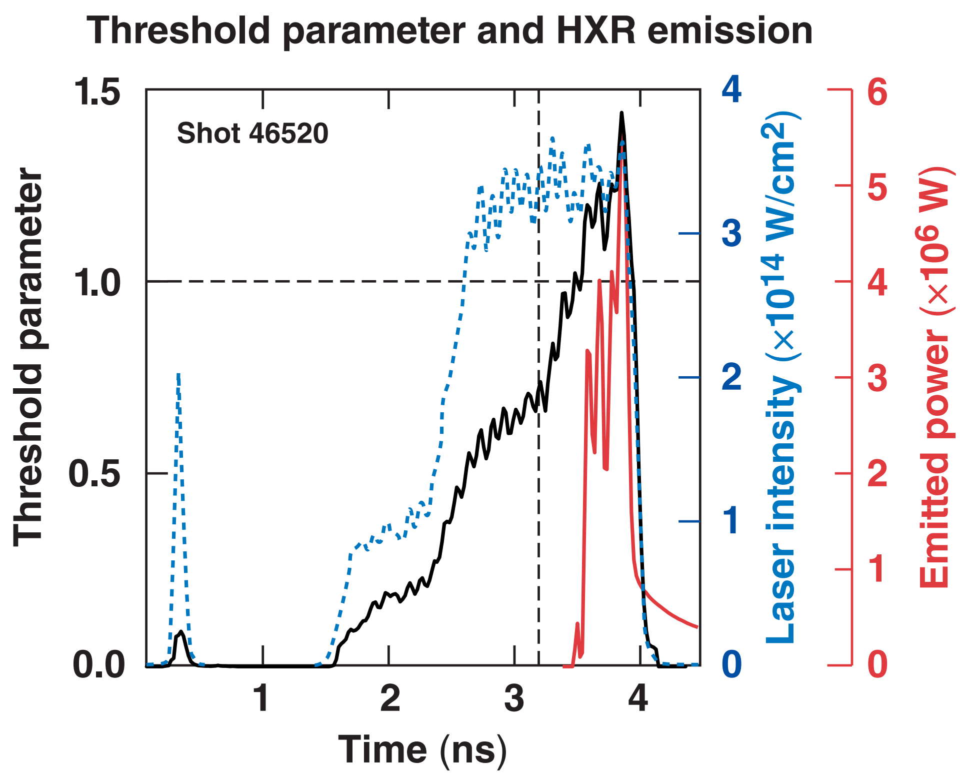
ICF Simulations of the Effect of Energetic Electrons Produced from Two-Plasmon Decay Instability



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Summary

Two fast-electron transport models have been developed to model preheat caused by the two-plasmon-decay instability

- Relativistic fast-electron transport is modeled in *LILAC* with multigroup diffusion model and straight-line model.
- The models were calibrated using warm CH implosions.
- Qualitative agreement is obtained with the diffusion model for the HXR emission and the ρR for a subset of thin CD cryogenic implosions (pre-December 2007).
- Doping the CD ablator with Si and Ge decreases the fast-electron production because of higher temperatures in the corona.

Collaborators

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Fast-electron transport modeling depends on the source distribution

- Fast-electron source distribution is under study[1]
  - the absolute TPD instability should send the electrons radially into the target, but it is believed that it is not the main mechanism for electron acceleration
  - the convective TPD instability may create electrons in a cone about the radial direction
  - experiments to resolve this question are in progress; recent results suggest that electrons are produced almost radially[1]

- Two models are used in the *LILAC* simulations
  - multigroup diffusion that assumes the electrons are created semi-isotropically
  - straight-line transport using the stopping power derived by Li and Petrasso[2]

[1] J. F. Myatt, this conference
[2] C. K. Li and R. D. Petrasso, Phys. Rev. E 70, 067401 (2004).

