SAND2016-7995PE

Title: ByvankDecelSummerOverview

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Description: Overview of summer internship work on the liner deceleration project

Deceleration Phase Instability Growth in Magnetically Driven Liner Implosions

Exceptional service in the national interest

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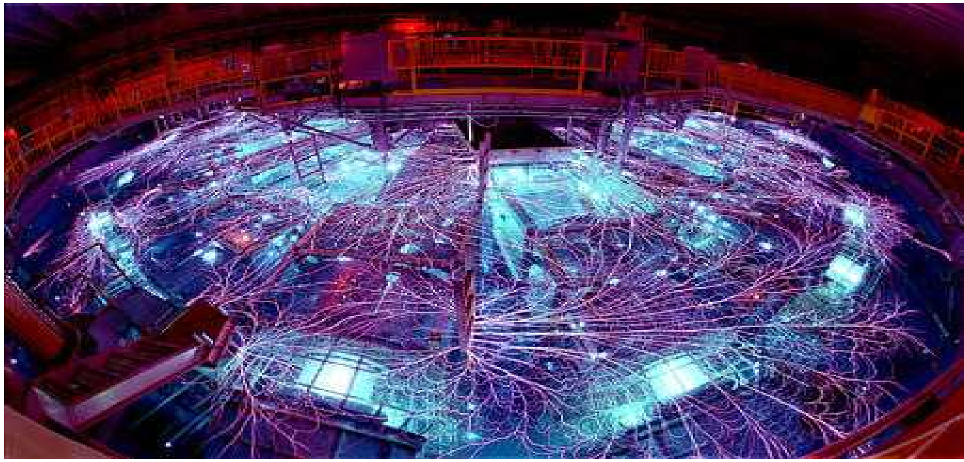

Summer 2016

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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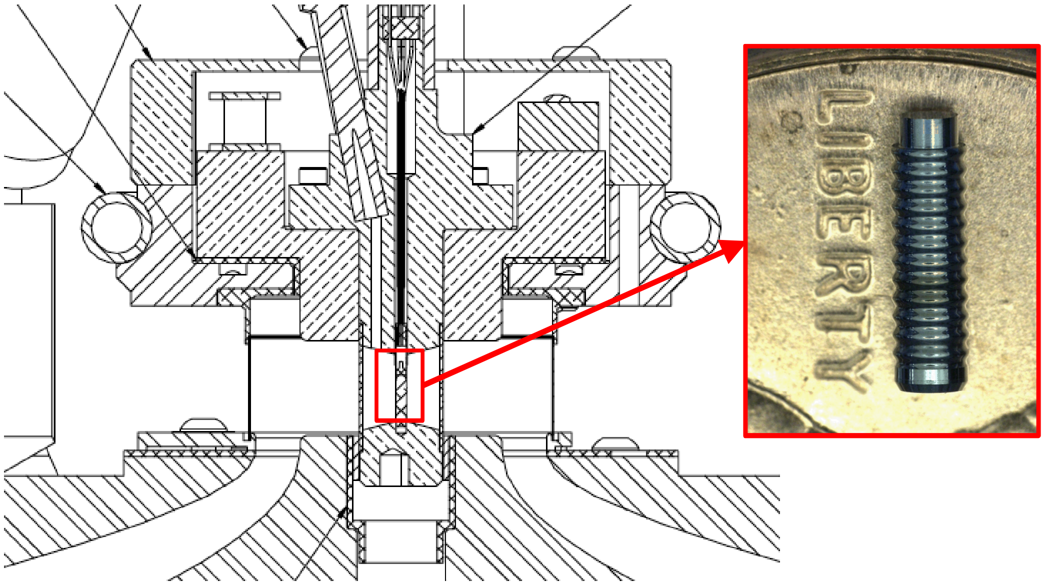
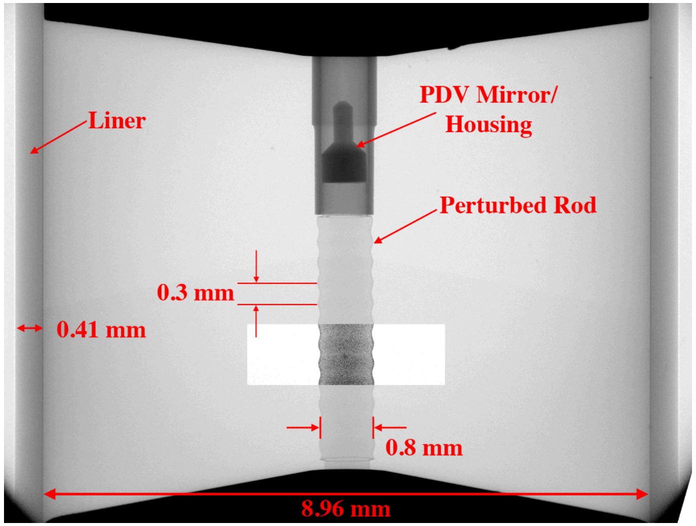
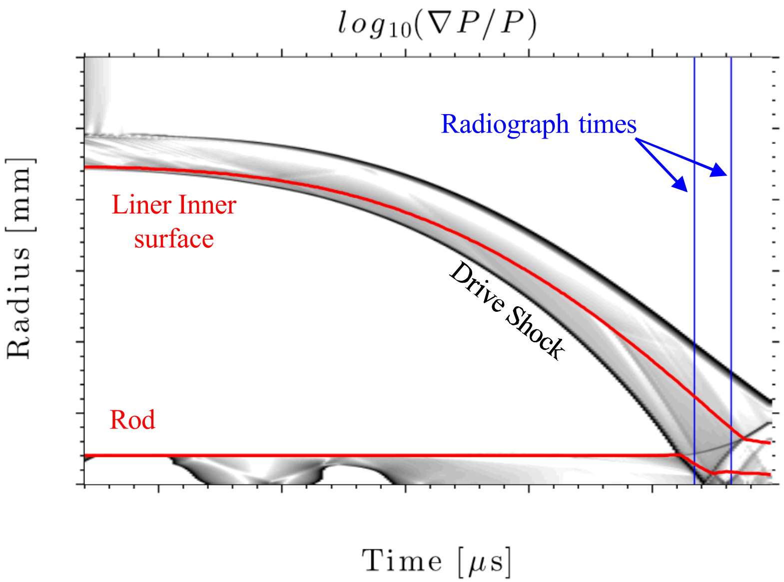
Experimental Setup



