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Measurement of the Dynamic β–γ Phase Boundary in Tin

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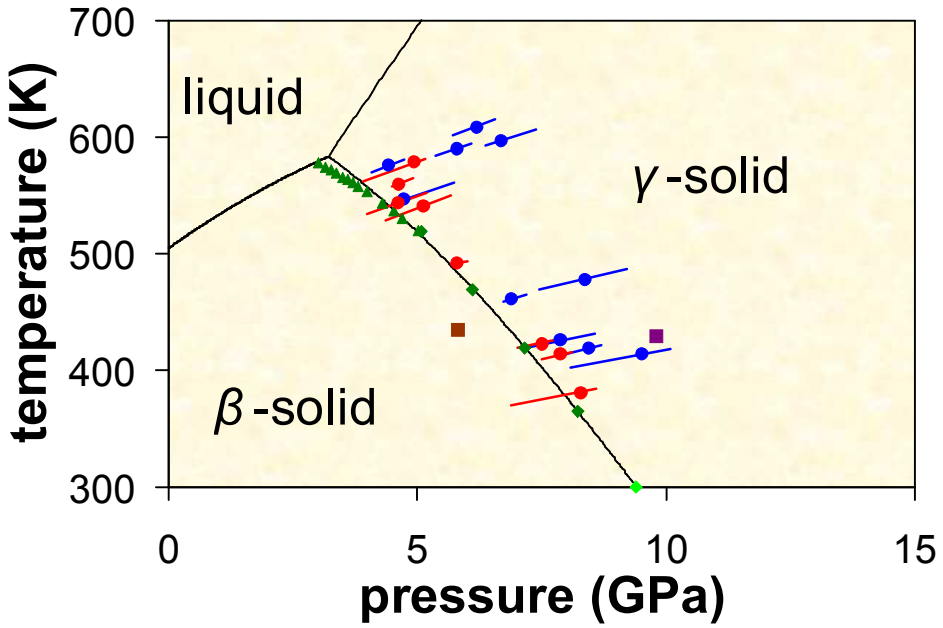

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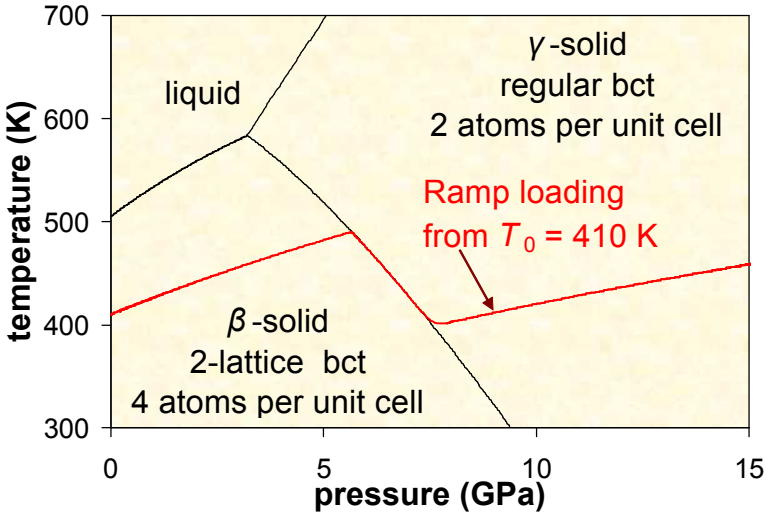
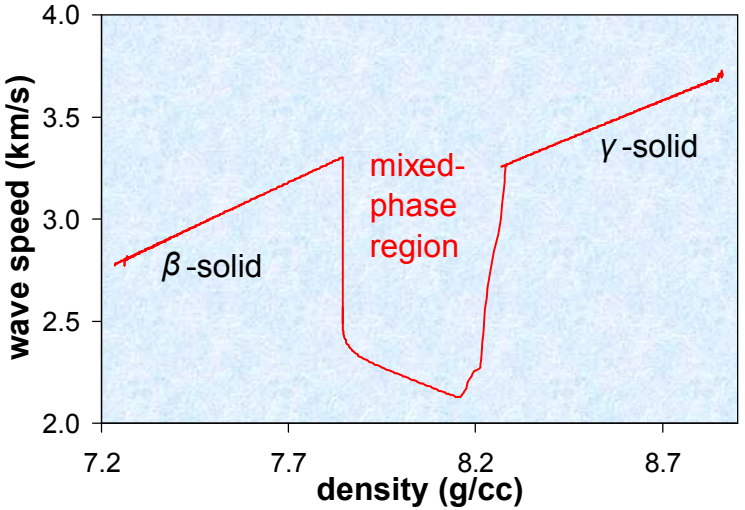
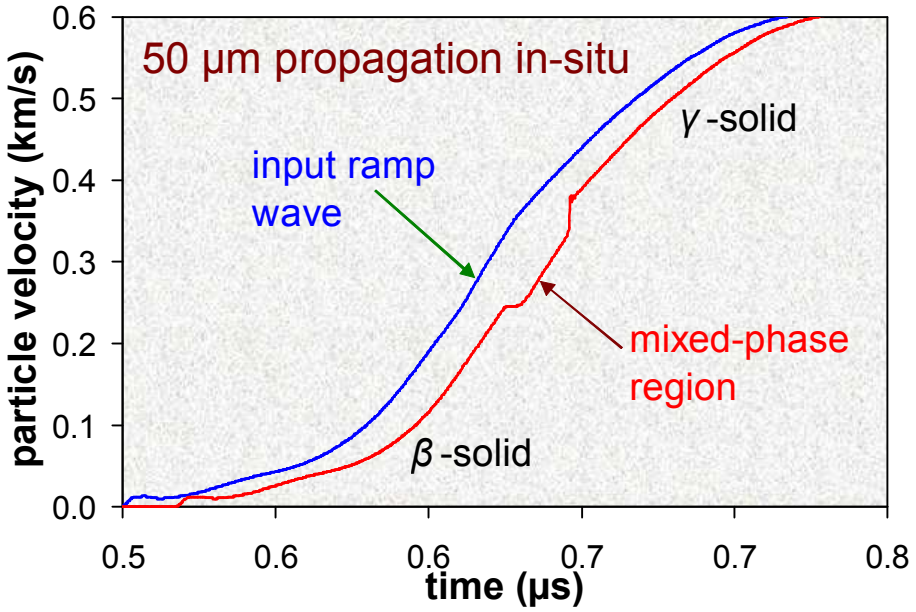
Ramp-wave loading experiments are useful for studying structural phase transitions







