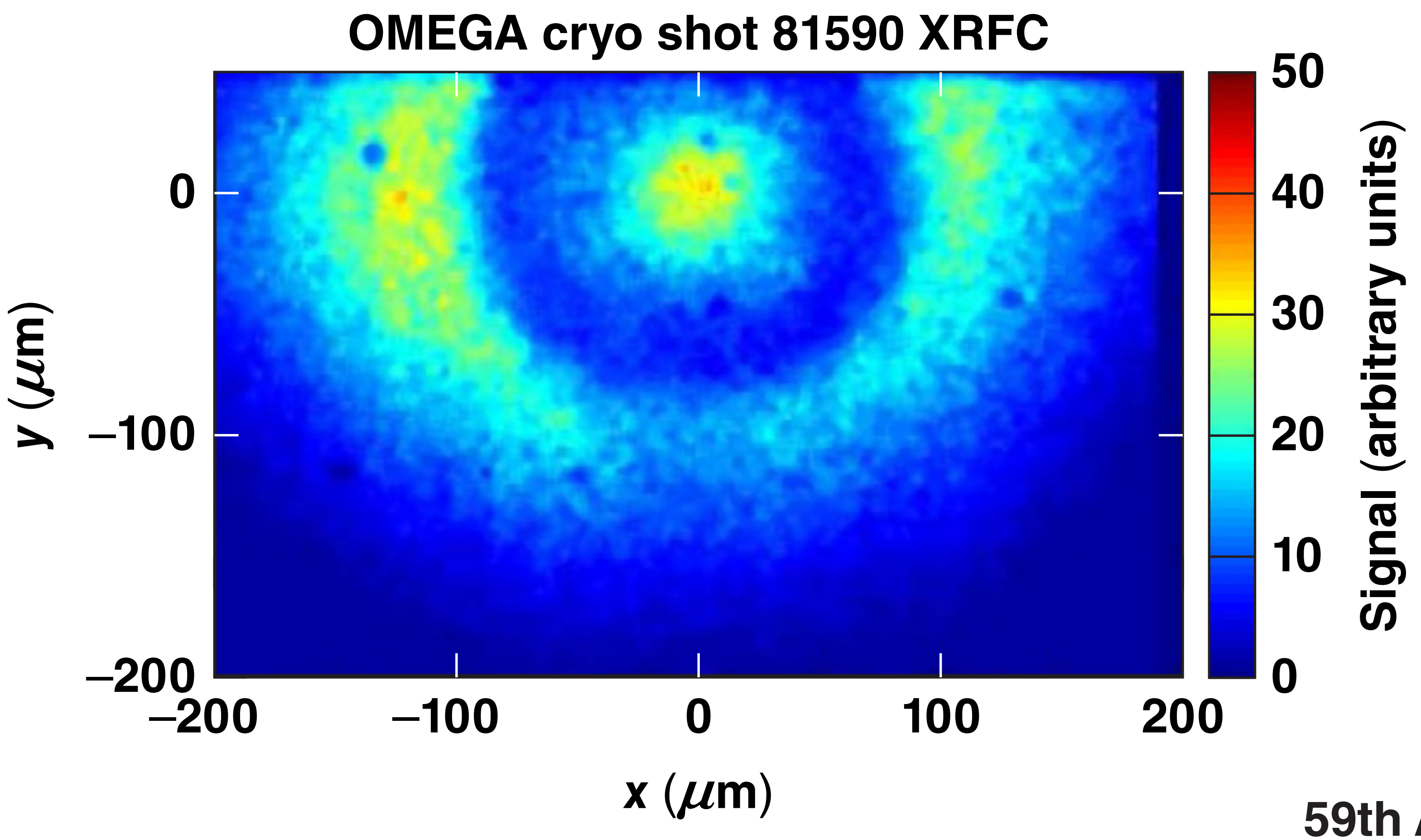
Simulation and Analysis of Time-Gated Monochromatic Radiographs of Cryogenic Implosions on OMEGA



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59th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Milwaukee, WI
23–27 October 2017

In-flight opacity profiles of converging cryogenic DT shells have been inferred with monochromatic soft x-ray radiography on OMEGA

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- Mass-density profiles are inferred from opacity profiles by assuming that the free–free opacity of hydrogen applies everywhere, which is compromised by unablated shell polymer
- Abel inversion of radiographs into radial opacity profiles can provide a useful view of the evolved distribution of unablated shell polymer

Collaborators

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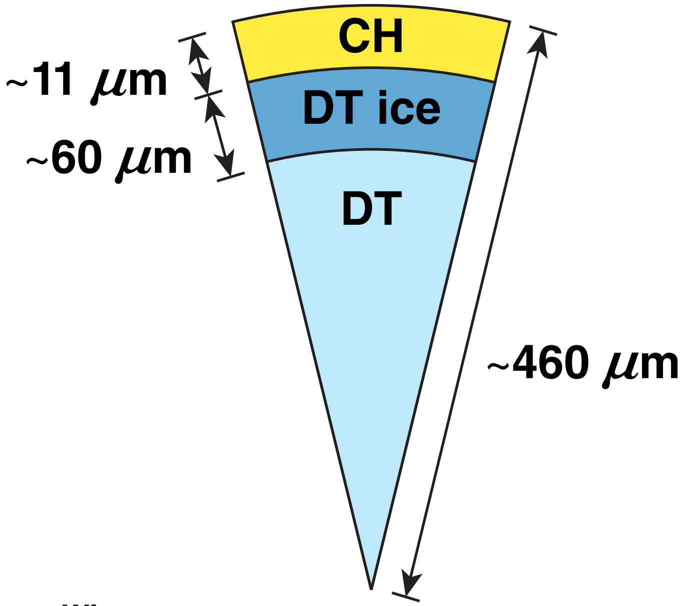
A Si He$_\alpha$ backlighter casts distinct DT shell and CH remnant shadows during the late convergence phase of an implosion

