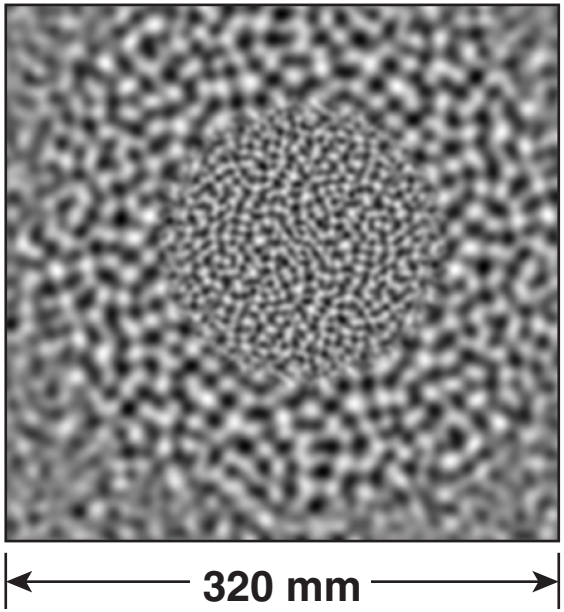
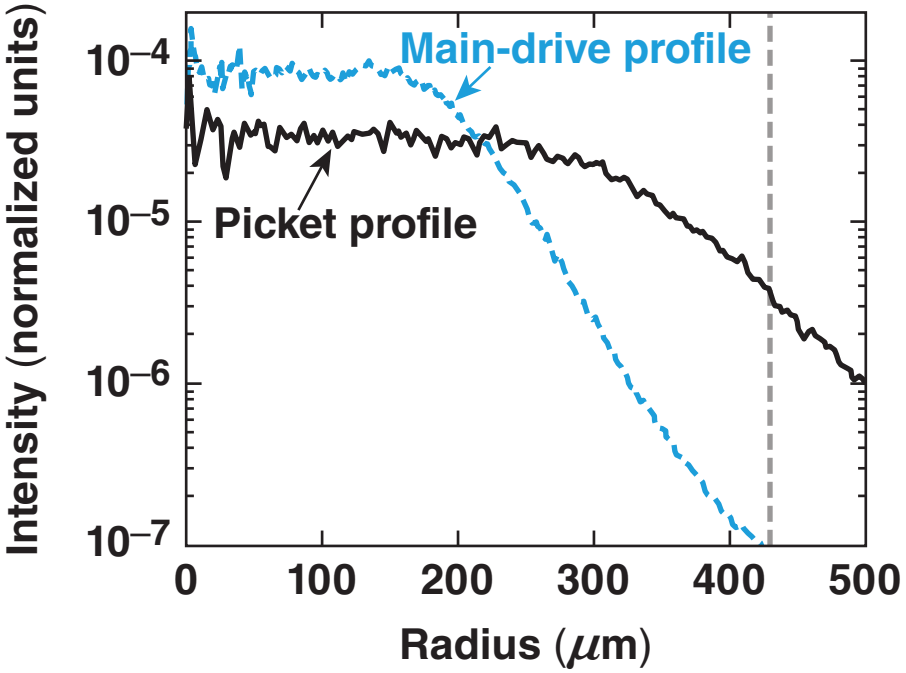
Implications of Two-State Focal Zooming on OMEGA to Mitigate Crossed-Beam Energy Transfer

Zooming phase plate design





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Summary

Implementing zooming on OMEGA with an incoherent picket array will allow the mass of the shell and the adiabat to be increased while maintaining ignition-relevant conditions

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- Crossed-beam energy transfer (CBET) reduces the hydrodynamic efficiency by 35%, which reduces the 1-D yield by a factor of 7 in OMEGA direct-drive implosions
- Reducing the diameter of the laser beams after a sufficient conduction zone is generated ("zooming"), is predicted to reduce CBET while maintaining good low-mode uniformity
- Zooming phase plates (ZPP) with an incoherent picket array (IPA) provides two-state focusing with enhanced beam smoothing

Implementing the proposed ZPP scheme on OMEGA will provide a more hydrodynamically stable implosion.

Collaborators

T. J. Kessler, I. V. Igumenshchev, V. N. Goncharov, H. Huang, S. X. Hu, E. Hill, J. H. Kelly, D. D. Meyerhofer, A. Shvydky, J. D. Zuegel, and R. Epstein

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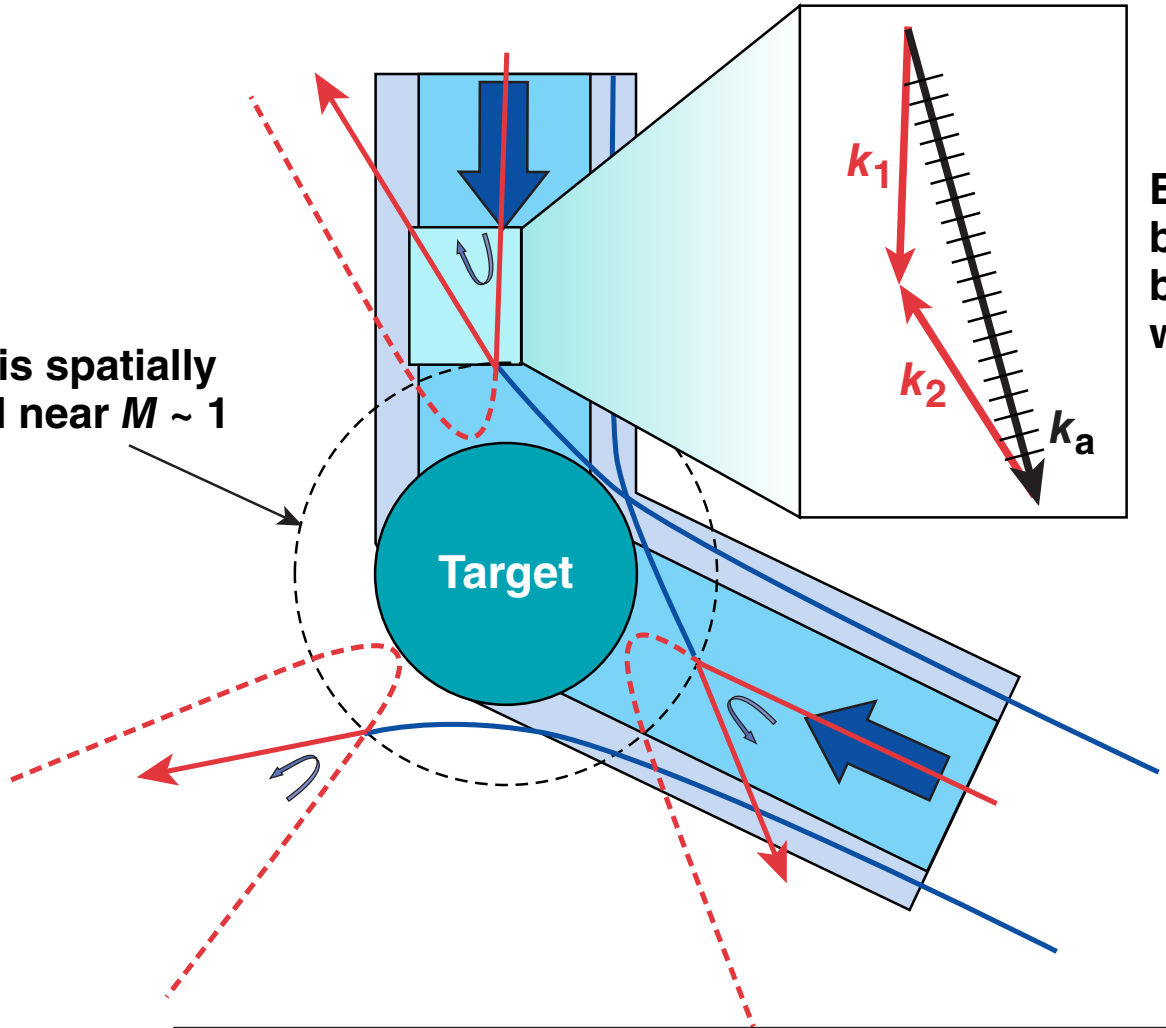
CBET reduces the energy coupled to the fusion capsule



