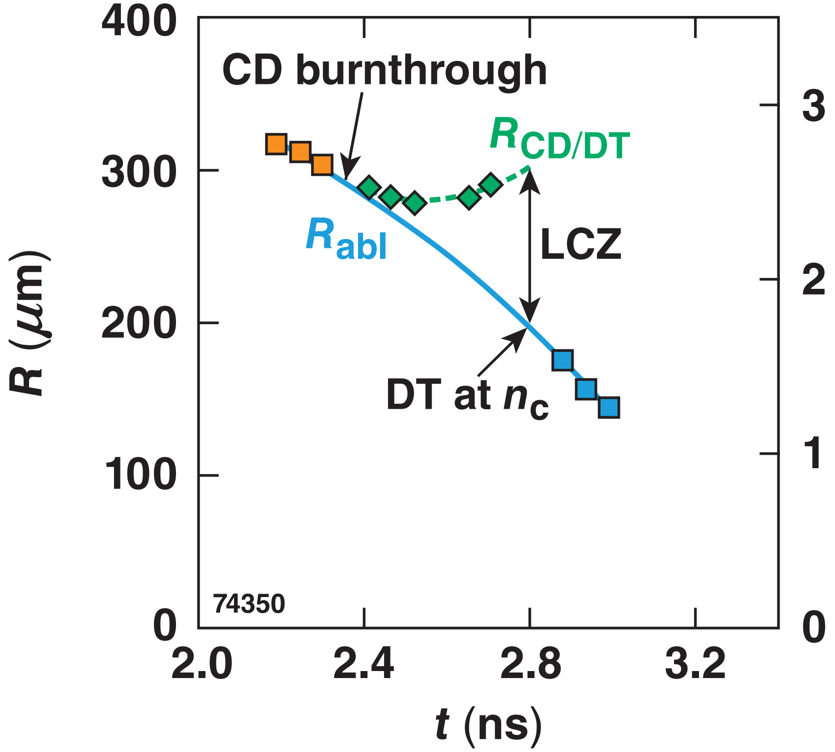
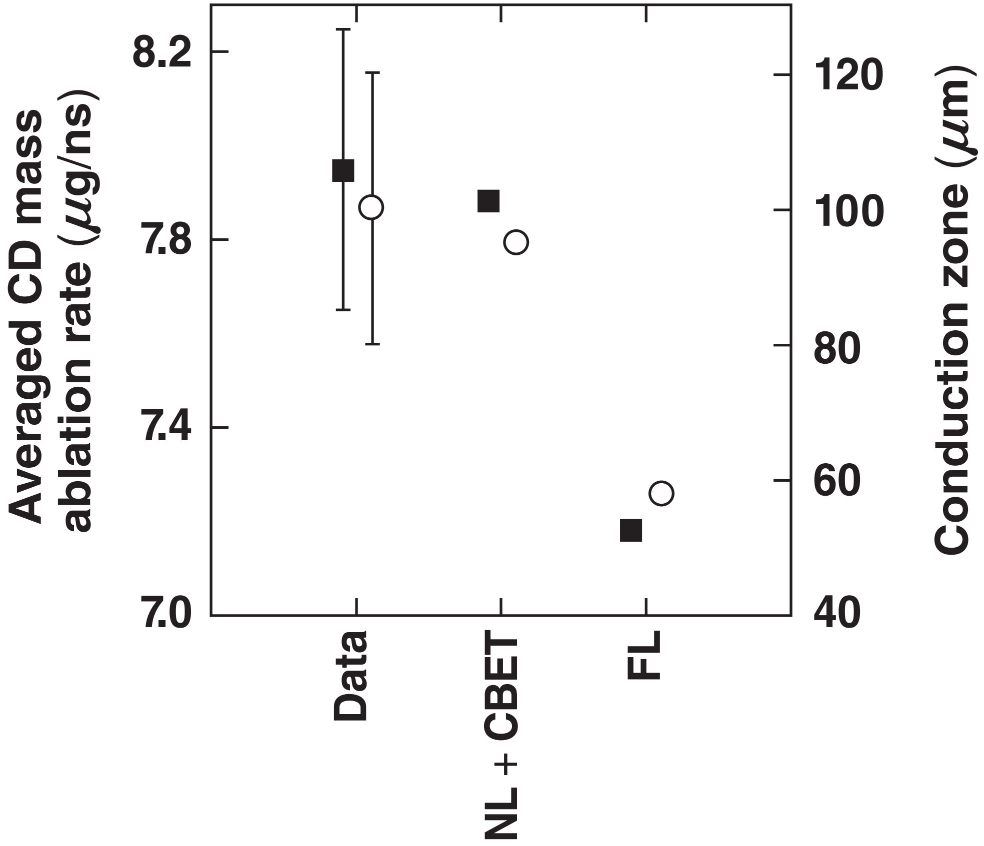
# Measurements of the Conduction-Zone Length and Mass Ablation Rate in Cryogenic Direct-Drive Implosions on OMEGA

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Summary

# NL* electron transport and CBET** models are required in 1-D *LILAC* simulations to reproduce the mass ablation rate and the length of the conduction zone in cryogenic implosions on OMEGA


- The averaged mass ablation rate of the outer CD layer in cryogenic implosions was measured by imaging the self-emission x rays emitted by the target
- The length of the conduction zone was determined from the combination of the measurement of the self-emission x-ray imaging and the scattered-light spectrum
- This experiment cannot be reproduced with a time-dependent flux limiter
- One-dimesional *LILAC* simulations, including NL electron transport and CBET, reproduce the experimental observables


* NL: Nonlocal
** CBET: Cross-beam energy transfer

# Collaborators

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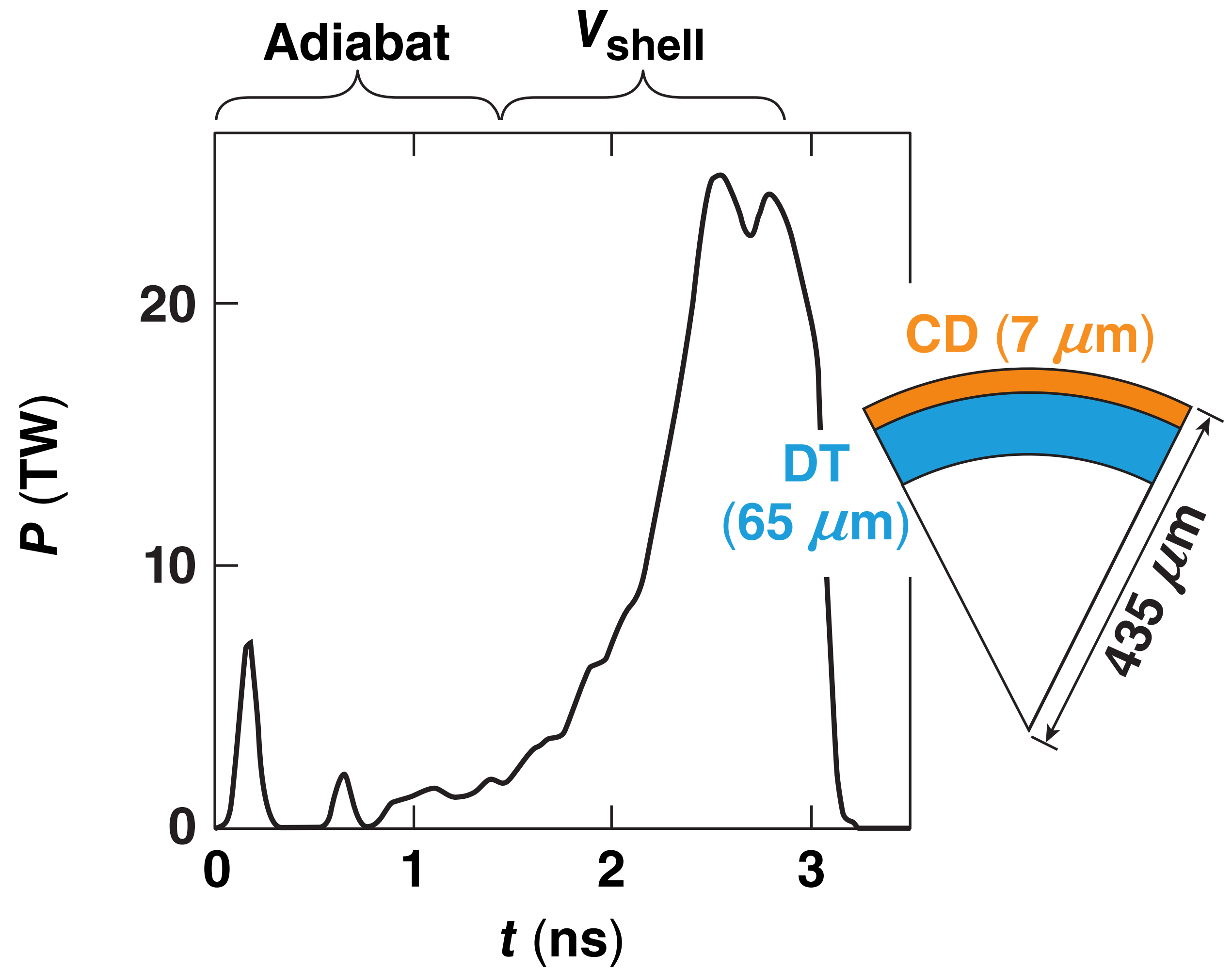
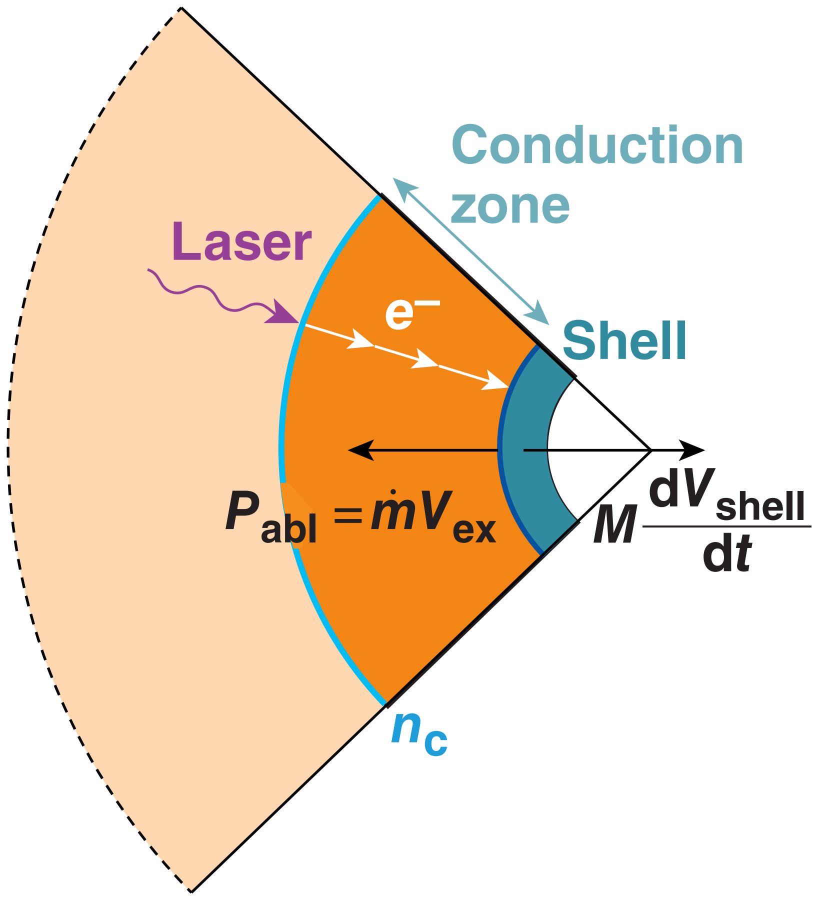
# Direct-drive inertial confinement fusion implosions are driven by laser energy absorbed near the critical density and transported by electrons to the ablation surface

