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Line VISAR options for the NTS Large Bore Powder Gun

Michael Furnish, Wayne Trott, Tom Ao, Tracy Vogler, William Reinhart

Sandia National Laboratories, Albuquerque NM

Lalit Chhabildas,

Air Force Research Laboratory, Eglin AFB, FL

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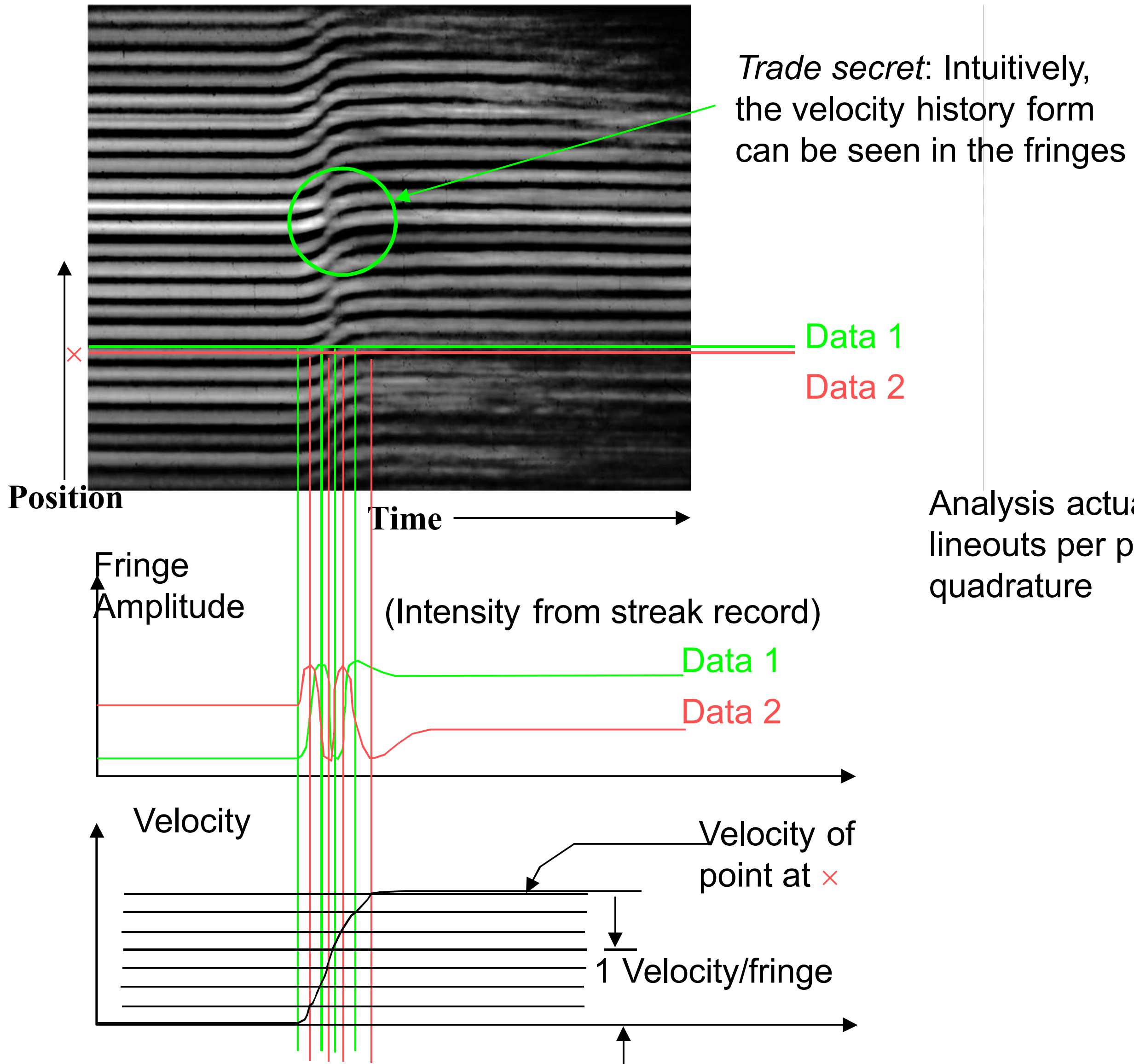
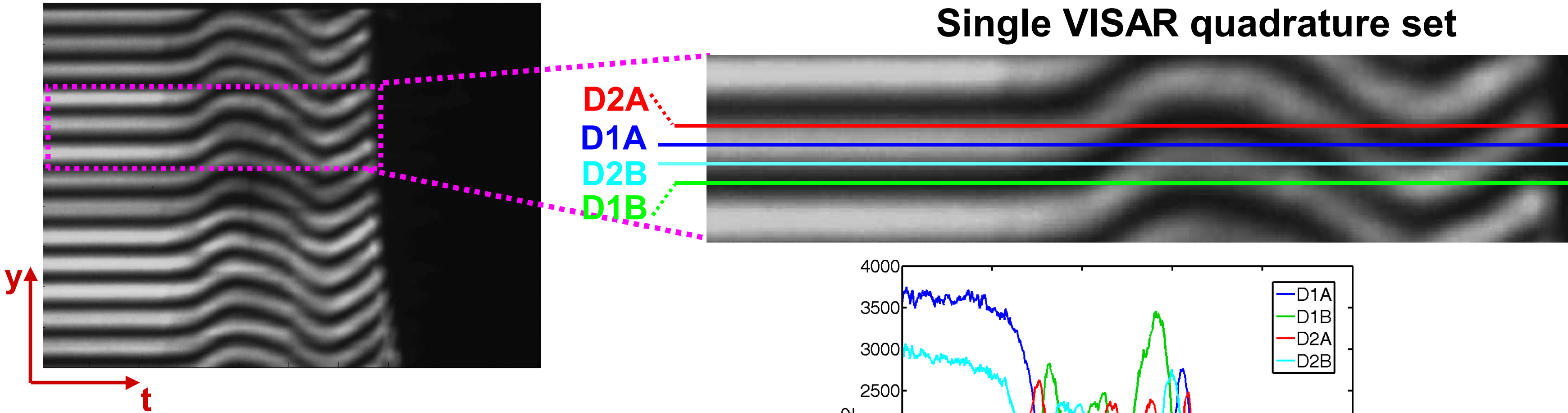
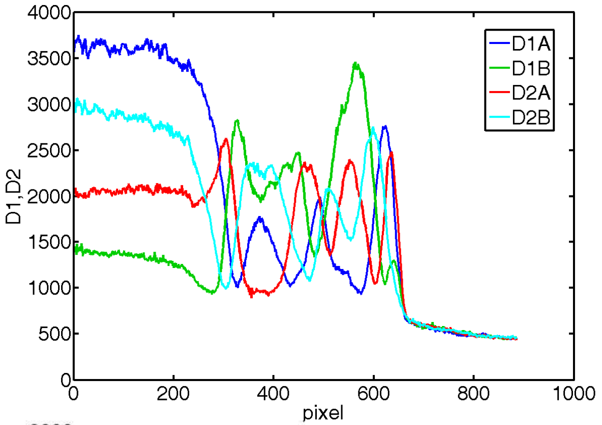
The line-imaging VISAR provides spatially-resolved velocity histories



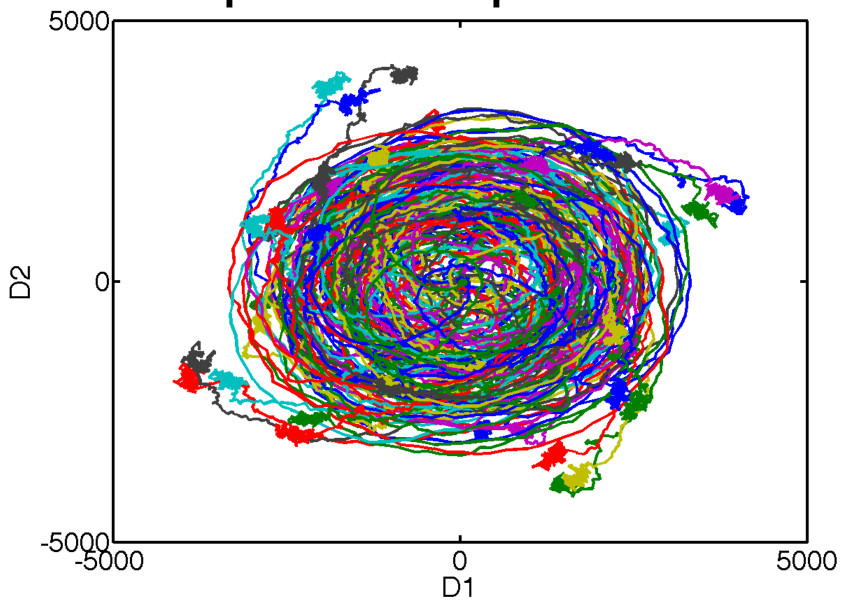
Analysis actually uses 4 lineouts per point for quadrature

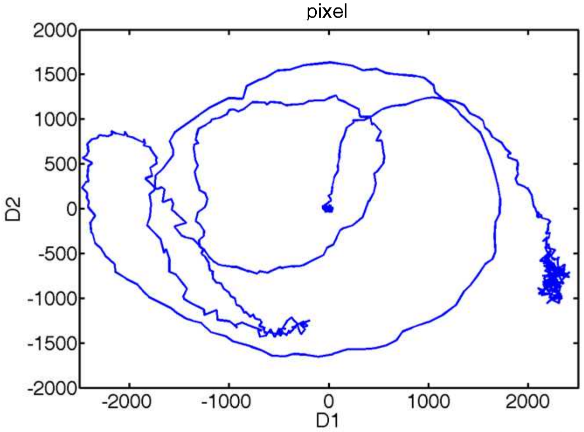
Analysis of Line VISAR data using quadrature extraction can provide consistent Lissajous centers





Complete VISAR quadrature sets





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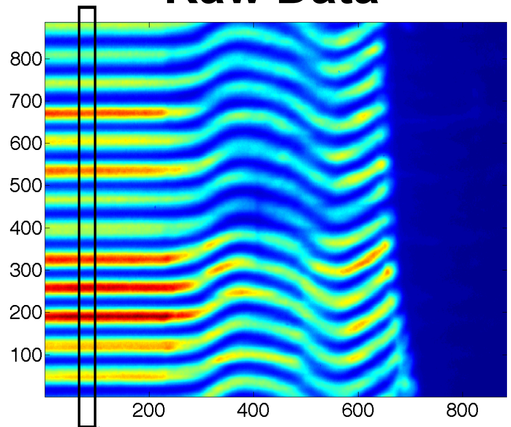
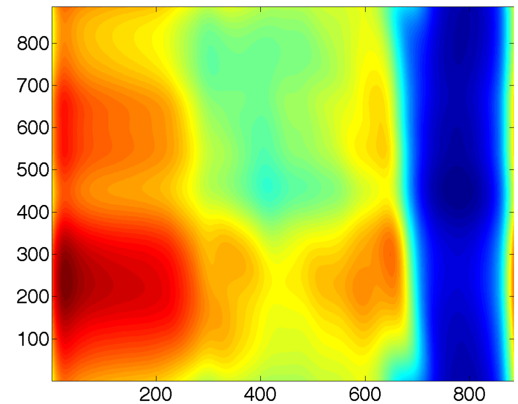
FFT-based balancing of fringe data provides reproducible pre-reduction data conditioning

