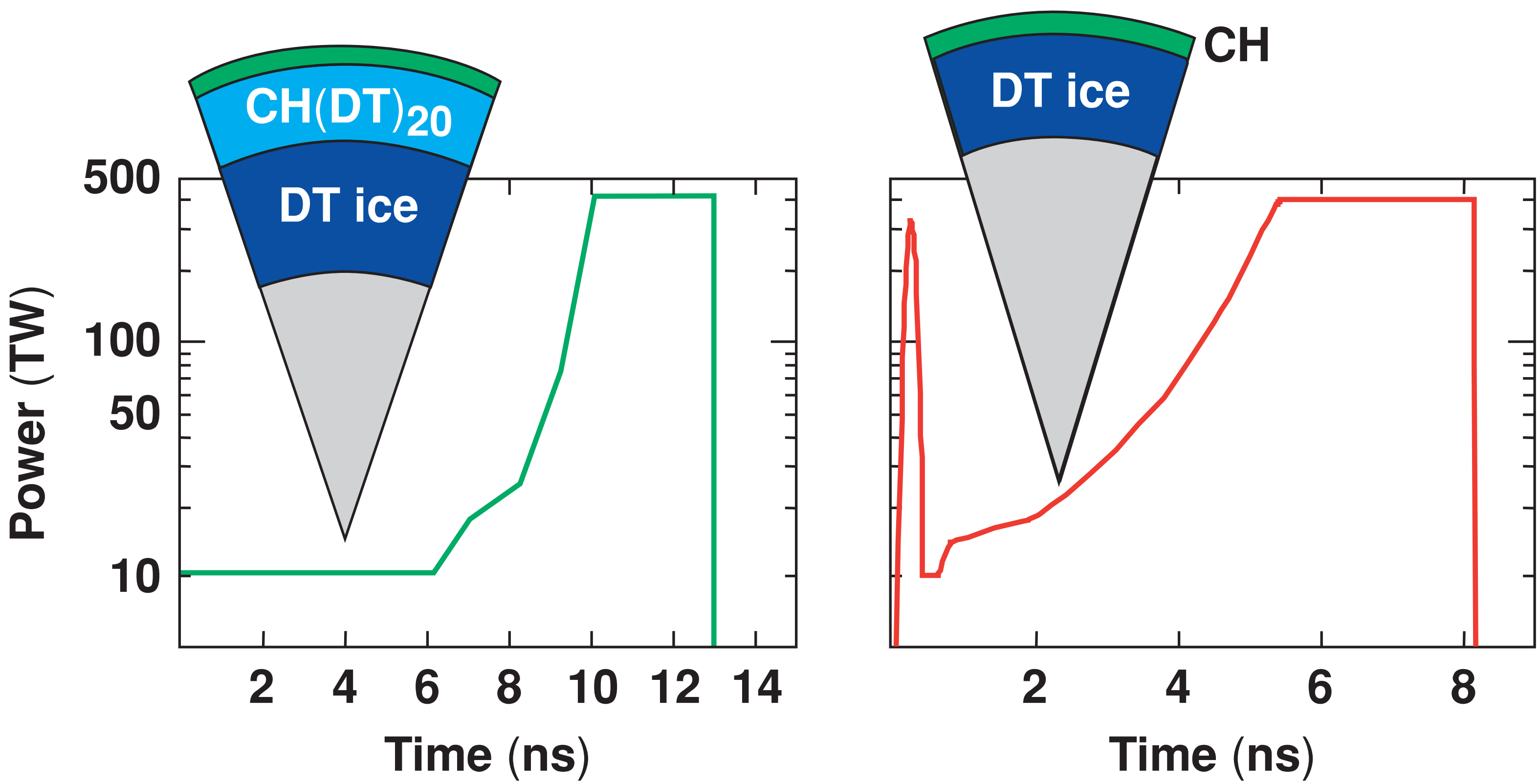
Advanced Target Designs for Direct-Drive Inertial Confinement Fusion



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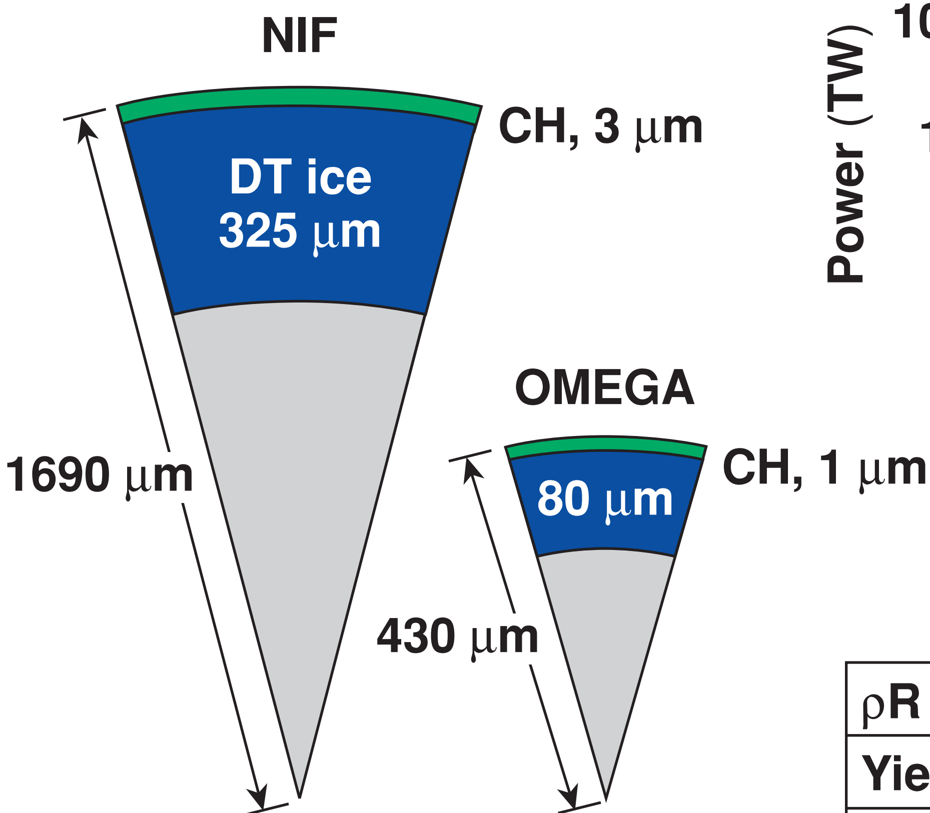
Summary

Improved-stability, high-gain designs are considered for direct-drive ICF

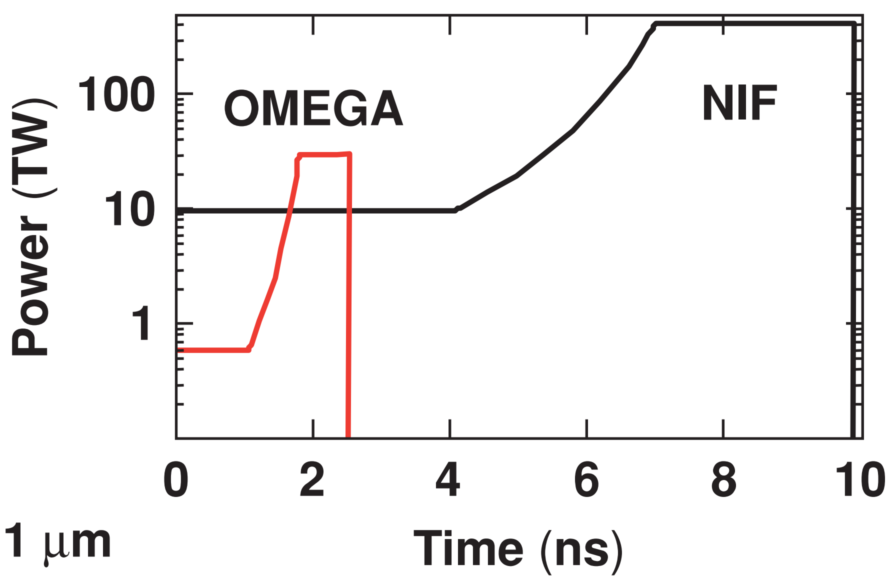
UR LLE

- Direct drive offers the possibility of significantly higher gains than indirect-drive ICF.
- New designs show significant improvements in shell stability and target gain.
- Such designs implement adiabat shaping and foams wicked with DT.
- The possibility of performing direct-drive ignition experiments in NIF's x-ray drive configuration (polar direct drive) is currently being considered.

