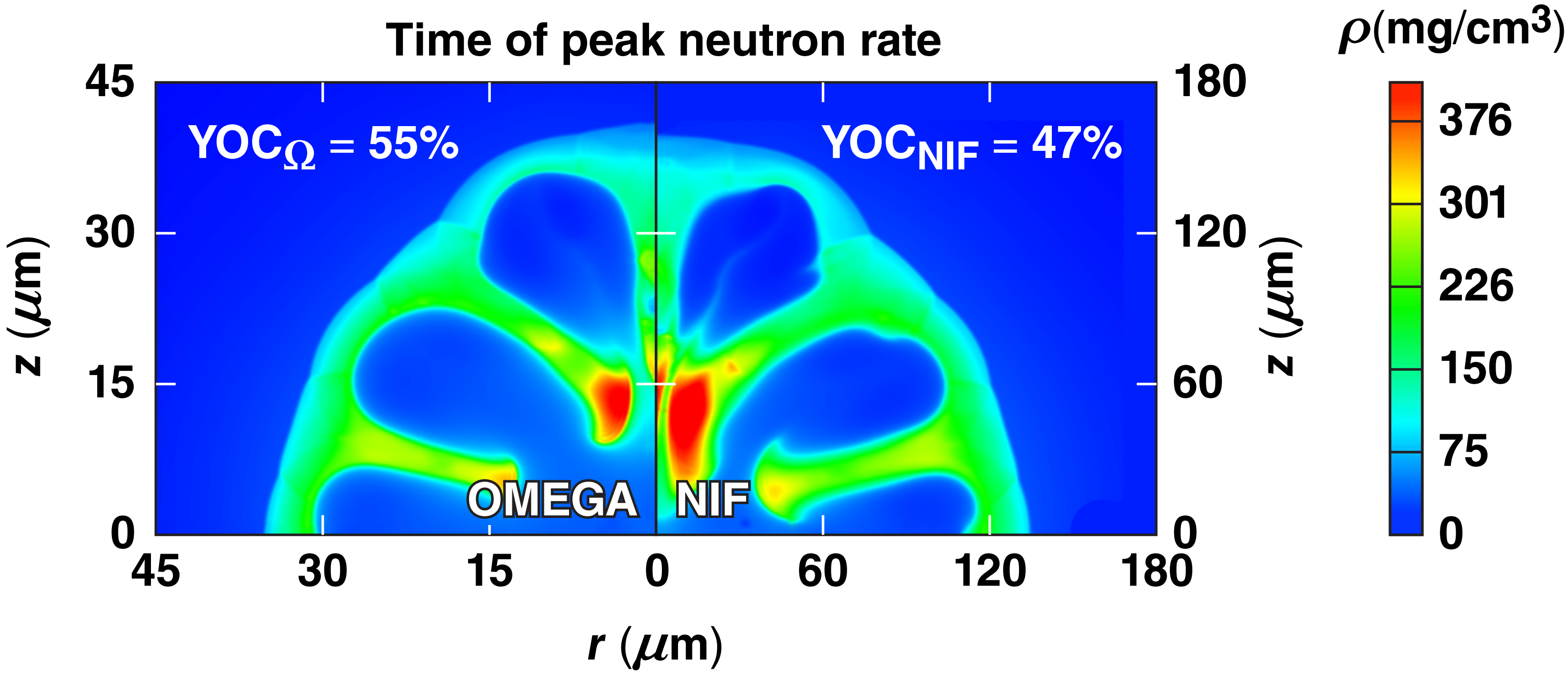
Hydrodynamic Scaling of the Deceleration-Phase Rayleigh–Taylor Instability



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Summary

With regard to the deceleration-phase, OMEGA cryogenic implosions are a good surrogate for National Ignition–Facility (NIF) scale implosions

- The deceleration-phase Rayleigh–Taylor instability (RTI) does not scale hydro-equivalently; stabilization caused by thermal and radiation transport scale oppositely with target size (or laser energy)
- Despite the lack of hydro-equivalence, simulations show that the deceleration-phase yield-over-clean (YOC) for OMEGA is only 17% higher than the YOC for ignition-scale targets
- A no-α ignition condition of $\chi_{\Omega\text{-eq-ig}} \approx 0.2$ is necessary to achieve ignition ($\chi_{\text{NIF}} \geq 1$)

