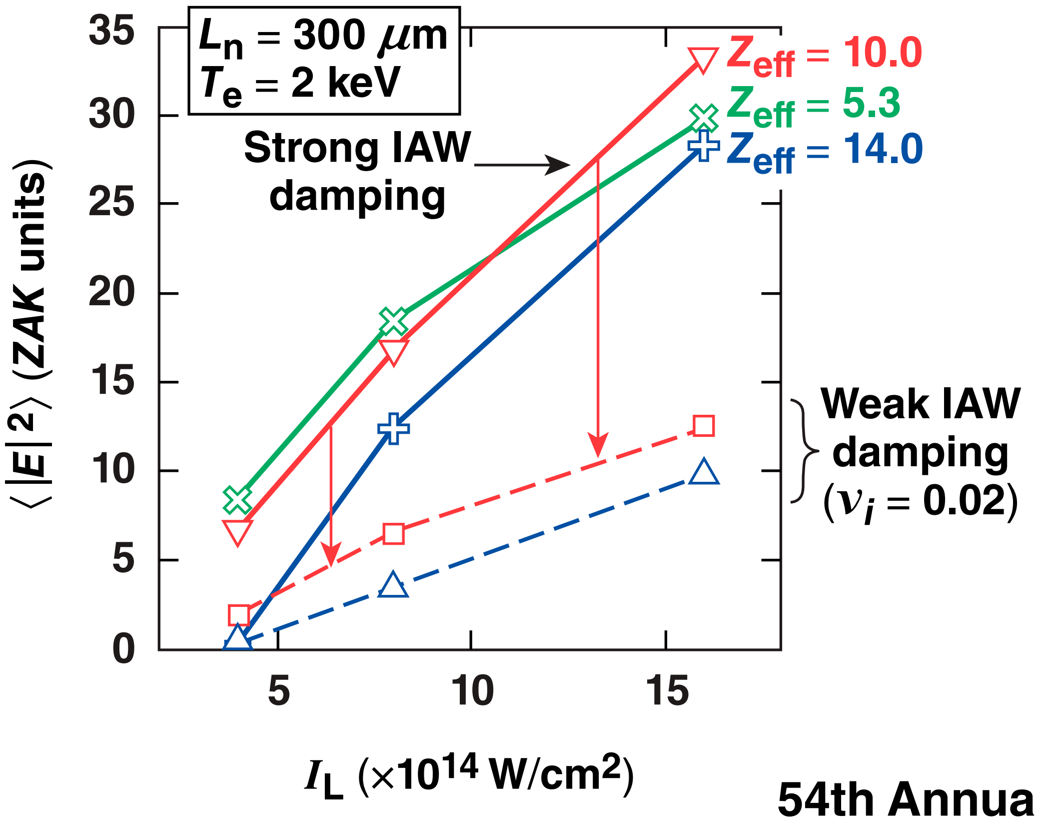
Mitigating Two-plasmon Decay Hot-electron Generation Through the Modification of Langmuir and Ion-acoustic Dissipation in Directly Driven Targets



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Summary

Two-plasmon–decay (TPD) preheat can be reduced through the manipulation of the collisional and Landau damping of Langmuir and ion-acoustic waves

- Langmuir wave (LW) collisional damping has an impact on the growth rate/thresholds [in addition to the hydrodynamic variables (∇n_e, T_e)]
  - – importance increases with the scale length
- Nonlinear saturation is sensitive to plasma composition ($\langle Z \rangle$, T_i, $\langle Z \rangle^2$) via the ion-acoustic damping rate
  - – predictions with the 2-D code *ZAK**
  - – hot-electron predictions with the 2-D code *QZAK***
  - – suggestions for planar experiments

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

**D. A. Russell *et al*., presented at the 42nd Annual Anomalous Conference, Key West, FL, 25–29 June 2012.

Collaborators

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The *ZAK*/*QZAK* model of TPD is used to predict linear instability and nonlinear saturation caused by density fluctuations and quasilinear diffusion

- “Extended” Zakharov equations used in *ZAK**

Gradient threshold

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

$$D_{IAW}\delta n=\nabla^2\left(|E|^2+\frac{1}{4}|E_0|^2\right)\Big/(16\,\pi M_i)+S_{\delta n}$$

TPD source term

Dispersion relations for LW’s
and ion acoustic waves (IAW’s)

