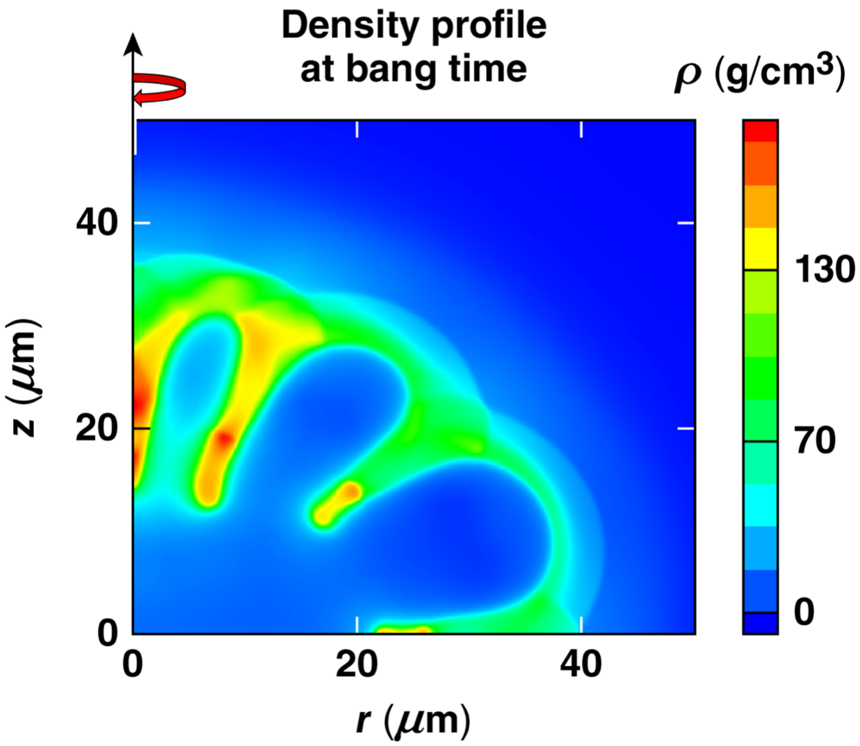
Analysis and Reconstruction of Highest-Performing OMEGA DT Layered Implosion Shot 90288



D. Patel
University of Rochester
Laboratory for Laser Energetics

61st Annual Meeting of the
American Physical Society
Division of Plasma Physics
Fort Lauderdale, FL
21–25 October 2019

Summary

Experimental observables for shot 90288 were reconstructed using 2-D radiation-hydrodynamics simulations

- Shot 90288 produced Yield = 1.51×10^{14} and ρR = 160 (mg/cm^2), yet showed significantly lower yield than 1-D with YOC $\approx$ 0.4
- Analysis of experimental data, suggests that degradation from a systematic low mode $(\ell = 2)$ and a mid-mode $(\ell \geq 10)$ is a viable hypothesis to explain lower performance
- The radiation-hydrodynamic code *DEC2D** was used to reconstruct the experimental data using *adhoc* combinations of low and mid-modes

*K. M. Woo *et al*., Bull. Am. Phys. Soc. 59, BAPS.2014.DPP.UP8.87 (2014).
YOC: yield over clean

Collaborators

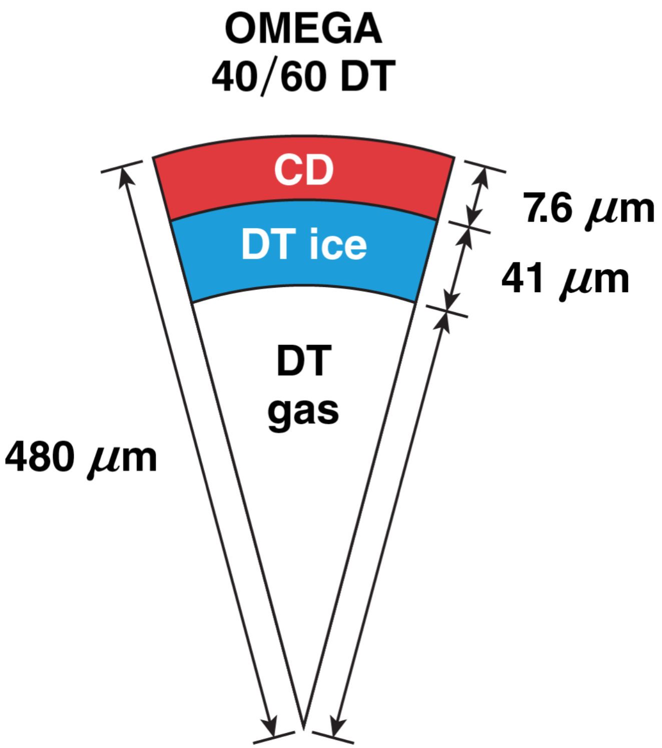
R. Betti, K. M. Woo, V. Gopalaswamy, J. P. Knauer, and R. C. Shah

