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Growth to detonation in hexanitrostilbene (HNS)

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Motivation

Why are we interested in run to detonation?

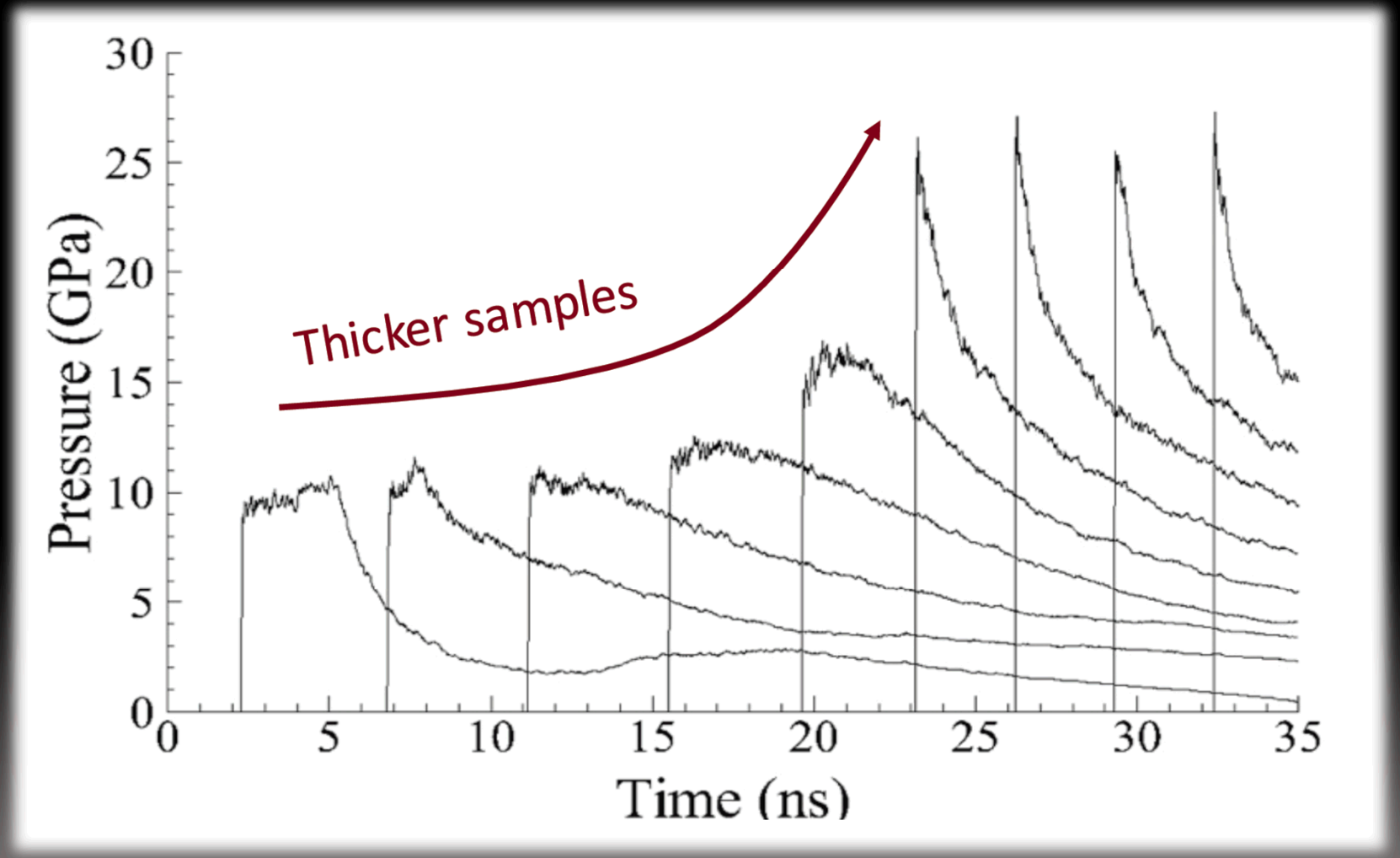
How can we measure the run to detonation in explosives?

What is the value from this data?

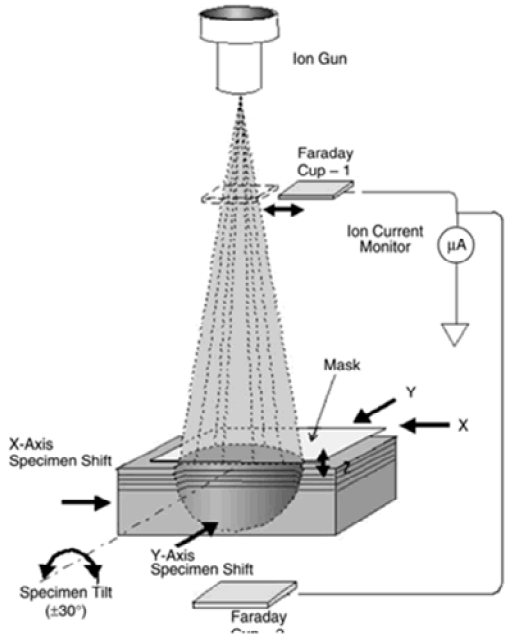
Run to detonation

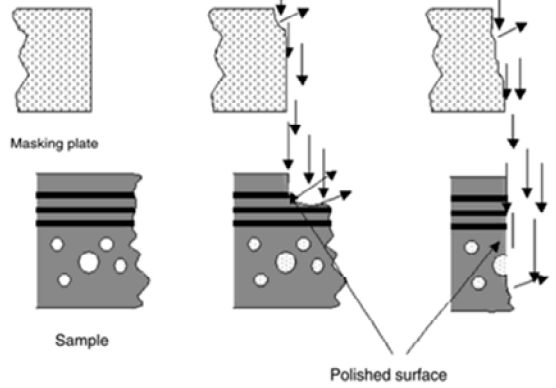
Design parameter

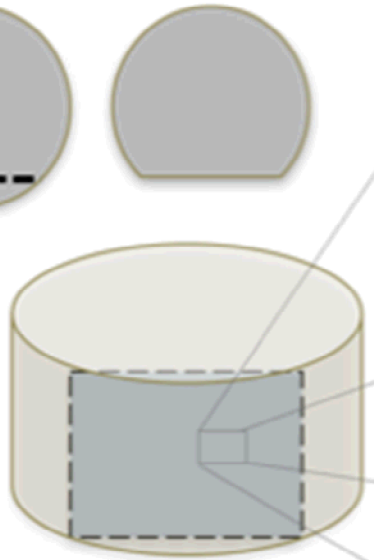
Needed for validation of predictive modeling

