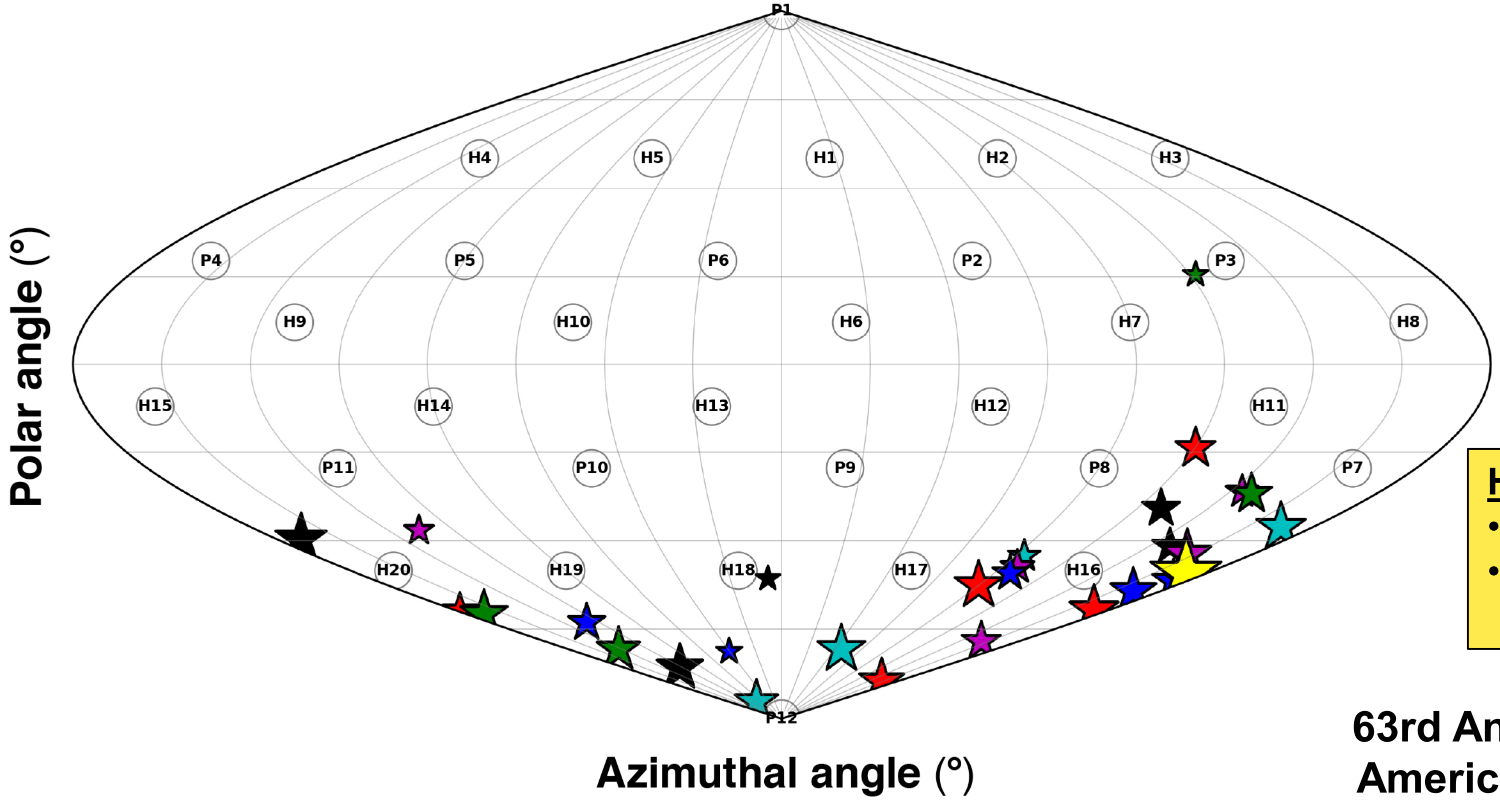
Systematic Trends of Hot-Spot Flow Velocity in Laser-Direct-Drive Implosions on OMEGA

UR LLE

Hot-spot flow velocity of DT cryogenic implosions



Hot-spot flow velocity:
- 30 to 150 km/s
- average direction $(\theta,\phi) = (142°,171°)$

S. P. Regan, O. M. Mannion, C. J. Forrest *et al.*
University of Rochester
Laboratory for Laser Energetics

63rd Annual Meeting of the American Physical Society Division of Plasma Physics
Pittsburgh, PA
8–12 November 2021

