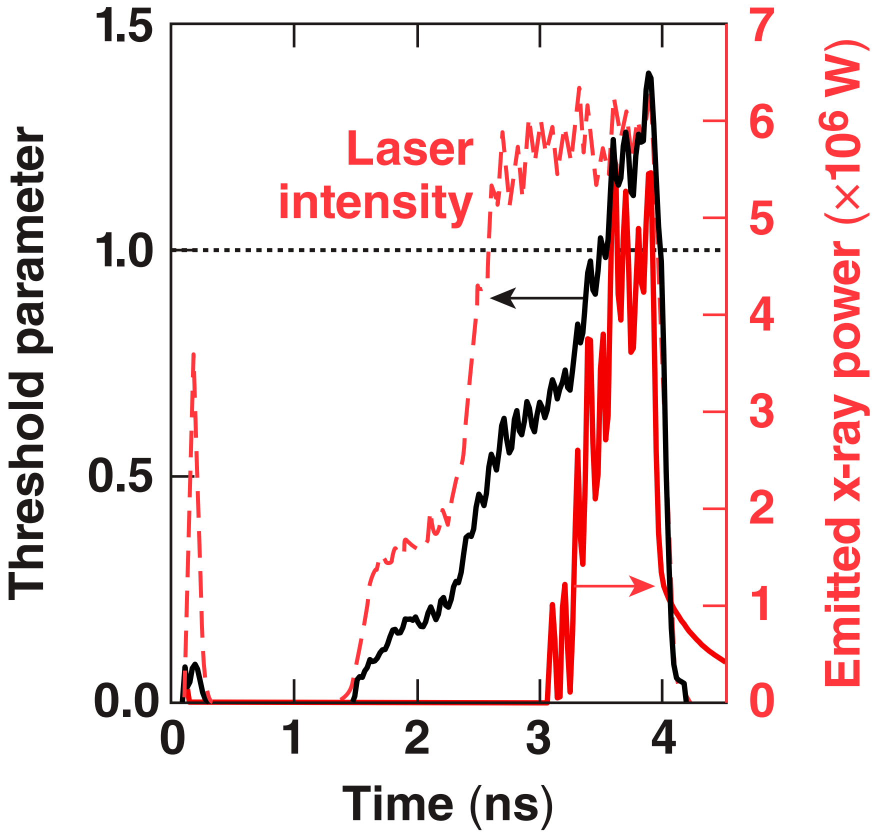
Simulations of the Effect of Energetic Electrons Produced from Two-Plasmon Decay in the 1-D Hydrodynamic Code *LILAC*



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

37th Annual Anomalous
Absorption Conference
Maui, HI
27–31 August 2007

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 (~0.3% of the laser energy) in preheat is required to obtain the observed ~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 logΛ 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:

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

- Two algorithms are used for the energy source
  - constant percentage of the energy reaching ¼ critical
  - variable that scales as the log (η) at ¼ critical with the maximum value given as the percentage

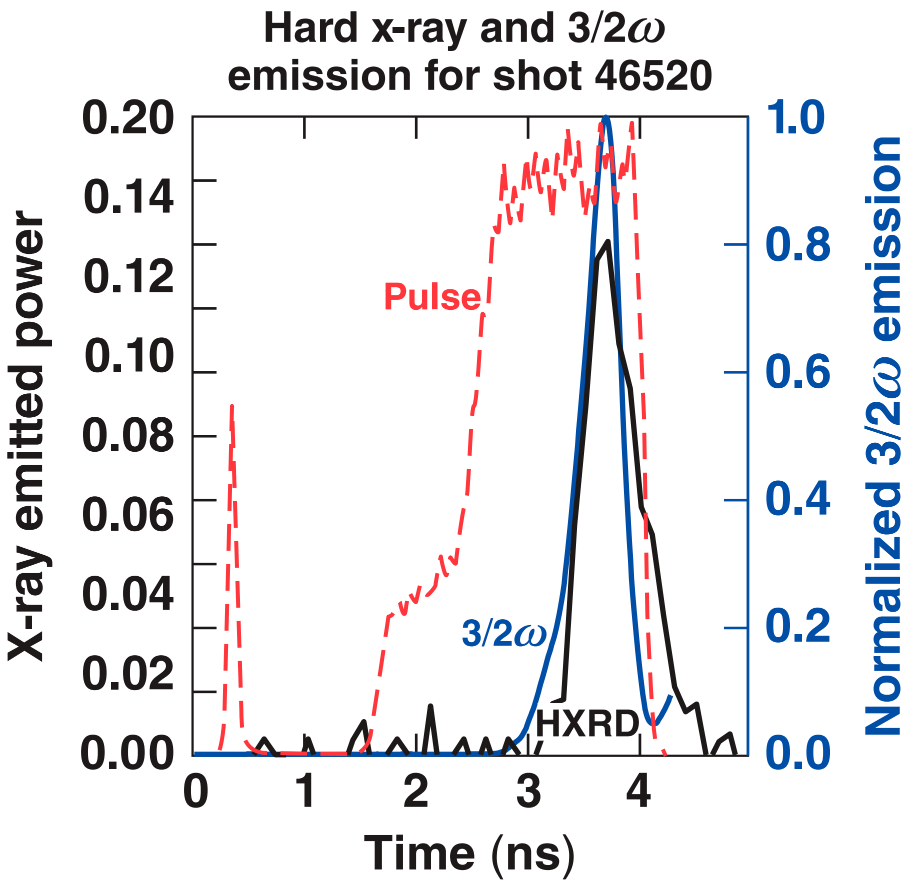
- The source temperature is obtained from a fit to the experimental measurement as

