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Multi-Megabar Magnetically-Driven Ramp-Compression Experiments on Tantalum

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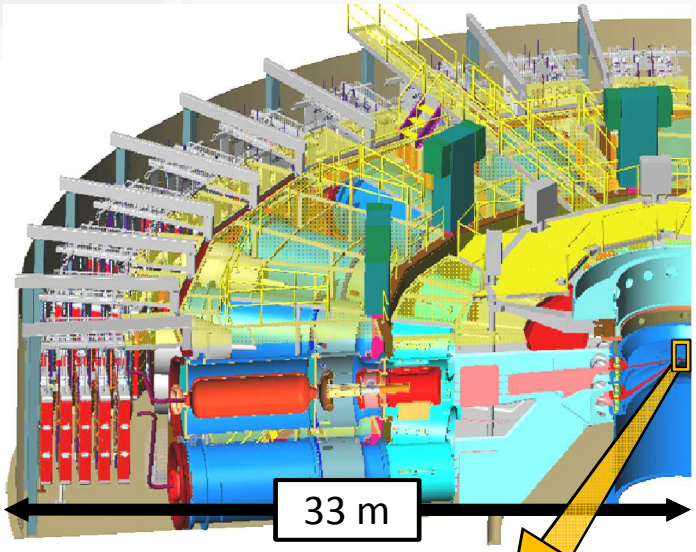
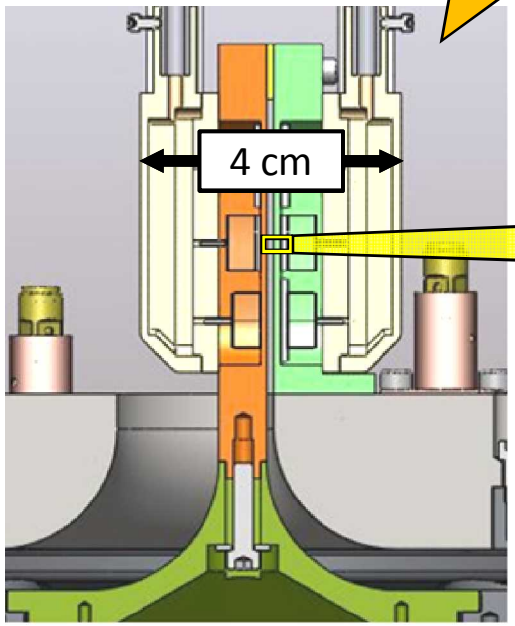
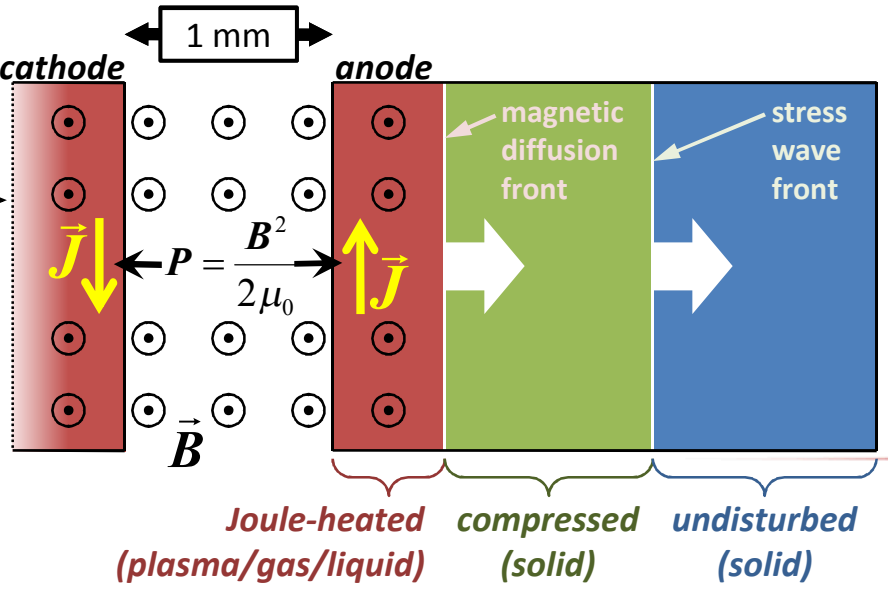
Ramp-compression experiments to > 400 GPa possible on refurbished Z machine using stripline loads



