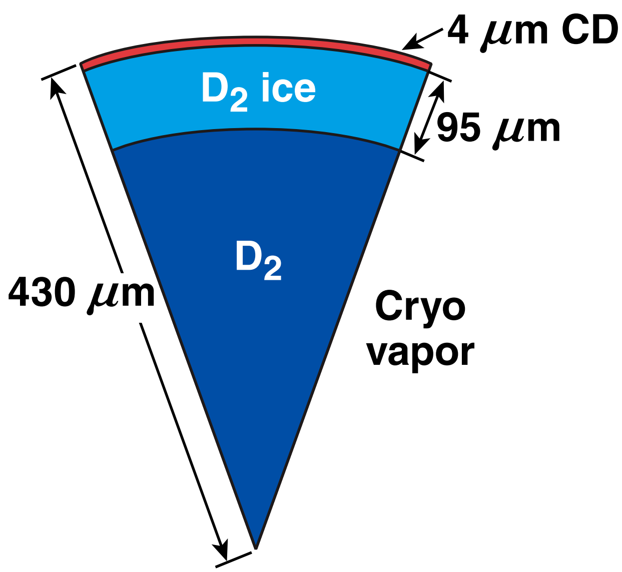
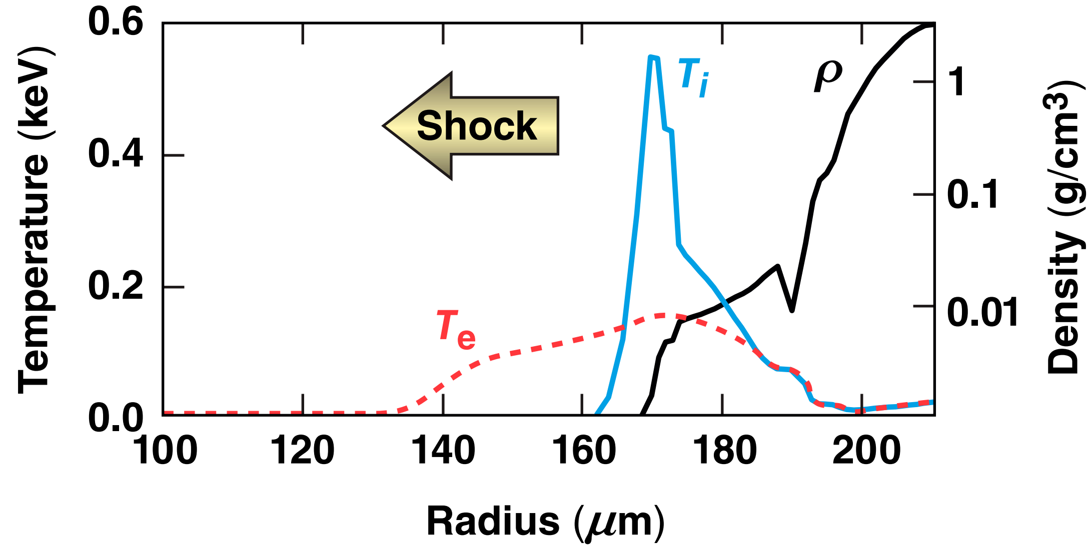
Nonlocal Ion-Heat and Momentum Transport in ICF Implosions





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Summary

Shock propagation in the cryo vapor region of ICF targets is substantially modified by nonlocal ion-transport effects

- Nonlocal ion transport does produce a shock structure consistent with ion mean-free paths—classical transport with artificial viscosity does not.
- New physics modules have been added to the nonlocal ion-transport code
  - mass transport (in addition to energy and momentum transport)
  - time-dependent transport

TC8383

Motivation

If nonlocal ion effects are important in OMEGA experiments then they might also be important for NIF ignition experiments

