Analysis techniques of heterodyne data for EOS and velocity history

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In collaborations with

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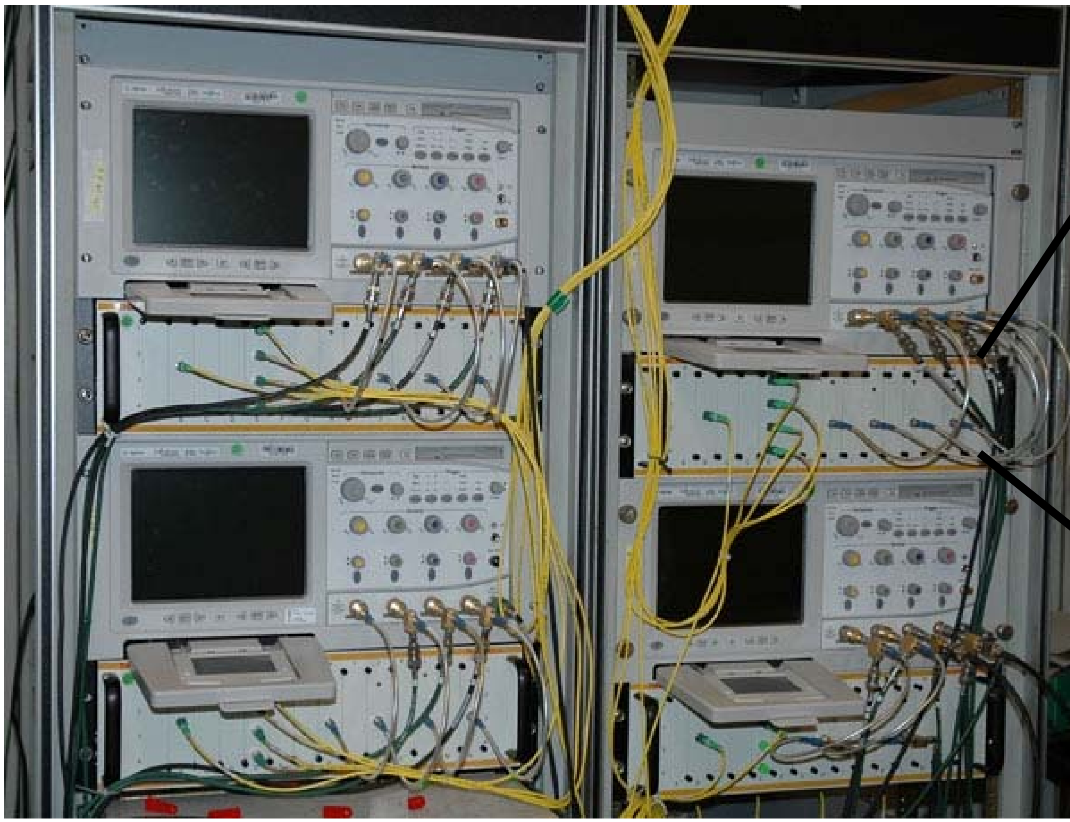
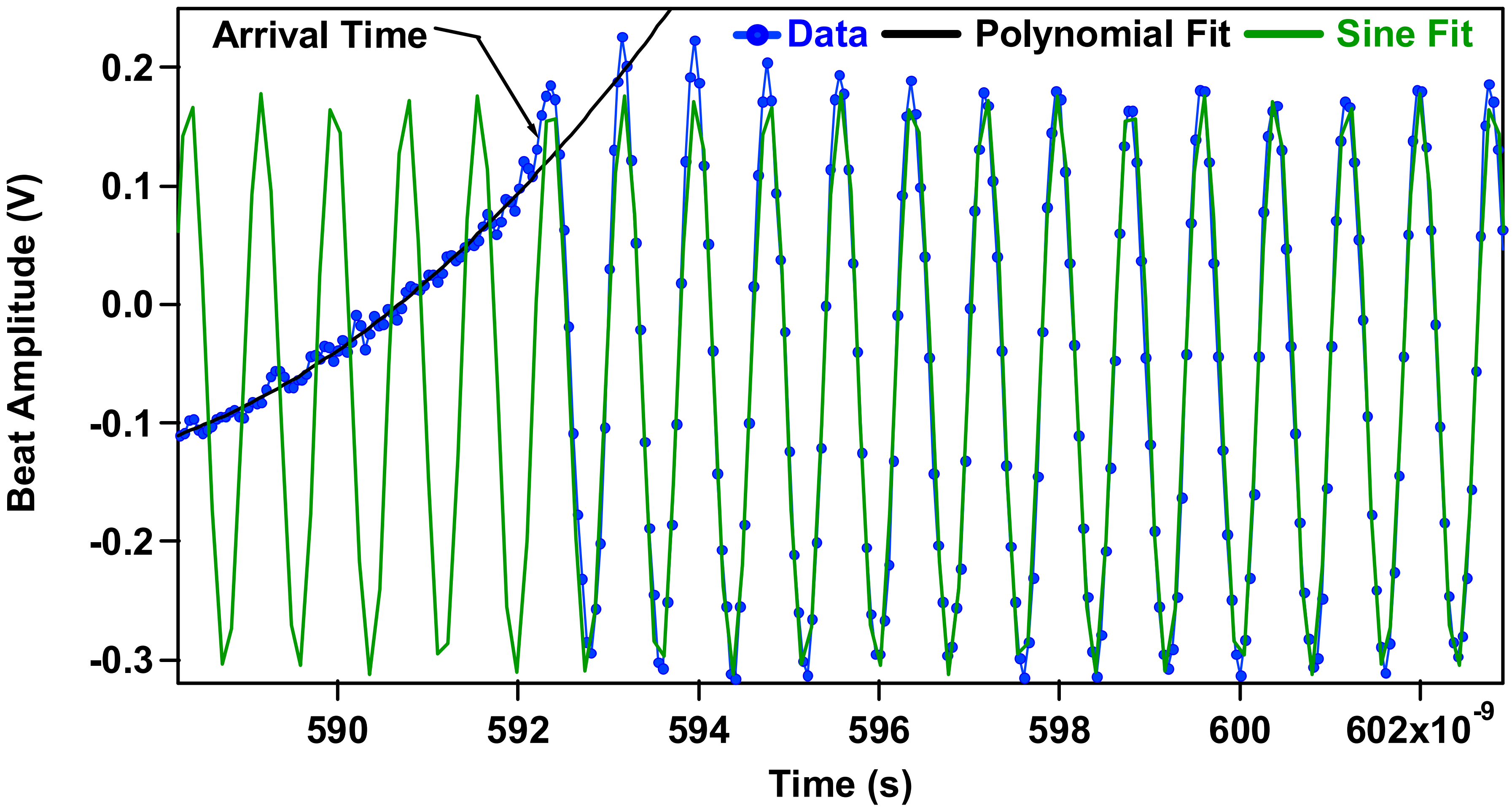
We are using a 13 channel heterodyne system



