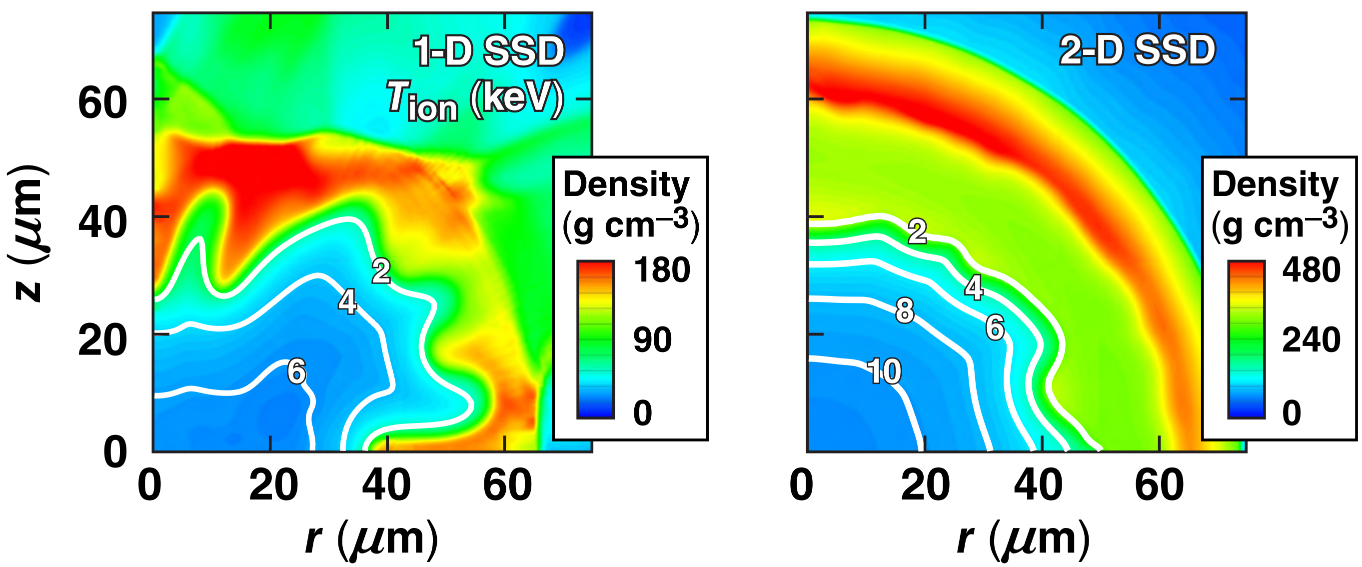
Single-Beam Smoothing Requirements for Wetted-Foam, Direct-Drive-Ignition Target Designs

Including imprint, power balance, surface, and ice roughness



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Summary

2-D simulations of direct-drive target designs indicate ignition requires 2-D SSD single-beam smoothing

- **A low-IFAR wetted-foam ignition design is used to minimize the effects of single-beam nonuniformity.**
- **This 1-MJ design was found to require 2-D SSD for ignition.**
- **Simulations show a 1.5-MJ design also needs 2-D SSD when single modulators are used in each direction.**
- **Multiple frequency modulators can be used to significantly increase the 1-D SSD single-beam smoothing rate.**

Collaborators

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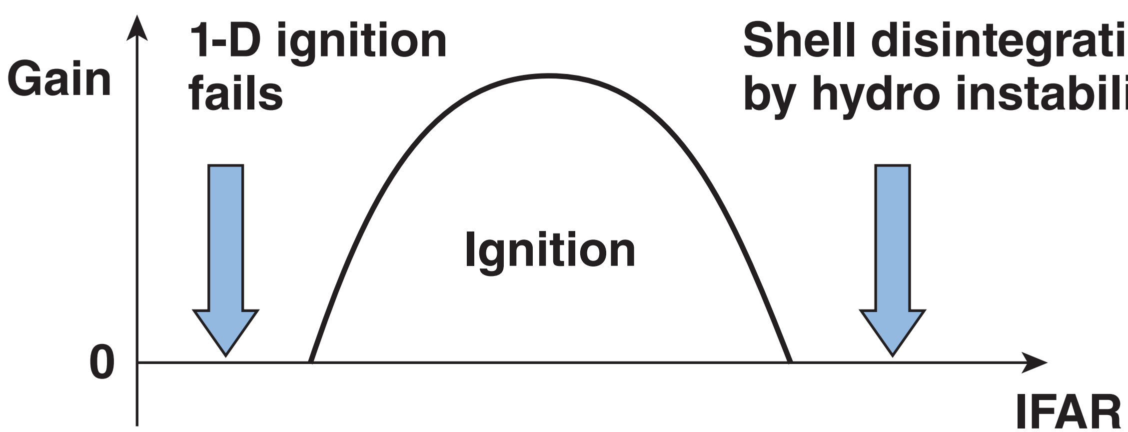
Conventional ICF requires an intermediate in-flight aspect ratio

