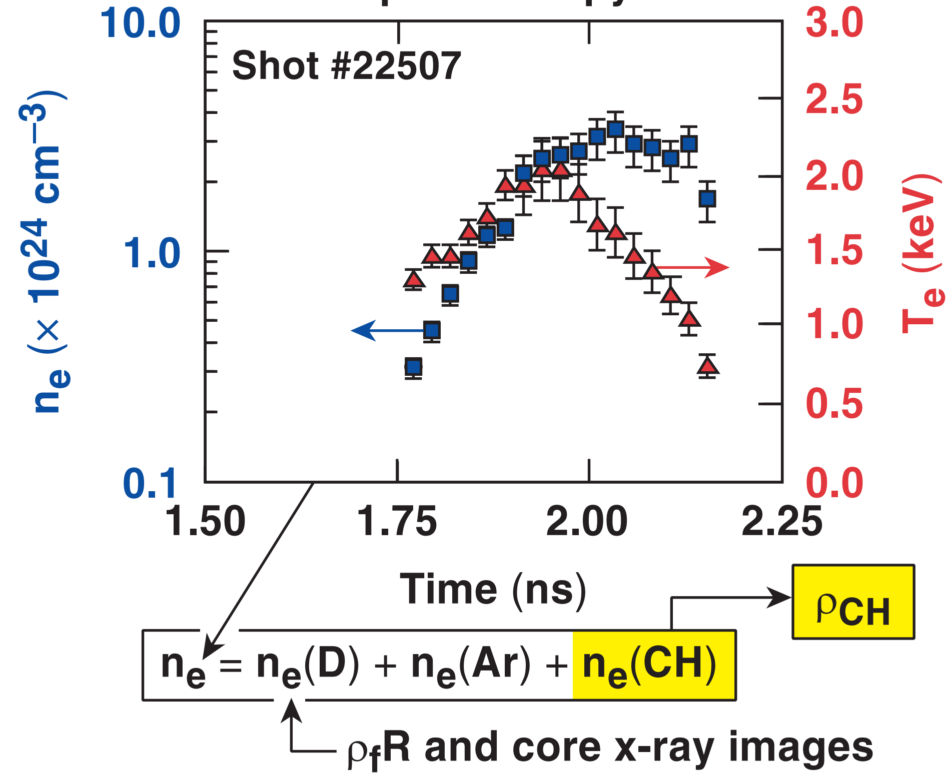
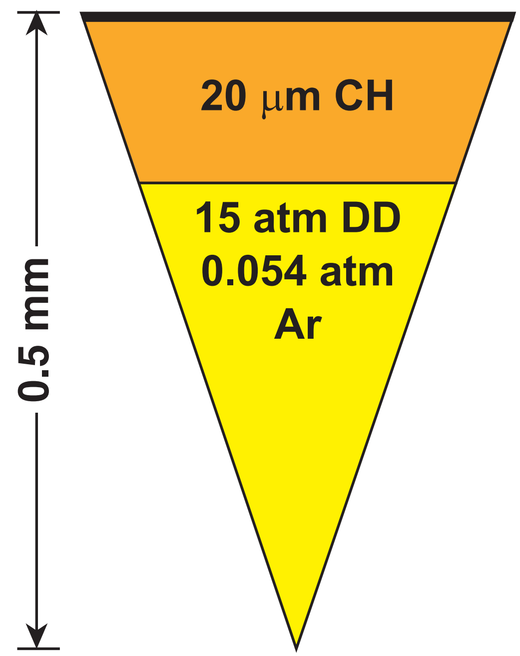
Core-Mix Measurements of Direct-Drive Implosions on OMEGA

Time-resolved Ar K-shell spectroscopy





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31st Annual Anomalous Absorption Conference
Sedona, AZ
3–8 June 2001

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Summary

The estimated core composition of OMEGA direct-drive implosions with a CR = 15 is ~ 2/3 deuterium and ~ 1/3 CH

- Plastic shells with an Ar-doped deuterium fill gas were driven with a 23-kJ, 1-ns square laser pulse with full smoothing.
- The emissivity-averaged core electron temperature and density were inferred from the measured time-dependent Ar K-shell spectral line shapes.
- Spectroscopic results were combined with other diagnostics to determine the amount of shell mass mixed into the core.
- The estimated core deuterium density ρ_f is 4.4(±1.3) g/cm^3, and the estimated core CH density is 2.6(±0.8) g/cm^3.

