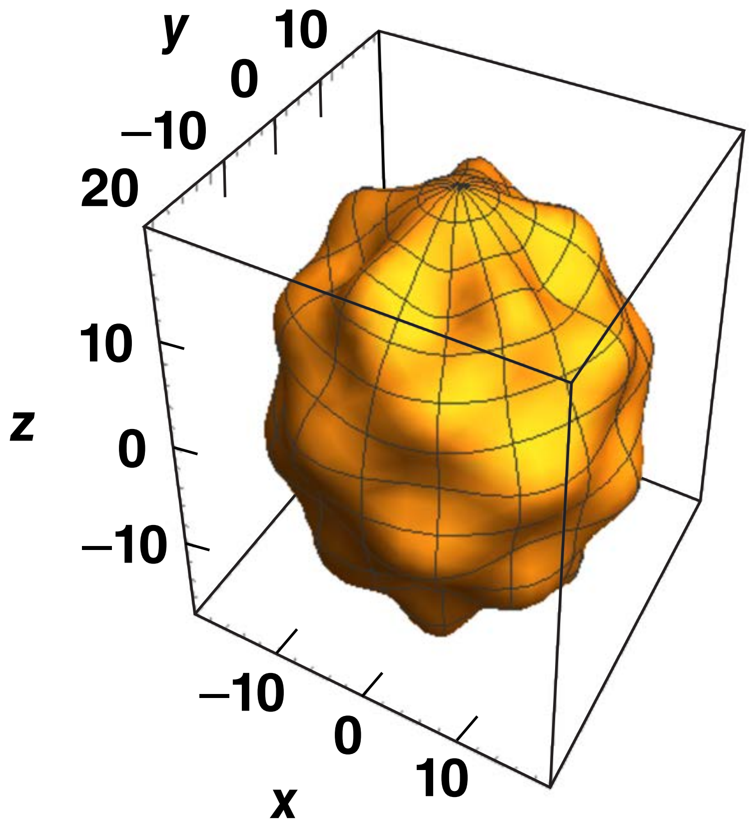
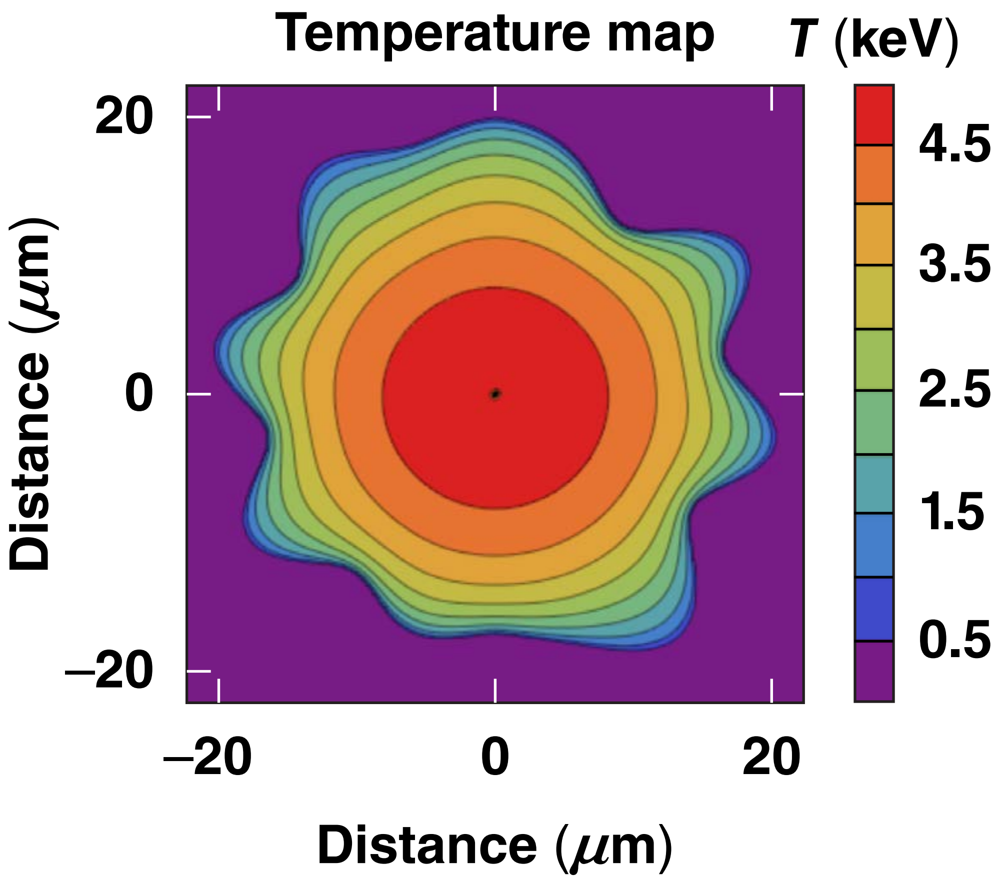
A 3-D Model of Hot-Spot Formation in Inertial Confinement Fusions Implosions





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Summary

A 3-D model describing the formation of a hot spot in inertial confinement fusion (ICF) implosions has been developed

- A hot-spot shape is calculated using the results of a sharp-boundary Rayleigh–Taylor (RT) model
- Modification of the hydro profile caused by 3-D effects is calculated using a model developed by Sanz *et al*.*
- Results of the model will be compared to detailed 3-D simulations in future work

* J. Sanz and R. Betti, Phys. Plasmas 12, 042704 (2005).

