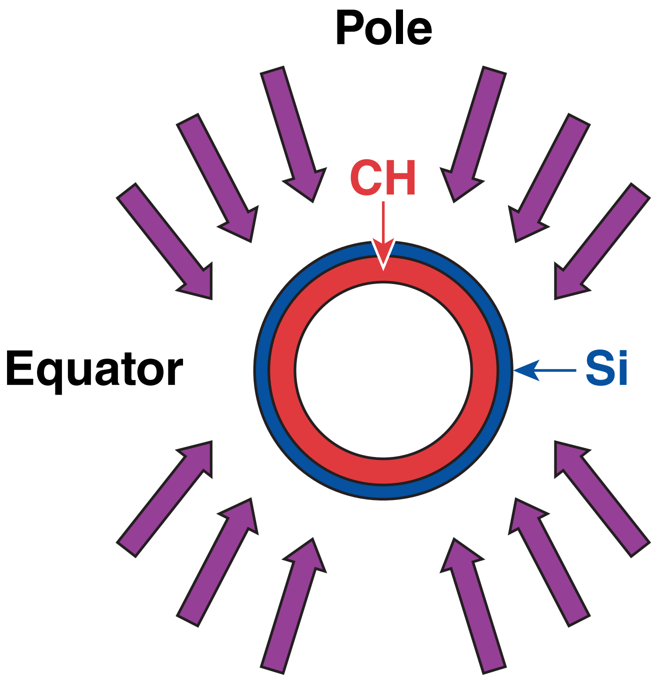
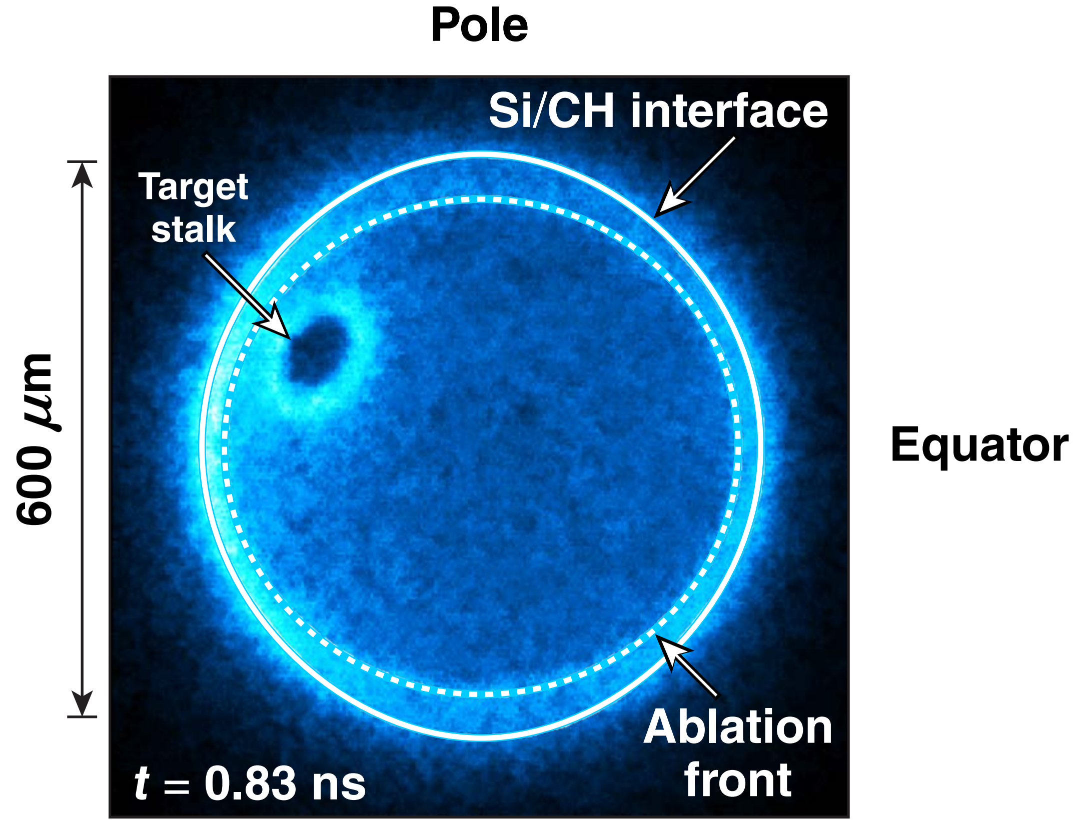
Angularly Resolved Mass Ablation Rate and Ablation-Front-Trajectory Measurements at the Omega Laser and National Ignition Facilities





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57th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Savannah, GA
16–20 November 2015

Summary

Simultaneous measurements of the 2-D mass ablation rate and ablation-front trajectory in polar-direct-drive (PDD) implosions allow the effects of cross-beam energy transfer (CBET) on hydrodynamic efficiency to be isolated and evaluated

- The PDD configuration limits CBET growth to the target equator, providing high- and low-CBET conditions in the same implosion
- Two-dimensional hydrodynamic simulations without a CBET model reproduced measured ablation rates and ablation-front trajectories at the pole, showing that coupling physics is well-modeled when CBET effects are negligible
- Running simulations with a ray-based CBET model improved agreement at the equator

Enhanced CBET growth beyond what is calculated with the current model is required to reproduce measurements made at the equator.

Collaborators

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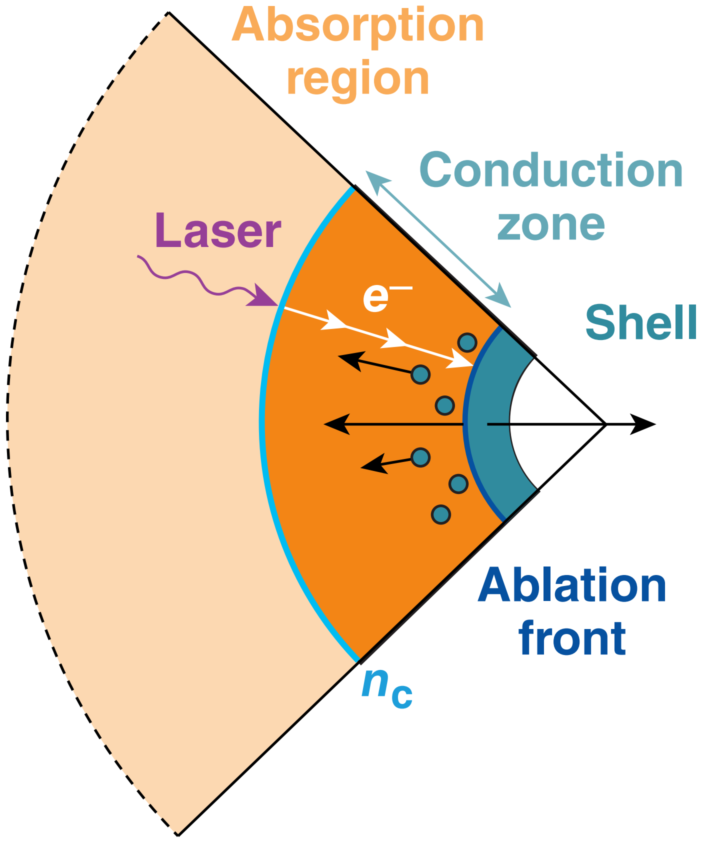
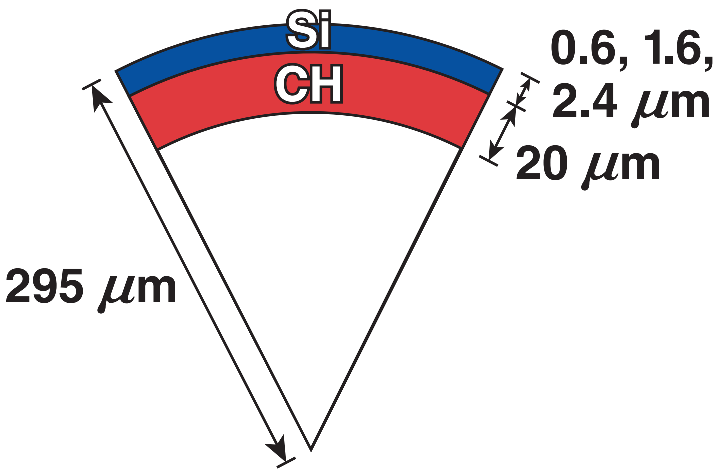
In direct-drive inertial confinement fusion experiments, the hydrodynamic coupling is governed by laser absorption and electron thermal transport



Rocket effect:

$$P_{abl} = -V_{ex}\left[\frac{d(m_{shell})}{dt}\right]$$

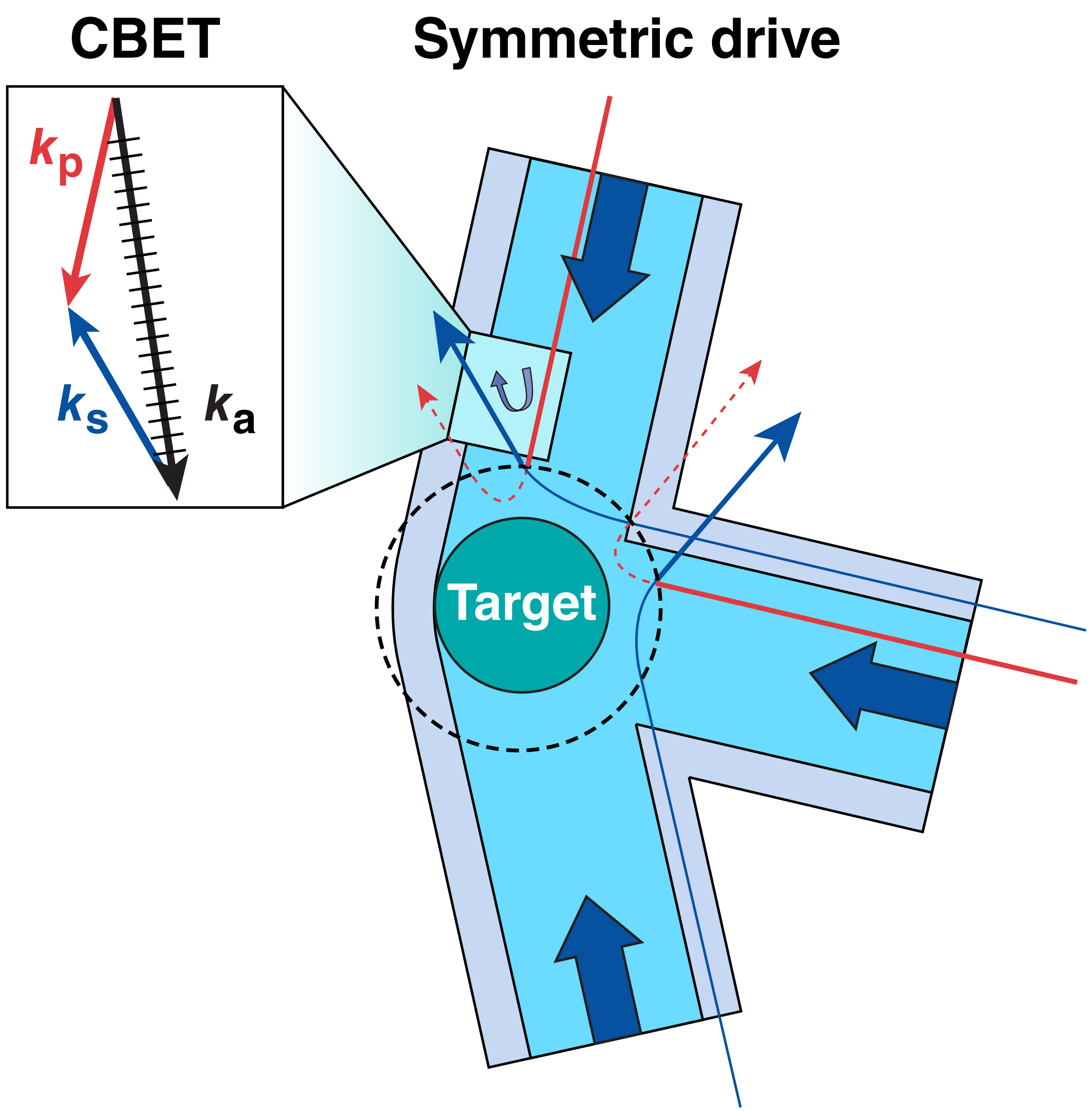
$$P_{abl} = \frac{M_{shell}}{4\pi {R_{shell}}^2}\left[\frac{d^2(R_{shell})}{dt^2}\right]$$



Simultaneous measurements of the mass ablation rate and shell velocity constrain the hydrodynamic coupling.

