ECN 1 Outcomes - Spray A

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ECN Web modeling meeting

Participants

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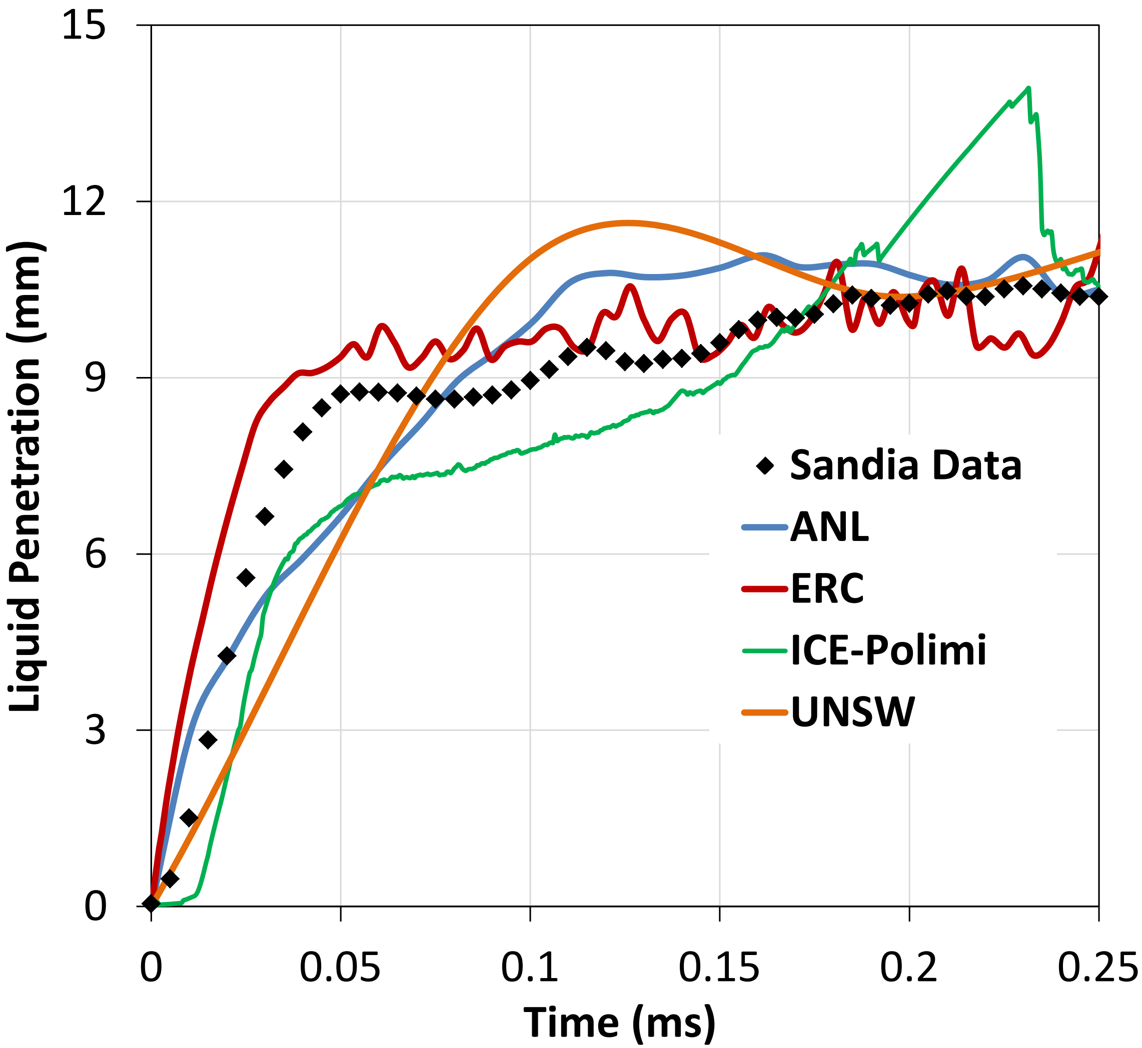
Outline

- ❑ Baseline Spray A: non-reacting conditions
- ❑ Spray penetration vs. time
  - ✓ Effect of grid size
  - ✓ Effect of time-step size
  - ✓ Effect of turbulence model
- ❑ Vapor penetration vs. time
  - ✓ Effect of grid size
  - ✓ Effect of time step size
  - ✓ Effect of turbulence model
- ❑ Mixture fraction at different radial positions
  - ✓ Two axial positions were chosen for comparison
- ❑ Comparison of vapor boundary location
- ❑ Comparison of liquid boundary location
- ❑ Battle of codes
- ❑ Summary of standardized definitions: Evatt Hawkes

