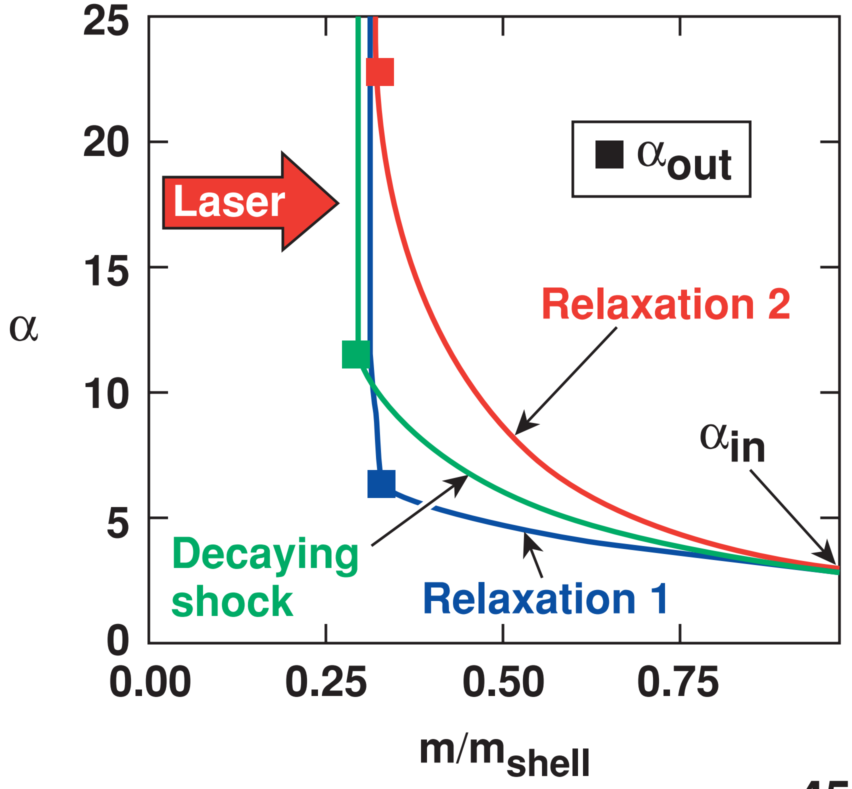
Theory of Laser-Induced Adiabat Shaping by Relaxation in ICF Implosions

LILAC Simulations



$$V_A \sim \alpha_{out}^{3/5}$$

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Summary

Adiabat shaping by relaxation with short, intense prepulses leads to ultrahigh ablation velocities

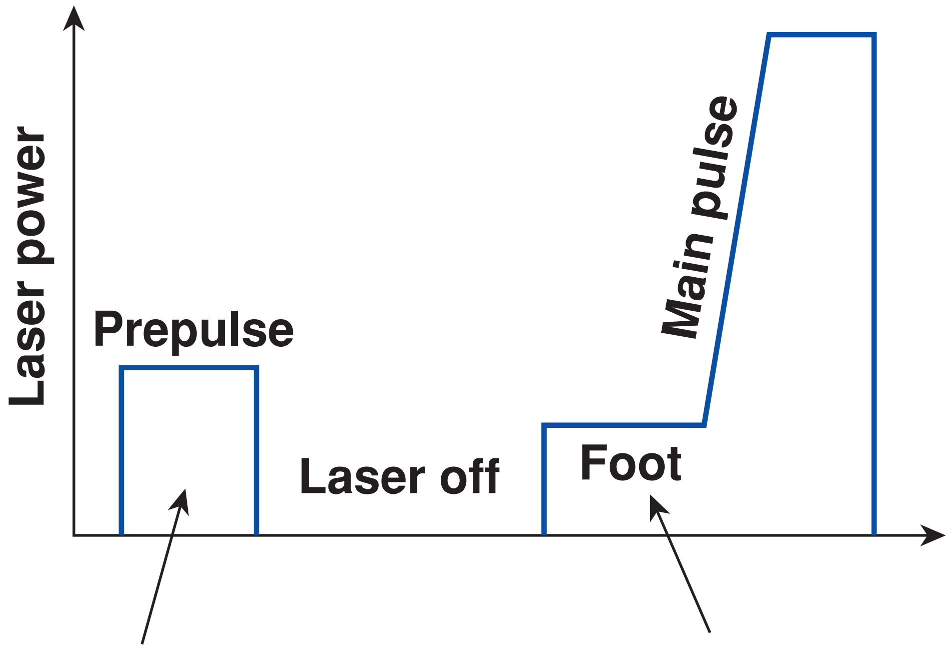
- The adiabat shape can be controlled by varying the prepulse intensity and duration.
- Short, intense prepulses lead to the steepest adiabat profiles, larger outer-surface adiabats, larger ablation velocities, and lower Rayleigh–Taylor growth rates.
- Due to its flexibility in shaping the adiabat, the relaxation method can be further optimized to minimize the imprinting level and/or reduce the impact of the convective instability.

