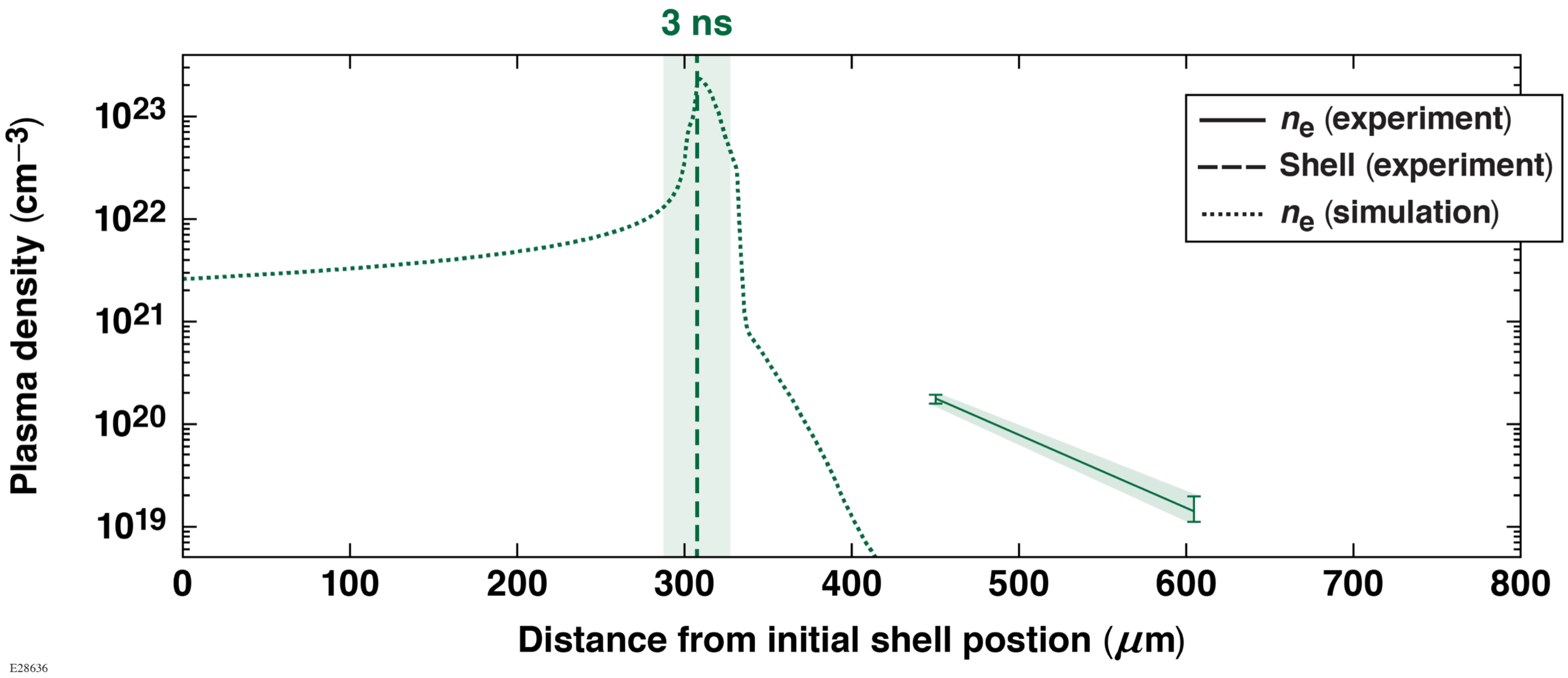
Density Measurements of the Inner Shell Release



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Summary

Measurements of the low-density plasma ahead of a driven CH shell indicate that the shell profile is relaxed before the shock breaks out of the undriven side

- A platform was developed to study the time history of the low-density plasma release ahead of a driven shell
- Streaked x-ray radiography was used to track the driven shell and an optical probe to track the underdense plasma ahead of the shell
- Hydrodynamic simulations are shown to agree with the experimental measurements when a gradient is added to the back side of the CH shell

D. Haberberger *et al.*, "Density Measurements of the Inner Shell Release," submitted to Physical Review Letters.

Collaborators

A. Shvydky, V. N. Goncharov, D. Cao, J. Carroll-Nellenback, S. X. Hu, S. T. Ivancic,
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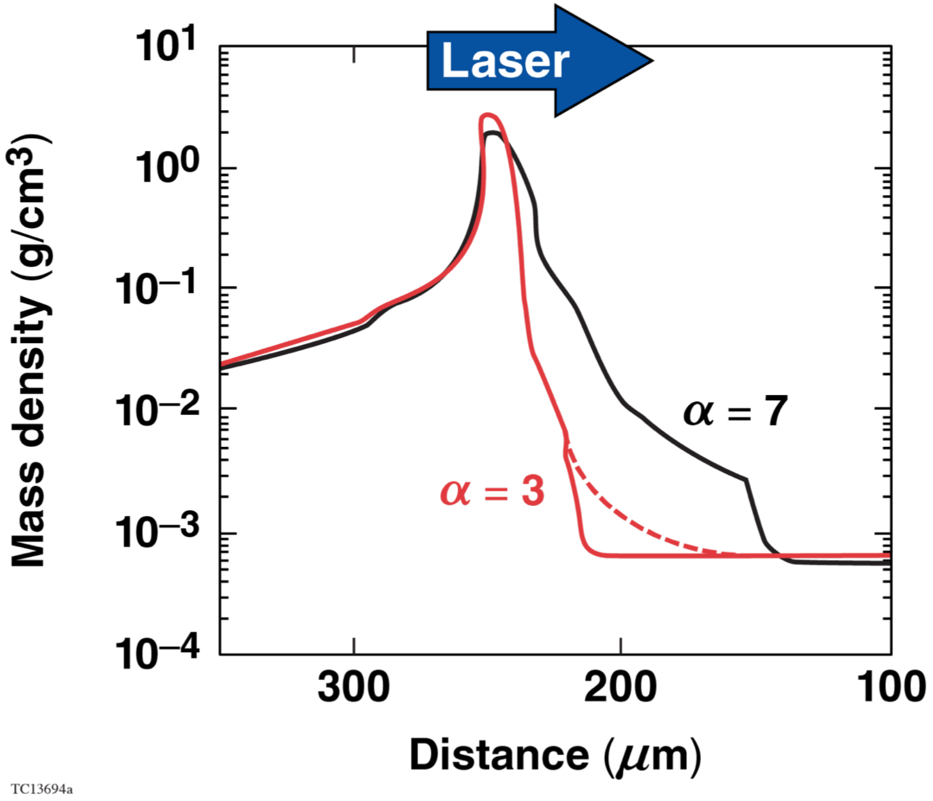
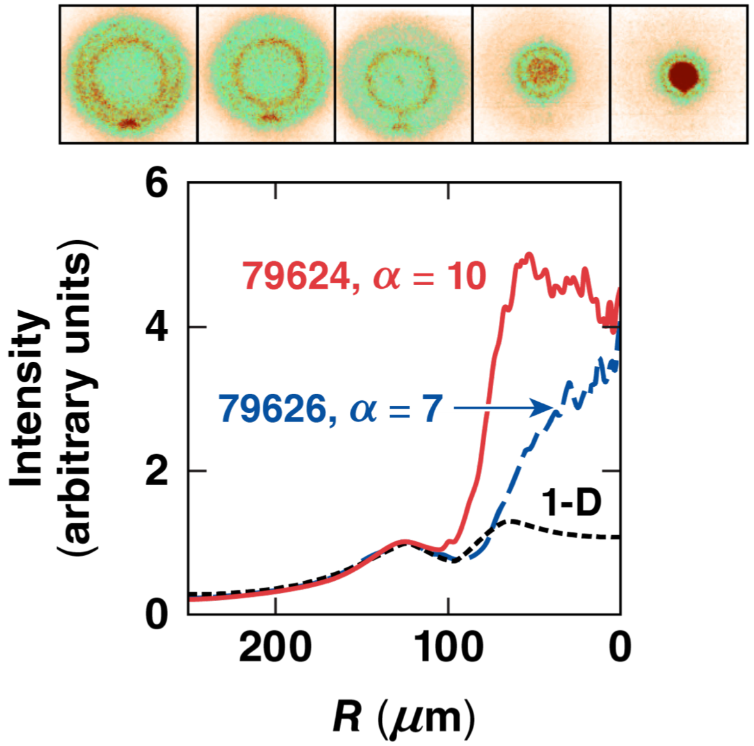
The low-density plasma ahead of the inner shell can have a detrimental effect on ICF target performance





