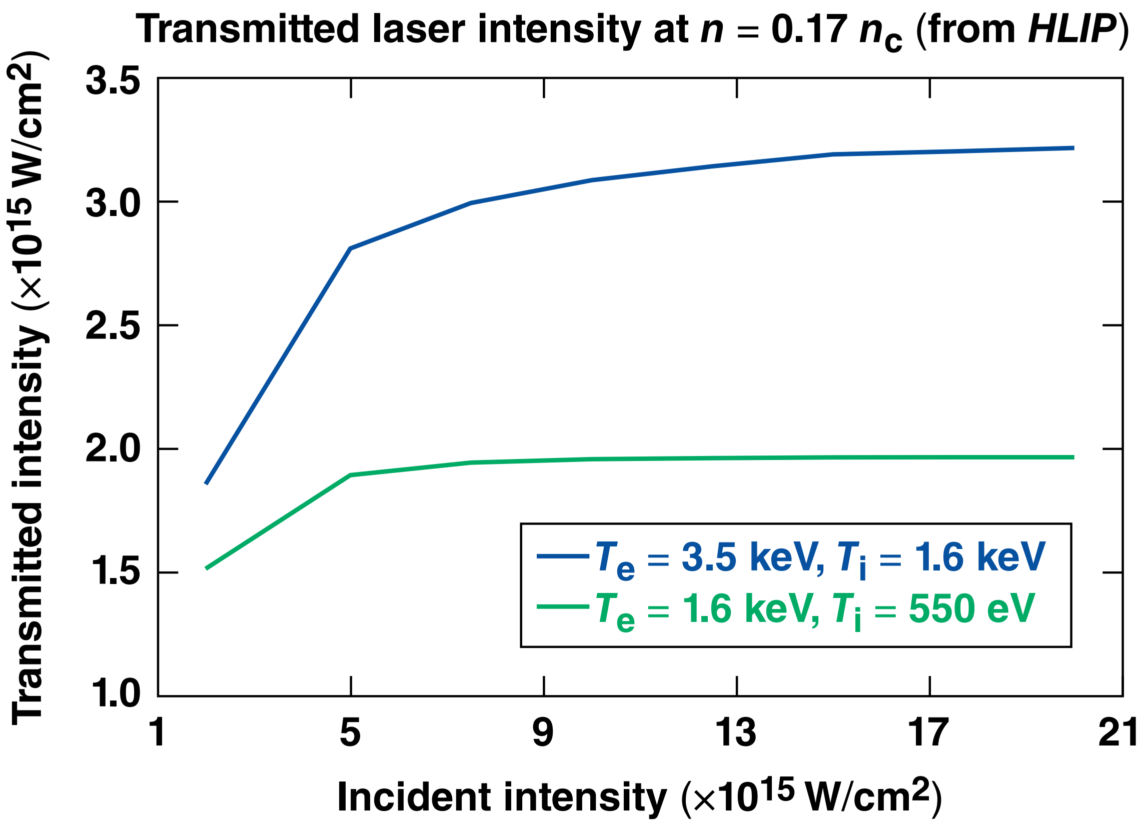
Simulation of Stimulated Brillouin Scattering and Stimulated Raman Scattering in Shock Ignition



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Summary

Laser–plasma instabilities below the quarter-critical surface are important in shock ignition

- Particle-in-cell (PIC) and fluid simulations find that stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS) in the low-density region can cause significant pump depletion of the ignition pulse in shock ignition
- SBS is reduced by the plasma flow
- New simulations with both realistic seed levels and nonlinear physics are needed

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Collaborators

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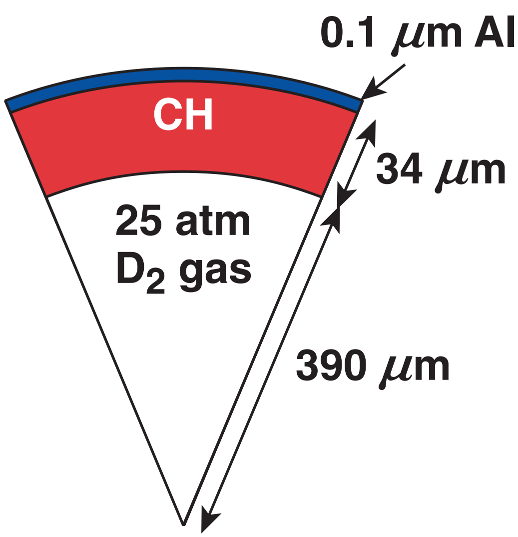
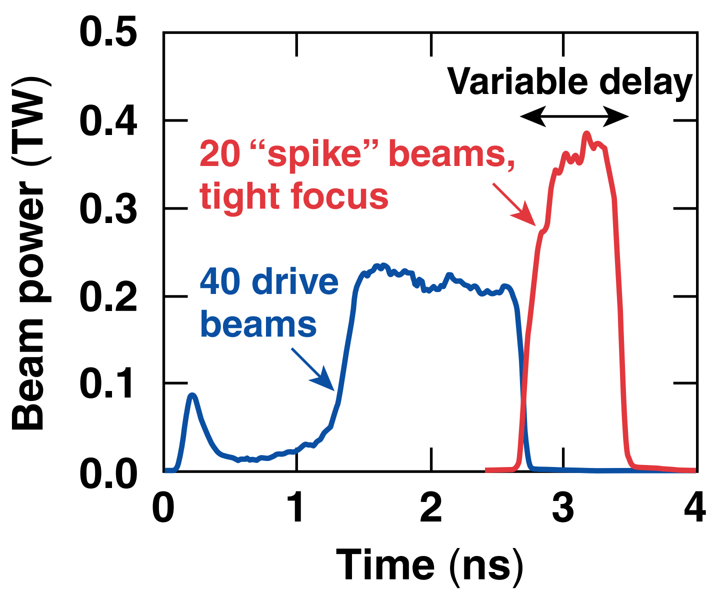
We thank the UCLA-IST Consortium for the use of the particle-in-cell code *OSIRIS**

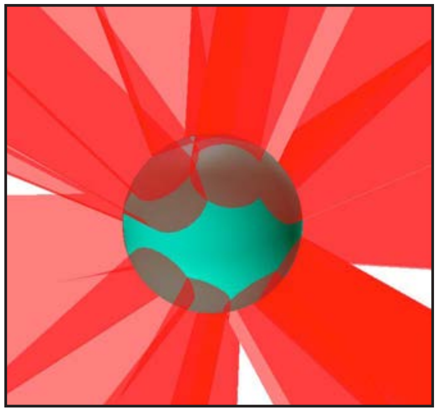
*R. Fonseca *et al*., Lect. Notes Comput. Sci. 2331, 342 (2002).

