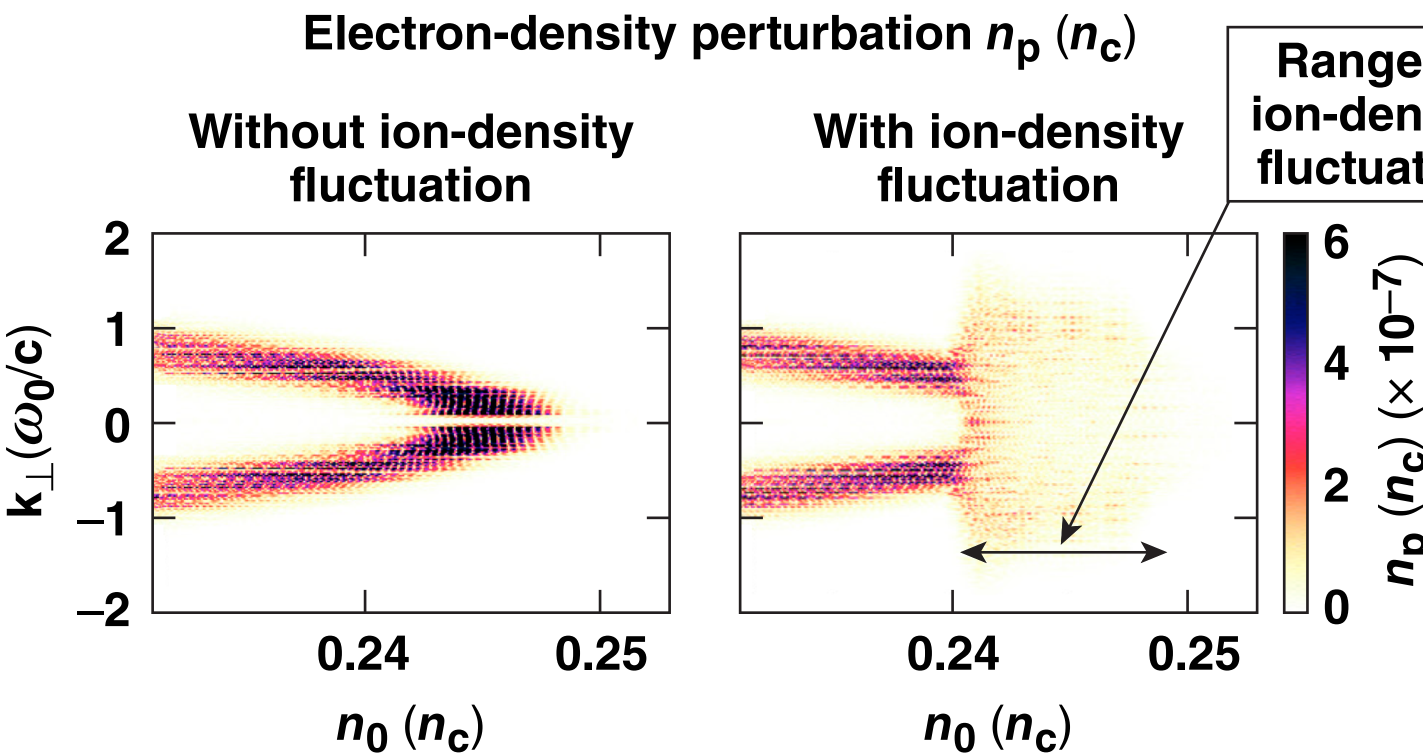
Suppression of Two-Plasmon Decay by Ion-Density Fluctuations



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Summary

Correlations between two-plasmon decay (TPD) and ion-density fluctuations were observed in particle-in-cell (PIC) simulations

- Analytical theory for homogeneous plasmas shows that transverse ion-density fluctuations can raise the TPD threshold by coupling the two otherwise independent pairs of plasmons.
- A fluid code has been developed to show the suppression of TPD caused by ion-density fluctuations in both homogeneous and inhomogeneous plasmas.

