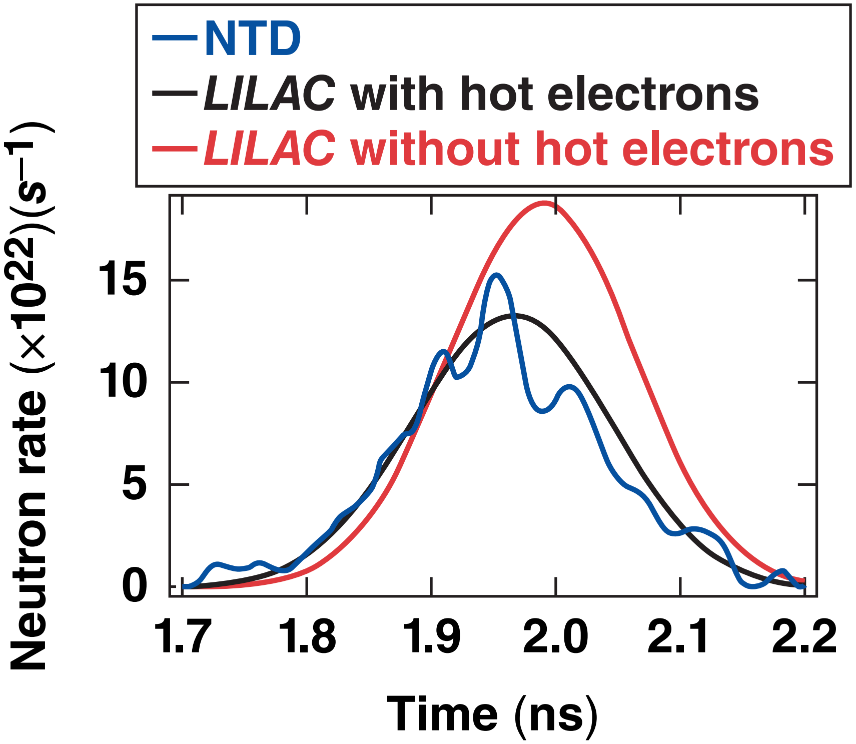
Analysis of a High-Adiabat Cryogenic Implosion on OMEGA



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Summary

We have approximately matched all experimental observables for a high-adiabat cryogenic implosion on OMEGA

- OMEGA shot 69515 was designed as a high-adiabat ($\alpha \sim 10$) implosion and is expected to behave one dimensionally
- The purpose of this experiment was to test 1-D physics models
- By including shell preheat, 1-D simulations are able to approximately recover all experimental observables; however, physics other than preheat may be at play