Collisional threshold

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

$$D_{IAW}=\left(D_t^2+2\nu_{i*}D_t-c_s^2\nabla^2\right)$$

- The diffusion equation $\dfrac{\partial e\langle f_e\rangle}{\partial t}+\dfrac{\partial}{\partial\vec{v}}\cdot\left(D(\vec{v})\cdot\dfrac{\partial\langle f_e\rangle}{\partial\vec{v}}\right)=\sigma(\langle f_e\rangle-f_M)$

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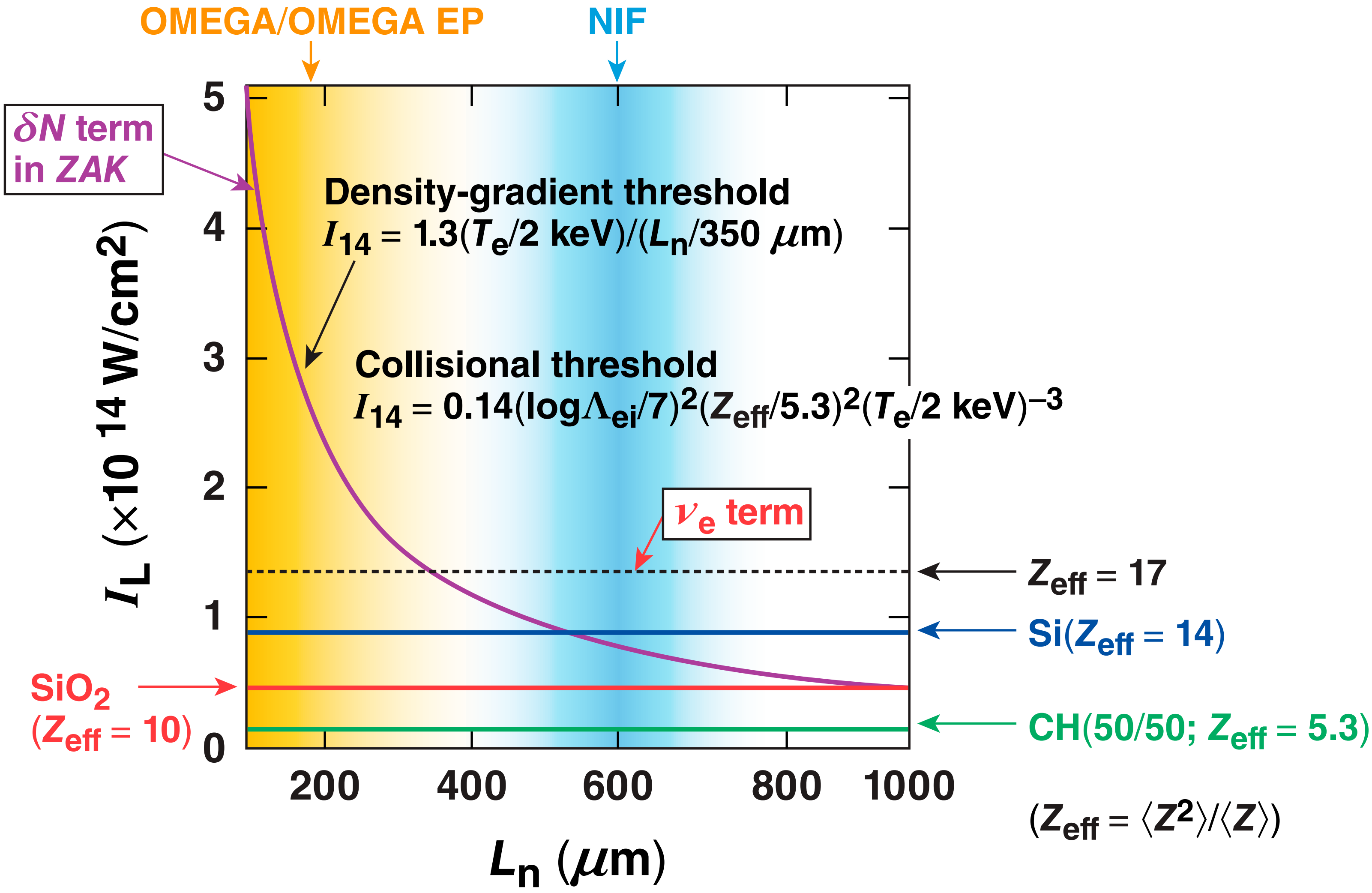
The collisional threshold can be made to exceed the gradient threshold (for Si at ignition scale)



