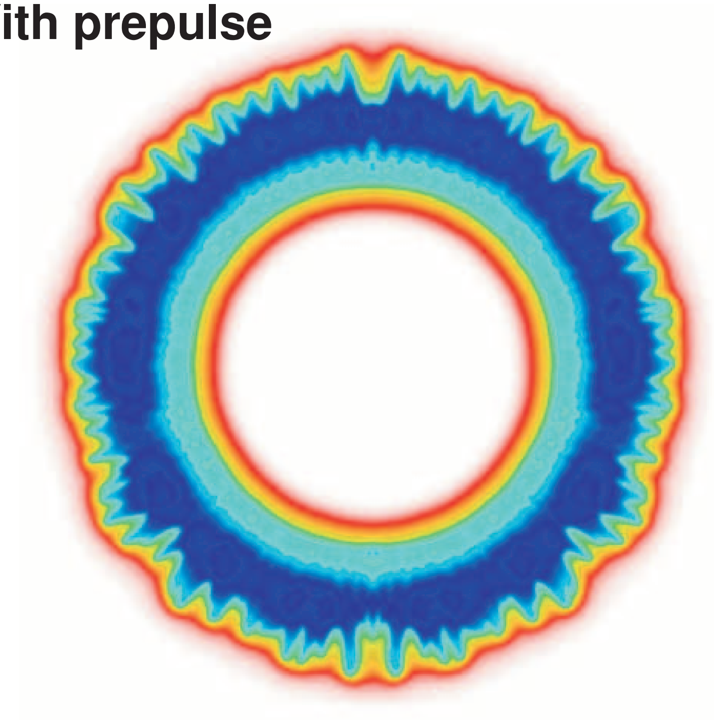
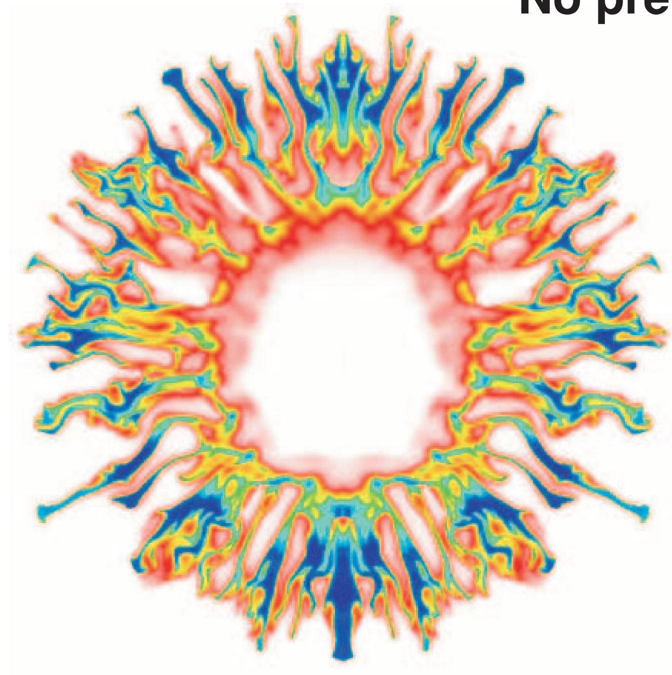
Simulations of Cryogenic Target Implosions on OMEGA

OMEGA α = 3 design

With prepulse



No prepulse



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44th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Orlando, FL
11–15 November 2002

Summary

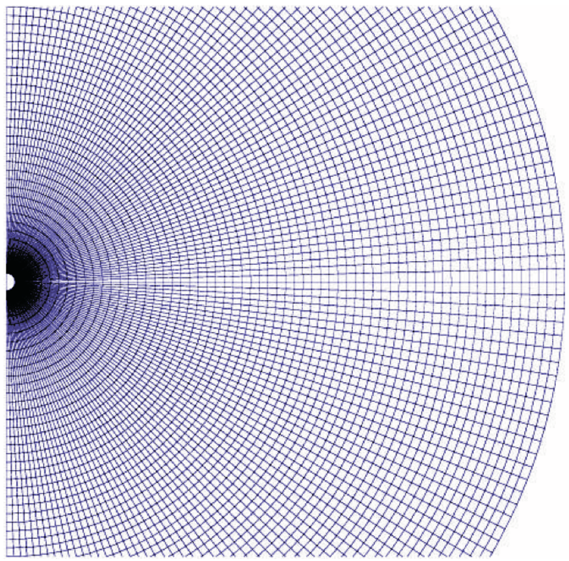
A 2-D hydrodynamic Eulerian code has been developed and tested on simulations of cryogenic target implosions

