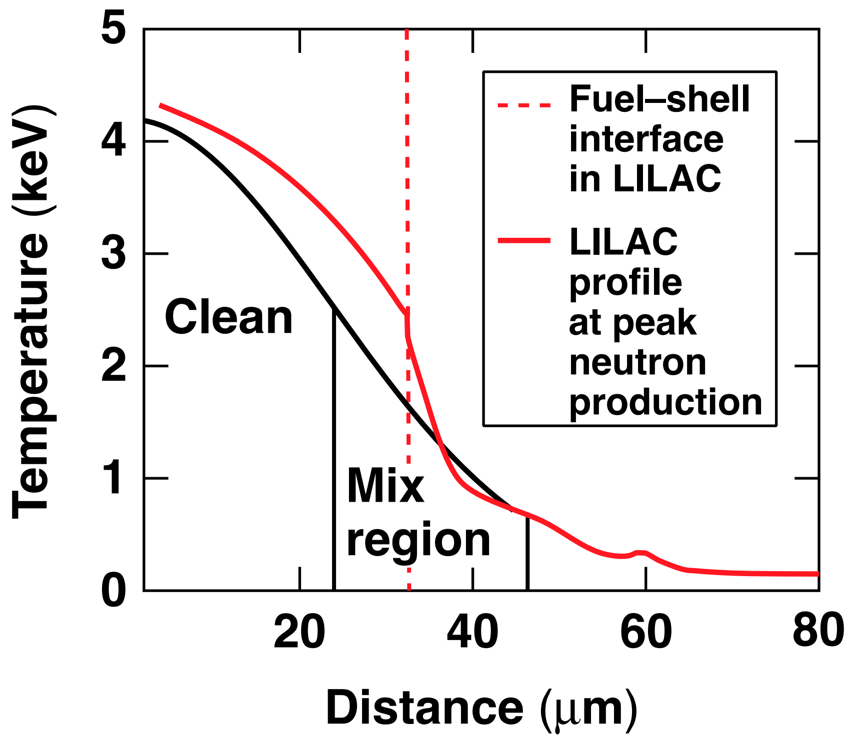
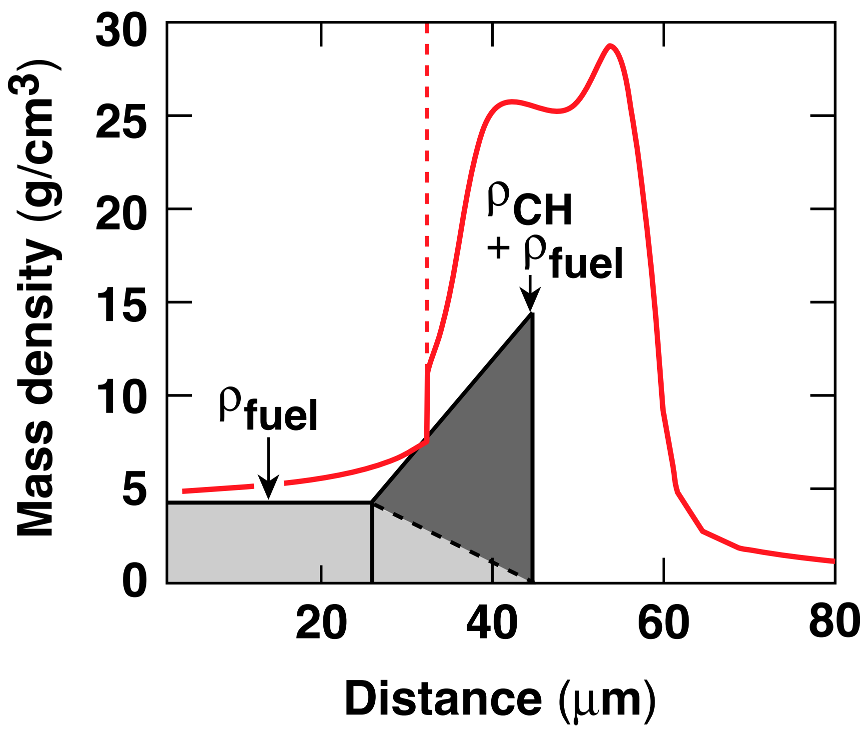
Inference of Mix in Direct-Drive Implosions on OMEGA





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Summary

Compressed core-mix is inferred from nuclear and x-ray diagnostics in direct-drive implosions on OMEGA

- A large suite of diagnostics has been brought to bear on a series of 20-μm-thick-plastic-shell implosions with differing gas constituents.
- Small-scale fuel–shell mix is evident from several nuclear and x-ray diagnostics.
- A static mix-picture can be constructed that suggests that about 70% of the compressed fuel areal density is unmixed for moderate-convergence-ratio implosions (CR~15).
- Future work will involve multidimensional simulations and the application of time-dependent 1-D mix models to these implosions.

TC5716a

Outline

Compressed core-mix is inferred from nuclear and x-ray diagnostics in direct-drive implosions on OMEGA

