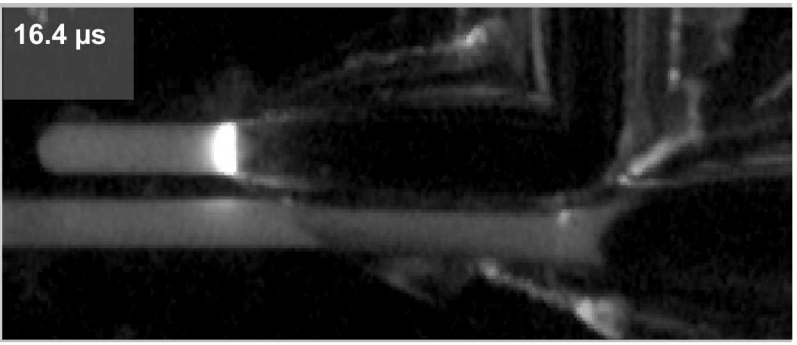
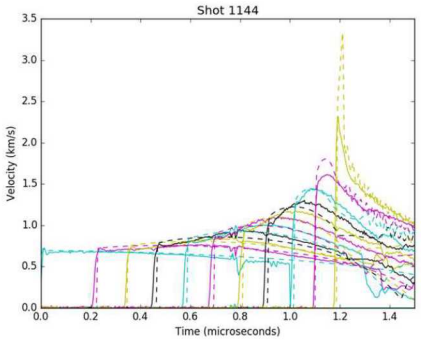
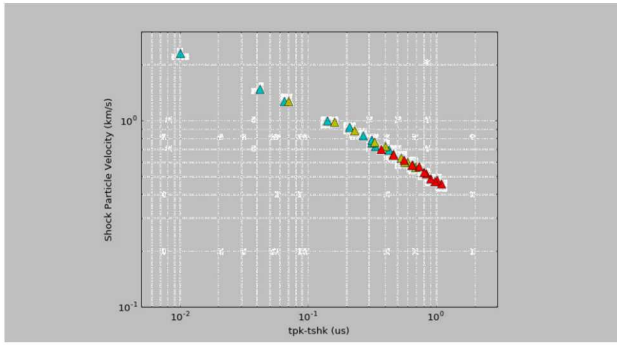
SAND2019-6910C







Evaluation of XHVRB for Capturing Transition to Detonation as Measured with Embedded Gages

Leah W. Tuttle, Jeff W. LaJeunesse, Robert G. Schmitt, Eric N. Harstad

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

What is XHVRB?

Pseudo-Entropy Approach

History Variable Reactive Burn (HVRB):

$$\phi = \frac{1}{\tau}\int_0^t \left(\frac{P - Pi}{P_r}\right)^{Z_r} dt$$

$$\varphi = \int_0^t \left[\frac{P_s - Pi}{P_r}\right]^{n_s} \left[\frac{P}{P_r}\right]^{n_b} \frac{dt}{\tau}$$

De-couple hot spot density from surface regression rate.

Replace hot spot density with pseudo-entropy

$$h(q_s) = \left(\frac{q_s}{c_{vo}} - \frac{p_i}{p_r}\right)^{n_s}$$

$$\frac{q_s}{c_{vo}} = \frac{q_{su}}{c_{vo}} + \frac{\Delta q_s}{c_{vo}}$$

Cumulative pseudo-entropy is defined here.

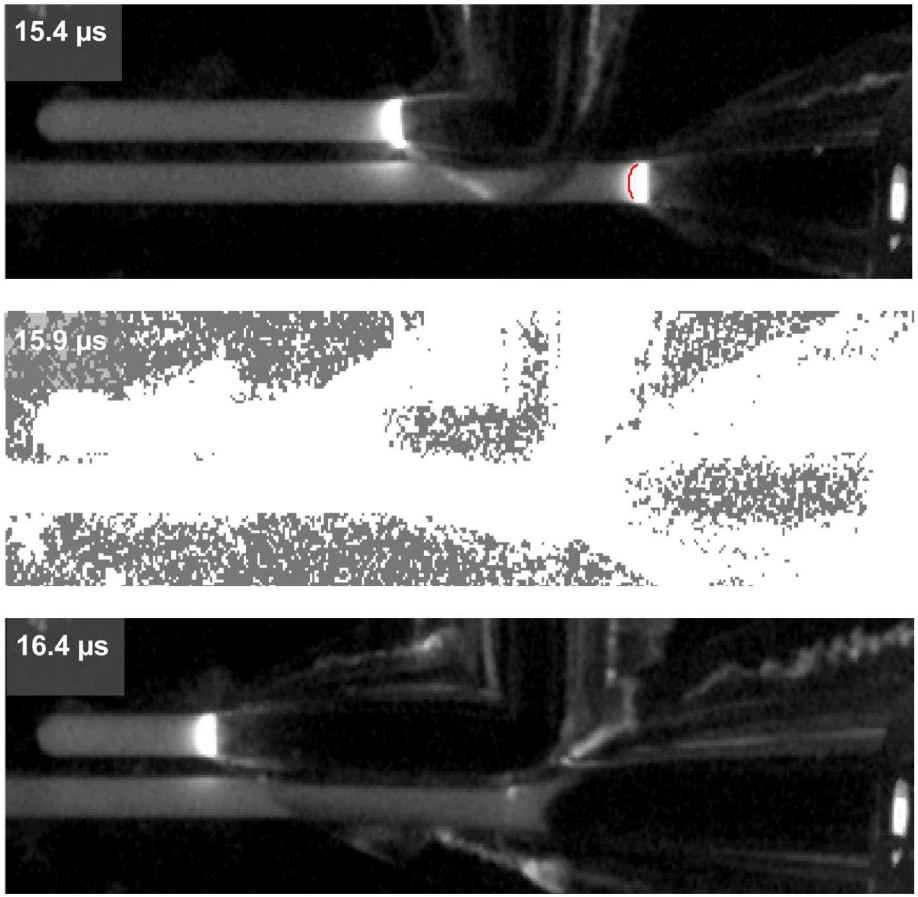
$$\frac{\Delta q_s}{c_{vo}} = \frac{\Delta ps/pr}{\left(\frac{p_{su}}{p_0}\right)^{n_d}}$$