Outline

Core-mix measurements of direct-drive implosions on OMEGA

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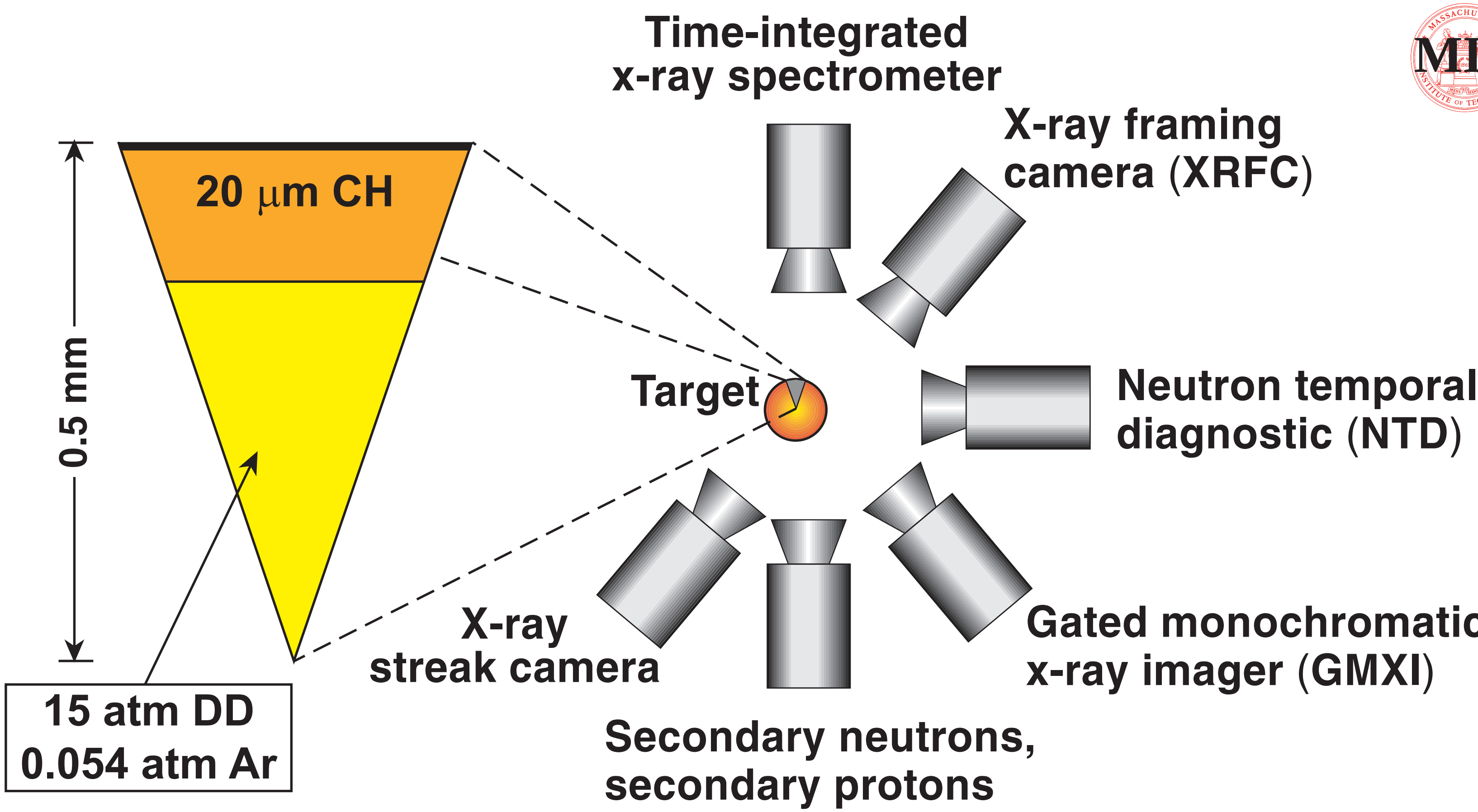
- High-density implosions on OMEGA
- Time-resolved Ar K-shell spectroscopy
- Core-mix estimates
- Conclusions

