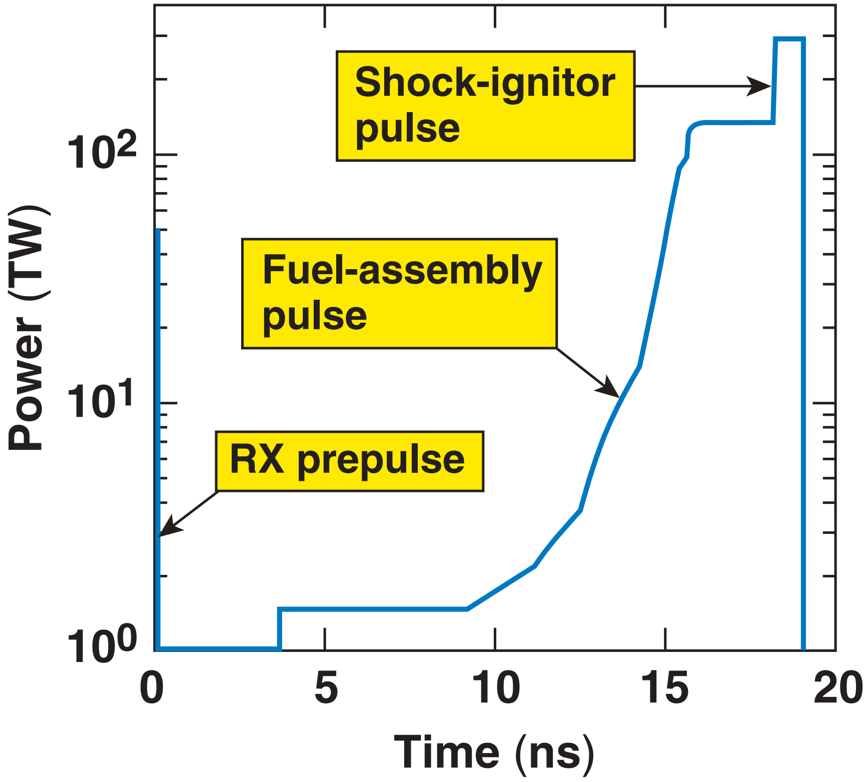
# Shock Fast Ignition of Thermonuclear Fuel with High Areal Density



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**Summary**

# Shock ignition offers interesting prospects for high gains at a low direct-driver energy

- High density/areal-density fuel can be assembled through low-velocity, low-adiabat implosions.
- 1-D simulations show that such a fuel assembly can be ignited by a spherically convergent shock.
- Two designs are presented with 100-kJ and 500-kJ fuel assemblies ignited by a 60-kJ and 200-kJ shock yielding 1-D gains of ~60 and ~120 respectively.
- 2-D simulations are being performed to evaluate the target robustness to inner surface roughness and laser imprinting.

# Low implosion velocity leads to small RT growth and high gain; however, slow targets are difficult to ignite with standard central ignition.

- Low velocity = high-gain G

$$\boxed{G \approx \frac{73.4}{I_{15}^{0.25}}\left(\frac{3\times10^{7}}{V_{i}\,(\mathrm{cm/s})}\right)^{1.25}\left(\frac{\theta}{0.2}\right)} \qquad \theta = \frac{1}{1+7/\rho r}$$

- Low velocity = low RT growth. Ne = number of RT e-foldings

$$\boxed{Ne\,(kd=1) \approx \frac{V_{i}}{3\times10^{7}}\left[\frac{6.7}{I_{15}^{2/15}\,\alpha_{if}^{0.3}}\left(\frac{\lambda_{L}}{0.35}\right)^{2/15} - \frac{0.5}{I_{15}^{1/3}}\left(\frac{0.35}{\lambda_{L}}\right)^{2/3}\right]}$$

- Low velocity = large energy for ignition  
  $E_{ign}$ is the energy required for ignition

