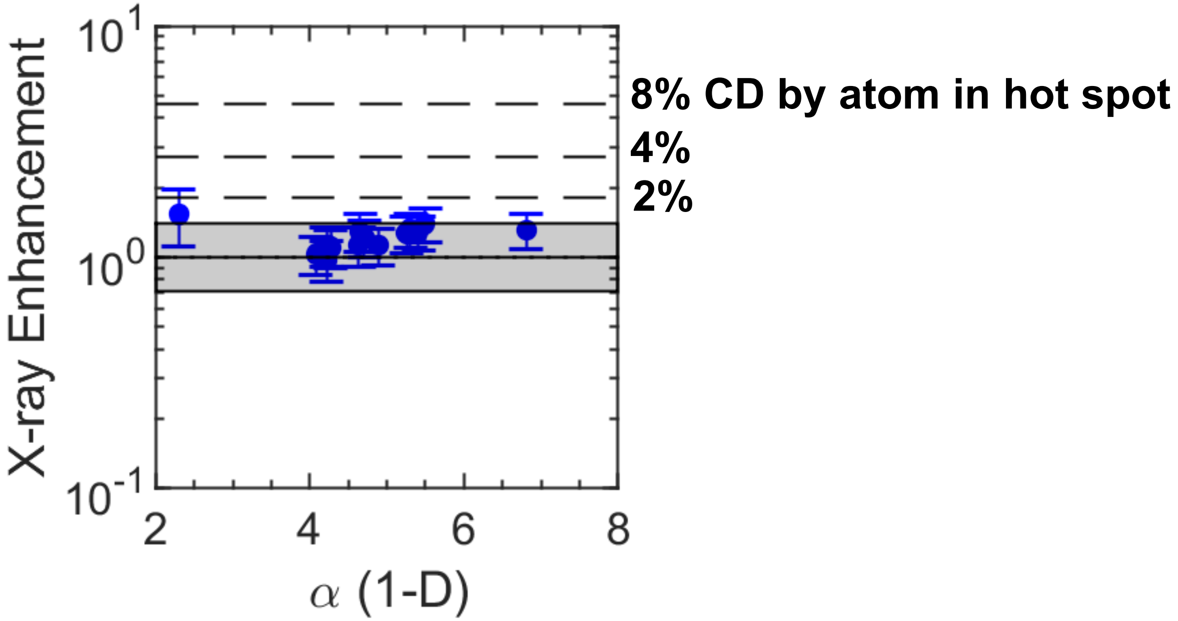
Mix, Temperature, and Compression of Statistical Model Optimized Cryogenic Implosions

$$\frac{\text{Measured x-ray yield}}{\text{X-ray yield predicted on the basis of neutron yield and hot-spot temperature measurements}}$$



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Summary

Absolute measurements of the hot-spot x-ray continuum have been used to study performance limits of presently optimized cryogenic implosions*

- Continuum hot-spot x rays are used to characterize hot-spot electron temperature and absolute x-ray yield
- The x-ray yield is not found to have a measurable enhancement (i.e., no detectable hot-spot mix)
- The x-ray yield indicates an inferred hot-spot density that is at best ~30% below 1-D as compared to a 20% reduction in the 2-D simulation
  - imprint, beam-geometry and other perturbations associated with direct drive reduce the hot-spot compression in the simulation

* R. C. Shah *et al.*, "Hot-Spot Mix and Compression in Statistical-Model-Optimized, Directly Driven Cryogenic Laser-Driven Implosions," submitted to Physical Review Letters.

