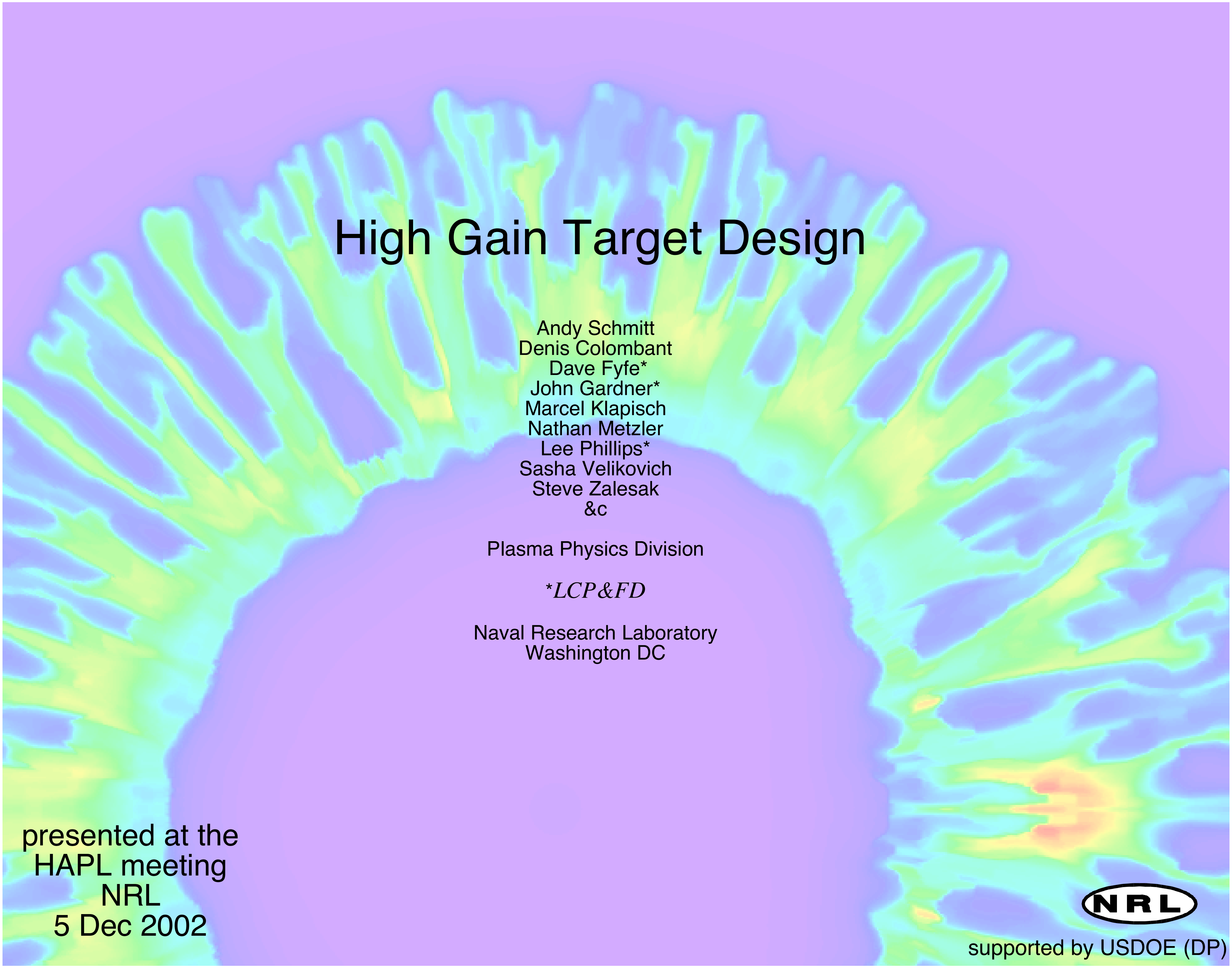

High Gain Target Design

Andy Schmitt
Denis Colombant
Dave Fyfe*
John Gardner*
Marcel Klapisch
Nathan Metzler
Lee Phillips*
Sasha Velikovich
Steve Zalesak
&c

Plasma Physics Division

LCP&FD

Naval Research Laboratory
Washington DC

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Overview

Design Methodology:

Initial designs in 1D, using piggyback hydrodynamic instability models to estimate stability

Use 2D high resolution simulations to predict the hydrodynamic instability during the compression phase (development of RT seeds) and acceleration phase (growth of RT seeds). Credibility? Benchmark each phase.

Example: All-DT pellet for NIF

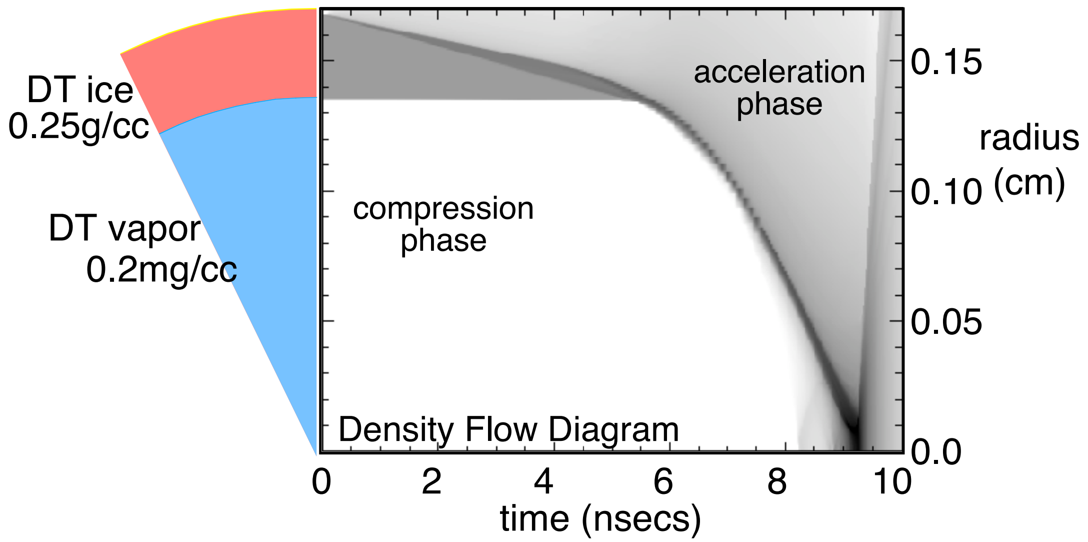
High Gain designs

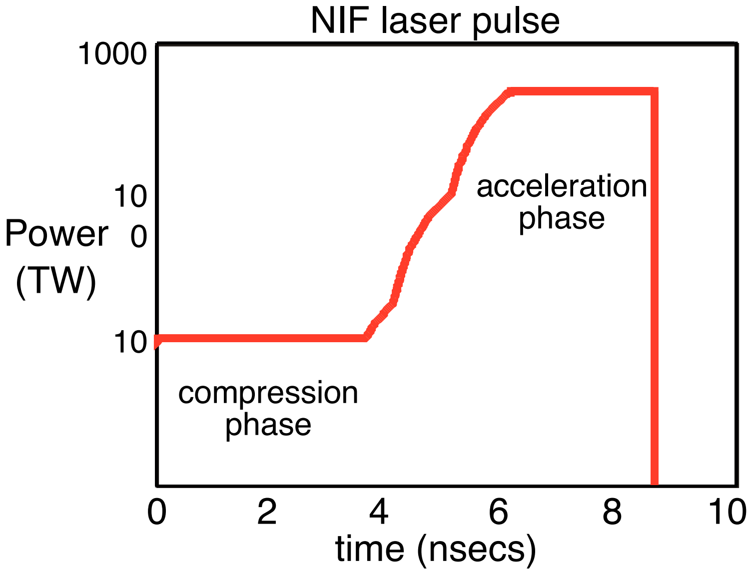
* Use KrF laser, with zooming to maximize coupling efficiency

