Integrated 1D PIC Simulation of Fast Ignition

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1D PIC Simulations provide insight into fast ignition physics

Important physics in FI

- Hot electron and fast ion generation
- Energy transport through coronal plasma
- Collisional energy coupling to core plasma
- Wave dampening in collisional plasmas

1D simulations performed to optimize the ignition laser pulse.

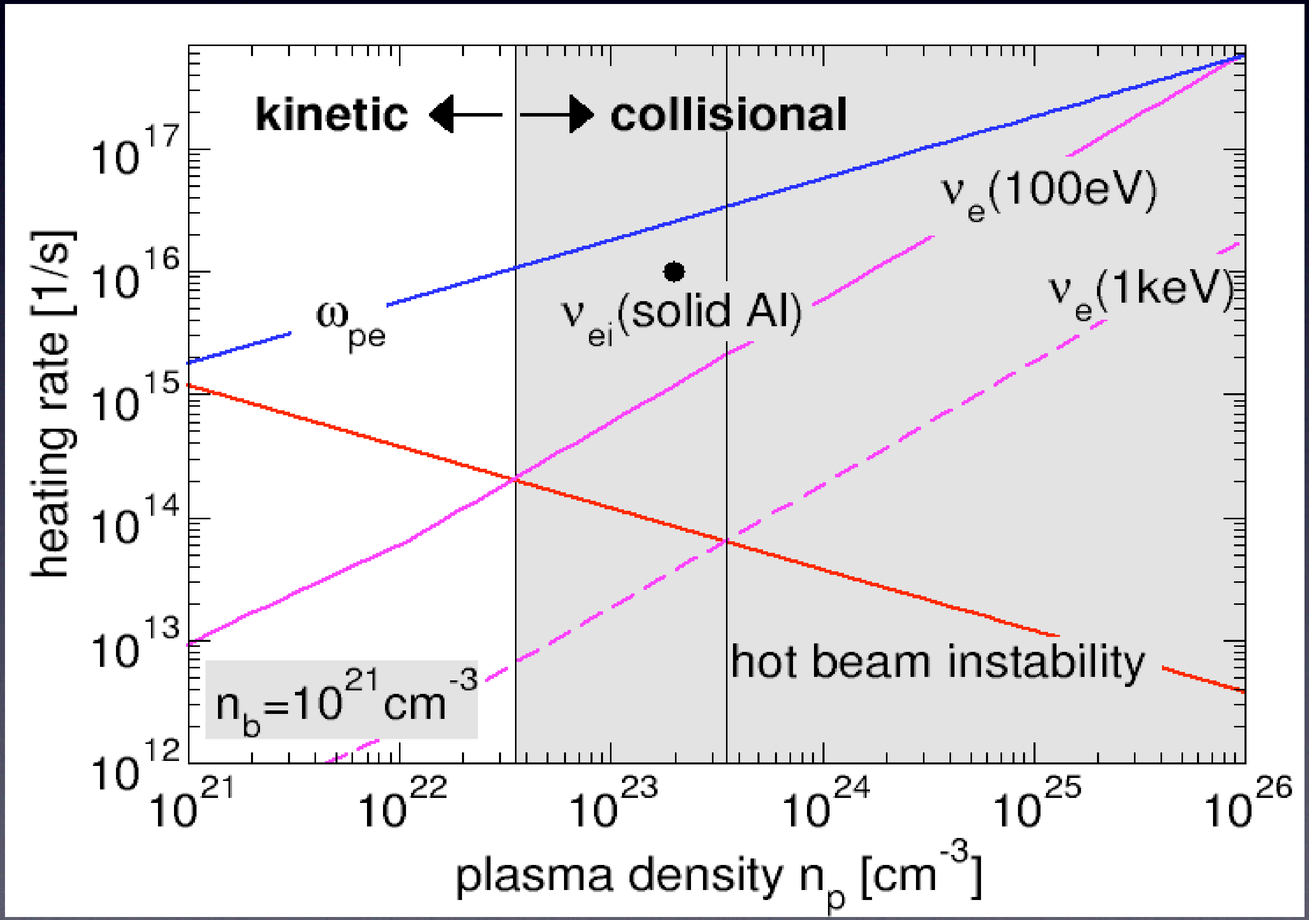
Aggregate energy coupling between laser and core heating increases with intensity

Collisional effects dominate energy transport at high densities (> 10^{23} $1/cm^3$)

Collisions suppress longitudinal beam-plasma instabilities.

Collisional processes dominate the core heating.

