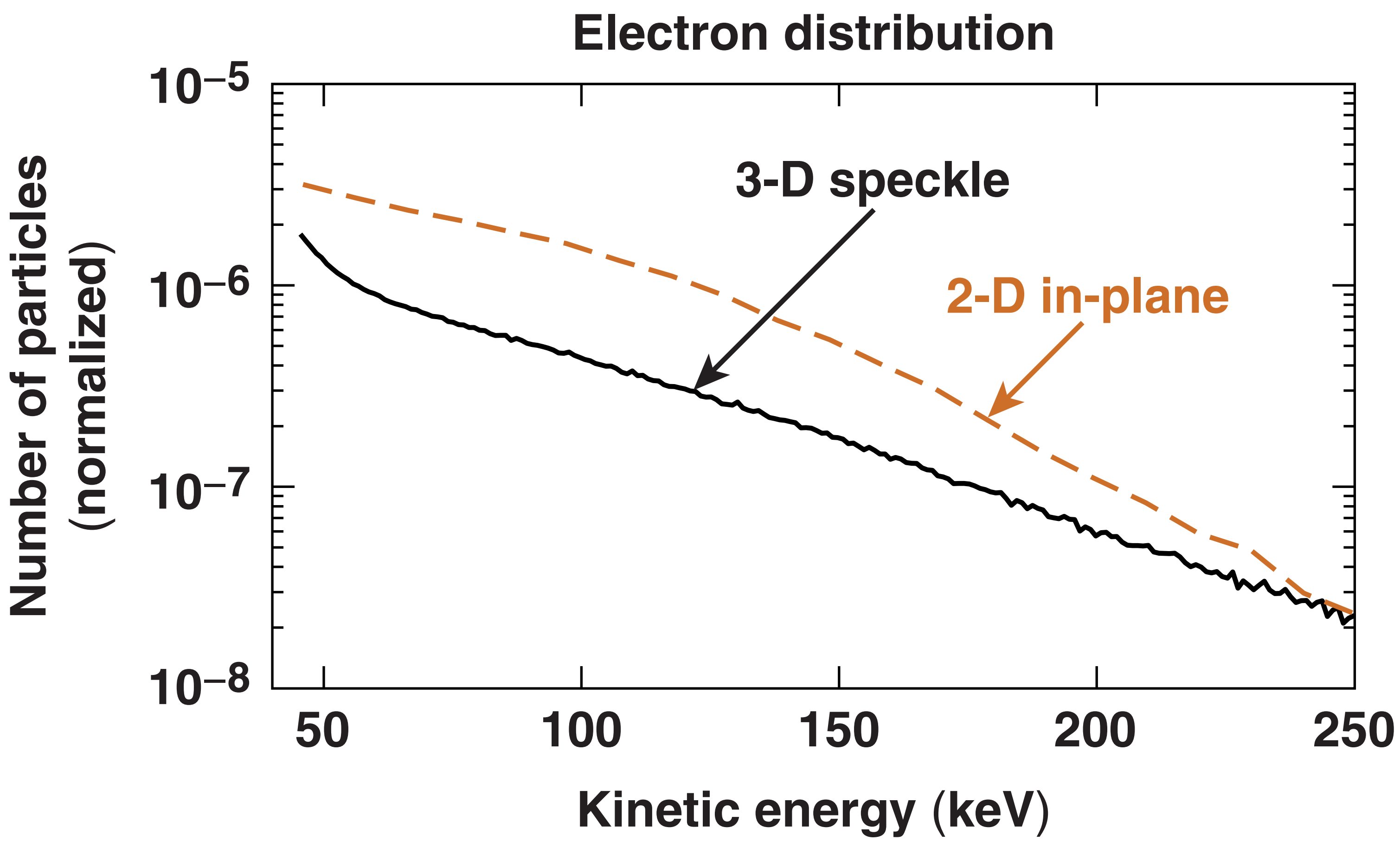
Three-Dimensional Modeling of Laser–Plasma Interactions Near the Quarter-Critical Density in Plasmas



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Summary

Fast-electron distributions generated by parametric instabilities near quarter-critical density have been calculated in 3-D and 2-D particle-in-cell (PIC) simulations

- In 3-D PIC simulations, the evolution of two-plasmon decay (TPD), stimulated Raman scattering (SRS), and stimulated Brillouin scattering (SBS) has been characterized
- The periodic boundary condition is important for modeling the growth of SBS but not as important for modeling the growth of SRS
- Fast electrons are accelerated mainly by the TPD-generated plasma waves
- The fast-electron energy distribution and angular distribution depend on the shapes of laser speckles