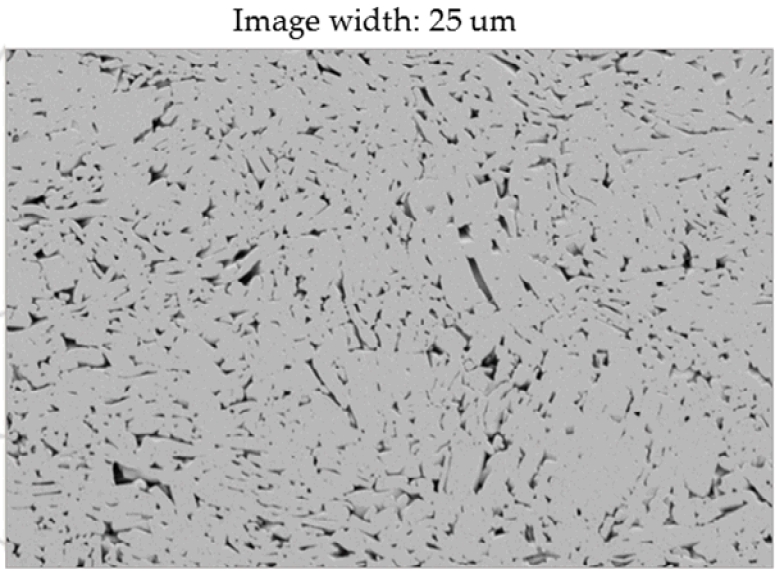


Capturing porosity





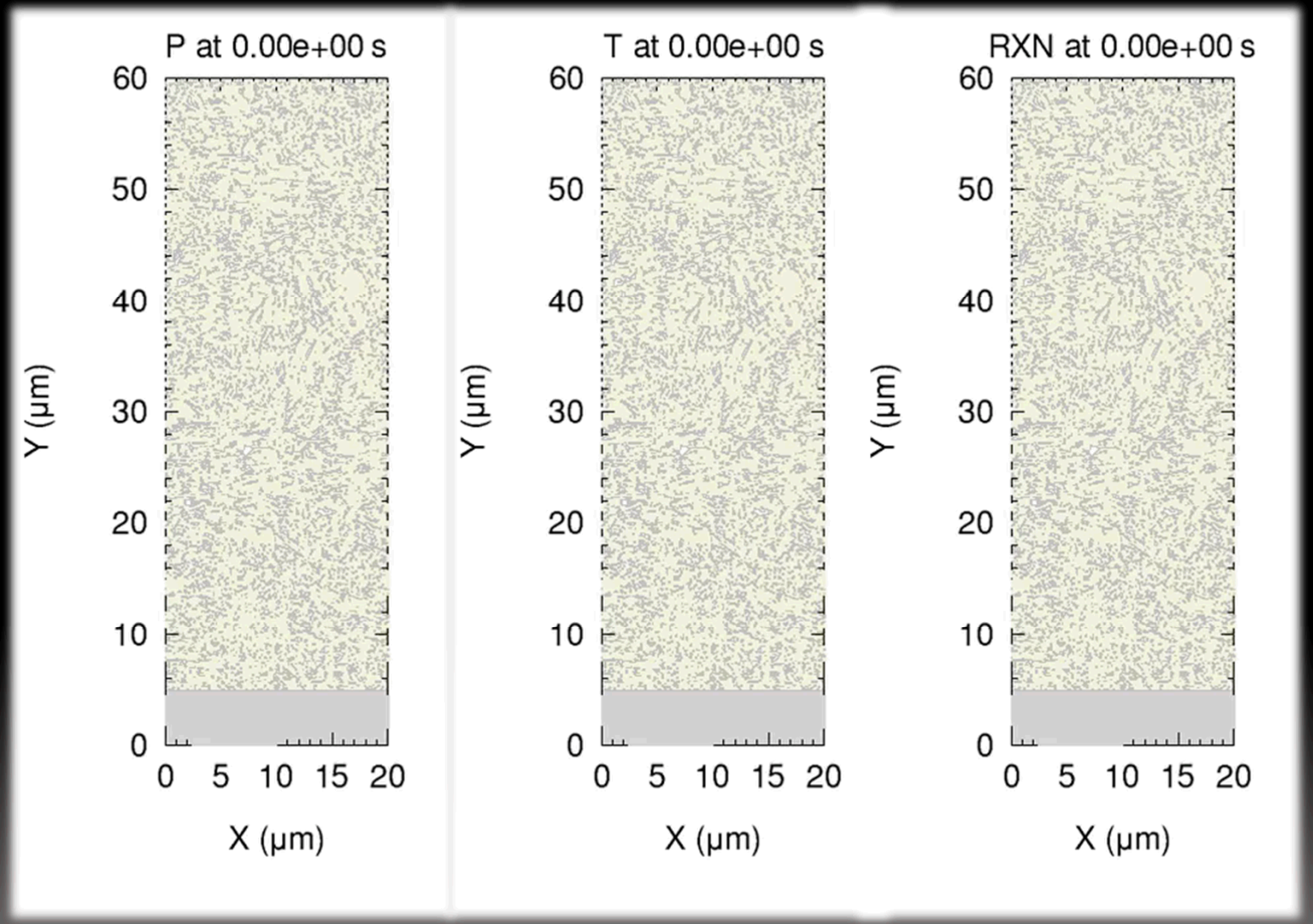




HNS-FP, 90% TMD

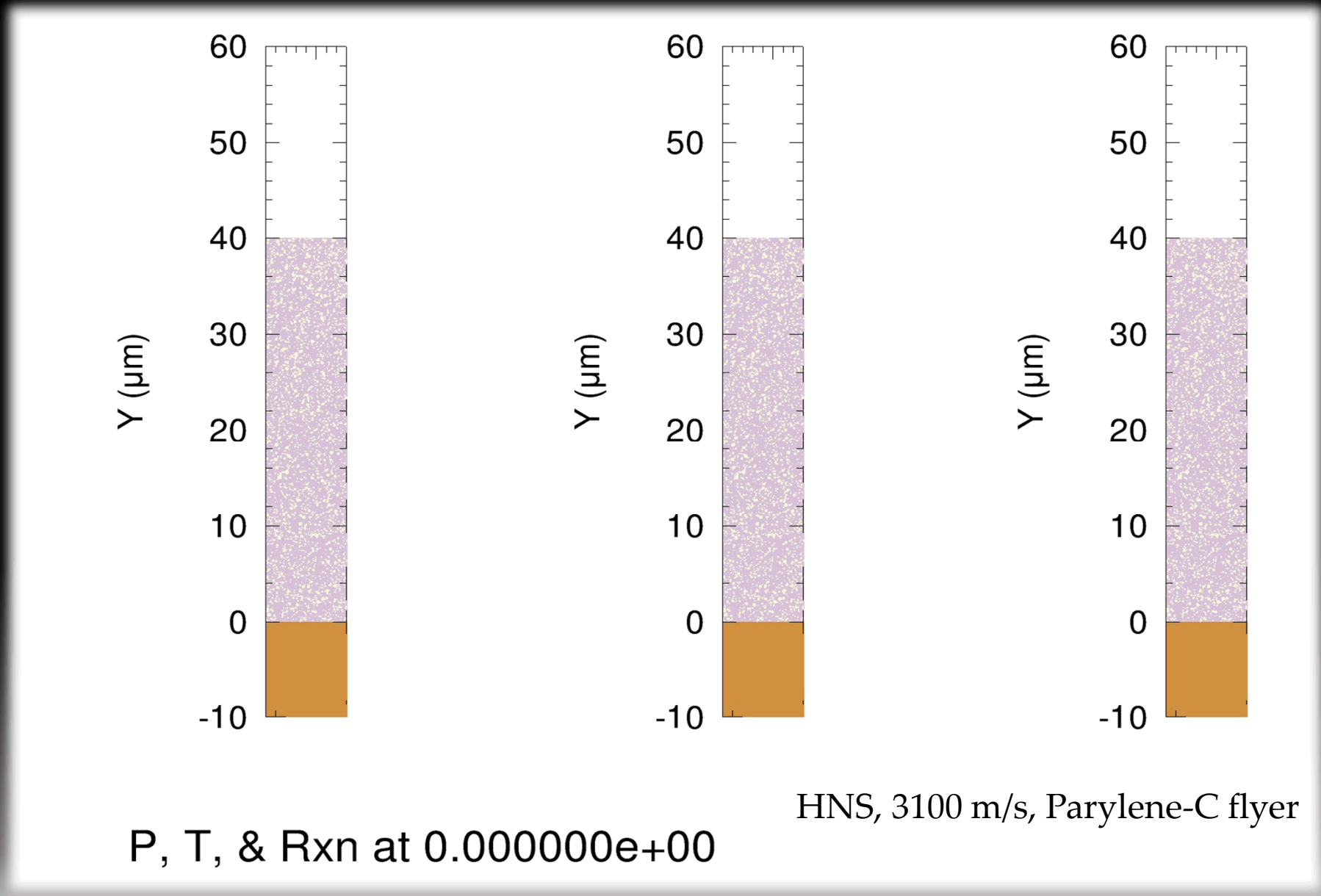
Cross-sectioned pellets, Ar-Ion beam milling technique

Grainscale modeling



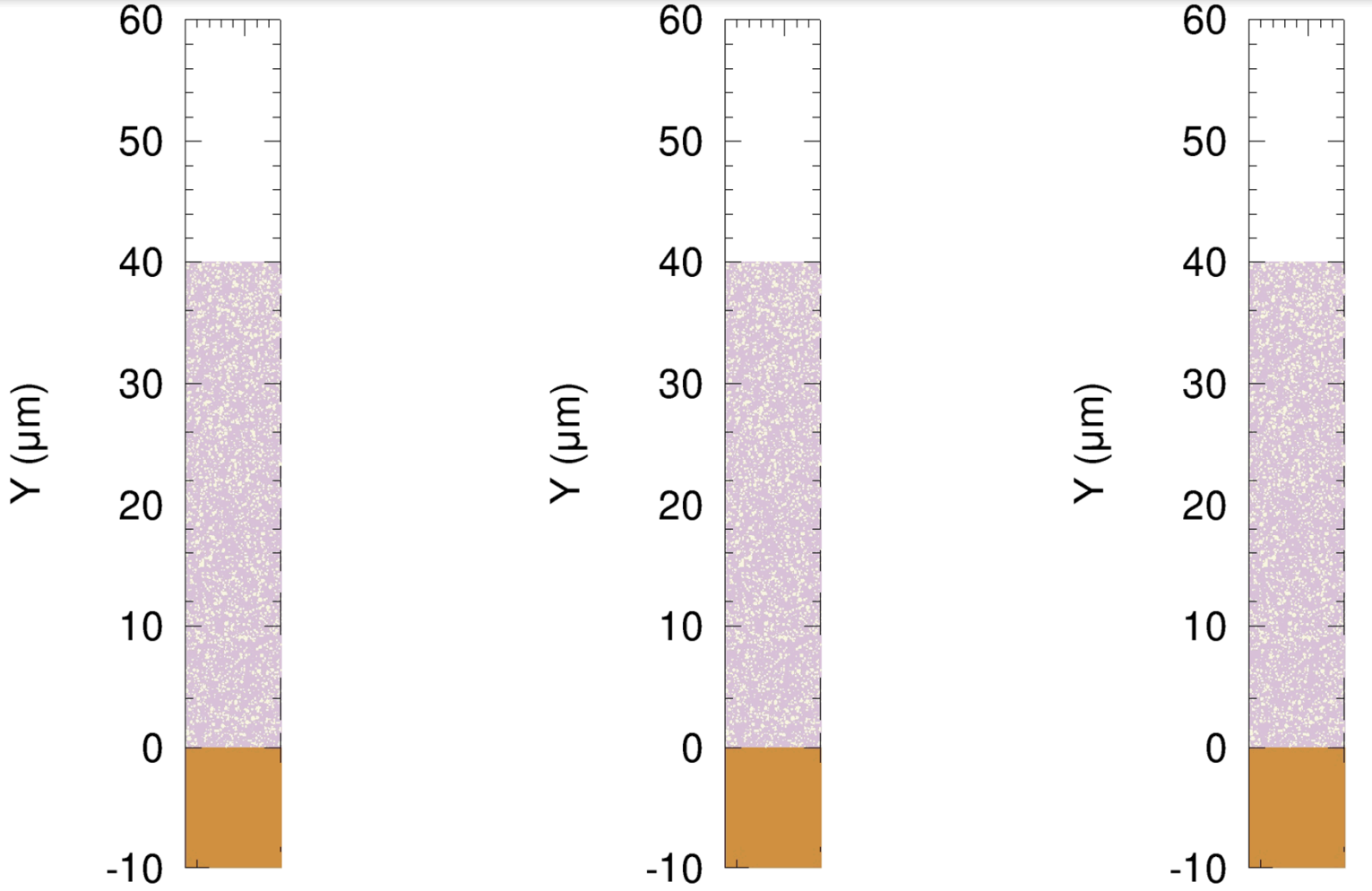
HNS simulations show build up to detonation ~100μm scale

Simulation of un-successful initiation



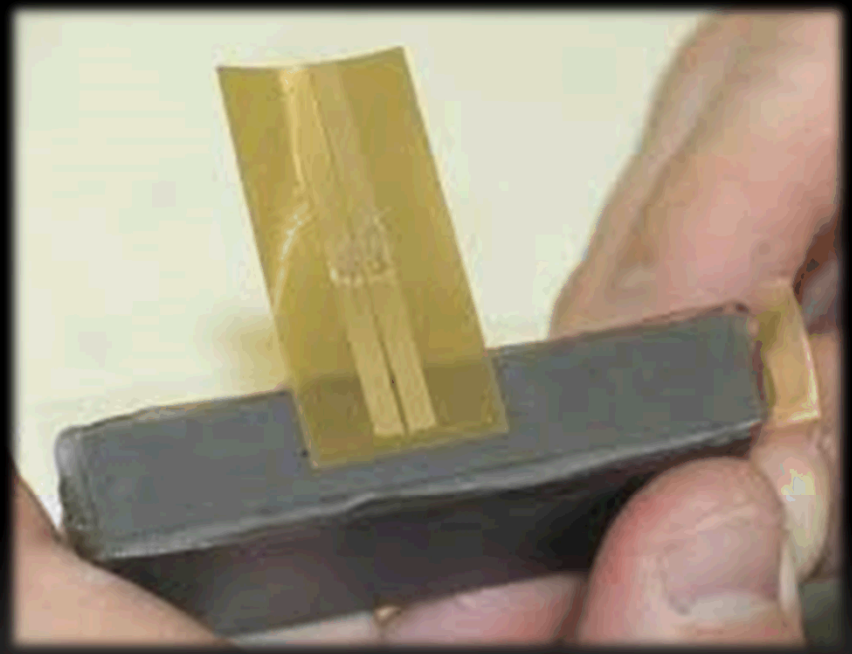
HNS, 3100 m/s, Parylene-C flyer

Simulation of successful initiation



Measurement techniques

- Typical gauges (wedge tests, PVDF, Manganin, etc.)



