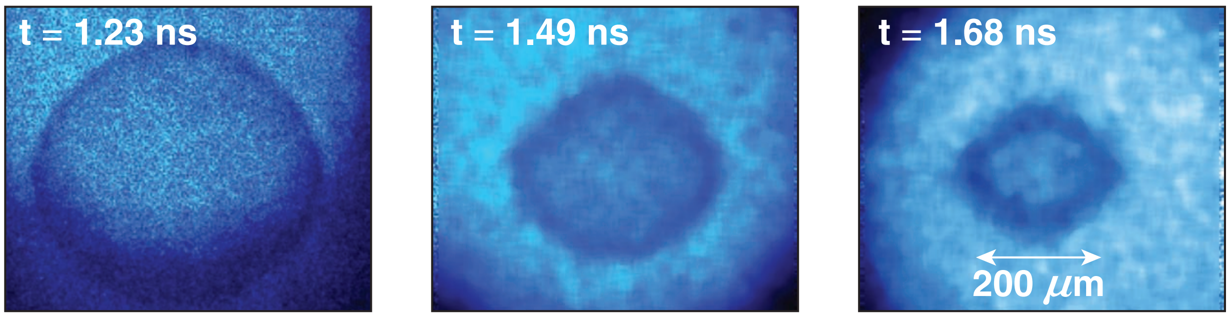
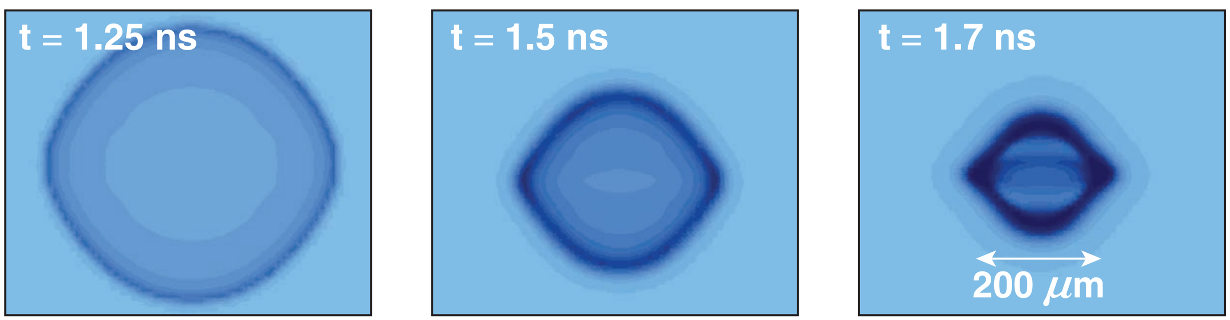
Progress in Polar-Direct-Drive Simulations and Experiments

OMEGA shot 38502 (TIM 5 view)



***DRACO*/Spect3D (simulation)**



47th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Denver, CO
24–28 October 2005

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

Summary

Polar direct drive (PDD) is a viable path toward ignition on the National Ignition Facility (NIF)

- OMEGA
  - Experiments and simulations have been performed on two types of PDD targets: standard and Saturn.
  - Experiments confirm simulation predictions.

- NIF
  - Substantial gain is predicted for cryogenic DT CH foam PDD designs.
  - Shell and shock-front uniformity are critical for ignition.

TC7114

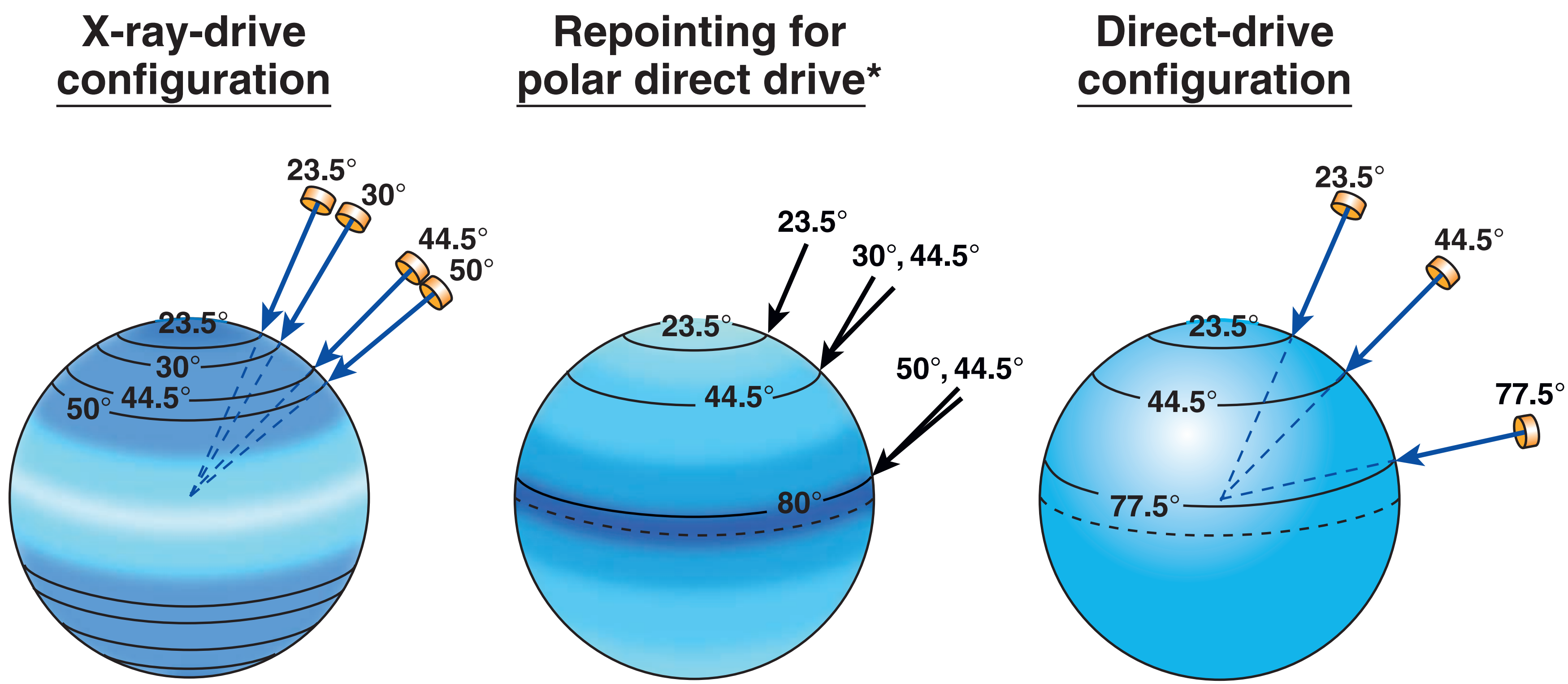
Contributors

F. J. Marshall, I. V. Igumenshchev, S. Skupsky, R. S. Craxton,
M. J. Bonino, T. J. B. Collins, R. Epstein, V. Yu. Glebov,
D. Jacobs-Perkins, J. Kilkenny, J. P. Knauer, R. L. McCrory,
P. W. McKenty, D. D. Meyerhofer, S. G. Noyes, P. B. Radha,
T. C. Sangster, W. Seka, and V. A. Smalyuk

Outline

- PDD concept
  - repointing of beams
  - 40-beam OMEGA emulates the NIF x-ray drive configuration
- OMEGA
  - standard PDD
  - Saturn PDD
- NIF
  - prospects for PDD ignition

