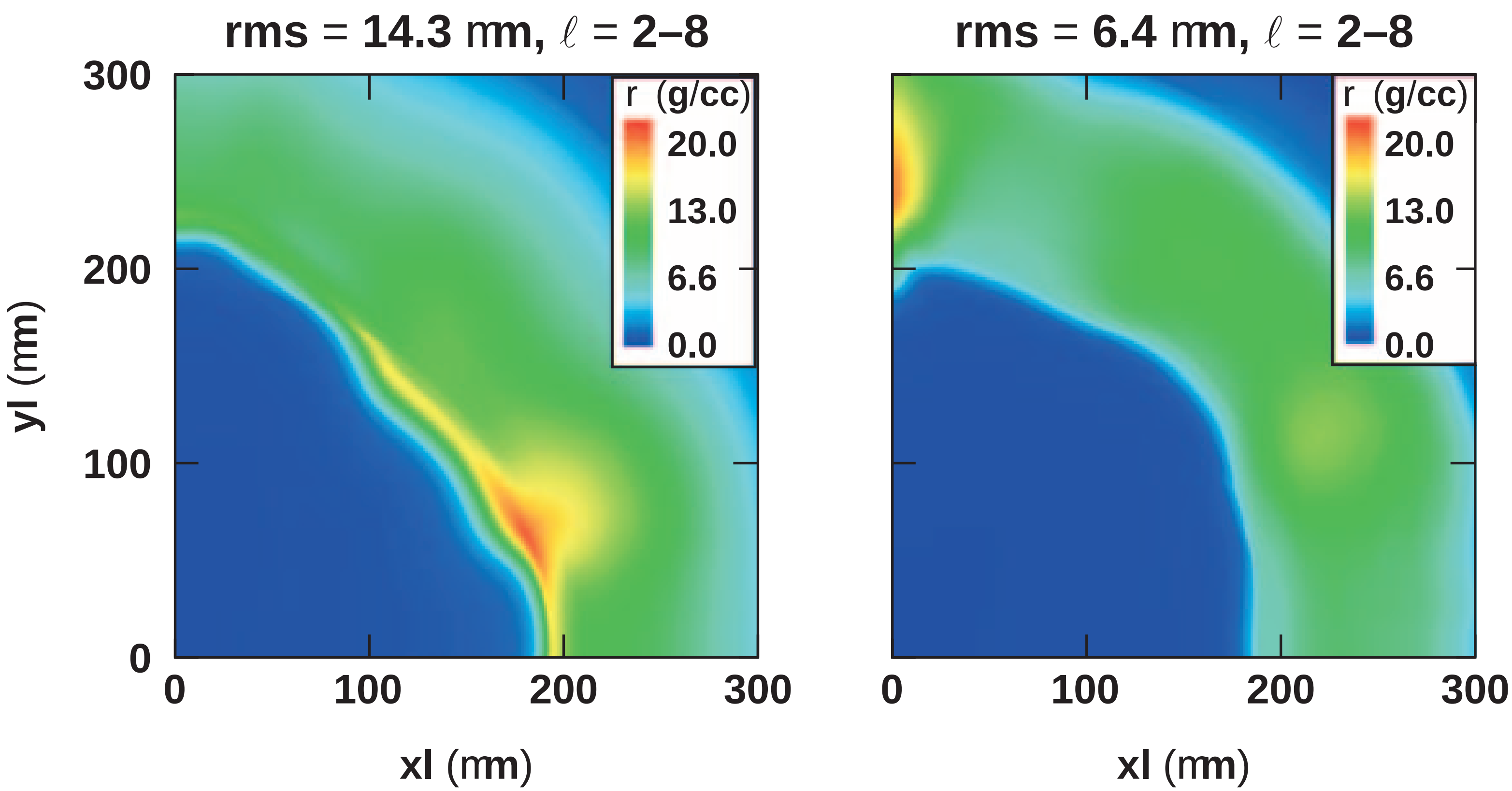
Optimization of Low-Order Uniformity for Polar Direct Drive (PDD) on the National Ignition Facility (NIF)

UR LLE



J. A. Marozas
University of Rochester
Laboratory for Laser Energetics

45th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Albuquerque, NM
27–31 October 2003

Summary

Optimized pulse shapes compensate 2-D effects due to nonuniform beam incident angles