Related talk: W. Seka (GO5.00006).

Collaborators

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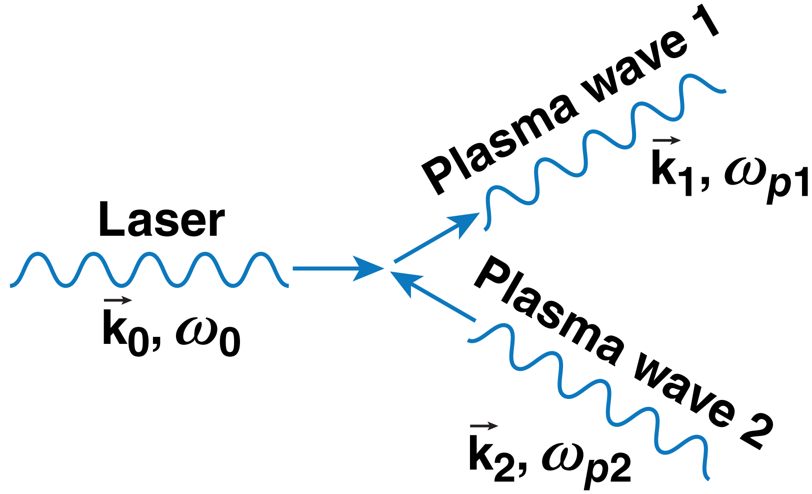
The two-plasmon decay (TPD) is an important concern in direct-drive ICF

- TPD is a laser–plasma instability with a low threshold and high-energy electron generation
- Energetic (hot) electrons generated from laser–plasma interactions can preheat the shell and degrade the implosion



PIC simulations show the correlation between TPD saturation with ion-density fluctuations

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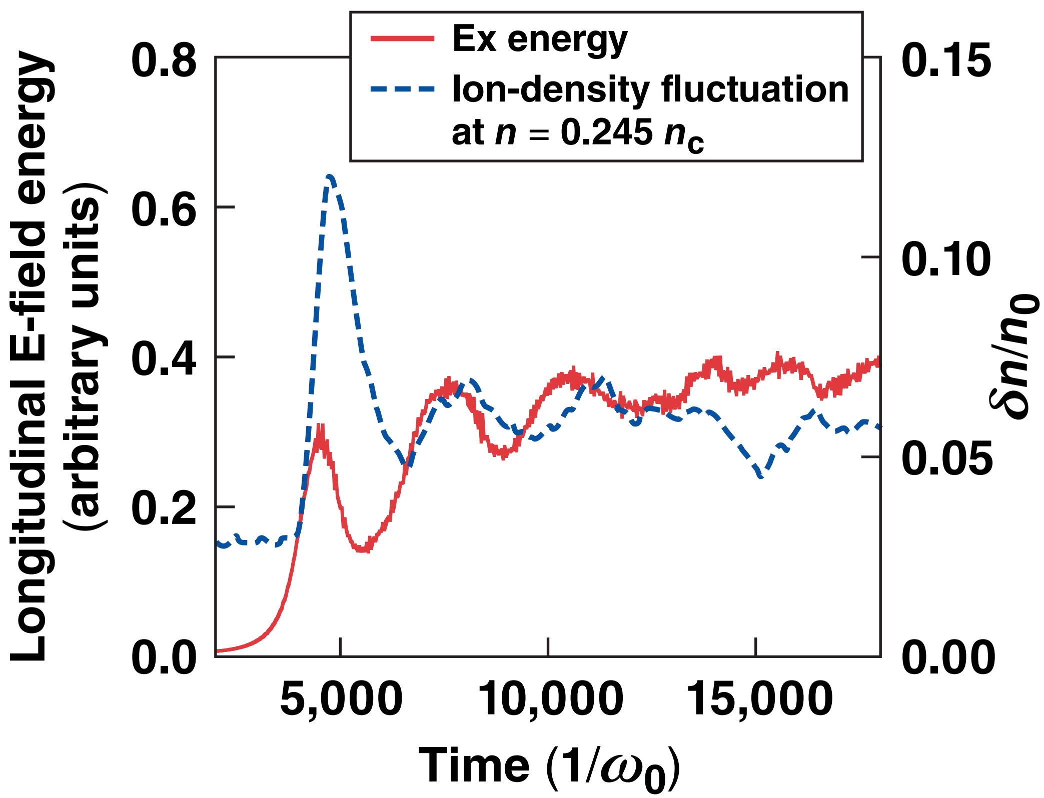
OSIRIS[1] simulations with
$I = 2 \times 10^{15}$ W/cm^2, $T = 1$ keV, $L = 25\ \mu$m