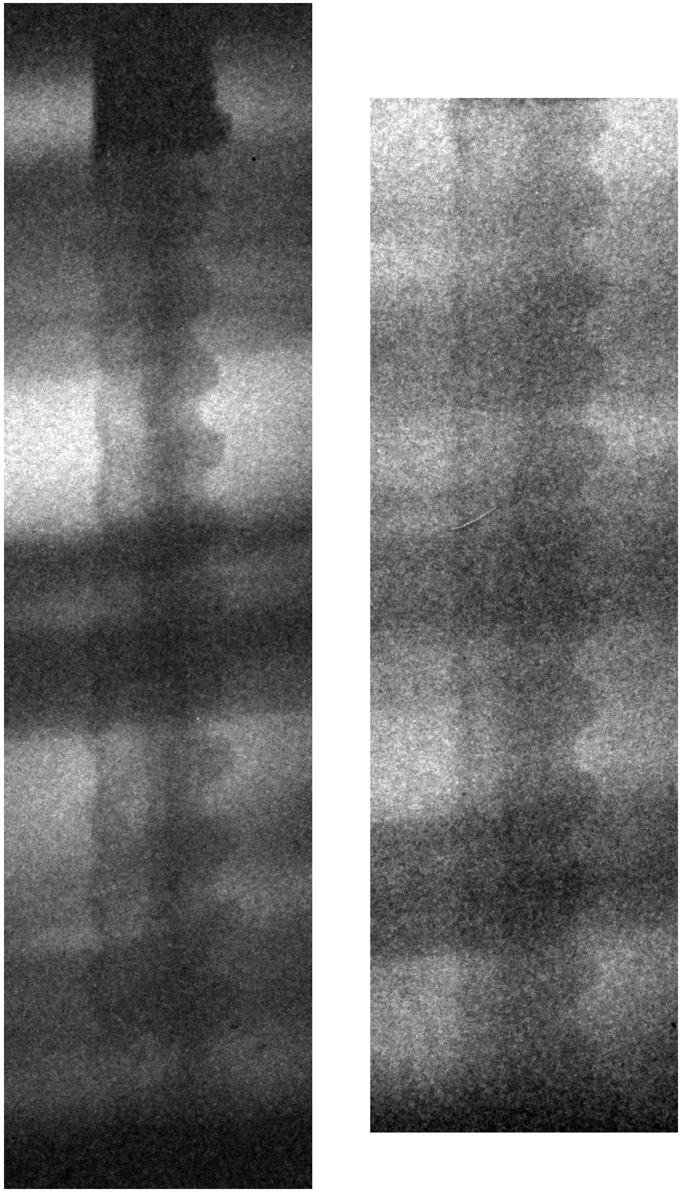




- A Be rod with a pre-imposed sinusoidal perturbation is placed on axis
- The target is filled with liquid deuterium
- The liner launches a shock in the deuterium which grows in strength and strikes the rod/fuel interface
- Interface is unstable to RM and RT
- After reflection, shock (now ~300 Mbar) crosses the interface again

Results from "New Data"

- Radiographs of "new data" (z2942 left and z2943 right) show (radial) asymmetry.
- Only the first radiograph (t1) for each shot produced a useful (analyzable) image.
- No PVD (photonic Doppler velocimetry) data for shock velocity measurements.



Summer Project Goals

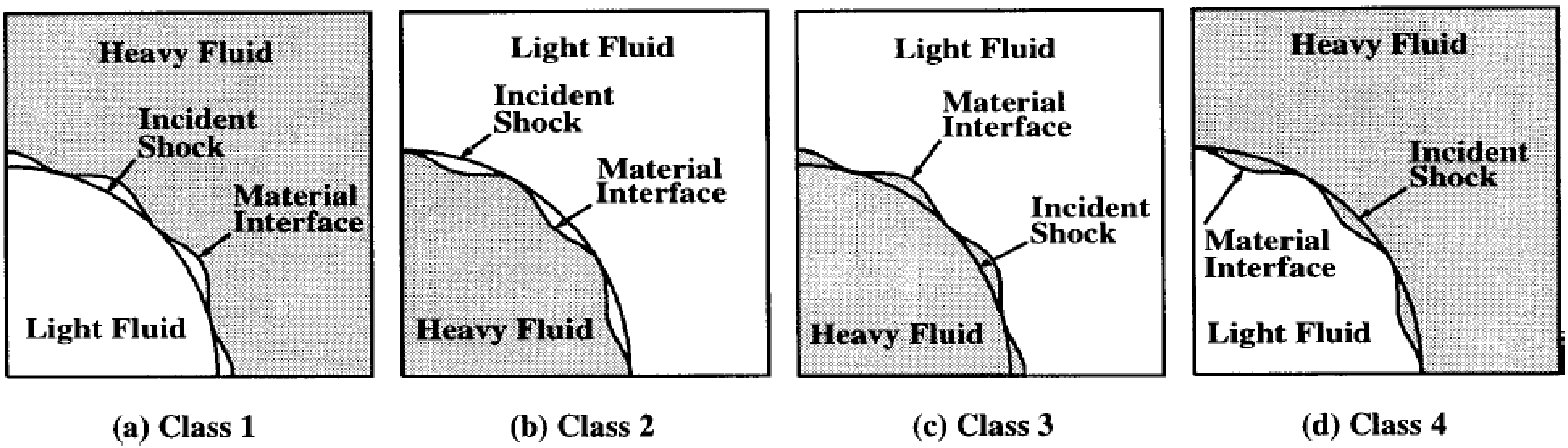
- Analyze experimental radiographs:
- Evaluate perturbation amplitude growth rates

- Using ALEGRA simulations:
- Estimate (linear) growth rate
- Estimate shock layer depth in rod and corresponding offset

- Consider how to improve future experiments

Richtmyer-Meshkov Instability

- Too simplistically (but intuitively helpful), RMI can be thought of as RTI with a delta function acceleration (shock).
- "Driving mechanism is baroclinic torque vorticity caused by misalignment of pressure and density gradients." [Ukai et al., DOI: 10.1007/s00193-011-0332-0] (*vorticity = curl of velocity*)



[Zhang et al., DOI: 10.1063/1.869624]

Richtmyer-Meshkov Instability Growth

- Planar linear amplitude growth:

$$a(t) = a_0 + ka_0A[u] * t$$

a(t) = mode amplitude

k = 2π/λ (wavenumber) = 20.9 mm^{-1}

a_0 = initial amplitude = 0.015 mm

A = (post-shock) Atwood number = 0.48

[u] = change in interface velocity = post-shock velocity = 23 km/s

t = time

$$\rightarrow a(t) = a_0 + (3.47\ km/s) * t$$

*Note: unstable for both A > 0 (like RTI) and A < 0 (unlike RTI)

