University of Wisconsin Chambers Work

John Santarius, Greg Moses, and Milad Fatenejad

HAPL Team Meeting

Georgia Institute of Technology

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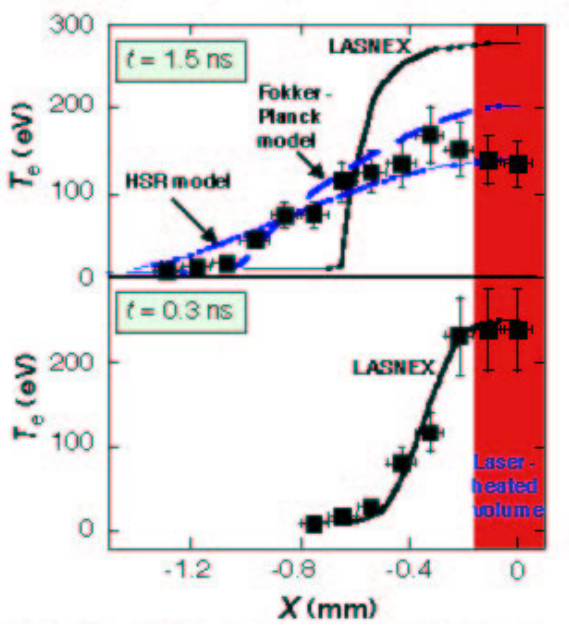
Talk will Focus on Predicting the Ion Energy Spectrum at the First Wall

Outline:

- Hydrodynamics-kinetic theory transition
  - Why is hydrodynamics not sufficient for the problem?
  - Related problems in the literature
- Status
  - Analyzing mean free paths for HAPL implosion/explosion cases
  - Formulating a long mean free path approach for BUCKY
- Future
  - Use modified BUCKY to predict ion threat spectrum
  - Investigate details of fast ion interaction with spherically expanding shock wave using discrete simulation Monte Carlo (DSMC) code, Icarus (SNL)

Why is Hydrodynamics Not Sufficient for the Problem?

- The hydrodynamic approximation breaks down for particles with mean free paths longer than the scale lengths of interest.
  - The figures below (for electrons) illustrate an analogous problem.
    - From LLNL *ICF Bimonthly Update*, Sep-Oct 2003.



  - For HAPL, two classes of ions violate the hydrodynamic assumptions for some fraction of the shot duration:
    - Fast fusion products
    - Maxwellian ion distribution tails
  - The explosion cannot efficiently accelerate ions with mean free paths longer than the shock thickness or, for some ions, the plasma extent.

