SAND2011-8595C

Task 2: Shock Physics Experimental Studies

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Anisotropic EOS Model Development

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Dynamic Experiments

What are you trying to do in this task?

- Develop experimental techniques and diagnostics for understanding material response at high pressures and strain rates
- Obtain high quality experimental data on materials of interest for development of new models as well as calibration and verification of existing models

What makes you think you can do it?

- Extensive and unique shock physics capabilities and expertise
- Experience with composites and other heterogeneous materials

What difference will it make?

- Phenomenology and high-quality data needed for improved continuum models for composite materials
- Better temperature measurements will lead to improved EOSs and understanding of reaction of energetics

What / When / To Whom Will You Deliver?

- Report on full CFRP data set (FY12)
  - SAND report available to TCG
- Reflectivity based temperature diagnostic for DoD use (FY13)
- TRL: 3 (composites), 1 (reflectivity)

Development of dynamic temperature diagnostics

Goal:

Develop a new technique to measure temperature during dynamic experiments

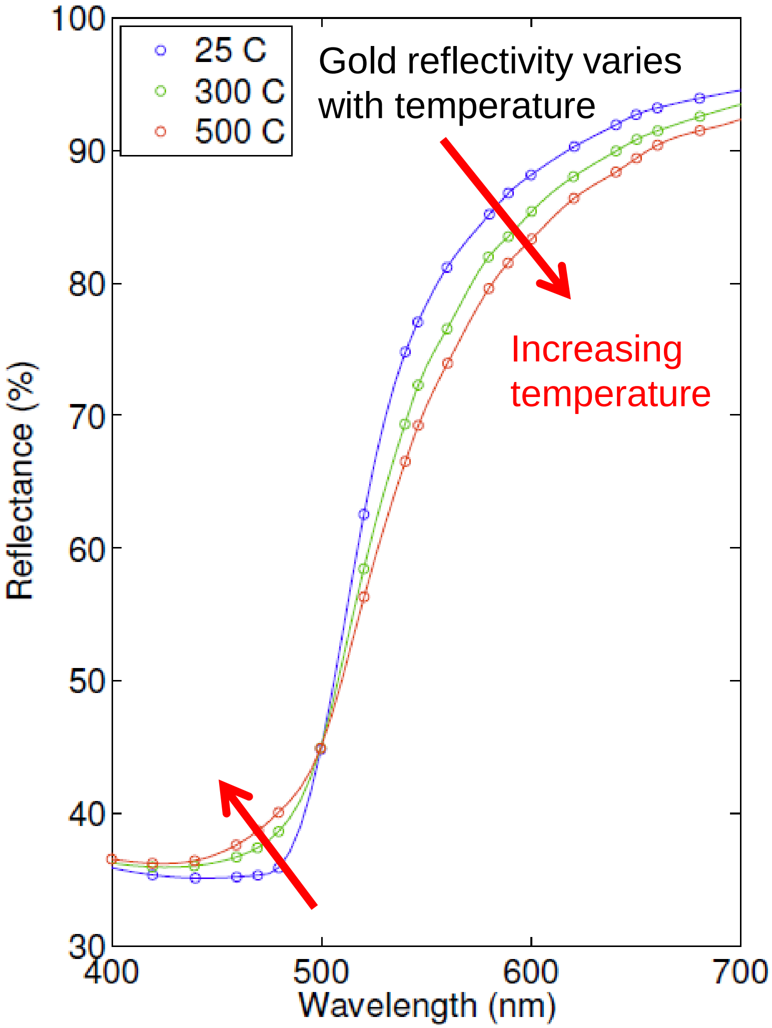
Motivation:

- Temperature measurements needed for improved EOS models and for understanding reaction of energetics
- Embedded gauges (e.g. thermocouples) have poor time resolution, disturb experiment, require wire leads, and are difficult to use in EM environments
- Pyrometry is light-starved at low to moderate temperatures (<1000 K)

Sub-Task Lead:

Dan Dolan

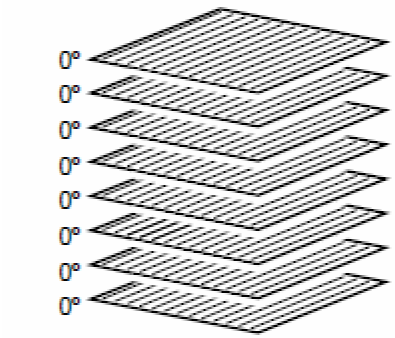
Low funding level ($50k/yr) combined DOE/DoD