A standard "all-DT" ignition design consists of a DT-ice layer overcoated with a thin polymer layer



α = 3 laser drive pulse



	NIF	OMEGA
ρR (mg/cm^2)	1300	300
Yield	2.5×10^{19}	1×10^{14}
Abs. (%)	62	40

TC6204

There are several disadvantages in using an "all-DT" design

- Advantages
  - Simplicity of the design
  - Easy to tune (need to control one shock and one compression wave)

- Disadvantages
  - Marginal shell stability (severe constraints on laser smoothing)
  - Low laser absorption (60% for NIF and 40% for OMEGA)
  - Moderate yields

Shell stability and compressibility depend on the adiabat

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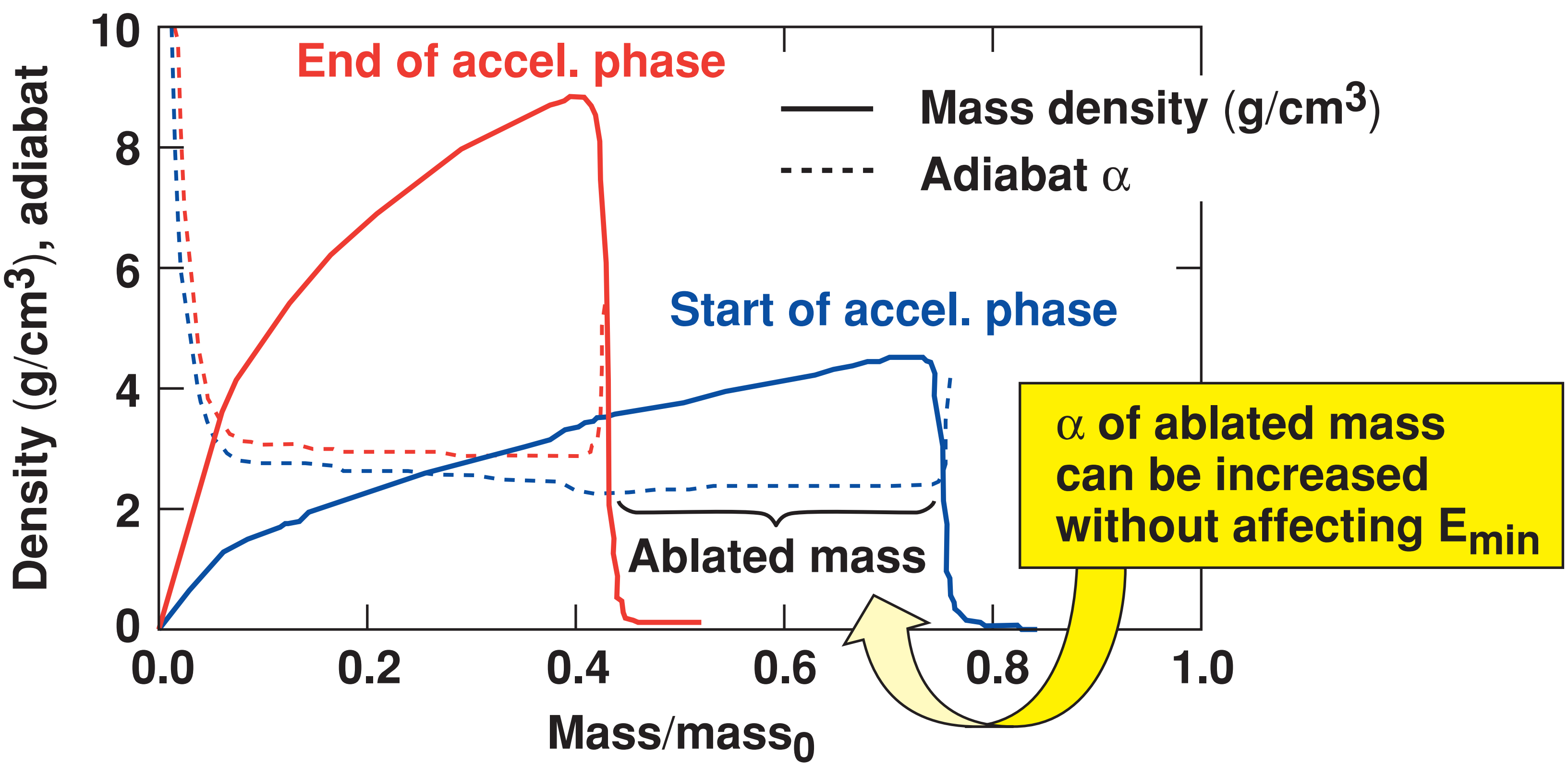
- Mimimum energy required for ignition:[1,2] $E_{min} \sim \alpha^{1.88}$
- Rayleigh–Taylor instability growth $\gamma = \alpha_{RT}(kg)^{1/2} - \beta_{RT}kV_a$

$\alpha = P/P_{Fermi}$

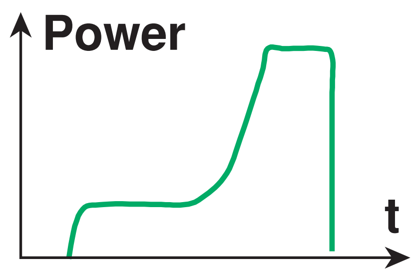
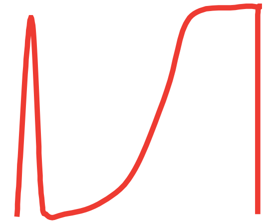
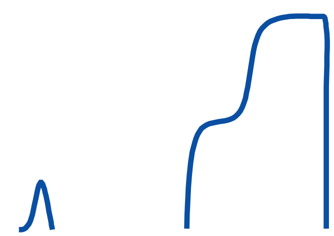
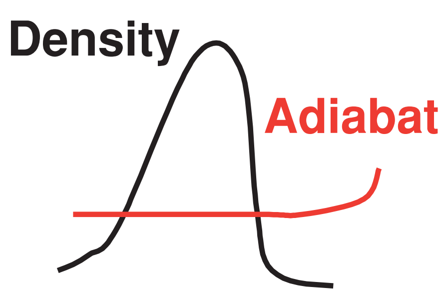
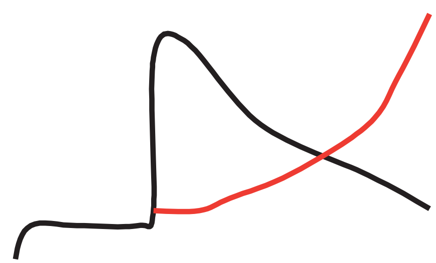
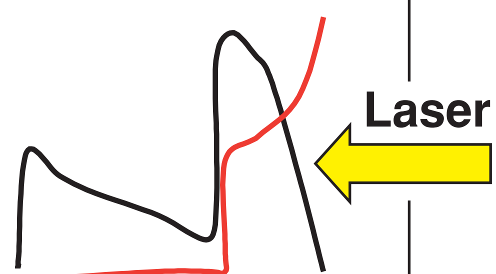
$V_a \sim \alpha^{3/5}$



[1]M. Herrmann *et al.*, Phys. Plasmas 8, 2296 (2001).
[2]R. Betti *et al.*, Phys. Plasmas 9, 2277 (2000).