- current pulse of 8-26 MA delivered to parallel flat-plate electrodes shorted at one end
- magnetic ($\vec{J} \times \vec{B}$) force induces ramped stress wave in electrode material
- stress wave propagates into ambient material, de-coupled from magnetic drive
- controllable pulse shape, rise time 100-800 ns
- identical magnetic loading of sample pairs





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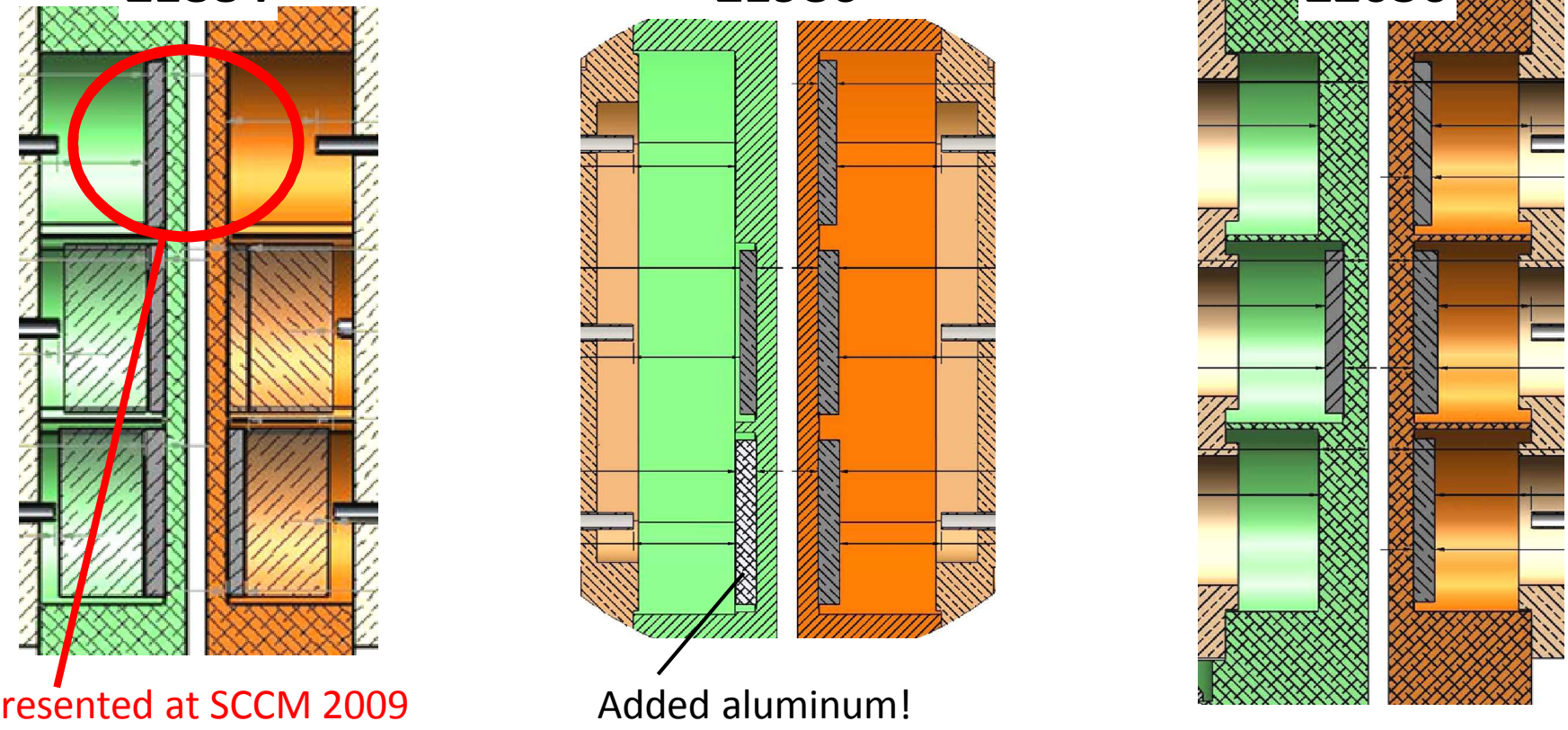
Several multi-megabar ramp-compression experiments on tantalum were attempted in 2009-2010



aluminum 6061-T6 electrodes:
floor thickness 0.85 mm (Z1841), 1.0 mm (Z1884, Z1986), 1.2 mm (Z2036)