Quick Recap

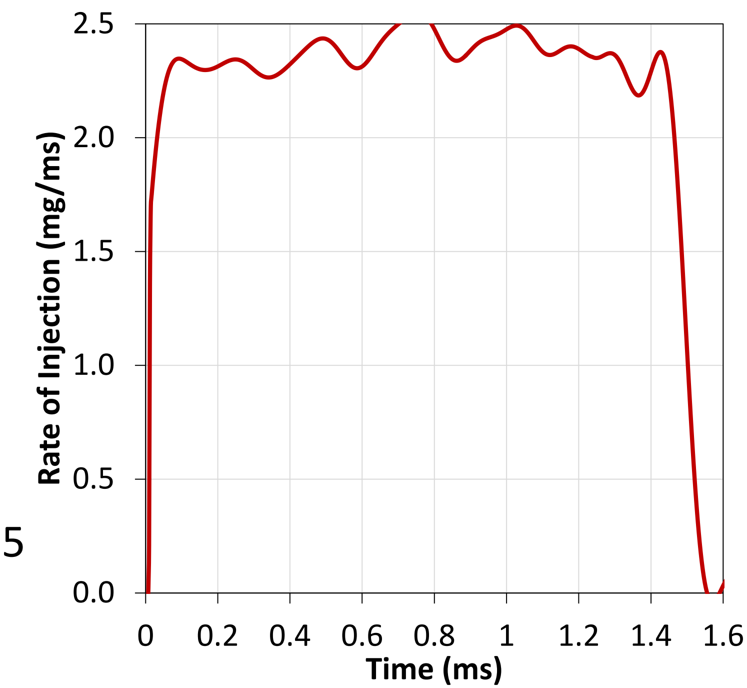
	ANL	ERC	ICE-Polimi	UNSW
Code/Software	CONVERGE	KIVA-ERC	OpenFOAM	FLUENT
Turbulence models	Standard k-ε, RNG k-ε, LES- Smagorinsky	Dynamic structure LES	Standard k-ε, RNG k-ε, Realizable k-ε	Realizable k-ε
Spray models: Injection Atomization & Breakup Collision Drag Evaporation	 Blob KH-RT NTC Dynamic Frossling	 Blob KH-RT O'Rourke Aerodynamic Frossling	 Huh-Gosman Bianchi, Wave No Dynamic Frossling	 Blob Wave O'Rourke Stokes-Cunningham Frossling
Grid: Type Dimensionality Smallest grid size	 Structured with AMR Full-3D domain 0.125 mm-LES, 0.5 mm-RANS	 Structured Cartesian 3D-Axisymmetric 0. 50 mm - LES	 Structured with ALMR Quarter-3D domain 0.5 mm	 Structured 2D-Axisymmetric 0.25 mm
Time discretization	PISO	KIVA-SIMPLE	PISO, SIMPLE	PISO
Preferred time-step size (ms)	Variable	Variable	5.0E-7	1.0E-7

