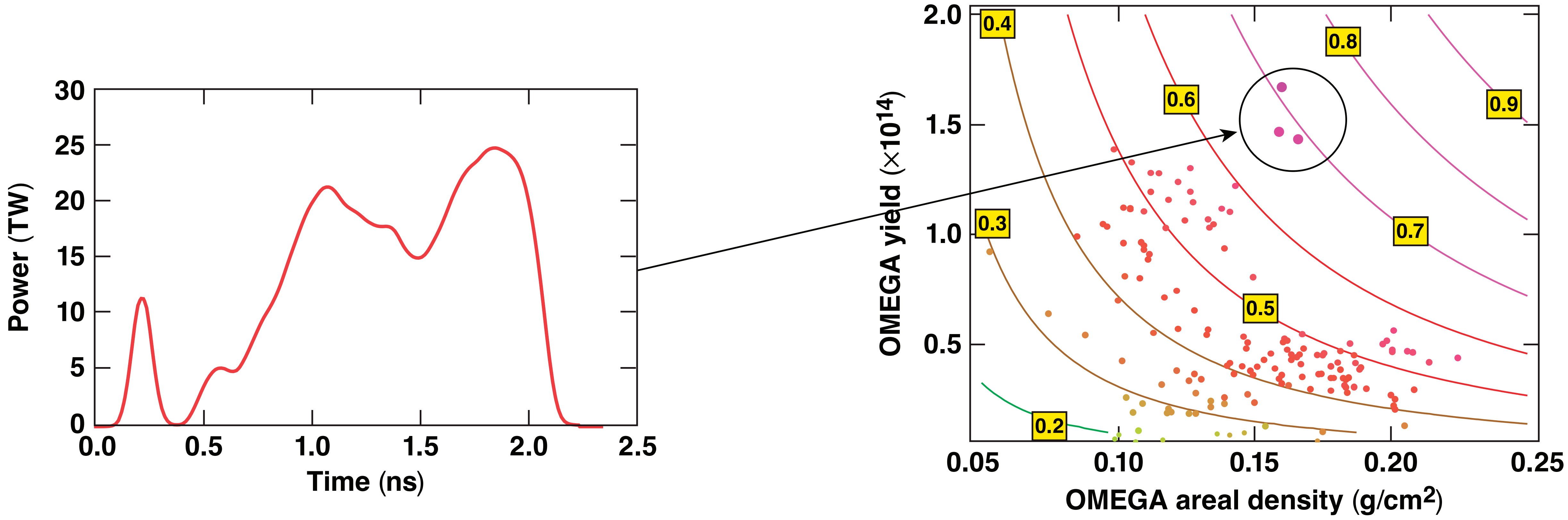
A Novel Double-Spike Pulse Shape for OMEGA Cryogenic Implosions



Double-spike pulse

Curves of constant $\chi_{no\ \alpha}$ at 1.9 MJ of symmetric drive

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Summary

Implosions with a "double-spike" pulse shape achieved the highest performance in OMEGA cryogenic implosions

- The new double-spike pulse led to yield = 1.56×10^{14} and ρR = 160 mg/cm^2, with $\chi_{\text{no }\alpha}$ = 0.74, when hydrodynamically scaled to laser energy of 1.9 MJ
- Comparison to other implosions with similar target dimensions, but with a flattop pulse, suggests that these implosions are more robust to instability growth
- Dedicated experiments need to be performed to clarify the role of "double-spike" pulse shapes in improved performance, and whether performance could be replicated with a flattop pulse
- Double-spike pulse shapes open up a path to implosions of targets with a high initial aspect ratio, which is otherwise inaccessible because of the IFAR stability cliff

