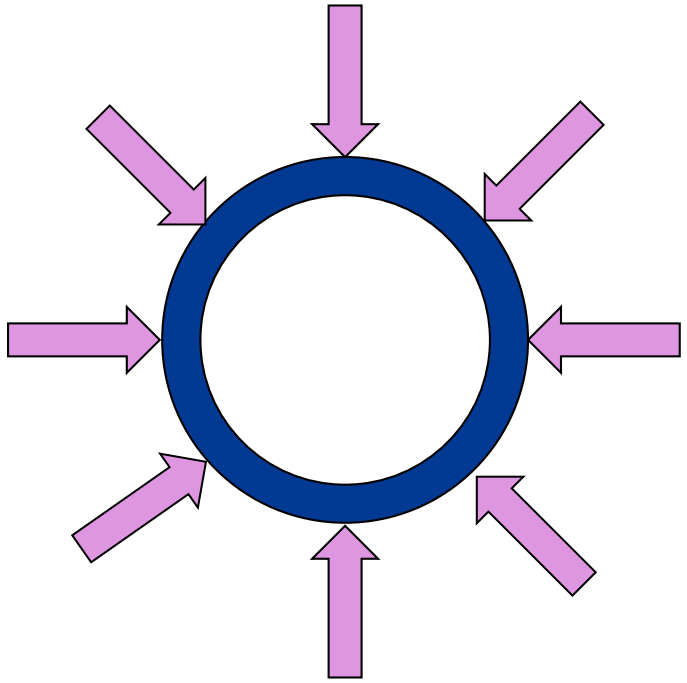
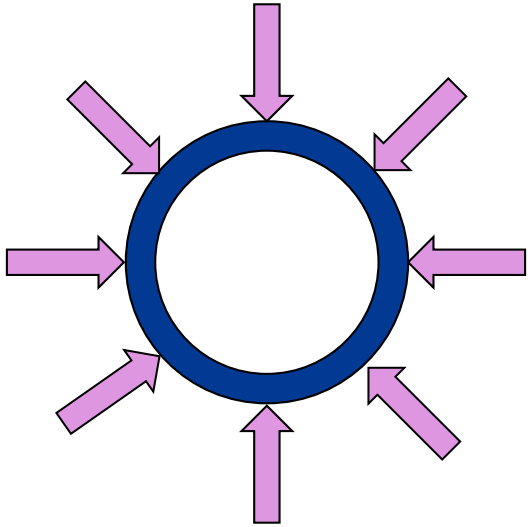
OMEGA Subscale Cryogenic Implosions in Symmetric and Polar-Direct-Drive Beam Geometry

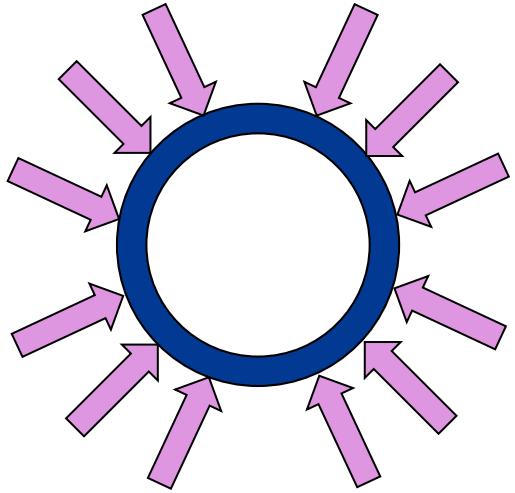
Symmetric full-scale 1× implosions



Symmetric subscale implosions (0.8× size)



Polar-direct-drive subscale implosions (0.8× size)



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Summary

Subscale implosions of cryogenically layered deuterium–tritium targets have begun on OMEGA to study SDD and PDD configurations

- The measured neutron yields and areal densities from symmetric subscale and full-scale OMEGA implosions increase faster with target size than predicted by hydro scaling
- The PDD beam geometry degrades the neutron yields and ρR's by ~60% and ~20%, respectively
- The partition of the ring energy in PDD implosions significantly affects the symmetry of the imploding shell and the shape of the hot spot

Target solutions such as shimmed ice layers and contoured shells* will be explored to improve the PDD implosion performance.

SDD: symmetric direct drive
PDD:polar direct drive
*F. J. Marshall *et al.*, Phys. Plasmas 23, 012711 (2016).

