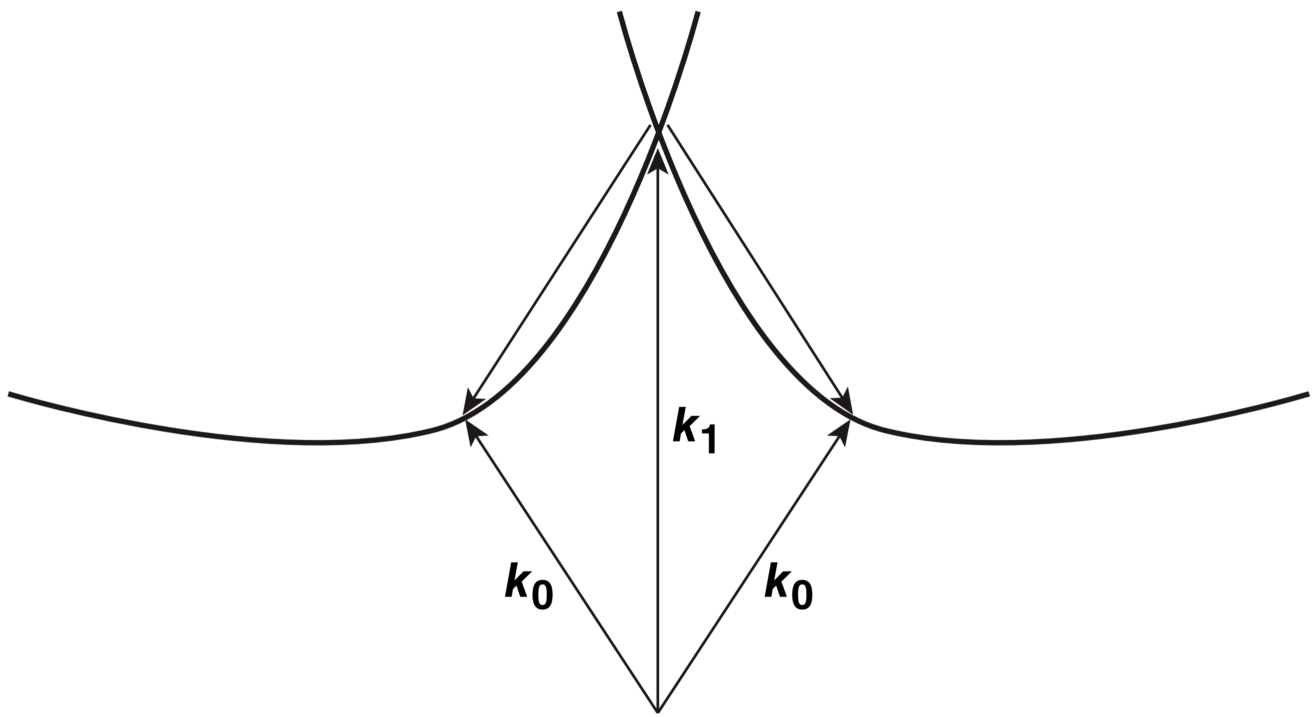
# Two-Plasmon Decay of Multiple Obliquely Incident Laser Beams in Direct-Drive Geometry

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Summary

# Calculation of convective gain and absolute thresholds for TPD is greatly simplified in Fourier space

- TPD occurs over a narrow range of densities near quarter-critical that are well approximated by a linear profile.
- In a linear profile Fourier analysis reduces the eighth-order TPD equation in configuration space to second order in k-space.
- Previous analysis of the absolute TPD instability* by this method suggests that the absolute instability is at or below threshold for OMEGA experimental parameters.
- The Fourier method can be extended to analyze the convective instability for multiple overlapping beams—the relevant situation for OMEGA.