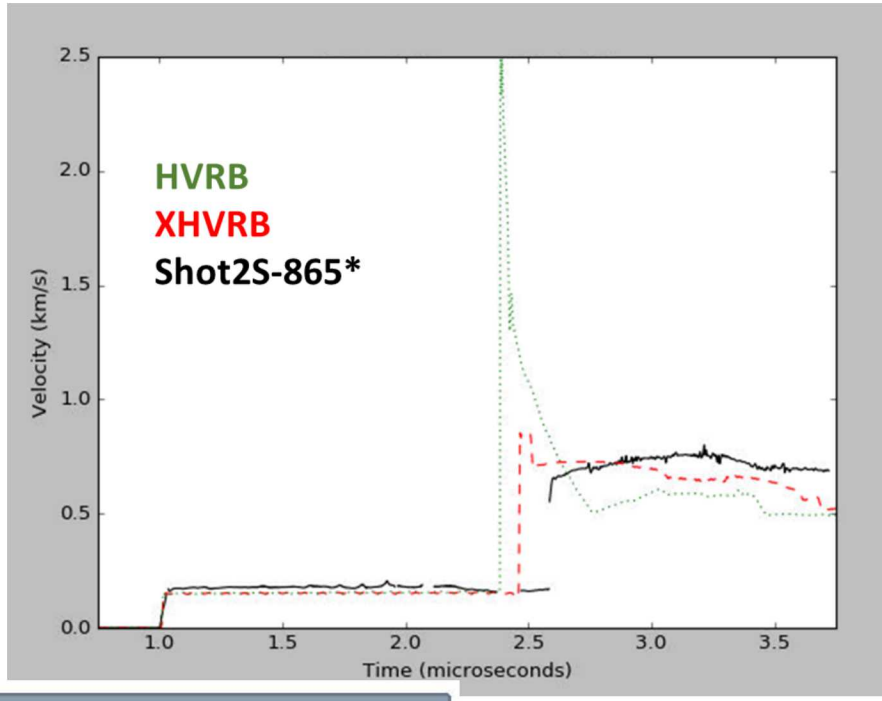
Change in pseudo-entropy is a function of the difference in shock pressures

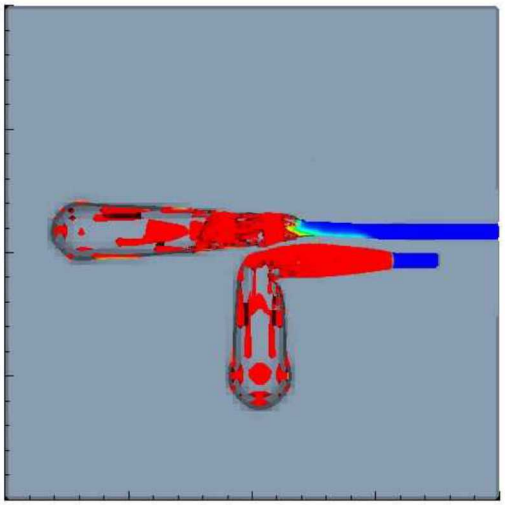
Parameters n_s and n_d can be used to fit model to material data for desensitization.

What capabilities does XHVRB offer?

