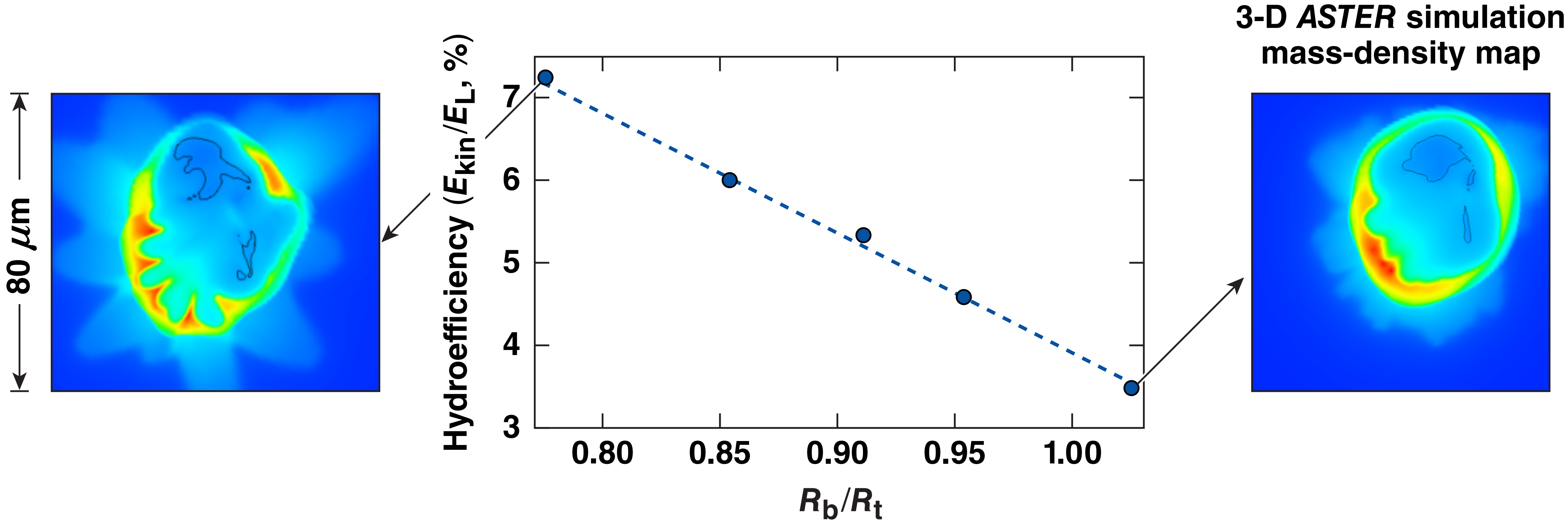
Cross-Beam Energy Transfer Mitigation in Cryogenic Implosions on OMEGA



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Summary

Increased hydrodynamic efficiency by mitigating cross-beam energy transfer (CBET) has been demonstrated in cryogenic implosions on OMEGA

- Target illumination with a focal spot size smaller than the target size ($R_b/R_t < 1$) was used to mitigate CBET; the target size varied from $R_t = 400\ \mu$m to $500\ \mu$m to reduce R_b/R_t
- Current cryogenic implosions on OMEGA have reached $P_{hs} = 56 \pm 7$ Gbar ($P_{hs}^{ign} > 120$ Gbar); implosions with convergence ratio (CR) < 17 and $\alpha > 3.5$ proceed close to 1-D prediction ($CR^{ign} > 22$)
- Improving target performance with $R_b/R_t < 1$ on OMEGA will require reducing long-wavelength nonuniformity seeded by power imbalance and target offset

