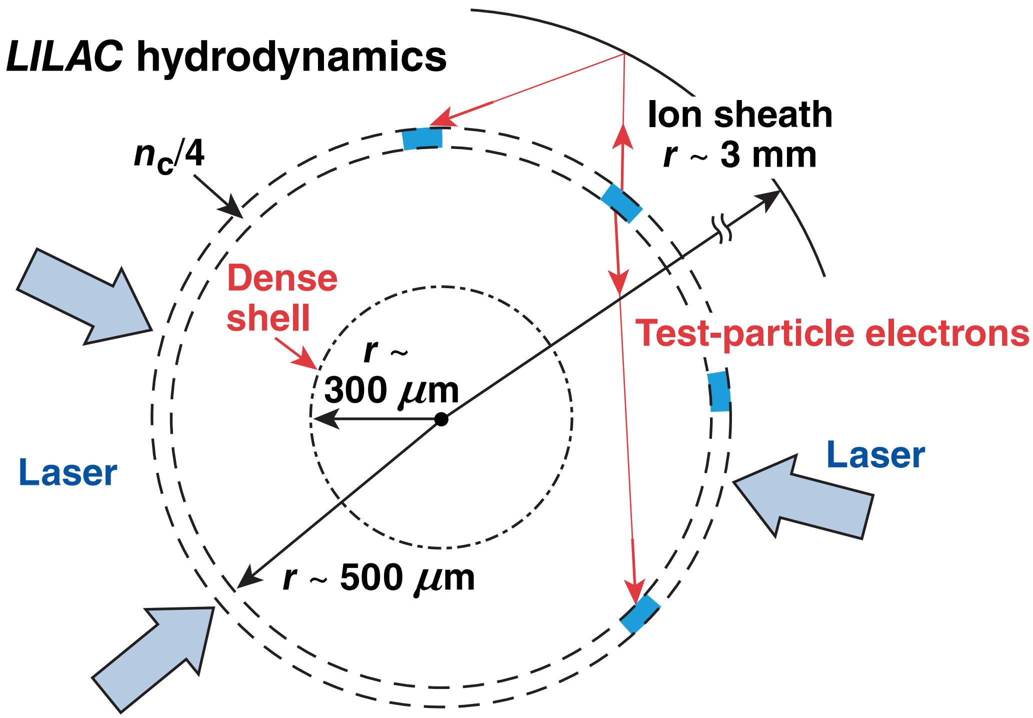
Two-Plasmon-Decay Calculations for OMEGA and Ignition-Scale Direct-Drive Inertial Confinement Fusion



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Summary

A physical model of TPD in direct-drive targets that gives scalings for hot-electron temperature has been constructed

- The scheme combines *LILAC* hydrodynamics, an extended Zakharov model of TPD growth and saturation, and hot-electron generation and transport in the test-particle approximation
- The scaling of hot-electron temperature is obtained for electron-density scale lengths in the range L_n = 100 to 350 μm and laser intensities between I_{15} = 0.1 to 2 that corresponds to either OMEGA- or ignition-scale targets
- The hot-electron temperature is well determined by the value of the threshold parameter η^* alone and is found to vary in the range T_e = 50 to 150 keV