Collaborators

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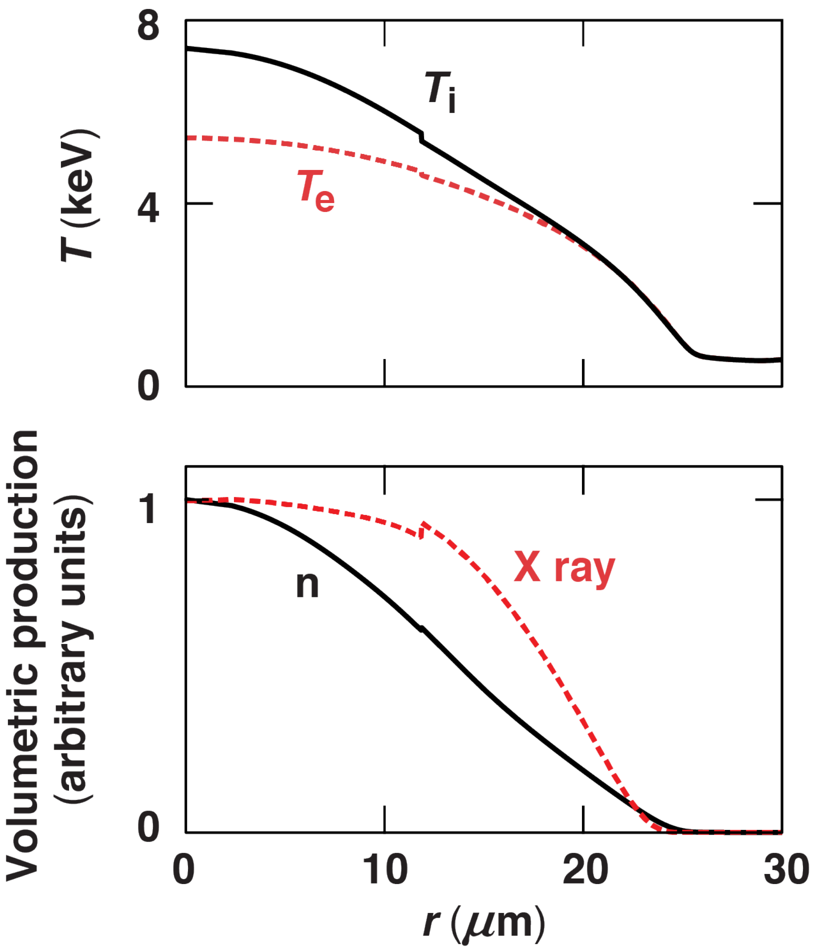
The absolute hot-spot x-ray yield can be used to indicate hot-spot mix*,**

- Yield (neutrons) $\sim \rho^2 \times <\sigma(T)> \times \tau \times V$
- Yield (x rays) $\sim \rho^2 \times e^{-h\upsilon/kT} \times \tau \times V \times Z^2$
- Ions and electrons are not in thermal equilibrium ($T_i \neq T_e$; $V_n \neq V_x$)

If the equilibration is different in the experiment, it will skew the expected ratio (and the mix inference).



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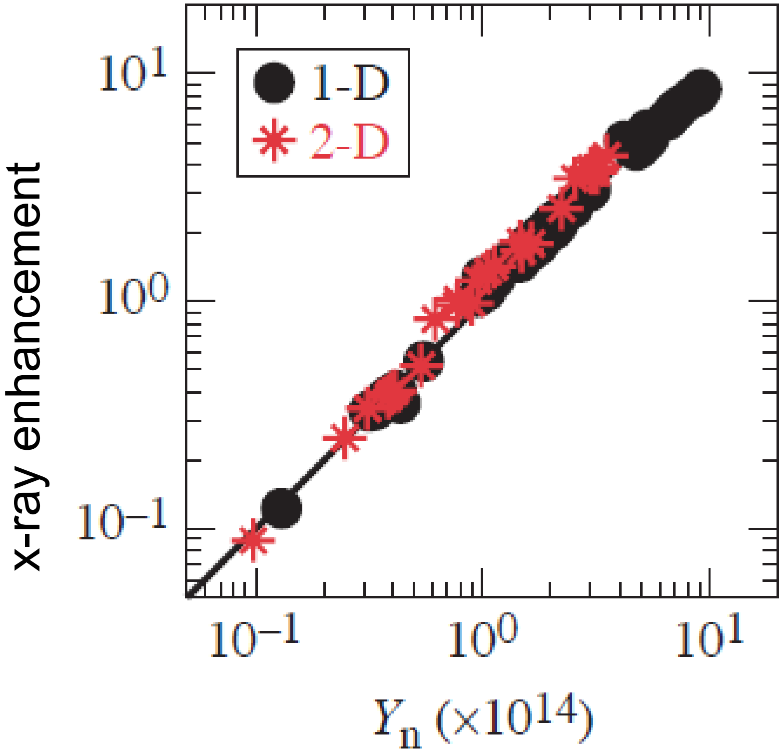
* T. Ma *et al.*, Phys. Rev. Lett. 111, 085004 (2013).
** R. Epstein *et al.*, Phys. Plasmas 22, 022707 (2015).

