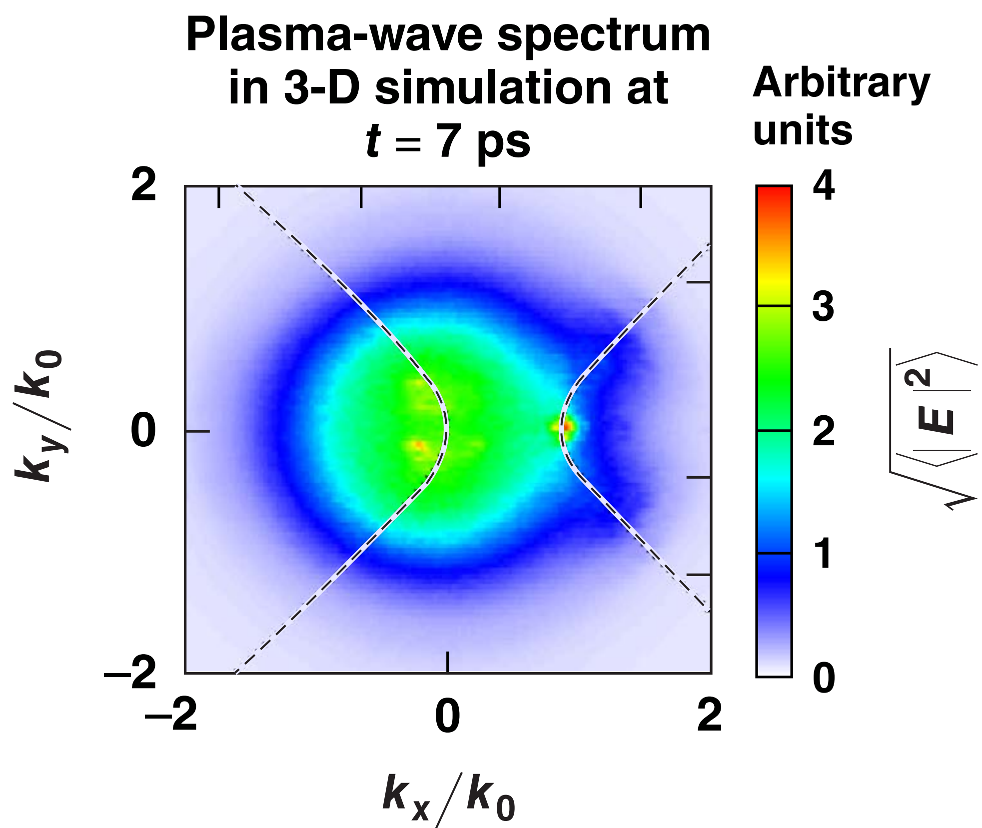
Particle-in-Cell Modeling of Laser–Plasma Interactions in Three Dimensions



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Summary

The hot-electron distribution near quarter-critical density has been studied by 3-D and 2-D particle-in-cell (PIC) simulations

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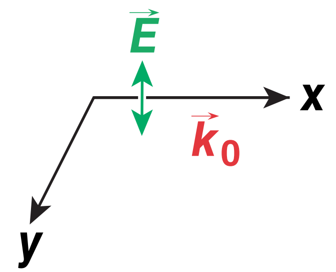
- Two-plasmon decay (TPD), stimulated Raman scattering (SRS), and stimulated Brillouin scattering (SBS) are found to coexist in 3-D PIC simulations
- In PIC simulations with laser speckles, TPD generates more hot electrons in the forward direction than in the backward direction
- Laser beams with speckles can generate more hot electrons than a plane wave because of TPD
- Collisional effects can reduce fast-electron generation by a factor of 2

PIC simulations have been performed for parameters relevant to direct-drive inertial confinement fusion (ICF) experiments

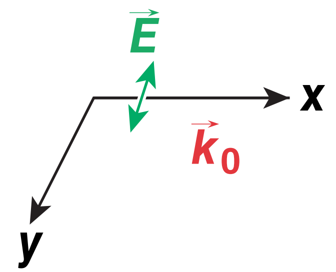
- Physical parameters (plane wave)
  - scale length $L_n = 100\ \mu m$
  - intensity $I = 9 \times 10^{14}$ W/cm^2
  - CH plasma, temperature $T_e = 2$ keV, $T_i = 1$ keV
  - laser propagates along the *x* axis
  - linear density profile from 0.21 to 0.26 n_c
  - $\eta^* = 1.9$
- Numerical parameters
  - simulation box size: $400 \times 150 \times 120\ c/\omega_0$ ($21 \times 8.4 \times 6.7\ \mu m$) for the 3-D simulation $400 \times 150\ c/\omega_0$ ($21 \times 16\ \mu m$) for the two 2-D simulations