- Evolution of ramp wave sensitive to derivative of stress-strain response
- Wave speed changes suddenly on entering/exiting mixed-phase region
- Pre-heat samples to different initial temperatures to map out phase boundary
- Tin has one of steepest dP/dT of any element, in easy-to-acess P, T ranges
- Volume change of 3-5% easily detected in velocity profiles

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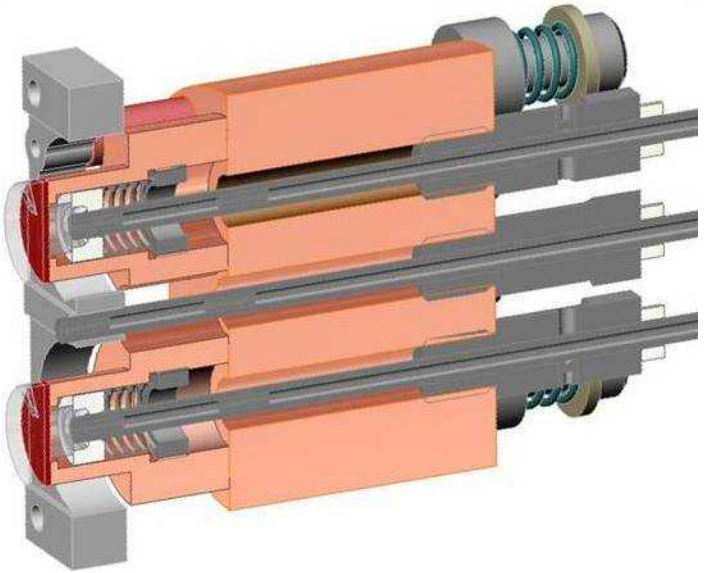
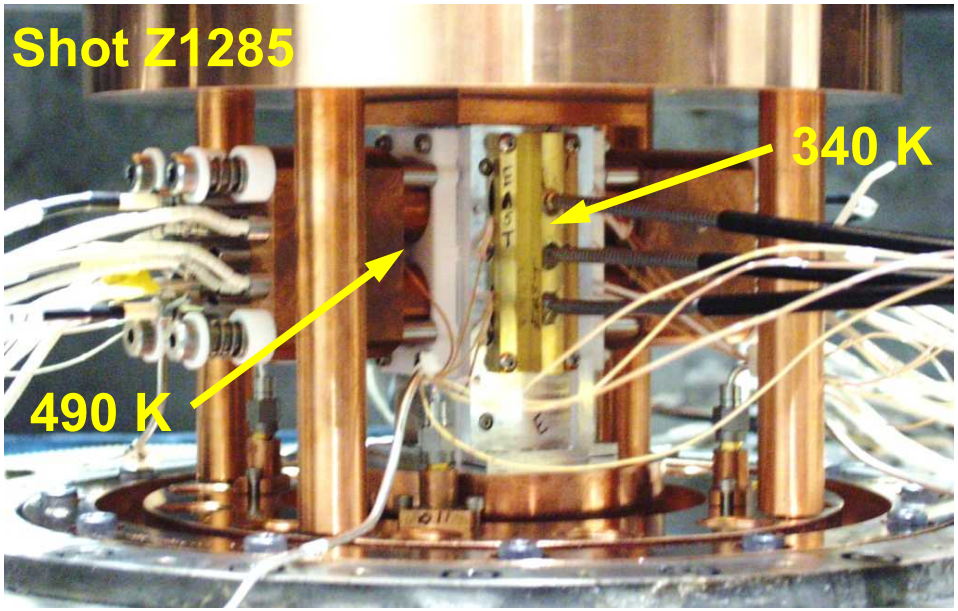
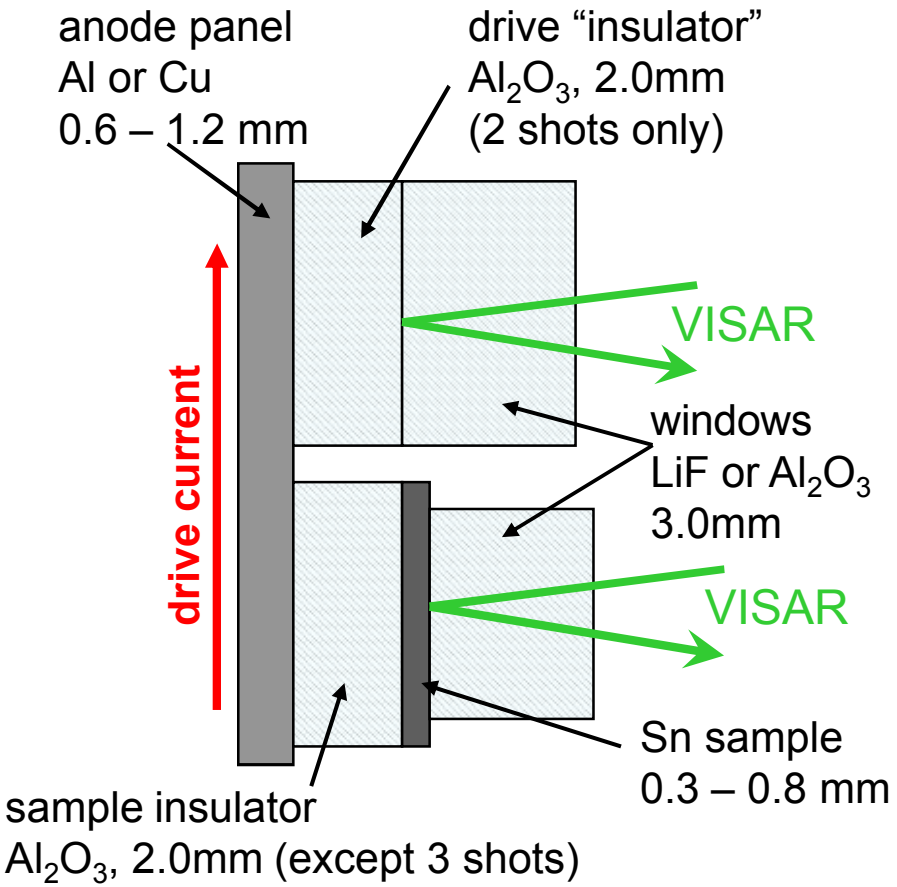
Data on pre-heated solid tin are available from 8 different shots on the Z pulsed-power machine







- direct, indirect heating
- polycrystalline (fine-, course-grained), single-crystal, resolidifed

