High Energy Density Simulations for IFE Reactor Design*

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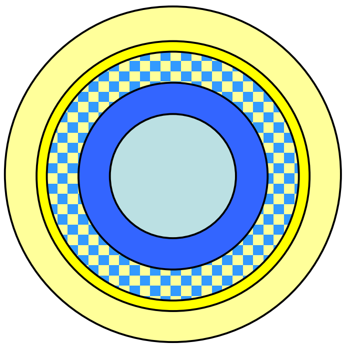
Outline of presentation

- Simulation of threat spectra.
- Focus on expanding ionic debris.
- Shock wave intensity along decreasing density gradient.
- What is wrong with the hydrodynamic picture?
- Summary

Threat spectra computed with conventional radiation hydrodynamics codes.

Direct drive laser target – No high Z
Ref: Perkins, HAPL website



Not to scale

Yield fraction:

Neutrons	73%
X-rays	1%
Ionic debris	26%

Neutron transport and x-ray emission are relatively high-confidence calculations. Nuclear cross sections and atomic opacities are "known".

Emitting plasma is hot and relatively stationary during emission.

Total energy in ionic debris is high-confidence because $E_{ion} = E_{total} - E_{neutron} - E_{xray}$.

Ionic debris spectrum – what remains after neutrons and x-rays leave.

Implosion (10's ns)
→TN burn (10's ps)
→emission (1's ns)
→ expansion (1,000's ns)

few milligrams in few cm^3

↓

few milligrams in many m^3.

Expansion cooling: $T_2 / T_1 = (v_1 / v_2)^{\gamma-1}$

T_1 = 50 keV → T_2 = 37 K!

Condensation?

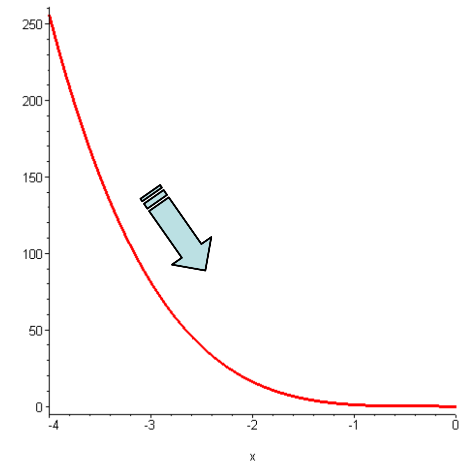
Is there a mechanism that can produce a higher temperature (energy density) than the initial state?

