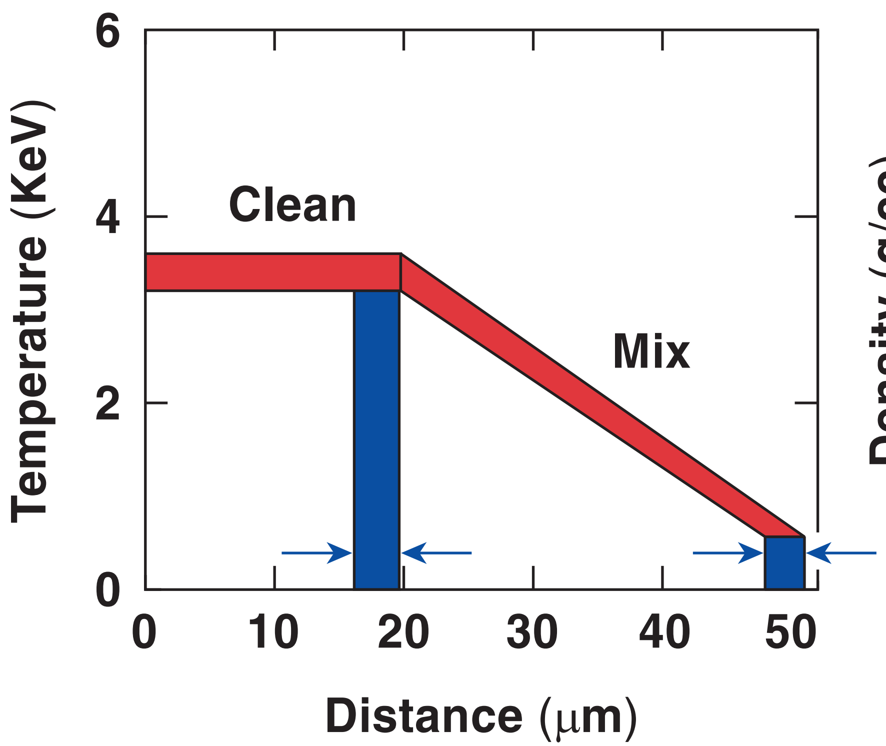
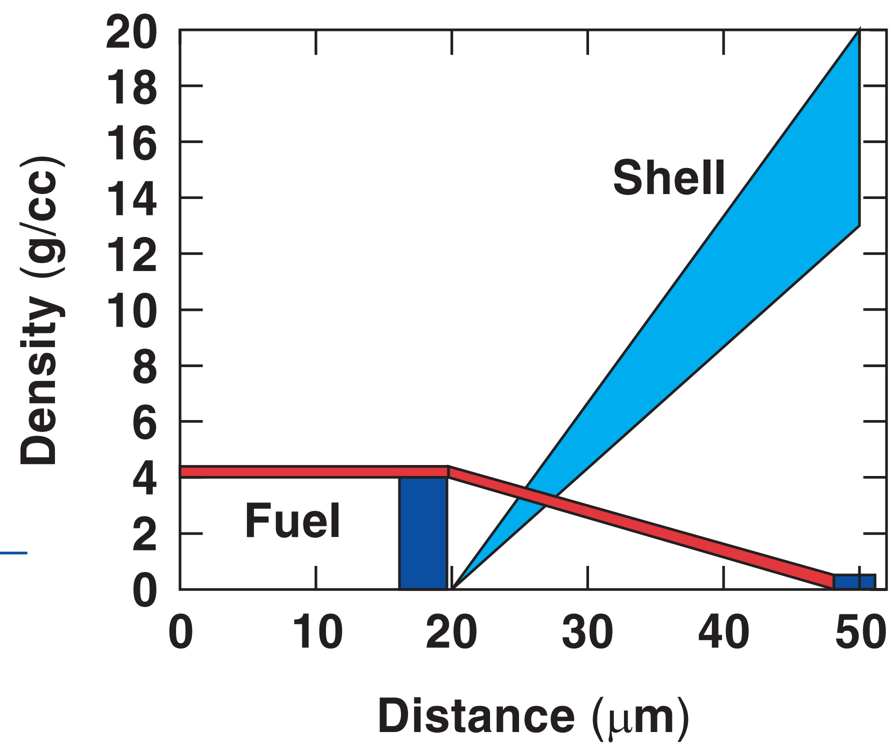
A Consistent Measurement-Based Picture of Core Conditions in OMEGA implosions





