Determining Shape Evolution of Electrothermally Launched Flyers in Impact Welding with Multi-point PDV
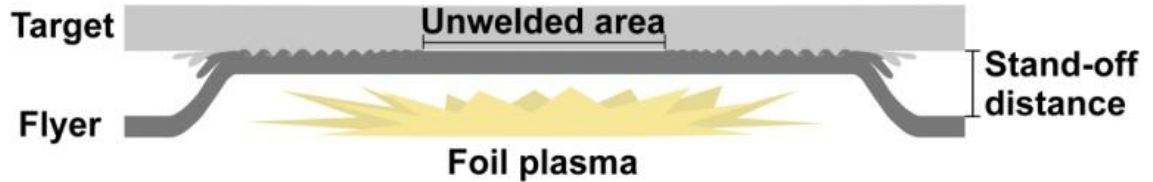
Taeseon Lee, Geoffrey Taber, Glenn Daehn

DEPARTMENT OF
MATERIALS SCIENCE
AND ENGINEERING
T·H·E OHIO STATE UNIVERSITY

1

Motivation

- Impact Welding
  - Contributing factors for joint efficiency
    - Velocity, collision angle, material thickness
    - Vaporizing Foil Actuator Welding (VFAW) was used to establish welding window of velocity and angle
  - Interface morphology
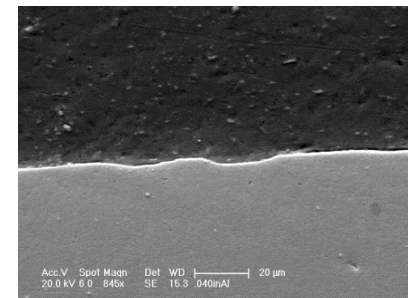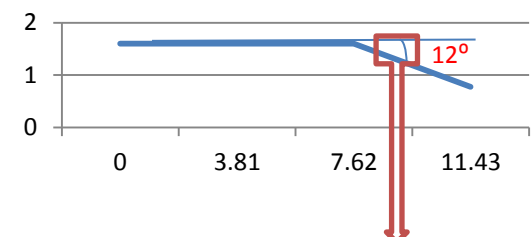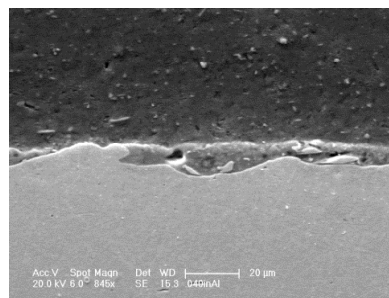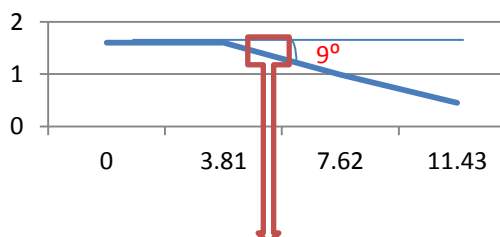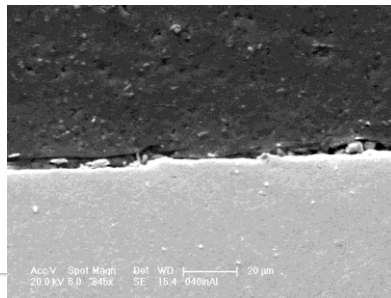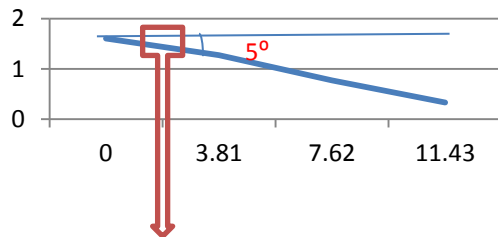   - Intermetallic compounds
    - Waviness

Sponsored by National Science Foundation

Motivation

Welding Window for Cu-Ti
(Vivek et al. 2014. JMPT)
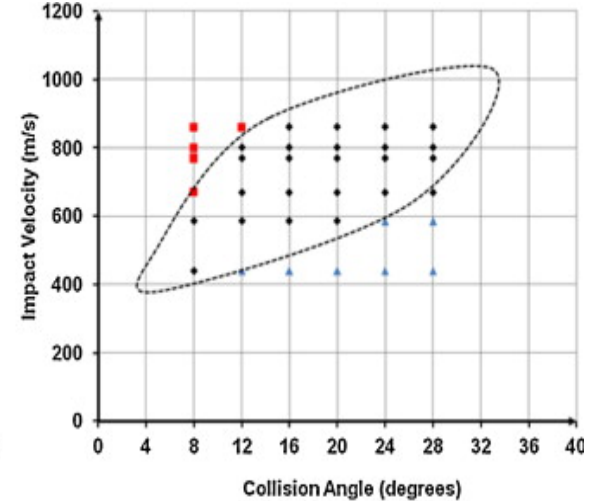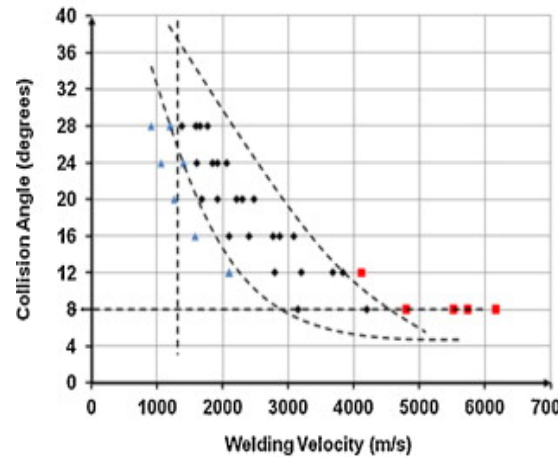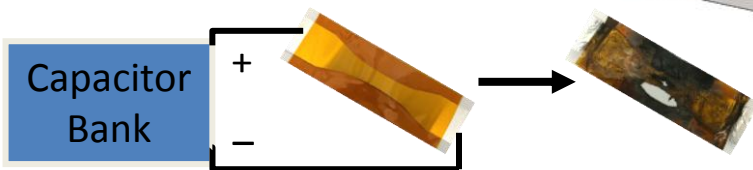

