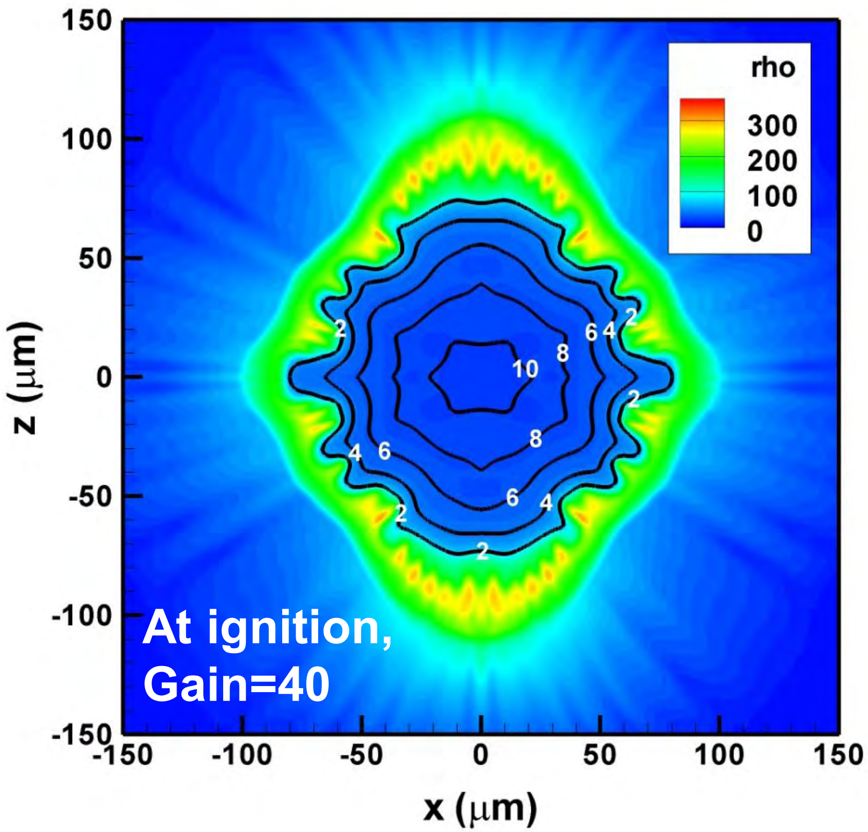
Polar-Drive Hot-Spot Ignition Design for the National Ignition Facility



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

- **A 2-D simulation of the polar-drive hot-spot point ignition design shows a gain of 40 with target and laser nonuniformities**
- **This design employs three relaxation pickets for adiabat shaping and to facilitate experimental shock timing**
- **This design employs a thick plastic ablator to mitigate the effects of hot-electron preheat**

