19th High Average Power Laser Workshop,
Madison WI 22 - 23 Oct 2008

Advances in high performance Direct Drive targets**

Andrew J. Schmitt, Jason W. Bates, and Steven P. Obenschain
Plasma Physics Division, Naval Research Laboratory, Washgingon DC

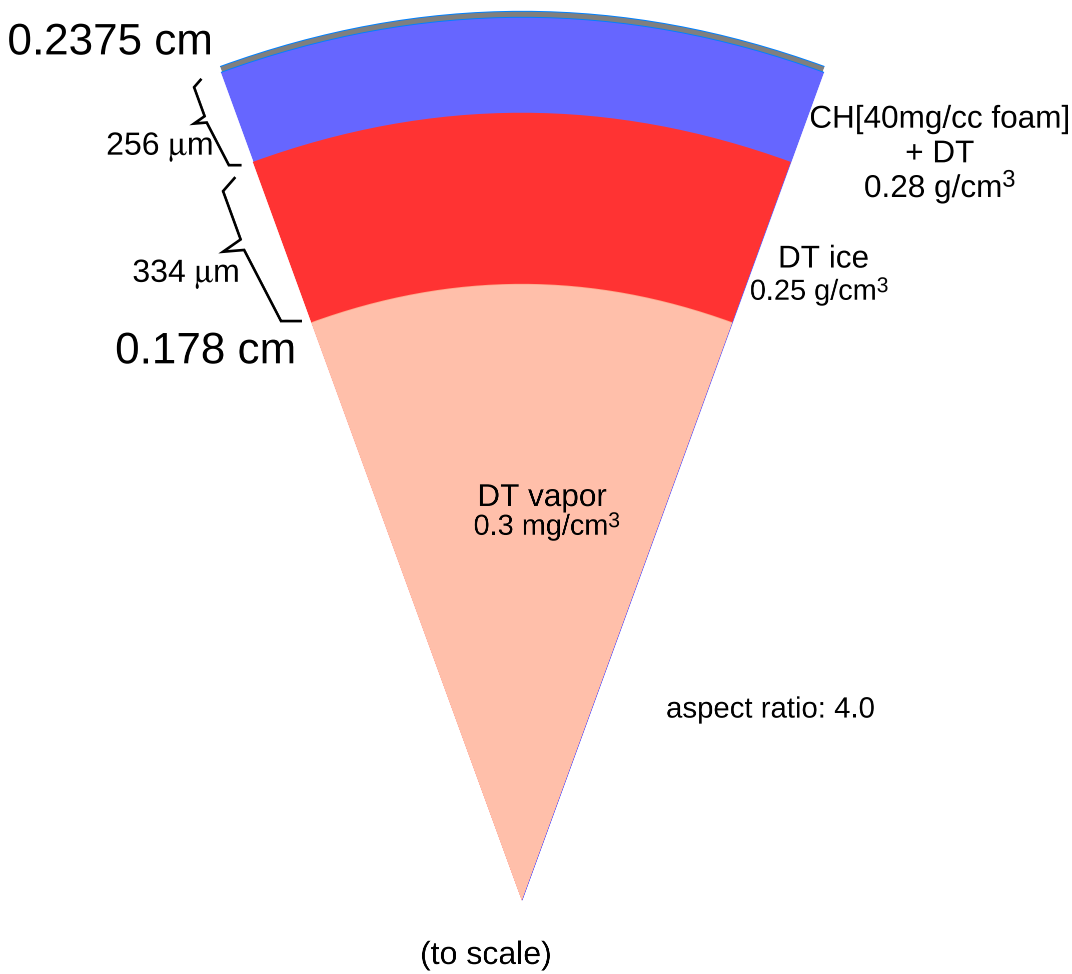
David E. Fyfe
Laboratory for Computational Physics and Fluid Dynamics, Naval Research Laboratory, Washington DC

Mark Quigley
SAIC, McLean, VA

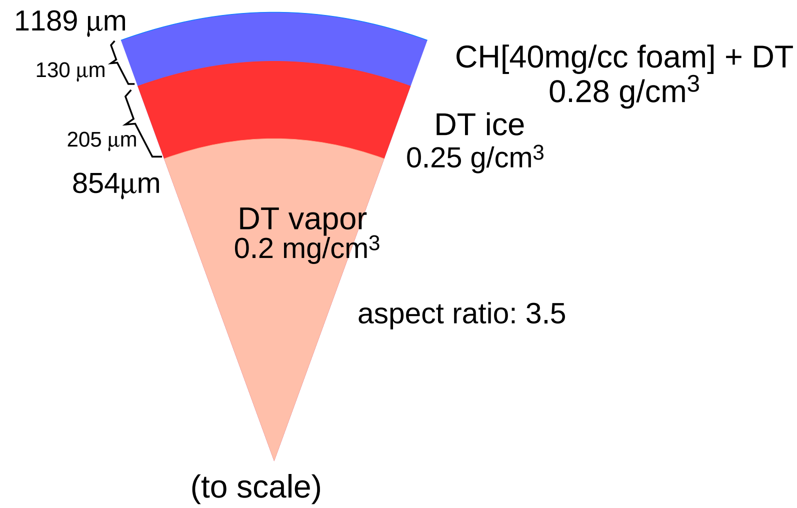
Riccardo Betti
Fusion Science Center and Laboratory for Laser Energetics, University of Rochester, Rochester NY

**This work was supported by US DOE (NNSA).

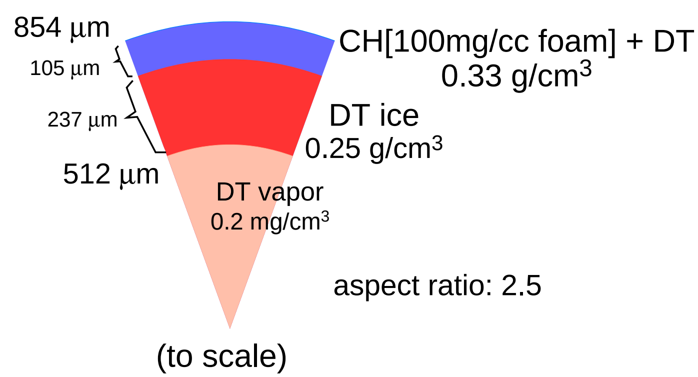
Honey, I shrunk the target !



