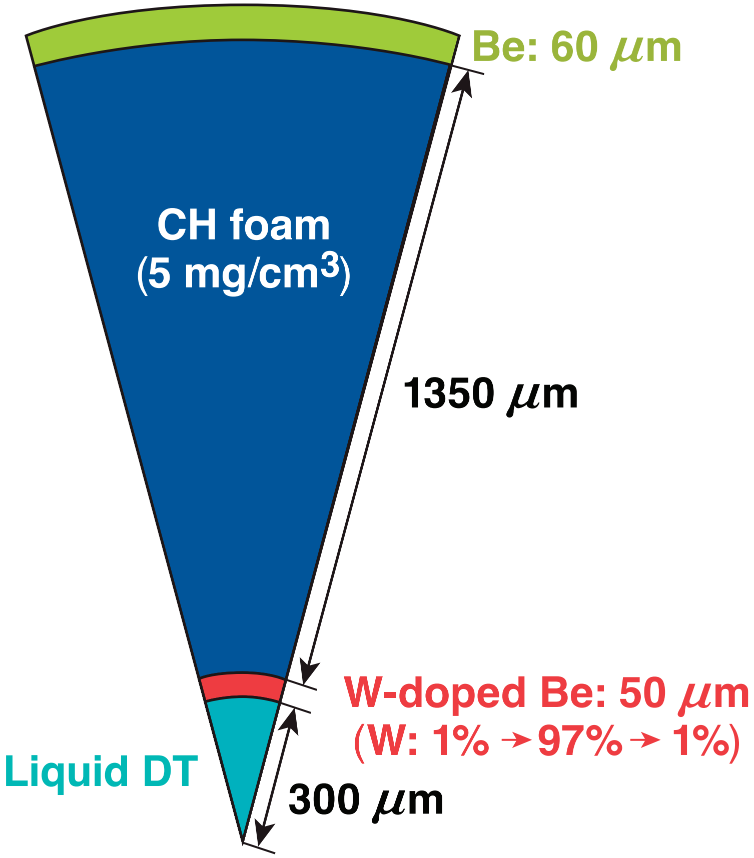
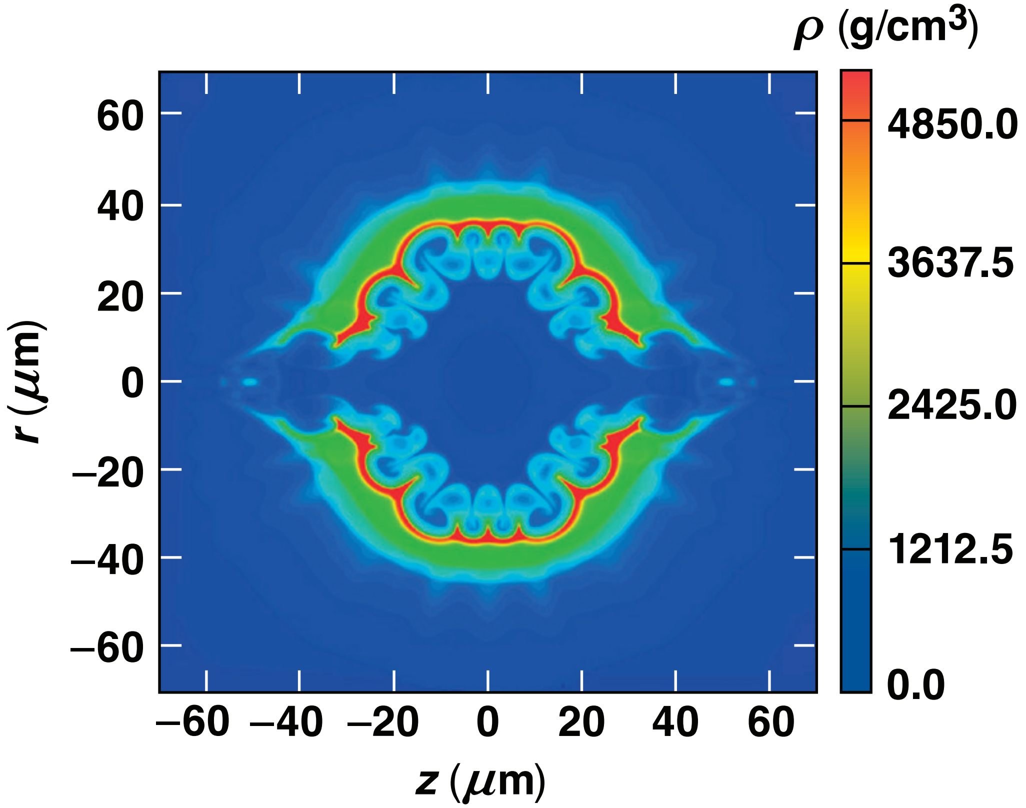
Direct-Drive-Ignition Designs with Gradient-Density Double Shells





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Summary

MJ neutron yield could be possible for direct-drive double-shell implosions with gradient-density shells

