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SEERI

SCIENCE OF EXTREME ENVIRONMENTS RESEARCH INSTITUTE

Copper Conductivity Model Validation Method Using Flyer Plate Experiments and Simulations

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Presented by Lauren Riford (1641 - HEDP Theory)

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NNSA National Nuclear Security Administration

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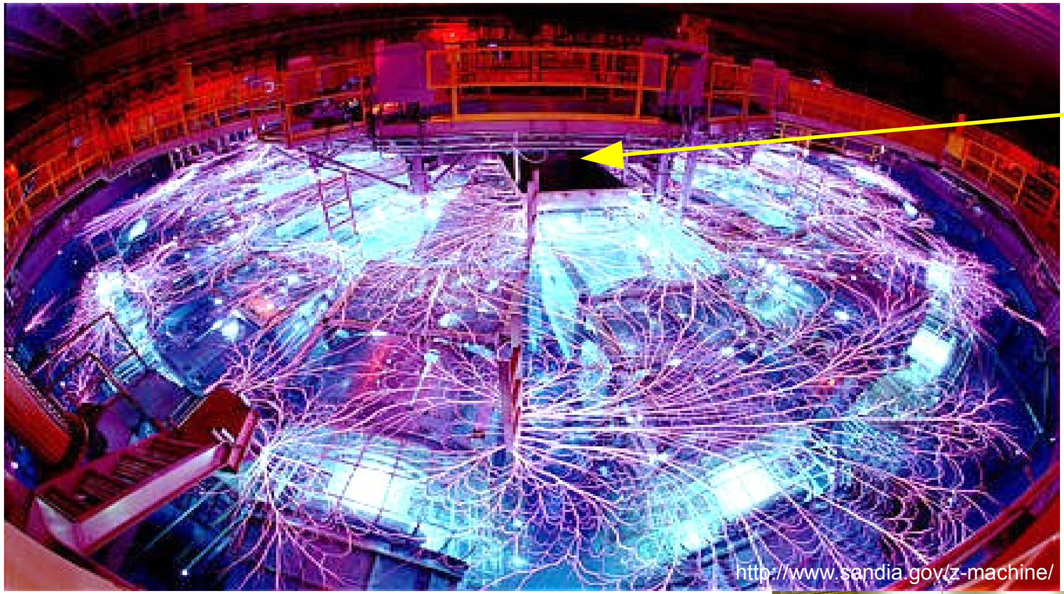
About the Presenter

- Summer Intern in 1641
- Mentor: Ray Lemke
- SEERI Program
- Senior at Lehigh University
- Physics & Asian Studies
- CSE Minor

Presentation Outline

- Introduction
  - Sandia's ZR Machine
  - Flyer Plate Experiment
- Main Purpose
- Challenges Faced
- Results
- Conclusions/Further Work
- Acknowledgements

