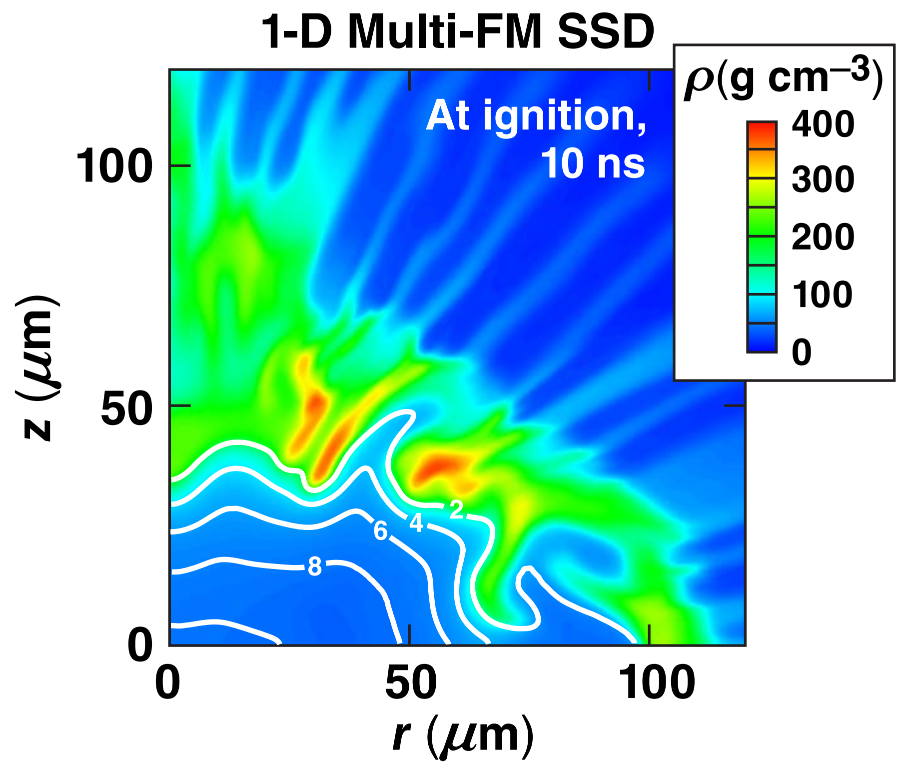
Polar-Drive Ignition Designs for the National Ignition Facility



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52nd Annual Meeting of the
American Physical Society
Division of Plasma Physics
Chicago, IL
8–12 November 2010

Summary

Simulations indicate that polar drive (PD) is a promising ignition alternative for the NIF

- A continuous-pulse design obtains a gain of 16 with 1-D Multi-FM beam smoothing
- Multiple-picket pulses are used to facilitate experimental shock timing
- A 2-D simulation of a triple-picket polar-drive ignition design shows a gain of 19 with target and laser nonuniformities

TC9005

Contributors

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In polar drive, the NIF x-ray-drive beams are pointed to three latitude rings in each hemisphere on the target

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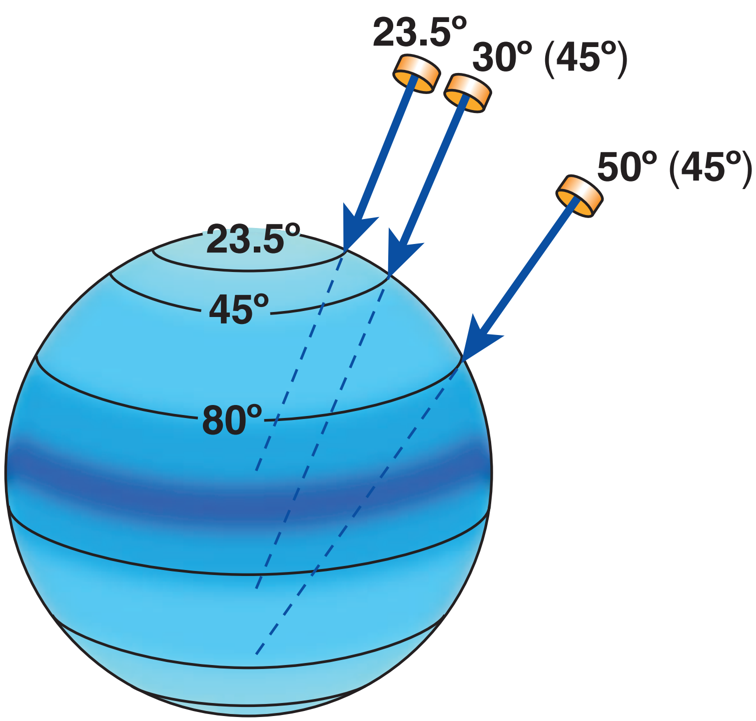
Repointing for PD*