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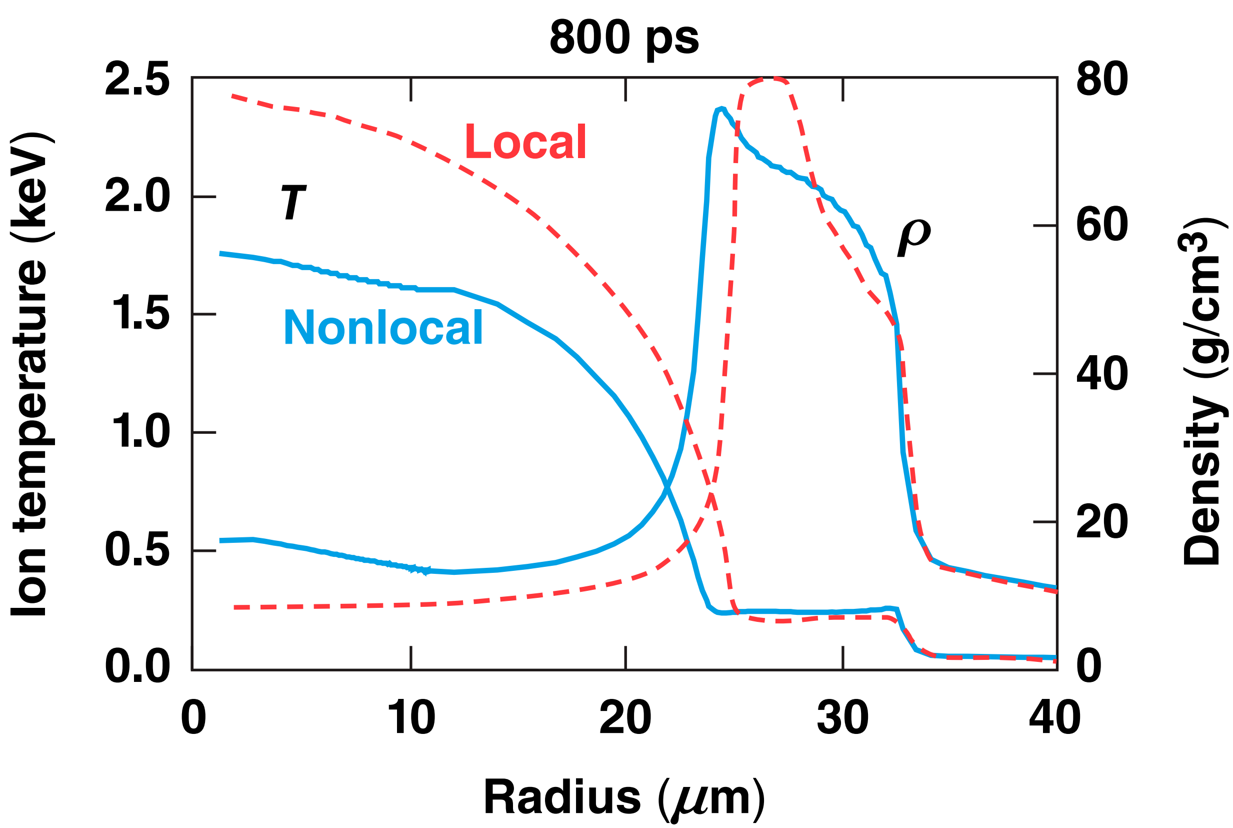
- Shock structure in the cryogenic fuel and vapor regions will be determined by similar densities, temperatures, pressures, and mean-free paths for OMEGA and the NIF.
- Nonlocal effects in hot-spot formation will be similar, despite the difference in size
  - mean-free path: $\lambda = 10\, T\,(\mathrm{keV})^2/\rho\,(\mathrm{g/cm^3})\ \mu\mathrm{m}$ (at $v = 3\, v_{th}$)
  - hot-spot scaling: $\lambda/R_{hot} = T\,(\mathrm{keV})^2/\rho R\,(\mathrm{mg/cm^2})$

	ρR (mg/cm^2)	T (keV)	λ/R_{hot}
OMEGA	20	2	0.2
NIF	300	10	0.3

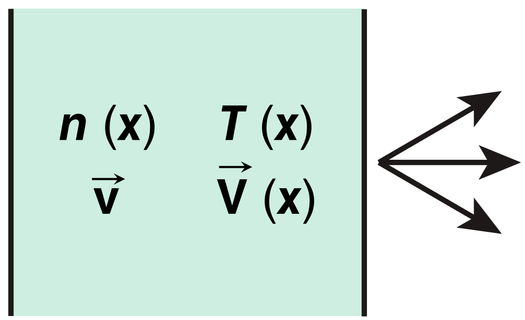
Preliminary simulations show that nonlocal ion transport modifies hot-spot formation for OMEGA



Transport model

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

Computational cell



Outgoing ions transport

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

Classical fluid equations with thermal conduction and viscosity are recovered in the limit of short mean-free paths.

