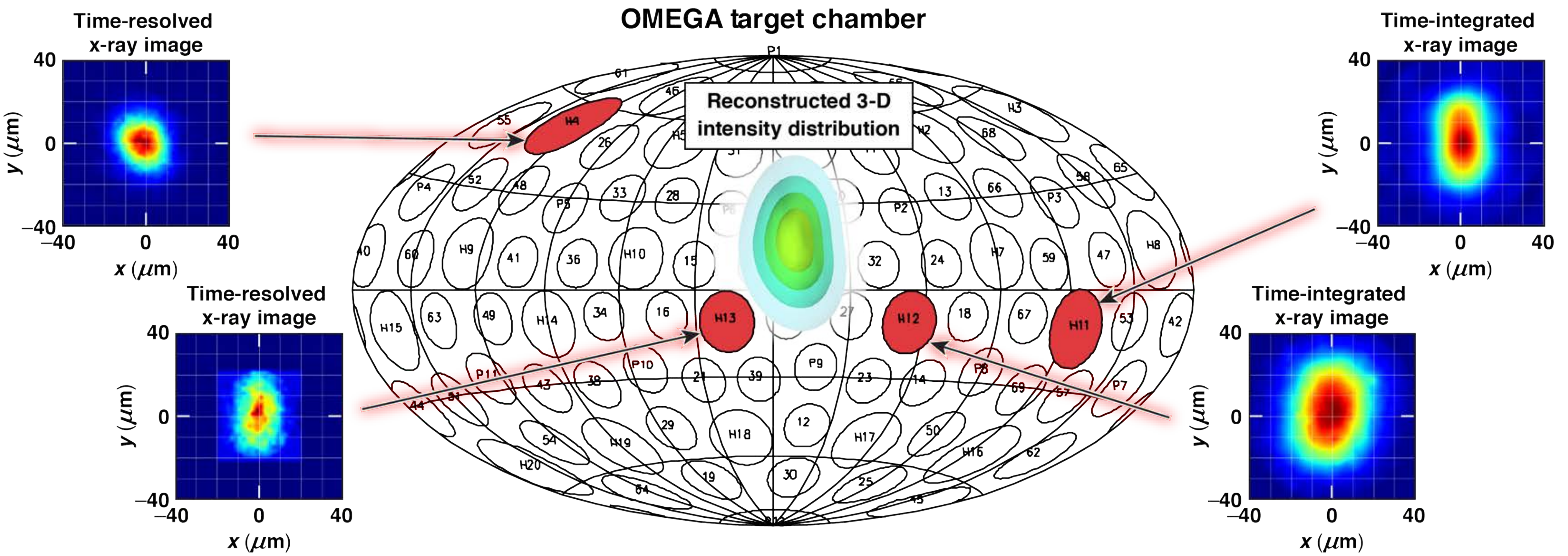
Three-Dimensional Hot Spot Reconstruction from Cryogenic DT Polar-Direct-Drive Implosions on OMEGA



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Summary

A 3-D hot-spot model* has been developed to study and interpret the symmetry of implosions at OMEGA

- A technique was developed to reconstruct the 3-D intensity profile using a Spherical Harmonic Gaussian function
- This technique was validated by reconstructing synthetic data produced by the hydrodynamic code DEC3D**, and then applied to experimental data
- Causal effects from the laser drive show the expected change in hot-spot shape from prolate to oblate, indicated by the change in sign of the inferred $A_{2,0}$ coefficients
  - The magnitudes of the inferred $A_{2,0}$ coefficients are in agreement with the magnitudes of laser drive asymmetries

* K. M. Woo *et al.*, ZO04.00006, this conference.
** K. M. Woo *et al.*, Phys. Plasmas 25, 052704 (2018).