IFAR: in-flight aspect ratio

TC14603

Collaborators

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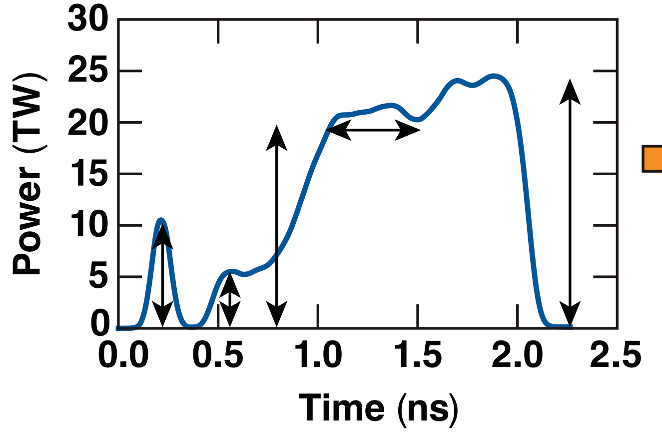
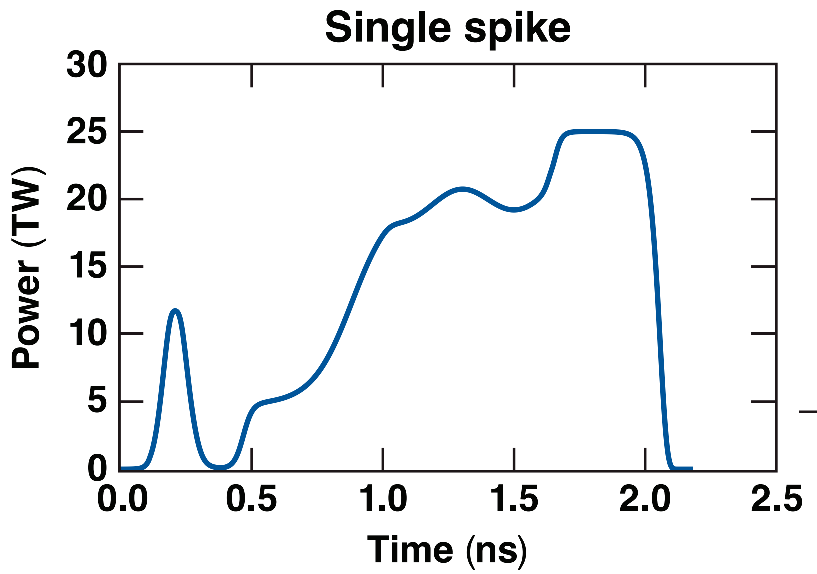
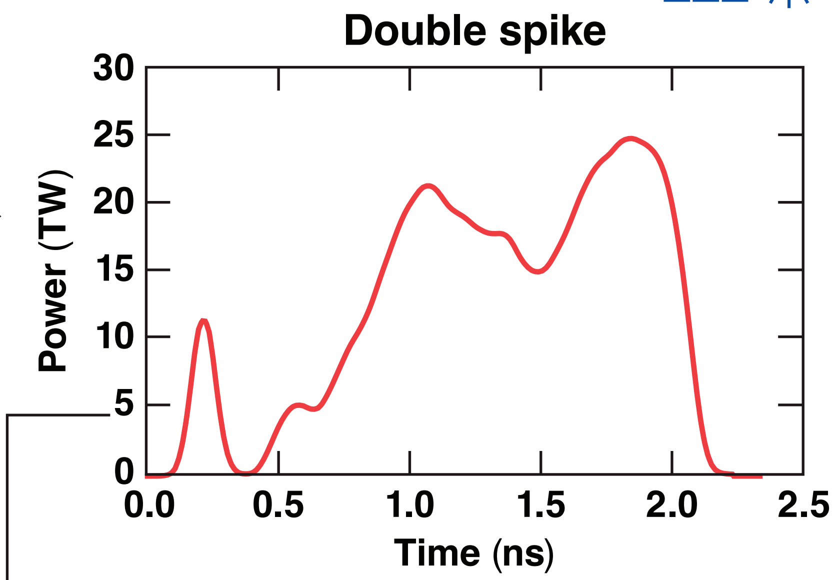
A single-spike pulse, optimized using statistical mapping,* was modified to give a double-spike pulse shape



