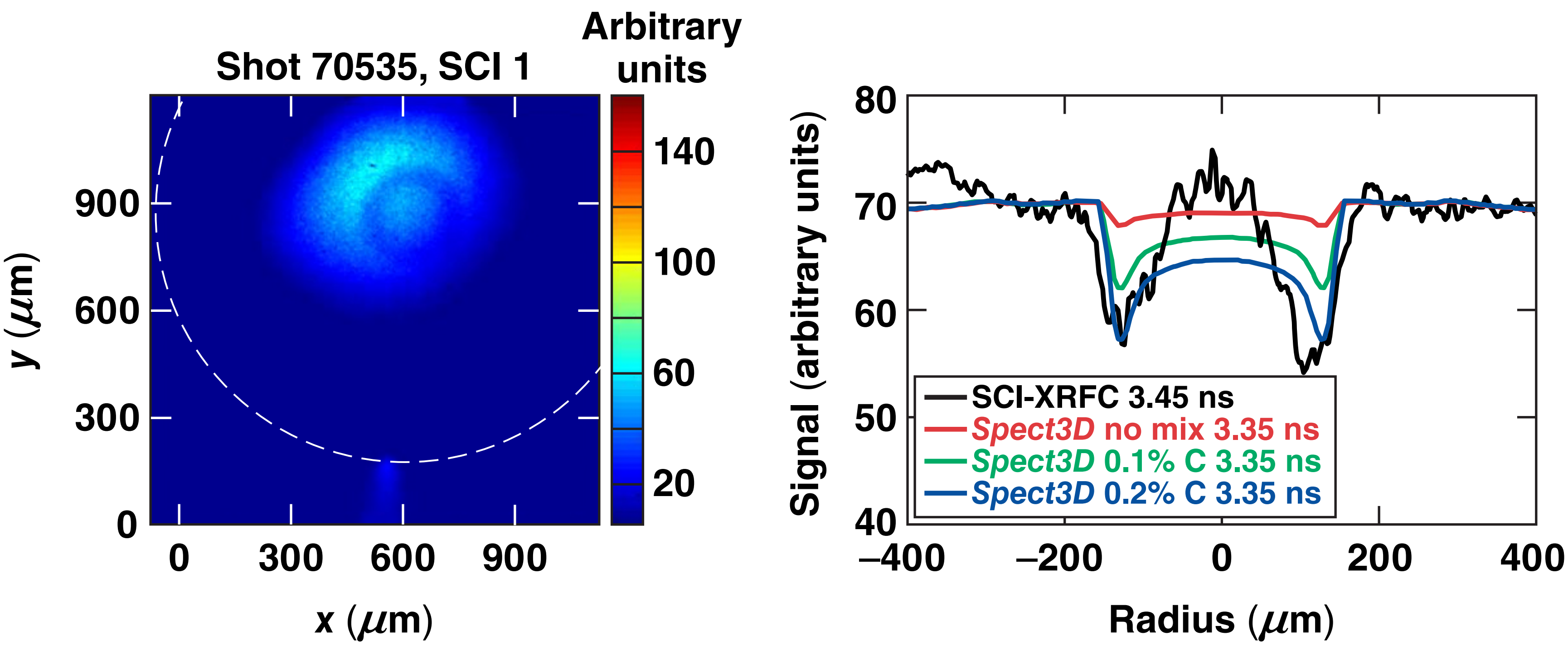
# Measuring Mix in Direct-Drive Cryogenic DT Implosions Using Soft X-Ray Narrowband Backlighting





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Summary

# Backlit images of low-adiabat cryogenic implosions show a clear signature of carbon mixing into the DT fuel layer

- A crystal imaging system with a backlighter target driven by the OMEGA EP short-pulse laser was used to obtain backlit images of the compressed DT*
- The images obtained in low-adiabat ($\alpha < 3$) implosions show a much higher x-ray absorption than calculated with a 1-D radiation hydrocode
- The higher measured absorption can be explained by mixing 0.2% carbon into the compressed DT shell at the end of the acceleration phase

**Images obtained in high-adiabat ($\alpha > 4$) implosions show no extra absorption and compare well with 1-D radiation hydro simulations.**

*C. Stoeckl *et al.*, Rev. Sci. Instrum. 85, 11E501 (2014).

