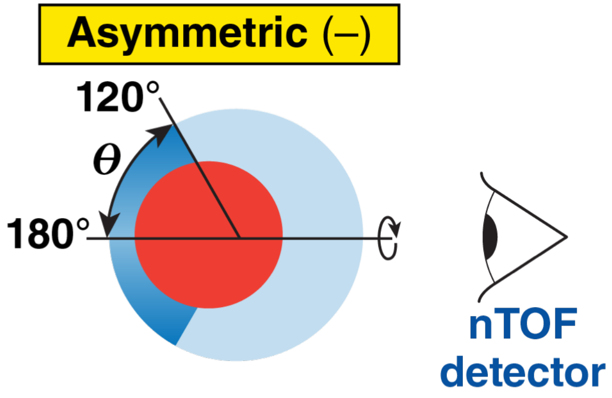
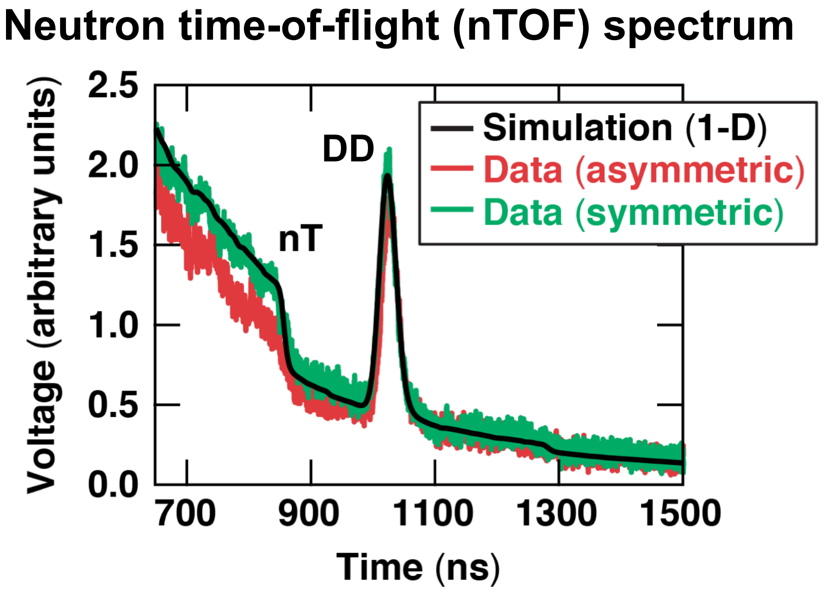
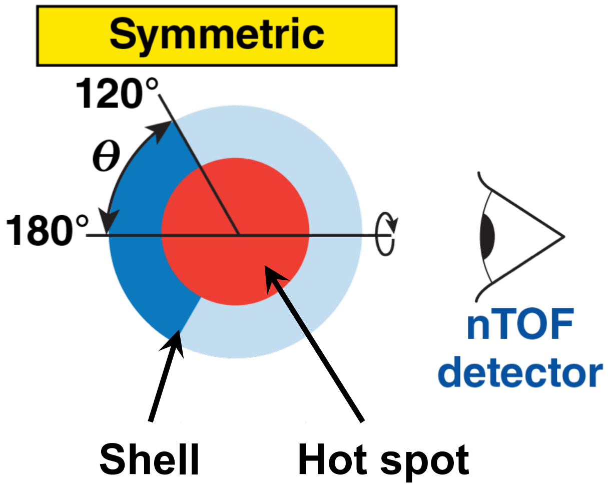
# Evaluating the Effects of Imperfections in Laser Illumination on Direct-Drive Cryogenic DT Implosions on OMEGA




E23429a




E28785a




C. Stoeckl
University of Rochester
Laboratory for Laser Energetics

61st Annual Meeting of the American Physical Society Division of Plasma Physics
Fort Lauderdale, FL
21–25 October 2019

Summary

# Minimizing low-mode illumination nonuniformities improves the performance of cryogenic implosions

- The performance of direct-drive cryogenic implosions is affected by both low-order modes like target offset and high-order modes like imprint-induced mix
- A large number of optical, x-ray, and nuclear diagnostics were used in a set of experiments to distinguish the effects of different degradation mechanisms
- The velocity of the hot core inferred from nTOF detectors* was used to intentionally offset the target minimizing the low-mode illumination nonuniformities
- With an optimized target offset of ~20 $\mu$m, the target performance improved significantly; yield increased by 2×, areal density by ~50%

* S. Regan *et al.*, YO5.00002, this conference;
O. M. Mannion *et al.*, "A Suite of Neutron Time-of-Flight Detectors for Measurements of Hot Spot Motion in Direct Drive Inertial Confinement Fusion Experiments on OMEGA," to be submitted to Nuclear Instruments and Methods.

