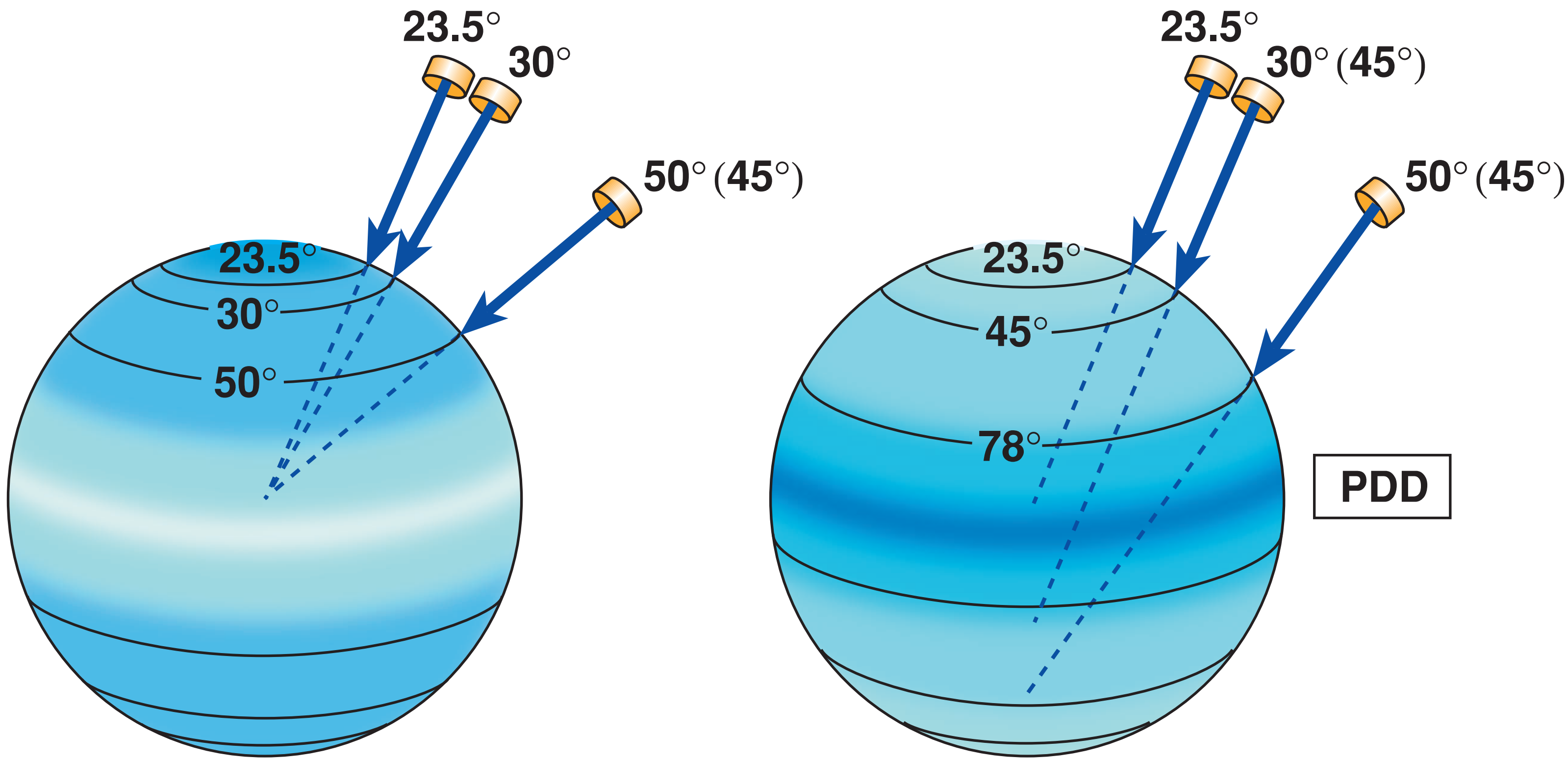
# Polar Direct Drive





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

Summary

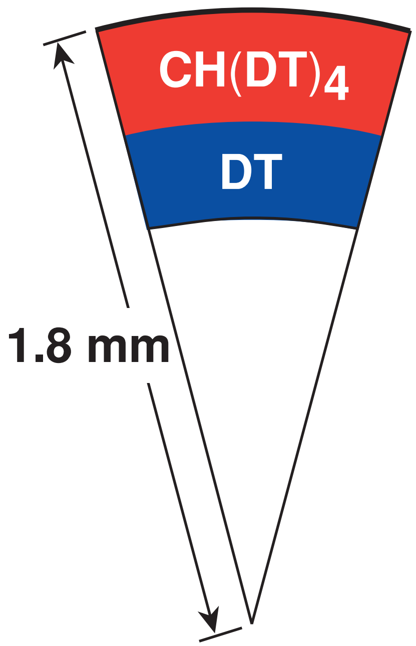
# Polar direct drive (PDD) is a promising technique to achieve ignition conditions using direct drive while the NIF is in the x-ray-drive configuration

UR LLE

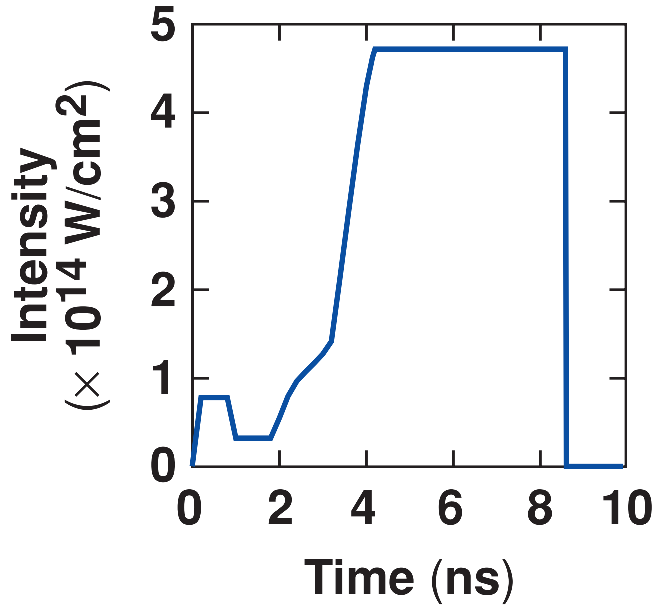
- PDD will employ all the techniques used in high-performance direct-drive target designs:
  - adiabat shaping
  - high laser–target coupling
- PDD is a more difficult design problem than "standard" direct drive.
- PDD simulations will be validated by experiments on the OMEGA laser.

TC6375

# The PDD simulations use a scaled-down version of a NIF high-performance direct-drive target design




**Equivalent 1-D design**



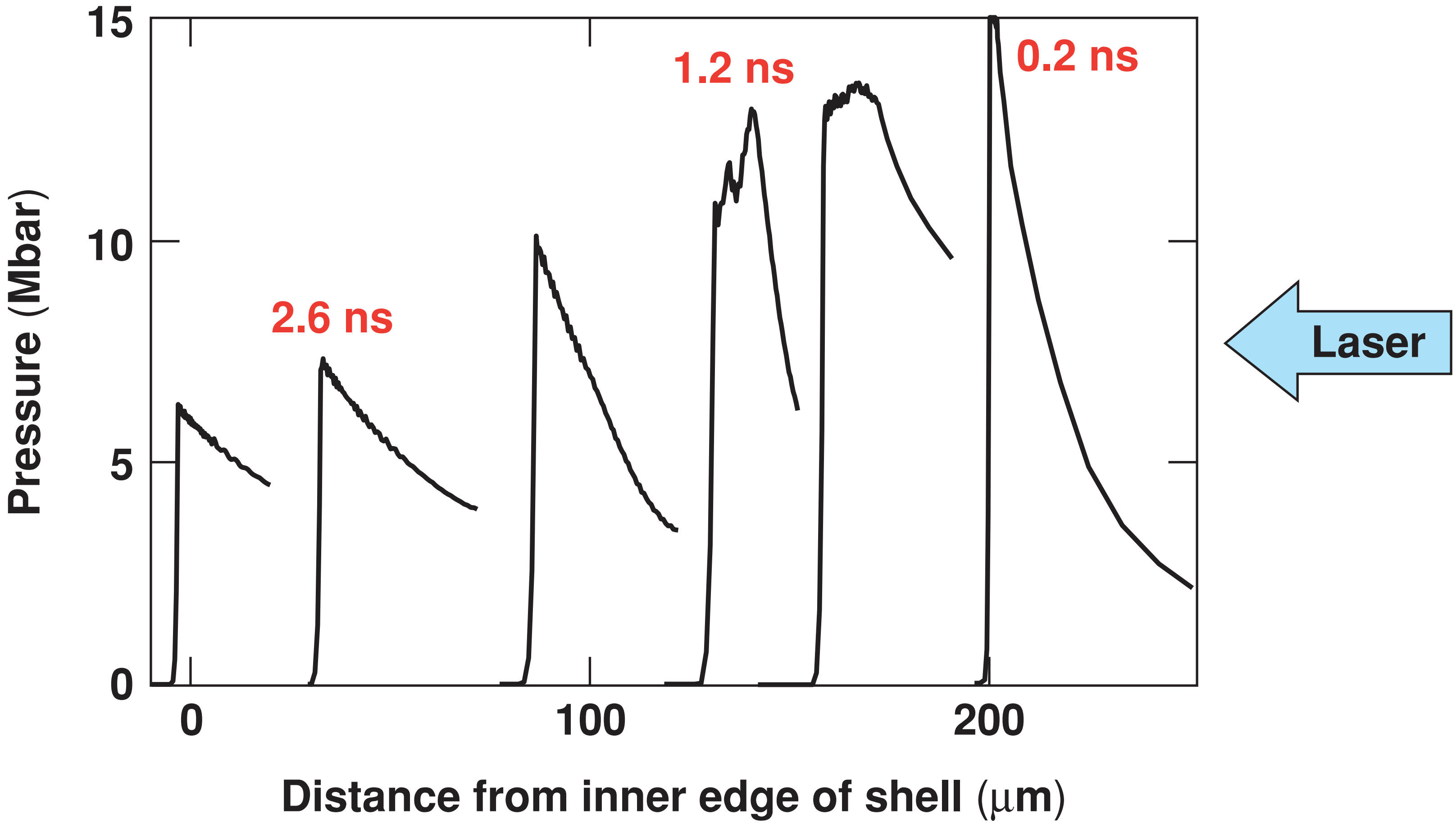

| | |
|---|---|
| Incident: | 1.1 MJ |
| Absorption: | 95% |
| $\rho r$ (peak): | 1.2 |
| Velocity: | $4.1 \times 10^7$ |
| Gain: | 54 |