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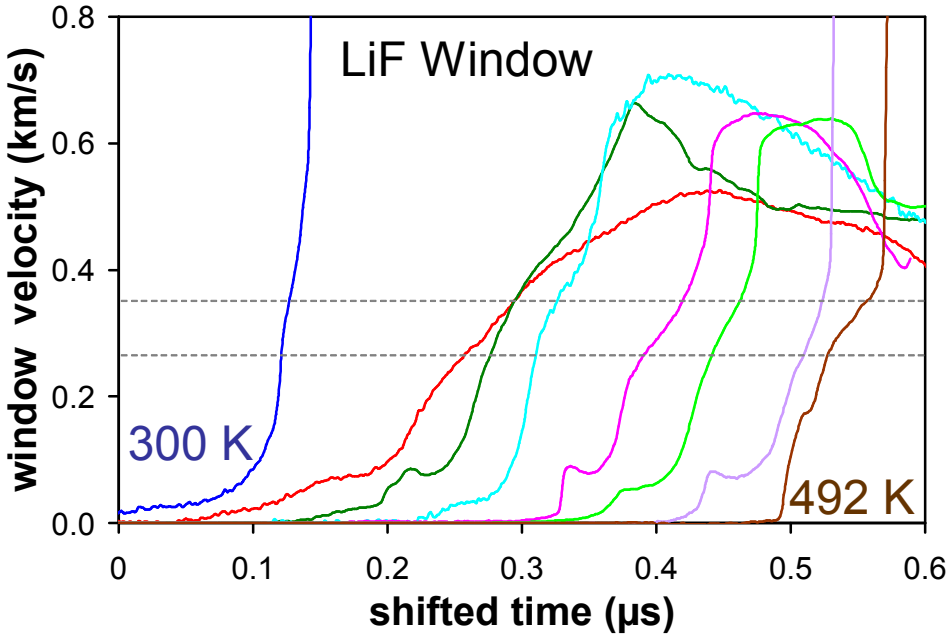
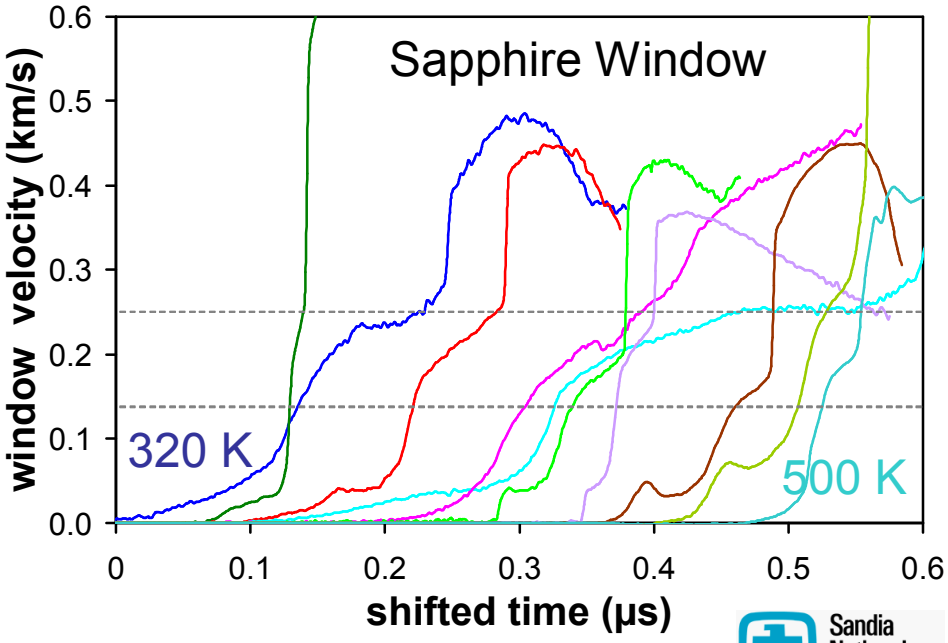
Velocity profile measurements exhibit a kink due to onset of the phase transformation

- Velocity measurements from 18 different samples considered
- Two-wave structured profile in bulk tin with kink at onset of transformation
- Wave interactions map this kink on to window interface velocity profile
- For sapphire window, transition at interface possible before kink arrival
- Large precursor unexplained, possibly due to thermal & bonding issues