Density release inconsistent with the design adiabat can be the culprit in early hot-spot emission and has not been experimentally measured.

ICF: inertial confinement fusion

A platform was developed on OMEGA EP to study the position of a driven shell, the location of the low-density plasma, and its profile

Two drive beams

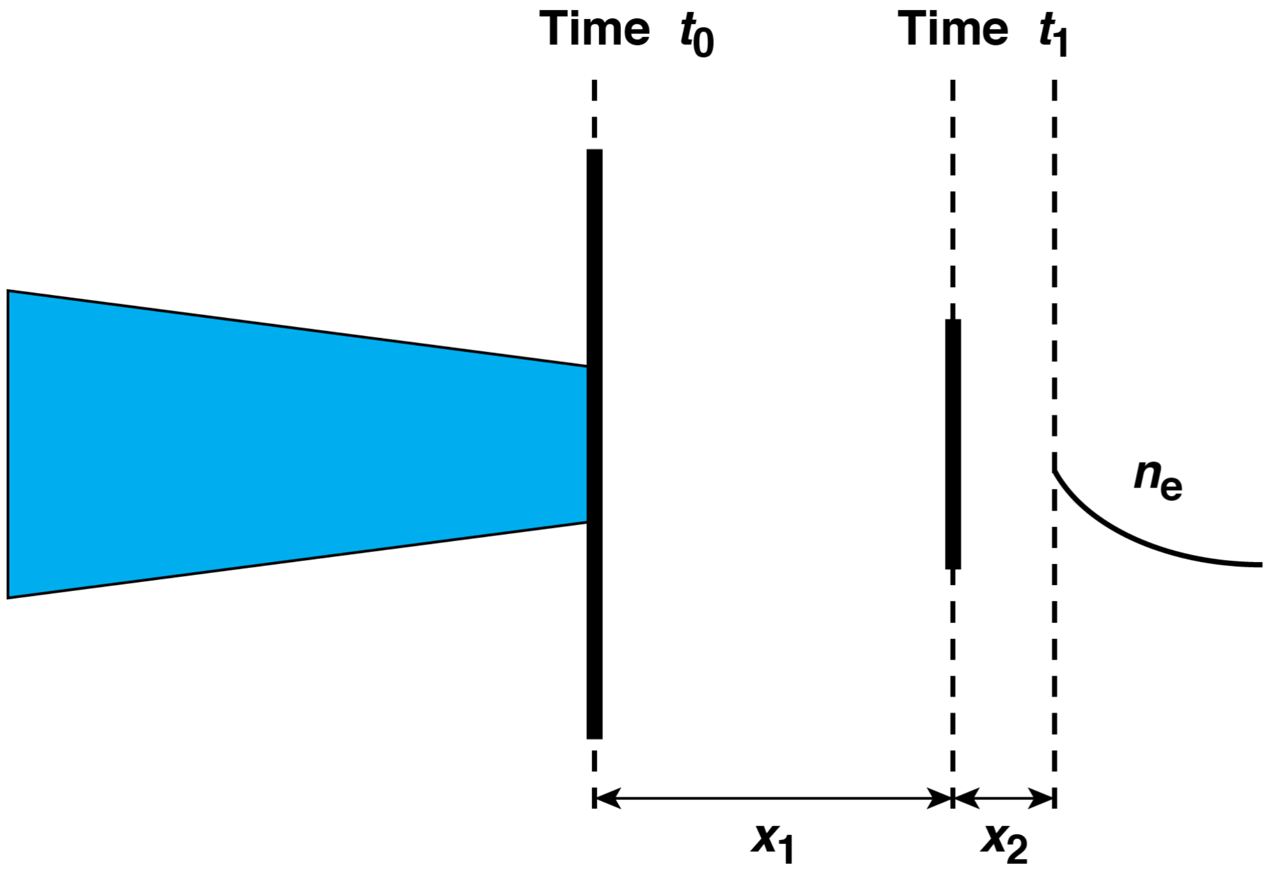
λ = 351 nm

750-μm DPP*

E_{total} = 6 kJ

Δt = 5 ns

$I_{overlapped} = 3 \times 10^{14}$ W/cm^2



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*DPP: distributed phase plate

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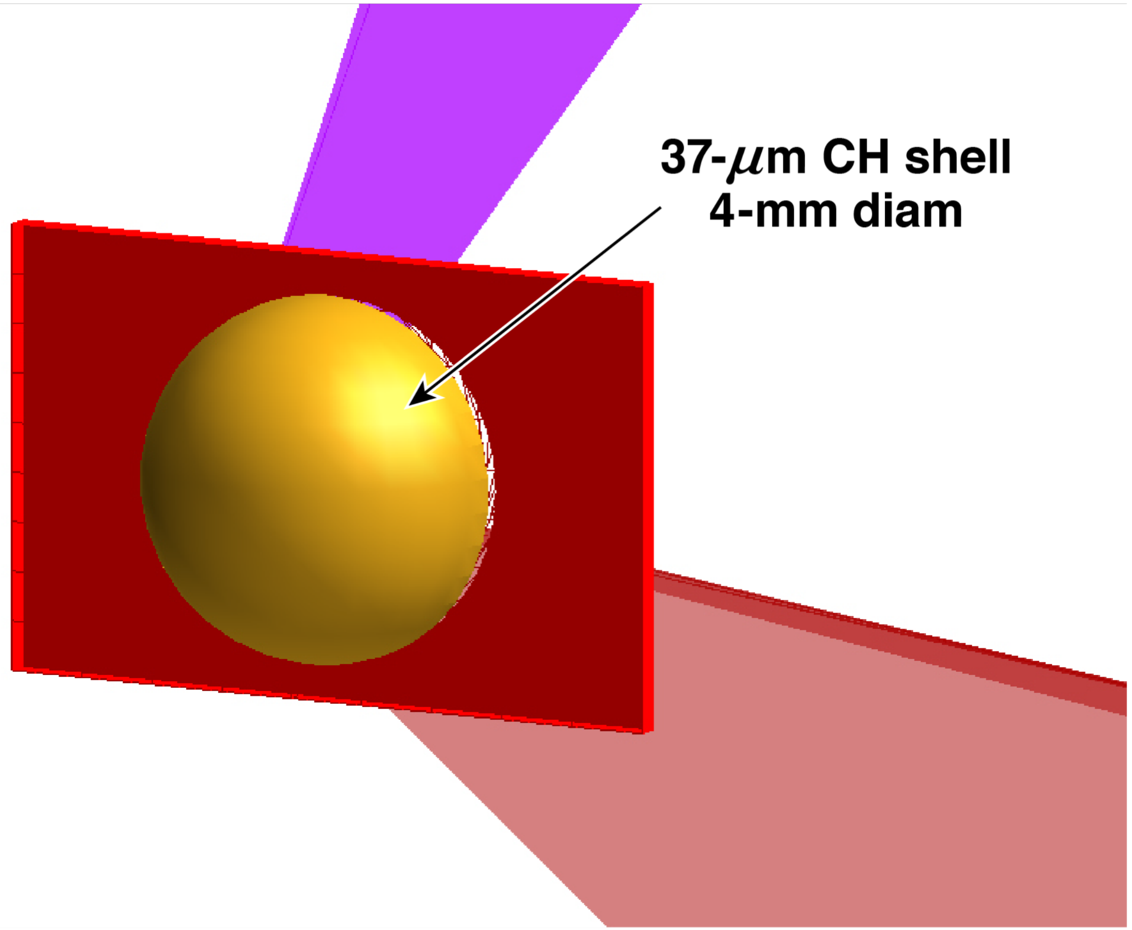