Shot 89224
Yield = 1.15×10^{14}
ρR = 143 mg/cm^2





LILAC

Statistical mapping

Predicted yield = 1.15×10^{14}
Predicted ρR = 155 mg/cm^2

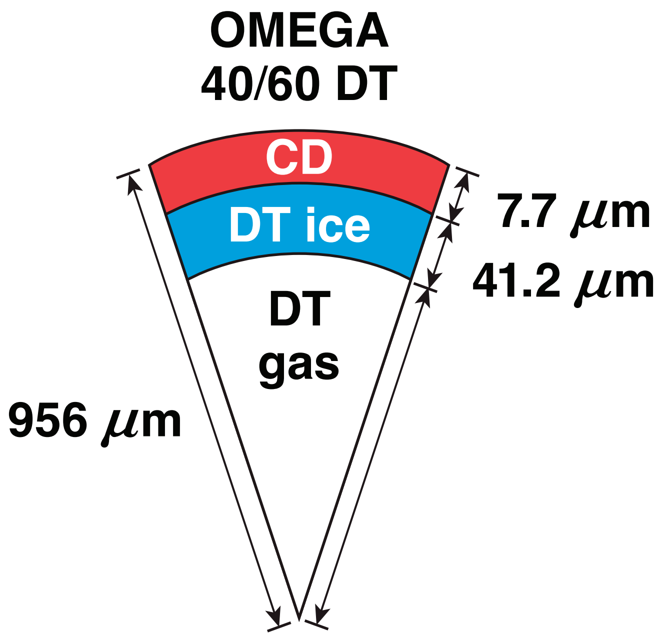
Predicted yield = 1.11×10^{14}
Predicted ρR = 170 mg/cm^2

This pulse predicted higher areal densities than the optimized single-spike pulse; therefore, it was chosen for the next OMEGA optimization campaign shot day.

TC14604

* V. Gopalaswamy, TI3.00002, this conference (invited).

Double-spike implosions achieved the highest performance to date on OMEGA



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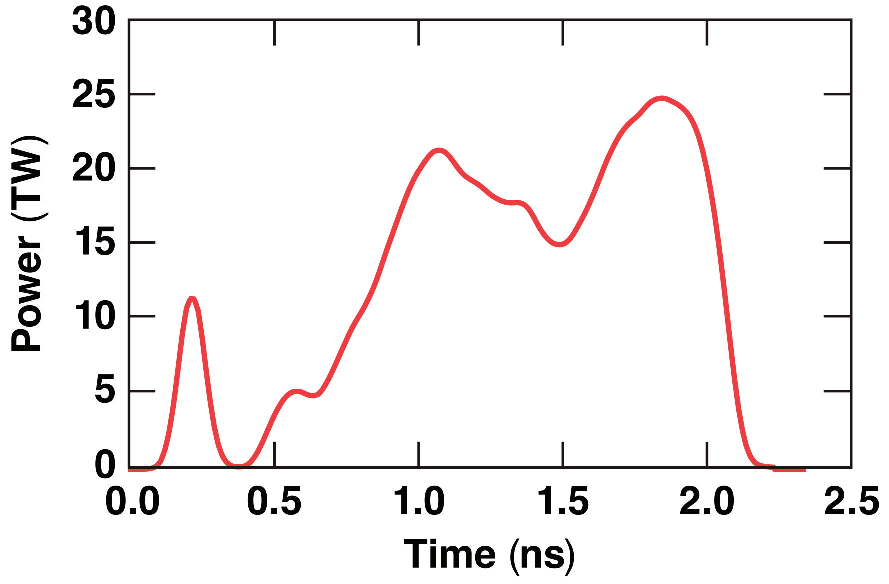