TC12309a

Collaborators

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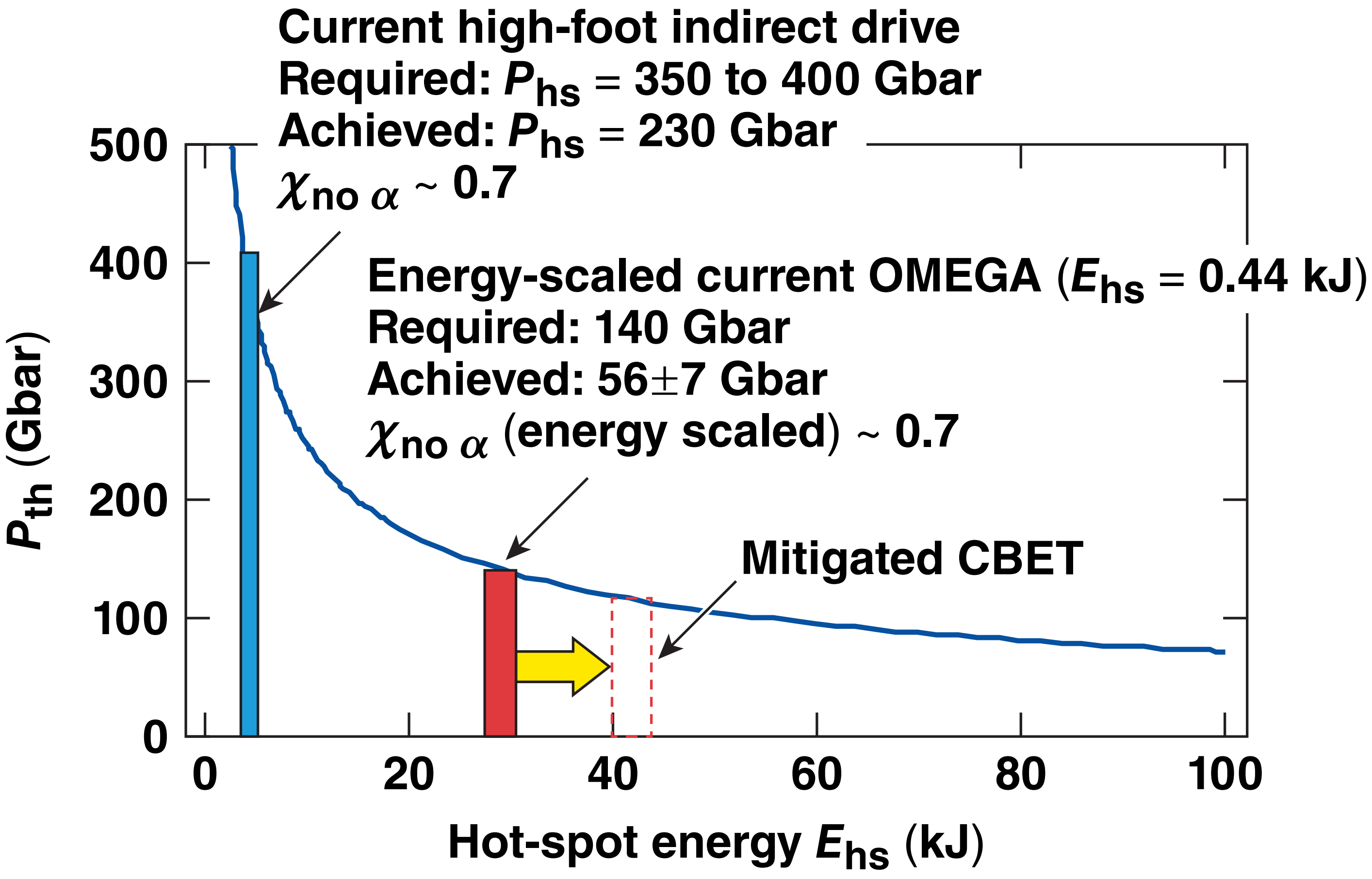
The hot-spot pressure in an ignition design must exceed a threshold value



- Pressure threshold for ignition

$$P_{th} \sim 1/\sqrt{E_{hs}}$$

- Generalized Lawson criterion*

$$\chi = P\tau/P\tau_{ign} = (\rho R)^{0.61}\,(0.24\,Y^{16}/M)^{0.34}$$

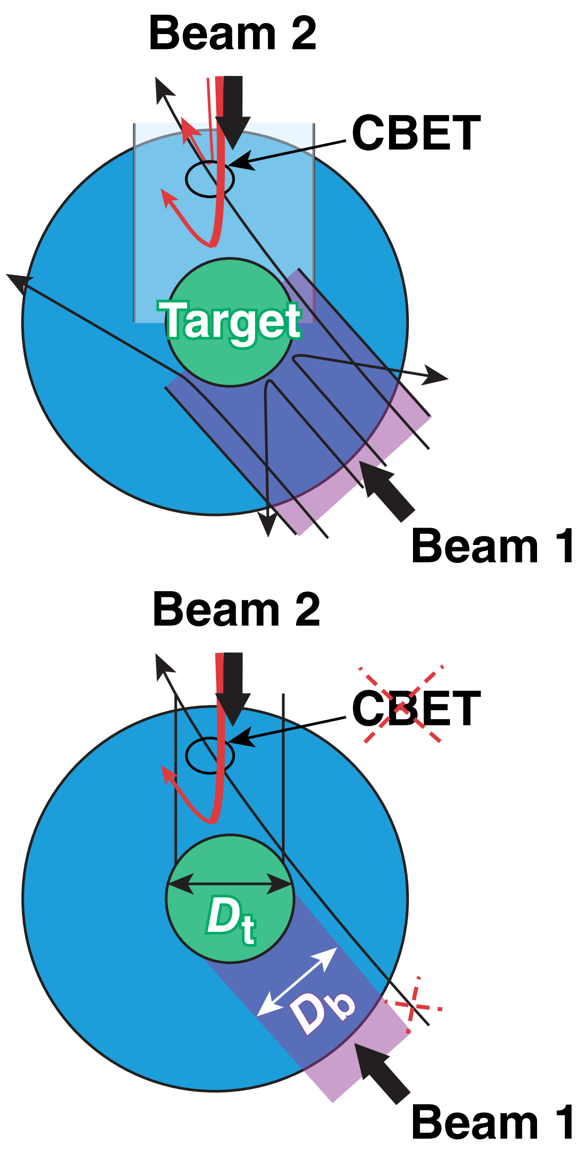
$$\chi_{\Omega \rightarrow NIF} \sim E^{0.37}$$