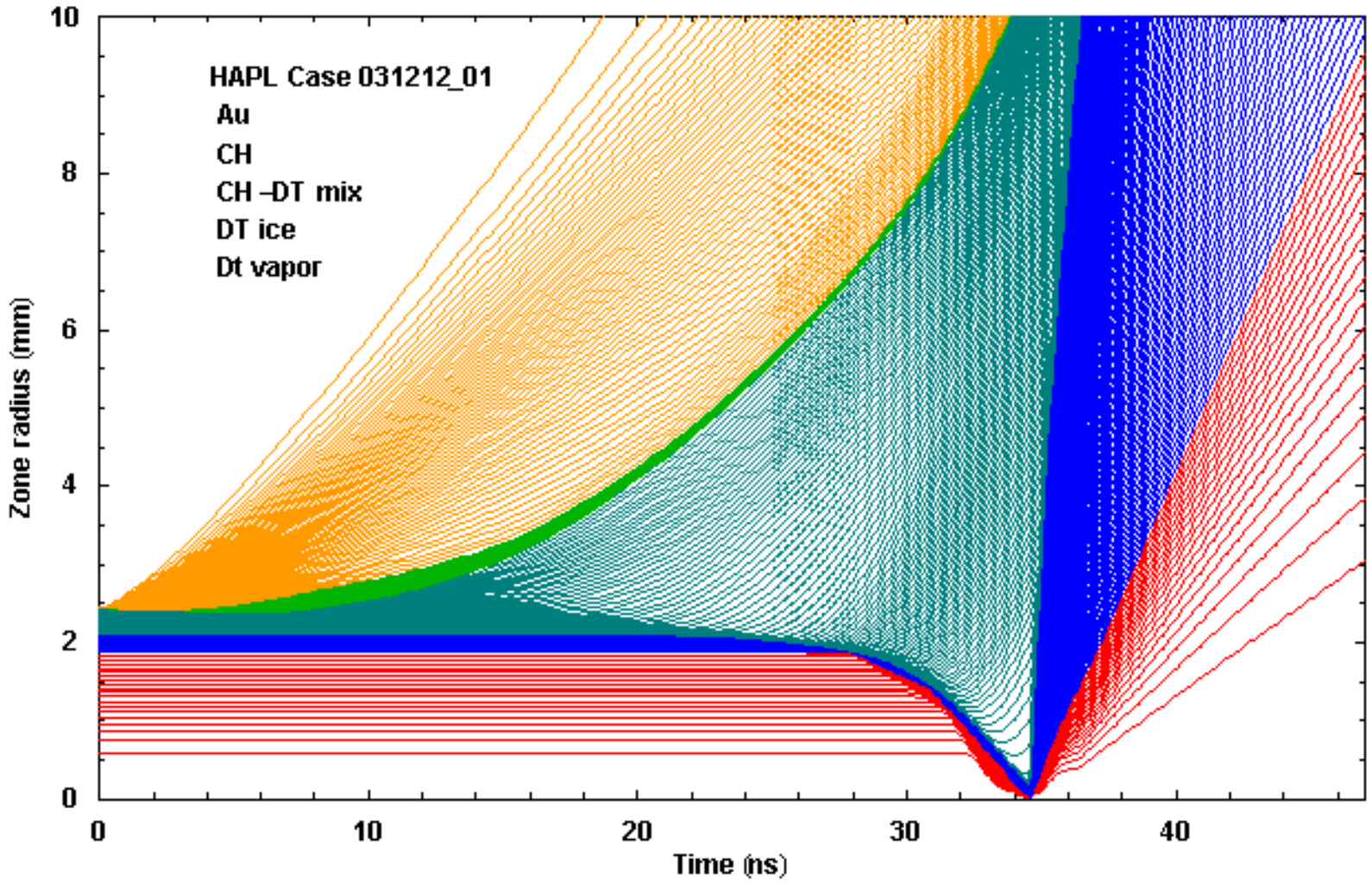
Related Research Exists, but the HAPL Fast-Ion Problem Has Not Been Addressed

- The transition between hydrodynamics and kinetic theory generally appears in the literature as modifications to the hydrodynamic equations:
  - E.g., the Mott-Smith (bi-Maxwellian) analysis, the 13-moment method, multi-fluid equations, and electron beamlets.
- Hydrodynamics texts, such as Zel'dovich and Raizer, discuss the issues but do not carry the analysis very far.
- Kinetic theory texts, such as Montgomery and Tidman, go into more detail, but the context is fundamental kinetic theory.