Density-gradient threshold

$I_{14} = 1.3(T_e/2\ \text{keV})/(L_n/350\ \mu\text{m})$

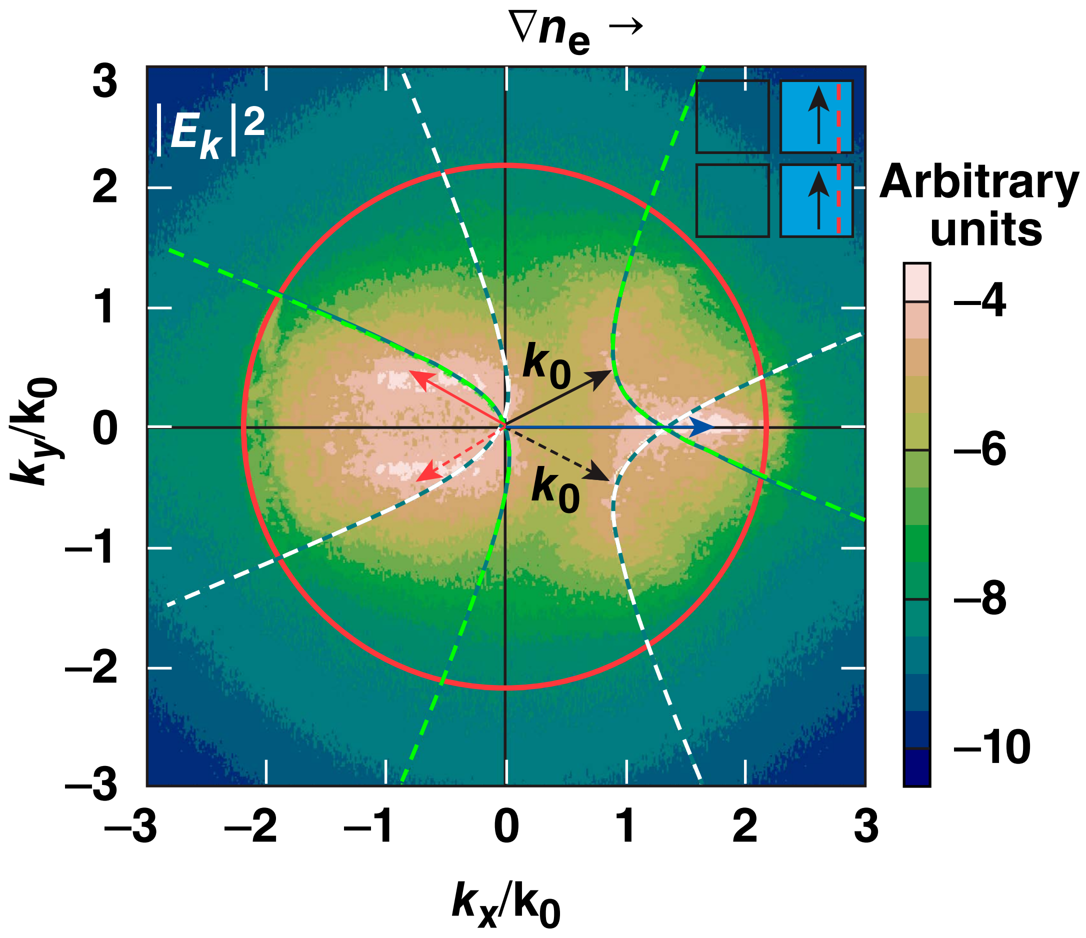
Collisional threshold

$I_{14} = 0.14(\log\Lambda_{ei}/7)^2(Z_{eff}/5.3)^2(T_e/2\ \text{keV})^{-3}$

$(Z_{eff} = \langle Z^2\rangle/\langle Z\rangle)$

Two-dimensional calculations assume two overlapped plane electromagnetic (EM) waves* polarized in their plane of incidence

- This has the feature that TPD is driven unstable convectively even when the single-beam intensities are below threshold
- $\langle |E|^2 \rangle$ is computed at saturation (*ZAK*)
- Hot-electron distribution (*QZAK*)