Richtmyer-Meshkov Instability Mix

- Planar linear mix width growth:

$$h = h_0 + cA[u] * t$$

h = mix width

$h_0 = 0$ = initial mix width

c = empirical constant between ~0.07-0.3; we take c = 0.1

A = (post-shock) Atwood number = 0.48

[u] = change in interface velocity = post-shock velocity = 23 km/s

t = time

$$\rightarrow h = (1.1\ km/s) * t$$

*Note: cylindrical effects (convergence ratio) increase mix rate

Rayleigh-Taylor Instability Growth

- Planar linear amplitude growth:
- $a(t) = a_0$ exp($\sqrt{Akg}$ Δt) = a_0 exp($\sqrt{Ak\Delta r}$)

a(t) = mode amplitude

k = 2π/λ (wavenumber) = 20.9 mm^{-1}

a_0 = initial amplitude = 0.015 mm

A = (post-shock) Atwood number = 0.48

t = time

Estimate acceleration as g = $\Delta r/(\Delta t)^2$ with radial compression Δr

$$\rightarrow a(t)[mm] = 0.015\ (\exp(\sqrt{\Delta r\ [mm]}))^{3.17}$$

Rayleigh-Taylor Instability Mix

- Planar linear mix width growth:

$$h = cAgt^2 = cA\Delta r$$

h = mix width

$h_0 = 0$ = initial mix width

c = empirical constant between ~0.07-0.3; we take c = 0.1

A = (post-shock) Atwood number = 0.48

t = time

Δr = radial compression

$$\rightarrow h = (0.048) * \Delta r$$

*Note: cylindrical effects (convergence ratio) increase mix rate

Richtmyer-Meshkov Instability Nonlinearity

- Nonlinearity (mode coupling, dependent modes) for:

$$a(t) \gtrsim 0.1\lambda$$

a(t) = mode amplitude

λ = wavelength = 0.3 mm for the seed mode on the rod

$$\rightarrow a(t) \gtrsim 0.03 \text{ mm} = 2 * a_0$$

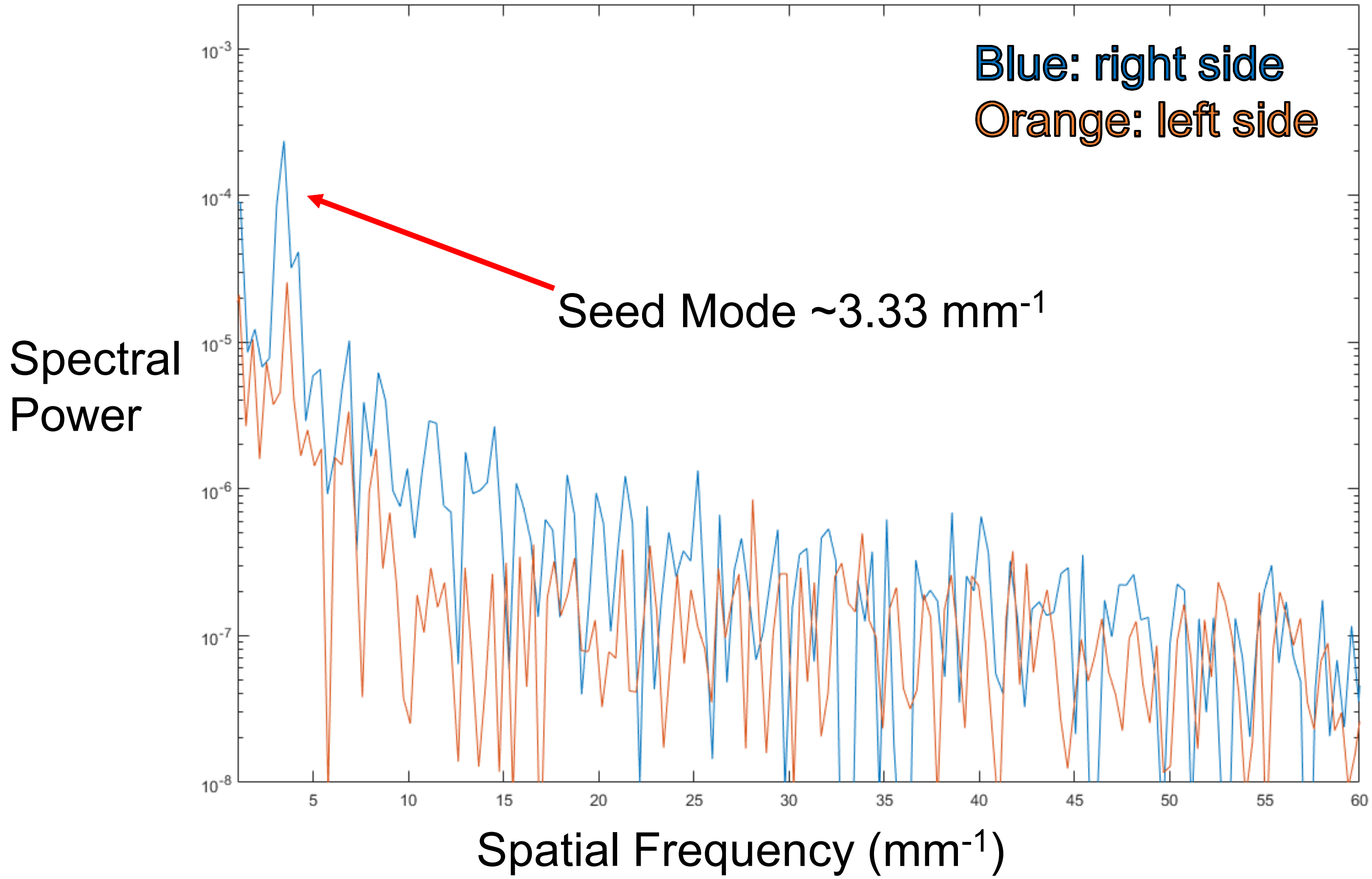
*Combining RMI & RTI growth rates, this condition occurs at

$$t \approx 2 \text{ ns}$$

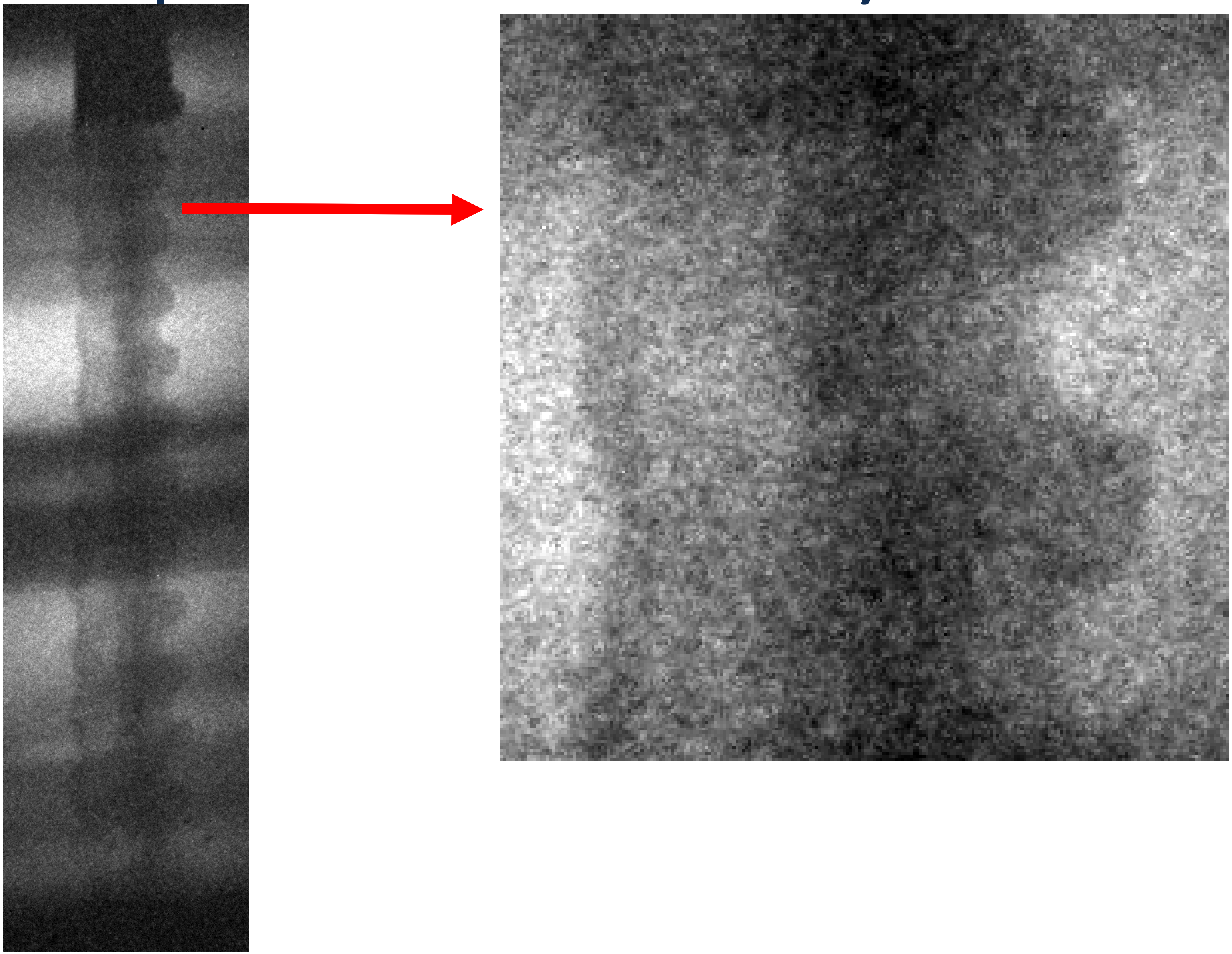
after the shock hits the perturbed surface.