Contributors

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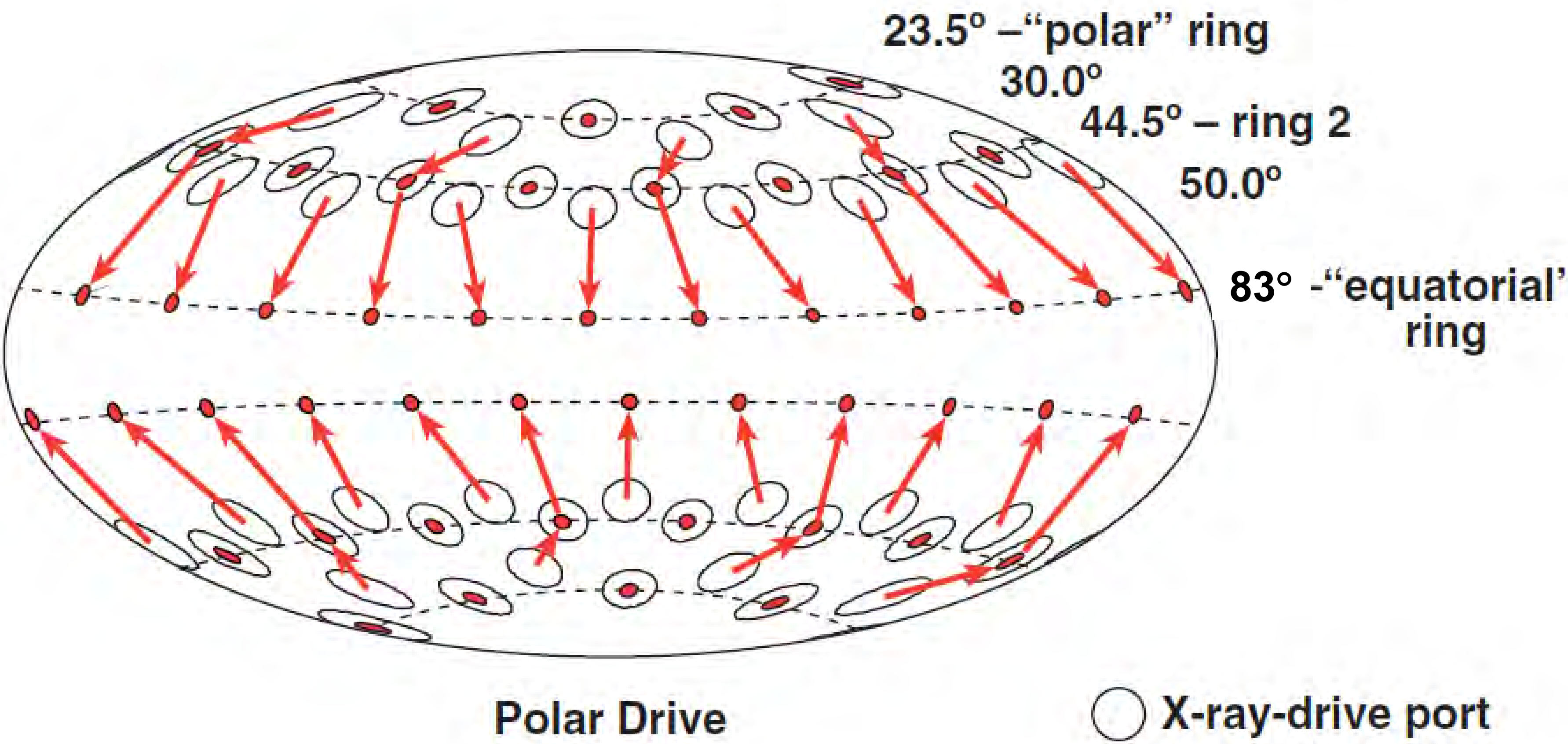
Outline

- **Polar Drive: Background and Lessons Learned**
- **The elements of the new Hot Spot, Triple-Picket Polar-Drive point design**

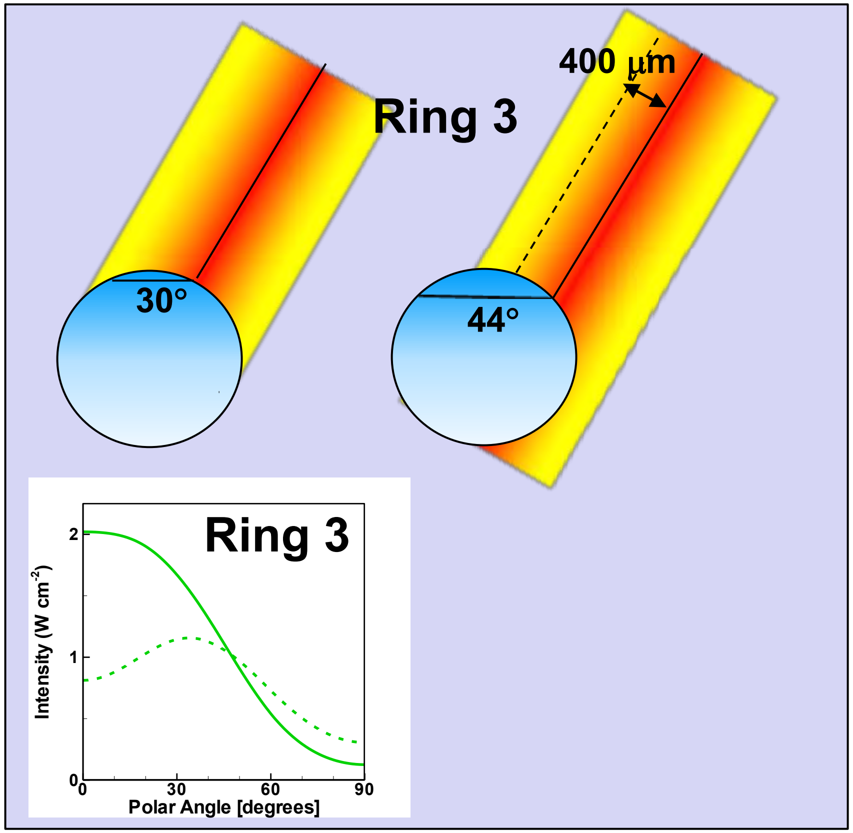
In polar drive, the NIF x-ray-drive beams are pointed to three latitude rings in each hemisphere on the target