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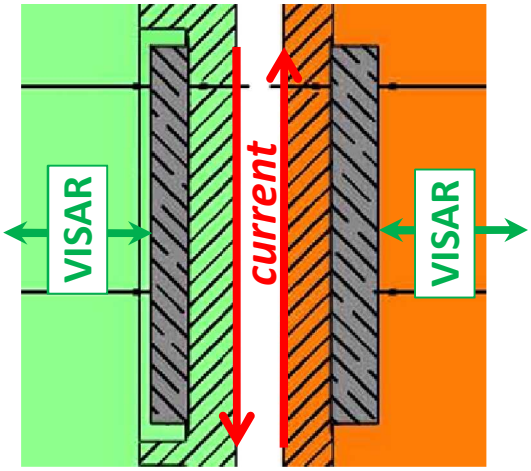
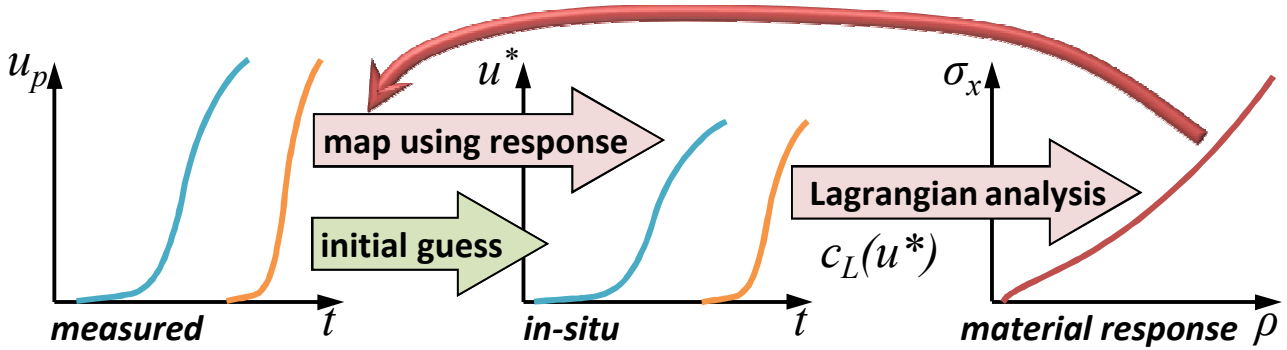
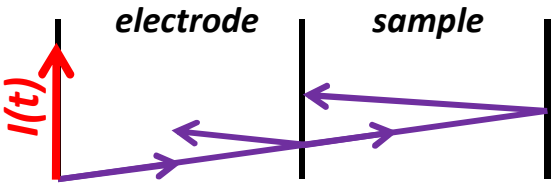
Two-sample analysis uses well-developed technique





Initial guess uses $U_{fs}/2$ approximation
Measured-to-in-situ mapping step uses backward-solved characteristics net



- assumes isentropic, simple-wave behavior
- **valid ONLY while electrode/sample interface states identical**

i.e., until first disturbance reflected from thin-sample free surface propagates back to electrode/sample interface (***LIMITS MAXIMUM Δx***)