# Collaborators

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# Backlighting the compressed core of a cryogenic target implosion is challenging

- The low opacity of DT requires a soft x-ray backlighter
  - the crystal imager uses the Si-He$_\alpha$ line at ~1.9 keV
- A bright backlighter is required to overcome the self-emission
  - the high energy of the 10-ps OMEGA EP laser allows for the illumination of a large target area
- The cryo implosion evolves at high speed ($>3 \times 10^7$ cm/s)
  - the short-pulse duration provides a time resolution of ~10 ps (motion blurring $<3$ $\mu$m)
- The small size of the core requires a high resolution ($<10$ $\mu$m)
  - a crystal on an aspheric substrate has a calculated resolution close to 1 $\mu$m


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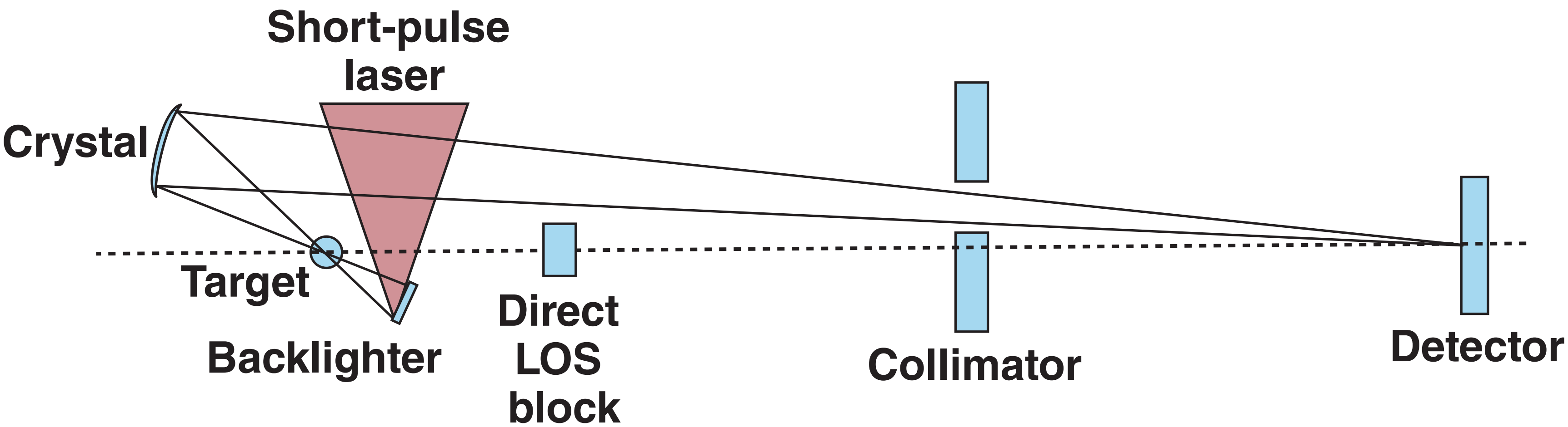
# High-quality backlit images of implosions are obtained with a crystal imaging system




- The backlighter foil is not in the focus of the imaging system, so the backlighter uniformity does not depend on the laser-intensity distribution
- A collimator blocks the line of sight (LOS) to the backlighter, minimizing the background from the short-pulse laser
- A direct LOS block shields the detector from background produced by the implosion target

