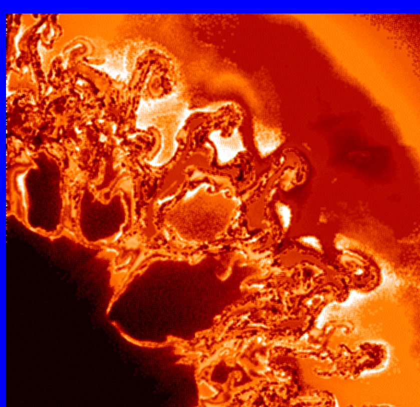
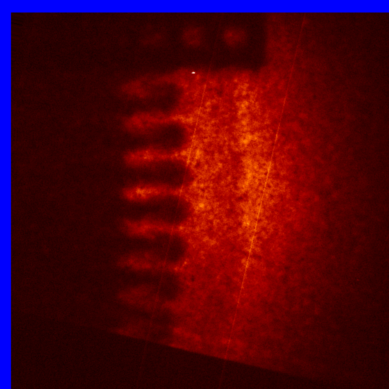
Design of Flyer-Plate-Driven, Compressible-Turbulent-Mix Experiments

R. P. Drake
University of Michigan

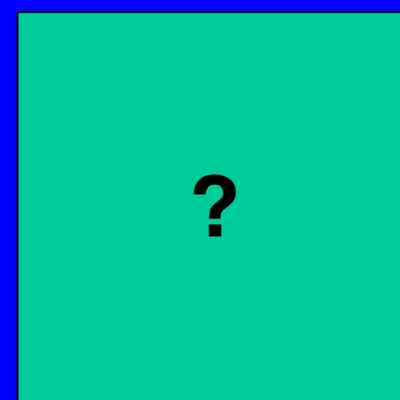
IWPCTM, Pasadena, December 2001



Supernova Simulation



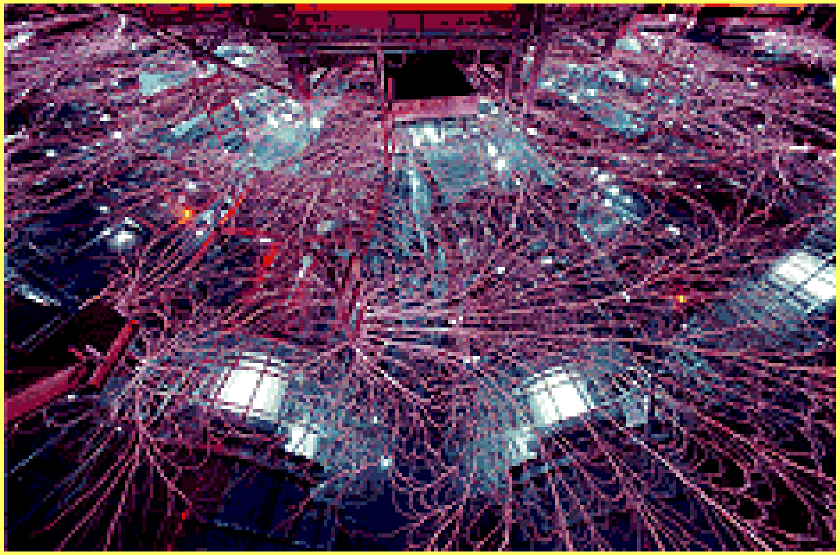
Omega Laser Experiment



Z Flyer Experiment

Work supported by the U.S. Department of Energy under grants DE-FG03-99DP00284, DE-FG03-00SF22021 and other grants and contracts

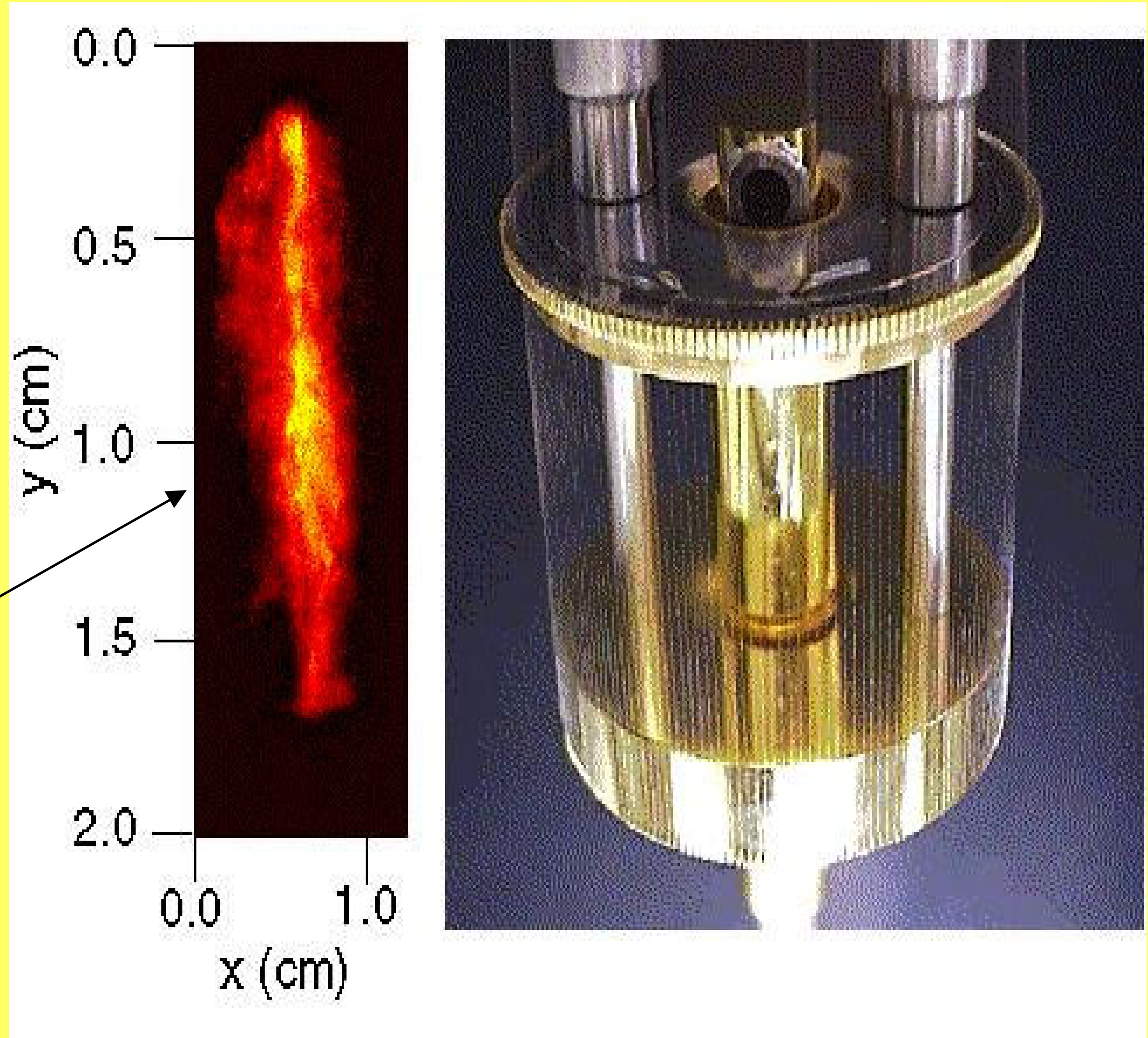
Z has opened up new experimental possibilities



