Shock wave experiments using Doppler velocimetry

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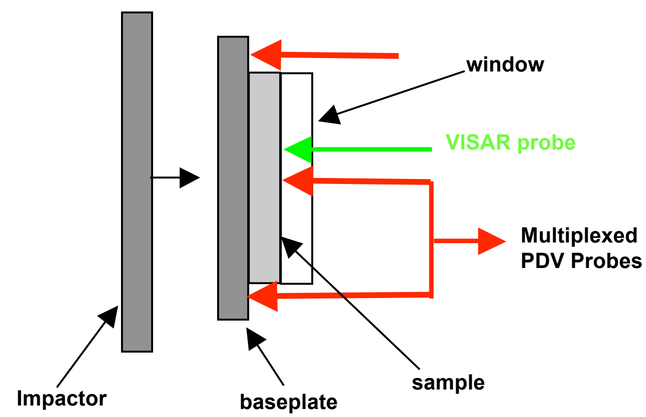
Introduction

- Multiplexing PDV probes to measure shock wave velocities and wave profiles
- Shock wave experiments to better define the low-pressure, overdriven Hugoniot for PBX 9502 using an explosive plane wave lens
- Shock wave experiments on Cerium to determine the melt transition using the large bore gun (3.5” bore)
- Summary

Multiplexing PDV Probes

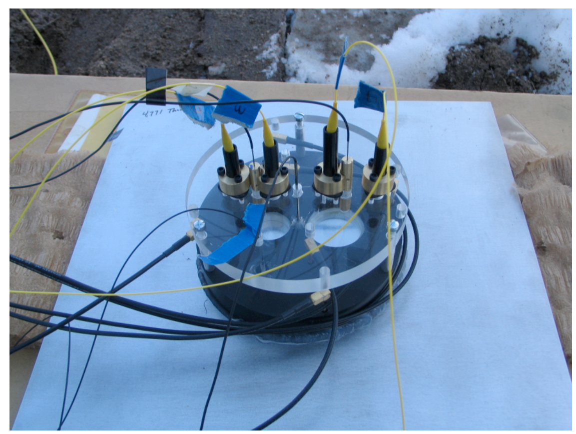
- Traditional shock velocity measurements have utilized pins and/or rotating mirror streak cameras, etc.
- Use PDV systems to obtain better shock velocity data using fewer channels by multiplexing PDV probes
- Simple concept: multiplex probes monitoring different surfaces (events separated in time) using 50/50 splitters

