Mode-1 Perturbations of Multi-Shell ICF Volume Ignition Implosions

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Motivation

- FLF's approach to projectile fusion converts a planar input drive into a spherical fuel collapse using a proprietary amplifier.
- Random tilt in the impact of the projectile is predominantly converted into a mode-1 perturbation on the fuel collapse.
- M4 – our gain demonstrator – will drive a fuel collapse based on the LANL Revolver[1] design.
- Developing simple models of the perturbed implosion allows for assessment of designs.

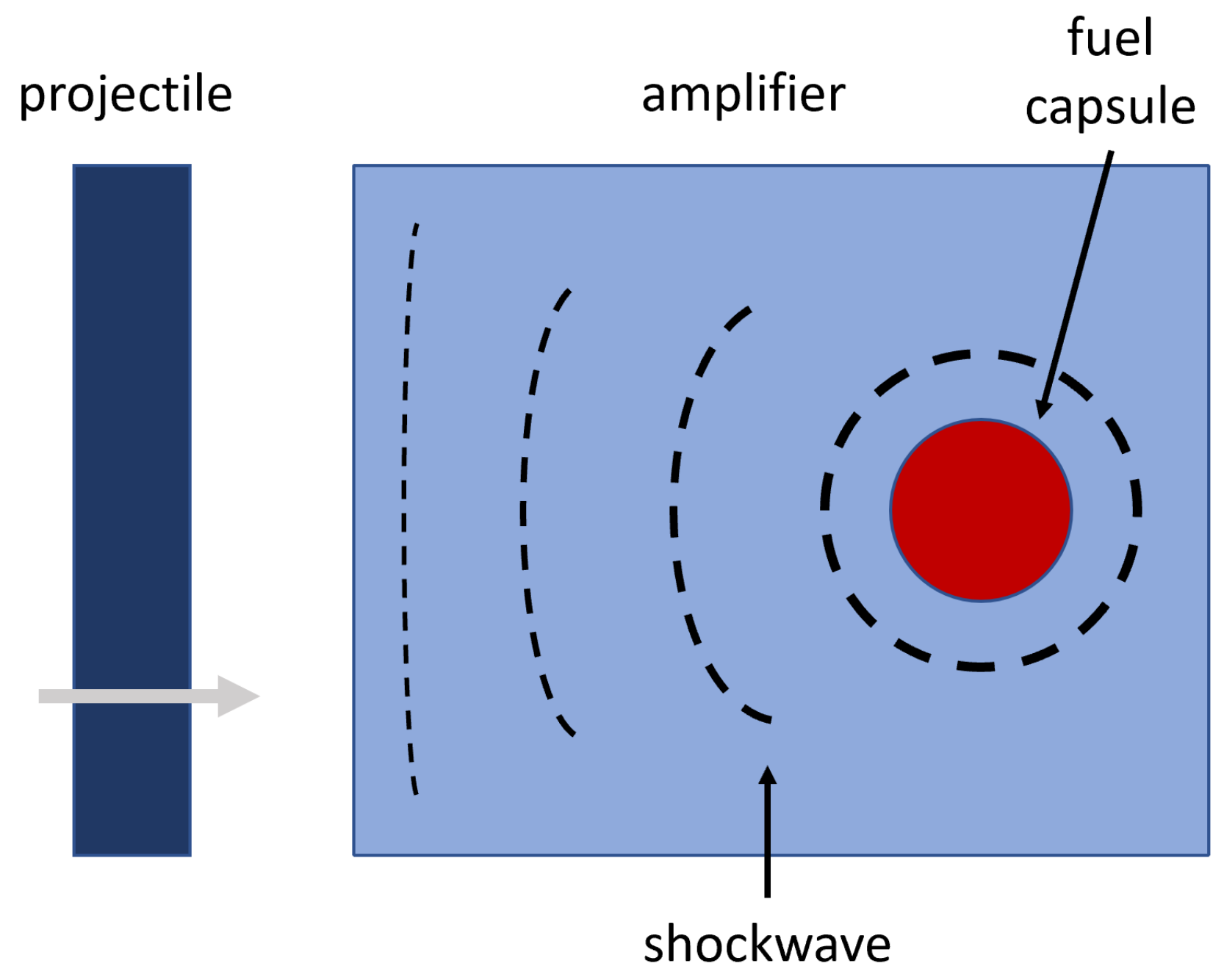


Fig. 1: Schematic of projectile fusion

Collapse Dynamics

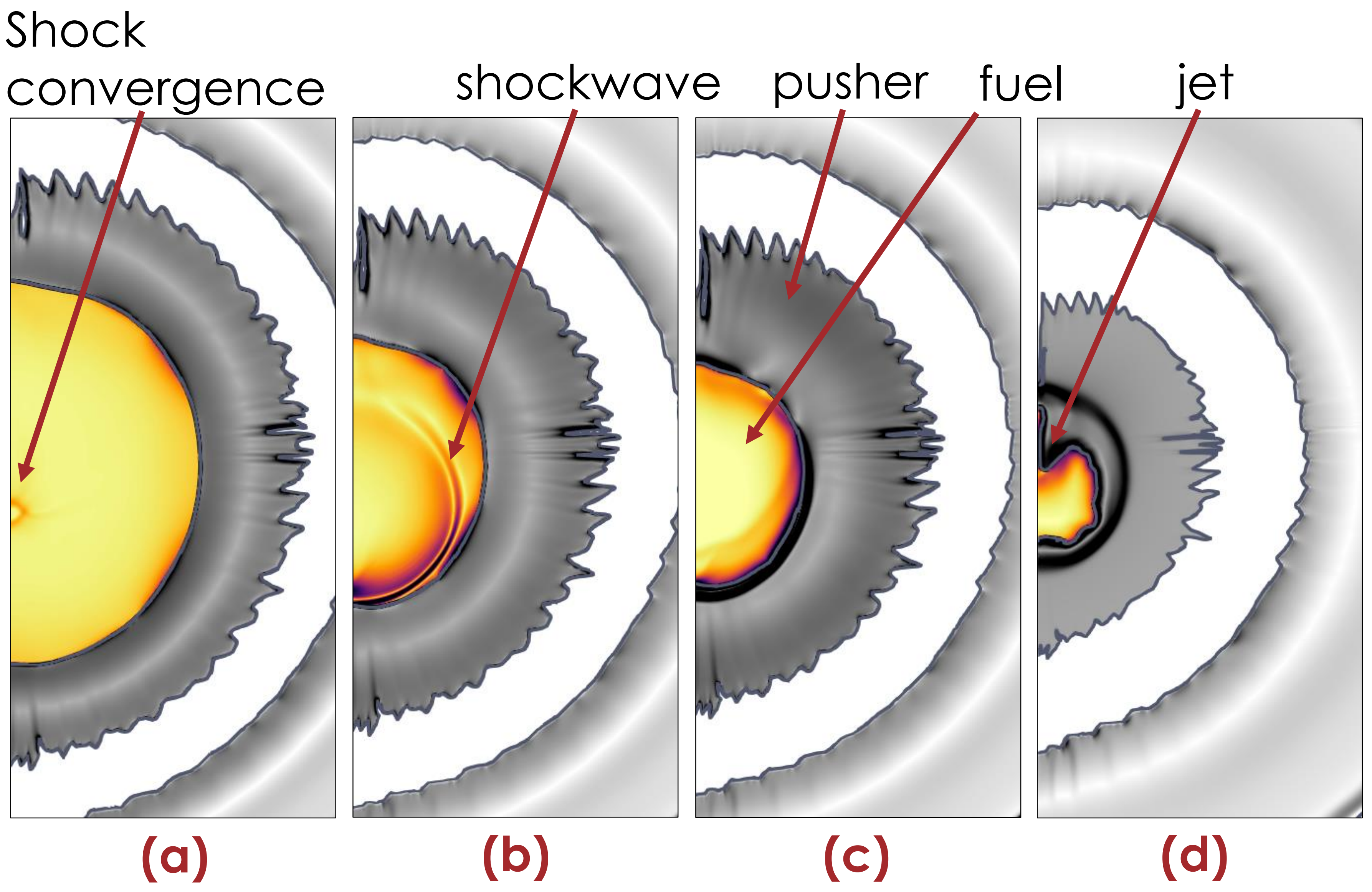


Fig. 4: Numerical schlieren of perturbed collapse

a) Shock converges off-axis
b) The reflected shock reaches the pusher-fuel interface at the south-pole, locally slowing the pusher.
c) The delayed shock reaches the pusher-fuel interface at the north pole.
d) The pusher at the north pole jets into the fuel.

