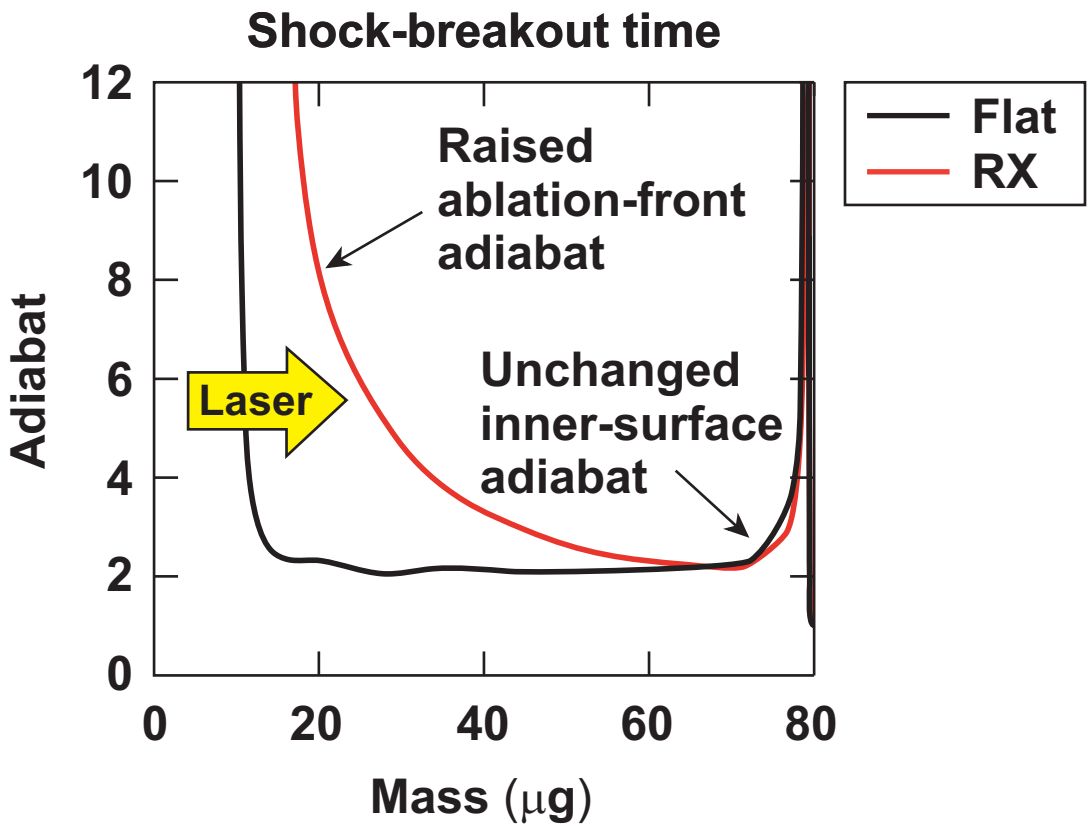
OMEGA Simulations and Experiments on Adiabat Shaping by Relaxation



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Summary

35-μm CH-shell simulations and implosions on OMEGA indicate greater stability for the relaxation design

UR LLE

- Numerical simulations predict higher ablation velocities and lower Rayleigh–Taylor growth rates for the relaxation (RX) design.
- Experiments with SSD for flat-adiabat and RX designs of the same laser energy and inner adiabat result in comparable neutron yields.
- Implosions without SSD result in 2× yield degradation for flat adiabat, while only a minimal change to yield for RX.