Collaborators

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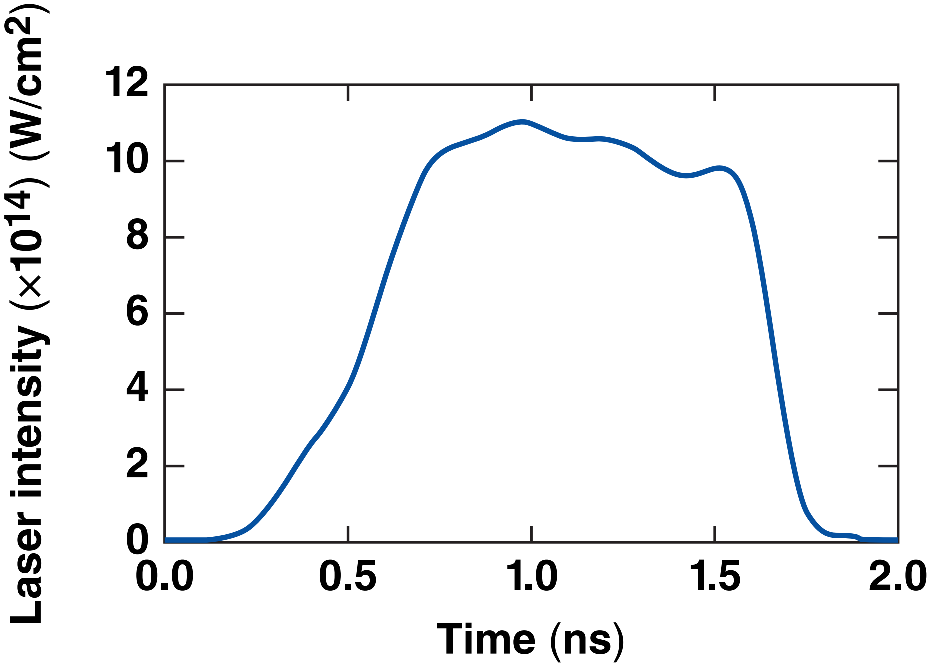
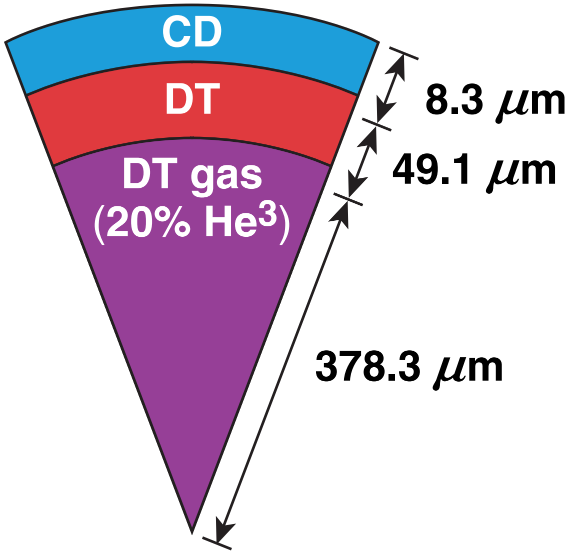
The objective of OMEGA shot 69515 was to analyze performance degradation in a regime where hydrodynamic instabilities can be neglected





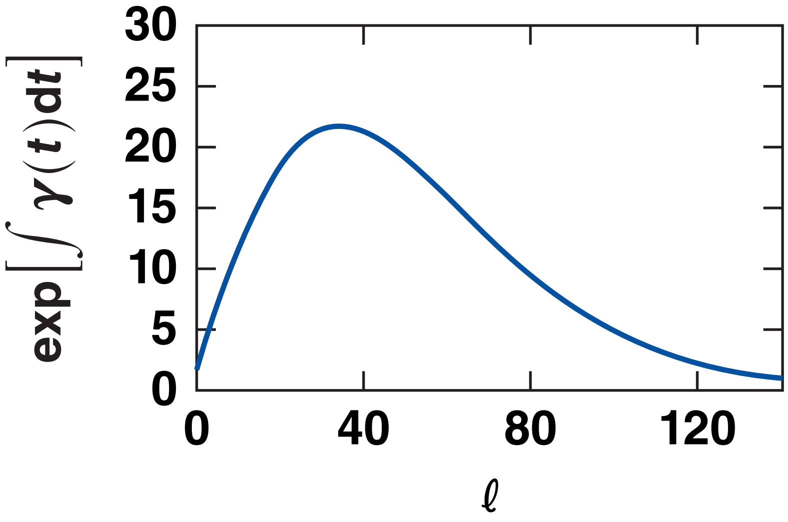
The fast ramp pulse launches a strong shock, which sets the shell on a high adiabat ($\alpha > 10$).

High-adiabat implosions exhibit strong ablative stabilization of the Rayleigh–Taylor instability (RTI)

- The linear RTI growth rate is*

$$\gamma(t)=0.94\sqrt{\frac{\ell}{R(t)}g(t)}-2.7\ell\frac{\boxed{V_a(t)}}{R(t)} \longleftarrow \boxed{V_a \sim \alpha^{3/5}}$$

- ℓ is the mode number
- $g(t)$ is the shell acceleration
- $R(t)$ is the shell position
- $V_a(t)$ is the ablation velocity
- α is the shell adiabat



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*H. Takabe *et al.*, Phys. Fluids 28, 3676 (1985).