**High-gain direct-drive target designs combine wetted foam with adiabat shaping for enchanced absorption and stability.**

TC6378

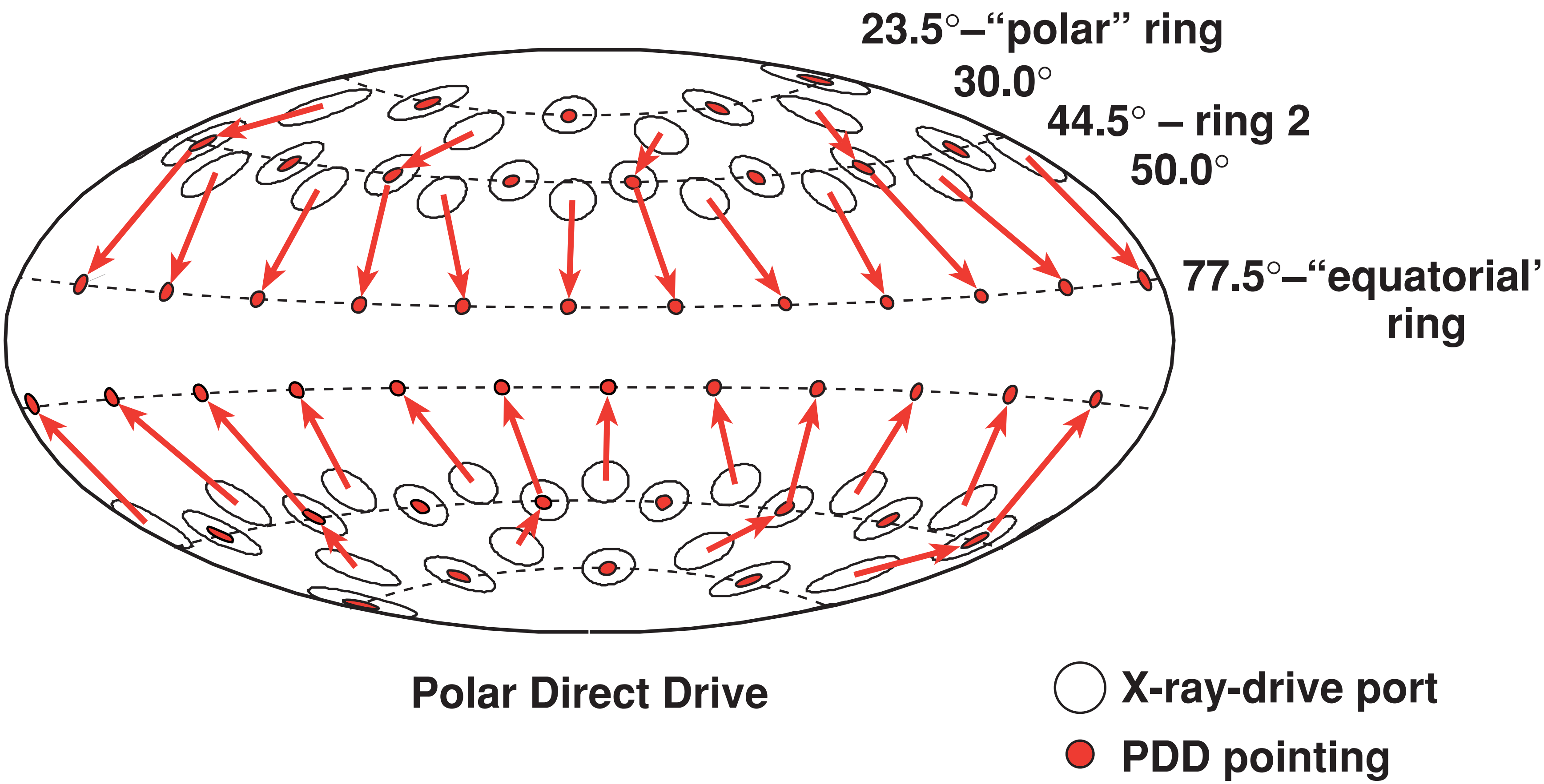
# The picket launches a decaying shock, placing the ablator on a higher adiabat than the fuel