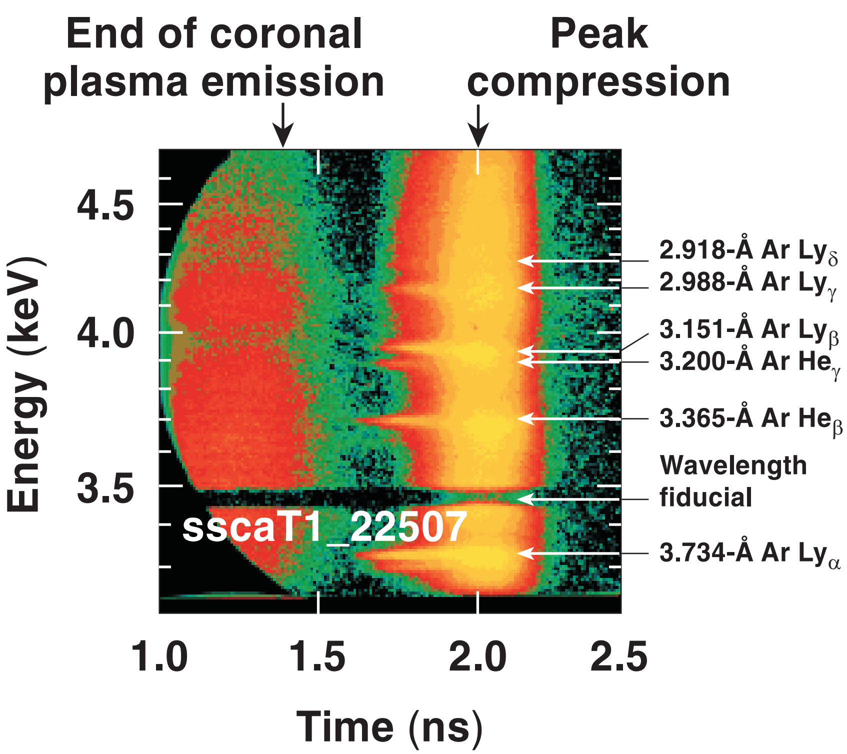
Plastic shells with an Ar-doped deuterium fill gas were driven with a 23-kJ, 1-ns square laser pulse

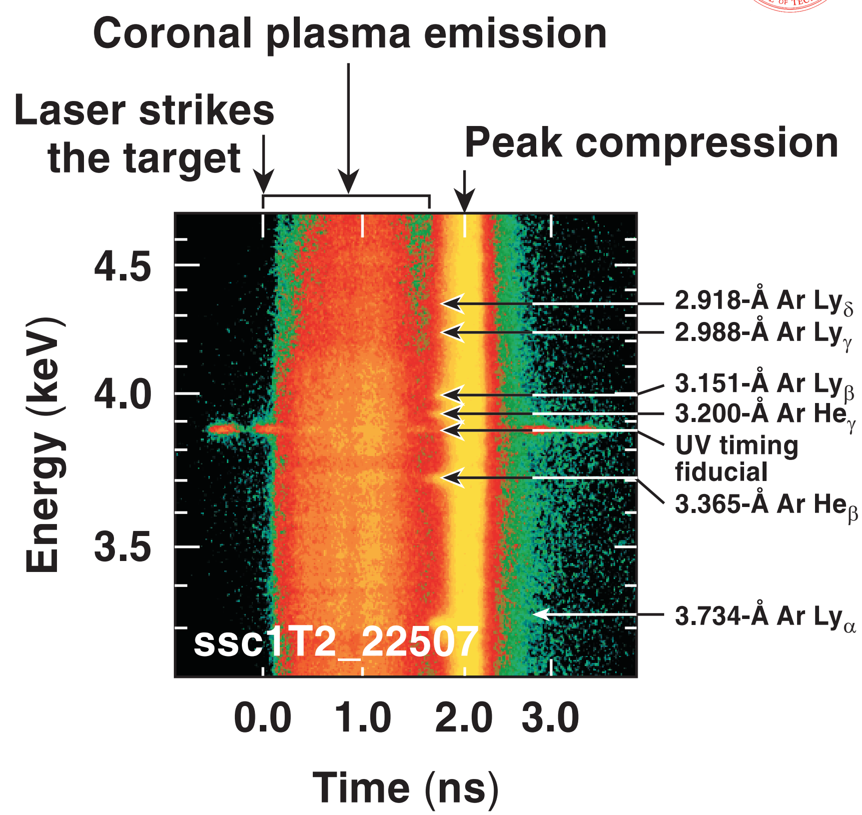


- Predicted convergence ratios ranged from 15 to 37.
- Laser irradiation with 1-THz SSD, PS, and on-target beam-to-beam power imbalance < 5% rms.