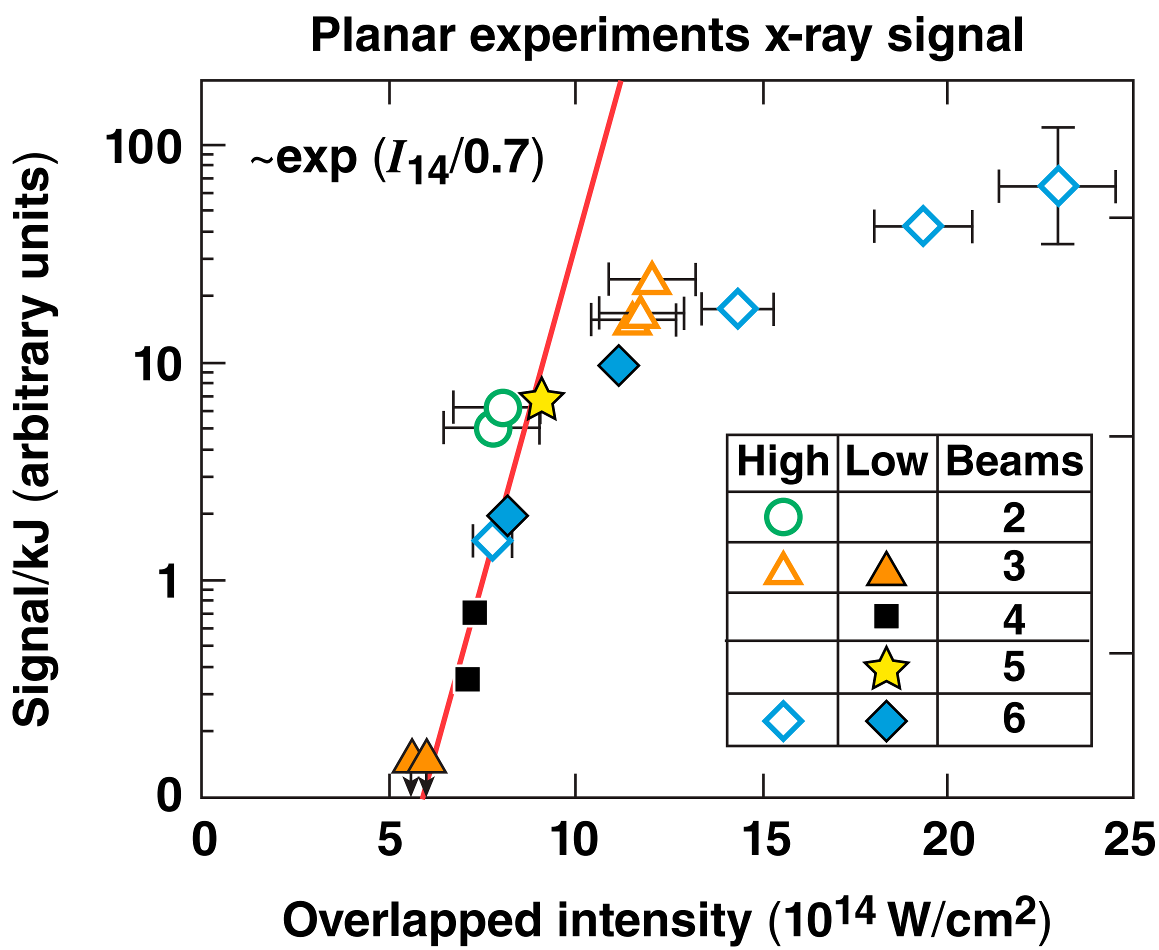
**Preliminary results: on OMEGA, TPD is generally convective, and driven collectively by nearest-neighbor beams.**

*Simon *et al*. 1983

# Both convective and absolute forms of the two-plasmon decay (TPD) instability are expected to play a role in laser-fusion experiments

- Convective instability: Plasma waves arising from noise enter the interaction region, are amplified, and propagate out at an enhanced level. Spatial growth; essentially a steady-state process. Spatial growth $\rightarrow \infty$ represents threshold of absolute instability
- Absolute instability: Waves in the interaction region are amplified faster than they can propagate out; temporal growth continues until limited by nonlinear effects.
- Absolute instability predominates at small plasmon-wave vectors; small group velocity, large phase velocity.
- Convective instability predominates at large wave vectors; large group velocity, smaller phase velocity (traps electrons more effectively).

# TPD is observed to depend on the overlapped intensity for multiple-beam experiments

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C. Stoeckl *et al.*, Phys. Rev. Lett. 90, 235002 (2003).