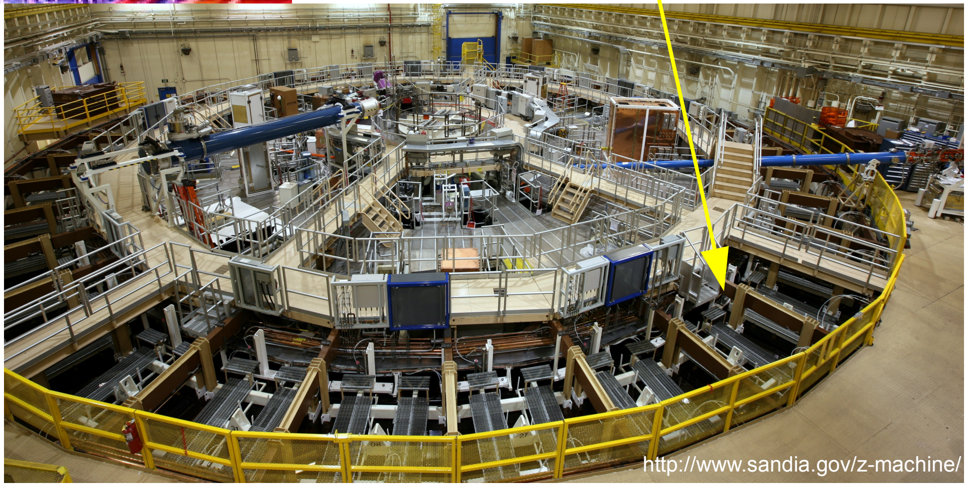
Sandia's ZR Machine Capabilities



Z Machine during shot

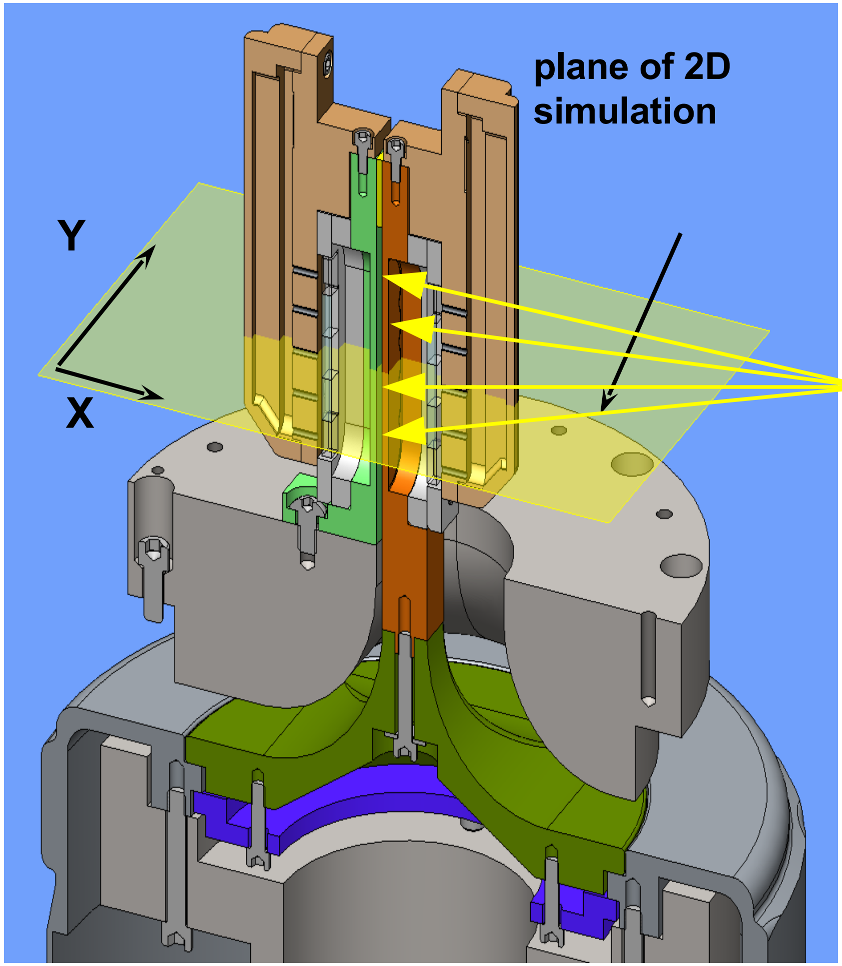
36 Storage Capacitors and laser-triggered gas switches

Marx Generators



22 MJ of stored energy
25 MA current delivered to load
Rise times of 100-1000 ns
Current pulse shaping capabilities

Flyer Plate Load Design Allows Multiple Sets of Collected Data in One Shot



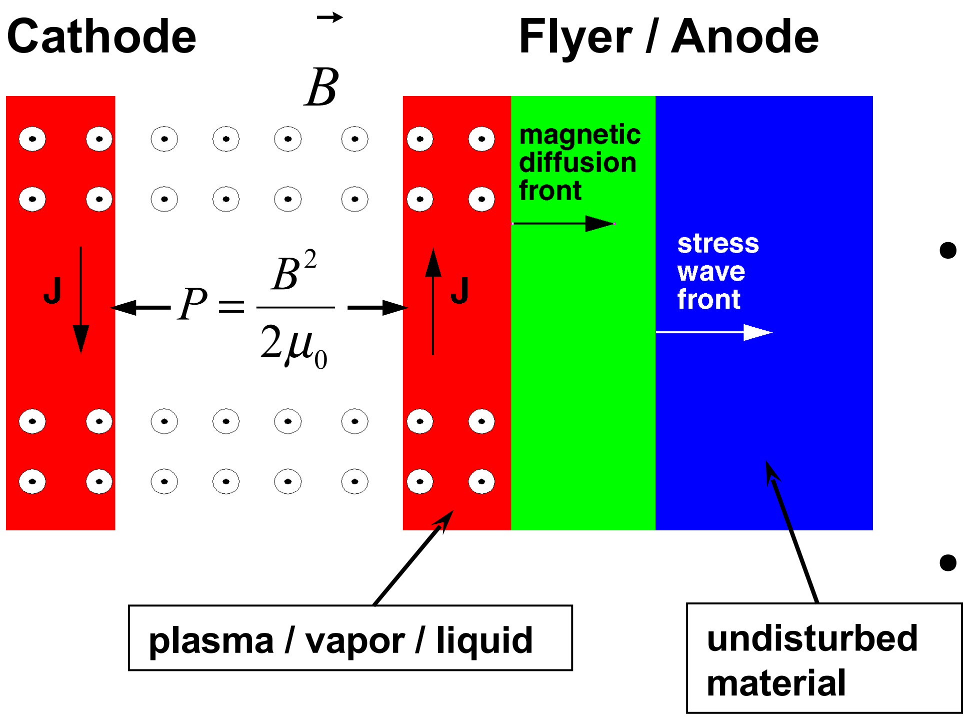
VISAR, shielded from electric current and magnetic field, provides plate velocity data

10 individual flyer plates:
500um,550um,...,900um,950um

All copper plates

Usual purpose of Flyer Plate experiments:
Find shock Hugoniot of target material

Flight Time of Flyer must be < Magnetic Breakthrough Time for Part of Flyer to Remain Solid



- Completely melted – will not provide accurate point on Hugoniot
- Experiment purposefully long enough to allow melt to reach surfaces
- Melt through shows up as bump in velocity trace

Main Question: Can We Relate the Measured VISAR Data to the Conductivity of Cu?