Experimental Configuration



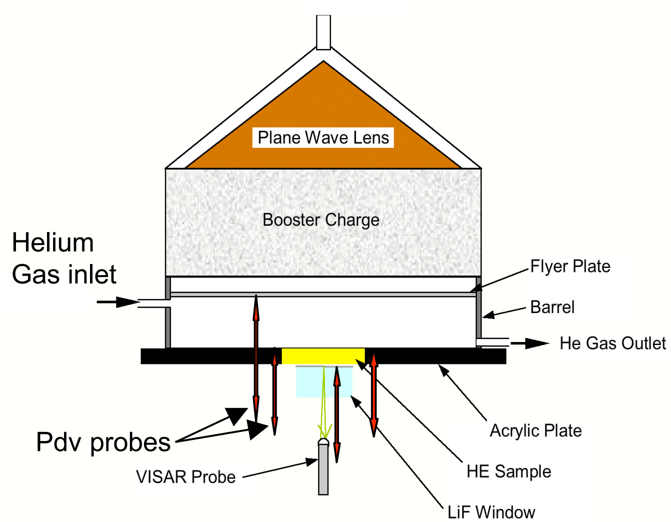
Target using rotating mirror camera

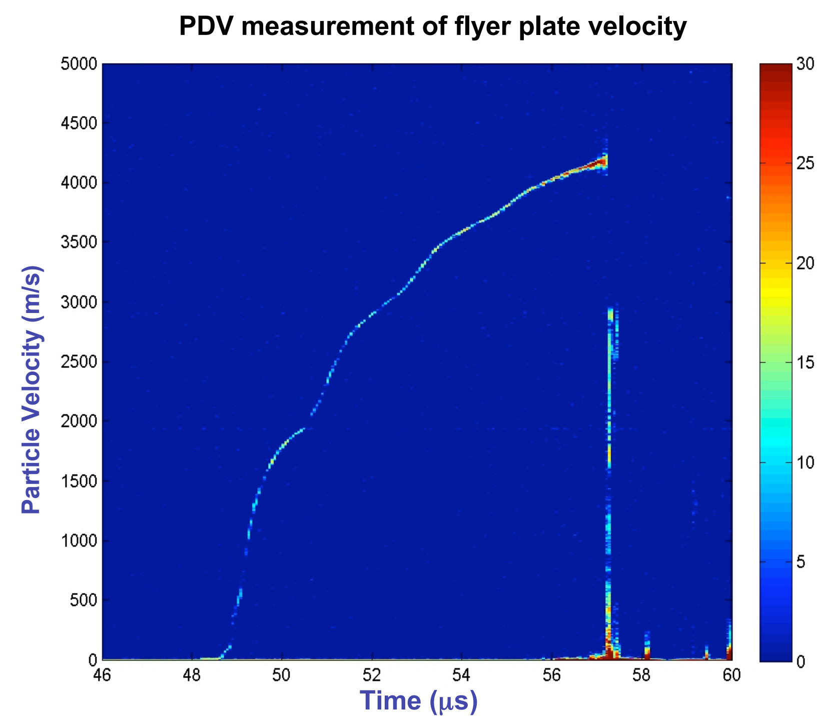
Target using PDV as diagnostic



Low-pressure, overdriven experiments on PBX 9502

- Shock response of PBX 9502 is of interest due to application in weapons systems
- High pressure Hugoniot is well-defined, but low pressure data exhibits significant scatter
- Plane wave experiments coupled with new diagnostics and thicker samples will provide data to refine the equation of state (EOS) for PBX 9502

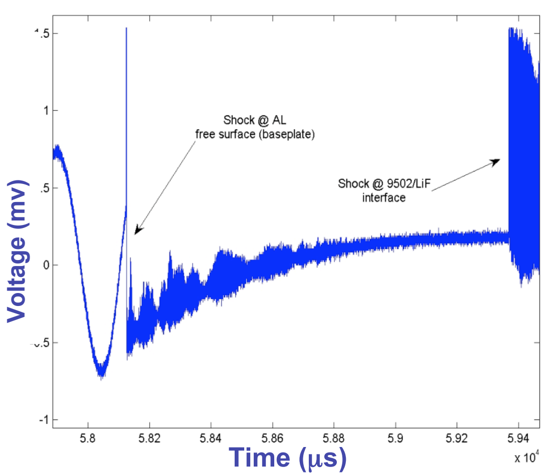




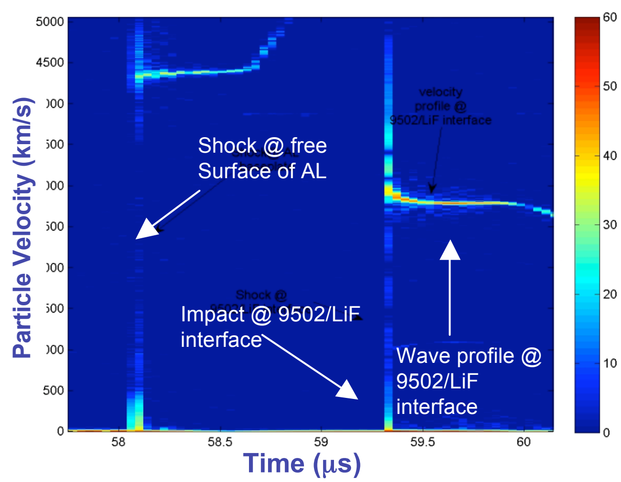
PBX 9502 Data

- Direct measurement of flyer velocity
- Shock breakout easily measured within 100s of picoseconds or better
- VISAR data also obtained at 9502/LiF interface to provide high-time-resolution wave profiles (not shown)
- Data obtained using PDV significantly reduces scatter in Us-Up (Hugoniot)