TC7855a

Transport model

Mass is transported out of computational cells and deposited elsewhere

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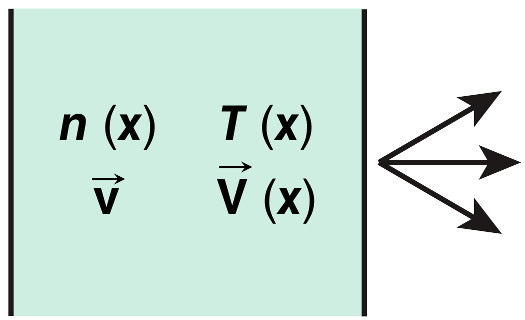
Computational cell



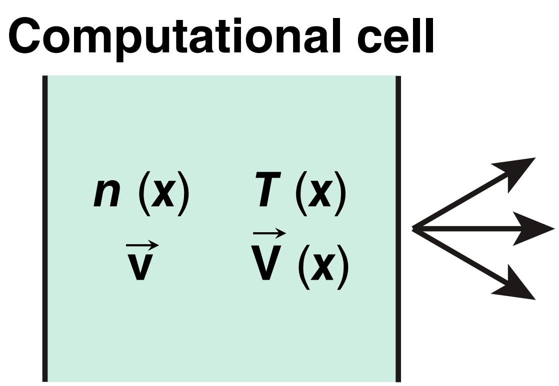
Outgoing ions transport

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

- Transport of high-*Z* ions from the shell to the fuel can be examined.

TC7855b

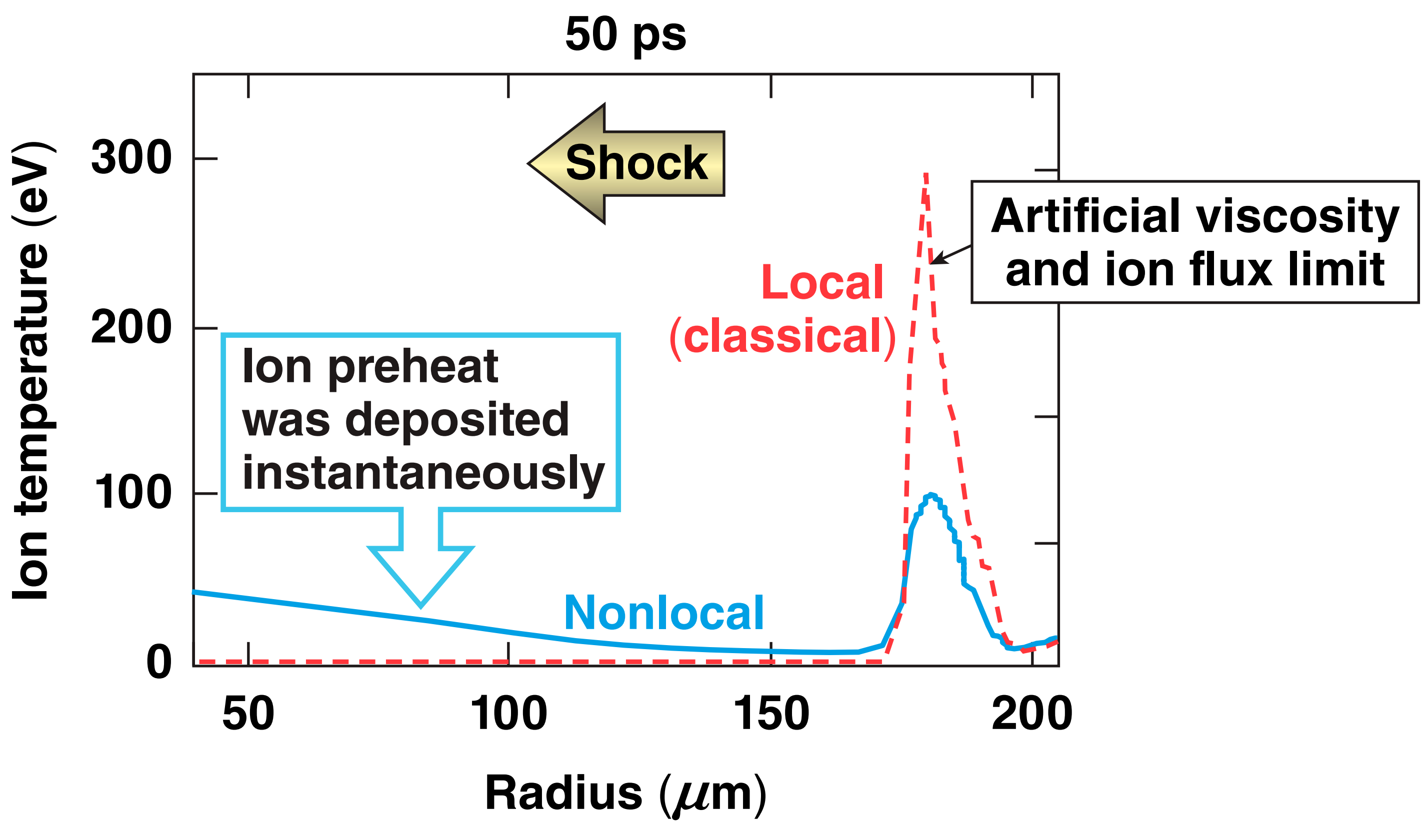
Thermal electrons are transported with the ions to maintain charge neutrality