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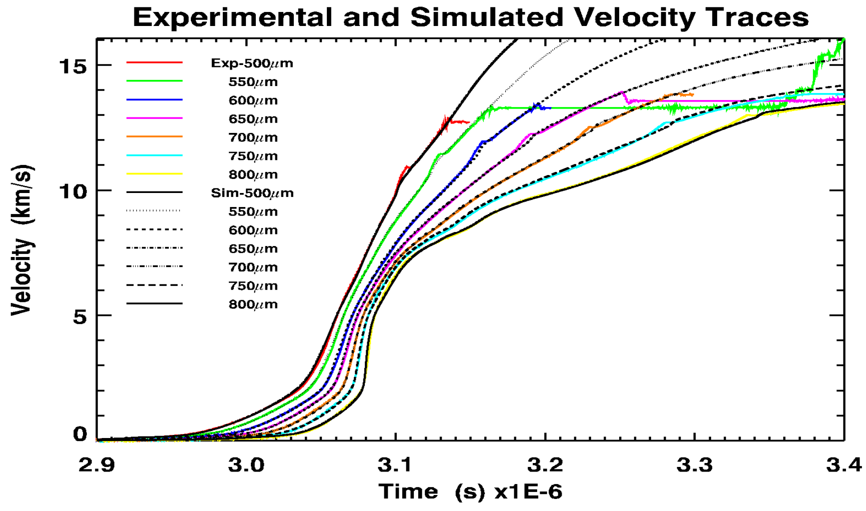
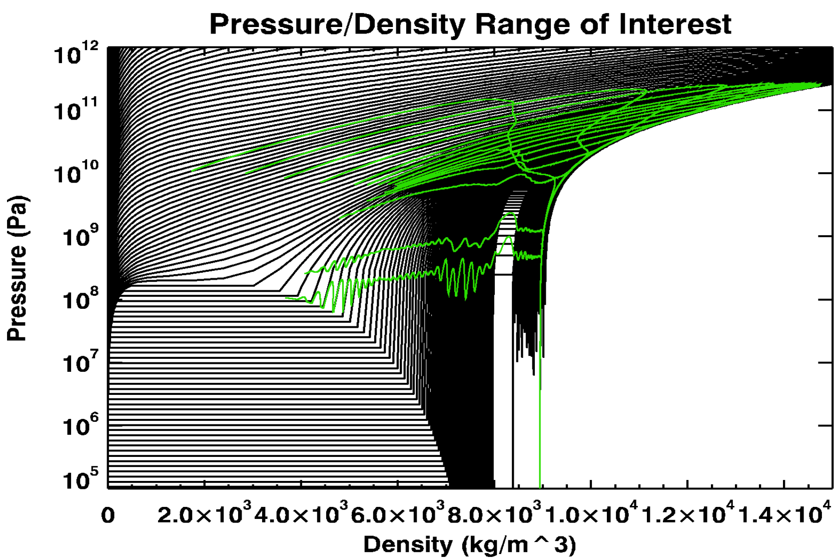
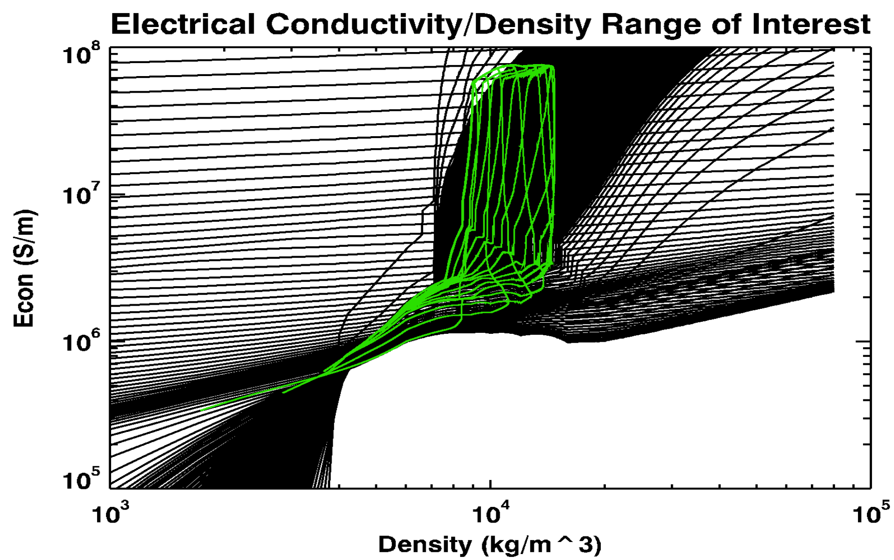
- Fast, simple method to validate Cu conductivity model
- Two approaches to getting Cu conductivity:
  - Find equation relating visar data to conductivity
    - Such as $V_{melt}=C*\sigma(\rho,T)$
    - Only possible if simulation accurate, V_{melt} same in all plates
  - Narrow down a range of interest, then use another method
- Sandia-owned Alegra code used to simulate experiment

Bump in Velocity Different Shape in Experiment Possibly Due to Inacuracies in EC Data