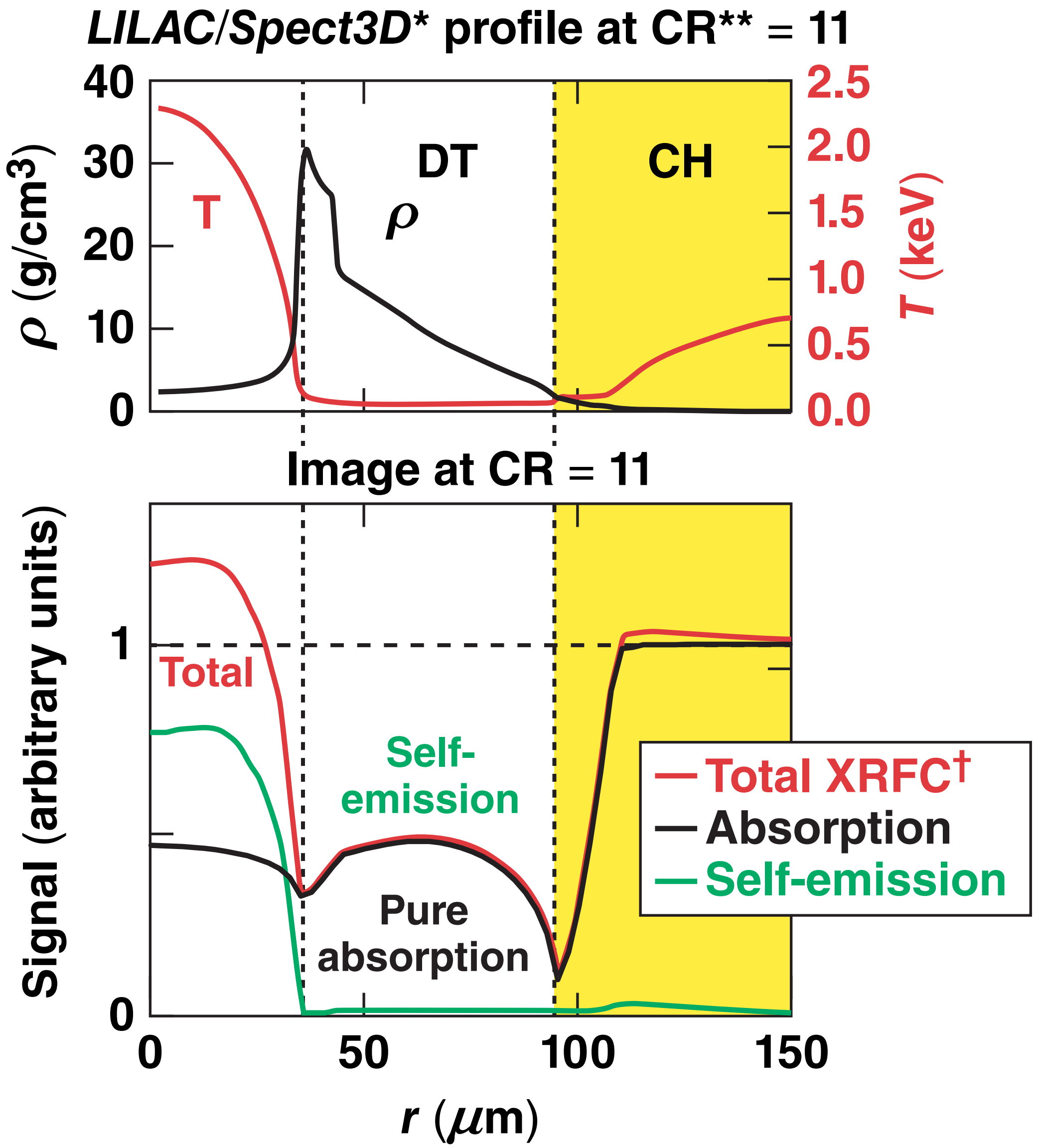
- 25-kJ, triple-picket, low-adiabat pulses
- 20-ps, 1.5-kJ backlighter pulse
- Monochromatic crystal imaging with a Si He$_\alpha$ backlighter (1865 eV)

- C outshines the H absorption per ion by a very large factor

$$\sigma_{H}^{ff} \propto n_e Z_H^2 \quad \sigma_{C}^{bf} \propto Z_C^4$$

$$\frac{Z_C^4}{Z_H^2} \approx 1300$$





*Spect3D, Prism Computational Sciences, INC. Madison, WI.
**CR: convergence ratio
†XRFC: x-ray framing camera
ff: free–free
bf: bound–free

TC13002d

Mass density can be inferred quantitatively where the shell is pure hydrogen

- Abel inversion gives the radial-opacity distribution $\kappa(r)$ from the planar optical thickness distribution projected onto a plane (x, y)

$$\tau(x,y) \propto \int_{\text{backlight}}^{\text{camera}} \kappa(x,y,z)dz \quad \text{assume: } \kappa = \kappa_{ff} \propto \left[\frac{\rho}{T^{1/4}}\right]^2 \longrightarrow \rho \propto \kappa_{ff}^{1/2} T^{1/4} \text{*}$$

- With the weak temperature (T) dependence of the free–free (ff) opacity, shell-average temperatures from simulations suffice for this purpose
- C absorption exceeds H absorption per ion by a very large factor

$$\sigma_H^{ff} \propto n_e Z_H^2 \quad \sigma_C^{bf} \propto Z_C^4 \quad Z_C^4 / Z_H^2 \approx 1300$$

