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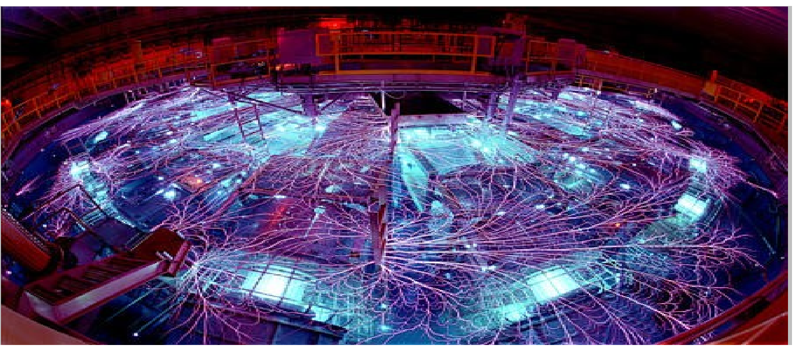

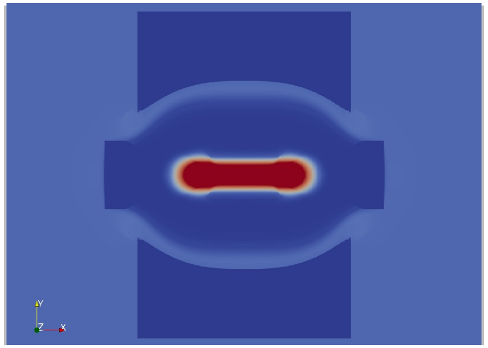

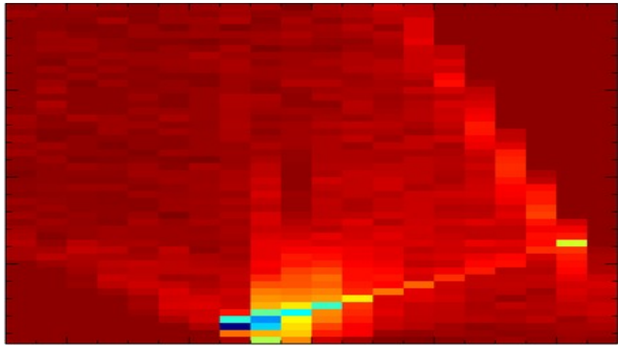

Current Loss on the Z Pulsed Power Machine and Copper Conductivity Model Validation Using Flyer Plate Experiment and Simulation

