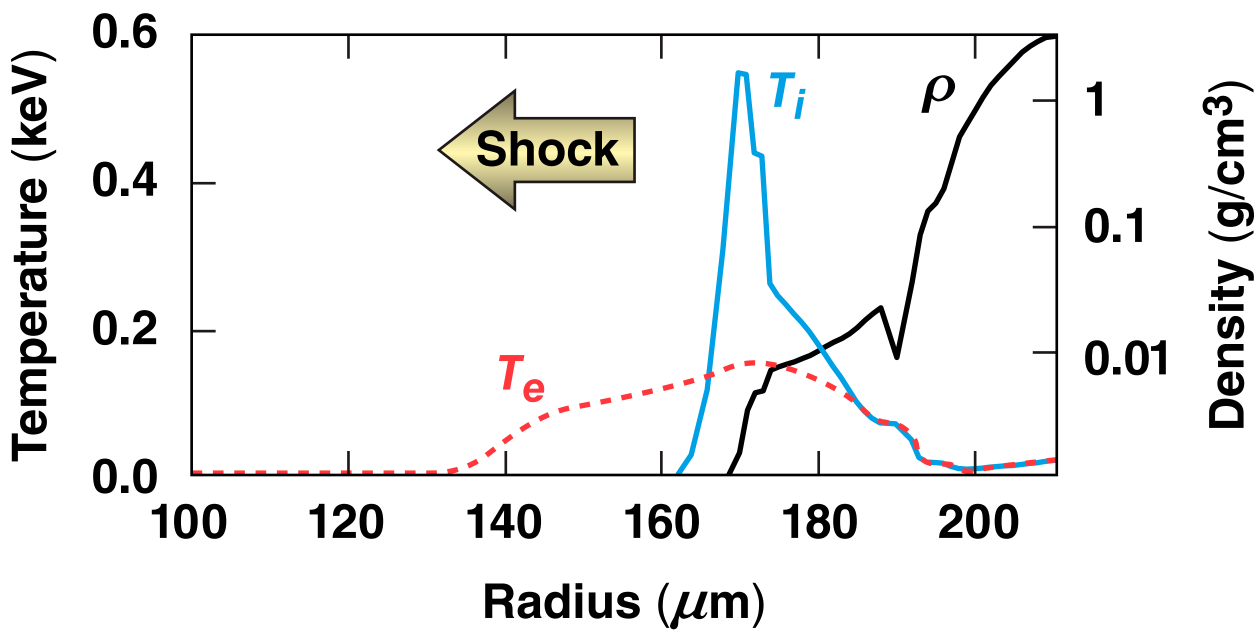
Nonlocal Ion-Heat and Momentum Transport in ICF Implosions



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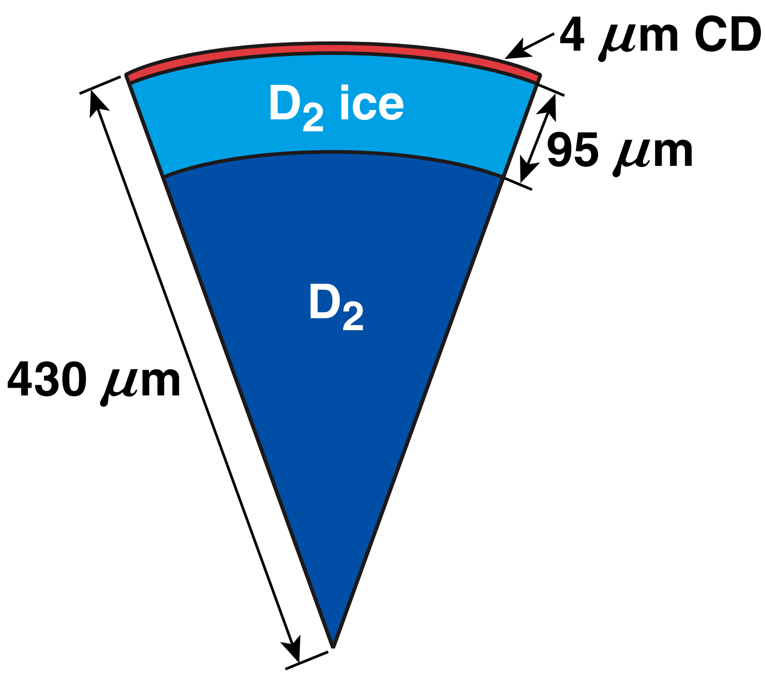
49th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Orlando, FL
12–16 November 2007