2-D simulations are in the *x*–*y* plane

2-D out-of-plane (SRS)



2-D in-plane (TPD)

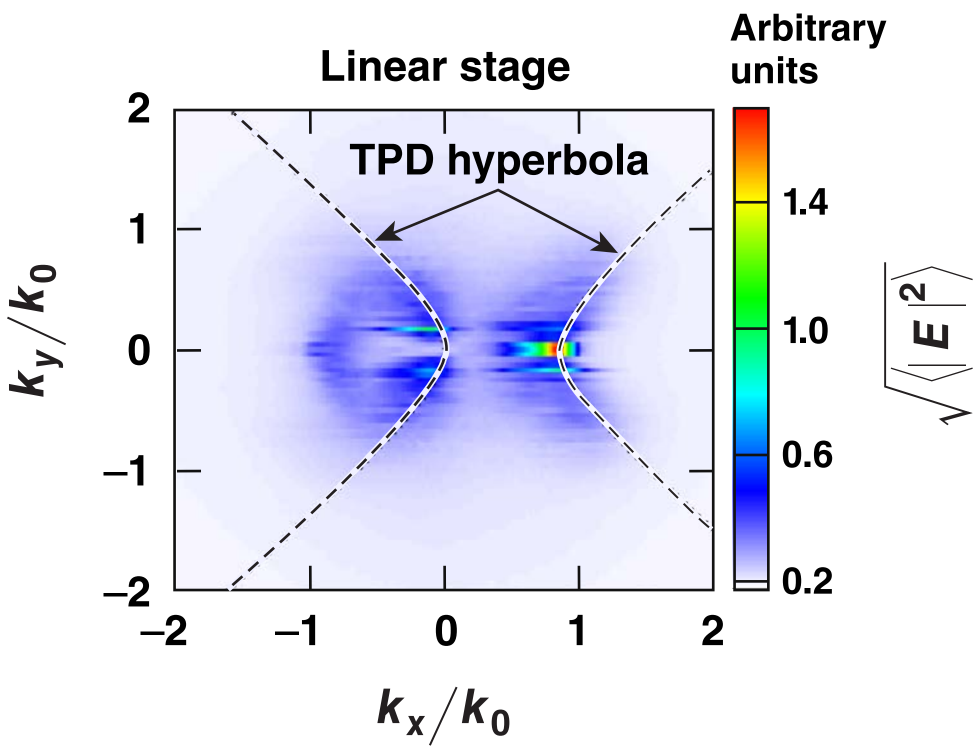


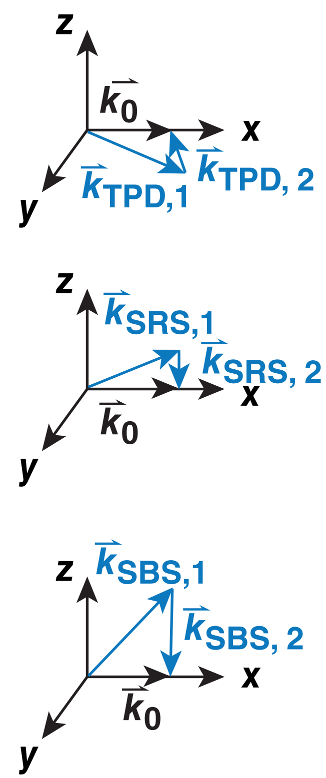
*A. Simon *et al*., Phys. Fluids 26, 3107 (1983).