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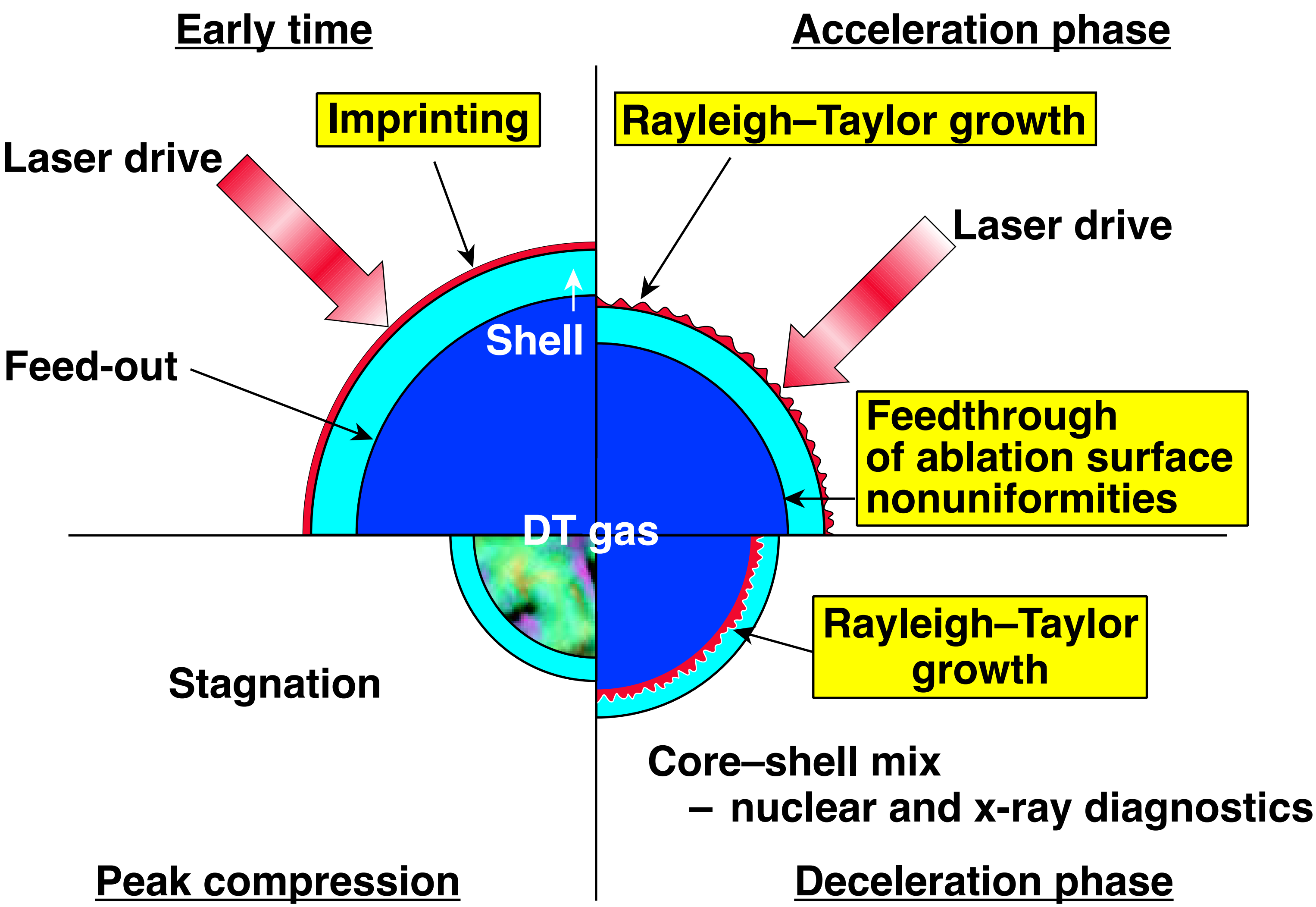
- Targets
- Estimate of small-scale mix
- Nuclear and x-ray diagnostics
- Experimental measurements
- Inferences of mix

TC5717

Rayleigh–Taylor growth during the deceleration phase of an ICF implosion can result in fuel–shell mix

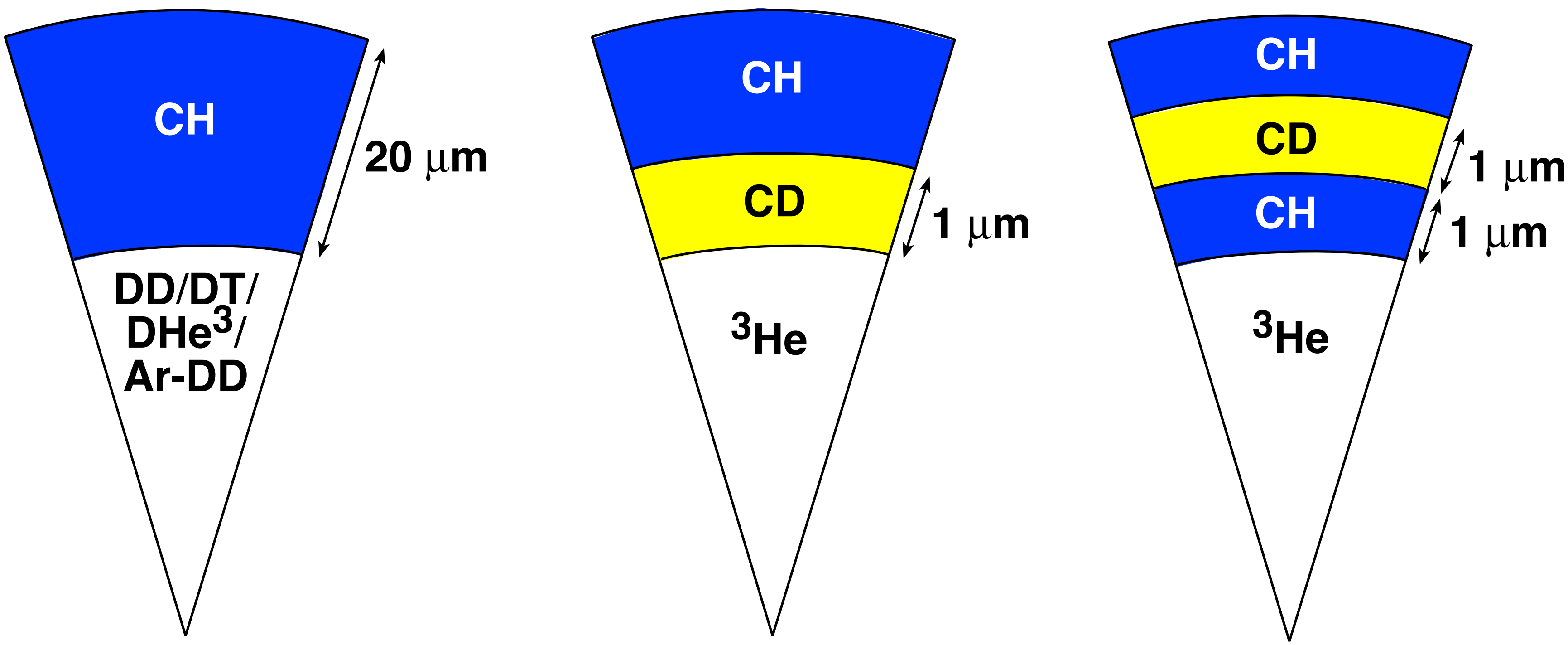


TC5723

Nominally identical shell thickness and laser conditions allow for a study of the deceleration phase