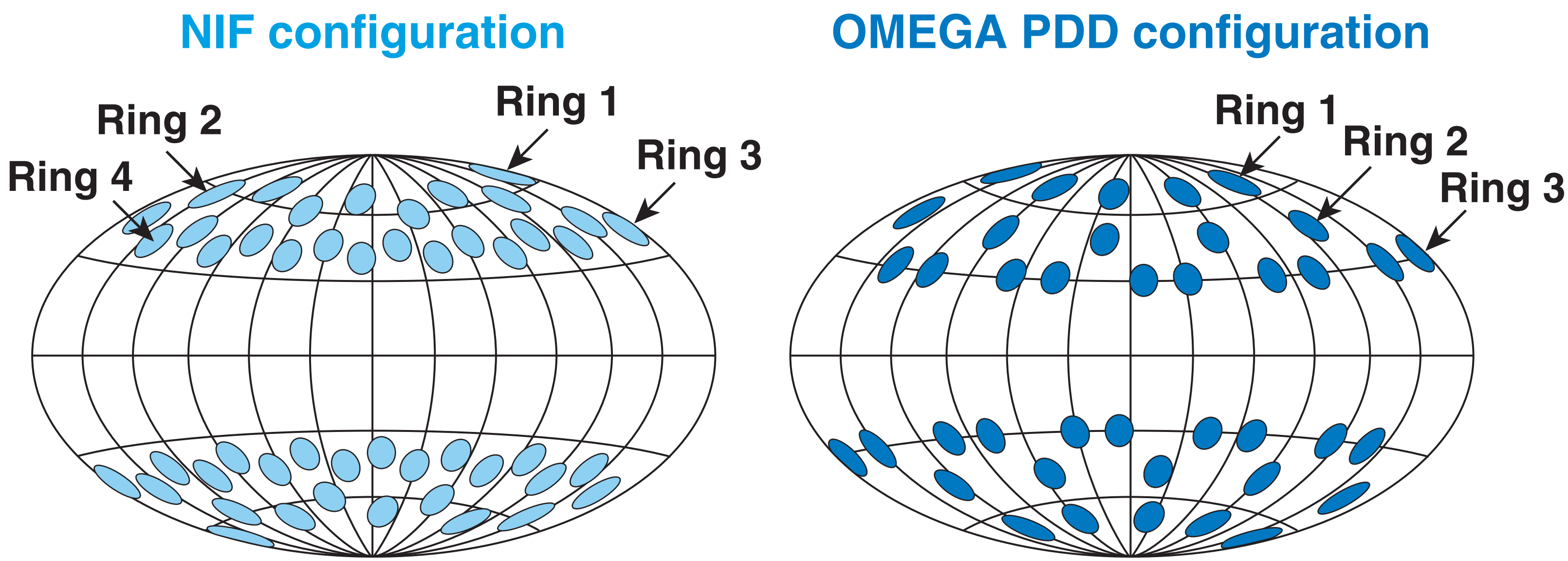
PDD can achieve ignition while the NIF is in the x-ray-drive configuration



*Pointing for standard PDD

TC7193

A 40-beam subset of the 60-beam OMEGA laser emulates the NIF x-ray-drive configuration



- OMEGA experiments are being used as a proof of principle for the NIF.

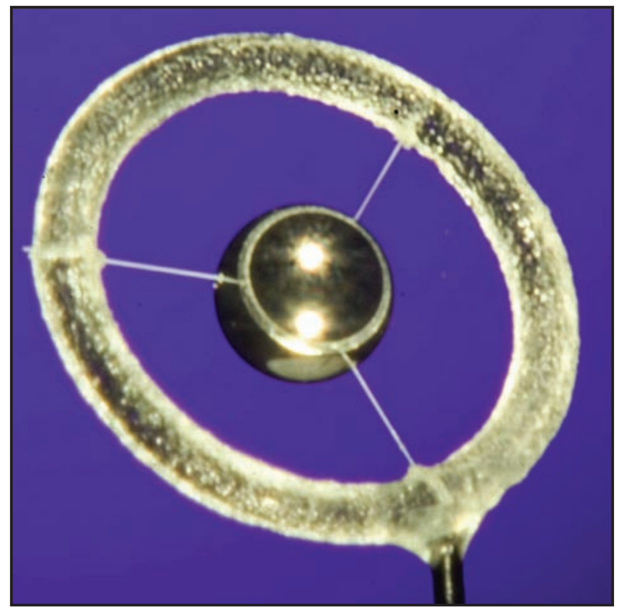
Outline

- PDD concept
  - repointing of beams
  - 40-beam OMEGA emulates the NIF x-ray drive configuration
- OMEGA
  - standard PDD
  - Saturn PDD
- NIF
  - prospects for PDD ignition

Two types of PDD target designs are being investigated: standard and Saturn

- **Standard design**

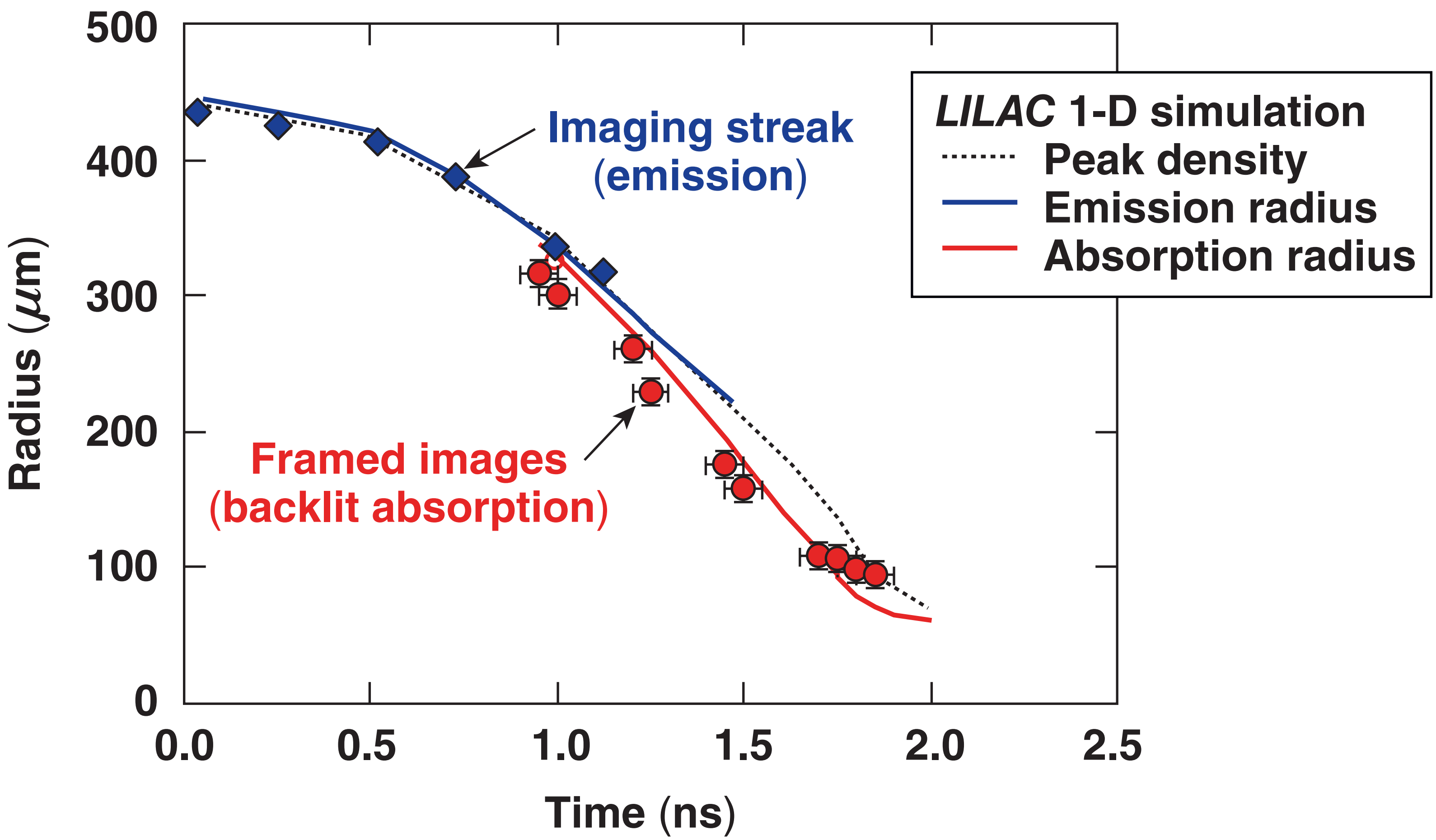
- **Saturn design***
  - CH ring redirects laser energy toward the equator



*R. S. Craxton and D. Jacobs-Perkins, Phys. Rev. Lett. 94, 095002 (2005).