Adiabat ($\alpha$) ~ pressure
Ablation velocity ~ $\alpha^{3/5}$



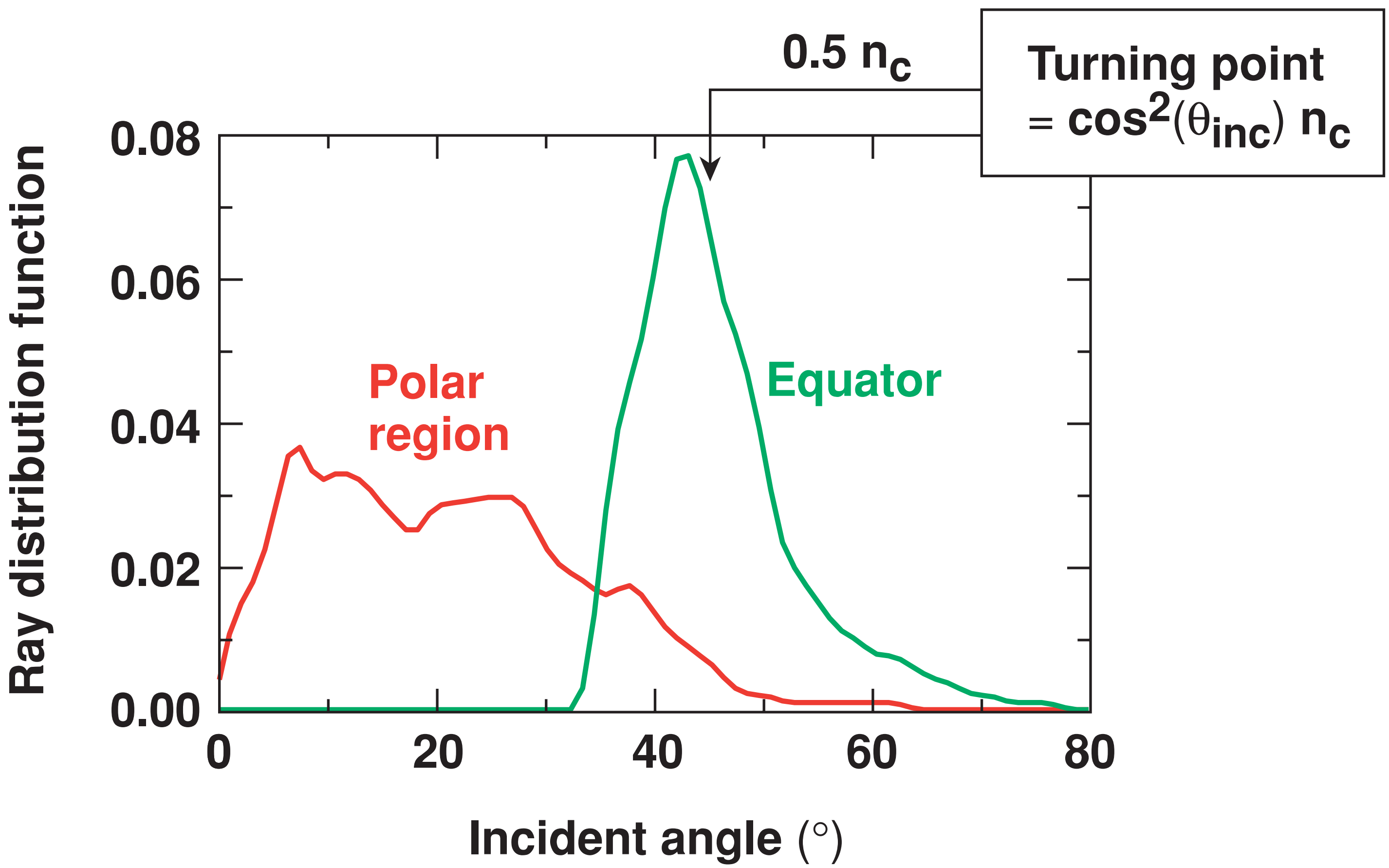

TC6299

# The x-ray-drive beams are pointed to six latitude rings on the target for PDD



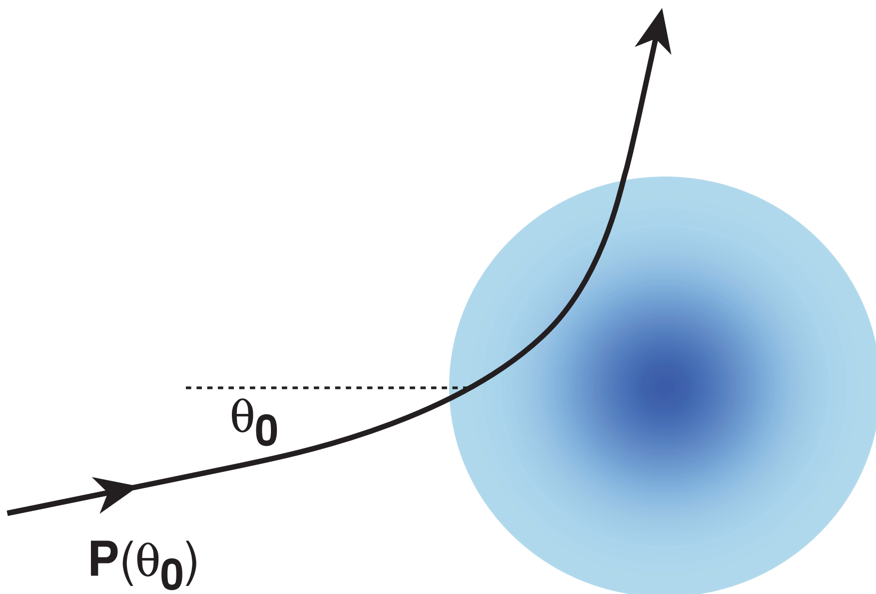

TC6149c

# Equatorial irradiation is at incident angles greater than ~ 40° for PDD




TC6379

# One-dimensional (spherical) simulations are used to estimate the effects of oblique irradiation



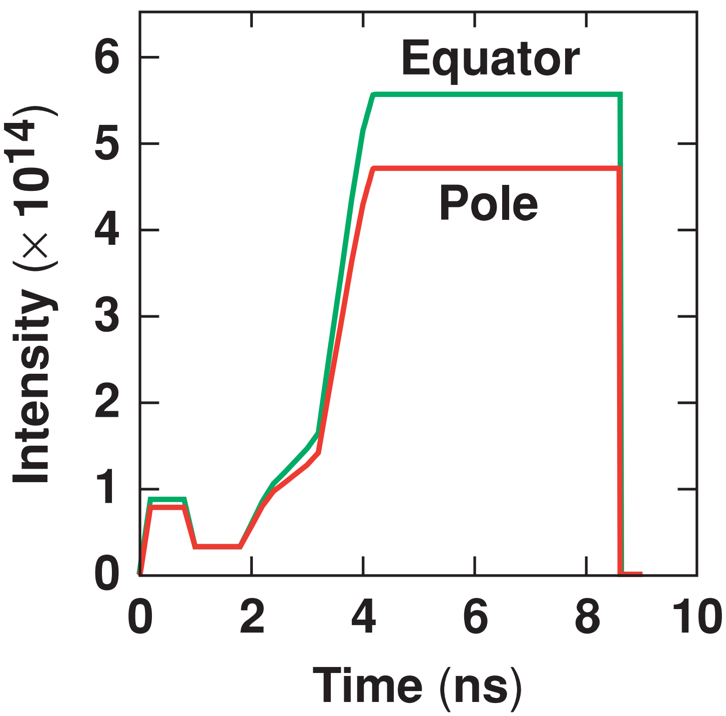

$$n \sin(\theta) = \text{constant}$$

$$n = (1 - n_e / n_c)^{1/2}$$

- The distribution function $P(\theta_0)$ of incident laser rays at any point on the target surface is calculated from a 3-D beam superposition code.

TC6380

# 1-D simulations estimate the increased laser intensity required to compensate for oblique irradiation at the equator



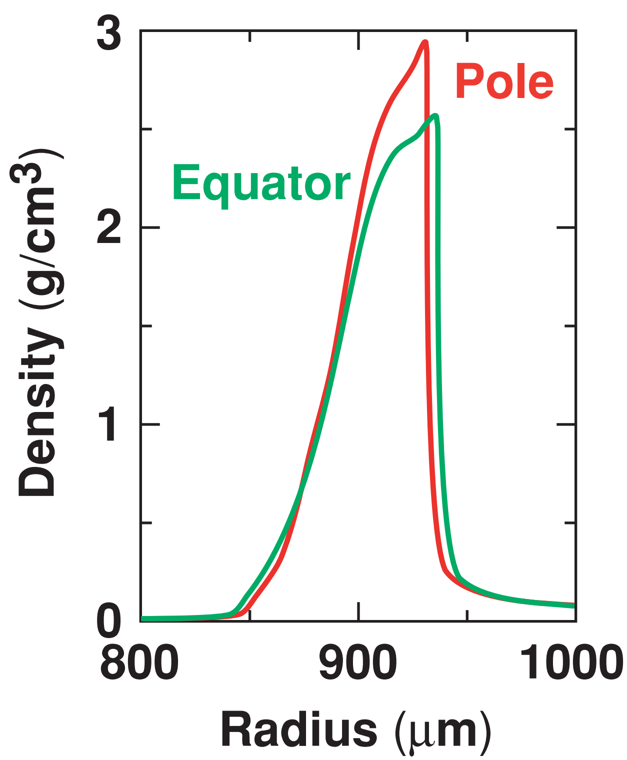

| | Pole | Equator |
|---|---|---|
| Incident (MJ): | 1.1 | 1.3 |
| Absorption: | 95% | 83% |
| V (× $10^7$ cm/s): | 4.1 | 3.9 |
| $\rho$R (g/cm$^2$): | 1.2 | 1.1 |
| Gain: | 54 | 10 |

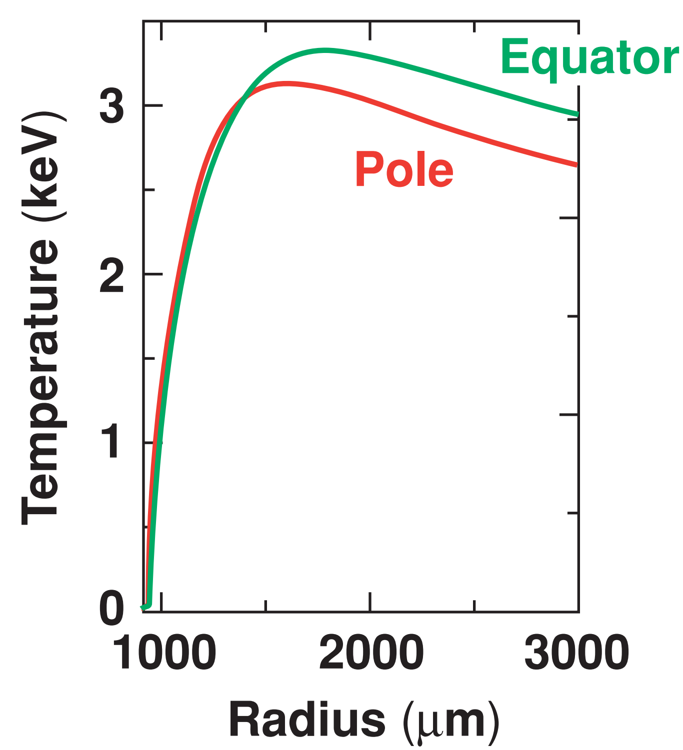
TC6381

# Differences in density and temperature profiles in the 1-D estimates indicate that full 2-D simulations are required to account for lateral flow



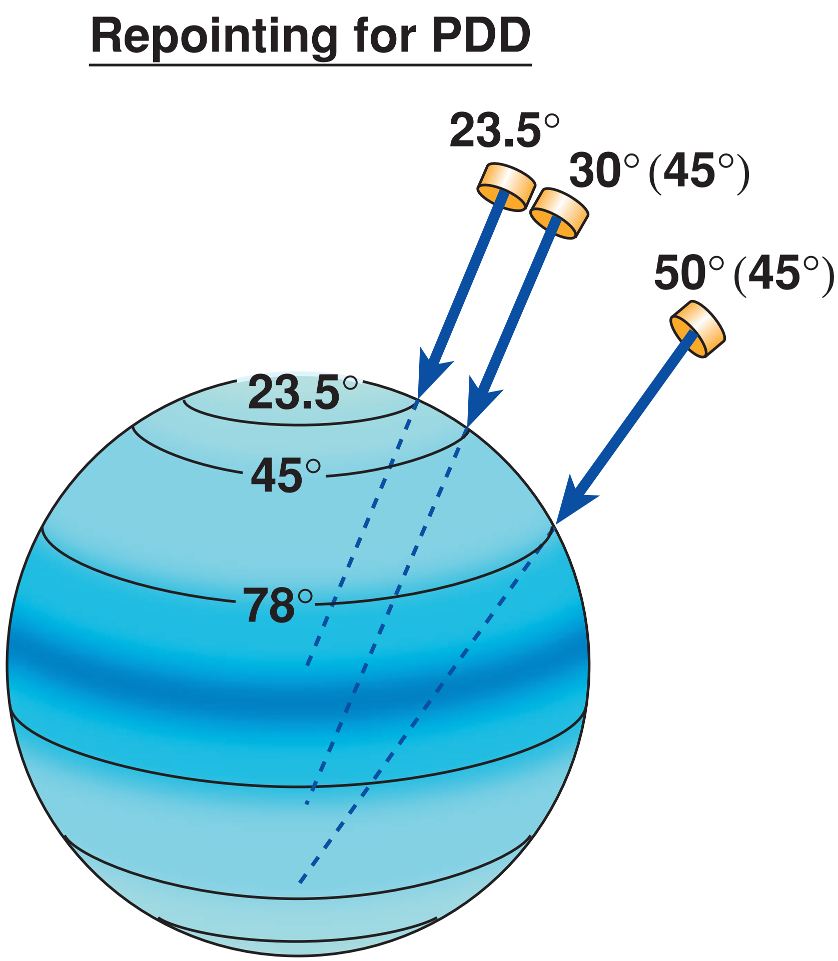
7 ns




TC6382

# Uniform target drive requires increased intensity at the equator to compensate for the oblique irradiation




- PDD issues at the equator
  - reduced absorption
  - reduced hydro-efficiency
  - lateral heat flow
  - nonradial beams