One-dimensional simulations overestimate the implosion performance

	Experiment	*LILAC* (1-D)
Neutron yield	2.5×10^{13}	3.5×10^{13}
Burn width	127 (±59) ps	100 ps
Hot-spot radius	52(±7) μm	38 μm
Areal density	50 (±10) mg/cm^2 (nTOF) 73 (±10) mg/cm^2 (MRS)	68 mg/cm^2
Bang time	1.75 (±0.06) ns	1.79 ns
Ion temperature	2.8 (±0.5) keV	3.0 keV

- **An additional source of performance degradation is likely present**

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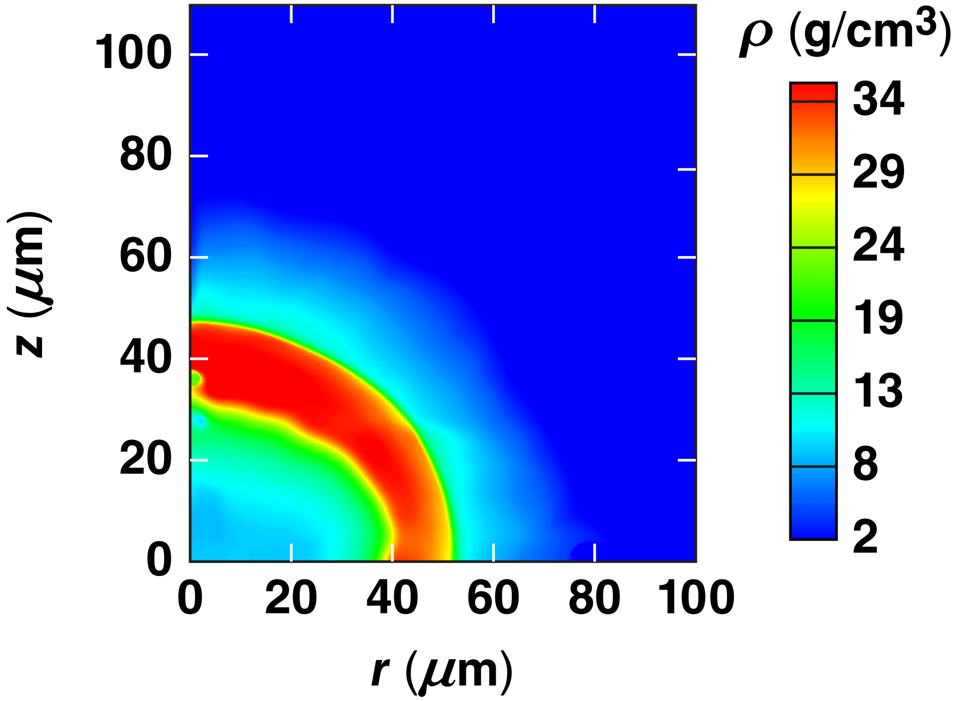
nTOF: neutron time of flight
MRS: magnetic recoil spectrometer

Two-dimensional *DRACO* simulations (laser imprint + ice roughness) confirm that hydro-instabilities were negligible in this experiment