Standard PDD implosions show nearly 1-D behavior

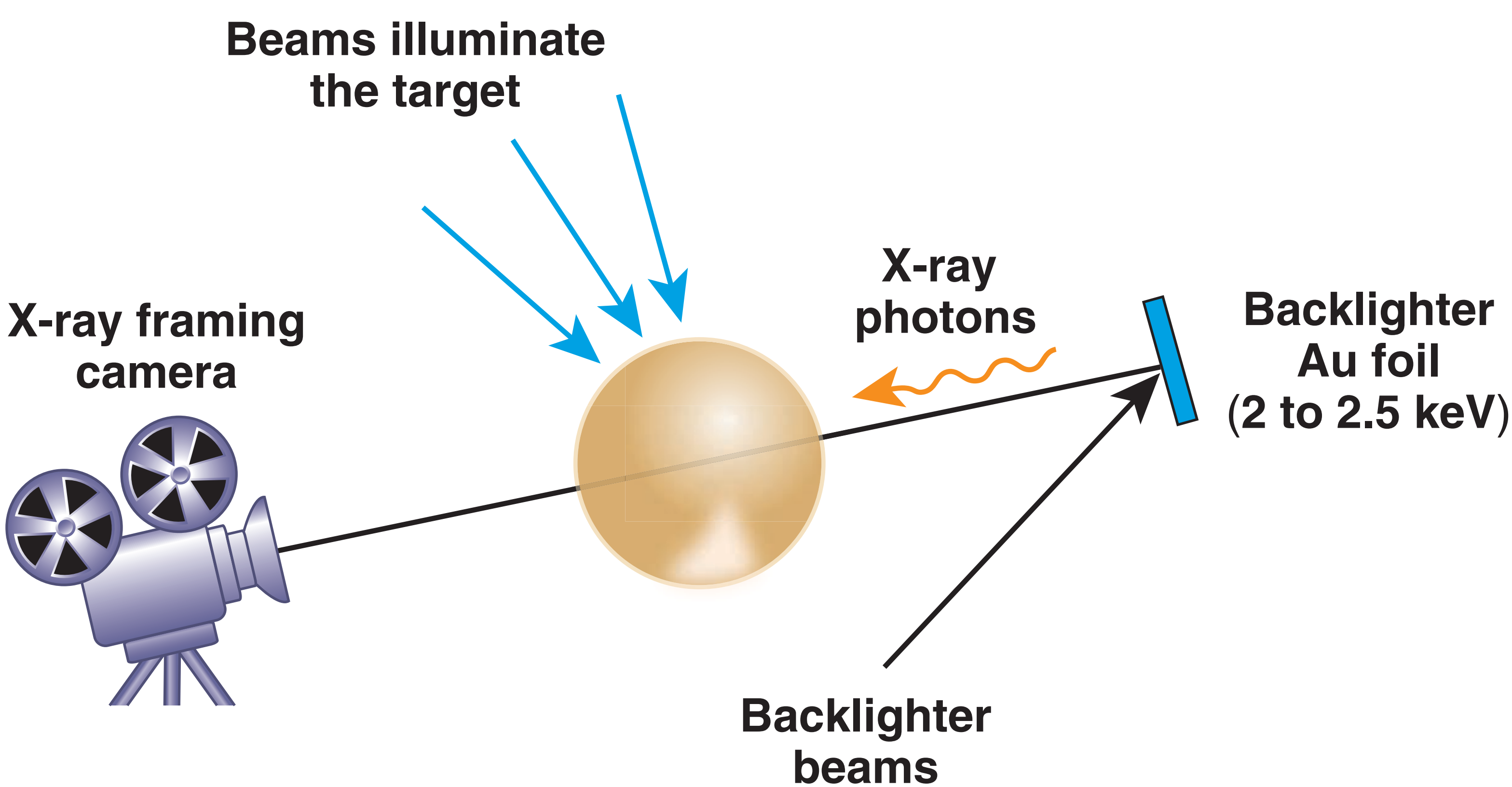
OMEGA shot 34669
20-μm-thick CH shell filled with 15-atm D_2



E14033

Backlit x-ray framing cameras diagnose the shell during an implosion

OMEGA PDD Experimental Schematic



PDD simulations are carried out with *DRACO*

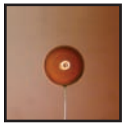
- Full 3-D raytrace for laser energy deposition
  - Necessary to implement repointing of beams
  - Can include mispointing and energy imbalance errors
- Different hydrodynamic implementations
  - Arbitrary Lagrangian Eulerian (ALE)
  - Sliding grid Eulerian
- Radiation transport; important for Saturn PDD simulations

TC7264

Targets with and without the Saturn ring were shot on OMEGA using the pointing designed for Saturn PDD

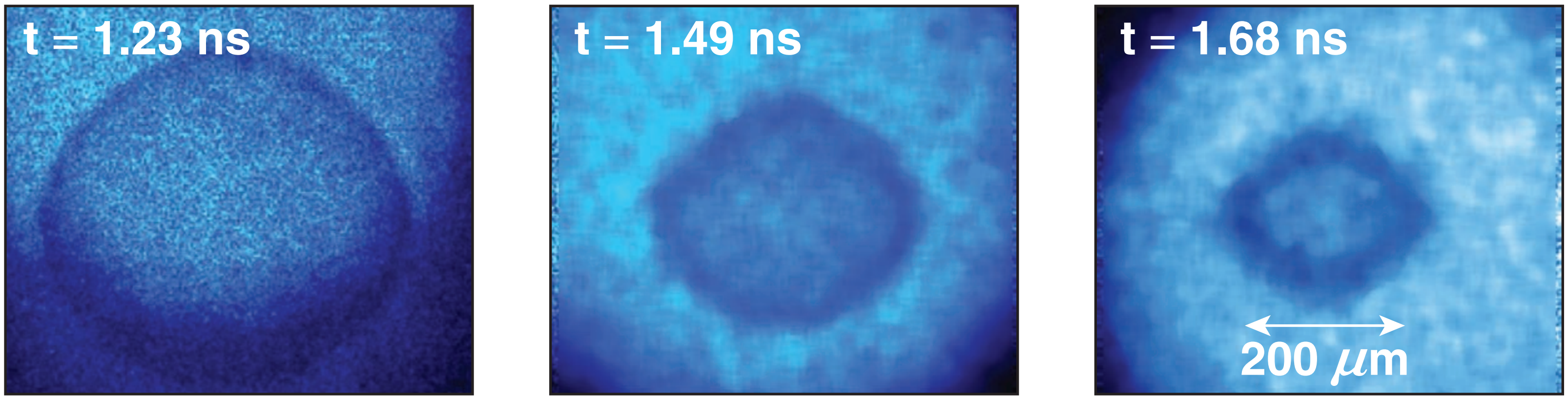
- Evaluate the ability to model PDD experiments with *DRACO* simulations

