DRACO—A New Multidimensional Hydrocode

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A program to develop a new multidimensional hydrocode is underway at LLE. *DRACO* is an arbitrary Lagrange-Eulerian (ALE) code designed to run in 1, 2, and 3 dimensions in planar (cartesian), cylindrical, and spherical geometries. The basic hydroportion of *DRACO* employs second-order rezoning and interface tracking. A mixed-material equation of state (EOS) using *SESAME* or Wisconsin table lookups has recently been incorporated. One of the main objectives of the program is to fully exploit the parallel capabilities of the 32-processor SGI Origin-2000. This paper will describe the basic code, present results of our parallel work, and show results of recent burnthrough calculations.
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—*DRACO*—
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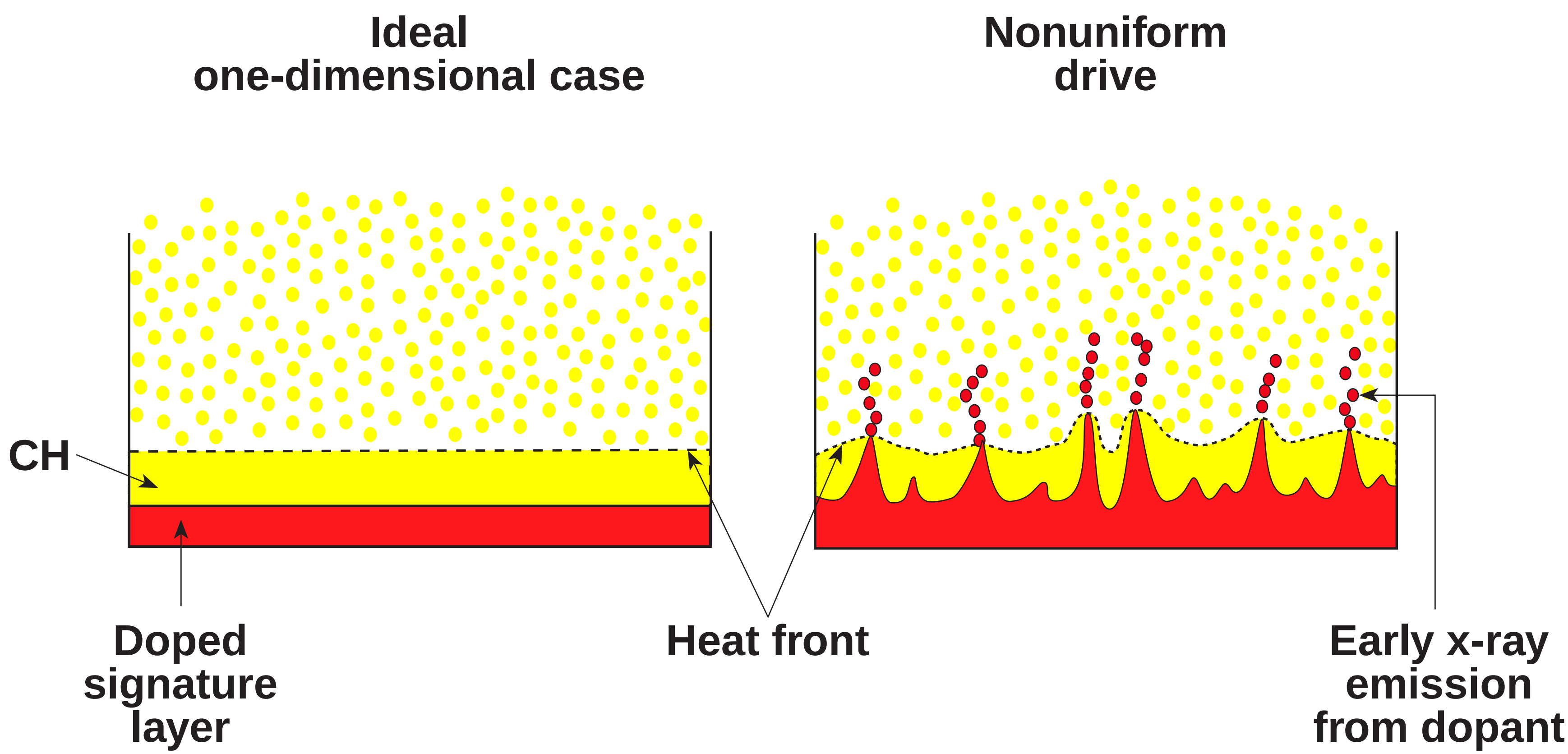
Abstract

A program to develop a new multidimensional hydrocode is underway at LLE. *DRACO* is an arbitrary Lagrangian–Eulerian (ALE) code designed to run in 1, 2, and 3 dimensions in planar (cartesian), cylindrical, and spherical geometries. The basic hydro portion of *DRACO* employs second-order rezoning and interface tracking. A mixed-material equation of state (EOS) using *SESAME* or Wisconsin table lookup has recently been incorporated. One of the main objectives of the program is to fully exploit the parallel capabilities of the 32-processor SGI Origin-2000. This paper will describe the basic code, present results of our parallel work, and show results of recent burnthrough calculations.

A number of top-level goals have been identified to guide the development of *DRACO*

- The goals of this effort are
  - Introduce new and improved algorithms into the code (based on physics requirements and machine/code performance).
  - Develop a code targeted for new multiprocessor machine architectures.
  - Develop a code capable of running 1-D, 2-D, or 3-D using common physics packages and algorithms (where possible).

RT instability growth of accelerating shell has been examined using burnthrough technique



E9254

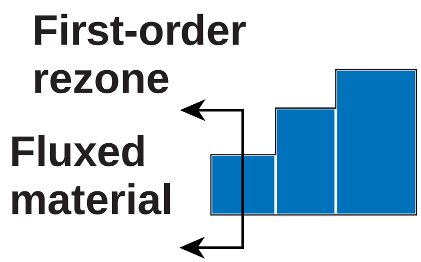
DRACO is a newly developed hydrodynamics code for direct-drive ICF research

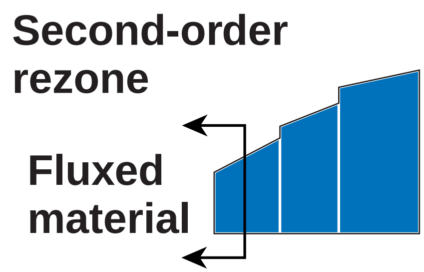
- ***DRACO* uses the ALE (arbitrary Lagrangian–Eulerian) formulation to solve the hydro equations.**

- **Physics modules to enable *DRACO* to simulate planar burnthrough experiments have been added:**
  - **second-order rezoning**
  - **interface tracking**
  - **mixed-material EOS**
  - **laser-energy deposition**
  - **radiation transport**