FFT Analysis Confirms Seeded Mode Growth

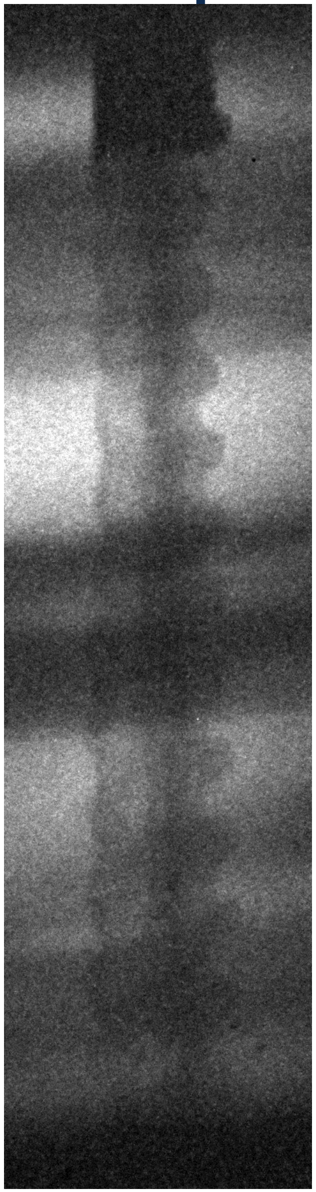
- (z2942) Dominant seed mode: right side amplitude ~3.0 times larger than left side amplitude.