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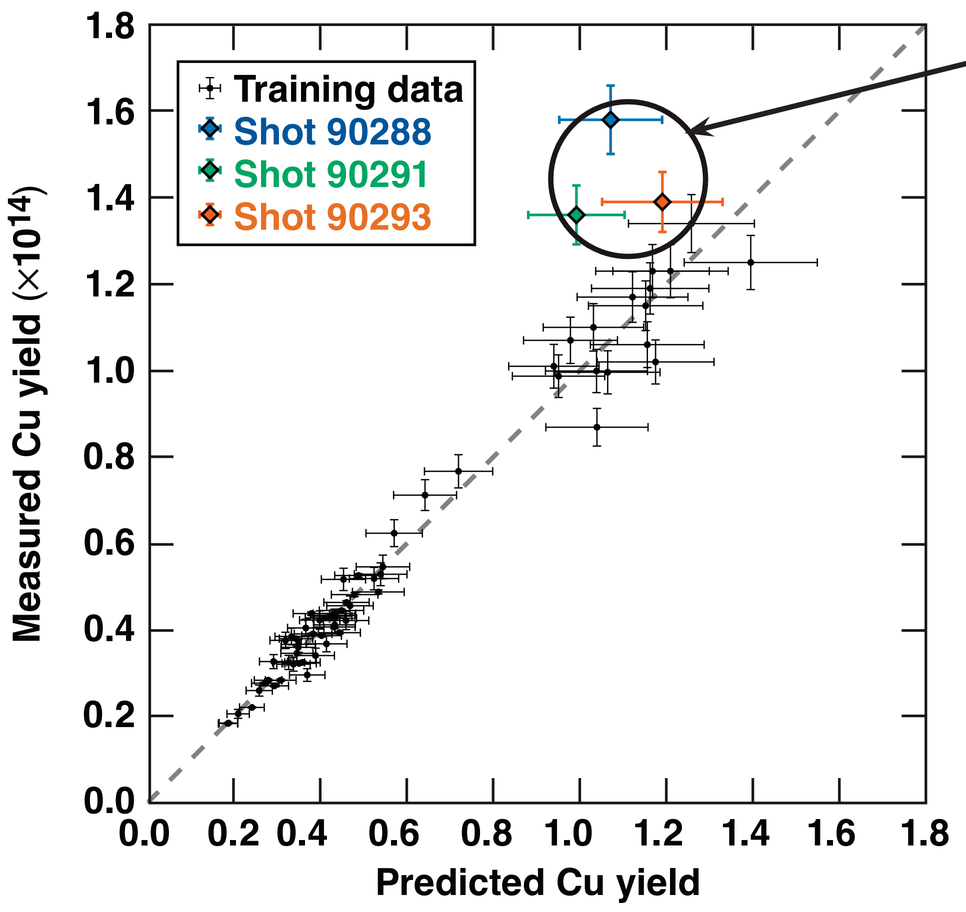
Yield	1.56×10^{14}
ρR	160 mg/cm^2
$\langle T_i \rangle_{n,\,min}$	4.55 keV
$\langle P \rangle_n$	52 Gbar
$\chi_{no\,\alpha}$ (1.9 MJ)	0.74