TC5950a

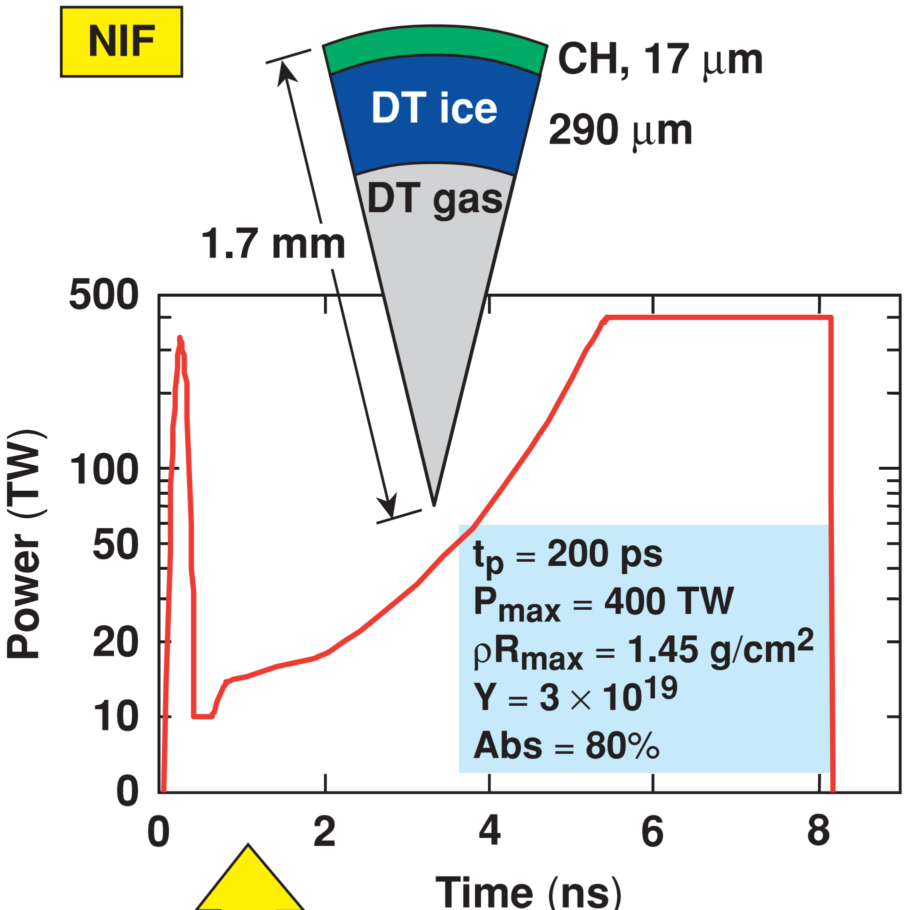
Stability of direct-drive targets can be substantially enhanced using adiabat shaping

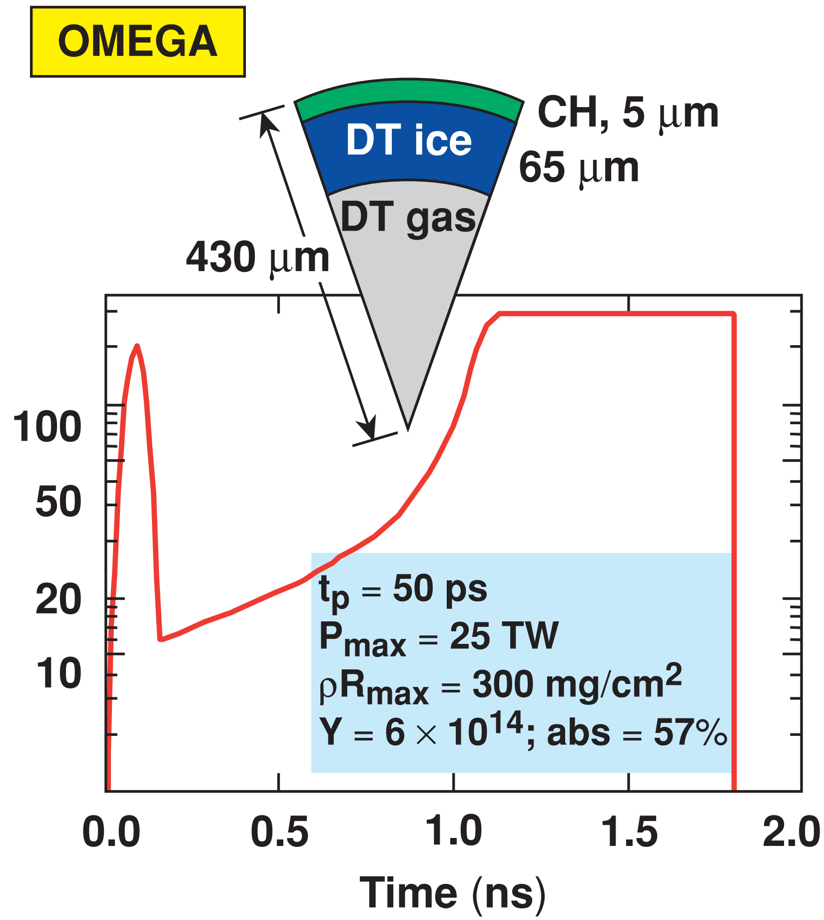
Design	Flat adiabat	Shaped adiabat	
		Decaying shock[1] (picket design)	Pressure relaxation[1]
Laser profile			
Abiabat profle			

[1] V. N. Goncharov *et al.*, Phys. Plasmas 10, 1906 (2003).
[2] K. Anderson *et al.*, submitted to Phys. Plasmas.

TC6207

α=3 picket-pulse target designs are considered for the NIF and OMEGA





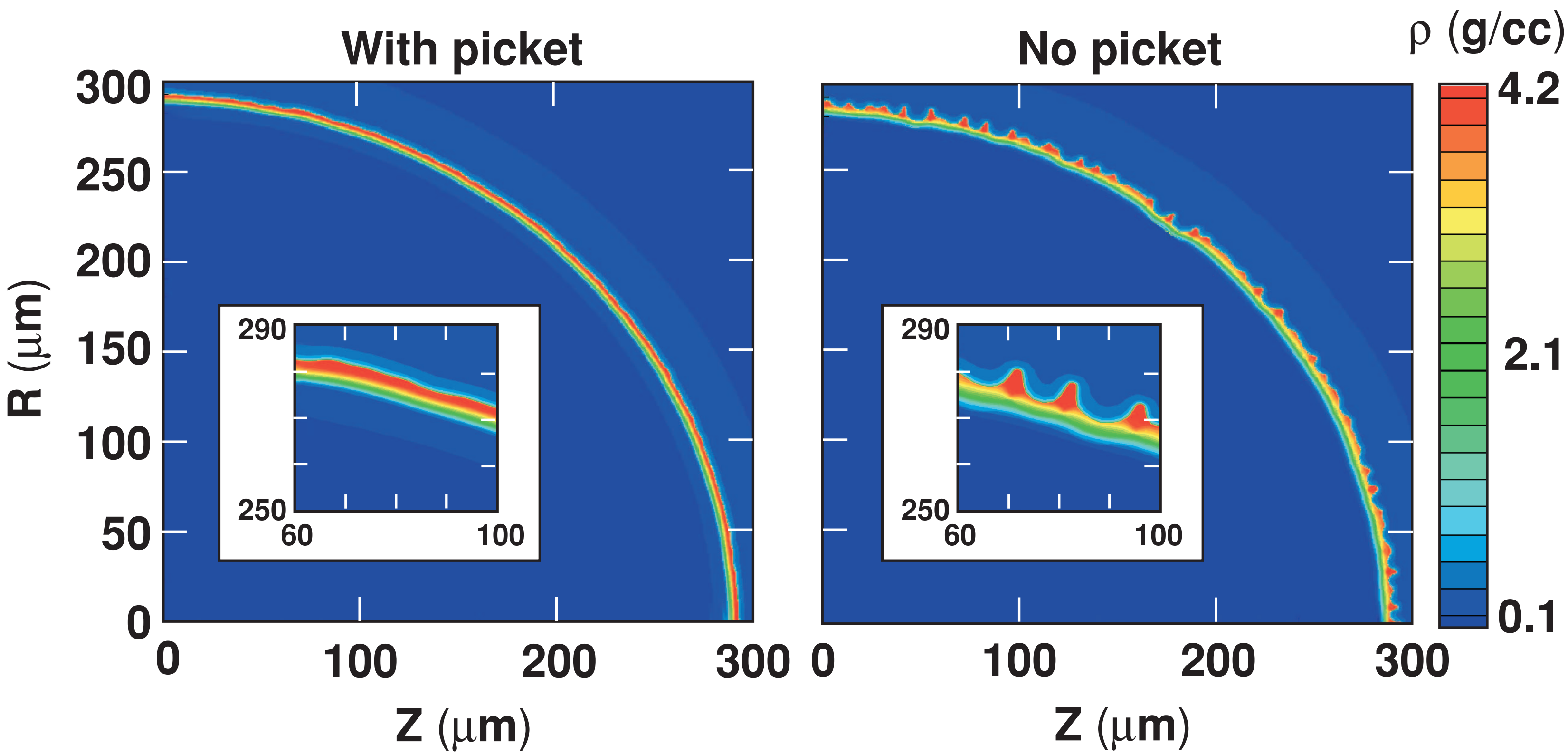
A potential target for polar direct drive

