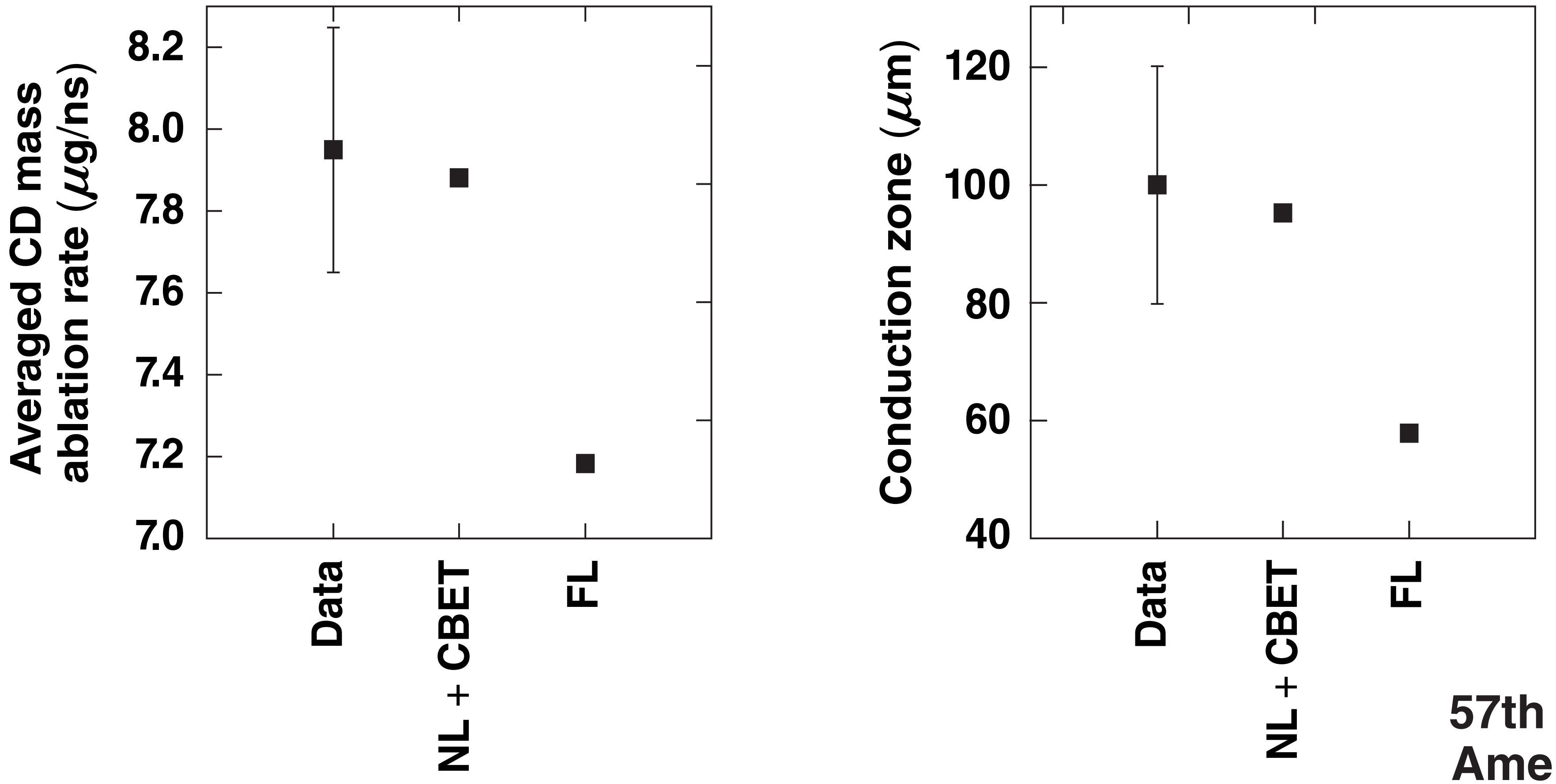
Measurements of the Conduction-Zone Length and Mass Ablation Rate in Cryogenic Direct-Drive Implosions on OMEGA Restrict Thermal-Transport Models



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Summary

Nonlocal (NL) electron transport and cross-beam energy transfer (CBET) models* are required to reproduce the mass ablation rate and the length of the conduction zone measured in cryogenic implosions on OMEGA

- An averaged CD mass ablation rate of 8.0±0.3 μg/ns was measured by imaging the self-emission x rays in cryogenic implosions
- The conduction zone length of 100±20 μm was determined from the combination of the measurement of the self-emission x-ray imaging and the scattered-light spectrum
- Time-dependent flux-limiter simulations underestimate the mass ablation rate by 10% and the length of the conduction zone by a factor of 2
- Simulations that include NL electron transport and CBET reproduce the experimental observables

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* V. N. Goncharov *et al.*, Phys. Plasmas 13, 012702 (2006);
I. V. Igumenshchev *et al.*, Phys. Plasmas 17, 122708 (2010).