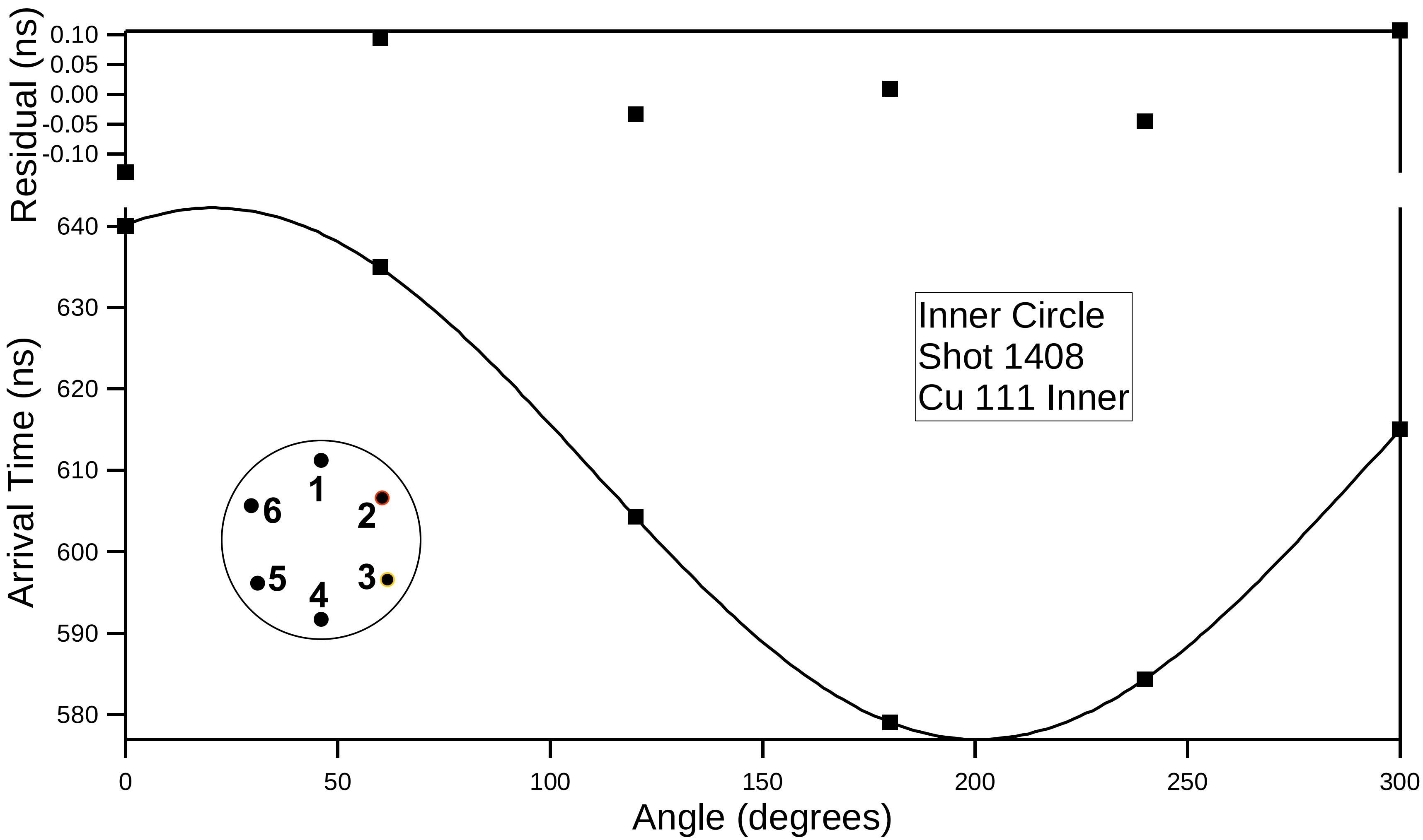
Band Widths	**Scope**	**10 GHz**	→	**Velocity Limit ~ 4.3 GHz**
	Photo Detector	**6 GHz**		**(-3dB) ~ 3.4 km/s**
	Amplifier	**8 GHz**		

Shock arrival time determined with sine and polynomial fits



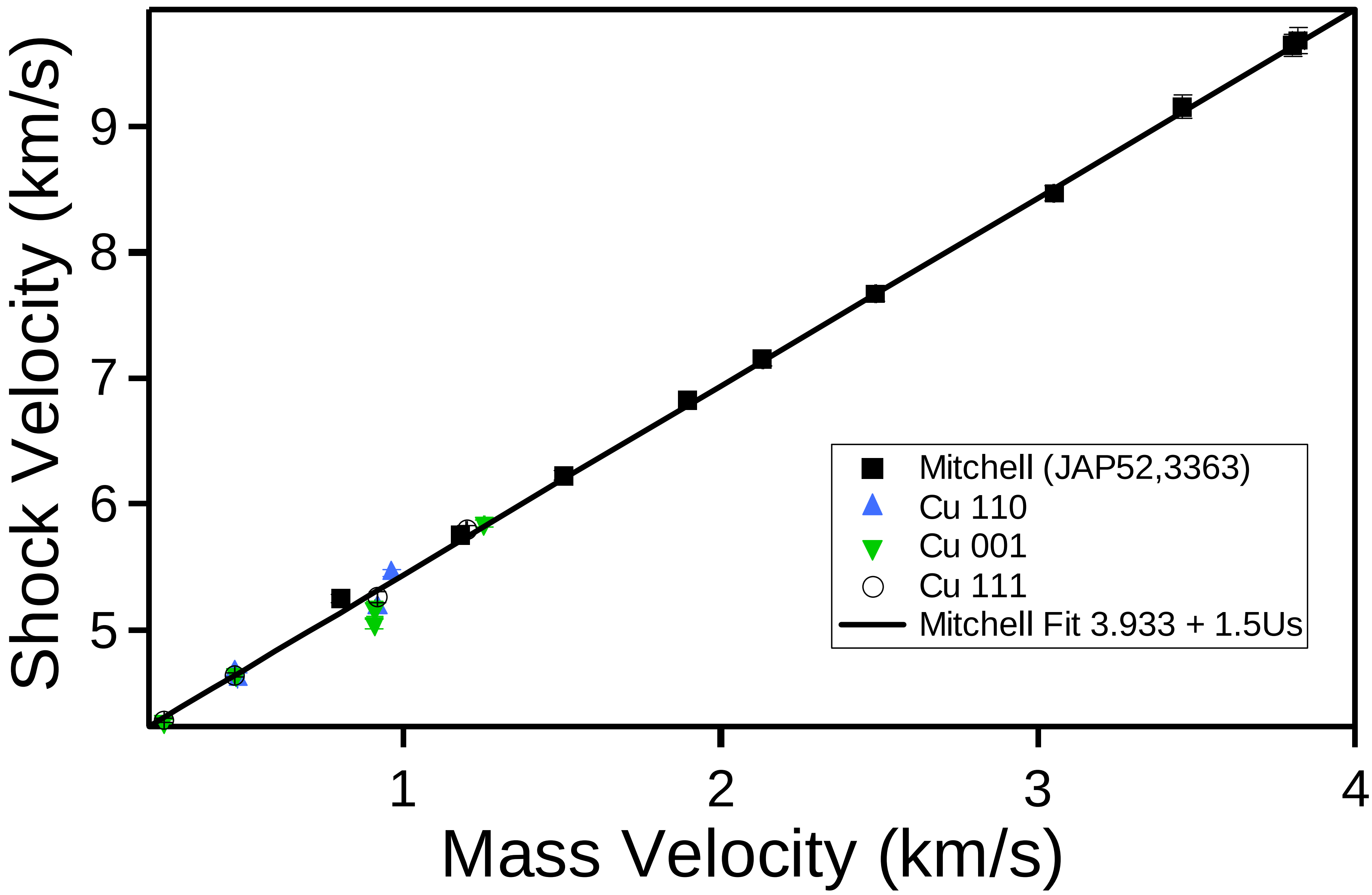
Arrival time derived from the trace to better than 200 ps