University of Rochester
Laboratory for Laser Energetics

A. Bose

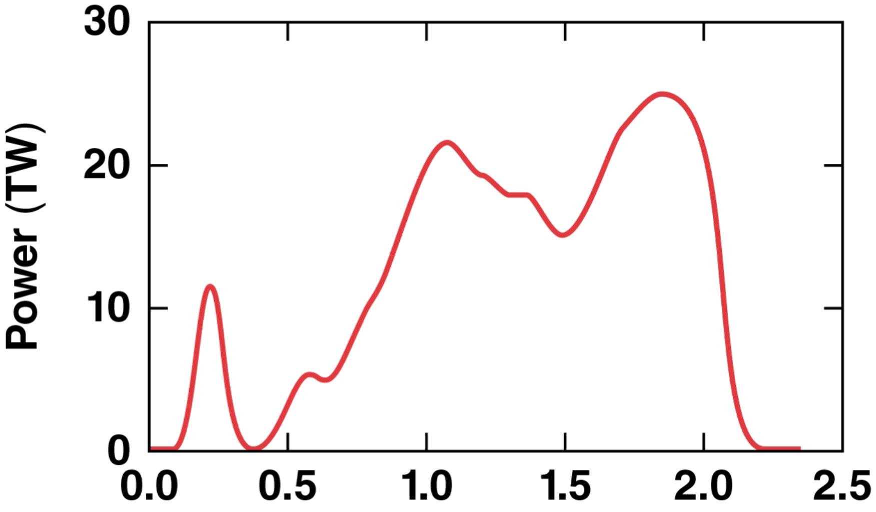
Massachusetts Institute of Technology

Shot 90288 used a new pulse-shape design and achieved the highest performance to date on OMEGA



TC13687k

+



=

Yield	1.51×10^{14}
ρR	160 mg/cm^2
$\langle T_{\mathrm{i}} \rangle_{\mathrm{n,min}}$	4.55 keV
$\langle P \rangle_{\mathrm{n}}$	52 Gbar
$\chi_{\text{no }\alpha}$ (1.9 MJ)	0.74

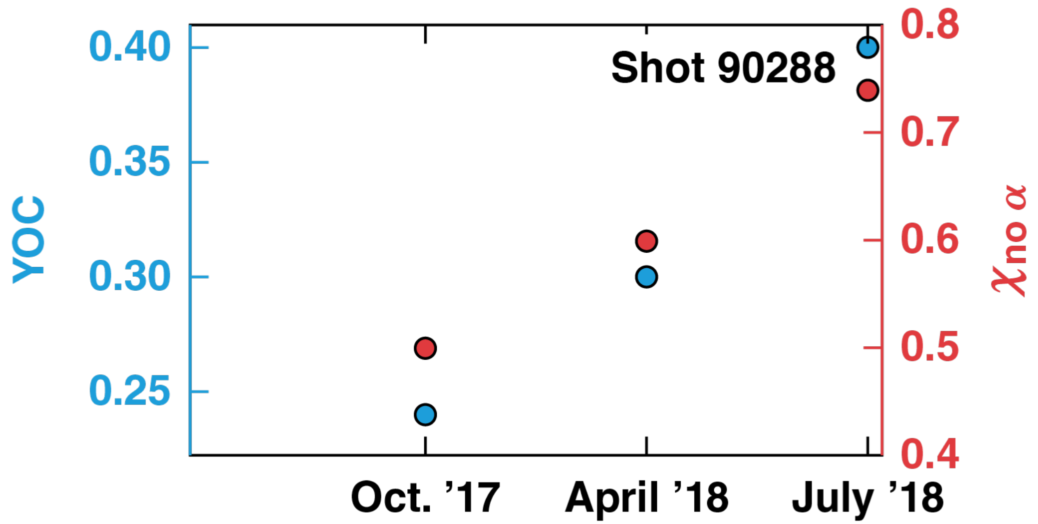
OMEGA cryo shot 90288

$\chi_{\text{no }\alpha}$ = no-α Lawson parameter for ignition

The performance of shot 90288 was significantly lower than predicted by 1-D code (*LILAC*)

When compared to performance as predicted by 1-D code *LILAC*

- **Yield is 60% lower**
- **Inferred $\langle P \rangle_n$ is ~50% lower**
- **Convergence is 10% lower**