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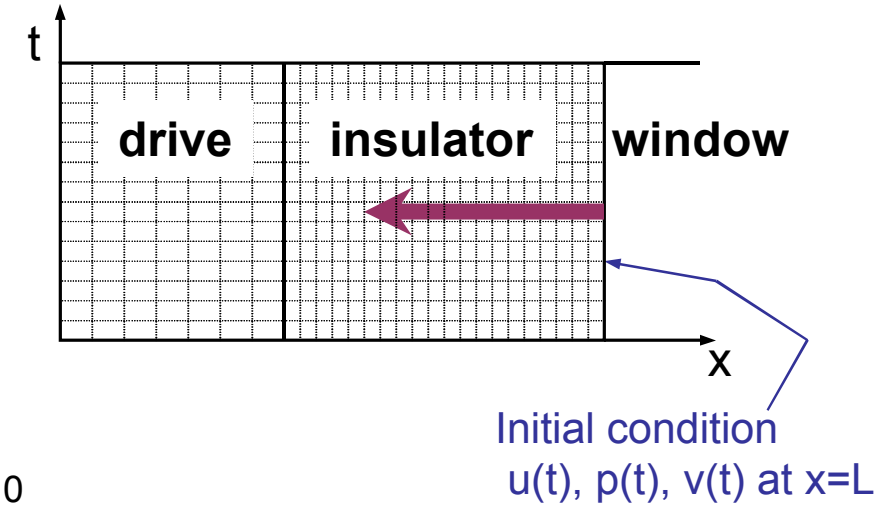
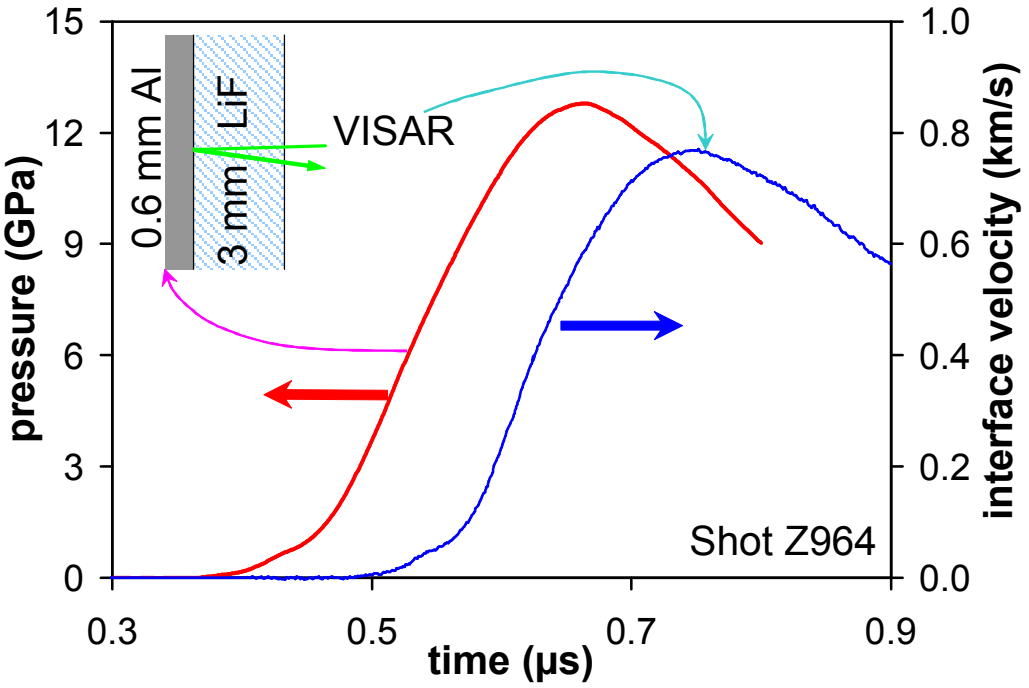
Backward integration gives effective stress loading history used in forward simulations

- backward finite-difference solution to equations of motion
- accounts for ramp-wave interactions due to difference in sample and window acoustic impedances