- Angle Effect on Weld Interface at 560 m/s
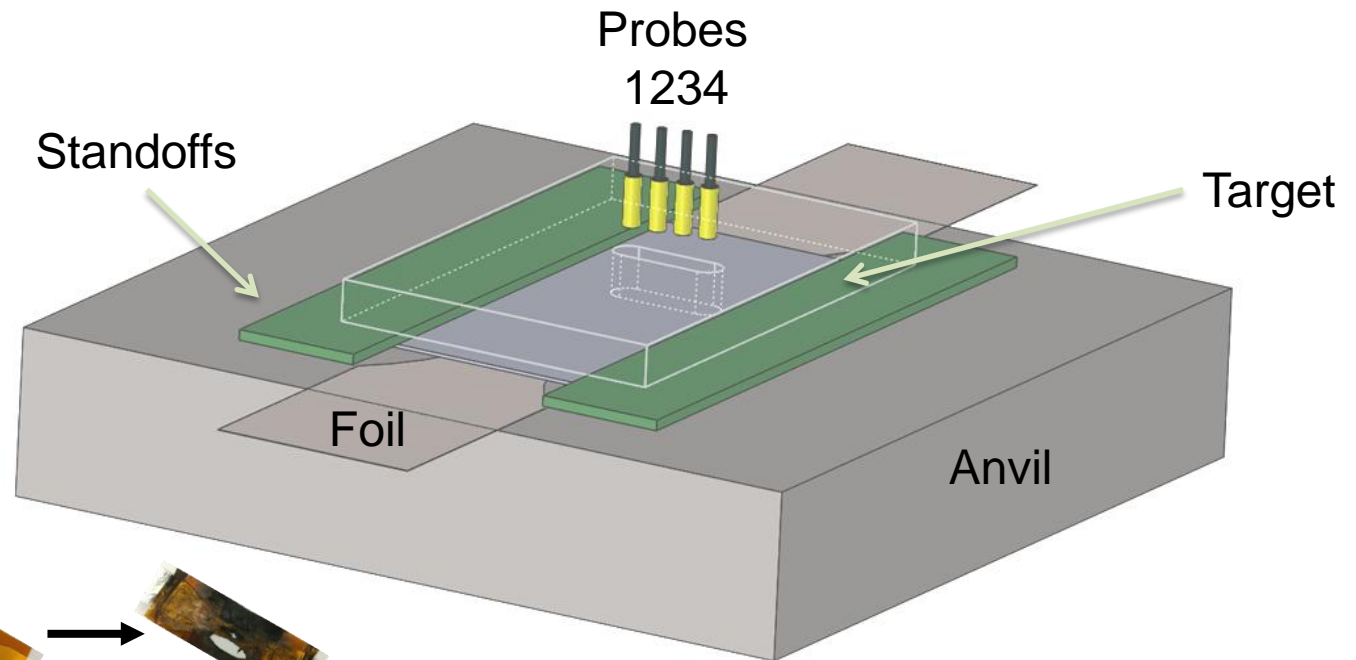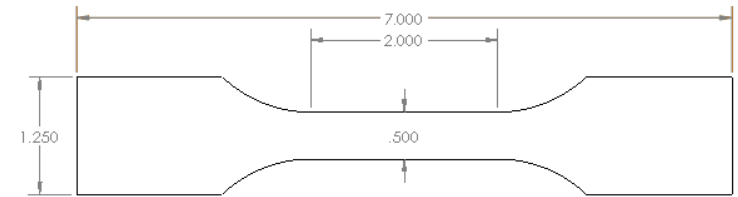

