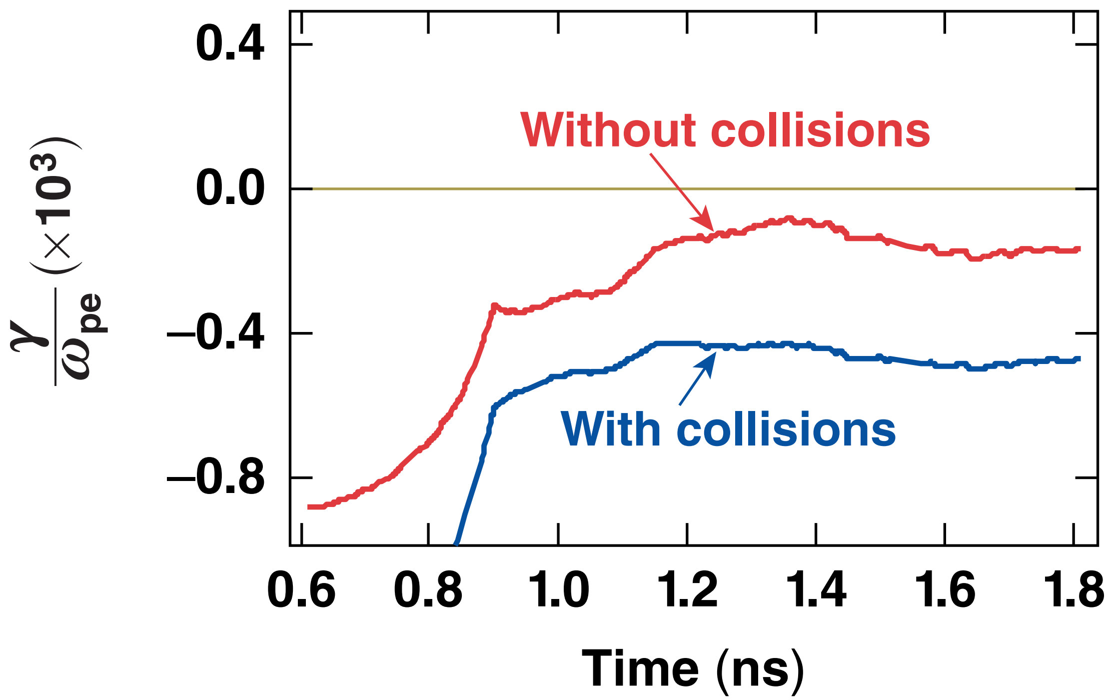
High-Z Ablator Targets for Direct-Drive Inertial Confinement Fusion

Two-plasmon decay in SiO_2, OMEGA at 10^{15} W/cm^2



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Summary

High-Z ablators offer a possible solution for laser–plasma instabilities in direct-drive inertial confinement fusion (ICF)

FSC

UR LLE

- There is strong experimental and theoretical evidence that hot-electron production is greatly reduced in high-Z ablators such as Si, SiO_2
- High-Z ablator targets must be designed with optically thick layers to prevent radiation preheat of the fuel
- OMEGA implosion experiments require glass/silicon-coated CH shells. The two-plasmon decay (TPD) is below threshold for glass ablators on OMEGA
- Shock ignition targets for the NIF using glass/silicon ablators can be designed below the linear threshold during the assembly pulse

*For 2-D hydrodynamics of high-Z ablators see, Lafon, JO4.00003, this conference.

Collaborators

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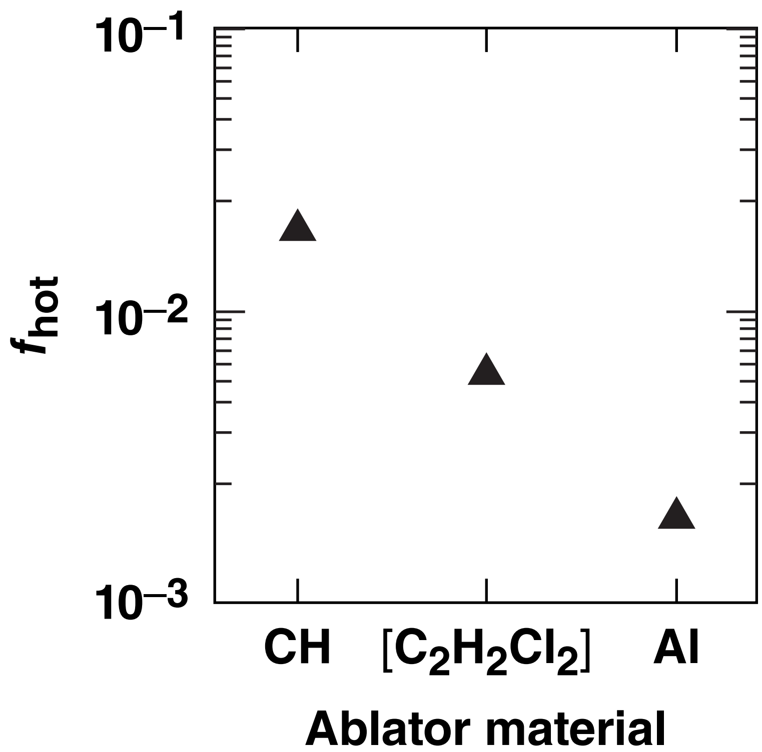
High-Z reduction of TPD is seen in experiments and simulations

- Hard x-rays (HRX) reduced by more than 40× in glass with respect to plastic at 10^{15} W/cm^2*
- Confirmed:
  - on multiple materials in planar targets**
  - in particle-in-cell (PIC) simulations†
  - in quasilinear Zakharov model simulations‡