- "effective" pressure loading history at drive boundary used in forward simulations without magneto-hydrodynamics
- method strictly valid only for isentropic flow, but works in many quasi-isentropic cases

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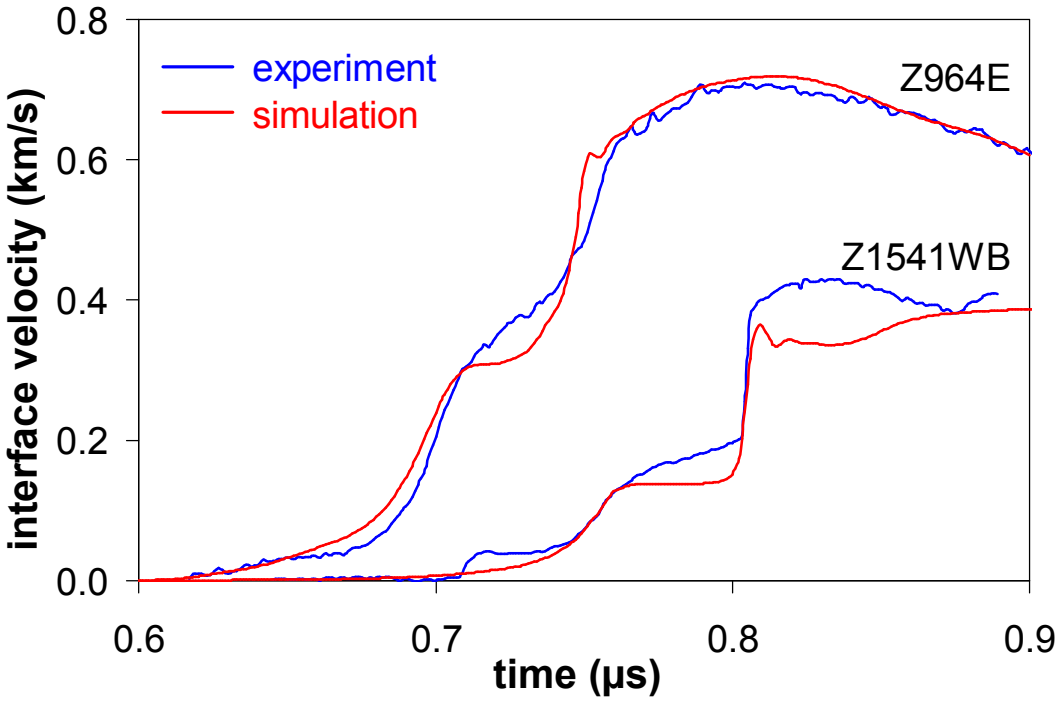
Forward simulations use multi-phase mixture model for tin in WONDY Lagrangian hydrocode