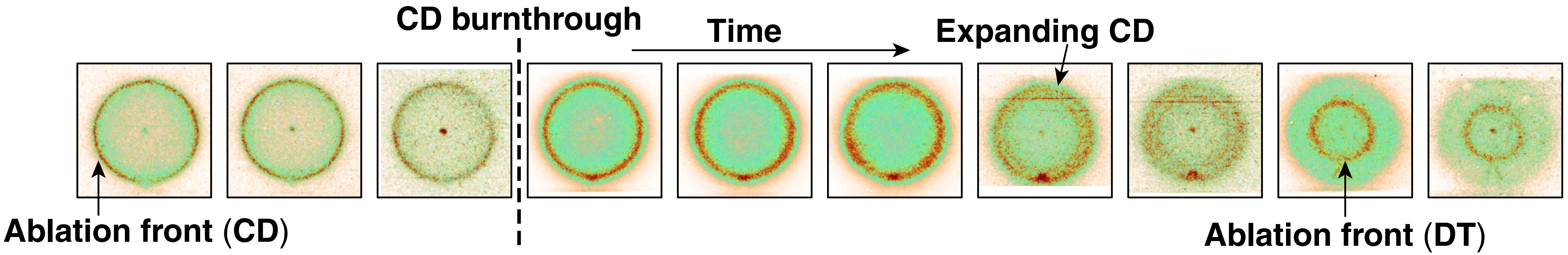


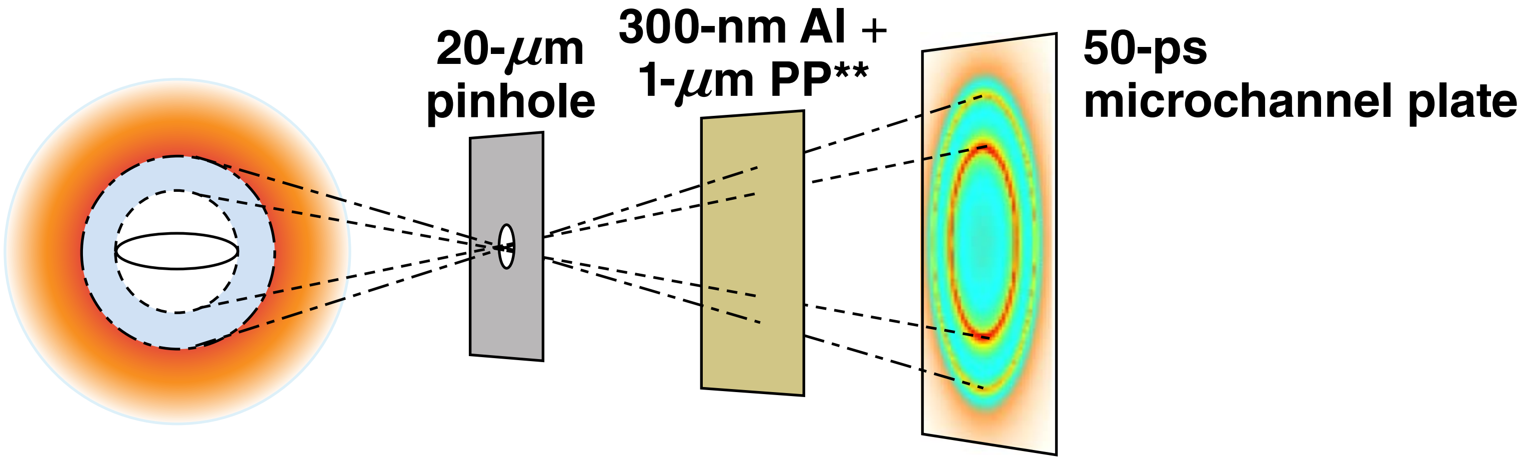

**Measurement of the mass ablation rate and the size of the conduction zone constrain the hydrodynamic coupling.**

E23040c

# In a cryogenic implosion, the averaged mass ablation rate of the CD outer layer was determined from the measurement of the time to burn through the CD



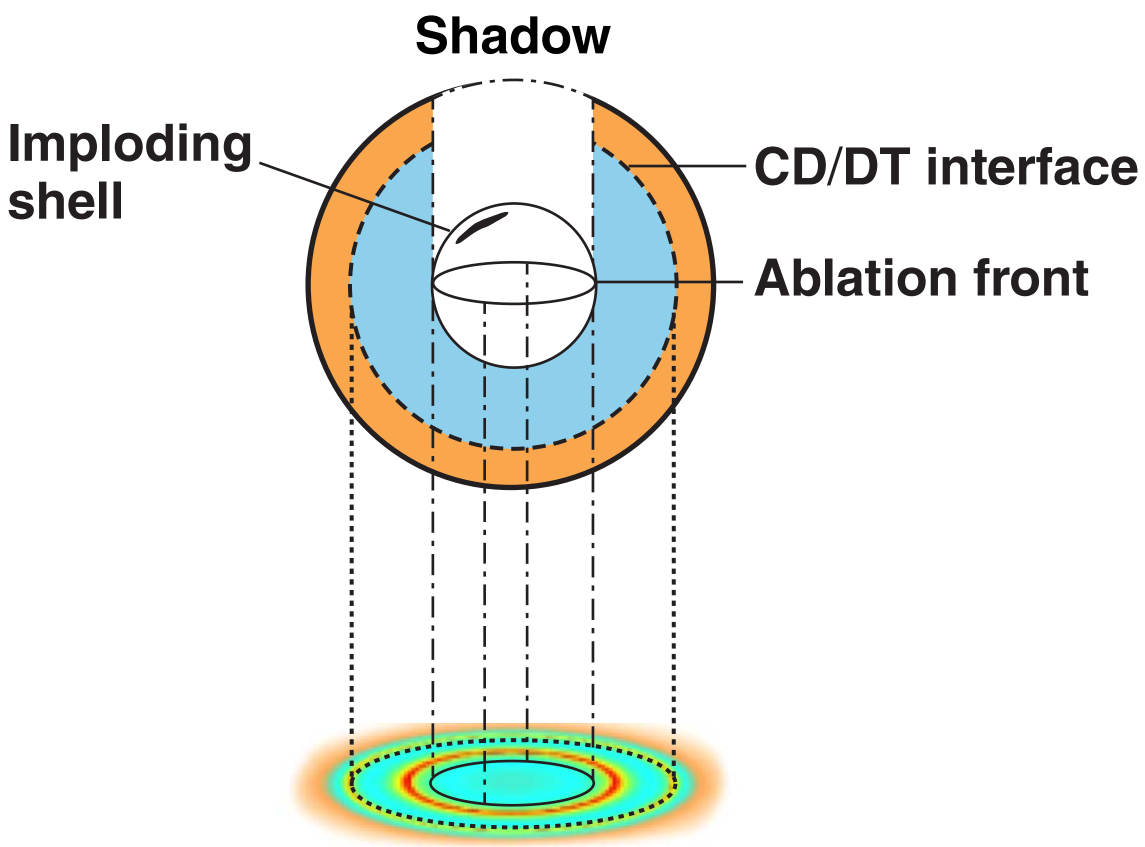

Self-emission x-ray imaging*

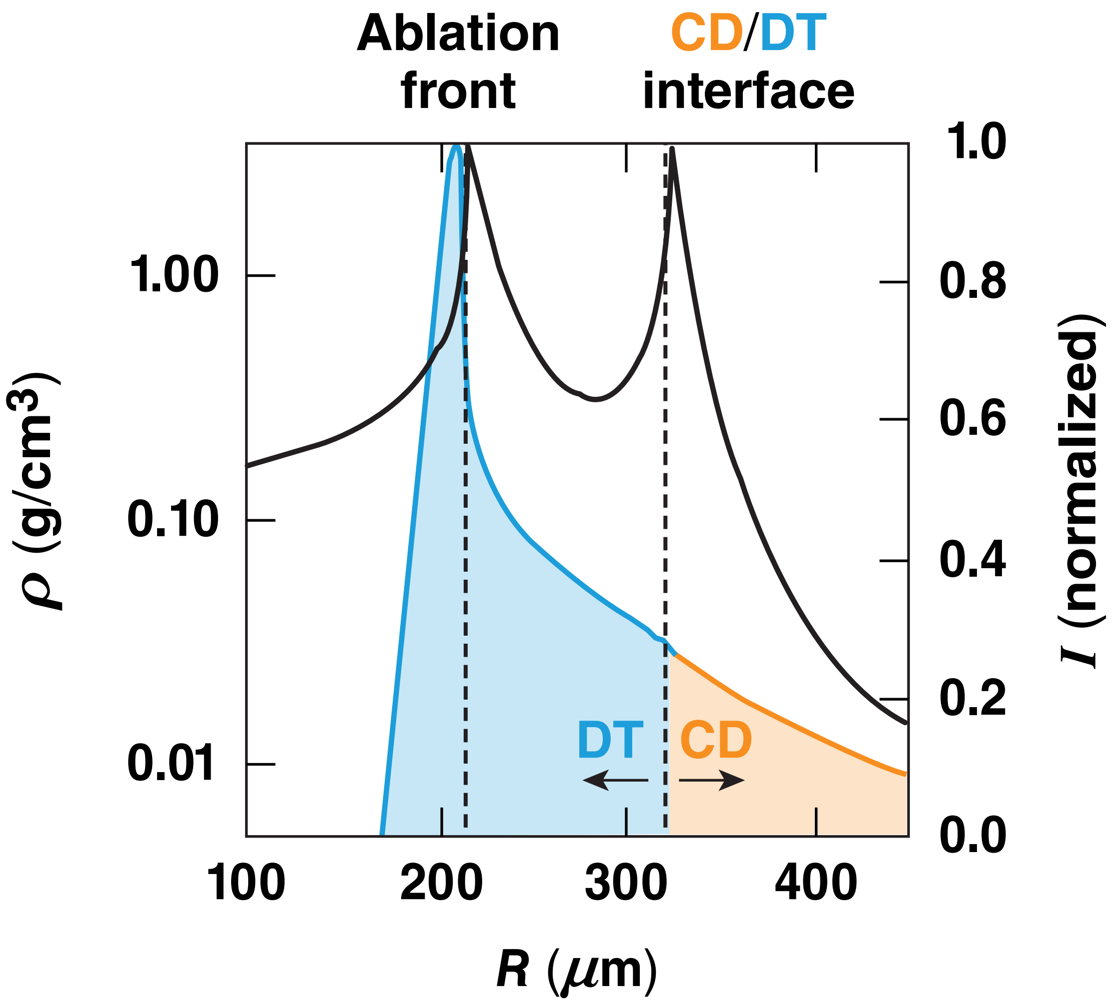



* D. T. Michel *et al*., Rev. Sci. Instrum. 83, 10E530 (2012).
** PP: polypropylene