Summary

Systematic trends of hot-spot flow velocity in laser-direct-drive implosions on OMEGA have been diagnosed using 3-D neutron spectroscopy*,**,†

- Seeds for the systematic mode-1 asymmetry♯ observed at stagnation include
  - inaccuracies in beam pointing,
  - beam-to-beam energy/power imbalance,
  - inaccuracies in target positioning,
  - laser–plasma interactions (LPIs),‡ and
  - target asymmetries
- The systematic trend is similar for implosions of DT cryogenic and DT gas-filled plastic shell targets, indicating the primary source of the asymmetry is due to the drive
- Beam mispointing leads to a significant mode $\ell = 1$ illumination nonuniformity being the dominate cause for the hot-spot flow**
  - with improved beam pointing, the beam-to-beam energy/power imbalance, inaccuracies in target positioning, and LPIs‡ are the leading causes for the hot-spot flow

Related talks:
A. Colaitis *et al.*, NO07.00002, this conference.
D. H. Edgell, ZI02.00005, this conference.

* O. M. Mannion *et al.*, Nucl. Instrum. Methods Phys. Res. A 964, 163774 (2020).
** O. M. Mannion *et al.*, Phys. Plasmas 28, 042701 (2021).
† O. M. Mannion *et al.*, Rev. Sci. Instrum. 92, 033529 (2021).
‡ D. H. Edgell *et al.*, Phys. Rev. Lett. 127, 075001 (2021).
♯ W. Theobald *et al.*, "Report on the status of OMEGA laser-beam pointing and its effects on laser drive uniformity," Laboratory for Laser Energetics (2021).

Collaborators

O. M. Mannion*, C. J. Forrest, H. McClow, Z. L. Mohamed, A. Kalb, J. Kwiatkowski, J. P. Knauer, C. Stoeckl, R. C. Shah, V. Yu. Glebov, W. Theobald, K. Churnetski, R. Betti, V. Gopalaswamy, H. G. Rinderknecht, I. V. Igumenshchev, P. B. Radha, V. N. Goncharov, D. H. Edgell, J. Katz, D. Turnbull, D. H. Froula, M. J. Bonino, D. R. Harding, and E. M. Campbell

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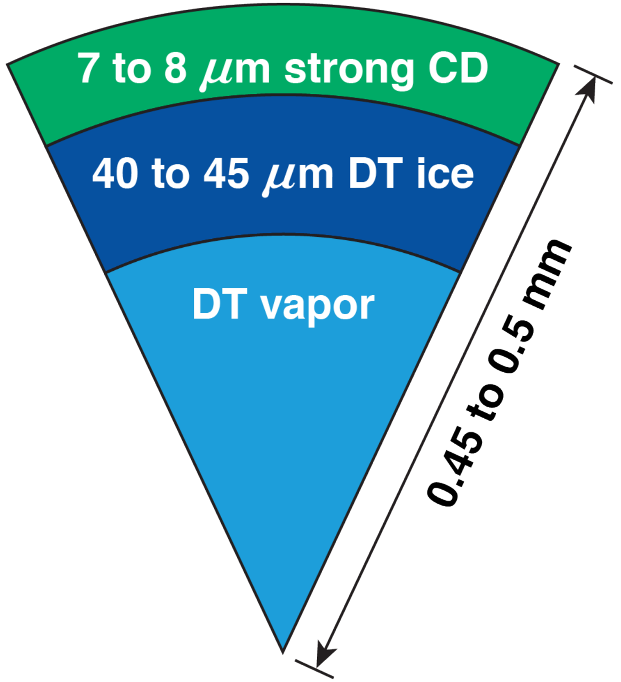
University of Bordeaux

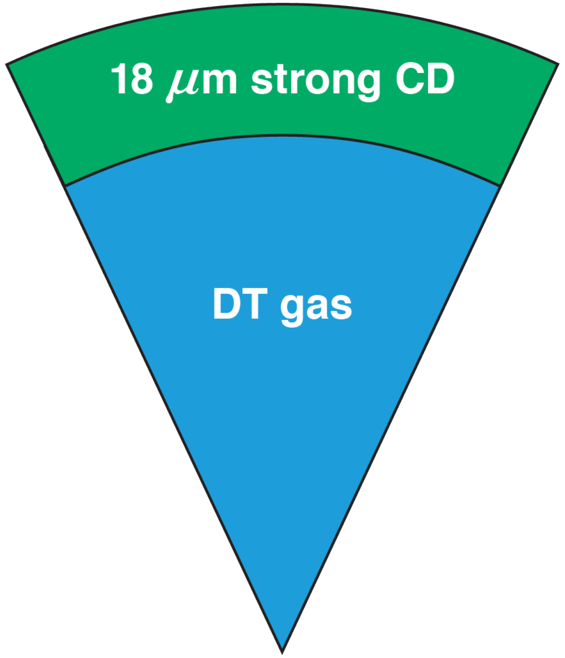
*Currently at Sandia National Laboratories

