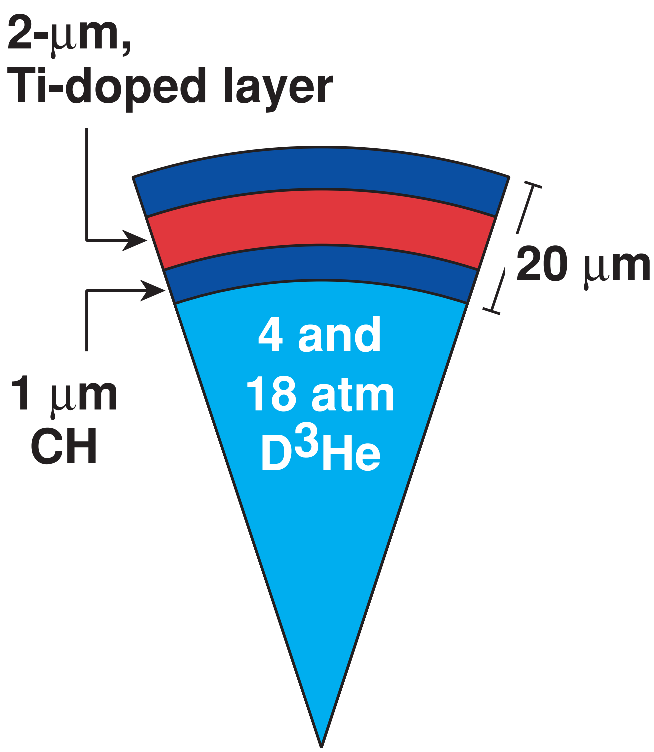
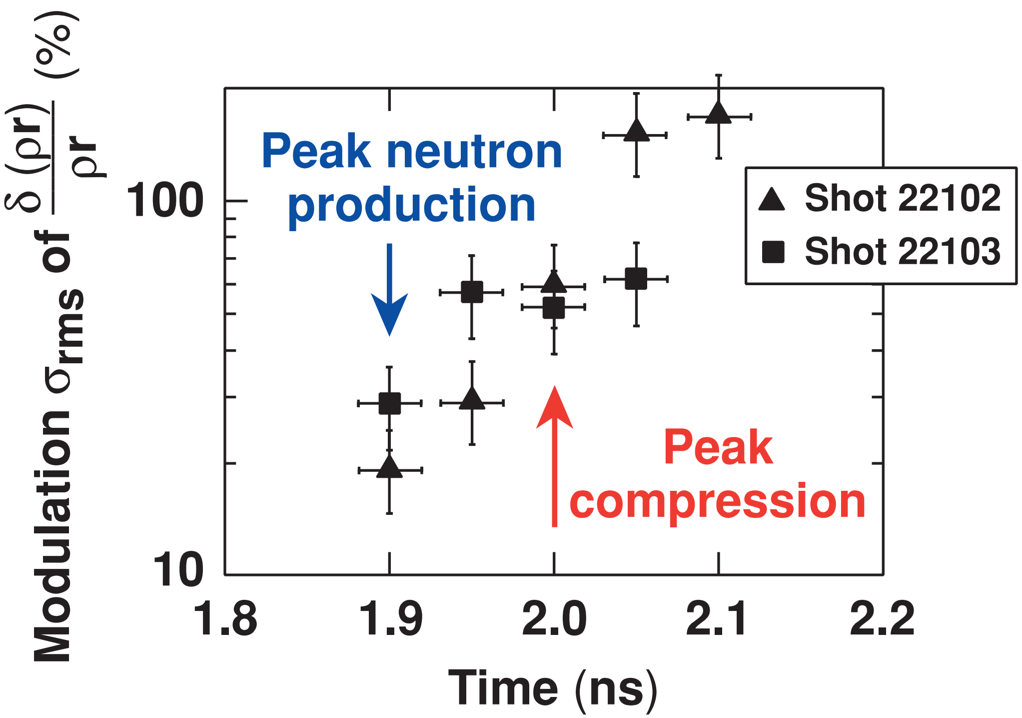
Hydrodynamic Growth of Shell Modulations in the Deceleration Phase of Spherical Direct-Drive Implosions





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Summary

Shell modulation growth has been measured near peak compression of spherical implosions

- 20-μm-thick CH shells with CH Ti layers, filled with 4 and 18 atm D^3He, were imploded with ~ 23-kJ, 1-ns square laser pulses.

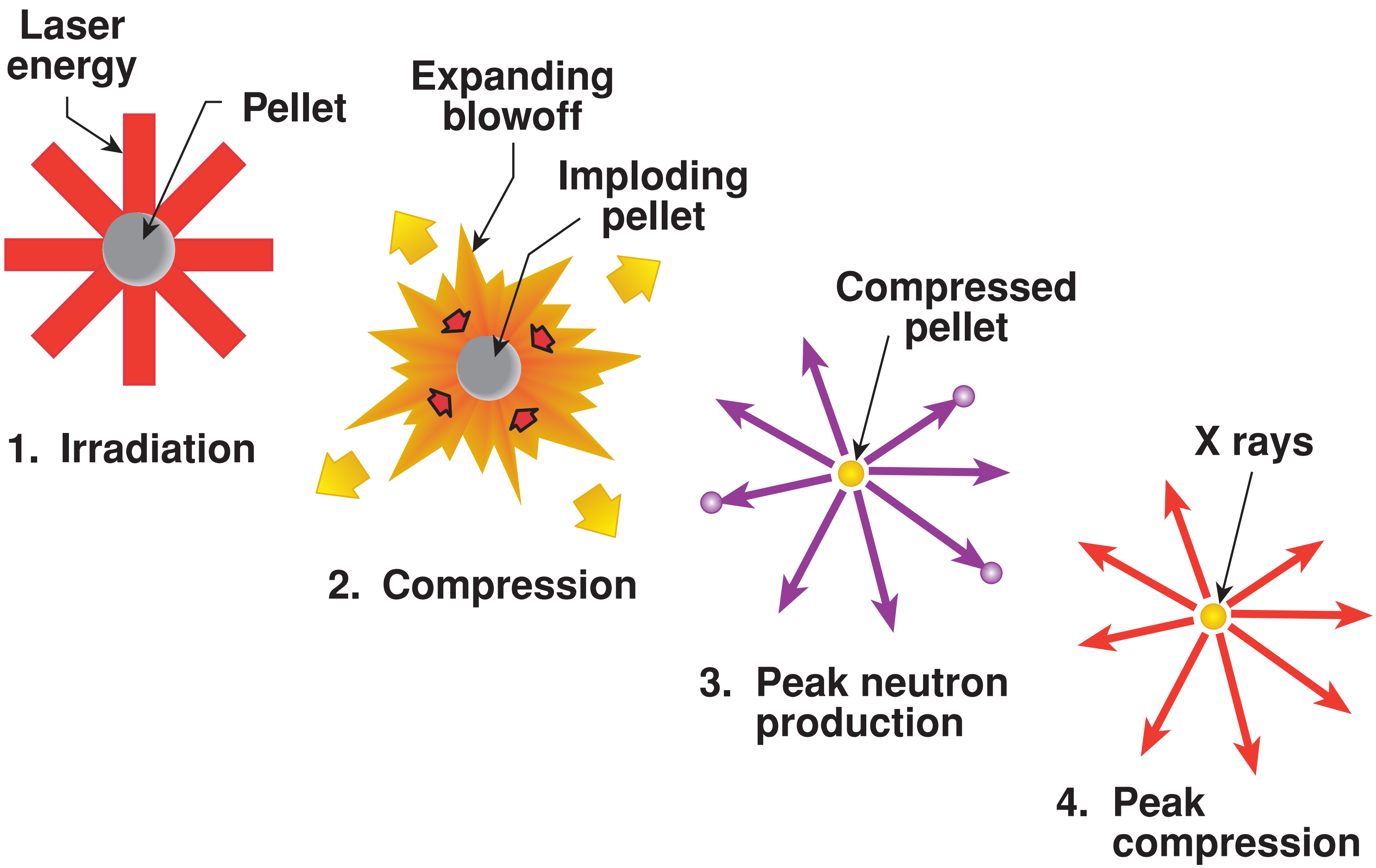
- Measured perturbations have highest amplitudes at wavelengths of about 40 to 50 μm (corresponding to mode number $\ell \sim 6$).