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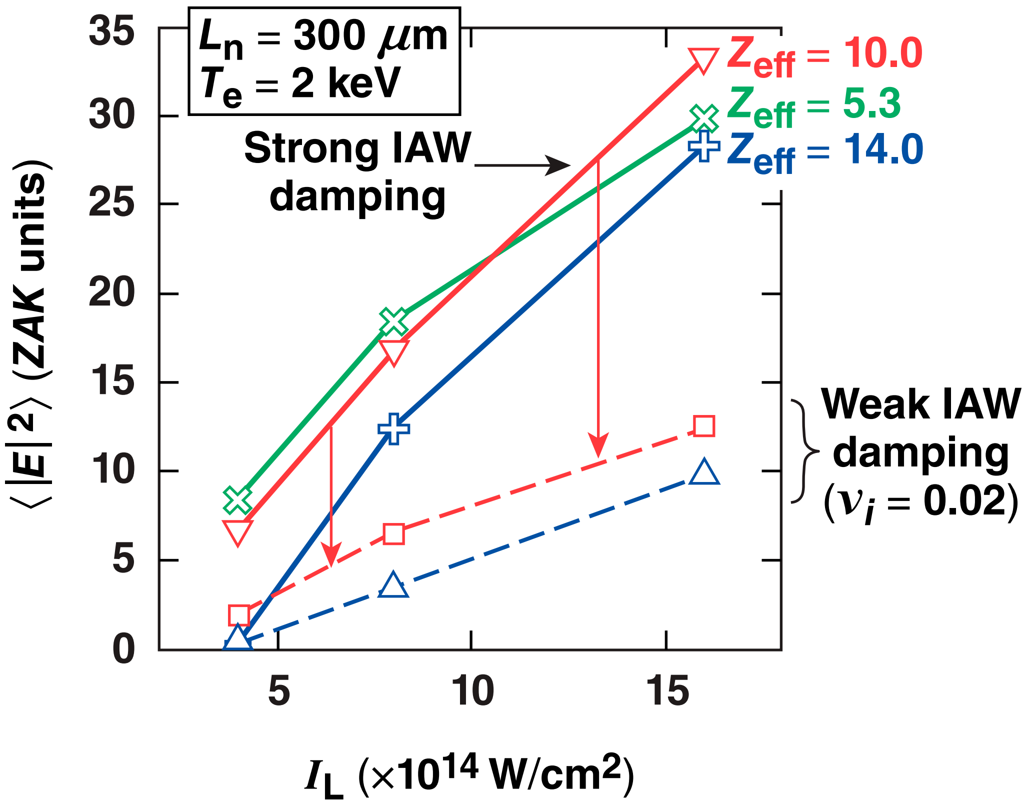
* D. T. Michel *et al.*, presented at the 42nd Annual Anomalous Conference, Key West, FL, 25–29 June 2012.

***ZAK* calculations**

Decreasing the IAW damping leads to a dramatic reduction in the level of electrostatic fluctuations

- **Increased collisional damping of LWs leads to a lower saturated level of electrostatic fluctuations* for Z_{eff} = 14**