- For now, the analysis will assume pure hydrogen throughout the imploded shell, but unablated and/or mixed CH will be easy to spot
- Multi-material radiography requires additional modeling and/or assumptions

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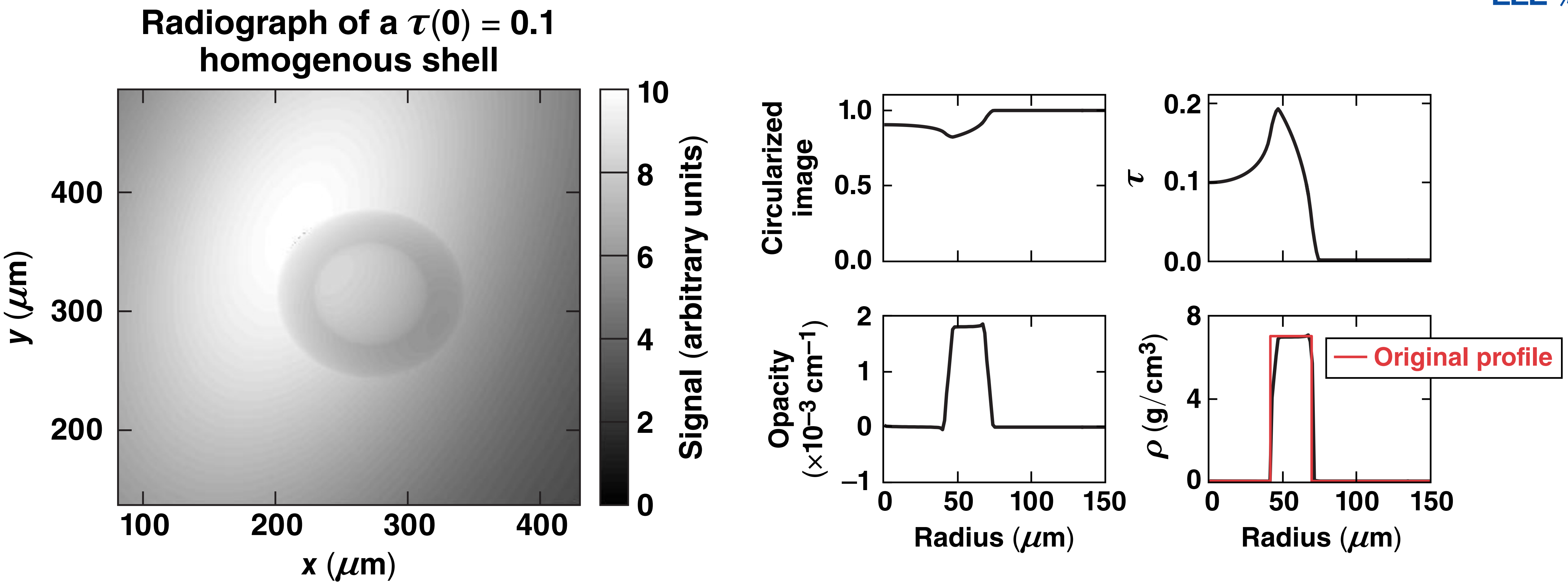
*_PrismSPECT_, Prism Computational Sciences Inc., Madison, WI 53711.

Flattening and circularizing a synthetic radiograph with a nonuniform backlight recovers the opacity profile of a hypothetical object



- An eight-parameter model is fit to the unobscured portion of the backlight distribution and then divided out of the entire radiograph
- The flattened radiograph is then circularly averaged, effectively using all the information available in the radiograph