A mapping was developed to determine the expected x-ray production based on measured neutron yield, T_i , and T_e

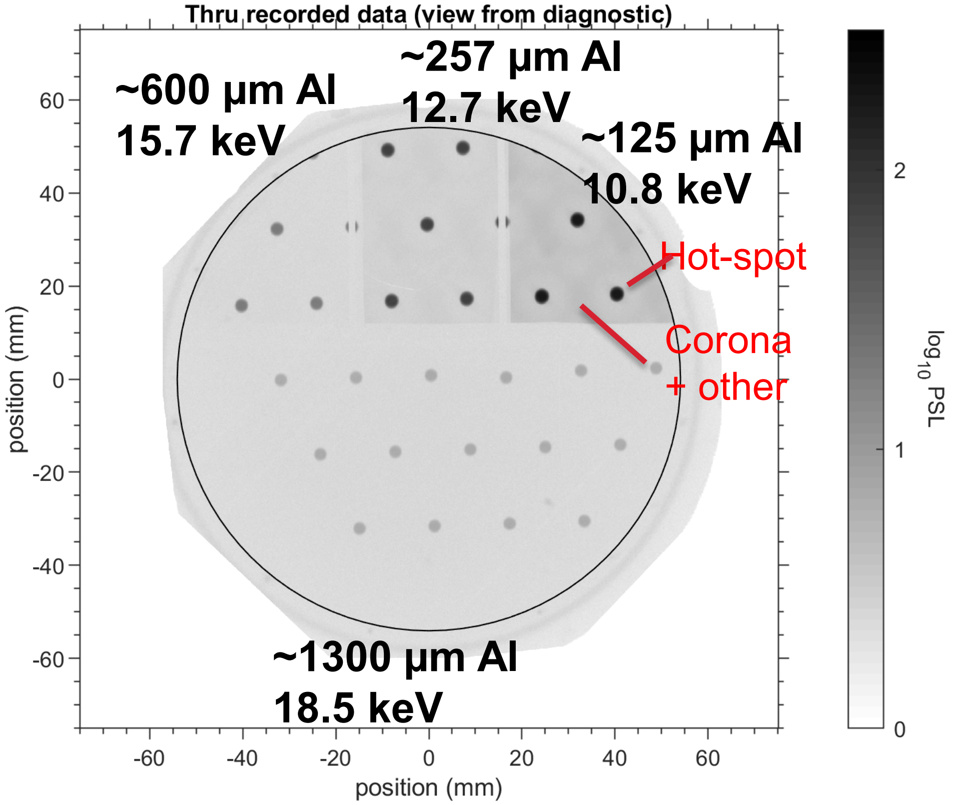
No-mix expected x-ray yield $= 2.2 \times 10^{-3}\ T_e^{4}\ T_i^{-2.39}\ Y_n$

$$\frac{\text{x-ray yield}}{\text{No-mix expected x-ray yield}}$$



These 2-D simulations show no hot-spot mix

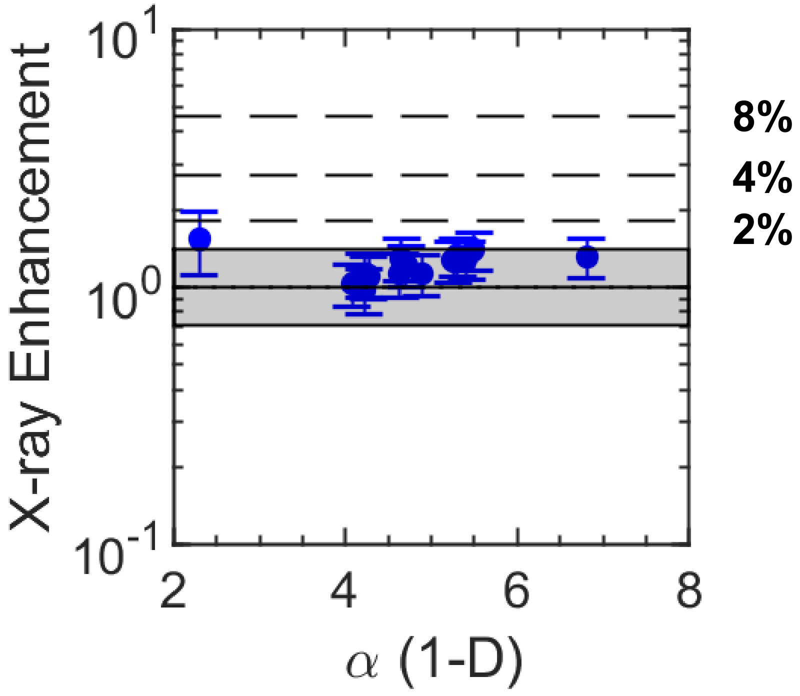
A filtered imaging array is used to obtain the x-ray data*,**



- Four channels (~10 to 20 keV, optically thin) were used to fit hot-spot model to extract T_e and Y_X
- Images discriminate coronal emission and were used to recover the hot-spot image†

* L. C. Jarrott *et al.*, Phys. Rev. Lett. 121, 085001 (2018).
** M. J. Rosenberg *et al.*, Rev. Sci. Instrum 90, 003506 (2019); 90, 029902(E) (2019).
† B. Bachmann *et al.*, Rev. Sci. Instrum. 87, 11E201 (2016).

