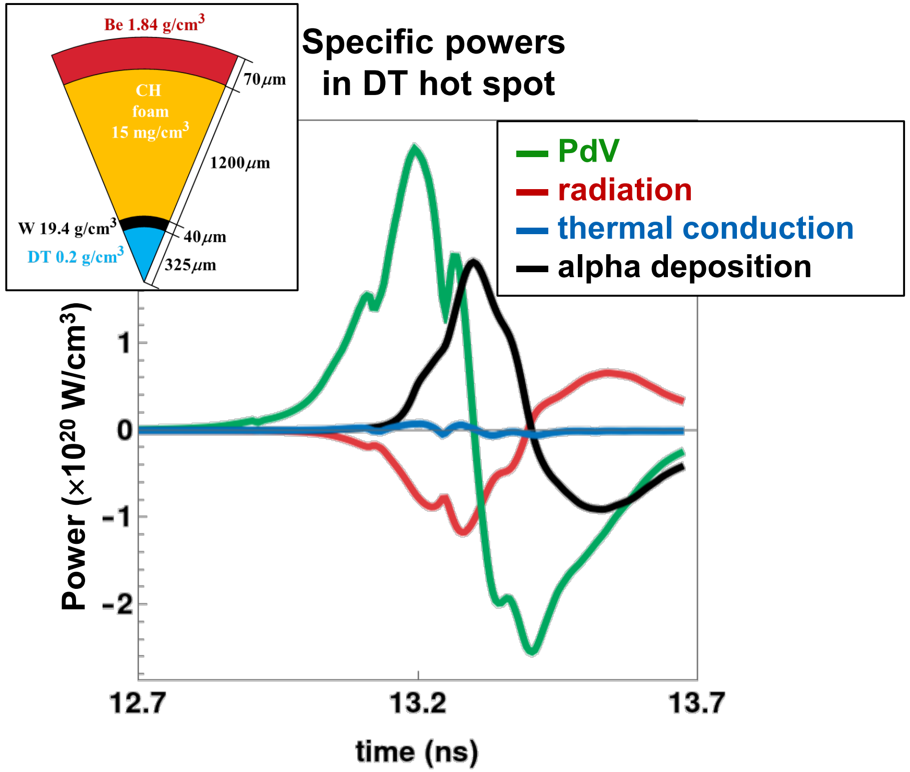
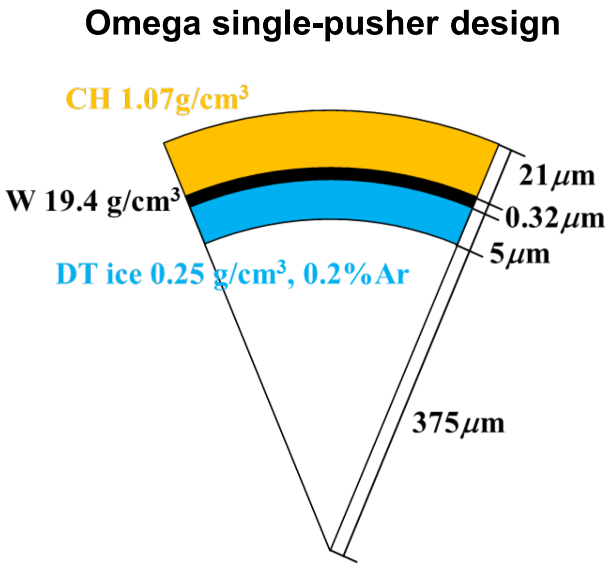
Radiation Trapping and Hot-Spot Energy Balance in High-Z Pusher Implosions





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64th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Spokane, WA
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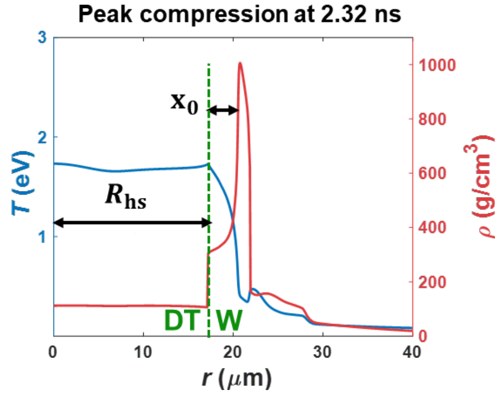
Radiation trapping in high-Z pushered implosions is effective in reducing the energy required for ignition



