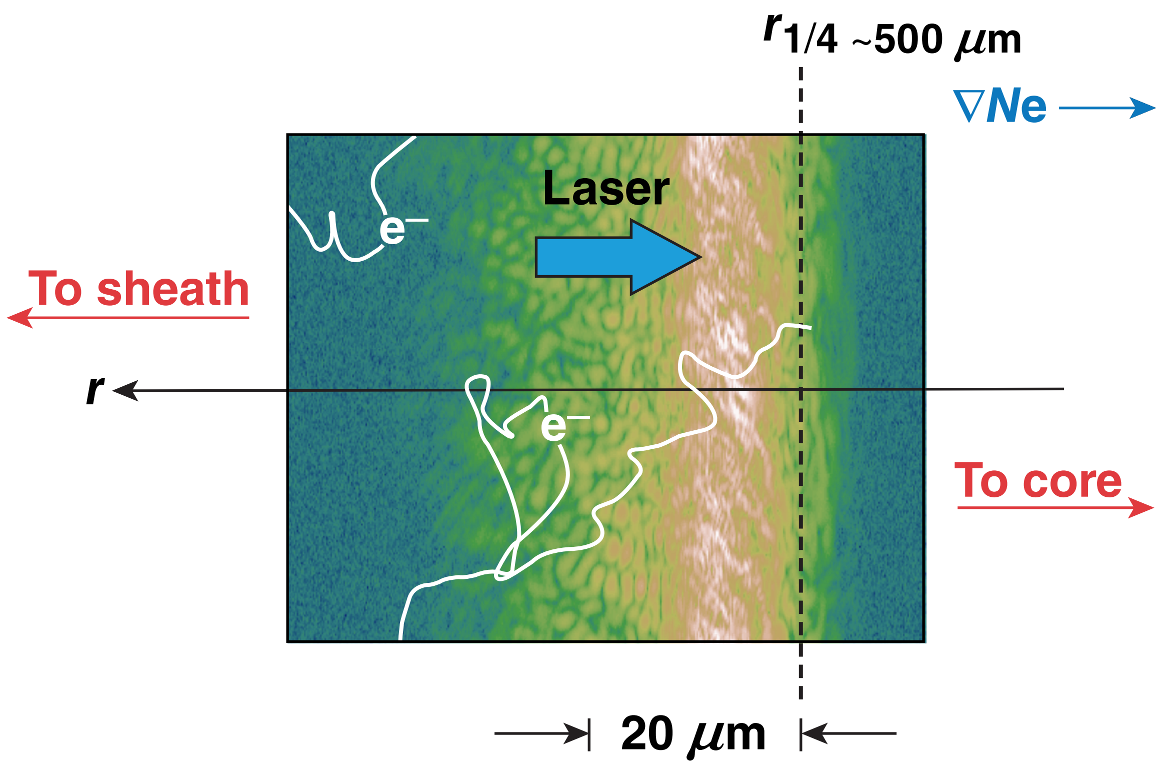
Two-Plasmon-Decay Hot–Electron Generation and Reheating in OMEGA Direct-Drive-Implosion Experiments



J. F. Myatt
University of Rochester
Laboratory for Laser Energetics

40th Annual Anomalous Absorption Conference
Snowmass Village, CO
13–18 June 2010

Summary

Hot-electron temperatures and preheat caused by TPD have been computed for OMEGA direct-drive parameters

- An extended Zakharov model of the two-plasmon-decay (TPD) instability is used to predict the saturated Langmuir wave spectrum for OMEGA implosions
  - the Langmuir wave spectrum extends right up to the Landau cutoff after profile modification is complete
- The hot-electron production is calculated by a test-particle approach using the Zakharov predictions for the electric fields
  - hot-electron recirculation and reheating is an important effect
  - for numerical simulations this effect manifests itself through the boundary conditions
- Hot-electron temperatures of 30 keV are obtained in comparison with 15 keV when recirculation is neglected