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

Collaborators

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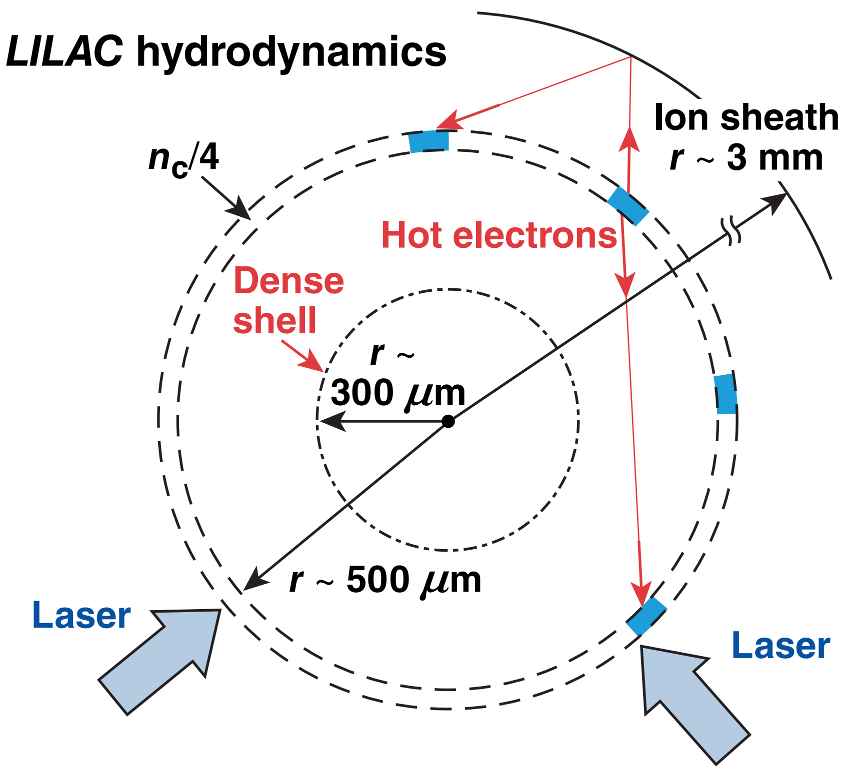
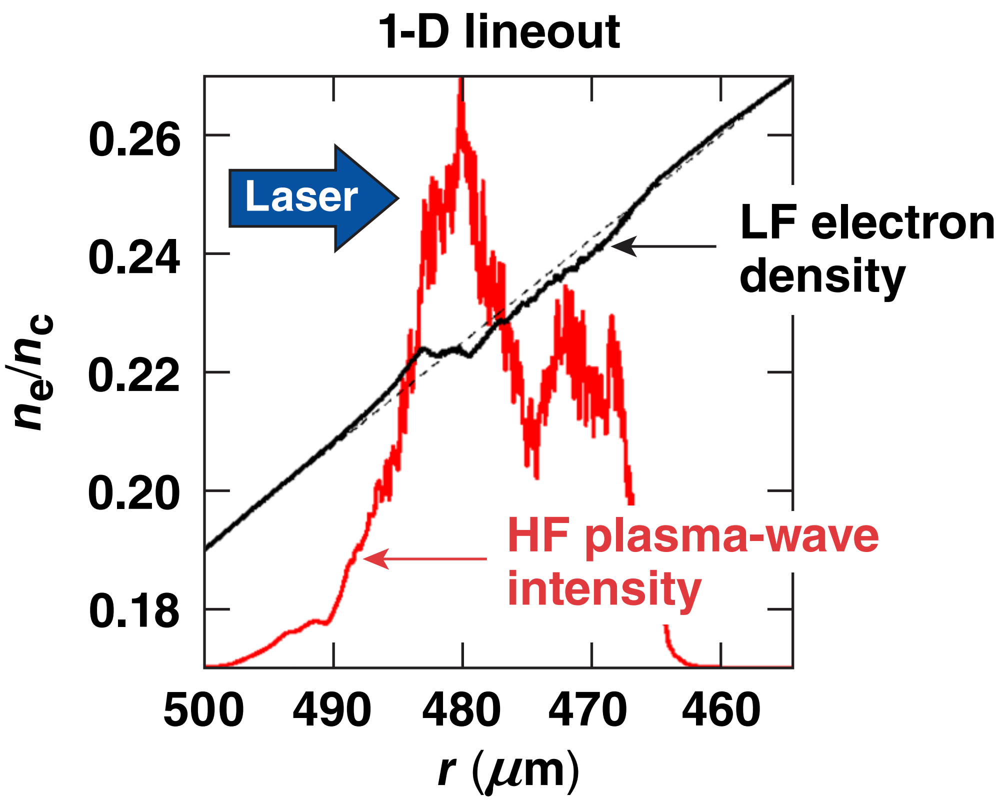
The model combines the effects of target hydrodynamics, TPD saturation, hot-electron production, and transport



- For a given implosion, *LILAC* calculations define the plasma parameters
- The extended Zakharov equations are solved to saturation
- Electron test particles are integrated to give heated distribution function
- Test particle transport is included

The nonlinear evolution of TPD is determined using an extended Zakharov model

- For a given implosion, *LILAC* calculations are used to determine the laser intensity and plasma parameters at quarter critical
- The Zakharov equations adopt these parameters and are run to full saturation (tens of picoseconds)



The "Zakharov" equations are extended when applied to the two-plasmon-decay problem