- Thermal conduction losses from the hot spot in high-Z pushered implosions are negligible
- The condition for effective radiation trapping by high-Z pushers is

$$R_{\mathrm{hs}} \gg x_0 \gg l_{\mathrm{Ross}}{}^*$$

- Single-shell cryo-layered high-Z pushered design is developed as a surrogate for multiple-shell NIF desings to study the radiation trapping on Omega
- Future work will include stability optimization using density graded W-Be shells and sensitivity studies to preimposed shell modulations

* R_{hs} – DT hot spot radius
x_0 – Marshak or ablative heat wave width
l_{Ross} – Rosseland photon mean free path

Related talk R. Epstein et al., JO04:00010, this session

Collaborators

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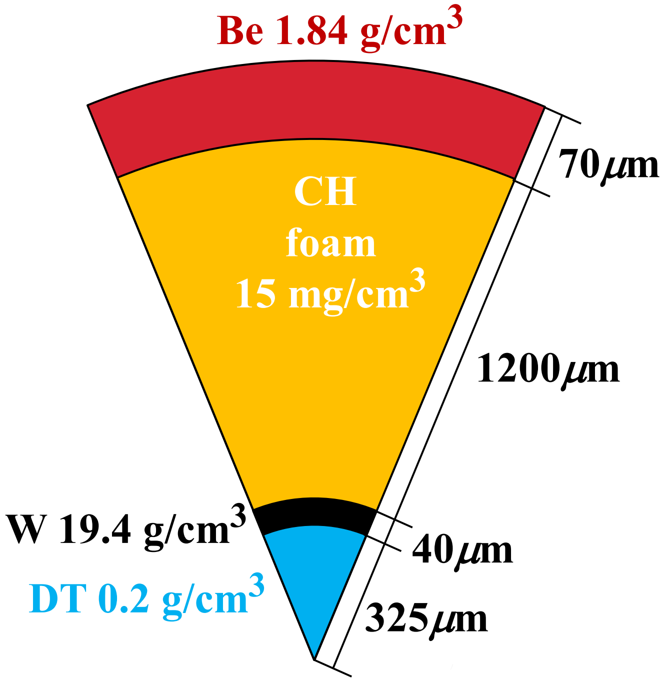
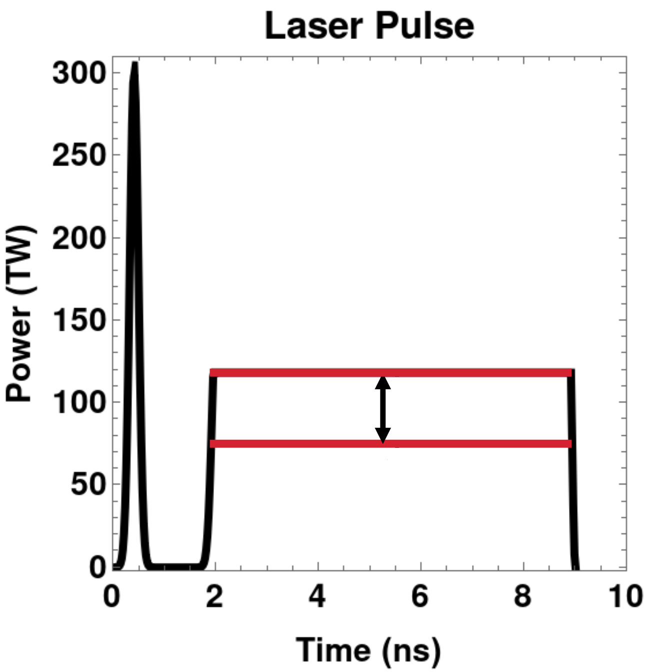
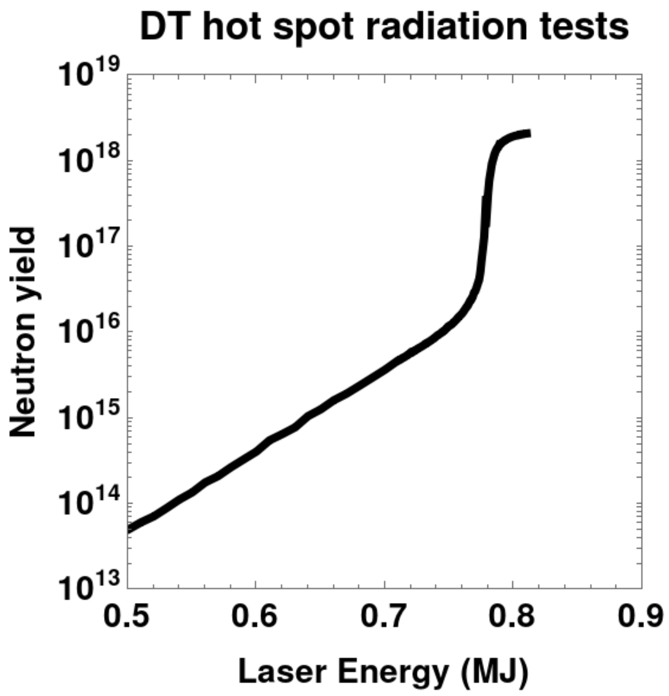
University of Rochester
Laboratory for Laser Energetics