Collaborators

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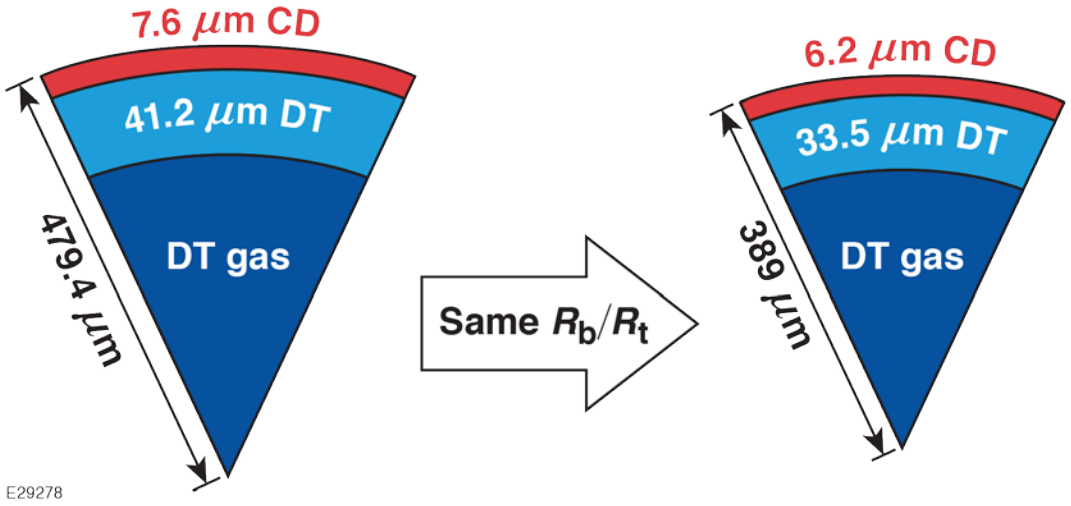
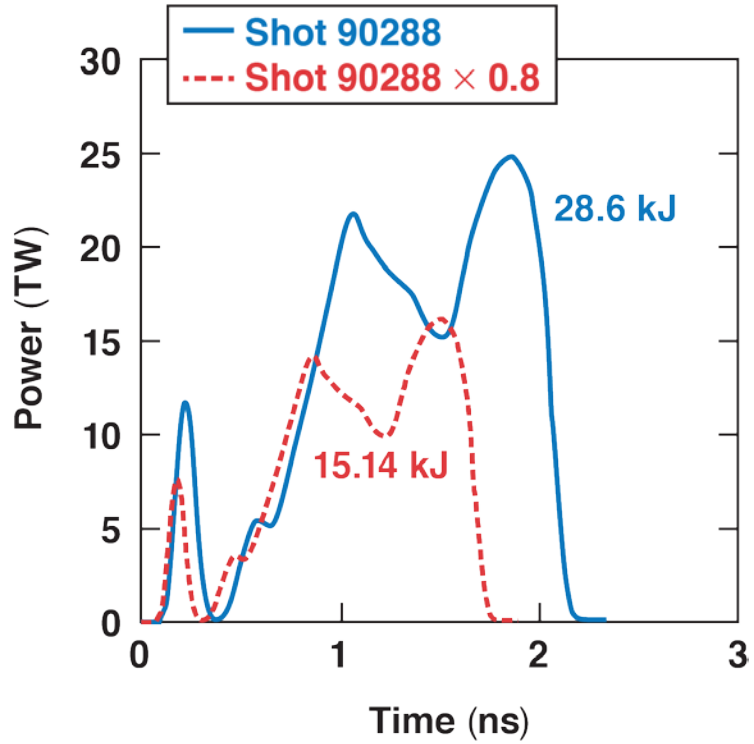
The implosions use a hydrodynamically scaled* version of the best-performing SDD implosion** with a smaller target, small-spot phase plates, and about half of the laser energy

- The hydrodynamic scaling relations preserve ablation pressure (or laser intensity I), adiabat α, implosion velocity v_{imp}, and the hot-spot pressure



E_L (kJ) = 28.6 kJ
V_{imp} = 469 km/s
1-D n yield = 4.4 ×10^{14}
1-D ρR = 177 mg/cm^2

E_L (kJ) = 15.4 kJ
V_{imp} = 479 km/s
1-D n yield = 1.8 ×10^{14}
1-D ρR = 140 mg/cm^2