# The equations describing TPD are difficult to treat in configuration space

- **Using the velocity potential defined by $\mathbf{v} \equiv \nabla\psi$, the equations governing TPD can be written**

$$\frac{\partial\psi}{\partial t} = \frac{e\phi}{m} - \frac{3\upsilon_e^2 n_1}{n_0} - \mathbf{v}_0 \cdot \nabla\psi; \quad \frac{\partial n_1}{\partial t} + \nabla \cdot (n_0 \nabla\psi) + \mathbf{v}_0 \cdot \nabla n_1 = 0; \nabla^2\phi = 4\pi e n_1.$$

- **These lead to an eighth-order ODE. Simplifications are of questionable validity near the plasma-wave turning points.**

- **Simple generic three-wave convective instability theory gives the spatial-gain formula $G = \exp\left(\frac{2\pi\gamma_0^2}{|\kappa' \upsilon_1 \upsilon_2|}\right)$.**
  - **exponential function of intensity**
  - **must break down at absolute threshold (G→∞ for finite intensity.)**

# For a linear density profile, a more sophisticated treatment is feasible using Fourier transforms

- **TPD is confined to a narrow range of densities below quarter-critical, so a linear density profile should be a good approximation.**

- **For a linear density profile, Fourier transforming in space leads to two coupled first-order ODE's in k-space:**

$$\frac{dW_+}{d\kappa} = h(\kappa)W_-, \quad \frac{dW_-}{d\kappa} = -h^*(\kappa)W_+$$

**coupling coefficient** $h(\kappa) = \dfrac{\alpha\left(\dfrac{k_y}{k_0}\right)\kappa e^{i\alpha\sqrt{\beta}\,\kappa(\kappa-2\Omega)}}{\sqrt{\left[\kappa^2+\dfrac{1}{4}+\left(\dfrac{k_y}{k_0}\right)^2\right]^2-\kappa^2}}.$

- **Previous studies have employed this k-space formulation to treat the absolute instability.***

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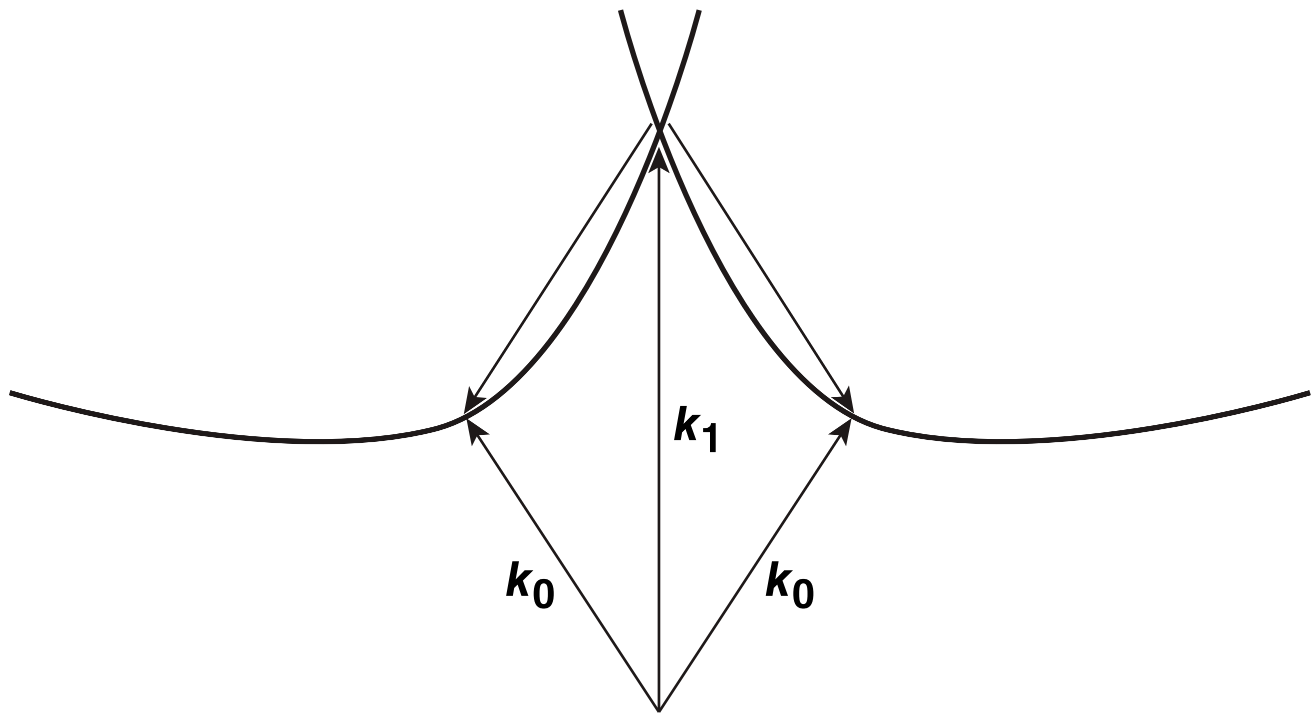
*Liu and Rosenbluth, 1976; Simon *et al*., 1983

