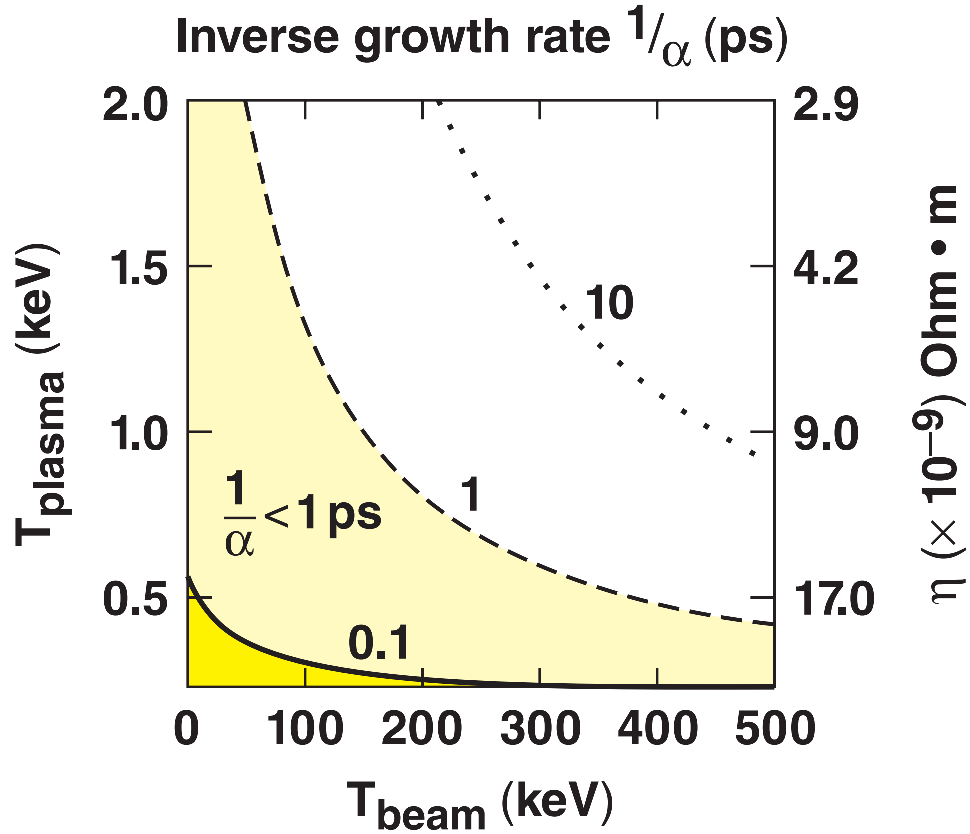
Numerical Studies of MeV Electron Transport in Fast-Ignition Targets



J. Myatt, A. V. Maximov, R. W. Short,
J. A. Delettrez, and C. Stoeckl
University of Rochester
Laboratory for Laser Energetics

46th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Savannah, GA
15–19 November 2004