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A Measurement-Based Picture of Core Conditions in OMEGA Implosions

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Experiments have been ongoing on the OMEGA laser to study core and mix conditions in gas targets relevant to LLE's cryogenic program. These implosions typically use 20-μm plastic shells that are irradiated with a 1-ns square pulse and have various fills such as DD or DT. Neutrons, charged particles, and x-ray emission have been used to infer conditions in the core and mix regions of these targets. We present one consistent scenario based on these measurements that provides a profile of these targets including density, temperature, and material distributions in the core and the mix region. A preliminary comparison of this picture with hydrodynamic simulations will also be presented. This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC03-92SF19460.

Collaborators

UR LLE

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Summary

A static model with mixing of fuel and shell provides a consistent picture of the core across diagnostics

- Several different diagnostics on D_2-, DT-, and ^{3}He-filled plastic (CH) and deuterated-plastic (CD) layered targets have tightly constrained core-temperature and density properties.
- Neutron and charged-particle diagnostics suggest fuel–shell mixing in direct-drive OMEGA implosions.
- A static model consistent across many diagnostics indicates that about 50% of the inferred compressed-fuel areal density and 20% of the inferred compressed-shell areal density is in a mixed region.

Outline

Neutron and charged-particle diagnostics suggest fuel–shell mixing in direct-drive OMEGA implosions

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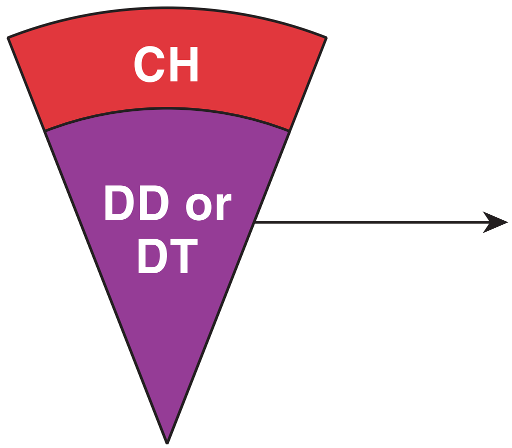
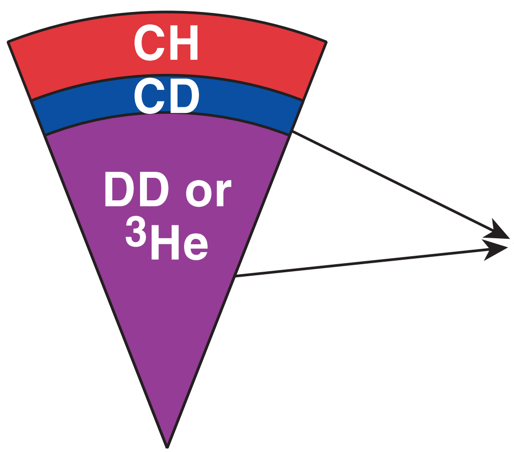
- Targets and pulse shapes
- Some evidence for mixing
- Parameters and constraints of the mix model
- Comparison of the model results with experimental observables

A large suite of diagnostics have been brought to bear on plastic shells with and without CD layers and with different gas fills

- The base-line target: 15 atm of gas in a 20-μm shell irradiated with a 1-ns square pulse and 23 kJ of energy



Primary neutrons
Secondary neutrons: T, ρR_f
$\langle T \rangle_{ion}$
Secondary protons: T, ρR_f
Elastically scattered
deuterons and tritons (DT): ρR_f
Neutron-production rates