* spike/picket prepulse for
- imprint mitigation
- adiabat tailoring

* High-Z layers for imprint mitigation

The all-DT ice NIF direct-drive pellet

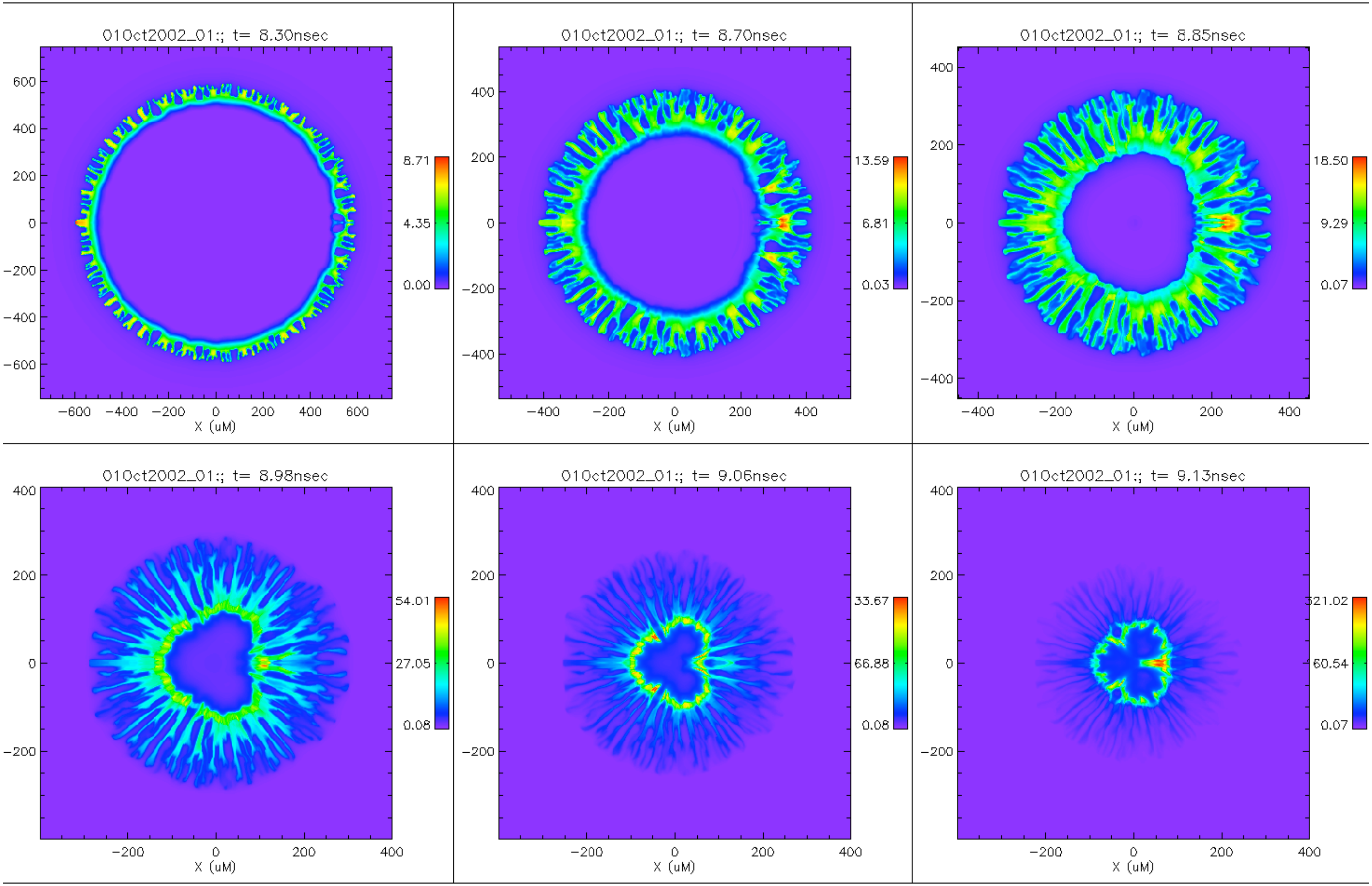




all-DT Pellet Design

Laser Energy	1.6 MJ
Laser Power (peak)	450 TW
Absorption fraction	0.65
Hydro Efficiency	11%
Implosion Velocity	4.9×10^{7} cm/s
Peak Fuel ρR	1.3 g/cm^{2}
Gain	~35

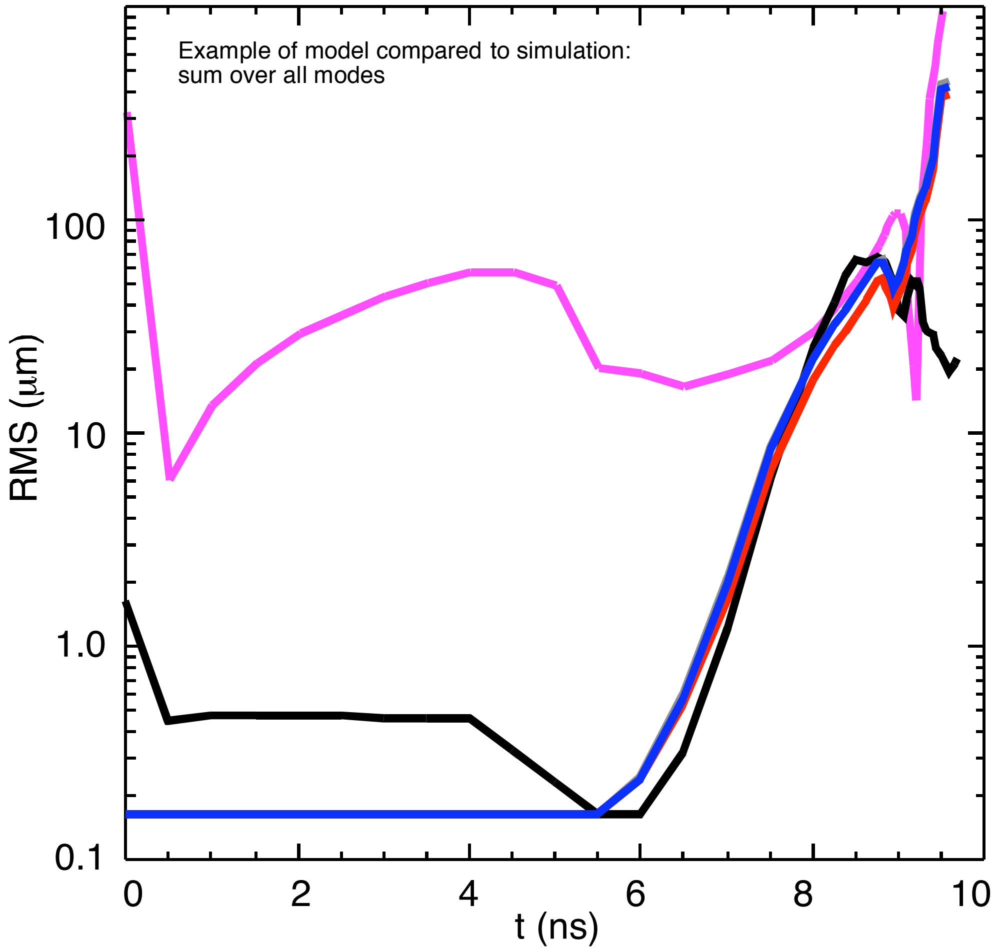
allDT NIF pellet: 0.125μm outer/1.0μm inner surface perturbations + 1THz ISI
absorbs 1.5 MJ, 0.35μm laser light, yields 1.79MJ



Comparison of simulation to theory during acceleration phase uses simple Rayleigh-Taylor dispersion formulae*, Bell-Plesset effects, and Haan-model saturation.

Rayleigh-Taylor with Compressible Bell-Plesset:

$$a = a_0 e^{\square t}\,\frac{R_0^2 \square_0}{R^2 \square}$$



- RMS amplitude from the simulation is calculated as $\square(\square R)/\square_{ablation}$

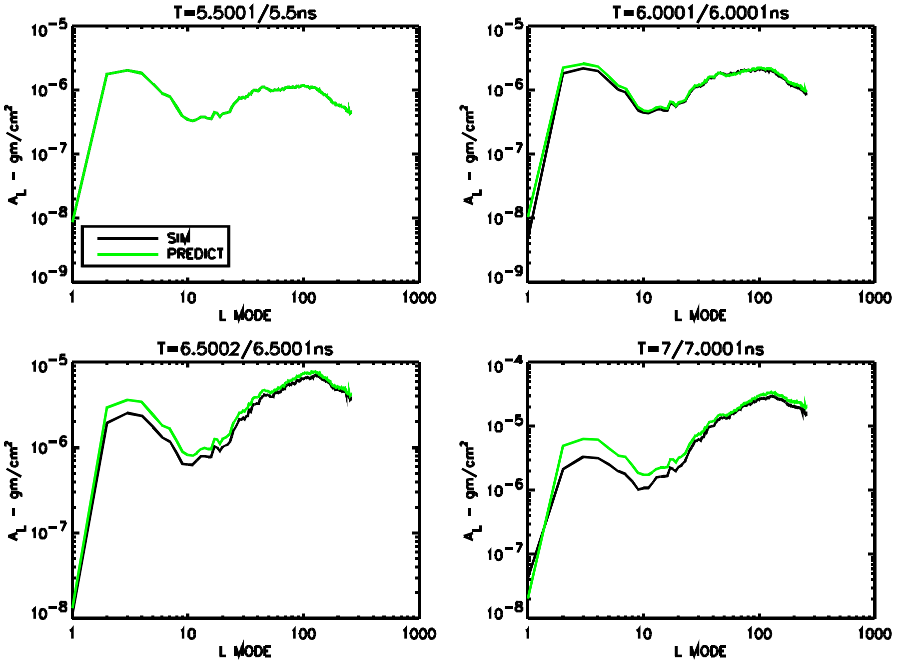
- predicted amplitudes include saturation effects a la Haan: secular growth at large amplitudes