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

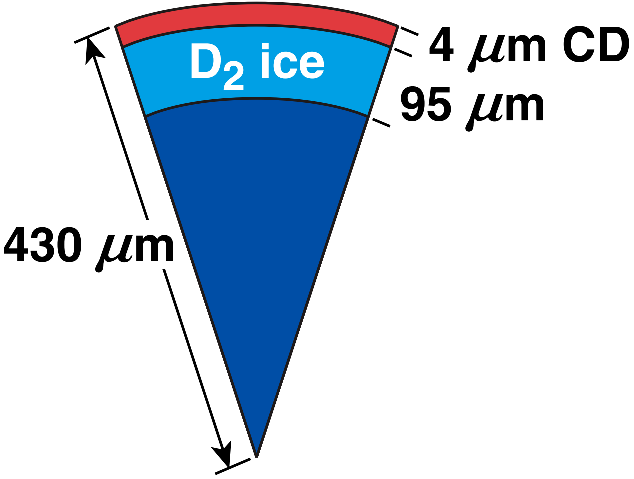
---

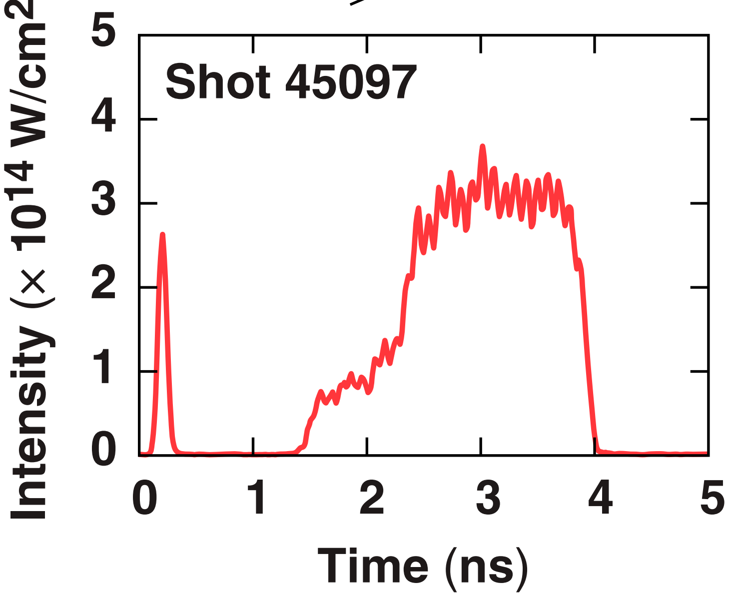
*A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).