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

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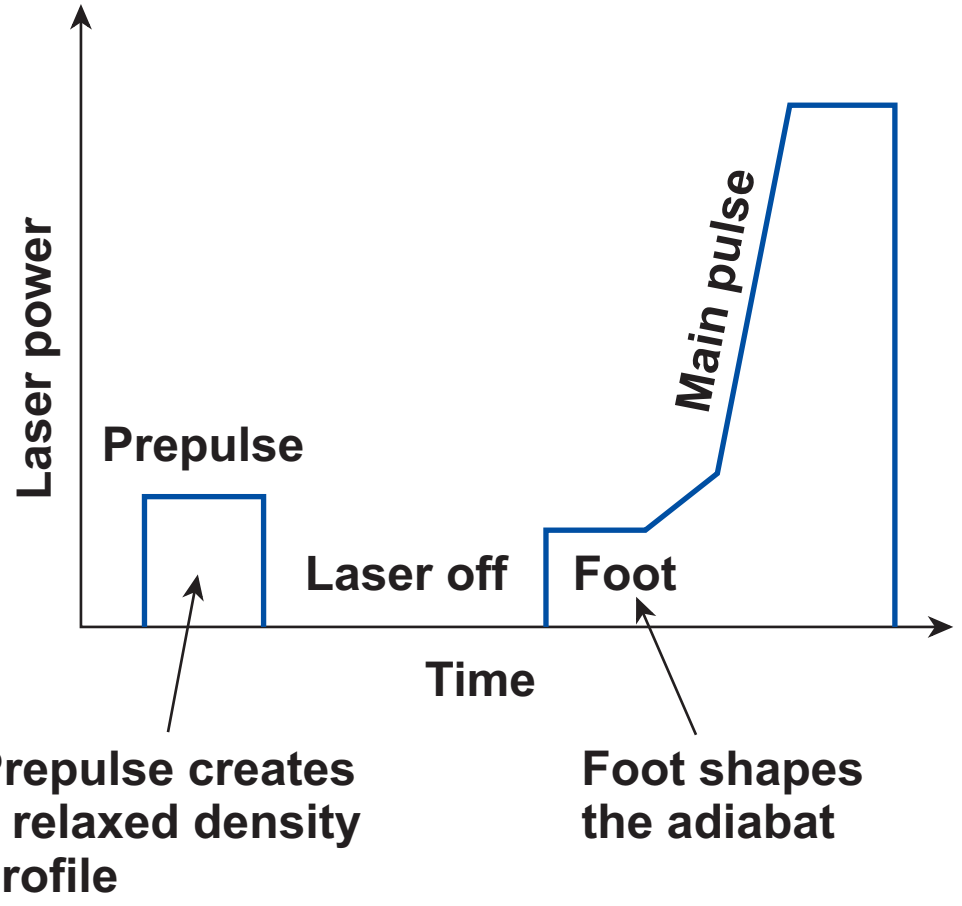
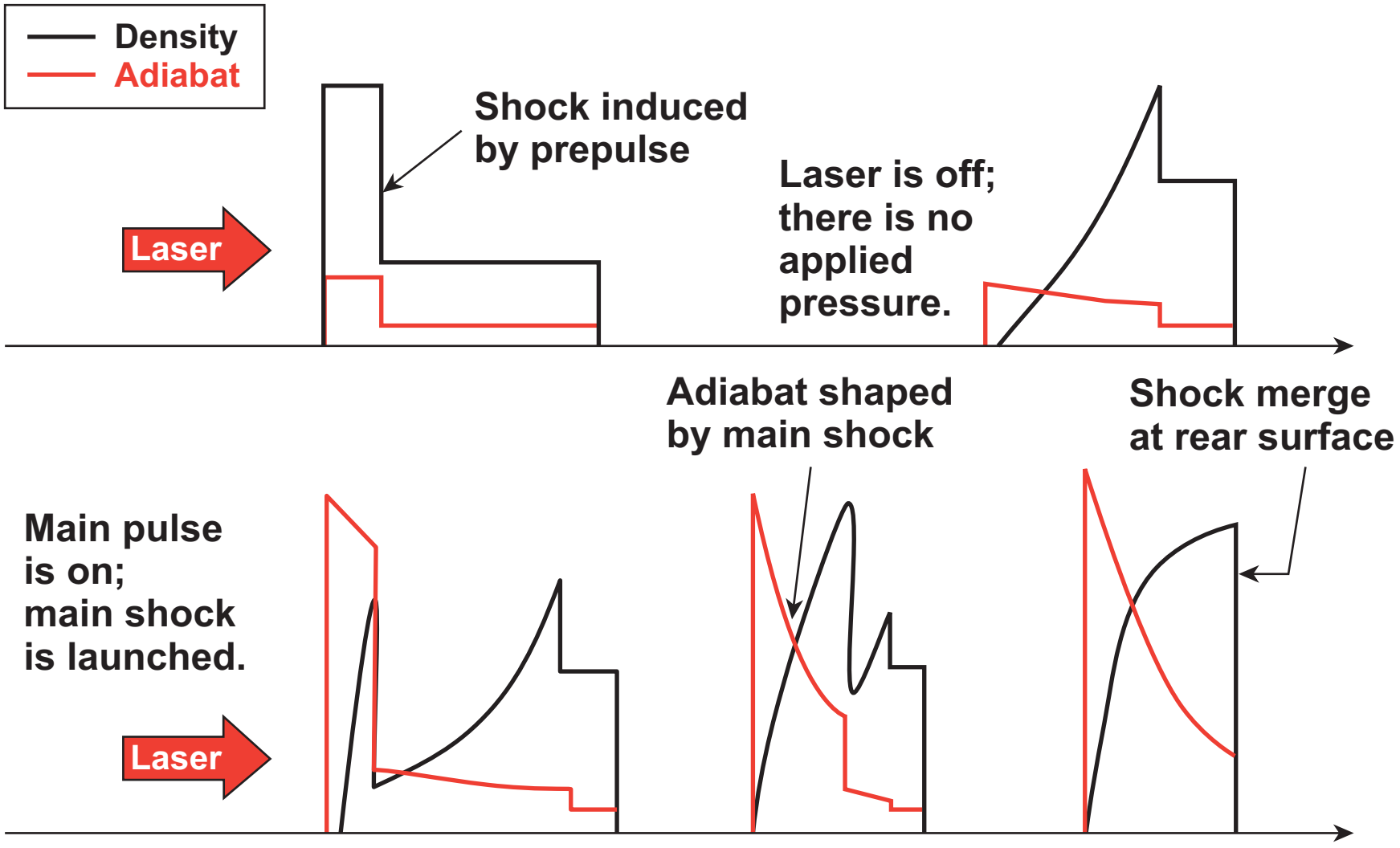
Decaying shock shapes P

$$\alpha = \frac{P(\text{Mb})}{2.3\ \rho(\text{g/cm}^3)^{5/3}}$$

Relaxation shapes ρ



The shock from the main pulse shapes the shell adiabat as it travels up the relaxed density and pressure profile