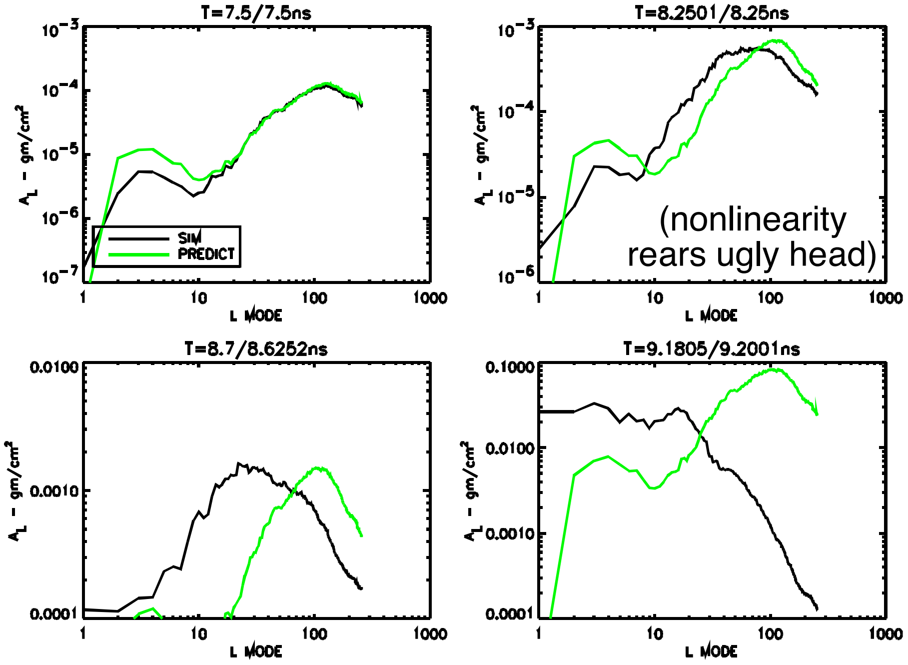
*e.g., Lindl/Weber formula is:

$$\square(t) = \sqrt{\frac{kg(t)}{1+kL(t)}} - k\square V_a(t)$$

Acceleration phase Rayleigh-Taylor Growth Spectra

Simulations (black) vs. simple-model expectations (green)

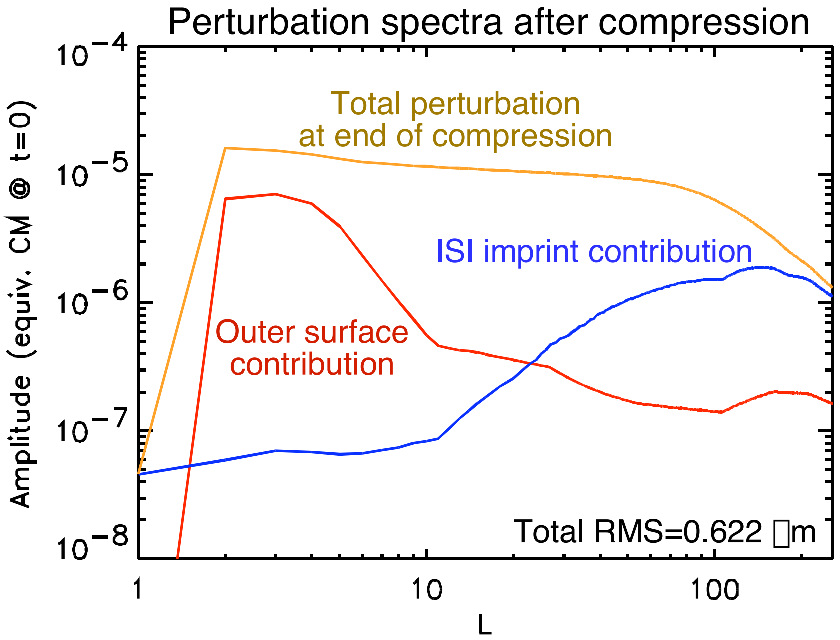


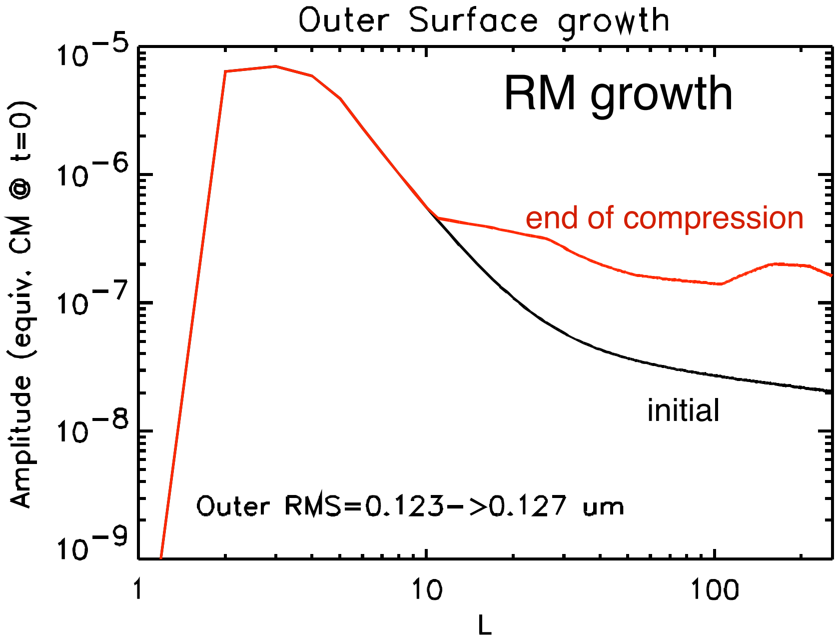


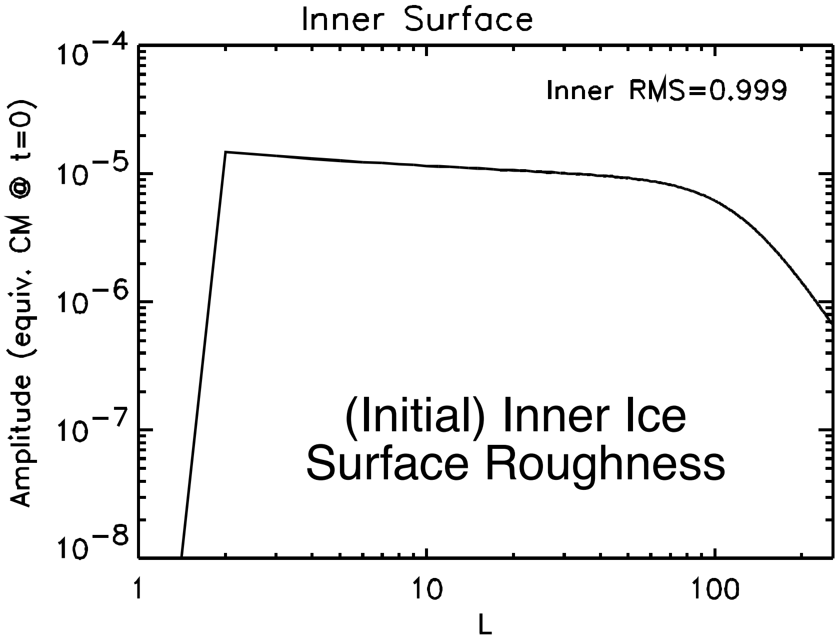
(nonlinearity rears ugly head)

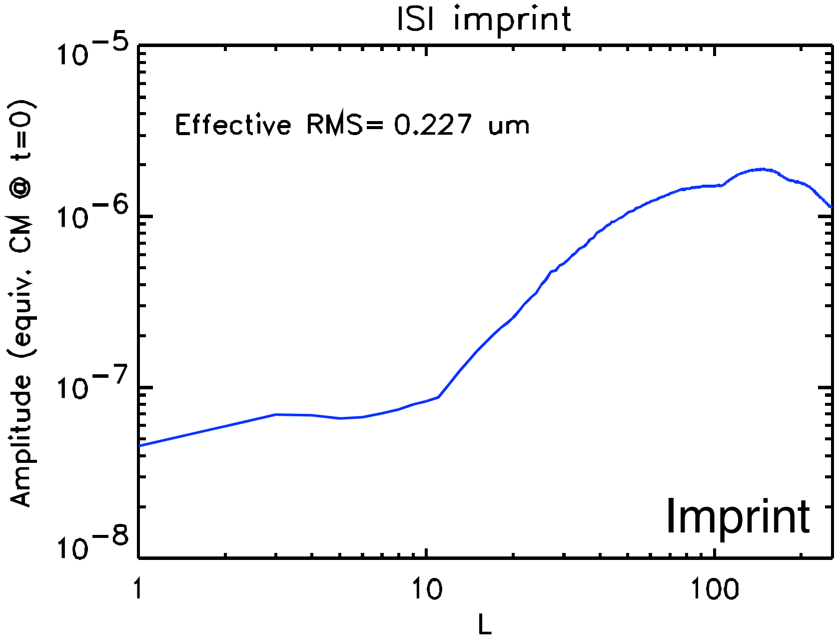
Starting with the observed spectra at the end of compression, the RT growth matches expectations fairly well until ~8ns (where nonlinearity is becoming evident).