- Homogeneous mixture model based on assumptions introduced by Horie & Duvall (1968)
- numerical method developed by Andrews (1970), extended to N phases by Hayes (1975)
- EOS of each phase = Birch isotherm EOS with constant C_v, Γ/v
- parameters, reference states for Sn based on Mabire & Héreil (2000)



- kinetics set close to equilibrium
- strength neglected
- **β-phase reference energy characterizes location of β-γ phase boundary**
- effect of elevated temperature on drive, window materials neglected

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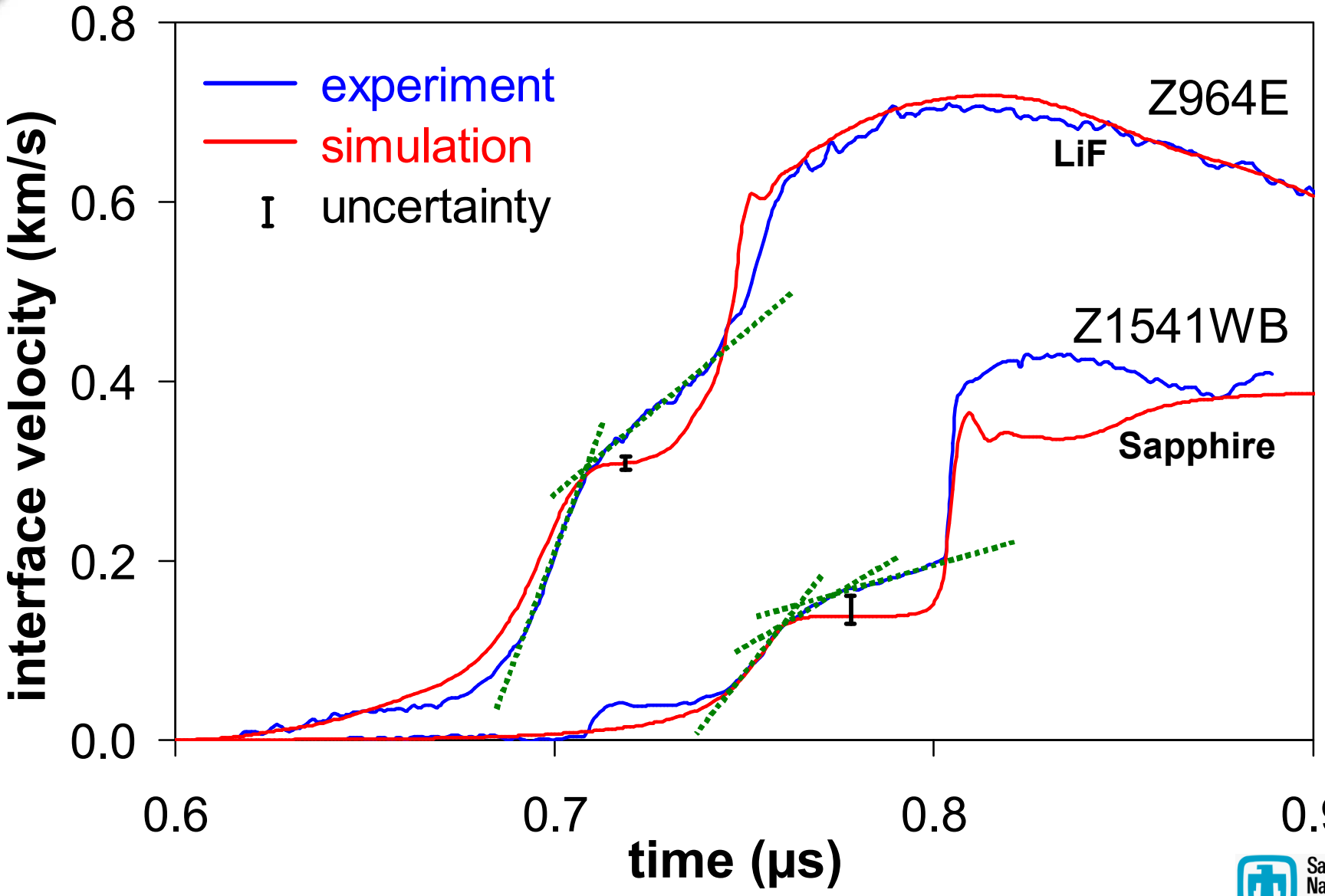
Phase boundary located by adjusting reference energy to match experimental velocity at kink …