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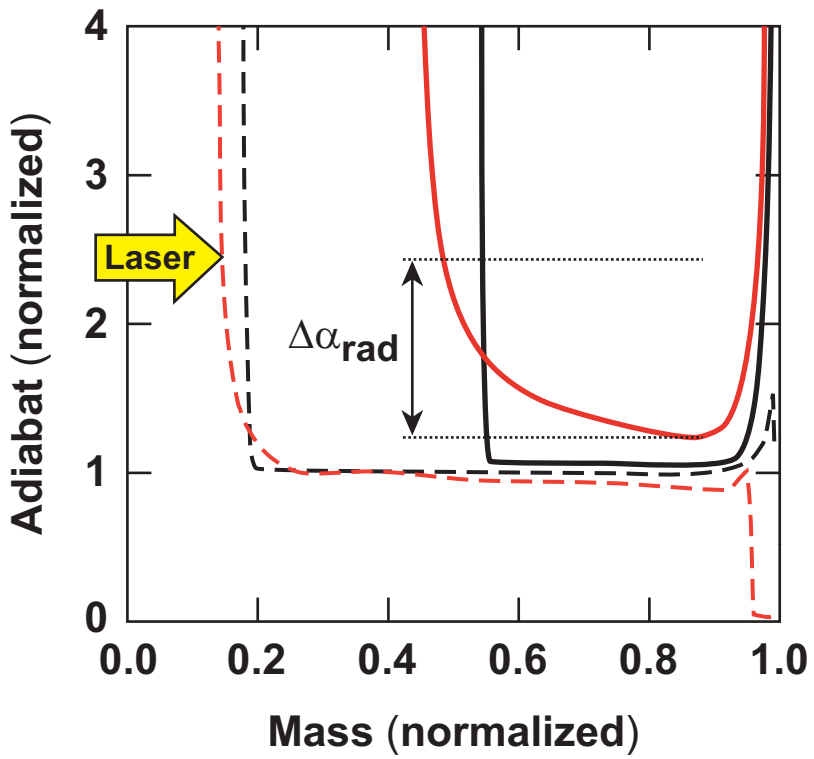
To effect significant shaping over radiative shaping in CH, implosions were designed for 35-μm shells

- Radiation from the hot corona is re-absorbed in shell near the ablation front, raising the local value of the adiabat.[1]



Cryo
- End of pulse
- Breakout

27-μm CH
- End of pulse
- Breakout

- Using a thicker (35-μm) shell allows greater difference in the outer-surface adiabat for the RX design:[2]

$$\alpha_{RX} = \alpha_{in}\left(\frac{m_{sh}}{m}\right)^{\delta},\ \delta = 1.6 \text{ to } 1.8$$

[1] Gardner (1991), Phillips (1999), Bodner (2000)
[2] R. Betti, Bull. Am. Phys. Soc. 48, 255 (2003).

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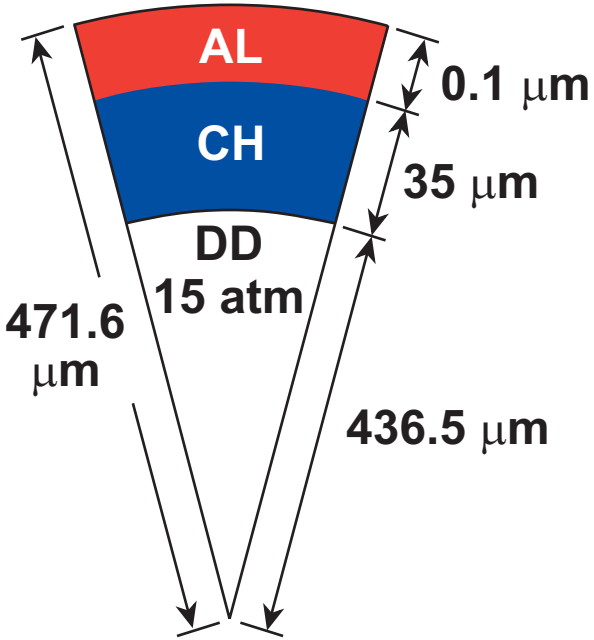
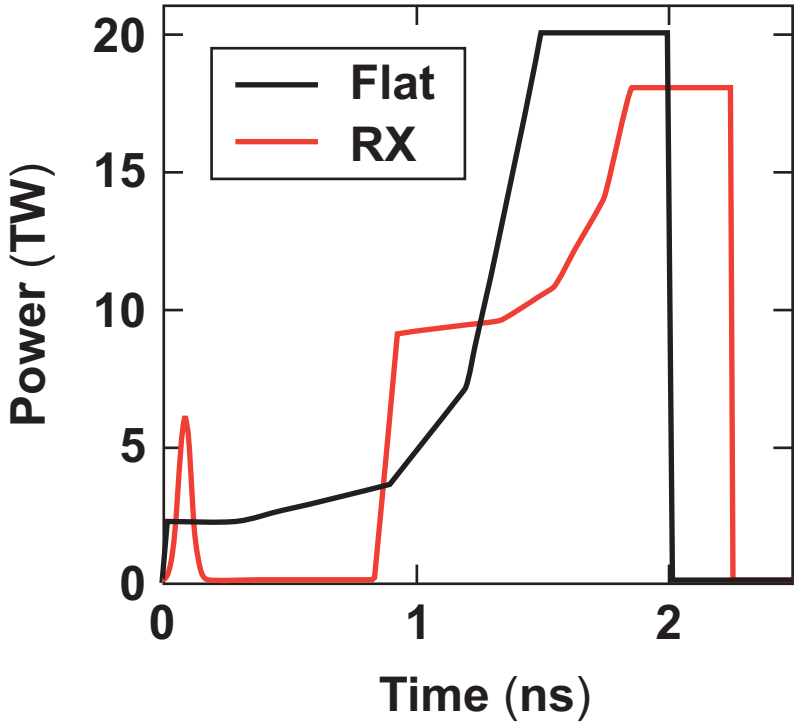
Flat and relaxation pulses have been designed for 35-μm plastic capsules