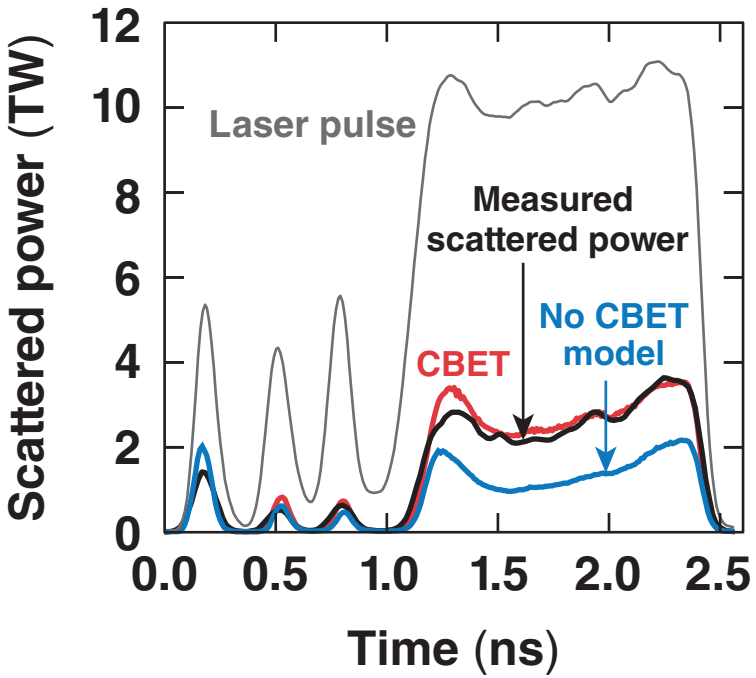
CBET is spatially limited near $M \sim 1$

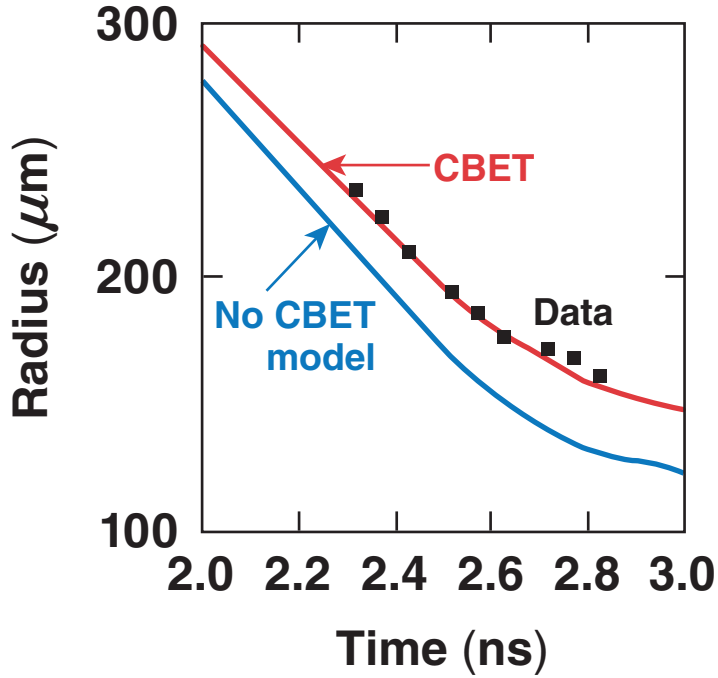
Energy is transferred between beams by ion-acoustic waves

CBET reduces the most hydrodynamically efficient portion on the incident laser beams.

E19971d

On OMEGA, CBET reduces the implosion velocity by 30%, which reduces the 1-D yield by a factor of seven



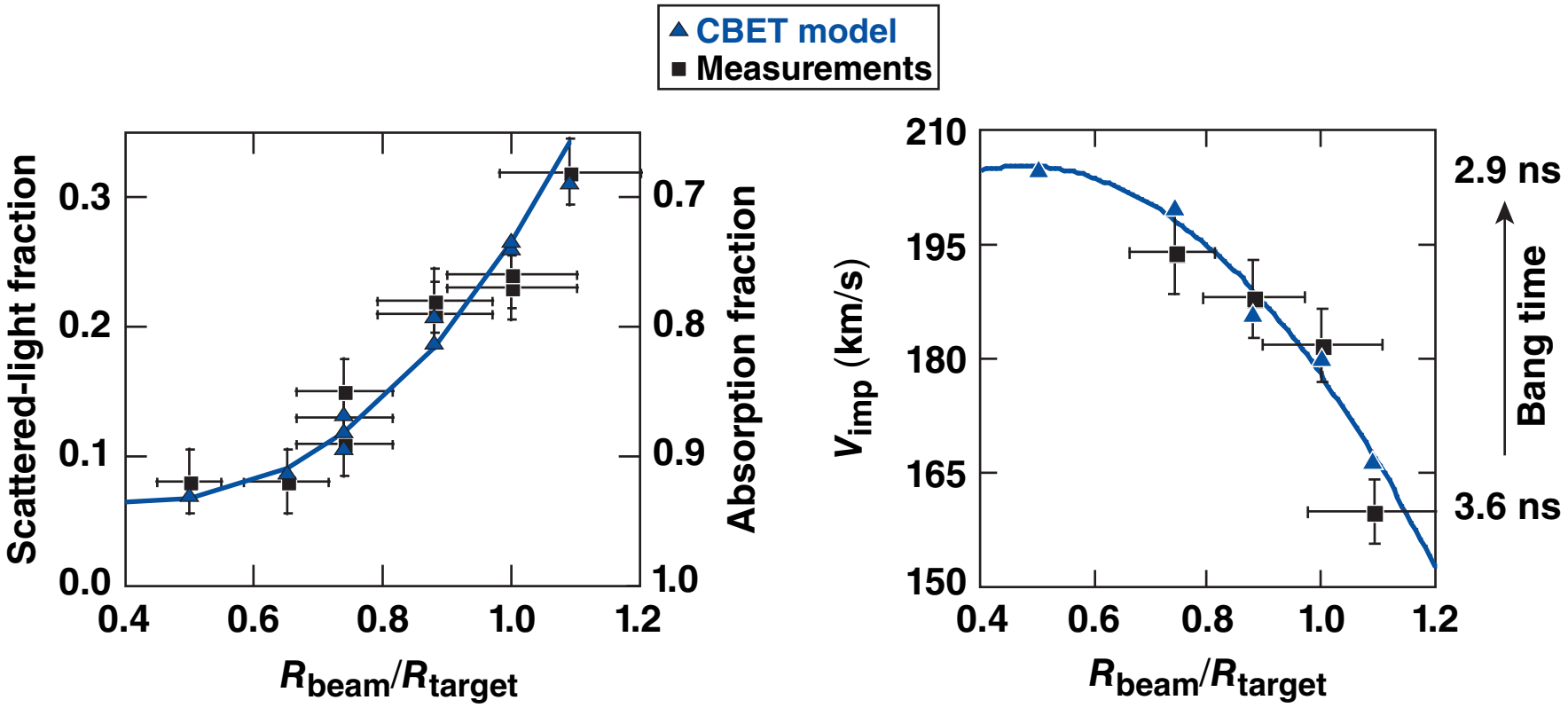


CBET modeling is required to match the experimental observables (scattered light, implosion velocity, and bang time).*

E21315b

*I. V. Igumenshchev *et al*. Phys. Plasmas 19, 056314 (2012).

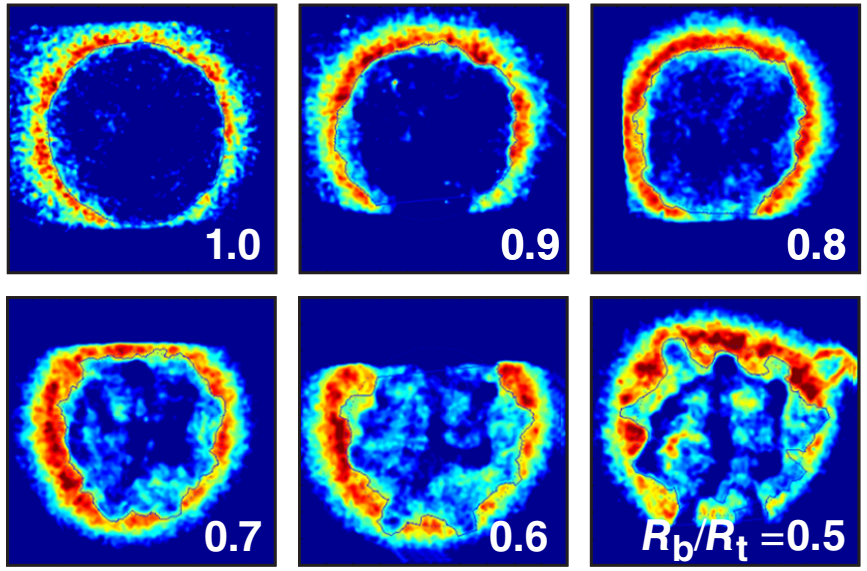
Experiments have demonstrated that CBET can be mitigated by reducing the radius of the laser beams