Collaborators

J. A . Delettrez, D. H. Edgell, A. V. Maximov,
W. Seka, and R. W. Short,

University of Rochester
Laboratory for Laser Energetics

D. F. DuBois

Los Alamos National Laboratory
and Lodestar Research Corporation

D. A. Russell

Lodestar Research Coporation

H. X. Vu

University of California, San Diego

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

- "Extended" Zakharov equations used in Zak*

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

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

TPD source term

Dispersion relations for LW and IAW

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

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

Wave envelopes

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

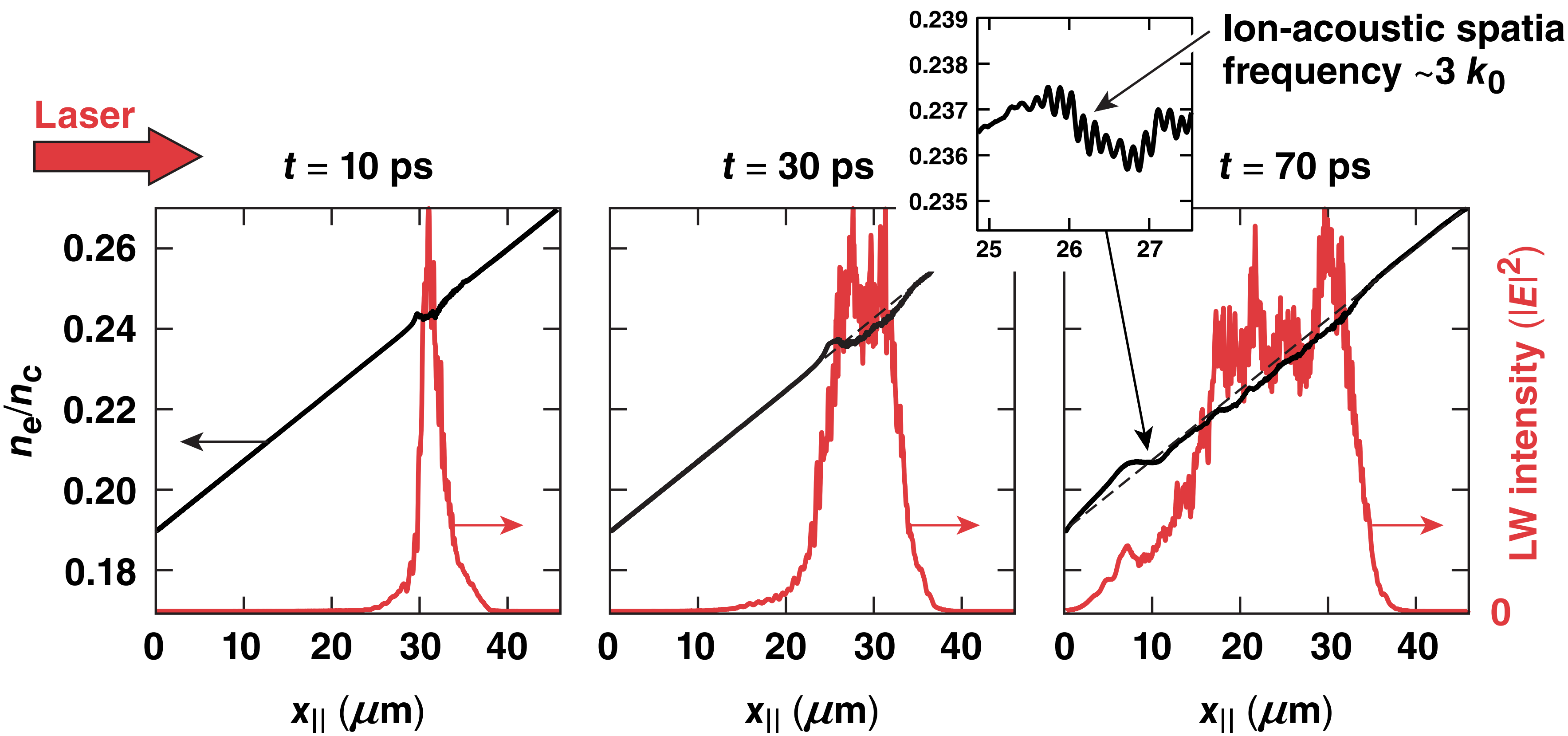
$$\tilde{E}_0=e_y\sum_i|E_0|_i\exp\left[i\,\vec{k}_{0i}\cdot\vec{x}-i\left(\omega_0-2\omega_{p0}\right)t\right]$$

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

TC8454a

The Zakharov model predicts that a saturated state is formed for OMEGA conditions after several tens of picoseconds