E24547

Laser absorption is significantly reduced by CBET

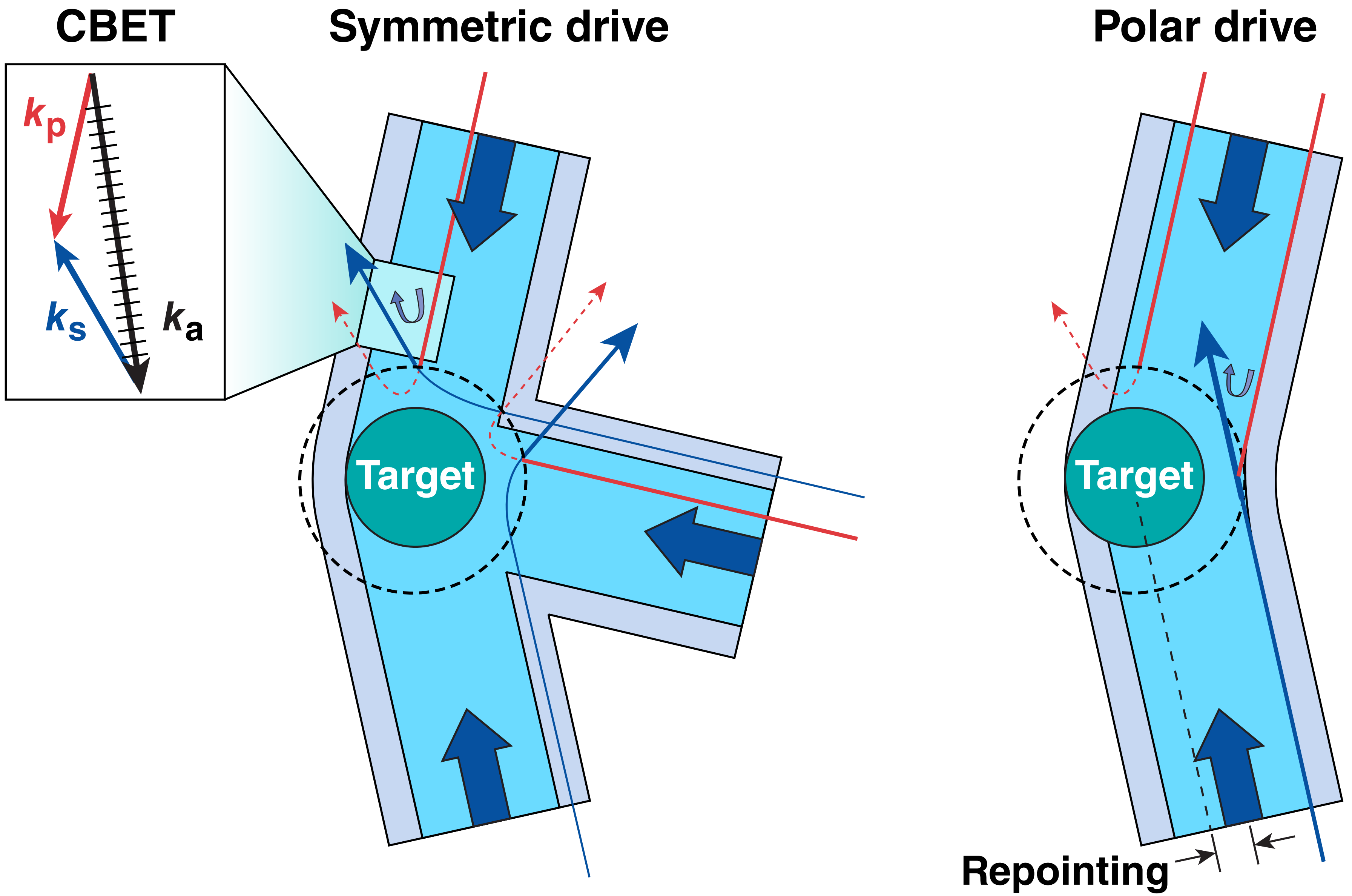


Simulations indicate that CBET reduces the ablation pressure by up to 40% in symmetric-direct-drive implosions on OMEGA.*

E24548

*V. N. Goncharov *et al.*, Phys. Plasmas 21, 056315 (2014).

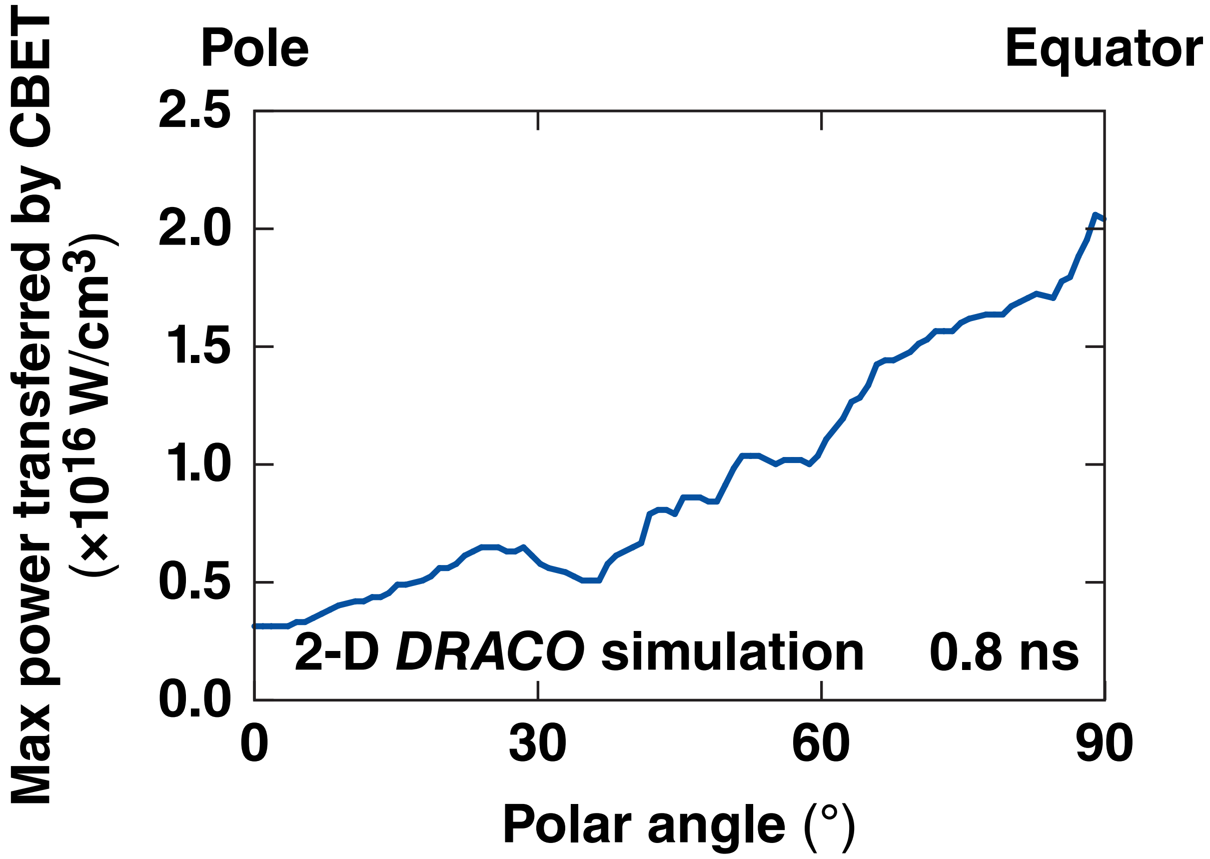
CBET can be studied by dropping beams at the equator

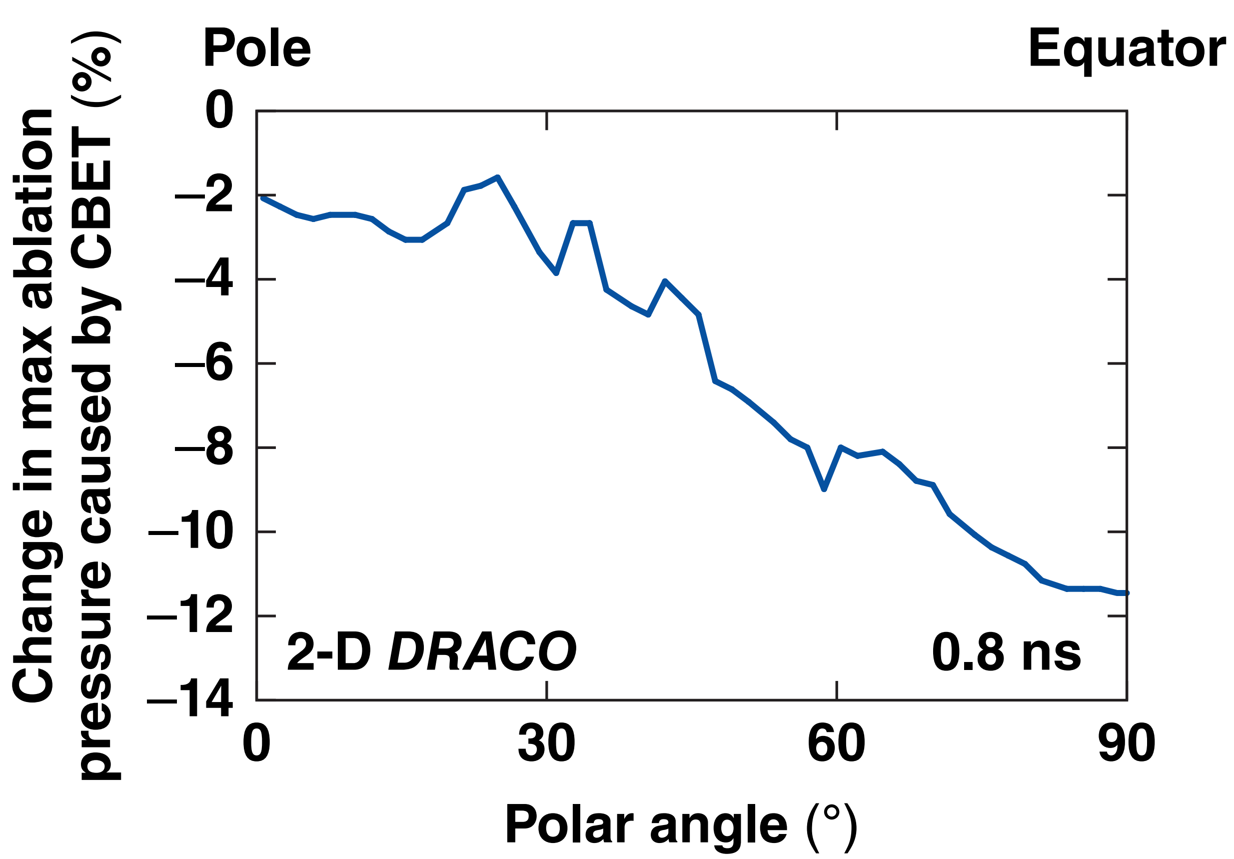


In PDD, CBET is isolated to the equator.