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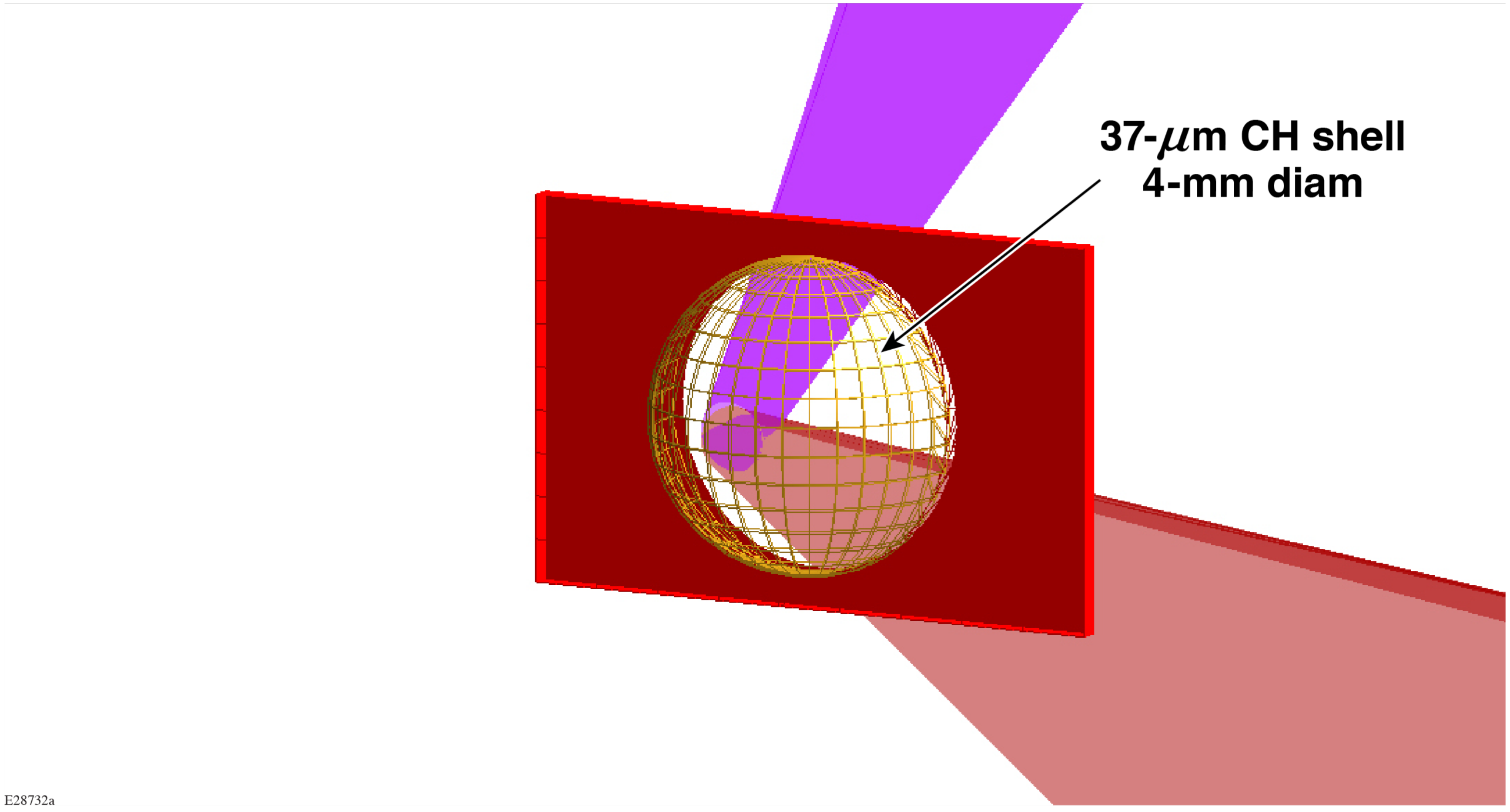
A platform was developed on OMEGA EP to study the position of a driven shell, the location of the low-density plasma, and its profile



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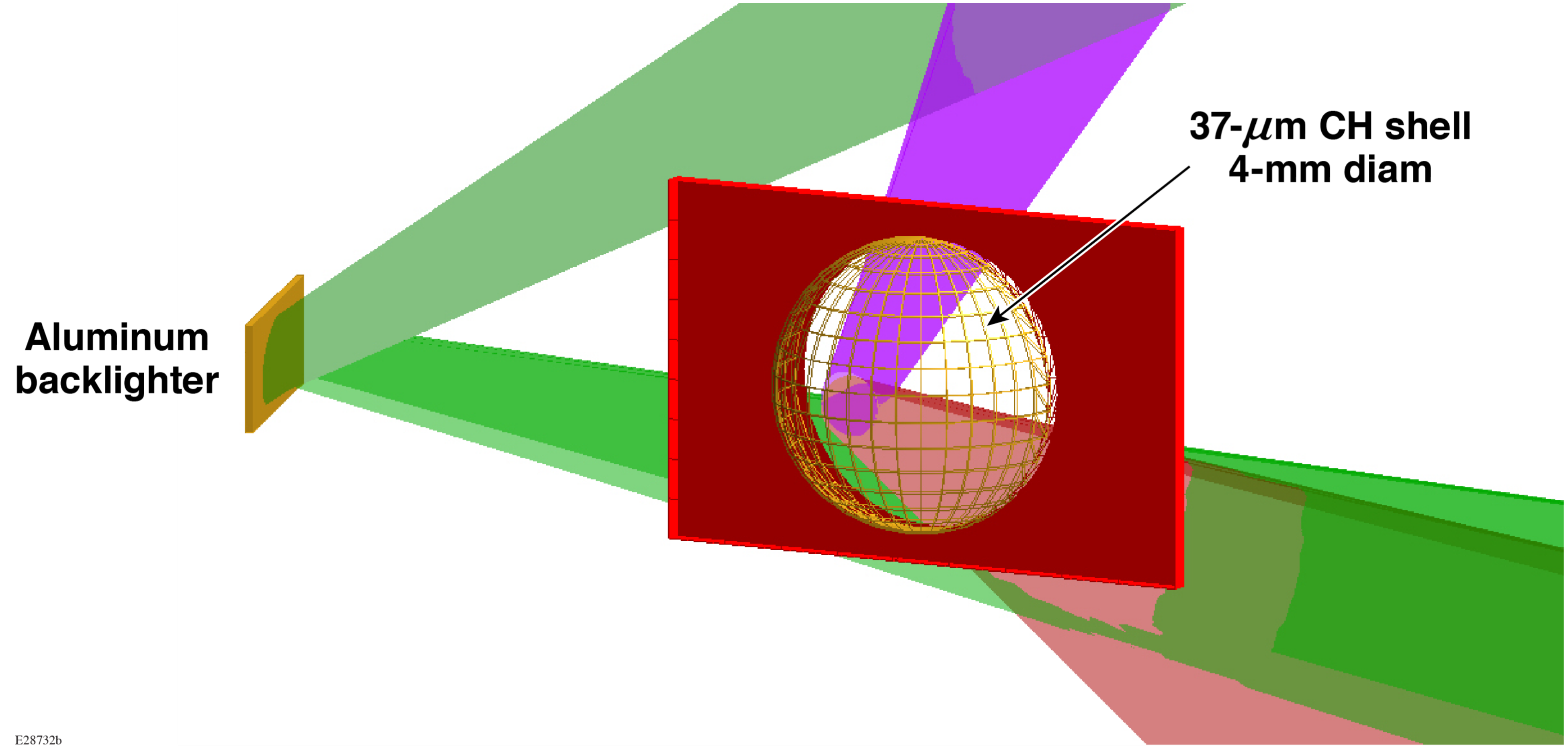