The fast electrons are created at the quarter-critical surface as a relativistic Maxwell–Boltzman–Jünter distribution function

- Electrons are created when the threshold parameter for the $2\omega_p$ instability[1], evaluated at the quarter-critical surface, exceeds unity:

$$\eta = I_{14} L_{\mu m} / 233\ T_c\ (\text{keV}) > 1$$

- The energy source scales as

$$\frac{E_{\text{fast}}}{E_{1/4\ N_c}} = \phi\ \frac{\log(\eta)}{\log(3.0)}$$

- The source temperature is obtained from a fit to the experimental measurement as

$$D_2:\ T_s = 180 \left[\frac{T_c\,(\text{keV})}{2.2}\right]^{0.4} \left[\frac{I_{14}}{8}\right]^{0.63} \text{keV}$$

$$\text{CH}:\ T_s = 10\, I_{14}\, \text{keV}$$

TC8124

[1]A. Simon *et al*., Phys. Fluid 26, 3107 (1983).

The multigroup fast-electron diffusion model assumes an isotropic electron distribution

- For each energy group in the flux-limited regime, the electrons are transported with a modified P_2 model.
- The source is half isotropic in the negative radial direction.
- Only energy loss to the thermal electrons caused by Coulomb collisions is considered (no self-interaction).
- Energy loss to fast ions is computed with a simple model that conserves momentum and energy as the electrons reflect from the outer boundary; ion acceleration includes the fast-electron pressure.

The straight-line radial transport follows electrons inward after their creation at the quarter-critical surface

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- Electrons are created in the same groups as in the multigroup diffusion model and are spread toward the target center in a cone.
- They travel in a straight line, are tracked in time, and are reflected at the outer target boundary.
- Their energy loss caused by collisions and plasma waves includes the effect of blooming as modeled by Li and Petrasso.[1]

[1] C. K. Li and R. D. Petrasso, Phys. Rev. E 70, 067401 (2004).

The two measurable quantities are the ρR and the hard x-ray (HXR) emission

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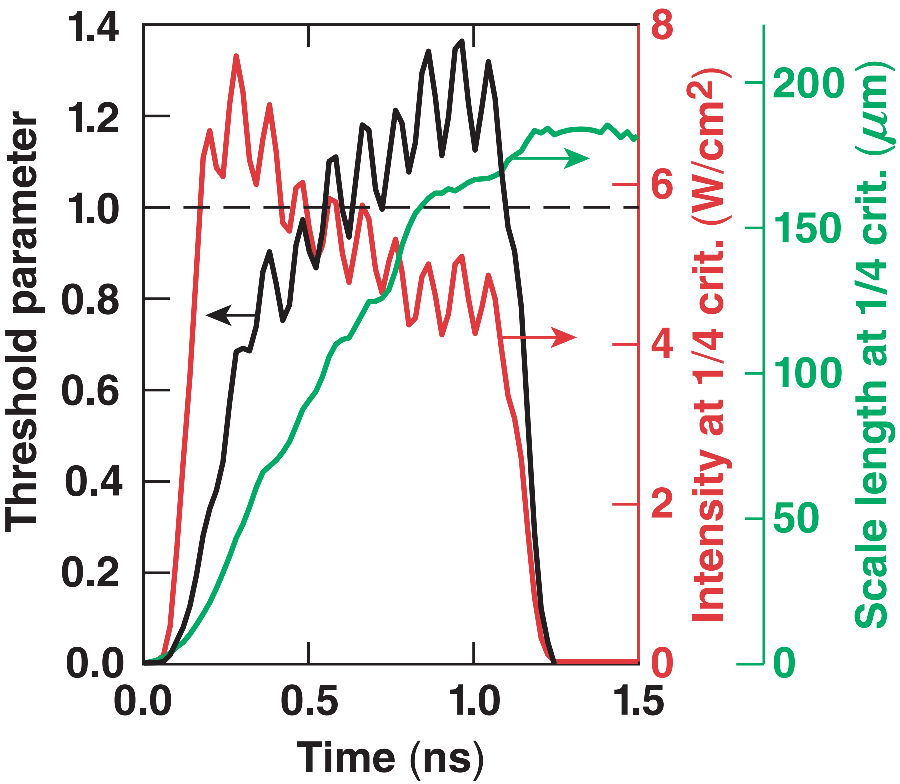
- The ρR obtained from *LILAC* is averaged over the entire neutron production and will be corrected for sampling effects in the future.[1]
- The HXR emission spectrum is computed from the cross section in Jackson[2] and the NIST cross sections.[3]
- A temperature is obtained from an exponential fit to the spectrum.
- A qualitative comparison with measured emission for cryogenic implosions is difficult because post-pulse emission may be generated outside the target.