Collaborators

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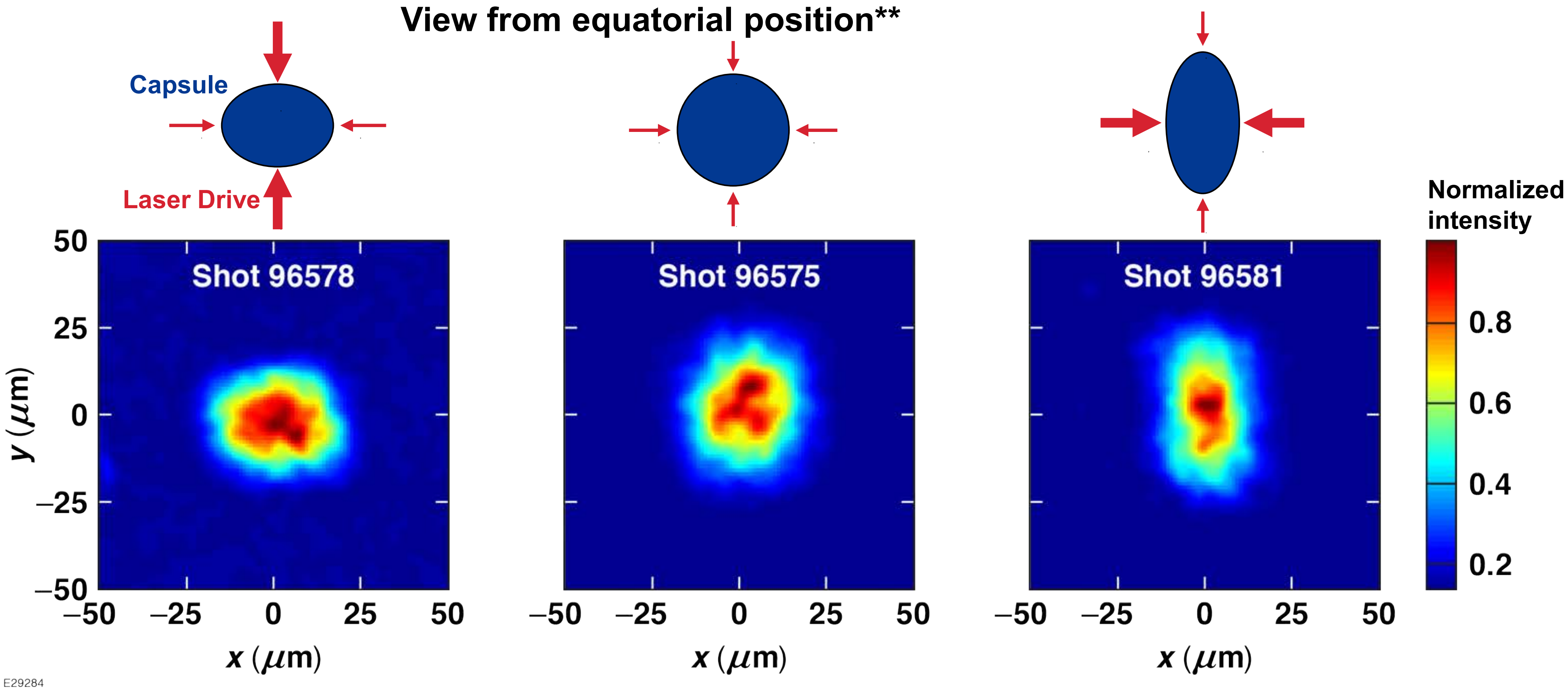
PDD implosions can be used to generate large asymmetries, and make a useful platform for testing aspects of 3-D reconstruction