Summary

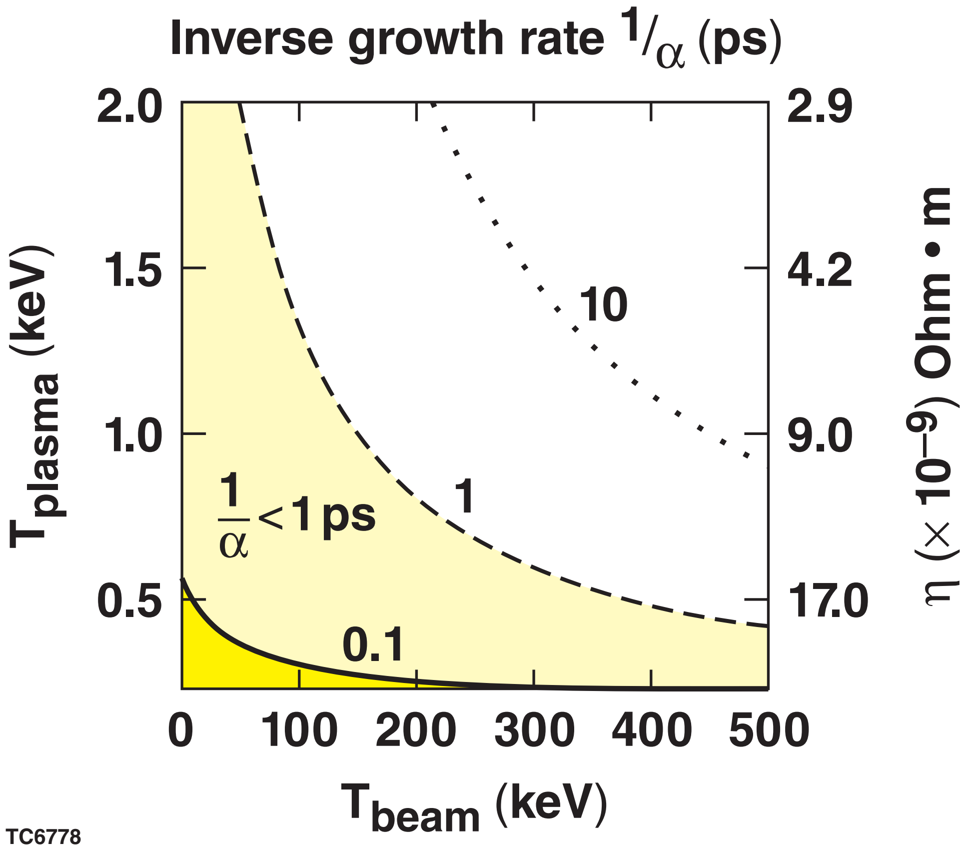
We have determined the maximum allowable transport distance to be no more than several tens of microns

- Transport efficiency in the FI scheme has been investigated numerically using the hybrid-implicit PIC code Lsp.[1]
  - Unlike Monte Carlo, the effects of self-fields are included.
- Three-dimensional calculations of 1-MeV electron beams have been made with parameters relevant to OMEGA EP imploded cyrogenic DT targets.
- Resistive filamentation of beam current plays a role for these parameters.
  - Finite collisionality between the cold-electron return current and plasma ions leads to filamentation of the beam current and emittance growth.
  - Subpicosecond growth times even for 1-keV DT plasma.
  - Growth rate depends upon beam thermal spread (temperature).

[1] D. R. Welch *et al*., Nucl. Instrum. Methods Phys. Res. A 464, 134 (2001).

Subpicosecond growth times for resistive filamentation can be obtained, even for hydrogenic (Z = 1) plasma at 1 keV

- **In the transport region, the collisionless current filamentation instability gives way to resistive filamentation.**



