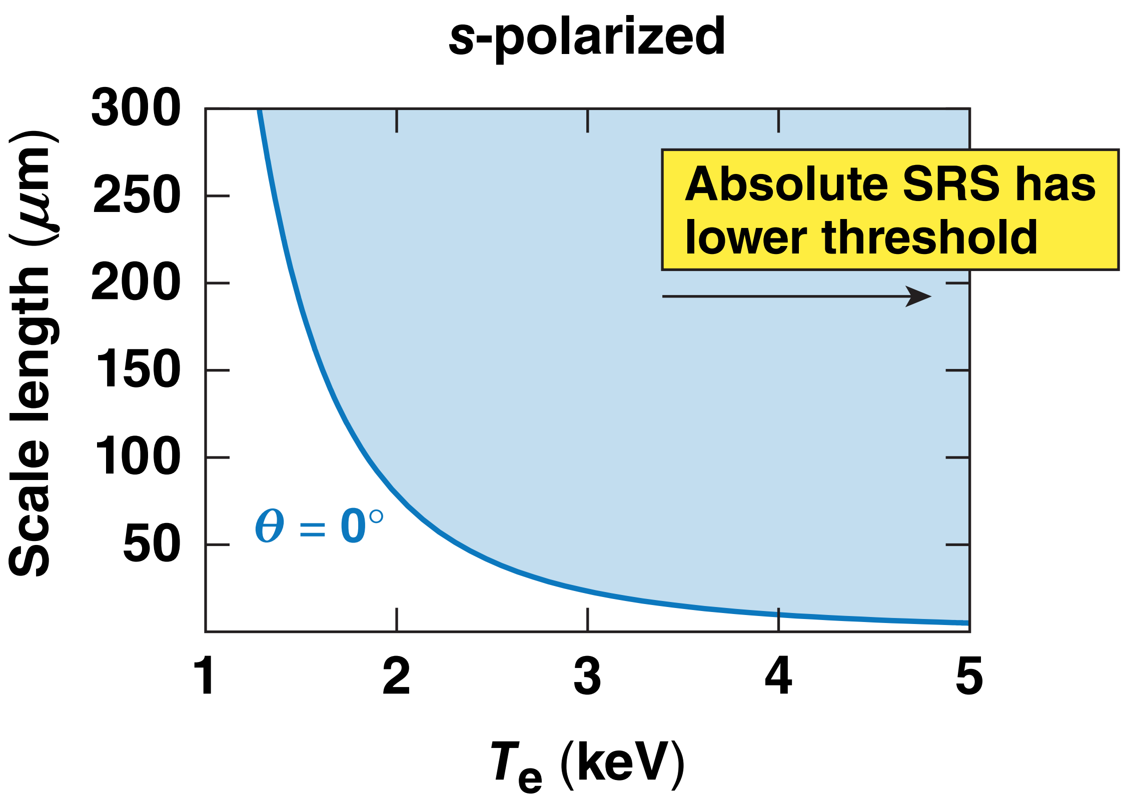
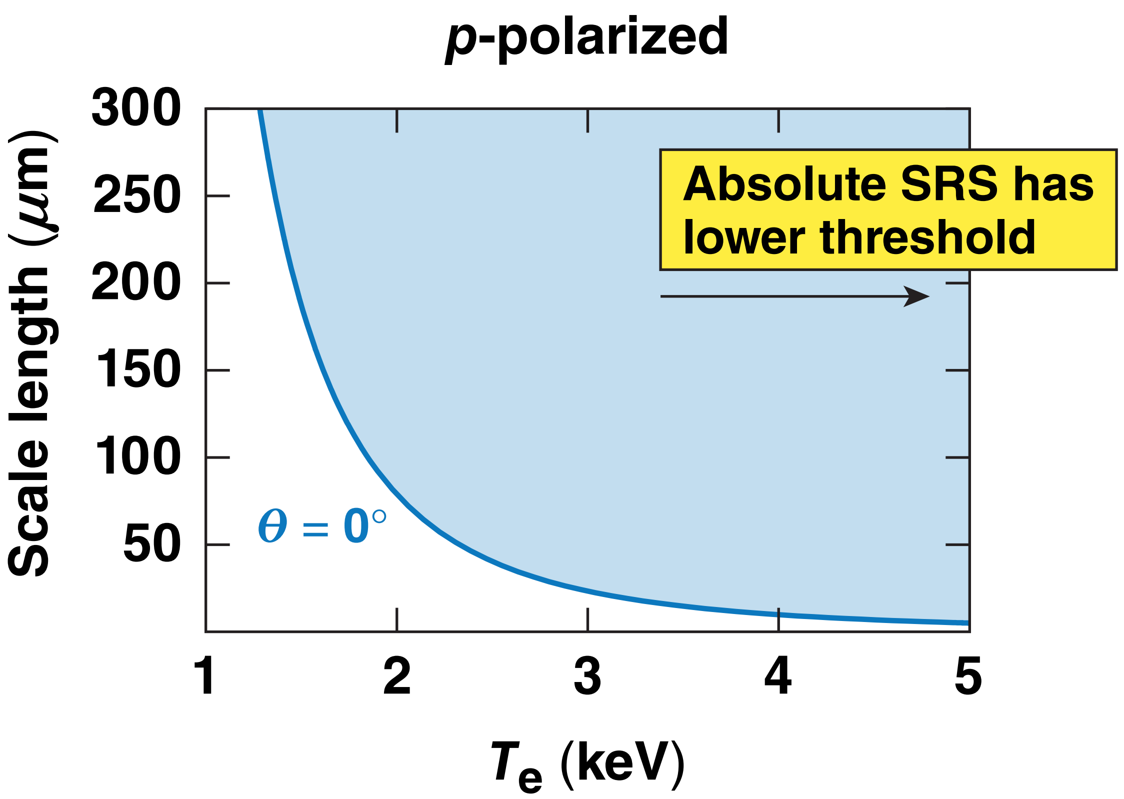
Relative Significance of the Stimulated Raman Scattering and Two-Plasmon-Decay Instabilities at Quarter-Critical Density