- Total laser energy: 18 kJ
- 1-D, DD neutron yields ~ 5×10^{10}
- 6-TW, 60-ps Gaussian prepulse (RX)
- Contrast ratio of 2 in RX main pulse

LILAC simulations indicate RX adiabat shaping is effective throughout the acceleration phase

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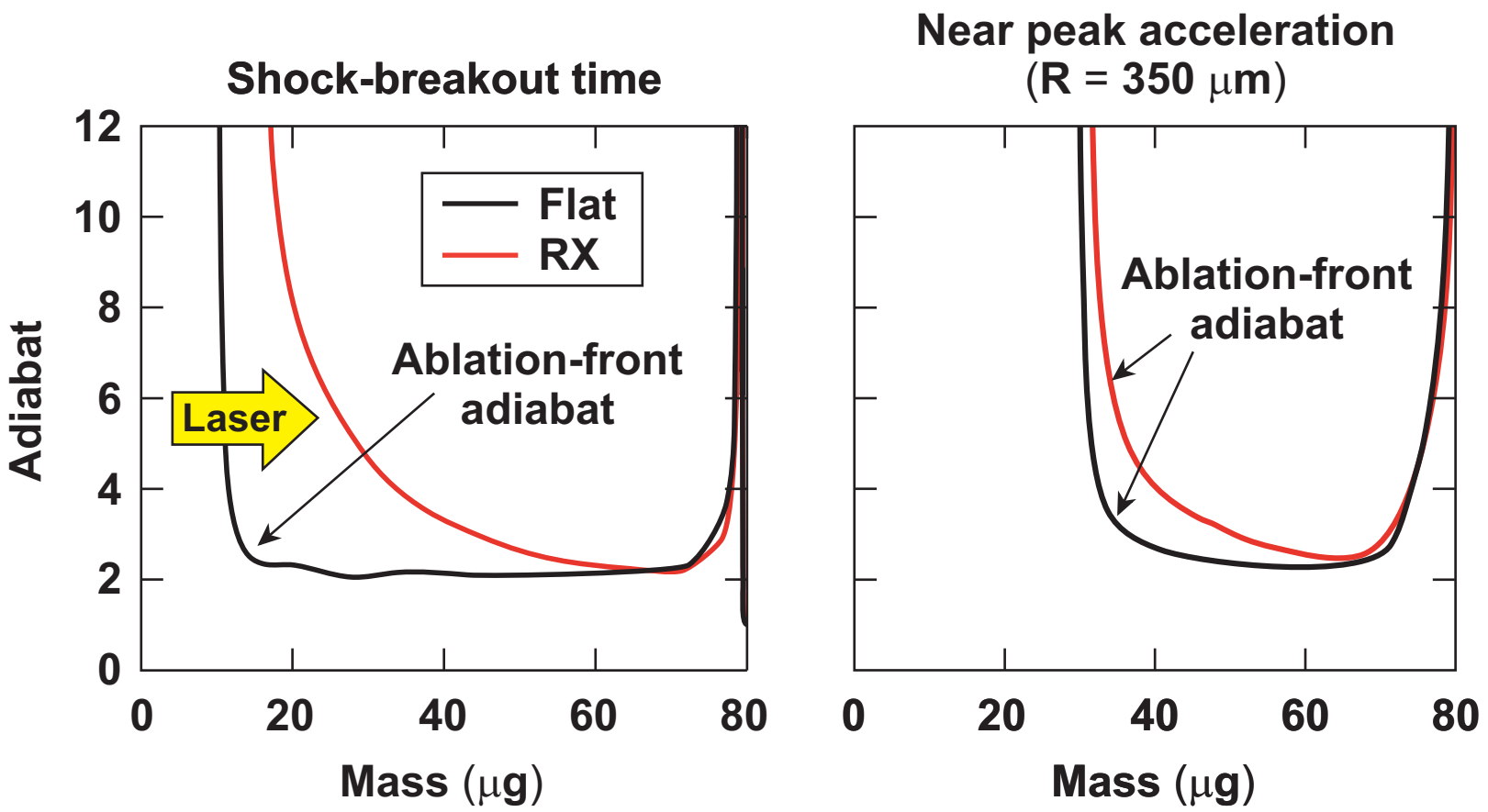
- RX shaping is significantly higher than "natural" radiative shaping.