Shock wave propagation down density gradient produces infinite temperature

$$\rho(x) = bx^{\delta}$$

$$T \sim 1/X^{4/3} \ \text{as}\ X \to 0,$$

$$X = \text{shock position}$$

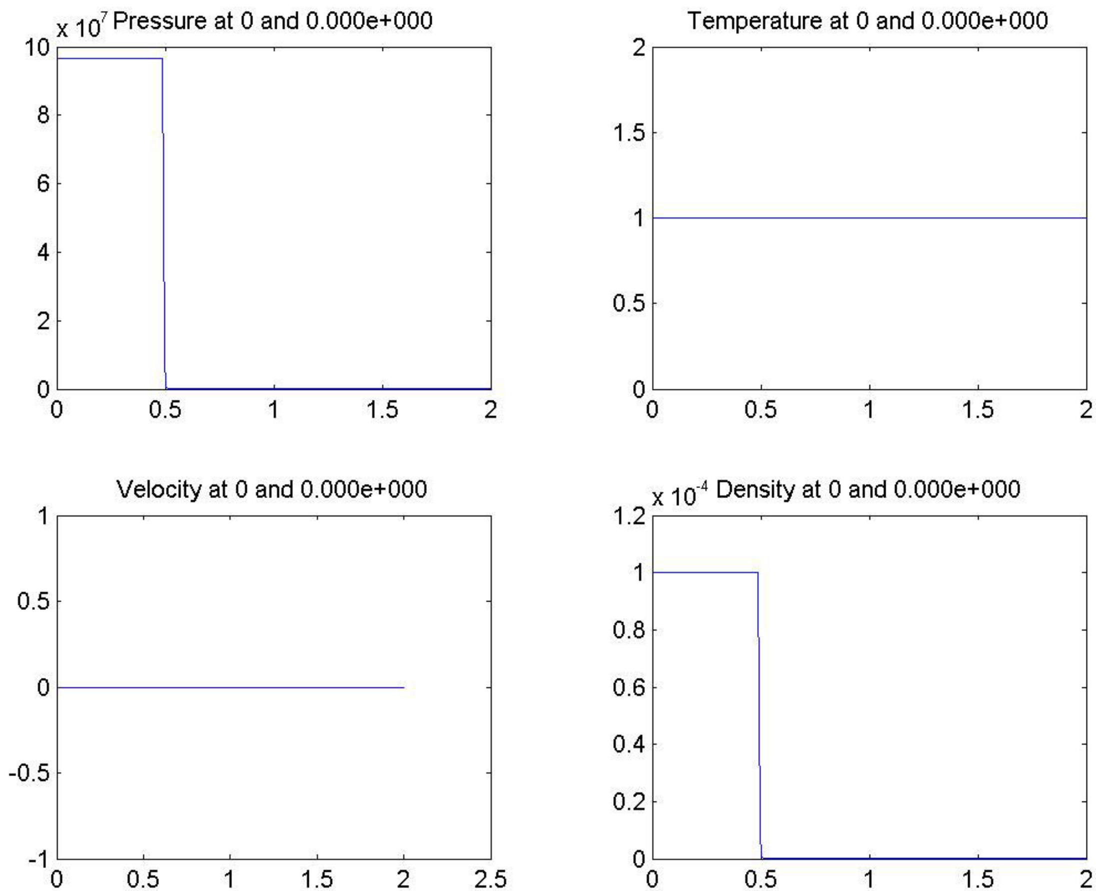


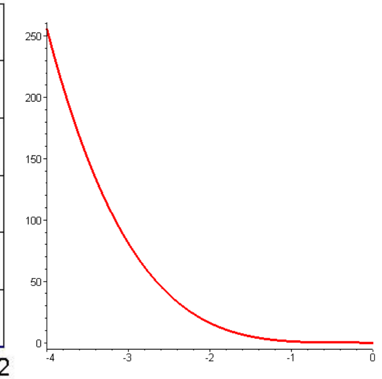
Gandel'man, G.M. and D.A. Frank-Kamenetskii, "Shock wave emergence at a stellar surface", *Soviet Phys. "Doklady" (English Translation)* **1**, 223-226(1956).

Colgate, S.A. and M.H. Johnson, "Hydrodynamic origin of cosmic rays", *Phys Rev. Lett*. **5**, 235-238(1960).

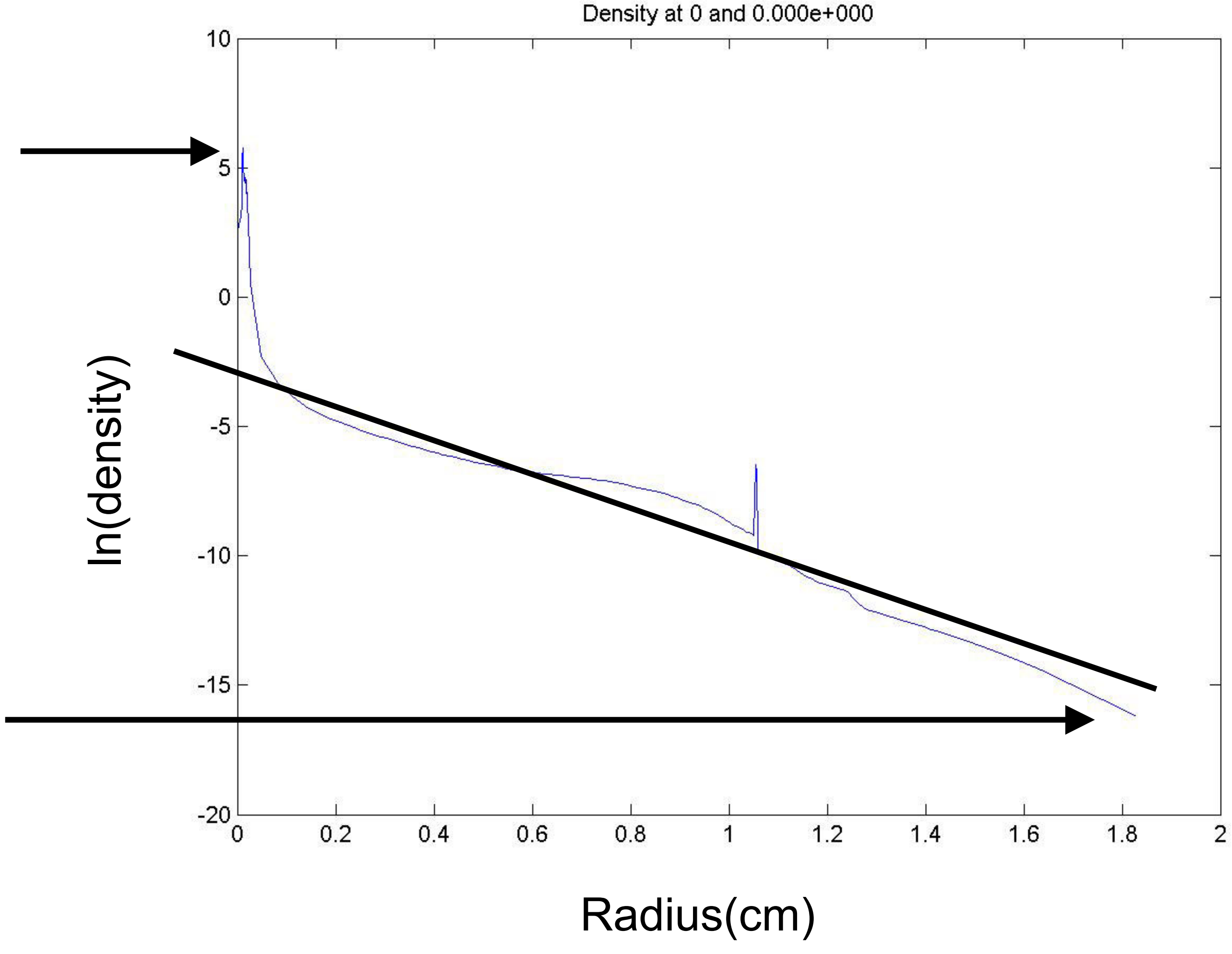
Zel'dovich and Raizer, Physics of Shock Waves and High-Temperature Hydrodynamic Phenomena, (Academic Press, 1967), pp. 812-820.