# Collaborators

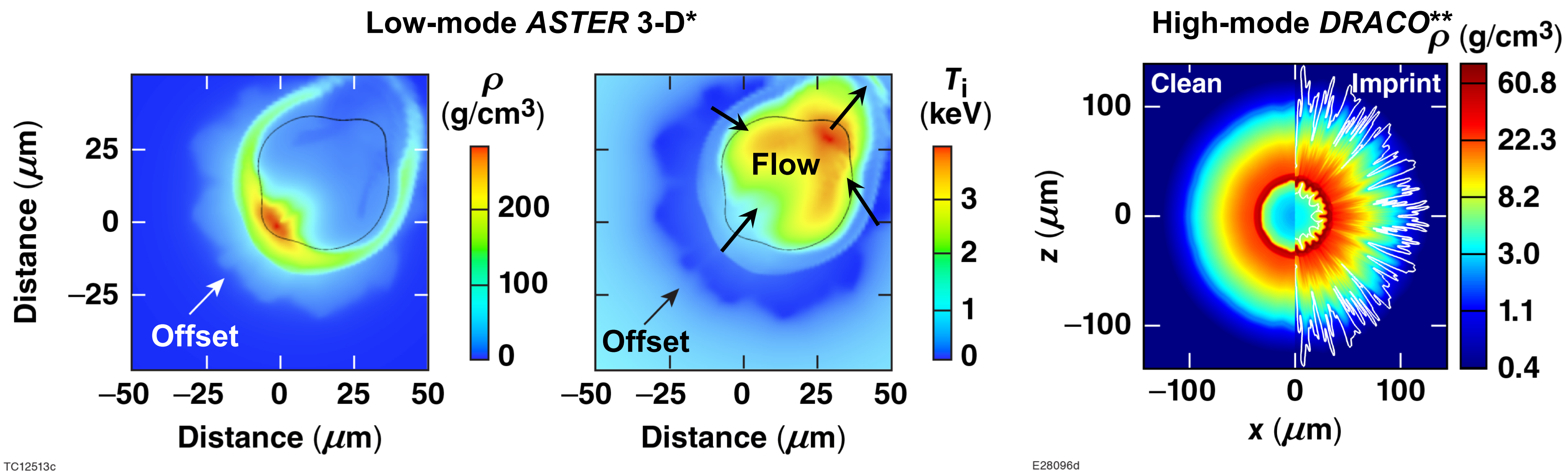
T. J. B. Collins, R. Epstein, D. Cao, C. J. Forrest, V. N. Goncharov, I. V. Igumenshchev, R. K. Jungquist, O. M. Mannion, F. J. Marshall, C. Mileham, Z. L. Mohamed, P. B. Radha, S. P. Regan, R. C. Shah, T. C. Sangster, and W. Theobald

