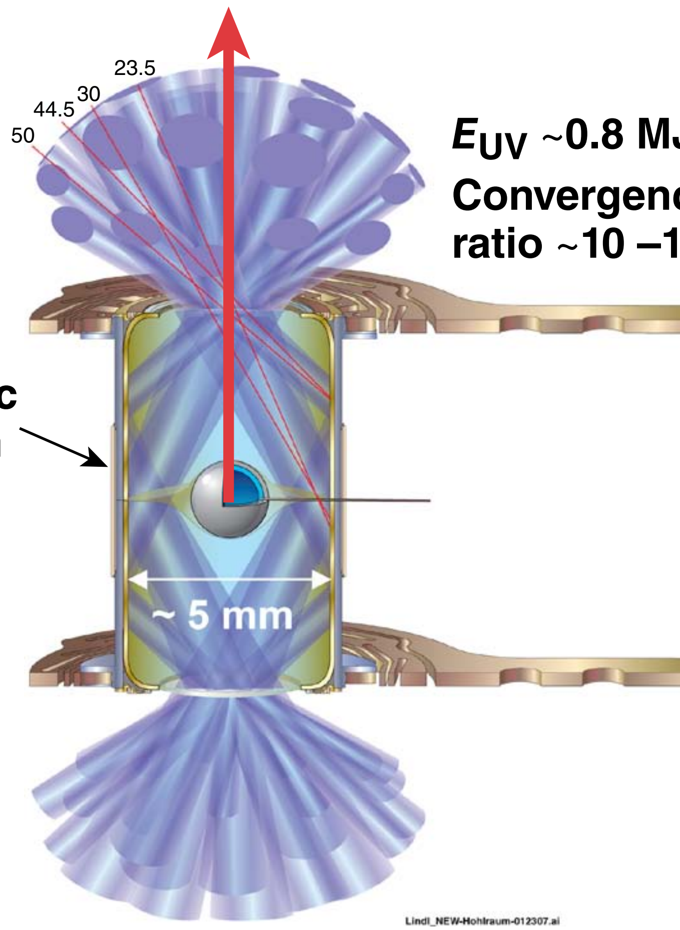
Our goal is to determine empirically the amount of mix mass.

E19329a

*B. A. Hammel *et al*., High Energy Density Phys. 6, 171 (2010).
B. A. Hammel (B12.00006).

Mix in MJ indirect-drive implosions on the NIF is diagnosed with Ge K-shell spectroscopy

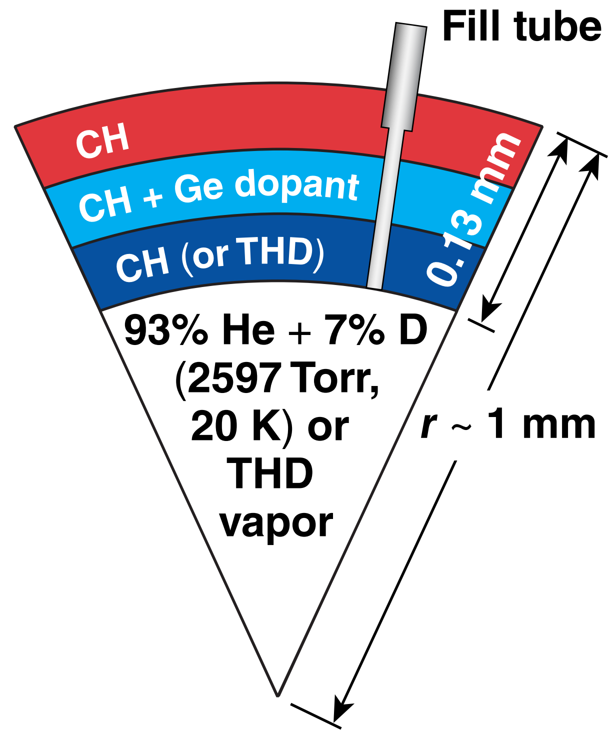
Polar view: hot-spot x-ray spectrometer (HSXRS)



E_{UV} ~0.8 MJ
Convergence ratio ~10 –15

Cryogenic hohlraum

Implosion capsule for symmetry campaign



THD = tritium hydrogen deuterium

Ge dopant provides a spectroscopic signature for hydrodynamic mix.