Expected hot-spot shape

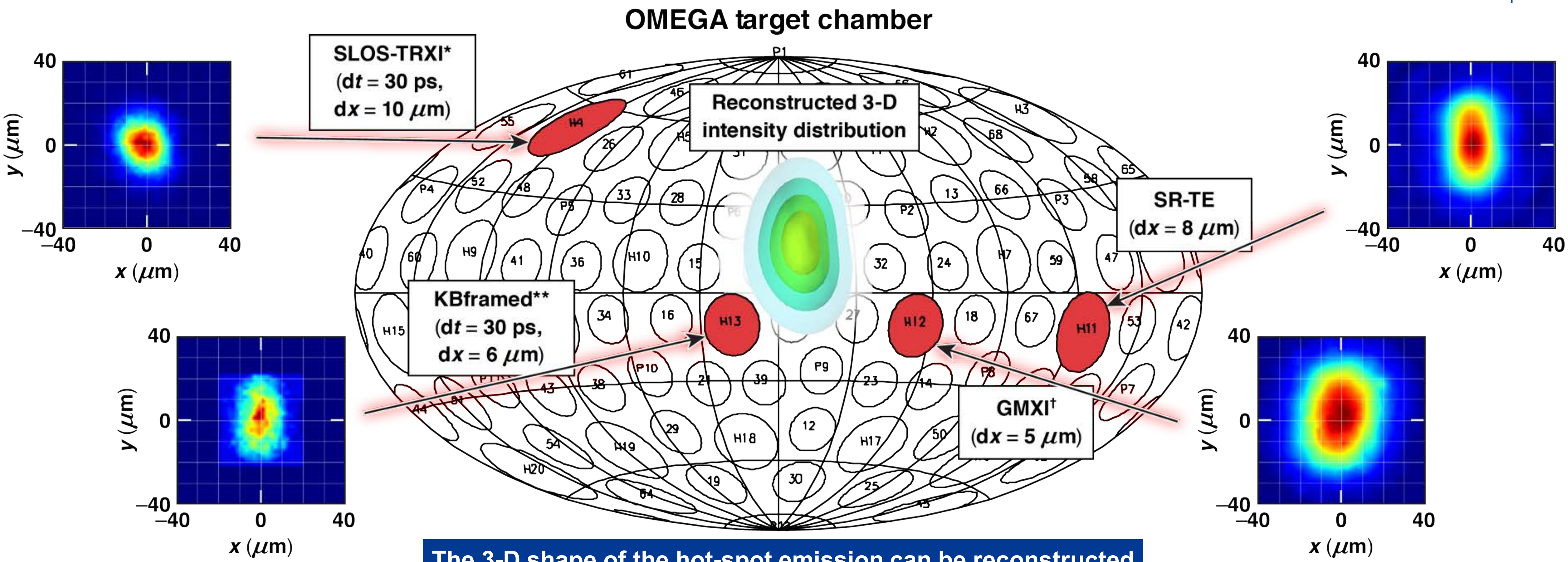
Experimental x-ray data



Precise characterization of these asymmetries could help us to improve implosion performance.

W. Theobald *et al.*, Bull. Am. Phys. Soc. 65, BO09.00010 (2020).
* P. B. Radha *et al.*, Phys. Plasmas 19, 082704 (2012).
** F. J. Marshall *et al.*, Rev. Sci. Instrum. 88, 093702 (2017).
PDD: polar-direct-drive

Magnitude and orientation of the low-mode shape can be inferred from x-ray images along different lines of sight



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The 3-D shape of the hot-spot emission can be reconstructed using data from several quasi-orthogonal lines of sight.

SLOS-TRXI: single line-of-sight time-resolved x-ray imager
SR-TE: spatially resolved electron temperature
GMXI: gated microscopic x-ray imaging

* W. Theobald *et al*., Rev. Sci. Instrum. 89, 10G117 (2018).
** F. J. Marshall *et al*., Rev. Sci. Instrum. 88, 093702 (2017).
† F. J. Marshall and J. A. Oertel, Rev. Sci. Instrum. 68, 735 (1997).