Shown above are pictures of the Z-pinch:
(left) prior to firing (right) during firing

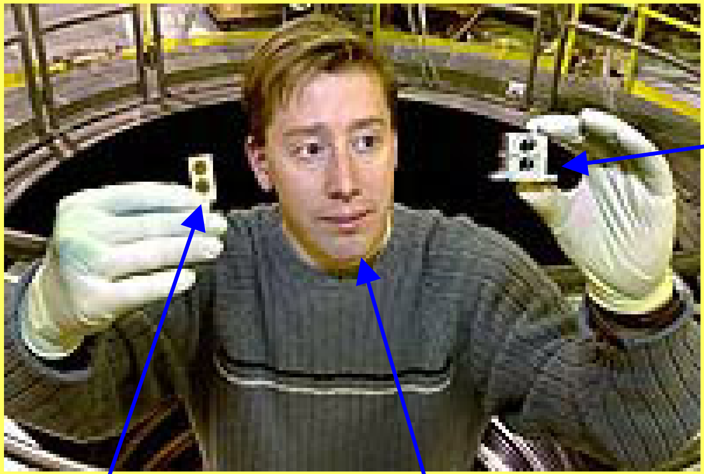
By imploding hundreds of wires, Z can make MJ of x-rays

When the wires collide they produce up to 2 Mega-Joules of x-rays

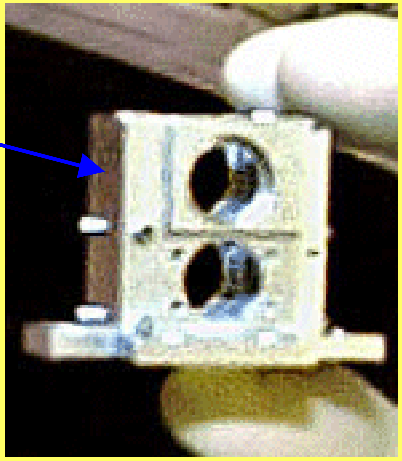


December, 2001

What matters here: Z can use J X B forces to launch Al flyer plates at > 20 km/s



The "gun" J X B launching structure



Flyer Plates

???
(your caption here)

Photo: www.spacedaily.com/news/milspace-tech-01a.html

Acknowledgements: useful discussions with

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S.G. Glendinning, H.A. Robey, J.O. Kane,