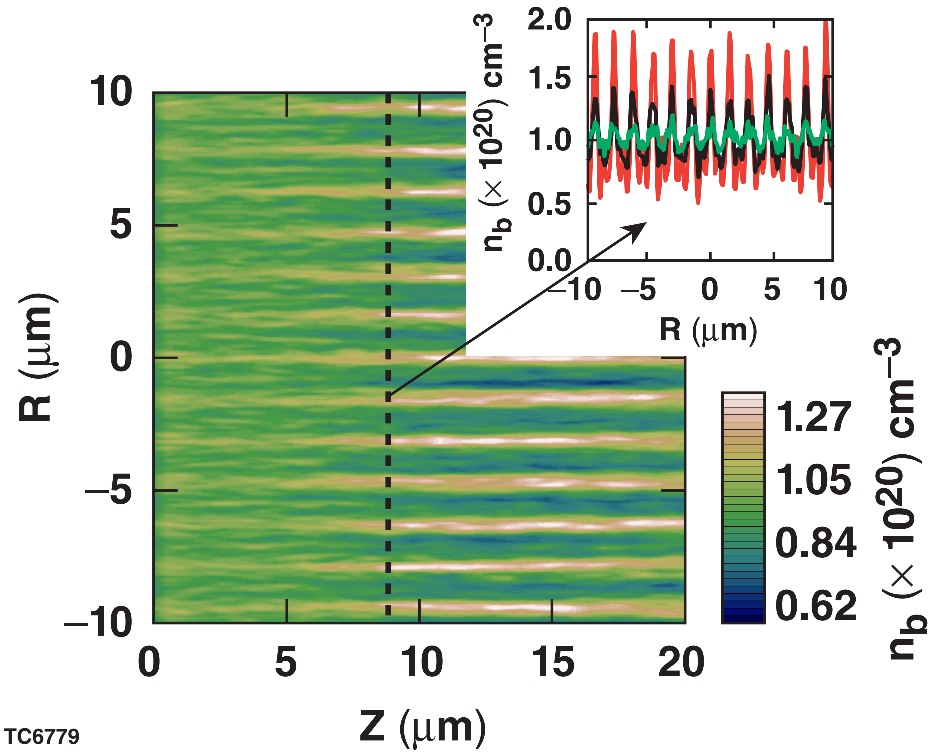
- **Collisionless Weibel suppressed for small n_b/n_p**
- **Silva *et al*., (PoP 2004) conclude $n_b/n_p < 0.1$ sufficient for 10-keV beam**
- **Resistive filamentation:** $\alpha\ (\eta, \beta_b, T_b, K, \omega_b)$
- **Validity of Ohm's Law**

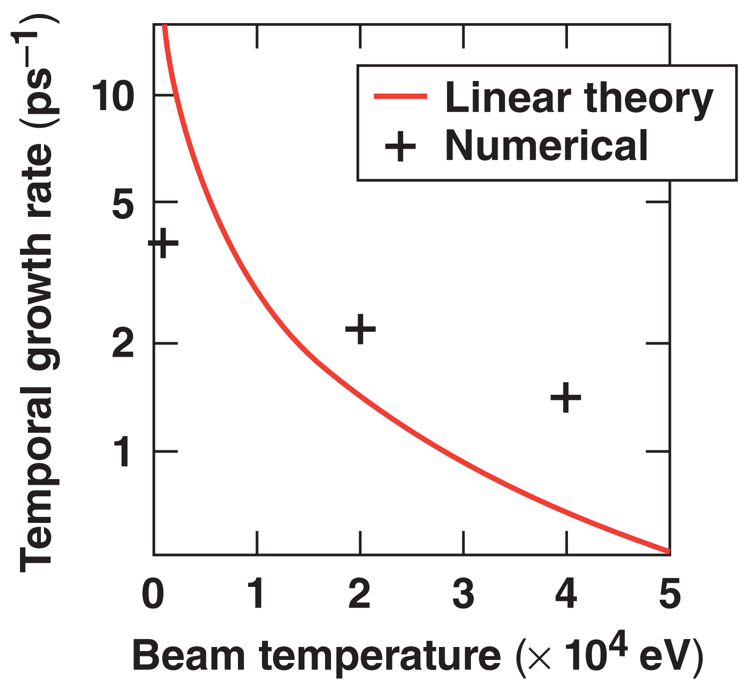
TC6778

Hybrid-implicit PIC (Lsp) is well suited to modeling of the transport region and is able to correctly describe resistive filamentation

UR LLE

- We have benchmarked the code against the linear theory.
- Scattering of cold return current with ions (finite resistivity) leads to resistive filamentation; electron inertial helps for $\alpha \gtrsim \nu_{ei}$.