UR LLE

- If the in-flight aspect ratio, IFAR = $R_0/\Delta R$, is too high, ignition is prevented by hydrodynamic instabilities.
- If the IFAR is too low, the low-implosion velocity results in too low a hot-spot temperature.
- The minimum energy for ignition scales as $E \sim (\text{IFAR})^{-3*}$



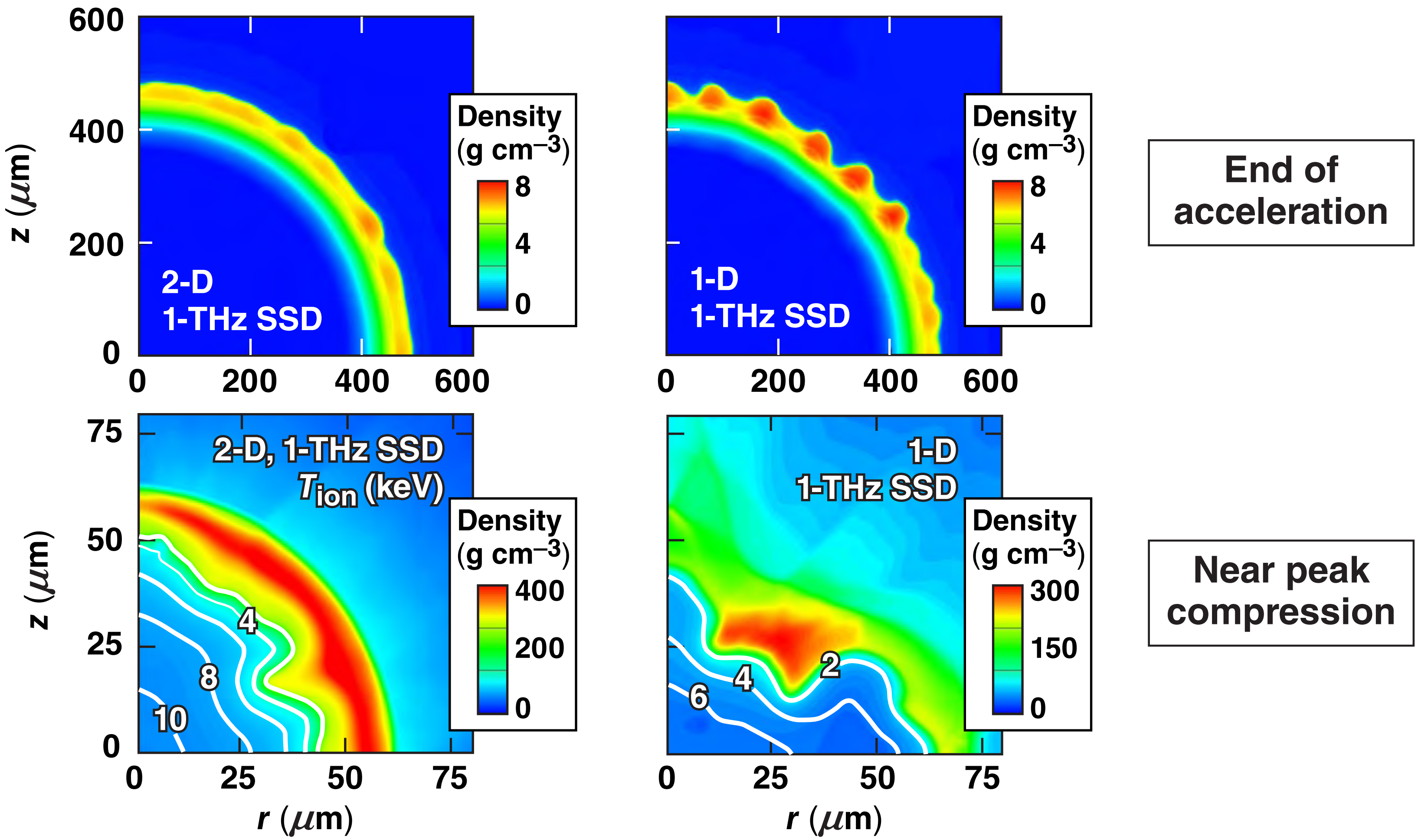
A low-IFAR wetted-foam design was developed for its comparative insensitivity to single-beam nonuniformity.