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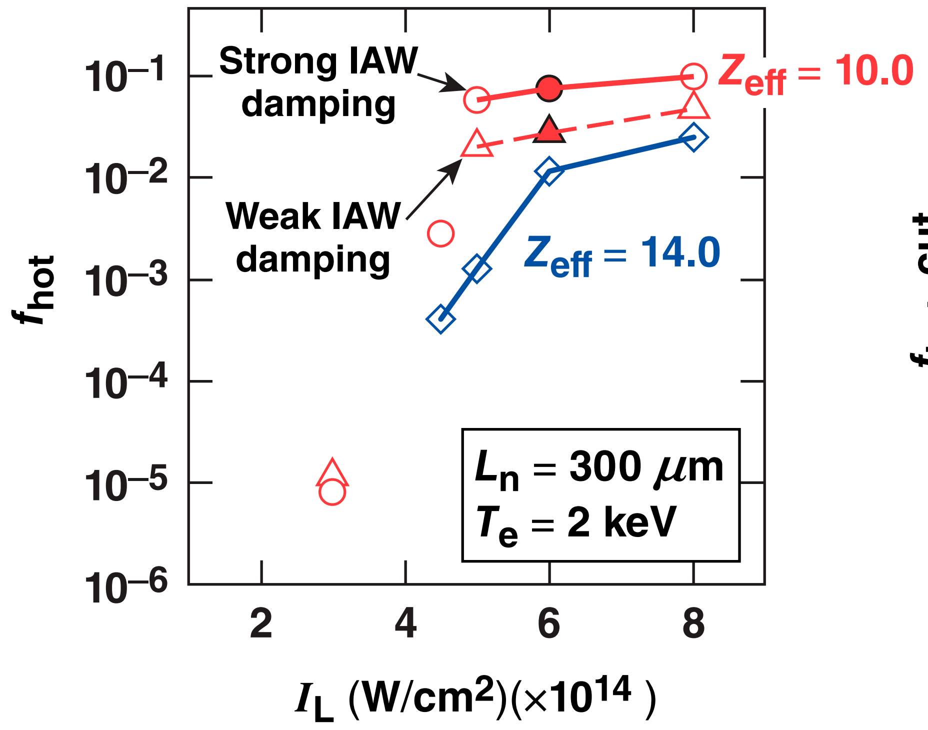
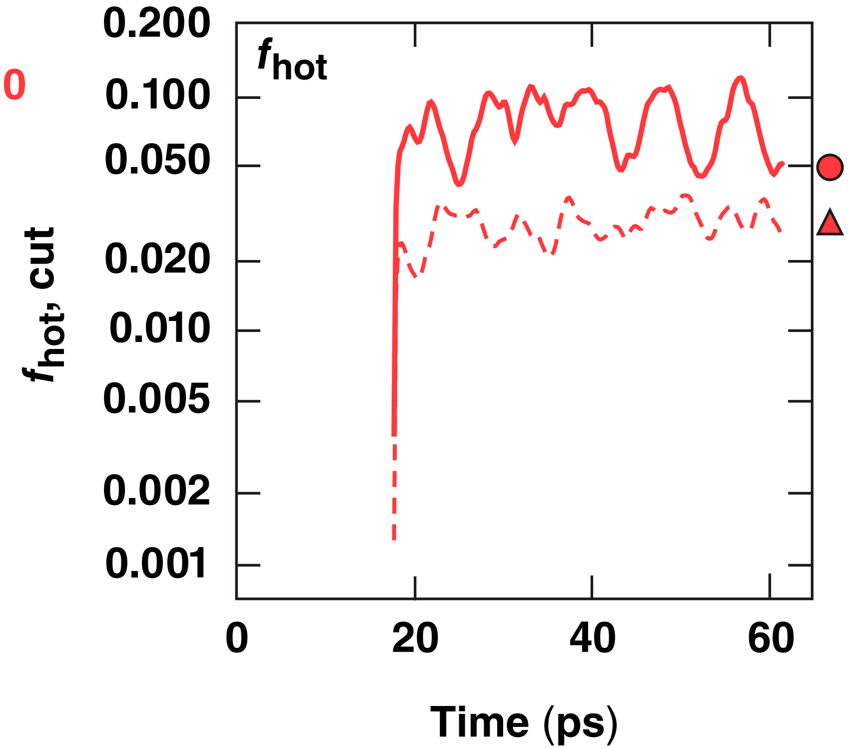
*R. Betti, JO4.00005, this conference.

QZAK calculations

QZAK predicts less hot-electron production for a plasma with weakly damped ion-acoustic waves



A factor 2 to 3 reduction in f_{hot}



Ion-acoustic damping can be manipulated by modifying the plasma composition

- Ion Landau damping decreases with ZT_e / T_i ($c_s \gg v_{ti}$)
- Electron Landau damping in IAW's is always weak ($v_{te} \gg c_s$)
- Light ions (e.g., hydrogen) can increase the damping rate
- The multi-ion dispersion relation is solved by finding the most weakly damped mode*
- Ion–ion collisions complicate the matter
- Part of the spectrum will be collisionally damped because of ion viscosity ($k\lambda_{ii} < 10$)