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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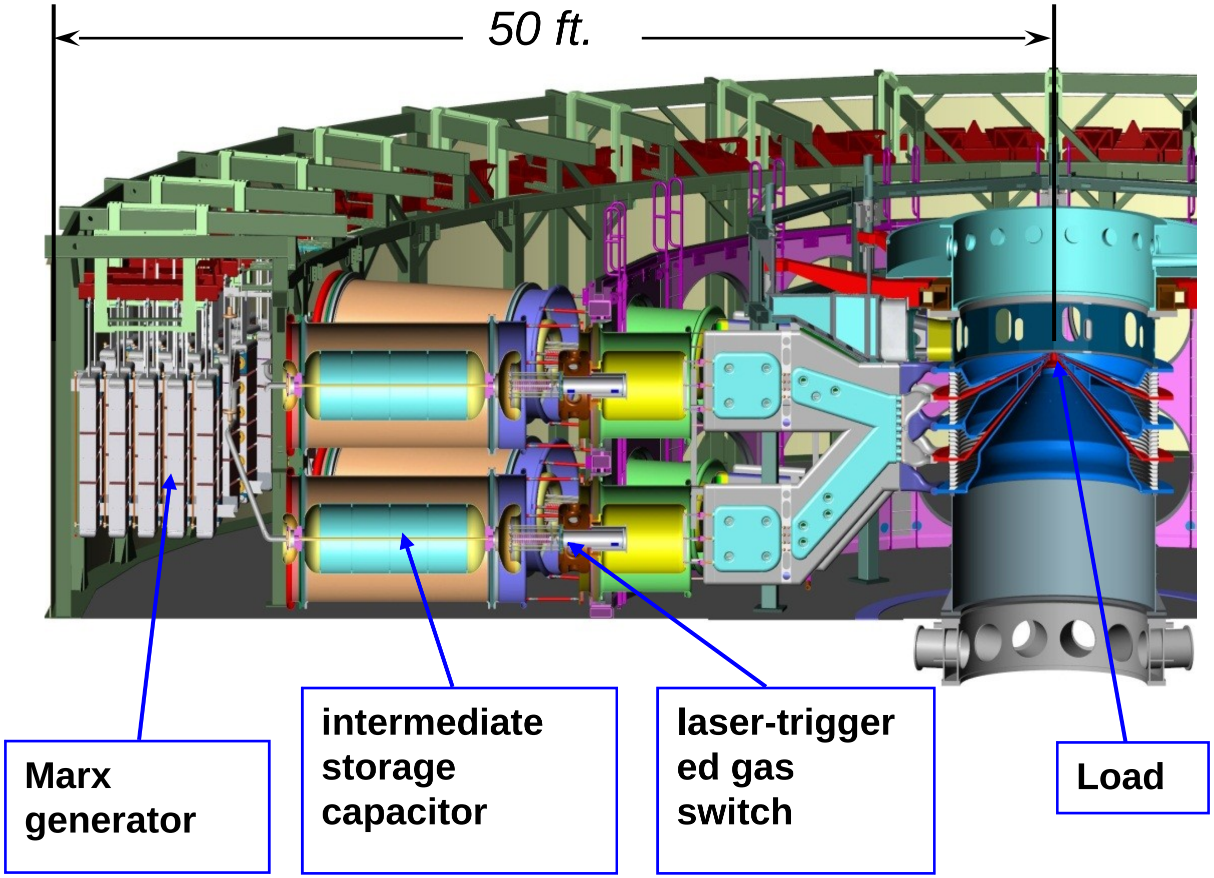
Outline

- Sandia's Z pulsed power machine
- Current loss on the Z machine
  - Collecting Z shot data
  - Creating a model of current loss
- Copper conductivity model validation
  - Finding a causal range in density/temperature space
  - Altering conductivity model in simulation to match experiment

Sandia's Z pulsed power machine can send up to 25 MA to a Load

- 100-1000ns current rise times
- 36 gas switches independently triggered for pulse shaping

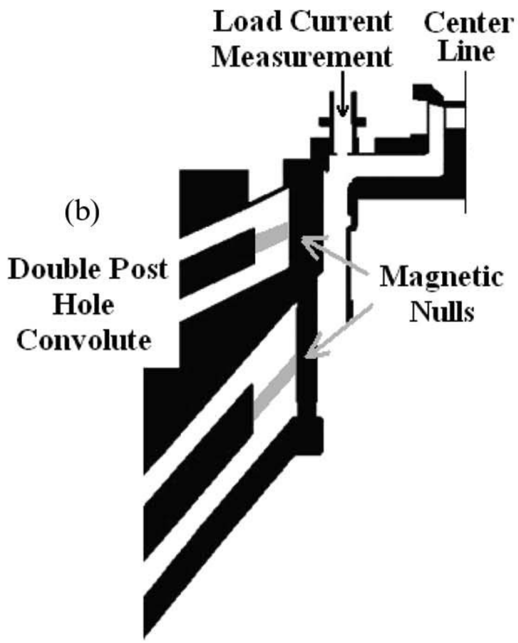


Current lost across magnetic nulls in convolute

- On Z, current diagnostics at magnetically insulated transmission lines (MITL) and load report different currents, indicating a loss