- Demonstrates the effect of the Saturn ring
  - the Saturn ring redirects laser energy towards the equator
  - increases the drive around the equator

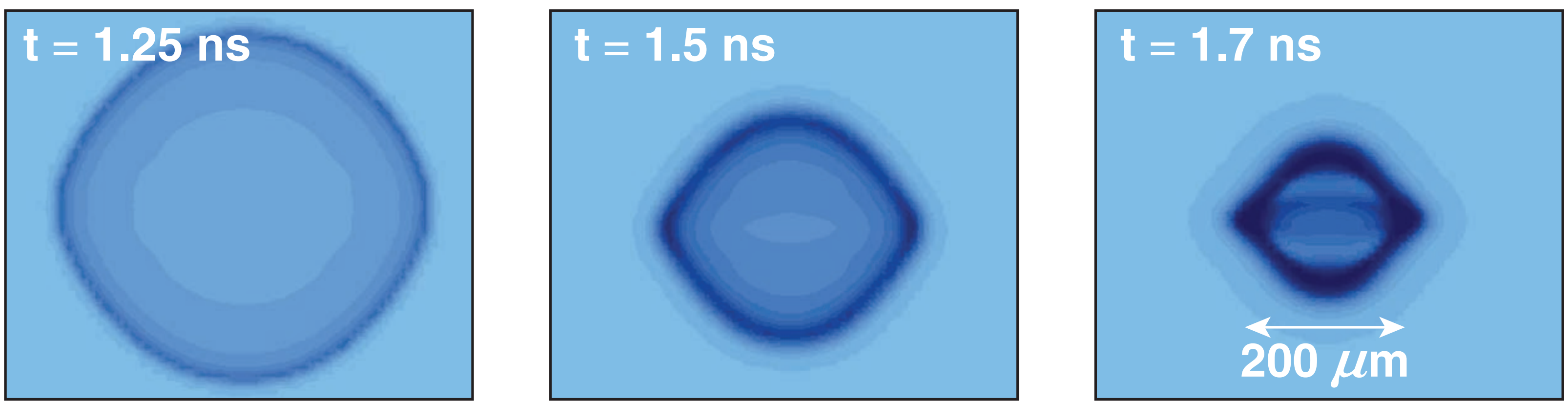


Experiments and simulations for Saturn pointing without a ring are in excellent agreement

OMEGA shot 38502 (TIM 5 view)

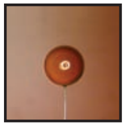


DRACO/Spect3D* (simulation)

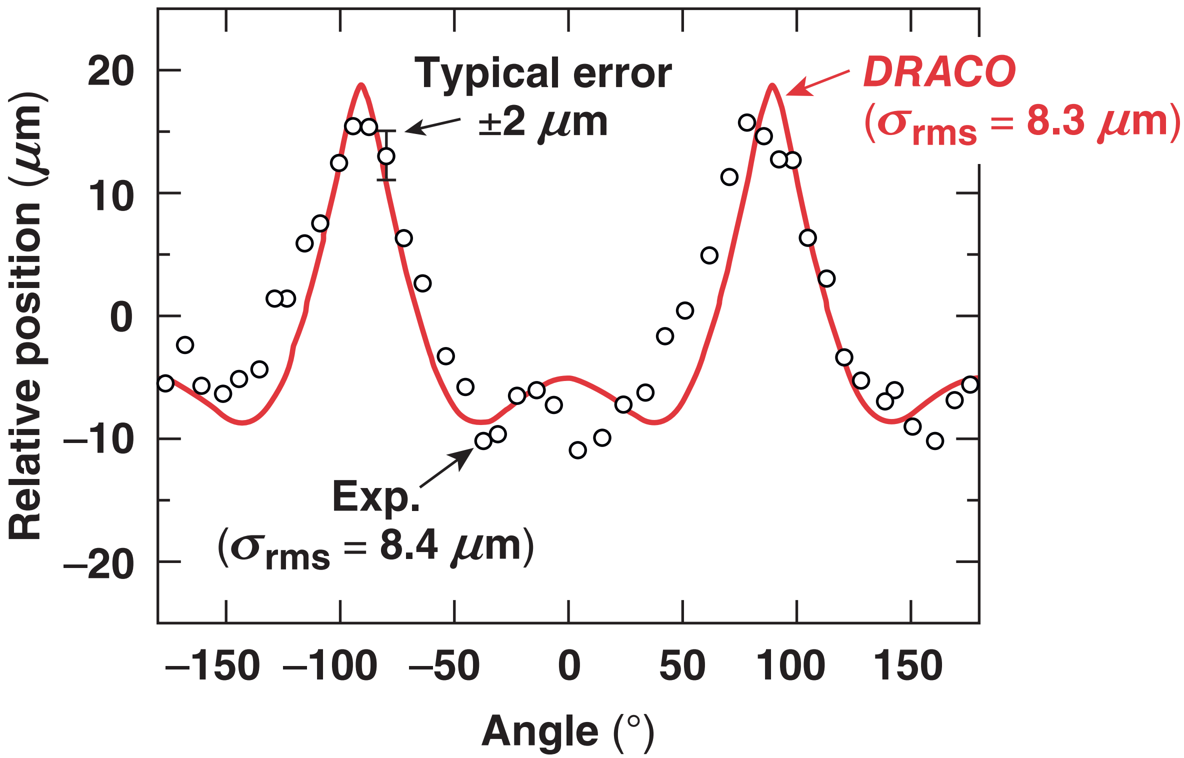


TC7254

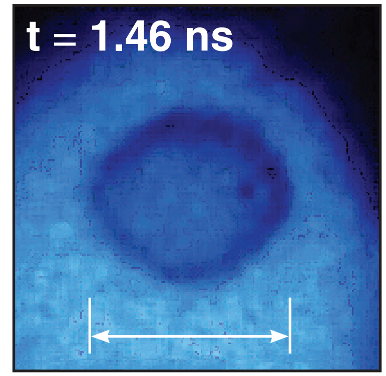
*Post processed with Spect3D, PRISM Computational Sciences, Madison, WI



* Analysis of the experimental and simulated radiographs show an enhanced equatorial perturbation

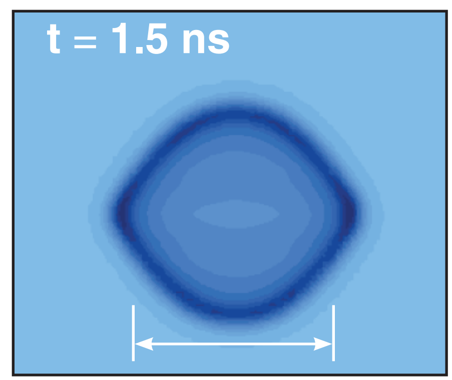


TIM 4 view ($\theta_V = 63°$)



