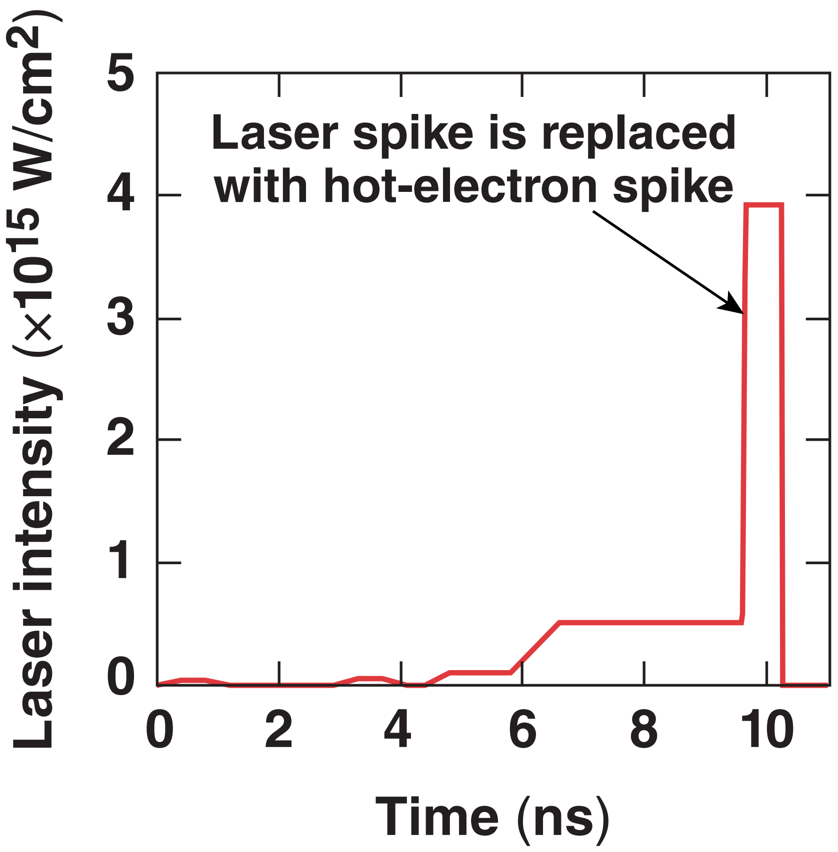
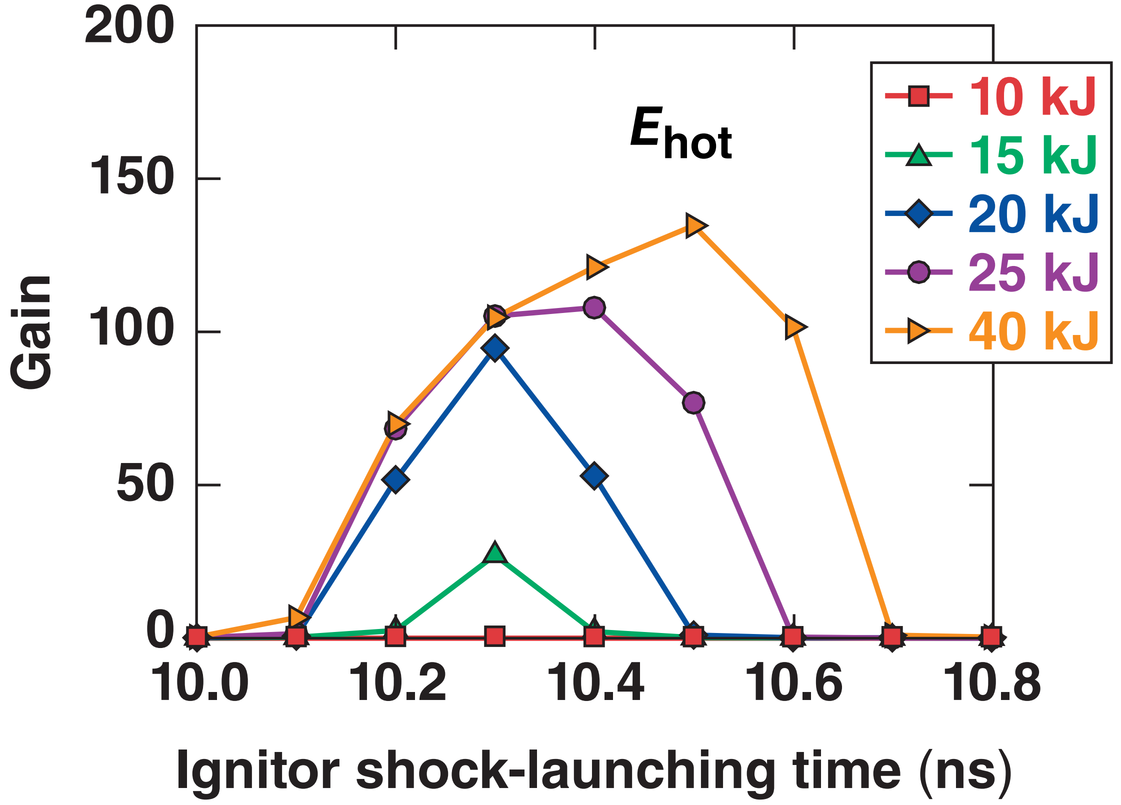
Two-Dimensional Simulations of Electron Shock Ignition at the Megajoule Scale