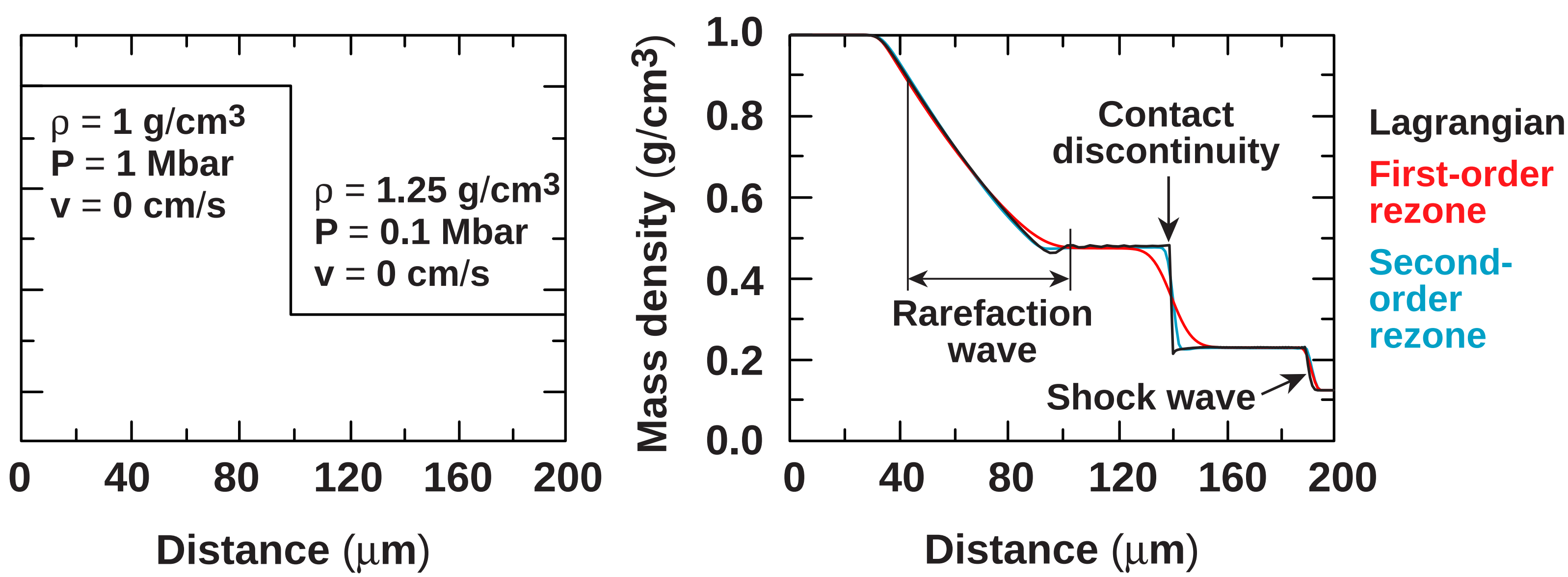
Van Leer's method has been added to *DRACO* to give second-order accurate advection

- Van Leer's method takes into account the gradients of the fluxed material necessary to achieve a second-order accurate solution:





- Van Leer's method captures the position of the contact discontinuity in Sod's problem*.

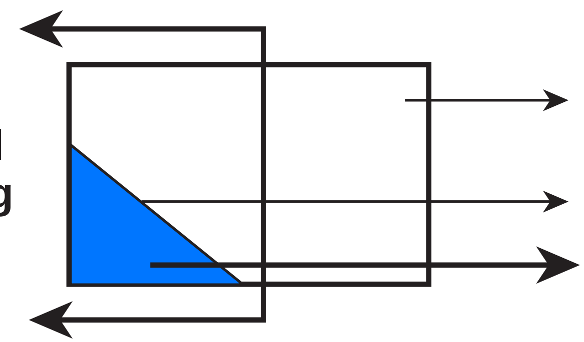


TC5242

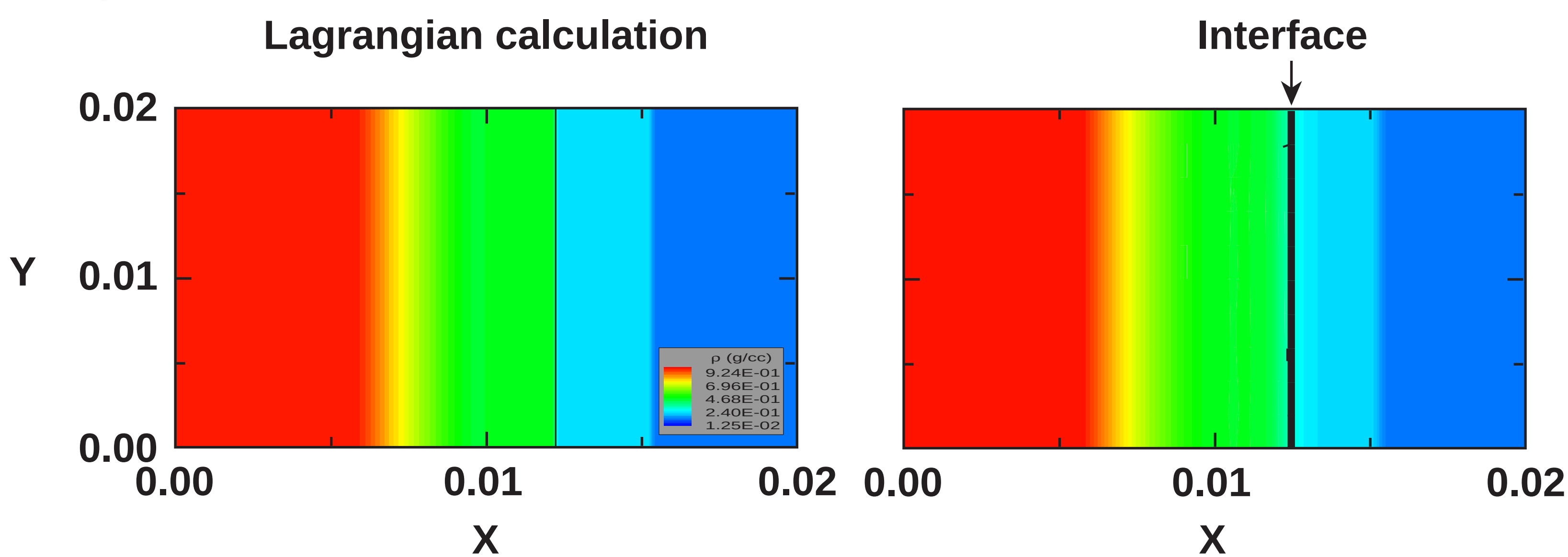
*G. A. Sod, J. Comput. Phys. 27, 1 (1978).

Interfaces between materials can be tracked in *DRACO* using methods based on volume fractions

- Youngs' method* uses the gradient of material volume fraction to draw a straight-line interface in the cell.



- Sod's problem



*D. L. Youngs, Physica D 12, 45 (1984).