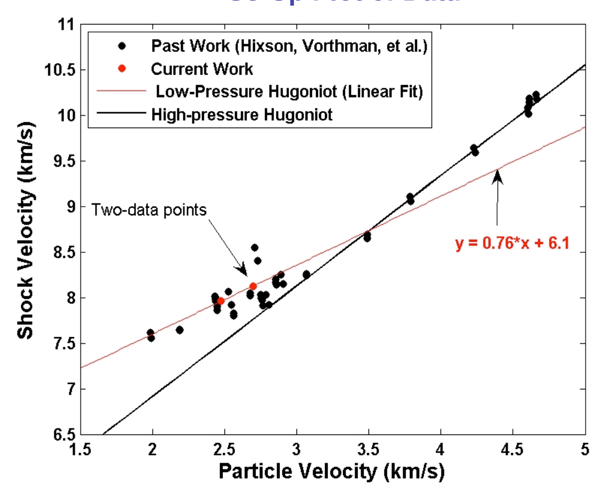
Raw PDV data



Wave profiles obtained from multiplexed data



Us-Up Plot of Data



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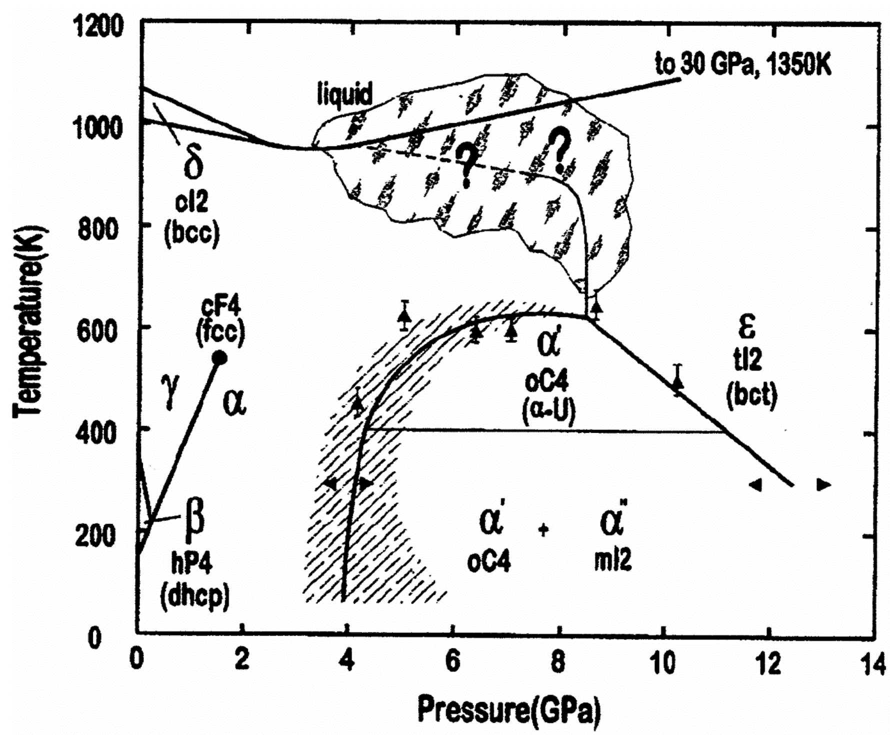
Multi-slug experiments on cerium (complex material)

- Four solid phases known at zero pressure, with at least three more phases at high pressure.
- Anomalous melting at low pressure
- Only pure element with a solid-solid critical point
- Slope (and sign) of α-α' phase boundary uncertain
- Objective of current work is to use PDV/VISAR to obtain C_L and Hugoniot data to locate the melt boundary

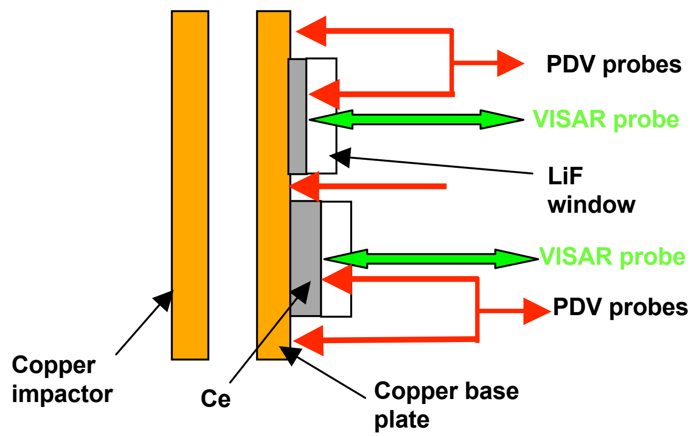


Zhao & Holzapfel; J. Alloys and Compounds (1997)