OMEGA cryo shot 90288

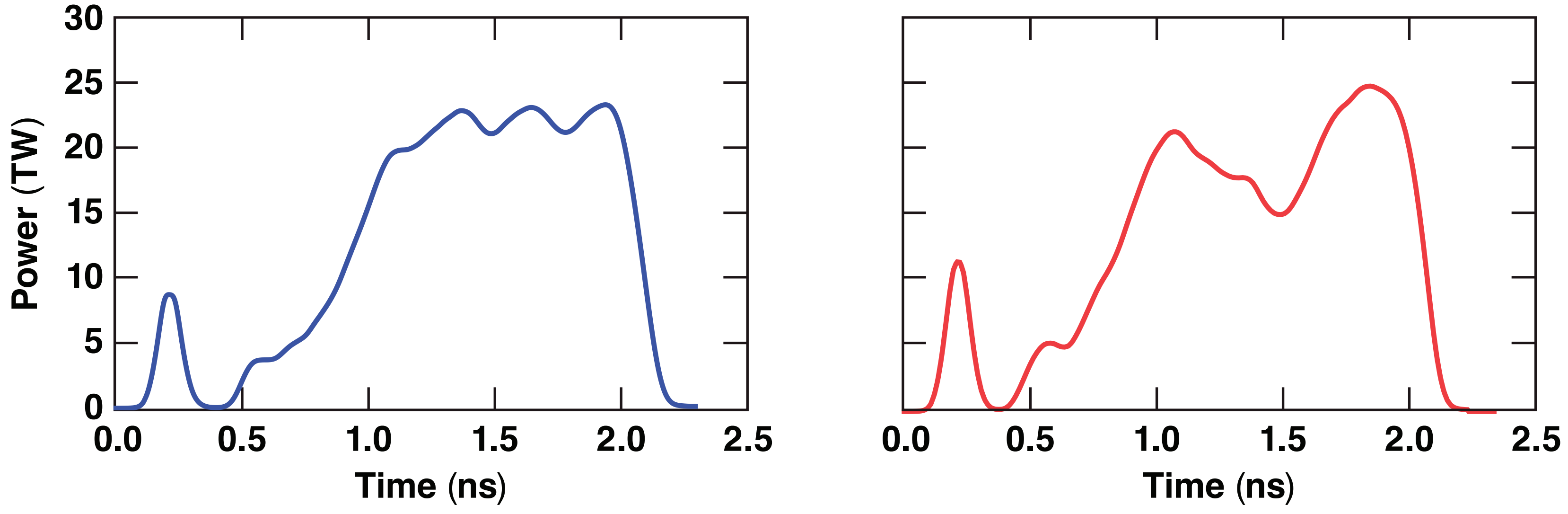
TC14605

The yields for double-spike cryogenic implosions were significantly underpredicted by statistical formulas based on previous experiments



Implosions with a double-spike pulse shape

This statistical mapping relies on a database largely consisting of flattop pulse implosions, and has proven to be a reliable prediction tool for flattop pulses.