OMEGA laser-direct drive implosions of DT cryogenic targets and DT gas-filled, plastic shell targets were studied

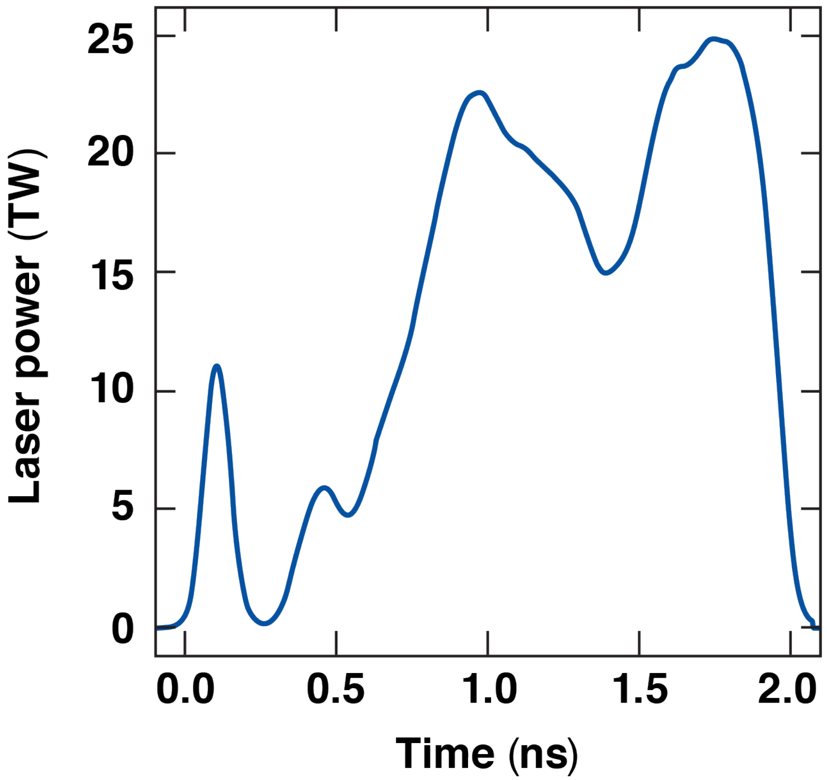
DT cryogenic target



DT gas-filled, plastic shell target



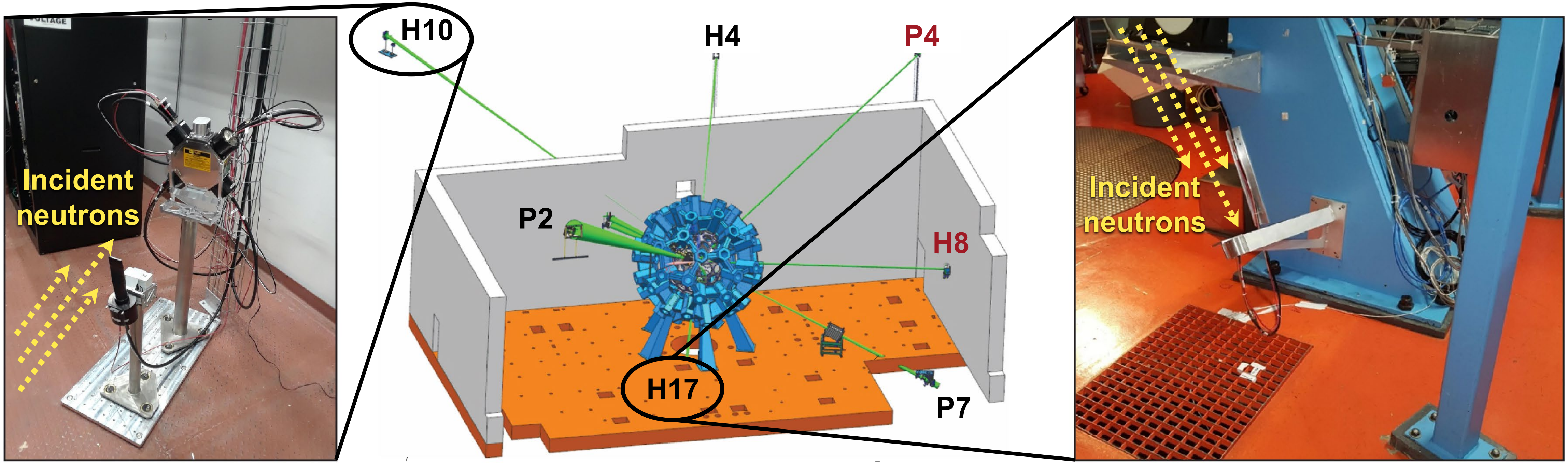
Laser drive



E29892

The hot-spot flow velocity was diagnosed using multiple neutron time-of-flight detectors arranged along quasi-orthogonal diagnostic lines of sight *,**,†