University of Rochester
Laboratory for Laser Energetics

M. Gatu Johnson and J. A. Frenje

Massachusetts Institute of Technology
Plasma Science and Fusion Center

# The signatures of low-mode (long-wavelength) and high-mode (short-wavelength) nonuniformities are different

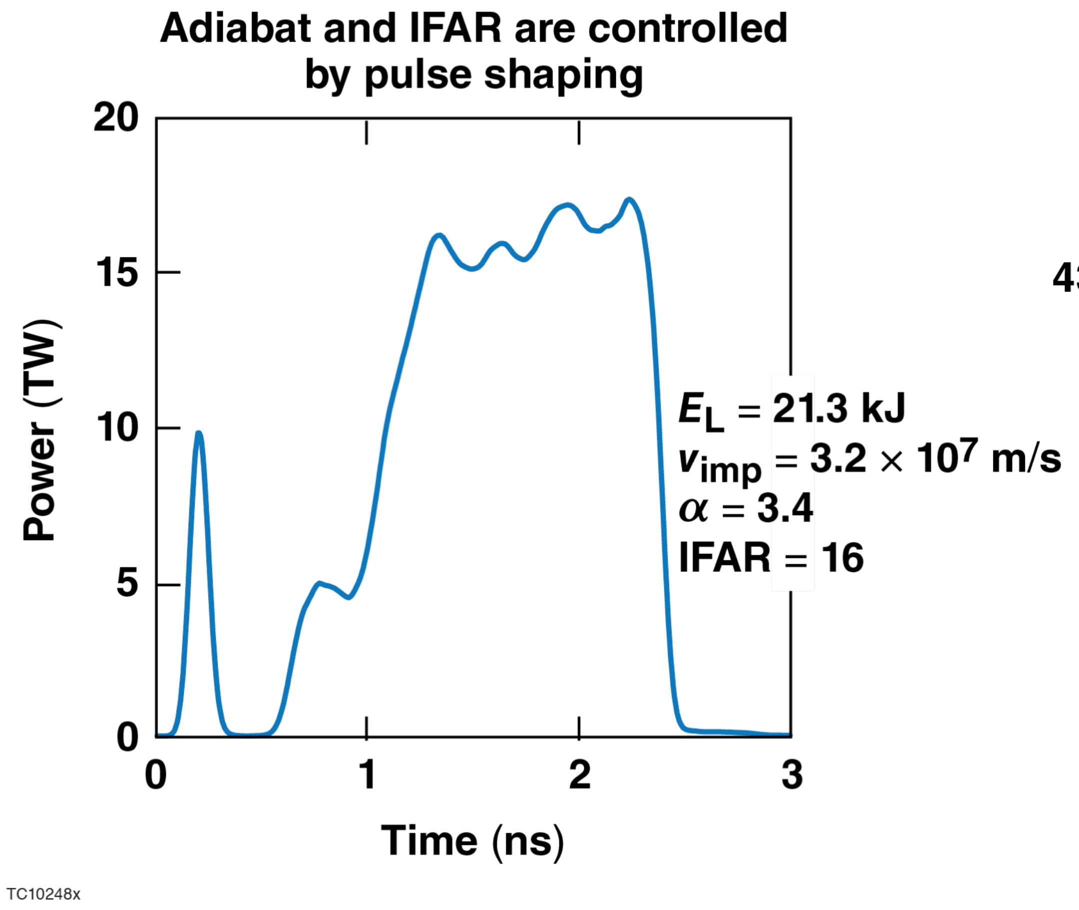


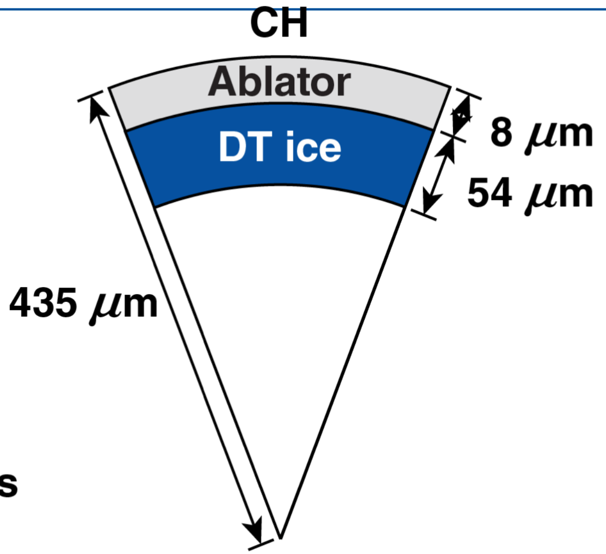

**Sources**

- 20-μm offset
- Beam overlap
- 10% imbalance
- 10-μm rms mispointing
- 5-ps rms mistiming

* I. V. Igumenshchev *et al.*, Phys. Plasmas 23, 052702 (2016).
** T. J. B. Collins *et al.*, PO7.00004, this conference.