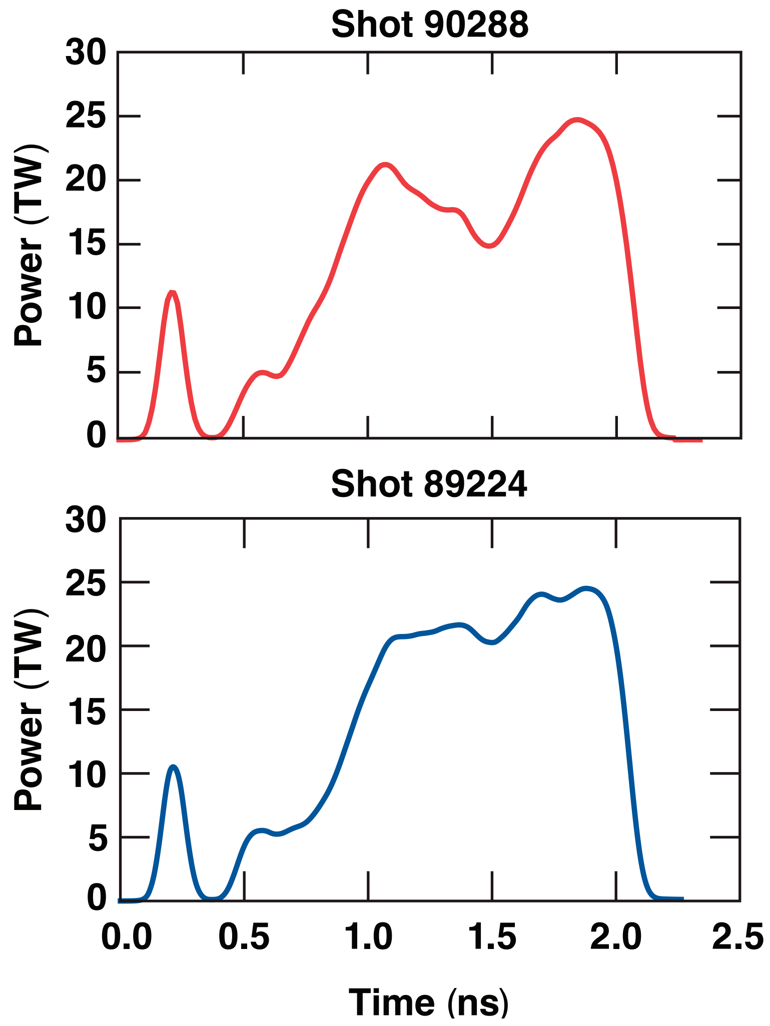


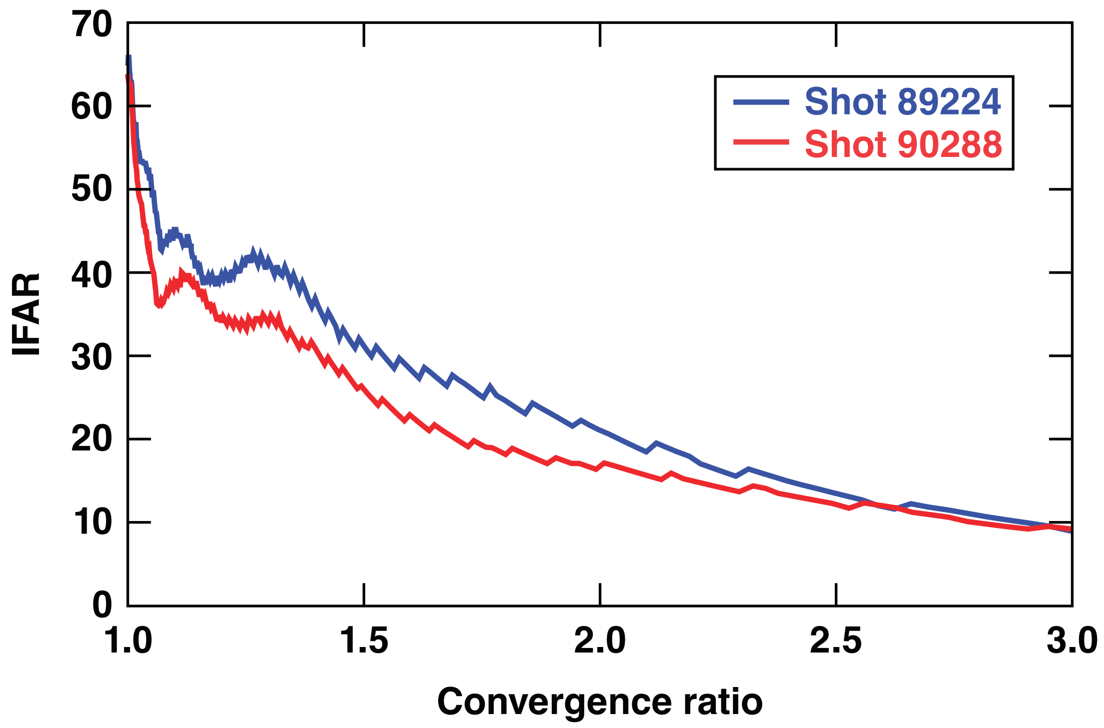
An unexpected outcome of the new pulse shape was significantly higher yields than predictions.

TC14606

V. Gopalaswamy, TI3.00002, this conference (invited).

Double-spike implosions have a lower IFAR compared to flattop pulse implosions with a similar target



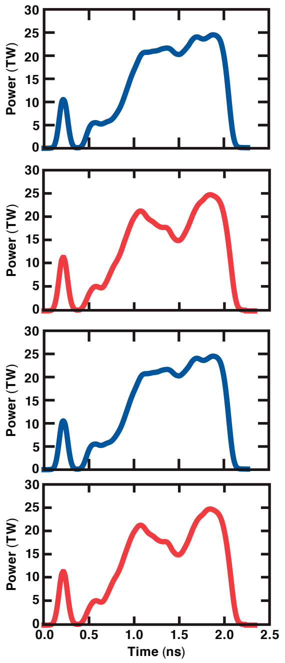


The reduction in IFAR is caused by a rapid decrease in intensity during the early phase of the main drive, resulting in decompression of the target.