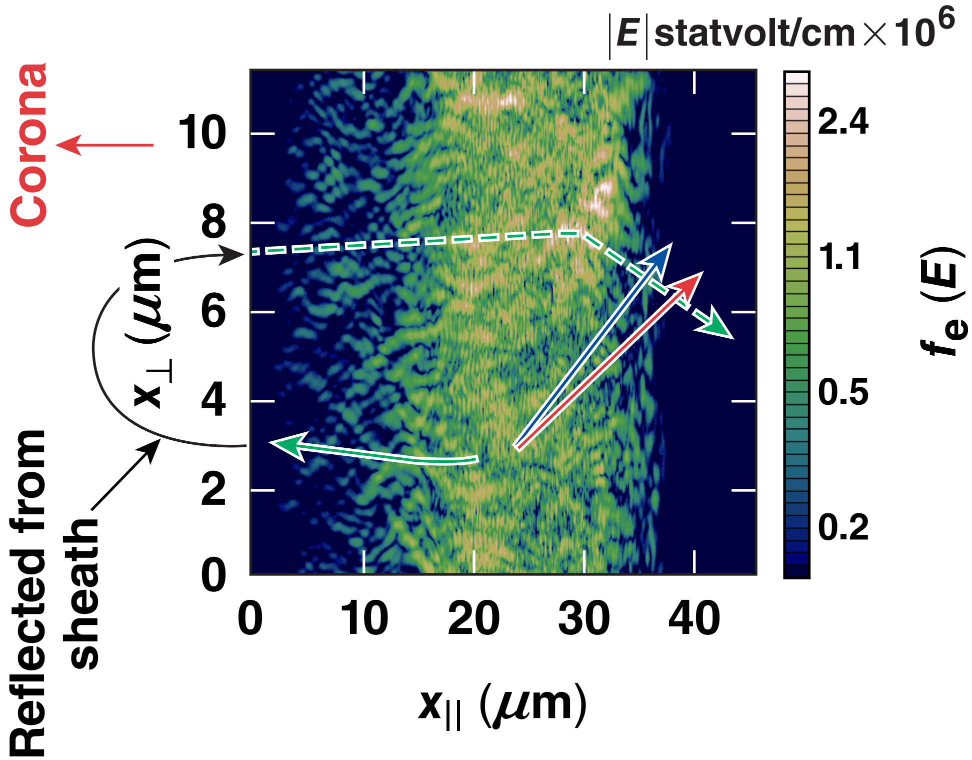
- A region of plasma-wave excitation rapidly spreads down the density gradient, modifying the density profile as it does so
- The LW electric field and the nonlinear density perturbations are averaged over the transverse coordinate

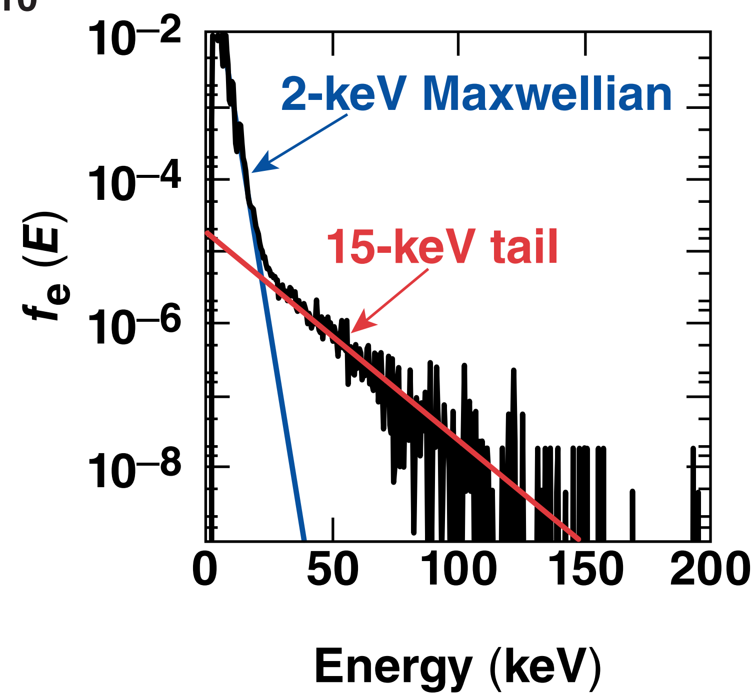


