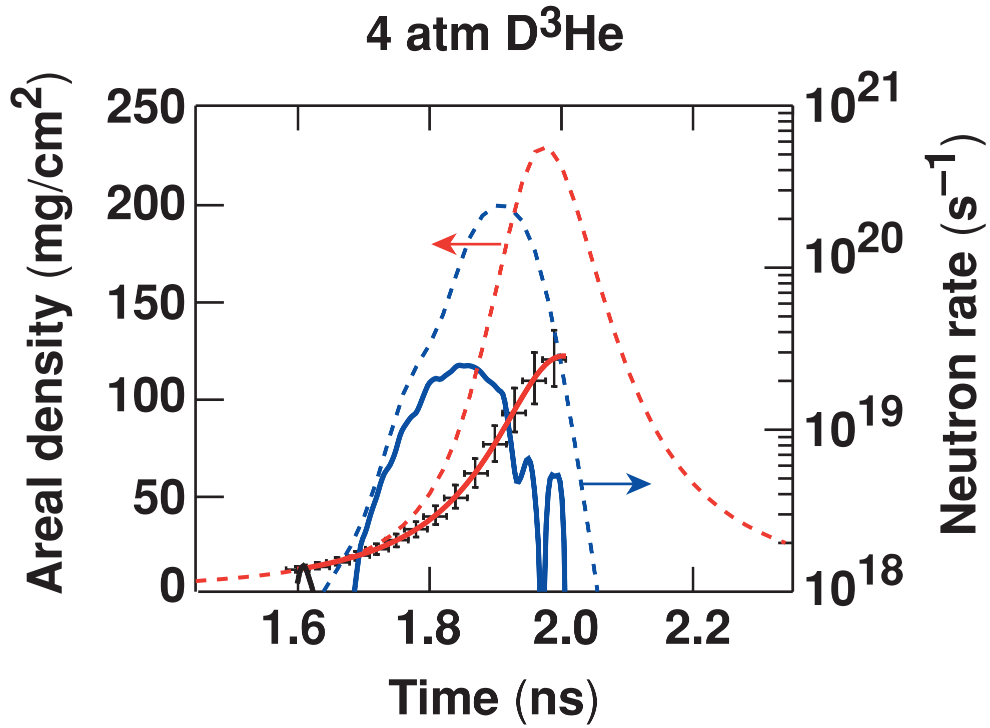
Areal-Density-Growth Measurements with Proton Spectroscopy on OMEGA



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32nd Anomalous Absorption Conference
Oahu, Hawaii
21–26 July 2002

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Summary

Areal density grows by ~8 times over time of neutron production (~400 ps) in implosions with 20-μm-thick shells and 4 atm D^3He fuel

- Neutron production history and 14.7-MeV proton spectra are used to infer target areal-density growth.
- ~70% of the proton spectral width is due to areal-density evolution.
- ~20% is due to geometrical effects.
- ~10% is due to shell modulations, ion temperatures, and instrumental broadening.
- Areal-density grows by a factor of 8 for 400 ps, reaching 123±16 mg/cm^2 at peak compression.
- For 18 atm fill targets, areal density reaches 109±14 mg/cm^2 at peak compression, close to 1-D predictions.
- For 4 atm fill targets, areal density reaches 123±16 mg/cm^2 at peak compression a factor of 2 lower 1-D predictions.

Outline

- Principle of areal-density-growth measurements using neutron production history and 14.7-MeV proton spectrum
- Geometrical broadening effects on proton spectra
- Short-scale shell modulation effects on proton spectra
- Results

Two types of targets were used in these experiments

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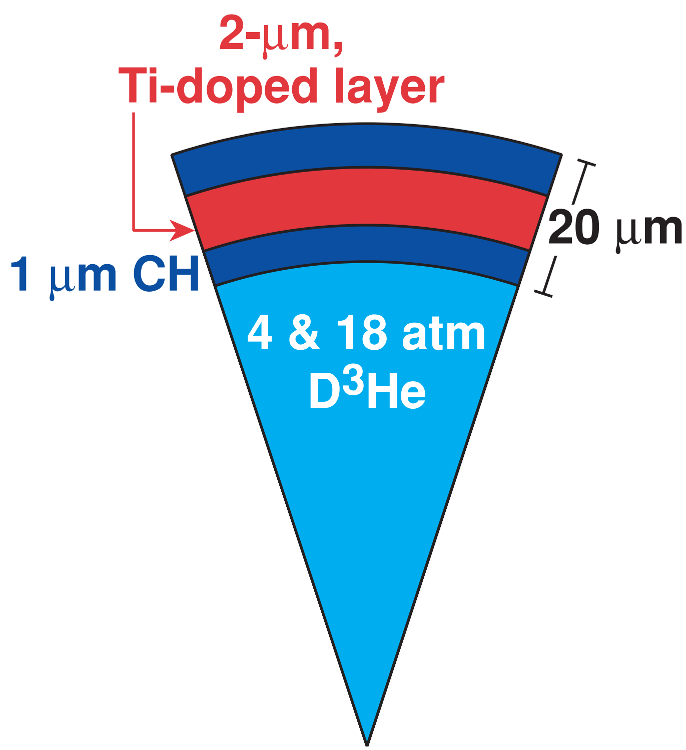

- Pure CH shells are used for areal-density-growth measurements.
- Titanium-doped shells are used for shell-modulation measurements.