- TPD was observed to be intermittent[2,3]
- TPD saturates as ion fluctuations increase to a certain level
- TPD recurs after ion fluctuations drop

[1] R. A. Fonseca, *et al.*, in Computational Science—ICCS 2002, edited by P. M. A. Sloot *et al.*, Lecture Notes in Computer Science (Springer, Berlin, 2002), Vol. 2331, p. 342.
[2] A. B. Langdon, B. F. Lasinski, and W. L. Kruer, Phys. Rev. Lett., 43, 133 (1979).
[3] R. Yan *et al.*, Phys. Rev. Lett. 103, 175002 (2009).

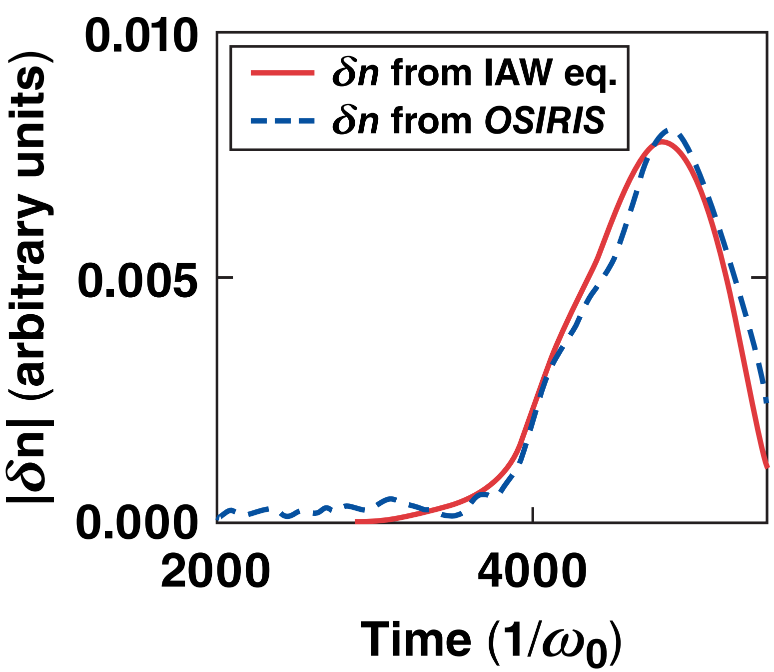
TC9117

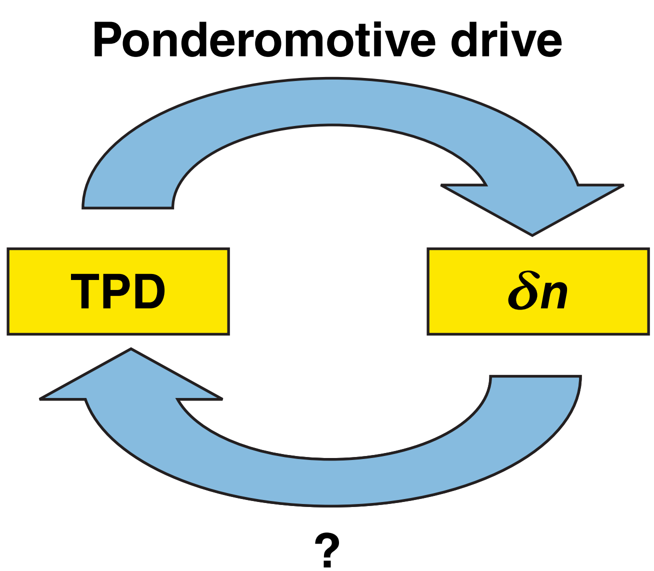
The ion-density fluctuation is driven by the ponderomotive pressure of the plasma waves