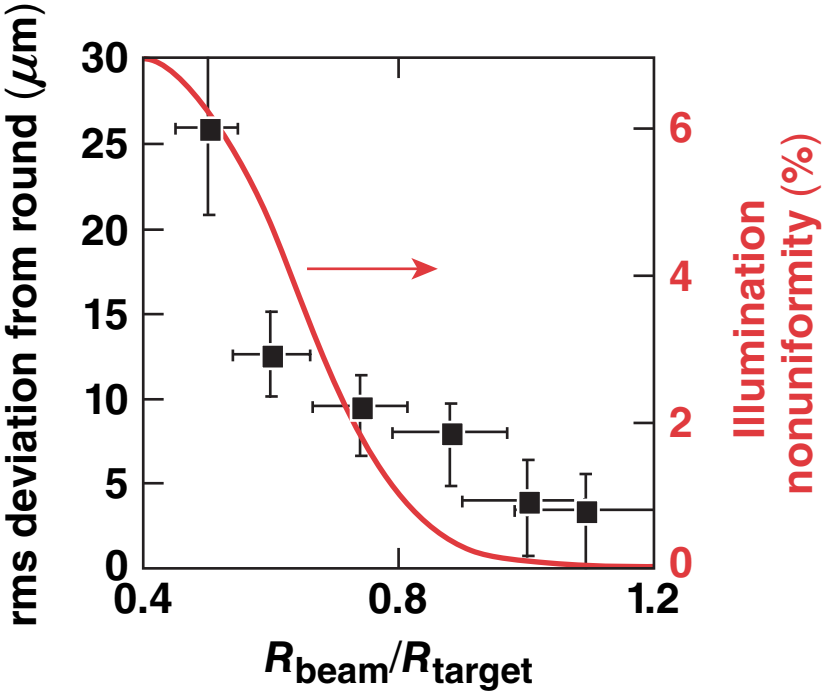
A 20% reduction in beam radius results in a 15% increase in laser absorption and a 17% increase in implosion velocity.

D. H. Froula *et al.*, Phys. Rev. Lett. 108, 125003 (2012).

The reduced-beam overlap results in nonuniformities on the imploding shell



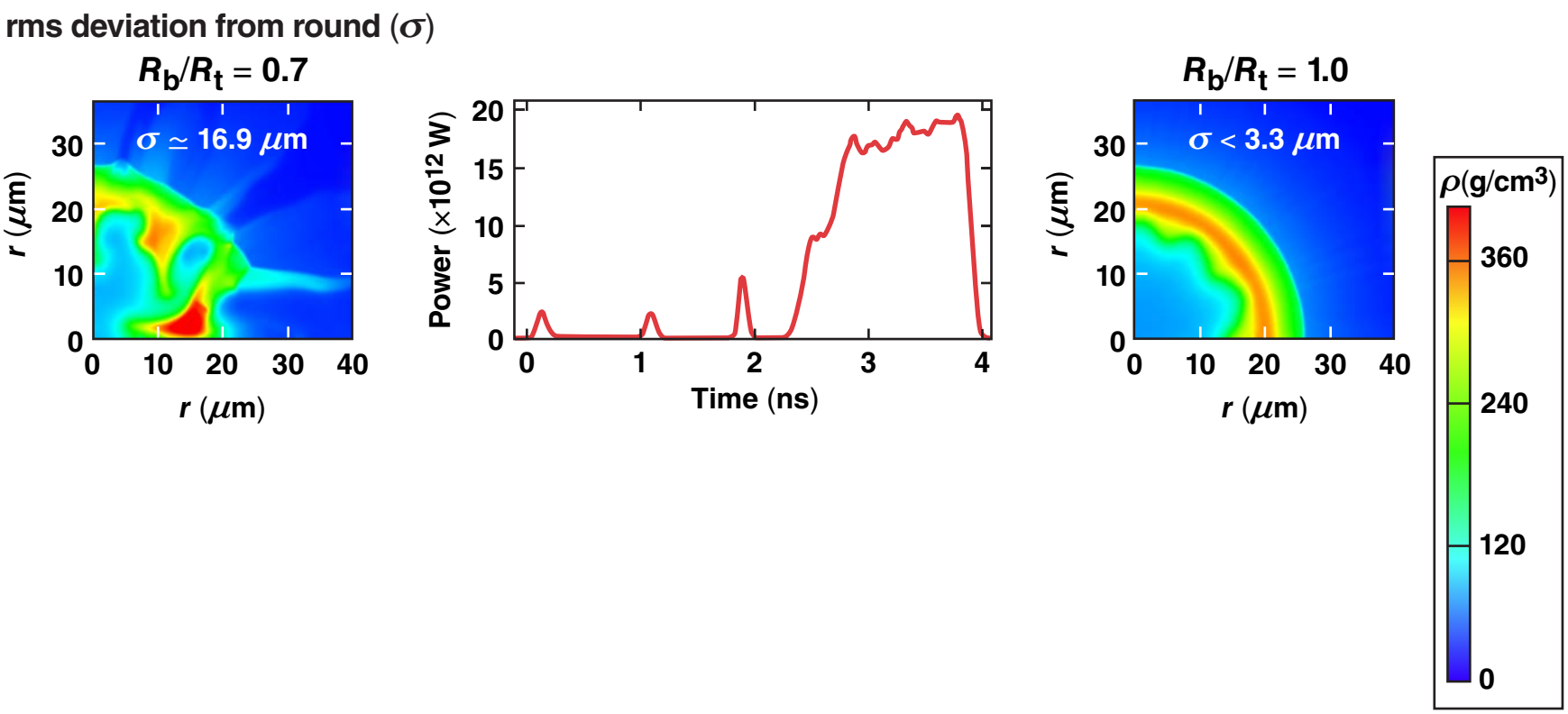
Convergence ratio = 2.5



U1265e

*D. T. Michel *et al.*, Rev. Sci. Instrum. 83, 10E530 (2012).

Reducing the diameter of the laser beams after a sufficient conduction zone is generated ("zooming") is predicted to maintain good low-mode uniformity



E21317d

*I. V. Igumenshchev *et al*. Phys. Rev. Lett. 110, 145001 (2013).

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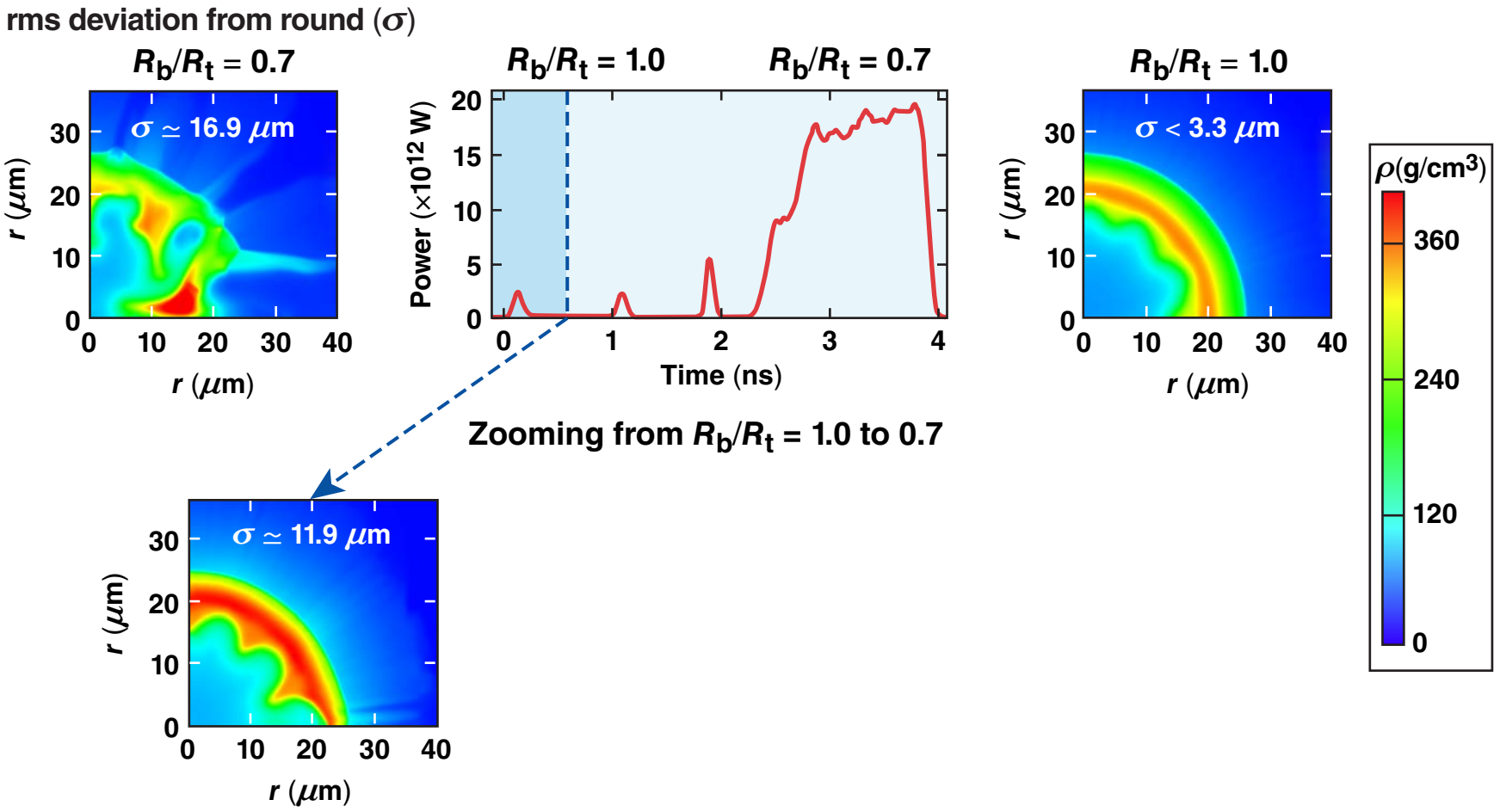