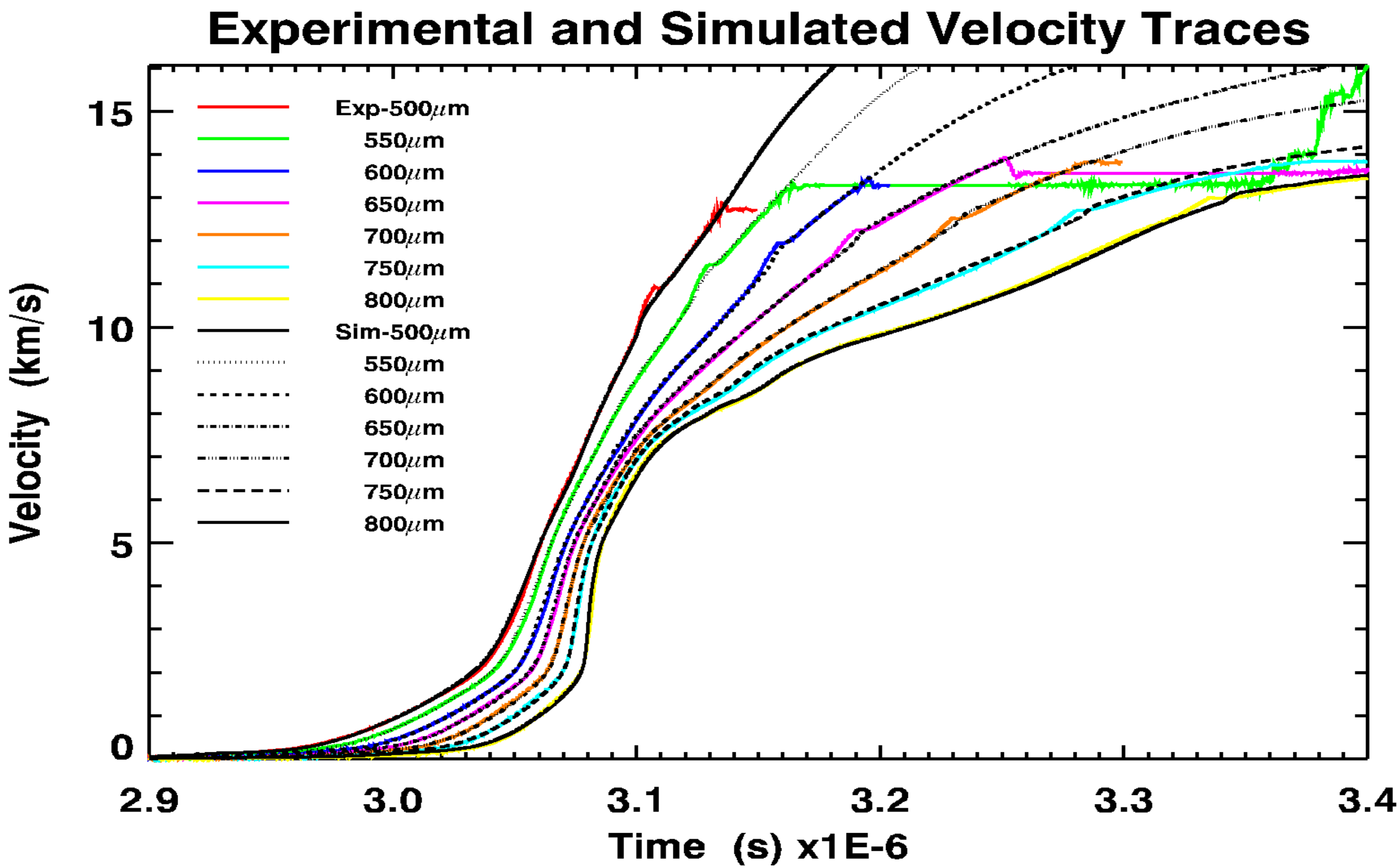
- Current pulse shape optimized and magnetic field strength correction found
- Velocity traces agree until melt through bump
- EOS data is assumed to be valid in this region, EC has not been validated



