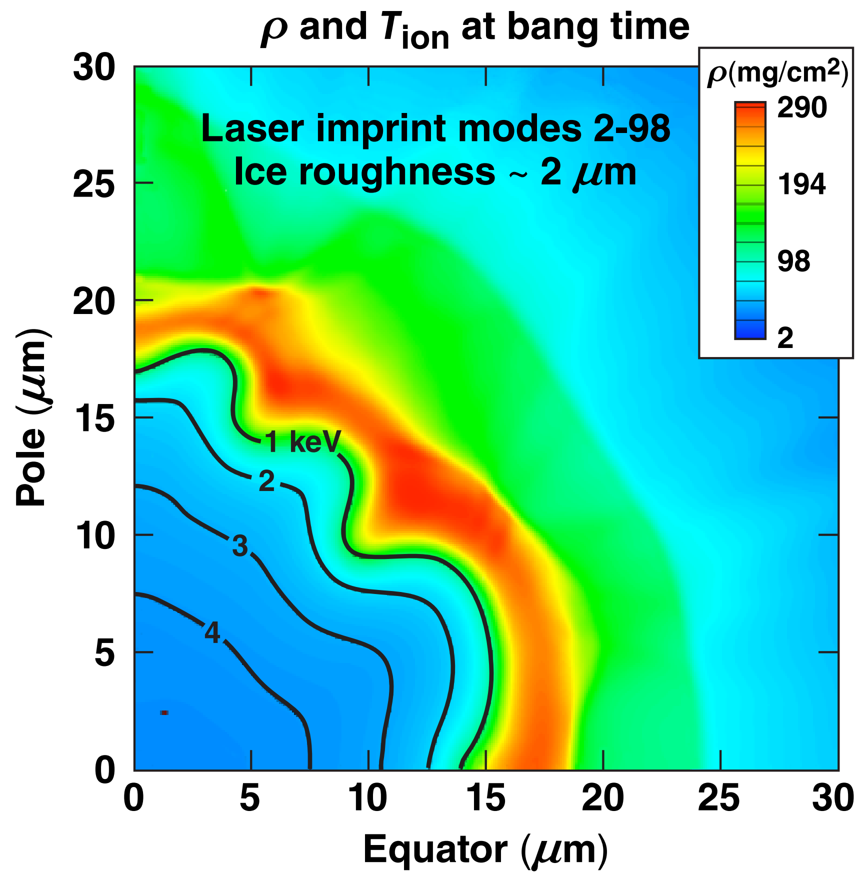
Cryogenic Shock-Ignition Target Designs for OMEGA



R. Nora
Fusion Science Center
for Extreme States of Matter
and University of Rochester
Laboratory for Laser Energetics

53rd Annual Meeting of the
American Physical Society
Division of Plasma Physics
Salt Lake City, UT
14–18 November 2011

Summary

A new triple-picket design has been optimized for cryogenic shock-ignition targets on OMEGA

- Early shock ignition (SI) targets had a neutron yield over clean (YOC) of ~12%
- A new triple-picket design will facilitate experimental shock tuning
- 1-D *LILAC* predicts yields of 5×10^{13} and a peak ρR of 450 mg/cm^2
- 2-D *DRACO* shows good stability to laser imprinting and ice roughness
- New cryogenic implosion experiments will begin early next year