E21317e

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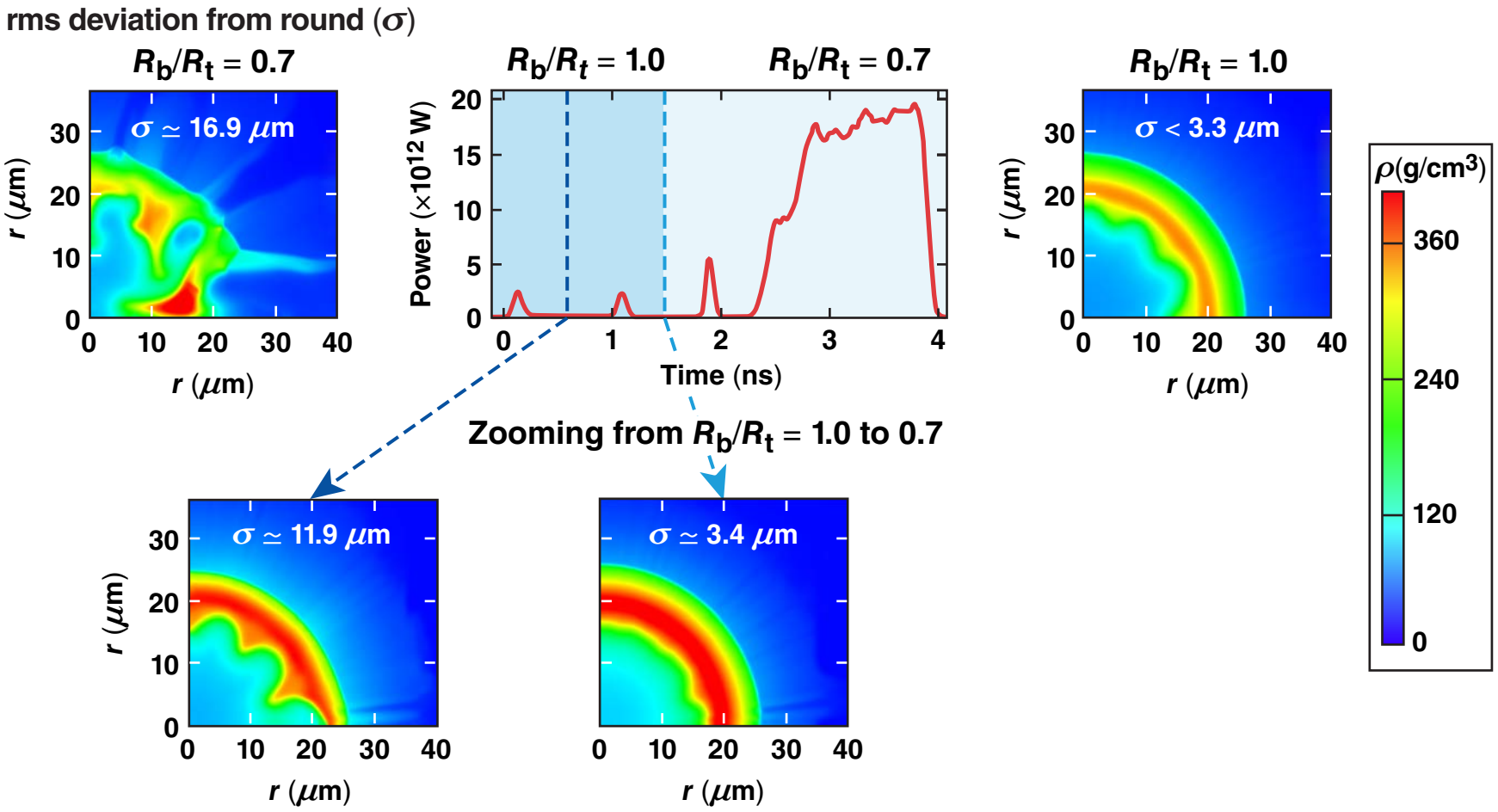

E21317f

*I. V. Igumenshchev *et al*. Phys. Rev. Lett. 110, 145001 (2013).