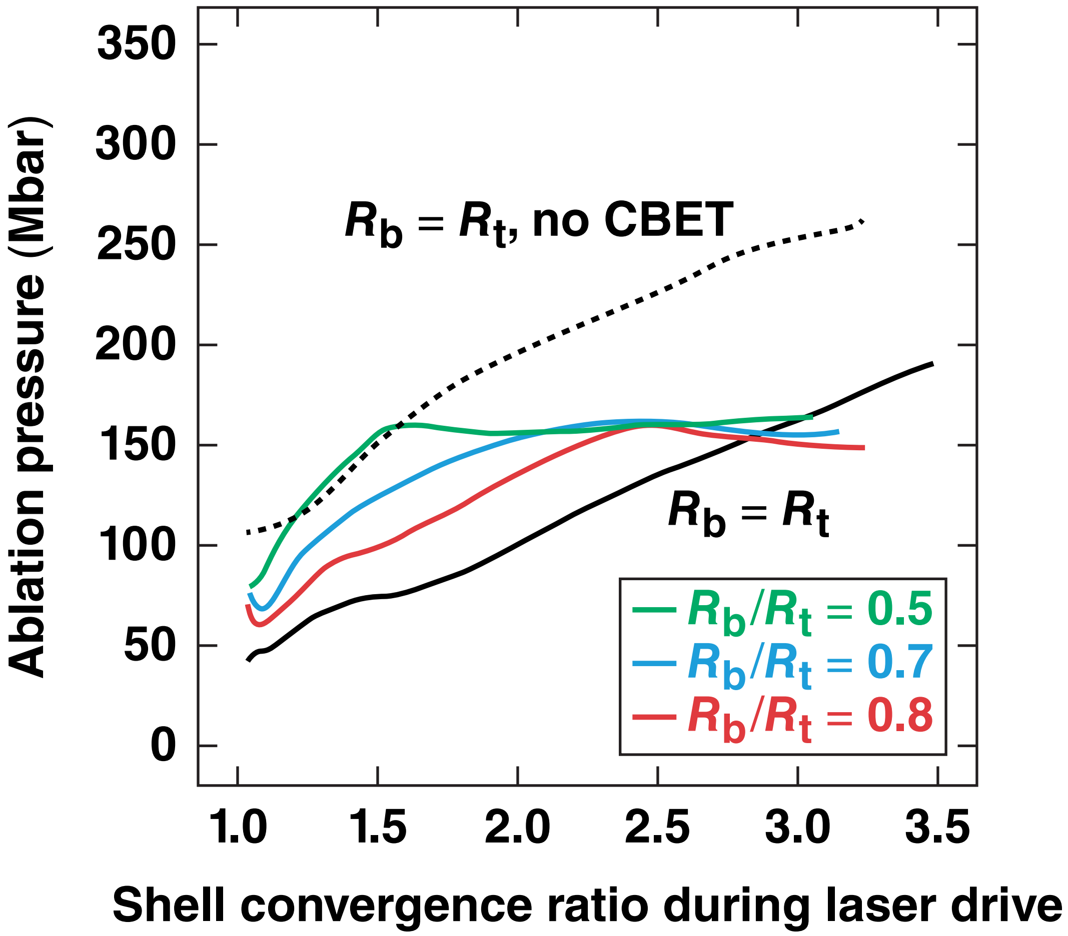
Direct-drive designs are in a less-challenging hydrodynamic regime with CR $\lesssim$ 22 and P_{hs} > 120 Gbar; indirect-drive–ignition targets require CR = 30 to 40 and P_{hs} > 350 Gbar.

*R. Betti *et al*., Phys. Plasmas 17, 058102 (2010).

TC12311e

The cryogenic implosion campaign on OMEGA was designed to demonstrate enhanced laser coupling by mitigating CBET