TC6208

Multimode *ORCHID* simulations demonstrate better stability of the shaped-adiabat design

UR LLE

Imprint simulations: ℓ = 2–200, DPP + PS, 1-THz SSD; OMEGA design

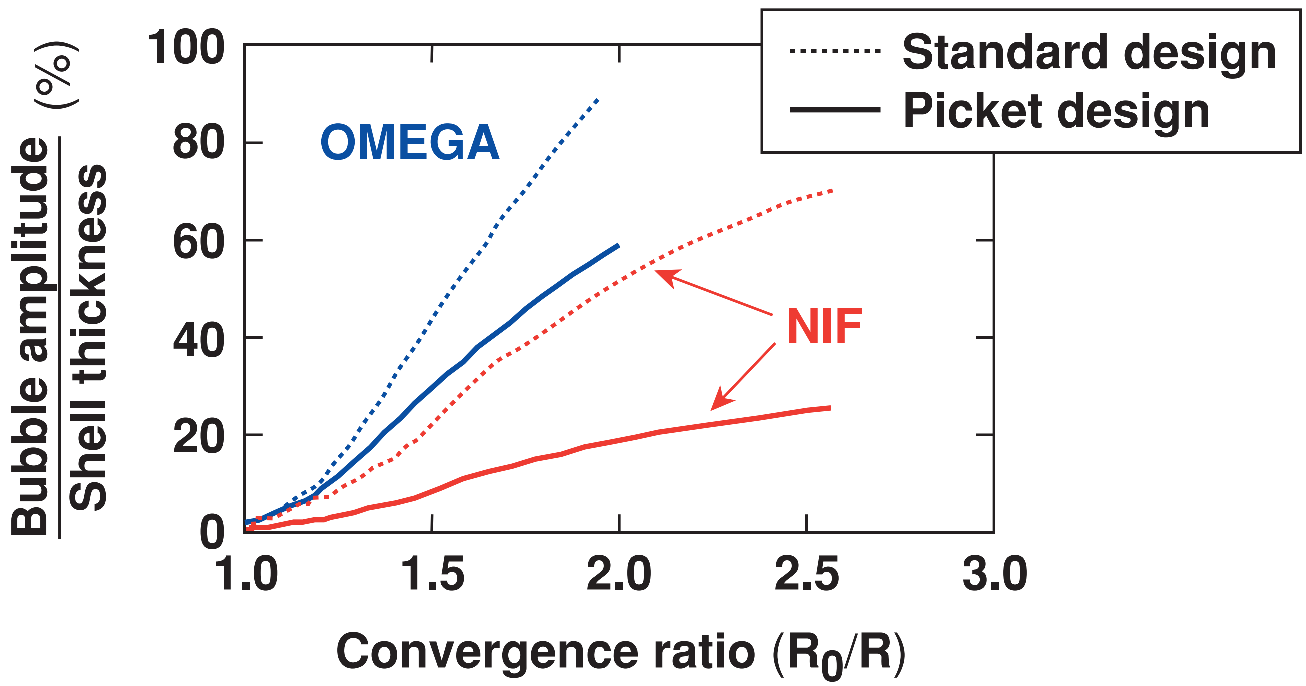


Shell is significantly less distorted in the picket design.

TC5957

Both NIF and OMEGA picket designs are predicted to stay intact during the acceleration phase

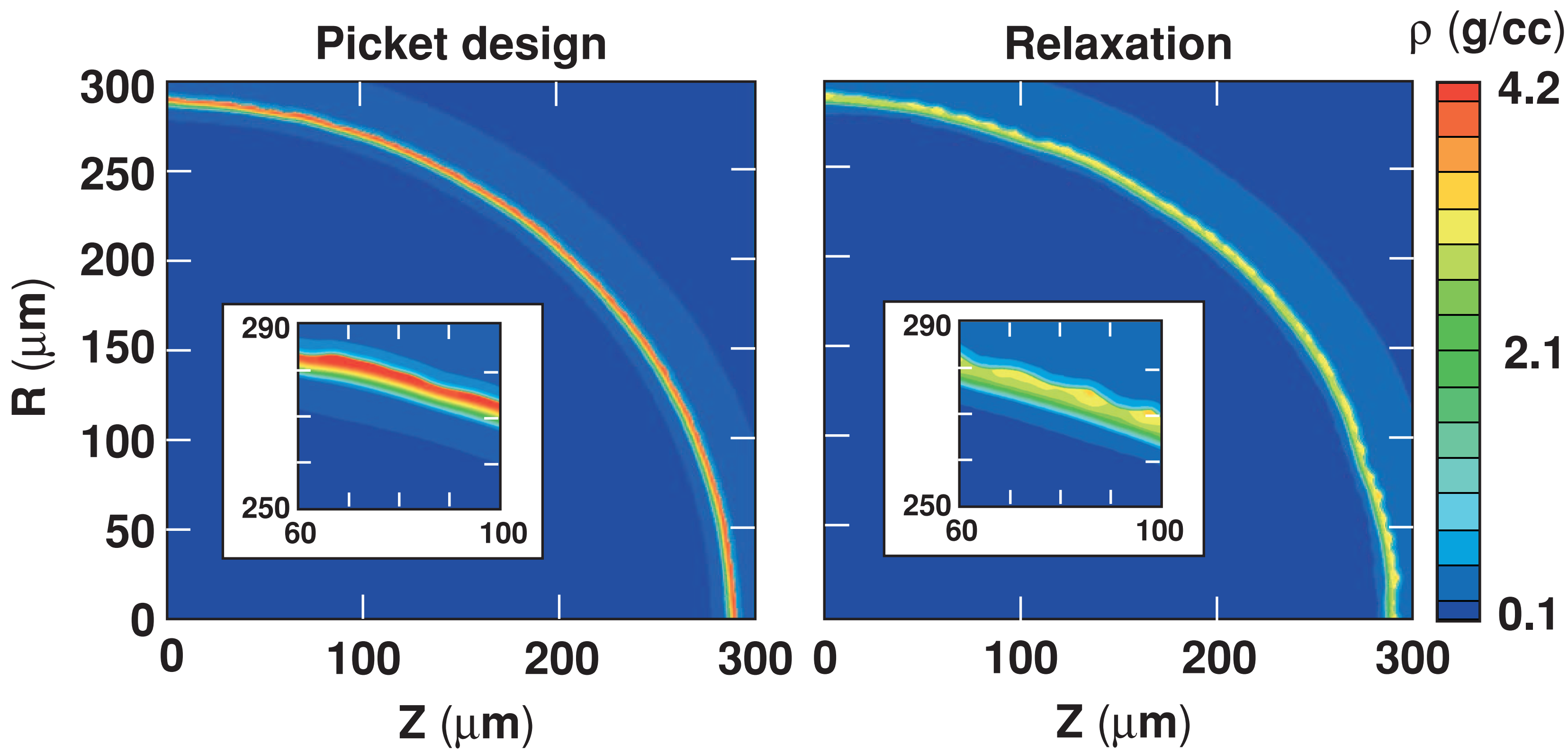
- 1-THz, 2-D SSD; 80-nm outer-surface roughness; 1-μm inner-ice roughness
- The bubble amplitude is calculated using the stability postprocessor.[1]