A 3-D hot-spot intensity model* was developed to reconstruct the hot-spot emission profile of direct-drive implosions on OMEGA

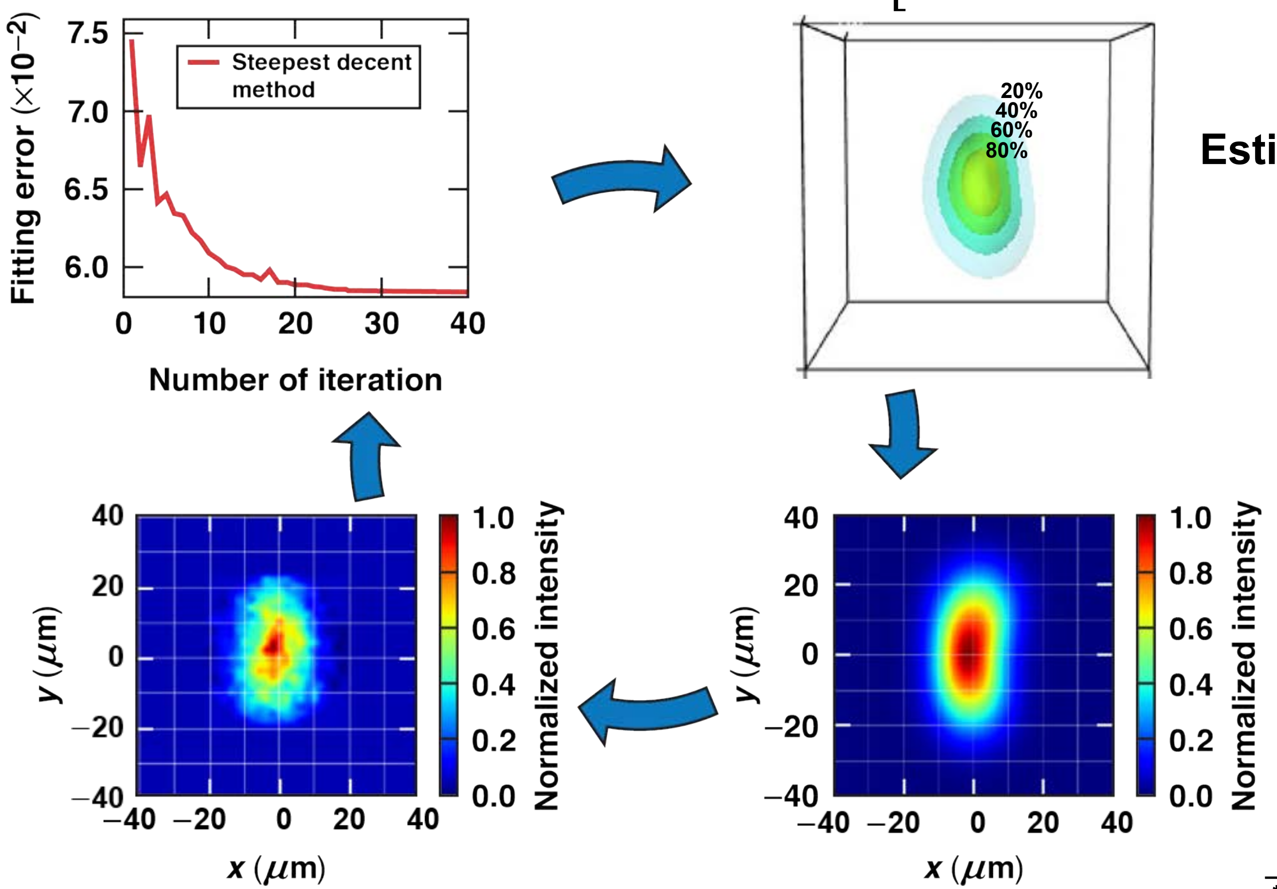
Spherical harmonic Gaussian function: $$\ln I(r,\theta,\phi) = \sum_{n=0}^{\infty} \sigma_n r(\theta,\phi)^n = \sum_{n=0}^{\infty} \sigma_n R^n \left[1 + \sum_{l=0}^{\infty} \sum_{m=-l}^{l} A_{lm}(R)\, Y_{lm}(\theta,\phi)\right]^n$$