TC6300b

# A spot shape for beams in the equatorial ring contributes to uniform irradiation toward the pole while providing enhanced intensity at the equator

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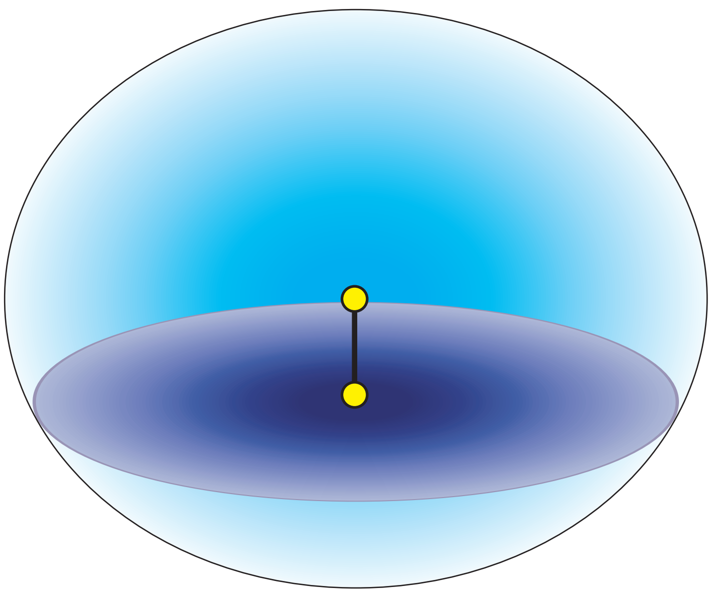
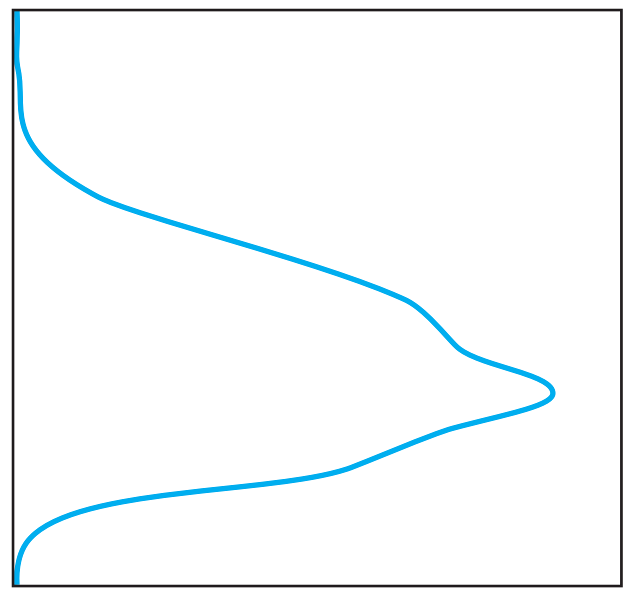
**Focal-spot shape for equatorial beam**

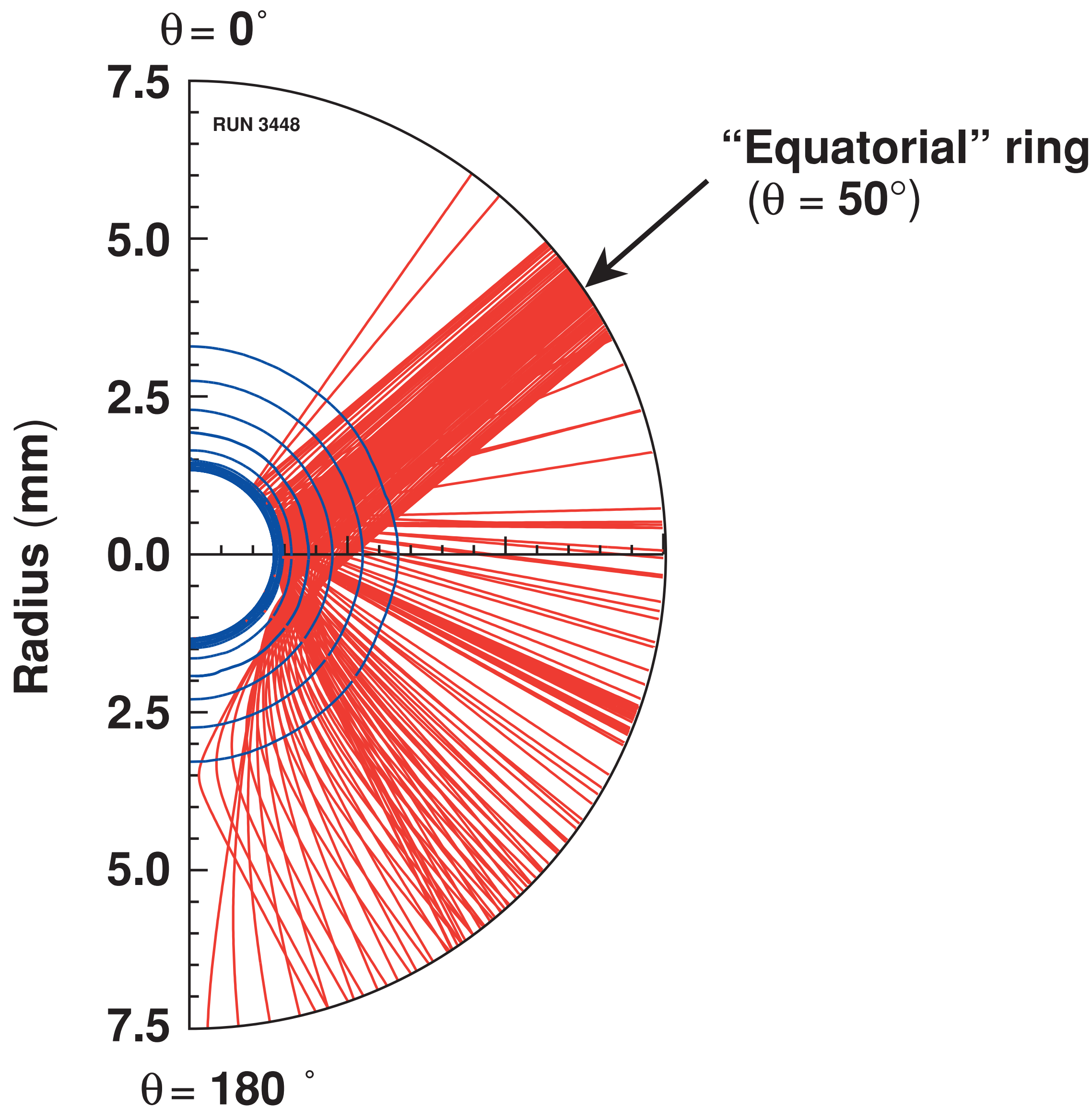


**Vertical lineout**



TC6316

# A 3-D ray-trace algorithm is used to simulate PDD

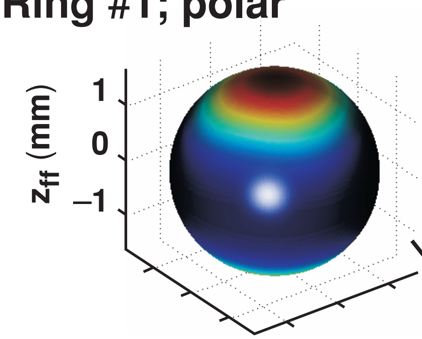



TC6238

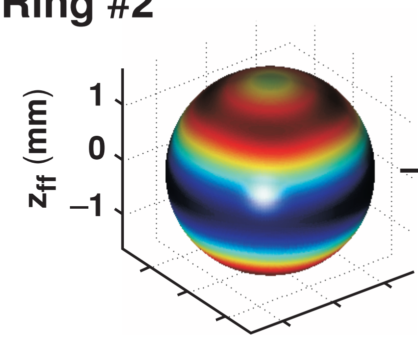
# An automated pulse-shape refinement technique is used in 2-D simulations of PDD to minimize drive nonuniformities

