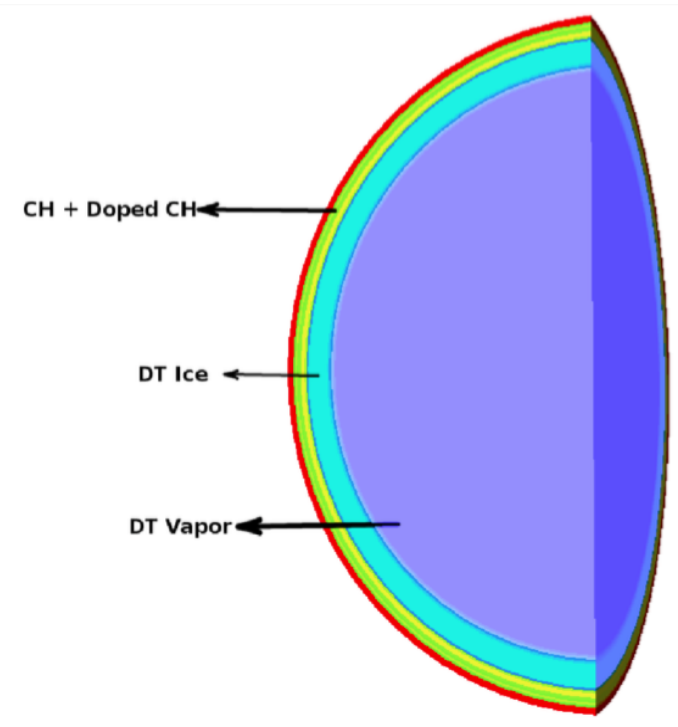
Mixing With Applications To ICF Implosions

V. Rana, H. Lim, J. Melvin, and J. Glimm
Department of Applied Mathematics & Statistics, Stony Brook University

1. Introduction: Overview and Motivation

- Rayleigh-Taylor and Richtmyer-Meshkov instabilities are detrimental to Inertial Confinement Fusion experiments.
- Mixing is sensitive to physical transport mechanisms.
- Numerical algorithms can give rise to artificial mixing and thus they need to be accounted for (FrontTracking).



2. Goal: Predict The Ablator Mix Into The Hot-Spot

- Our goal is to predict that unmodeled instabilities could lead to significant levels of mix.
- Couple Buoyancy-Drag Mix model which selects a range of maximum growth rates.
- Mix generation is due to: physical (Physical Transport), turbulent (Sub Grid Terms) and numerical (Algorithmic Transport)

5. Buyoancy Drag and Mix Model Predictions

$$(\rho_i + k_i\rho_{i'})\frac{dV_i}{dt} = (\rho_i - \rho_{i'})g(t) - (-1)^i \frac{C_i\rho_{i'}V_i^2}{|h_i|}, \quad i = 1,2 \ ,$$

$$C_i = \frac{1/\alpha_i - (1+(-1)^i A) - k_i(1-(-1)^i A)}{2(1-(-1)^i A)},$$

- Minor effect of from concentration diffusion into the hot-spot.
- FrontTracking reduces numerical (algorithmic) mix across the RT instability threshold.
- Combined effects of amplitude growth at initial DT-Gas/DT-ice boundary along with RT unstable thermal gradient produces mix.
- Additional ablation instability with RT instability can cause mix.

