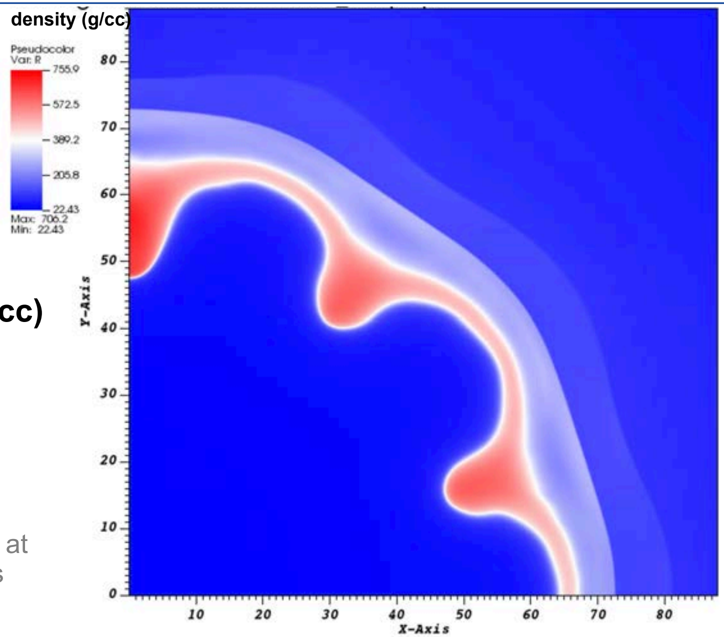
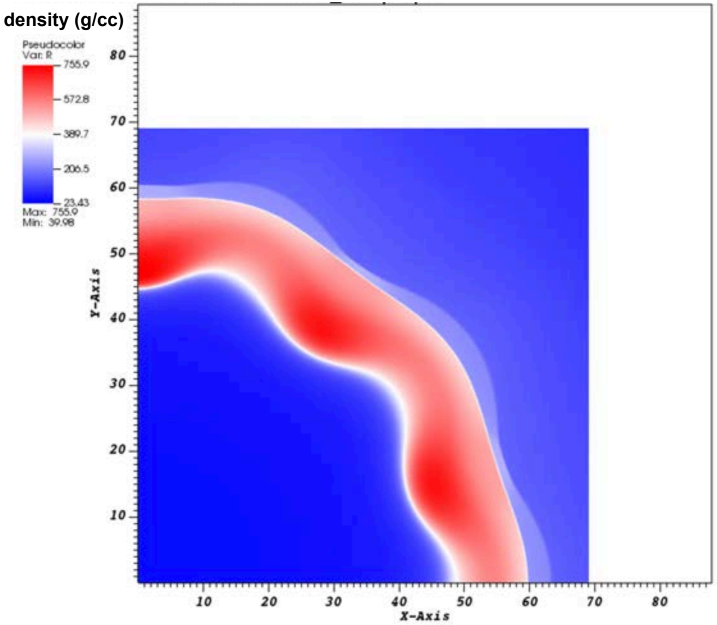
Deceleration Phase Rayleigh-Taylor Growth in Dynamic Shell Inertial Confinement Fusion Designs

Mode ℓ = 10, High Central Density (ρ_{c0} ~ .056 g/cc)





Mode ℓ = 10, Low Central Density (ρ_{c0} ~ .025 g/cc)

Both plots taken at ~10^{27} neutrons/s

Yousef Lawrence
University of Chicago &
Laboratory for Laser Energetics

63rd Annual Meeting of the American Physical Society Division of Plasma Physics
8–12 November 2021

Summary

The dynamic shell concept can significantly reduce deceleration phase Rayleigh-Taylor (RT) growth by lowering the central density

UR LLE

- Dynamic shell formation enables lower central densities for direct drive implosions*
- Lower central density enhances deceleration RT stabilization effects (e.g. mass ablation)
- 2-D simulations show significant suppression of deceleration RT for all modes tested (ℓ = 2, 4, …, 20, 24, 30, 40) when using a low central density