TC7719a

*R. Betti *et al*., Plas. Phys. and Cont. Fusion, 48 (2006).

2-D SSD single-beam smoothing is required for ignition for the 1-MJ wetted-foam design*

- **Integrated simulations include imprint, power imbalance, foam-surface nonuniformity (370-nm rms), and 0.75-μm initial ice roughness.**



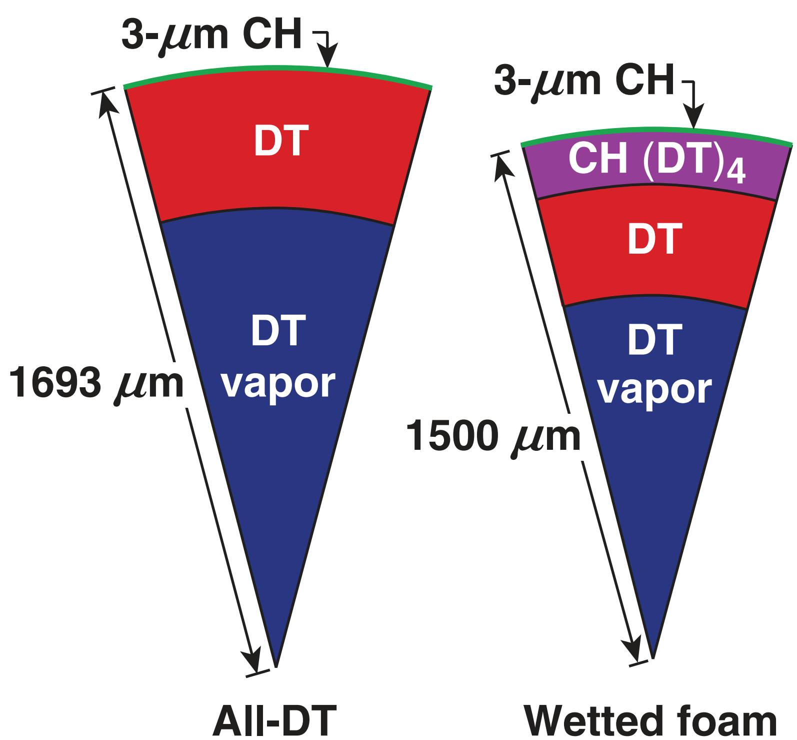
TC7645a

*T. J. B. Collins *et al*., Phys. Plasmas 14, 056308 (2007).

A new, low-IFAR, wetted-foam design has been developed to study SSD requirements at 1.5 MJ

UR LLE

- This design was simulated with power imbalance, surface and ice roughness, and imprint