Collaborators

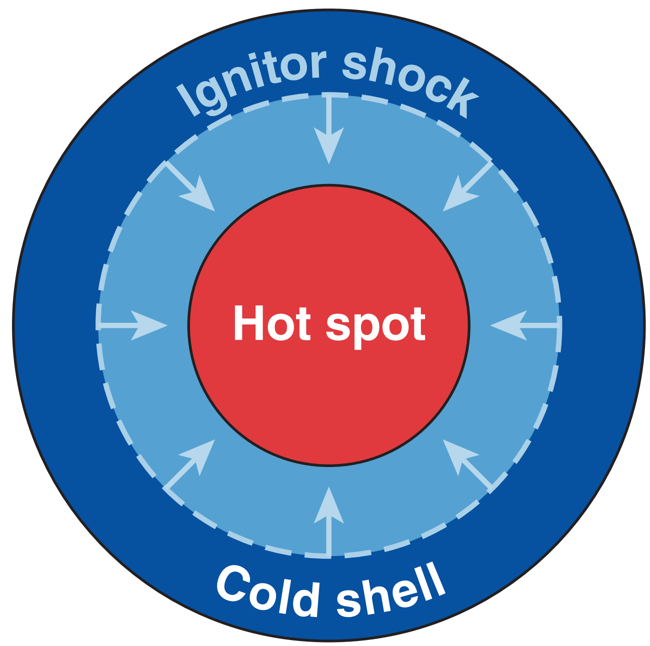
R. Betti, K. S. Anderson, and W. Theobald
Laboratory for Laser Energetics
and Fusion Science Center
University of Rochester

A. Casner
Commissariat à l'Énergie Atomique
et aux Énergies Alternatives (CEA)

M. Lafon, X. Ribeyre, and G. Schurtz
Centre Laser Intenses et Applications,
University of Bordeaux, France

Shock ignition decouples the compression and ignition stages to achieve ignition*

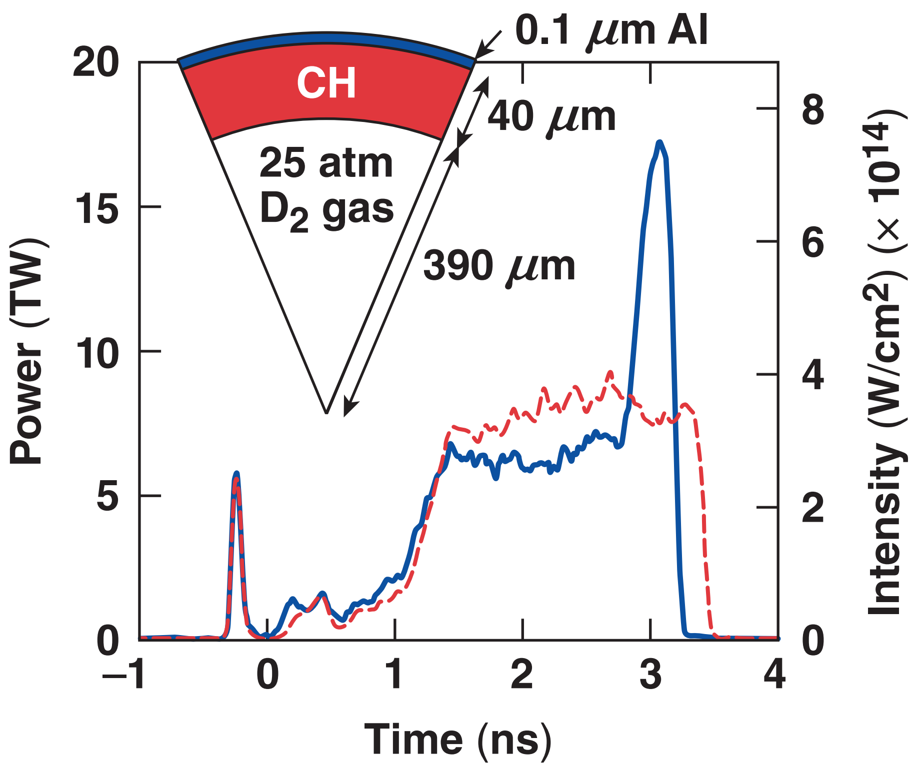
- SI uses thick, slow massive targets which exhibit small in-flight aspect ratios (IFAR's)
- Targets have a reduced susceptibility to Rayleigh–Taylor (RT) instabilities
- The ignitor shock couples additional kinetic energy into the hot spot to achieve ignition
- Performance metrics: areal density and YOC



*R. Betti *et al*., Phys. Rev. Lett. 98, 155001 (2007).