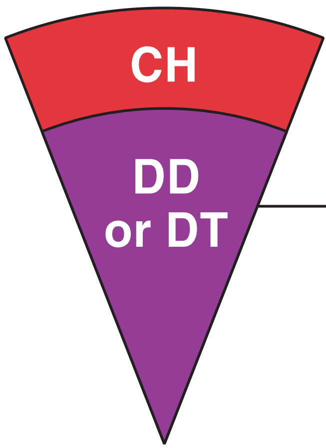


Primary neutrons
Secondary neutrons
Secondary protons
$\langle T \rangle_{ion}$
Neutron-production rates
Primary D-^{3}He protons
(only if small-scale mixing)

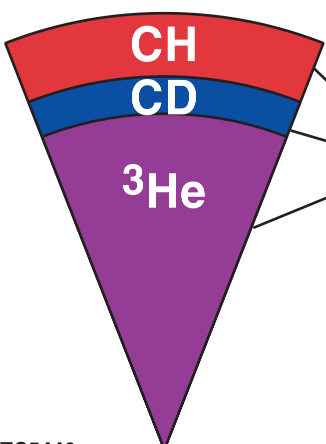
Meyerhofer Invited BI3.003, GP1.080, HO1.007, HO1.008, HO2.001, HO2.002, HO2.003

TC5445

Primary yields and secondary ratios suggest mixing of the fuel and shell



	Experiment (average over four shots)	Experiment (% of 1-D *LILAC*)
Fuel ρR (DT)	15±2	94
Neutron yield	$(1.6 \pm 0.05) \times 10^{11}$	33
Secondary-neutron ratio	$(2.4 \pm 0.4) \times 10^{-3}$	139
D-^{3}He proton yield	1.4×10^{7}	~10,000*



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*Assumes ^{3}He has equal pressure throughout the target

A static, five-parameter model can be constructed to reproduce experimental data

- The core conditions and mix properties are inferred from a simple, static model.
- Assumptions:
  - The core is divided into clean and mixed regions.
  - The temperature is uniform in the clean region and falls linearly in the mix region.
  - The fuel and mixed-plastic densities change linearly in the mix region.
  - Fuel mass is conserved.
- Parameters
  - Temperature at center and outer edge of mix region
  - Total fuel ρR } determines radius of clean and mix region
  - Fraction of fuel ρR in mix region } determines radius of clean and mix region
  - Amount of plastic in mix region
- The model should reproduce all core measurements.

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The model produces a tightly constrained set of core properties for 15-atm-fill, 20-μm-thick shells with PS