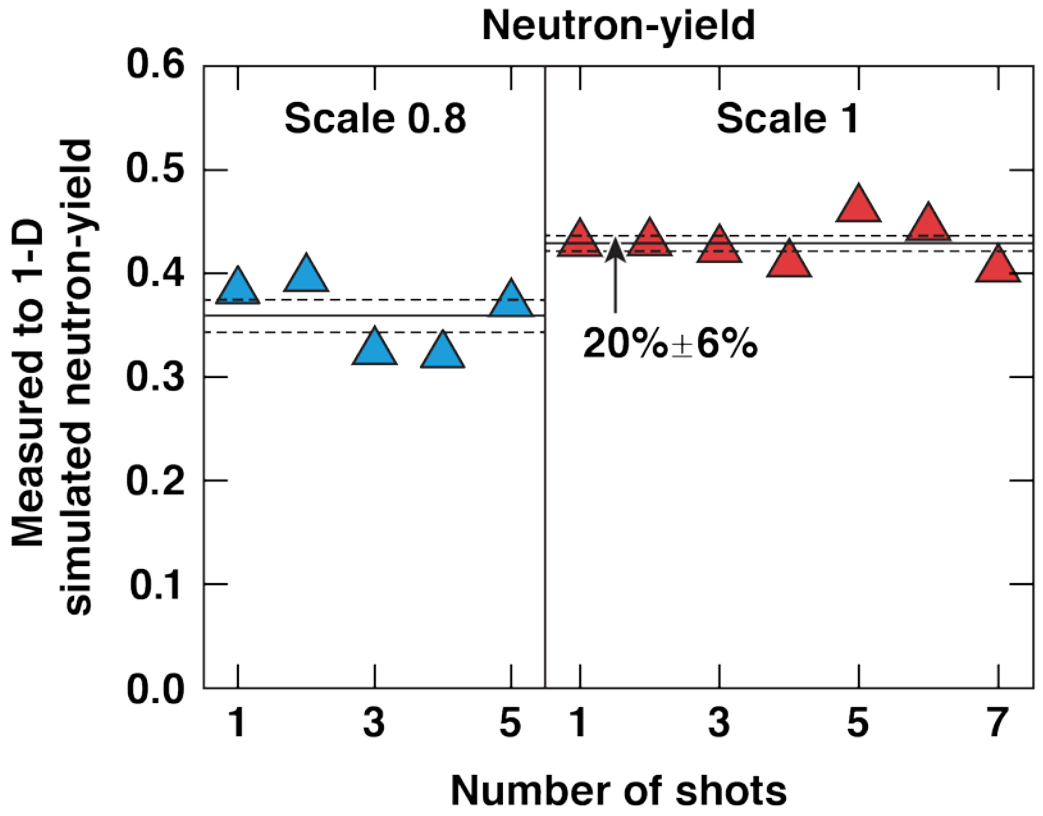


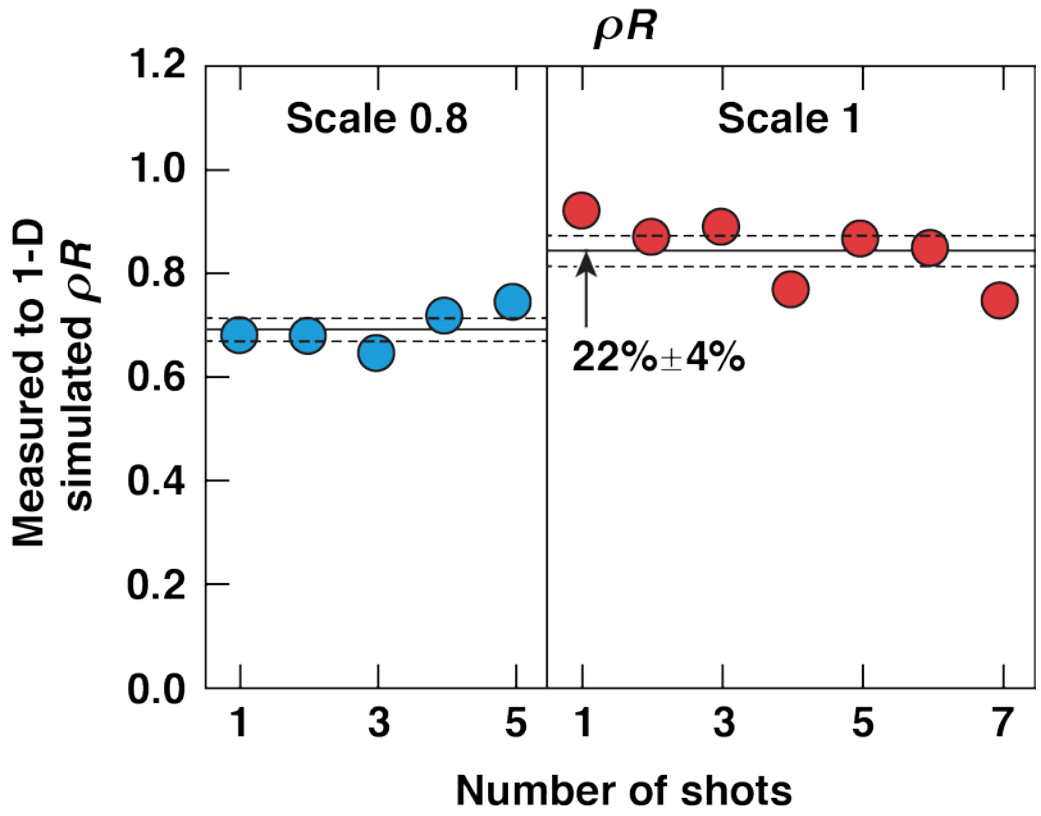
$$nY_{subscale} \approx scale^{4.5} \cdot nY_{full}$$