Collaborators

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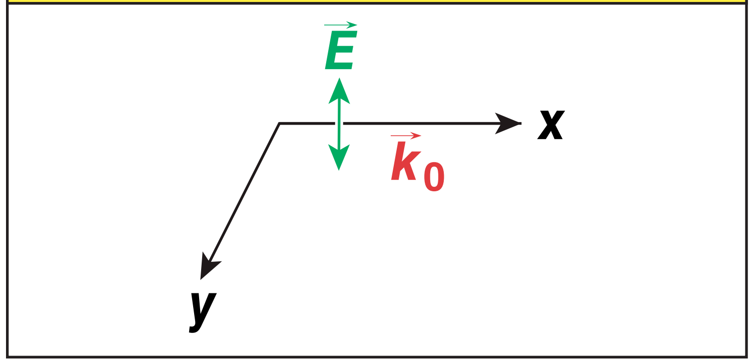
PIC simulations have been performed for direct-drive inertial confinement fusion (ICF)–related parameters

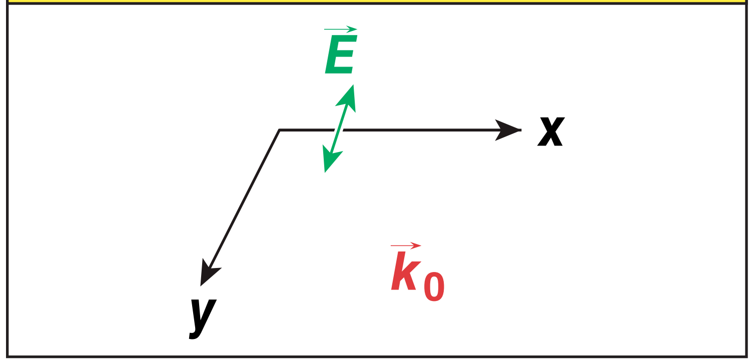
- Physical parameters (plane wave)
  - scale length L_n = 100 μm
  - intensity $I = 9 \times 10^{14}$ W/cm^2
  - CH plasma, temperature T_e = 2 keV, T_i = 1 keV
  - laser propagates along the *x* axis
  - linear density profile from 0.21 to 0.26 n_c
  - η = 1.9*
- Numerical parameters
  - simulation box size: $400 \times 150 \times 120$ c/ω_0 ($21 \times 8.4 \times 6.7$ μm) for the 3-D simulation

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

2-D out-of-plane (SRS,SBS)



2-D in-plane (TPD)



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

The growth rates of TPD in 2-D and 3-D simulations are in agreement with linear theory