Adiabat shaping by relaxation is performed with a laser prepulse followed by a laser shutoff and the main pulse

Decaying shock shapes P

$$\alpha = \frac{P(\text{Mb})}{2.2\,\rho(\text{g/cm}^3)^{5/3}}$$

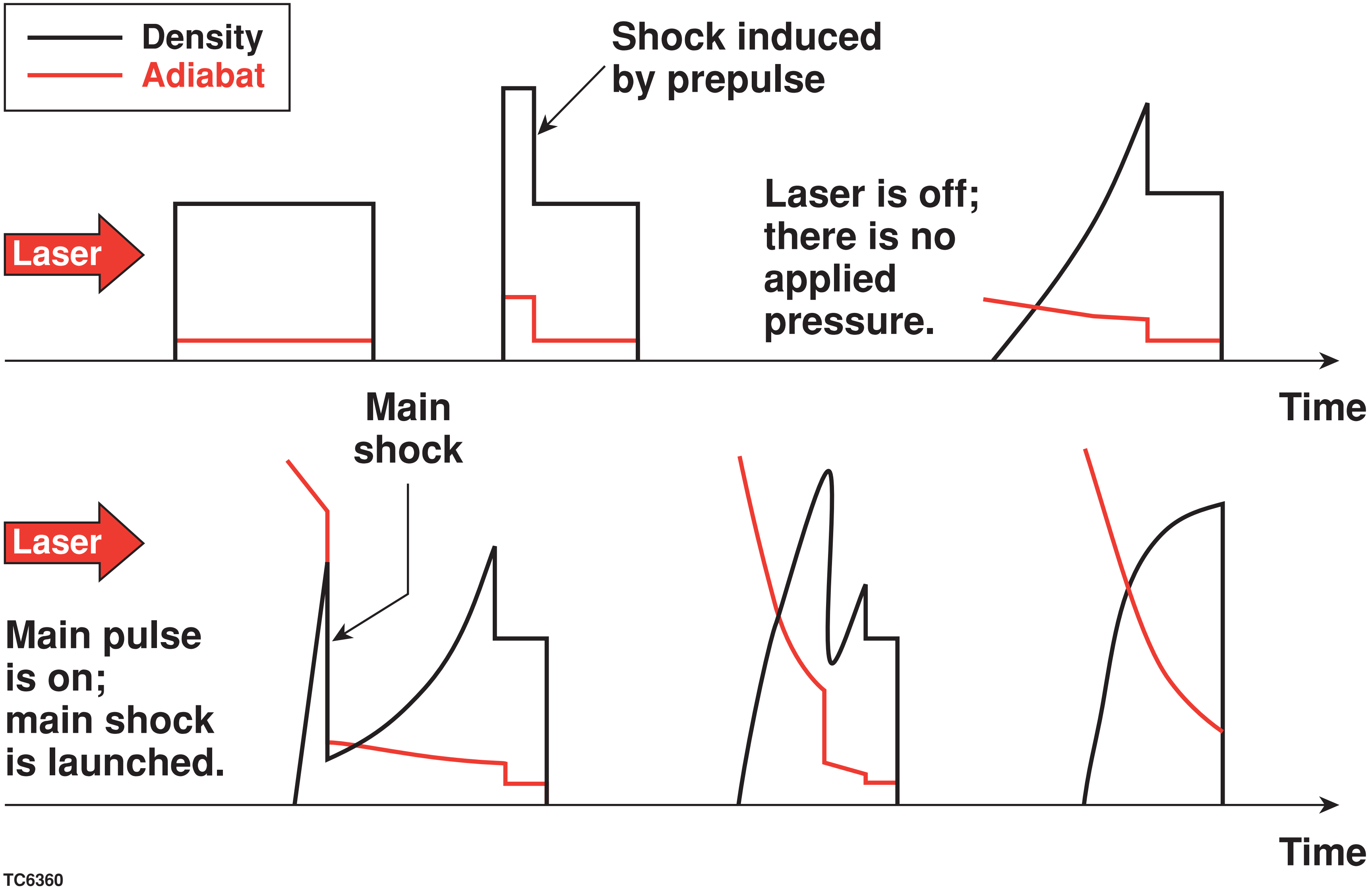
Relaxation shapes ρ



The prepulse is used to generated relaxed density profiles.

The foot of the main pulse is used to shape the adiabat.

The main shock (from the main pulse) shapes the adiabat as it travels up the density profile relaxed by the prepulse



Density
Adiabat

Laser

Shock induced by prepulse

Laser is off; there is no applied pressure.

Time

Laser

Main shock

Main pulse is on; main shock is launched.