Dynamic Behavior of Composite Materials

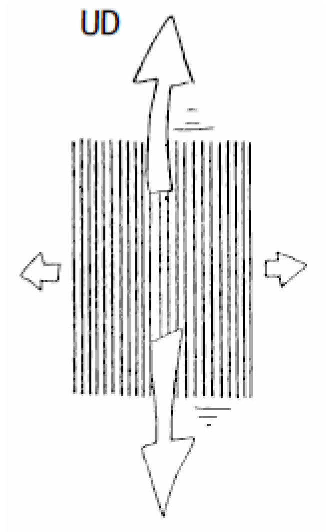
Goal:

Obtain shock data to characterize the anisotropic response of fiber composite materials for development of advanced EOS and constitutive models



Materials of interest:

Hexcel IM7/8552
unidirectional / laminate
vary volume fraction (62, 65, 68%)



Components:

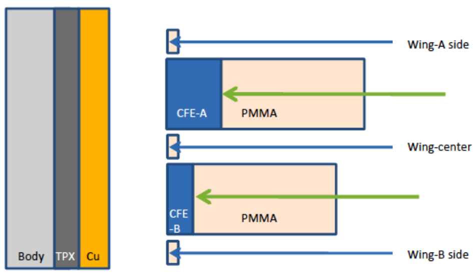
Hugoniot, pressure-shear, spall, validation

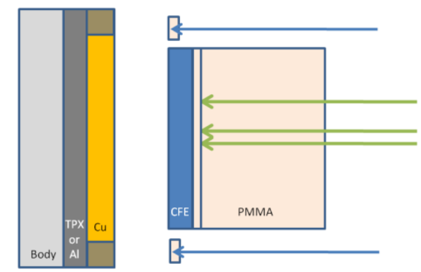
Sub-Task Lead:

Scott Alexander

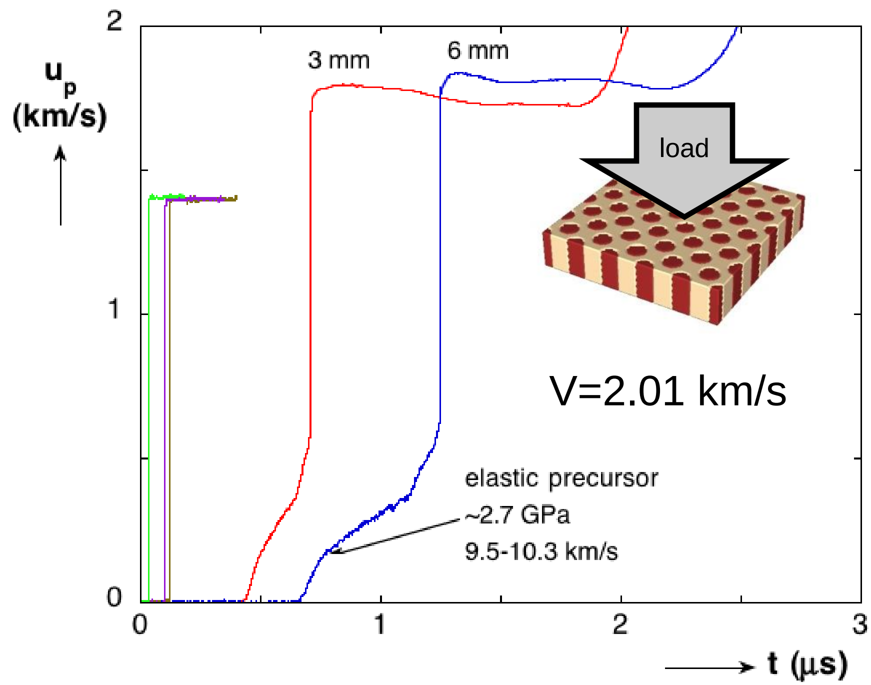
Hexcel Prepreg Technology Guide
Publication No. FGU 017b
March 2005