Our model treats smooth transition from kinetic to Monte Carlo regime.



$$\Gamma_L = \frac{\sqrt{3}}{2^{4/3}} \omega_p (n_b / n_p)$$

Beam instability

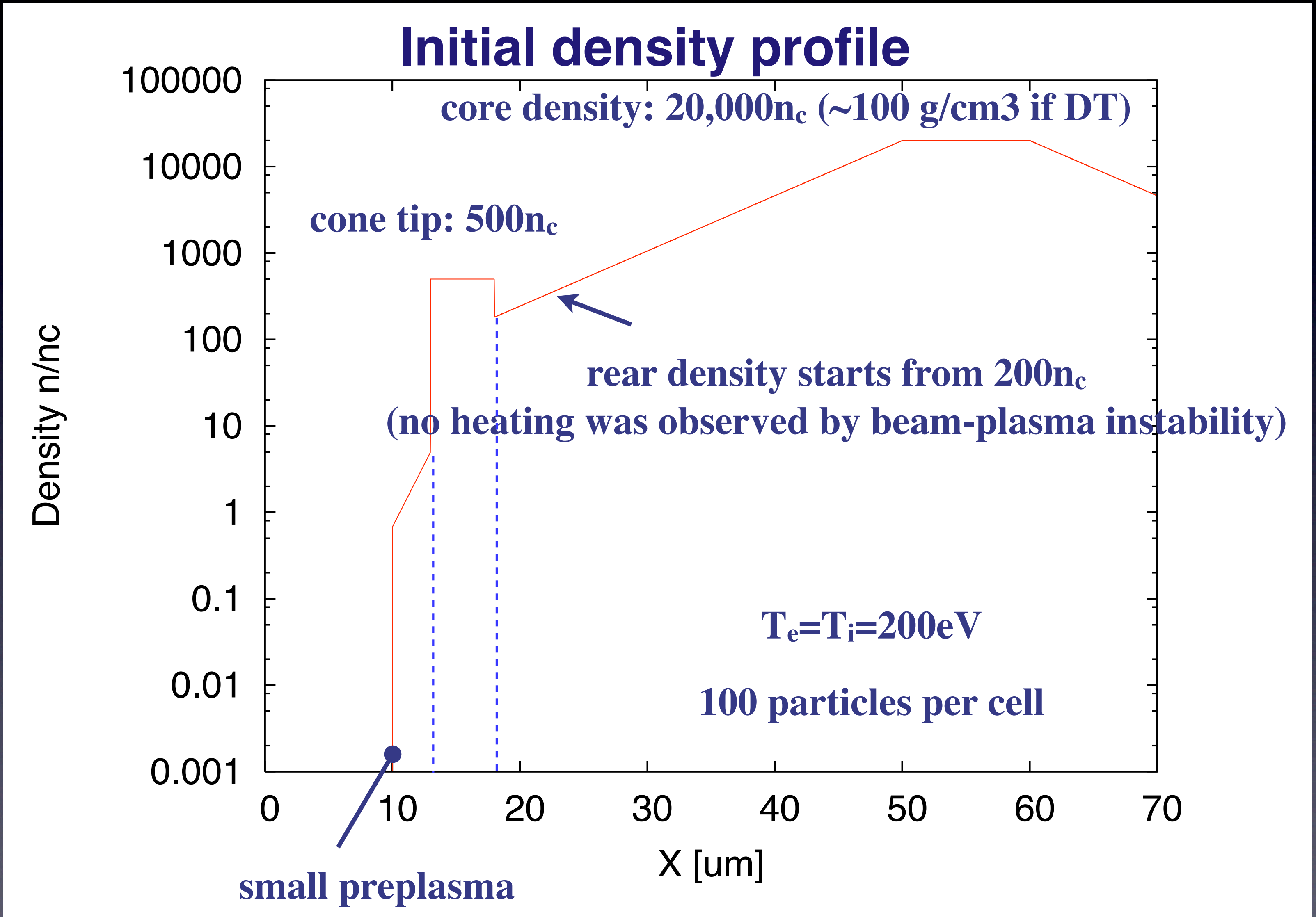
n_b: beam density

n_p: plasma density

Detail will be discussed in presentation by A. Kemp