Collaborators

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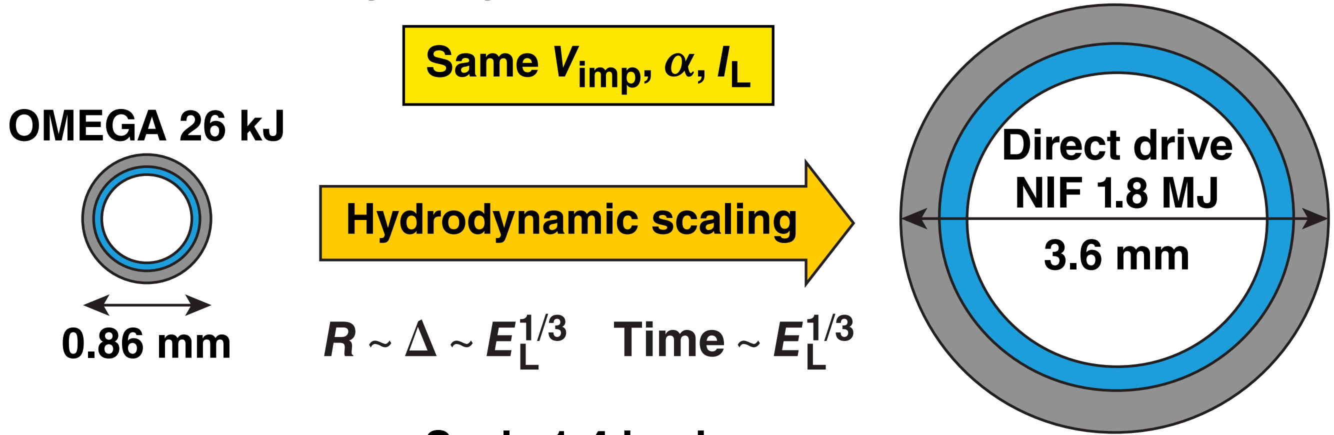
Hydrodynamic equivalence provides a tool to scale the performance of OMEGA implosions to NIF energies

1-D hydrodynamic equivalence:*



Scale 1:4 in size

- YOC scaling is used to investigate the scaling of implosion nonuniformities

$$\text{YOC} = \left(\frac{\text{Yield}_{\text{RTI}}}{\text{Yield}_{\text{1-D}}}\right)$$

TC11589

*C. D. Zhou and R. Betti, Phys. Plasmas 14, 072703 (2007).

Thermal and radiation transport in the hot spot reduces the deceleration-phase RTI growth

- The number of e-foldings of deceleration-phase RTI is*

$$N_e^{RT} = 0.9\sqrt{\frac{k\langle g\rangle t^2}{1+k\langle L_m\rangle}} - 1.4\,k\langle V_a\rangle t$$

** α: 0.9
β: 1.4

- The diffusion terms (thermal conduction and radiation) in the energy equation in spherically converging geometry do not scale hydro-equivalently with target size
- Thermal conduction determines the ablation-velocity (V_a) scaling
- Radiation transport determines the scaling of density-gradient scale length (L_m)