The 40 + 20 spherical shock-ignition experiment on OMEGA used separate compression and ignition beams

- 60 OMEGA beams were split into 40 low-intensity drive beams (~14 kJ) and 20 tightly focused, delayed beams (~5 kJ)







Target design and laser pulse shape*

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*W. Theobald *et al.*, Phys. Plasmas 19, 102706 (2012).

Simulation parameters similar to the 40 + 20-beam shock-ignition (SI) experiments on OMEGA*

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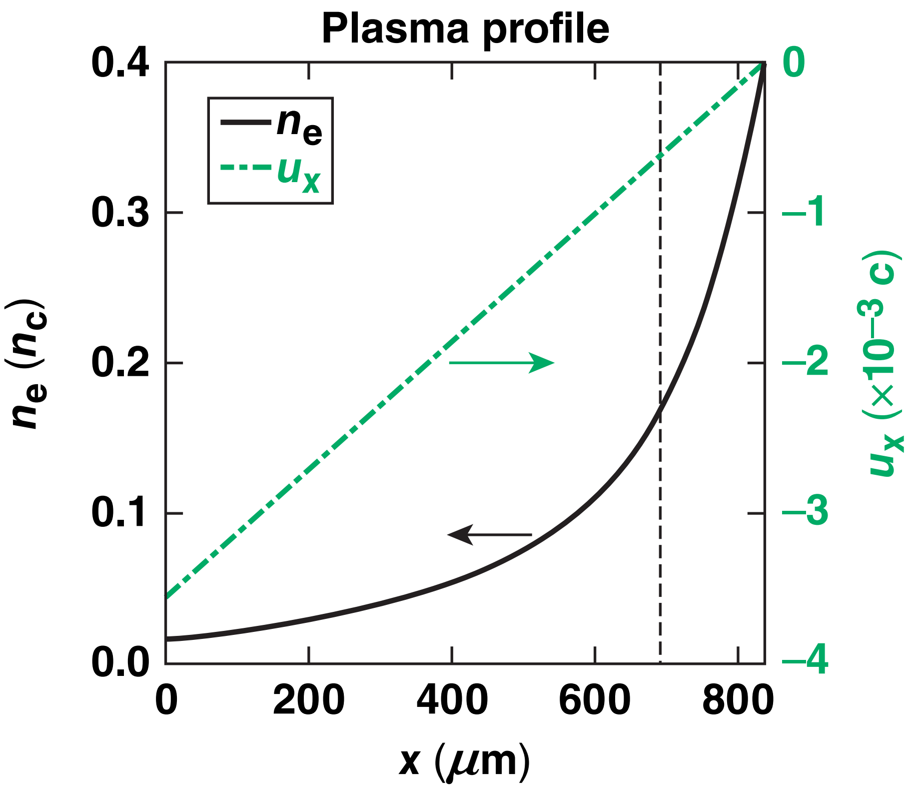
Typical plasma profile in shock ignition**

- $L_n = 170\ \mu m$
- $U_{x/c} = 4.26 \times 10^{-6}\ x\ (\mu m) - 0.00356$
- Two temperatures:
  $T_e/T_i = 3.5\ keV/1.6\ keV = 2.2$ (HT)
  $T_e/T_i = 1.6\ keV/0.55\ keV = 2.9$ (LT)
- $I = (2\ to\ 20) \times 10^{15}\ W/cm^2$



HT: high temperature
LT: low temperature
* W. Theobald, *et al.*, Phys. Plasmas 19, 102706 (2012).
** R. Yan, J. Li, and C. Ren, Phys. Plasmas 21, 062705 (2014).