- At peak neutron production, inner-shell areal-density modulation level, $\delta(\rho r)/\rho r$, is 20% and grows to ~ 50% at peak compression 100 ps later due to Rayleigh–Taylor instability.

- For the same period, shell modulations grow up to about 1.5 times due to Bell–Plesset effects.

- At peak compression the inner part of the shell has a higher modulation level than the bulk of the shell.

Laser-induced ablation is used to generate ultra-high pressures on a fusion capsule to compress it



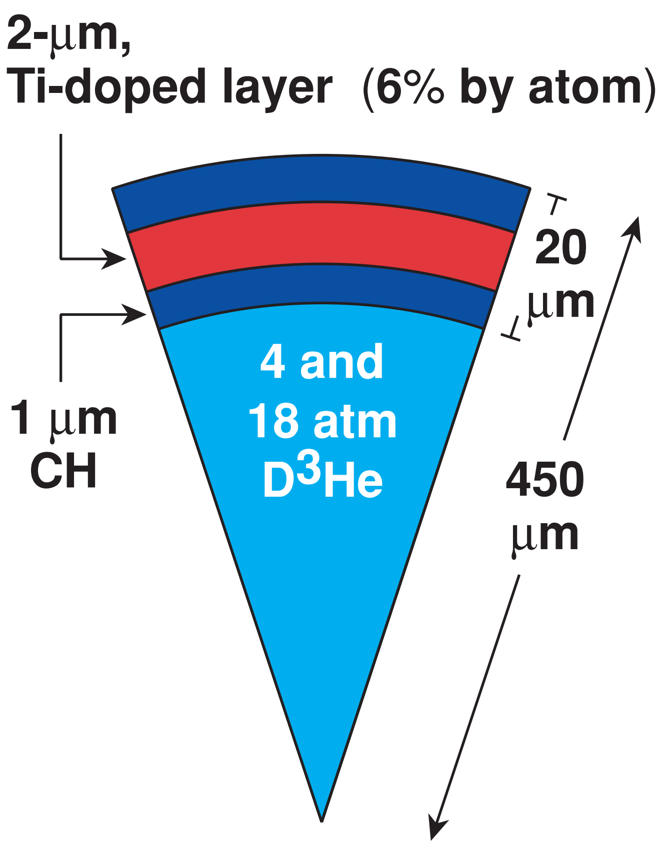
S5c

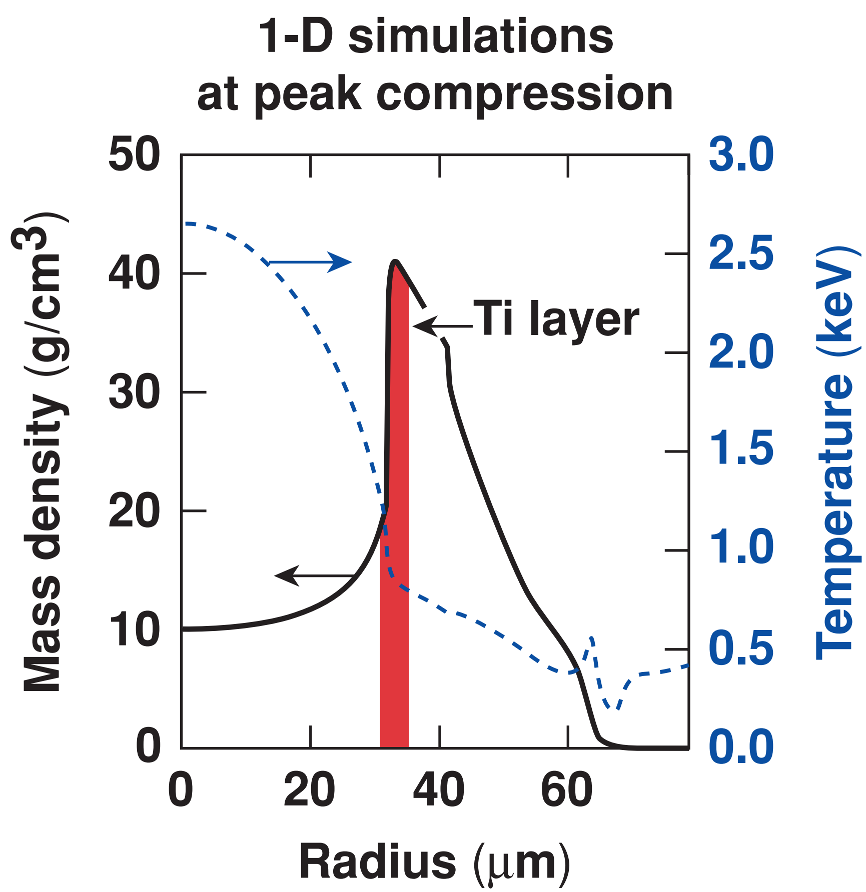
Related talks

BO2.001	R. Epstein *et al*., Modeling of Fuel–Pusher Mix Effects in 1-D Simulations of Cryogenic, All-DT Ignition Capsule Implosions
BO2.002	S. P. Regan *et al*., Experimental Investigation of Fuel–Pusher Mix in Direct-Drive Implosions on OMEGA
BO3.003	J. A. Frenje *et al*., Effects of Fuel–Pusher Mix on Direct-Drive Implosions of ^{3}He-Gas-Filled, CD-Layered Plastic Capsules on OMEGA
FO2.001	P. B. Rahda *et al*., The Effect of Laser Nonuniformities on Plastic-Shell Direct-Drive Implosions on OMEGA
RI1.005	C. K. Li *et al*., Capsule Areal-Density Asymmetrics and Time Evolution Inferred from 14.7-MeV Proton Line Structure in OMEGA D^{3}He Implosions