- **Direct-drive double-shell designs for inertial confinement fusion (ICF) have been performed with the 2-D hydrocode *DRACO* using the best physics models currently available**

- **Gradient-density inner shells are found to be essential for igniting a double-shell target in which the outer shell can be driven at a very high adiabat ($\alpha \sim$ 8 to 10)**

- **Our *DRACO* simulations show that such designs could survive both laser-imprint and classical Rayleigh–Taylor (RT) instability growth, leading to the production of ~MJ neutron yields**

TC14478

Collaborators

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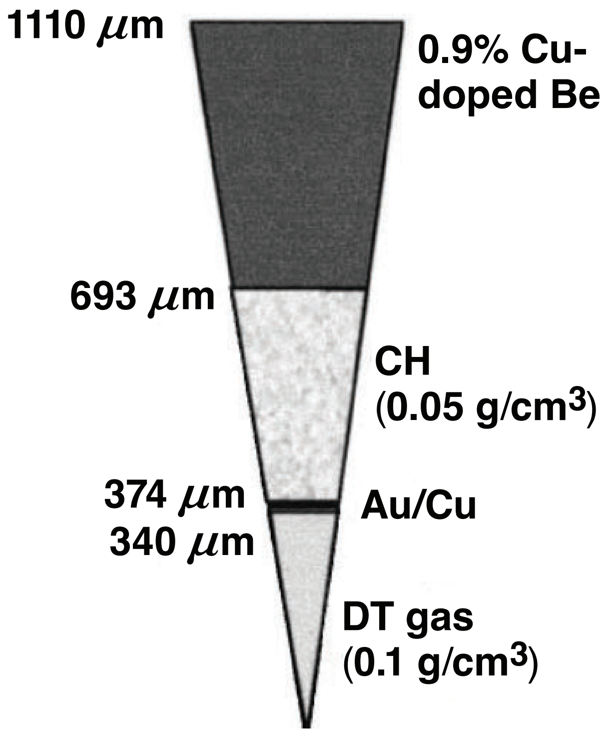
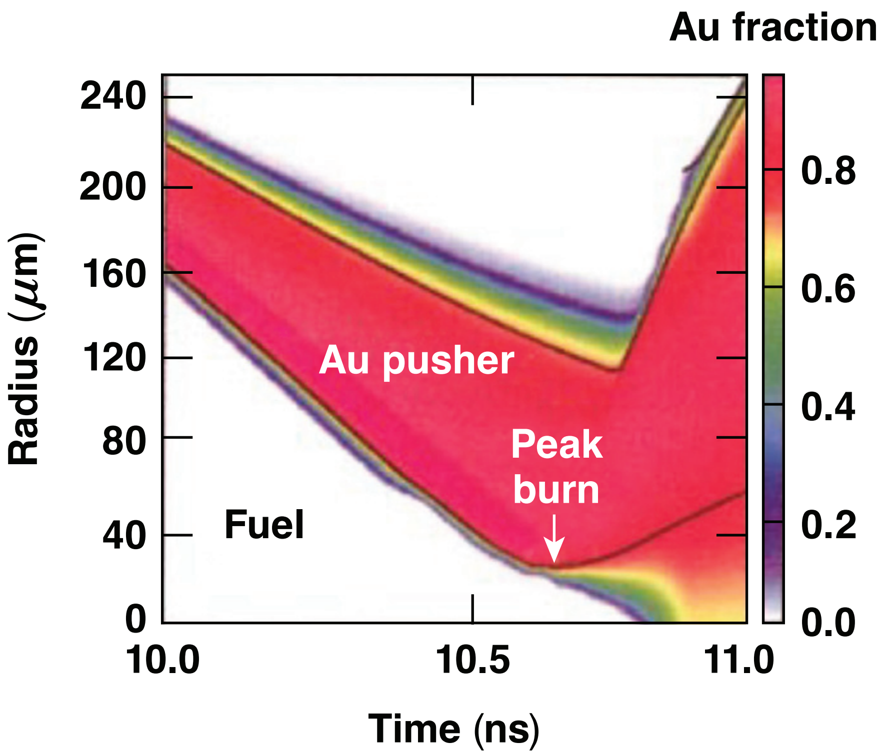
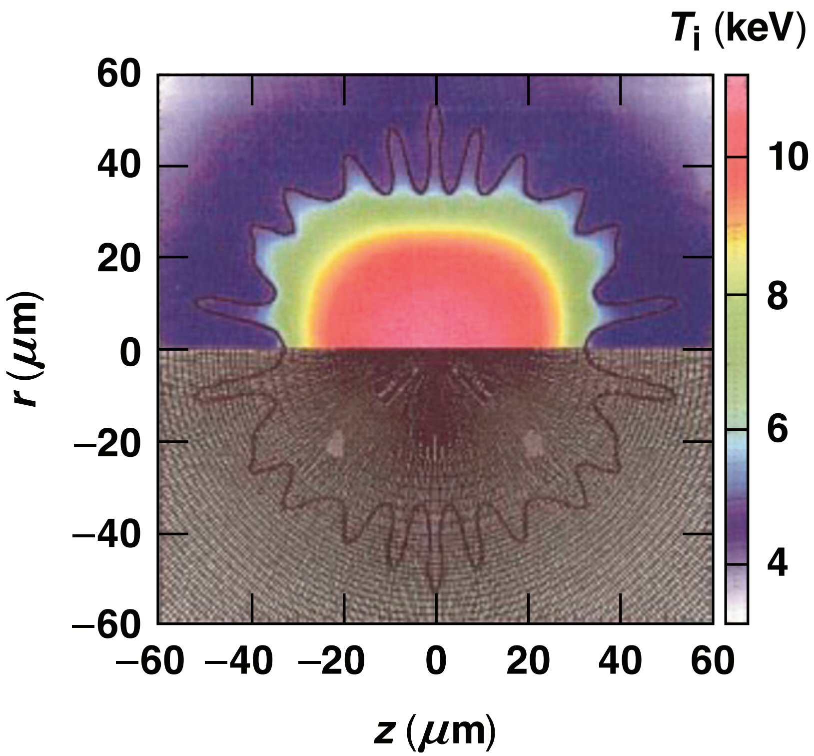
Indirect-drive double-shell designs have been investigated for noncryogenic targets* in the past