200 μm

DRACO/Spect3D simulation



200 μm

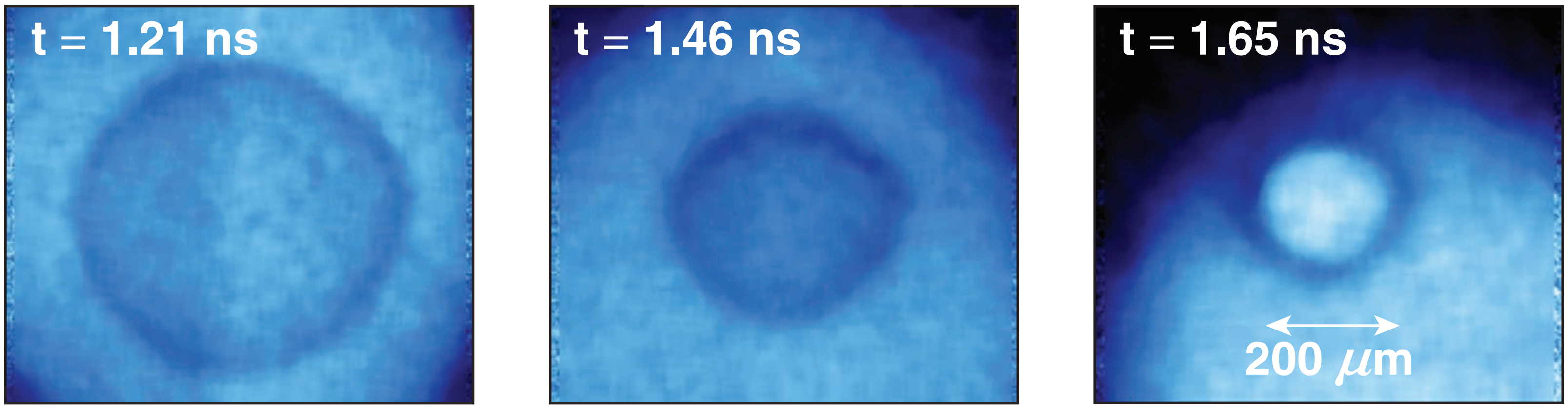
*Saturn PDD pointing without a ring was used to evaluate the effect of the CH ring.

TC7119

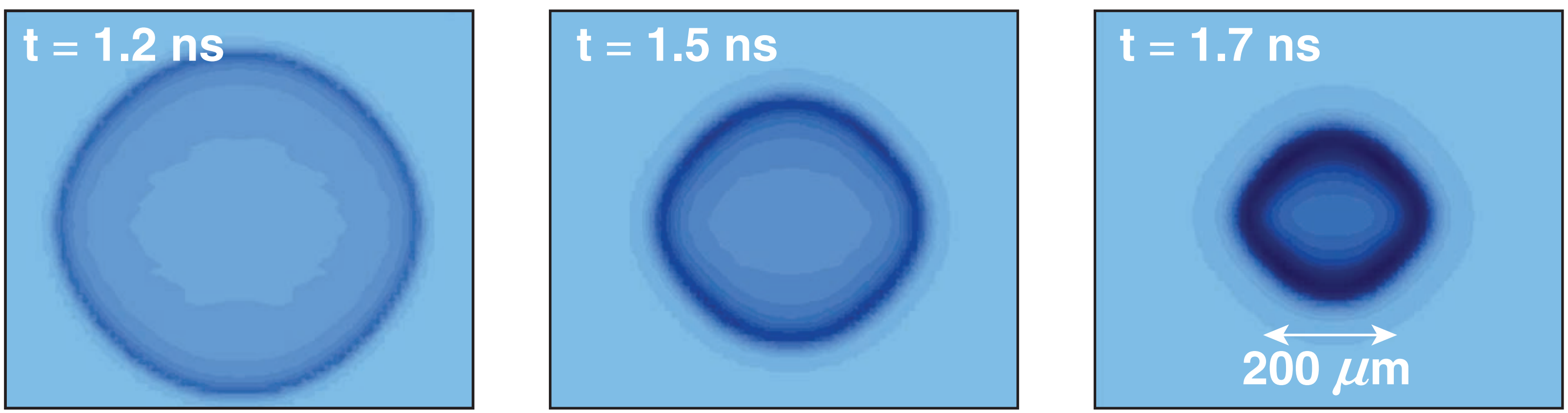
Saturn PDD experiments and simulations also show excellent agreement

UR LLE

OMEGA shot 39281 (TIM 4 view)

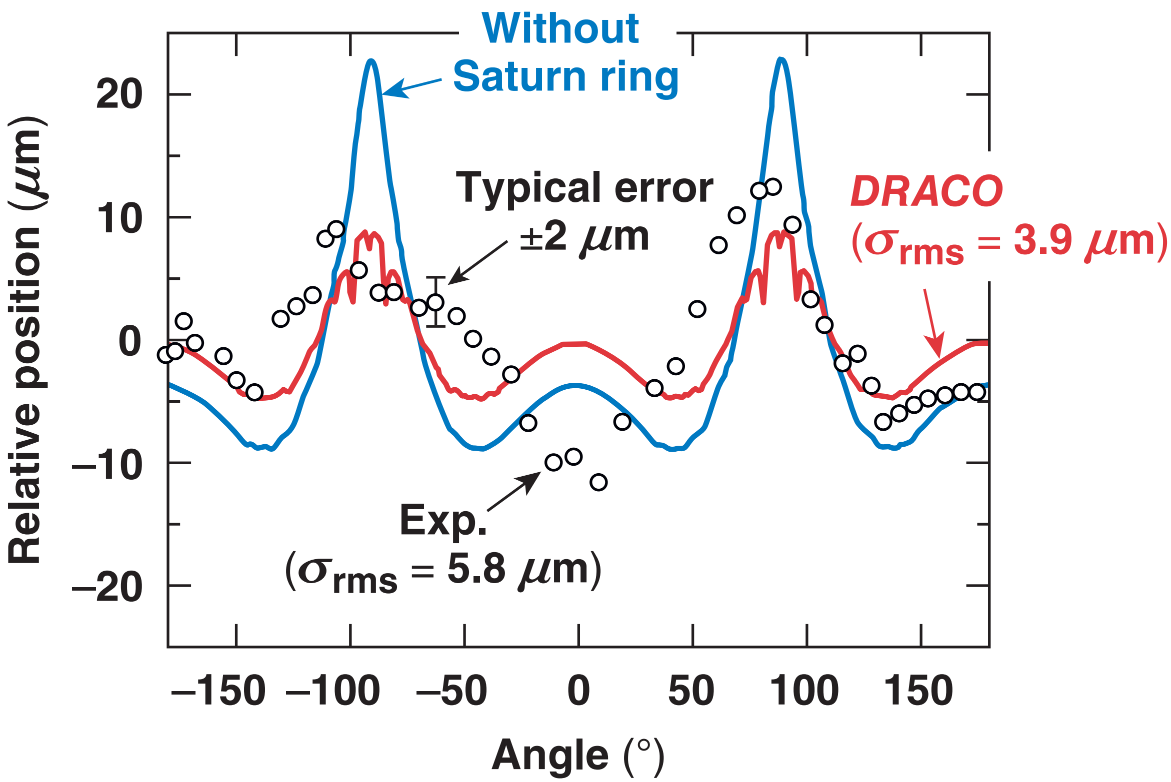


DRACO/Spect3D (simulation)

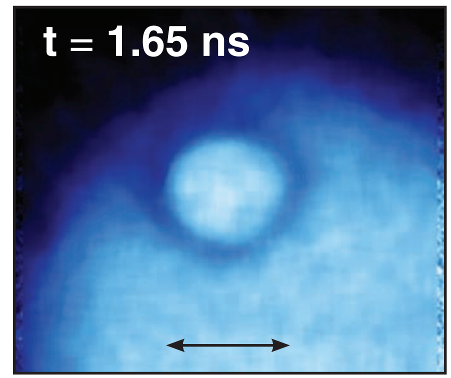


TC7120

Analysis of the Saturn radiographs shows a reduction of the equatorial perturbation

