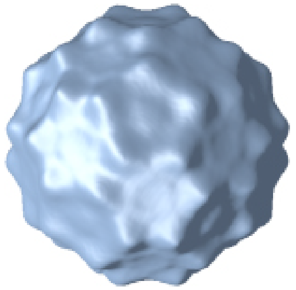
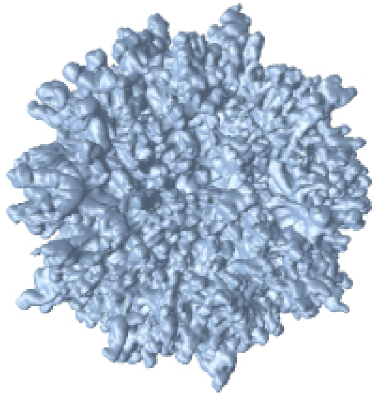
Three-Dimensional Hydrodynamic Simulations of the Effects of Laser Imprint in OMEGA Implosions

Fuel–ablator interface in room-temperature shot 84629 at neutron peak

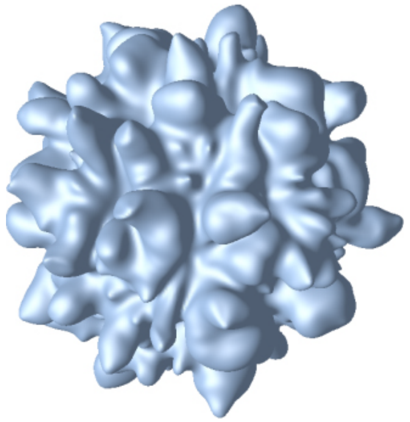


No imprint



Imprint (SSD on)

Hot-spot shape (surface T_{i} = 1 keV) in cryogenic shot 77066 at neutron peak



Imprint (SSD on)

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Division of Plasma Physics
Milwaukee, WI
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Summary

Simulations indicate that the effects of laser imprint alone are insufficient to explain the underperformance of cryogenic $\alpha \sim 4$ implosions on OMEGA

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- The imprint model was developed and implemented in the 3-D hydrodynamics code *ASTER**
- Simulations reproduce observed improvement in implosion performance when polarization smoothing** (PS) and smoothing by spectral dispersion† in two dimensions (2-D SSD) are applied
- Room-temperature targets suffer from imprint that introduces significant small-scale ($\ell \sim 50$ to 150) modulations
- Imprint in cryogenic implosions develops broadband modulations with dominant $\ell \sim 30$; these modulations have a moderate effect on the implosions

*I. V. Igumenshchev *et al.*, Phys. Plasmas 23, 052702 (2016).
**T. R. Boehly *et al.*, J. Appl. Phys. 85, 3444 (1999).
†S. Skupsky *et al.*, J. Appl. Phys. 66, 3456 (1989).

TC13766

Collaborators

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ASTER models imprint in OMEGA implosions by calculating far-field intensity modulations

- **Evolution of the electric near field**

$$E(x,y,t) = E_0(x,y)e^{i[\psi_{DPP}(x,y)+\psi_{SSD}(x,y,t)]}$$

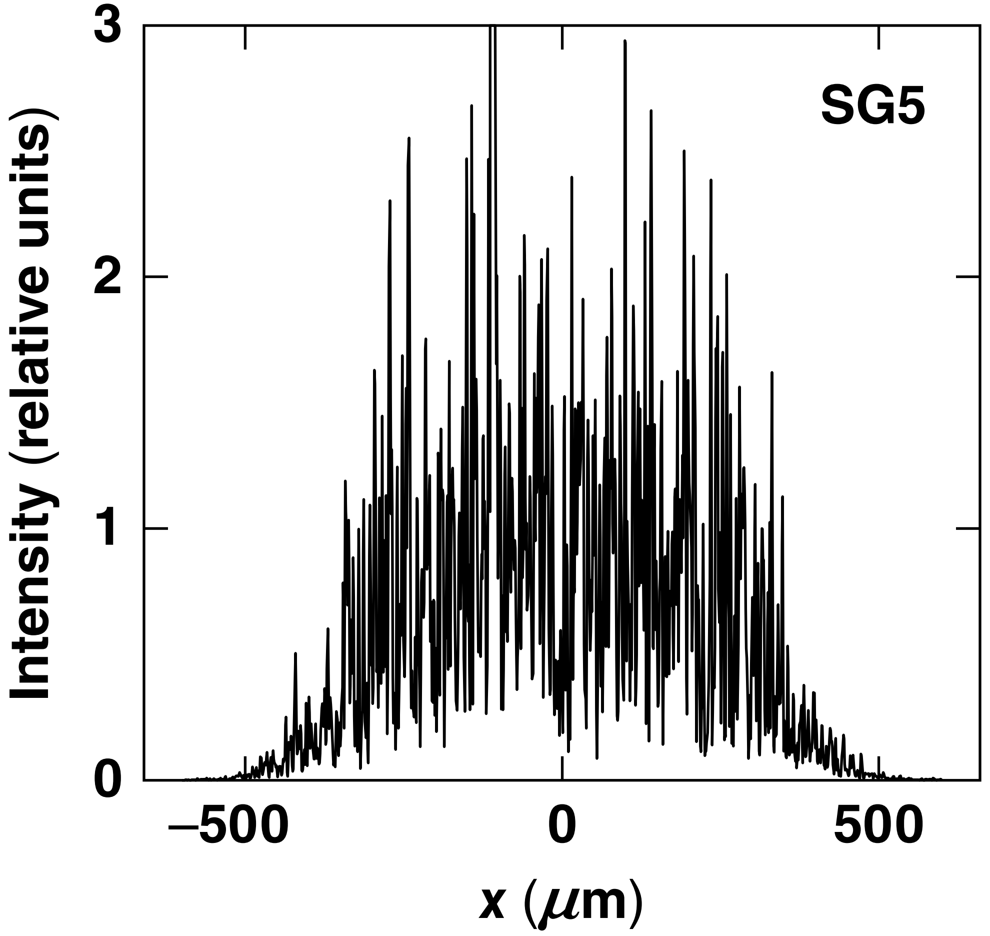
$$\psi_{SSD}(x,y,t) = \delta_x \sin(k_x x - 2\pi f_x t) + \delta_y \sin(k_y y - 2\pi f_y t)$$