$$\rho R_{subscale} \approx scale \cdot \rho R_{full}$$

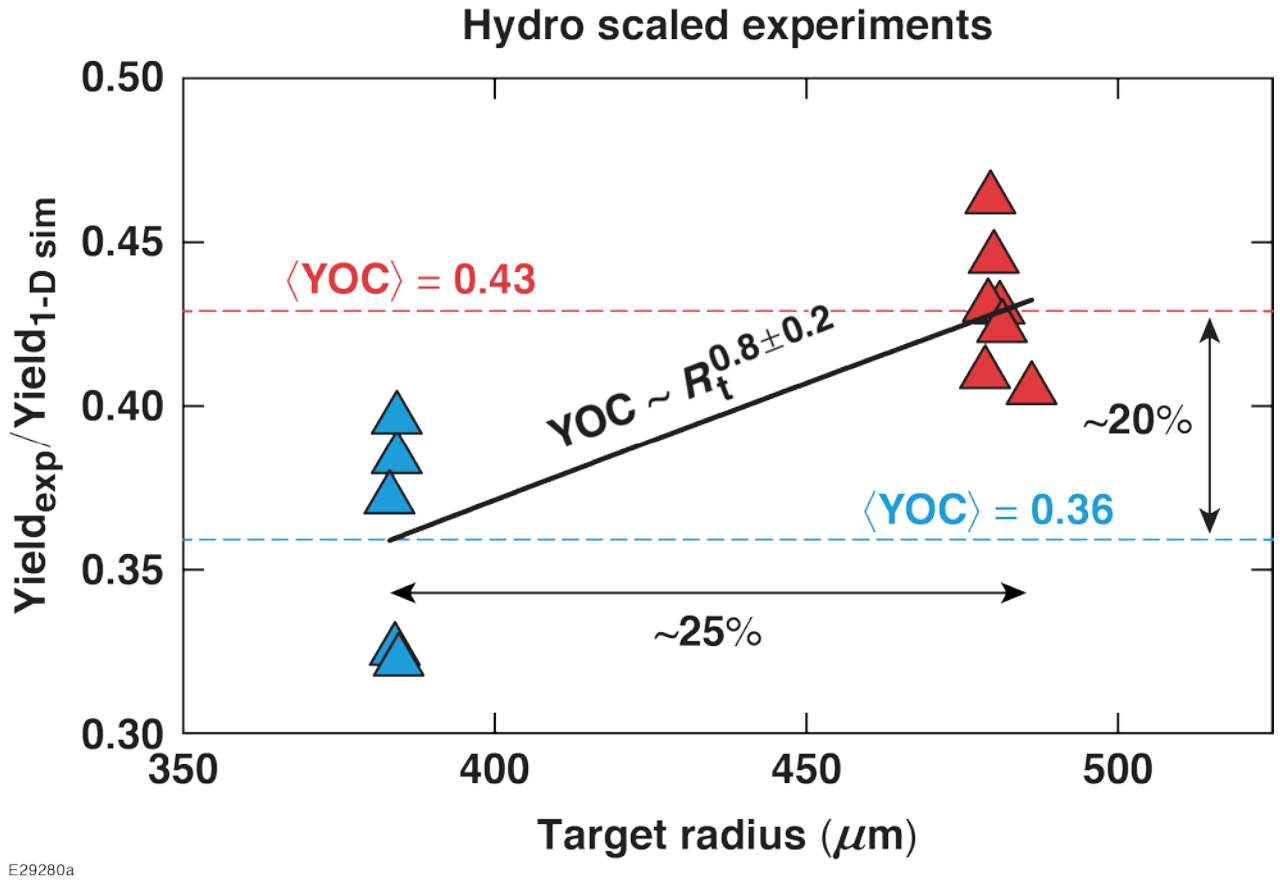
* R. Nora *et al.*, Phys. Plasmas 21, 056316 (2014).
** V. Gopalaswamy *et al.*, Nature 565, 581 (2019).