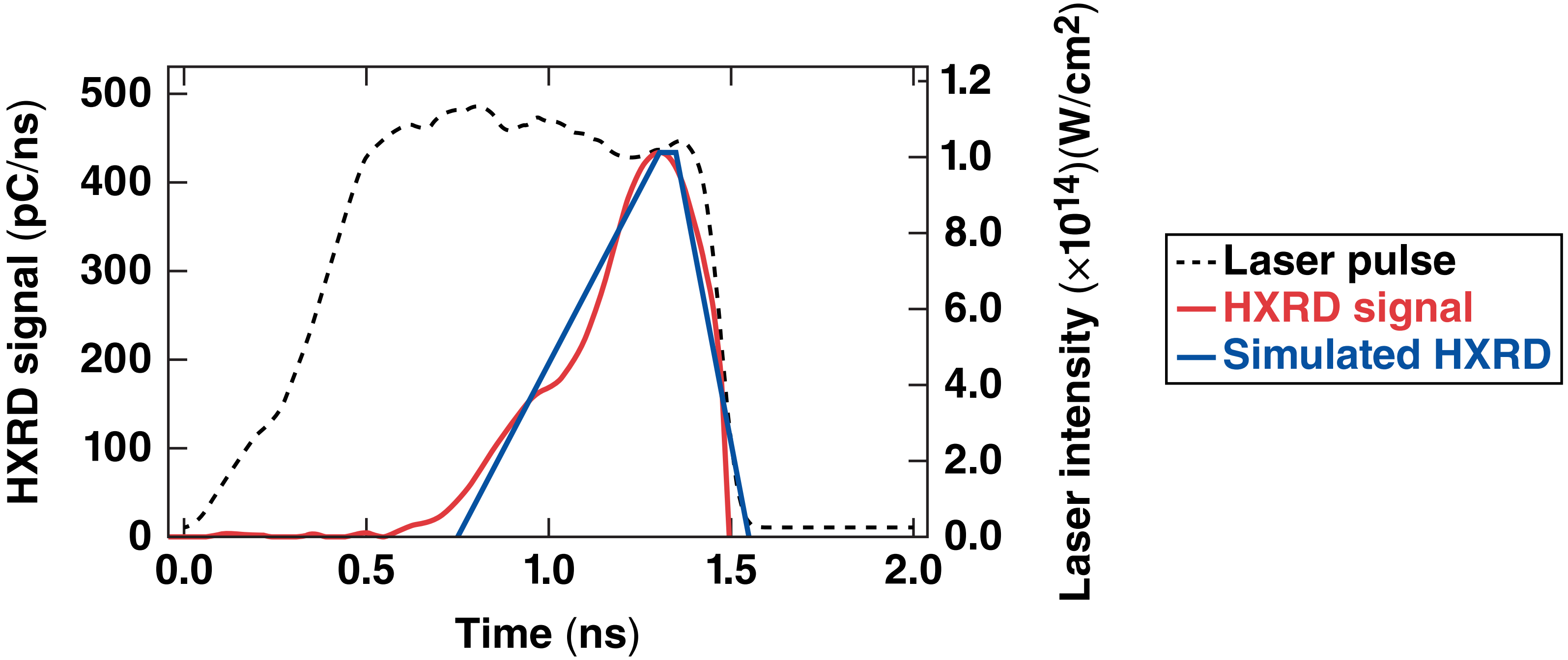
- Two-dimensional simulation of shot 69515 at stagnation $\left(\frac{\text{Yield}_{\text{2-D}}}{\text{Yield}_{\text{1-D}}} = 0.98\right)$



We conclude that any performance degradation with respect to 1-D simulations is not caused by instabilities for this experiment.

A possible source of degradation is hot-electron preheat from the two-plasmon–decay (TPD) instability

- Hard x rays from hot electrons are temporally measured and the corresponding source is put into the simulation
- A hard x-ray detector (HXRD) signal is measured in this high-intensity shot >10^{15} W/cm^2



- The HXRD calibration (5.18-pC/mJ hard x rays) implies there are 174 J of hot electrons, of which 34 J deposit their energy into the unablated DT shell