*** V. Goncharov, previous talk**

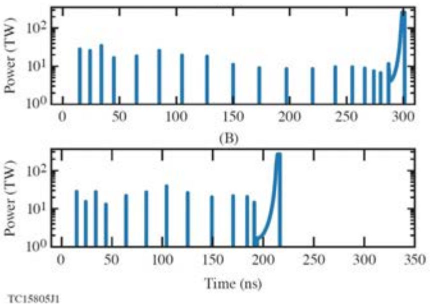
Collaborators

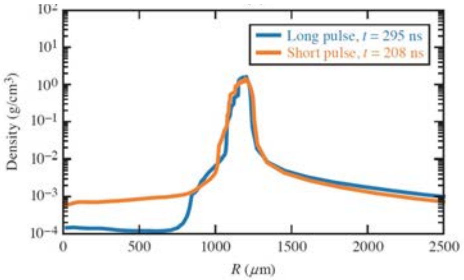
Valeri Goncharov, Will Trickey, Igor Igumenshchev, Jack Woo, Jonathon Caroll-Nellenback, Laboratory for Laser Energetics, NSF REU

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0003856 and ARPA-E BETHE Grant No. DE-FOA-0002212.

Low central density enhances deceleration RT stabilization effects

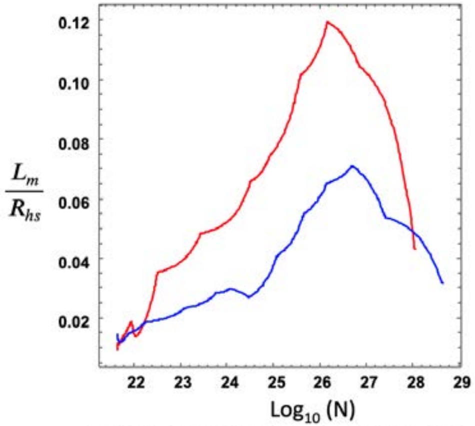
- Dynamic shell formation allows for greater control over central density
  - Short pulse → high central density
  - Long pulse → low central density

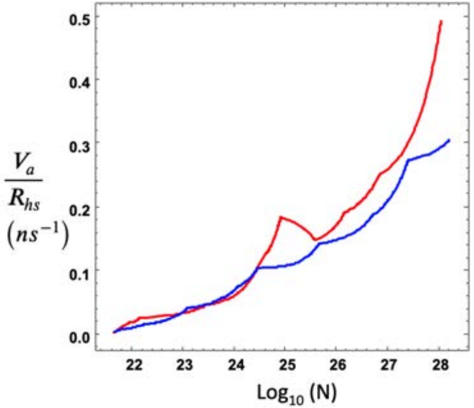




- With low central density: shorter deceleration distance → less perturbation amplification
- Longer density scale length, L_m → reduces effective Atwood number
- Higher ablation velocity, V_a → greater mass ablation

$$V_a = C_{va}\frac{T_{hs}^{5/2}}{r_{hs}\rho_{sh}}$$





DEC2D was used to simulate deceleration phase of dynamic shell implosions

UR LLE

DEC2D: hydro + thermal + (radiation) + (alpha)

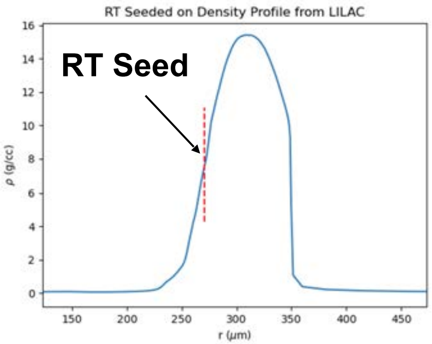
Time — **1-D *LILAC*** — **Deceleration phase** → **Stagnation**