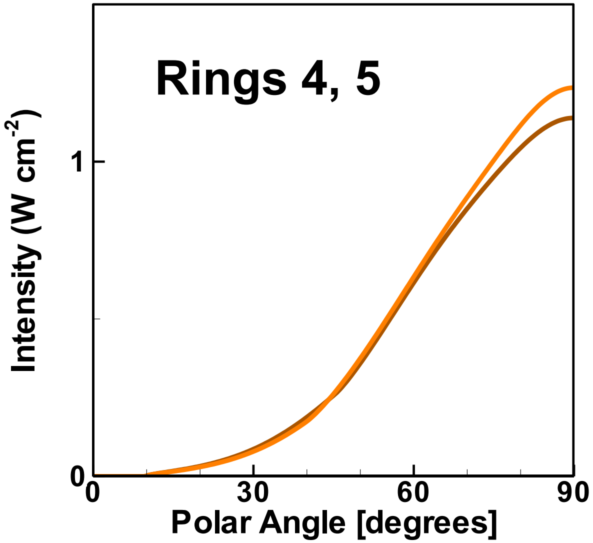


- **This is also relevant to IFE, insofar as polar port geometry is desired**

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

Repointing corresponds to a lateral translation of the beam in the target plane



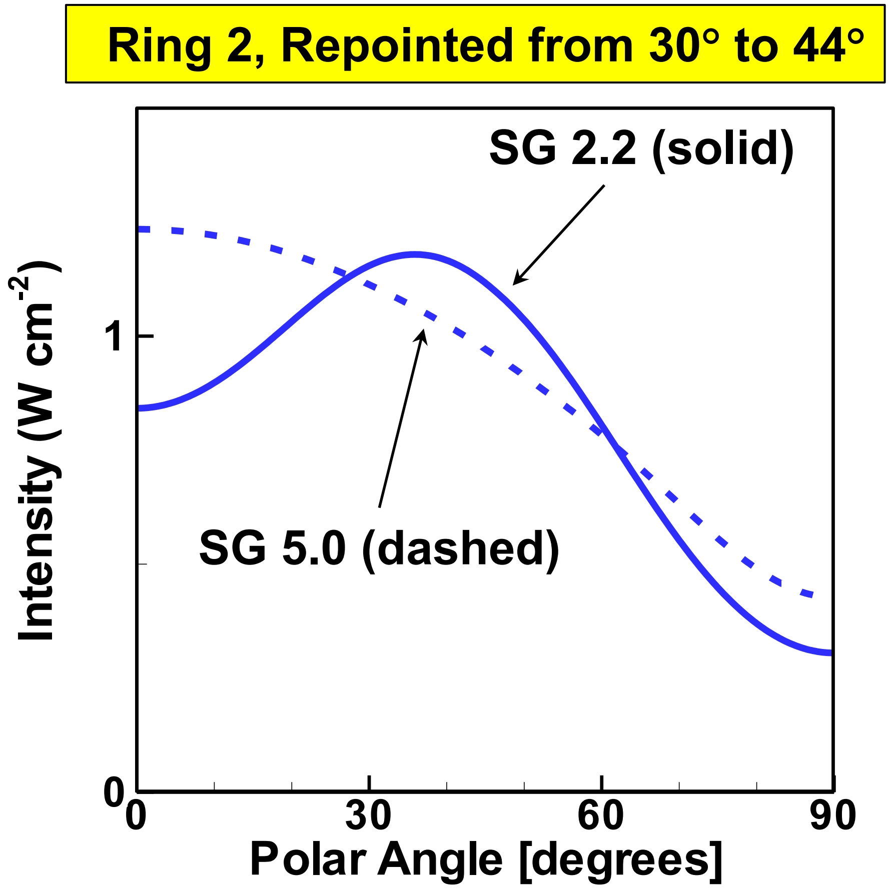


