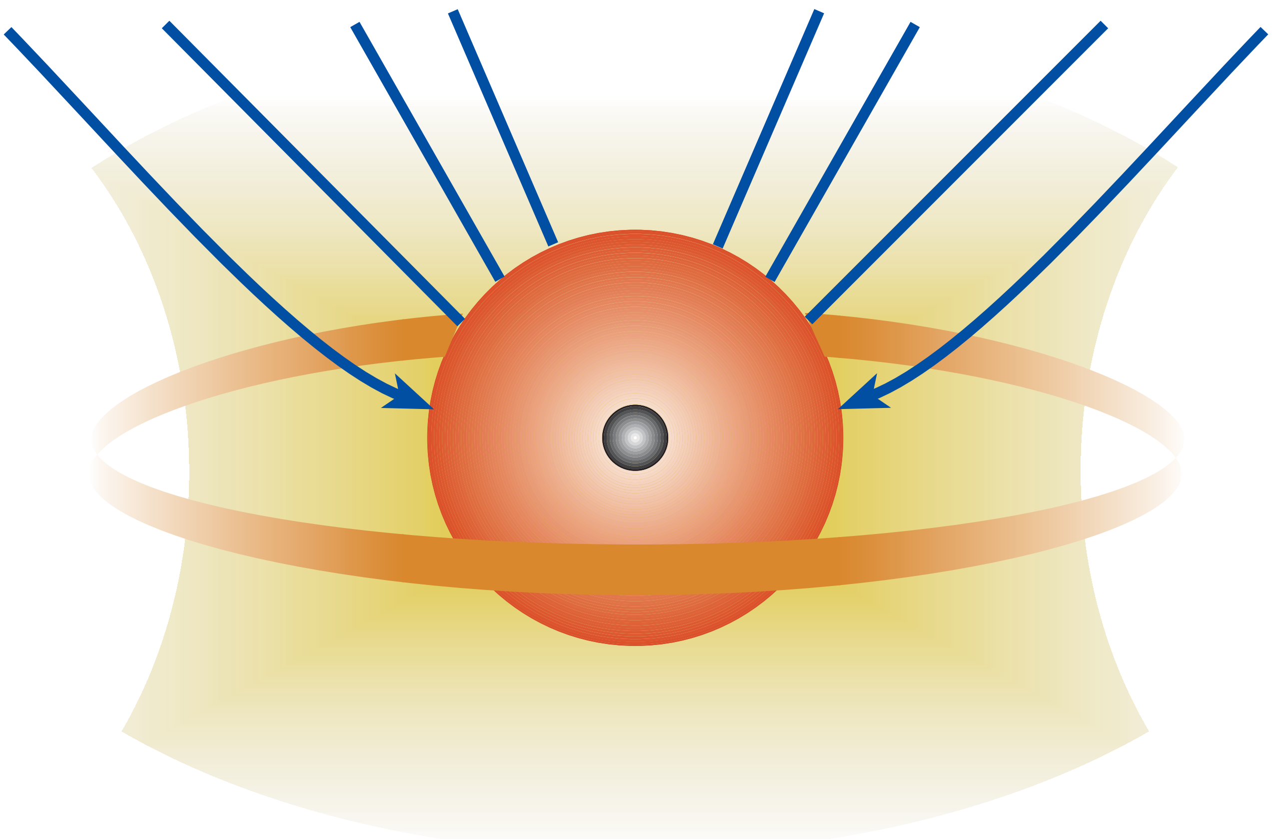
Polar Direct Drive–Proof-of-Principle Experiments on OMEGA and Prospects for Ignition on the NIF



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R. S. Craxton
University of Rochester
Laboratory for Laser Energetics

This work has been made possible by many collaborators

F. J. Marshall
M. Bonino
J. A. Delettrez
R. Epstein
I. V. Igumenshchev
D. W. Jacobs-Perkins
J. P. Knauer
J. A. Marozas
P. W. McKenty
P. B. Radha
W. Seka
S. Skupsky

Summary

Using polar direct drive (PDD), the prospects for ignition on the NIF are very good

- Current *SAGE*/*DRACO* simulations of NIF PDD targets give moderate gains.
- The Saturn design has the potential to give yields approaching 1-D gain.
- OMEGA PDD experiments have demonstrated close agreement between the observed nonuniformity and *SAGE* predictions.
- The first Saturn PDD experiment on OMEGA has shown that the ring can be used to change the drive uniformity.

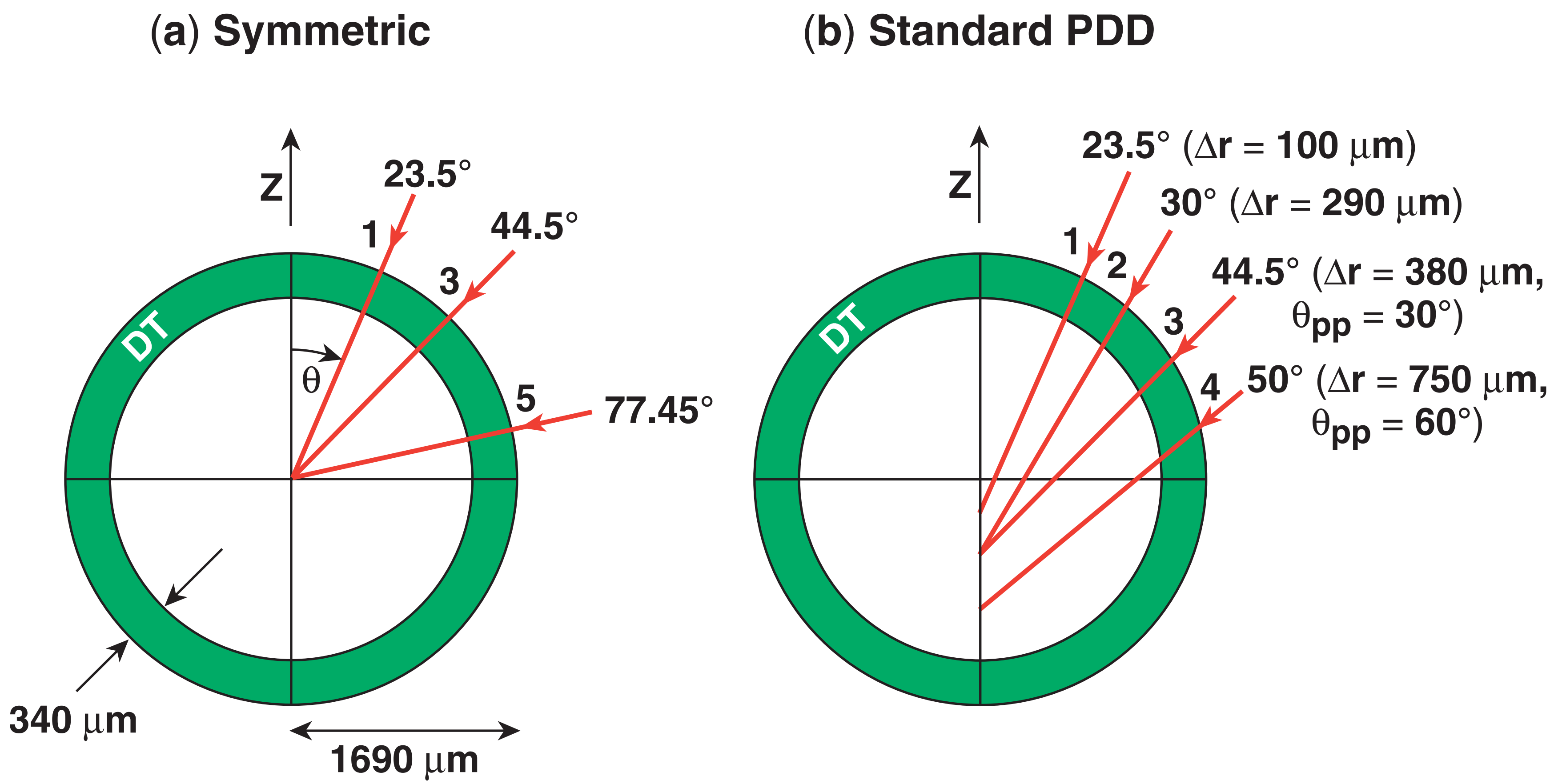
See also: J. Soures (HO1.012)
R. Epstein (HO1.013)
J. Marozas (HO1.014)

TC6643

Outline

- Polar-direct-drive (PDD) concept for the NIF
  - "Symmetric" target (uses 77° ports)
  - "Standard PDD" target
- Standard-PDD experiments on OMEGA
- "Saturn" target for the NIF
- Saturn experiments on OMEGA

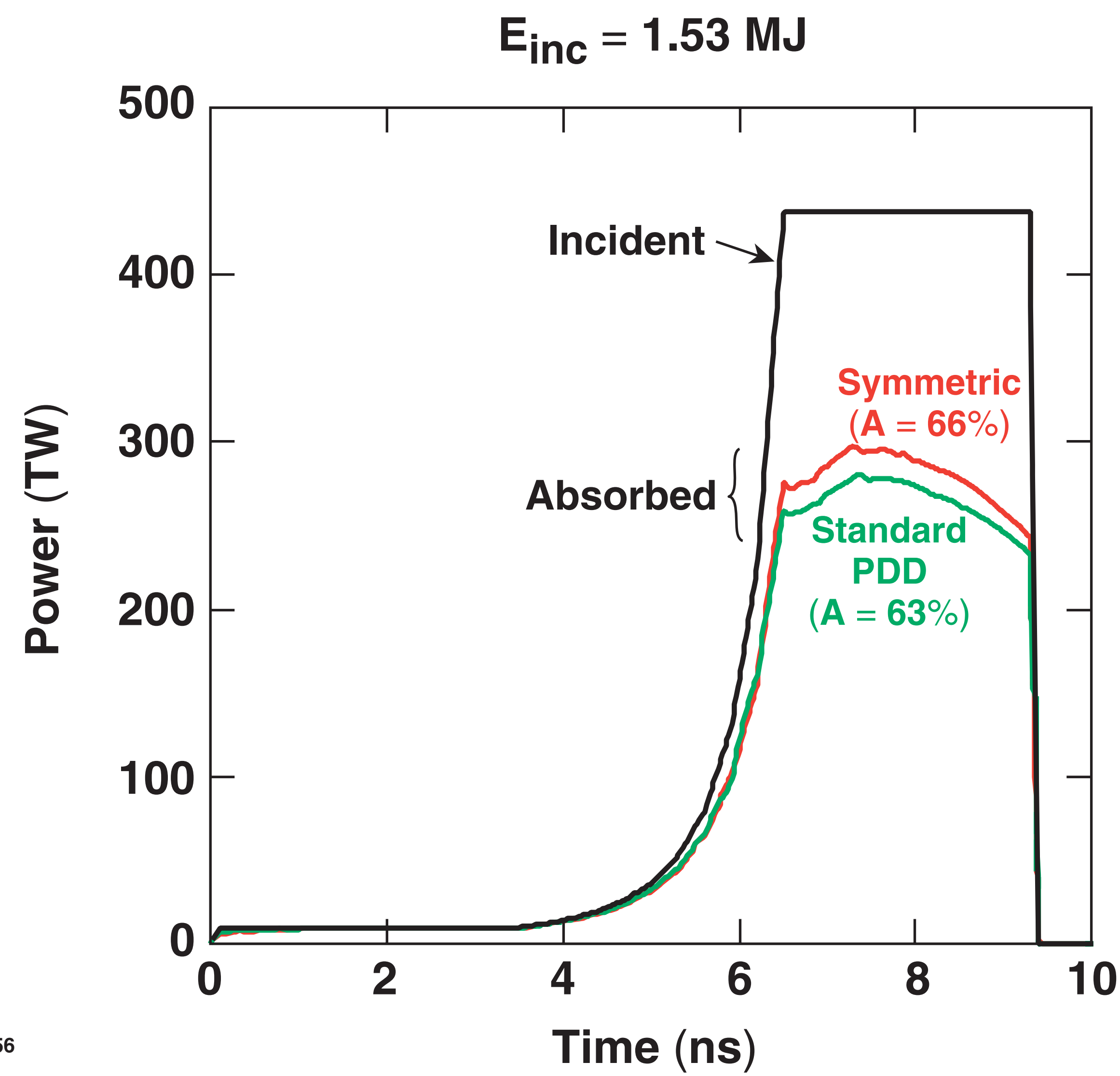
Polar direct drive entails repointing the NIF laser beams toward the equator