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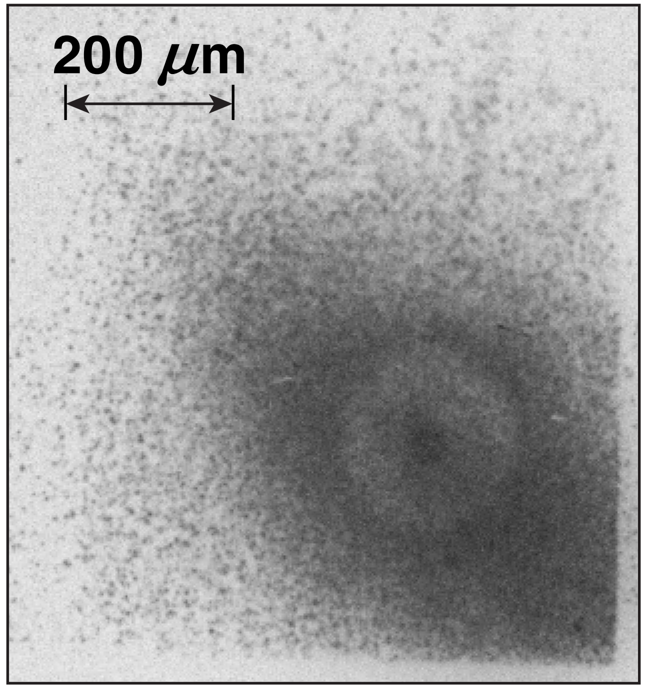
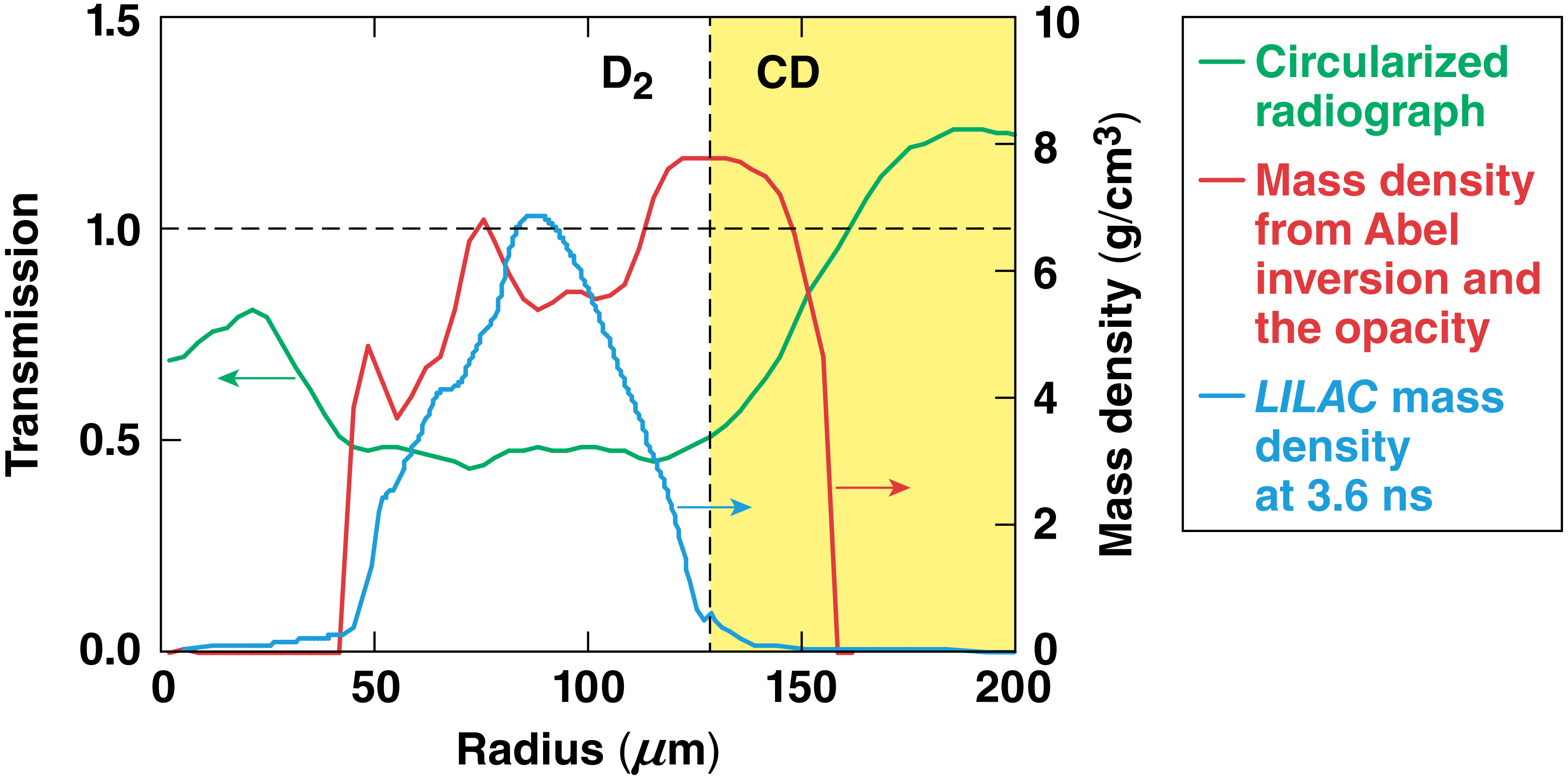
The simulated radiograph shows consistency with the simulated D_2 shell density profile with additional absorption as a result of an unablated trace of shell CD

UR LLE

10.1-μm shell, 95-μm cryo D_2, 866-μm-diam, 80-ps framing camera gate

Shot 54395





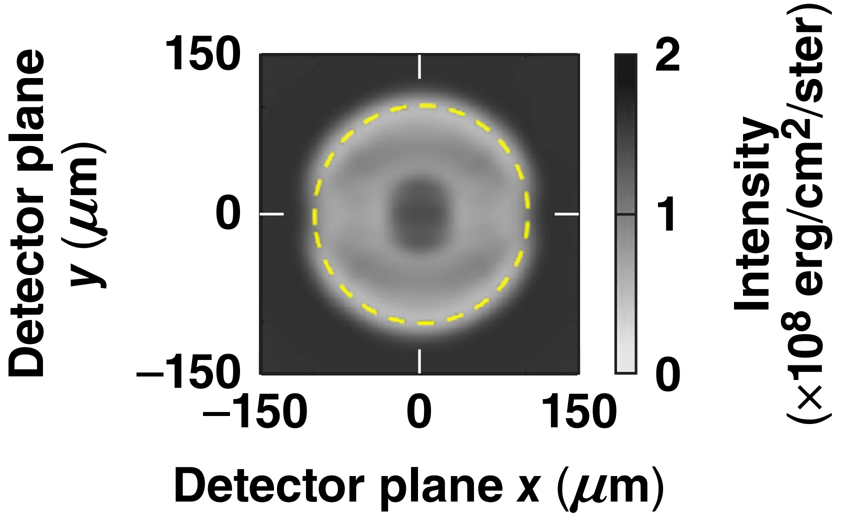
- CD absorption compromises analysis based on the free–free opacity of hydrogen