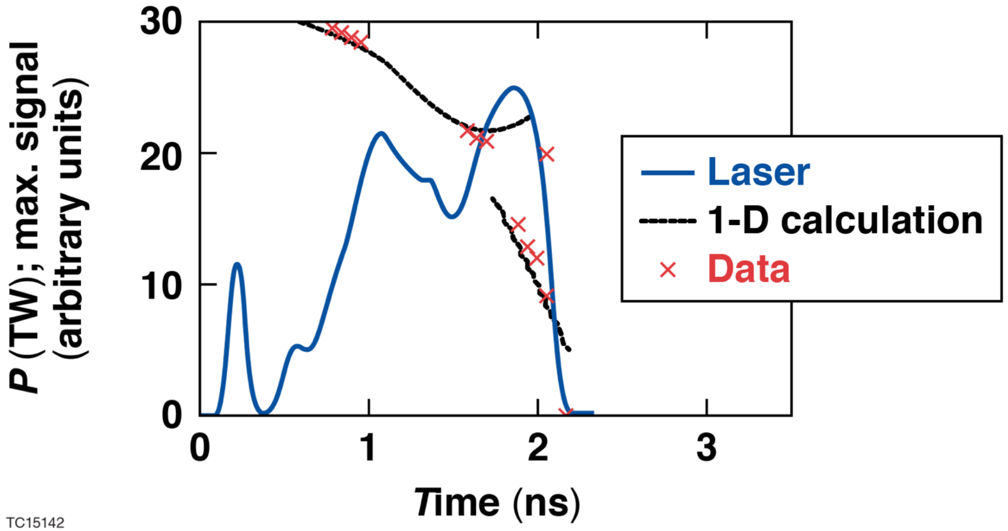


TC15221

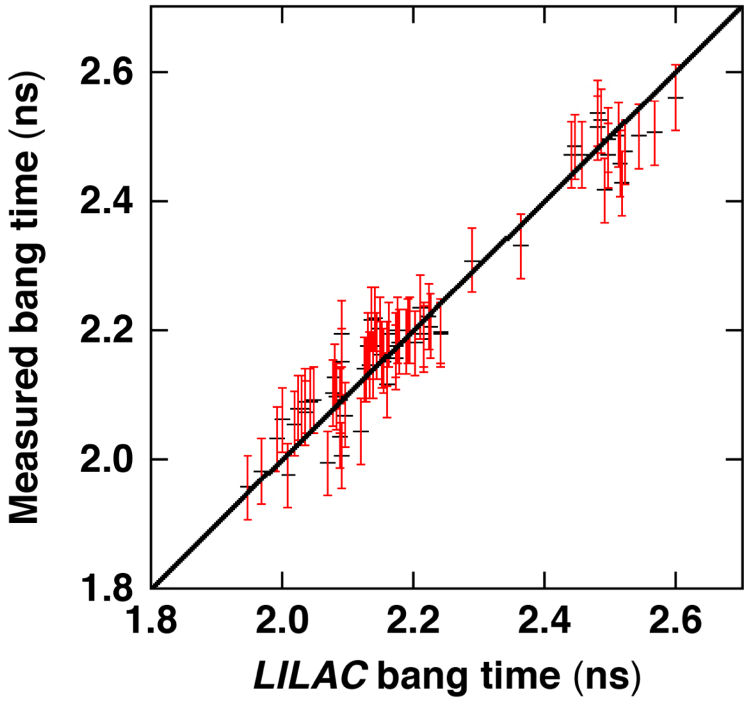
This motivated an effort to find the dominant cause(s) of degradation for shot 90288.

Measured bang time, absorption, and trajectory are in general agreement with the 1-D simulation

	LILAC	Experiment
Absorption (%)	70	67
Bang time (ns)	2.090	2.109±005



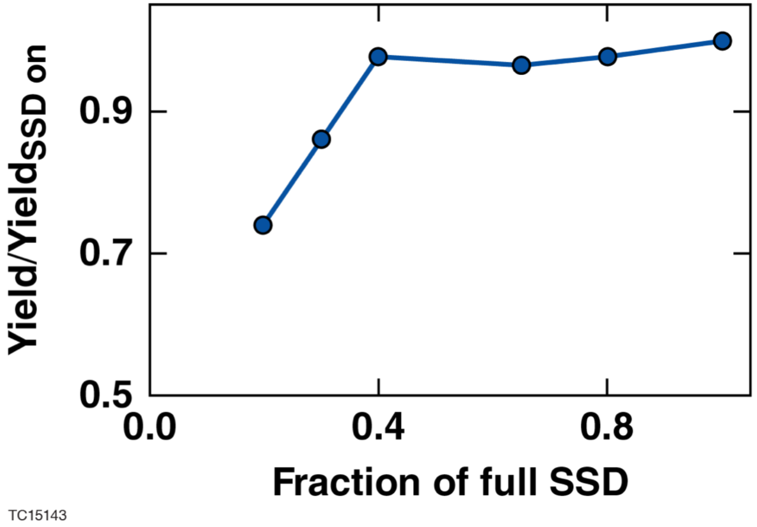
TC15142

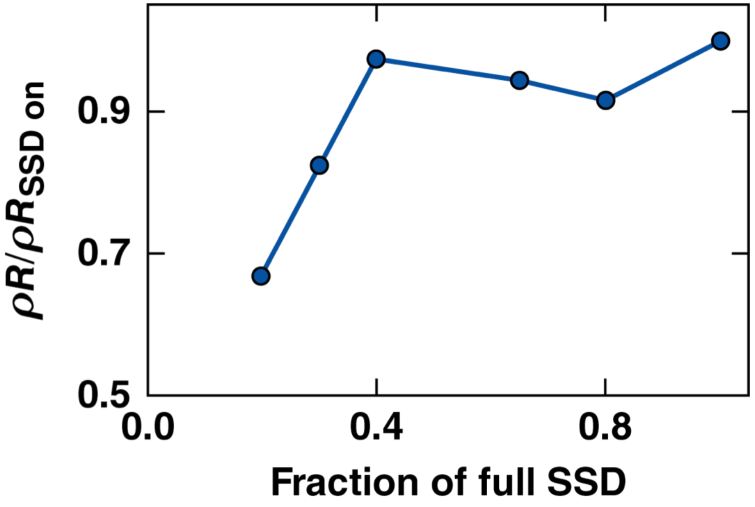


It is unlikely that 1-D degradation is responsible for lower performance.

