Laser Channeling in mm-scale Underdense Plasmas of Fast Ignition Targets

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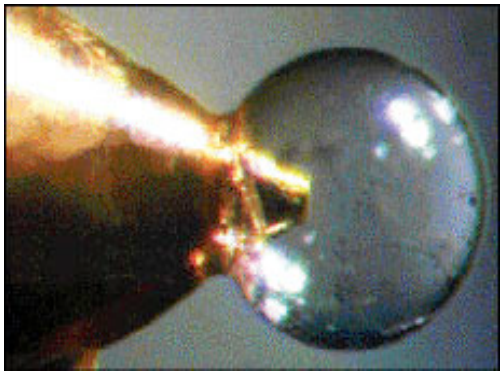
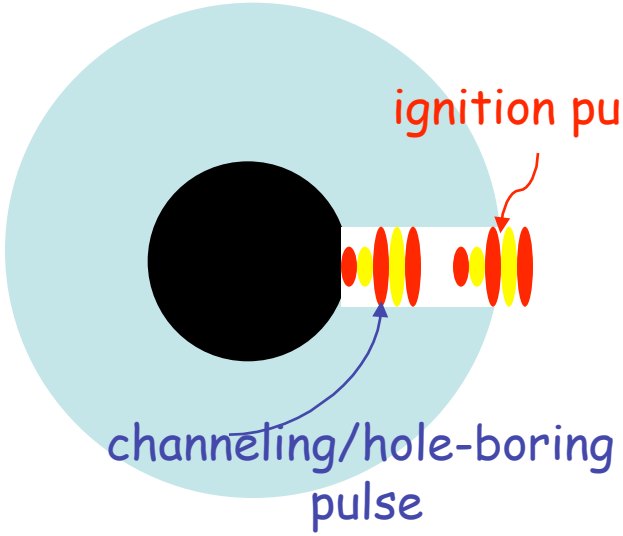
Channeling reduces energy loss for the ignition pulse in fast ignition



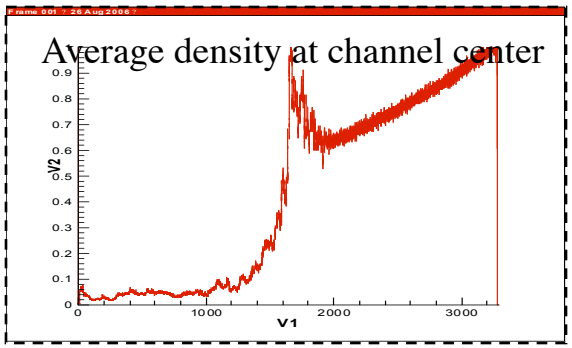


- High-intensity ignition pulse can lose energy in the mm underdense corona of the FI targets
- Two ways of avoiding loss in corona
  - Using cone targets
  - Using a channeling pulse allows
    - Symmetric implosion
    - Avoid issues associated with a gold cone
    - May not place the ignition pulse as close
- Key questions
  - Can laser create a straight channel?
  - What is the channeling speed?
  - What is the optimum intensity for the channeling pulse
    - Density- and intensity-scalings

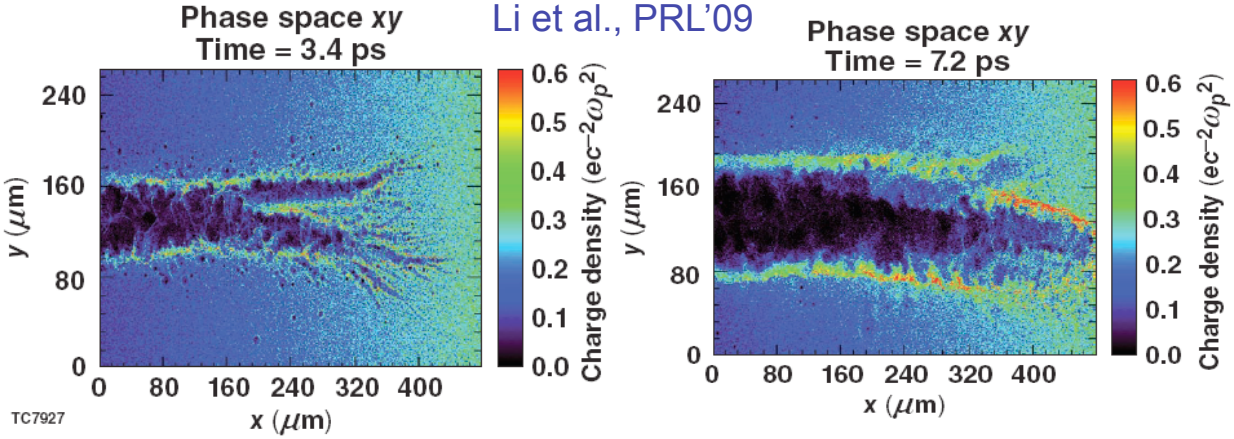
Laser channeling in mm scale plasmas is a highly nonlinear and dynamic process