Raw Data

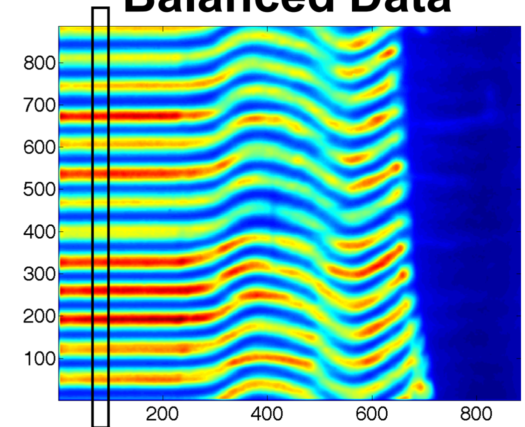


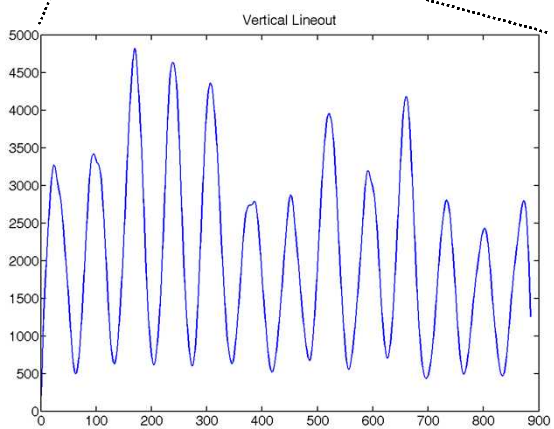
Form Factor



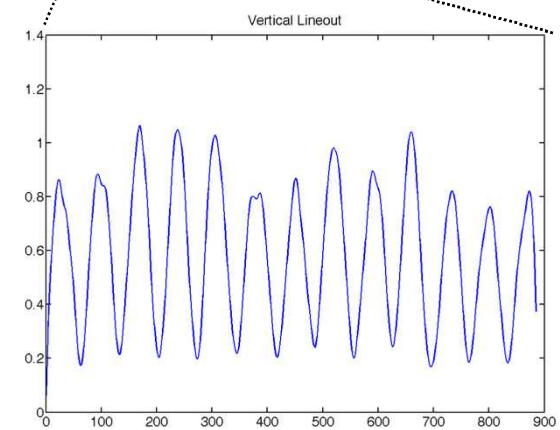
Low frequency signal

Balanced Data





$$\text{Balanced Data} = \frac{\text{Raw Data}}{\text{Form Factor}}$$



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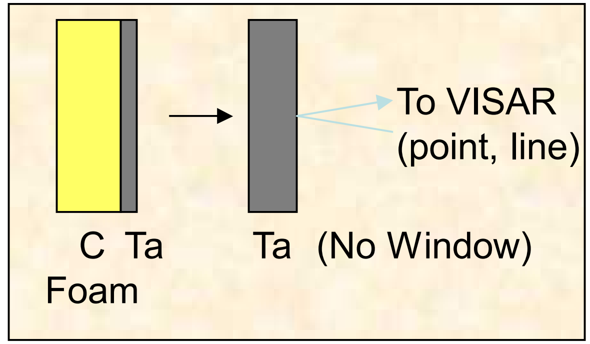
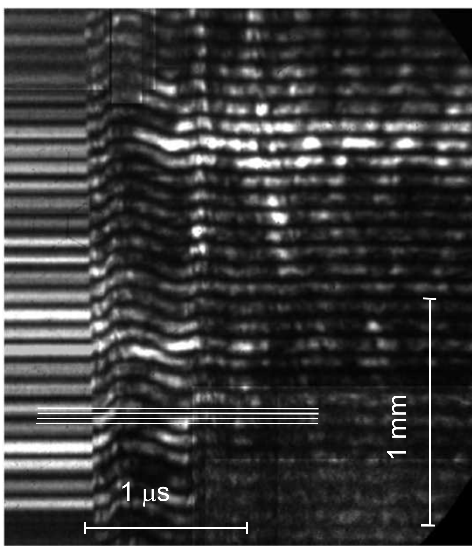
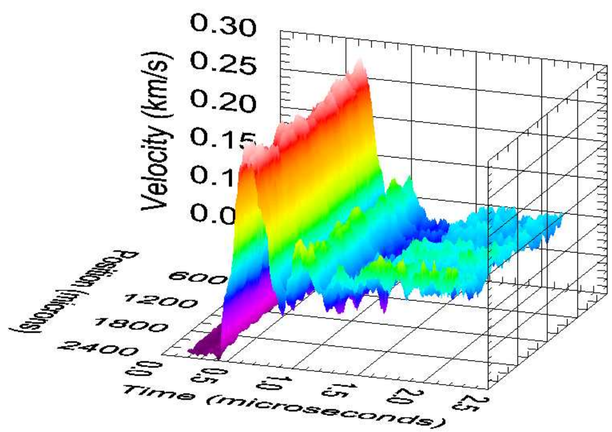
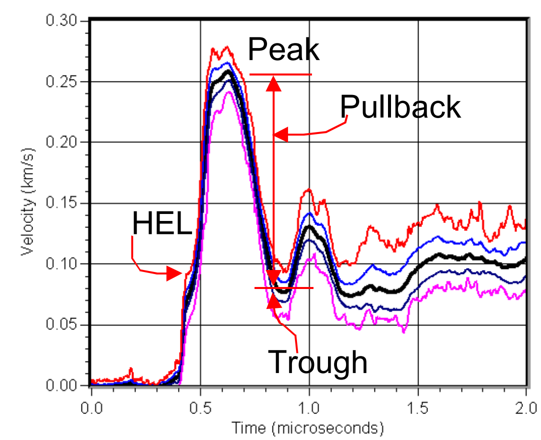
From the streak camera image velocity versus time and position may be derived









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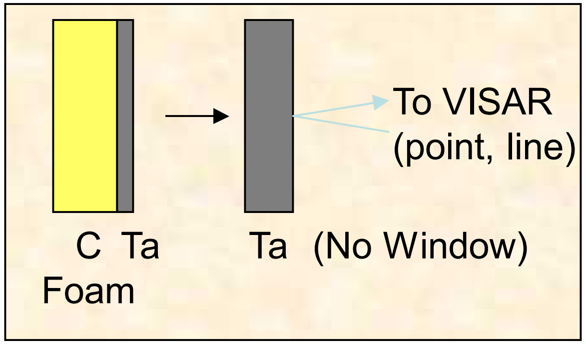
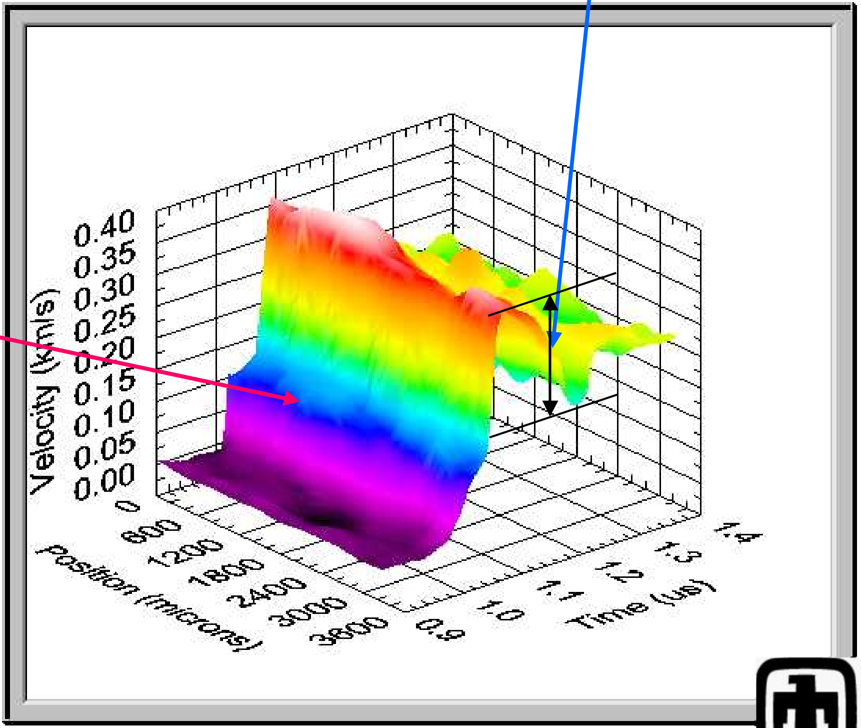
Case study: Ta is a mesoscopically heterogeneous material, with heterogeneous yield behavior



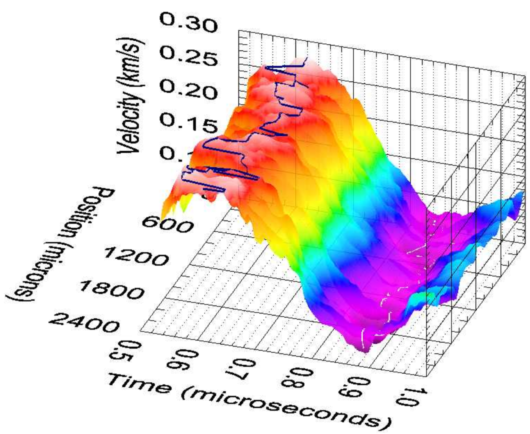
Spall strength calculated from pullback

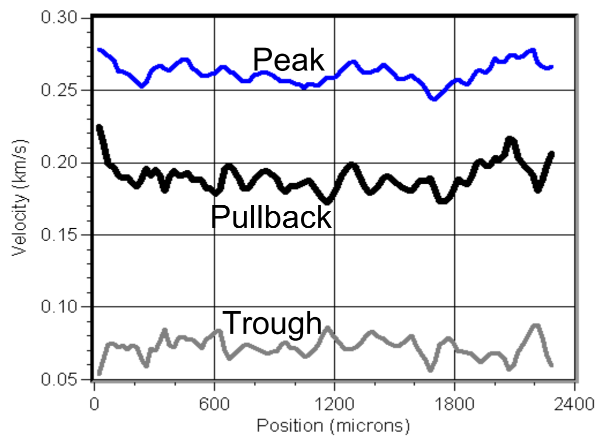
HEL strength calculated from elastic wave amplitude

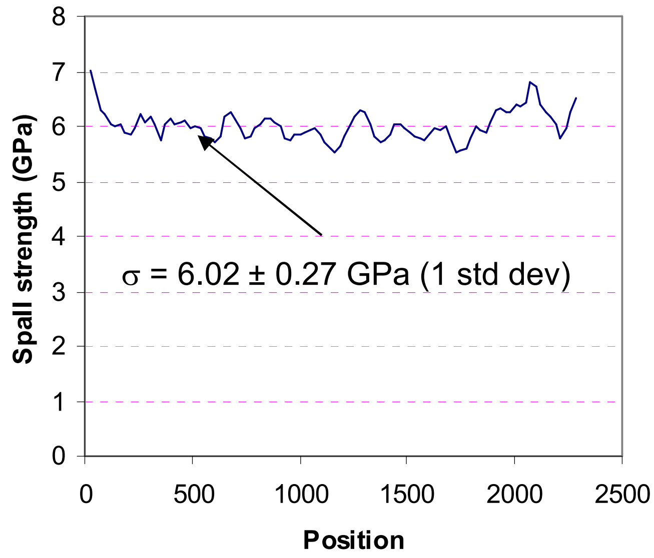


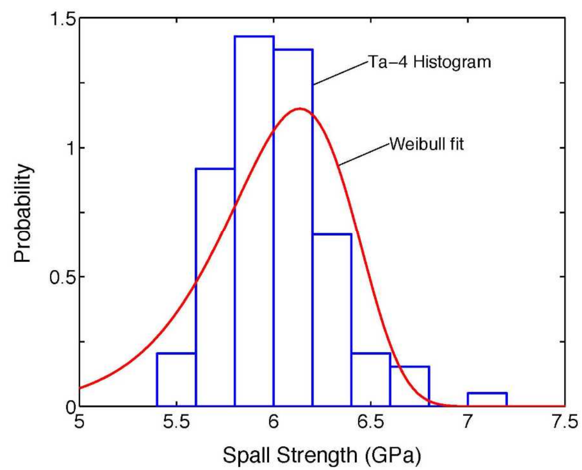
The spall strength is calculated at each point, and variability is determined

Spall strength = $0.5 \cdot Pullback \cdot \rho_0 \cdot C_0 + h/2 \cdot (dp/dt) \cdot (1/C_b - 1/C_l)$