Neutron time of flight (nTOF) suite on OMEGA*



E29893

* O. M. Mannion *et al.*, Nucl. Instrum. Methods Phys. Res. A 964, 163774 (2020).
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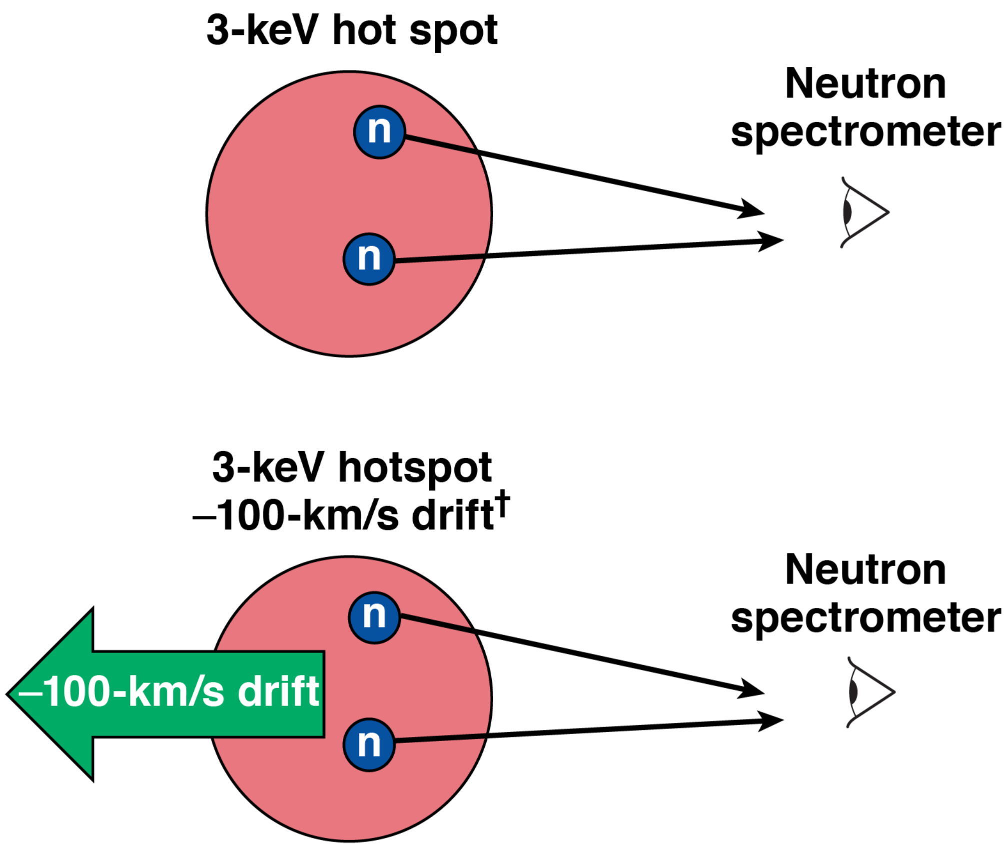
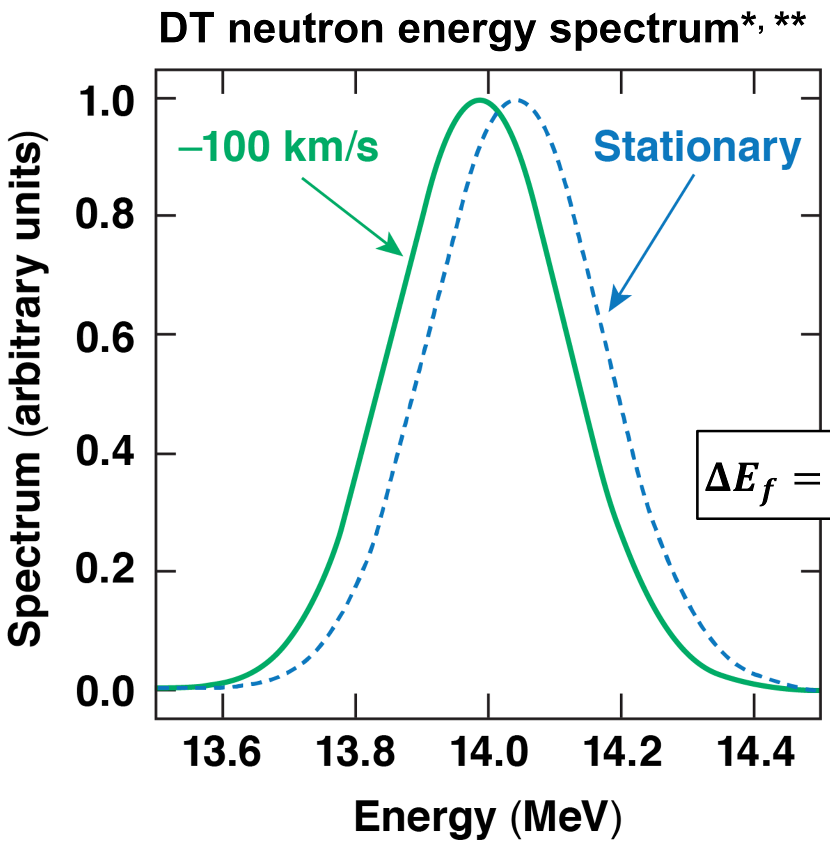
The hot-spot flow velocity is inferred from the Doppler-shifted position of the primary neutron energy spectrum