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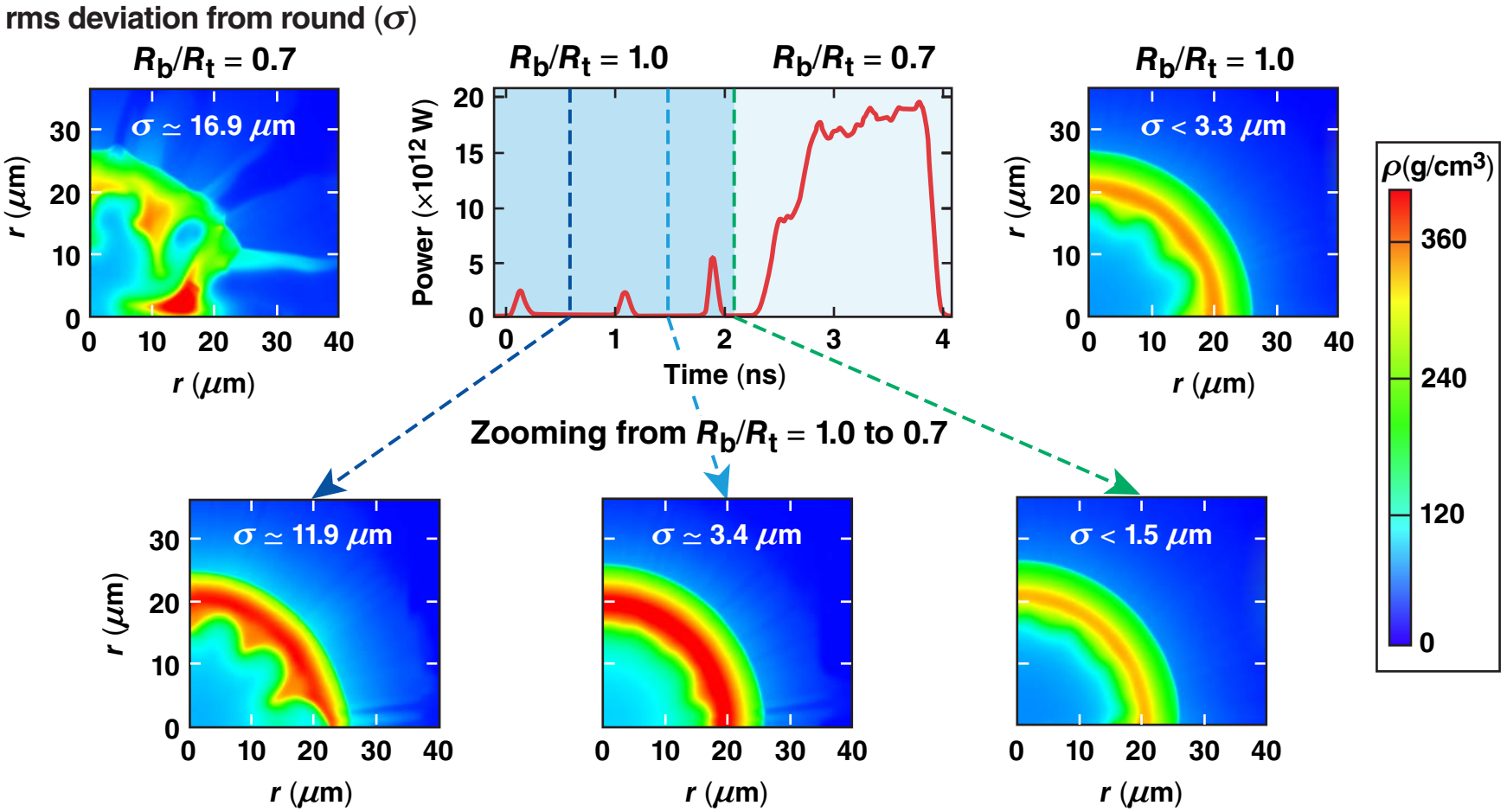
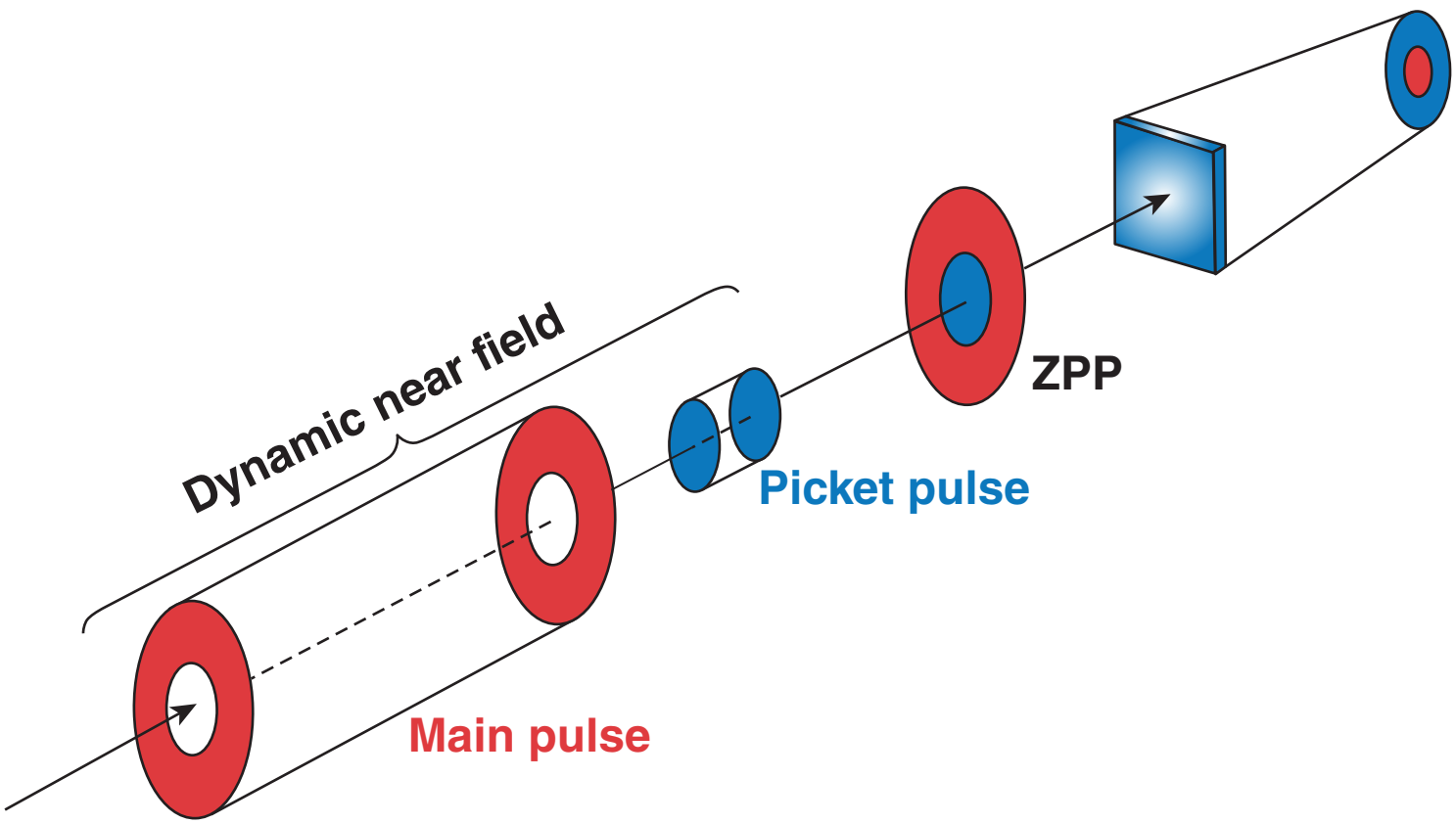


E21317g

*I. V. Igumenshchev *et al*. Phys. Rev. Lett. 110, 145001 (2013).

Zooming can be implemented on OMEGA using a radially varying phase plate and a dynamic near-field



Using 15% less energy, this design is predicted to increase the implosion velocity by 25%, resulting in 5× more 1-D yield.

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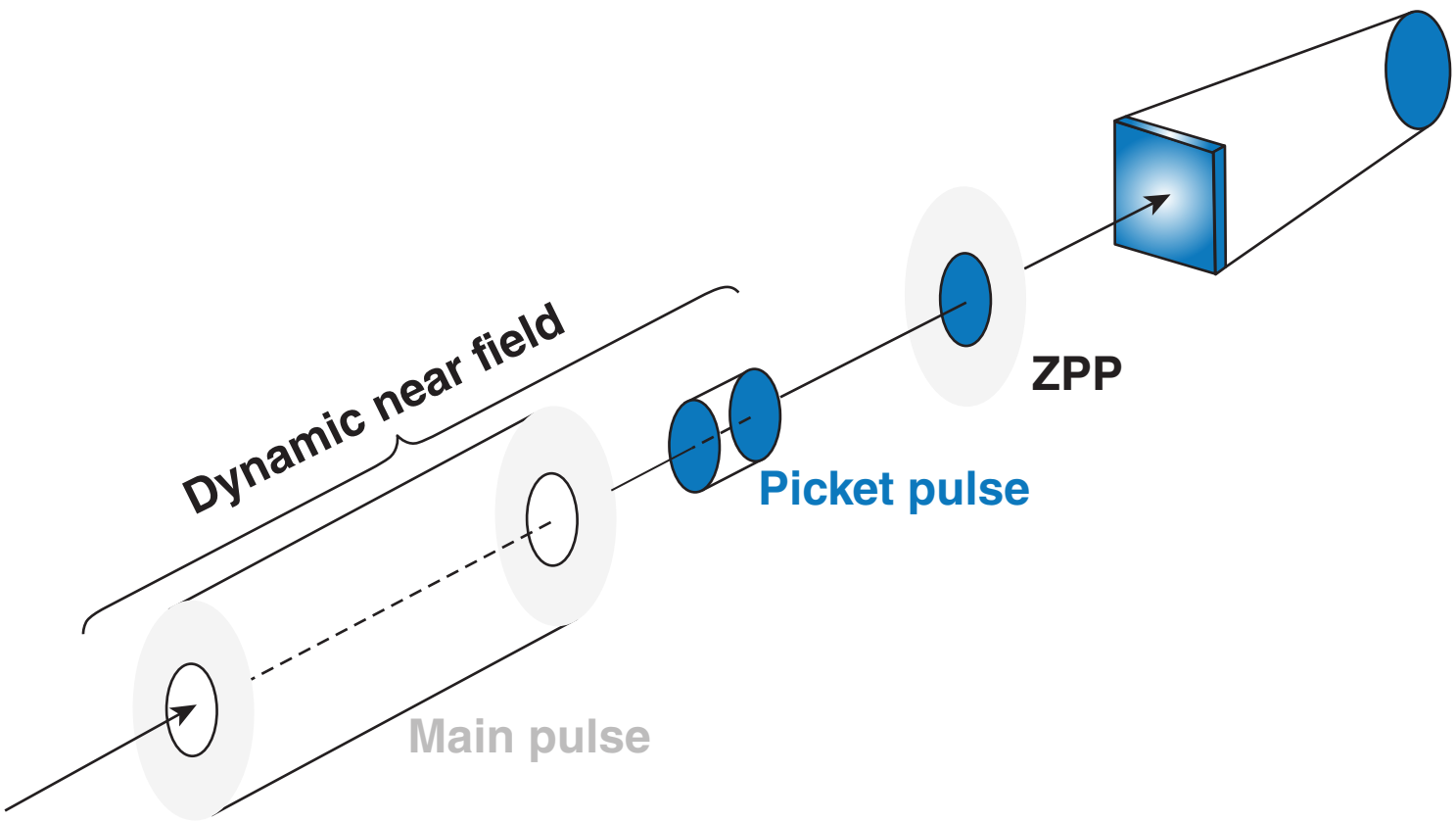