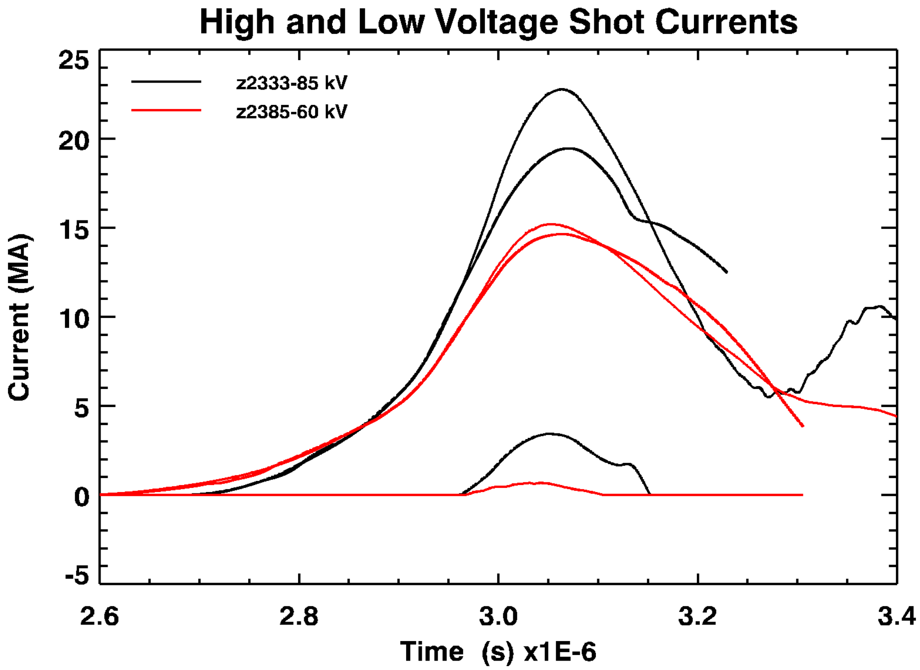
- Magnetic field nulls in convolute between MITL and load likely cause a loss of electrons

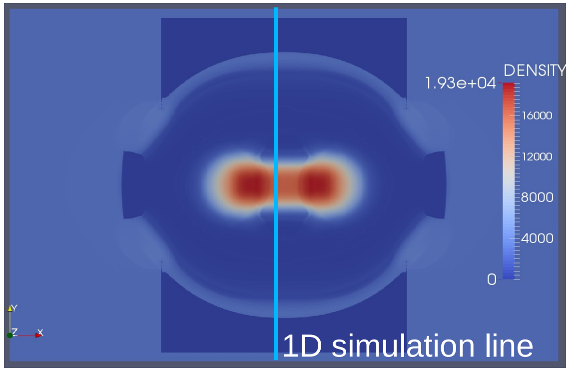
- Currently, loss is estimated pre-shot using trends in previous shots, instead of an accurate working model



Load and loss currents obtained using Al flyer plate velocities, MHD simulation, optimization

- 2D MHD using MITL current provides guess at 1D magnetic field drive
- 1D DAKOTA-ALEGRA optimization produces precise magnetic drive for target flyer velocity
- Iteration of 2D ALEGRA simulation with 1D magnetic drive produces load current
- Loss current = (MITL current) – (load current)