Effect of Fiber Orientation

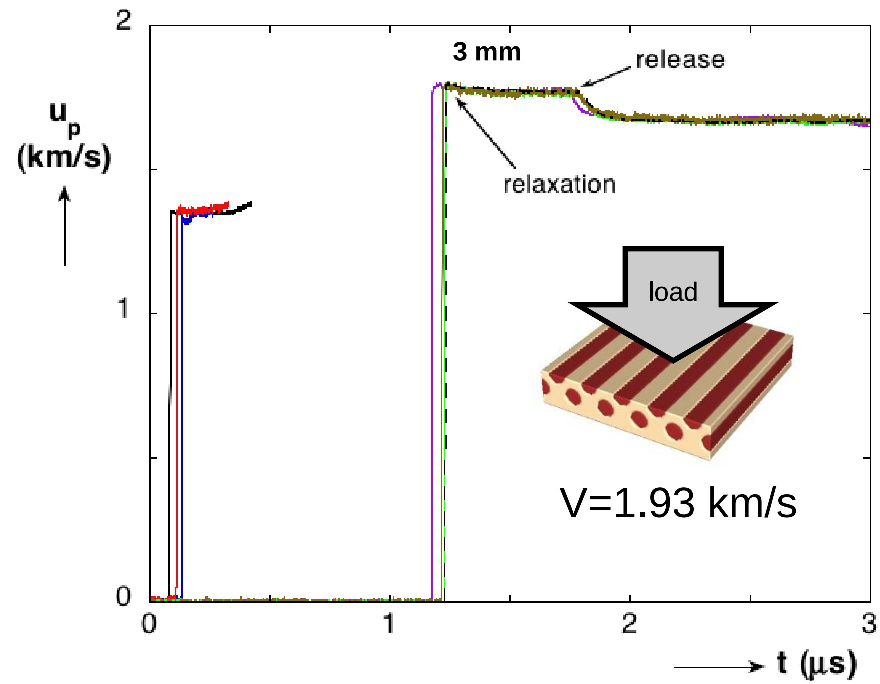




0° (shock along fiber direction)

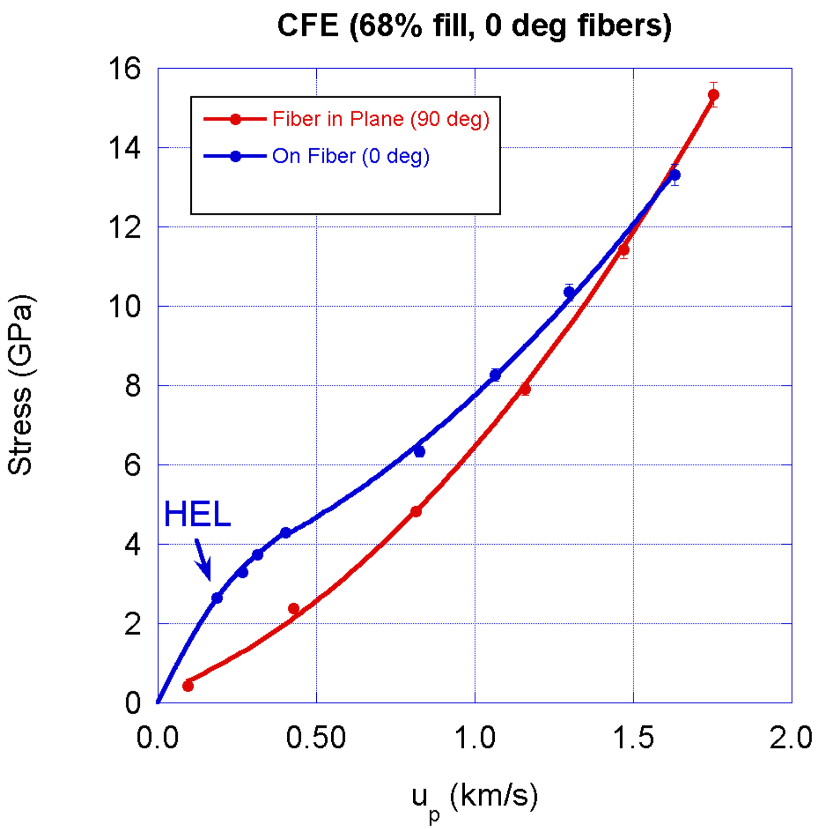


90° (shock normal to fiber direction)