Compression phase: Predicted perturbation spectra due to RM, imprint, and feedout


Perturbation spectra after compression


Outer Surface growth

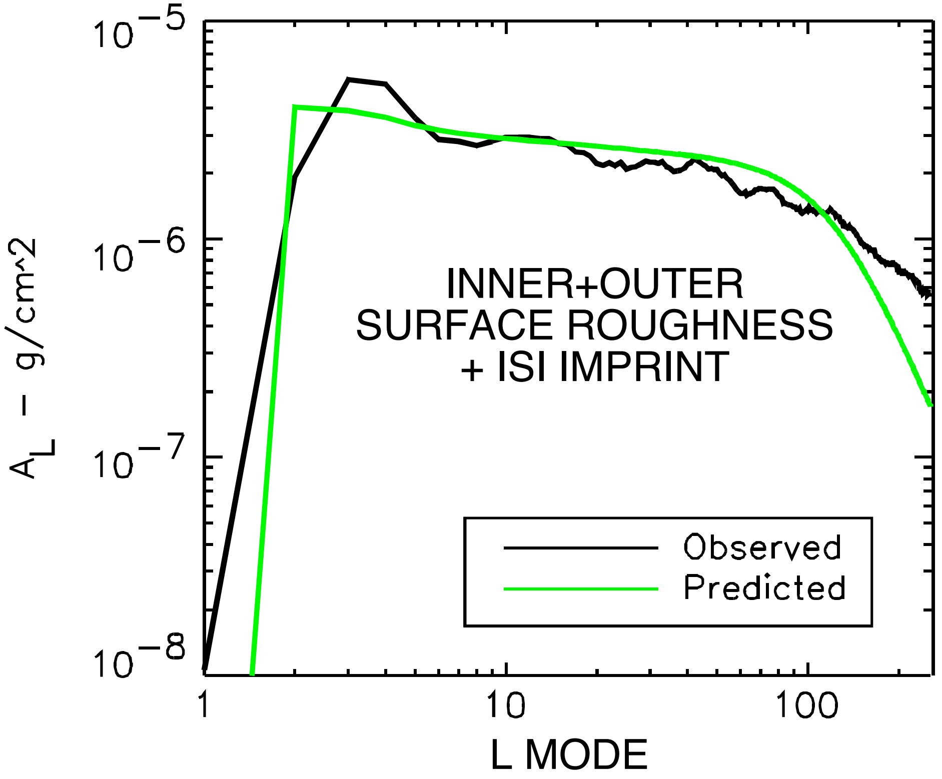

Inner Surface


ISI imprint

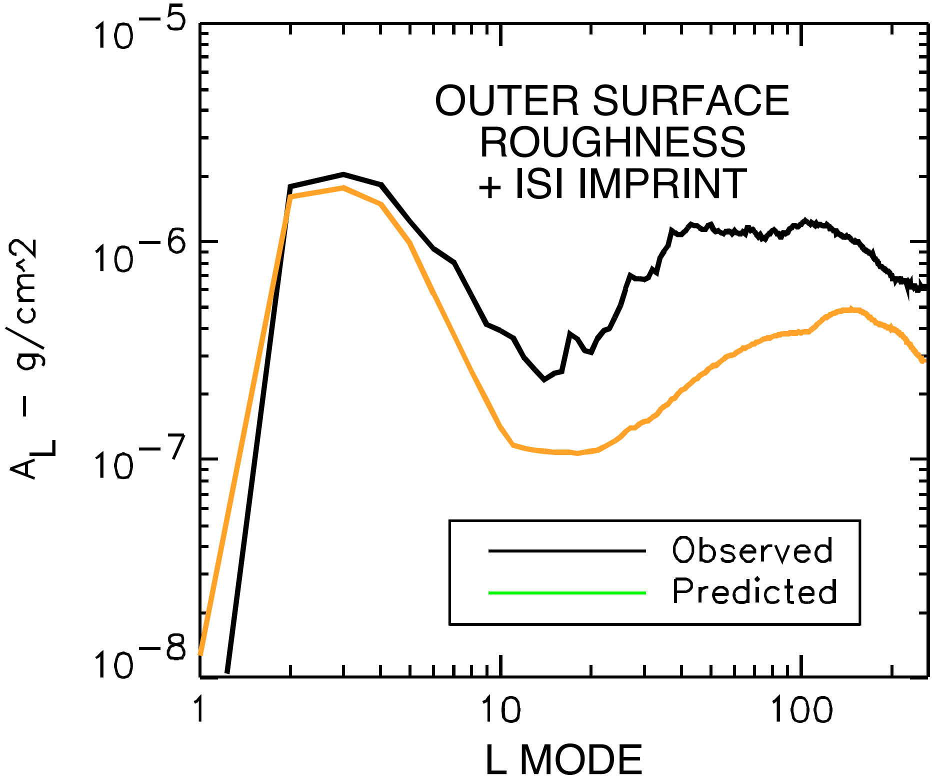
Comparison of predictions to simulations for the all-DT NIF pellet:

Compare the perturbation spectrum at end of compression:

These are spectra of areal-mass perturbations;
the “predictions” are from single-mode planar
simulations, cross-checked (when possible) by basic
ablative Richtmyer-Meshkov SBM theory



Comparison is very good ---
because the (unchanged) initial inner surface
spectrum dominates the diagnostic

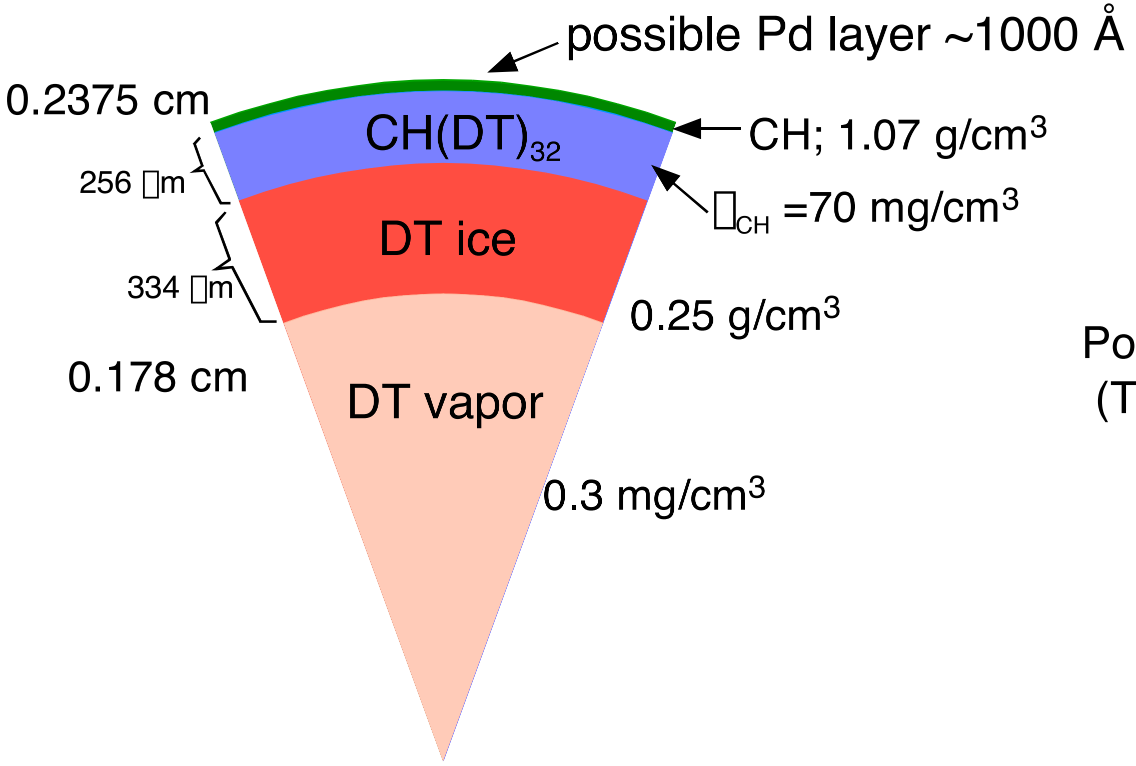


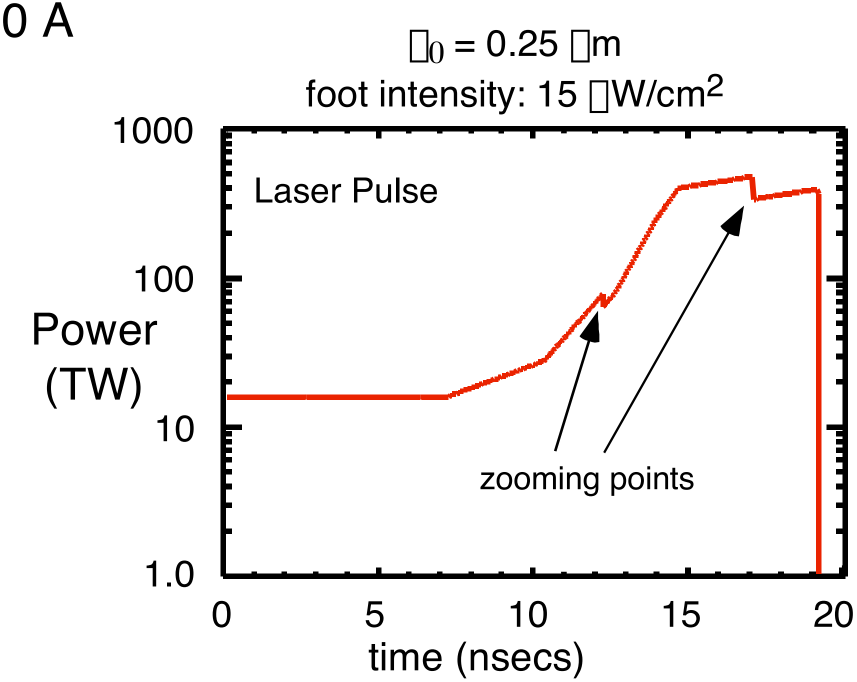
Comparison of simulation with smooth
inner surface: hydrocode has difficulty
resolving very small amplitude modes.
This is capability is being improved.

$$\square_{RMS} = \sqrt{(\text{GrowthFactor*Outer})^2 + \text{ISI\_imprint}^2 + \text{Inner}(t{=}0)^2}$$