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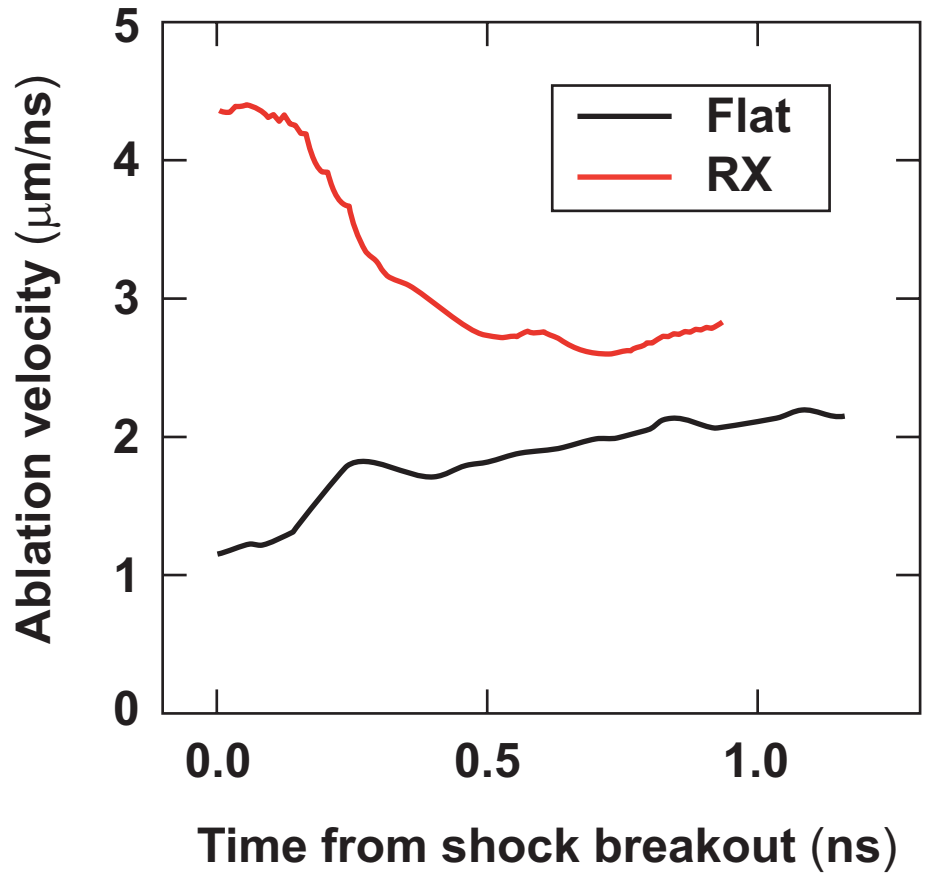
Ablation velocity predicted for the RX design is significantly higher than for flat-adiabat design



- Ablation velocity scales with outer-surface adiabat:

$$V_A \propto \alpha^{3/5}$$

- Theoretical RT growth rates[1] in CH plastic:

$$\gamma_{CH} \simeq \sqrt{\frac{kg}{1+kL_m}} - 1.7\, kV_a$$

- Short wavelength modes more strongly mitigated by increased ablation velocity.

[1] R. Betti *et al.*, Phys. Plasmas 5, 1446 (1998).

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Single-mode 2-D *DRACO* simulations show lower Rayleigh–Taylor growth rates for the RX design

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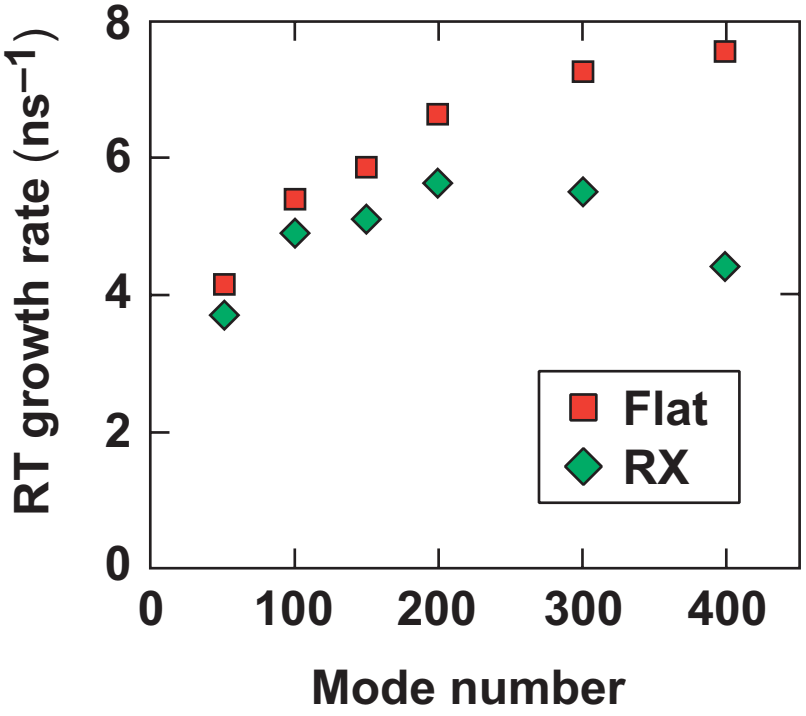
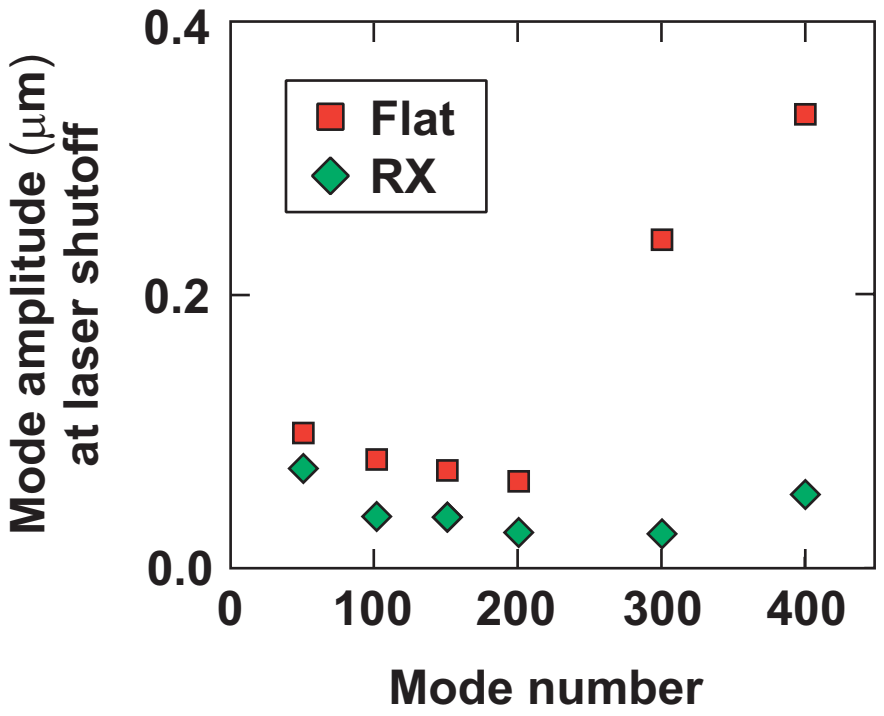
• Laser perturbations, $\delta I/I = 10^{-3}$