AA 1100

1018 Steel

Method One – Normal linear array

- Experimental Setup

Probes 1234

Standoffs

Target

Foil

Anvil

Capacitor Bank

+

−

Method One

- ## Schematic

PDV Probes

| 3.81 mm | 3.81 mm | 3.81 mm | 4.45 mm |

Target

$V_{collision}$

V_{impact}

Pressure

Traveling distance (1.6 mm) in this study

Flyer

Explosion

CH1
CH2
CH3
CH4
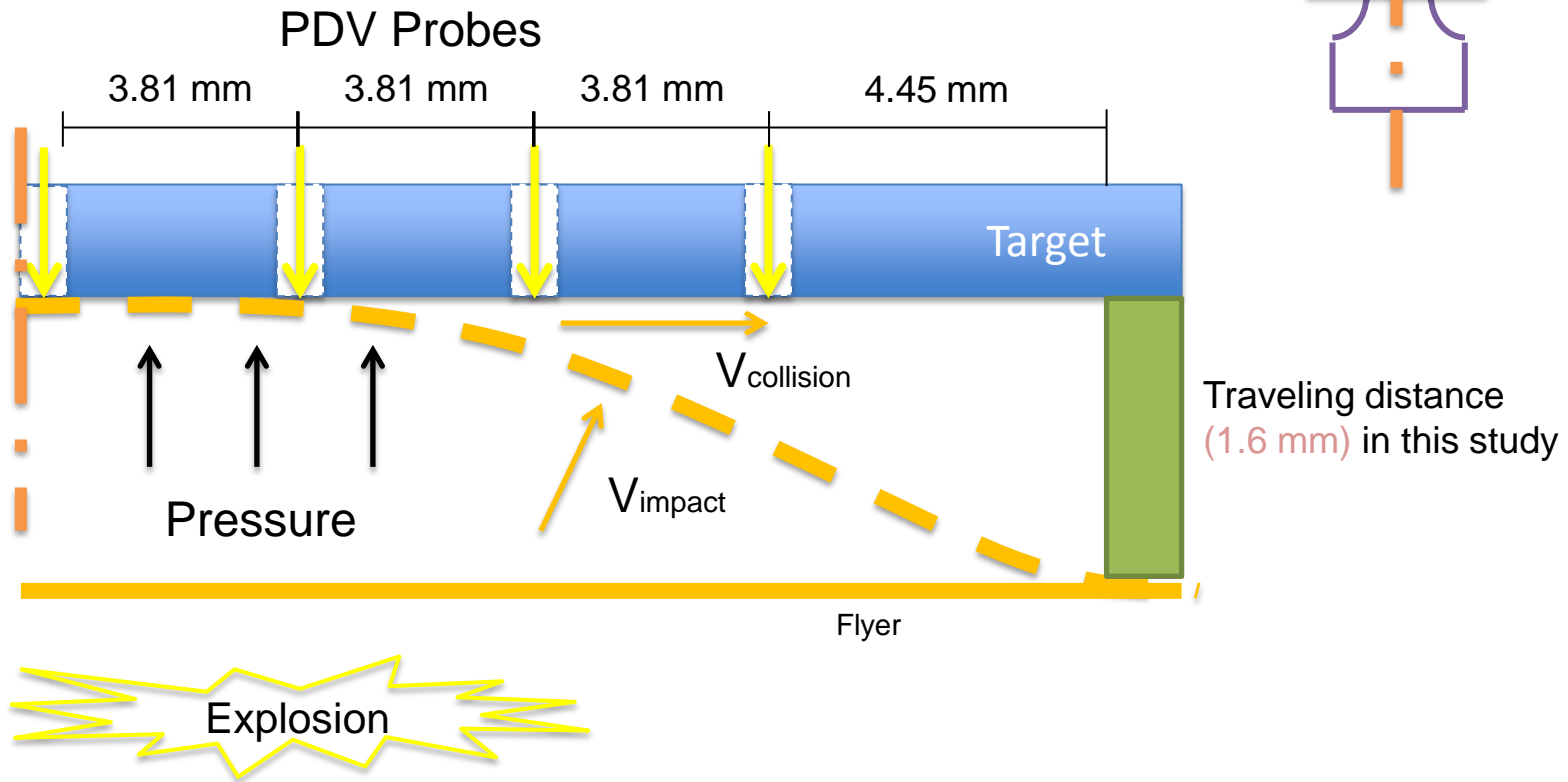
Results

● = standoff distance