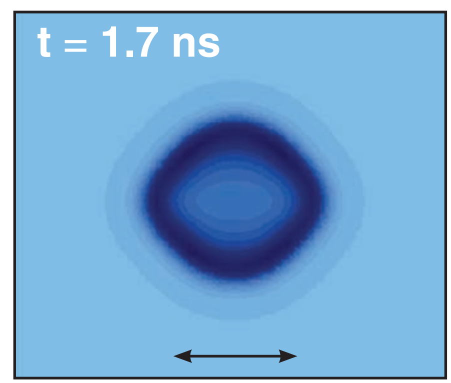


TIM 4 view (θ_v = 63°)



200 μm

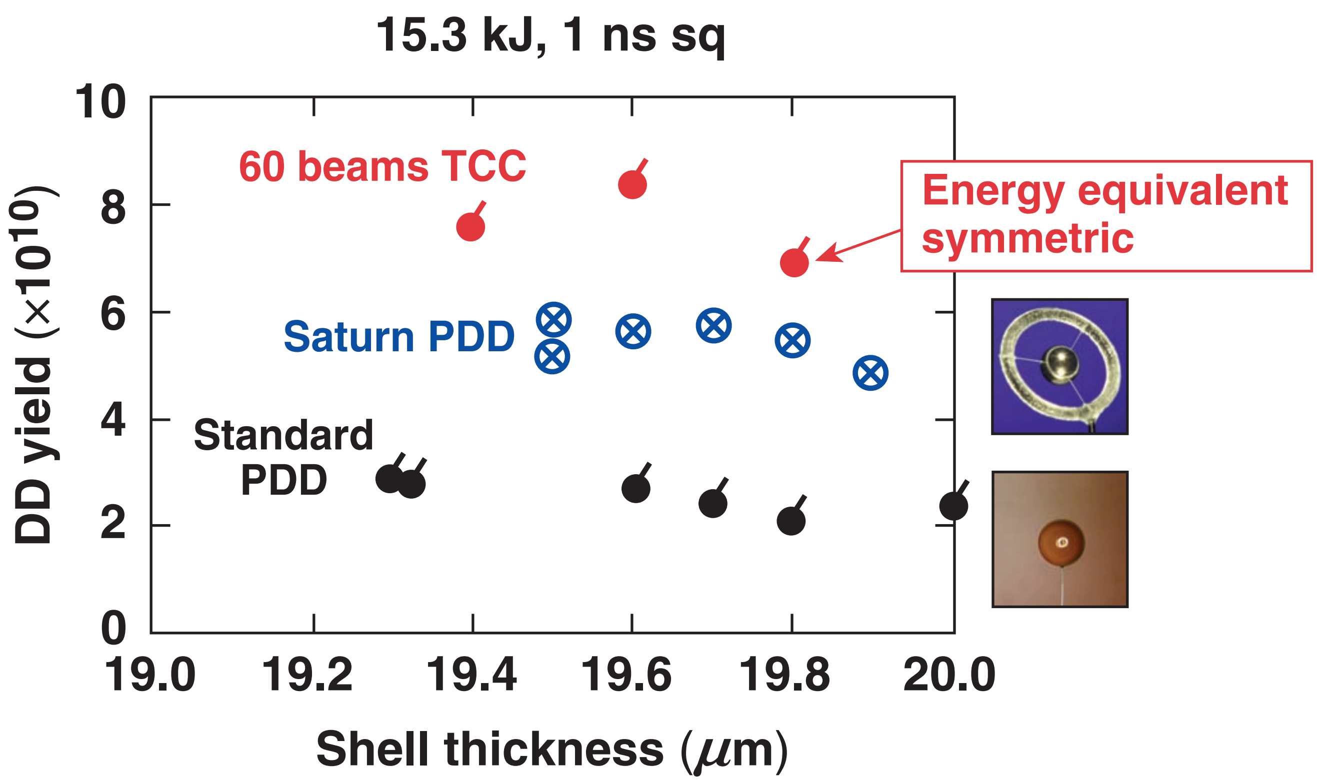
DRACO/Spect3D simulation



200 μm

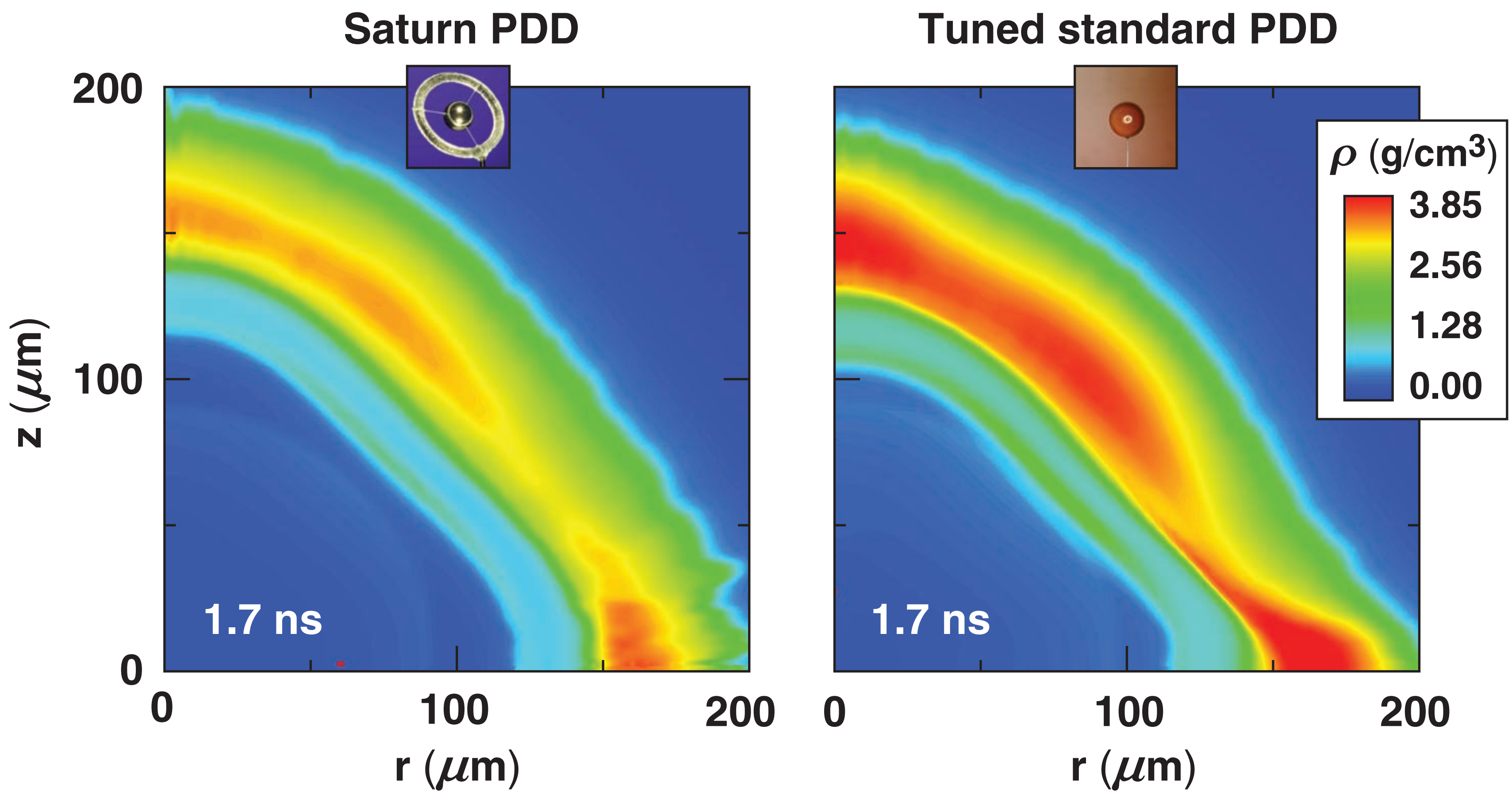
TC7121

Saturn targets obtained the best PDD experimental yields to date relative to energy-equivalent symmetric targets



The yields from Saturn targets are 70% of energy equivalent symmetric yields.