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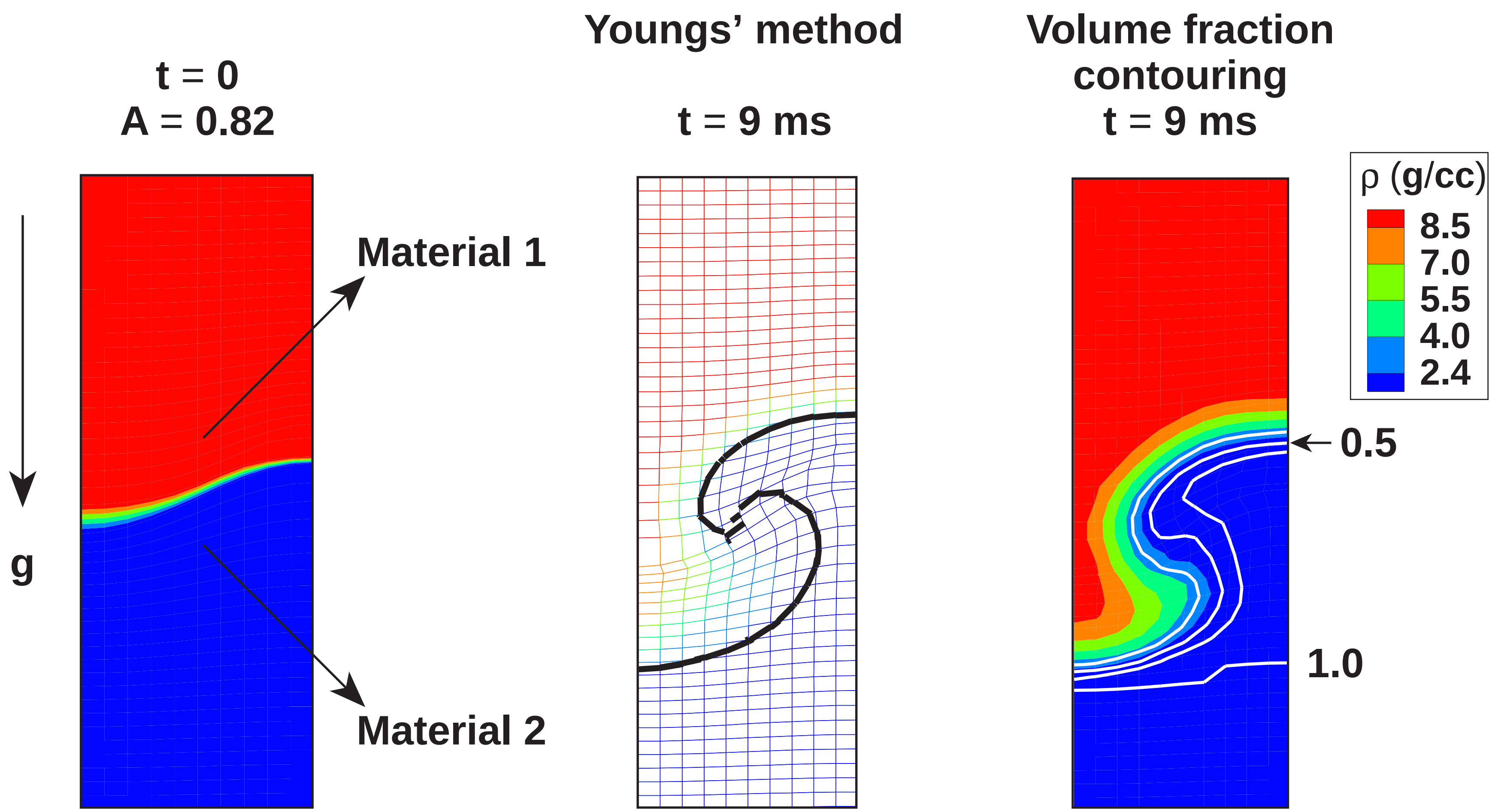

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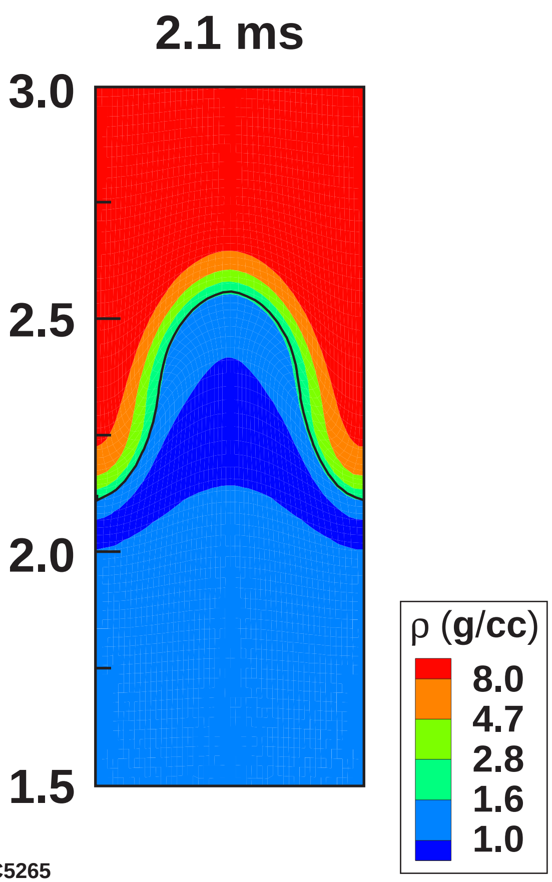
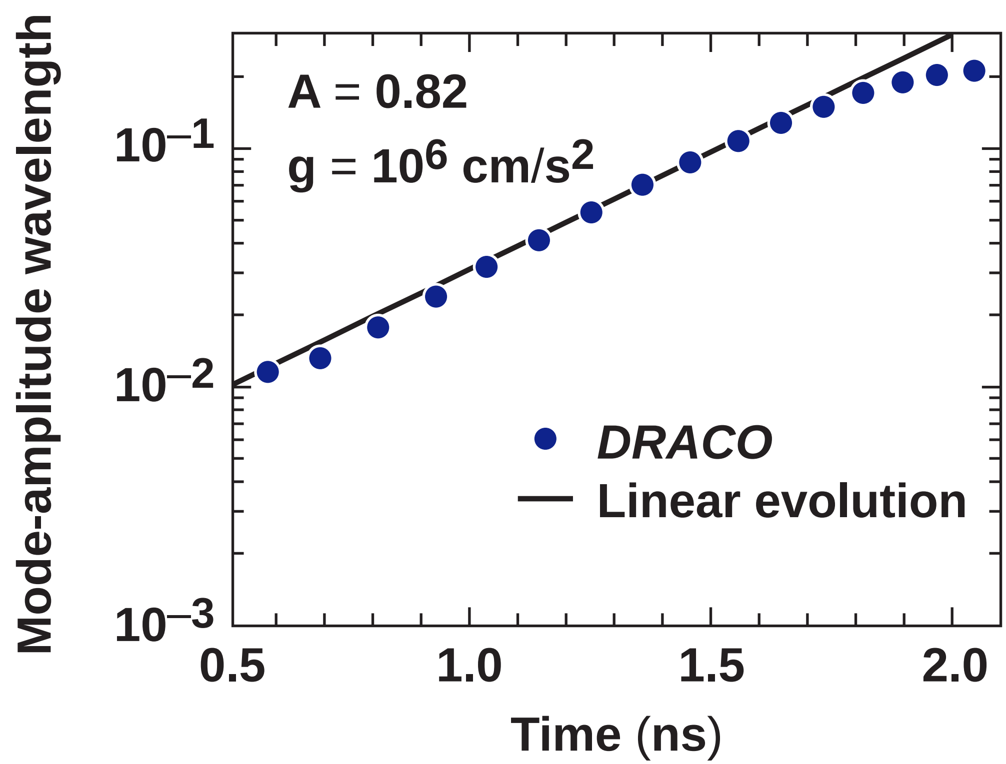
Interface tracking in *DRACO* has been tested on a variety of problems