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

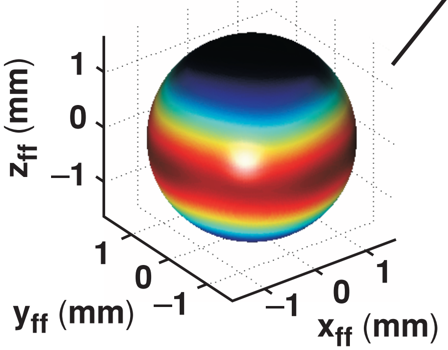
Ring #1; polar




Ring #2



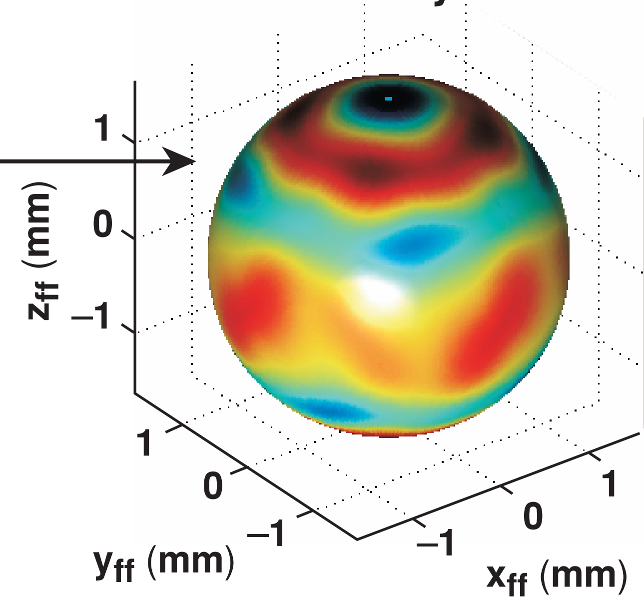

Ring #3; equatorial




**Levenberg–Marquardt**

**Nonlinear optimization**

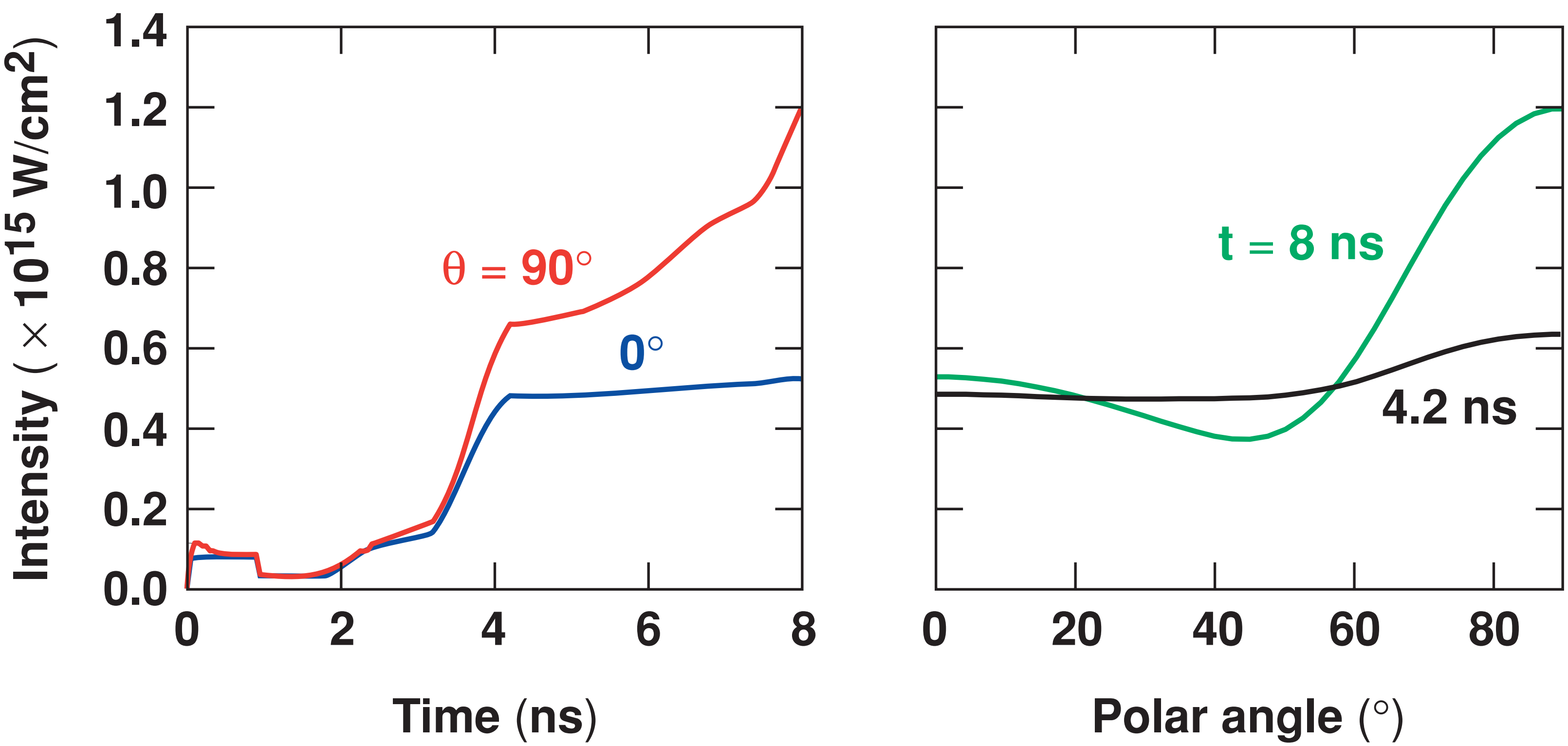
Nonuniformity ~ 1.2%




- The optimizer can be biased for different $\ell$-modes.