Desensitization

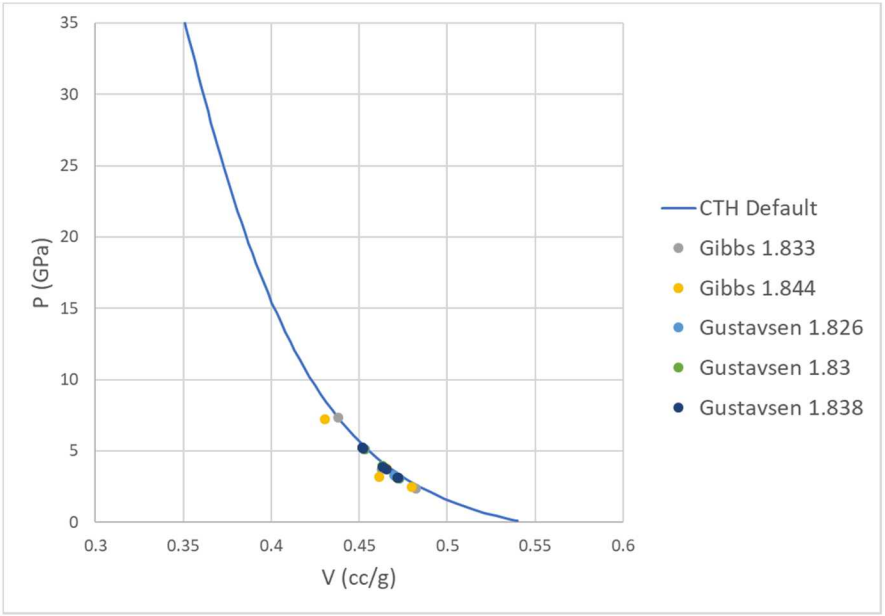


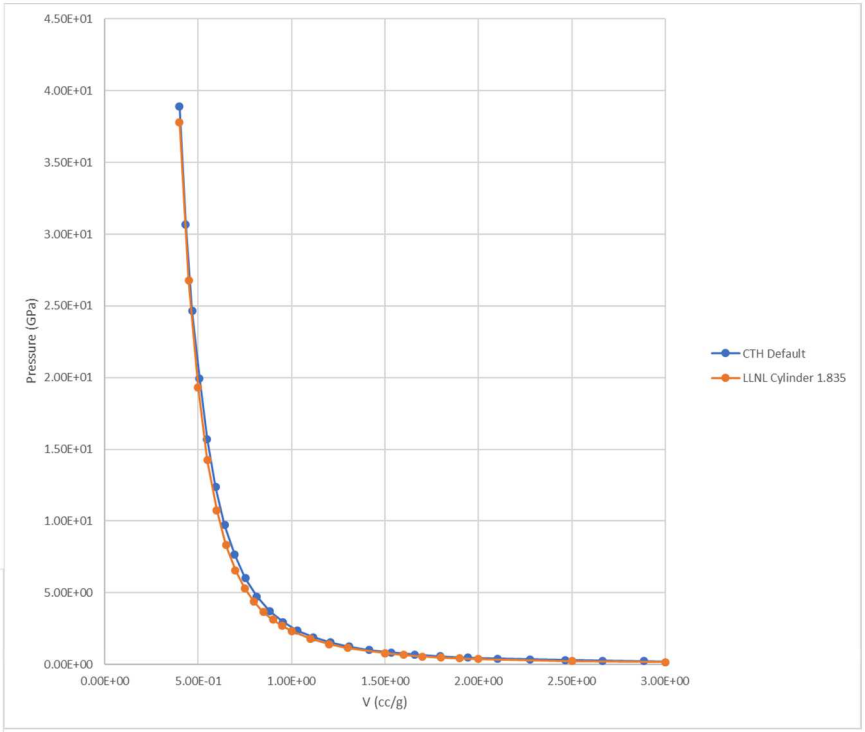


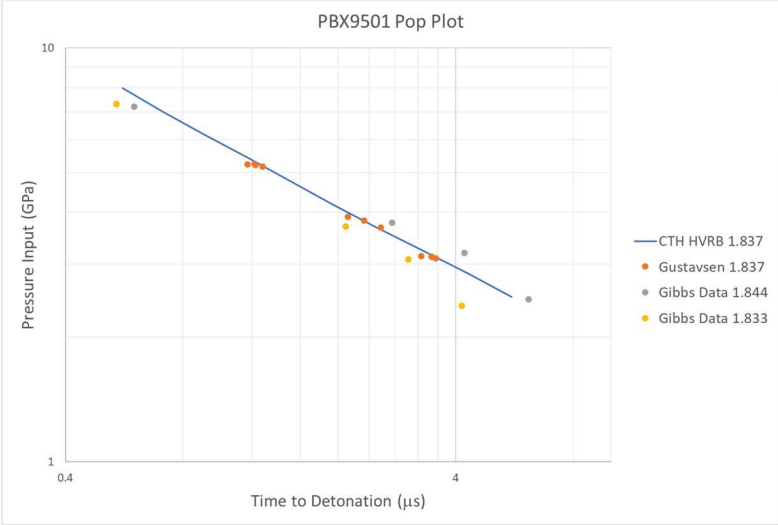


[2]

How have we fit HVRB in the past?



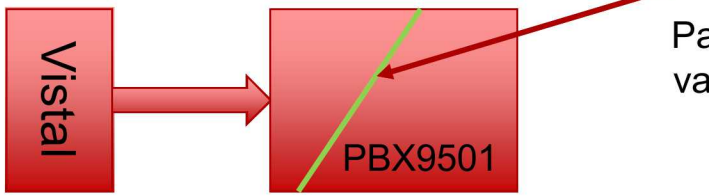




Fit unreacted EOS to hugoniot data, fit the expansion to cylinder data, and fit the reactive flow model to pop plot data. Relatively simple, not a lot of data needed to run!

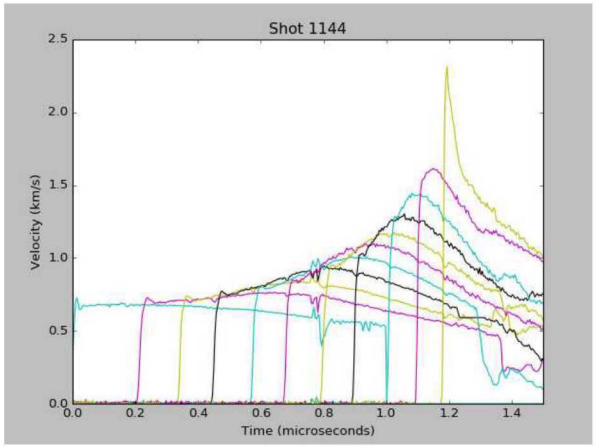
[3,4]