- **Evolution of the far-field (focal-spot) intensity**

$$I_{ff}(x_{ff}, y_{ff}, t) \propto \left| \iint_{(x,y)} E(x,y,t) \cdot \exp\left[-i\frac{2\pi}{\lambda F}(x_{ff}\cdot x + y_{ff}\cdot y)\right] dxdy \right|^2$$

- **Polarization smoothing: overlapping two copies of the intensity pattern separated by $\Delta y = 86.4\ \mu m$**

Example beam-intensity profile



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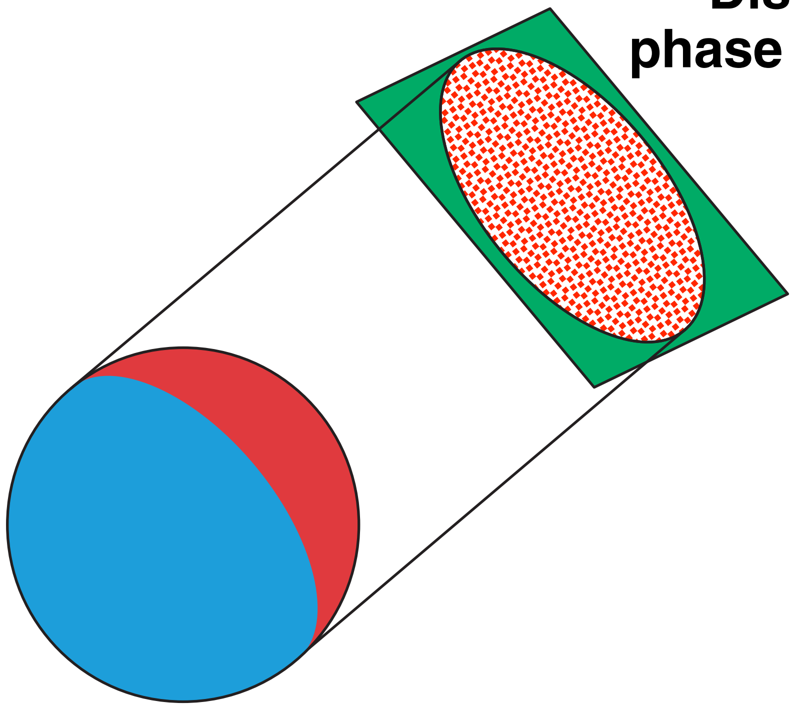
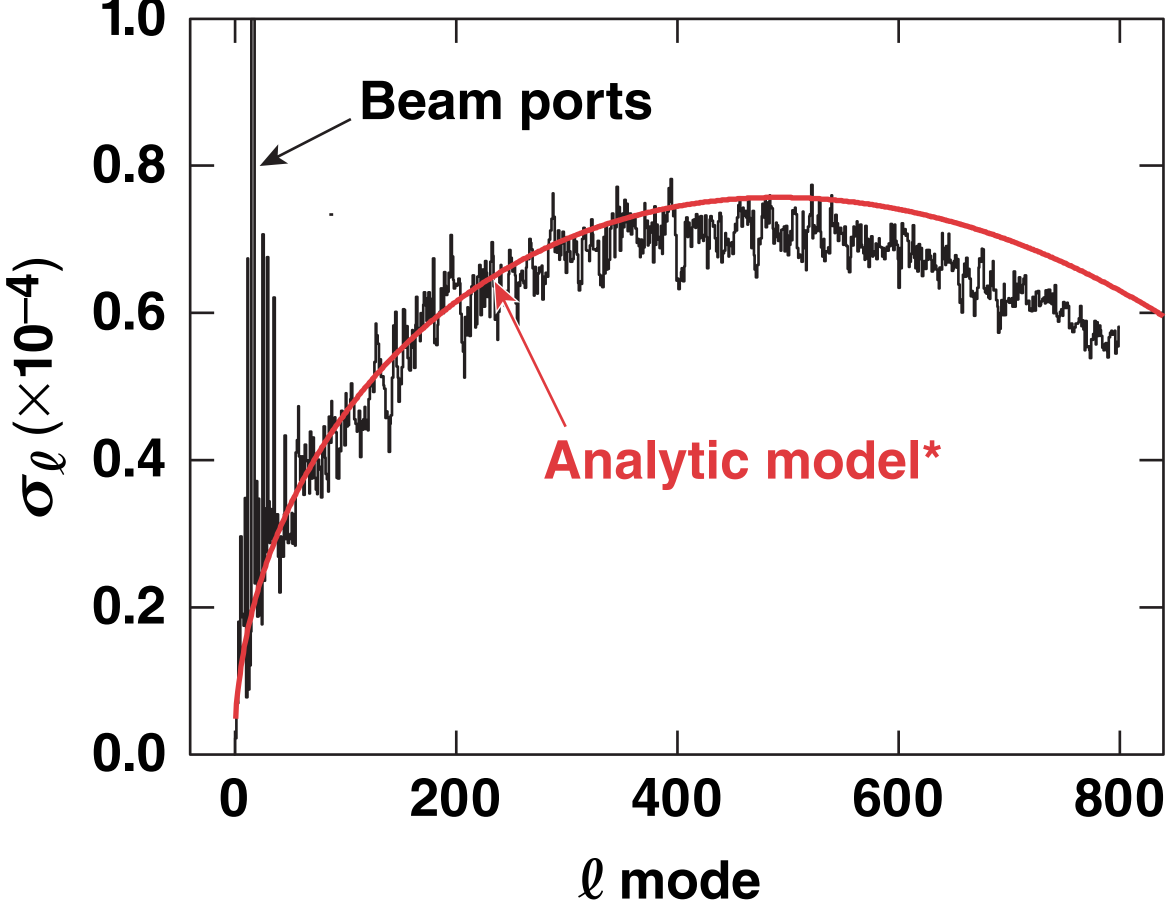
ASTER models imprint in OMEGA implosions by calculating far-field intensity modulations (continued)