TC8457c

Test-particle trajectories are integrated in the saturated Zakharov fields showing the importance of boundary conditions

UR LLE





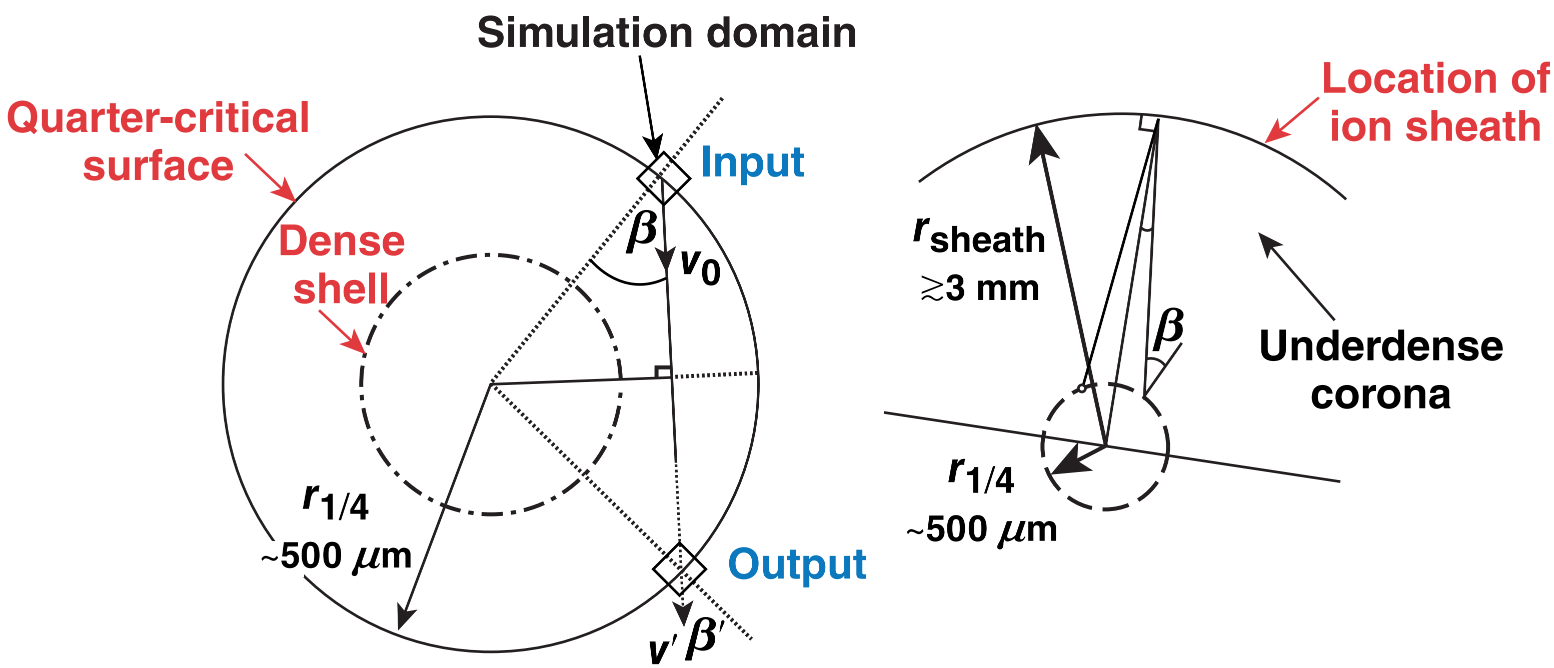
- Hot-electron temperature is consistent with RPIC*
- **The heating problem cannot be investigated in isolation.**