E10928

Streaked x-ray spectroscopy is used to measure time-dependent Ar K-shell spectral line shapes





- **Absolute timing of peak x-ray signal is established with a slower streak camera.**

E10931

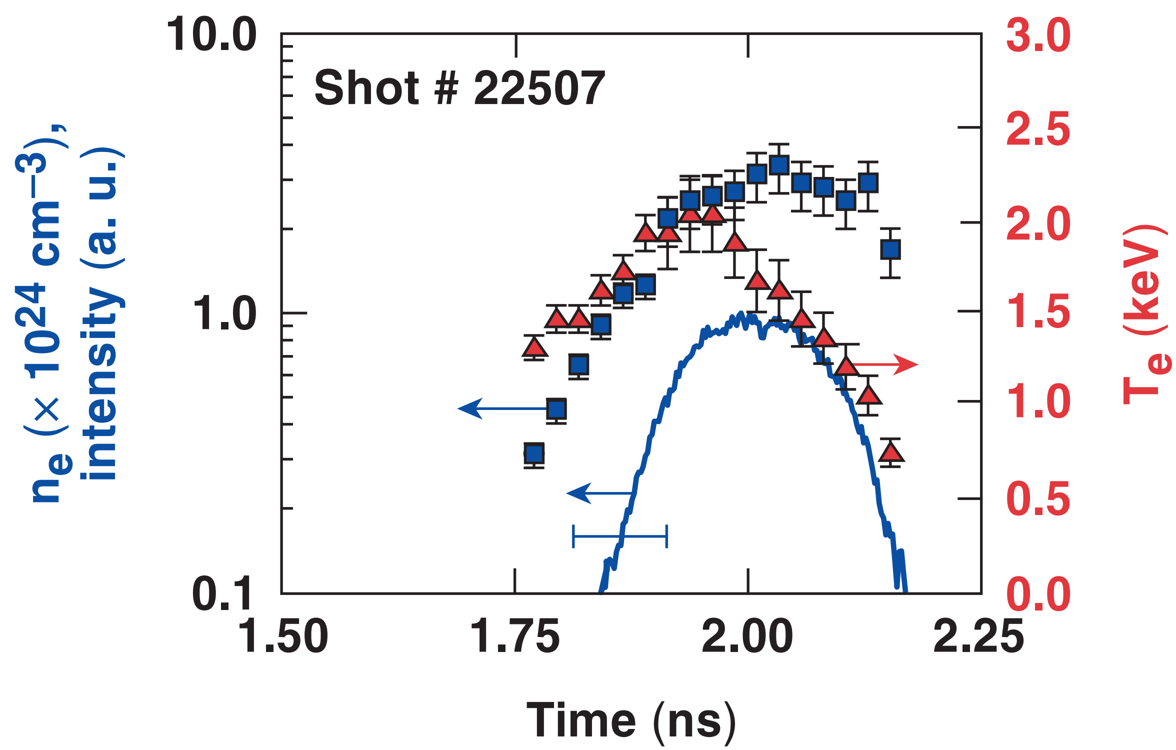
Time-resolved Ar K-shell spectroscopy provides a direct measure of the core electron density to diagnose core-mix

- Ar K-shell emission from hot, dense plasma ($n_e > 1 \times 10^{23}$ cm^{-3} and $T_e > 1$ keV) has line shapes that depend strongly on density and are insensitive to variations in electron temperature.
- The relative intensities of the Ar K-shell lines and their associated L-shell satellites are sensitive to variations in electron temperature and density.
- Stark-broadened Ar K-shell resonance lines and satellites are calculated with *MERL*.[1,2]

[1]R. C. Mancini *et al*. Comput., Phys. Commun. 63, 314 (1991).

[2]D. A. Haynes *et al*. Phys Rev., E 53, 1042 (1996).