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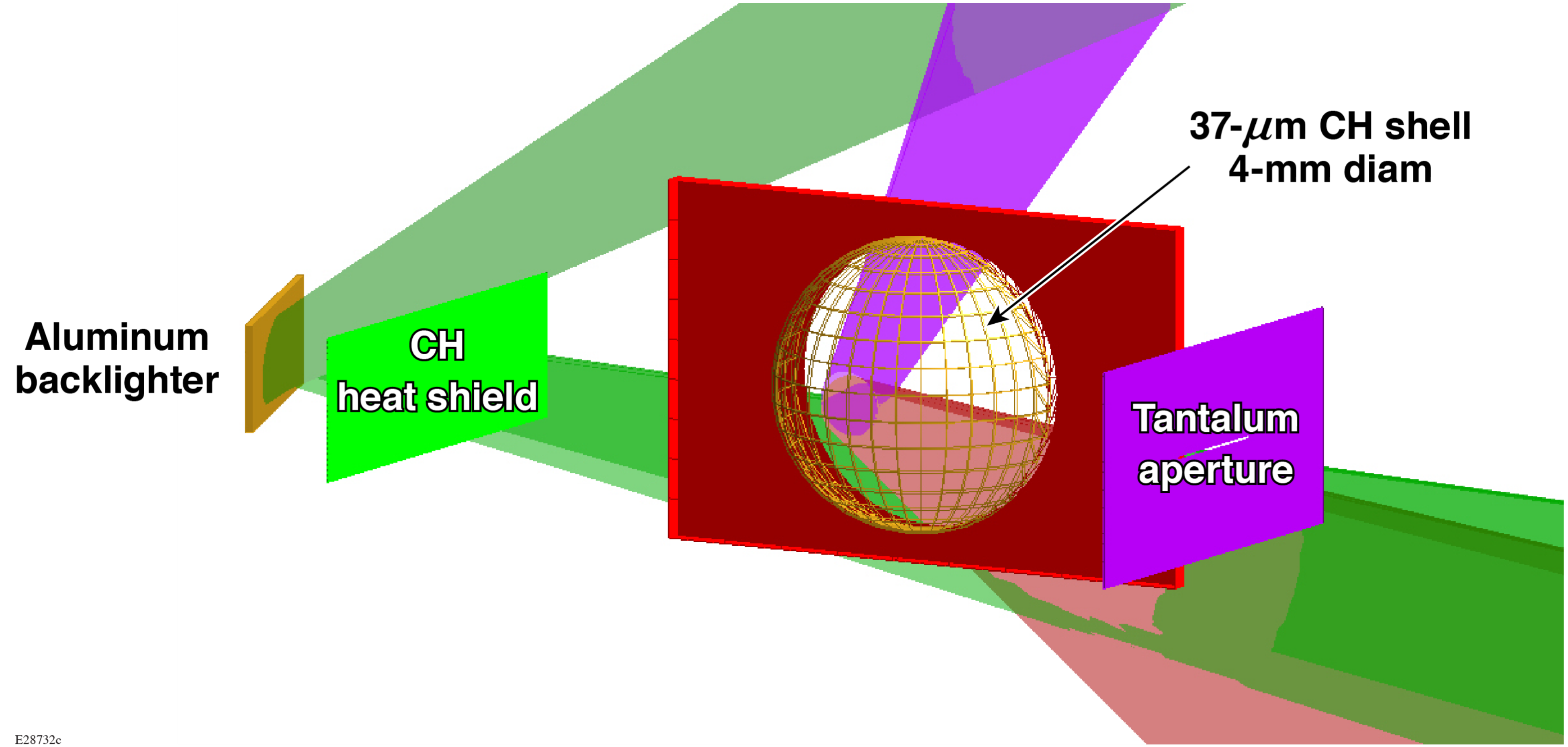