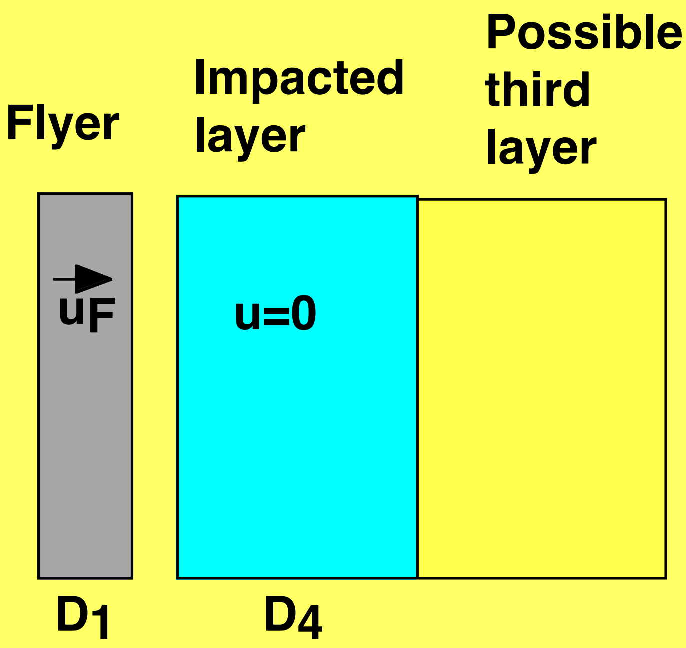
Lawrence Livermore National Laboratory

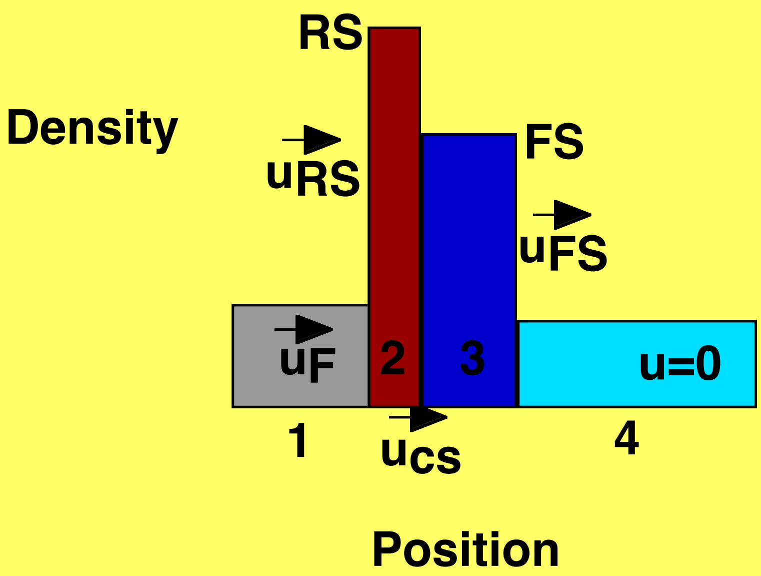
Flyer-plate mix experiments differ from flyer-plate EOS experiments

- **EOS experiments**
  - Need rock-steady shock
  - Experiment ends when shock exits material

- **Mix experiments**
  - Experiment begins when interface of interest is shocked
  - May not want steady shock
  - Even steady shock need not meet EOS constraints

Basic geometry for flyer plate experiments





In the following:

Analytic results use γ-law gas, strong shock equations

Simulations used the HYADES Lagrangian hydrocode with SESAME EOS

Basic relationships for strong shocks in this system

In lab frame:

$$u_{cs} = \frac{1}{1+\sqrt{\rho_4/\rho_1}} u_F$$

$$u_{RS} = \left(1 - \frac{\gamma - 1}{2}\sqrt{\frac{\rho_4}{\rho_1}}\right)\frac{u_F}{1+\sqrt{\rho_4/\rho_1}}$$

$$u_{FS} = \frac{\gamma + 1}{2}\frac{u_F}{1+\sqrt{\rho_4/\rho_1}}$$

In flyer frame:

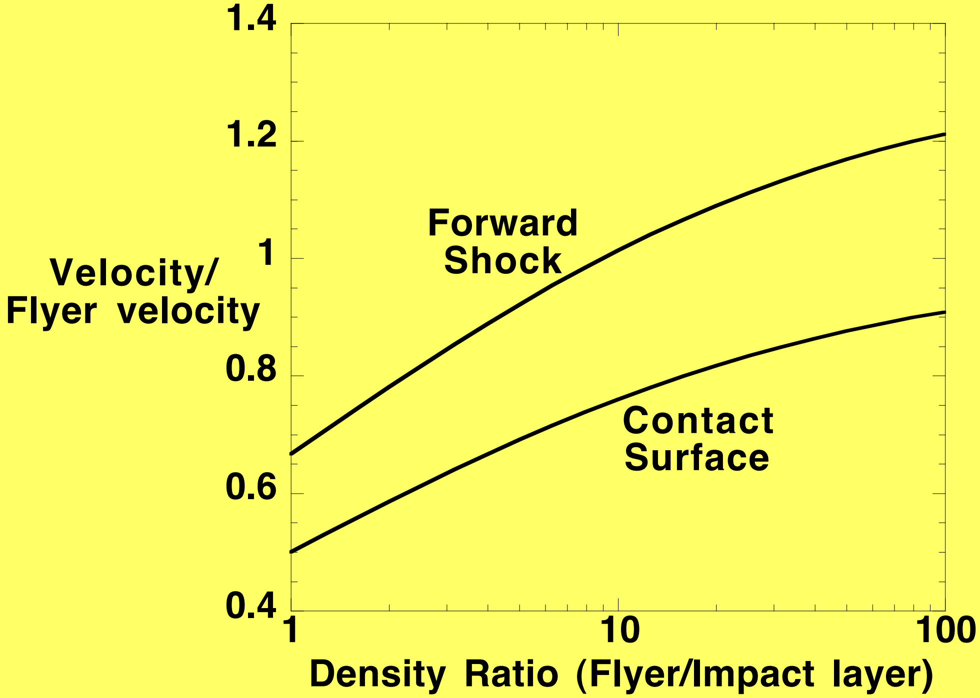
$$u''_{RS} = \frac{-\sqrt{\rho_4/\rho_1}}{1+\sqrt{\rho_4/\rho_1}}\frac{\gamma + 1}{2} u_F$$