E24161

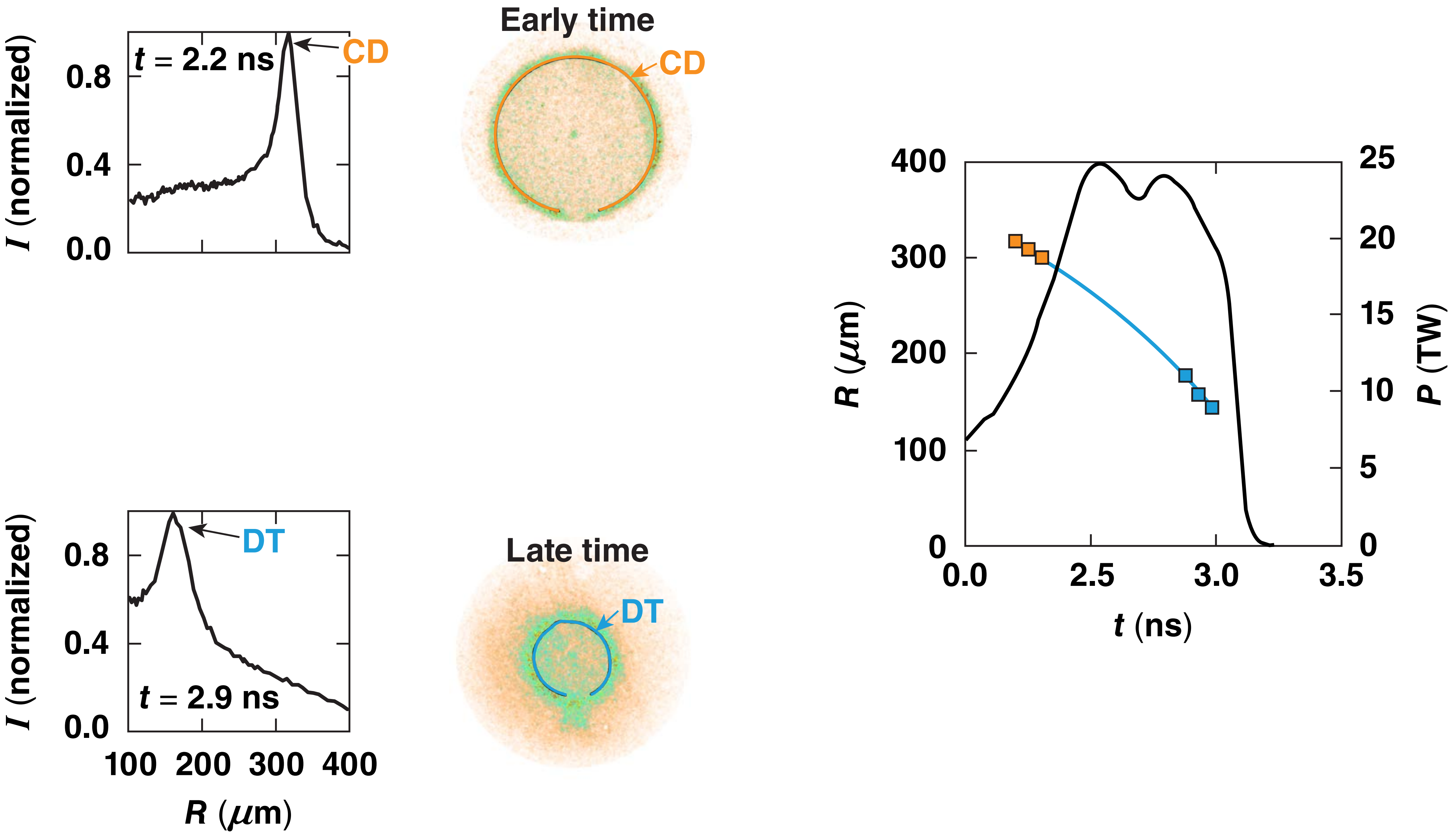
# After the laser burns through the CD layer, the inner peak corresponds to the ablation surface and the outer peak corresponds to the CD/DT interface



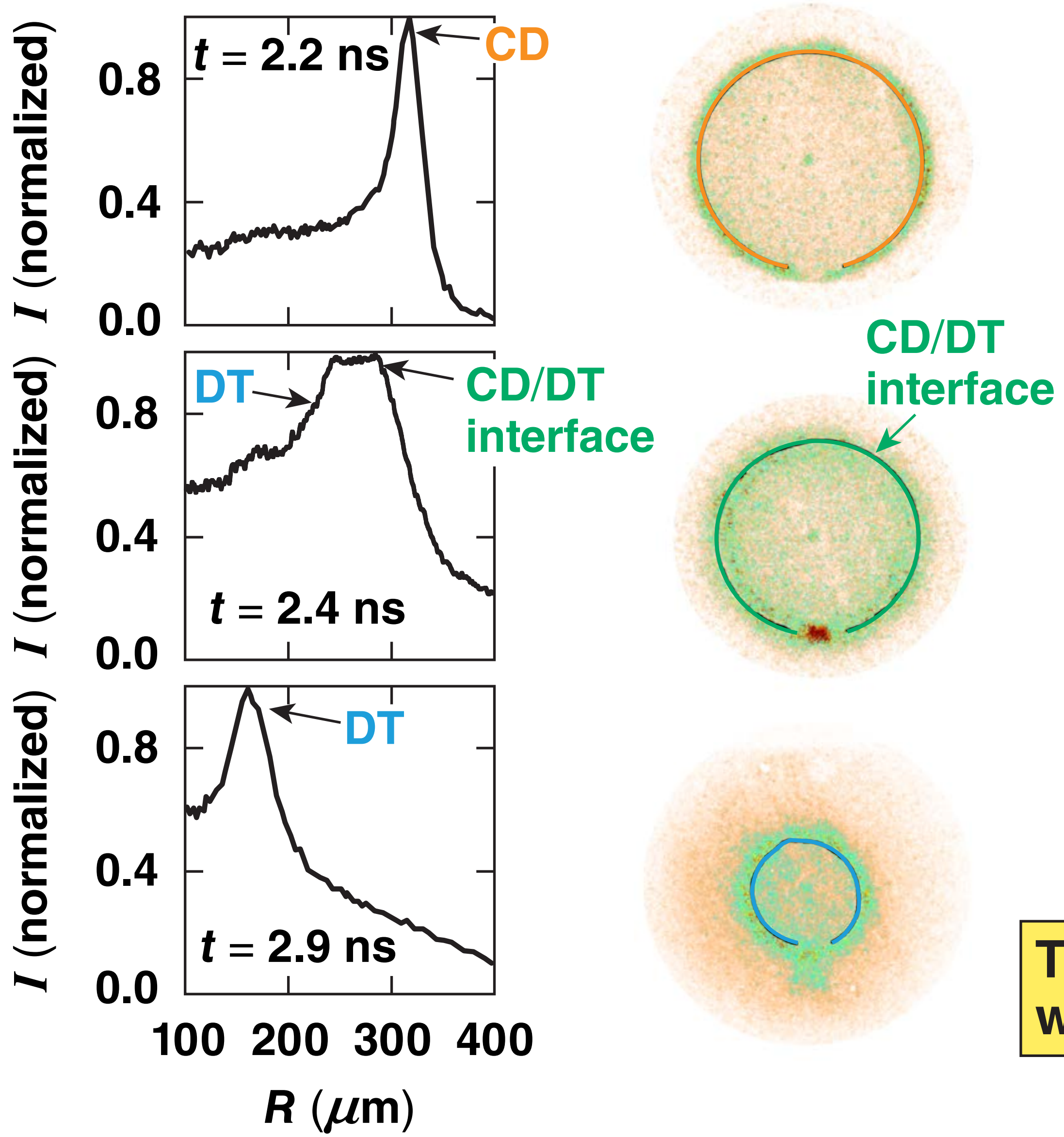

D. T. Michel *et al.*, Rev. Sci. Instrum. 83, 10E530 (2012).

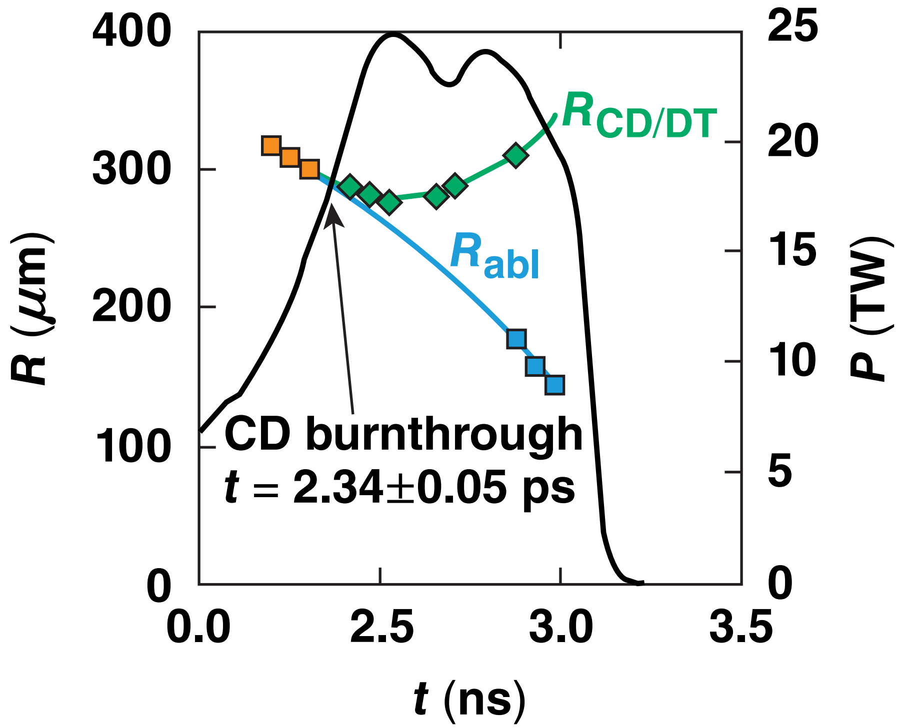
# The ablation-front trajectories were determined from a series of self-emission images