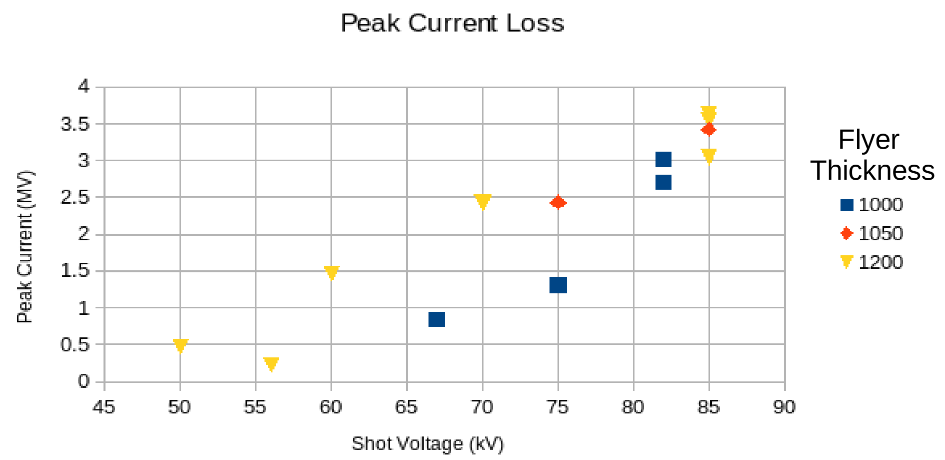


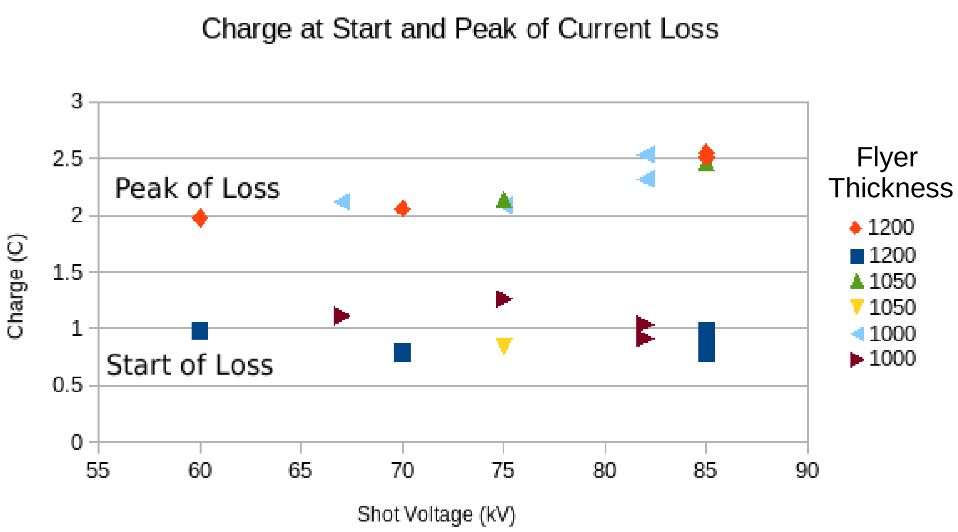
Trends revealed by shot analysis can lead to phenomenological model of current loss

- Various data from 12 shots recorded
  - Measured and optimized currents
  - Current loss
  - Resistance in convolute
  - Convolute voltage
  - Total charge at time t