But we now have a more rigorous test: embedded gage data

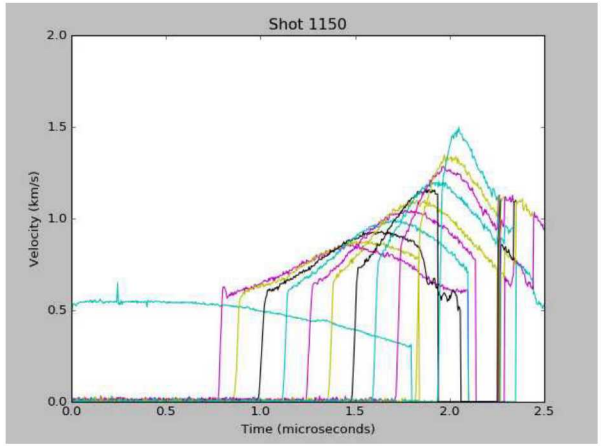


Embedded Gage Package puts gages at varying depths into the explosive

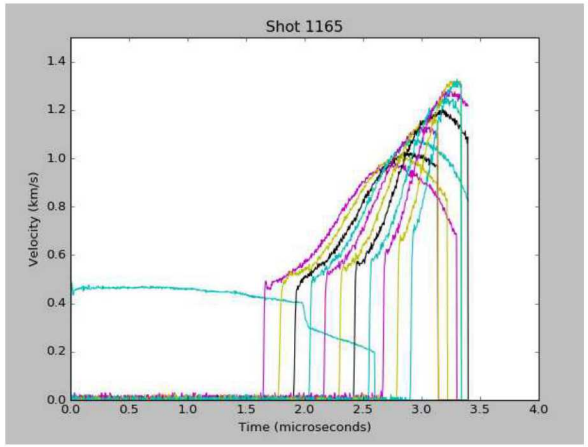
Shot 1144



Shot 1150



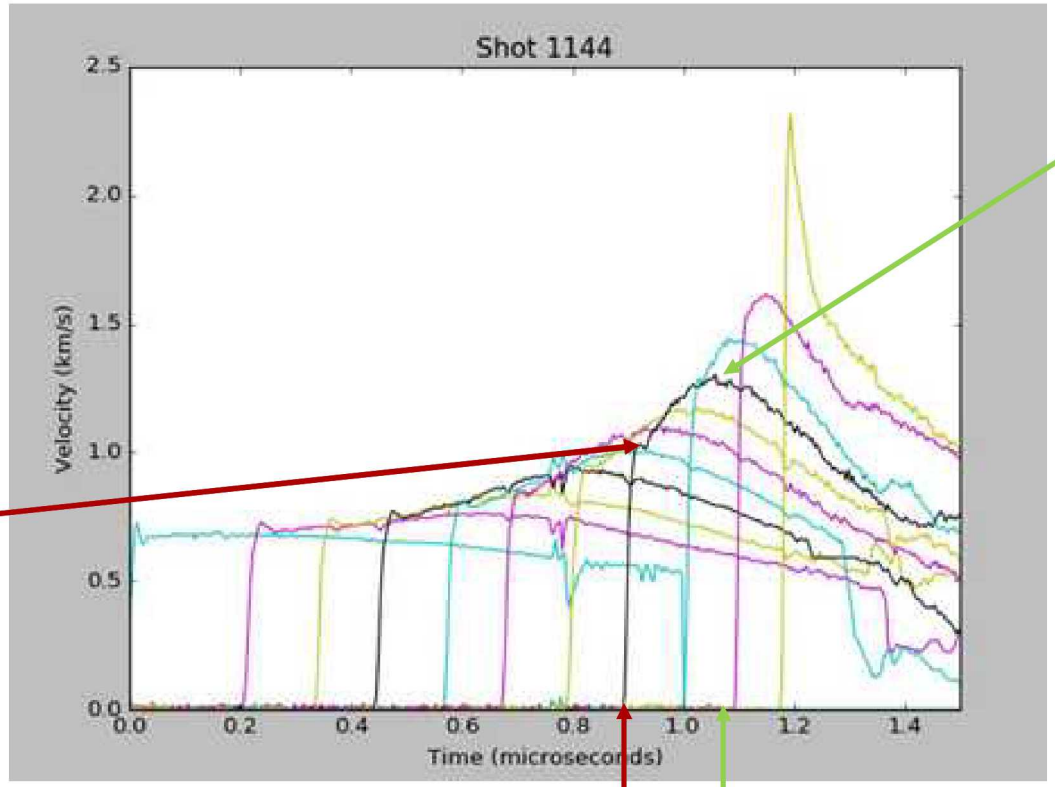
Shot 1165



This study included 20 shots, I chose three that had distinct impact conditions, but the same impact material and the same density of PBX9501.

[2]

New Metrics



Magnitude of peak particle velocity

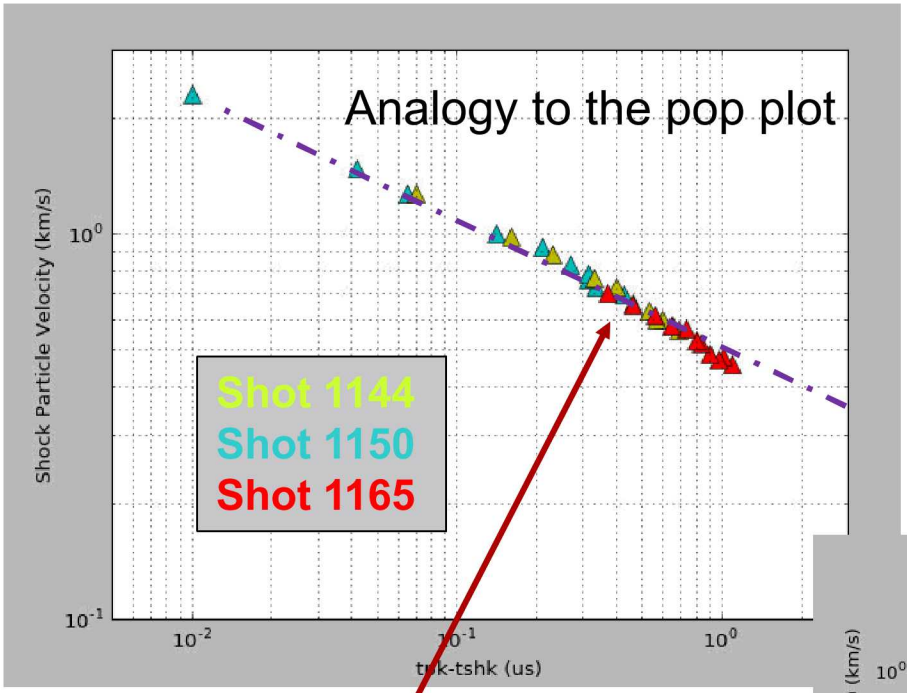
Magnitude of initial particle velocity

Time of arrival of initial shock

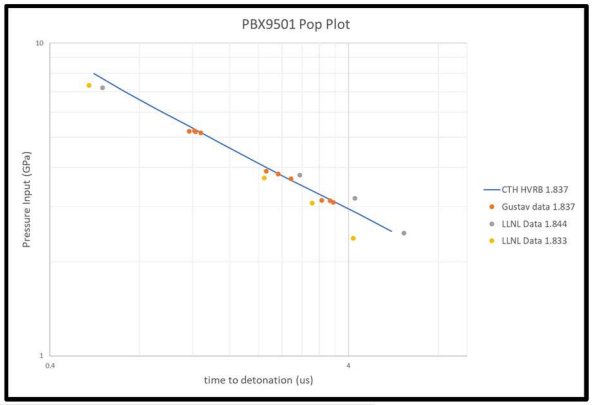
Time of peak particle velocity

We can record these metrics from test and simulations and make quantitative comparisons.

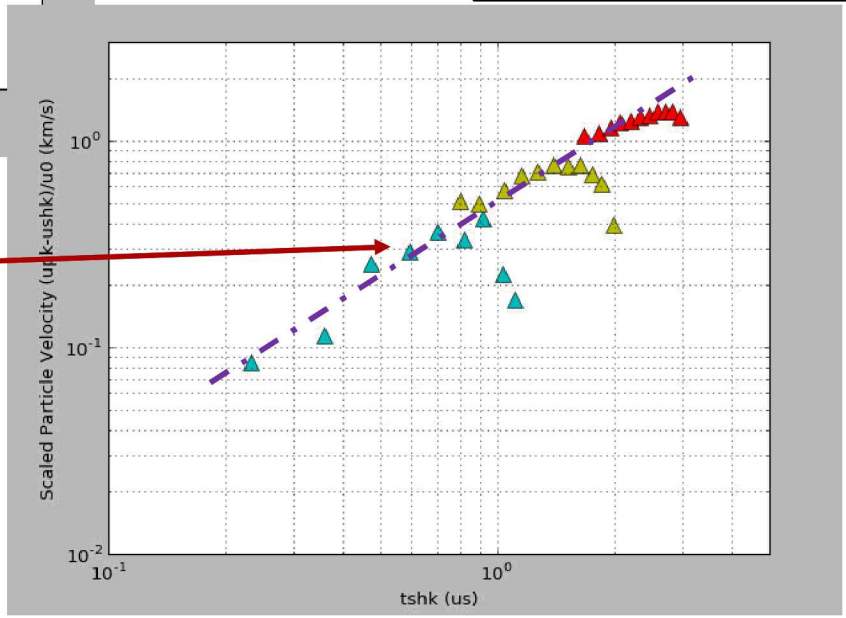
Let's get Quantitative!