Collaborators

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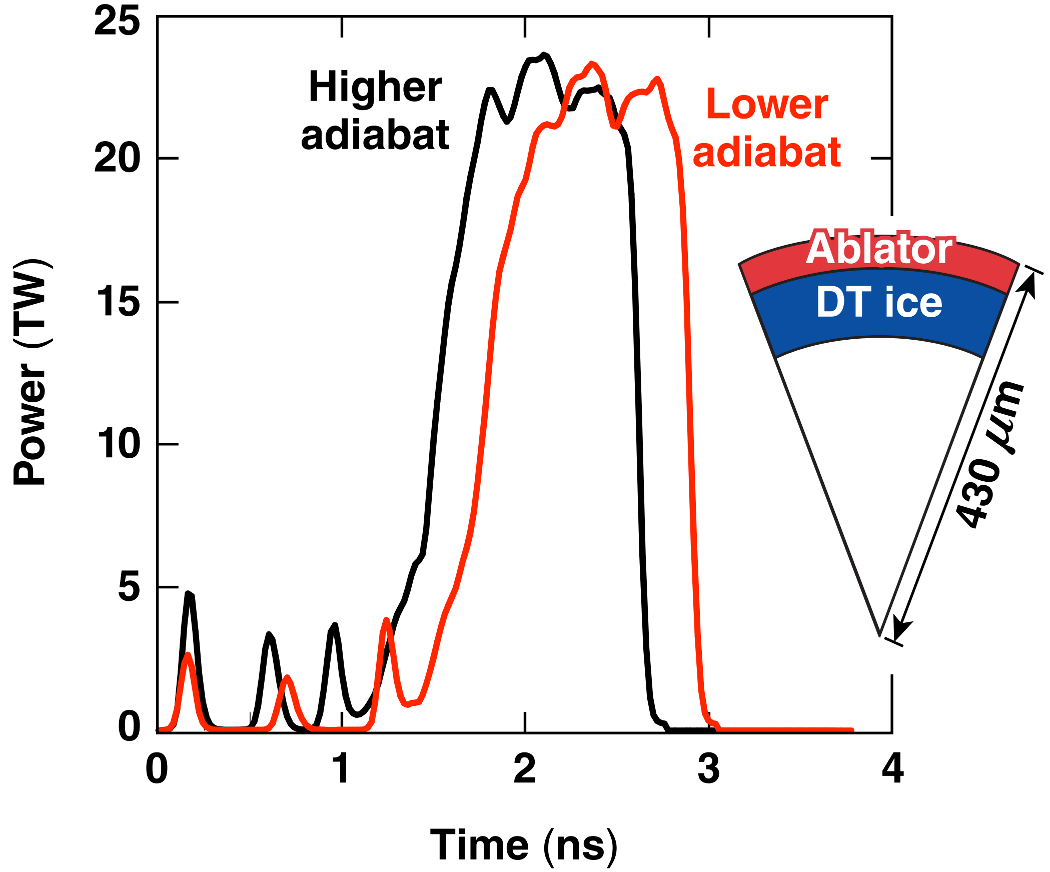
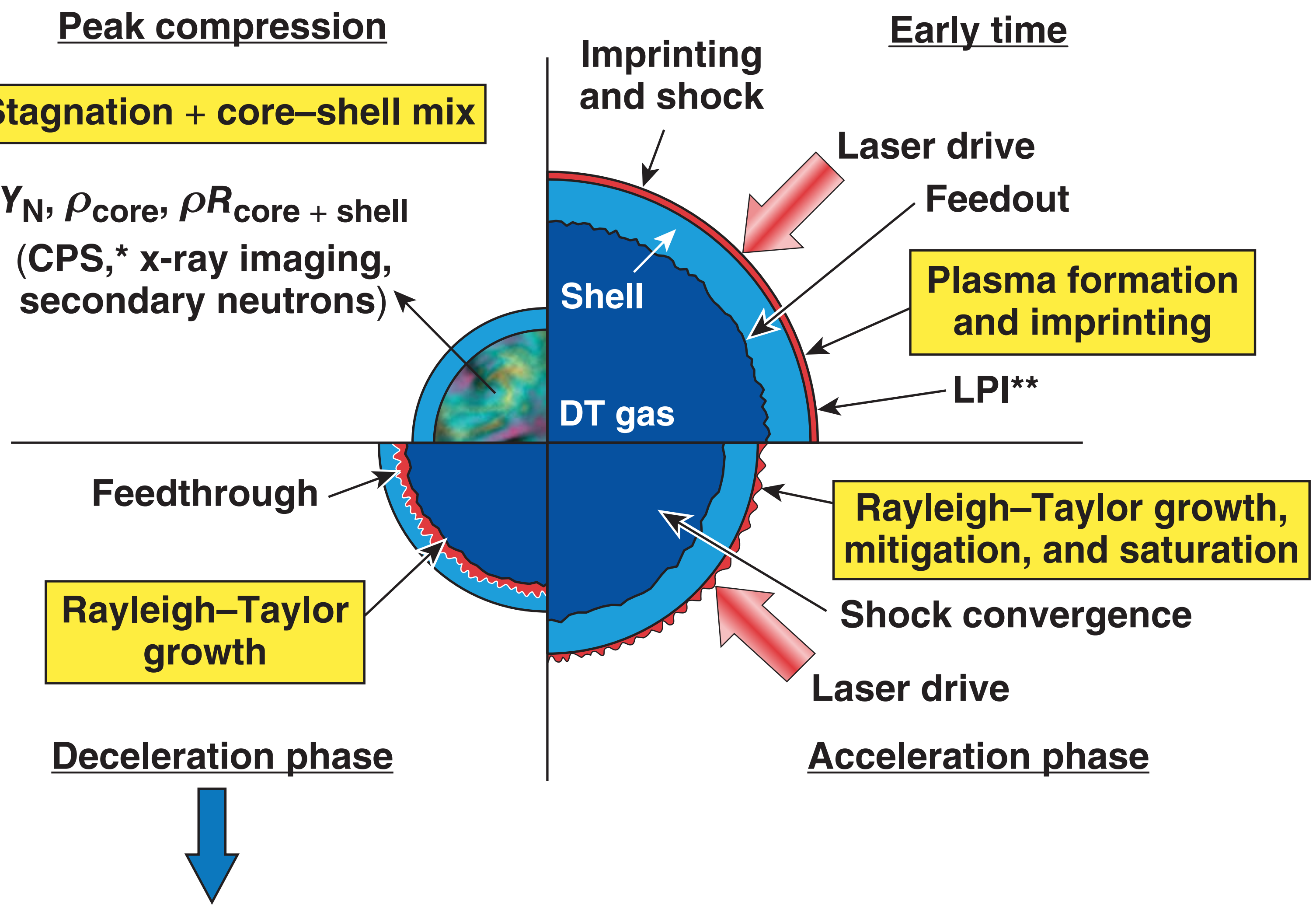
ICF implosions evolve through several stages