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Summary

In general, both stimulated Raman scattering (SRS) and two-plasmon decay (TPD) will play a role in direct-drive laser–plasma interactions

- Absolute TPD and SRS thresholds have different dependences on laser and plasma parameters, but are comparable
- The modes with lowest thesholds tend to be either SRS or TPD; mixed polarization modes seem unimportant
- Larger scale lengths and temperatures favor SRS; larger incidence angles favor TPD
- The analysis presented here is linear; however, there is evidence that the absolute SRS/TPD it describes persists well into the nonlinear regime

The origin in k-space corresponds to the plasma-wave turning point, allowing SRS and TPD to be absolute at that point

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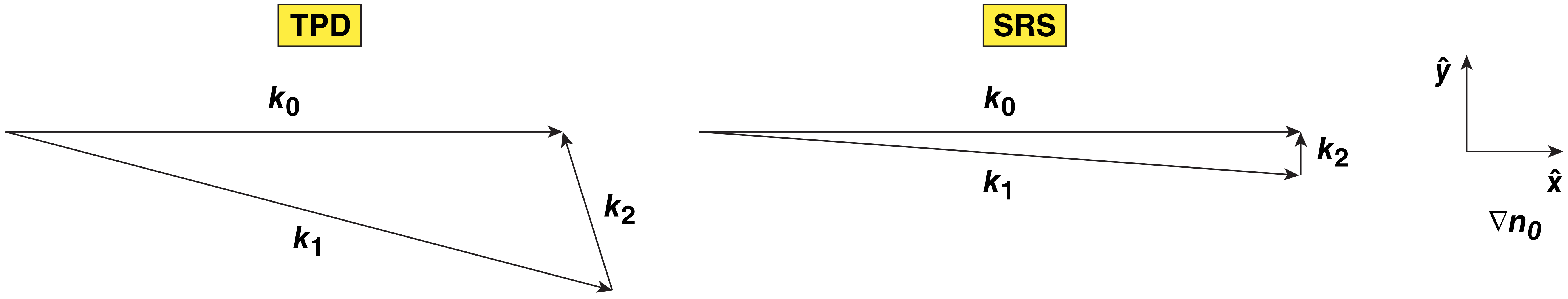
- In general, instabilities can only be convective in inhomogeneous plasmas*
- Near the turning point, however, there is a finite threshold for absolute instability**
- Enhanced multibeam convective gain near the origin in k-space suggests the potential for absolute instability at that point
- Convective SRS occurs for $\frac{n}{n_c} \leq \frac{1}{4}$; for absolute SRS the electromagnetic (EM) decay wave must have $k \cong 0$, and originate at $\frac{n}{n_c} \cong \frac{1}{4}$

*M. N. Rosenbluth, Phys. Rev. Lett. 29, 565 (1972).
**C. S. Liu, M. N. Rosenbluth, and R. B. White, Phys. Rev. Lett. 31, 697 (1973); A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).