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



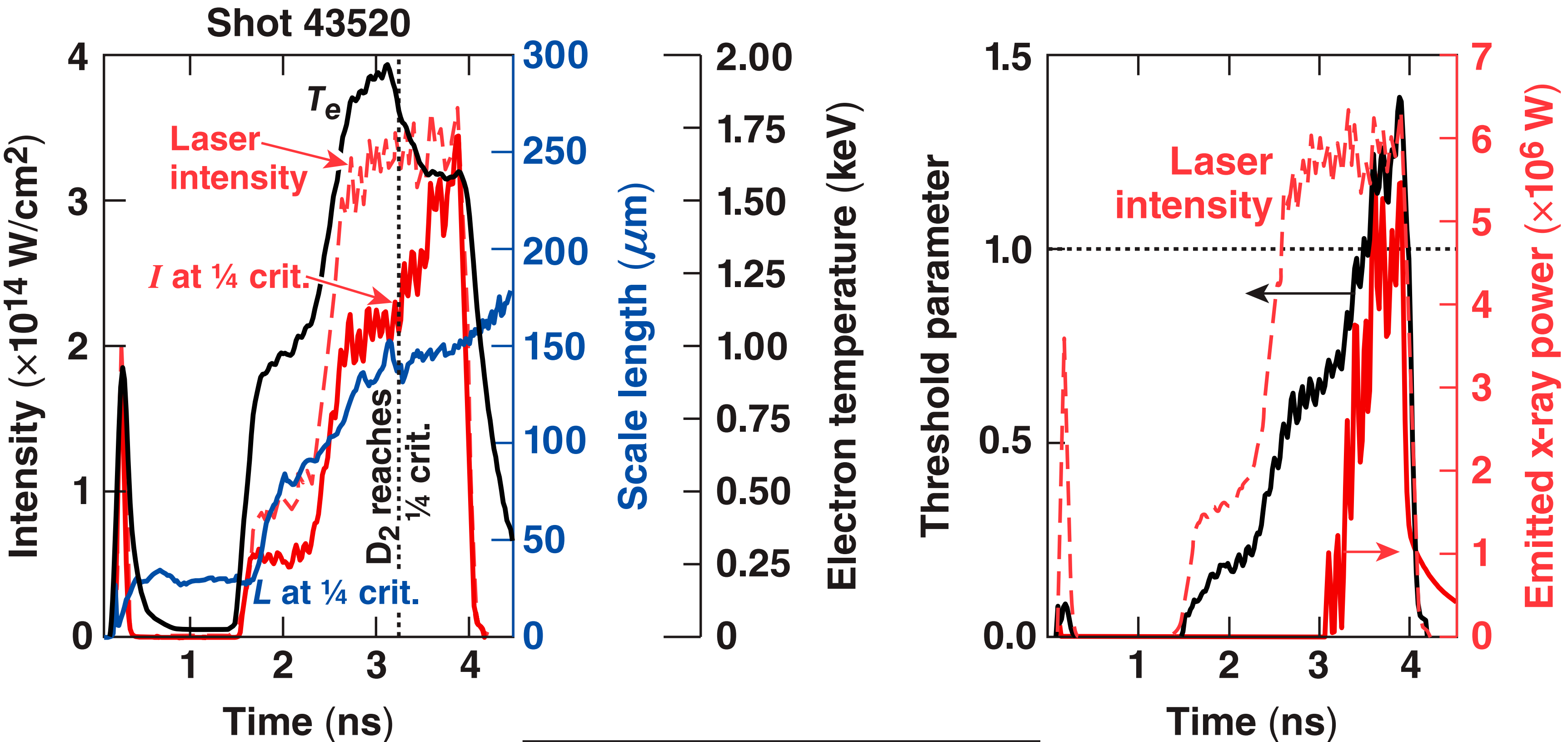
Hard x-ray and 3/2ω emission for shot 46520





The threshold parameter increases after burnthrough into the D_2 due to the decreasing T_e and increasing intensity at the ¼ critical surface

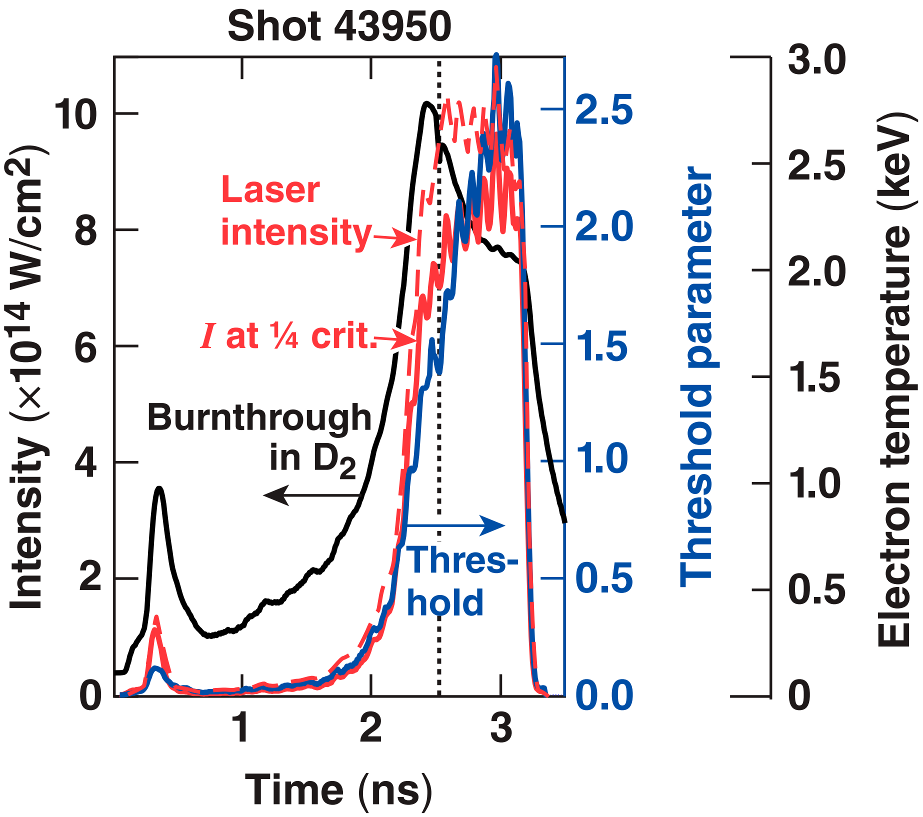
$I = 3.5 \times 10^{14}\ \mathrm{W/cm^2}$