E24548a

Angularly resolved measurements of the hydrodynamic coupling in PDD allow the effects of CBET physics to be isolated



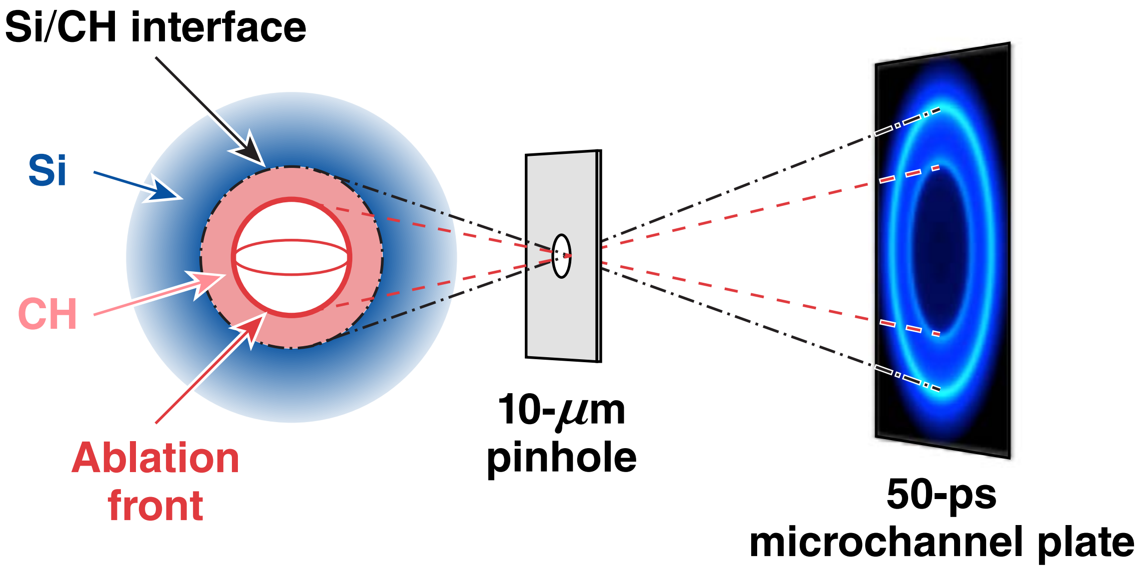


CBET primarily affects the ablation pressure at the equator.

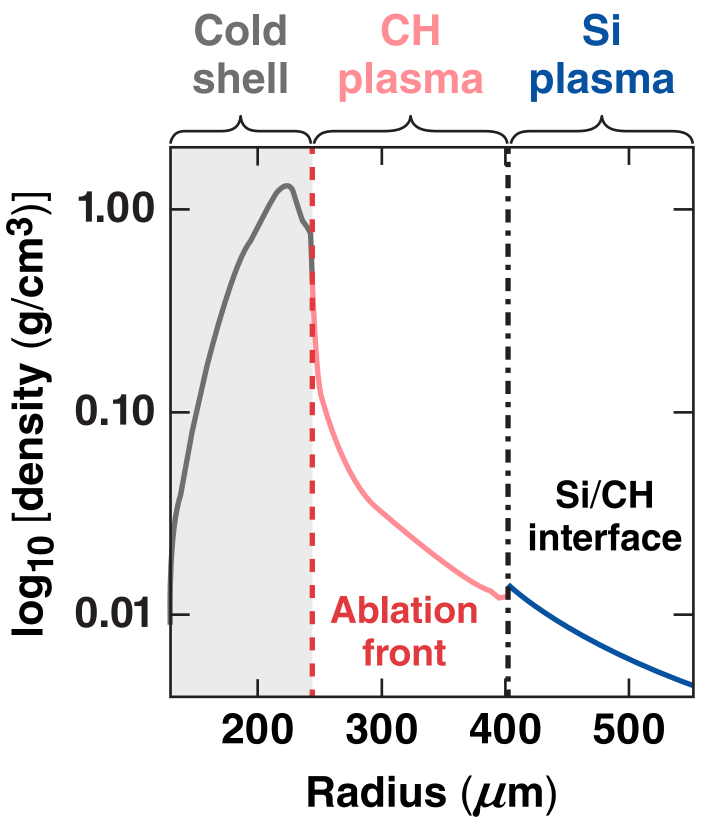
E24549

The Si mass ablation rate and ablation-front trajectory were measured by imaging the soft x rays emitted by imploding Si-coated CH targets

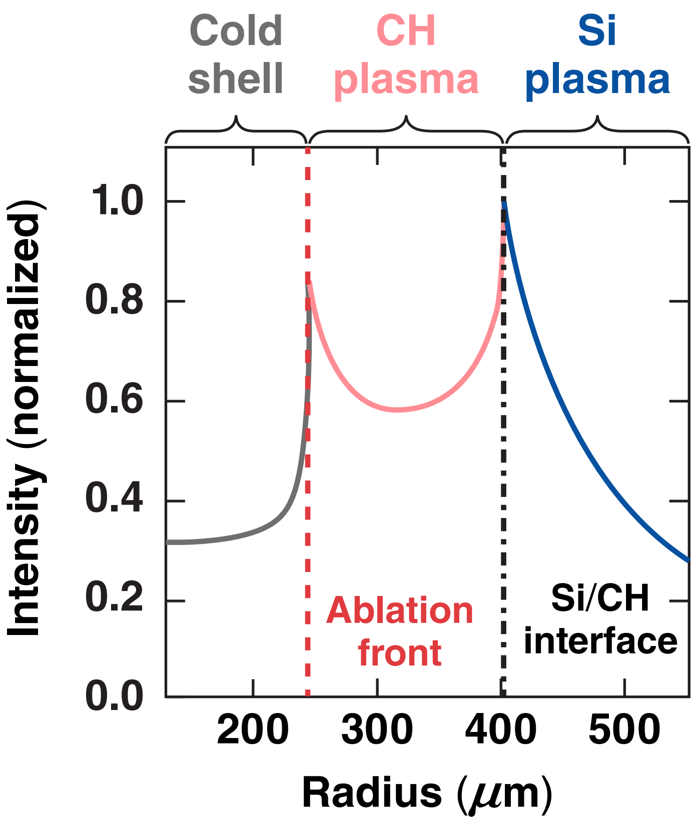
Self-emission x-ray imaging*



Shell density**



Intensity at diagnostic plane***

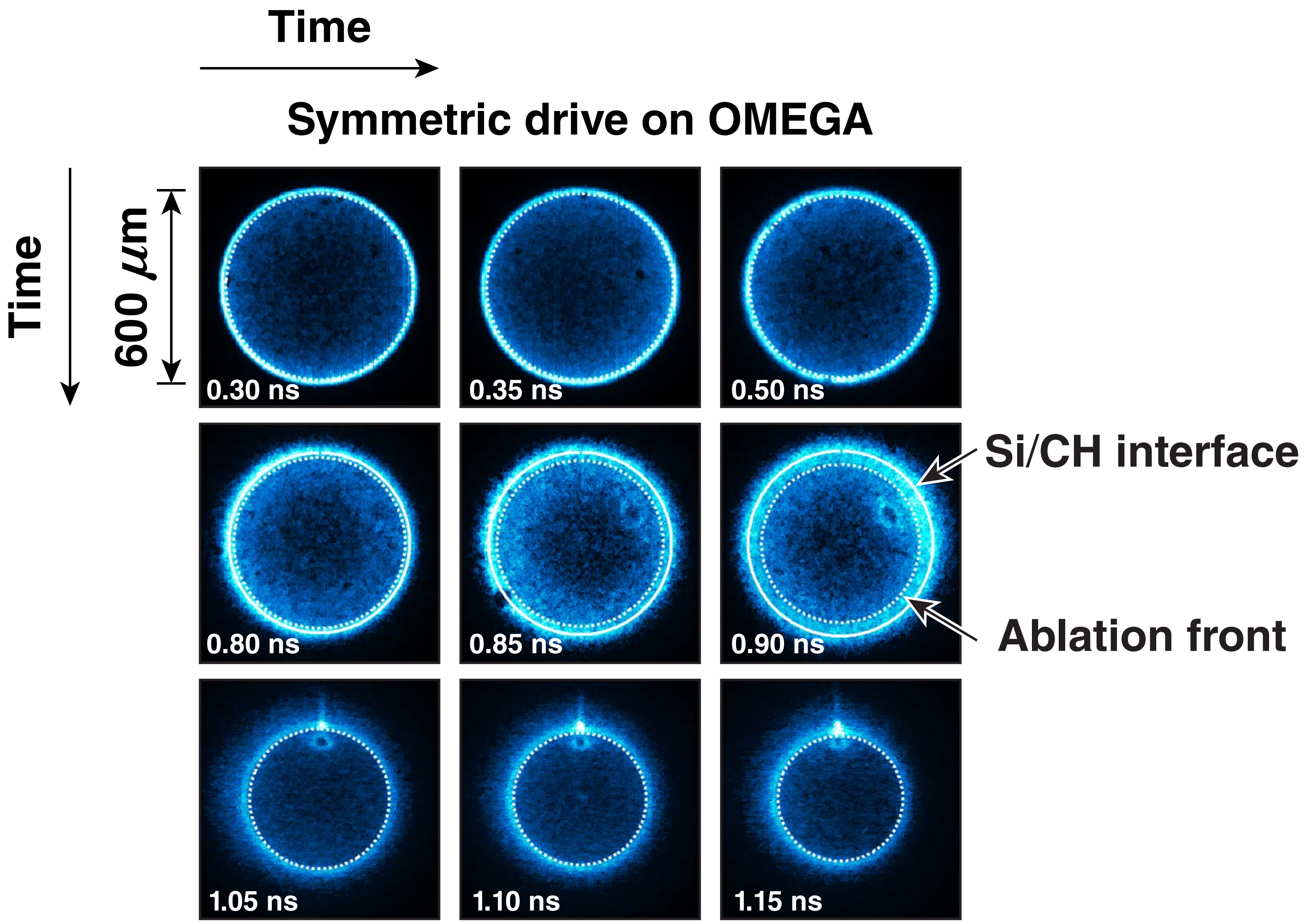


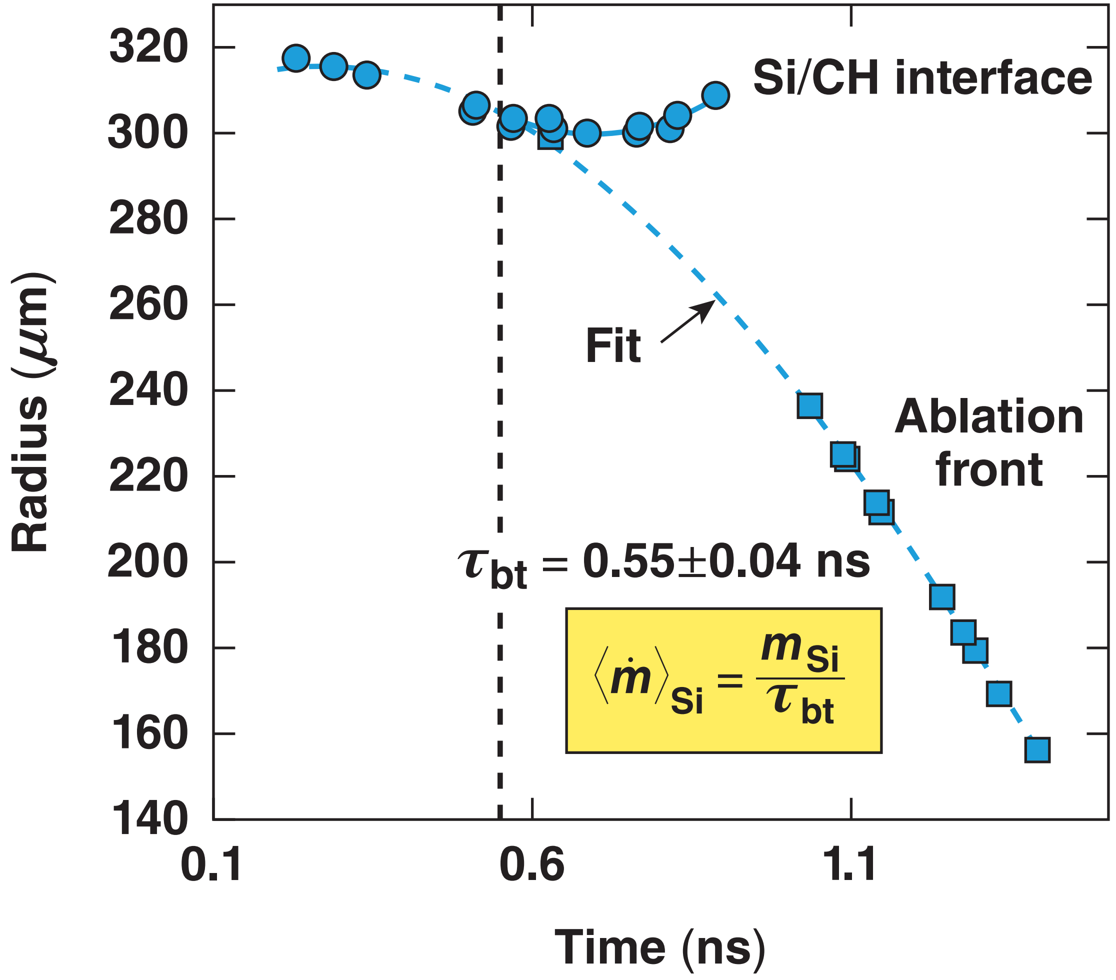
The two intensity peaks provide measurements of the corresponding Si/CH-interface and ablation-front locations.