TC14607

Double-spike implosions were more robust because of low IFAR's without sacrificing 1-D (*LILAC*) performance

	Shot	Max V_{imp} (km/s)	IFAR at 2/3	Adiabat at 2/3	*LILAC* yield	*LILAC* ρR (g/cm^2)	*LILAC* $\langle P \rangle_n$ (Gbar)
980 μm	87266	526	44	4.3	5.44×10^{14}	132	75
	90291	456	24	4.5	3.98×10^{14}	189	90
960 μm	89224	476	34	4.6	4.00×10^{14}	164	83
	90288	467	25	5.0	3.87×10^{14}	178	91



TC14608

Double-spike implosions have significantly better experimental performance compared to flat-pulse implosions with similar targets

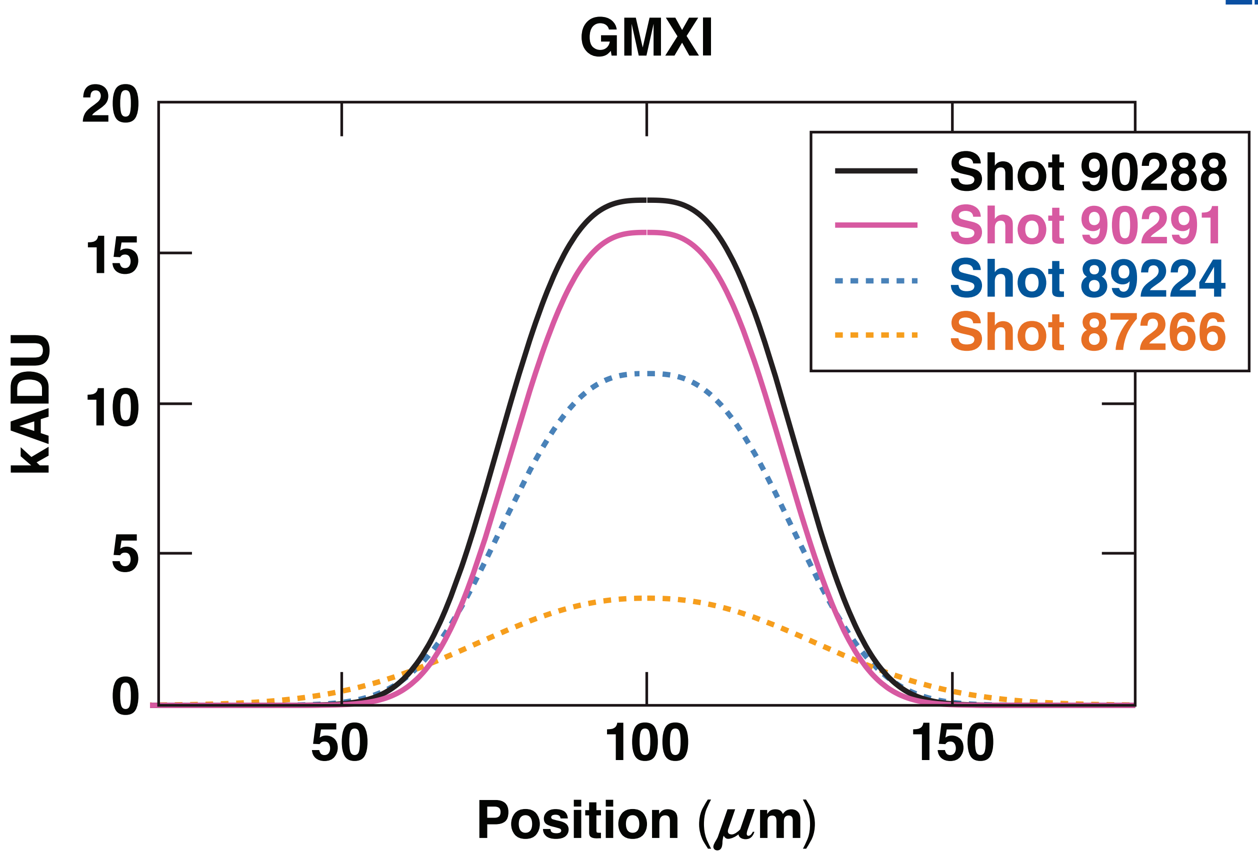
Shot	89224	90288	87266	90291
Yield	1.17×10^{14}	1.56×10^{14}	1.34×10^{14}	1.35×10^{14}
ρR (mg/cm^2)	143 ± 23	160 ± 22	100 ± 14	166 ± 25
Pressure (Gbar)	41	52	32	52
R_0 (μm)	30	28	36	26
$\chi_{\text{no}\ \alpha}$ (1.9 MJ)	0.61	0.74	0.58	0.71

Double-spike implosions showed higher ρR's at higher adiabats and higher yields at lower implosion velocities, suggesting higher robustness to 3-D effects.