Lateral Gauge Response in Polymers
Gareth Appleby-Thomas, 2010

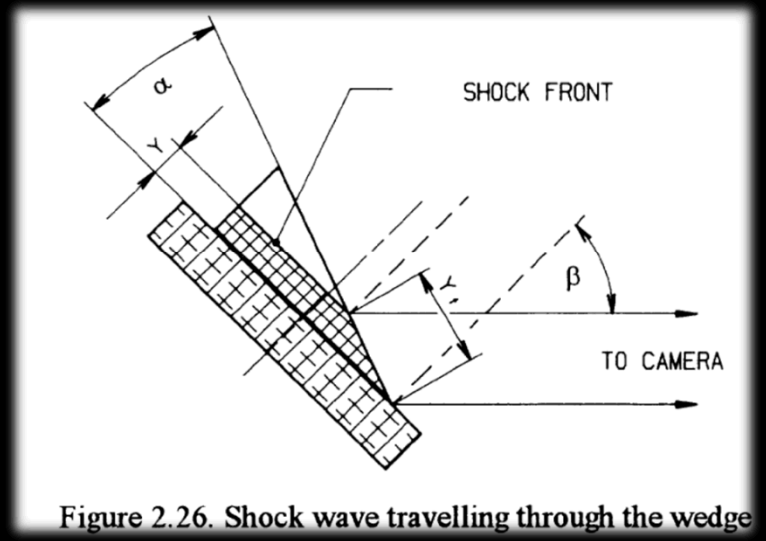


Figure 2.26. Shock wave travelling through the wedge

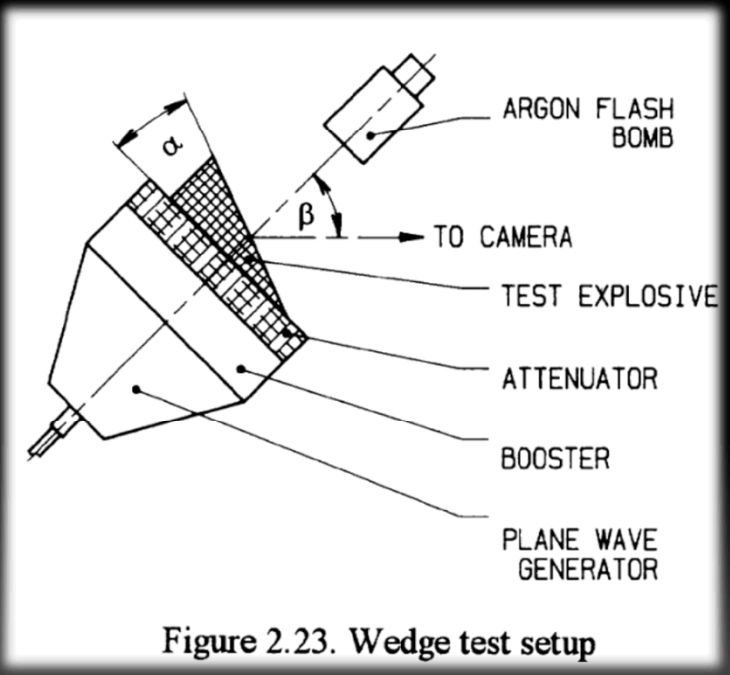
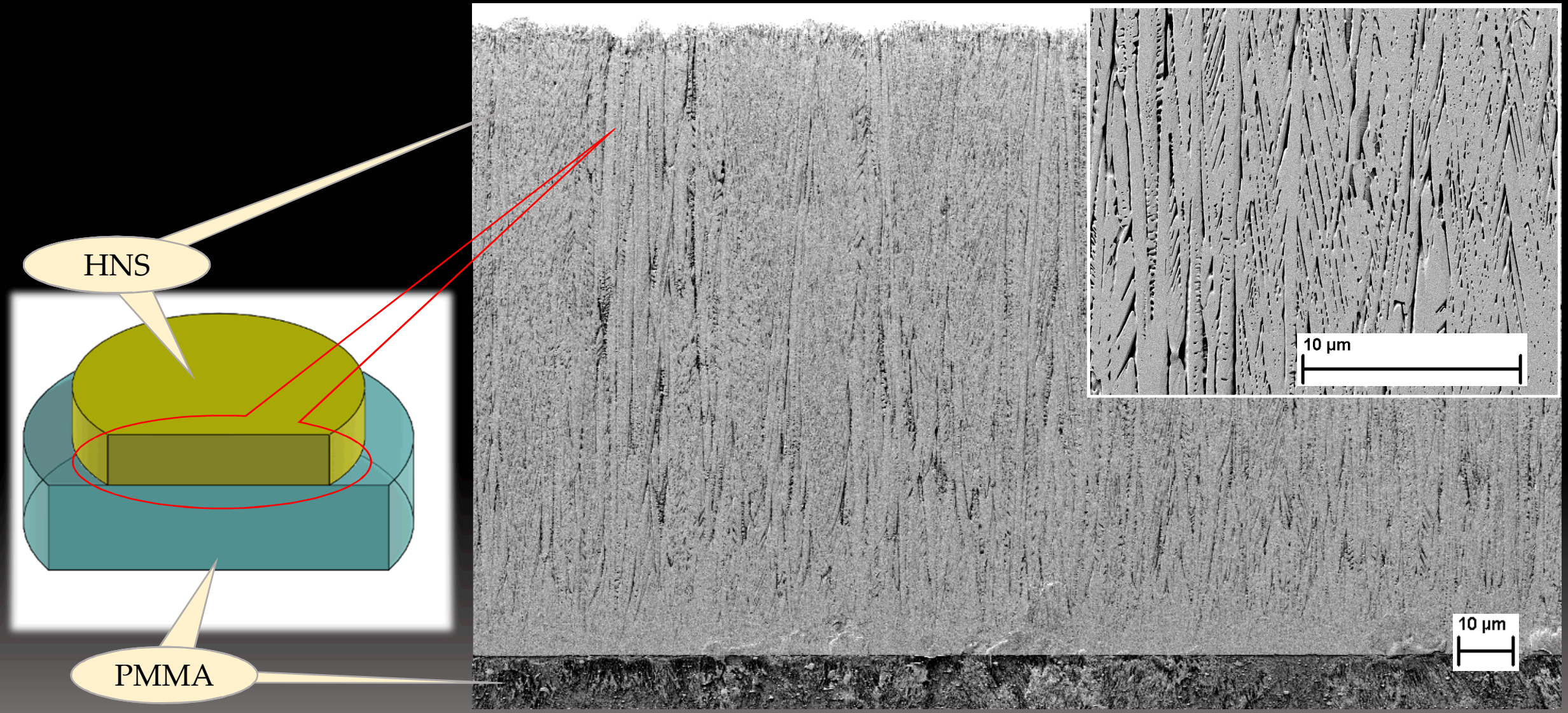


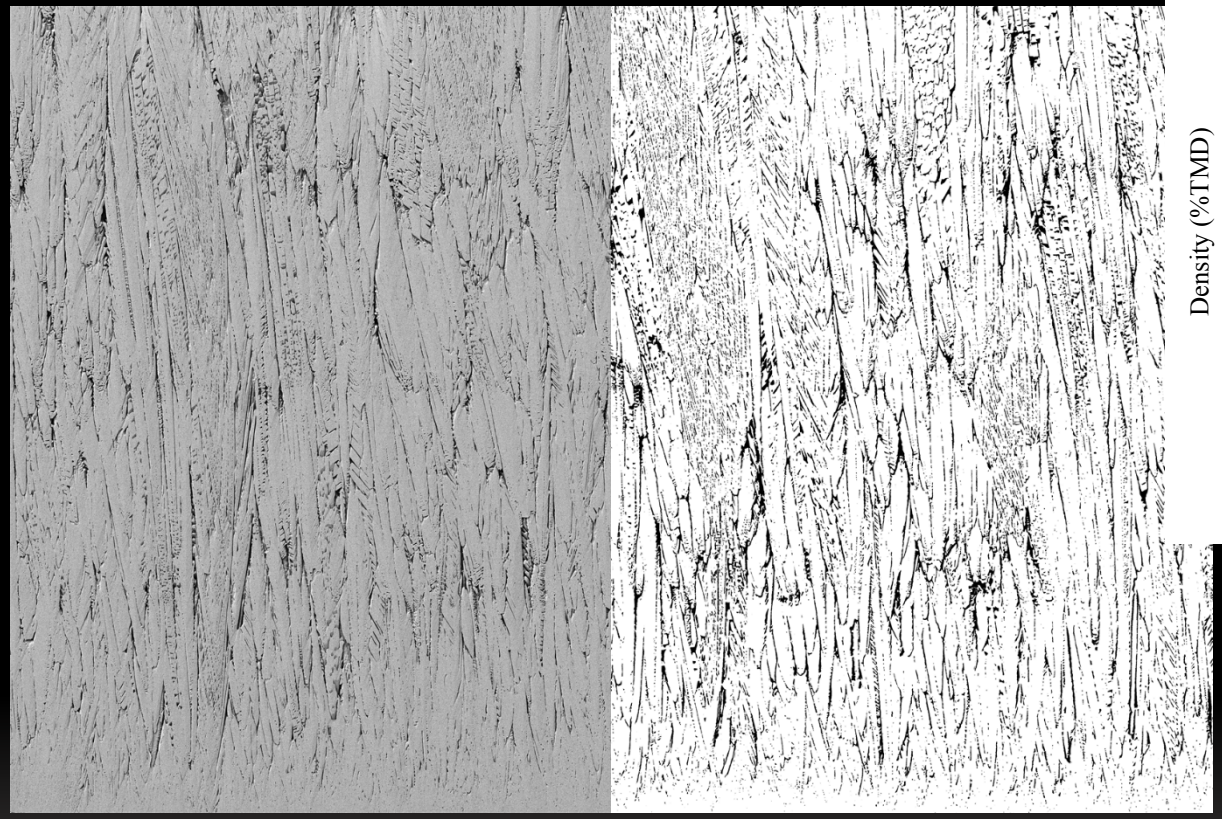
Figure 2.23. Wedge test setup

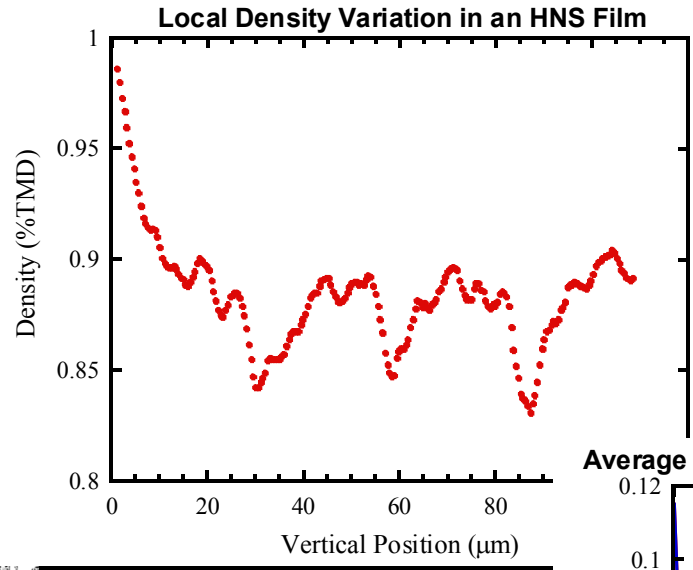
Suceska, Muhamed. *Test methods for explosives*. Springer Science & Business Media, 2012.

