# Resolving the Velocity Vector in Two Dimensions

Presentation for the 5th annual PDV Conference and Workshop,

Ohio State University, Columbus, Ohio

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Abstract: Velocimetry techniques measure only the component of velocity along the beam. The dynamics of the vector nature of the velocity are of interest in the modeling of the responses of materials to shock loading. We present an example of using 2 crossed PDV beams to resolve the direction of motion in addition to the speed.

# Resolving the Velocity Vector in Two Dimensions

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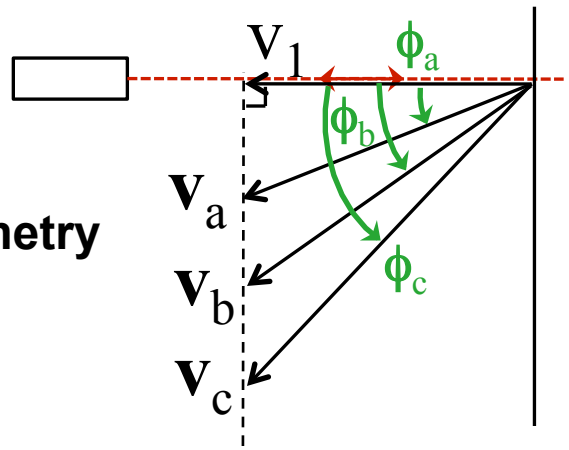
**What we really do is**