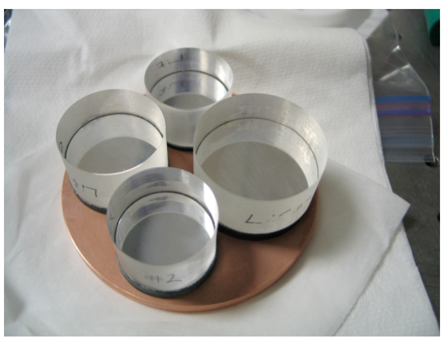
Multi-slug experiments on cerium

- Multi-slug experiments performed using PDV and VISAR to obtain shock velocity, wave profiles including release, and sound speeds at pressure
- 4 cerium samples used per target backed by LiF windows
- 8 PDV probes used to measure shock velocity and wave profiles – 4 VISAR probes used

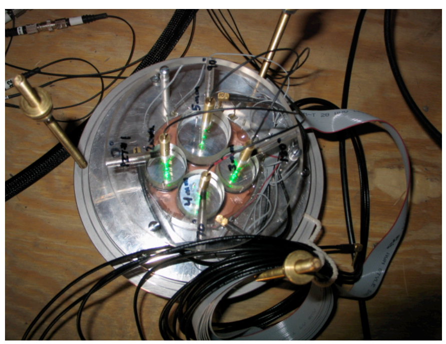
Experimental Configuration (only 2 samples shown)