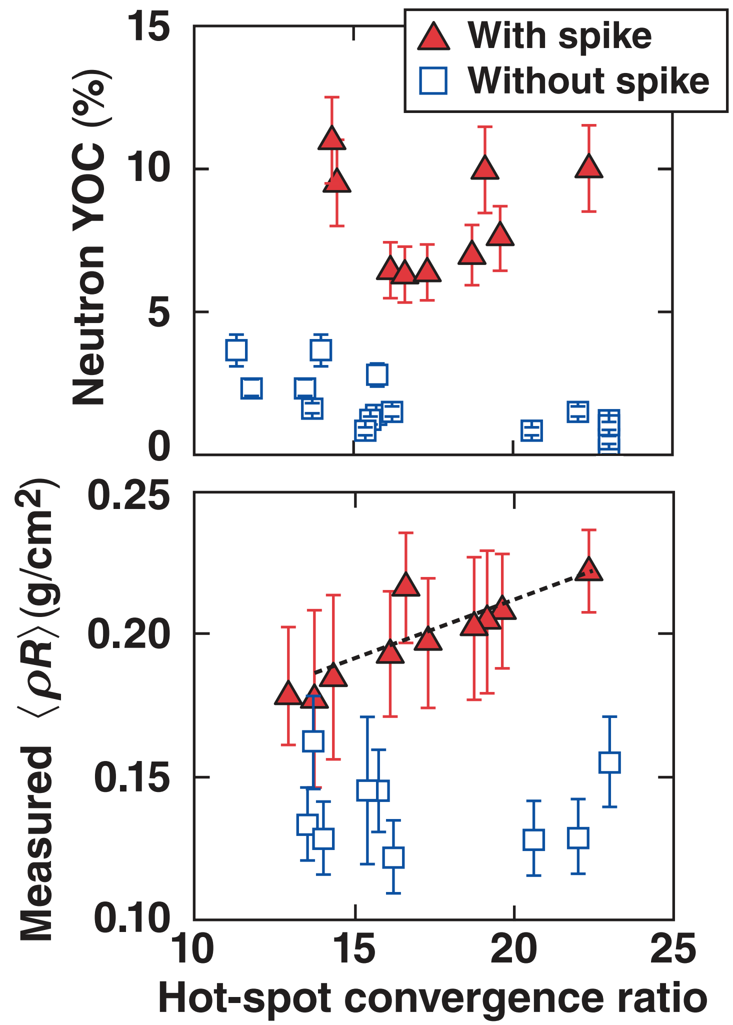
Warm targets have been imploded on OMEGA to test the performance of SI pulse shapes*