Collaborators

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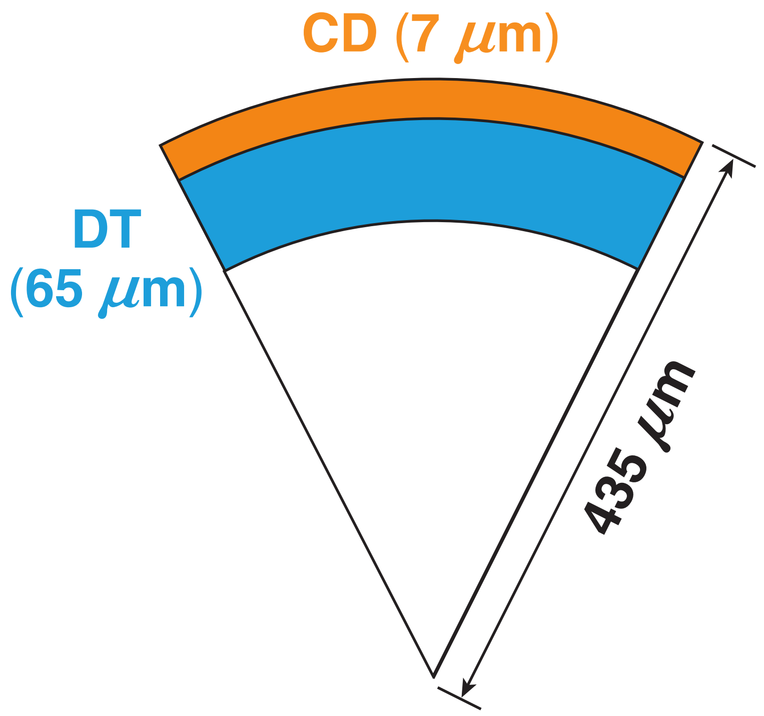
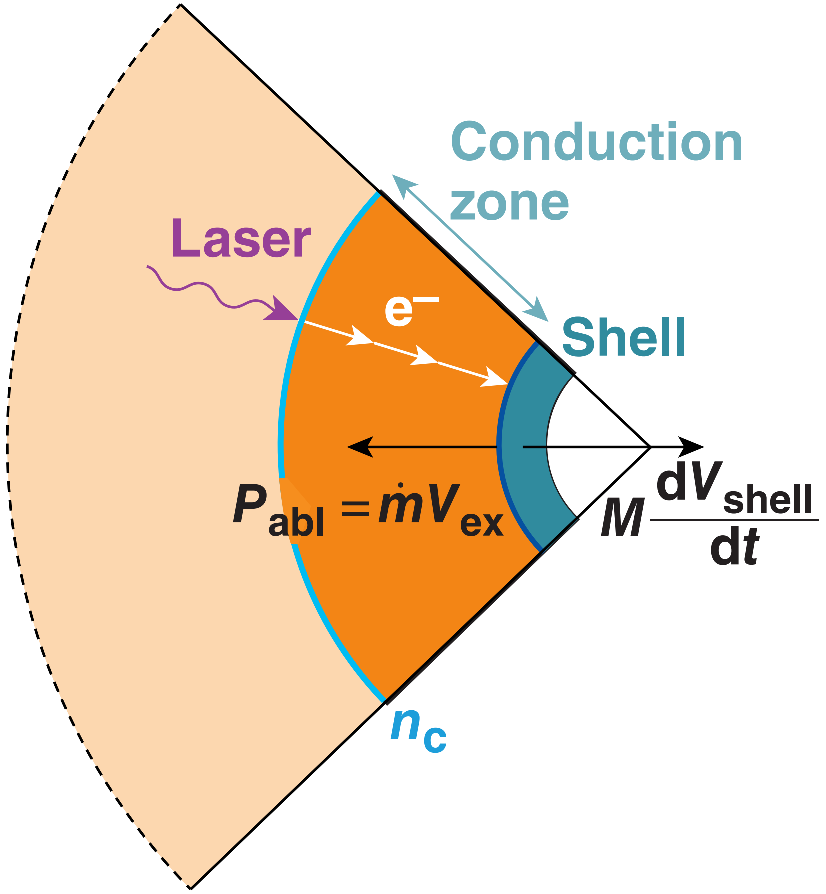
Direct-drive inertial confinement fusion implosions are driven by laser energy absorbed near the critical density and transported by electrons to the ablation surface

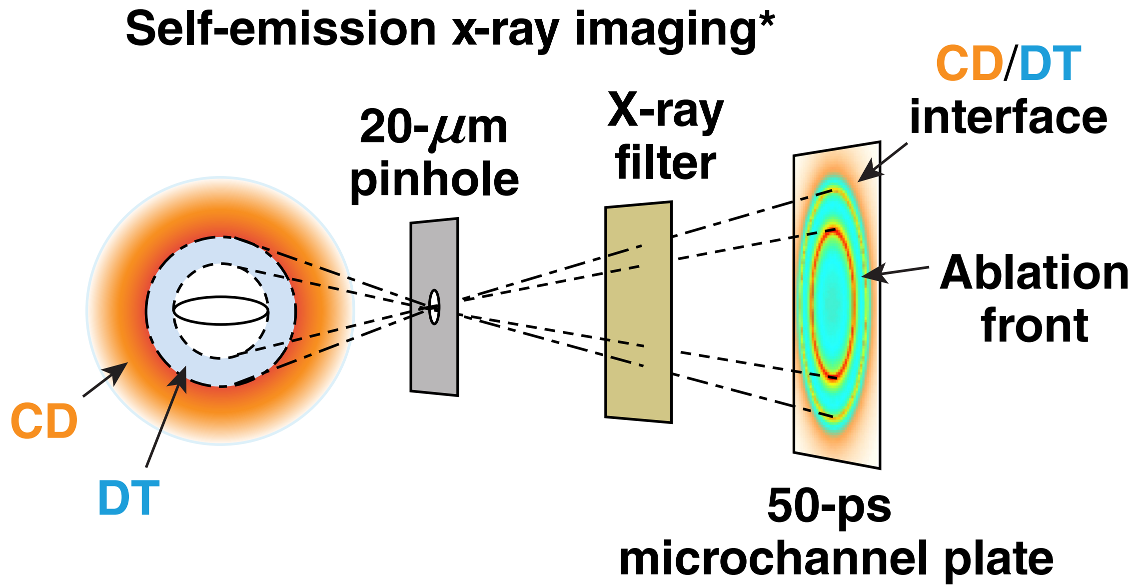


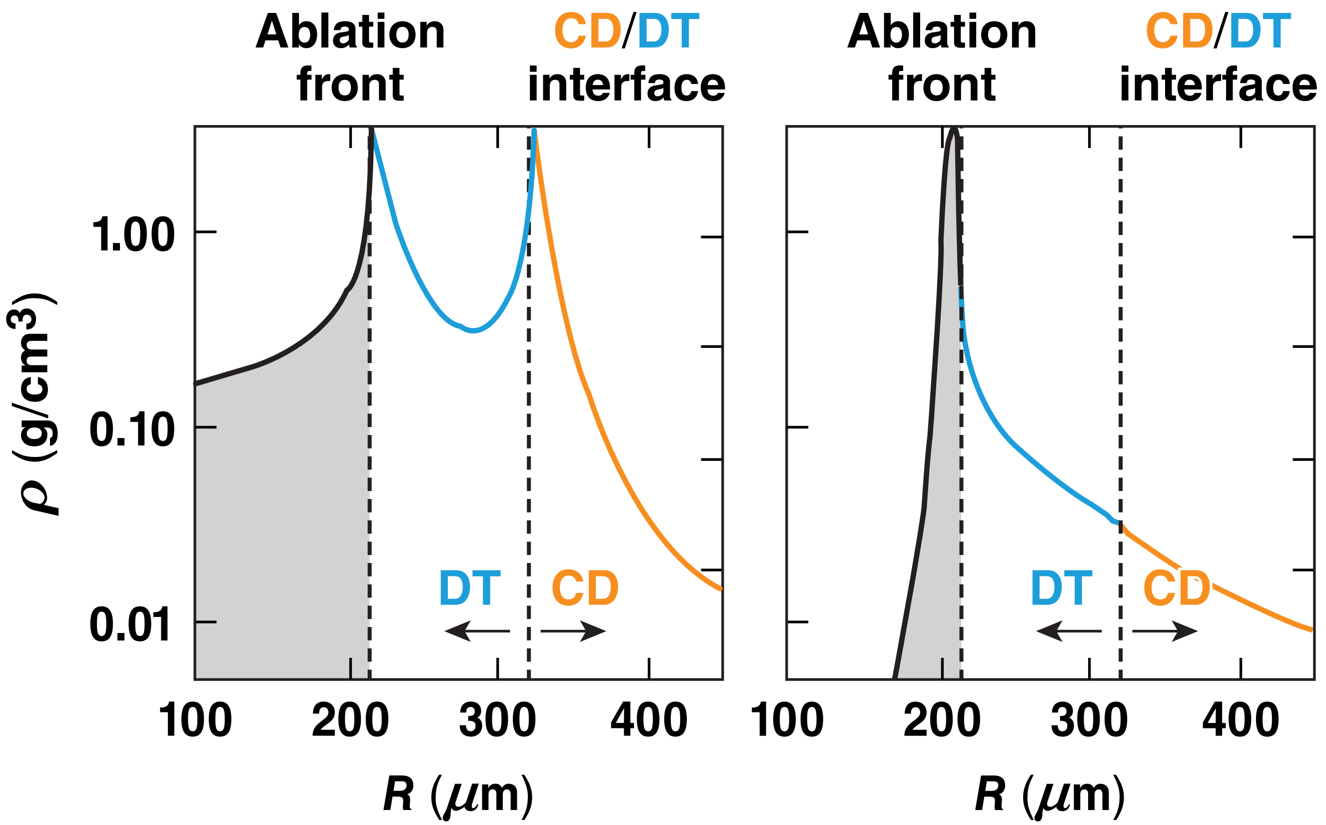


Measurement of the mass ablation rate and the size of the conduction zone constrain the hydrodynamic coupling.