Stagnation

- The shock trajectory model sets up the perturbed stagnation phase of the implosion.
- 2D perturbed simulations of stagnation are hard to analyse as the stagnation can be dominated by grid imprint induced high mode growth.
- An asymmetric-piston model[3] could be used to relate the perturbation at the time of peak pusher KE to the YOC.

Simulation Setup

- 1D full physics simulations of random geometry and energy three-shell capsules are run using B2* until the shock breaks out of the pusher.

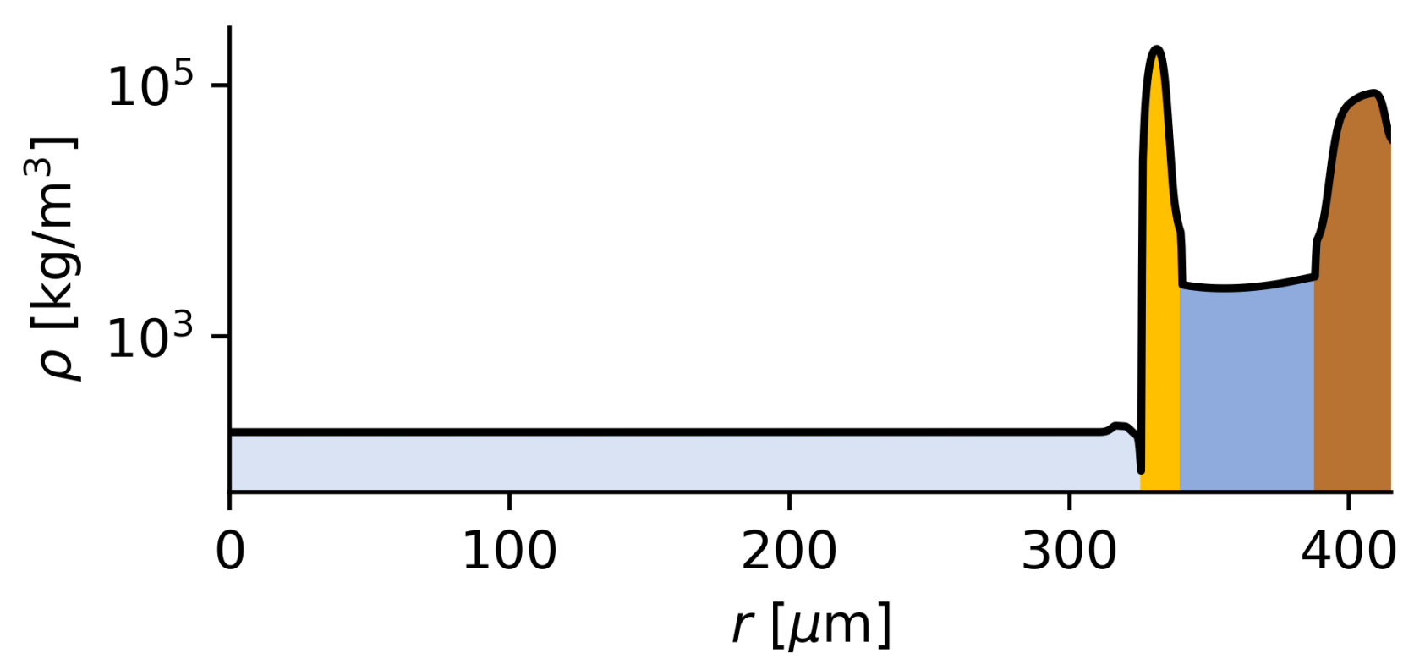


Fig. 2: Density profile of 1D multi-shell implosion

- The 1D simulation is revolved whilst the extraction time is varied to produce a 2D axi-symmetric perturbed simulation.