Calculated imprint patterns for all 60 OMEGA beams are projected onto a target



Spectrum of on-target laser-intensity modulations

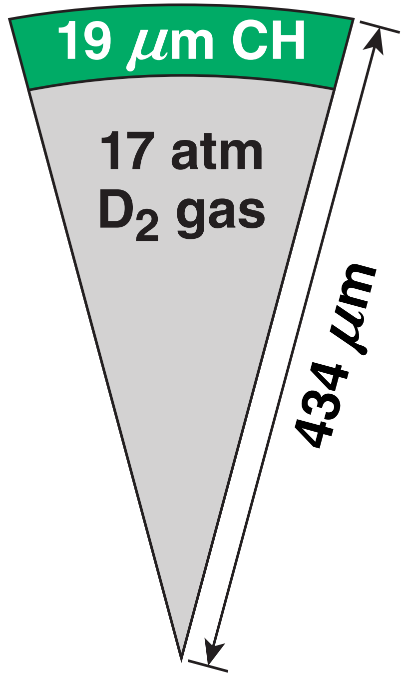


*R. Epstein, J. Appl. Phys. 82, 2123 (1997).

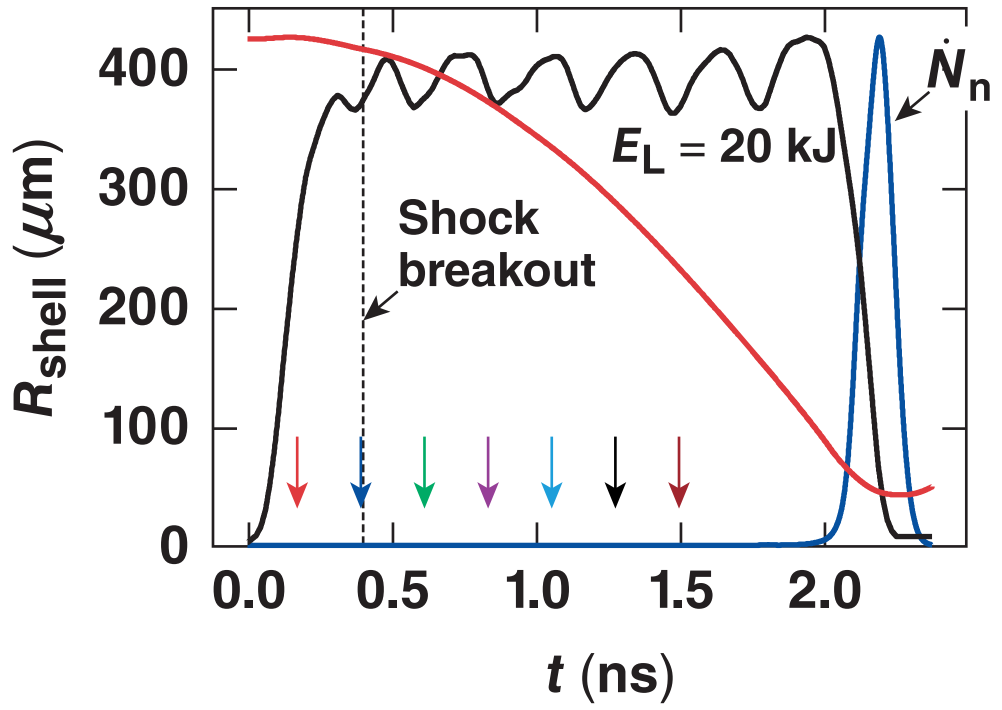
TC13768

Three-dimensional *ASTER* simulations of shot 84629 include imprint and beam overlapping effects