E_L = 19 kJ, α = 1.3,
$V_i = 1.7 \times 10^7$ cm/s, SSD off



$Y_n = 2 \pm 0.2 \times 10^9$

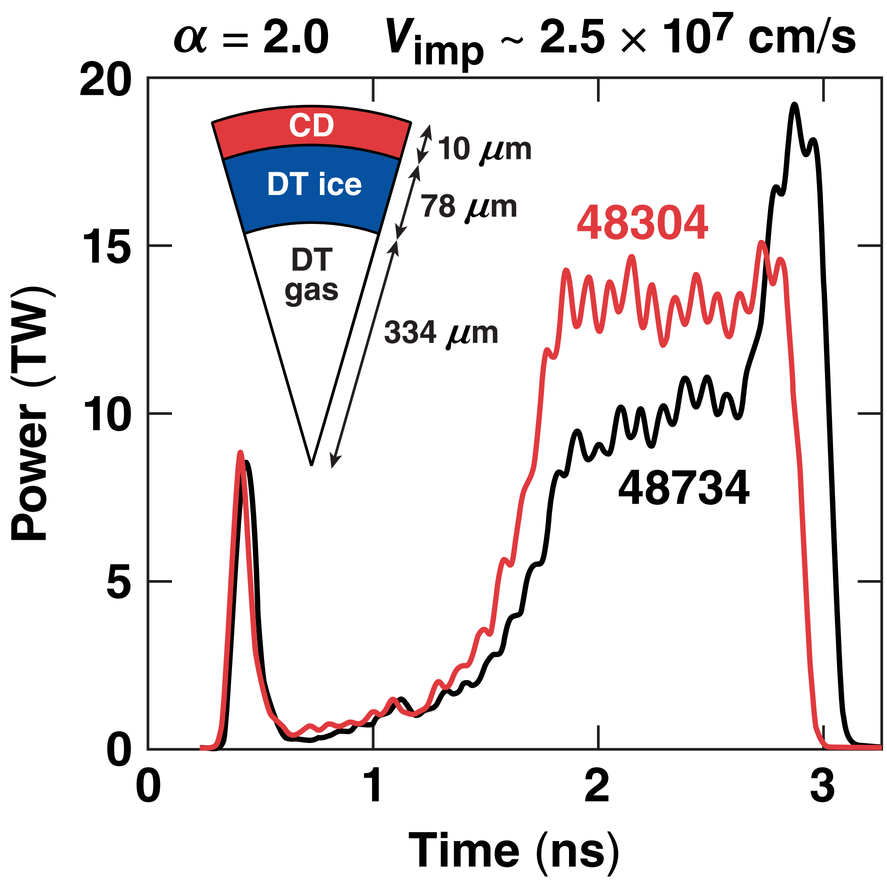
$Y_n = 8 \pm 0.8 \times 10^9$



TC9875

*W. Theobald *et al.*, Phys. Plasmas 15, 056306 (2008).

There is no database for cryogenic SI experiments



Shot number	48304	48734
E_{laser} (kJ)	19.3	17.9
Y_n	1.60×10^{12}	1.43×10^{12}
YOC (flux)	9.8%	12.3%
$\langle \rho R \rangle_{exp}$ (g/cm^2)	—	0.205
T_{ion} (keV) (exp)	2.5	1.9
Ice layer (μm)	0.7	0.9
Target offset (μm)	—	10±5

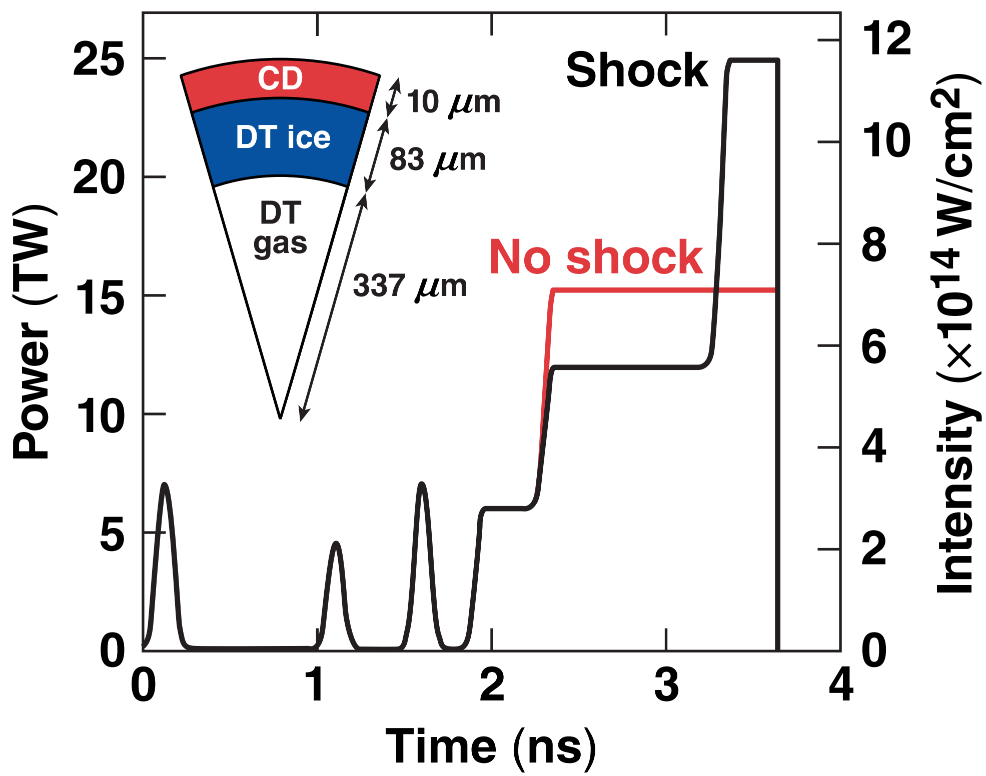
W. Theobald *et al*., Phys. Plasmas 15, 056306 (2008).