6. Tracked vs. Untracked Eulerian Simulations

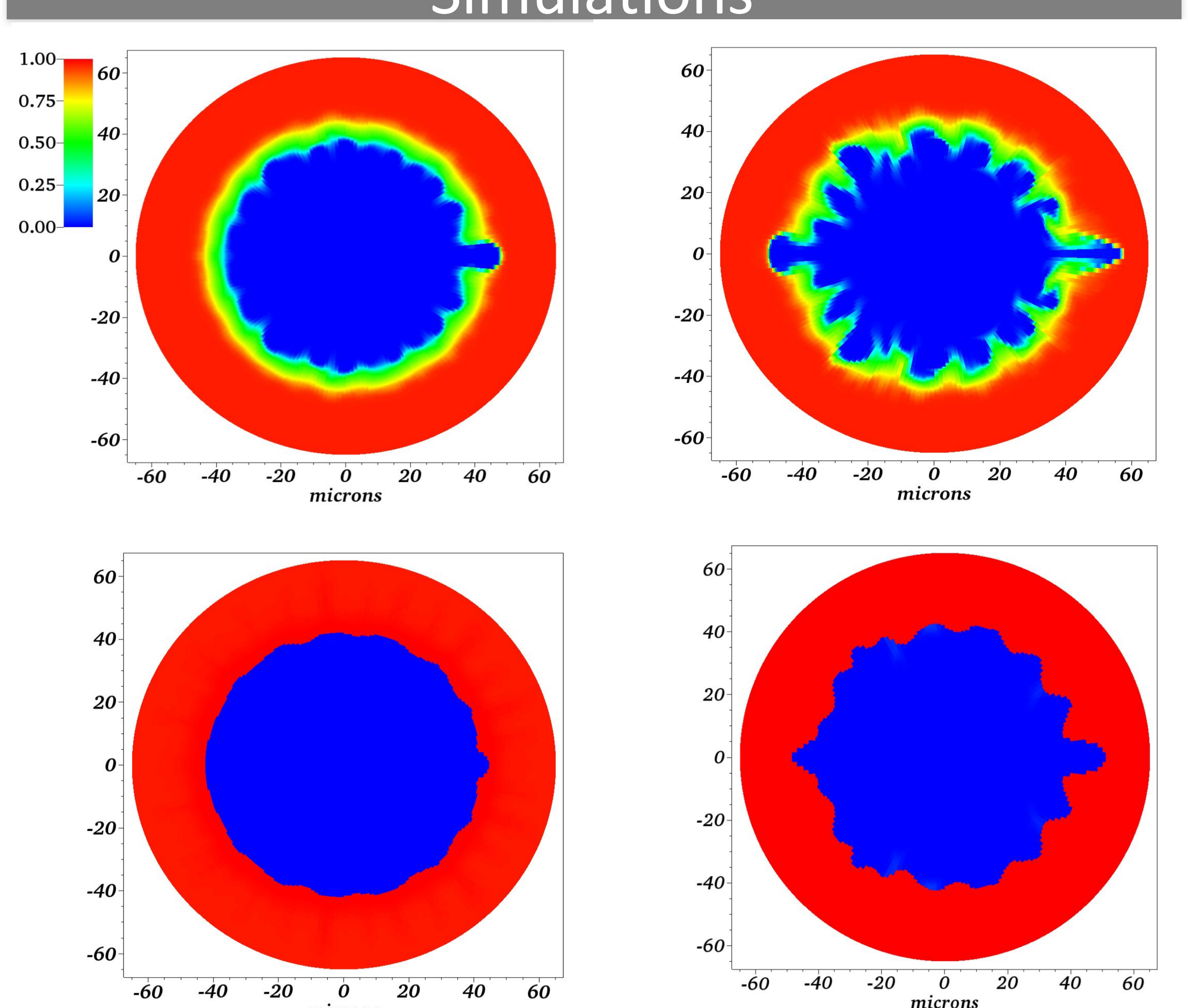


Figure 4: CH spike edges at bang time for both nominal (left) and strong (right) RM initial conditions. Top row (without front tracking) and bottom row (with front tracking) show a large impact on the CH penetration due to numerical diffusion

3. Transport Package (TICF)

- Fluid mixing depends on fluid transport.
- TICF is a package that consists of molecular, concentration and thermal transport models and covers ICF domain.
- Schmidt and Prandtl numbers show strong dependence on the relative CH/DT concentration
- Dependence results from how dense the electron gas in the system is.