2.6 MJ High Gain target



480 kJ FTF target

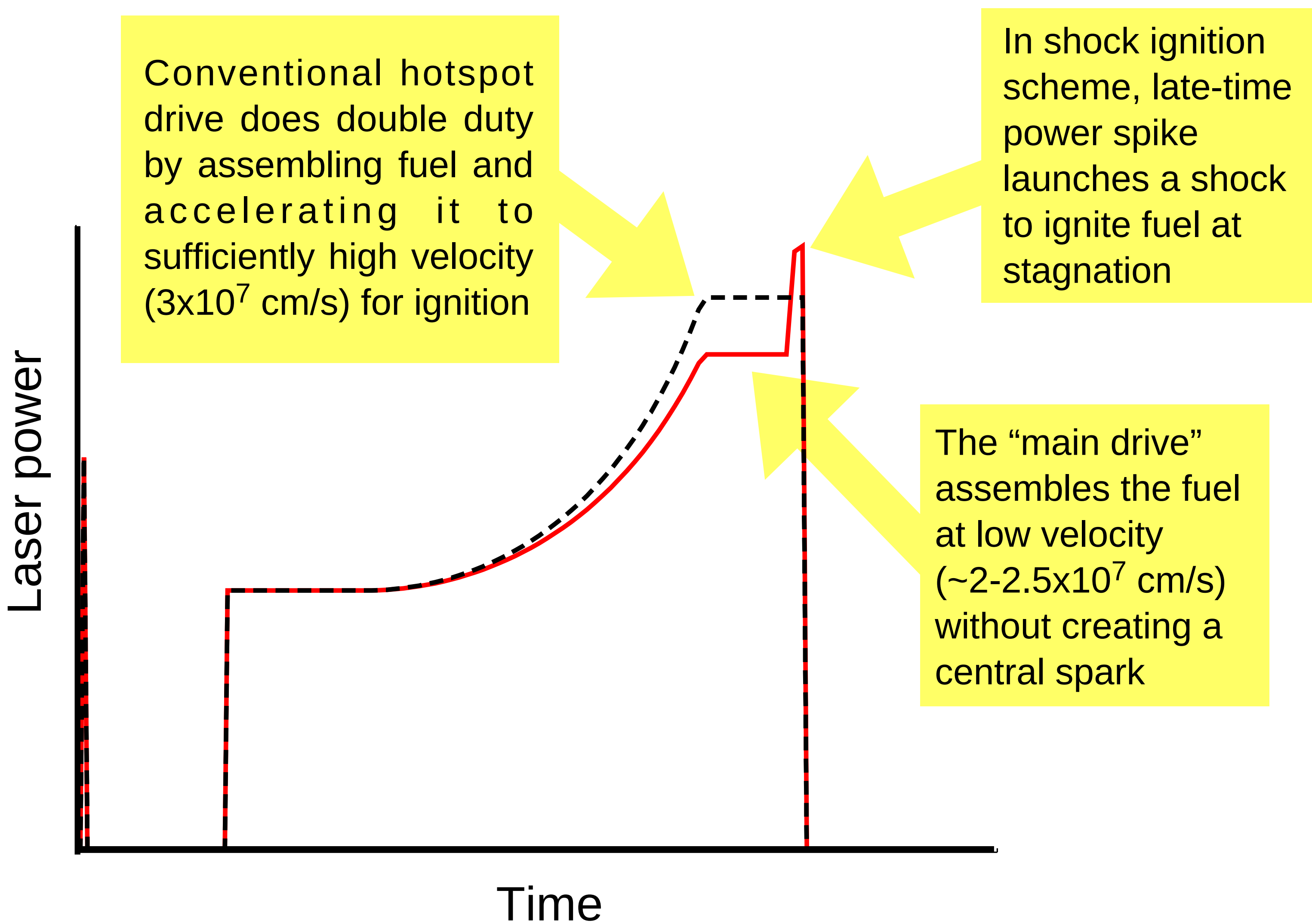


250 kJ Shock-Ignition target

*R. Betti et al., PRL **98**, 155001 (2007)*

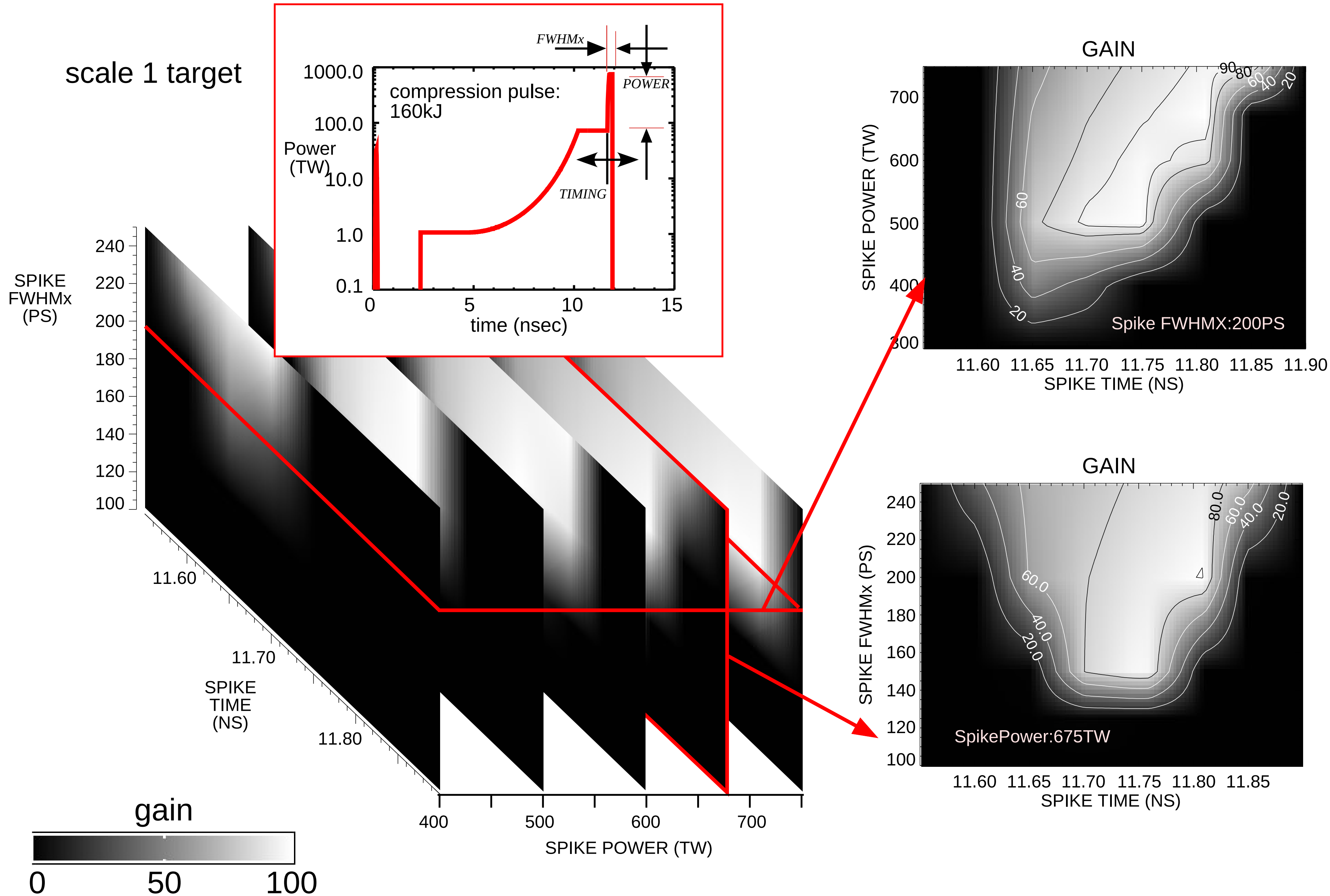
all targets use KrF (0.25μm) light with laser-spot zooming

The Shock Ignition approach: implode low-aspect-ratio targets at low velocities and ignite with a separate ignition spike



1D simulations

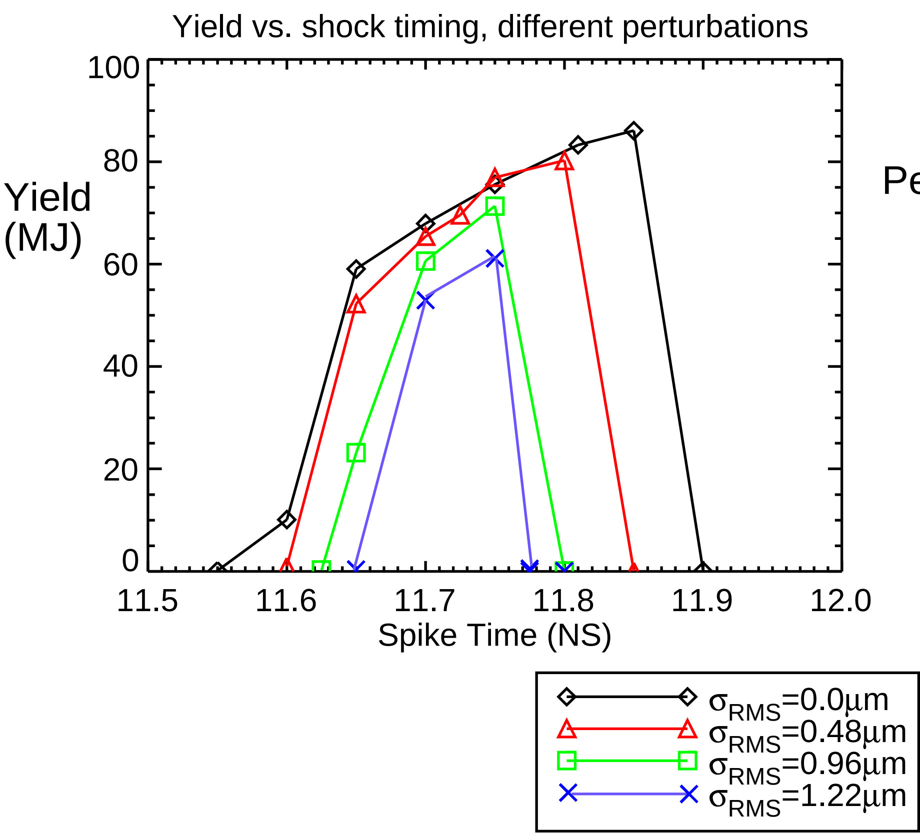
1D parameter space scans for shock ignition have been done...