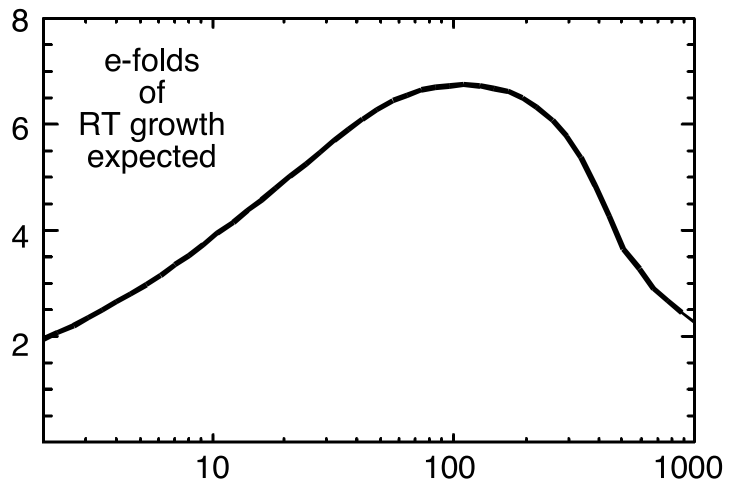
Status of High-Gain Target Designs

High gain target uses KrF laser with zooming



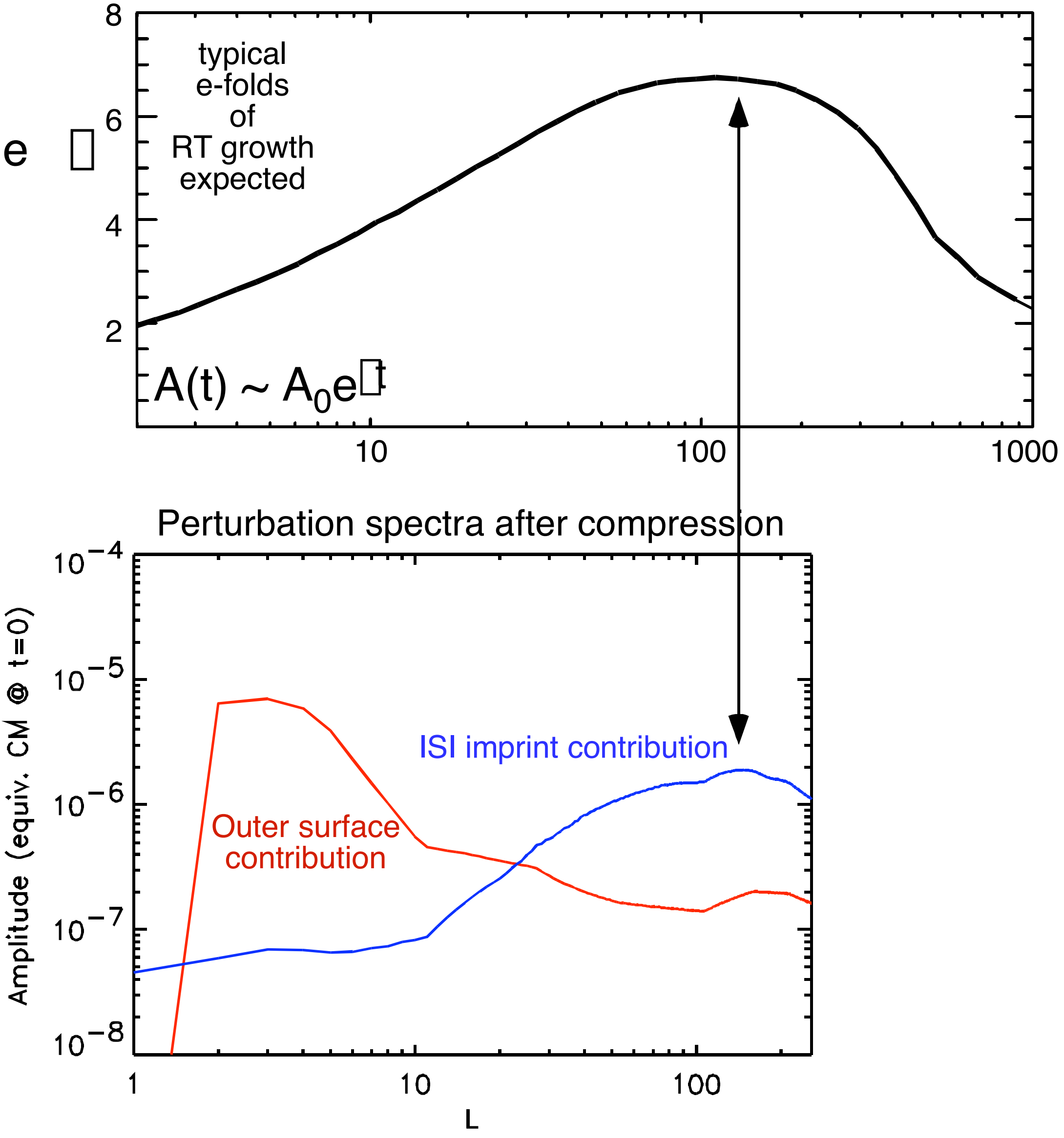


Laser Energy: (with zooming)	2.55 MJ
1D Yield:	384 MJ
1D Gain:	~150
absorption	93 %
hydroefficiency	11.5 %

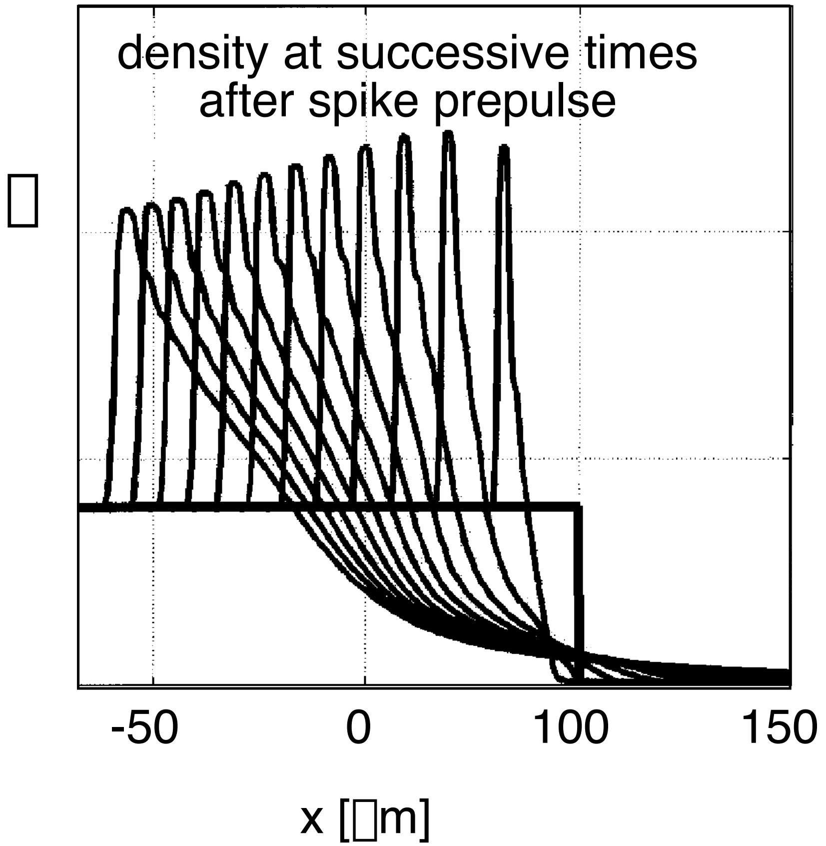


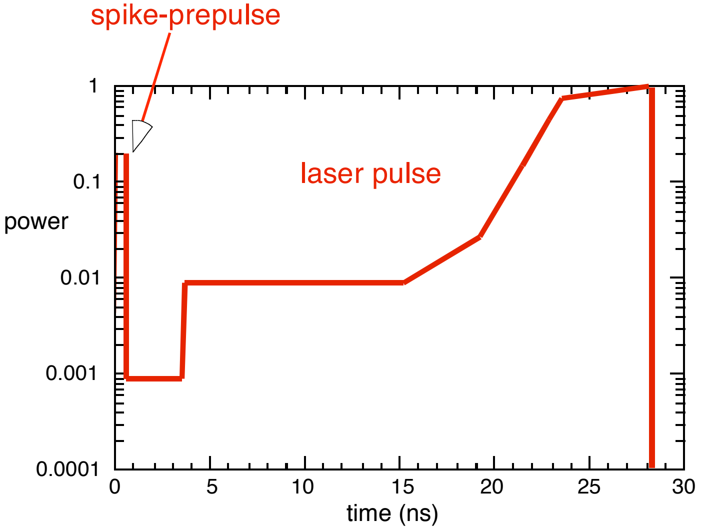
Imprint maximizes for the modes where the RT instability is worst

- Imprint is dominant for the most unstable RT modes
- New target designs stress imprint mitigation