**PDS = Photon Doppler Speedometry**

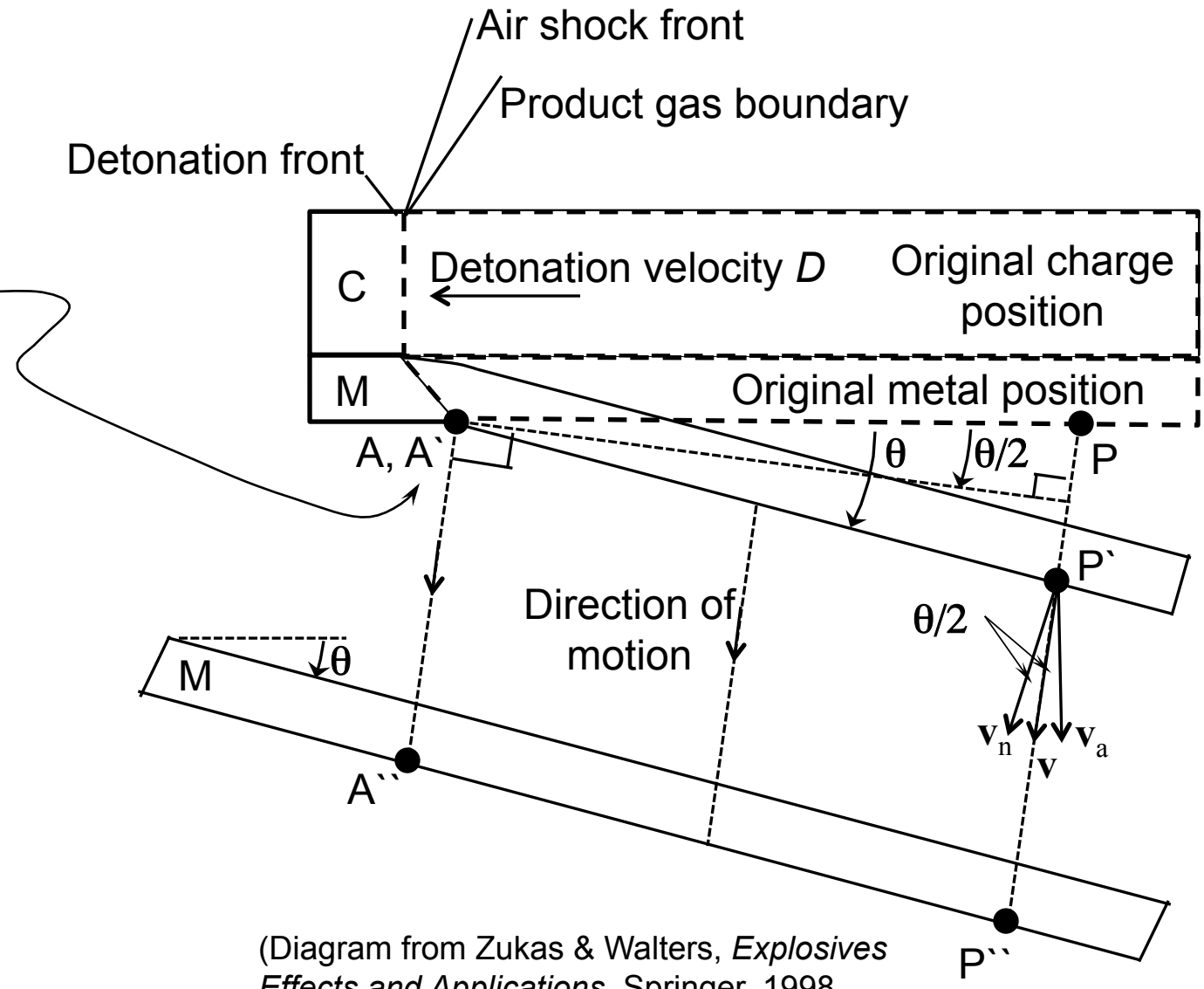



PDViants: Steve Hare, Mike Shinas, Jim Faulkner, Larry Hull.

Firing site: Michael Archuleta, Rudy Archuleta, John Echave, Joe Lynch, Pam Scott.

# Measuring direction elucidates dynamics

The dynamics of many tests involve changes in direction in 2 and 3-D. The evolution from $\mathbf{v}_a$ to $\mathbf{v}$ is about to occur at A, A` in the