# The expected target performance is determined by the laser pulse shape and the target dimensions

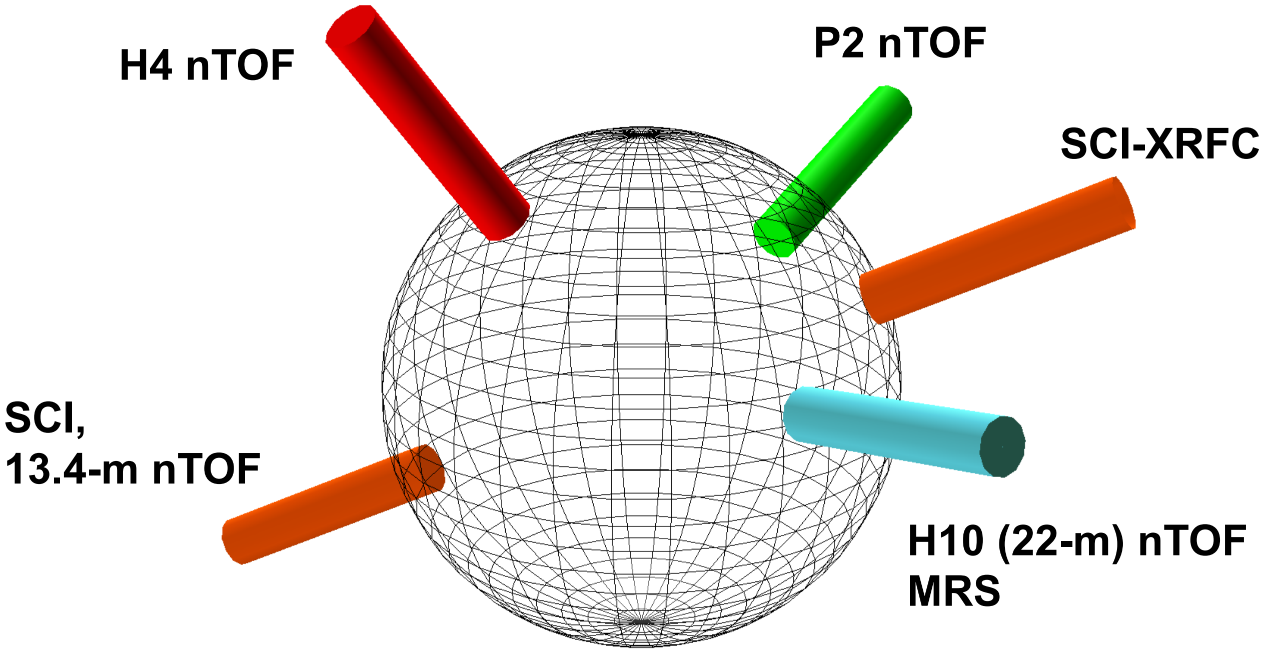


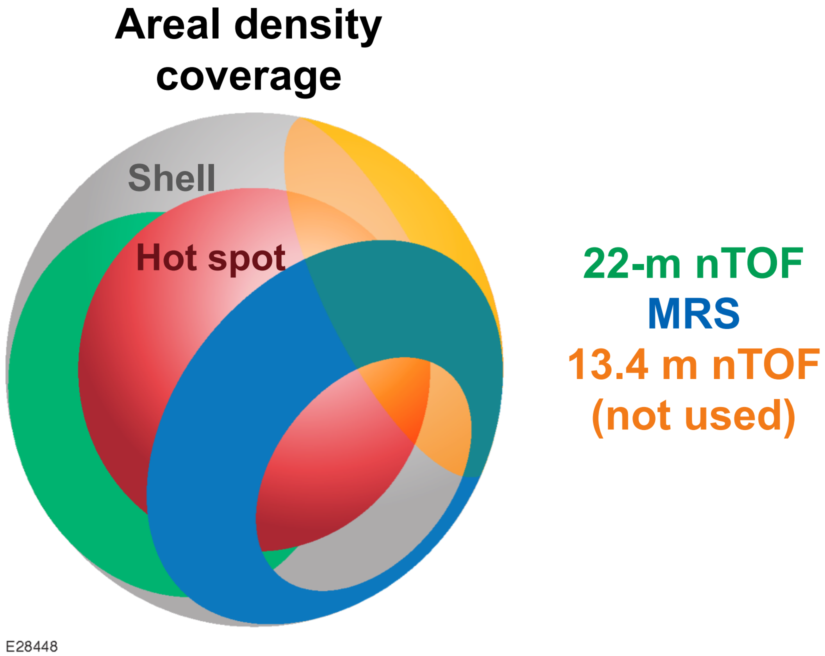




- Adiabat $\alpha = P/P_{Fermi}$
- $v_{imp}$ = implosion velocity
- $E_L$ = laser energy
- IFAR = shell radius/shell thickness

IFAR: in-flight aspect ratio

# A number of nuclear and x-ray diagnostics are used in these experiments to assess the performance of these implosions

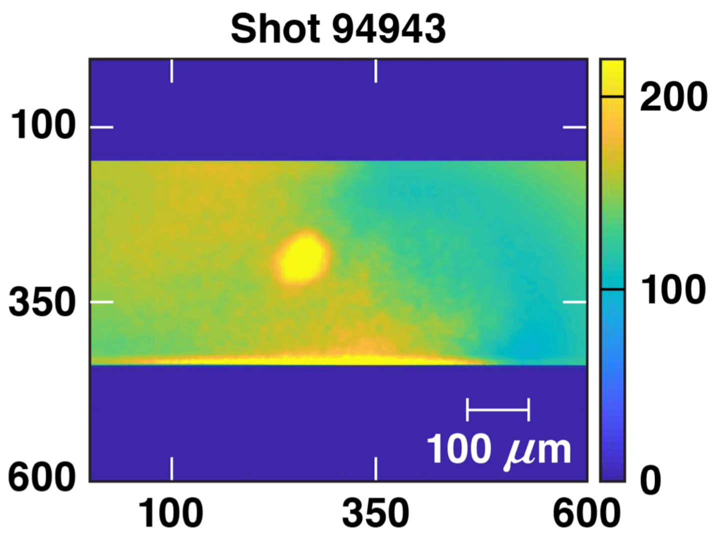


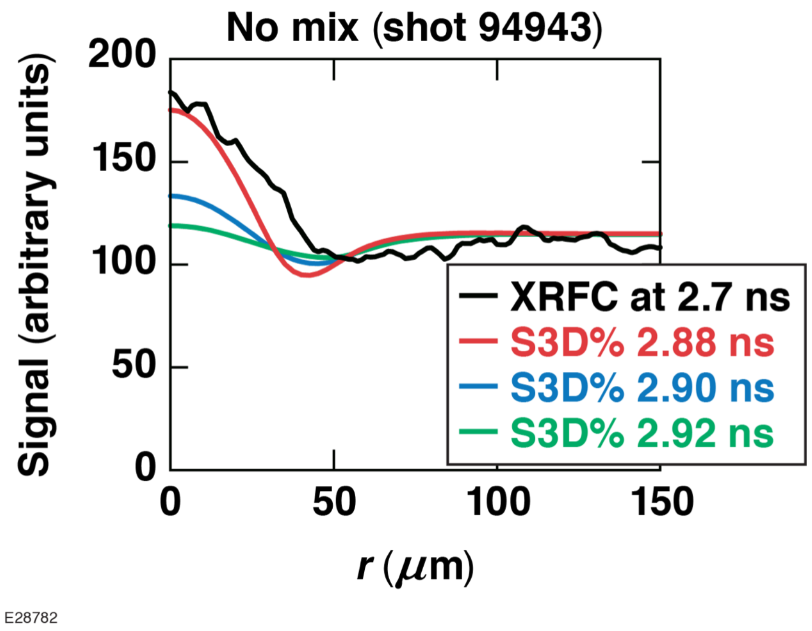

- X ray
  - SCI: spherical crystal imager
    - ablator mix
- Nuclear
  - nTOF: neutron time-of-flight
    - yield, ion temperature,
    - plasma flow, areal density
  - MRS: magnetic recoil spectrometer
    - areal density