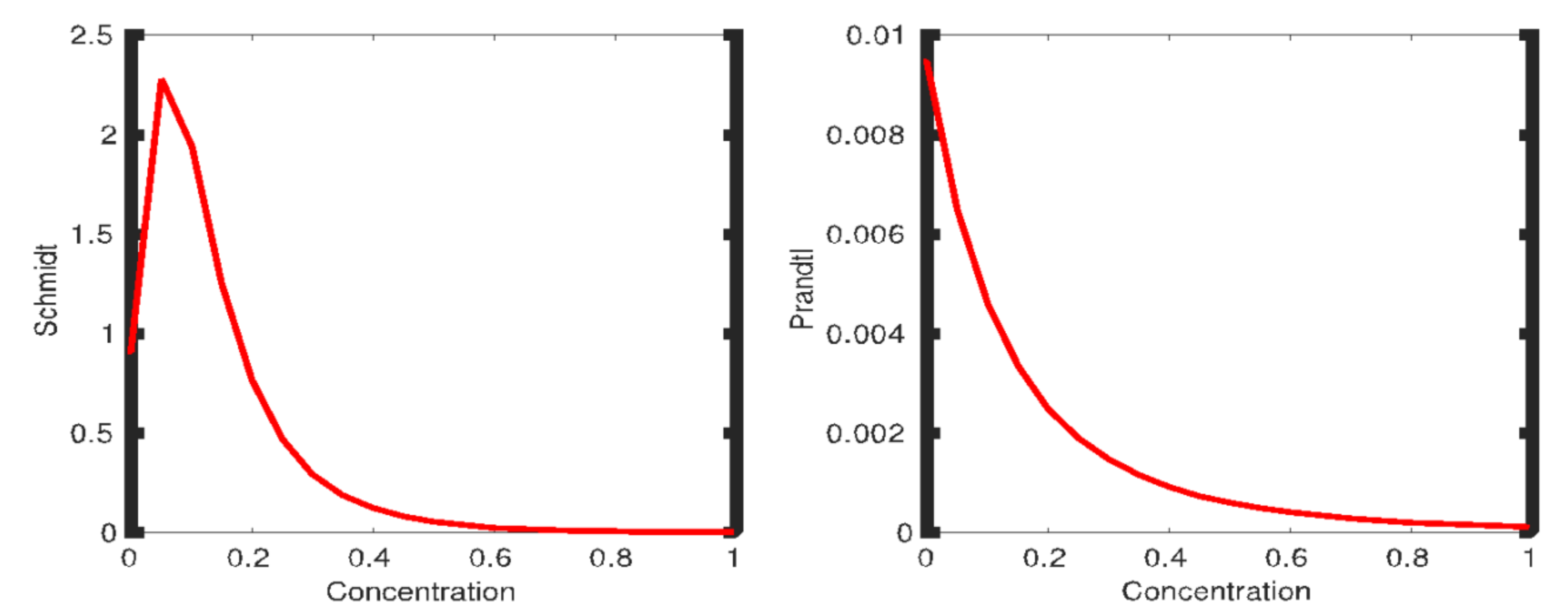


Figure 1 : The range Sc and P r values as the concentration is varied for fixed T = 4.5keV and ρ = 63 g\cm^3, typical values for the hot spot at bang time.