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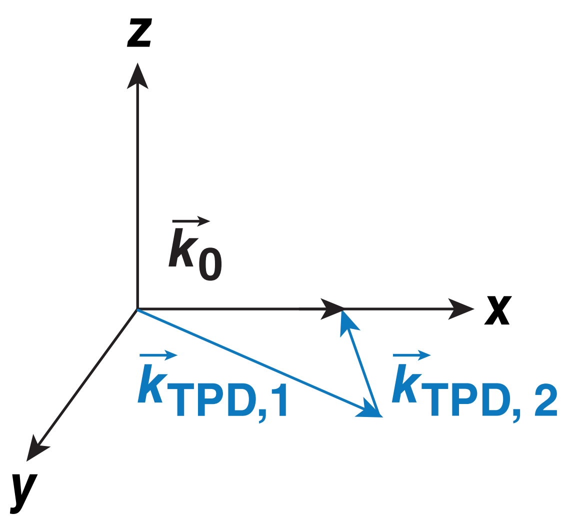
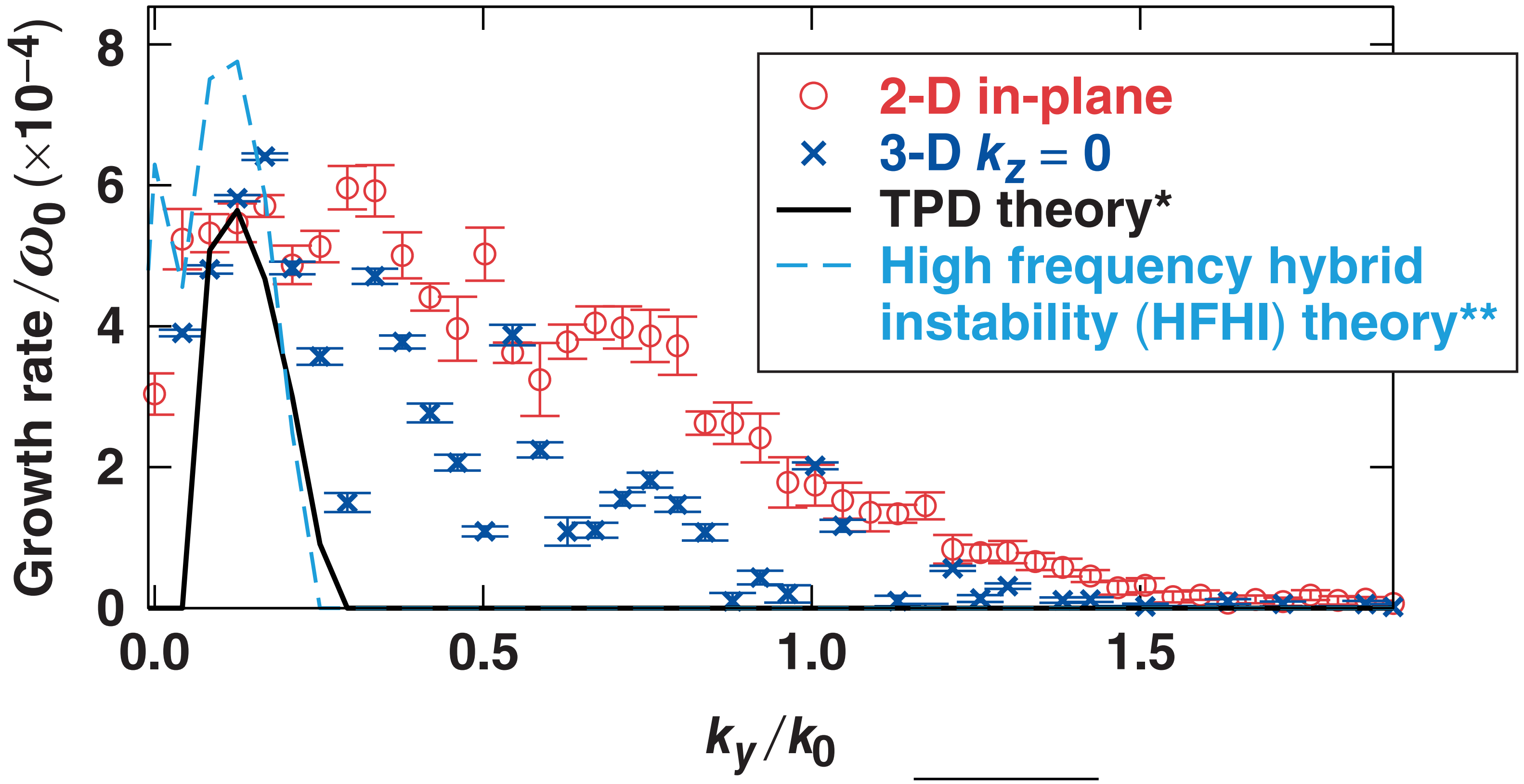
- The growth rates are obtained by integrating the E_x spectrum over k_x
- The growth rates of absolute modes with small k_y are in agreement with linear theory





*A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).
**B. Afeyan *et al.*, Phys. Rev. Lett. 75, 4218 (1995).