Repointing rings 4,5 moves energy to the equator

Oblique irradiation near the equator is at lower densities, causing

- **reduced absorption**
- **reduced hydrodynamic efficiency and**
- **lateral heat flow**

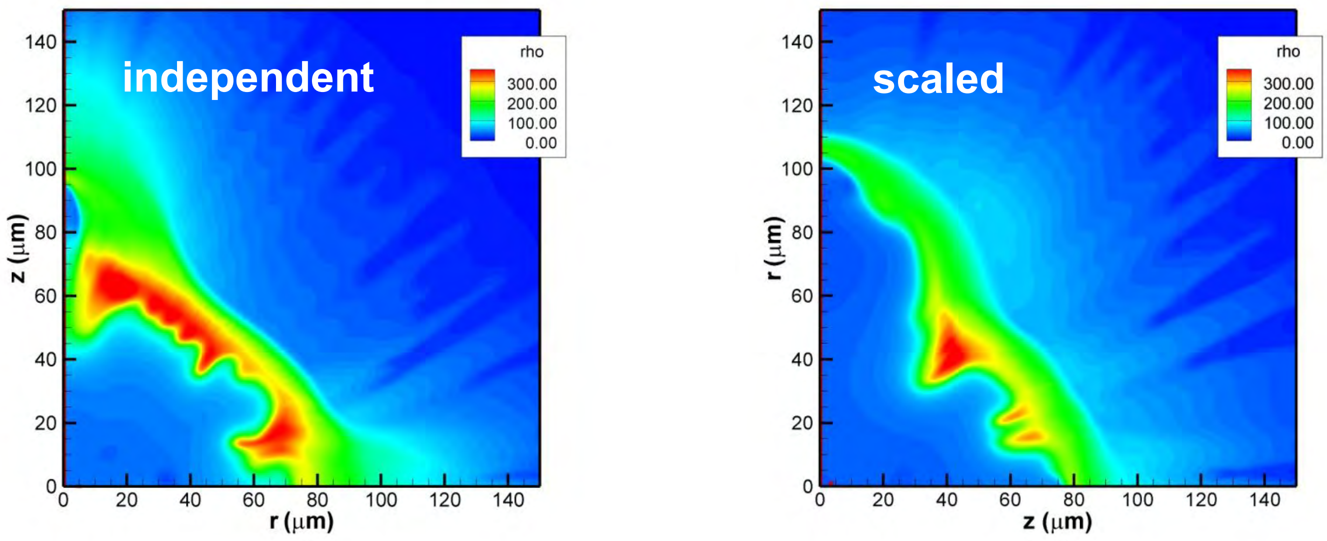
Lower super-Gaussian beam-shape orders offer greater control of the energy density on the target