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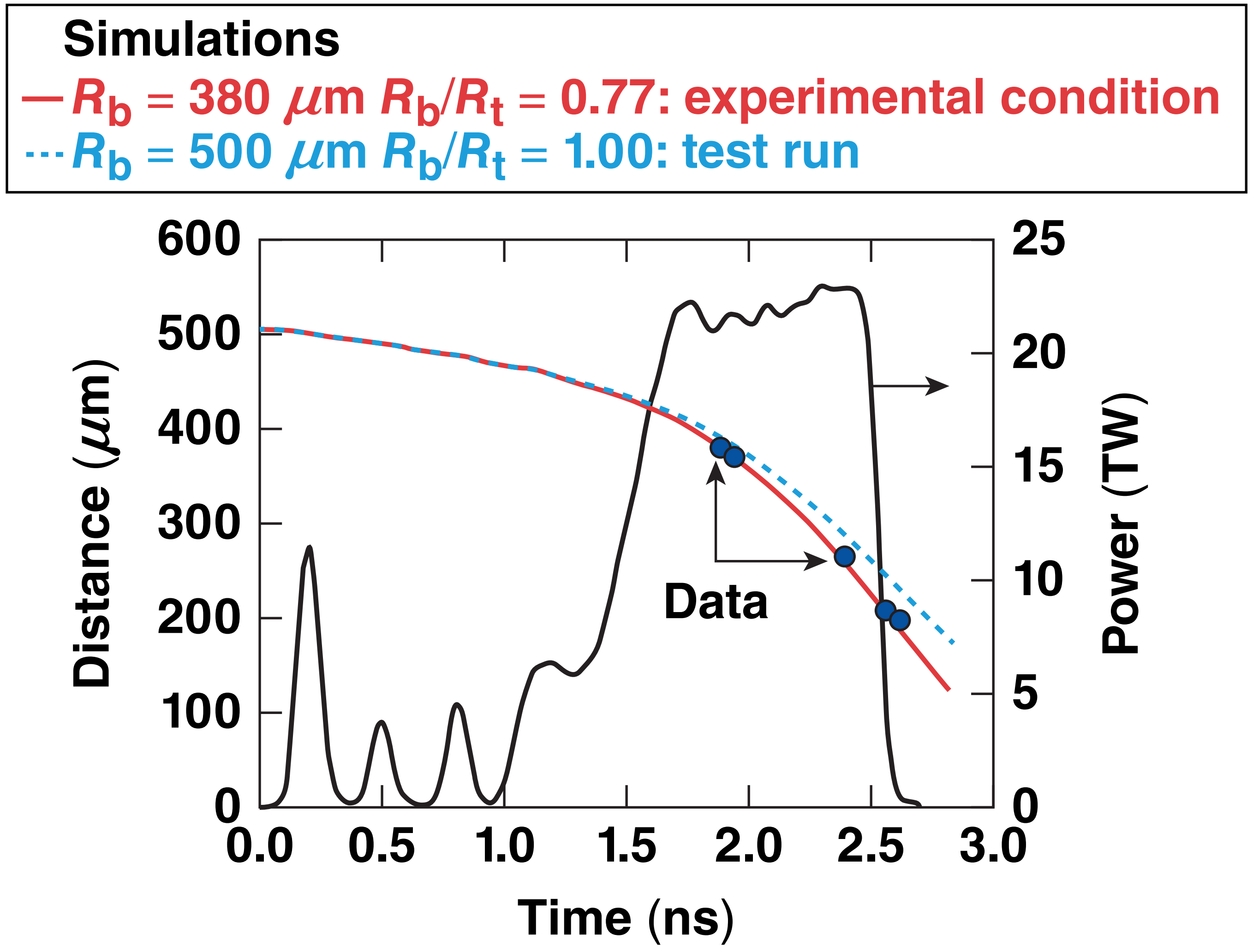
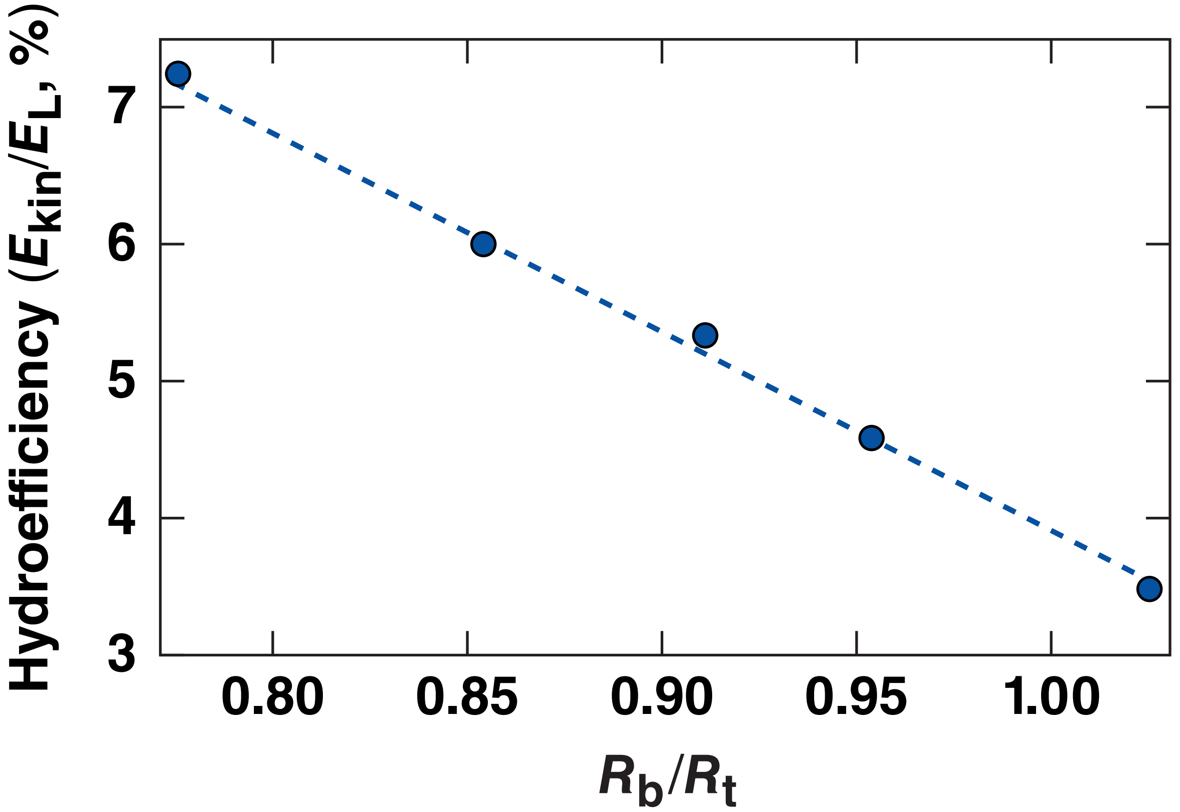
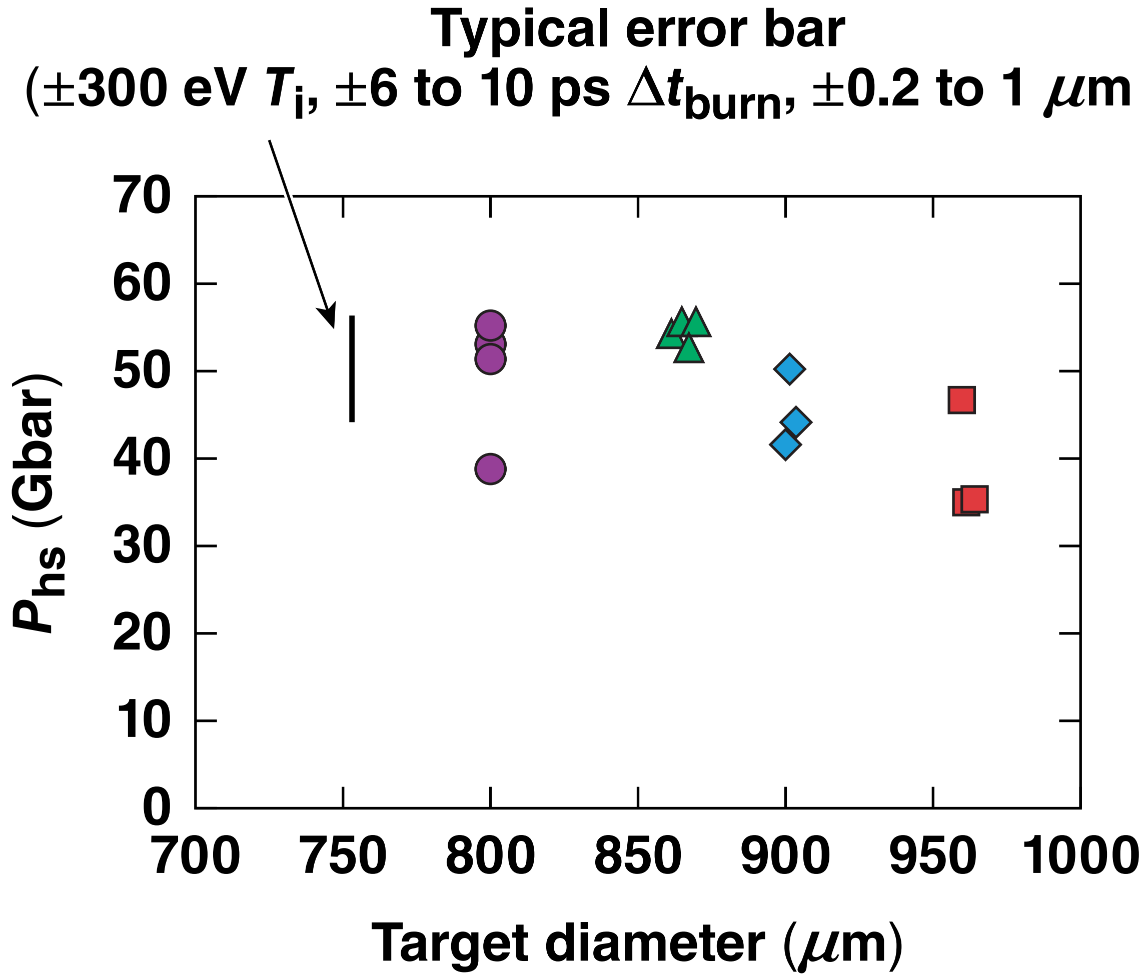
Implosions with $R_b/R_t < 1$ reach a larger hydrodynamic efficiency