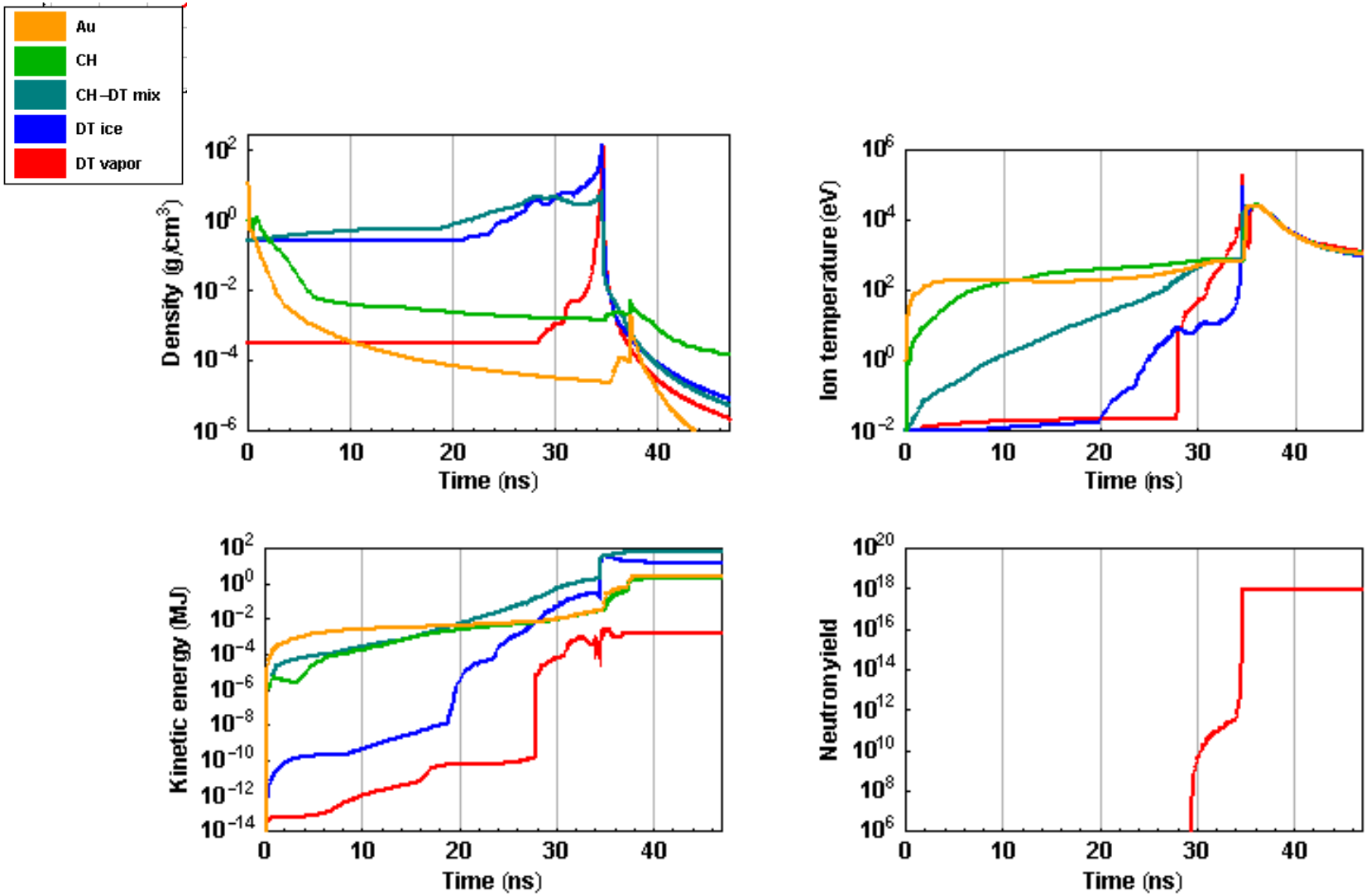
Hydrodynamic Approximation Suffices for Most ICF Applications

- For reactors, the details of the ion energy spectrum versus time are critical, requiring kinetic modifications to the analysis.
- Some related experimental and theoretical ICF literature exists, mainly focused on kinetic modifications in the approximation of counter-streaming plasmas.
- Discrete simulation Monte Carlo (DSMC) and other Monte Carlo (e.g., BGK) computational analyses are beginning to appear.

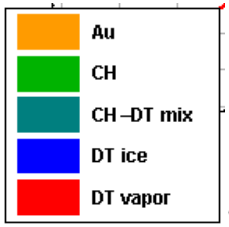
We Are Analyzing HAPL Burn Dynamics with the BUCKY 1-D Radiation Hydrodynamics Code