.001 inch thick AA1100 at 2.5kJ

.010 inch thick AA1100 at 3.5kJ

Probes separated by 30 μs delay

Results

- Flow Chart for Data Acquisition

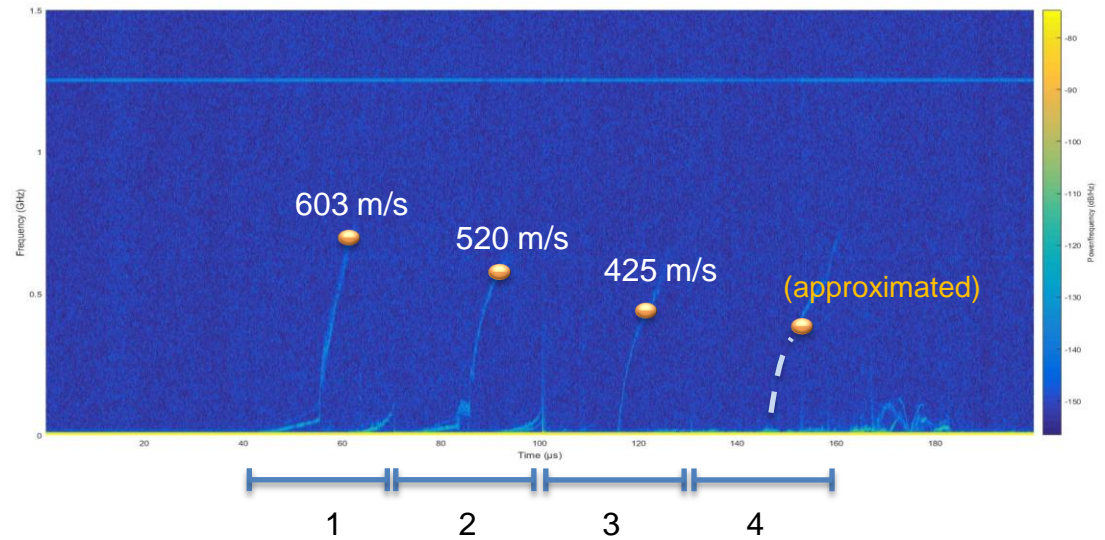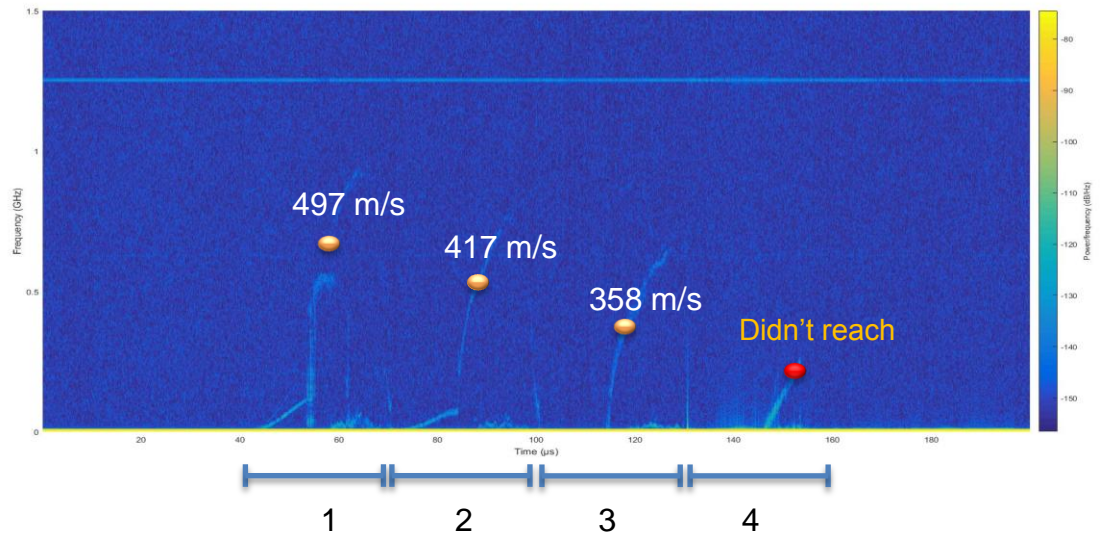| Raw Data	→	Spectrogram	→	Select working window based on the geometry

→	Convert Frequency to Velocity	→	Integrate travel distance	→	Velocity vs. Distance Curve
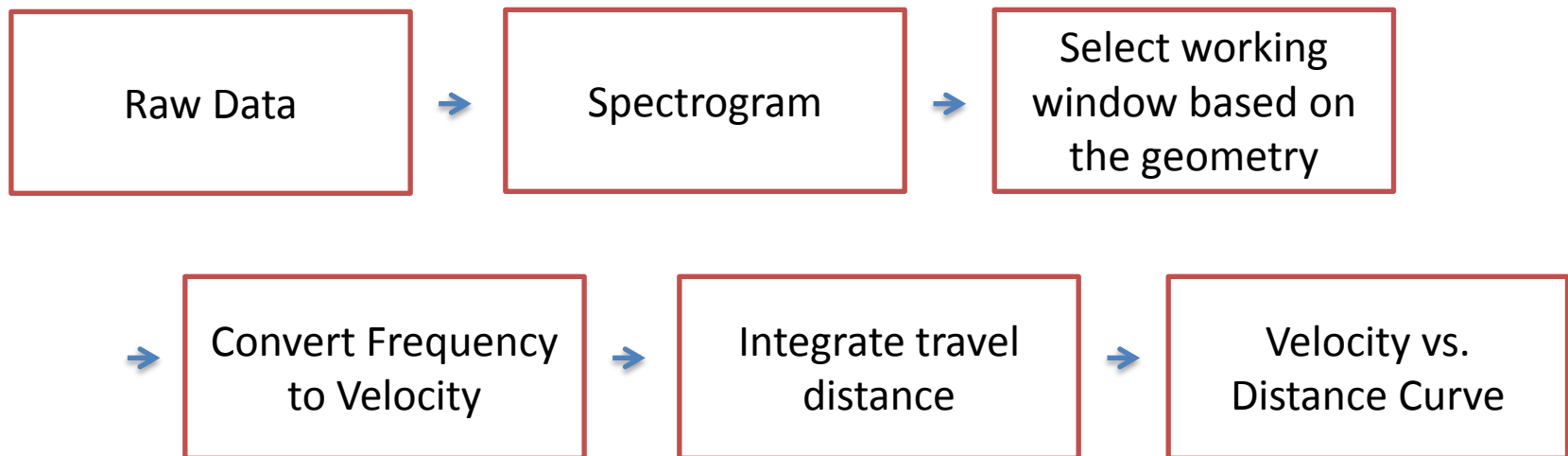
Results