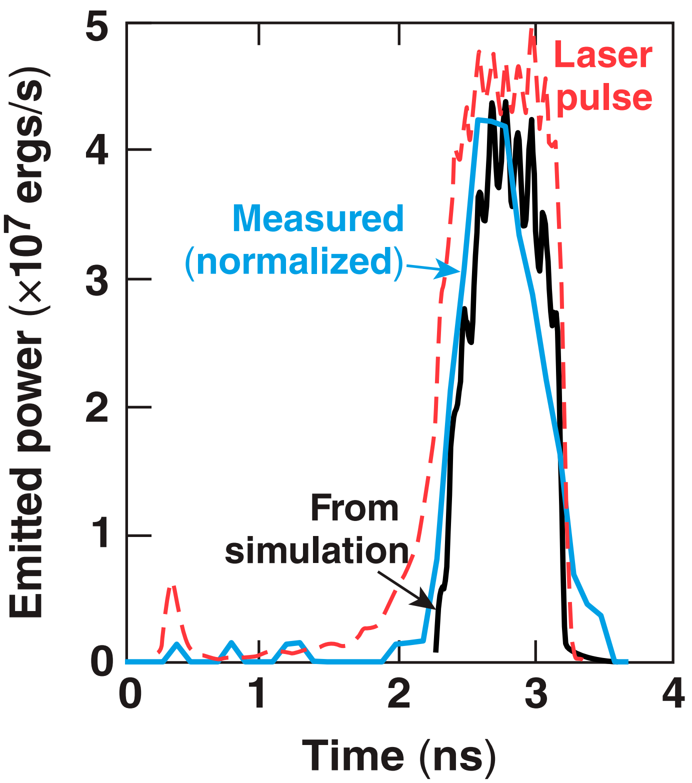


$\eta = I_{14} L_{\mu m} / 233\, T_c\ (\mathrm{keV})$

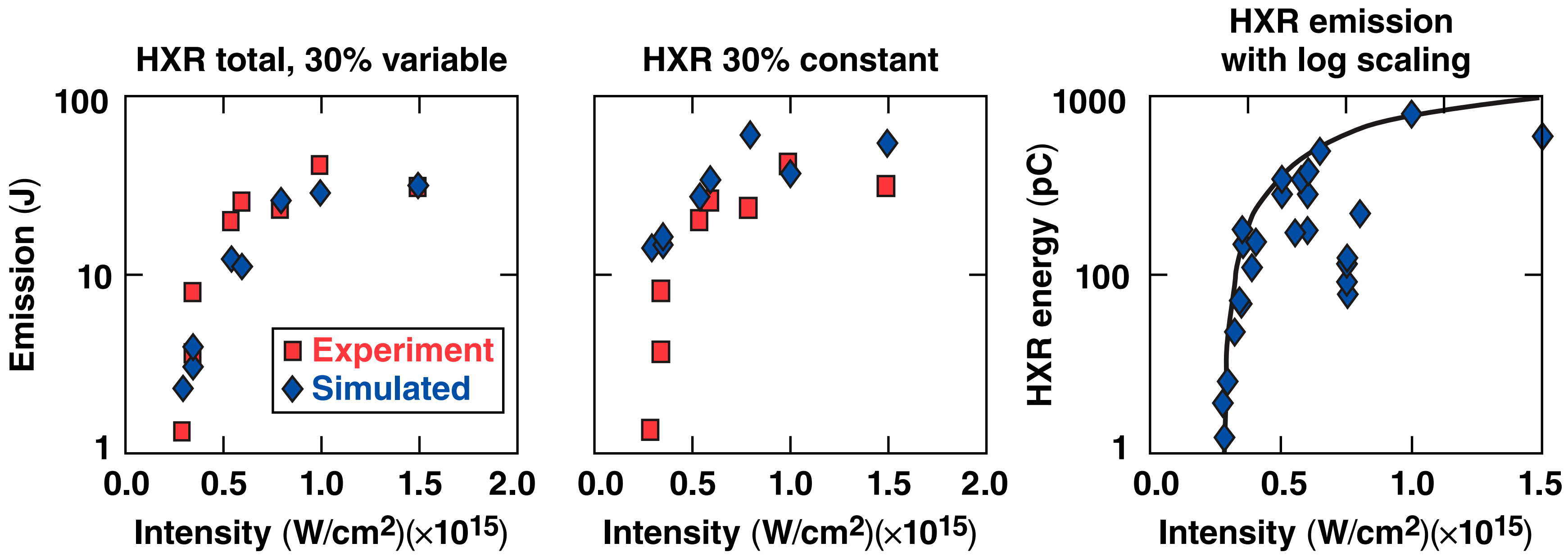
At high intensity (1×10^{15} W/cm^2) the laser burns through to the D_2 early in the pulse resulting in a longer x-ray emission