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2-D *DRACO* multimode simulations show the RX design is more stable

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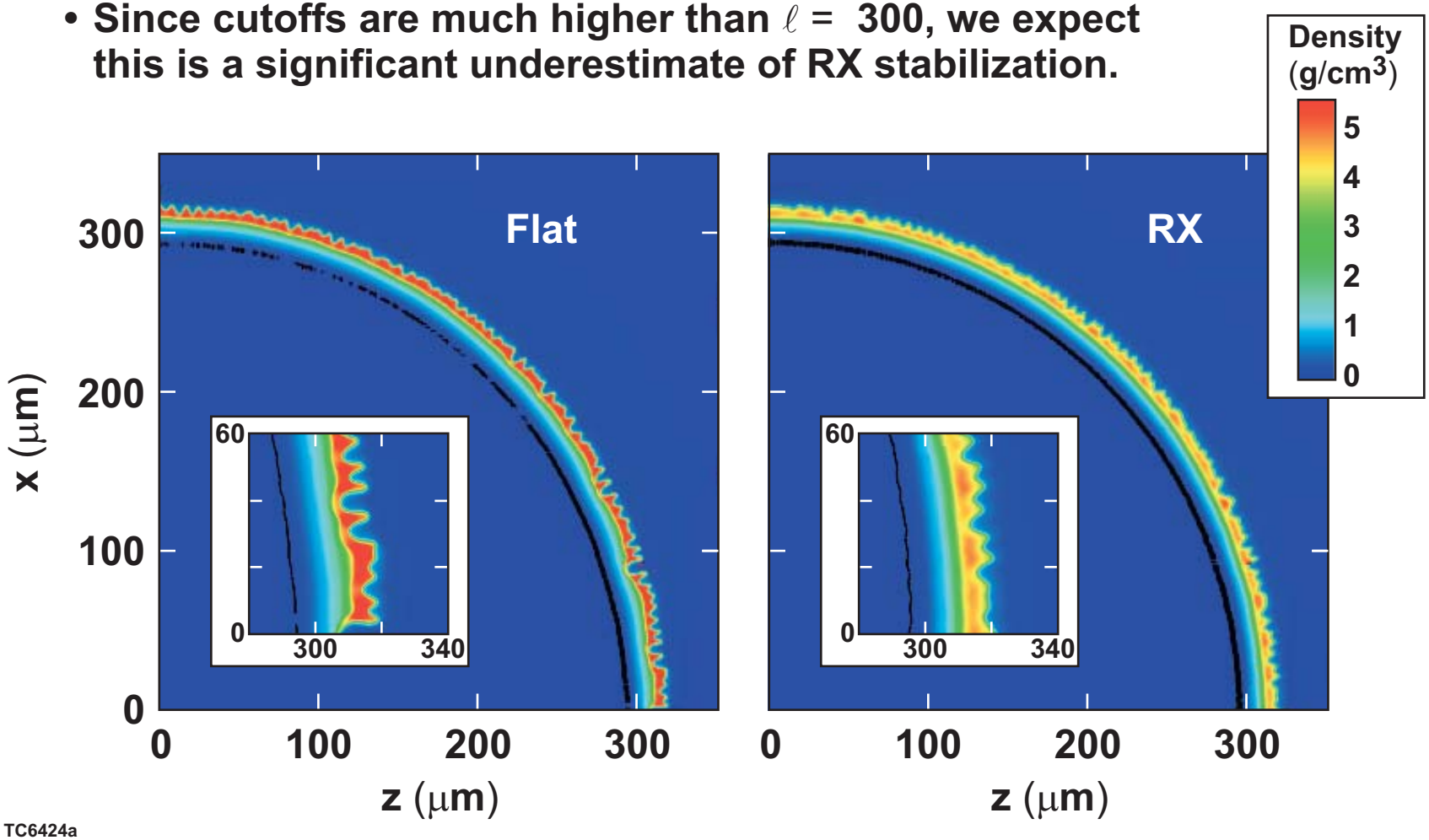
- Even modes ℓ = 2 to 300 simulated up to 130 ps after laser shutoff.
- Since cutoffs are much higher than ℓ = 300, we expect this is a significant underestimate of RX stabilization.