Calculate error between experimental data and model

Estimate for solution

Compare with experimental data

2-D projection in detector planes



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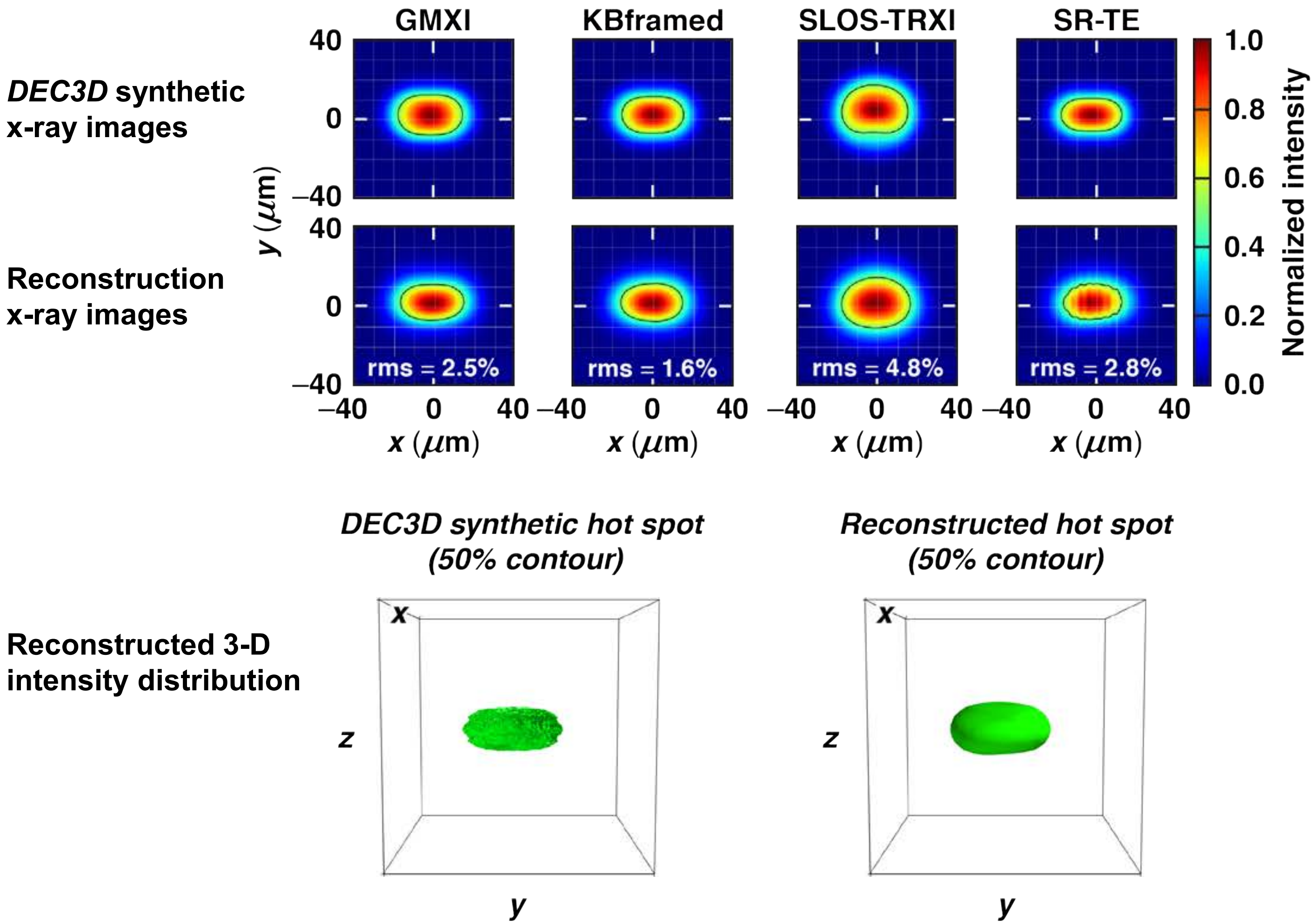
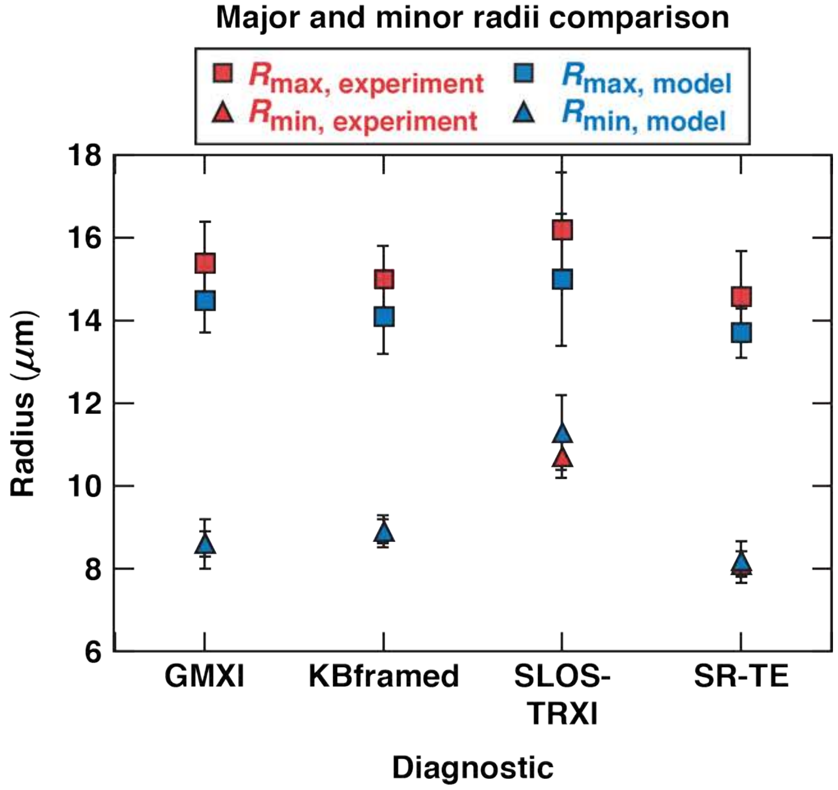
* K. M. Woo *et al.*, ZO04.00006, this conference.