- The code is developed as an Eulerian option for the Lagrangian 2-D code *DRACO*.
- Results of test simulations have shown good agreement with both results of the 1-D code *LILAC* and predictions of the linear theory of ablative Rayleigh–Taylor instability.
- The code has an advantage in the simulation of highly distorted flows in 2-D.
- Simulations of cryogenic OMEGA targets were conducted for different shapes of laser pulses and imprints, and for different surface perturbations of the target. The effects of these factors on neutron yield were studied.

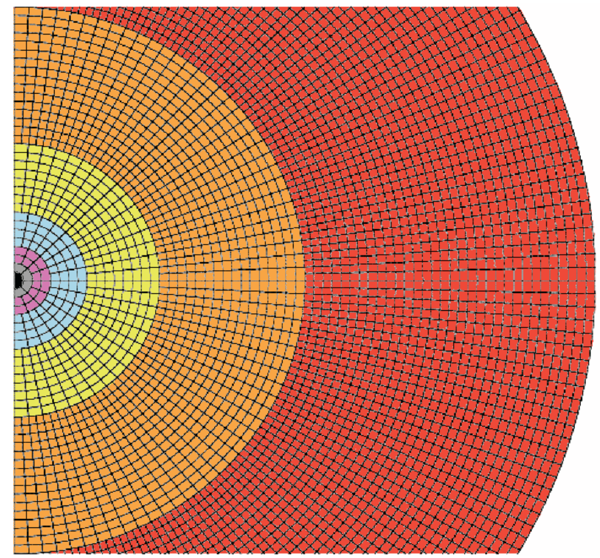
TC5991

A sparse numerical grid allows a significant increase timestep in spherical implosion simulations

Conventional spherical grid



Sparse spherical grid



Courant condition for the time step: $\Delta t < \dfrac{\Delta}{c_s + |v|}$ **(Δ is the gride size)**

$\Delta t_{sparse} = 2^{N-1}\, \Delta t_{conv}$ **(N is the number of subgrids)**

Typical grids: $N = 8\ ;\ N_R = 300\ ;\ N_\theta = 512$ **(low resolution)**

$N = 9\ ;\ N_R = 600\ ;\ N_\theta = 1024$ **(high resolution)**

TC5992

The code is based on the piecewise-parabolic-interpolation Godunoz-type scheme (PPM)

Hydrodynamic equations in conservative form:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho\vec{v}) = 0,$$

$$\frac{\partial(\rho v_k)}{\partial t} + \nabla(\rho v_k \cdot \vec{v}) = -\nabla_k P + \begin{cases} \rho \dfrac{v_\theta^2}{R}, & \text{if } k = R \\ -\rho \dfrac{v_R v_\theta}{R}, & \text{if } k = \theta \end{cases} \qquad k = (R, \theta)$$

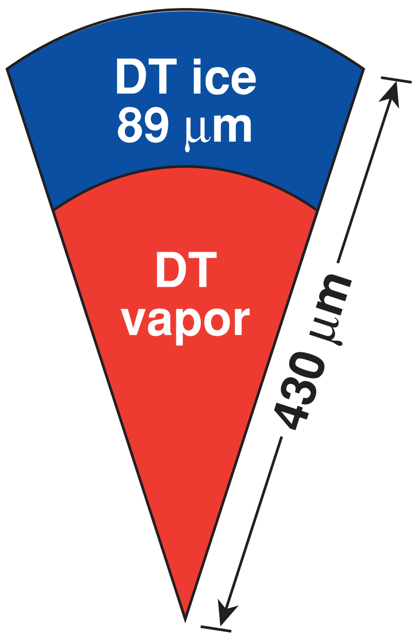
$$\frac{\partial(\rho e)}{\partial t} + \nabla(\rho e \cdot \vec{v}) = -\nabla(P \cdot \vec{v}) + \ldots, \qquad e = \frac{v^2}{2} + \varepsilon_e + \varepsilon_i$$