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Summary

Hot-electron–driven shocks can ignite direct-drive targets at megajoule laser energies (electron shock ignition)

- At 10^{16} W/cm^2, hot electrons can be more effective than laser ablation for driving ignitor shocks into shock-ignition targets
- 1-D simulations show ignition and high gain for shock-ignition targets at megajoule energies
- 2-D simulations are used to evaluate the robustness of electron shock ignition

TC13078

Collaborators

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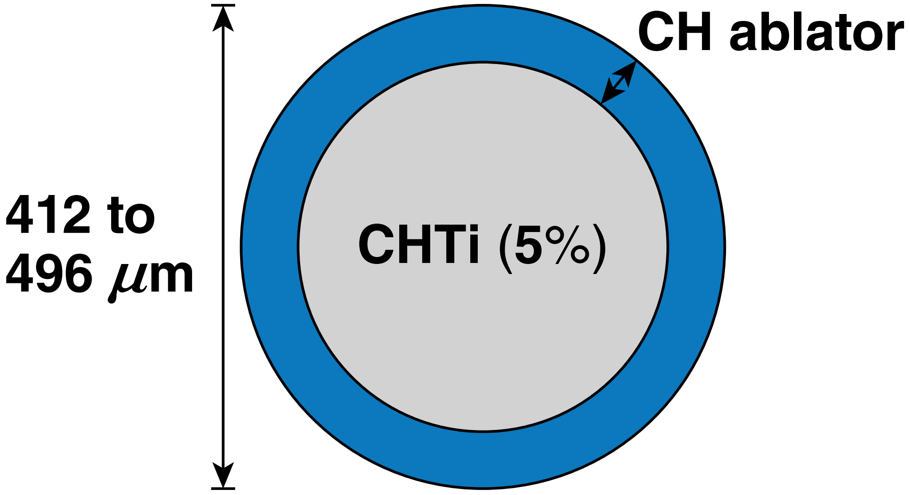
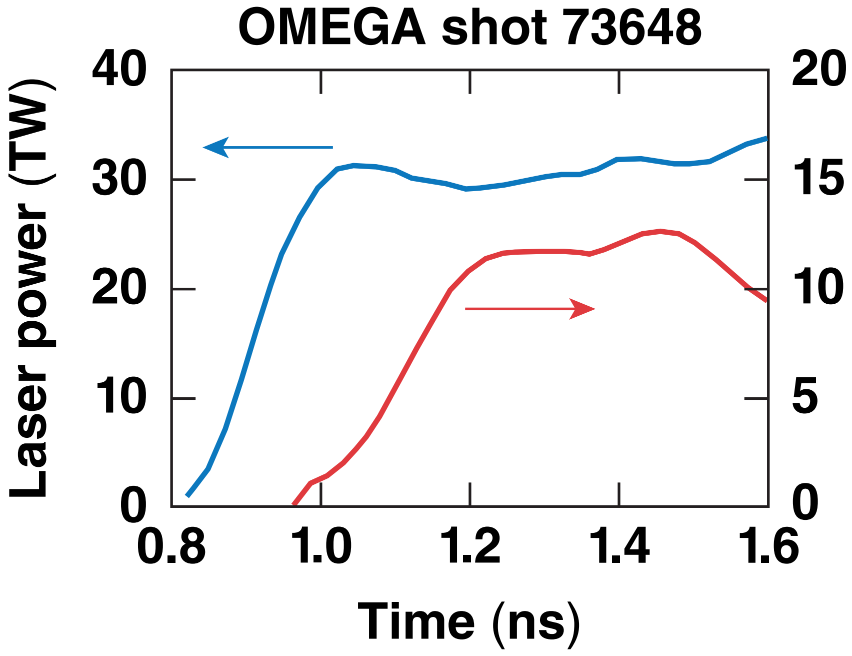
A large amount of hot electrons are produced at shock-ignition-relevant laser intensities

- OMEGA experimental data show that the laser-to-hot-electron instantaneous conversion efficiency can be up to 13% in CH targets*
- For a laser intensity of 5 × 10^{15} W/cm^2, with smoothing by spectral dispersion (SSD) off, T_{hot} ~ 60 keV is observed and the dominated scheme is stimulated Raman scattering (SRS)
- National Ignition Facility (NIF)-scale targets will likely produce even more hot electrons because of the larger plasma scale length





η: laser-to-hot-electron conversion efficiency

R. Nora *et al.*, Phys. Rev. Lett. 114, 045001 (2015).

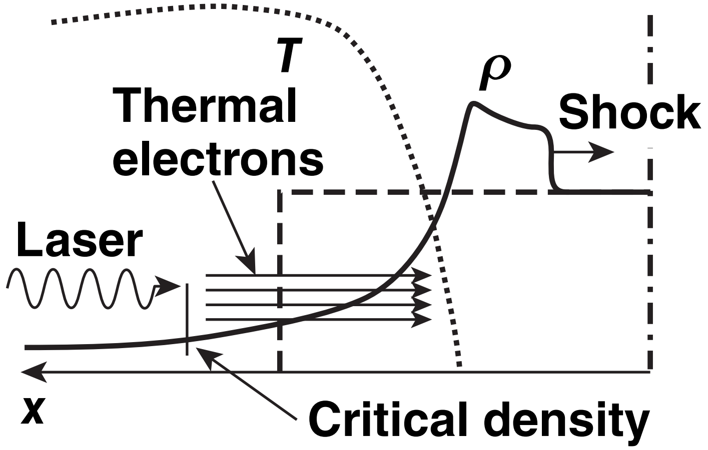
* W. Theobald *et al.*, "The Effect of the Ablator Material on Hot Electrons and Ablation Pressure in Shock Ignition," to be submitted to Physical Review Letters.