E23045d

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



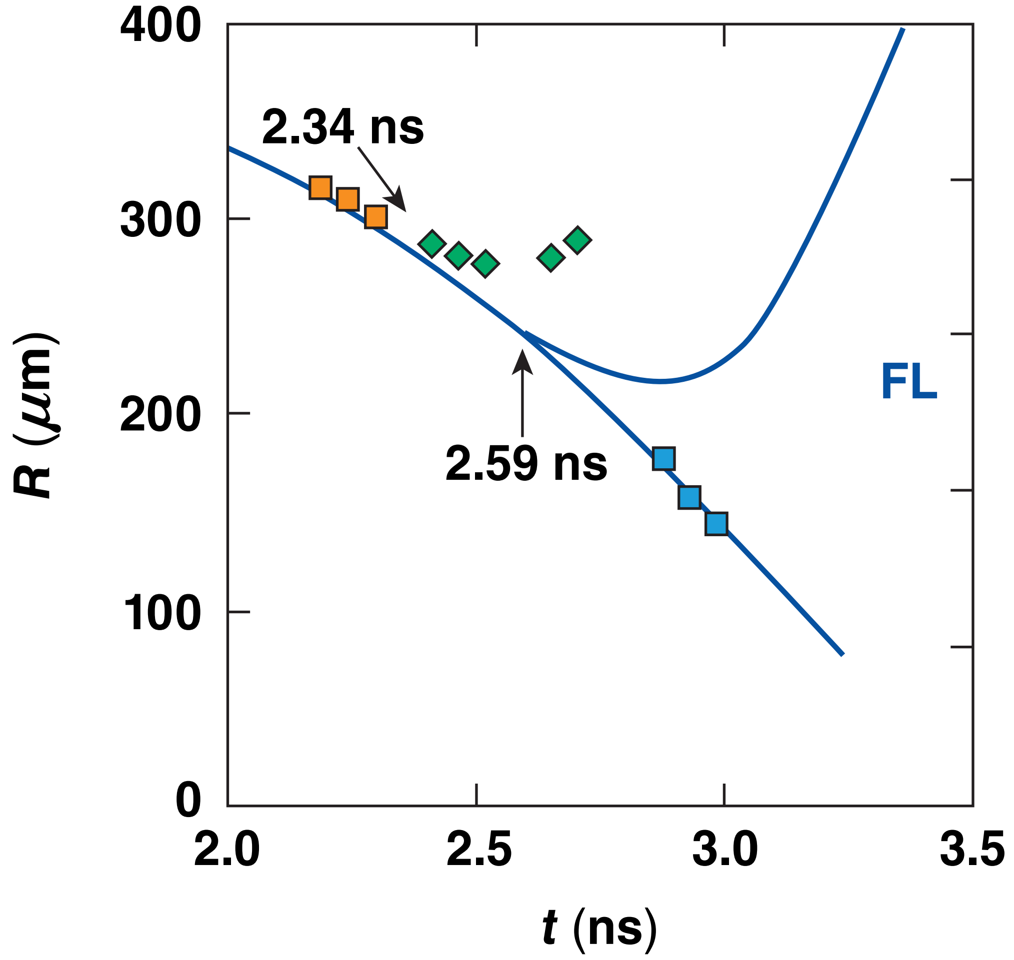



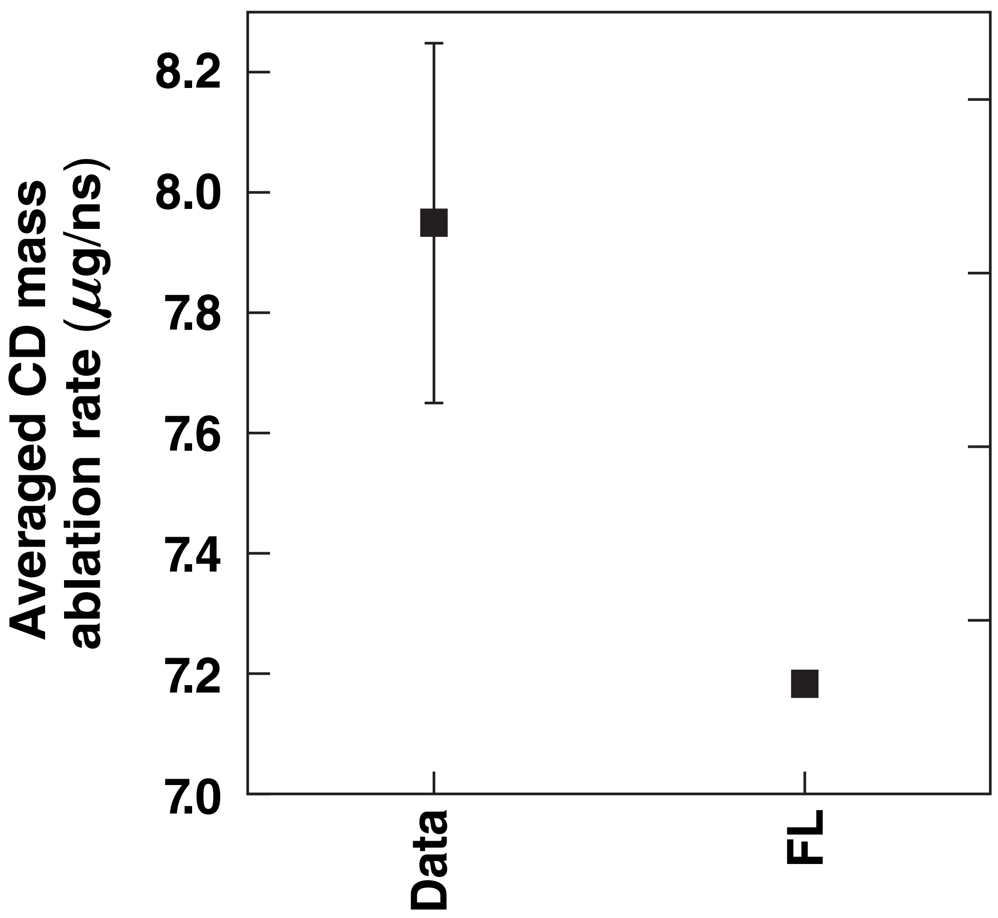

**The CD burnthrough corresponds to the time when the CD expands from the ablation surface.**

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

E23045e

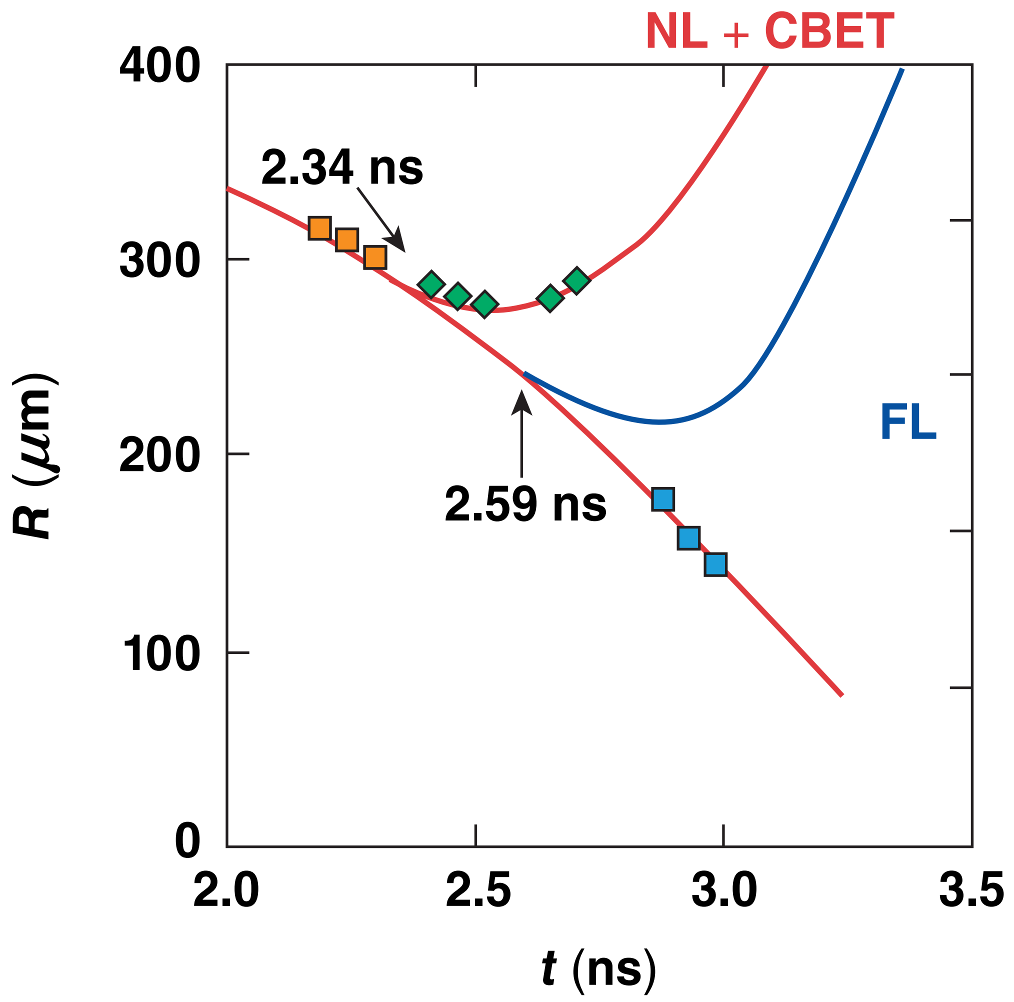
# When matching shell trajectory, time-dependent flux-limited (FL) simulations underestimate the averaged mass ablation rate of the CD by 10%