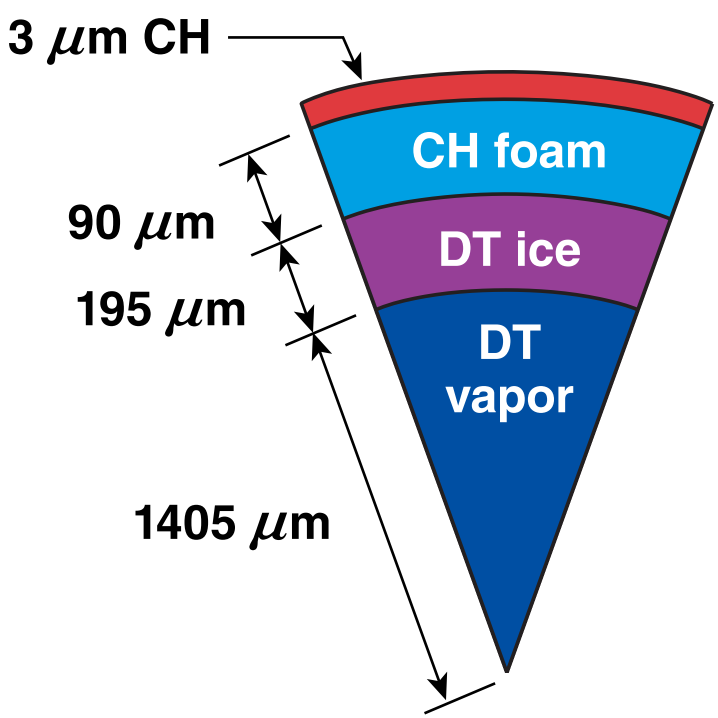


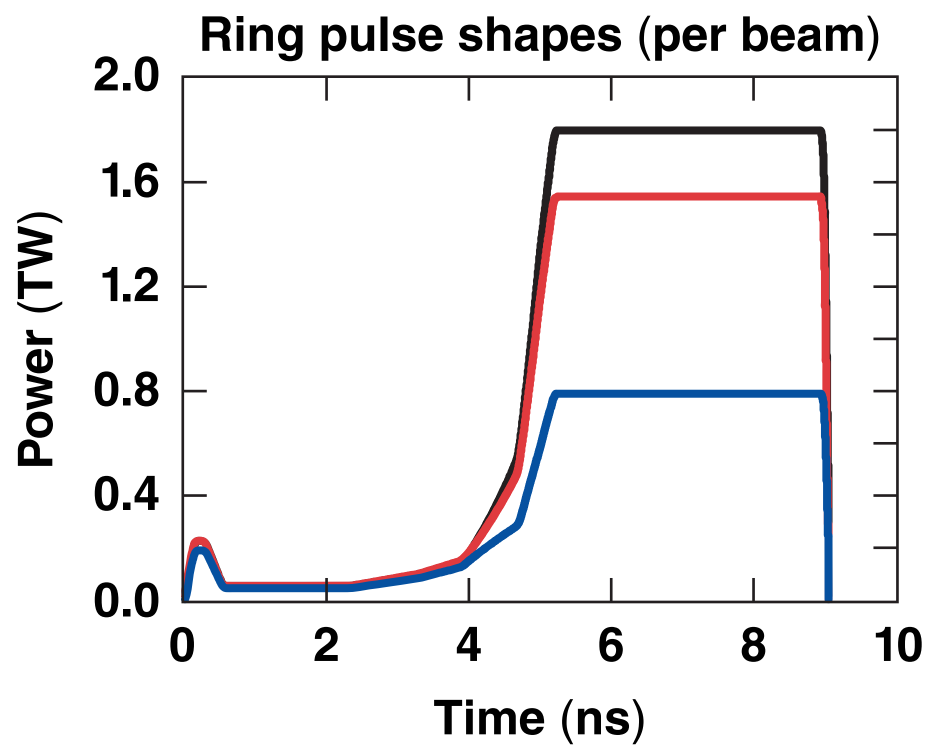
- Oblique irradiation near the equator is at lower densities, causing
  - reduced absorption
  - reduced hydro-effciency
  - lateral heat flow
- Uniform target drive requires increased power for equatorial beams

TC6300r

*S. Skupsky *et al*., Phys. Plasmas 11, 2763 (2004).