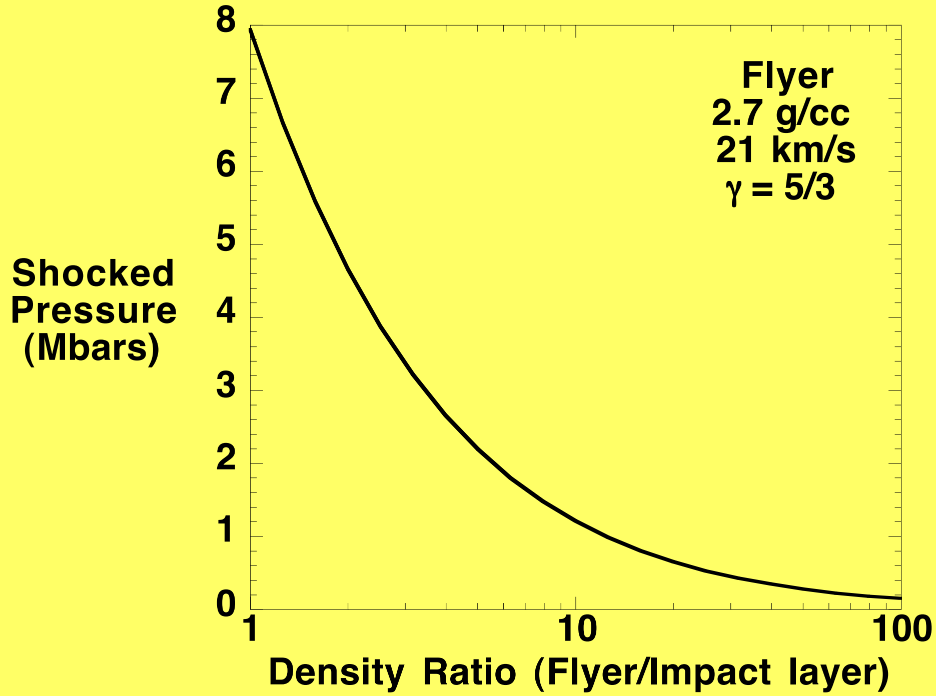
Sound speeds:

$$c_3 = \sqrt{\frac{\gamma(\gamma - 1)}{2}} u_{CS} = \sqrt{\frac{\gamma(\gamma - 1)}{2}}\frac{u_F}{1+\sqrt{\rho_4/\rho_1}}$$

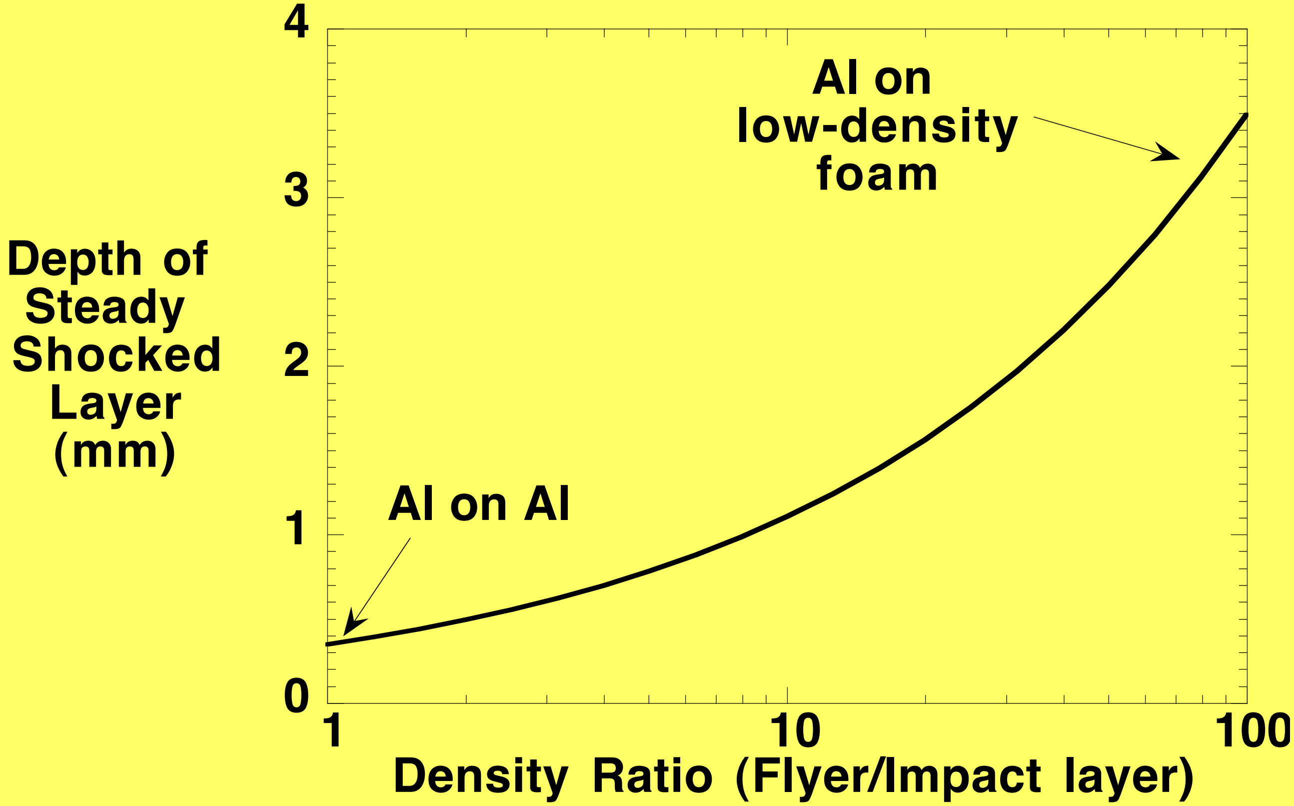
$$c_2 = \sqrt{\frac{\gamma(\gamma - 1)}{2}}(u_F - u_{CS}) = \sqrt{\frac{\gamma(\gamma - 1)}{2}}\frac{\sqrt{\rho_4/\rho_1}}{1+\sqrt{\rho_4/\rho_1}} u_F$$