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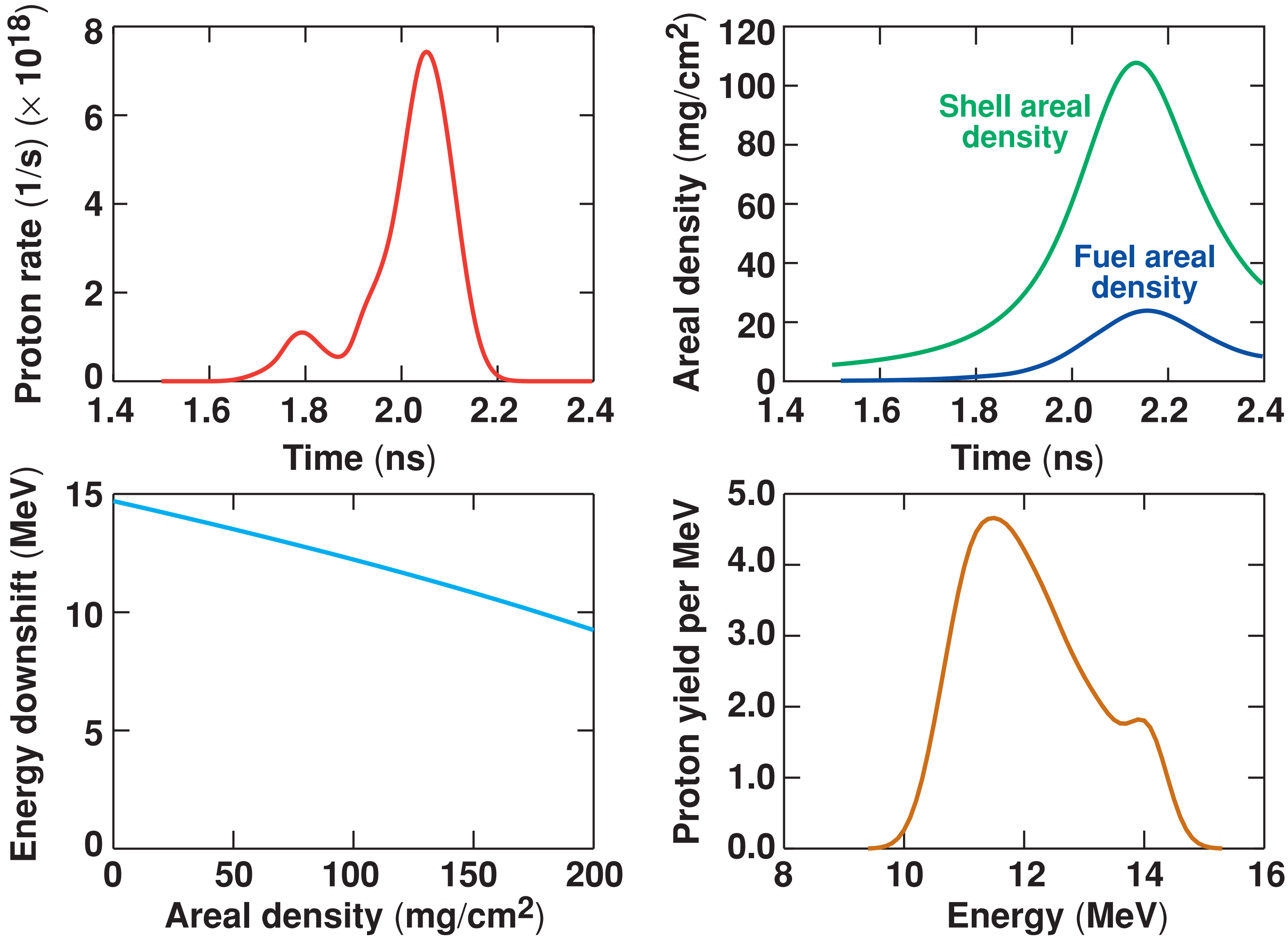
Shape of 14.7-Mev D^{3}He proton spectrum depends on proton-production rate and areal-density evolution



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The shape of the D^3He proton spectrum is primarily due to target areal density evolution in implosions with 20-μm-thick shells

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- ~70% target-areal-density evolution; ~20% geometric broadening; ~10% shell-areal-density modulations with $\ell > 6$; ion temperature and diagnostic broadening

- Assumptions:

  – Bethe-Bloch stopping power in plasma

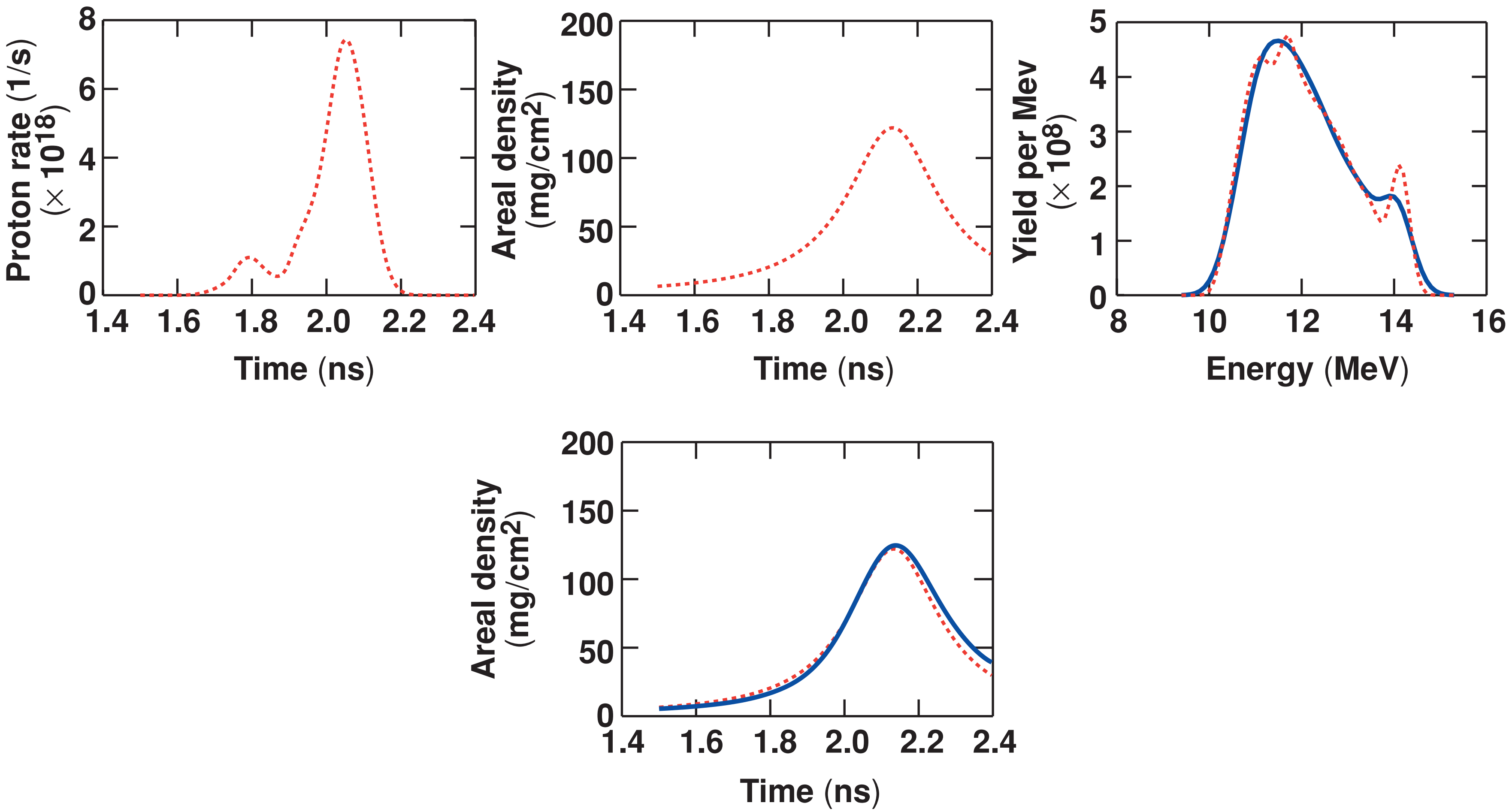
$$-[dE/dx] = [e\,\omega_p / v_p]^2 \quad \ln(1.428 \cdot m\upsilon_p^2 / \hbar\omega_p)$$

  – Proton production history is the same as neutron production history.

  – The effective ion temperature is the same throughout implosions.

  – Geometrical broadening depends primarily on areal density and less on proton source size and shell thickness.

Areal-density evolution is inferred by fitting to measured proton spectrum



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Geometrical broadening of D^3He proton spectrum depends primarily on a target areal density

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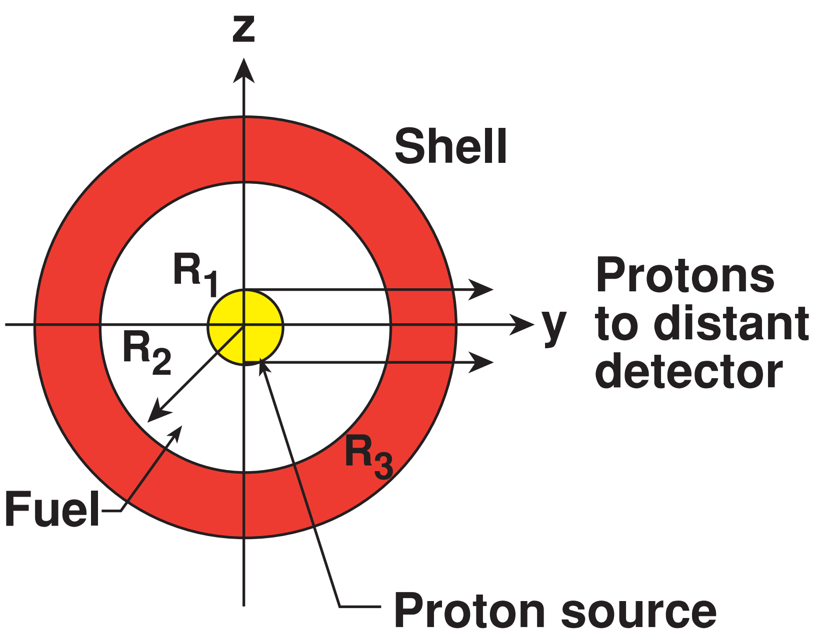