This work focuses on deceleration phase instability growth

*CPS: charged-particle spectrometer
**LPI: laser–plasma interaction

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Three-dimensional simulations and experimental data suggest that long-wavelength nonuniformity growth limits target performance

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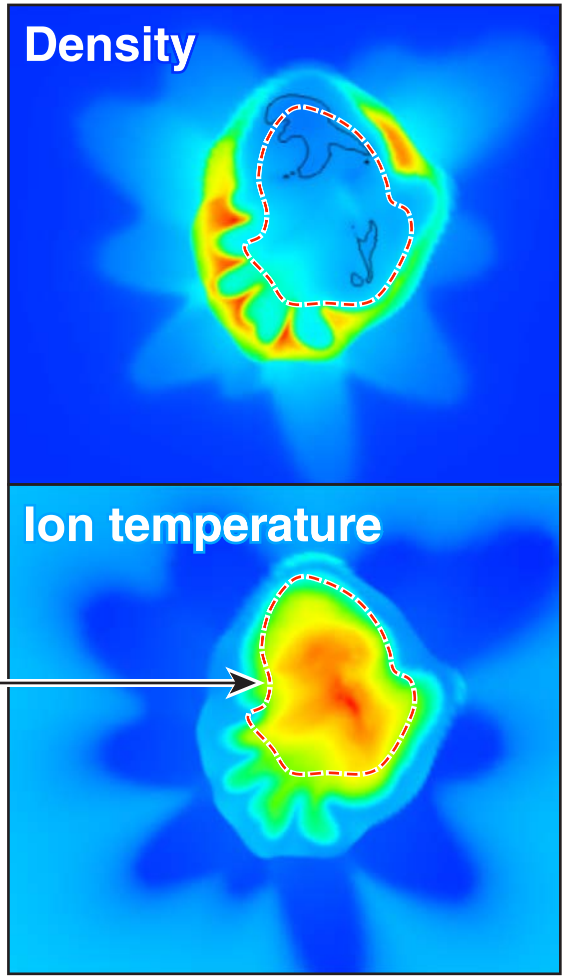
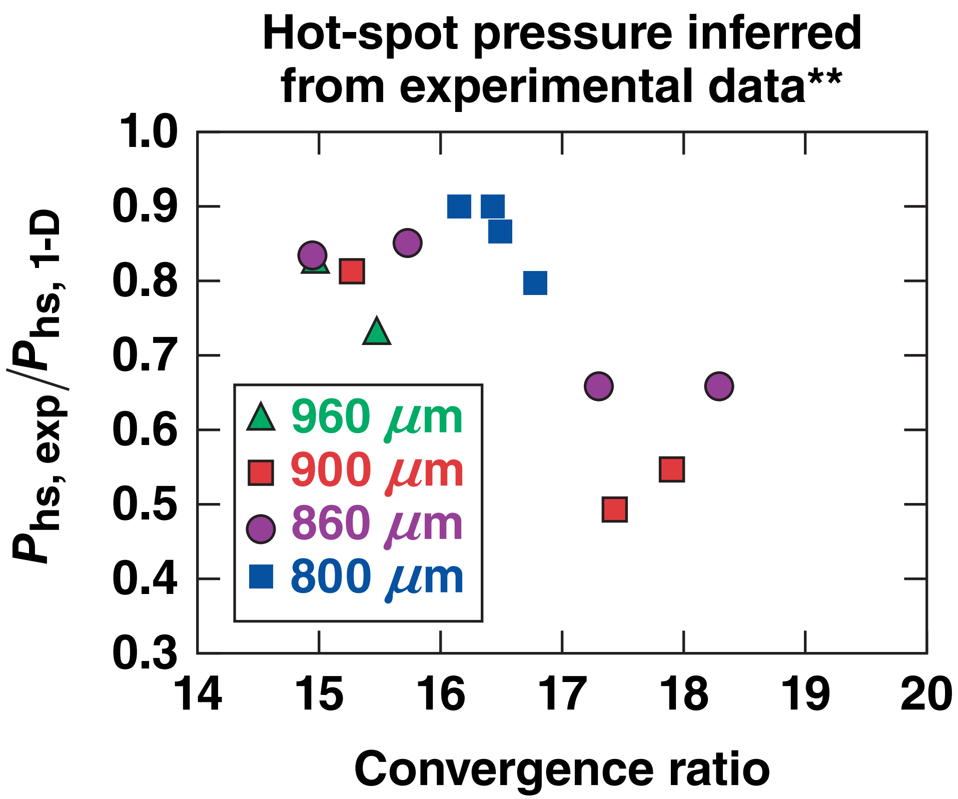
- *ASTER** 3-D simulation, including power imbalance and target offset (at peak neutron-production time)

Hot spot





*I. V. Igumenshchev *et al*., UO4.00015, this conference.
**S. P. Regan, CI3.00005, this conference (invited); V. N. Goncharov *et al*., UO4.00005, this conference.

TC12623