The continuous-pulse PD design uses a wetted-foam ablator*





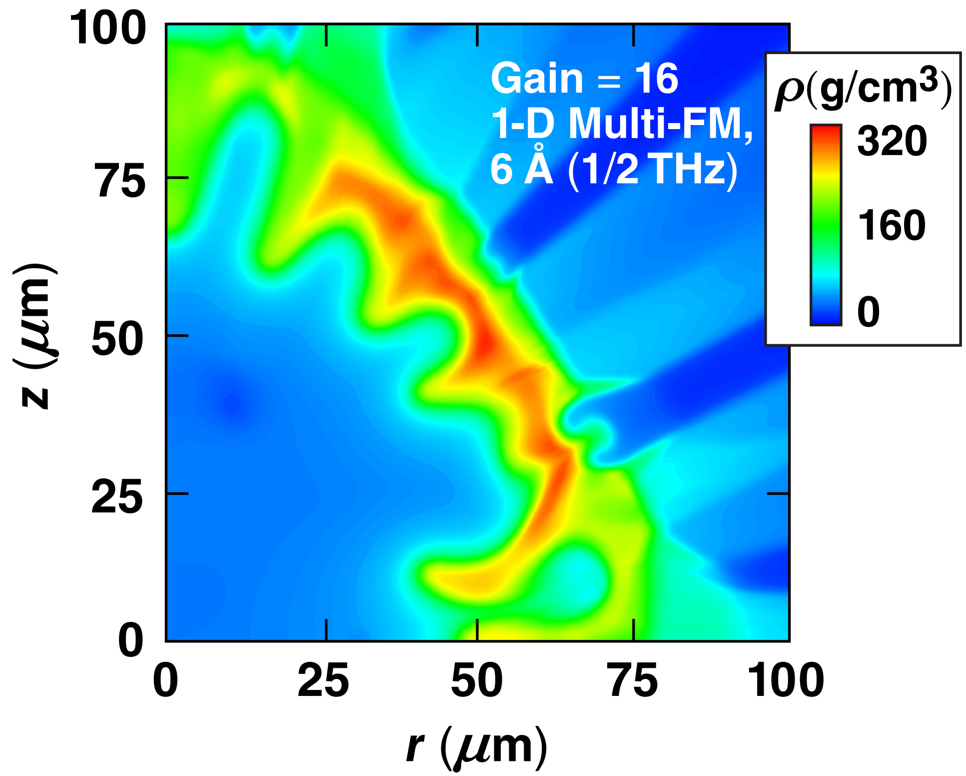
- The wetted-foam layer provides higher absorption than DT
- The fuel adiabat is $\alpha \sim 2$
- The laser energy is 1.2 MJ
- All designs shown here use a flux limiter of 6% for thermal transport

TC8623i

*J. A. Marozas, J. D. Zuegel, and T. J. B. Collins, Bull. Am. Phys. Soc. 54, 306 (2009).

The wetted-foam PD design achieves a 2-D gain of 16 with expected levels of NIF nonuniformities

At peak compression, 9.8 ns

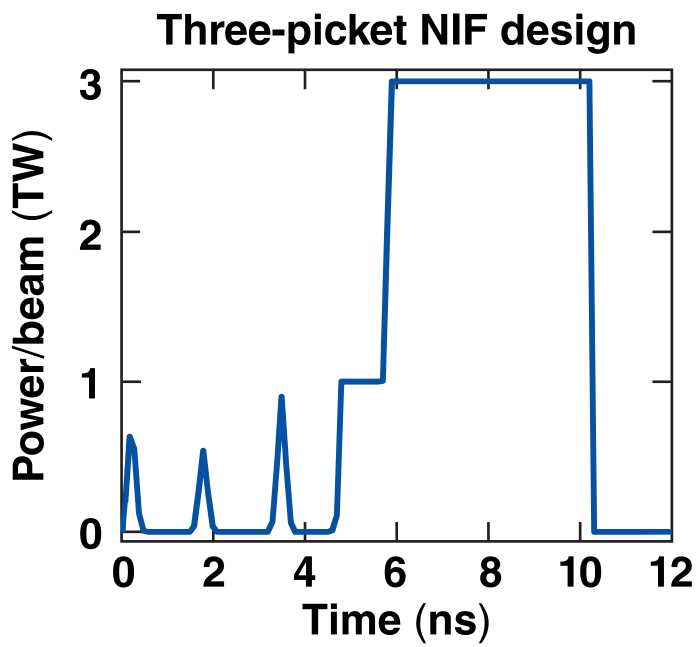


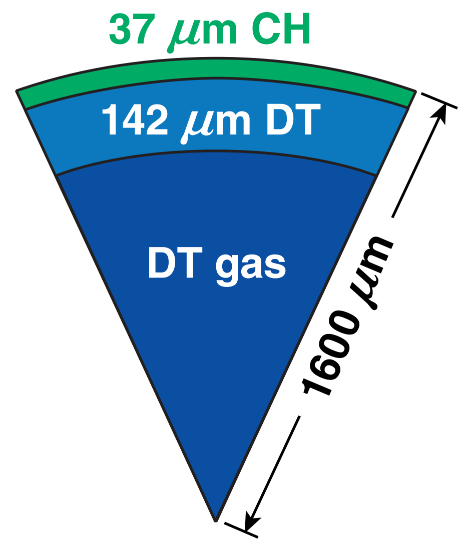
- Nonuniformities modeled included single-beam imprint with power imbalance, 1-μm ice roughness, 30-ps rms mistiming, and surface roughness
- Multiple-FM, 1-D SSD beam smoothing was used

