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Author(s): D.T. Offermann, P.A. Keiter, E. Loomis, L. Welser-Sherrill, J. Fincke, N. Lanier

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Preliminary results investigating mix in colliding-shock experiments (U)

D.T. Offermann, P.A. Keiter, E. Loomis, L. Welser-Sherrill, J. Fincke, F. Doss, S. Evans, B. Haines, D. Schmidt N. Lanier

Los Alamos National Laboratory, Los Alamos, New Mexico

Abstract (U): Experiments have been performed at the Omega laser facility to investigate turbulence-driven mix from two colliding shocks, such as expected in ICF ignition capsules. Two shocks were generated at either end of a cylindrical, CH foam. The evolution of an Al tracer layer at one end of the foam was measured using point-projection radiography. Comparison of this data with simulations from the code, RAGE has been done to improve its predictive capability for ICF experiments. RAGE implements the Besnard-Harlow-Rauenzahn (BHR) model, which is intended for turbulent transport in fluids with large density variations.

Introduction

Proper modeling of turbulent mixing in plasmas has relevance in a number of applications ranging from astrophysical phenomena to inertial confinement fusion (ICF). A number of hydrodynamic codes relying on a number of models exist that try to accurately reproduce observed behavior. However, in cases like ICF, direct observations of mixing cannot be made to the level of precision necessary. Instead, we can only infer its role in degraded fusion performance. Hence, there is a need to have a robust model which can reliably predict mix.

A particular model of interest to Los Alamos is the Besnard-Harlow-Rauensahn (BHR-2) turbulent mix model. It is currently implemented in the hydrodynamics code, RAGE[1]. This model requires users to set the magnitude of certain coefficients which modify the rate of particular behavior. Values for these coefficients are determined by experimental data. In this work, we have developed an experimental platform which is sensitive to the term which modifies compression. Presently, no experimental data exists which can be used to set this coefficient and has been assumed to be zero.

Turbulent mixing in re-shocked fluids occurs naturally in astrophysical phenomena as well as inertial confinement fusion (ICF), where reflected shocks in an imploding capsule are present. We are motivated to develop computational models which can accurately predict the magnitude of this mixing. A particular model of interest is the Besnard-Harlow-Rauensahn (BHR) turbulent mix model. It is currently implemented in the hydrodynamics code, RAGE.

Experimental Setup

The expansion of a tracer layer that has been subjected to counter propagating shocks is sensitive to the coefficient of interest. We have designed an experimental platform for use at the Omega laser at the Laboratory for Laser Energetics (LLE) in which counter propagating shocks are launched at either end of a 60 mg/cc, cylindrical foam. Turbulent mixing occurs when the two shocks collide. The foam is a simple plastic, CH and the magnitude of the mixing is observed by measuring the width of an aluminum tracer layer which is initially 20 microns thick and located at one end of the foam. The foam/tracer package is encapsulated by a cylindrical, beryllium can. See figure one for the initial configuration.

The first shock is initially launched on the end of the target with the tracer layer. To produce the shock, 5 kJ of ultraviolet laser light is focused onto a plastic cap at the end of the package with a pulse duration of 1 ns. This ablates the plastic cap, and the ejection of mass produces a shock that propagates into the tracer and foam. The second shock, driven by 4 kJ, at the opposite end is delayed 5 ns from the first shock so as to allow the tracer enough time to reach the central region of the foam.

The width of the foam is measured using x-ray point-projection imaging of the target. A back-lighter source foil (either chlorine, scandium, chromium, or iron) is energized by 2 to 3 kJ of focused laser light, delayed relative to the first shock drive. The intensity of the laser is such that it is ionized and emits x-rays. The emission is dominated by the transition from the n = 2 state to the n = 1 state of the helium-like ions. For x-rays of these energies (2.8 to 6.7 keV), the foam and beryllium can are transparent enough that the aluminum tracer can be easily seen, but opaque enough that density variations across the shock boundaries can also be seen. This is important because the location of the boundaries verses the delay time of the x-ray probe will tell us if we have the basic hydrodynamics correctly modeled before we attempt to compare the mixing with simulation.