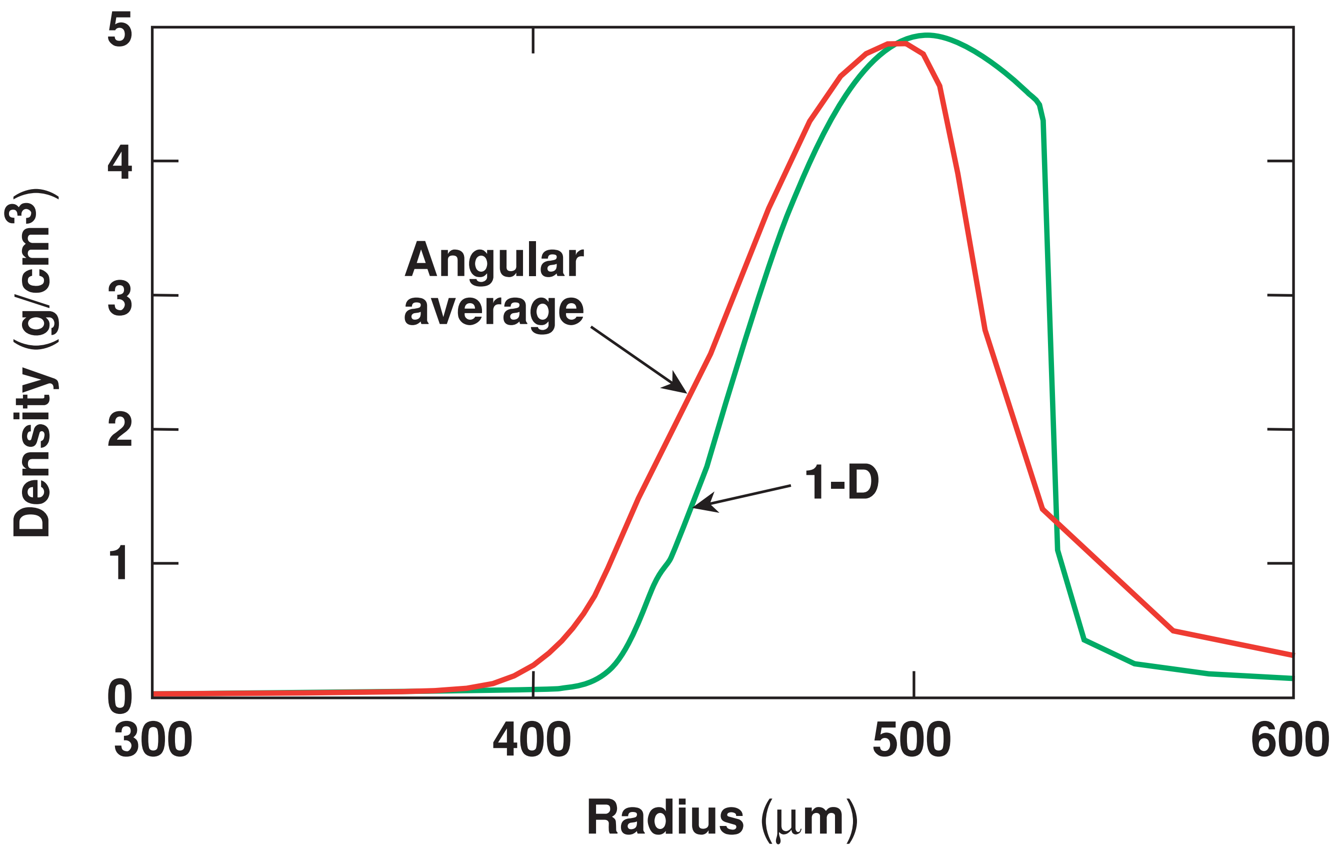
TC6168

# The variation in intensities at the pole and equator show the compensation required for PDD



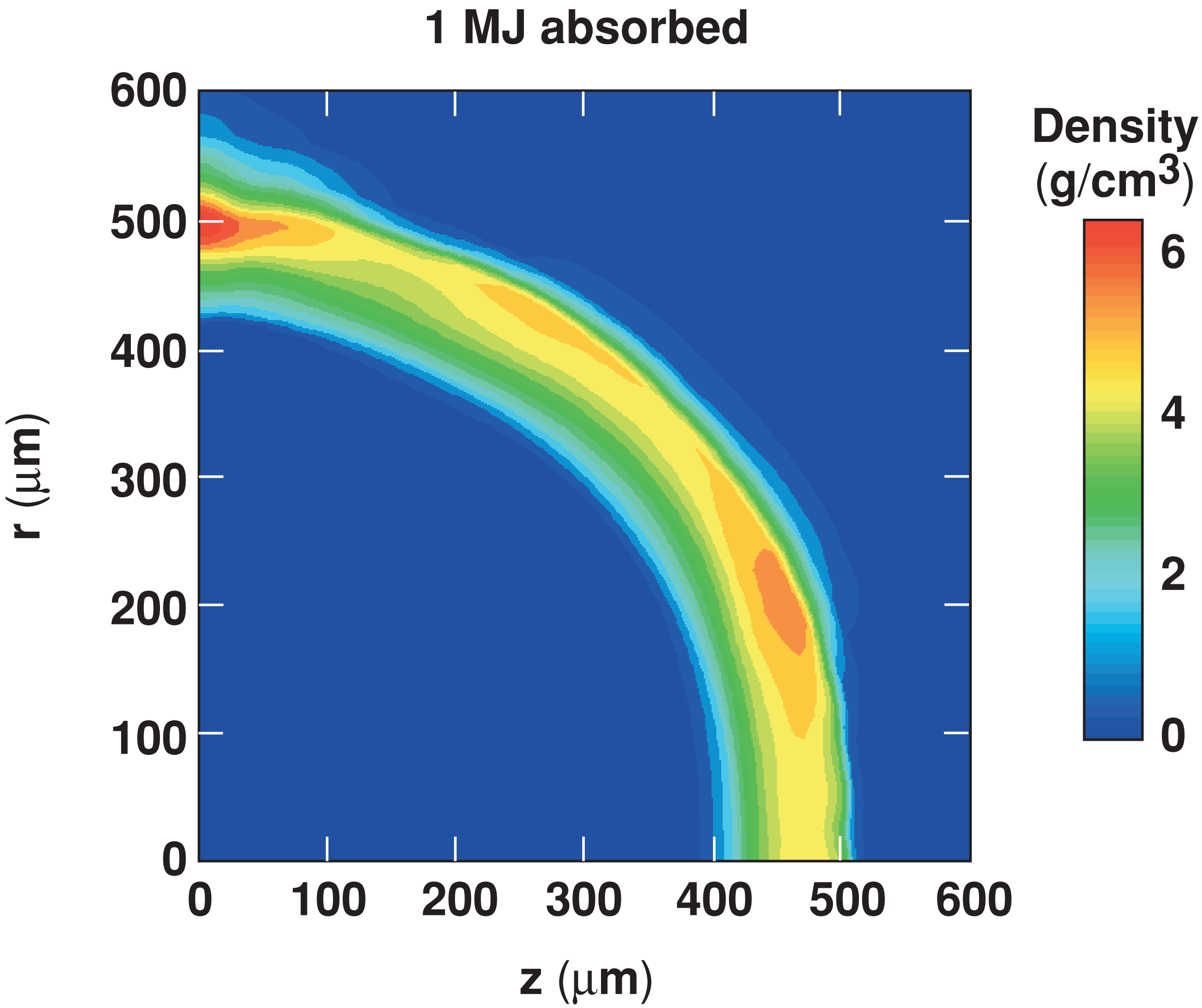

TC6326

# The angular averaged density profile at the end of the acceleration phase is similar to the 1-D profile (8.2 ns)



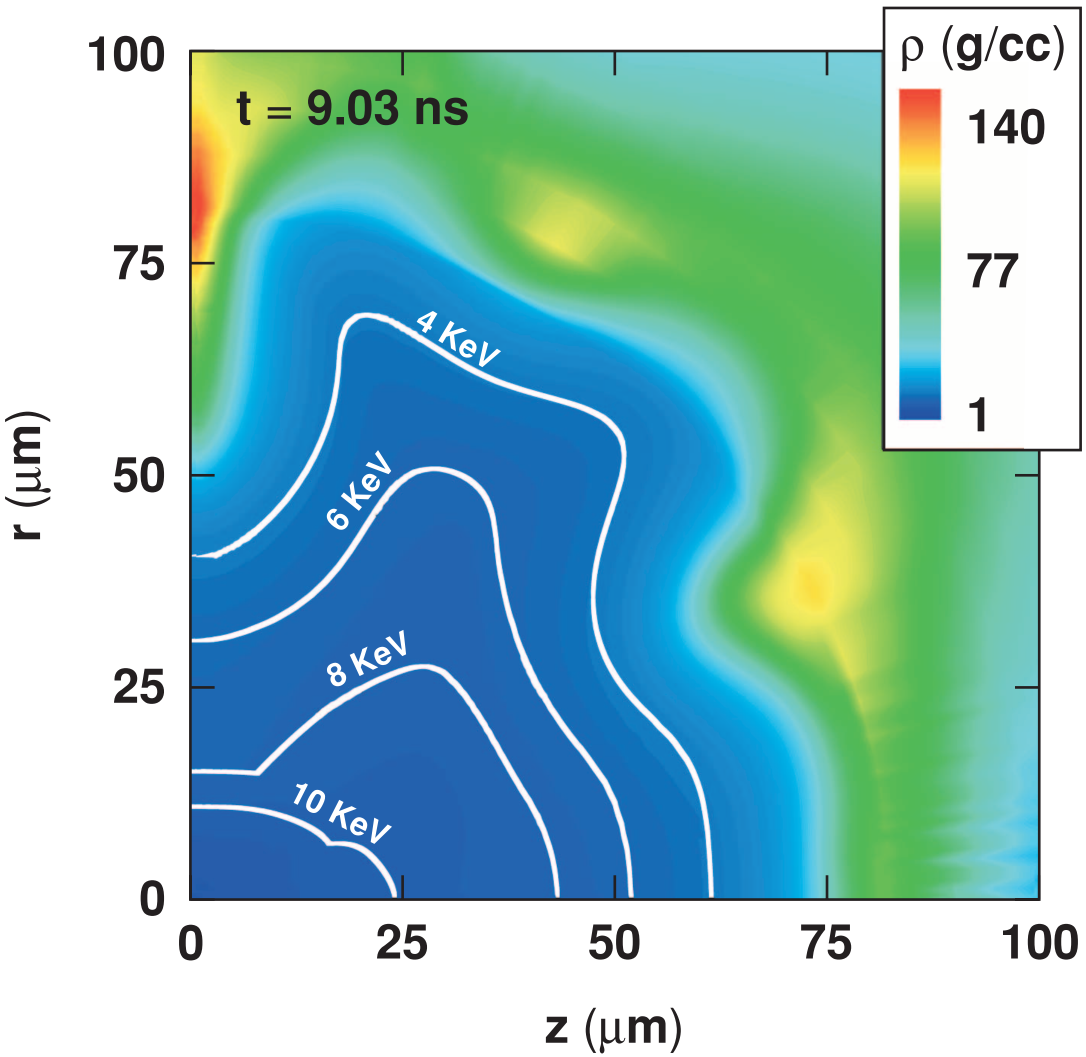

TC6318a

# Density variations at the end of the acceleration phase of the implosion show that further optimization in drive uniformity is required (8.2 ns)