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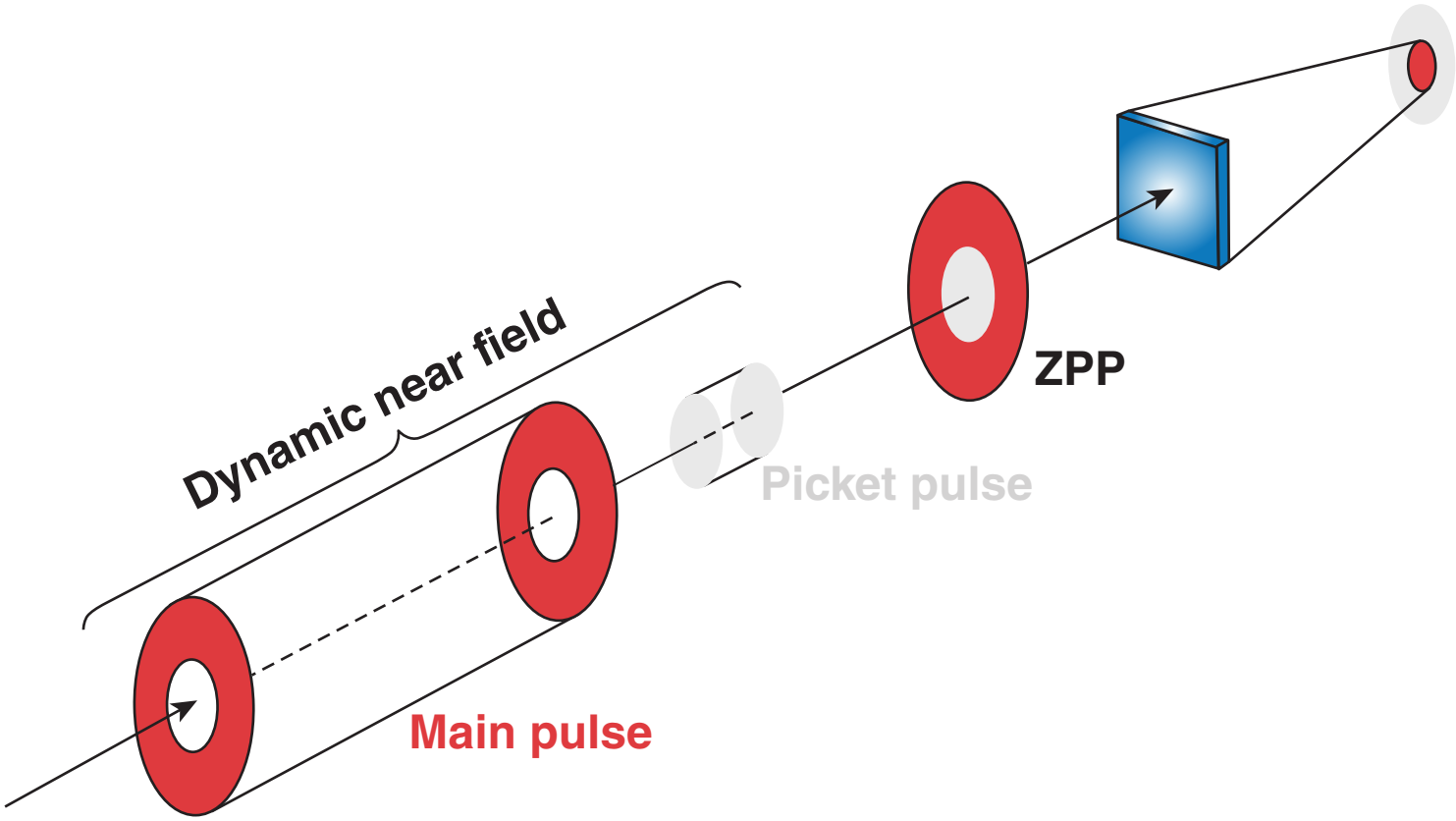

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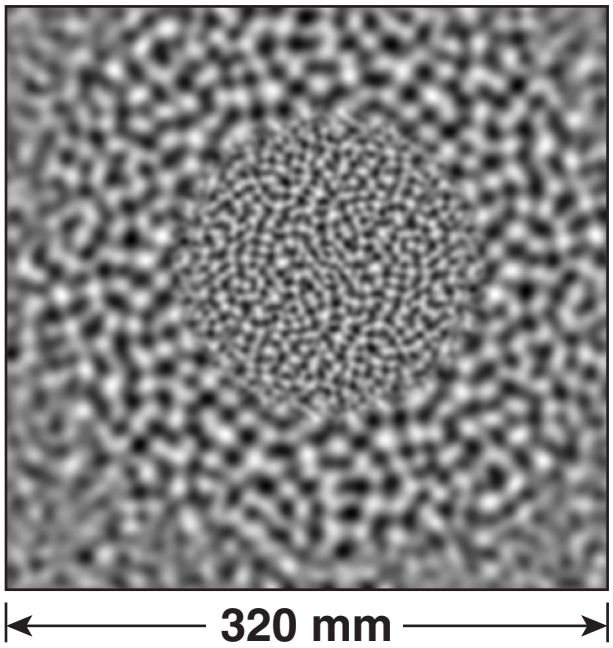
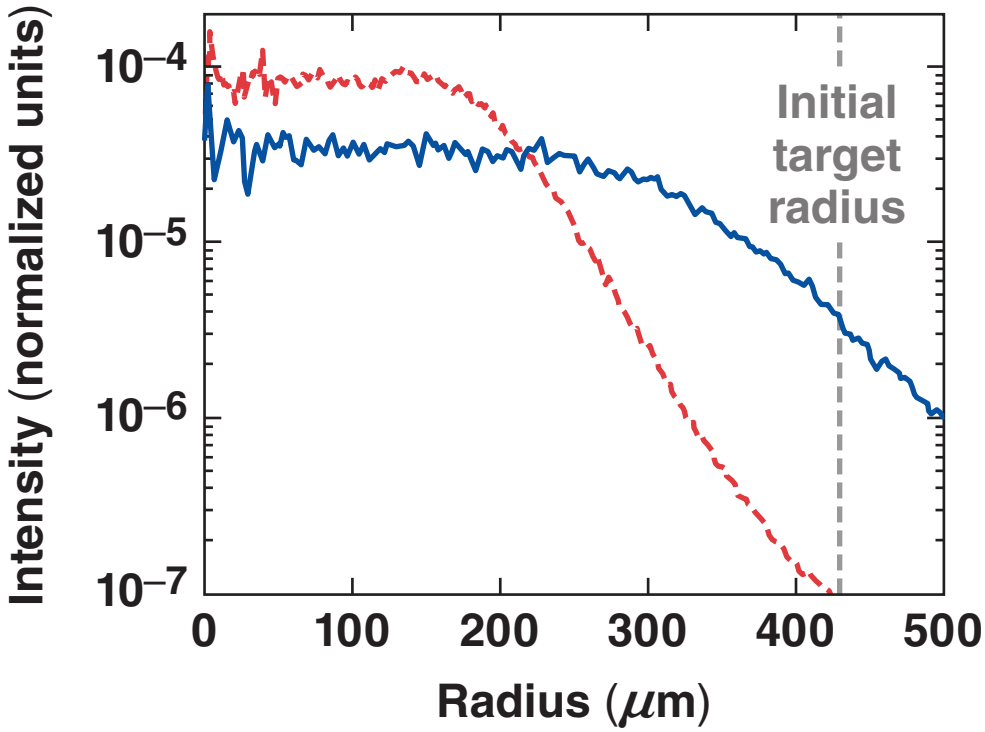
A ZPP design has a region of high-spatial-frequency phase to produce a large spot and a region of low-frequency phase to produce a small spot