TC13079

Simple models are used to compare the laser and hot-electron ablation pressure

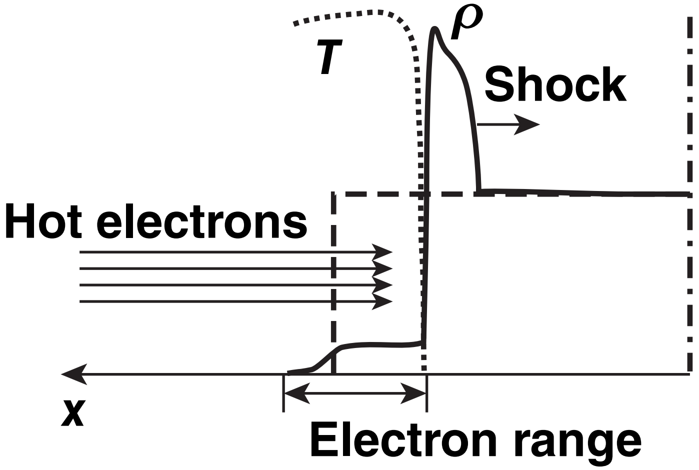
- Laser driven
  - isothermal rarefaction
  - ablation pressure

$$P_{\text{laser}} = 40\left(\frac{I_{15}}{\lambda}\right)^{2/3}\ \text{Mbar}$$



- Electron driven
  - range
  - launching time
  - ablation pressure*

$$P_{\text{hot}} = 175\rho^{1/3}\left(I_{15}\eta\right)^{2/3}\ \text{Mbar}$$



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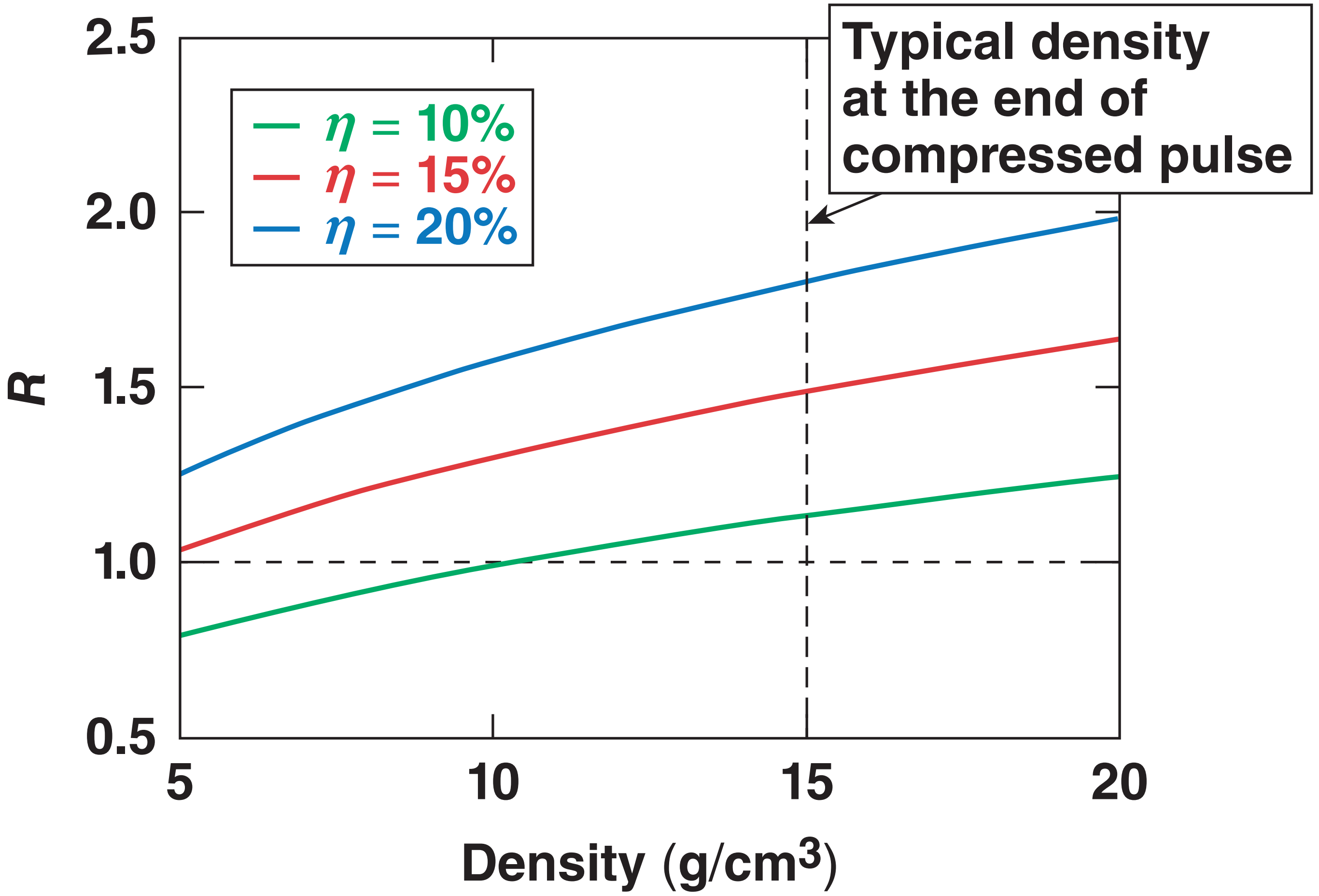
*X. Ribeyre *et al.*, Phys. Plasmas 20, 062705 (2013);
A. R. Piriz, S. A. Piriz, and N. A. Tahir, Phys. Plasmas 20, 112704 (2013);
S. Gus'kov *et al.*, Phys. Rev. Lett. 109, 255004 (2012).