TC8647a

*H. X. Vu (this conference)

The recirculation at the inner boundary (pointing toward the center of the target) and the outer boundary (pointing into the corona) have a different physical origin

- Angle β is the angle with respect to the outward normal of the simulation volume

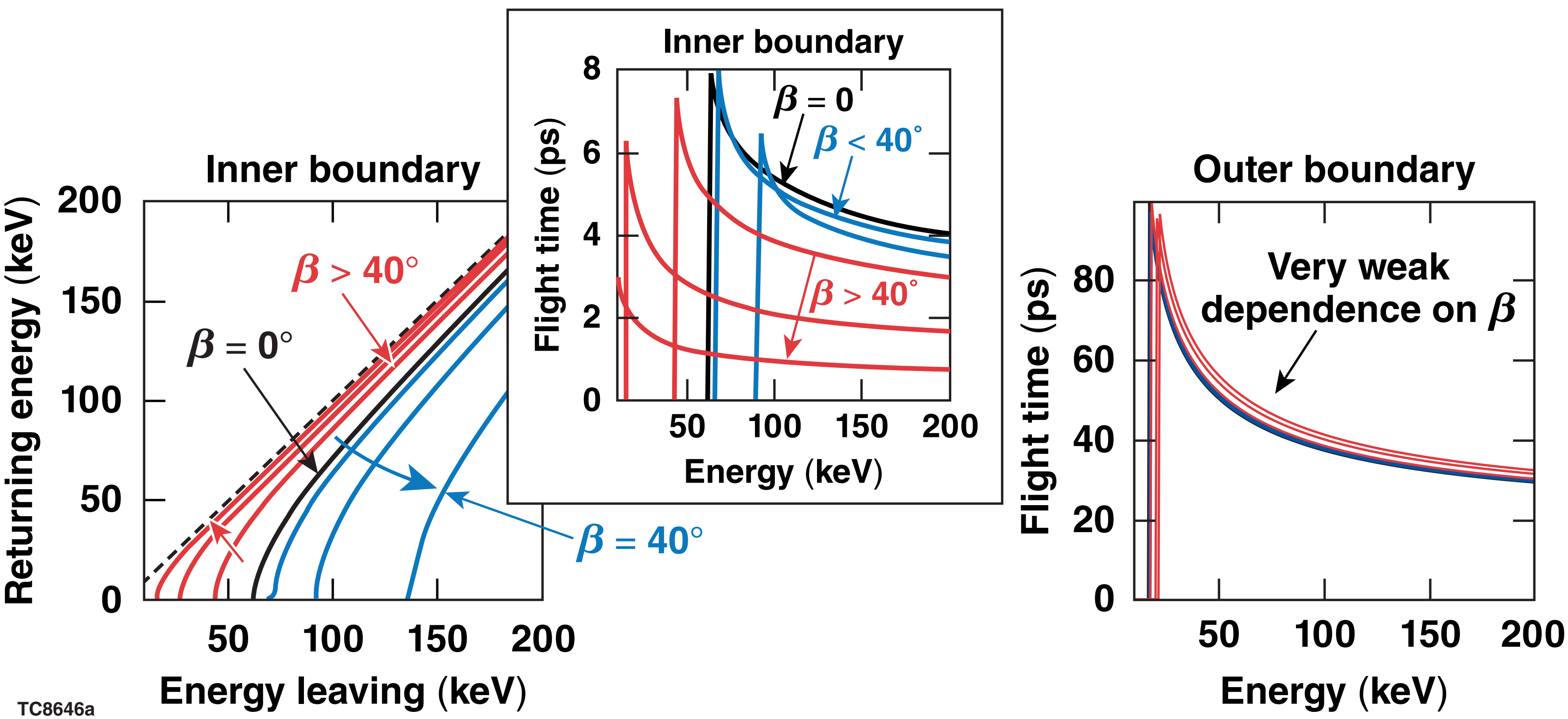


- The delay at the inner boundary is short, with significant energy loss; the delay at the outer boundary is long, with little energy loss

TC8644a

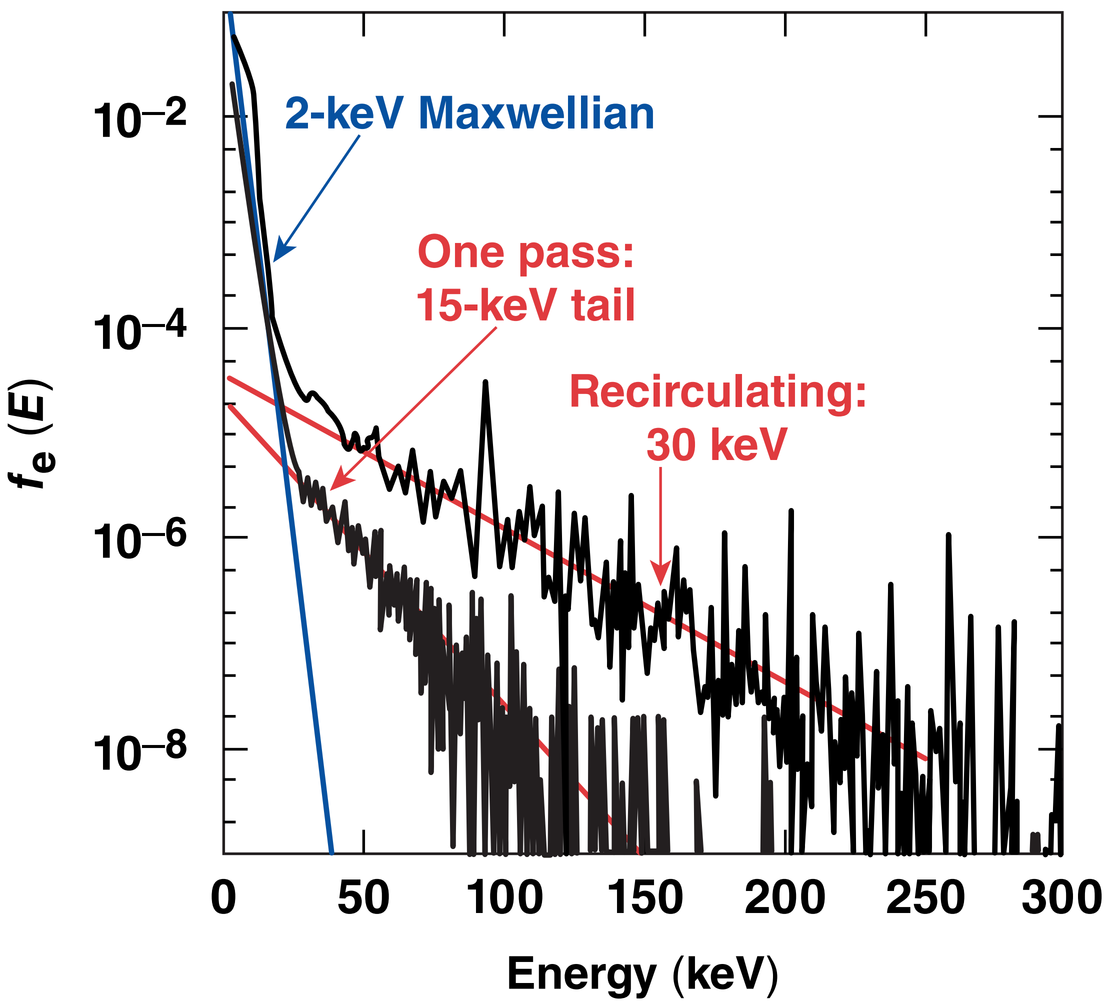
The energy and time of flight of the returning electrons has been tabulated at both boundaries for typical OMEGA cryogenic-implosion parameters

- For $\beta \gtrsim 40°$: hot electrons with $E \gtrsim 40$ keV can easily recirculate through the inner boundary
- For $E > 10$ keV: electrons can return to the outer boundary



