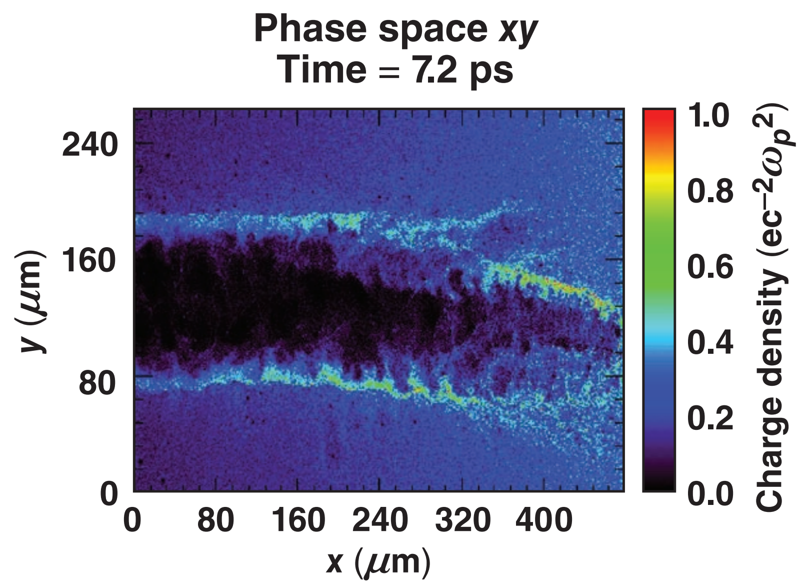
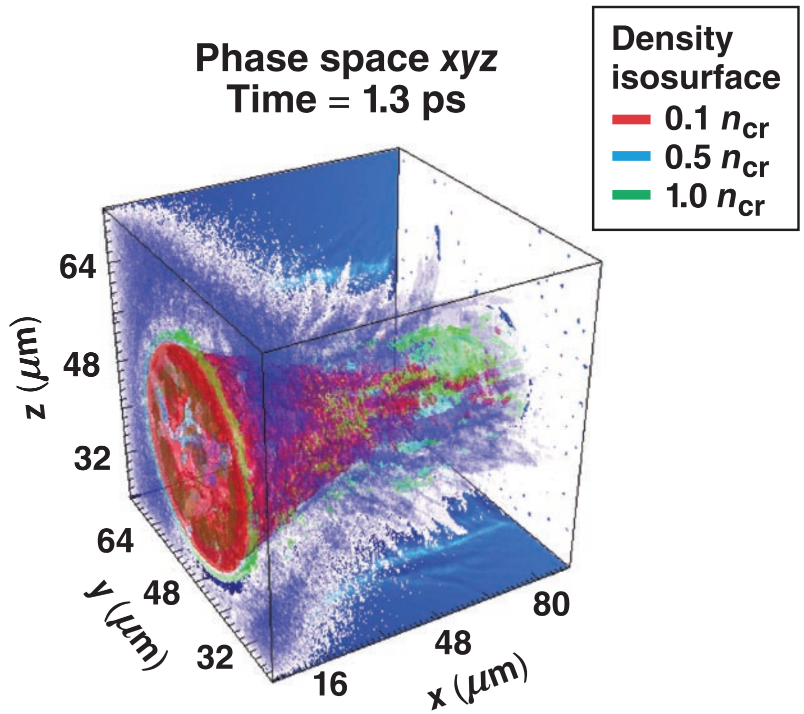
Laser Channeling in Millimeter-Scale Underdense Plasma of Fast Ignition





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49th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Orlando, FL
12–16 November 2007

Summary

A clean channel can be established by a high-intensity laser in the underdense plasma of fast-ignition targets

- Laser channeling in mm-scaling plasmas is a highly nonlinear and dynamic process.
- Channel bifurcation/self-correction leads to oscillating $v_c << v_g$
  - laser snowplowing causes $v_c \sim v_{hb}$
- A lower-intensity pulse reduces the required energy
  - the T_c < 100-ps requirement sets $I_{min} = 5 \times 10^{18}$ W/cm^2 and E_c = 3 kJ
- Channeling significantly improves the ignition-pulse transmission