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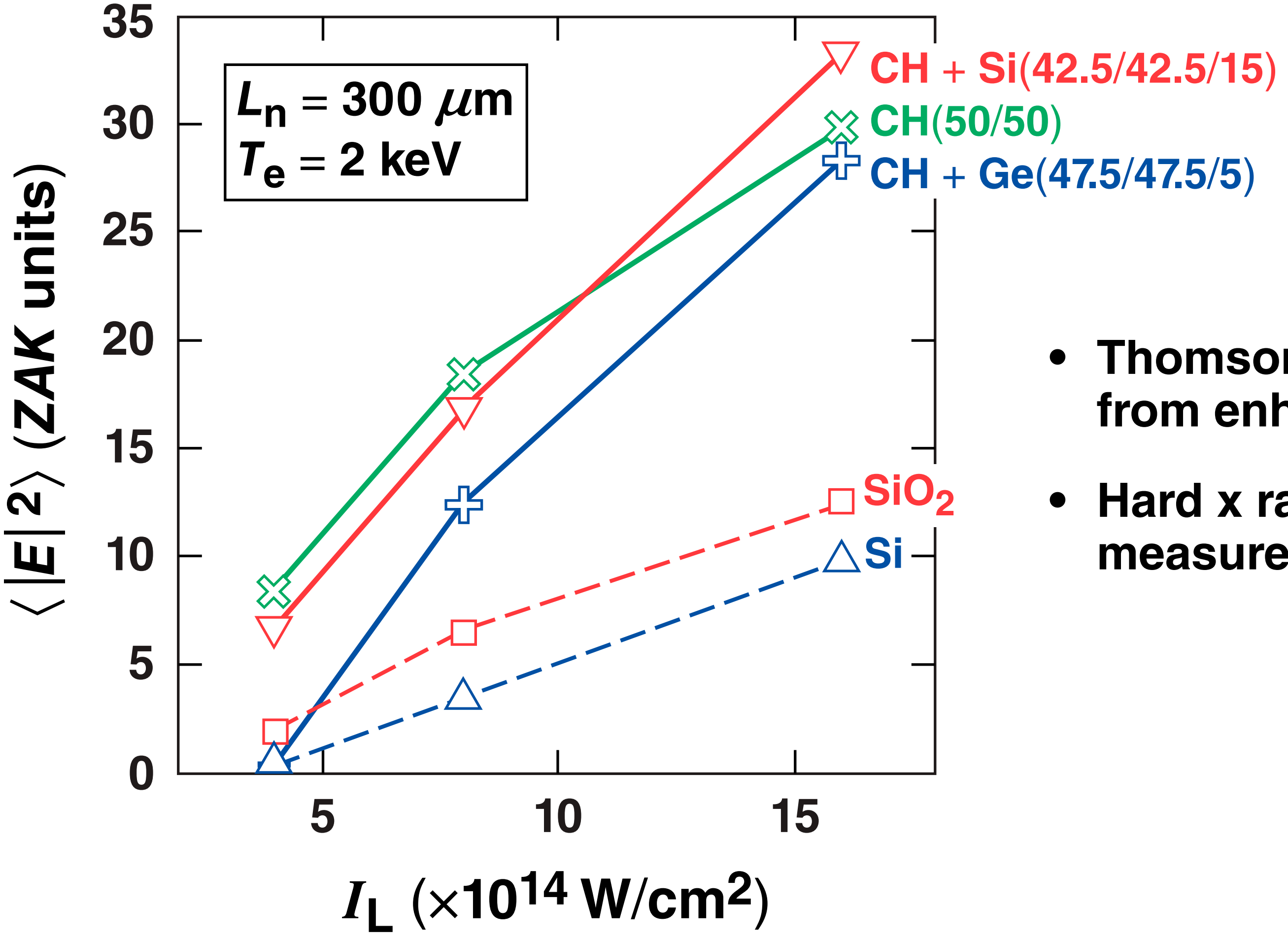
*E. A. Williams *et al.*, Phys. Plasmas 2, 129 (1995).

These effects can be investigated experimentally in planar targets on OMEGA/OMEGA EP†



- **Thomson scattering from enhanced IAW***
- **Hard x rays can be measured**

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† S. X. Hu *et al.*, presented at the 42nd Annual Anomalous Conference, Key West, FL, 25–29 June 2012.

* R. K. Follet *et al.*, presented at the 42nd Annual Anomalous Conference, Key West, FL, 25–29 June 2012.