$$\frac{\partial(\rho \varepsilon_e)}{\partial t} + \nabla(\rho \varepsilon_e \cdot \vec{v}) = -P_e \nabla\vec{v} + \ldots, \qquad P = P_e + P_i$$

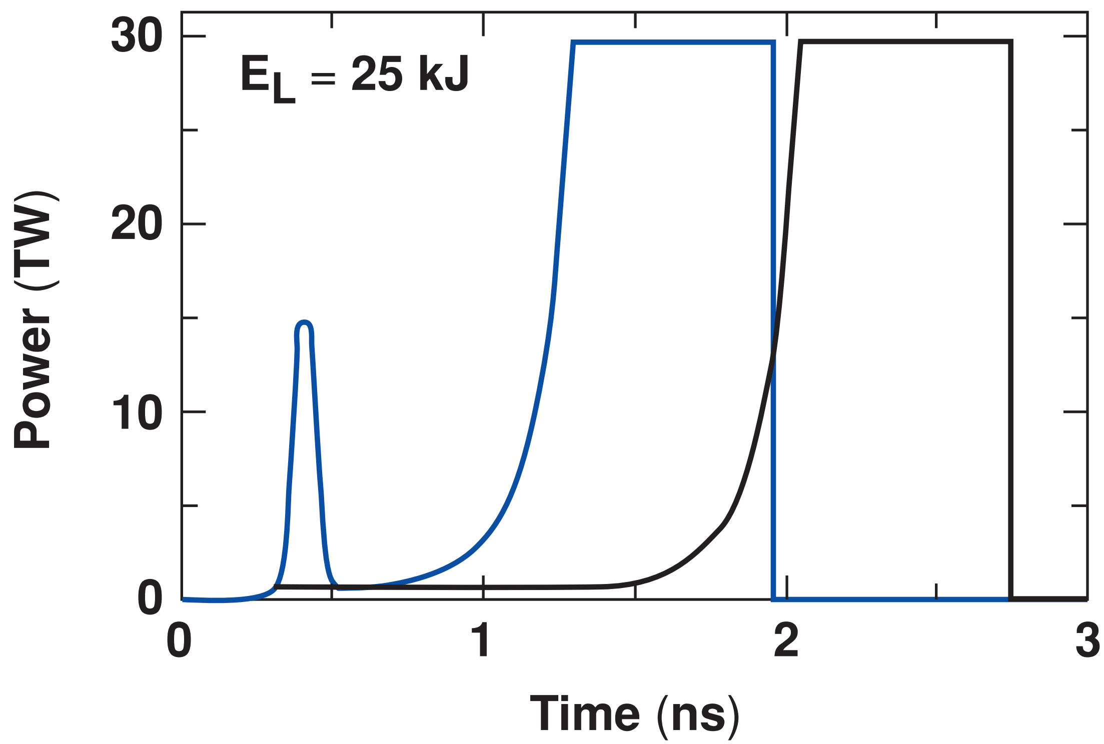
The code includes the essential physics:

- two-temperature ion-electron plasma
- thermal and radiative transports
- ion viscosity
- laser energy deposition
- selected nuclei reactions

The stabilizing effect of the laser prepulse was tested on the "all-DT," $\alpha = 3$ OMEGA target design



Two laser pulse shapes were considered.