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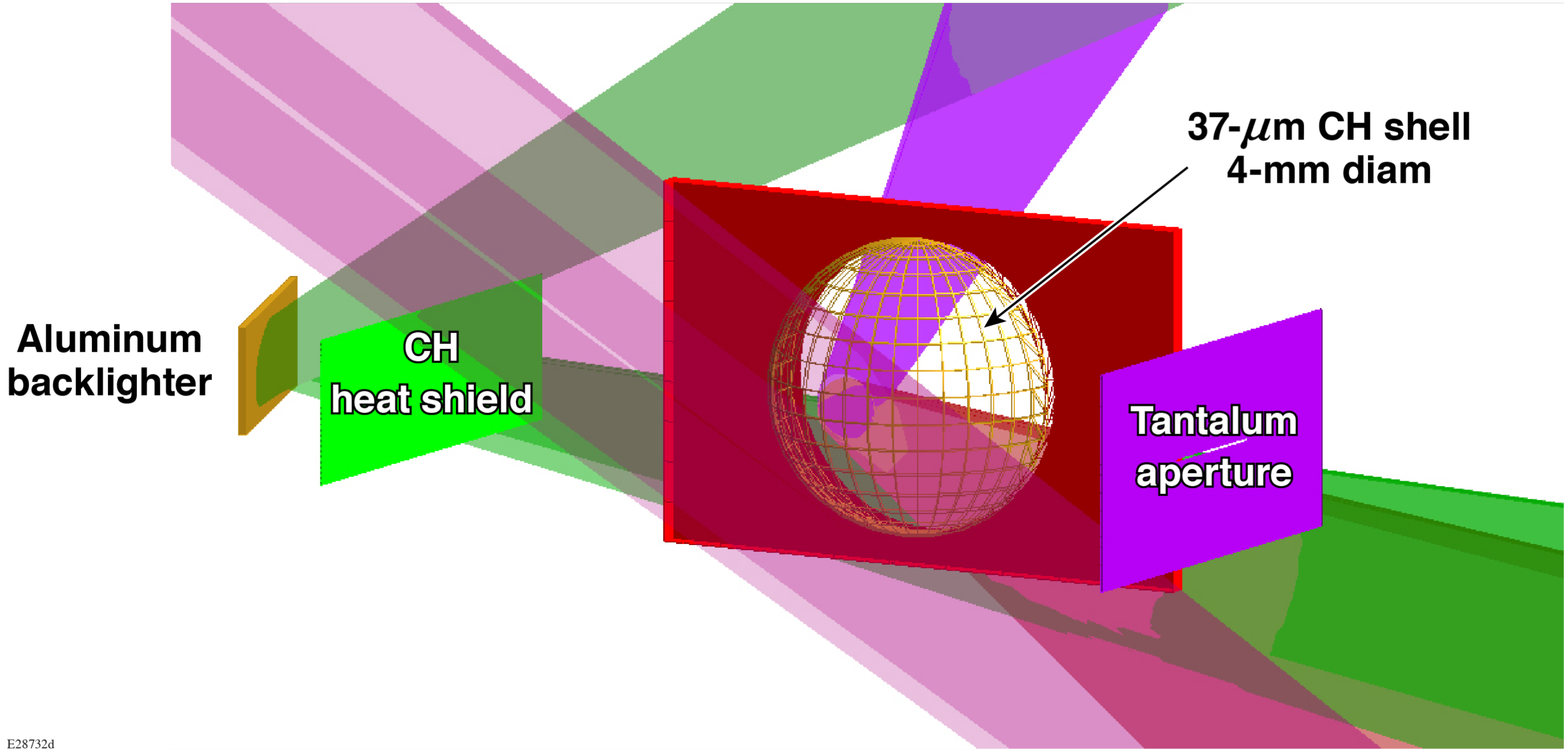
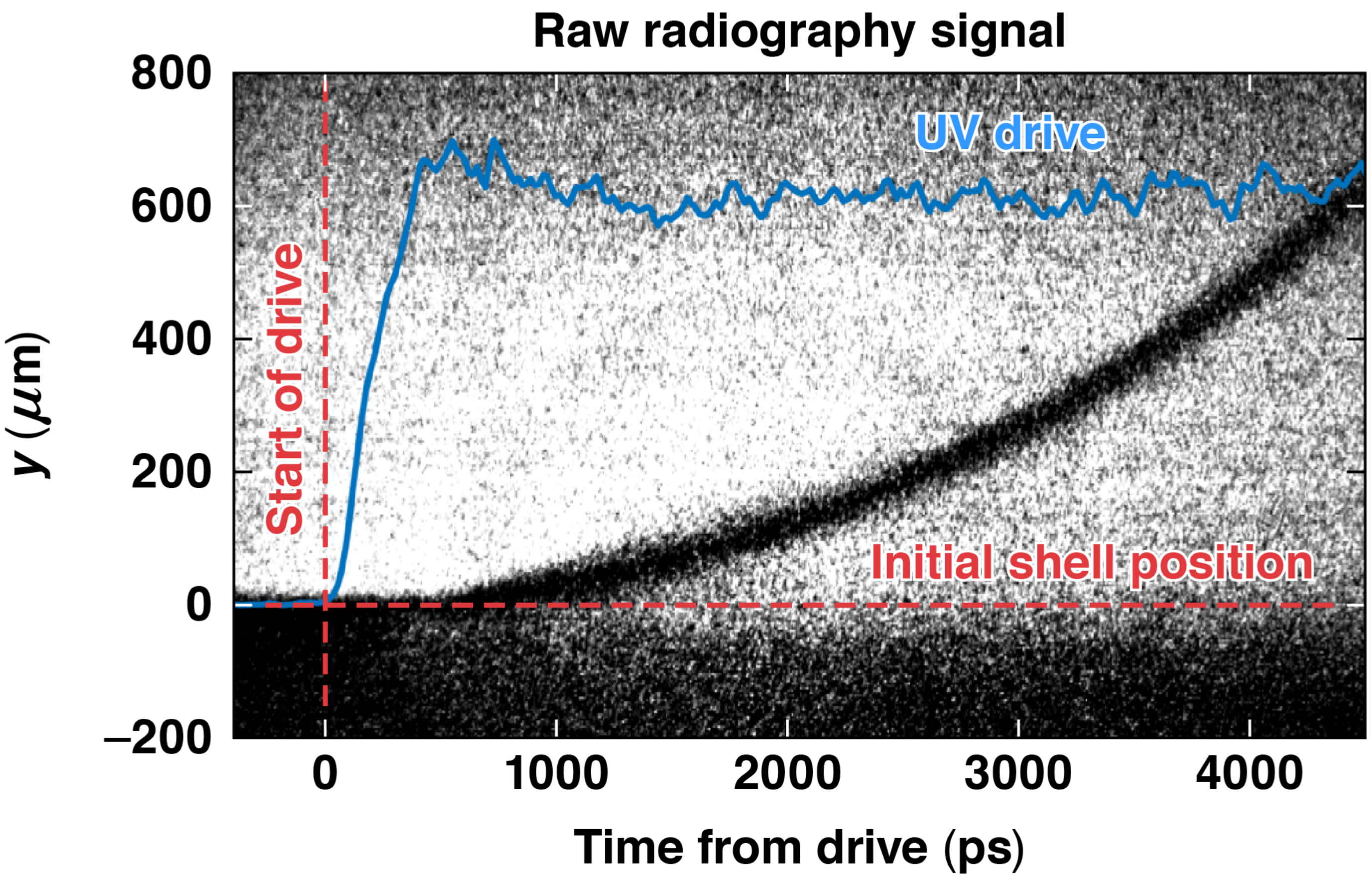


The x-ray radiography using ~1.5-keV (Al He_α) photons tracked the driven shell position across 700 μm over 5 ns



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Space

- Spatial resolution ~20 to 25 μm as measured by the undriven shell and Ta edge
- Spatial synchronization with the 4ω diagnostic obtained by the undriven shell position

Time

- Temporal synchronization with the 4ω diagnostic obtained through a timing fiducial with an accuracy of $\pm$20 ps

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Optical interferometry and angular filter refractometry (AFR)* were used to track the low-density plasma expansion on the back side of the driven shell

UR LLE

Probe Laser

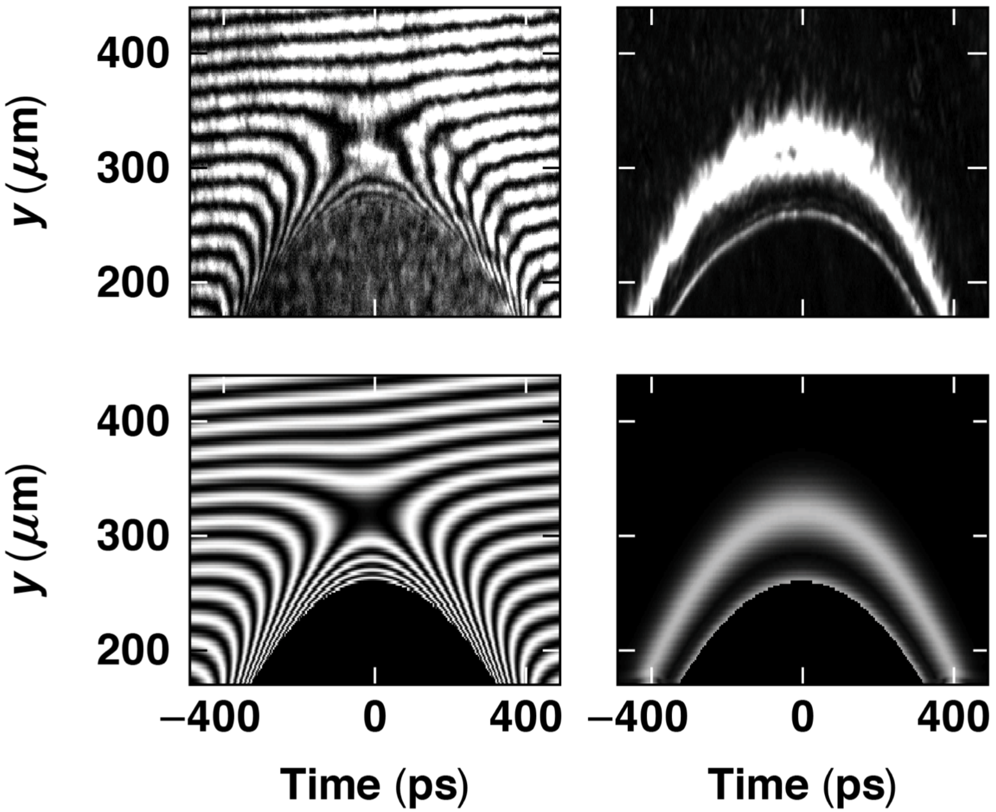
$\lambda_{\text{probe}} = 263$ nm $\qquad \Delta t = 8$ ps