A spiked prepulse can be used for both imprint mitigation and adiabat control



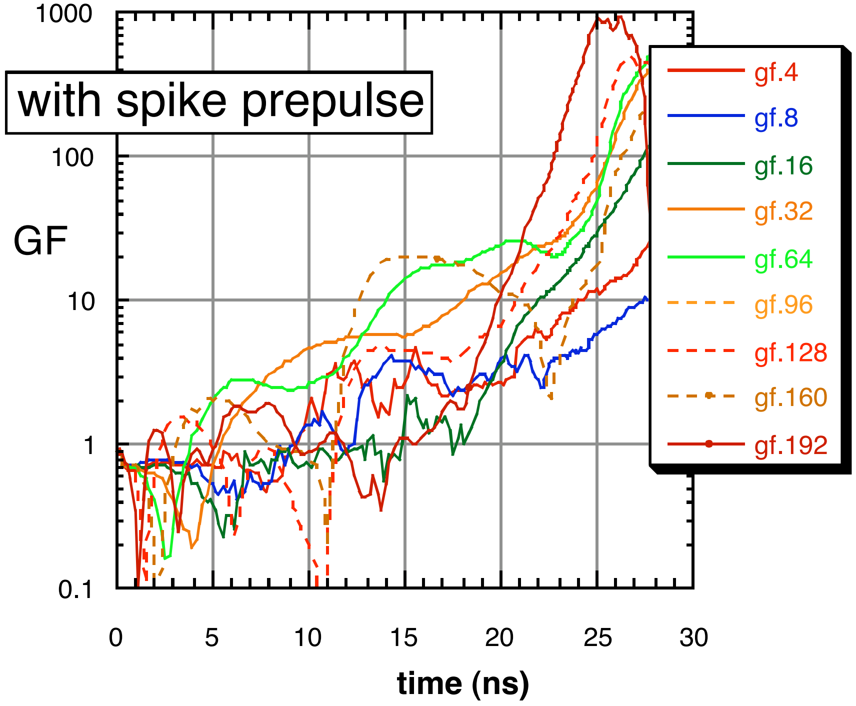


The prepulse drives a decaying shock through the pellet; the rarefaction behind it produces a stabilizing density gradient on the outside of the pellet

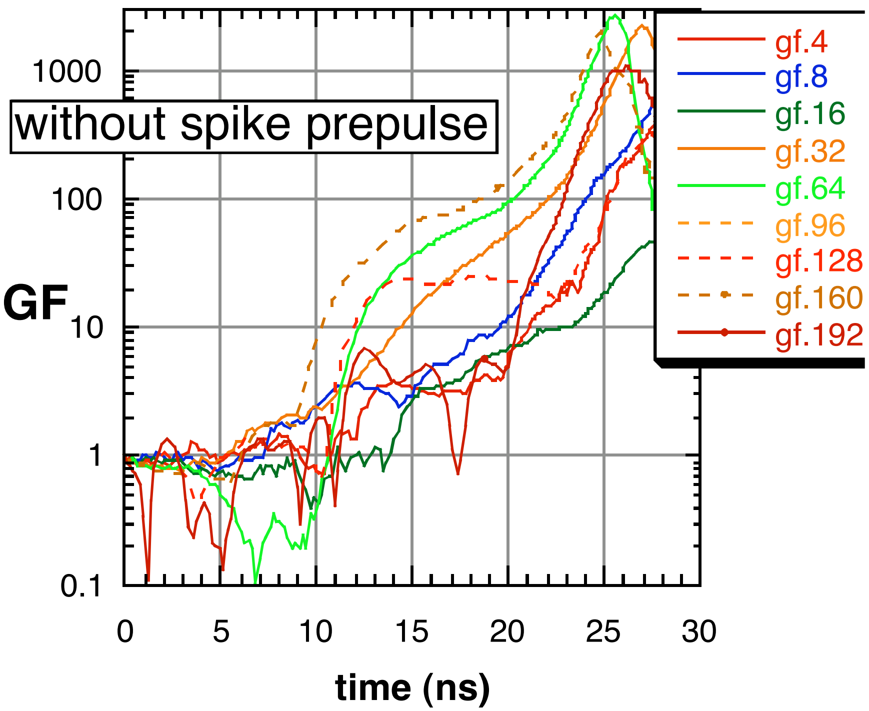
The spike also can be used to preferentially increase the ablator adiabat, producing a net increase in the stability of the pellet (c.f., Collins, Skupsky, Goncharov, Betti, et al., Rochester/LLE)

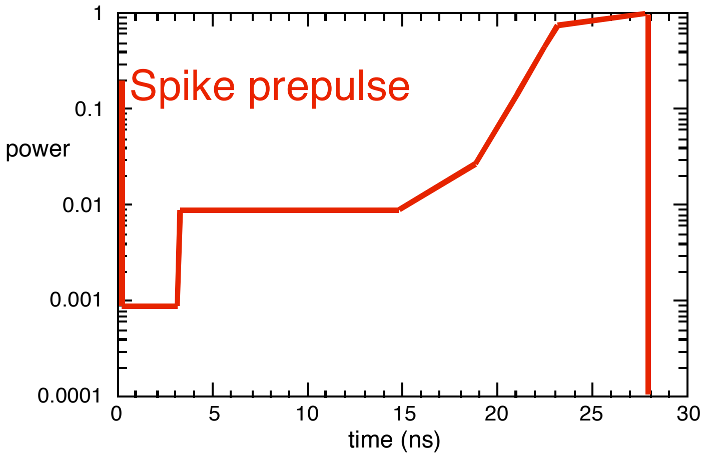
High gain DT/DT-CHfoam/CH pellet: single mode growth of outer surface perturbations

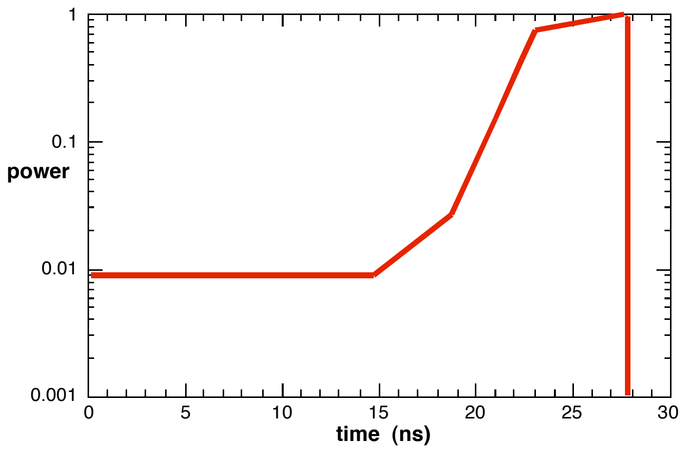
single mode growth factor (outer surface)



single mode growth factor (outer surface)

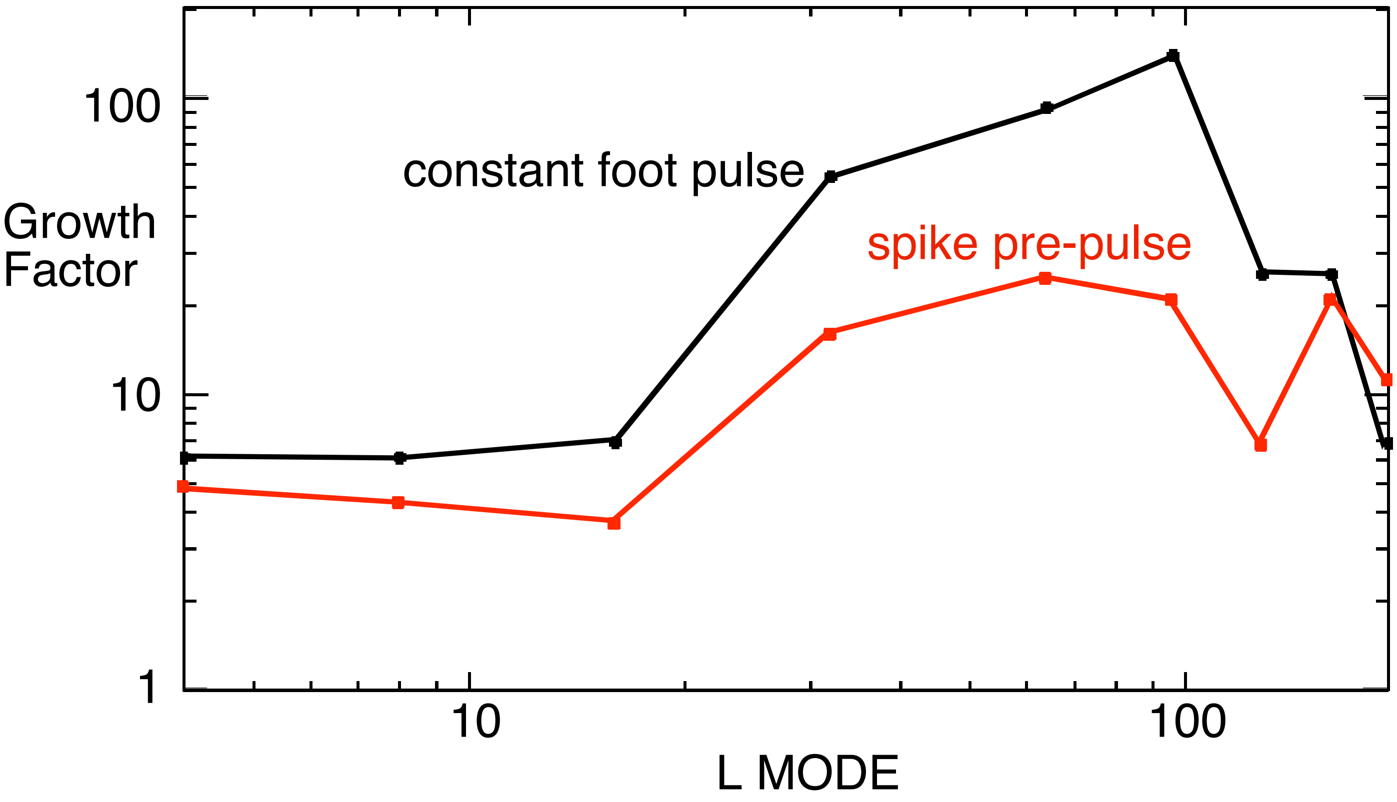






High gain DT/DT-CHfoam/CH pellet: growth factors during compression phase can be mitigated with a spike prepulse