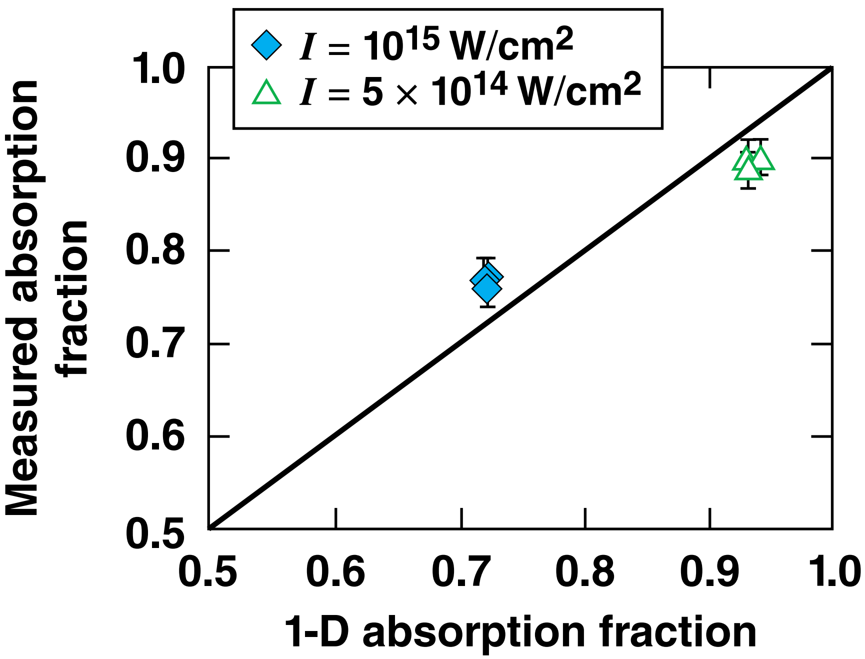


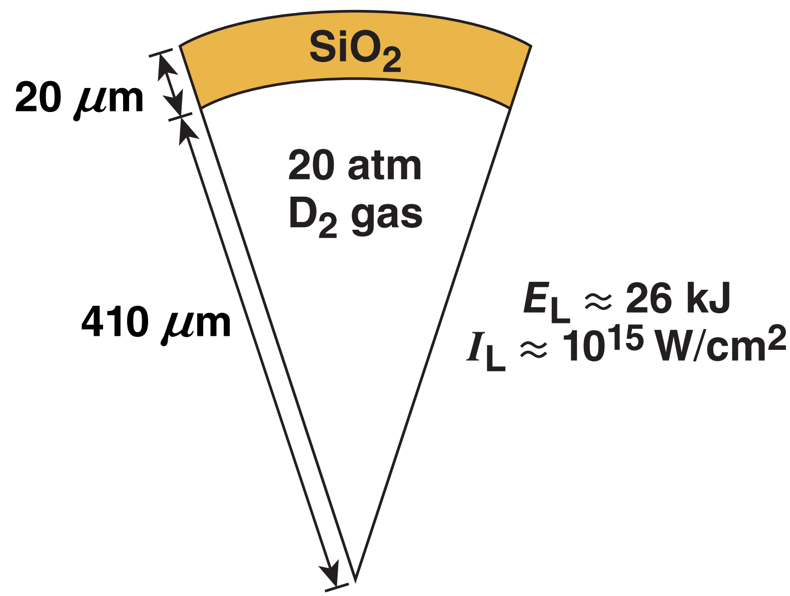
*V. A. Smalyuk *et al.*, Phys. Rev. Lett. 104, 165002 (2010).
**D. H. Froula *et al.*, "Direct-Drive Laser-Plasma Interactions Experiments," to be published in Plasma Physics and Controlled Fusion.
†R. Yan *et al.*, Phys. Rev. Lett. 108, 175002 (2012); J. Li, TO5.00003, this conference.
‡J. F. Myatt, TO5.00005, this conference.

TC10315

High laser absorption and 1-D areal density were measured in thick glass–shell implosion experiments

- Measured areal density = 140 to 150 mg/cm^2
- Predicted areal density = 140 to 170 mg/cm^2
- Areal density modulation $\Delta(\rho R)/\rho R \leq 4\%$ (from four directions)