Standard PDD with tuned pointing and spot shapes is predicted to perform as well as the current Saturn design



σ_{rms} = 3.8 μm
Yield = 60%*

σ_{rms} = 4.8 μm
Yield = 59%*

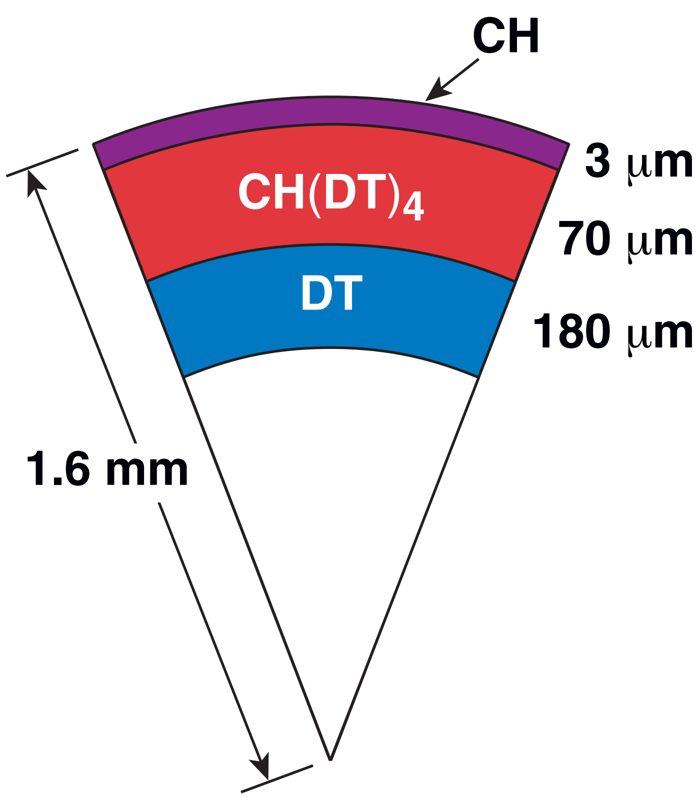
*Yields are relative to energy equivalent symmetric drive simulations.

TC7122

Outline

- PDD concept
  - repointing of beams
  - 40-beam OMEGA emulates the NIF x-ray drive configuration
- OMEGA
  - standard PDD
  - Saturn PDD
- NIF
  - prospects for PDD ignition

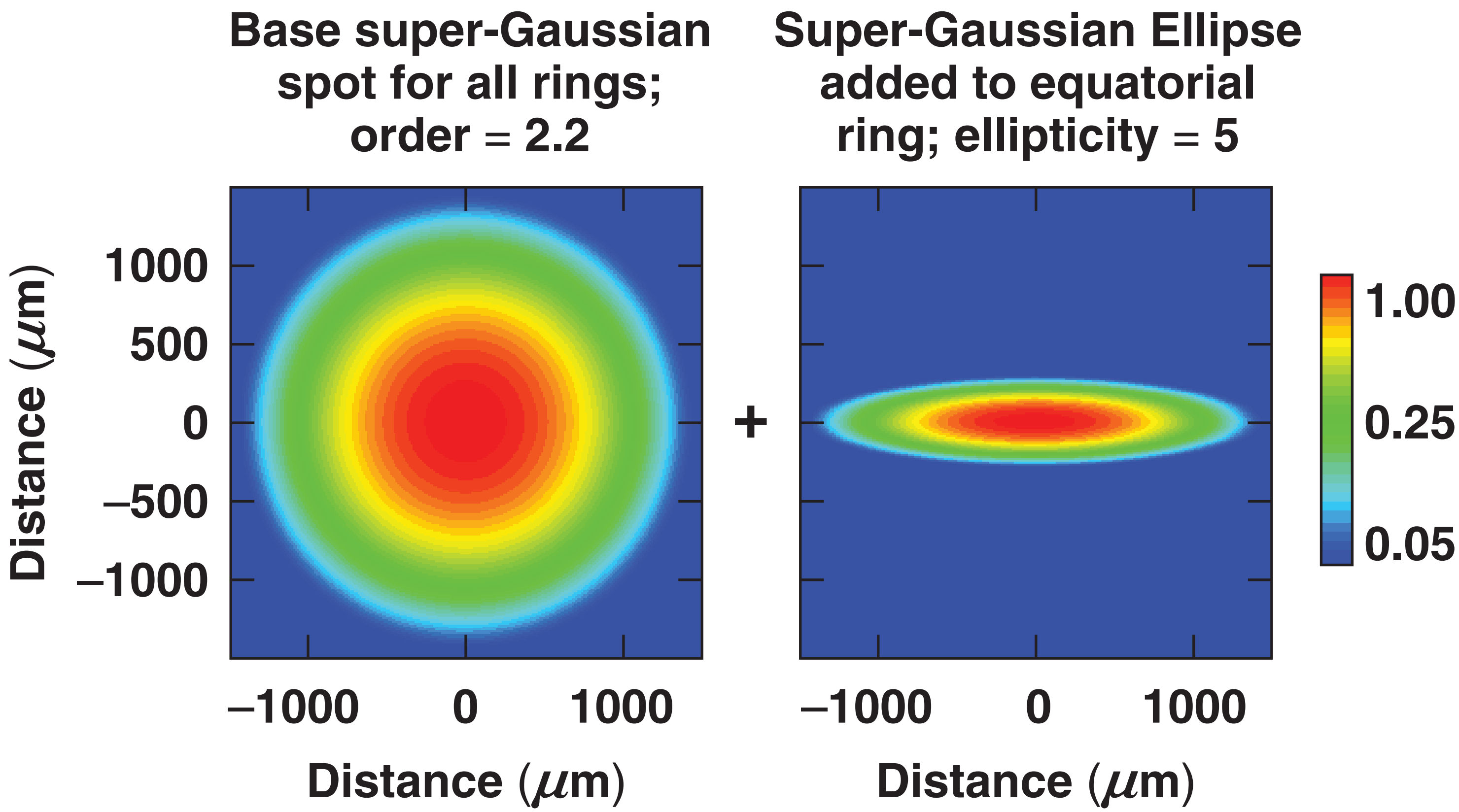
Cryogenic foam targets show great promise for PDD on the NIF



- Success requires that shell and shock uniformity are maintained through
  - spot shapes
  - beam repointing
  - time-dependent control via pulse shaping (critical for both shell and shock front uniformity).