E23040e

In a cryogenic implosion, the average mass ablation rate of the CD outer layer was determined from measuring of the time needed to burn through the CD





After the laser burns through the CD layer, the inner peak corresponds to the ablation surface and the outer peak corresponds to the CD/DT interface.

E23547e

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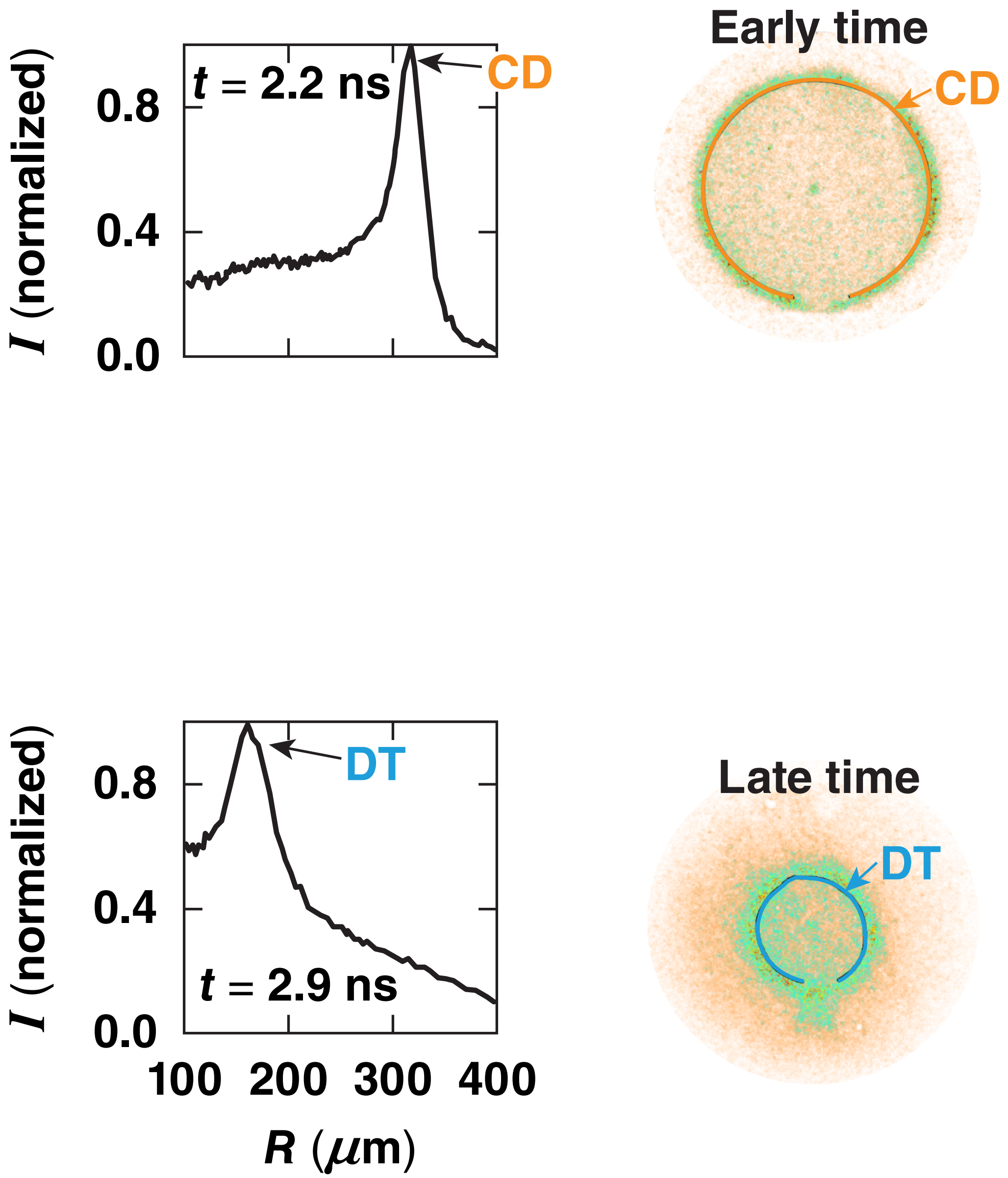
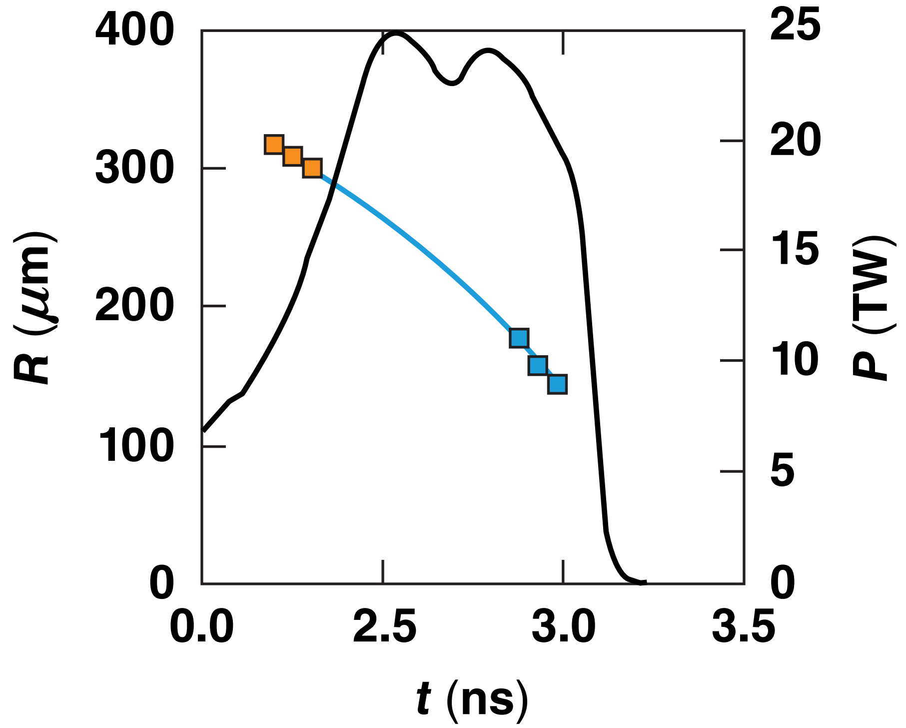
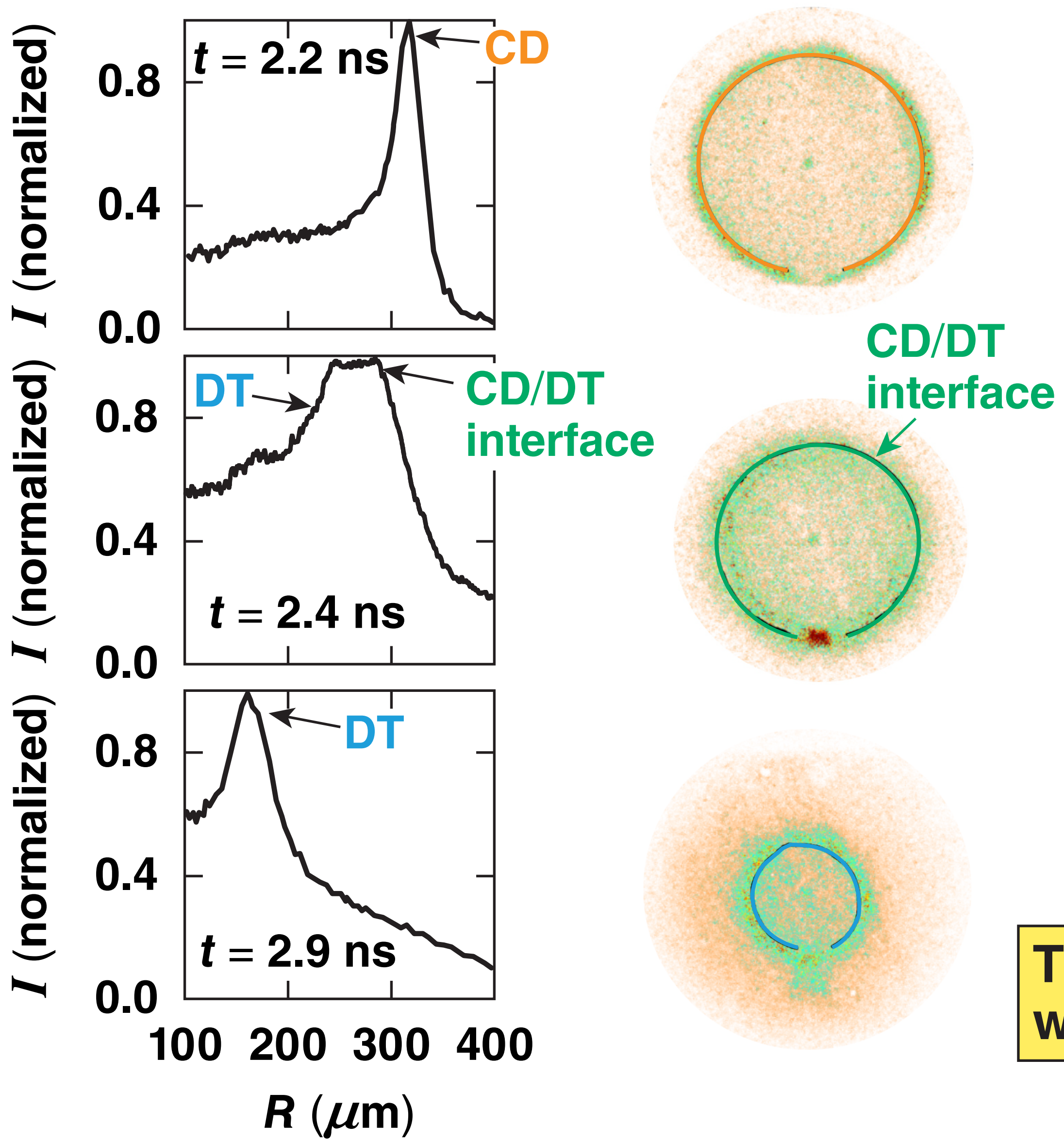
*D. T. Michel *et al*., Rev. Sci. Instrum. 83, 10E530 (2012).