Time

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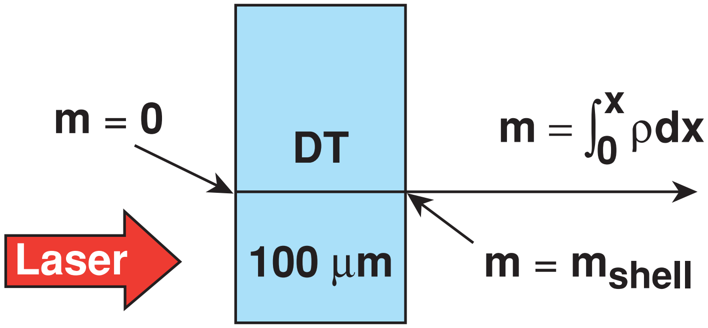
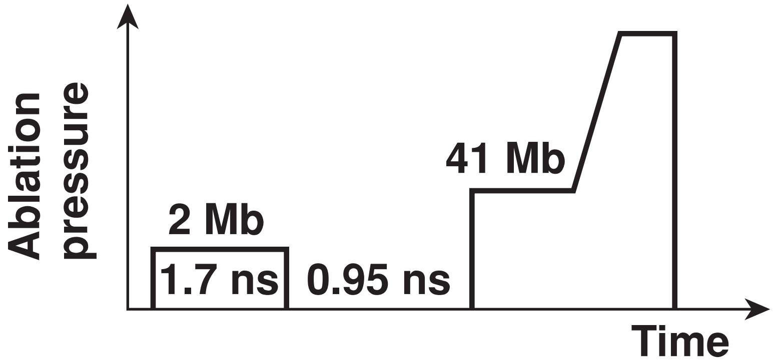
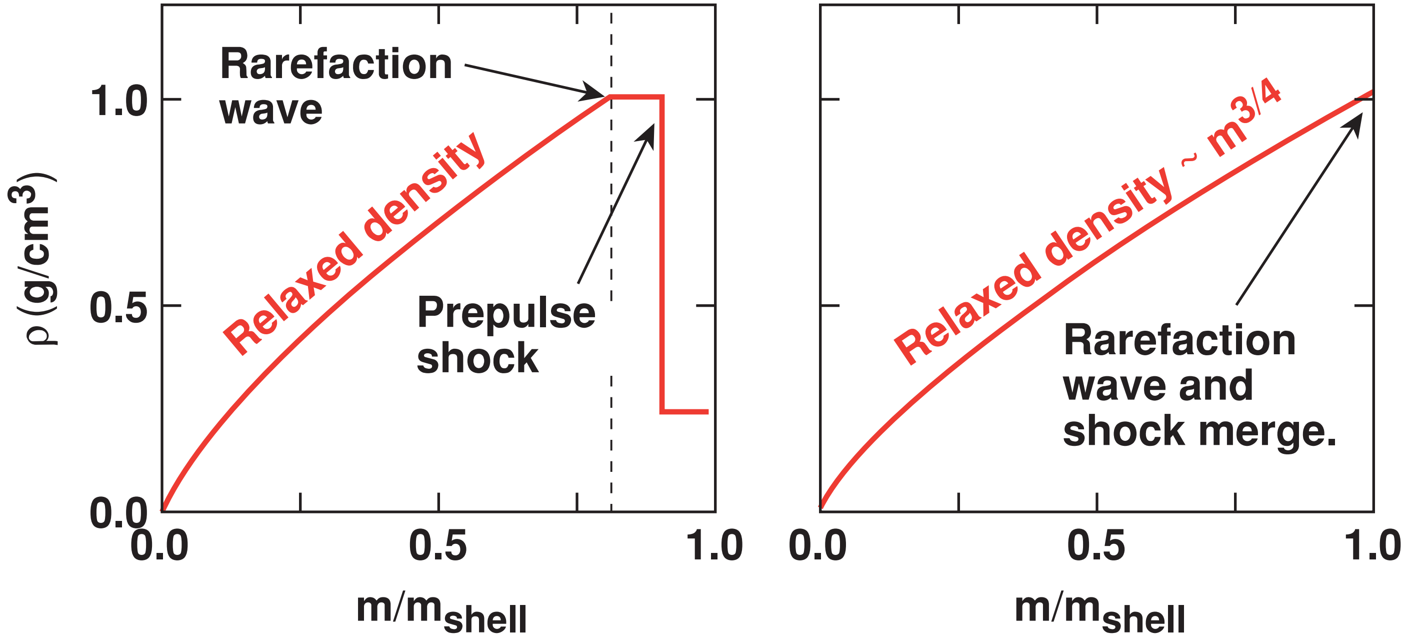
Relaxed profiles of the first kind

The prepulses are long and weak; prepulse rarefaction does not meet the prepulse shock inside the shell







