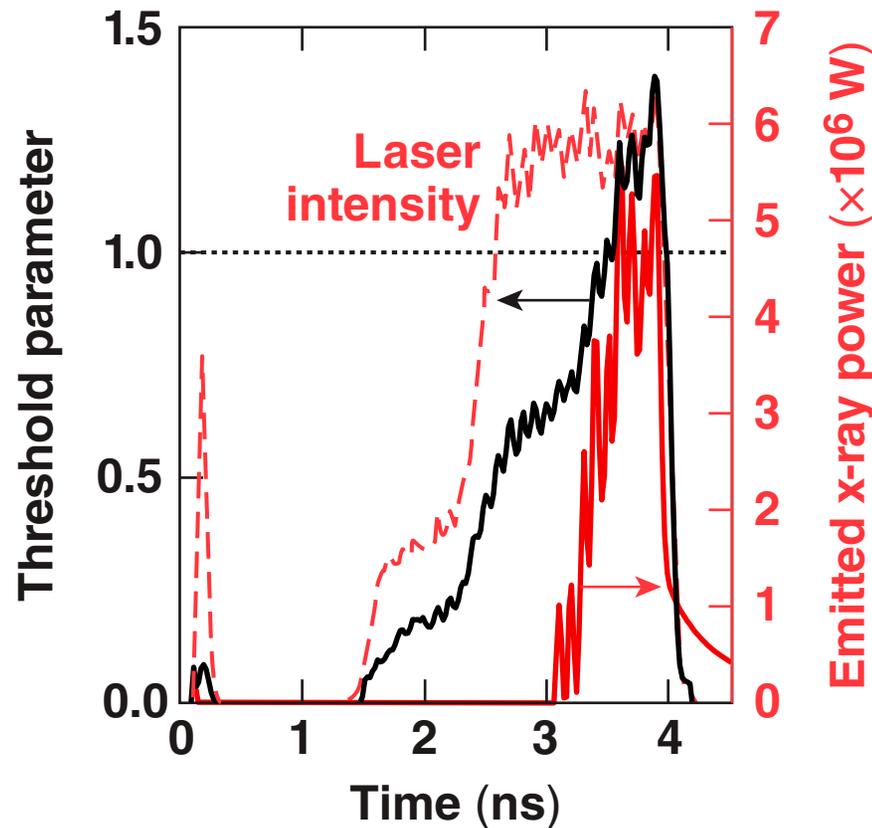


Simulations of the Effect of Energetic Electrons Produced from Two-Plasmon Decay in the 1-D Hydrodynamic Code *LILAC*



J. A. Delettrez
University of Rochester
Laboratory for Laser Energetics

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Summary

Preheat from the $2\omega_p$ instability could explain the observed ρR reduction in cryogenic implosions



- The existing fast-electron transport in the 1-D code *LILAC* was modified to model the source and transport of electrons produced by the $2\omega_p$ instability.
- Moderate agreement was obtained for the measured fuel ρR and the emitted HXR energy.
- The simulations reproduced the overall temporal evolution of the hard-x-ray (HXR) emission and, by inference, that of the $3/2\omega$ emission for cryogenic targets.
- Simulations indicate that about 50 J ($\sim 0.3\%$ of the laser energy) in preheat is required to obtain the observed $\sim 50\%$ reduction in ρR from 1-D, in agreement with estimates.

Collaborators



**D. Shvarts*, V. N. Goncharov, P. B. Radha, C. Stoeckl,
V. A. Smalyuk, A. V. Maximov, and T. C. Sangster**

**University of Rochester
Laboratory for Laser Energetics**

**R. D. Petrasso and J. A. Frenje
Massachusetts Institute of Technology**

***also: Nuclear Research Center, Negev, Israel**

The fast electrons are transported with a multi-group diffusion model in the 1-D hydrocode *LILAC*



- Electrons are slowed down through Coulomb collisions with a term in the $\log\Lambda$ accounting for electron plasma waves.
- The free-streaming electrons are treated with a modified P_2 model.
- The electrons lose energy to the ions at the outer boundary from momentum conservation.
- The ions are accelerated by the fast-electron pressure.
- The Bremsstrahlung radiation is computed using the Bethe–Heitler nonrelativistic formula.