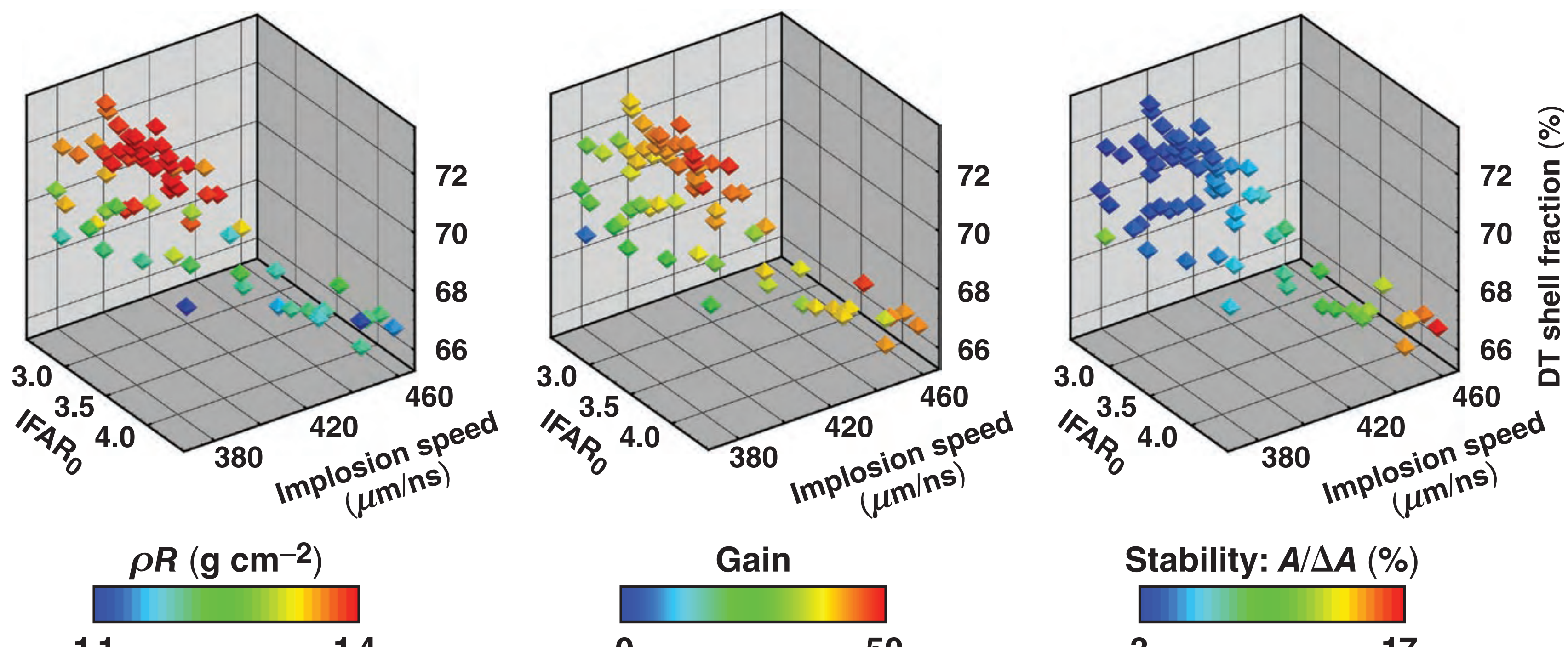
	All-DT pt. design	1.5-MJ foam
V (μm/ns)	450	409
1-D Gain	45	44
IFAR	60	33
$A/\Delta R$ (%)	30	5
ρR (g/cm^2)	1.2	1.4
Margin (%)	40	40

TC7996

*P. W. McKenty *et al*., Phys. Plasmas 8, 2315 (2001).

A downhill simplex method was used to automatically optimize the 1.5-MJ, low-IFAR design

- The design was optimized in 1-D using a postprocessor to gauge stability.
- The 7-D parameter space includes target radius, layer thicknesses, and pulse shape.
- Starting from an all-DT design, the areal density was raised, IFAR lowered, and stability improved.