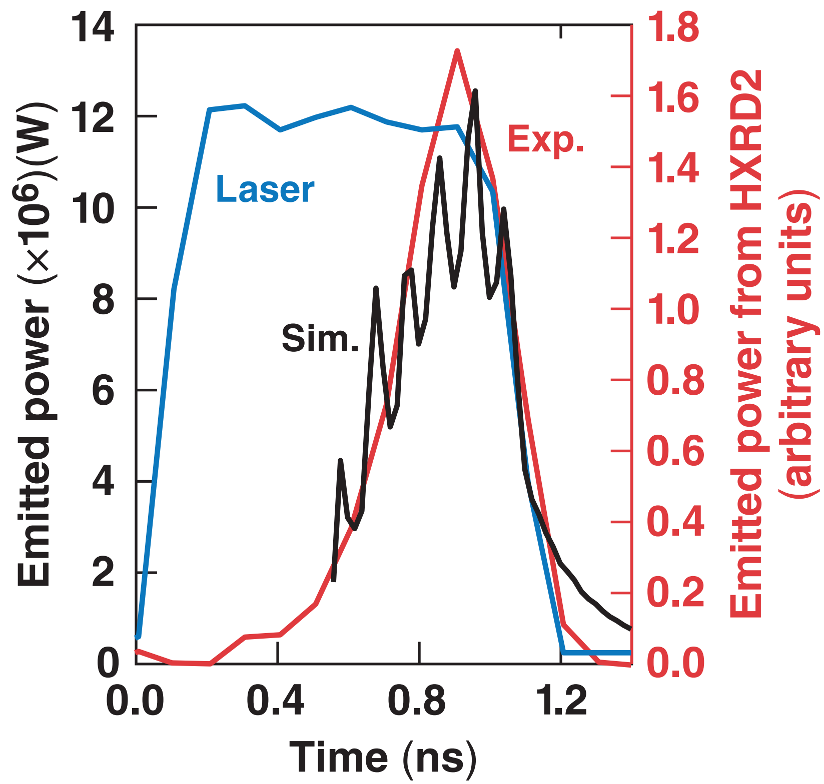
1 P. B. Radha *et al*., Bull. Am. Phys. Soc. 51, 106 (2006).
2 J. D. Jackson, *Classical Electrodynamics* (Wiley, New York, 1962), p.513.
3 H. O. Wyckoff, *ICRU Report*, 37, International Commission on Radiation Units and Measurements, Inc. Bethesda, MD (1984).

The computed onset of the hard x-ray emission matches the measured onset, confirming the validity of the threshold

The electron temperature rises only slightly during the pulse.