$$\Delta E_f = \sqrt{2 m_n E_0} (\vec{u} \cdot \hat{d})$$

E29910

* H. Brysk, Plasma Phys. 15, 611 (1973).
** L. Ballabio, J. Källne, and G. Gorini, Nucl. Fusion 38, 1723 (1998).
† T. J. Murphy, R. E. Chrien, and K. A. Klare, Rev. Sci. Instrum. 68, 614 (1997).

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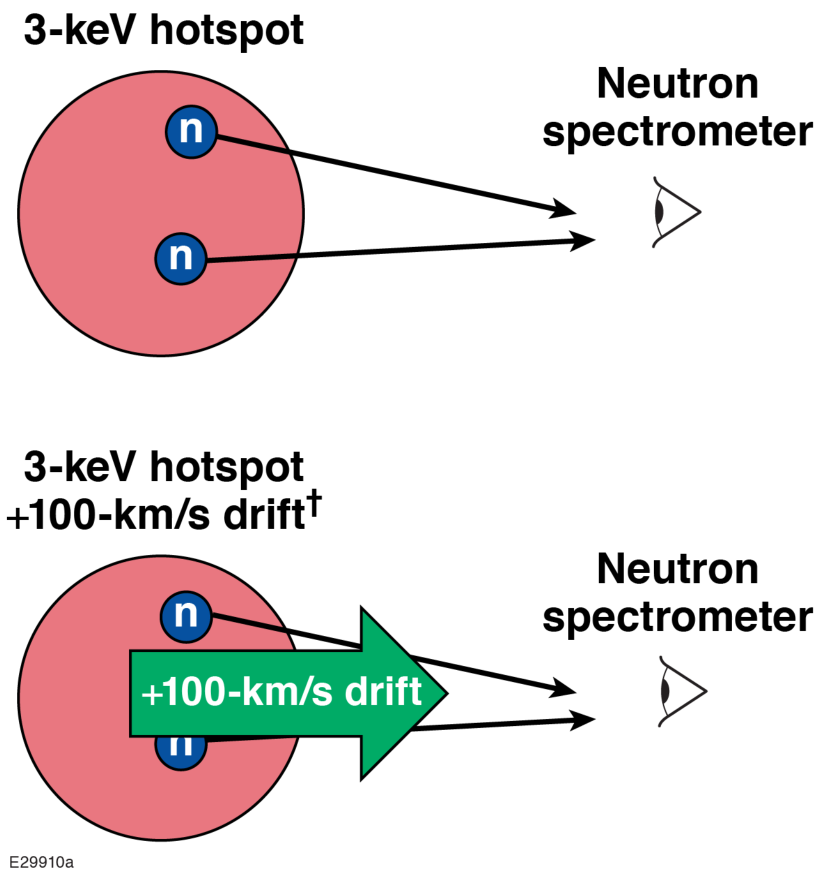