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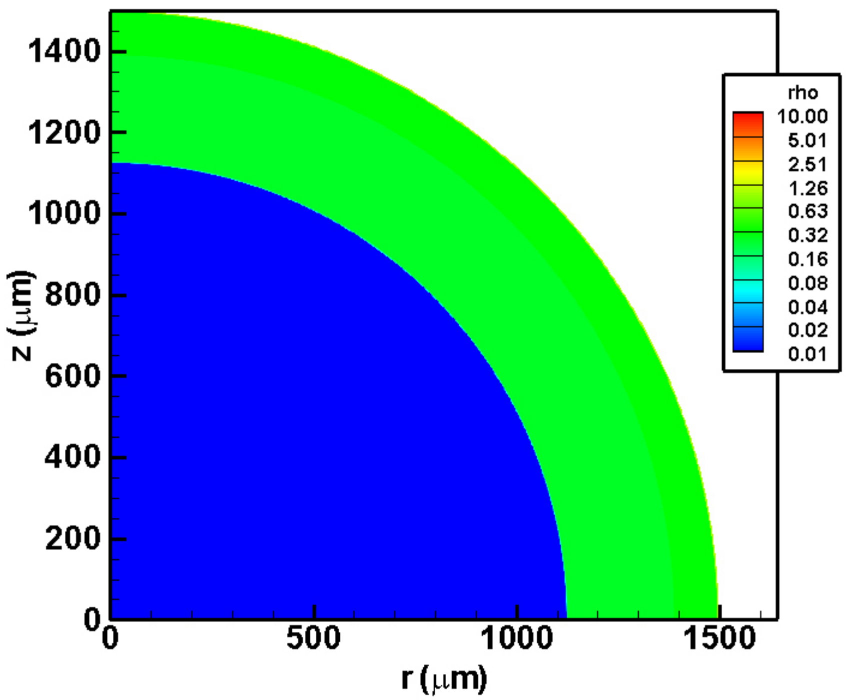
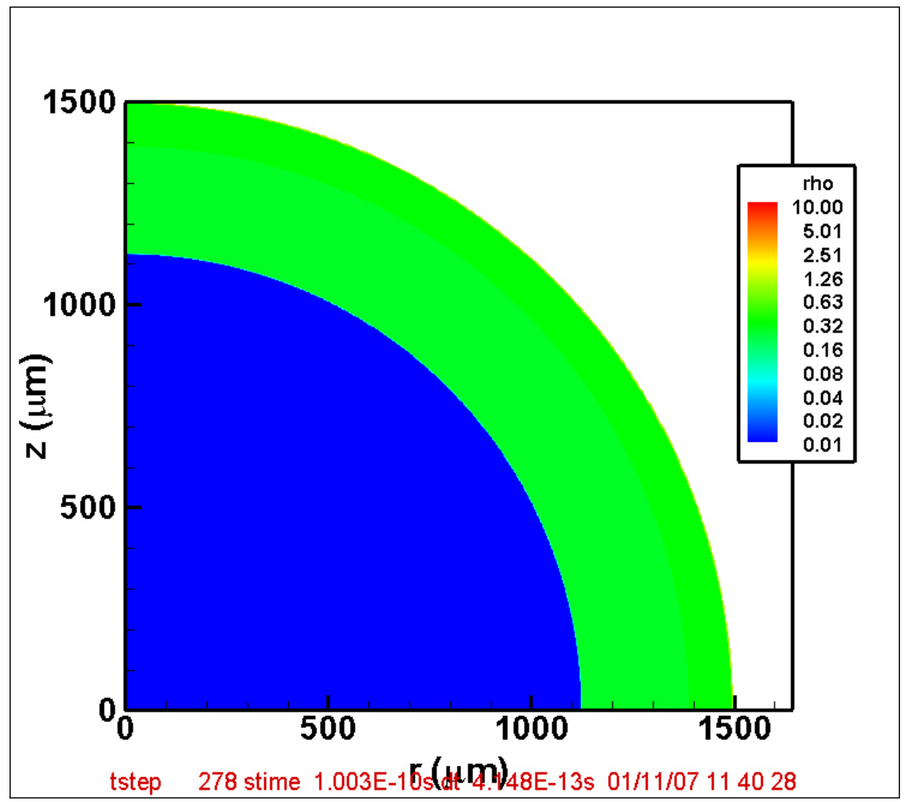
2-D SSD smoothing is also required for ignition for the 1.5-MJ wetted-foam design