E12038

Targets with titanium-doped layers were used to measure shell modulations

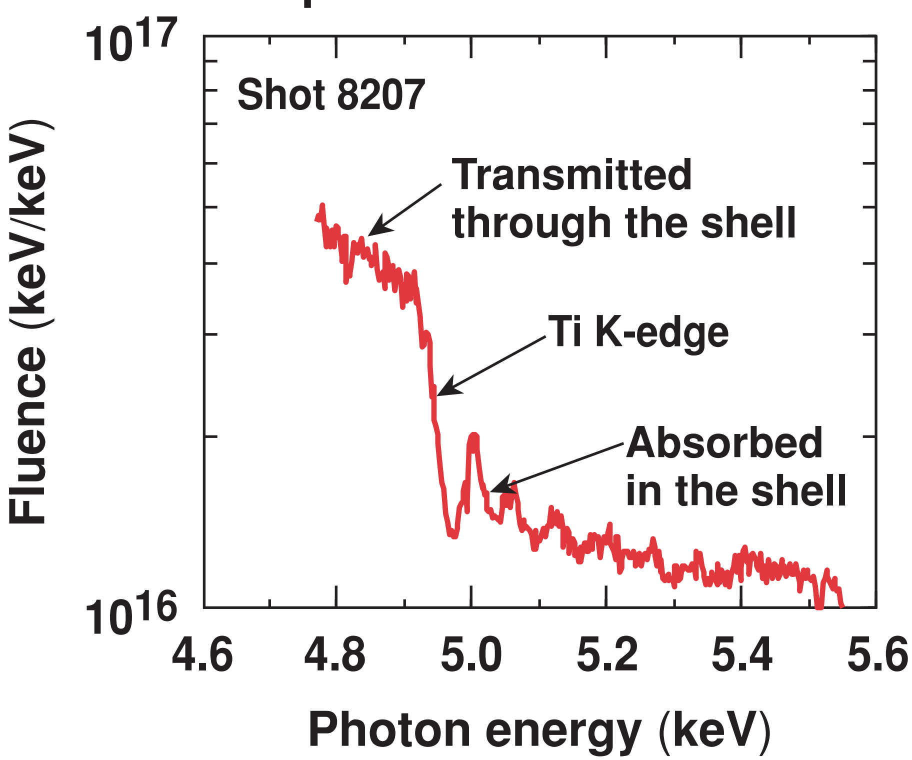


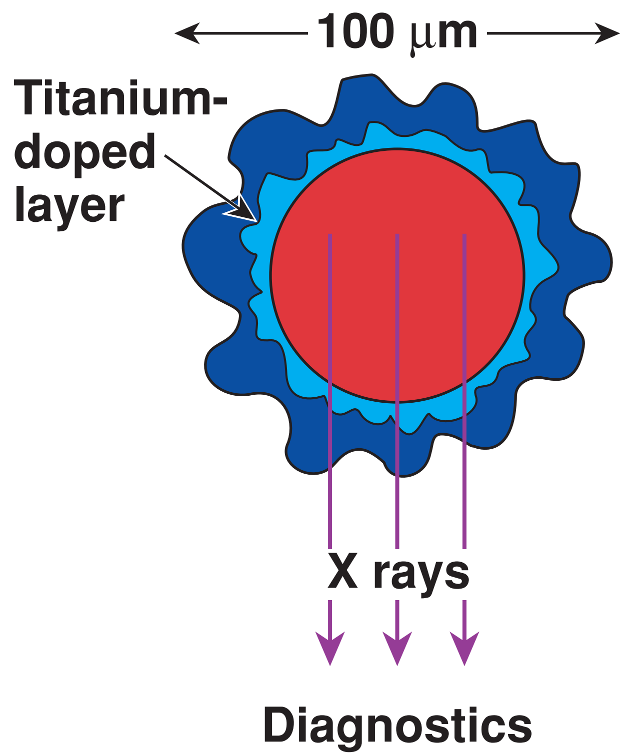


E11885

Core images at two x-ray energies, highly absorbed and nonabsorbed by the shell, are used to measure the integrity of the inner portion of the shell

Spectrum from the core





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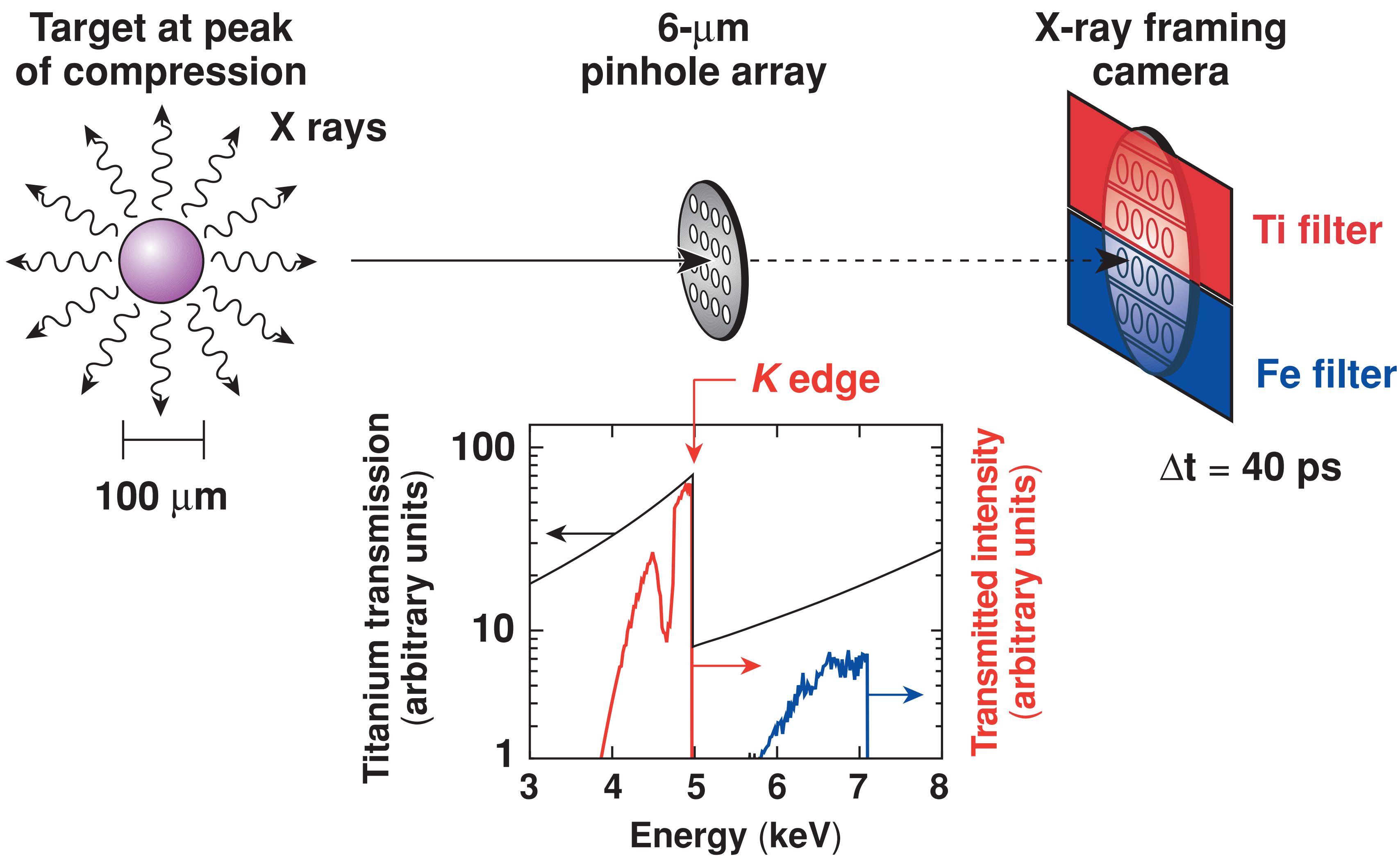
Shell-Integrity Measurements

X-ray framing cameras are the primary diagnostics of shell nonuniformity*



E10409b

* V. A. Smalyuk *et al.*, Rev. Sci. Instrum. 72, 635 (2001).