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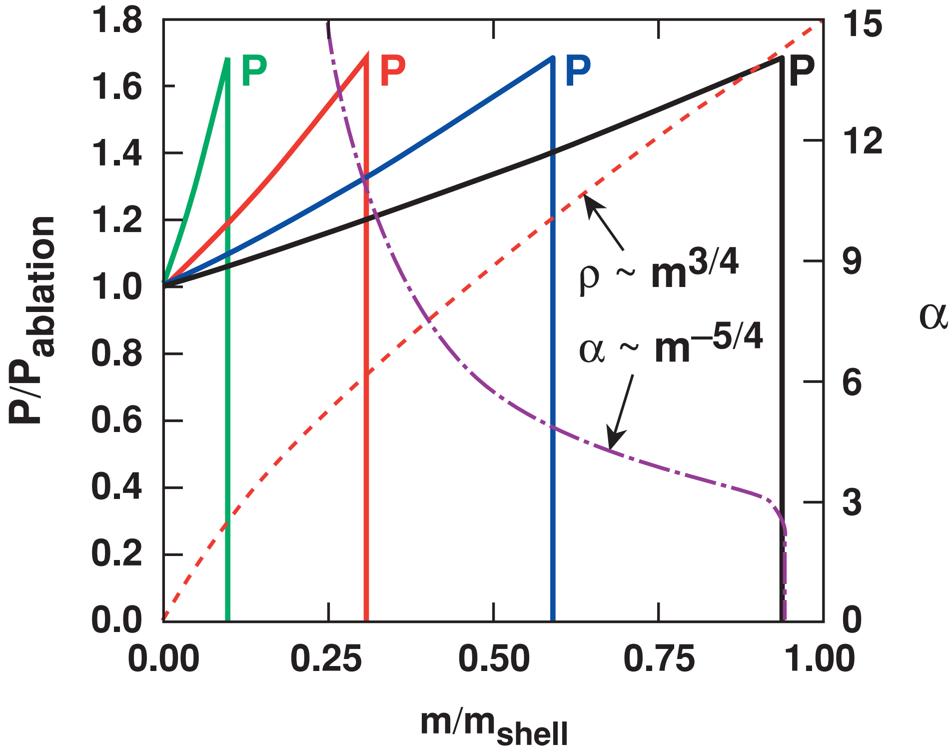
Adiabat profiles of the second kind

The main shock propagation through the rarefaction wave is calculated analytically yielding $\alpha \sim 1/m^{5/4}$

- The relaxed rarefaction-wave density profile goes as $\sim m^{3/4}$.
- The pressure at the shock front is constant, yielding $\alpha \sim \rho^{-\gamma}$.

$$\alpha \sim \frac{1}{\rho^{\gamma}} \sim \frac{1}{m^{\frac{3}{4}\gamma}} \sim \frac{1}{m^{5/4}}$$