- The ion-density fluctuations calculated from the ion-acoustic equation match the PIC results
- Ion-acoustic wave (IAW) equation

$$\left(\partial_{tt} - C_s^2 \nabla^2\right) \delta n = \nabla^2 \left|E\right|^2 / \left(16 \pi m_i\right)$$

Drop $\nabla_{||}^2$, since $\nabla_{||}^2 << \nabla_{\perp}^2$





TC9118

Understanding how the ion fluctuations saturate TPD is important for modeling the long-term behavior of TPD

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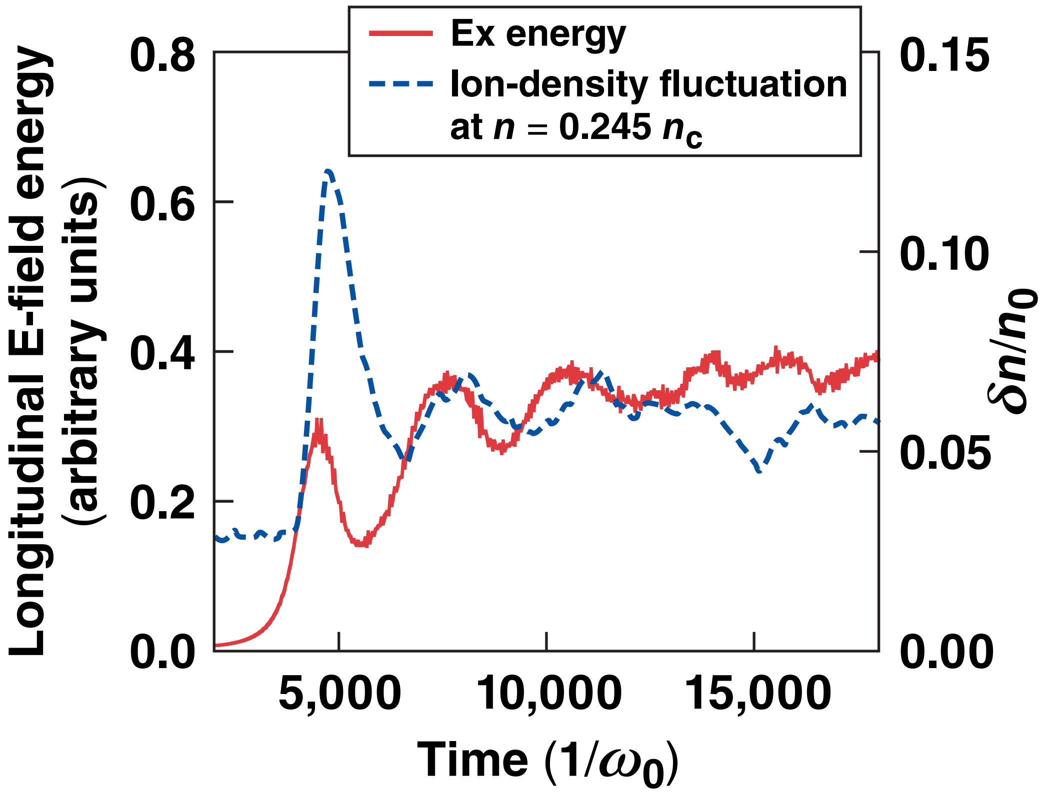
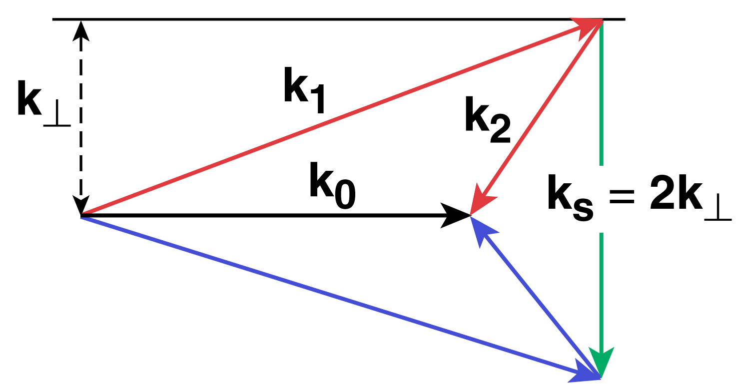
- Previously, various energy sinks were proposed as saturation mechanisms
  - ion fluctuations can scatter the plasma waves to high $k_\perp$ regions, where they are Landau damped[1]
  - Langmuir decay instability (LDI) as an energy sink described by the Zakharov model[2]
- The observed decrease of |Ex| indicated TPD suppression