Shock arrival times around circular detector arrays follow sine behavior

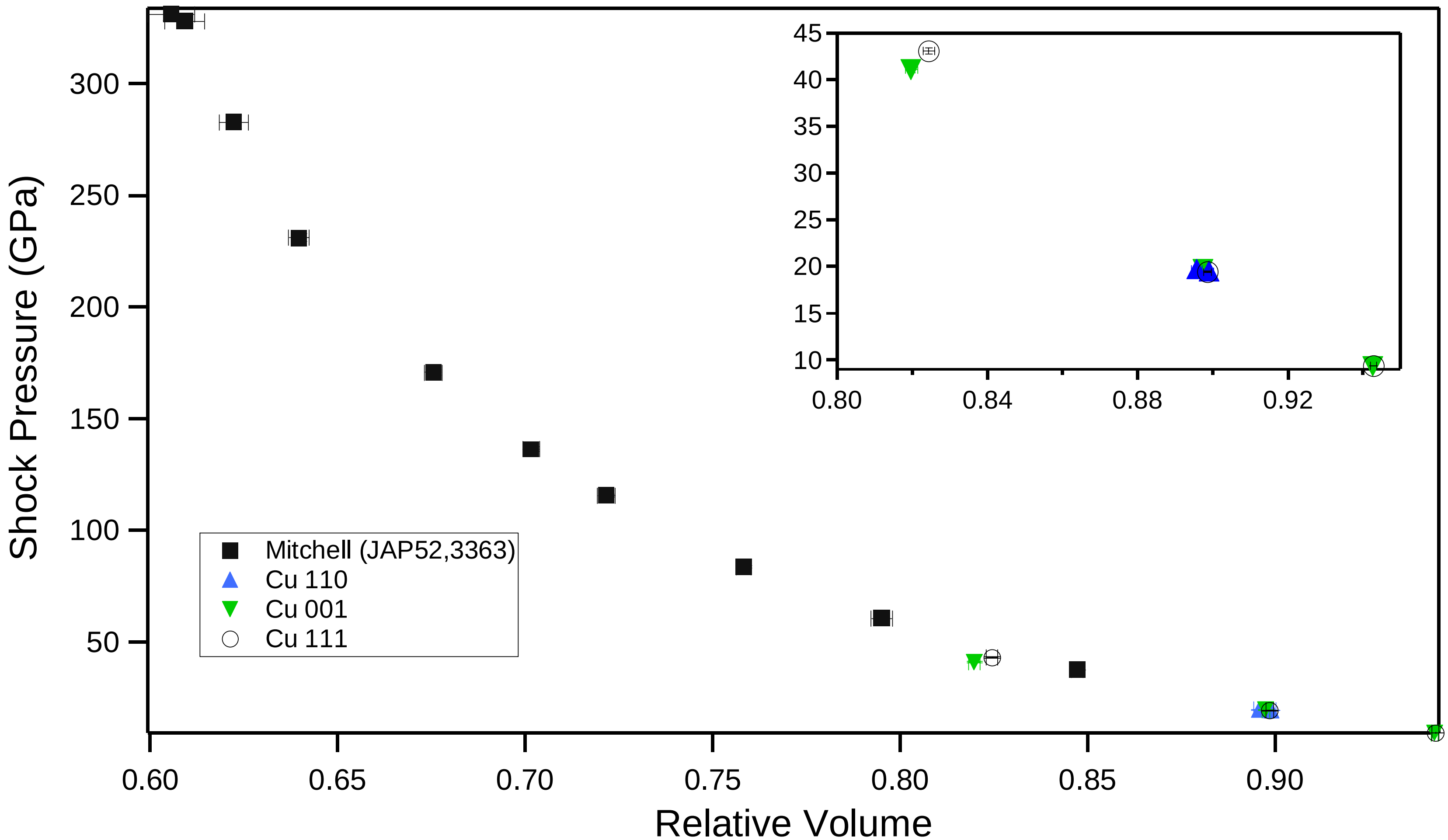


Arrival time detection similar to/better than conventional pin system

Hugoniot Data from Single Crystal Copper

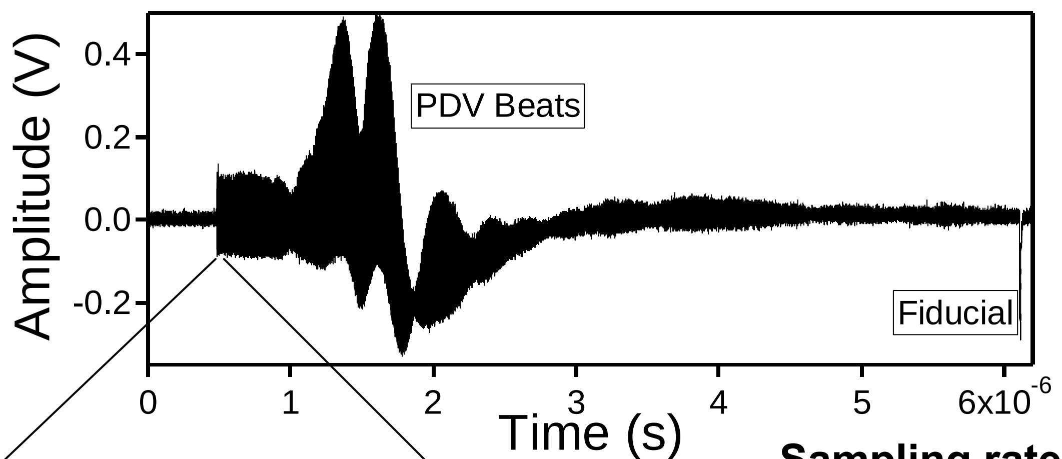


Comparison of single crystal Cu EOS data to previous OFHC Cu data

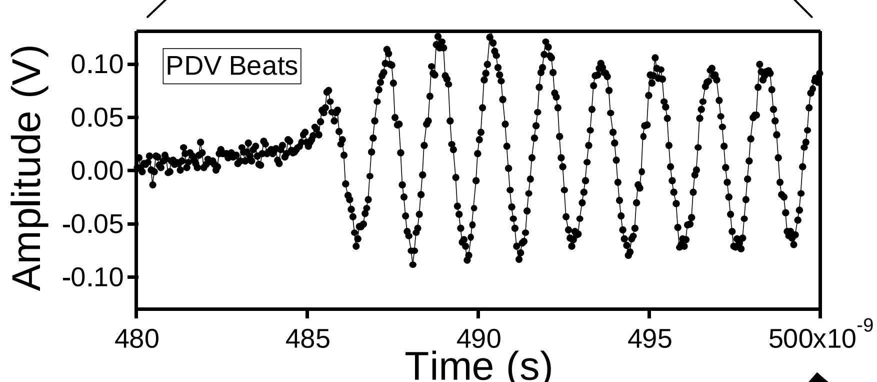


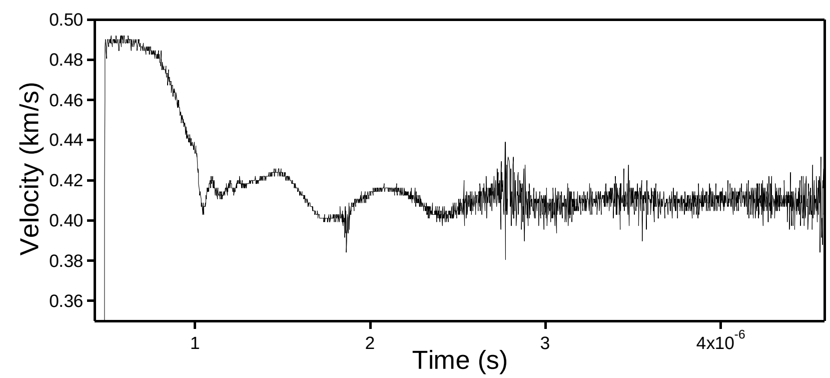
Orientation dependence is not evident in the EOS data