Laser conditions: 1-ns square pulse with 23 kJ of energy with 1 THz, one-color-cycle, 2-D SSD and polarization smoothing (PS)

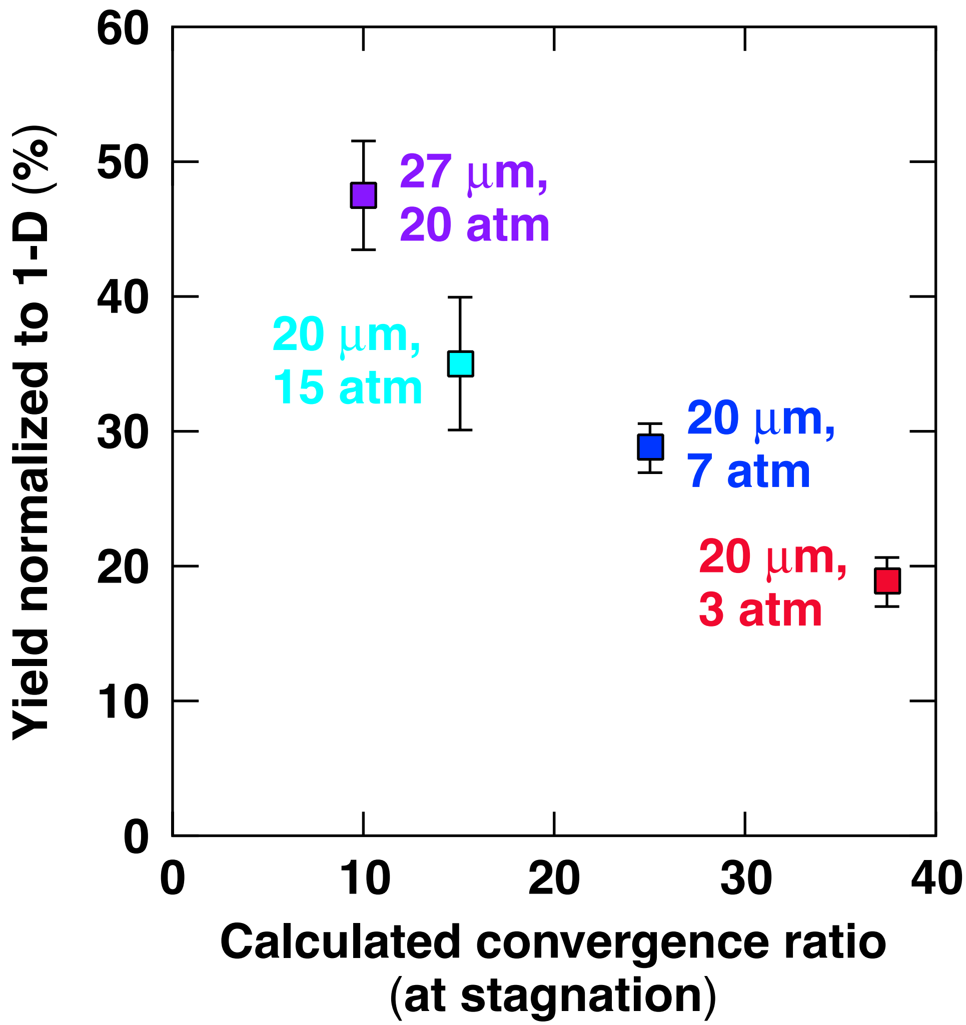
Target: 20-μm-thick CH shell with varying fill constituents