# OMEGA beam angles make it difficult to drive multiple-beam absolute TPD




- The closest beams are separated by about 23°.
- The absolute instability is most readily driven in a region near the apex of the hyperbola in k-space.
- The gain in intensity from combined beams appears insufficient to drive absolute TPD at the necessary angles.

# Both absolute and convective forms of TPD can be studied using the k-space approach

- Absolute modes are found by searching for temporally growing modes localized in k-space. This involves complicated contour integrations in complex k-space for complex frequencies.*
  It can be difficult to obtain accurate results near the threshold.

- The convective instability can be studied using real $k$ and $\omega$; the absolute threshold can be identified with divergent spatial gain.

- $\begin{pmatrix} W_+ \\ W_- \end{pmatrix}$ represents the plasma wave amplitudes at $\begin{pmatrix} k + k_0, \omega + \omega_0 \\ k - k_0, \omega - \omega_0 \end{pmatrix}$.

- Incoming waves at large negative $x$ are represented by $W_\pm (\kappa \to \pm\infty)$ and outgoing waves by $W_\pm (\kappa \to \mp\infty)$.

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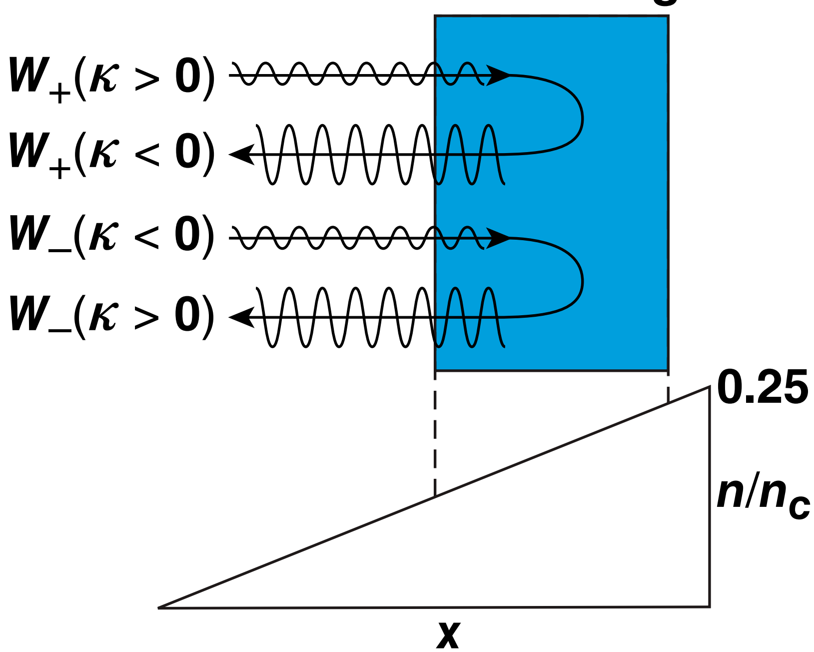
*Simon *et al*., 1983

# TPD amplification factors can be obtained by numerical integration of the k-space equations




- Define the growth factor $G = \frac{\text{out}}{\text{in}} = \frac{|W_+(\kappa \to -\infty)|^2 + |W_-(\kappa \to +\infty)|^2}{|W_+(\kappa \to +\infty)|^2 + |W_-(\kappa \to -\infty)|^2}$.