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

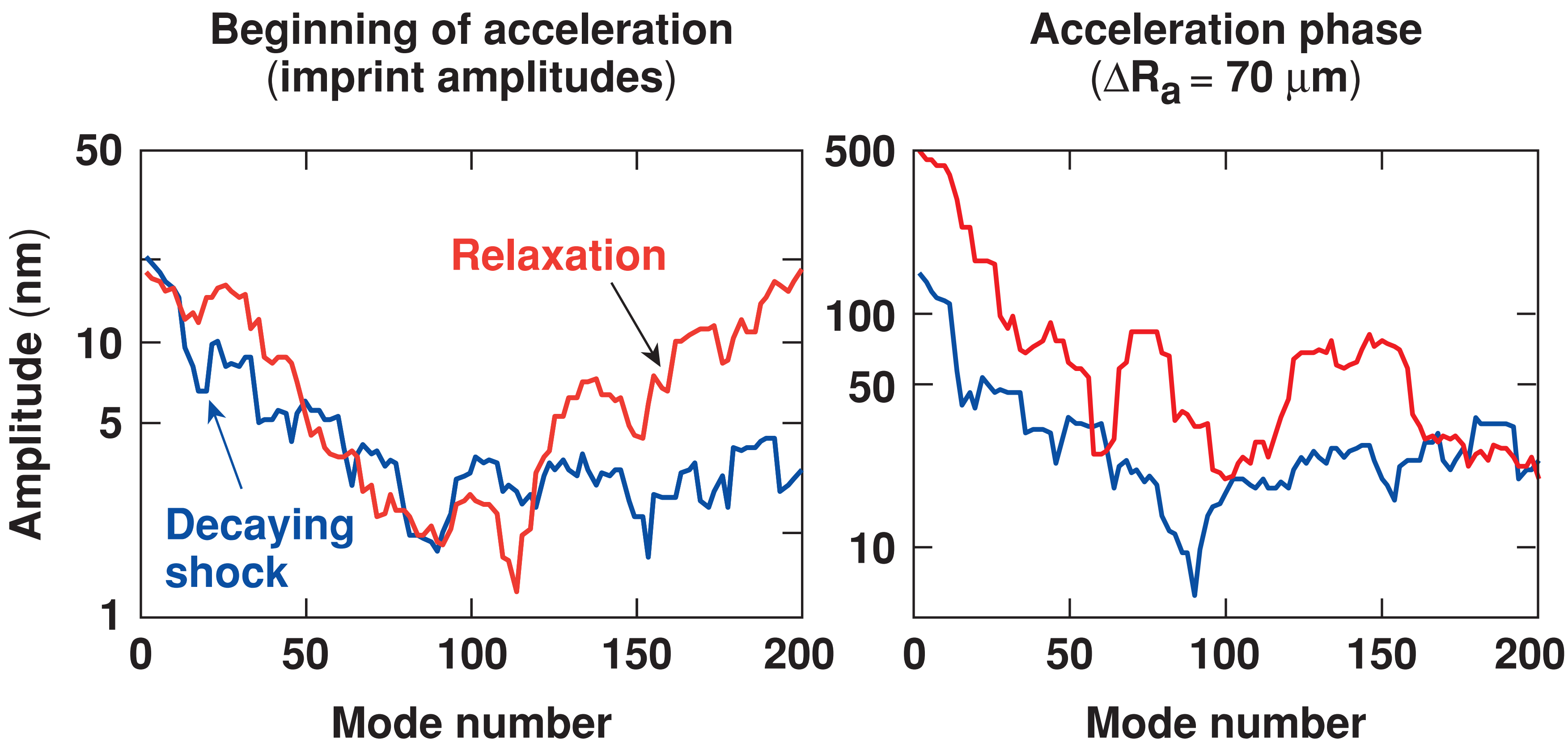
TC6209

2-D *ORCHID* simulations of an OMEGA target show higher nonuniformity levels in the relaxation design



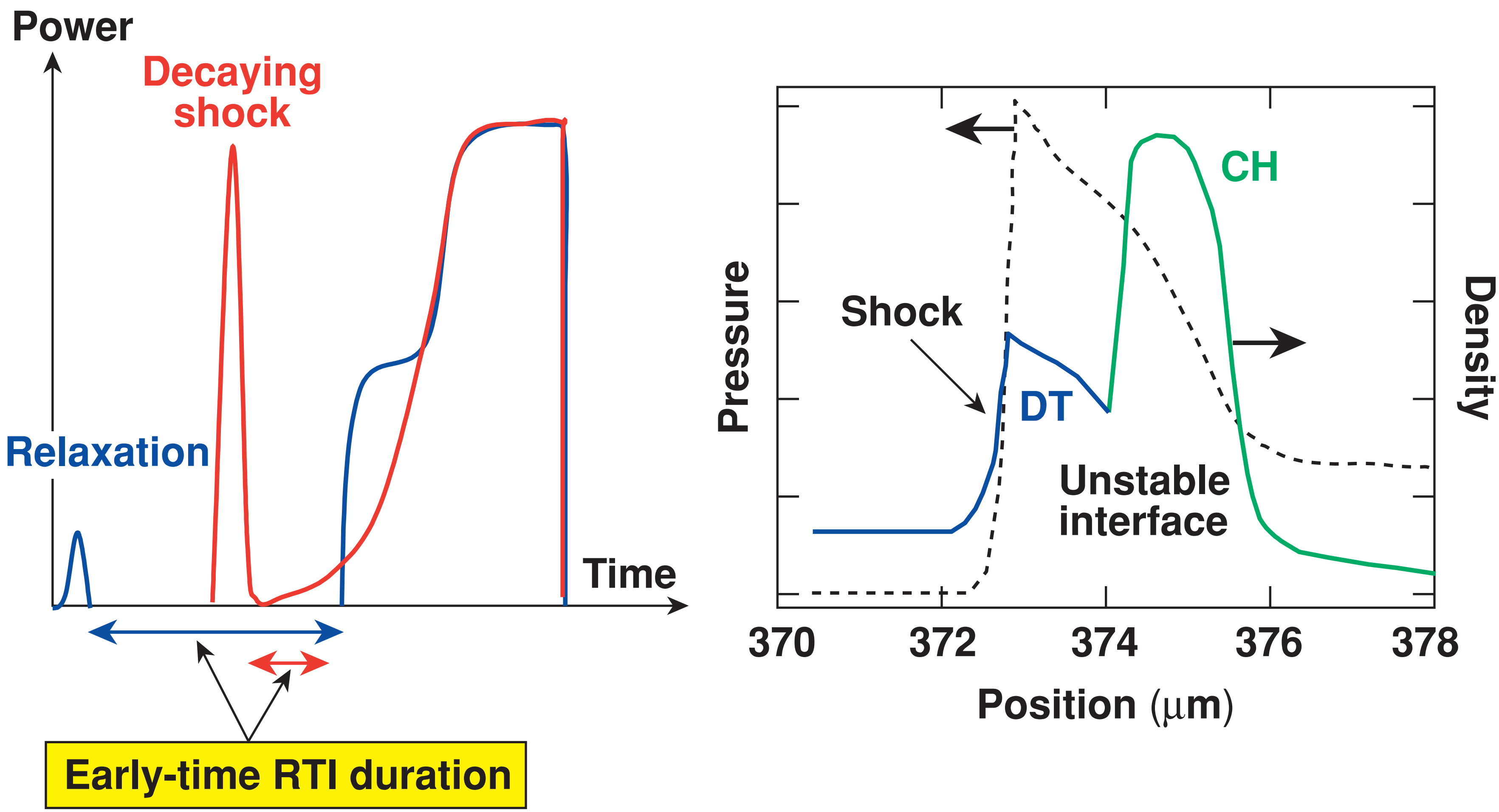
TC6215

Mode decomposition reveals enhanced high ℓ-mode amplitudes in the relaxation design



TC6216

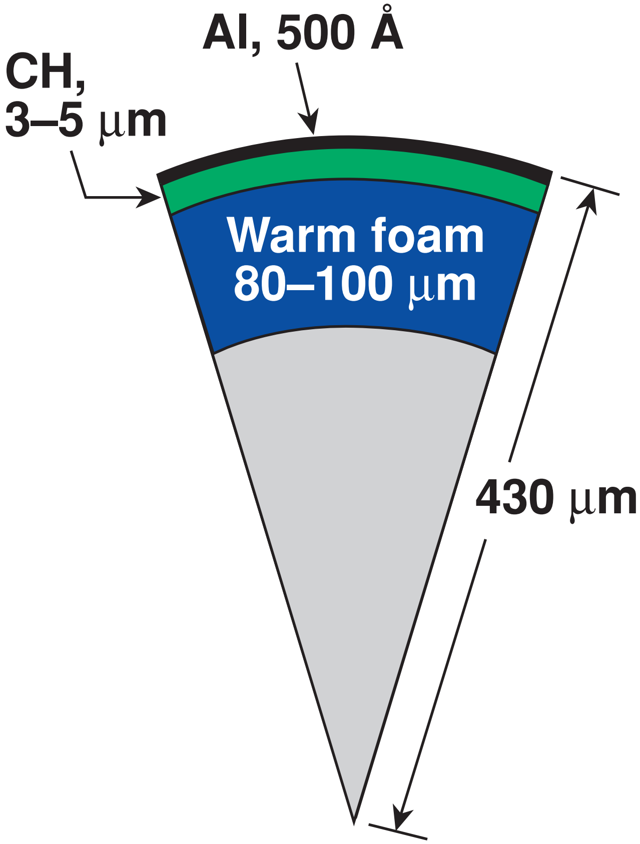
High ℓ-mode enhancement is due to early-time Rayleigh–Taylor growth



TC6217

A surrogate foam target is proposed to mimic conditions of the cryogenic designs

- Cryogenic targets cannot be routinely used to study details of implosion.