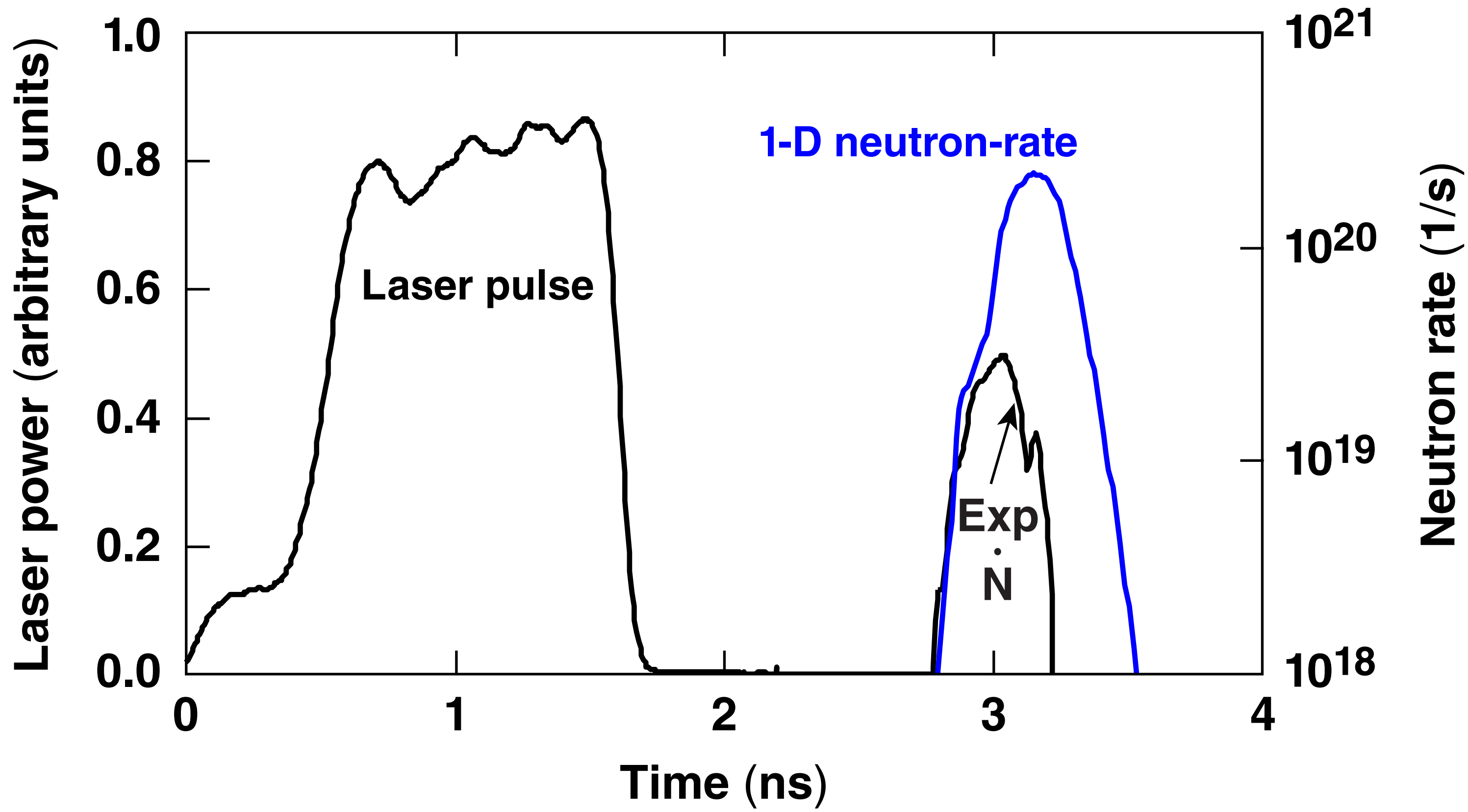




TC10316

*V. A. Smalyuk *et al.*, Phys. Rev. Lett. 104, 165002 (2010).

Implosion experiments with thick glass shells show highly truncated neutron rates



TC10317

A density jump at the D_2–SiO_2 interface likely drives short-wavelength mixing leading to burn truncation

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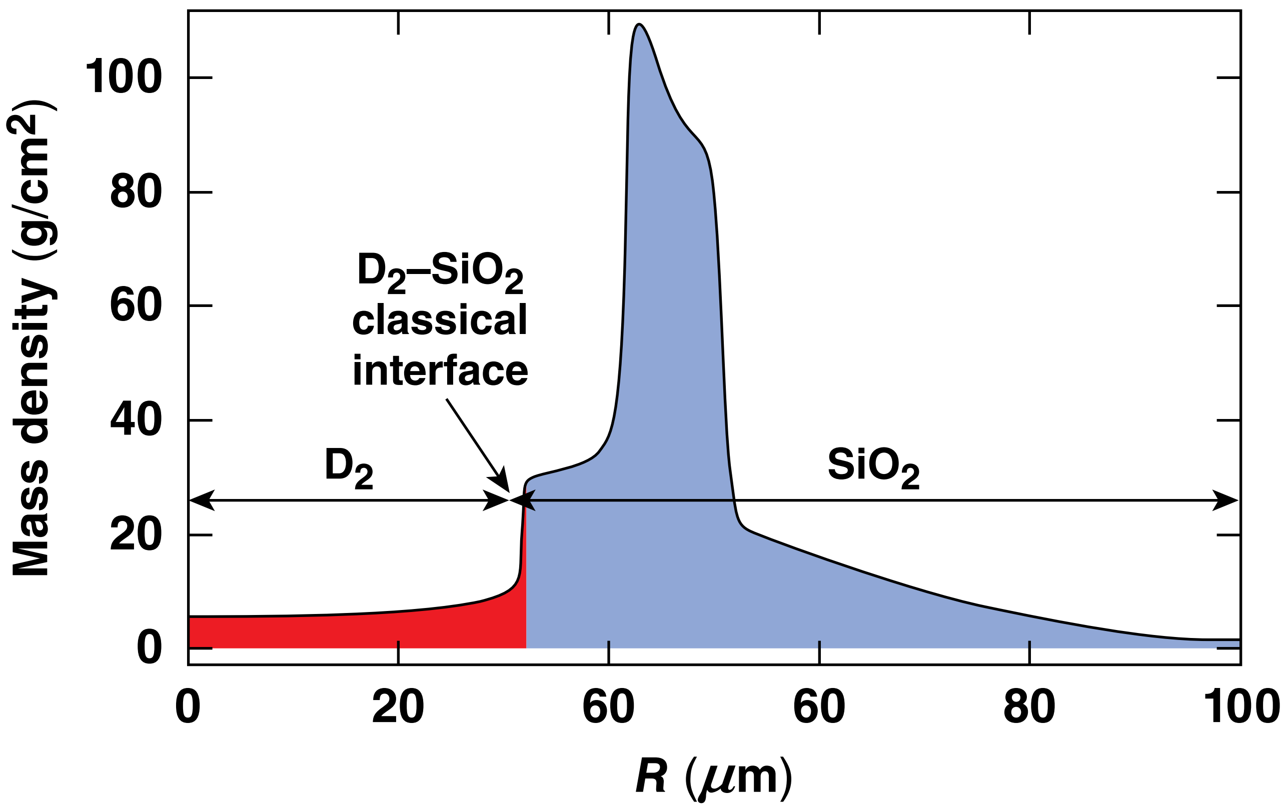

TC10318

The measured yield is consistent with the predictions of the free-fall model for mix-front penetration and clean hot-spot volume