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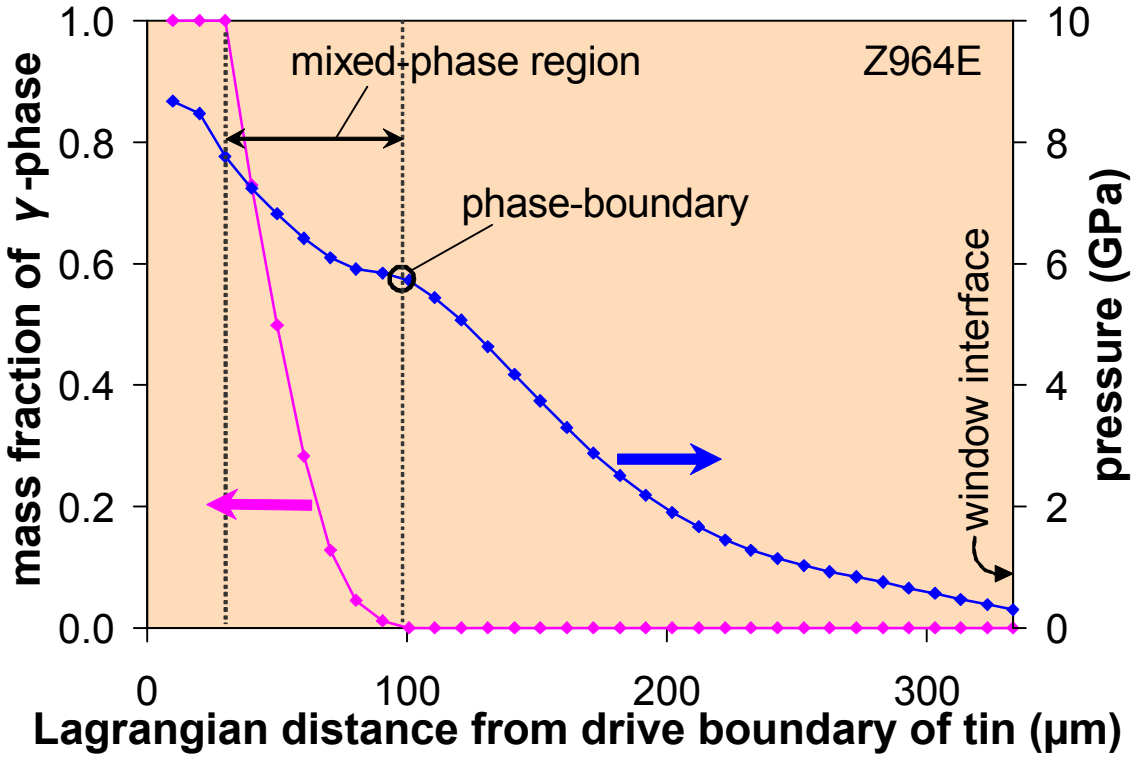
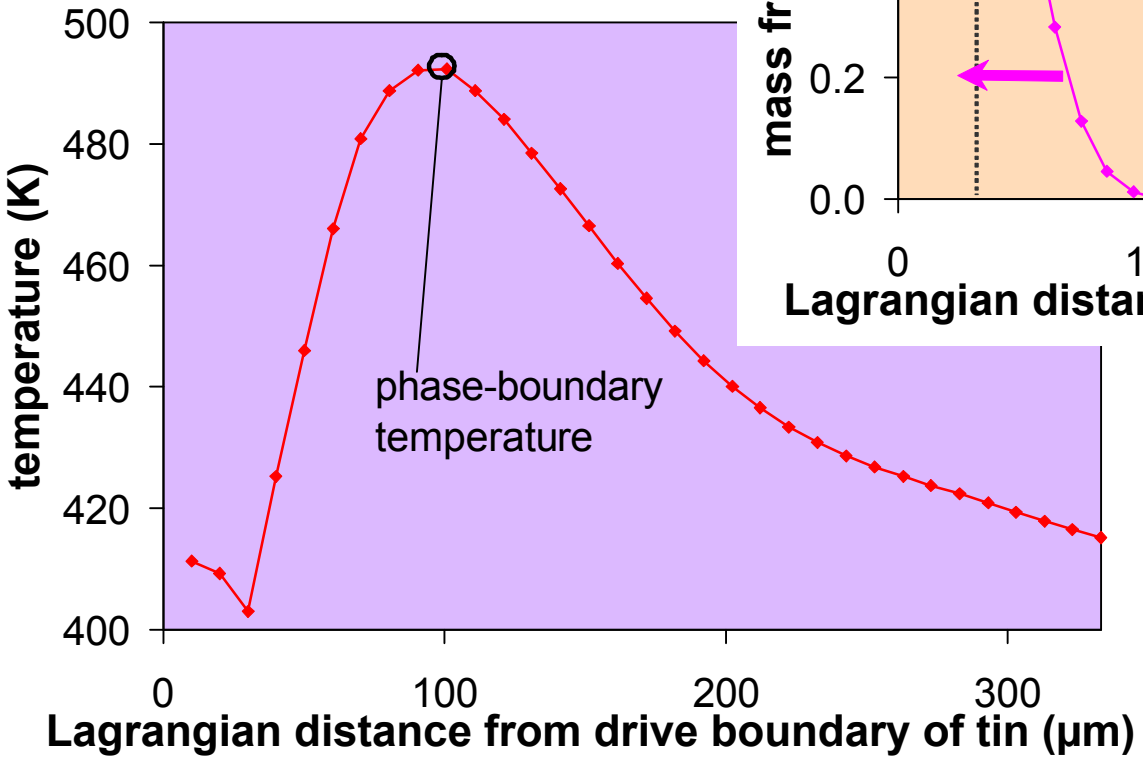
… and extracting *P*, *T* from simulation at material point in bulk tin away from window interface