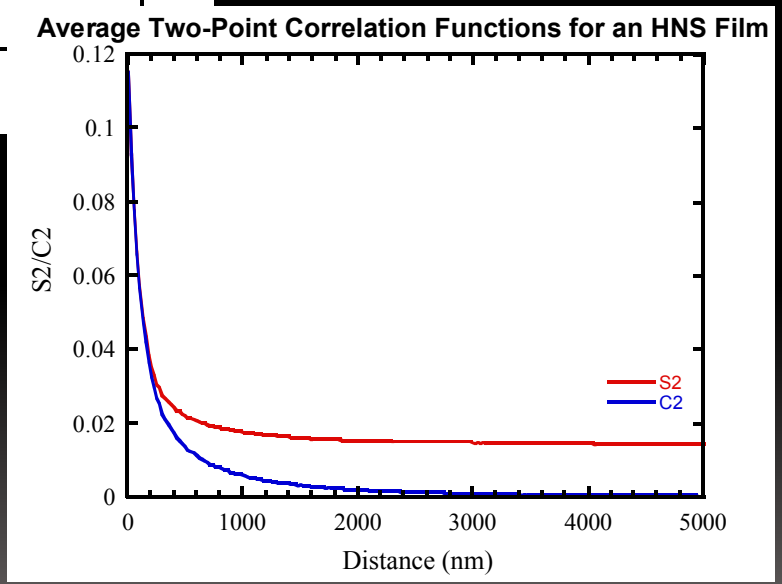
Vapor deposition of energetics



Porosity in vapor-deposited HNS



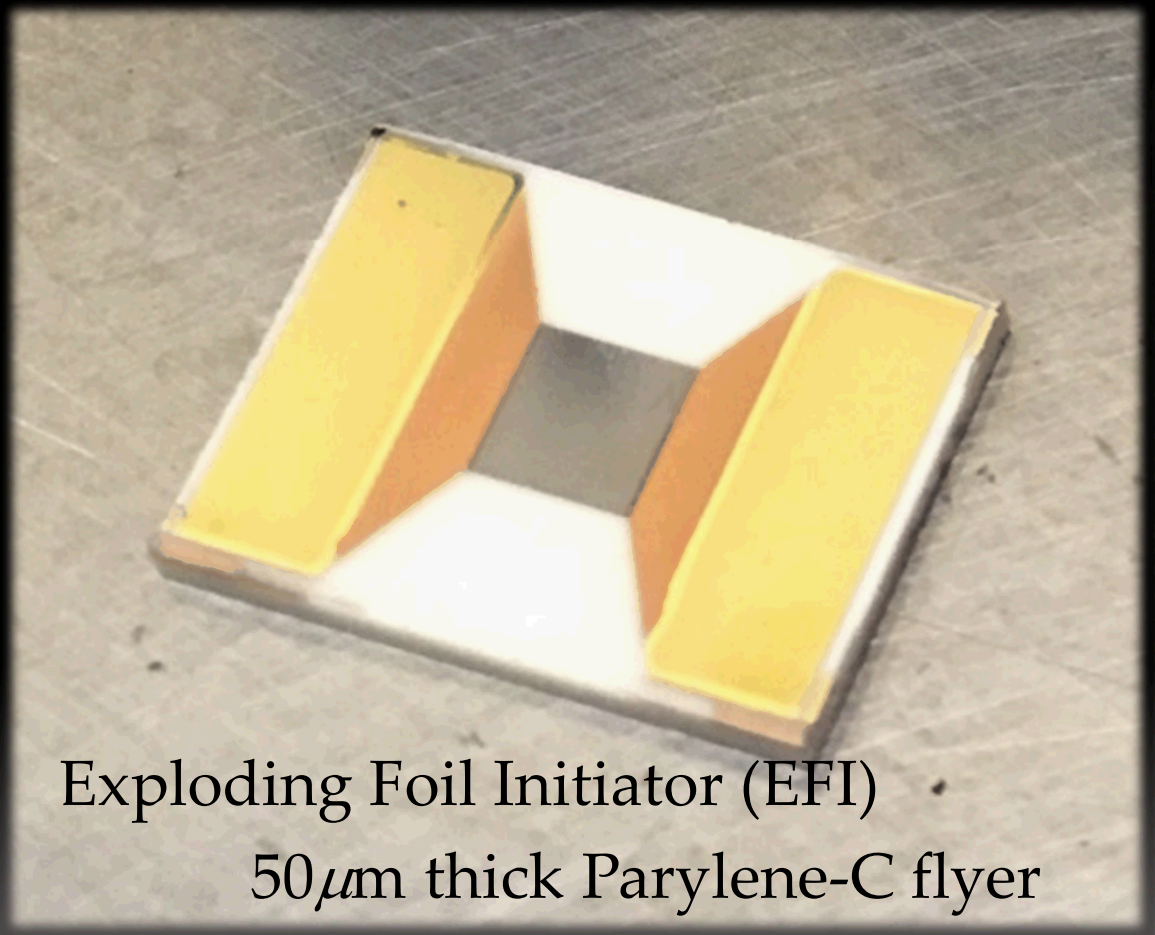




Cross-sectioned HNS film

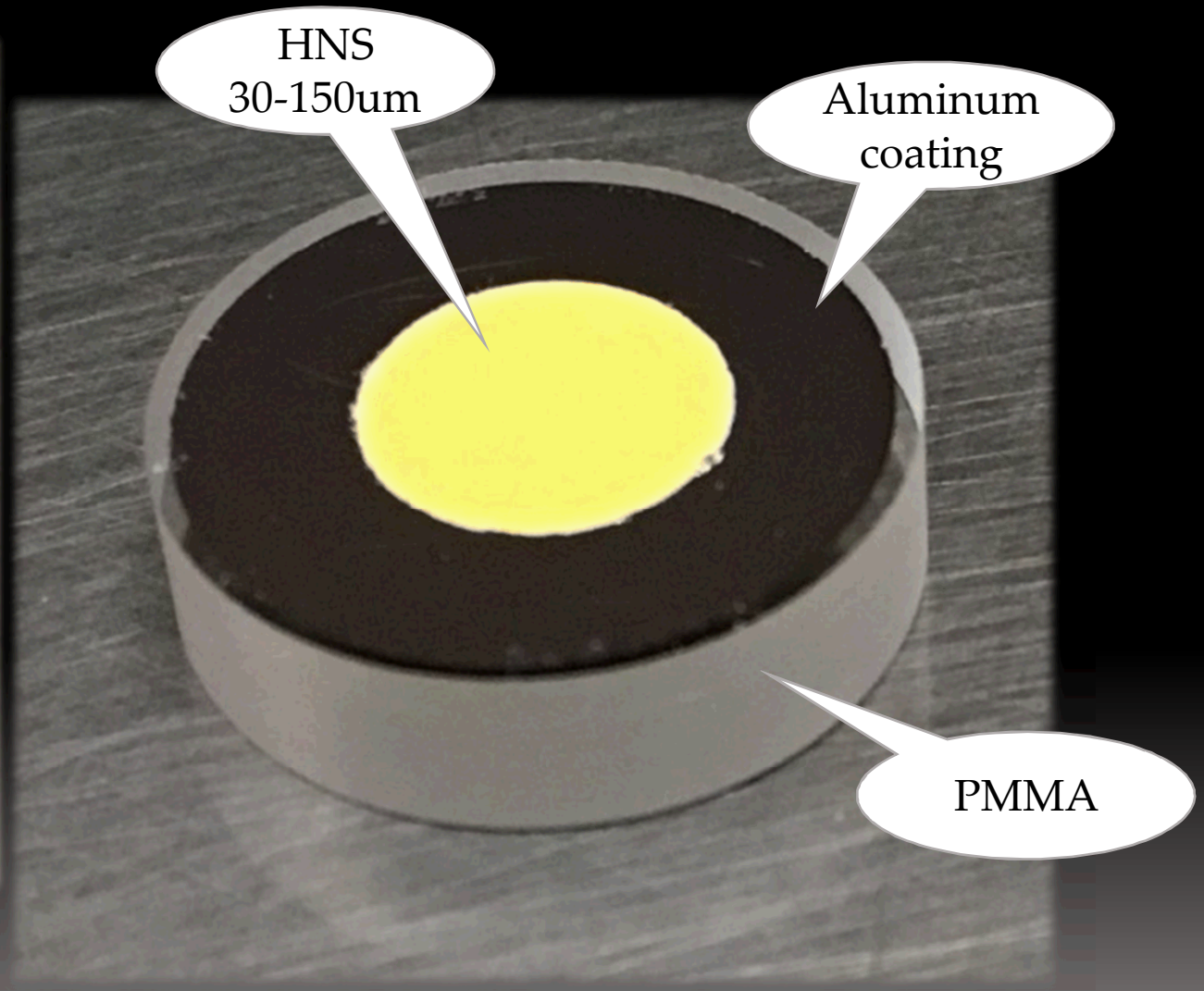
Thresholded and binarized to quantify distribution of porosity

Measuring the run distance

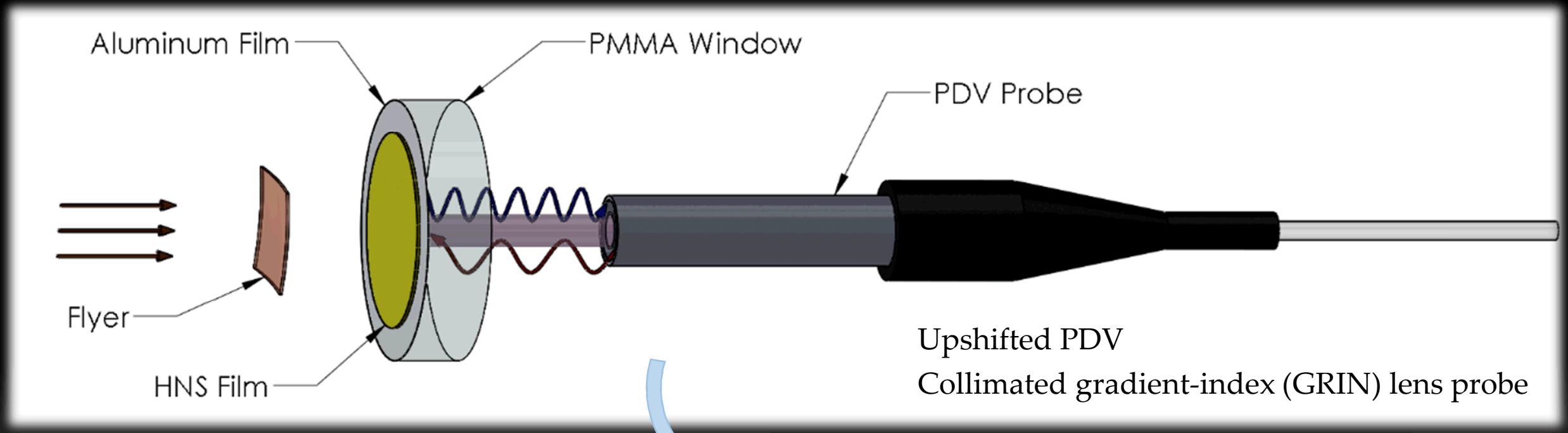


Exploding Foil Initiator (EFI)