- Classical Rayleigh–Taylor instability





TC5265

Mixed-material EOS has been added to enable *DRACO* to track materials

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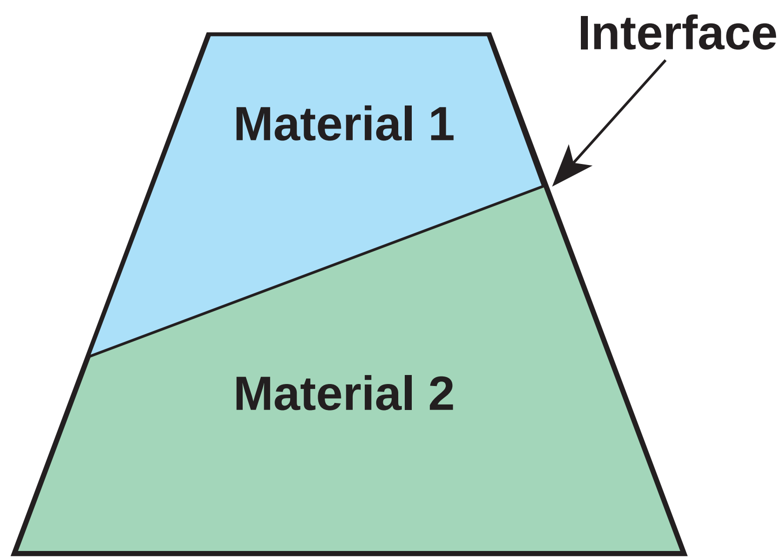
- Supported EOS models:
  - ideal gas
  - perfect gas
  - linearly interpolated EOS table lookup (*SESAME*)
  - Logarithmically interpolated EOS table lookup (*SESAME*)

- Assumptions:
  - thermal equilibrium
  - constant volume fraction
  - Cell pressure is the volume fraction-weighted average of the individual pressures.



Lagrangian cell

In two cases EOS calculation/lookup is required during a timestep

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- Following Lagrangian physics:
  - known: $T^{i(e)}, f_{vj}, \rho_j$
- Following rezoning:
  - known: $E^{i(e)}_{int_{tot}}, f_{vj}, \rho_j$
  - "inverse" calculation/lookup of values for $T^{i(e)}$

For logarithmic table lookup, this requires nonlinear, iterative root finding.

- In both cases
  - "forward" calculation/lookup of values for $P_j^{i(e)}, E^{i(e)}_{int_j}, c^{i(e)}_{v_j}, \dfrac{\partial P_j^{i(e)}}{\partial T^i}$
  - cell-averaged values are calculated for

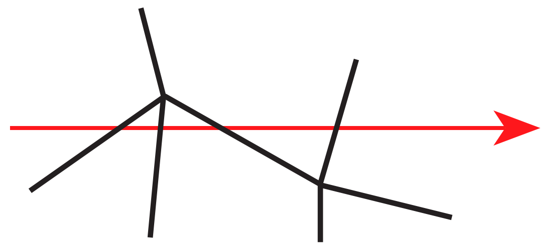
$$P^{i(e)} = \sum_j P_j^{i(e)} \bullet f_{v_j} \qquad \frac{\partial P^{i(e)}}{\partial T^{i(e)}} = \sum_j \frac{\partial P_j^{i(e)}}{\partial T^{i(e)}} \bullet f_{v_j}$$

$$E^{i(e)}_{int_{tot}} = \frac{1}{M_{tot}} \sum_j E^{i(e)}_{int_j} \bullet m_j \qquad c_v^{i(e)} = \frac{1}{m_{tot}} \sum_j c^{i(e)}_{v_j} \bullet m_j$$

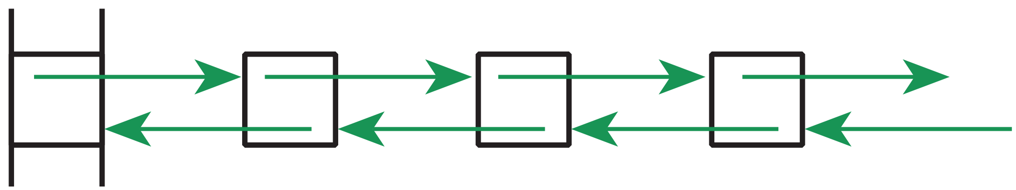
TC5238

DRACO models inverse-bremsstrahlung laser-energy deposition in one and two dimensions

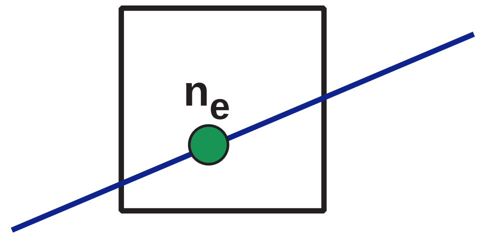
- Ray trace, using direction cosines, determines ray path through distorted mesh.



- Ray paths are stored in an array of doubly linked list, allowing minimal memory use.



