Low Energy Target Designs
using higher implosion velocities and higher intensity*

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We are studying a new class of target designs:

* Reduce substantially the required laser energy

* Take advantage of KrF short wavelength
  (for constant $I\lambda^2$, allow double intensity compared to 1/3 μm laser)

* Make use of spike pulse to improve target gain
  and/or stability

Conditions for ignition:

$\rho R > 0.4\ g/cm^2$ and $T > 5$ keV

(mean free-path for α's < R) (α heating > rad. losses)

At stagnation, kinetic energy is converted into thermal energy:

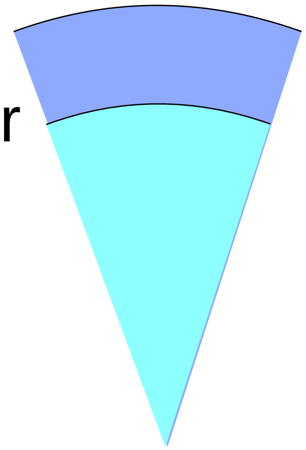
From isobaric model (Meyer-ter-Vehn),

$$E_{ign} \sim \alpha^3 / v_{imp}^{10}$$

(in another model, $E_{ign} \sim \alpha^{1.7} / v_{imp}^{5.5}$)

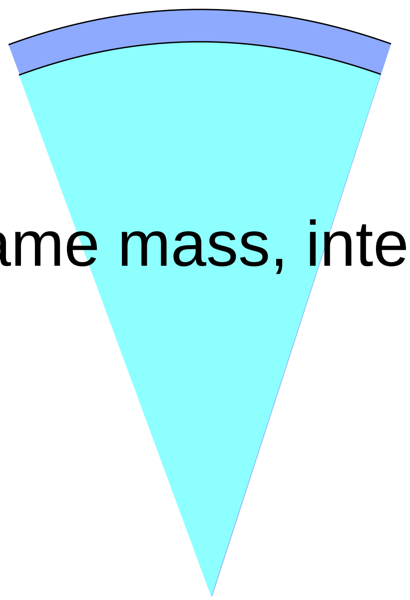
ignition energy is very sensitive to implosion velocity!

Given a target of fixed mass and laser energy



if we want to increase its velocity, we have two options:

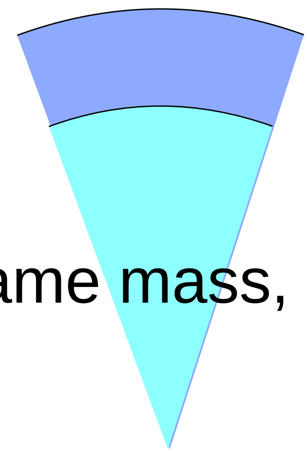
1. increase radius



same mass, intensity

less stable:
further acceleration distance

2. increase intensity



same mass, radius

more stable:
smaller IFAR,
higher ablation velocity

Conditions for fluid stability (RT)

e-folds < 6 (may be less because smaller size, RM instability)

$\gamma_{cl} = (kg)^{1/2}$

Using $R = gt^2/2$, $k = 2\pi/\lambda$ and $\lambda = \Delta R$ then $\gamma t \sim (R/\Delta R)^{1/2}$

In fact, we use for 1D stability analysis:

$\gamma = [\, kg/(1+kL)]^{1/2} - 3\, k\, v_a$ (Modified Bodner-Takabe)

Restriction used in study:

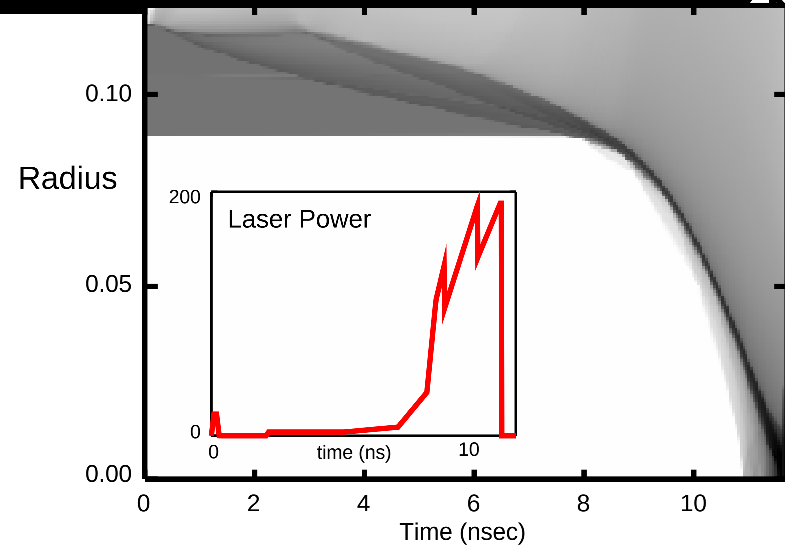
LCR (laser contrast ratio) < 100 ($\alpha > 3$)