Plasma Density Analysis

$$n(y) = \exp\left[-\frac{y}{L_y}\right]$$

$$n(x,z) = \exp\left[-\frac{x^2, z^2}{L_{\text{FWHM}}}\right]$$

At $t = 2$ ns: $L_y = 38\ \mu$m $\quad L_{\text{FWHM}} = 340\ \mu$m



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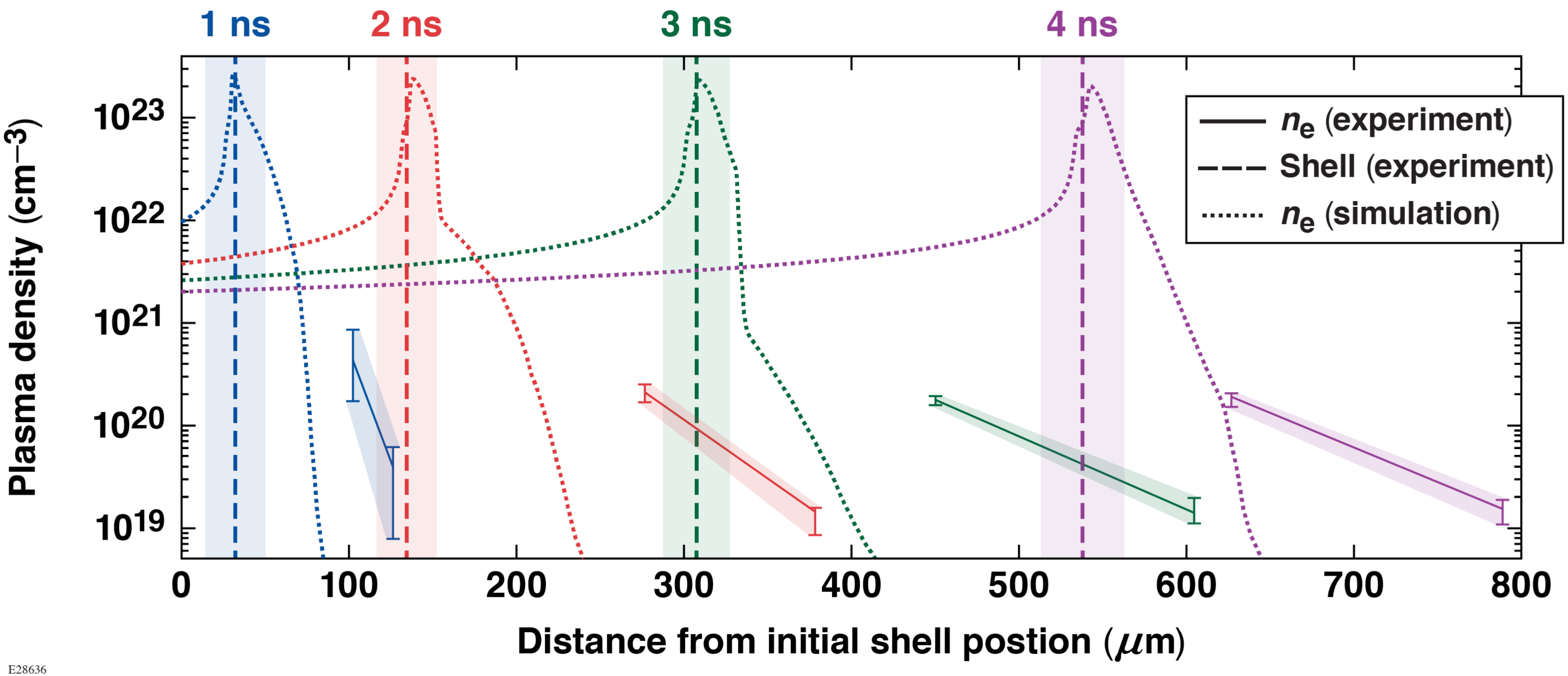
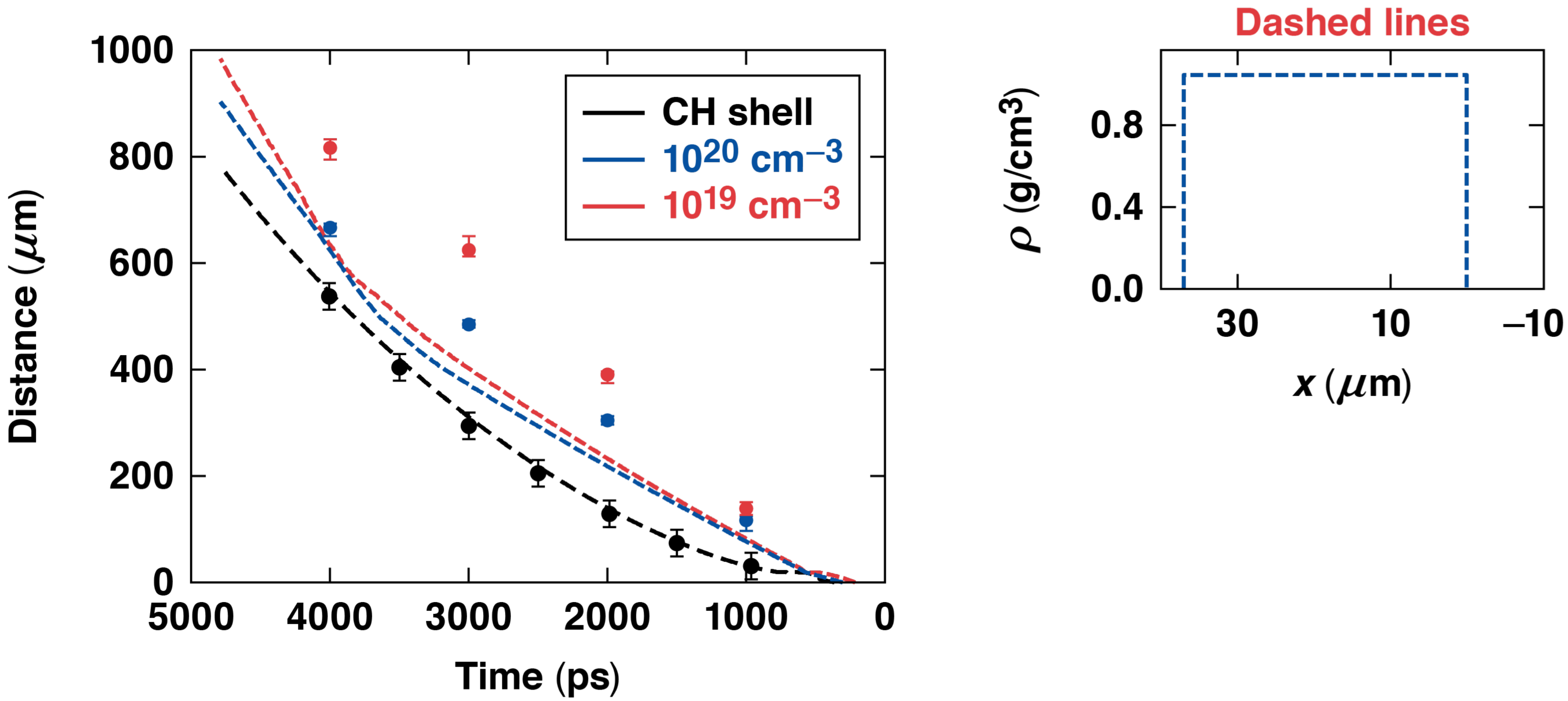
*D. Haberberger *et al.*, Phys. Plasmas 21, 056304 (2014).
FWHM: full width half max