  If integration from $\begin{bmatrix} W_+(\kappa \to -\infty) \\ \hline W_-(\kappa \to -\infty) \end{bmatrix} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ gives $\begin{bmatrix} W_+(\kappa \to +\infty) \\ \hline W_-(\kappa \to +\infty) \end{bmatrix} = \begin{pmatrix} a \\ b \end{pmatrix}$, then $G_{max} = \frac{1+|b|}{1-|b|}$.

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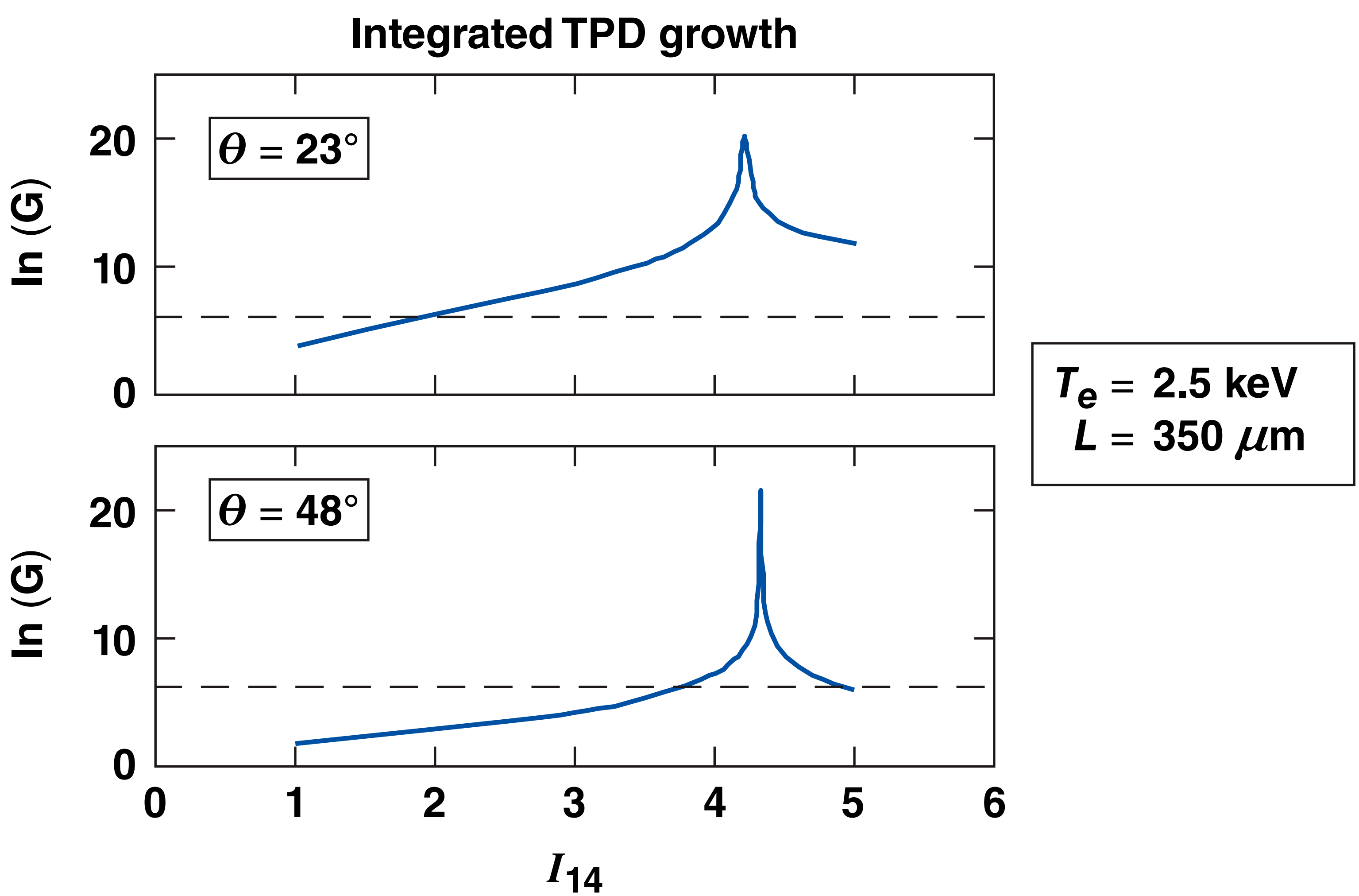
# Beams at larger angles of incidence contribute less to TPD