[1] A. B. Langdon, B. F. Lasinski, and W. L. Kruer, Phys. Rev. Lett. 43, 133 (1979).
[2] D. F. Dubois, D. A. Russell, and H. A. Rose, Phys. Rev. Lett. 74, 3983 (1995).

Ion-density fluctuation (δn) can suppress TPD by coupling the two otherwise independent pairs of plasmons[1]

- Two symmetric pairs of plasmons with $\pm k_\perp$ can be coupled by the transverse ion-density fluctuation with $k_s = 2k_\perp$
- Theory predicts a threshold δn above which the growth of four coupled plasmons becomes zero in a homogeneous plasma

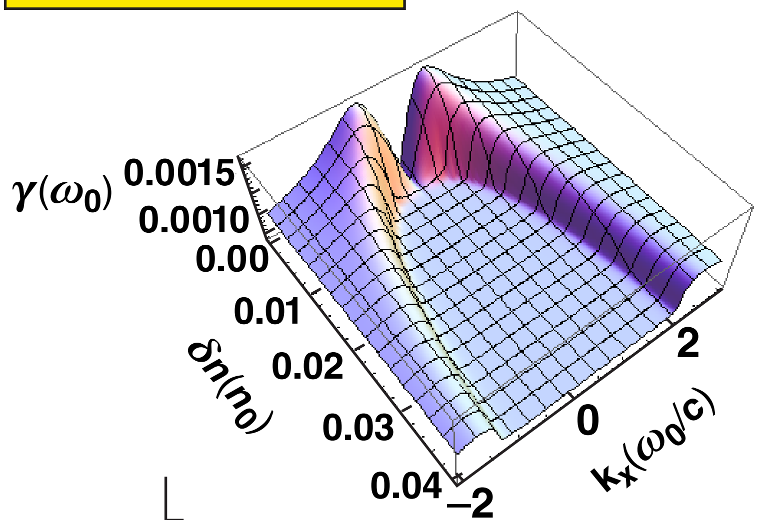


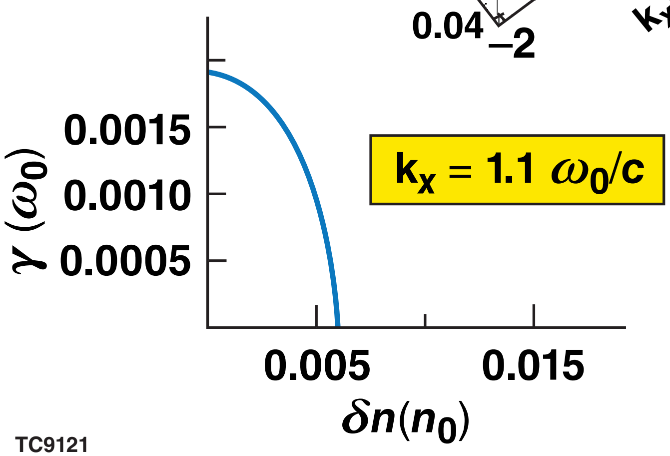
TC9120

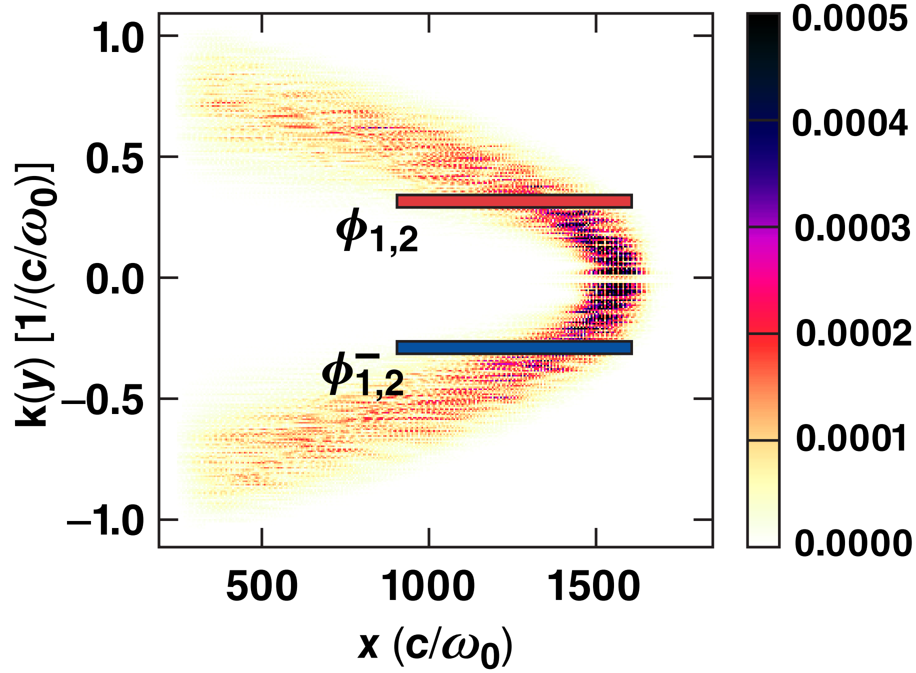
[1]R. Yan *et al.*, Phys. Rev. Lett. 103, 175002 (2009).

A four-plasmon model predicts that a large δn can suppress TPD growth in homogeneous plasmas

$I = 1 \times 10^{15}$ W/cm^2
$T = 2$ keV
$k_\perp = 0.5\ \omega_0/c$







- We solved two coupled three-wave equations and found the dispersion relation for homogeneous plasmas

TC9121

A linear fluid code has been developed to study the influence of ion-density fluctuation in inhomogeneous plasmas

$$\frac{\partial \psi}{\partial t} = \frac{e\phi}{m} - \frac{3\nu_e^2 n_p}{n} - \vec{v}_0 \nabla \psi$$

$$\frac{\partial n_p}{\partial t} + \vec{v}_0 \cdot \nabla n_p = -\nabla (n \nabla \psi)$$