$$\boxed{E_{ign} \sim \alpha_{if}^{1.8}\,V_{i}^{-6}\,P^{-0.8}}$$

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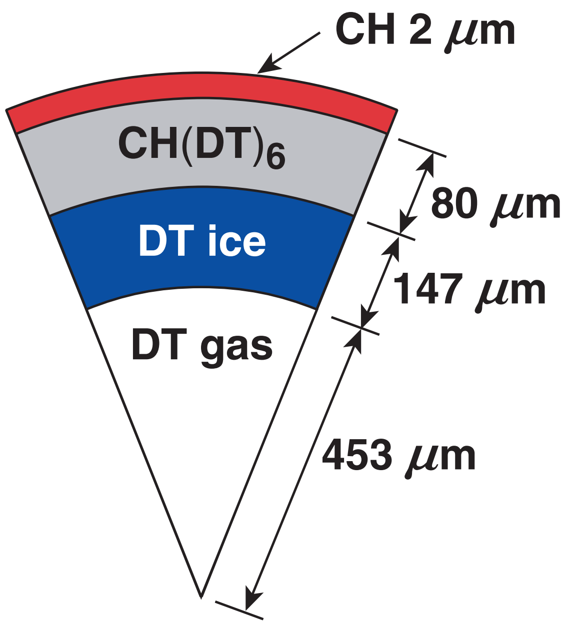
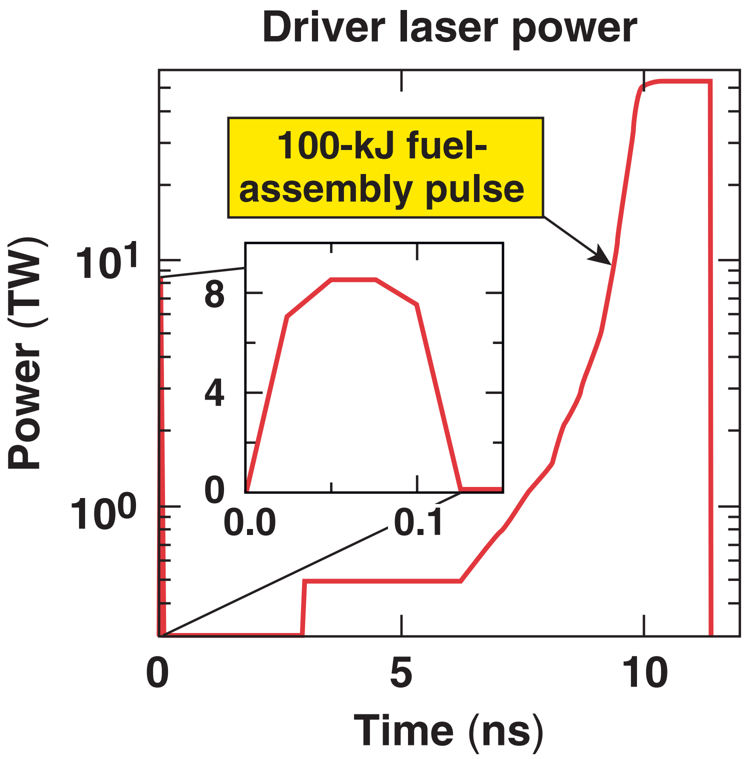
R. Betti, GO1.07  
M. C. Herrmann *et al.*, Nucl. Fusion 41, 99 (2001).

# A 100-kJ, RX-shaped pulse can assemble fuel with $\rho R = 1.6\ \mathrm{g/cm^2}$ through a slow ($V_i = 2.5 \times 10^7$ cm/s), low-adiabat implosion ($\alpha = 0.7$)