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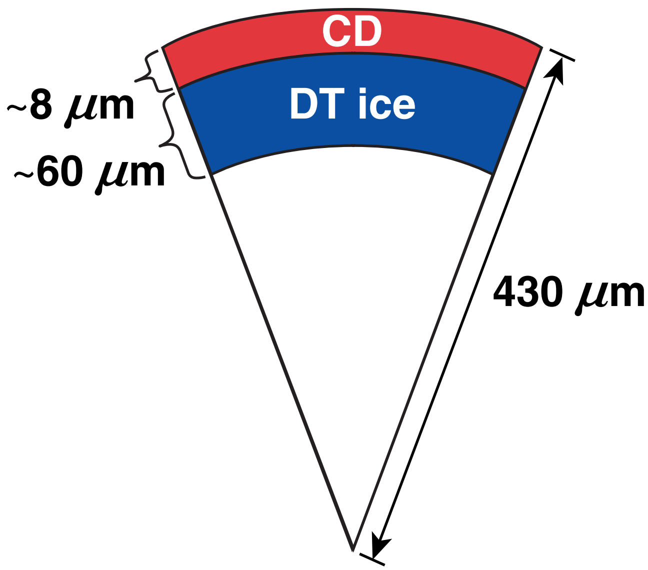
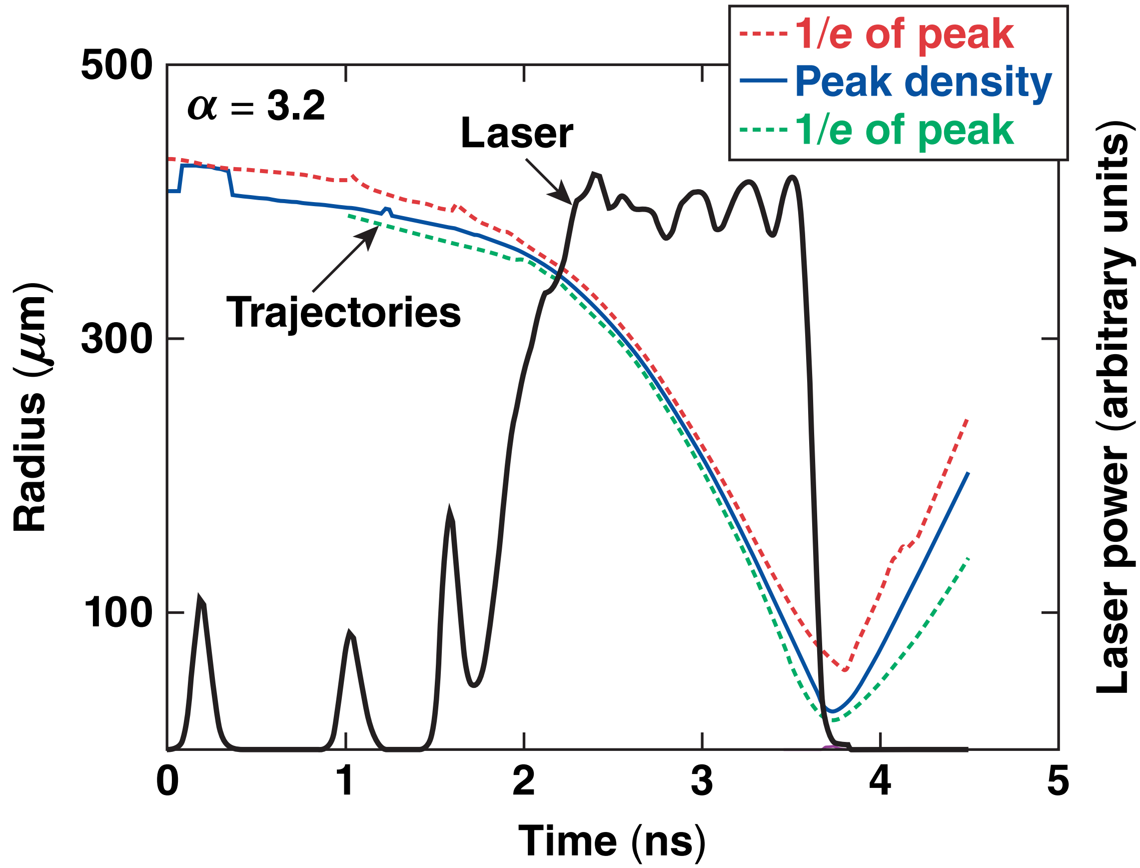
# Low-adiabat, triple-picket pulses were used for the cryogenic target experiments*