*D. T. Michel *et al.*, Rev. Sci. Instrum. 83, 10E530 (2012).
**1-D *LILAC*
***Calculated with *Spect3D*

E24665

The Si/CH interface and ablation-front trajectories were obtained by tracking their positions in a series of images taken throughout the implosion*

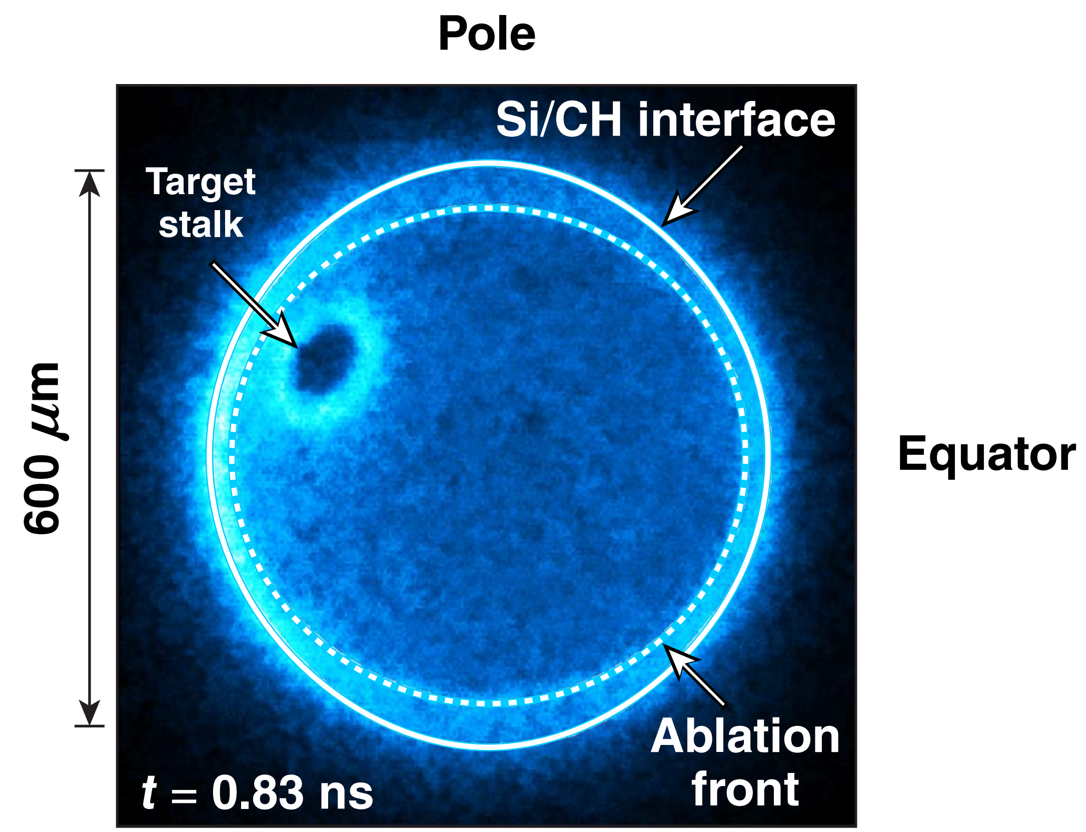


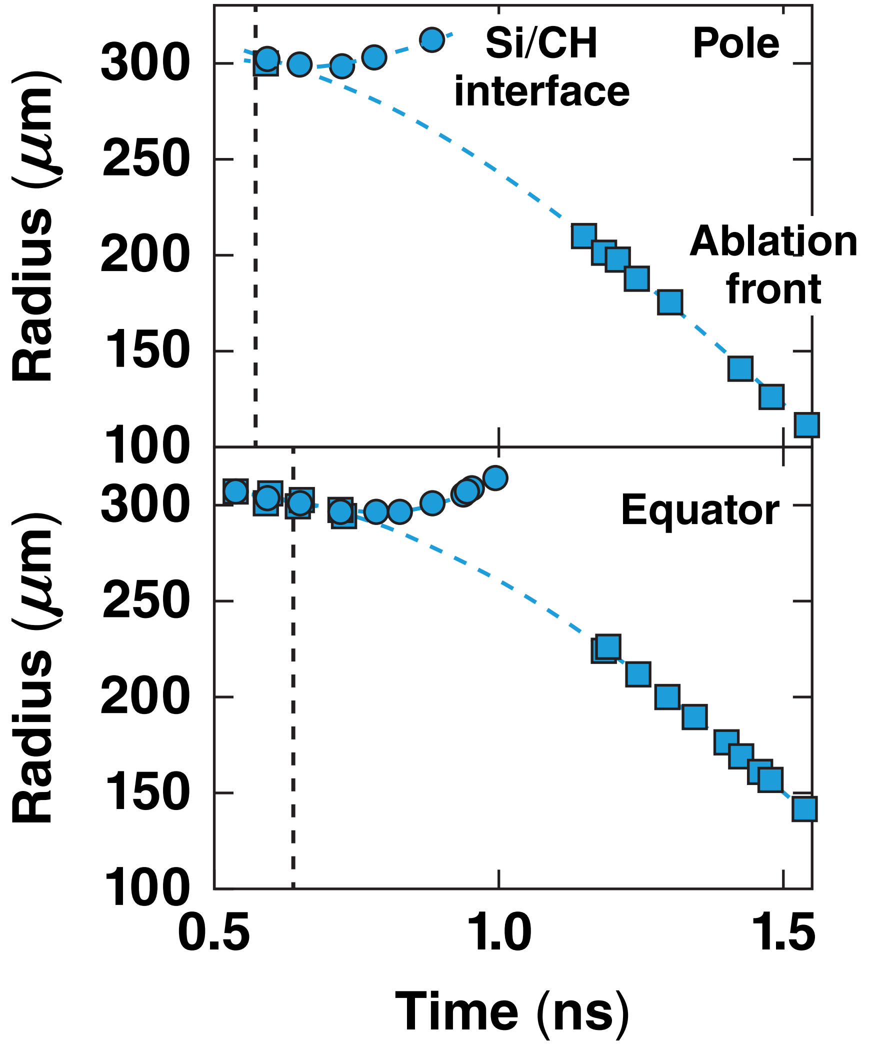


*A. K. Davis *et al*., Rev. Sci. Instrum. 85, 11D616 (2014).

E24666

In PDD, the mass ablation rate and shell velocity are lower at the equator than at the pole