- "Extended" Zakharov equations used in Zak*

$$\nabla \cdot \left[D_{LW} - \omega_0^2 (\delta n + \delta N) / n_0 \right] E = (e/4\, m_e) \nabla \cdot \left[\nabla (E_0 \cdot \bar{E}) - E_0 \nabla \cdot \bar{E} \right] + S_E$$

$$D_{IAW} \delta n = \nabla^2 |E|^2 / (16\, \pi m_i) + S_{\delta n}$$

TPD source term

Dispersion relations for LW and IAW

$$D_{LW} = \left[2i\omega_{p0} (\partial_t + \nu_e *) + 3\nu_e^2 \nabla^2 \right]$$

$$D_{IAW} = \left(\partial_t^2 + 2\nu_i * \partial_t - c_s^2 \nabla^2 \right)$$

Wave envelopes

$$\tilde{E} = 1/2\, E(x, y, t) \exp\left[-i (\omega_{p0} t) \right] + c.c$$

$$\tilde{E}_0 = e_y \sum_i |E_0|_i \exp\left[i\, \vec{k}_{0i} \cdot \vec{x} - i (\omega_0 - 2\omega_{p0}) t \right]$$

*D. F. DuBois *et al.*, Phys. Rev. Lett. 74, 3983 (1995);
D. A. Russell and D. F. DuBois, Phys. Rev. Lett. 86, 428 (2001).

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Hot-electron generation is computed in the test-particle approximation

- A large ensemble of electron test-particle trajectories are run to determine the hot-electron distribution function by randomizing over the initial position while drawing the initial energy from a thermal distribution

- Inside the Zakharov simulation volume, the electron trajectories are integrated in the microscopic electrostatic fields

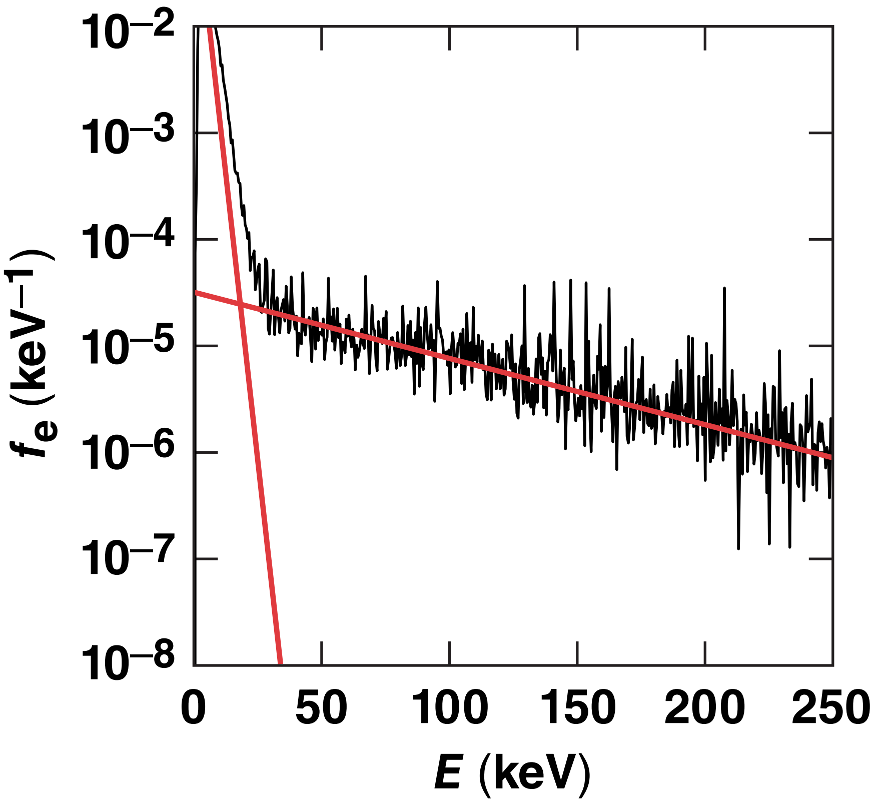
- Outside of the simulation volume, the trajectories are subject to specular reflection at the ion sheath and energy loss caused by collisional stopping in the target