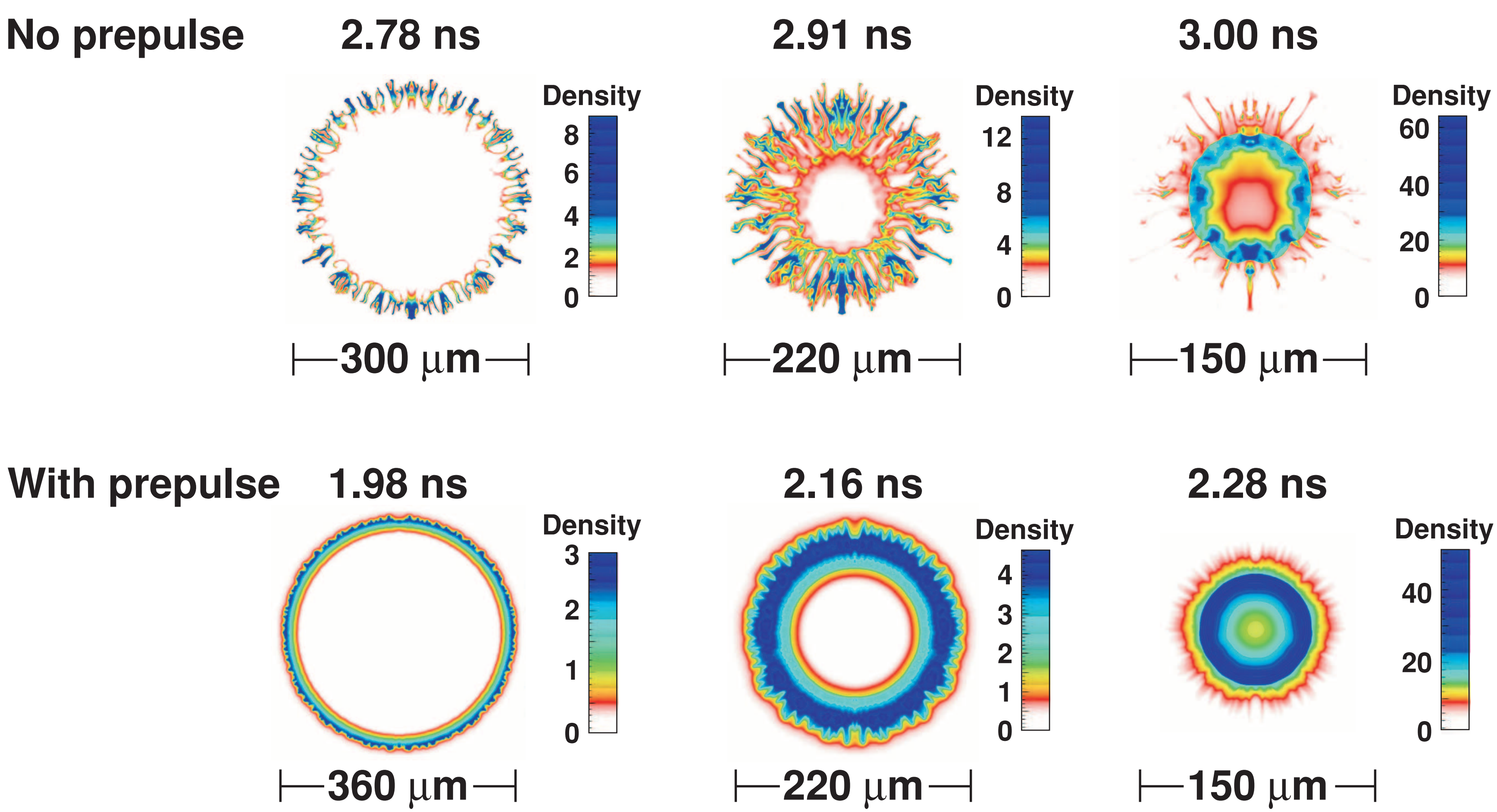


Imprint simulations: DPP spectrum, $\ell = 1$–200
1-THz, one-color SSD

TC5993

Simulations demonstrate improved stability of the targets with the laser prepulse

Density contours (g/cm^3)