TC12318a

Current cryogenic implosions on OMEGA have reached P_{hs} = 56±7 Gbar



$$\text{Yield} = \int_{\Delta t_{burn}} dt \int_{V_{hs}} n_D\, n_T \langle \sigma v \rangle\, dV$$

$$\text{Yield} \sim n_D\, n_T\, T^2 \left(\int_{V_{hs}} \frac{\langle \sigma v \rangle}{T^2} dV \right) \Delta t_{burn}$$

- Yield: Measured yield
- $n_D\, n_T\, T^2$: $P_{hs}{}^2$
- $\left(\int_{V_{hs}} \frac{\langle \sigma v \rangle}{T^2} dV \right)$: Depends on measured T_i and V_{hs}
- Δt_{burn}: Measured burnwidth

- Target yield and hot-shot pressure degrade (relative to 1-D predictions) with an increase in target diameter and a reduction in R_b/R_t*

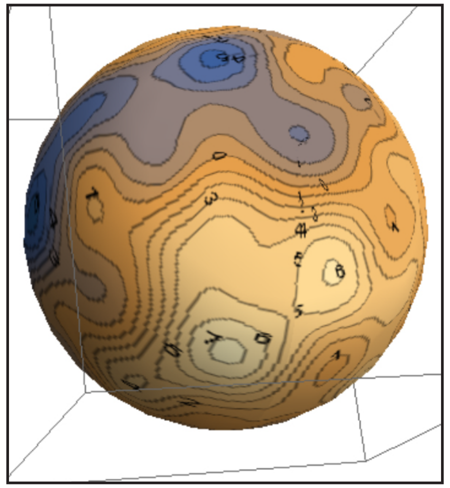
*S. P. Regan *et al*., CI3.00005, this conference (invited).