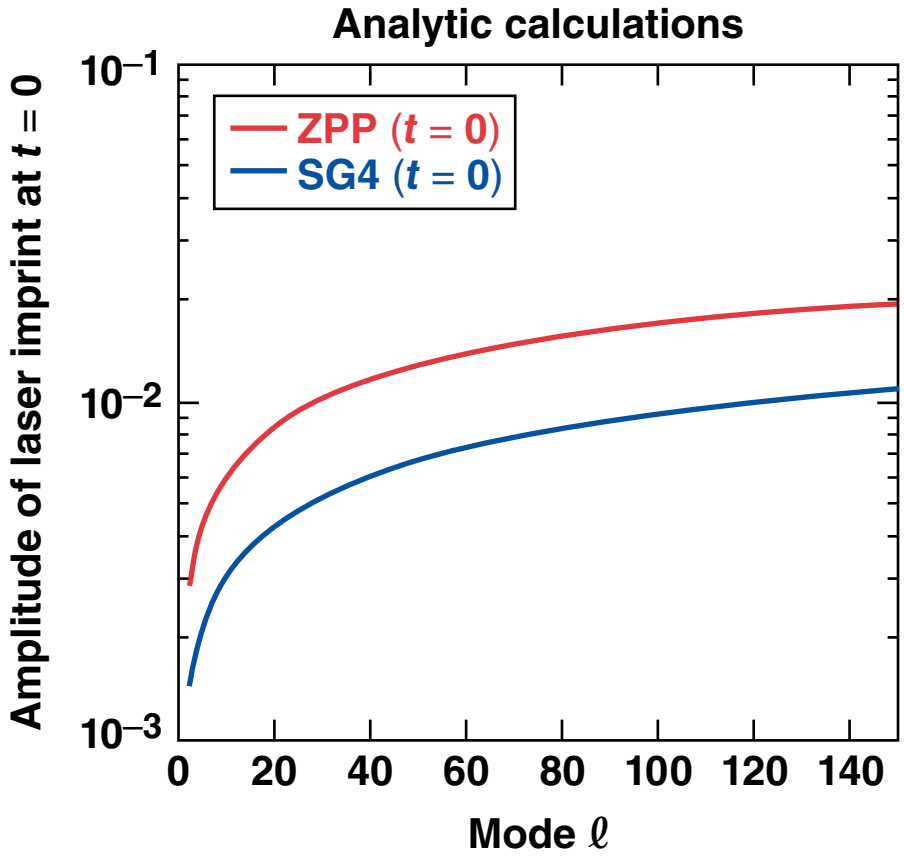
E22158

The smaller diameter laser beams used during the pickets in this design may increase the imprint power spectrum over the modes with the highest Rayleigh–Taylor growth rates

Analytic calculations are used for a first-order imprint estimate:

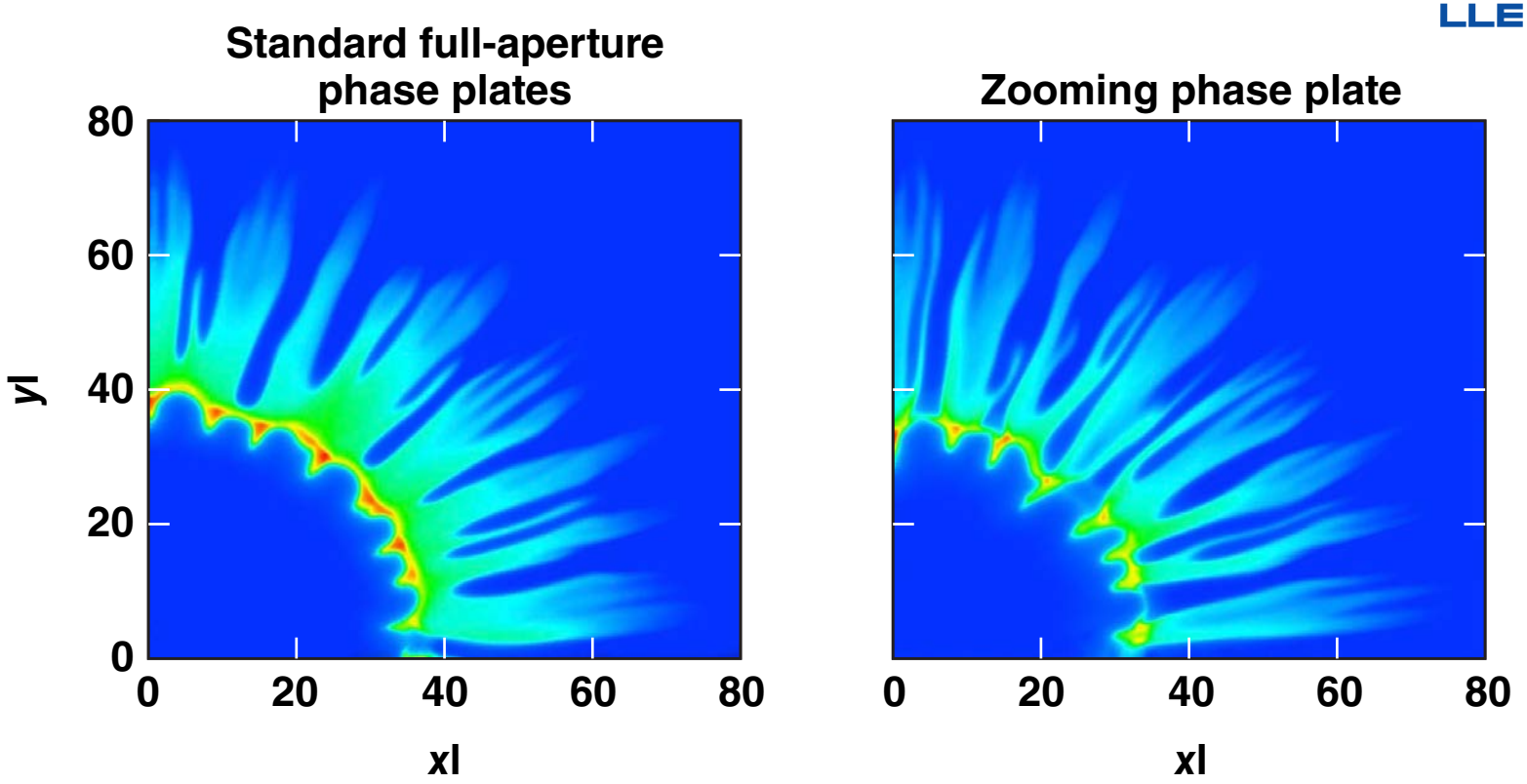
$$\sigma_I^2 = \frac{16}{\pi \ell_{max}} \frac{\ell}{\ell_{max}} \times \left[\cos^{-1}\left(\frac{\ell}{\ell_{max}}\right) - \left(\frac{\ell}{\ell_{max}}\right)\sqrt{1-\left(\frac{\ell}{\ell_{max}}\right)^2} \right]$$

$$\ell_{max} = Rk_{max} = \frac{2\pi}{\lambda}\left(\frac{R_{target}}{FL}\right) D_{beam}$$



*R. Epstein, J. Appl. Phys. 82, 2123 (1997).

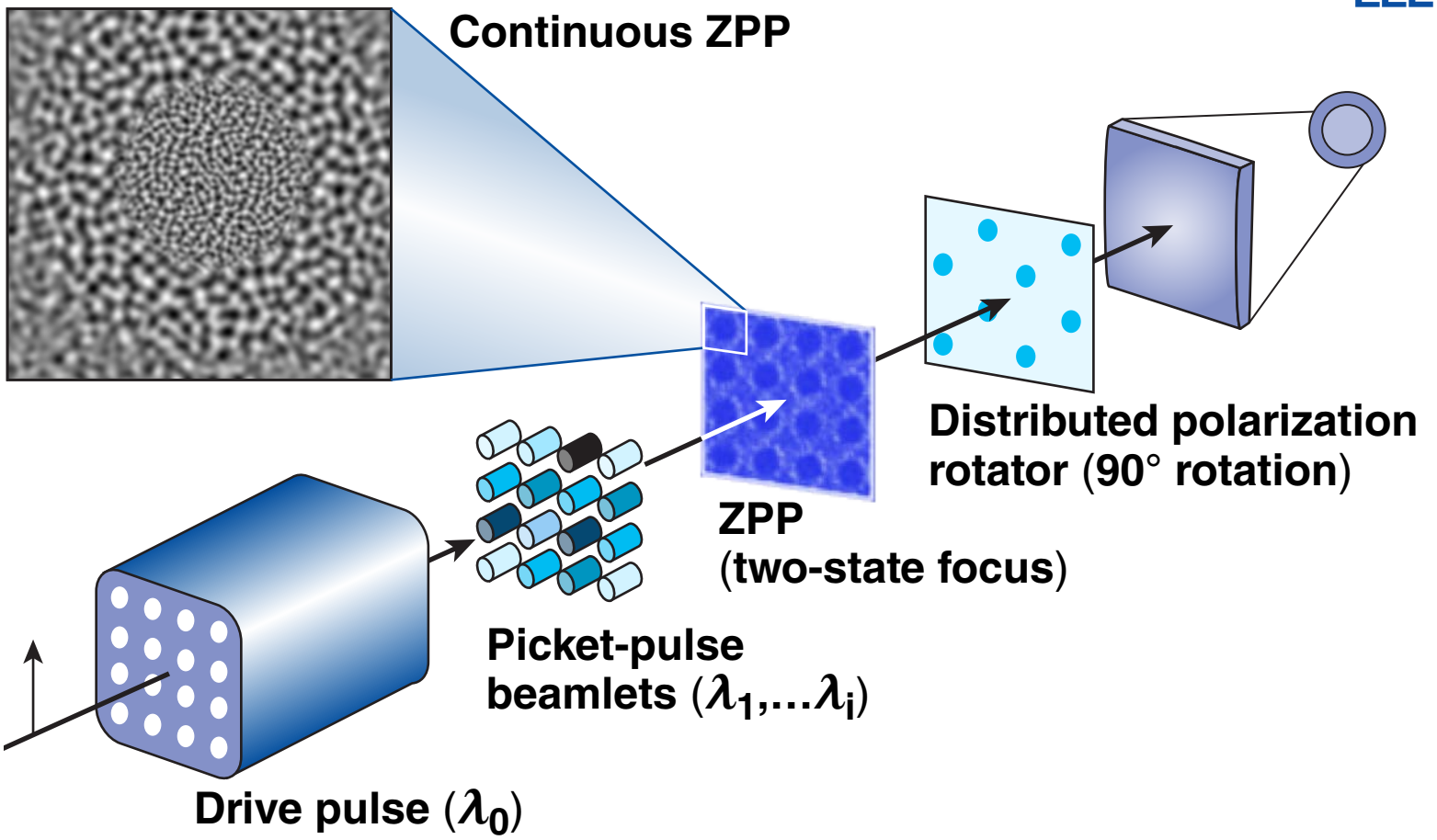
Two-dimensional simulations, which include the analytic ZPP power spectrum, show that the increased imprint leads to a 40% reduction in the neutron yield