TC13928

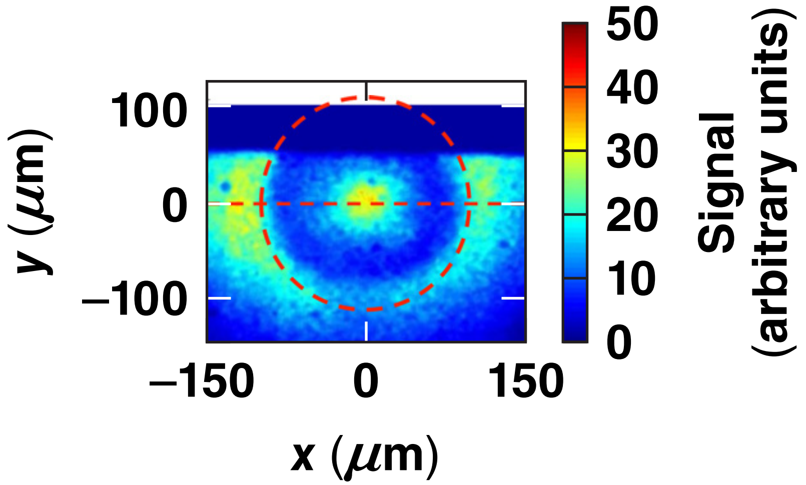
*R. Epstein, V. A. Smalyuk *et al.*, Bull. Am. Phys. Soc. 54, 306 (2009).

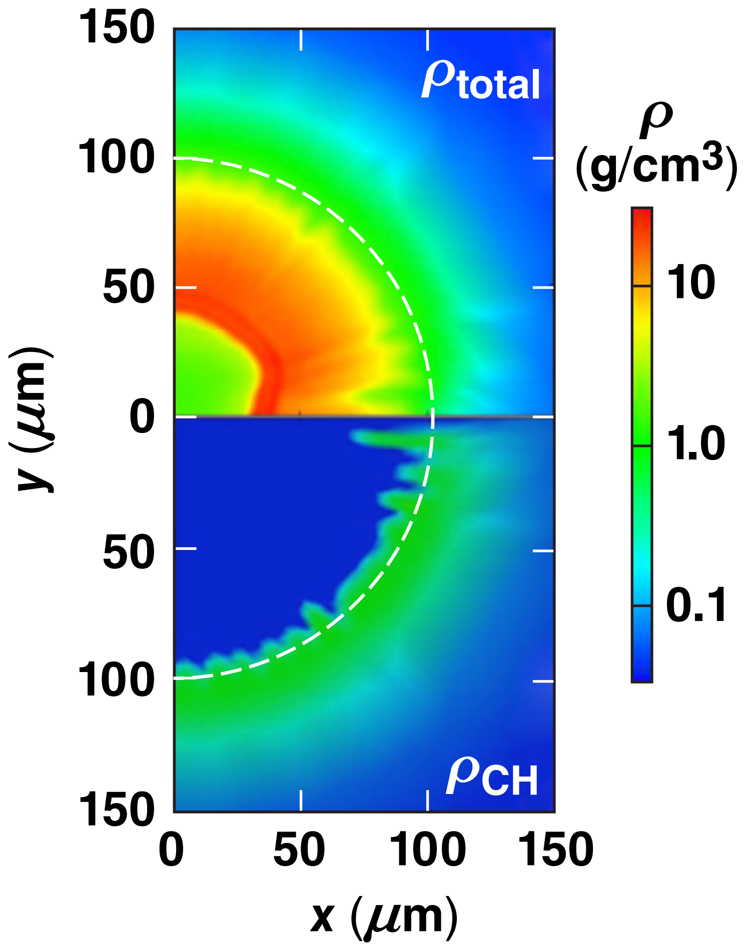
Laser nonuniformity imprint perturbs the implosion, which blurs and broadens radiographic features