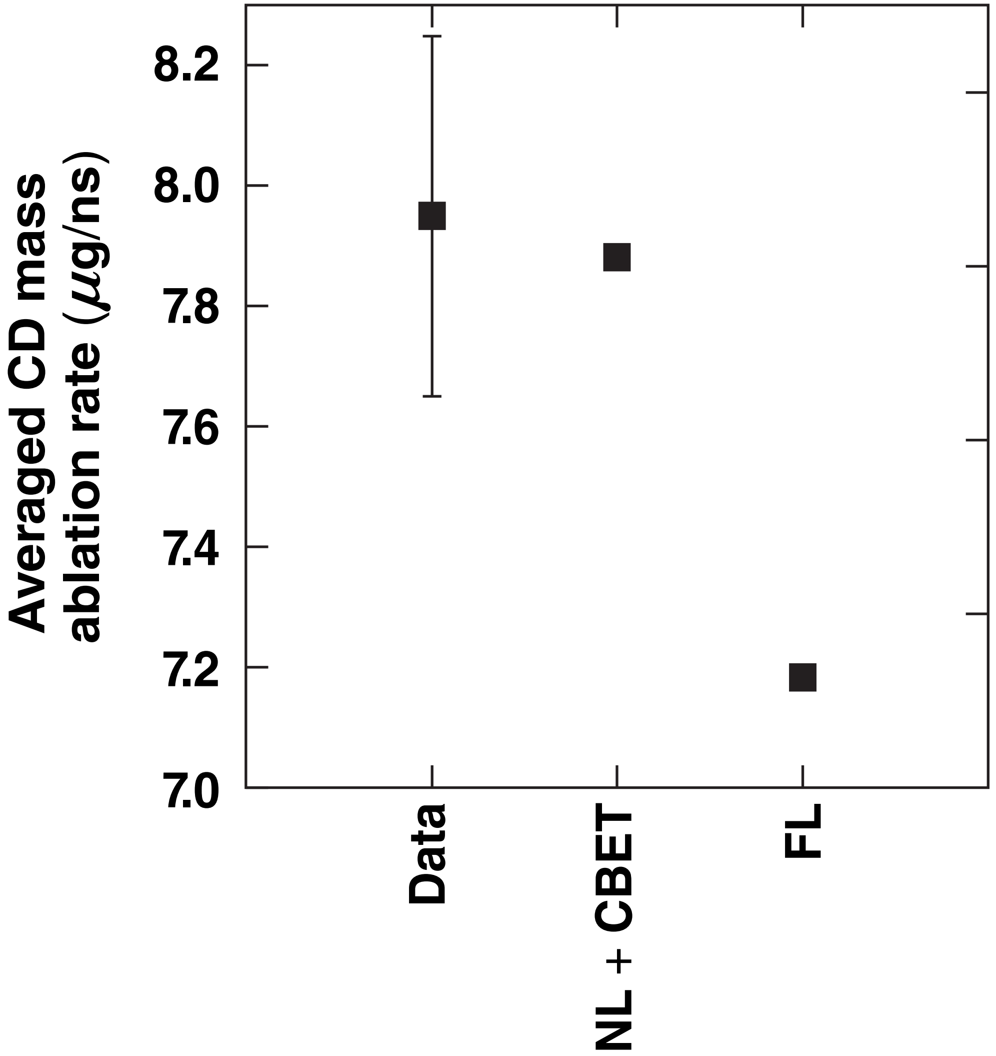



E24162

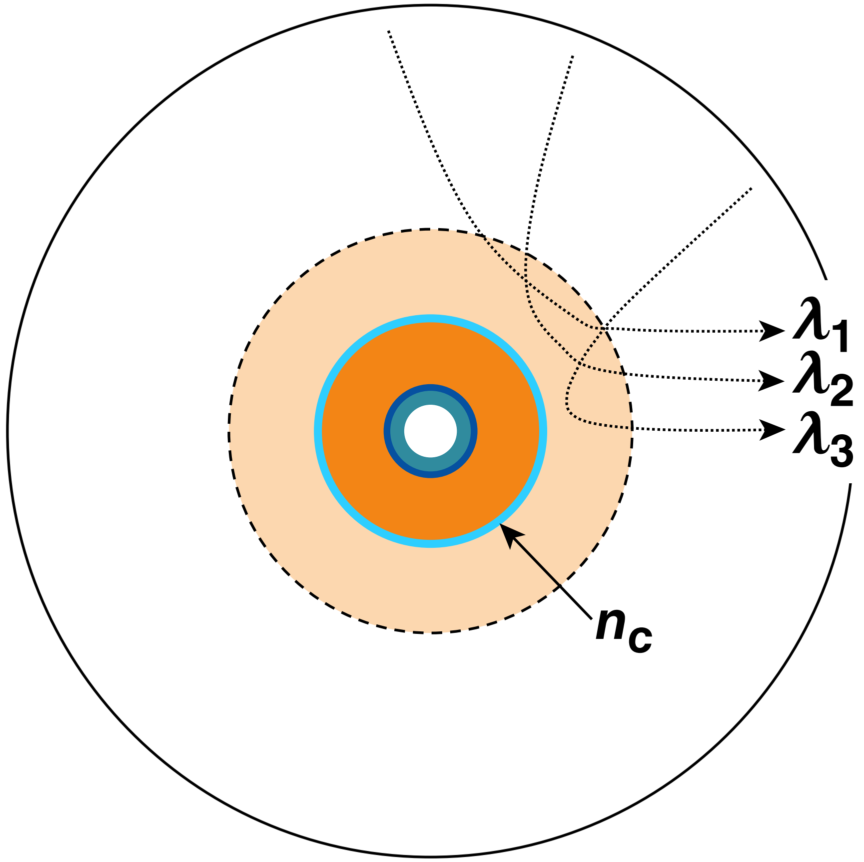
# The averaged mass ablation rate of the CD was reproduced when using NL and CBET models