This approach has been tested against forward-simulated data from DEC3D*, and shows good agreement on major and minor radii





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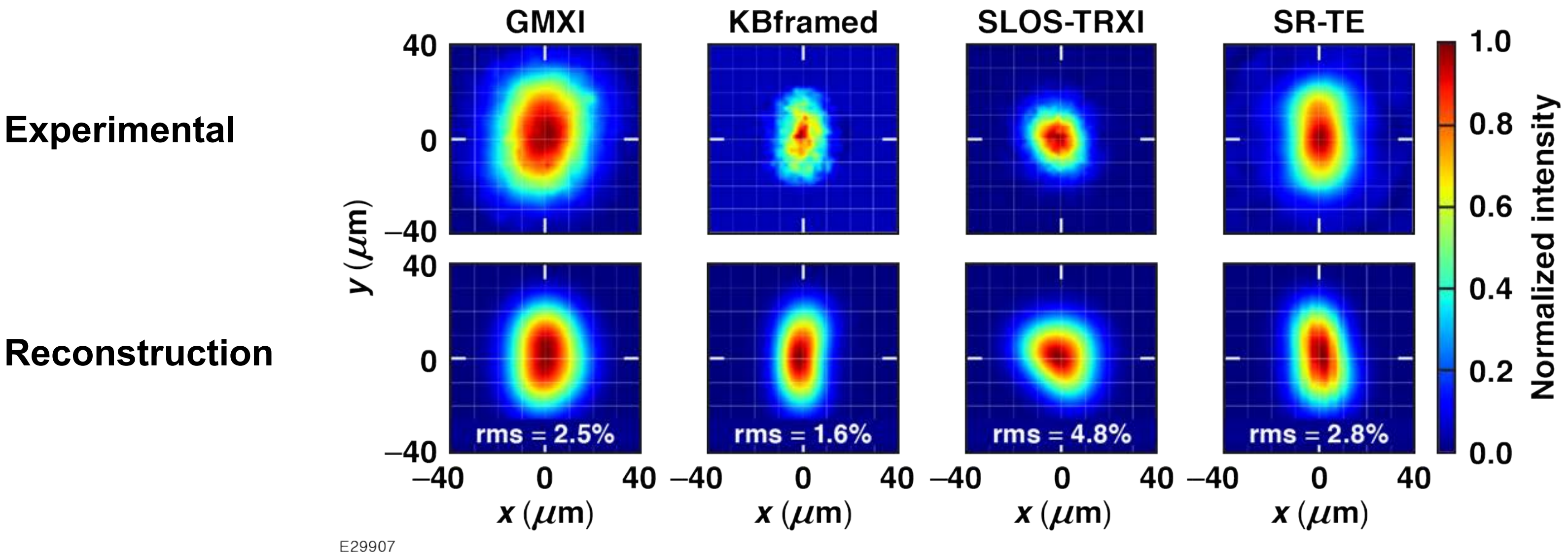
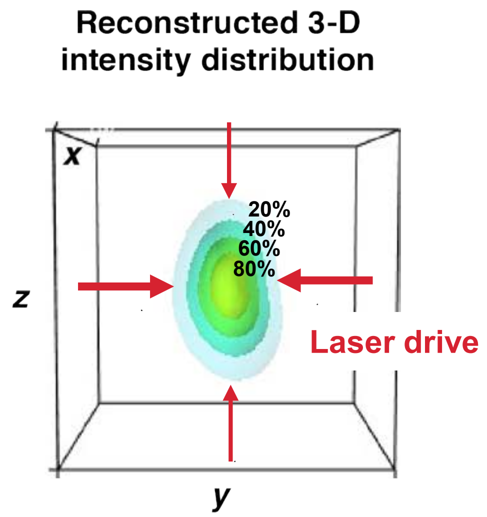
* K. M. Woo *et al.*, Phys. Plasmas 25, 052704 (2018).

Reconstruction of experiment 96581 shows a prolate-shaped hot-spot, indicated by a negative $A_{2,0}$ coefficient