TC10918a

TPD, SRS, and SBS are observed in a plane wave 3-D PIC simulation

- TPD is localized in the x–y plane
- SRS and SBS sidescattering are observed at $k_z \neq 0$
- Integrate the spectra $S\,(k_x, k_y, k_z, \omega)$ over k_z and $\omega \sim (0.44, 0.56)$





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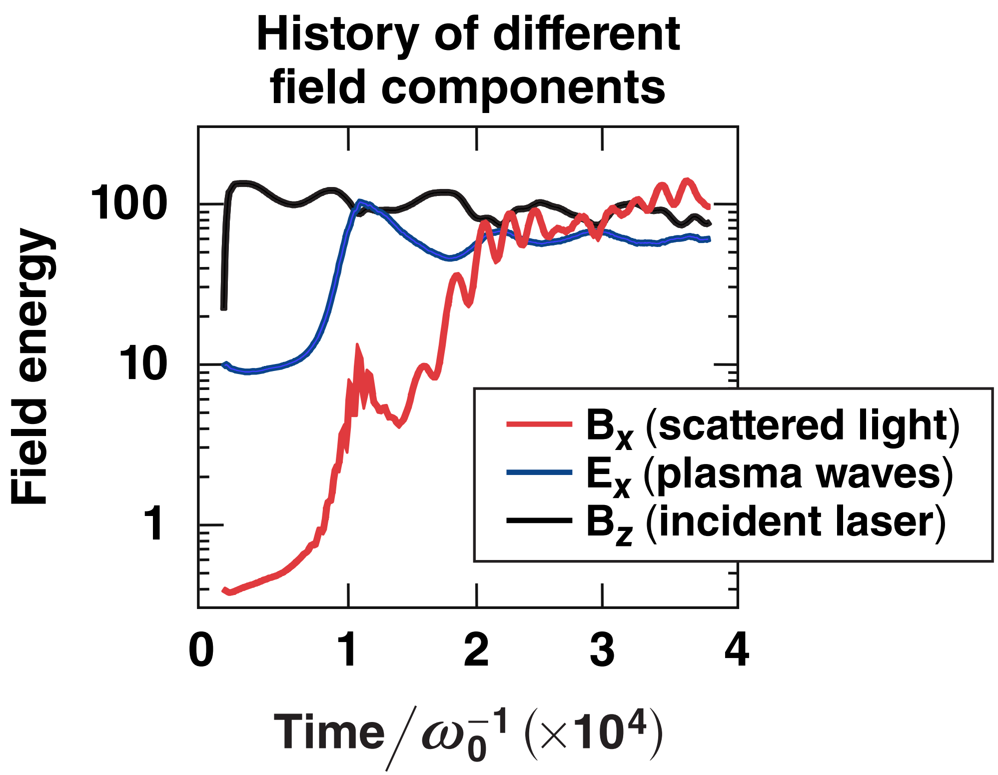
The growth of different instabilities in 3-D simulations can be illustrated by the time history of field components

- Steady state has been reached at the end of the simulation



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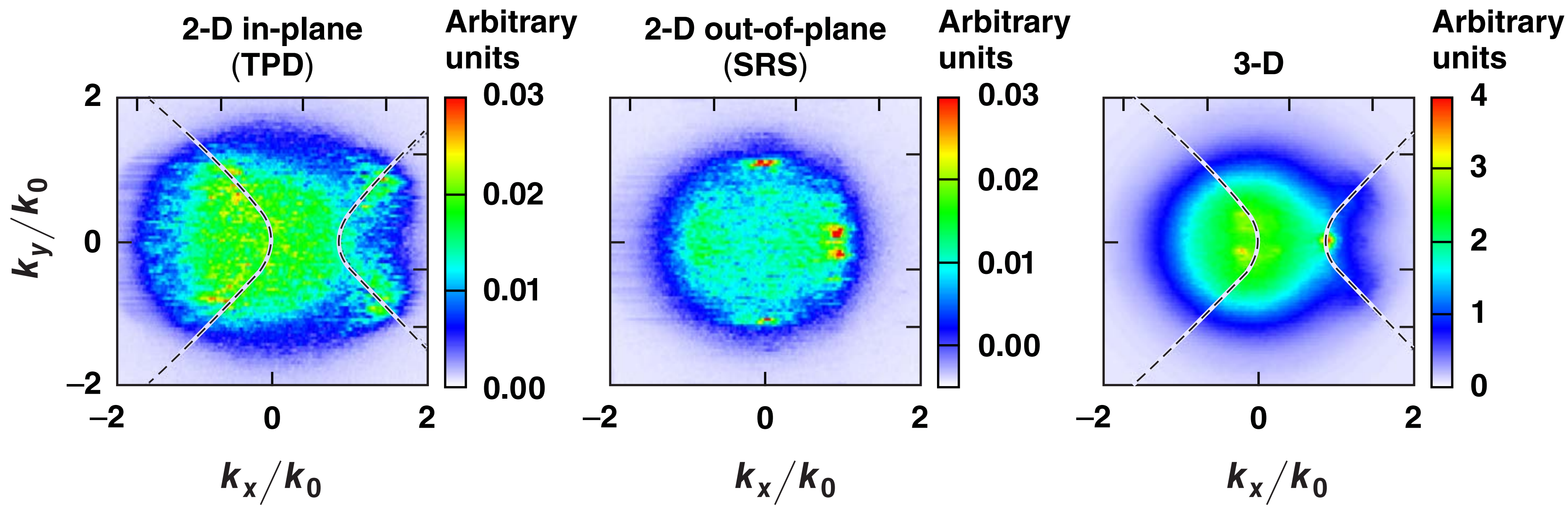
In the saturation stage, TPD spectra are broader in k_x than SRS spectra