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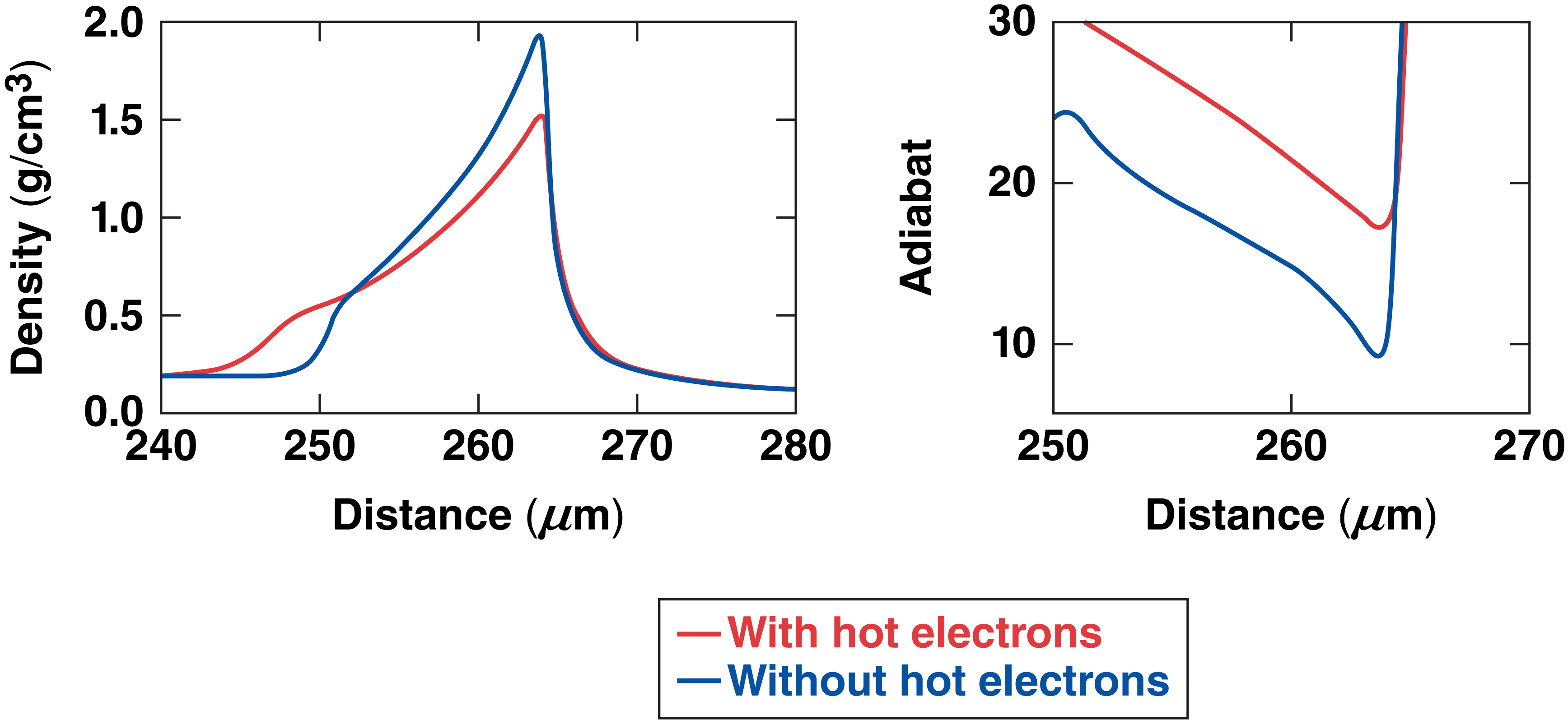
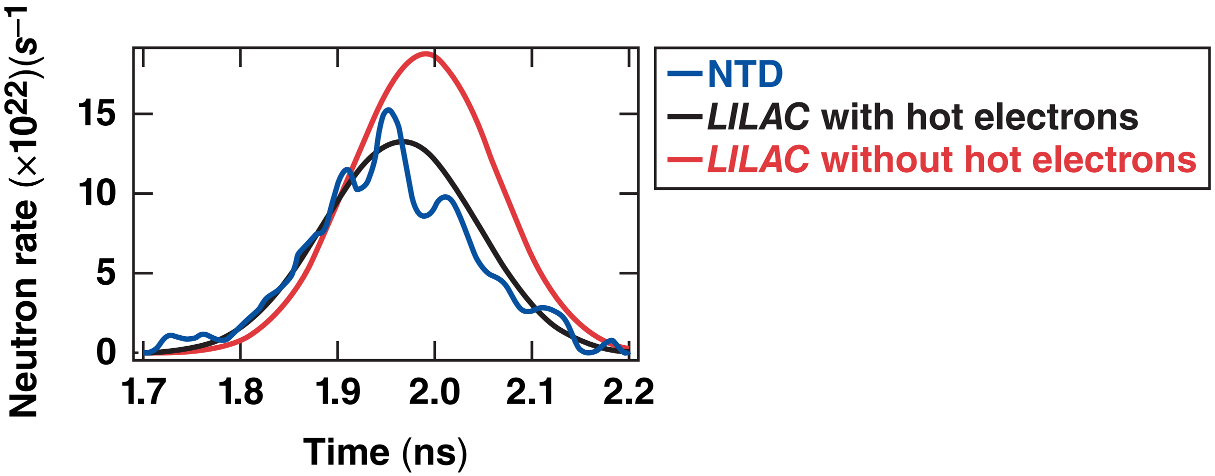
Hot electrons degrade the implosion by preheating the shell and raising the adiabat