grazing detonation test shown at right. We have been asked to measure this in damage/recovery tests, cylinder tests and expansion tests to help understand the material response.




(Diagram from Zukas & Walters, *Explosives Effects and Applications,* Springer, 1998

# 2 Beams Resolve the Velocity Vector **v** in 2D

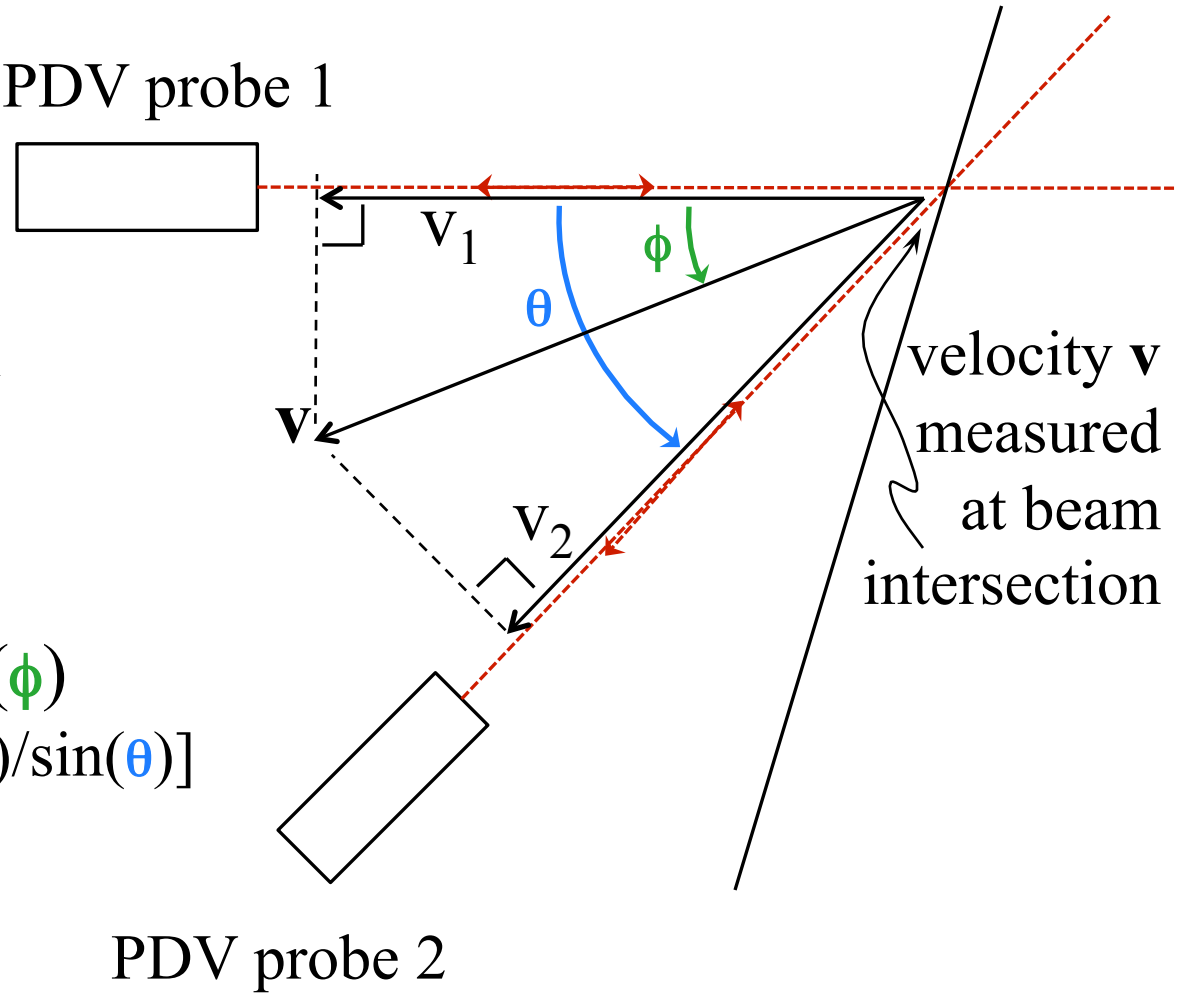
One convenient choice is to pick beam 1 as a coordinate axis:

$v_1 = v\cos(\phi)$

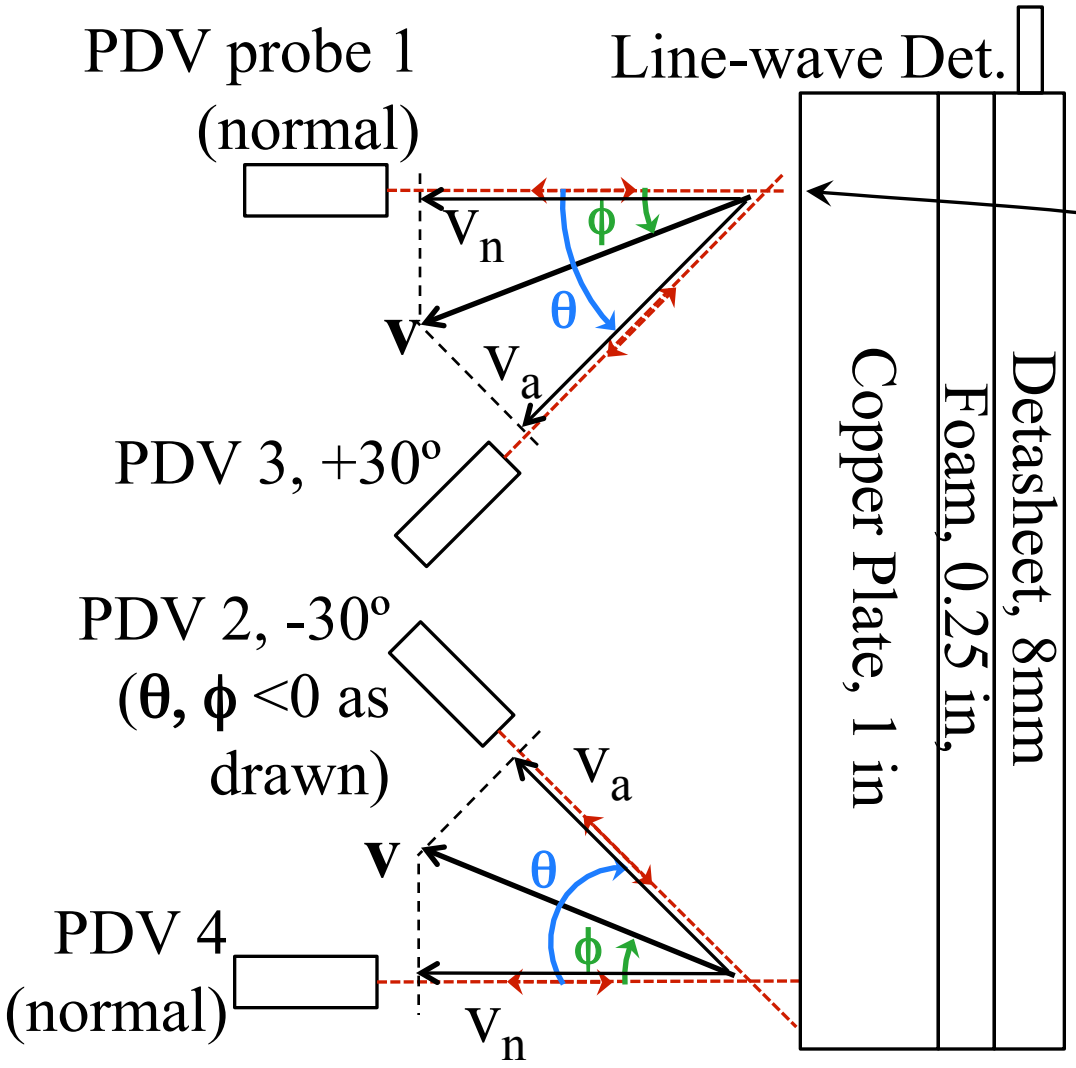
$v_2 = v\cos(\theta - \phi)$

$v_2 / v_1 = \cos(\theta - \phi)/\cos(\phi)$

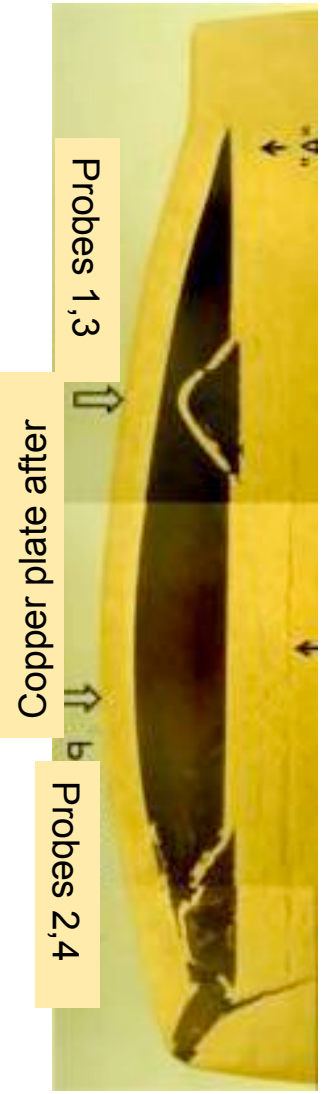
$\phi = \tan^{-1}[\,(v_2/v_1 - \cos(\theta))/\sin(\theta)]$