$$I(r) \propto \exp - (r/1200\ \mu m)^{2.5}$$

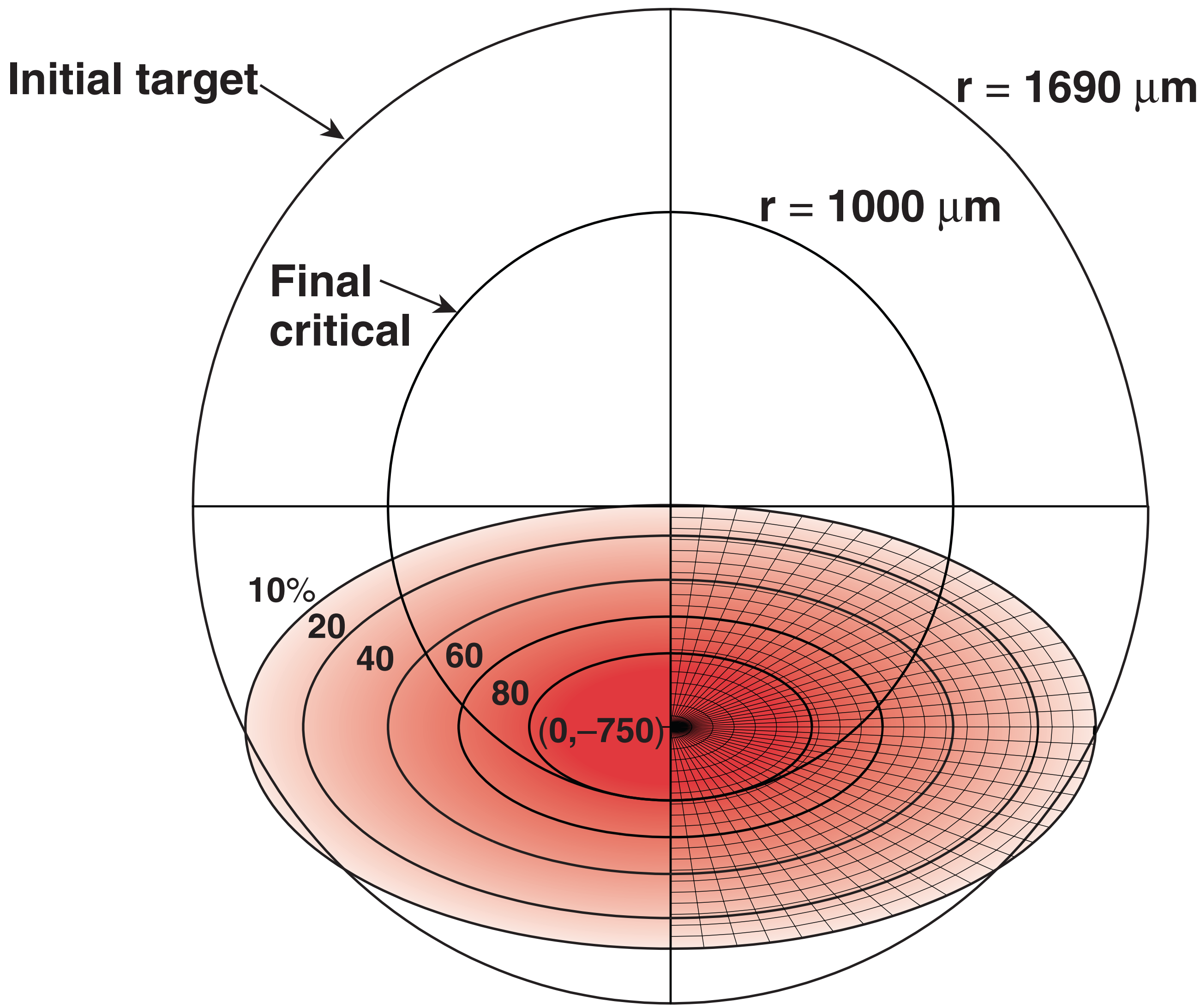
Sub 38, Runs 4533, 4056
TC6645

The absorbed energy penalty for polar direct drive is minimal



Runs 4533, 4056
TC6646a

For PDD on the NIF, the ring-4 beams are repointed 750 μm and use 2:1 elliptical phase plates (θ_{pp} = 60°)

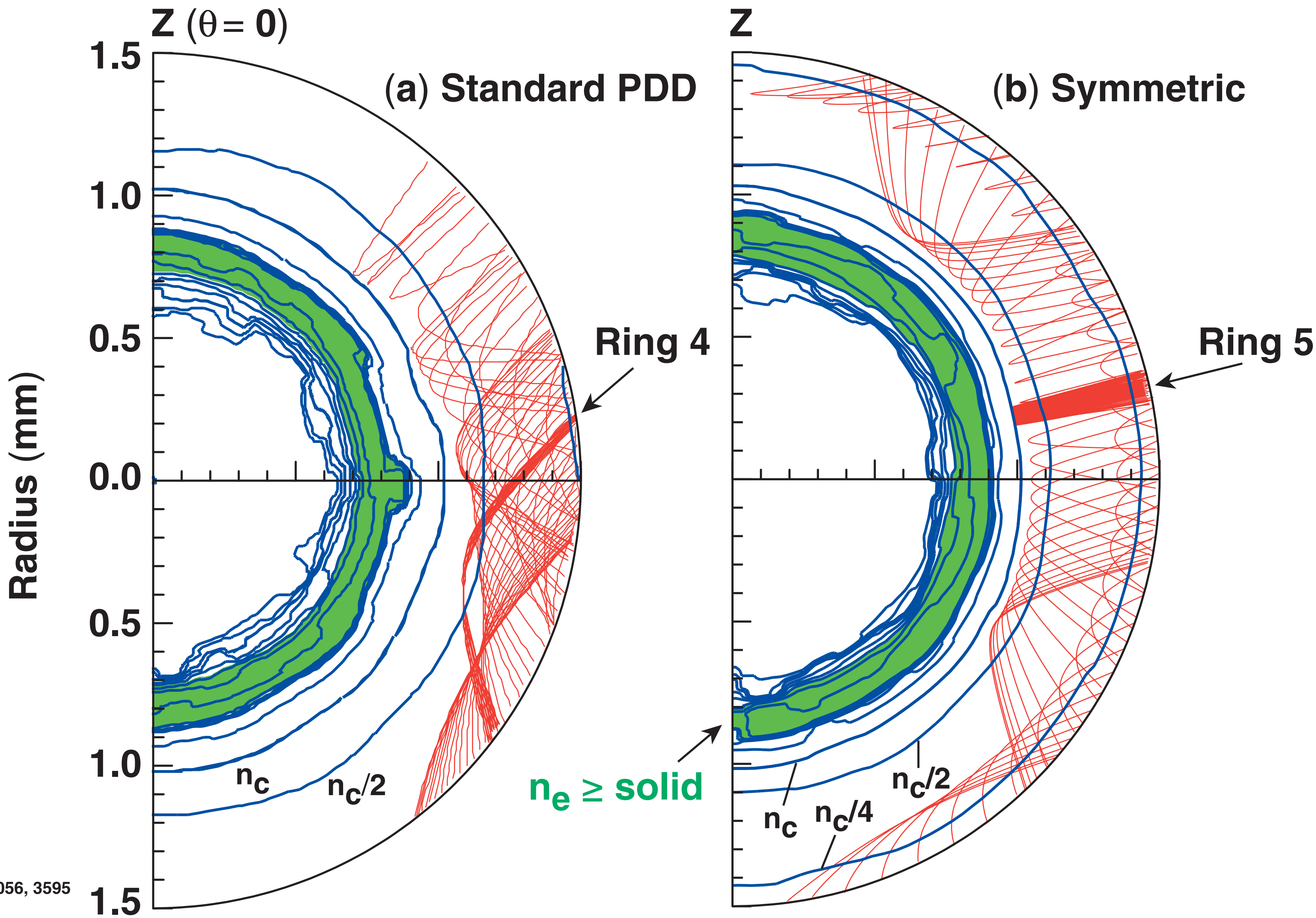


Two hydrocodes are used to model PDD implosions

- *SAGE* (fully self-consistent 3-D ray tracing) models the implosion until the end of the laser pulse.
- The center-of-mass velocity perturbations are then transferred to a *DRACO* simulation.
- *DRACO* (full burn physics) follows the implosion through stagnation and calculates the yield.

At the end of the laser pulse (9 ns), the standard PDD case is almost as uniform as the symmetric case

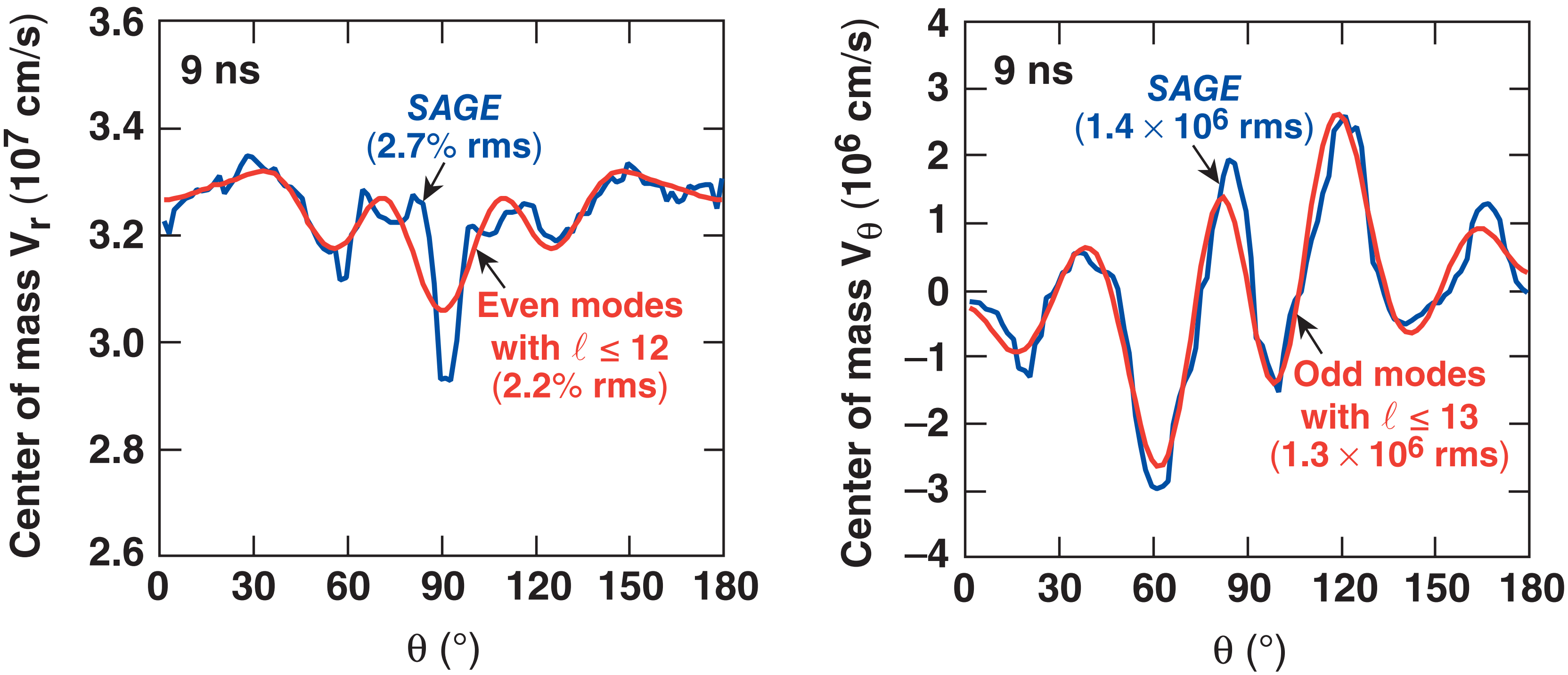
- NIF



Runs 4056, 3595
TC6648

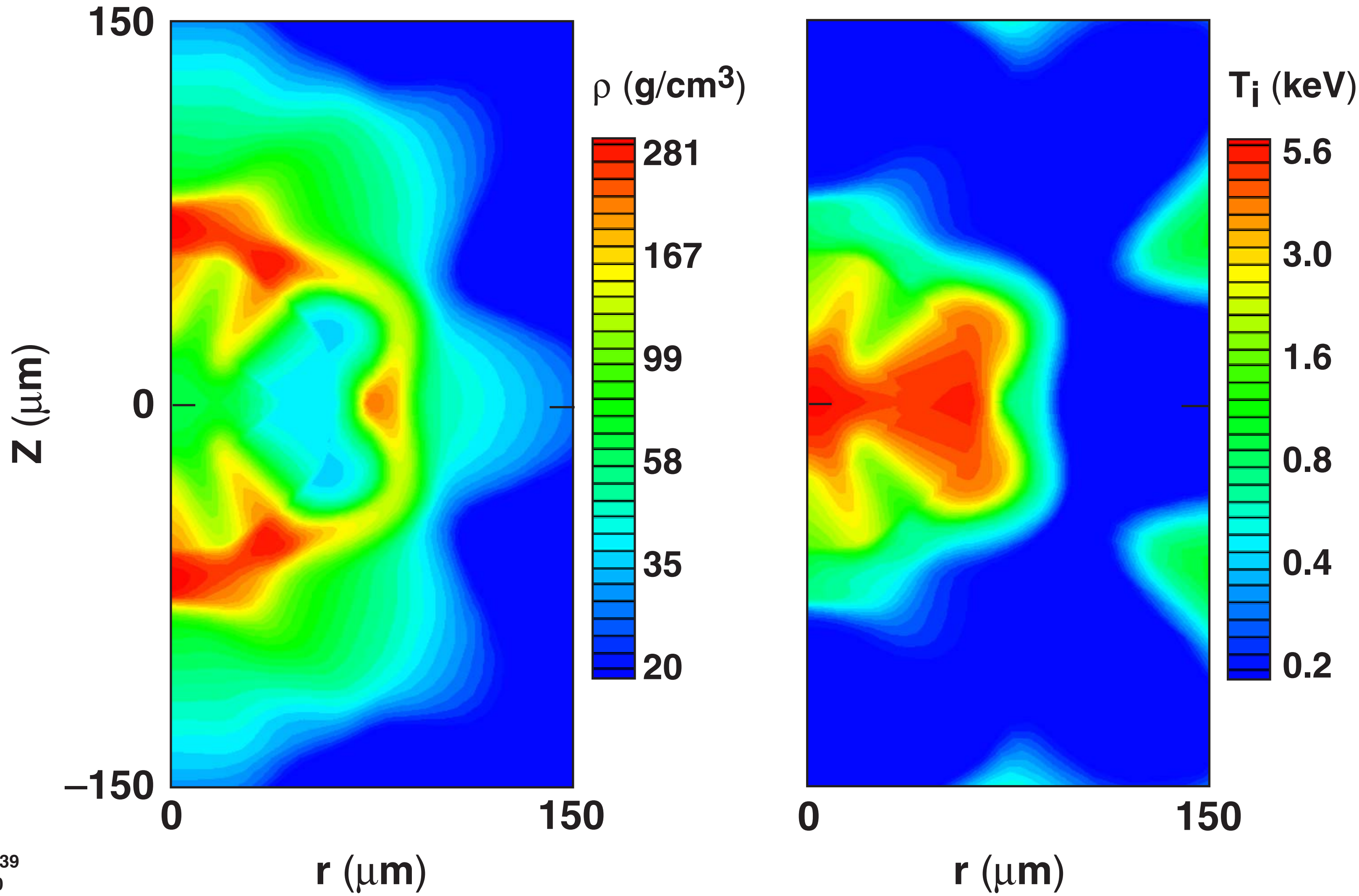
The *SAGE* velocity perturbations at the end of the laser pulse are used to perturb a uniform *DRACO* simulation