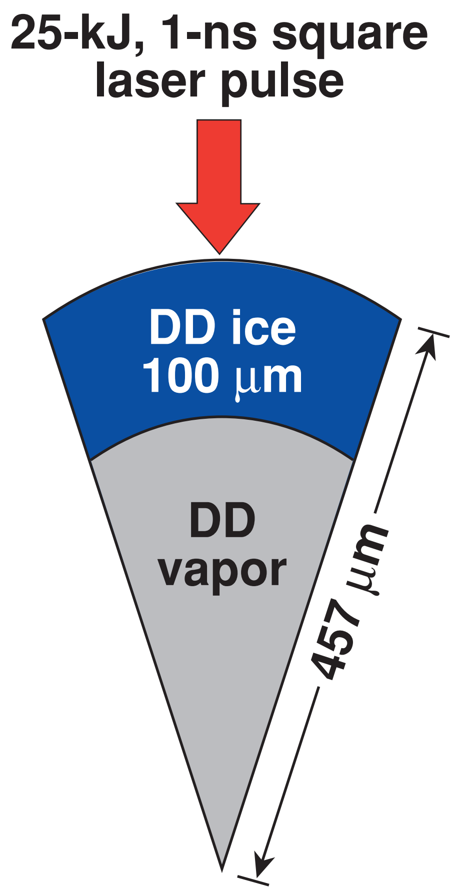
TC5994

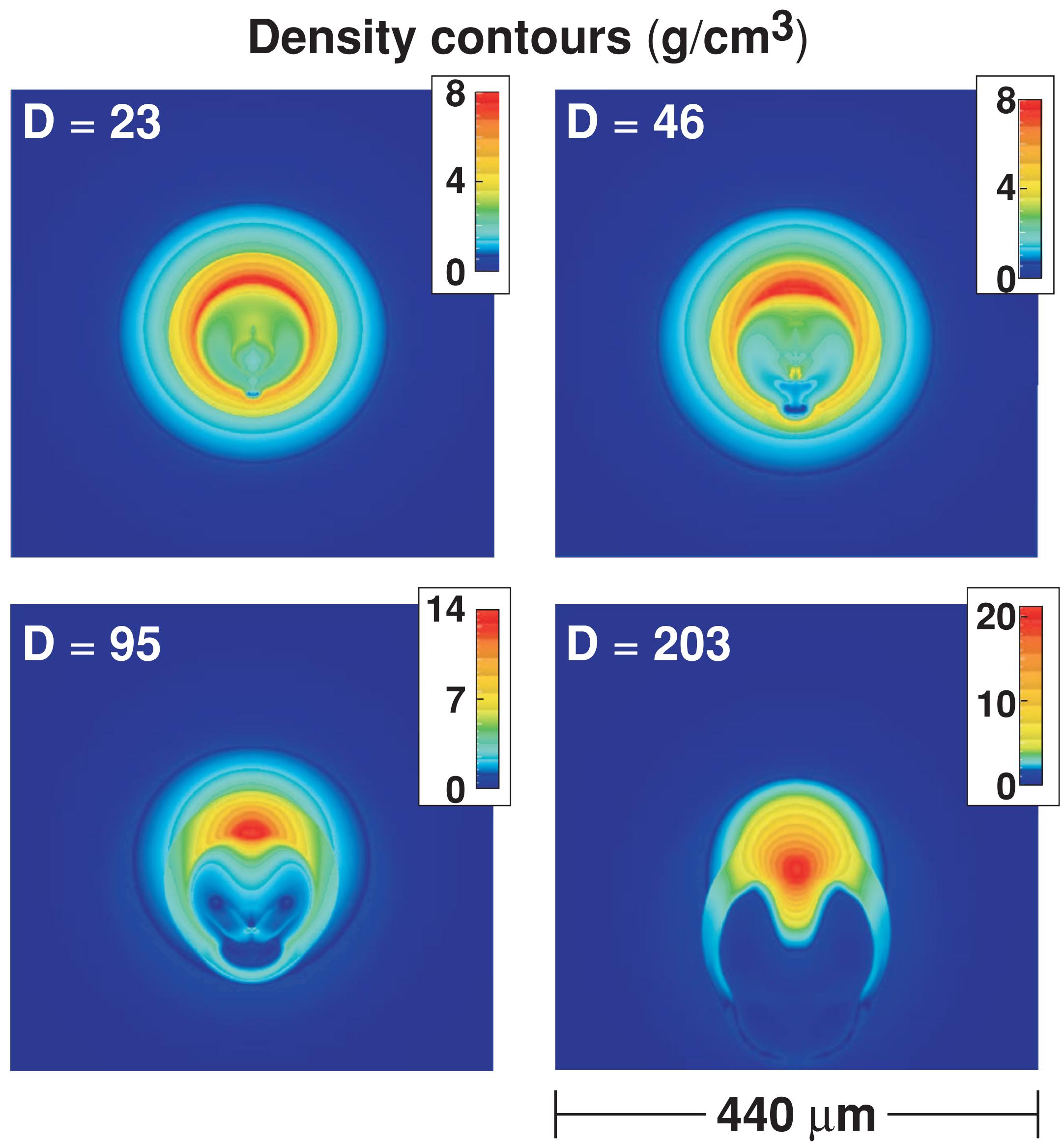
Neutron yield is decreased in the Rayleigh–Taylor unstable targets