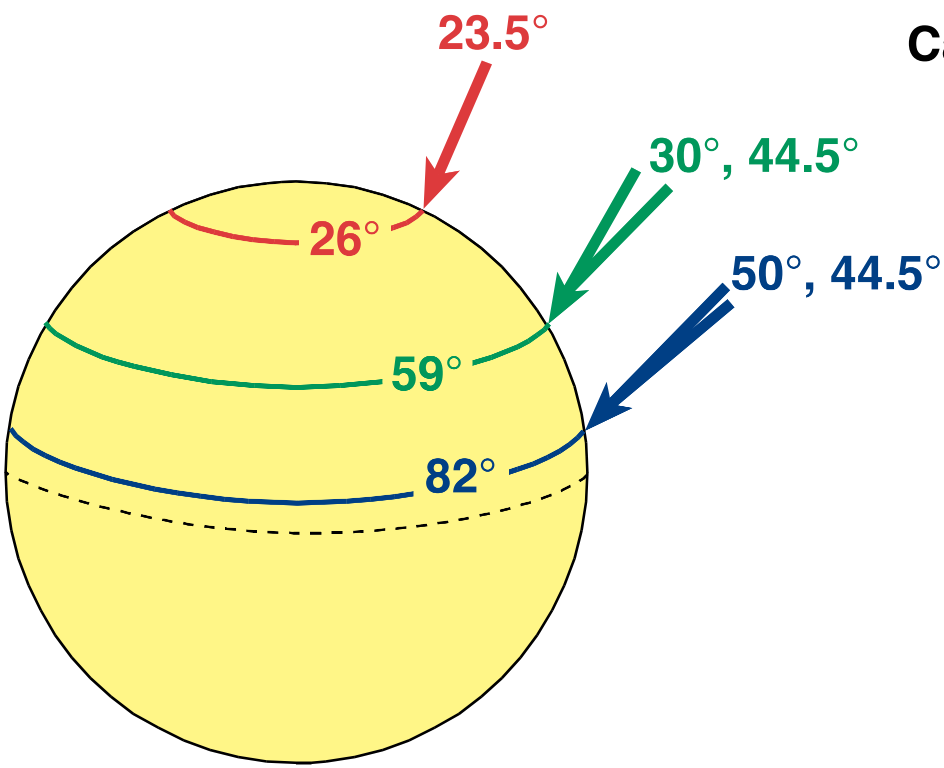
- PDD enables direct-drive ignition experiments while the NIF is in the x-ray drive configuration.
- The 48 quads are logically grouped into three rings based on their incident angles: 26°, 59°, and 82°.
- Rings with different incident angles lead to variations around the target.
  - laser absorption
  - hydrodynamic efficiency
  - lateral heat and mass flow
- A nonlinear optimization algorithm within a feedback loop generates compensated ring pulse shapes.

TC6389

Outline

- Description of ray-trace algorithm
- Description of feedback loop
- Description of target and 2-D *DRACO* simulation results

PDD enables direct-drive-ignition experiments while the NIF is in the x-ray-drive configuration



Solution:

- Intensity variations on target can be manipulated through a combination of spot ellipticity and pulse shape.

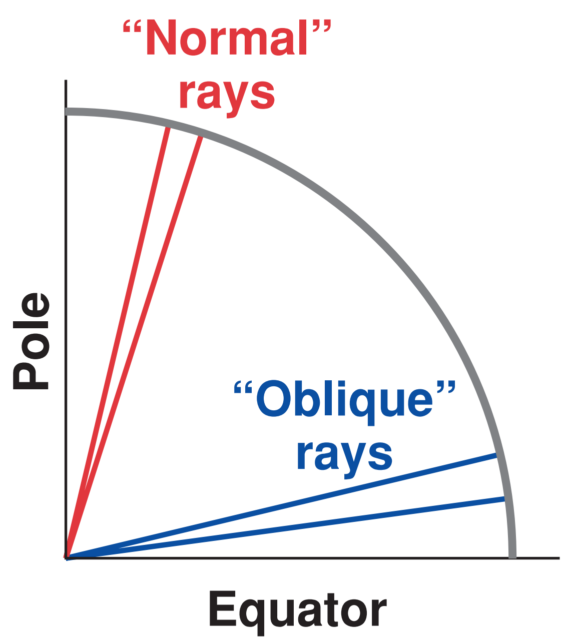
Caveats:

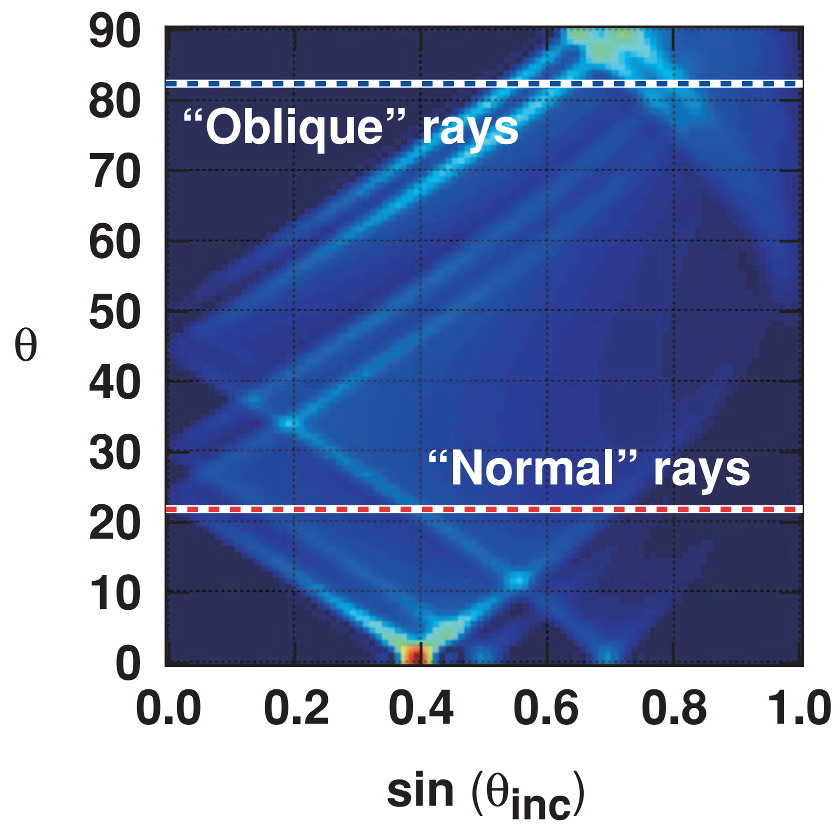
- Repointing the x-ray-drive ports leads to variations in incident angles.
- The equator requires the highest incident intensity to compensate for higher refraction losses, lower hydrodynamic efficiency, etc.
- 2-D effects also become important: lateral mass flow, lateral heat flow, etc.
- The “pointing” changes as the target compresses.

TC6468

Each sector of a *DRACO* simulation is driven by an angular spectrum of rays

- The spectrum changes as a function of polar angle due to the nonuniform overlap of beams in the PDD configuration.
- The rays propagate and deposit energy as if each sector is 1-D; exact temperature and density profiles are used.





TC6391

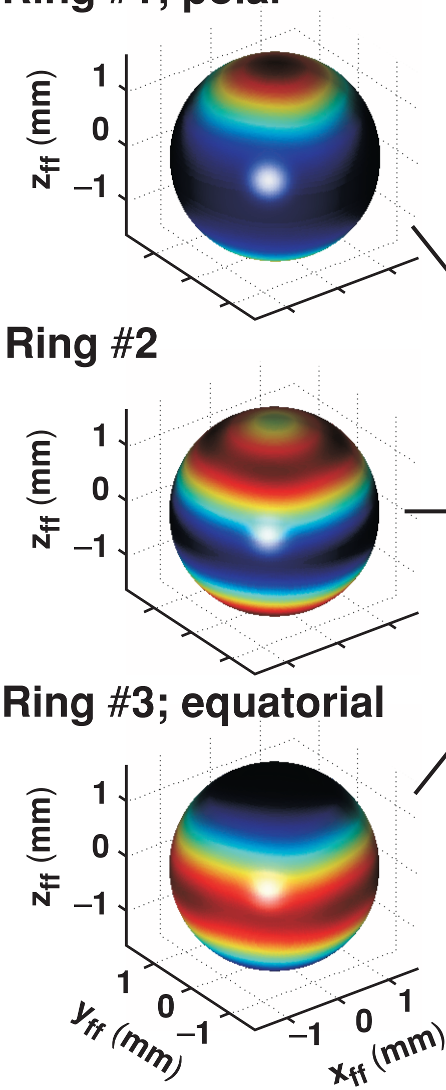
The “open-loop” model optimizes the ring energy to minimize the nonuniformity of absorbed energy

UR LLE

Ring #1; polar

Ring #2

Ring #3; equatorial

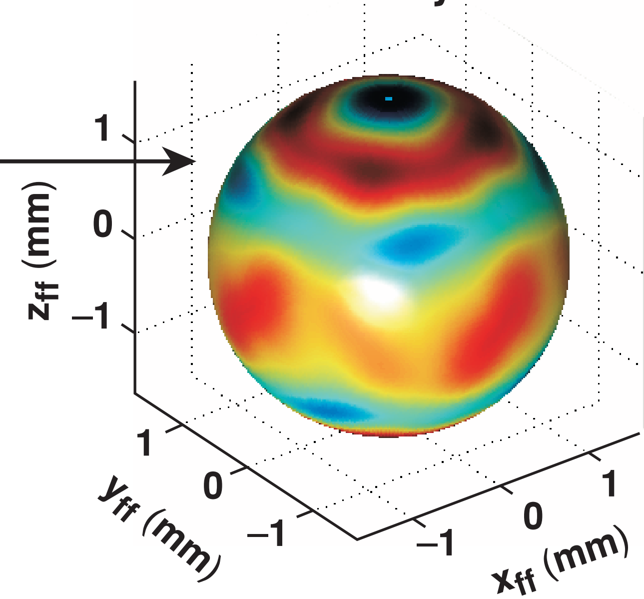


- Current state of the absorption profile is sampled from *DRACO*; determines surface illumination pattern.
- Surface-illumination pattern due to each ring is decomposed and fed into optimizer; forms basis set.

