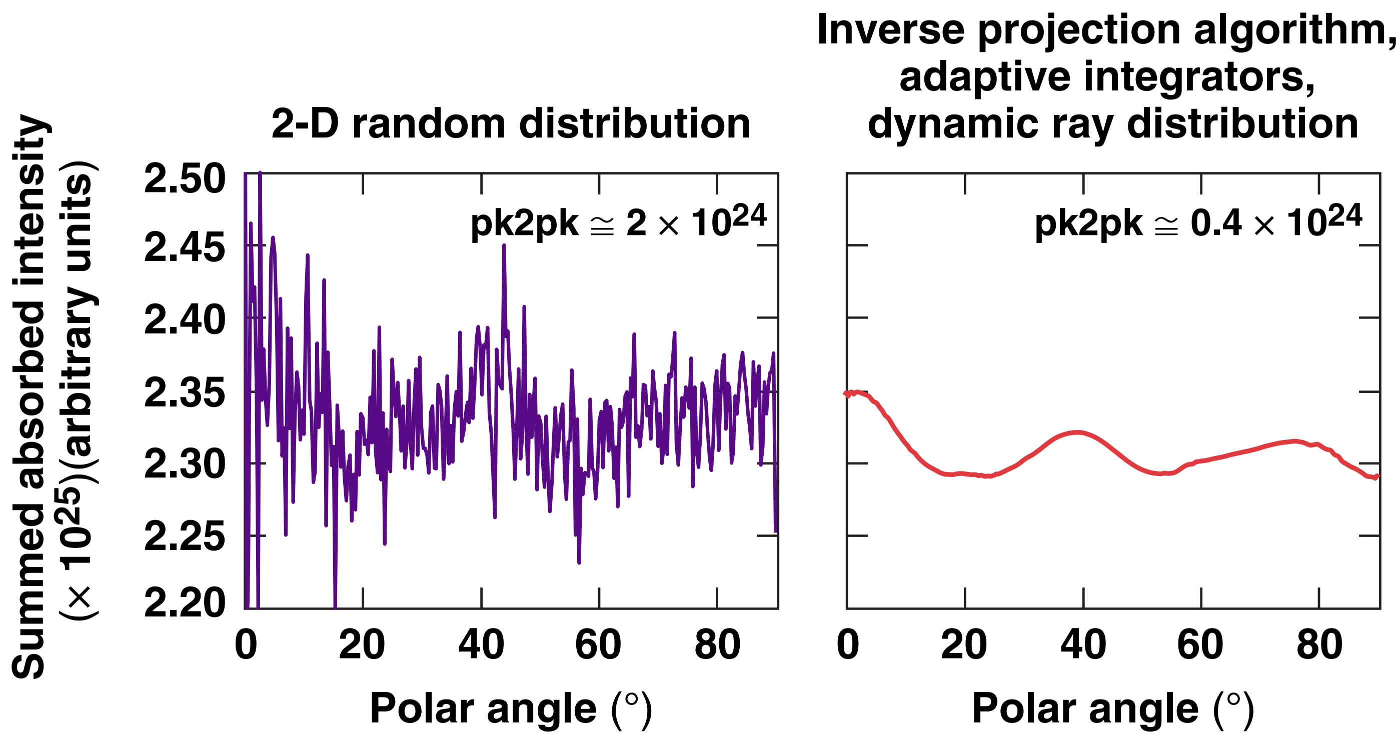
Imprint Simulations of 1.5-MJ NIF Implosions Using a Refractive 3-D Ray Trace with an Analytic SSD Model



1 Mrays at 50 ps

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

48th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Philadelphia, PA
30 October–3 November 2006

Summary

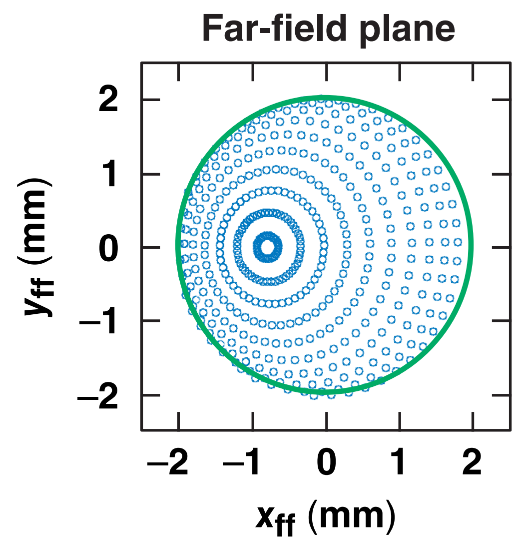
Imprint simulations of 2-D SSD in a 3-D refractive ray trace are possible by minimizing noise sources