UR LLE





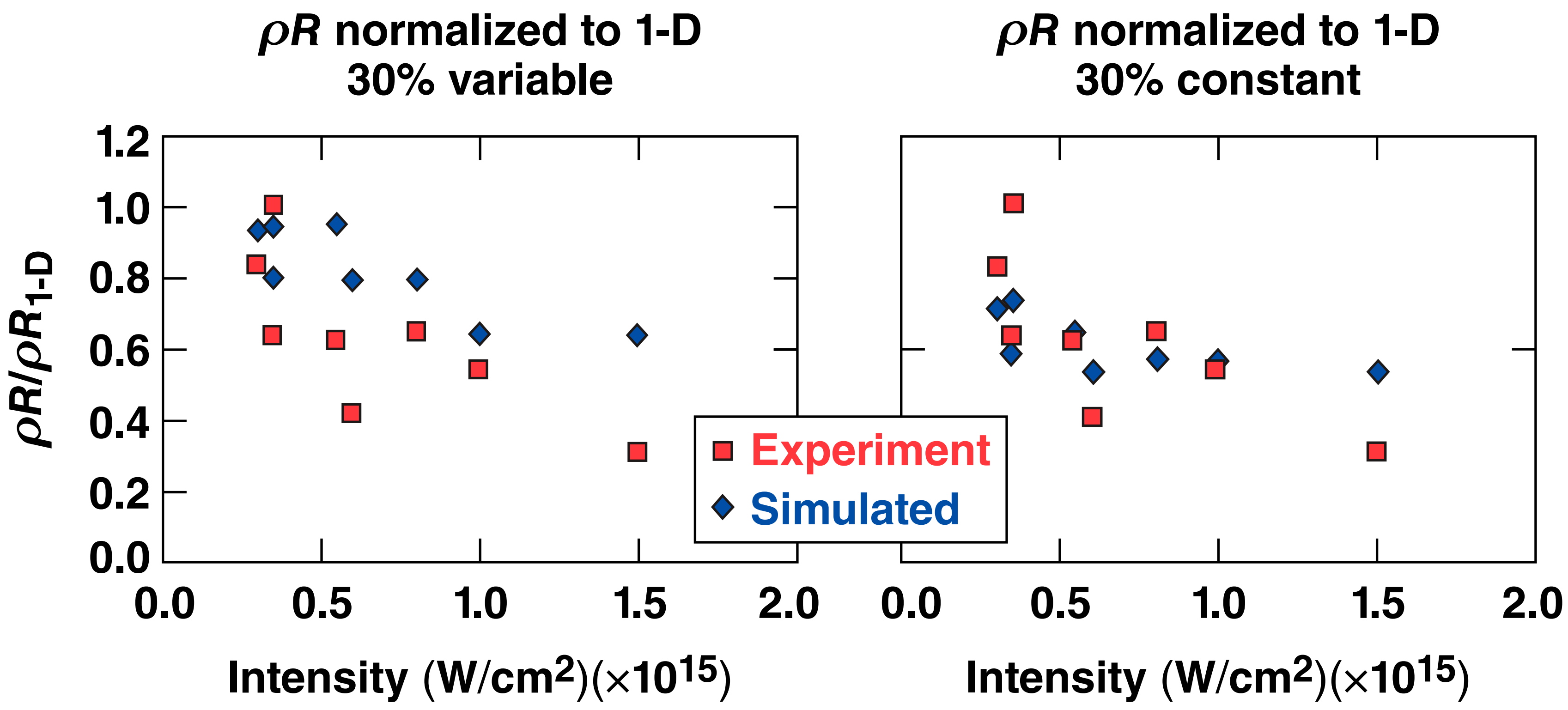
The hard x-ray emission scales closer to experiment with variable energy input than with constant energy input