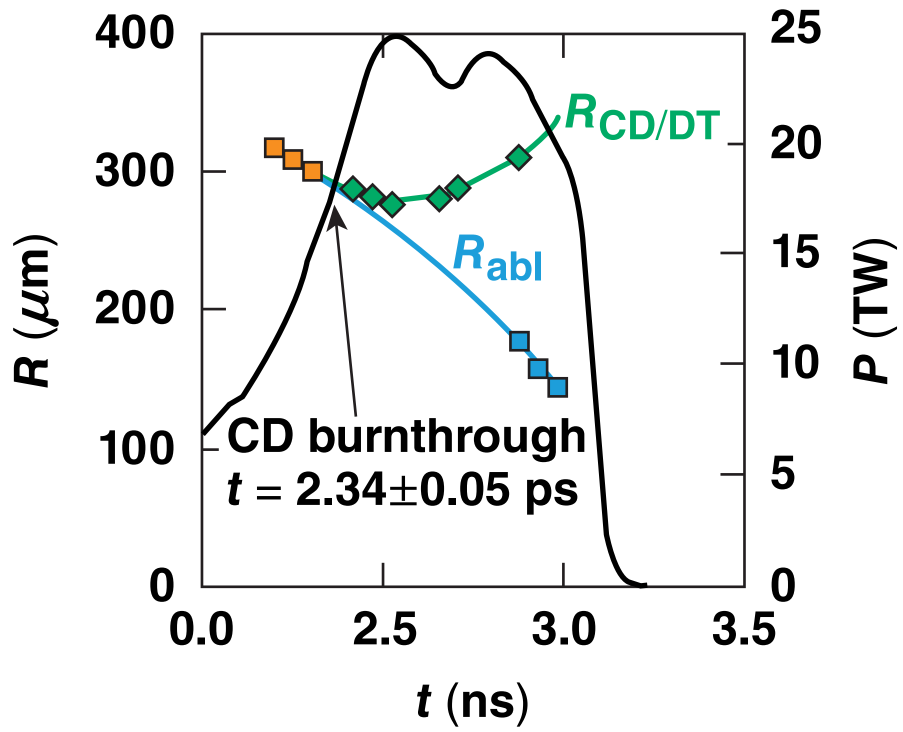
The ablation-front trajectories were determined from a series of self-emission images





The CD/DT interface trajectory was measured from the CD emission peak after the CD burnthrough*





The CD burnthrough corresponds to the time when the CD expands from the ablation surface.