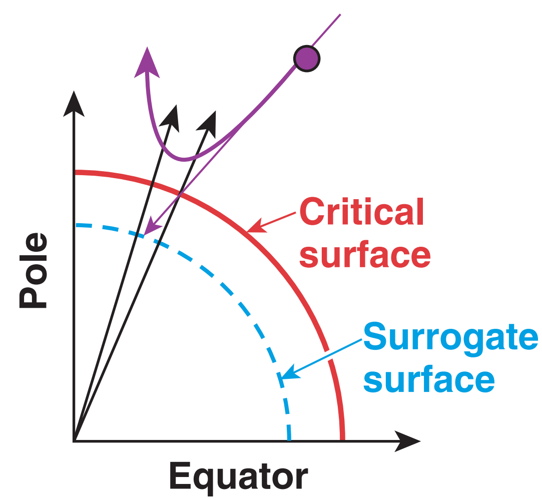
- Motivation: a 3-D ray trace is required to simulate imprint in a PDD target.*
- The 3-D ray trace accurately models the geometric effects of port angles and beam overlap.
- The imprint amplitude using the 3-D ray trace with minimized noise sources agrees with benchmarked symmetric direct-drive simulations.
- The imprint amplitude is ten times larger without minimizing the noise sources.

*Marozas *et al.*, Bull. Am. Phys. Soc. 49, 8180 (2004).

Three methods of reducing laser deposition noise are included in the 3-D ray trace

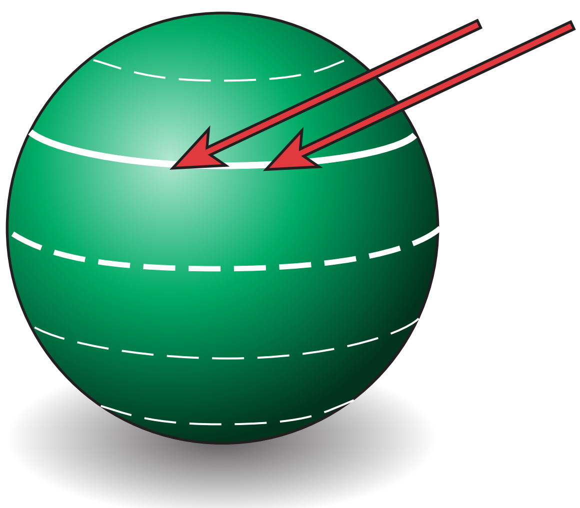
- Ray trace noise reduction
  - The initial ray-position distribution is defined by an inverse projection algorithm.
  - Adaptive integrators are employed.
  - Dynamic adjustment of the inverse-projection algorithm attempts to compensate for refraction.



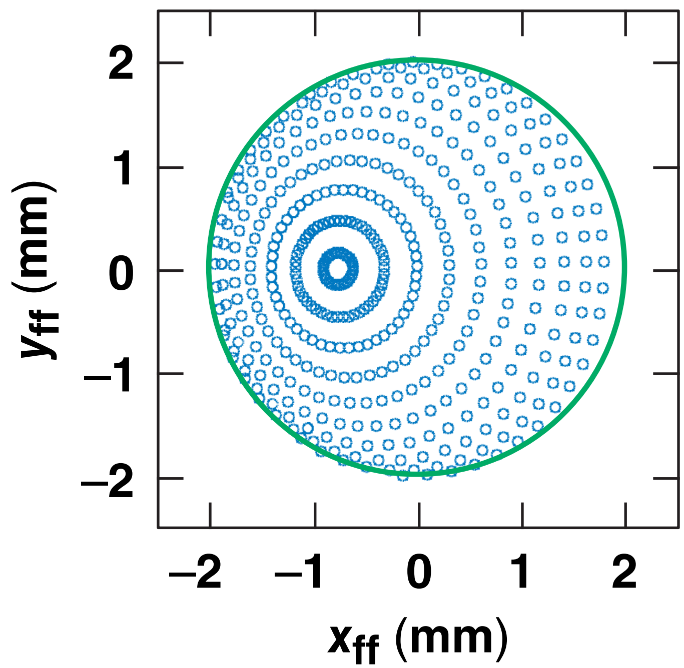


The inverse projection algorithm distributes the ray positions in the far field to point at the target's latitudes