OMEGA cryo shot 81590 *DRACO*

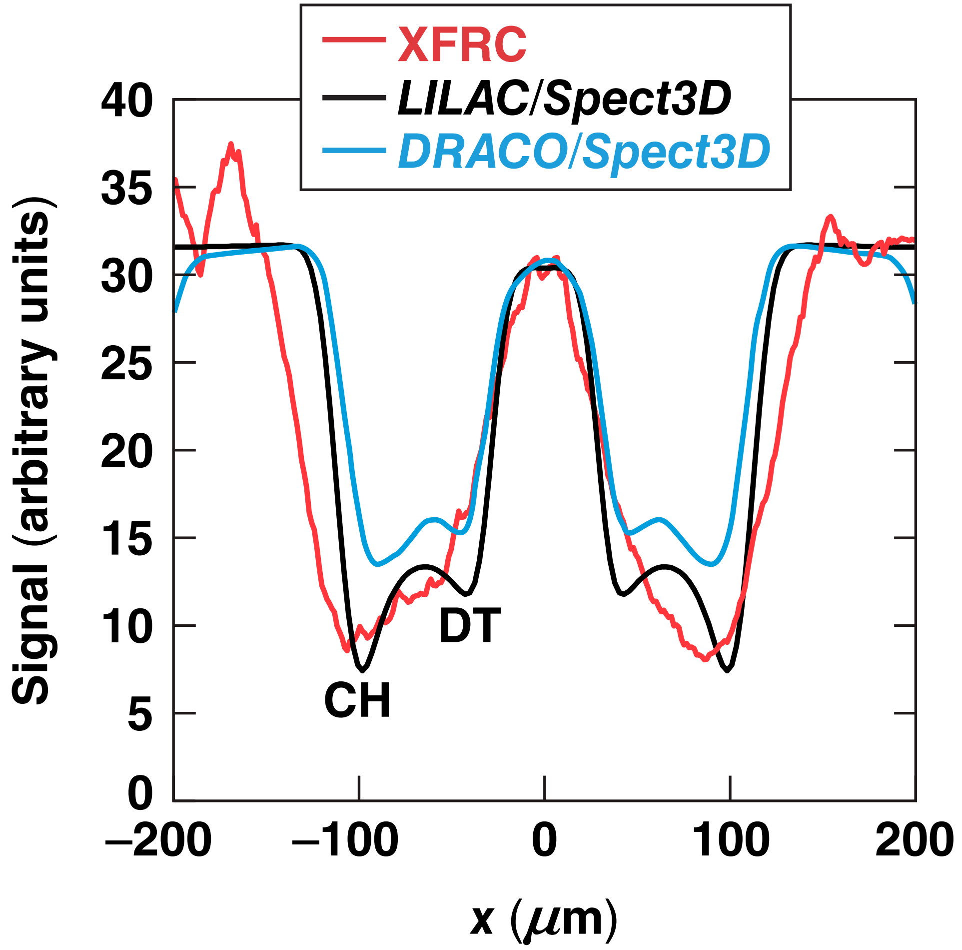


OMEGA cryo shot 81590 XFRC





Flattened data and simulations



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