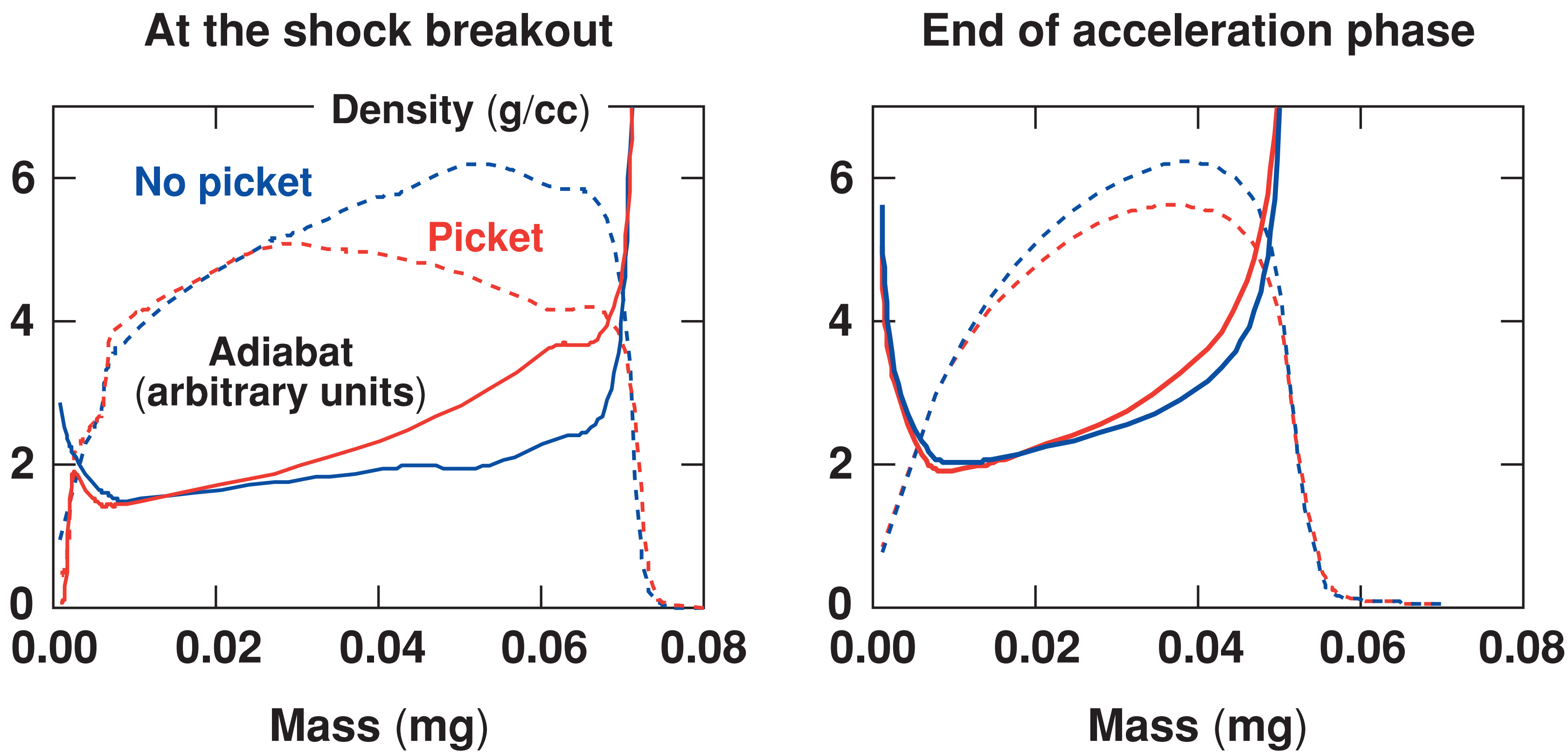
<u>Requirements for a surrogate:</u>

1. Design should capture early RT growth.
   - Density ratio overcoat/foam = 3 to 4
   - Overcoat thickness 3 to 5 μm
2. Adiabat shaping is not compromised by radiation from corona ($\rho < 500$ mg/cc, restrictions on high-*Z* constituents).
3. No additional instabilities are created ($\rho > 150$ mg/cc).
   - An unstable radiation ablation front is created in low-density foams.

The optimal foam density is 180 to 250 mg/cc.

TC6218

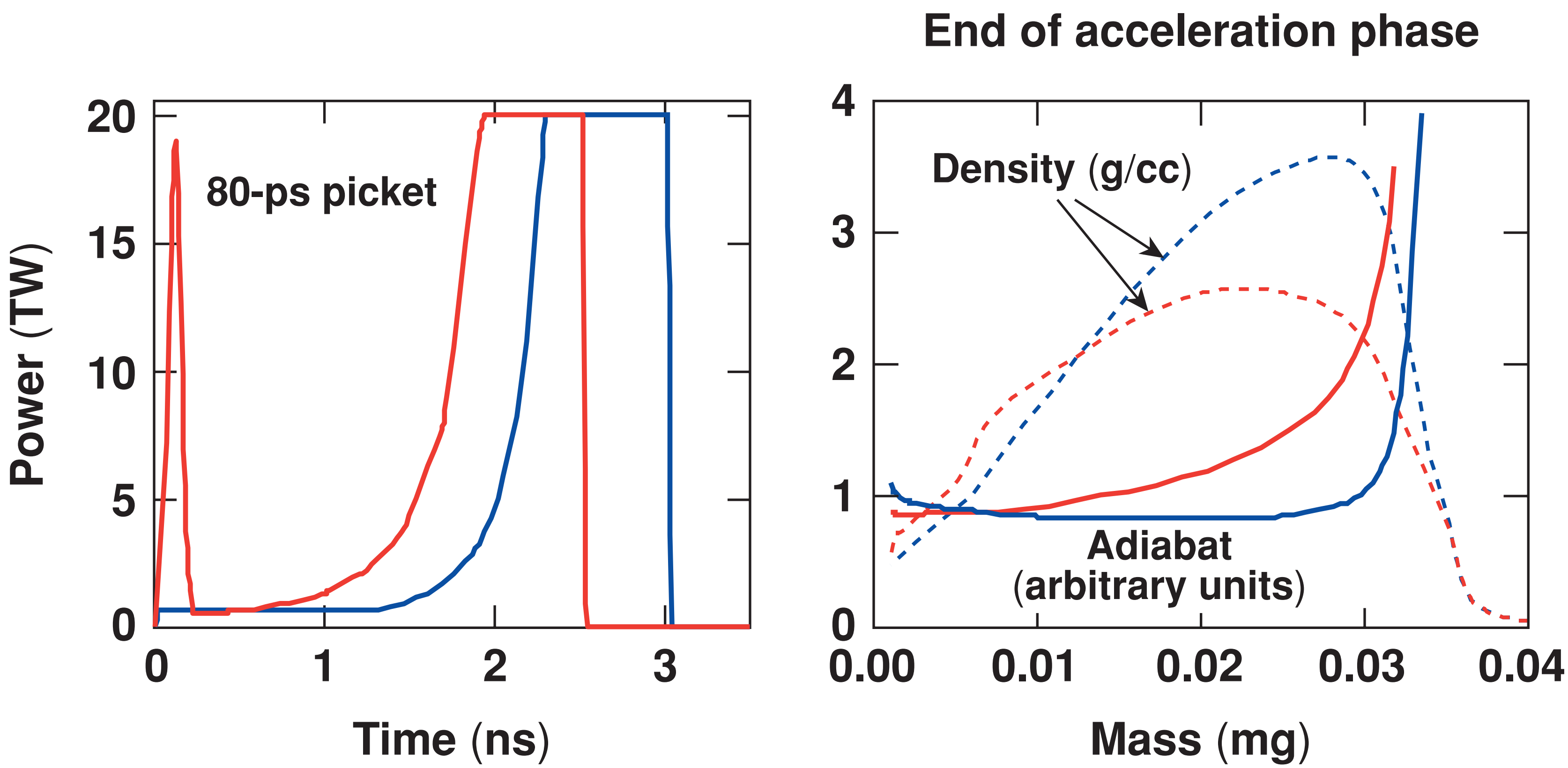
Adiabat shaping is compromised by coronal radiation in CH shells