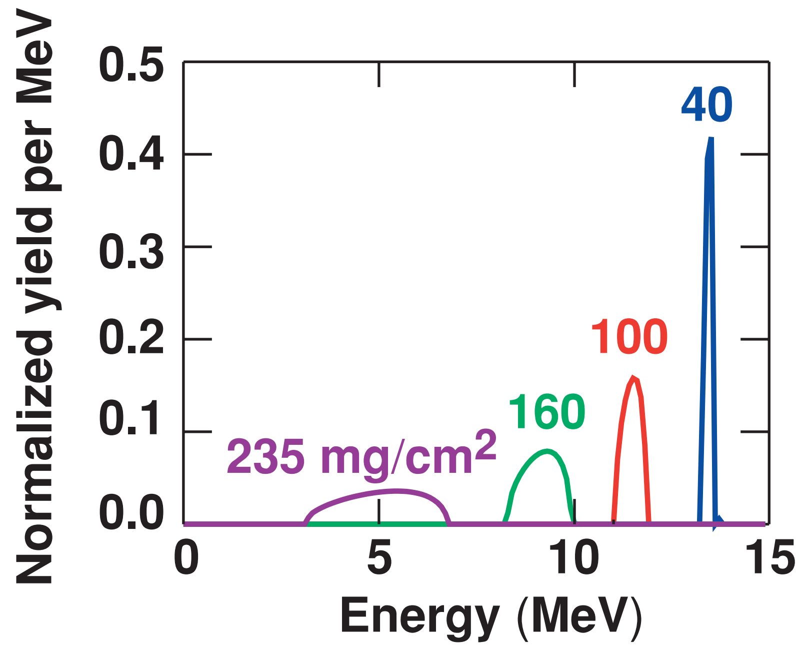

- Parameters R_1 and R_2 are calculated using experimentally measured neutron yield on burn time, fuel areal density, and ion temperature.

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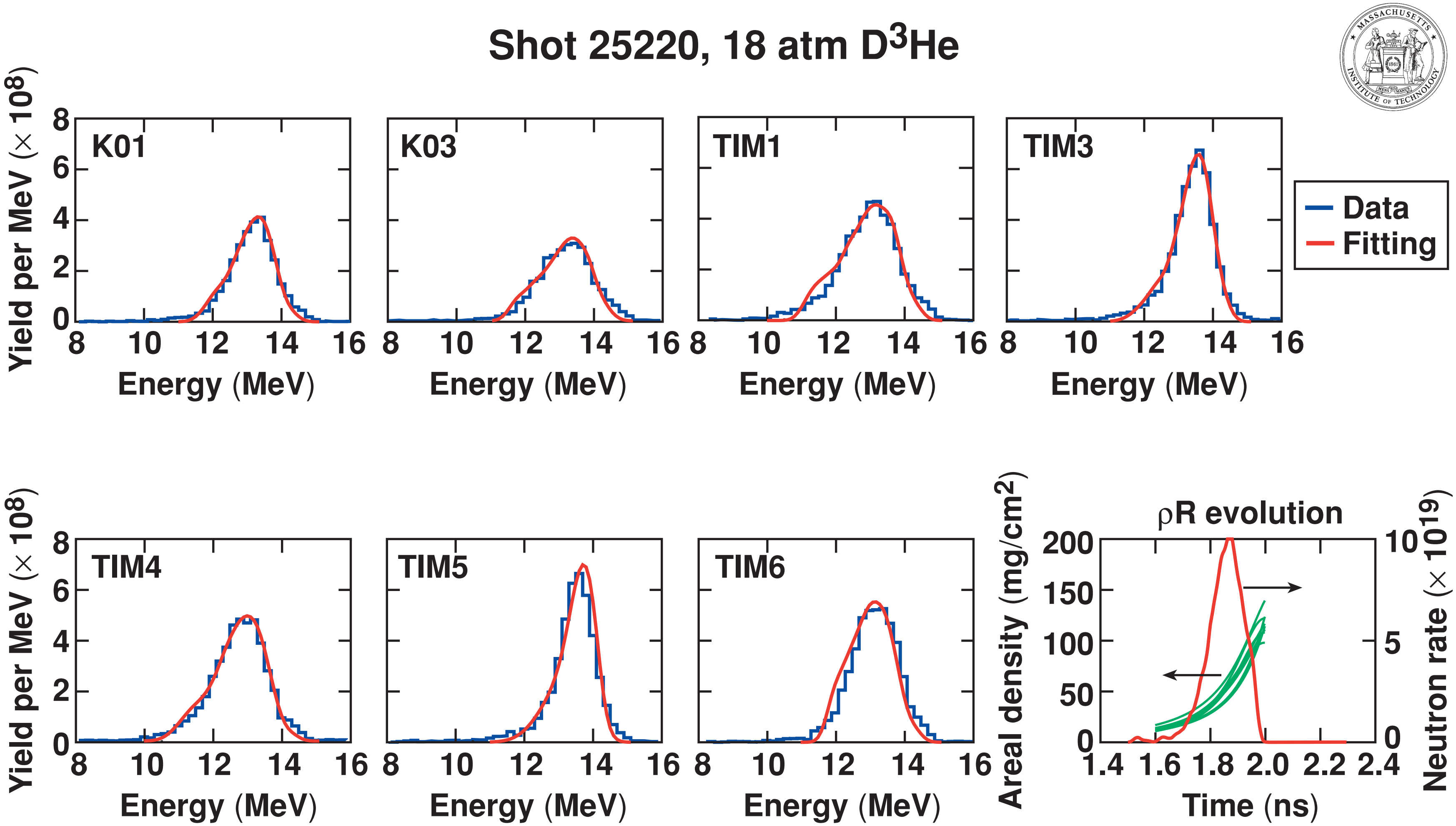
Areal-density evolution is measured in seven directions for approximately uniform coverage of the shell