Rays are pointed around the target's latitudes



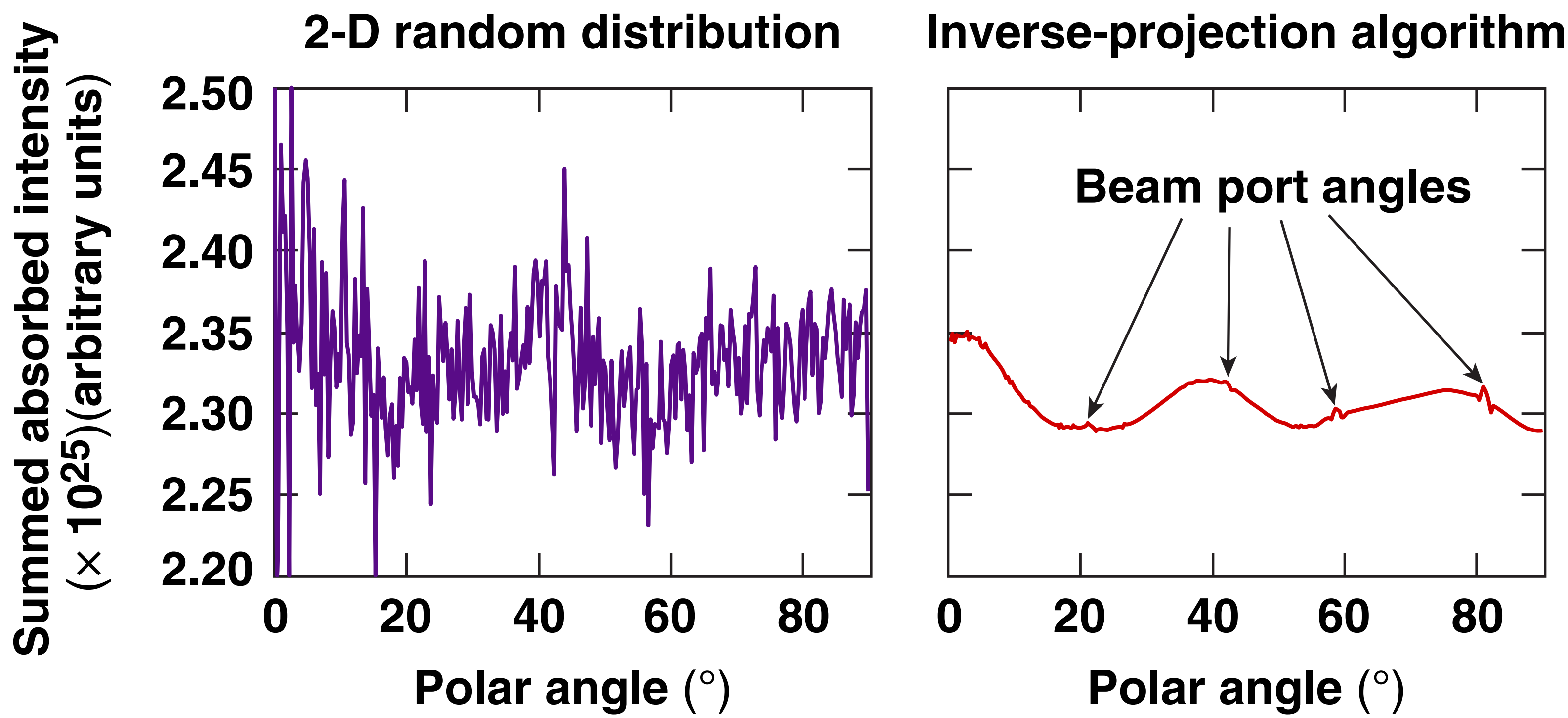
In the far-field plane, the latitudes map onto concentric ellipses



- **Rays are pointed to the initial target radius until the plasma atmosphere forms.**

TC7538

Ray-position distribution in the far-field plane dramatically affects the laser deposition noise