50μm thick Parylene-C flyer

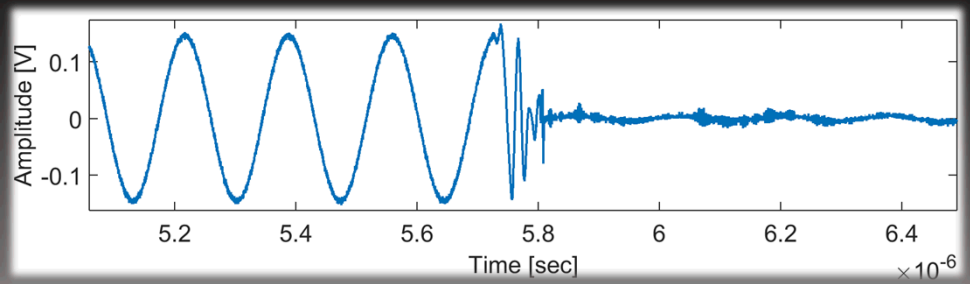


Experiment and measurement



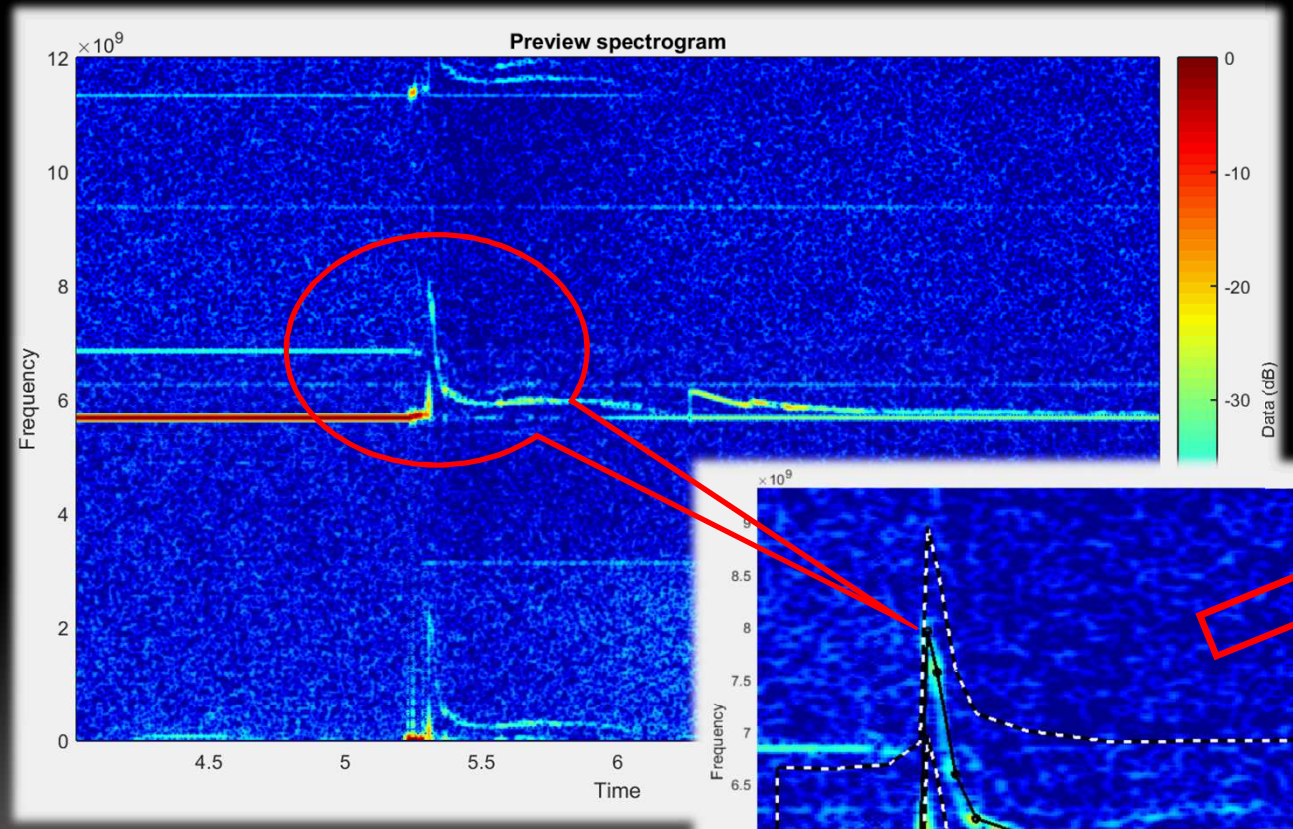
Upshifted PDV

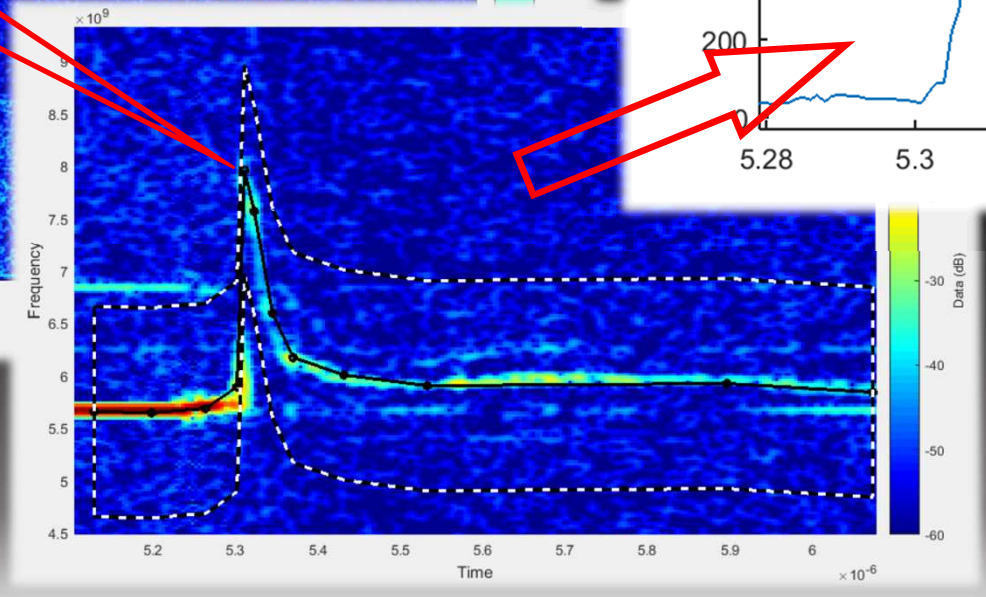
Collimated gradient-index (GRIN) lens probe