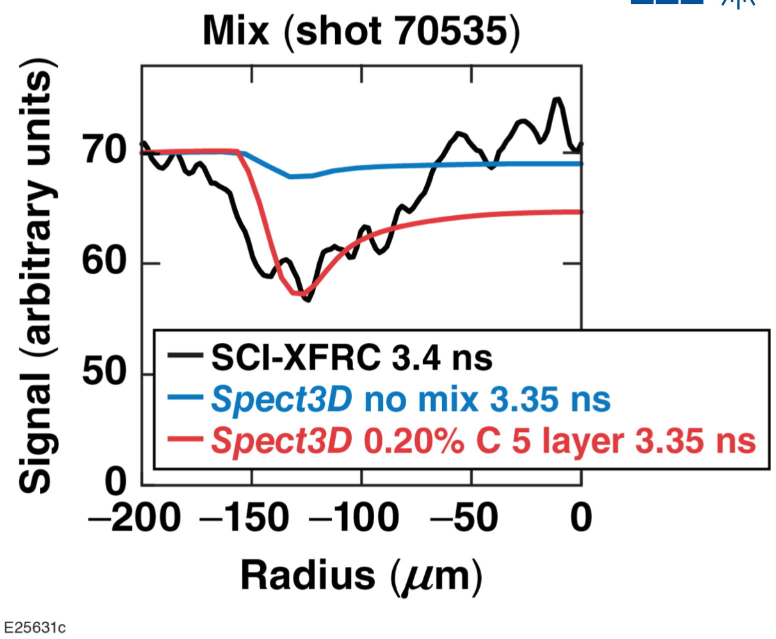
XRFC: x-ray framing camera

# Backlit radiographs* show no indication of mix from the CH ablator into the DT ice




Backligher shape removed**




- DT (54 $\mu$m) CH (8 $\mu$m) 870-$\mu$m diam
- $\alpha$ ~ 3.5, IFAR ~ 17
- YOC = 40%, $\rho R$/clean > 100%

- DT (61 $\mu$m) CH (8 $\mu$m) 880-$\mu$m diam
- $\alpha$ ~ 2.5, IFAR ~ 17;
- YOC = 9%, $\rho R$/clean > 92%

YOC: yield over clean

* C. Stoeckl *et al.*, Phys. Plasmas 24, 056304 (2017).
** C. Stoeckl *et al.*, Rev. Sci. Instrum. 85, 11E501 (2014).

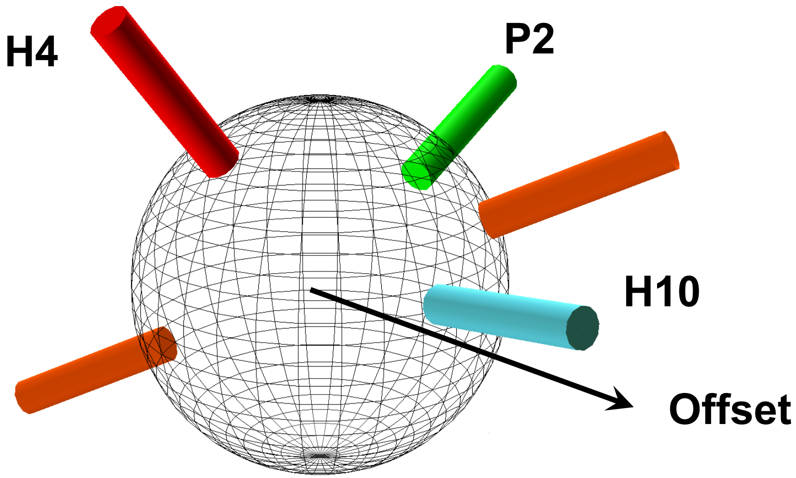
# Measurements of the hot-spot motion* were used to generate a new "optimal" target position

| Shot | H10 velocity (km/s) | H4 velocity (km/s) | P2 velocity (km/s) |
|---|---|---|---|
| 94943 | –90 | 20 | 75 |
| 94946 | 64 | – | –19 |
| 94948 | 5 | 37 | 17 |

The H10 velocity component was similar to what was previously observed. A similar target-position correction as in previous shots was used (~40 $\mu$m).