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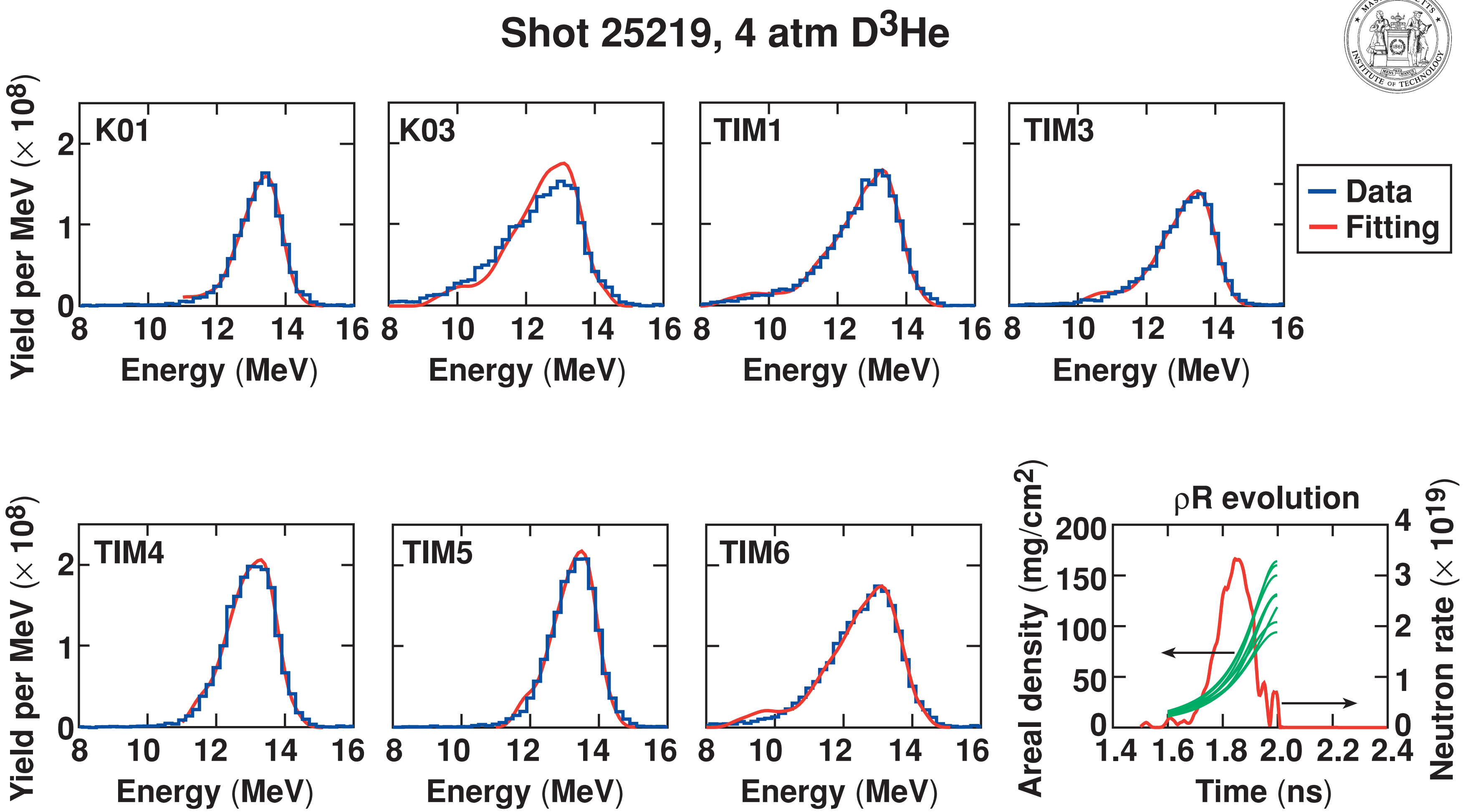
In 4 atm D^3He shot areal density grows by a factor of 8 over time of neutron production (400 ps)