Shot 50264: 27-μm CH shell
ϕ = 0.30 (2.3% of laser); diffusion transport





$$\eta = I_{14} L_{\mu m} / 233\, T_c\,(\text{keV})$$

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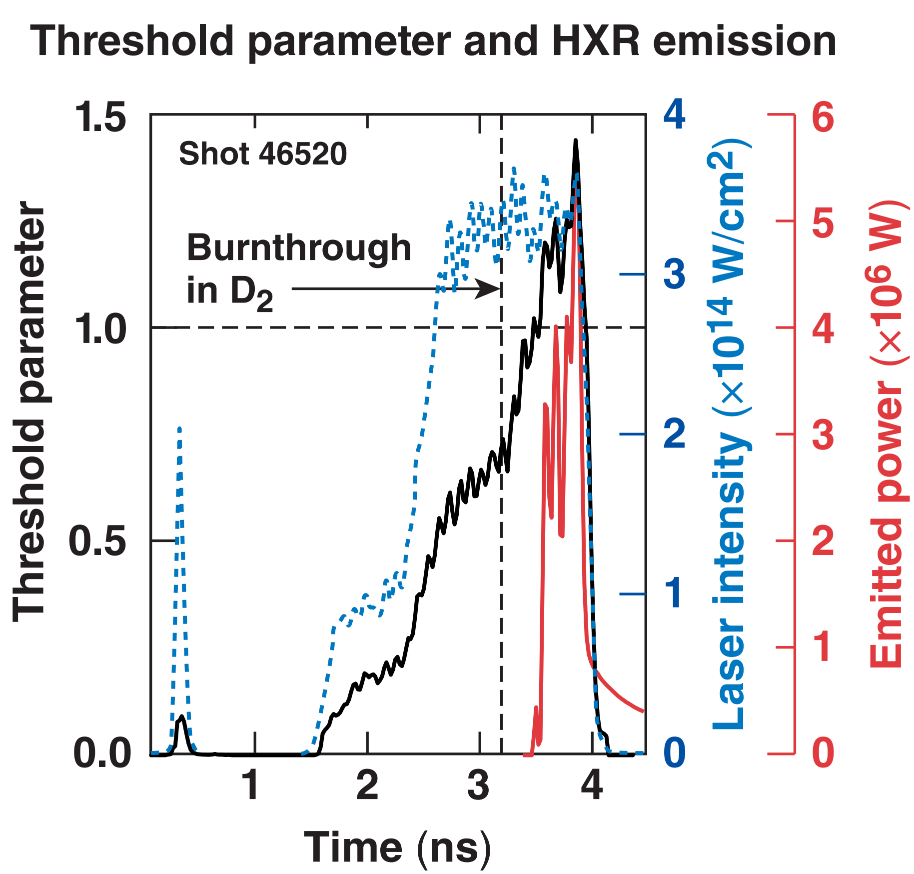
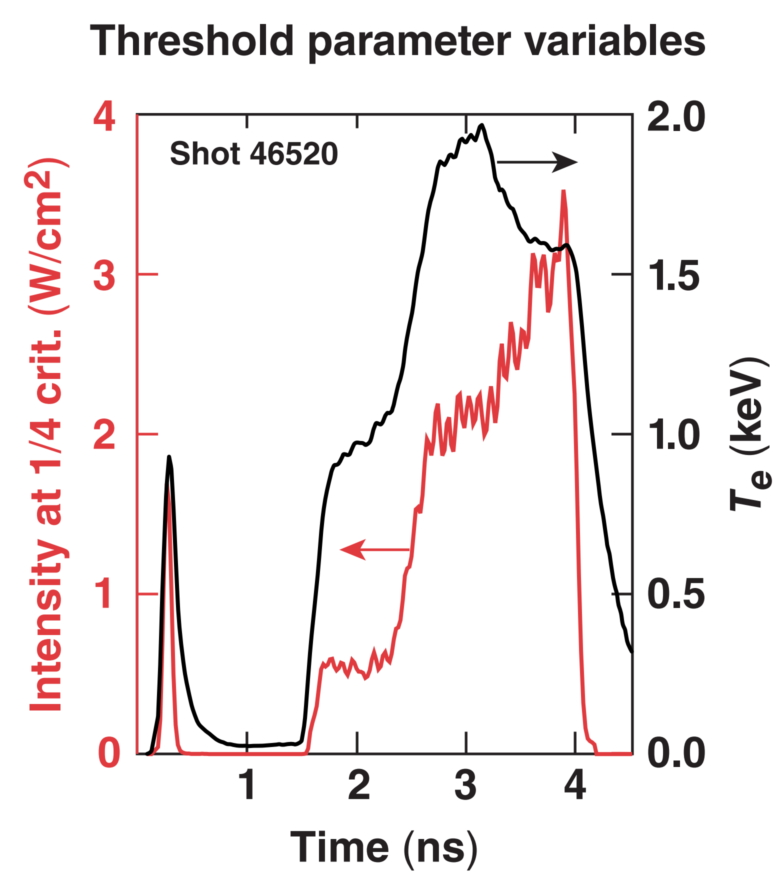
For cryogenic targets with a thin CD shell, the threshold parameter increases after burnthrough into D_2