Results of P. Amendt *et al.* (2002)







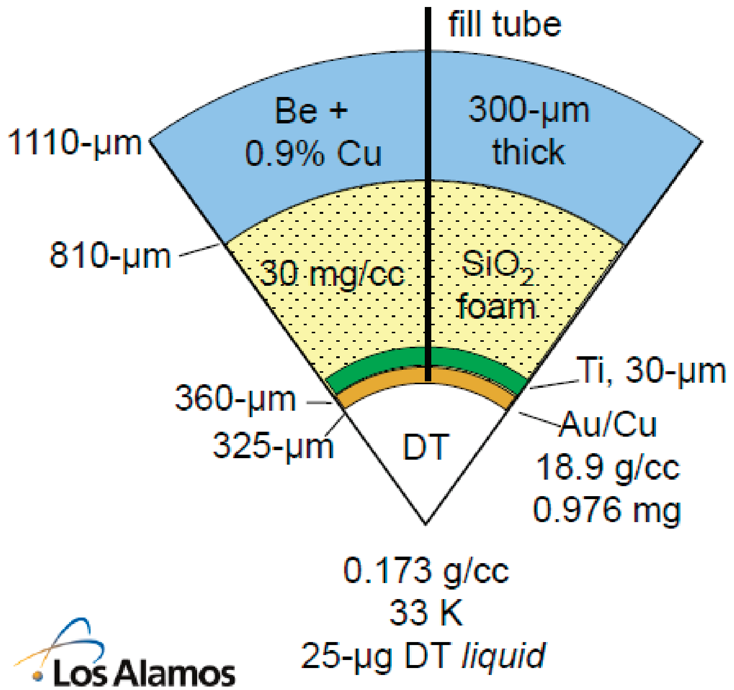
Mixing between the inner shell and DT fuel is always a concern for double-shell targets.

*W. S. Varnum *et al.*, Phys. Rev. Lett. 84, 5153 (2000);
P. Amendt, J. D. Colvin *et al.*, Phys. Plasmas 9, 2221 (2002); P. A. Amendt *et al.*, Phys. Rev. Lett. 94, 065004 (2005);
J. Milovich *et al.*, Phys. Plasmas 11, 1552 (2004);
H. F. Robey *et al.*, Phys. Plasmas 12, 072701 (2005); H. F. Robey *et al.*, Phys. Rev. Lett. 103, 145003 (2009).

TC14471

Interest in indirect-drive *cryogenic* double-shell* (or multiple-shell**) targets has been recently renewed because they may provide an alternative path to ignition

Results of D.S. Montgomery *et al.* (2015)