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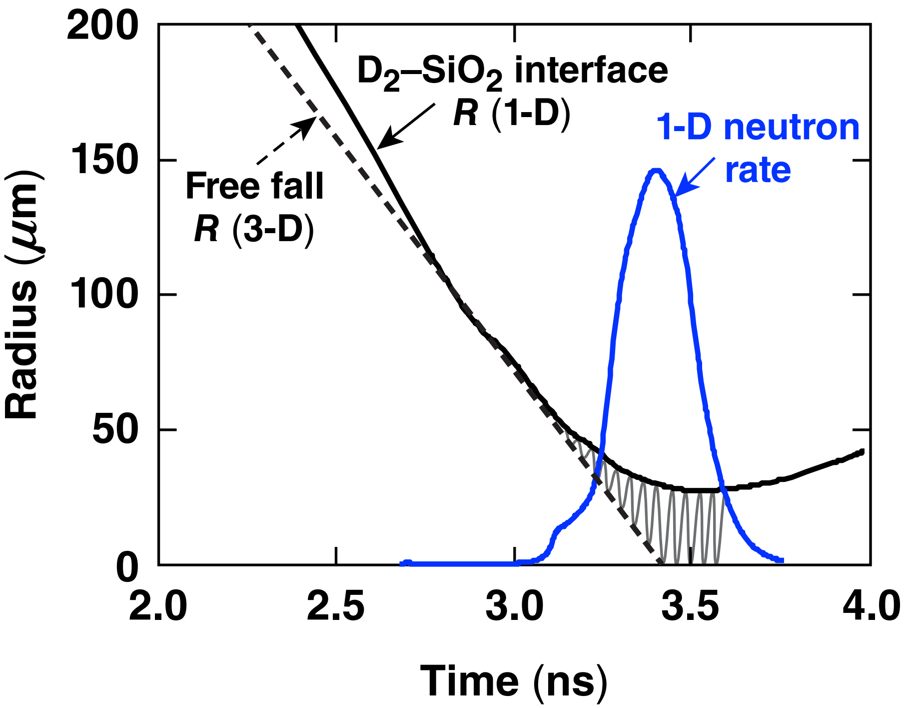
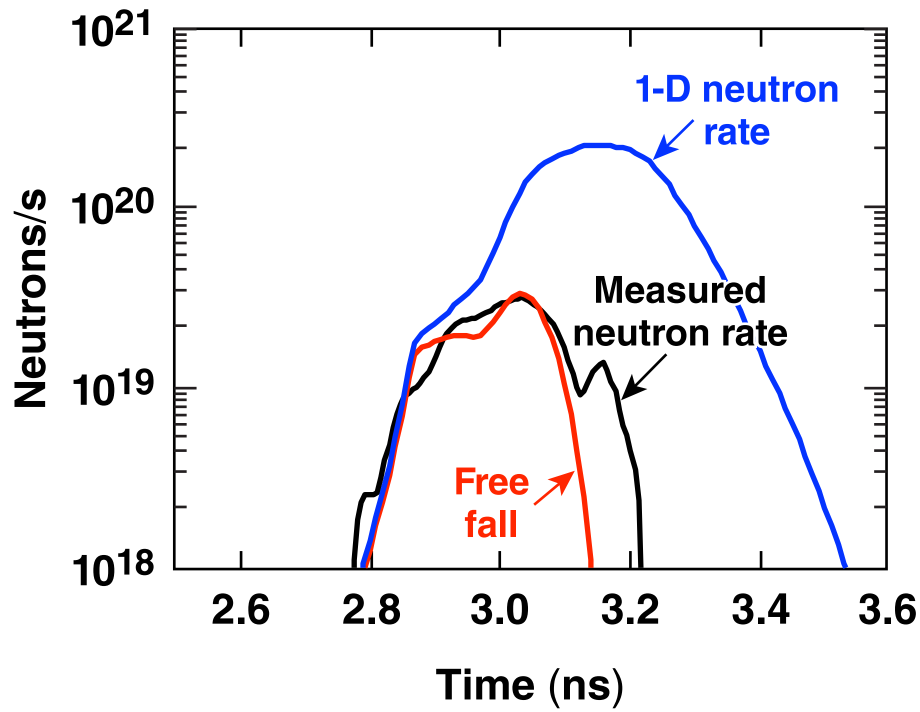
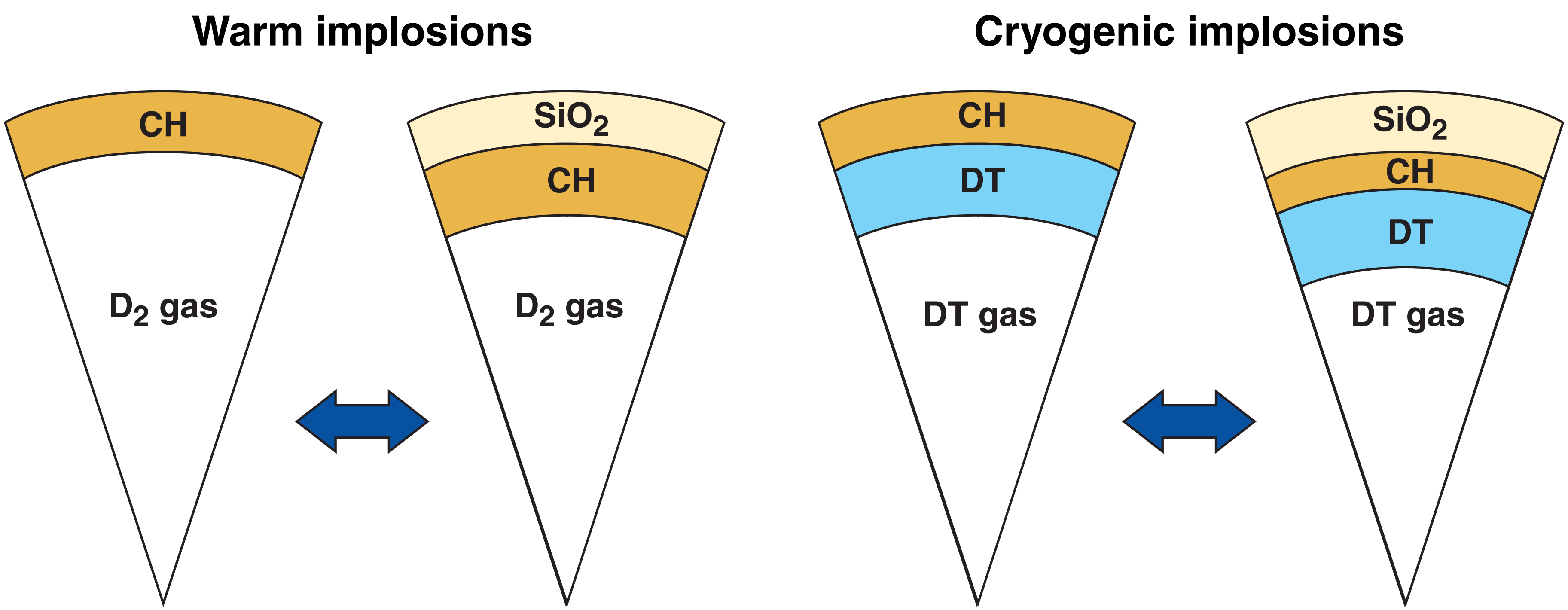




$$\text{Free-fall neutron rate} = \text{1-D neutron rate} \times \left(\frac{R\,[\text{3-D}]}{R\,[\text{1-D}]}\right)^3$$

TC10319

An assessment of the hydrodynamics of high-Z ablators requires hydro-equivalent implosions with the same gas–shell interface



Hydro-equivalency → same "payload" velocity and adiabat, and SiO_2-coated plastic for similar Rayleigh–Taylor (RT) growth at classical interface.