Adiabat: $\alpha = \frac{P}{P_{\text{Fermi}}}$

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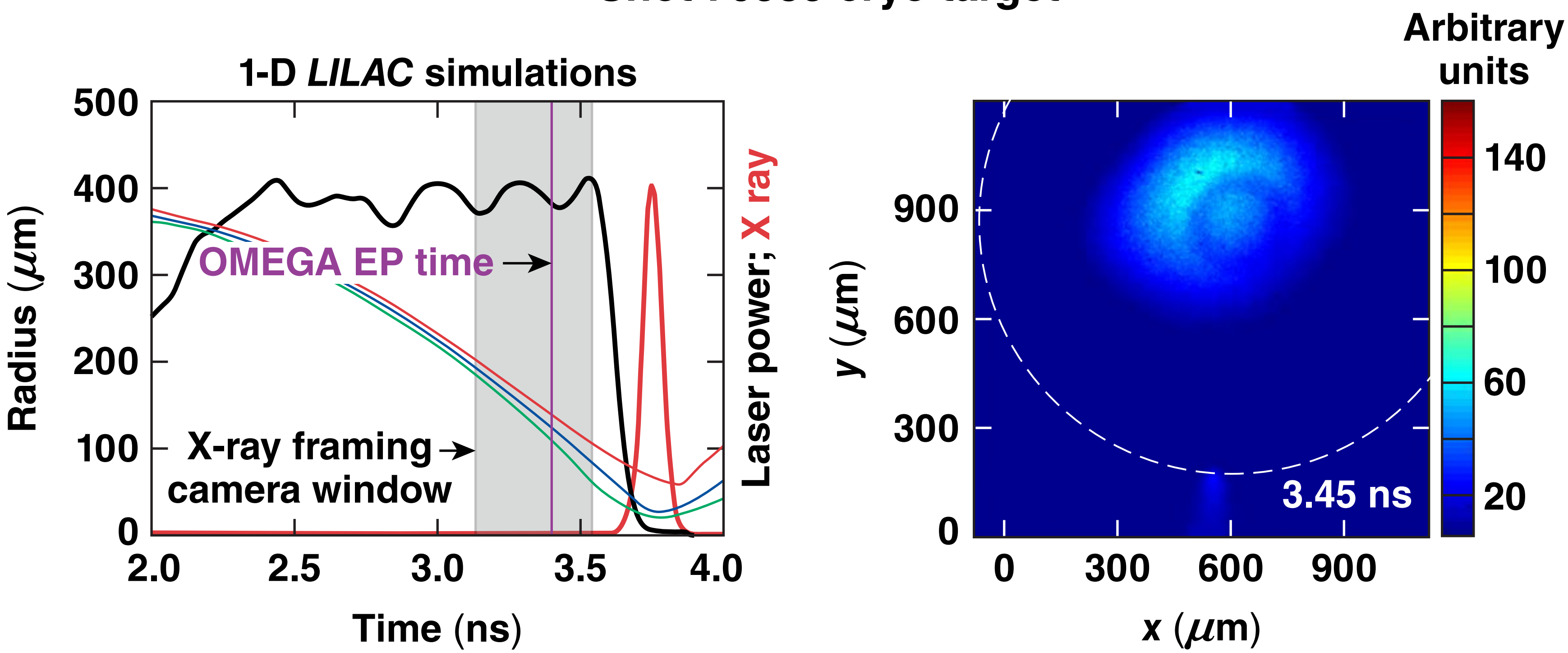
*V. N. Goncharov, Phys. Plasmas 21, 056315 (2014).