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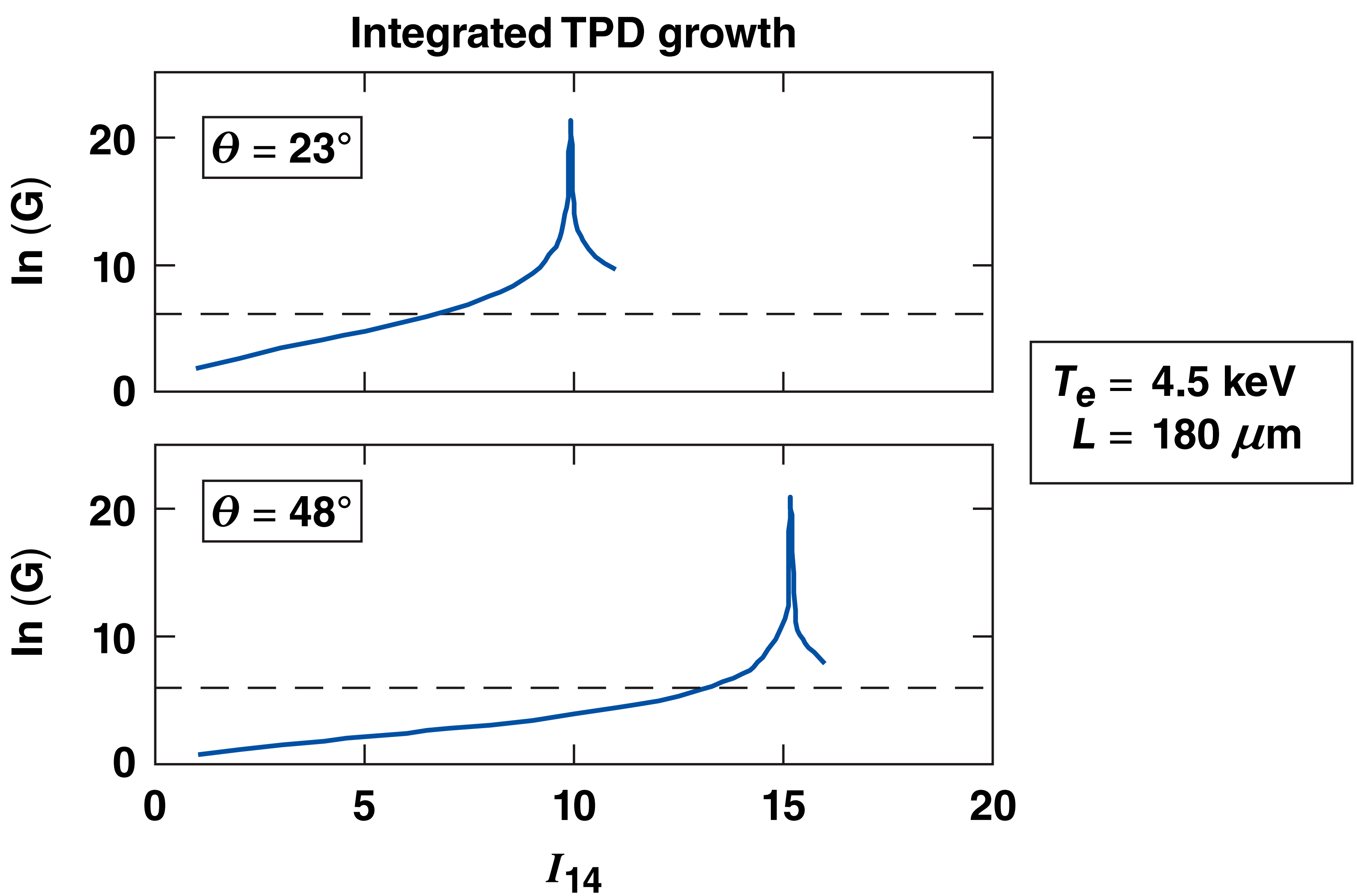


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Summary/Conclusions

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