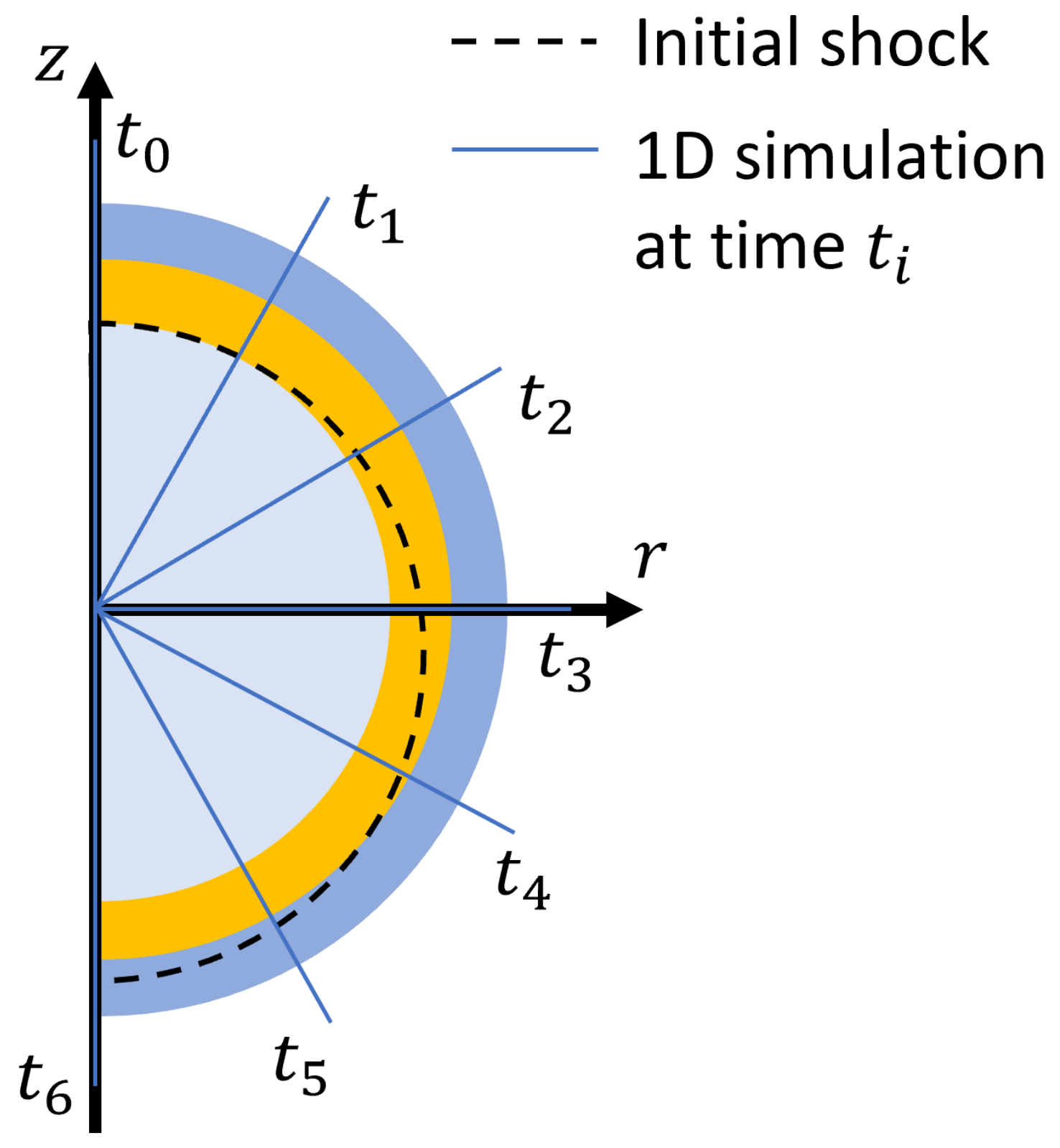