TC9039

A second ignition design uses a multi-picket, multi-shock drive instead of the continuous low-intensity foot*

Gain$_{1\text{-}D}$ = 49, symmetric-drive energy = 1.6 MJ





- A thick CH ablator is used to minimize the risk of hot-electron preheat
- OMEGA experiments have demonstrated that picket pulses are better suited to experimental shock tuning because of greater pulse reproducibility**
- The laser pulse is based on the triple-picket pulse used on OMEGA to achieve an areal density of nearly 300 mg/cm^2***

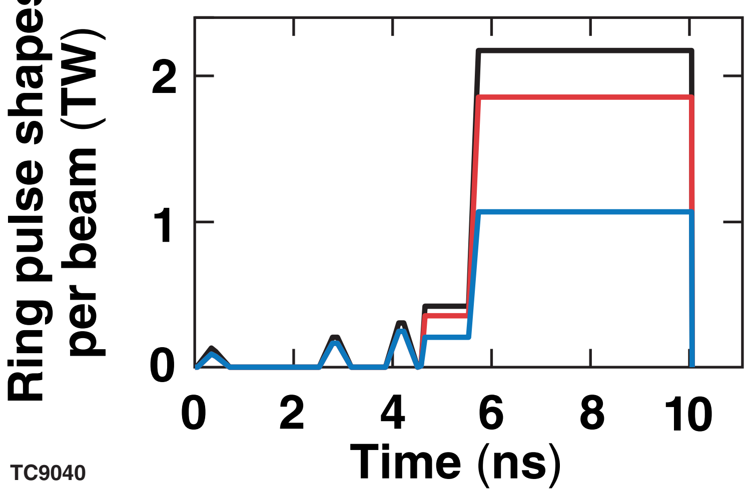
* V. N. Goncharov *et al.*, Phys. Rev. Lett. 104, 165001 (2010).
** T. R. Boehly *et al.*, Phys. Plasmas 16, 056302 (2009).
*** T. C. Sangster *et al.*, Phys. Plasmas 17, 056312 (2010).

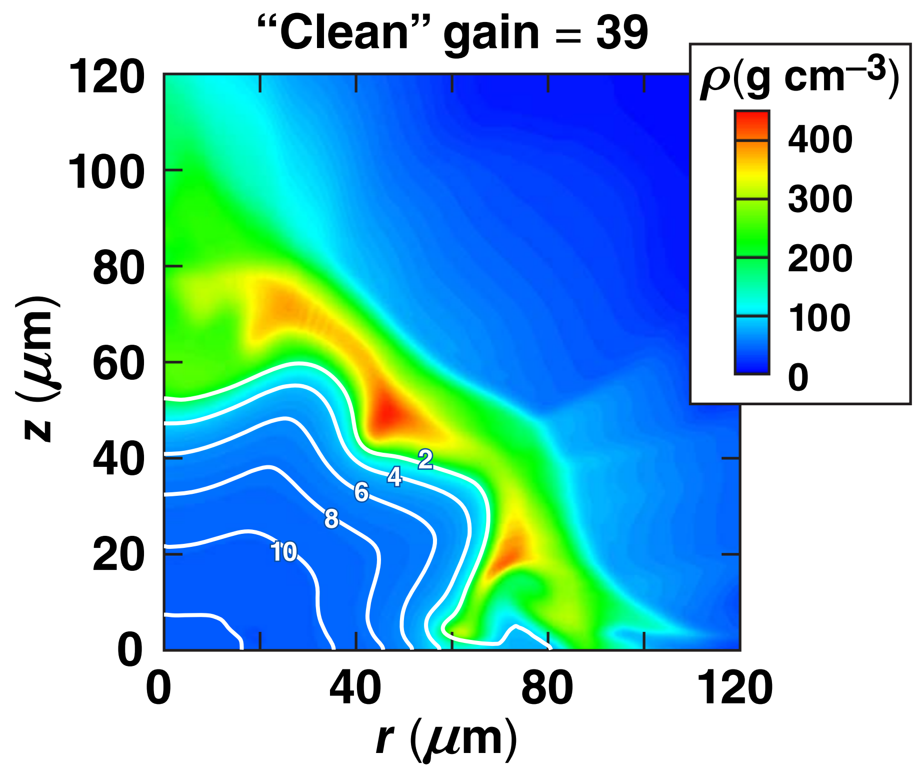
E18400g

A triple-picket PD ignition design has been developed based on this 1-D design

- A 9-μm, $\ell = 2$ ice-layer shim reduces mass at the equator and increases shell uniformity