$$\eta = I_{14} L_{\mu m} / 233\, T_c \text{ (keV)}$$





The scale lengths do not change significantly during the high-intensity part of the pulse.

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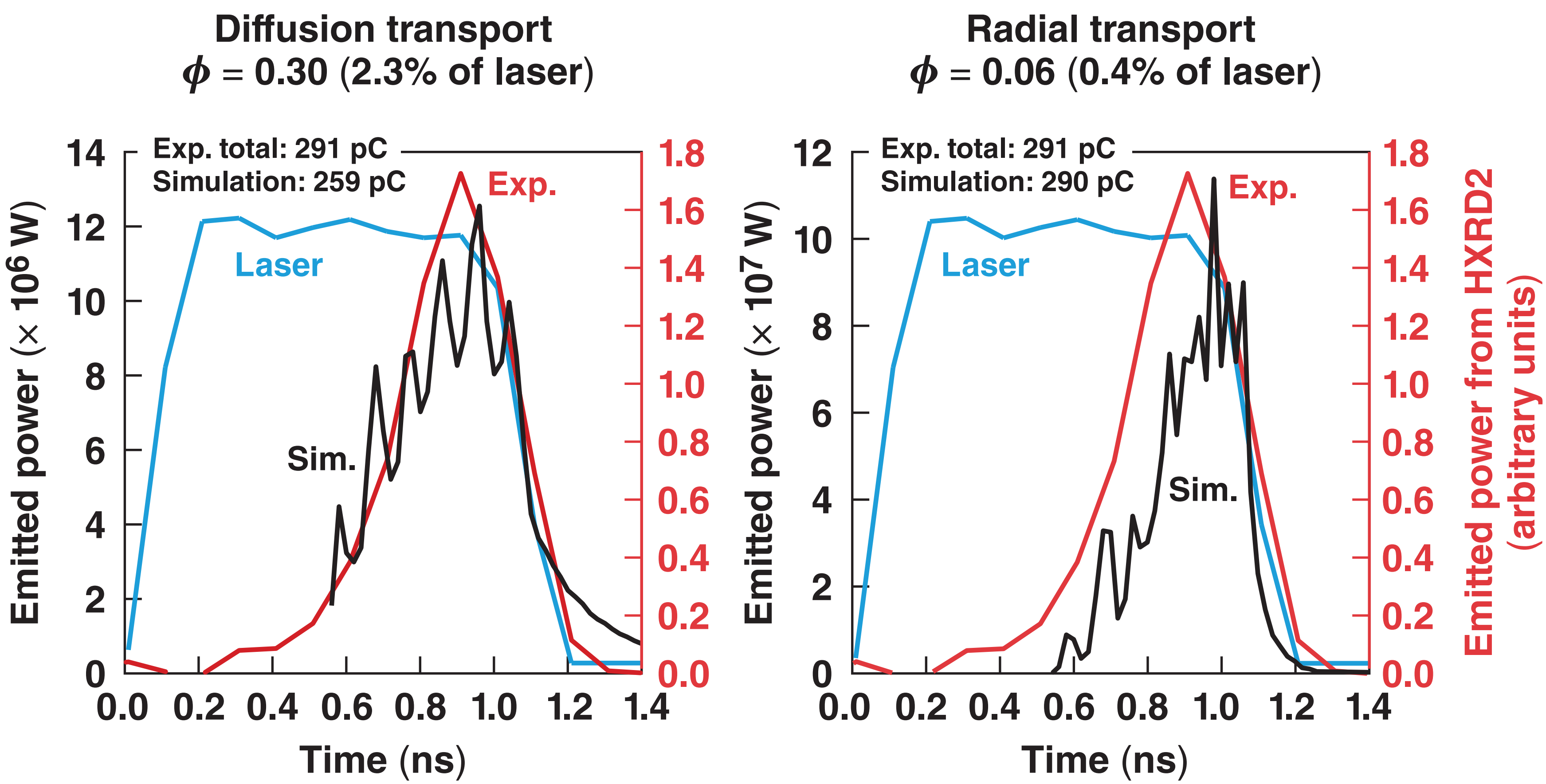
The free parameter ϕ is normalized to the measured hard x-ray emission using 32 pC/mJ*

