X-ray Radiography and Radiating Shock Experiments

F.W. Doss

R.P. Drake, H.F. Robey(LLNL), C.C. Kuranz, M.J. Grosskopf and D.C. Marion

University of Michigan

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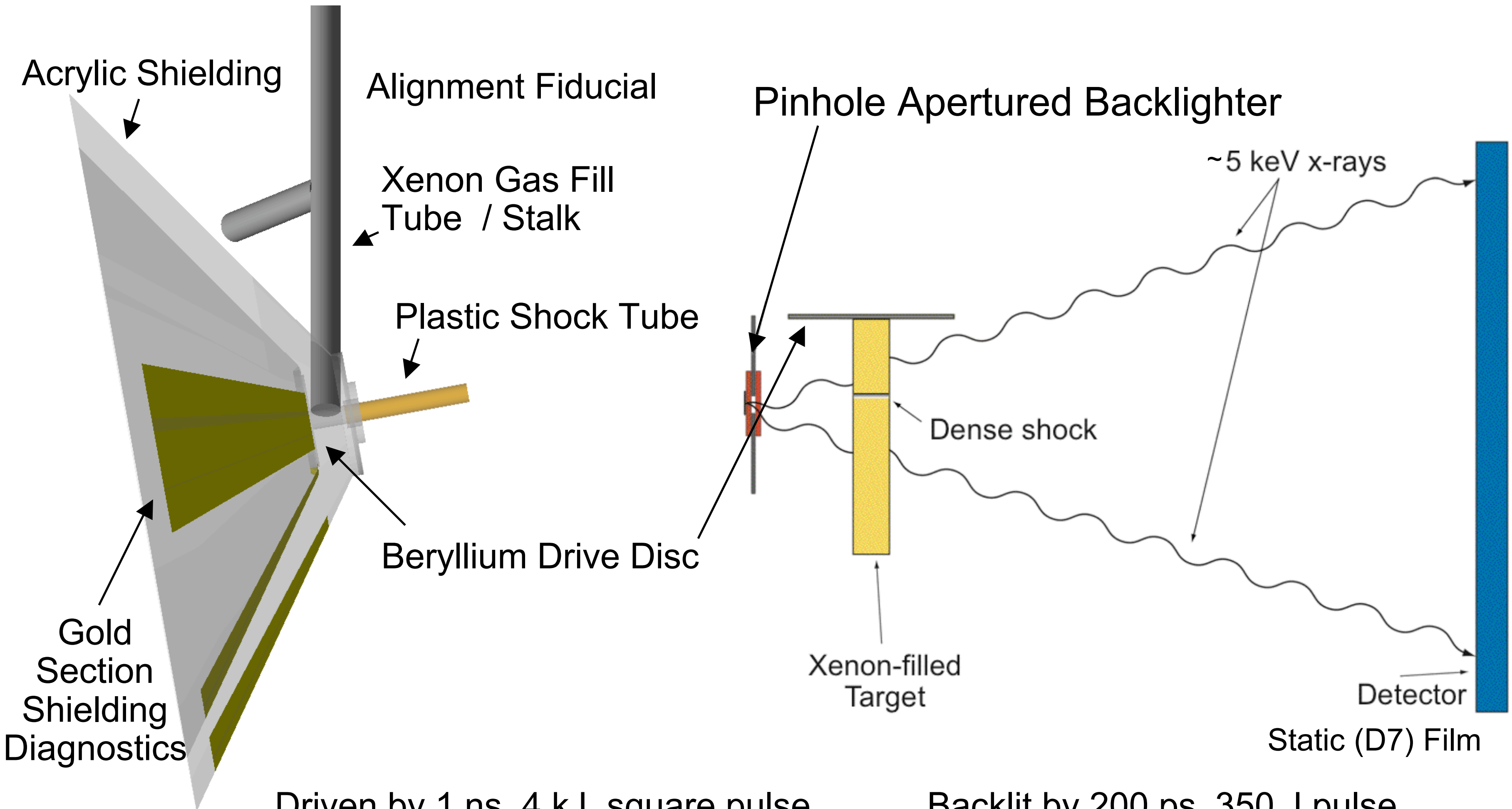
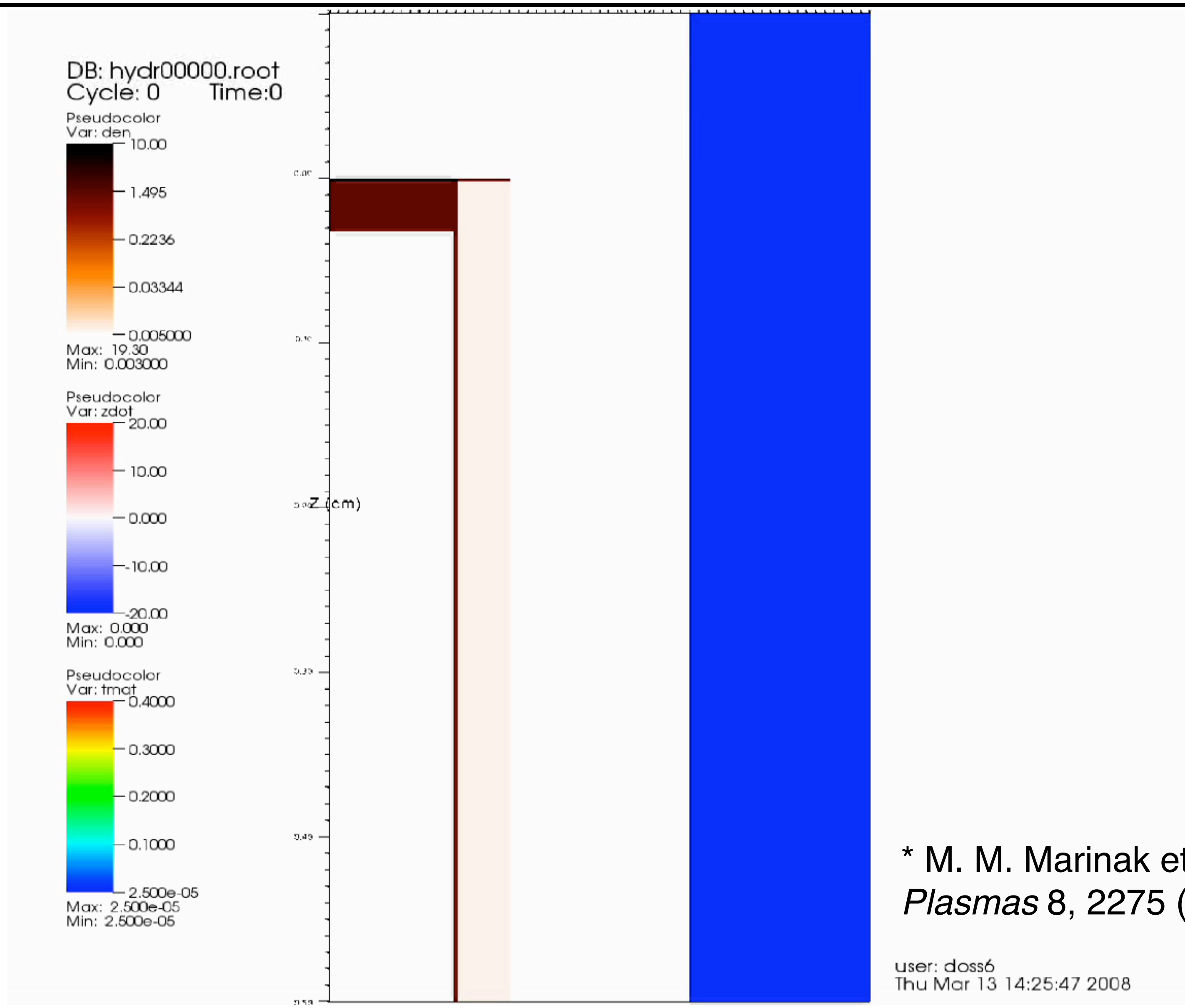
Radiating shock experiments are conducted in directly driven Xenon filled shock tubes on the Omega laser