In mix experiments one will often not use an Aluminum impact layer





At lower impact layer density, one can drive steady shocks over larger distances



350 μm, Al (2.7 g/cc) flyer

Time until the shock reaches the rear of the flyer plate

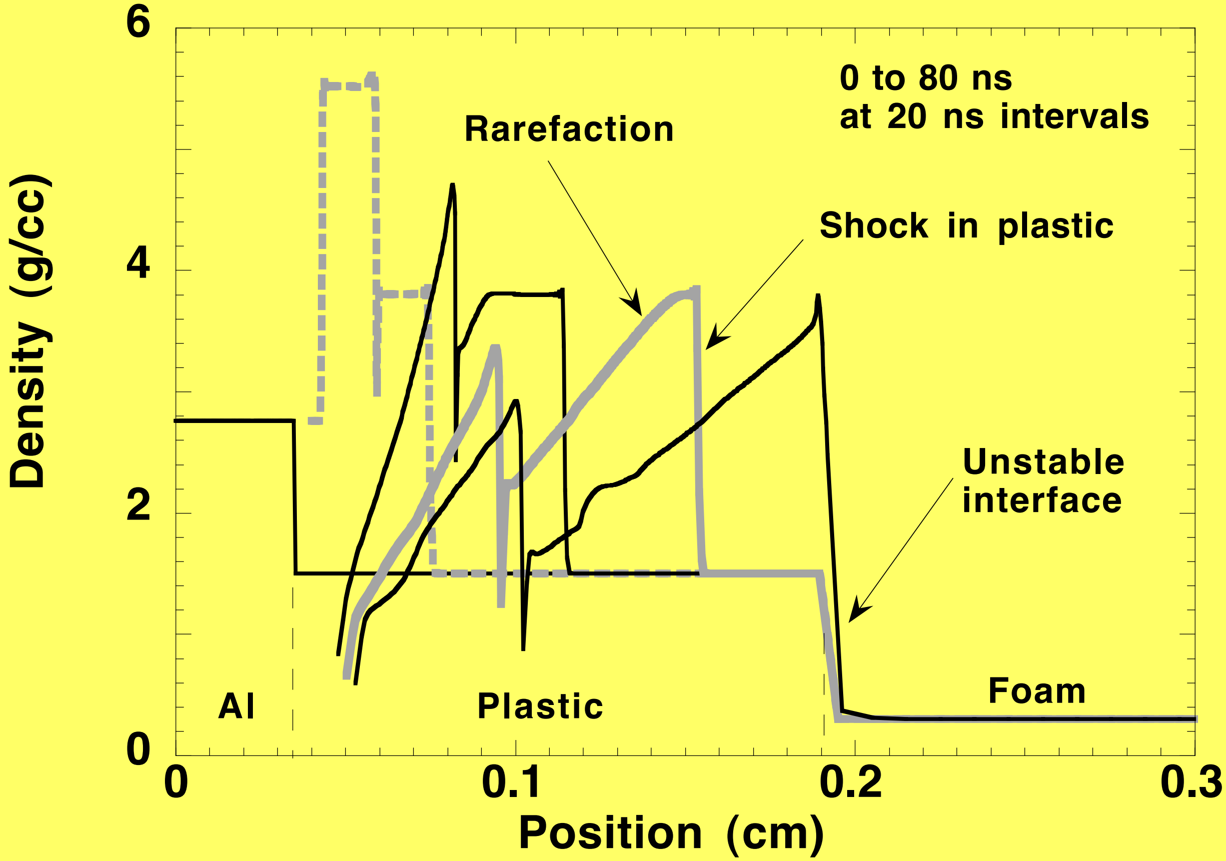
$$t = \frac{D_1}{\left| u''_{RS} \right|}$$

How far the shock goes into the impact layer

$$D_4 = u_{FS} t = \frac{u_{FS}}{\left| u''_{RS} \right|} D_1 = \sqrt{\frac{\rho_1}{\rho_4}} D_1$$

For RT experiments, one creates a blast wave

350 μm thick, 21 km/s flyer



Goal: waste none of the deceleration

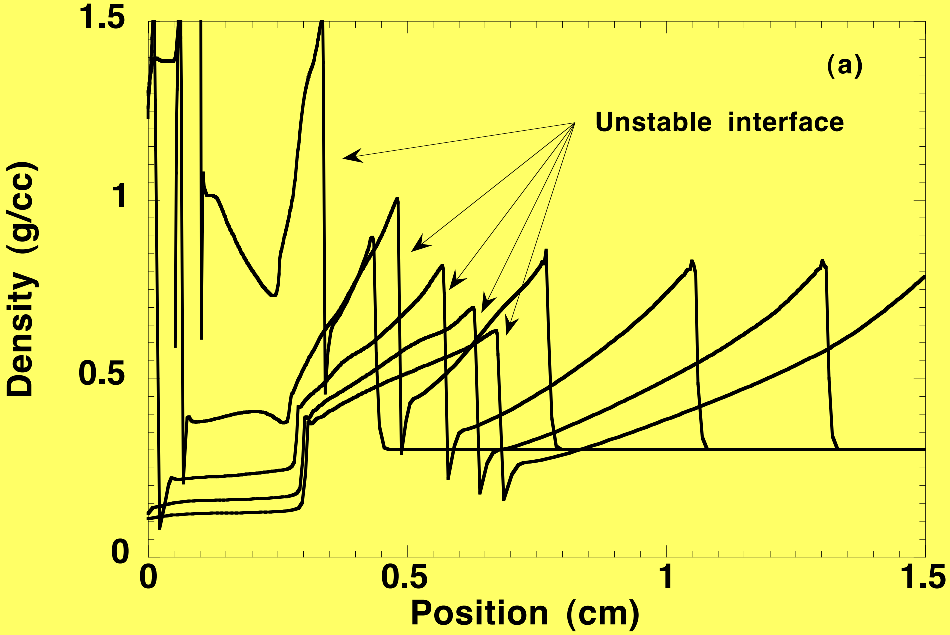
$$t_4 = \frac{D_4}{u_{FS}} = \frac{D_4}{u_F}\frac{2(1+\sqrt{\rho_4/\rho_1})}{\gamma+1}$$