$$\nabla^2 \phi = 4\pi e n_p$$

BC's

$$\partial_x \psi|_0 = \partial_x \psi|_L = 0$$

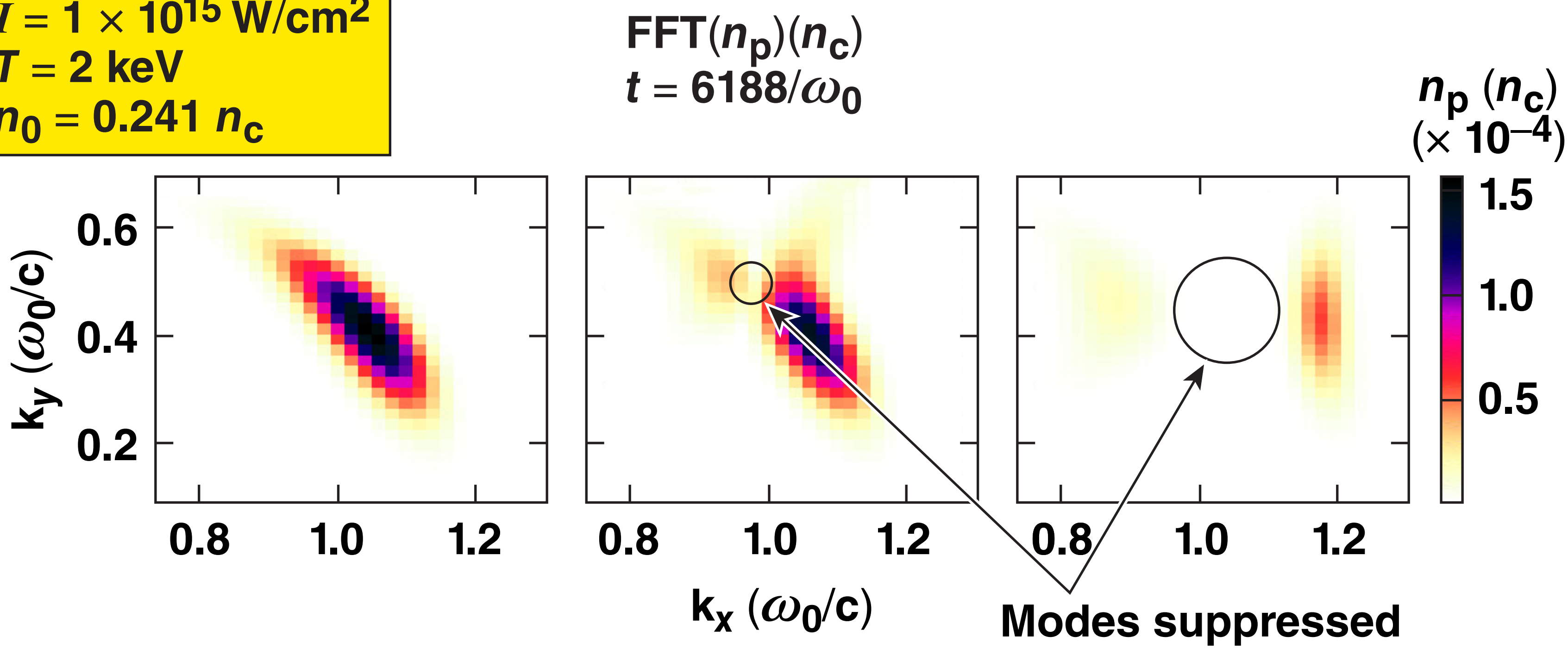
$$\partial_x \phi|_0 = \partial_x \phi|_L = 0$$

$$n_p|_0 = n_p|_L = 0$$

The density fluctuation is included in $n = n_0(x) + \delta n$ as a prescribed function

The theoretical results for homogeneous plasmas are verified by the fluid code

$I = 1 \times 10^{15}$ W/cm^2
$T = 2$ keV
$n_0 = 0.241\ n_c$



Without δn

$\delta n = 0.6\%\ n_0$
$k_s = 1.0\ \omega_0/c$

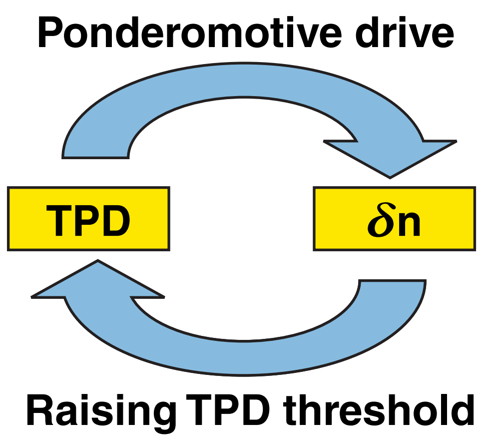
$\delta n = 3\%\ n_0$
$k_s = 0.9\ \omega_0/c$