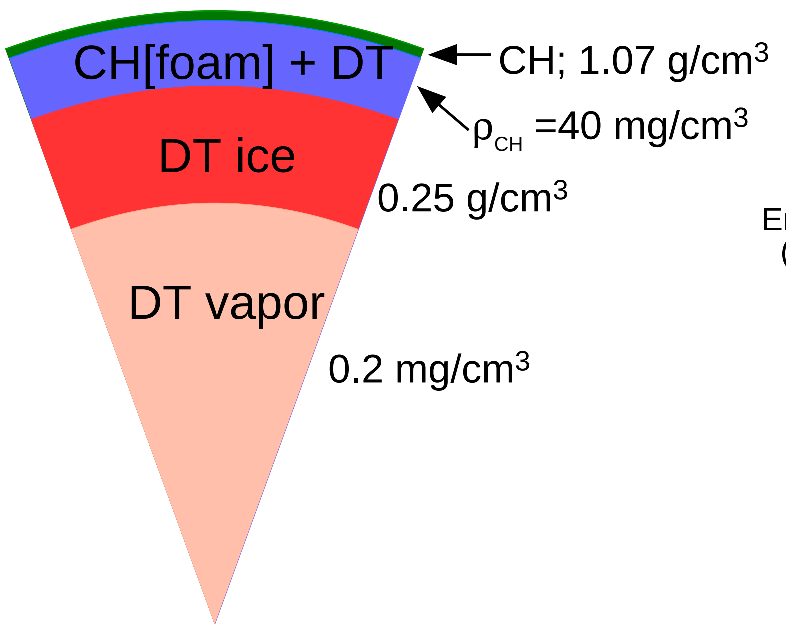
As I max increases, strength of initial shock increases and adiabat increases (target should be more stable)

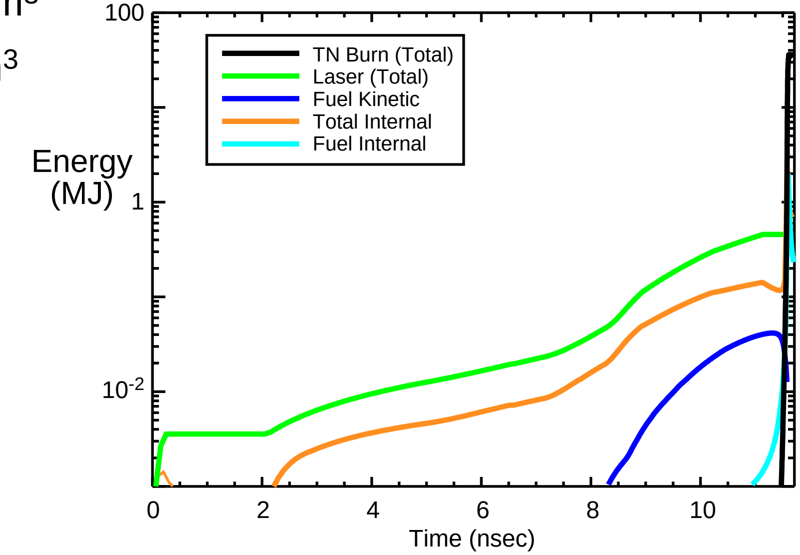
Low Energy KrF-driven target produces gain with high laser intensity and implosion velocity

460 kJ KrF Pellet Design

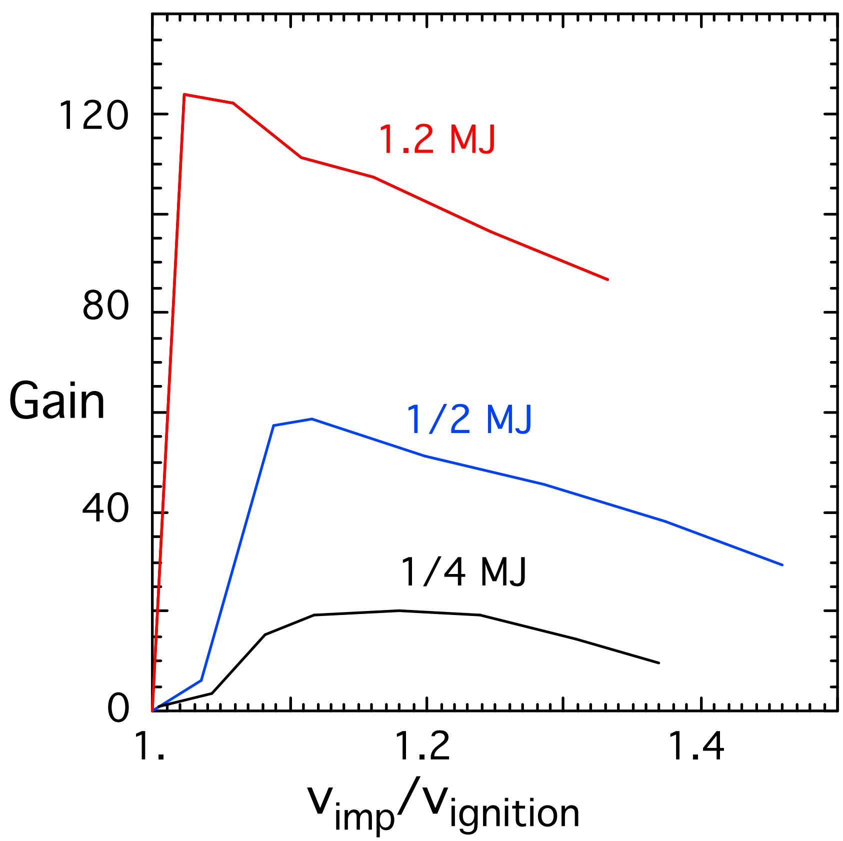
Laser Energy	460 kJ
Max Laser Intensity	2.4×10^{15} W/cm^2
Laser Power (peak)	440 TW
Absorption fraction	0.91
Hydro Efficiency	10.2%
Implosion Velocity	4.0×10^{7} cm/s
Peak Fuel ρR	1.9 g/cm^2
Peak IFAR	< 60
Gain	79