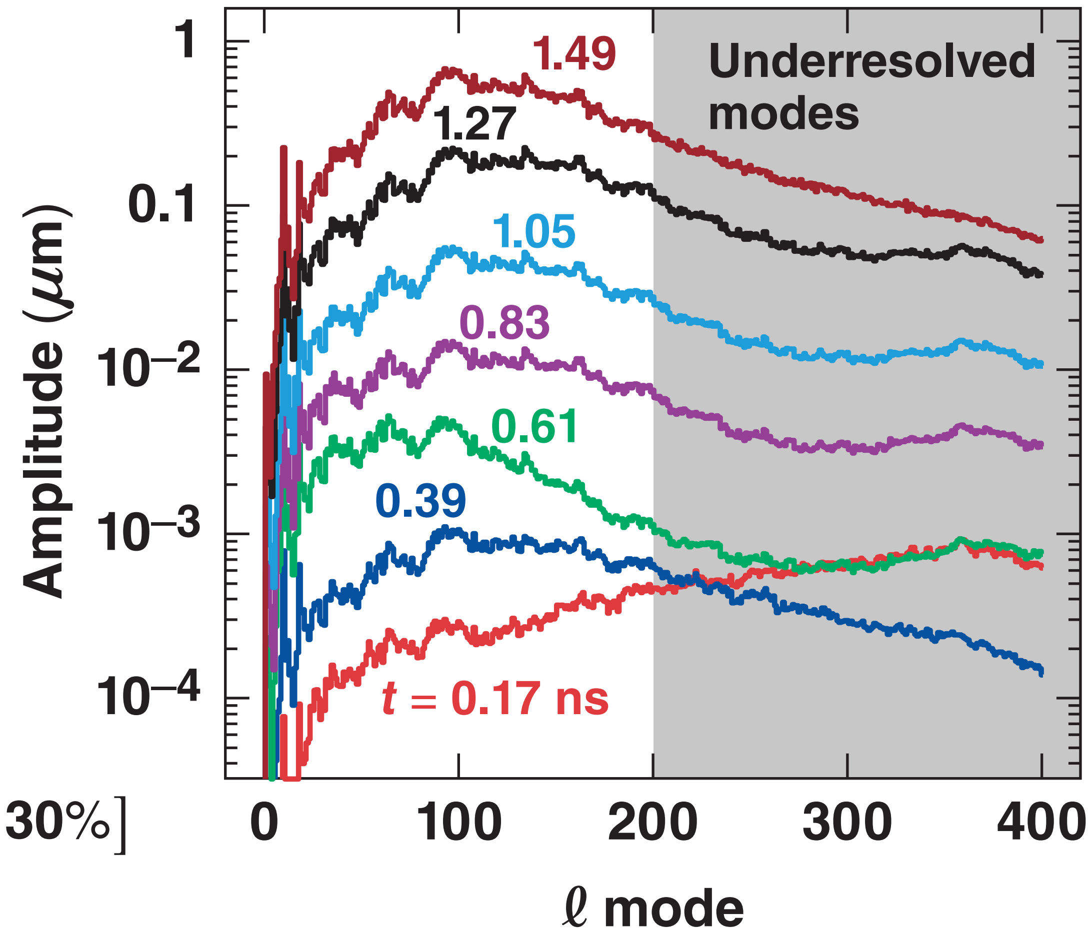
Target of shot 84629



Laser pulse and simulated shell trajectory



Evolution of ρR modulation spectrum (up to end of linear RT* growth, SSD on)



neutron $\text{yield}_{\text{exp}} = (1.05 \pm 0.03) \times 10^{11}$ [yield over clean (YOC) = 30%]