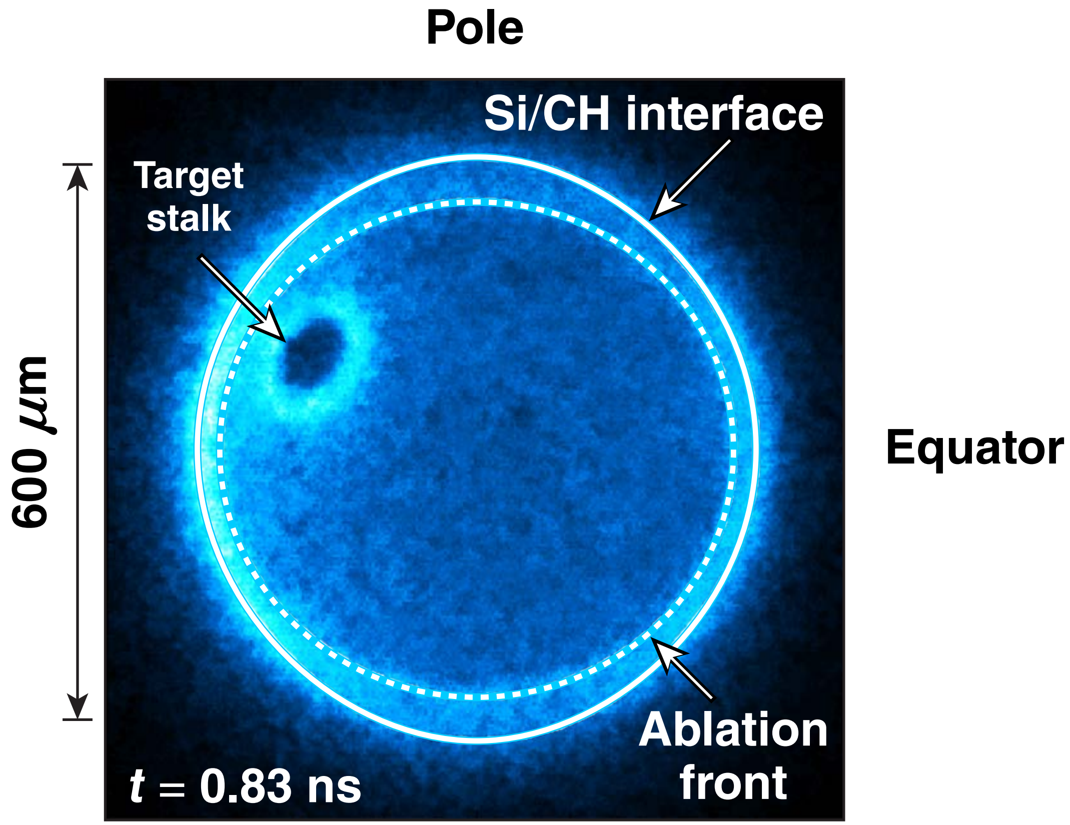


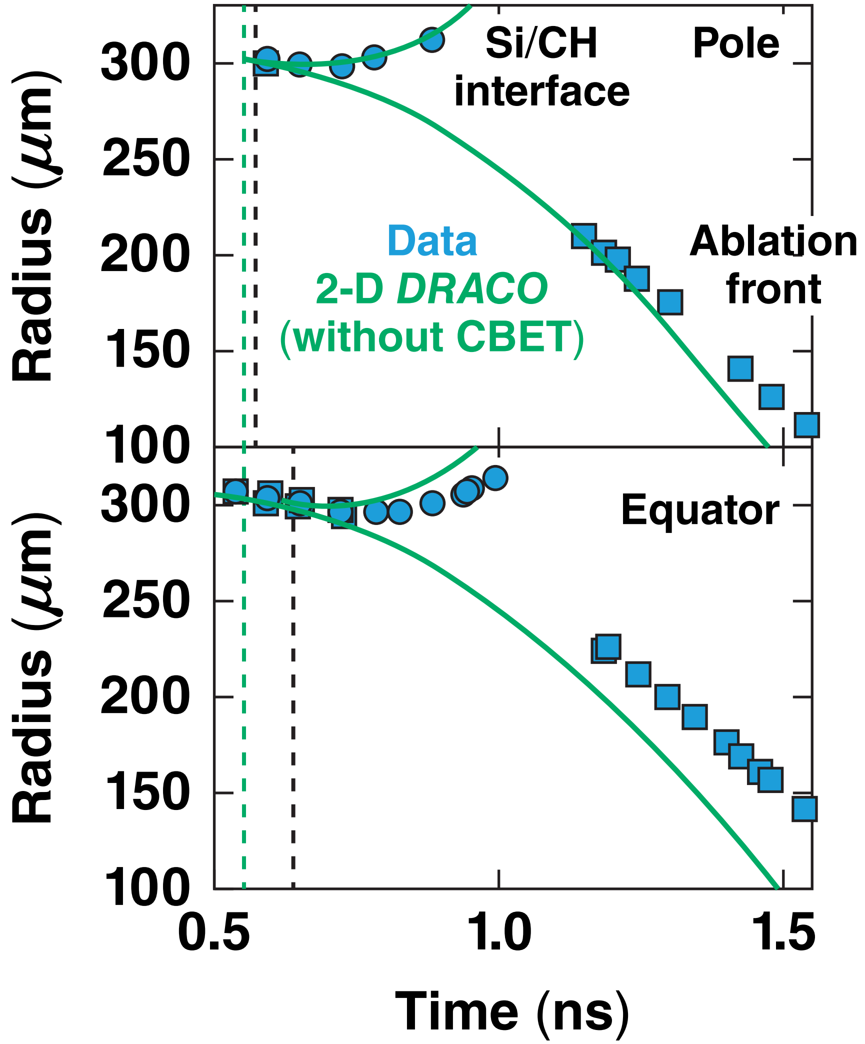


The implosion was designed to be round without CBET, so differences in hydrodynamic coupling result from CBET.

E24667

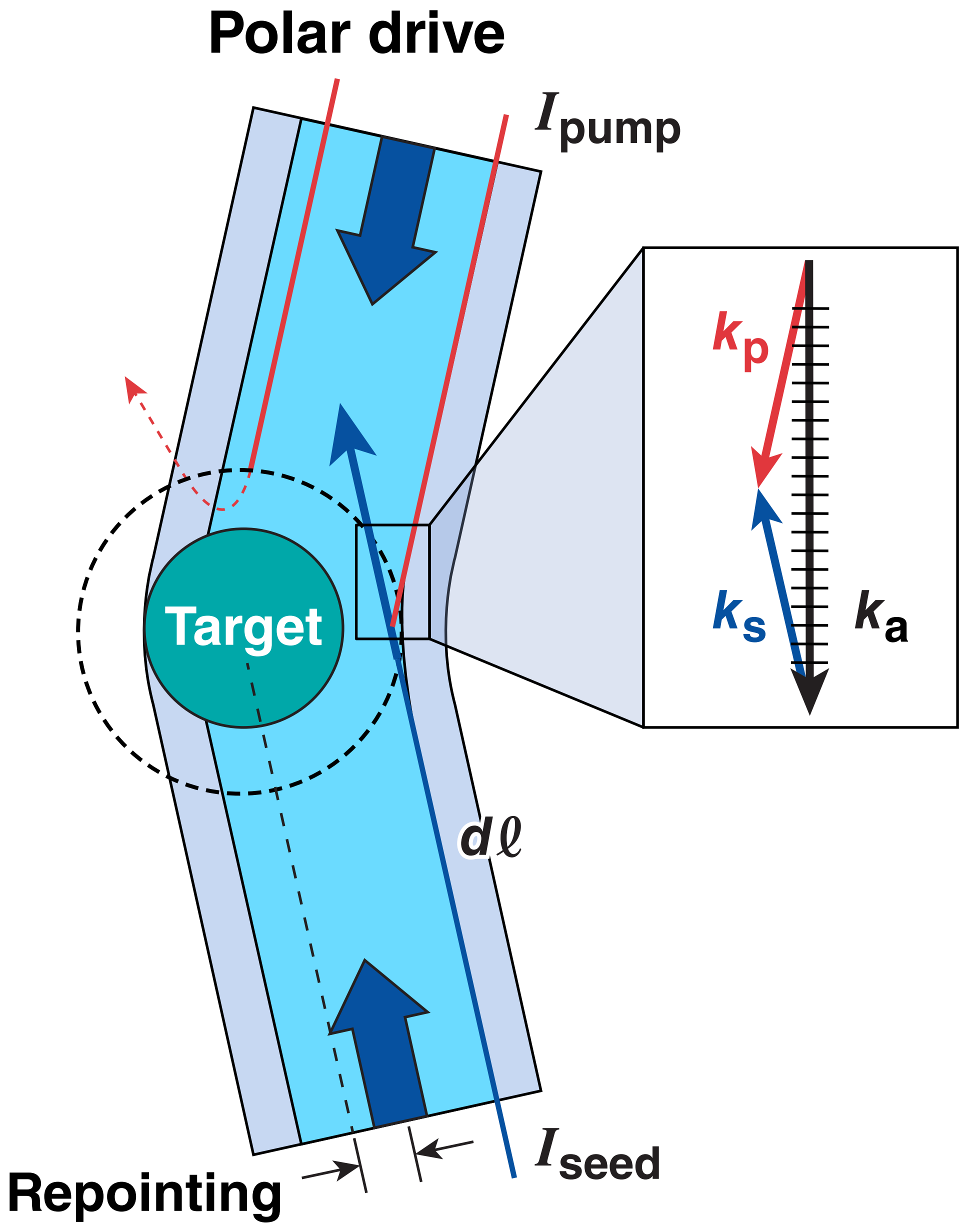
*DRACO** 2-D hydrodynamic simulations without a CBET model reproduce the drive at the pole, validating the nonlocal electron thermal-transport model**





*P. B. Radha *et al*., Phys. Plasmas 12, 056307 (2005).
**D. Cao *et al*., Phys. Plasmas 22, 082308 (2015).

A 3-D ray-tracing model for CBET* has been implemented in *DRACO*



Direct-drive CBET:**

- No ion-wave saturation (small $\delta n/n$)
- Linear plasma response
- Many interactions
- Complex geometry

***DRACO* CBET model:**

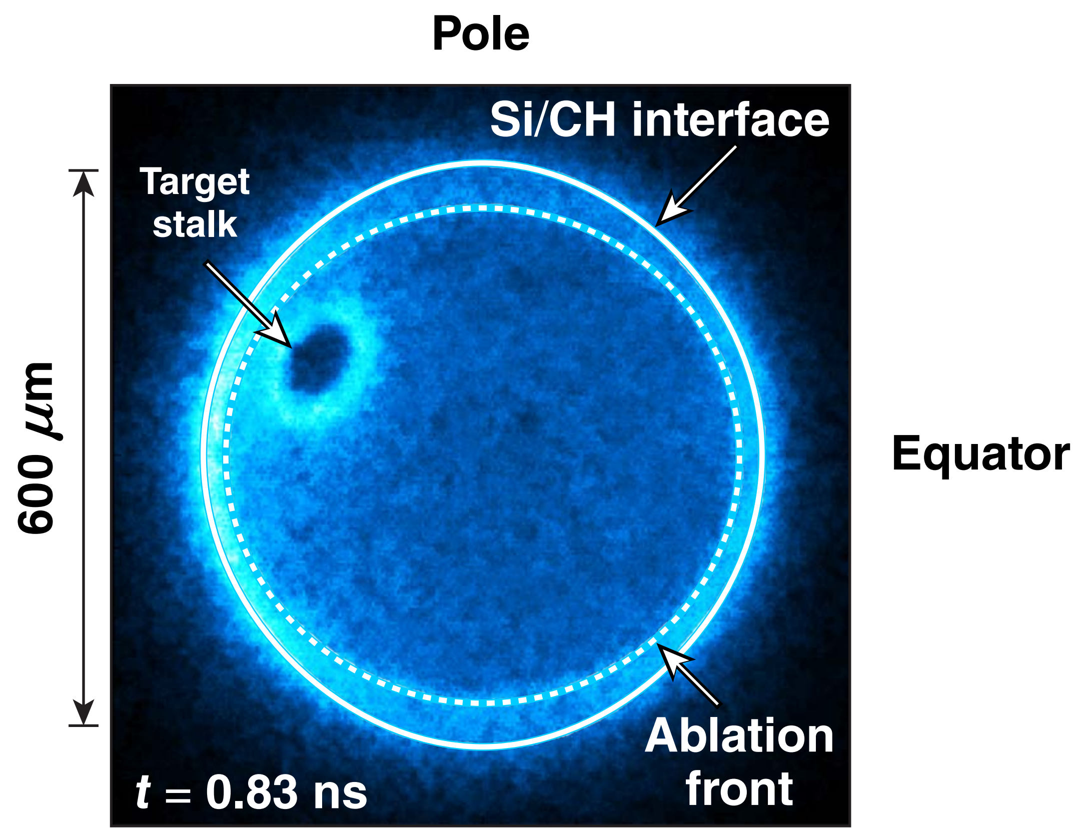
- Relatively computationally inexpensive
- 3-D ray tracing
- Local plane-wave approximation for CBET coupling
- Ray energies decomposed onto hydrodynamics grid to calculate intensities

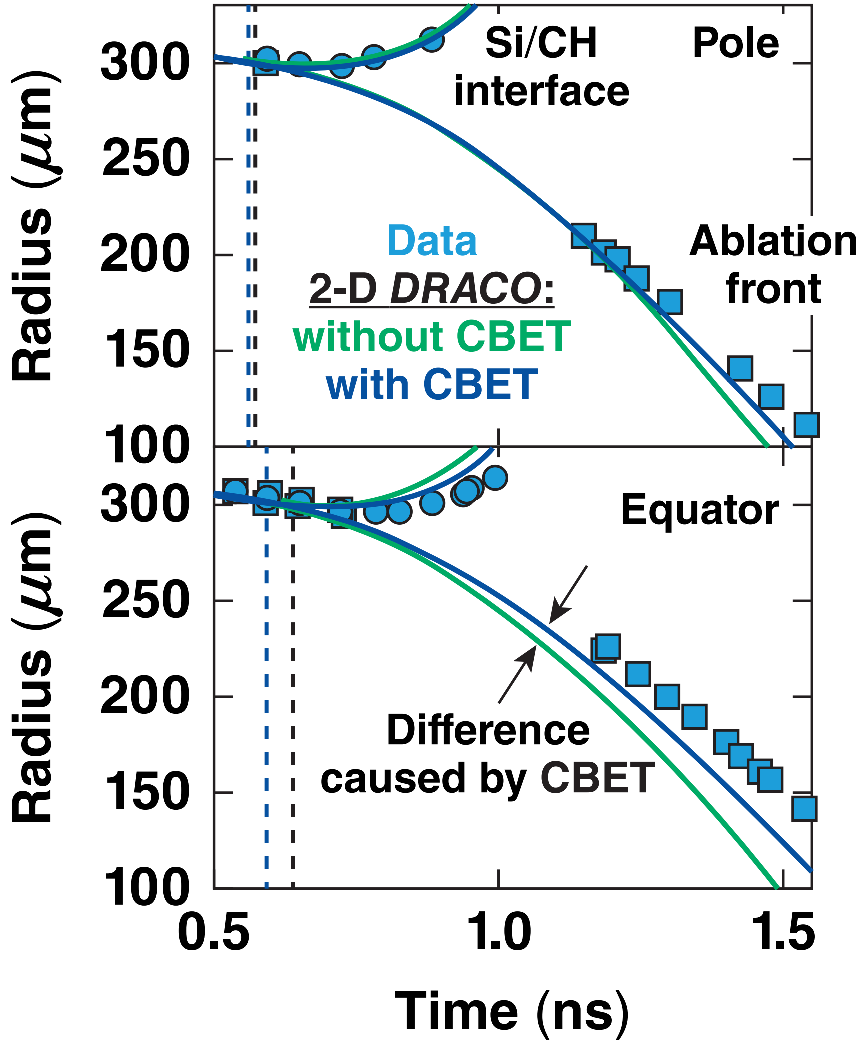
*J. A. Marozas *et al.*, presented at the 44th Annual Anomalous Absorption Conference, Estes Park, CO, 8–13 June 2014.