1D Model of Cone guiding fast ignitions

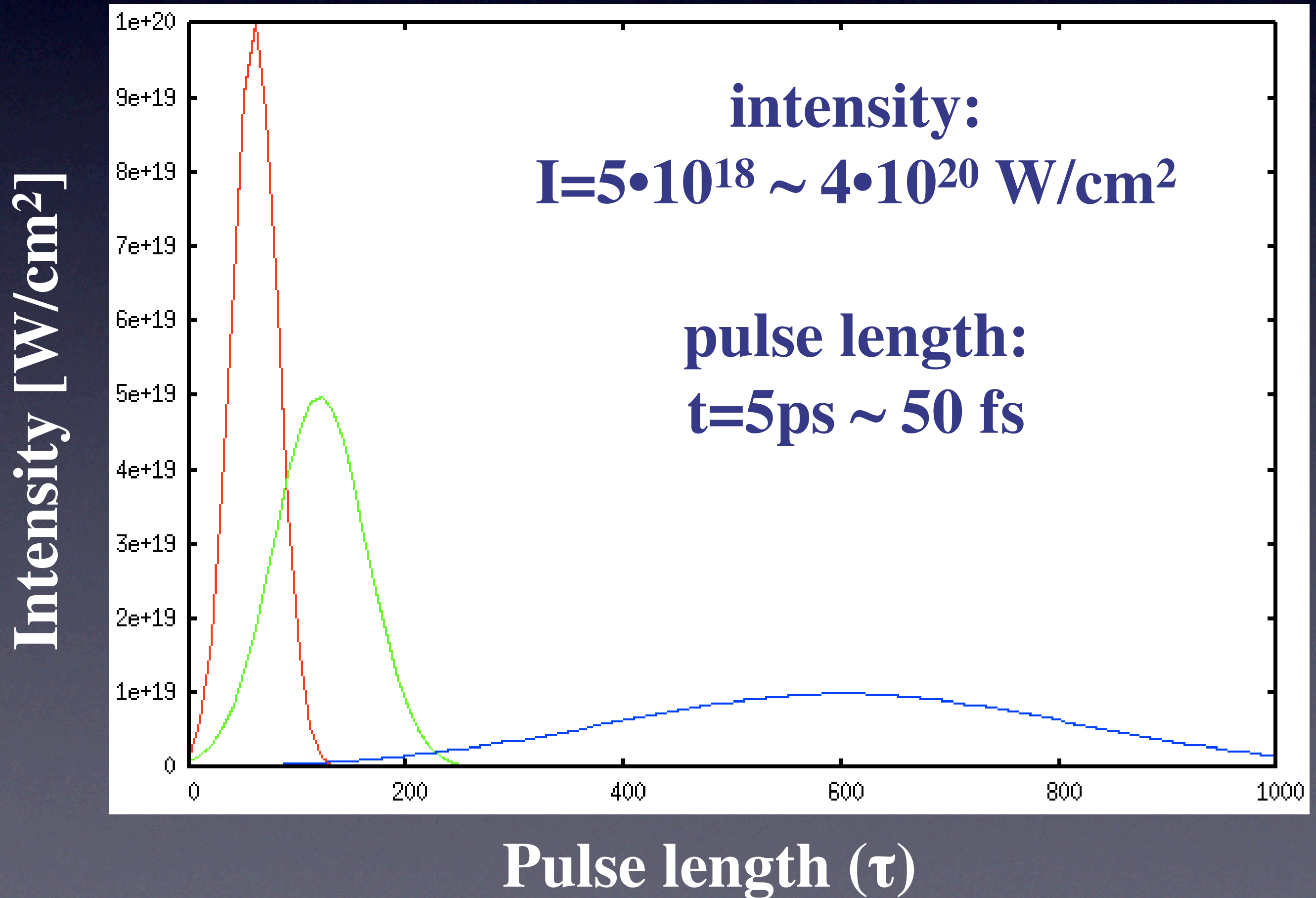
plasma density varies in density from sub critical to 20,000 n_c



4th order interpolation avoids numerical heating for up to 10 ps.

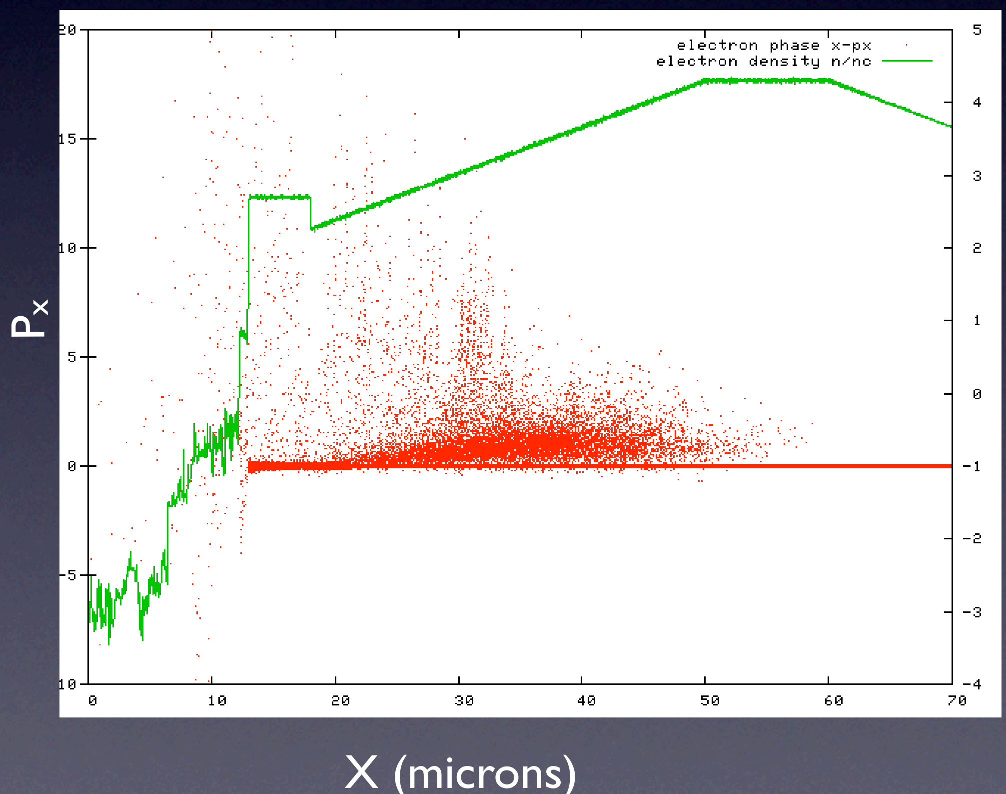
With total laser energy constant, intensities are varied