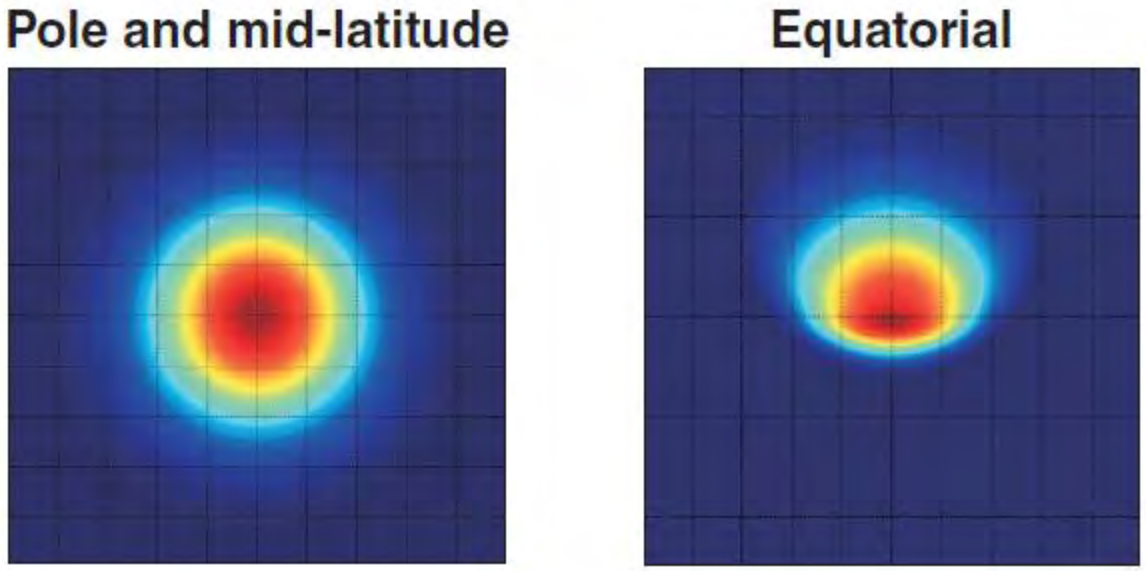
- Less energy is spilled over the horizon when lower super-Gaussian-order beams are repointed

Independent ring pulse shapes are used to compensate for variations in angle of incidence

- **The equatorial rings are driven at a higher power than the other rings**
- **The mid-latitude rings must be lowered due to beam overlap**
- **The polar ring power is raised for the same reason**
- **Pickets and drive pulse required different relative ring powers; using ring pulse shapes which are multiples of each other reduces this target's gain by 40%**

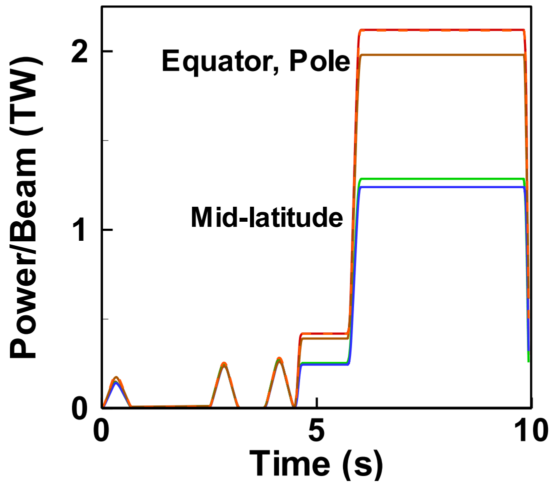


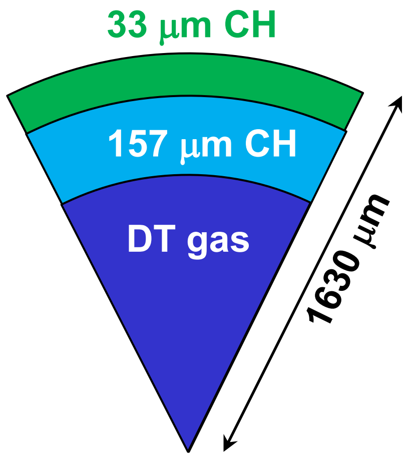
Equatorial beam coupling can be increased using tailored phase plates



- The equatorial spot shape combines a round spot with an elliptical spot to mitigate loss of coupling near the equator
- The resulting spot is asymmetric to reduce loss of energy over the horizon