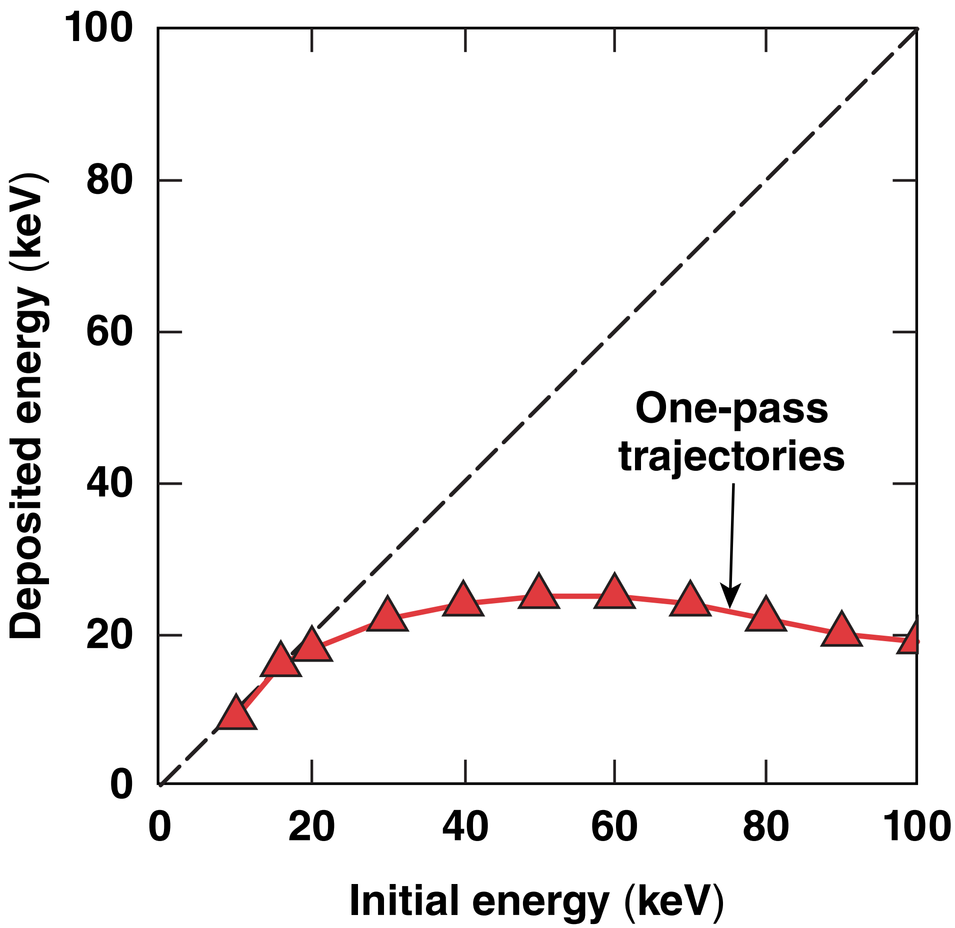
TC8646a

Use of physical boundary conditions leads to a higher-temperature test-particle distribution