Driven by 1 ns, 4 kJ, square pulse

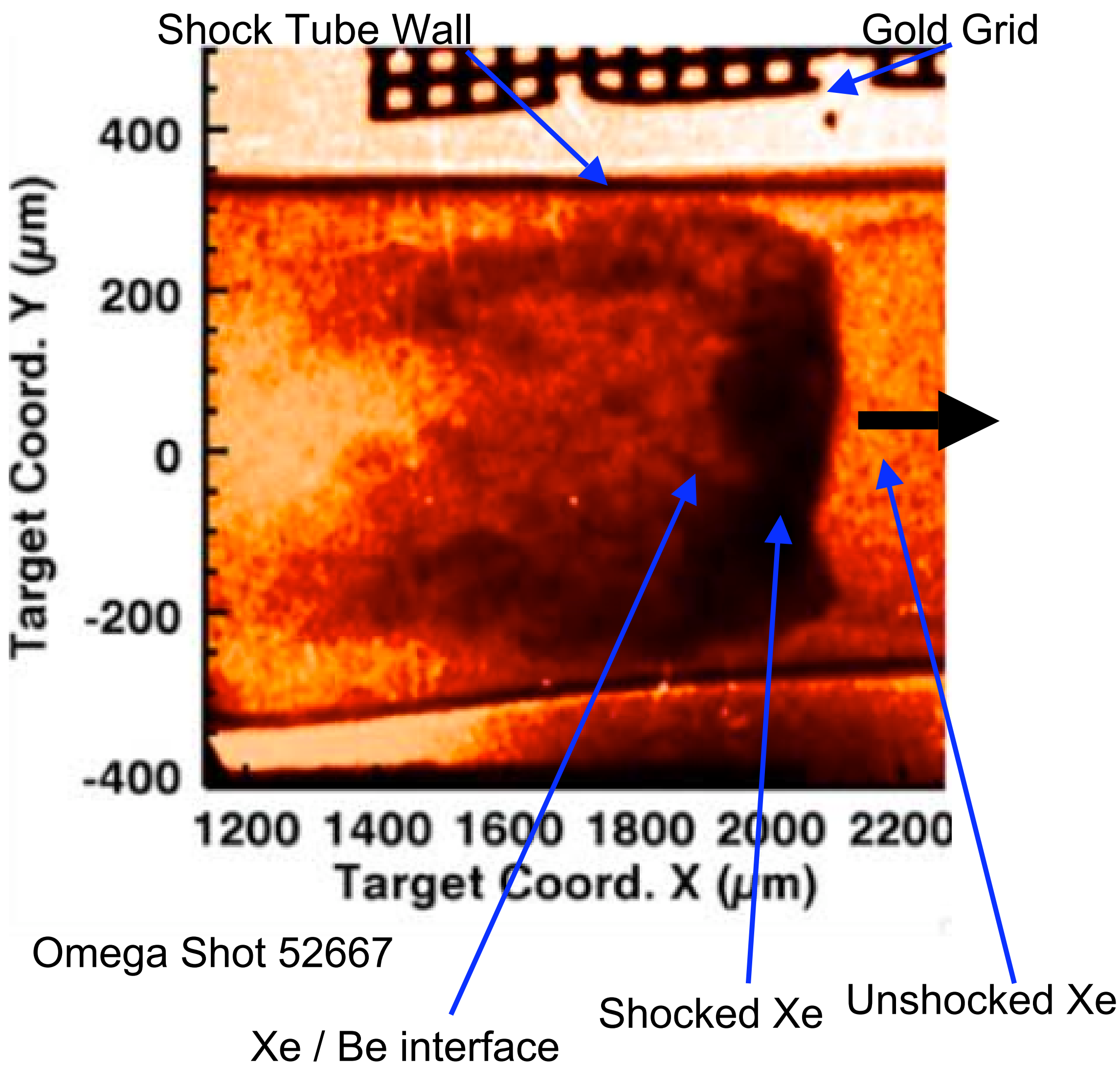
Backlit by 200 ps, 350 J pulse

HYDRA* simulations reproduce some experimental features



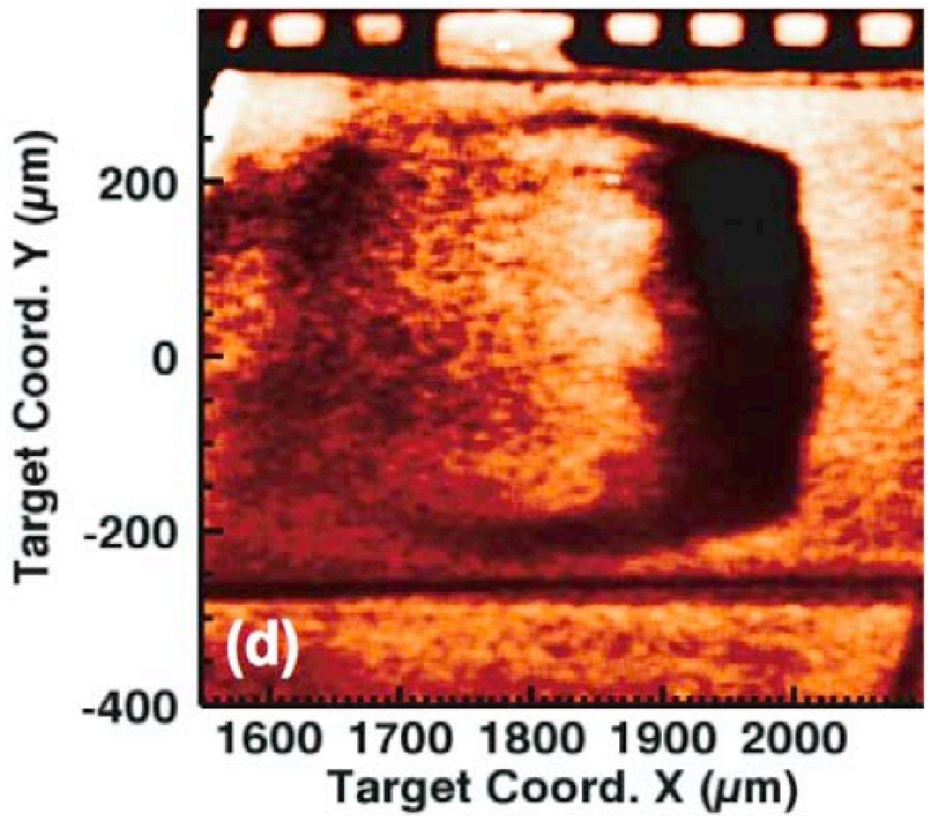
* M. M. Marinak et al., *Phys. Plasmas* 8, 2275 (2001)

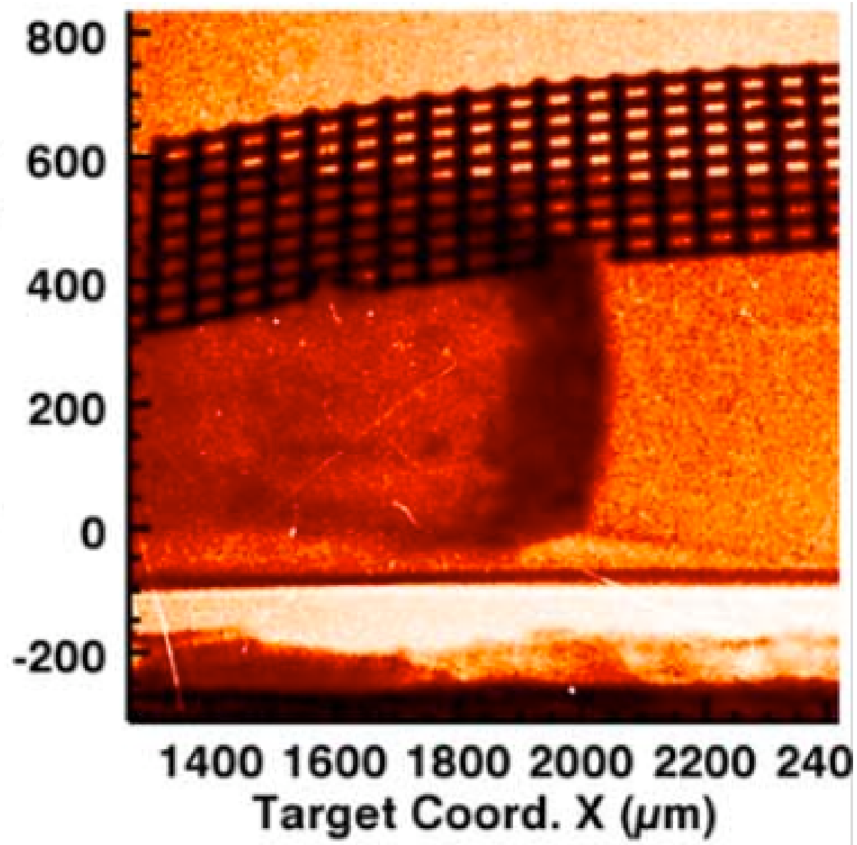
Radiography directly measures shock position features



- Gold Grid serves as a spatial fiducial.
- Data from pre-shot metrology is used to diagnose lengths in target image.
- Photon intensities diagnose material densities.
- Shock is driven with 20 micron Be driver, t = 13 ns, shock travelling at ~110 km/sec.