- Previous experiments and simulations on channeling used 100-μm plasmas

- Full-scale 2D simulations with OSIRIS show many non-linear phenomena
  - plasma piling up
  - laser hosing/refraction leads to channel bending
  - channel bifurcation/self-correction

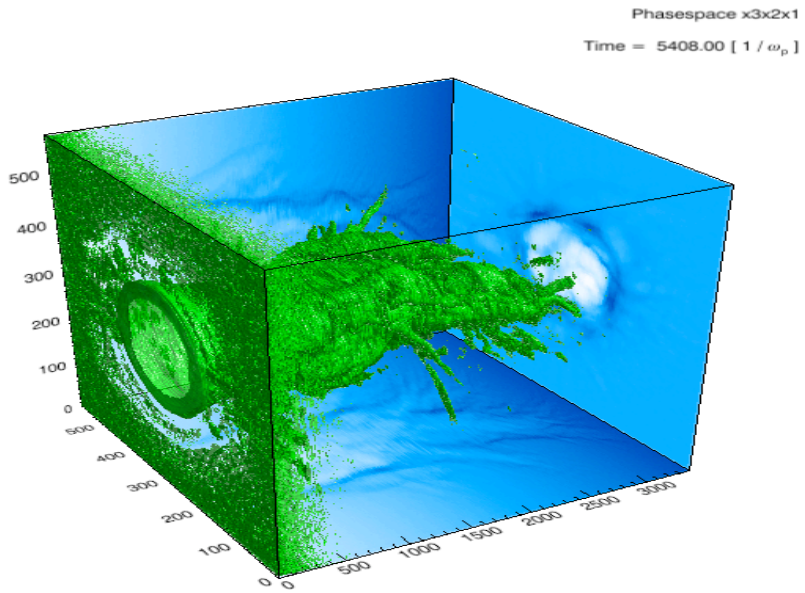


Li et al., PRL'09

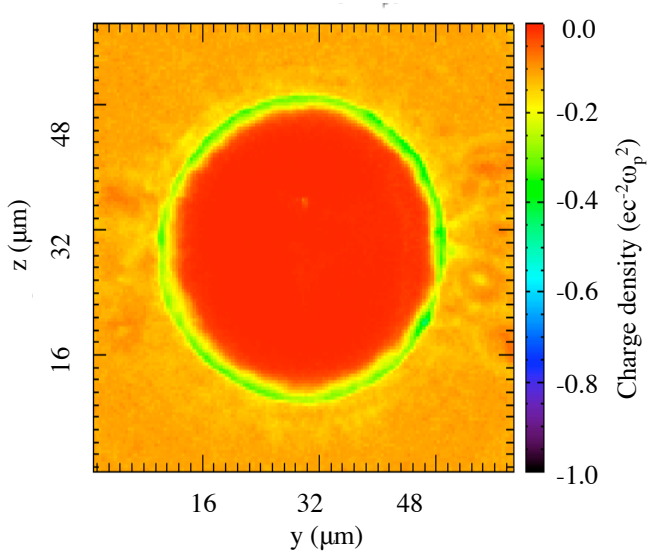


3D simulations have also shown the same nonlinear and dynamic phenomena

3D simulations [up to 540μm×(90μm)^2 plasma, 17 billion particles]