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Collaborators

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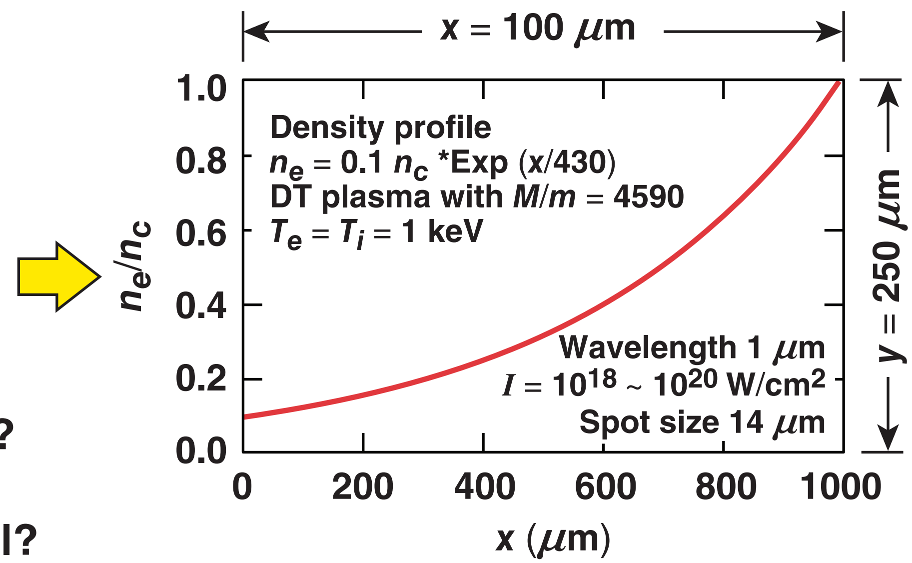
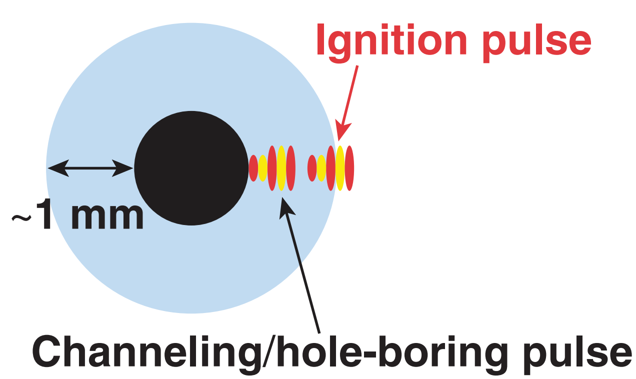
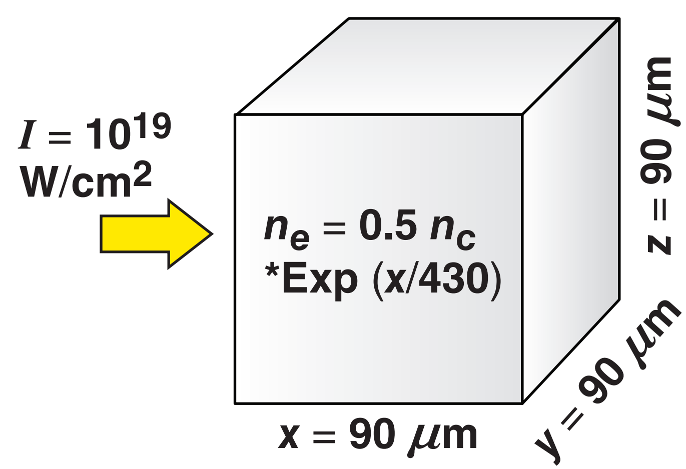
Channeling in the underdense plasma can reduce the energy loss of the ignition pulse

- An initial channeling pulse can be used to establish a channel to reduce energy loss of the ignition pulse
- We have performed 2-D and 3-D PIC simulations to find
  - what is the channel-advancing speed?
  - what is the required pulse energy?
  - what is the transmittance of the ignition pulse through the channel?