The measured neutron yields and areal densities from symmetric sub-scale and full-scale OMEGA implosions increase faster than predicted with scale size



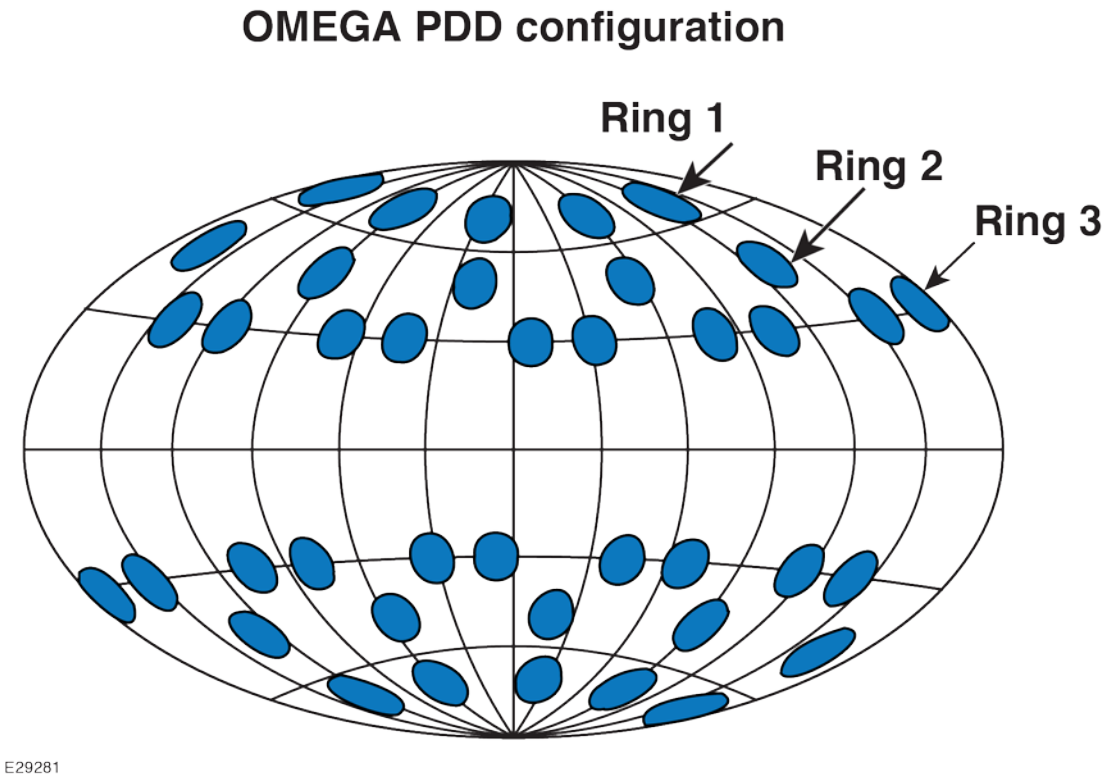


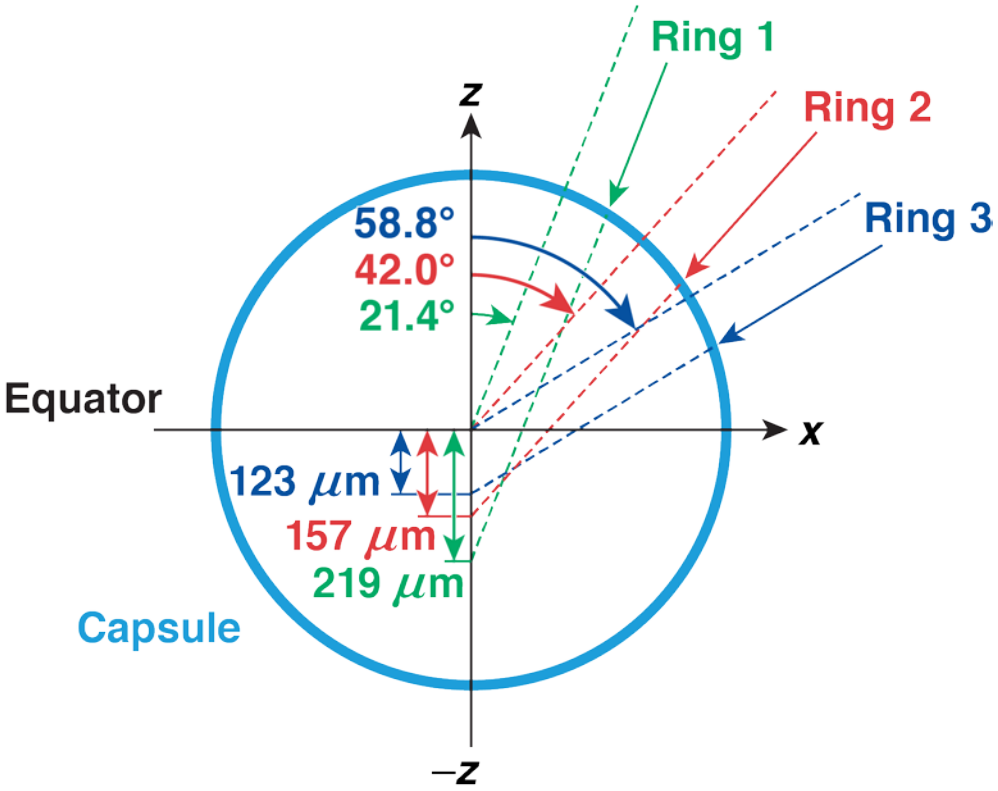
The hydro-scaled implosion experiments exhibit a size dependence of the fusion yield faster than hydro scaling*,**



* R. Betti *et al.*, BO09.00011, this conference.
** C. A. Thomas *et al.*, BO09.00010, this conference.

Polar-direct-drive*,** sub-scale implosions were performed to assess the effect on implosion performance from the PDD geometry