The ratio of images above and below the *K* edge is related to areal-density modulations in the shell*

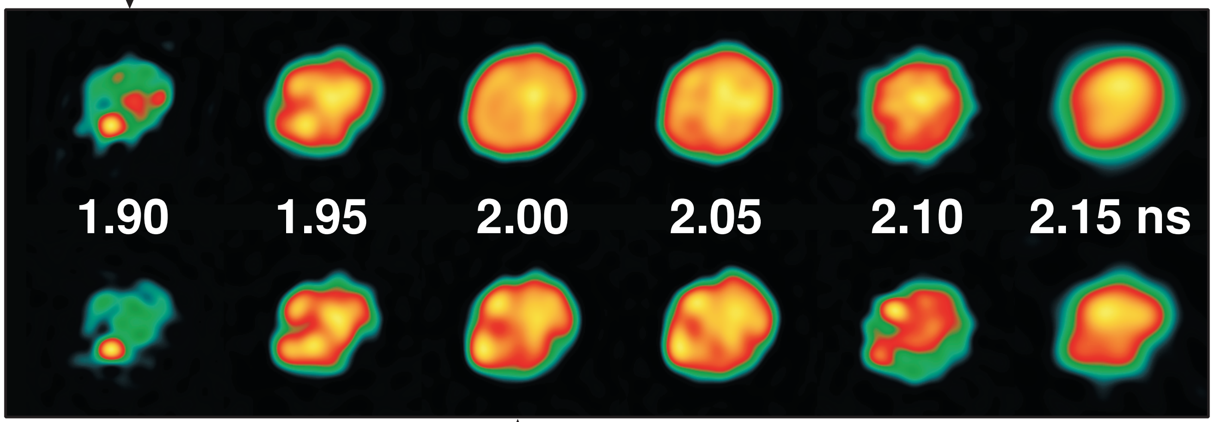
UR LLE

Peak neutron production

Shot 22102, 4 atm D^3He, 20-μm shell

$I_{<K}$, below *K* edge

$I_{>K}$, above *K* edge



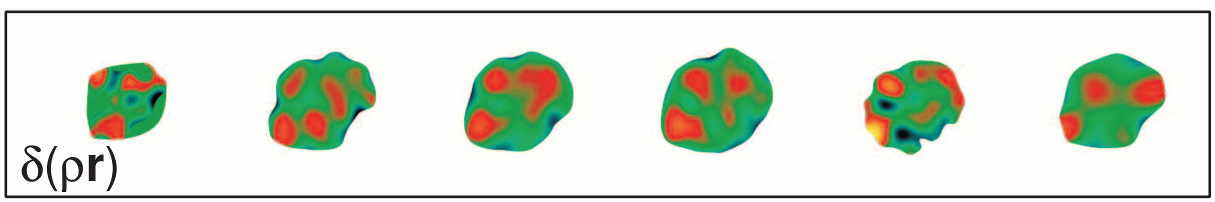
50 μm

Peak compression

$$\delta(\rho \mathbf{r}) = \frac{\delta\left\{\ell \mathbf{n}\left(\frac{I_{<K}}{I_{>K}}\right)\right\}}{\mu_{>K} - \mu_{<K}}$$

$\mu_{>K}$, $\mu_{<K}$: titanium absorption rates above and below the *K* edge

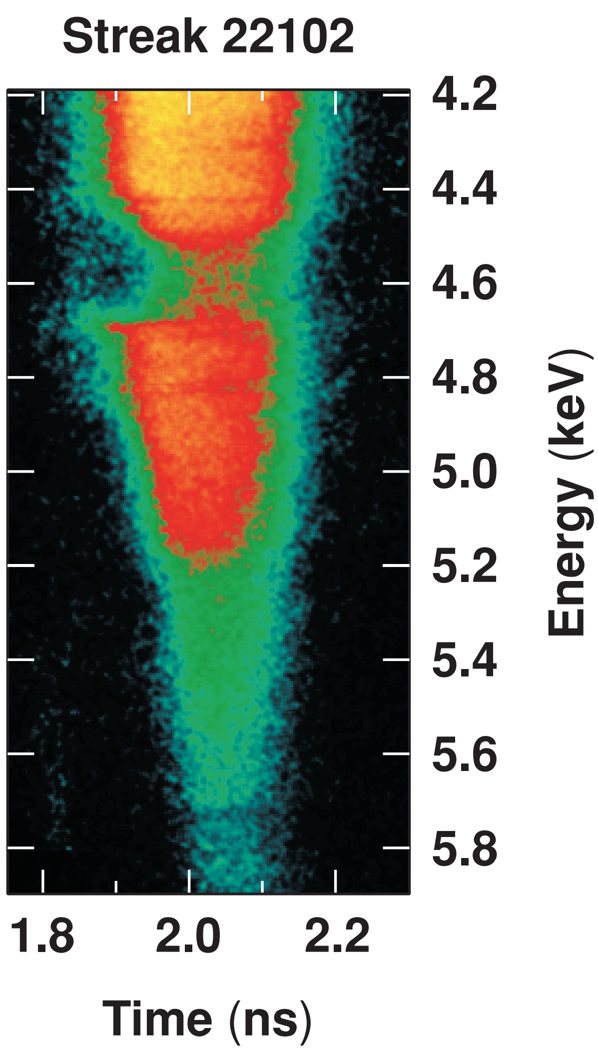
50 μm

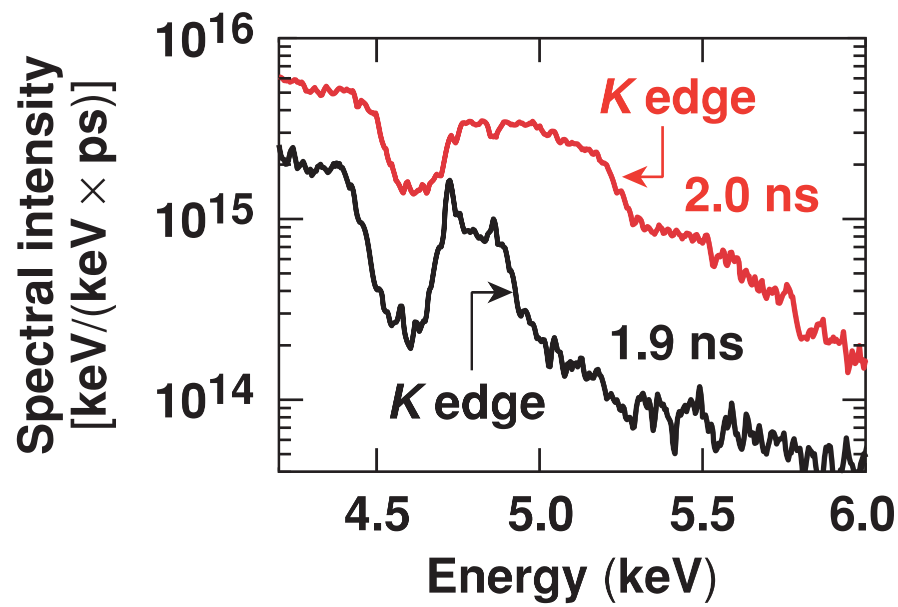


E11234b

* V. A. Smalyuk *et al.*, Phys. Rev. Lett. 87, 155002 (2001).