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

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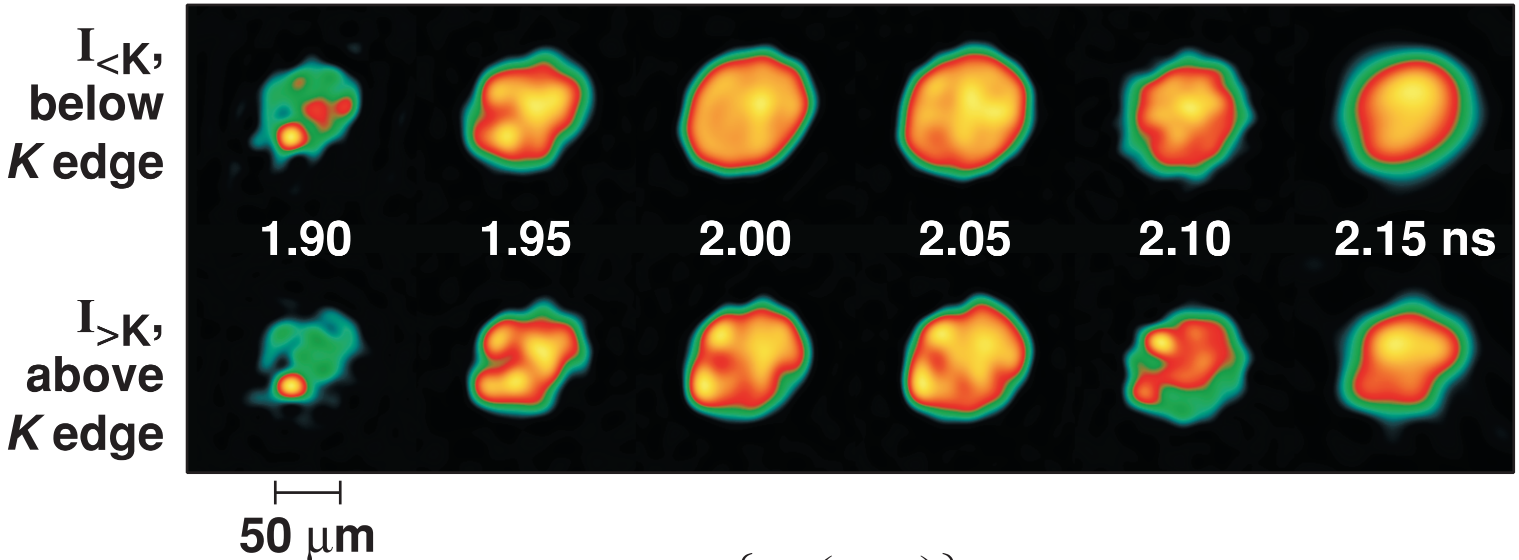
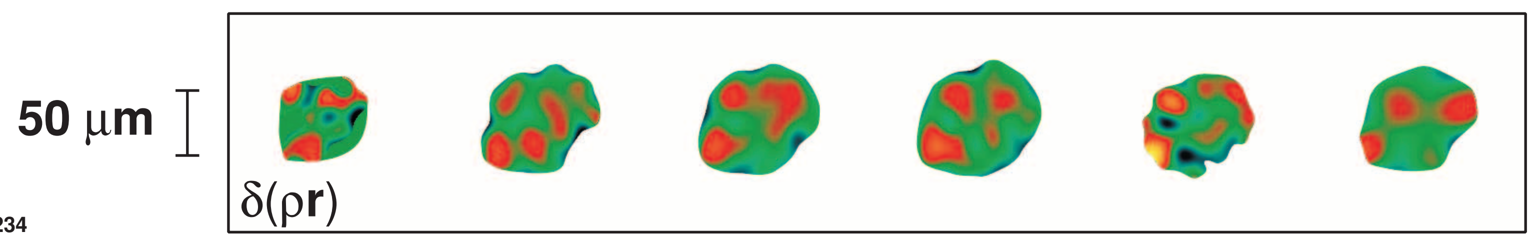
Shot 22102, 4 atm D^3He, 20-µm shell



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

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



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At peak neutron production, areal-density modulations are ~15% at inner layer and ~7% for whole shell