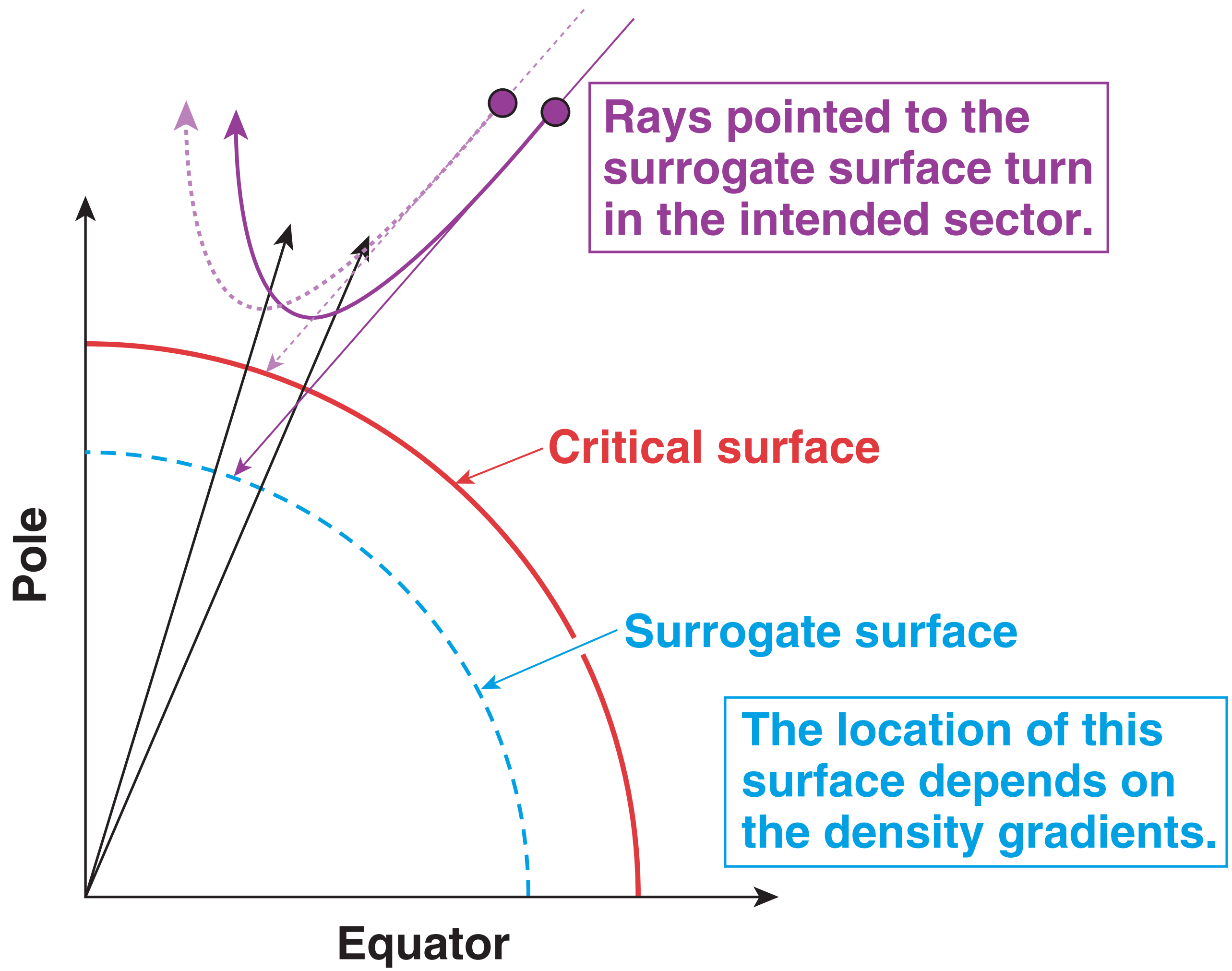


Both methods use the same adaptive integrators.

TC7539

Dynamic adjustment of the inverse-projection algorithm attempts to compensate for refraction

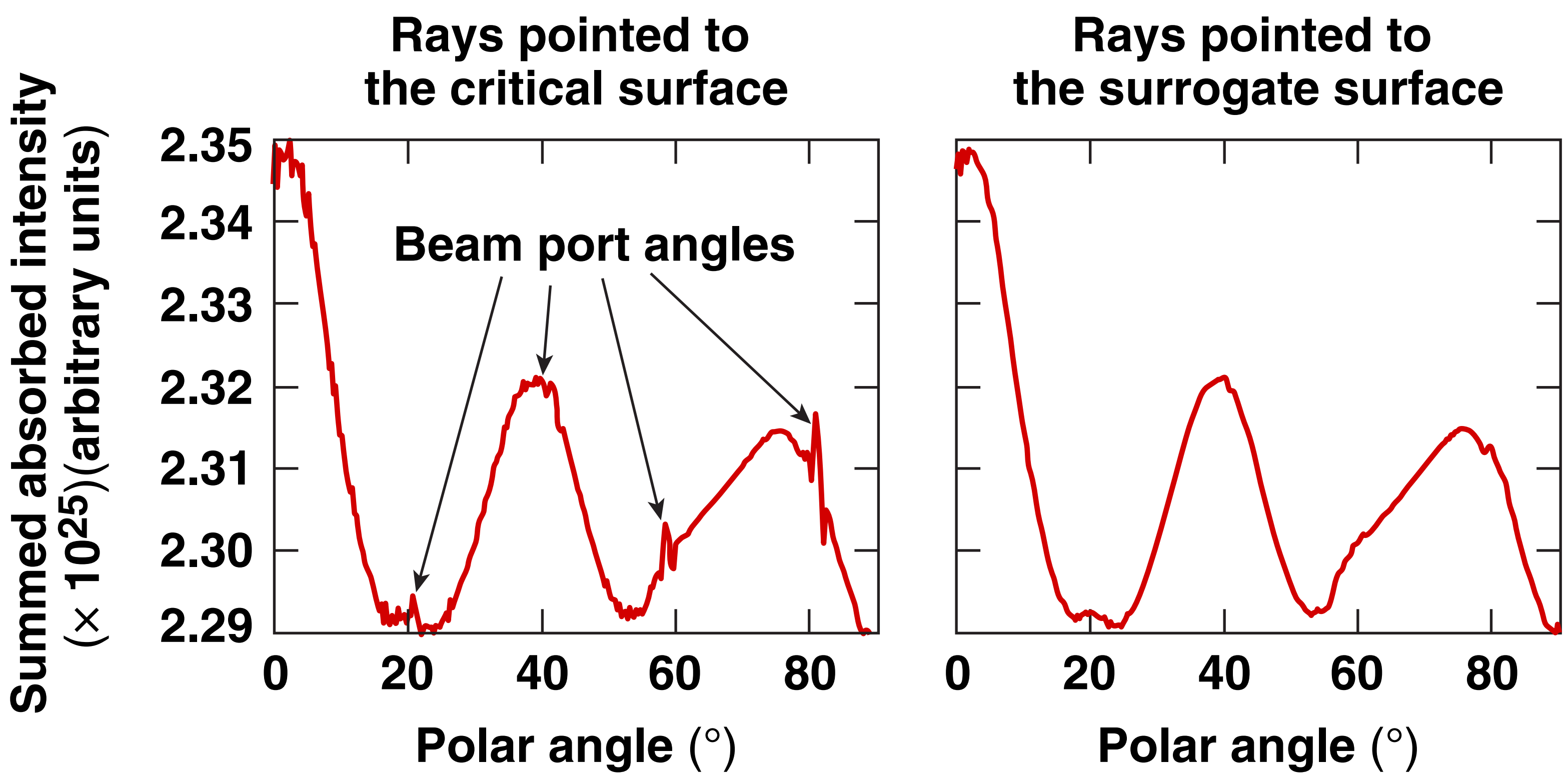
- Rays are pointed to a surrogate surface interior to the critical surface.