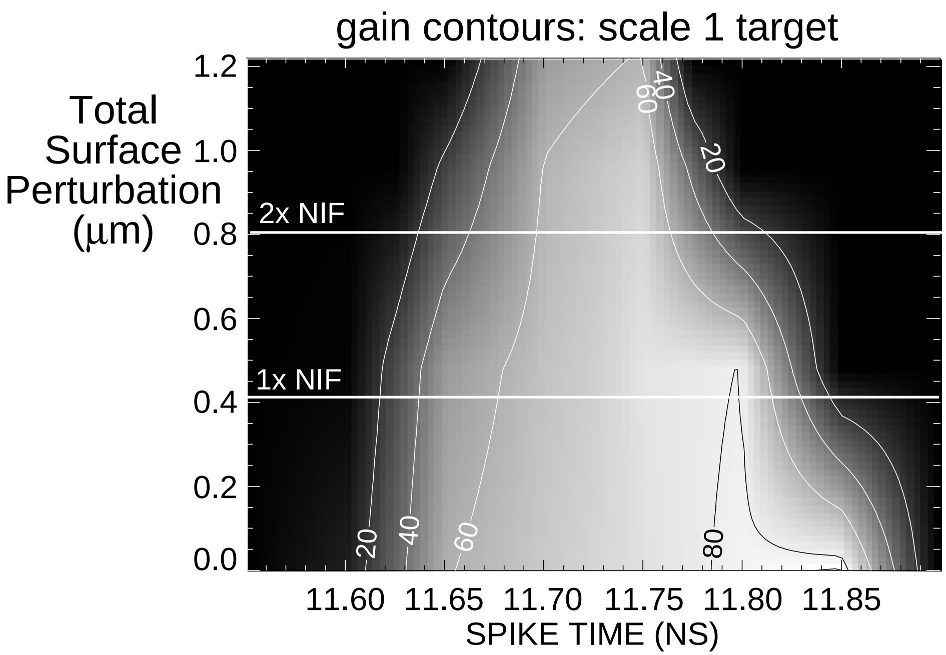


2D low-mode simulation (ℓ=2-8)

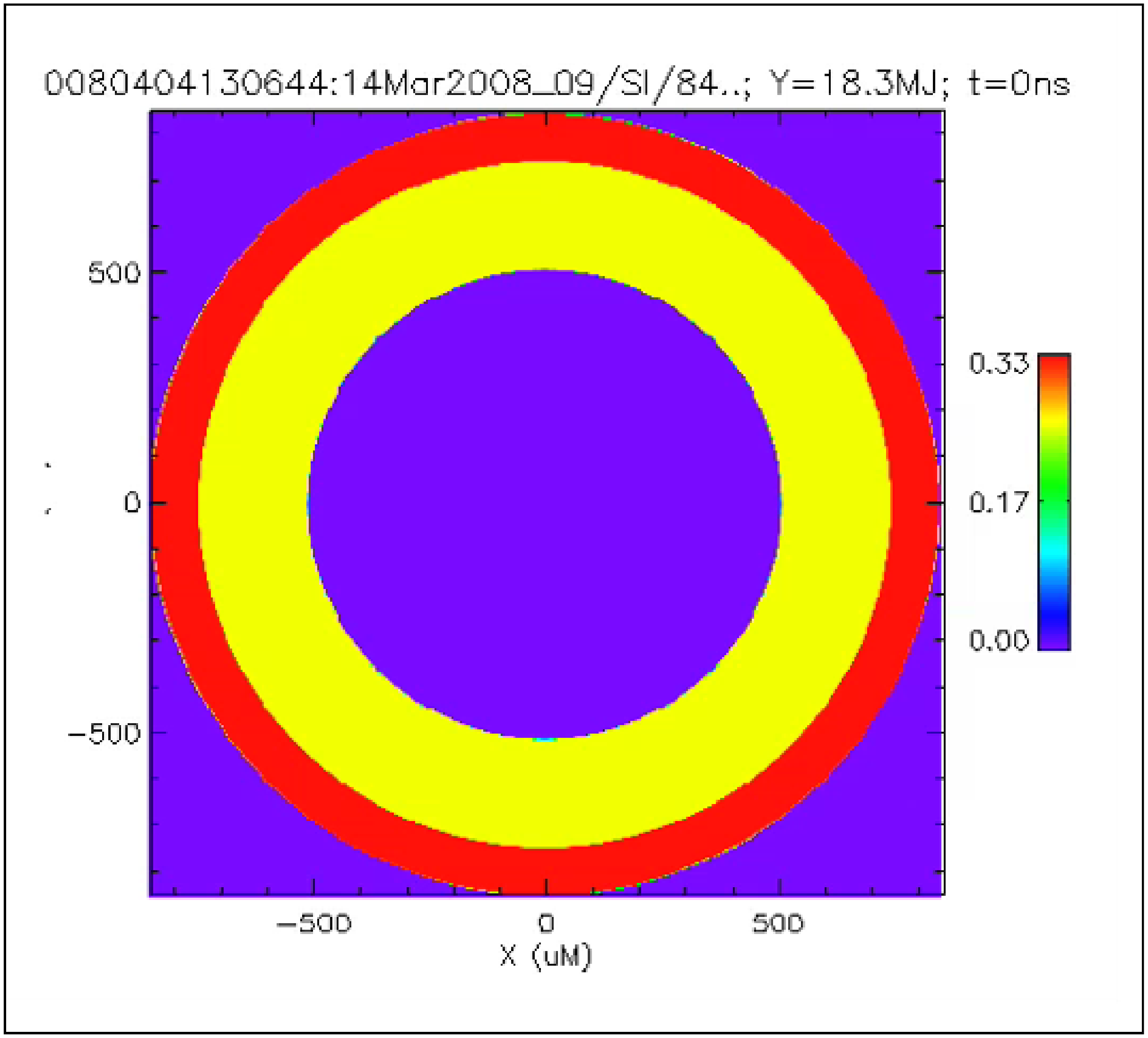
Low resolution simulations show that gain drops as surface perturbation increases

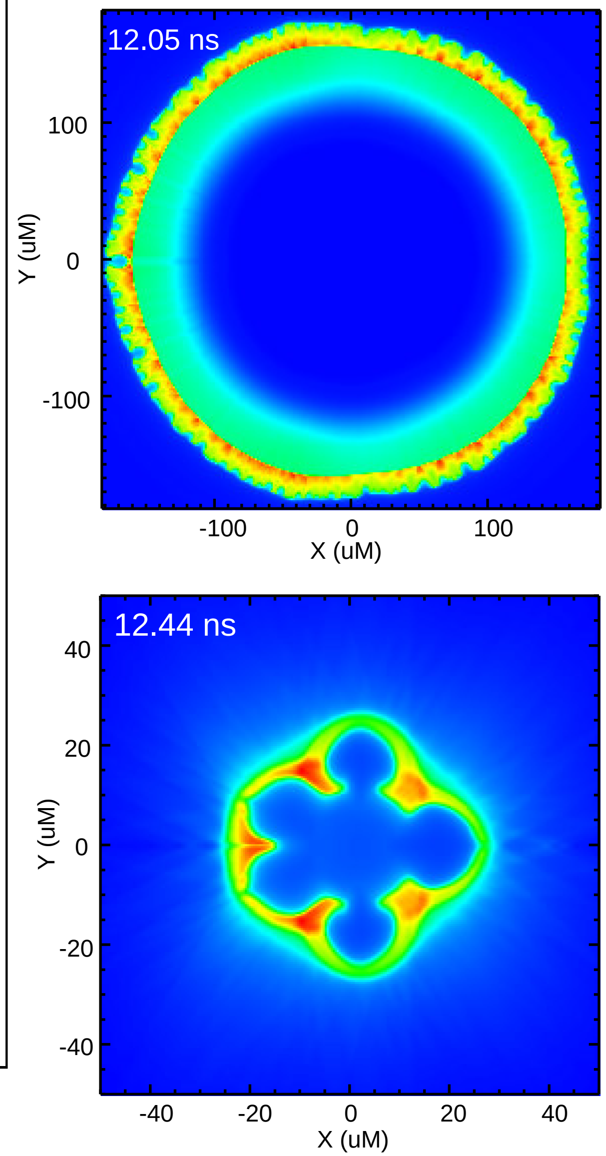
- The low-mode simulations (860 x 64 pts)
- Use a spike power that is ~2x minimum required (750TW)