Evolution of average titanium areal density is measured using streaked spectrometers





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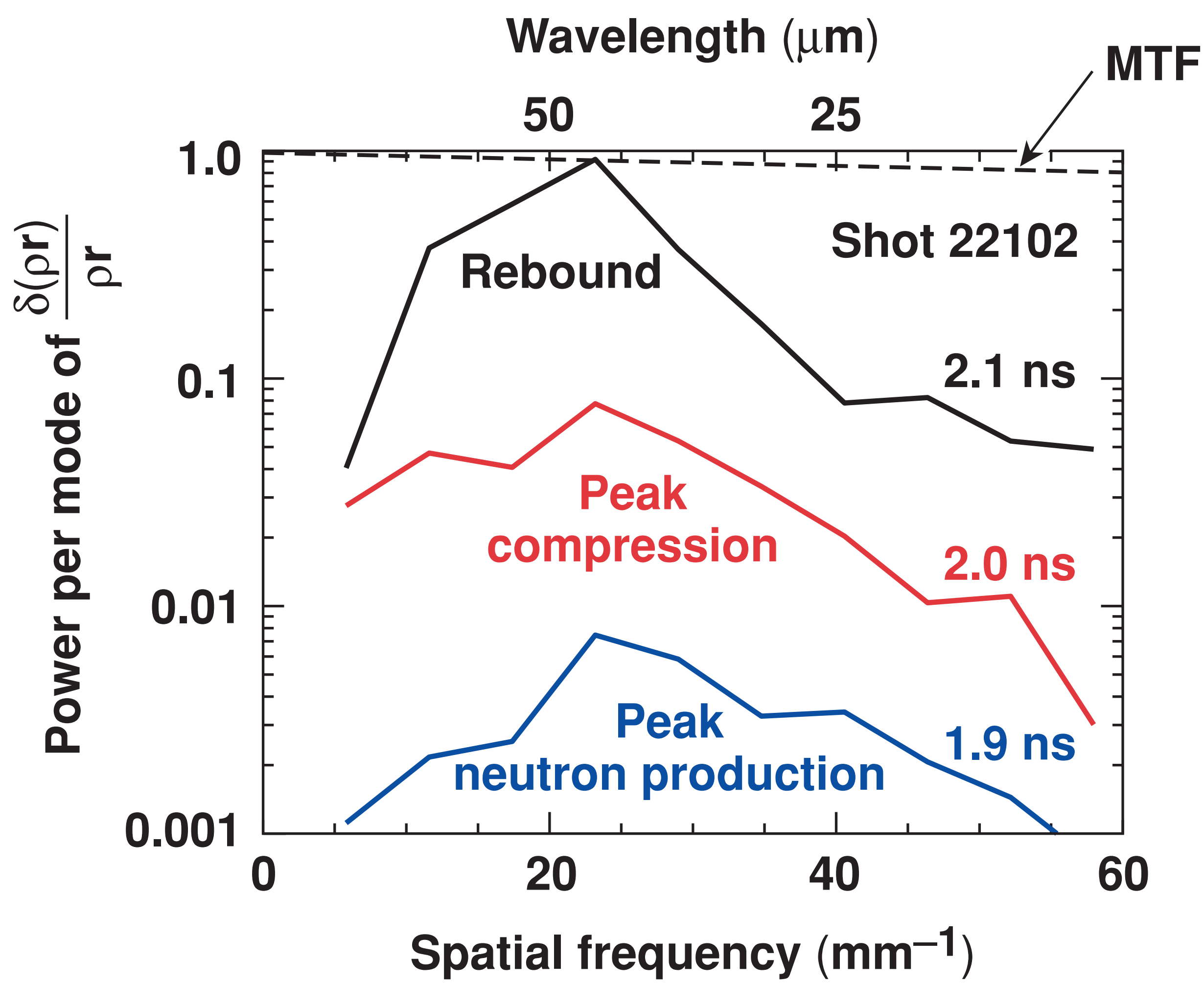
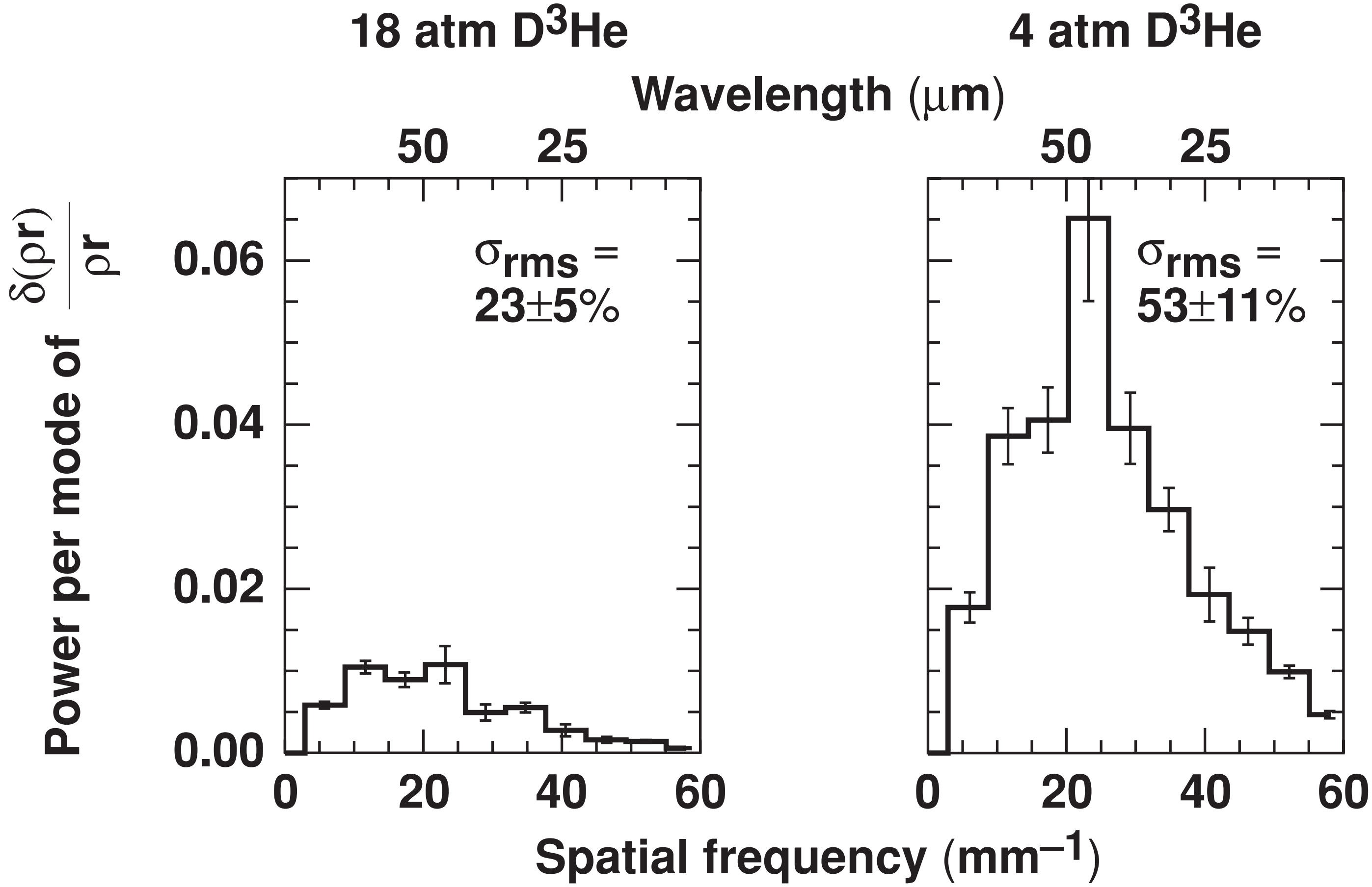
Inner-shell modulations grow throughout the implosion's deceleration phase