A new triple-picket configuration will provide a better performing and experimentally tunable design*

Switching from a single- to a triple-picket configuration will

- increase the maximum UV laser energy on target
- reduce hydrodynamic instabilities
- allow the adiabat to be experimentally tunable

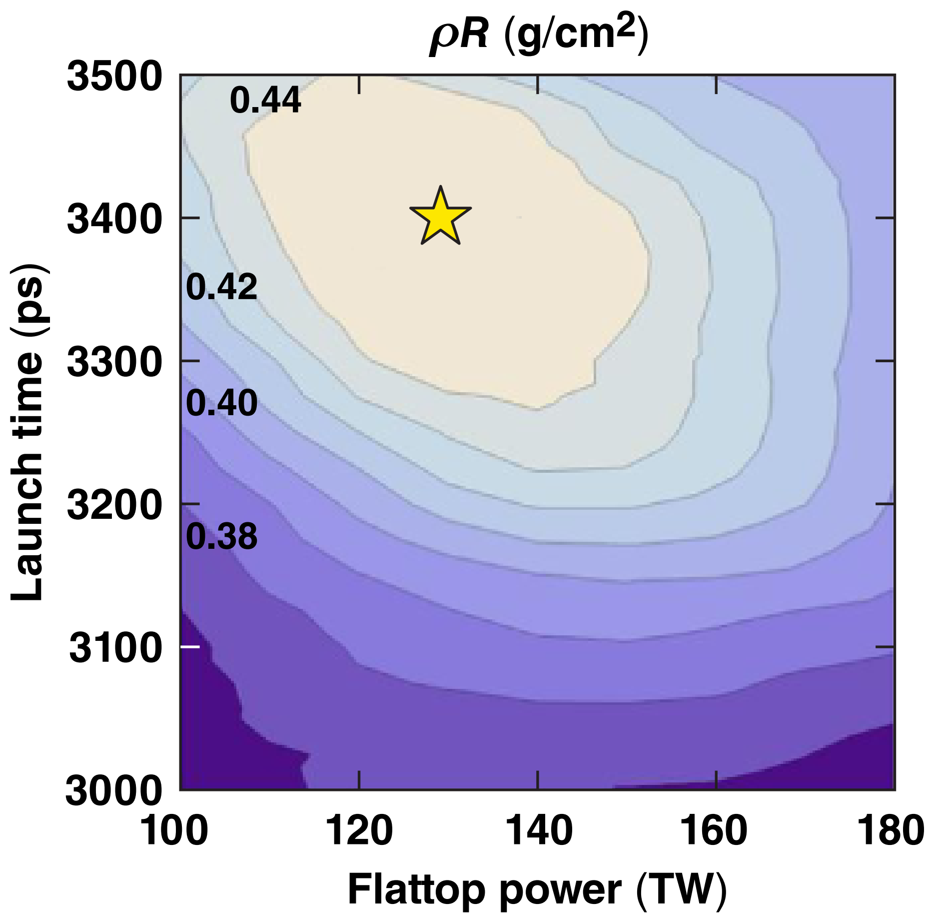
This design still has a lower than optimal ignitor shock strength