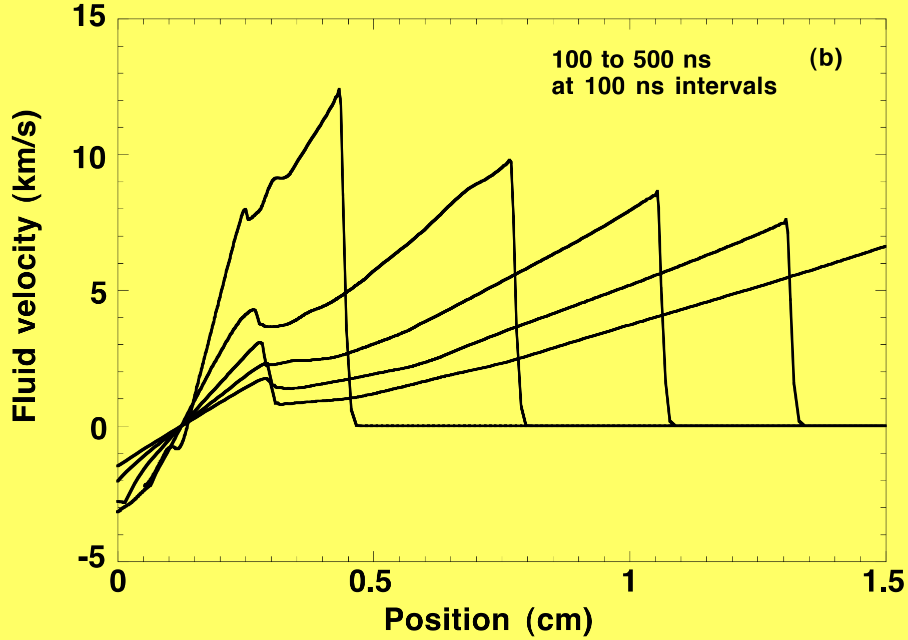
$$t_1 = \frac{D_1}{\left|u''_{RS}\right|} + \frac{\gamma-1}{\gamma+1}\frac{D_1}{c_2} + \frac{\gamma-1}{\gamma+1}\frac{D_4}{c_3}$$

$t_4 = t_1$ so

$$\frac{D_4}{D_1} = \sqrt{\frac{\rho_1}{\rho_4}\frac{(1+\sqrt{(\gamma-1)/2\gamma})}{(1-\sqrt{(\gamma-1)/2\gamma})}}$$