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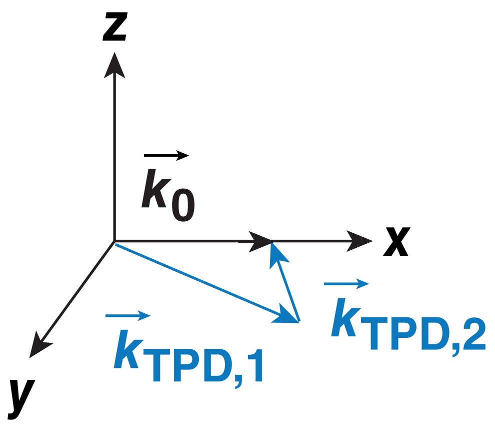
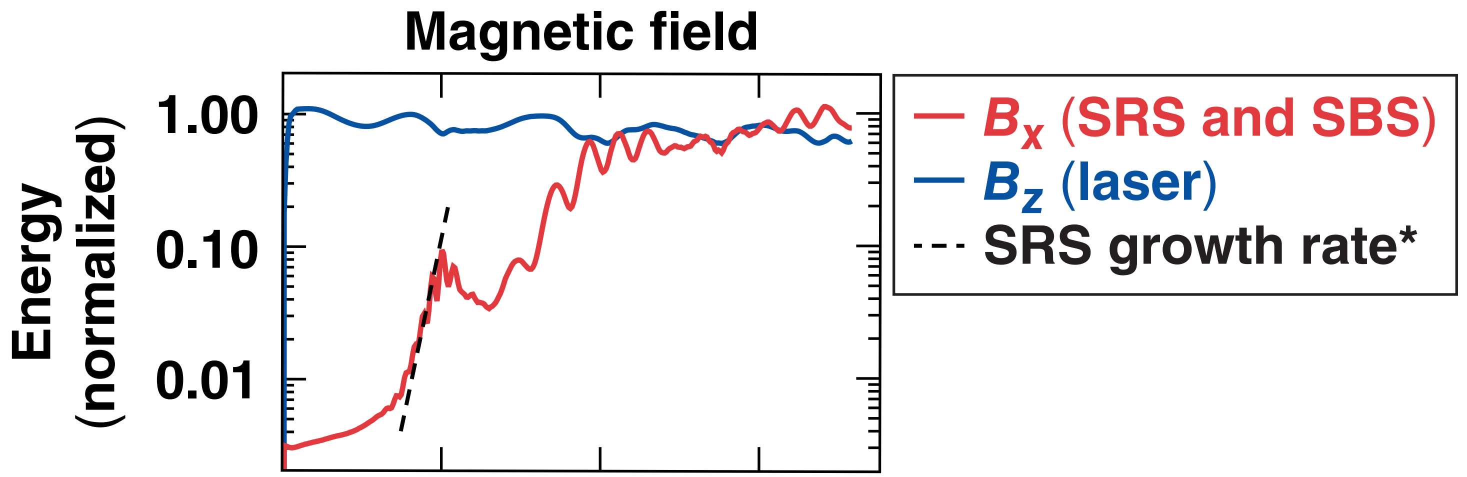
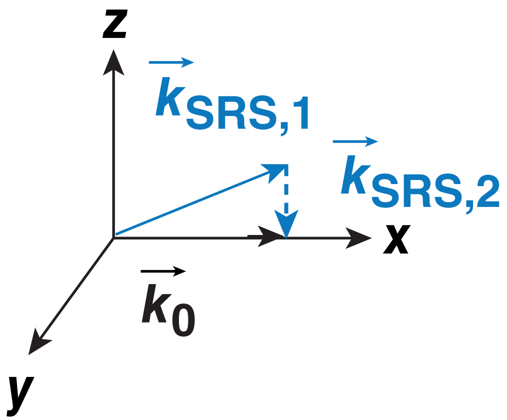
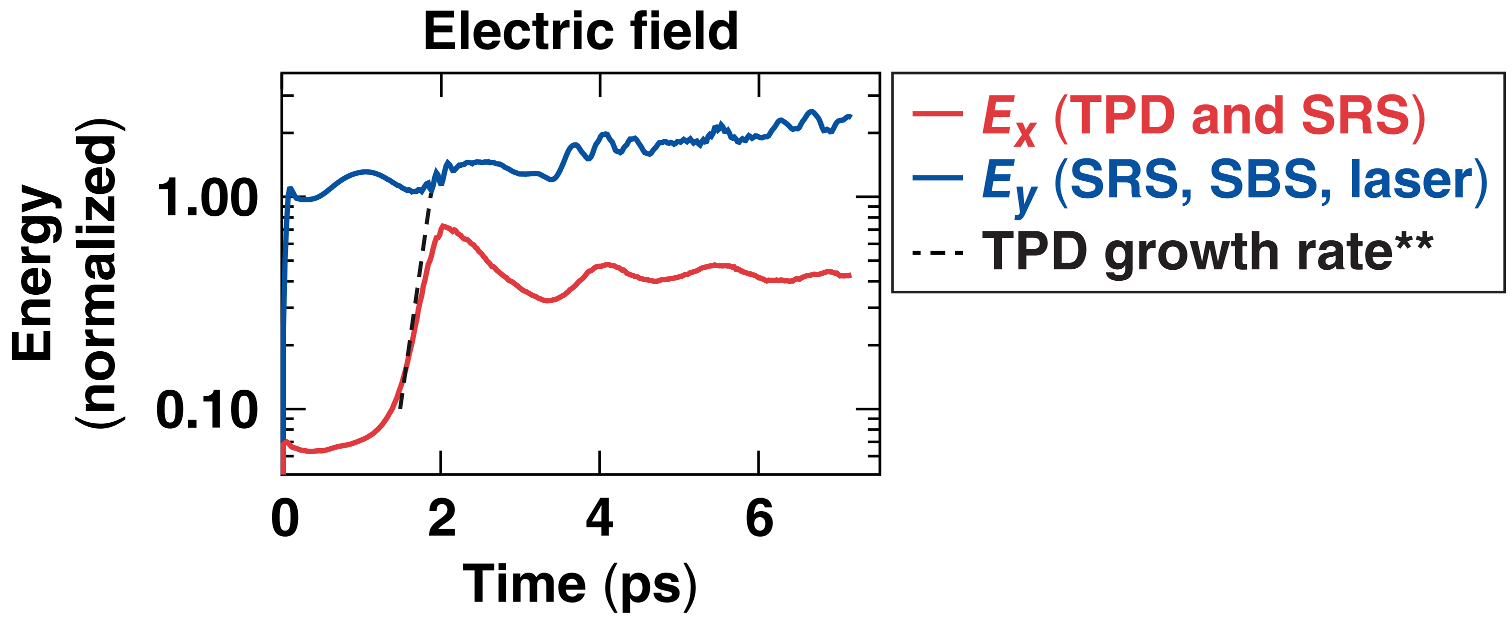
In the early stage of 3-D PIC simulations, the growth of TPD and SRS is consistent with theoretical results









*C. S. Liu *et al.*, Phys. Fluids 17, 1211 (1974).
**A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).