- Flyer Evolution
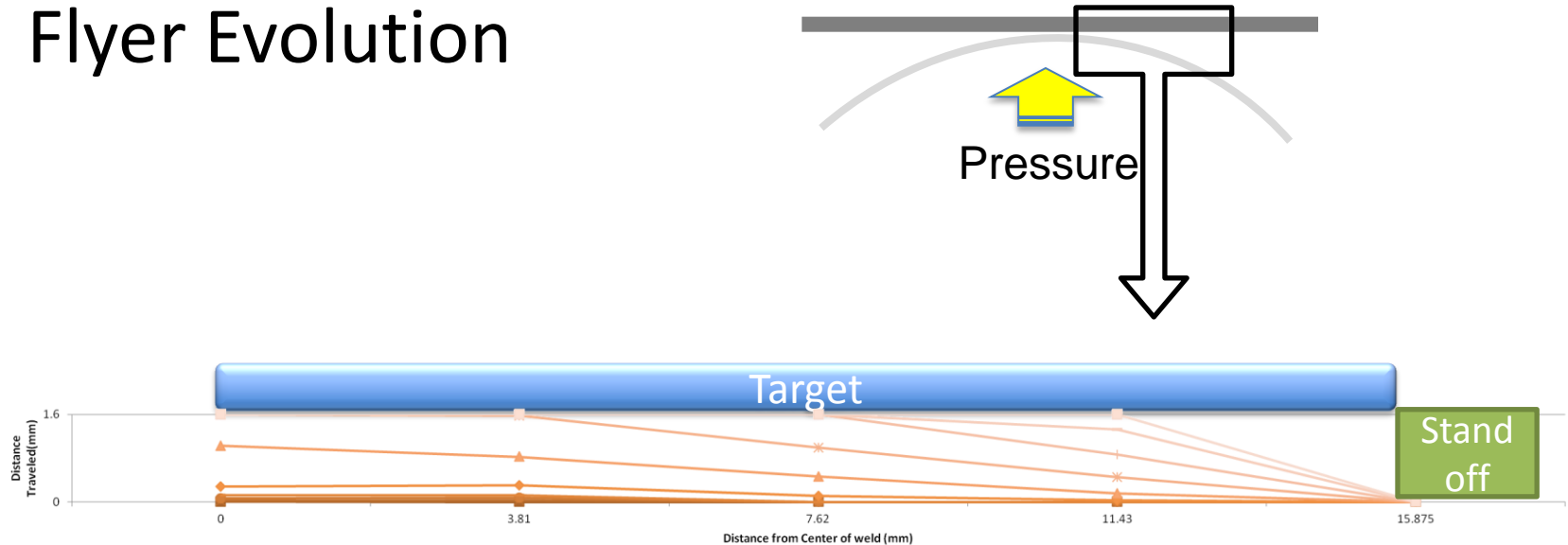
AA 1100 .040 in thick at 5kJ
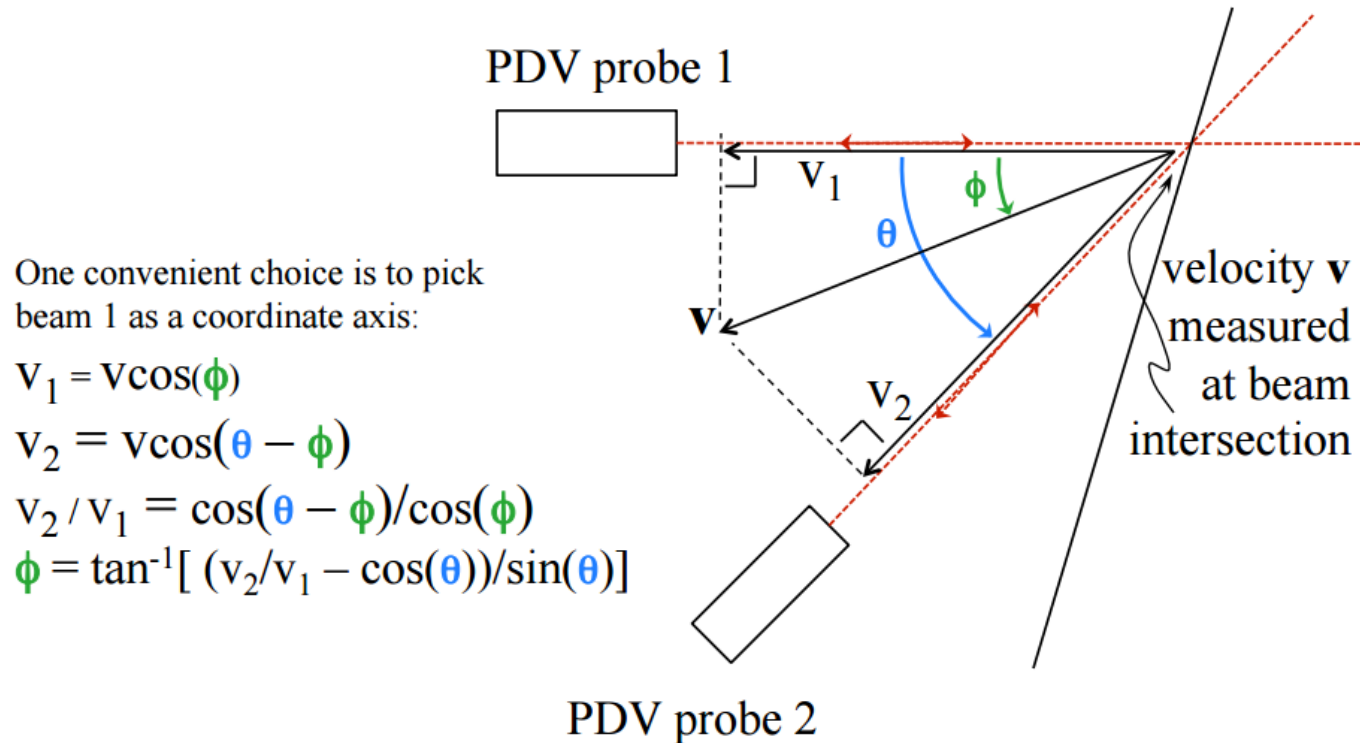Center velocity at collision: 560m/s