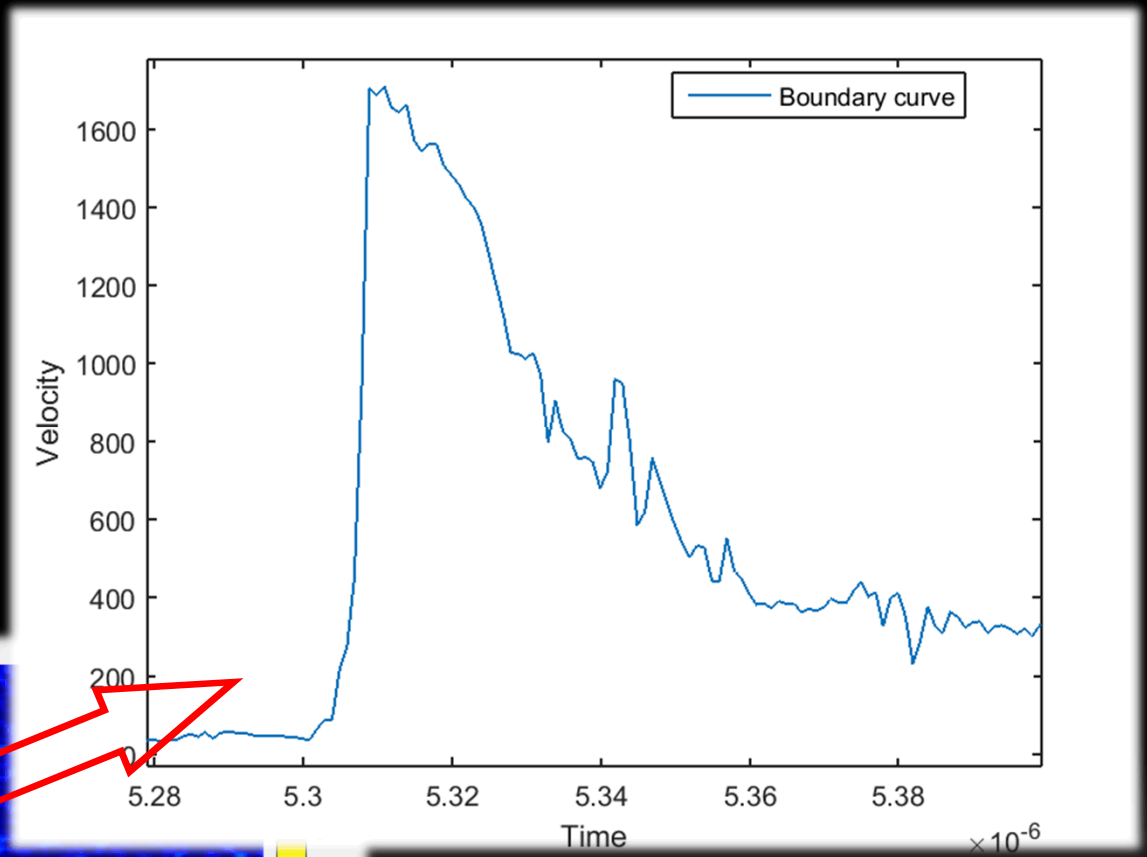


PDV analysis

Spectrogram and analysis

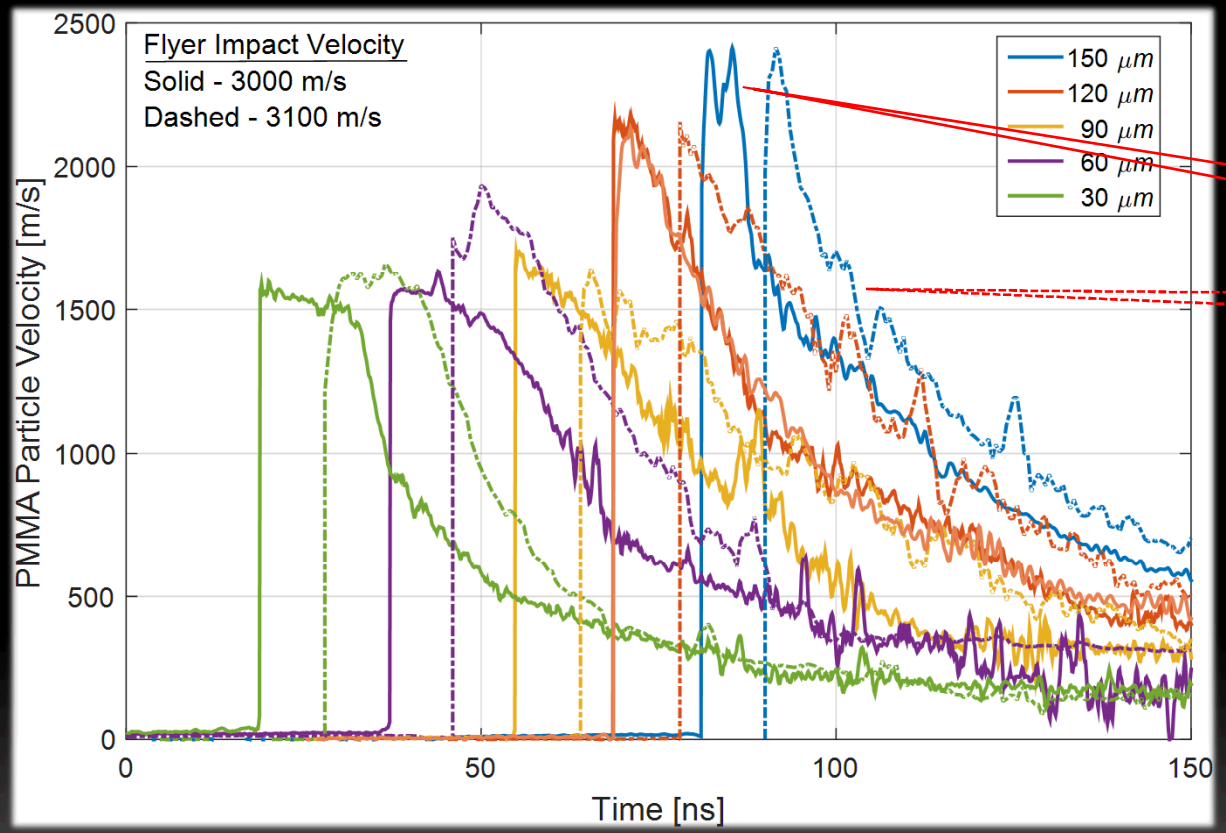


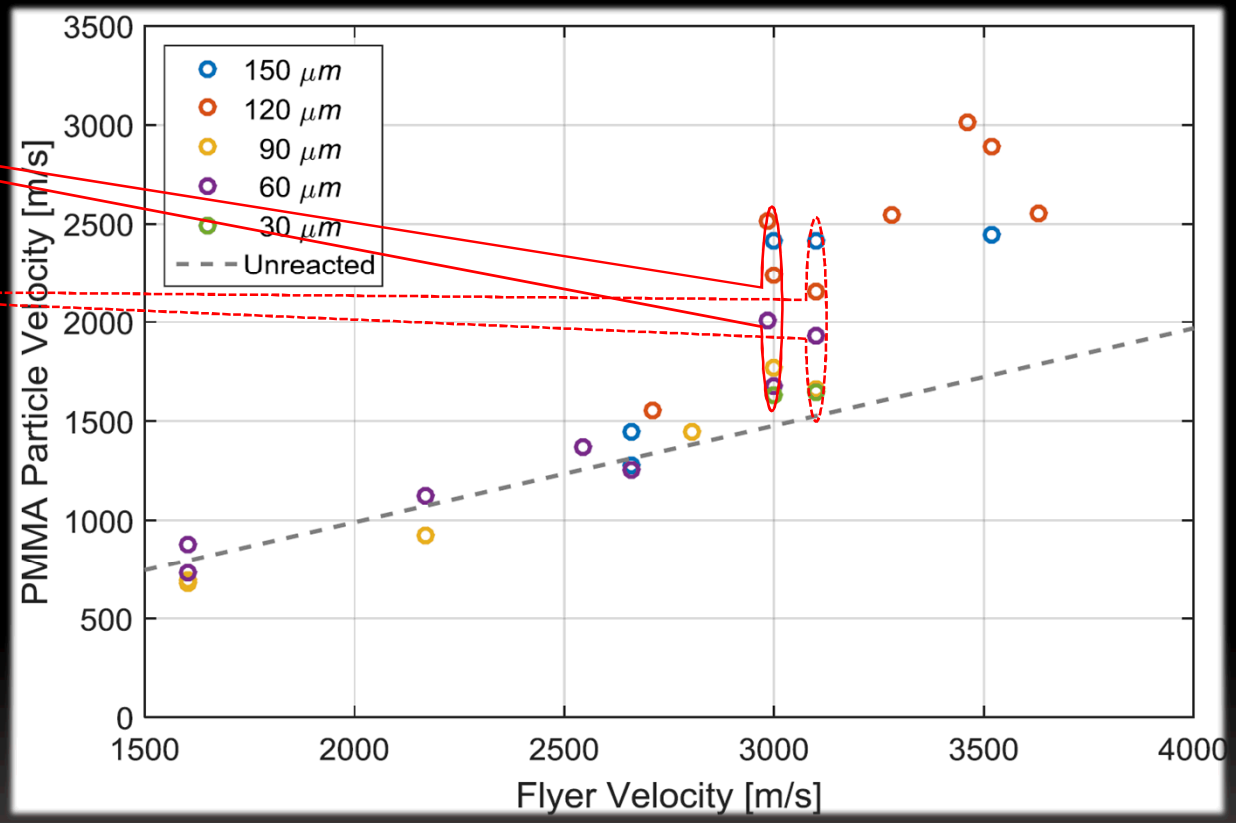




Acquired run to detonation

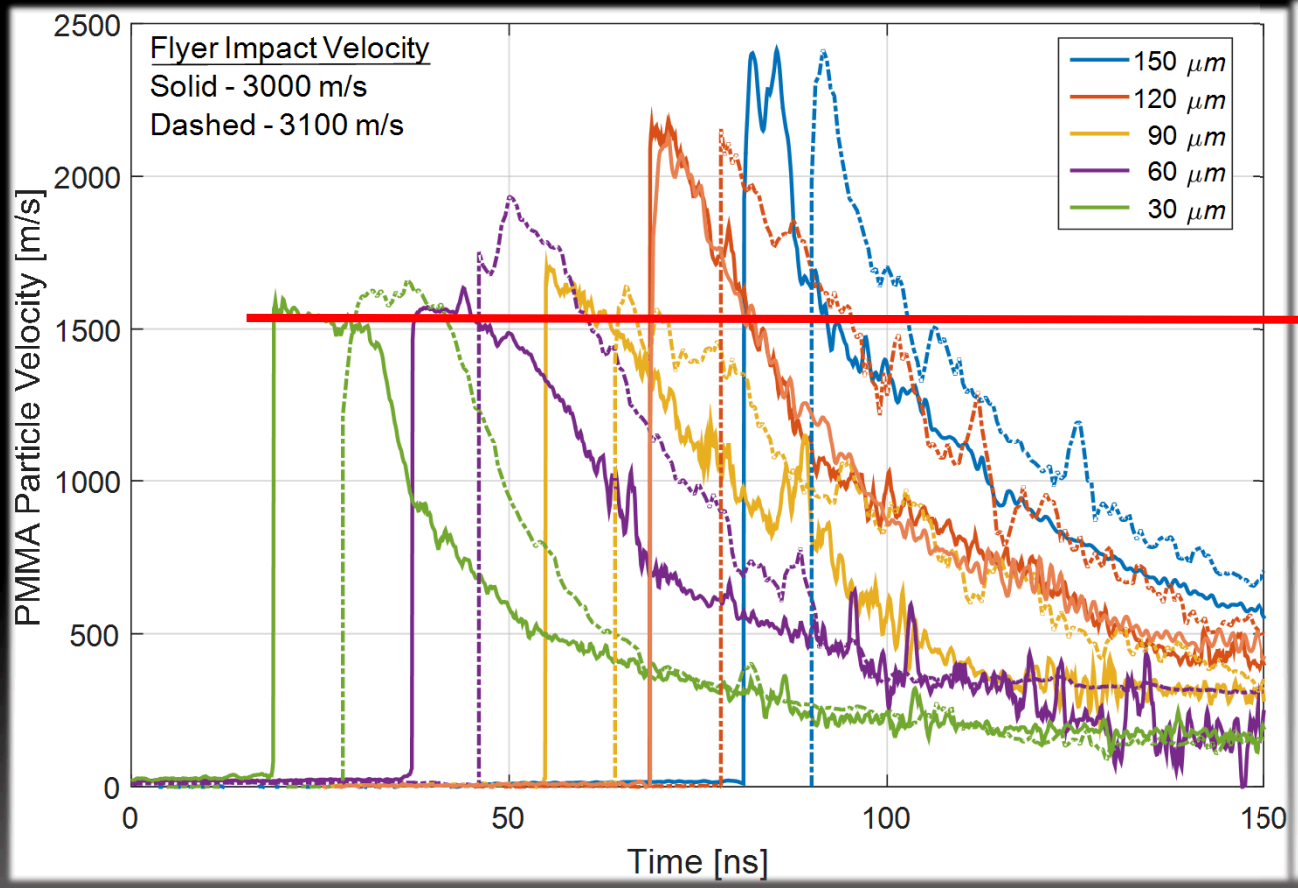
Experimental results for HNS films

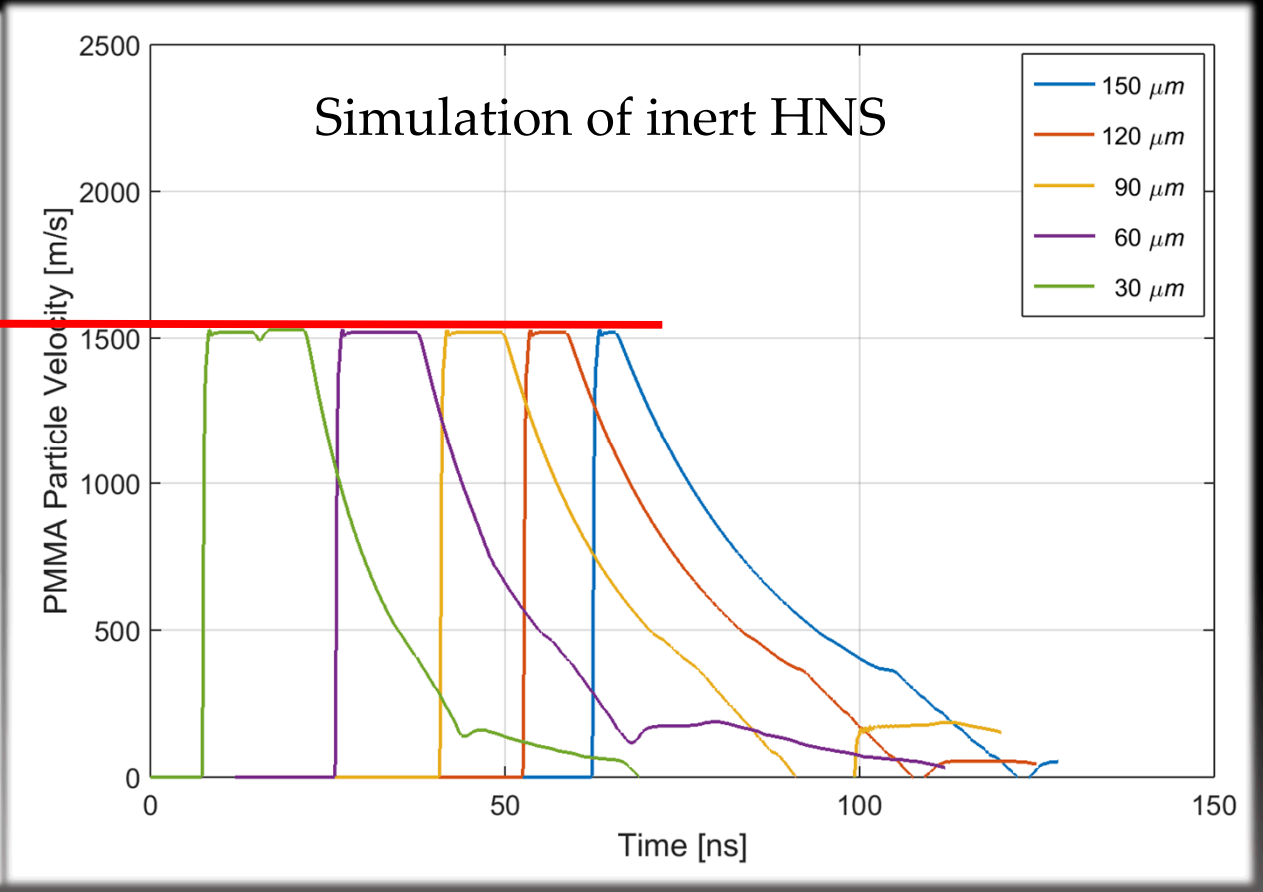




Comparison with inert

Experimental results versus inert simulations of HNS films

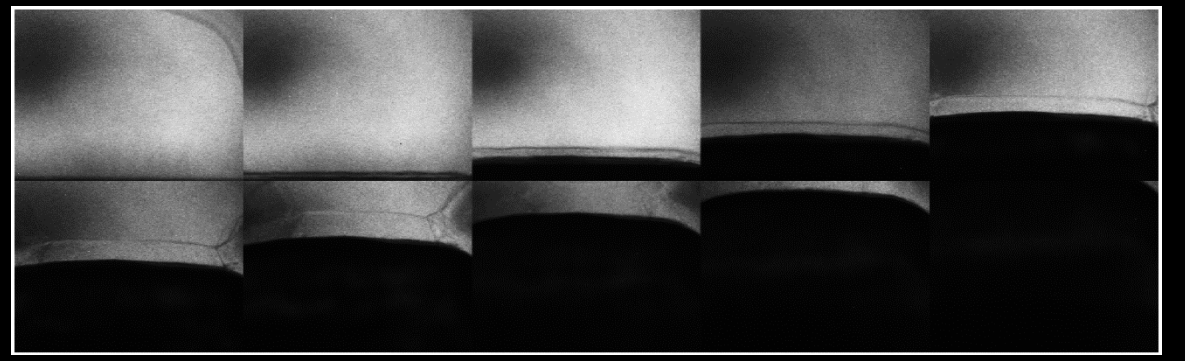




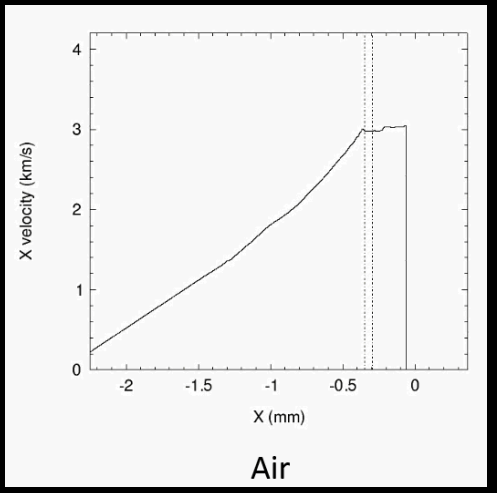
HNS Model Calibration

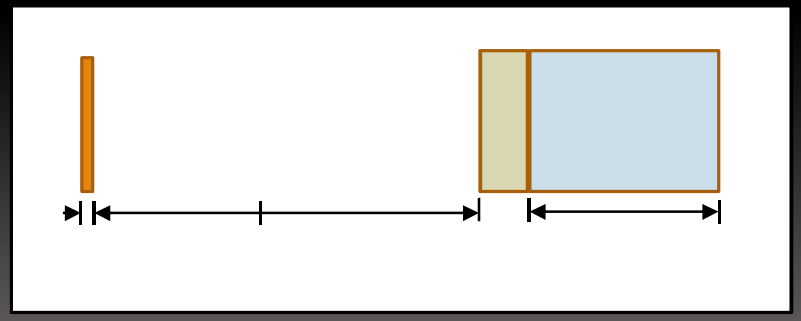
ARB Parameter Space Sampling

- 2 parameters within ARB Frequency Factor (FF) & Activation Temperature (AT)