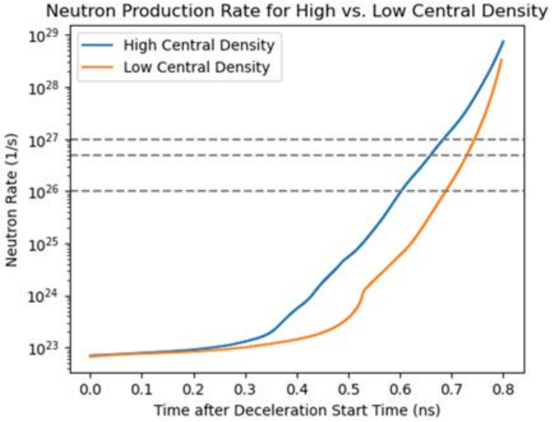
t = 0

Initial data = r, ρ, P, v, T_e, T_i

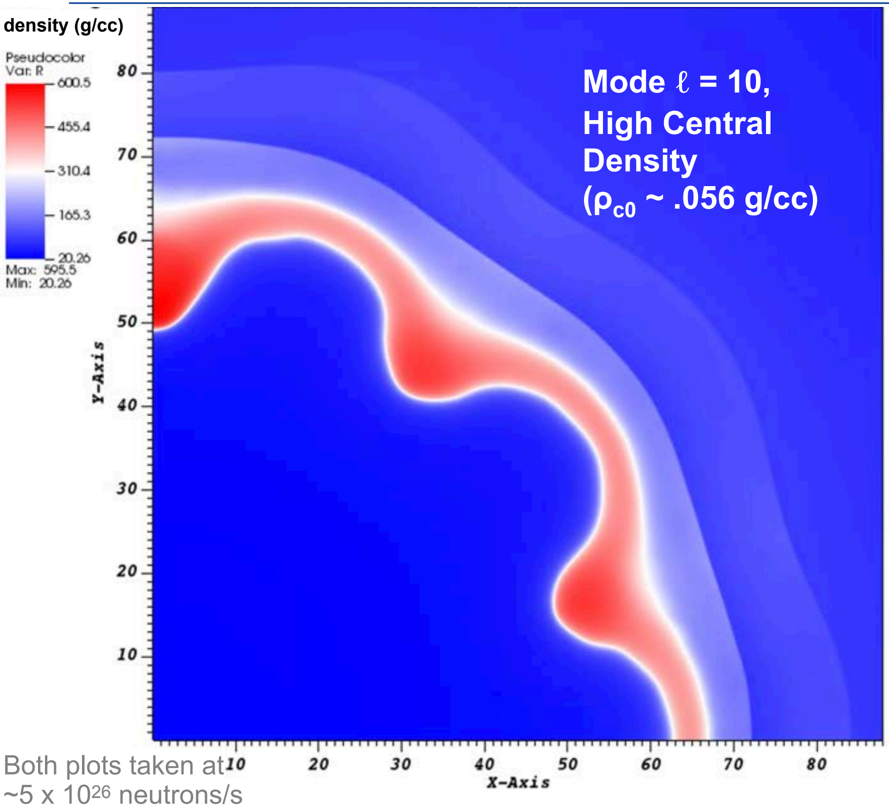
Impose mode perturbations:
ℓ = 2, 4, … 20, 24, 30, 40

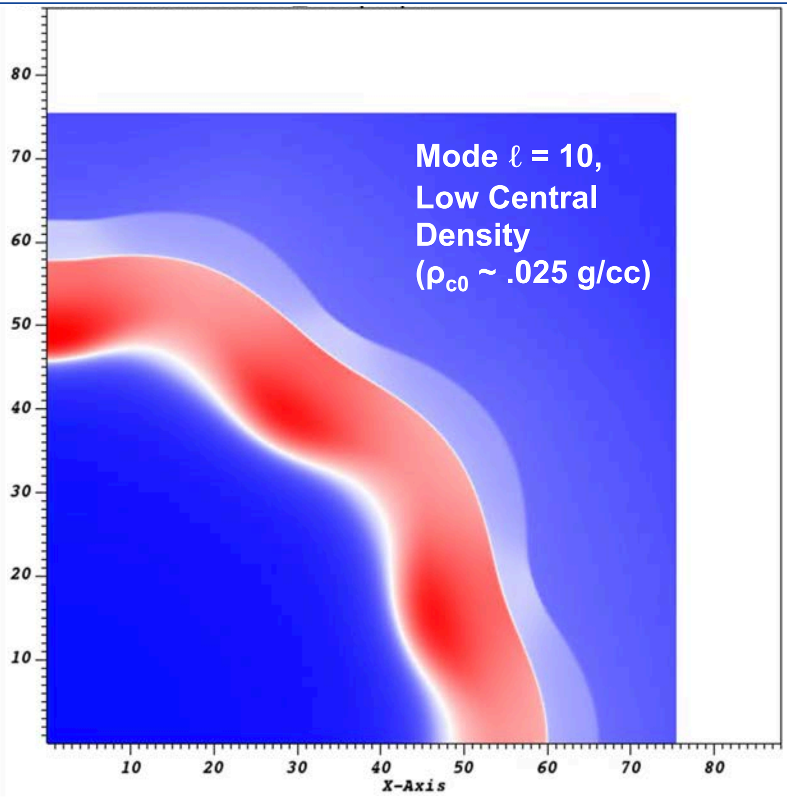
Initial velocity perturbations:
$U_{2\text{-}D} = U_{1\text{-}D} + \Delta U\, Y_\ell(\theta)$