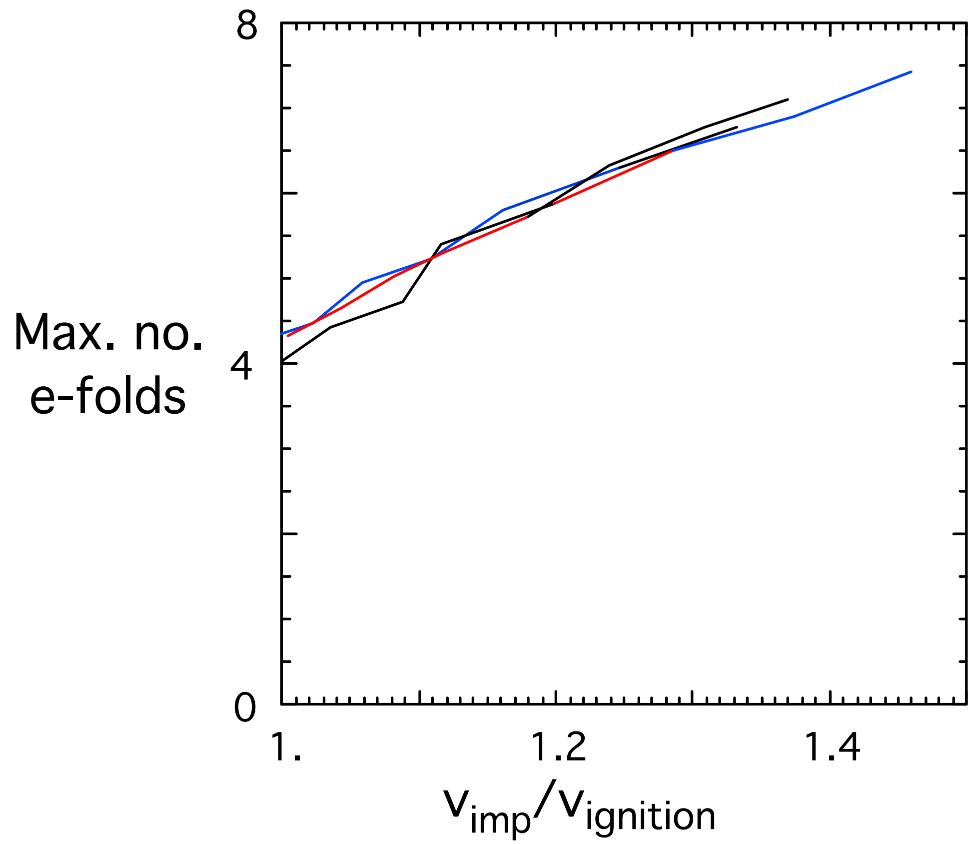






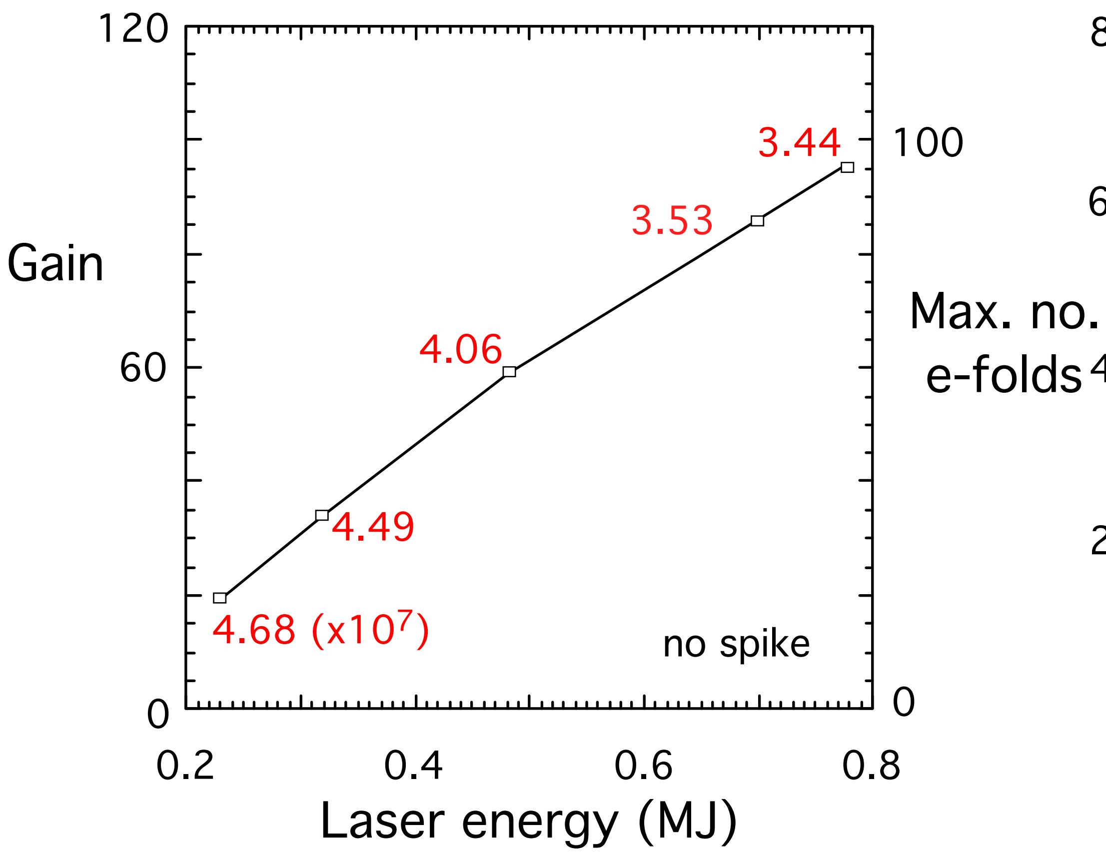
Gain and 1D stability for targets as a function of v_{imp}/v_{ign}