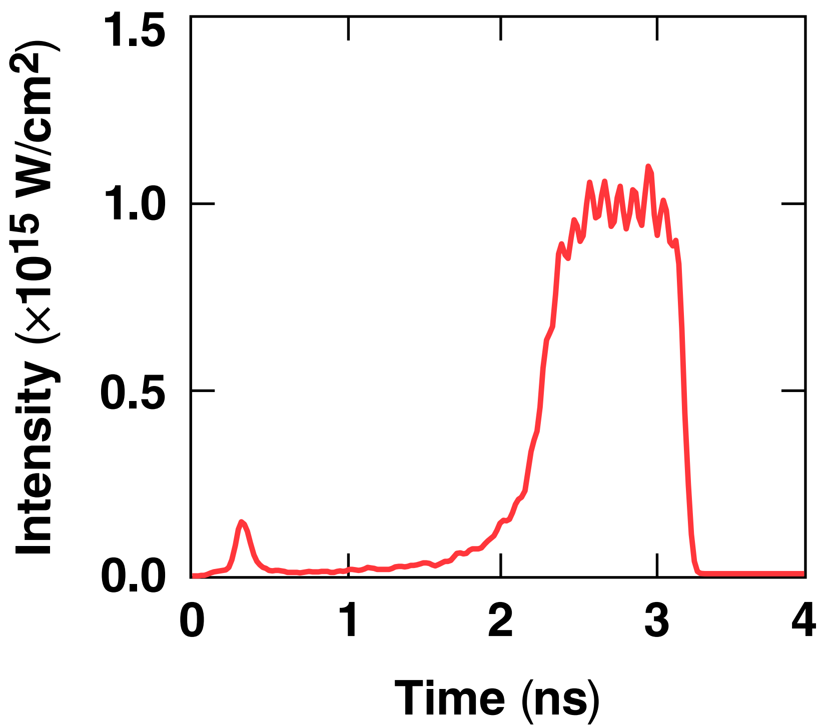
Summary

Nonlocal ion transport significantly modifies shock propagation and affects peak compression conditions

- Hydrodynamic shock heating, with local transport (and artificial viscosity), produces a temperature structure that is not consistent with the ion-mean-free paths
- With nonlocal ion transport (in the vapor region)
  - the shock front is more diffuse
  - material ahead of the shock is preheated
- Simulations with nonlocal ion transport show modifications of peak-compression conditions
  - temperature is ~25% lower
  - smaller hot spot
  - neutron yield reduced by a factor of 2

Nonlocal ion transport is being applied to simulations of recent low-adiabat cryogenic implosions on OMEGA