TC5718

Good reproducibility on OMEGA allows for comparisons of performance across shots

1-ns square, 23-kJ, D_2-filled shells,
1-THz, one-color-cycle SSD, and PS



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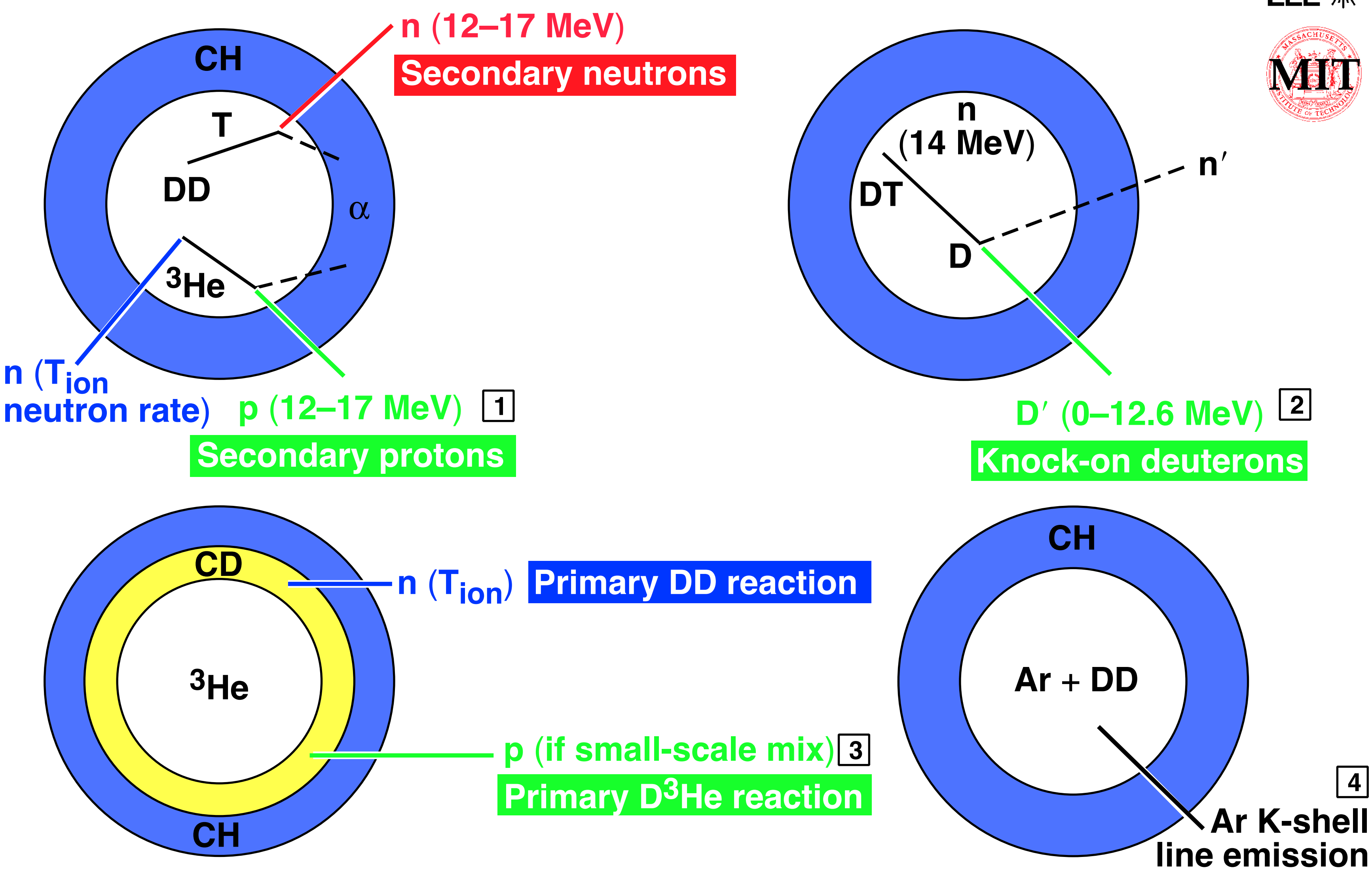
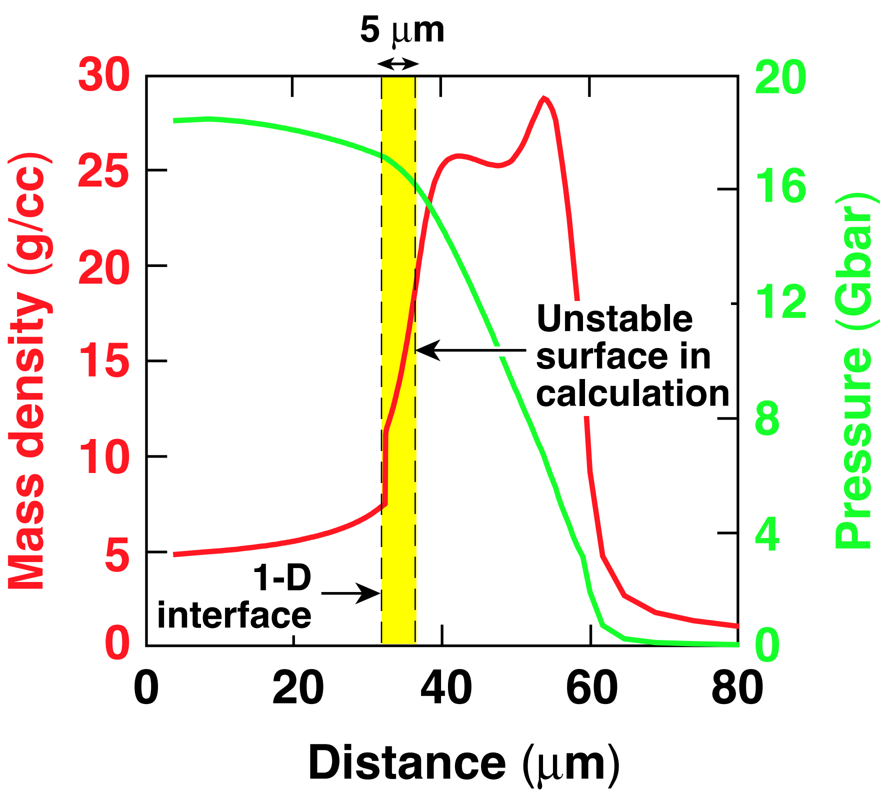
Differing mixtures allow for the use of complementary diagnostics across hydrodynamically similar implosions

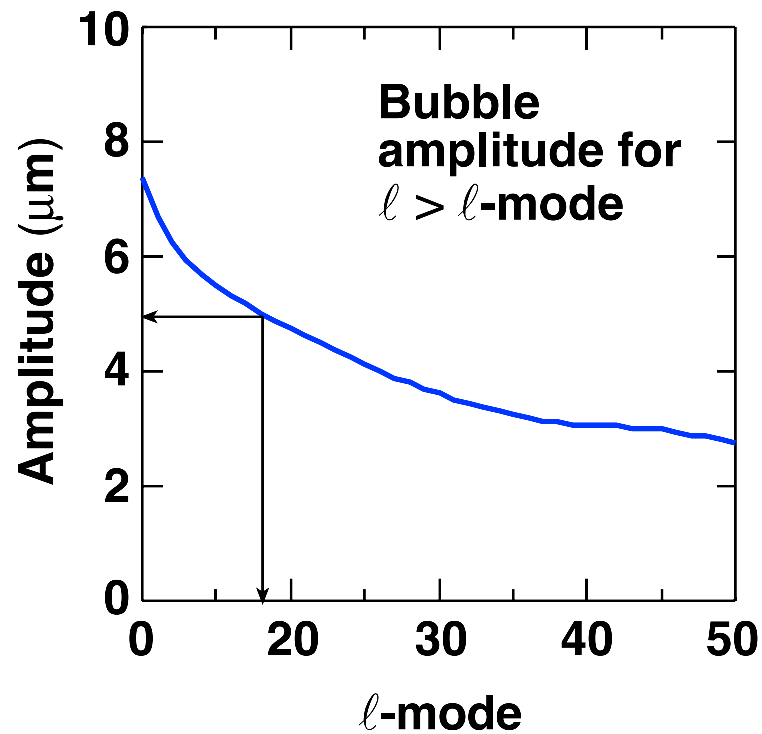


TC5724a

[1] F. Seguin et al., FO2.004; [2] C. Li et al., FO2.003; [3] R. Petrasso et al., FO2.005; [4] S. Regan et al., FO2.006