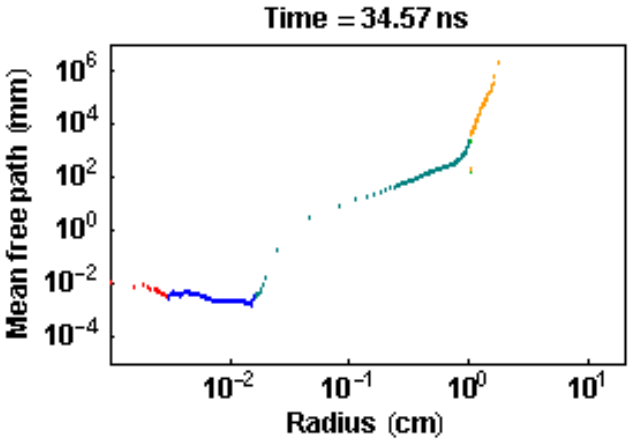


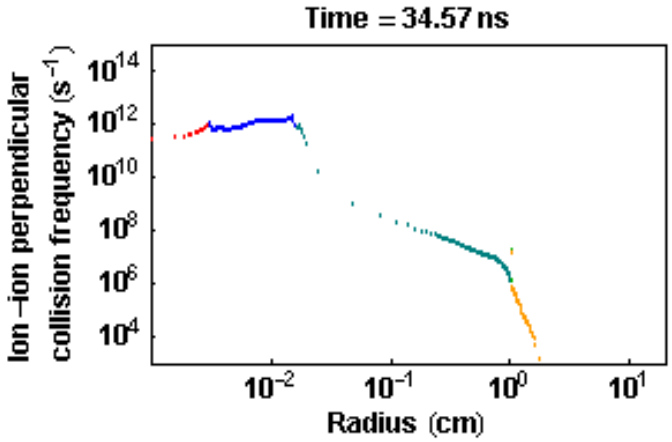
Post-Processing and Detailed Analyses Are Accomplished Using Mathematica®

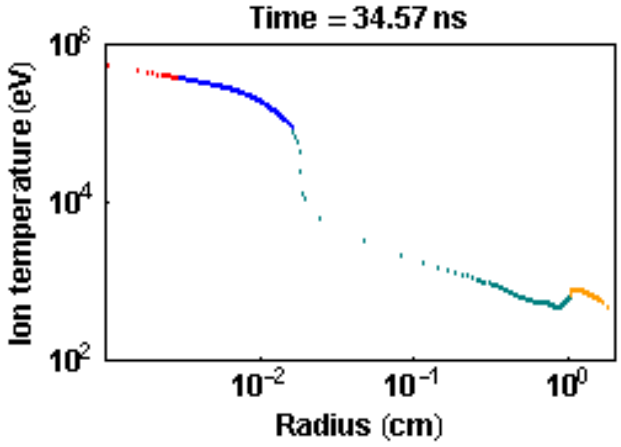


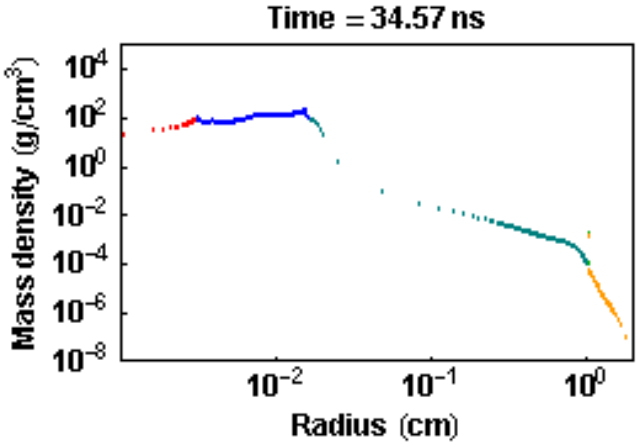
Fast Ions Possess Mean Free Paths Larger than the Shock Thickness