Gain	39
IFAR = $(R/\Delta R)_t$	43
Peak ρR	1.2 g/cm^2
V_{imp}	423 μm/ns
Adiabat	1.4
E_{inc} (MJ)	1.6



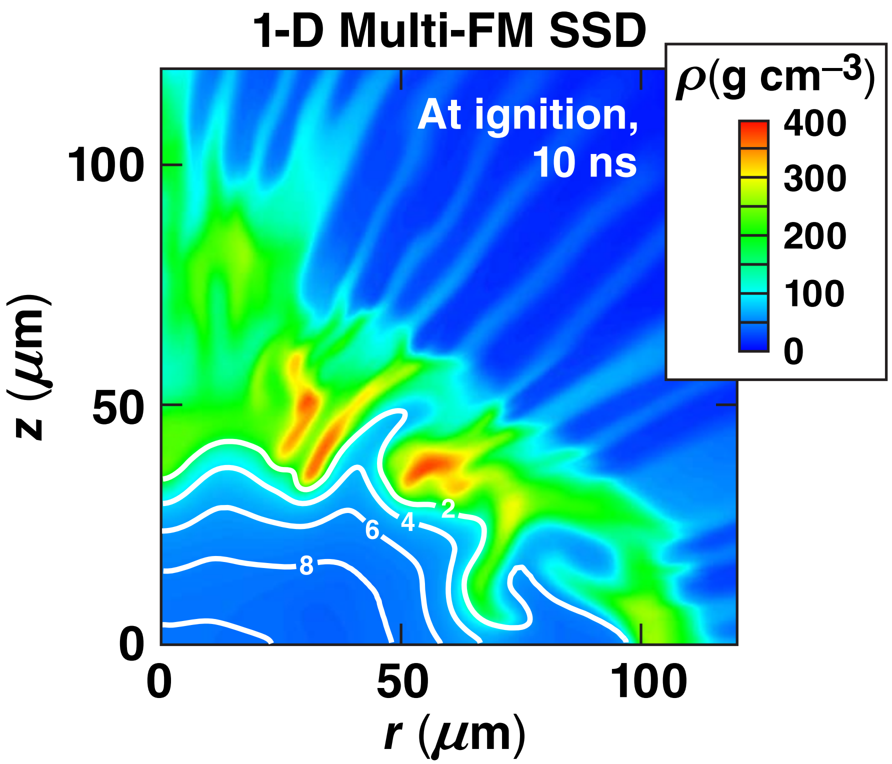


Target and hot spot shown at the time of ignition, 10.13 ns

TC9040

The triple-picket PD design with target and beam nonuniformities and Multi-FM beam smoothing achieves a 2-D gain of 19

- A 1-μm ice roughness is included in these calculations, as well as single-beam imprint, 8% rms power imbalance, 30-ps rms beam mistiming, and surface roughness



- This design will also be scaled to lower energies
- For more information on the Multi-FM configuration see J. A. Marozas (TO5:0008)