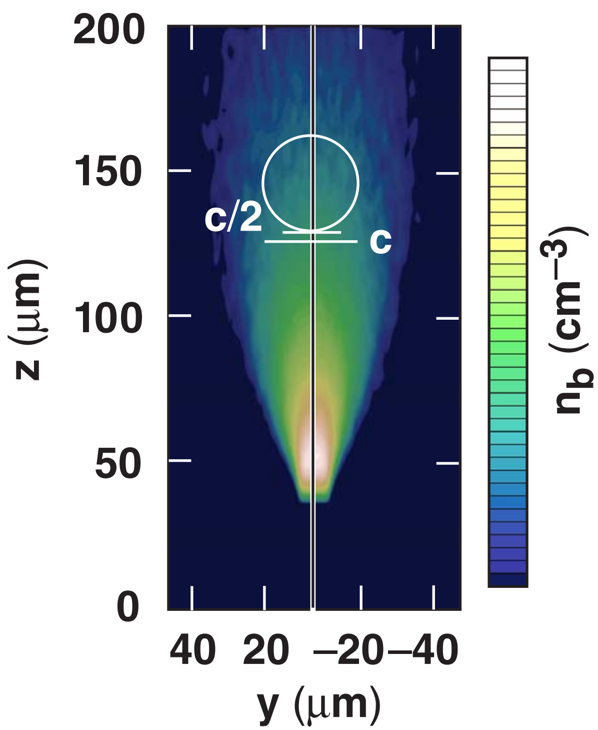


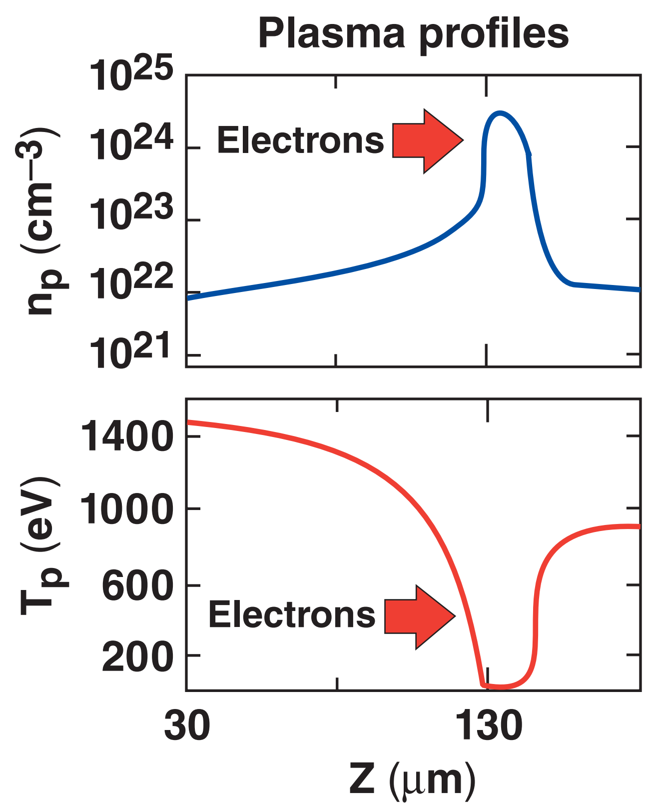


TC6779

We have evaluated transport efficiency for OMEGA EP parameters as a function of beam temperature and stand-off distance for the core