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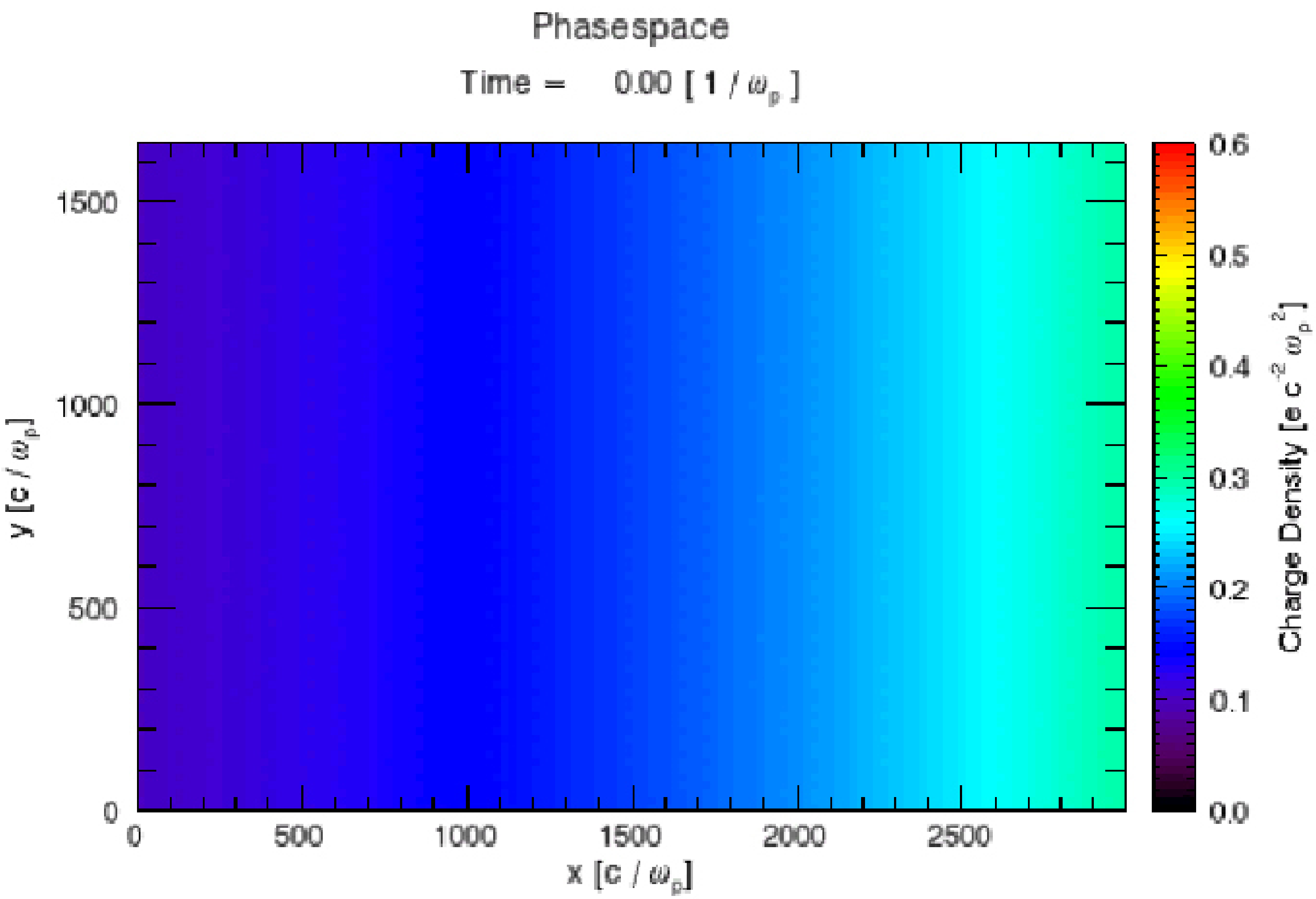
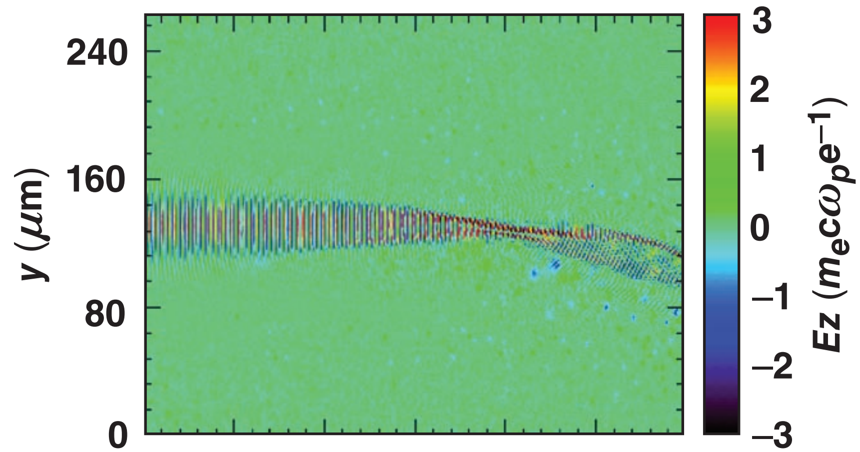
Channeling is a complicated process involving many nonlinear phenomena