E23045e

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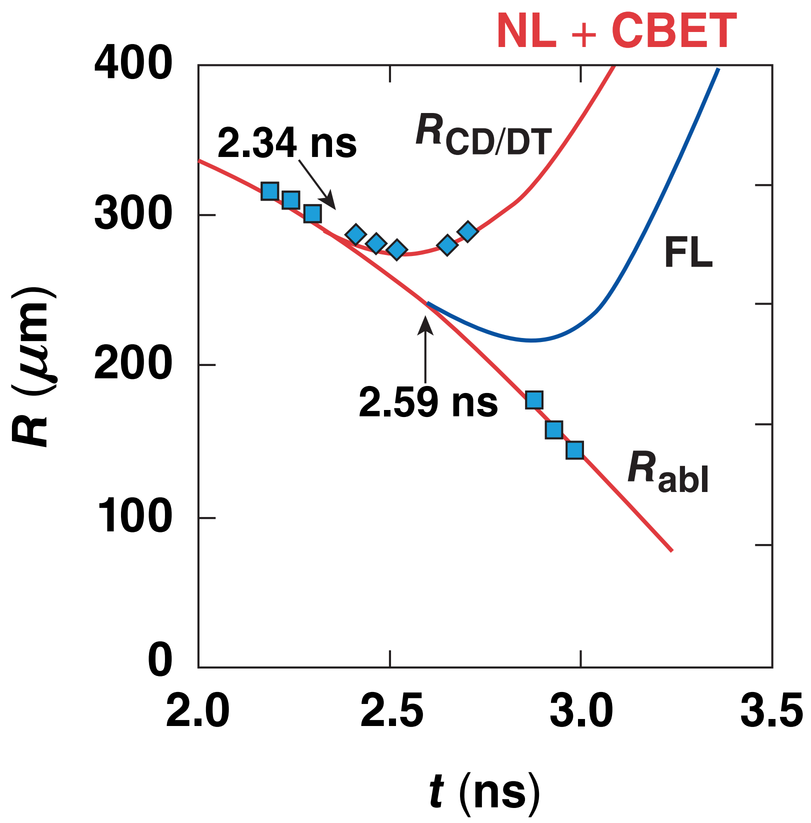
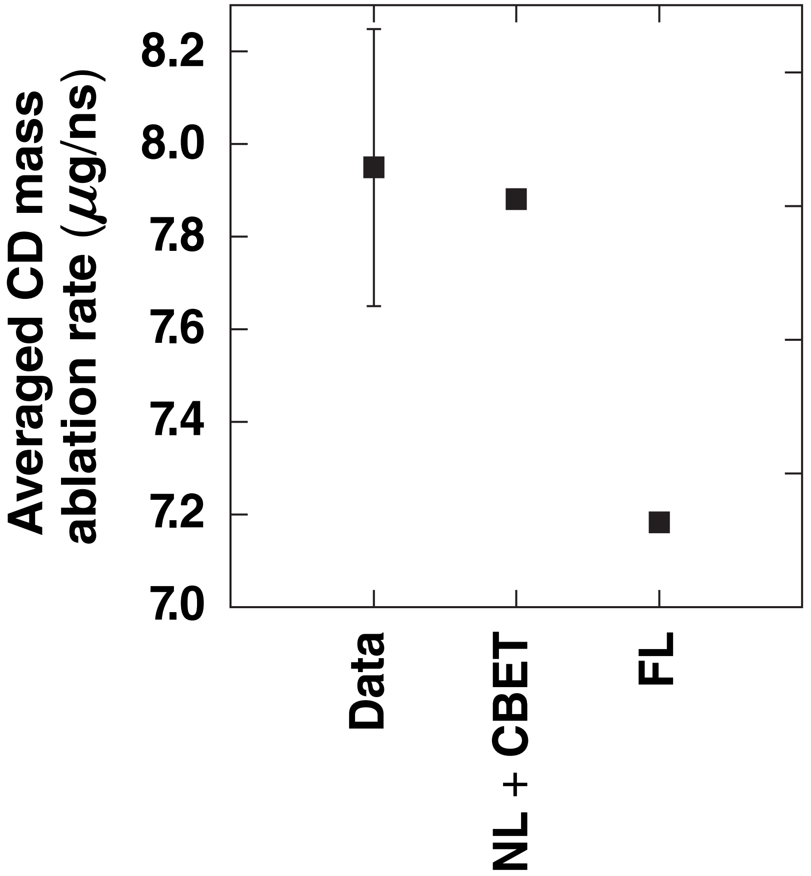
*A. K. Davis *et al.*, Rev. Sci. Instrum. 85, 11D616 (2014).

The averaged mass ablation rate of the CD was reproduced when using NL and CBET models*





When matching shell trajectory, time-dependent flux-limited (FL) simulations underestimate the averaged mass ablation rate of the CD by 10%.