For an ensemble of the larger, high-speed targets, the measured x rays are compared to the values obtained using the equilibration mapping

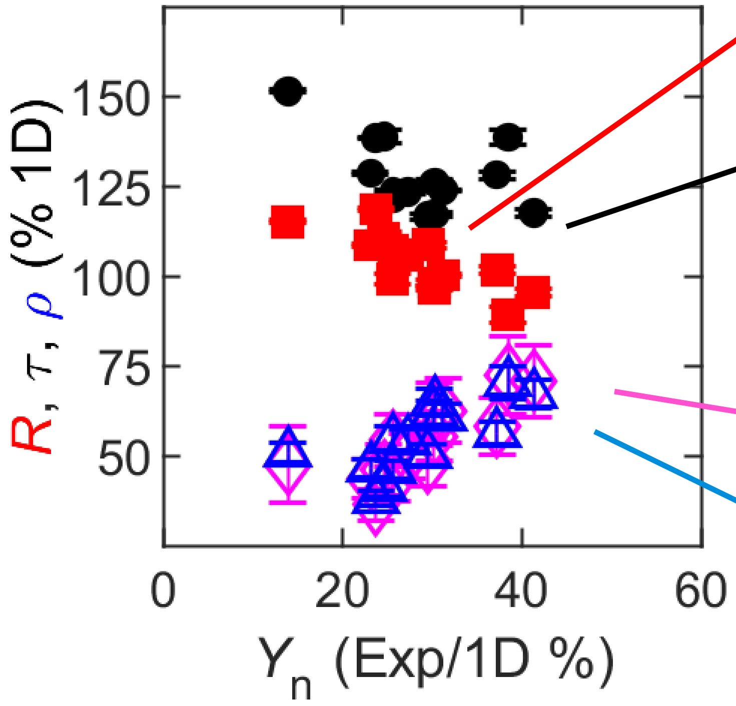


- **Approaches 2% by atom CD mix sensitivity**
- **This is a bounding sensitivity (10× decrease of mix in defect calculations* as α increased from 1.7 to 3.4)**

A CD mix of 2% by atom is a bounding sensitivity for the higher adiabats since mix will decrease as stability increases.

* I. V. Igumenshchev *et al.*, Phys. Plasmas 20, 082703 (2013).

The hot-spot density is inferred using the x-ray measurements



Hot-spot radius

neutron burn-width

- Yield (x rays) $\sim \rho^2 [e^{-h\nu/T_e}]\, \tau R^3 Z^2$
- Yield (neutrons) $\sim \rho^2 < \sigma_v(Ti) > \tau R^3$

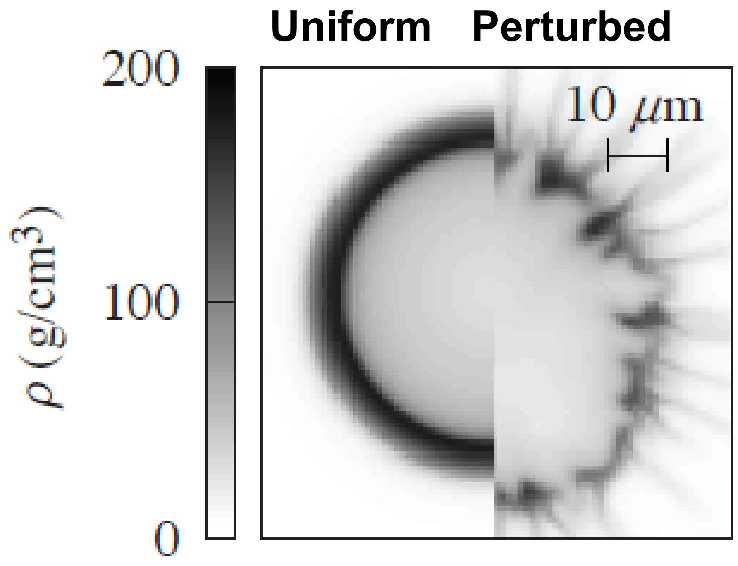
Using DT yield and Min-T_i

Density, using x-ray yield and T_e

The hot-spot density is maximally ~70% of 1-D.