The energy source is prescribed using semi-empirical scaling laws

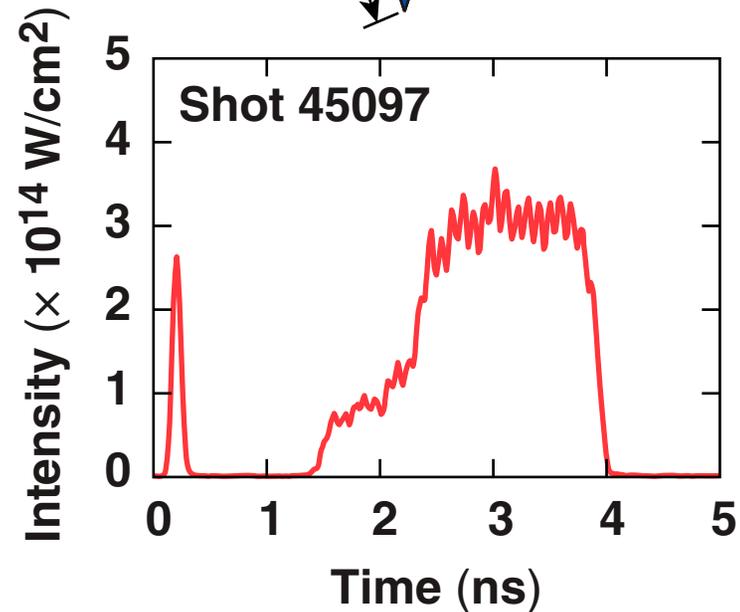
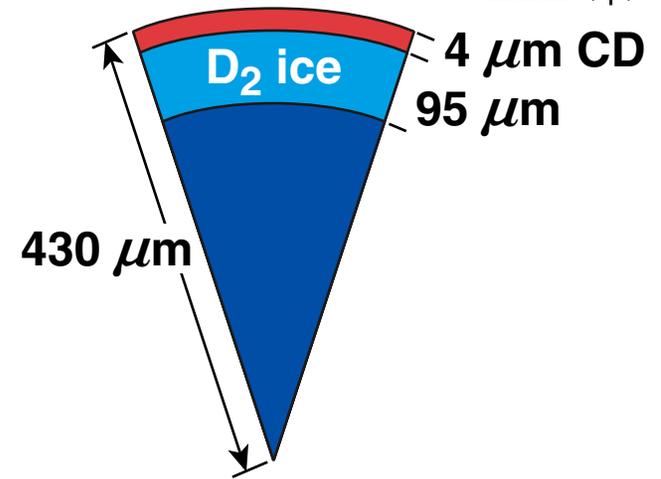
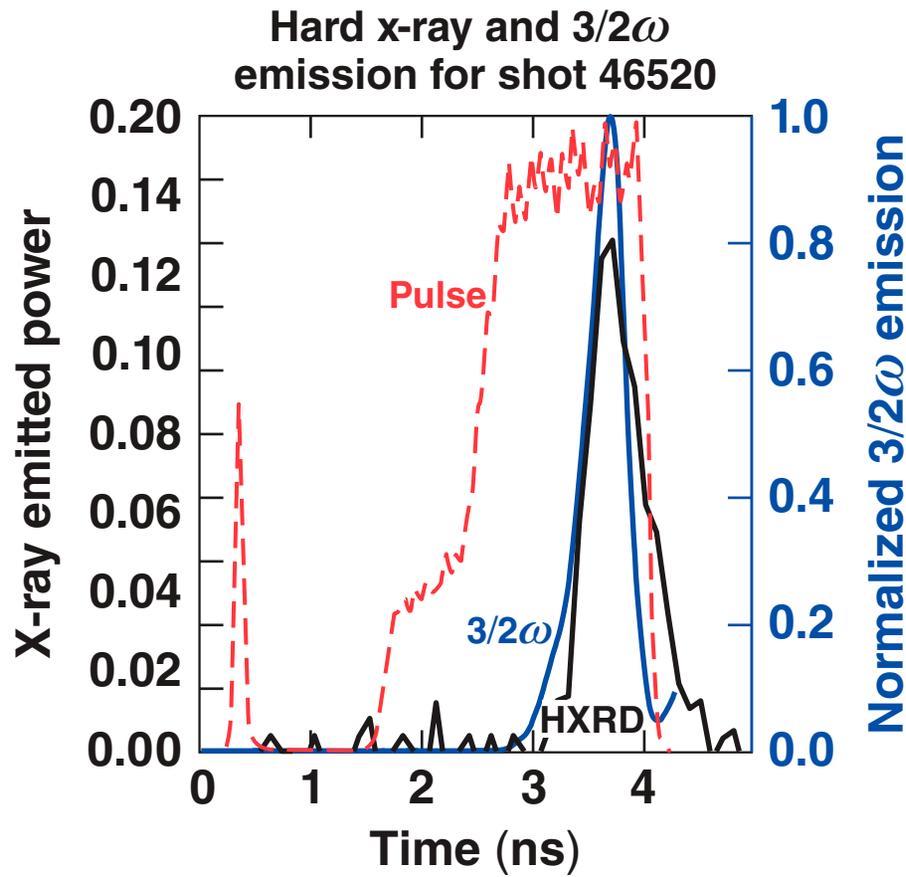
- Electrons are created when the threshold parameter for the $2\omega p$ instability* exceeds unity:

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

- Two algorithms are used for the energy source
 - constant percentage of the energy reaching $\frac{1}{4}$ critical
 - variable that scales as the $\log(\eta)$ at $\frac{1}{4}$ critical with the maximum value given as the percentage
- The source temperature is obtained from a fit to the experimental measurement as