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The modeling of absolute SBS growth depends on the transverse boundary conditions

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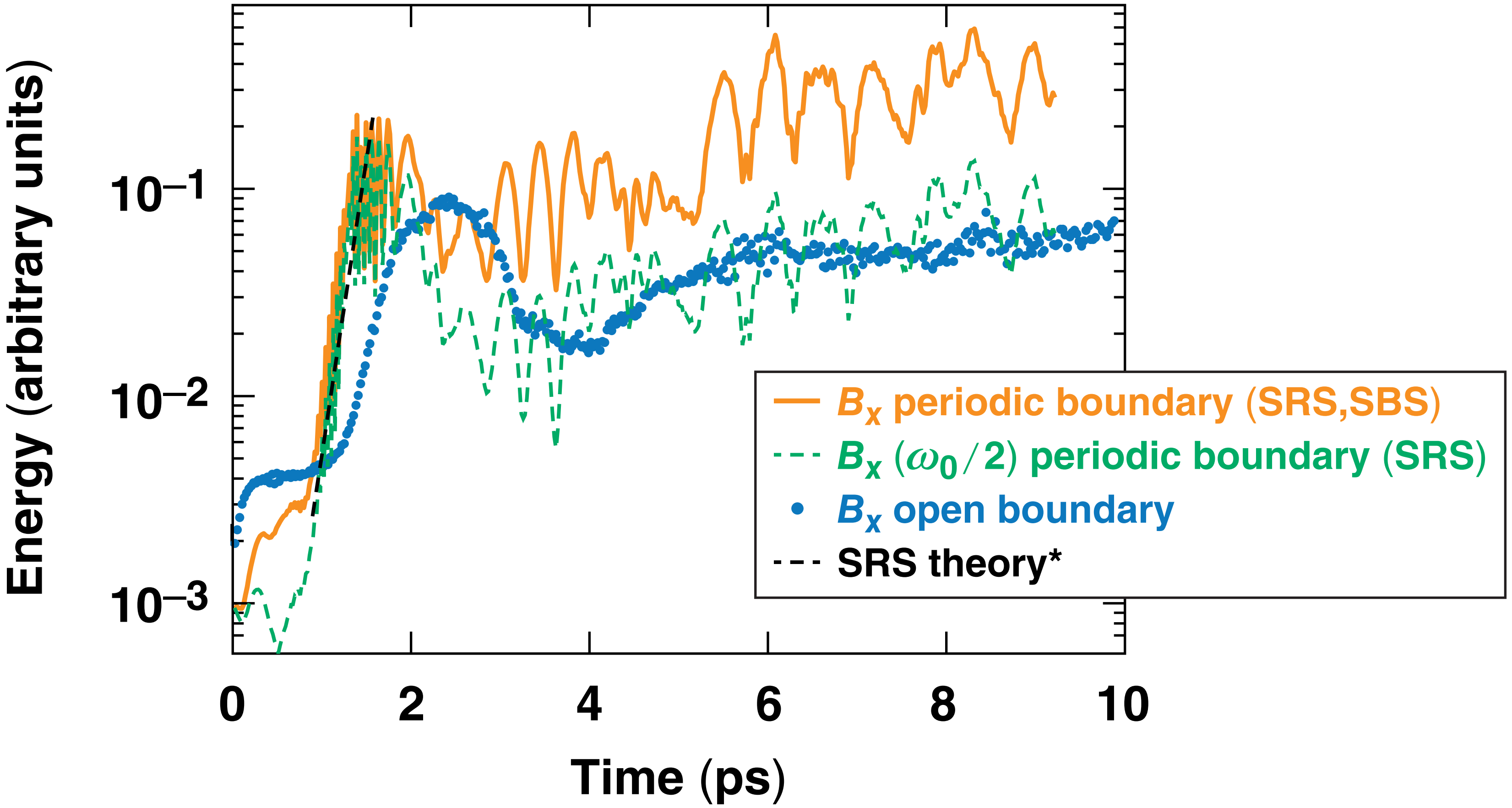
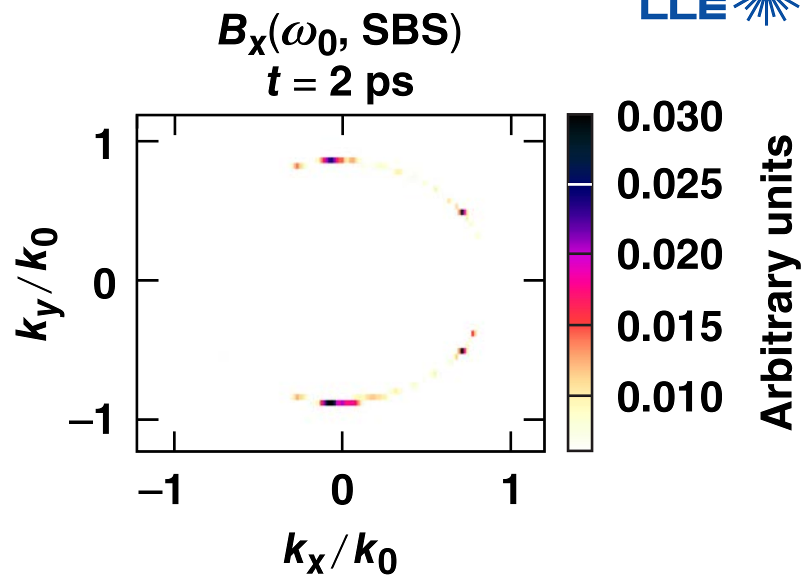
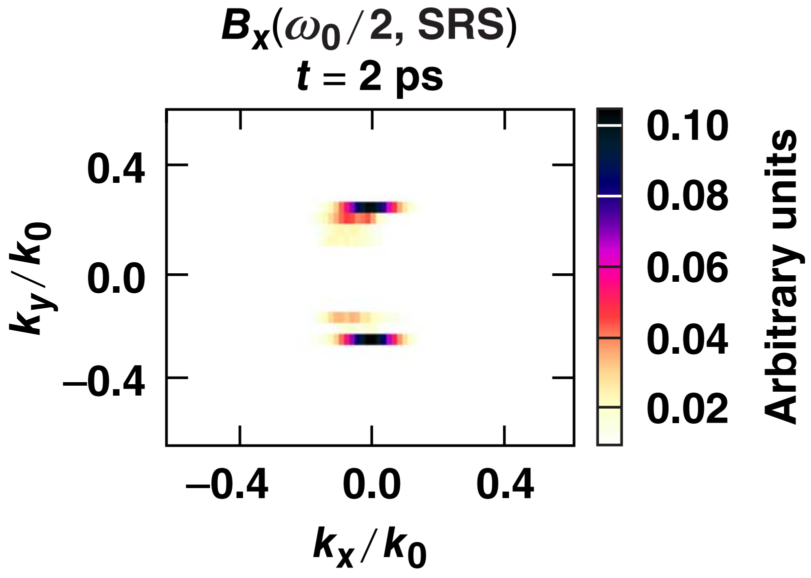
- The green line was obtained assuming $E_{total} = E(\omega_0) + E(\omega_0/2)$
- The angular spread of scattered light is smaller for SBS than for SRS