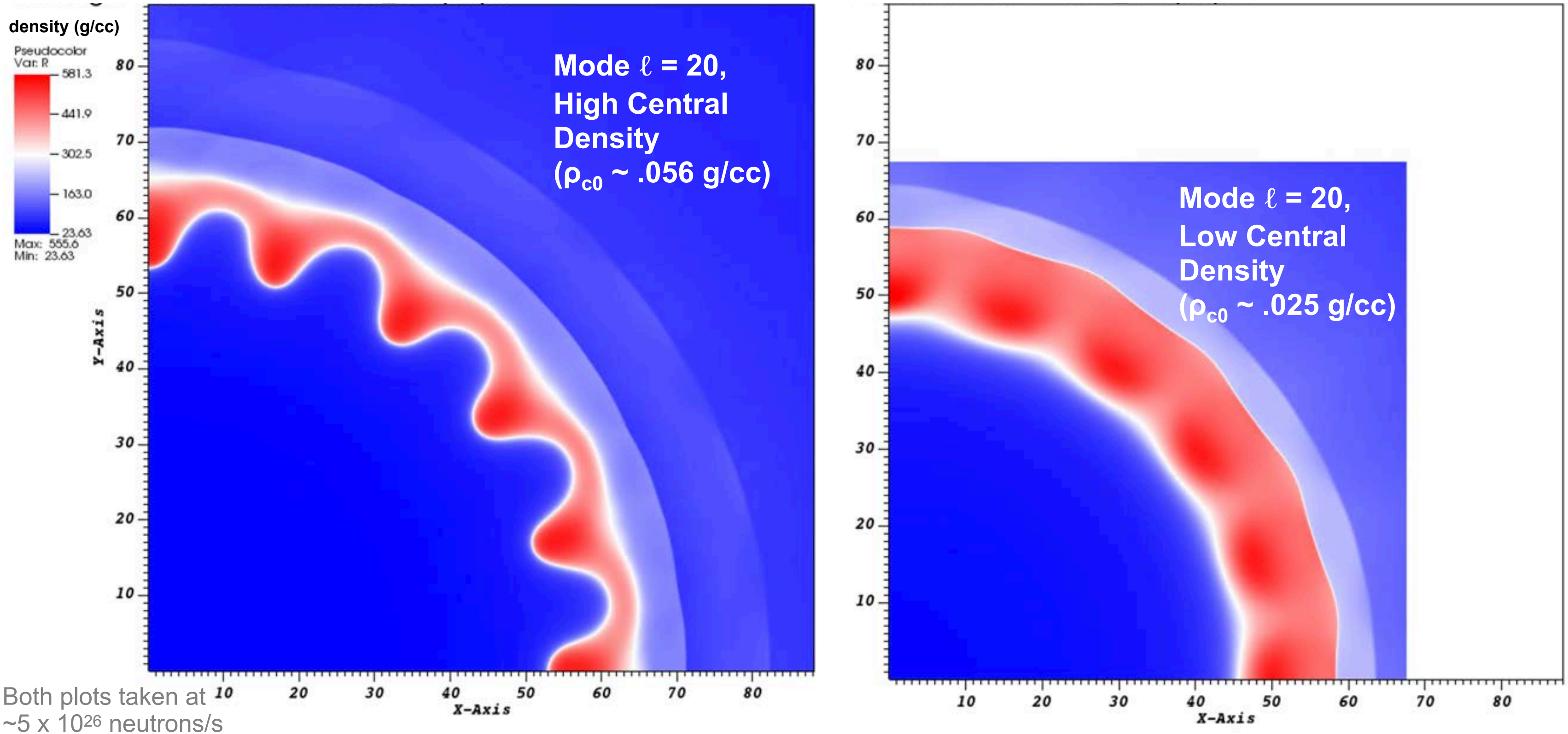
Density maps from DEC2D simulations show less RT growth for low central density targets





Both plots taken at
~5 x 10^{26} neutrons/s

Density maps from DEC2D simulations show less RT growth for low central density targets (cont.)