S.M. Finnegan and J. Smidt
Los Alamos National Laboratory

Direct-drive double shell* (D3S) implosion was used to study the hot spot energetics







No CBET and no nonlocal thermal transport

* S. H. Hu et al., Phys. Rev. E 100, 063204 (2019).

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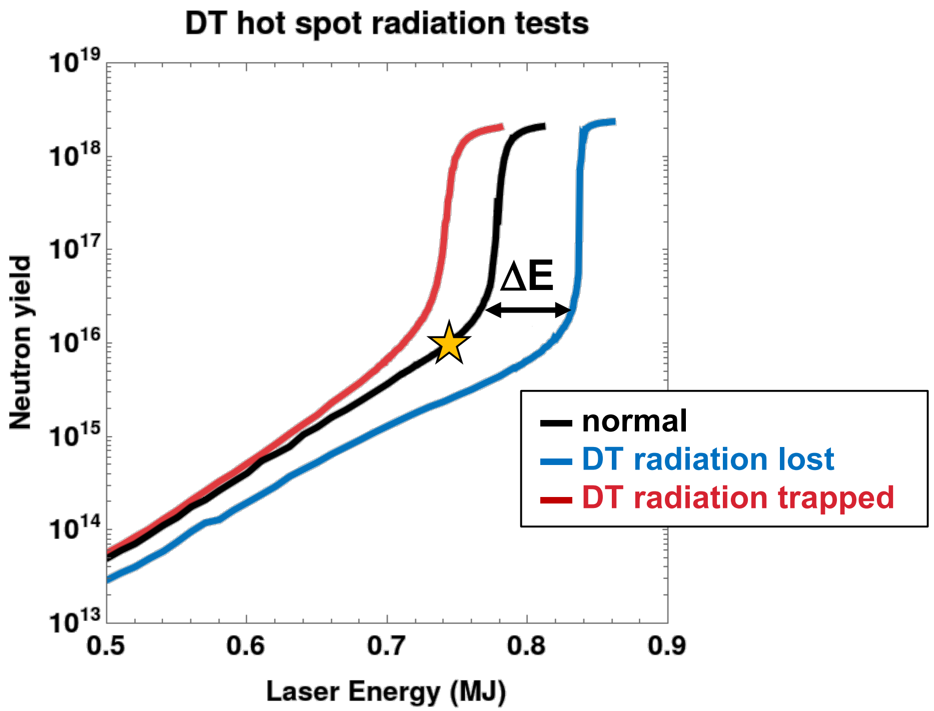
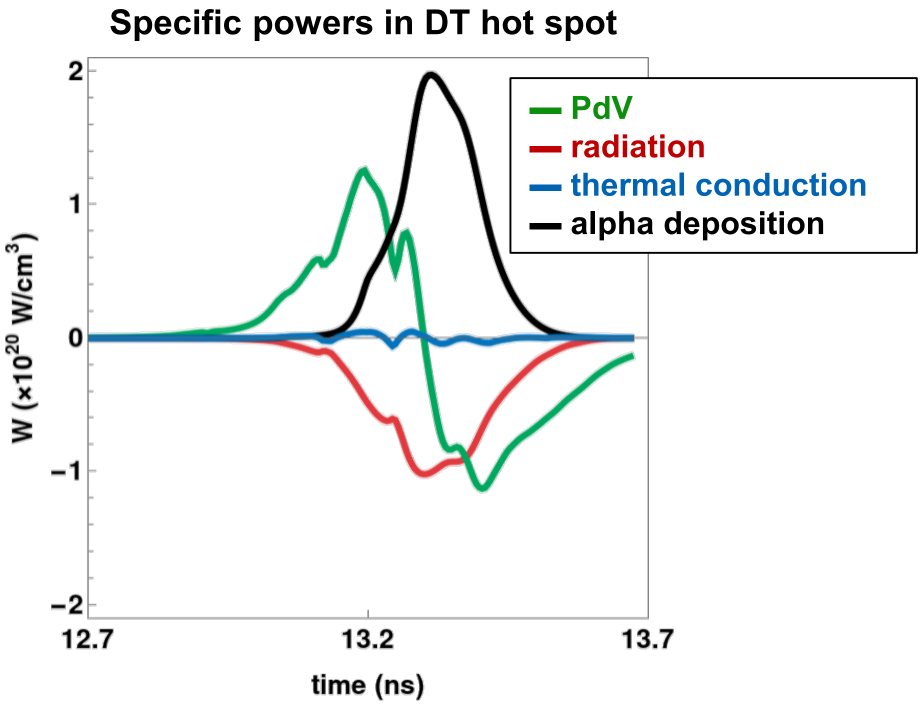
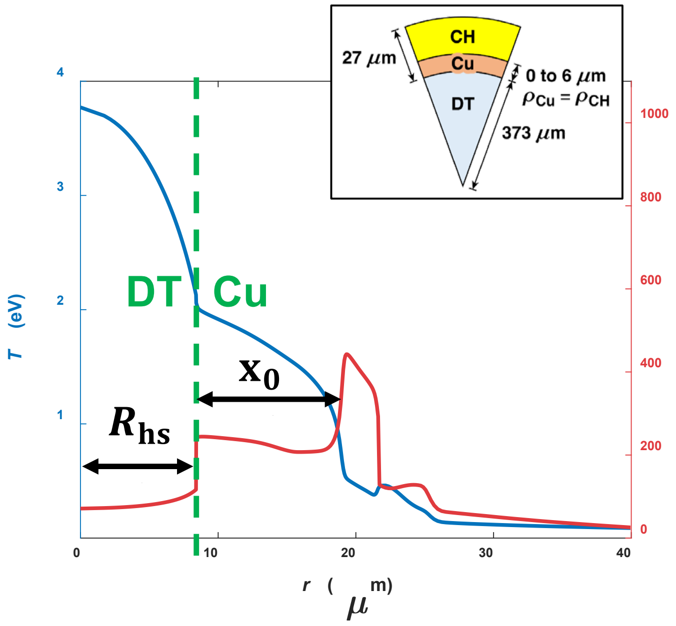