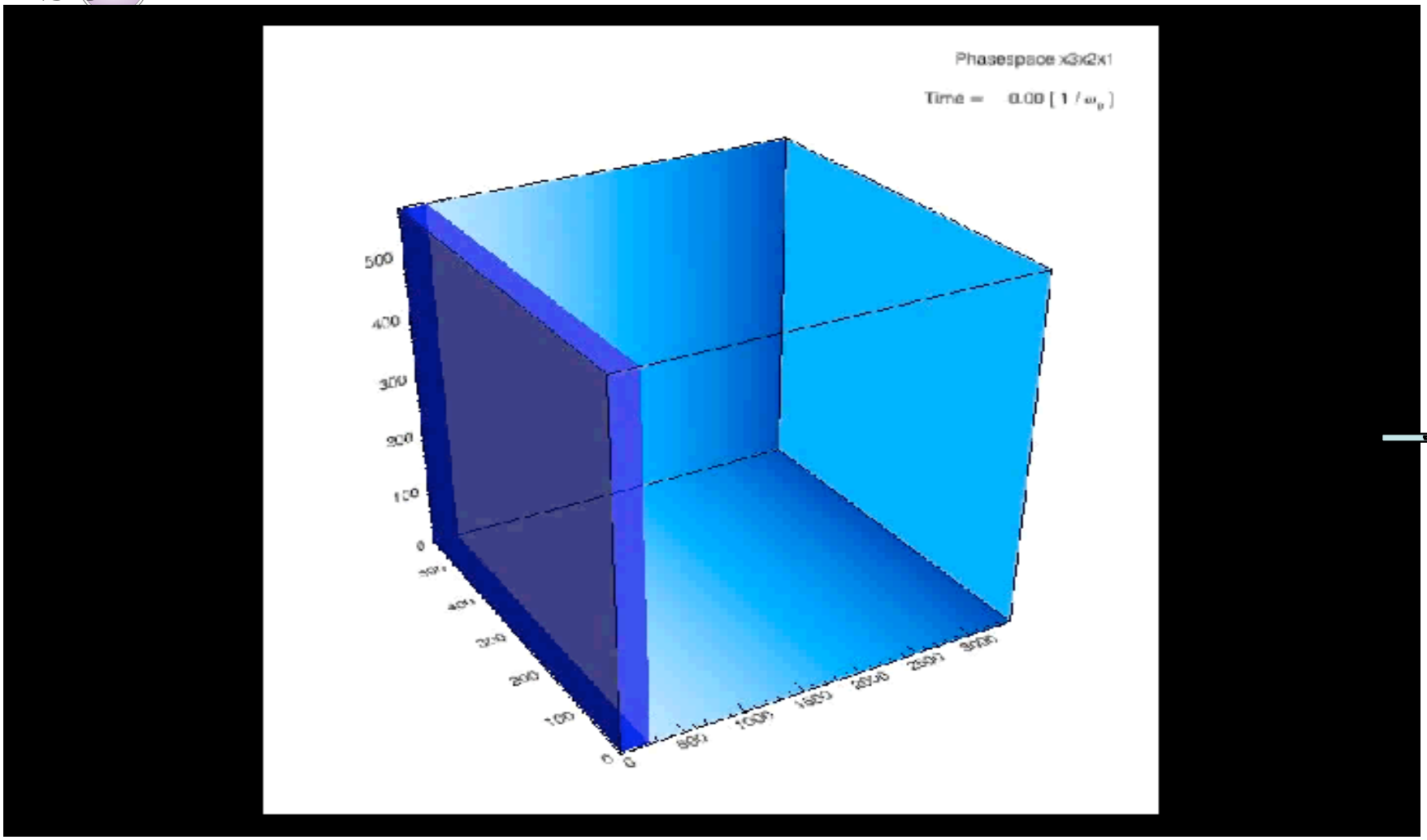


Laser hosing/channel bending
& branching/self-correction seen in 3D

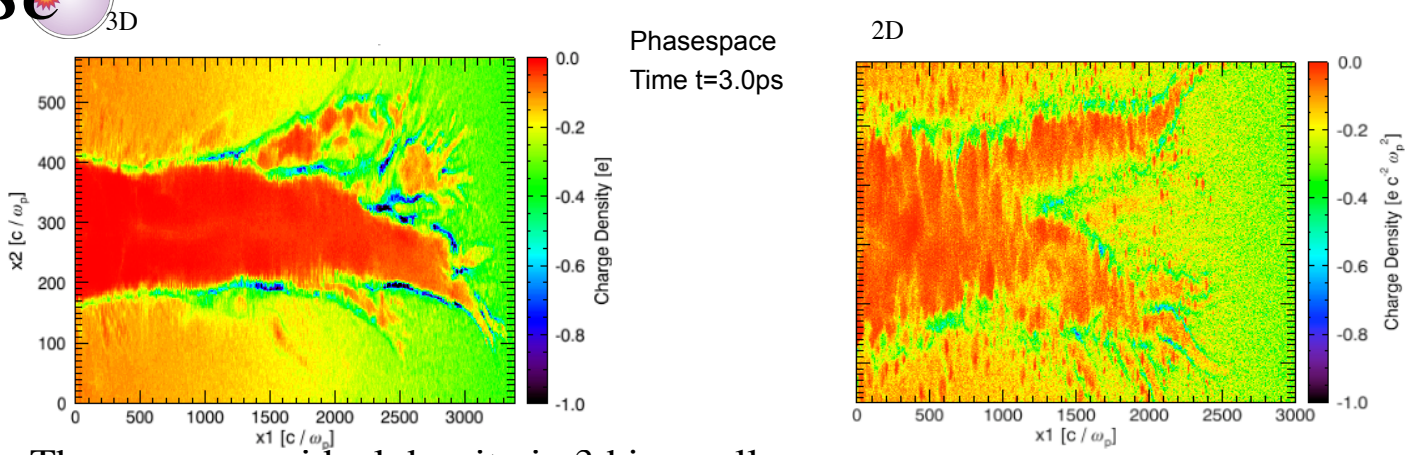


The eventual channel cross section is round