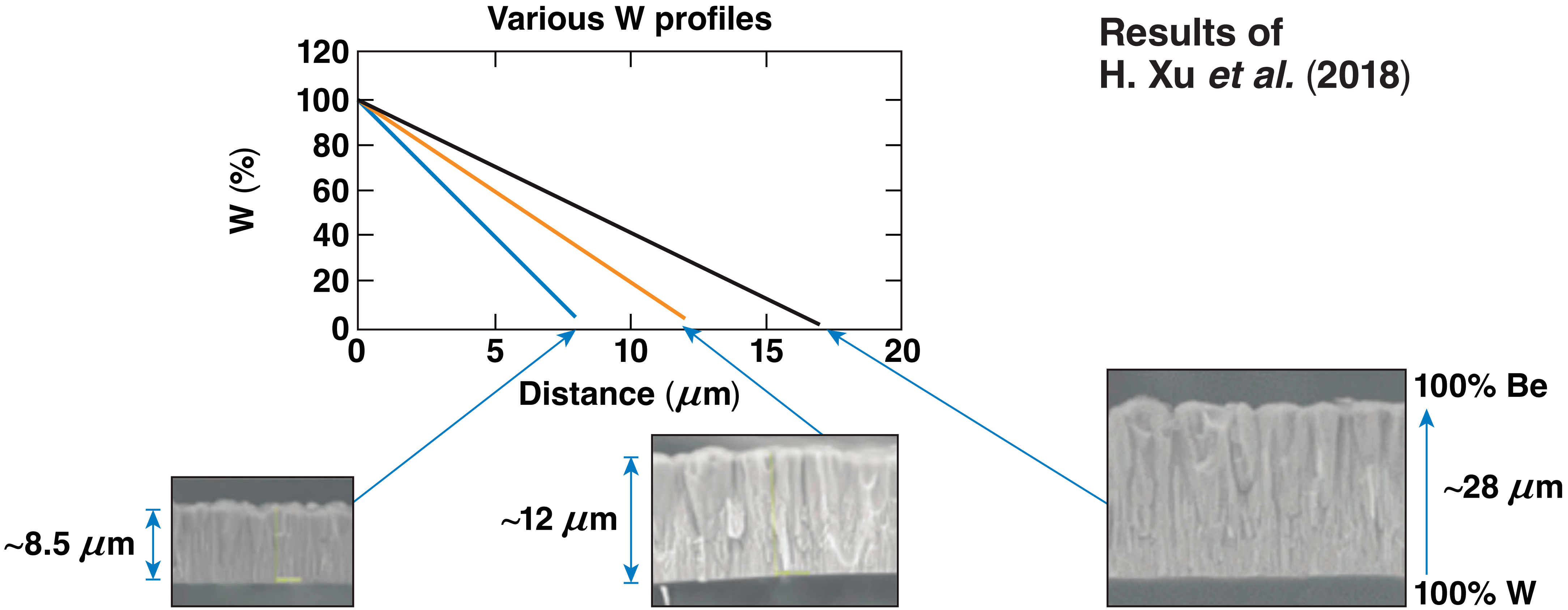
- 1.8-MJ laser energy
- 1-D clean yield ~3 MJ (22% burn)
- 1-D fall-line mix ~1 MJ
- 1-D *RAGE* with BHR mix ~0.5 MJ
- 30-μm Ti tamper outside Au improves 1-D performance; Be tamper is also proposed to use for indirect-drive double-shell designs†

*D. S. Montgomery *et al.*, Phys. Plasmas 25, 092706 (2018);
E. C. Merritt *et al.*, Bull. Am. Phys. Soc. 61, BAPS.2016.DPP.PO5.3 (2016).
**K. Molvig *et al.*, Phys. Rev. Lett. 116, 255003 (2016);
P. McKenty *et al.*, Bull. Am. Phys. Soc., CO4.00002 (2018).
†E. Loomis, presented at the 22nd Target Fabrication Meeting, Las Vegas, NV, 12–16 March 2017.
BHR: Besnard–Harlow–Rauenzahn

TC14472

Recent progress to make *gradient-density shells** at General Atomics could significantly help to mitigate the classical Rayleigh–Taylor instability for double-shell target designs

Results of
H. Xu *et al.* (2018)