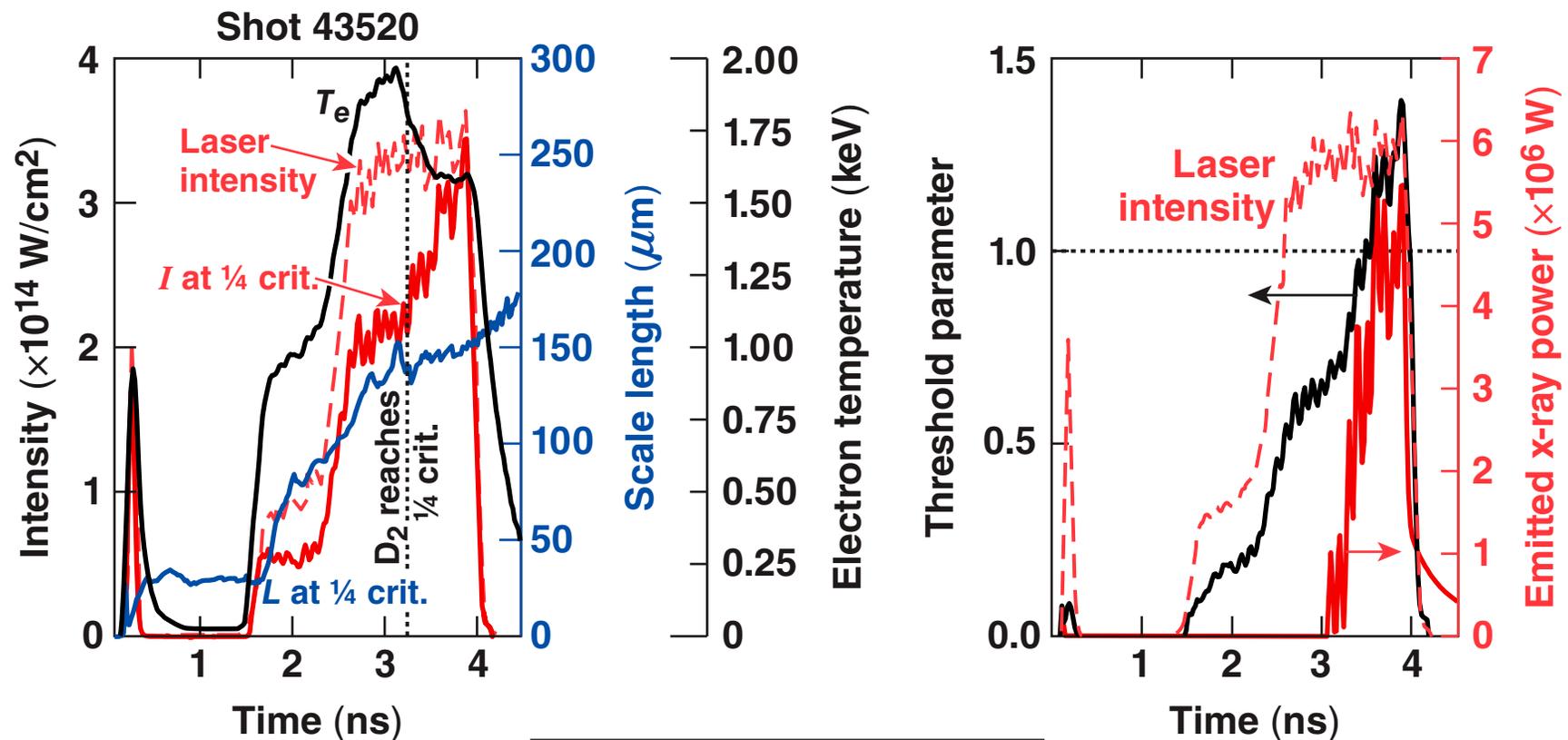
$$T_s = 130 \left[\frac{T_c \text{ (keV)}}{2.2} \right]^{0.4} \left[\frac{I_{14}}{8} \right]^{0.63}$$

$3/2\omega$ light and hard-x-ray emissions at energies above 60 keV indicate the presence of the two-plasmon-decay instability