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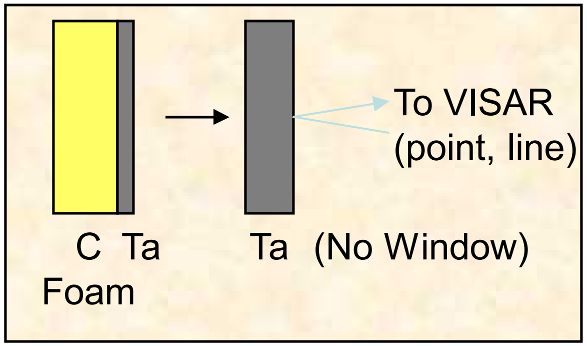
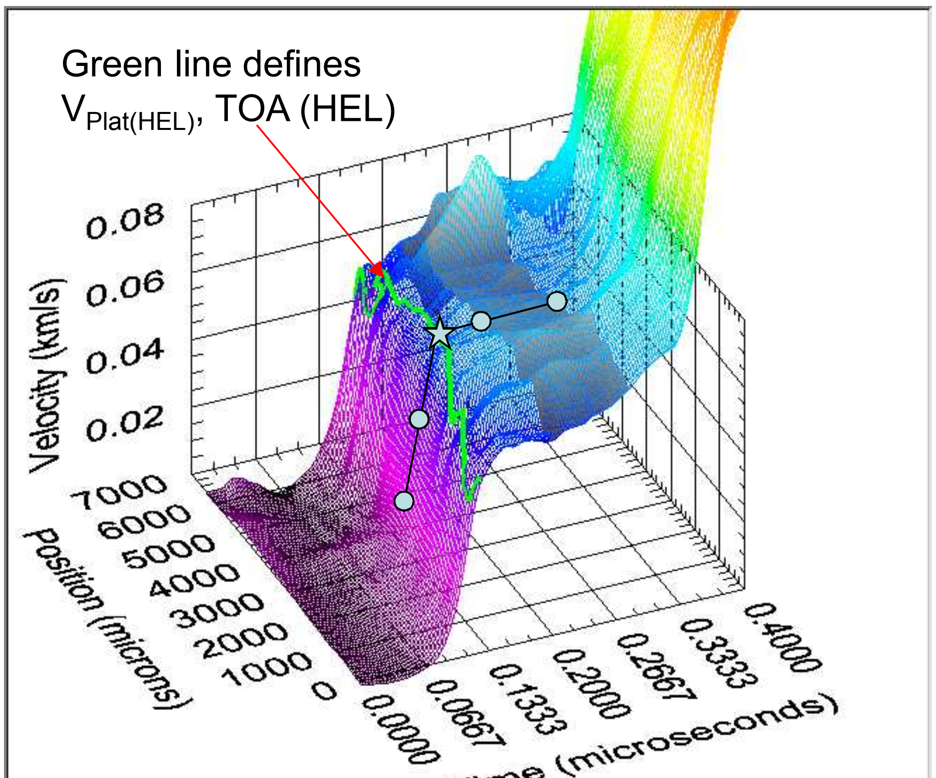
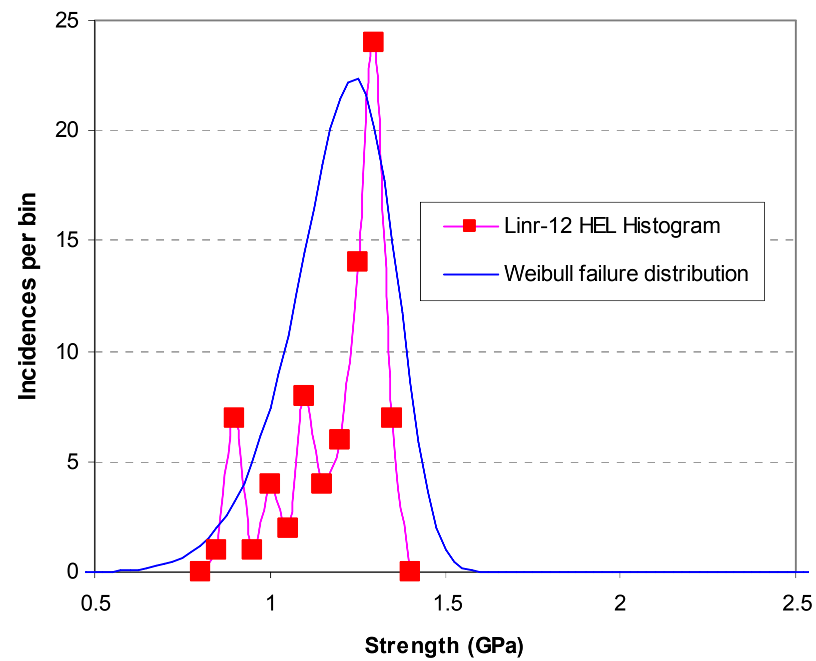
HEL levels vary from shot to shot and from point to point as well



Strength at HEL = σ_{HEL}*(1-2ν)/(1-ν)

= (1/2)*$V_{Plat(HEL)}$*$U_{S(HEL)}$*(1-2ν)/(1-ν)





A useful way to express failure properties is via Weibull statistics

The probability of failure at or below a given stress $P(\sigma)$ is:

$$P(\sigma) = 1 - \exp[-(\sigma/\alpha)^{\beta}]$$

Here, α is a scale parameter (dimensions of stress) and β is the Weibull modulus. Larger β means a narrower range of σ over which yield occurs.

For a set of *n* samples (ordered from first-to-fail to last), the *j*th result is assigned a cumulative probability of failure P_j. A common estimator is:

$$P_j = j / (n + 1)$$

(although there are others)

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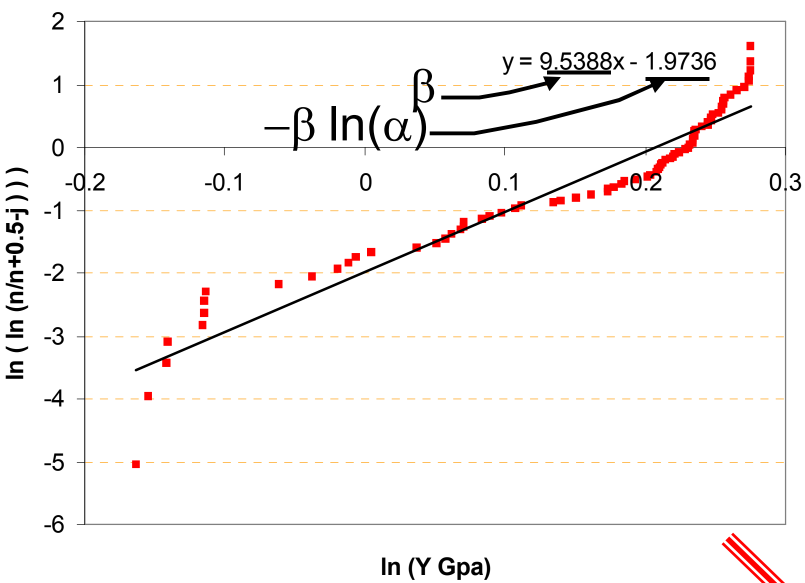
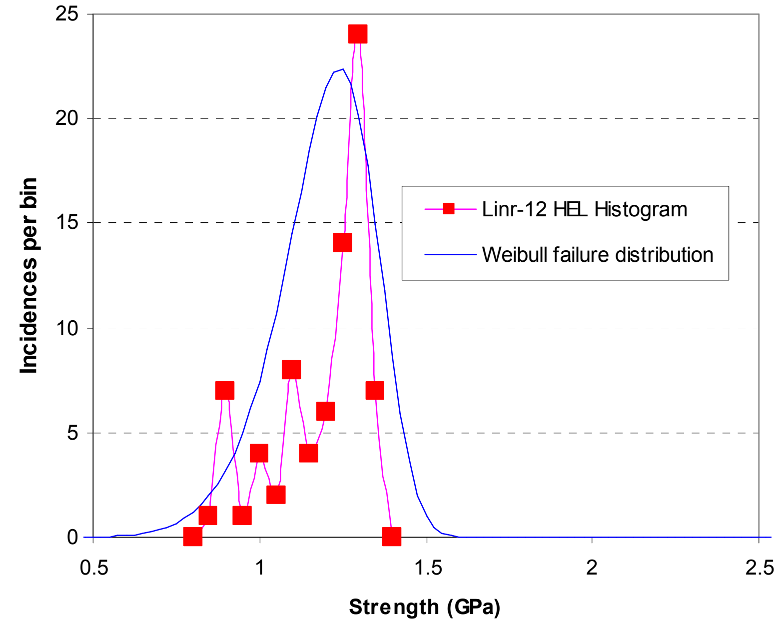
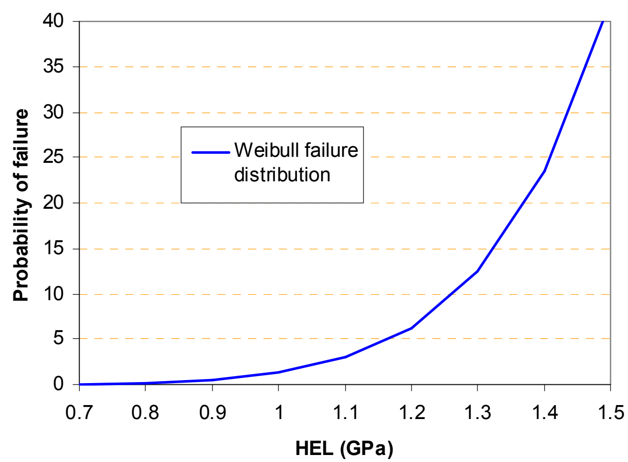
Weibull statistics parameterize the failure histogram of a sample







The rate function is what fraction of the unfailed points will be expected to fail over the next 1 GPa stress increment.

α = 1.23 (~ centroid)
β= 9.54 ($\propto$ 1/spread)
$P(\sigma) = 1 - \exp[- (\sigma/\alpha)^{\beta}]$

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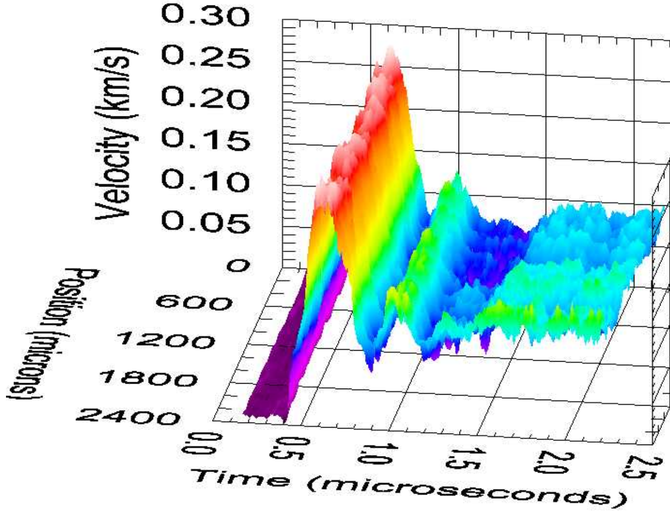
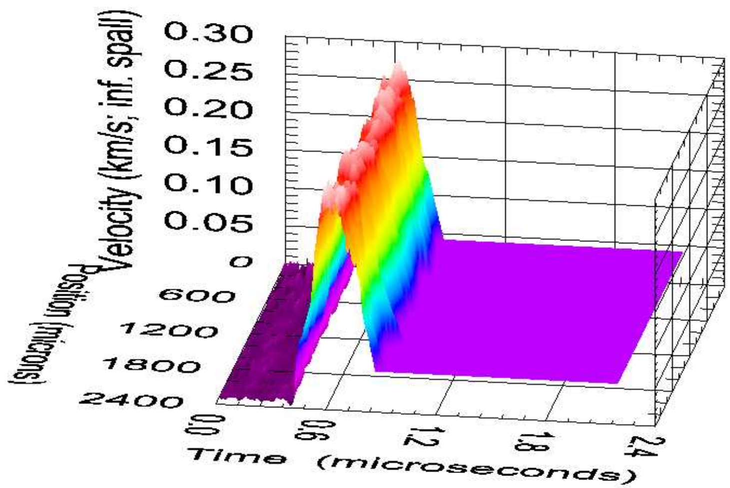
The degree of material distension may be measured versus position via line VISAR