*C. S. Liu *et al.*, Phys. Fluids 17, 1211 (1974).

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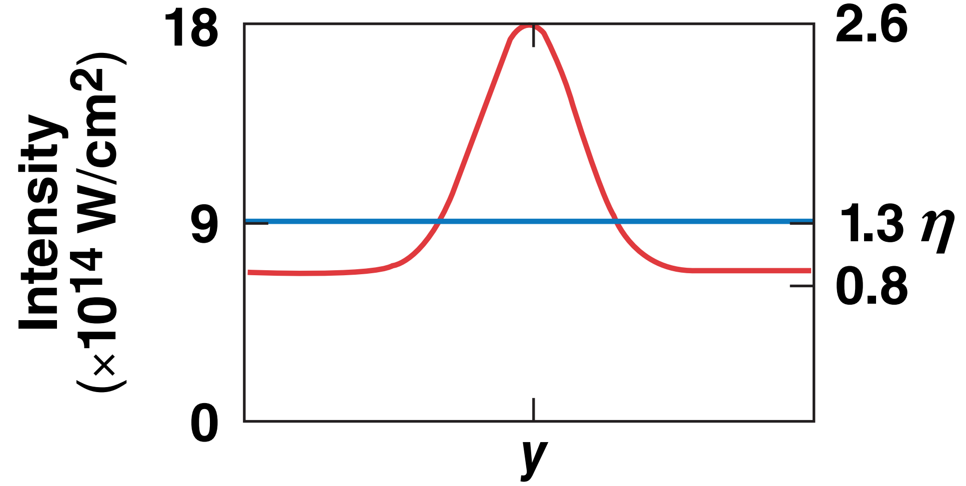
Fast-electron generation has been studied in 3-D and 2-D PIC simulations for different laser-speckle shapes