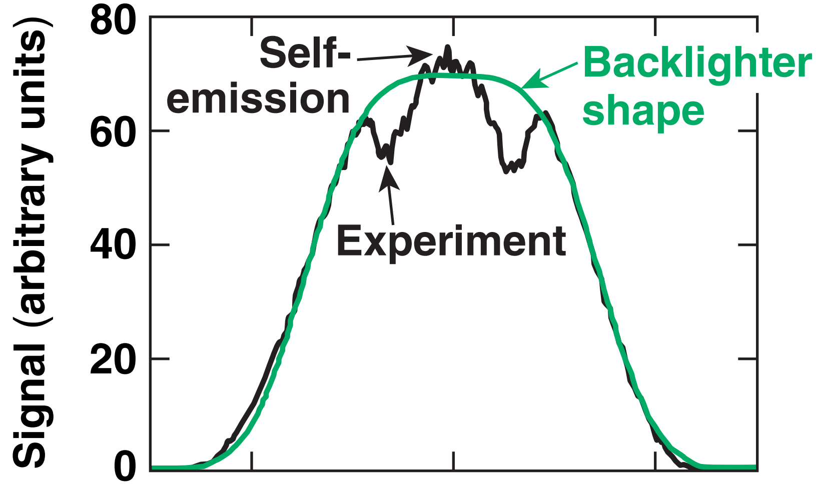
# High-quality backlit images of the compressed DT shell were obtained close to stagnation

Shot 70535 cryo target

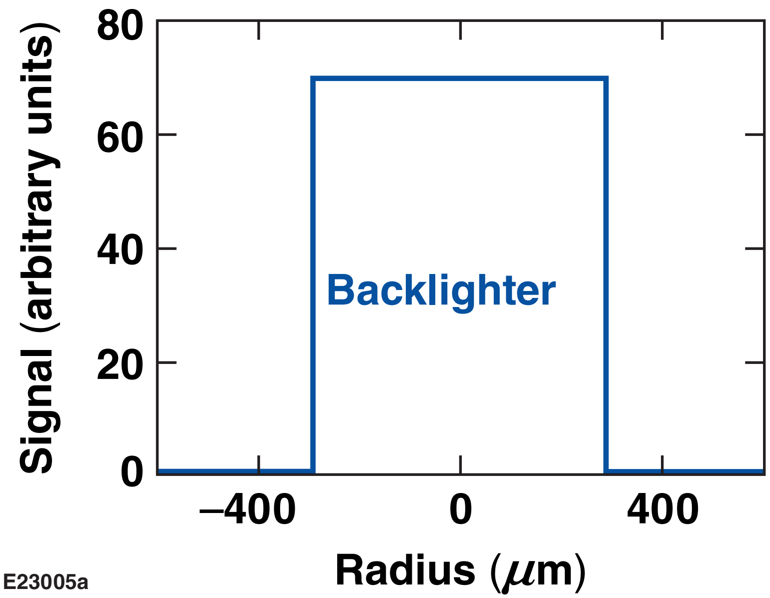


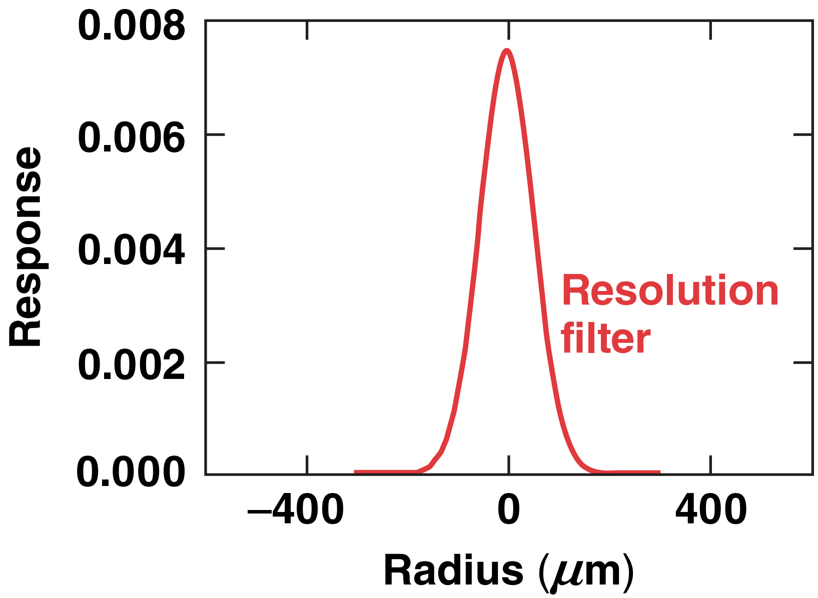

- The adiabat of the implosion was calculated to be 2.5
- The calculated areal density at 3.4 ns is ~14 mg/cm$^2$