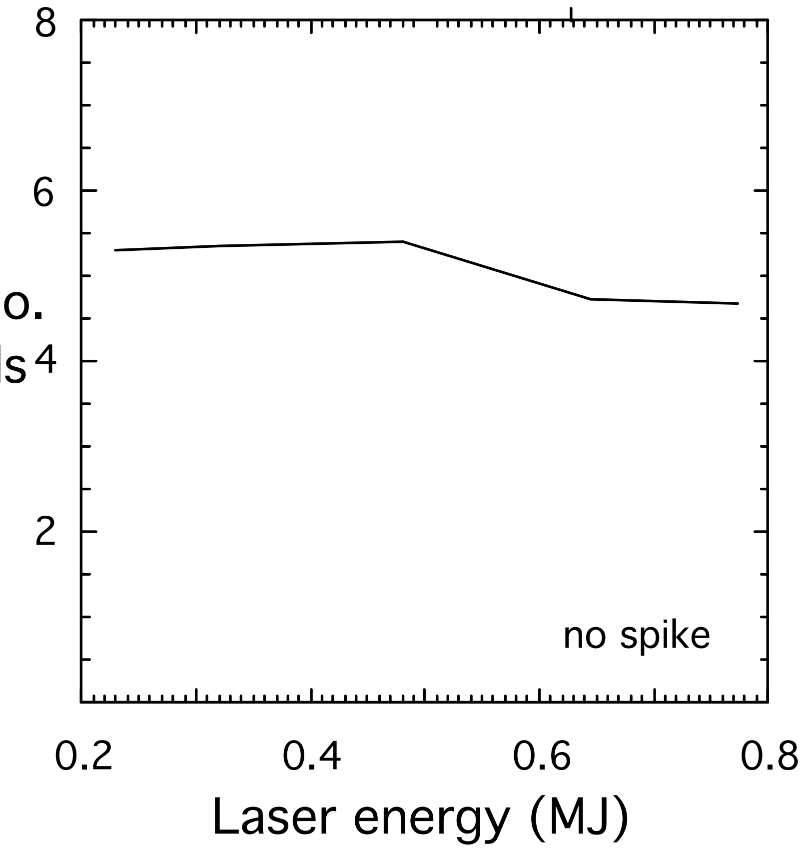




Gain and 1D stability vs. laser energy

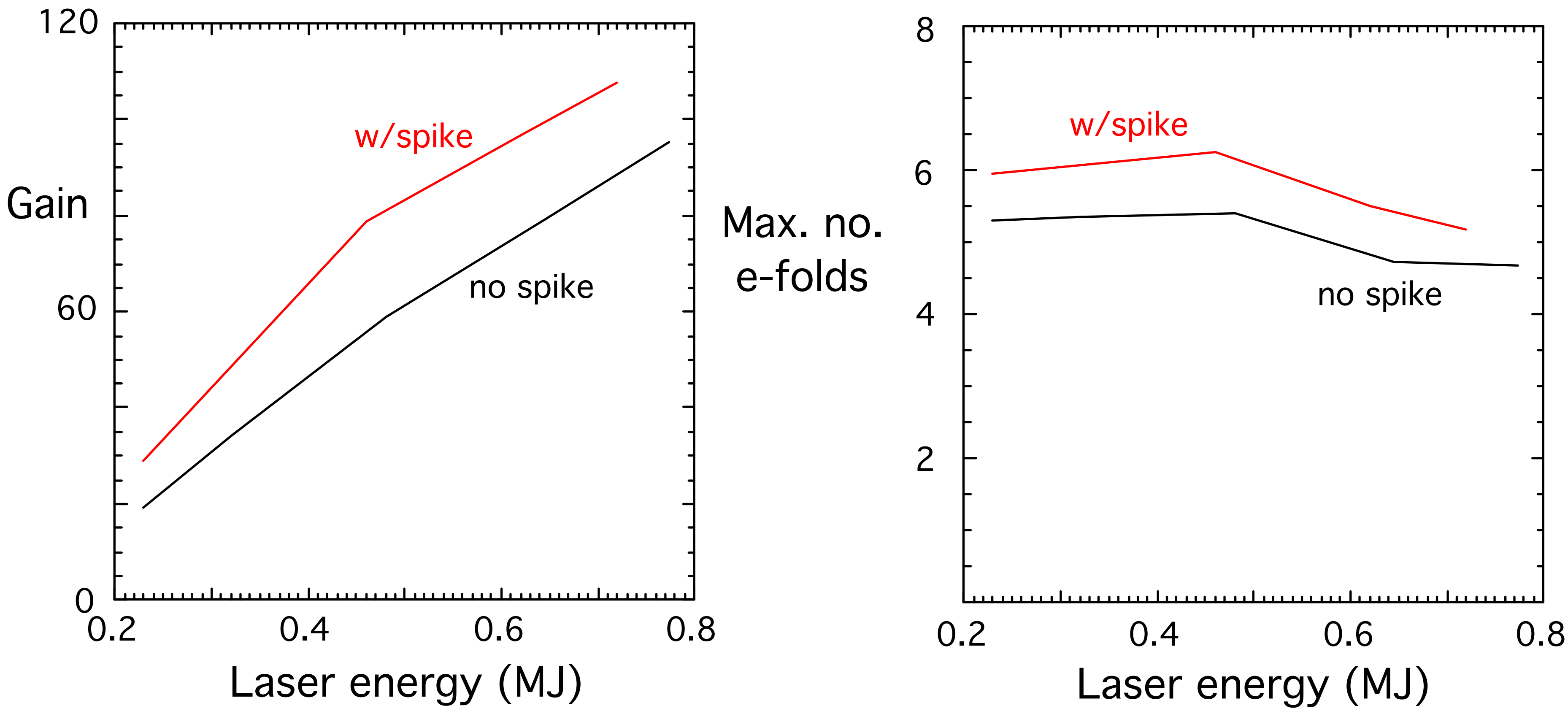
(0.25μ, 2.2-2.7x10^{15} W/cm^2)