- The spectrum peaks at ℓ-mode ~6

E11237

At peak compression more-unstable implosions have a higher level of inner-shell of modulations*



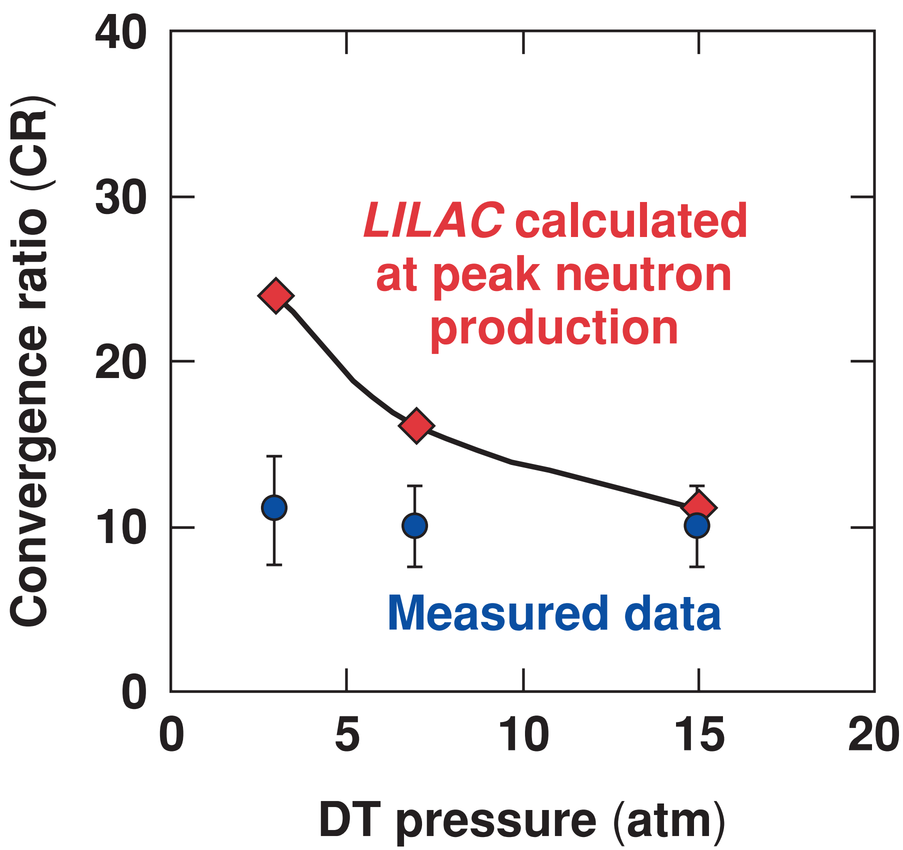
Calculated convergence ratio = 15

Calculated convergence ratio = 42

* V. A. Smalyuk *et al.*, Phys. Plasmas 9, 2741 (2002).

E11886

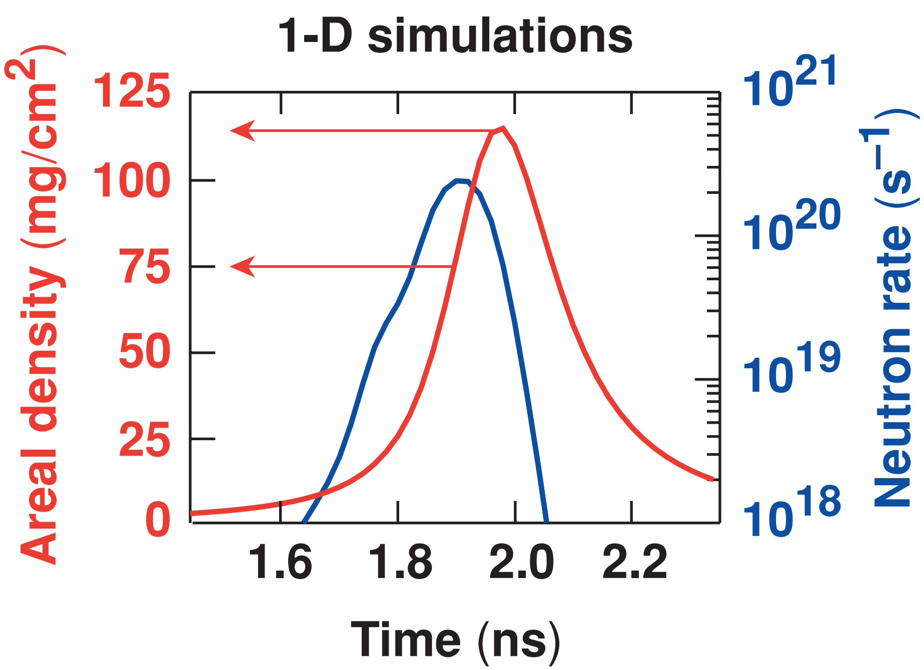
Measured target convergencies are similar for implosions with 3 and 15 atm of DT