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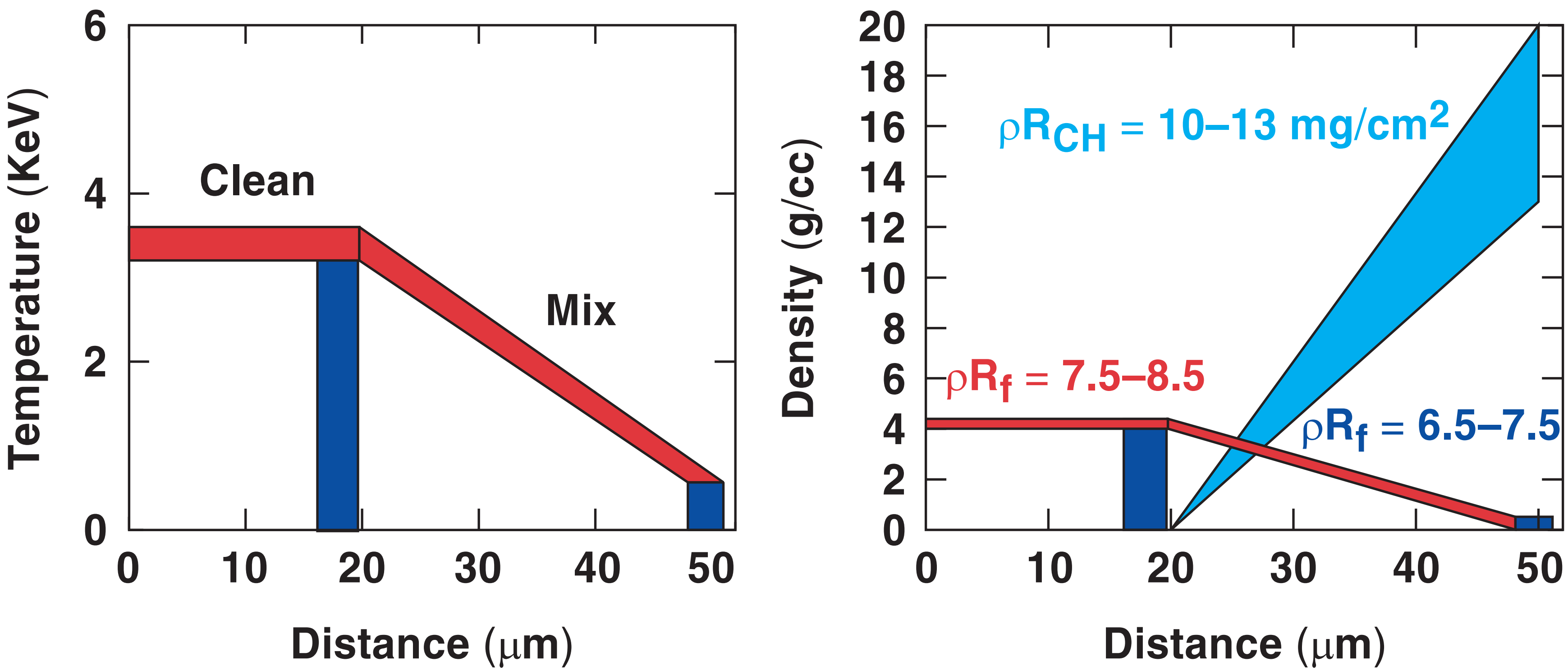
- 1-THz SSD, one color cycle, polarization smoothing (PS), ~0.5 to 1 μm of original CH mixed (~20% of shell ρR)

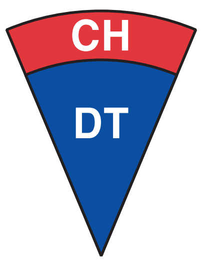


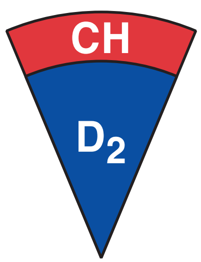
- The model should reproduce many measurements
  - secondary particle ratios with different target (3),
  - fusion-rate, <T>$_{ion}$, radius of emission region
- The model parameters are tightly constrained by the experiments (ranges shown on graph).

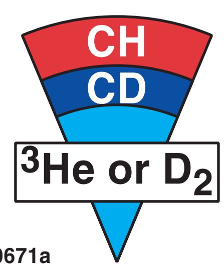
TC5523

The model reproduces many experimental observables with 1 μm of shell material mixed in the fuel

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







Parameter	Measurement	Model (% of expt.)
Fuel ρR (mg/cm^2)	15±2	100
T_{ion} (DT)(keV)	4.4±0.4±0.5 (sys)	86
Max: neutron burn rate (n/s)	$(9\pm1)\times10^{20}$	110
T_{ion} (D_2)(keV)	3.7±0.2±0.5 (sys)	89
Secondary neutron ratio	$(2.4\pm0.4)\times10^{-3}$	100
Secondary proton ratio	$(1.8\pm0.3)\times10^{-3}$	78
Secondary neutron ratio (D_2)	$(3.1\pm0.5)\times10^{-3}$	94
D-^{3}He proton yield (^{3}He fill)	$(1.3\pm0.2)\times10^{7}$	66
D_2 neutron yield (^{3}He fill)	$(8.5\pm0.4)\times10^{8}$	97

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