TC10320

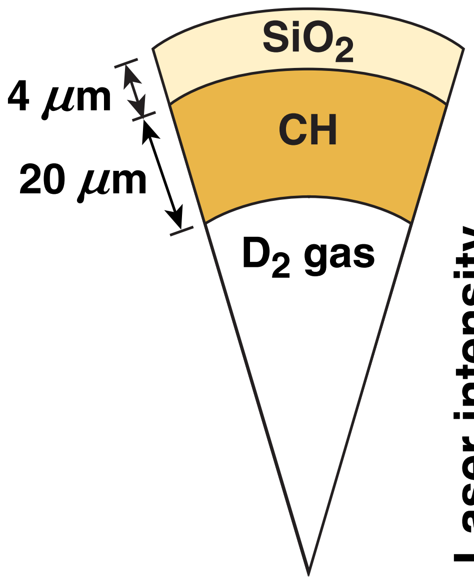
Compression experiments of warm OMEGA targets require thick-SiO_2 and a Si-doped CH layer to prevent radiation preheat of the CH payload

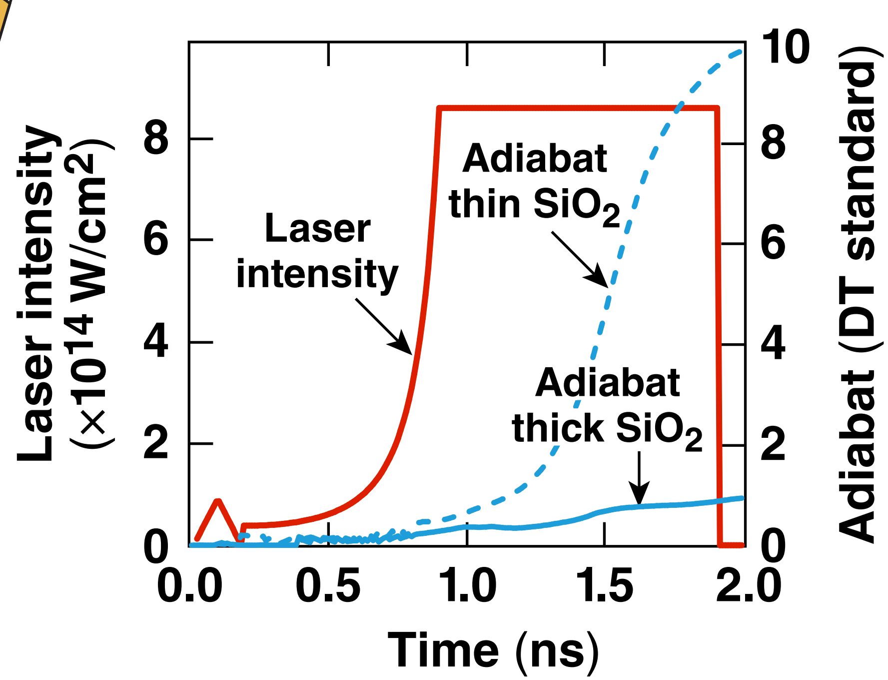
Thin-SiO_2 ablator

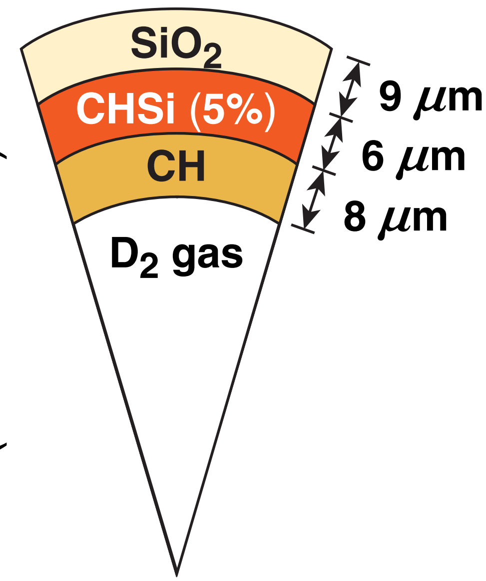
- SiO_2 is at 1/4 critical
- ρR = 90 mg/cm^2

Thick-SiO_2 ablator

- SiO_2 is at 1/4 critical
- ρR = 230 mg/cm^2







TC10321

The TPD cannot be driven above the linear threshold in SiO_2-ablator targets on OMEGA at 10^{15} W/cm^2