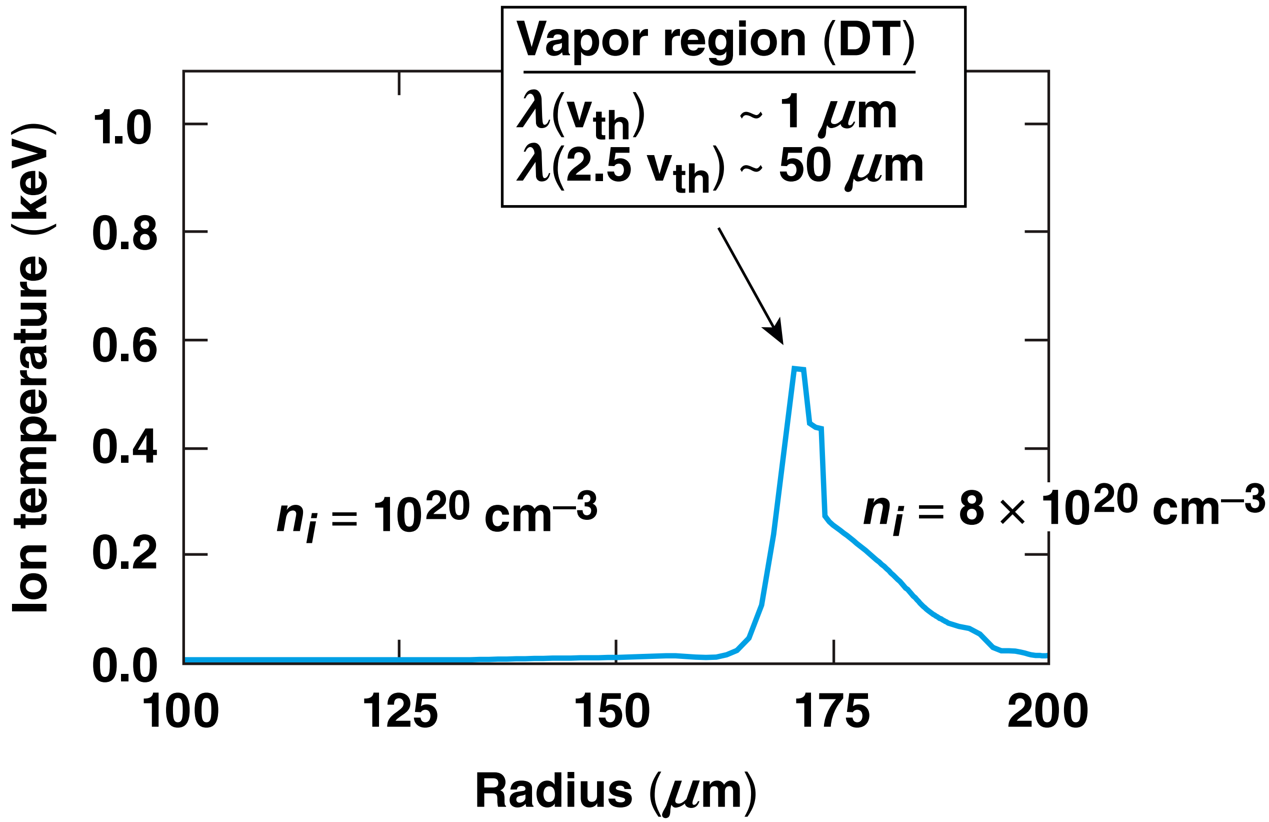




- Nonlocal simulation starts at 2.9 ns when the shock is at 200 μm

TC7858

The mean-free path is large for ion energies characteristic of heat flow in the vapor region of the target for local transport



TC7569a

Previous work examined the effects of "real" versus "artificial" viscosity and nonlocal ion transport

- Yabe[1] and Tanaka used real viscosity with local transport
  - higher temperature and lower density at peak compression
- Larroche[2] used an ion Fokker–Planck kinetic code that included real viscosity and nonlocal ion transport
  - shock propagation was modified but had very similar density and temperature profiles at peak compression
- The effect on fusion rates of long mean-free path ions escaping from the "hot spot" has been estimated[3].

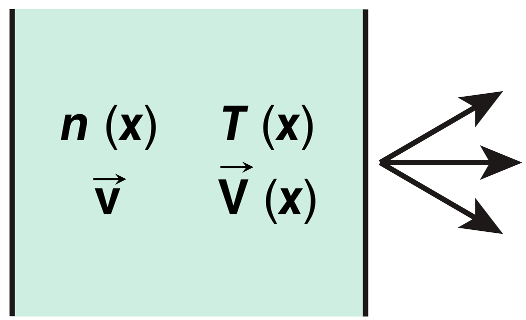
[1] T. Yabe and K. Tanaka, Laser Part. Beams 7, 259 (1989).
[2] O. Larroche, Eur. Phys. J. D. 27, 131 (2003).
[3] D. Henderson, Phys. Rev. Lett. 33, 1142 (1974).

TC7852

Transport model

Ions are transported in straight lines through the computational grid and deposited according to their mean-free paths