Improvements in radiography has improved our ability to diagnose wall shocks

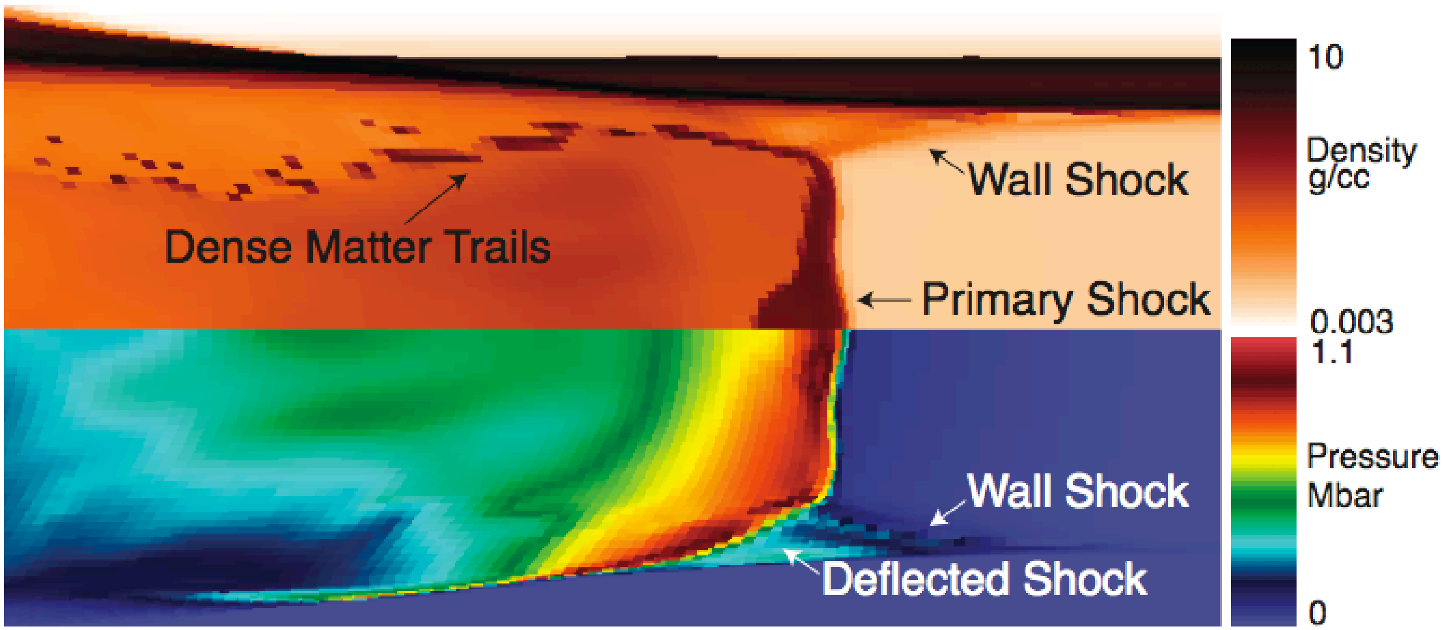




- Shot 40703 (shot by A. Reighard)
- Gated X-ray framing camera, 2 ns beam pulse, 200 ps gate, V

- Shot 52670
- Ungated D7 film, 200 ps backlighter pulse, V

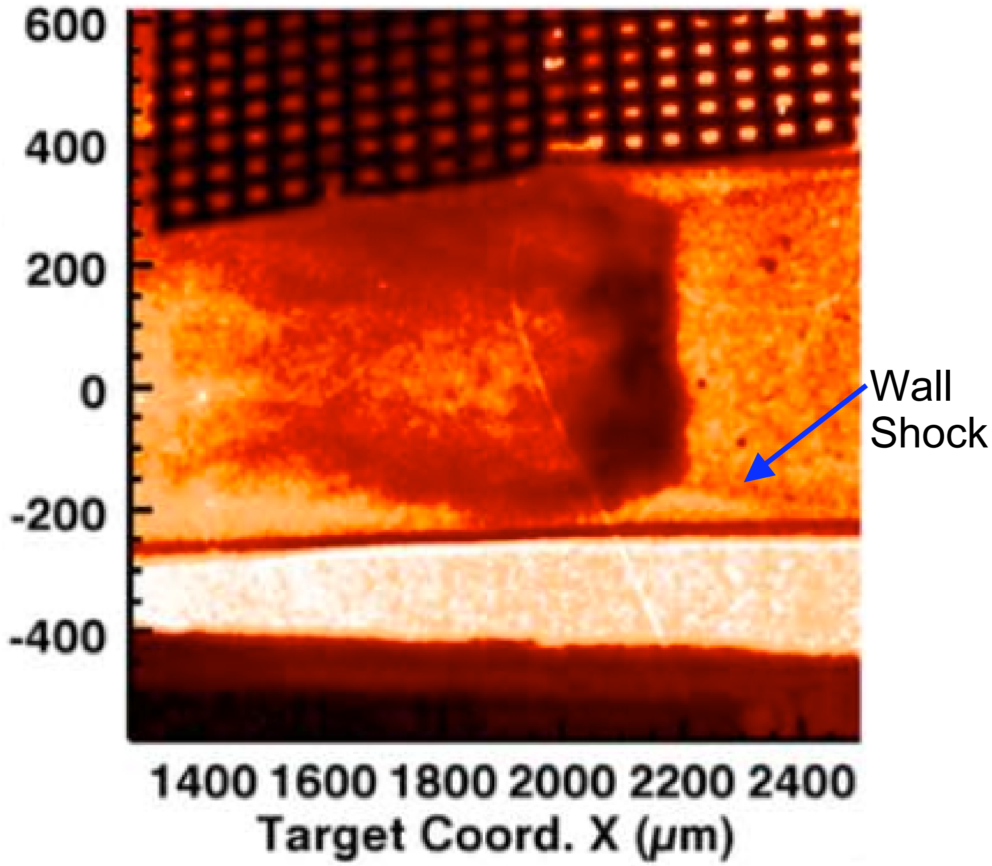
Wall shocks control the primary shock morphology