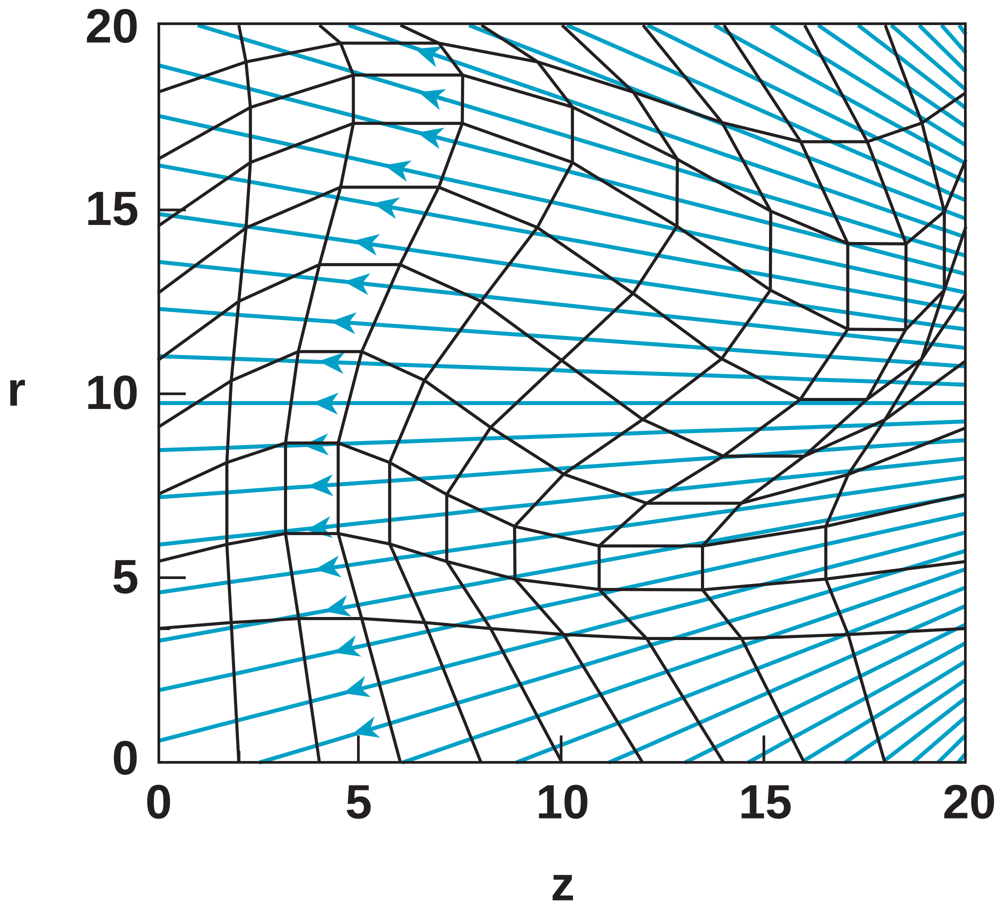
- Given cell-centered electron number densities [$n_e(x)$] and vertex locations, path-centered and ray/cell-edge $n_e(x)$ values are determined using linear interpolation.



- The Langdon effect to take account of the non-Maxwellian velocity distribution is included.

Normal-incidence ray trace and laser-energy deposition have been tested in 2-D

- 2-D ray trace employs direction cosines.
- Laser energy-deposition has been compared to *LILAC*.



TC5236

The large number and dynamic nature of global variables require organized maintenance

- *DRACO* currently has 1122 variables shared via modules (including 717 input variables).
- The simultaneous development of new physics modules is constantly adding new controls and simulation features.
- Keeping the user and development community informed requires accurate and up-to-date documentation.
- Conventional coding requires adding information about a new variable in many places: declaration, initialization, input processing, checkpoint, restart, output, plotting, etc.

A data structure of attribute information about each global variable is maintained in a linked list

Variable attribute

Record

Name description
usage
version module defined input status allocation status namelist ...

Code snippet

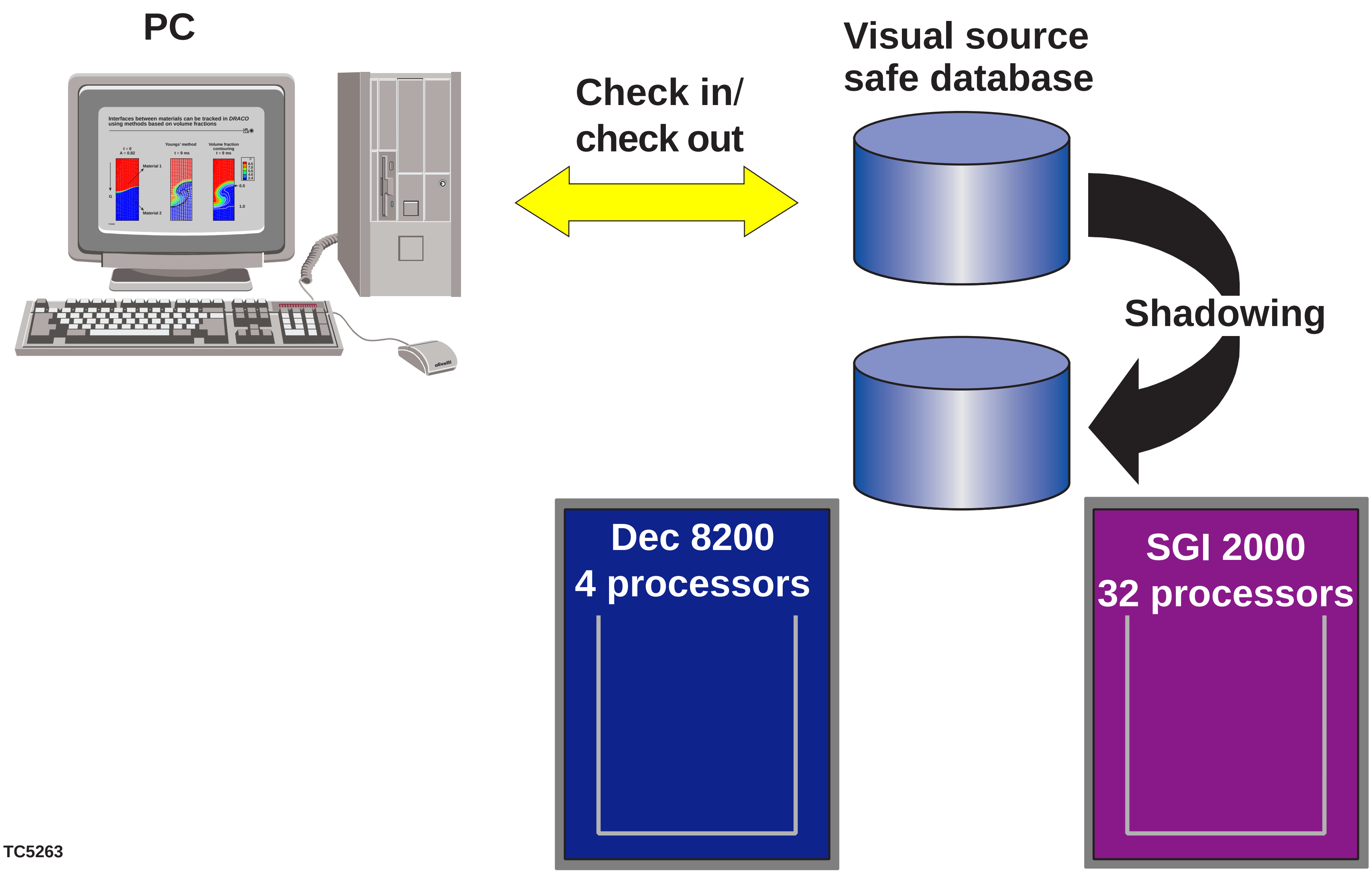
```
...
do while (associated(g_var))
   if (g_var%usage/= 'constant') then
     call write_ckpnt_record(g_var)
   endif
   g_var => g_var%next
enddo
...
```

- **New variables automatically included throughout the code based on attributes defined in a single instance results in easier maintenance.**

Maintaining attributes about variables has many advantages

- All attribute information is recorded in a single place.
- Variables are automatically included in code loops where the defined “usage” attribute of the variable applies.
- At least some minimal variable usage is documented in the description field.
- All attributes are automatically formatted into a help file.
- Unique global variable names are guaranteed.