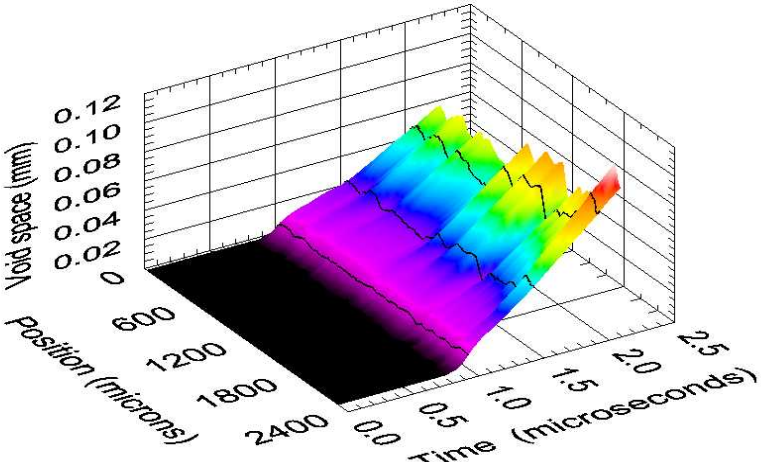


Observed Velocity



If spall had not occurred

Subtract and integrate over time to calculate material distension (“void size” for spall)



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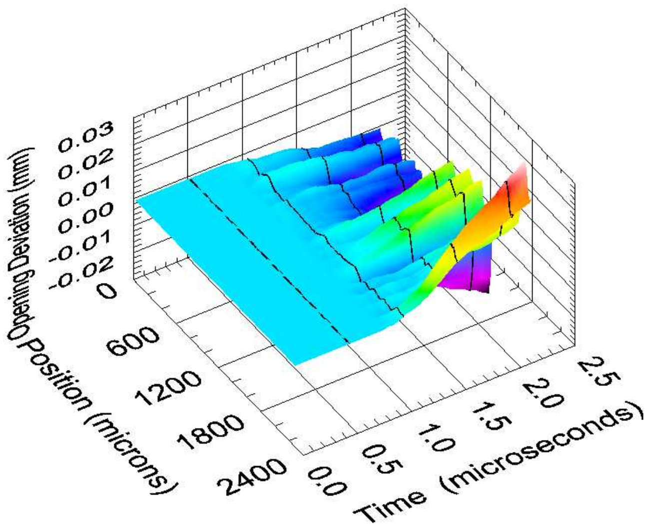
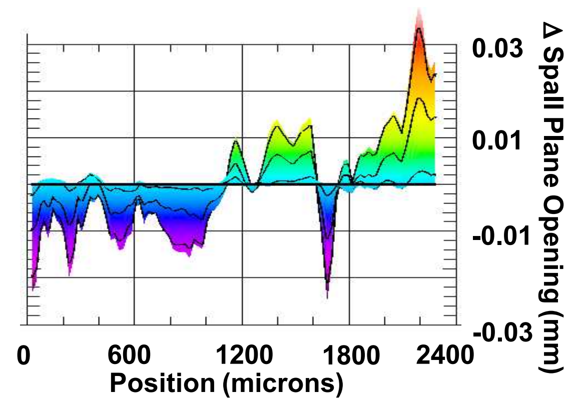
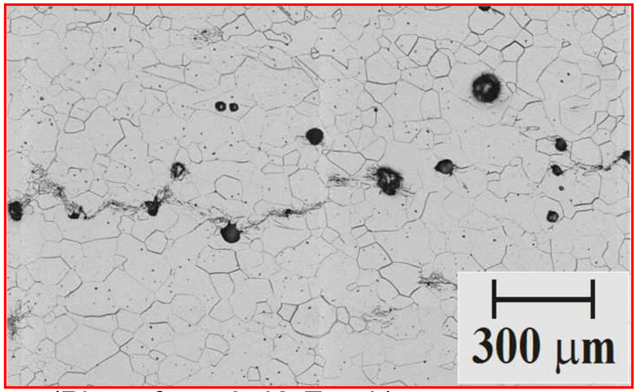
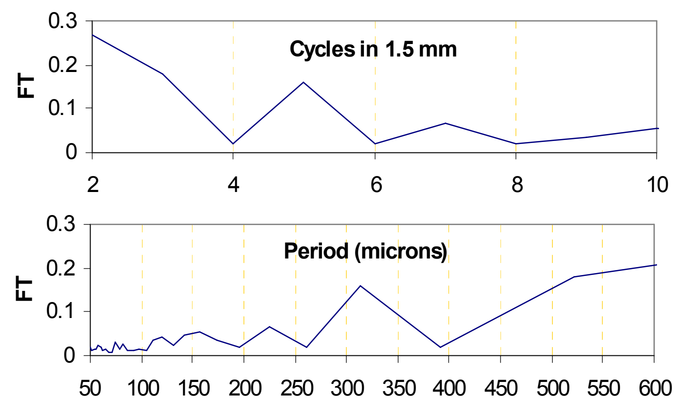
For an incipient spall experiment, void sizes are generally less than 30 microns (~ grain size)





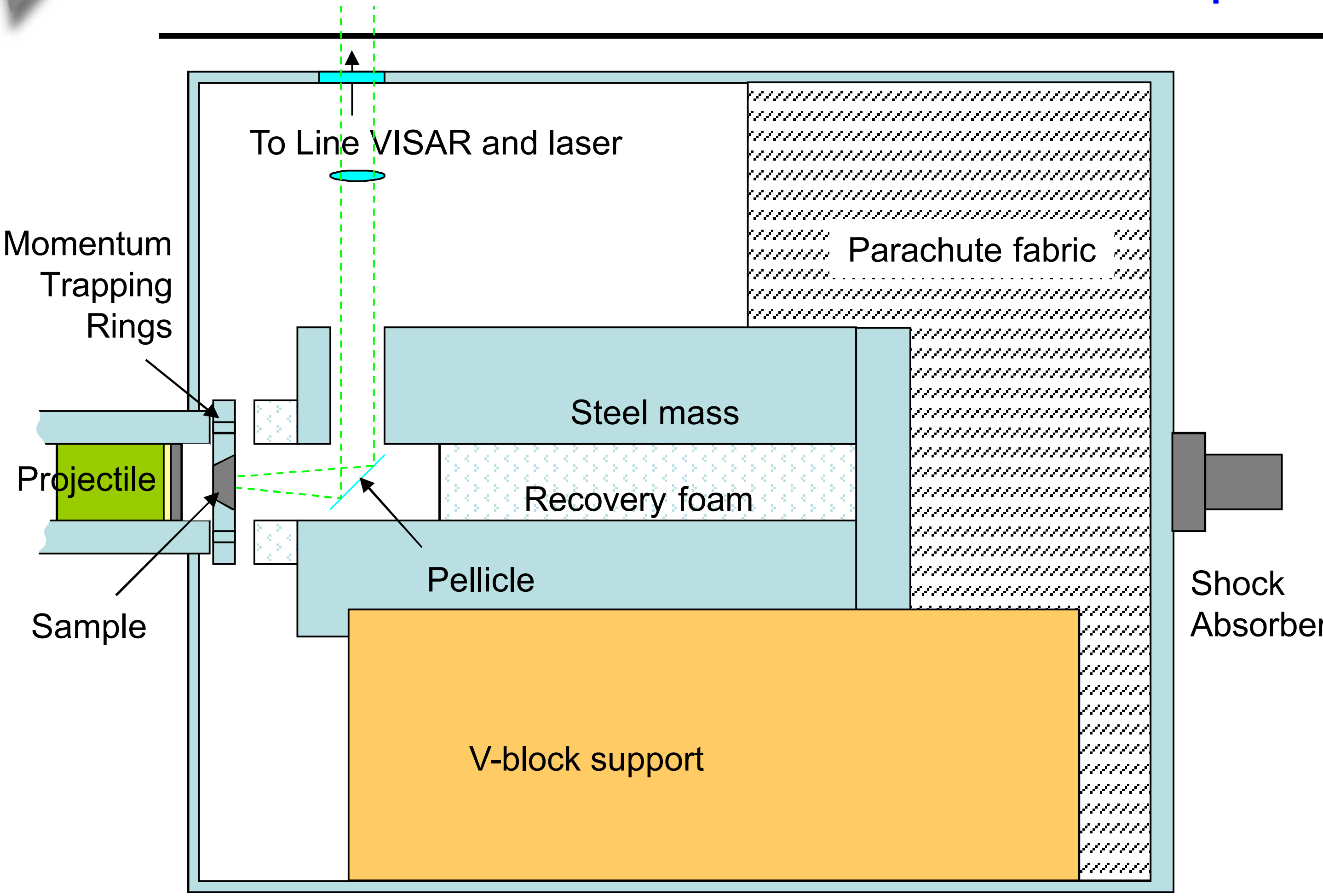


(Photo from A. K. Zurek)



Separations ~ 300 microns apart.

Validation experiments are in preparation using simultaneous line VISAR and sample recovery



Samples: Ta and OFE Cu (supplied by G. T. Gray III, LANL)

Incipient spall conditions (also unyielded?)

Post-shot metallography (geometry tied to line VISAR position via indentations)

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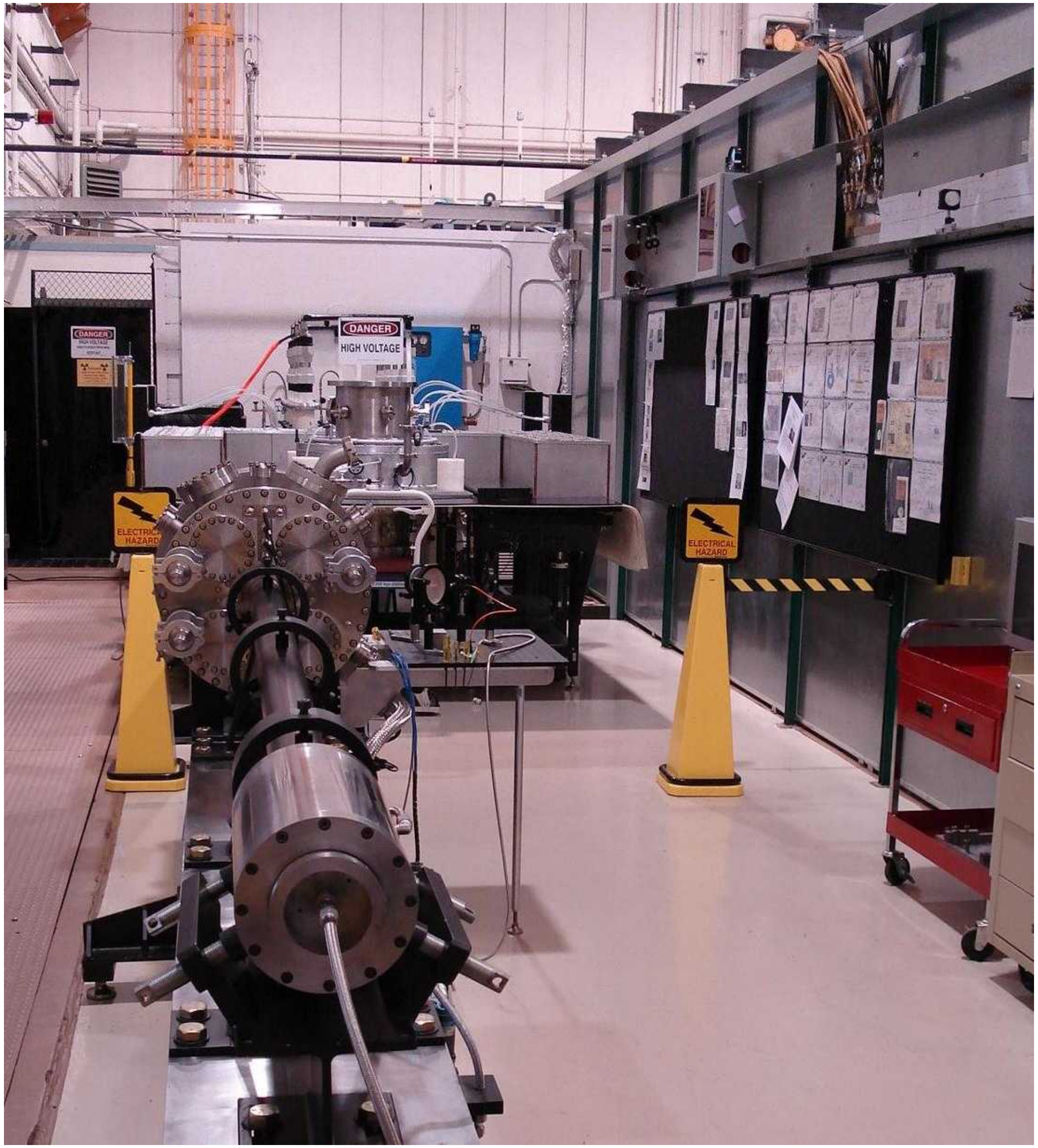
These experiments are to in preparation on the DICE Gas Gun