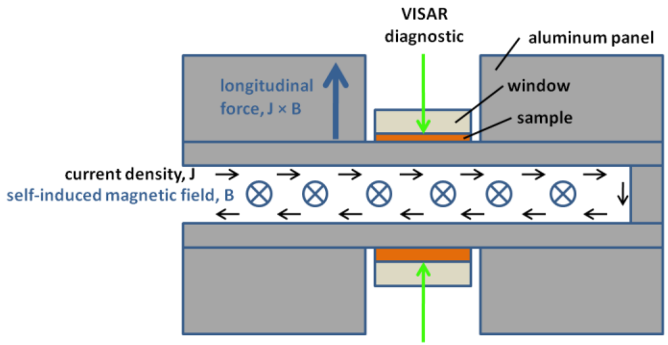
Data for 68% fiber FV

Anisotropic Behavior of Composites

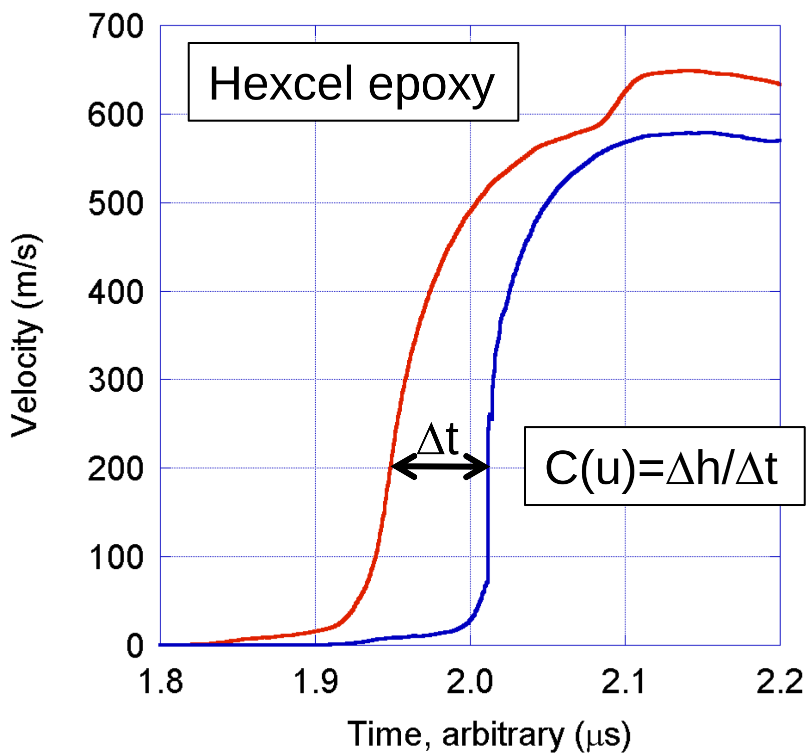


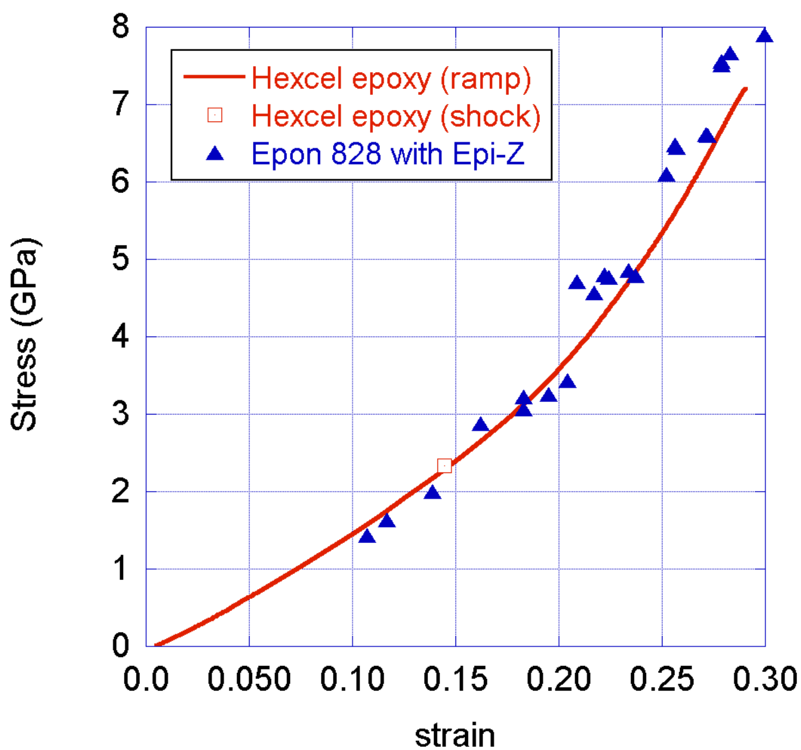
- Material behaves differently under through thickness and fiber direction loading
- The vast majority of models in the dynamic regime assume isotropic behavior, especially for shock behavior