Beat Signal is analyzed to get velocity as a function of time



Sampling rate: 20GS/s → 50 ps/point

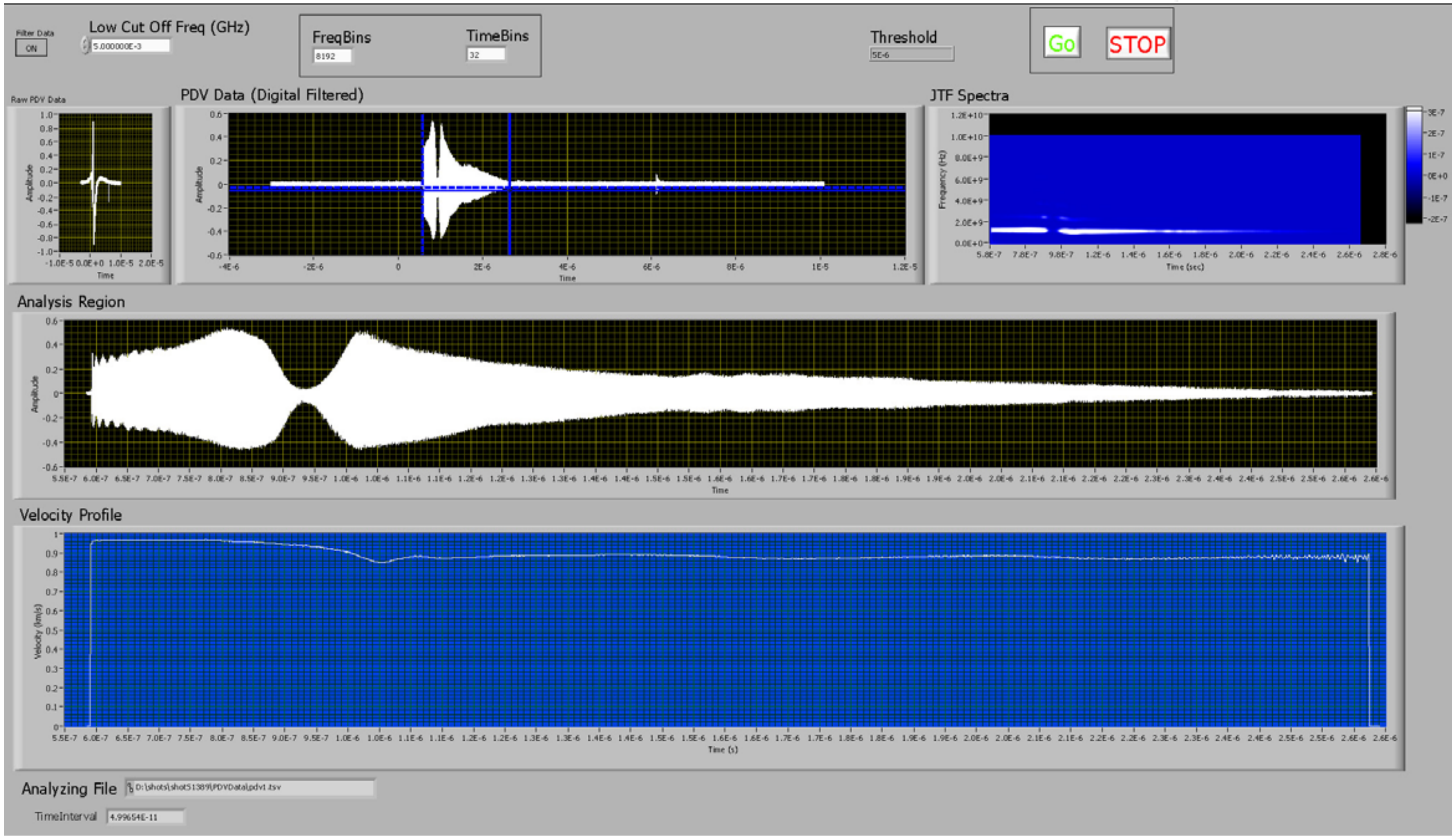




Joint Time-Frequency Analysis

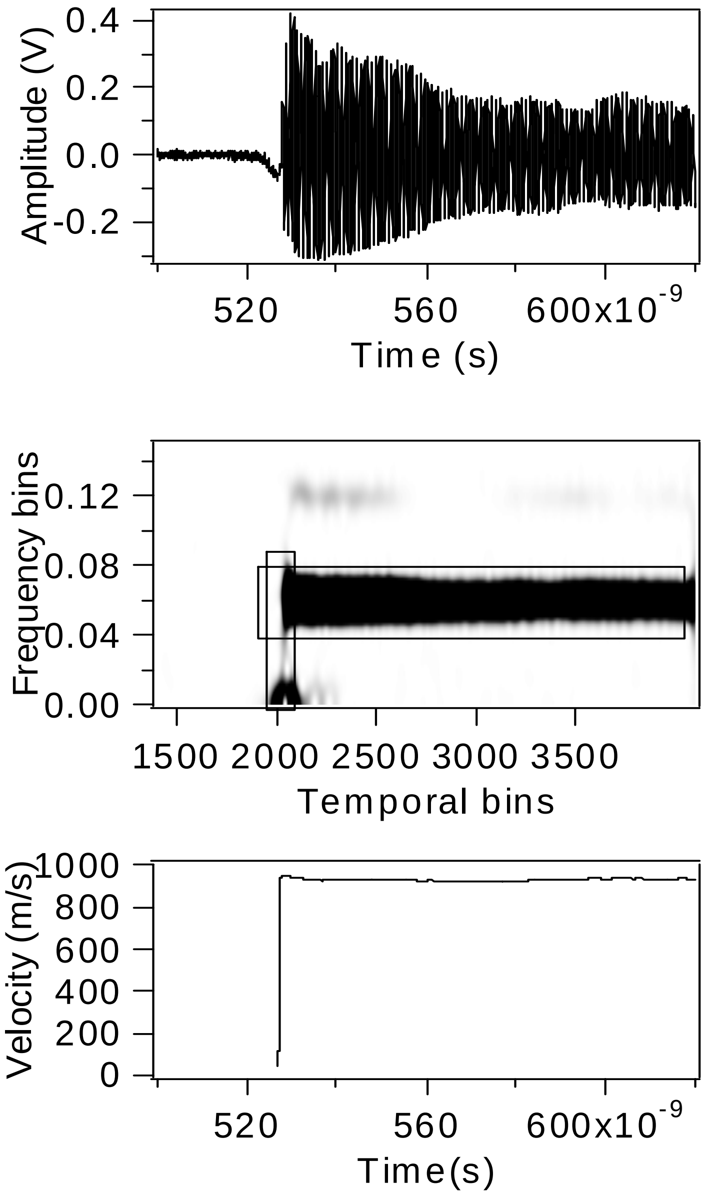
We have developed multiple data reduction tools to analyze data

Beat signals that are evolving in time requires frequency analysis that is local in time



Joint time-frequency analysis derives velocity-time history using Gabor Transform or Short Time Fourier Transform

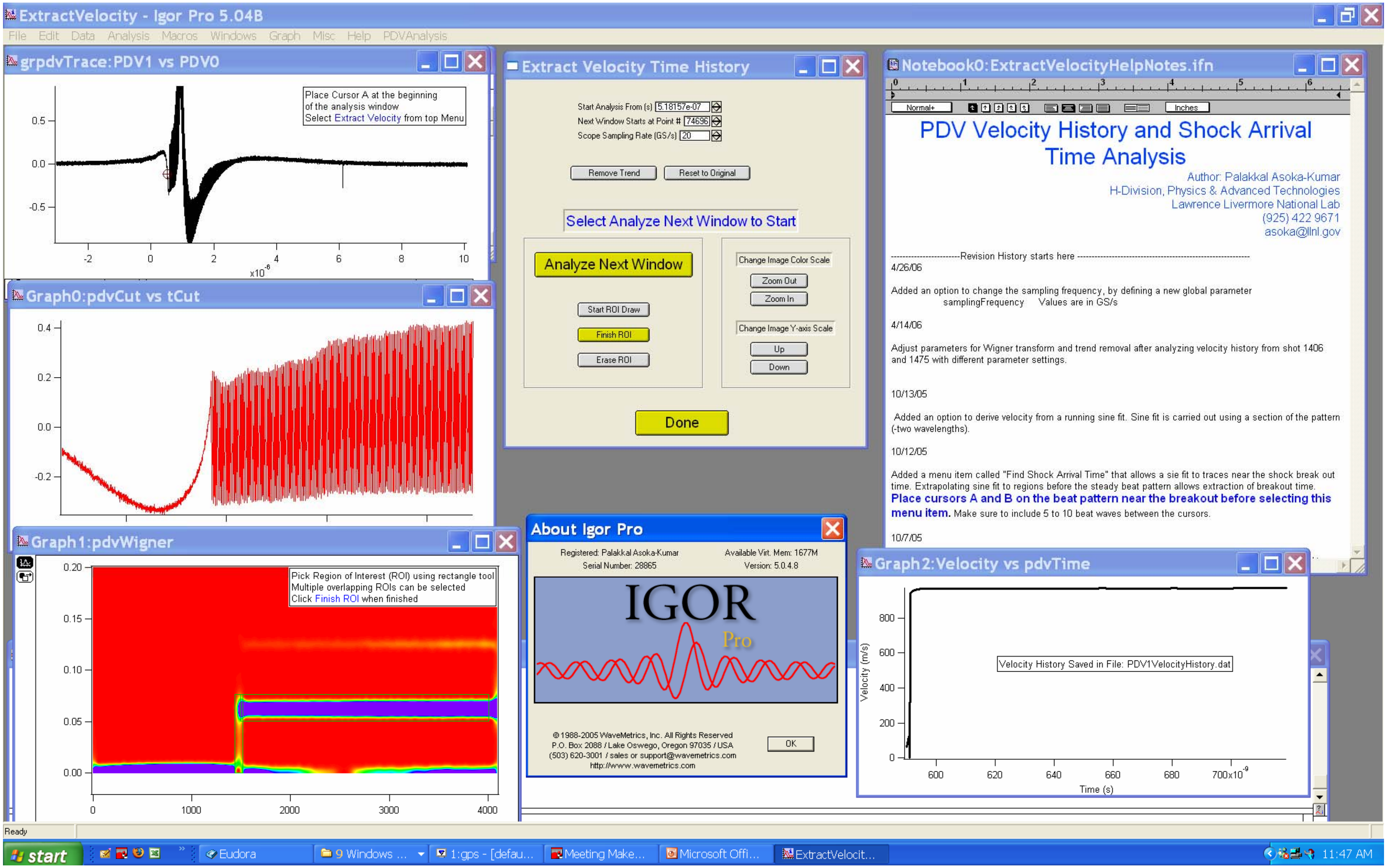
Time history can also be derived using Wigner transform