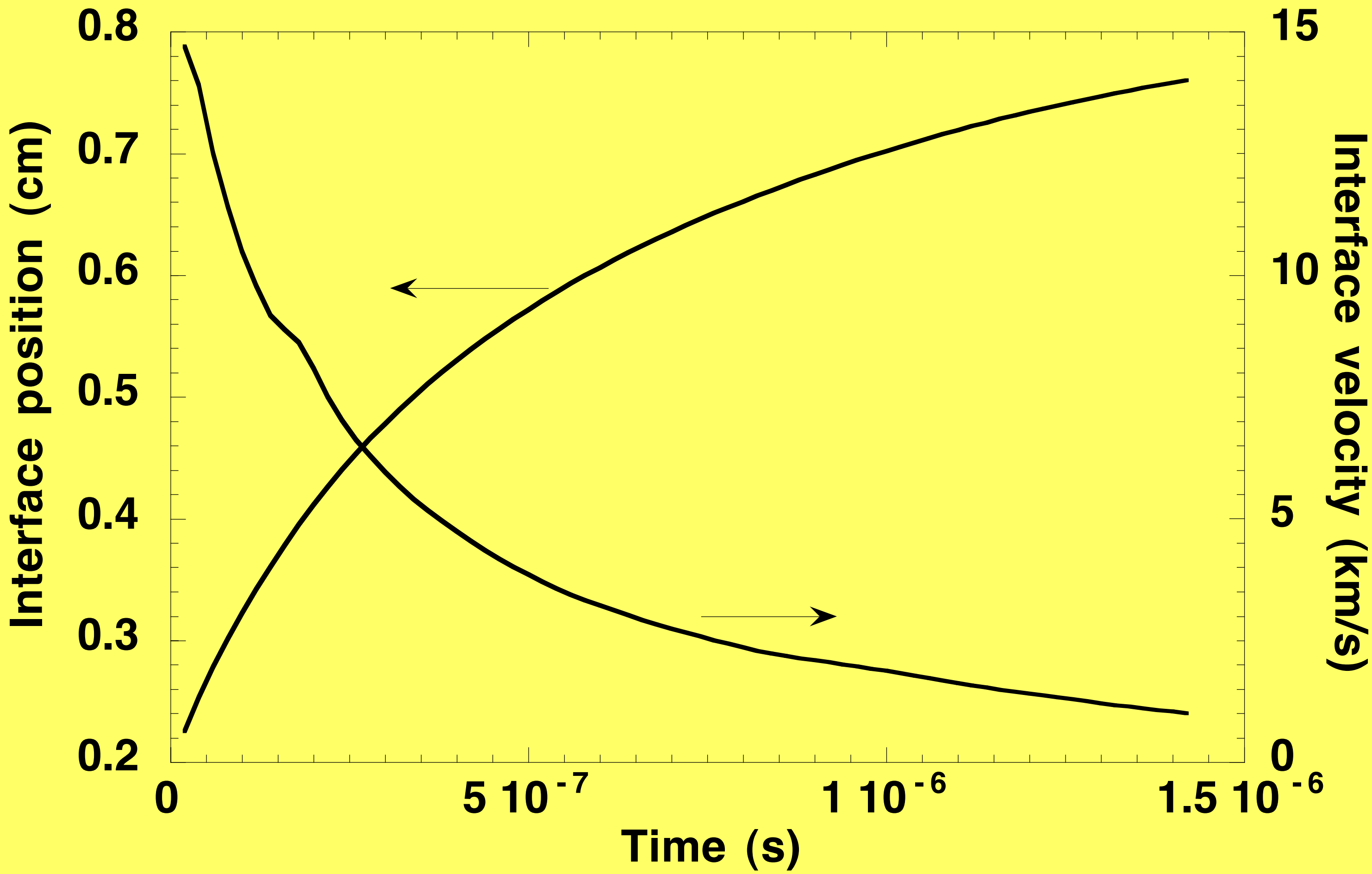
The unstable interface moves several mm





This graph shows the interface behavior

- **The linear growth exponent is ~ 30 by 1.5 *μ*sec**



Richtmyer-Meshkov experiments are harder

Goal: maximum steady post-shock motion of interface

Means: make rarefactions in flyer and impact layer meet at contact surface

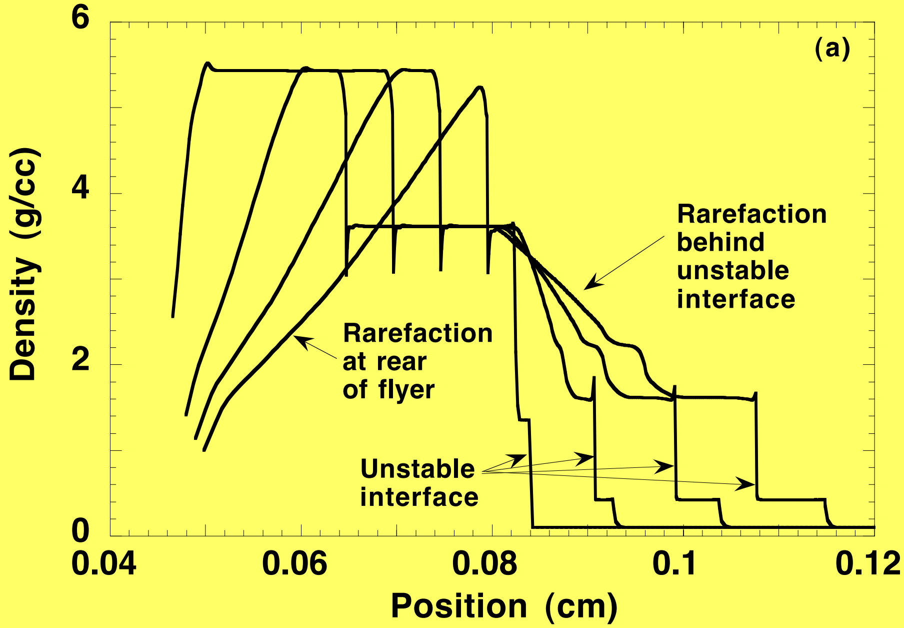
$$t_1 = \frac{D_1}{\left|u''_{RS}\right|} + \frac{\gamma - 1}{\gamma + 1}\frac{D_1}{c_2} = \frac{D_1}{u_F}\frac{(1+\sqrt{\rho_4/\rho_1})}{\sqrt{\rho_4/\rho_1}}\left(\frac{2}{\gamma+1} + \sqrt{\frac{2}{\gamma(\gamma-1)}}\right)$$