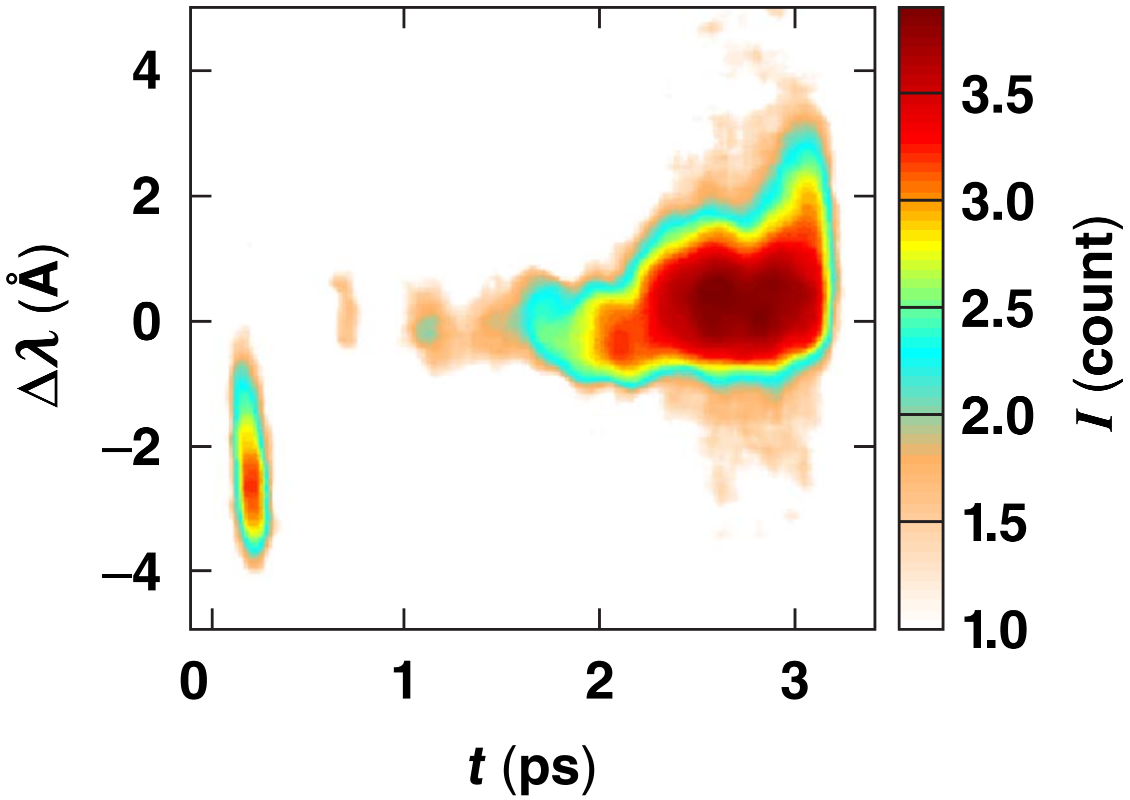



E24162a

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

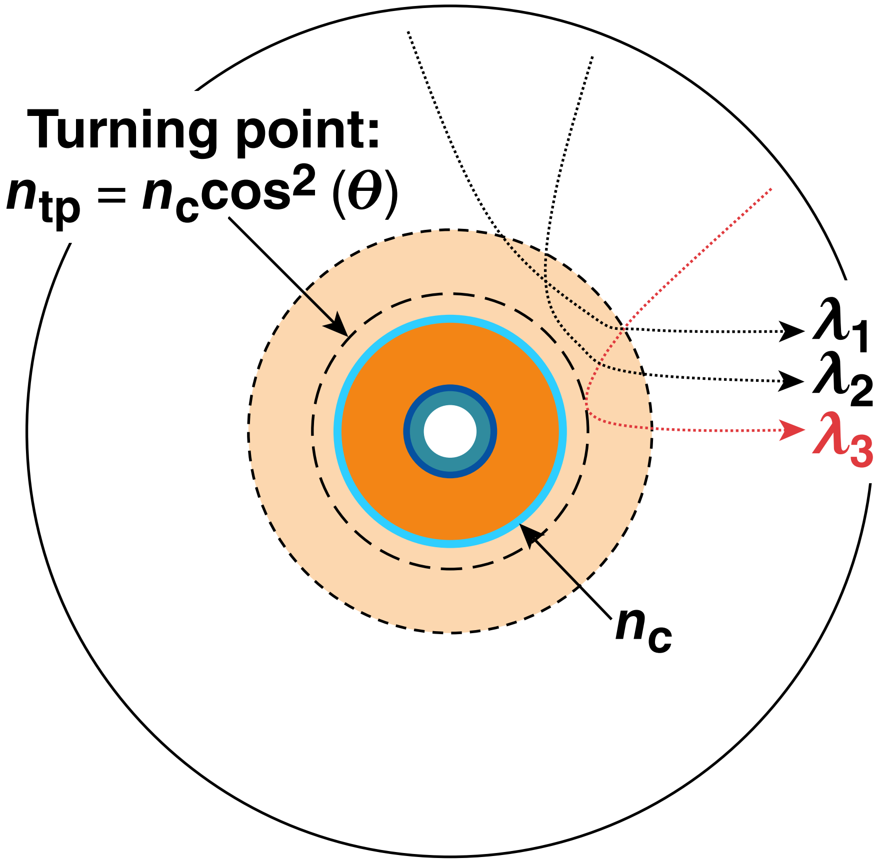


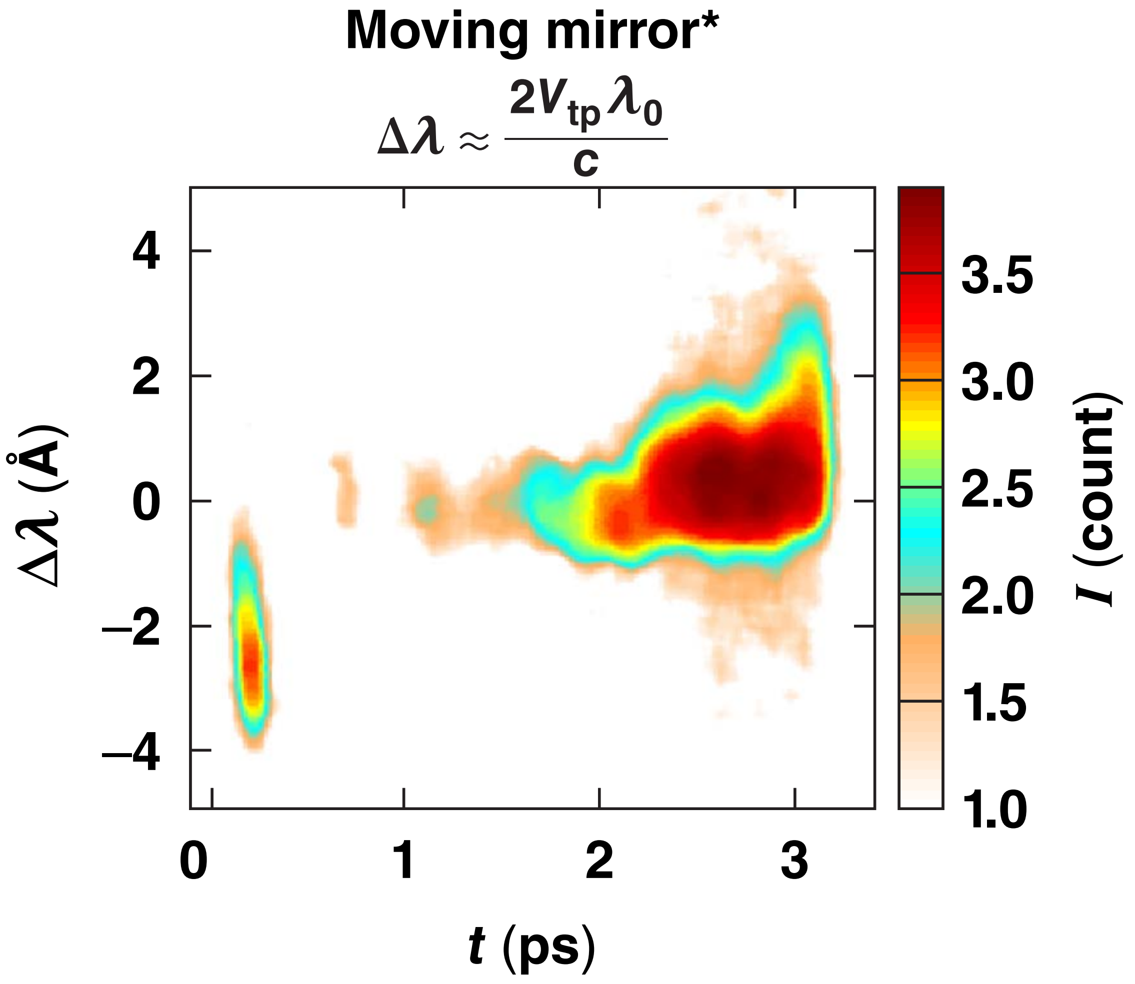




**The scattered-light diagnostic collects the light coming from every beam with various angles of incidence.**

E24163

# The more red-shifted light comes from the rays with a lower angle of incidence that penetrate closer to the ablation surface

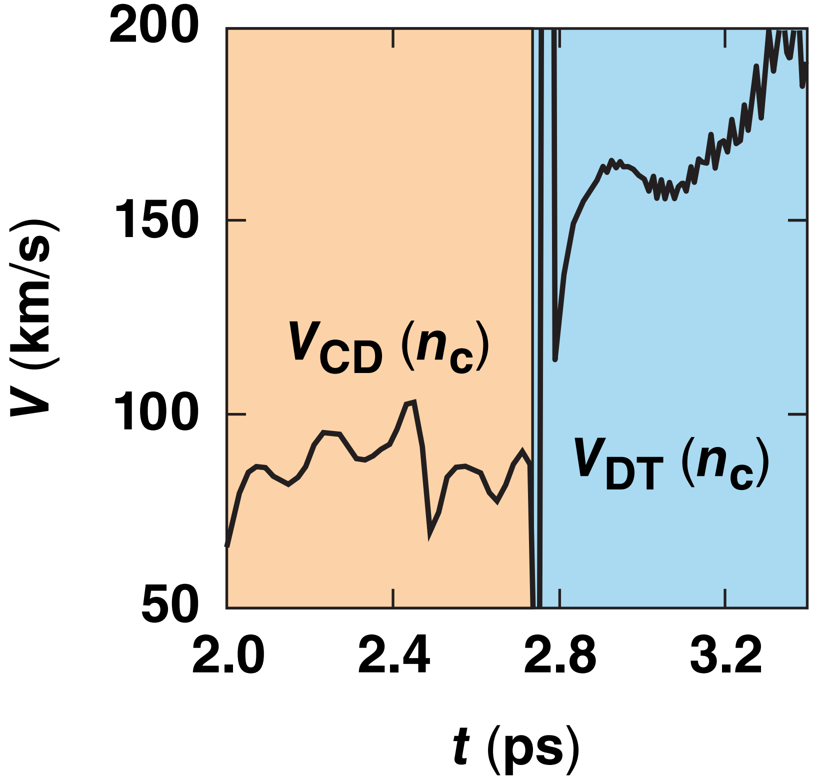


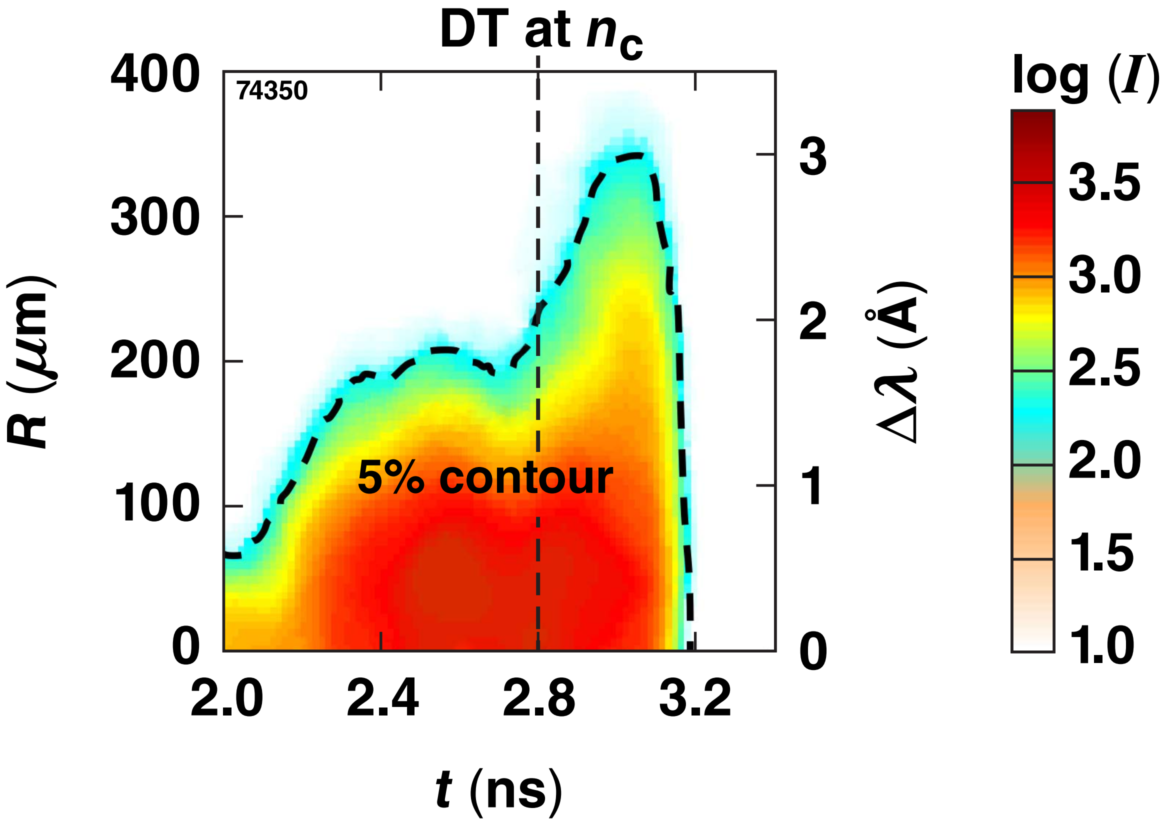




**The closer to the turning point is to the ablation surface, the larger the inward velocity of the reflecting surface and the larger the red shift.**