FSC

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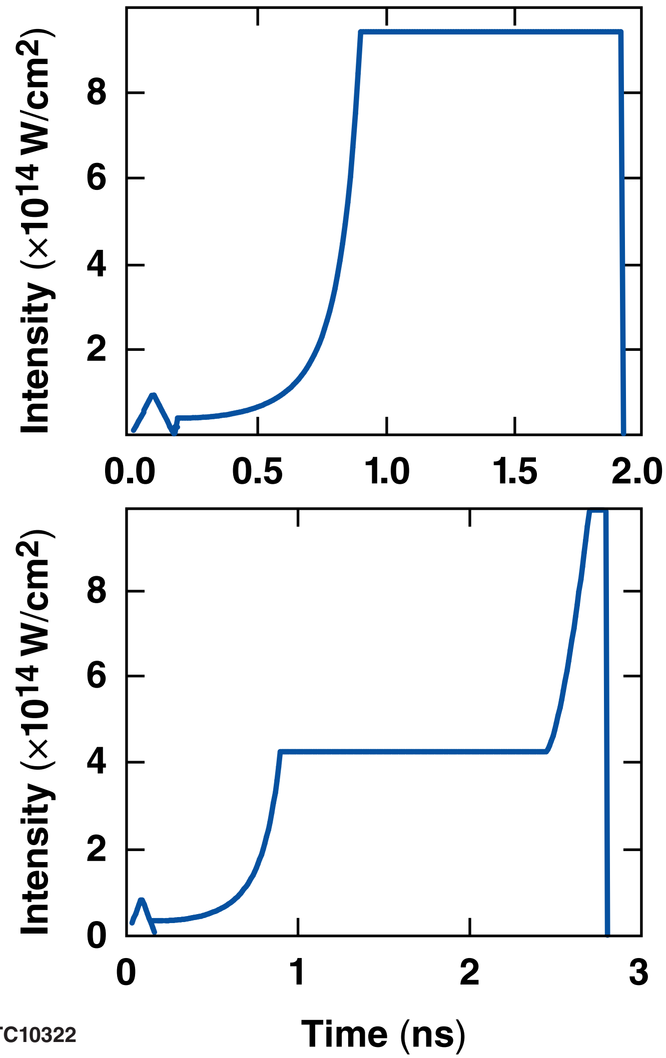
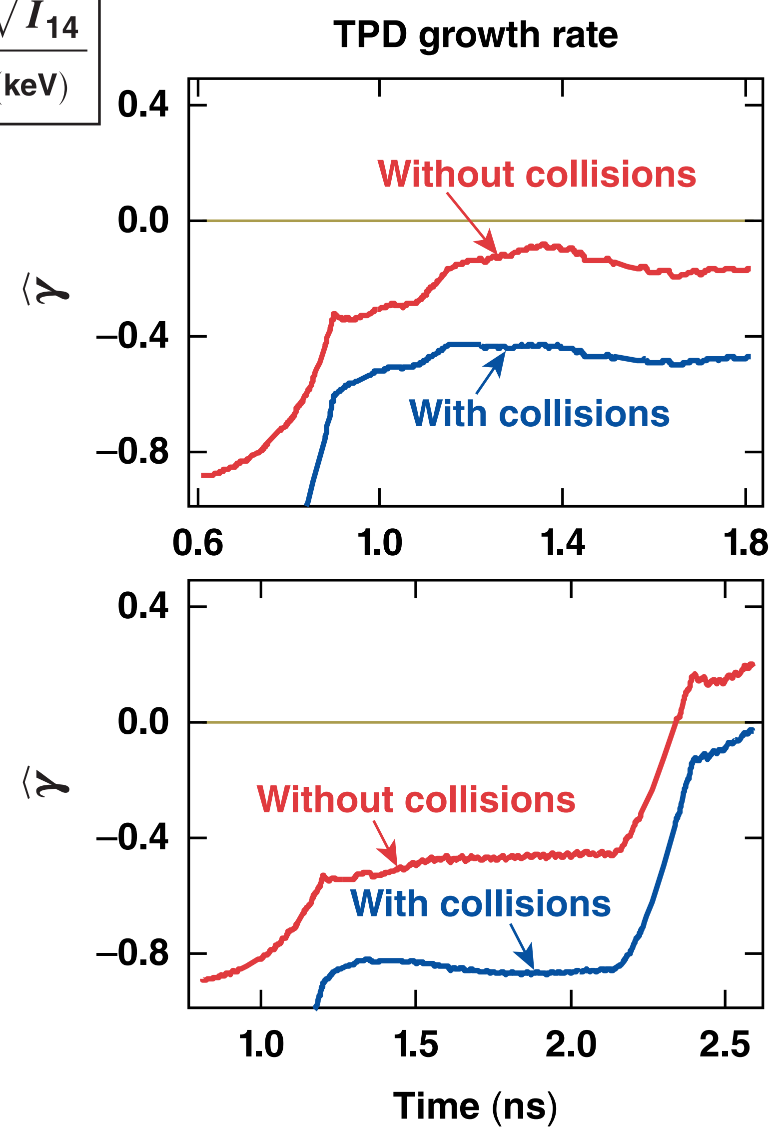
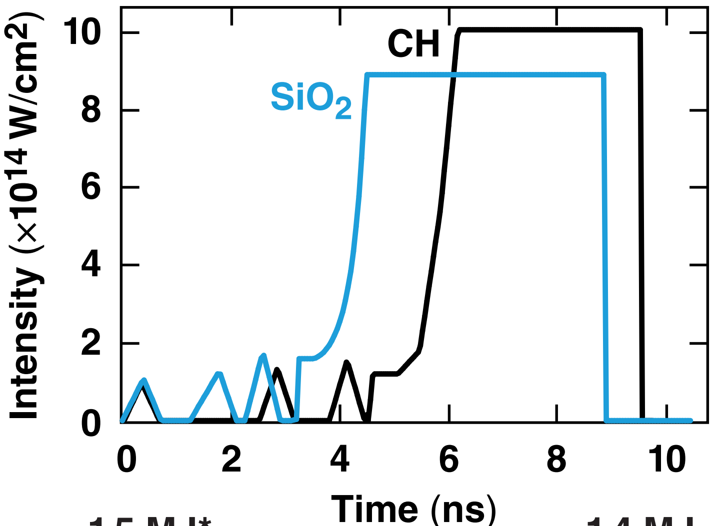
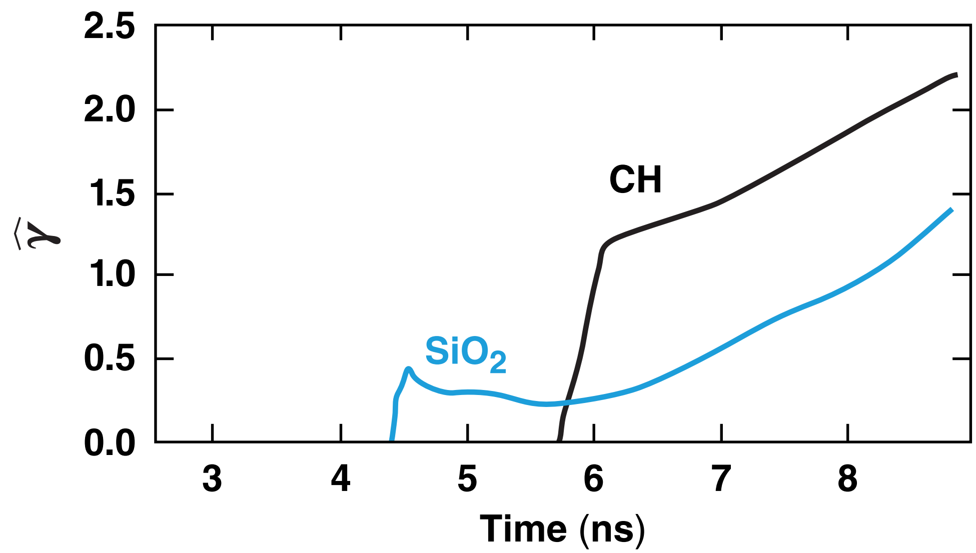
$$\hat{\gamma} = \frac{4\gamma L_{\mu m}\sqrt{I_{14}}}{\omega_{pe} T_{e(keV)}}$$