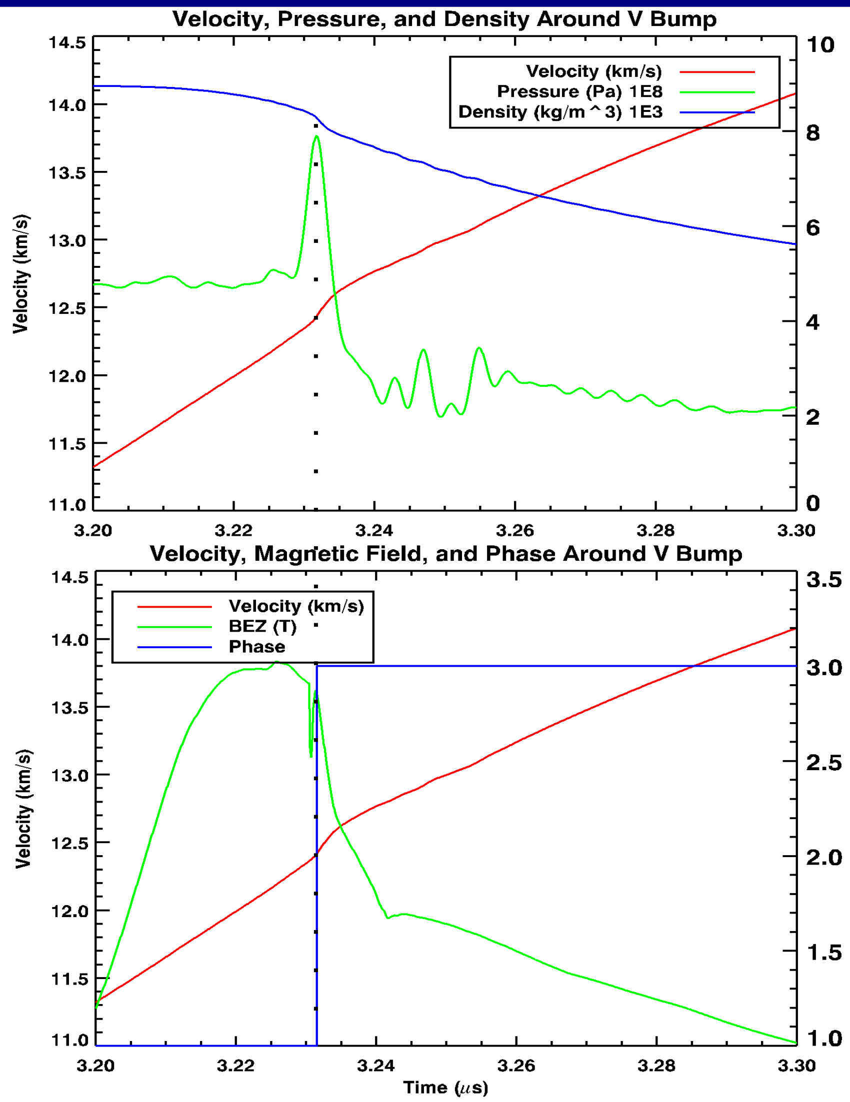




Bump in Velocity Different Shape in Experiment Possibly Due to Inacuracies in EC Data



Bump in Velocity at Melt Through is Important for Experiment/Simulation Comparison



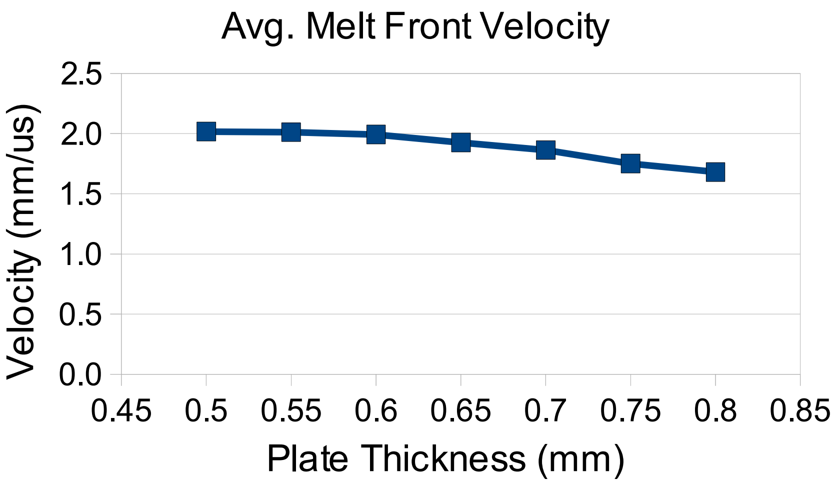
Caused by melt front reaching surface of flyer

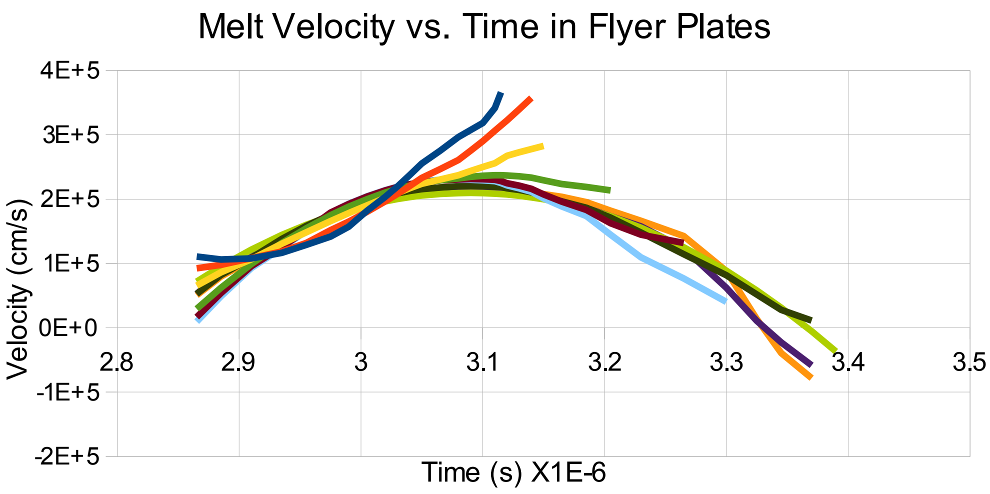
Pressure increases, material expands outward, then settles