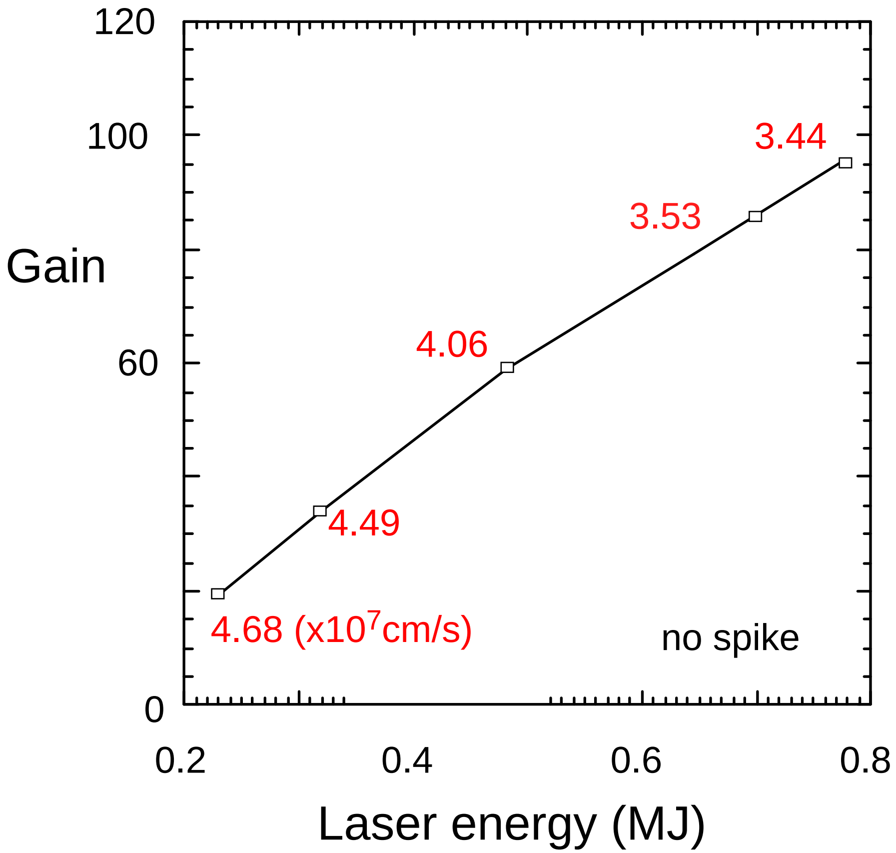
Gain and 1D stability vs. laser energy w/ spike

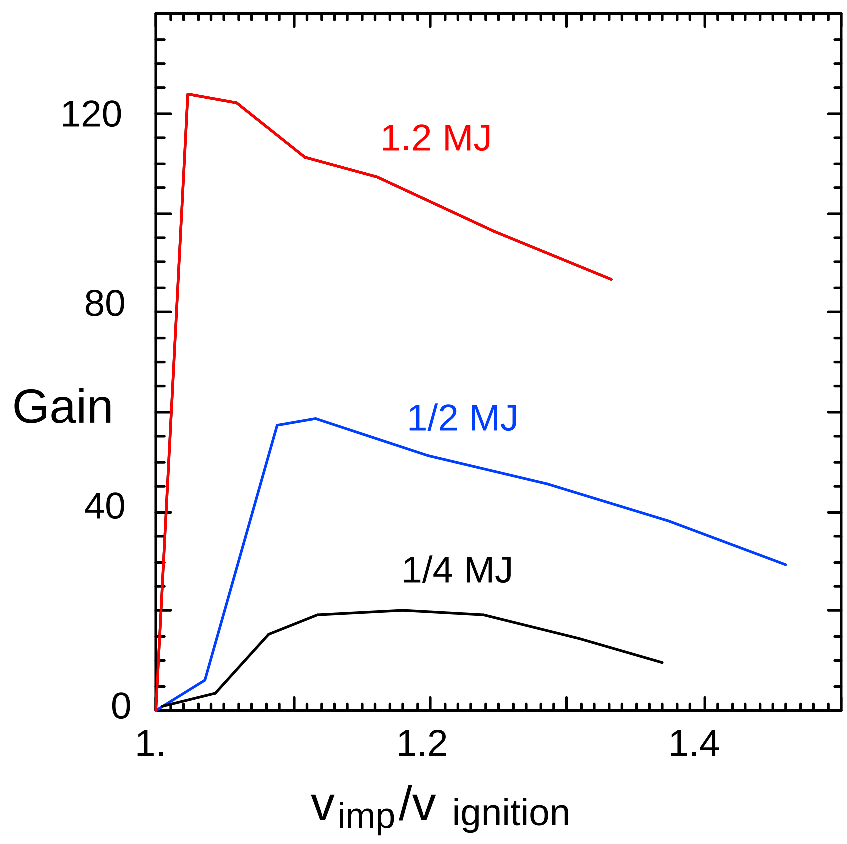
(0.25μ, $2.2\text{-}2.7 \times 10^{15}$ W/cm^2)