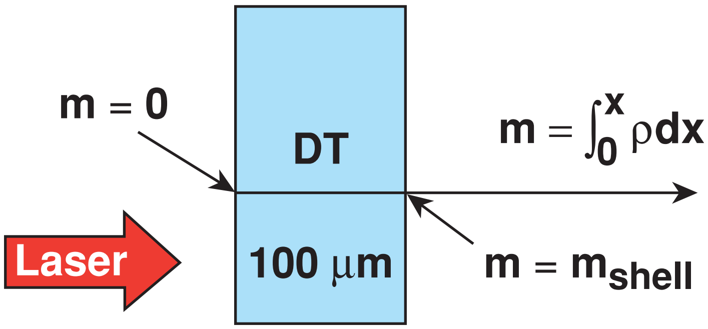
$$\alpha \sim \frac{1}{m^{1.25}}$$

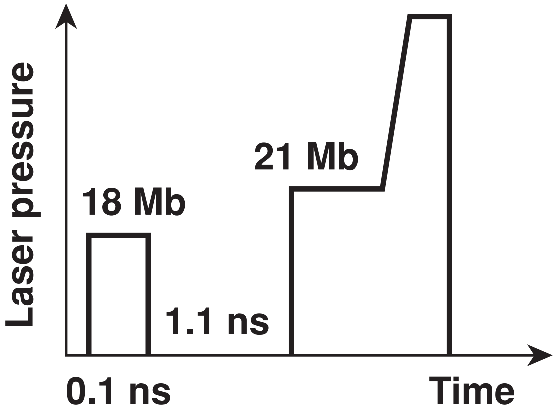


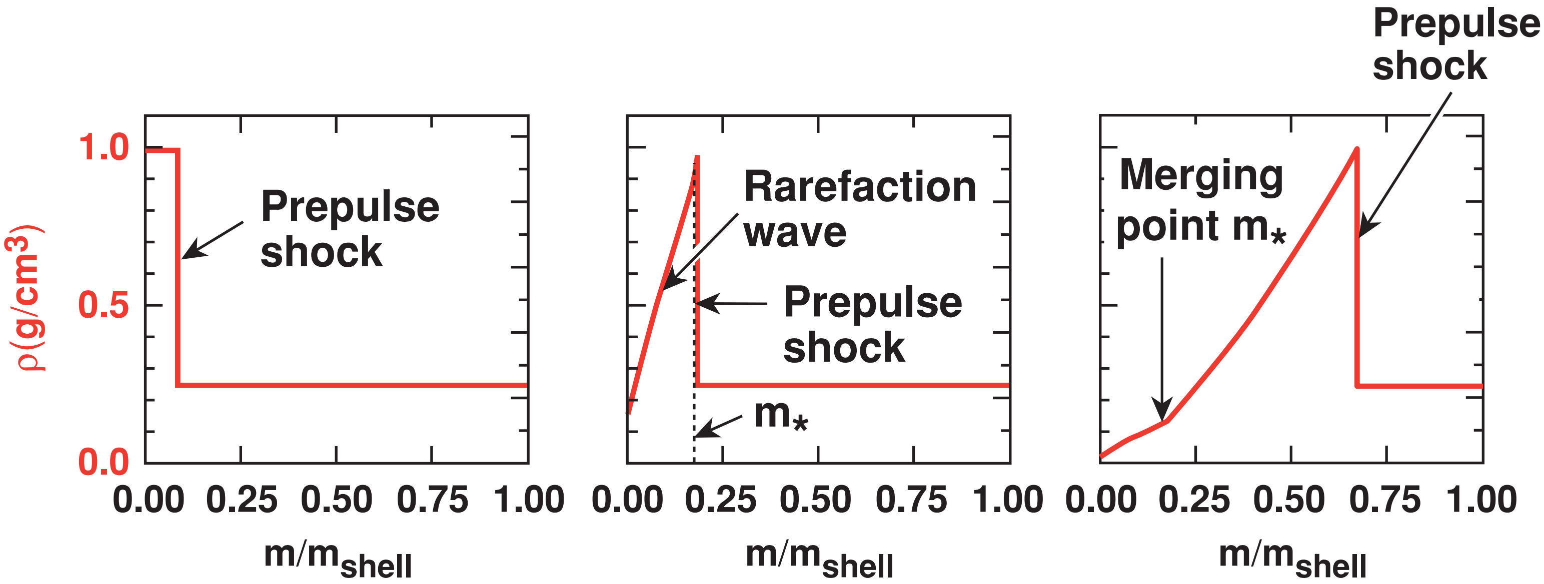
K. Anderson and R. Betti, Phys. Plasmas (in press).

Relaxed profiles of the second kind

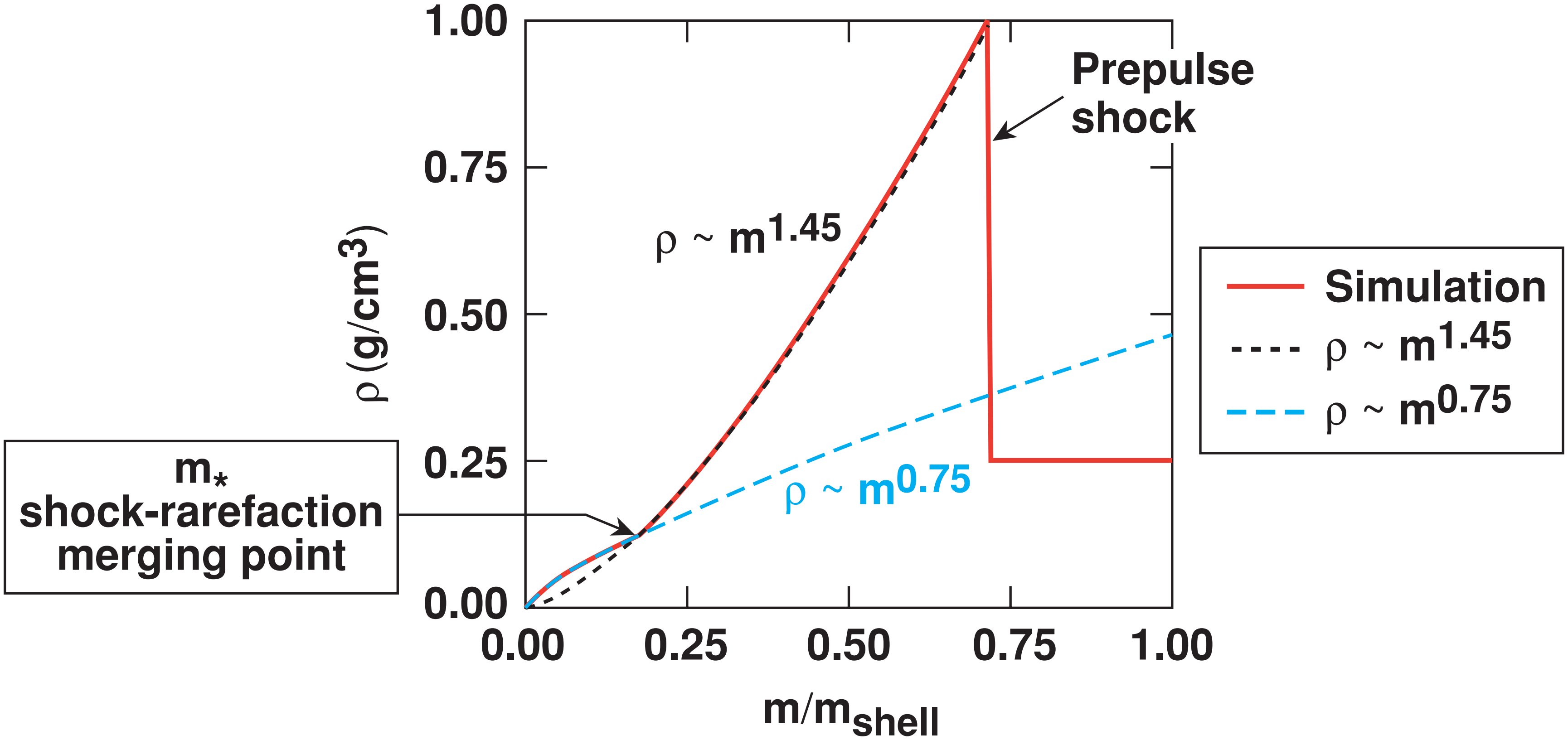
The prepulse is short and intense; the rarefaction wave and prepulse shock merge inside the shell