Click *Slide Show* for video

Limitation

- Requires very good reflectivity from flyer
  - Retrotape (sometimes spalls off)
  - Marker
  - Brushed surface
- Limited to rough estimation of angle
  - Shorter distance between probes?

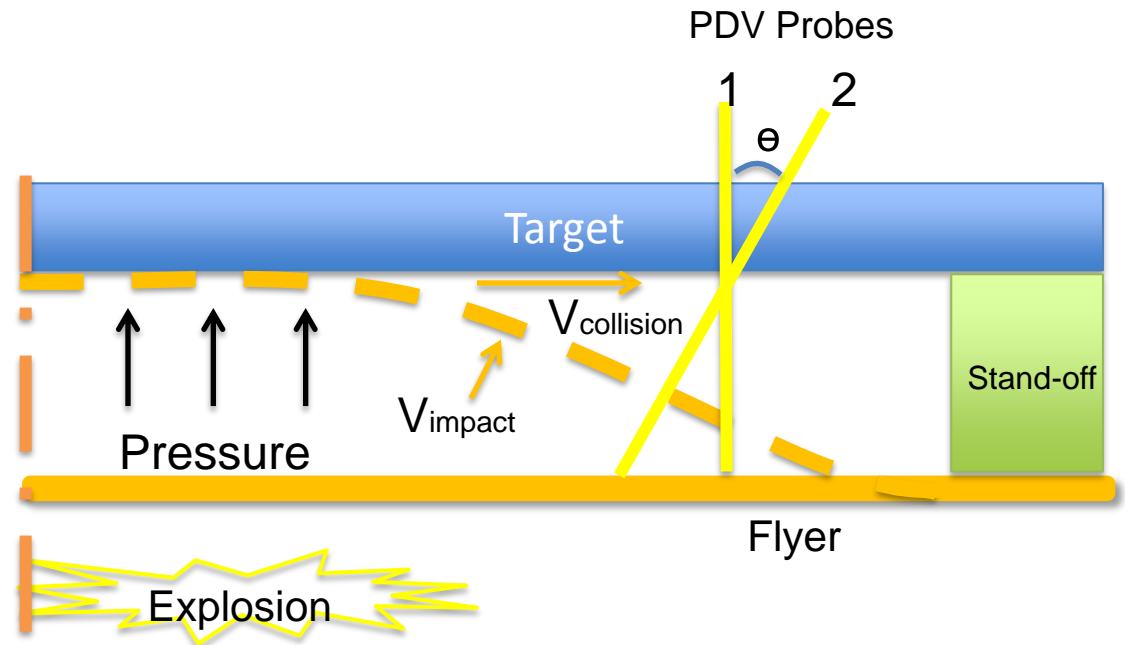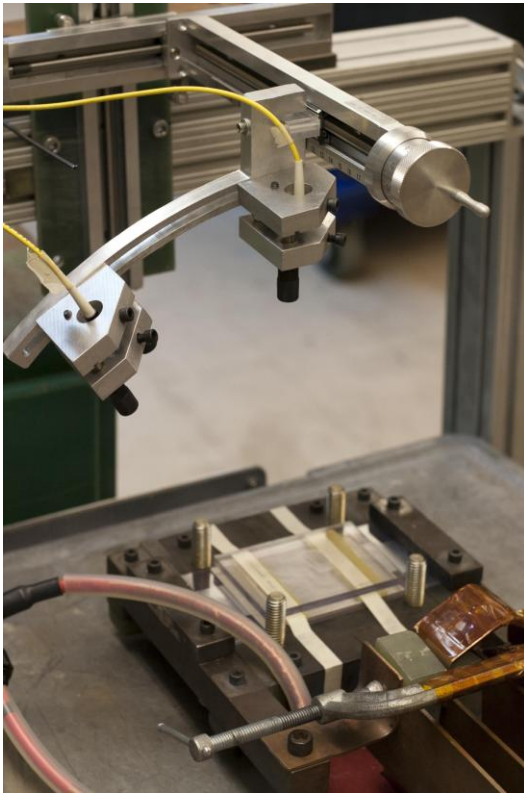DEPARTMENT OF
MATERIALS SCIENCE
AND ENGINEERING