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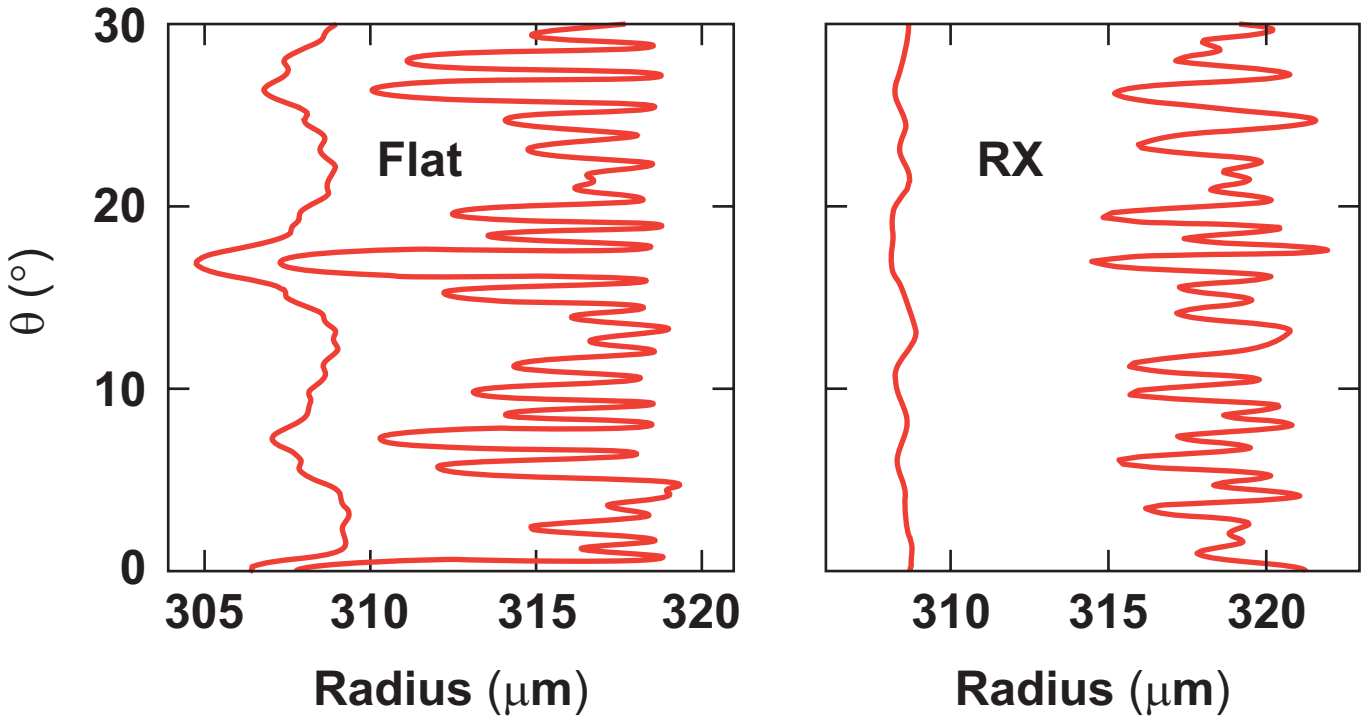
Multimode simulations show the RX design exhibits better shell integrity

- Contours drawn at time = laser shutoff time + 130 ps.
- Density contours are drawn at 1/*e* points from maximum density.



σ_{rms} (μm)	Flat	RX
Outer	2.90	1.73
Inner	1.22	0.23

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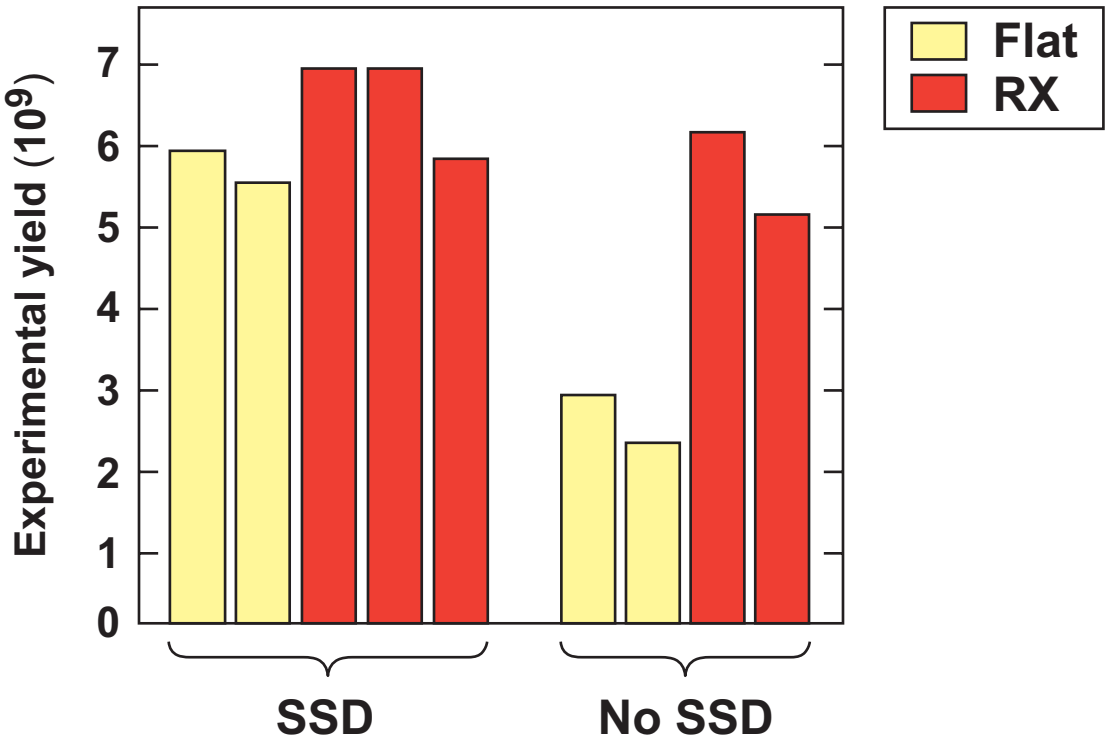
Experiments show significantly higher yields for RX shots without SSD than for flat adiabat shots