- Plasma waves with a larger *k* vector can accelerate electrons with lower kinetic energy



	2-D in-plane (TPD)	2-D out-of-plane (SRS)	3-D
Net energy flux (carried by electrons above 50 keV)	12%	0.3%	7%

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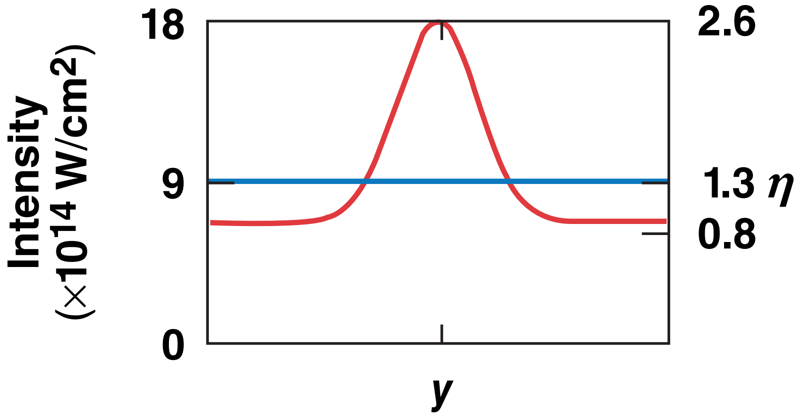
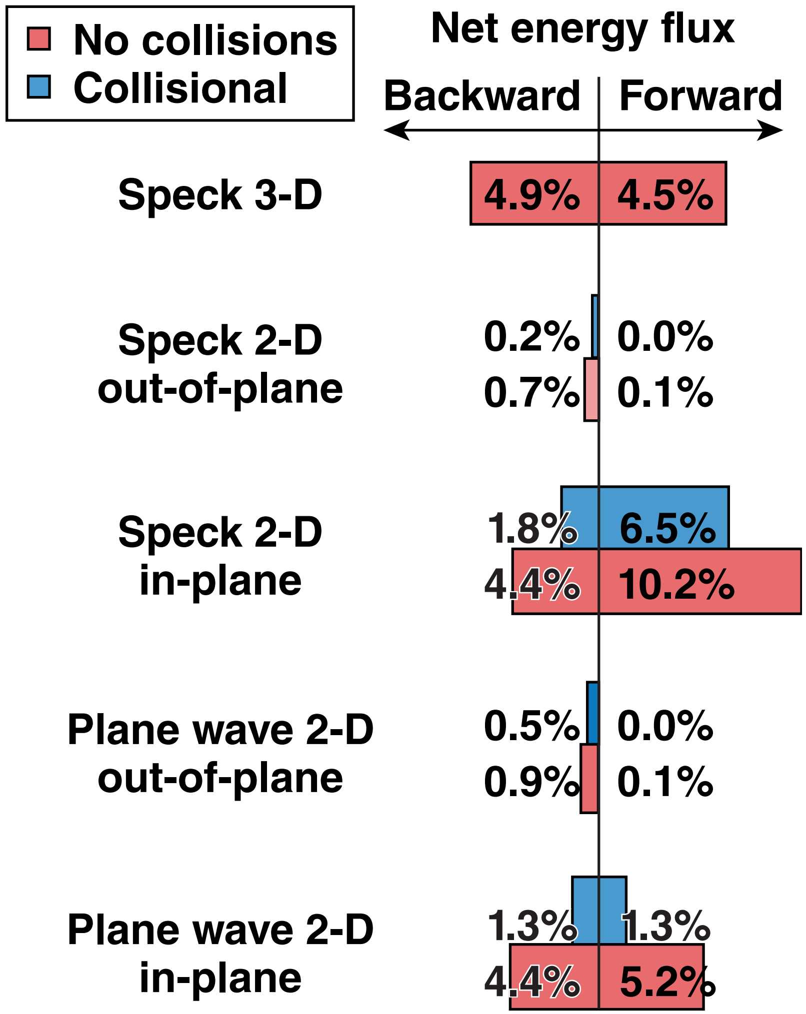
Laser speckles and Coulomb collisions affect hot-electron generation