Comparison with BHR

To directly compare the data with the 2-D, simulated results from RAGE, we have generated simulated x-ray radiographs of the codes output by assuming cylindrical symmetry and revolving the profiles about the axis. Qualitatively, we see good agreement between simulations and experiment, as is shown in figure 2. However, it the first obvious deficiency is that the shock speeds in the 60 mg/cc foam are faster in the experiment than what is simulated. We expect that this is due to the foam cell size and can be better accounted for in future simulations with the inclusion of a crush model.

Simulations have been run both with and without the BHR model included. The inclusion of the BHR model clear matches the data better, but still substantially underestimates the with of the tracer (See figure 3).

Summary

We have developed an experimental platform on the Omega laser which will allow us to fix the coefficient in the BHR model that is responsible for modifying compression. This is done by measuring the with of a tracer layer that has been subjected to two colliding shocks in a 60 mg/cc foam. Results are preliminary at this point, but indications are clear that the BHR model with the default selection for the parameters underestimates the magnitude of the turbulent mixing taking place. However, inclusion of the BHR model does a better job than if the simulations are run with no mix model turned on.

Fig. 1: **Pre-shot x-ray radiograph of a target. Dashed circle shows the field of view of the imaging diagnostic at Omega. The aluminum tracer layer can be seen on the right side of the foam package.**

Fig. 2: **From left to right x-ray radiographs of RAGE simulation with BHR using default parameters, experimental data from Omega, RAGE simulation with no BHR; all taken at 8 ns.**

Fig. 3: **Measurement of the tracer width vs. time since the launch of the first shock.**

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1. K. Stalsberg-Zarling and R. Gore, "The BHR-2 Turbulence Model: Incompressible Isotropic Decay, Rayleigh-Taylor, Kelvin-Helmholtz and Homogeneous Variable Density Turbulence", Technical Report, LA-UR 11-04773, Los Alamos National Laboratory, 2011.