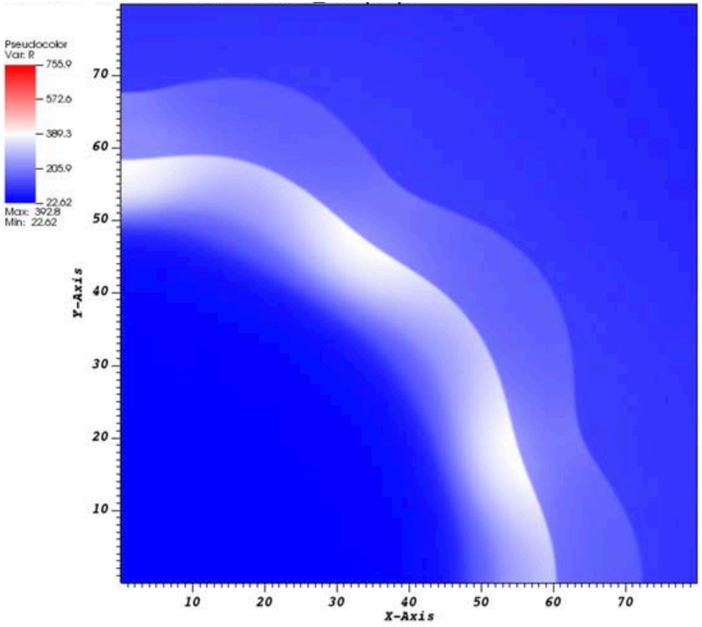


Both plots taken at
~5 x 10[26] neutrons/s

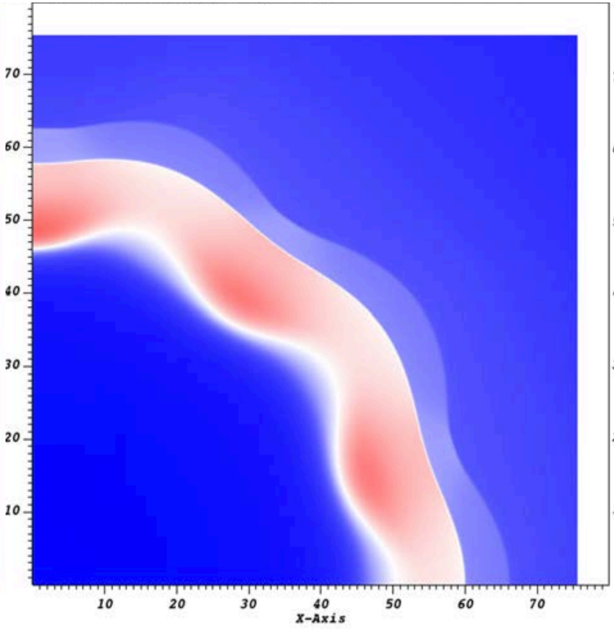
Density maps from DEC2D simulations show less RT growth for low central density targets (cont.)

UR LLE

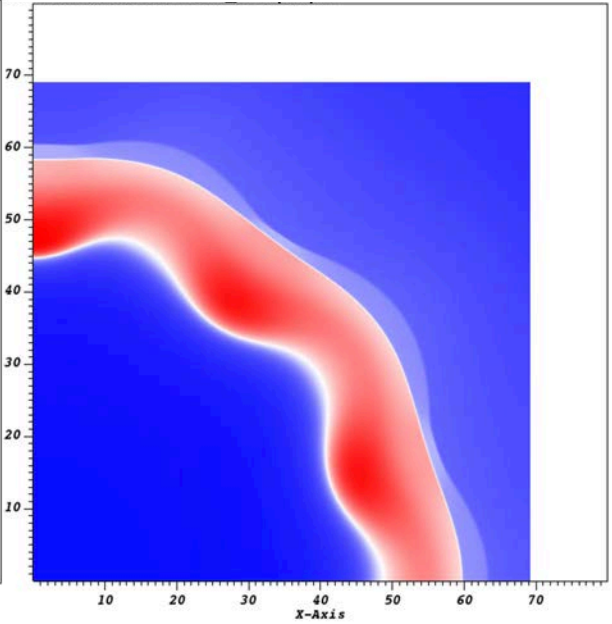
Mode ℓ = 10, Low Central Density, Perturbation growth over time