Hot-electron–driven ablation pressure exceeds laser-driven ablation pressure for high-density material

- **High density and high hot-electron conversion efficiency benefit the hot-electron–driven ablation pressure**

η: laser-to-hot-electron conversion efficiency

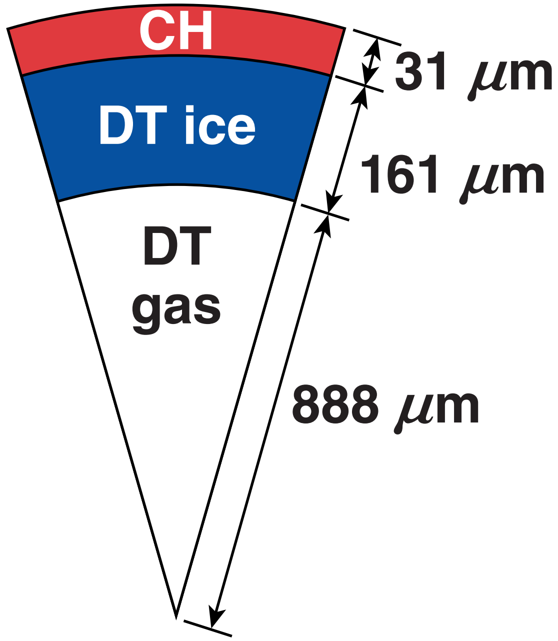
$$R = \frac{P_{\text{hot}}}{P_{\text{laser}}} = 2.17\rho^{1/3}\eta^{2/3}$$

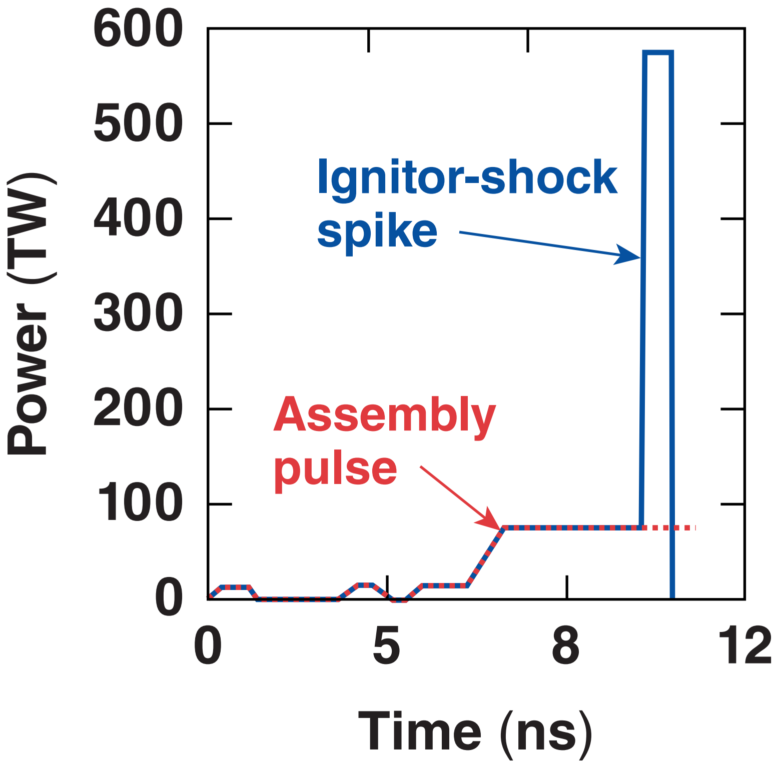


TC13081

Simulations of electron shock-ignition implosions use targets previously designed for shock ignition on the NIF

- The assembly pulse target design* uses low implosion velocity ~200 km/s, low adiabat ~1.5, and low main-drive intensity ~5 × 10^{14} W/cm^2
- In our simulations, the laser spike is replaced with a hot-electron spike with $\eta \sim$ 10% to 20%