TC7541

The dynamic inverse-projection algorithm accounts for refraction and helps to maintain smooth deposition

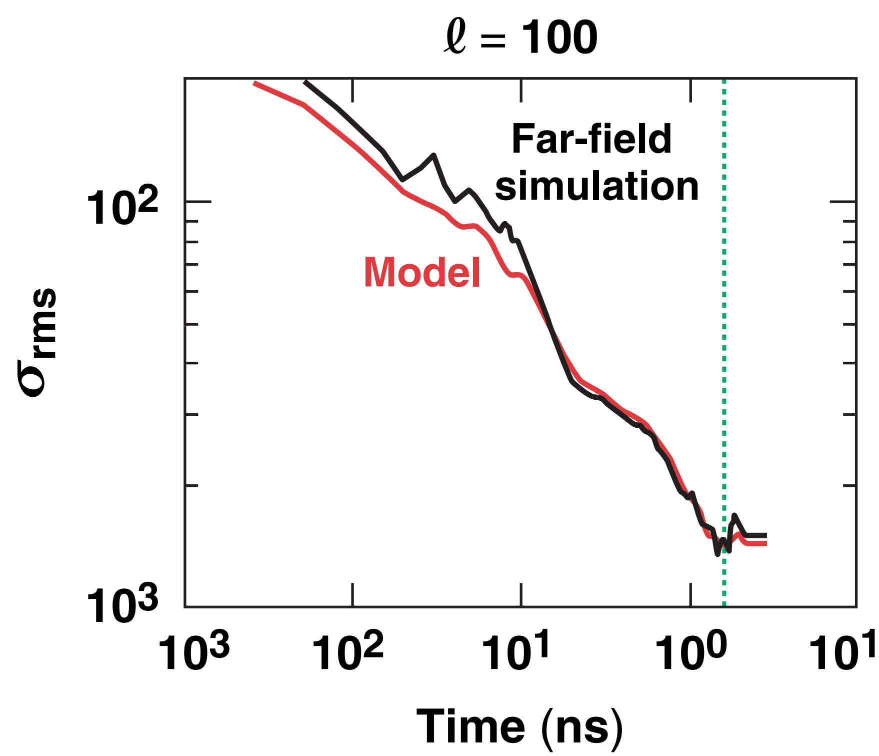
- As the plasma atmosphere expands, the surrogate surface moves further into the interior.
- An optimization algorithm tunes the surrogate radius for the beam's peak energy density's angle of incidence.



TC7542

The analytic 2-D SSD model accurately calculates the time-integrated ℓ-mode amplitudes*

- The modal phases are assumed to be stationary while the modal amplitudes are adjusted to match the time-integrated behavior
- Works for arbitrary pulse shapes
- Provides a continuous evolution and reduces spurious imprint noise of stochastic models
- Works in conjunction with the 3-D ray trace or the sector ray trace