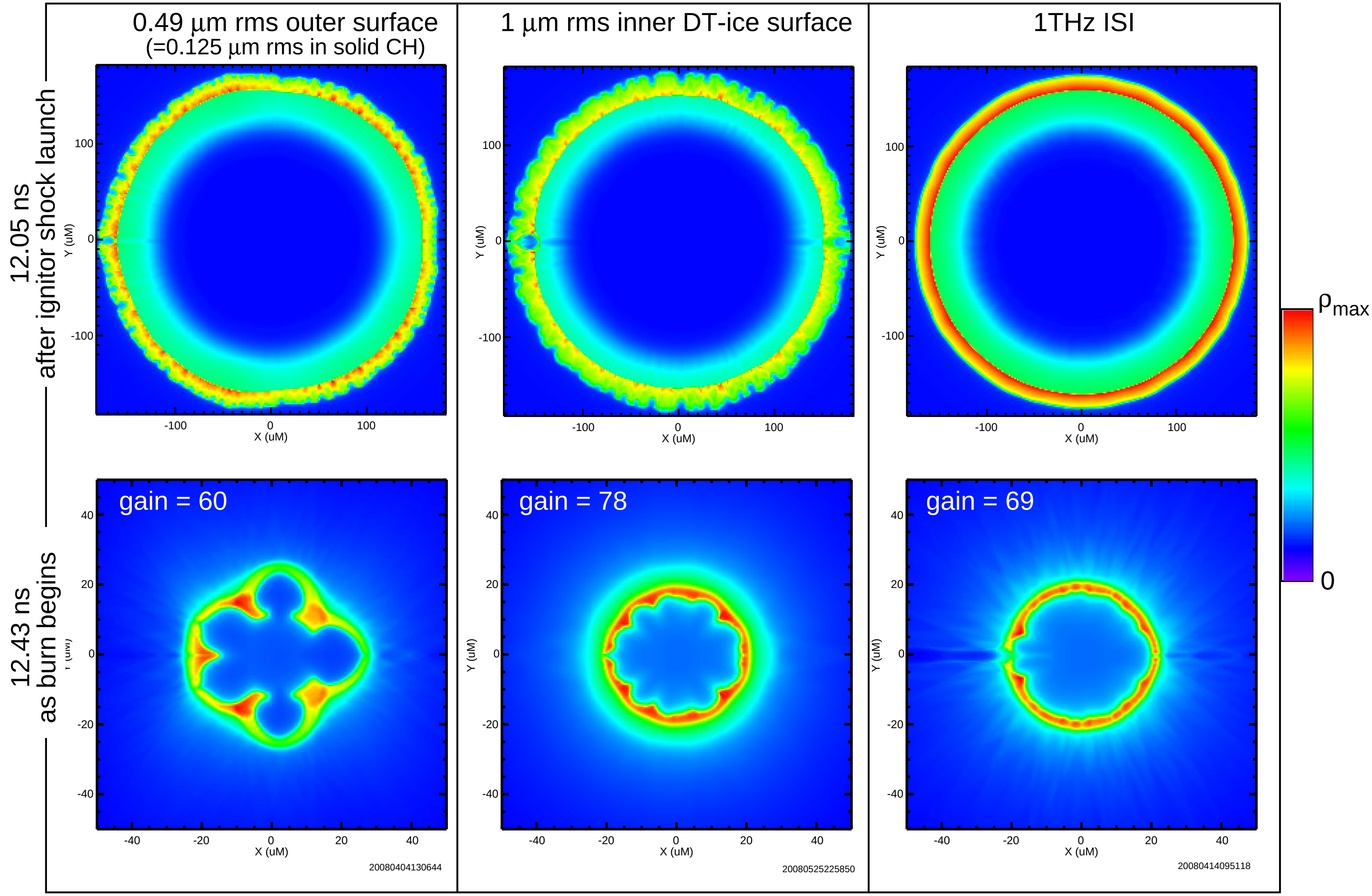
High-resolutions simulation shows pellet survives 1xNIF spec surface perturbation and produces gain ~60



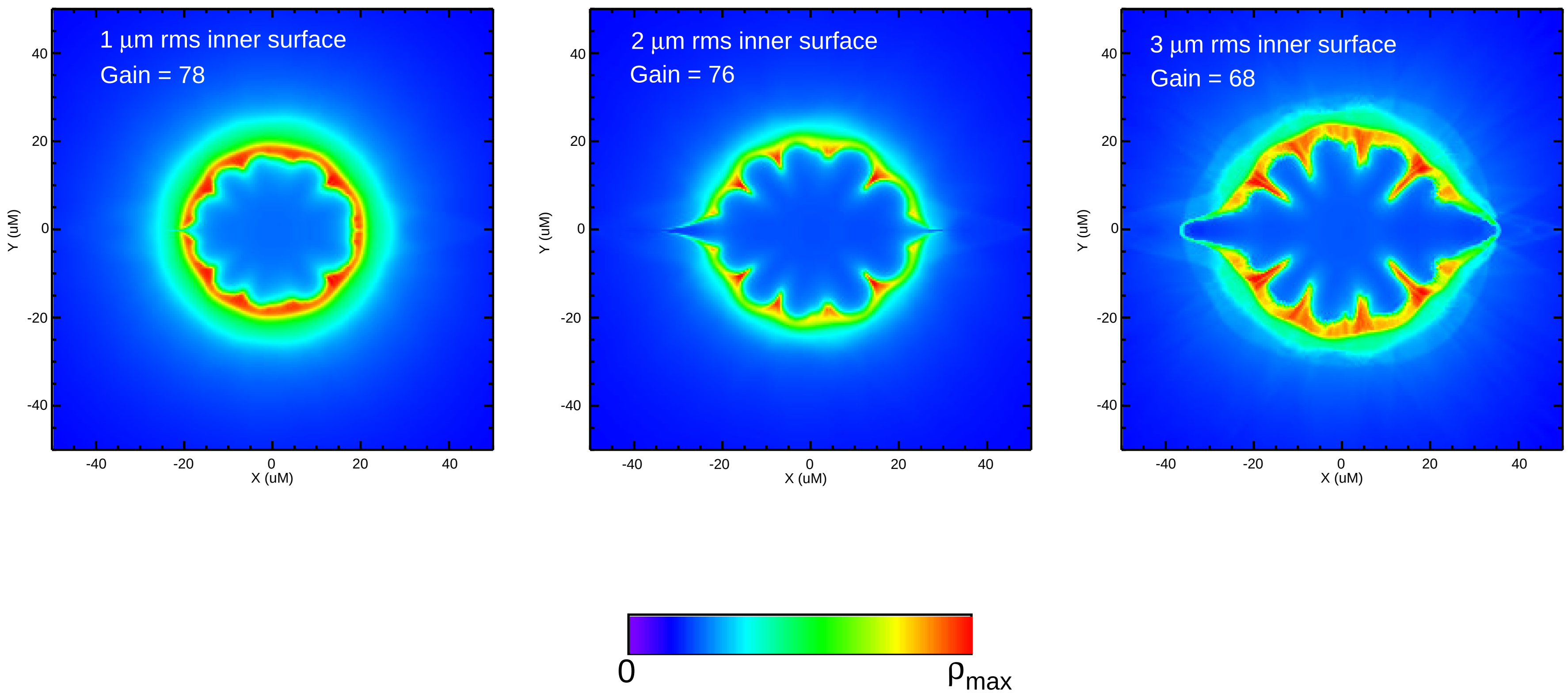


2D High-resolution simulation (ℓ=1-256)