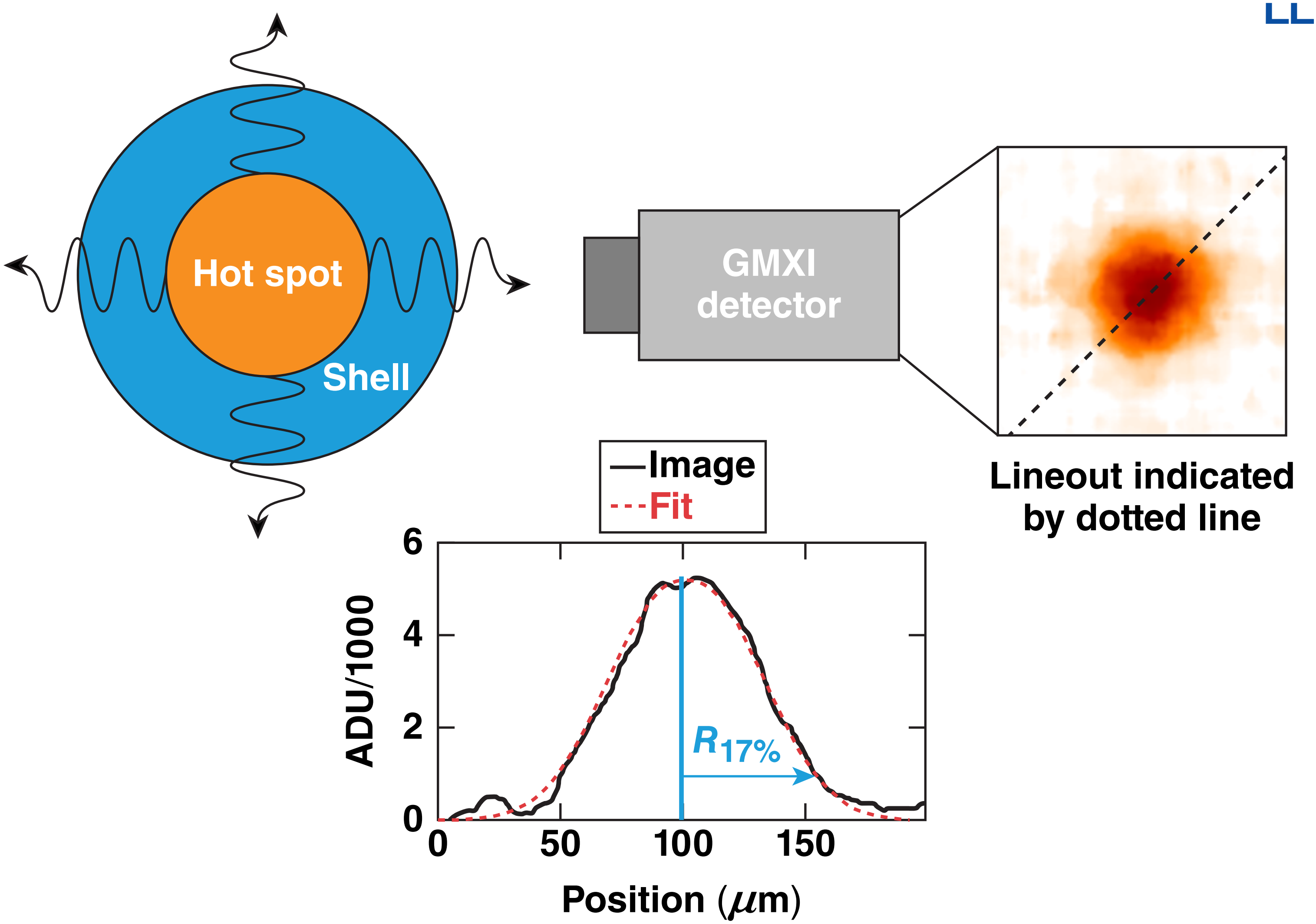


Many of the observables are recovered when 37 J of hot electrons are deposited into the unablated shell