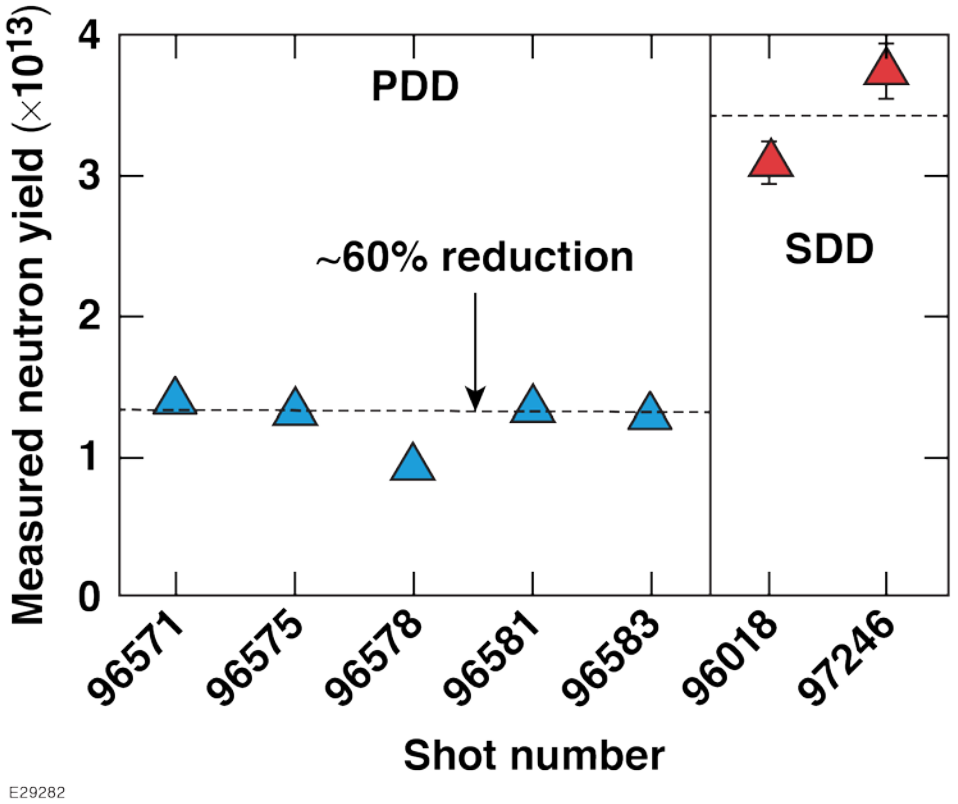


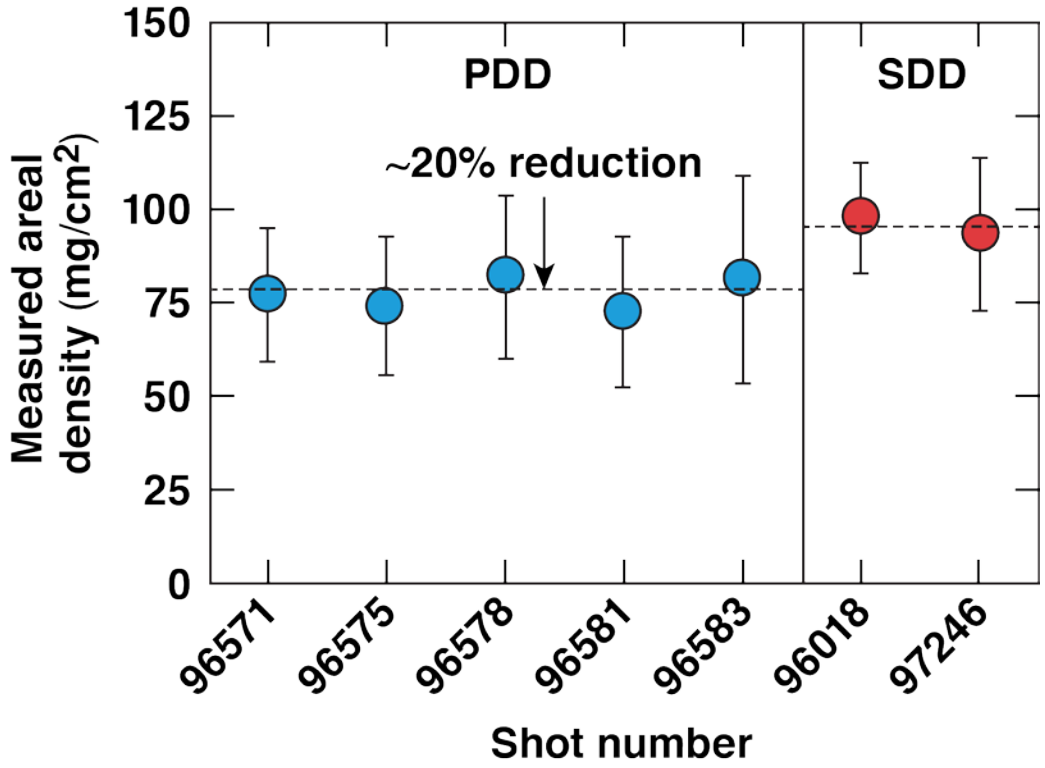


- **40 beams**
- **13 kJ of total energy**

* P. B. Radha *et al.*, Phys. Plasmas 19, 082704 (2012).
** P. B. Radha *et al.*, BO09.00013, this conference.

The PDD geometry affects the neutron yield more than the ρR





The results are consistent with previous PDD CH-shell implosions* on OMEGA.

* P. B. Radha *et al.*, Phys. Plasmas 19, 082704 (2012).

Gated x-ray images of the imploding shell* show that the partition of the ring energy ratio significantly affects the symmetry of the imploding shell