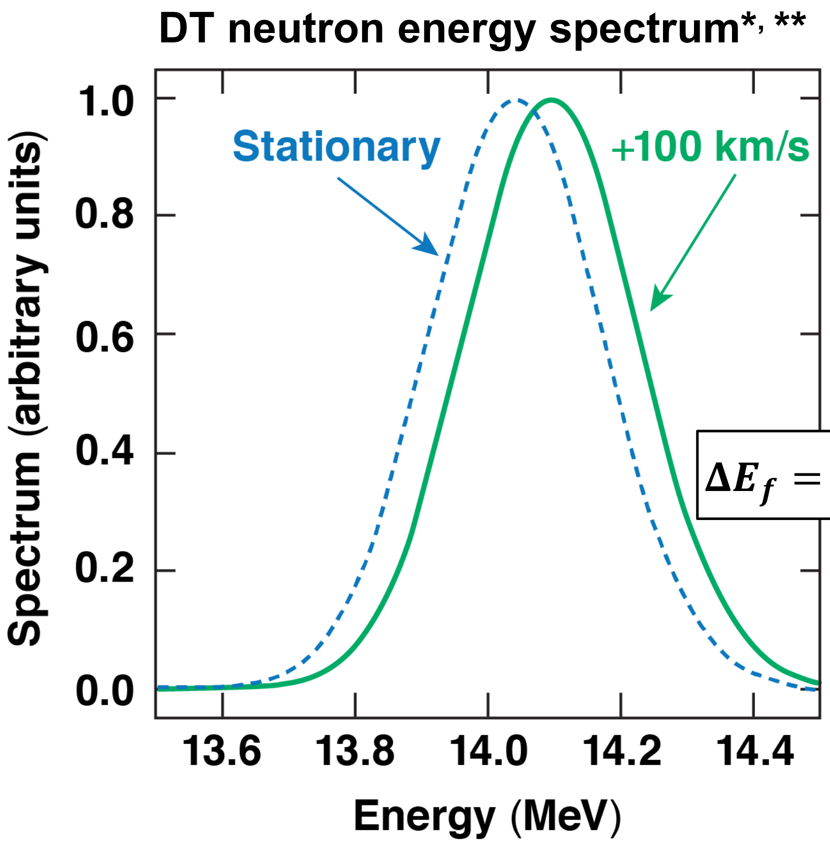

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Multidimensional effects are seeded by several sources of nonuniformities in the laser and the target[♯]

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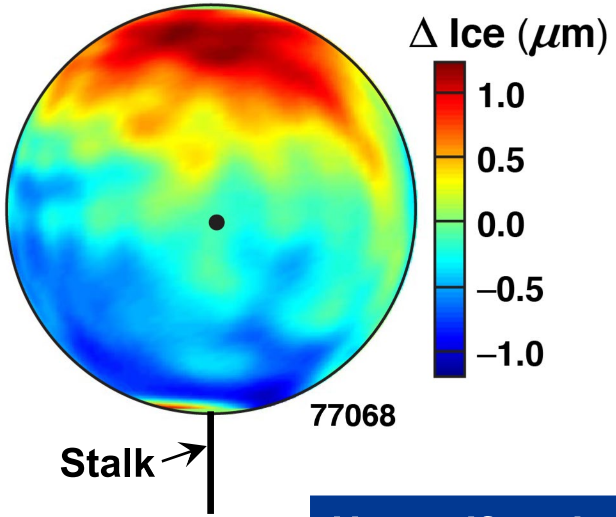
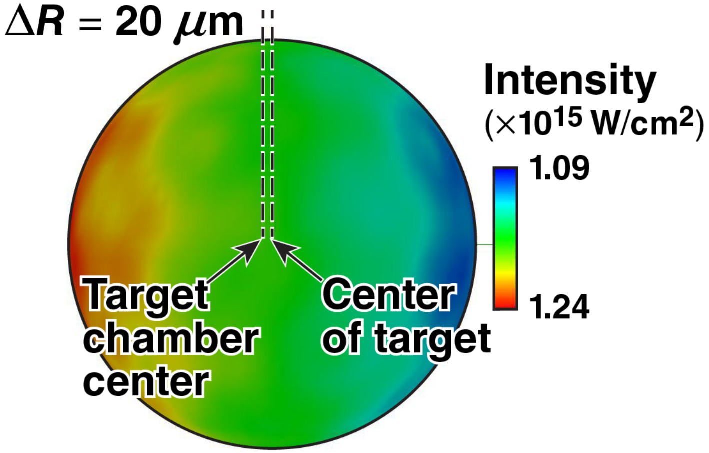
Target asymmetries from nonuniform layers and the target stalk → asymmetric implosion

Ice-shell thickness variation (cryo)