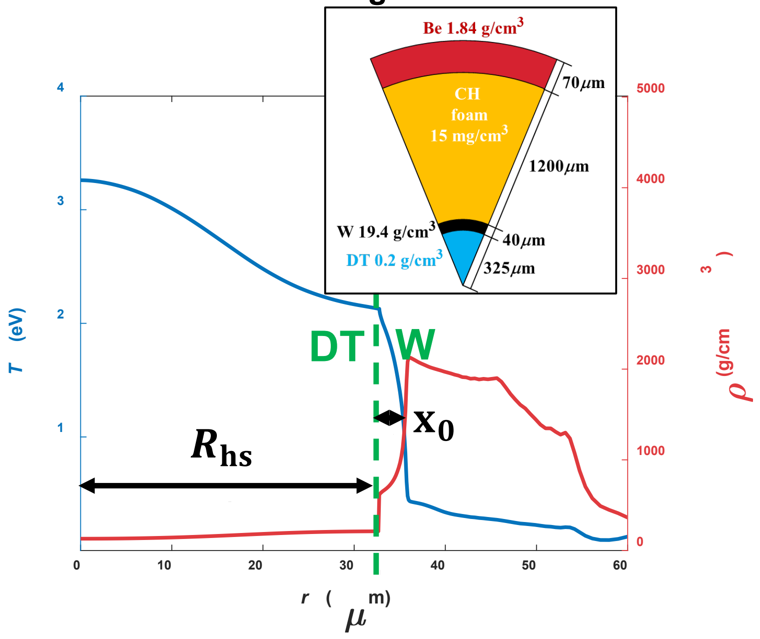


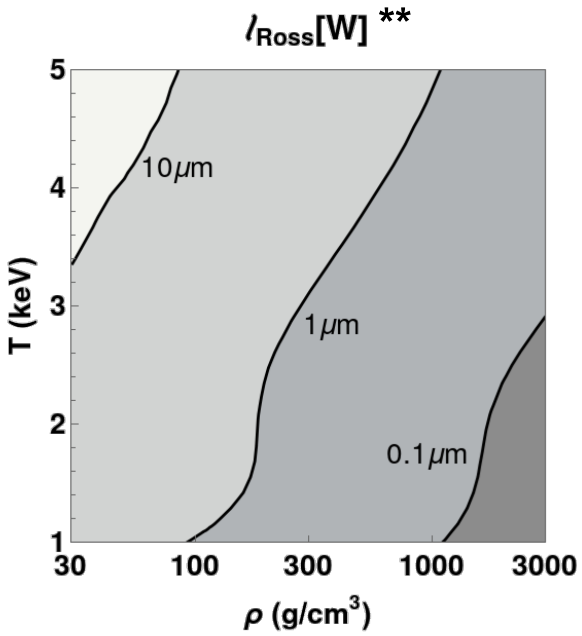
The radiation trapping is effective when $R_{hs} \gg x_0 \gg l_{Ross}$

Omega warm Cu-pusher design



NIF D3S design





$R_{hs} \gg x_0$ – internal energy in the Marshak/ablative wave ≪ hot spot energy

$x_0 \gg l_{Ross}$ – the radiation is trapped since radiation flux $F_R \overset{*}{\sim} \sigma_{SB} T^4 \frac{l_{Ross}}{x_0}$