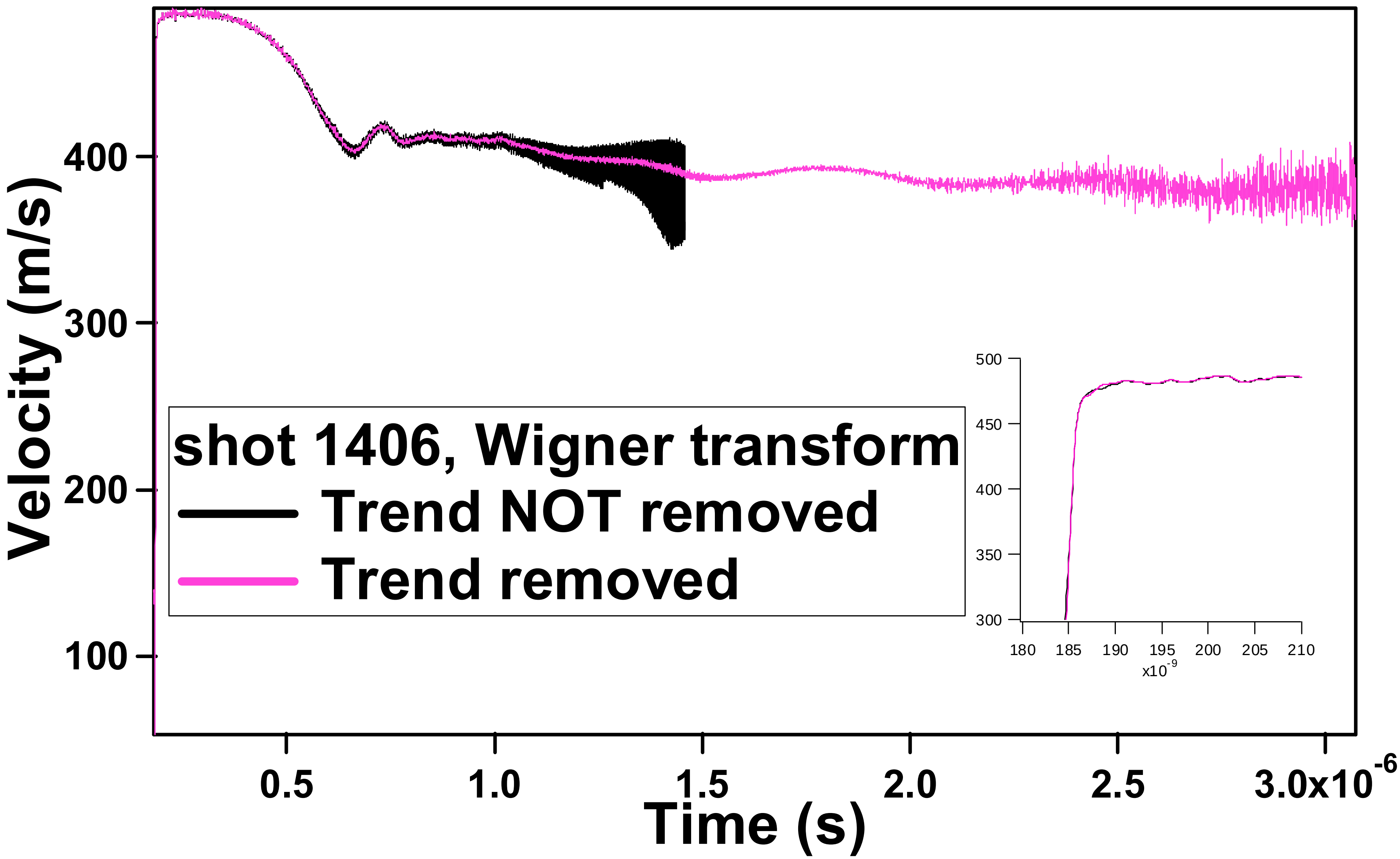
Wigner Transform maps a time signal U(t) into a 2D time-frequency representation (Fourier transform of the autocorrelation function).

$$W(t,\nu) = \int_{-\infty}^{\infty} U(t + \tfrac{x'}{2}) U^*(t - \tfrac{x'}{2}) e^{-2\pi i x' \nu} dx'$$

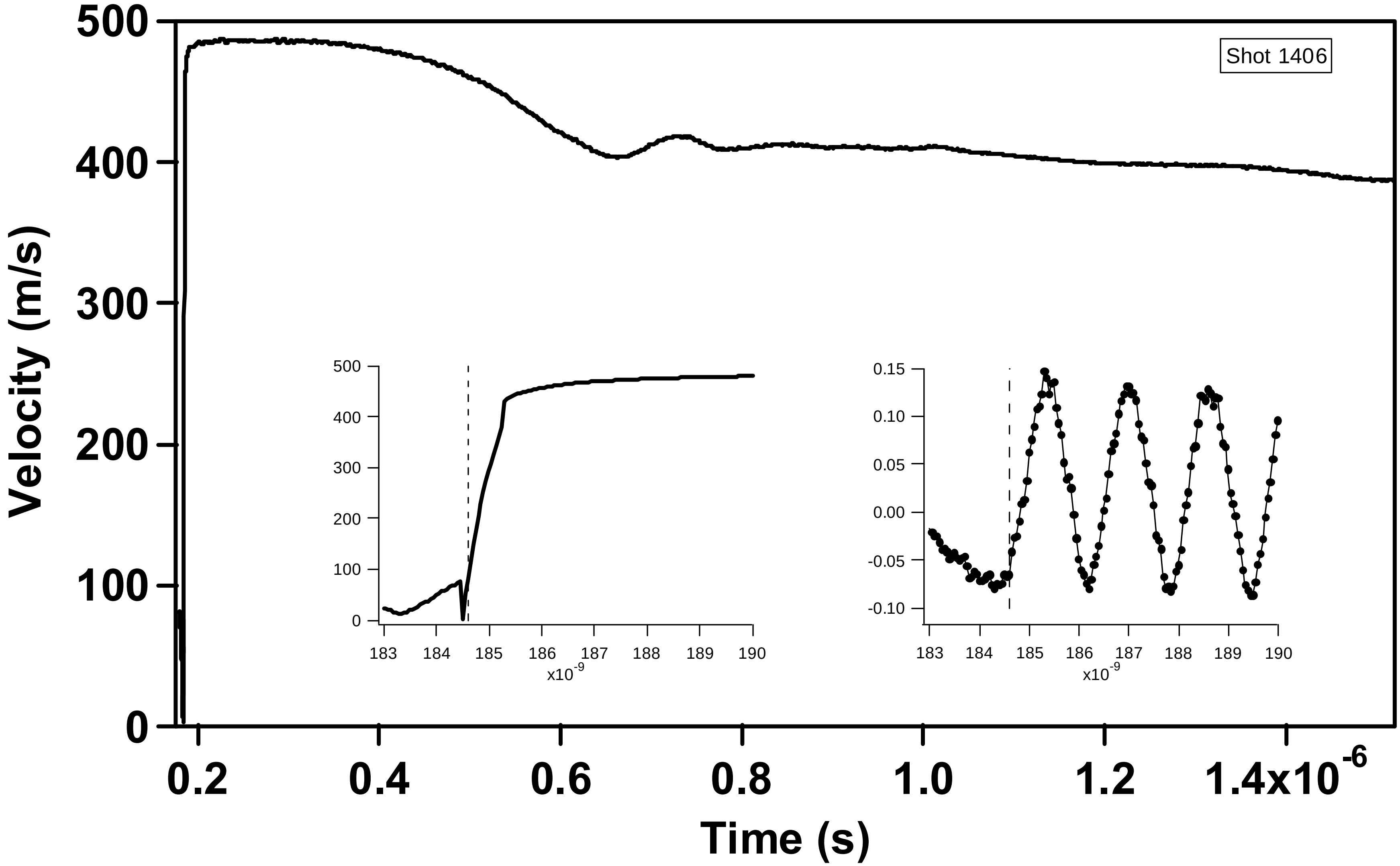
IGOR based Analysis tool for shock arrival time and velocity history