**C. J. Randall, J. R. Albritton, and J. J. Thomson, Phys. Fluids 24, 1474 (1981).

E24668

The simulations run with the CBET model showed better agreement with measurements at the equator

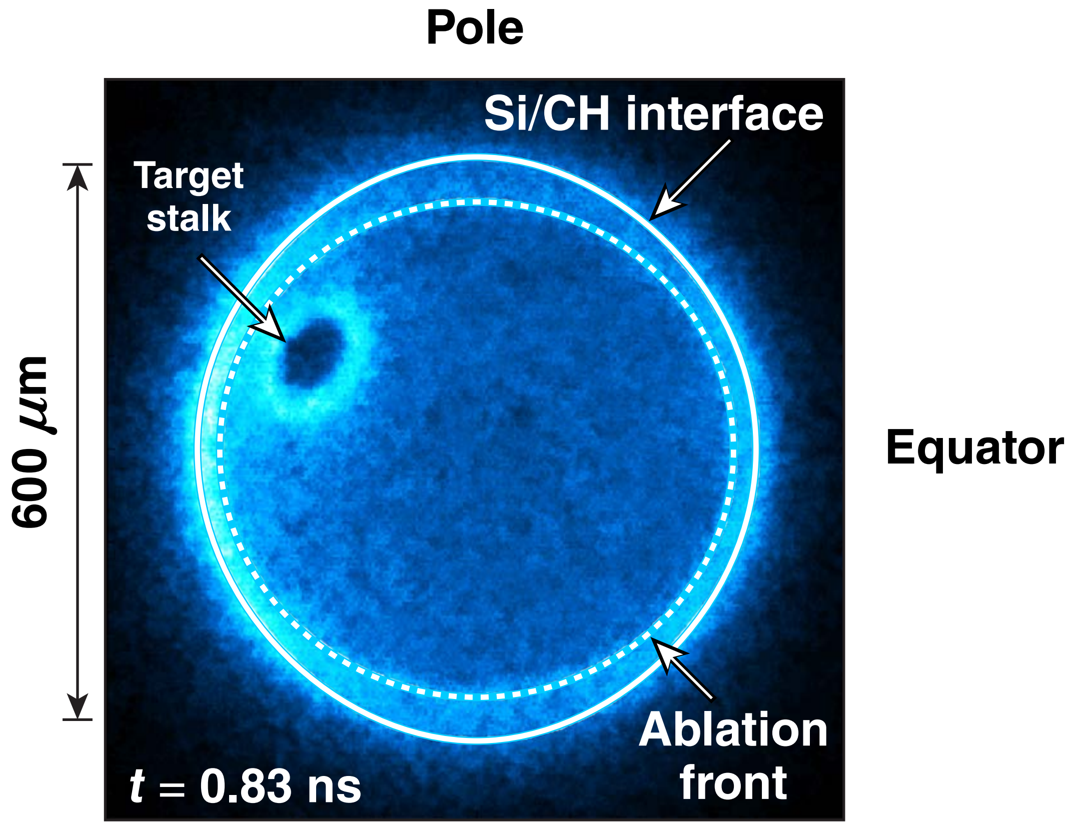


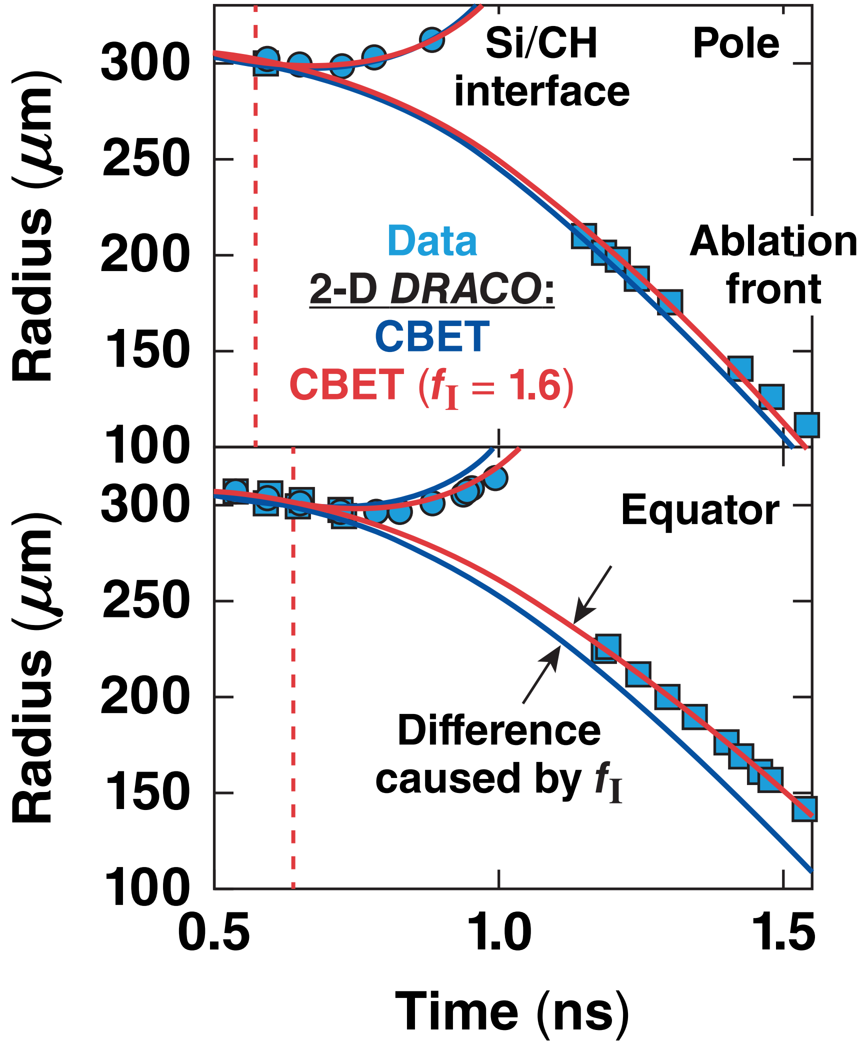


This model underestimates the effect of CBET on hydrodynamic coupling at the equator.

E24667b

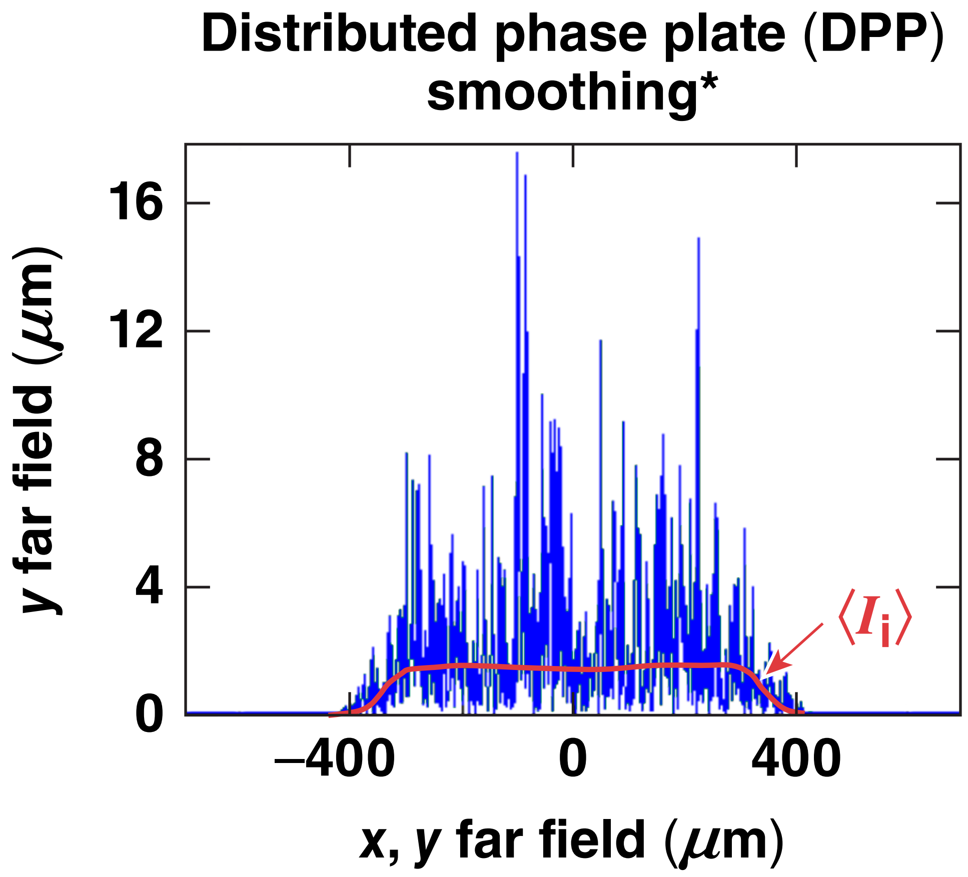
Simulations reproduce measurements at the pole and equator when an intensity factor is introduced into the CBET model