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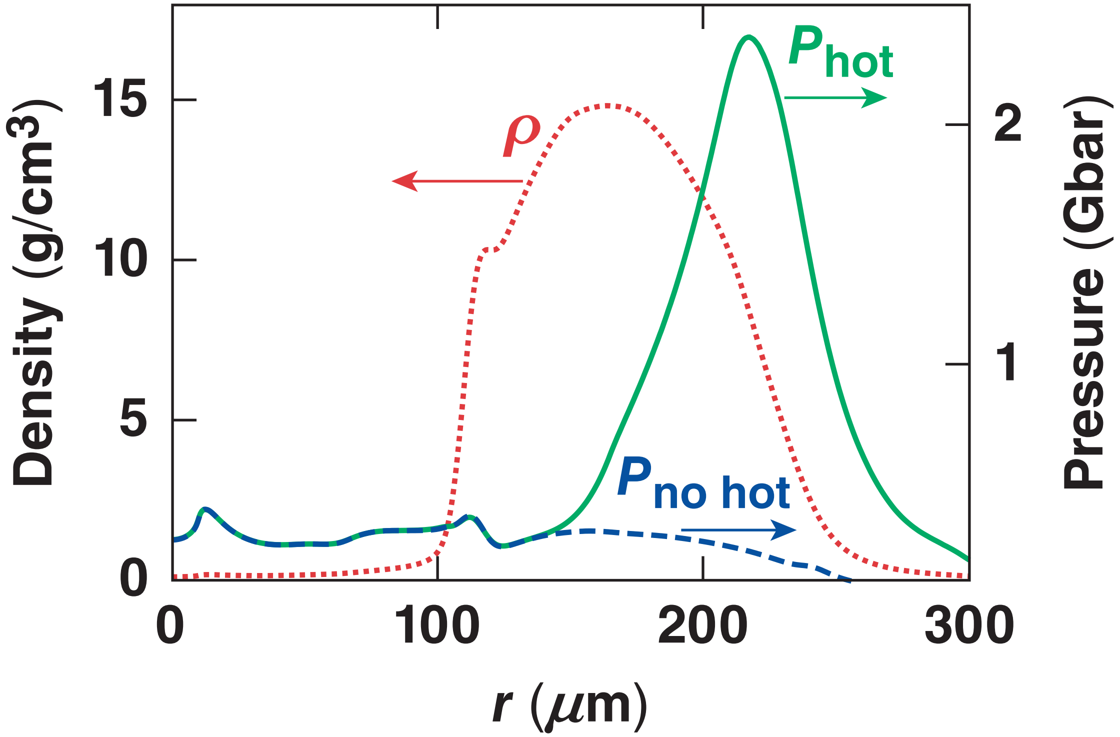
*K. S. Anderson *et al.*, Phys. Plasmas 20, 056312 (2013).

TC7712

Hot electrons are included in the *DEC2D** code to simulate electron-driven shocks, and shocks are produced by increasing the static pressure

- Hot electrons have Maxwellian distribution with stopping power modeled by Solodov–Betti** using the straight-line method
- 50 groups up to 400 keV, T_{hot} = 60 keV,† E_{hot} = 25 kJ



The dense shell pressure increases through hot-electron-energy deposition.

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* K. Anderson, R. Betti, and T. A. Gardiner, Bull. Am. Phys. Soc. 46, 280 (2001).

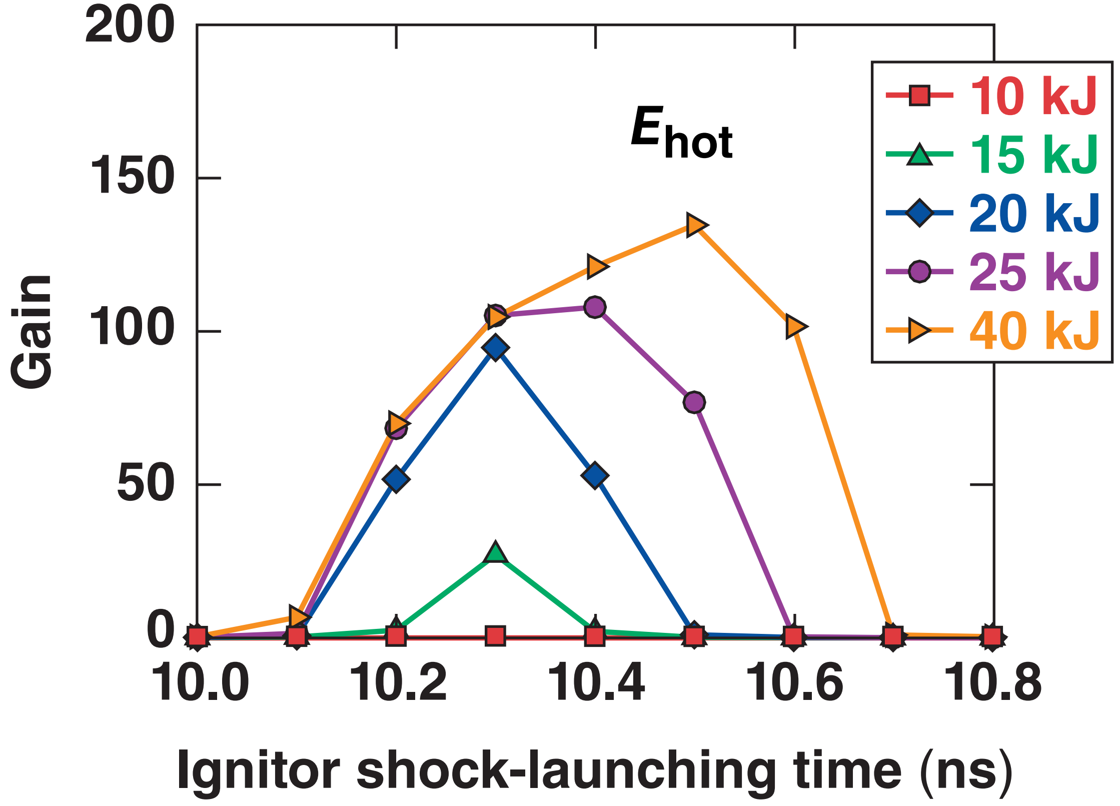
** A. A. Solodov and R. Betti, Phys. Plasmas 15, 042707 (2008).