The triple-picket design uses a multiple-picket, multiple-shock laser pulse





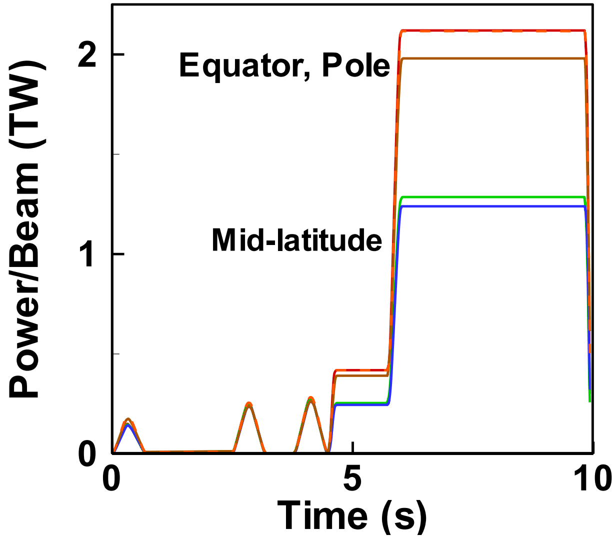
- This design is based on the triple-picket design* used on OMEGA to achieve an areal density of nearly 300 mg/cm^2**
- A thick CH ablator is used to minimize the risk of hot-electron preheat
- Individual pulse energies lie within NIF limits for energy (9.3 kJ/beam) and power/beam

* V. N. Goncharov *et al*., Phys. Rev. Lett. 104, 165001 (2010).

** T. C. Sangster *et al*., Phys. Plasmas 17, 056312 (2010).

A relaxation-picket pulse is used with a rapid-rise drive pulse

- OMEGA experiments have demonstrated that picket pulses are better suited to experimental shock tuning because of greater pulse reproducibility*
- Use of a rapid-rise drive pulse reduces uncertainties in shock timing caused by low-adiabat slow-rise pulses
- Relaxation pickets, for which the laser power is small or zero between the pickets, allow greater adiabat shaping and greater shell stability**
- Subsequent pickets must have diminishing relaxation times, limiting the number of pickets
- A "step" pulse is used at the start of the drive to allow a lower drive-pulse power



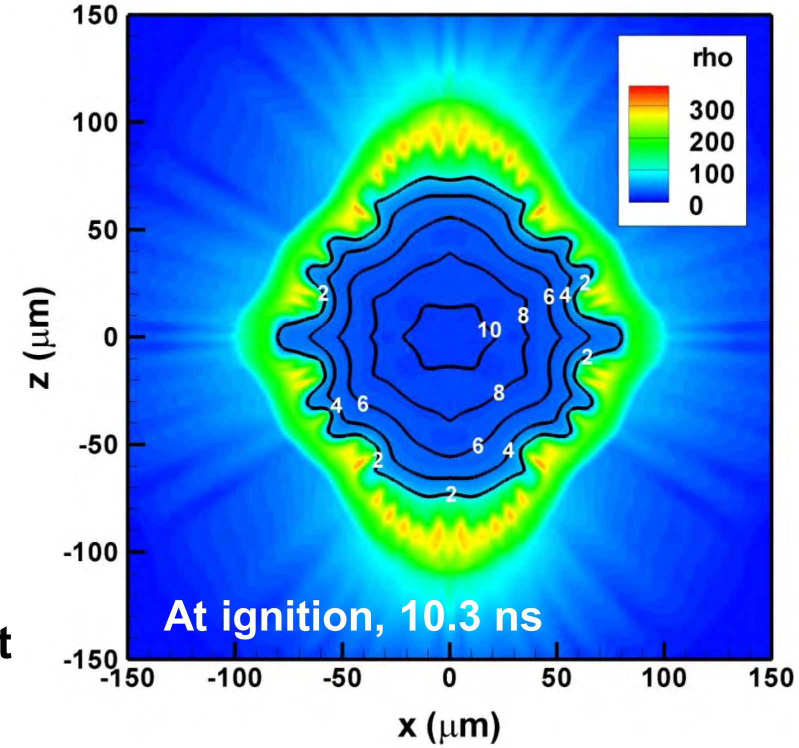
* T. R. Boehly *et al*., Phys. Plasmas 16, 056302 (2009).