Spray Penetration vs. Time

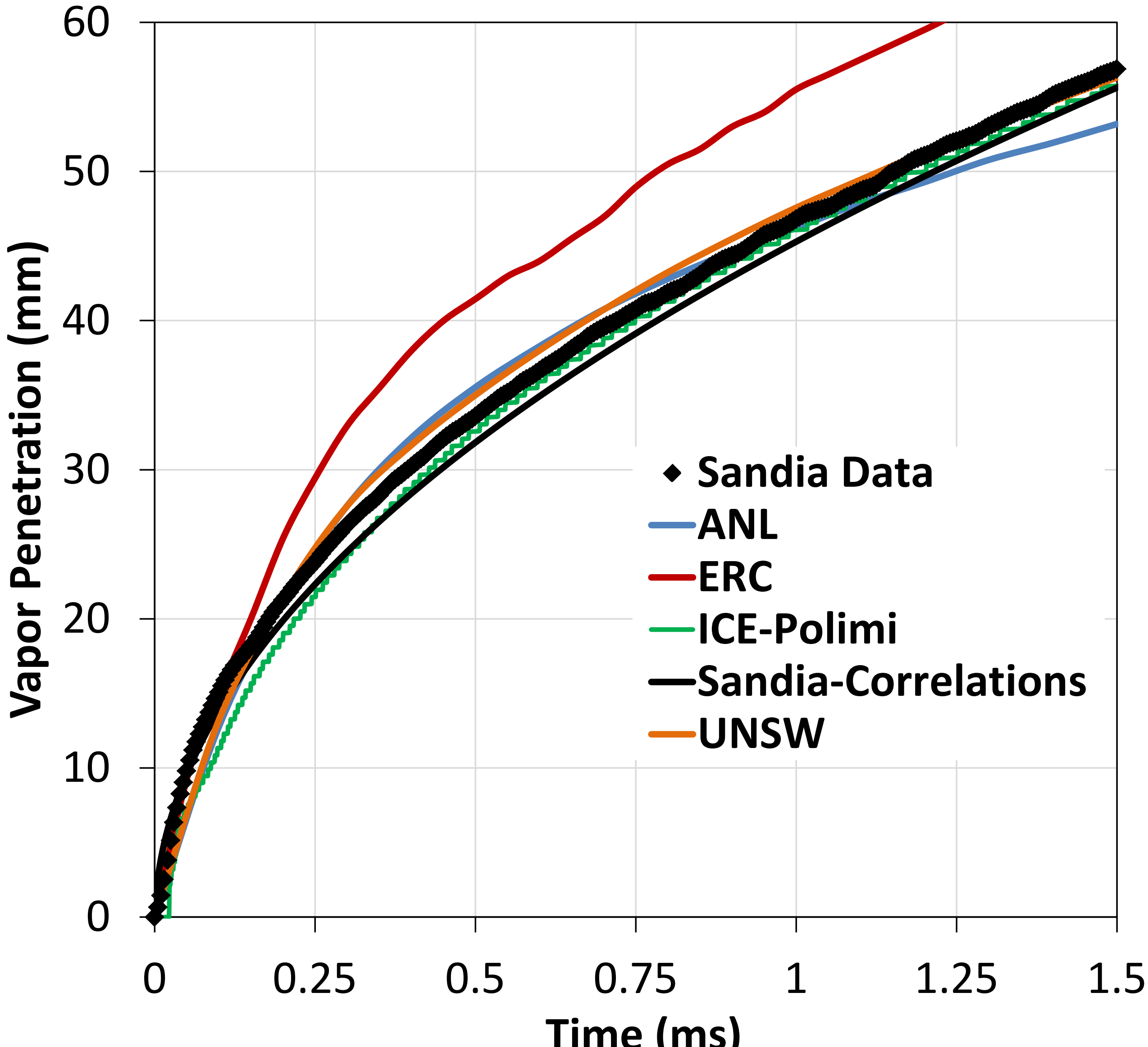


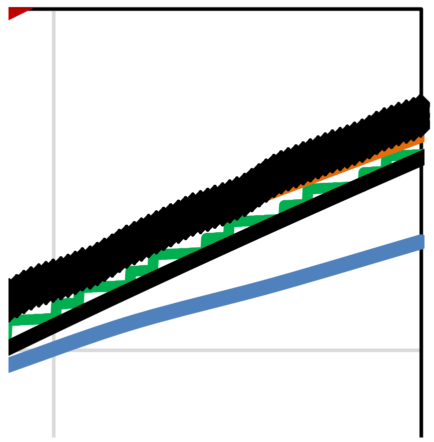
Initial transience not well predicted by any model. Possible causes:

- Accurate representation of ROI?
- Need to account for nozzle geometry and needle-lift effects?