Outgoing ions transport

- Thermal energy $1/2\ mv^2$
- Fluid kinetic $1/2\ mV^2$
- Momentum $m(\vec{v} + \vec{V})$
- Mass
- Electrons $3/2\ kT_e$

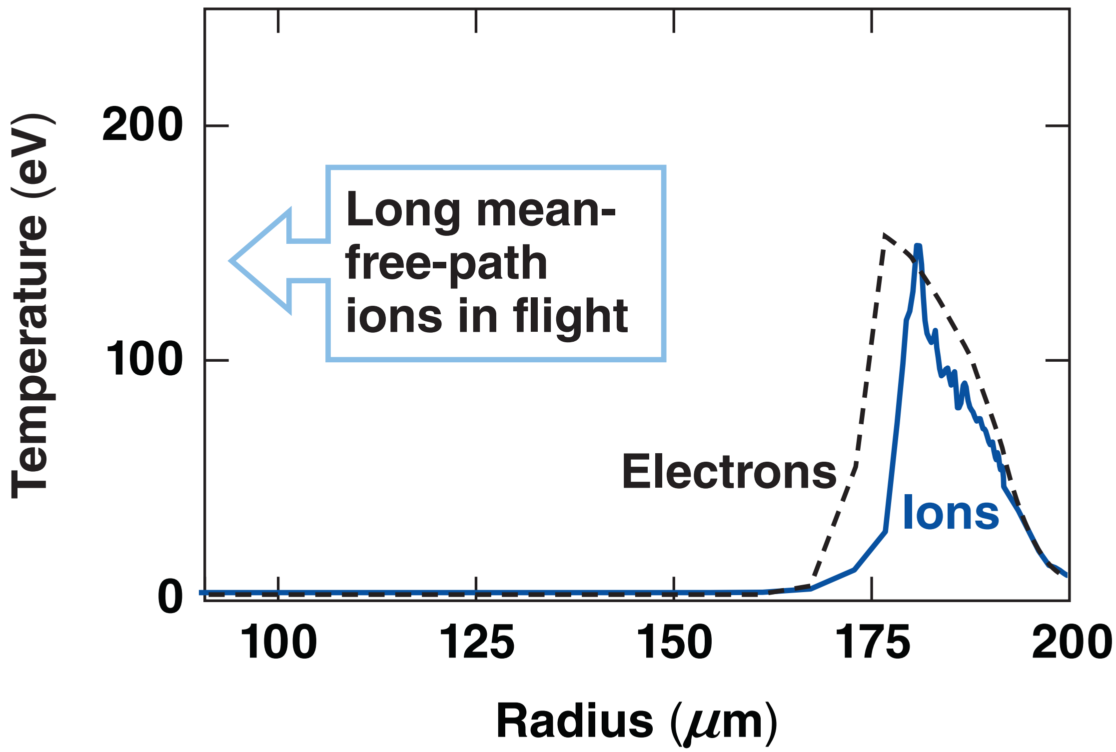
Nonlocal transport produces a shock structure consistent with ion mean-free paths



- Preheating ions will stay ahead of the shock, but will take >100 ps to reach the center.