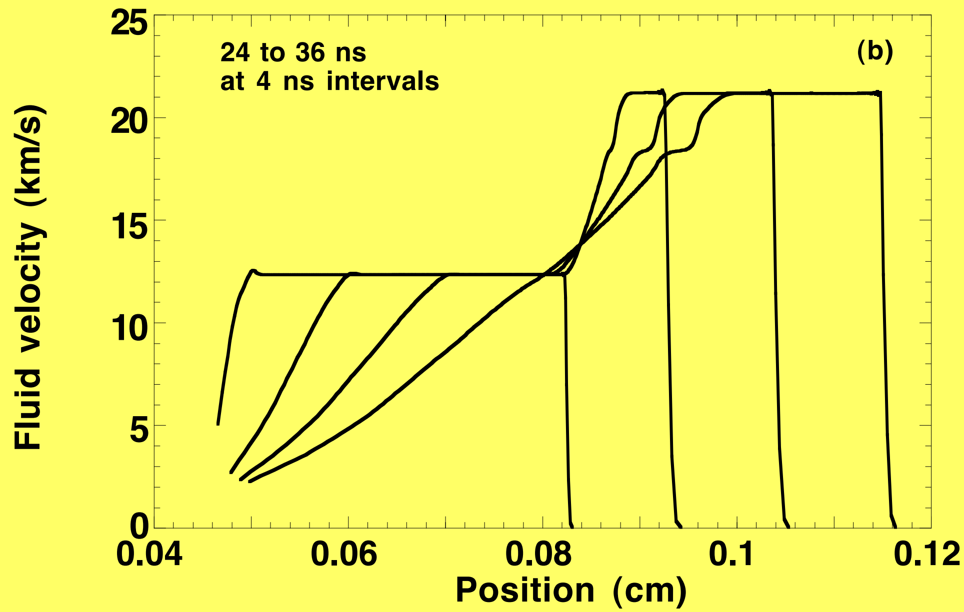
$$t_4 = \frac{D_4}{u_{FS}} + \frac{\gamma - 1}{\gamma + 1}\frac{D_4}{c_3} = \frac{D_4}{u_F}(1+\sqrt{\rho_4/\rho_1})\left\{\frac{2}{\gamma+1} + \sqrt{\frac{2}{\gamma(\gamma-1)}}\right\}$$

$t_4 = t_1$ so

$$D_4/D_1 = \sqrt{\rho_1/\rho_4}$$

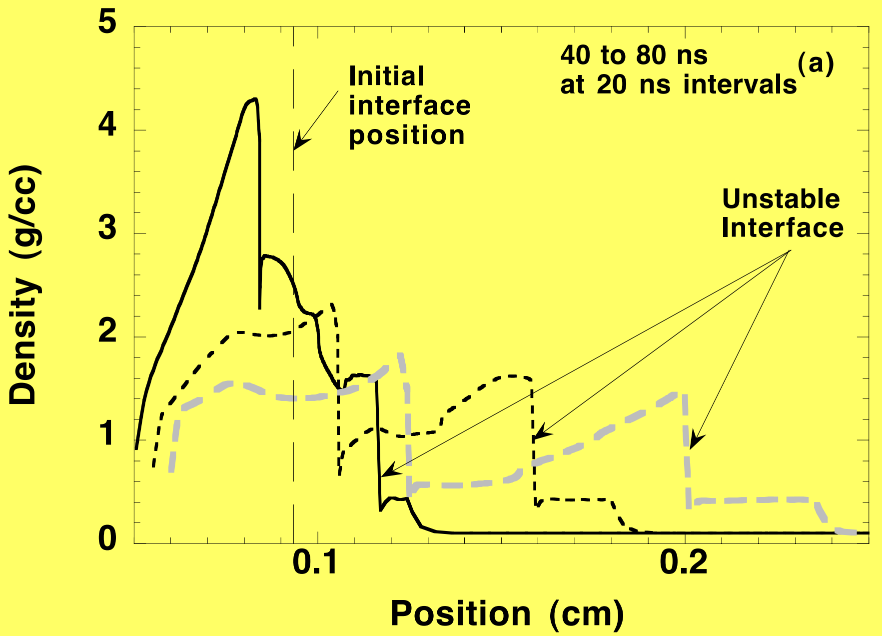
An example where the rarefactions meet

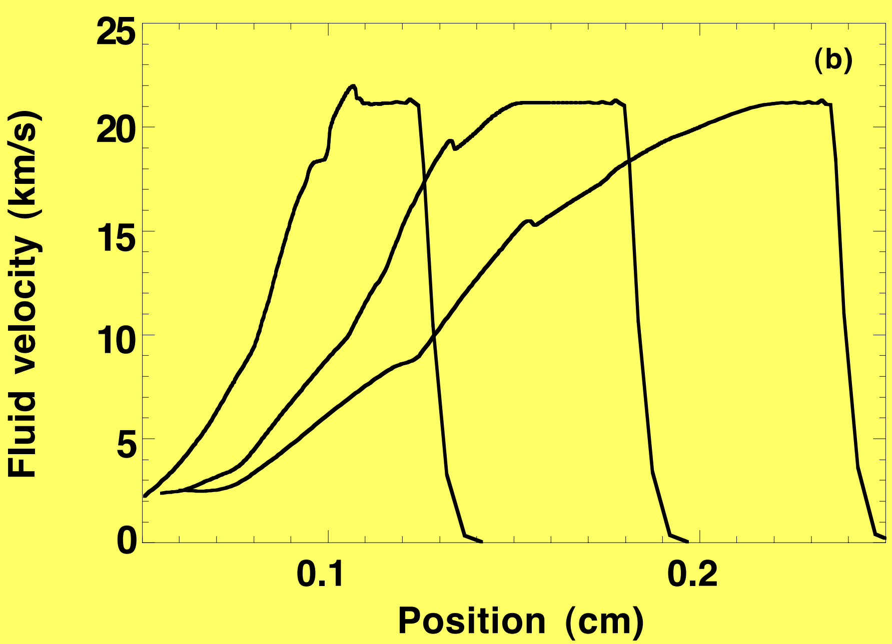




350 μm thick, 21 km/s flyer

The unstable interface moves steadily for ~ 1mm





Conclusions

- **This poster has described design approaches for flyer-driven RT and RM experiments on Z**
- **The advent of the Z backlighter makes these timely**
- **Z should be able to accomplish *very interesting* compressible turbulent mix experiments**

- **Join us the February 23-25, 2002 for the**
- ***4th International Conference on High Energy Density Laboratory Astrophysics***
- **At the University of Michigan in Ann Arbor**