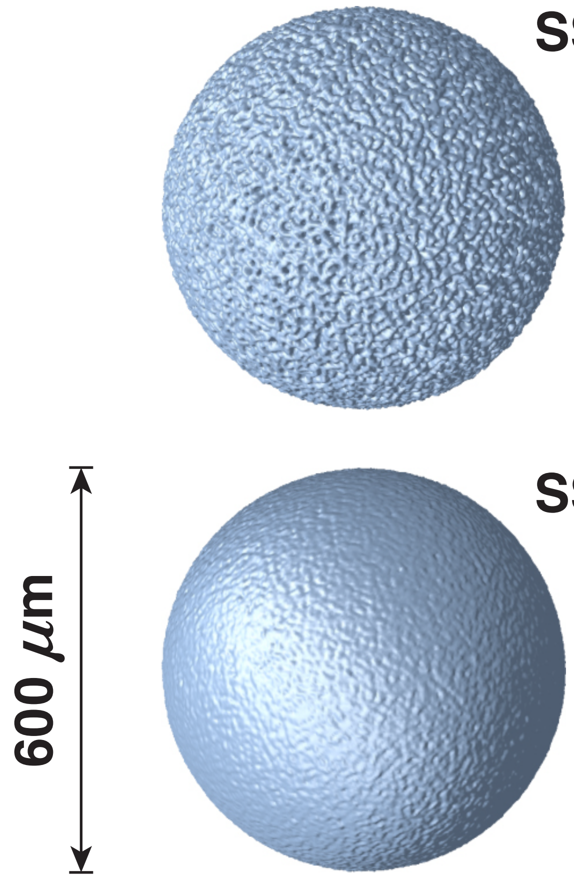
neutron $\text{yield}_{\text{3-D}} = 1.63 \times 10^{11} / 0.30 \times 10^{11}$ (SSD on/off)

*RT: Rayleigh–Taylor

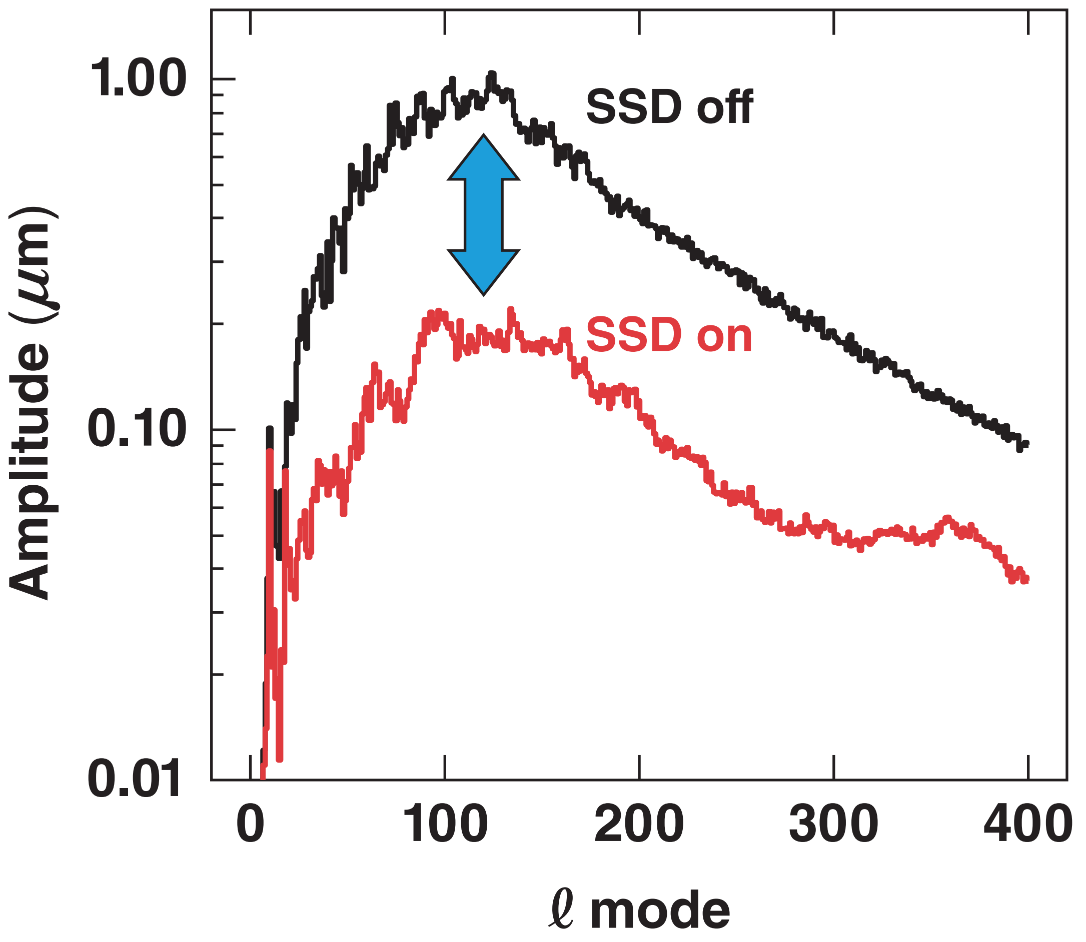
TC13769

OMEGA 2-D SSD reduces imprint perturbations by a factor of ~5

Density modulations at the ablation surface (ρ = 0.4 g/cm^3)