# Copper Plate, Driven Transversely



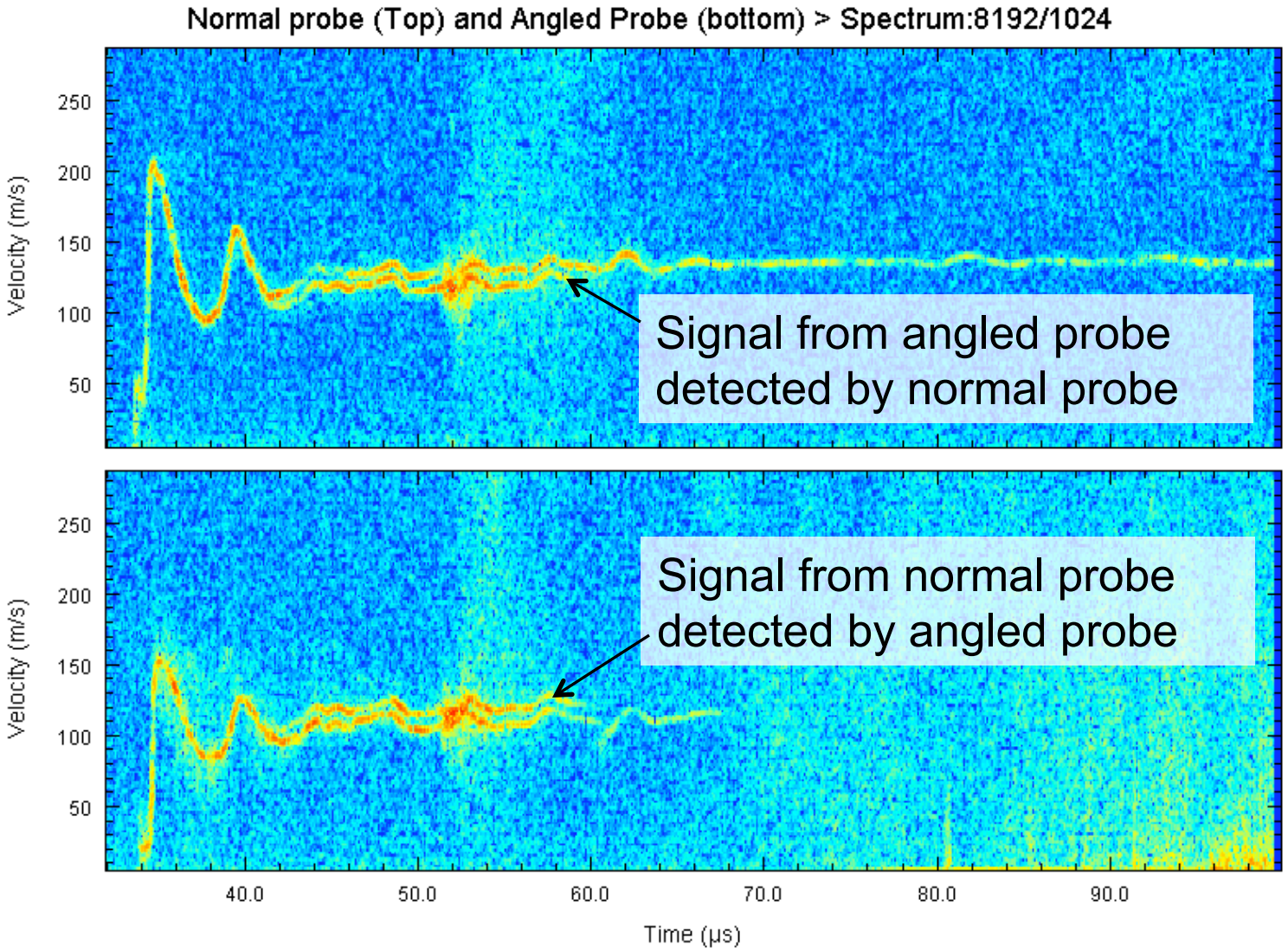

Note beams cross ~ 1mm in front of surface; only at crossing is interpre-tation certain.