TC11607

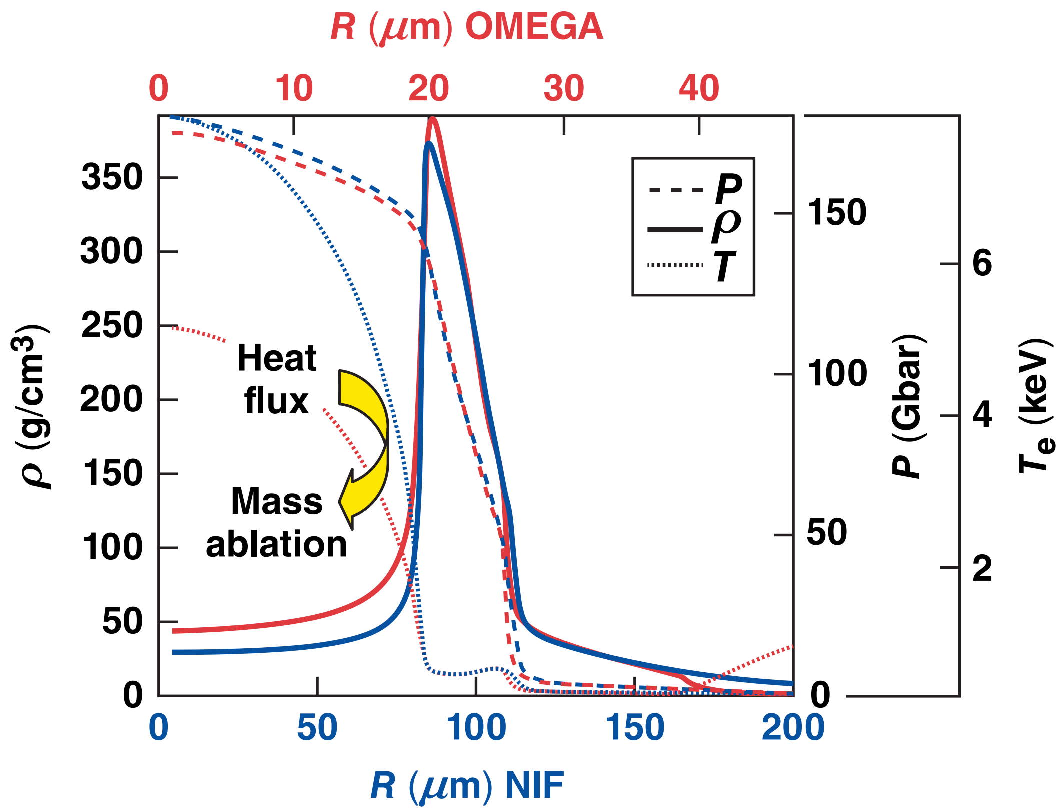
*H. Takabe *et al.*, Phys. Fluids 28, 3676 (1985).
**V. Lobatchev and R. Betti, Phys. Rev. Lett. 85, 4522 (2000).

NIF implosions show lower hot-spot mass-ablation rate than OMEGA implosions in simulations

$$V_a \sim \frac{\kappa_0 T_{hs}^{5/2}}{\rho_{sh} R_{hs}} \sim \frac{1}{\sqrt{R_{hs}}}$$

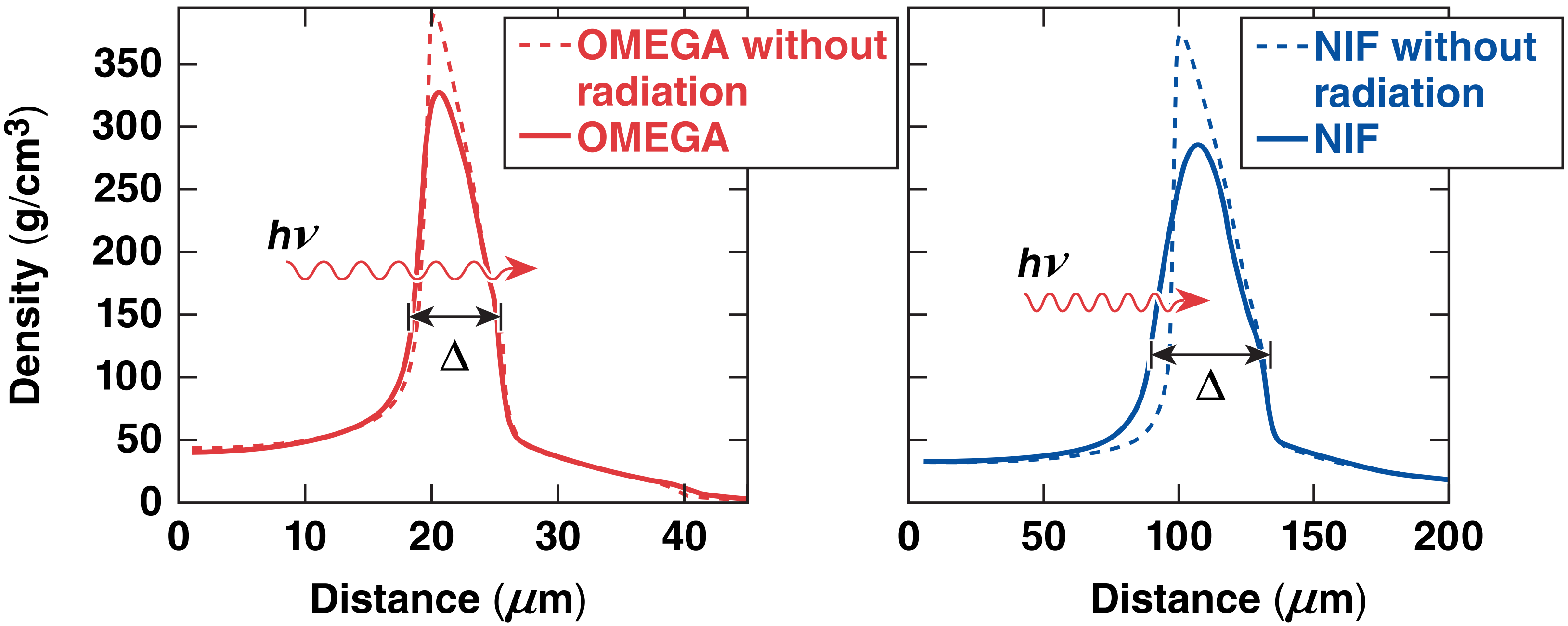
$$\frac{V_a^{NIF}}{V_a^{\Omega}} \sim \left(\frac{R_{hs_{NIF}}}{R_{hs_{\Omega}}}\right)^{-0.5} \sim 0.5$$