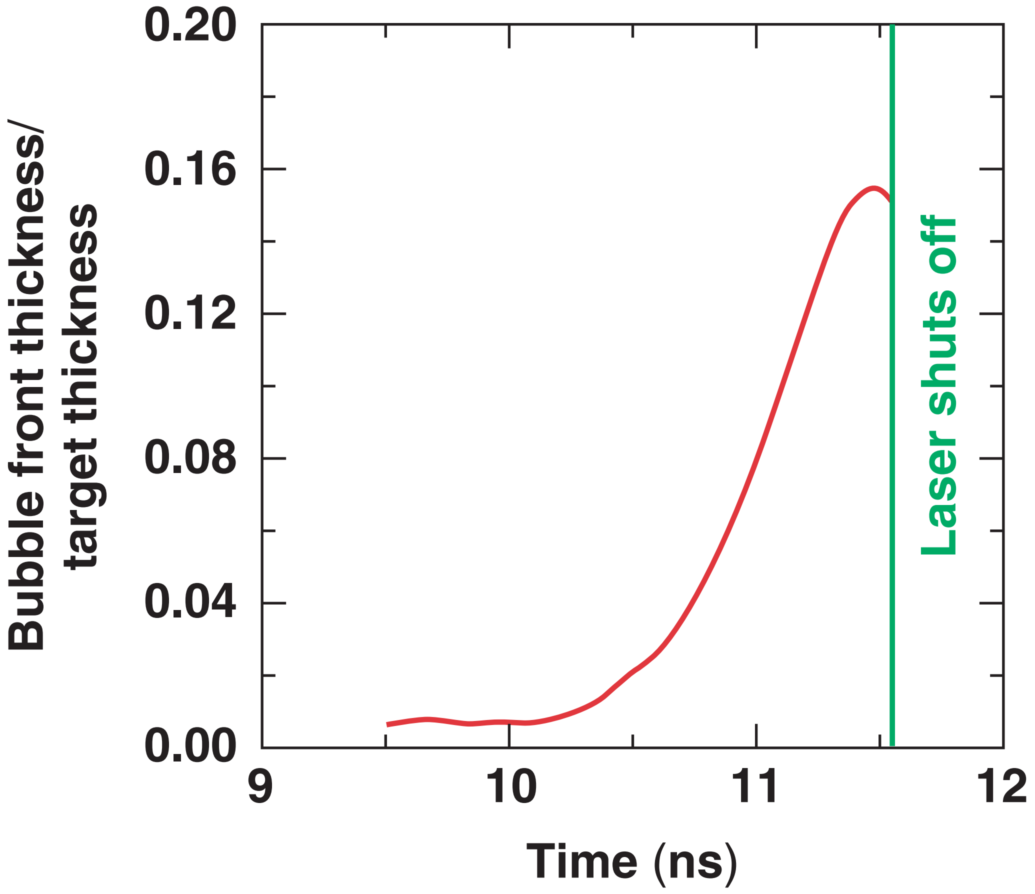




| Energy (kJ) | In-flight aspect ratio IFAR | Max. areal density ($\mathrm{g/cm^2}$) | Implosion velocity (cm/s) | Gain (not ignited) |
|---|---|---|---|---|
| 100 | 29 | 1.6 | $2.5 \times 10^7$ | 1.7% |

TC7268

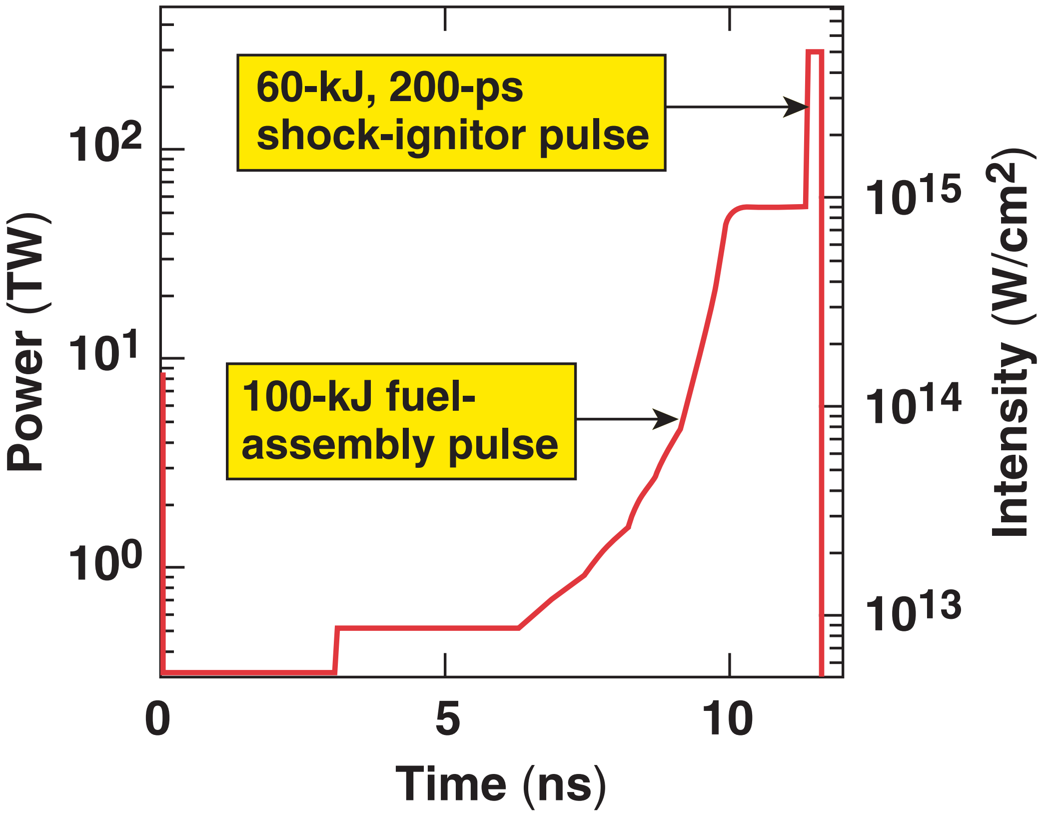
# The slow implosion velocity leads to small Rayleigh–Taylor growth during the laser flattop



- Results from RT postprocessor based on Haan–Goncharov models and OMEGA laser nonuniformities with 1-THz SSD.