Fig 1

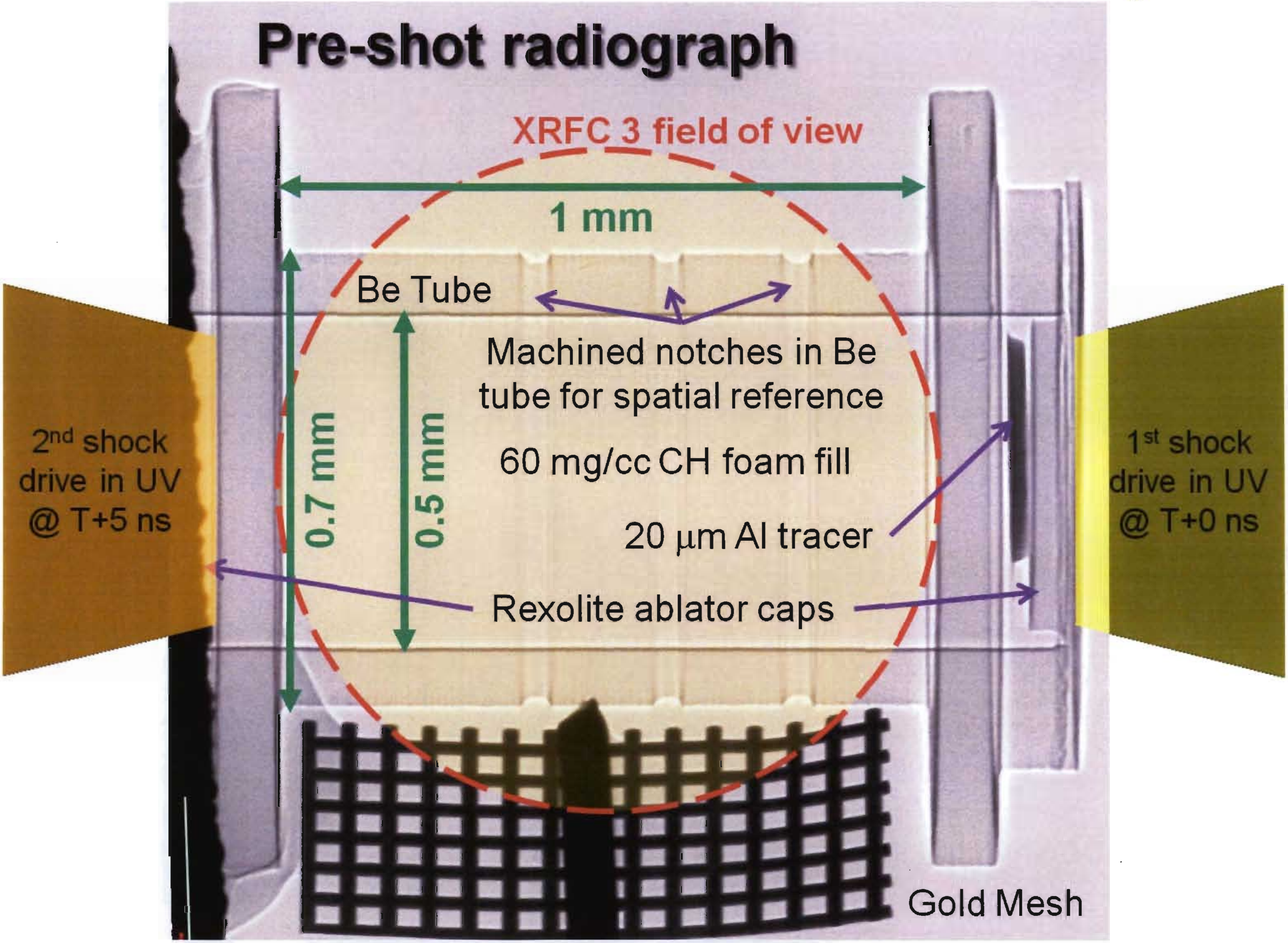

Pre-shot radiograph
XRFC 3 field of view
1 mm
Be Tube
Machined notches in Be tube for spatial reference
60 mg/cc CH foam fill
20 μm Al tracer
Rexolite ablator caps
0.7 mm
0.5 mm
2nd shock drive in UV @ T+5 ns
1st shock drive in UV @ T+0 ns
Gold Mesh