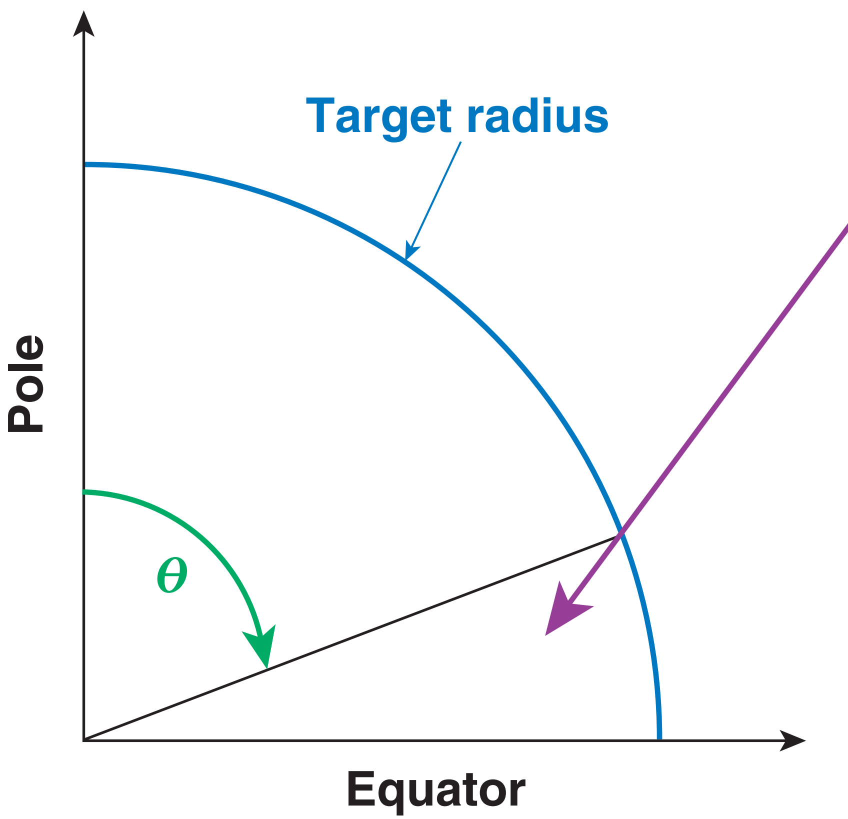


TC7543

*Marozas *et al.*, Bull. Am. Phys. Soc. <u>47</u>, 999 (2002).

The analytic 2-D SSD model defines the time-integrated laser uniformity on the initial target radius

- Cosine/Legendre modes that match the hydrodynamic boundary conditions are used.

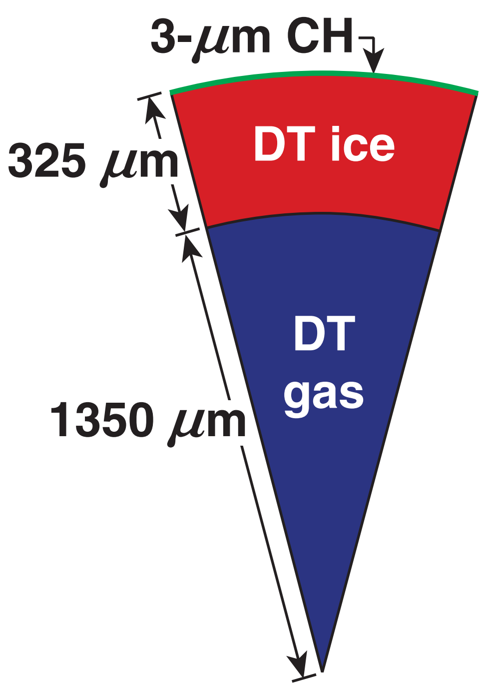


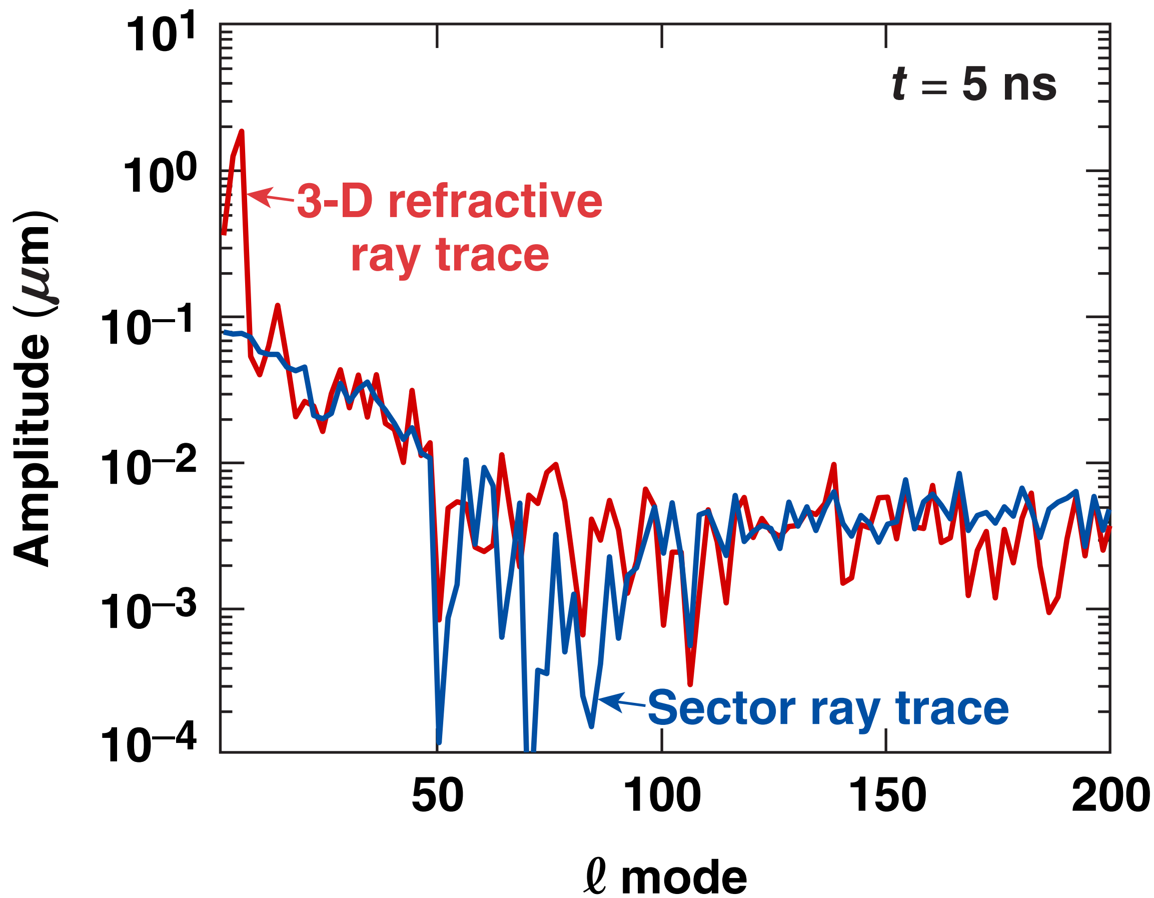
- A straight-line trajectory defines the polar angle that the ray intersects when refraction is ignored.
- This intersection determines the perturbation amplitude given to the ray prior to the 3-D refractive ray trace.