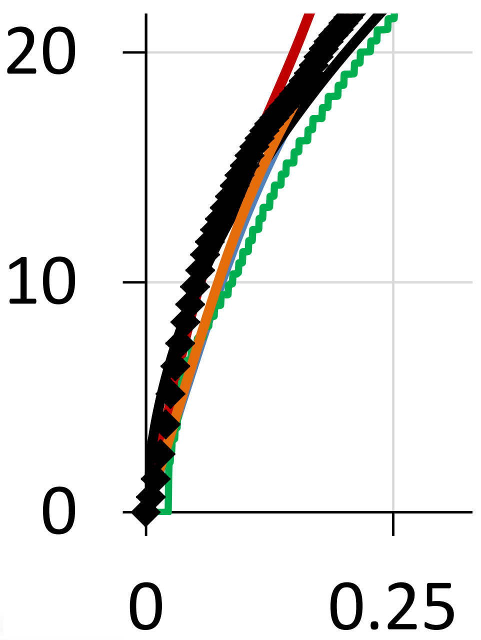


Vapor Penetration vs. Time

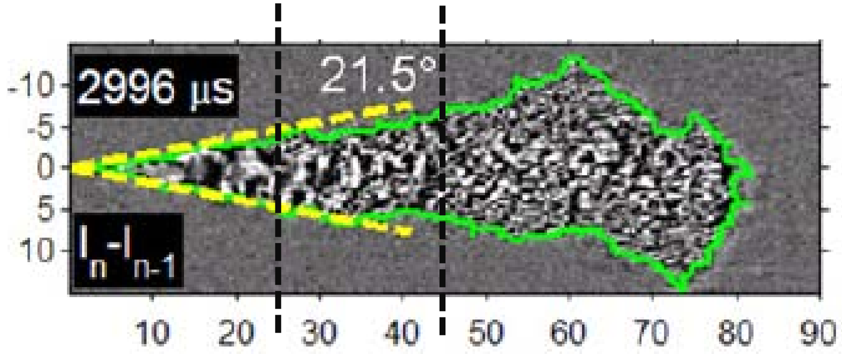




In general, the CFD models are unable to match the slopes

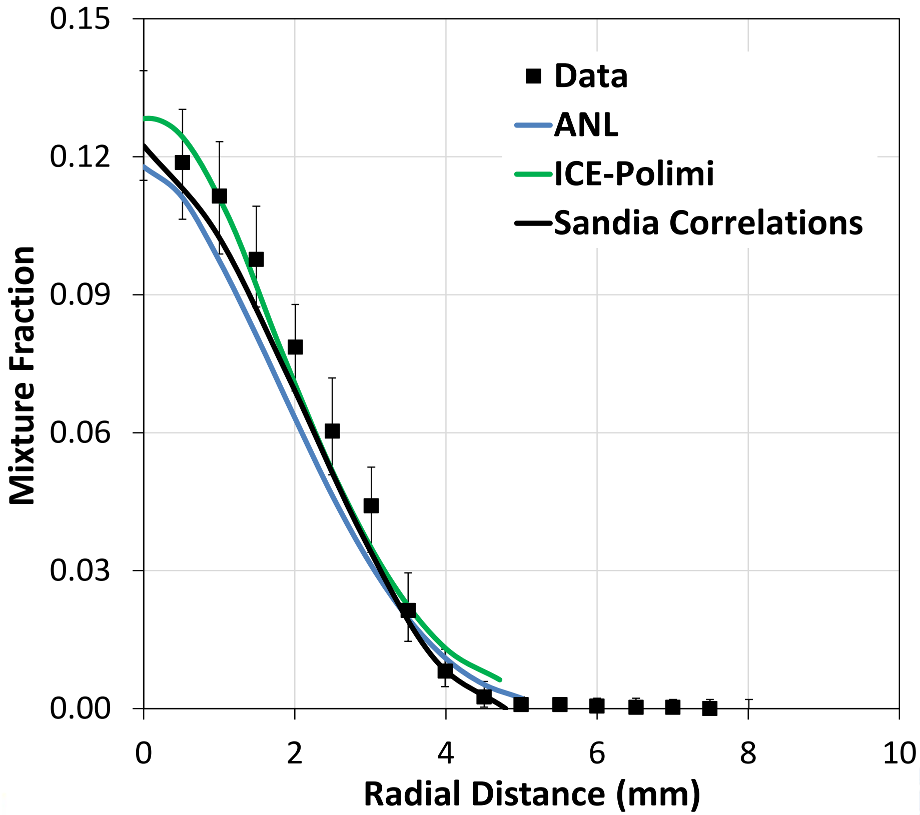


Radial Mixture fraction Distribution

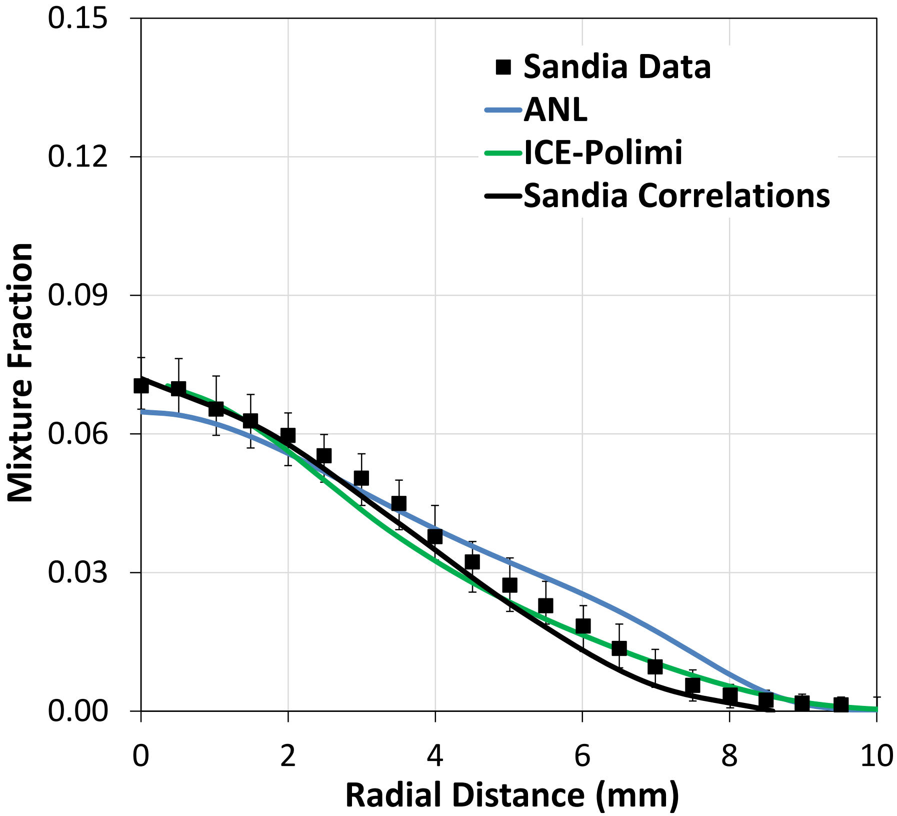


- Simulations plots at 1.5 ms
- In general, Gaussian mixture fraction profiles are well-predicted by all models at both axial locations
- Mixture fraction distribution along the center line need to be compared