High resolution
HYDRA simulation

- Radiation from the shock induces plastic ablation, forming a radial blast wave in the tube.
- Primary shock then meets the wall shock, inducing obliqueness in the primary shock.

Effects of the wall shock are clearly seen in radiating shock experiments

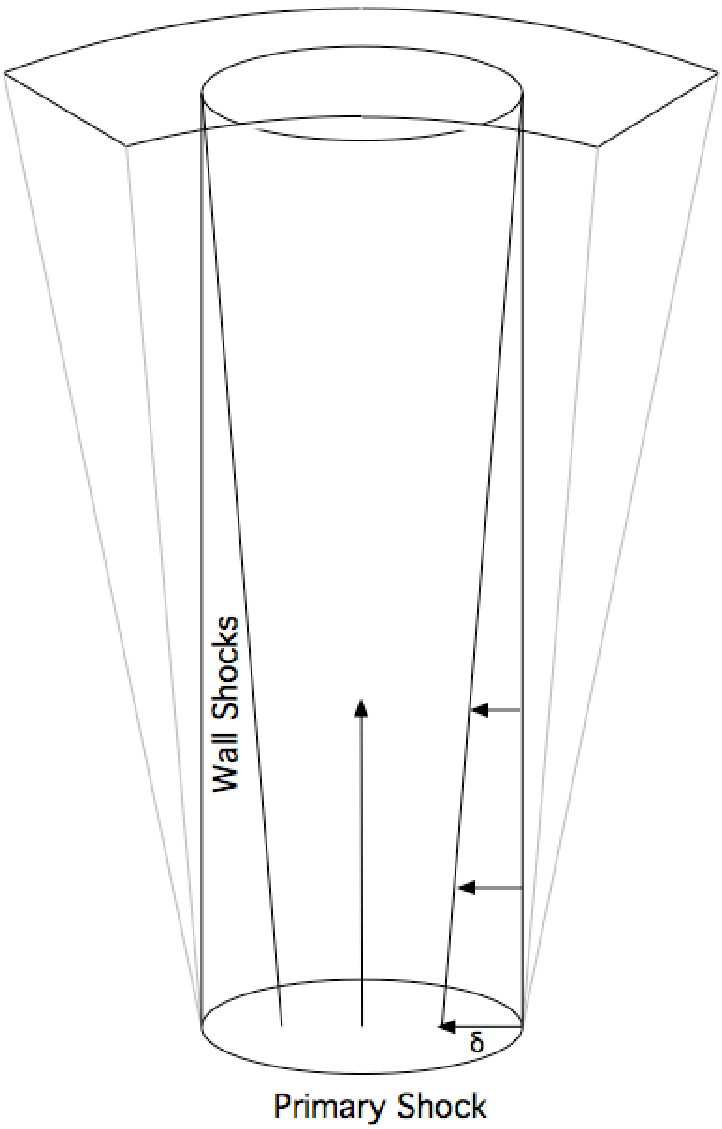


Omega Shot 52665

Wall shock induced features include:

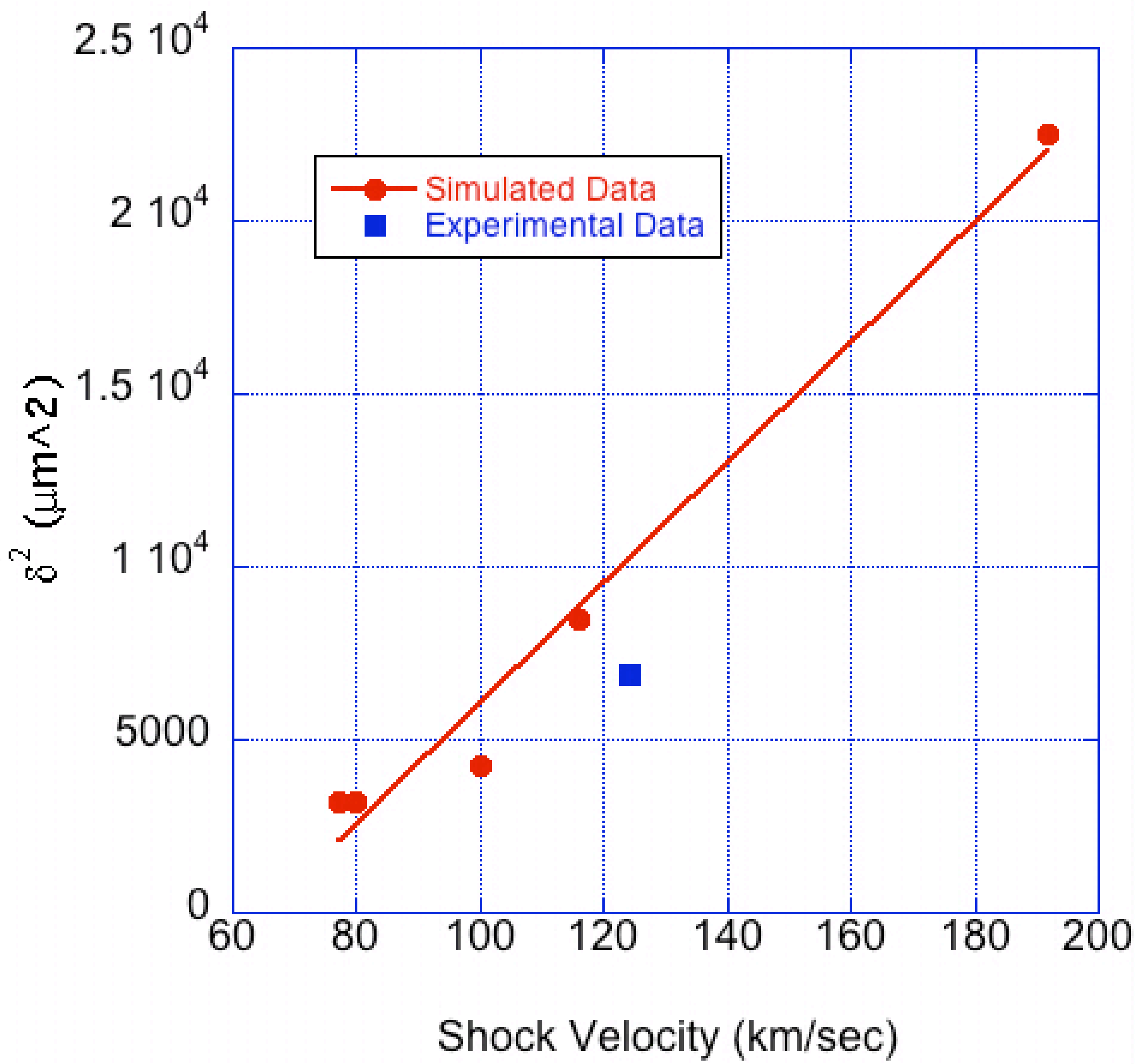
- Finite displacement of shock edges from tube walls
- Angle of primary shock deflection at kink
- Angle of wall shock off of wall
- Curvature and thicknesses of the trails
- Dense Xenon collected behind the primary shock.

We can learn information from these features



- The edge displacement distance is likely correlated with shock speed.
- The dominant terms as the radiation disperses is $1/d^2$. The radiation increases with shock speed as V_s^3. So, the distance at which critical heating occurs goes as $d \sim V_s^{3/2}$.
- After blowout, the wall shock travels inward until it reaches the primary shock. It travels for an interval $\Delta t \sim d/V_s \sim \delta / V_w$.
- So, we expect $\delta \sim V_s^{1/2}$.
- Once this is calibrated for given materials and geometry, we can use the wall shock as a primary shock speed diagnostic.

Edge displacement correlates with primary shock speed



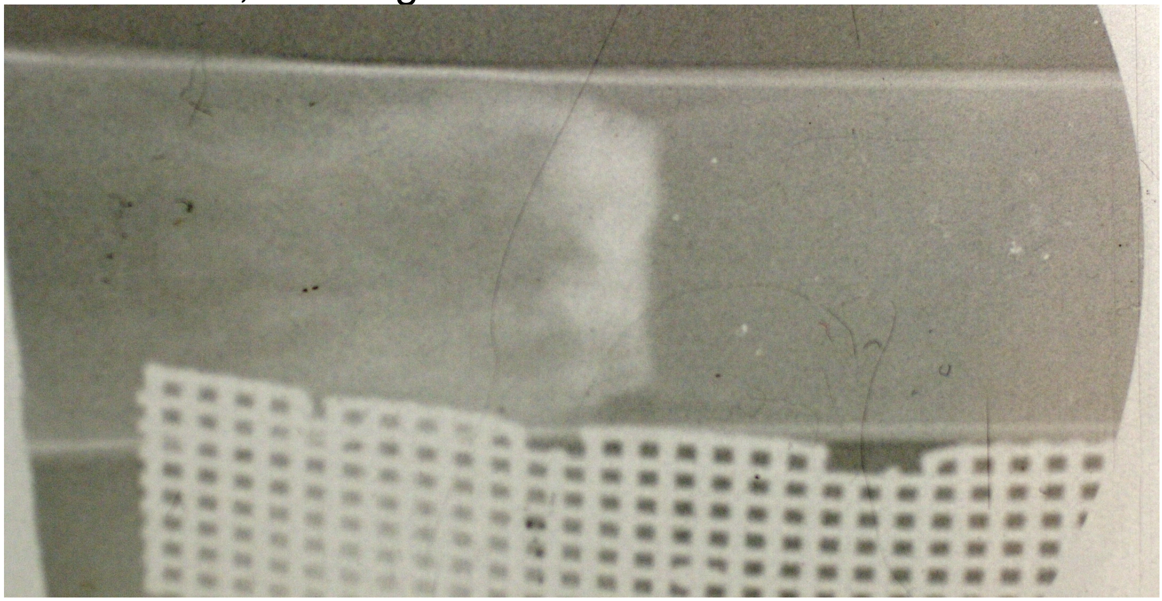
A few sample shocks, from experiments taken by me and others, plotting edge displacement squared against HYADES estimates of shock speed.

If $\delta \sim V_s^{1/2}$, δ^2 vs. V_s should be a straight line.