Calculations suggest that the rear surface of the shell is perturbed by small scales at peak neutron production



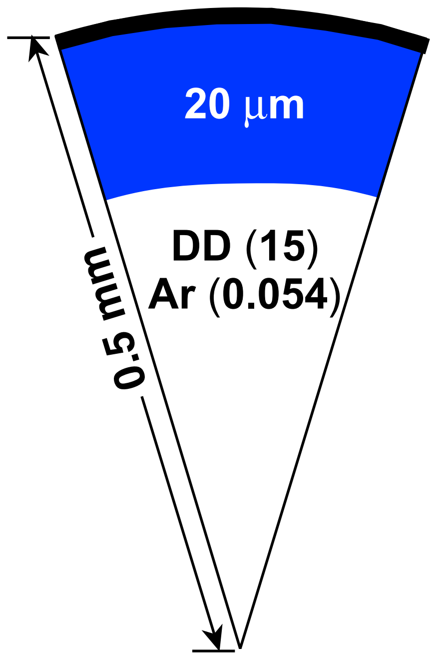


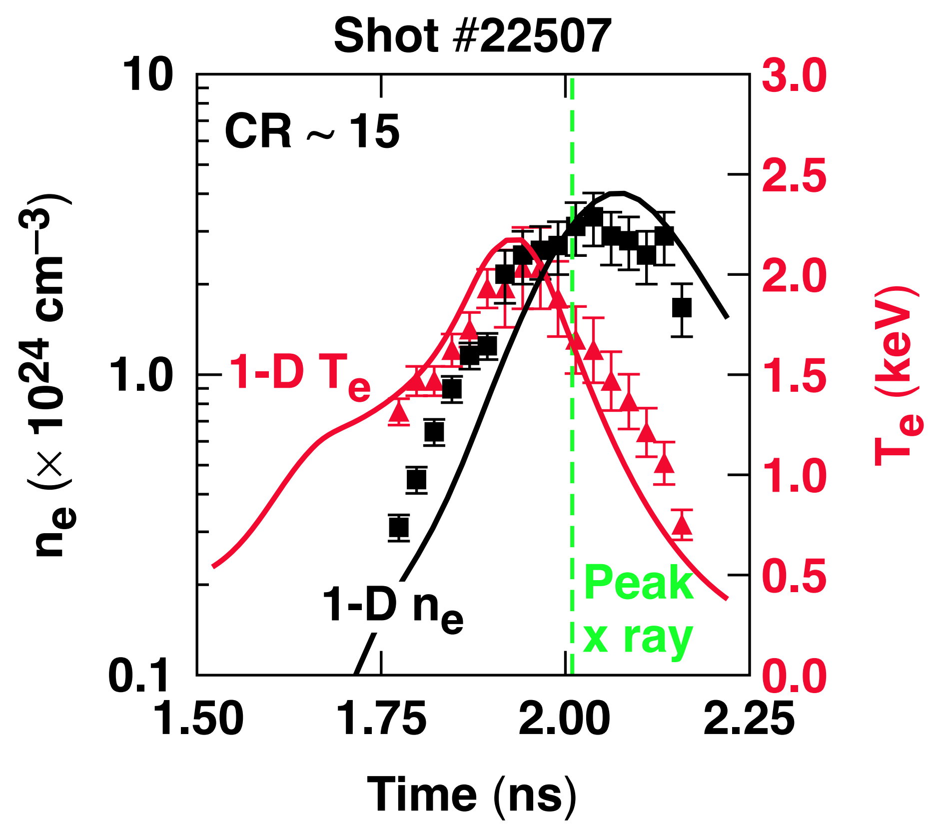
- **Imprint and outer-surface roughness are initial nonuniformity seeds.**
- **Feedthrough during the acceleration phase, convergence effects, and rear-surface RT growth during deceleration are modeled.**

TC5719

V. Goncharov et al., Phys. Plasmas 7, 5118 (2000).

Core mix can be diagnosed from time-resolved Ar K-shell spectroscopy





- The emissivity-averaged core electron temperature and density were inferred from the measured time-dependent Ar K-shell spectral line shapes.
- Higher measured electron density than 1-D is attributed to fuel–pusher mix.

S. Regan et al., FO2.006

Measured proton yields for CR ~ 15 implosions are significantly enhanced relative to 1-D simulations