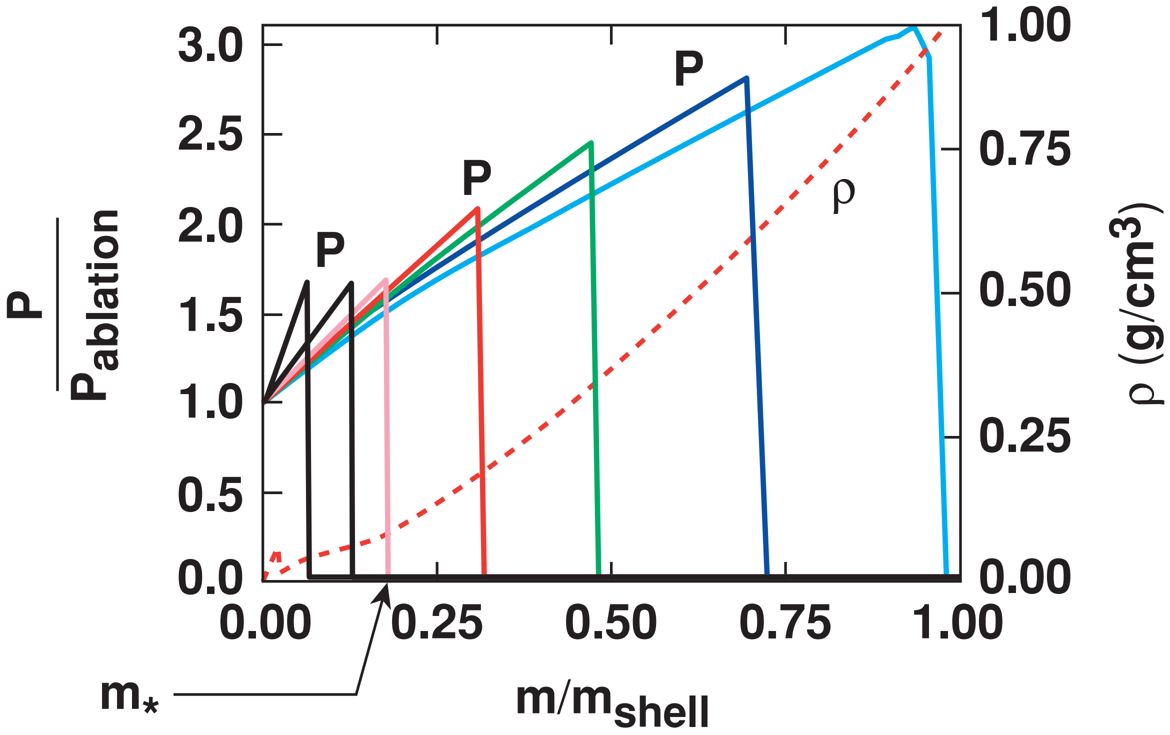


The relaxed density profile of the second kind can be described by two power laws of the mass coordinate