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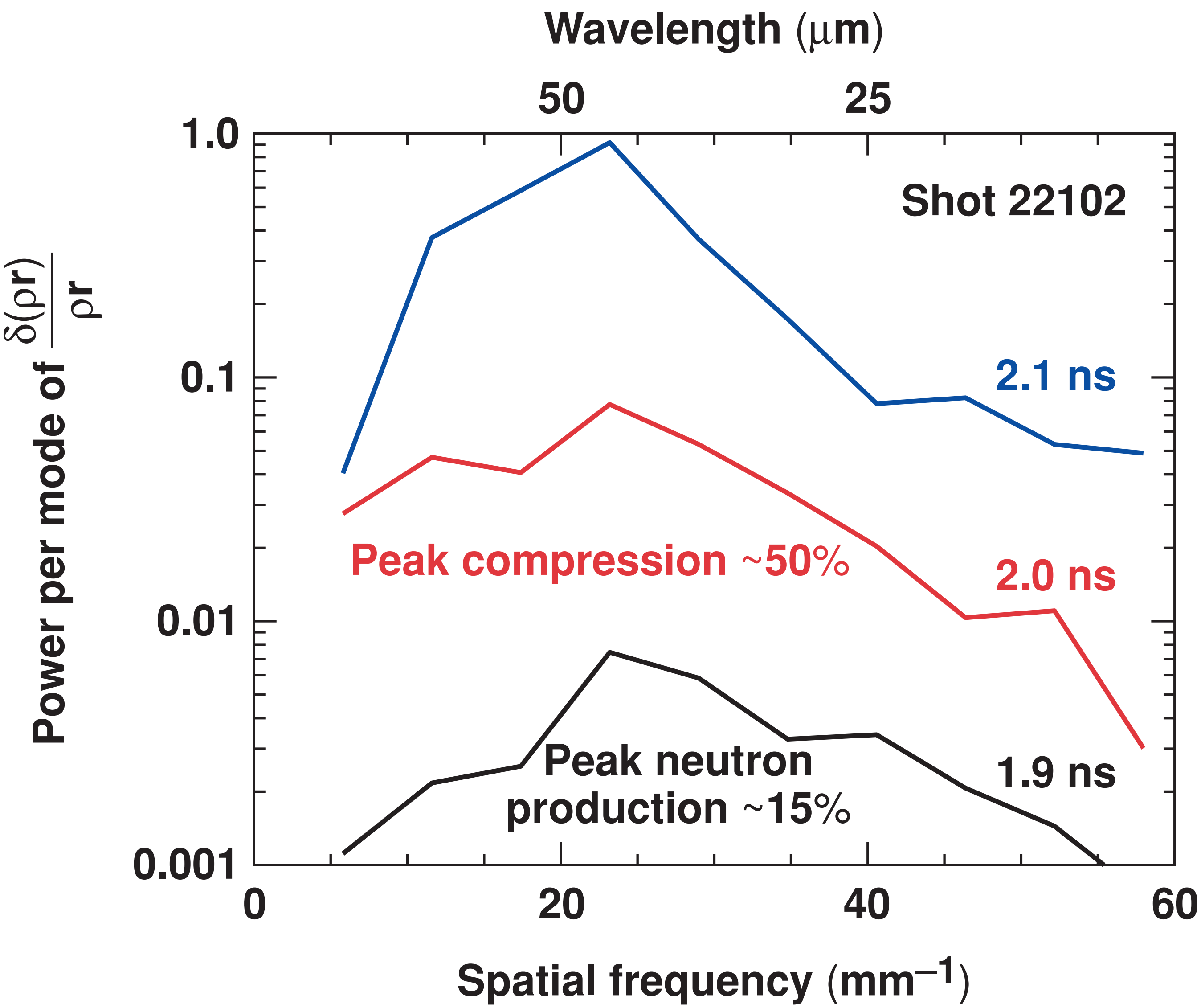
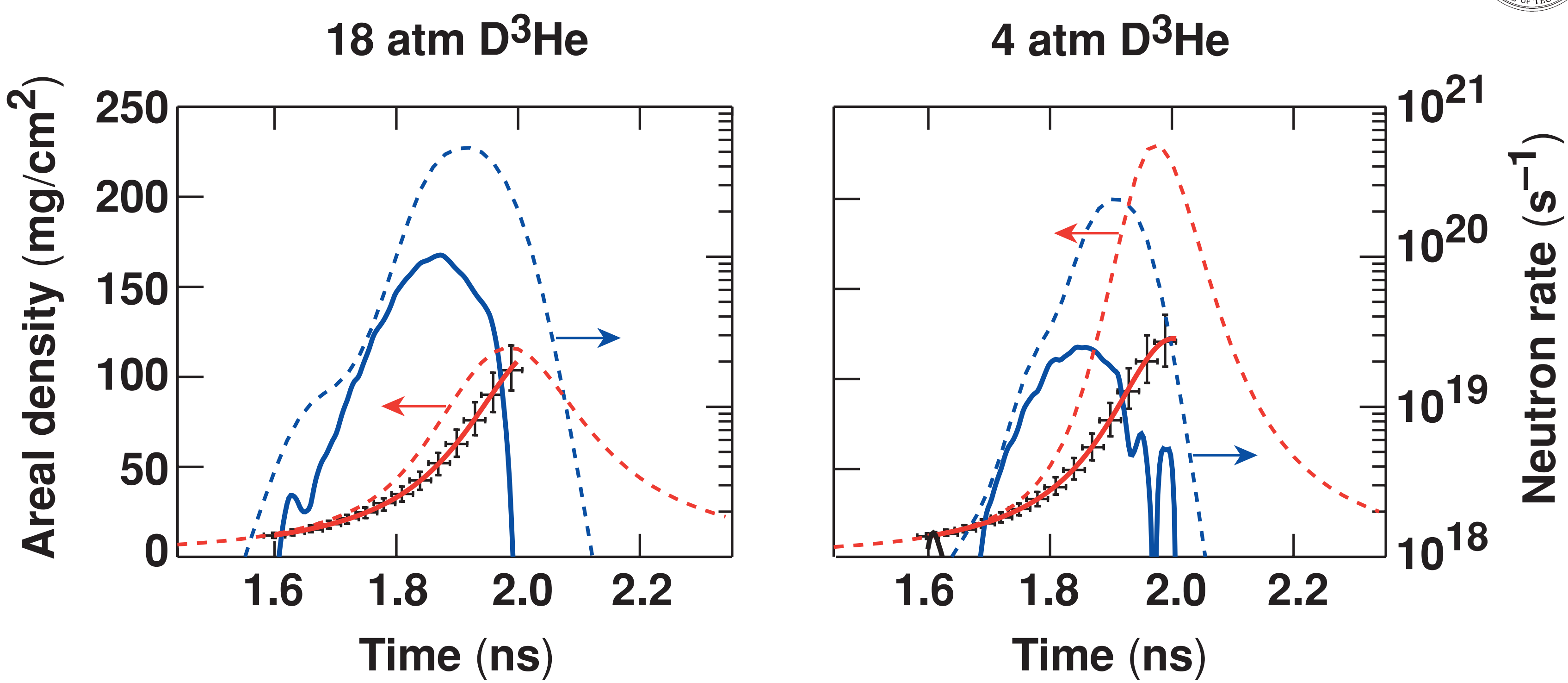