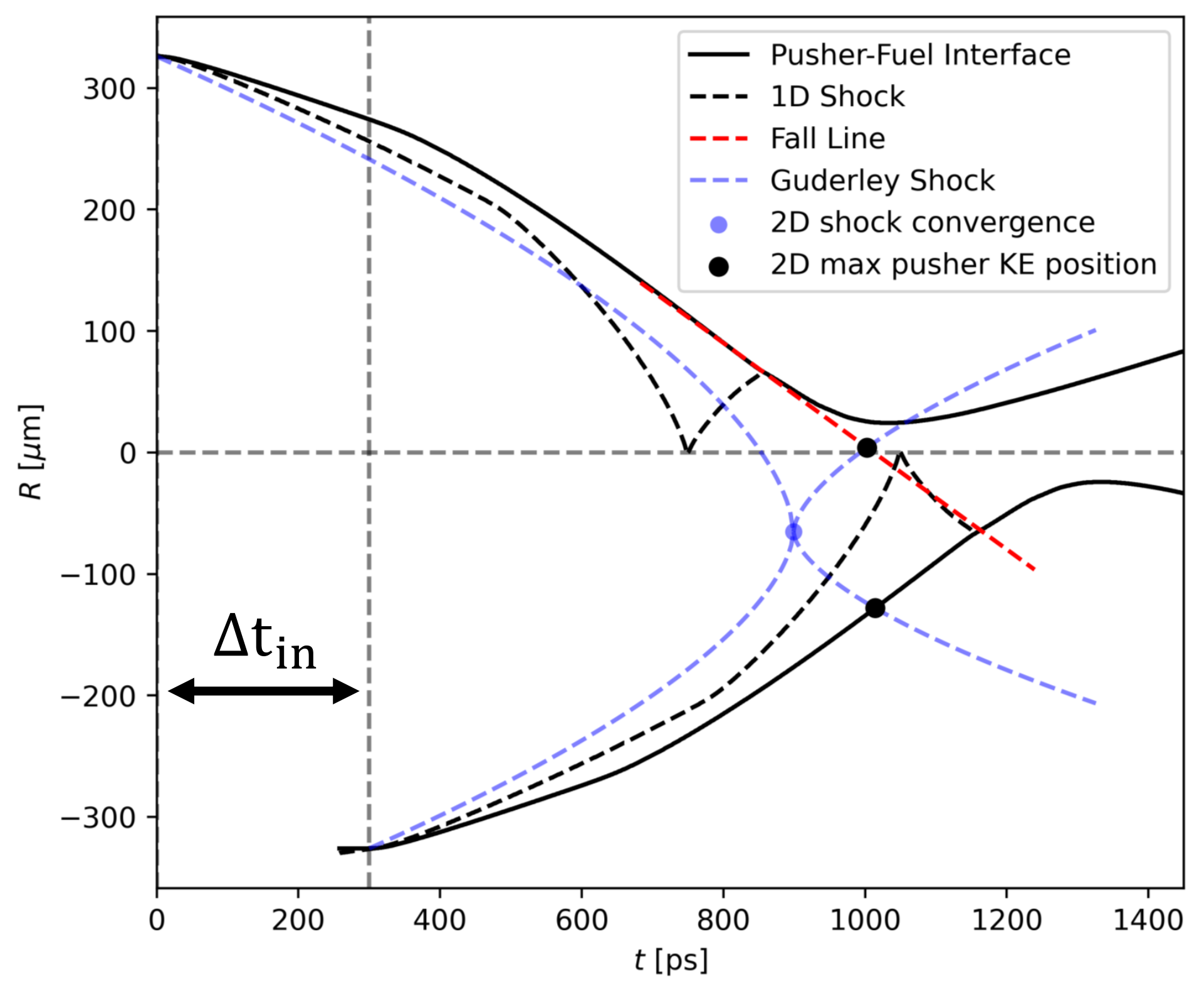