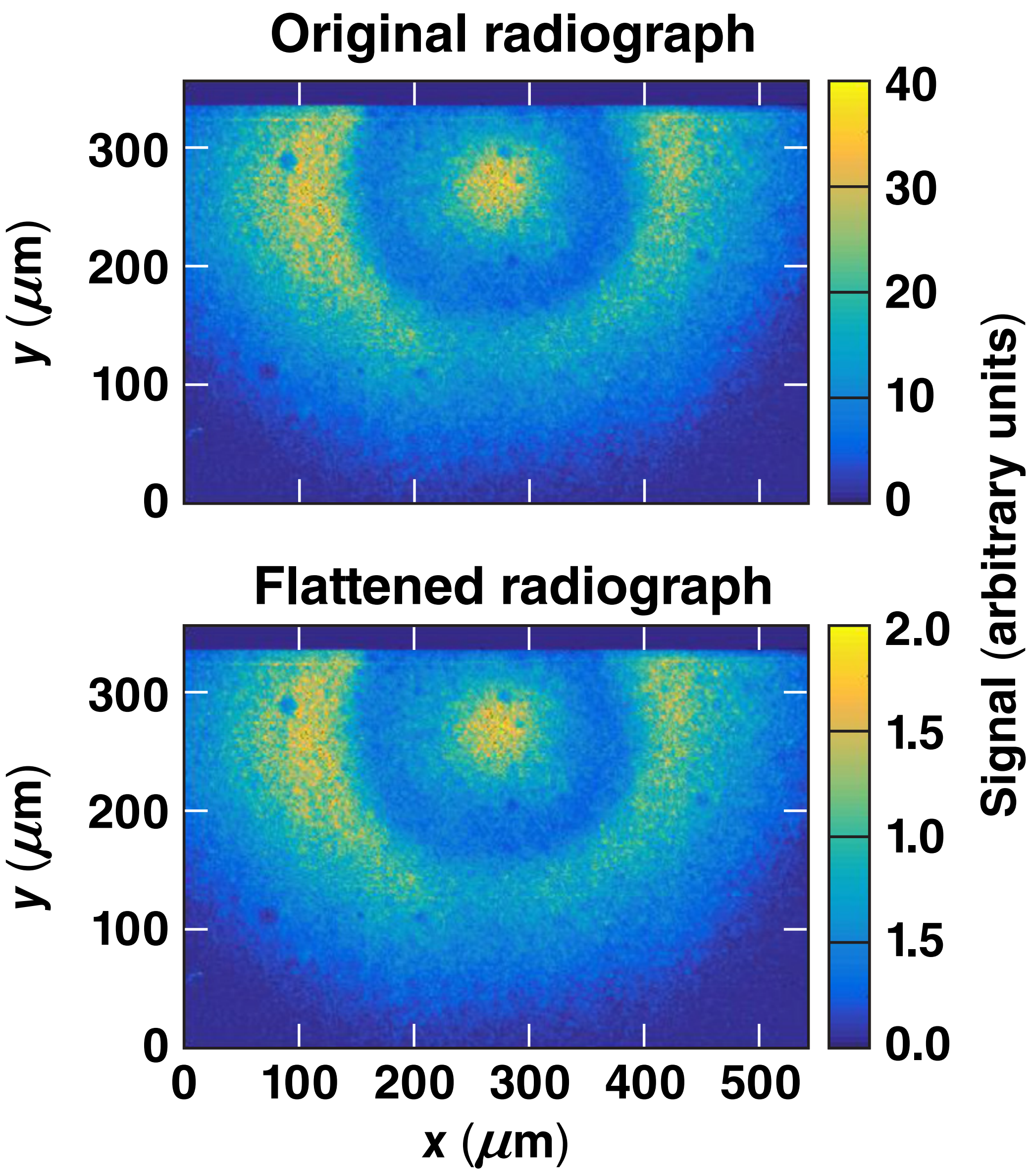
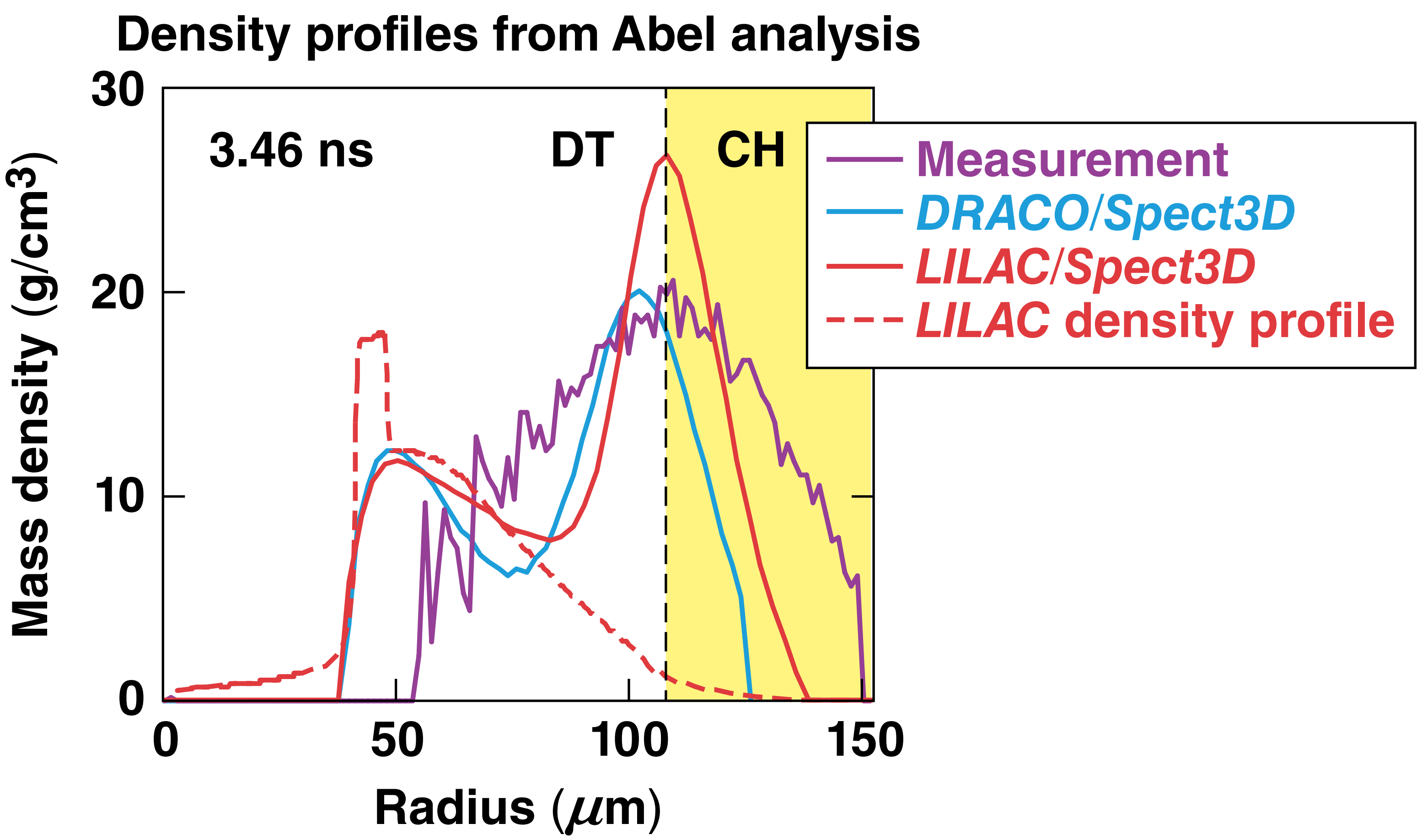
Abel inversion separates the hydrodynamically mixed shell CH distribution from the cryogenic DT shell distribution