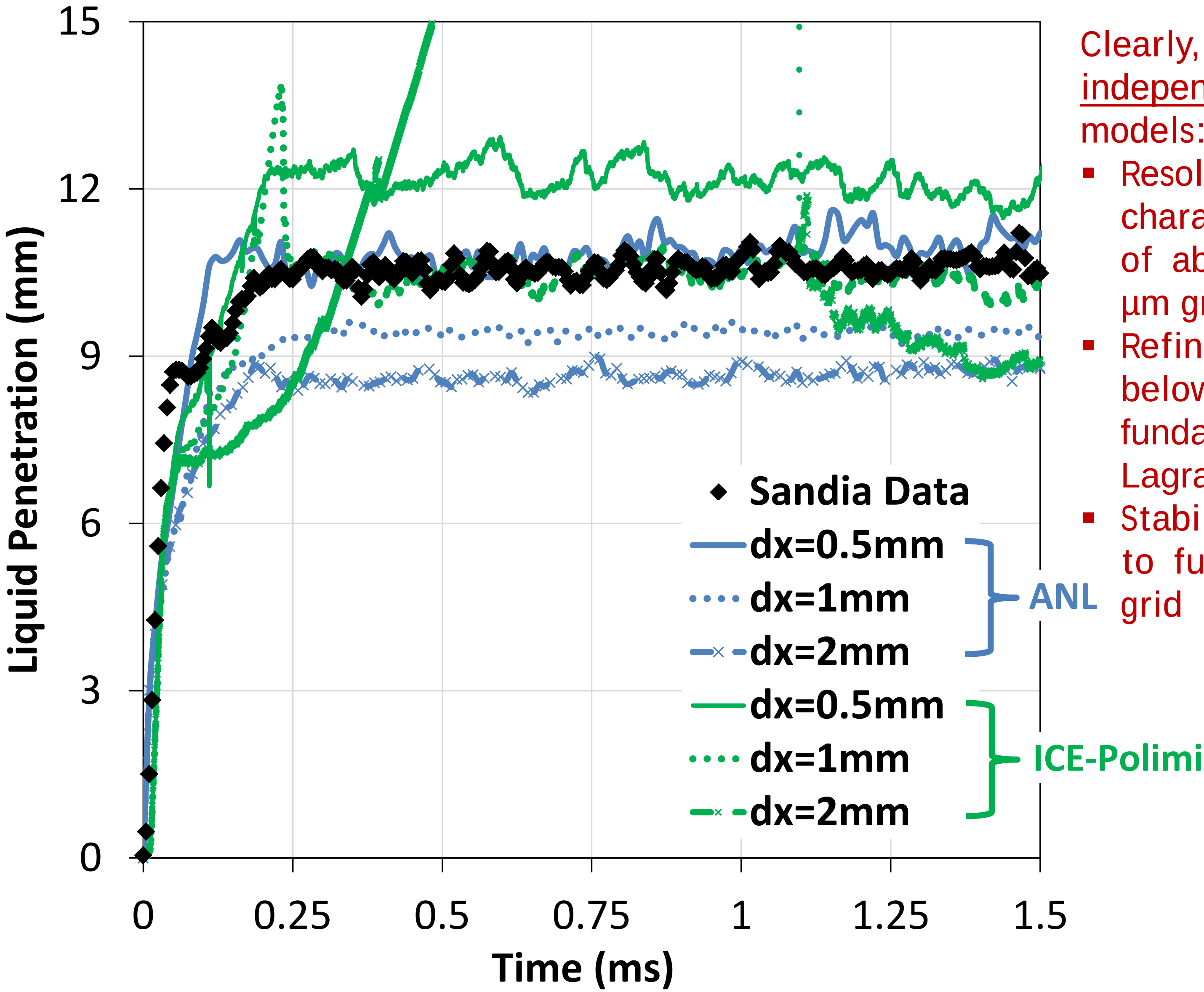
X = 25 mm



X = 45 mm



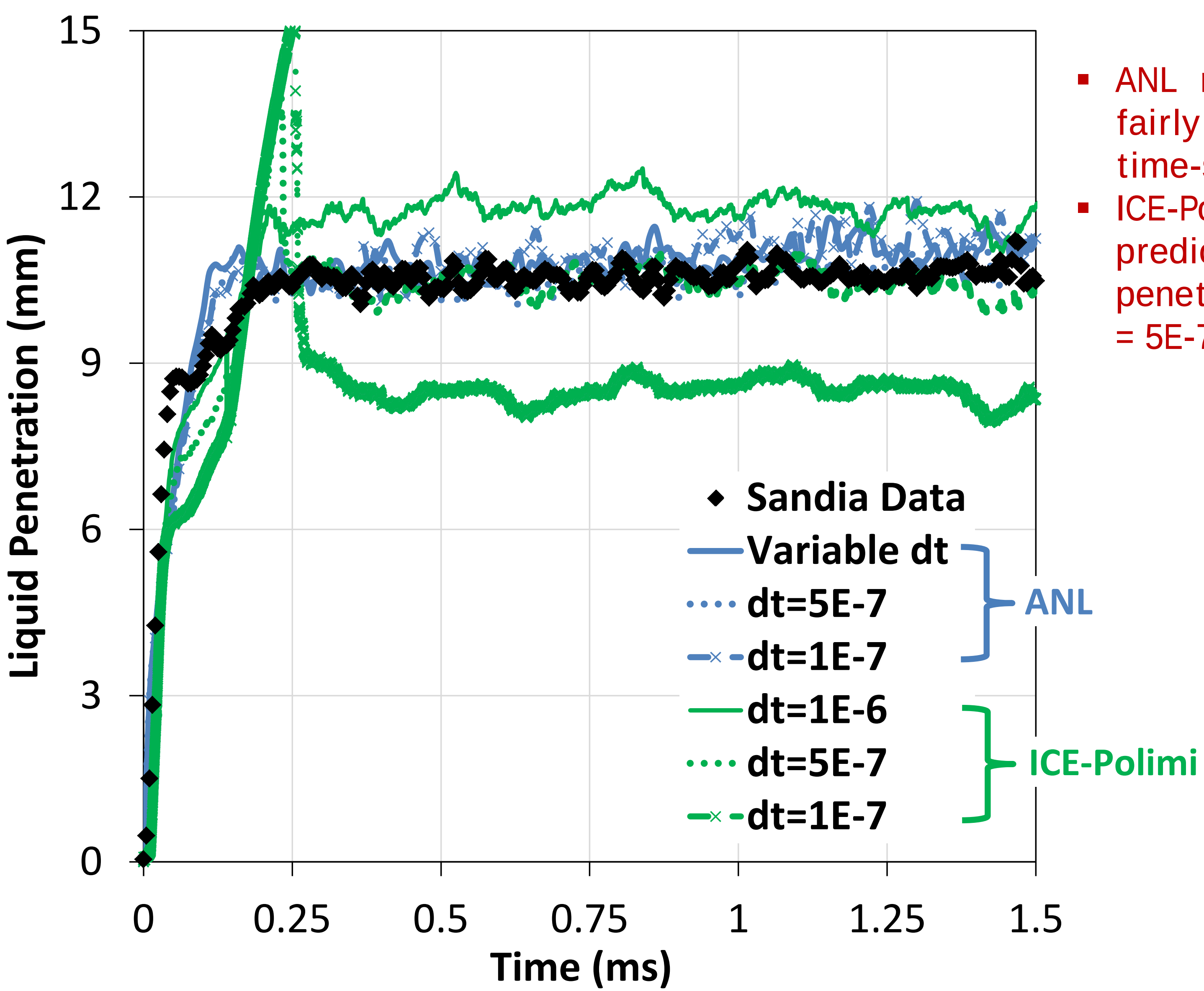
Spray Penetration: Effect of Grid size



Clearly, results are <u>not grid-independent</u> with the RANS models:

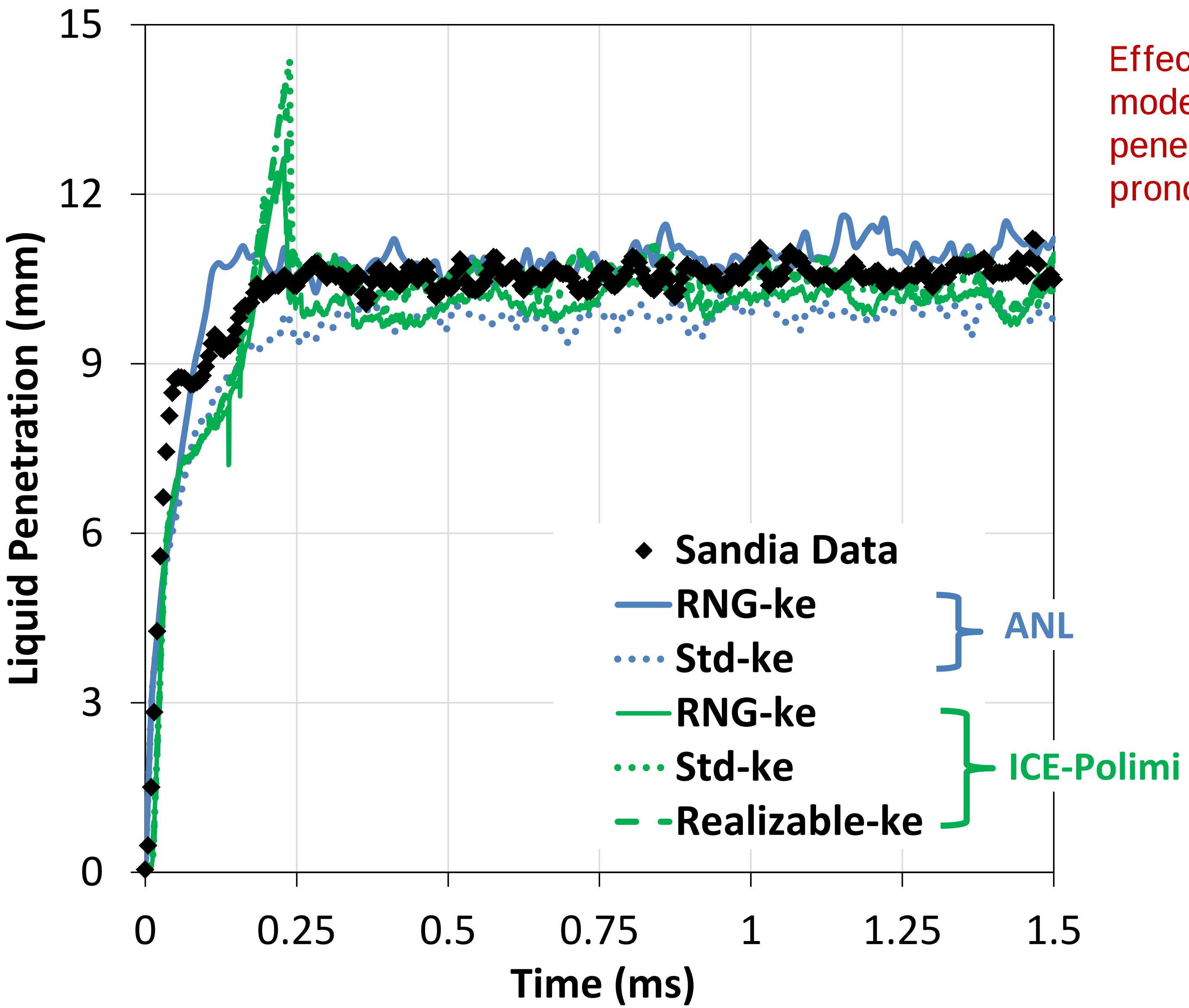
- Resolving a flow with characteristic length scale of about 90 µm with 500 µm grid sizes
- Refining the grid size below 125 µm may violate fundamental Eulerian-Lagrangian assumptions
- Stability issues arise due to further refining of the grid