- Peak loss linear with voltage

- Start and peak of current loss near a set total charge





Copper flyer plate experiments for validation of electrical conductivity model

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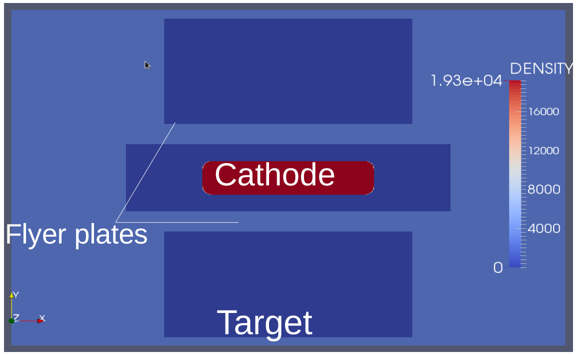
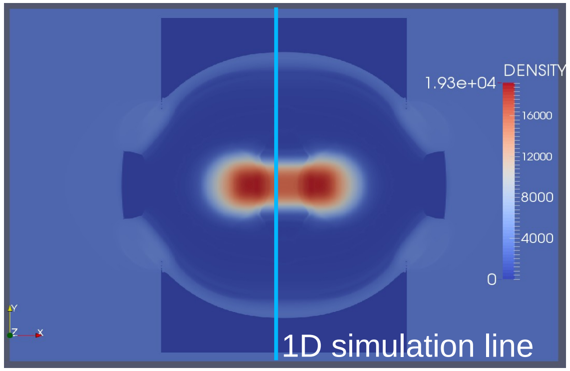
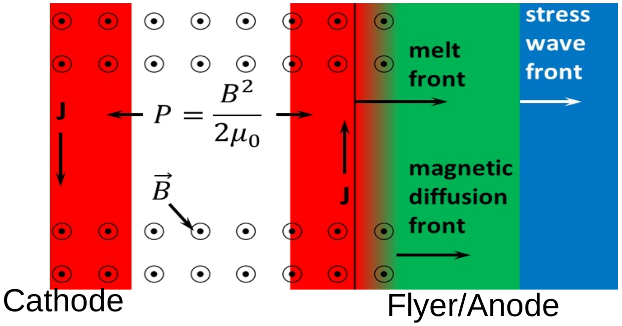
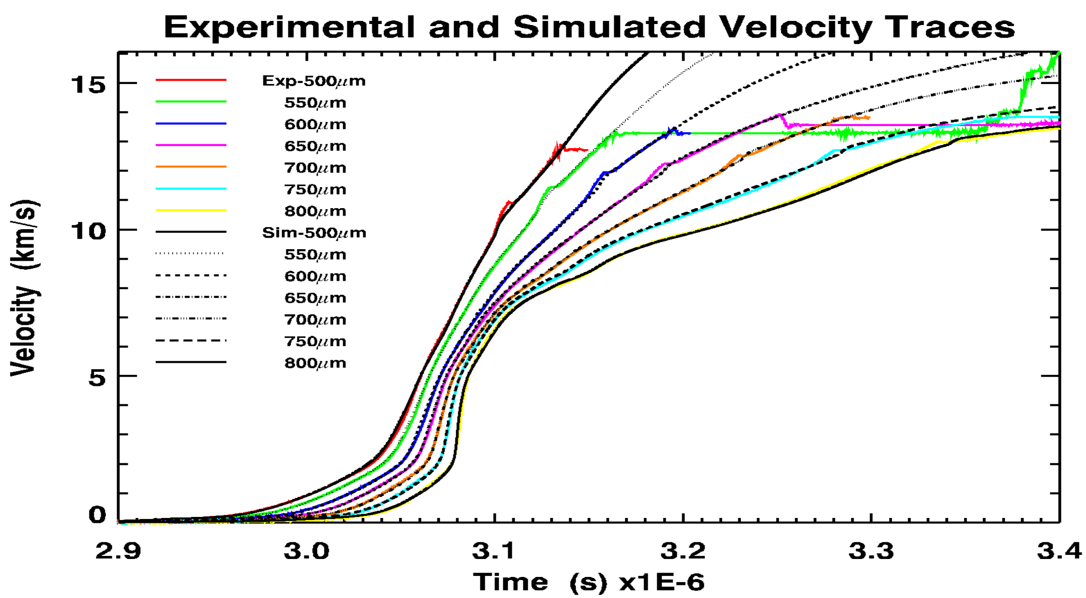


2D simulation ^start^ and $_v$end$_v$





- Stripline experiment with 10 Cu flyer plates with thicknesses from 500-950 microns
- Flyer plate velocity reveals magnetic break-out at free surface
- Thin and thick flyer plates bound relevant conductivity space for this experiment
- Use density functional theory (DFT) simulation to tweak conductivity until MHD magnetic break-out accurate