An SSD scan* was performed on a similar implosion (shot 90291) to infer the effect of imprinting at the highest available smoothing

	Shot 90288	Shot 90291
OD (μm)	960	980
v_{imp} (km/s)	467	455
$\alpha_{2/3}$	5.2	4.5
$IFAR_{2/3}$	24	25





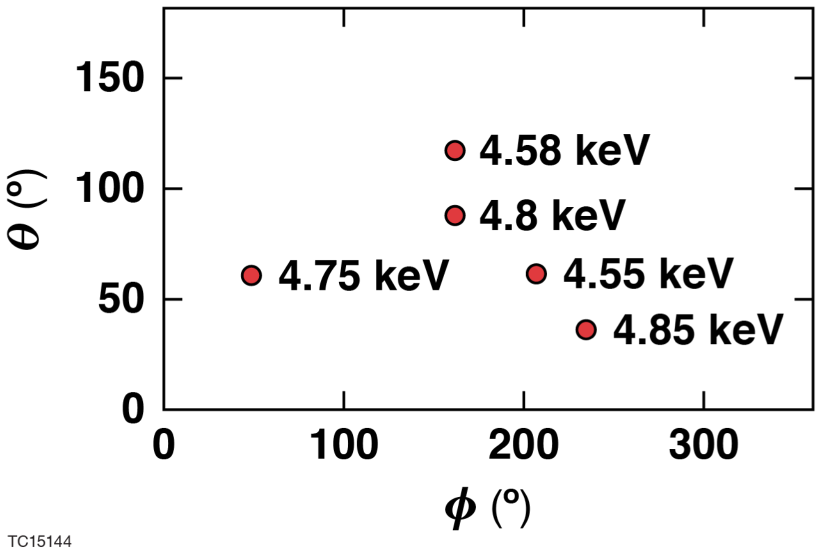
Data from the SSD suggest that the performance of implosions at this adiabat and IFAR is insensitive to imprinting at 100% SSD.

*J. P. Knauer *et al.*, YO5.00004, this conference.
SSD: smoothing by spectral dispersion
OD: outer diameter
IFAR: in-flight aspect ratio

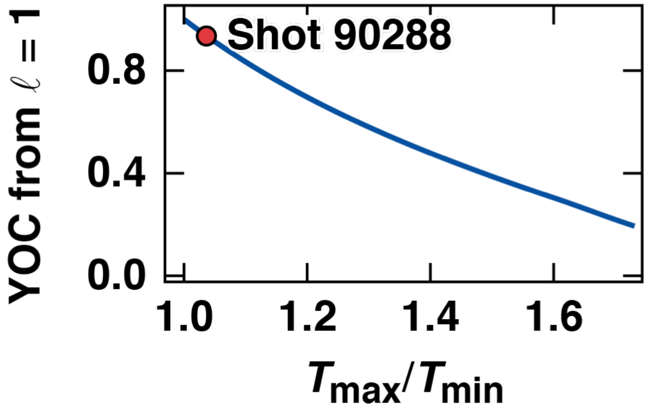
Shot 90288 showed almost no T_i asymmetry, suggesting mode 1 is not a dominant source of degradation