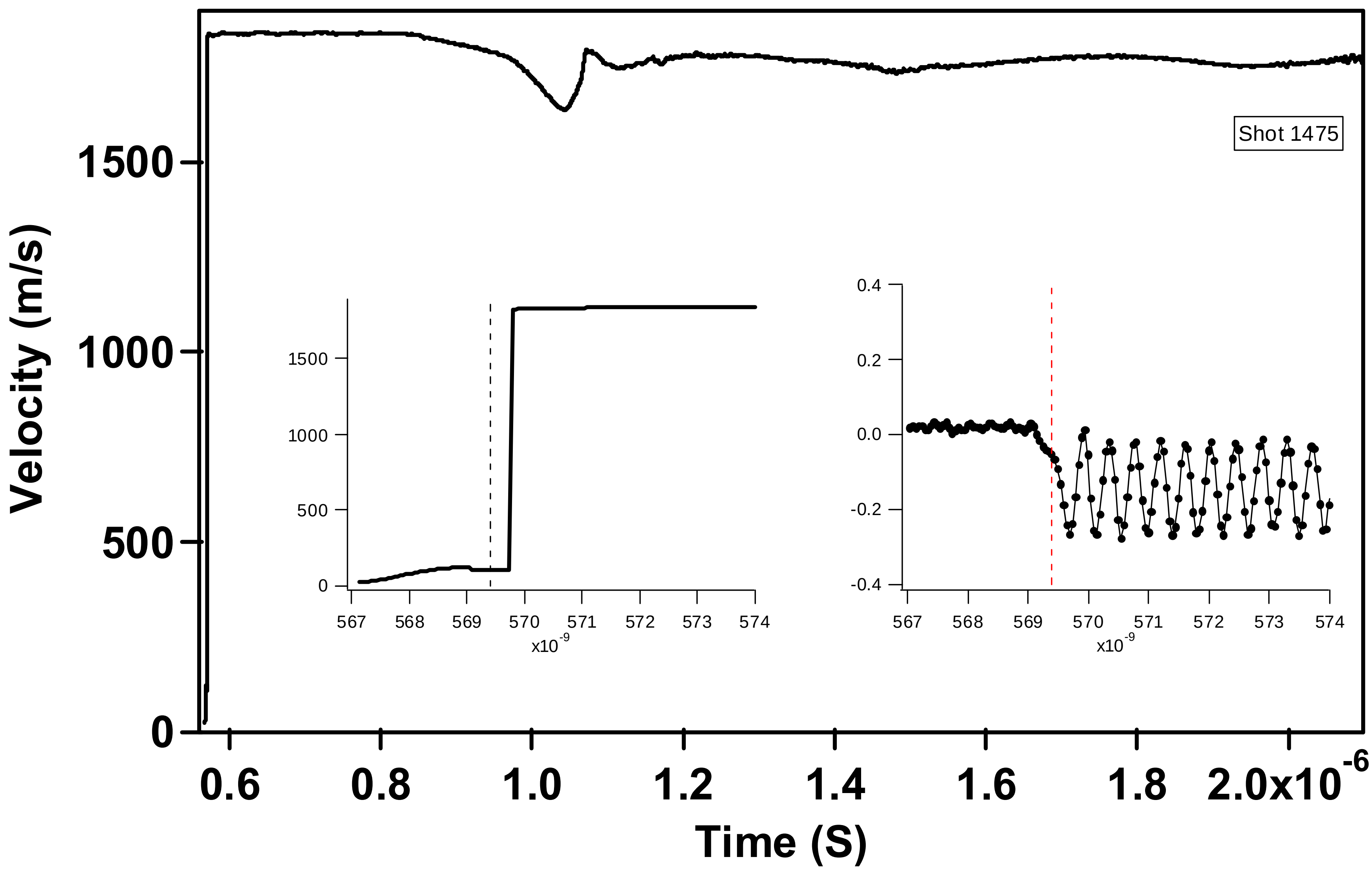
Detrending allows velocity determination to later times



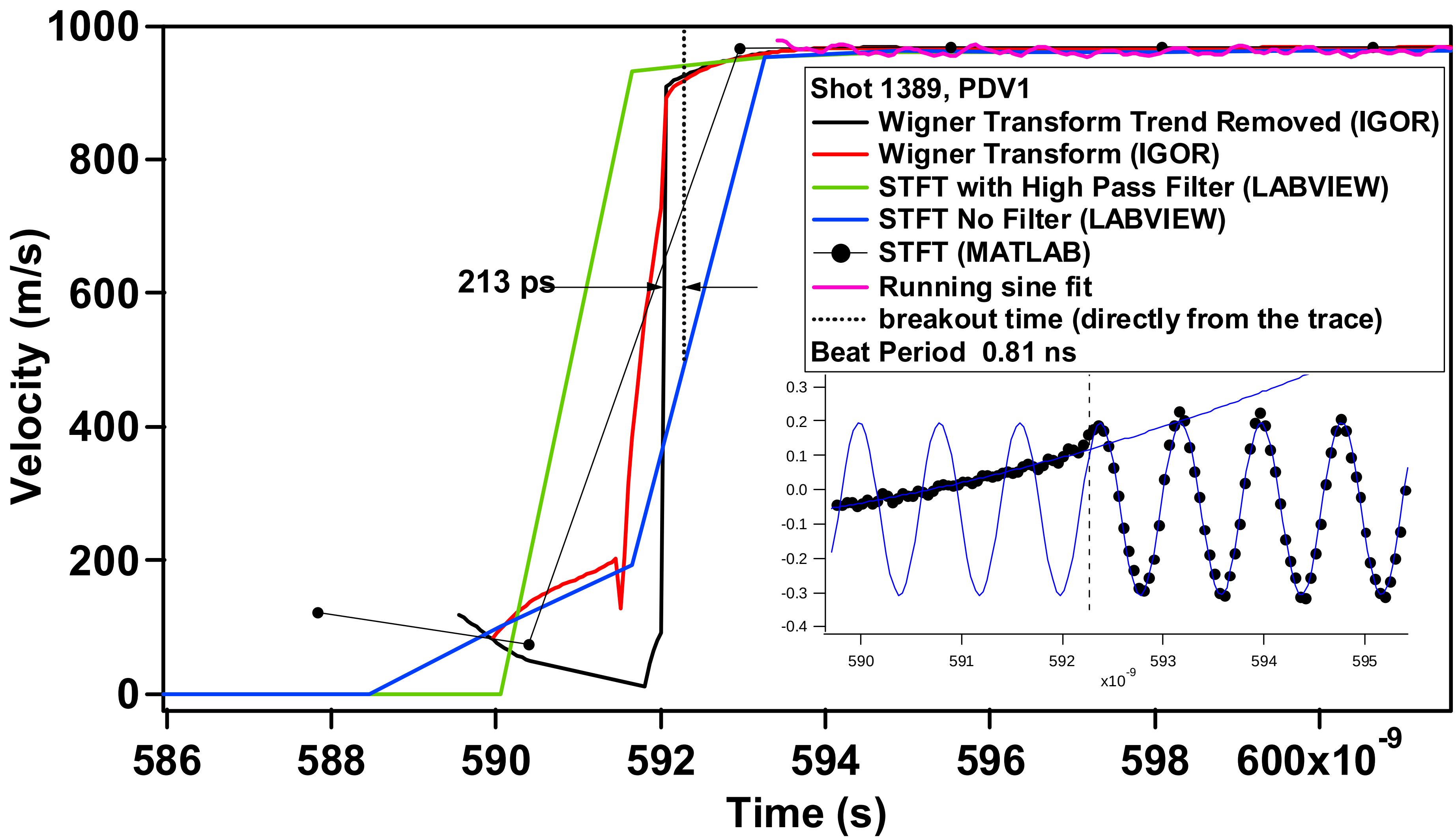
Automated velocity determination near breakout is difficult



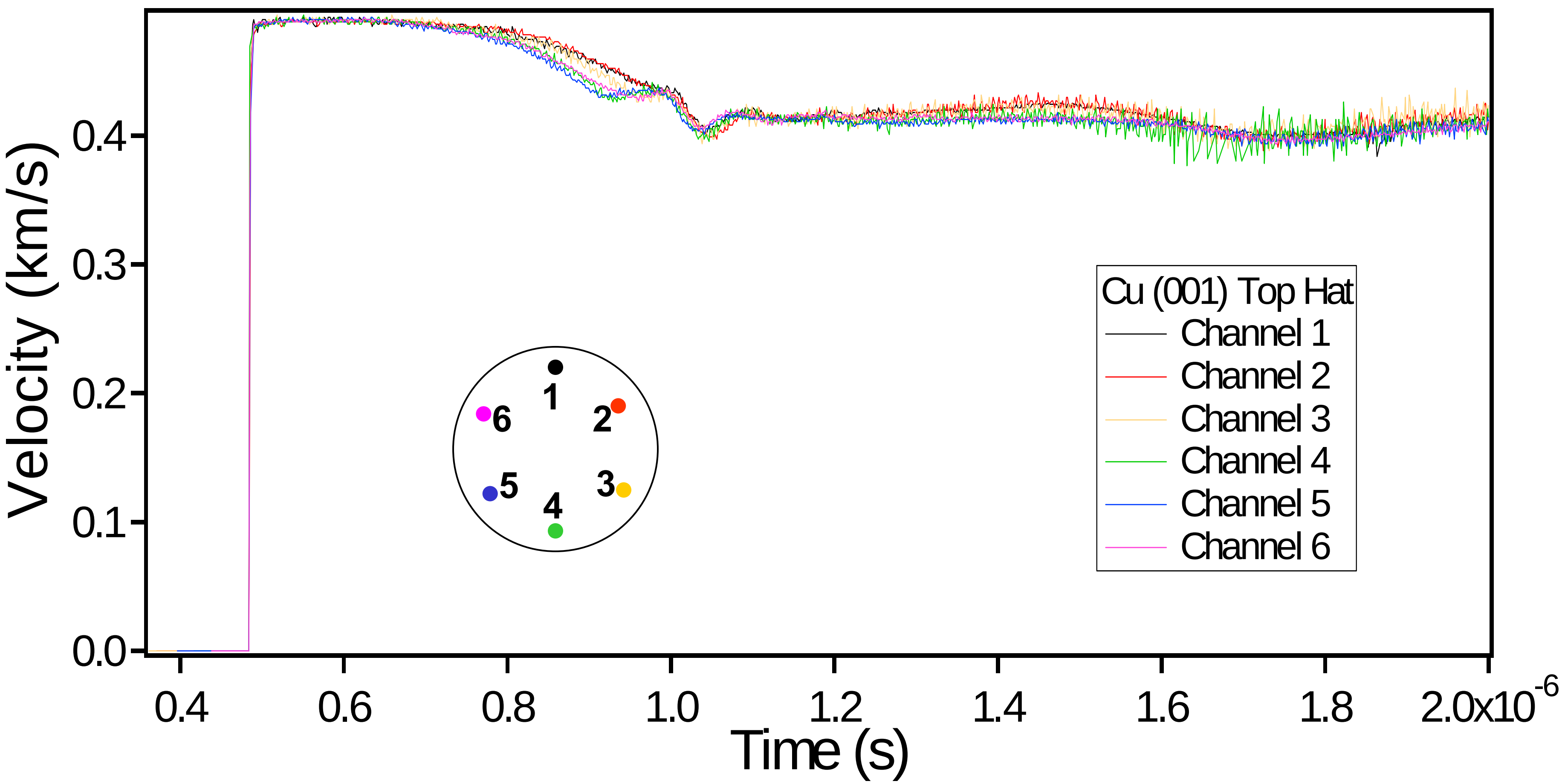
Automated Velocity Determination near breakout is difficult (contd.)