V_a scaling	$V_{a_{NIF}}/V_{a_{\Omega}}$
NIF without radiation	0.6
OMEGA without radiation	
NIF	0.6
OMEGA	



NIF and OMEGA 1-D profiles without radiation at peak neutron production (*LILAC*)

Radiation emitted from the hot spot is reabsorbed by the NIF shell, increasing L_m on the NIF more than on OMEGA



	Distance (μm)
5-keV photon MFP in shell	10.3
Δ shell (OMEGA)	12.5
Δ shell (NIF)	50

$$\frac{L_m^{NIF}}{4 \times L_m^{\Omega}} \sim \left(\frac{\Delta_{sh_{NIF}}}{\Delta_{sh_{\Omega}}}\right)^{0.5} \sim 2$$

MFP: mean free path

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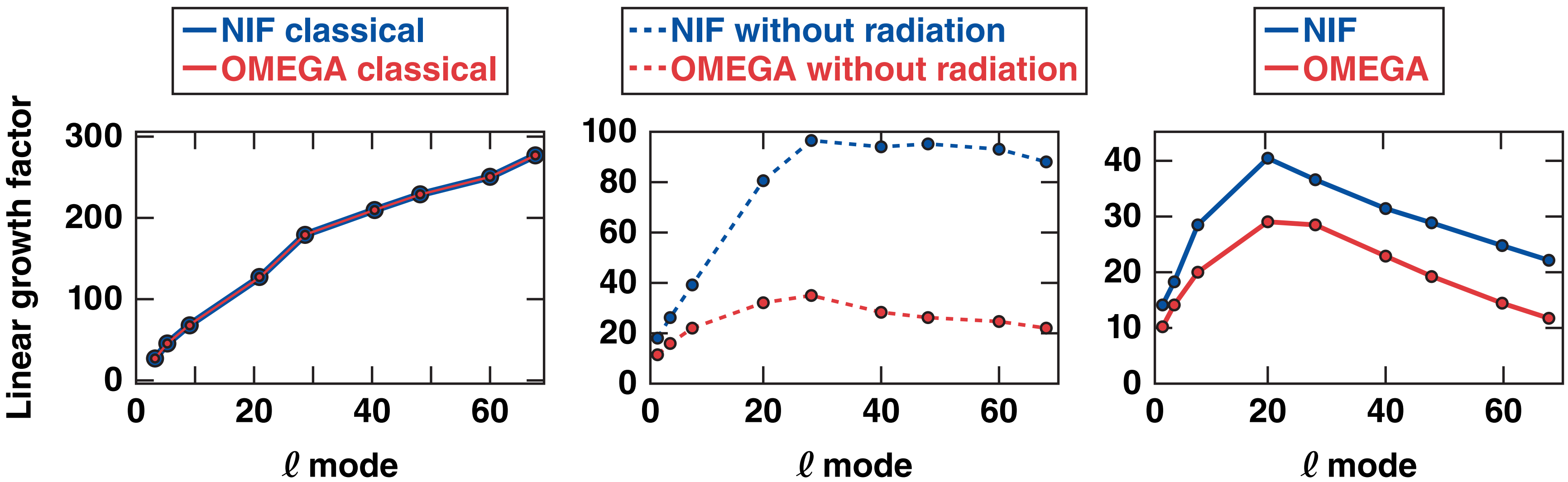
Stabilization of deceleration-phase RTI caused by V_a and L_m scale oppositely with target size