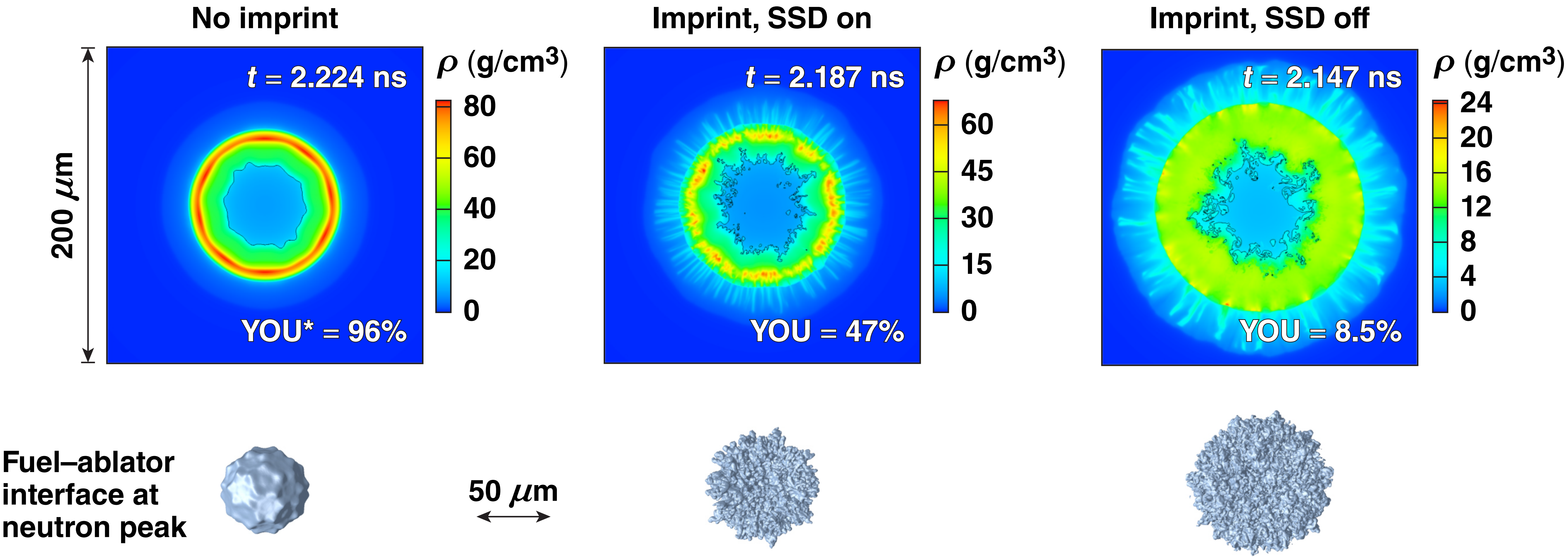
ρR modulation spectra (t = 1.268 ns)



TC13770

Imprint introduces fuel–ablator material mix and increases the effective implosion adiabat by thickening the dense shell