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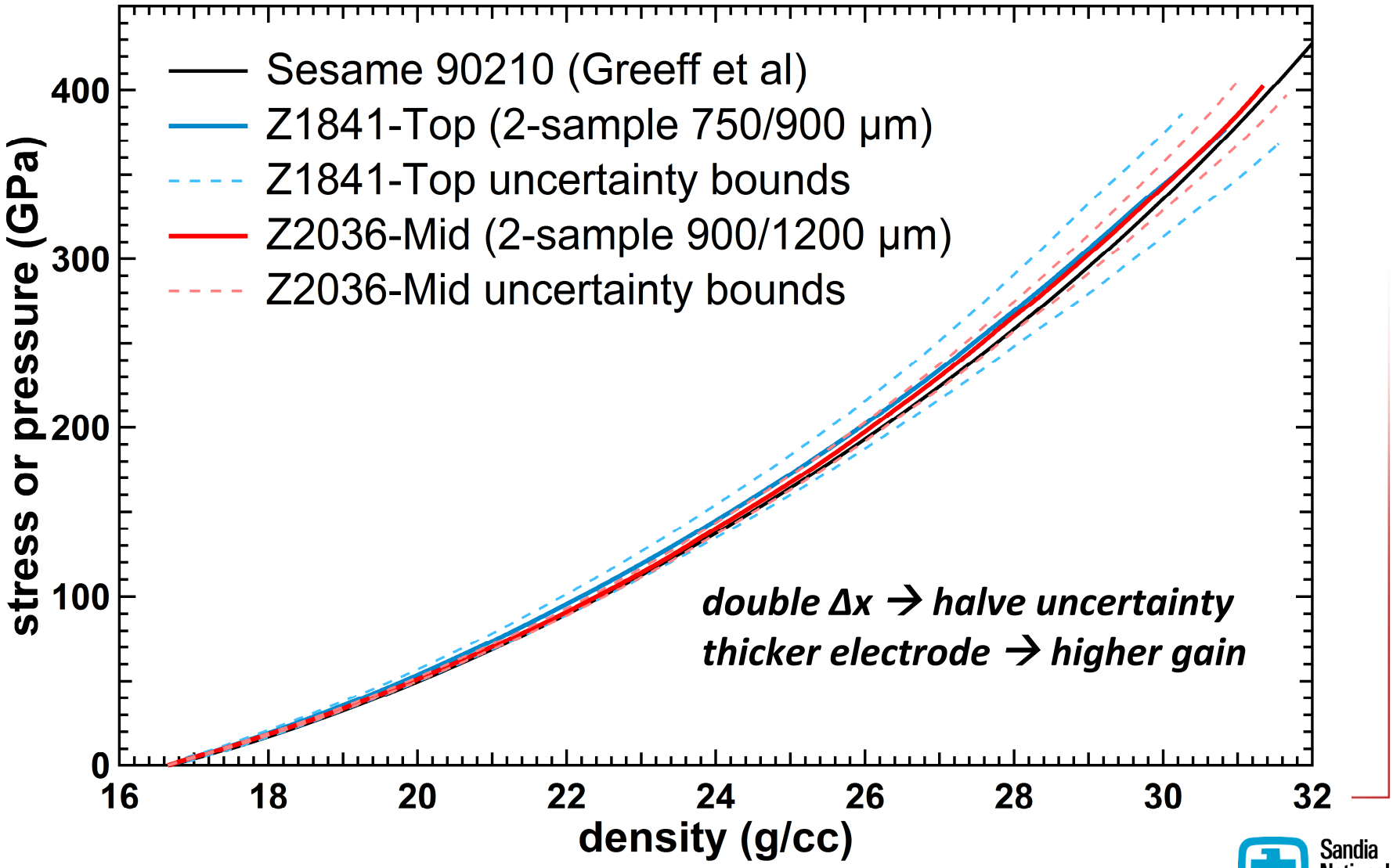
Two-sample analysis of Z2036-Mid reached 400 GPa