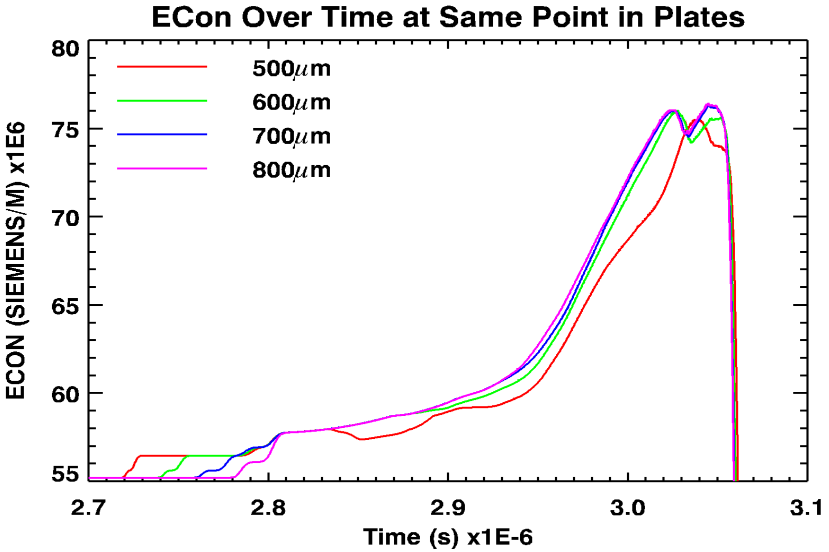
Difficulties Faced Finding the Melt Front Velocity

Ran into non-physical results for melt front velocity

1. Average velocity slowing down in thicker flyers
2. Not constant through flyer (not in-situ)
3. Material properties show vibrations before first rarefraction wave
   - Not in-situ while material properties are not constant