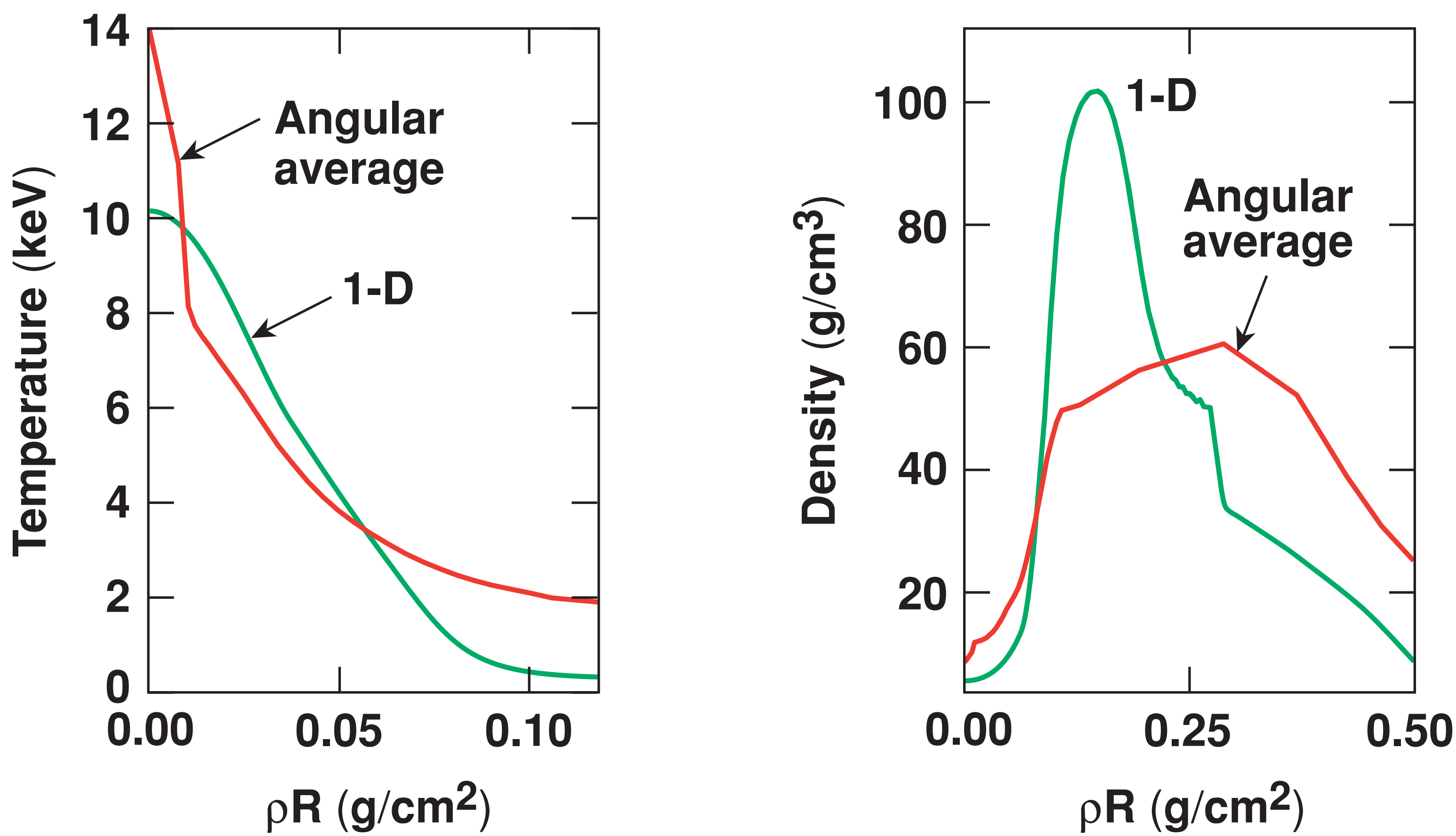

TC6317b

# PDD simulations are starting to show the onset of hot-spot formation (9.03 ns)



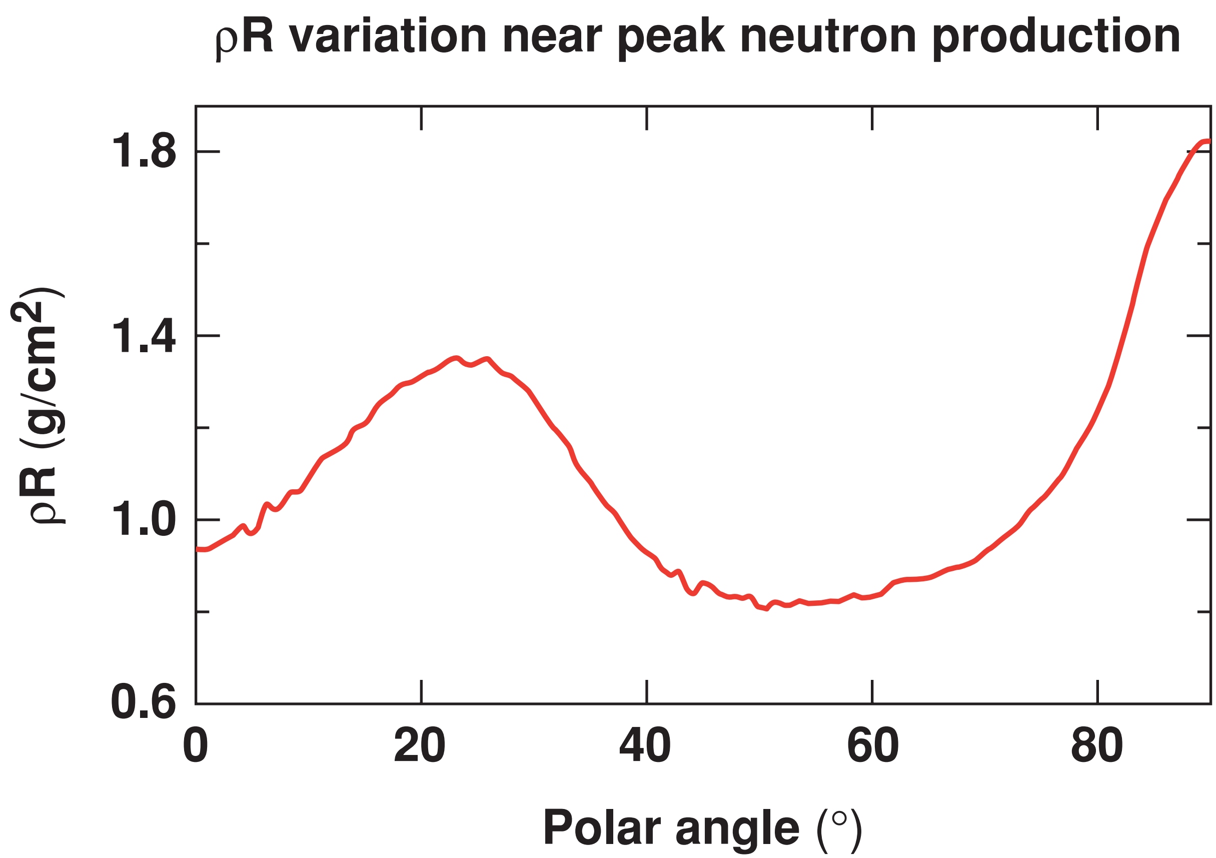

TC6319b

# Angular averaged profiles of the PDD simulation show the characteristics of the 1-D simulation at the onset of hot-spot formation (9.03 ns)




TC6320a

# The total fuel ρR is 1.1 g/cm$^2$ during neutron emission ($Y = 6 \times 10^{16}$, $G = 0.1$)



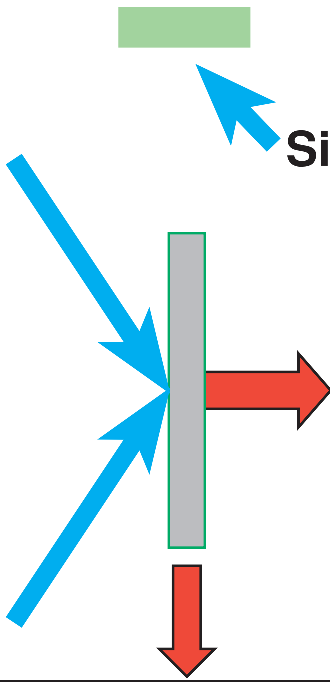

TC6321a

# Strategies to improve irradiation uniformity for PDD are being developed

- The automated pulse-shape refinement algorithm will be further optimized to better detect drive uniformity and adjust pulse shapes accordingly.
- Drive uniformity will be “fine tuned” by optimizing beam pointing, focal spot shape and spot size.
- Target “shimming”.

**PDD experiments on OMEGA over the coming year will validate the computer modeling of PDD.**

# Measurements of shock-wave propagation in planar targets will study laser coupling of oblique beams



Side-lighter beams

Incident angles:
23°
48°
60°

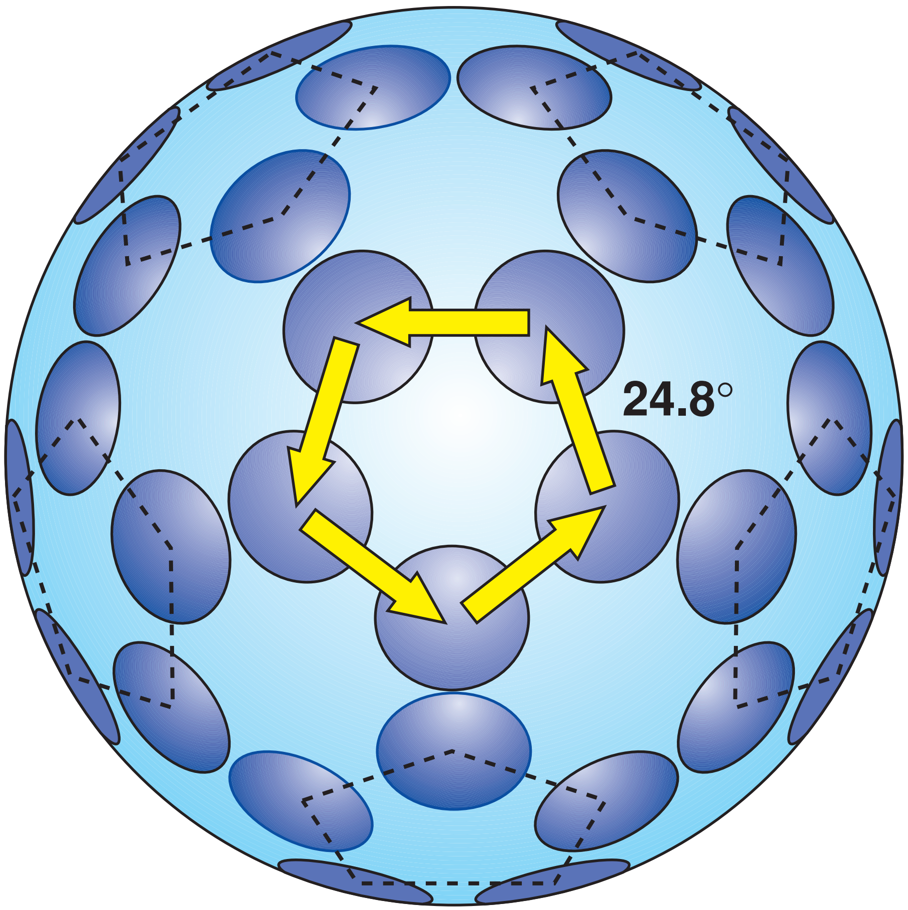
Shock-wave arrival at the rear surface and velocity for transparent targets are measured with a VISAR* diagnostic on OMEGA.