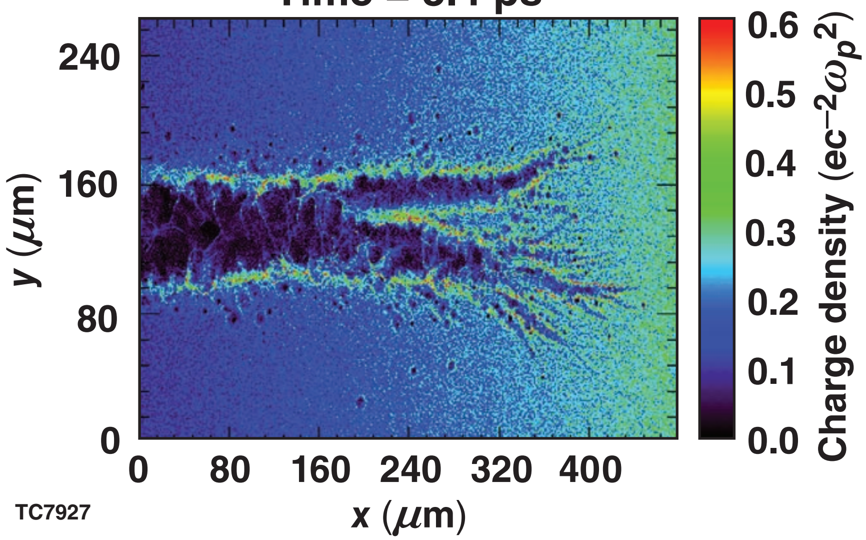
Longitudinal channel advancing is intermittent

- Longitudinal advancing involves many highly nonlinear processes
  - plasma piling up
  - laser hosing/refraction leads to channel bending
  - channel bifurcation/ self-correction
- These phenomena can be observed only in simulations with $L_x > 100\ \mu$m