TC12319a

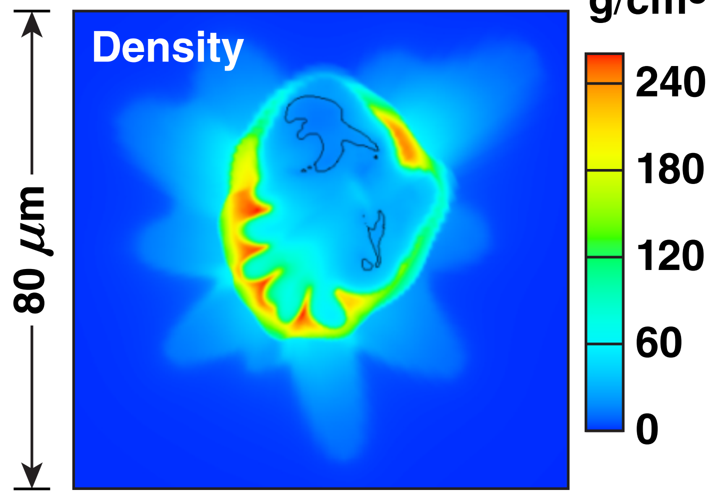
Long-wavelength modes ($1 < \ell < 5$) cause a reduction in peak pressure and burn truncation

On-target nonuniformities caused by beam geometry, power imbalance, beam mispointing

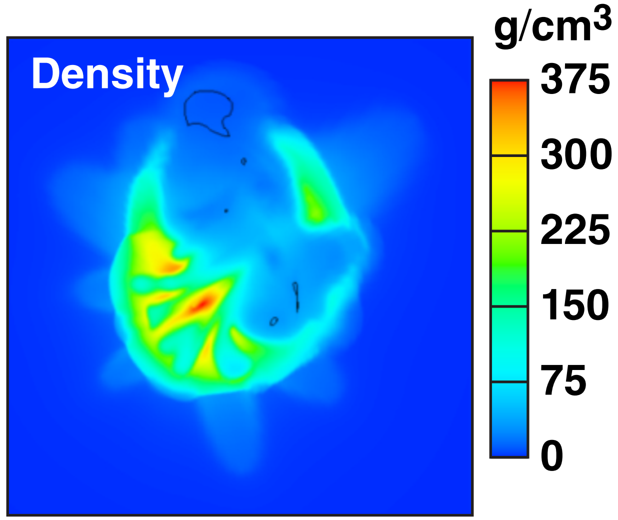
Illumination nonuniformity 3-D solid-sphere projection



*ASTER** 3-D simulation of a CR = 20 cryogenic implosion $R_b/R_t = 0.75$ (10-μm offset, 15% power imbalance, 10-μm rms mispointing)



Peak neutron production in 3-D



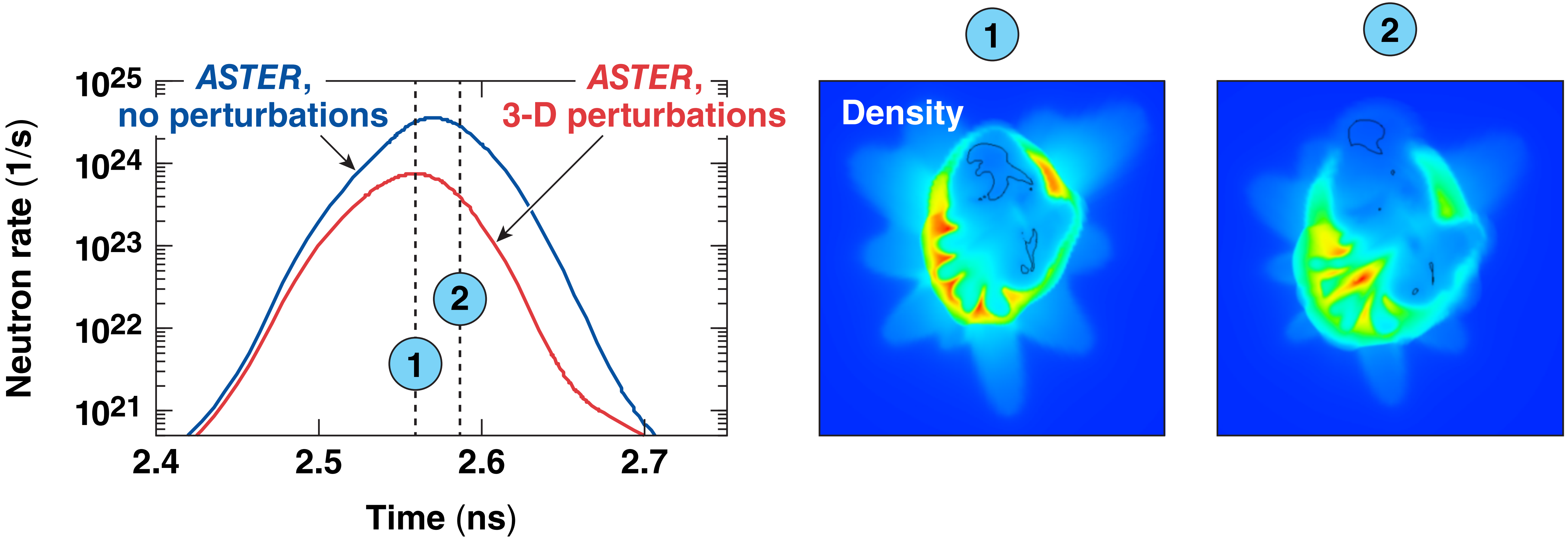
Time of peak neutron production in 1-D; bubble burst causes drop in P_{hs} and burn truncation