Standard PDD



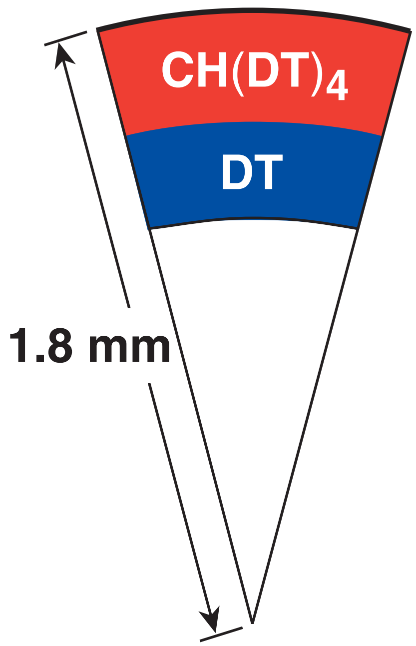
Run 4056
TC6649

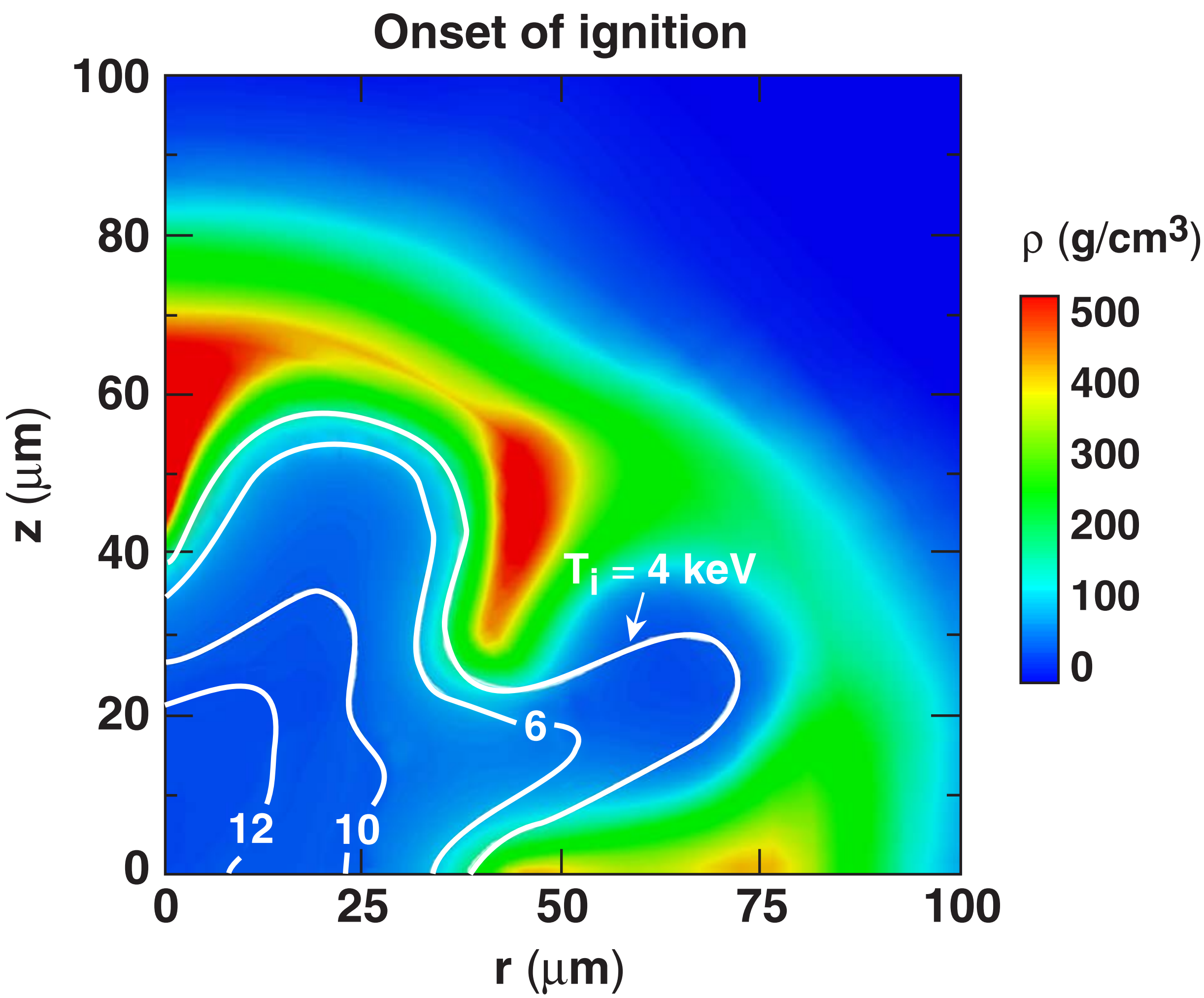
The *DRACO* simulation near peak compression is consistent with the imposed velocity perturbations



Run 4539
TC6650

A *DRACO* simulation of a wetted-foam PDD design gives a gain of ~10





TC6651

Outline

- Polar-direct-drive (PDD) concept for the NIF
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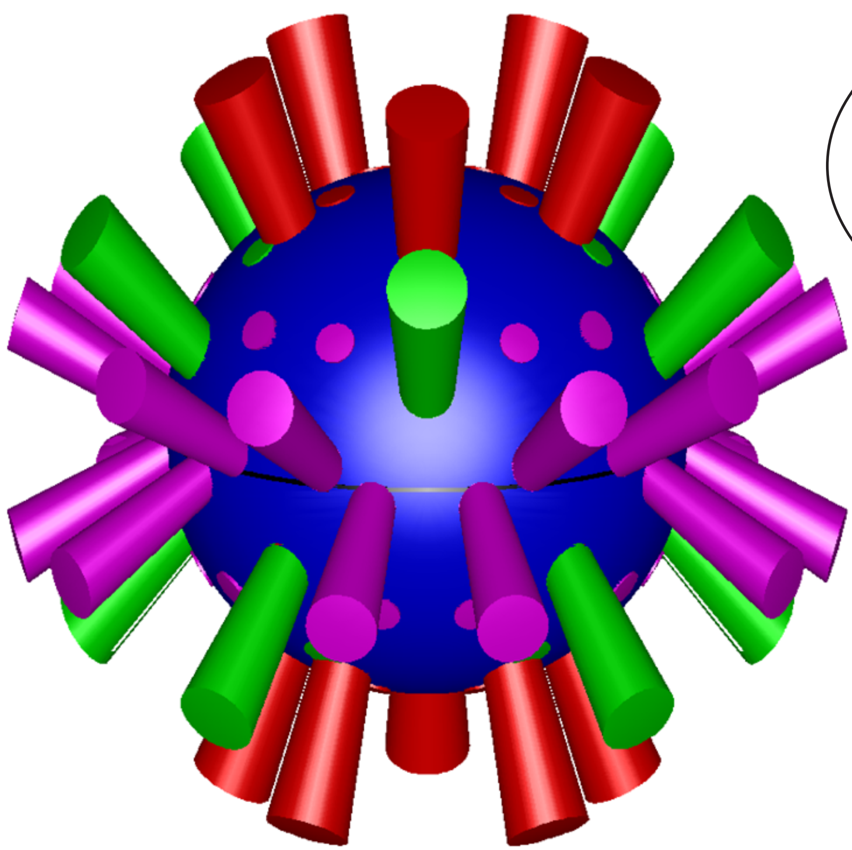
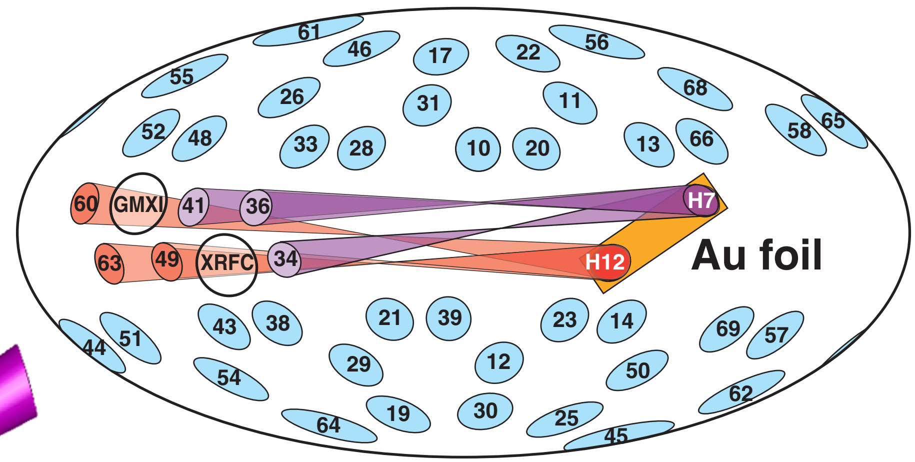
- Saturn experiments on OMEGA

For the OMEGA PDD experiments, forty beams irradiated the target while six beams were used for backlighting



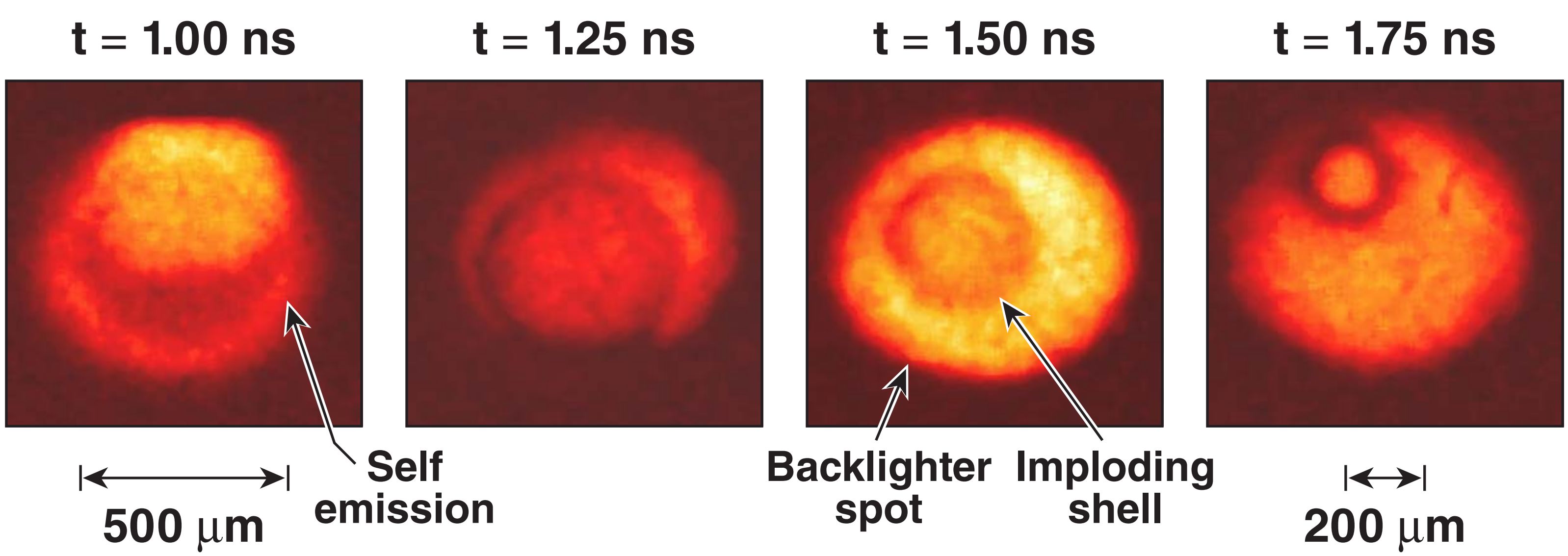


20-μm CH shell
865-μm diameter
15-atm D_2 fill
1-ns square pulse
385 J/beam

Ring	θ	Δr (μm)
1	21°	91
2	42°	188
3	59°	196

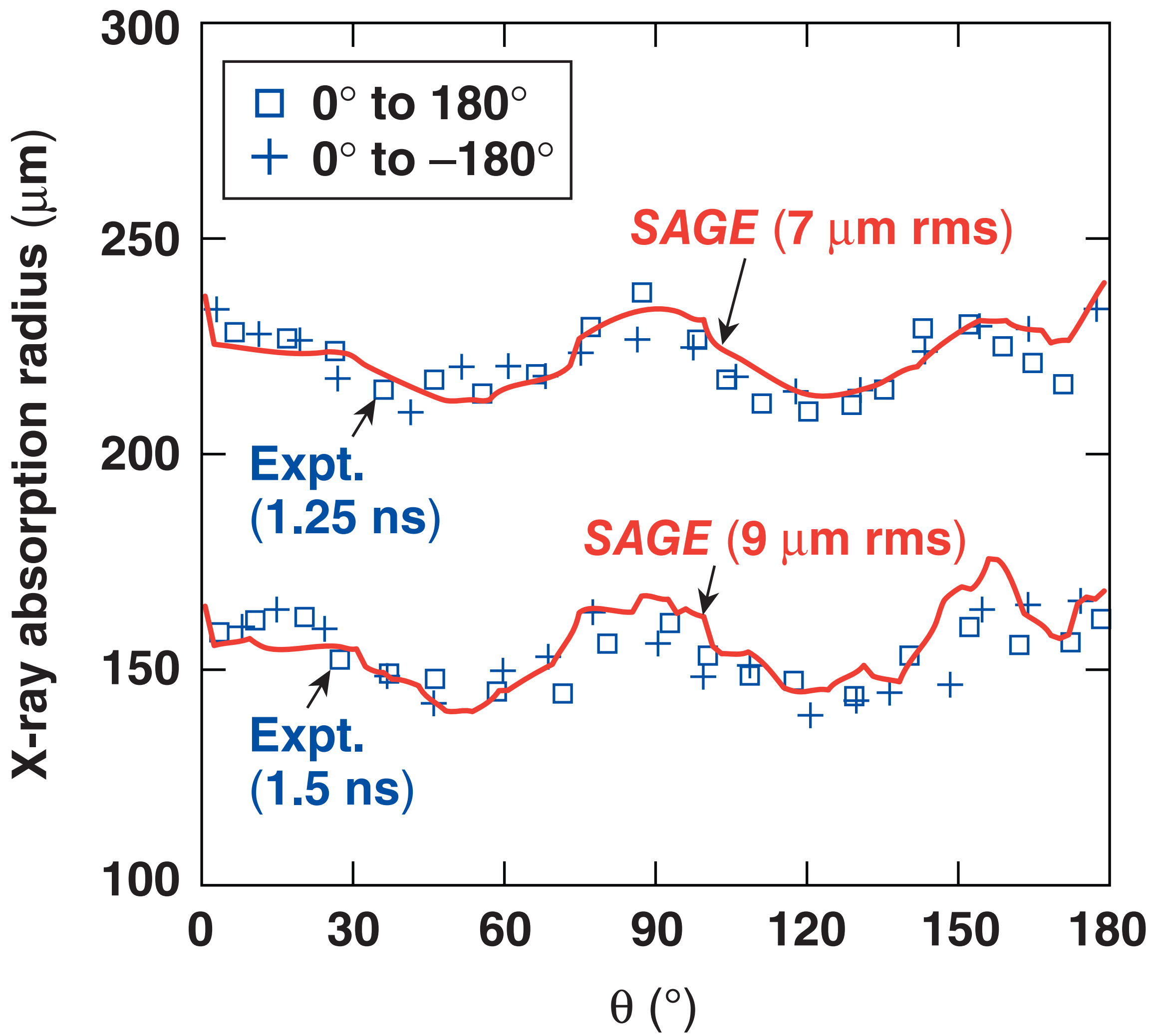
Gated backlit x-ray images show a nearly symmetric target implosion