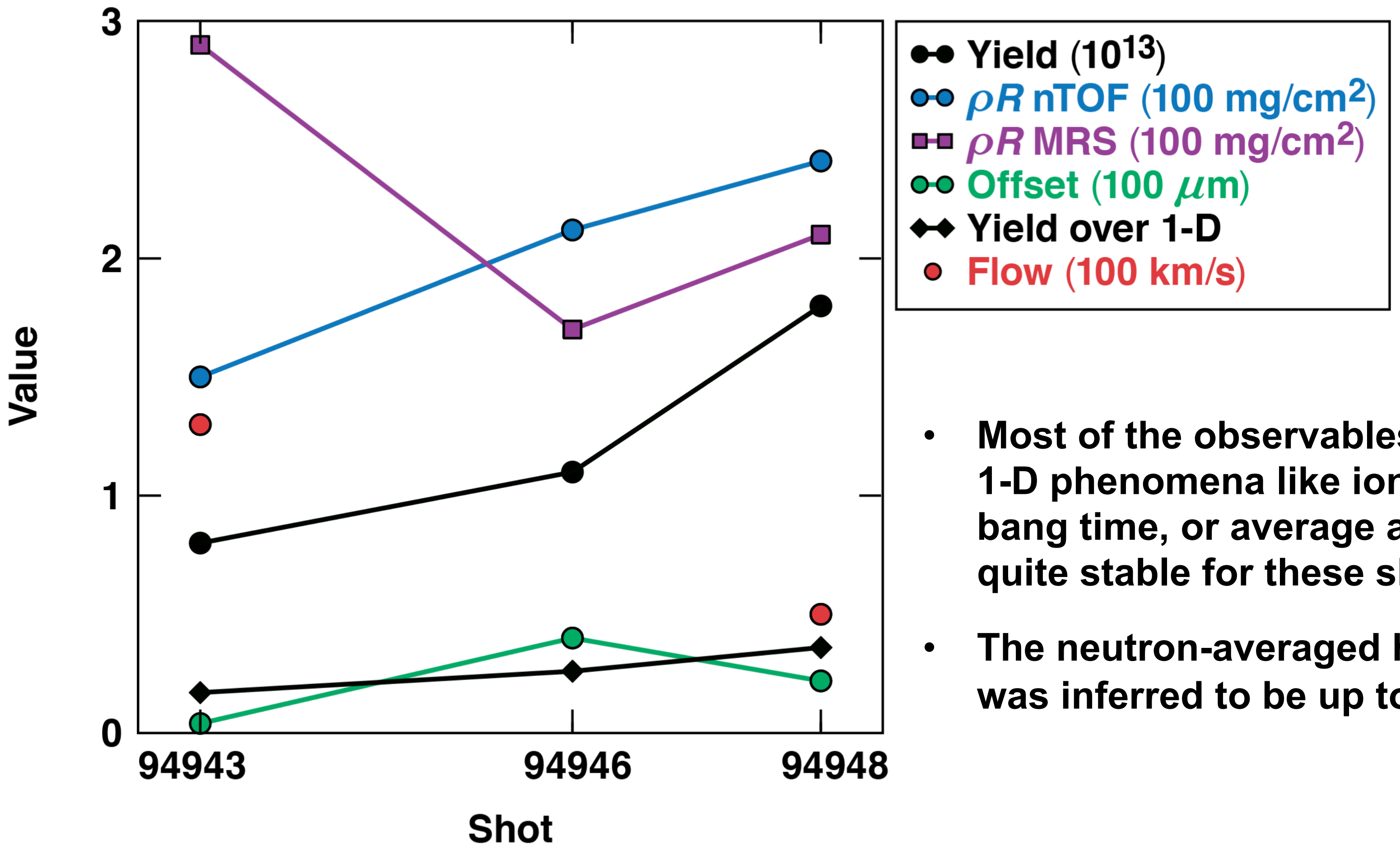
The P2 component was near zero, but H10 changed the sign. This indicated the target was too far in the *x*–*y* plane. The target offset was reduced to 20 $\mu$m.

Note that this was most likely not the optimal target offset because four distinct lines of sight are required for a full reconstruction.




* S. Regan *et al*., YO5.00002, this conference;
O. M. Mannion *et al*., "A Suite of Neutron Time-of-Flight Detectors for Measurements of Hot Spot Motion in Direct Drive Inertial Confinement Fusion Experiments on OMEGA," to be submitted to Nuclear Instruments and Methods.

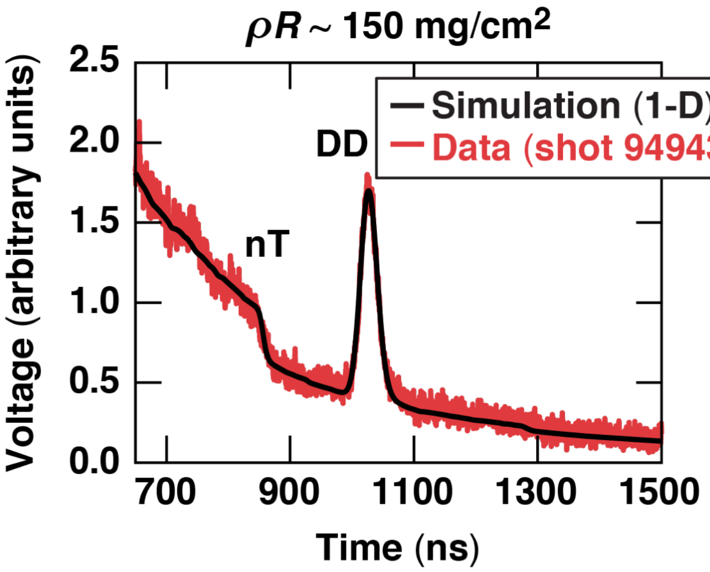
# The nuclear data show a significant performance improvement at the best target position (offset)