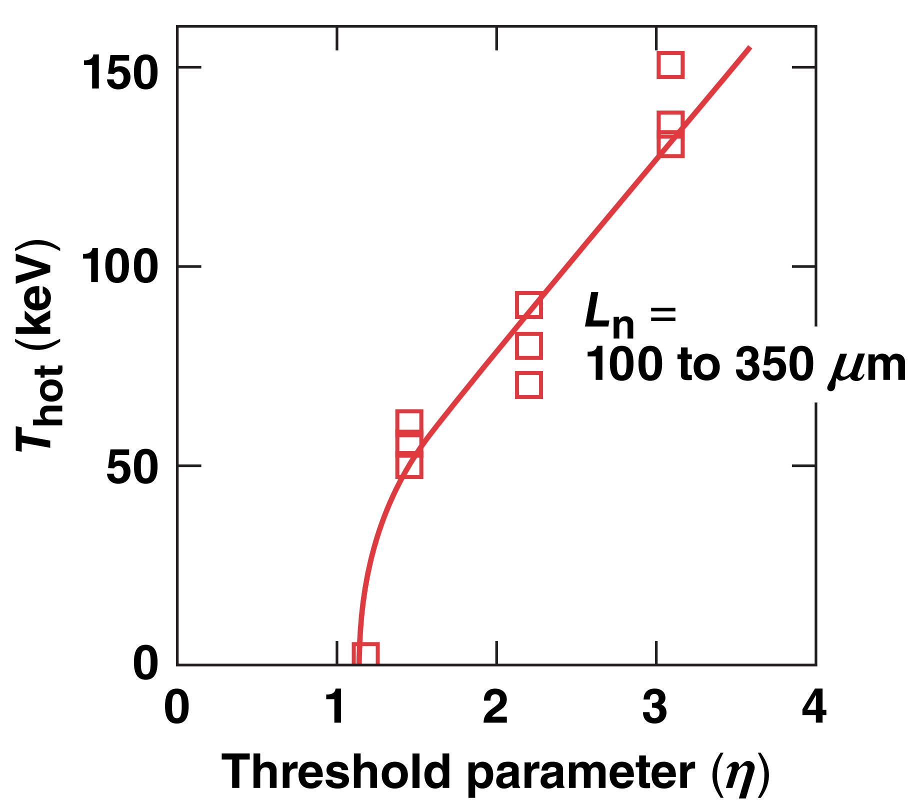
- These effects are implemented as boundary conditions[1]

[1] J. F. Myatt *et al*., Bull. Am. Phys. Soc. 54, 145 (2009).

Heated electrons are observed once the TPD threshold is exceeded and the temperature scales with the "η" parameter

The threshold parameter* is given by $\eta = I_L/I_{thr} = I_{14}L_{\mu m}/(230\ T_{keV})$.





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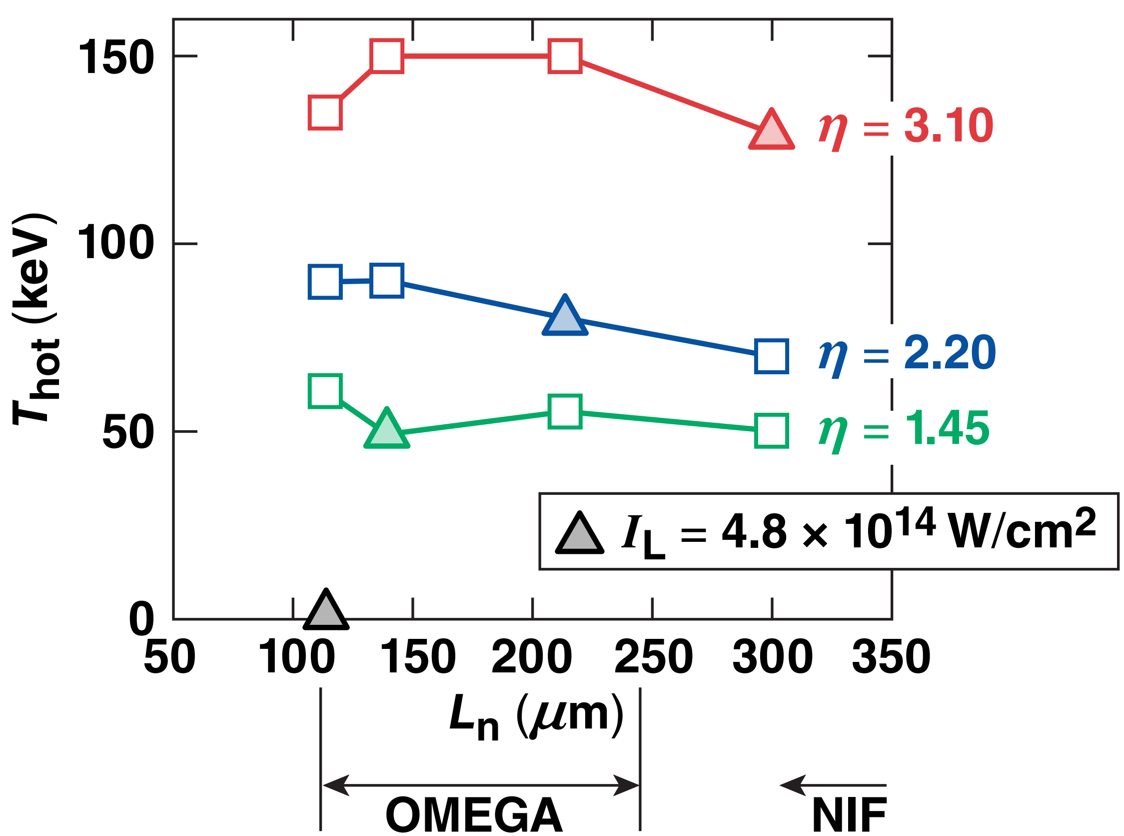
*A. Simon *et al*., Phys. Fluids 26, 3107 (1983).