Dynamic response of epoxy

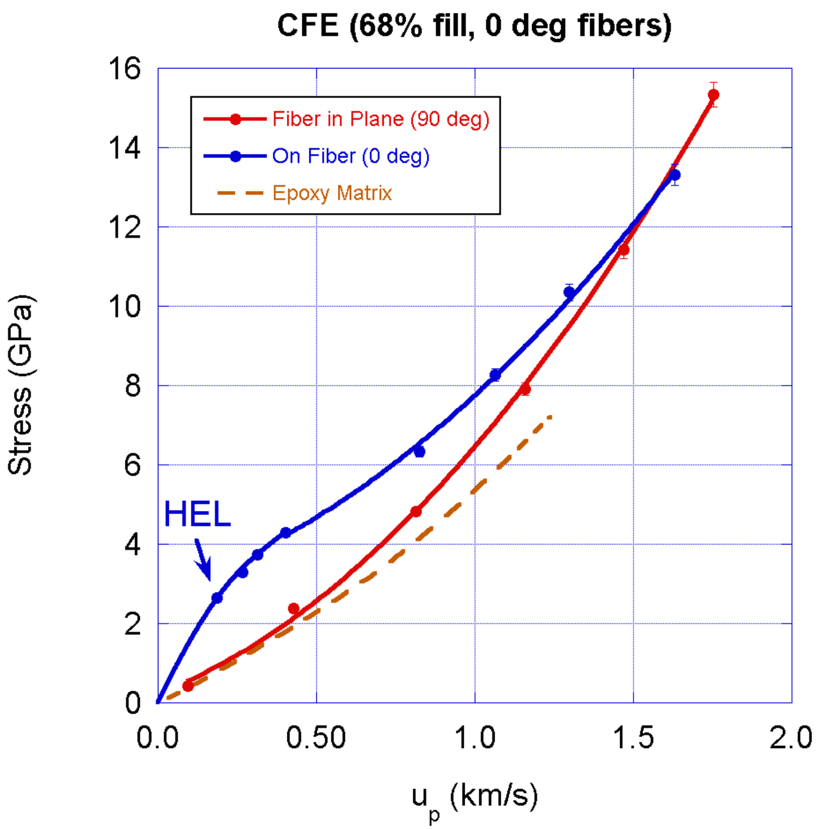


- Epoxy response is needed by model development effort
- Response measured via shock and ramp loading techniques
- Data similar to another common (well characterized) epoxy



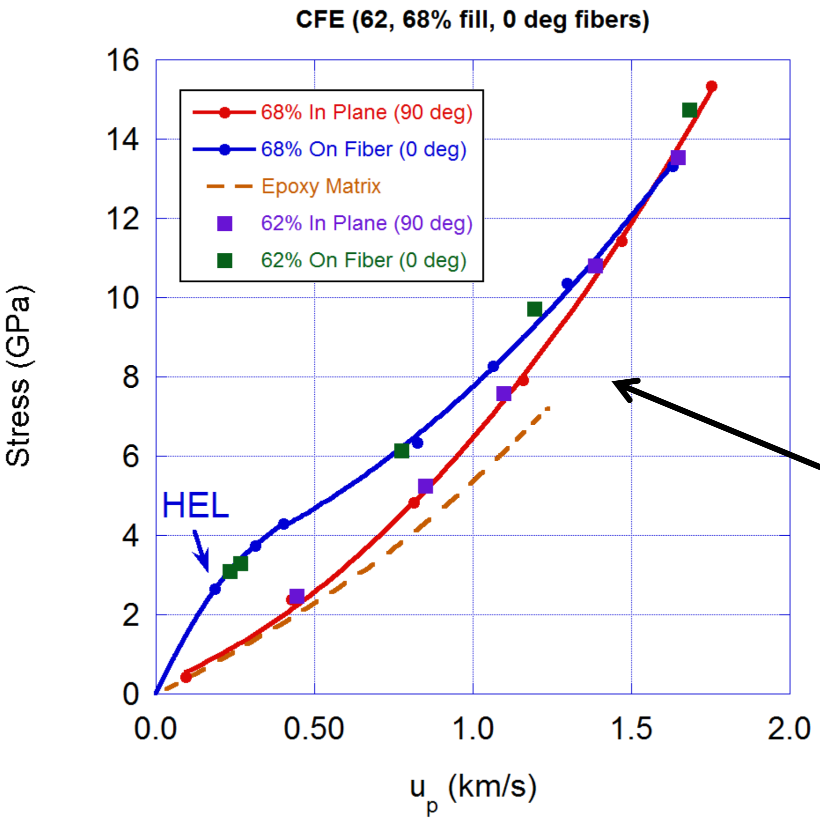


Anisotropic Behavior of Composites



- Fiber stiffens matrix at low-intermediate pressures (up to ~10 GPa)
- Response appears to become isotropic at higher pressures