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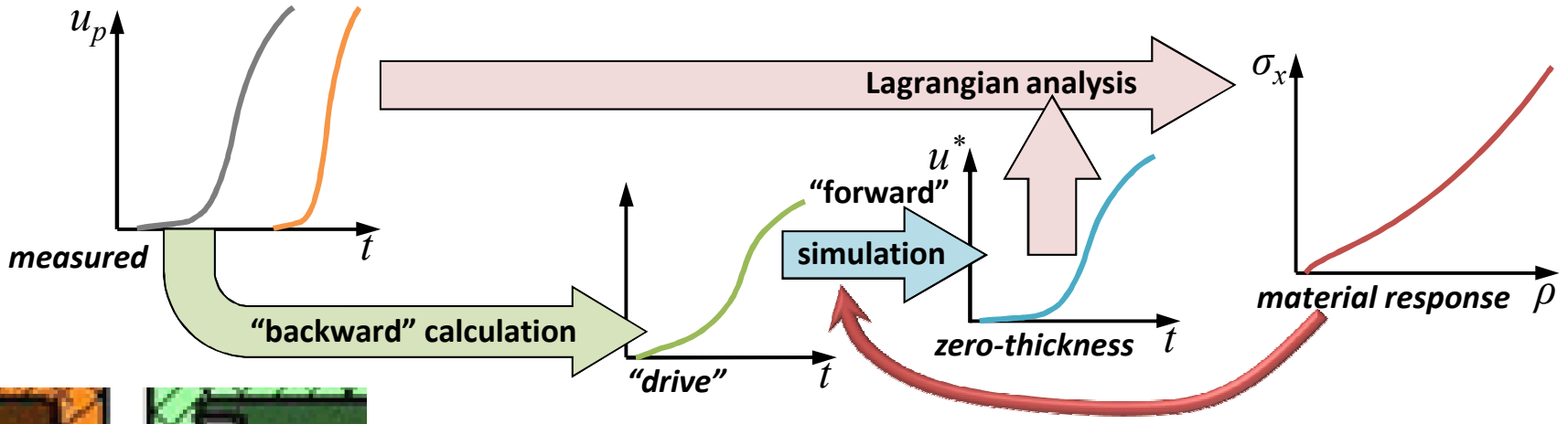
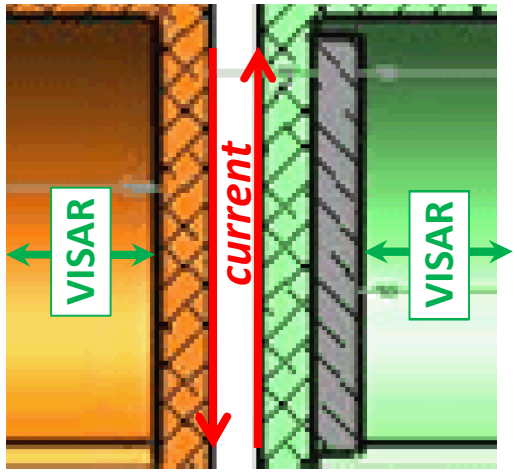
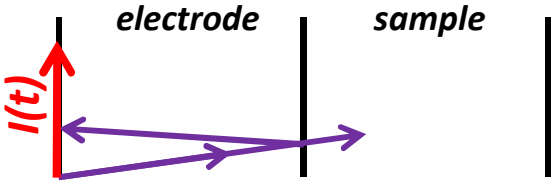
Single-sample (input-output) approach iterates on two-sample analysis with simulated zero-thickness velocity





- **valid ONLY while electrode driven surface states are identical**

  i.e., until first disturbance reflected from electrode/sample interface propagates back to driven surface of electrode



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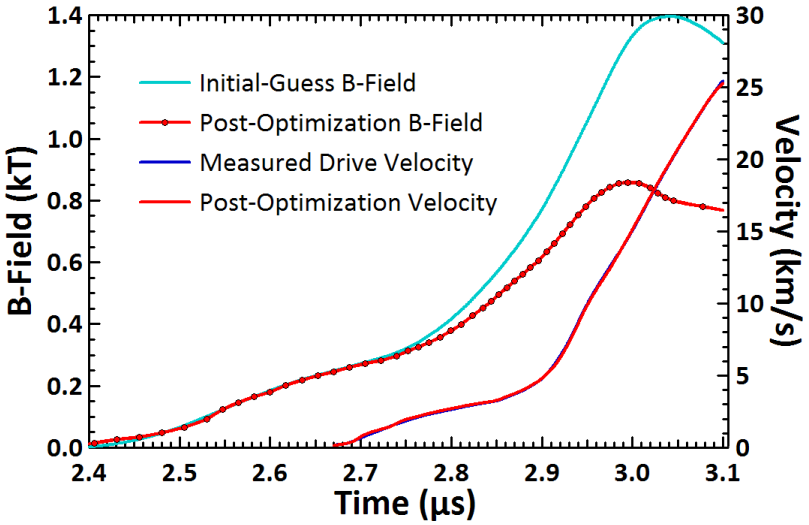
Backward calculation of drive with or without MHD