The measured shell trajectory along with the low-density released plasma are compared to *LILAC* hydrodynamic simulations



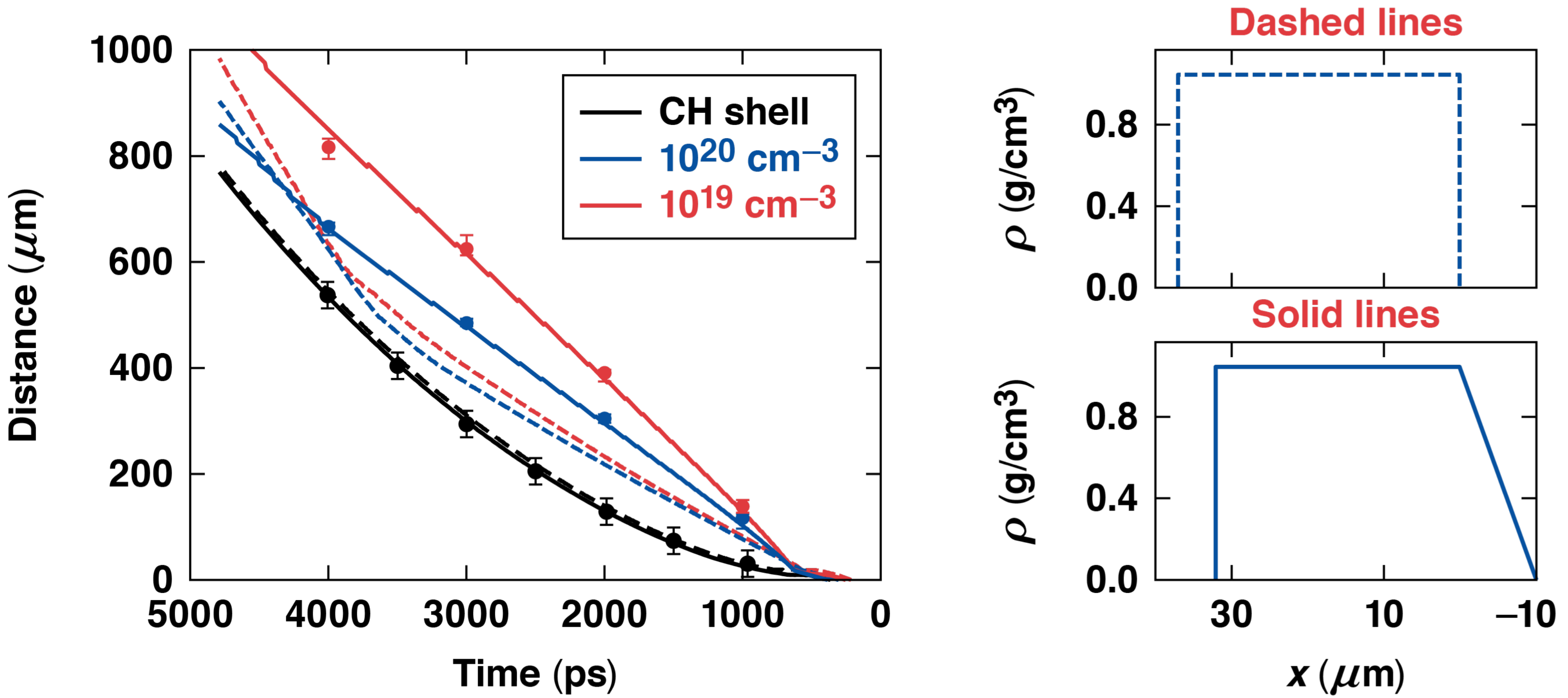
E28636

The density profile on the back side of the CH shell before the shock breaks out was found to strongly affect the rarefaction expansion



E28637

The density profile on the back side of the CH shell before the shock breaks out was found to strongly affect the rarefaction expansion



E28637a

Measurements of the low-density plasma ahead of a driven CH shell indicate that the shell profile is relaxed before the shock breaks out of the undriven side