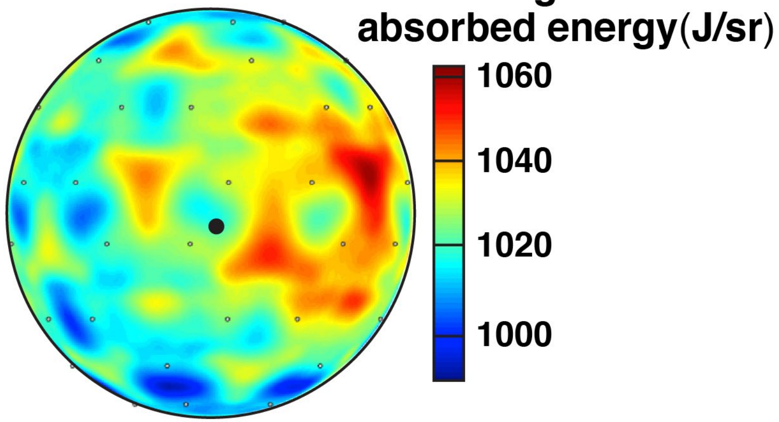
E28713

Target positioning*,**



E28714

Beam pointing, beam-to-beam energy/power imbalance, and LPIs†



E29911

Nonuniformity leads to asymmetric compression of the target, resulting in inefficient *PdV* work being done by the shell on the hot spot.

* M. Gatu Johnson *et al.*, Phys. Plasmas 27, 032704 (2020).
** K. S. Anderson *et al.*, Phys. Plasmas 27, 112713 (2020).
† D. H. Edgell *et al.*, Phys. Rev. Lett. 127, 075001 (2021).
♯ W. Theobald *et al.*, “Report on the status of OMEGA laser-beam pointing and its effects on laser drive uniformity,” Laboratory for Laser Energetics (2021).

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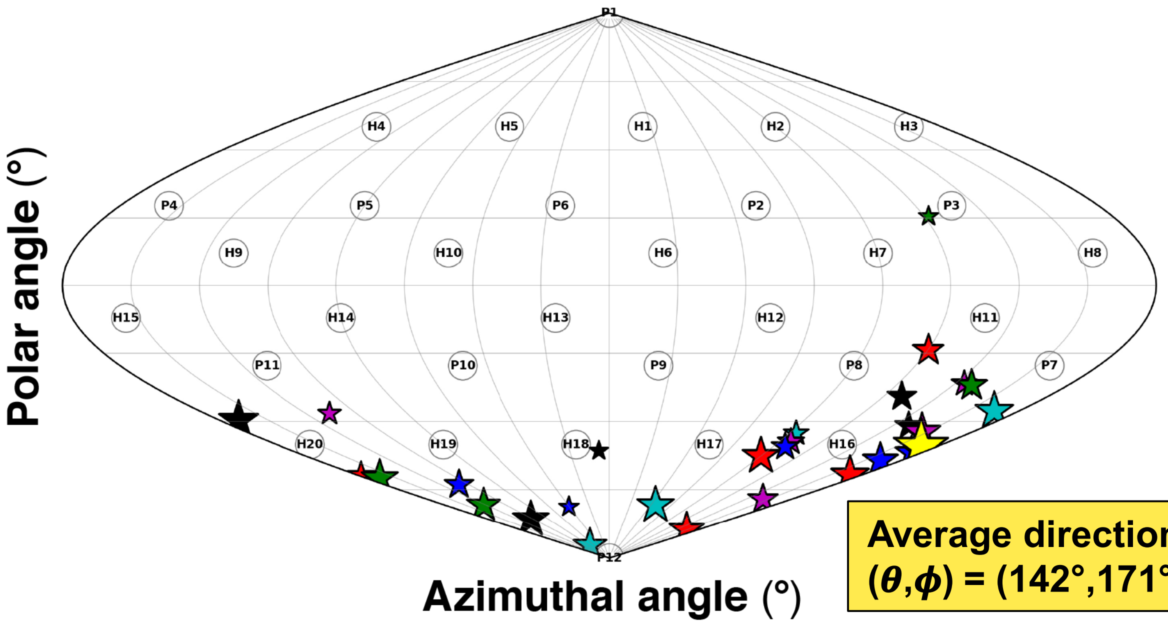
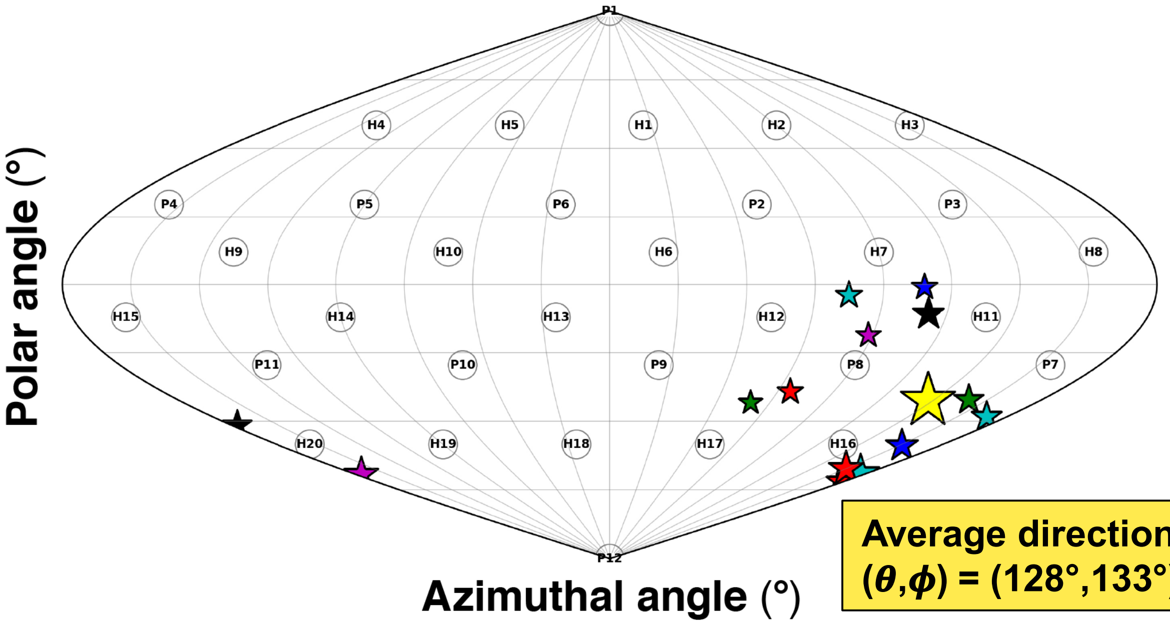
DT cryogenic target implosions