† W. Theobald *et al.*, "The Effect of the Ablator Material on Hot Electrons and Ablation Pressure in Shock Ignition," to be submitted to Physical Review Letters.

TC13082

One-dimensional simulations show high gains with E_{laser} ~ 600 kJ and E_{hot} > 20 kJ lead to a large shock-launching window

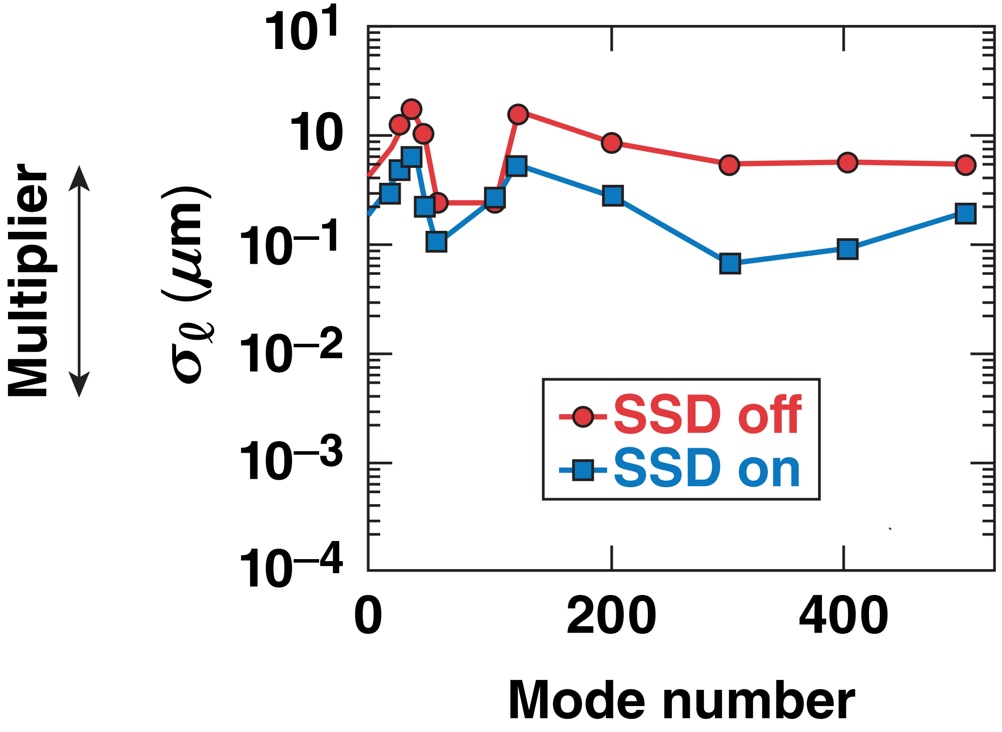
- >10-kJ hot electrons can ignite
- Greater hot-electron energy leads to higher gain
- Greater hot-electron energy leads to a wider ignition window