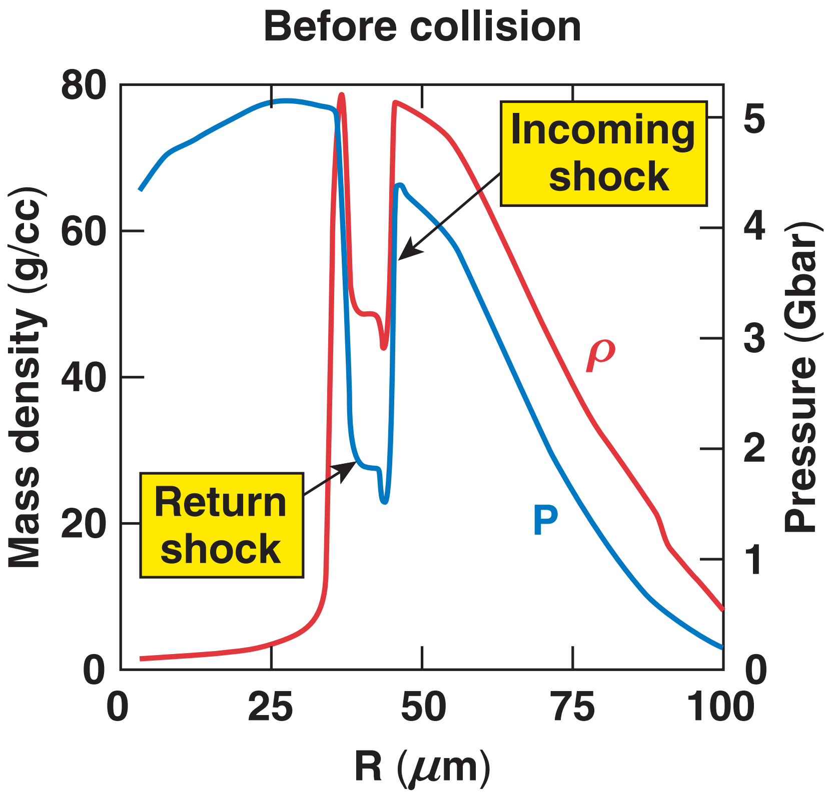
# A spherically convergent shock driven by a 60-kJ spike in the laser intensity can ignite the hot spot of the 100-kJ fuel assembly

Laser power and intensity

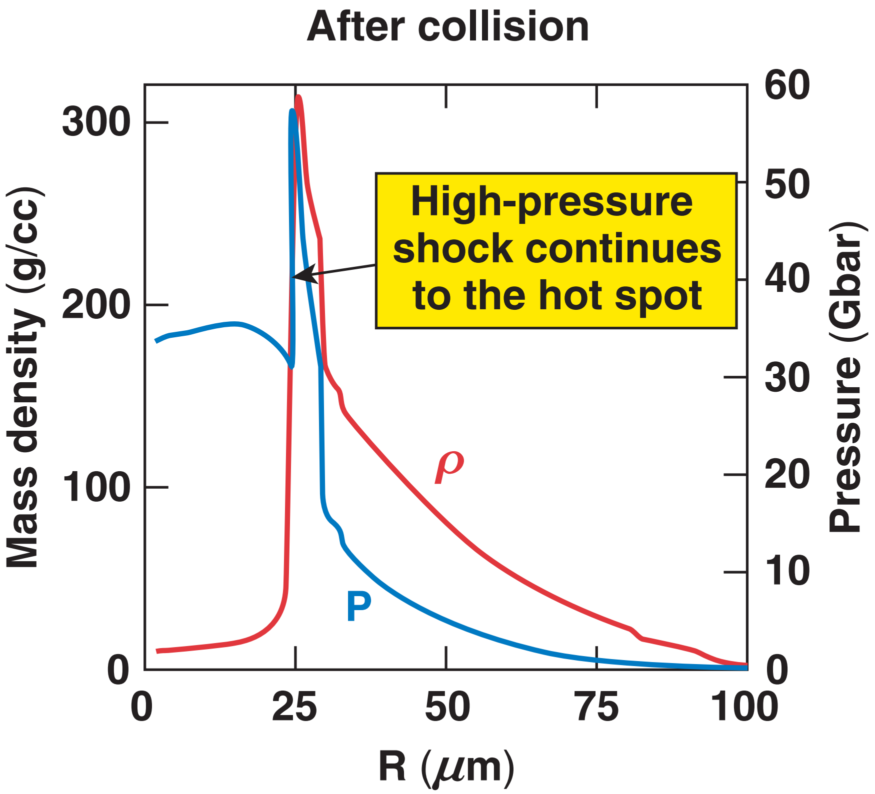


Energy gain = 68
(1-D *LILAC* simulation)

# The laser-driven shock collides with the return shock, generating a high-pressure reflected shock propagating to the hot spot