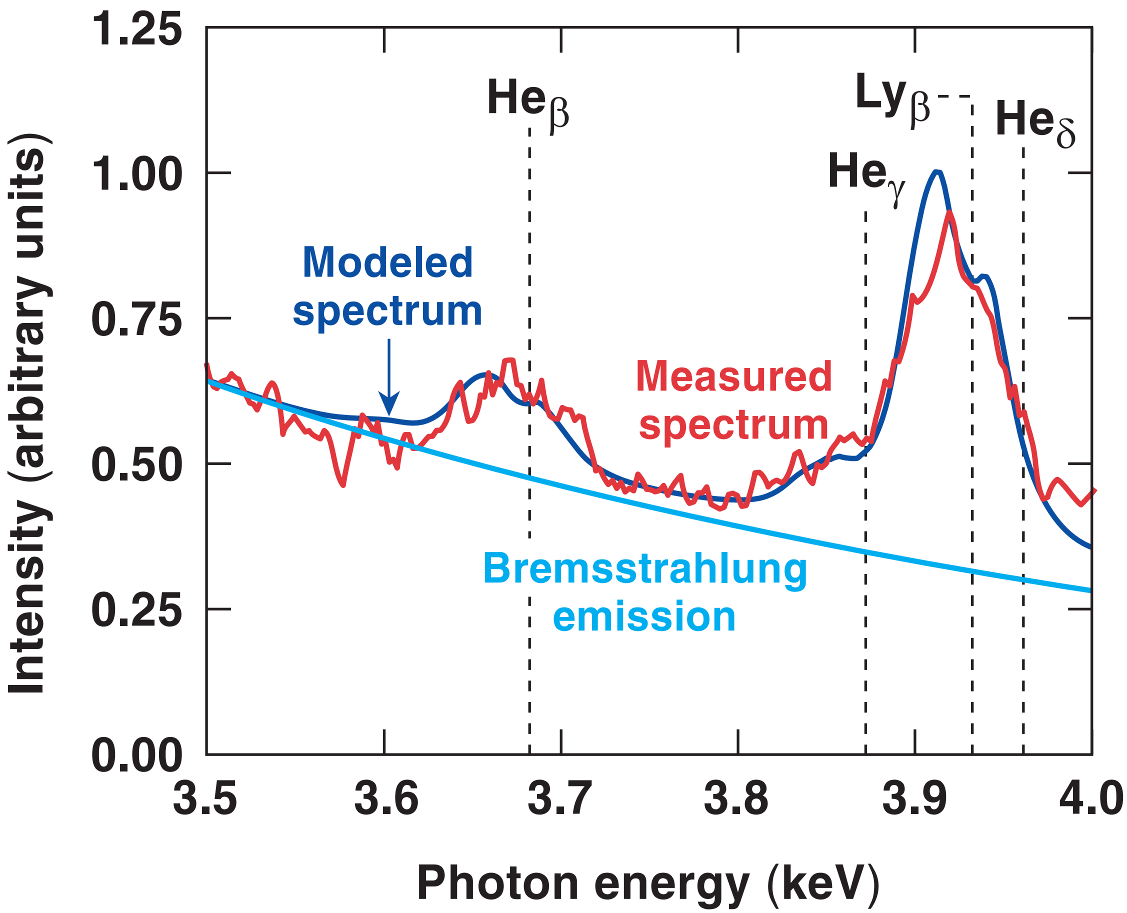
Time history of emissivity-averaged core n_e and T_e is inferred from the Ar K-shell spectroscopy



- Significant changes in the Ar K-shell emission spectrum occur during the implosion.
- Peak neutron production is measured ~ 170 ps ±100 ps before peak x-ray production.
- *LILAC* simulations indicate that peak neutron production occurs at the same time as peak emissivity-averaged T_e.

E10861

At peak neutron production $n_e = 2.5 \times 10^{24}$ cm^{-3} and $T_e = 2.0$ keV