OMEGA Shot 34669



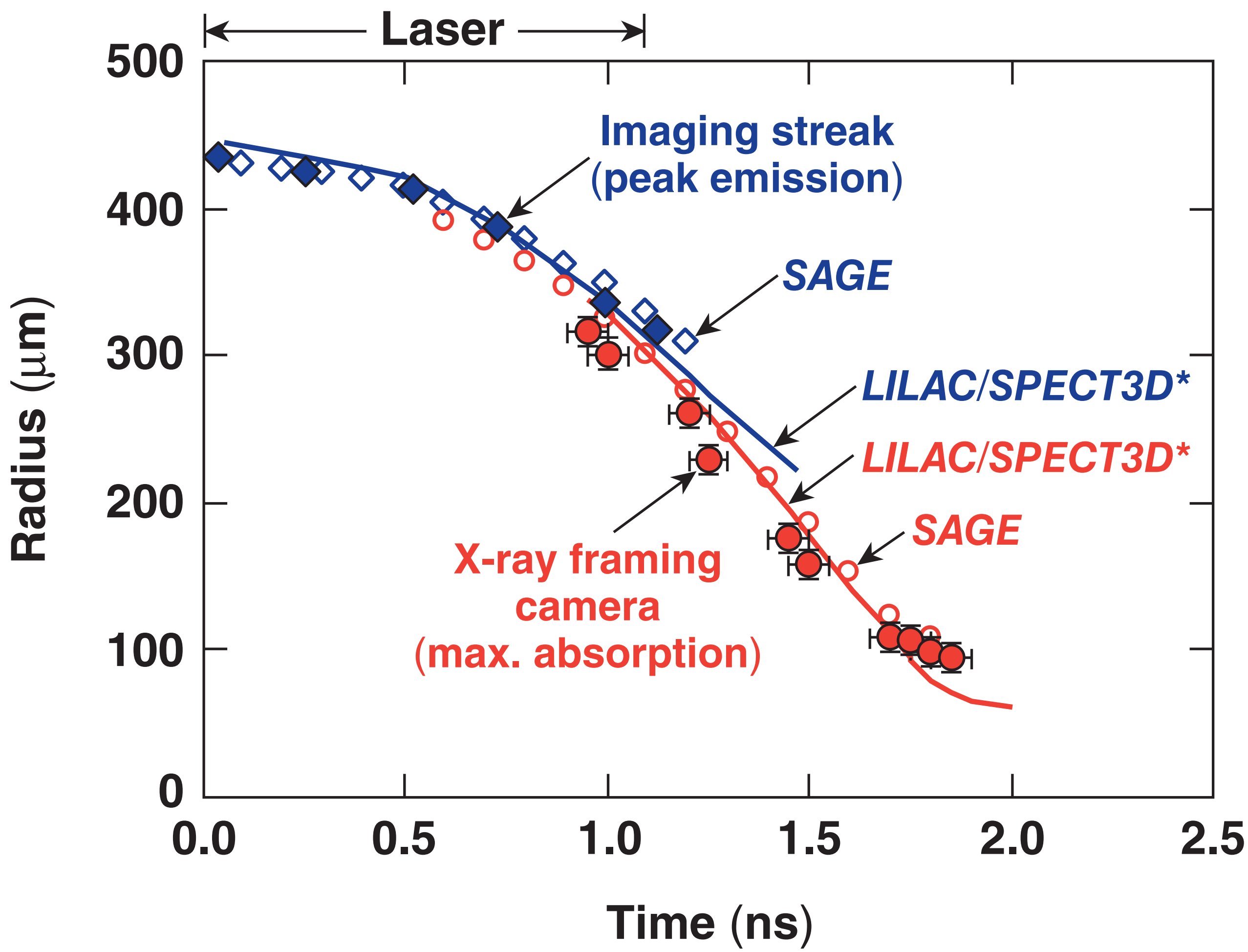
Shot 34669
U435a

The experimental data follow the predicted center-of-mass variations very closely at two successive times



Shot 34669
Run 4187
TC6531c

The shell trajectory, measured using streaked imaging and framed x-ray radiography, is consistent with 1-D *LILAC* and *SAGE* simulations



Shot 34669
Run 4184
TC6528

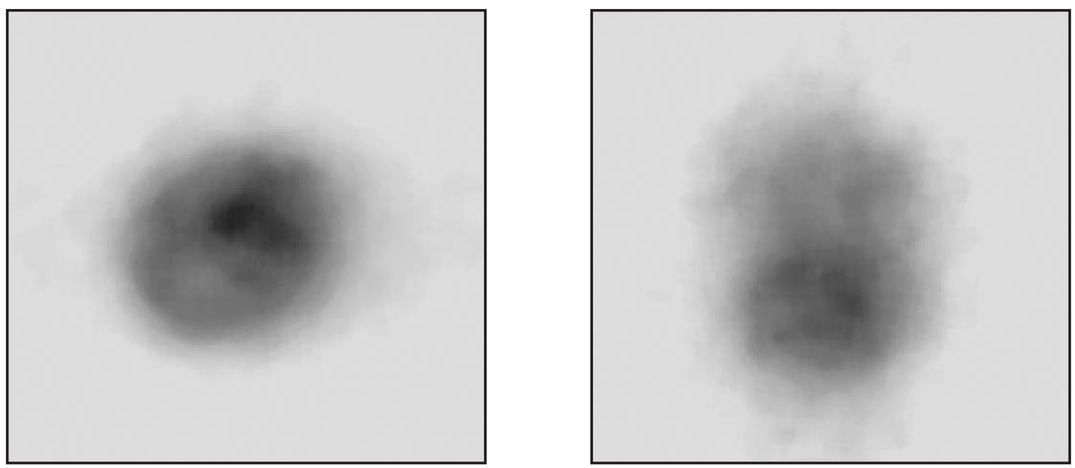
*SPECT3D: Prism Computational Sciences, Inc.

The core-stagnation symmetry is affected by the illumination configuration

Time-integrated KB microscope images

60 beams	40 beams
TCC	PDD
15.6 kJ	15.4 kJ
$Y_{DD} = 8.4 \times 10^{10}$	$Y_{DD} = 2.9 \times 10^{10}$

Shot 34644

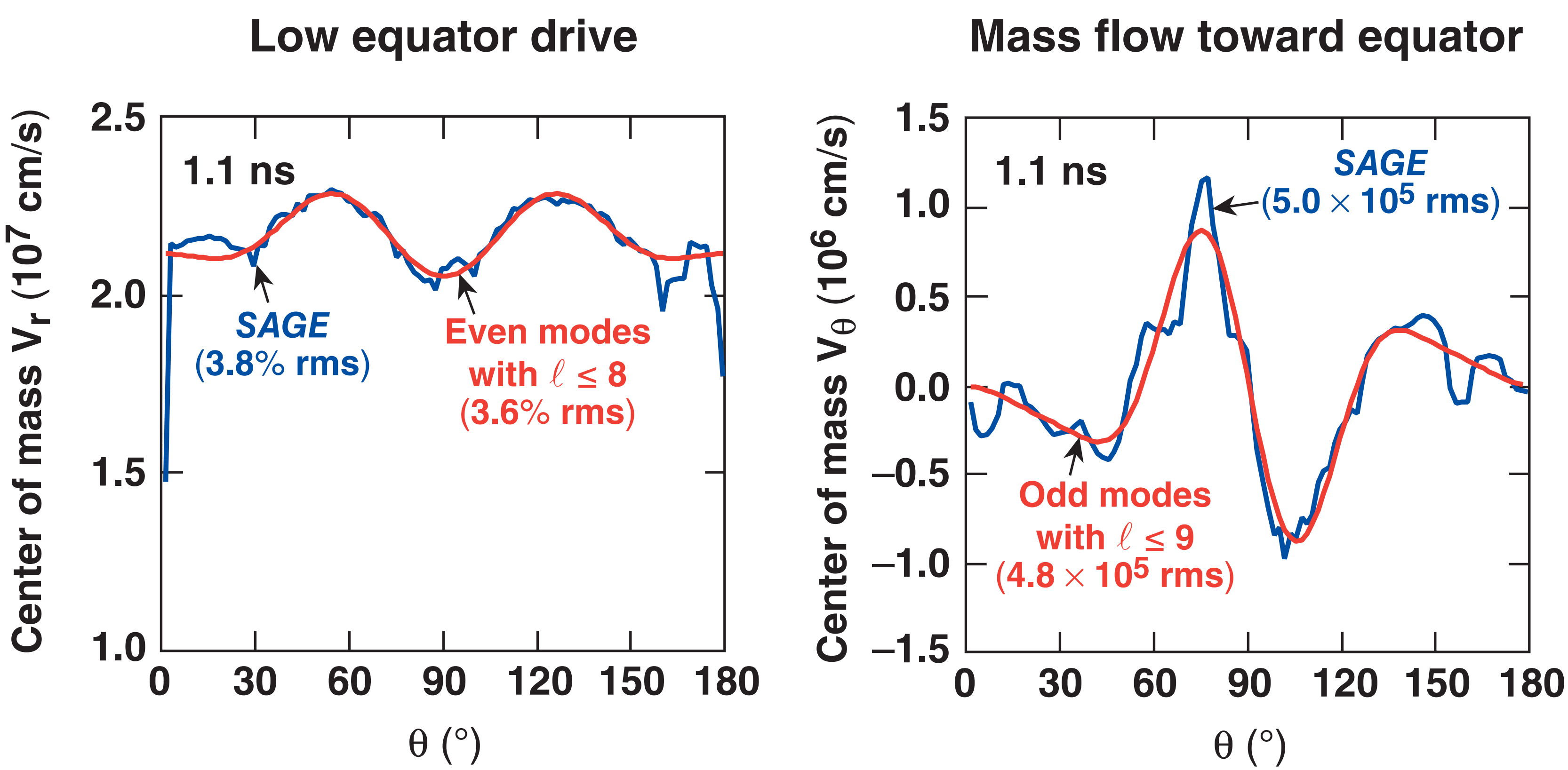


Shot 34668

100 μm

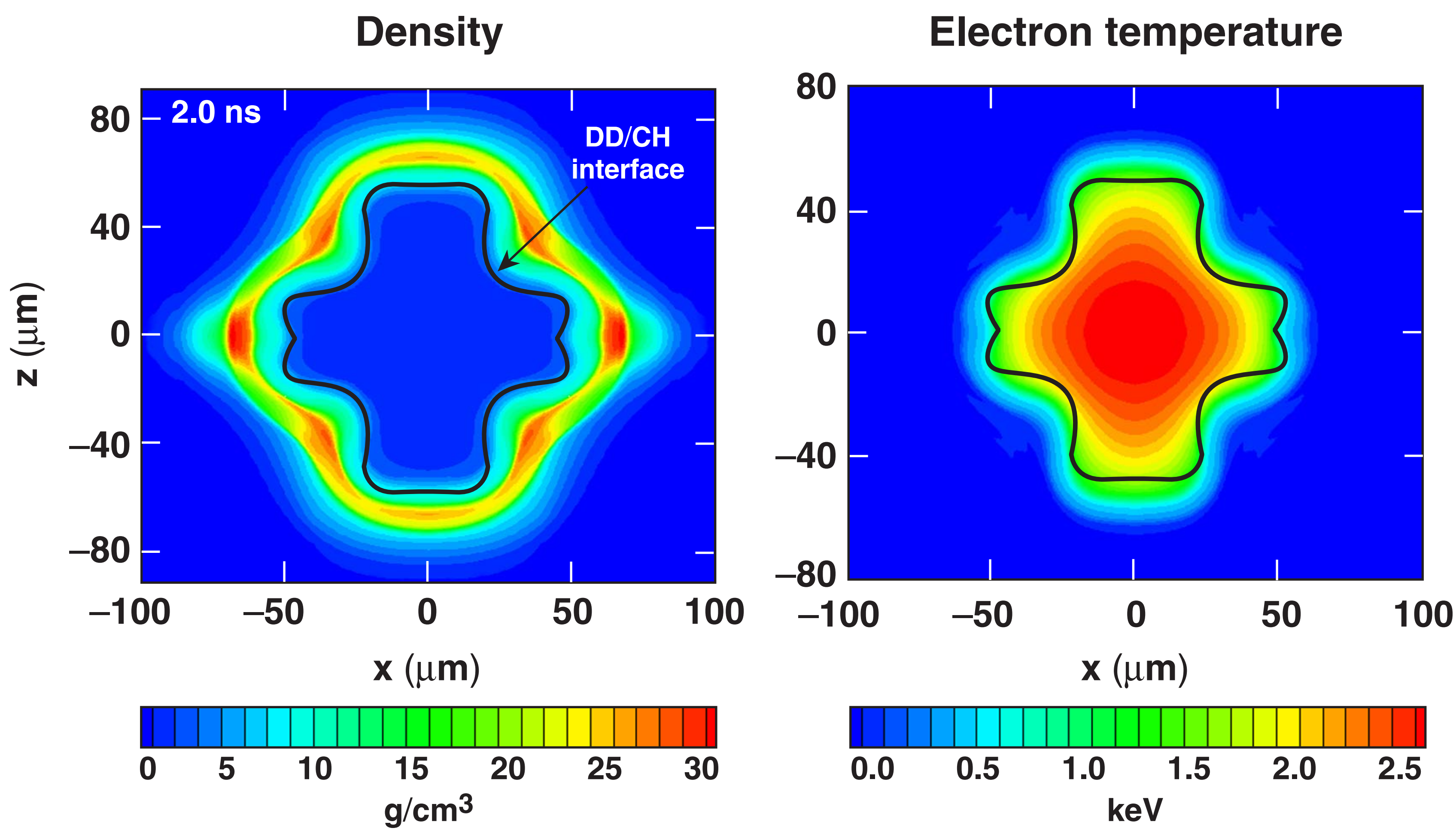
TC6533

The *SAGE* velocity perturbations at the end of the laser pulse were transferred to *DRACO*