Hydro simulation of shock propagation down power law density gradient



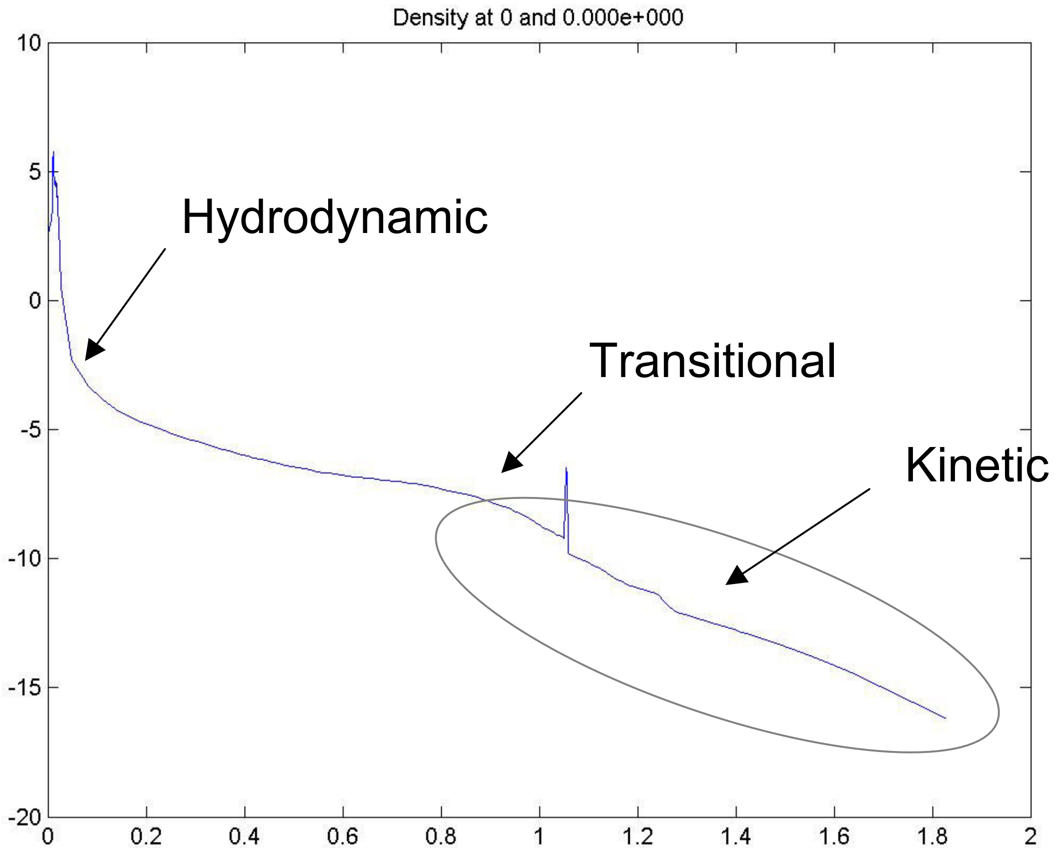


Shock propagation down density gradient of HAPL target with bang time as initial condition