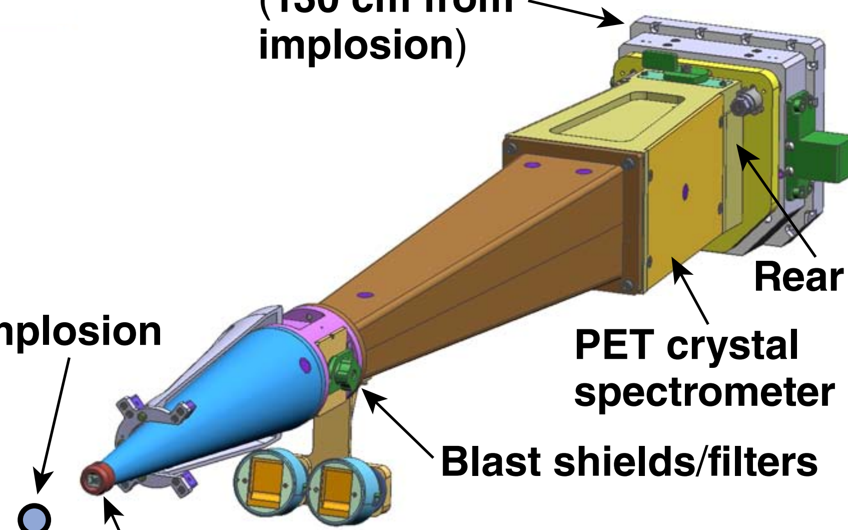
E19326a

The hot-spot x-ray spectrometer (HSXRS) in the "Supersnout" was fielded on the NIF to diagnose mix

UR LLE

NIC

HSXRS records 1-D spectral images of hot spot in Ge K-shell emission (9.75 to 13.1 keV).

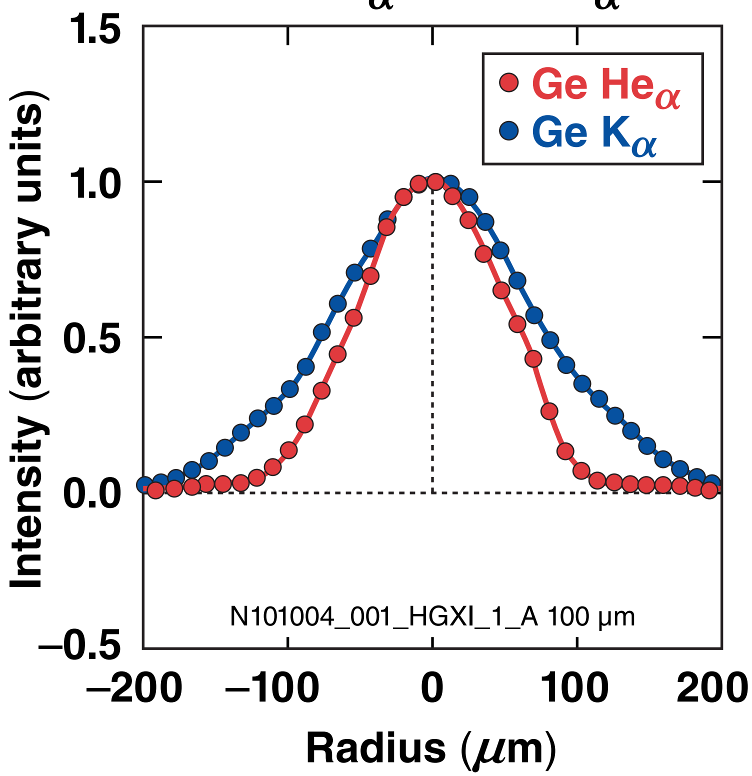


Ge mixed into the hot spot emits K-shell radiation, but Ge in the shell does not.