# The lineouts from the spherical crystal imager (SCI) backlit images must be corrected for the backlighter shape




- The backlighter is assumed to be uniform
- It is convolved with a Gaussian representing the geometric resolution of the imager
- The width and amplitude of the backlighter is adjusted to match the signal

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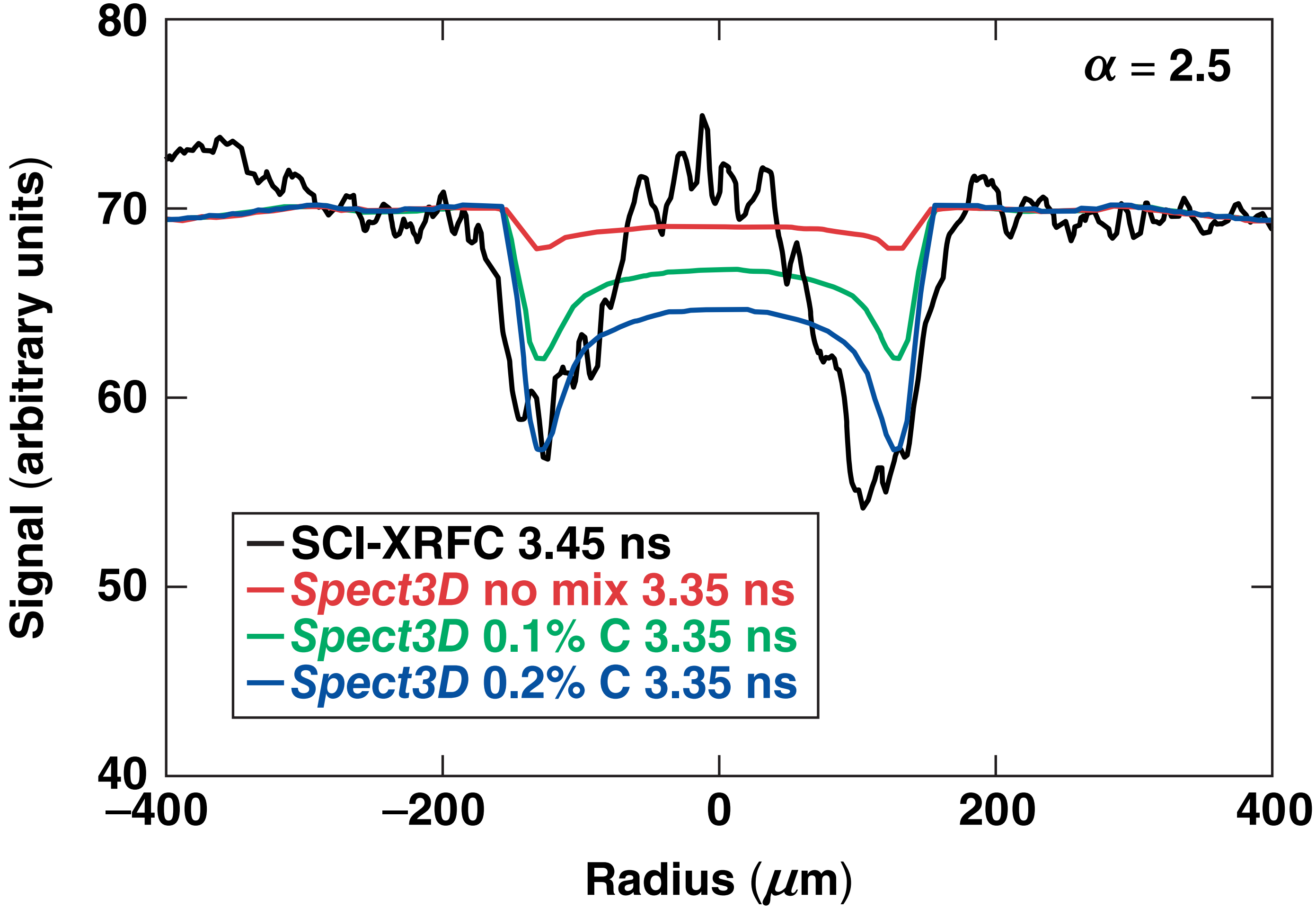
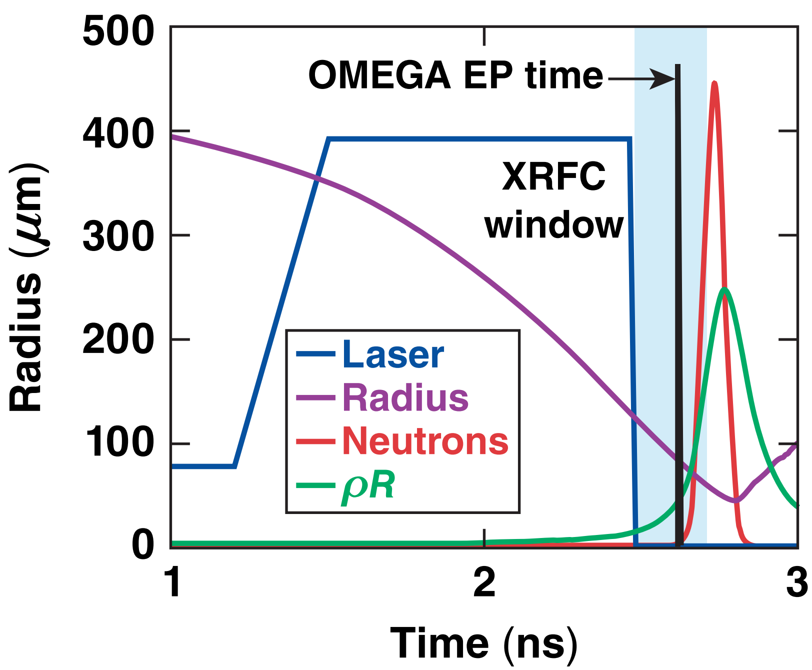
# Simulations assuming mixing of carbon into the DT shell can reproduce the measured absorption