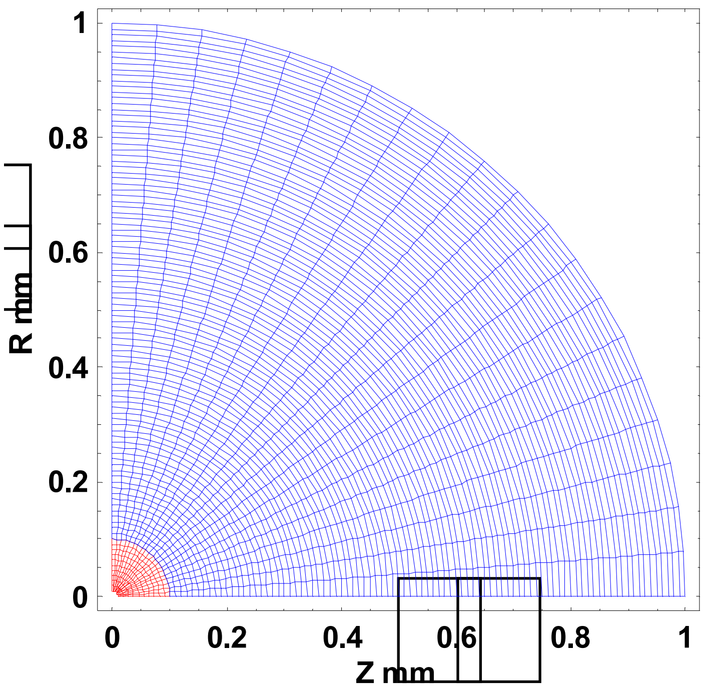
What is wrong with this picture?

Ion mean free path >> shock width as $\rho \rightarrow 0$.

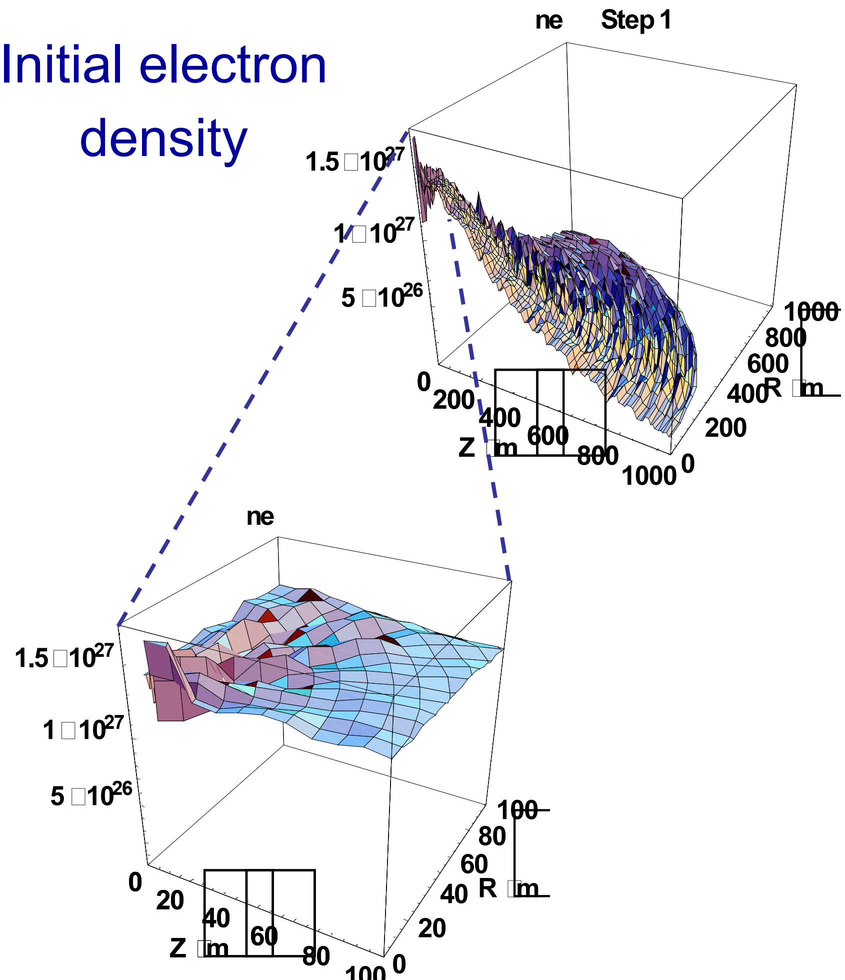


UW is Simulating Target Explosions Using the *Icarus* Direct Simulation Monte Carlo (DSMC) Code

Icarus mesh for the HAPL problem.