$t = 1.93$ ns

$n_e = 2.5(\pm 0.5) \times 10^{24}$ cm^{-3}

$T_e = 2.0(\pm 0.2)$ keV

E10863a

At peak compression $n_e = 3.1 \times 10^{24}$ cm^{-3} and $T_e = 1.7$ keV

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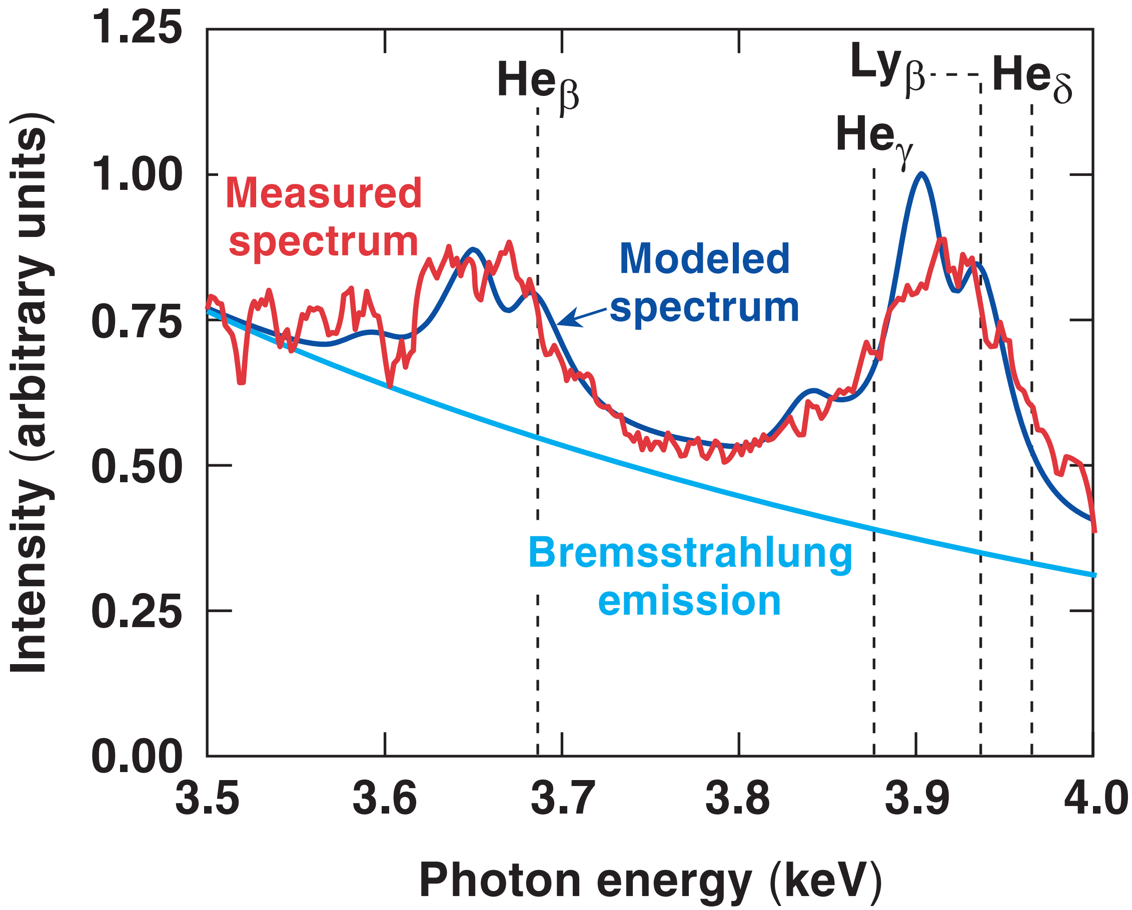

$t = 2.01$ ns
$n_e = 3.1(\pm 0.6) \times 10^{24}$ cm^{-3}
$T_e = 1.7(\pm 0.17)$ keV

- Peak compression occurs at the time of peak x-ray emission.

E10864a

Spectroscopic results are compared with nuclear measurements of $\rho_f R$ and x-ray core images to estimate the amount of core-mix

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- The $\rho_f R$ measurement is obtained from knock-on deuteron spectra recorded on similar implosions with a DT fill gas.

$$\rho_f R \text{ (knock-ons)} = 15 \text{ mg/cm}^2$$

- The radius of the imploding core is estimated from time-integrated monochromatic (4.9 keV) x-ray core images.