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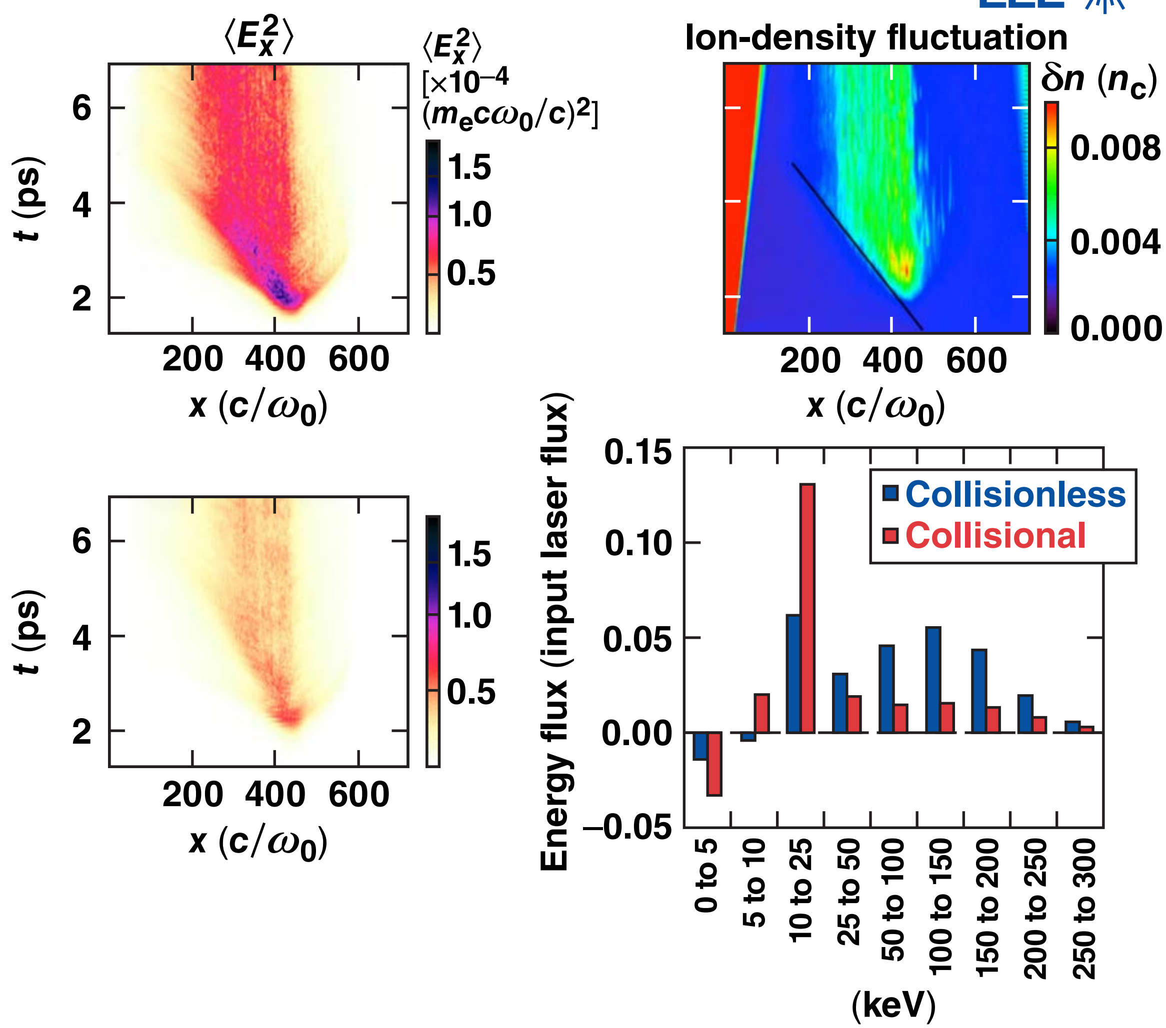
In a conventional inertial confinement fusion (ICF) scheme, laser–plasma interactions (LPI's) at $n_c/4$ reach a steady state

- $I = 6 \times 10^{14}$ W/cm^2
  $L = 150\ \mu$m
  $T_e = 3$ keV
  $T_i = 1.5$ keV
  $n = 0.21$ to $0.27\ n_c$
- Hot electrons are staged, accelerated from left to right
- Collisions can reduce hot electrons



R. Yan *et al*., Phys. Rev. Lett. 108, 175002 (2012).

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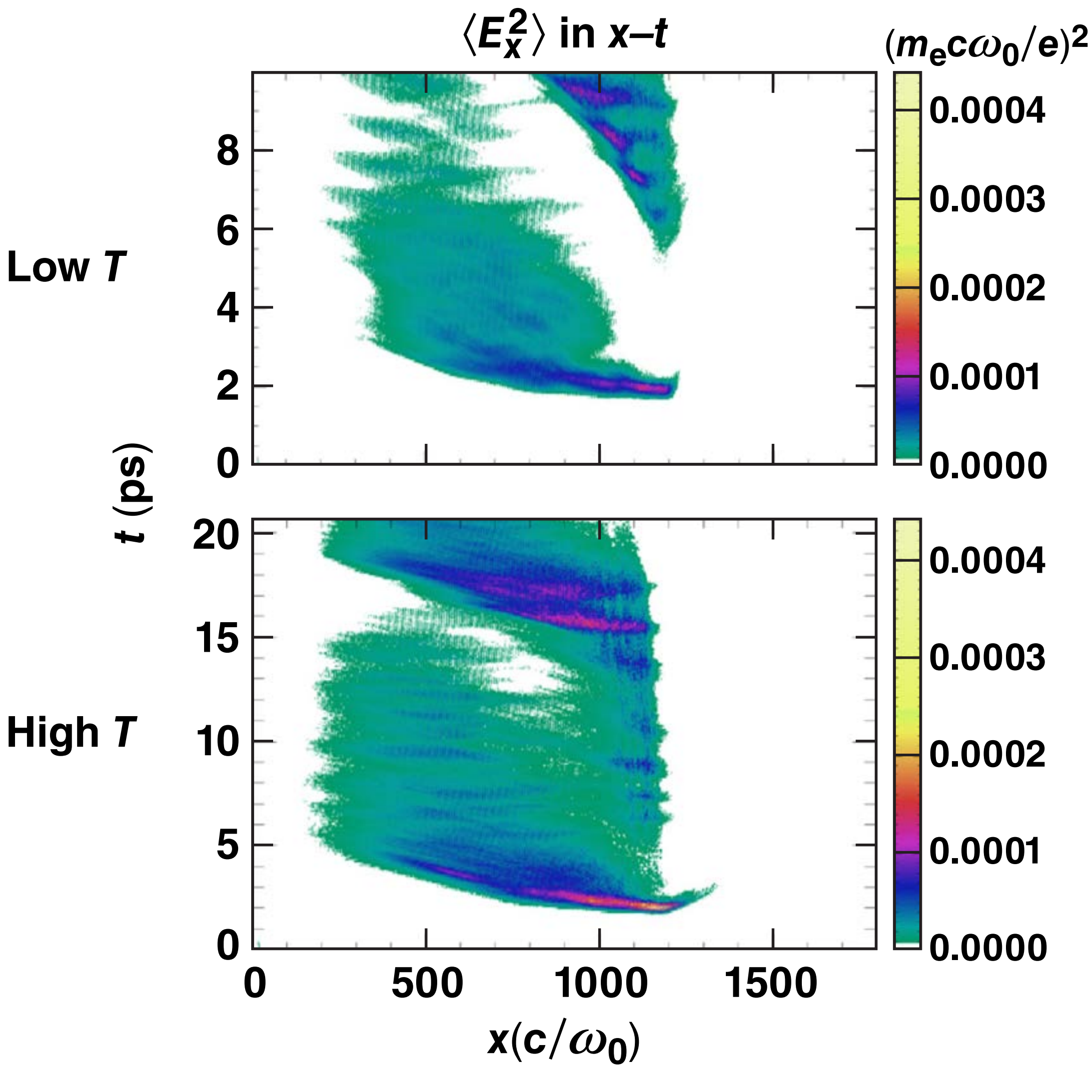
Interplay of the modes at different densities leads to intermittent LPI activities at SI intensities