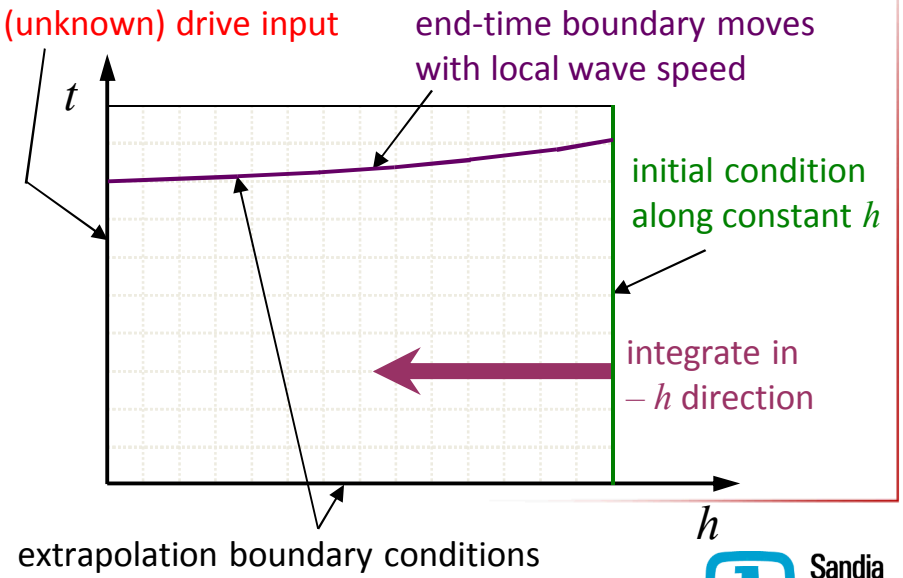
with MHD:

- optimization to determine applied B-field waveform from drive velocity
- requires wide-range EOS and strength models for electrode
- forward simulation with same models recovers sample input loading

without MHD:

- backward integration to determine applied "effective" pressure waveform that reproduces drive velocity
- neglect strength and use limited EOS for electrode (solid quasi-isentrope only)
- waveform shape mimics effect of electrode's elastic-plastic behavior
- forward simulation recovers sample input loading if decoupled from MHD region





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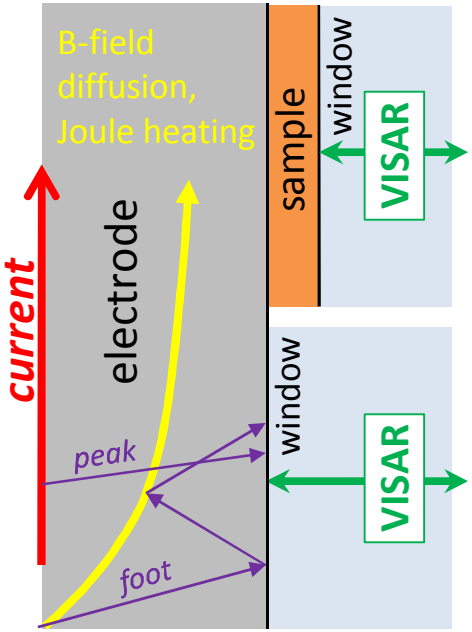
If electrodes are thick enough, then backward-forward analysis works without MHD



Sample is decoupled from MHD region until peak stress

You'll have to take my word for it!