TC6219

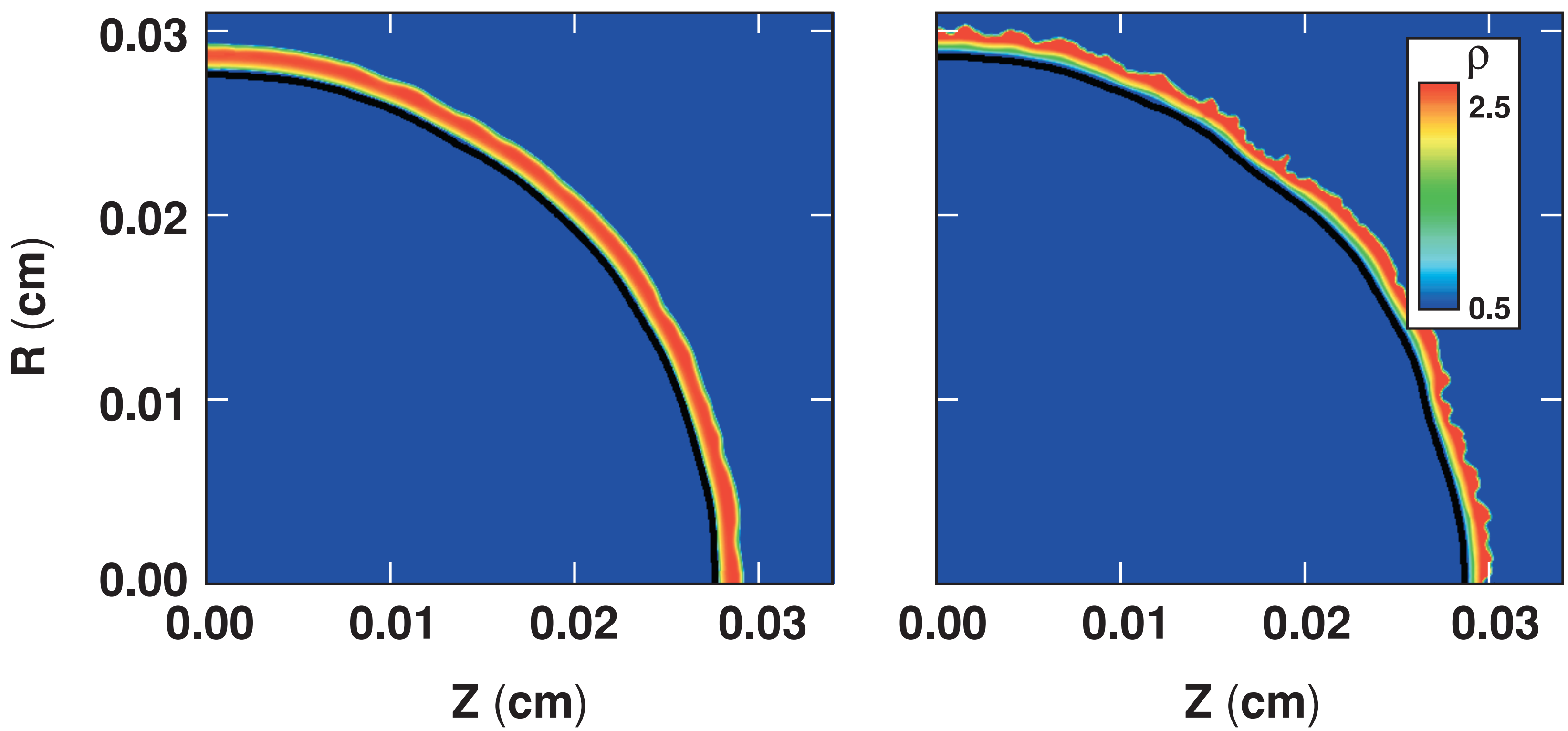
Adiabat shaping is maintained throughout the implosion in 200-mg/cc foam design

$Y = 1.7 \times 10^{11}$ for 15-atm-D_2 fill, ρR_{total} = 166 (no picket), 162 (picket) mg/cm^2



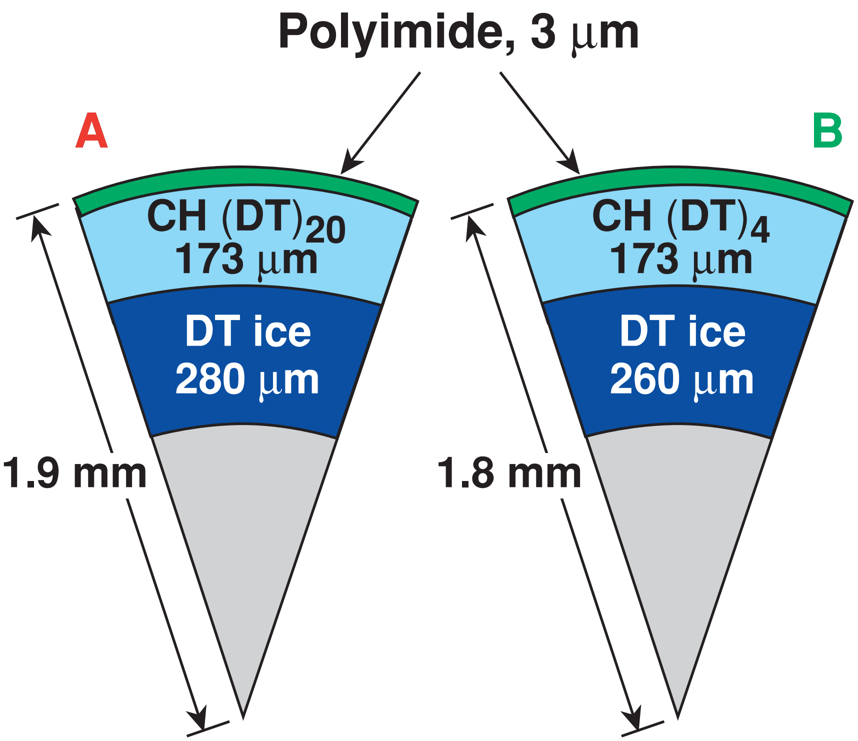
Multimode *DRACO* simulations indicate greater shell stability in the picket design

OMEGA foam target (200 mg/cm^3) with 5-μm-CH overcoat
(modes 2 to 200; 1-THz, 2-D SSD with PS)