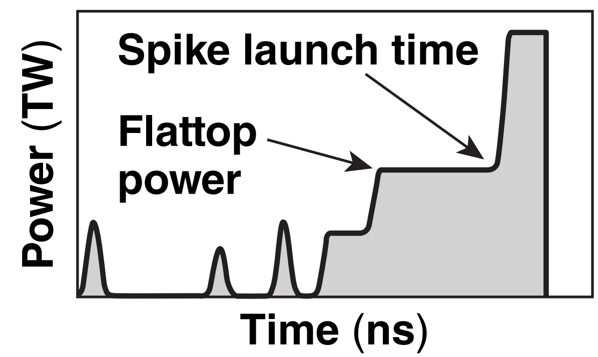


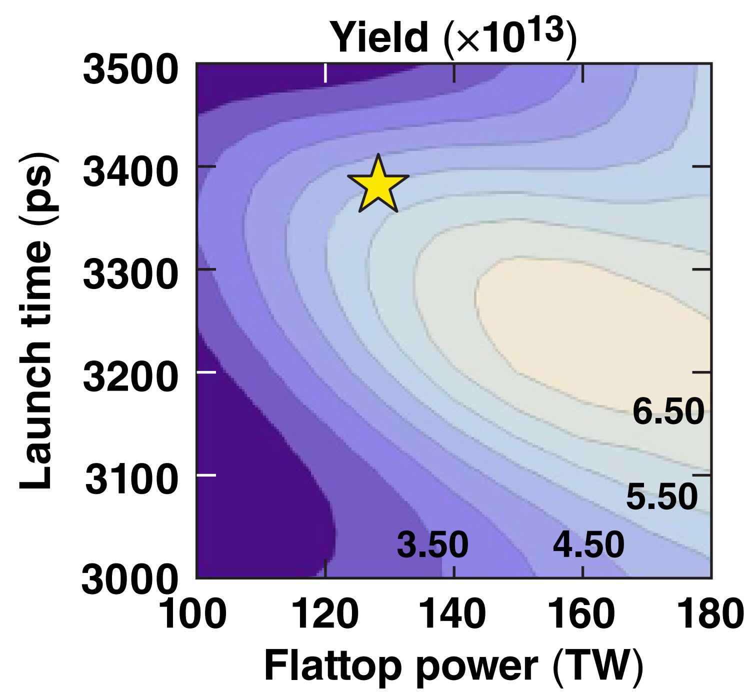
TC9820

*V. N. Goncharov *et al*., Phys. Rev. Lett. 104, 165001 (2010).

The triple-picket design is optimized for the OMEGA constraints of 25 kJ and 25 TW







- Design chosen to maximize the areal density

$$\text{ITFX} \sim \chi_{\text{Lawson}}^{2.2} \sim \rho R^2 \, Y_n$$

TC9821

DRACO simulations of the proposed SI design (25 kJ) shows moderately improved performance