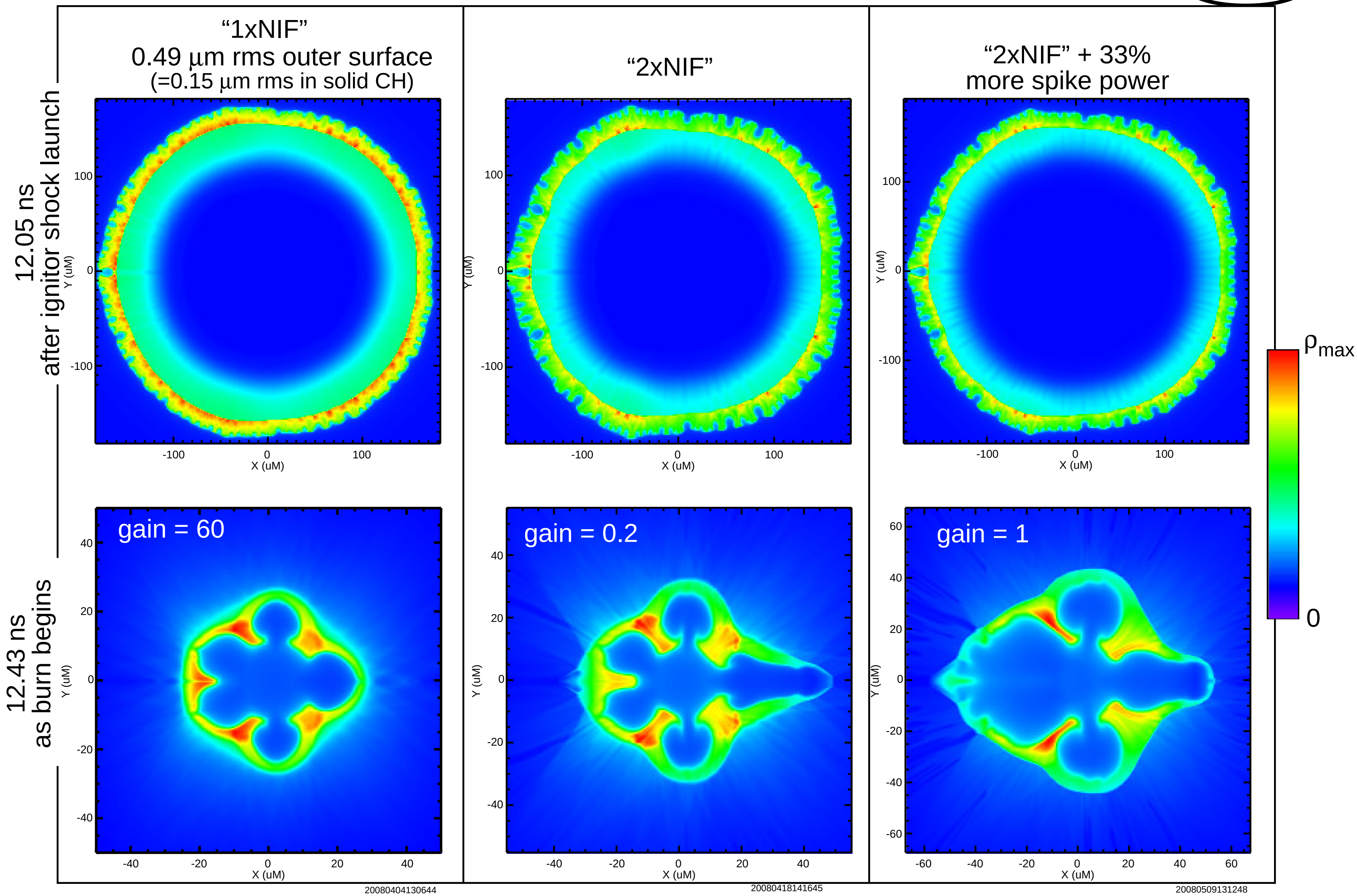
Three different sources have been simulated: outer and inner surface perturbations and laser imprint. Outer surface perturbations are dominant



Simulations show pellet survives typical 1-3 μm inner surface perturbations with near 1D yield



The target is sensitive to the outer surface perturbation amplitude



Current design constraints for shock ignition target

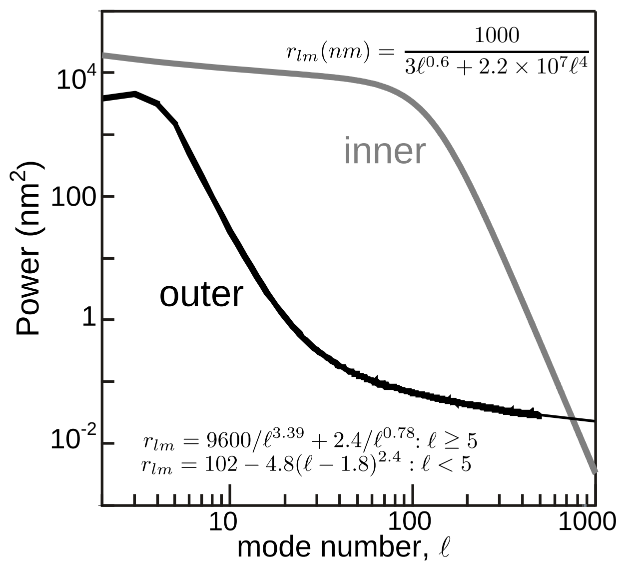
NRL

Outer surface finish: $\lesssim$ 0.125 μm rms in modes ℓ = 2-512

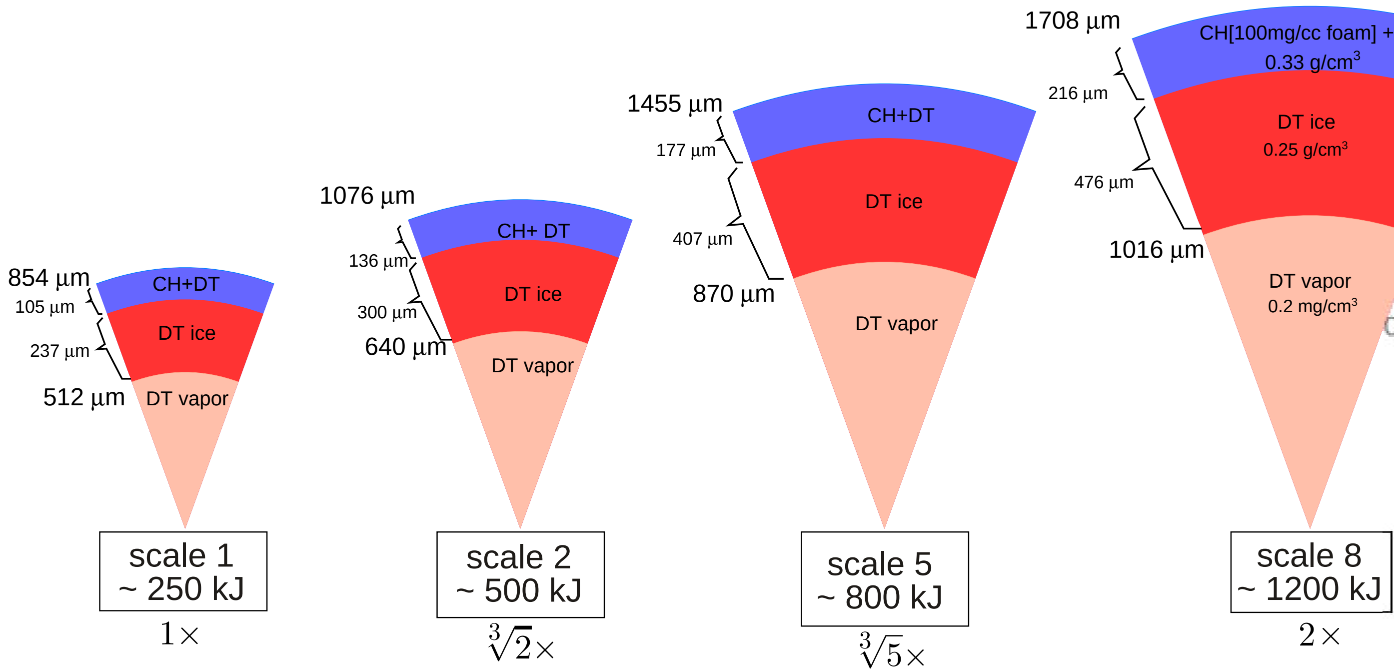
Inner surface finish: $\lesssim$ 4 μm rms in modes ℓ = 2-512