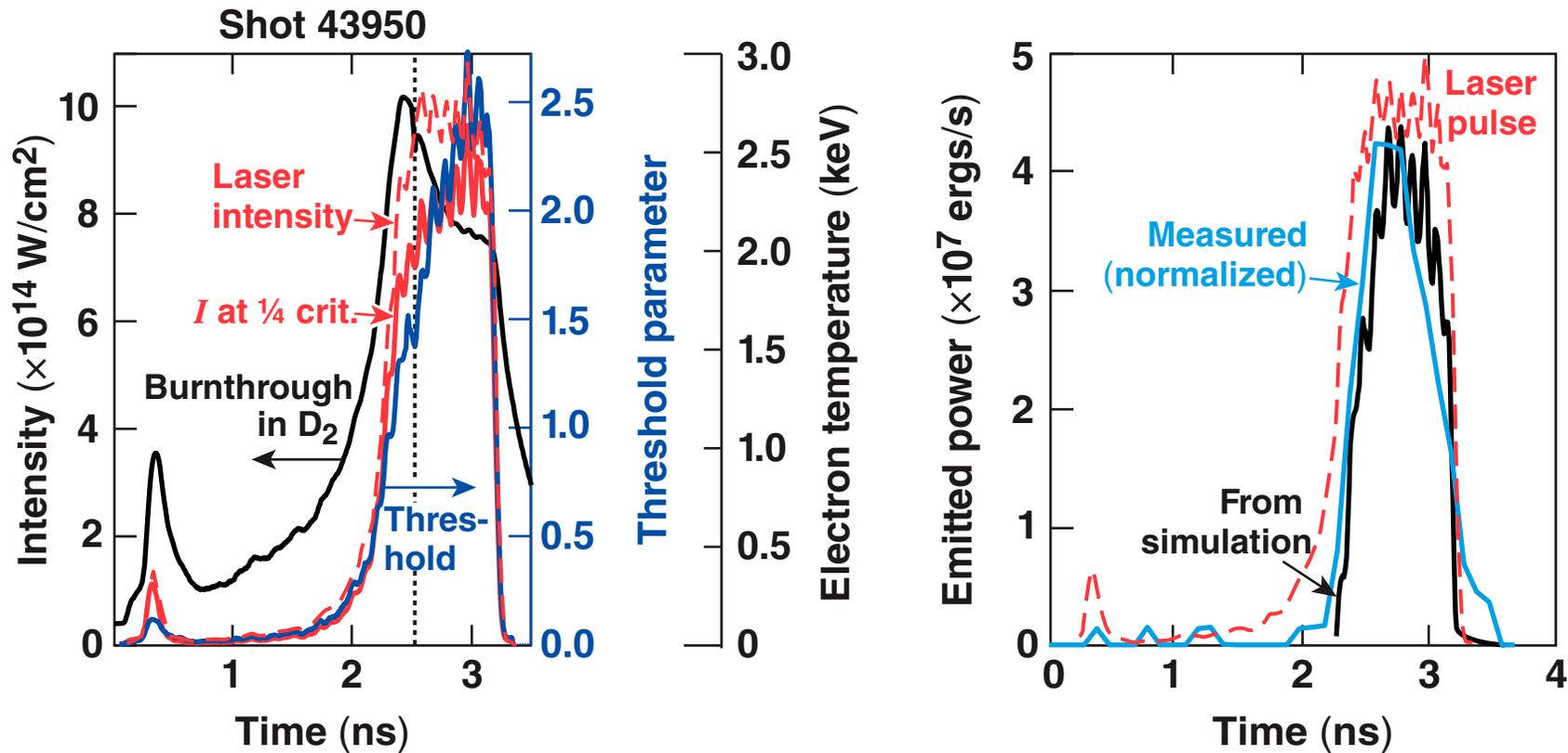
The threshold parameter increases after burnthrough into the D₂ due to the decreasing T_e and increasing intensity at the 1/4 critical surface