- $I = 2 \times 10^{15}$ W/cm^2
  $L = 170\ \mu$m
  $n = 0.17$ to $0.33\ n_c$
  - low T: $T_e = 1.6$ keV
    $T_i = 0.55$ keV
  - high T: $T_e = 3.5$ keV
    $T_i = 1.6$ keV
- Significant pump depletion is seen at $n_c/4$

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R. Yan, *et al.*, Phys. Plasma 21, 062705 (2014).

A single Maxwellian fit T_{hot} = 29.5 keV was consistent with the experimental values T_{hot} = 30 to 40 keV

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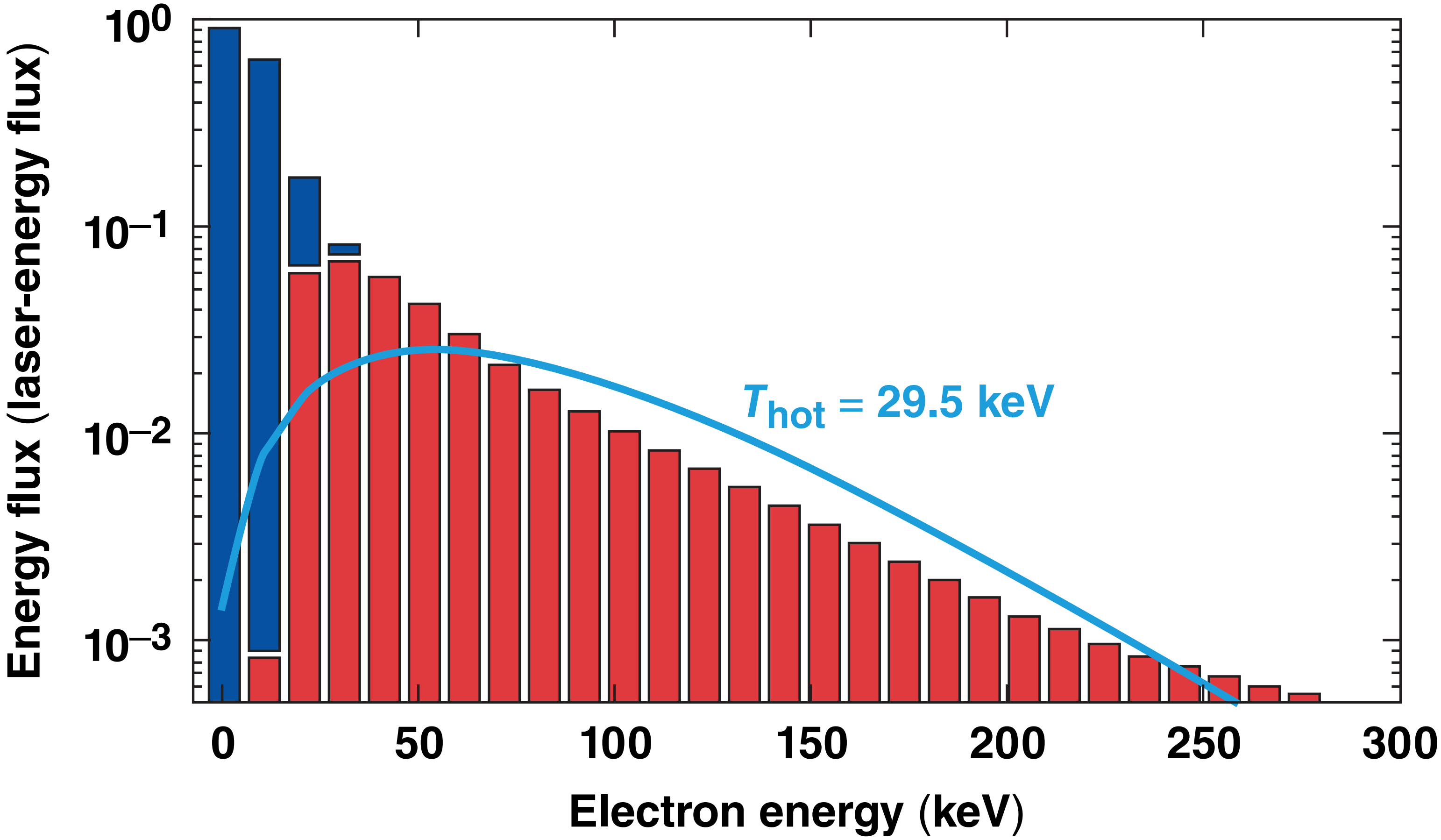