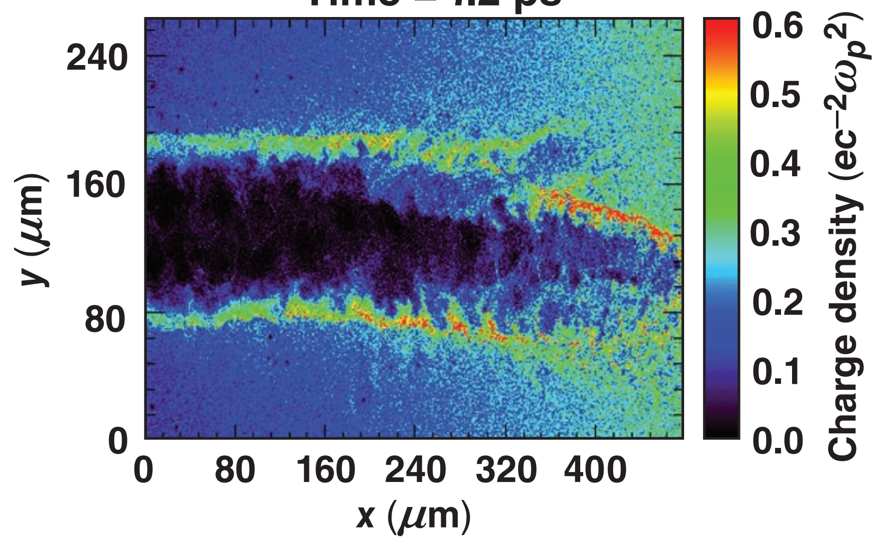
***Ez* field**
Time = 7.2 ps



Phase space *xy*
Time = 3.4 ps



Phase space *xy*
Time = 7.2 ps



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