The spike-prepulse decreases the initial RM growth of outer surface perturbations



High gain DT/DT-CHfoam/CH pellet: growth factors during compression phase can be mitigated with a spike prepulse

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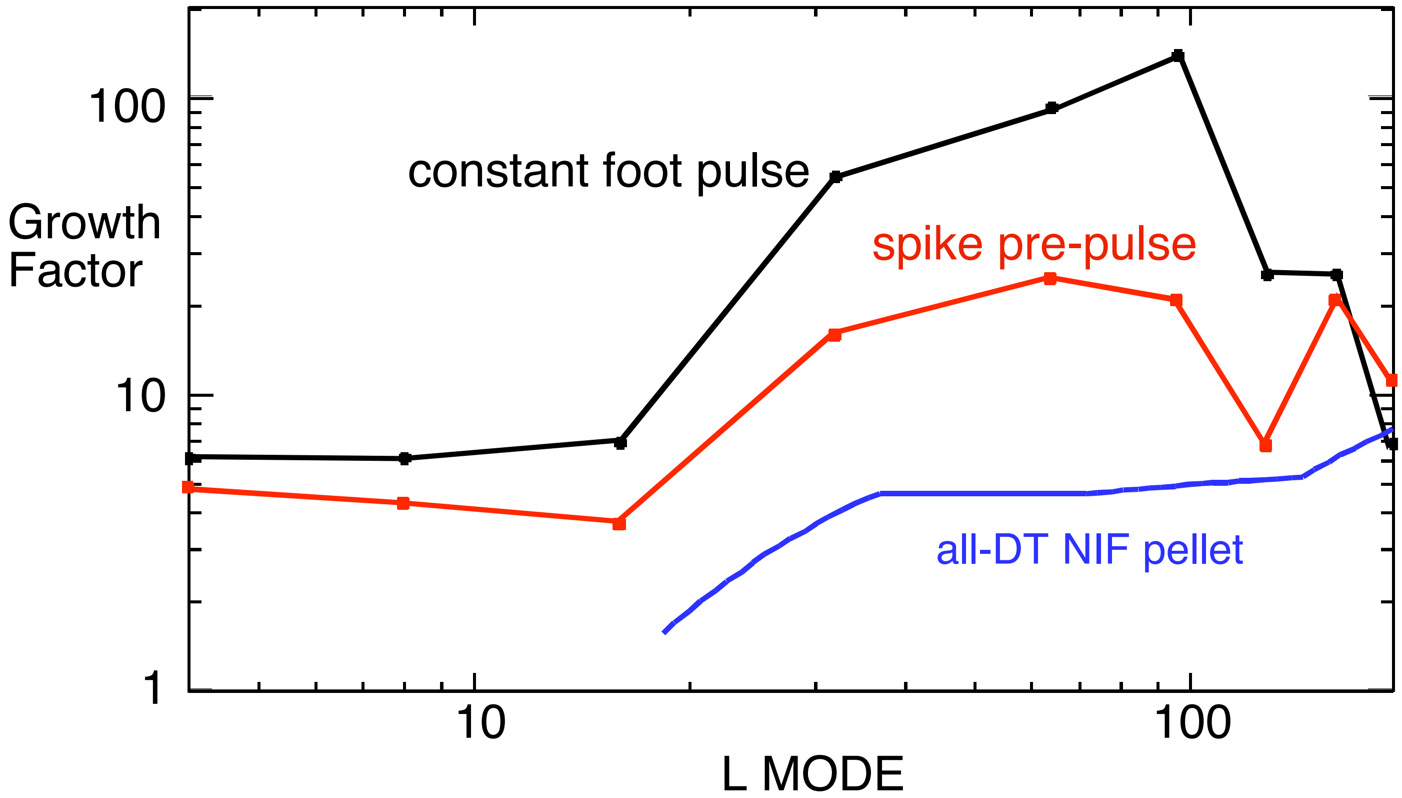
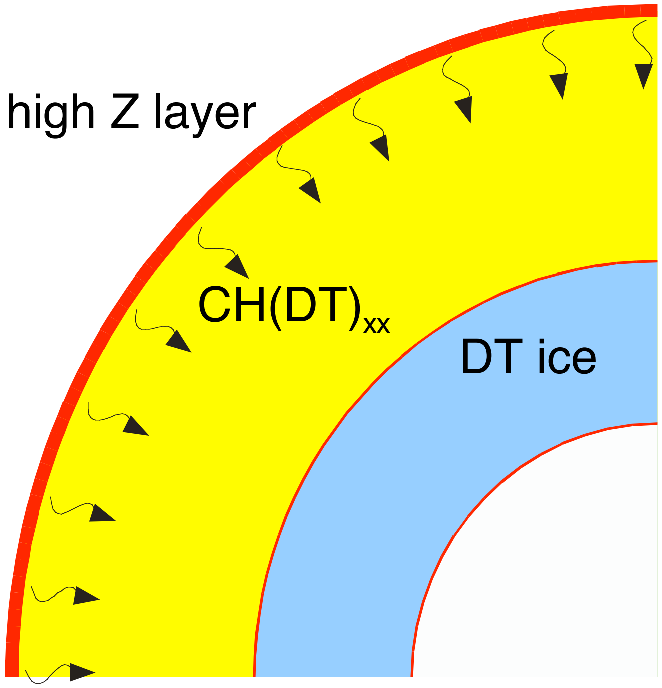


However, growth during compression is still appreciably higher than for alll-DT NIF pellet

High-Z layers also reduce imprint

during the early part of the laser pulse, the high-Z layer heats the outside pellet surface and produces a plasma that buffers the pellet from the laser perturbations

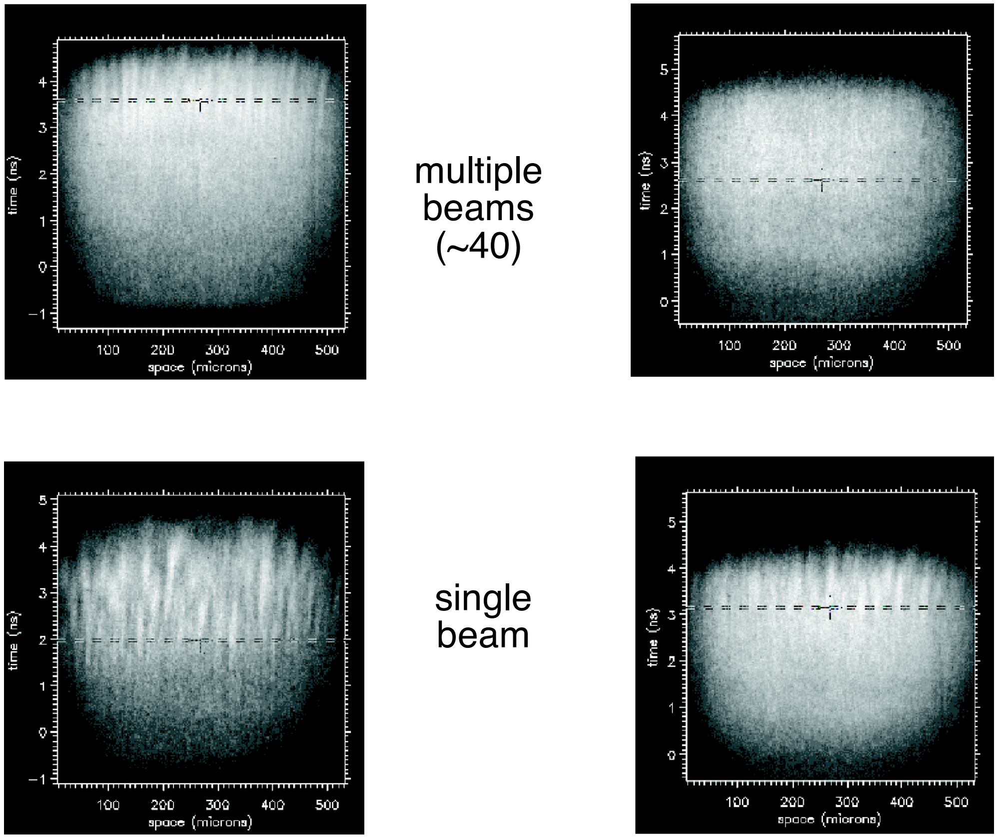


Pure CH

CH + ~380 Å Au

multiple beams (~40)