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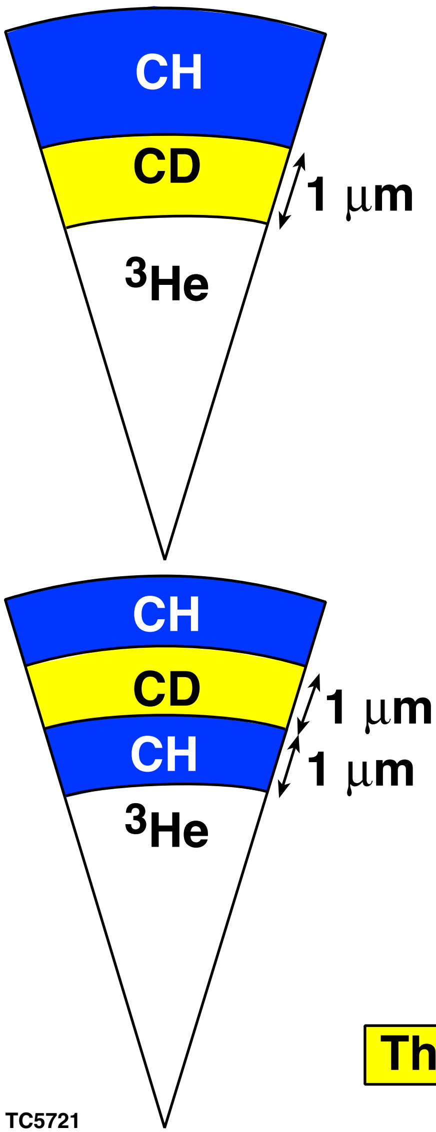
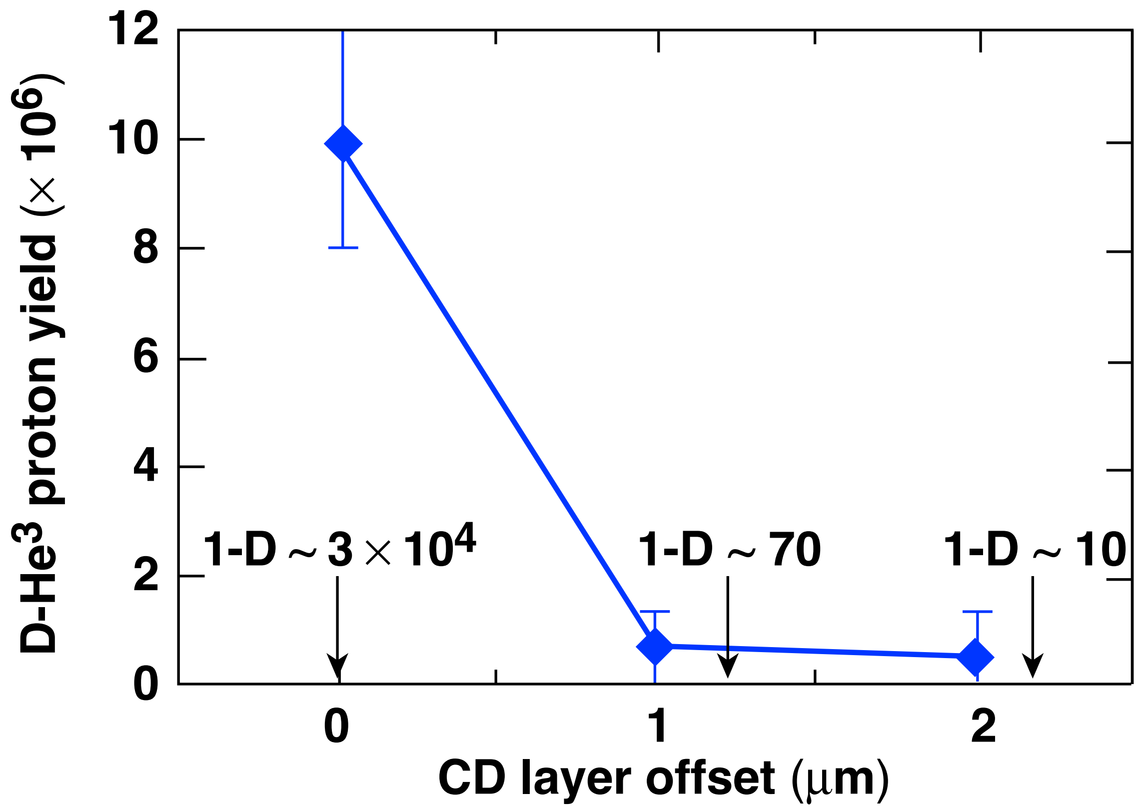
- 1-D calculations assume that ^{3}He is isobarically diffused throughout the shell.
- Similar order-of-magnitude enhancements are observed for higher-convergence-ratio implosions.





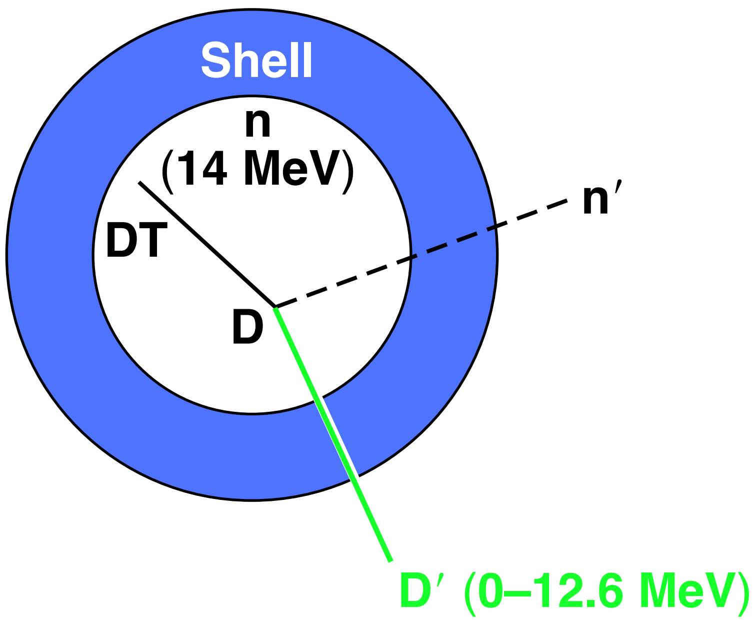
This experimental enhancement suggests small-scale mix.