$$R_{x\ ray} = 34\ \mu\text{m}$$

Time-resolved x-ray spectroscopy → n_e

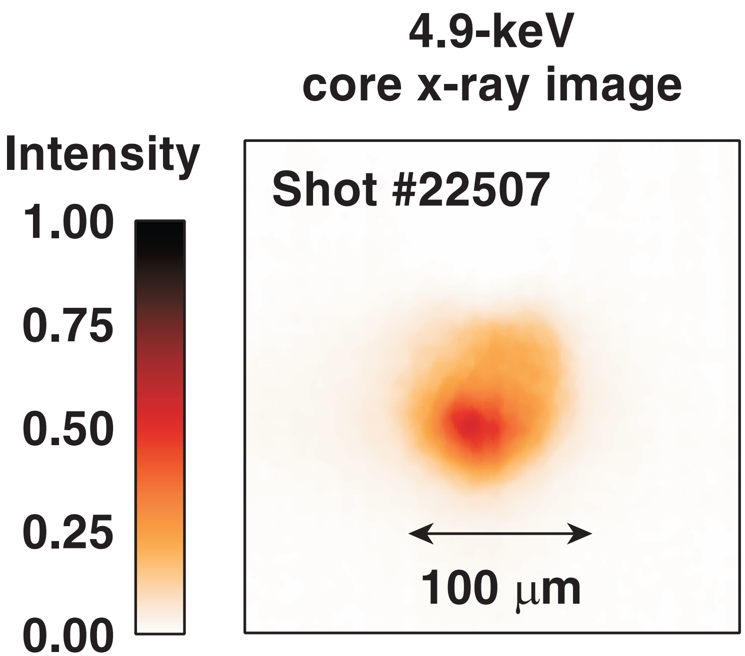
$$n_e = n_e(D) + n_e(Ar) + n_e(CH)$$

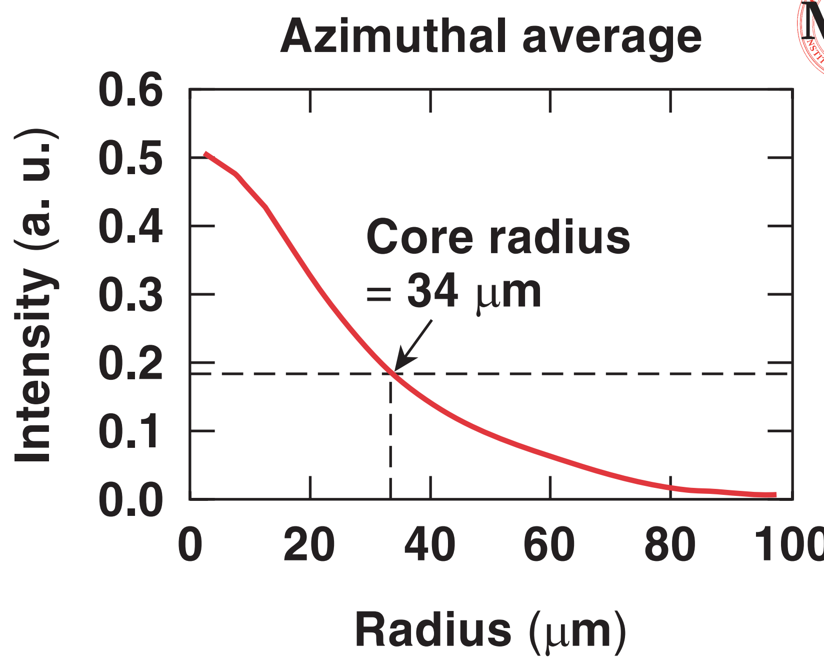
$\rho_f R$ and core x-ray images → $n_e(D)$

$n_e(CH)$ → ρ_{CH}

E10984

$\rho_f = 4.4(\pm 1.3)\ g/cm^3$ is inferred from nuclear and x-ray measurements for implosions with CR = 15





Shot(s)	Target	$Y_n \times 10^{11}$	Y_{2n}/Y_n	$\rho_f R$ (from Y_{2p})	$\rho_f R$ (from Y_{2n})
22507	DD (15), Ar (0.18%), CH (20)	1.0	1.8×10^{-3}	>8.5 mg/cm^2	<18.1 mg/cm^2
Multiple	DD (15), CH (20)	1.3(±0.08)	$2.1(\pm 0.28) \times 10^{-3}$	—	—

- Ar has a limited effect on target performance.