Shot 50264: 27-μm CH shell



*B. Yaakobi *et al*., Phys. Plasmas 12, 062703 (2005) and private communication.

TC8131

For 5-μm-thick CD cryo targets, the simulation of the HXR emission and ρR agree qualitatively with the measurements

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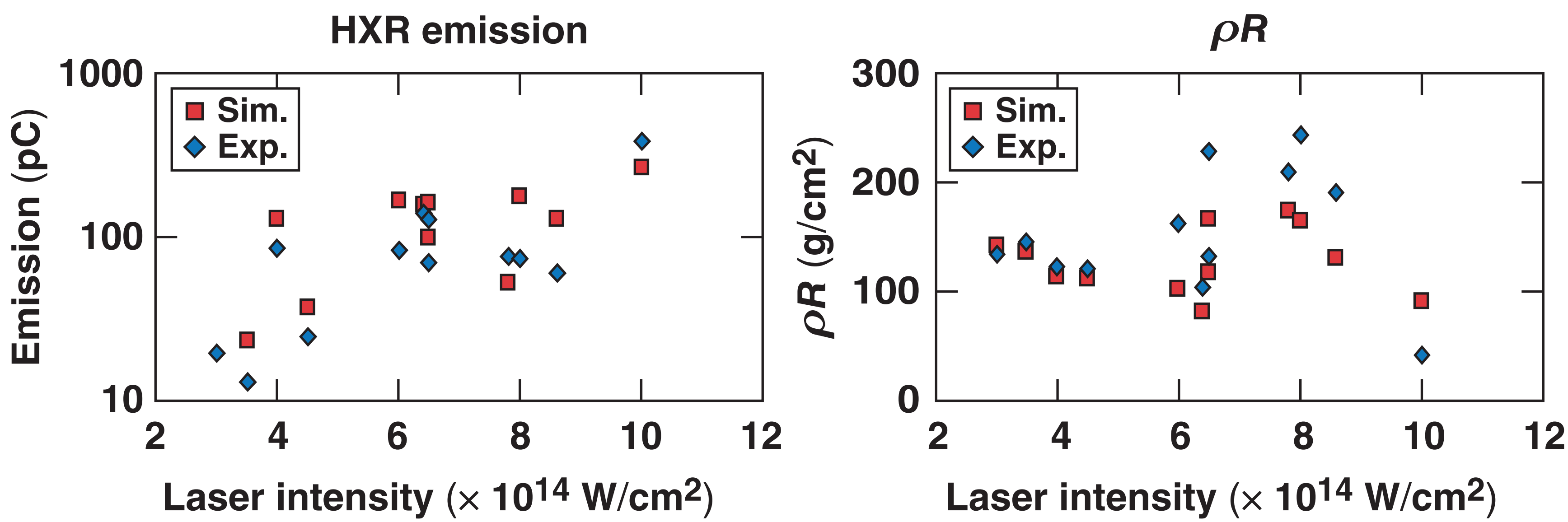
Diffusion model with ϕ = 0.30