We can also compare our traditional metric – the pop plot!



We can compare our simulation results to these data to make a quantitative metric

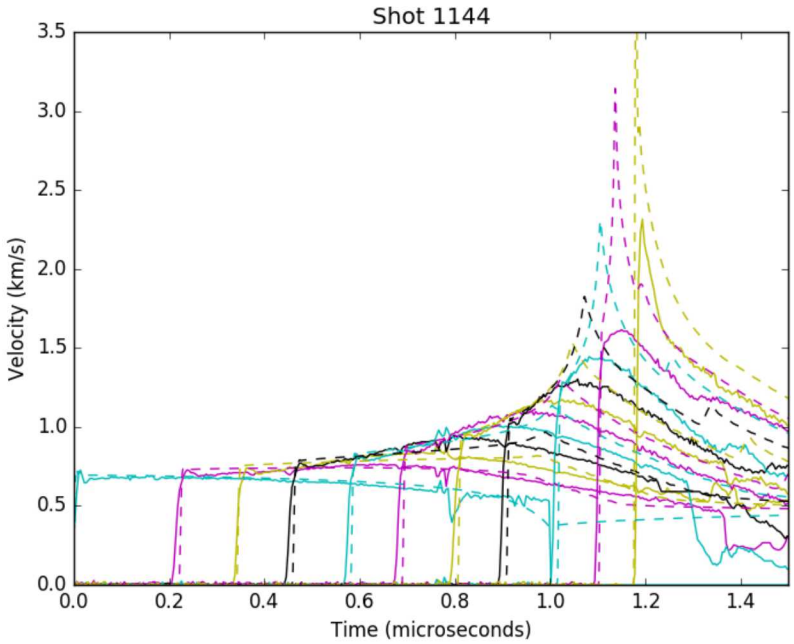


[6]