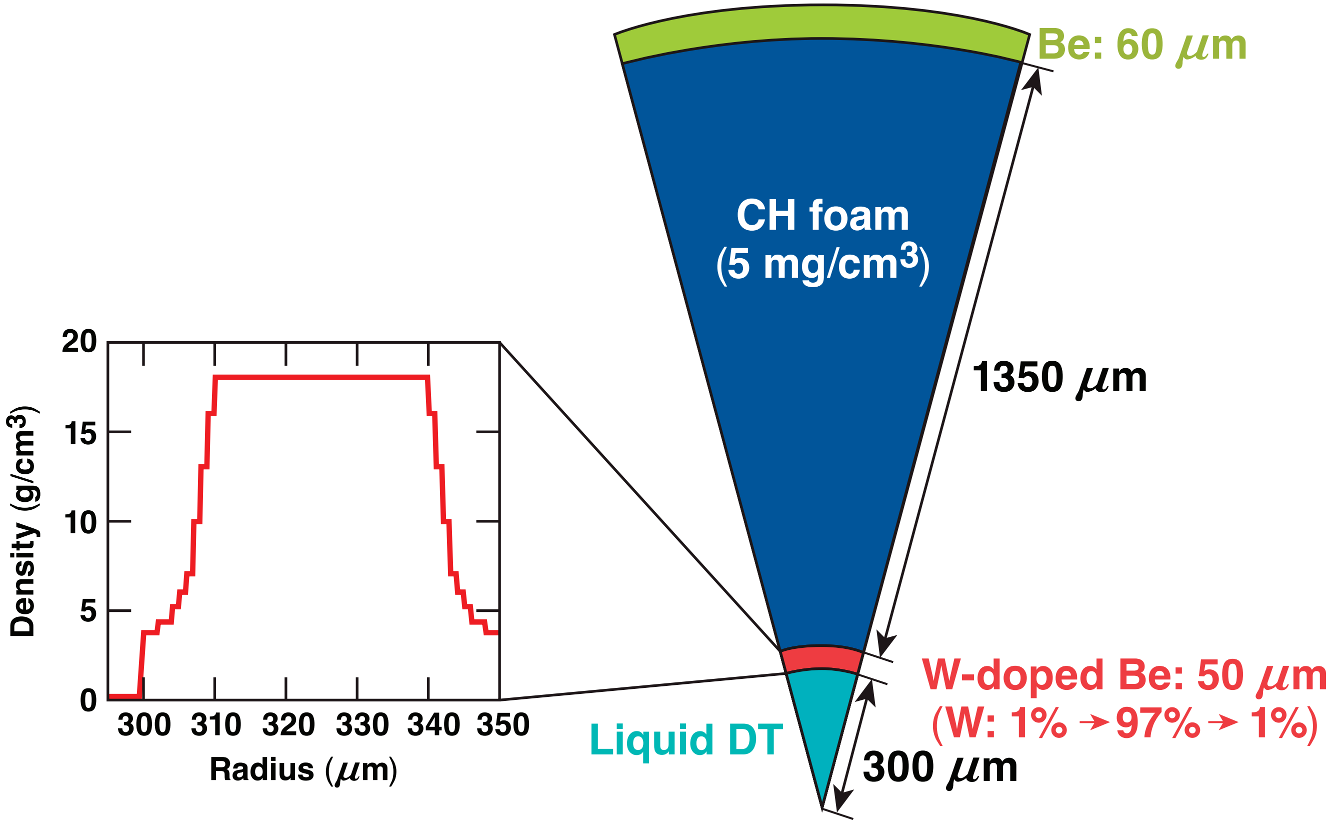
A density gradient for the inner shell could reduce the Atwood numbers at interfaces for double-shell targets.

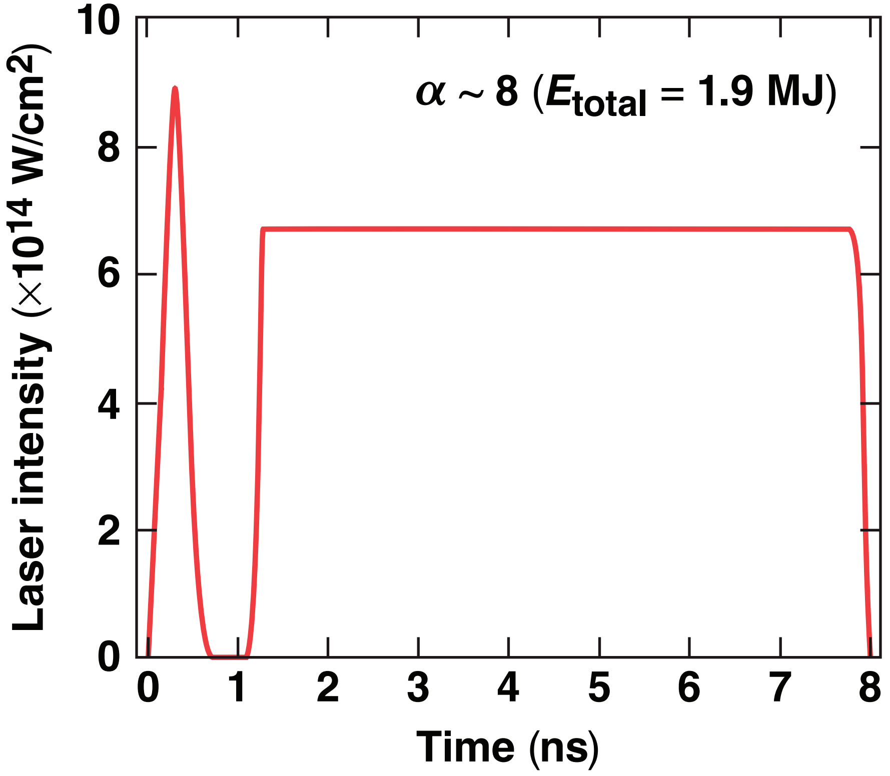
*H. Xu *et al.*, Fusion Sci. Technol. 73, 354 (2018).

TC14473

High-adiabat ($\alpha \approx 8$ to 10) direct-drive double-shell designs with a *gradient-density* inner shell were examined using *DRACO* with comprehensive physics models (NL + CBET + FPEOS)

1-D yield: ~1.8×10^{18} (~5.1 MJ)