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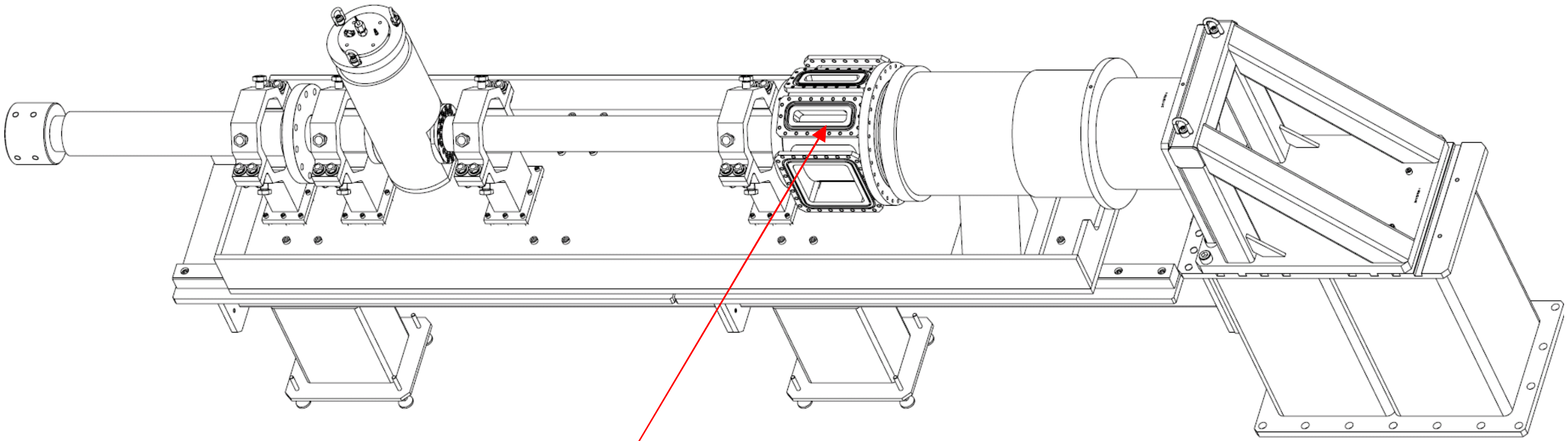
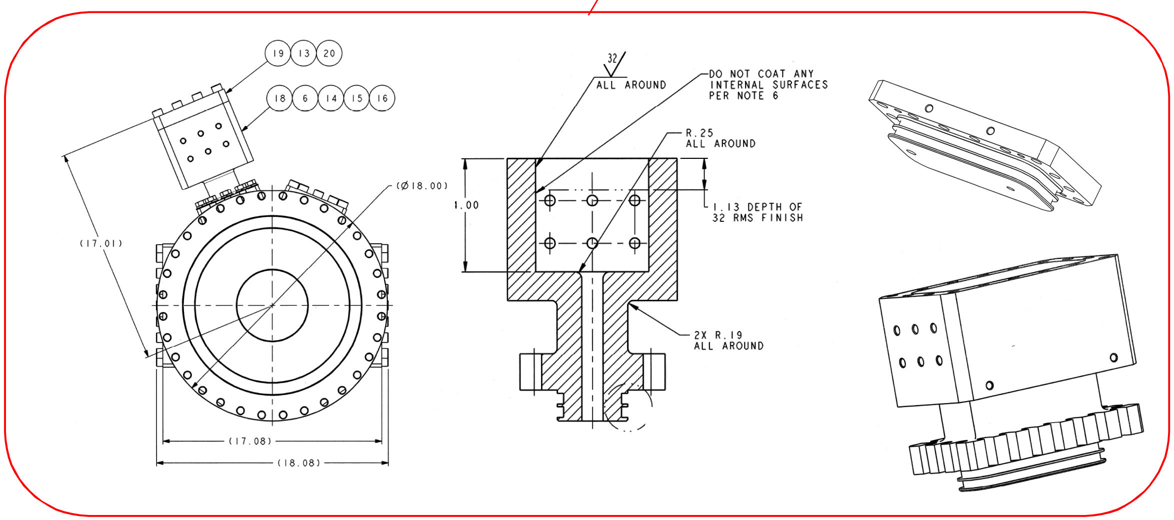
Implementation of Line VISAR on LBPG is possible, but not trivial (3/4” slot?)





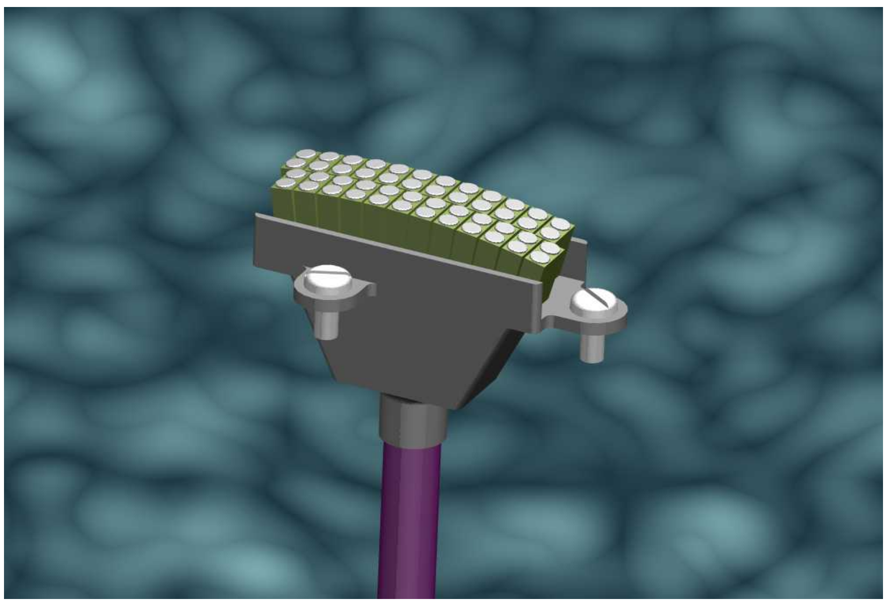
Issues:

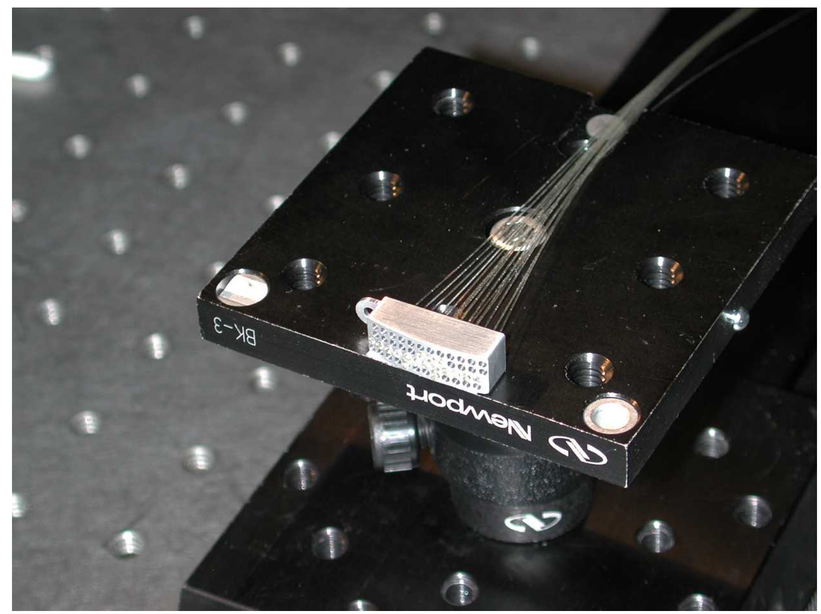
- Periscope
- Zero room deployment vs. relay thru bulkhead

Drawings from Robert Valdiviez, LANL

An Alternative: Multipoint Probe

- Method demonstrated on Krakatau series
- Can be done with pulsed laser (36 pt) or CW/Pockel cell (up to ~12 pts)
- Spot separations ~ 1 mm (possible down to ½ mm with probe demagnification)
- Would fit more easily into existing LBPG diagnostic access design
- Physics: Would still allow some yield statistics studies, but not scale studies





(Images from D. A. Clark and V. Romero)

Conclusions

- Line Imaging VISAR provides 50 – 100 micron-level resolution of yield phenomena (e.g. spall, HEL) as well as other spatially interesting phenomena (edge effects, instabilities)
- It also provides statistical information on failure
- Fielding it on the Large-Bore Powder Gun is difficult, but possible
- Multipoint VISAR offers failure statistics as well, and is easier to implement. However, it does not offer the detailed spatial information afforded by line VISAR.
- Validation experiments for line VISAR (also applicable to multipoint VISAR) are in preparation, including VISAR and recovery on the same samples, and spatial correlation of the VISAR readings and later metallography. These will establish how material distension inferences from line VISAR measurements correspond to post-shot metallographic measurements.

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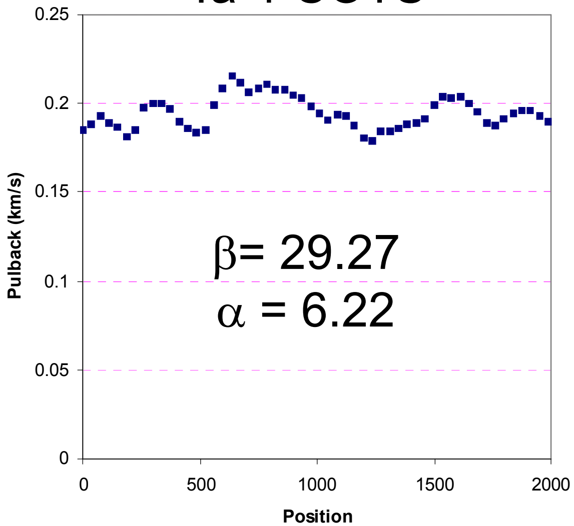
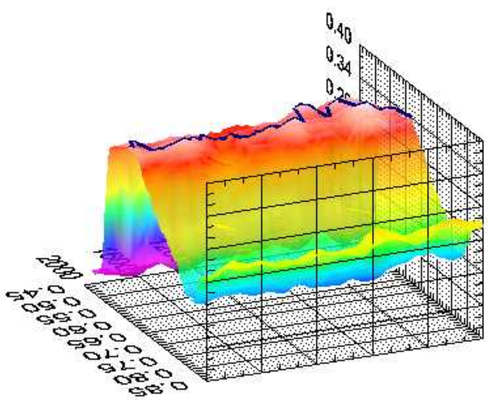
The following slides are extras in case discussion warrants

Similar samples will occasionally show markedly different behaviors, visible with line VISAR