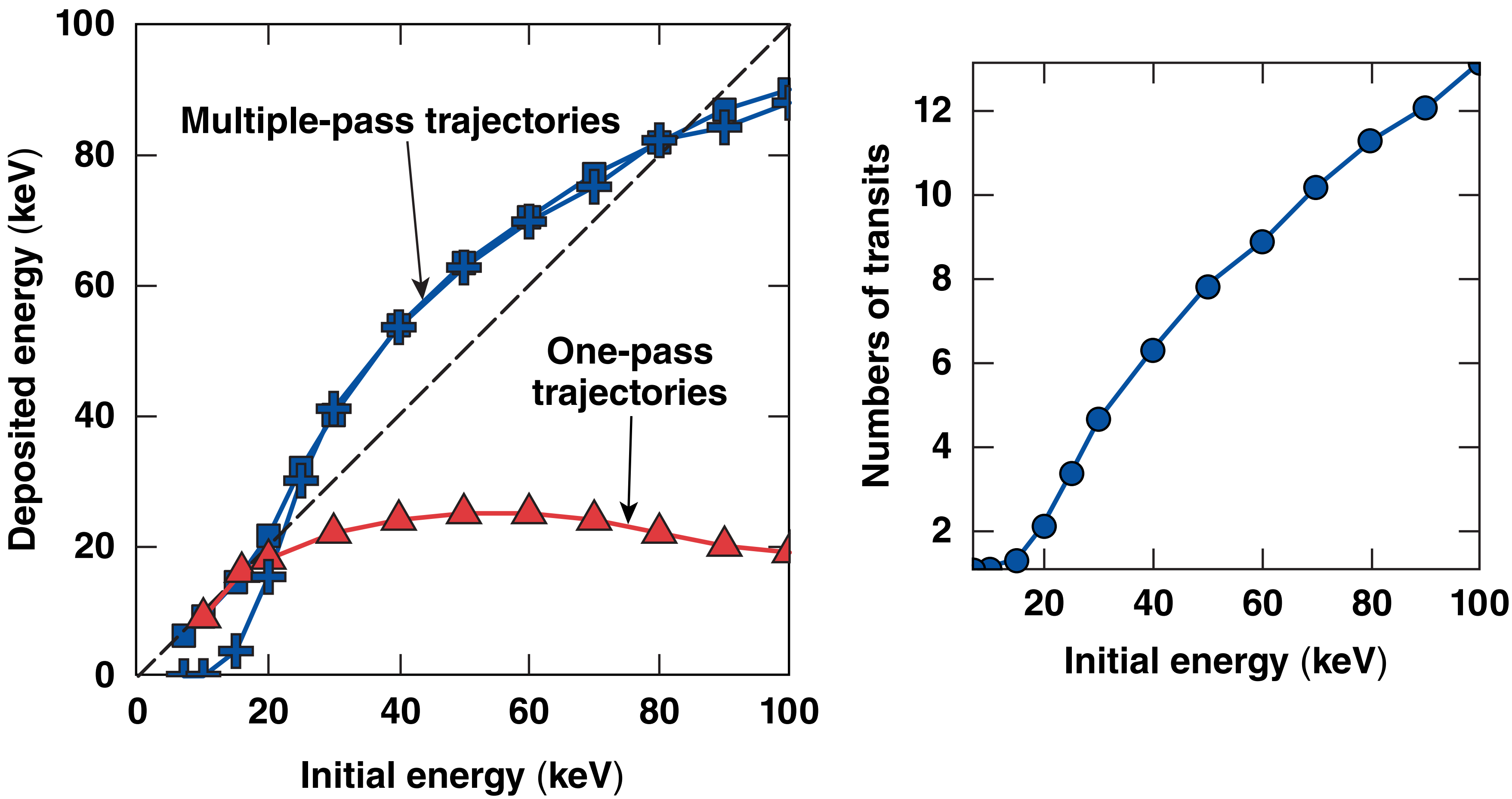
TC8852

The coupling of test-particle energy to the target core is increased dramatically when recirculation is included