Run 4187
TC6652

DRACO contours at the time of peak neutron production continue to show the $\ell = 4$ mode



$$\frac{Y_{PDD}}{Y_{Sym}} = \begin{array}{l} 0.35 \text{ (expt)} \\ 0.42 \text{ } (\textit{DRACO}) \end{array}$$

Run 4187, a rad 4
Shot 34669
TC6653

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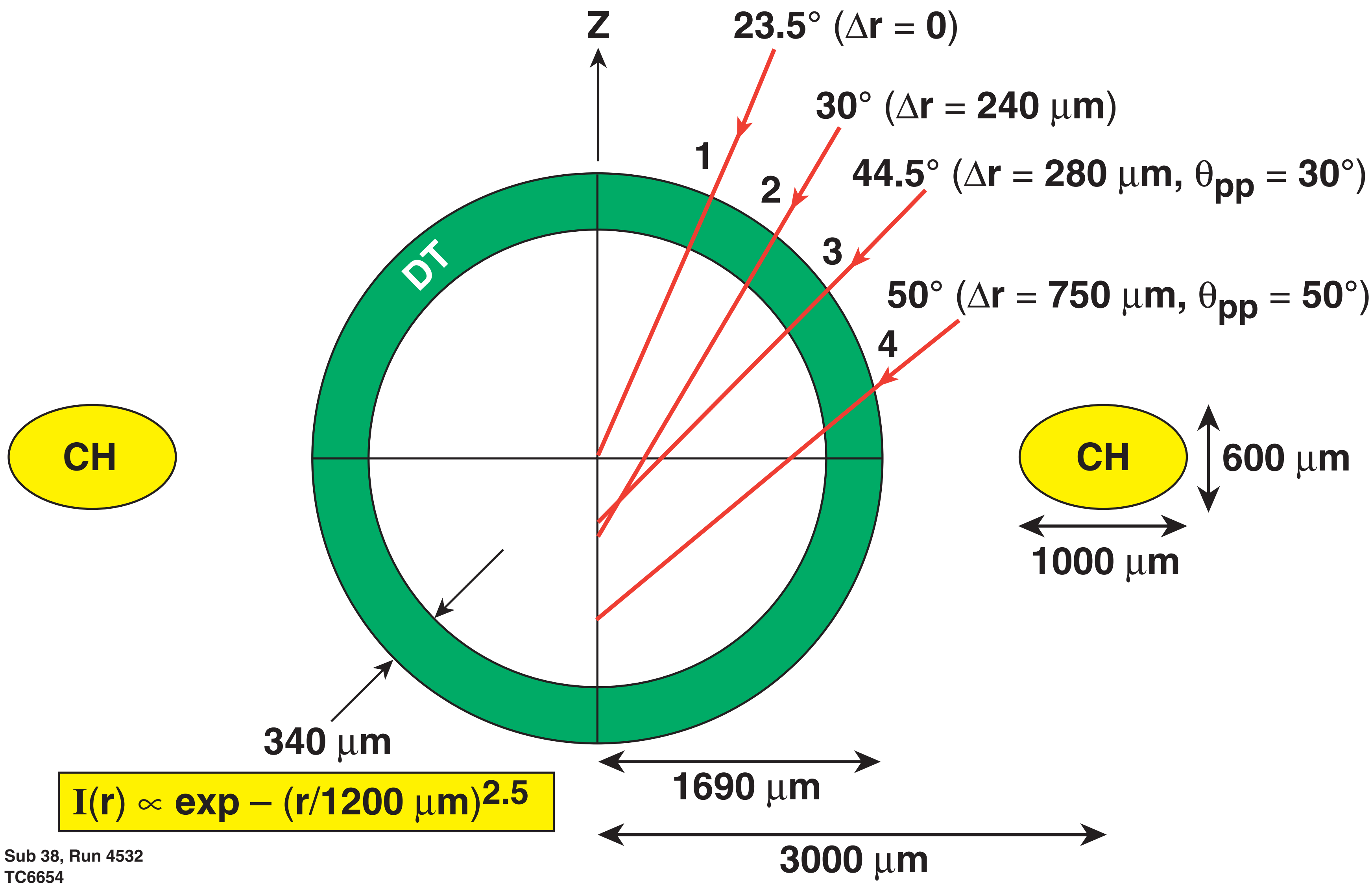
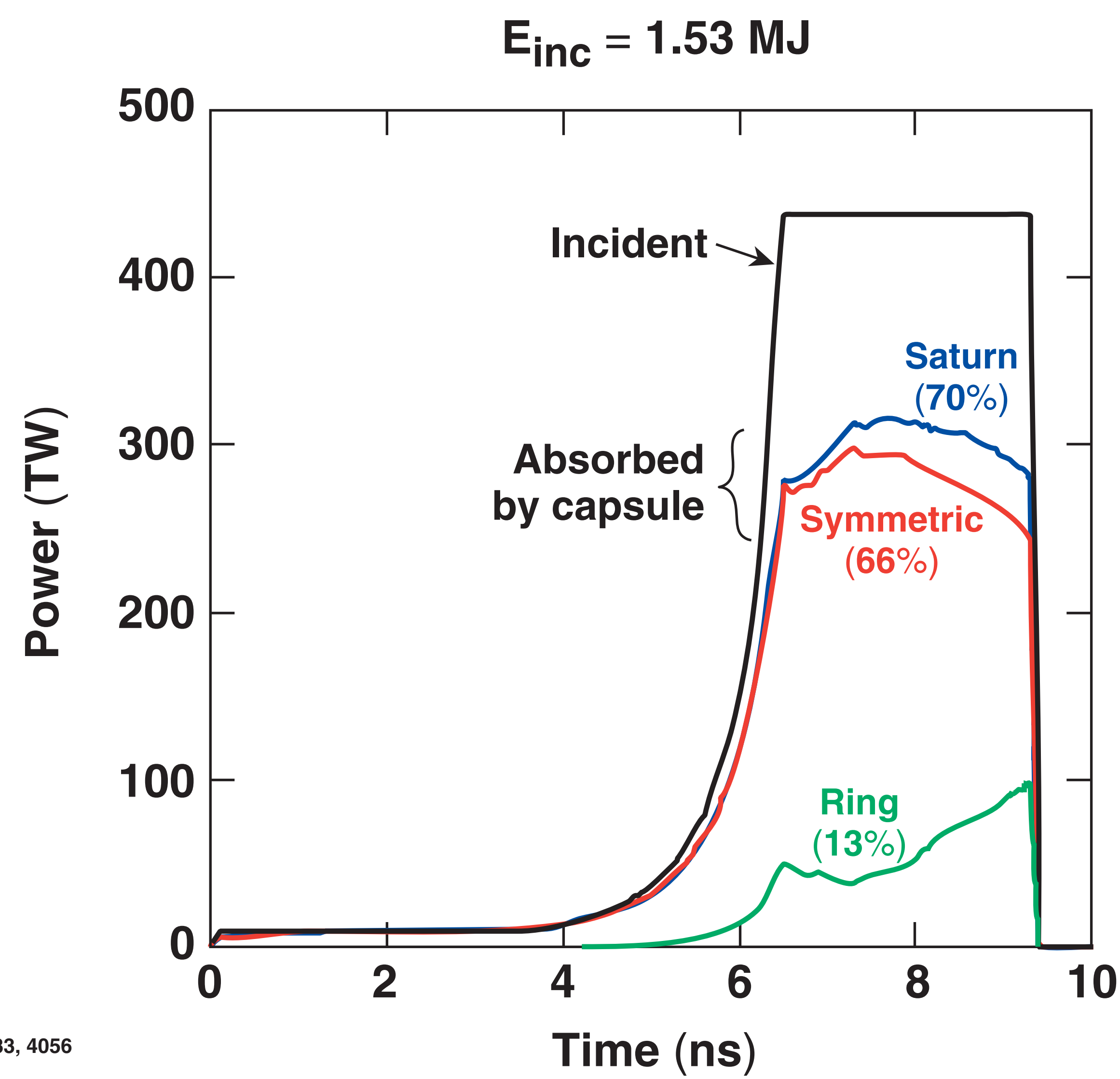
The Saturn design results from an optimization over many parameters



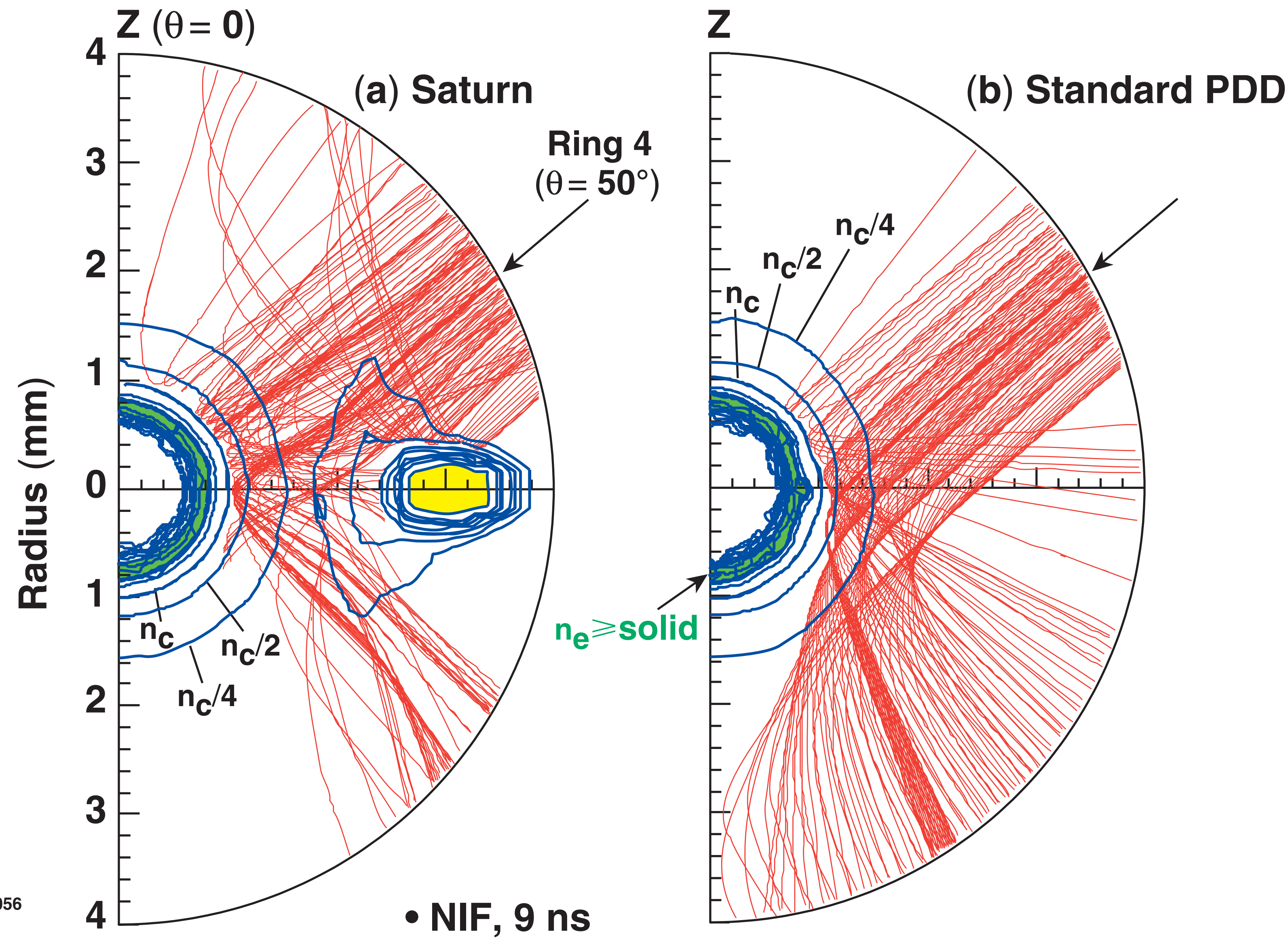
Sub 38, Run 4532
TC6654

About 50% of the energy not absorbed by the capsule is absorbed by the ring



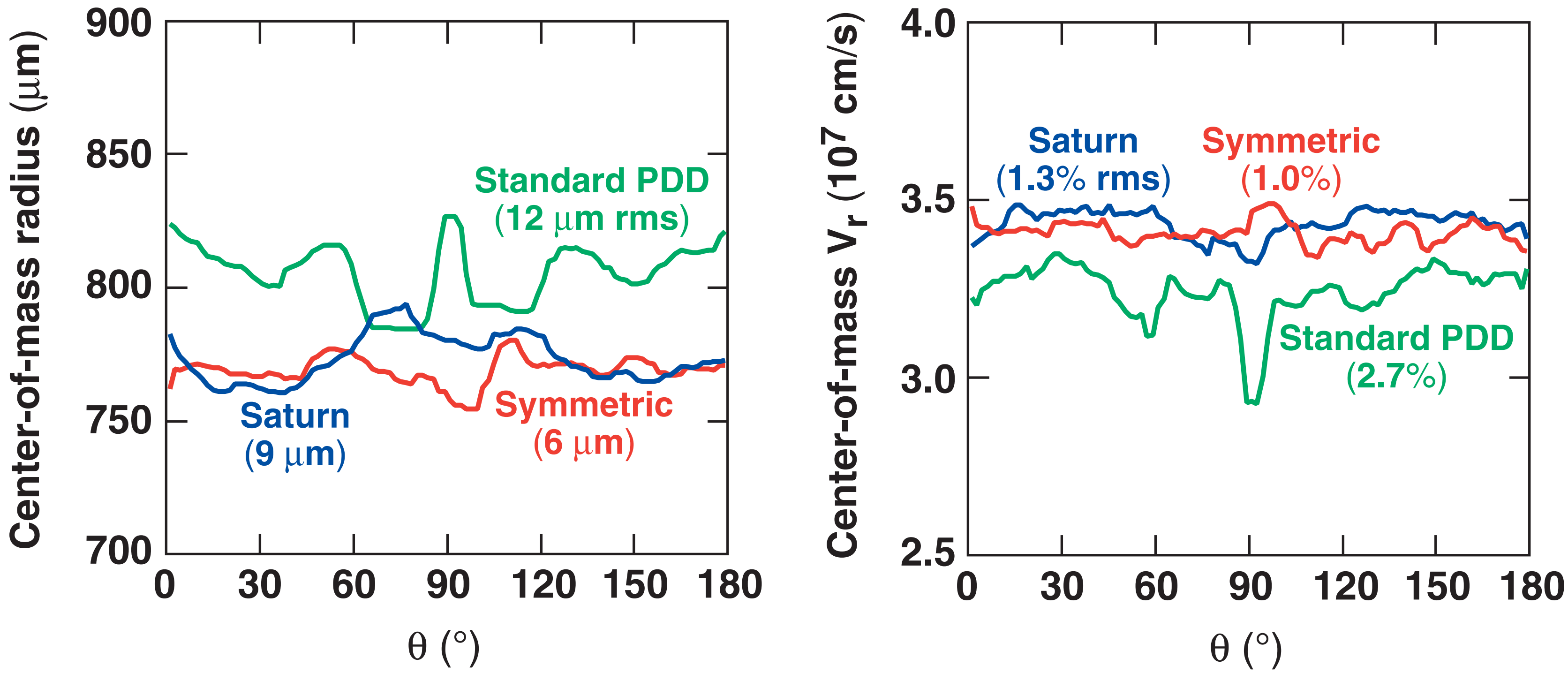
Runs 4532, 4533, 4056
TC6655a

As the critical surface moves in, the ring of the Saturn target refracts rays back toward the equator