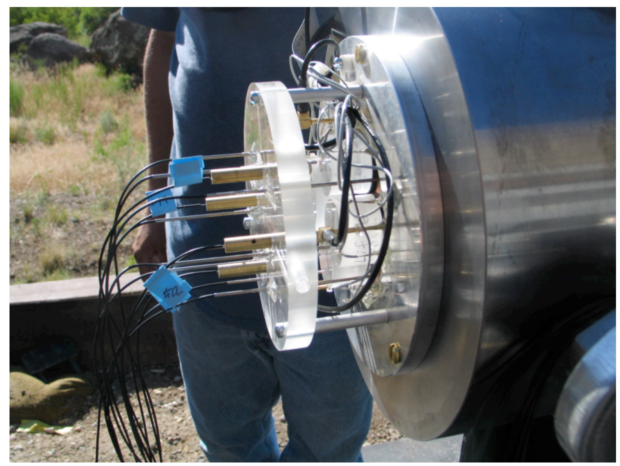


Copper base plate, Ce, and LiF



Completed Target in prep. room

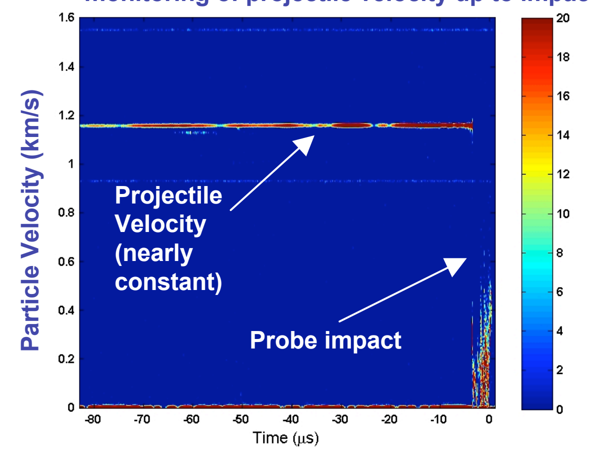




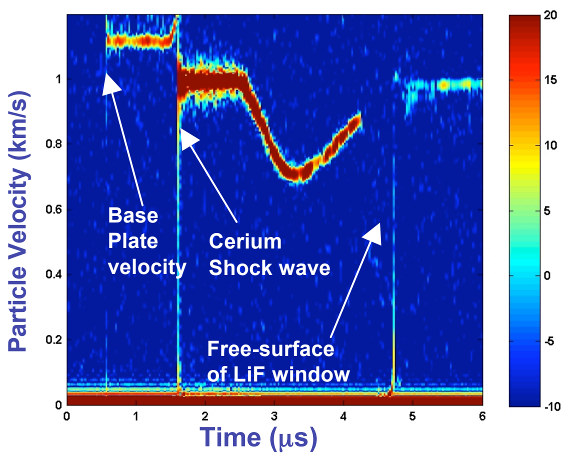
Doppler velocimetry data on cerium

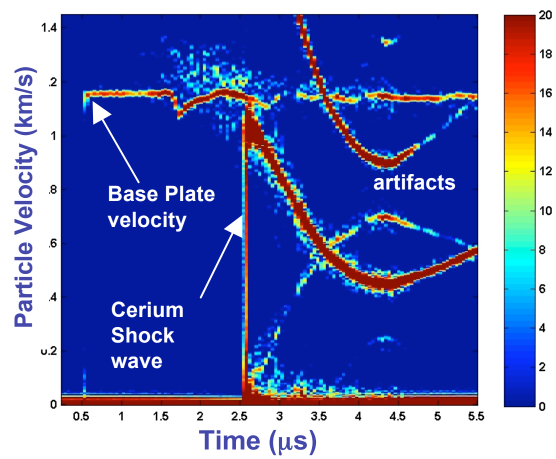
- Multiplexed PDV probes (9 probes total) used to monitor shock breakout at base plate and cerium/LiF interface
- 1 PDV probe used to monitor projectile velocity
- Raw PDV data provides shock wave transit time
- PDV data also provides a check on velocities for VISAR analysis (see next slide)

Collimated PDV probe provides continually monitoring of projectile velocity up to impact

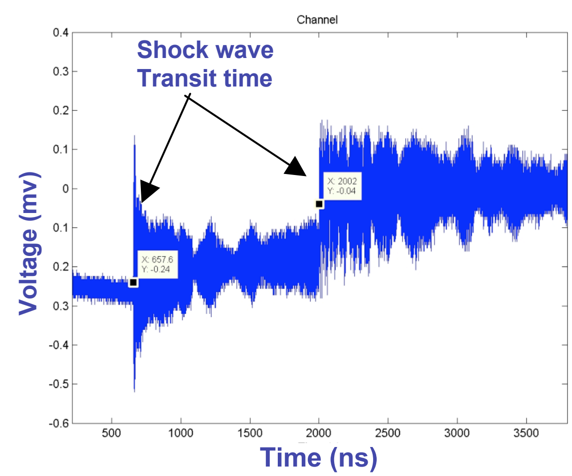


Multiplexed Doppler probes provide data from base plate and cerium/LiF interface





Raw PDV signals provide direct measure of the shock wave transit time



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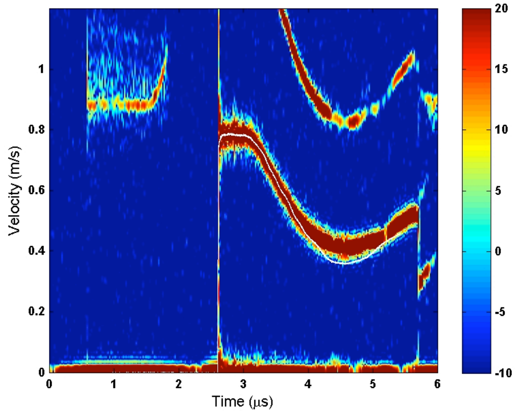
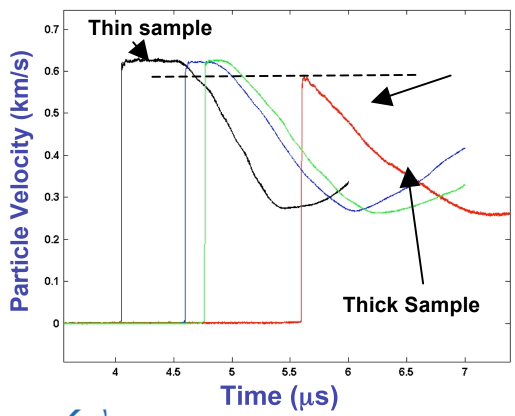
VISAR Data on cerium

- Four VISAR probes were used to obtain the wave profile (ns resolution) at the cerium/LiF interface
- Time between shock arrival and release for multiple sample thicknesses (overtake method) provides a measure of the sound speed at pressure
- Sound speed analysis underway
- Calculations using a 1-D code underway