Average direction
(θ,ϕ) = (142°,171°)

DT gas-fill plastic shell implosions



Average direction
(θ,ϕ) = (128°,133°)

E29912

The systematic trend is similar for two types of implosions, indicating the primary source of the asymmetry is due to the drive.

* O. M. Mannion *et al.*, Nucl. Instrum. Methods Phys. Res. A 964, 163774 (2020).
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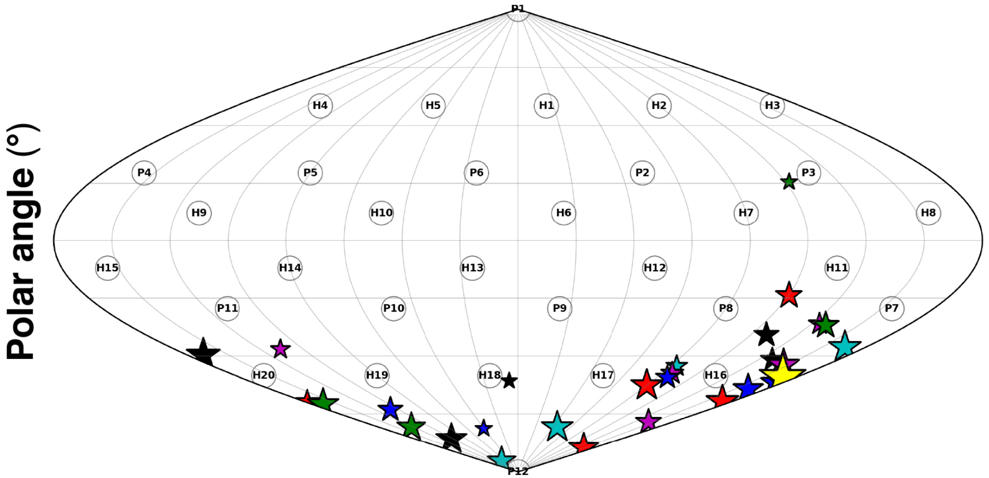
DT cryogenic target implosions



E29912

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ℓ-mode amplitudes of drive asymmetry♯

ℓ mode	Beam pointing (worst)**	Beam pointing (typical)	Energy / power imbalance (typical)	Target positioning (typical)	LPI effects‡
1	~5%	~1-1.5%	~0.5-1%	~0.5%	~0.4%

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