Density map at neutron peak

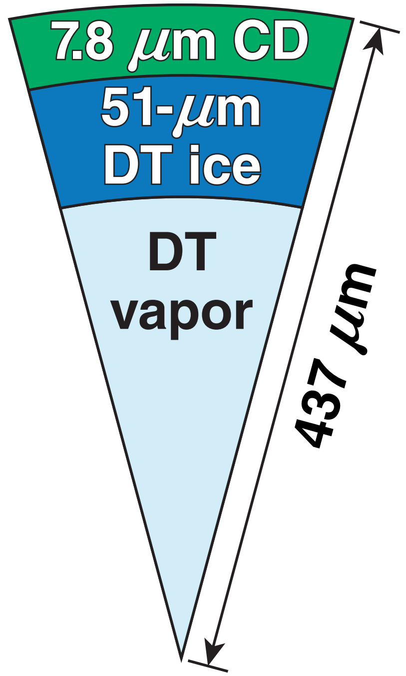


TC13771

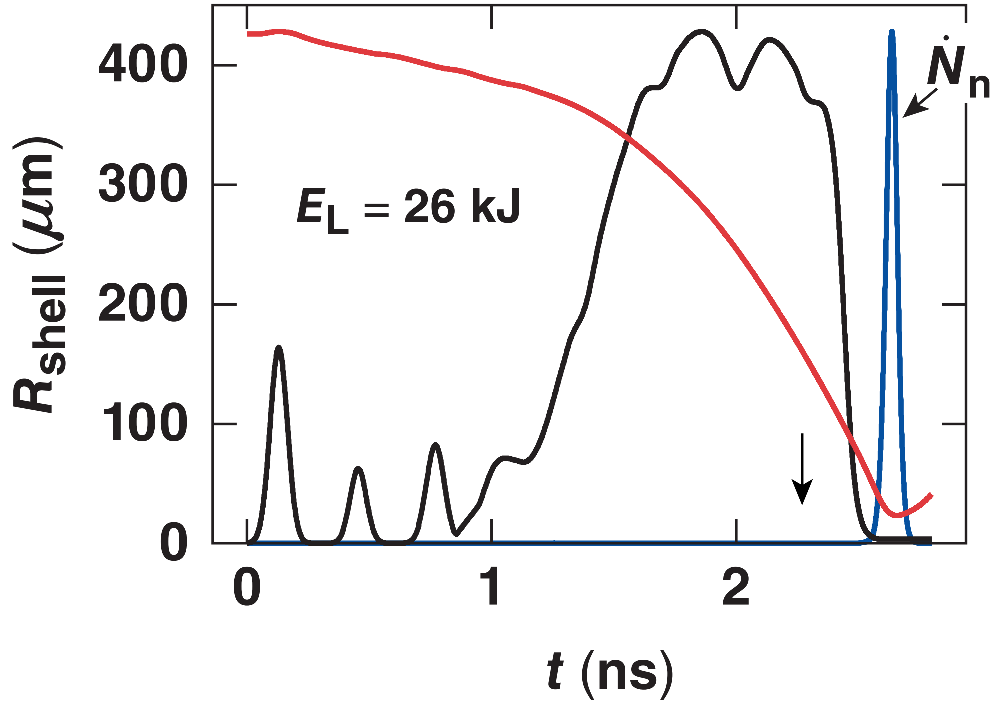
YOU: yield over uniform

Simulations indicate that cryogenic implosions are more affected by imprint at low modes (ℓ < 50) and less at high modes (ℓ ~ 100)

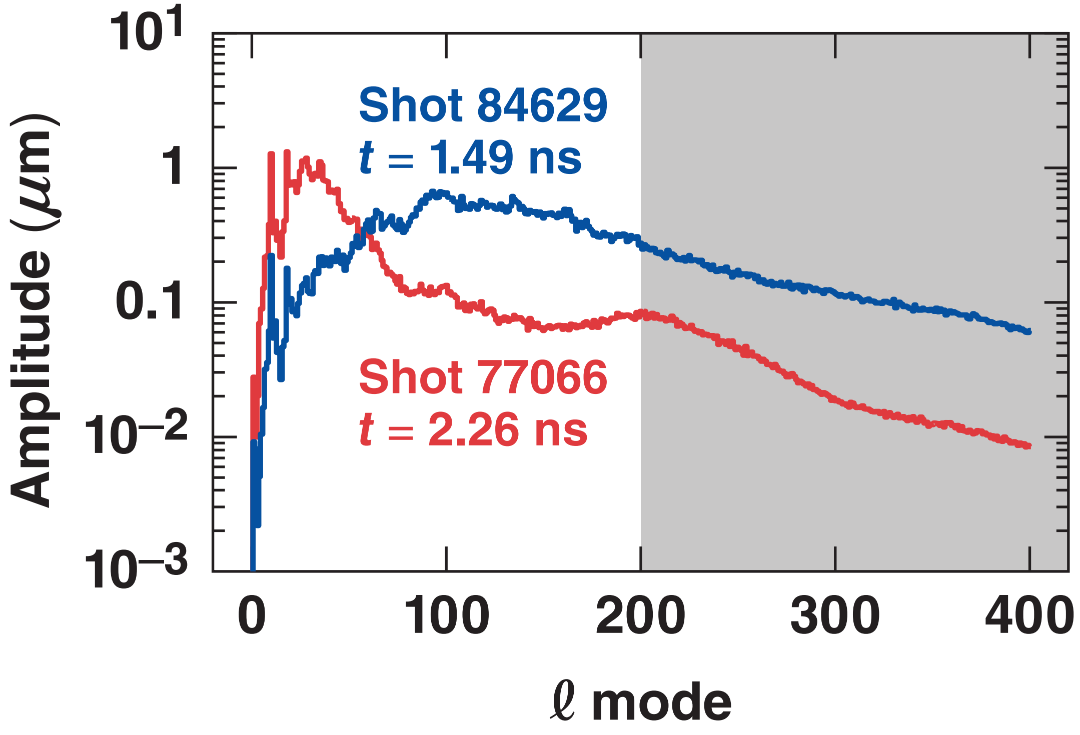
Target of shot 77066



Laser pulse and simulated shell trajectory



Spectrum of ρR modulations at the end of linear RT growth (SSD on)



neutron $\text{yield}_{exp} = (3.93\pm0.2) \times 10^{13}$ (YOC = 30%)

neutron $\text{yield}_{3\text{-}D} = 9.785 \times 10^{13}/4.09 \times 10^{13}$ (SSD on/off)