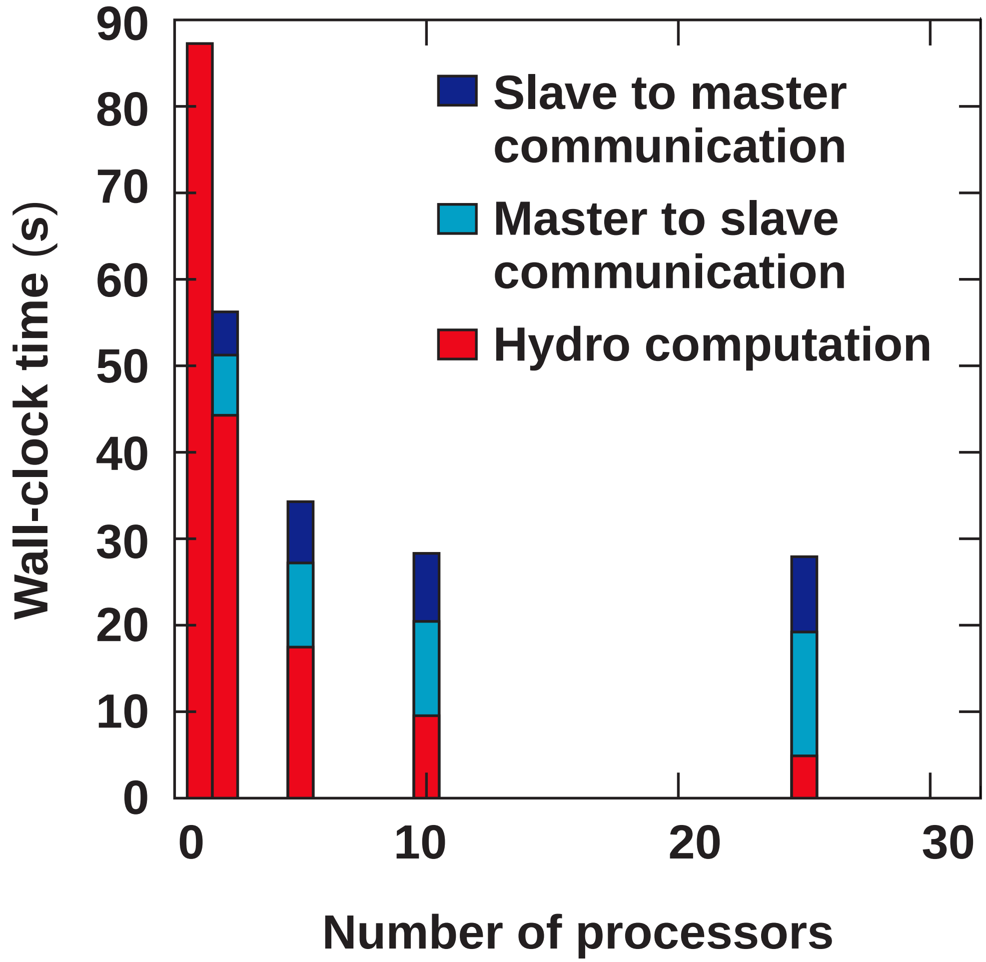
DRACO coding environment uses state-of-the-art software tools for cross-platform development



TC5263

For efficient parallelization, the communication costs must be minimized

- **A 400 × 200 hydrodynamic problem shows almost perfect parallelization of the computational portion.**



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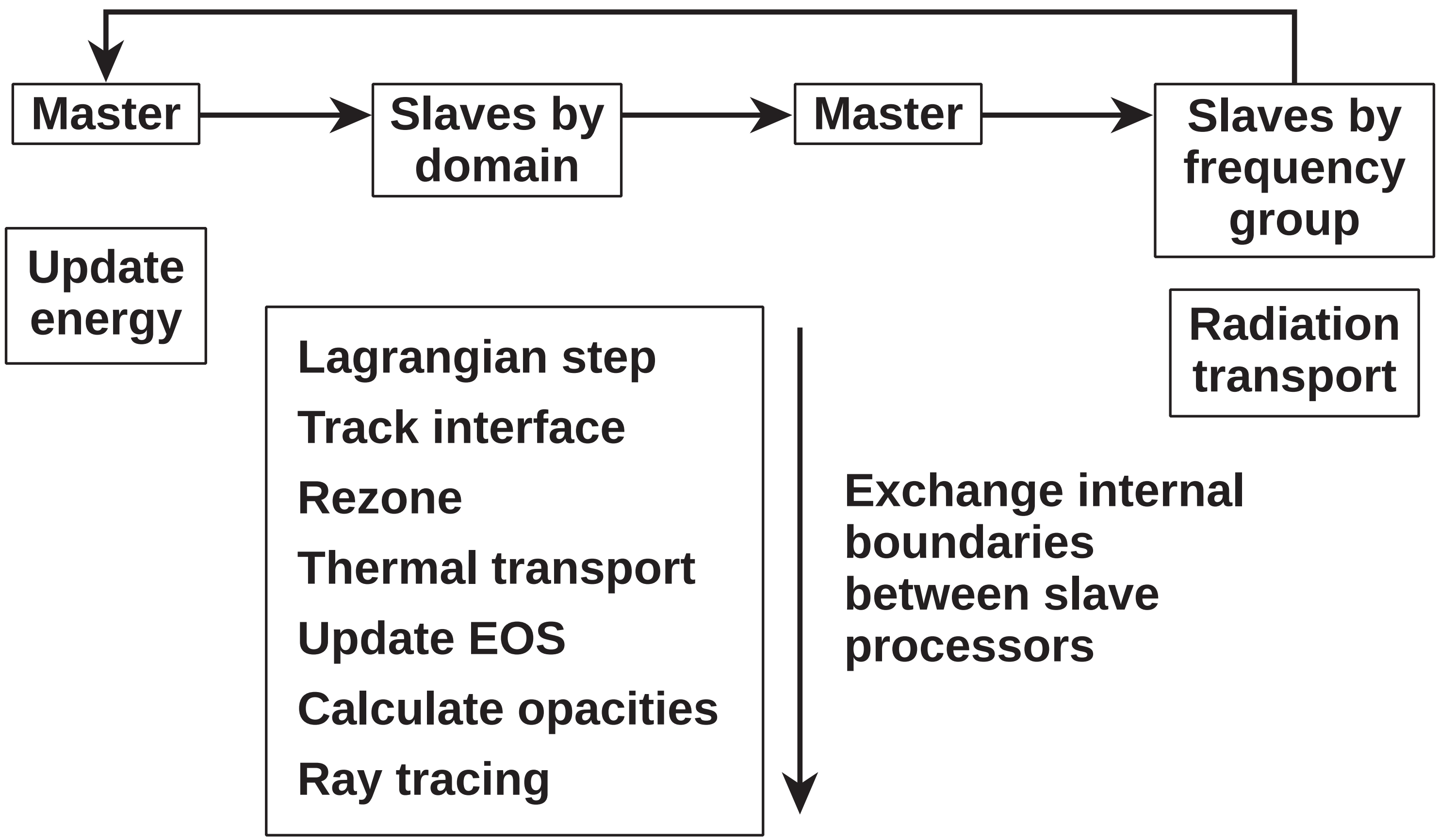
Parallelization will use a mixture of domain decomposition and the master-slave approach