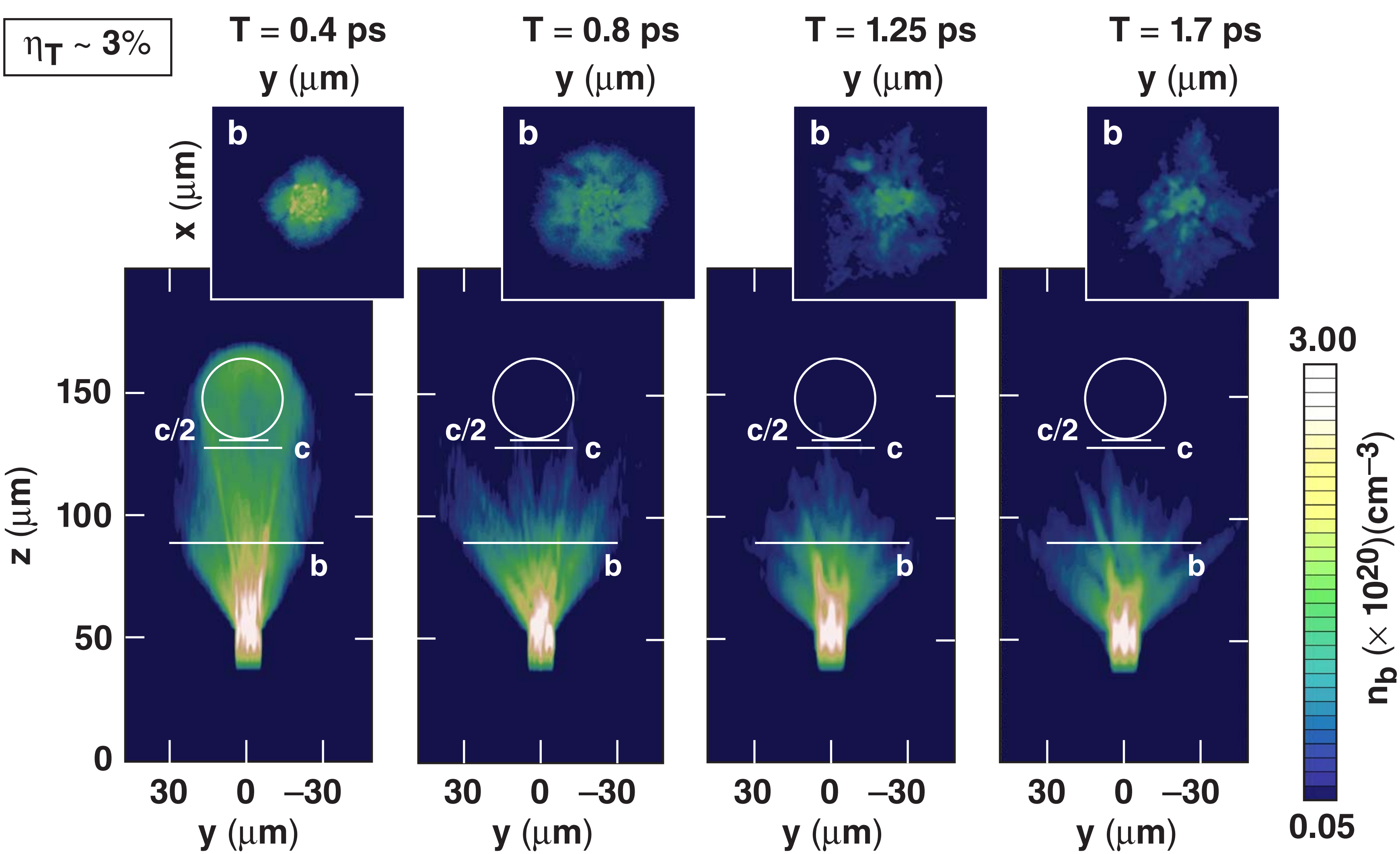
- OMEGA EP relevant parameters are chosen for the beam source: $n_b \sim 10^{20}$, $I_b \sim 2$ MA, $r_G \sim 10\ \mu m$
- Transport efficiency is calculated by measuring the fractional energy flux of hot electrons through the compressed shell/core.