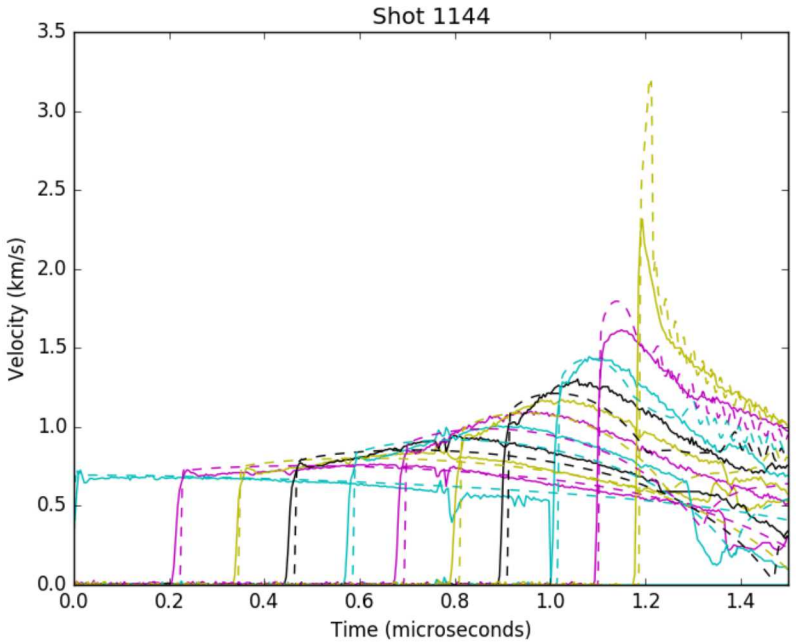
Comparisons: Shot 1144

Embedded tracers compared to gages

HVRB



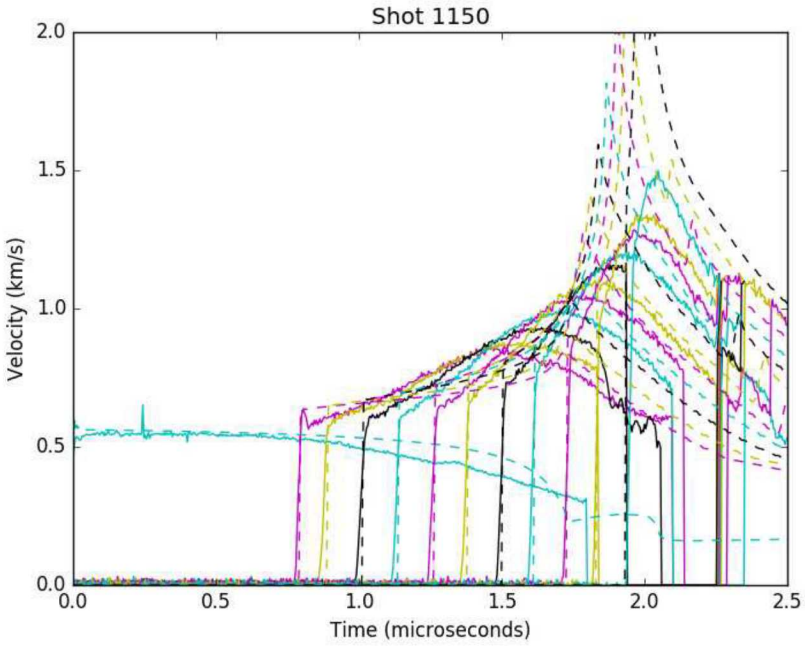
XHVRB



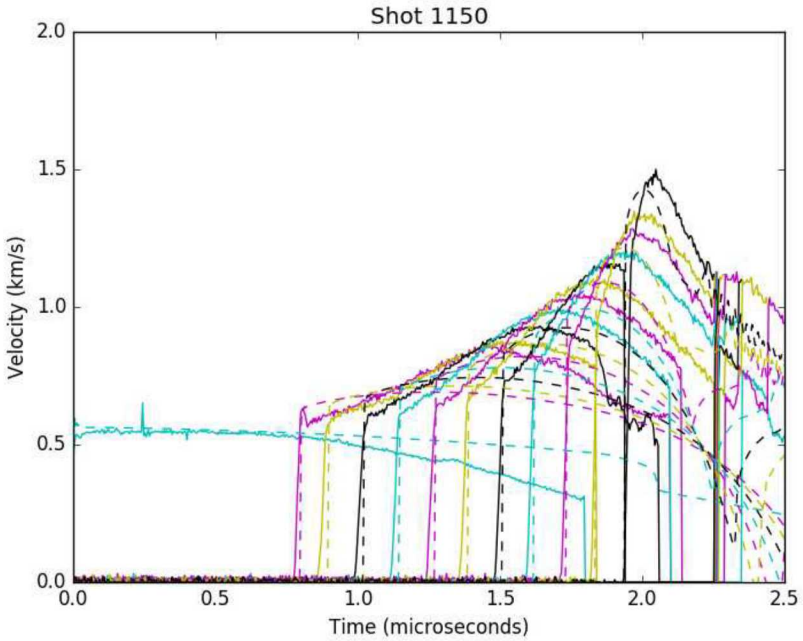
Comparisons: Shot 1150

Embedded tracers compared to gages

HVRB



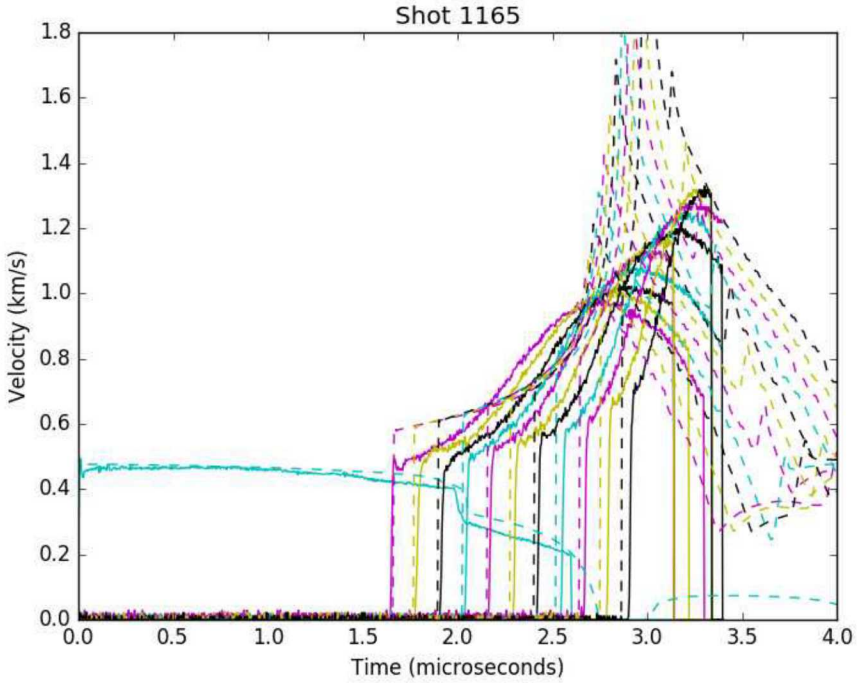
XHVRB



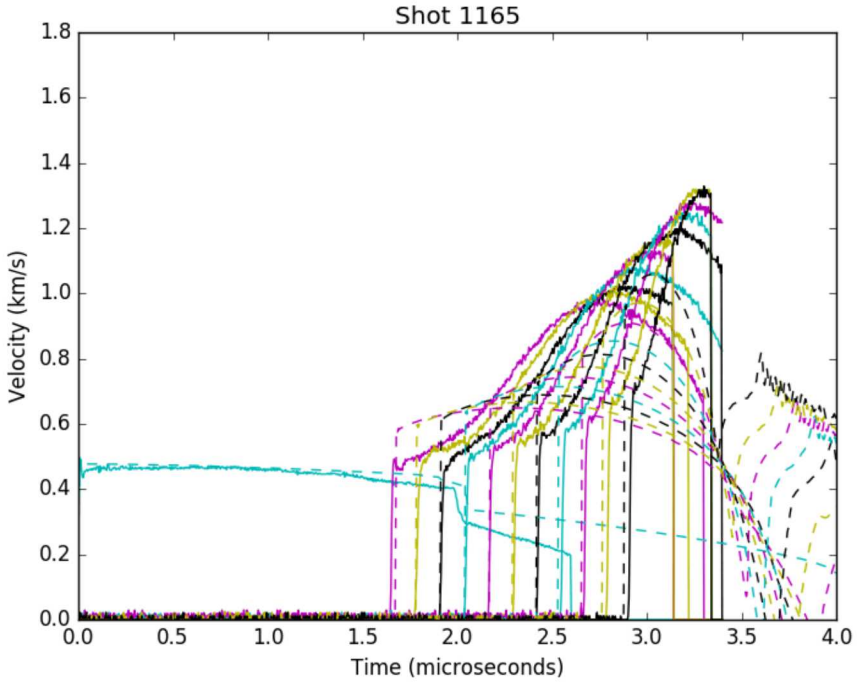
Comparisons: Shot 1165

Embedded tracers compared to gages

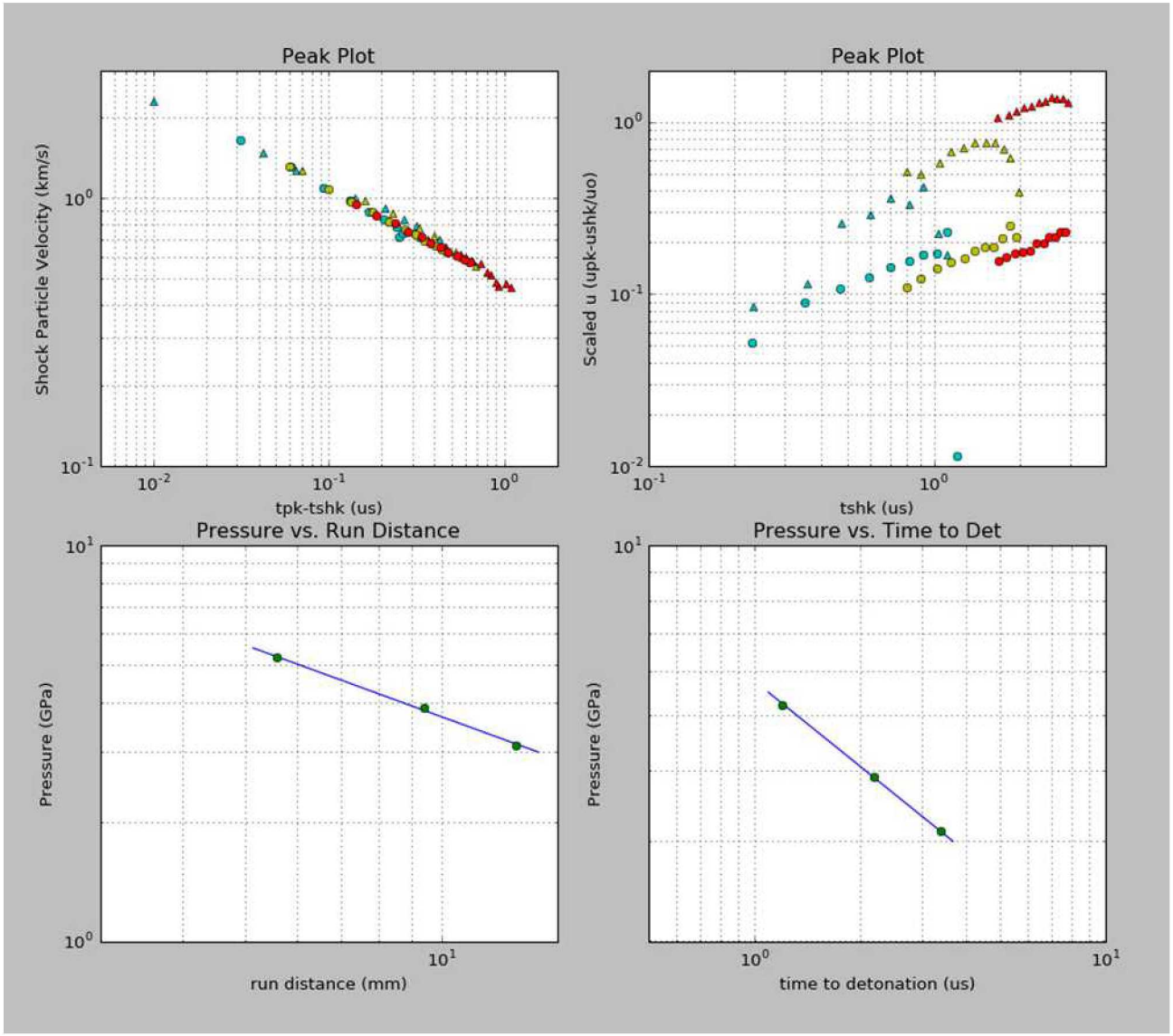
HVRB



XHVRB



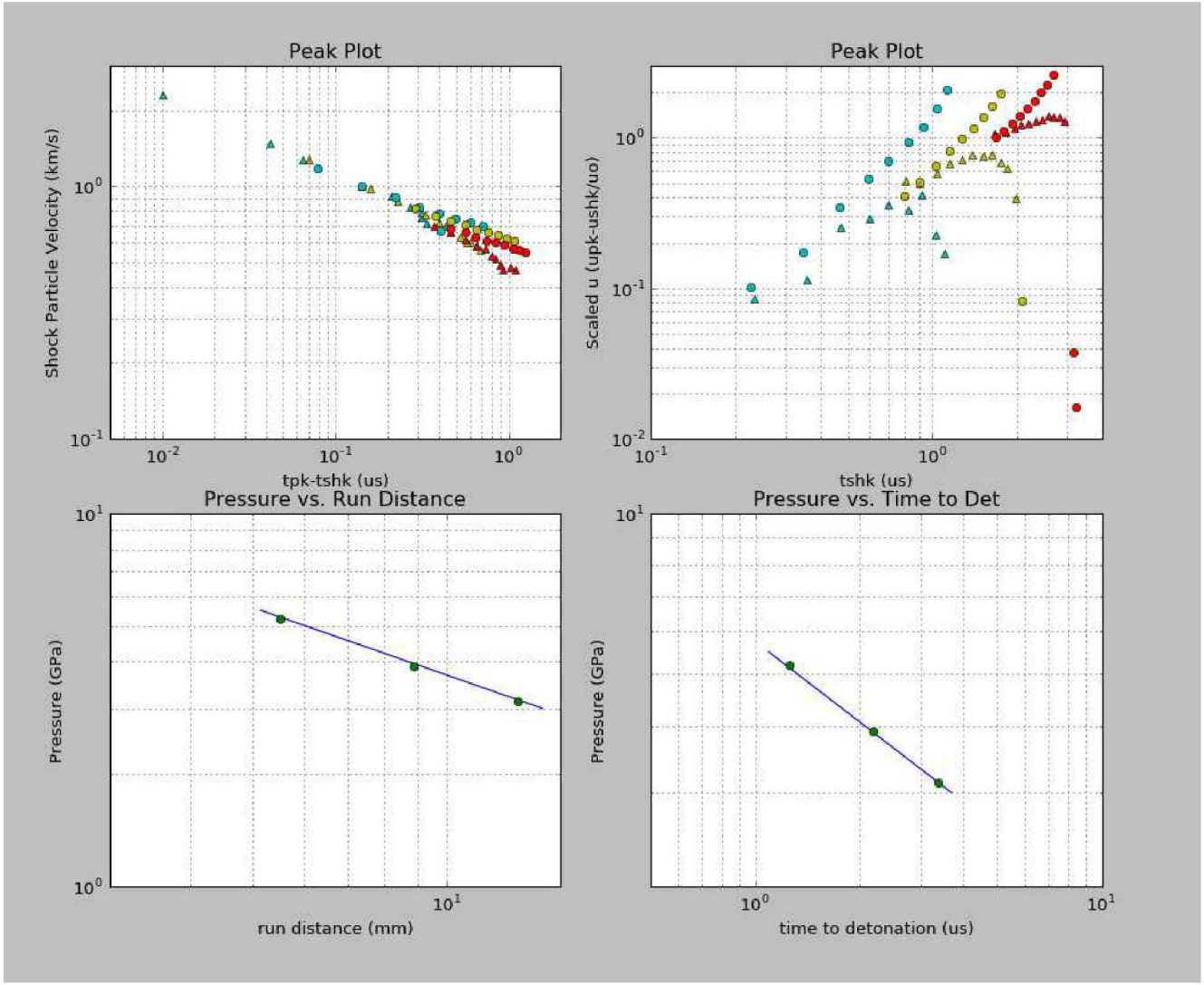
Evaluating the Comparison: XHVRB



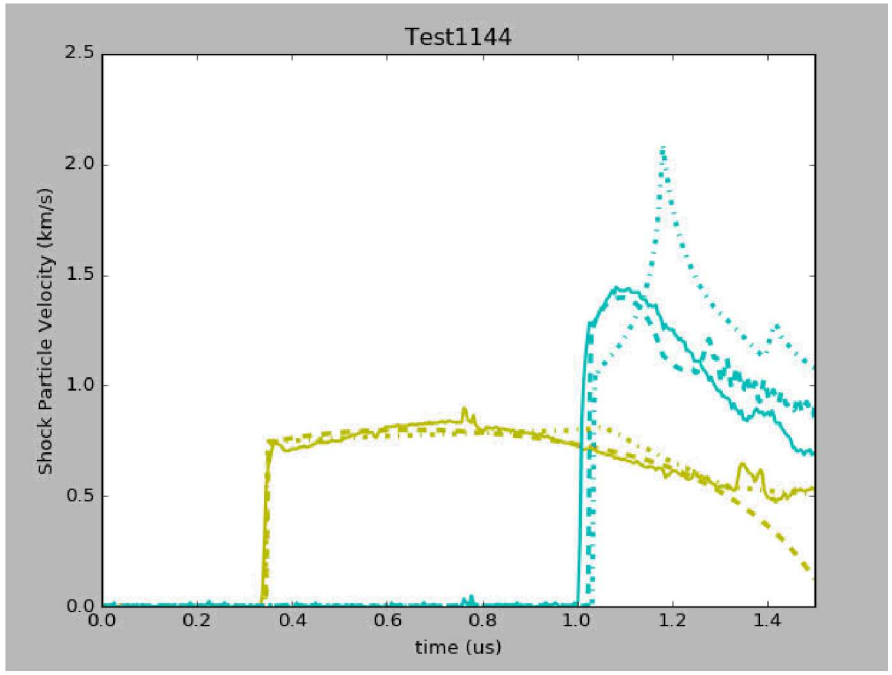
Shot 1144
Shot 1150
Shot 1165

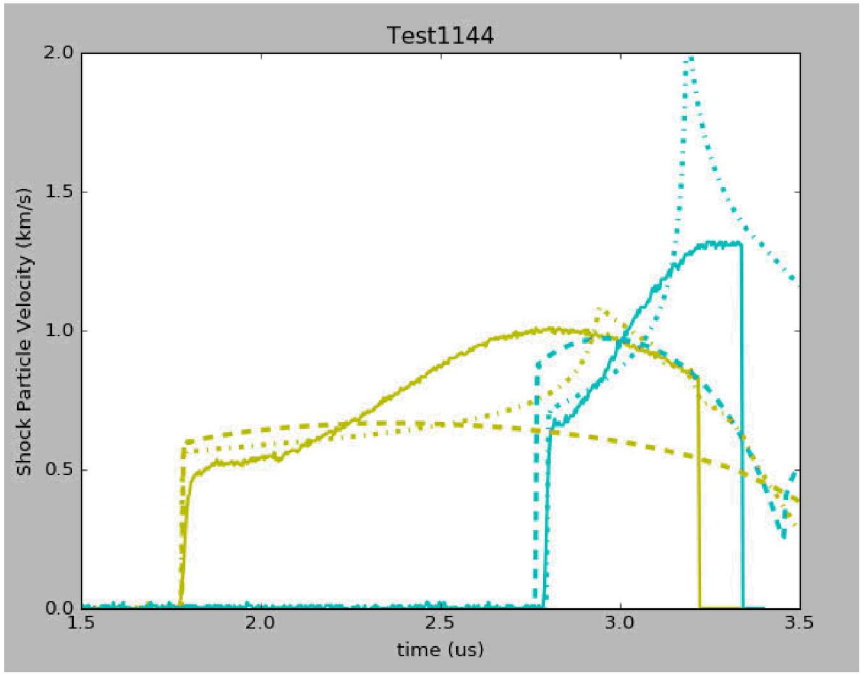
Sim 1144
Sim 1150
Sim 1165

Evaluating the Comparison: HVRB



Digging in: closer look at individual gage comparisons





Reflections