- Consistent laser energy on target = 17.40±0.45 kJ
- No significant difference between RX and flat shots with SSD



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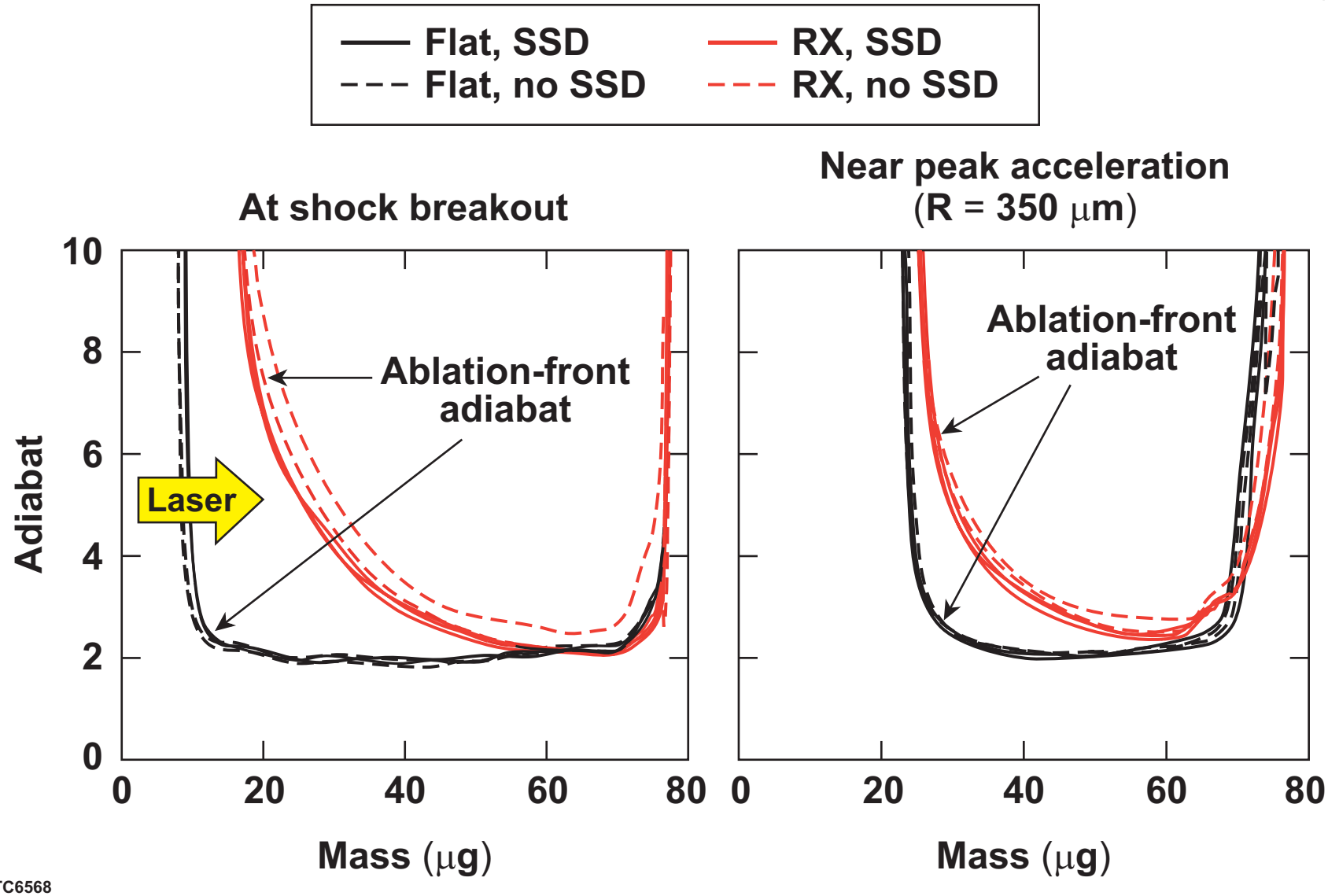
Simulations of OMEGA shots show inner-surface adiabats are consistent for flat and RX designs



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Several possible explanations exist for reduction in flat-adiabat designs and no reduction in RX

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- Lower Rayleigh–Taylor growth rates in RX than in flat designs, indicative of increased ablation velocity due to adiabat shaping.[1]
- Imprint is reduced in the RX design due to prepulse.[2]
- Increased low-mode imprint from irradiation nonuniformity due to ellipticity in non-SSD beams more significant in flat-adiabat designs.

[1] K. Anderson and R. Betti, Phys. Plasmas 11, 5–8 (2004).

[2] T. J. B. Collins (2002, 2004), Metzler (1999, 2002, 2003), Lebo (1999), Krousky (2000), Iskakov (2000).

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