Levenberg–Marquardt

Nonlinear optimization

Nonuniformity ~ 1.2%

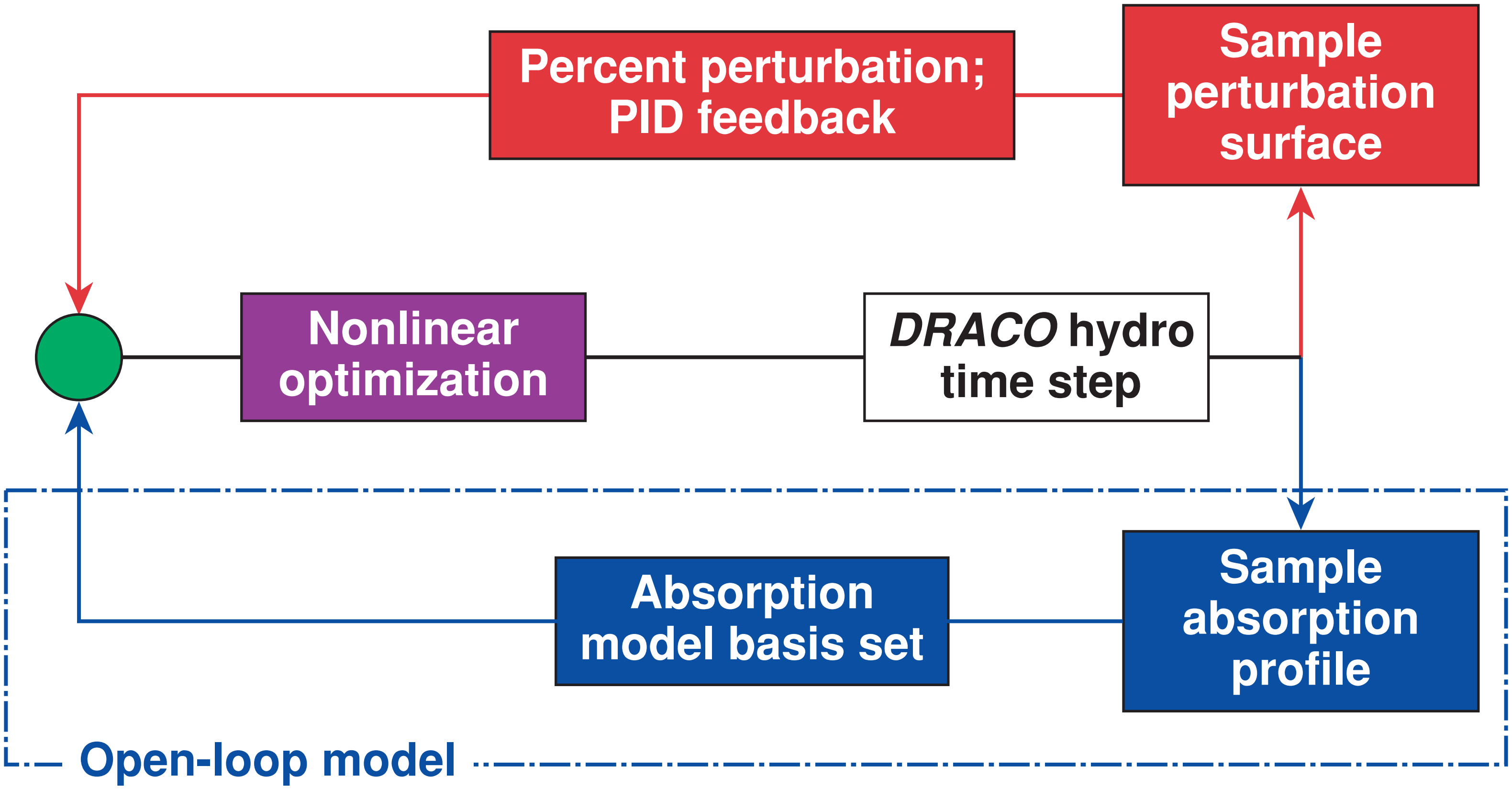


- The optimizer can be biased for different ℓ modes.

TC6168a

The "closed-loop" model incorporates feedback to predict the required compensating pulse shapes

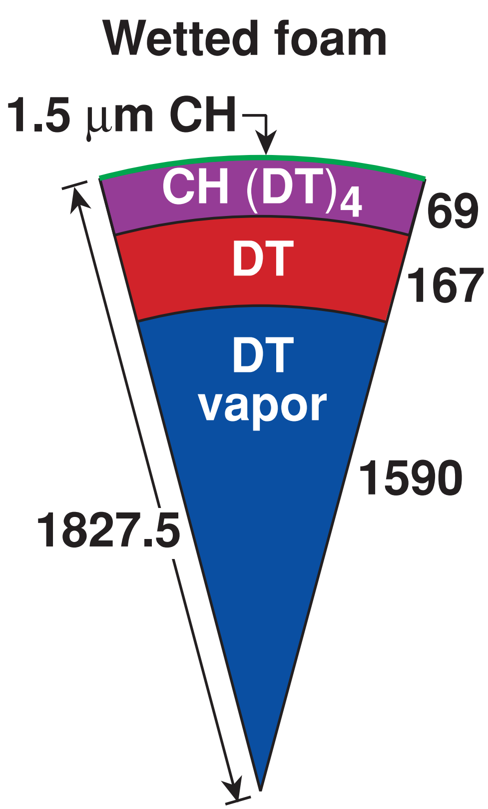
- Compensates for hydro-efficiency, lateral thermal transport, and other 2-D effects.