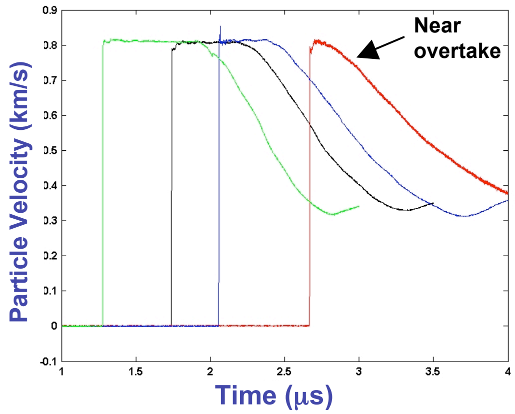
PDV and VISAR (white trace) comparison



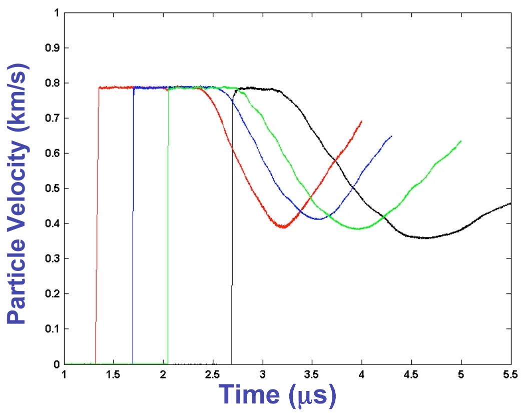
VISAR profiles for Exp 2 (Vp = 0.92 km/s)



VISAR profiles for Exp 3 (Vp = 1.158 km/s)



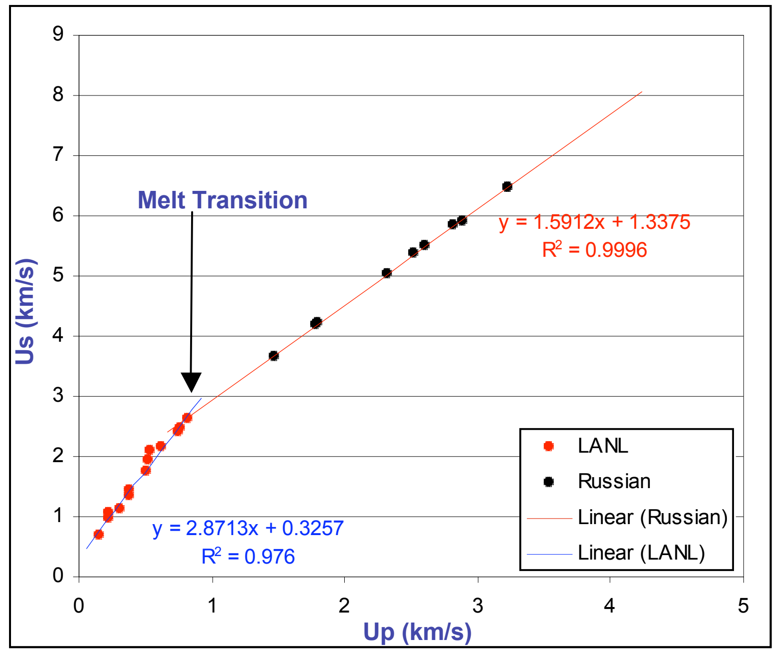
VISAR profiles for Exp 4 (Vp = 1.119 km/s)



Us-Up data obtained for cerium (using PDV)

- Us-Up data obtained from PDV shock velocity measurements
- Total of 7 data points obtained from 8 PDV probes and 4 VISAR probes
- Additional data obtained from LANL and Russian experiments (recent)
- Data shows two linear trends in the data with a kink at approximately 138 kbar (melt transition)
- Melt transition is higher than that estimated from LANL compendium (120 Kbar) and lower than the Russian estimate (> 200 Kbar)

Us-Up data for shocked cerium



Summary

- PDV used to obtain accurate shock velocities and wave profiles for cerium and PBX 9502
- Multiplexing of probes (2 probes per digitizer channel) was successful
- Data obtained for PBX9502 better constrains low-pressure, overdriven Hugoniot
- Data obtained for cerium better constrains Hugoniot - dynamic melt transition occurs at 138 kbar

Explosively Driven Flyer Plate

Large-Bore Powder Gun (NTS PG)