Fill volumes between 62 – 68% have similar dynamic response

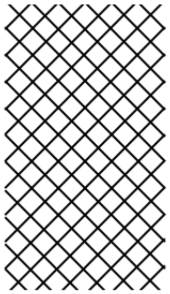


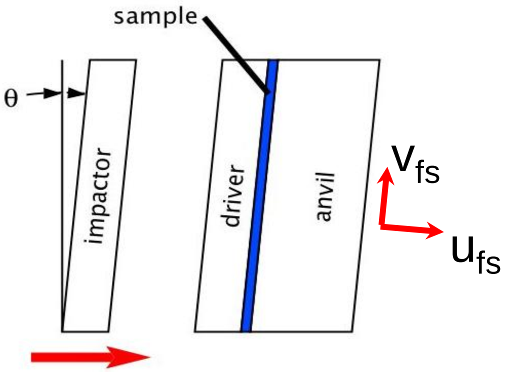
62% data shown by enlarged square points

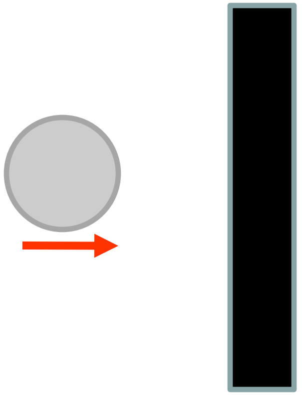
- 62% fill material shows similar dynamic response
- Samples tested are maximum and minimum manufacturable fill for this composite
- Testing will not be performed on 65% fill material

Future Work on composite materials

- 65% volume fraction characterization will not be completed
- cross-fiber (±45°) to probe more complex material behavior
- spall
- pressure-shear
- validation tests
- GFRP



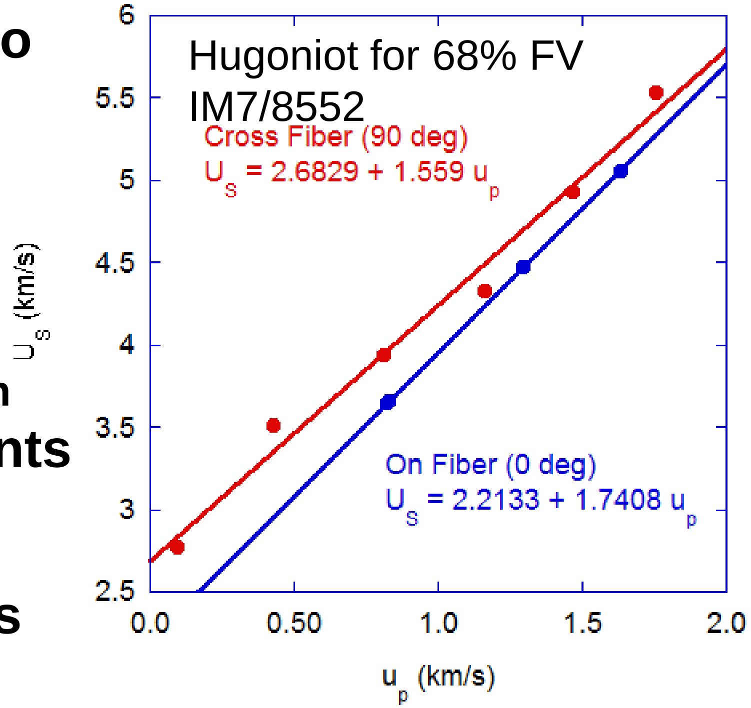




	Milestone/Deliverable	Planned Date
2.1	*Final report on CFRP experimentation*	Q4 FY12