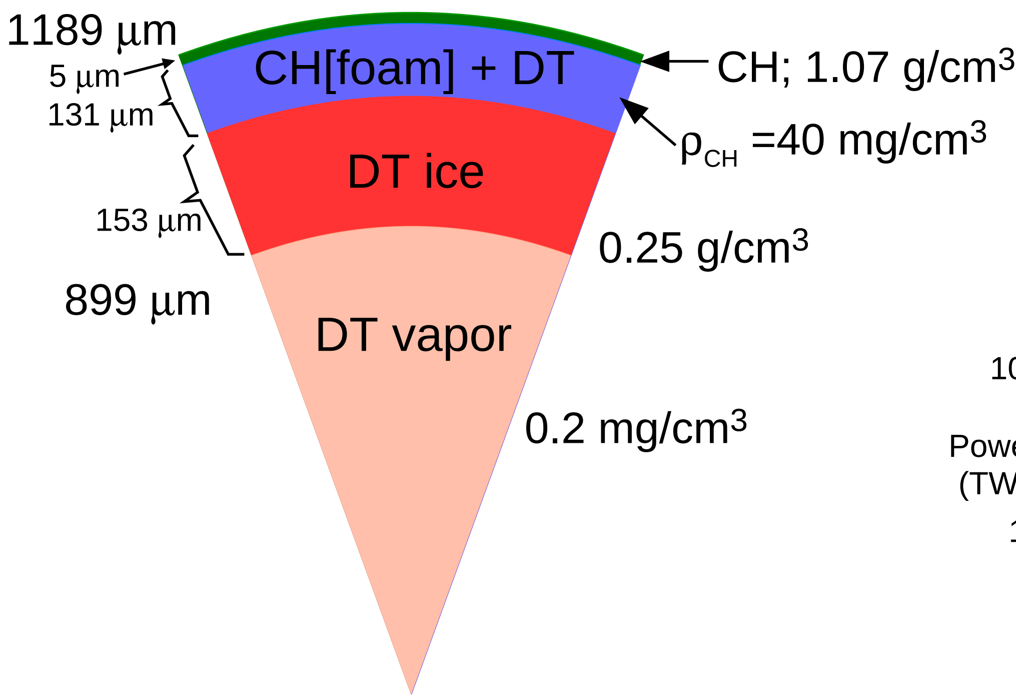
Gain vs. laser energy and Gain vs. v_{imp}/v_{ign}

(λ=0.25 μm; I = 2.2-2.7x10^{15}W/cm^{2})



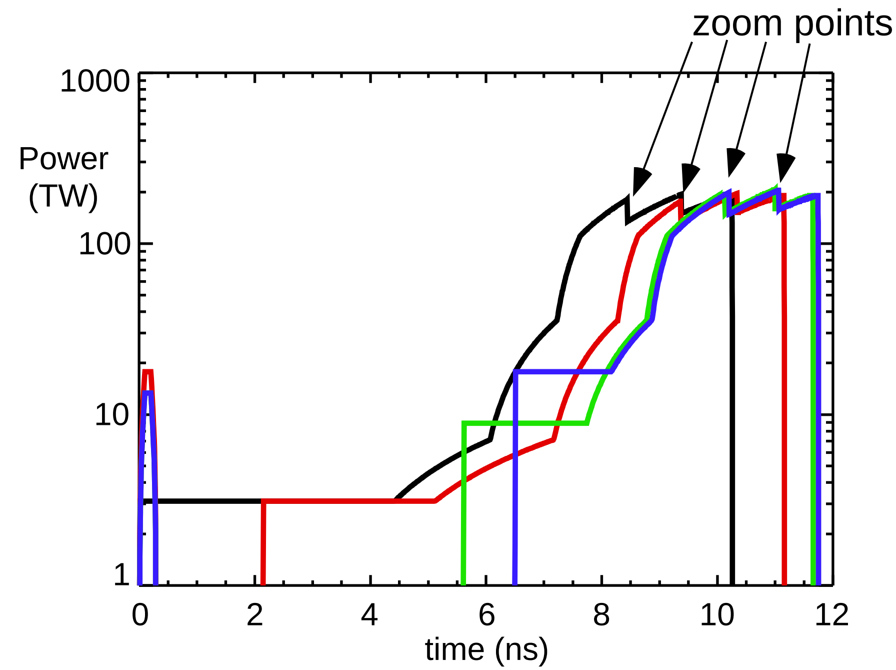


The pulse shape can be used to control the stability of the designs we use the ~500 kJ design as an example