Runs 4341, 4056
TC6636

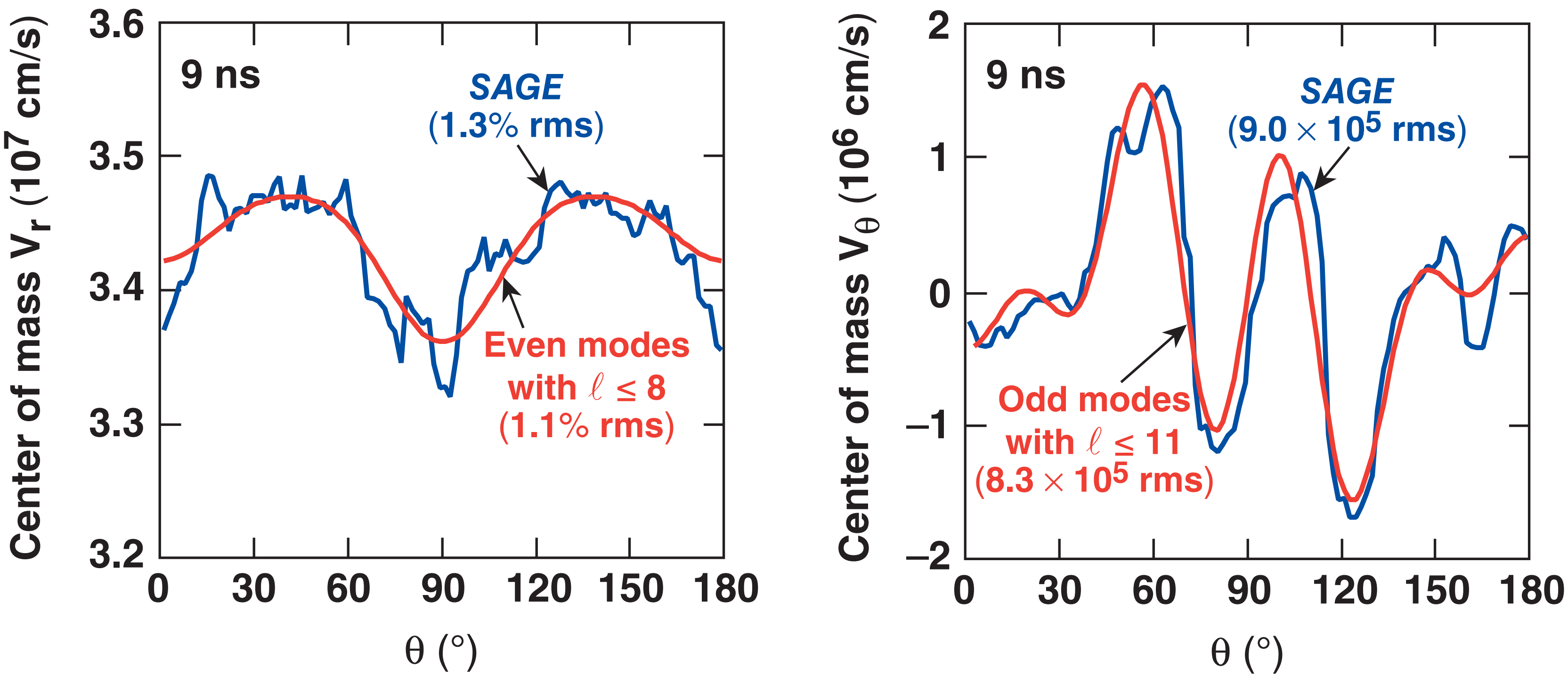
The uniformity at 9 ns for the Saturn target is almost as good as for the symmetric target



Runs 4533, 4056, 4532=4341
TC6656

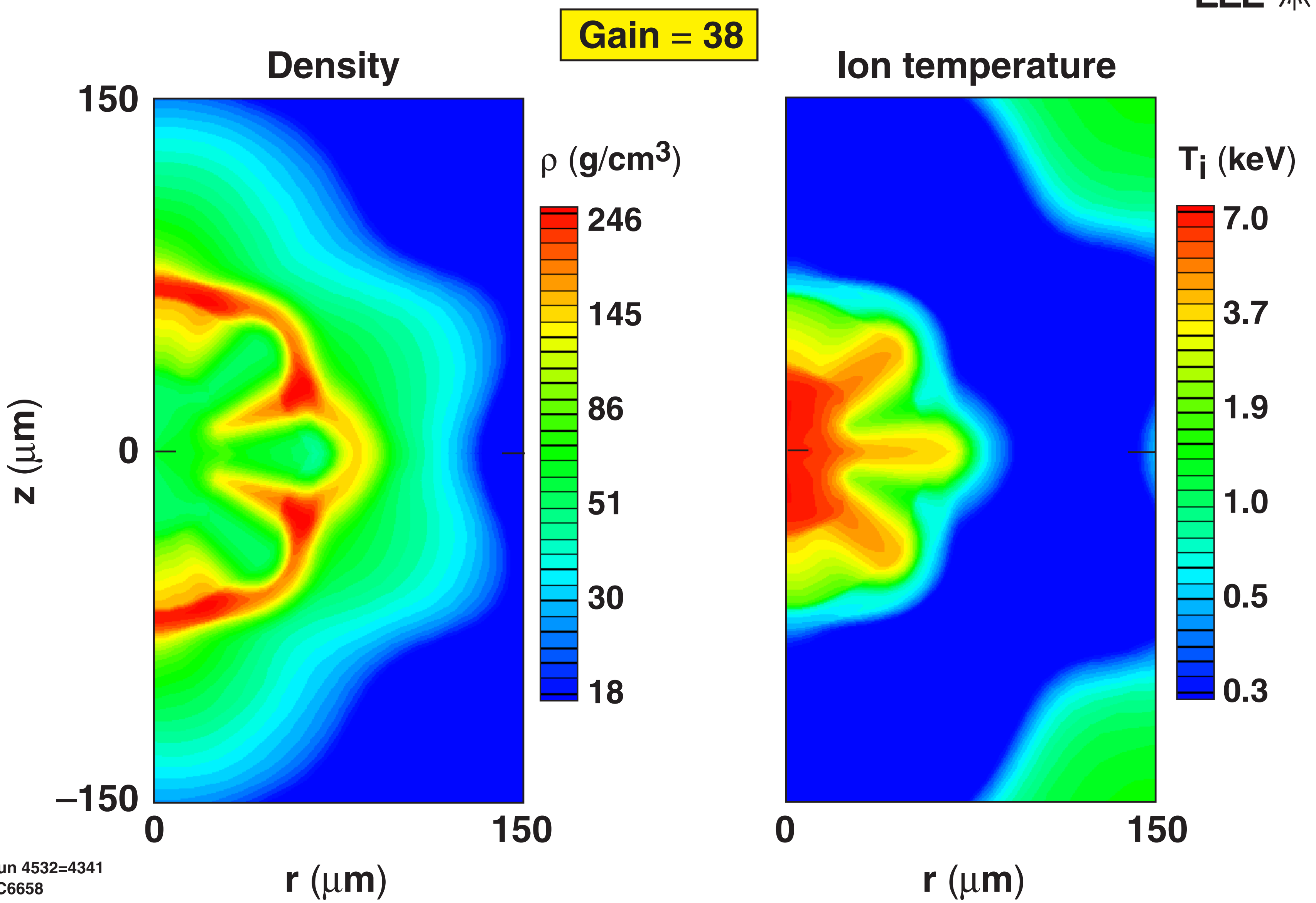
The *SAGE* velocity perturbations at 9 ns are transferred to *DRACO*

Saturn



Runs 4532=4341
TC6657

The *DRACO* density and temperature profiles show some low-mode structure at the onset of ignition



Run 4532=4341
TC6658

Outline

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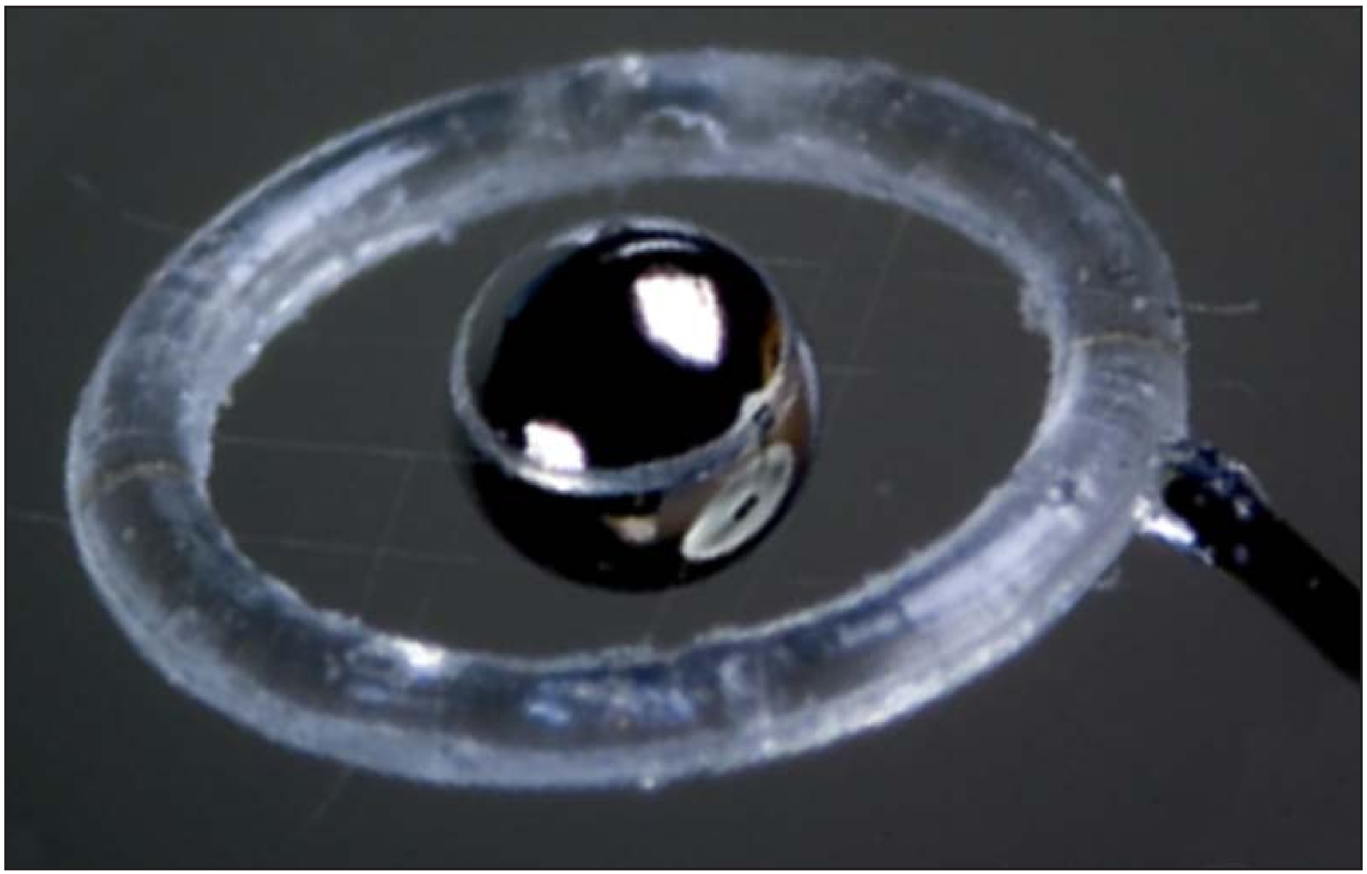
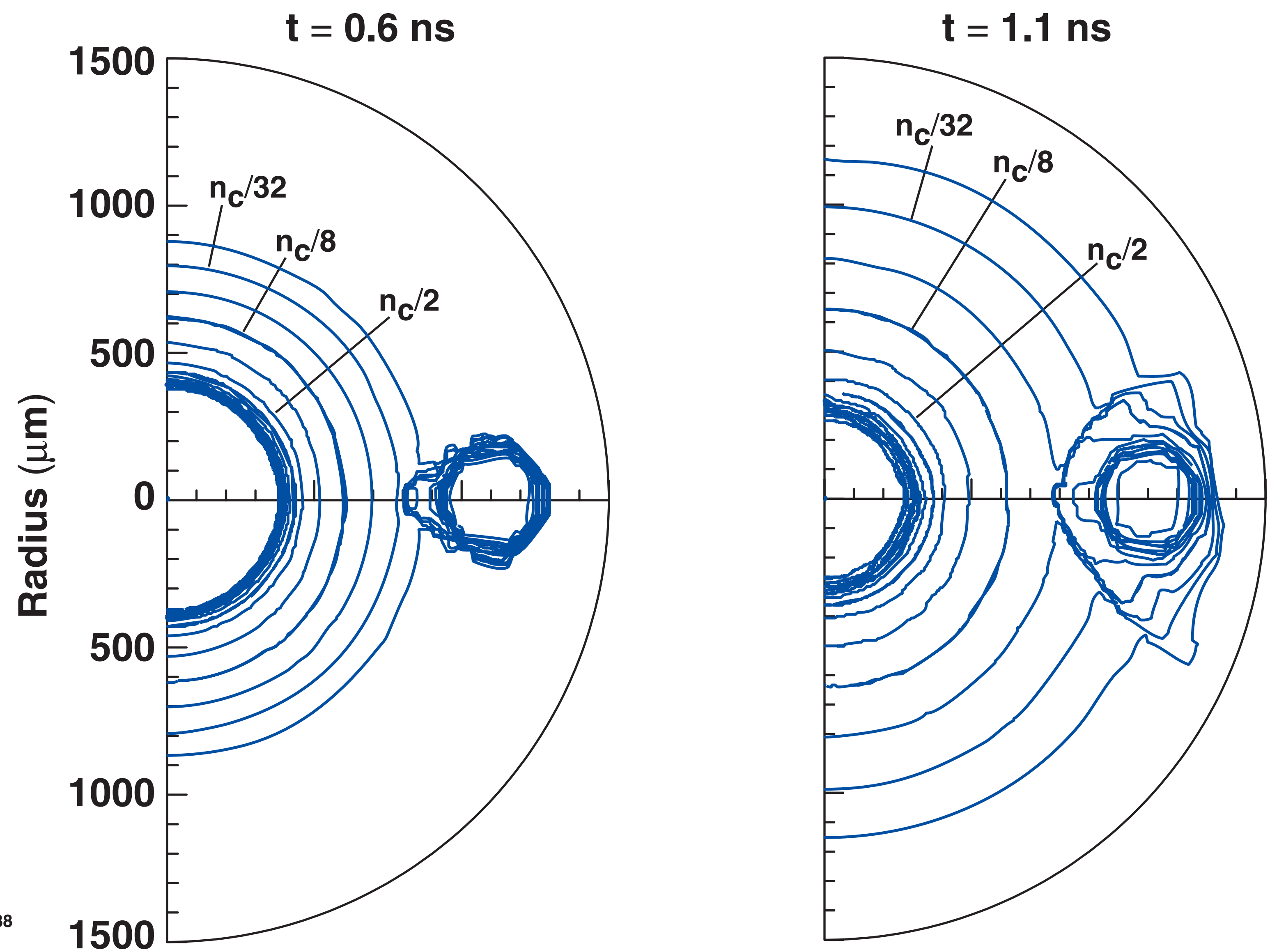
Saturn targets have been shot on OMEGA