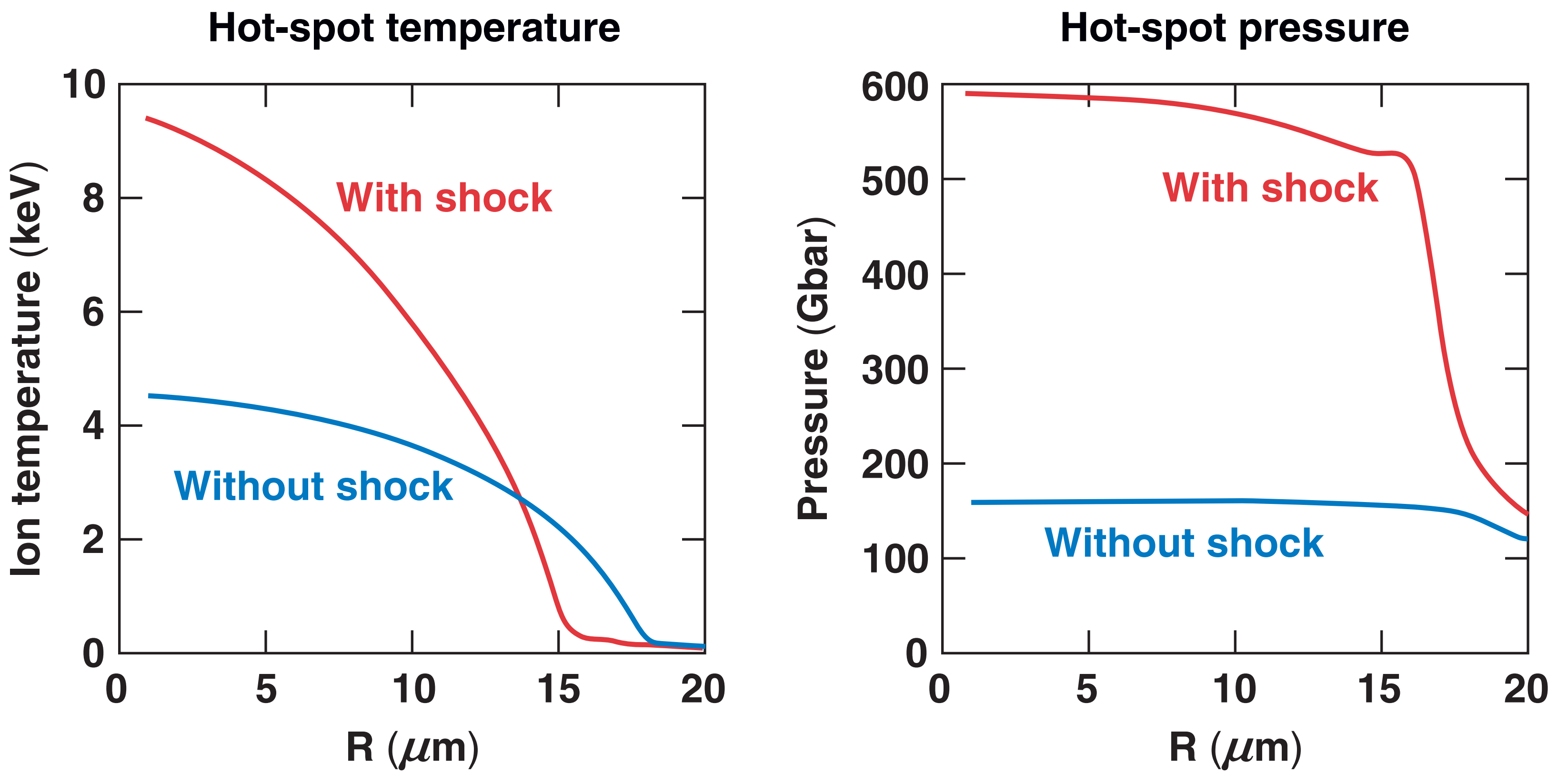

Before collision

The ignitor pulse drives an incoming shock that collides with the return shock inside the shell.