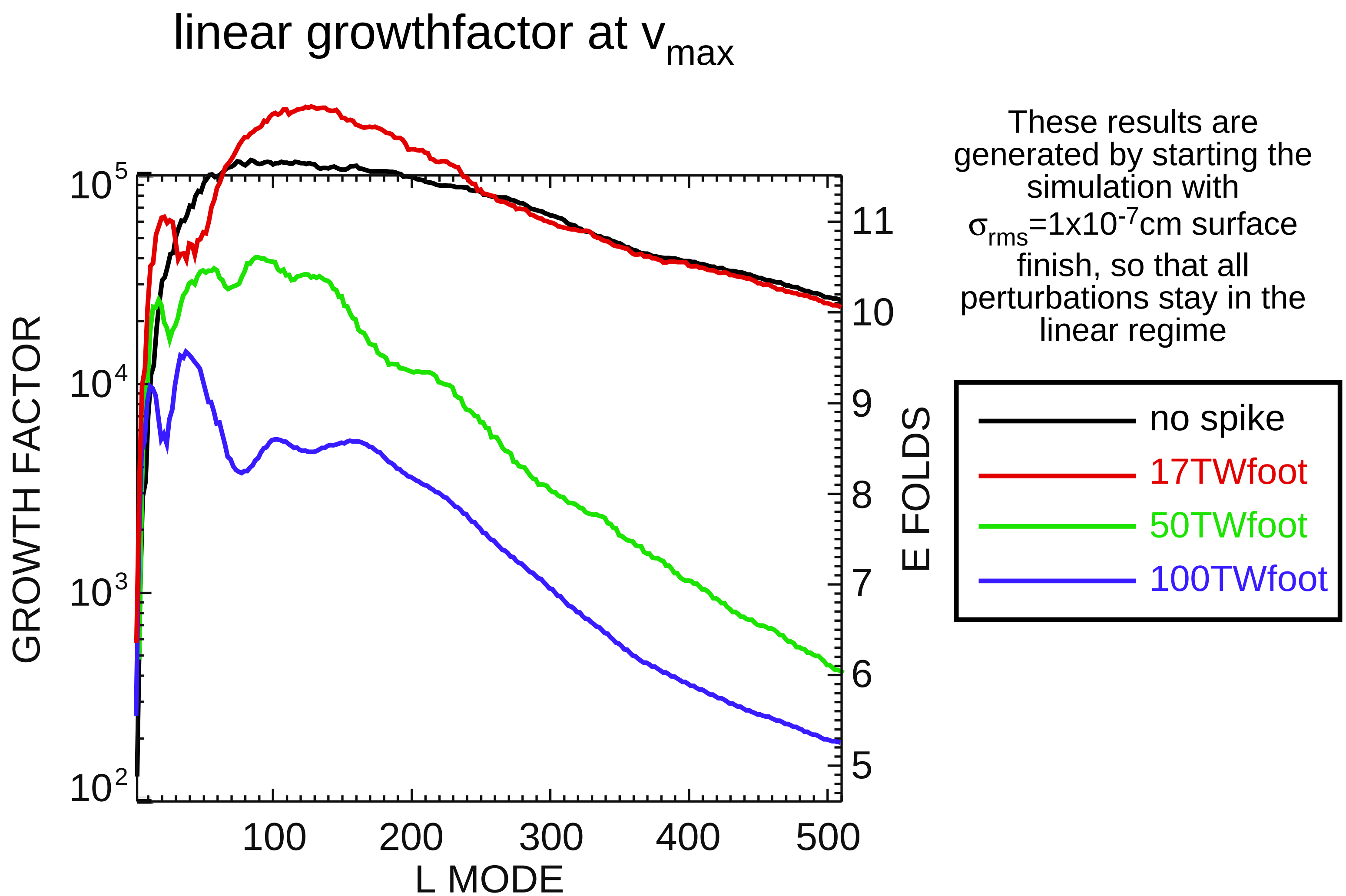


~500 kJ target
initial Aspect Ratio=4.1

Pulse Shape		
Spike [TW/cm^2]	Foot [TW/cm^2]	Gain:
n/a	17	42.7
100	17	48.2
75	50	29
82	100	20.7

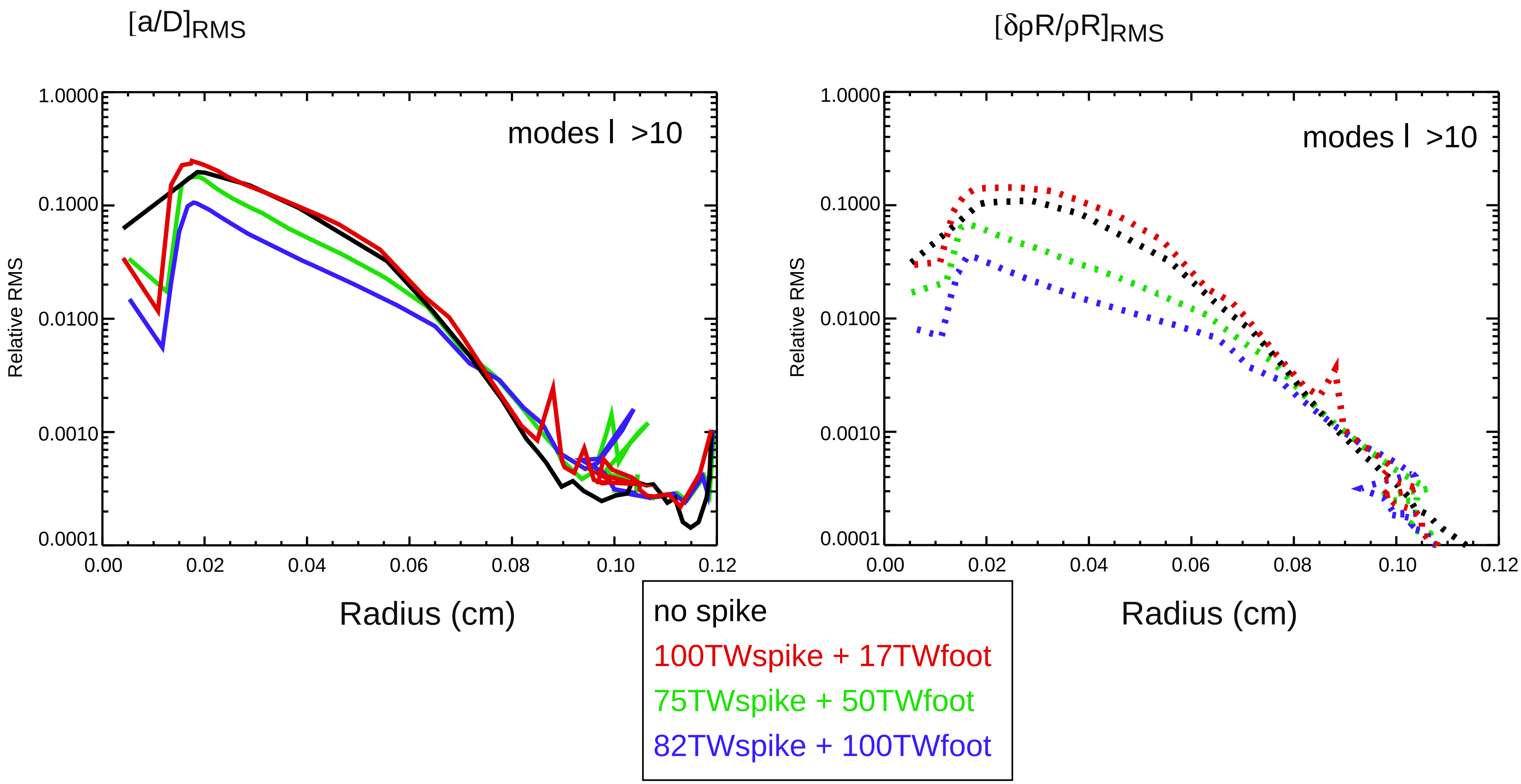


Total instability growth is lower when used with a large foot pulse



These results are generated by starting the simulation with σ_{rms}=1x10^{-7}cm surface finish, so that all perturbations stay in the linear regime