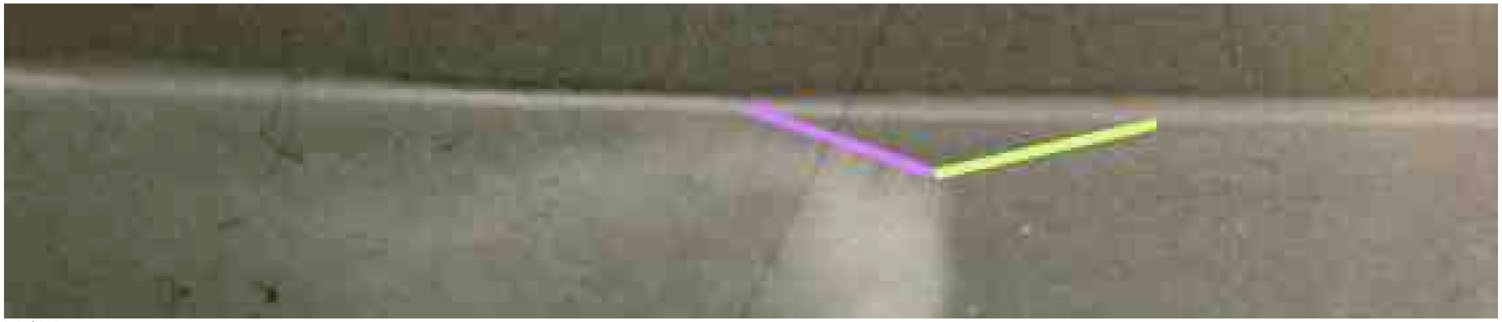
Future experiments will provide a more complete statistical analysis.

We should also be able to infer information from the angle of deflection where the shocks meet

- Shot 52665 in October, showing a clear wall shock effect.

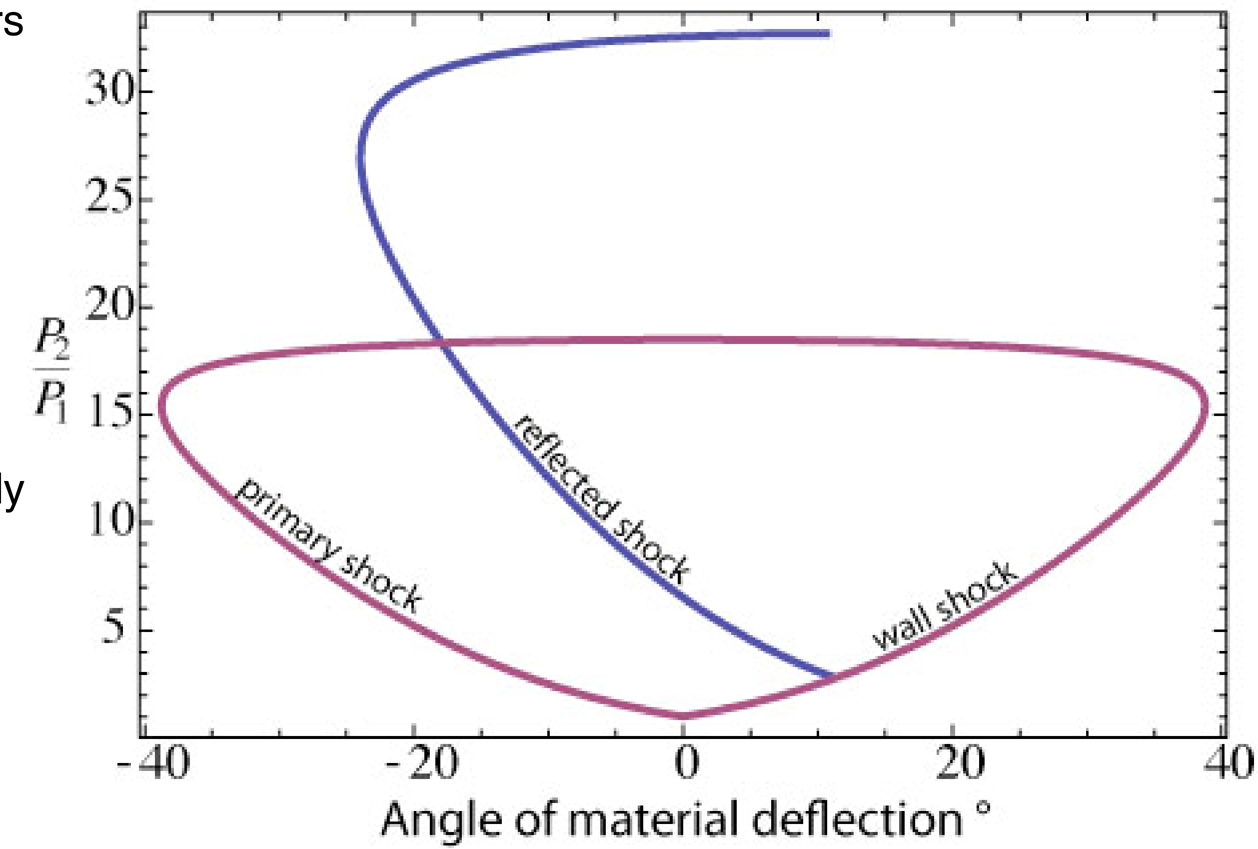


- Both shocked and unshocked wall material are x-ray transparent, so shock angles are not necessarily easy to infer. Material boundaries of shocked xenon, however, are more visible.