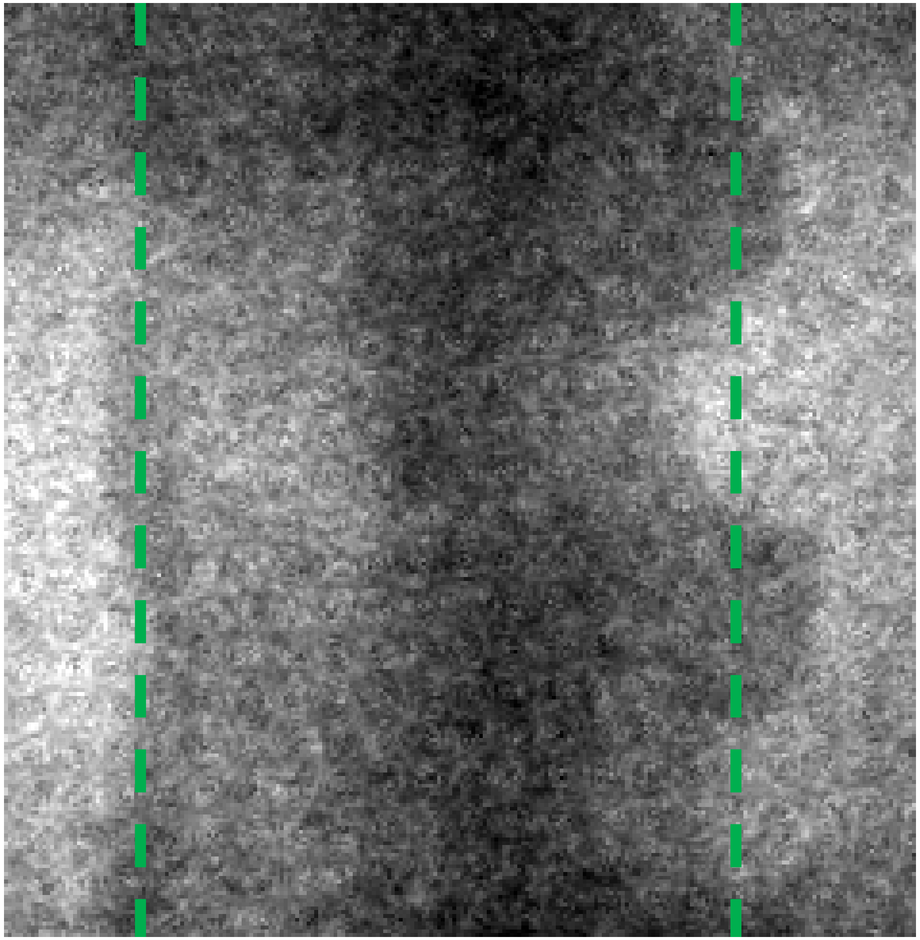


Experimental Shock Layer Widths



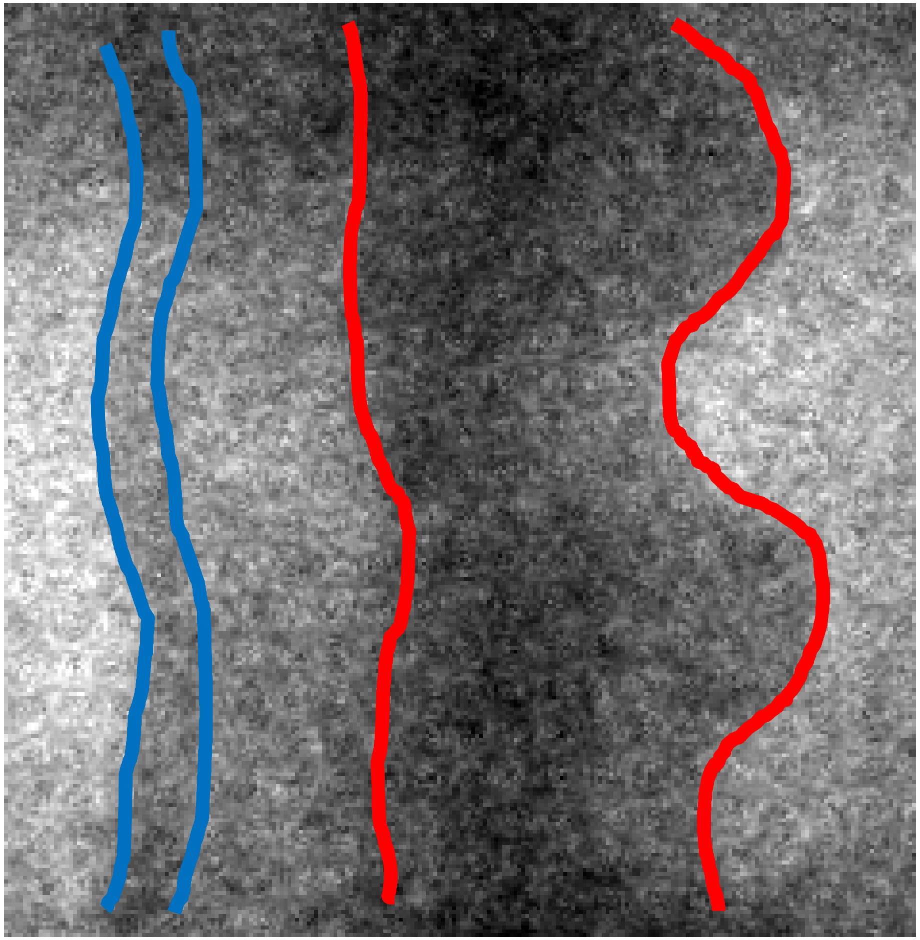
Experimental Rod Compression





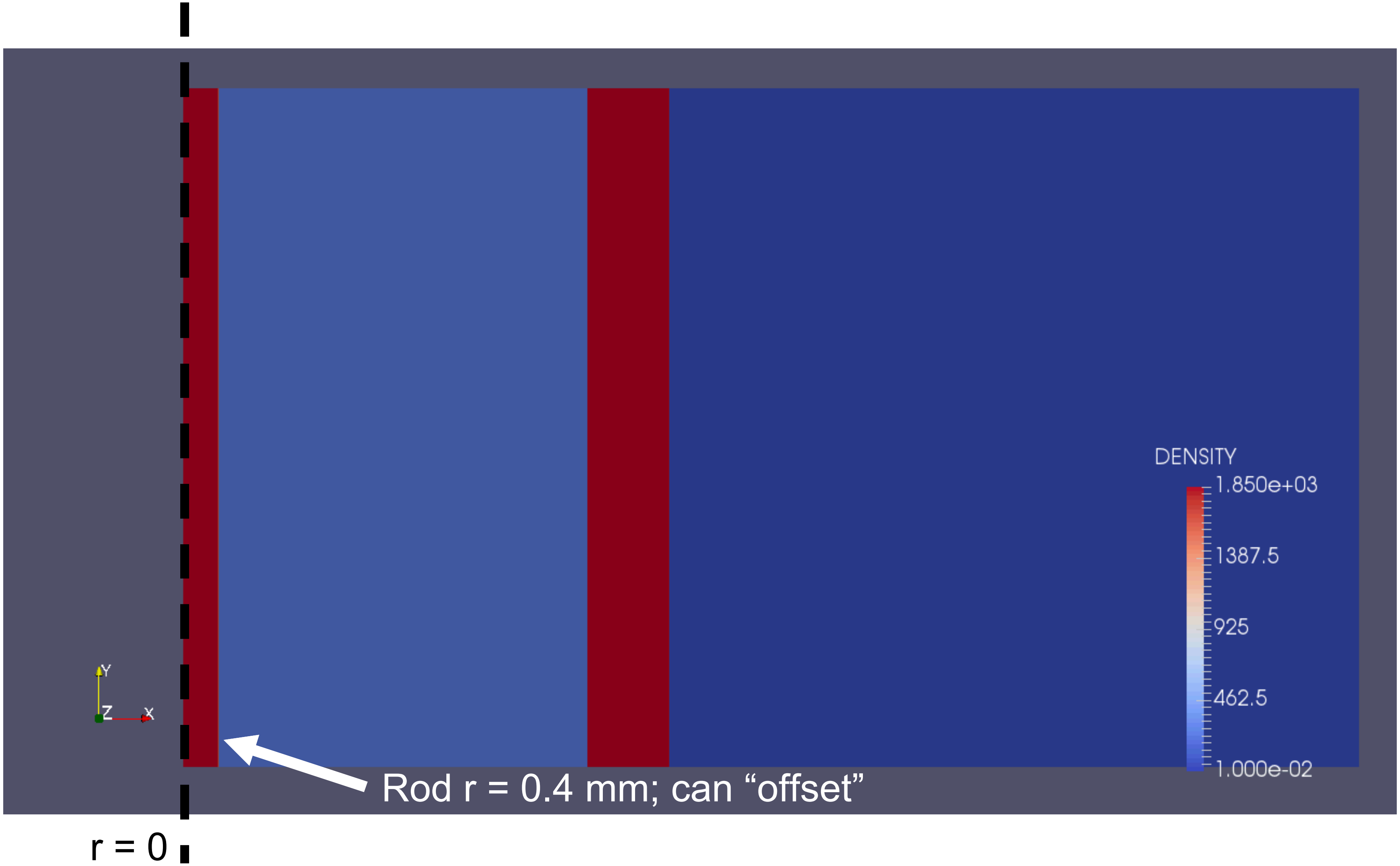
- Initial rod diameter = 0.8 mm
- Rod diameter = 0.426 $\pm$ 0.048 mm