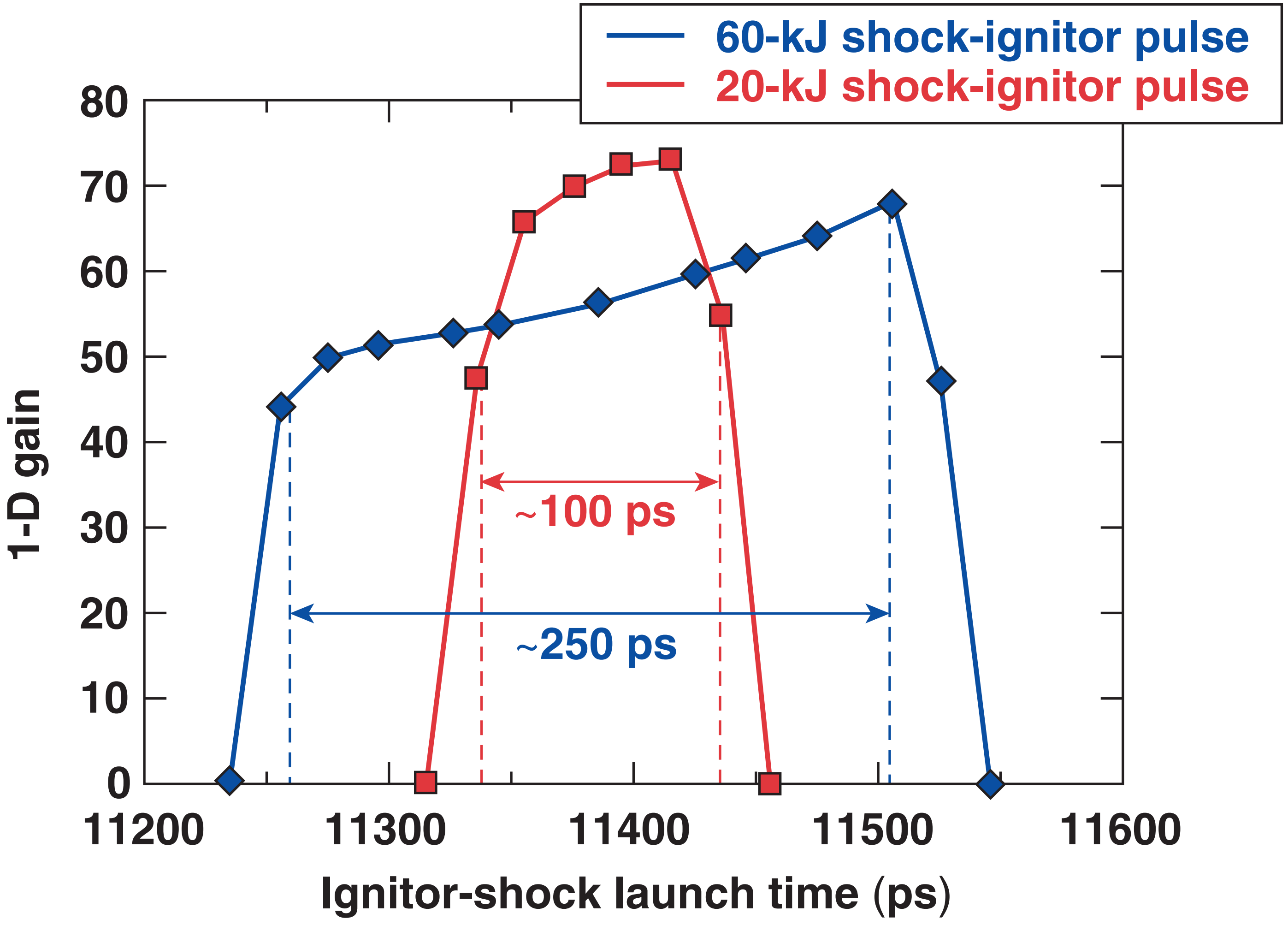

After collision

A high-pressure shock resulting from the collision continues to propagate to the central hot spot, leading to ignition.

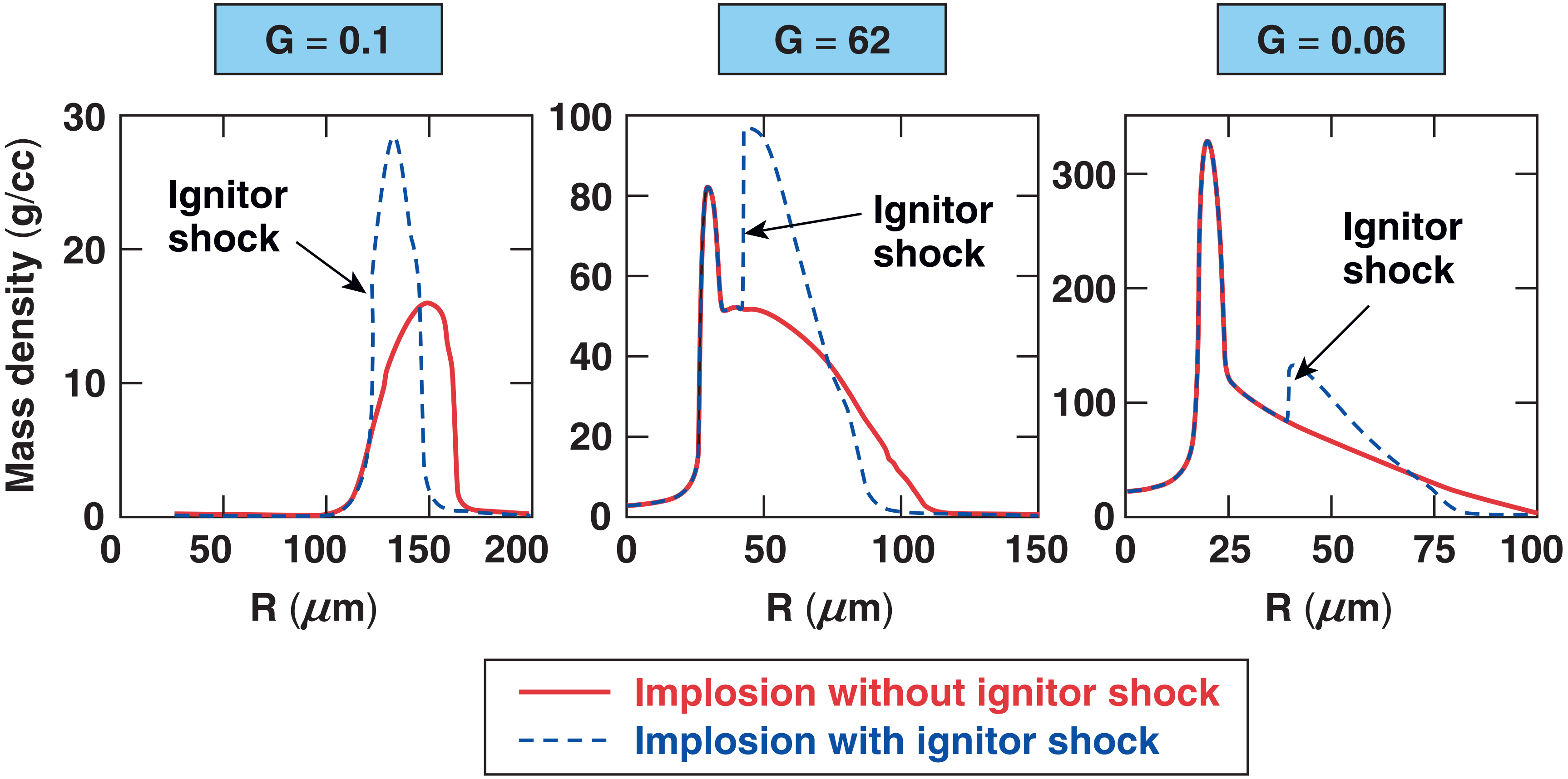
# The high-pressure shock heats the hot spot above the ignition threshold