- High-resolution simulations of the deceleration phase were performed the using Eulerian hydrocode *DEC2D/3D**



*See K. M. Woo *et al.*, UP8.00087, this conference.

TC11592

Stabilization of deceleration-phase RTI caused by V_a and L_m scale oppositely with target size

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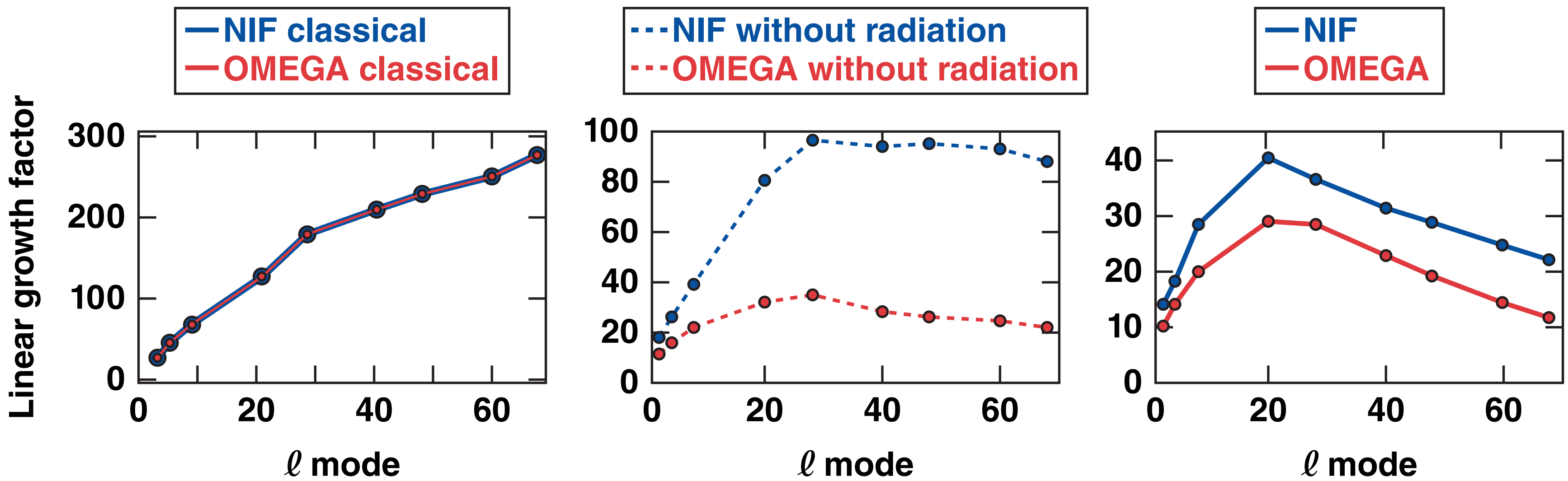
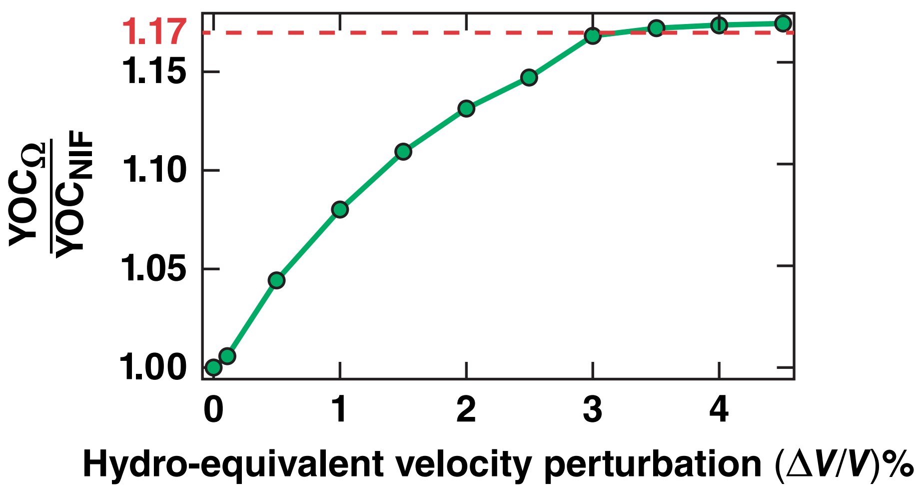