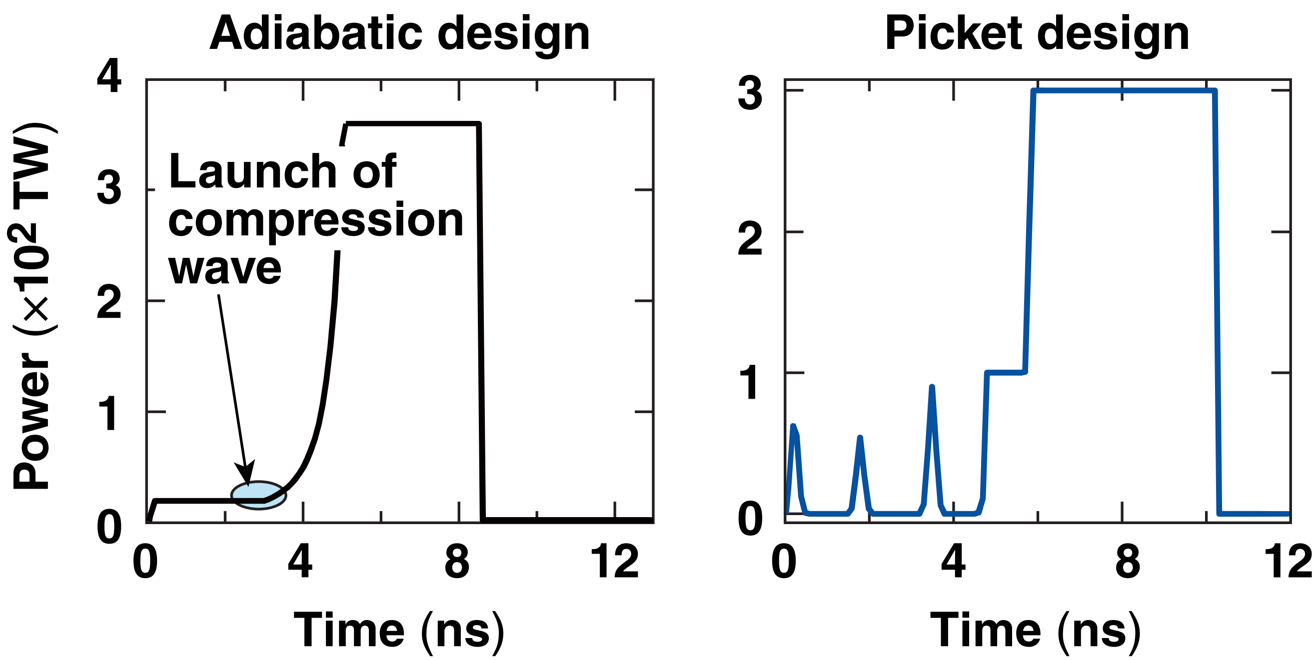
TC9006

Summary/Conclusions

Simulations indicate that polar drive (PD) is a promising ignition alternative for the NIF

- A continuous-pulse design obtains a gain of 16 with 1-D Multi-FM beam smoothing
- Multiple-picket pulses are used to facilitate experimental shock timing
- A 2-D simulation of a triple-picket polar-drive ignition design shows a gain of 19 with target and laser nonuniformities

Low-adiabat fuel compression can be achieved using a variety of target designs

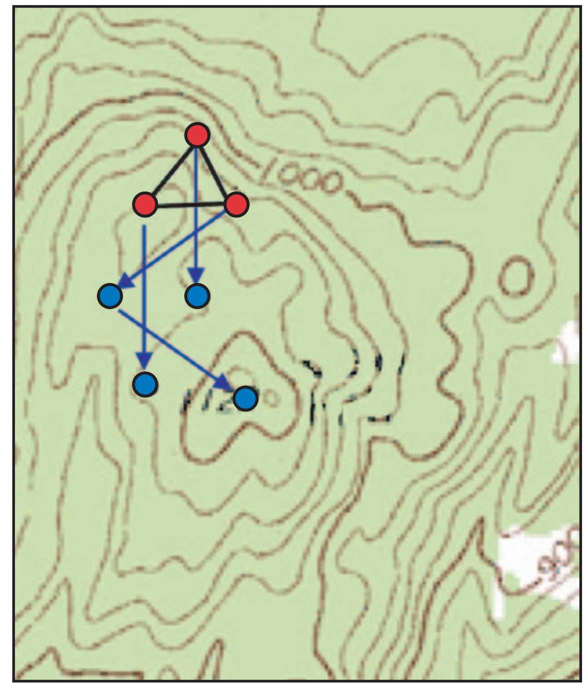


- Target-design selection is based on the accuracy of shock tuning and target stability
- OMEGA experiments have demonstrated that picket pulses are better suited to experimental shock tuning because of their greater pulse reproducibility*

*T. R. Boehly *et al*., Phys. Plasmas 16, 056302 (2009).

The triple-picket PD ignition design has been optimized in 1-D with a simplex method

- A *simplex* is a polyhedron in *n* dimensions with *n* + 1 vertices
- The lowest point is reflected across the plane connecting the others
- The points in the pulse shape (power, time) and target dimensions may be optimized
- This design was optimized to maximize gain, requiring peak power to stay below optics damage threshold limits; this, in turn, fixes the implosion velocity