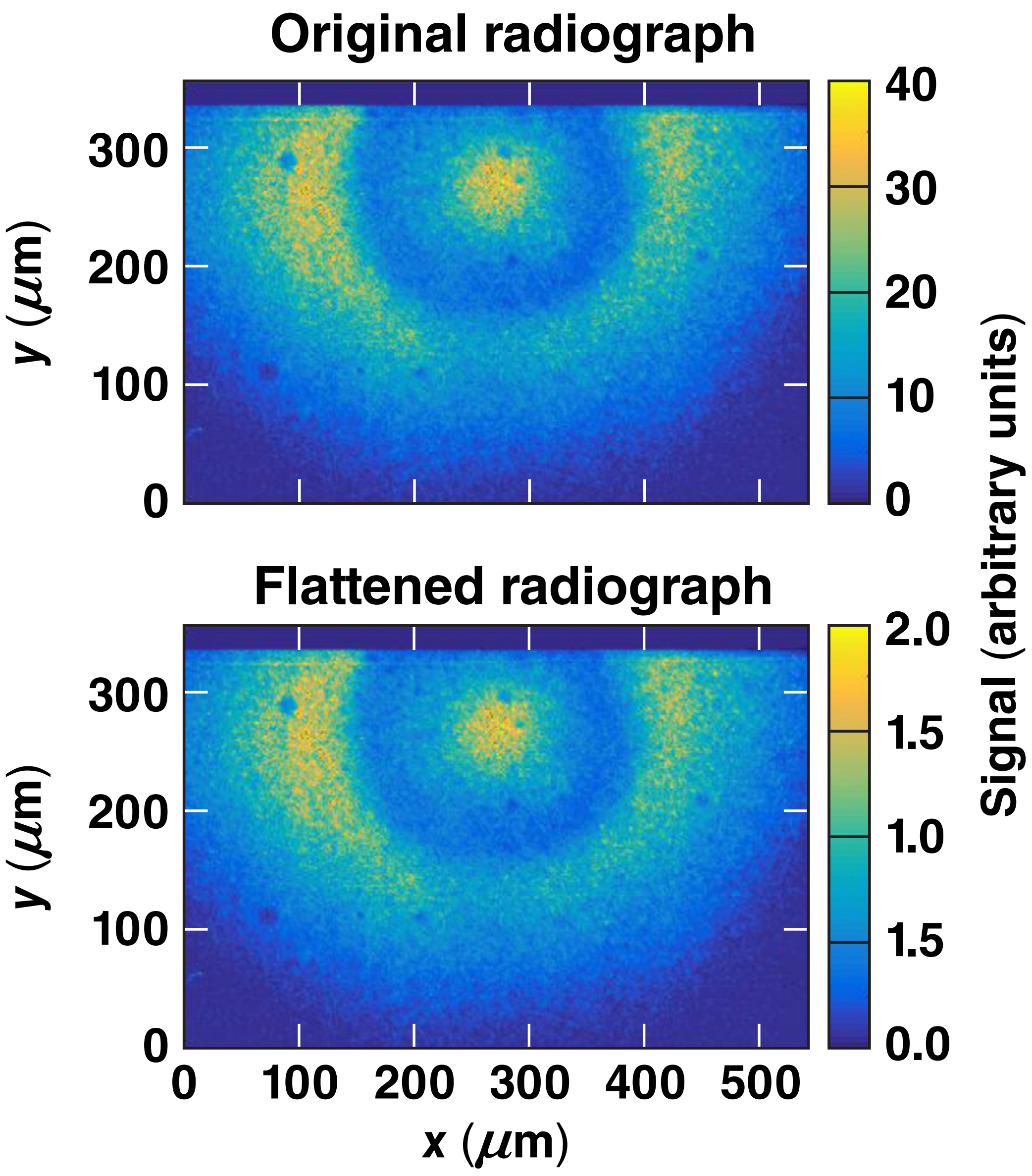


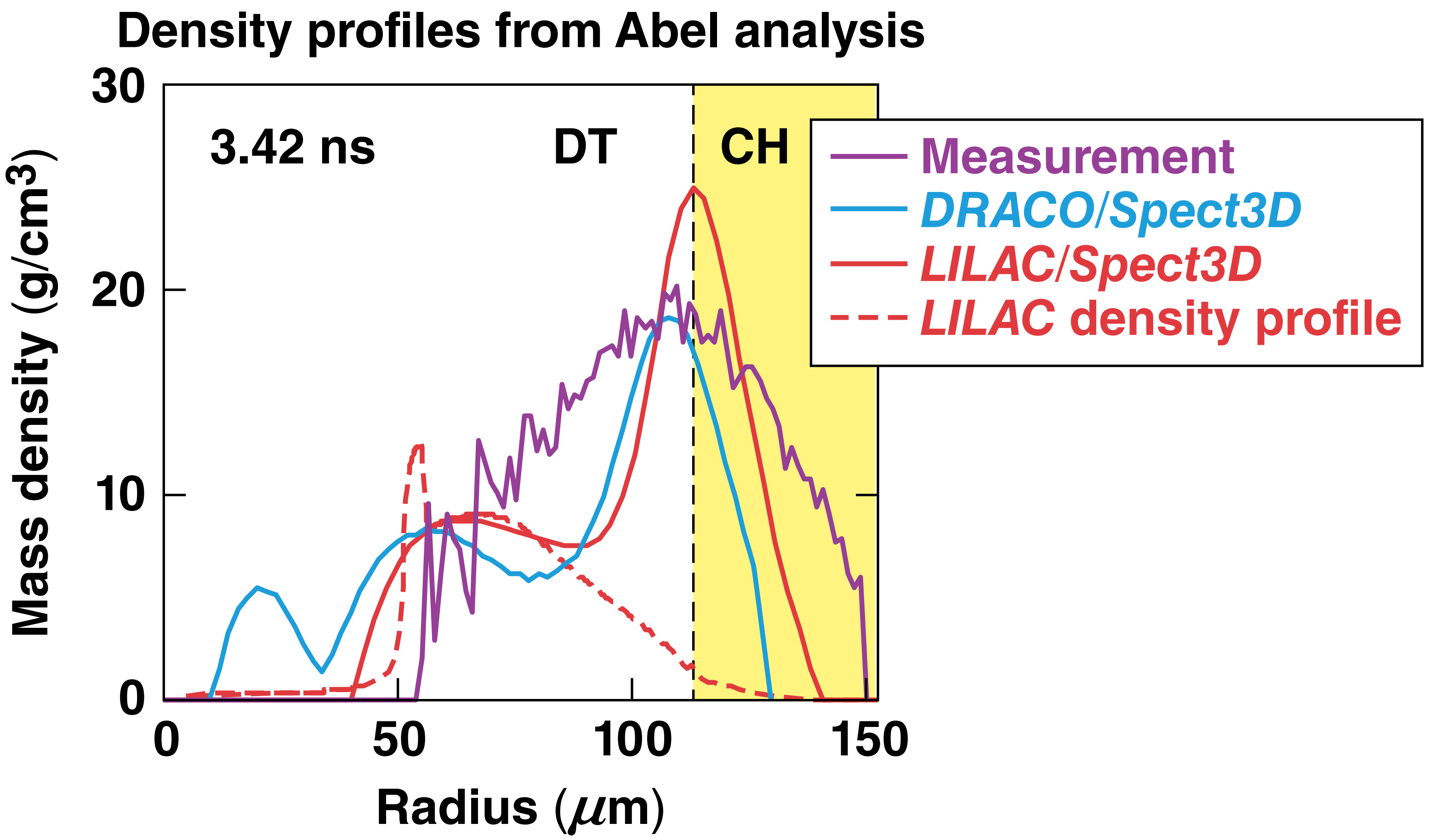


- Was the radiograph taken before the core rebound had reached the inner shell?

TC13929

Abel inversion separates the hydrodynamically mixed shell CH distribution from the cryogenic DT shell distribution





TC13929a

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