- Those modes with $k_\perp \sim k_s/2$ are most effectively impacted
- Only a range of k_x can be suppressed, consistent with the dispersion relation

TC9123

Preliminary results show static ion-density fluctuations can suppress TPD in inhomogeneous plasmas

- δn can suppress TPD by raising the threshold



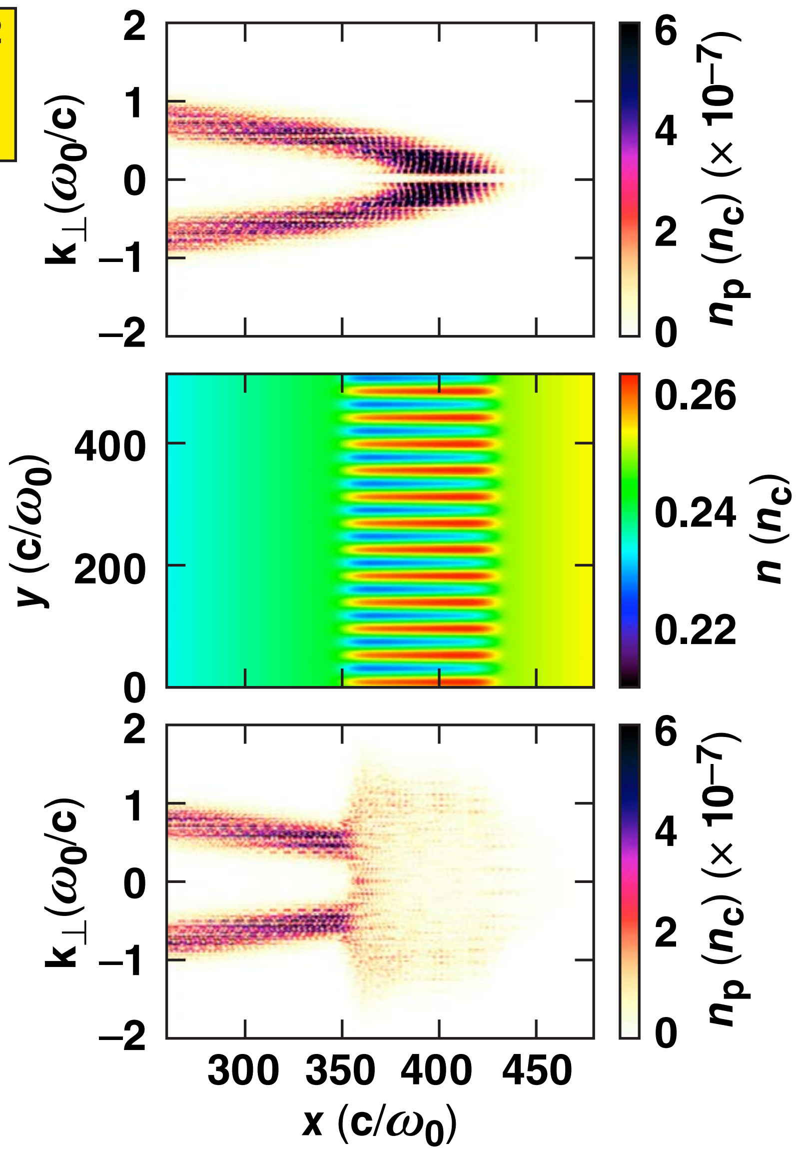
- This can help find ways to reduce TPD

$I = 1 \times 10^{15}$ W/cm^2
T = 2 keV
L = 150 μm

Without ion-density fluctuation

δn = 6% n_0
k_s = 0.15 ω_0/c

With ion-density fluctuation



TC9124

Correlations between two-plasmon decay (TPD) and ion-density fluctuations were observed in particle-in-cell (PIC) simulations

UR LLE

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