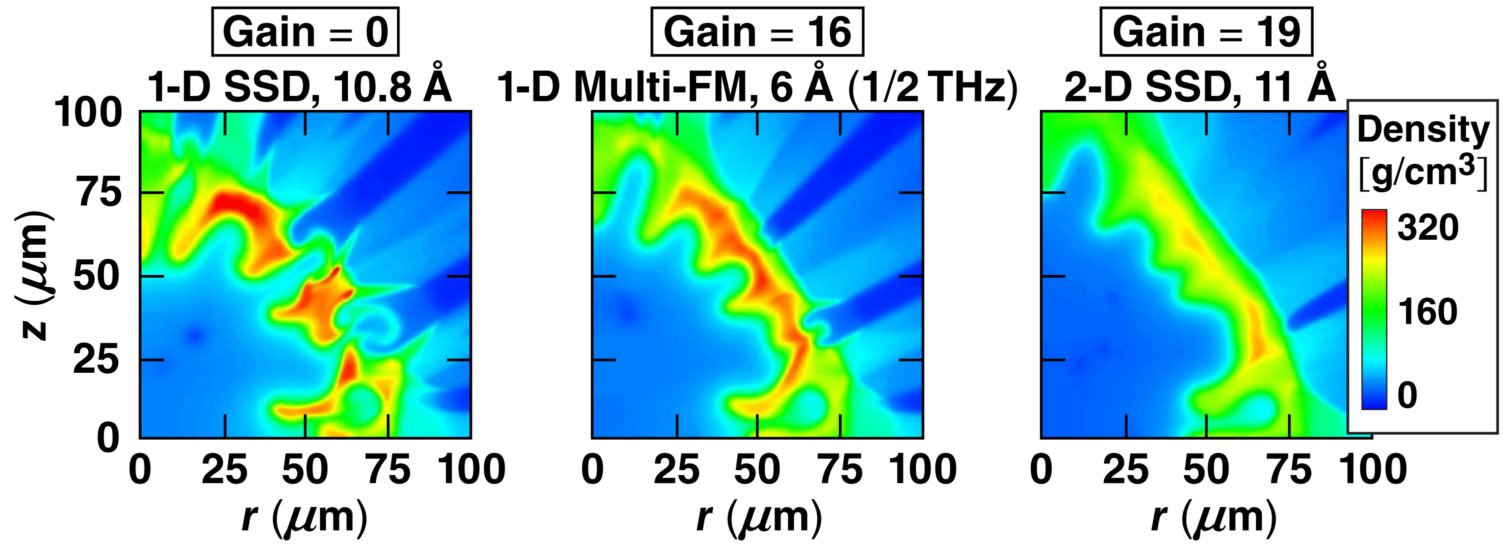
A simplex on a topographical map optimizing for maximum height

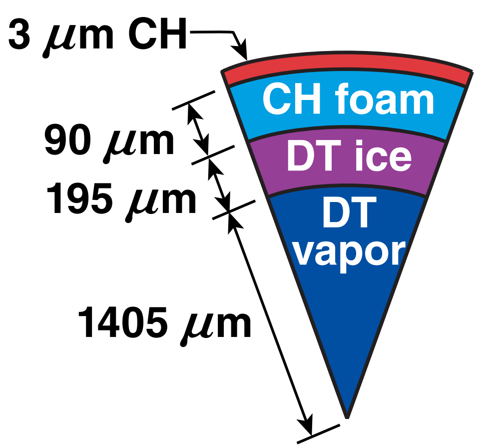
This method allows for tuning of more variables than would be feasible by hand (in this case, 12).

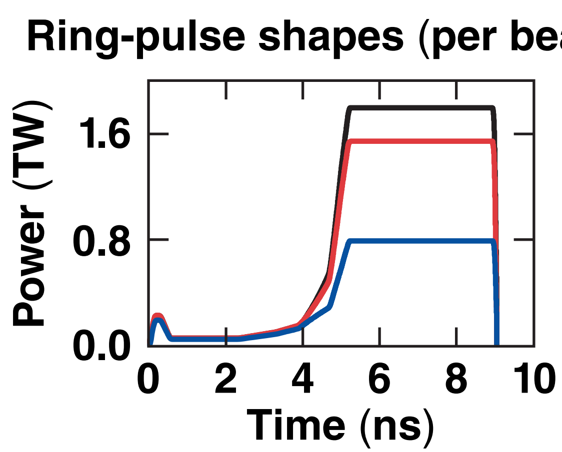
TC7716a

One-dimensional Multi-FM beam smoothing has been developed to relax the need for 2-D SSD on the NIF