*Calculated for normal incident rays

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



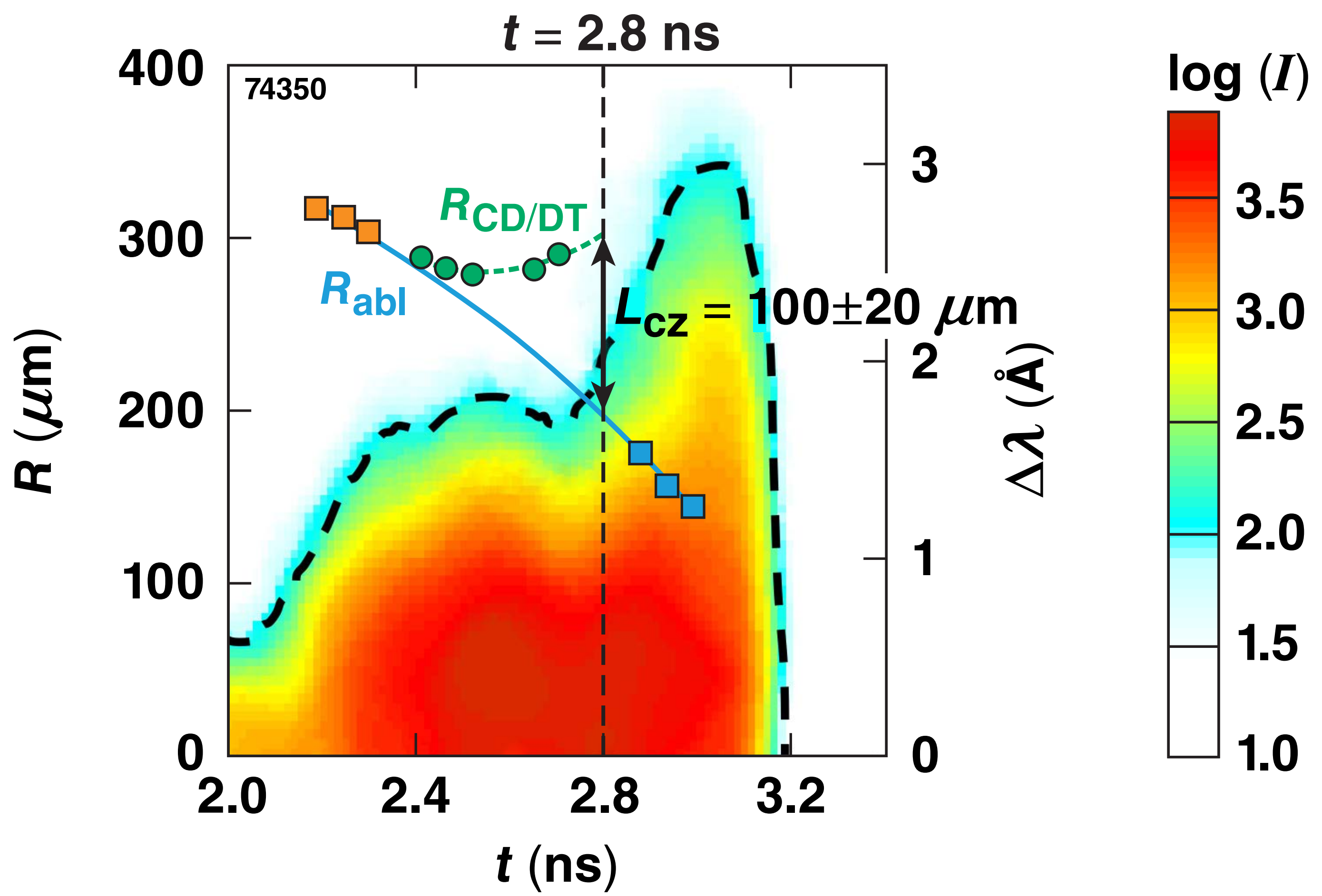




**This jump in a red-shifted light provides a measure of the time when the DT reaches the absorption region.**

E24164

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

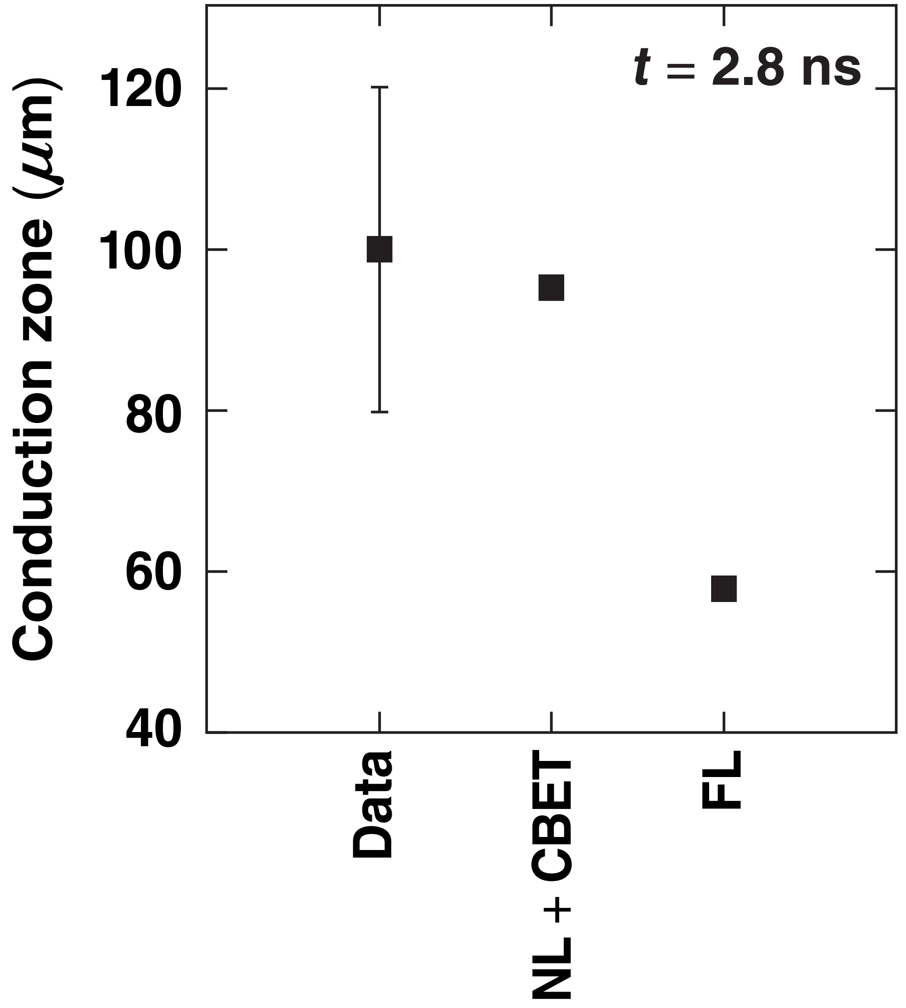
# The combination of the scattered-light spectrum and the self-emission x-ray imaging allows the length of the conduction zone to be determined*




**When the DT reaches the absorption region, the length of the conduction zone corresponds to the distance between the CD/DT interface and the ablation front.**

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

# The size of the conduction zone is well reproduced when using NL and CBET models




When matching shell trajectory, time-dependent flux-limited simulations underestimate the length of the conduction zone by nearly a factor of 2.

E24166

# NL electron transport and CBET models are required in 1-D *LILAC* simulations to reproduce the mass ablation rate and the length of the conduction zone in cryogenic implosions on OMEGA

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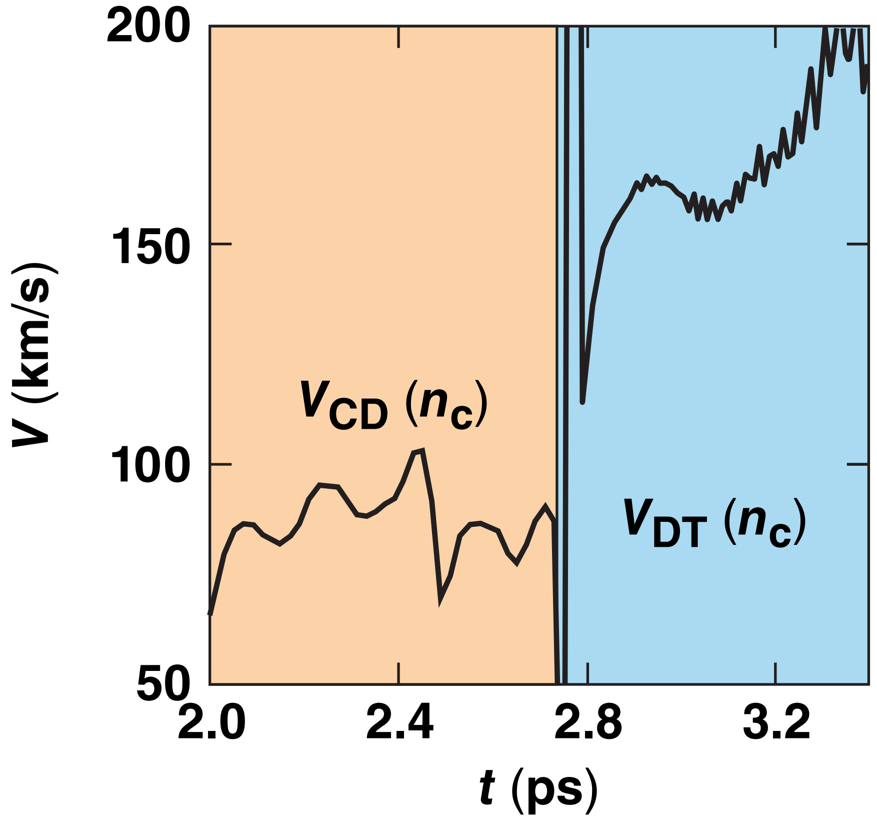
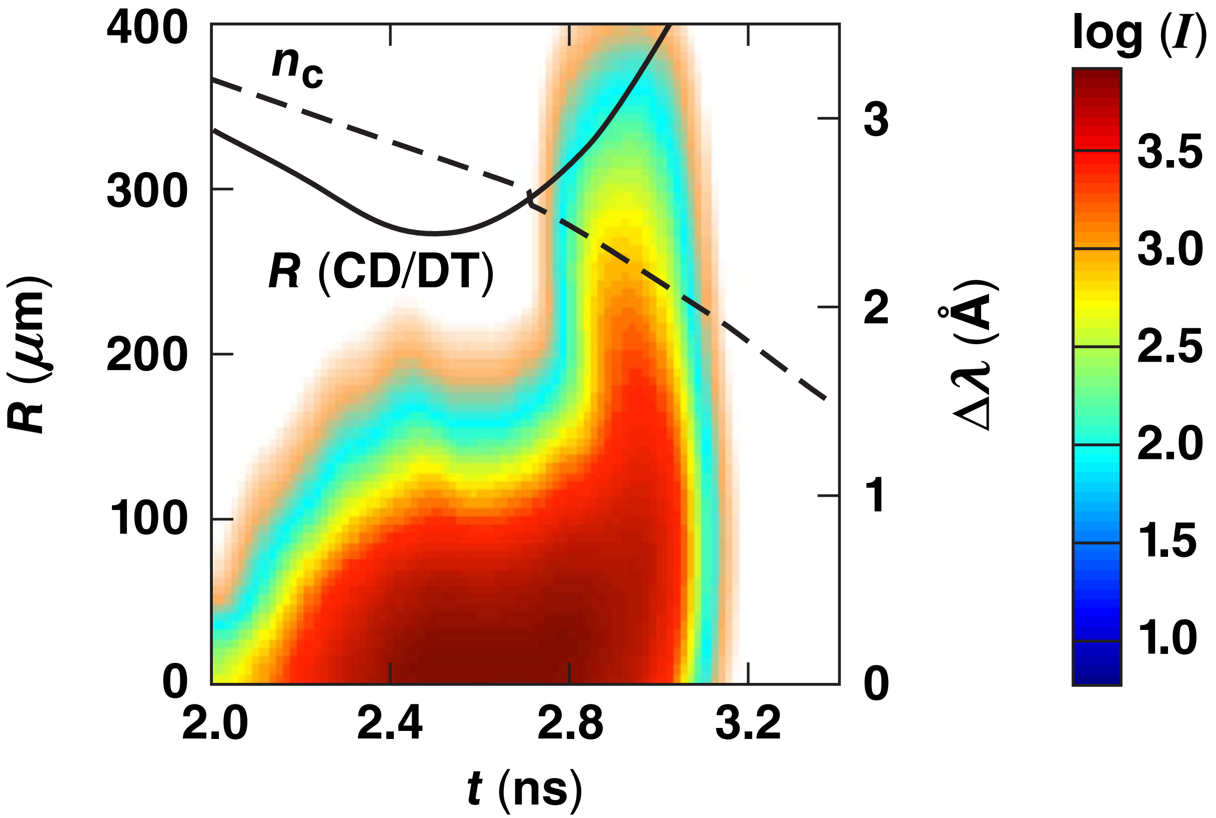
- The averaged mass ablation rate of the outer CD layer in cryogenic implosions was measured by imaging the self-emission x rays emitted by the target
- The length of the conduction zone was determined from the combination of the measurement of the self-emission x-ray imaging and the scattered-light spectrum
- This experiment cannot be reproduced with a time-dependent flux limiter
- One-dimesional *LILAC* simulations, including NL electron transport and CBET, reproduce the experimental observables