E11237a

Areal-density with more-stable 18-atm-D^3He fill is closer to 1-D prediction than with 4 atm D^3He



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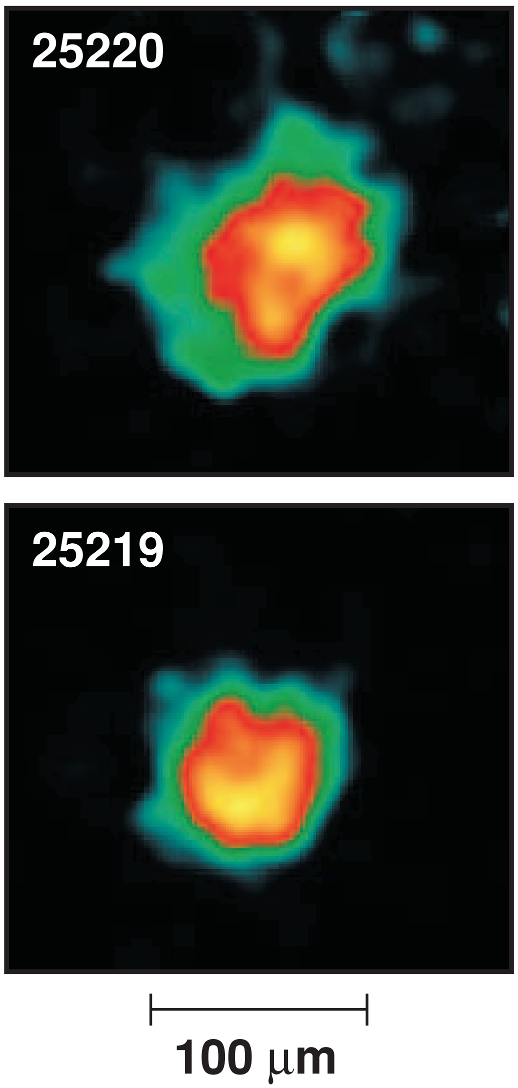
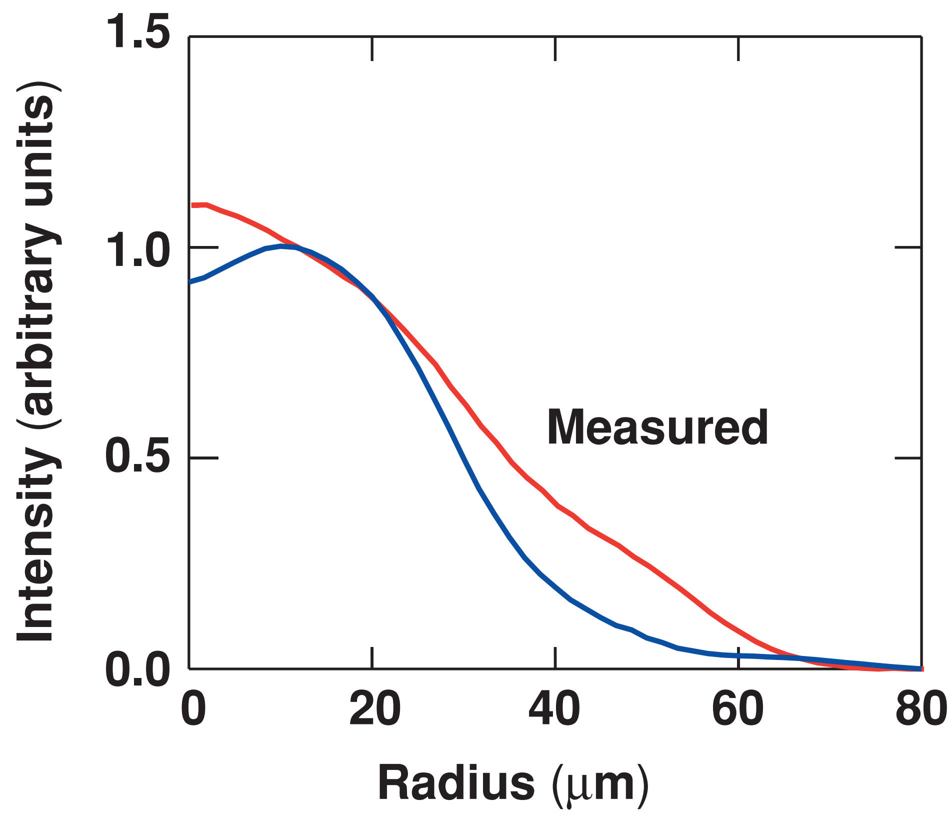
At peak compression, core images are slightly larger for 18-atm than for 4-atm-filled targets





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