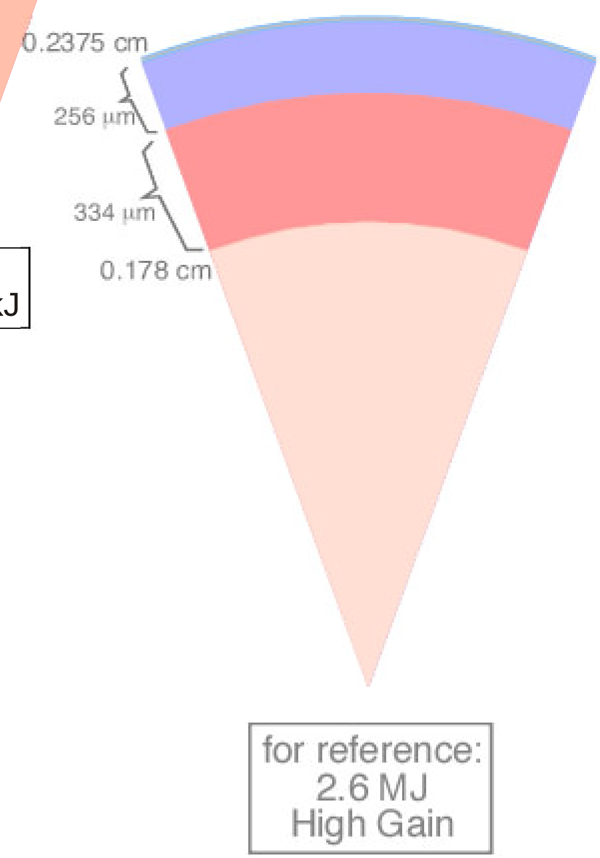
beam aiming: < 1% r_0 ??

power balance: ??



Shock ignition targets have been designed at 4 different energies



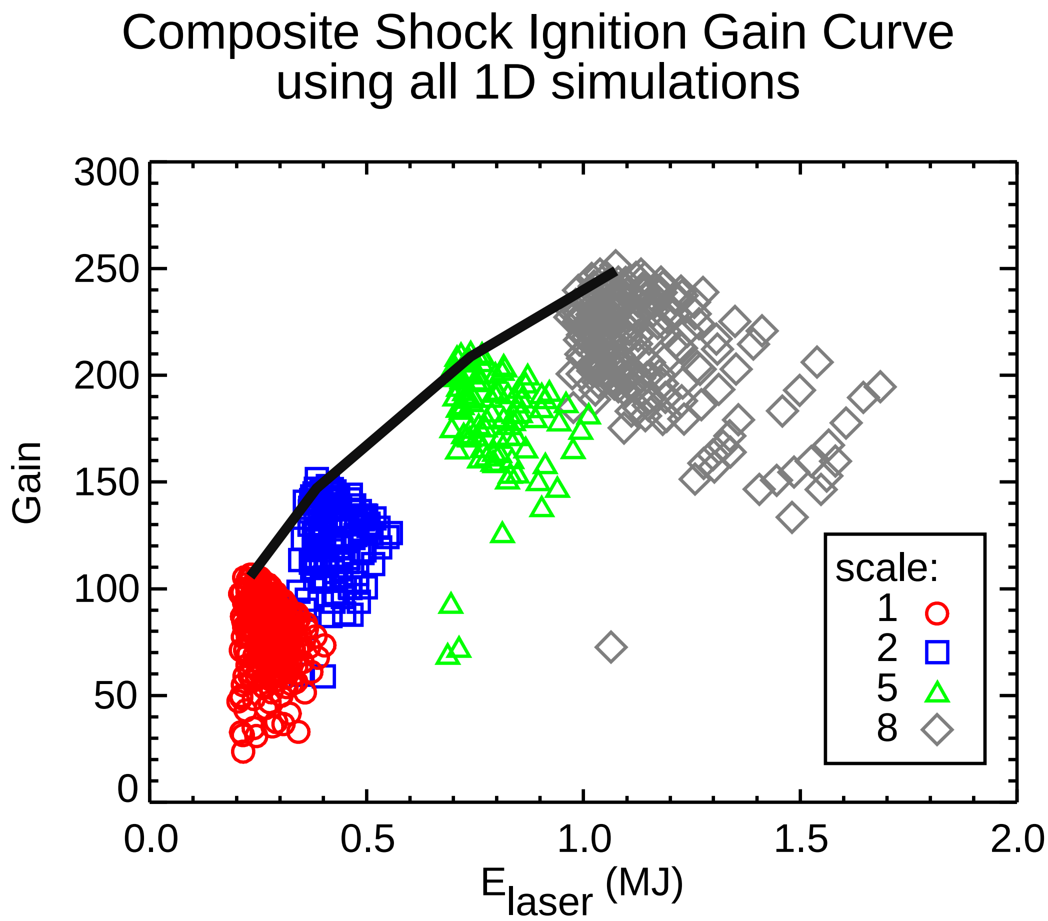


(to scale)

Shock ignition targets are thick (aspect ratio=2.5) and driven to low velocity (2.5×10^{7}cm/s) (w/o spike)

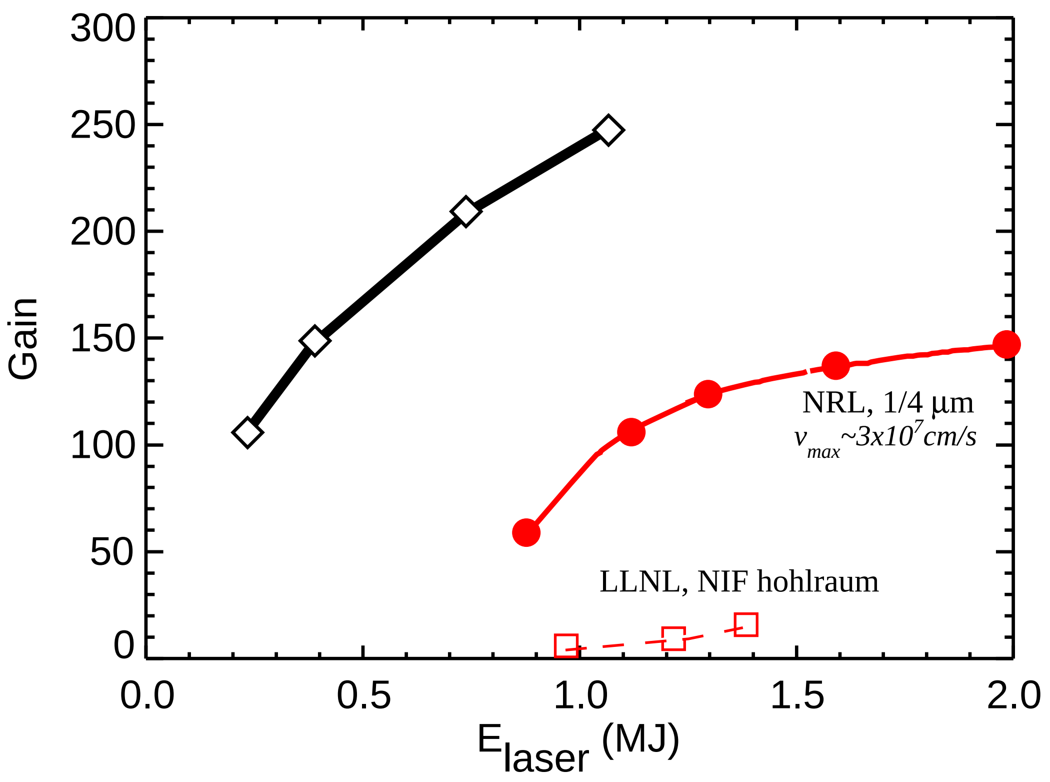
*R. Betti et al., Phys.Rev.Lett. **98**, 155001 (2007)*