Intensity range	$5 \cdot 10^{18}$ - $4 \cdot 10^{20}$ W/cm^2
Total laser energy	200J (assuming 30μm spot)

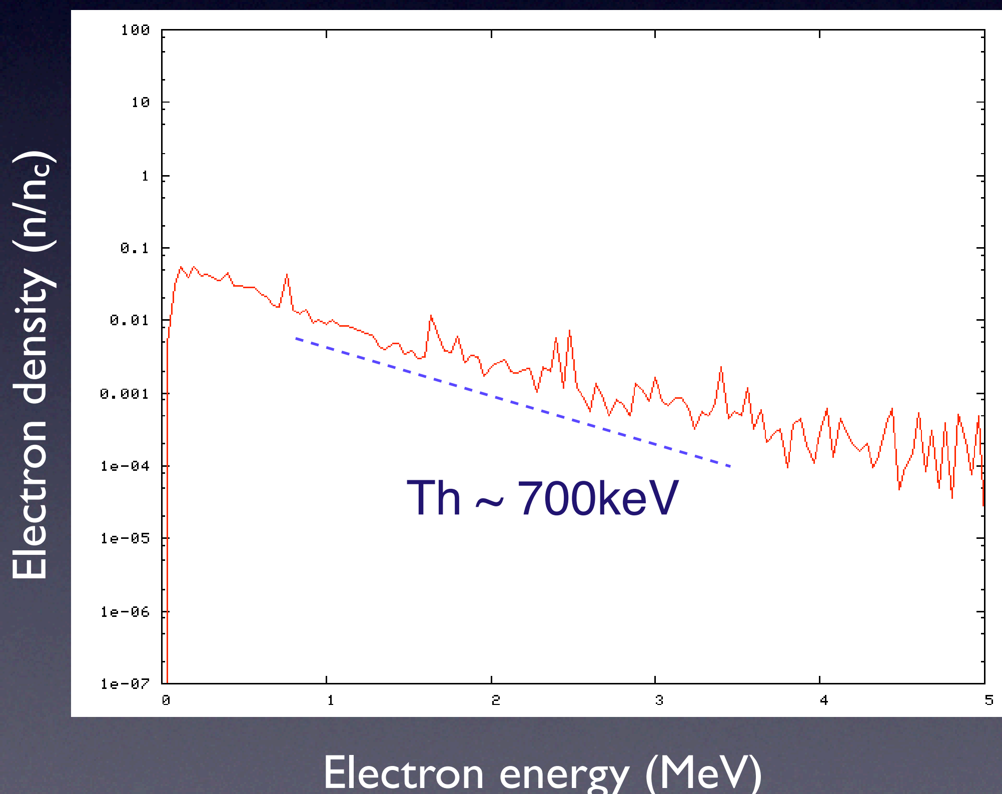


Interaction with pre-plasma generates high energy electrons ($I=5x10^{19}$ W/cm^2, pulse duration 500fs)