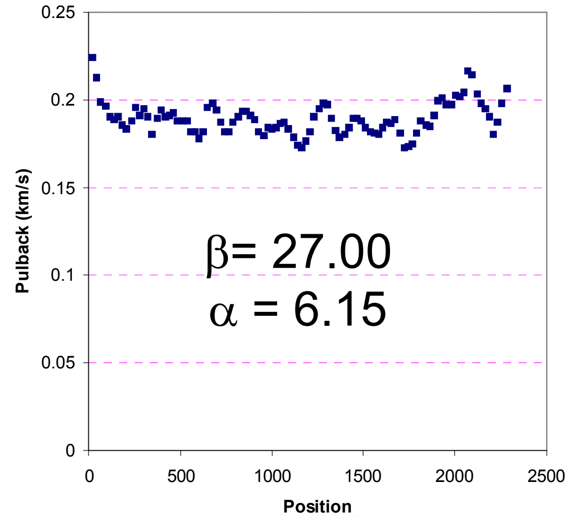
Ta-1 COTS

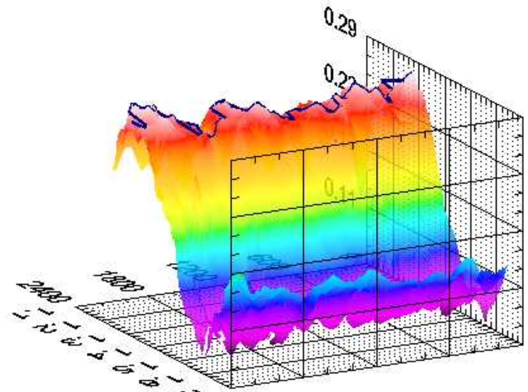




Spall depth: 0.45 mm
Stress level: 11 GPa

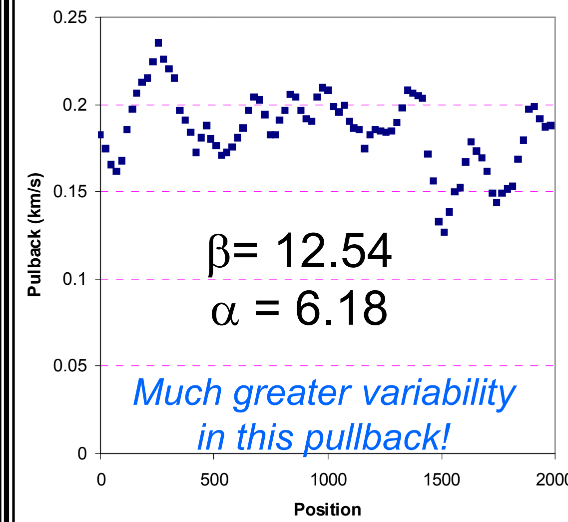
Ta-4 LANL

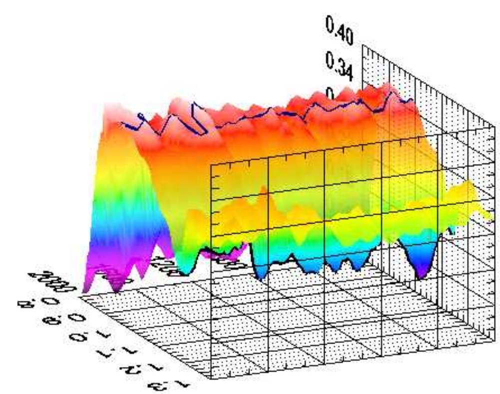




Spall depth: 0.5 mm
Stress level: 8 GPa

Ta-6 LANL





Spall depth: 0.53 mm
Stress level: 11 GPa

Remember – larger β means less variability in failure level

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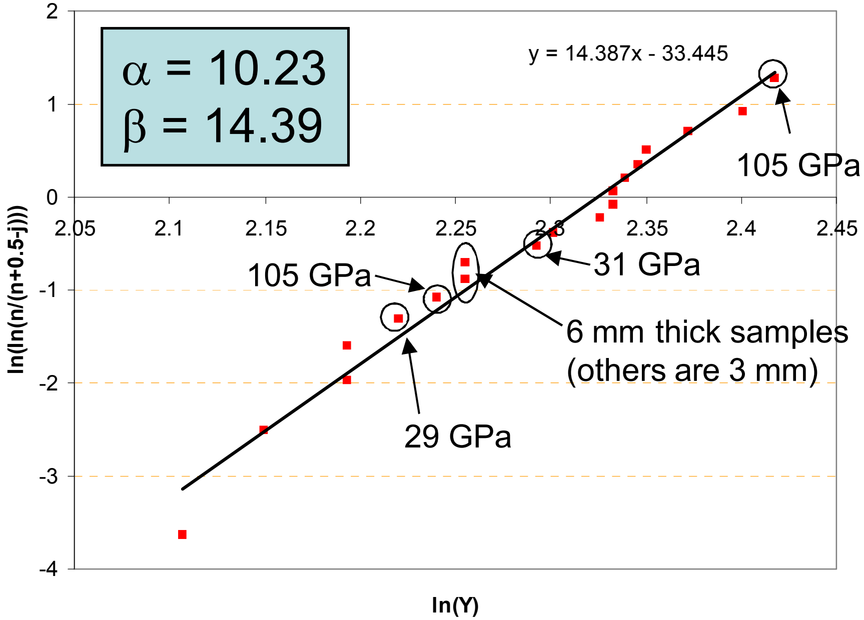
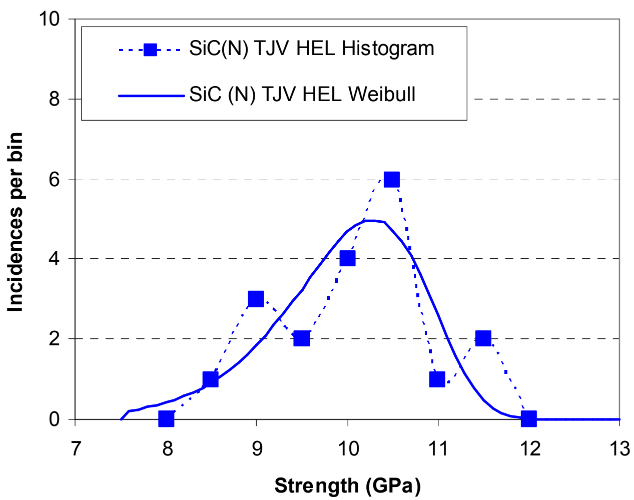
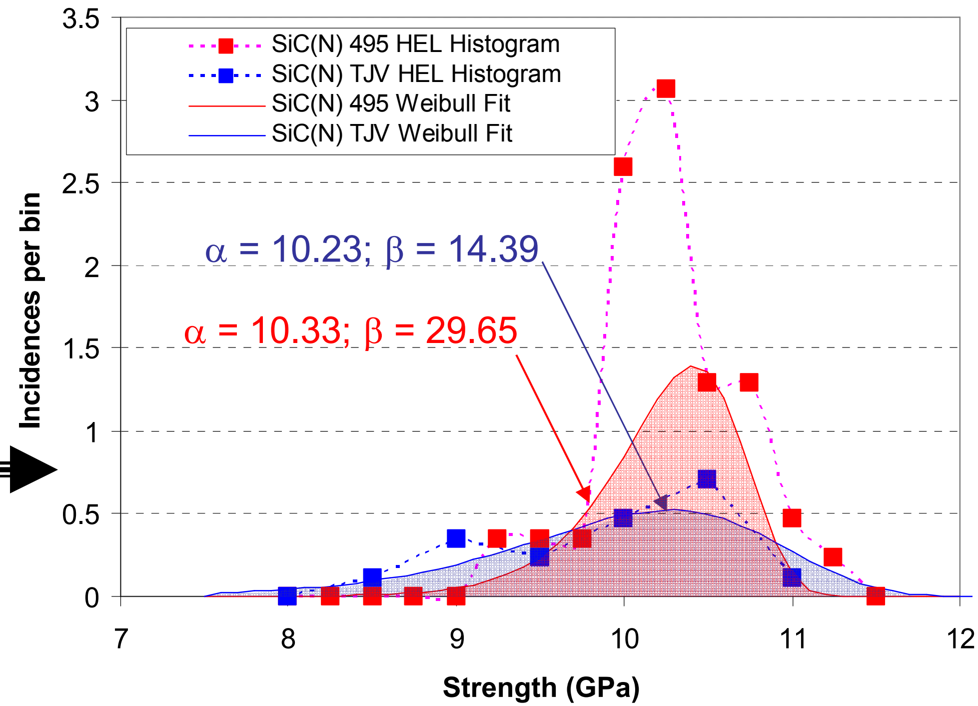
Shot-to-shot variability of the HEL of SiC is *slightly* larger than that obtained on a single line VISAR shot





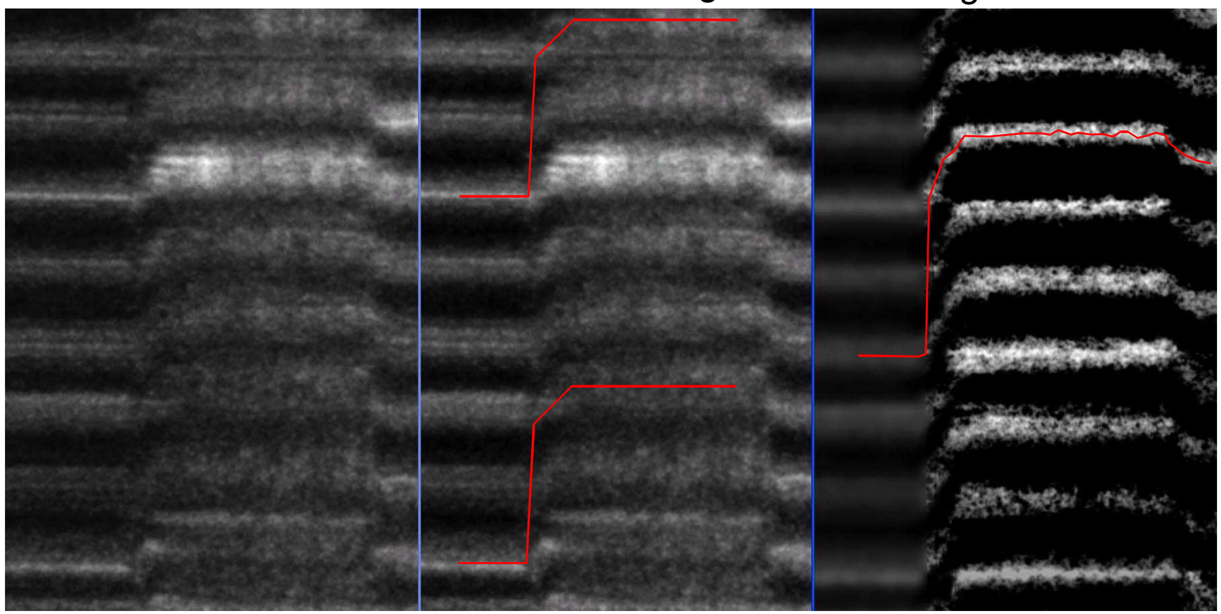
Red symbols from line VISAR on one shot
Blue symbols are from point VISAR on a series

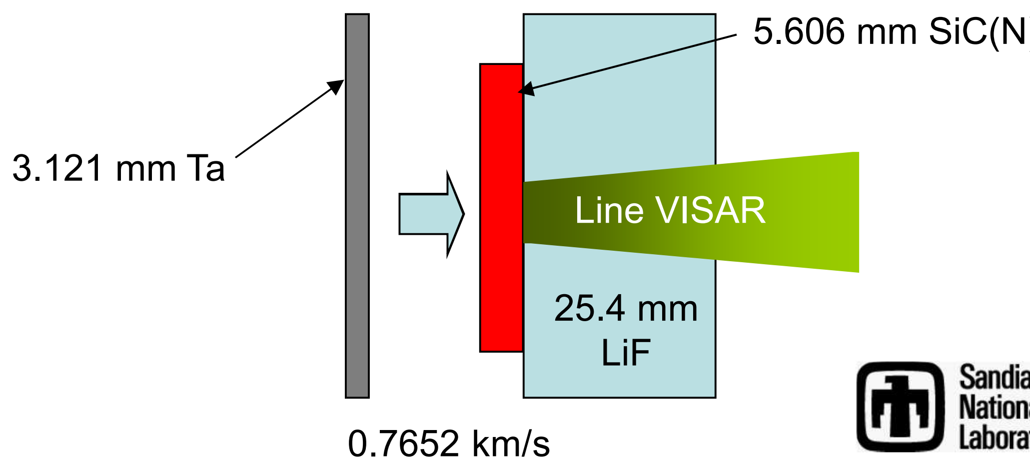


"TJV" Data from: Hugoniot and strength behavior of silicon carbide
Vogler, T.J.; Reinhart, W.D.; Chhabildas, L.C.; Dandekar, D.P.,
Journal of Applied Physics; Jan 15 2006; v.99, no.2, p.1-15