TC7544

The imprint amplitude modeled by the 3-D refractive ray trace agrees with the sector ray trace*

- The NIF 1.5-MJ point design, ℓ modes = 2:2:200, 750 K rays



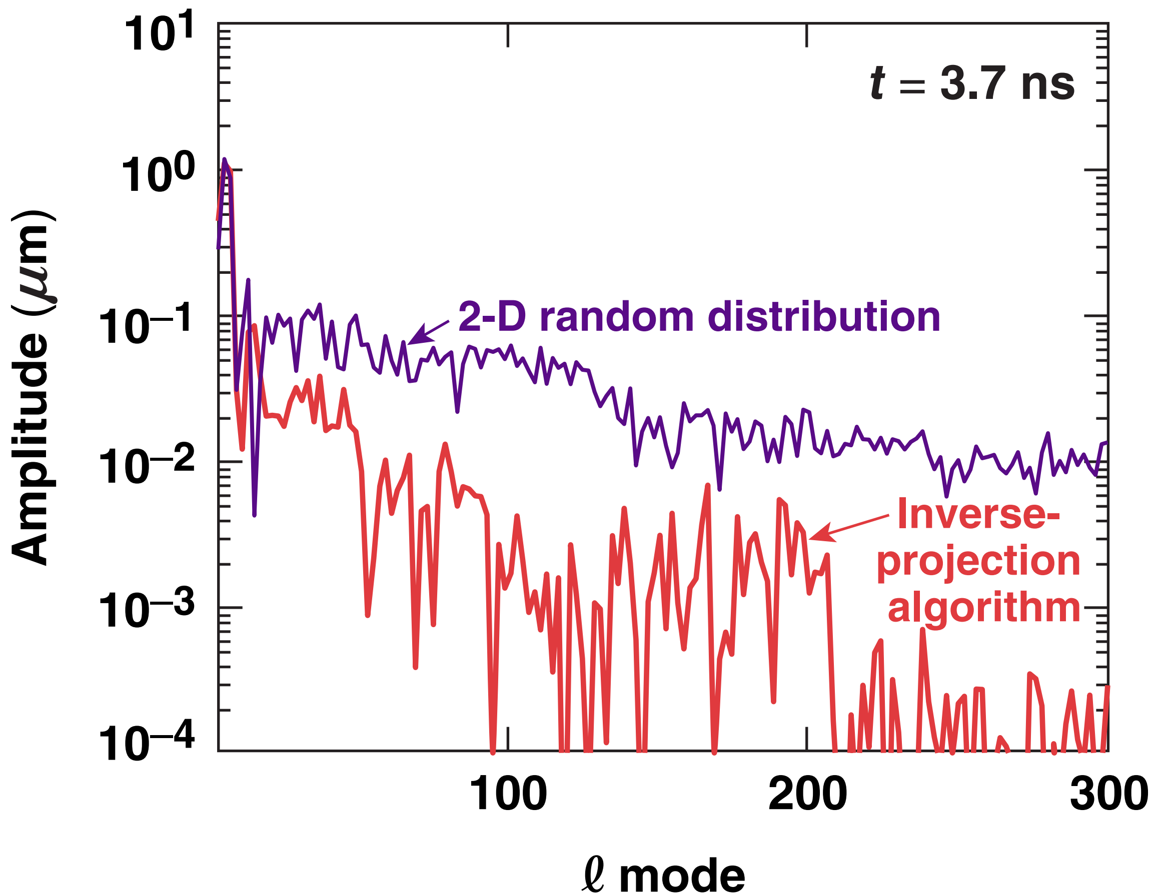


TC7545

*Marozas *et al.*, Bull. Am. Phys. Soc. 48, 756 (2003).