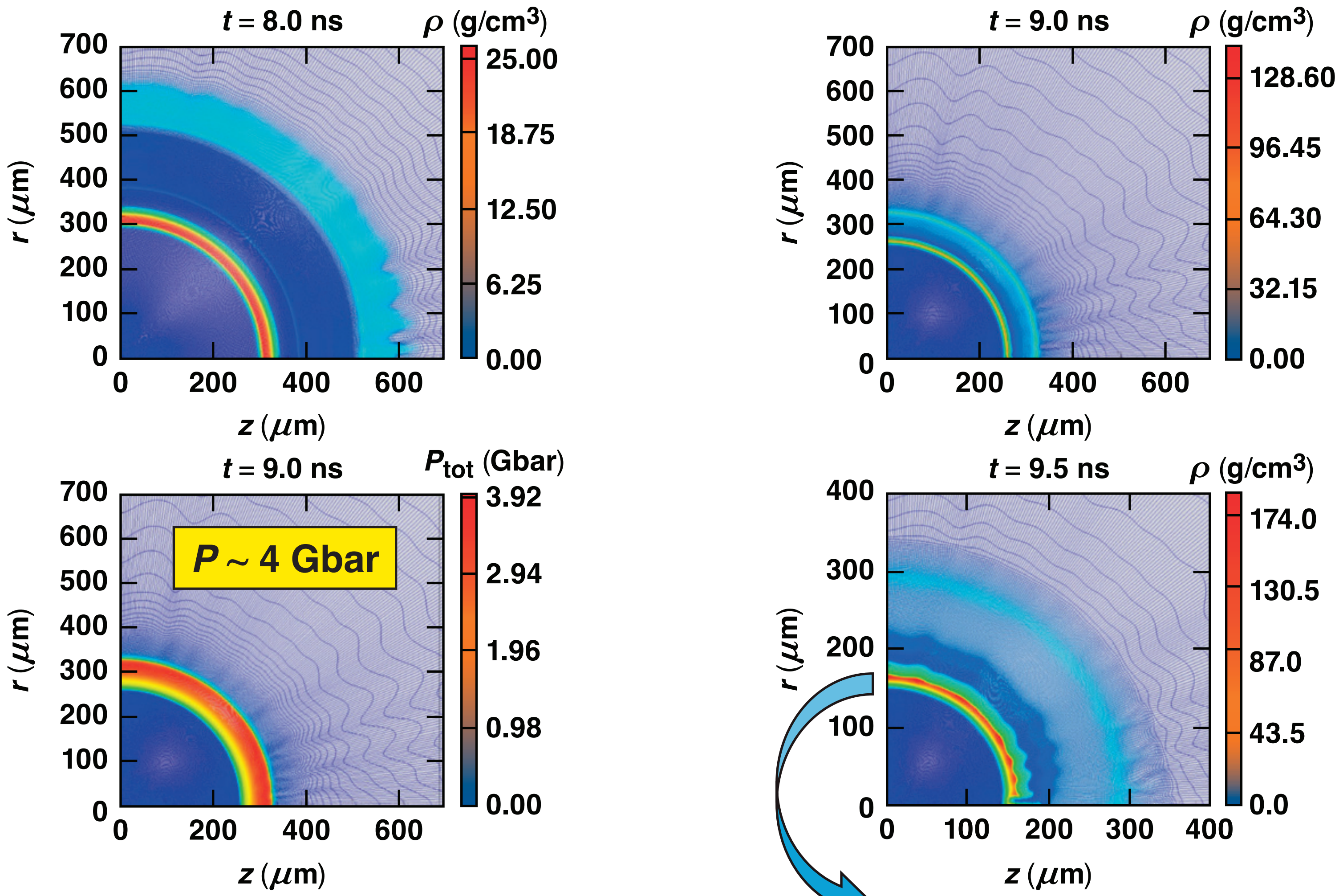


Direct drive can couple more energy to targets: E_k (outer shell) ≈ 90 kJ and E_k (inner shell) ≈ 40 kJ.

NL: nonlocal
CBET: cross-beam energy transfer
FPEOS: first-principles equation of state