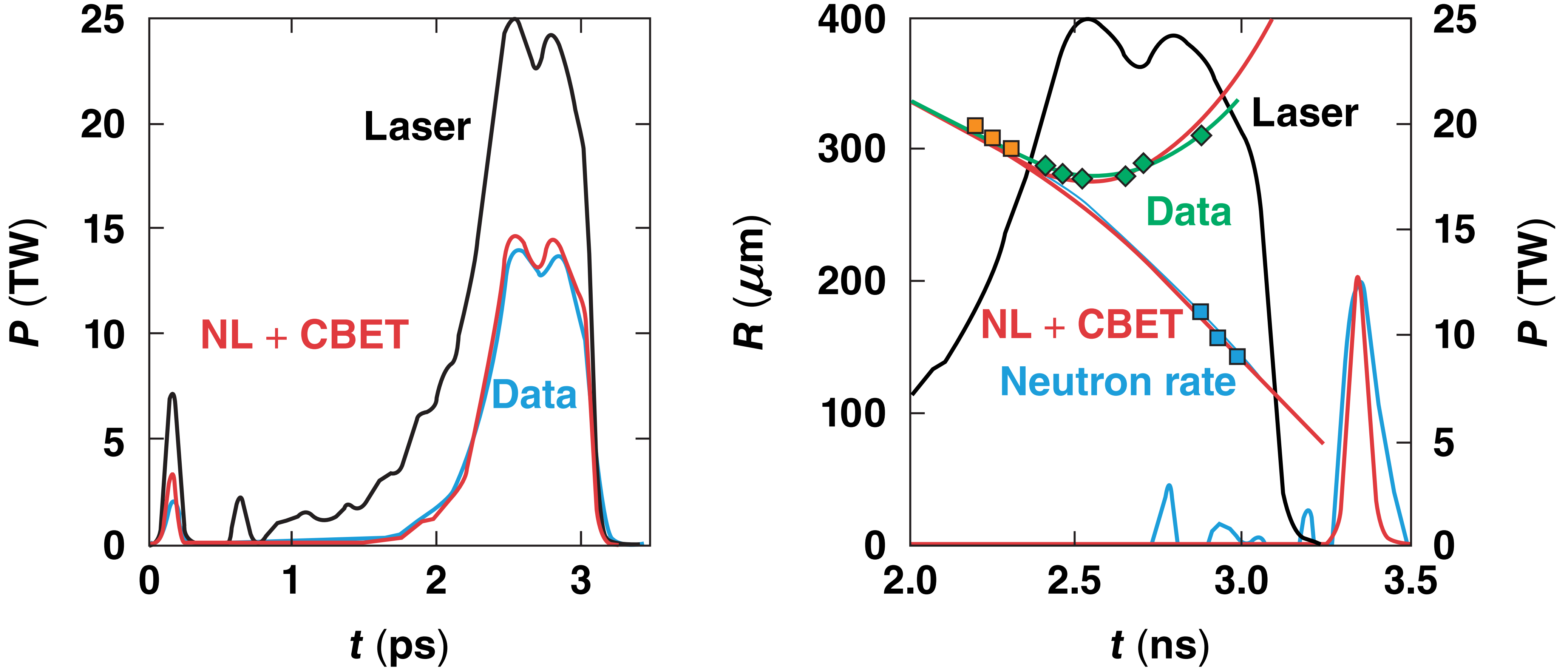
# When the DT reaches the absorption region, the maximum red-shifted wavelength jumps in the scattered light spectrum



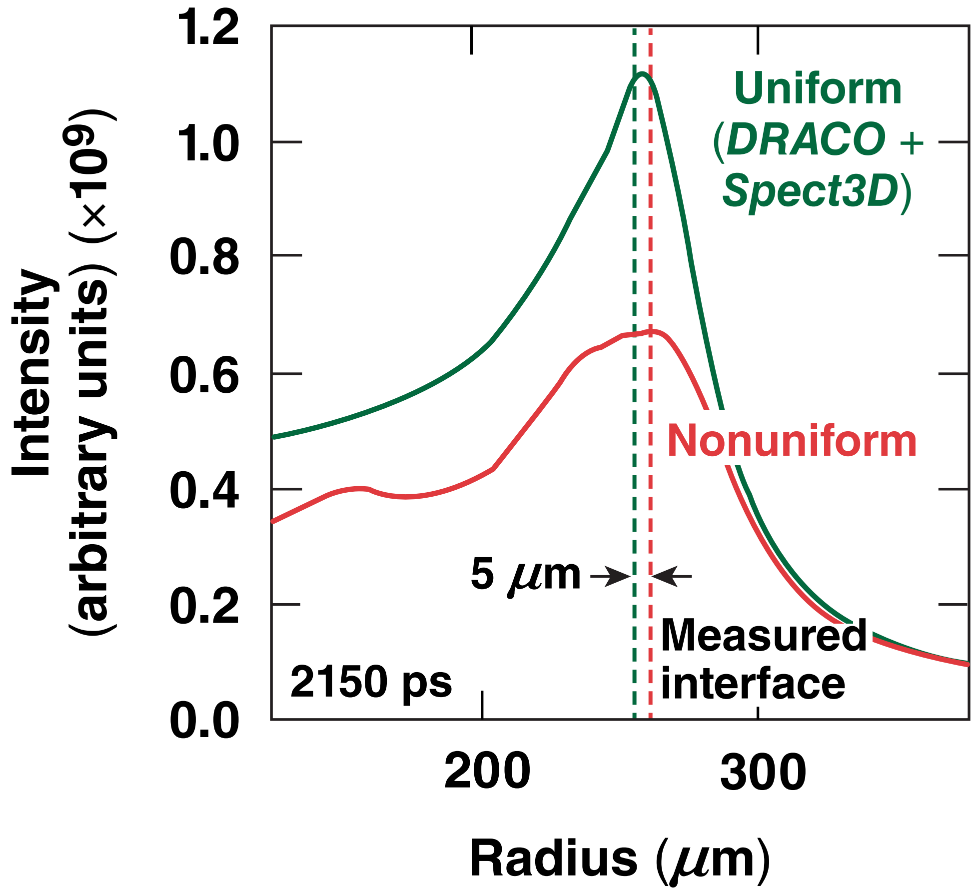

When the DT reaches the absorption region, the velocity of the critical surface jumps, resulting in a jump in the maximum red-shifted wavelength in the scattered-light spectrum.

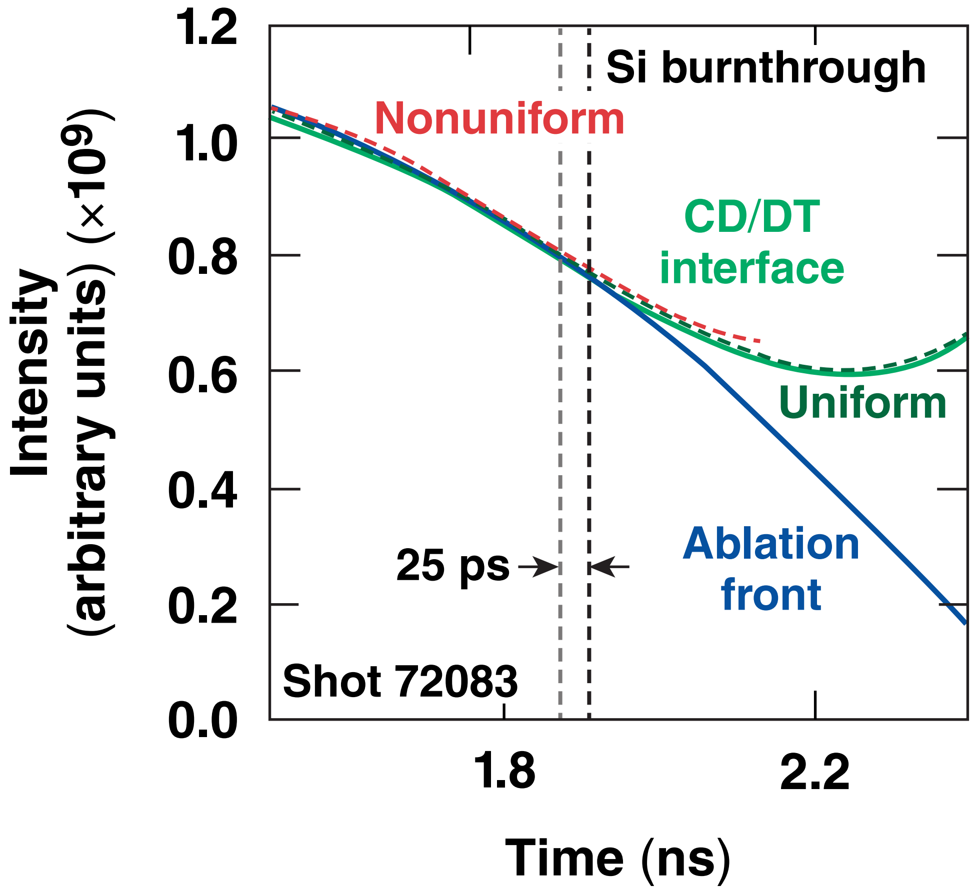
# *LILAC* simulations that include NL and CBET reproduce both the absorption and the kinetic energy of the shell




**The code accurately models the hydrodynamic coupling in cryogenic implosions.**

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



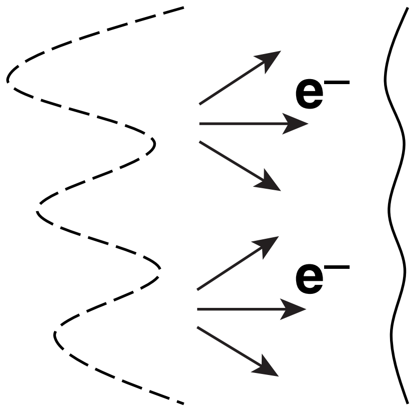

**DRACO* simulations were performed with and without perturbations seeded by target offset, DT ice roughness, and laser imprint up to mode 150.

E23157b

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

**Conduction zone smoothing**

$\Delta P(n_c) \Rightarrow \Delta P(\text{abl})$




➡ Reduce the imprint

**Ablation velocity stabilization ($V_{abl} \propto \dot{m}_a$)**

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

➡ Reduce the Rayleigh–Taylor growth**

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

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

* V. N. Goncharov *et al.*, Phys. Plasmas 7, 2062 (2000).
** R. Betti *et al.*, Phys. Plasmas 5, 1446 (1998).

E24160