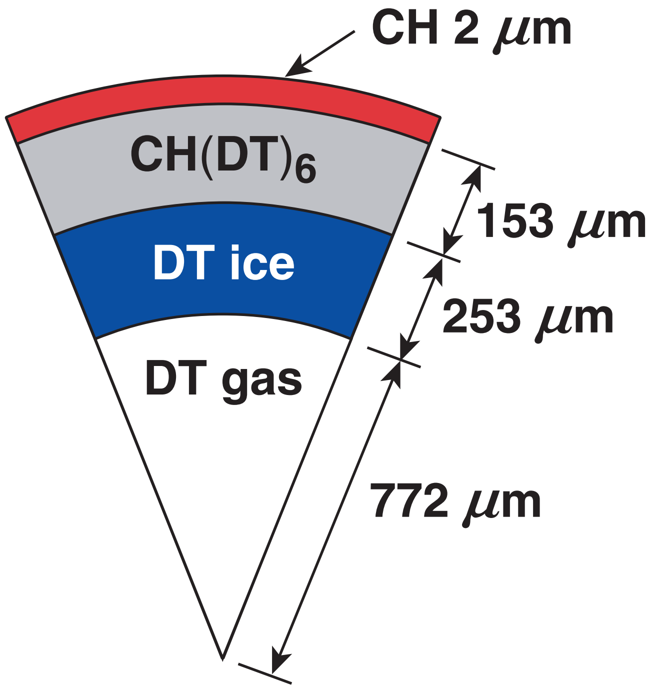
# Ignition is sensitive to the ignitor-shock launch time