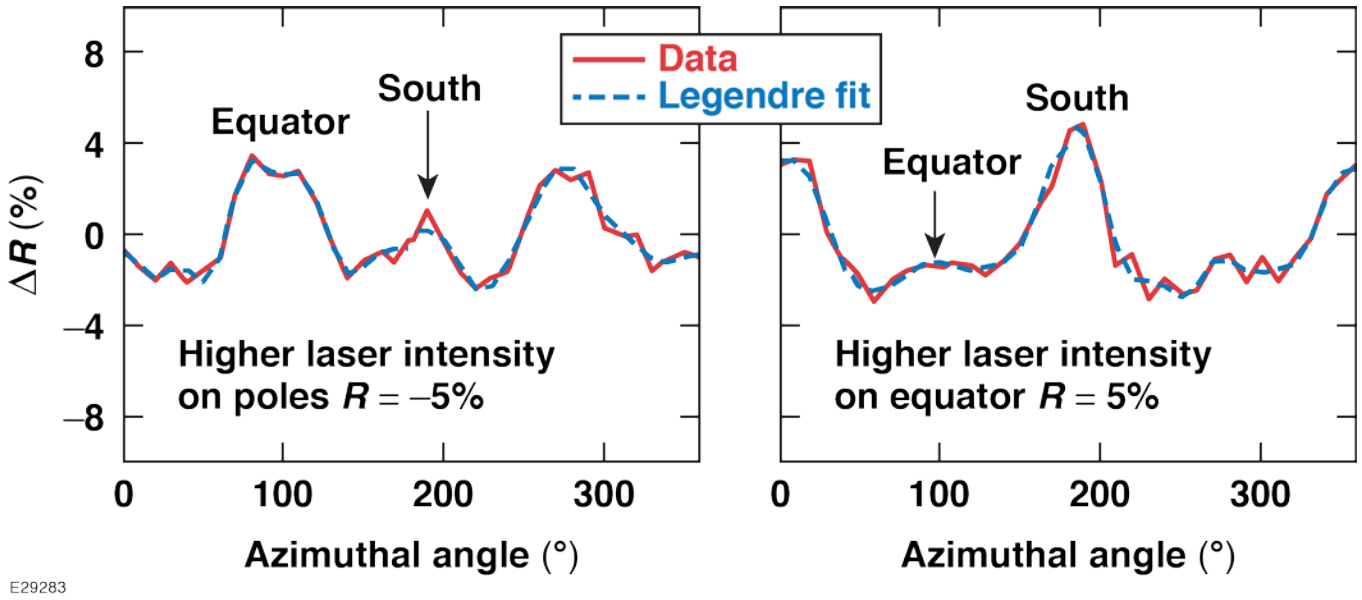
Ring energy ratio: $R = \Delta R_3 - \Delta R_1$, with $|\Delta R_3| = |\Delta R_1|$

Negative R: more drive on poles

Positive R: more drive on equator

R	Ring 1	Ring 2	Ring 3
–5%	27.5%	25%	47.5%
0%	25.0%	25%	50.0%

Shell contour for r = 300 μm



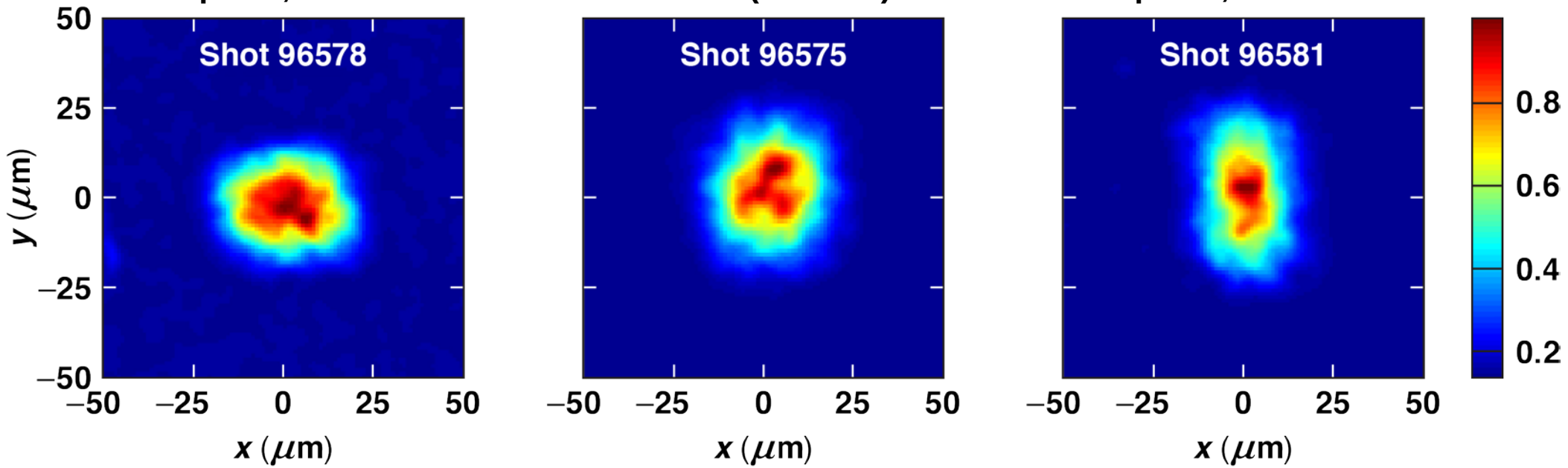
*D. T. Michel *et al.*, Rev. Sci. Instrum. 83, 10E530 (2012).

Gated hot-spot x-ray images from the KBframed diagnostic* show how the ring energy partition affects the shape of the hot spot

Observation from equatorial position

Higher laser intensity on poles, *R* = *-5%*

Higher laser intensity on equator, *R* = *+10%*



* F. J. Marshall *et al.*, Rev. Sci. Instrum. 88, 093702 (2017).

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