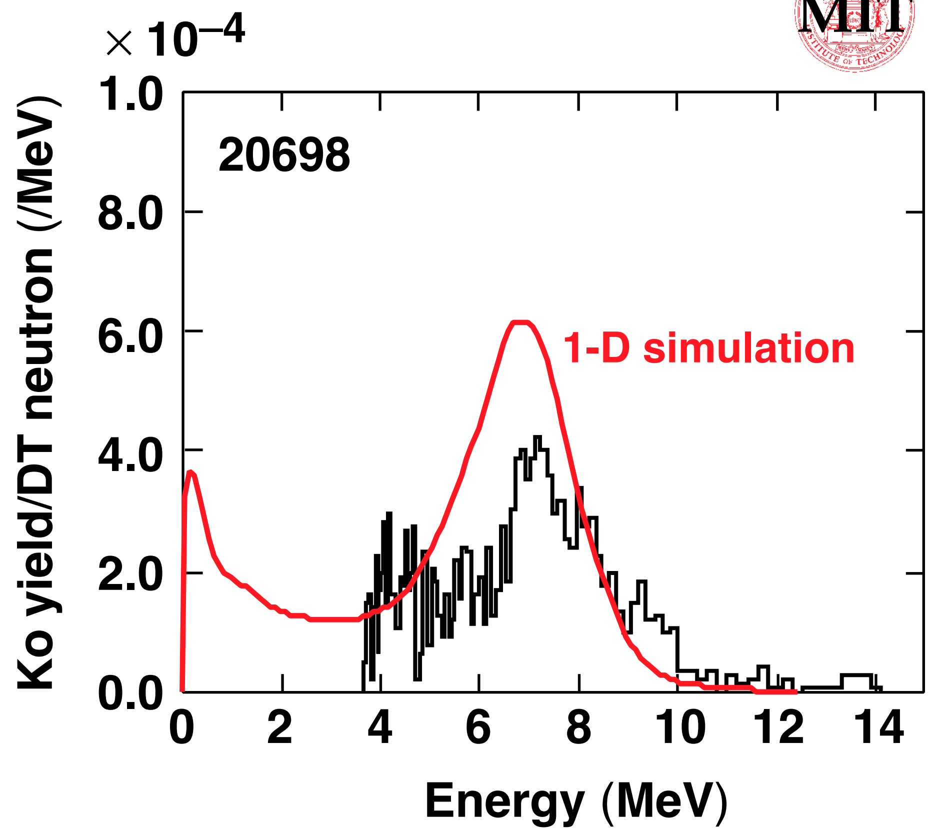
TC5721

R. Petrasso et al., FO2.005

Fuel areal density is inferred from the knock-on deuteron spectrum

Fill: 15 atm DT, 20-μm-thick CH shell, CR ~ 15





ρR (expt) ~ 13 mg/cm^2; ρR (1-D) ~ 17 mg/cm^2.

- The average DT fuel ρR is (15±3) mg/cm^2.

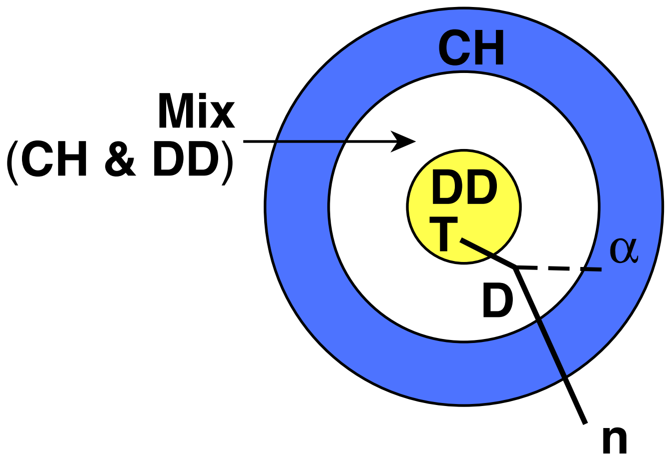
Knock-on deuterons are relatively insensitive to mix.

TC5720

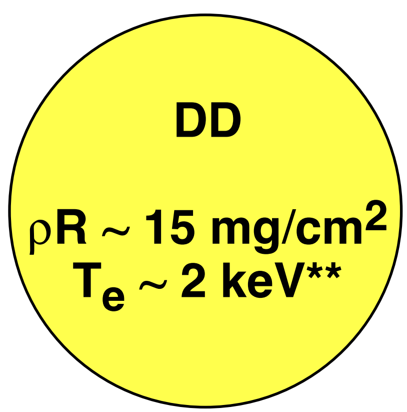
C. Li et al., FO2.003

Enhanced experimental secondary neutron* ratios suggest fuel–shell mixing

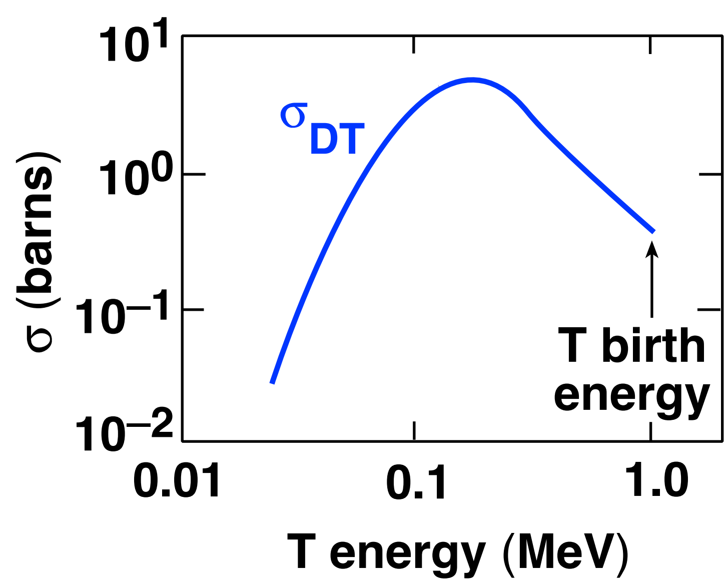
Mix picture
ratio (expt): 2.1 (±0.4) × 10^{-3}



"No-mix" ice block model
ratio: 1.6 × 10^{-3}



- The ratio of secondary neutrons to primary DD neutrons is sensitive to ρR and electron temperature.
- The ratio from 1-D simulation is 1.75 × 10^{-3}.