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

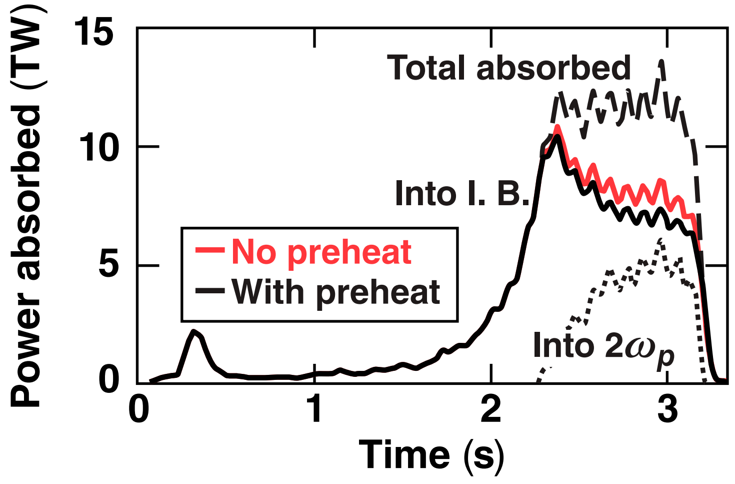
TC7778

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

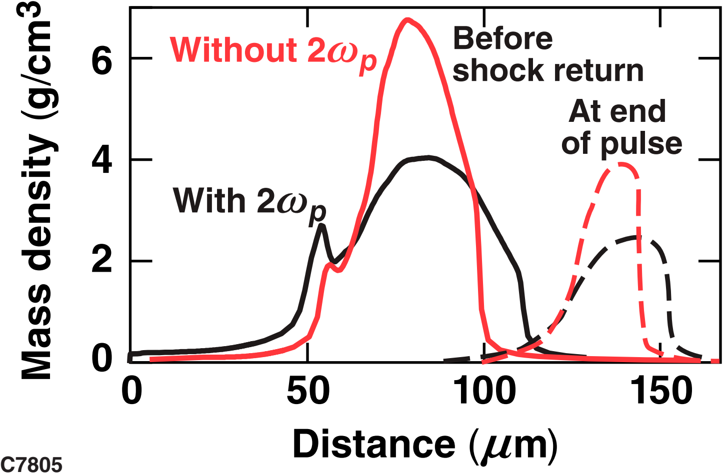


for α = 2 to 4 shots

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



Shell position during implosion; shot 43950



Shot 43950 (10^{15} W/cm^2), 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}