E11125a

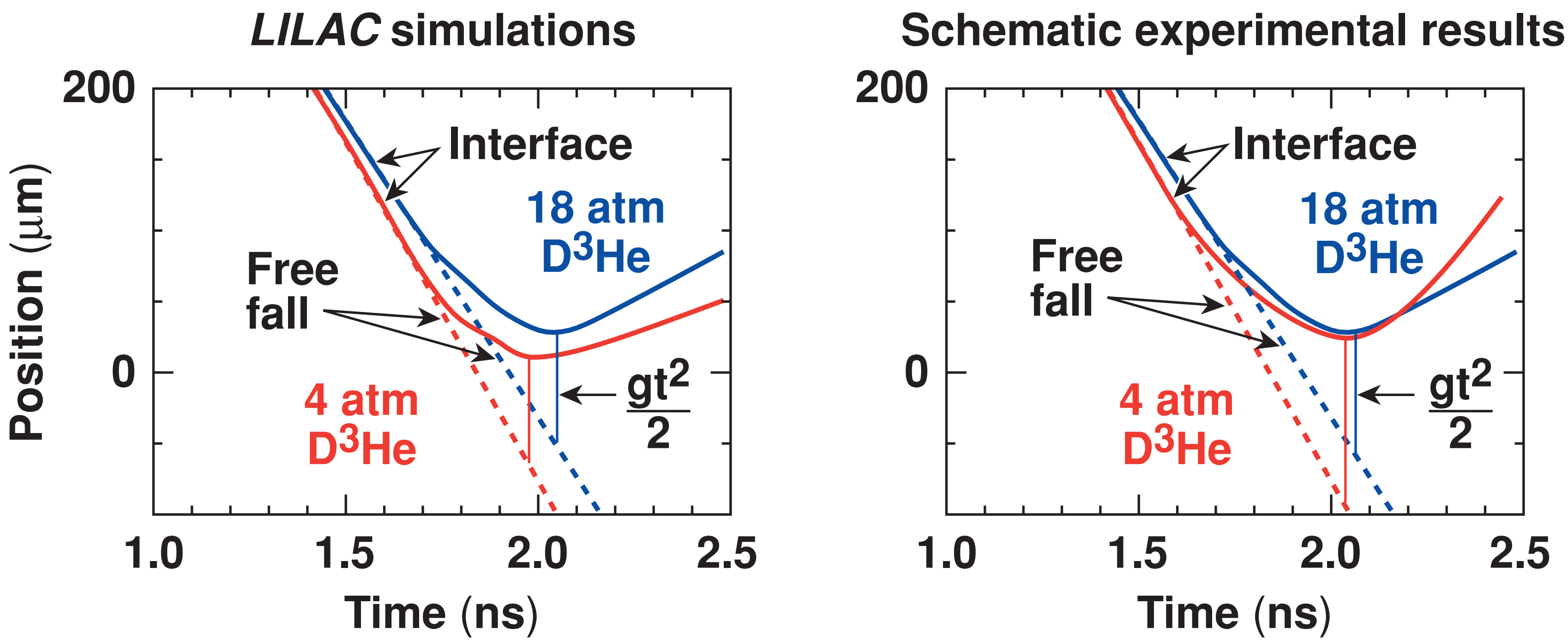
* C. K. Li *et al*. Phys. Rev. Lett. 89, 165002-1 (2002).

The target areal density grows by a factor of 1.5 from time of peak neutron production (~1.9 ns) to time of peak compression (~2.0 ns)



- Shell modulation due to Bell-Plesset (BP) convergent growth is proportional to shell thickness: $\delta r \sim d$.
- Measured shell integrity growth $\delta\rho r/\rho d$ does not include Bell-Plesset effects.
- Areal density ρd increases 1.5 times for 100 ps due to both thickness *d* and density ρ; therefore Bell-Plesset growth is up to 1.5 times for 100 ps.

Targets with 18 atm are more stable than targets with 4 atm D^3He in the deceleration phase of spherical implosions



Classical Rayleigh–Taylor growth factor

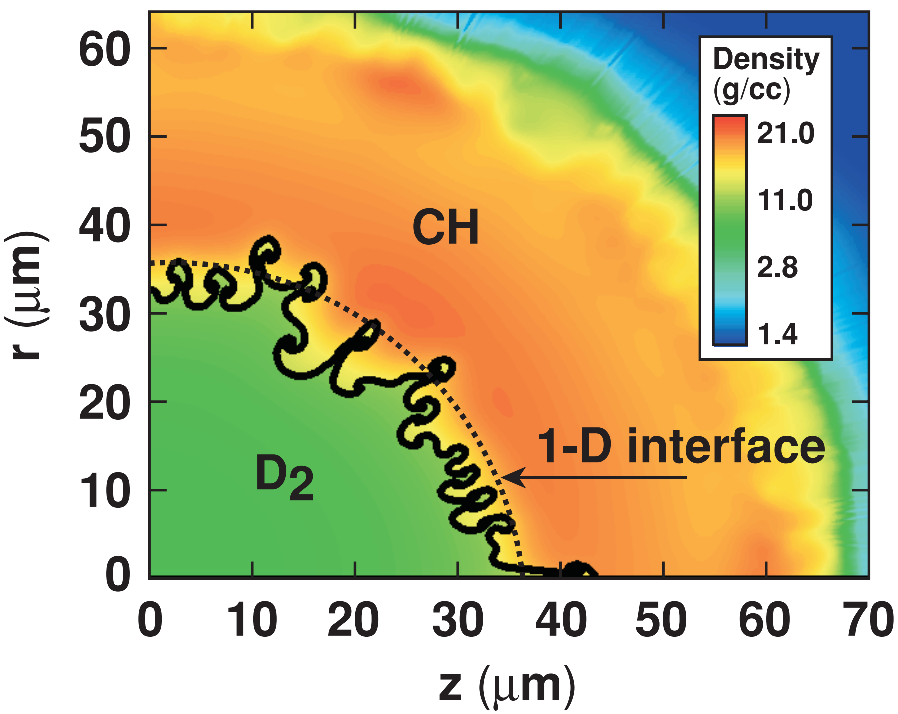
$$GF = \exp\left[\sqrt{A_T \frac{\ell g t^2}{R}}\right], \text{ where}$$

ℓ – mode number, g – acceleration, R – inner surface radius, t – time, and A_T – Atwood number.