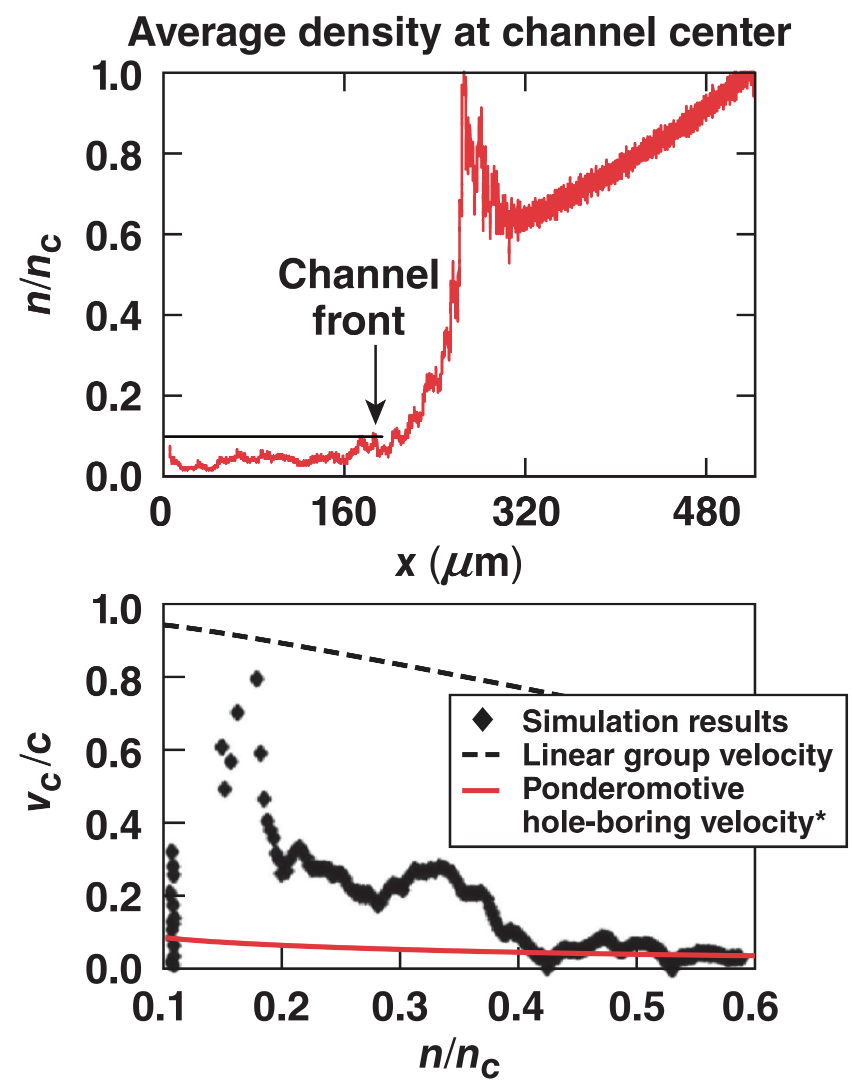
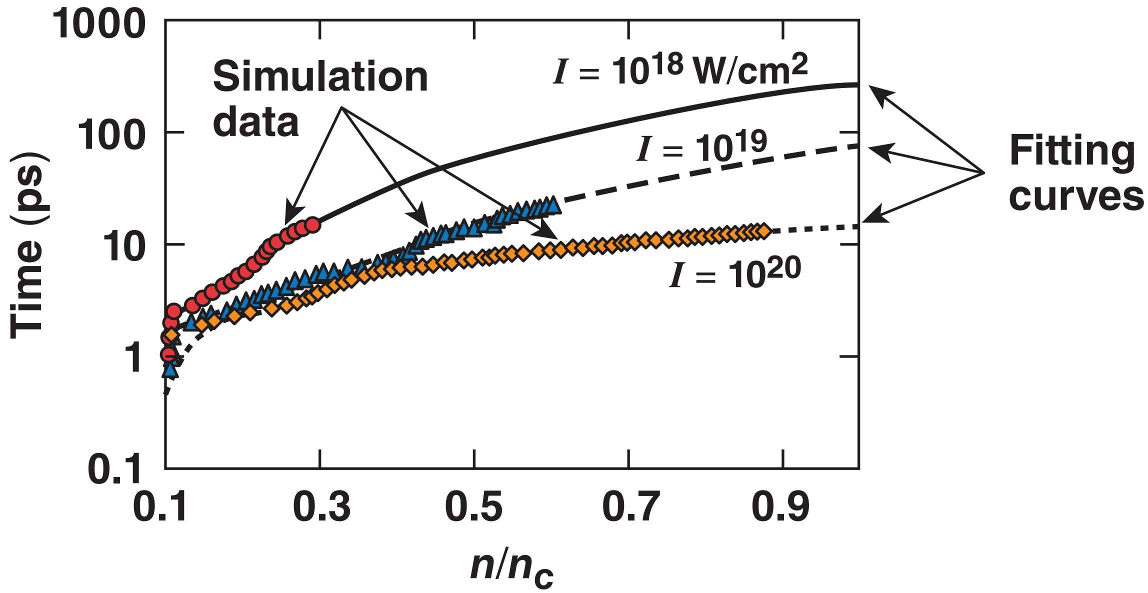
Channeling speed oscillates and asymptotes to hole-boring speed*