- Parameters (laser speckles)
  - $L_n = 100\ \mu m$
  - Average $I = 9 \times 10^{14}$ W/cm^2
  - $T_e = 3$ keV, $T_i = 1.5$ keV
  - $\eta = 1.3$





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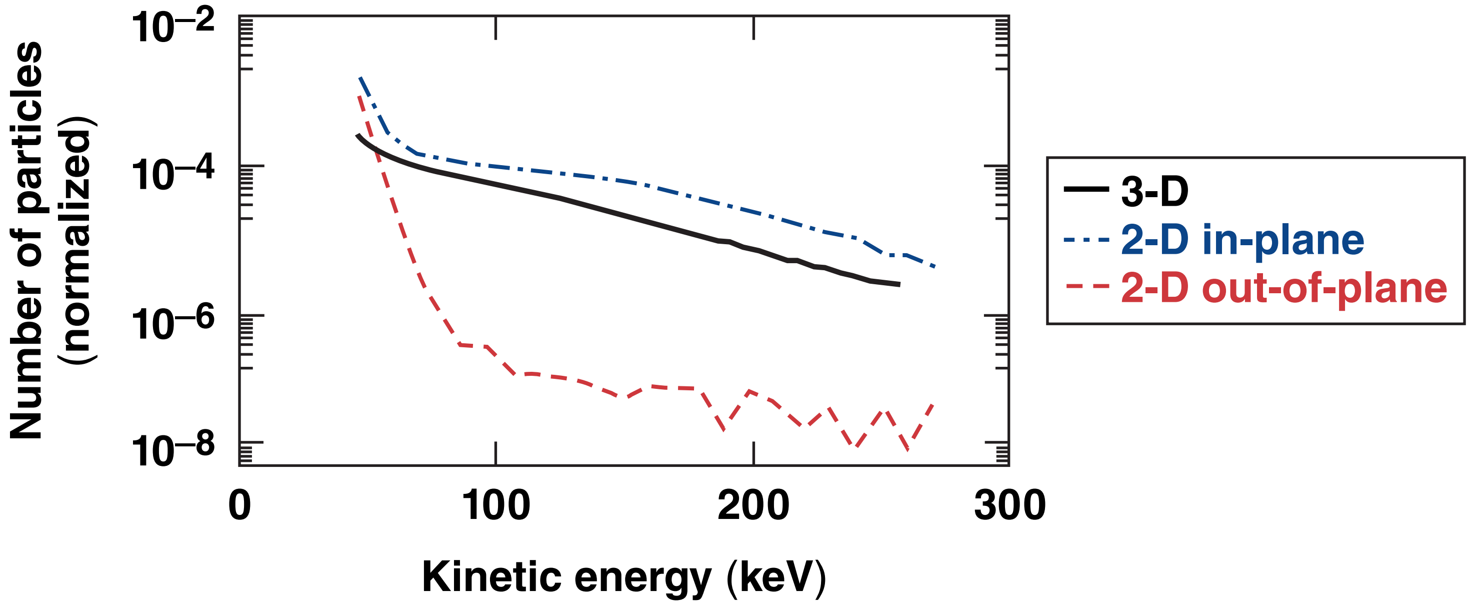
The distributions of hot electrons indicate that 2-D in-plane simulations may overestimate hot-electron generation