E19341b

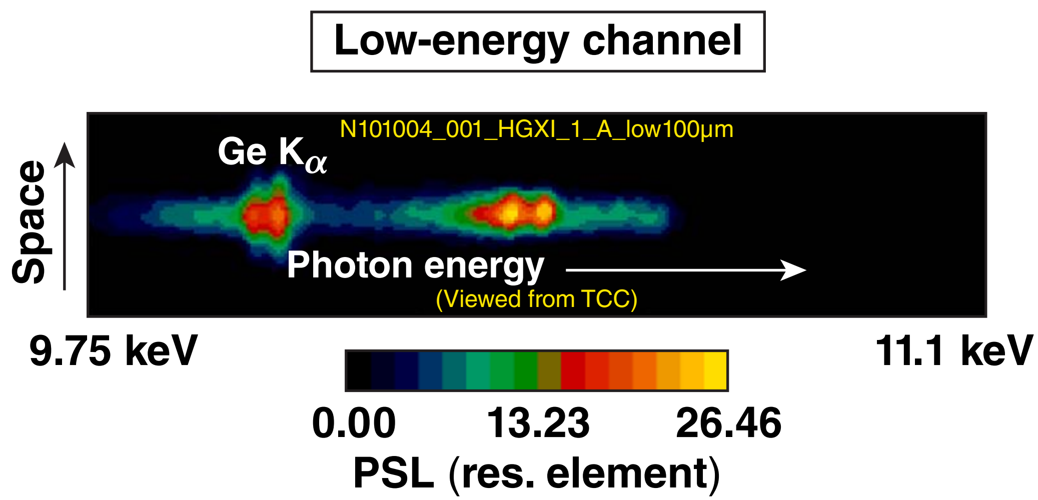
Ge emits K-shell emission from the hot spot and K_α emission from the doped shell layer surrounding the hot spot

Spatial profiles of Ge He_α and Ge K_α



100-μm spatial resolution

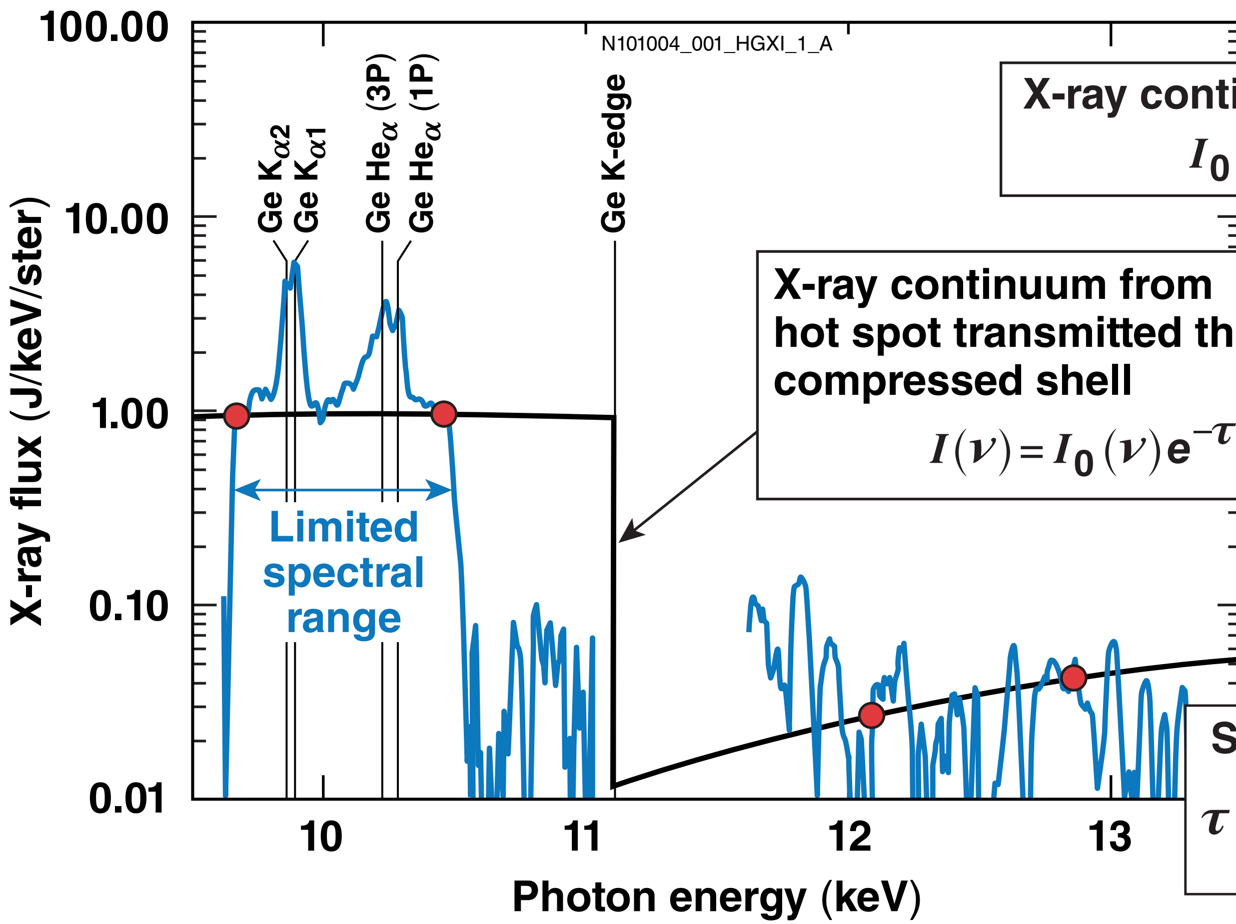
Time-integrated, background subtracted 1-D spectral images from NIF implosion