Electron phase and density



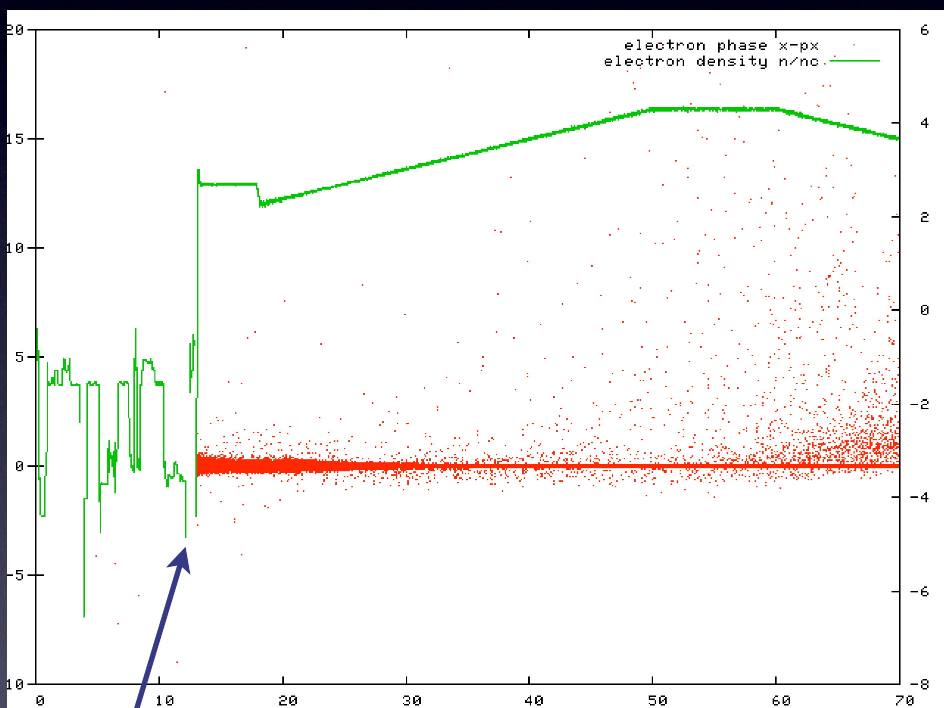
Electron energy spectrum



snapshot at 200fs

Hot electrons temperature drops significantly after preplasma has been swept away

Electron phase and density

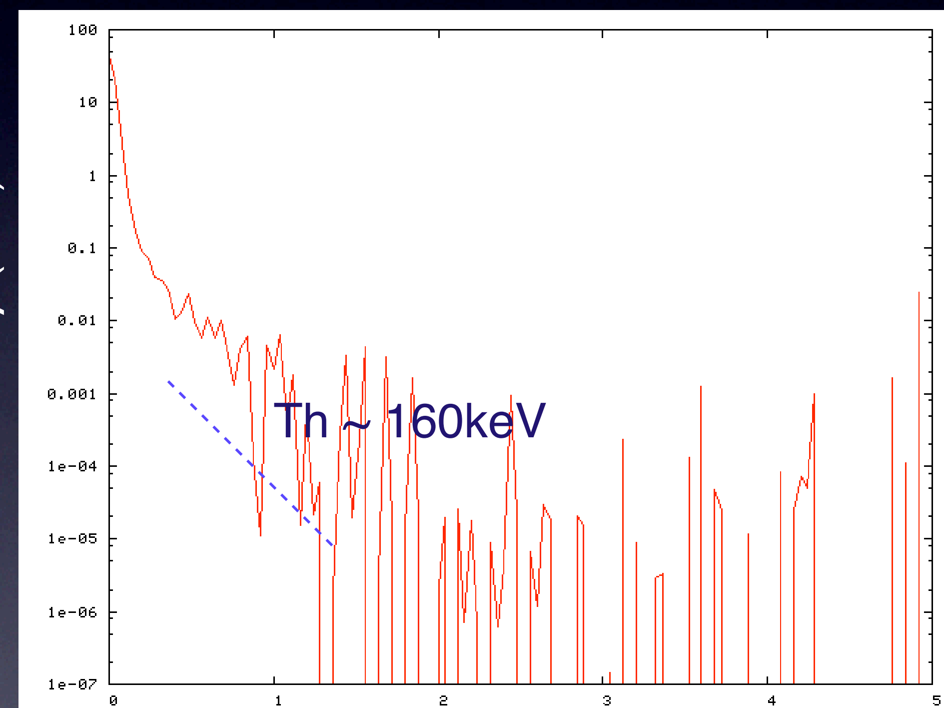


P_x

X (microns)

Interface steepened by photon pressure.

Electron energy spectrum



Electron density (n/n_c)