E11881

Small-scale perturbations are in their nonlinear phase during deceleration

20-μm-CH shell; 15-atm-fill laser imprint at peak neutron production
ℓ = 2–80

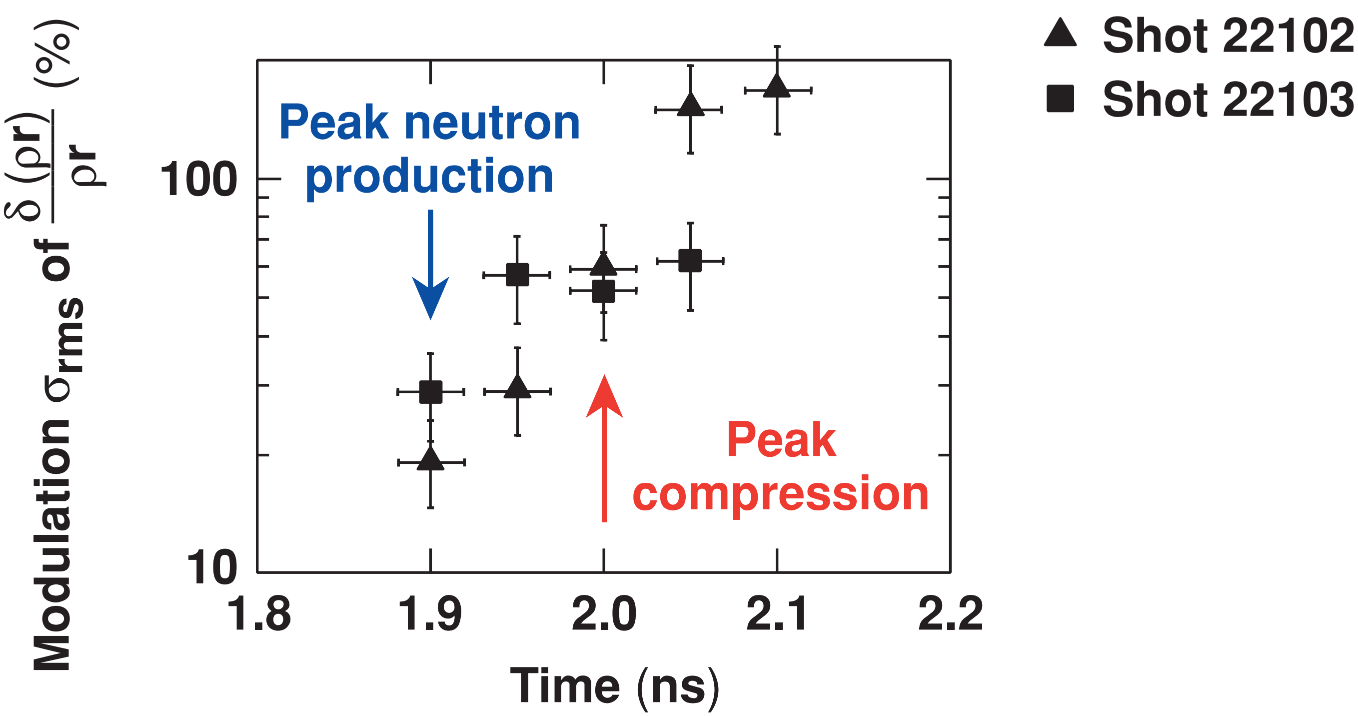


- **Fuel–shell mix has been measured with neutron, particle, and spectroscopic diagnosis.**

D. D. Meyerhofer *et al.*, Phys. Plasmas 8, 2251 (2001).
P. B. Radha *et al.*, Phys. Plasmas 9, 2208 (2002).
S. P. Regan *et al.*, Phys. Rev. Lett. 89, 085003-1 (2002).
C. K. Li *et al.*, Phys. Rev. Lett. 89, 165002-1 (2002).

TC6026a

Inner-shell modulation grows from 20% at peak neutron production to 50% at peak compression for ~ 100 ps due to Rayleigh–Taylor instability.



- In addition, the shell modulations grow by up to a factor of ~ 1.5 due to Bell-Plesset effects.

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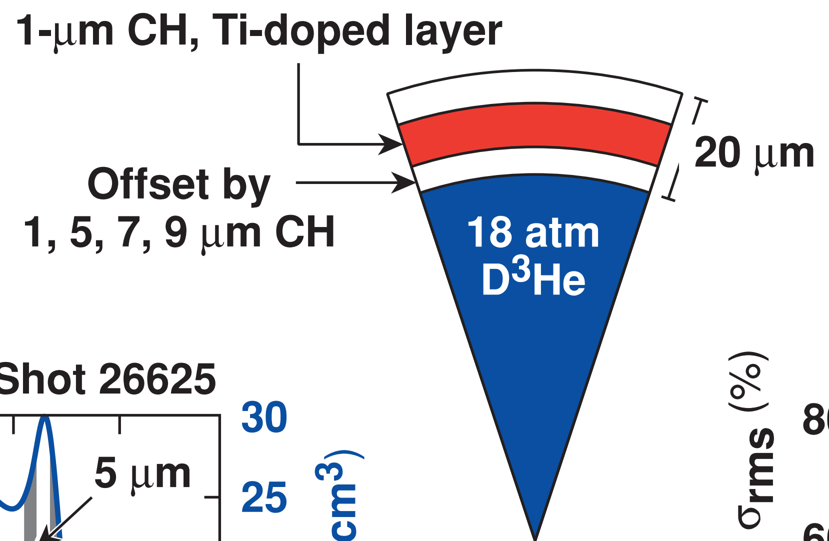
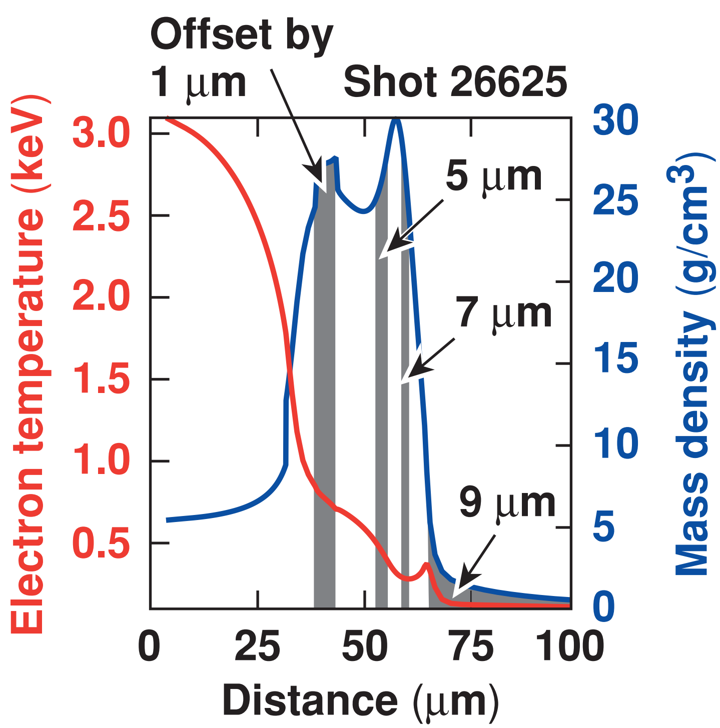
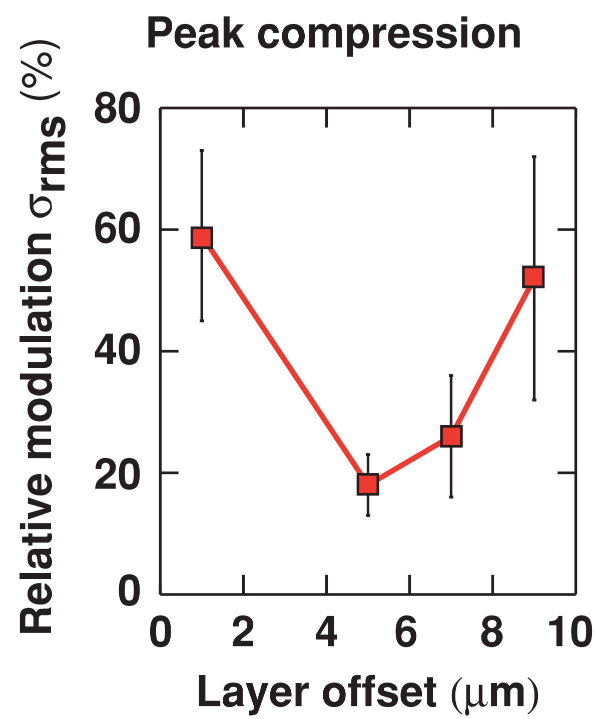
The central part of the shell is more uniform than the inner and outer surfaces*







* V. A. Smalyuk *et al.*, submitted to Phys. of Plasmas (2002).

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Future Work

Future work will combine time-resolved shell areal-density with fuel–shell mix measurements

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- Differential imaging with titanium 1s–2p absorption will provide much more sensitive shell-integrity $\delta(\rho r)/\rho r$ measurements.
- Absorption spectroscopy of titanium 1s–2p region will provide shell-density, temperature, and areal-density measurements.
- Time-resolved fuel–shell mix measurements will be performed using CD shells filled with T_2 fuel.
- Time-resolved spectroscopic measurements of mix will be performed with Cl dopants in the shell and Ar dopants in the fuel.

Summary/Conclusion

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UR LLE

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