E24162d

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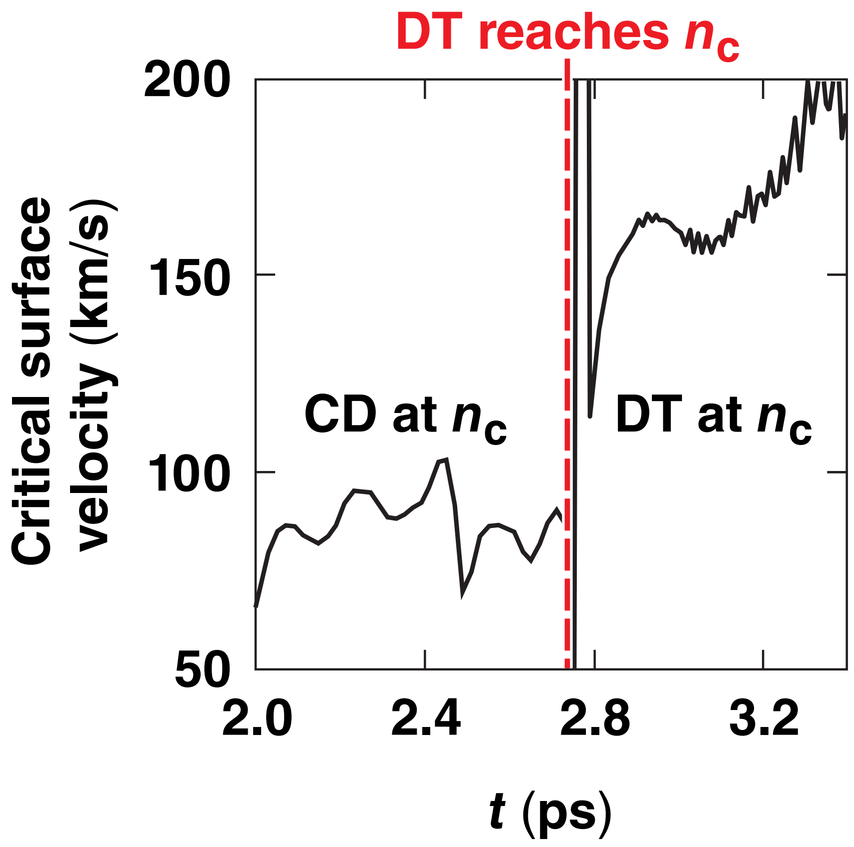
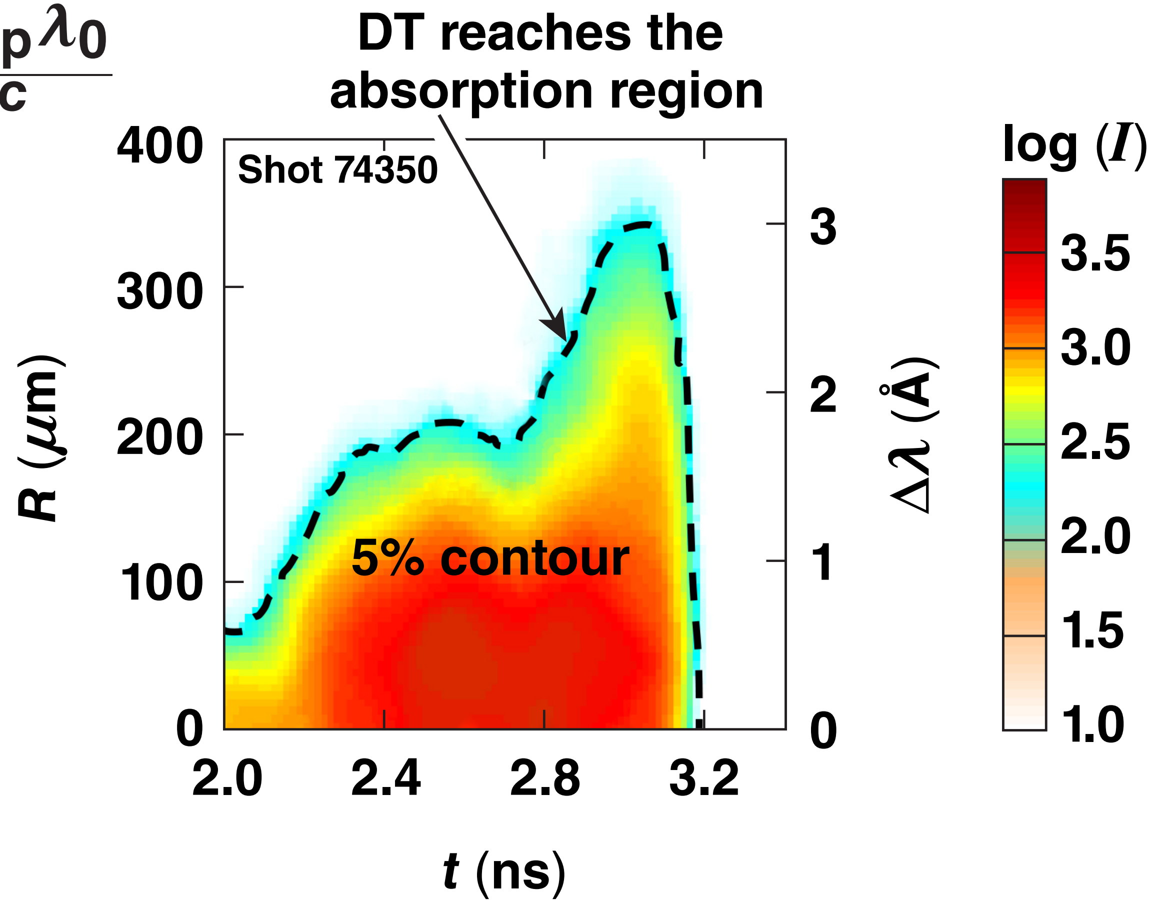
* D. T. Michel, Phys. Rev. Lett. 114, 155002 (2015).

The scattered-light spectrum provides a measure of the time when the CD/DT interface reaches the laser-absorption region

Moving mirror*

$$\Delta\lambda \approx \frac{2V_{tp}\lambda_0}{c}$$





When the DT reaches the absorption region, the velocity of the critical surface jumps, resulting in a jump in the maximum red-shifted wavelength in the scattered-light spectrum.**

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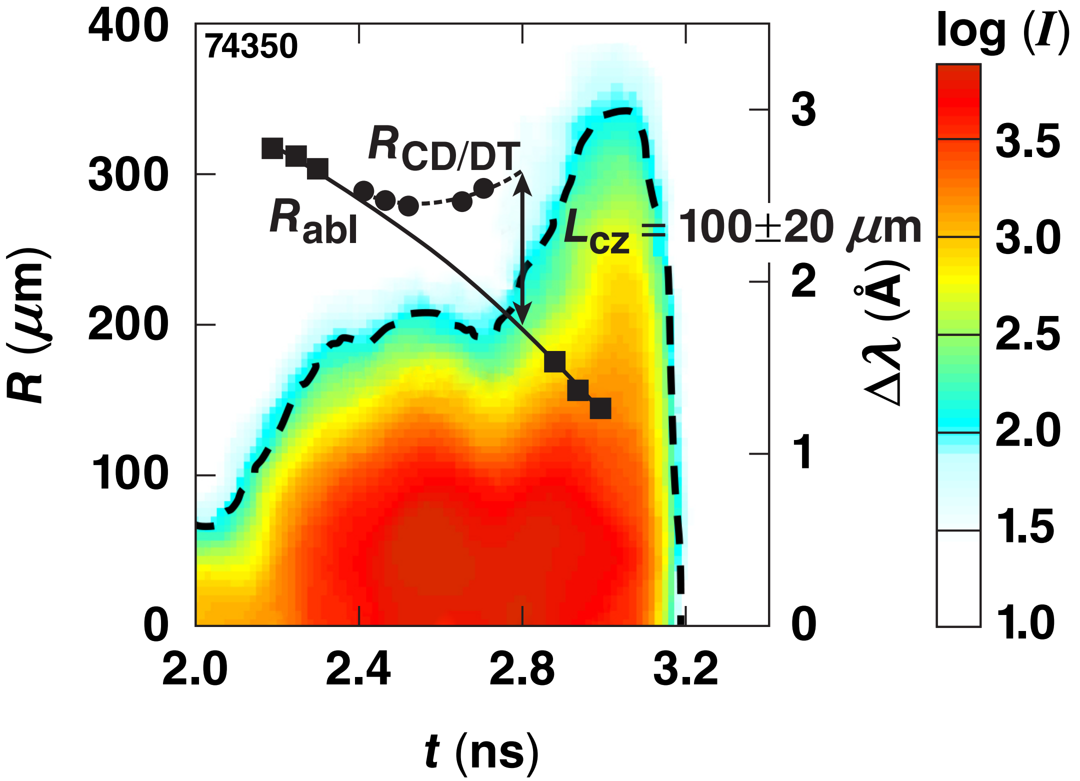
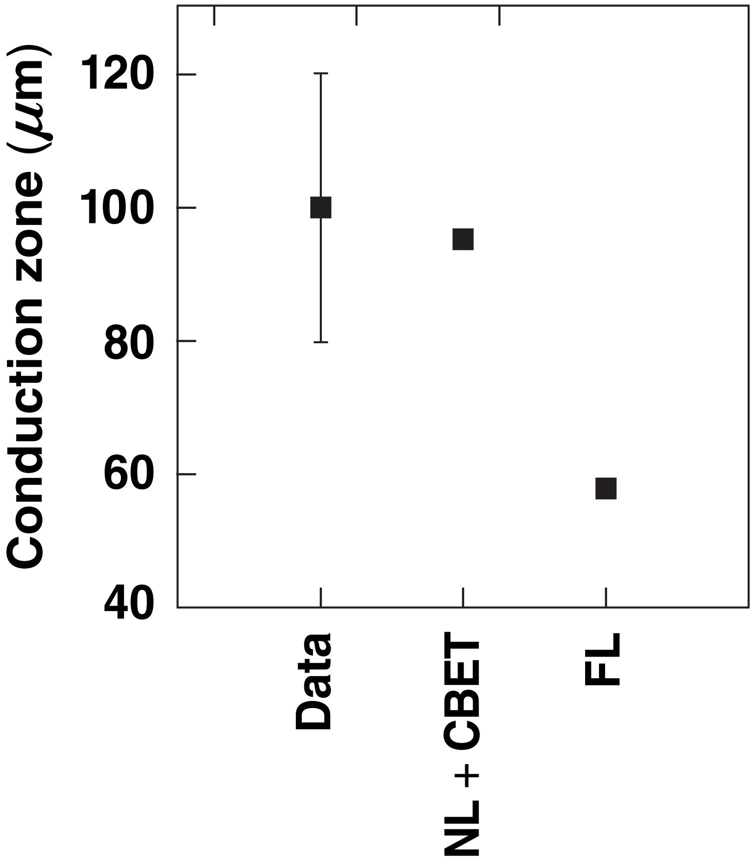
*Calculated for normal incident rays.