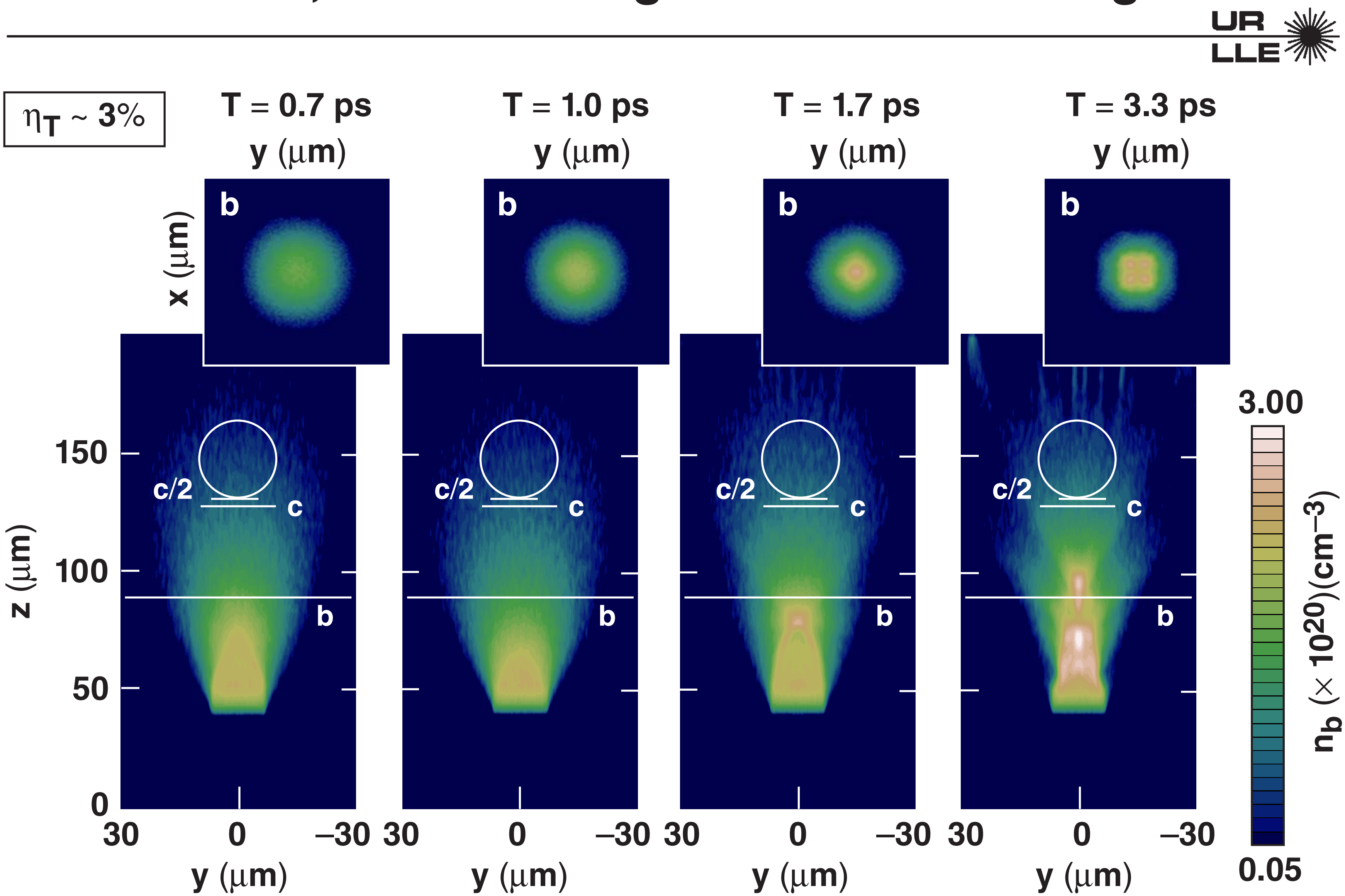
TC6510a

An initially well-collimated beam has a poor transport efficiency due to the rapid onset of beam spraying



TC6511a

Beam temperatures greater than 100 keV suppress filamentation, but have a significant initial divergence