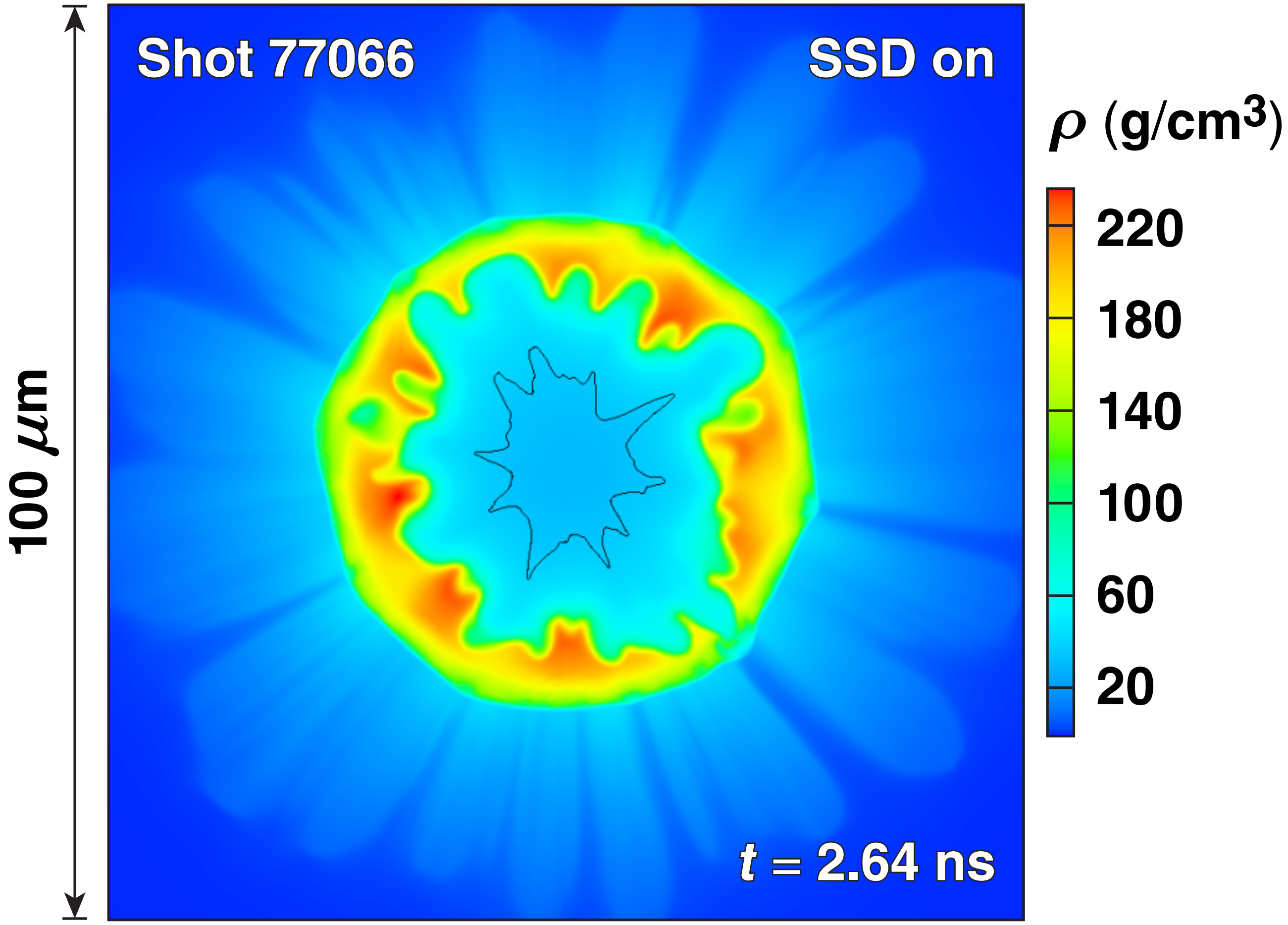
$P^{hs}_{exp} = 56\pm7$ Gbar

$P^{hs}_{3\text{-}D} = 107/56$ Gbar

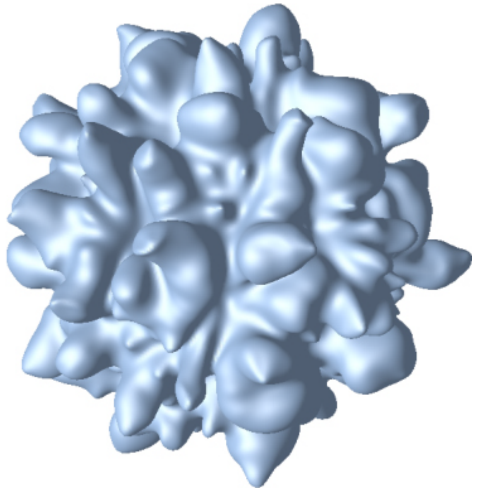
TC13772

Imprint with applied 2-D SSD moderately affects mid-adiabat ($\alpha \sim 4$) cryogenic OMEGA implosions

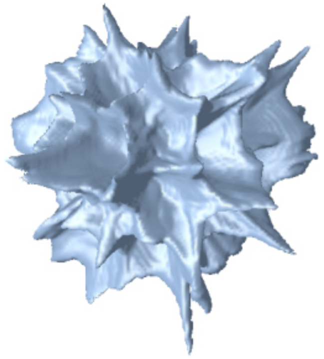
Density shell cross section at neutron peak



Hot-spot shape (surface T_i = 1 keV)



Interface between the original DT ice and vapor materials



YOU = 74% $P^{hs}_{3\text{-}D}/P^{hs}_{1\text{-}D} = 0.94$

- Similar conclusions from *DRACO* simulations*

*P. B. Radha *et al.*, CO8.00012, this conference.

Effects other than imprint should be added into simulations to explain the underperformance of cryogenic OMEGA implosions

- Low-mode nonuniformities*
  - target offset
  - beam power imbalance
  - beam mispointing
  - beam mistiming
- Surface defects (in progress)
- Target-engineering structures
  - stalk mount**
  - fill tube

} ← the effect of shadow could be important

*I. V. Igumenshchev *et al.*, Phys. Plasmas 24, 056307 (2017).
**I. V. Igumenshchev *et al.*, Phys. Plasmas 16, 082701 (2009).

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