- Latin hypercube sampling (LHS) attempts to generate sample points evenly dispersed

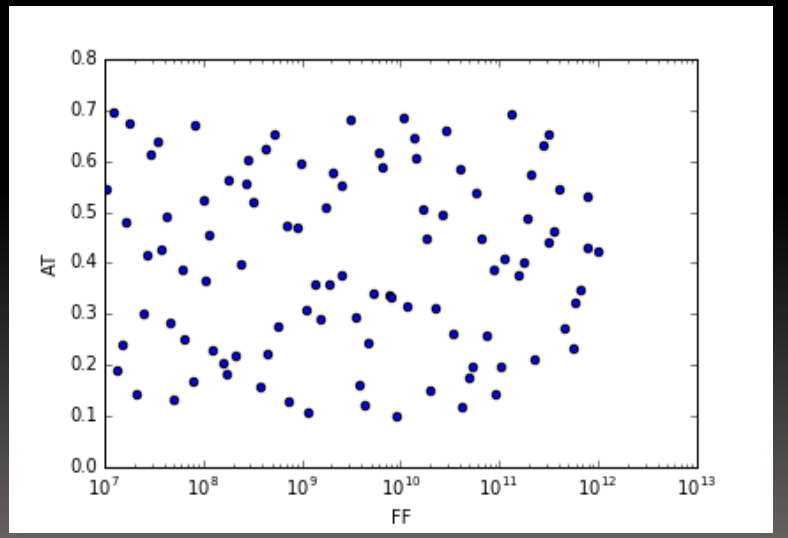


Olles, Joseph, et al. "Acquisition of high-fidelity flyer characteristics using PDV and streak imaging." *APS Meeting Abstracts*. 2016.

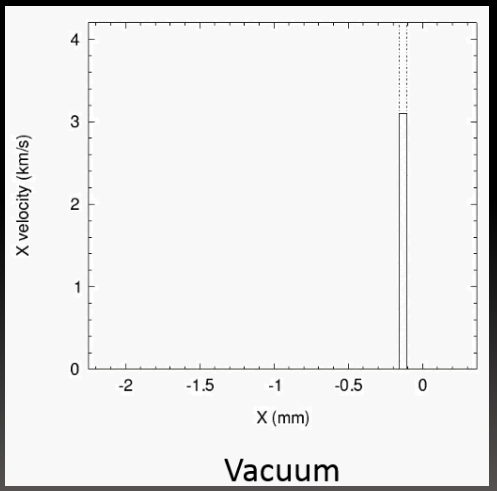




CTH Input Geometry Sketch

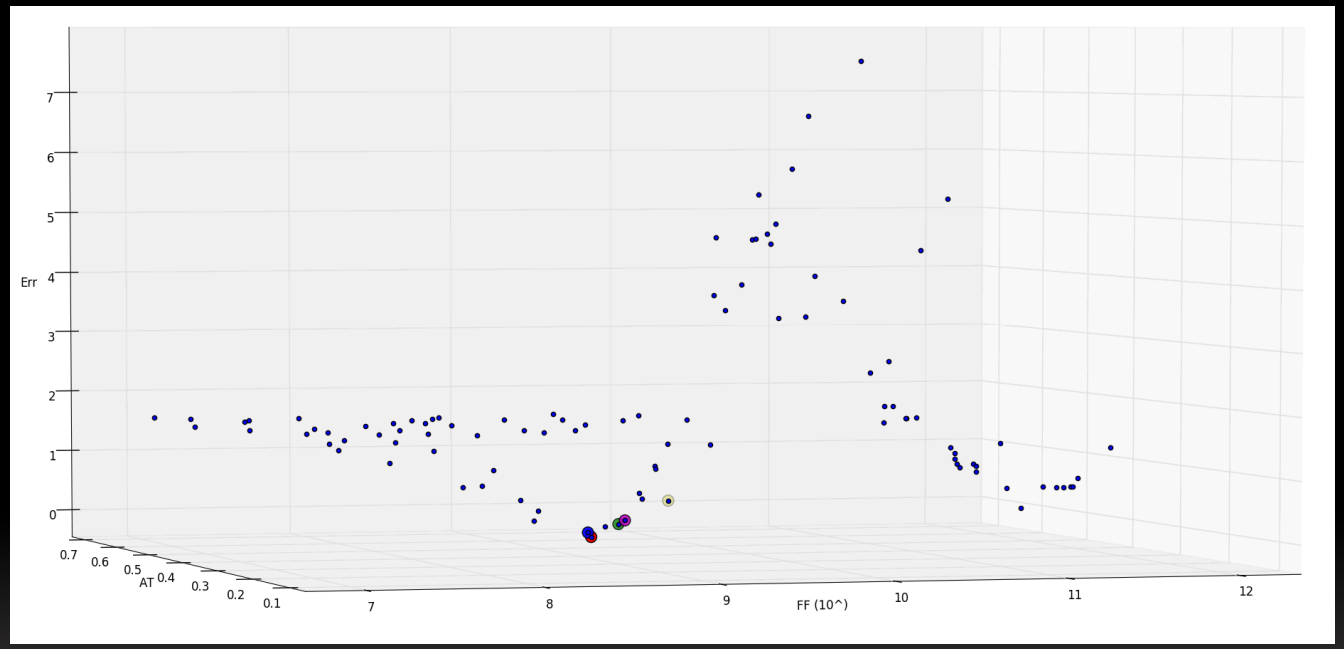


100 LHS Points



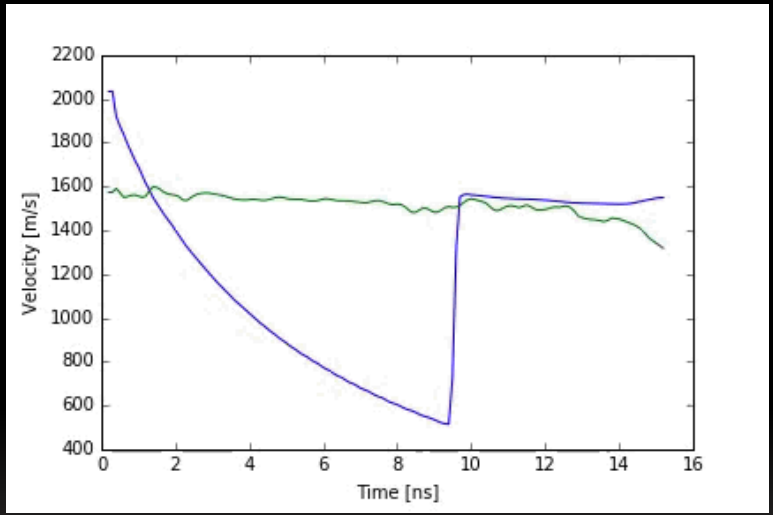
HNS Model Calibration

- Several objective function designs were tested
  - Peak velocity
  - 3 velocities
  - Designated time band (pulse width)
- Each objective function type calculates both error and FF/AT