Models	No Prepulse		With Prepulse	
	Neutron yield (10^{14})	YOC	Neutron yield (10^{14})	YOC
1-D run	2.35	–	0.922	–
DPP only	0.164	0.070	0.862	0.935
DPP + SSD + PS	0.507	0.216	0.899	0.975

TC5995

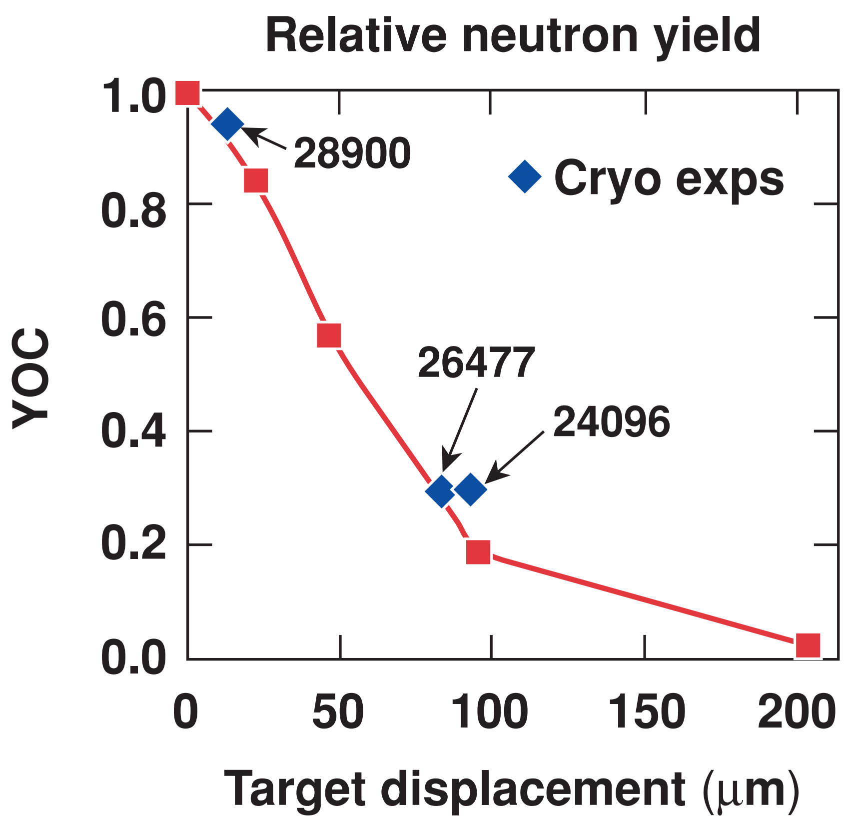
Target displacement results in nonuniform implosions