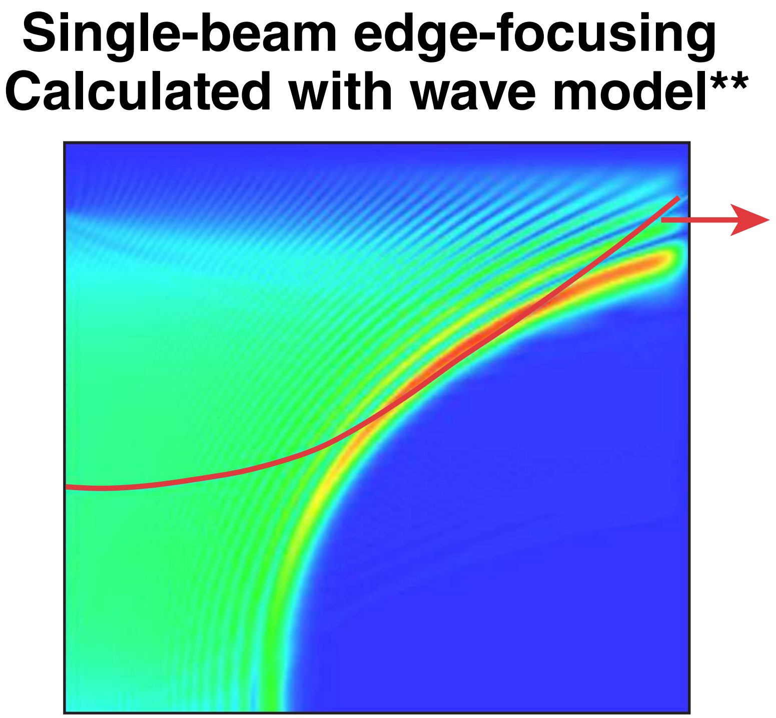


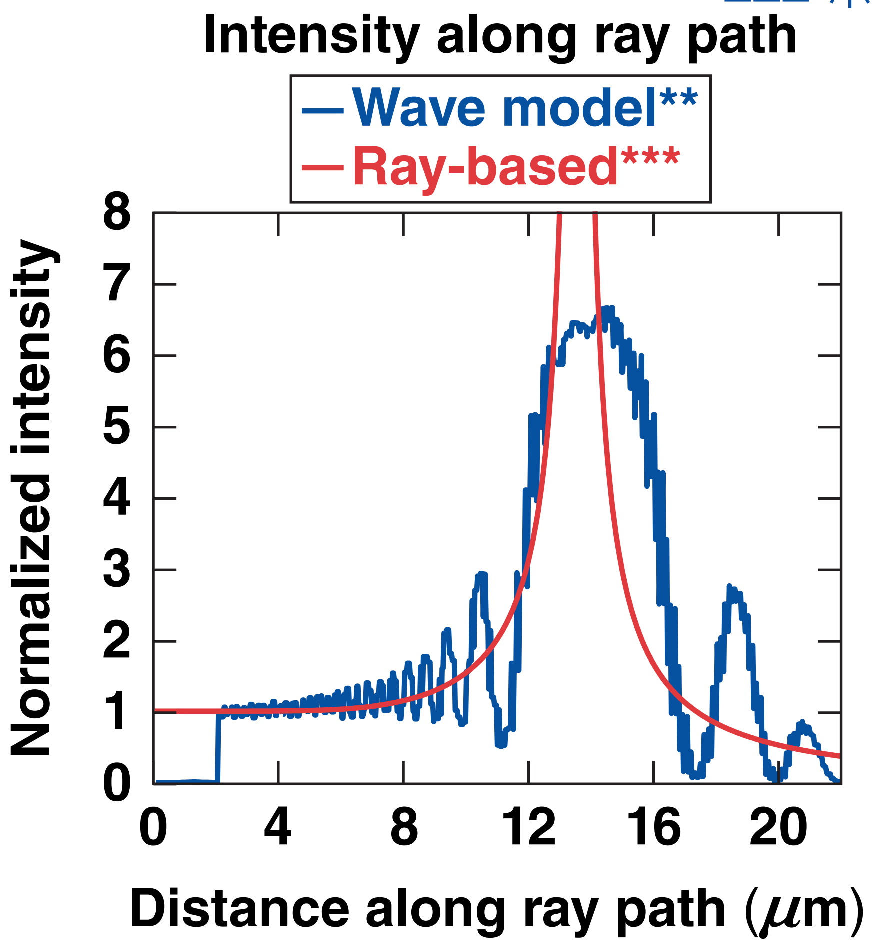


E24667c

The CBET enhancement could be caused by speckle and edge-focusing effects that are not modeled in the ray-based calculation





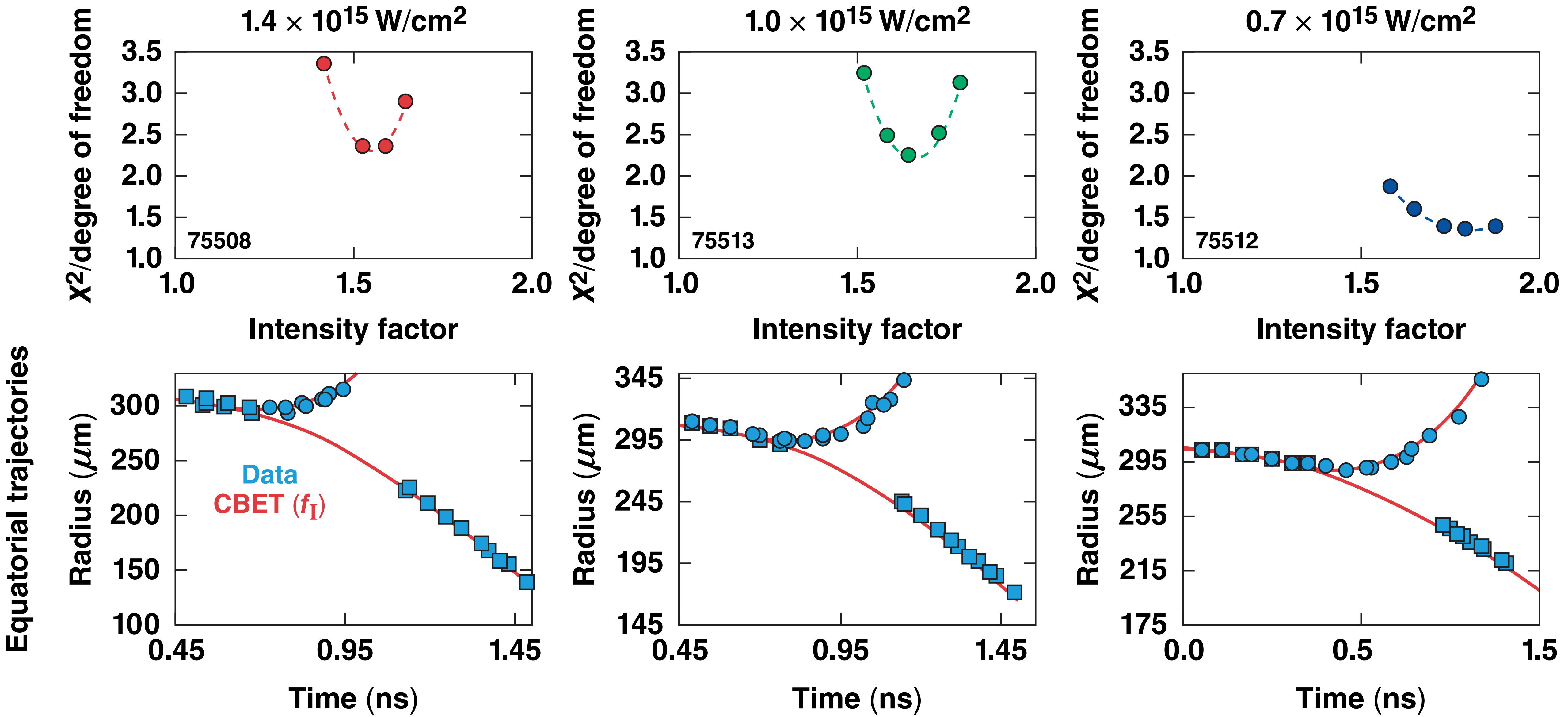


These effects are being investigated with a wave-based model.**

*SBS enhancement caused by high-intensity speckles was observed for single-beam interactions; V. T. Tikhonchuk *et al*., Phys. of Plasmas 8, 1636 (2001).
**J. F. Myatt *et al*., presented at the 45th Annual Anomalous Absorption Conference, Ventura, CA, 14–19 June 2015.
***D. H. Edgell *et al*., JO5.00004, this conference.

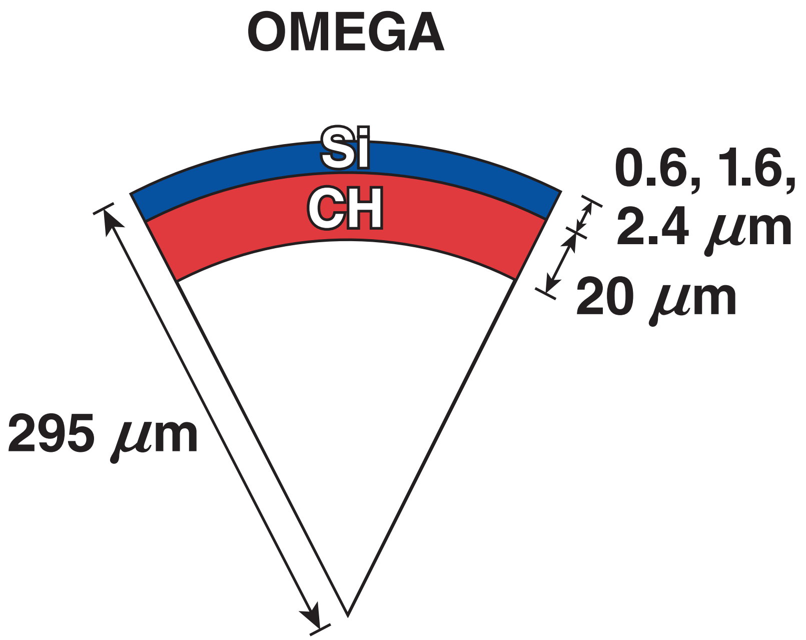
E23321a

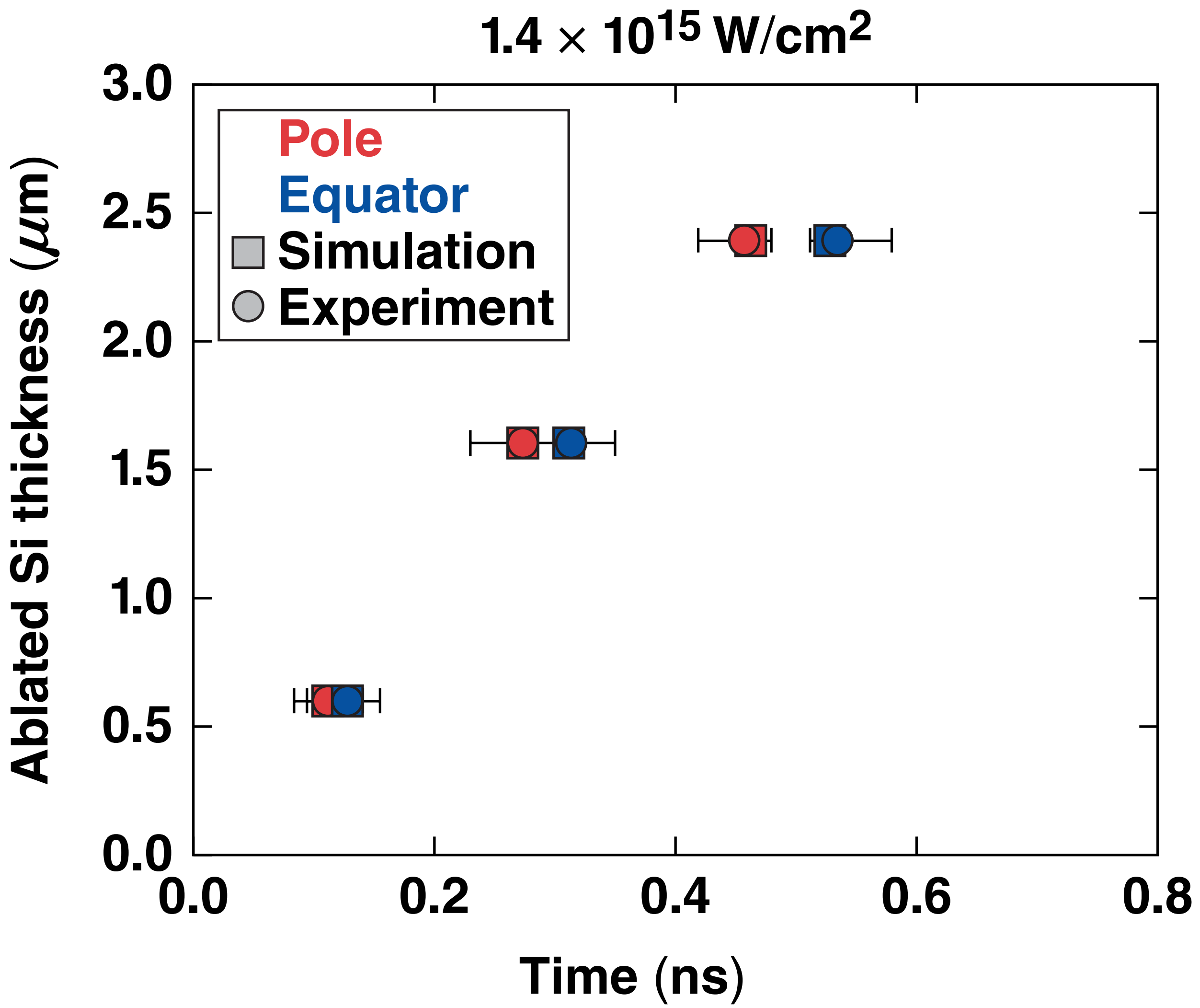
A similar intensity factor was determined for three different laser intensities