$$I = 3.5 \times 10^{14} \text{ W/cm}^2$$

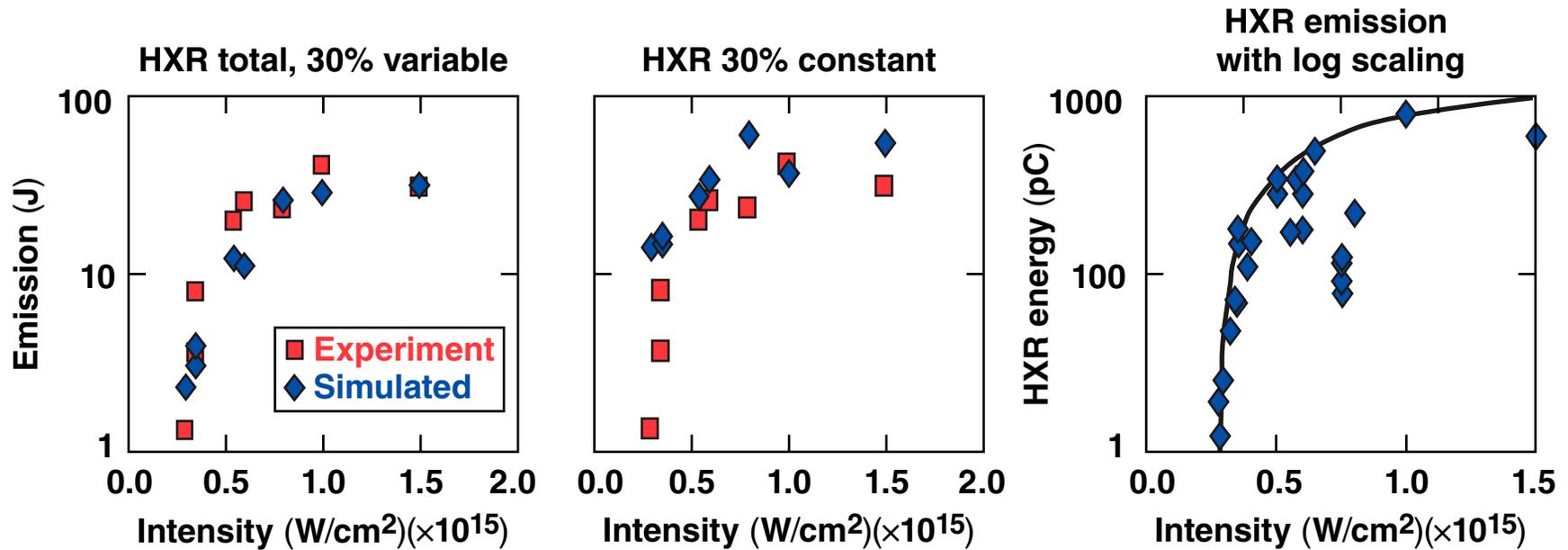


$$\eta = I_{14} L_{\mu\text{m}} / 233 T_c \text{ (keV)}$$

At high intensity (1×10^{15} W/cm²) the laser burns through to the D₂ early in the pulse resulting in a longer x-ray emission

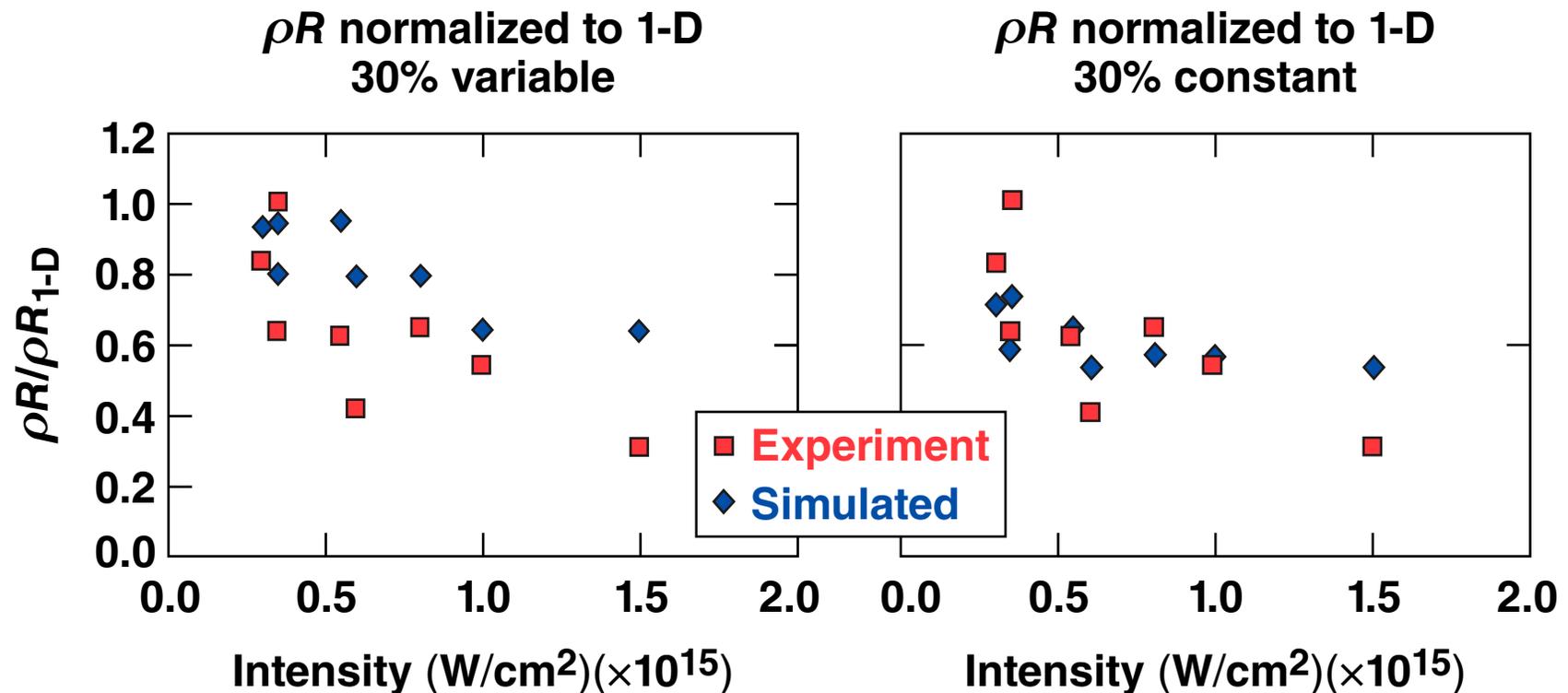


The hard x-ray emission scales closer to experiment with variable energy input than with constant energy input