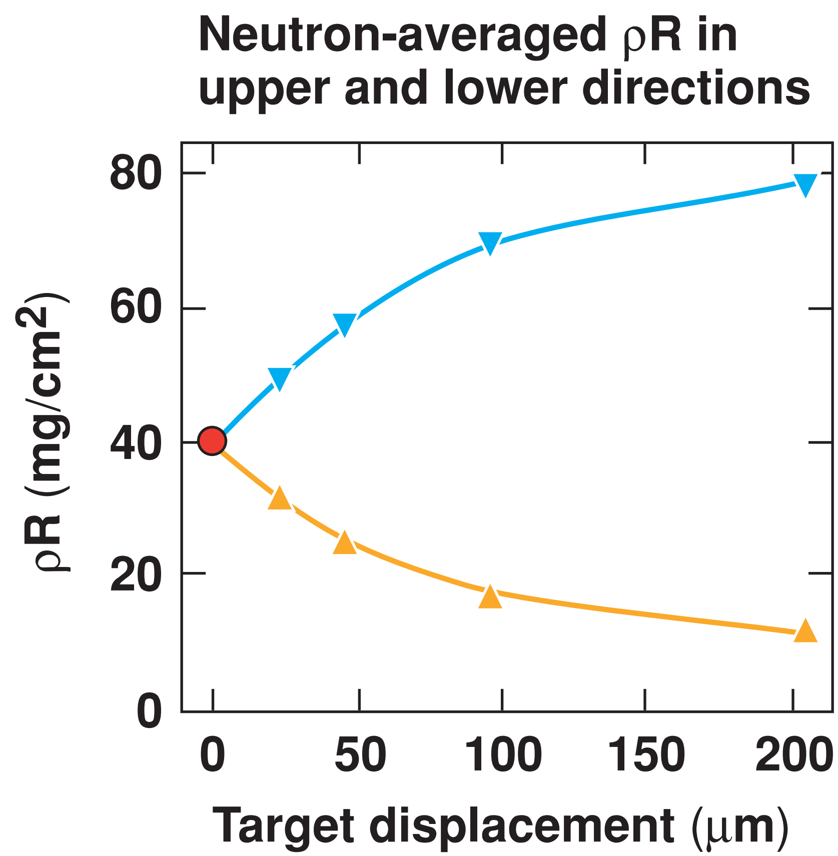




TC5996

Simulations show the strong effect of target displacement on neutron yield and measured ρR