Summary/Conclusions

Two-plasmon–decay (TPD) preheat can be reduced through the manipulation of the collisional and Landau damping of Langmuir and ion-acoustic waves

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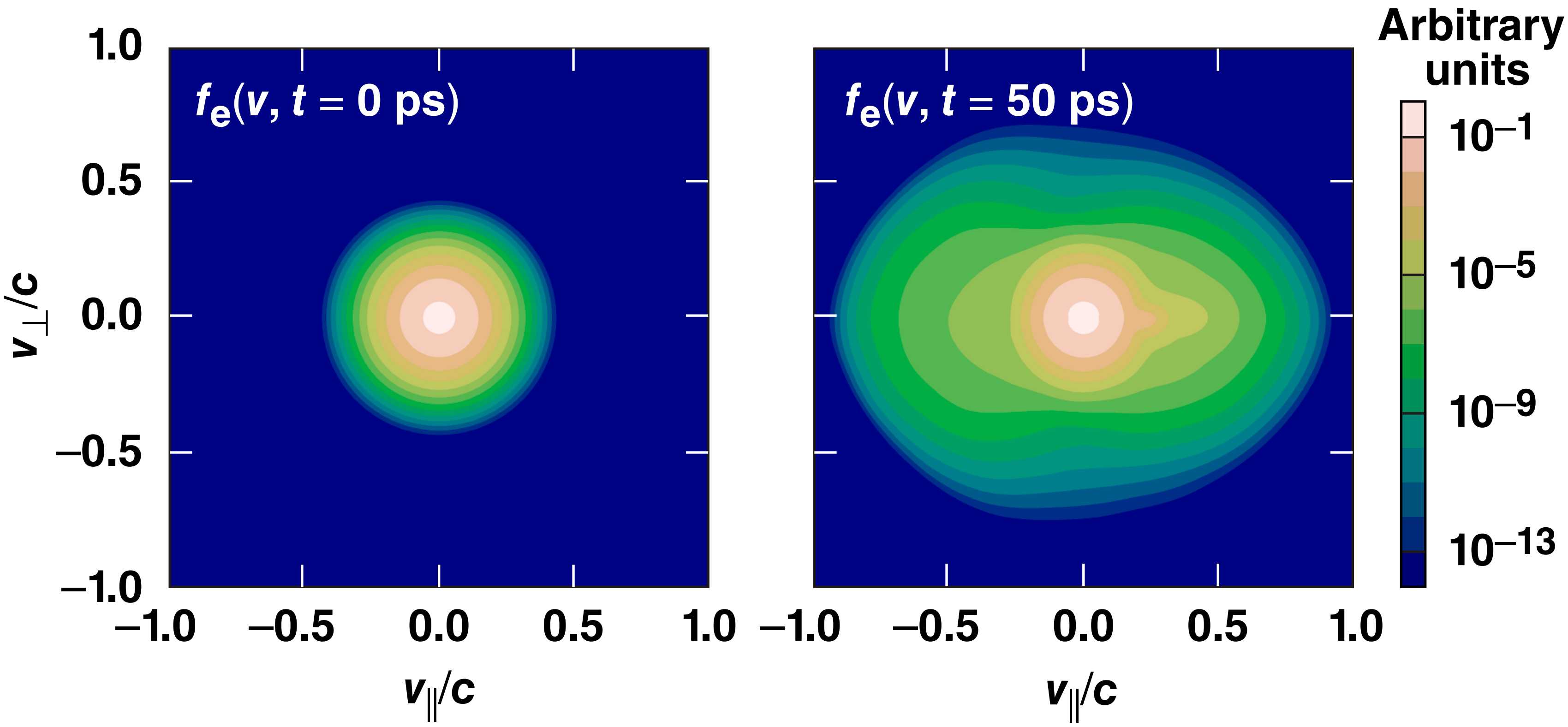
*QZAK** is an extension of *ZAK* to self-consistently include hot-electron generation in the quasilinear approximation

- **The diffusion equation** $\frac{\partial\langle f_e\rangle}{\partial t}+\frac{\partial}{\partial\vec{v}}\cdot\left(D(\vec{v})\cdot\frac{\partial\langle f_e\rangle}{\partial\vec{v}}\right)=\sigma(\langle f_e\rangle-f_M)$



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* D. A. Russell *et al*., D. A. Russell et al., presented at the 42nd Annual Anomalous Conference, Key West, FL, 25–29 June 2012.; H. X. Vu *et al*., presented at the 42nd Annual Anomalous Conference, Key West, FL, 25–29 June 2012.