- R = peak intensity/average intensity
- Parameters (laser speckles)
  - L_n = 100 μm
  - average $I = 9 \times 10^{14}$ W/cm^2
  - T_e = 3 keV, T_i = 1.5 keV
  - same transverse size (8 μm)



Laser-speckle shape	Net fast electrons energy flux/laser flux forward/backward
2-D plane wave	5.2%/4.4%
2-D speckle R = 2	10.2%/4.4%
2-D speckle R = 5	17.1%/4.2%
2-D speckle R = 8	25.6%/6.2%
3-D speckle R = 2	4.9%/4.5%

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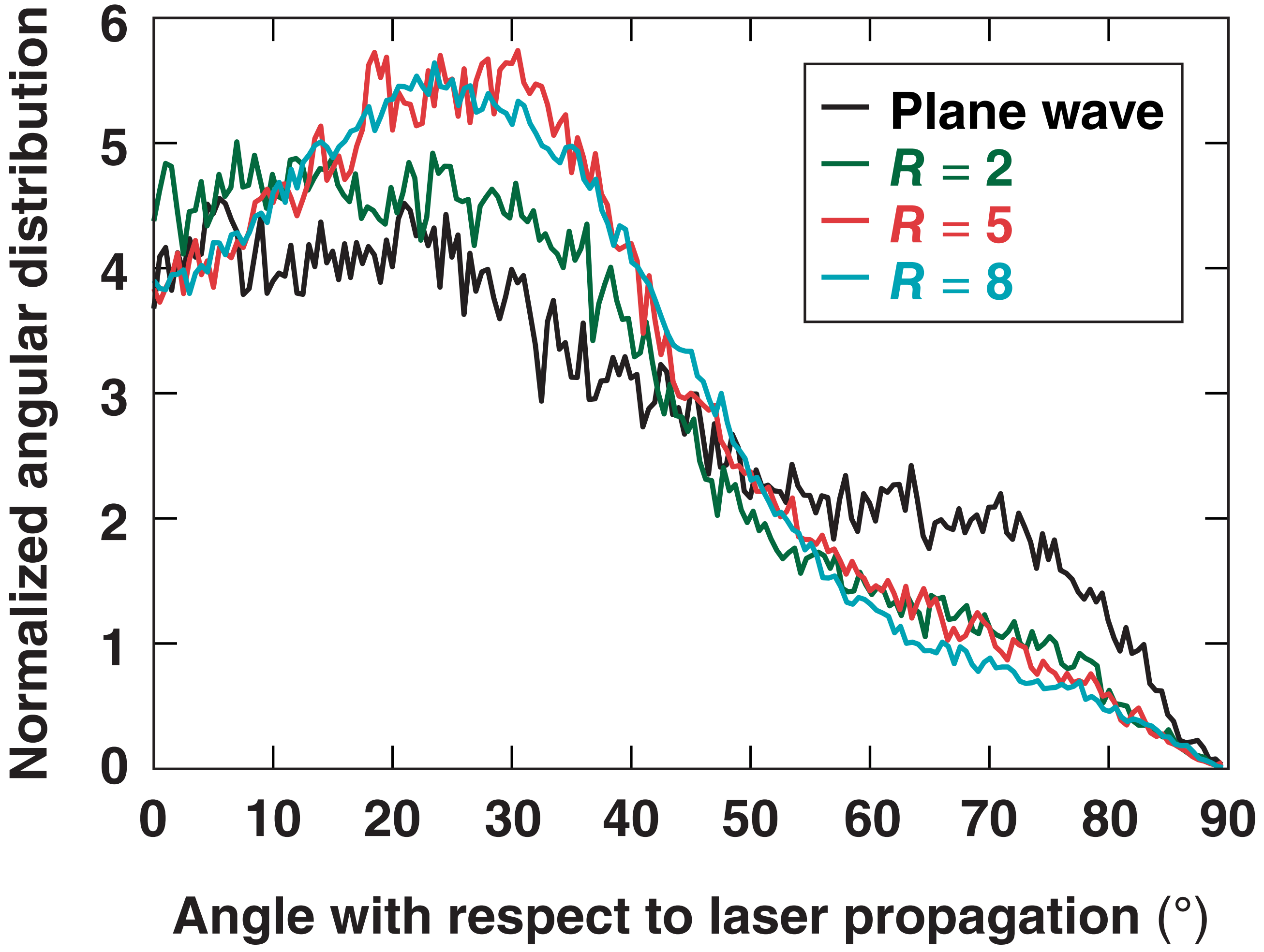
The acceleration of electrons caused by TPD leads to a characteristic angular distribution