** K. Anderson and R. Betti, Phys. Plasmas 11, 5 (2004).

The triple-picket PD design with target and beam nonuniformities and Multi-FM beam smoothing* achieves a gain of 40

- One-μm RMS ice roughness is included as well as single-beam imprint ($\ell \in [2,100]$), 8% RMS power imbalance, 30-ps RMS beam mistiming, 50-μm beam mis-pointing and surface roughness

Energy	1.54 MJ
Gain	40
v_{imp}	440 μm/ns
Shell integrity	26%
α	2
Peak ρR	1.42 g/cm²

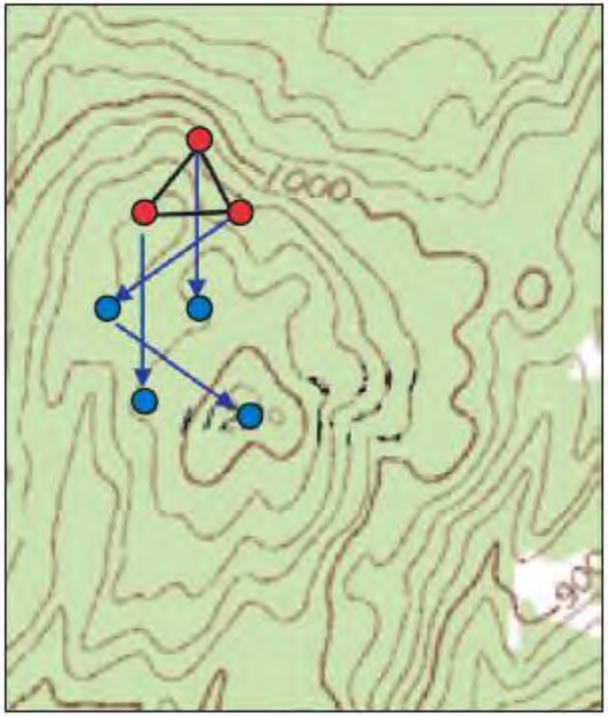


- Flux-limited diffusive thermal transport was used (6%)
- Gas density = 0.225 g cm^{-3}

* See Marozas, next talk

The triple-picket PD ignition design was optimized in 1-D with a downhill simplex method

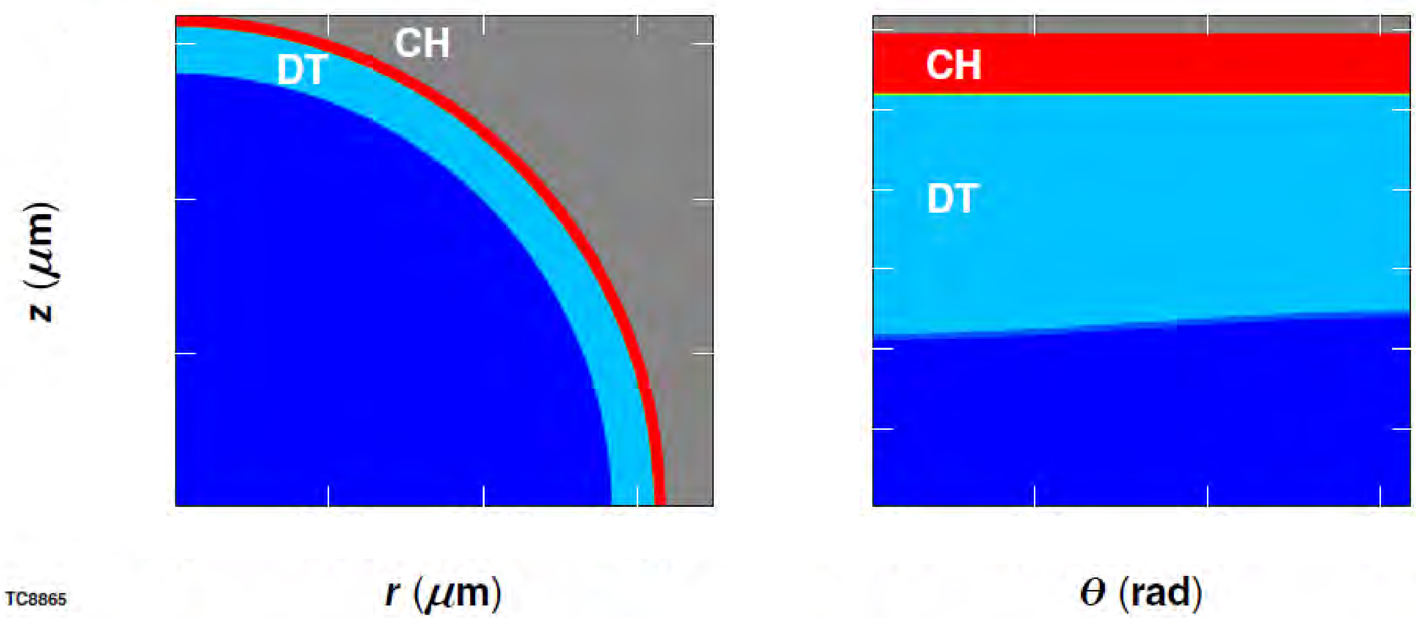
- **This points in the pulse shape (power, time) and target dimensions were optimized**
- **This design was optimized to maximize gain while requiring peak power not to exceed damage threshold limits, in turn fixing the implosion velocity**
- **This method allows for tuning of more variables than would be feasible by hand (in this case, 12)**
- **Other metrics have proven useful: *f*(Gain, IFAR, ρR), etc.**