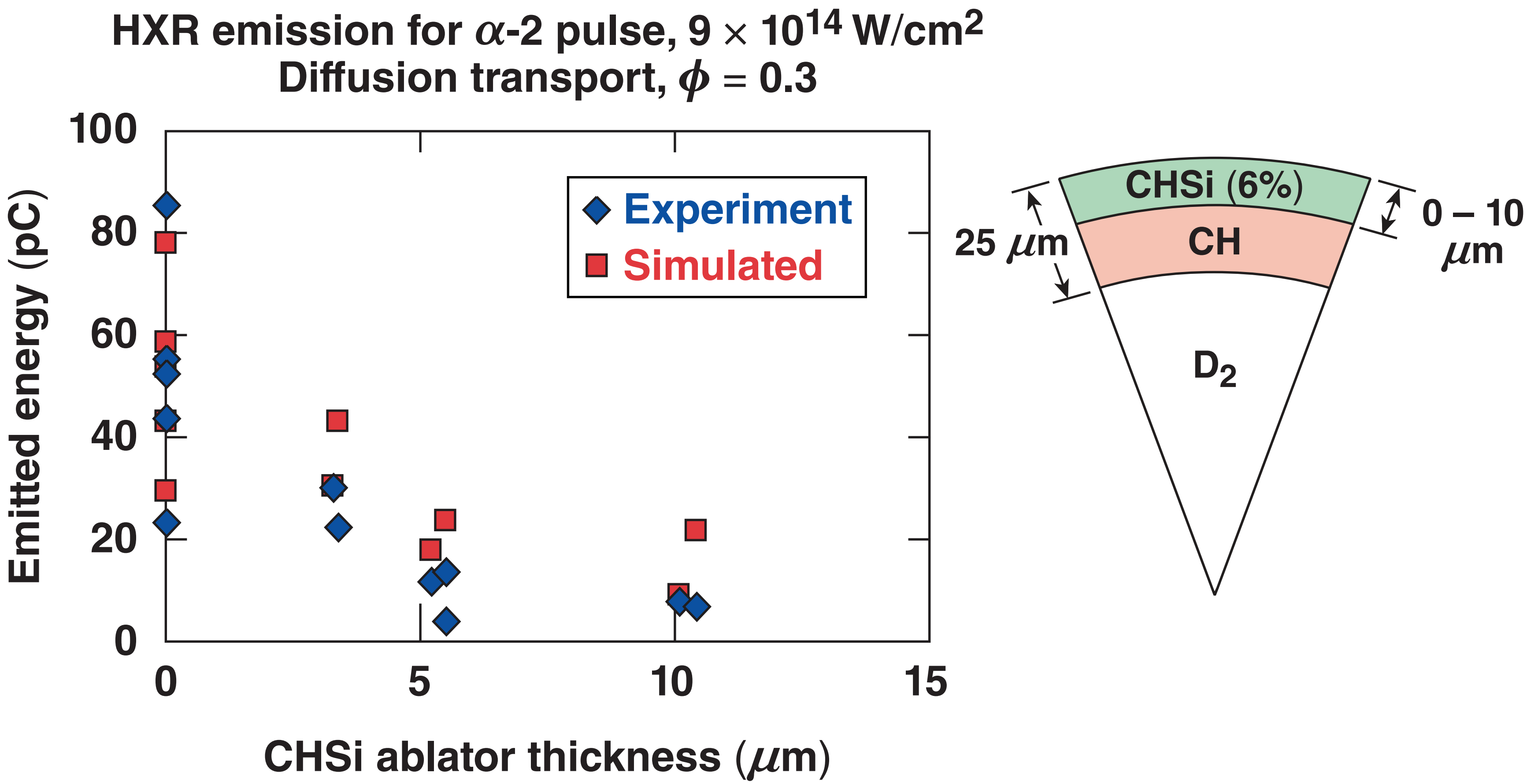


Exp. HXR emission divided by 3 to account for after-pulse emission.