3D simulations have also shown the same nonlinear and dynamic phenomena

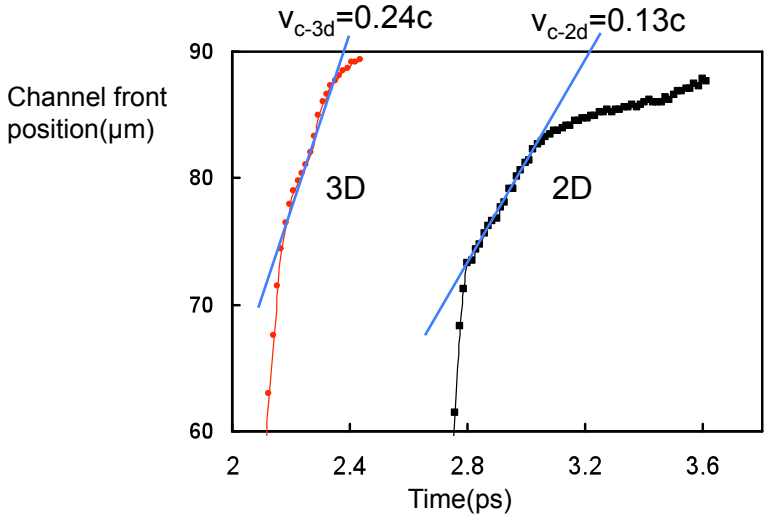


3D simulations show a larger channeling speed than in 2D



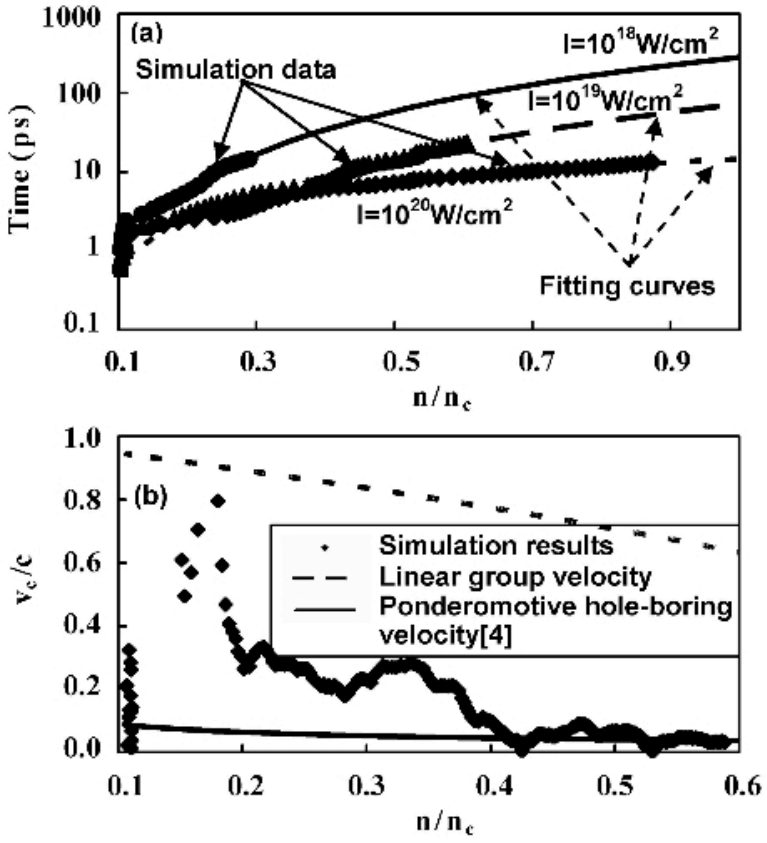
The average residual density in 3d is smaller