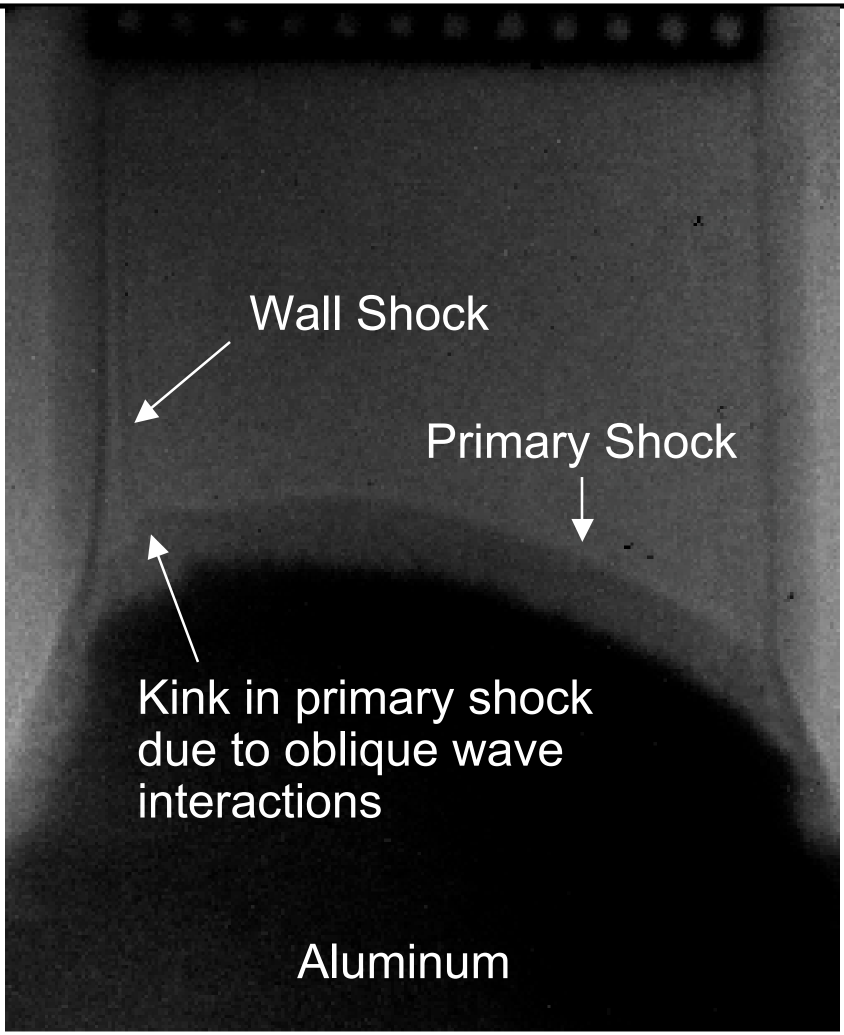


Measurements of angles constrain Mach number

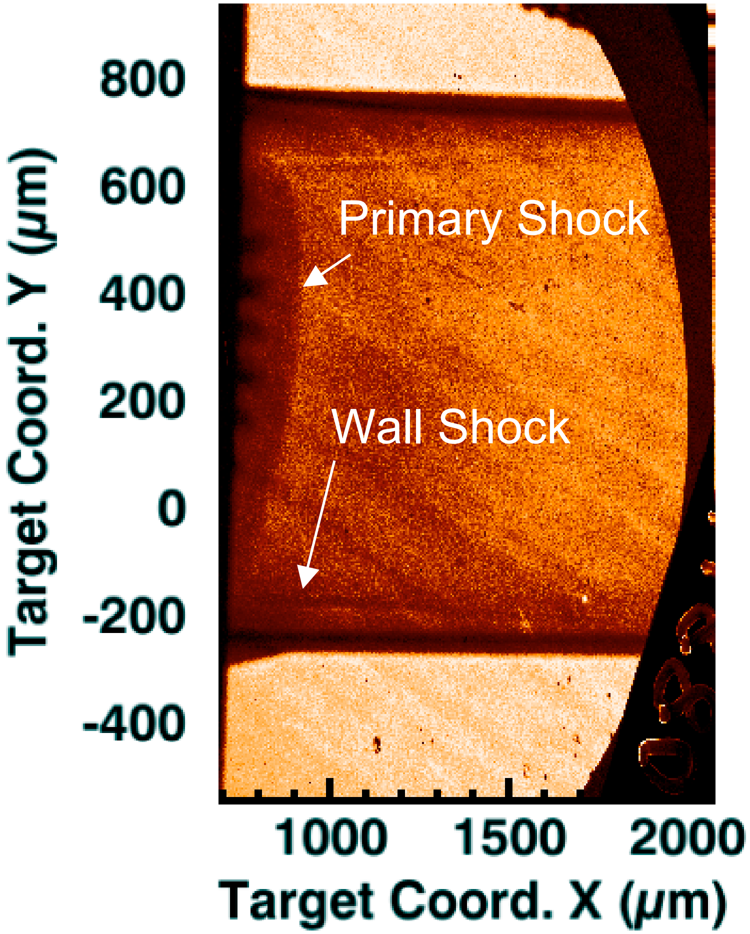
- The method of shock polars plots, across all angles of obliqueness, the possible angular deflections of material against the pressure increase across the shock.
- The material interface angles measured from the radiograph translate directly to the θ coordinates of points of intersection.
- Only particular Mach numbers will consistently link the angles of intersection.
- Coupled with a velocity diagnostic, this gives speed of sound in the radiative preheat region.



Wall shocks have also been seen in laser-driven experiments



NEL Al jet experiment
040520-001



Omega SNRT
experiment 41880

Summary

- Radiography allows for direct measurement of shock position, layer thickness, densities, velocity (with two).

- The radiative precursor of a sufficiently fast shock causes the evaporation of tube material ahead of the shock. The resulting expansion wave drives a converging wall shock into the gas volume. This acts as a dynamic constriction of the tube, and modifies the edge conditions experienced by the primary shock.

- Wall shock radiography allows for indirect measurement of Mach numbers, velocities, sounds speeds, temperatures.

- Wall shocks in experiments in which the principal shock waves themselves should not be radiative have also been seen, in which the wall shocks have been launched by some other factor, possibly laser preheat.