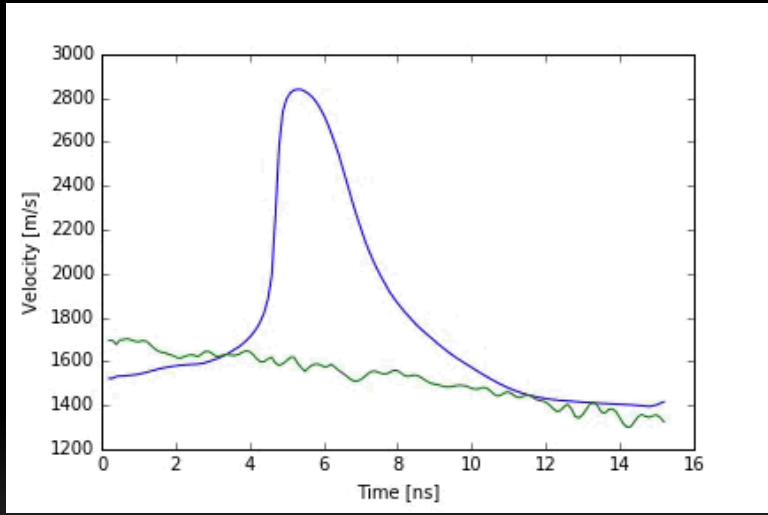


HNS Model Calibration

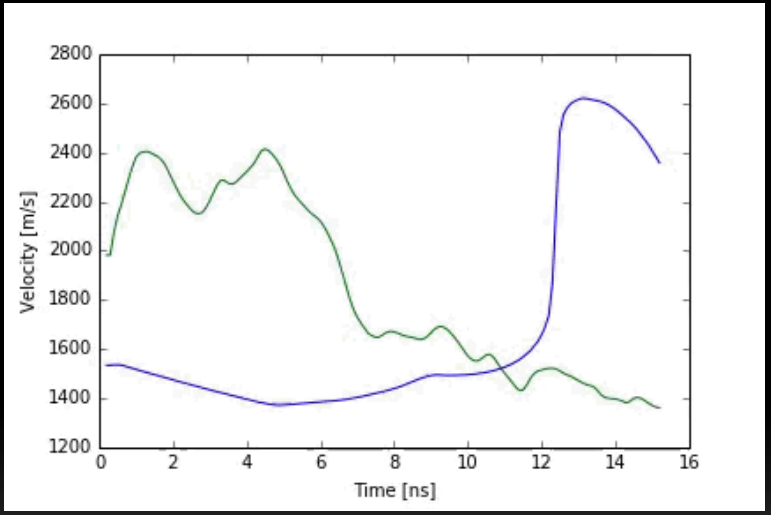
Time Band objective function



Exp. vs Sim. First 15ns after impact - 30um



Exp. vs Sim. First 15ns after impact - 90um

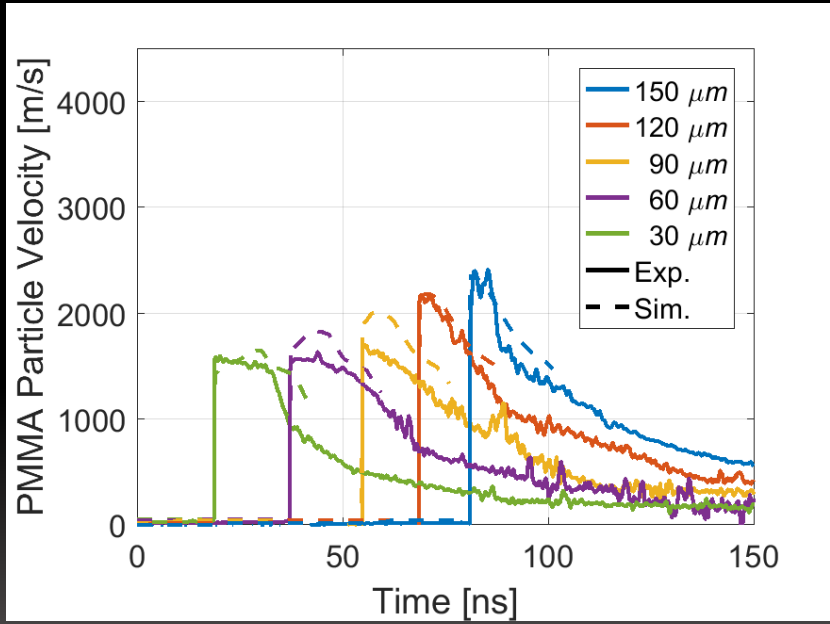


Exp. vs Sim. First 15ns after impact - 150um

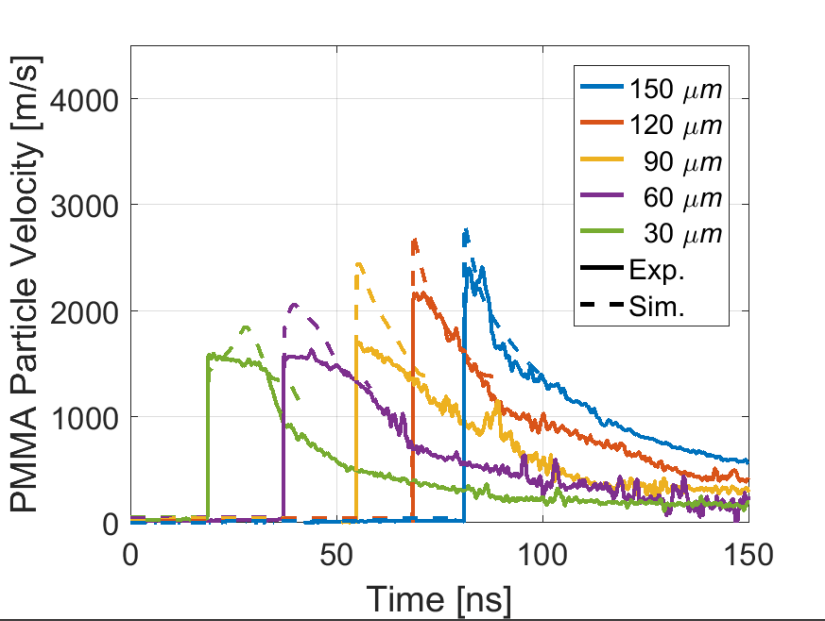
HNS Model Calibration

Continuum ARB simulations
1 AT/FF pair

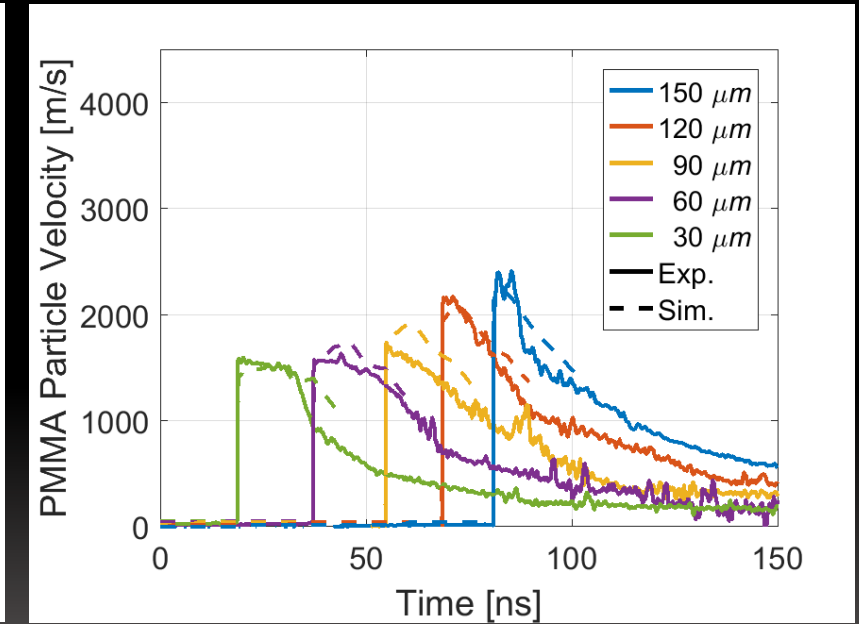
Peak Velocity



3 Point Velocity



Time Band



Summary

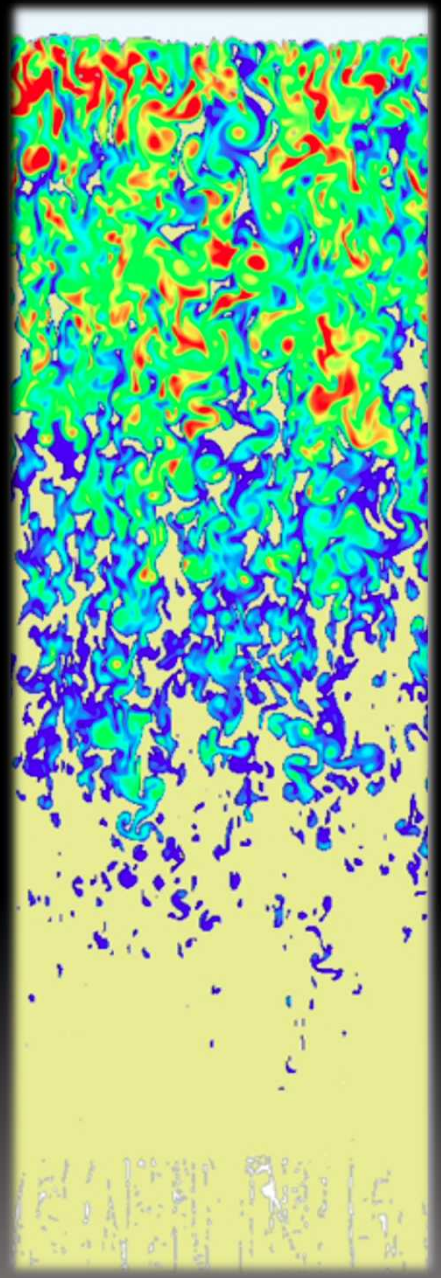
First time the run distance has been measured in HNS

Great tool when run to detonation distances are small

This is a special case where experiments can be fully modeled with grainscale detail

Tuned burn model parameters for continuum scale simulations based on experimental results

Working on effects of ARB parameters in grainscale



Acknowledgments
Graham Kosiba, J. Pat Ball, Michael Marquez, and Barry Ritchey