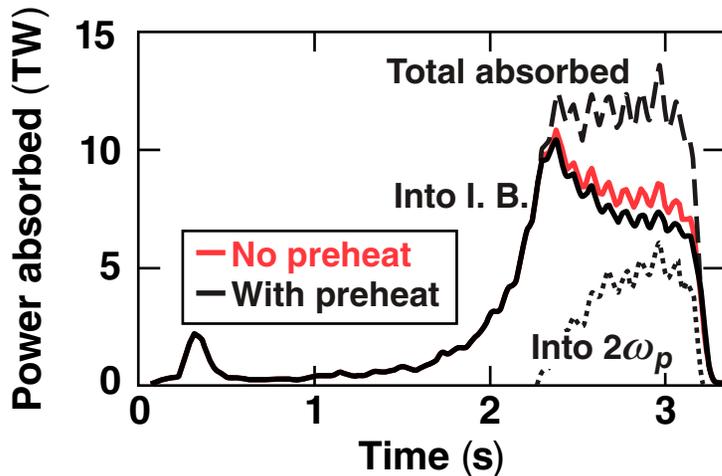
- $\text{HRX}_{\text{tot}} \text{ (mJ)} = \text{HXR (pC)} \times 0.05 \text{ (mJ/pC)}$
 - Obtained from a Mo calibration using $T_{\text{hot}} = 65 \text{ keV}$
 - Calibration at higher T_{hot} is needed

The neutron-averaged ρR , obtained with the variable energy input, agrees better with measurements at low intensity but not at high intensity



for $\alpha = 2$ to 4 shots

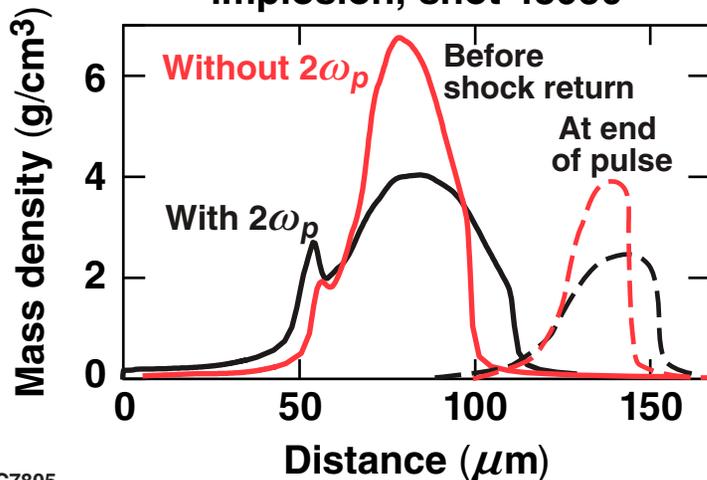
Depositing 15% of the laser energy into fast electrons does not affect the shell dynamics, only its peak density



Shot 43950 (10^{15} W/cm²), 30% variable

	Energy	Fraction of E laser
E laser	23.2 kJ	1.0
E into f.e.	3.38 kJ	0.15
E into fast ions	3.19 kJ	0.14
E_{dep} total	179 J	7.7×10^{-3}
E_{dep} in ice	145 J	6.2×10^{-3}
E_{dep} in high ρ	47 J	2.0×10^{-3}