TC14474

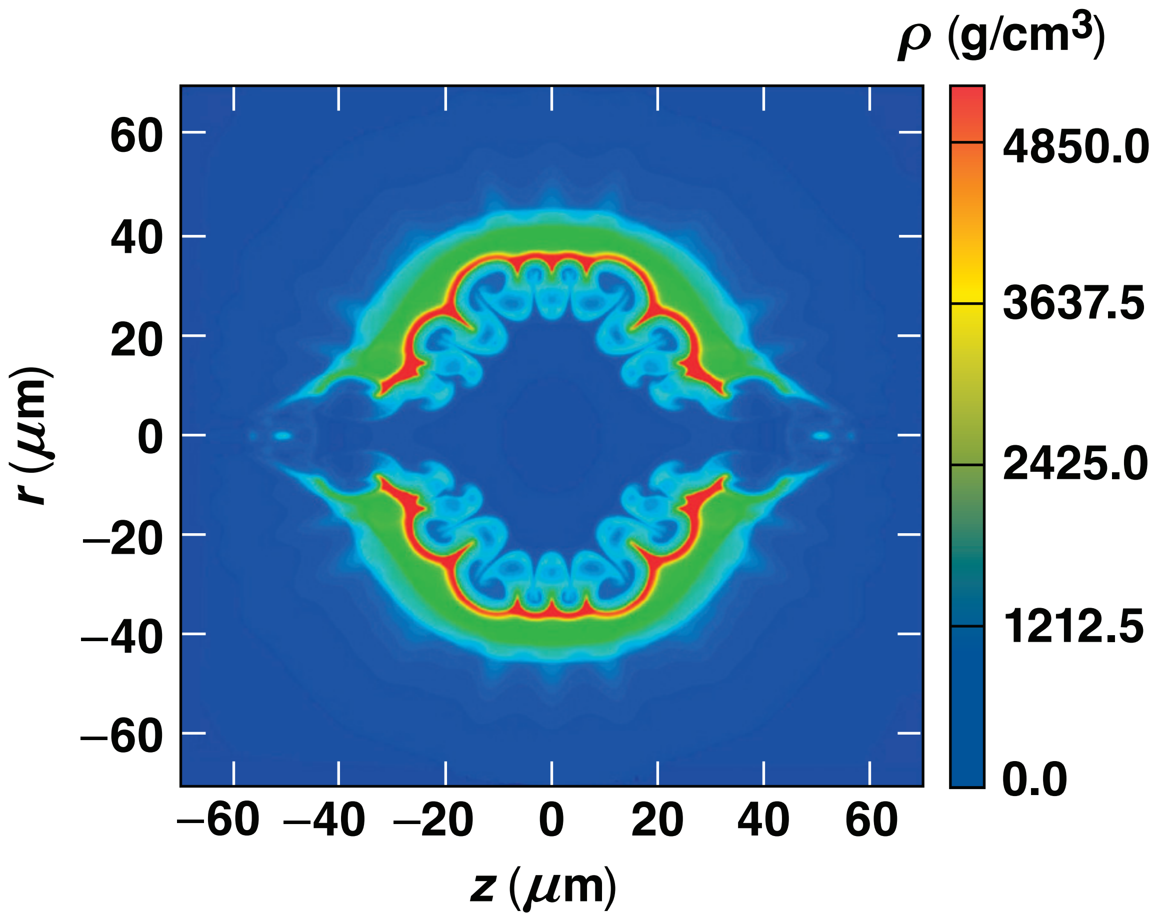
DRACO simulations with long-wavelength drive nonuniformities (up to $\ell = 50$) have indicated an *impact pressure* of $P \sim 4$ Gbar when the outer shell stagnates on the inner shell

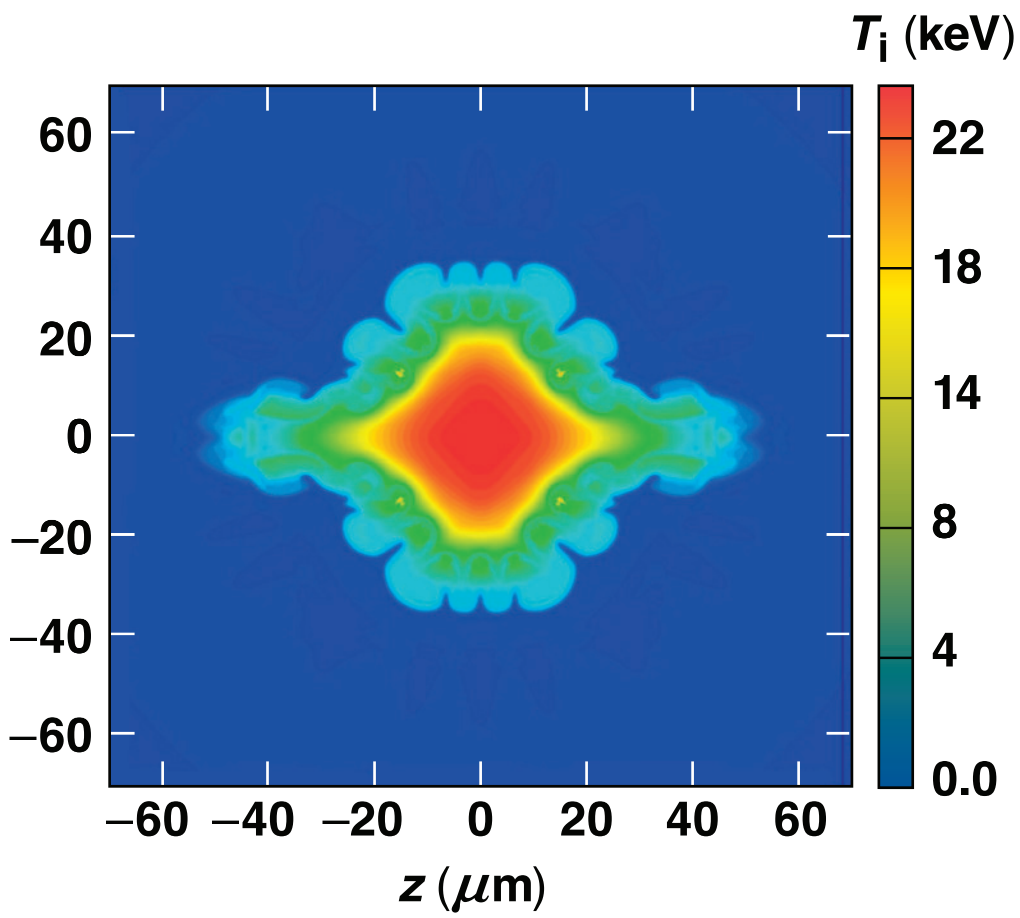


Long-wavelength modes have "imprinted" on the imploding inner shell.