- Normalized angular distribution of hot electrons crossing the right boundary



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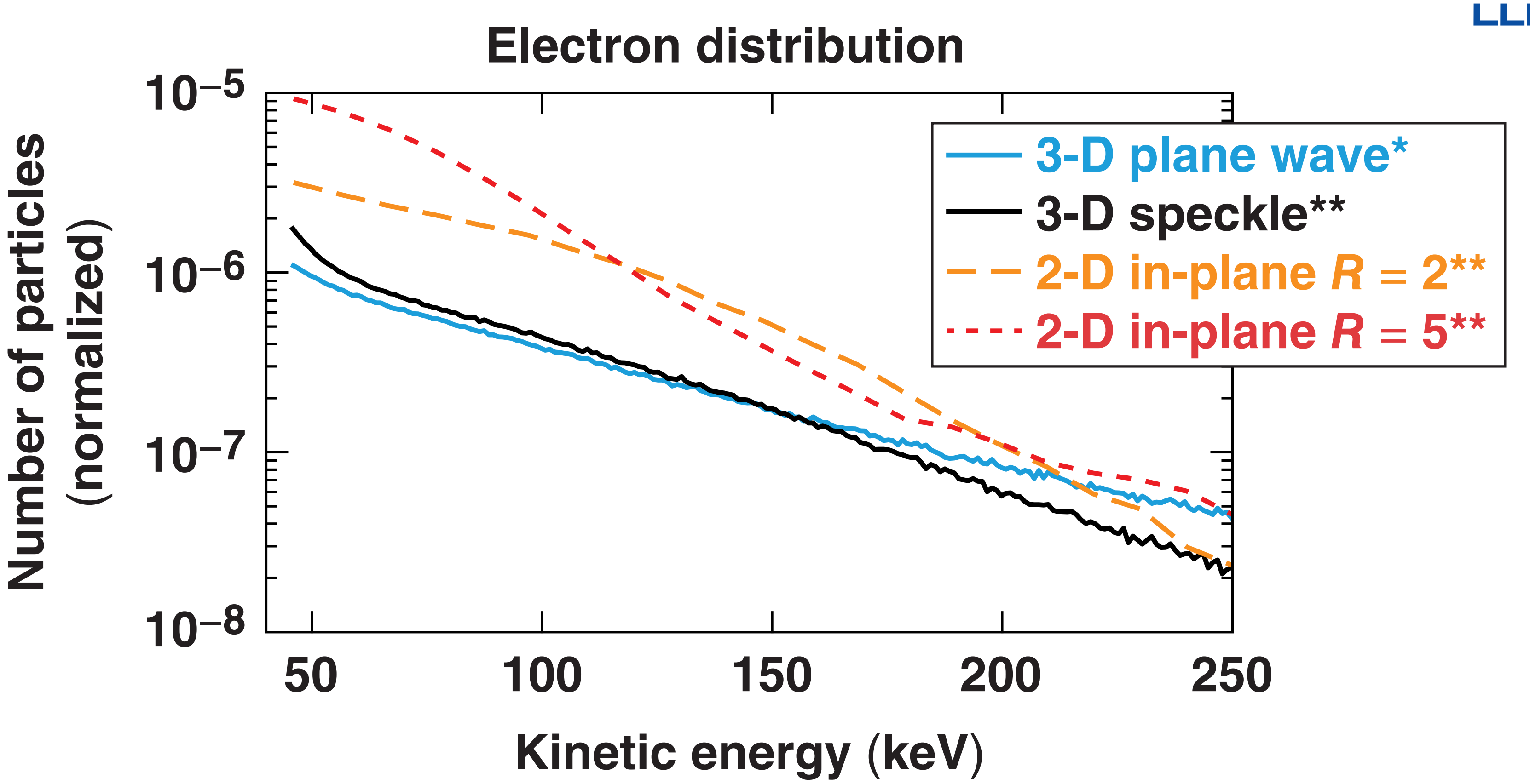
Fast-electron energy distributions have similar temperatures in 3-D and 2-D PIC simulations

- The distributions of fast electrons crossing the right boundary



	3-D plane wave	3-D speckle $R = 2$	2-D in-plane $R = 2$	2-D in-plane $R = 5$
Temperature***	62 keV	56 keV	62 keV	31 keV

$\eta = 1.9$ (3-D plane wave, 3-D speckle $R = 2$); $\eta = 1.3$ (3-D speckle $R = 2$, 2-D in-plane $R = 2$, 2-D in-plane $R = 5$)

*η = 1.9; **η_{av} = 1.3; ***Fitting between 55 keV and 150 keV

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Fast-electron distributions generated by parametric instabilities near quarter-critical density have been calculated in 3-D and 2-D particle-in-cell (PIC) simulations

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