TC7123

The spot shapes designed for PDD on the NIF are round super-Gaussians with one exception

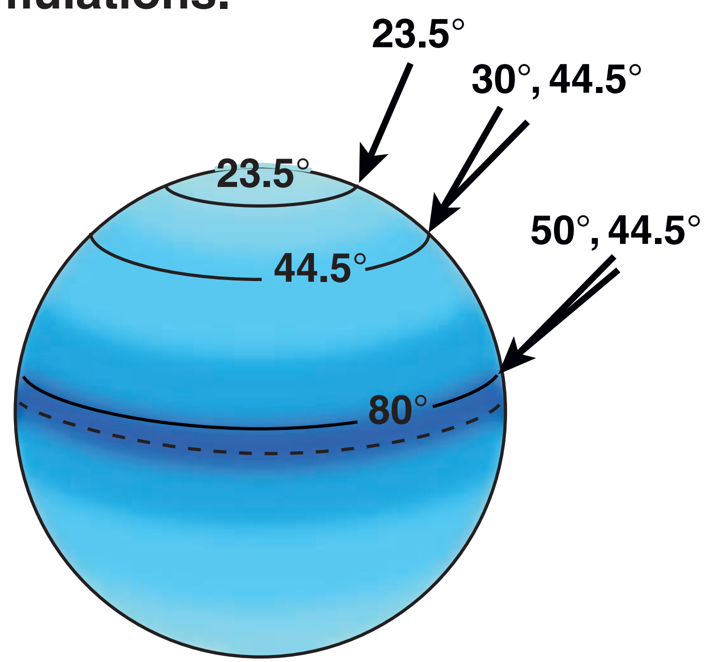


Lower super-Gaussian orders are preferred for PDD because they offer greater control of the energy density on the target.

TC7079a

Beam repointing and spot shapes determine the “baseline” drive uniformity

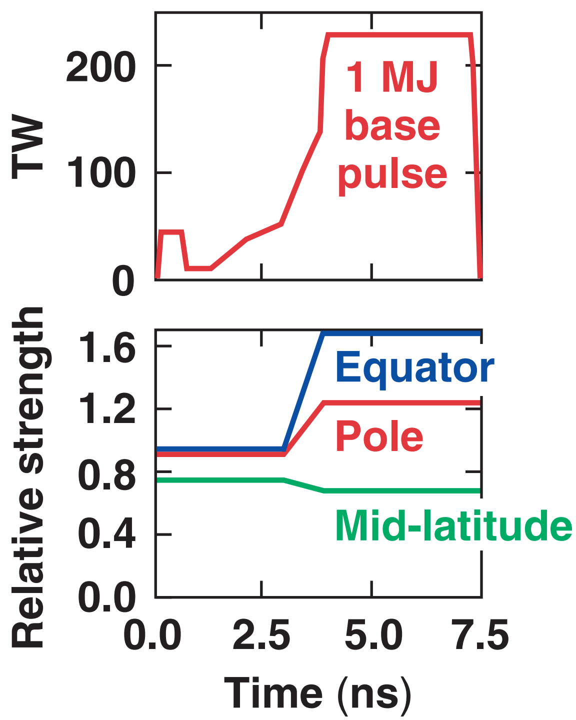
- An initial guess is made by using an optimization algorithm that iterates spot positions (as well as spot shapes).
  - imports a laser absorption angular spectrum from *DRACO*
- The repointing strategy can then be refined after running further *DRACO* simulations.
- The repointing strategy used here is: (23.5, 44.5, 80)

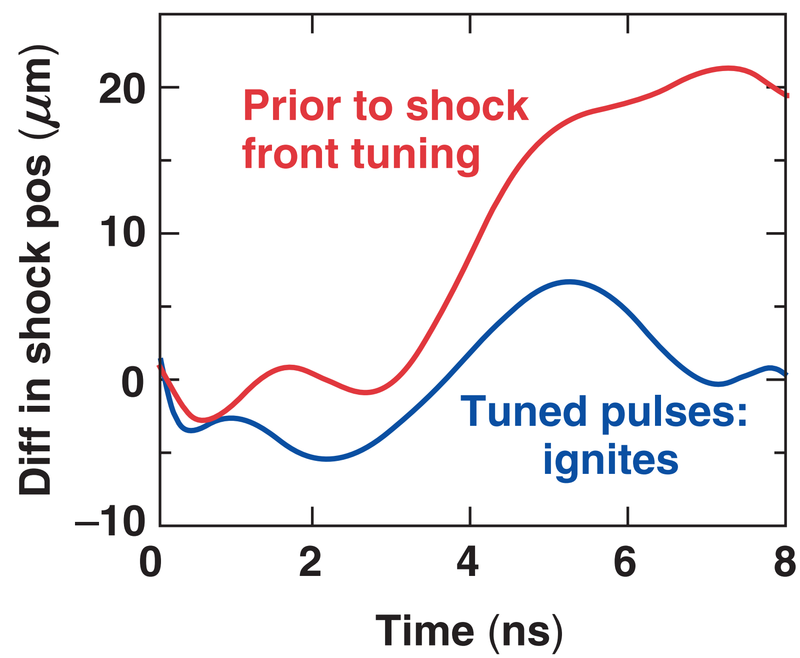


Maintaining both shell and shock front uniformity is critical to obtaining substantial gains

- Time dependent control of the relative pulse strengths is required
- Shell uniformity is adjusted throughout the pulse as a first pass
- Shock front uniformity is tuned using the foot of the pulse shape

Optimized Ring Pulse Shapes





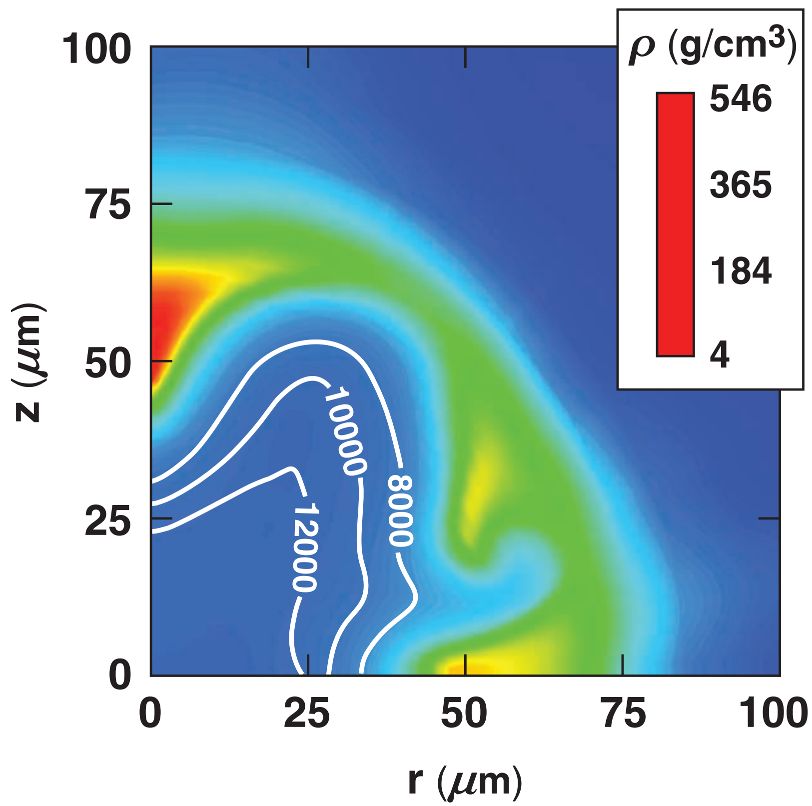
TC7125

The latest NIF-scale PDD simulations ignite and achieve significant gain

Cryogenic DT wetted CH foam

Simulation type	Incident energy	Absorbed energy	Gain
LILAC	1.0 MJ	0.87 MJ	33
DRACO PDD	1.3 MJ	1.0 MJ	20

Near peak compression, 8.12 ns



TC7116

Summary/Conclusions

Polar direct drive (PDD) is a viable path toward ignition on the National Ignition Facility (NIF)

UR LLE

- OMEGA
  - Experiments and simulations have been performed on two types of PDD targets: standard and Saturn.
  - Experiments confirm simulation predictions.

- NIF
  - Substantial gain is predicted for cryogenic DT CH foam PDD designs.
  - Shell and shock-front uniformity are critical for ignition.