A 3-D hot-spot nonuniformity model has been developed to study hot-spot–formation physics

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3-D hot-spot formation model

- Shell nonuniformity is described by a sharp-boundary RT instability model
- Hot-spot properties (mass ablation rate, hydro profiles) are obtained using the 3-D hot-spot models of Sanz *et. al*
- The sharp-boundary model and Sanz model are applied using 1-D hydro profiles from *LILAC*

J. Sanz and R. Betti, Phys. Plasmas 12, 042704 (2005).

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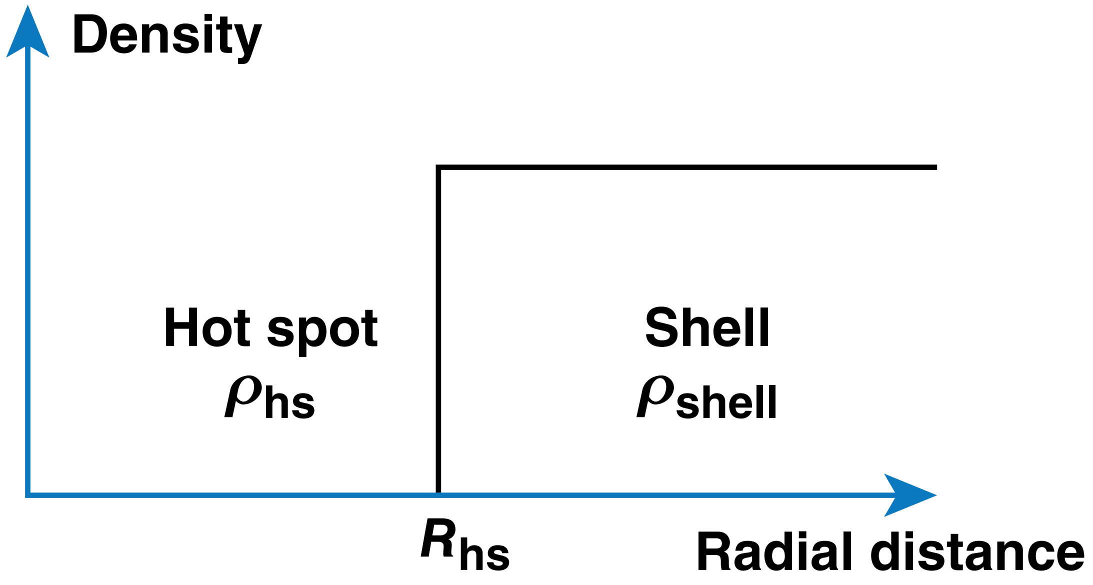
A 3-D sharp boundary model was used to determine the perturbation evolution at the inner shell surface