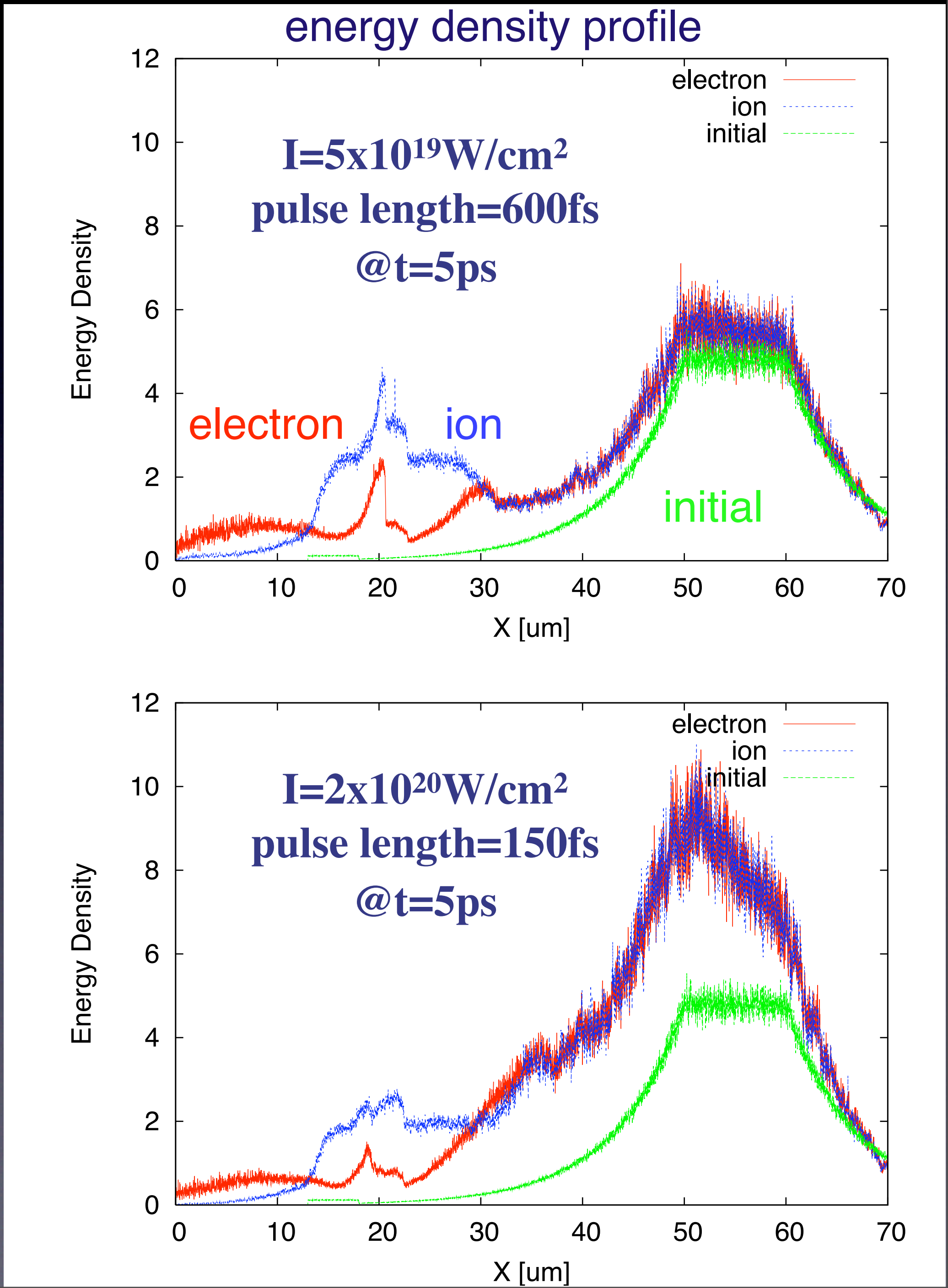
Electron energy (MeV)

(snapshot at 400fs)