Experimental Shock Layer Widths

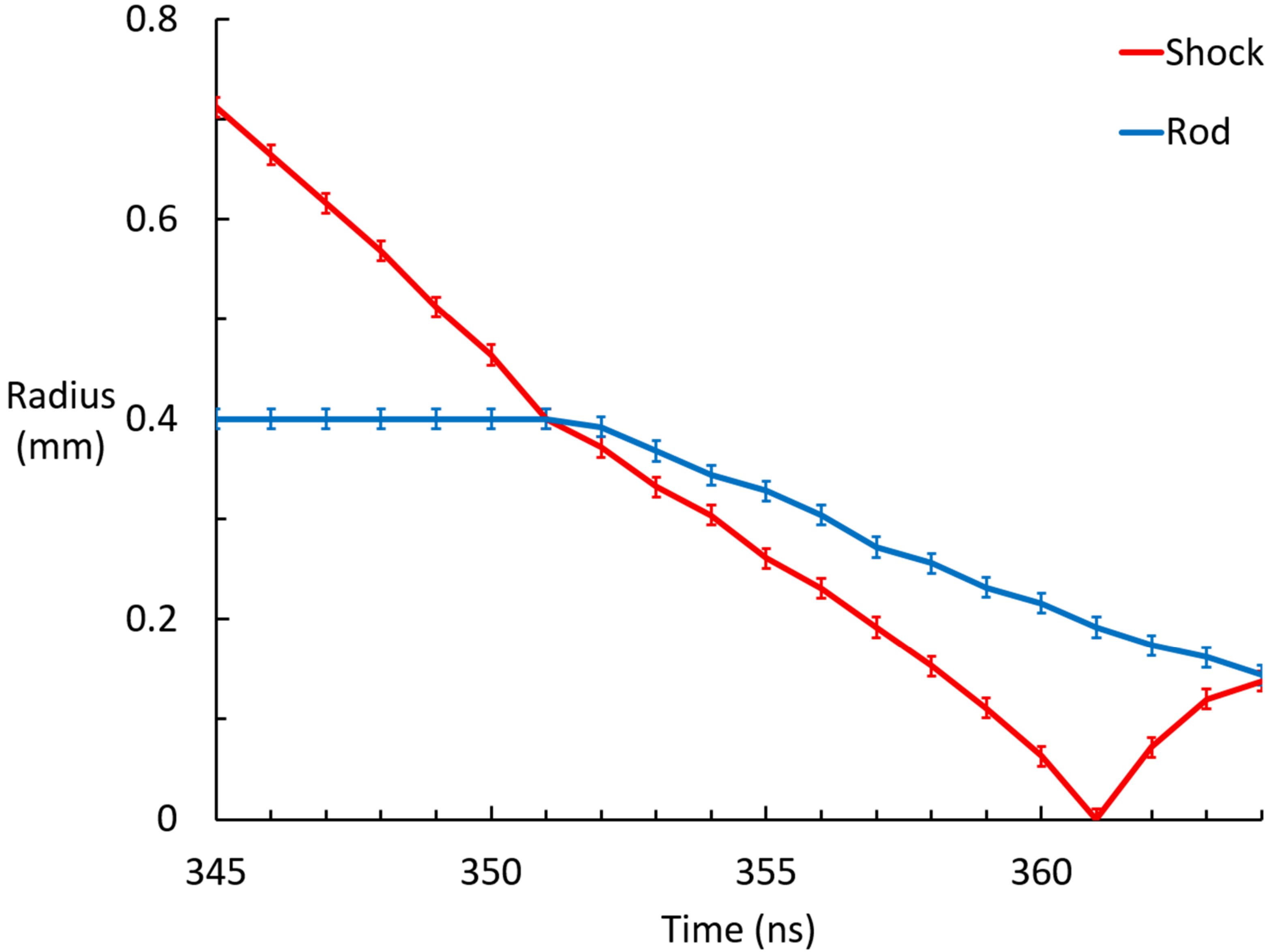


- Left side: 0.042 $\pm$ 0.014 mm
- Right side: 0.256 $\pm$ 0.049 mm

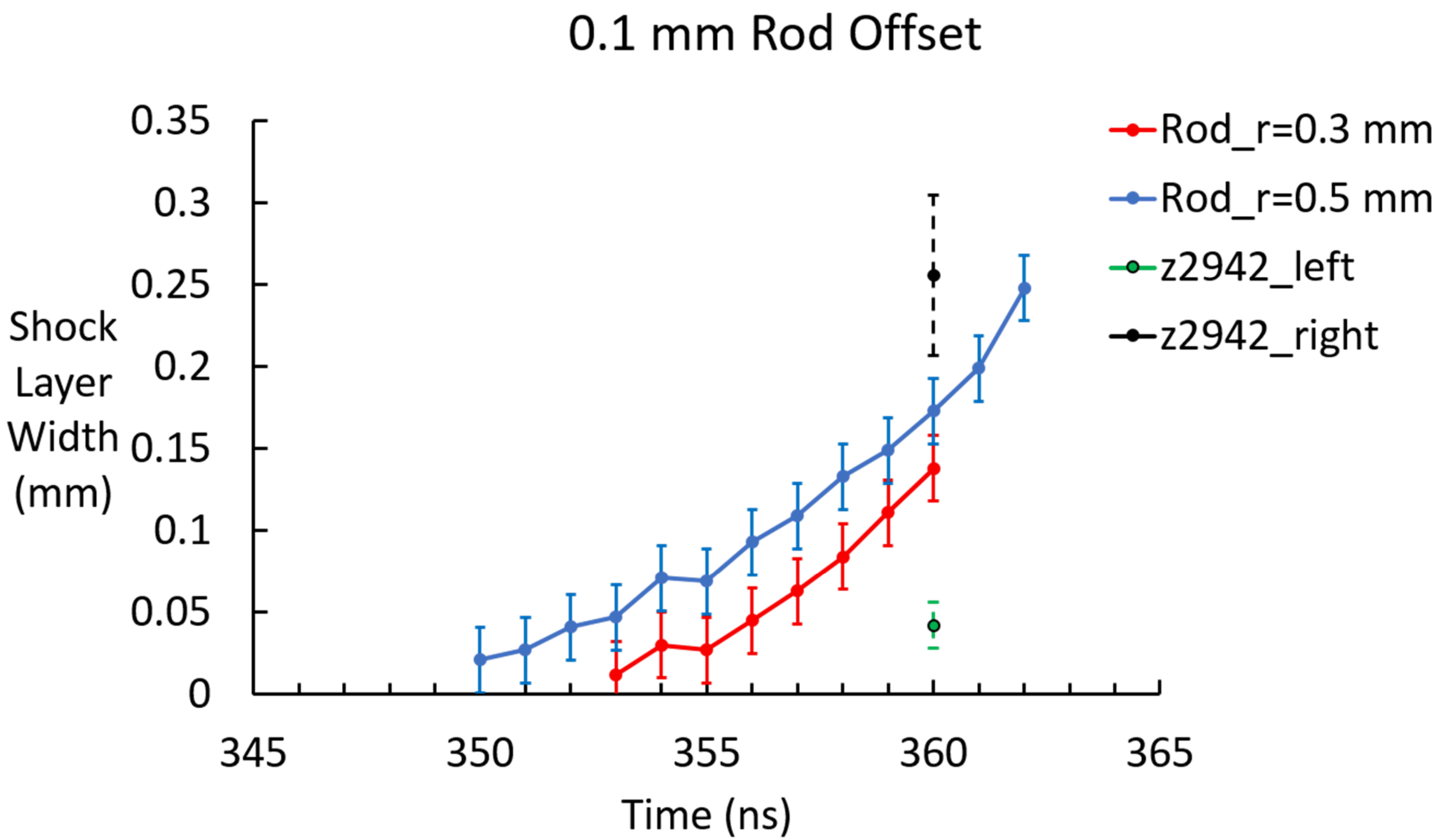
1D ALEGRA Helps Estimate Rod Offset



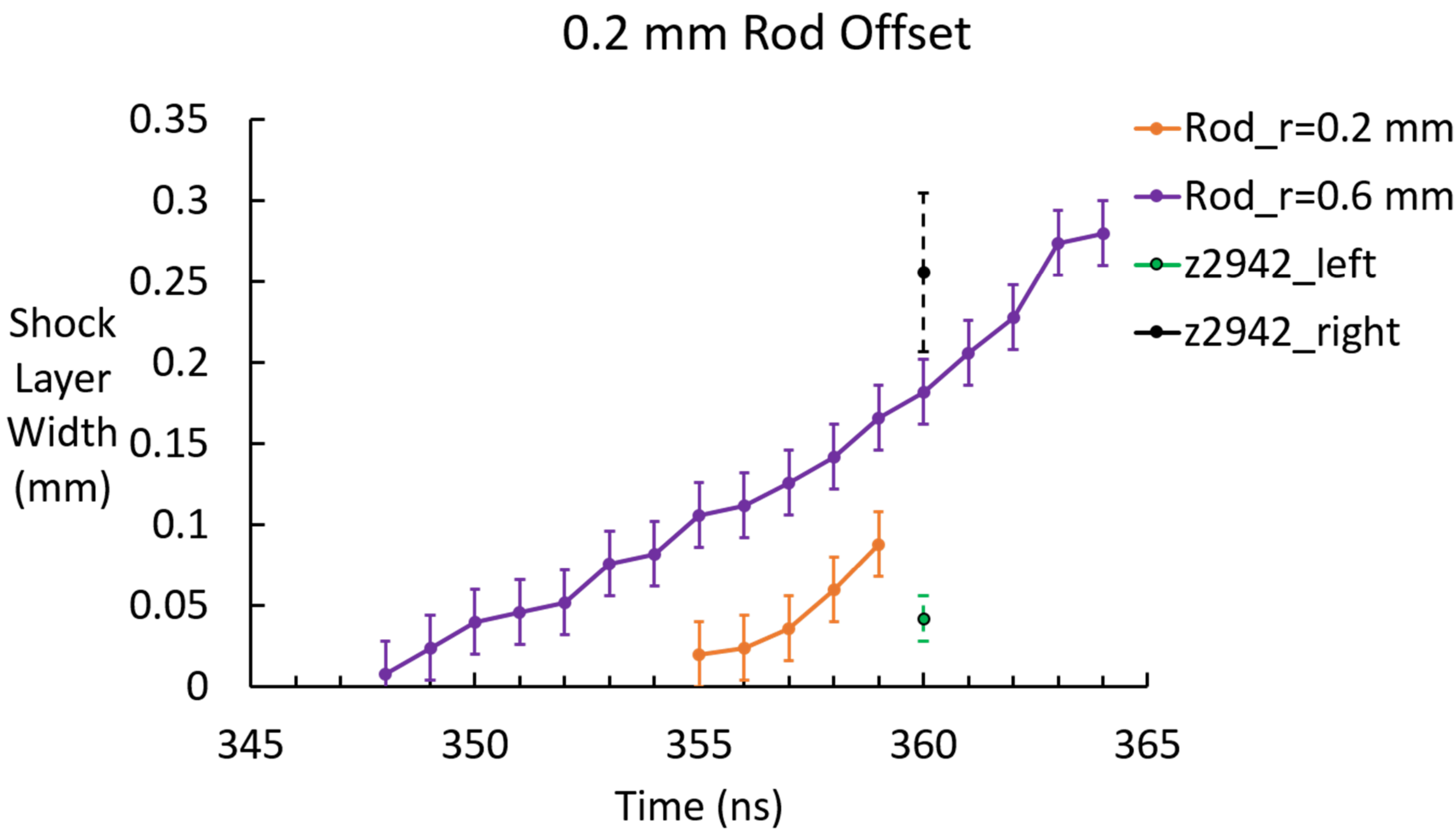
1D Alegra with No Rod Offset



Experimental Shock Layer Width is Not Consistent with 1D ALEGRA



Experimental Shock Layer Width is Not Consistent with 1D ALEGRA