Yielding at the SiC HEL was apparent in one experiment

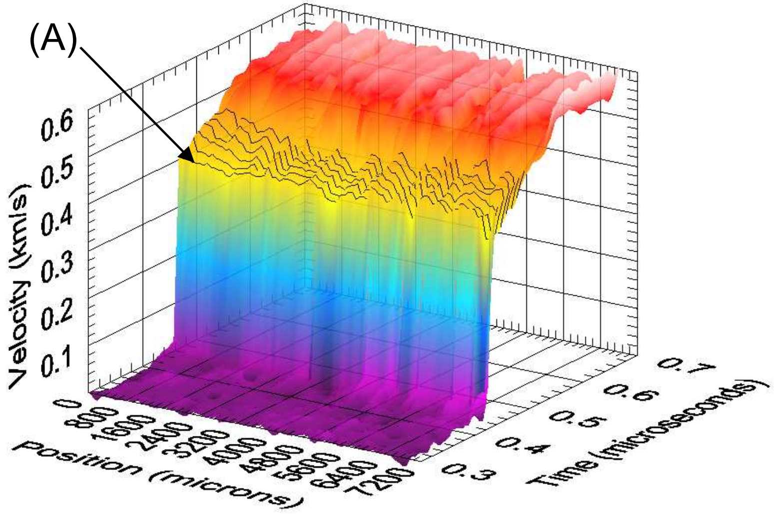
Raw Streak Image | FFT-Filtered Streak Image | FFT-Filtered Streak Image, subtracting horizontal “blur”

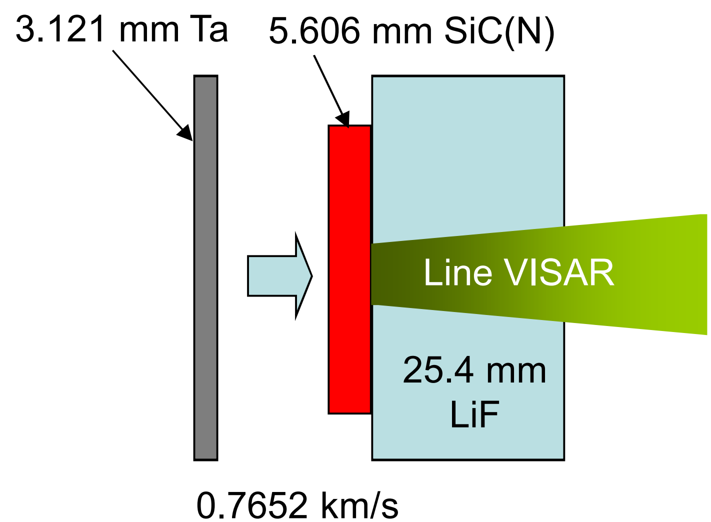


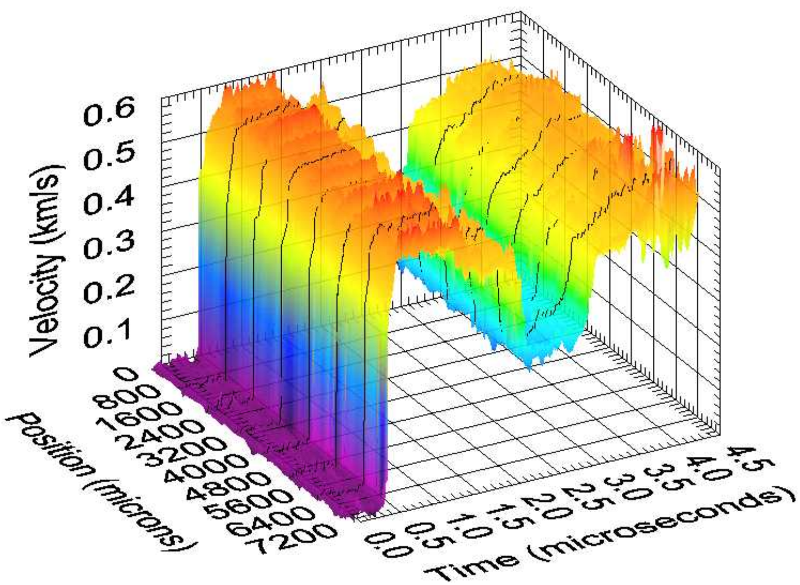


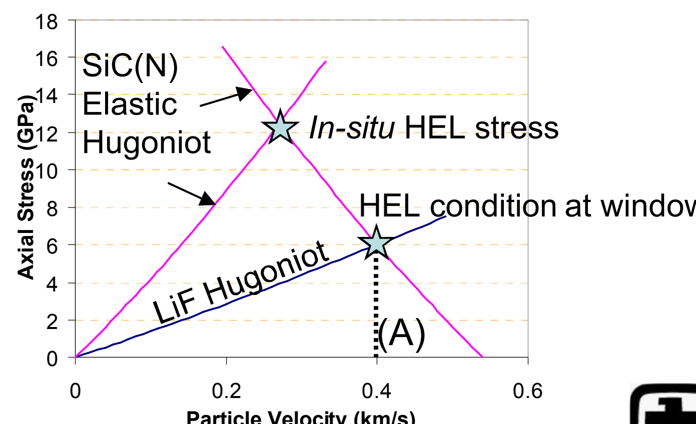
Cercom SiC(N):
Grain size = 4 μm
6H polytype (hexagonal)
ρ_0 = 3.227 gm/cm^3 nominal

The HEL of SiC and its variability may be defined in this single experiment









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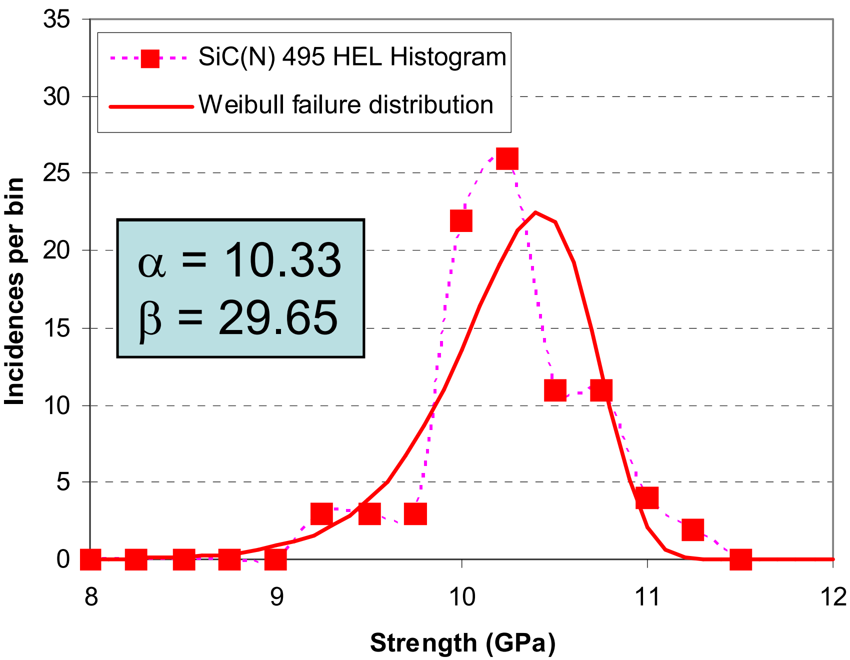
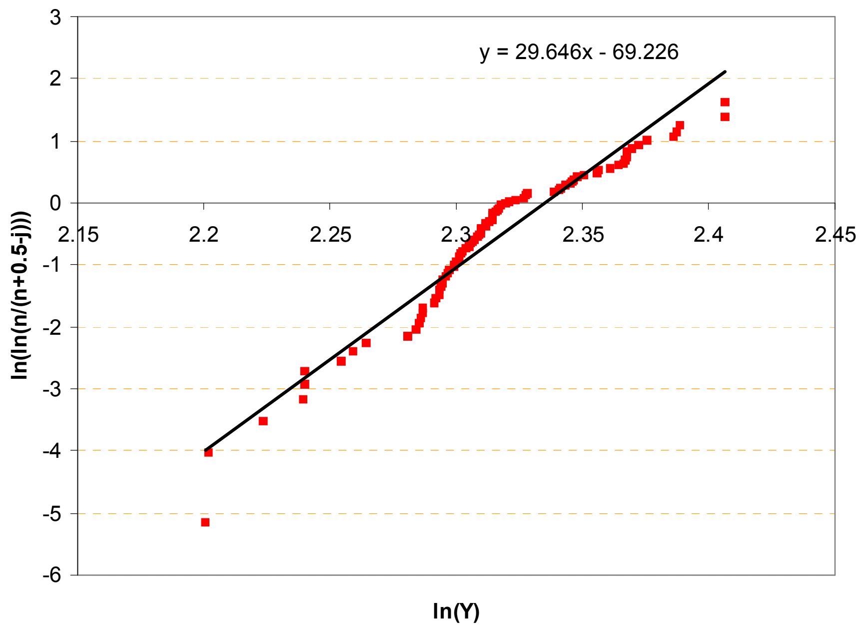
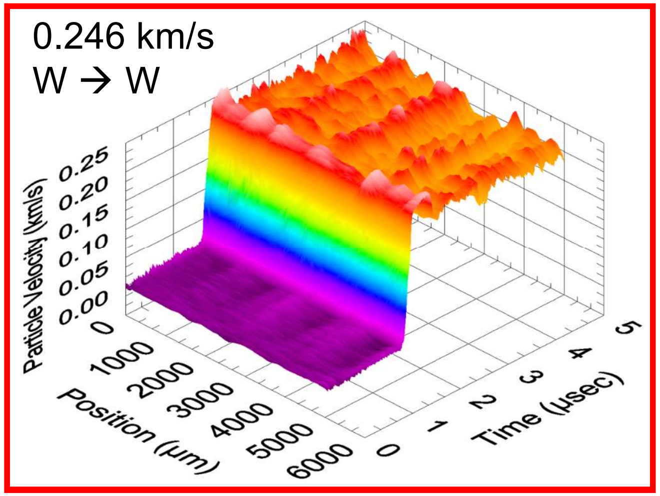
Variability of the HEL of SiC on this shot may be summarized by Weibull statistics

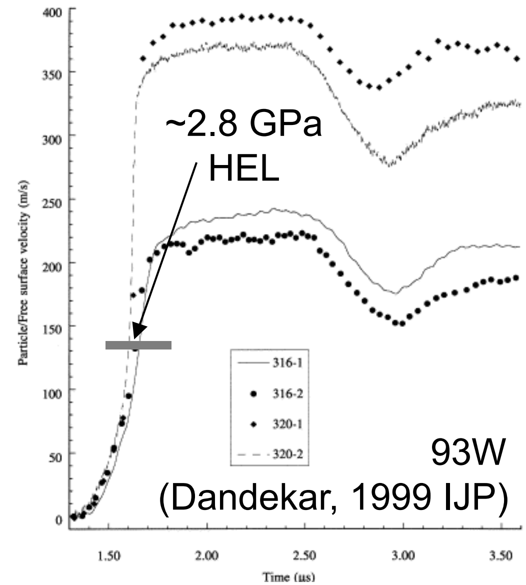


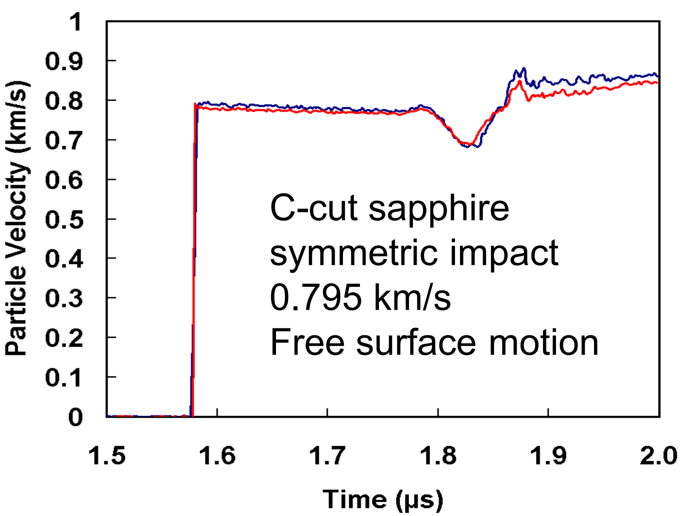


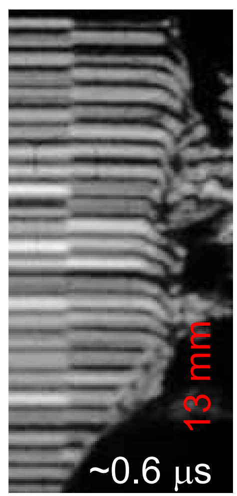
HEL variability information was not obtained for tungsten or sapphire