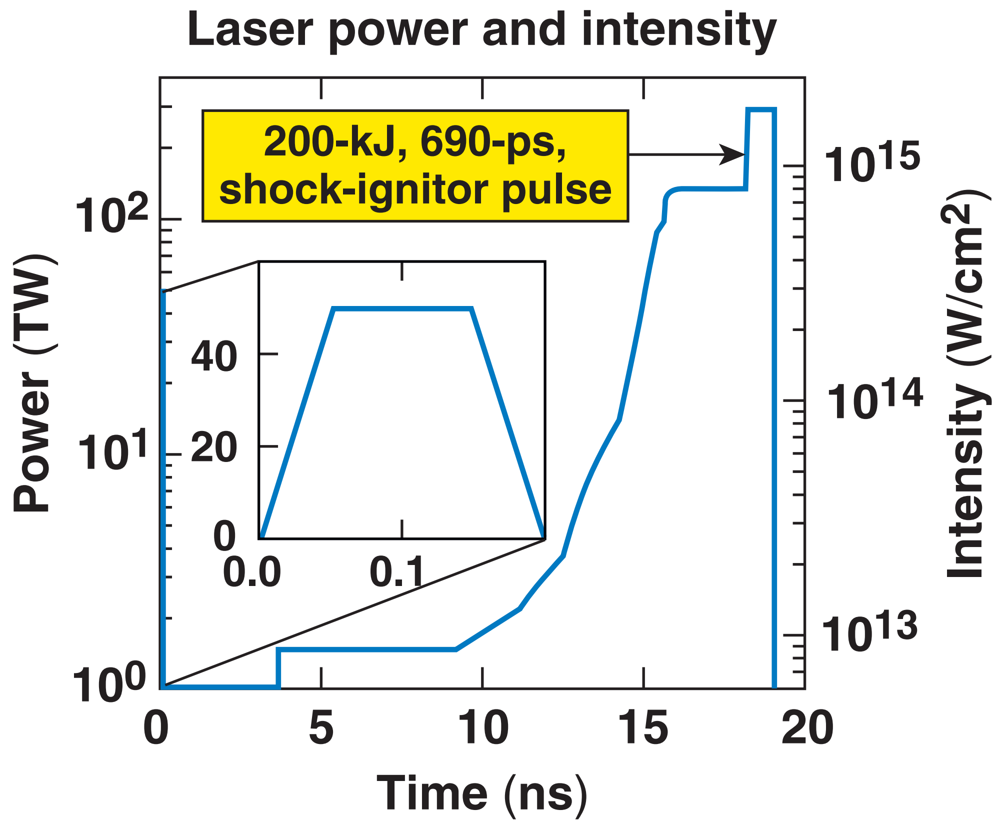


# The ignitor and return shocks must be synchronized to collide in the region of peak density



# A 500-kJ. NIF-size fuel assembly is ignited by a 200-kJ ignitor shock to produce a gain of 116



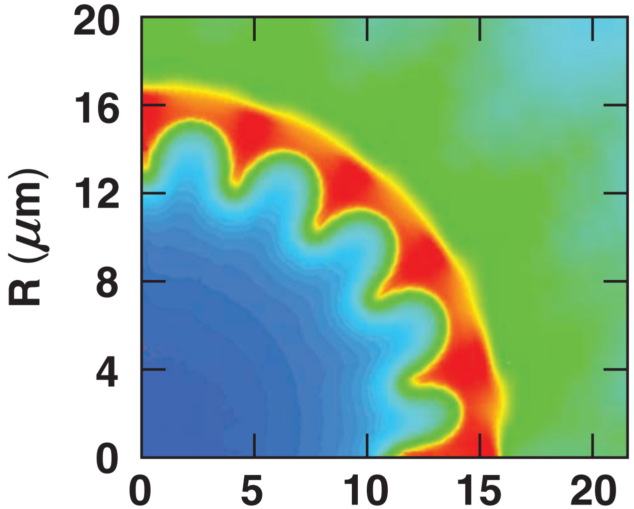


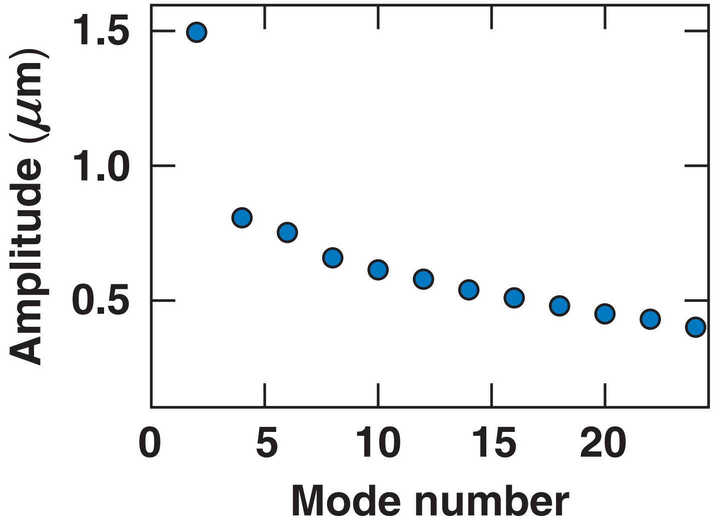
| Energy (kJ) | Ignitor pulse power (TW) | Ignitor intensity (W/cm$^2$) | In-flight aspect ratio IFAR | Max. areal density (g/cm$^2$) | Implosion velocity (cm/s) | Gain |
|---|---|---|---|---|---|---|
| 700 | 290 | $1.7 \times 10^{15}$ | 29 | 2.6 | $2.5 \times 10^7$ | 116 |

TC7275

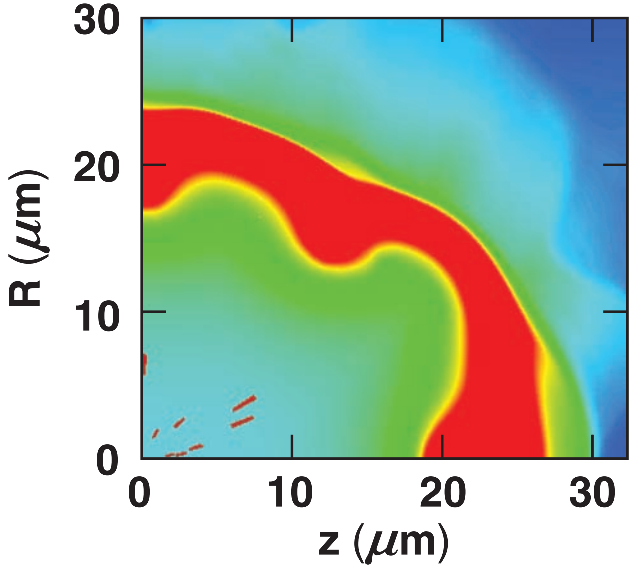
# Preliminary work on the effect of ice-surface roughness shows encouraging results with respect to design robustness

Single mode $\ell = 20$, $a(0) = 2\ \mu m$
YOC = 1





Multimode $\ell = 2$ to 24, $\sigma_{rms} = 2\ \mu m$
YOC = 0.82



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