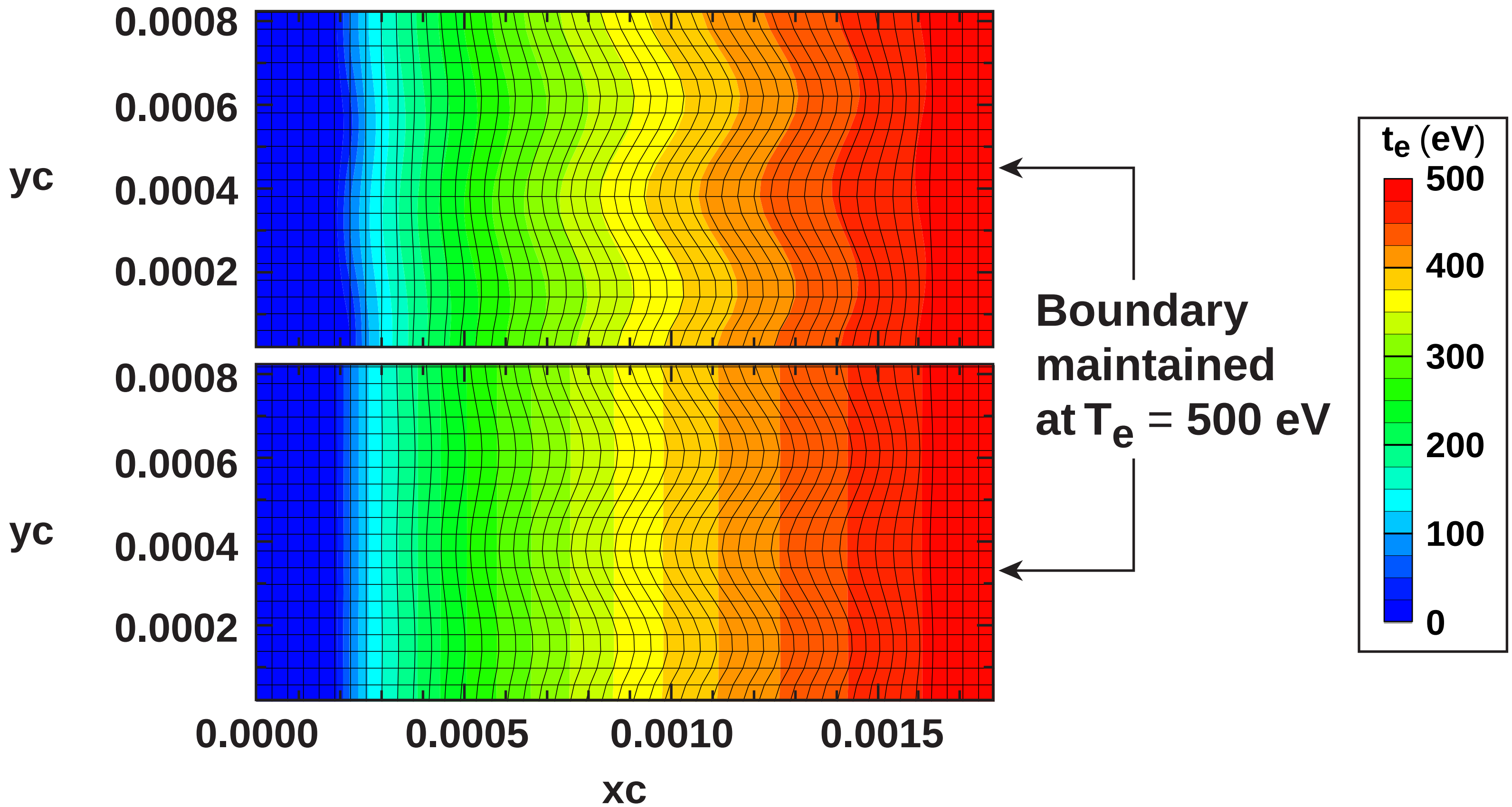
- LLE's work on parallelization to date has shown that it is essential to minimize the communication costs and maximize the computational work.



TC5078

Maintaining a planar thermal wave through a Lagrangian grid requires a nine-point differencing scheme

- Five-point differencing scheme shows perturbed temperature front.