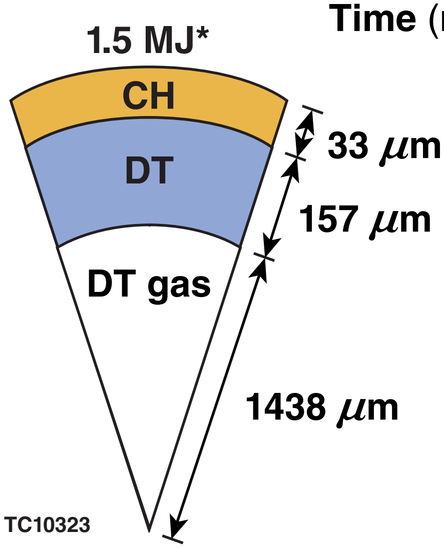


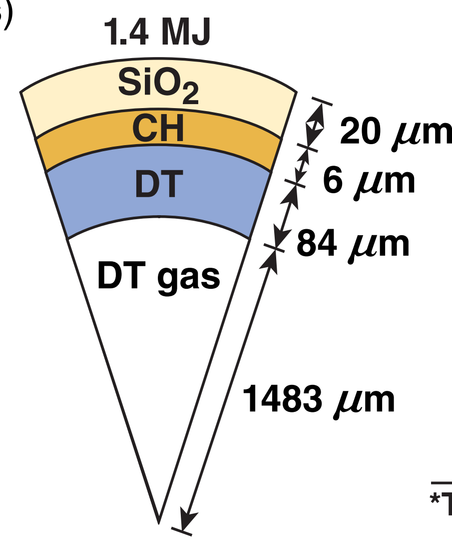


Because of the large scale length at quarter critical in NIF targets, designs below linear TPD threshold may be difficult to achieve







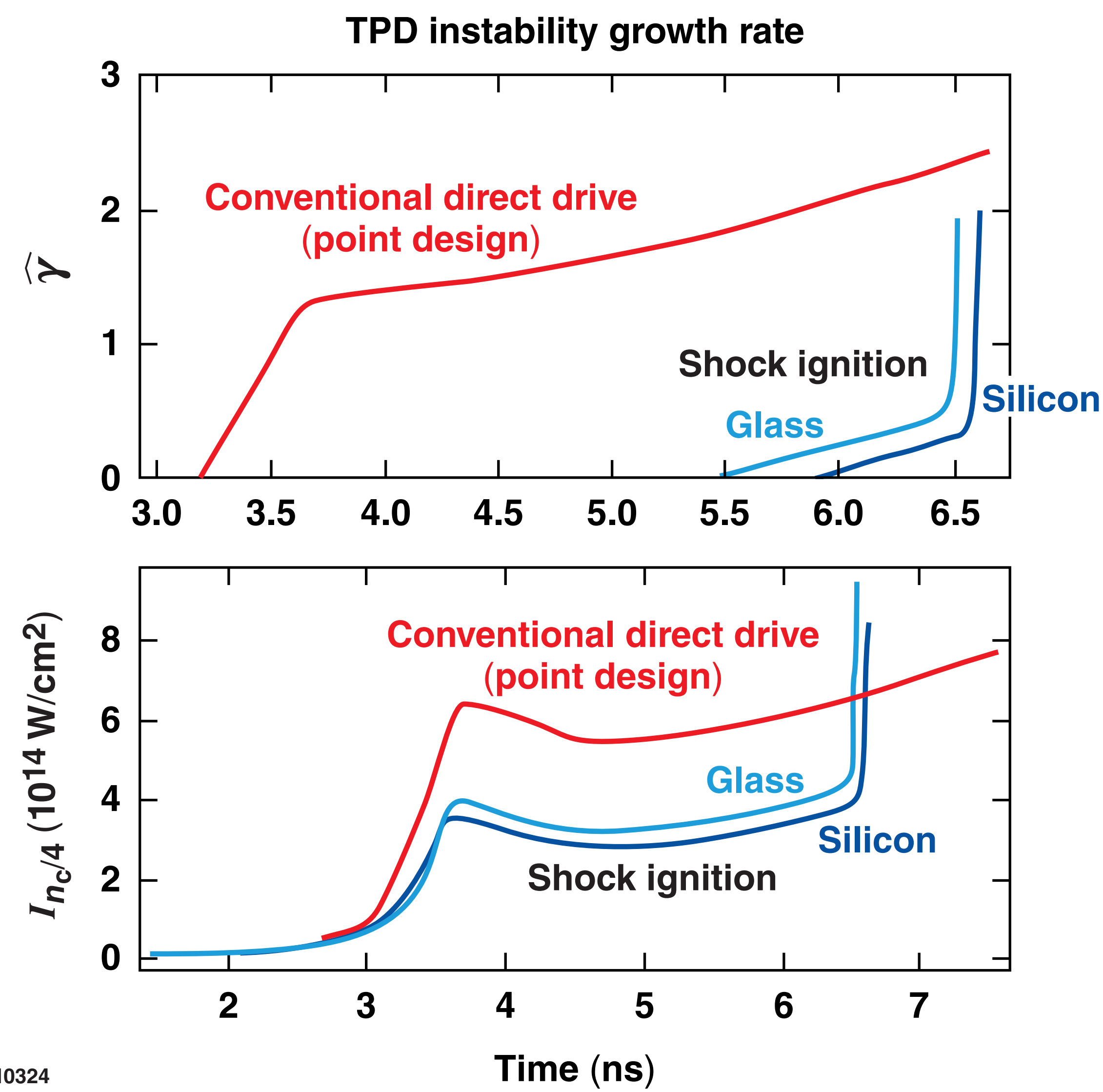


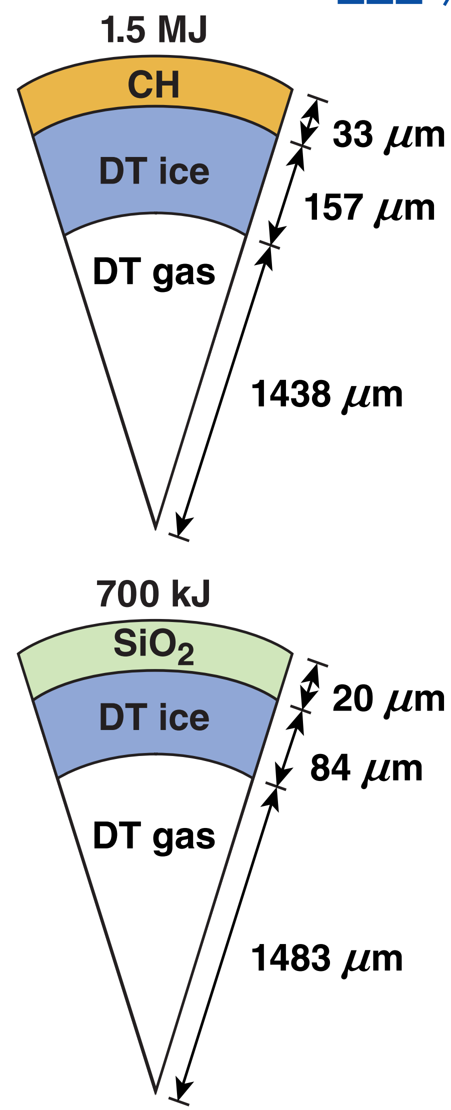
$$\widehat{\gamma} = \frac{4\gamma L_{\mu m}\sqrt{I_{14}}}{\omega_{pe} T_{e(keV)}}$$

TC10323

*T. J. B. Collins *et al.*, Phys. Plasmas 19, 056308 (2012).