R_{hs} – DT hot spot radius
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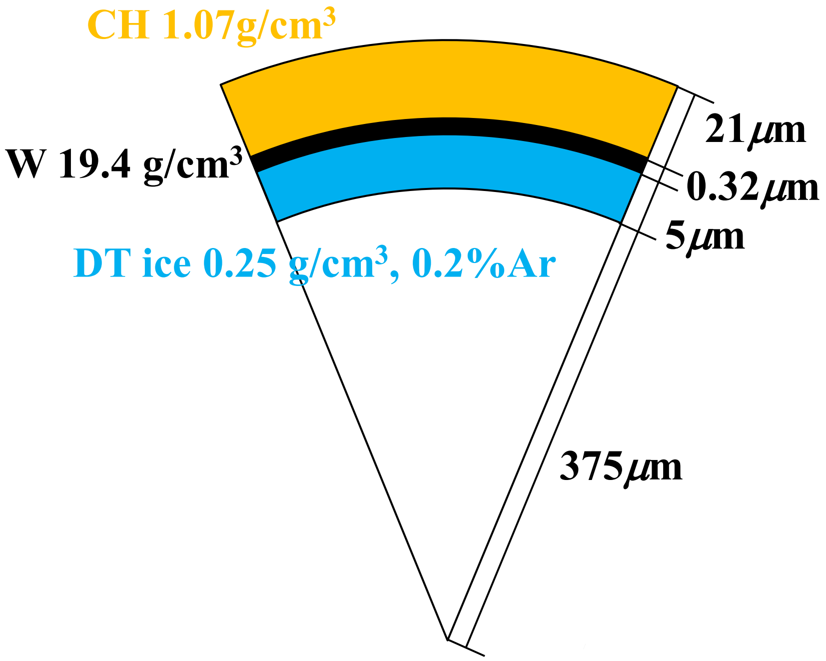
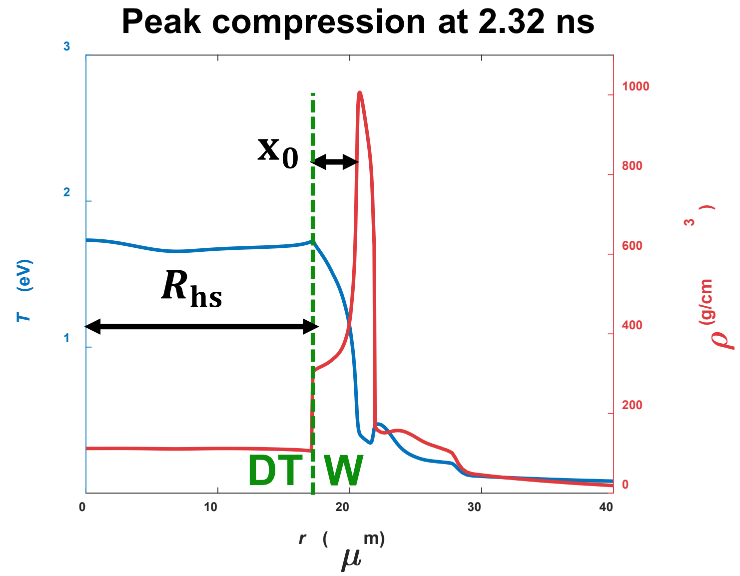
* R. Epstein et al., JO04:00010, this session
** AOT: astrophysical opacity tables
W. F. Huebner et al., Los Alamos National Laboratory, Los Alamos, NM, Report LA-6760-M (1977);