High-*T* case

f_{50} = 19%, f_{100} = 8%

Experimental measurement: $f_{50} \leq 12\%$

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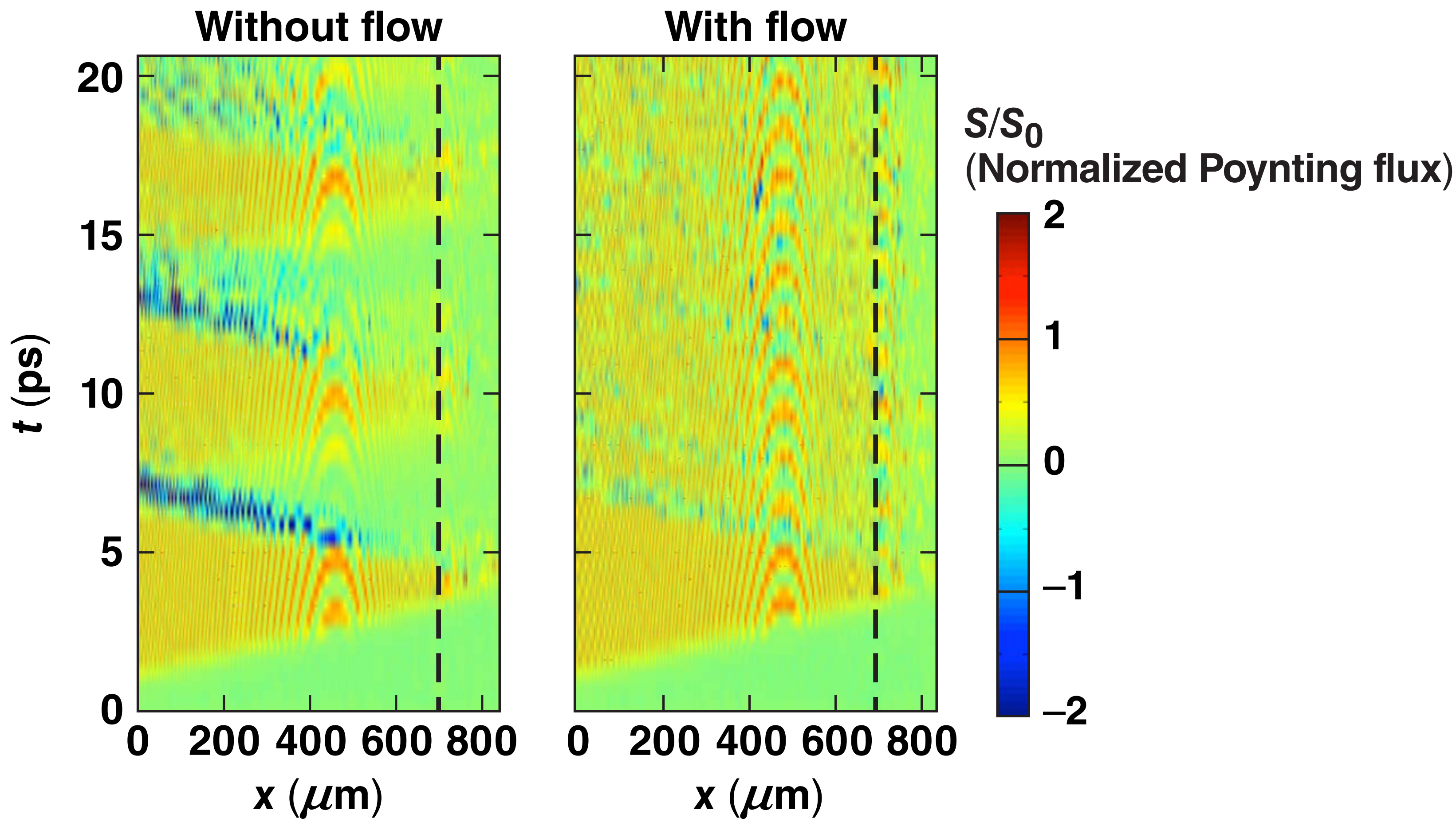
SBS in the $n = 0.015$ to $0.17\ n_c$ region can cause significant backscattering—plasma flow is important



One-dimensional PIC simulations, $I = 2 \times 10^{15}$ W/cm^2, high-T*

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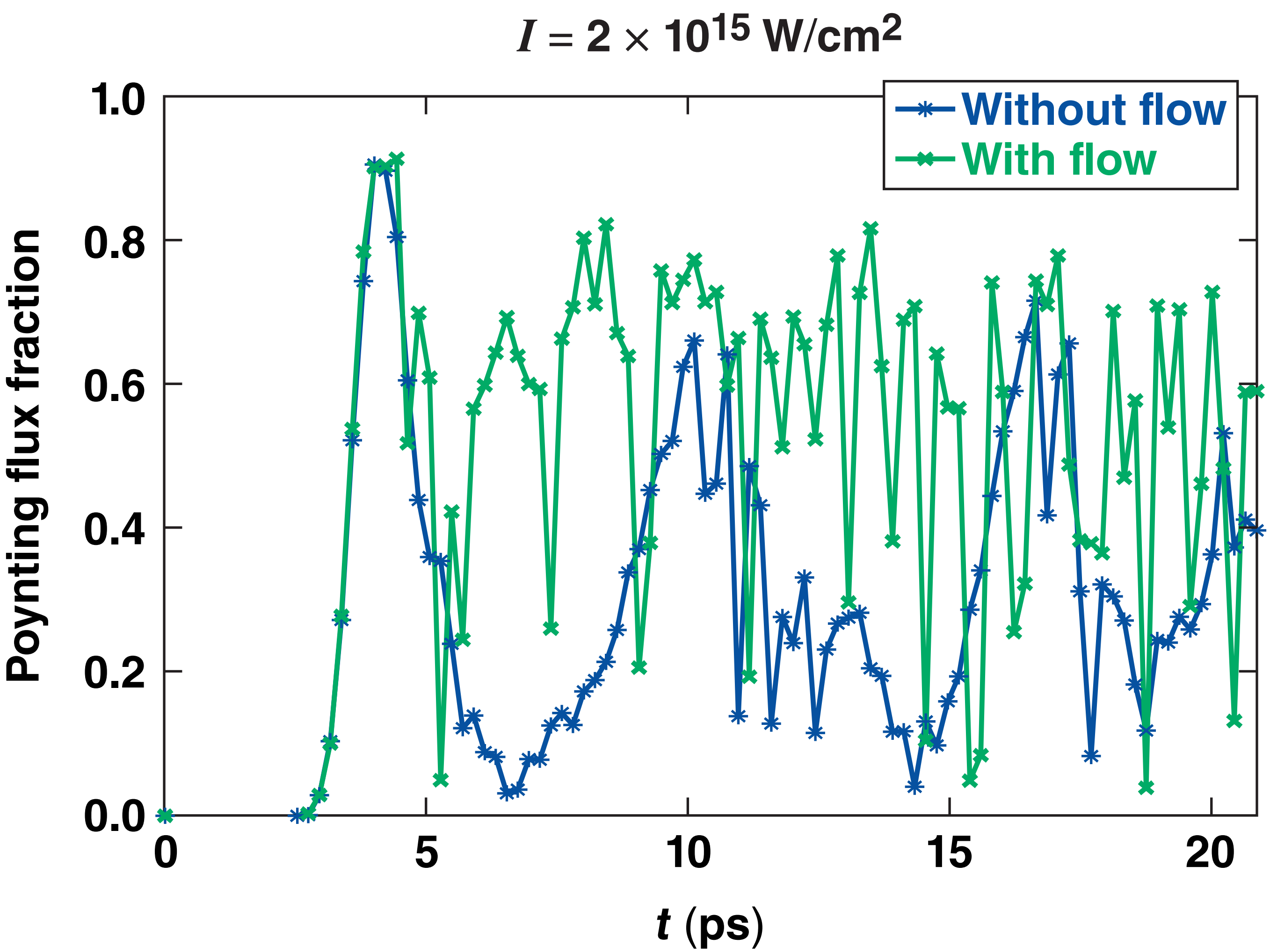
L. Hao *et al*., Phys. Plasmas 23, 042702 (2016).