- XHVRB and it's algorithm for capturing shock pressure seem to offer some improvement over HVRB for modeling the details of the build up to detonation that has been revealed by embedded gage data.
  - For stronger initial shock conditions the model does a very good job of mimicking the build up
  - For lower inputs the model does not capture the first "stage" of build up
- A multi-rate approach seems necessary for slow or long transitions based on the shape of the growth shown in test data.

Thanks and References

The authors would like to thank Dave Kittell, Mike Hobbs, Bill Erikson, Kevin Ruggirello, Paul Specht, Ryan Marinis, and Nick Kerschen for valuable input and peer review.

[1] Starkenberg, J., "Shock Pressure and Pseudo-Entrpoic Approaches to Explosive Initiation Modeling", Proceedings of the 15th International Detonation Symposium, pp. 908-916, San Francisco, CA, 2014
[2] Tuttle, et al., "Desensitization in Multi-Dimensional Scenarios", Proceedings of the 16th International Detonation Symposium (in process), Cambridge, MD, July 2018
[3] Gustavsen, et al., "Shock Initiation of New and Aged PBX9501", Proceedings of the 12th International Detonation Symposium, p. 530 July 2002
[4] T. R. Gibbs and A. Popolato, eds., *LASL Explosive Property Data*, University of California, Berkeley, 1980.
[5] Pemberton, S.J.; Sandoval, T.D.; Herrera, T.H.; Echave, J.A.; Maskaly, G.R., Test Report for Equation of State Measurements of PBX-9501, LA-UR-11-04999, 2011
[6] James and Lambourne, "On the systematics of particle velocity histories in the shock-to-detonation transition regime", J. Appl. Phys. 100, 084906 (2006); https://doi.org/10.1063/1.2354416