- Takes into account the time variation in the unperturbed state
- Solves the sharp-boundary model in two regions
- Unperturbed velocity

$$U_{shell} = \frac{R}{3}\frac{\dot{\rho}_{shell}}{\rho_{shell}}\left(\frac{R_{shell}^3}{R^3} - 1\right) + \left(\frac{R_{hs}}{R}\right)^2 (R_{hs} - V_{abl})$$

$$U_{hs} = \frac{R}{R_{hs}}\left(R_{hs} - \frac{\rho_{shell}}{\rho_{hs}} V_{abl}\right)$$



- The model involves solving a temporal second-order ordinary differential equation
- 1-D hydroprofiles are determined from *LILAC* simulations

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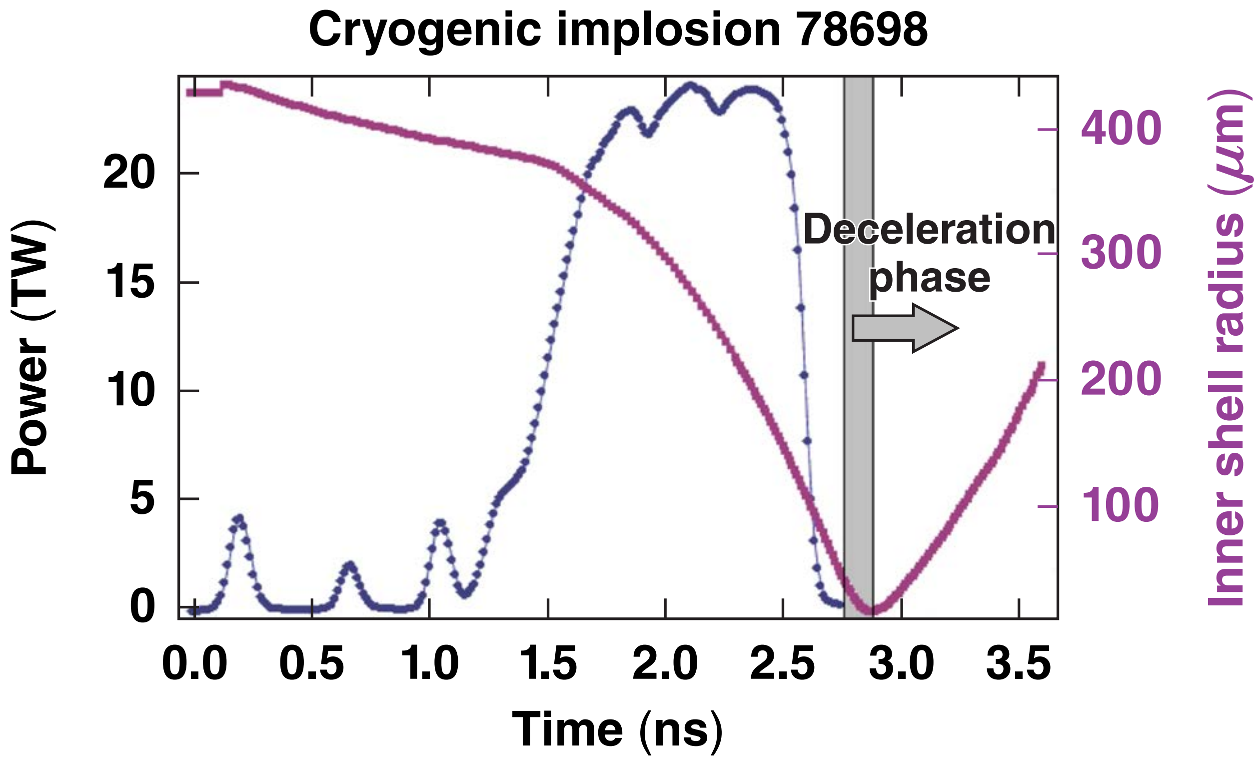
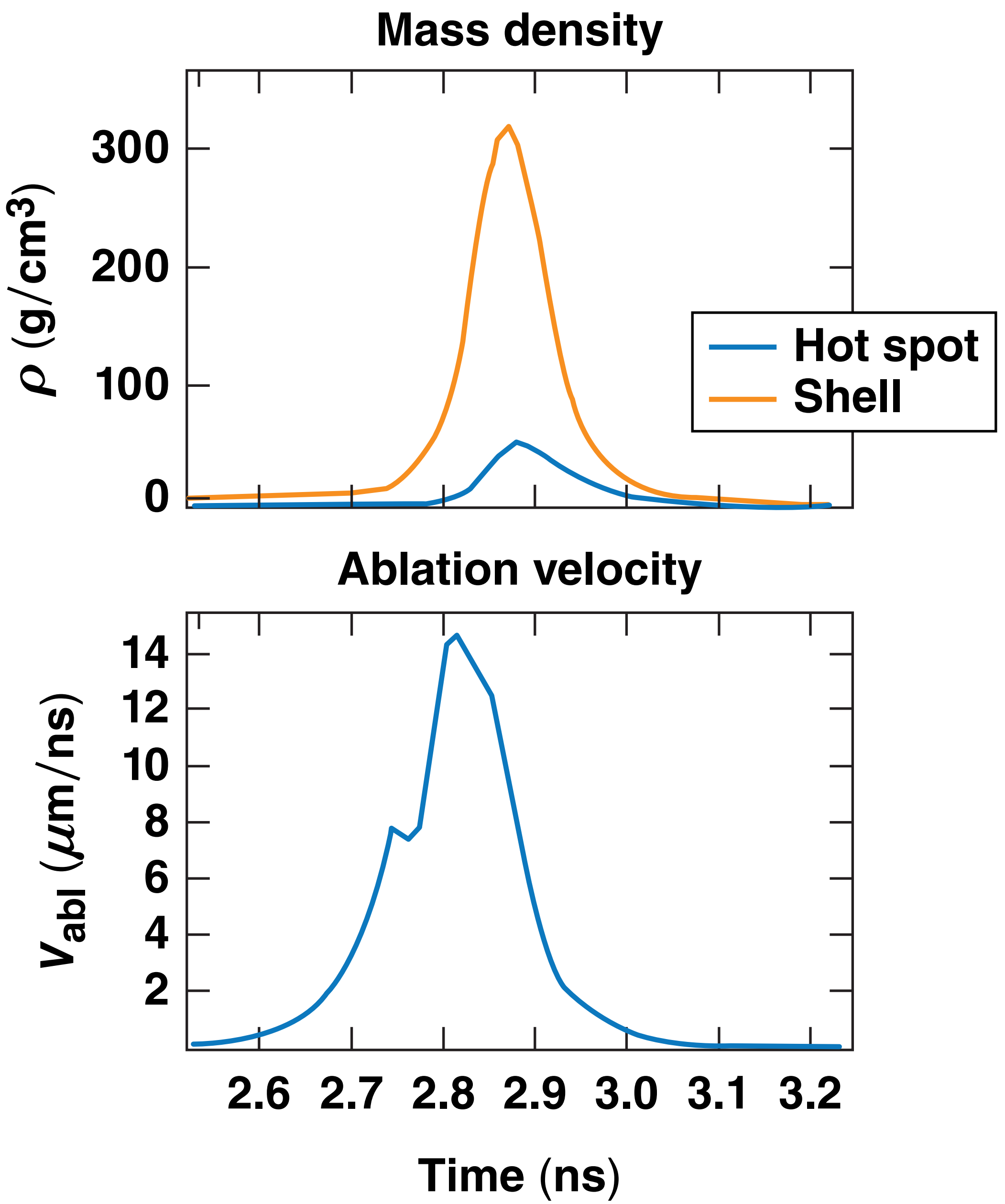
Hydro profiles are extracted using *LILAC* 1-D simulations