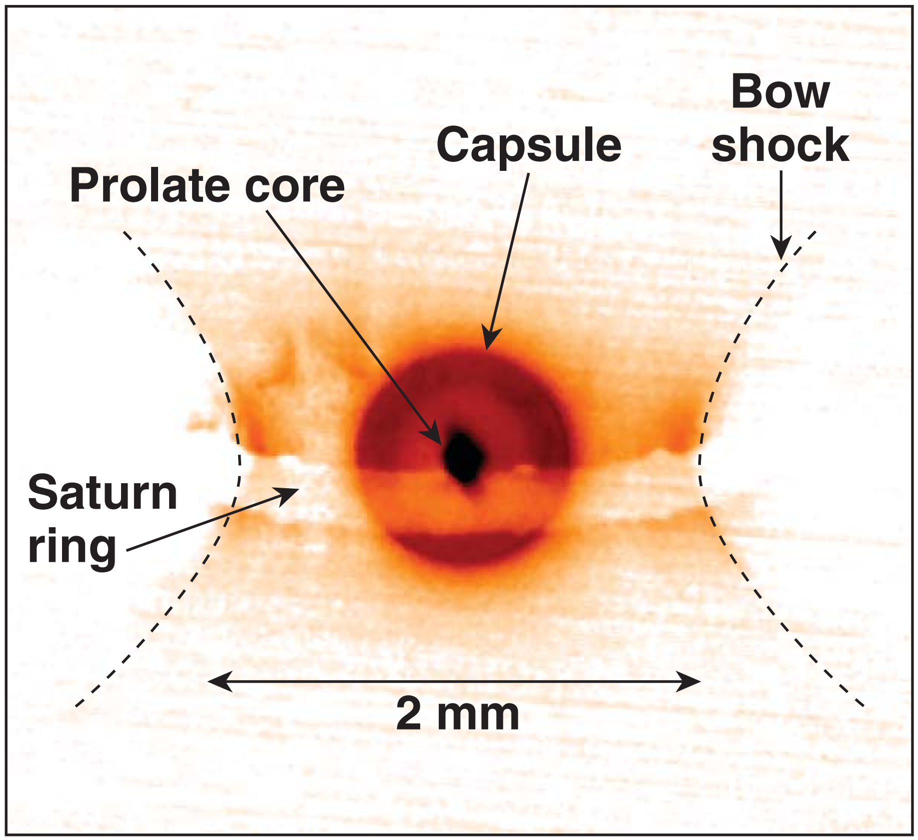


The ring plasma grows mainly in the second half of the laser pulse and leads to the formation of a “bow shock”



Run 4488
TC6660

A time-integrated x-ray pinhole camera image (~2 to 5 keV) shows the bow shock



OMEGA shot 37430

TC6661

The prolate core is seen most clearly in a KB microscope image at higher photon energies

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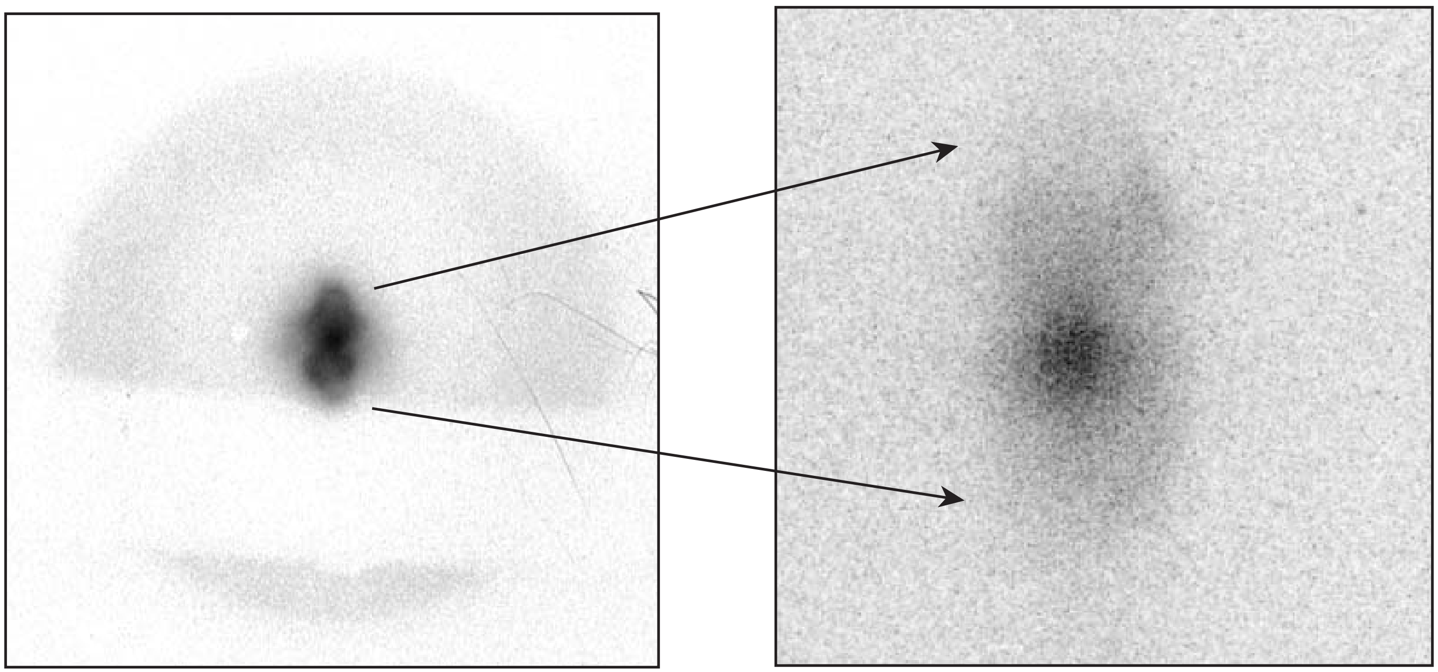
Pinhole camera (2 to 5 keV)

KB microscope (4 to 7 keV)



865 μm

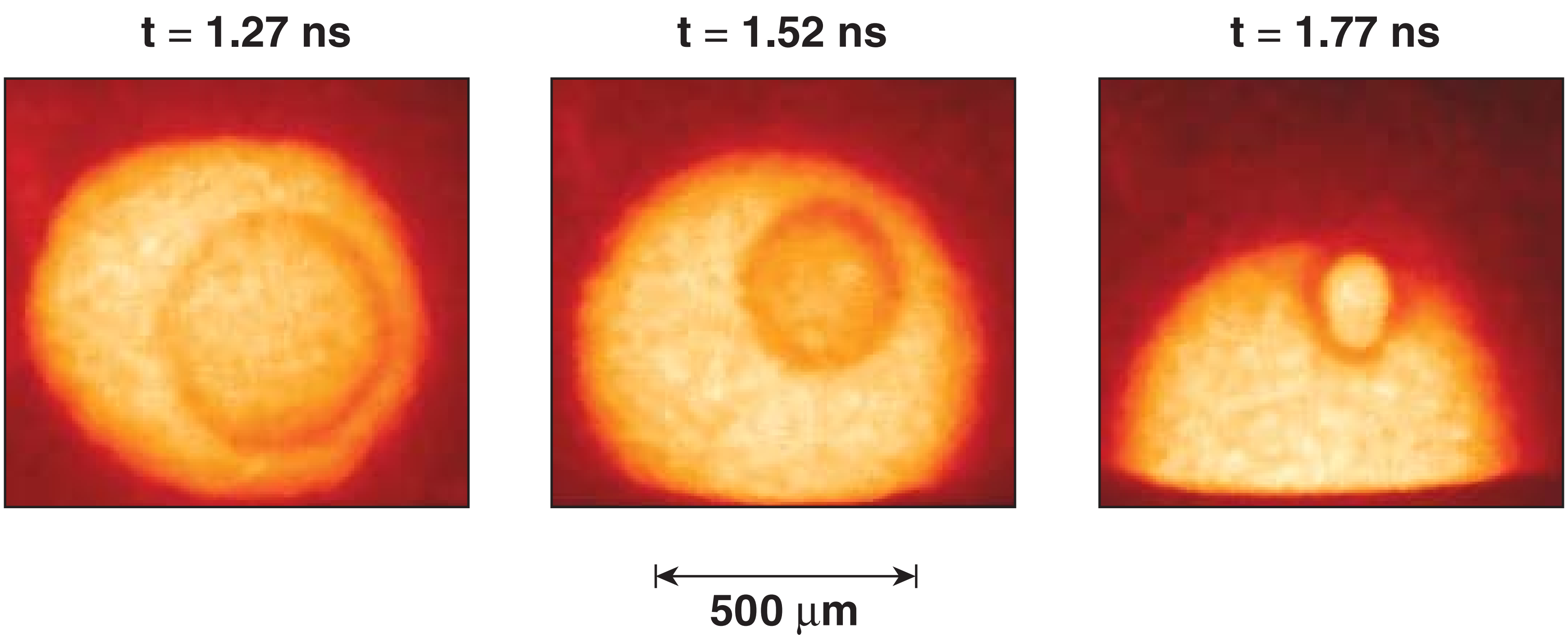
100 μm

OMEGA
Shot 37428
(Saturn)

TC6771

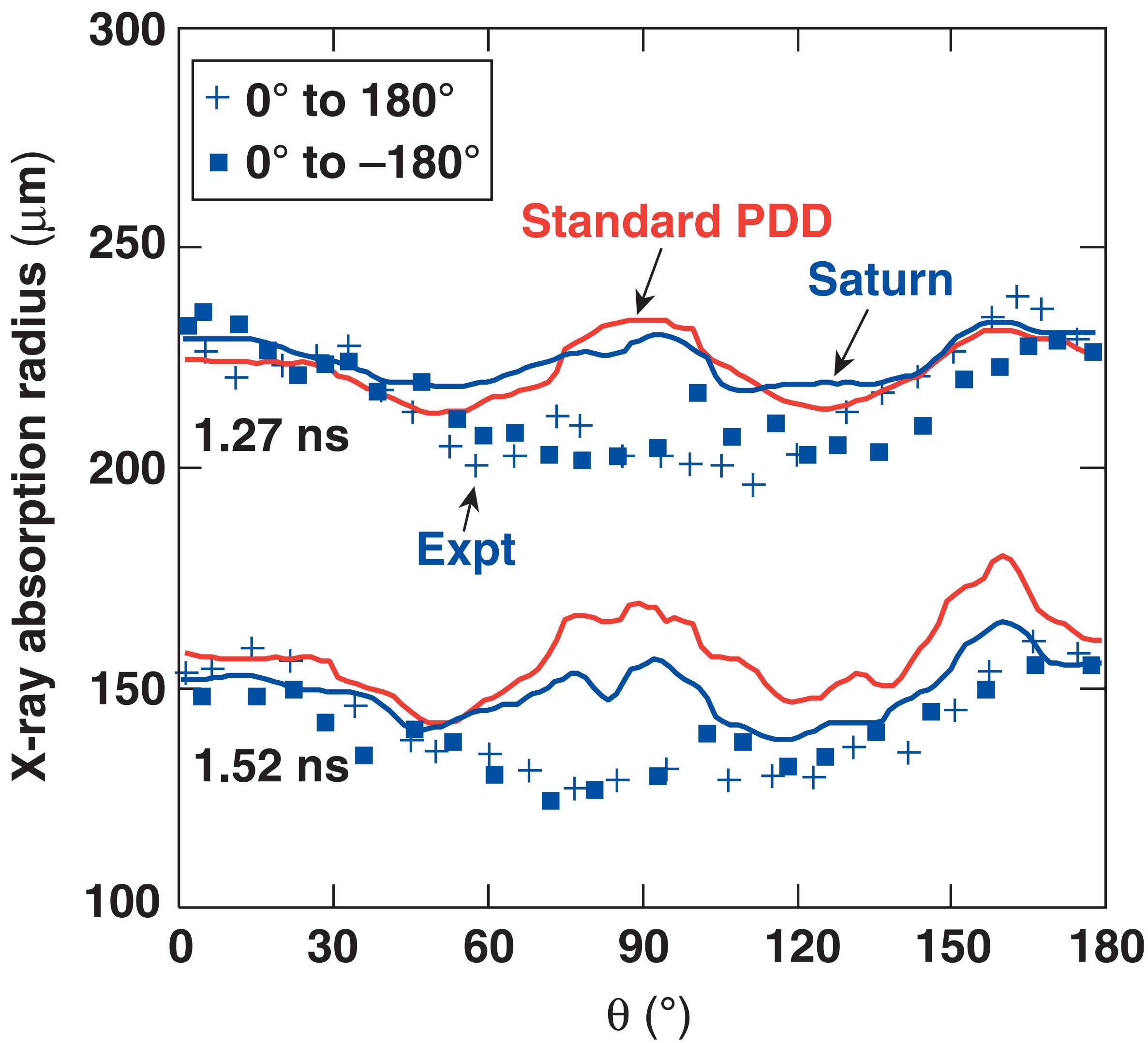
Framing-camera backlit images show increased drive on the equator