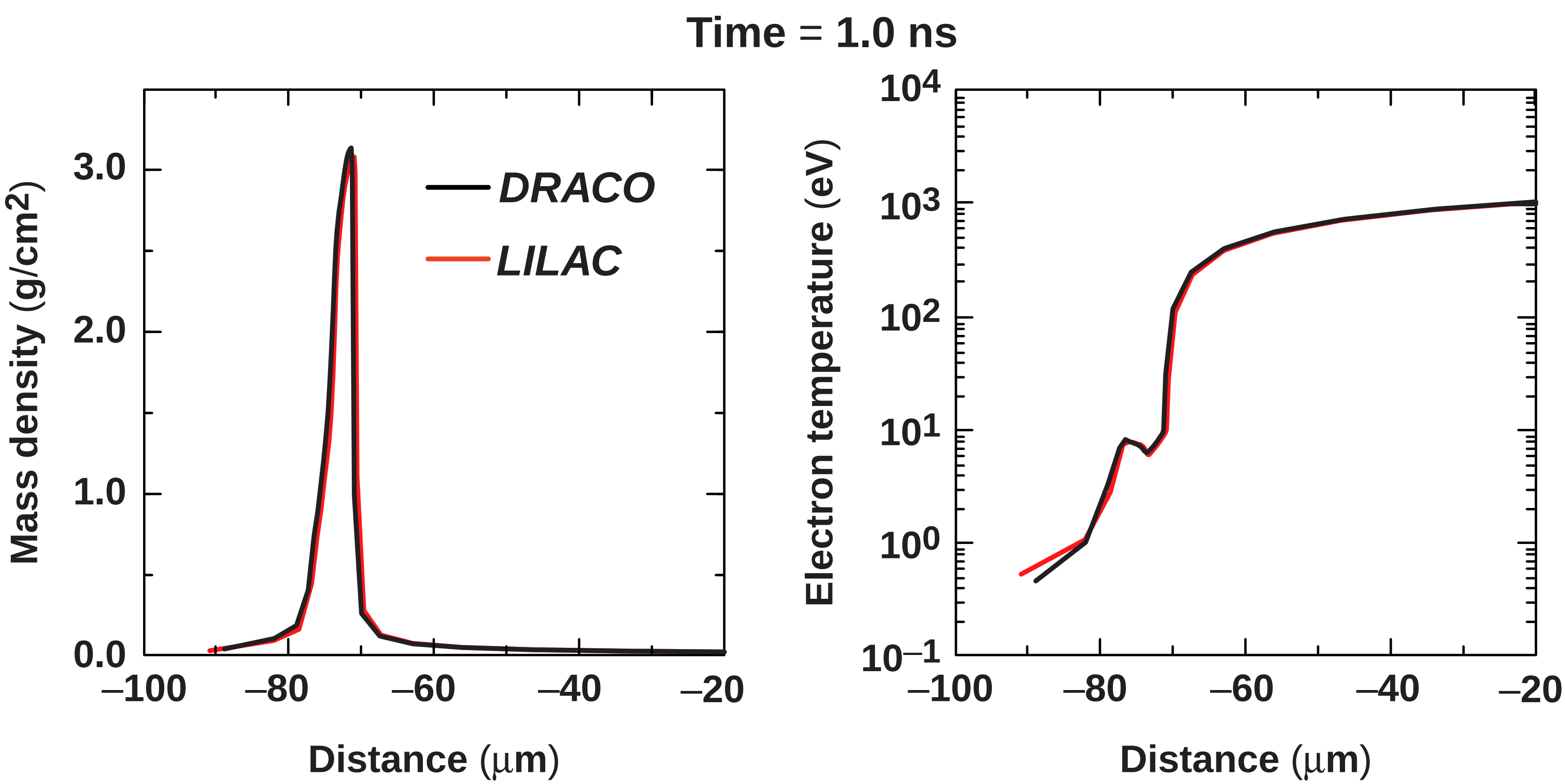


- Nine-point differencing scheme maintains a planar wave.

TC5243

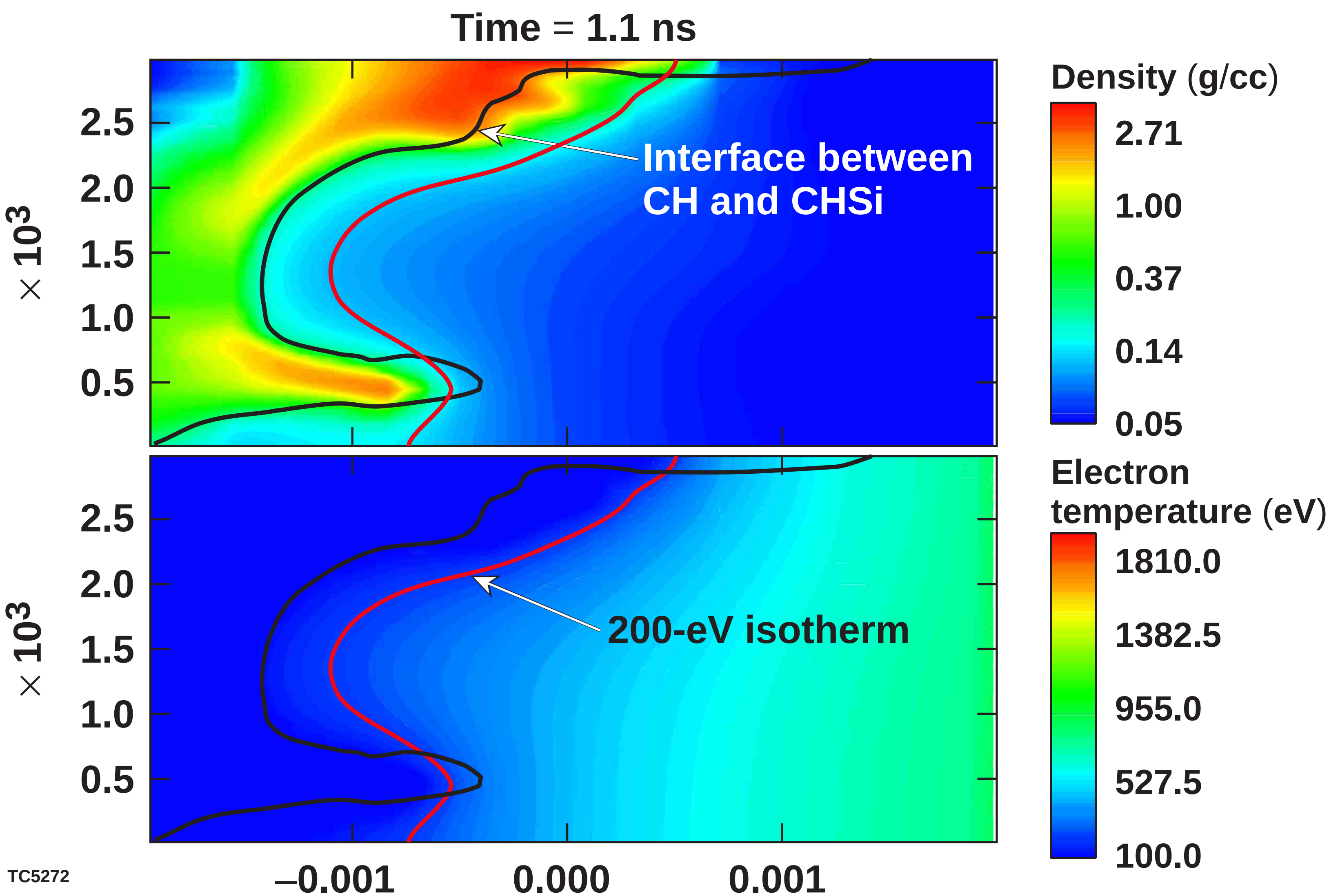
DRACO shows good agreement with *LILAC* calculations

- A 20-μm planar CH foil is accelerated by a 2-ns flat-top laser pulse with an intensity of 2×10^{14} W/cm^2.



TC5244

A multimode nonuniform laser beam shows burnthrough at the tips of the spikes



TC5272

Summary

Future work on *DRACO* will include a detailed comparison to experimental and investigations of direct-drive ignition designs

- Comparisons with planar-foil experiments will include
  - effect of laser imprint
  - Rayleigh—Taylor growth of single modes
  - burnthrough event
- Additional physics modules to be added include
  - alpha-particle transport and burn
- Comparisons with implosion experiments will include
  - yields from gas-filled CH shells and CD buried layers
  - emission from buried Ti layers
- Work will continue on parallelization techniques.