Shell position during implosion; shot 43950

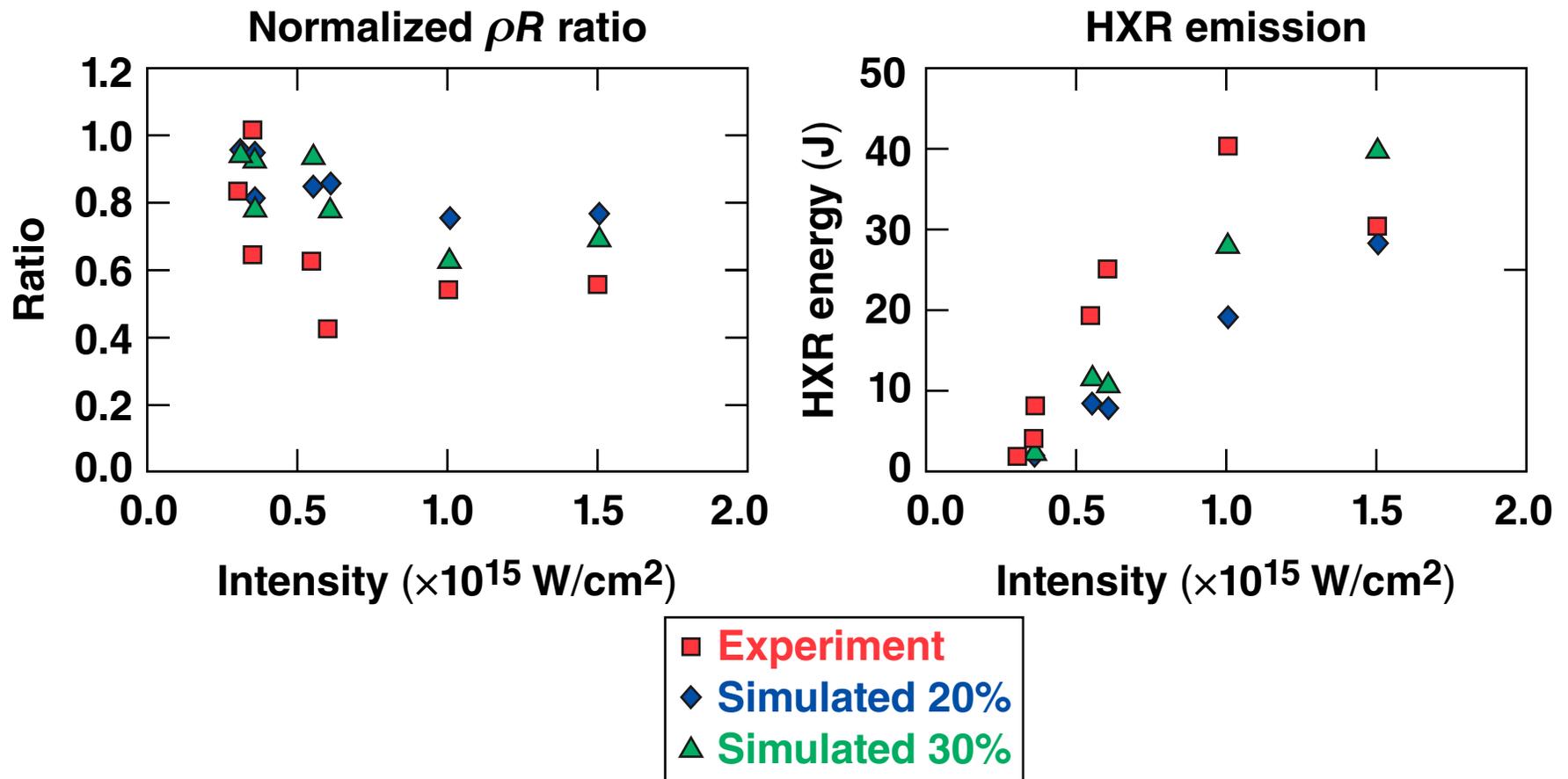


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- Simulations indicate that about 50 J ($\sim 0.3\%$ of the laser energy) in preheat is required to obtain the observed $\sim 50\%$ reduction in ρR from 1-D, in agreement with estimates.
- More work is required in predicting the source of $2\omega_p$ electrons and in modeling their transport.

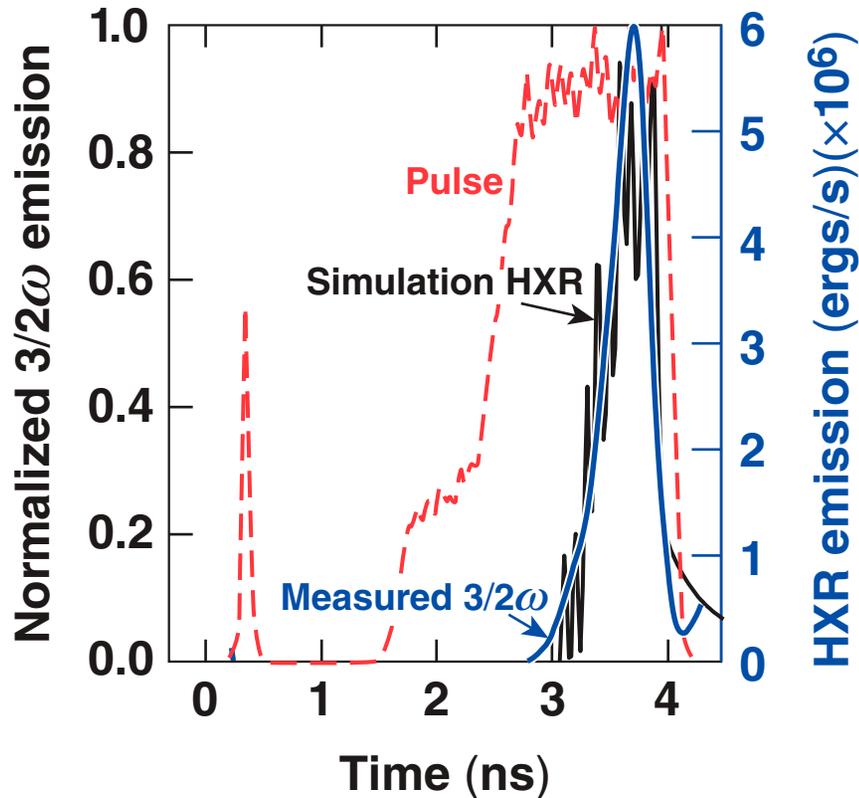
With the present input energy scaling, at least 30% of the laser energy reaching quarter critical needs to be deposited into the fast electrons