4. Concentration Dependent Schmidt Numbers

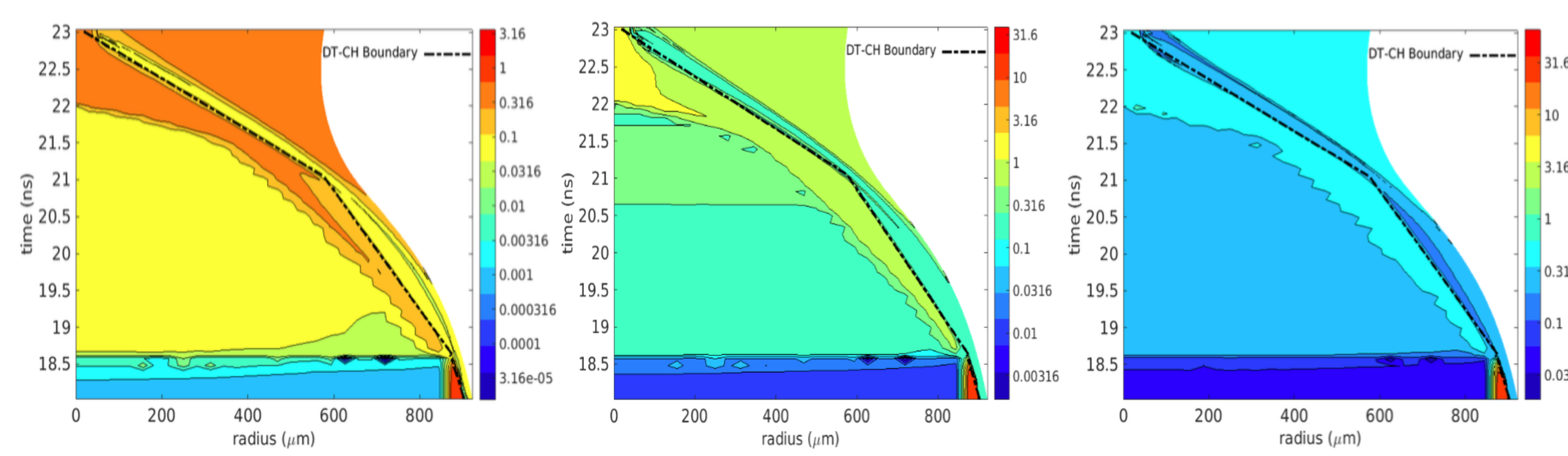


Figure 2: Schmidt number in the (radius,time) space of a NIC implosion. From left to right: 0% CH - 100% DT, 10 % CH - 90% DT, 20% CH - 80% DT

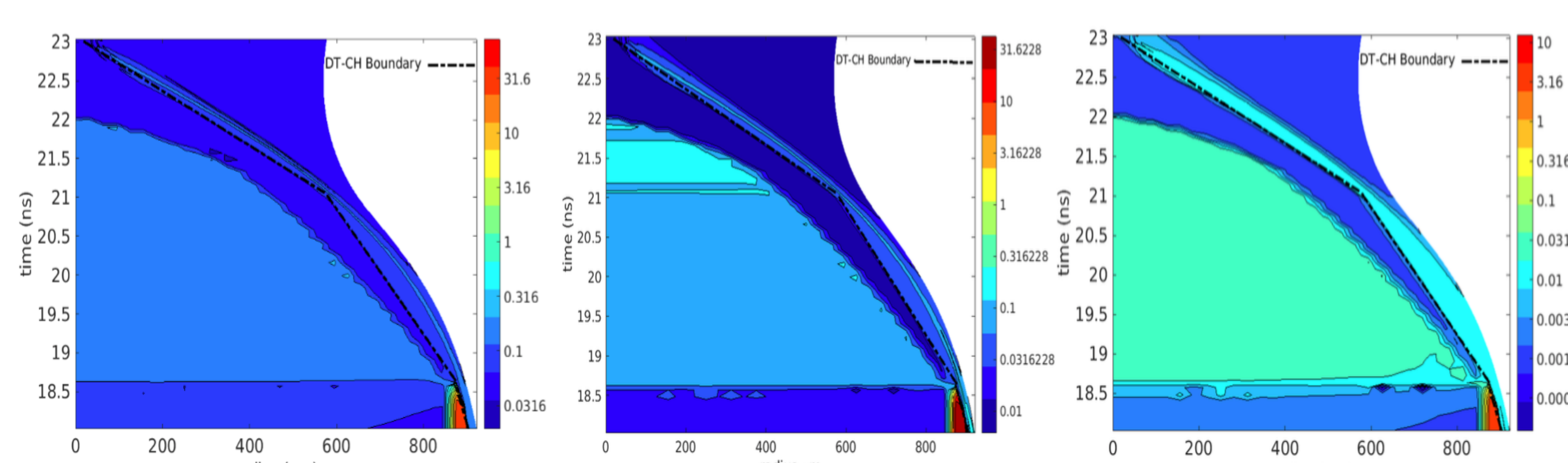


Figure 3: Schmidt number in the (radius, time) space of a NIC implosion. From left to right: 50% CH - 50% DT, 70 % CH - 30% DT, 90% CH - 10% DT

7. Conclusion

- The findings are indicative of no single mechanism that can cause mix to occur but rather combined effects.
- There is a marginal amount of mixing that occurs due to mass diffusion but mostly combined effects from RT/RM instabilities that affect the hot-spot.
- Possible ablation instabilities with transport along with RT/RM instabilities are a main driver of mix.
- The basis for these results come from a Buoyancy Drag model enhanced with FrontTracking and TICF package.