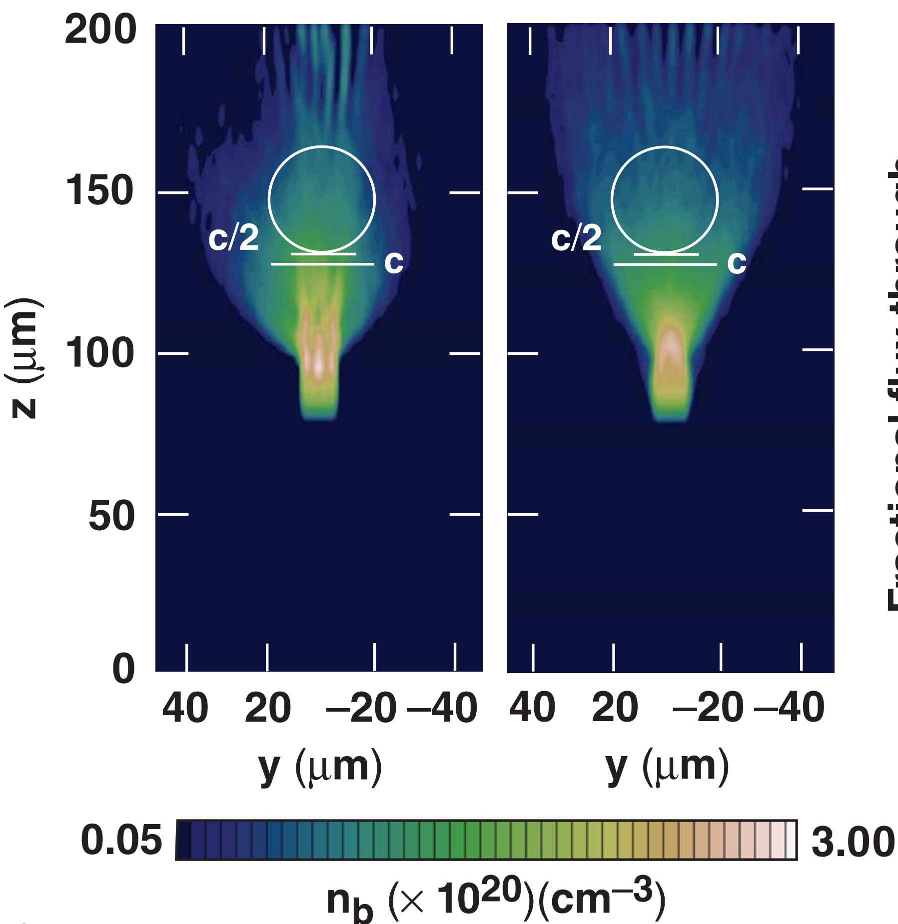


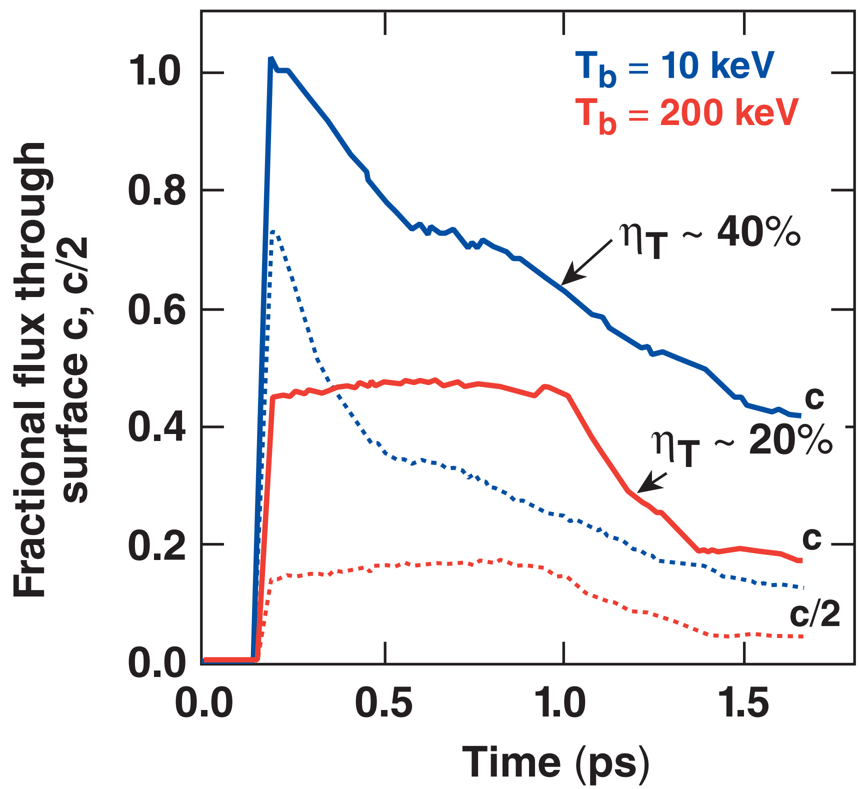
TC6781

Reasonable efficiencies can be obtained for stand-off distances of $\lesssim$40 μm and moderate beam temperatures

UR LLE

- The cold beam sees an order of magnitude improvement in efficiency.
- Geometric losses are smaller.
- The beam is weaker [(n_b/n_p) smaller].





TC6513a

Summary/Conclusions

We have determined the maximum allowable transport distance to be no more than several tens of microns

- Transport efficiency in the FI scheme has been investigated numerically using the hybrid-implicit PIC code Lsp.[1]
  - Unlike Monte Carlo, the effects of self-fields are included.
- Three-dimensional calculations of 1-MeV electron beams have been made with parameters relevant to OMEGA EP imploded cyrogenic DT targets.