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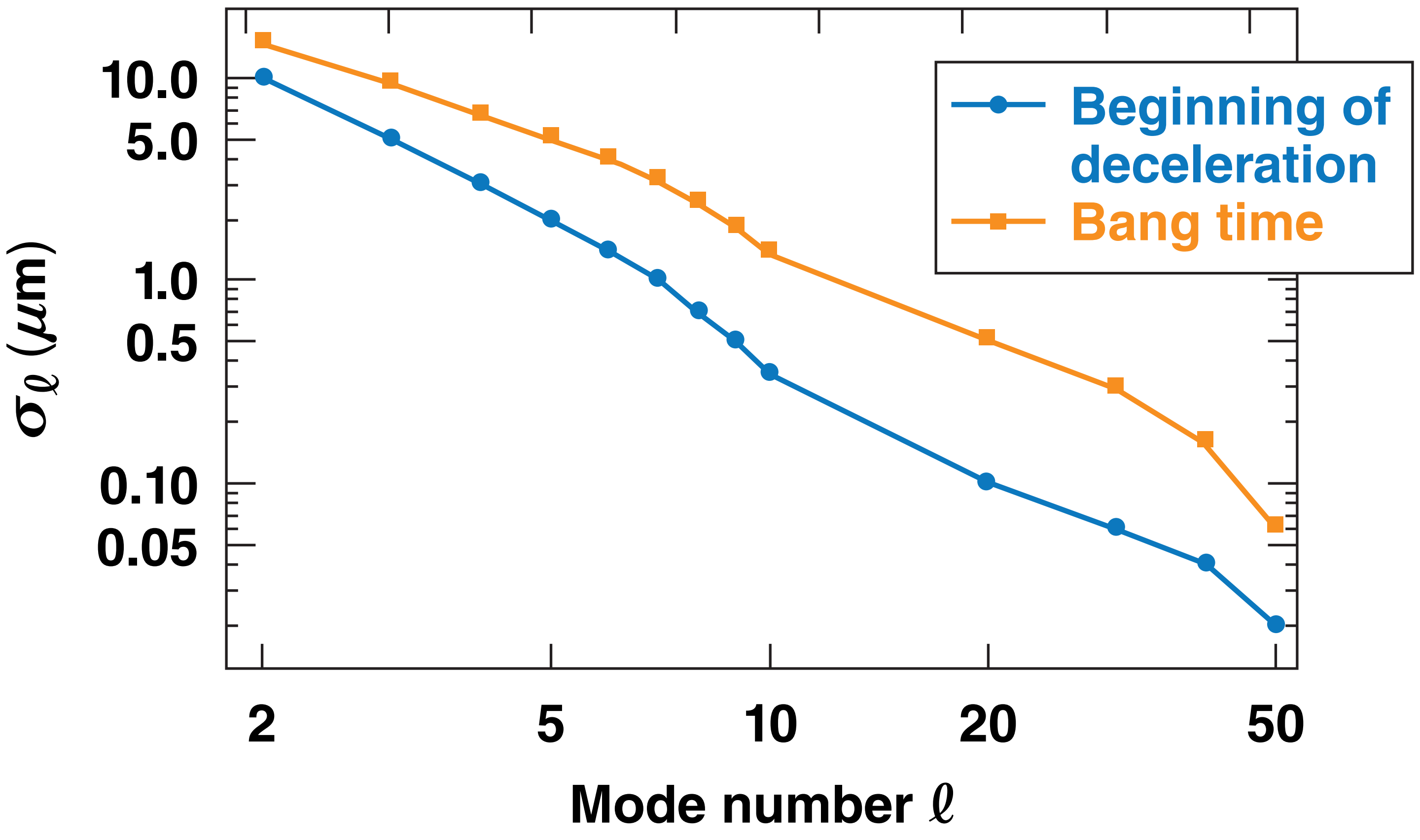
The RT model was used to calculate perturbation evolution during shell deceleration



- Perturbation at the beginning of the deceleration comes from the study of acceleration-phase instability*
- Perturbation comes only from laser imprint

*V. N. Goncharov *et al.*, Phys. Plasmas 7, 5118 (2000).

Three-dimensional hot-spot profiles are obtained using the isobaric model of Sanz *et al*.

- Solve the Poisson equation

$$\nabla^2 \psi = -1, \; \psi \big|_{\text{shell}} = 0, \text{ where } \psi \equiv \frac{2\kappa T_{hs}^n}{5n\bar{\rho}_{hs} \partial_t \ln m_{hs}}$$

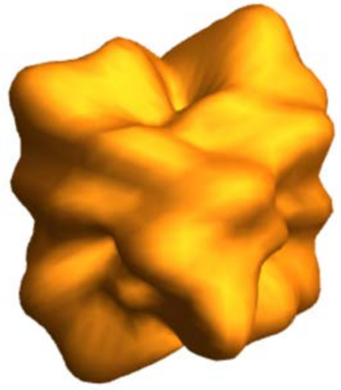
in 3-D successive-over-relaxation

- The boundary is the solution of sharp-boundary model
- Solve for hot-spot pressure, mass, and temperature

$$P_{hs} V_{hs}^{5/3} = P_0 V_0^{5/3}$$

$$T_{hs} = \frac{C P_{hs} V_{hs}}{m_{hs}} \left(\frac{\psi}{\psi_{max}} \right)^{1/n}$$

- Neutron yield and average temperature are calculated using 3-D constant = 1.89 hydroprofiles predicted by this model



κ	Thermal conductivity $\kappa = kT^n$, take $\eta = 2.5$
T_{hs}	Hot-spot temperaure
m_{hs}	Hot-spot mass
V_{hs}	Hot-spot volume
$\bar{\rho}_{hs}$	m_{hs}/V_{hs}
P_{hs}	Hot-spot pressure (uniform)
C	Constant