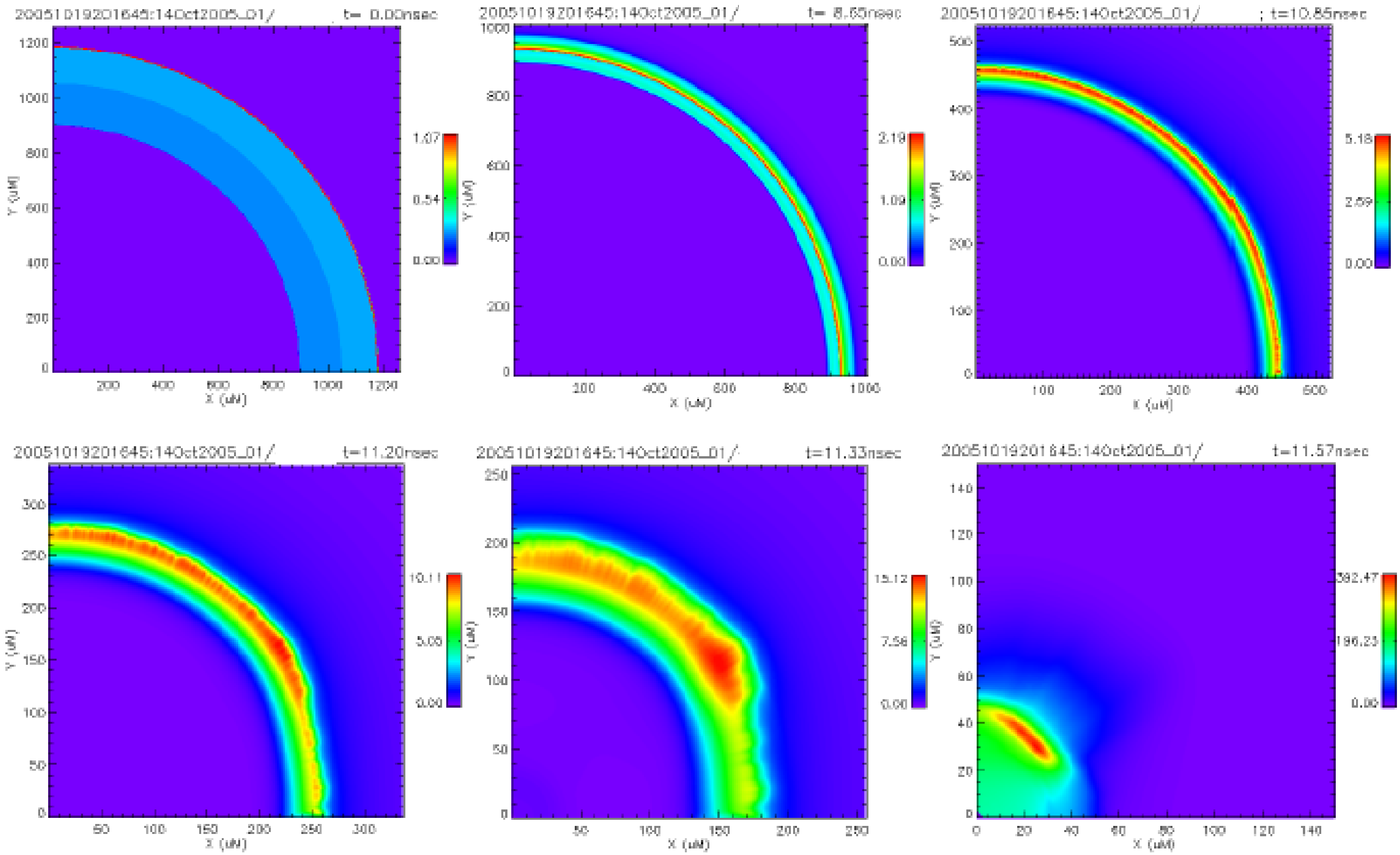
Using the spike with a large foot increases the pellet stability



A/d (rms amplitude/target-thickness) is found by using the density at the ablation surface and via quasi-linear (Haan) analysis;
δρR/ρR is strictly a linear scaling

With NIF-spec outer surface perturbations (0.125μm, l =2:512), simulations show a ~19% decrease in yield.

470kJ KrF pulse: 81TWcm^2 spike+100TW/cm^2 foot; 7.8MJ yield
density is shown at different times through the implosion



Conclusion / Summary

We have looked at designs with low energy (250 kJ-750 kJ), high velocity (3.4-5x10^7cm/s), high intensity (2.2-2.7x10^{15} W/cm^2) and found that moderate/high gains can be achieved. 1d stability studies used for estimates of RT growth.

We have studied the 2d stability of targets designed to be driven by a KrF laser system with about 500 kJ of absorbed energy and relatively high intensity (2.5x10^{15}W/cm^2) and implosion velocity ~4-5x10^7cm/s.

We find that the stability can be substantially altered by judicious use of spike pulses, and a small energy pellet (480kJ) can be stabilized enough to produce order 1d yield.

These are preliminary results. We are still looking at stability of targets (more complete studies) and at various ways of improving their robustness (high-Z layer, initial density gradient/ spike).