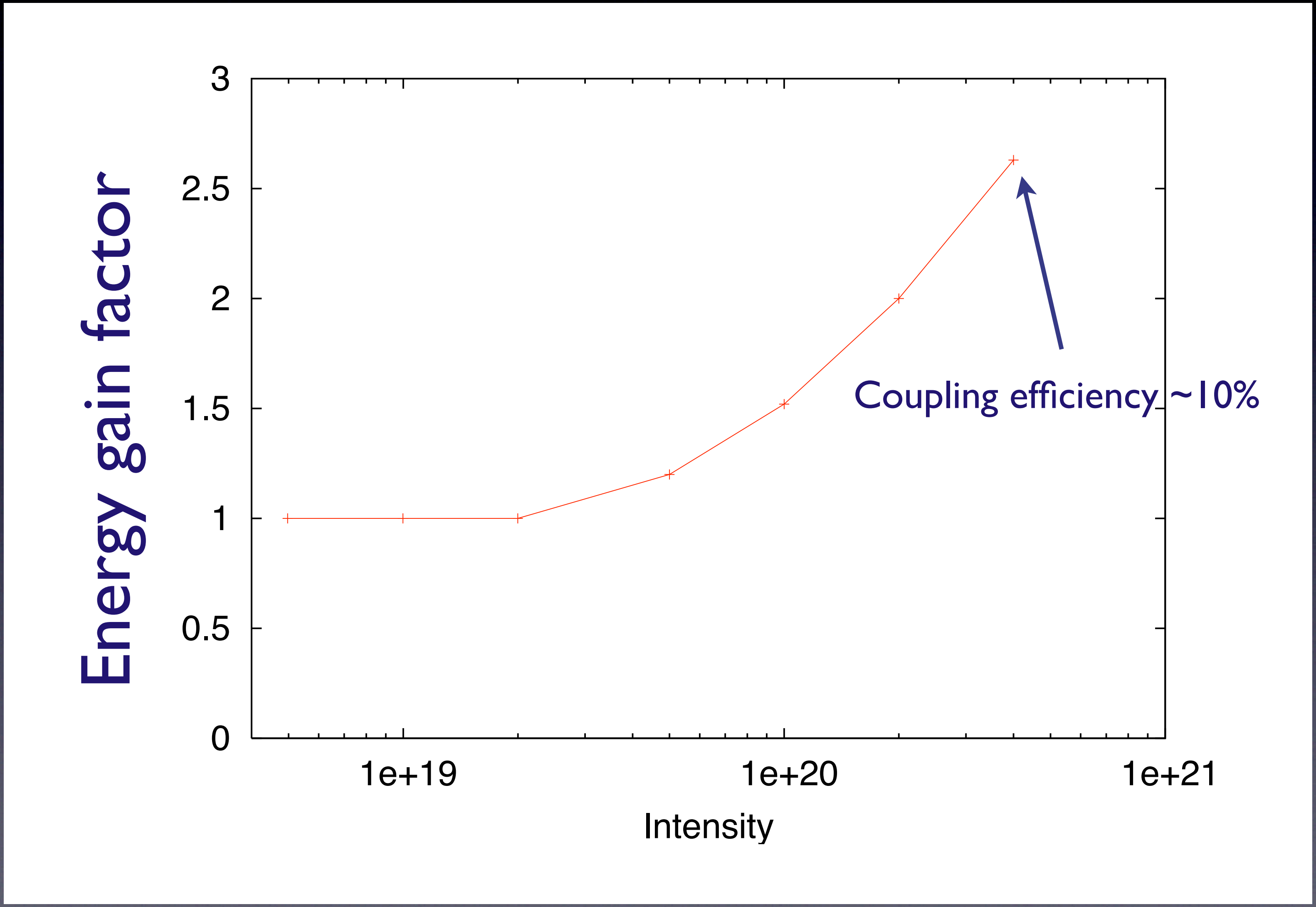
Best heating efficiency observed at highest intensity

Hot electrons generated by the low intensity pulse from the direct cone interaction heat corona plasmas, not core.

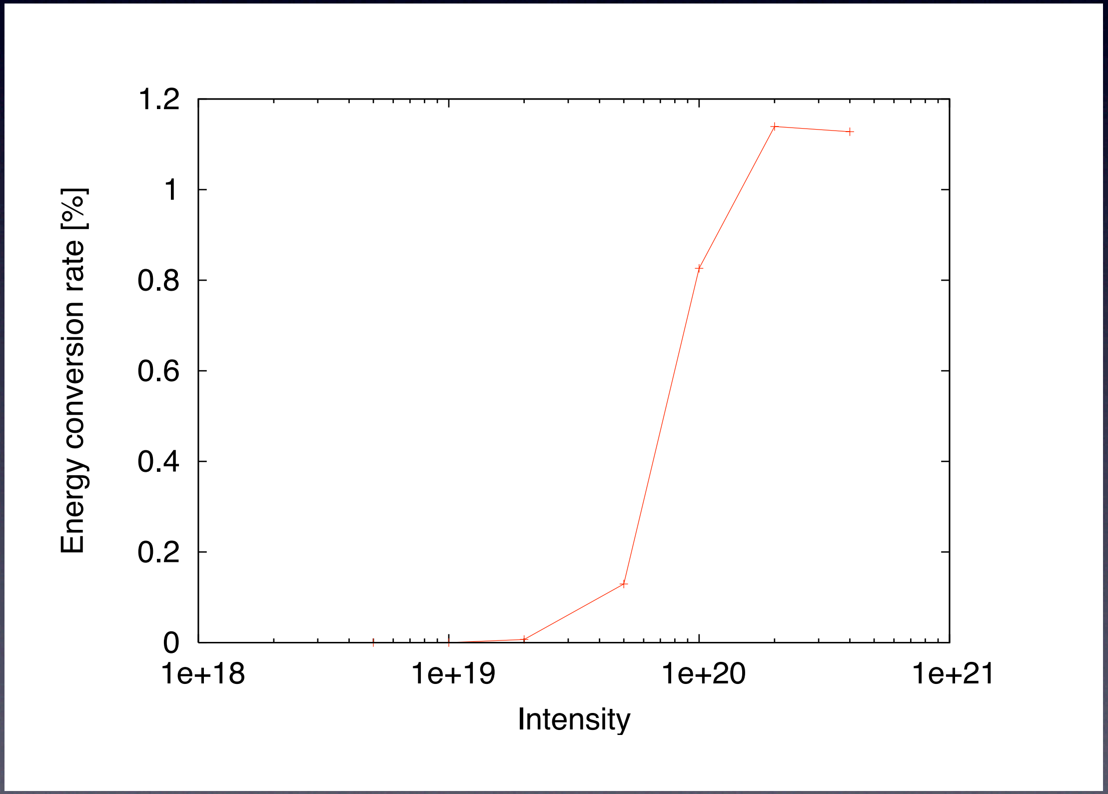
Hot electrons generated by the high intensity pulse from the direct cone interaction heats the core efficiently.