- Channeling speed v_c should measure the density-modification speed
- Oscillating v_c reflects the bifurcation-self-correction process
- $v_c << v_g$ and asymptotes to v_{hb}
  - $v_{hb} = 0.6\ c\ (n_c m_e I_{18} \lambda_\mu^2 / n_0 m_i)^{1/2}$
  - v_{hb} assumes 100% laser reflection (not satisfied)



*S. C. Wilks *et al.*, Phys. Rev. Lett. 69, 1383 (1992).

A lower-intensity pulse is preferred to minimize incident laser energy



- Simulation scaling
  - for v_c analysis $T_c = 290\ I_{18}^{-0.64}$ ps and $E_c = 1.71\ I_{18}^{0.36}$ kJ
  - for v_{hb} analysis $T_{hb} = 220 \times L_\mu/430 \times I_{18}^{-0.5}$ ps and $E_{hb} = 1.3 \times L_\mu/430 \times I_{18}^{0.5}$ kJ
- $E_c \sim I_{18}^{0.36}$ shows that a low-intensity pulse is preferred to minimize E_c
- If $T_c < 100$ ps is required, $I_{min} = 5 \times 10^{18}$ W/cm^2 and $E_c = 3$ kJ

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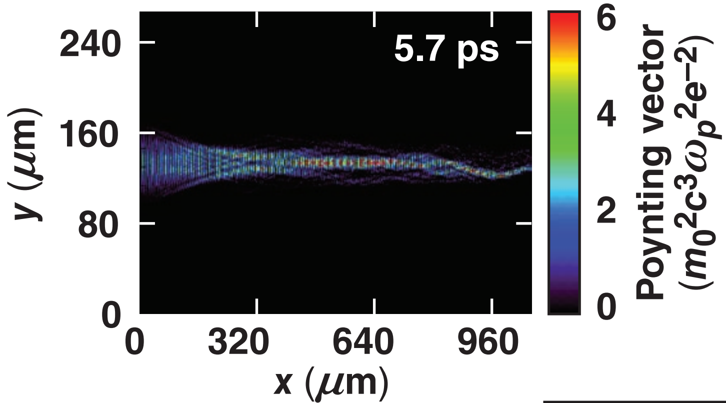
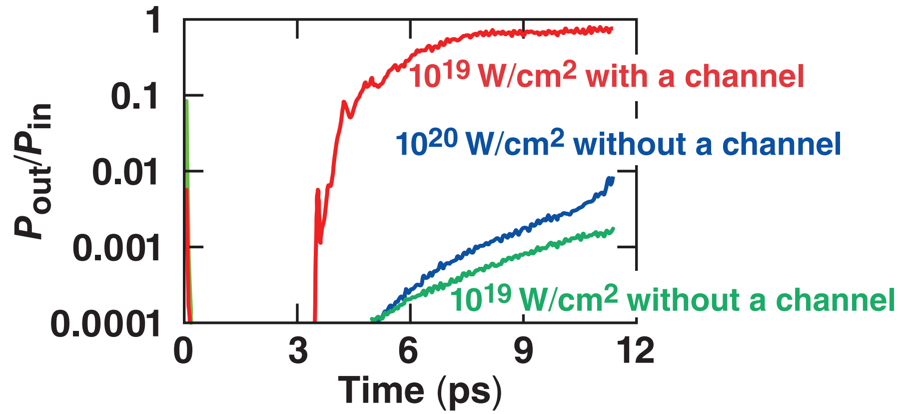
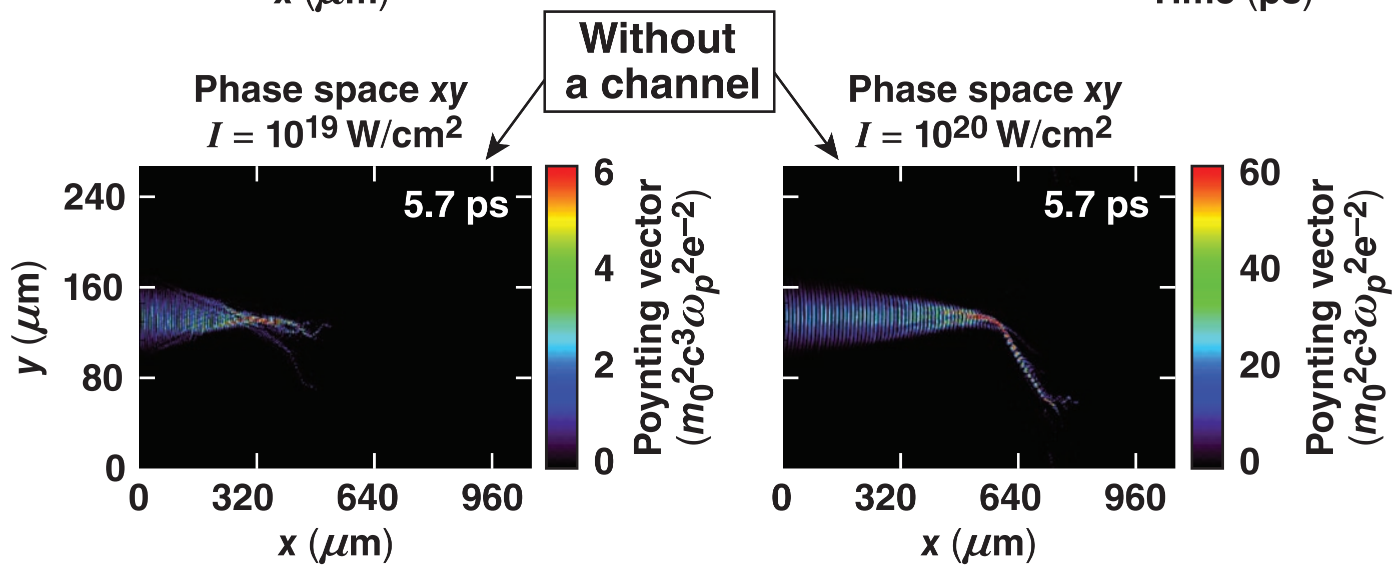
A preformed channel significantly improves the transmission of the ignition pulse

10^{19} W/cm^2 with a channel performed at 0.1 nc

Phase space *xy* ($w_C = w_L$)