TC7805

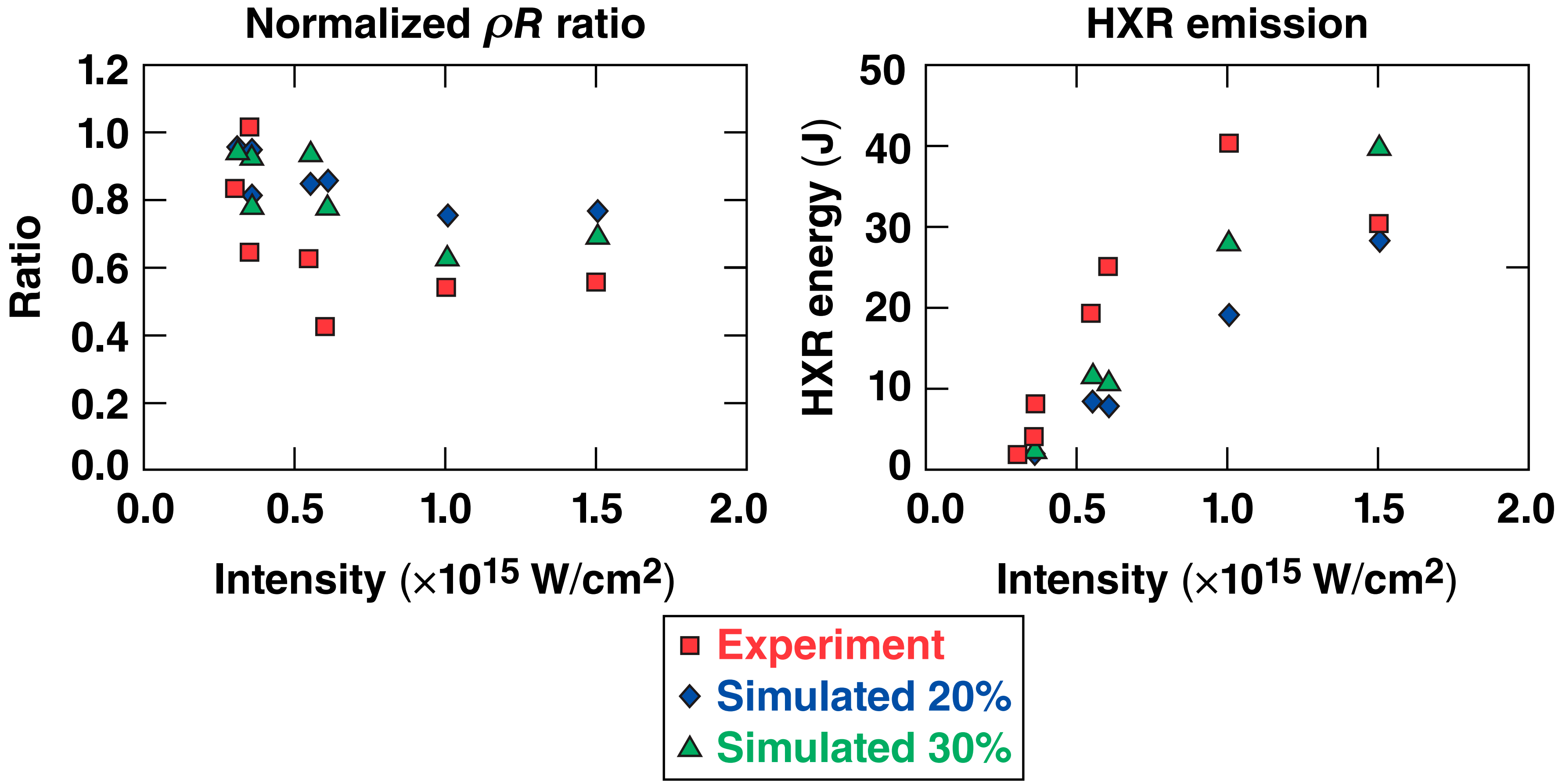
Summary/Conclusions

Preheat from the 2ω_p instability could explain the observed ρR reduction in cryogenic implosions

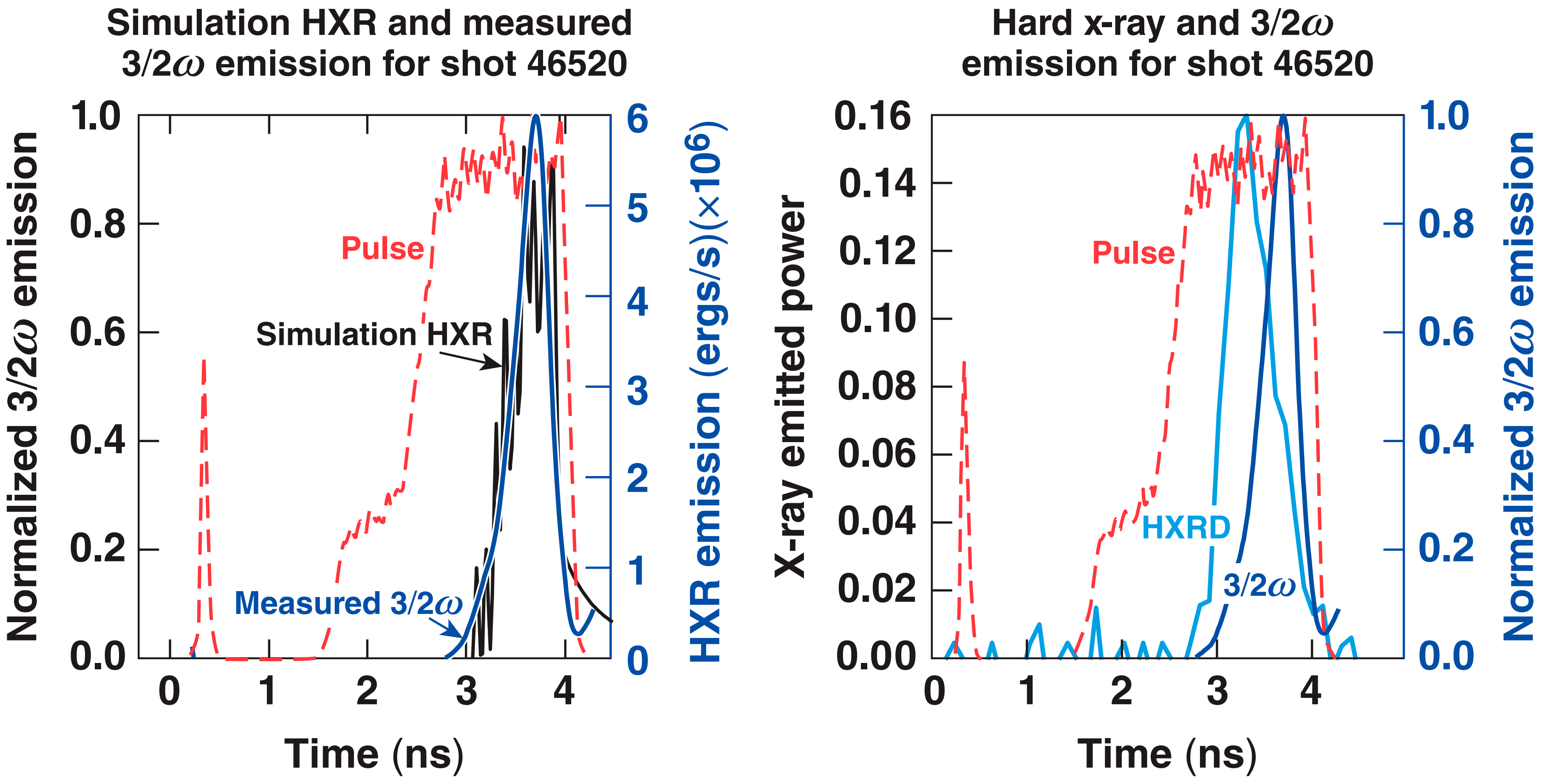
- The existing fast-electron transport in the 1-D code *LILAC* was modified to model the source and transport of electrons produced by the 2ω_p instability.
- Moderate agreement was obtained for the measured fuel ρR and the emitted HXR energy.
- The simulations reproduced the overall temporal evolution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