TC7875a

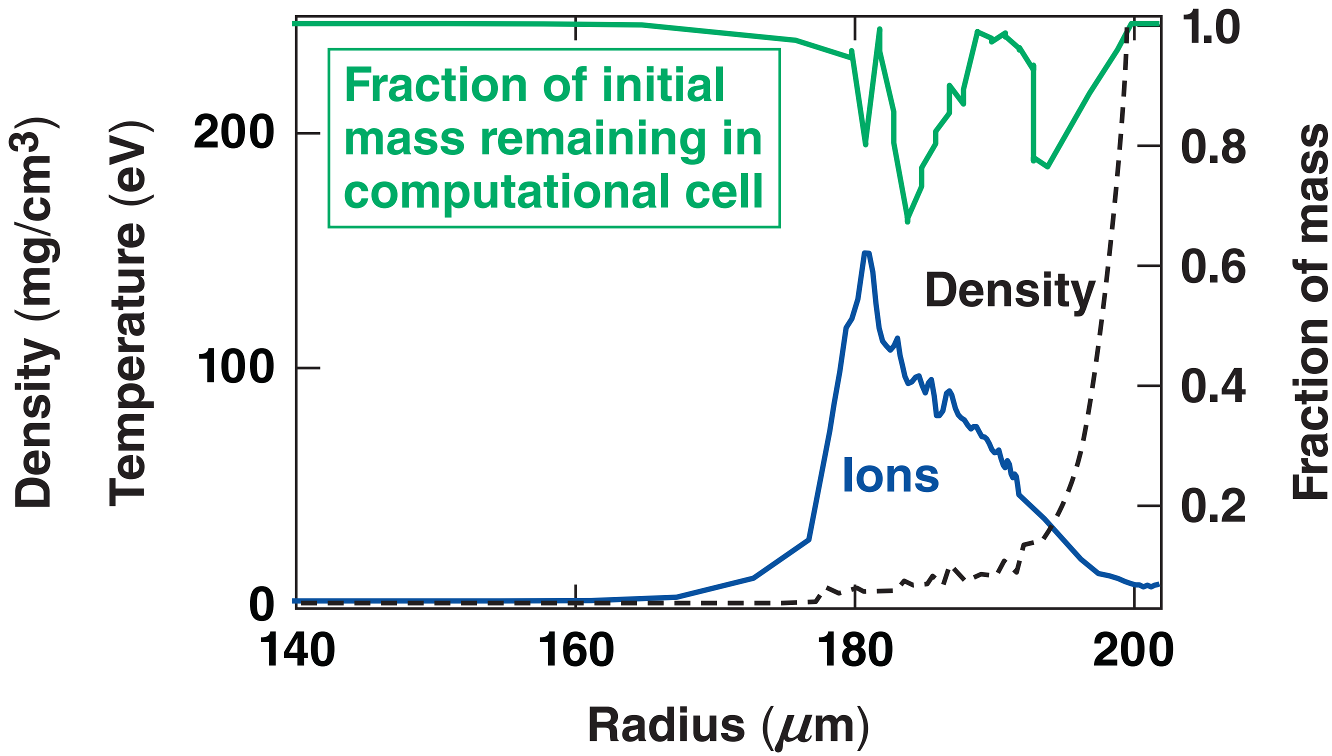
With time-dependent transport, artificial preheating far ahead of the shock is removed



- Electrons and ions contribute equally to the shock-front pressure.

TC8385

Mass is moved around during shock propagation



TC8387

Summary/Conclusions

Shock propagation in the cryo vapor region of ICF targets is substantially modified by nonlocal ion-transport effects

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The nonlocal ion-transport model is being added to *LILAC* for the full simulation of OMEGA experiments and NIF ignition designs.