The nonuniformity spectrum shifts to more-damaging shorter wavelengths for smaller R_b/R_t (larger R_t).

*I. V. Igumenshchev *et al.*, "Three-Dimensional Modeling of Direct-Drive Cryogenic Implosions," to be submitted to Physics of Plasmas.
I. V. Igumenshchev *et al.*, UO4.00015, this conference.

TC12322a

Three-dimensional simulations predict an early burn truncation because of long-wavelength, hot-spot distortion growth



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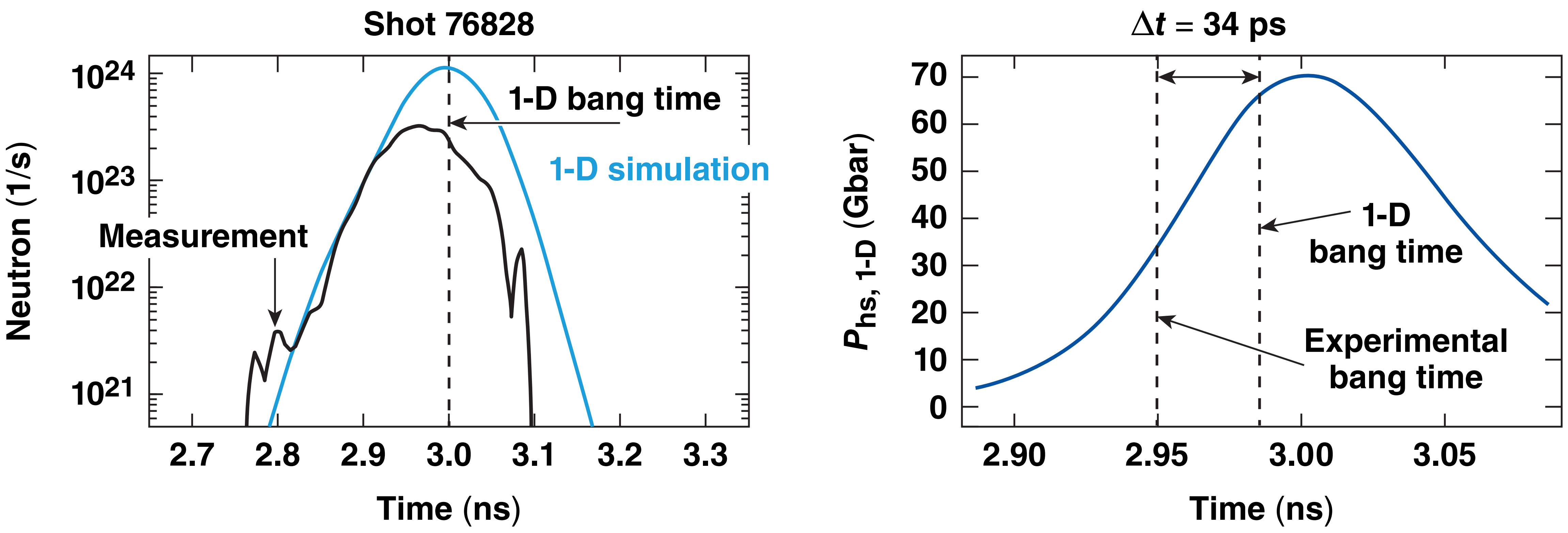
Measurements show earlier peak burn and burn truncation



Pressure evolves on an ~100-ps time scale; a tens of picoseconds shift in the temporal sampling region makes a significant difference in the inferred pressure.