<u>Target parameters</u>

$IFAR_{2/3}$: 13

V_{imp}: 2.7 × 10^7 cm/s

α_{min}: 1.7

<u>No shock</u>

1-D yield: 3.6 × 10^{13}

YOC: 52%

ρR: 0.40 g/cm^2

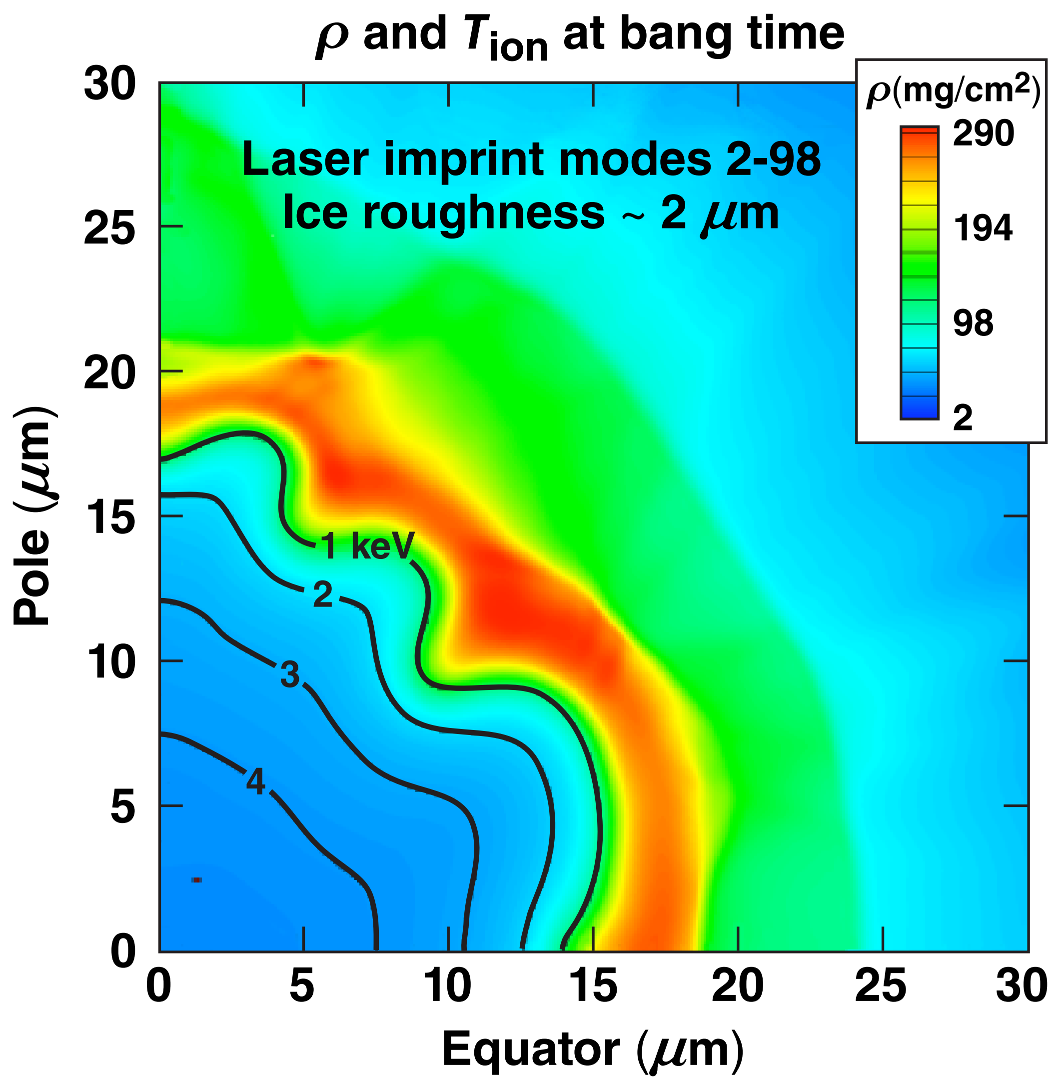
<u>Shock</u>

1-D yield: 5.0 × 10^{13}

YOC: 61%

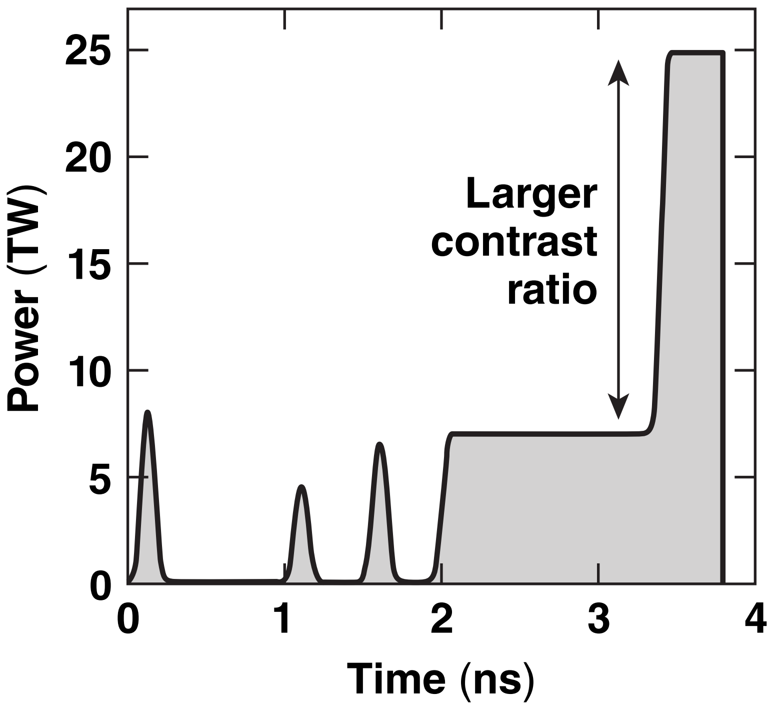
ρR: 0.45 g/cm^2

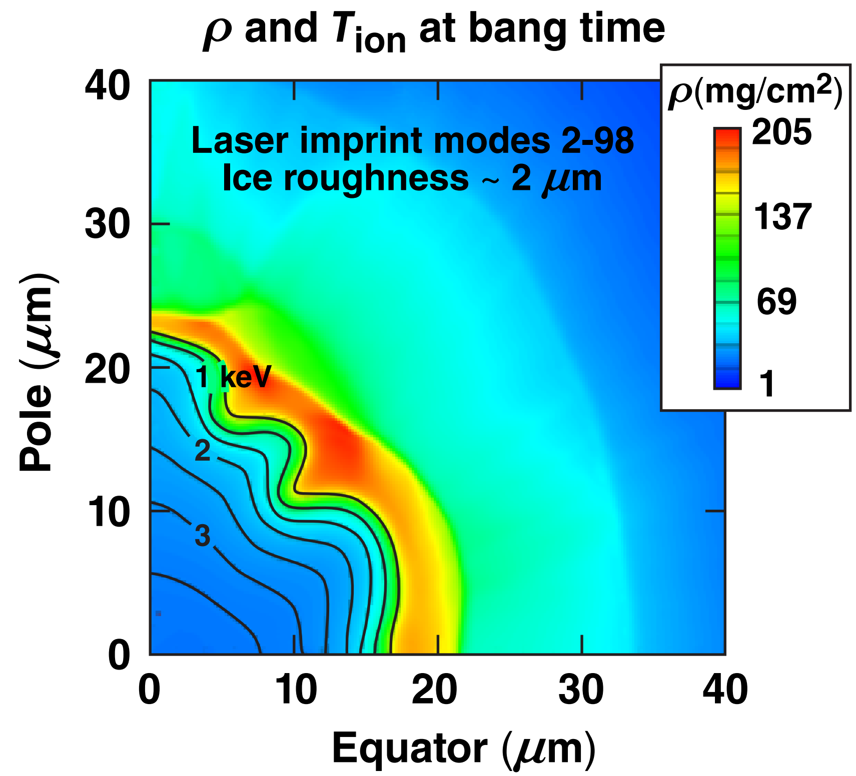
- Simulations do not include beam power imbalance or target offset



TC9822

A second design (21 kJ) with a stronger shock but weaker drive is also under consideration





- Nonpropagating test shot of the previous design predicts a weak ignitor shock
- Reduced but extended drive improves shock strength at the expense of the assembly pulse

LILAC yield: 1.71×10^{13}
YOC: 74%
IFAR: 8
V_{imp}: 2.3×10^{7} cm/s
ρR: 0.34 g/cm^2
α_{min}: 2.0

TC9823

Summary/Conclusions

A new triple-picket design has been optimized for cryogenic shock-ignition targets on OMEGA

- Early shock ignition (SI) targets had a neutron yield over clean (YOC) of ~12%
- A new triple-picket design will facilitate experimental shock tuning
- 1-D *LILAC* predicts yields of 5×10^{13} and a peak ρR of 450 mg/cm^2
- 2-D *DRACO* shows good stability to laser imprinting and ice roughness
- New cryogenic implosion experiments will begin early next year