Prediction	$\langle T_i \rangle_n$ (keV)	$\langle \rho R \rangle_n$ (mg/cm^2)	Yield	YOC
Uniform (1-D)	4.3	283	2.60×10^{14}	100%
SG4	4.3	253	1.76×10^{14}	~68%
ZPP	4.2	211	1.08×10^{14}	~42%

E22159

To improve the power spectrum, the ZPP is being redesigned to reduce the energy over the modes that most significantly contribute to imprint

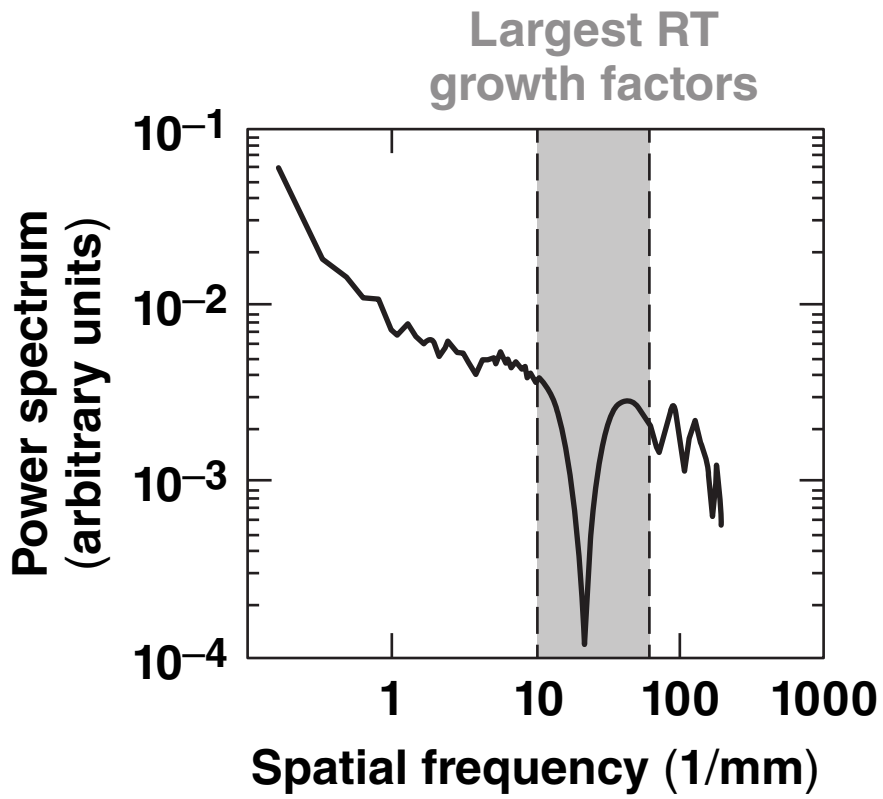


ZPP's with an incoherent picket array provide two-state focusing with enhanced beam smoothing.

E22160

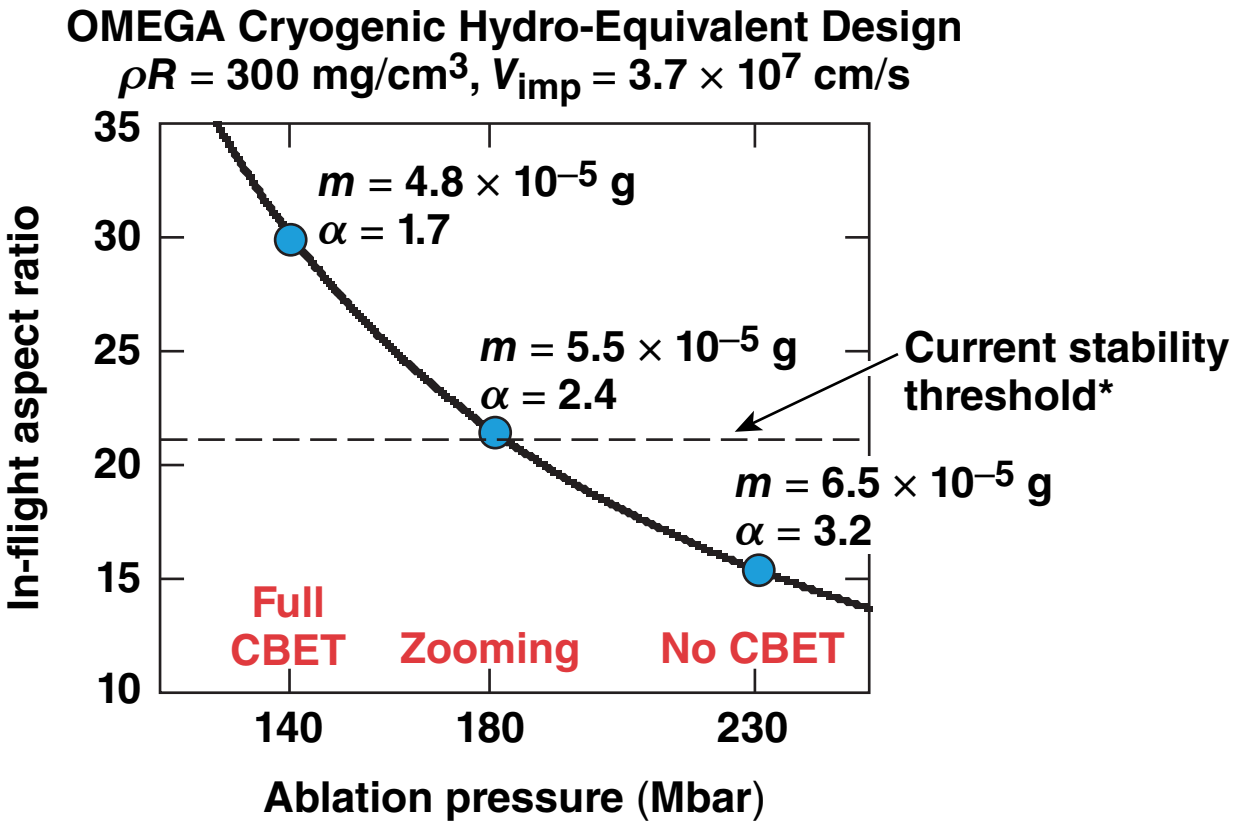
T. J. Kessler, *et al.*, to be submitted to Optics Letters

The incoherent picket array produces a notch in the power spectrum



The notch in the power spectrum can be tuned to the frequency of the most dominate Rayleigh–Taylor mode.

Zooming will allow the mass of the shell and the adiabat to be increased while maintaining ignition-relevant conditions



Implementing zooming on OMEGA will provide a more robust implosion to hydrodynamic instabilities.

*T. C. Sangster *et al.*, Phys. Plasmas 20, 056317 (2013).

Summary/Conclusions

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