P6 view (26.6° above equator)



Shot 37428-7,11,15
TC6662

The additional drive at the equator for the Saturn target is greater than predicted



Shot 37428
Run 4488, 4187
TC6860

Summary/Conclusions

Using polar direct-drive (PDD), the prospects for ignition on the NIF are very good

UR LLE

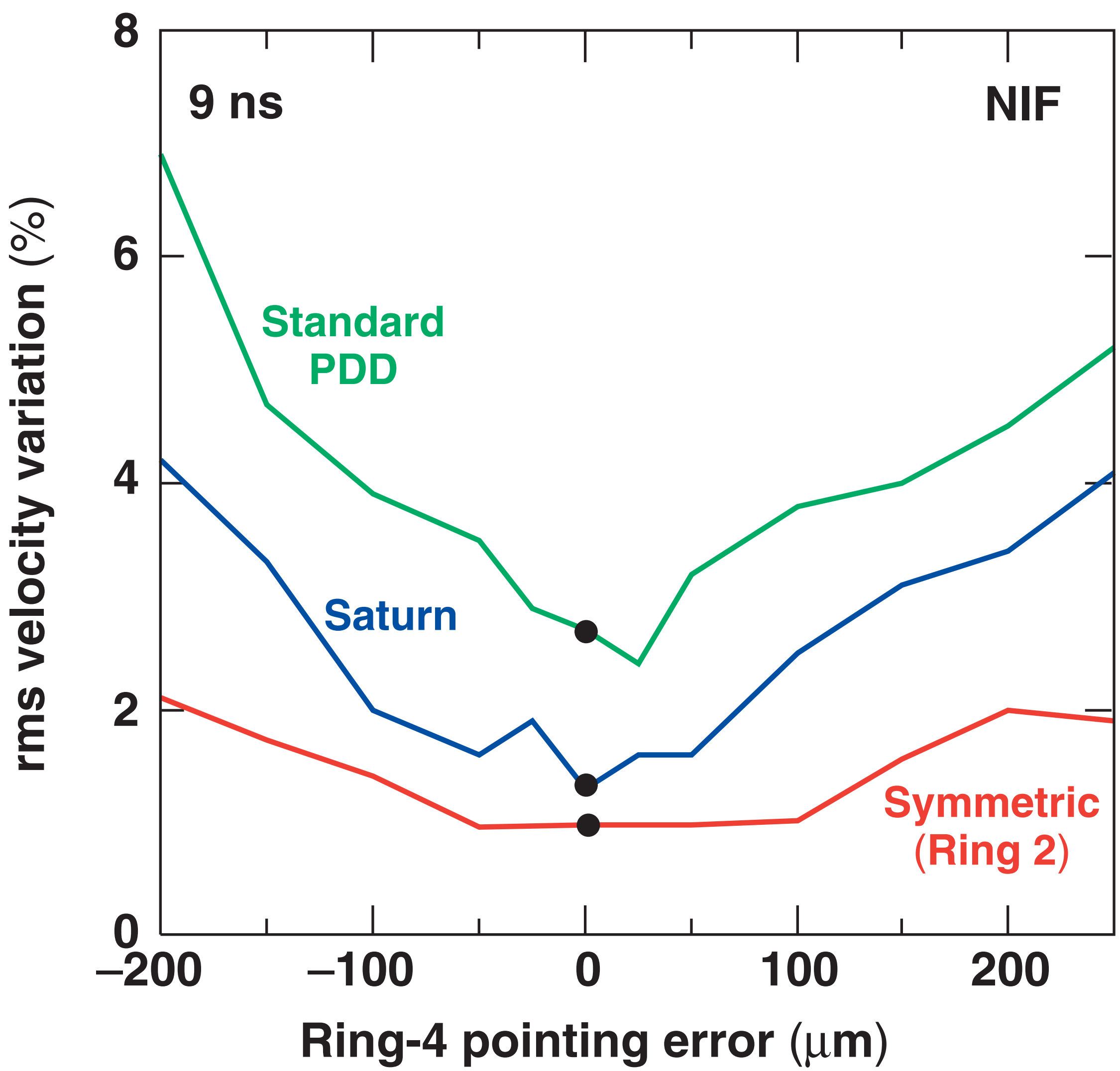
- Current *SAGE*/*DRACO* simulations of NIF PDD targets give moderate gains.
- The Saturn design has the potential to give yields approaching 1-D gain.
- OMEGA PDD experiments have demonstrated close agreement between the observed nonuniformity and *SAGE* predictions.
- The first Saturn PDD experiment on OMEGA has shown that the ring can be used to change the drive uniformity.

The PDD concept can be tested on the NIF as soon as 192 beams are available

See also: J. Soures (HO1.012)
R. Epstein (HO1.013)
J. Marozas (HO1.014)

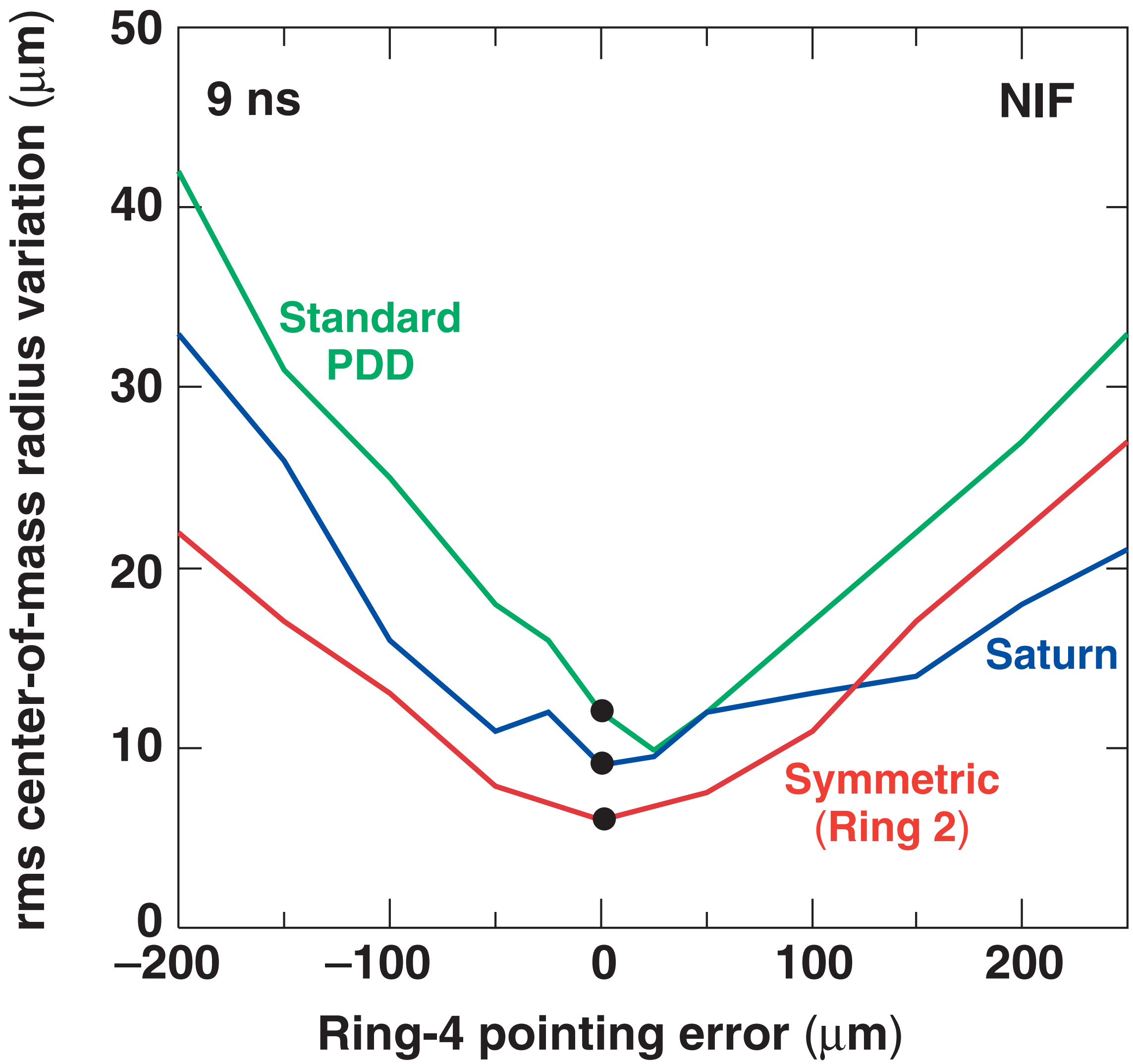
TC6643a

The standard PDD and Saturn designs require reasonable Ring-4 pointing tolerances of ~ ±50 μm



Sub39-1-11
TC6665

All three designs require reasonable Ring-4 pointing tolerances of ~ ±50 μm based on center-of-mass variations

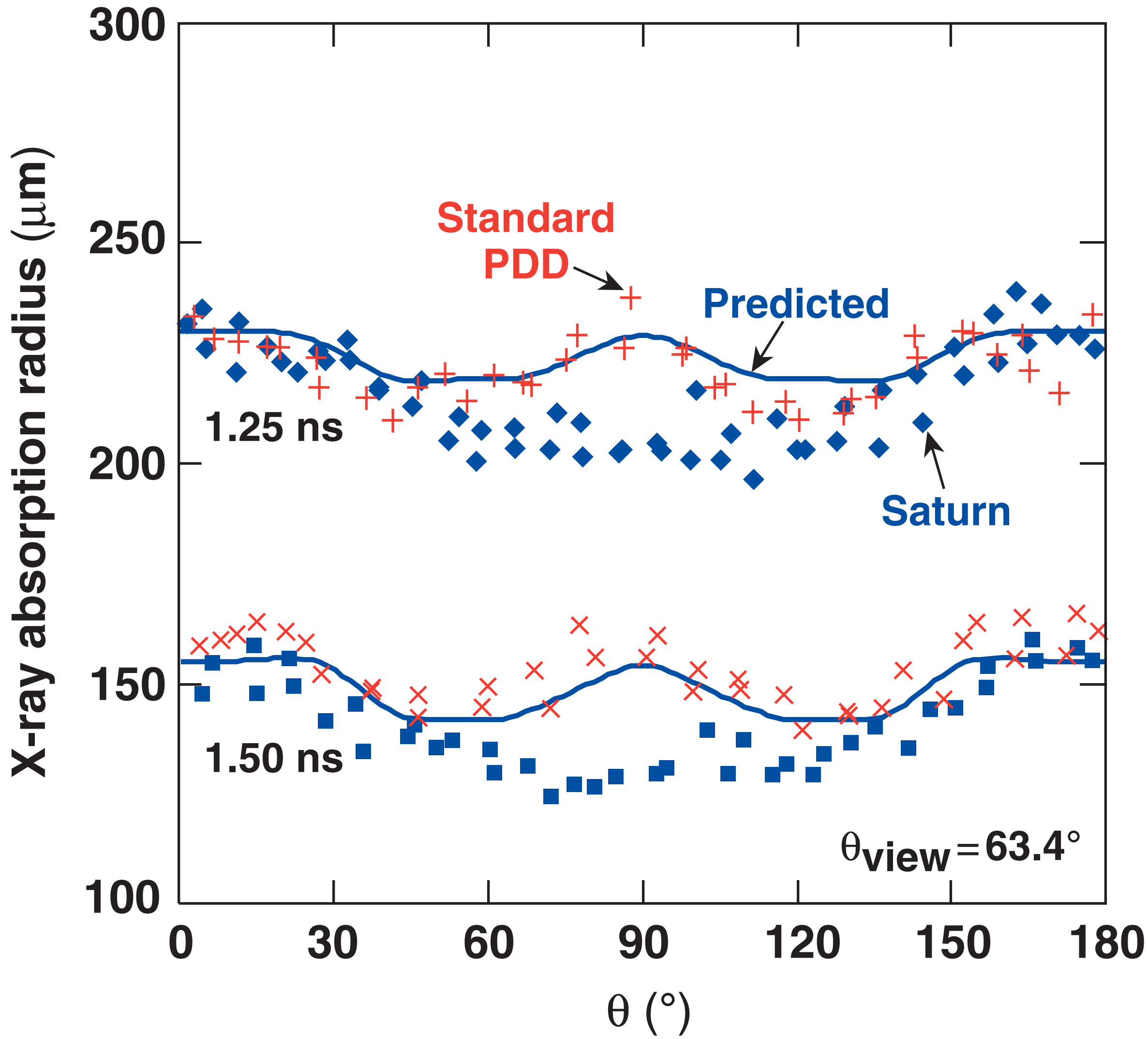


Sub39-1-12
TC6666

The neutron yield correlated with the quality of the Saturn target

Shot		Pressure (atm)	Yield (10^{10})	Comment
Symmetric	37419	13.3	6.9	
Standard PDD	37426	13.3	2.1	
	37427	13.1	2.4	
Saturn	37428	13.9	1.8	Target very close to spec
	37429	13.8	1.6	Ring offset 35 μm in Z
	37430	13.1	1.4	Ring offset 42 μm in Z, lower pressure

The additional drive at the equator for the Saturn target is greater than predicted



Shots 34669, 37428
Run 4488
TC6663

Gated backlit x-ray images show a nearly symmetric target implosion

UR LLE

OMEGA shot 34669