Causal range of conductivity in experiments found using "box plot" method

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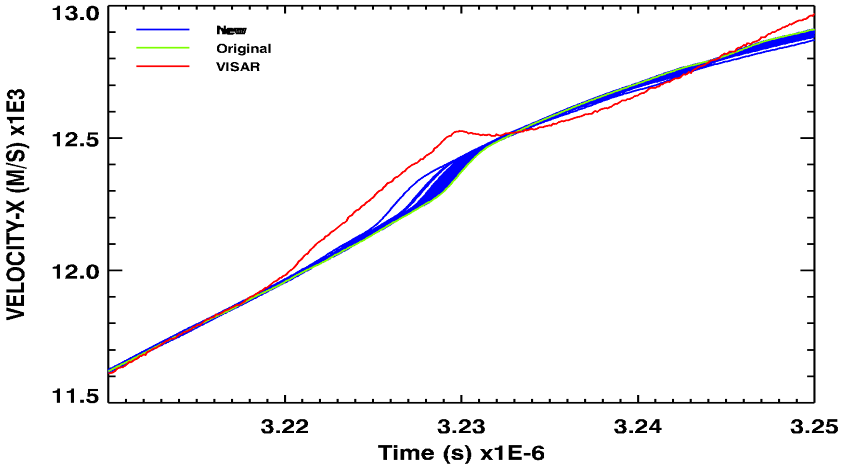
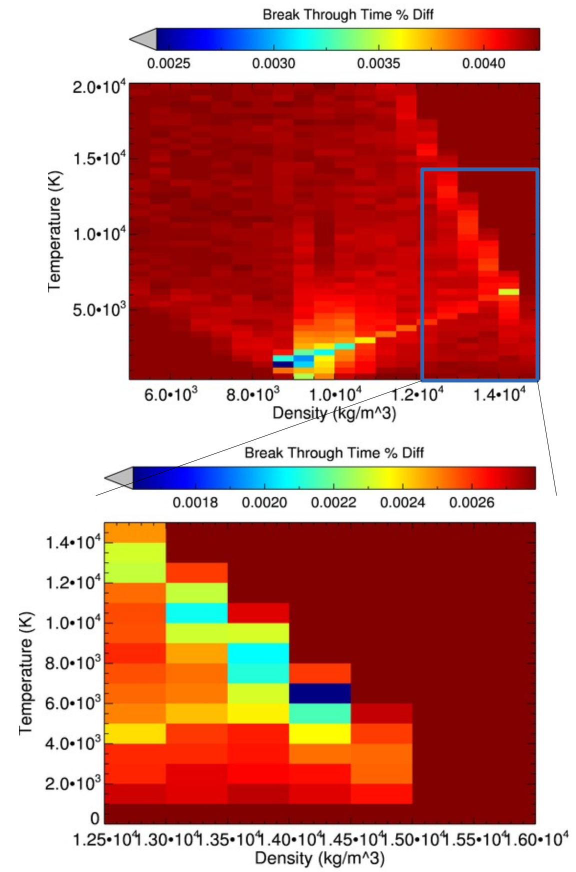
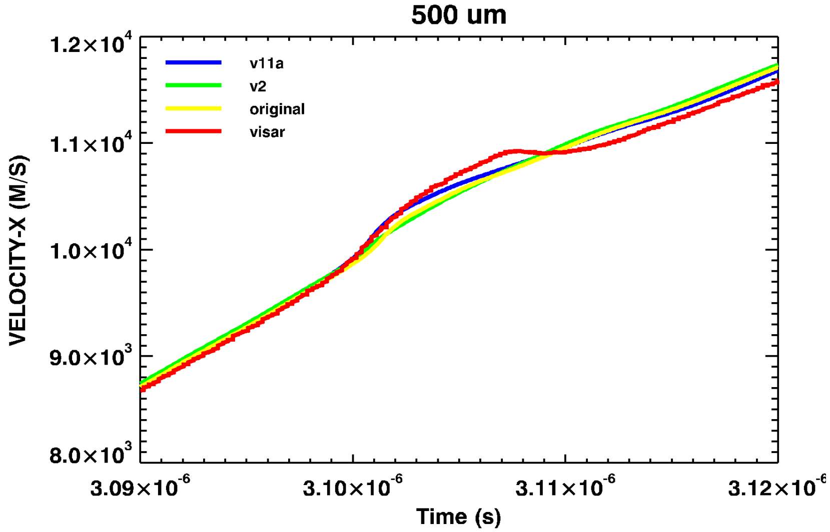
- "Box Plots" allow defining electrical conductivity range of interest in density/temperature space
- Track changes in velocity trace made by multiplying the electrical conductivity in each box