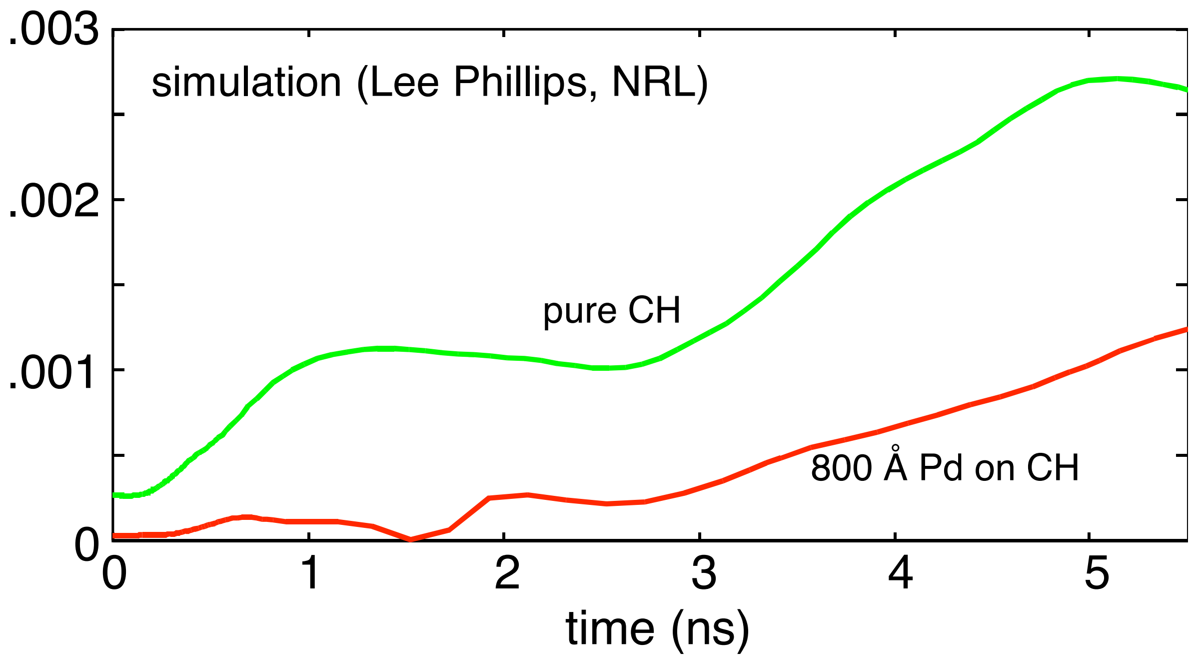
single beam

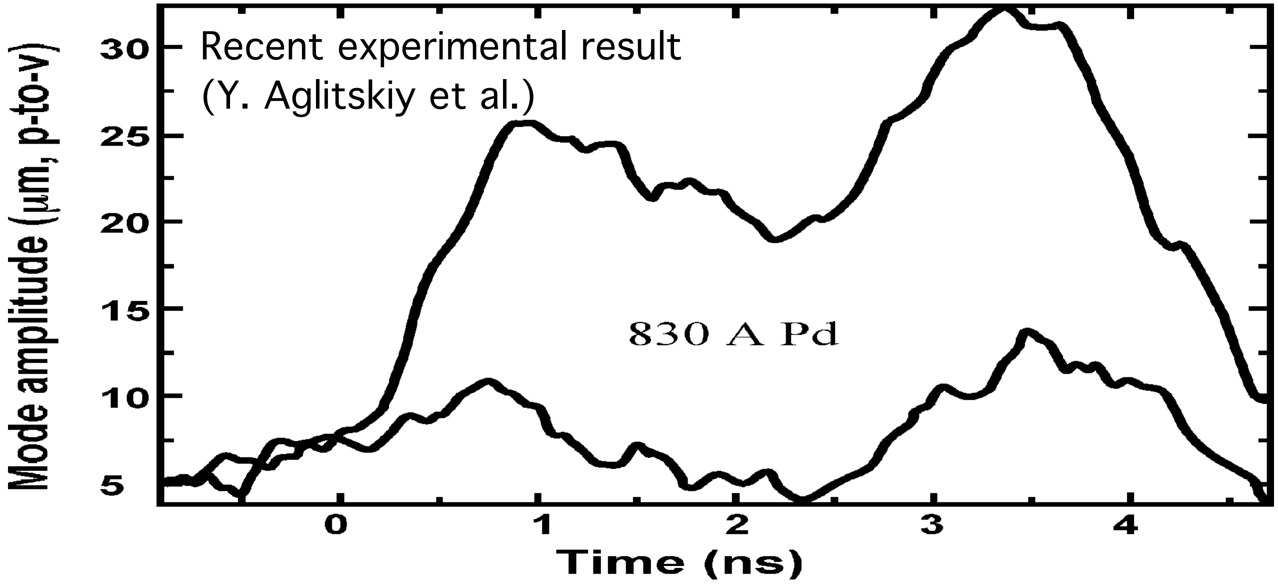


Thick overcoats (> 350 Å) **decrease** the observed imprint in experiments

Simulations now agree with experiment: Richtmyer-Meshkov growth decreases when high-Z layers are thick enough

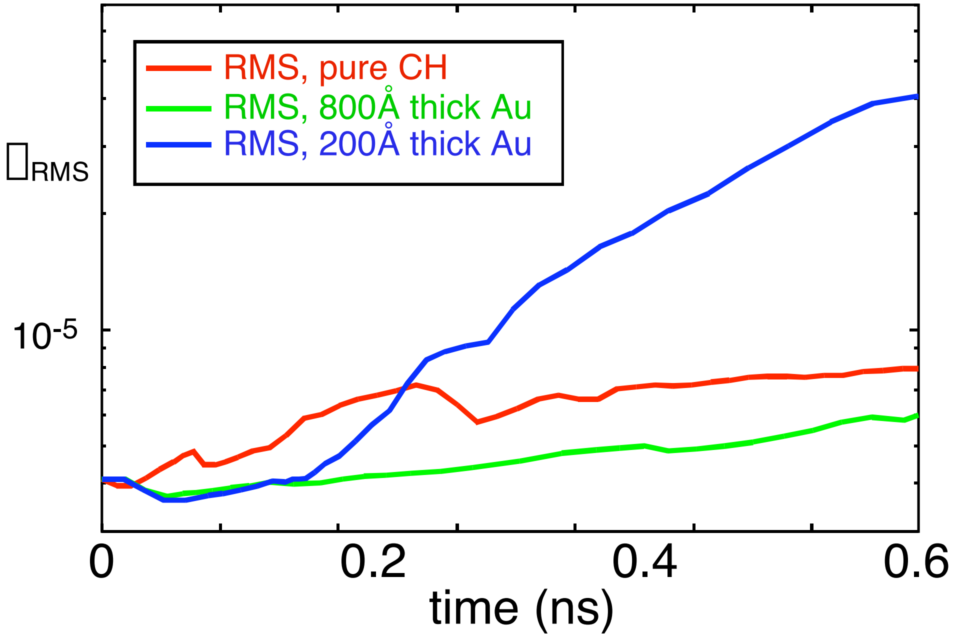
Modal mass perturbation of a rippled plastic foil illuminated by a KrF laser with ISI-smoothed nonuniformities, compared with the same target clad with an 800 °A palladium overcoat. Growth of the initially applied 30 μm sinusoidal mode is shown.



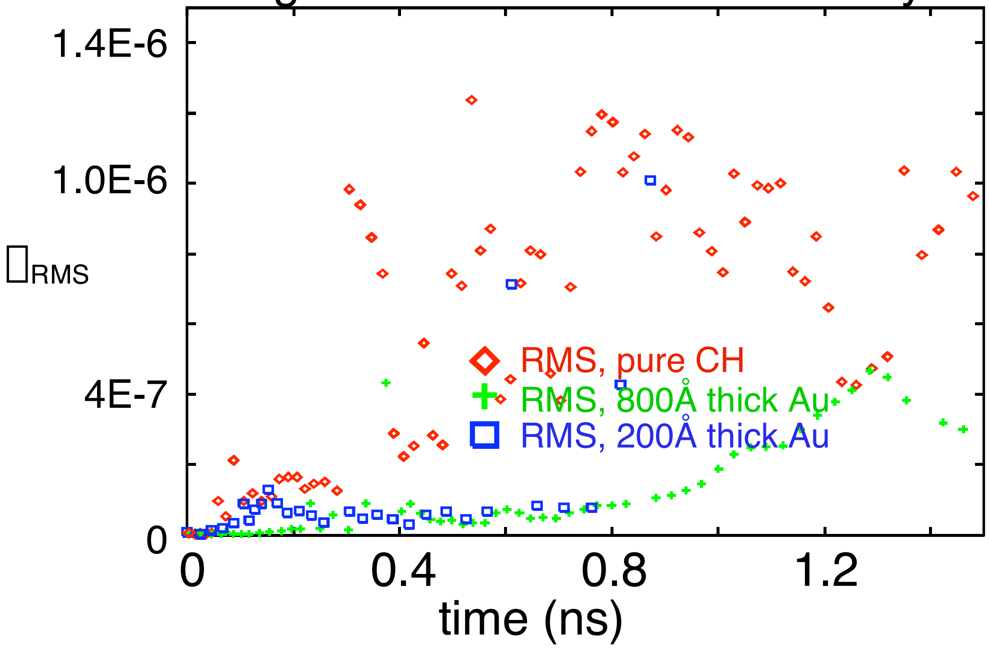


Both laser imprint and surface roughness growth are reduced by high-Z layers that are “thick enough”.

Total □$_{\mathrm{RMS}}$ with imposed 60 □m mode on target surface



Total □$_{\mathrm{RMS}}$ on ablator with flat target and ISI laser nonuniformity



Summary: status of target design

Modeling of targets with 2D hydrocodes is ongoing. The goal is to predict gain degradation resulting from non-ideal conditions

+ RT growth phase appears to be in agreement with models

- Compression phase is problematic: simulations show enhanced growth (due to numerical noise coupled with small mode amplitude?).

+ Gain degradation studies are beginning

Recent Developments:

In depth 2D modeling of high gain pellets is beginning. Newer designs use either a spike prepulse or high-Z layers

- initial perturbation growth is significantly larger than all-DT pellet design

+ picket/spike prepulses is being used to mitigate imprint and reduce RT growth

+ Both experiments and simulations agree that thin high-Z layers reduce imprint and RM growth