Absolute SRS requires the component of $k_\perp$ to the density gradient to vanish



- The y components of the plasma-wave group velocity $v_g = \frac{3v_T^2 k}{\omega}$ are equal and opposite, so TPD is absolute in the y direction

- For SRS $v_{g1y} = \frac{3v_T^2 k_{1y}}{\omega}$ and $v_{g2y} = \frac{c^2 k_{2y}}{\omega}$, so SRS will be convective in y unless $k_{2y} \cong 0$

TC13016

For a single beam the absolute TPD threshold* is lower than the Rosenbluth convective threshold

- The Simon threshold (adjusted for *s*-polarized oblique incidence) is $\eta \equiv \frac{I_{14} L_{\mu}}{233\, T_{\text{keV}}} > \cos\theta$
- The Rosenbluth convective gain is $G_R = \frac{2\pi\gamma_0^2}{\kappa' V_1 V_2} \cong 4.35\,\eta$
- The nominal convective threshold is $G_R > 2\pi$, or $\eta > \frac{2\pi}{4.35} \cong 1.44$
- Therefore, the TPD absolute instability threshold lies below the convective instability threshold; this remains true in general for multiple beams
- The threshold for absolute SRS is comparable**

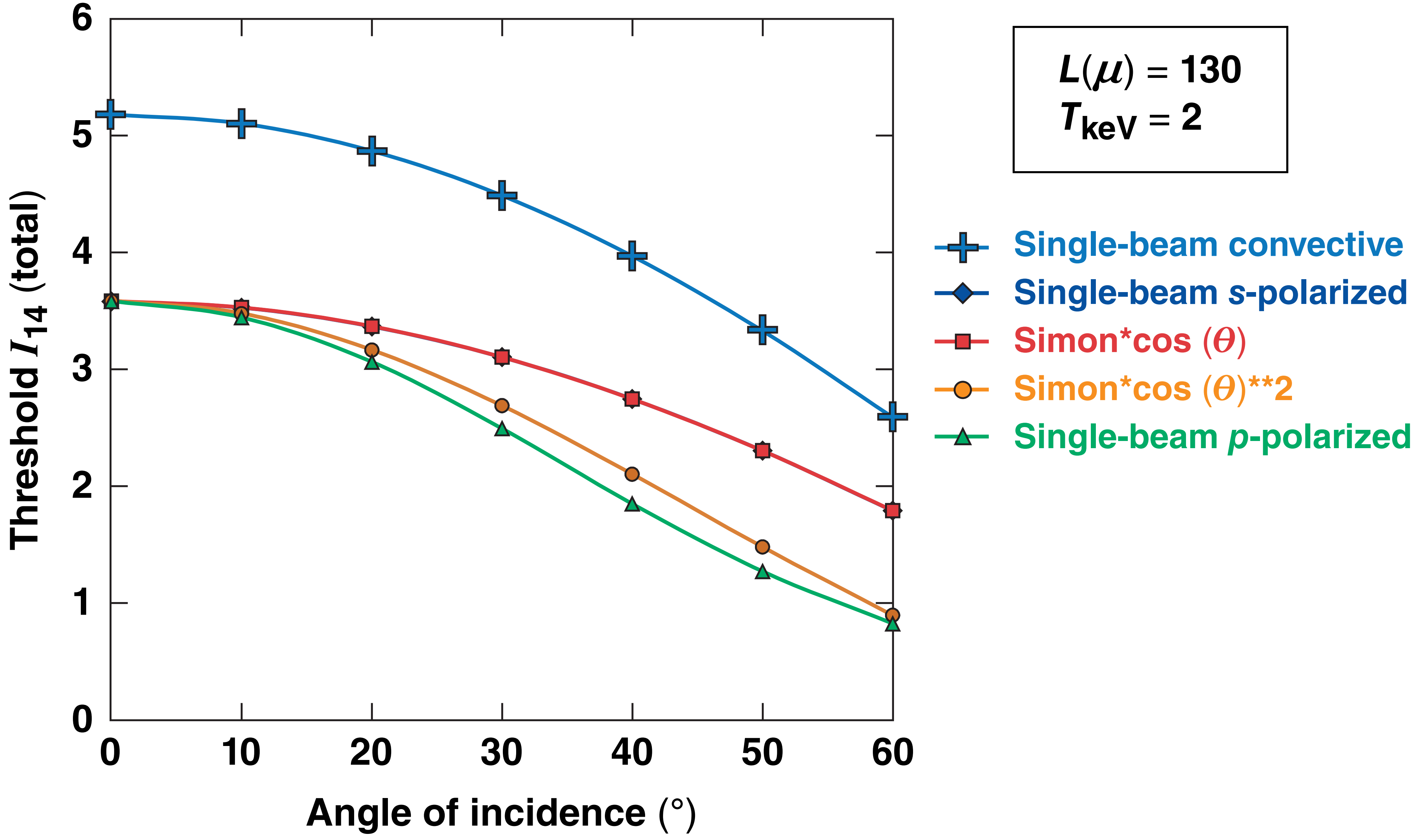
*A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).
**C. S. Liu, M. N. Rosenbluth, and R. B. White, Phys. Fluids 17, 1211 (1974).