Computational cell



Boundary condition

No incoming particles

Outgoing ions transport

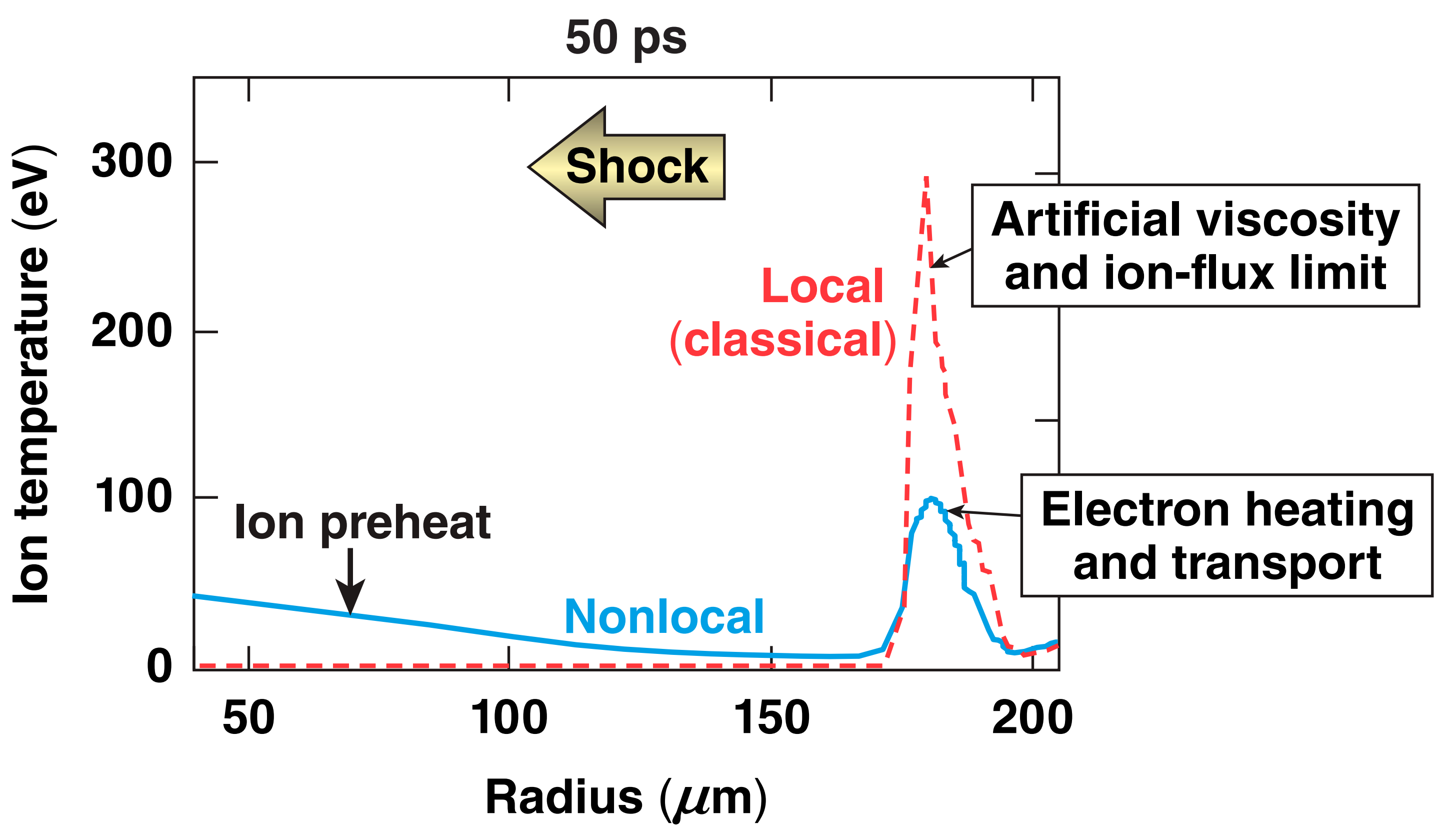
- Thermal energy $1/2\ mv^2$
- Fluid kinetic $1/2\ mV^2$
- Momentum $m(\vec{v} + \vec{V})$

- Temperature variation $T(x)$ produces thermal conduction
- Fluid velocity variation $\vec{V}(x)$ produces viscosity

Classical fluid equations (with viscosity) are recovered in the limit of short-mean-free paths.