Spectral imaging discriminates implosion emission from hohlraum plasma emission.

E19529

Time- and space-integrated spectrum is dominated by shell (Ge K_α, Ge K-edge) and hot-spot (Ge He_α) features



X-ray continuum from hot spot

$$I_0(\nu) = I_c e^{-h\nu/kT}$$

X-ray continuum from hot spot transmitted through compressed shell

$$I(\nu) = I_0(\nu) e^{-\tau(\nu)}$$

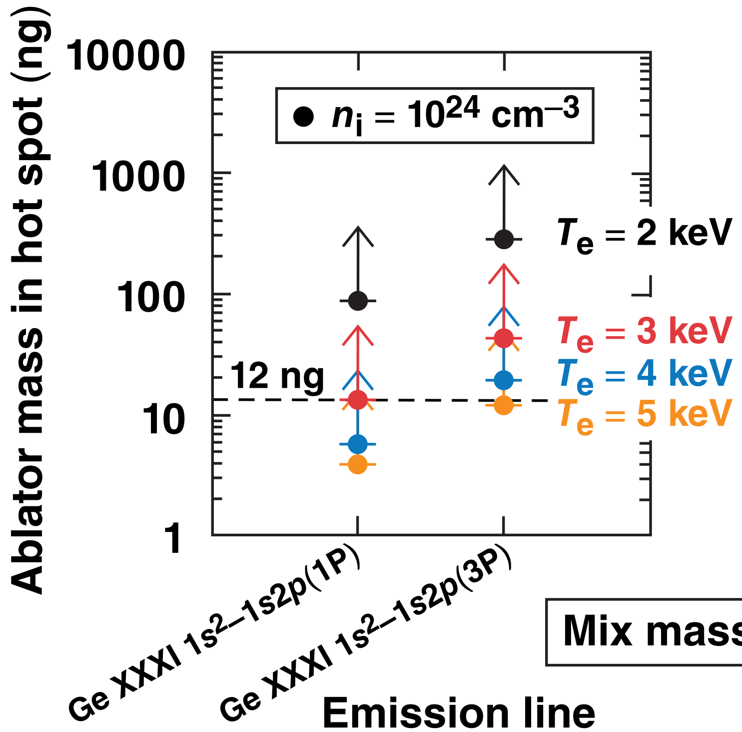
Shell opacity

$$\tau(\nu) = \frac{1}{(h\nu)^3} \begin{Bmatrix} M_L; h\nu \le h\nu_K \\ M_{K+L}; h\nu > h\nu_K \end{Bmatrix}$$

T_e = 3±0.5 keV is inferred from the slope of the x-ray continuum from the hot spot.

E19530

Assuming uniform plasma conditions, the mix mass is estimated from the absolute line brightness using a detailed atomic physics model



Mix mass ~ $1/n_e$

$$N_{Ge} = \frac{F_{21}\Delta h\nu}{p_2(T, n_e)\, A_{21}\tau E_{21}}$$

- N_{Ge}: Total number of Ge ions
- $F_{21}\Delta h\nu$: Area under measured line
- $p_2(T, n_e)$: Fraction in the upper level of the transition
- A_{21}: Spontaneous emission rate
- τ: Burnwidth
- E_{21}: Line energy