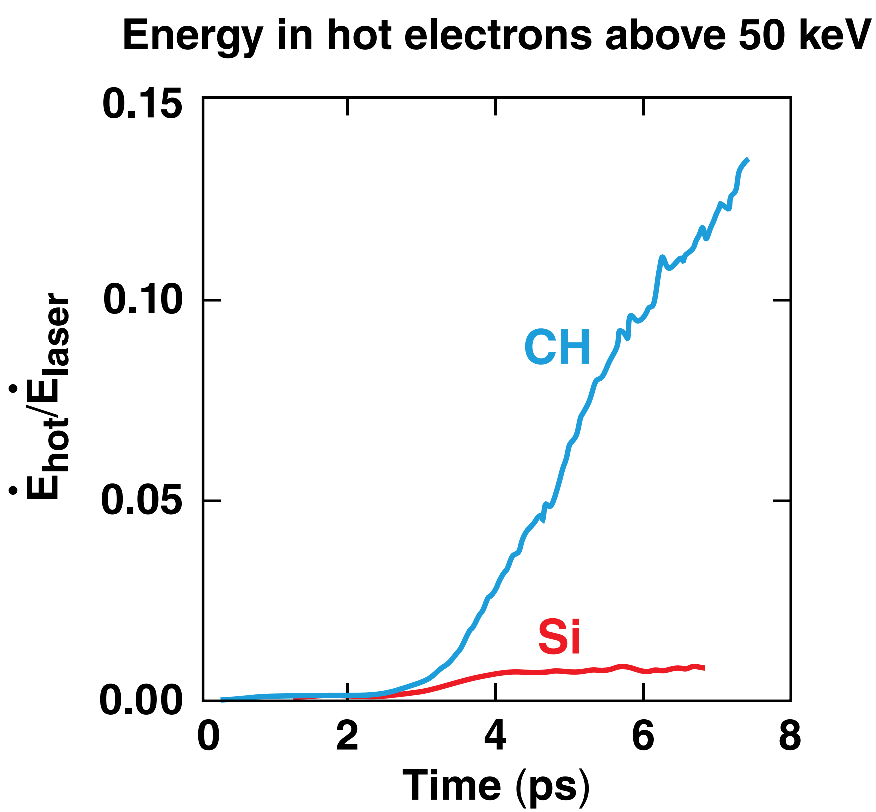
Shock-ignition, 700-kJ NIF SiO_2 targets can be designed to be almost fully below threshold during the assembly pulse

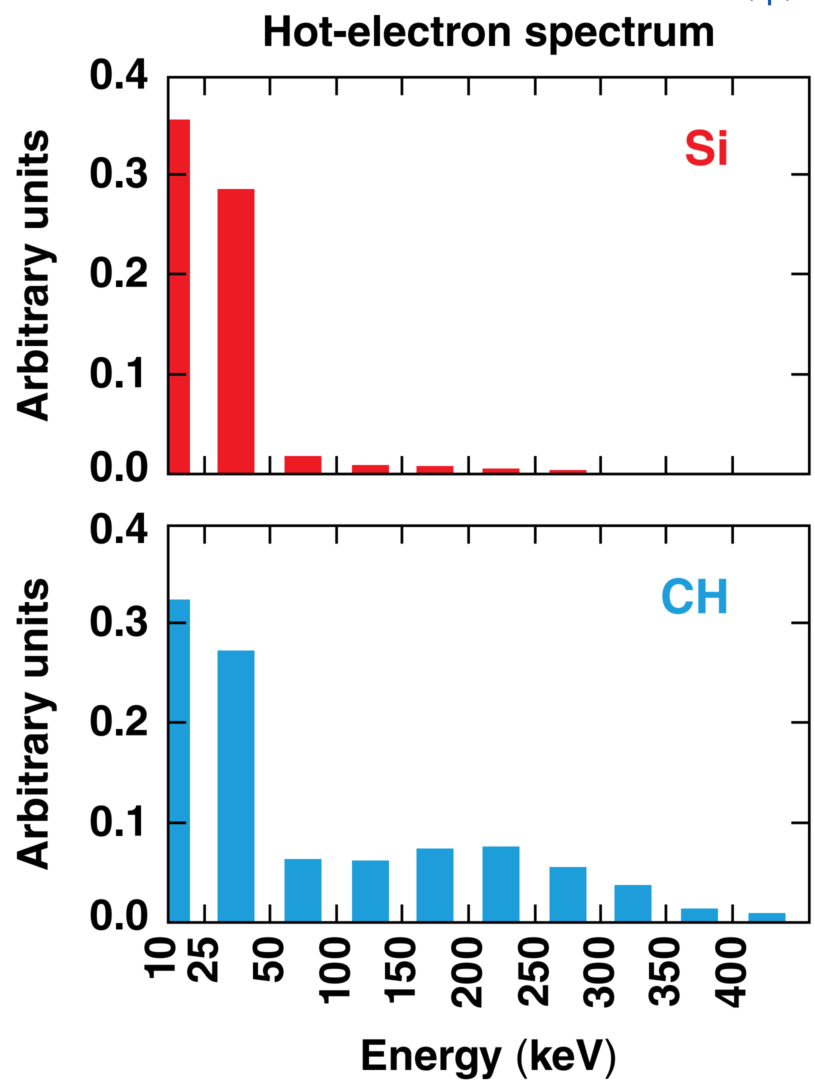




TC10324

PIC simulations show that hot-electron production in Si is negligible even at the end of the assembly pulse





*See J. Li *et al.*, TO5.00003, this conference.

Summary/Conclusions

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TC10314

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