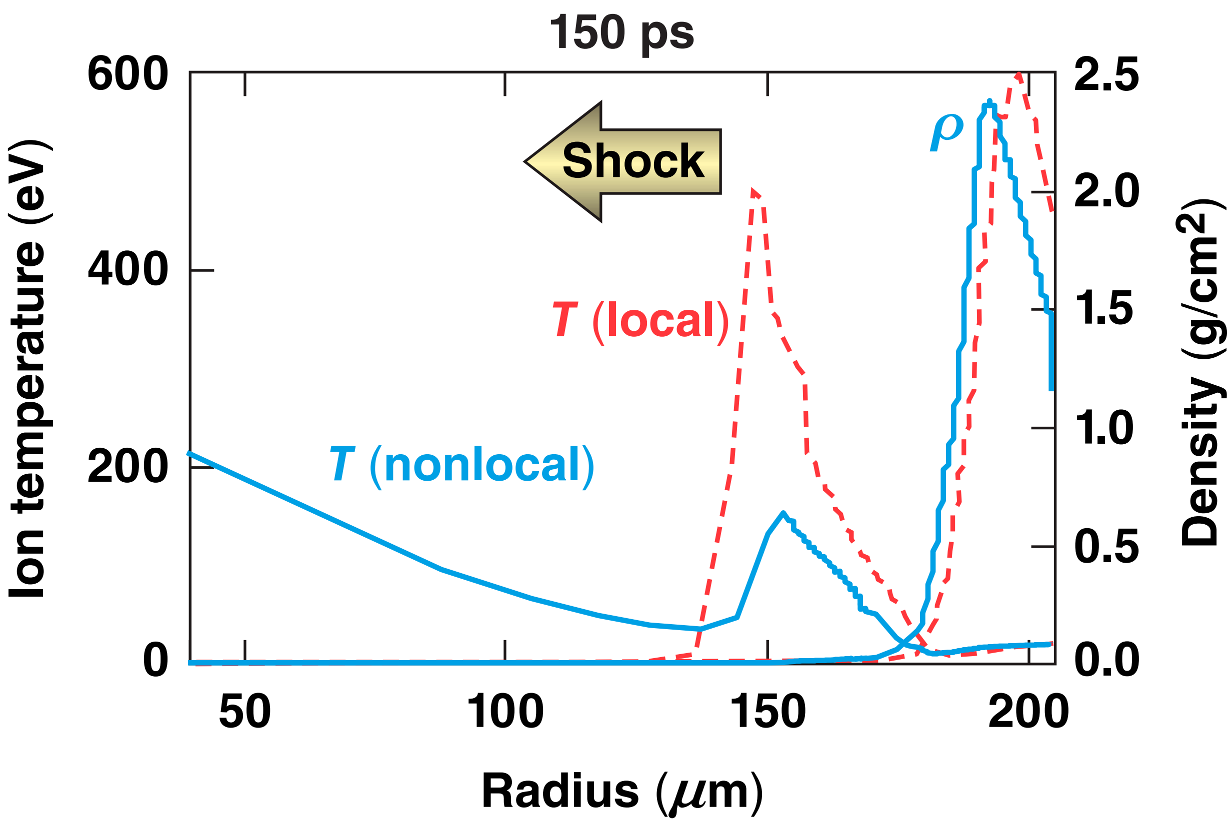
TC7855

Nonlocal transport preheats ahead of the shock



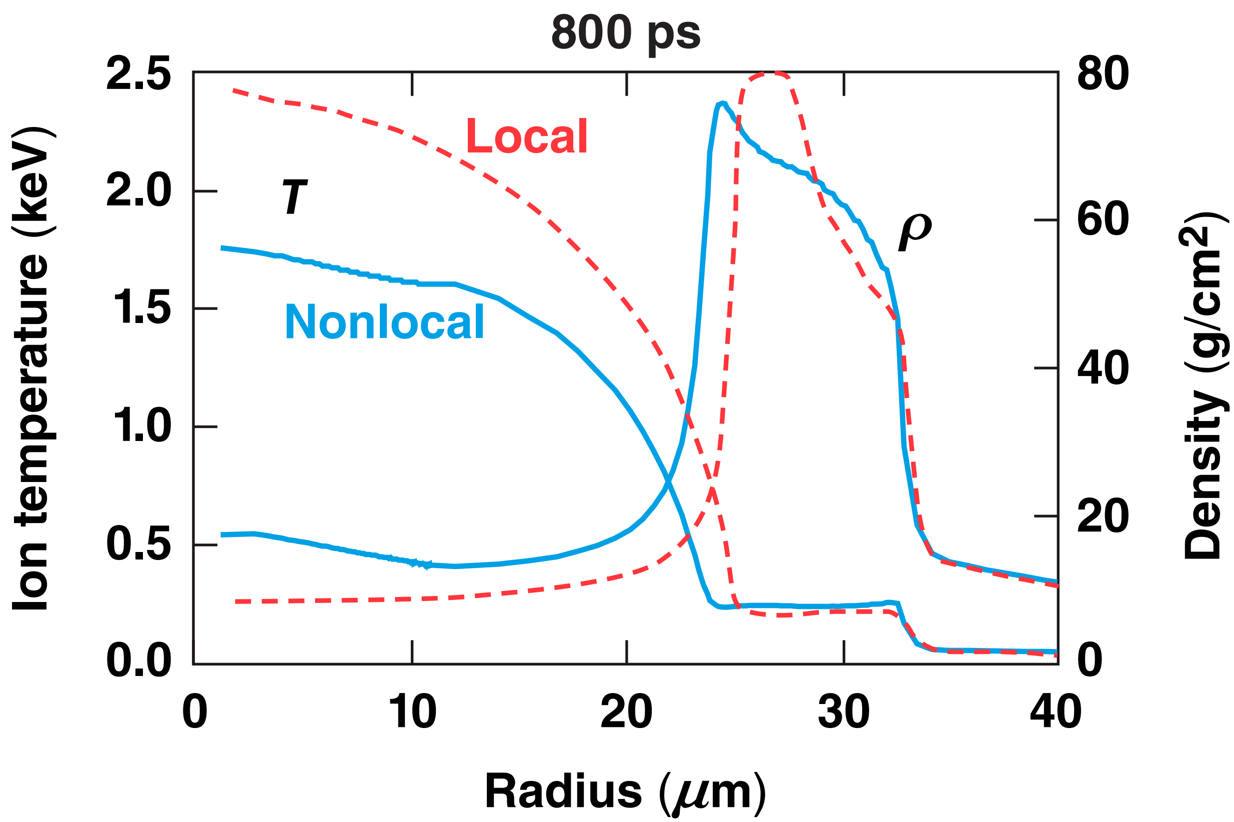
TC7875

The nonlocal ion temperature ahead of the shock becomes nearly isothermal as the shock propogates



TC7862

Nonlocal ion transport results in lower temperature at peak compression—consistent with x-ray emission

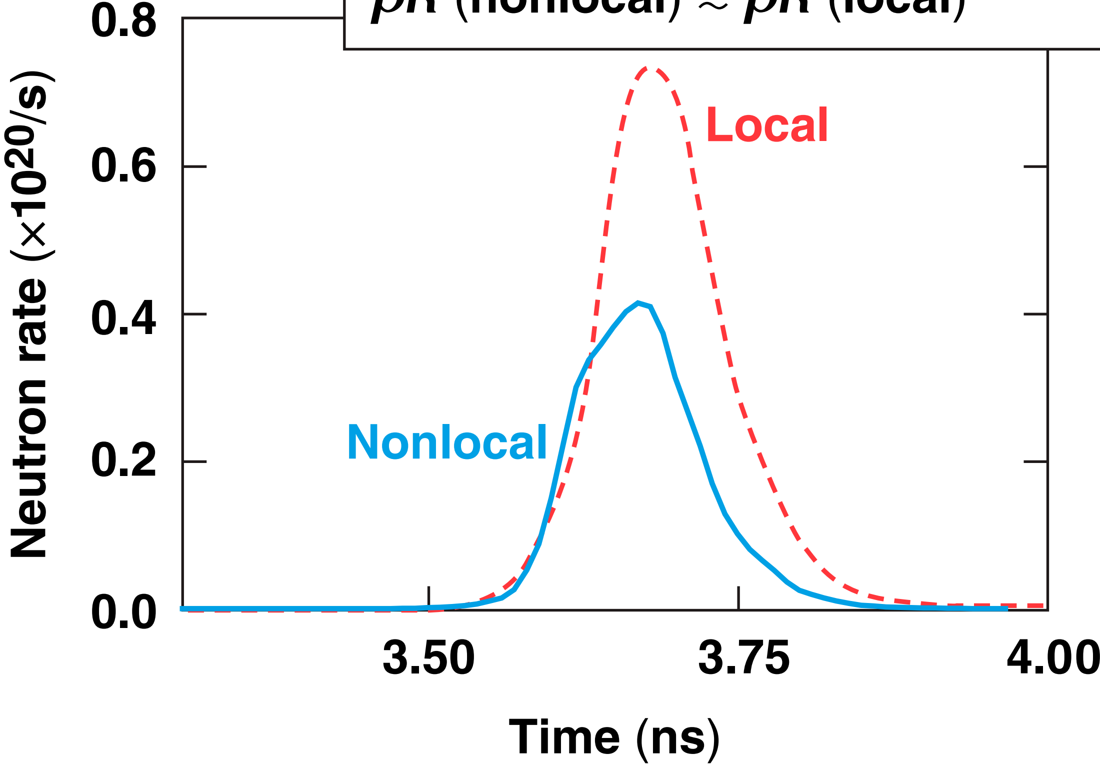


- X-ray emission data at peak compression shows a lower temperature than predicted by 1-D simulations, but NTOF shows a higher temperature.

TC7861

The neutron yield is a factor of 2 lower for nonlocal transport

Yield (nonlocal) ≈ 0.5 × yield (local)
ρR (nonlocal) ≈ ρR (local)



TC7876

Summary/Conclusions

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Full simulations with nonlocal ion transport are in preparation.

TC7565a