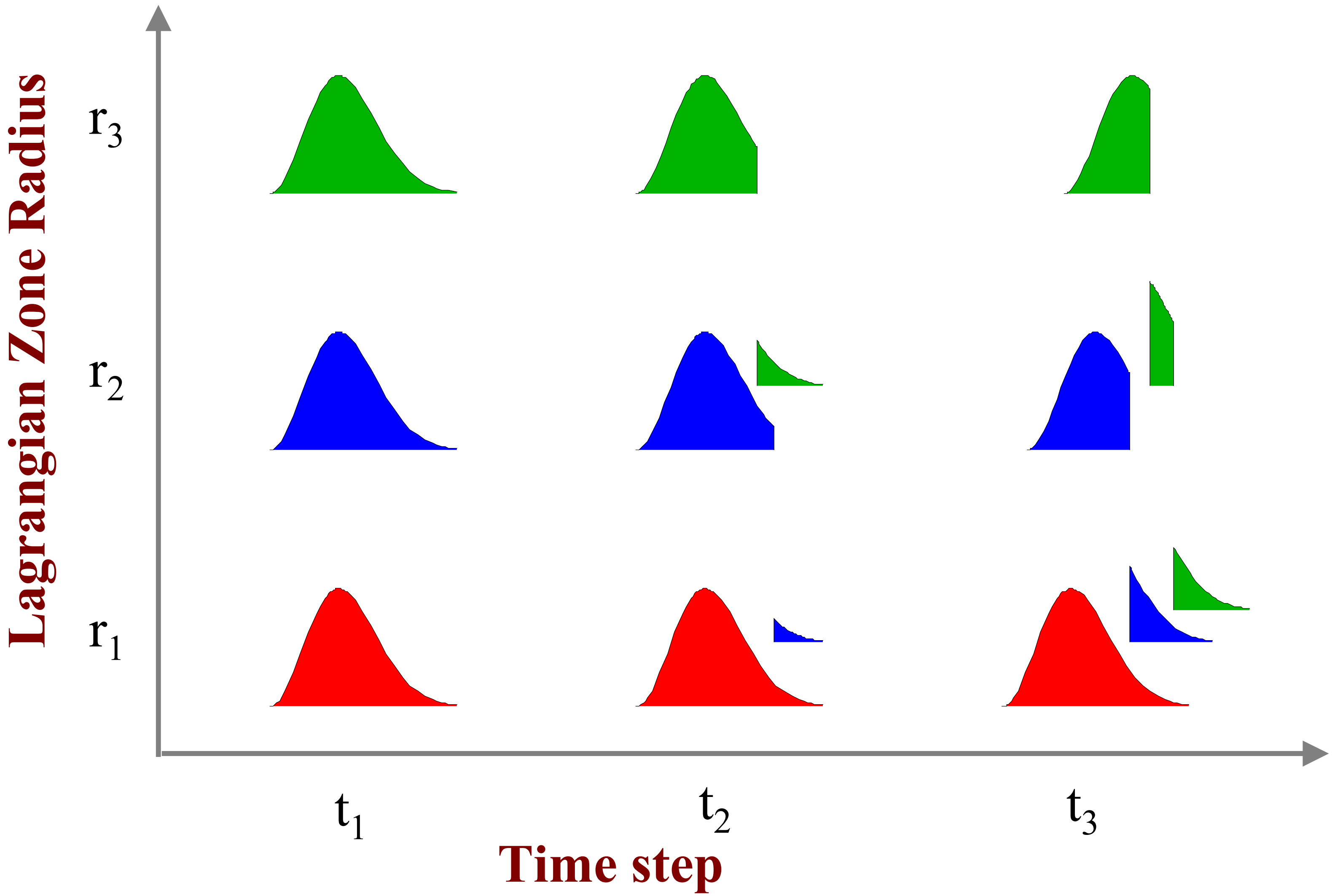


Initial electron density



- Code written by Dr. Tim Bartel, SNL.

BUCKY radiation hydrodynamics code will be modified to accelerate only the "appropriate" plasma ions



Conclusions

- Arbitrarily large temperatures can be generated at the outer boundary of the target by shock breakout into vacuum.
- Ion kinetic effects must be included in target expansion simulation to accurately predict shock propagation down density gradient and resultant temperature.