- Resistive filamentation of beam current plays a role for these parameters.
  - Finite collisionality between the cold-electron return current and plasma ions leads to filamentation of the beam current and emittance growth.
  - Subpicosecond growth times even for 1-keV DT plasma.
  - Growth rate depends upon beam thermal spread (temperature).

[1] D. R. Welch *et al*., Nucl. Instrum. Methods Phys. Res. A 464, 134 (2001).

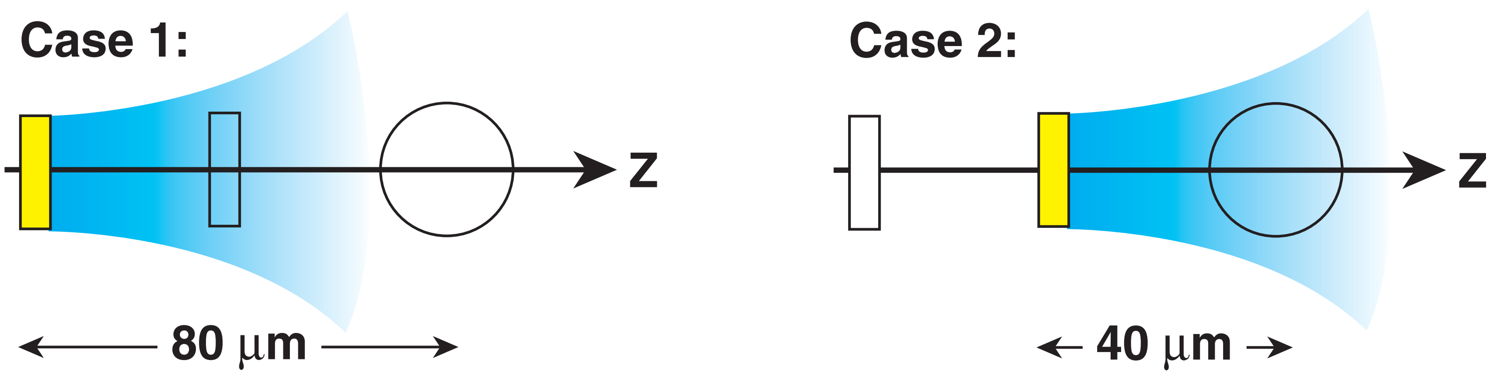
TC6777

We have evaluated transport efficiency for OMEGA EP designs as a function of beam temperature and stand-off distance from core

UR LLE

- An electron beam is generated by promotion from the background over a 20-μm spot with a pulse duration of 10 ps.
- FI relevant parameters are chosen the beam source.

$n_b \sim 10^{20}\ cm^{-3}$, $I_b \sim 2$ MA, $r_G = 10\ \mu m$



TC6780