Polar-drive simulations of 1.2-MJ CH-foam ignition target







- At peak compression, t = 9.8 ns

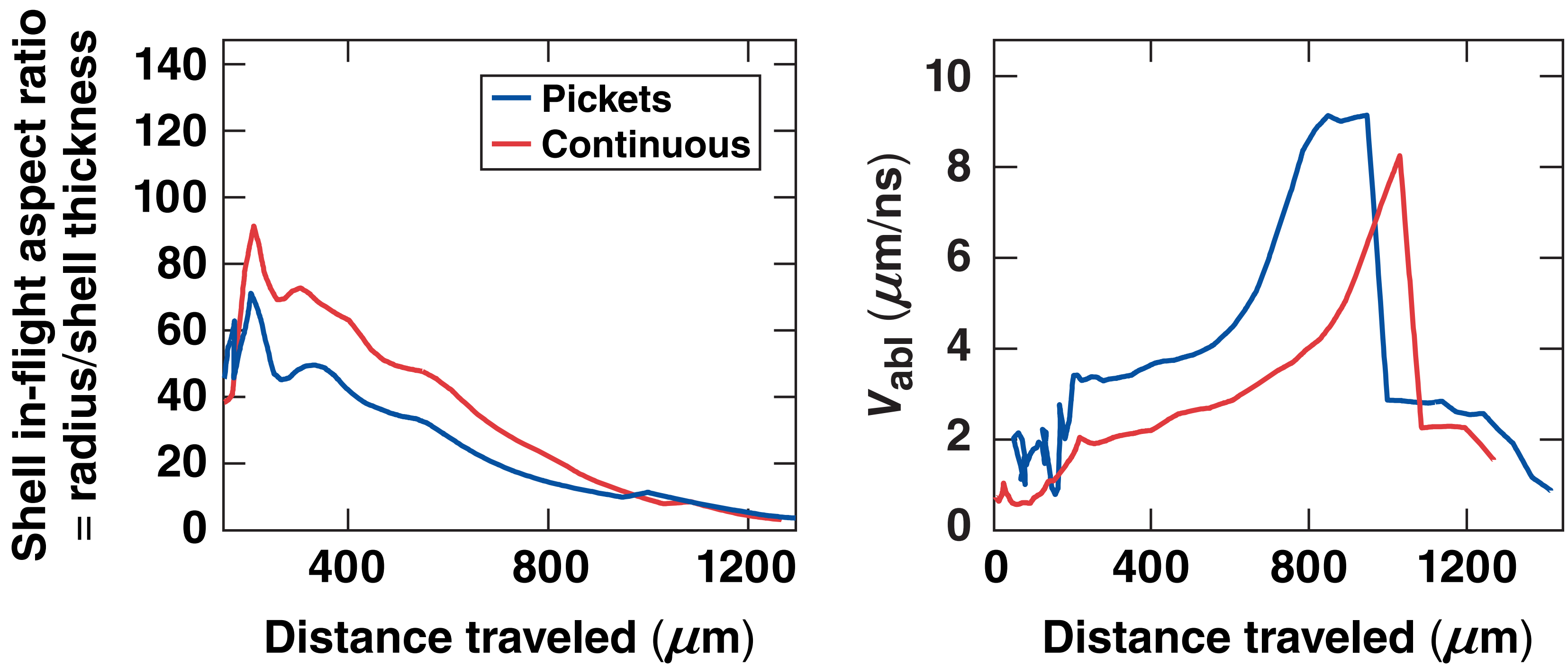
- Multi-FM beam smoothing will be tested on OMEGA EP

TC8623f

J. A. Marozas, J. D. Zuegel, and T. J. B. Collins, Bull. Am. Phys. Soc. 54, 306 (2009).

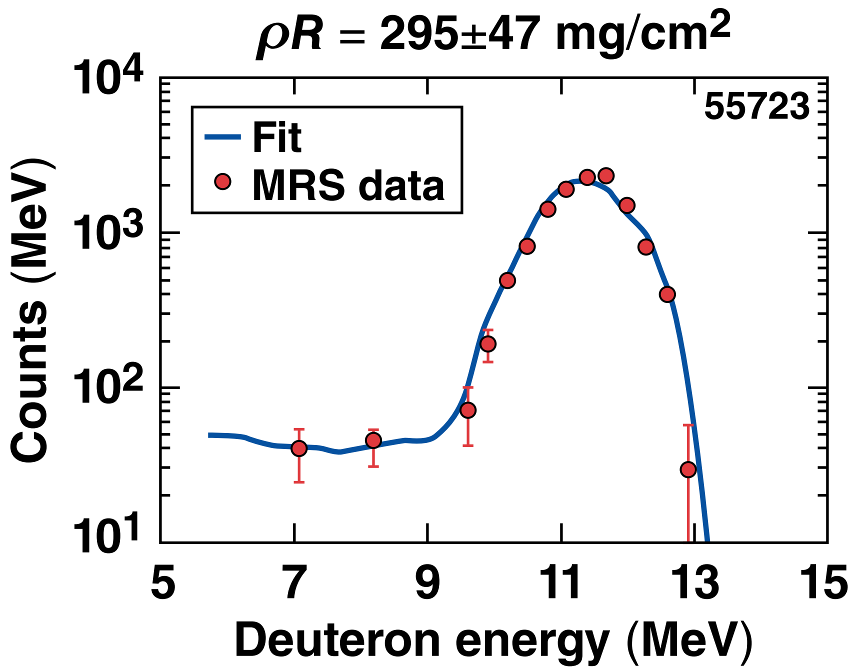
Shell stability improves with multiple-picket designs

$$\gamma_{RT} = \alpha\sqrt{kg} - \beta k V_{abl}$$



TC8288b

Recent symmetric-drive, multiple-picket, cryogenic-DT implosions have produced an areal density of nearly 300 mg/cm^2



The error bar is dominated by the hit statistics.

This is, by far, the highest areal density achieved in a cryogenic target implosion.

Two-body T-T neutron peak removed in the modeling.
T. C. Sangster *et al*., Phys. Plasmas 17, 056312 (2010).
V. N. Goncharov *et al*., Phys. Rev. Lett. 104, 165001 (2010).

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