m_*
shock-rarefaction merging point

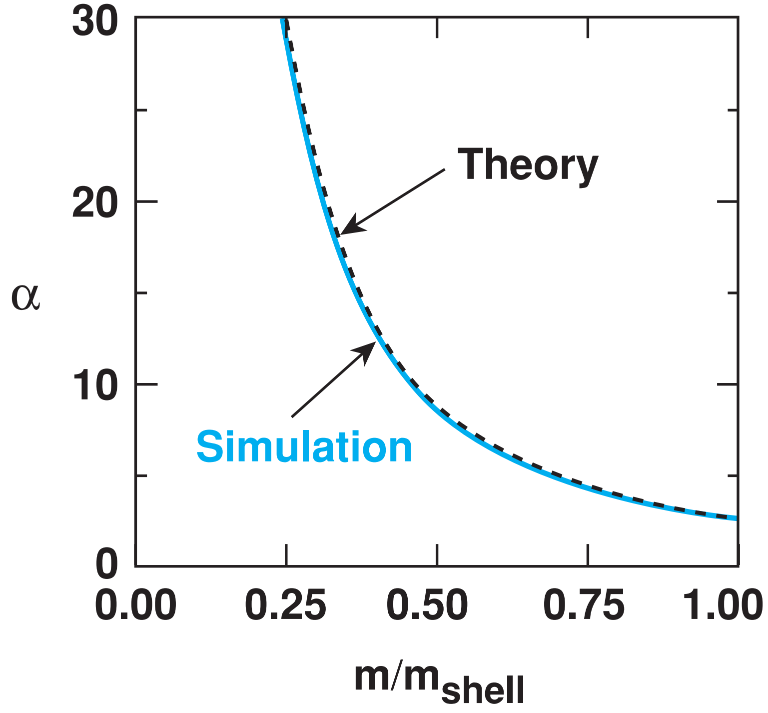
The shock pressure is constant for $m<m_*$ and increases for $m>m_*$; the pressure profile is approximately linear in the mass coordinate



$$\text{Ansatz: } P \approx 1.5\, P_{ablation}\left[1 + A(t)\left(\frac{m}{m_*} - 1\right)\right]$$

Adiabat profiles of the second kind

The adiabat profile is very steep and scales as $\alpha \sim 1/m^{\delta}$ with $\delta \approx 2$



Theory

$$\alpha \sim \frac{1}{m^{2.4}}\left[1+\theta\left(\frac{m}{m_*}\right)\right]$$

$$\theta = \frac{2.6\left(\frac{m}{m_*}\right)^2 - 8\left(\frac{m}{m_*}\right)^{1.5} + 6.4\left(\frac{m}{m_*}\right) - 1}{\left(\frac{m}{m_*} - 1\right)^2}$$

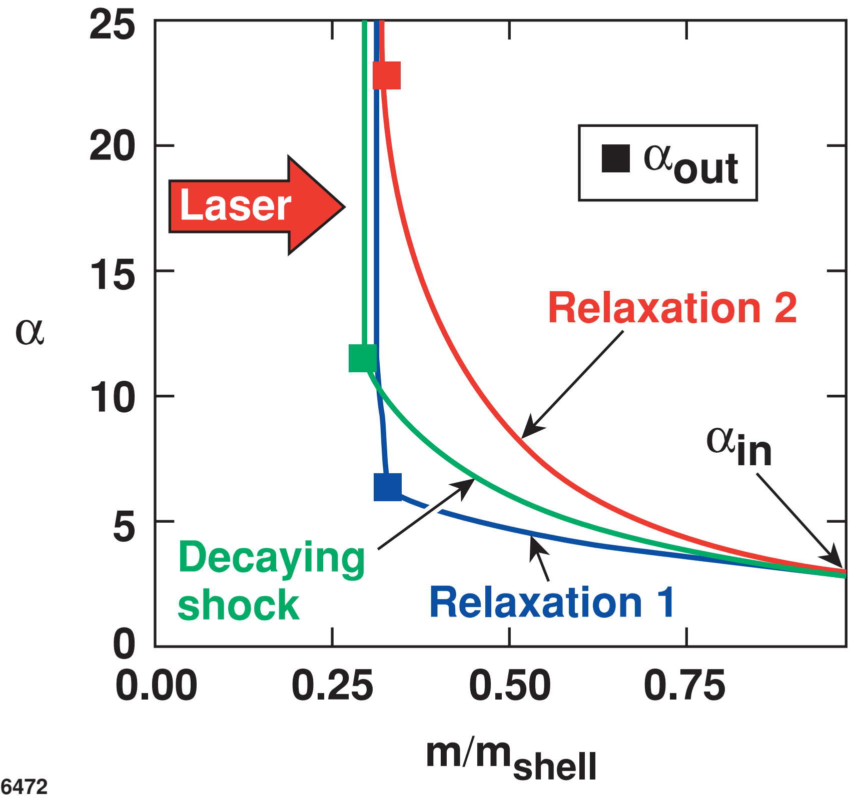
Approximate adiabat

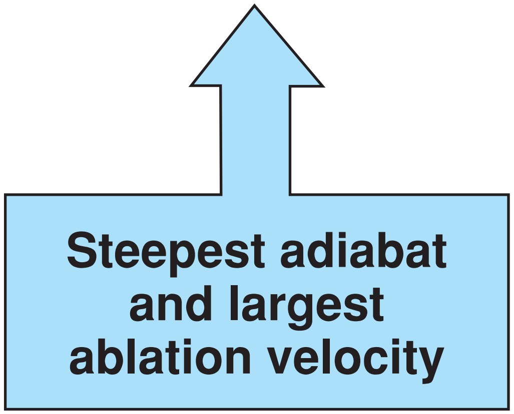
$$\alpha \sim \frac{1}{m^2}$$

K. Anderson and R. Betti, Phys. Plasmas (in press).

Including the effects of finite shock strength and finite ablation leads to somewhat shallower adiabat profiles