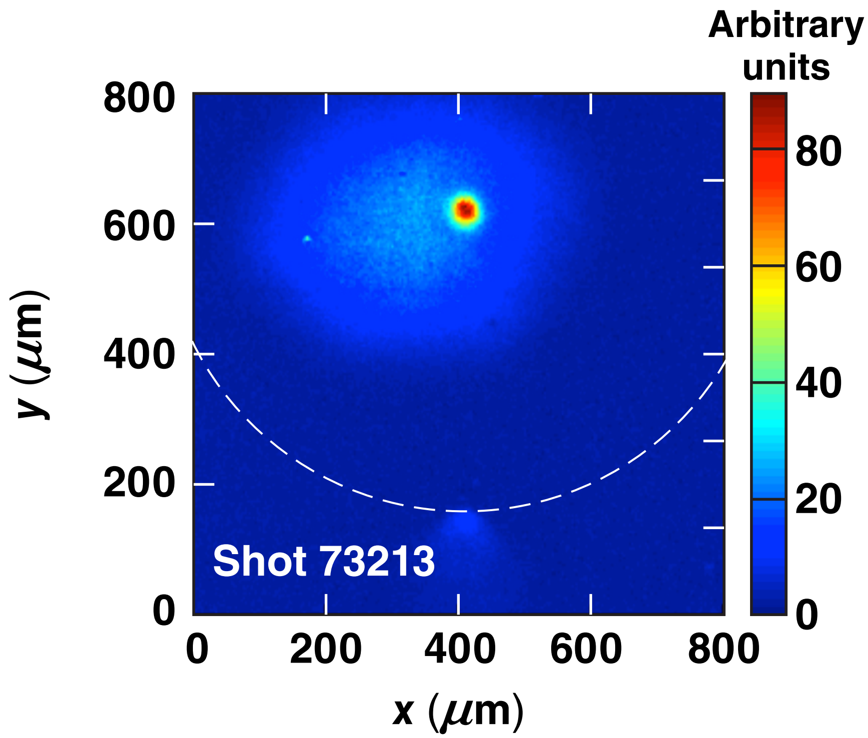



- The carbon is uniformly mixed into the DT shell

E23006d

# A backlit image of a higher-adiabat DT cryo implosion closer to peak compression was obtained




- The adiabat of the implosion was calculated to be 4.3
- The calculated areal density at 2.7 ns is ~40 mg/cm$^2$