Acceleration phase



1-D 1-THz SSD

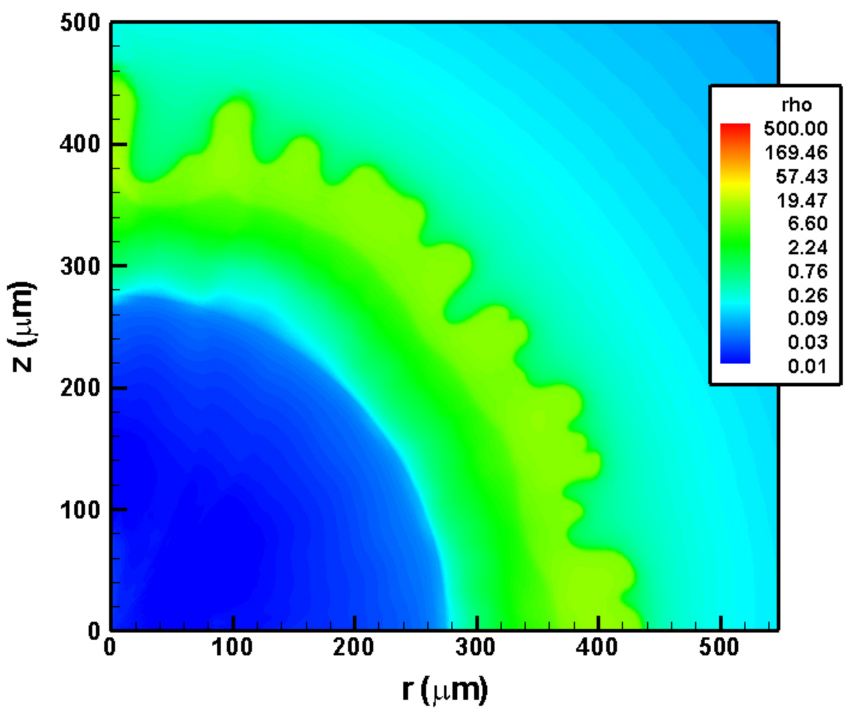


2-D 1-THz SSD

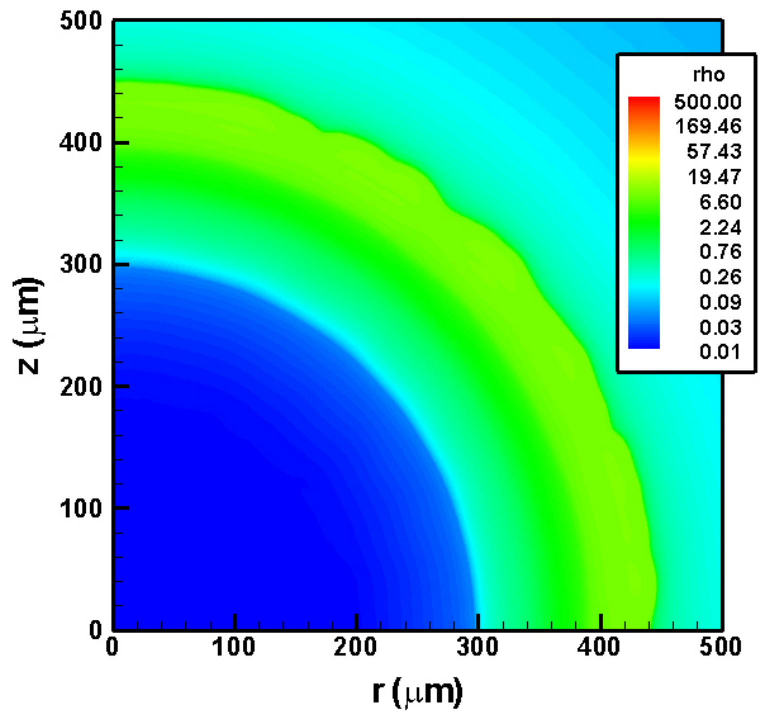
TC7994

2-D SSD smoothing is also required for ignition for the 1.5-MJ wetted-foam design