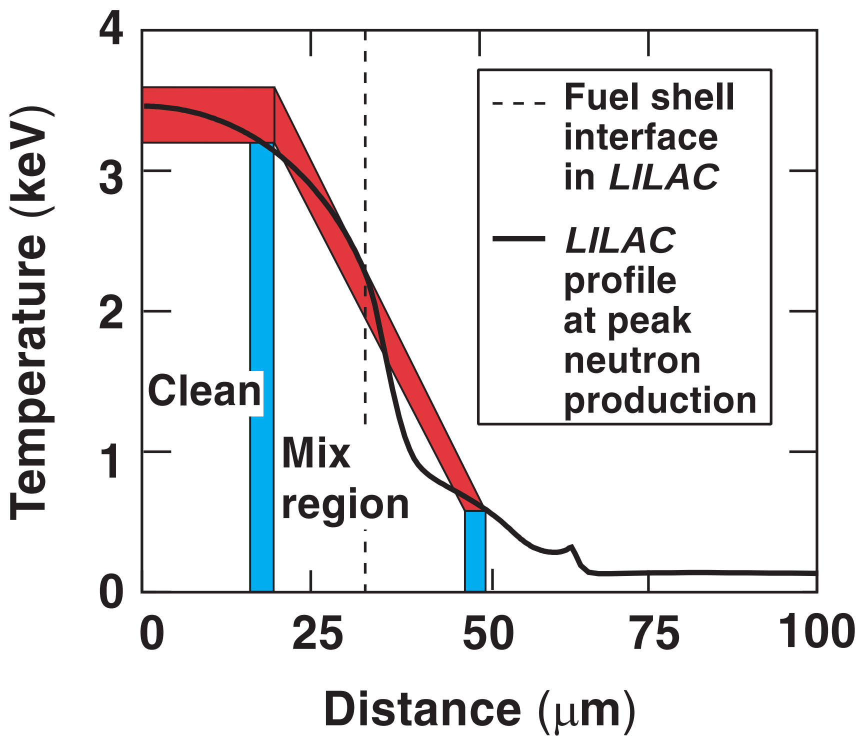
E10929

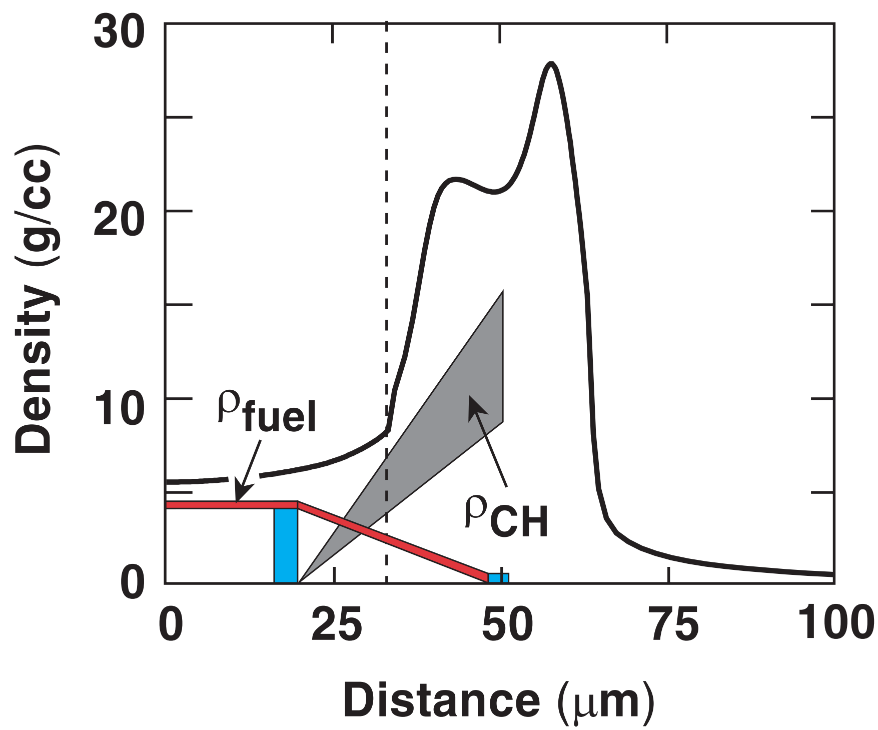
Direct-drive implosions with CR = 15 have an estimated core composition of ~ 2/3 deuterium and ~ 1/3 CH

$$n_e(CH) = n_e - n_e(D) - n_e(Ar)$$

n_e	2.2×10^{24} e^-/cm^3 (averaged over 170-ps neutron burnwidth)
T_e	1.9 keV (averaged over 170-ps neutron burn width)
$n_e(D)$	1.3×10^{24} e^-/cm^3
$n_e(Ar)$	4.0×10^{22} e^-/cm^3
$n_e(CH)$	0.8×10^{24} e^-/cm^3
ρ_{CH}	2.6 (±0.8) g/cm^3
ρ_f	4.4 (±1.3) g/cm^3

The consistent model for CR~15 implosions compares favorably with 1-D simulations





D. D. Meyerhofer *et al.*, Phys. Plasmas 8, 2251 (2001).

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