The improved noise characteristics are evident when imprint amplitude is compared to other methods

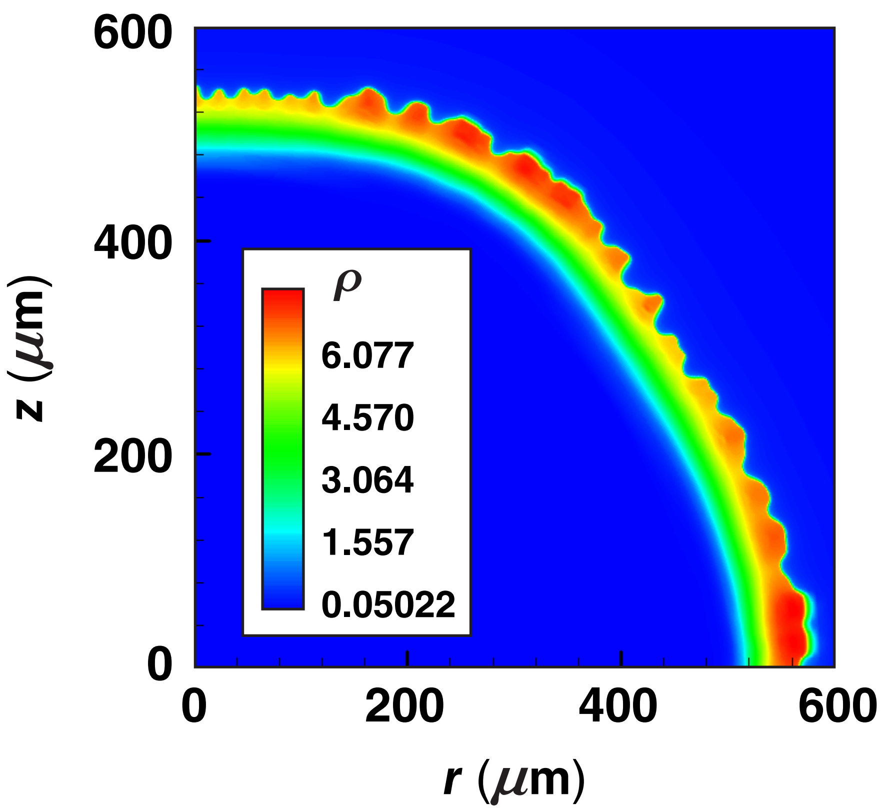
- The NIF 1.5-MJ point design, ℓ modes = 2:2:200, 750 K rays

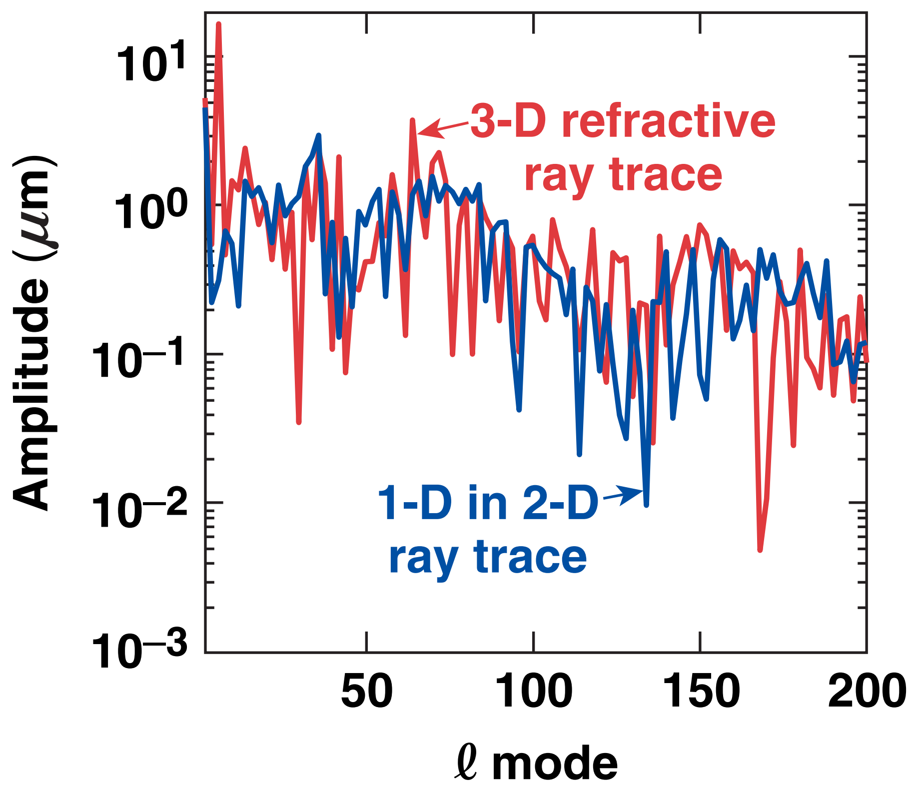


TC7546

The ℓ-mode amplitude growth predicted by the 3-D refractive ray trace agrees with the sector ray trace

- Near the end of the pulse; t = 8.6 ns





TC7637

Imprint simulations of 2-D SSD in a 3-D refractive ray trace are possible by minimizing noise sources

UR LLE

- Motivation: a 3-D ray trace is required to simulate imprint in a PDD target.*
- The 3-D ray trace accurately models the geometric effects of port angles and beam overlap.
- The imprint amplitude using the 3-D ray trace with minimized noise sources agrees with benchmarked symmetric direct-drive simulations.
- The imprint amplitude is ten times larger without minimizing the noise sources.

*Marozas *et al.*, Bull. Am. Phys. Soc. 49, 8180 (2004).