Deceleration phase



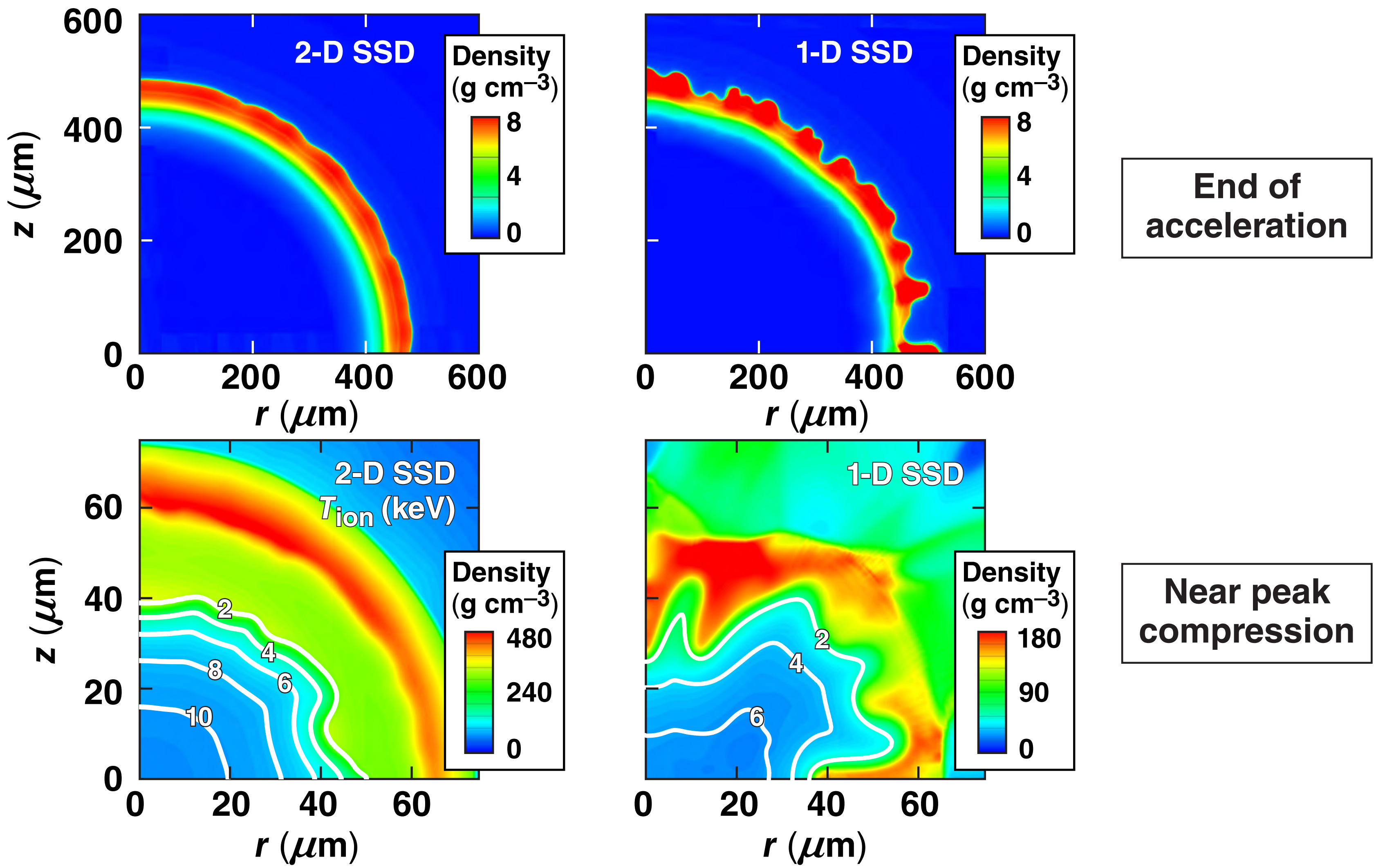
1-D 1-THz SSD



2-D 1-THz SSD

TC7995

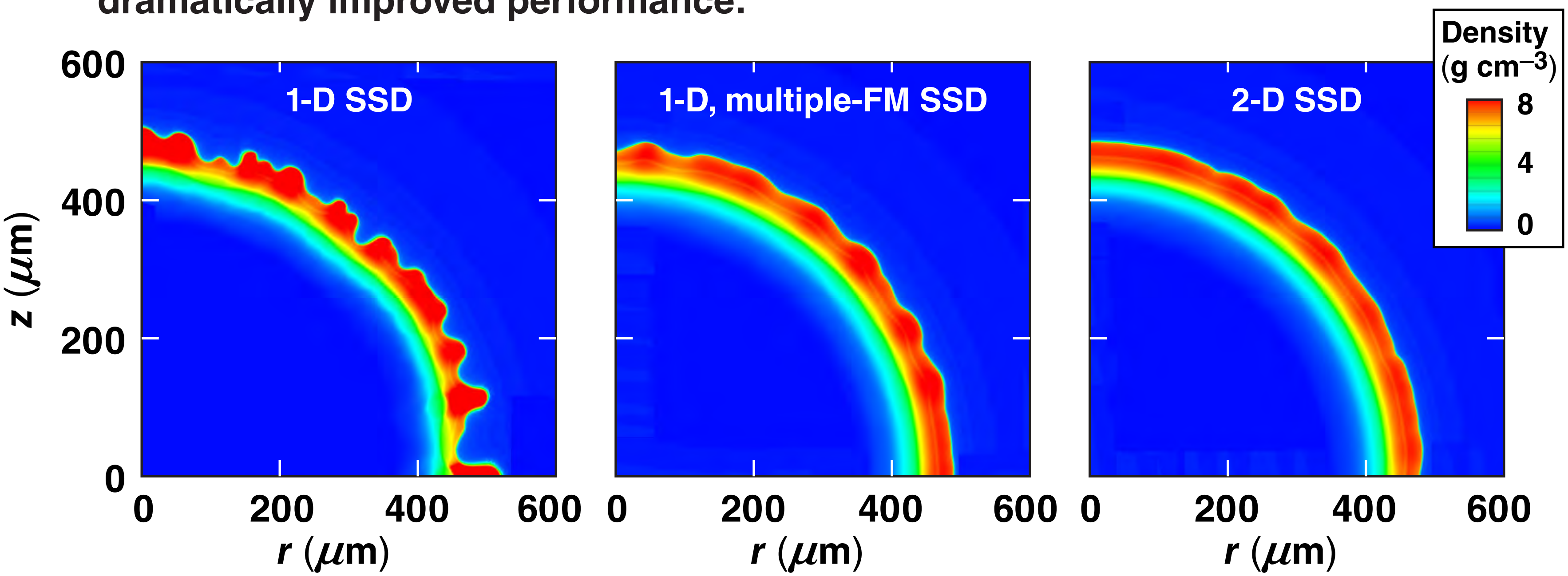
The 1.5-MJ wetted-foam target ignites with 2-D SSD but not with 1-D SSD



TC7997

Multiple frequency modulators can be used to increase the 1-D SSD single-beam smoothing rate

- The smoothing rate is increased by increasing the number of color cycles.
- The resulting resonance regions are filled with multiple frequency modulators[1].
- The 1.5-MJ design, simulated with 1-D multiple-frequency SSD, showed dramatically improved performance.



Integrated simulations at the end of the acceleration phase.

See Marozas, JO3.00013, next.

TC7944

[1]J. E. Rothenberg, J. Opt. Soc. Am. B 14, 1664 (1997).

Summary/Conclusions

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- This 1-MJ design was found to require 2-D SSD for ignition.
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- Multiple frequency modulators can be used to significantly increase the 1-D SSD single-beam smoothing rate.

The shell stability can be increased by lowering the implosion velocity and raising the in-flight shell thickness

- The most-dangerous Rayleigh–Taylor modes feed through to the inner surface and have wavelengths comparable to the shell thickness, with wave numbers $k \sim \Delta R^{-1}$.

- The linear growth of these modes depends on the in-flight aspect ratio, IFAR:

$$\text{Number of } e \text{ foldings} = \gamma t \sim \sqrt{kgt^2} \sim \sqrt{\frac{R_0}{\Delta R}} \equiv \sqrt{\text{IFAR}}$$

- The in-flight aspect ratio depends mainly on the implosion velocity and average adiabat:*

$$\text{IFAR} \sim \frac{V^2}{\langle \alpha \rangle^{3/5}},$$

where $\alpha = P/P_{\text{Fermi}}$ is the adiabat.

TC7450

*J. D. Lindl, *Inertial Confinement Fusion* (Springer-Verlag, New York, 1998).