Fig. 3: 2D perturbed simulation setup

Model of shock trajectories

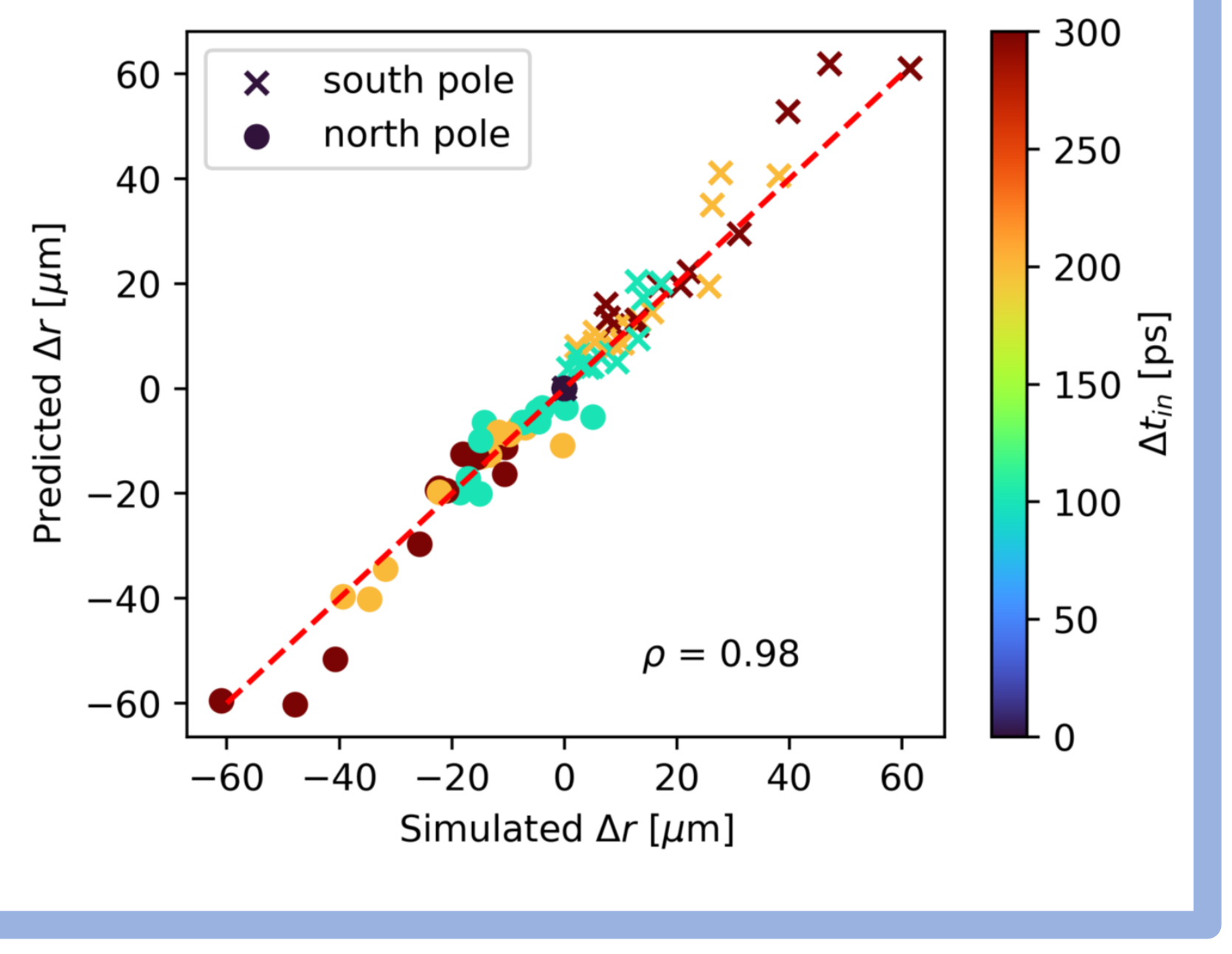


- The interface and shock streaks of the 2D perturbed simulation through the north and south poles are predicted using the 1D simulation, and the Guderley shock solution[2].

Fig. 5: Shock trajectory model

Fig. 6: Validation

- The model is validated by predicting the difference in position of the pusher-fuel interface north and south poles at the time of peak kinetic energy for a set of simulations with varying energy, geometry and perturbation amplitude.



Summary

- 2D axi-symmetric simulations of mode-1 perturbed volume ignition ICF implosions were performed.
- A model for predicting the perturbation at the point of maximum pusher KE was formulated and validated.

References

1. *Molvig et al.* "Low Fuel Convergence Path to Direct-Drive Fusion Ignition" (2016)

2. *Guderley* "Strong spherical and cylindrical shock fronts near the center of the sphere or cylinder axis" (1942)

3. *Hurricane et al.* "An analytic asymmetric-piston model for the impact of mode-1 shell asymmetry on ICF implosions" (2020)

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* In-house 3D resistive MHD code with volume of fluid interface tracking and FEOS equations of state.