Significant pump depletion is seen at $n = 0.17\ n_c$



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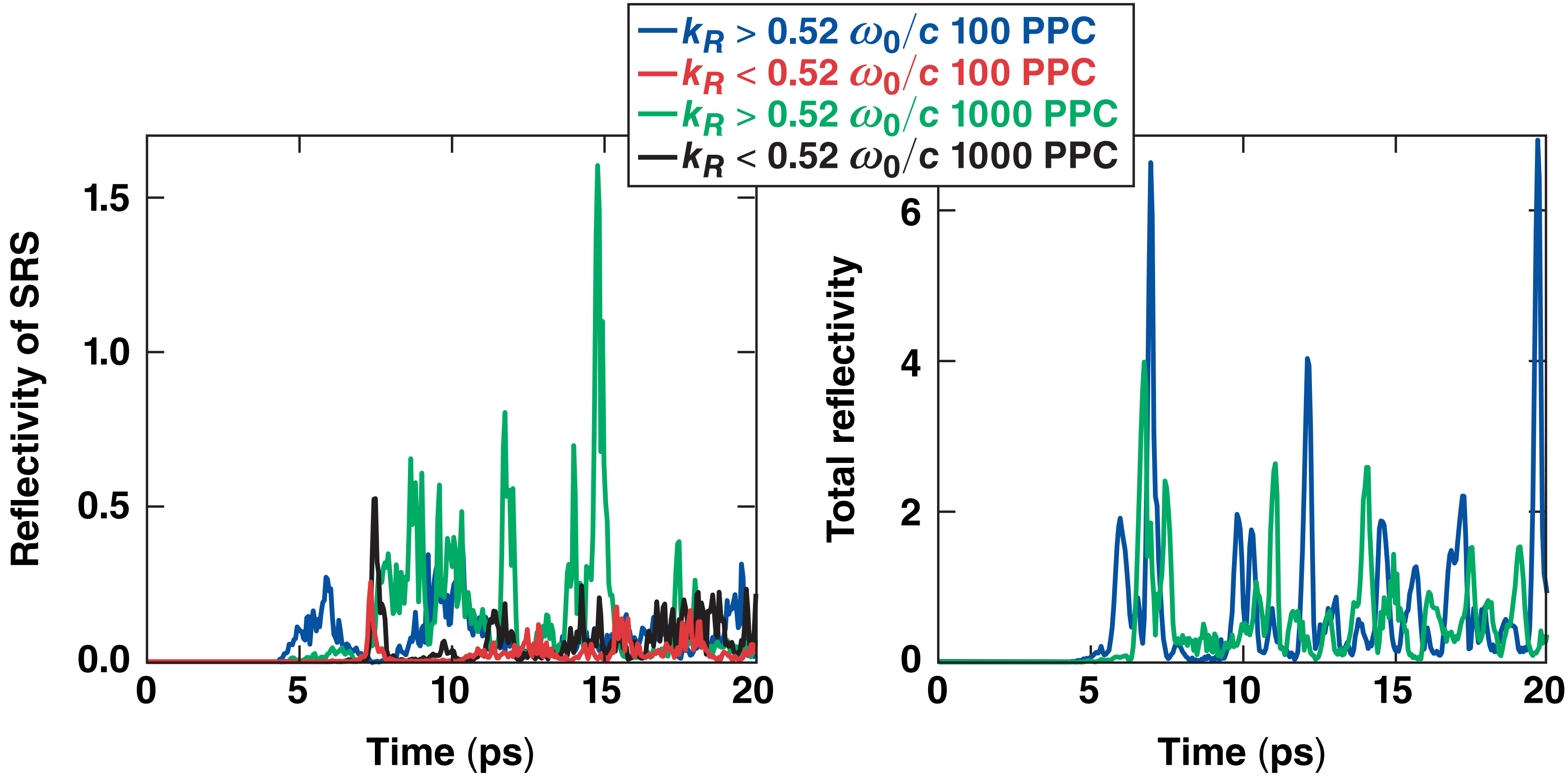
Significant SRS is also seen at high intensities

$I = 5 \times 10^{15}$ W/cm^2, low T
100 PPC = 64% total, 50% SBS, 14% SRS
1000 PPC = 50% total, 30% SBS, 20% SRS