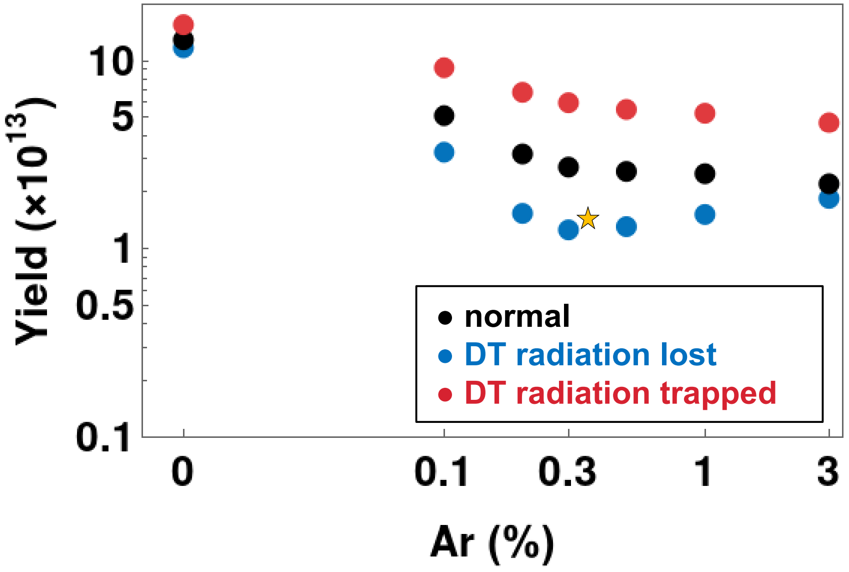
Adding cryo DT tamper layer to Omega single-pusher prevents high-Z material from releasing into gas and becoming part of the hot spot

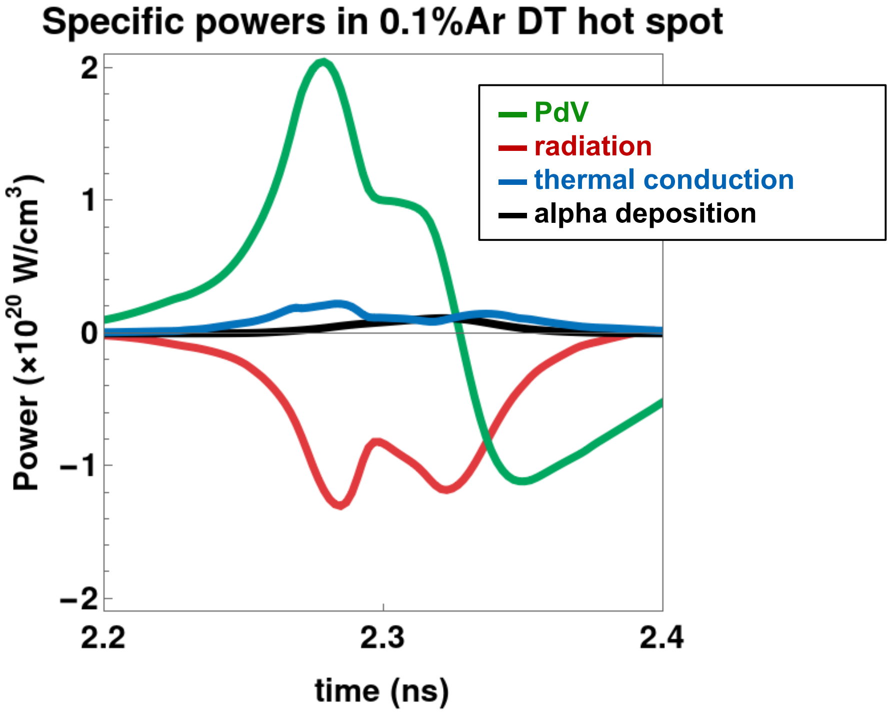


25kJ, 2ns square pulse



Adding Argon to DT enhances the radiation from the hot spot, making the implosion performance sensitive to radiation losses