For a fixed value of the threshold parameter η, the scaling of hot-electron temperature with electron-density scale length is weak

- For all cases, the initial electron temperature $T_e = 2$ keV
- As L_n is increased, I_L is decreased to keep the product constant

$$\eta = I_{14} L_{\mu m}/230\, T_{keV}$$



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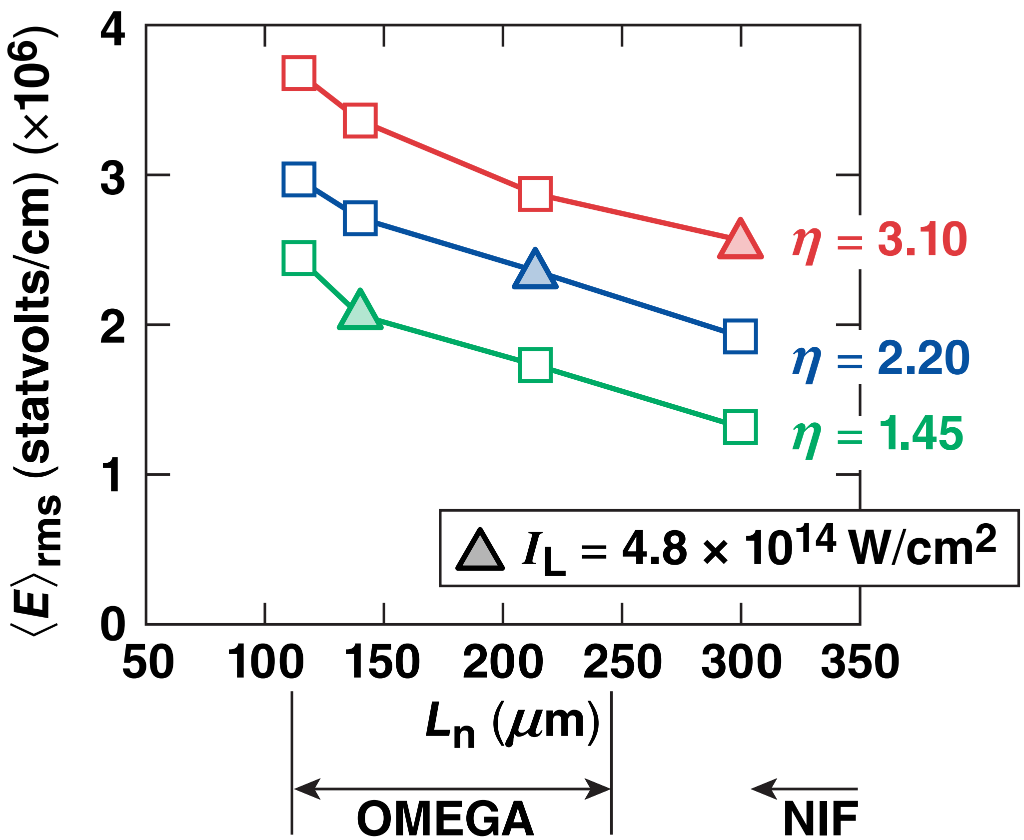
The weak dependence of the hot-electron temperature on density scale-length arises due to the reduction in rms electric field

- The hot-electron temperature depends upon the electric field excitation level and the acceleration length



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Summary/Conclusions

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