Method Two

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

PDV probe 1

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

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

velocity **v** measured at beam intersection

PDV probe 2

Courtesy: Briggs et al. (2010)
PDV Workshop

Method Two

- Tilted Probing

Results

Spectrogram

PDV Probes

1   2

θ

Nominal beam intersect

30 degrees
Normal

Velocity (m/s)

Time (microsec.)

DEPARTMENT OF
MATERIALS SCIENCE
AND ENGINEERING

THE OHIO STATE UNIVERSITY

12
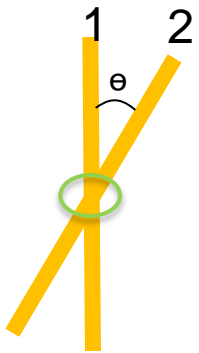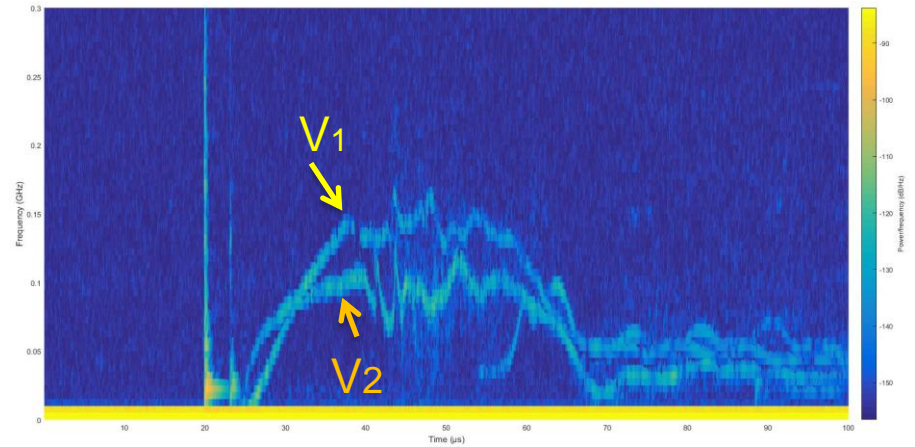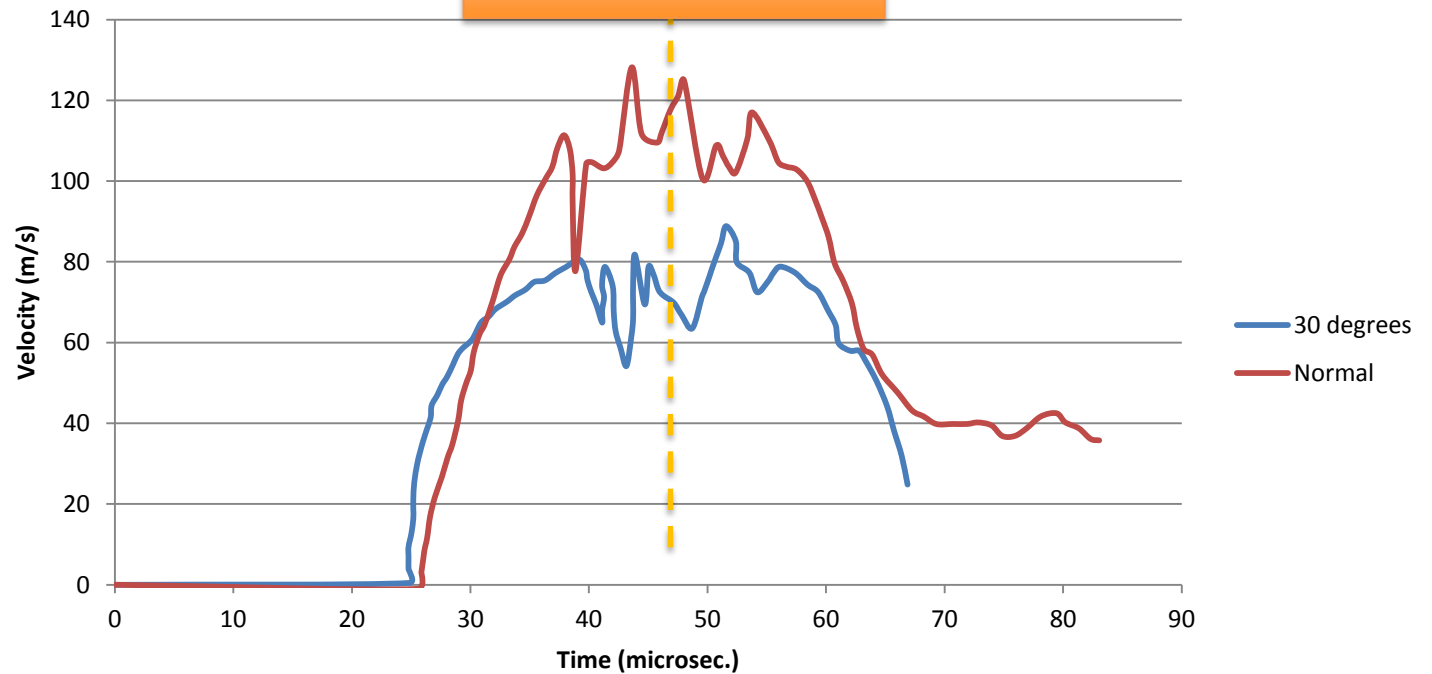
Results