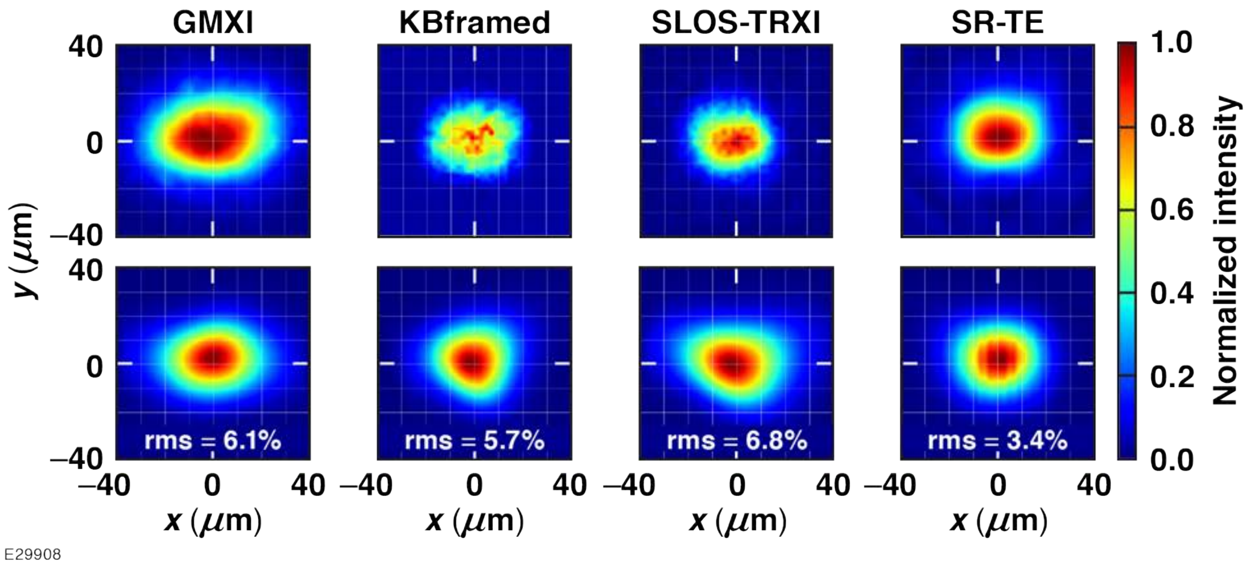


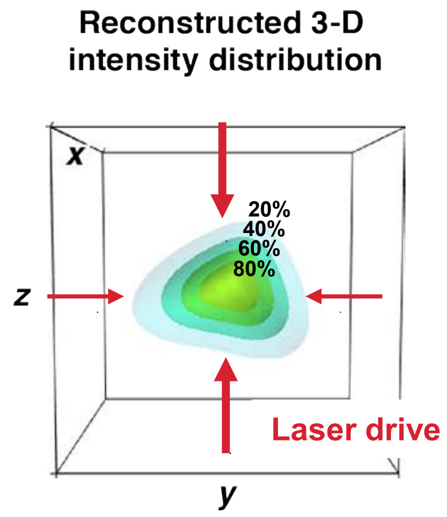
Spherical harmonic coefficients:

	$M=-3$	$M=-2$	$M=-1$	$M=0$	$M=1$	$M=2$	$M=3$
$L=1$			0.02 ± 0.01	0.03 ± 0.01	0.04 ± 0.01		
$L=2$		-0.21 ± 0.01	0.1 ± 0.01	-0.47 ± 0.03	0.033 ± 0.003	-0.24 ± 0.02	
$L=3$	0.02 ± 0.01	0.08 ± 0.03	-0.05 ± 0.01	0.03 ± 0.01	-0.07 ± 0.01	-0.09 ± 0.02	0.23 ± 0.03

A better understanding of the fitting process and uniqueness is needed.

Experiment 96578 shows the expected change to an oblate hot-spot, indicated in the change in sign of coefficient $A_{2,0}$





Spherical harmonic coefficients:

	$M=-3$	$M=-2$	$M=-1$	$M=0$	$M=1$	$M=2$	$M=3$
$L=1$			-0.13 ± 0.01	0.18 ± 0.01	-0.13 ± 0.01		
$L=2$		-0.2 ± 0.01	-0.08 ± 0.01	0.17 ± 0.01	-0.09 ± 0.01	-0.24 ± 0.01	
$L=3$	-0.05 ± 0.01	-0.13 ± 0.01	-0.17 ± 0.01	-0.18 ± 0.01	-0.07 ± 0.01	-0.22 ± 0.01	0.25 ± 0.02

The magnitude of the $A_{2,0}$ coefficient is reduced by a factor of 2 in accordance with the reduction in laser drive asymmetry by a factor of 2.

Summary/Conclusions

A 3-D hot-spot model* has been developed to study and interpret the symmetry of implosions at OMEGA

- A technique was developed to reconstruct the 3-D intensity profile using a Spherical Harmonic Gaussian function
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Future work will consider uniqueness, the highest mode that is resolved by existing data, and the potential value of improvements in resolution and additional lines of sight

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