UR LLE

Shot 90288 T_i distribution

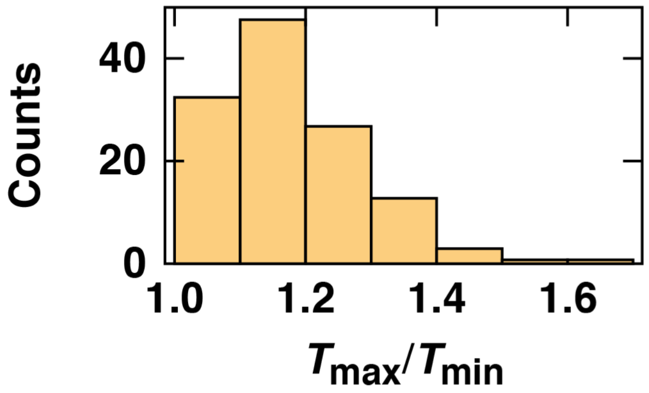


TC15144



YOC versus DT_i for ℓ = 1 only*

$DT_i = T_{max}/T_{min}$

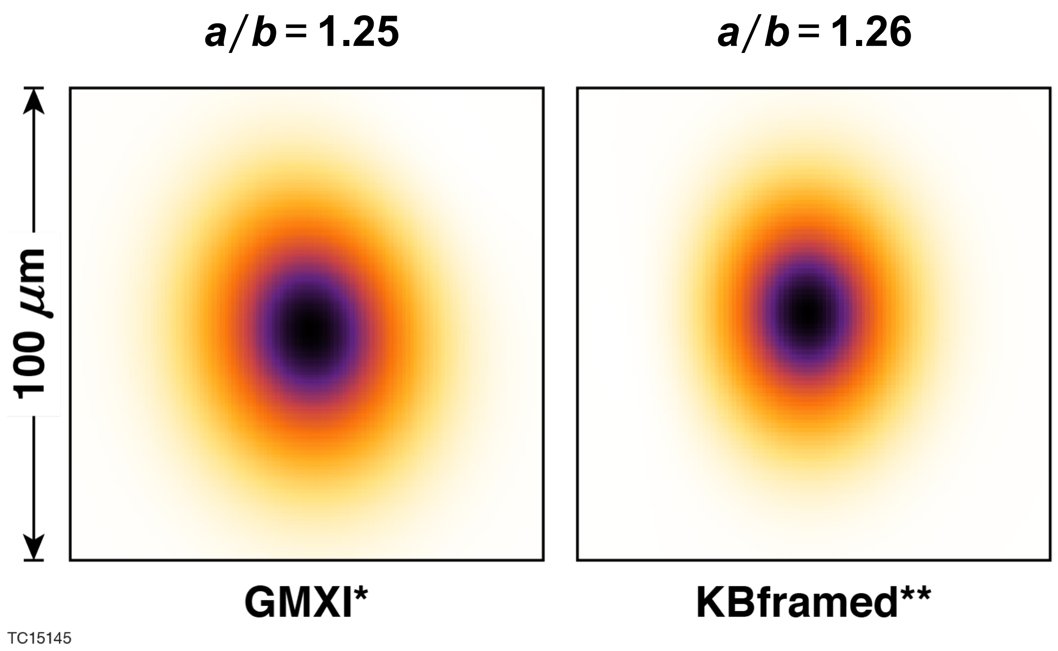


DT_i histogram

Target offset, beam mispointing, ice roughness (sources for mode 1), etc. are unlikely sources of degradation.

*K. M. Woo, UI2.0002, this conference (invited).

Both framed and time-integrated x-ray self-emission images show a hot spot with ellipticity oriented in the general direction of the stalk (up–down)



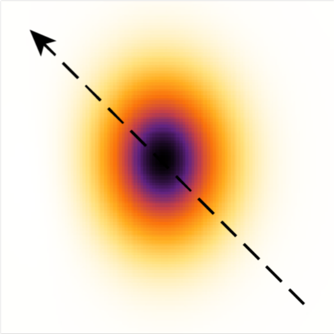
- Separate experiments have been conducted to quantify in-flight low-mode asymmetry†
- These measurements evidence a systematic $\ell = 2$ aligned to the capsule mounting (stalk)
- Since cryogenic targets use similar mounting, we expect the results to hold true for the present analysis

The in-flight measurement of warm implosions also shows a residual $\ell = 2$ along the axis of the stalk consistent with the $\ell = 2$ asymmetry observed in x-ray images.

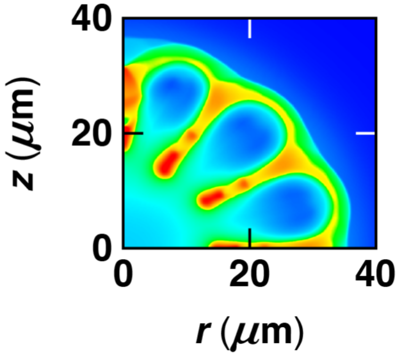
* GMXI: gated monochromatic x-ray imager
** F. J. Marshall and J. A. Oertel, Rev. Sci. Instrum. 68, 735 (1997).

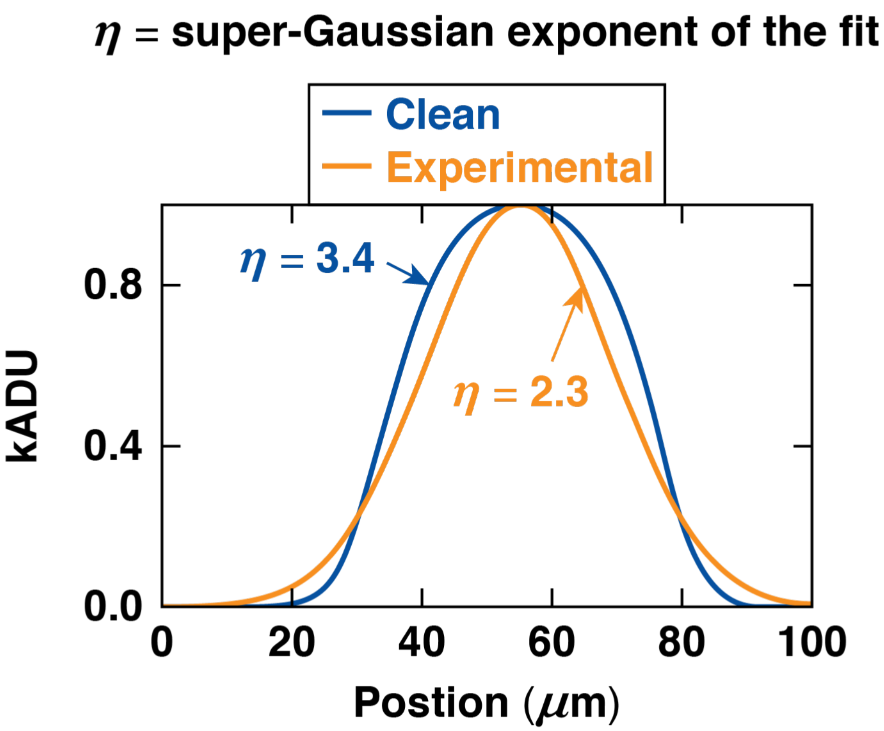
†R. Shah *et al*., "First Observation of Inflight Symmetry Affecting Implosion Performance at Stagnation," to be submitted to Physical Review Letters.