Laser IFE gain curve
can be constructed by plotting runs at all scales



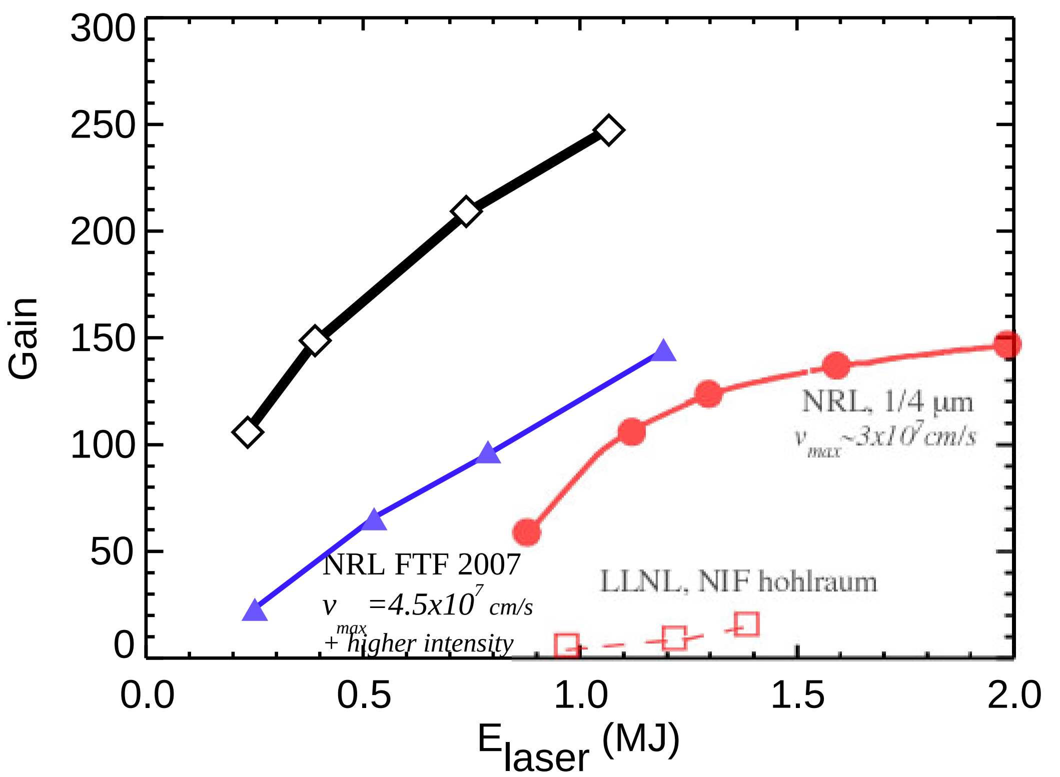
Laser IFE gain curve

comparison to previous conventional ignition designs



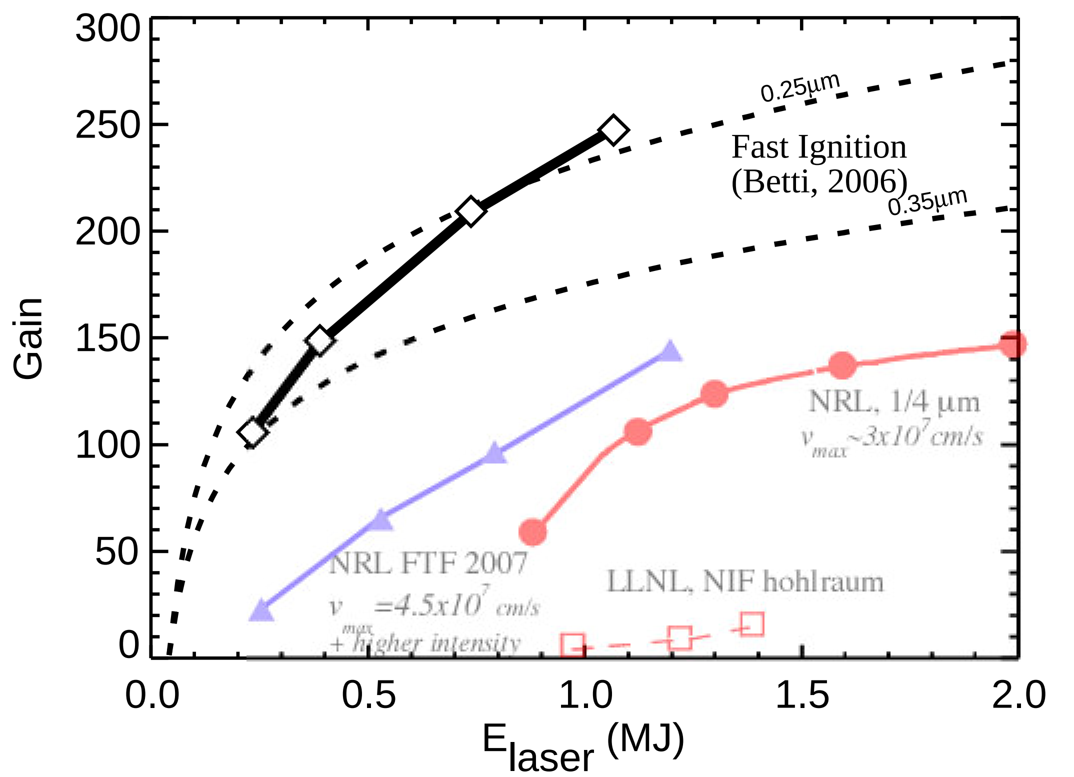
Bodner et al., IAEA Madrid meeting, June 2000.

Laser IFE gain curve
comparison to FTF sub-MJ designs



Bodner et al., IAEA Madrid meeting, June 2000.
*Colombant et al., Phys. Plasmas **14** 056317 (2007).*

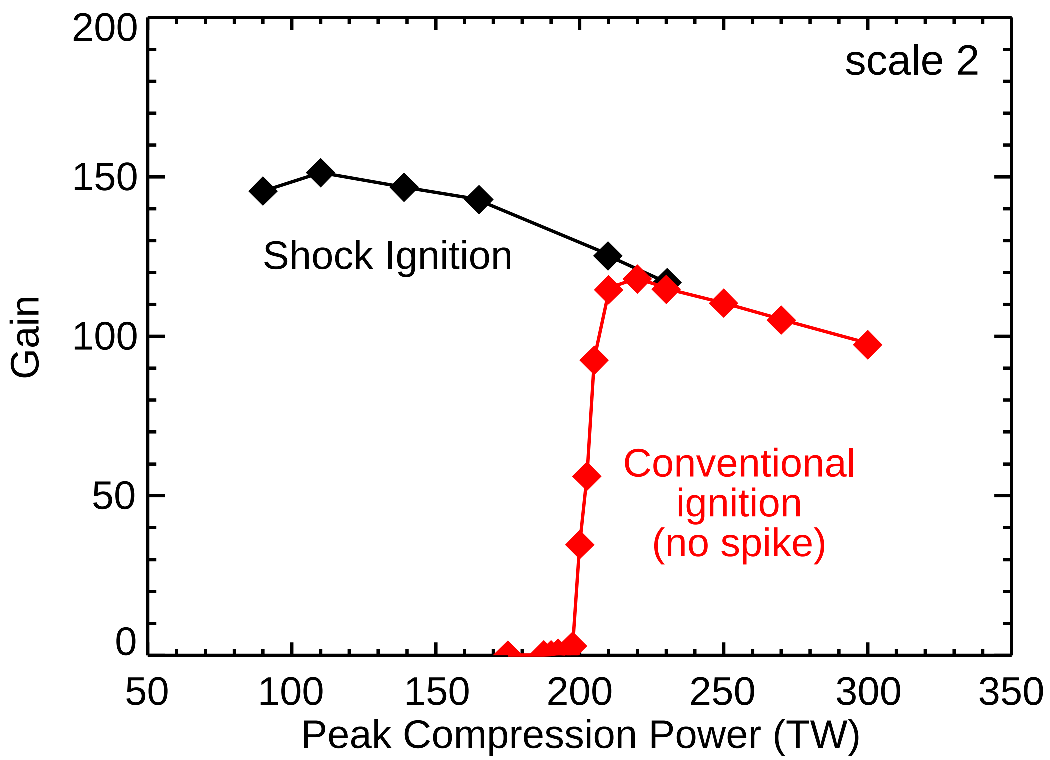
Laser IFE gain curve
comparison to Fast Ignition designs