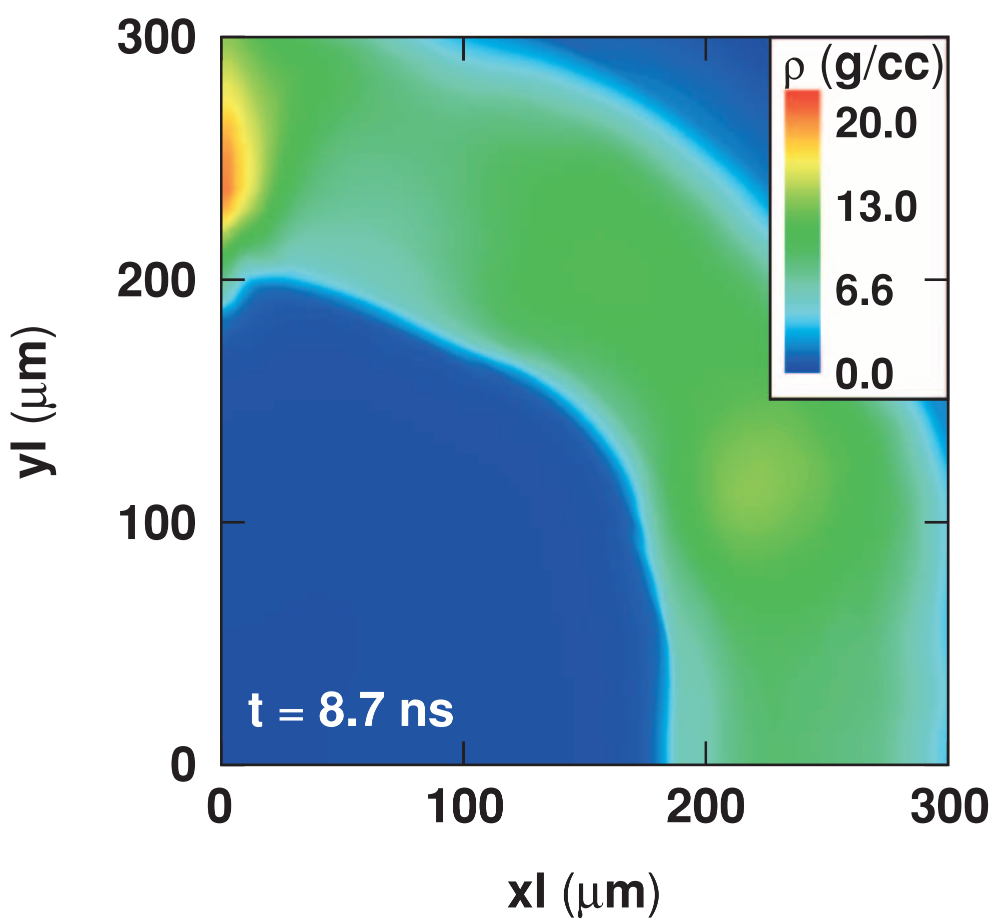


- Supplies higher intensity to regions on target that require compensation.

TC6392

The optimized ring pulse shapes drive the shell with improved low-ℓ-mode nonuniformity