A simplex on a topographical map optimizing for maximum height

An ℓ=2 ice-layer "shim" is used to lower the equatorial mass

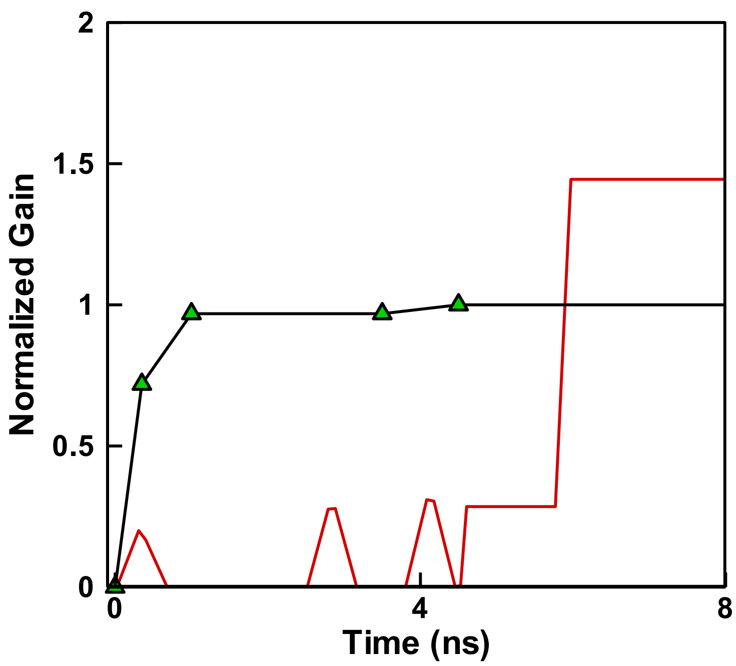
- An 11.5-μm ℓ=2 ice-layer "shim" is used to lower the equatorial mass and compensate for reduced equatorial drive
- This perturbation could be introduced by shimming the cryogenic layering sphere itself or adding an IR source around the equator
- The resulting perturbation would be repeatable *but not necessarily precise*
- A 10-μm shim allows a ~10% reduction in equatorial beam power, allowing greater overall power while remaining below laser damage thresholds



TC8865

Simulations show little gain degradation when SSD is only active for the first picket

- **Motivation**: "Turning off" SSD early reduces the risk of damage to the laser
- Single-beam smoothing asymptotes on timescales comparable to 1 ns (Marozas, this session)



P. W. McKenty *et al*., Bull. Am. Phys. Soc. 51, 295 (2006).

Future work includes modeling of plasma effects

- A 2-D Schurtz-type nonlocal thermal transport model has been implemented in *DRACO* by G. Moses and his team at U. Wisconsin and is currently being tested
- A cross-beam energy transfer package is under development for *DRACO* 2D
- This design will be simulated in *HYDRA* in 2D and 3D
  - Enhancements to *HYDRA*'s 3D ray trace are underway for use in direct-drive simulations
- A scaled version of the design is under development

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Sensitivity (1-D)

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