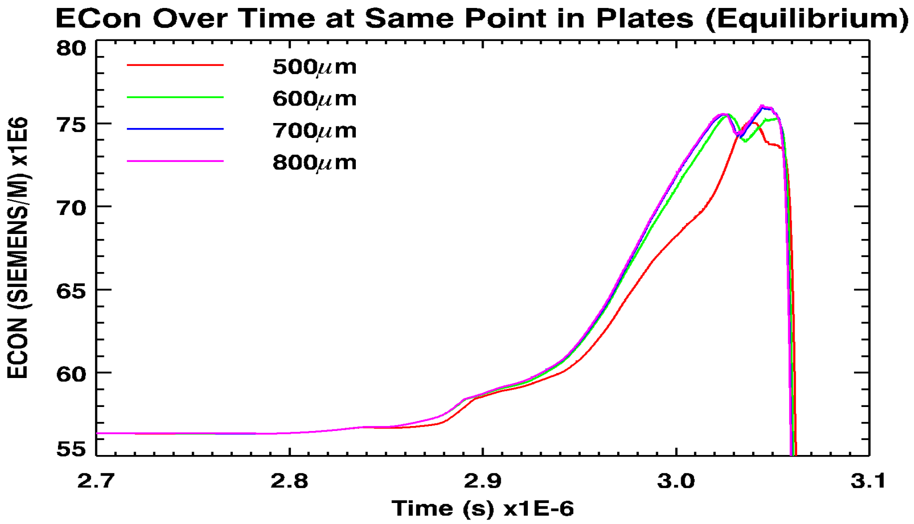


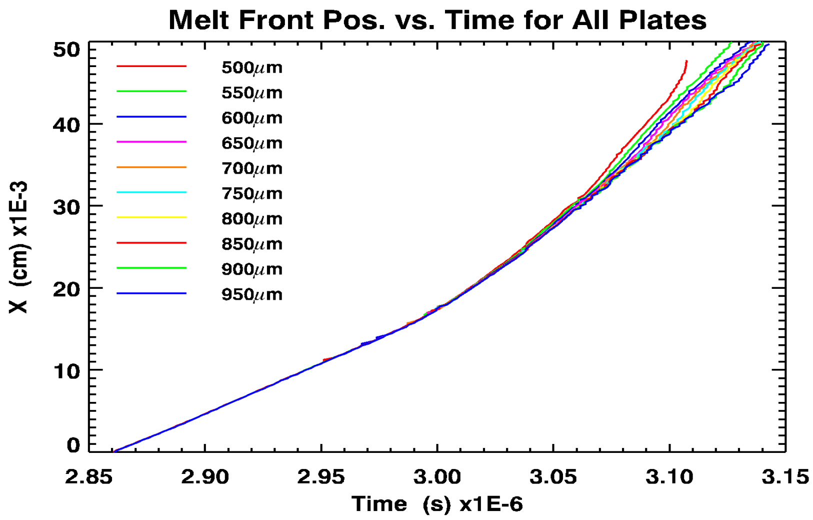


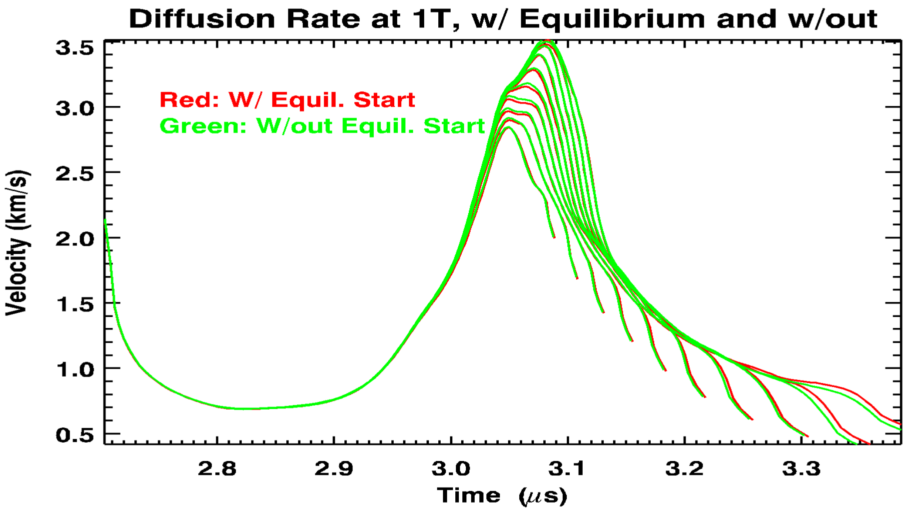


Melt Front Velocity Valid for Short Time

- Current and magnetic field were varied in each plate to match experiment
- When set to equal current and magnetic field, melt front velocity is constant from about 2.86 to 2.96 uS (1.2 km/s)
- Altering initial properties slightly does not effect early B diffusion rate
  - (Density: 8.90 to 8.94e3 kg/m^3 Temperature: 293.0 to 296.93 K)