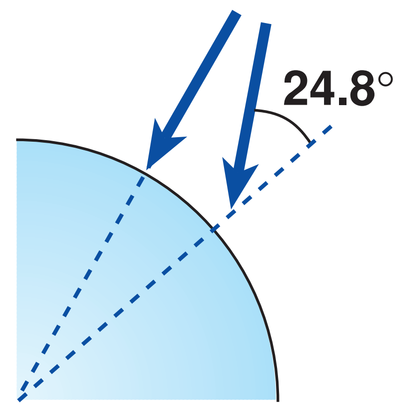
The position of the target and shock wave are determined by x-ray radiography with either a streak camera or a framing camera for targets opaque to the VISAR probe.

*Barker and Hollenbach, "Velocity Interferometry System for Any Reflector," J. Appl. Phys. 43, 4669 (1972).

TC6253

# OMEGA symmetry can be maintained for non-normal incidence implosions by repointing all beams

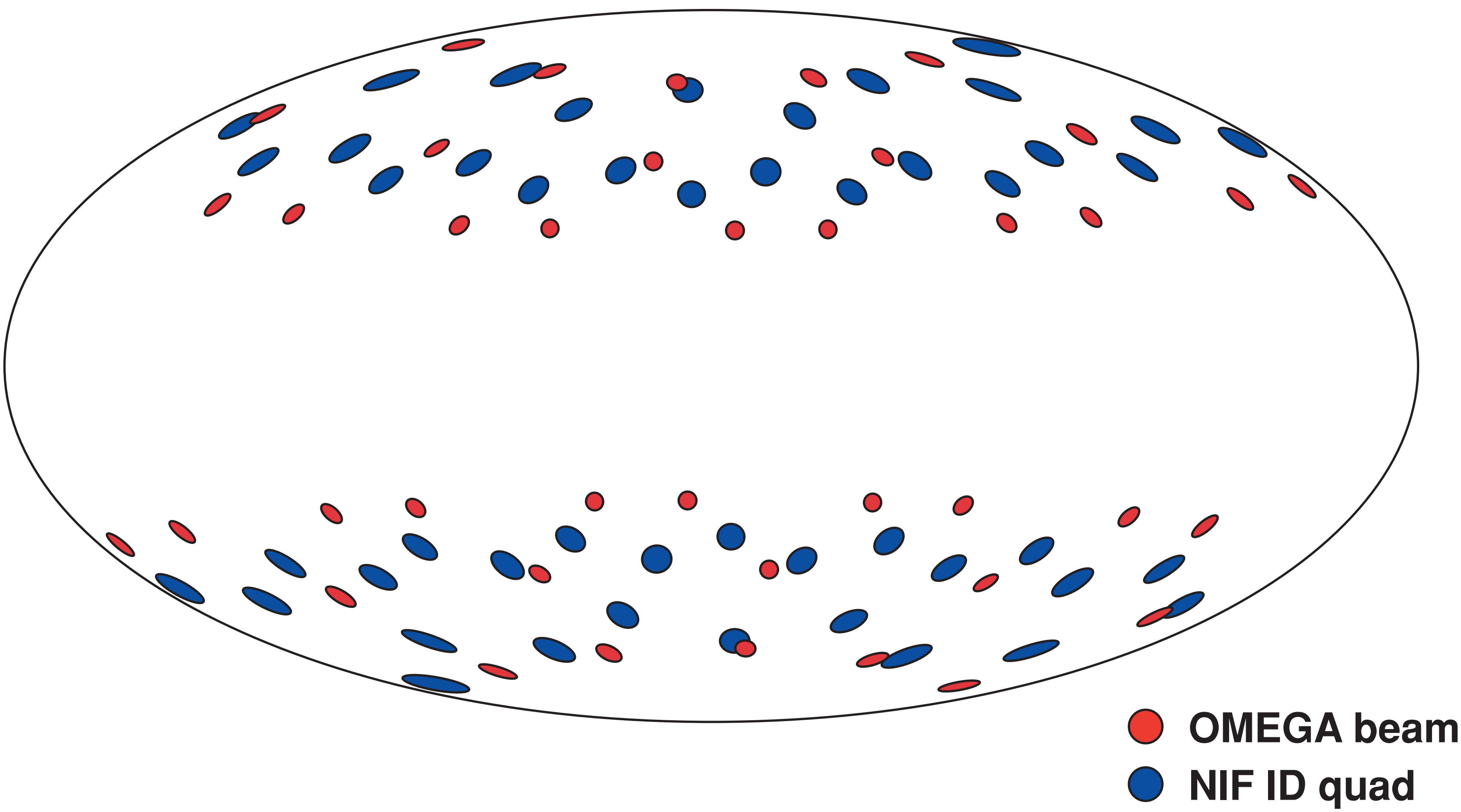



TC6248

# The NIF polar-direct-drive configuration with 48 quads can be approximated by repointing 40 beams of OMEGA







TC6247

Summary/Conclusions

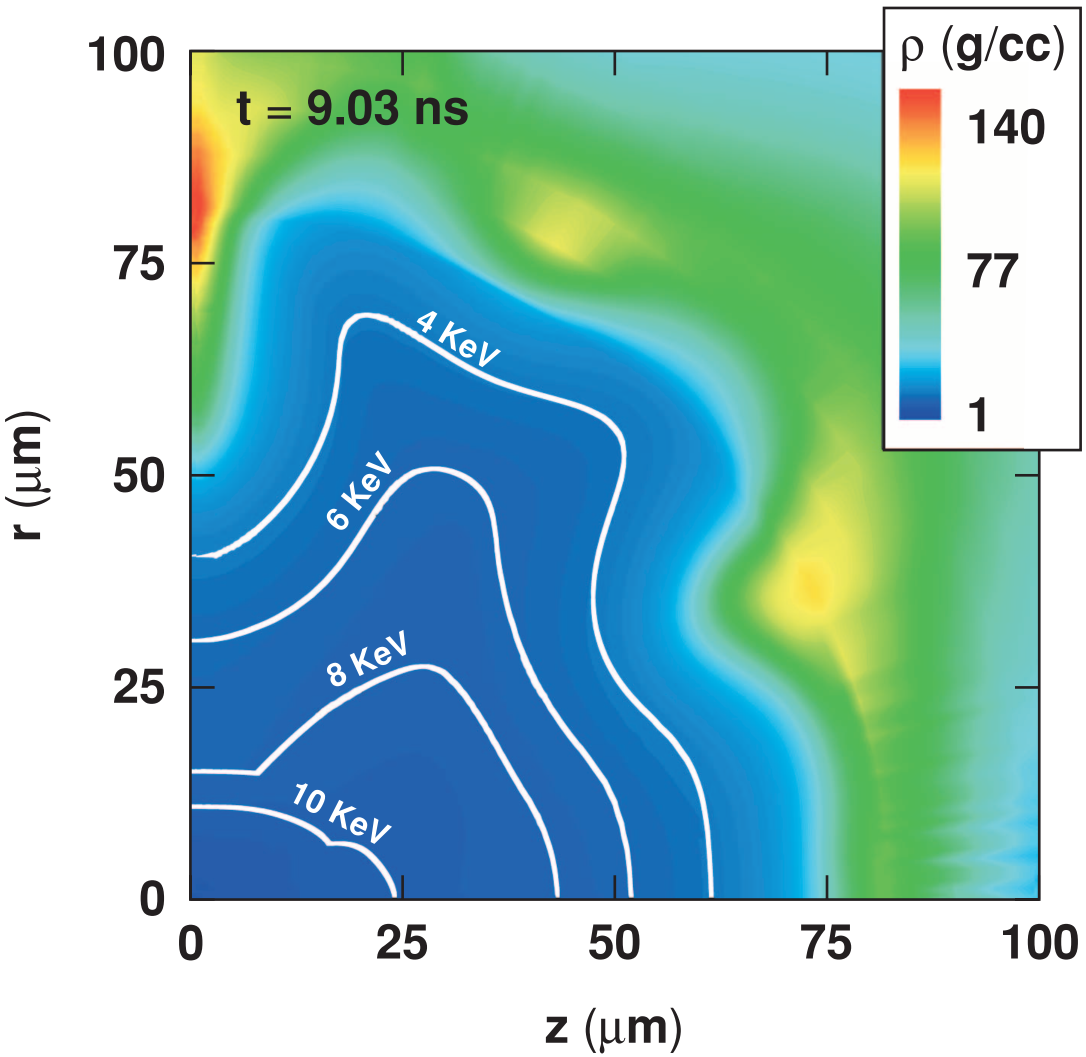
# Polar direct drive (PDD) is a promising technique to achieve ignition conditions using direct drive while the NIF is in the x-ray-drive configuration

- **PDD will employ all the techniques used in high-performance direct-drive target designs:**
  - **adiabat shaping**
  - **high laser–target coupling**
- **PDD is a more difficult design problem than "standard" direct drive.**
- **PDD simulations will be validated by experiments on the OMEGA laser.**

**PDD might be the best approach for fast-ignitor experiments and for high $\rho R$ diagnostic development.**

TC6375a

# PDD simulations are starting to show the onset of hot-spot formation (9.03 ns)




TC6319b