WHA tungsten ~ 9 GPa yielded dispersed front with no distinct 2-wave loading







C-cut sapphire loaded to 18 GPa displayed no yielding

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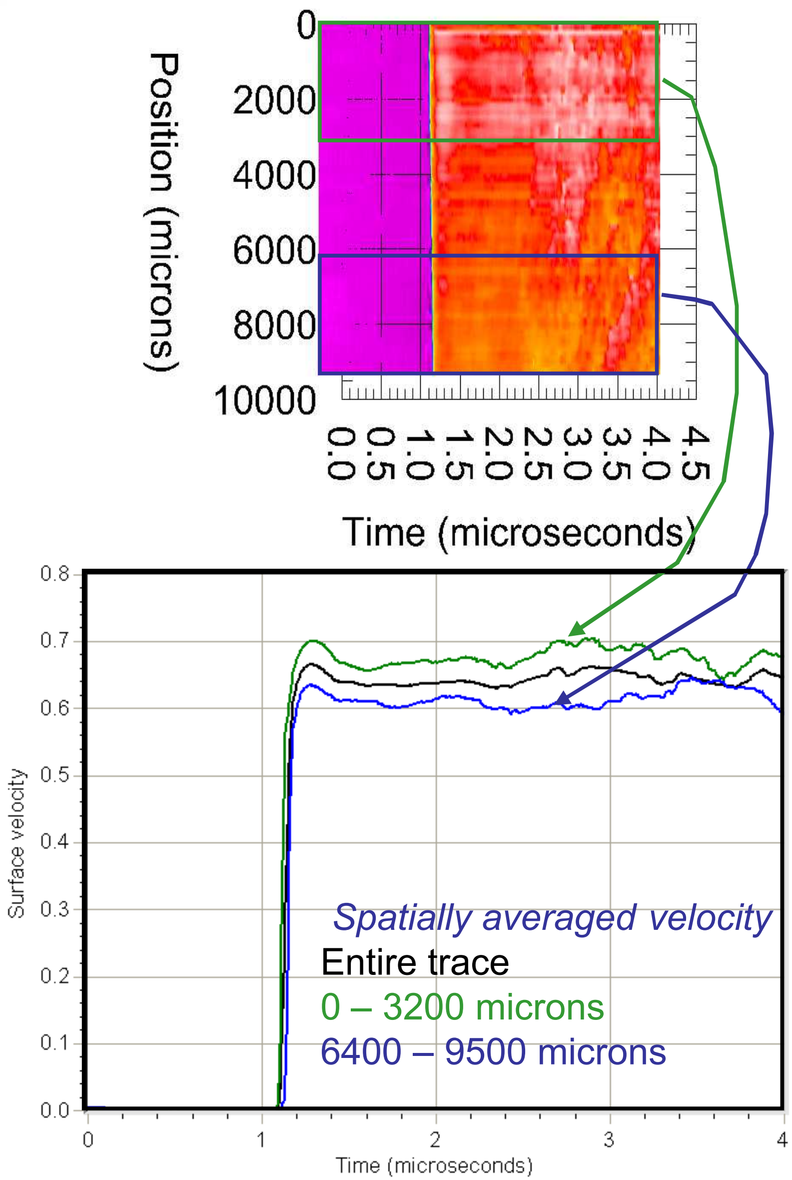
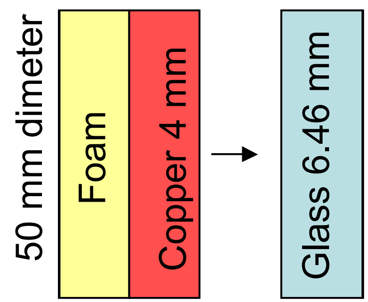
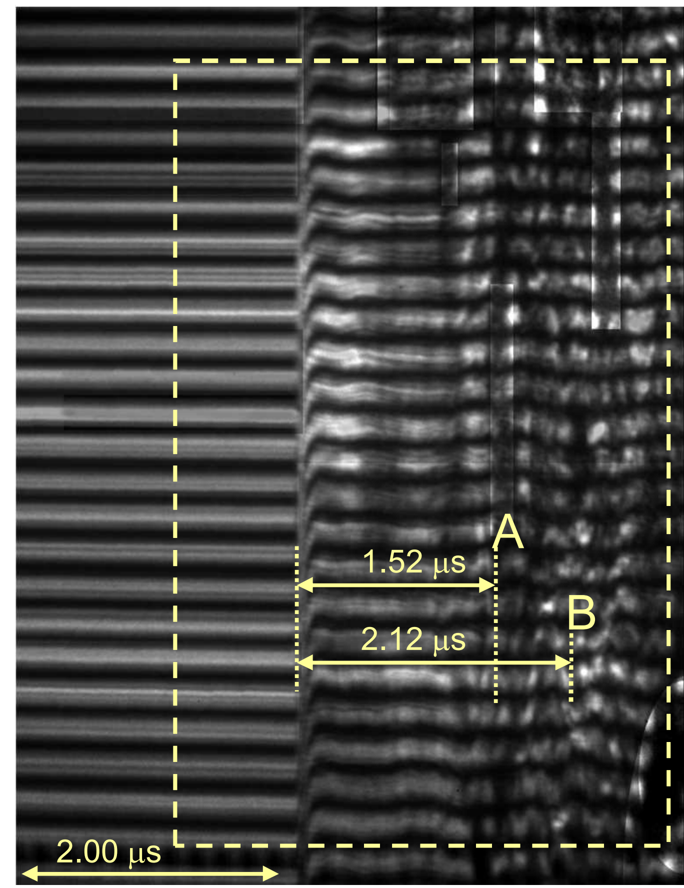
HEL data were not obtained for starphire glass either





Impact velocity: 0.5117 km/s
Stress: ~5.2 GPa?



HEL data for this system are difficult to obtain (cf C.S. Alexander, B2.6)

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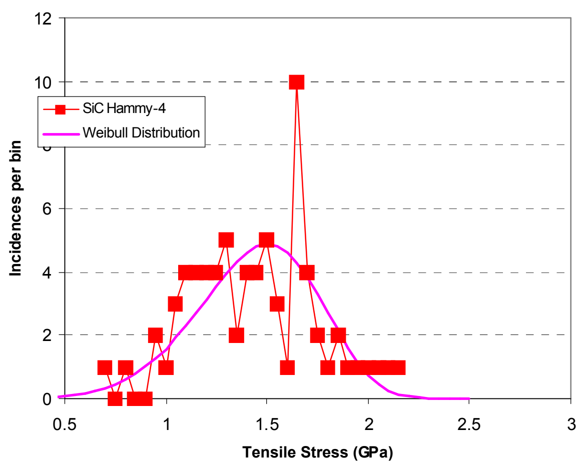
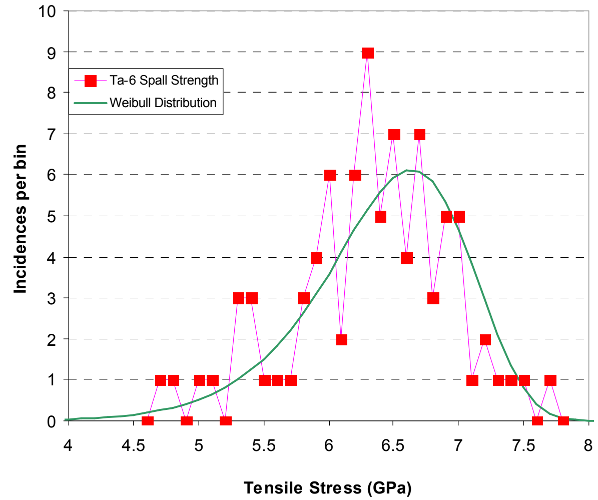
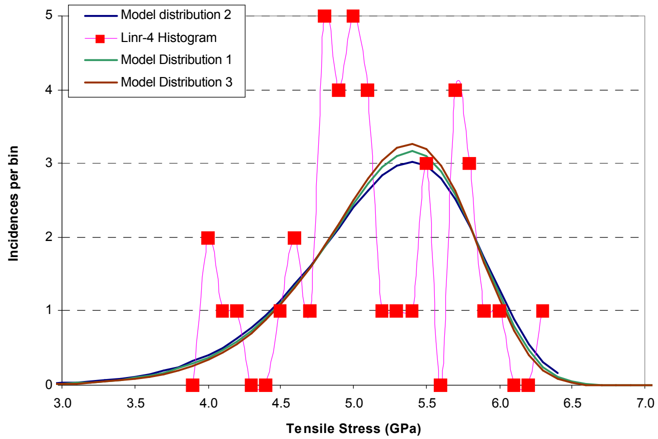
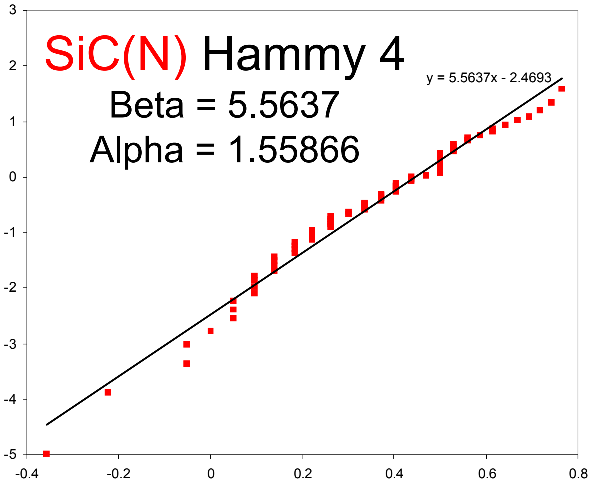
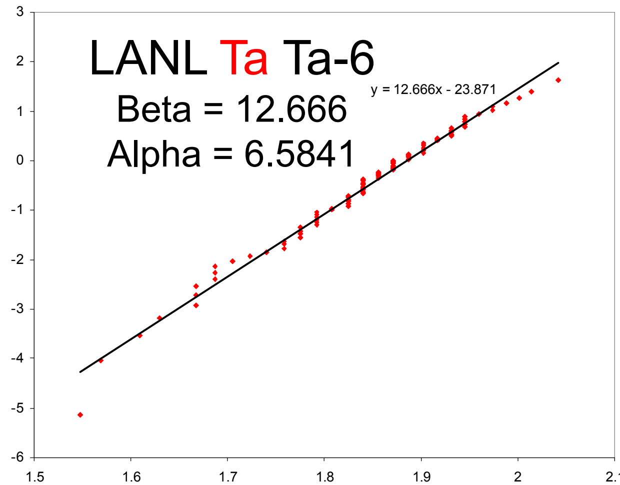
Spall strength distributions vary according to material, stress level, waveform, and possibly other factors

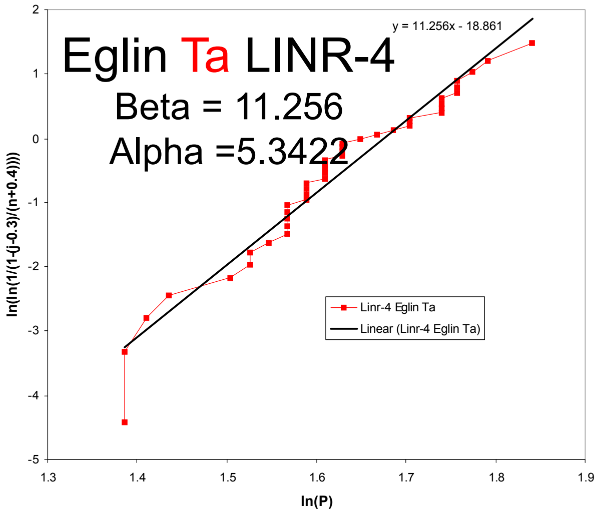












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