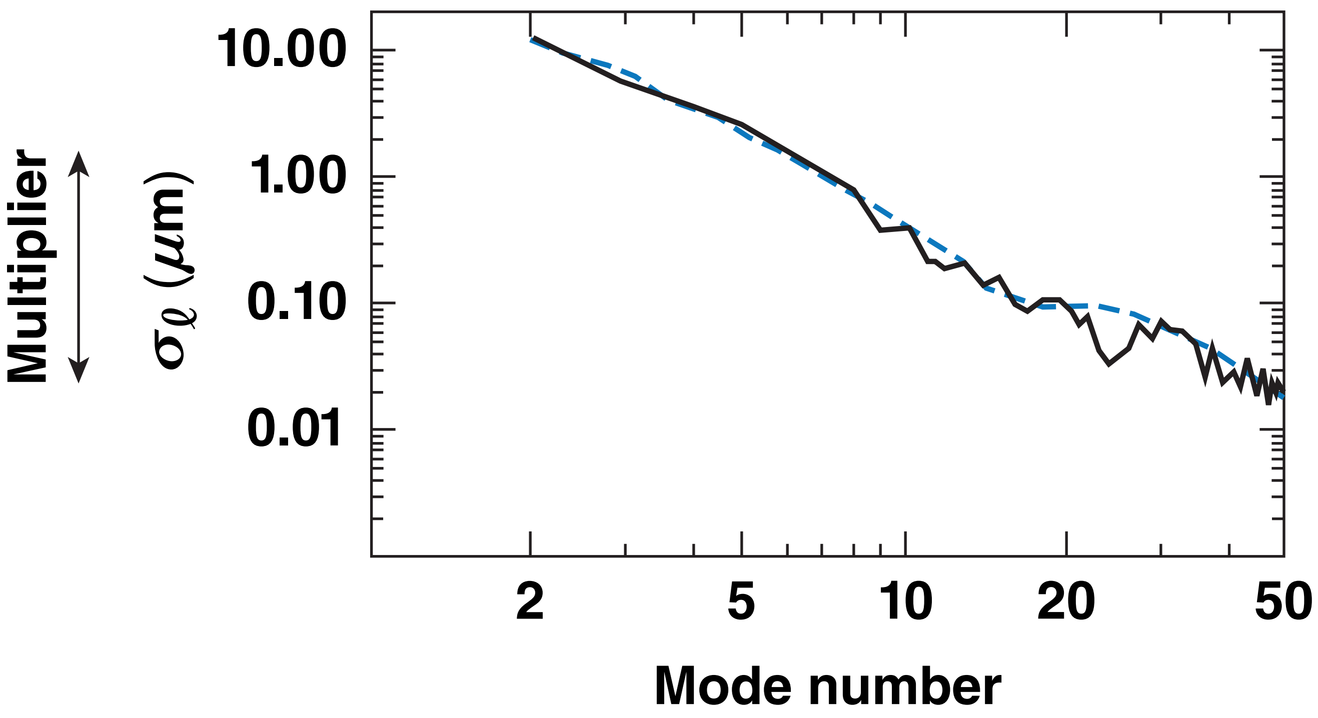


TC13083

Perturbation spectra are introduced at the end of the main pulse (before the ignitor shocks)

- Density perturbations are utilized
- Two kinds of multimode perturbation spectra are used from available references


OMEGA target spectra
(ablation surface)*


NIF target spectra
(inner surface)**

TC13084

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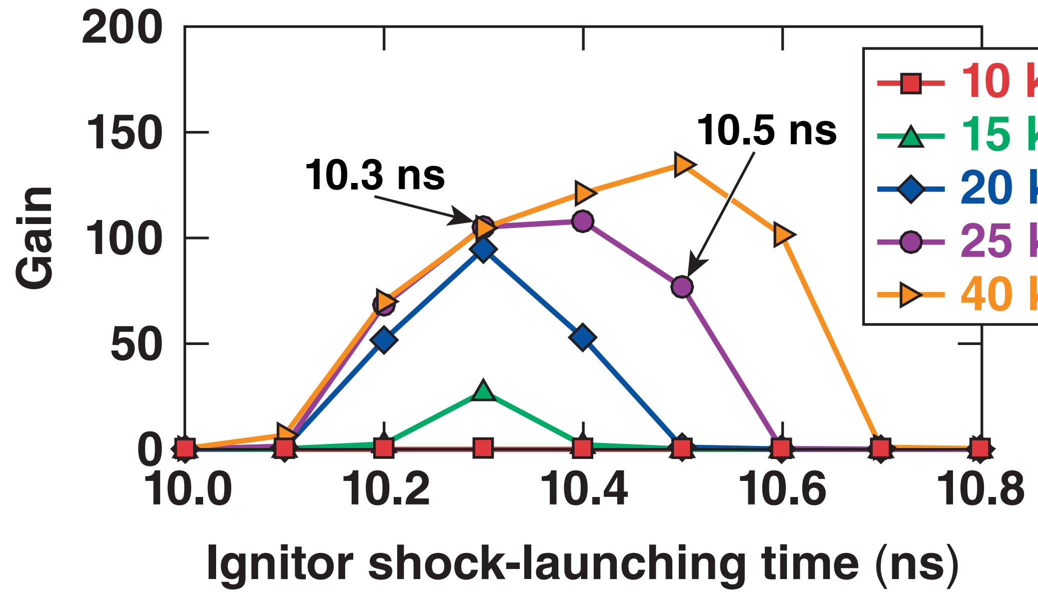
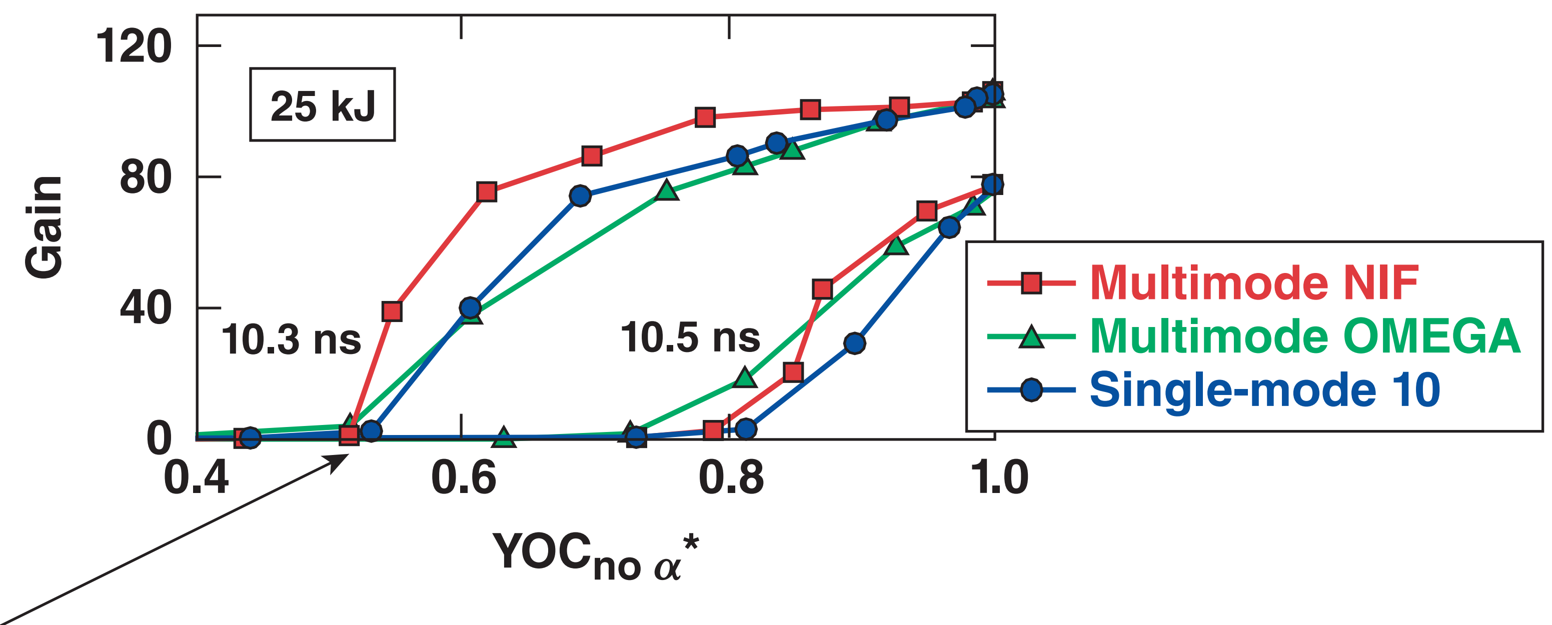
*S. X. Hu *et al.*, Phys. Plasmas 17, 102706 (2010).