Hydro approach better reproduces foot region of sample's input loading

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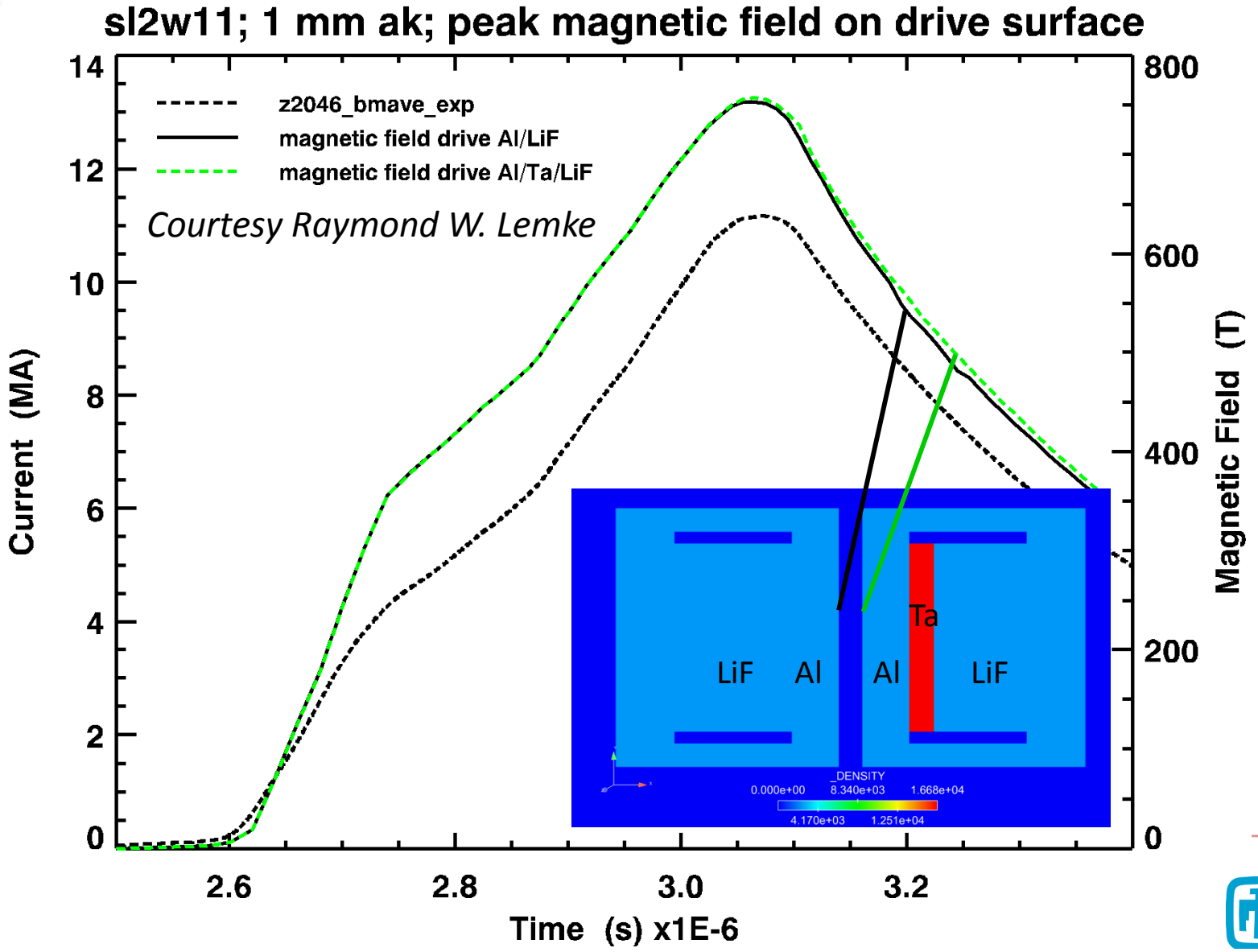
Even MHD backward-forward is limited by electrode thickness



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Future experiments will use thicker electrodes!

Two-sample analysis:

- electrodes can be thin (thick enough to prevent B-Field diffusion into sample)
- impedance gain for high-Z materials limited by thickness
- maximum Δx limited by shock-up in thick sample, reverberation in thin sample
- precision limited by maximum Δx

Single-sample analysis:

- electrodes must be thick to decouple sample from driven surface of electrode
- even a little thicker electrodes can decouple sample from MHD entirely
- uncertainty quantification for backward-forward technique is underway
- potential for significant reduction in uncertainty

Tantalum experiments:

- measurements exist to 400 GPa, possibly higher
- future experiment design may reach 500 GPa