V_{3D} =2 V_{2D} due to stronger laser self-focusing and easier channeling in 3D



Lower intensity pulse reduces channeling energy

- 2D Simulation scaling
  - $T_c=290I_{18}^{-0.64}$ps & $E_c=1.7I_{18}^{0.36}$kJ
- 3D results indicate T_c & E_c may be halved
  - For $I_{18}=2$, $T_c=93$ ps & $E_c=1.1$kJ
  - In the OMEGA/EP parameter range



A preformed channel significantly improves the transmission of the ignition pulse

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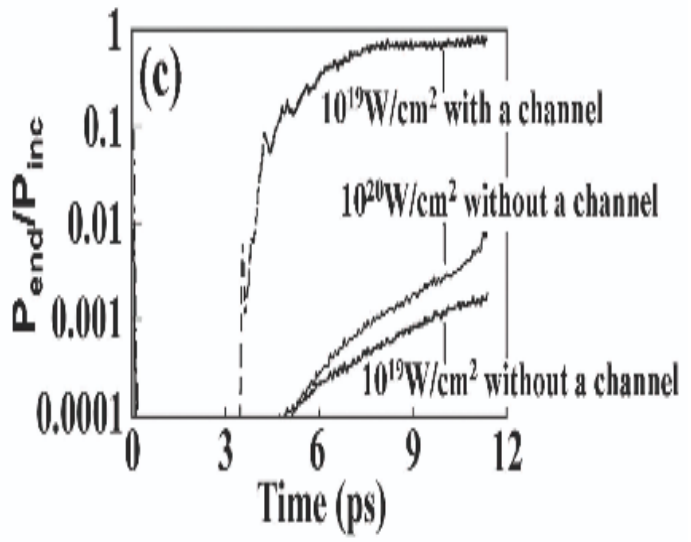
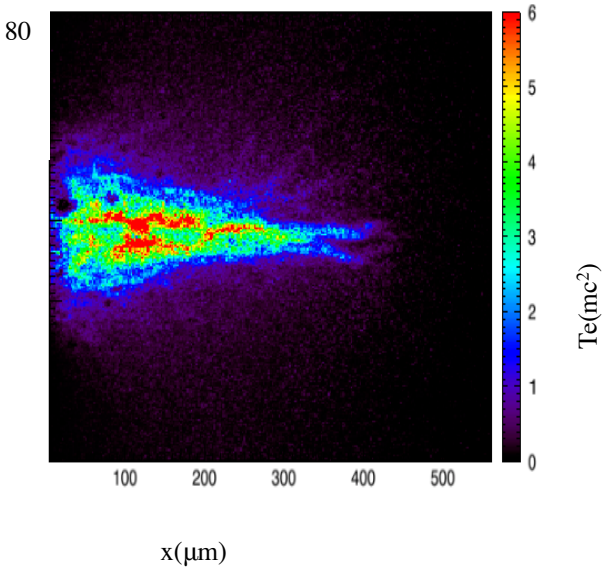
- The residual plasma is heated to relativistic temperatures
  - $\langle\gamma\rangle \sim 12$
  - Reduced ponderomotive force
  - Reduced nonlinear interactions





Summary

Laser channeling can produce a regular, low-density channel in FI targets

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- Laser channeling in mm-scale plasmas is a highly nonlinear and dynamic process
- Lower-intensity pulse reduces total energy
- Electrons are heated to relativistic temperatures, which reduces laser-plasma coupling in the channel
- A low-density channel can significantly increase the transmission of the ignition pulse
- Experiments will increase our confidence in the codes and the new designs they can provide