J. Sanz and R. Betti, Phys. Plasmas 12, 042704 (2005).

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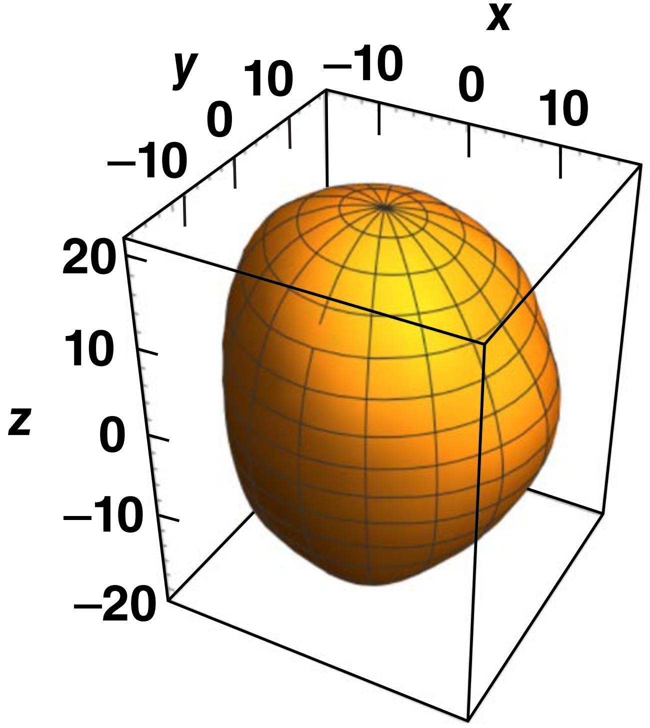
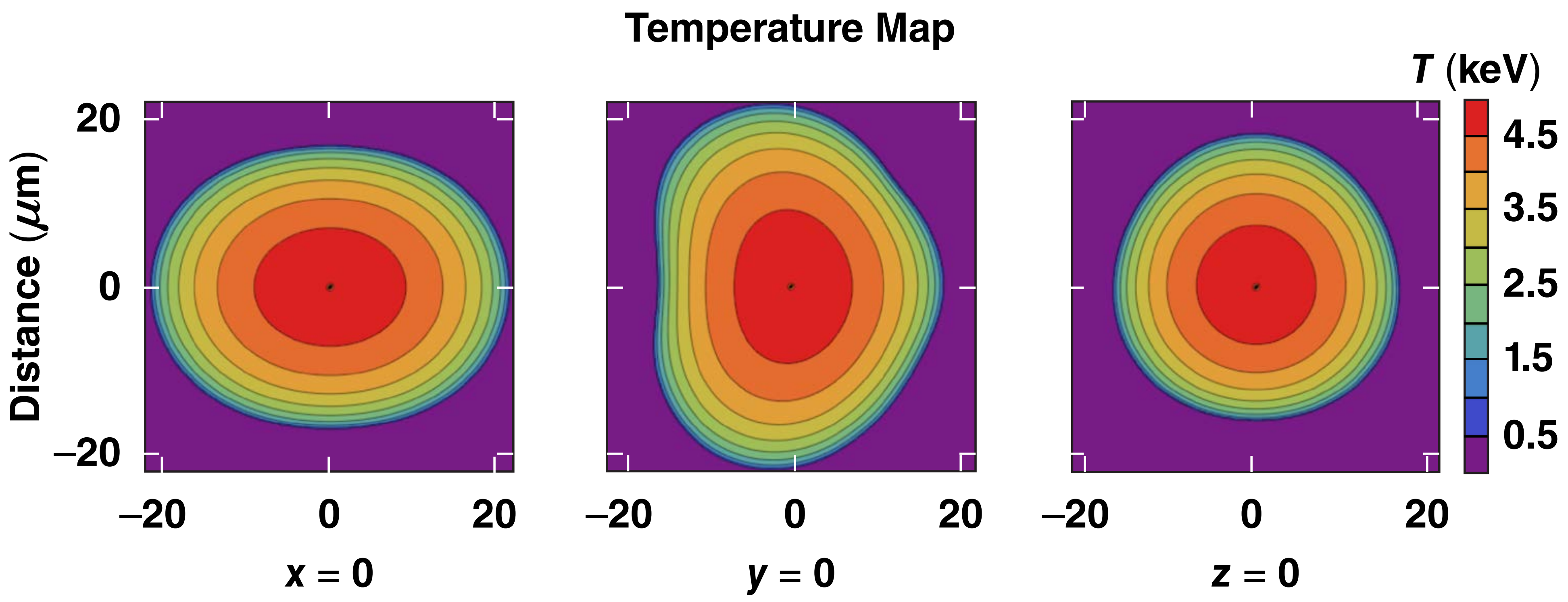
Neutron yield and ion temperature are obtained using derived hydro profiles





	T_{max} (keV)	d*N*/dt ($\times 10^{24}$/s)
1-D, unperturbed	4.946	4.594
3-D, unperturbed	4.793	4.123

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Summary/Conclusions

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*J. Sanz and R. Betti, Phys. Plasmas 12, 042704 (2005).

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