Spray Penetration: Effect of time-step size



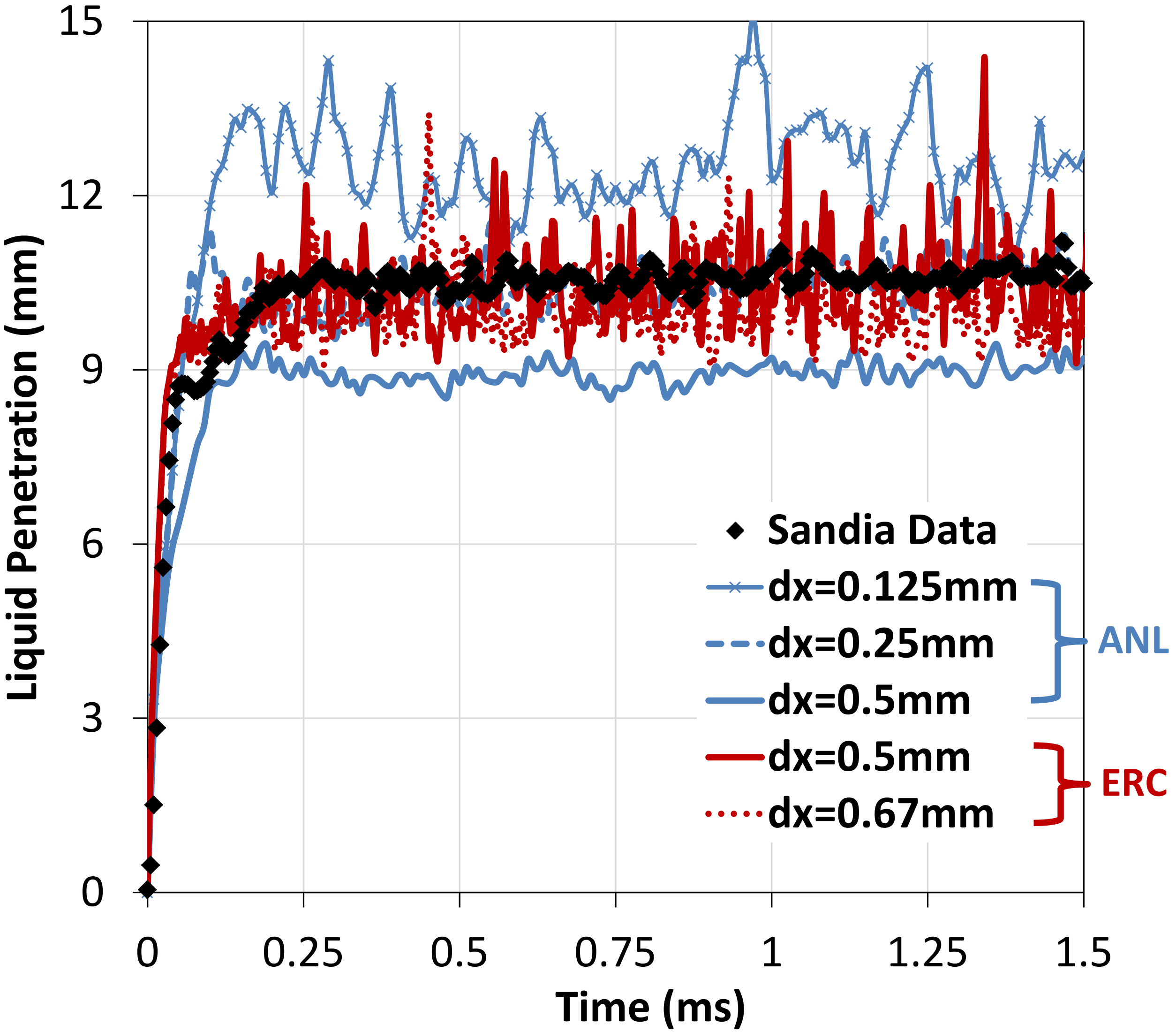
- ANL results seem to be fairly independent of time-step size
- ICE-Polimi simulations predict accurate liquid penetration values for dt = 5E-7

Spray Penetration: Different RANS models



Effect of RANS turbulence models on spray penetration is not pronounced!