15% higher growth factors on NIF than on OMEGA.

*See K. M. Woo *et al*., UP8.00087, this conference.

The lack of hydro-equivalence in the deceleration phase leads to a small correction on the hydro-equivalent ignition condition



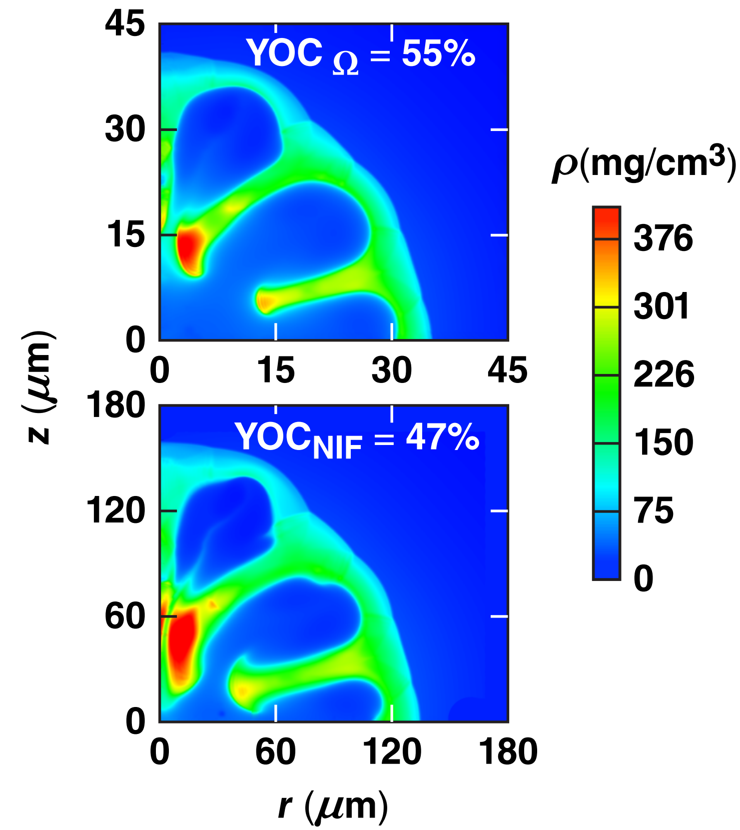
$$\chi \sim E^{0.37}\, YOC^{0.5}$$

$$\chi_{\Omega\text{-eq-ig}} \approx 0.19 * \underbrace{\left(\frac{YOC_{\Omega}}{YOC_{NIF}}\right)_{\text{dec-RT}}^{0.5}}_{1.17}$$

$$\chi_{\Omega\text{-eq-ig}} \approx 0.2$$

$4 \leq \ell \leq 20$ with $\Delta V/V_{imp} = 4\%$

$22 < \ell \leq 68$ with ℓ^{-2} spectrum



*R. Nora *et al.*, Phys. Plasmas 21, 056316 (2014).

TC10888b

Summary/Conclusions

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UR LLE

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TC11588