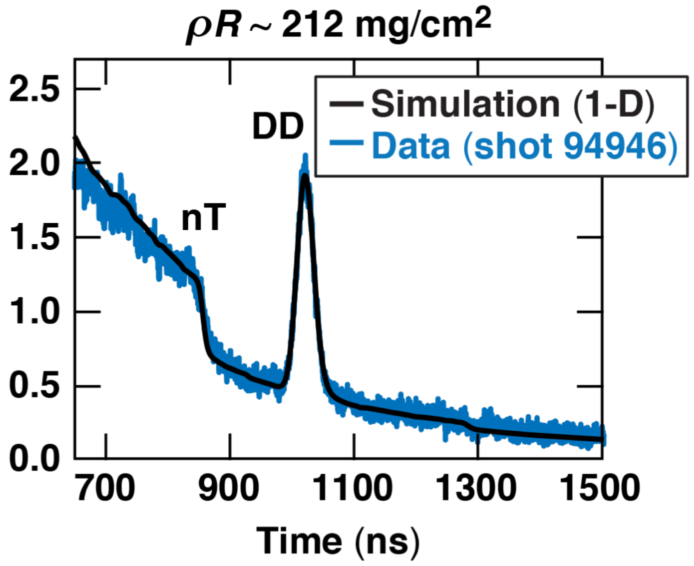

E28853

- **Most of the observables that depend on 1-D phenomena like ion temperature, bang time, or average areal density are quite stable for these shots**
- **The neutron-averaged hot-spot pressure was inferred to be up to 40 GBar**

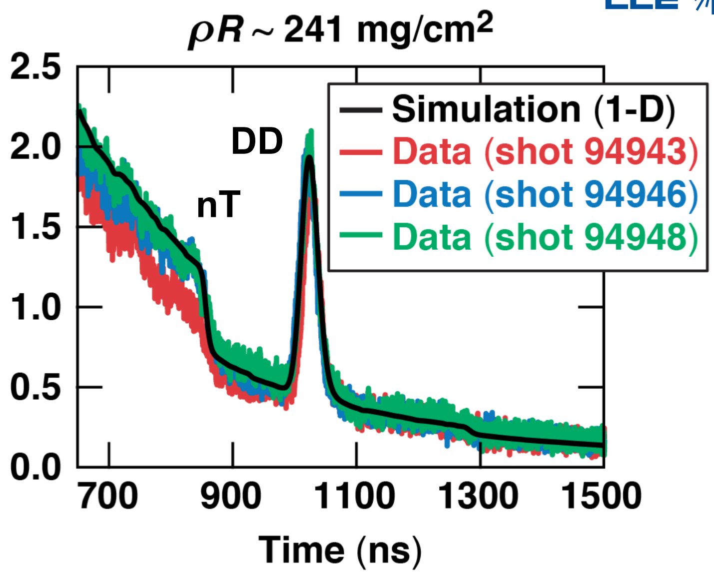
# The 22-m nTOF spectra* show clear indications of angular nonuniformites for two of the three shots



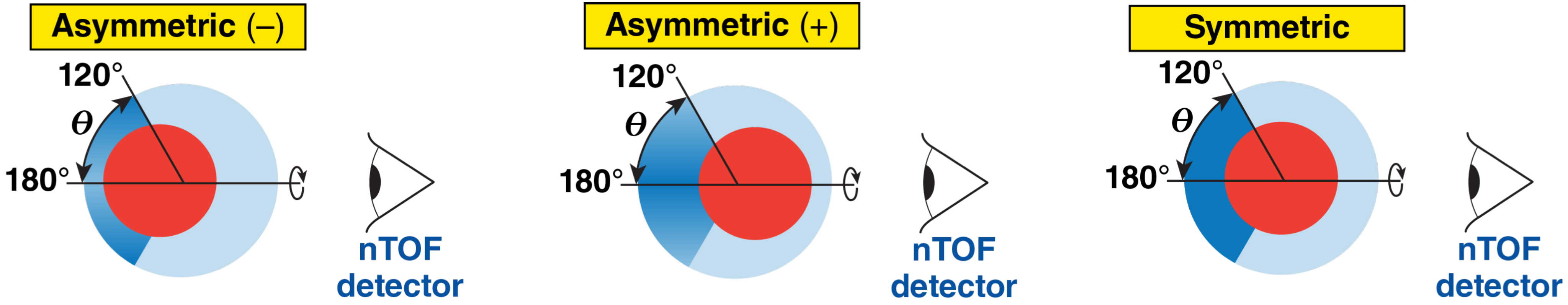

E28783




E28784




E28785




E23429a

* Z. L. Mohamed *et al.*, YO5.00008, this conference.