Results Summary

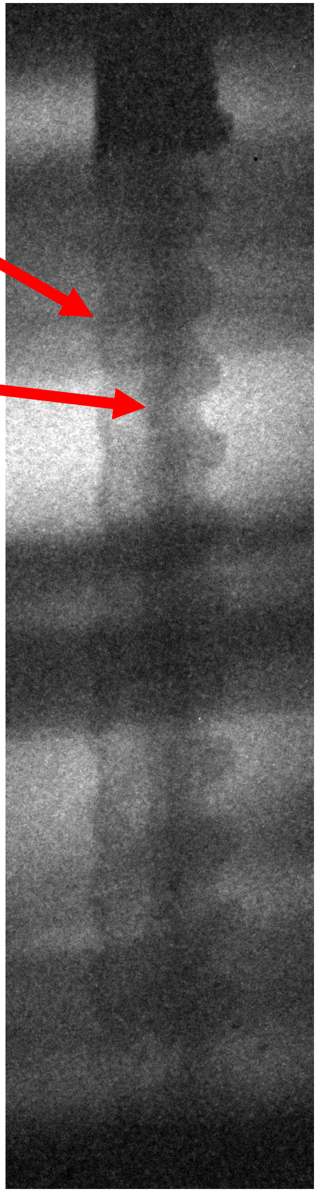
- FFT Analysis: right side seed amplitude is 3.0 times left side seed amplitude
- Linear Theory Growth→ a(t = 4 ns) = 3.0 $* a_0$
- Experiment shock layer width is NOT consistent with 1D ALEGRA simulation with a rod "offset."
- Shock width corresponds with shock propagating in right side for t $\gtrsim$ 13 ns.
- Nonlinear growth condition occurs at t $\sim$ 2 ns.