The reduction of hot-spot compression in the experiment is qualitatively captured by 2-D simulation

2-D *DRACO*, peak neutron production



- **Imprint**
- **Beam geometry**
- **Layer roughness**
- **Balance, pointing**
- **Typical offset**

- **Inferred ρ_{hs} 70% to 80% of uniform**

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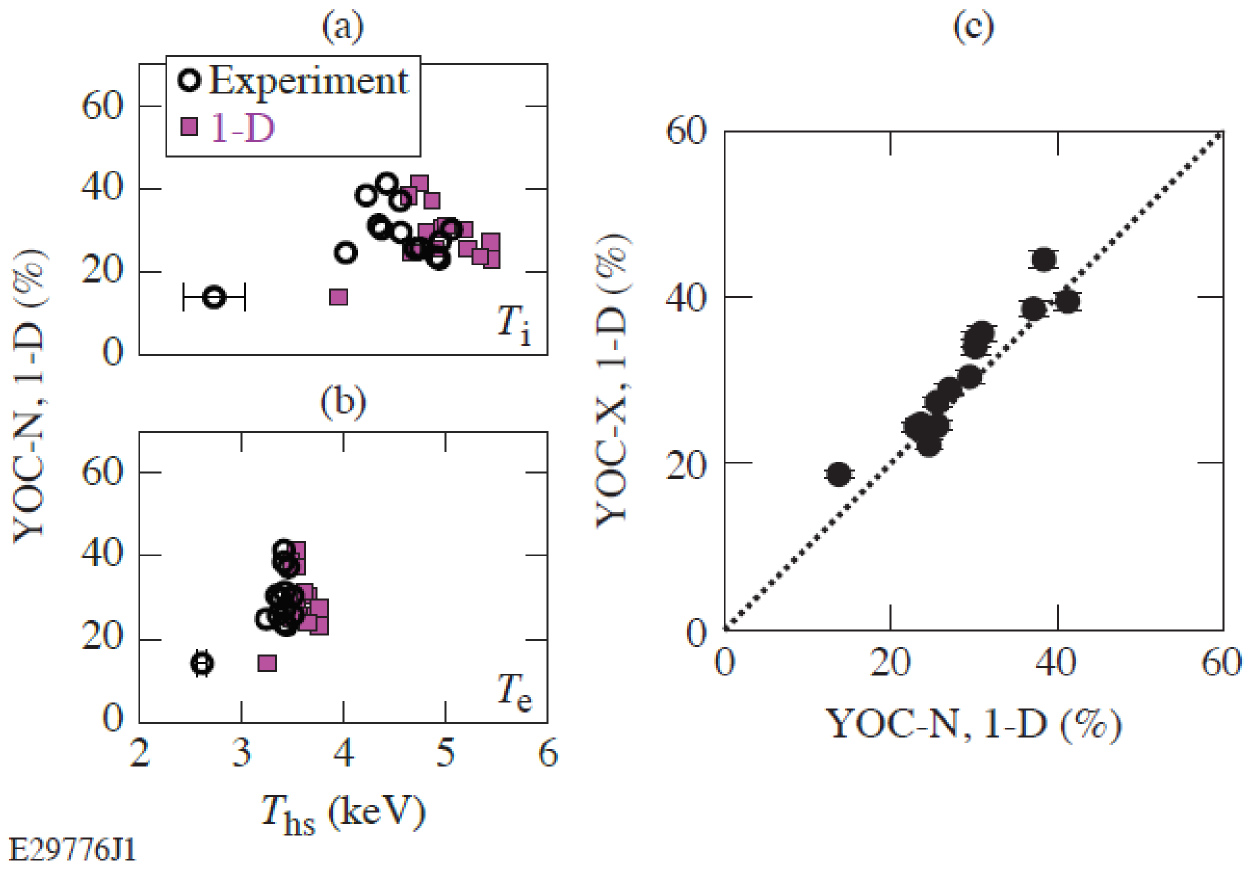
Temperatures and yields were measured for an ensemble of high velocity, high-adiabat implosions



- T_i is minimum of 5 detectors
- T_e lower as expected (though greater drops from 1-D are expected from 2-D)
- YOCS do not suggest mix enhancement