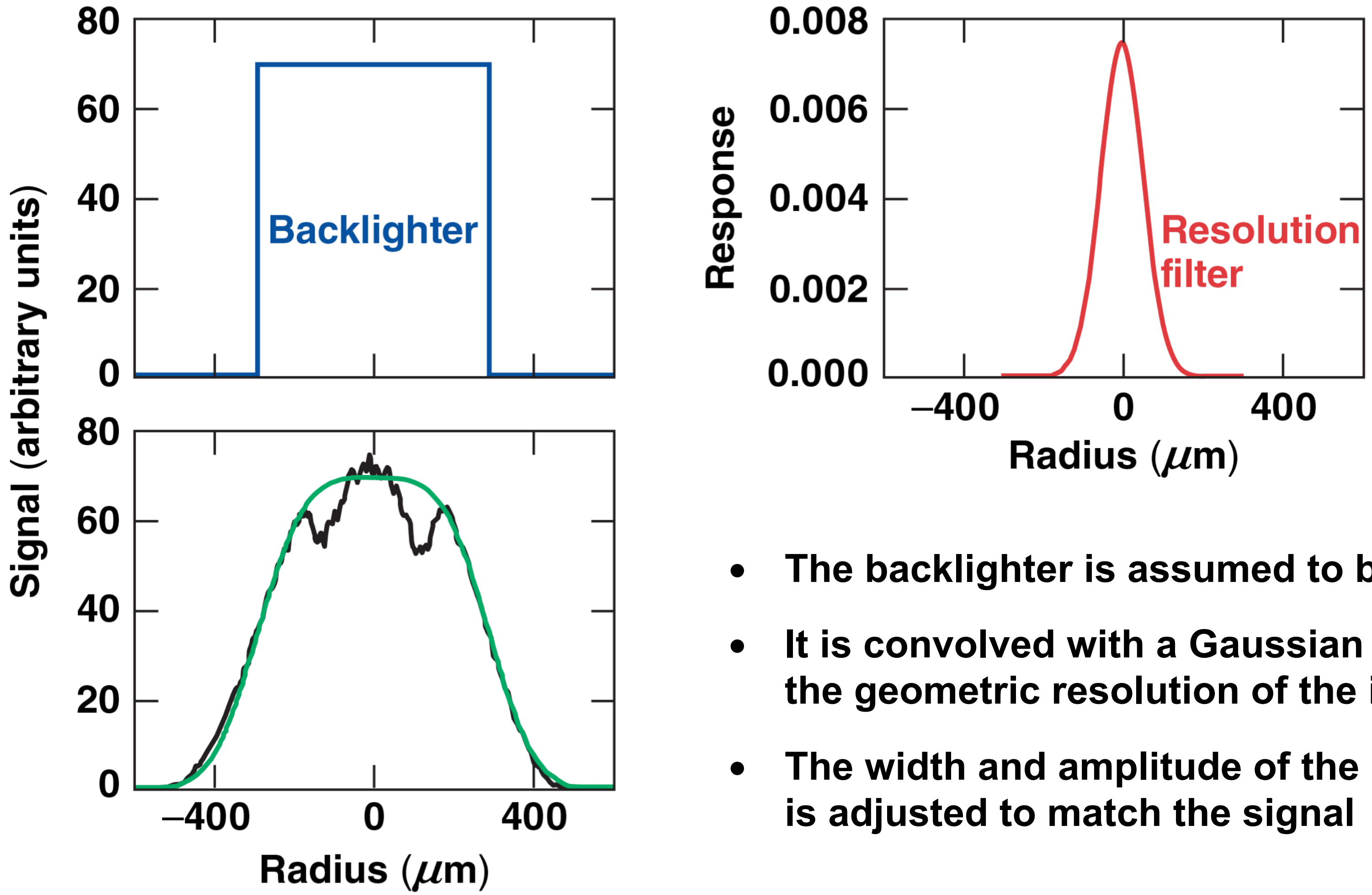
# Minimizing low-mode illumination nonuniformities improves the performance of cryogenic implosions

- The performance of direct-drive cryogenic implosions is affected by both low-order modes like target offset and high-order modes like imprint-induced mix
- A large number of optical, x-ray, and nuclear diagnostics were used in a set of experiments to distinguish the effects of different degradation mechanisms
- The velocity of the hot core inferred from nTOF detectors* was used to intentionally offset the target minimizing the low-mode illumination nonuniformities
- With an optimized target offset of ~20 $\mu$m, the target performance improved significantly; yield increased by 2$\times$, areal density by ~50%

* S. Regan *et al.*, YO5.00002, this conference;
O. M. Mannion *et al.*, "A Suite of Neutron Time-of-Flight Detectors for Measurements of Hot Spot Motion in Direct Drive Inertial Confinement Fusion Experiments on OMEGA," to be submitted to Nuclear Instruments and Methods.

# Backup

# The lineouts from the SCI backlit images must be corrected for the backlighter shape




E23005c

- The backlighter is assumed to be uniform
- It is convolved with a Gaussian representing the geometric resolution of the imager
- The width and amplitude of the backlighter is adjusted to match the signal