Estimated hot-spot conditions

$n_e = 2 - 3.5 \times 10^{24}$ cm^{-3} ← x-ray images

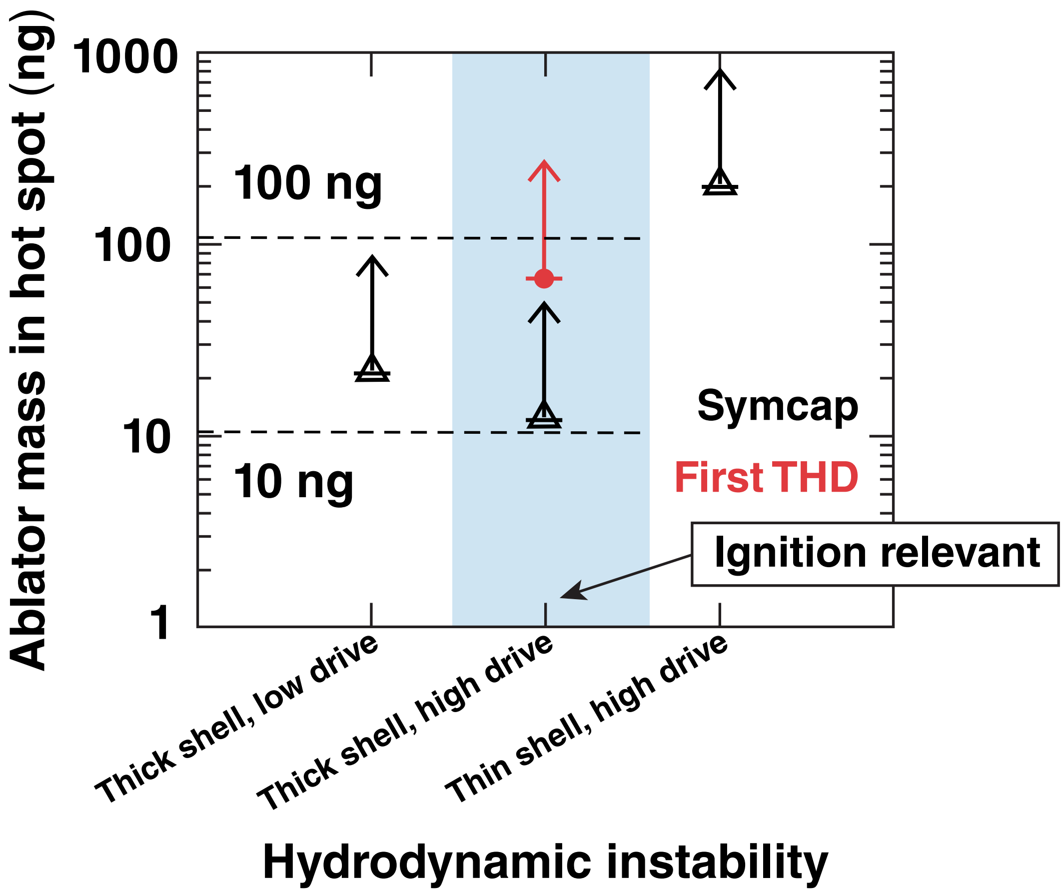
T_e = 3 keV ← x-ray continuum

A lower bound is estimated because:

1. Only the hot Ge mass is observed.
2. Line emission is assumed to be optically thin in hot spot (i.e., no self absorption).
3. Ge:CH atomic ratio is assumed to be 0.6%.

E19340b

The lower bound on mix mass for ignition-relevant implosions ranges from 10 to 100 ng



Controlling the seeds and growth factors of high-mode mix is crucial for ignition.

Summary/Conclusions

Mix in MJ indirect-drive implosions at the National Ignition Facility (NIF) are diagnosed with Ge K-shell spectroscopy

- Hydrodynamic instabilities and jets seeded by isolated shell-surface mass modulations and the gas fill tube are predicted to mix ablator mass deep into the hot spot at ignition time (deep mix)*
- Estimates of "deep mix" using measured spectroscopic signatures are presented
  - lower bound of mix mass for ignition-relevant implosions ranges from 10 to 100 ng
- The mix mass depends on the hydrodynamic stability of implosion

Controlling the amount of mix mass (<100 ng) is crucial for ignition.

*B. A. Hammel *et al*., High Energy Density Phys. 6, 171 (2010).

Related talks: B. A. Hammel (B12.00006).
S. Haan (B12.00001).

E19527