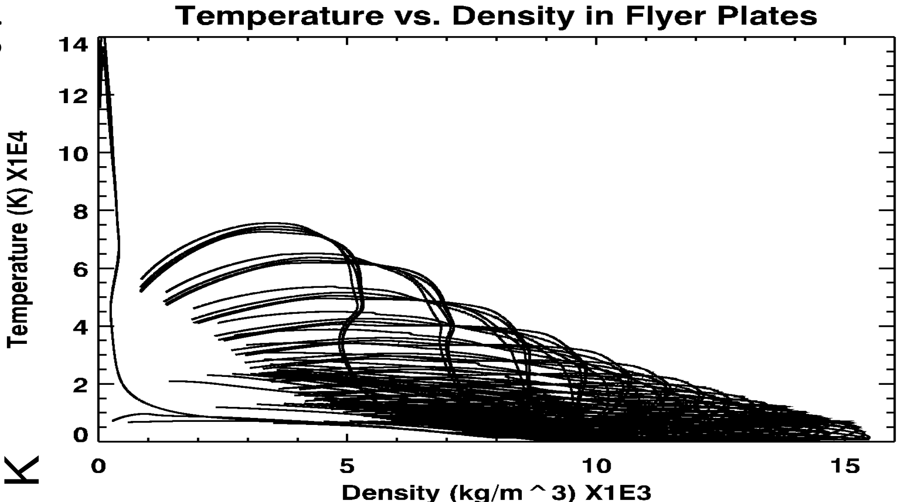


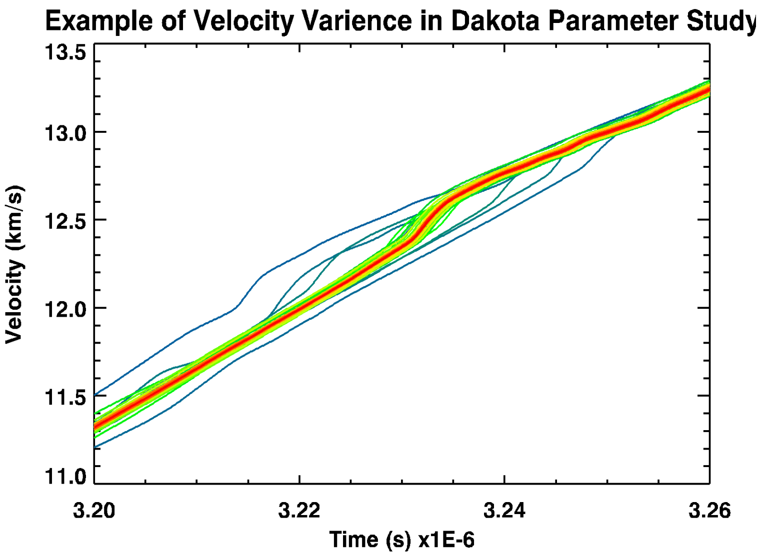


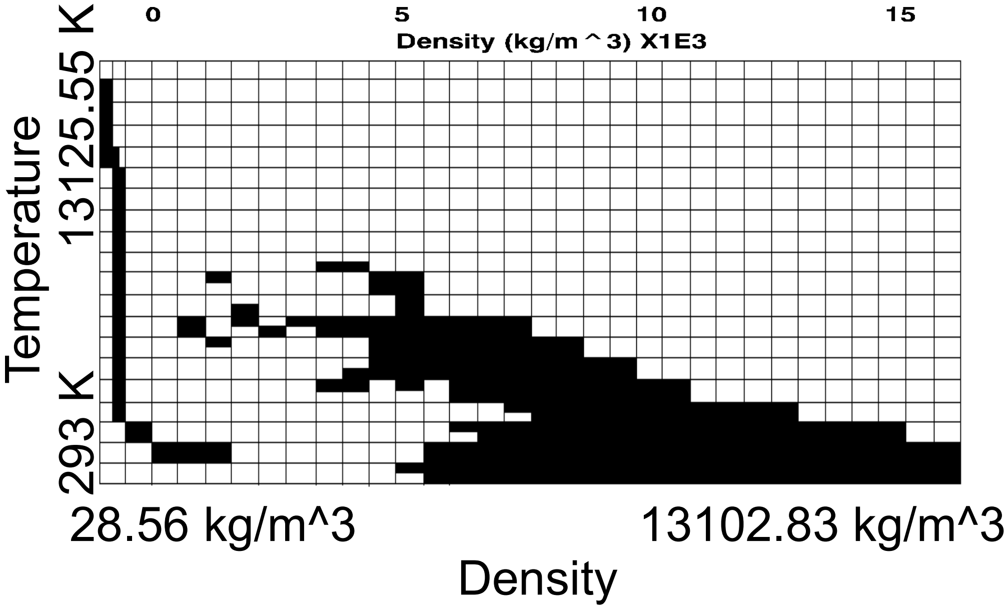


Using DAKOTA to Narrow Down Important Temperature/Density Range

- Run many simulations at once varying electrical conductivity in temperature/density ranges
- Narrow down to smallest range of influence
- Kyle Cochrane uses VASP to correct conductivity data

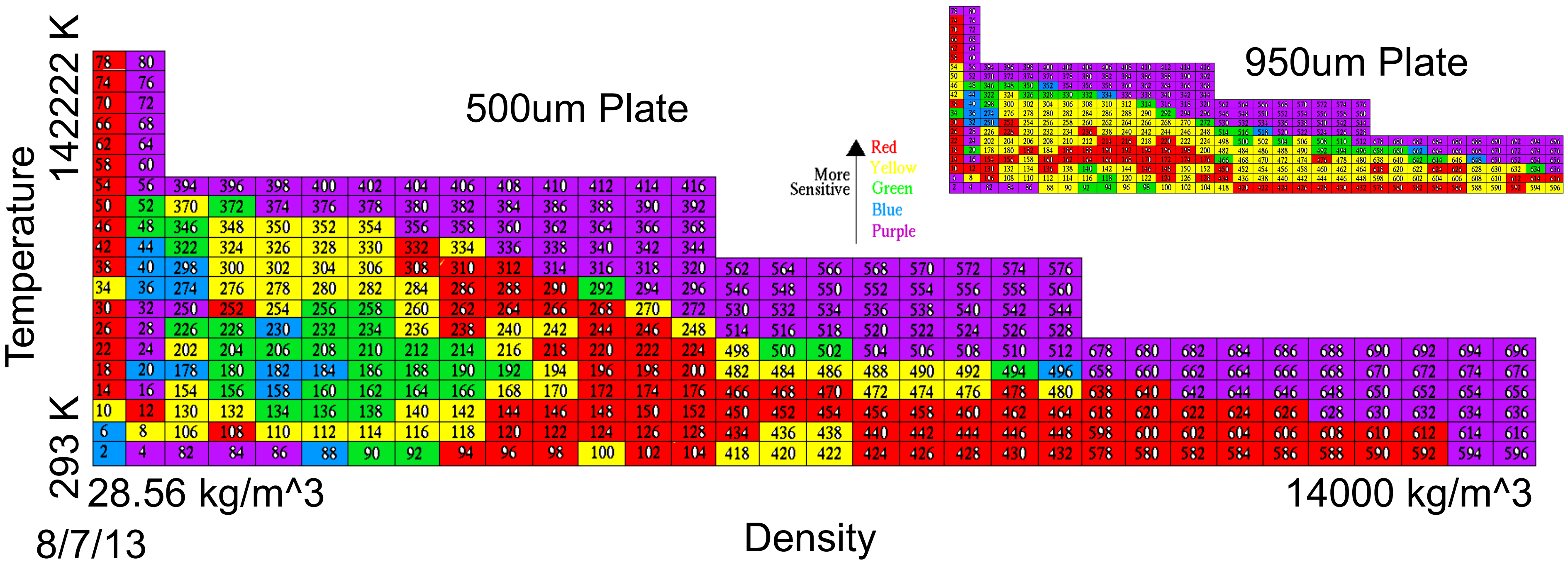






Using DAKOTA to Narrow Down Important Temperature/Density Range

- Improved sensitivity study with addition of weights
  - Show how important each range is to velocity near melt
- Shows low density, high temperature plasma range has large effect, along with lower temperature, high density range.



Conclusions and Further Work

- Alegra simulation provides excellent model of flyer plate experiments on Z
- Simulation validation is of great importance when working with complicated experiments in abnormal conditions
- Experiment shows goodness of conductivity model for a material
  - Model for Cu currently very good, but could be fine-tuned
  - Region of importance better found by adding weights to sensitivity analysis
- Similar experiment would be useful for baseline check of other material conductivities

Acknowledgments

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- Kyle Cochrane (1641)

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