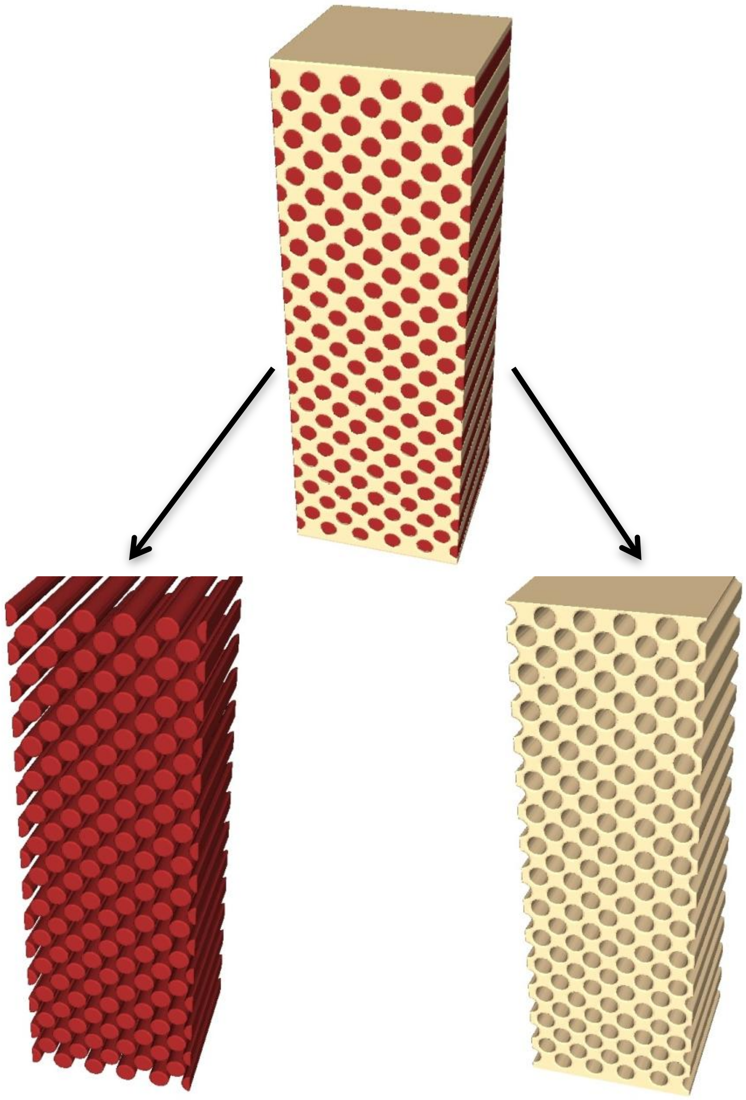
Anisotropic EOS Model Development

- **Current efforts are focused on polymer matrix composite anisotropic EOS model**
- **Macroscopic shock response from fiber and matrix constituent data using micromechanics**
- **Generate model at the macroscopic level to capture shock in an anisotropic material**
- **Using micromechanics to develop directional EOS response**
  - **Previously generated directional EOS response curves based on bulk composite**
  - **Investigates fiber and matrix EOS decomposition**
- **Validating micromechanics with experiments**
  - **68% fiber volume transverse and longitudinal**
  - **62% fiber volume transverse and longitudinal**
- **Woven/Harness fabric composite materials**
  - **Specimens for testing – ARL, LJ Holmes**
  - **Glass and Vinyl Ester/Phenolic**
- **Continued work with LANL on stochastic field analysis**
  - **Working with Todd Williams to verify concept for CTH**



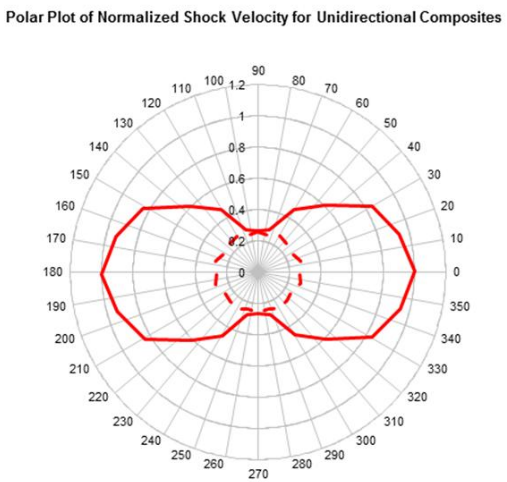
Anisotropic EOS Model Development - Microscopic

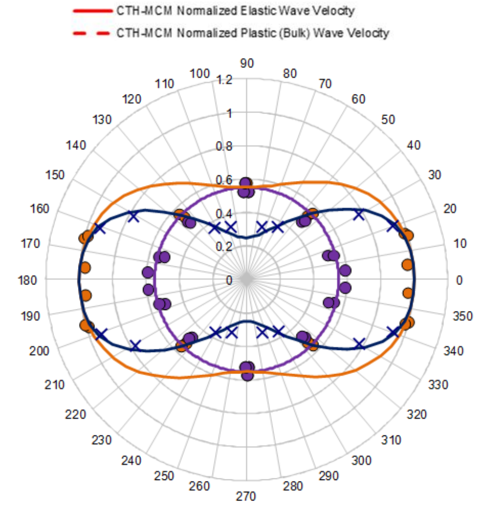
- Developed microscopic models for unidirectional materials
  - 62%, 65% and 68% FV
- Uniform fiber arrangement in matrix
- Using matrix and fiber material properties can generate composite response
- Validation performed by comparing model results to experiments
- MCM model also captures the directional shock behavior