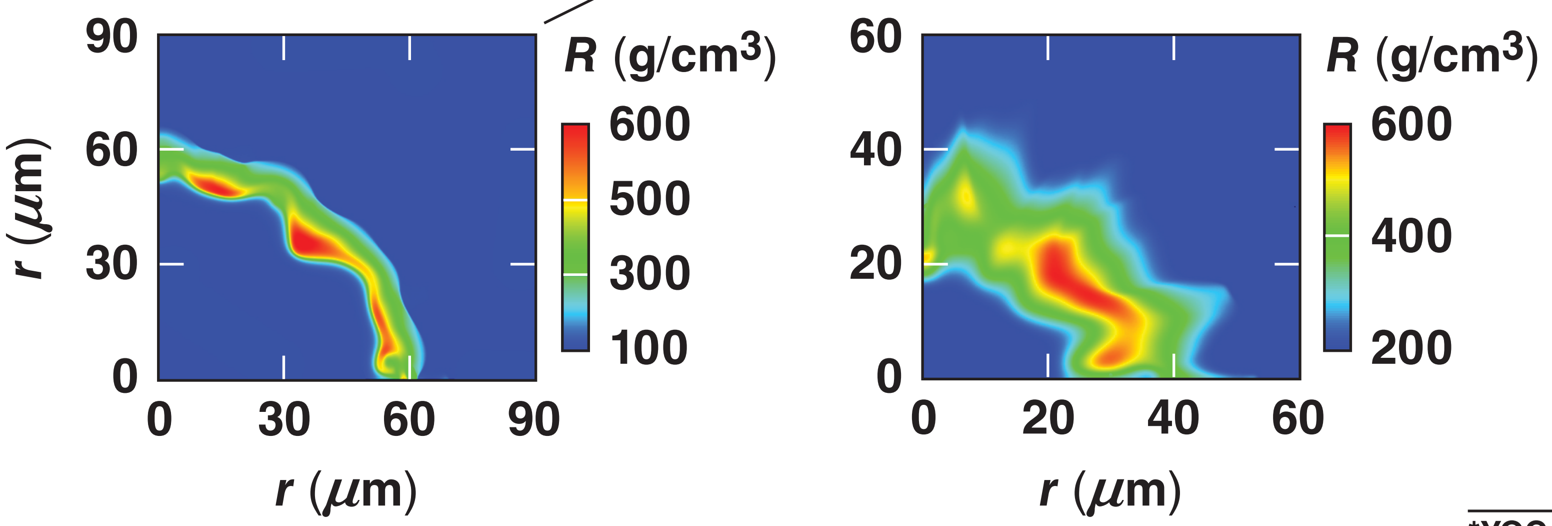
**P. W. McKenty *et al.*, Phys. Plasmas 8, 2315 (2001).

Two-dimensional simulations show the target robustness depends on the shock-launching time





Marginal ignition with α heating, Gain = 4



Without α heating

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*$YOC_{no\ \alpha}$ = yield-over-clean without alphas

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