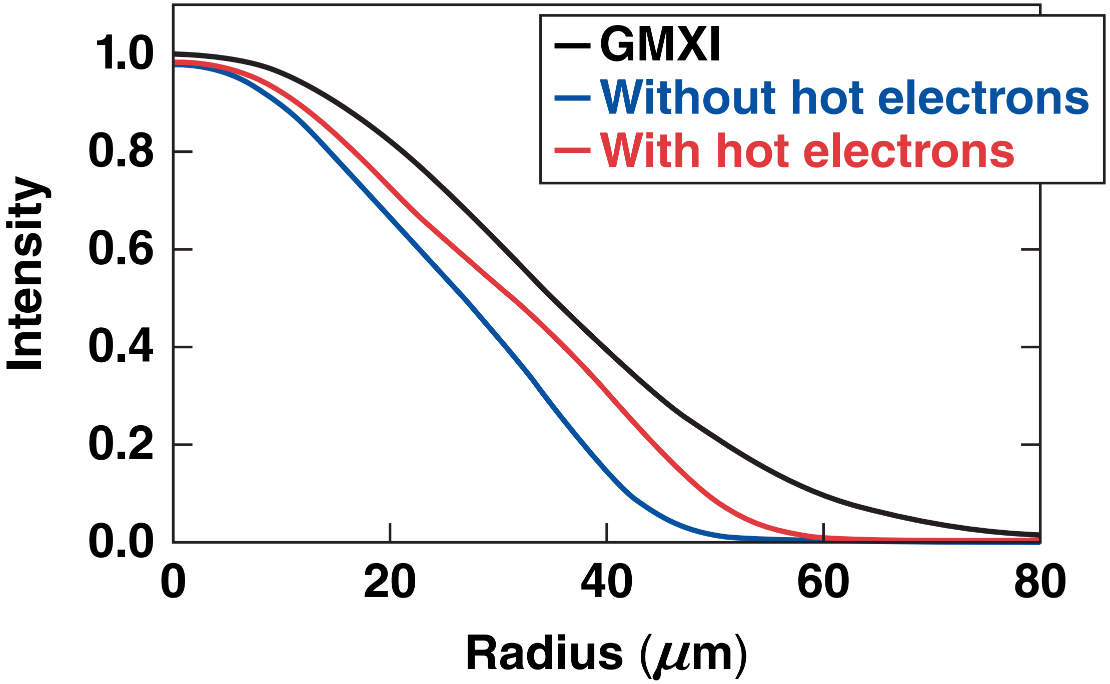
	Neutron temporal diagnostic (NTD)	*LILAC* without hot electrons	*LILAC* with hot electrons
Yield	2.5×10^{13}	3.5×10^{13}	2.7×10^{13}
Burnwidth	127 ps	100 ps	125 ps
Bang time	1.75 ns	1.79 ns	1.77 ns
Areal density	50 mg/cm^2 (NTOF) 73 mg/cm^2 (MRS)	68 mg/cm^2	50 mg/cm^2
Ion temperature	2.8 keV	3.0 keV	2.9 keV

The hot-spot radius can be inferred from the gated monochromatic x-ray images (GMXI) detector that measures x rays emitted from the hot spot during burn



Lineout indicated by dotted line

Spect3D simulations of the core self-emission show a large hot-spot radius in preheated implosions



	GMXI-c	*LILAC* without hot electrons	*LILAC* with hot electrons
R_{17}	52±7 μm	38 μm	45 μm

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*J. J. MacFarlane *et al*., High Energy Density Phys. 3, 181 (2007).

Summary/Conclusions

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