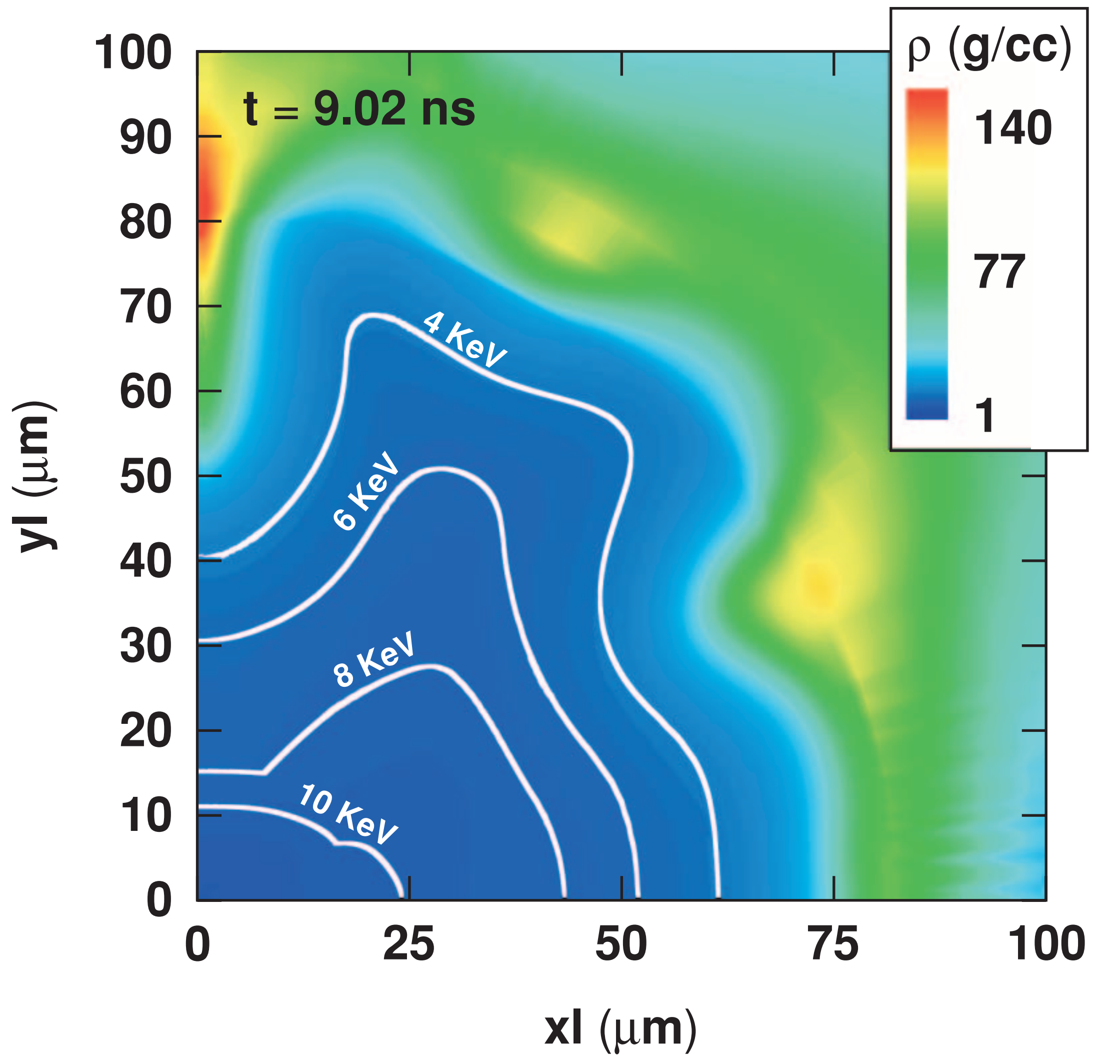




Radius converged by a factor of 6

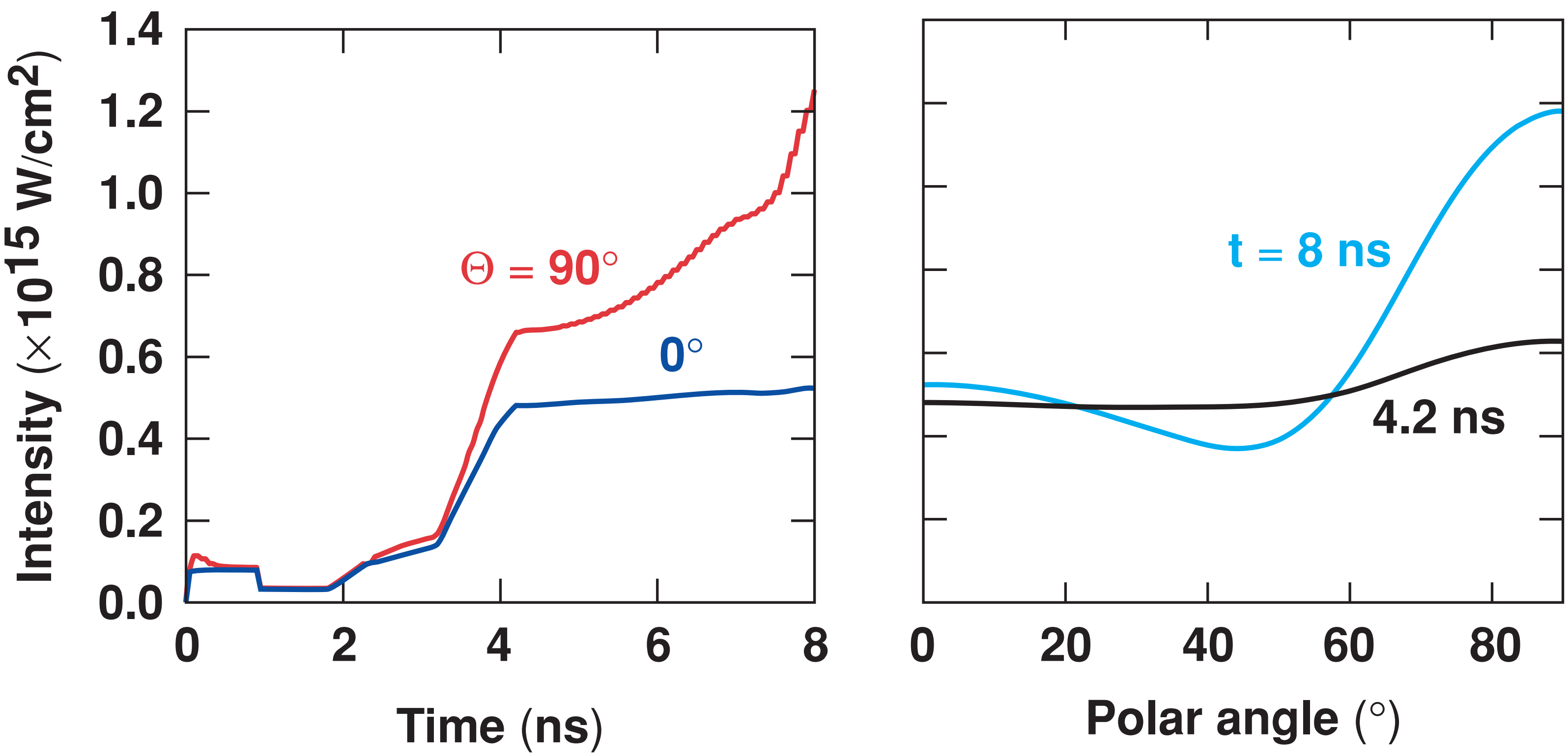
TC6394

Evidence of hot-spot formation is seen near the end