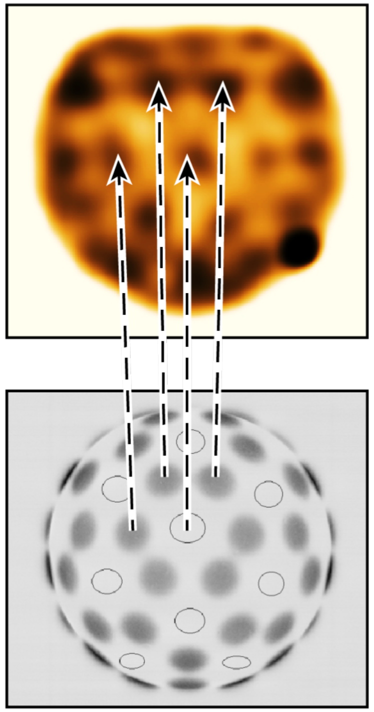
X-ray self-emission images of the hot spot show a more peaked profile than a synthetic GMXI from a clean simulation at equal convergence



GMXI







Framed image of Ge-doped cryogenic Implosions showing illumination nonuniformity

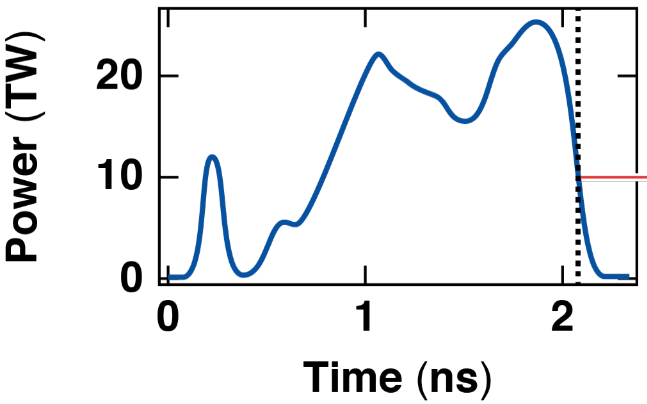
Image from a pointing shot showing the location of beams on a 4-mm-diam Au target

TC15146

Converging spikes from a mid-mode driven by OMEGA 60-beam port geometry is a likely cause for a more peaked profile.*

*A. Bose *et al.*, Phys. Rev. E 94, 011201(R) (2016).

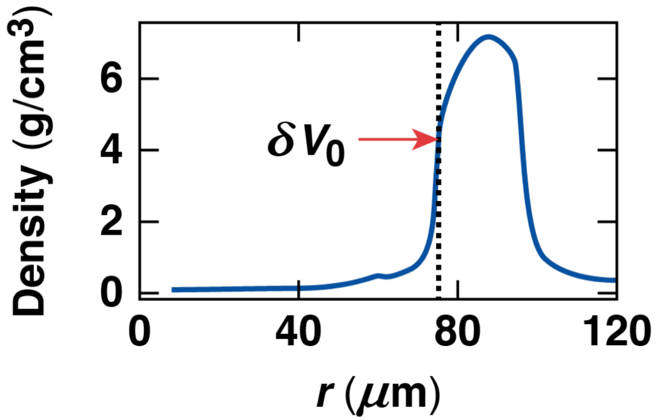
The radiation-hydrodynamic code *DEC2D* was used to match the experimental observables by varying the amplitudes of ℓ = 2 and ℓ = 12*



TC15147

LILAC
ρ, μ, *P*, *T*
profiles at
maximum v_{imp}

+



DEC2D

*Spect3D***

IRIS3D†

Synthetic x-ray images

Neutronics $\langle T_i \rangle_n$, $\langle \rho R \rangle_n$

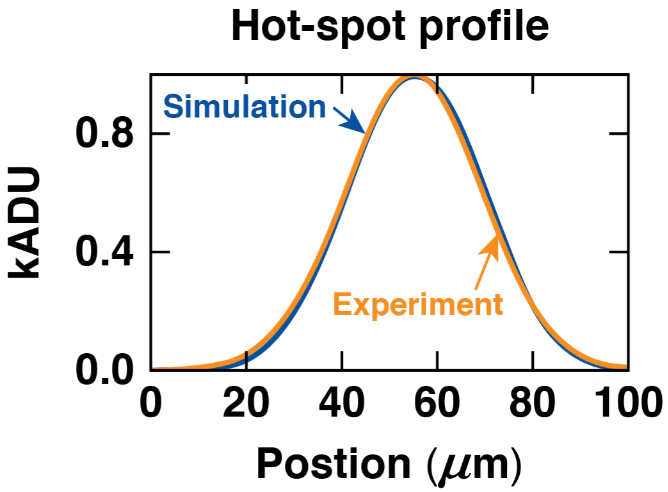
* A. Bose *et al*., Phys. Rev. E 94, 011201(R) (2016).
** PrismSPECT, Prism Computational Sciences, Inc., Madison, WI
† F. Weilacher, P. B. Radha, and C. Forrest, Phys. Plasmas 25, 042704 (2018).