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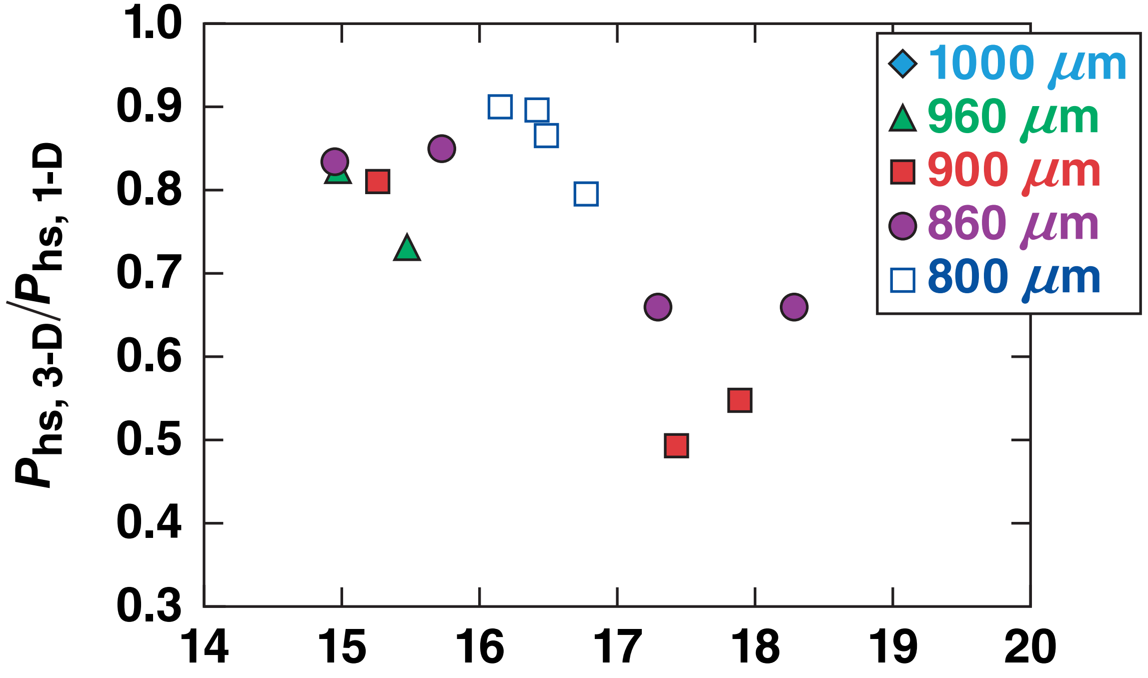
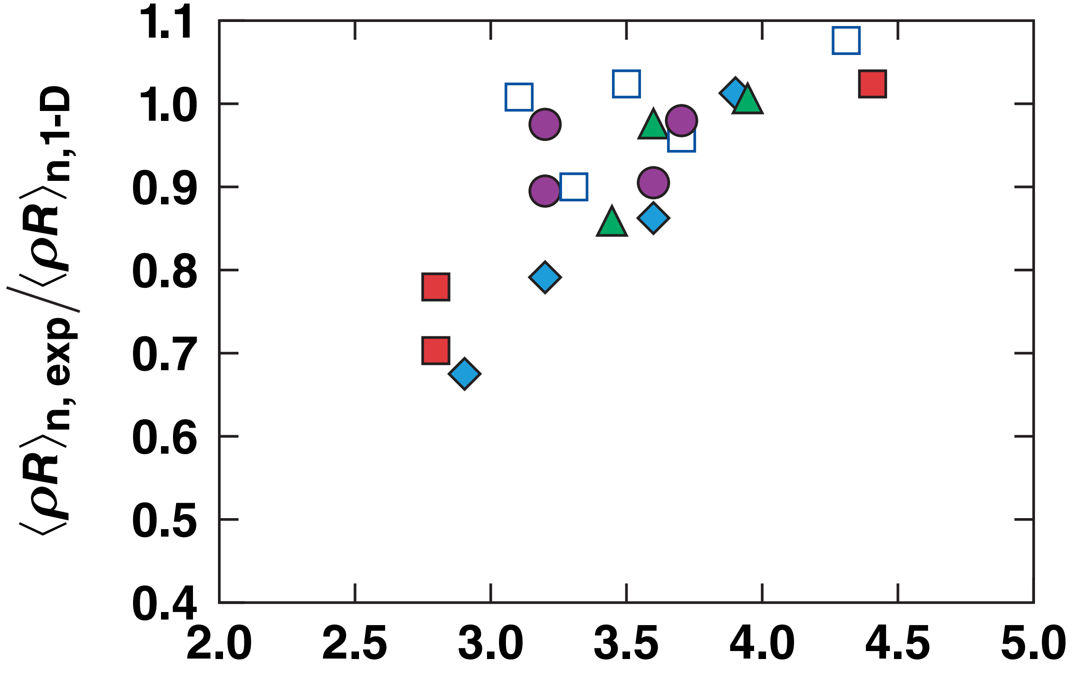
When the measured burn rate is included in the analysis, inferred P_{hs} and ρR agree with 1-D predictions in implosions with CR < 17 and α > 3.5

Inferred from experiment



1-D ρR averaged over experiment burn (with burn truncation)



Because of a reduced beam overlap, long-wavelength nonuniformity increases with a reduction in R_b/R_t, truncating burn earlier and reducing the observed P_{hs}. Reducing beam power imbalance and target offset are required to improve the target performance with $R_b/R_t < 1$.

TC12393

Summary/Conclusions

Increased hydrodynamic efficiency by mitigating cross-beam energy transfer (CBET) has been demonstrated in cryogenic implosions on OMEGA

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TC12309a