of the deceleration phase



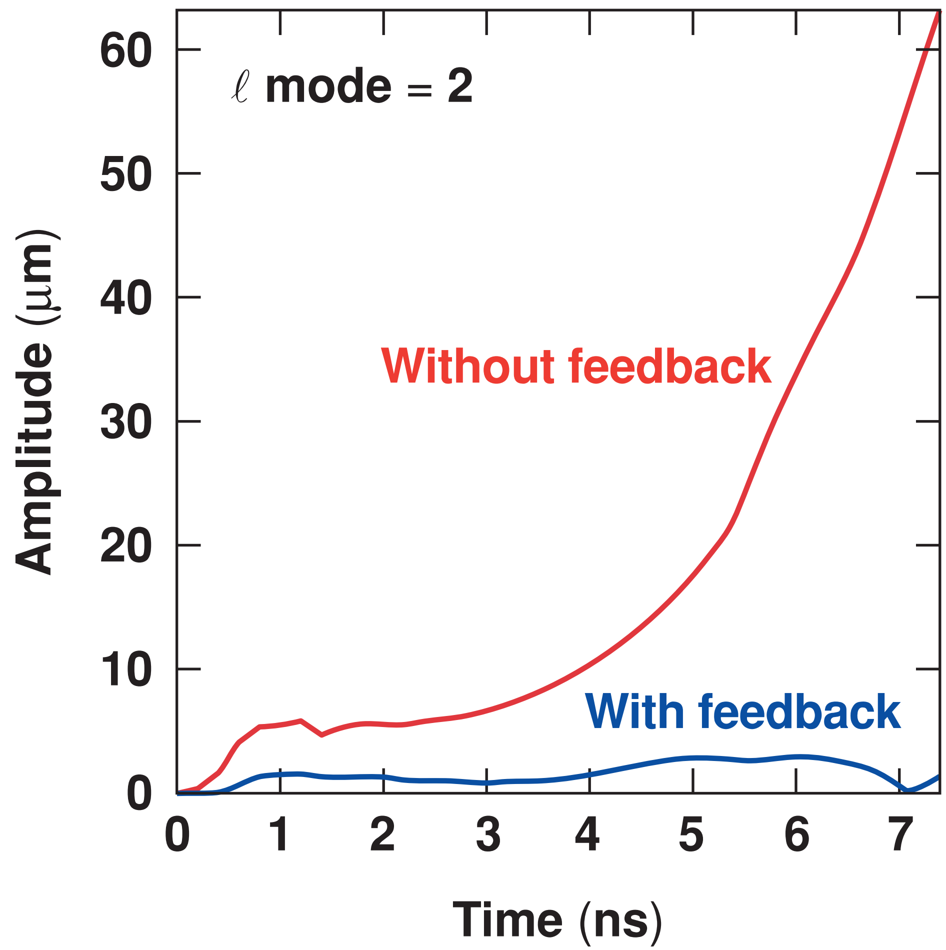
TC6467

The optimizer compensates for 2-D effects by increasing the equatorial drive relative to the pole