Neutron yield, observed hot-spot profile (R_0, η), neutron-averaged temperatures $\langle T_i \rangle_n$, and areal density $\langle \rho R \rangle_n$ were matched for the reconstruction

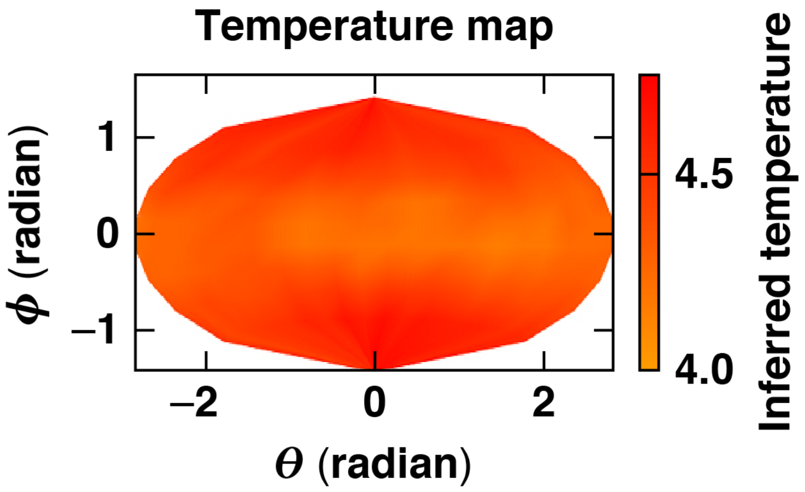
ℓ = 2 at 8% $\tilde{v}/v_{imp}$

ℓ = 12 at 20% $\tilde{v}/v_{imp}$

	Experiment	Simulation
Yield	1.51×10^{14}	1.47×10^{14}
ρR (mg/cm^2)	159.5	162



TC15148



	Experiment	Simulation
R_0 (μm)	27.5	27.3
η	2.3	2.25

	Experiment	Simulation
$\langle T_i \rangle_{n,\,max}$ (keV)	4.85	4.79
$\langle T_i \rangle_{n,\,min}$ (keV)	4.55	4.39

ℓ = 2 corrected yield → 2.27×10^{14}
ℓ = 12 corrected yield → 2.02×10^{14}

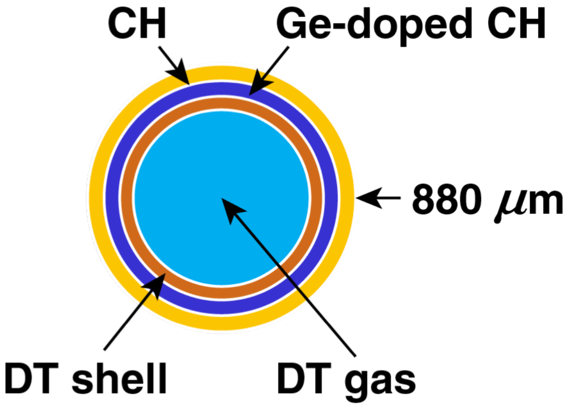
Experimental observables for shot 90288 were reconstructed using 2-D radiation-hydrodynamics simulations

- **Shot 90288 produced Yield = 1.51×10^{14} and ρR = 160 (mg/cm^2), yet showed significantly lower yield than 1-D with YOC $\approx$ 0.4**
- **Analysis of experimental data, suggests that degradation from a systematic low mode $(\ell = 2)$ and a mid-mode $(\ell \geq 10)$ is a viable hypothesis to explain lower performance**
- **The radiation-hydrodynamic code *DEC2D** was used to reconstruct the experimental data using *adhoc* combinations of low and mid-modes**

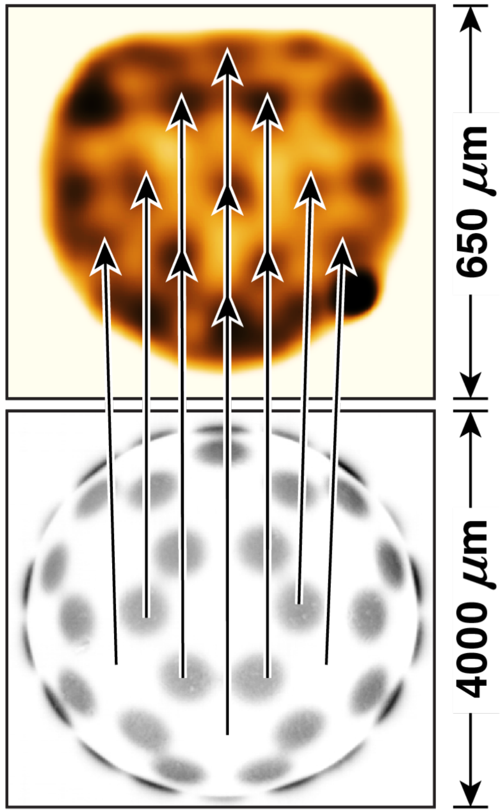
*K. M. Woo *et al.*, Bull. Am. Phys. Soc. 59, BAPS.2014.DPP.UP8.87 (2014).
YOC: yield over clean