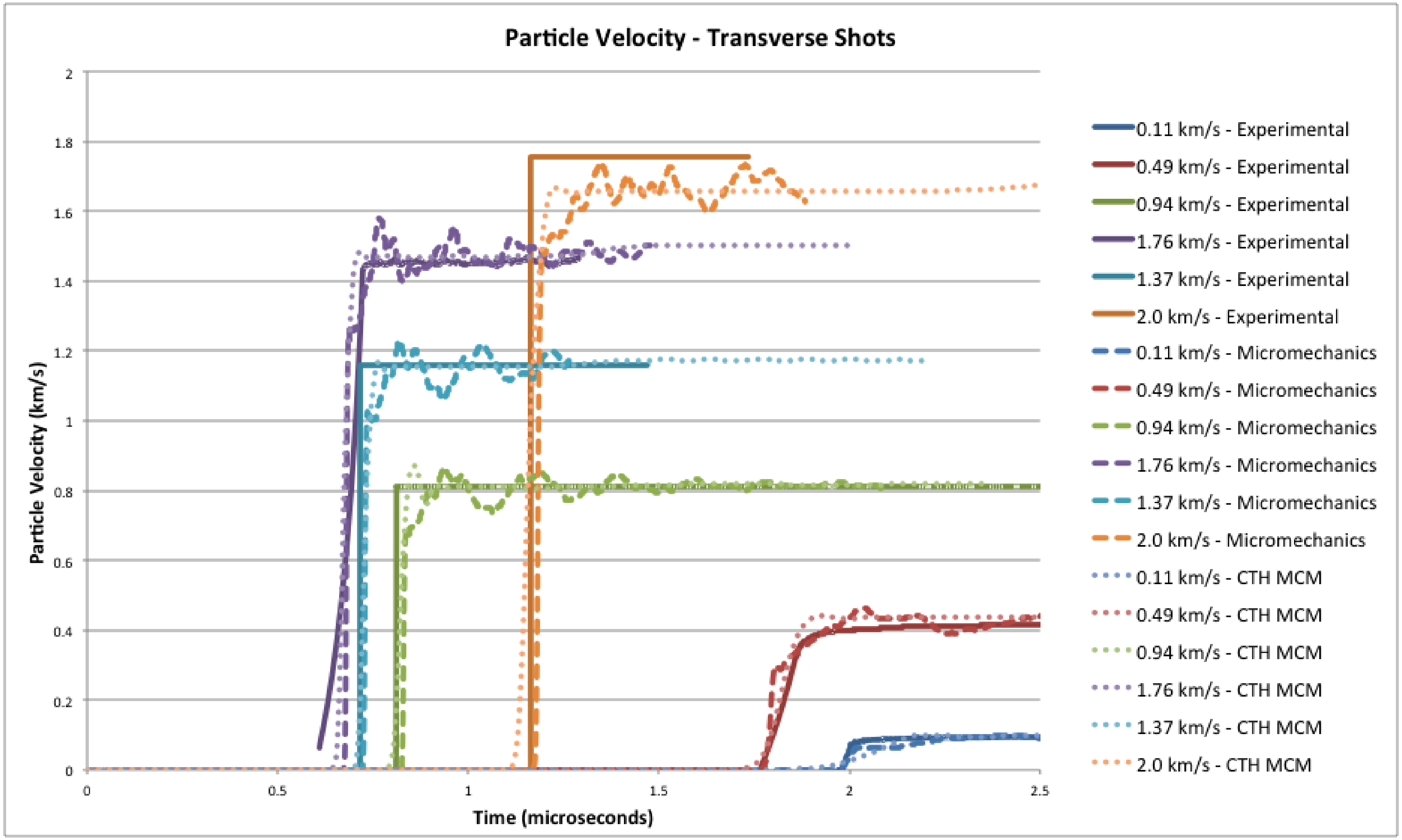
Anisotropic EOS Model Development - Macroscopic

- **Multi wave material response**
  - **Strong elastic wave from 0° to ~45°**
  - **Plastic dominated from ~45° to 90°**
    - **Matches bulk matrix response**
- **Elastic wave response follows material rotation/transformation**
- **MCM coupled EOS captures rotated bulk composite response**
- **Validating micromechanics models with MCM coupled response, experimental data and literature**
- **Results of above used to develop EOS constituent decomposition – Multicontinuum EOS**





Transverse 68% Results



Longitudinal 68% Results