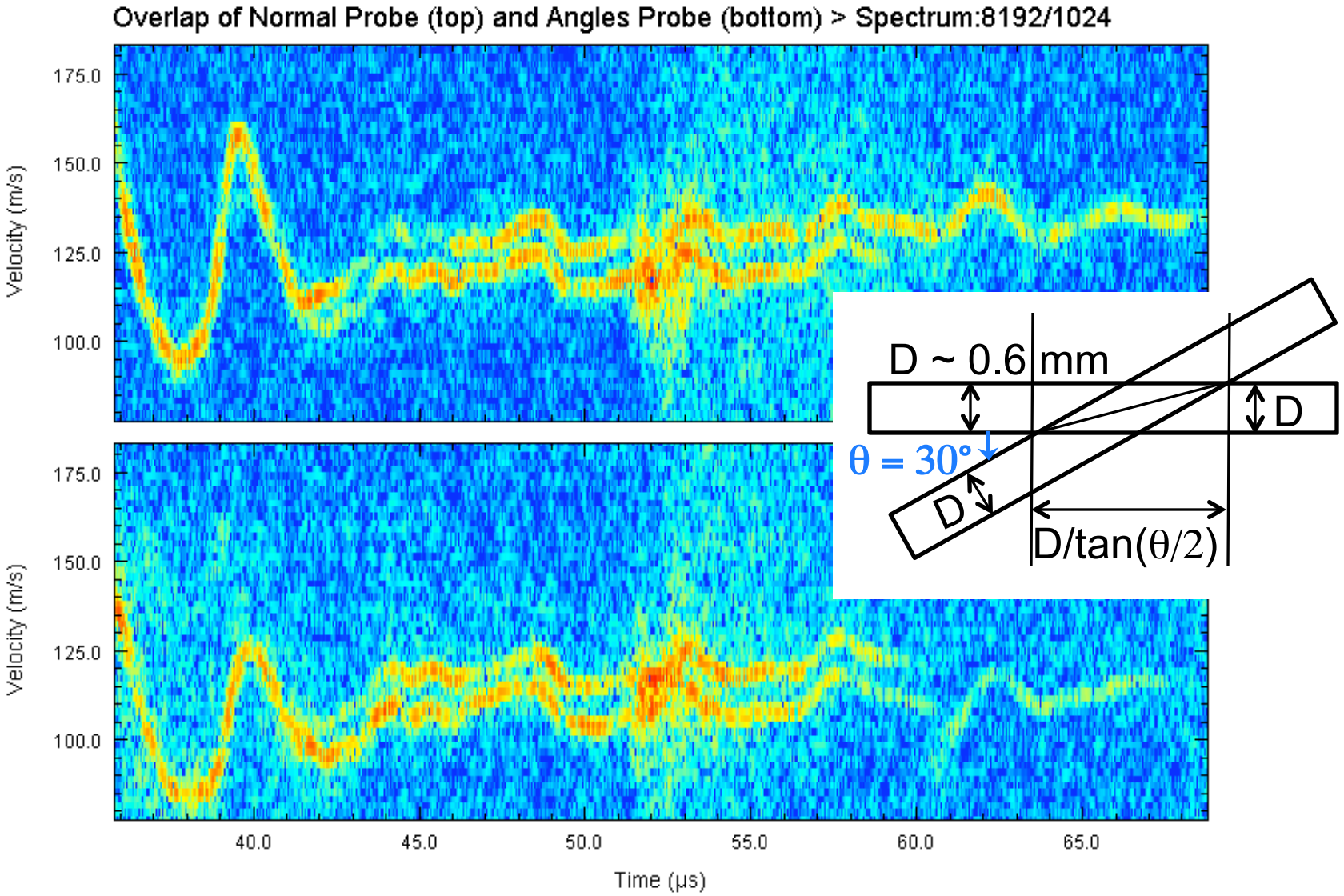



"The effects of shockwave profile shape and shock obliquity on spallation: kinetic and stress-state effects on damage evolution," R.T. Gray et al., Shock Compression of Condensed Matter – 2009, CP1195, Ed M.L. Elert, 2009

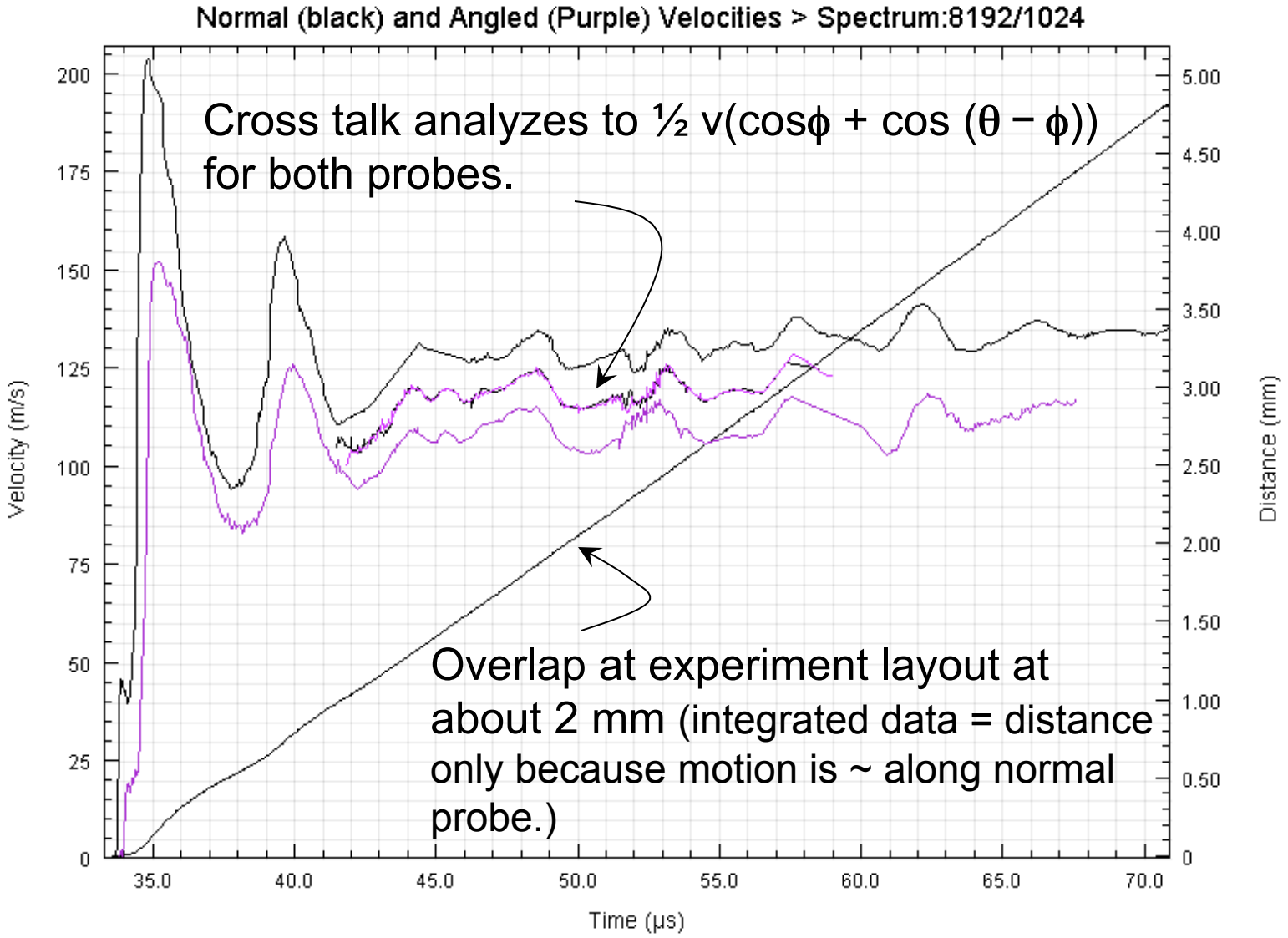
# The lower pair show overlap (results from Ta plate)