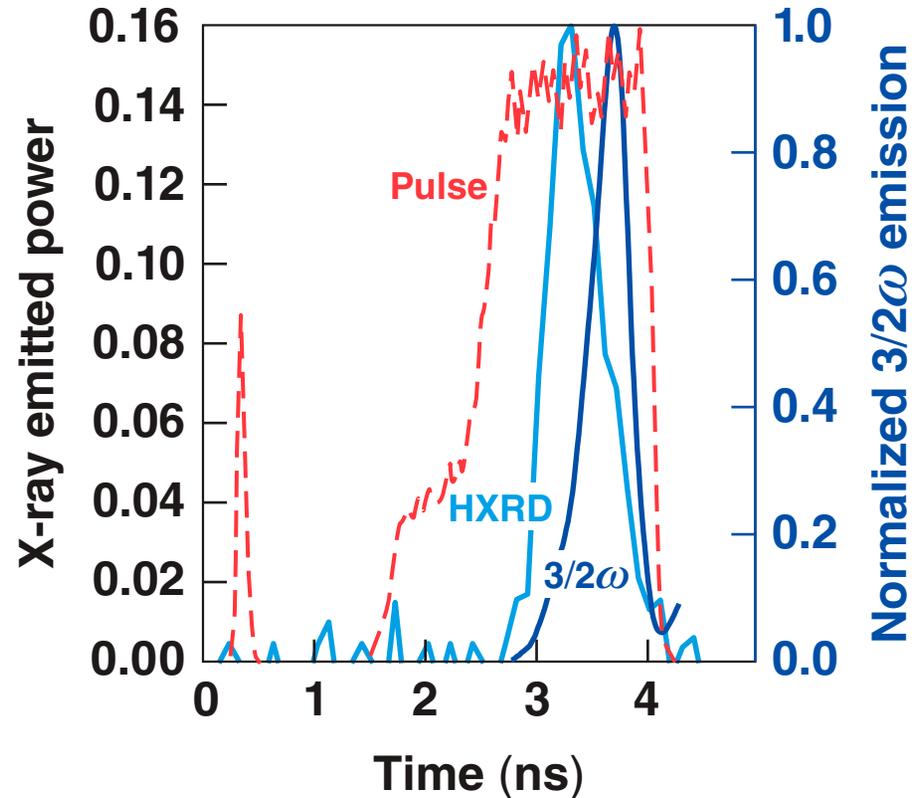
For a cryogenic shot, the measured HXR emission comes earlier than the $3/2\omega$ emission and the computed HXR emission



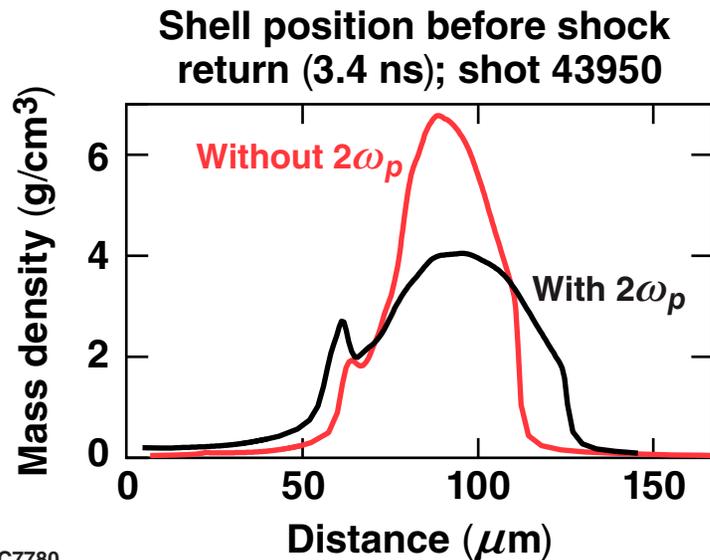
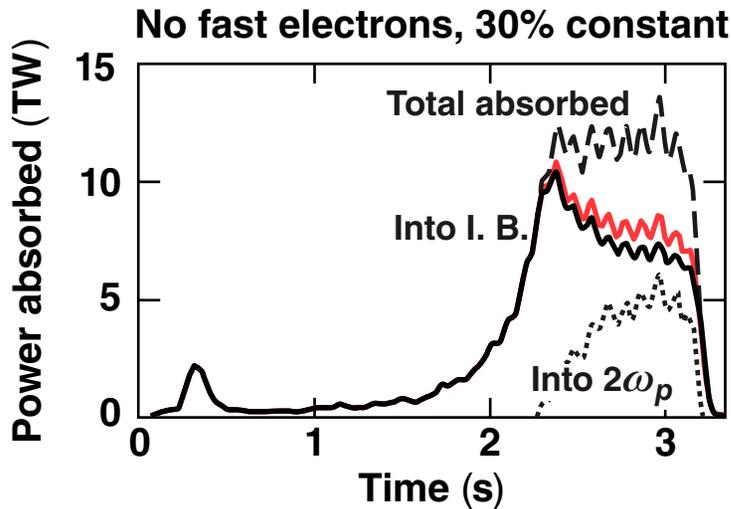
Simulation HXR and measured $3/2\omega$ emission for shot 46520



Hard x-ray and $3/2\omega$ emission for shot 46520



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HXR total	28 mJ	1.2×10^{-6}
HXR > 50 keV total	2.33 mJ	1.0×10^{-7}
HXR > 50 keV in ice	0.73 mJ	3.1×10^{-8}