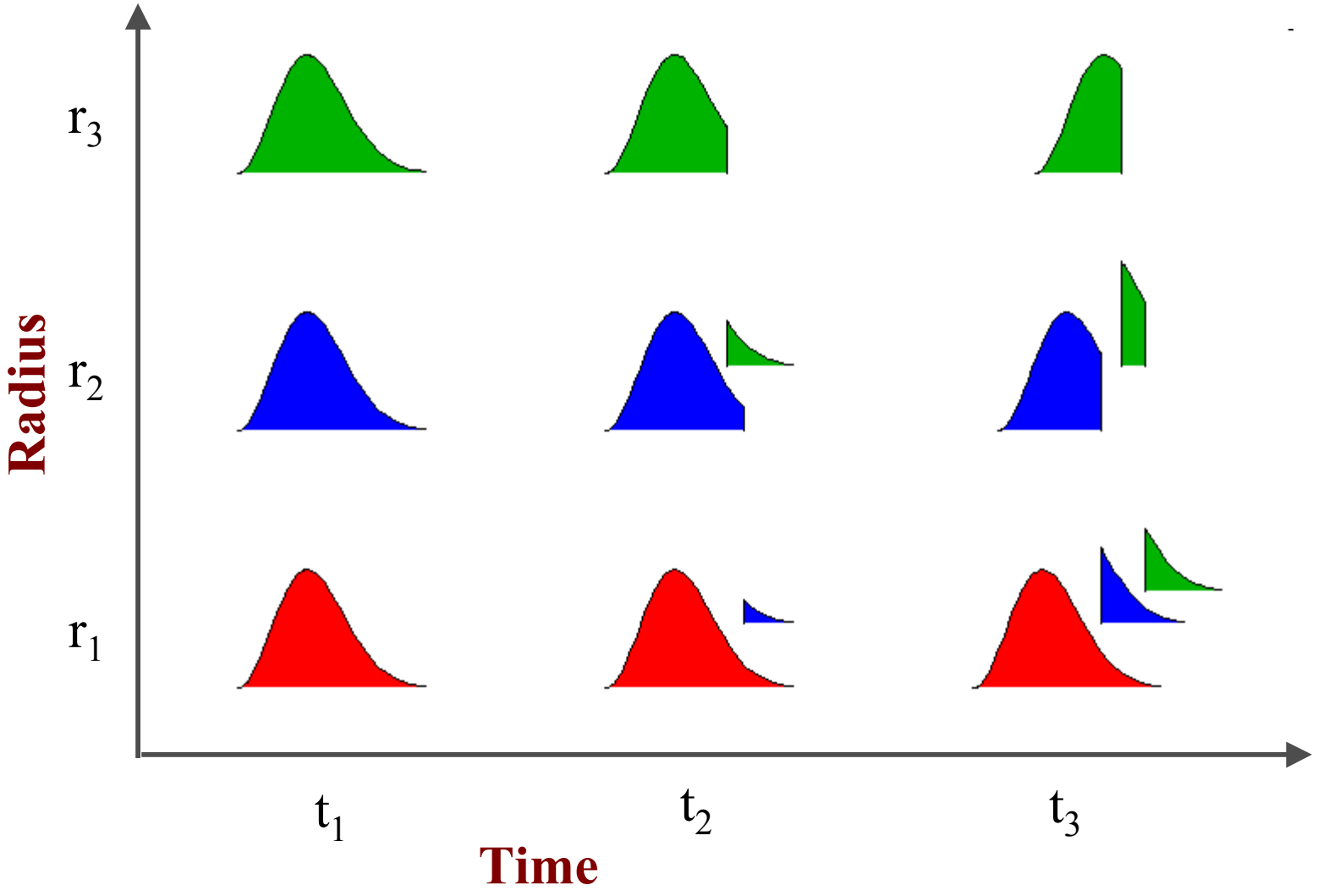








We Will Modify BUCKY to Accelerate Only the Appropriate Ions



We Will Benchmark the BUCKY Calculations against the Icarus 2-D Discrete Simulation Monte Carlo Code

- Key feature of Discrete Simulation Monte Carlo (DSMC) codes:
  - Arbitrary mean free paths,
  - Chemical and gas-surface reactions, and
  - Sophisticated computational grids.
- The Icarus code (Tim Bartel, et al., SNL) goes beyond most other DSMC codes in that it includes plasma effects:
  - Neutral gas collisions with plasma,
  - Charged particle collisions with each other,
  - Atomic physics reactions,
  - Electrostatic fields, and
  - Plasma-surface interactions.

Summary

- Hydrodynamics does not suffice for the HAPL ion energy spectrum, and kinetic effects must be assessed.
- We are analyzing a HAPL implosion/explosion case and formulating a long mean free path approach
- Future work includes
  - Using a modified BUCKY to predict ion threat spectrum
  - Investigating details of fast ion interaction with spherically expanding shock wave using discrete simulation Monte Carlo (DSMC) code, Icarus (SNL)