Spray Penetration: Different LES models

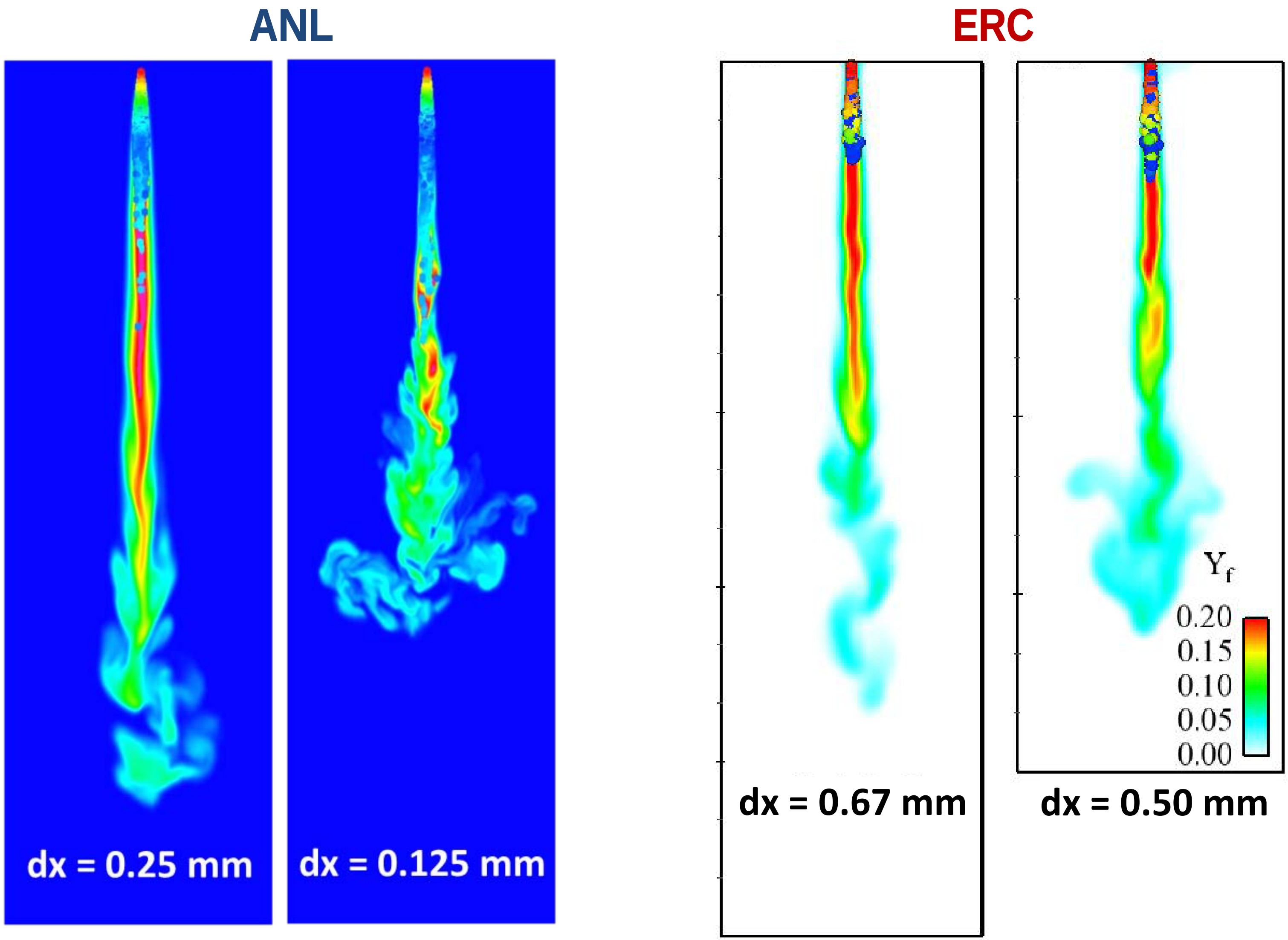


Grid independence on spray penetration observed with ERC-LES model

ANL model:

- Spray penetration increases with decrease in grid-size
- dx=0.25mm does the best job in predicting spray penetration

Fuel Mass fraction distribution



Smaller grid sizes results in earlier initiation of instabilities at the vapor-air interphase which results in faster breakup and reduction in vapor penetration!