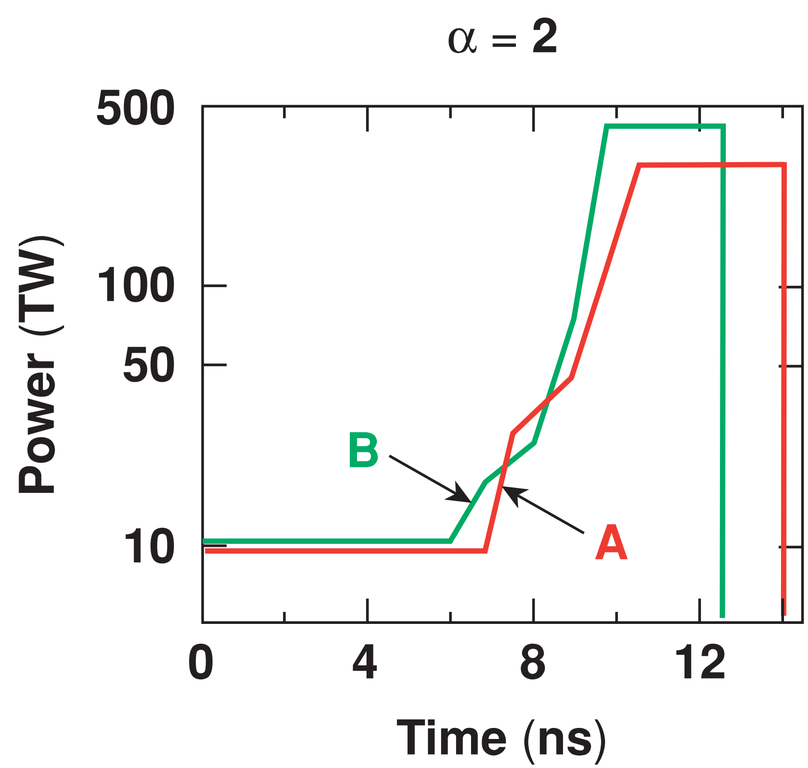
TC6221

High-gain "wetted foam" designs have been considered for the NIF



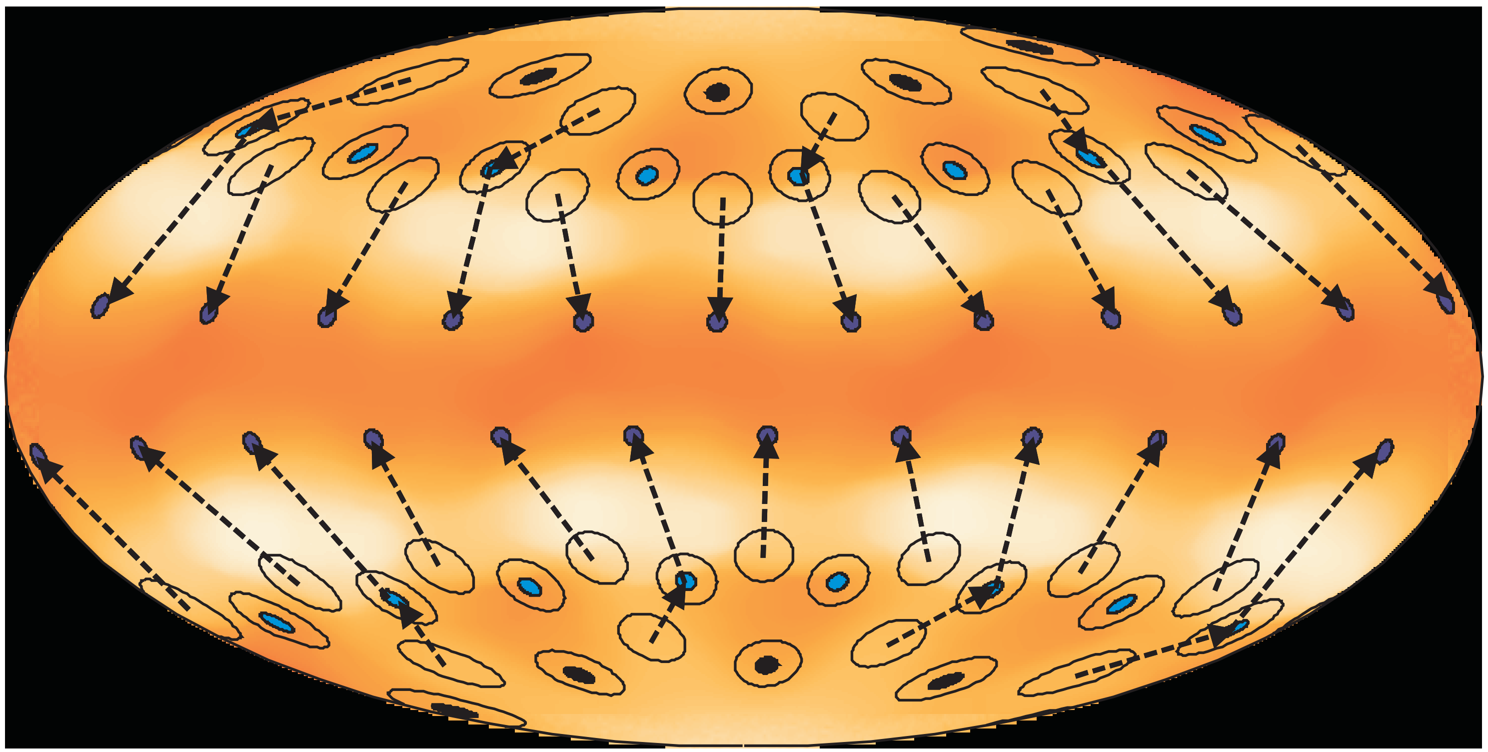
$G = 124$
$V_{imp} = 3 \times 10^7$ (cm/s)
$\rho R_m = 1.7$ g/cm^2
Abs = 85%

$G = 82$
$V_{imp} = 3.9$
$\rho R_m = 1.5$
Abs = 86%



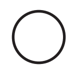
TC6222

The possibility of performing direct-drive ignition experiments in NIF's x-ray drive configuration (polar direct drive) is currently considered[1]



σ_{rms} = 0.9%
n = 2.5 beams

At t = 0 with 100% absorption



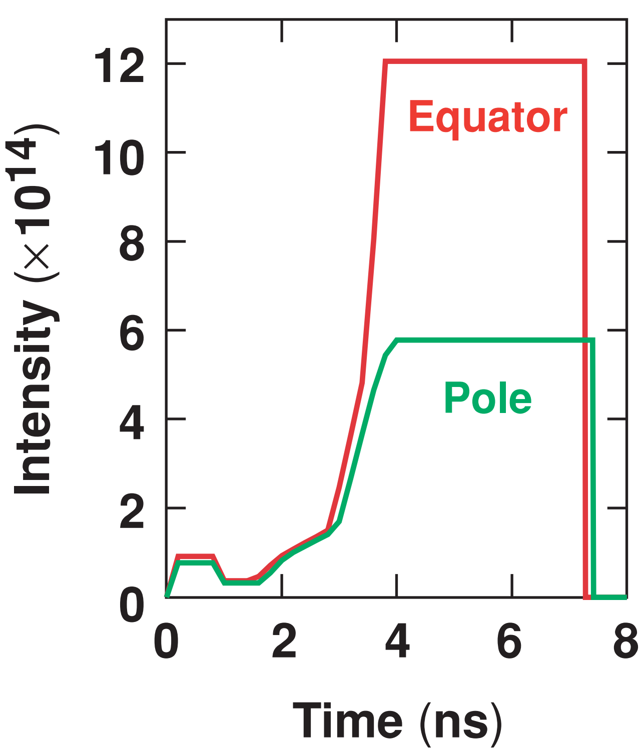
NIF x-ray drive beam ports

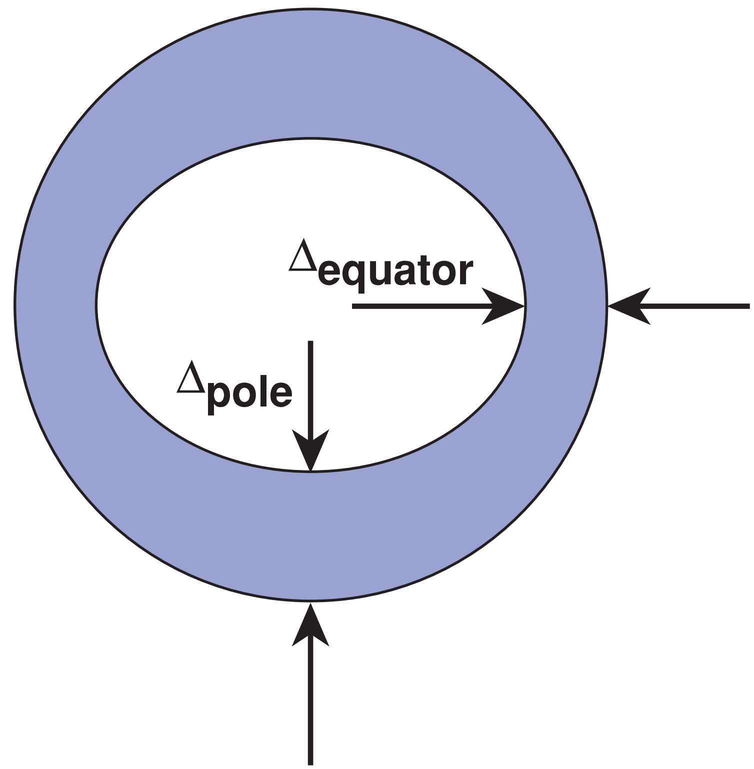
48 beam direct-drive directions

[1] See W03 by R. S. Craxton.

TC6151a

Angular-dependent pulse shaping and target shimming are considered to achieve implosion symmetry





TC6223

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