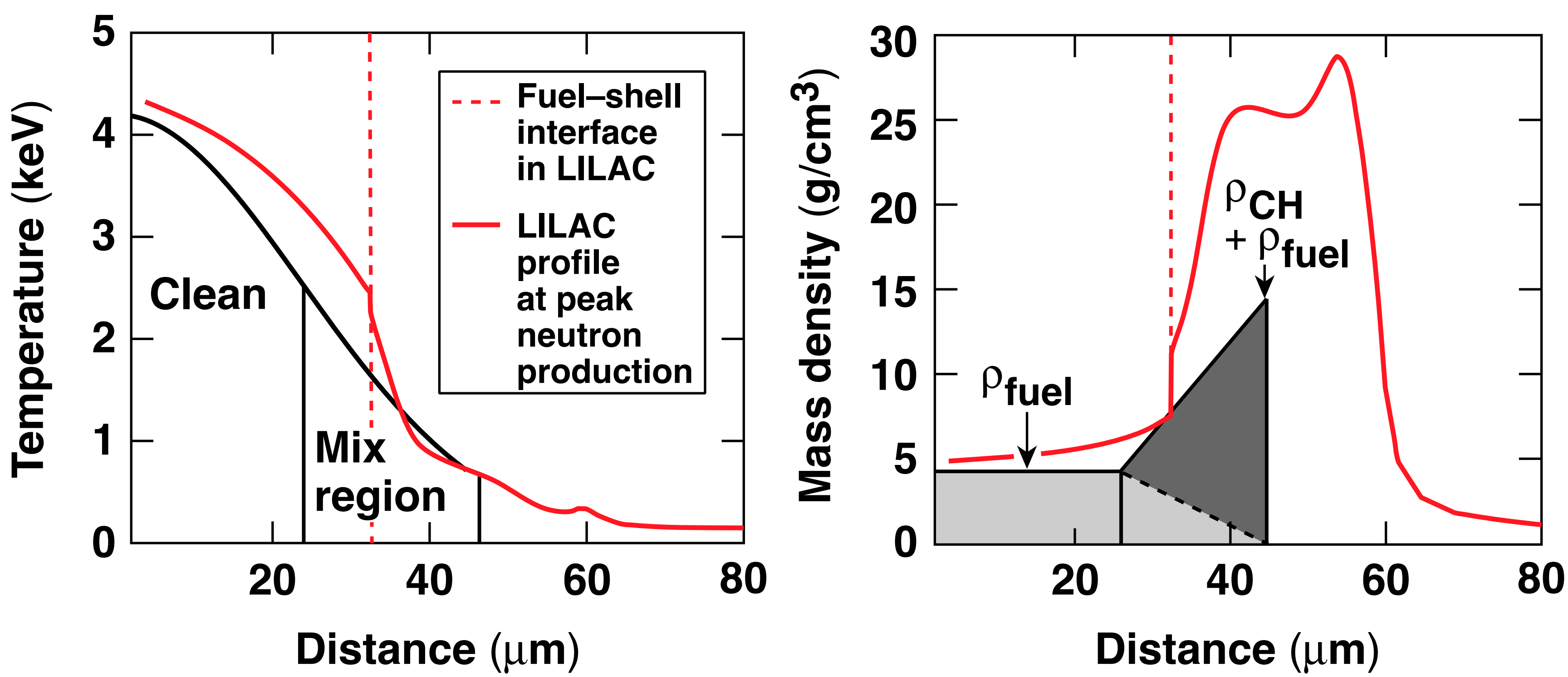


* H. Azechi et al., Phys Rev Lett. 59, 2635 (1987).
** S. Regan et al., FO2.006

TC5722

A mix model produces a constrained set of core properties for 15-atm-fill, 20-μm-thick shells

- 1-THz, one-color-cycle SSD, polarization smoothing (PS)

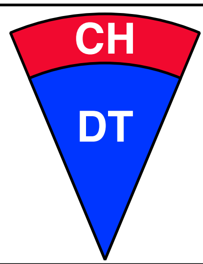
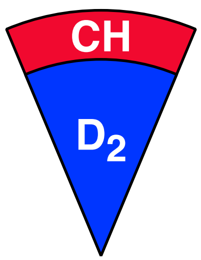
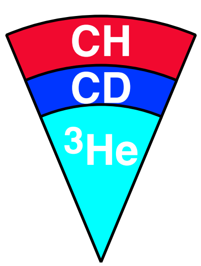


- Roughly 70% of the compressed fuel ρR is in the clean region, and 20% of the compressed shell ρR is in the mixed region.

TC5725a

The model reproduces most experimental observables

- 1-ns square, 23 kJ, 20-μm-CH and -CD-shells, 15 atm fill, CR ~ 15

	Parameter	Measurement	Model (% of expt.)
	Fuel ρR (mg/cm^2)	15±3	100
	Max: neutron rate	$(9\pm2) \times 10^{20}$	120
	Burn width (ps)	170±20	94
	T_{ion} (D_2)(keV)	3.7±0.5	90
	Secondary neutron ratio)	$(2.1\pm0.4) \times 10^{-3}$	90
	Secondary proton ratio	$(1.8\pm0.3) \times 10^{-3}$	100
	D-^{3}He proton yield	$(1.0\pm0.2) \times 10^{7}$	100
	D_2 neutron yield	$(4.5\pm1.5) \times 10^{8}$	135
	T_{ion} (CD)(keV)	1.7±0.5	110

E10671c

Electron densities from the model are in reasonable agreement with Ar measurements*

- 15-atm-fill, 20-μm-thick CH shell, CR ~ 15
- 1-THz, one-color-cycle SSD, PS
- Argon K-shell line emission from mix-model is calculated using a non-LTE radiation package.

	n_e ($\times 10^{24}/cm^3$)	T_e (keV)
Experiment (averaged over burn)	2.2 (0.4)	1.9 (0.2)
1-D simulation (averaged over burn)	1.7	2.0
Mix-model (emissivity averaged)	2.7	1.2

* S. Regan et al., FO2.006

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