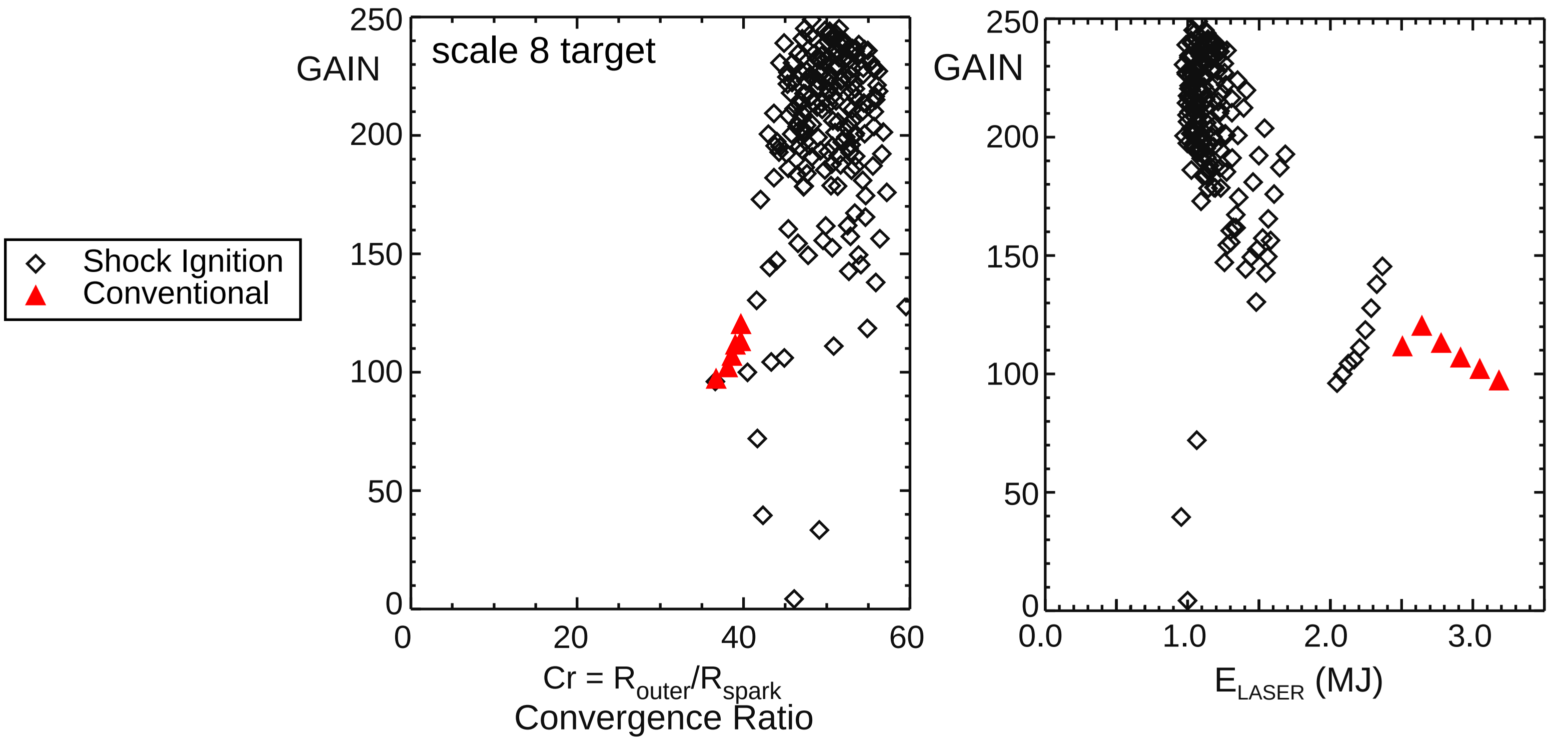
Bodner et al., IAEA Madrid meeting, June 2000.
Colombant et al., Phys. Plasmas ***14*** *056317 (2007).*
Betti et al., Phys. Plasmas ***13,*** *100703 (2006).*

1D simulations

Increasing the compression power, without adding an ignition spike, will eventually produce conventional central spark ignition



The biggest constraint for shock ignition may be the high convergence ratio



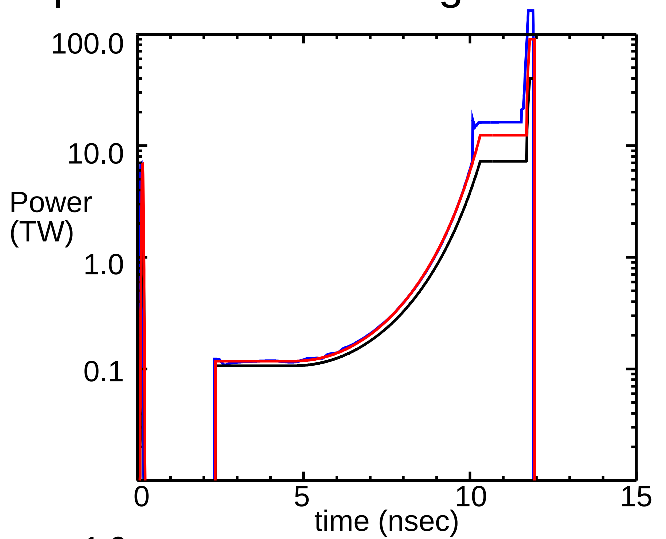
The convergence ratios are lower for conventional ignition, but are similar to marginal shock ignition cases (except they also use more laser energy)

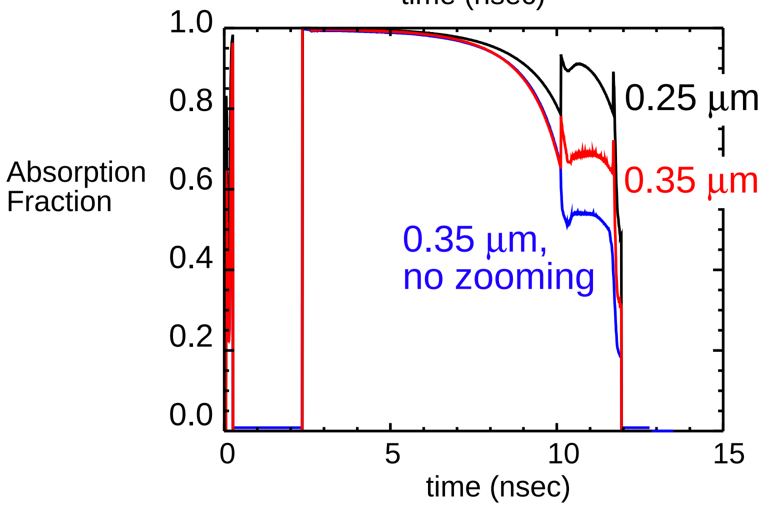
High convergence ratios imply more stringent requirements for laser beam alignment and power imbalances

How much more efficient is KrF light (0.25μm) than Nd:Glass light (0.35μm)?

The scale 1 target was simulated with frequency-tripled Nd:glass laser drive; the pulse shape was changed so the drive pressure was as close as possible to the original.

The importance of zooming was also tested by turning it off.





	KrF 0.25 μm zoom	glass 0.35 μm zoom	glass 0.35 μm no zoom
total energy	230 kJ	430 kJ	645 kJ
compression energy	160 kJ	280 kJ	360 kJ
gain	97	56	35
absorption	77%	56%	39%
compression absorpt.	87%	70%	55%
max. intensity (PW/cm^2)	16.3	28	21.8

Summary

- Shock ignition targets have been designed and investigated at ~ 250kJ, 500 kJ, 800kJ and 1.2 MJ laser energies

- The target at 250kJ has been analyzed extensively and found to be robust to:
  low-mode and broad-spectrum NIF-spec surface perturbations
  low-mode drive asymmetry
  broad-spectrum ISI and inner-ice perturbations
  however, all perturbation sources have not yet been simultaneously simulated.

- gains can be much higher than conventional spark-ignition direct-drive targets, and can be of order 100 particularly for KrF laser drive with zooming.

- The high convergence ratio (smaller hot-spot) of the shock ignition appears to make the shock ignition targets more sensitive to low-mode perturbations

- There is a significant advantage in using zooming and shorter wavelength laser light