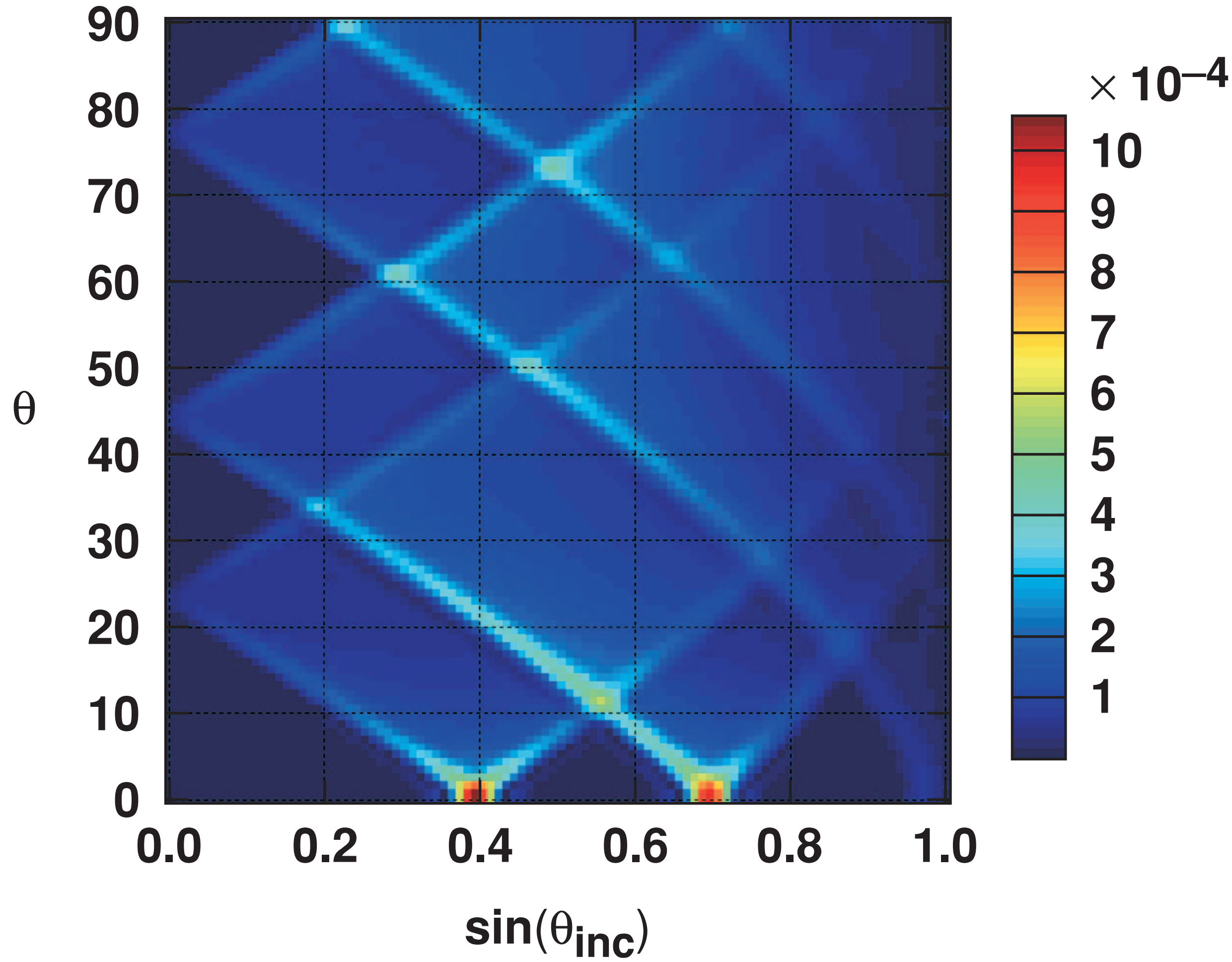
TC6396

The “closed-loop” model shows a dramatic improvement for ℓ = 2



TC6395

The angular spectrum in the direct-drive configuration is more evenly distributed than PDD



TC6398

Feedback gains are selected using the following prescription*

UR LLE

- Kd and Ki are set to 0
- Kp is varied until oscillation breaks out; note Kcr and Pcr

- Kp = 0.6 Kcr
- Ki = Kp/(0.5 × Pcr)
- Kd = Kp (0.125 × Pcr)

*Ziegler-Nichols tuning rules, K. Ogata, *Modern Control Engineering*, 3rd ed. (Prentice Hall, New Jersey, 1997), pp. 672–674.

Summary/Conclusions

Optimized pulse shapes compensate 2-D effects due to nonuniform beam incident angles

- PDD enables direct-drive ignition experiments while the NIF is in the x-ray drive configuration.
- The 48 quads are logically grouped into three rings based on their incident angles: 26°, 59°, and 82°.
- Rings with different incident angles lead to variations around the target.
  - laser absorption
  - hydrodynamic efficiency
  - lateral heat and mass flow
- A nonlinear optimization algorithm within a feedback loop generates compensated ring pulse shapes.