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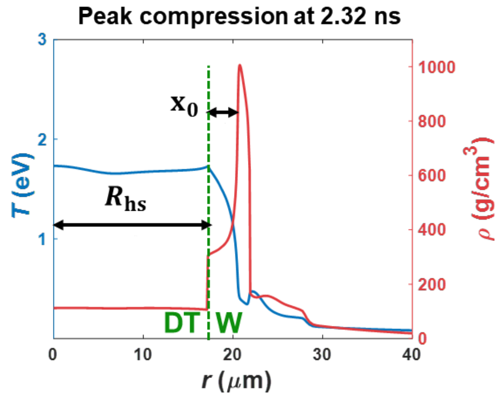

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Heat conduction in high-Z materials is through radiation

Spitzer electron thermal conduction flux:*

$$Q_S = -\chi_S \nabla T, \text{ where}$$

$$\chi_S = \frac{(8/\pi)^{\frac{3}{2}}}{(1+3.3/Z)} \frac{(k_B T)^{5/2} k_B}{Z e^4 m^{1/2} \ln\Lambda}$$

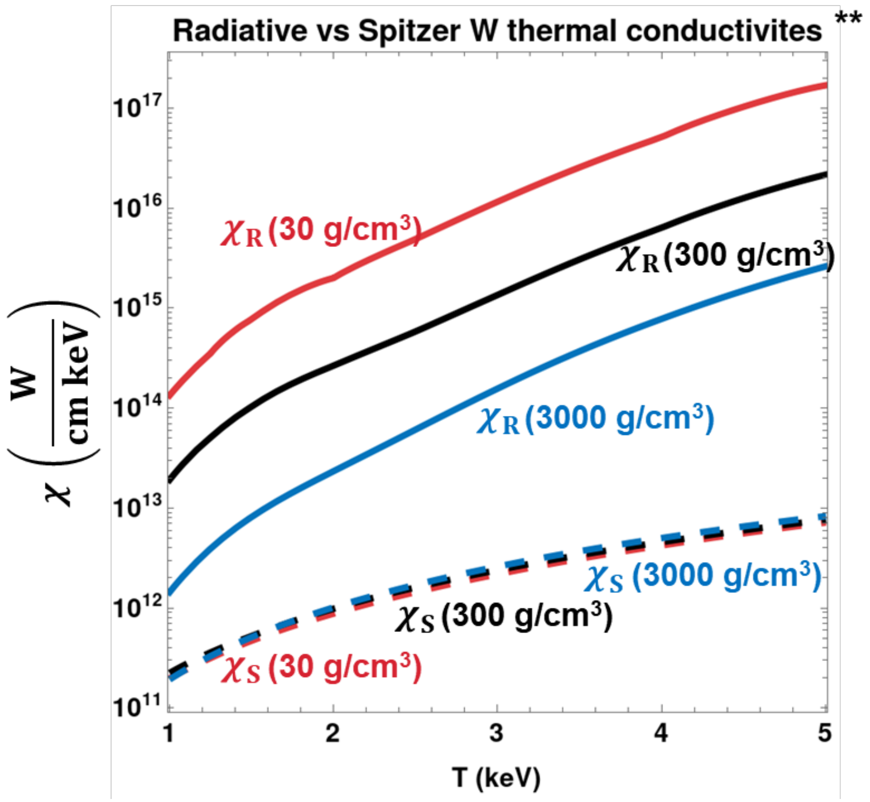
k_B is Boltzmann constant, Z is ionization state
e is electron charge, m is electron mass
$\ln\Lambda$ is Coulomb logarithm

Radiation flux when $T_r = T$:*

$$Q_R = -\chi_R \nabla T, \text{ where}$$

$$\chi_R = \frac{16}{3} l_{Ross} \sigma_{SB} T^3$$

l_{Ross} is Rosseland mean free path
σ_{SB} is Stefan-Boltzmann constant



* S. Atzeni and J. Meyer-ter-Vehn, The Physics of Inertial Fusion (Clarendon Press, Oxford, 2004)
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