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

The combination of the scattered-light spectrum and the self-emission x-ray imaging makes it possible to determine the length of the conduction zone*





The size of the conduction zone is well reproduced when using NL and CBET models, but significantly underestimated when using a time-dependent flux limiter.*

E24330a

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*D. T. Michel, Phys. Rev. Lett. 114, 155002 (2015).

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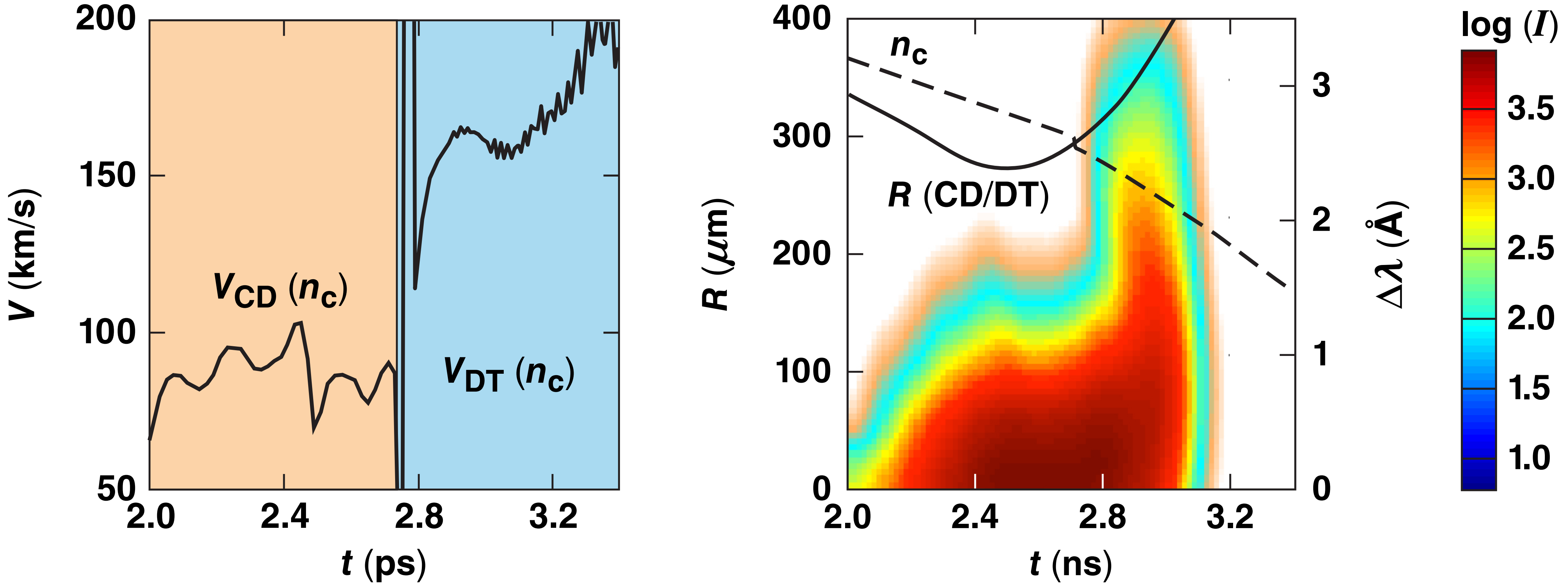
I. V. Igumenshchev *et al.*, Phys. Plasmas 17, 122708 (2010).

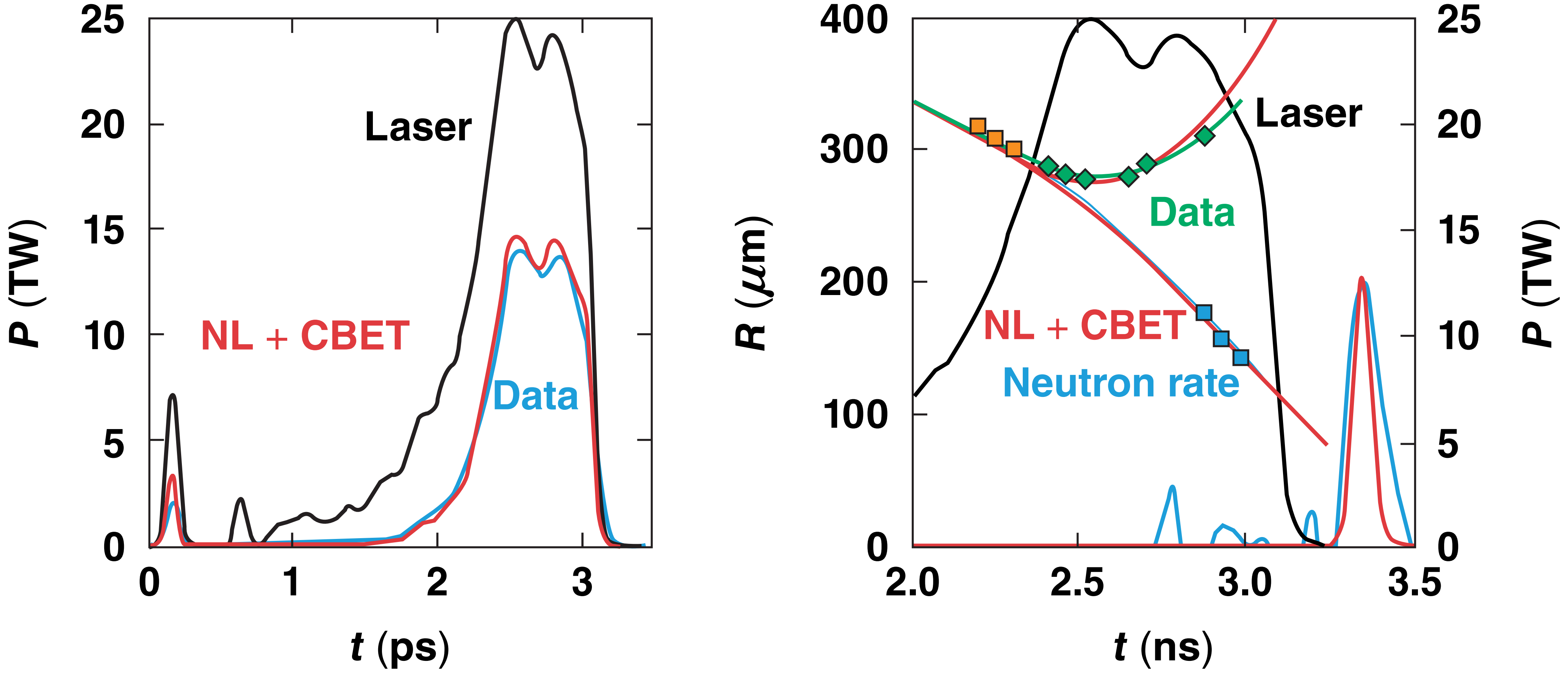
When DT reaches the absorption region, the maximum red-shifted wavelength jumps in the scattered-light spectrum