Backup

Asymmetry in the laser Illumination pattern is observed in Ge-doped* implosions



Pointing shot from TIM-5 (bottom)



Framed image of the acceleration phase from TIM-5 (top)

Dark spots

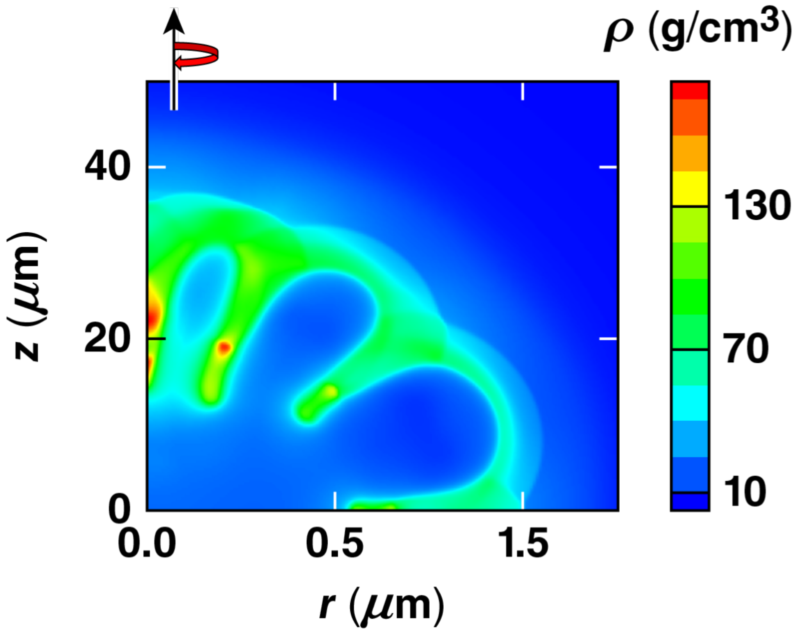
↓

Lower x-ray flux

↓

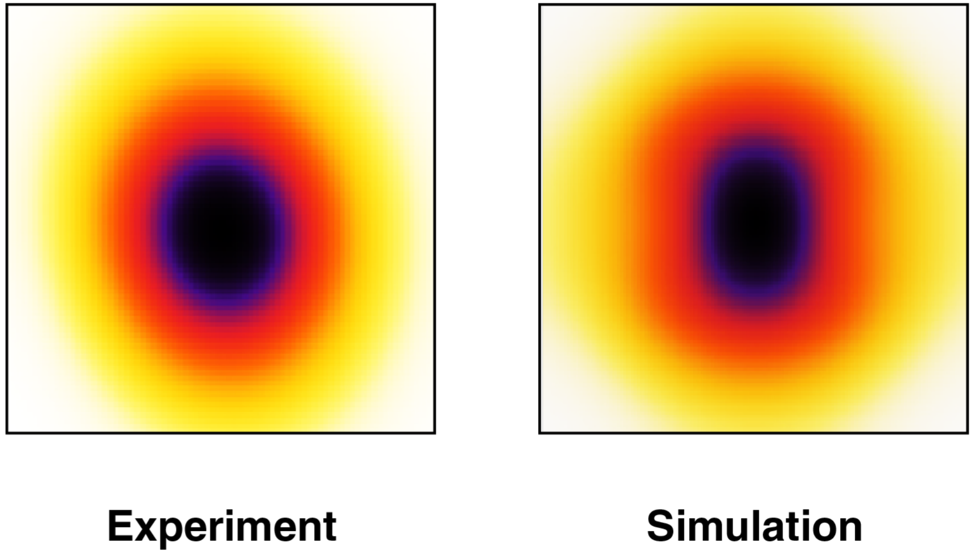
Higher laser illumination

*D. Patel *et al.*, JO7.0004, presented at the 59th Annual Meeting of the APS Division of Plasma Physics, Milwaukee, Wisconsin, 23–27 October 2017.
TIM: ten-inch manipulator



Shot 90288 simulation

Time-integrated x-ray images



The performance of shot 90288 was significantly lower than predicted by 1-D code (*LILAC*)

When compared to performance as predicted by 1-D code *LILAC*

- **Yield is 60% lower**
- **Inferred $\langle P \rangle_n$ is ~50% lower**
- **Convergence is 10% lower**

	Experiment	*LILAC* (1-D)	Fraction
Yield $\times 10^{14}$	1.51	3.8	0.4
ρR (mg/cm^2)	160	180	0.9
$\langle T_i \rangle_{n,min}$ (keV)	4.55	4.97	0.9
$\langle P \rangle_n$ (Gbar)	50	92	0.54
R_0 (μm)	27	24.5	0.9

This motivated an effort to find the dominant cause(s) of degradation for shot 90288.