- The distributions of hot electrons crossing the right boundary in laser speckle simulations



	2-D in-plane (TPD)	2-D out-of-plane (SRS)	3-D
Temperature*	46 keV	21 keV	27 keV
Net energy flux	14.6%	0.8%	9.4%

*Fitting between 70 keV and 150 keV

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TPD modes with larger *k* vectors are found in 2-D in-plane speckle simulations

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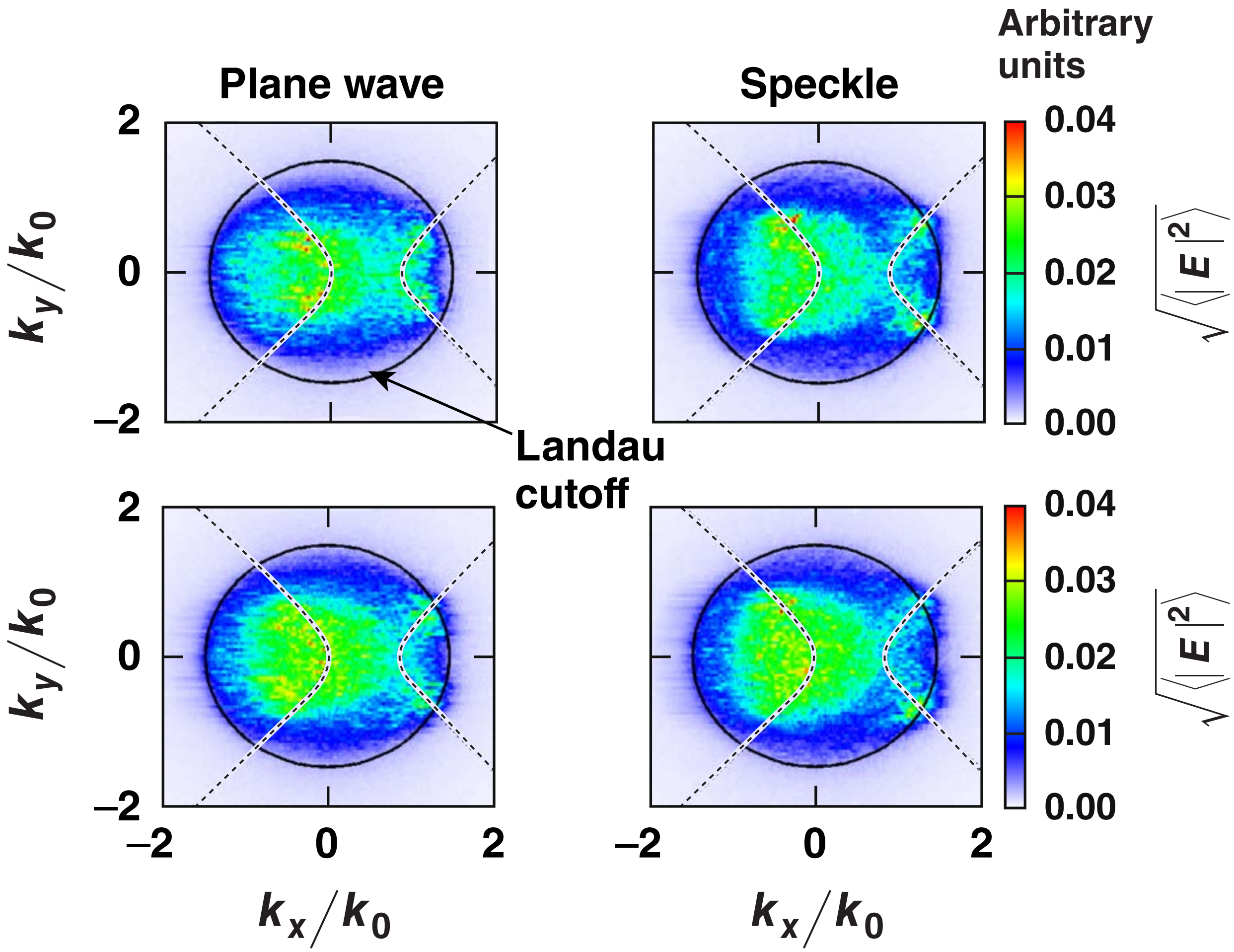