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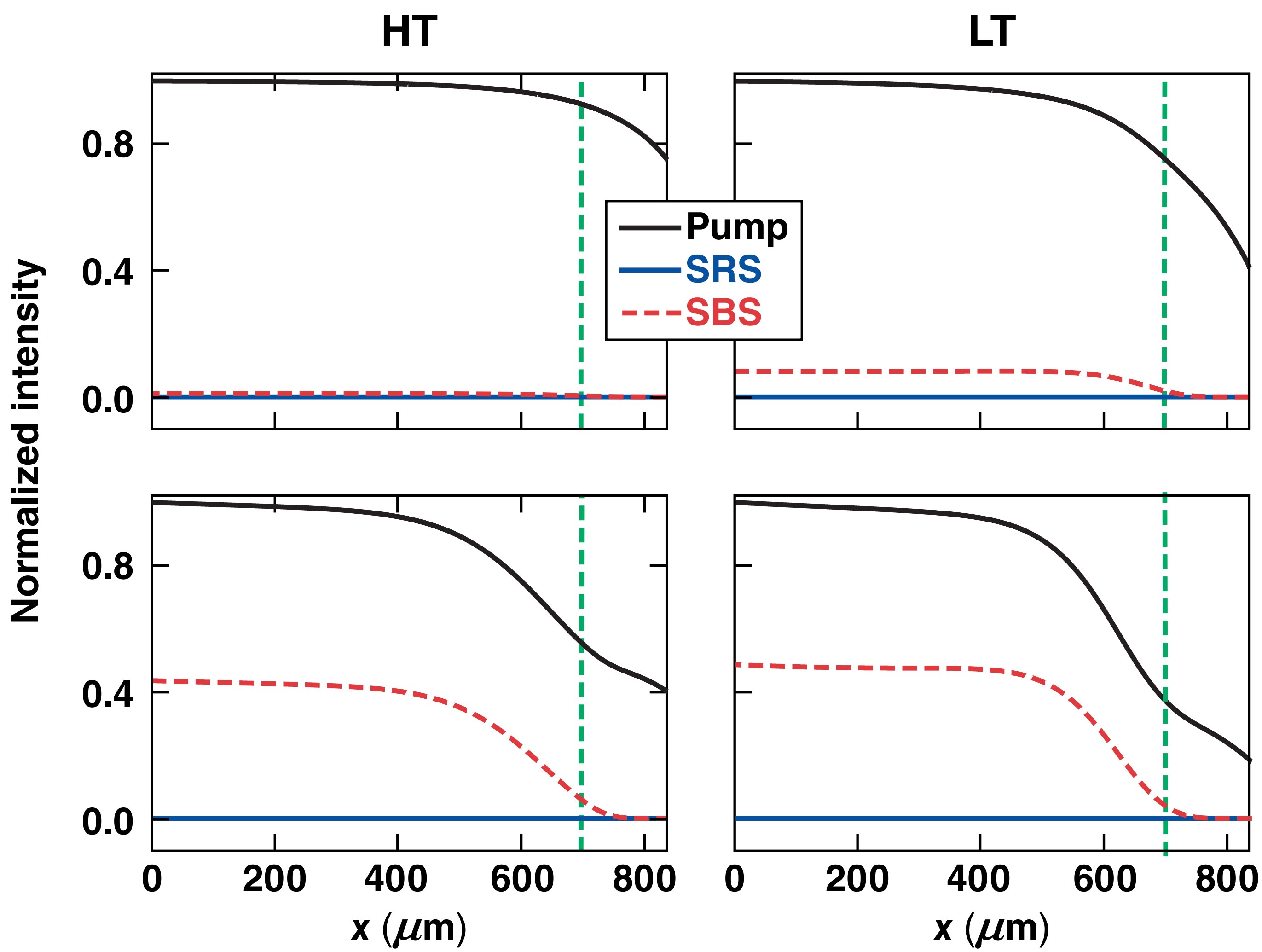
PPC: particles per cell