Pressure from experimental measurement of kink in velocity profile, with wave interactions accounted for by model EOS of tin





Temperature directly from model EOS of *β* phase

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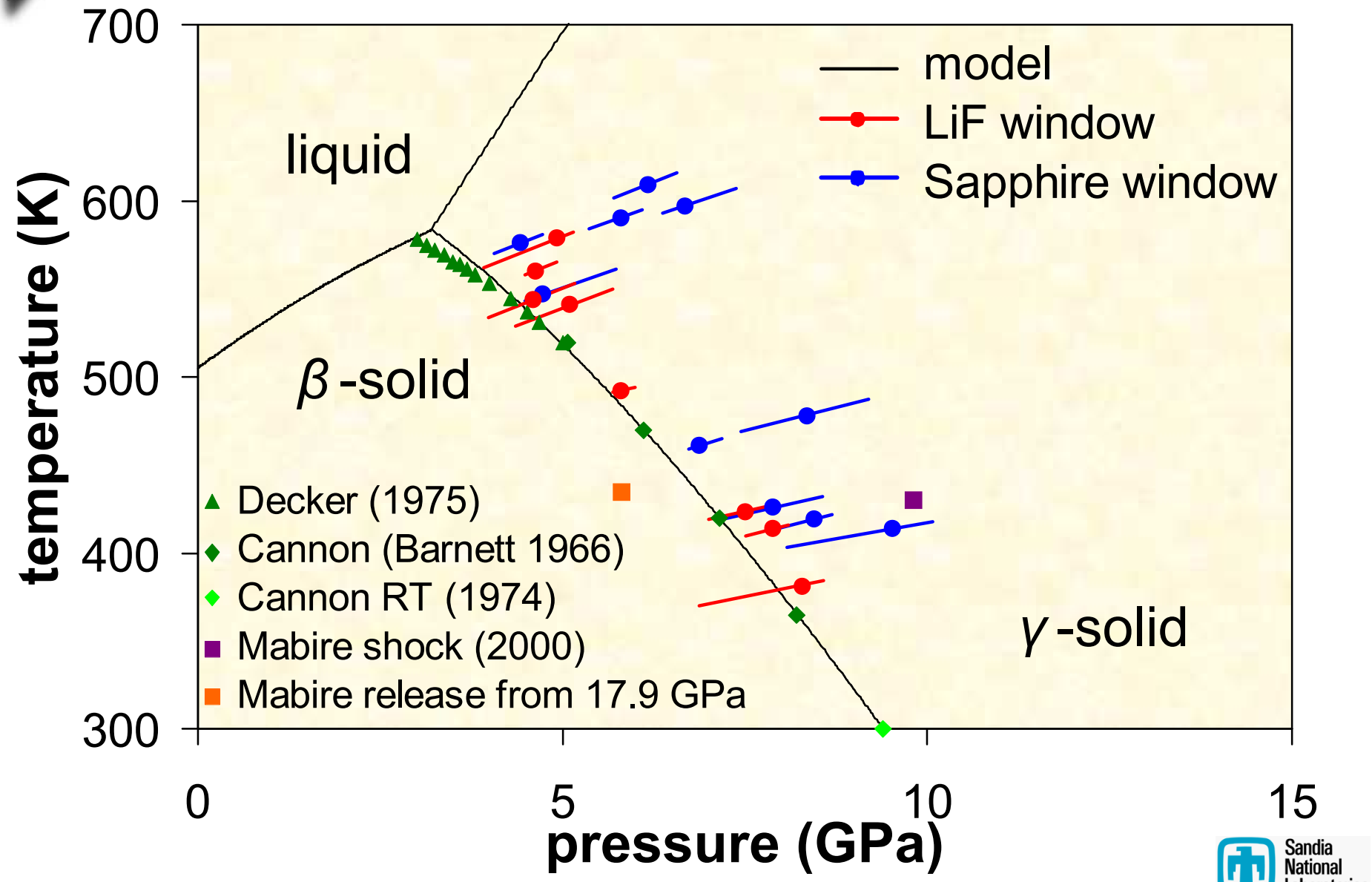
Most results fall close to equilibrium boundary, but scatter is high for data using sapphire window



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