Best heating efficiency observed at highest intensity



Energy conversion more efficient at higher intensities



Interface investigation

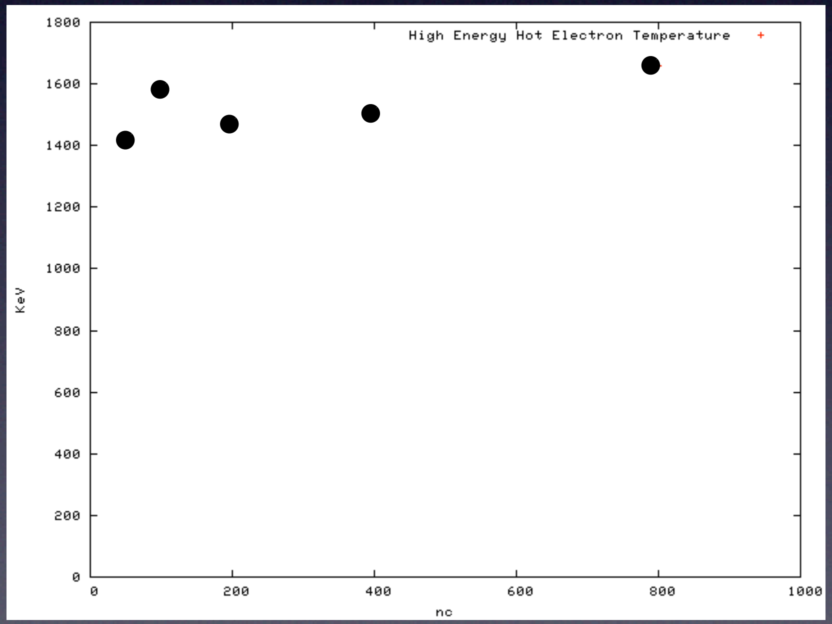
500fs @ 10^{20} W/cm^2

$5n_c$ - $800n_c$ Density Range

25μm Preplasma

High energy hot electron temperature varies little

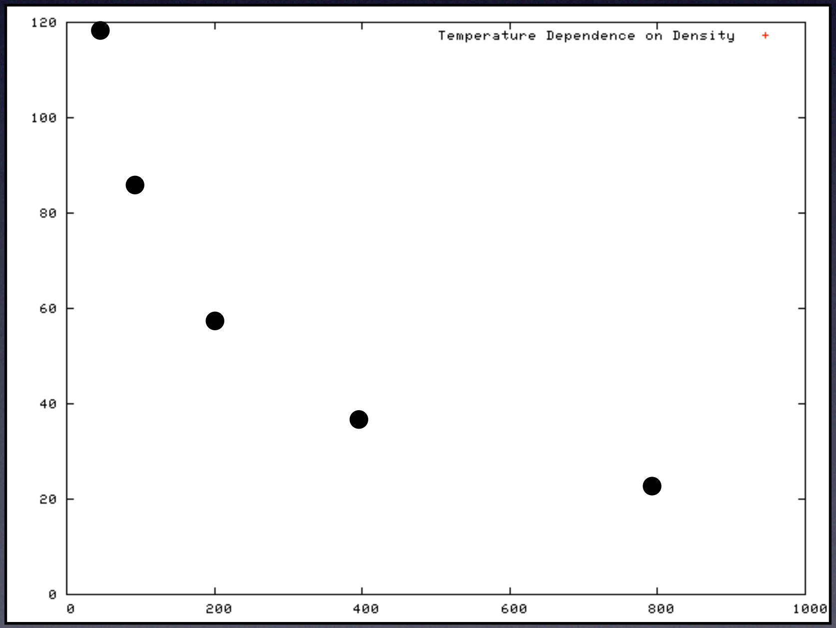
KeV



n/n_c

Low energy hot electron temperature scales with $1/\sqrt{n}$

KeV



n/n_c

Summary of 1D simulations

- Preplasma is swept away causing the hot electron temperature to drop.
- Hot electrons generated after the preplasma blow off mainly contribute to core heating. Higher intensities increase coupling efficiency.
- Control of the hot electron temperature is a key issue.
- Direct interaction with a solid plasma after the preplasma is swept away makes the hot electron range too short, causing less coupling to the core.
- Reducing the solid plasma density by coating plastic inside the gold cone might increase the coupling efficiency.
  1D simulation shows bulk hot e- temperature is proportional to $1/n_e^{1/2}$.

In the FI scheme, if we use a kJ laser energy as the ignition pulse, the intensity will be greater than 10^{20} W/cm^2. This intensity may not be a problem.