~10^{26} neutrons/s (680 ps since t_{decel})

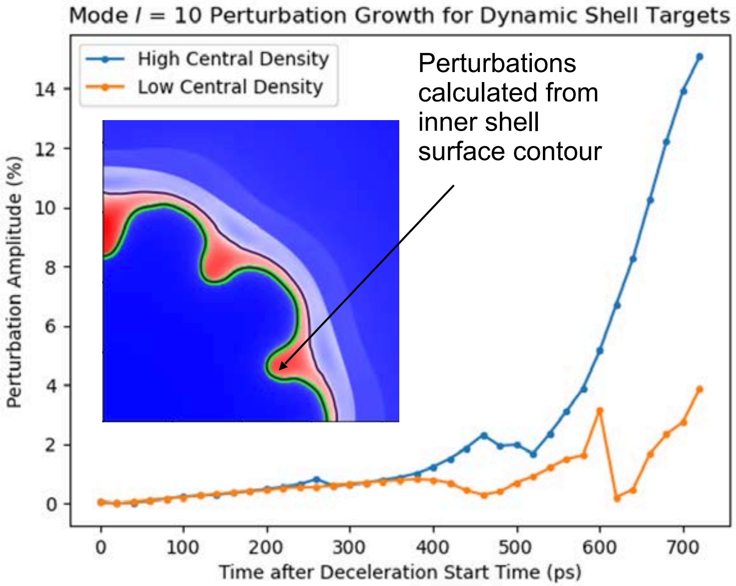


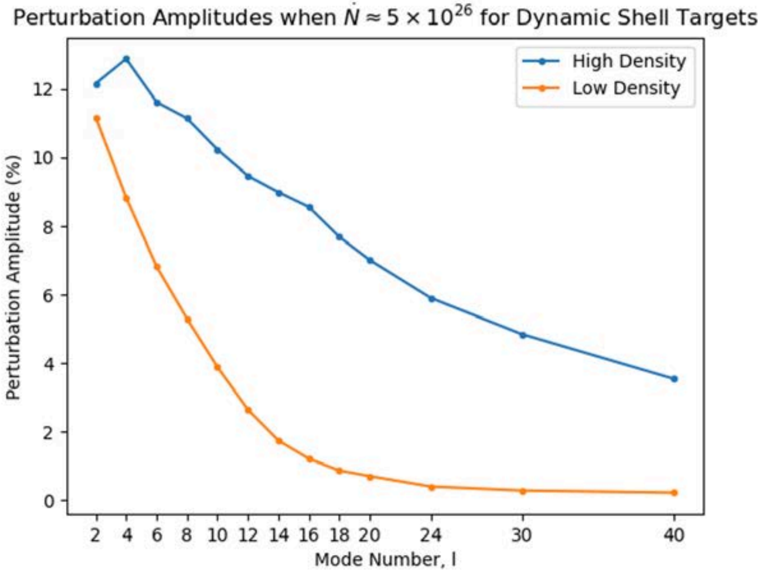
~5 x 10^{26} neutrons/s (720 ps since t_{decel})



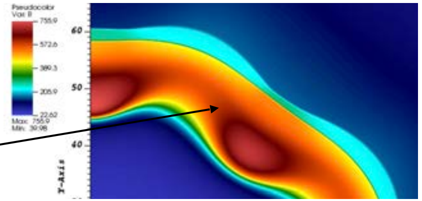
~10^{27} neutrons/s
(740 ps since t_{decel})

Deceleration RT growth in low central density target is smaller across all modes (ℓ = 2, 4, … 20, 24, 30, 40)





- Contributions to deceleration RT perturbation evolution
  - Ablative RT growth
  - Shell mass modulation: fed through from shell to inner shell surface



Summary

The dynamic shell concept can significantly reduce deceleration phase Rayleigh-Taylor (RT) growth by lowering the central density

- Dynamic shell formation enables lower central densities for direct drive implosions
- Lower central density enhances deceleration RT stabilization effects (e.g. mass ablation)
- 2-D simulations show significant suppression of deceleration RT for all modes tested (ℓ = 2, 4, …, 20, 24, 30, 40) when using a low central density