When DT reaches the absorption region, the velocity of the critical surface jumps, resulting in a jump in the maximum red-shifted wavelength in the scattered-light spectrum.

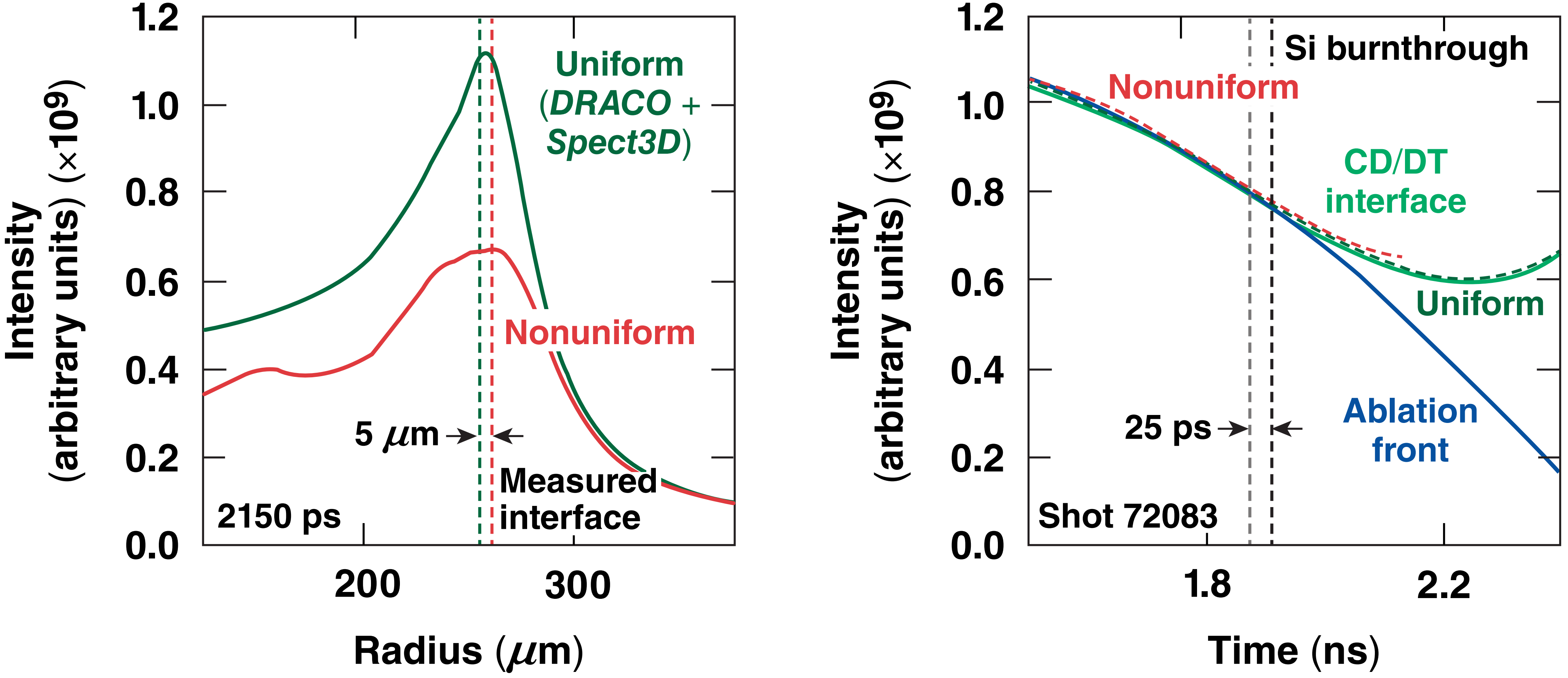
E24168

LILAC simulations that include NL and CBET reproduce both the absorption and the kinetic energy of the shell



The code accurately models the hydrodynamic coupling in cryogenic implosions.

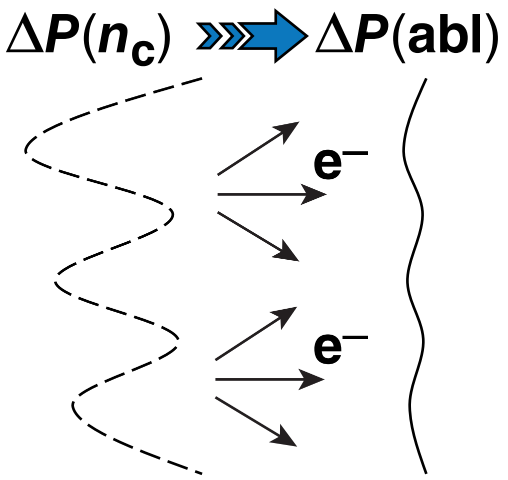
DRACO simulations of cryogenic implosions show that perturbations have a minimal impact on the burnthrough time measurement*



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

The growth of perturbations on the shell are governed by the mass ablation rate and the length of the conduction zone

Conduction zone smoothing



➡ Reduce the imprint

Ablation-velocity stabilization ($V_{\text{abl}} \propto \dot{m}_{\text{abl}}$)

➡ Reduce the imprint:*
- reduce the time needed to create the conduction zone
- reduce the amplitude of the modulations caused by the dynamic overpressure

➡ Reduce the Rayleigh–Taylor growth**

$$\gamma_{\text{RT}} = \sqrt{kg - k^2 V_{\text{abl}}\left(V_{\text{bl}} - 4V_{\text{abl}}\right)} - 2kV_{\text{abl}}$$

The conduction zone smooths the laser imprint while the mass ablation rate reduces the imprint and the growth of the Rayleigh–Taylor instability.

E24160

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*V. N. Goncharov *et al.*, Phys. Plasmas 7, 2062 (2000).

**R. Betti *et al.*, Phys. Plasmas 5, 1446 (1998).