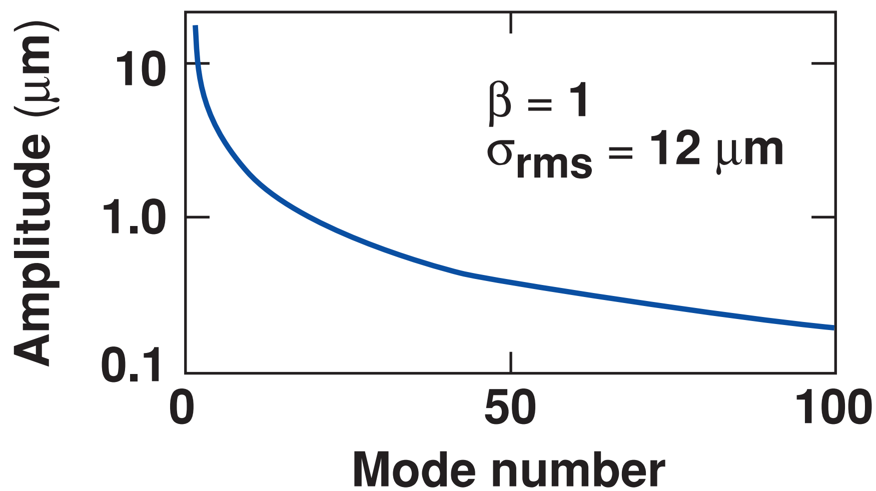


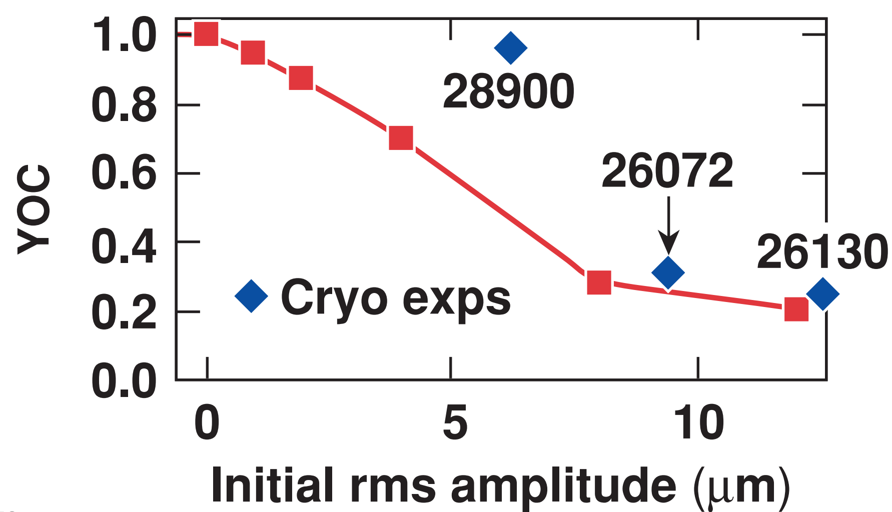


TC5997

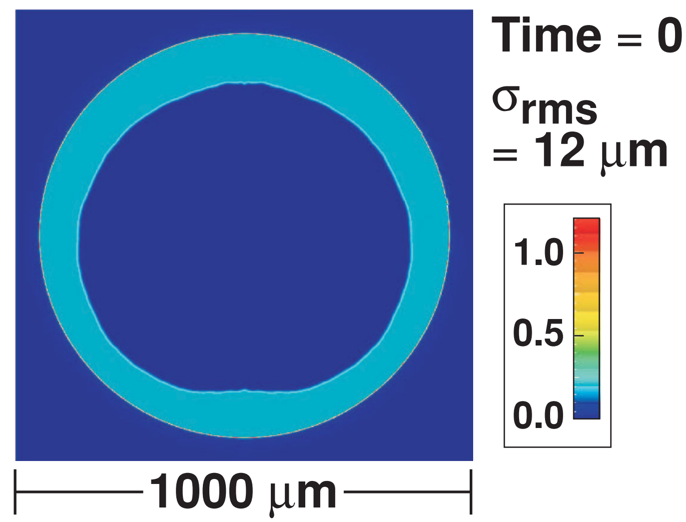
Large inner-ice-surface roughness distorts targets and reduces neutron yield

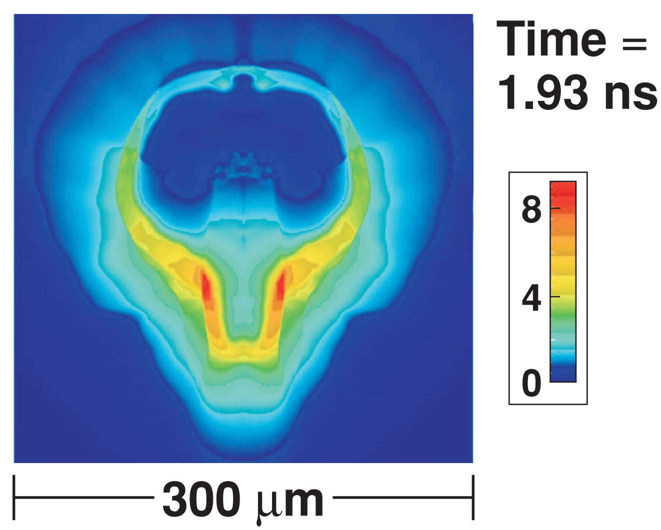
Perturbation amplitude: $a_\ell = a_0/\ell^\beta$





Density contours (g/cm^3)





TC6085

Summary/Conclusions

A 2-D hydrodynamic Eulerian code has been developed and tested on simulations of cryogenic target implosions

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- The code has demonstrated a good ability to simulate ICF problems under a wide variation of conditions.
- Simulations of cryogenic OMEGA targets have demonstrated improved stability of the low-adiabat implosions with a laser prepulse.
- Large inner-ice-surface roughness of the cryo targets and large laser power imbalance or target shift result in distortion of the targets at peak compression and significant reduction of neutron yield.