Velocity history near breakout using different analysis

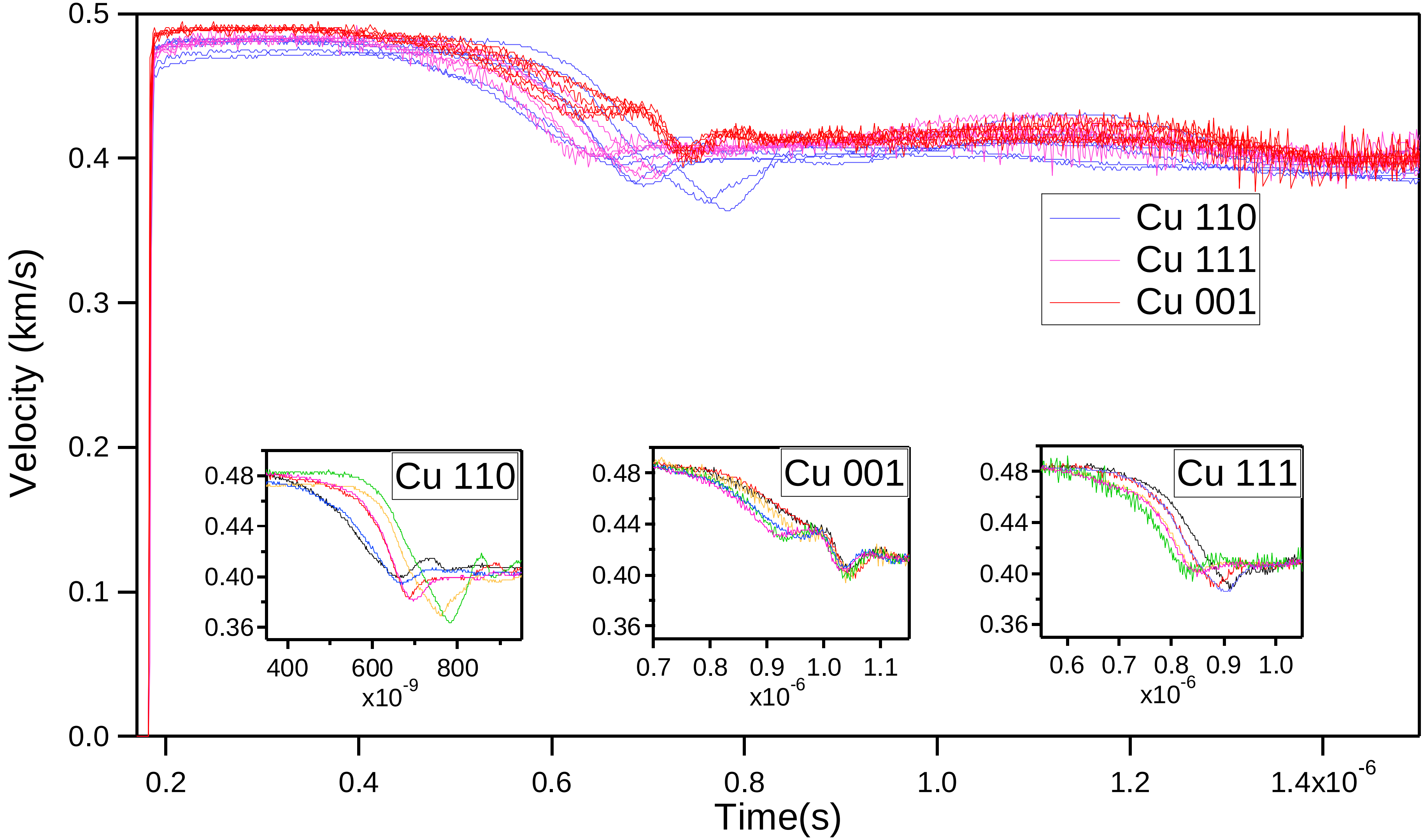


Velocity-time history shows features not easily visible in VISAR traces

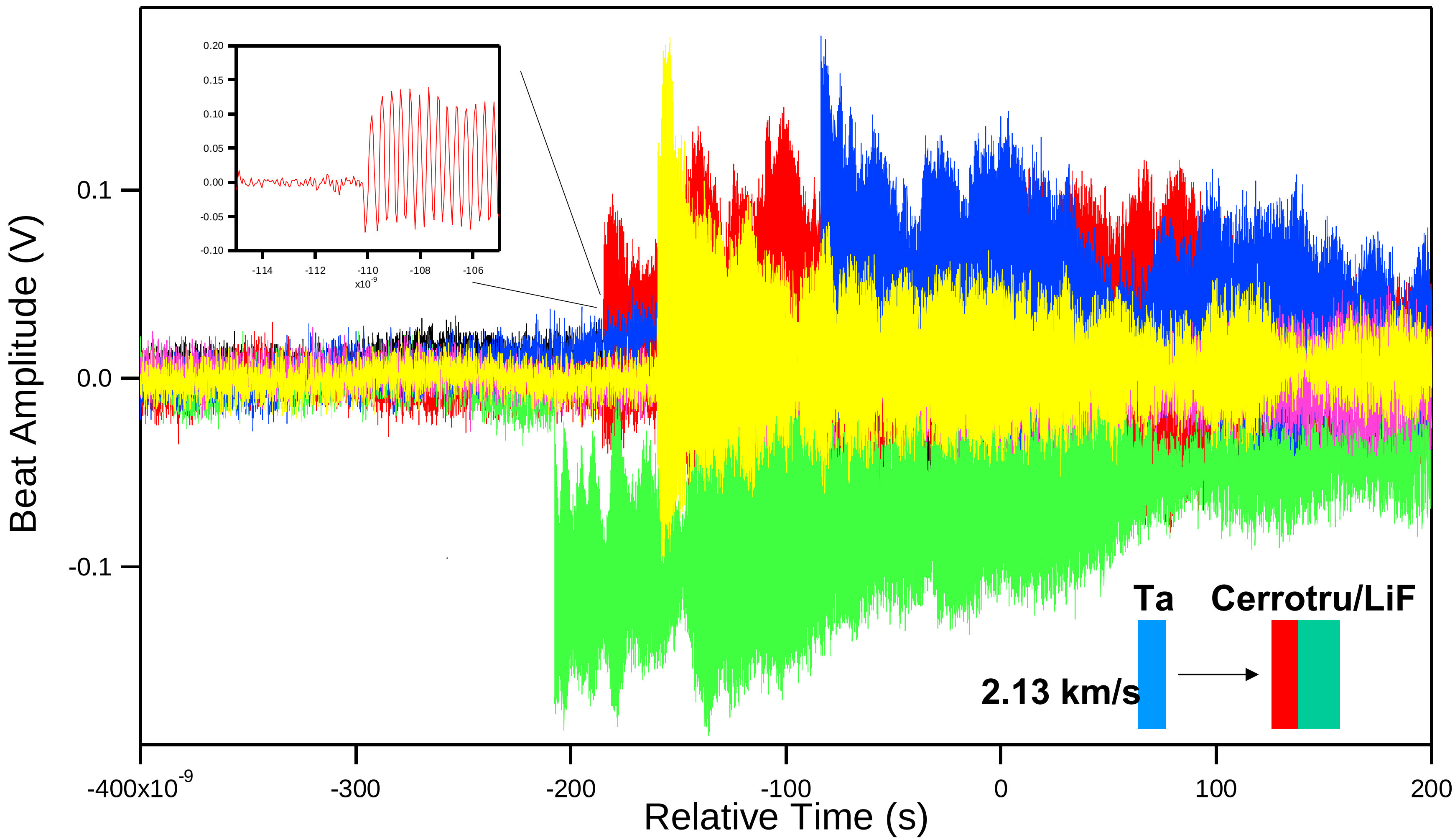


Pull back signals can be used to measure spall strength

Velocity-time history for 3 different crystal orientations



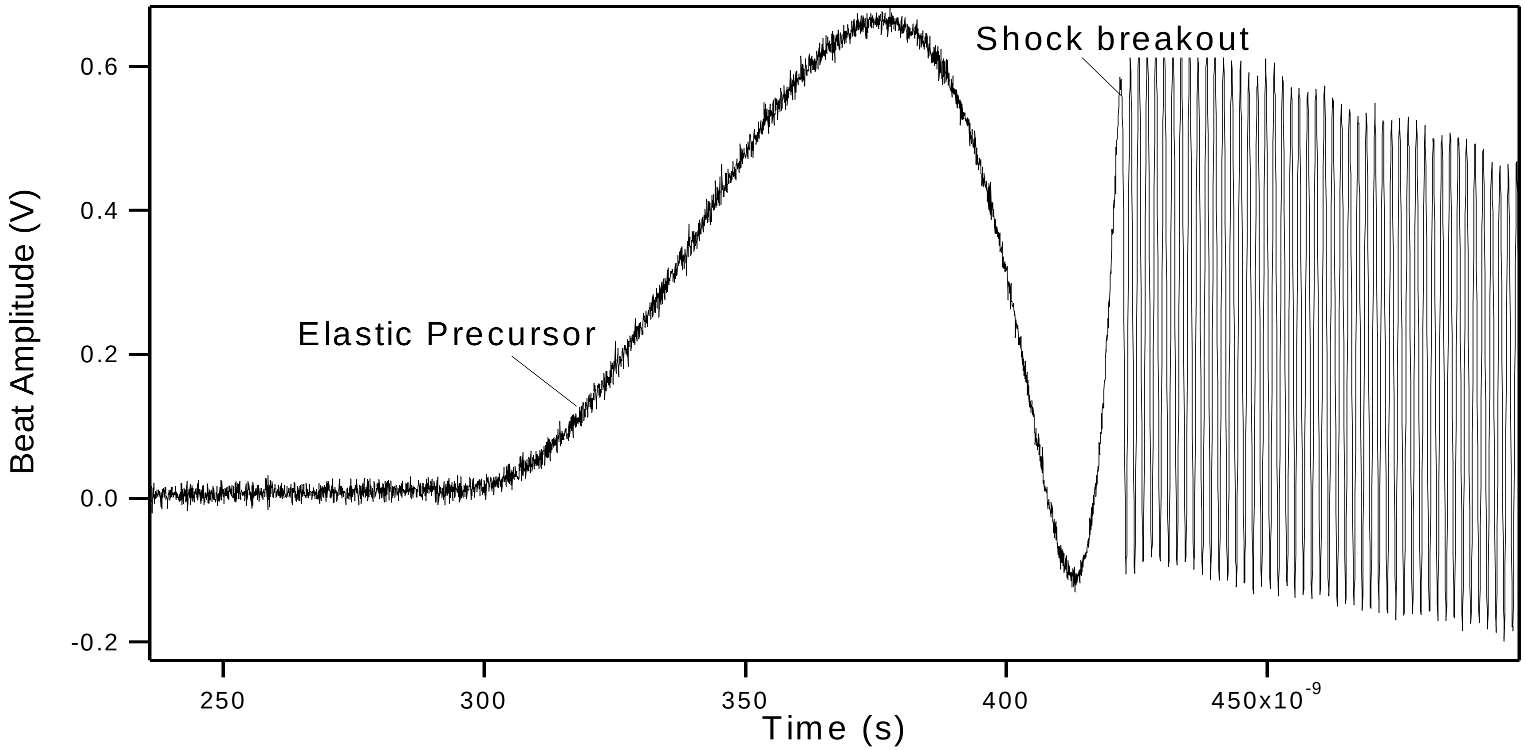
We have performed measurements on targets with LiF windows



Velocity measured through shocked LiF is approximately 28% higher.
LiF surface preparation is important to get good fringe contrast.

Elastic precursor and shock breakout are clearly visible in beat recordings

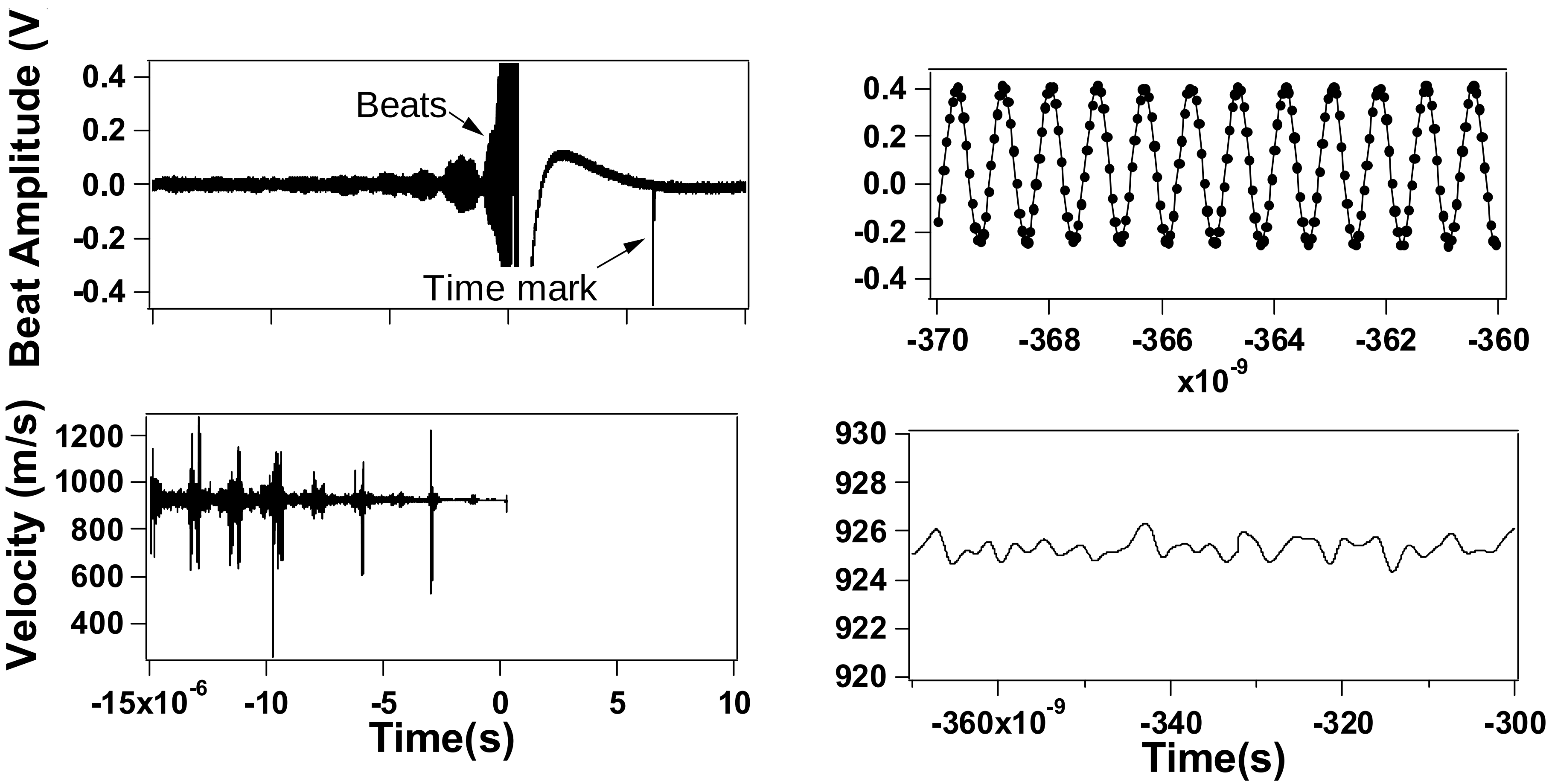
Target & projectile: Cu (111), Projectile velocity 0.49 km/s



Sound Velocity

	Beats	Derived from Elastic Stiffness (RT)
Cu 001	4.303 km/s	4.347 km/s
Cu 110	4.907 km/s	4.987 km/s
Cu 111	5.053 km/s	5.183 km/s

Projectile velocity history mapped with a bare fiber probe



Conclusion

- Velocity-time history shows detailed features that are not easily discernable with other techniques.
- Shock arrival time and velocity-time history can be obtained using same channel.
- We developed several methods to analyze beat signals.
- EOS measurements form single crystal copper show no orientation dependence in the pressure range of 9-45 GPa.
- Elastic-plastic release is evident in velocity-time history.