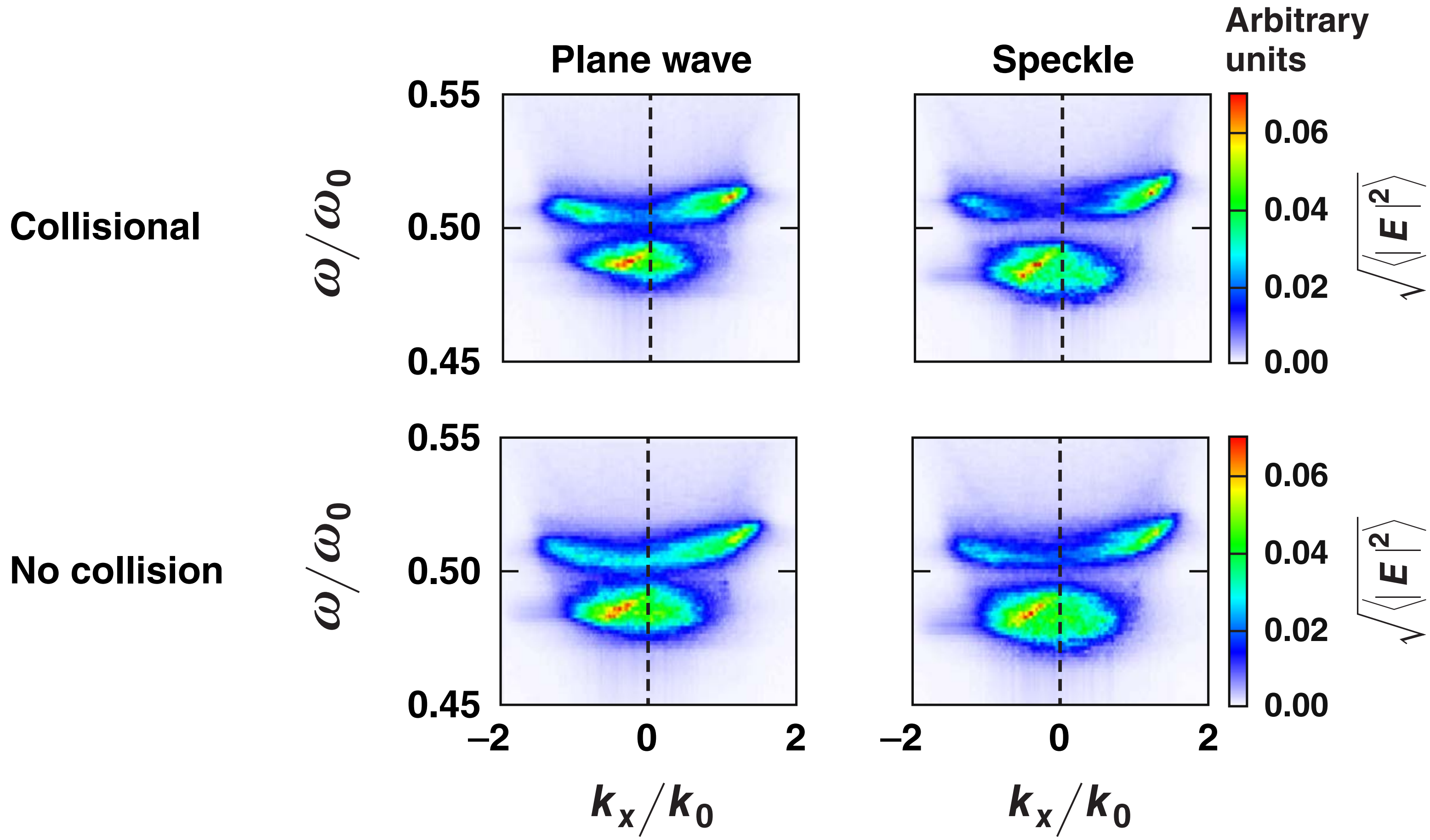
- Integrate the plasma-wave spectra $S(k_x, k_y, \omega)$ over ω



TC11633

Forward-going and backward-going plasma waves generate asymmetric hot electrons in 2-D in-plane simulations

- **Integrate the spectra $S\,(k_x, k_y, \omega)$ over k_y**



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Summary/Conclusions

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