Revisiting Assumptions

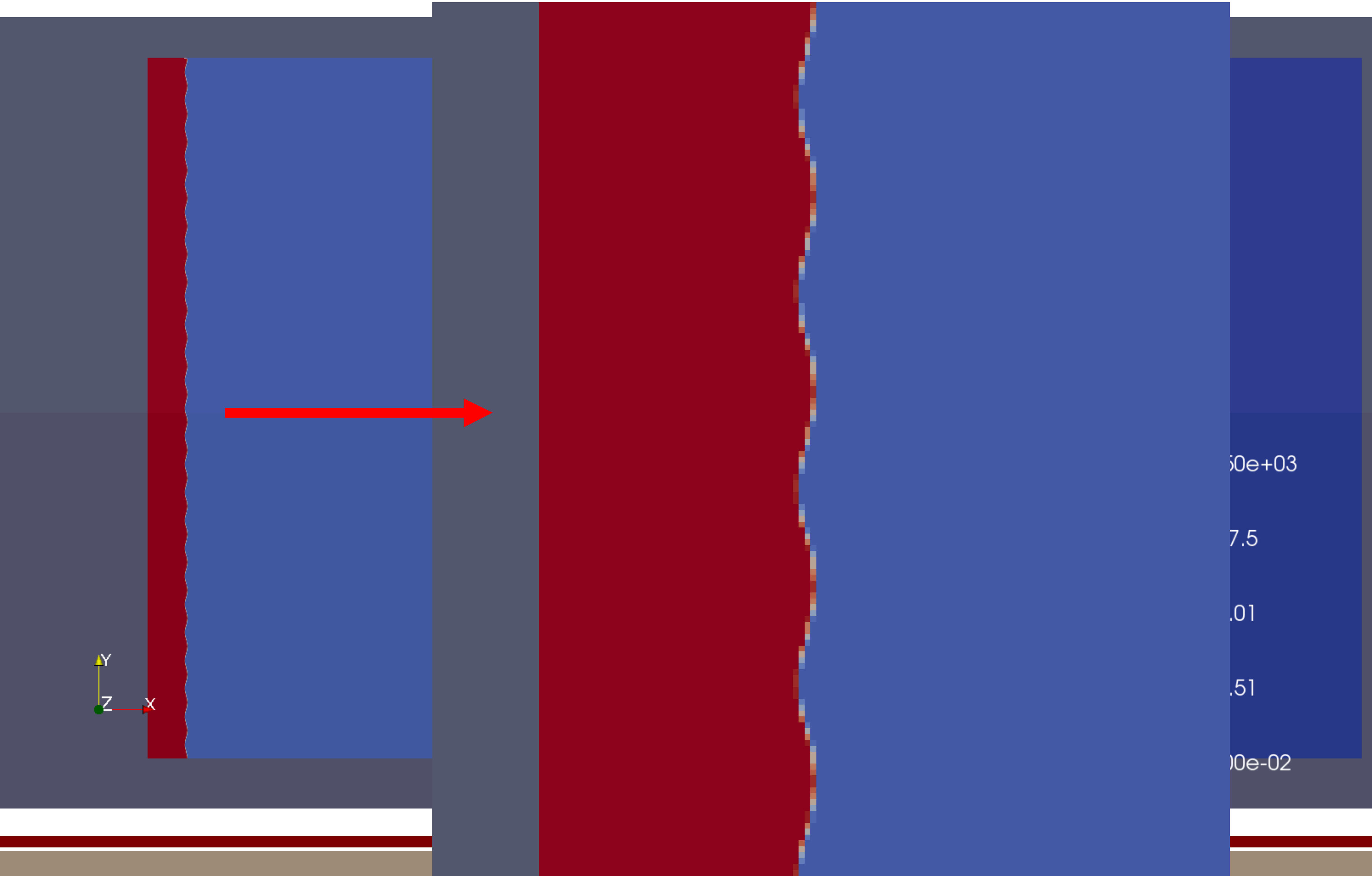
- The shock has hit the left side and has not yet hit the axis.
- The shock position from the right side is the farthest-left dark area.

→ 2D projection effects?

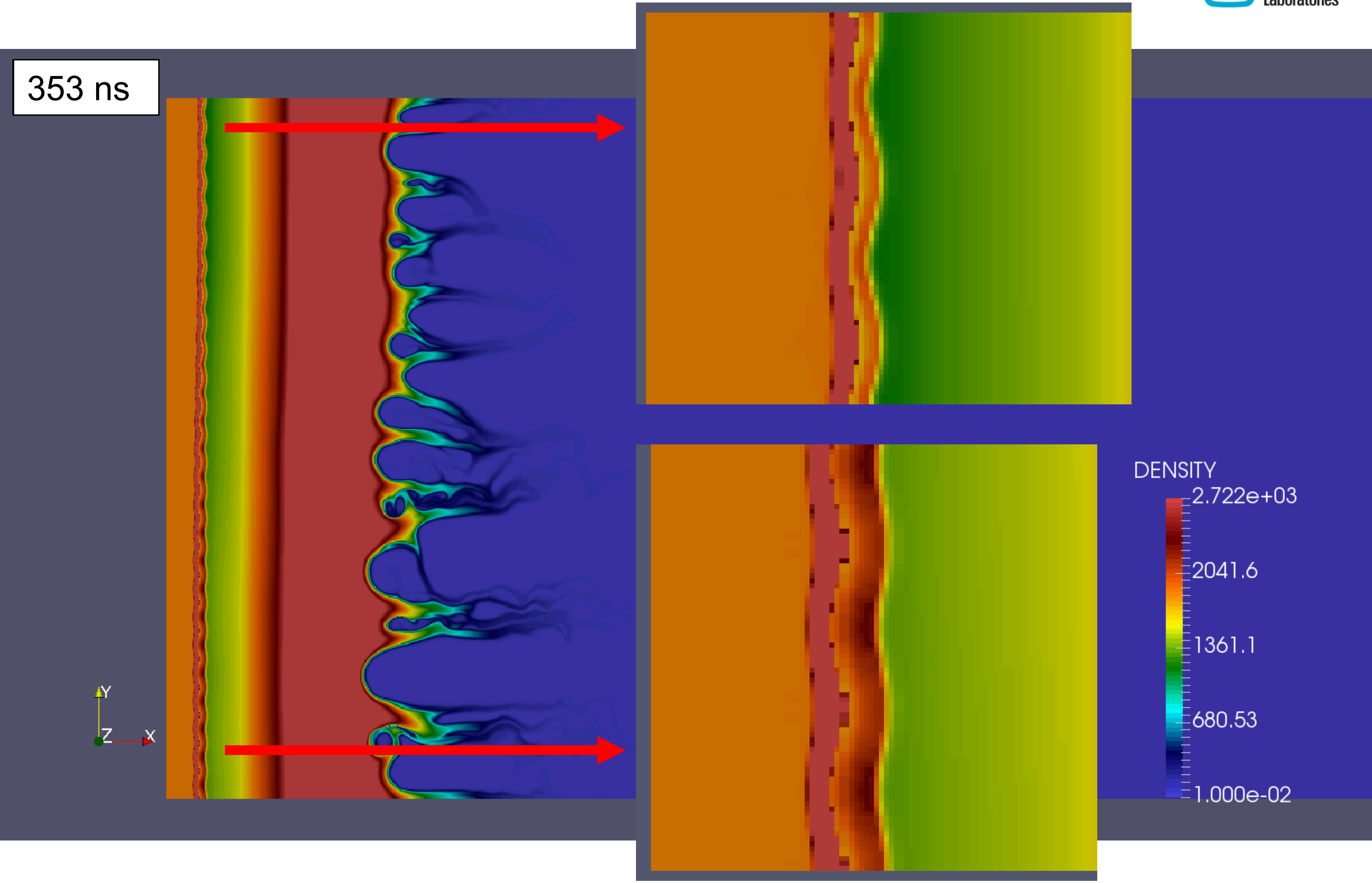
- 1D Alegra is “good enough” for our estimates.



2D ALEGRA “Results”: Initial Setup



2D ALEGRA "Results"



Next Steps for Deceleration Project

- Project Goal: Better diagnose and understand stagnation physics (at larger radius than MagLIF)

  → instability growth, mix, shock velocities, etc.

- Obtain better time history→ get useful t2; use standard 6 keV backlight (as in "old data" z2793).
- Make shock interaction more symmetric→ improve centering, concentricity, and tilt of rod.
- Obtain PDV data (experimental shock velocity measurement).