See also D. Shvarts talk Wednesday morning

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

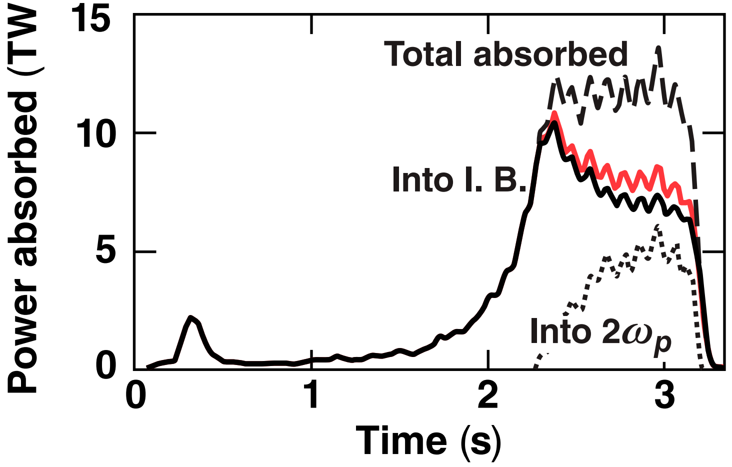


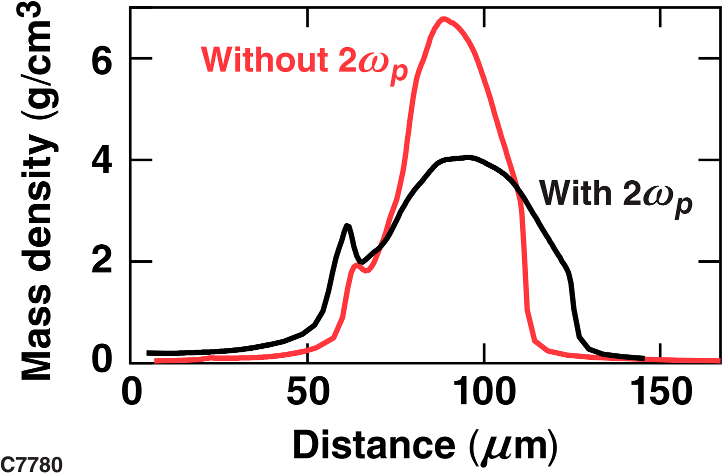
For a cryogenic shot, the measured HXR emission comes earlier than the 3/2ω emission and the computed HXR emission



TC7850

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


No fast electrons, 30% constant


Shell position before shock return (3.4 ns); shot 43950

Shot 43950 (10^{15} W/cm^2), 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}
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}

TC7780