TC14475

The low-mode *DRACO* simulation has resulted in an igniting double-shell target with a neutron yield of ~3.2-MJ energy

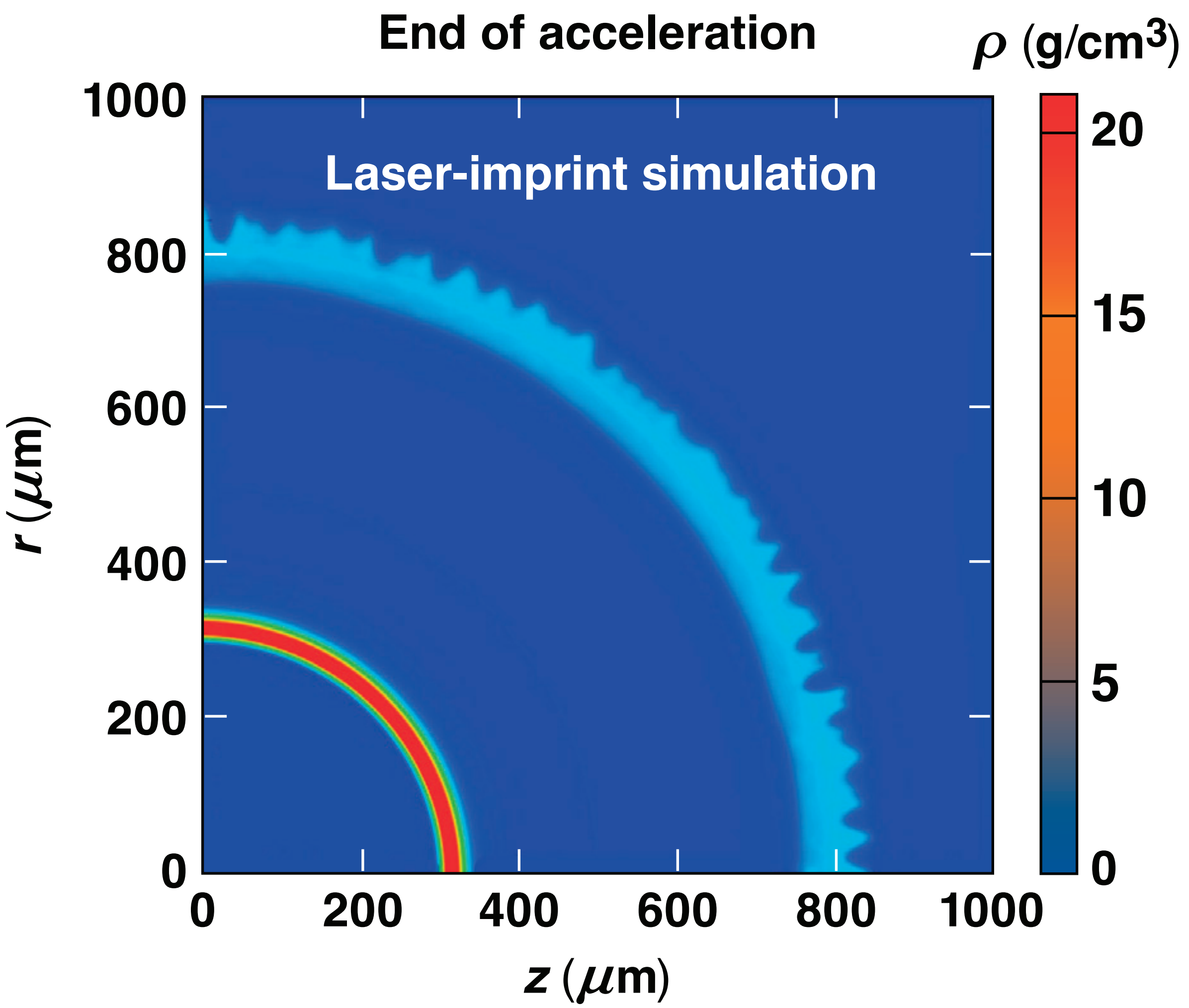




$Y \approx 1.14 \times 10^{18}$ and $\langle T_i \rangle = 22.9$ keV

TC14476

Setting the outer shell on high adiabat ($\alpha \approx 8$ to 10) helps to reduce laser-imprint effects in high-mode *DRACO* simulations (up to $\ell = 150$)



High-mode *DRACO* simulations with laser imprinting are in progress (MJ yield is expected).

TC14477

MJ neutron yield could be possible for direct-drive double-shell implosions with gradient-density shells

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