# Overlap region: 19 μs, 2.4 mm ~ D/tan(θ/2)



# Cross talk, location of overlap are as expected



# Find ϕ and v from the measured data

One convenient choice is to pick beam 1 as a coordinate axis:

$$v_4 = v\cos(\phi)$$

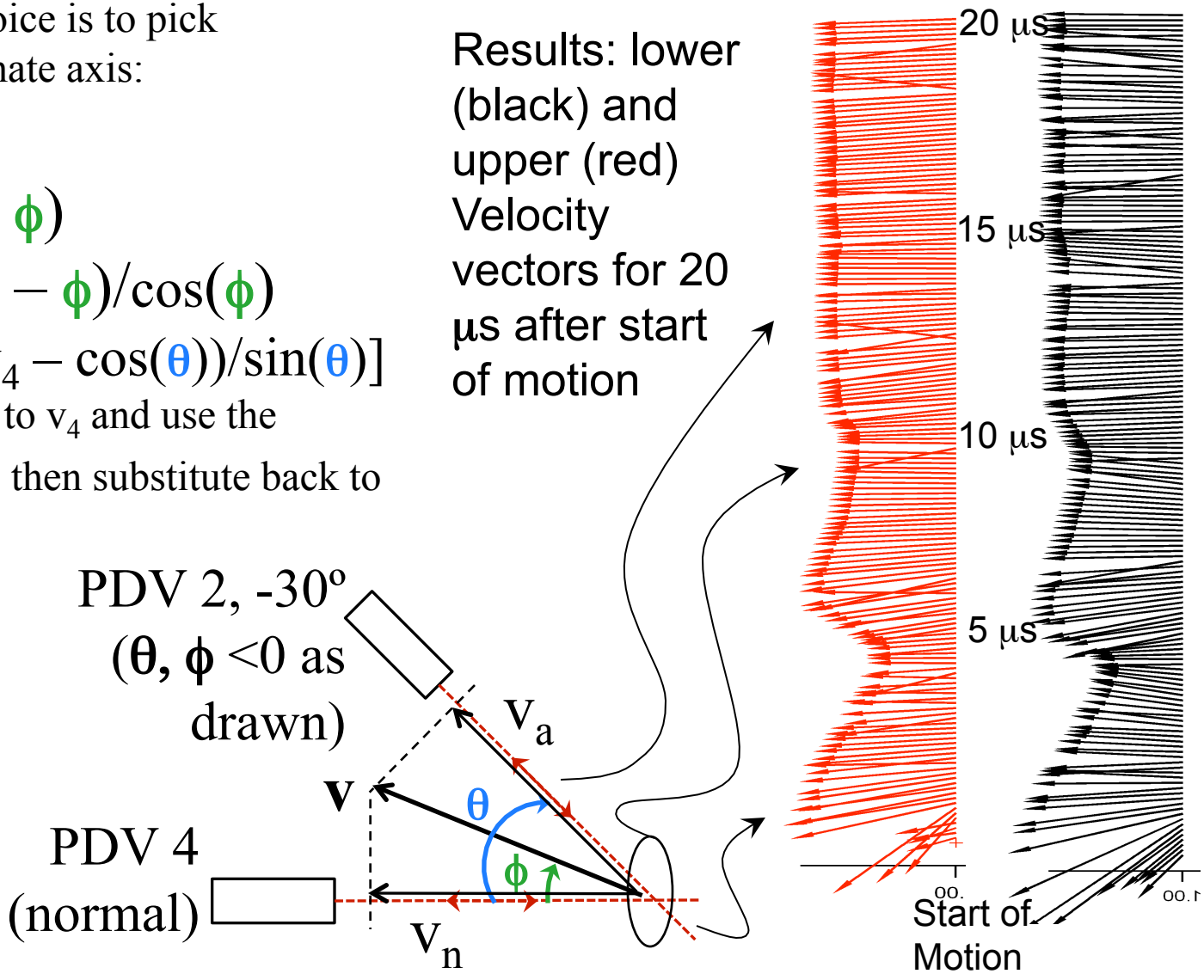
$$v_2 = v\cos(\theta - \phi)$$

$$v_2 / v_4 = \cos(\theta - \phi)/\cos(\phi)$$

$$\phi = \tan^{-1}[\,(v_2/v_4 - \cos(\theta))/\sin(\theta)]$$

Take the ratio of $v_2$ to $v_4$ and use the measured θ find ϕ, then substitute back to find v.