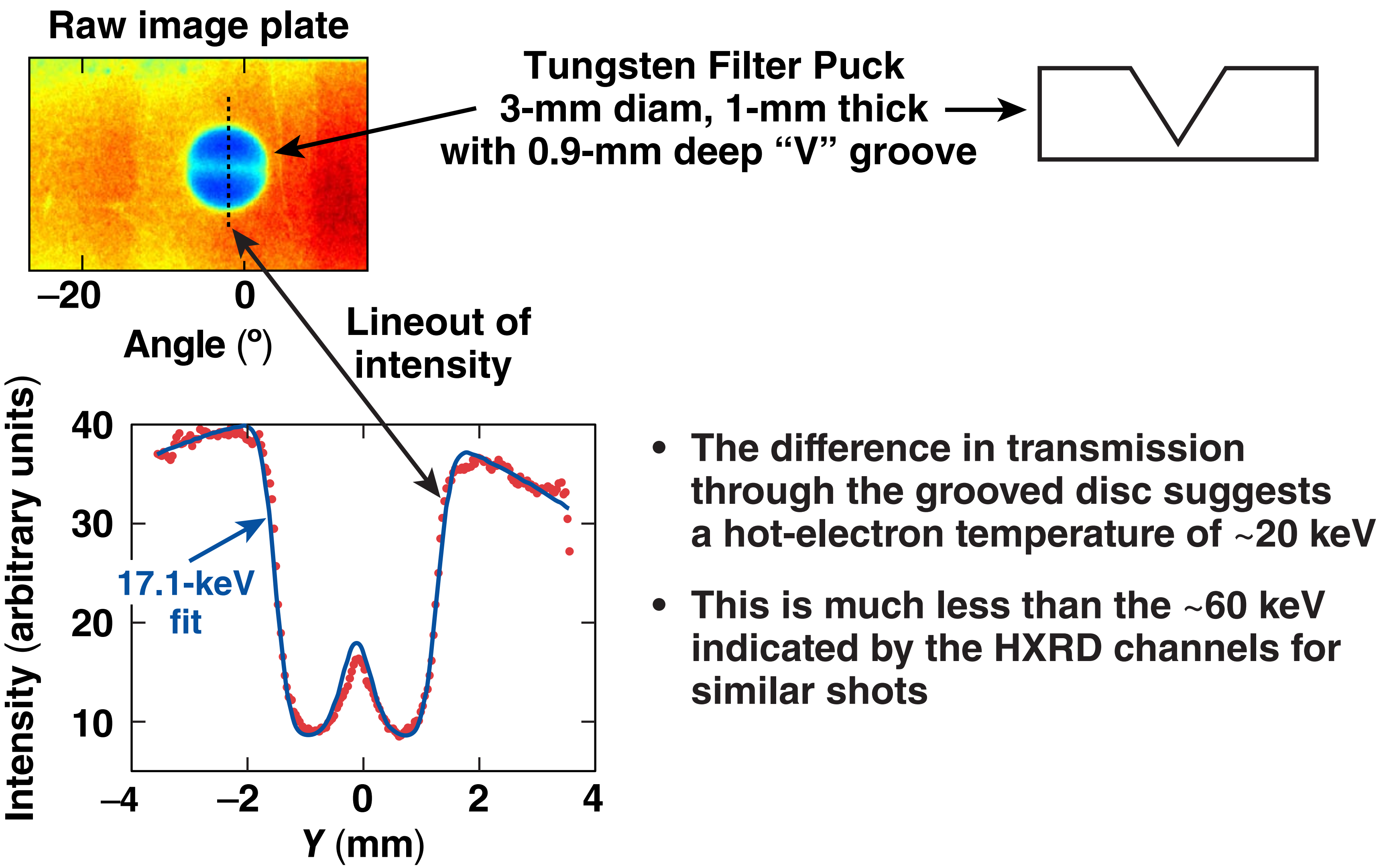
TC8853

The coupling of test-particle energy to the target core is increased dramatically when recirculation is included



TC8853a

In planar-foil experiments the hot-electron temperature is estimated to be ~20 keV



- The difference in transmission through the grooved disc suggests a hot-electron temperature of ~20 keV
- This is much less than the ~60 keV indicated by the HXRD channels for similar shots

E19017a

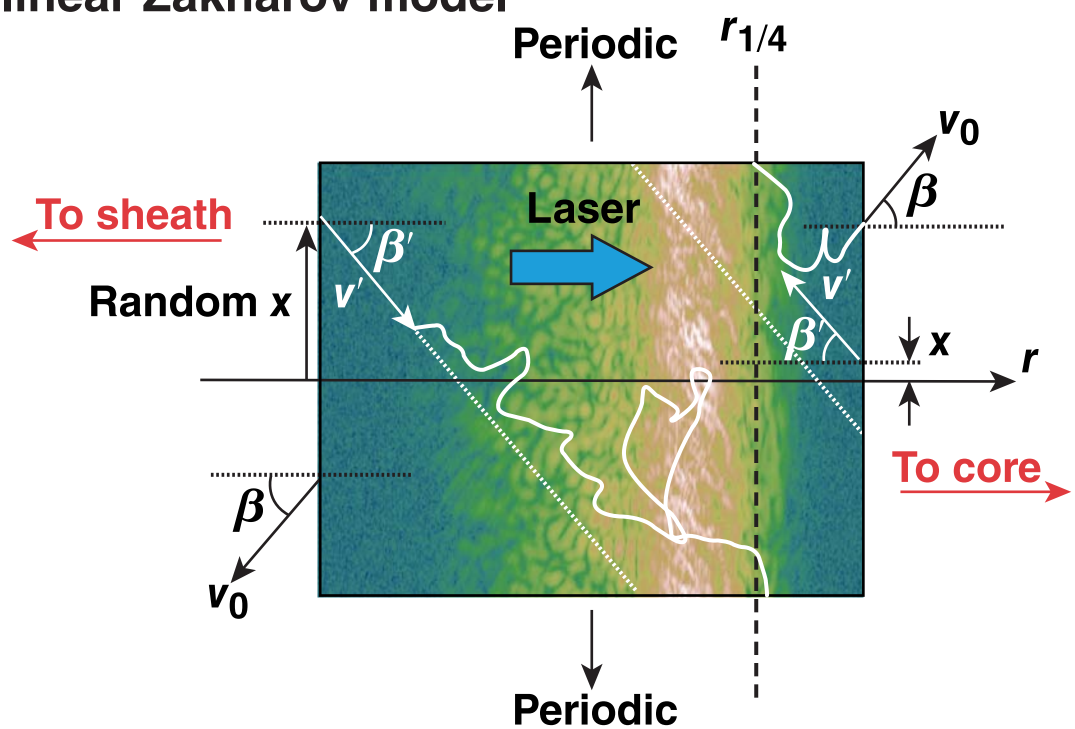
Summary/Conclusions

Hot electron temperatures and preheat due to TPD have been computed for OMEGA direct-drive parameters

- An extended Zakharov model of the two-plasmon-decay (TPD) instability is used to predict the saturated Langmuir wave spectrum for OMEGA implosions
  - the Langmuir wave spectrum extends right up to the Landau cutoff after profile modification is complete
- The hot-electron production is calculated by a test-particle approach using the Zakharov predictions for the electric fields
  - hot-electron recirculation and reheating is an important effect
  - for numerical simulations this effect manifests itself through the boundary conditions
- Hot-electron temperatures of 30 keV are obtained in comparison with 15 keV when recirculation is neglected

Delay-type boundary conditions are proposed that will mimic the effect of the target in kinetic calculations

- Exiting particles come back at a later time with a modified velocity vector based on look-up tables
- Preheat and x-ray accounting will be done
- For example: consider an electron exiting the inner boundary
- The test-particle calculations will guide the development of a quasilinear Zakharov model



TC8643a