fig 2

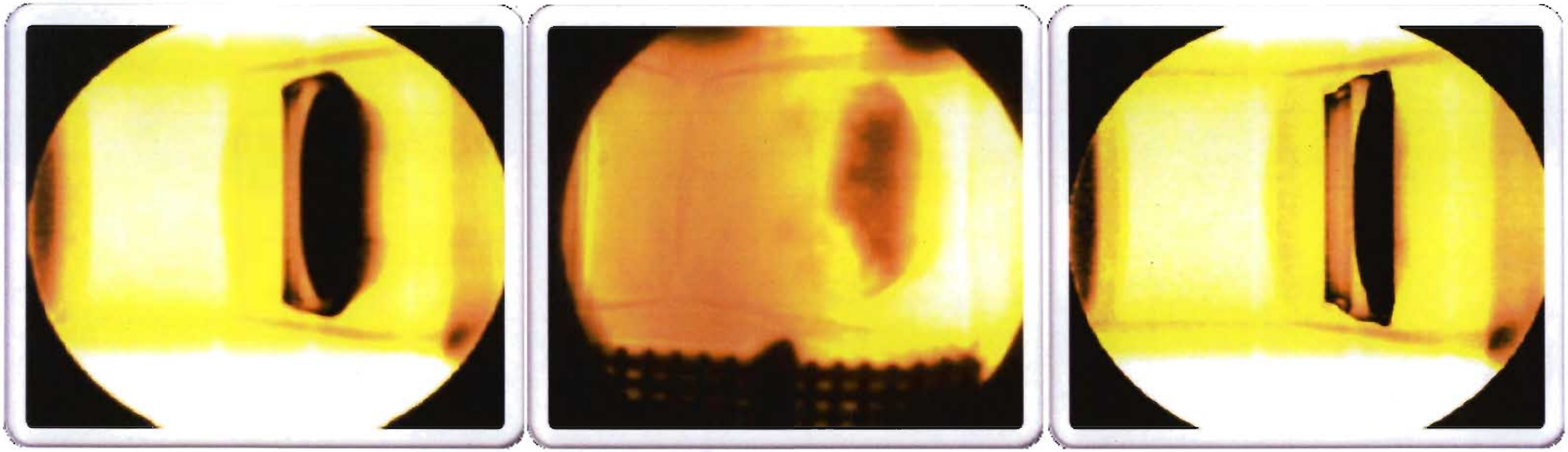
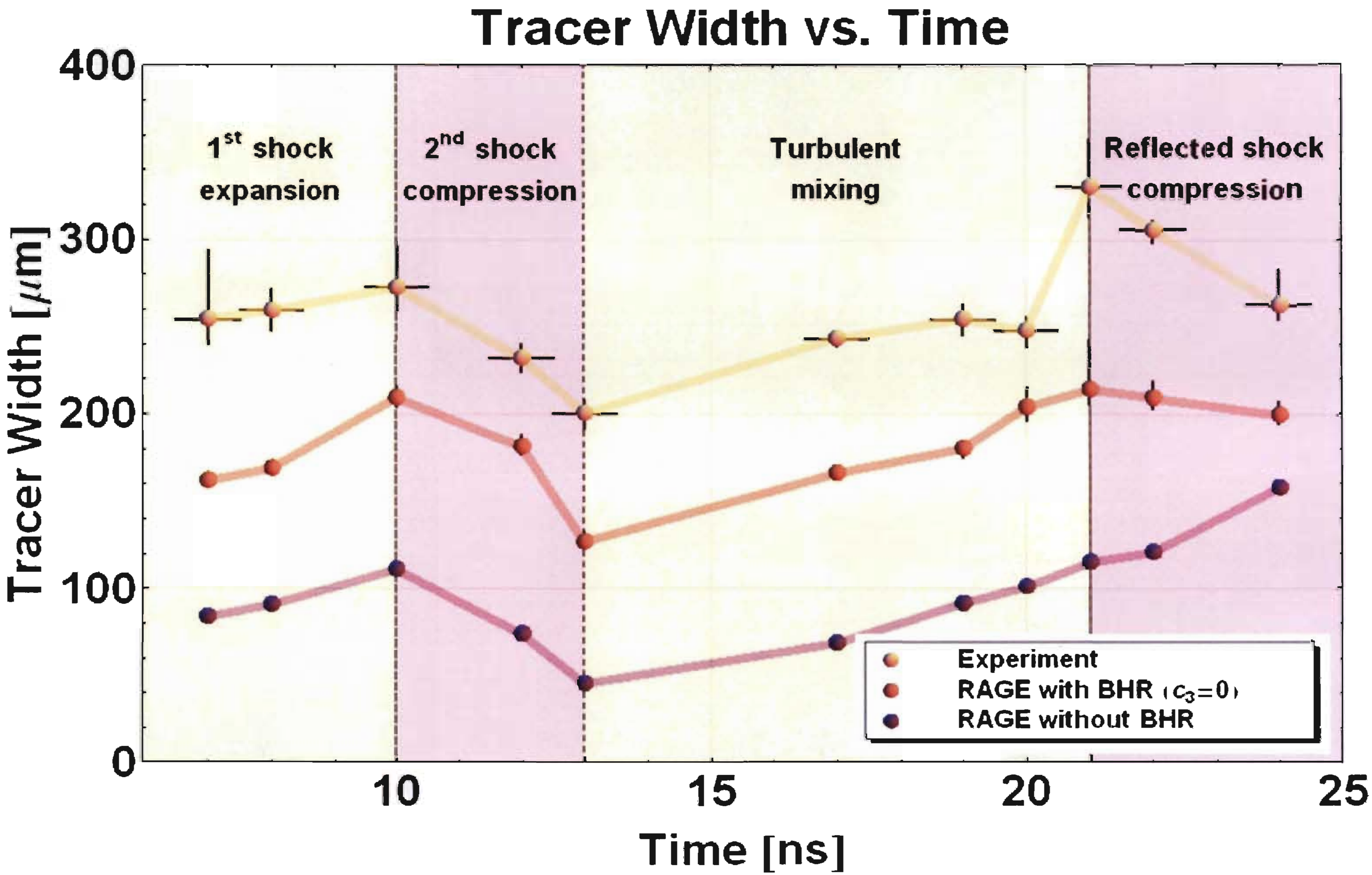


Fig 3



Tracer Width vs. Time
1st shock expansion
2nd shock compression
Turbulent mixing
Reflected shock compression
Tracer Width [μm]
Time [ns]
400
300
200
100
0
10
15
20
25
Experiment
RAGE with BHR (c3=0)
RAGE without BHR