- Tilted Probing Example

$$\varphi = \tan^{-1}[(\frac{V_2}{V_1} - \cos\theta)/\sin\theta]$$

$$V = V_1/\cos\varphi$$

At 1.8 mm,

$V_1 = 121$ m/s $V_2 = 77$ m/s
$\varphi = 25^0$
$V = 134$ m/s
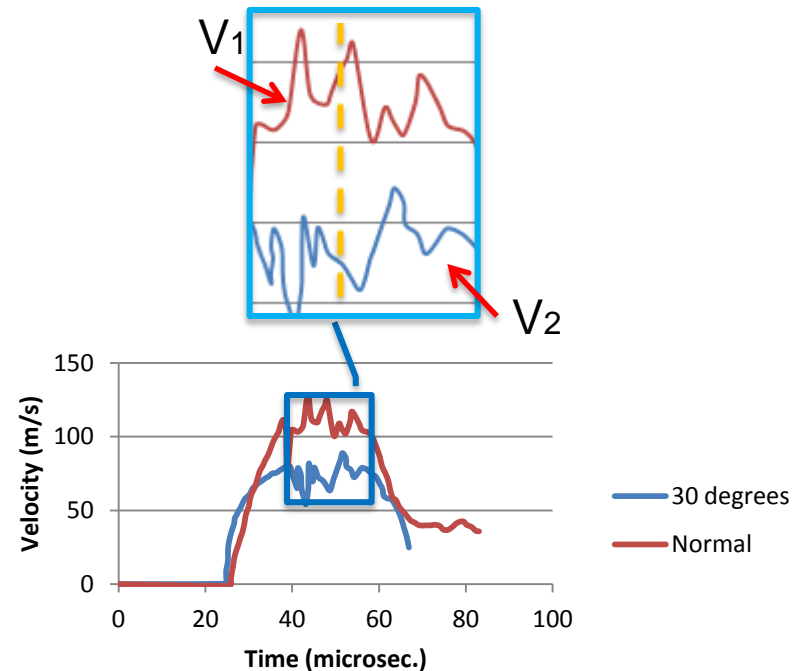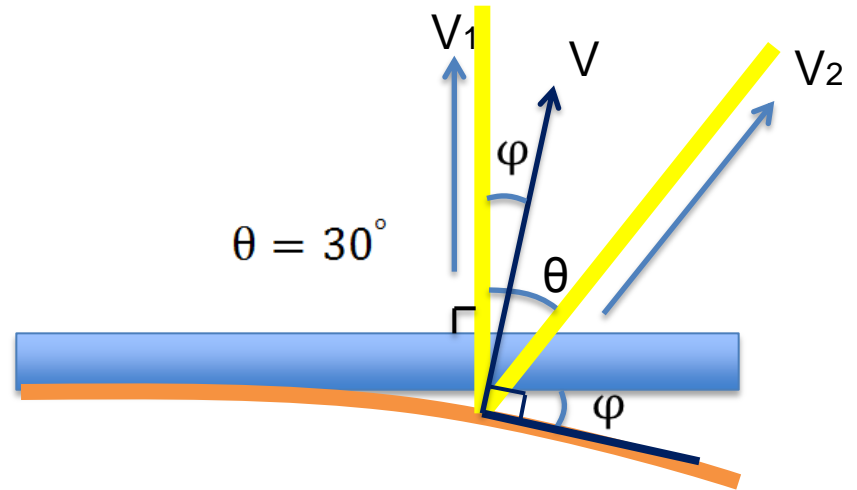
Conclusions

- High Fidelity Signal is required for both methods

- Normal probe array shows unique flyer evolution for different thicknesses

- Two or more arrays of tilted probing will give us more precise angle at multiple locations

Thank you

Questions?

Taeseon Lee
lee.7272@osu.edu