TC13017

Fourier analysis of the time-independent SRS/TPD equations results in a set of first-order linear differential equations

- Absolute TPD and SRS occur near quarter-critical, so the local density profile may be approximated by a linear gradient
- Fourier transforming in space, the wave equations become first-order linear equations for the longitudinal and transverse components of the small-*k* decay wave
- The larger-*k* decay wave may be taken to be longitudinal
- For *N* beams there are, therefore, $3N + 1$ linear differential equations that are integrated from $k_x \to -\infty$ to $k_x \to +\infty$ to obtain the spatial gain
- Divergence of the gain indicates onset of absolute instability; optimizing over ω gives the threshold and frequency

The absolute threshold for TPD depends on angle of incidence and polarization



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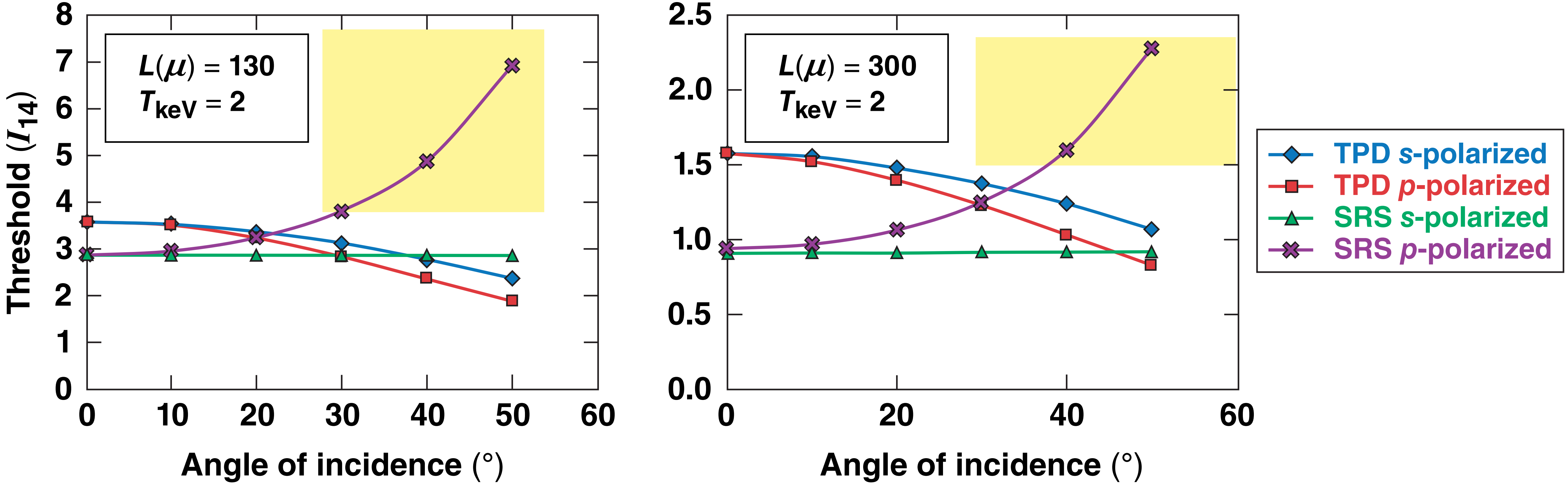
Light from absolute SRS will be emitted along the density gradient

- The much higher group velocity of the EM wave means the instability must be absolute, as well, in the direction perpendicular to the density gradient; i.e., $k_y \sim k_z \sim 0$, and the wave is purely transverse
- Phase matching and, therefore, threshold will be insensitive to temperature
- The spectrum of the emitted $\frac{\omega_0}{2}$ light will have the same dependence on temperature as for TPD
- For *s*-polarization the threshold will be independent of pump incidence angle, while for *p*-polarization the coupling is reduced for oblique incidence and, therefore, the threshold increases with angle
- Analysis of the *k*-space equations for a normally incident beam gives a threshold of $I_{14} > \frac{1995}{L_{\mu}^{4/3}}$, close to the Liu, Rosenbluth, and White* result

*C. S. Liu, M. N. Rosenbluth, and R. B. White, Phys. Rev. Lett. 31, 697 (1973).