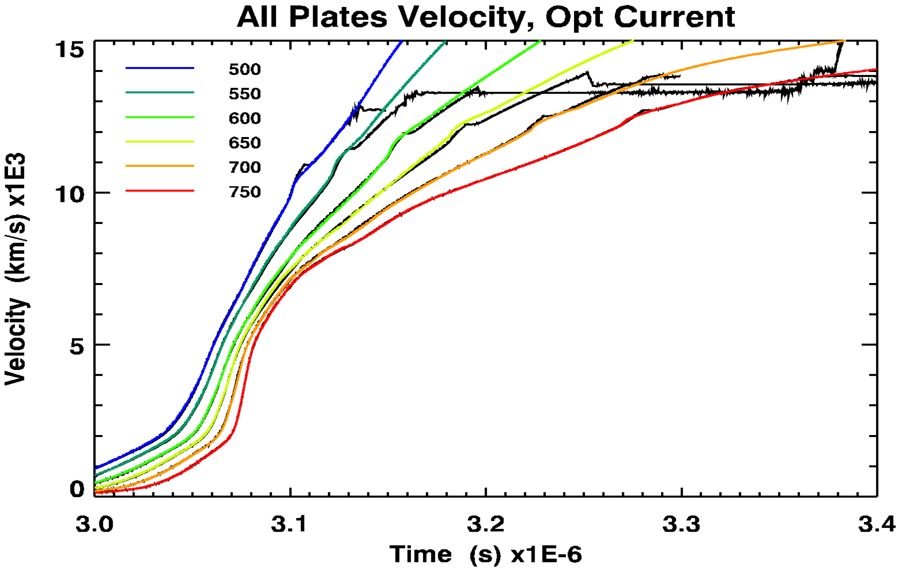


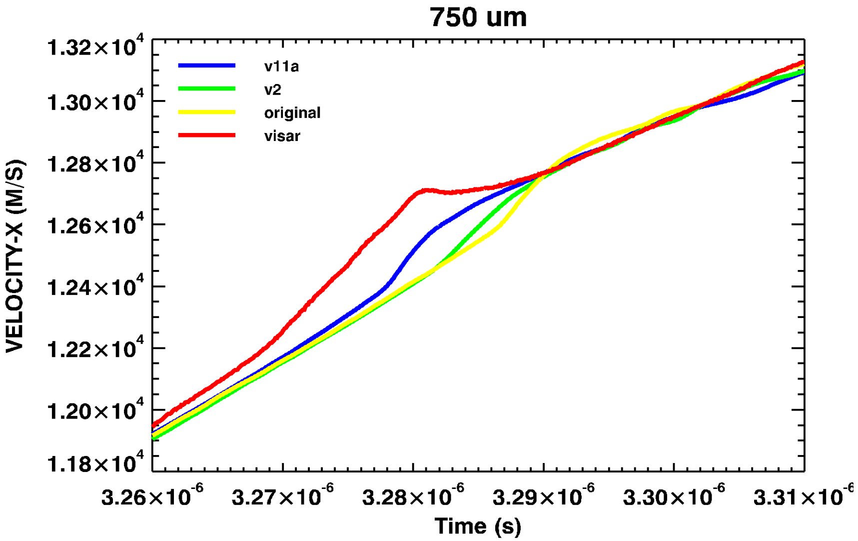
Blue areas are velocity traces made by altering the EC seperately in each the D/T boxes



Initial conductivity corrections found by altering conductivity to match experiment







Guess and check alterations in conductivity model until magnetic breakthrough velocity bumps line up

Shaping the bump a challenge – deficiency in equation of state or elsewhere?

Next step: Run VASP in areas discovered, create new conductivity model

Conclusions

- Flyer plate experiments on Z are useful for a plethora of important problems

- Analysis of Al flyer plate experiments reveals trends in loss current from 50-85kV charging voltage
  - Loss begins at same total input charge (integrated current) independent of charge voltage
  - Peak loss current approximately linear with charging voltage

- Copper and other material models can be validated using flyer plate experiments and simulations

Questions?