E24669

The time-resolved mass ablation rate was investigated by using three thicknesses of the outer Si layer

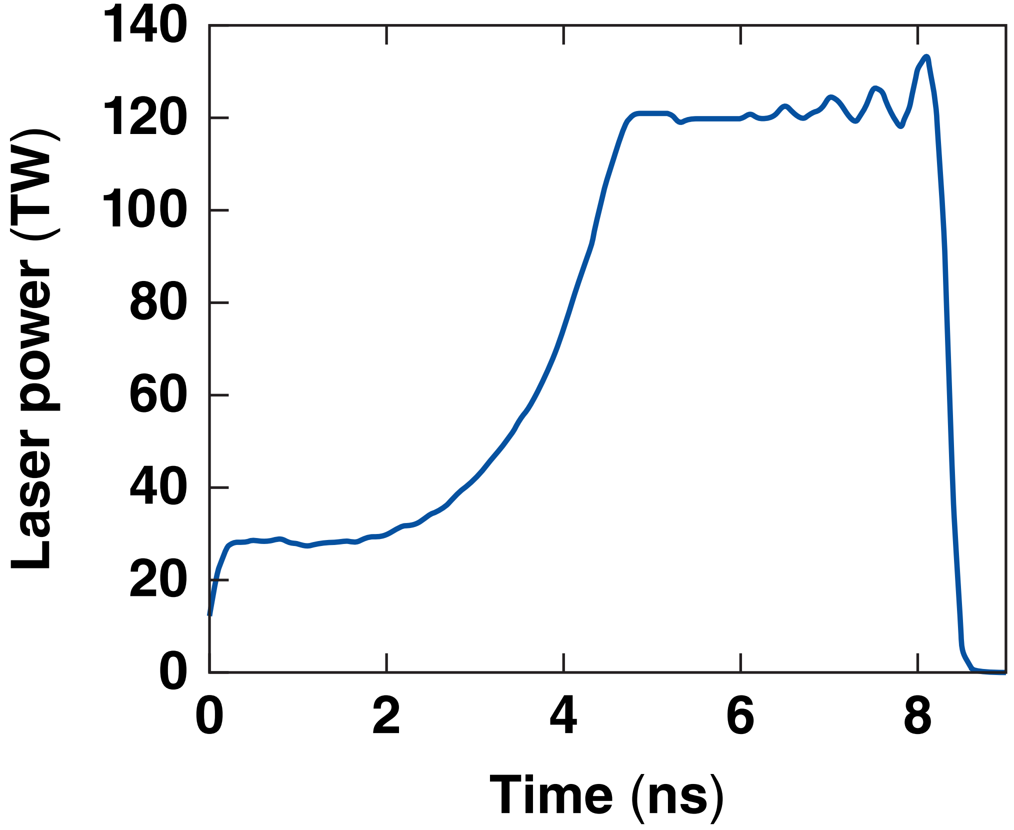


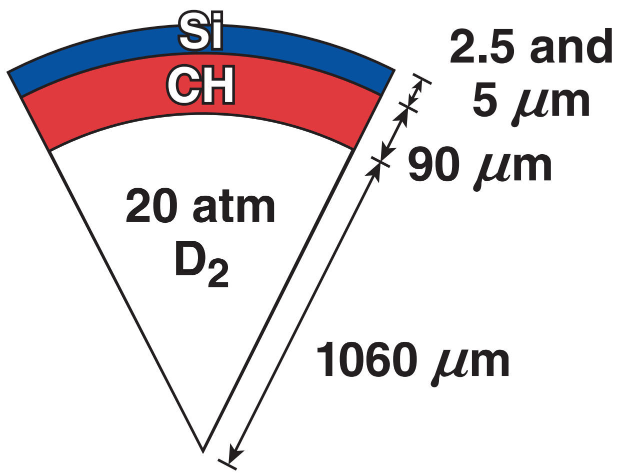


The mass ablation rate was well-reproduced by simulations.

E24670

These experiments were performed at the National Ignition Facility (NIF) to test scale-length dependence of the 2-D CBET model and intensity factor

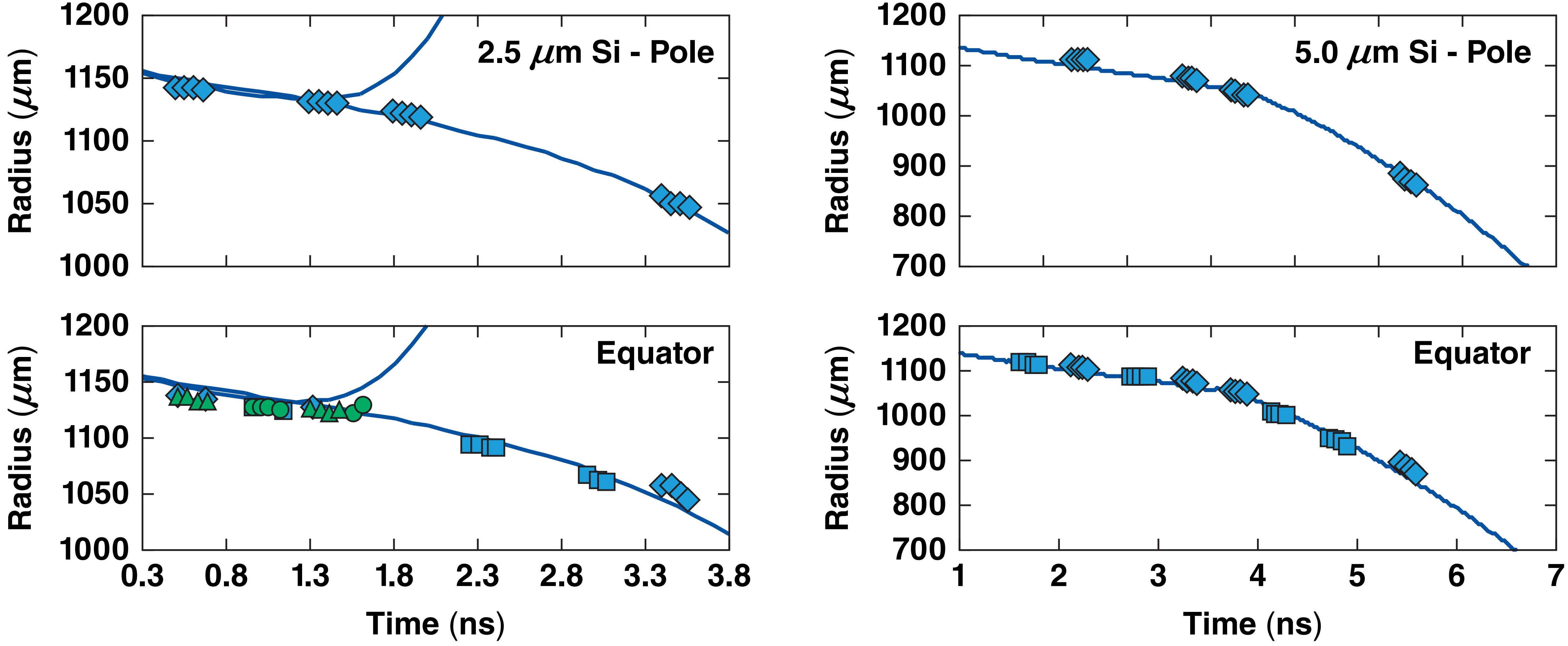




Parameter	OMEGA	NIF
E_L	24 kJ	660 kJ
T_e	3 keV	3 keV
L_n	100 μm	500 μm

E24671

Ablation-front trajectories show good agreement with corresponding pre-shot simulations that used an intensity factor of 1.4



No fundamental changes were required in the modeling of CBET between OMEGA and the NIF.

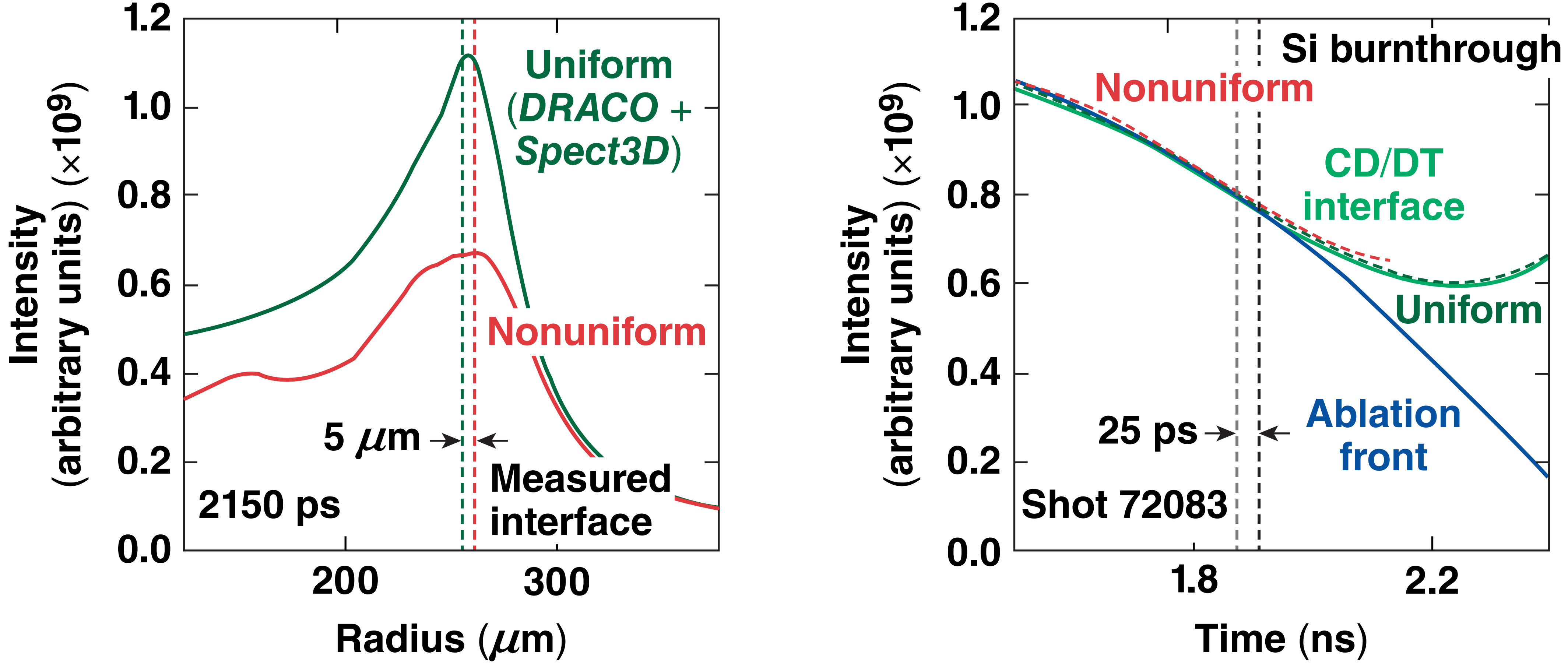
E24672

Simultaneous measurements of the 2-D mass ablation rate and ablation-front trajectory in polar-direct-drive (PDD) implosions allow the effects of cross-beam energy transfer (CBET) on hydrodynamic efficiency to be isolated and evaluated

- The PDD configuration limits CBET growth to the target equator, providing high- and low-CBET conditions in the same implosion
- Two-dimensional hydrodynamic simulations without a CBET model reproduced measured ablation rates and ablation-front trajectories at the pole, showing that coupling physics is well-modeled when CBET effects are negligible
- Running simulations with a ray-based CBET model improved agreement at the equator

Enhanced CBET growth beyond what is calculated with the current model is required to reproduce measurements made at the equator.

DRACO simulations of cryogenic implosions show that perturbations have a minimal impact on the measurement of the burnthrough time*



*DRACO simulations were performed with and without perturbations seeded by target offset, DT ice roughness, and laser imprint up to mode 150.

E23157c