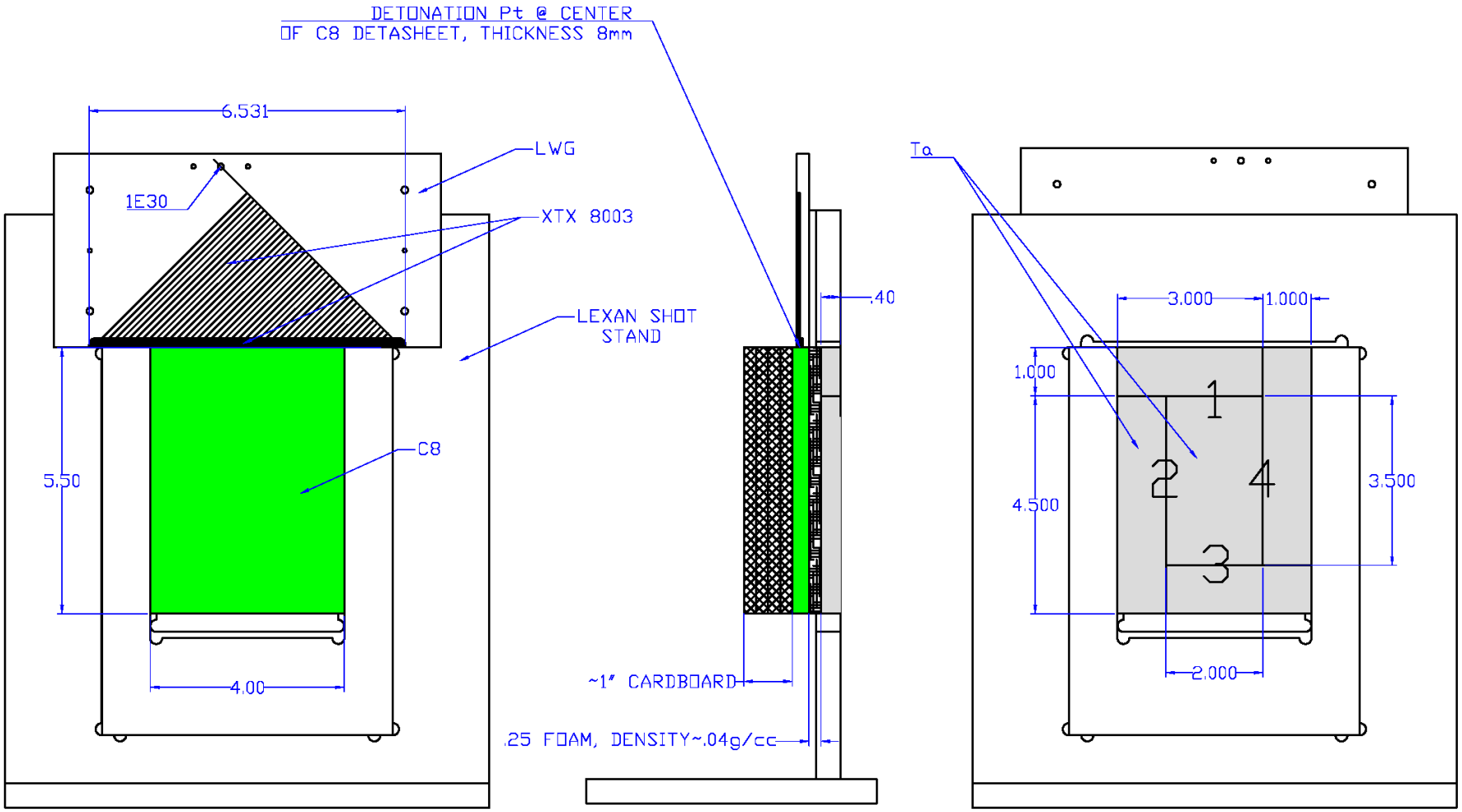
Results: lower (black) and upper (red) Velocity vectors for 20 μs after start of motion



# Technique works, next need to optimize

- We can measure the direction of the velocity vector over the 1 to 2 mm overlap region.
- The resolution was ~ ± 1° , ± 2% estimated from noise in the results.
- Need to test for systematic errors (model, use redundant probes or 1-D tests.)
- Need to understand optimization: angle resolved better with larger angle between probes, but signal strength falls off with angle from surface normal.

# Details of the HE Assembly




SHOT H3951
4/20/10

# As Built Shot 2