For oblique incidence, TPD and SRS behave differently as a function of incidence angle

- Increasing temperatures and scale lengths favor SRS; increasing incidence angles favor TPD



- Points in the shaded region show poor convergence when hybrid terms are included; absolute mode may not exist for these angles

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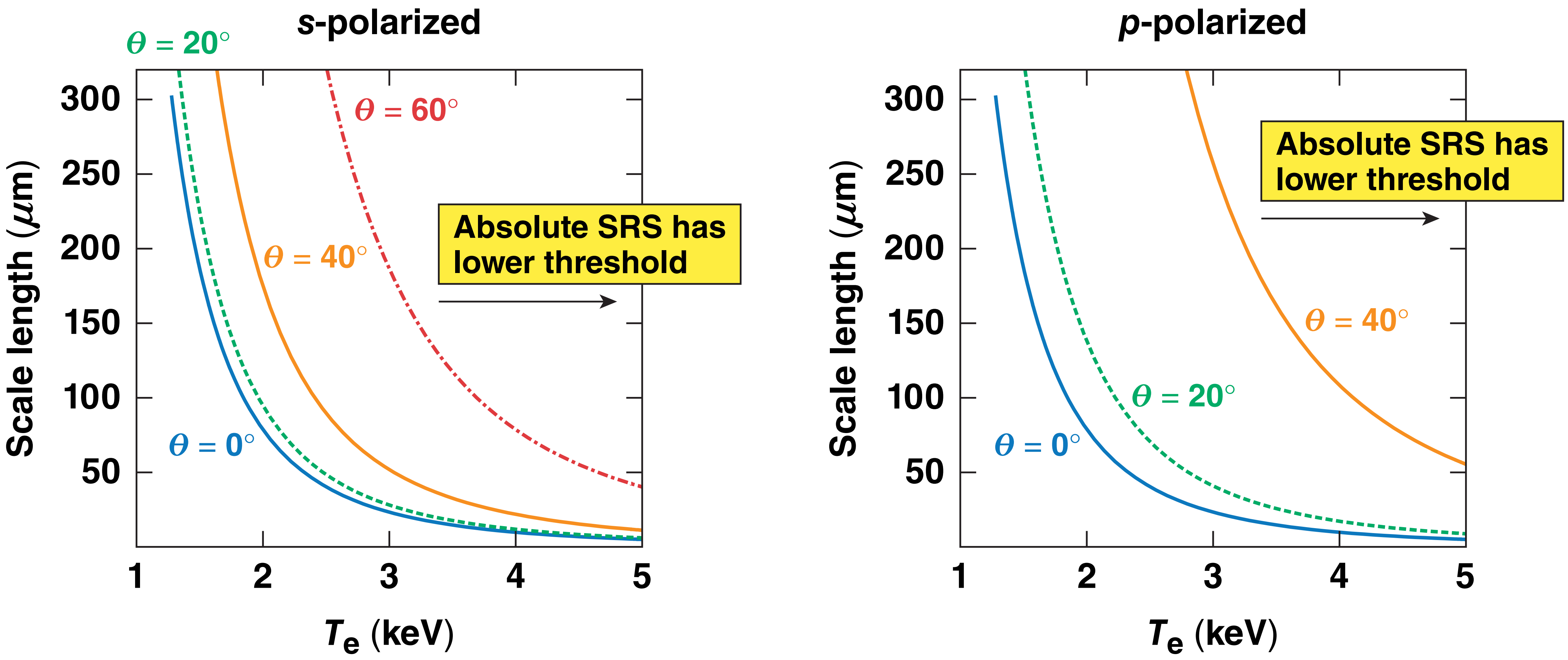
Angular effects are more pronounced for *p*-polarized incidence



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Summary/Conclusions

In general, both stimulated Raman scattering (SRS) and two-plasmon decay (TPD) will play a role in direct-drive laser–plasma interactions

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TC13014