TC14609

Double-spike implosions have higher inferred pressures compared to previous shots from the Optimization Campaign currently underway on OMEGA

Shot	Pressure (Gbar)
89224	41
90288	52
87266	32
90291	52

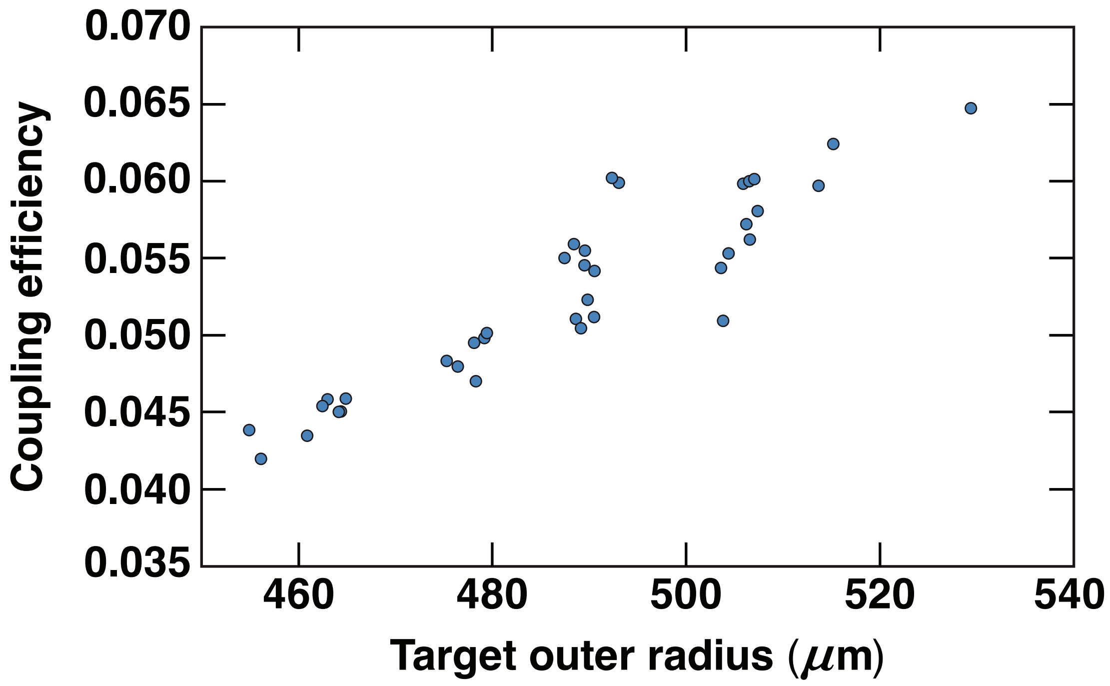


Higher brightness in time-integrated self-emission x-ray images of hot spots affirm the higher values of inferred pressures.

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

TC14621

The double-spike pulse shape opens up a path to implosions of targets with a high initial aspect ratio, which is otherwise inaccessible because of the IFAR stability cliff



Coupling efficiency versus radius for 1-D implosions

$$\text{Coupling efficiency} = \frac{\text{Shell KE at start of deceleration phase } (\textit{LILAC})}{\text{Laser energy}}$$

$v_{imp}^2 \propto P_{abl} * AR_0$ *

lower $\frac{R_{beam}}{R_{target}} \Rightarrow$ Higher absorption

Shot 88314 (1015-μm OD, 41-μm ice thickness)		
	LILAC	Experiment
Yield	8×10^{14}	1.25×10^{14}
ρR (mg/cm^2)	183	125
IFAR at 2/3	44	N/A

- The performance of such targets is limited by the growth of small-scale fluctuations from laser imprint penetrating the shell
- If this can be alleviated by lowering the IFAR with a double-spike pulse shape, a large fraction of 1-D performance could be recovered

*R. E. Kidder, Nucl. Fusion 16, 3 (1976).

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TC14603