Fluid simulations with *HLIP* see smaller reflectivities

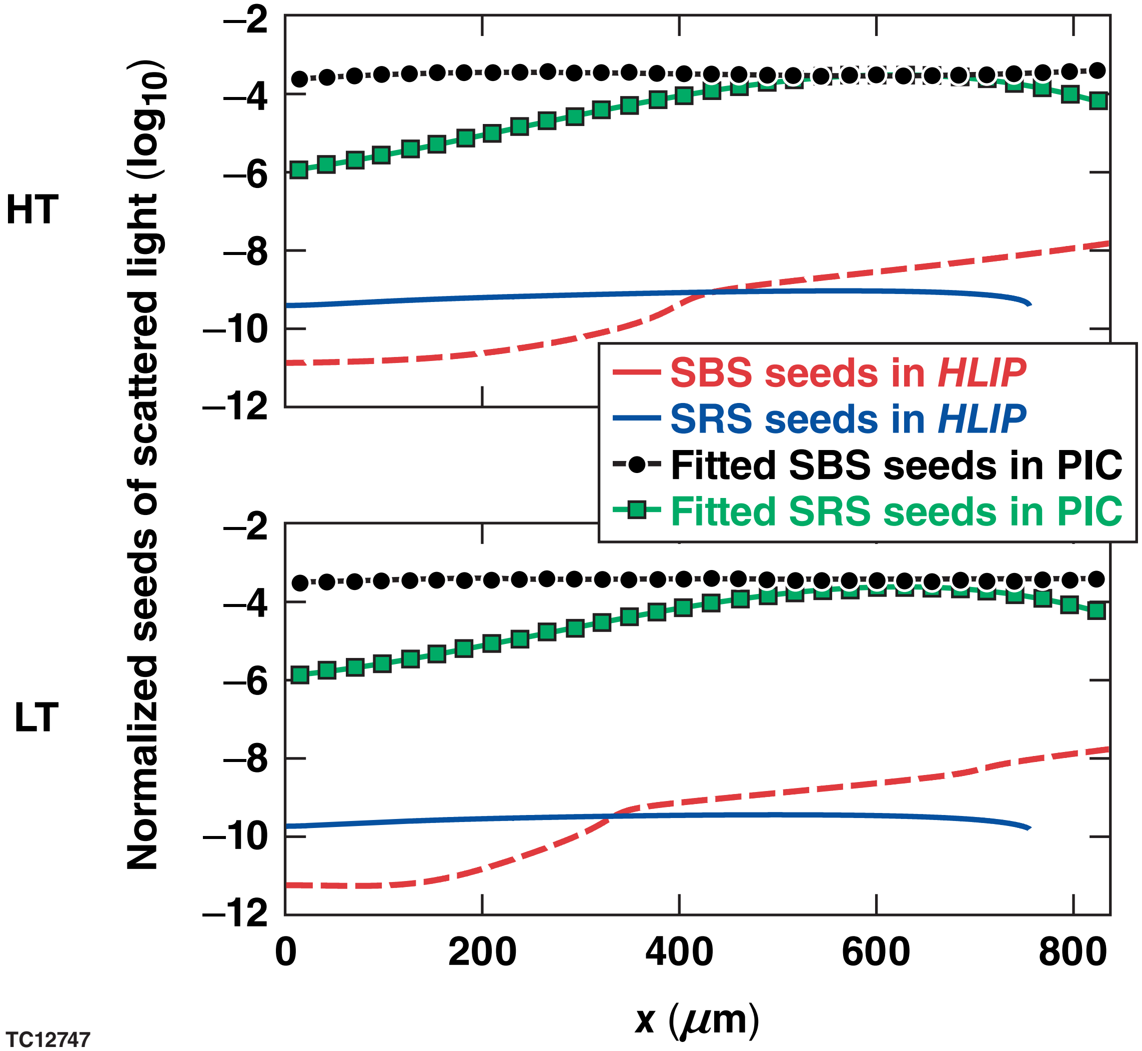
2×10^{15} W/cm^2

5×10^{15} W/cm^2



*L. Hao *et al*., Phys. Plasmas 21, 072705 (2014).

Compared to *HLIP*, *OSIRIS* has kinetic and nonlinear physics but also higher seed levels for convective SRS and SBS



- High seed levels can lead to high saturation levels for convective modes
- *HLIP* lacks nonlinear physics such as density-modulation–induced absolute SRS*

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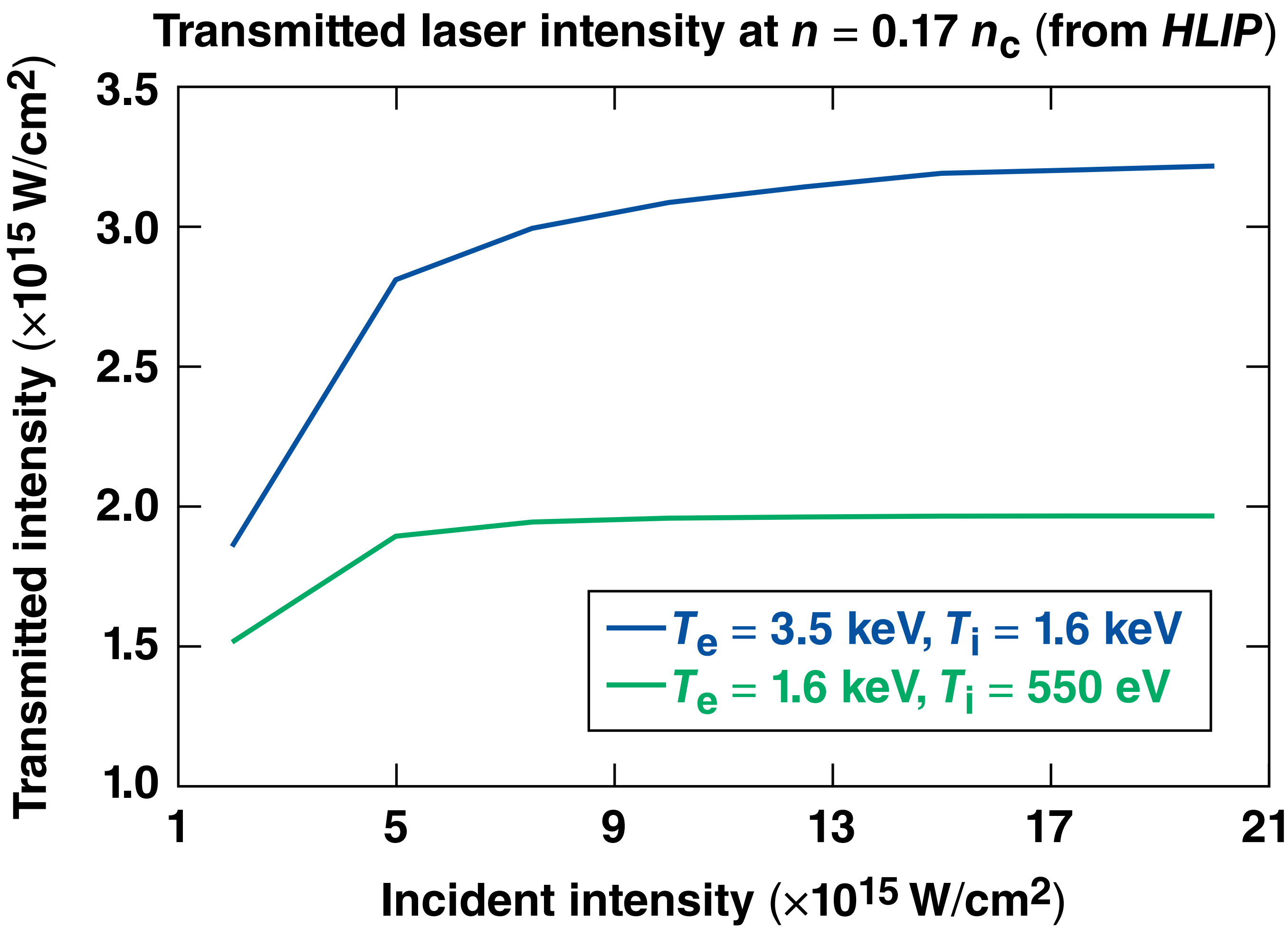
*J. Li, this conference.

Laser transmittance may be limited by LPI



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Open questions

- Modeling of LPI coupling in the entire coronal region
  - computation challenge (10^{20} FLOPS in 2-D)
  - seed levels for convective modes
- Coupling LPI and hydro simulations
- Integrated design for ICF

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FLOPS: floating-point operations per second

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