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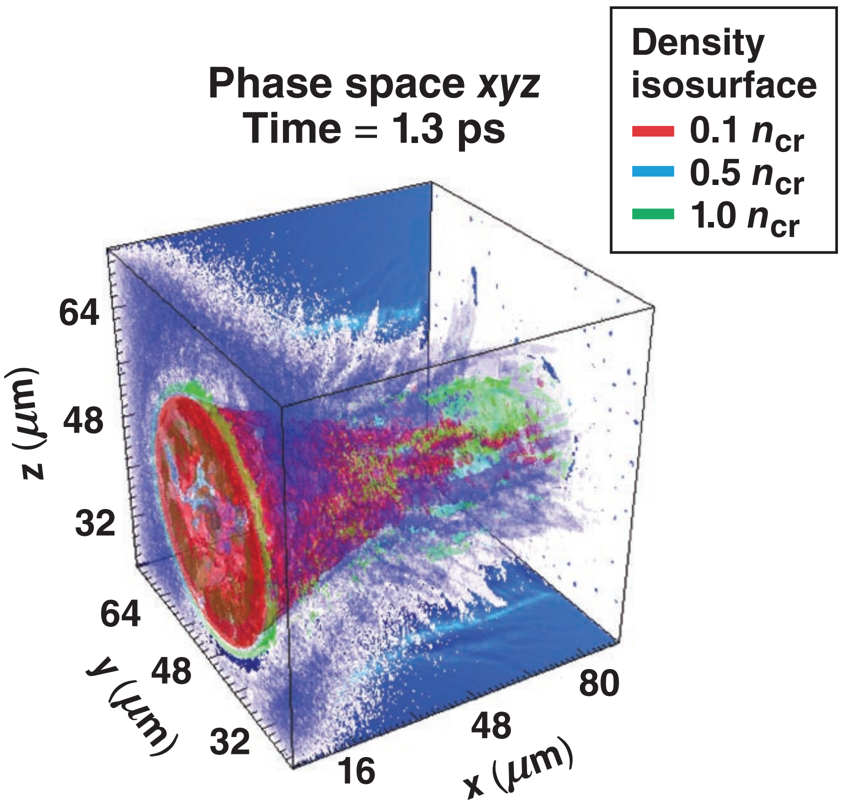
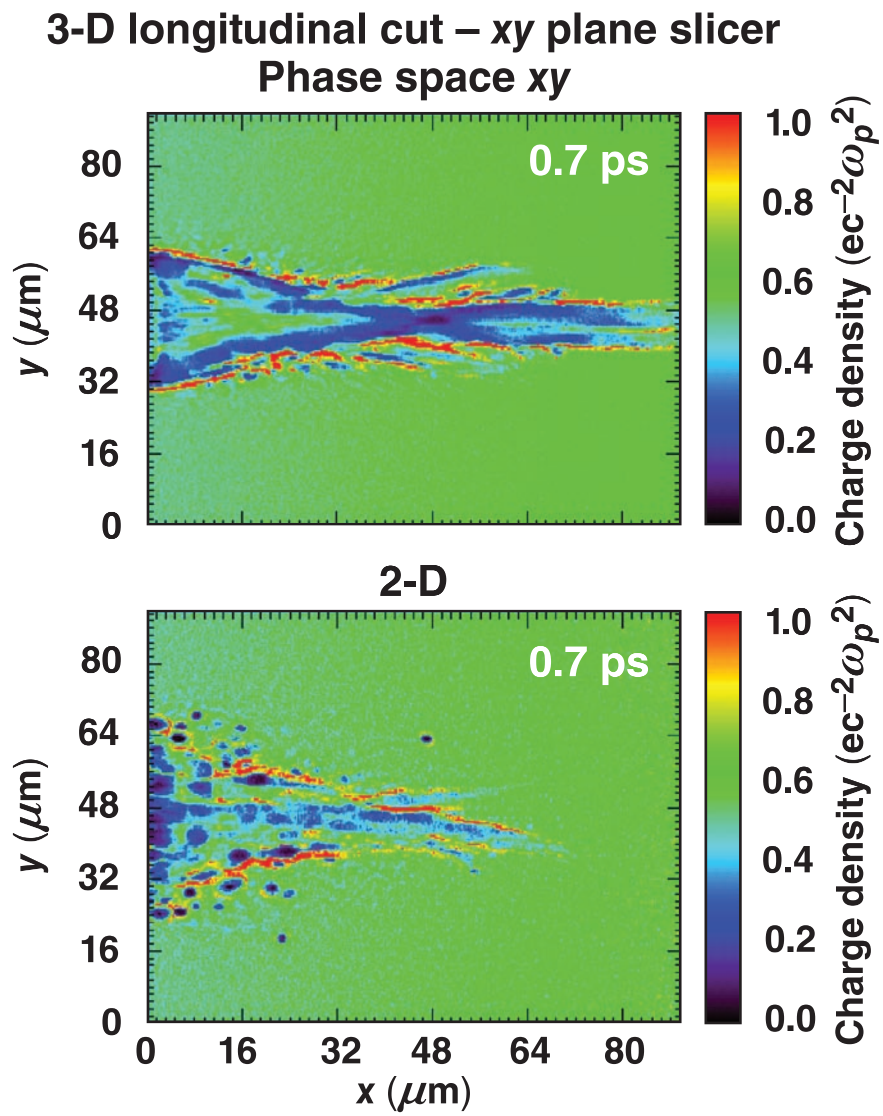
3-D channeling is faster than 2-D because of stronger self-focusing





For 3-D: w^2a^2 = const

For 2-D: wa^2 = const

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Summary/Conclusions

A clean channel can be established by a high-intensity laser in the underdense plasma of fast-ignition targets

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