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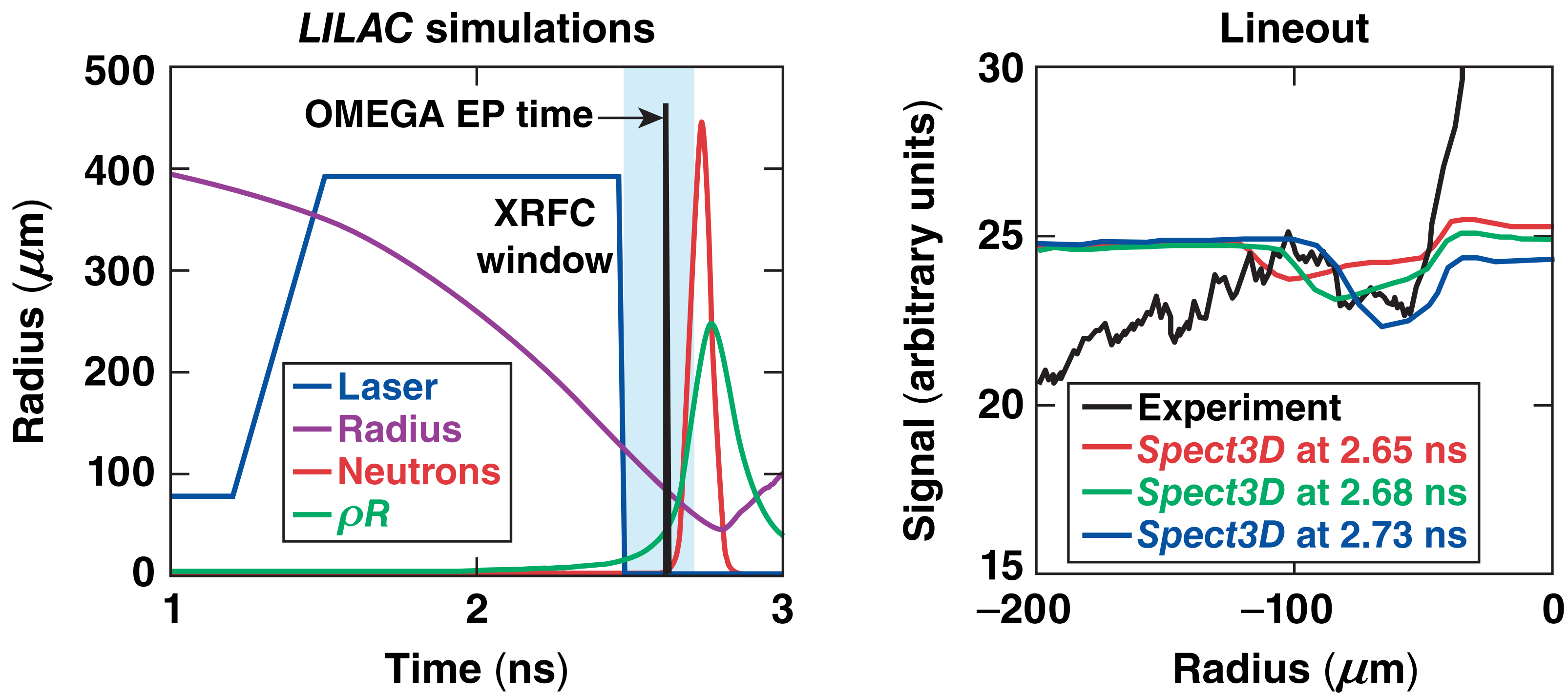
# The measured absorption compares well with the post-processed *LILAC* simulations

Shot 73213 cryo target, $\alpha = 4.3$




- The 1-D calculated areal density at 2.7 ns is 40 mg/cm$^2$
- No indication of enhanced absorption caused by mixing is observed

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Summary/Conclusions

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