Decaying shock	Relaxation (1^{st} kind)	Relaxation (2^{nd} kind)
$\alpha \sim \dfrac{1}{m^{1.1-1.2}}$	$\alpha \sim \dfrac{1}{m^{0.8-1.0}}$	$\alpha \sim \dfrac{1}{m^{1.6-1.8}}$





Steepest adiabat and largest ablation velocity

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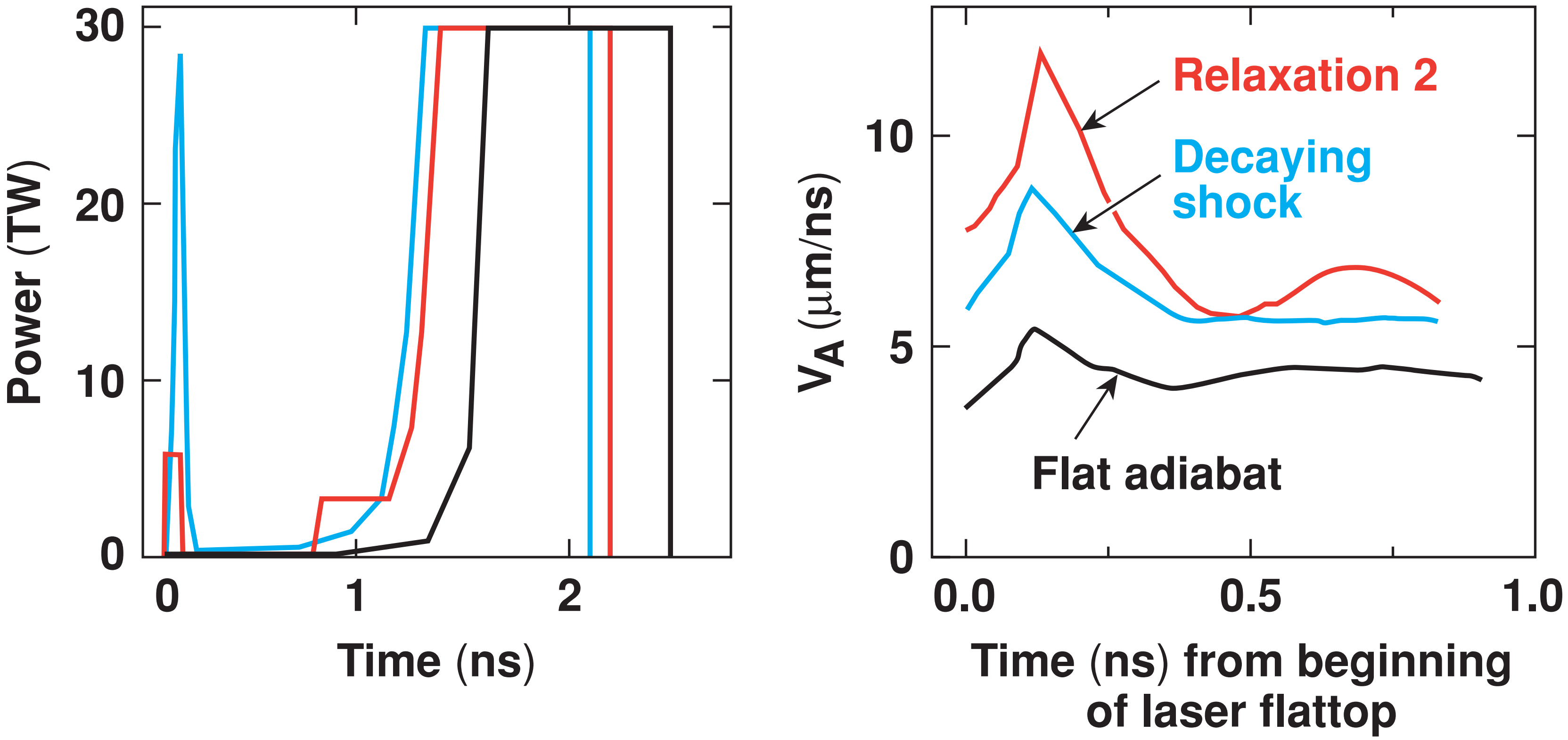
Adiabat shaping by relaxation of the second kind (with short/intense prepulses) leads to ultrahigh ablation velocities

LILAC simulations of 85-µm-thick, all-DT OMEGA capsules



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Summary/Conclusions

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