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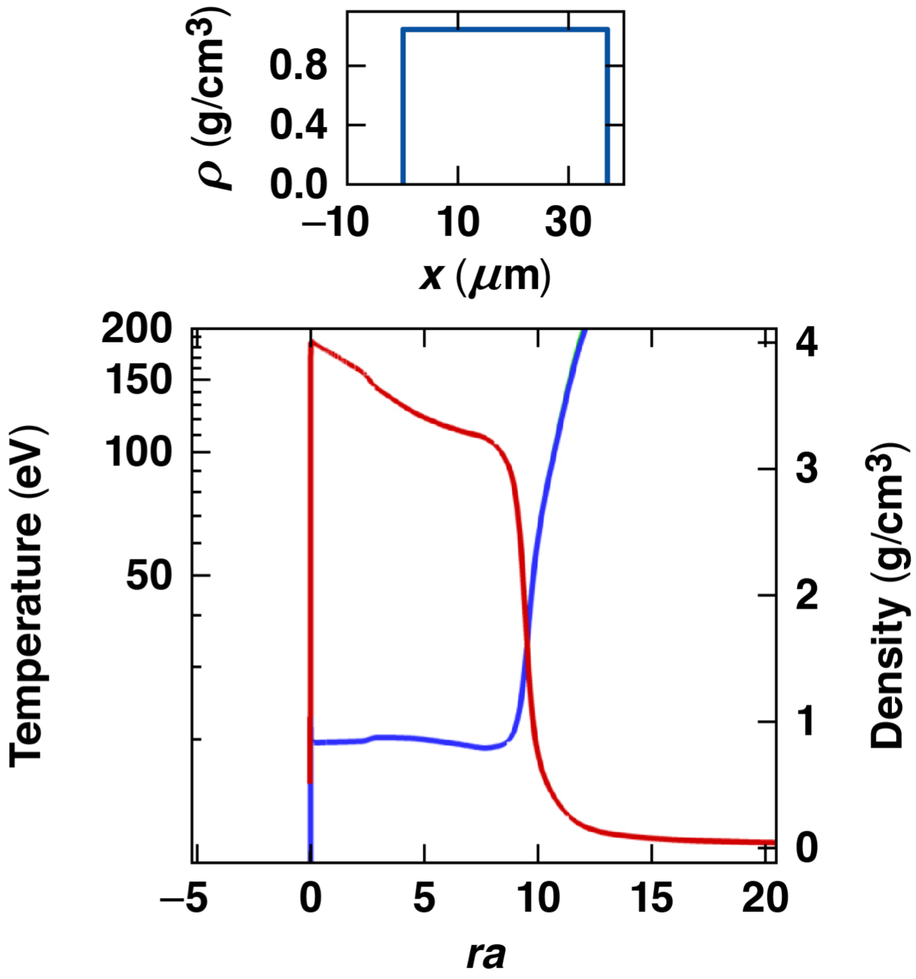
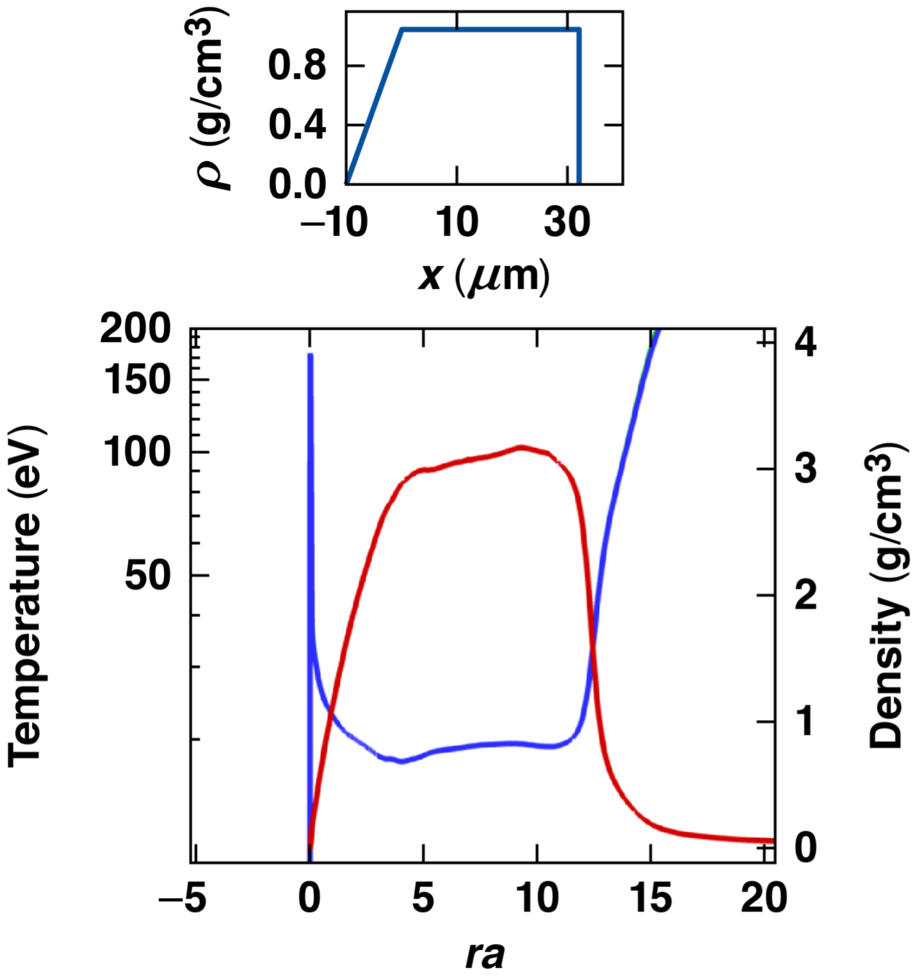
Backup

When the shock driven through the CH traverses the lower-density material at the back of the shell, it heats it to a higher temperature and therefore expands faster





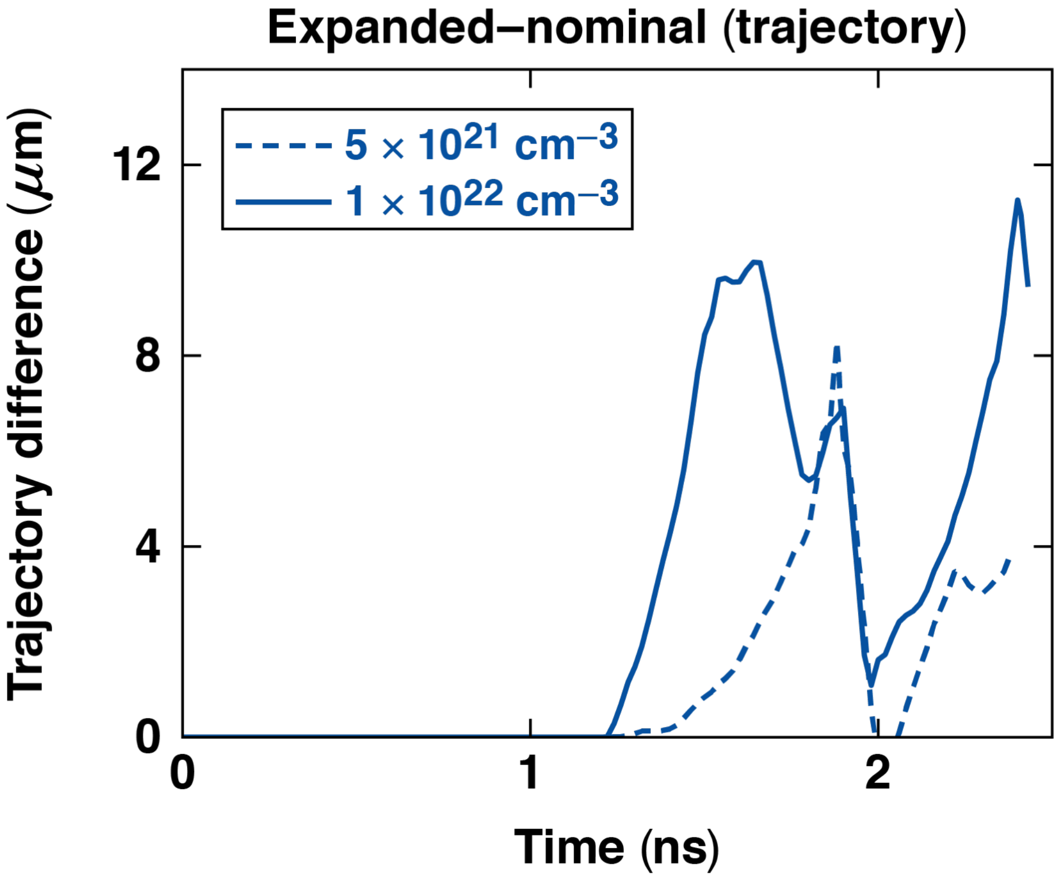
E28634

The effect of a relaxed DT ice layer in a cryogenic implosion simulation was studied by depositing energy on the inner surface of the DT

Nominal: 900-μm shell, triple-picket drive

Expanded: 10 J deposited on the inner 10 μg of DT ice layer before the main drive

	Nominal	Expanded
T_i (keV)	3.17	2.64
ρR (mg/cm^2)	179	146
Yield	8.1×10^{13}	3.8×10^{13}



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A possible mechanism for the relaxation of the shell is radiation preheat by coronal x rays

- According to *LILAC*, the x-ray energy absorbed over the shock transit time is 10 kJ/cm^3
- Using 1400-to 1900-K/kg/J specific heat, this increases the temperature of CH to 0.4 to 0.6 eV
  - molecular bonds are broken and the solid can decompress
- The width of the density gradient is estimated as 4 $C_{\mathrm{s,CH}} \times \frac{1}{2}\, t_{\mathrm{shock}} = 3$ to 4 μm
  - $C_{\mathrm{s,CH}} = 2350$ m/s for solid CH or 3500 using ideal gas at 0.5 eV
  - $t_{\mathrm{shock}} = 600$ ps (time to traverse CH shell)

Estimating the preheat-induced decompression is difficult because solid-state dynamics are not modeled in hydrodynamic codes.