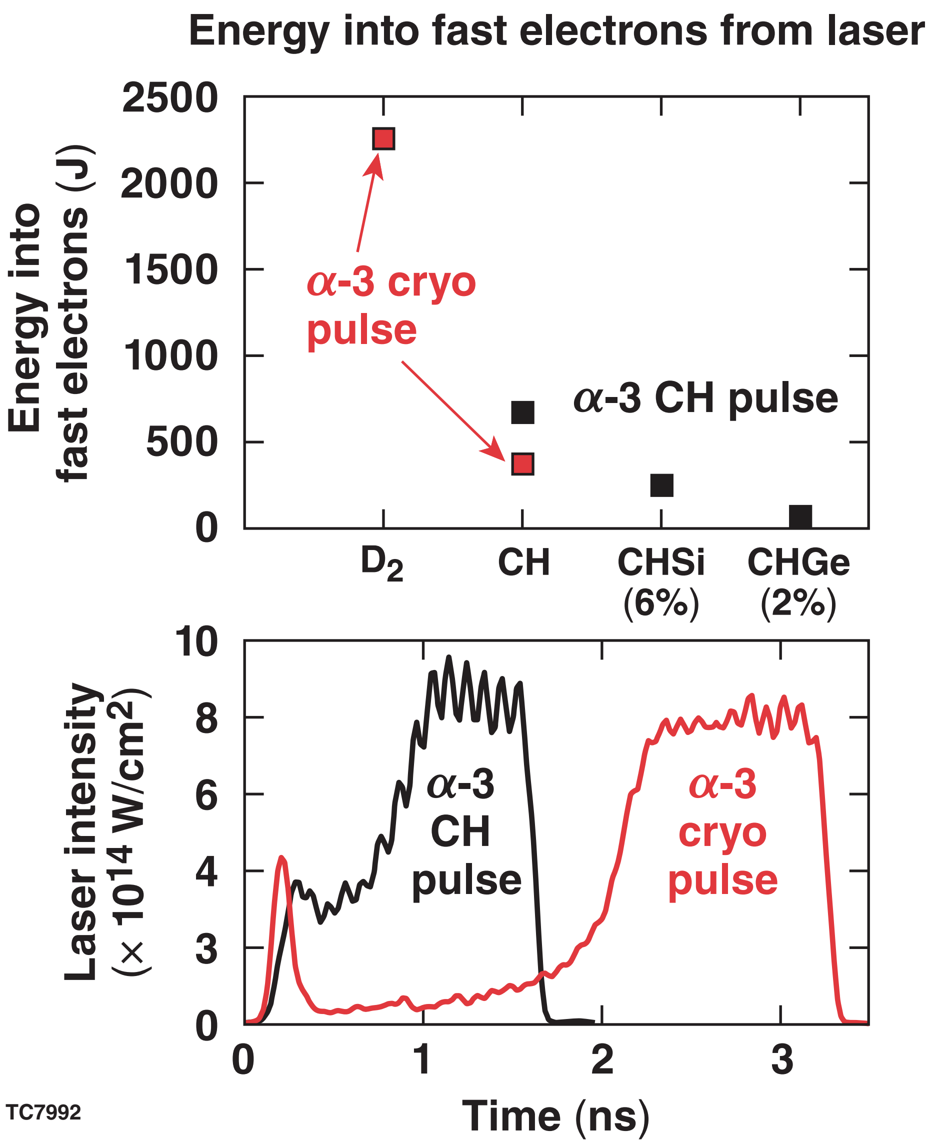
Simulation ρR does not include the effect of sampling.

TC8132

Warm targets with a thick CHSi outer ablator produce a lower HRX emission than CH ablators



The energy deposited into the fast electrons decreases with increasing ⟨Z⟩ of material ablated



- The differences in the energy deposited between cryogenic and warm targets are due to a decrease in $I_{1/4}$ and an increase in T_e.
- The difference due to CH dopants is mainly caused by an increase in T_e.
- The scale length is the same in all cases.

TC7992

Summary/Conclusions

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*See A. V. Maximov's presentation for an alternate explanation.