SAND2015-4268C

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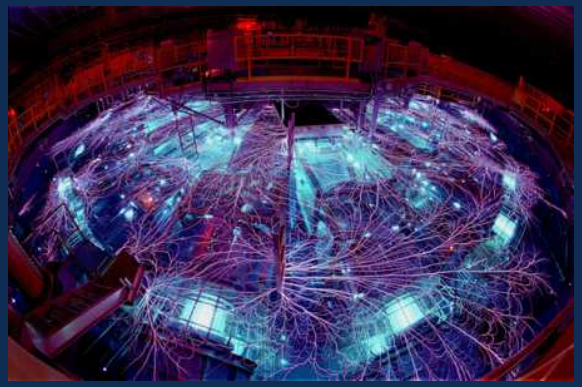

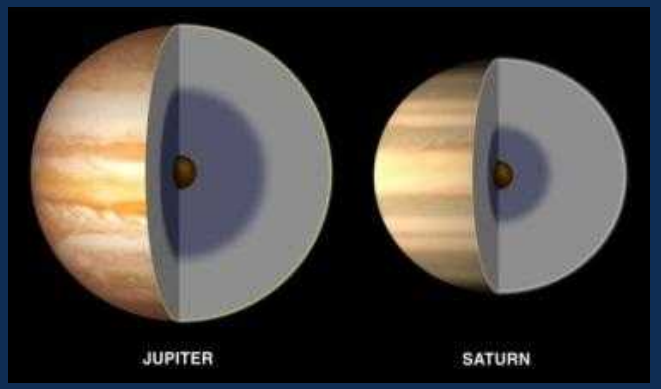

Direct observation of an abrupt Insulator-to-Metal transition in dense liquid deuterium

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U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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Acknowledgements

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Planetary Modeling

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Pulse Shaping

Ray Lemke

Jean-Paul Davis

Mark Savage

Ken Struve

Keith LeChien

Brian Stoltzfus

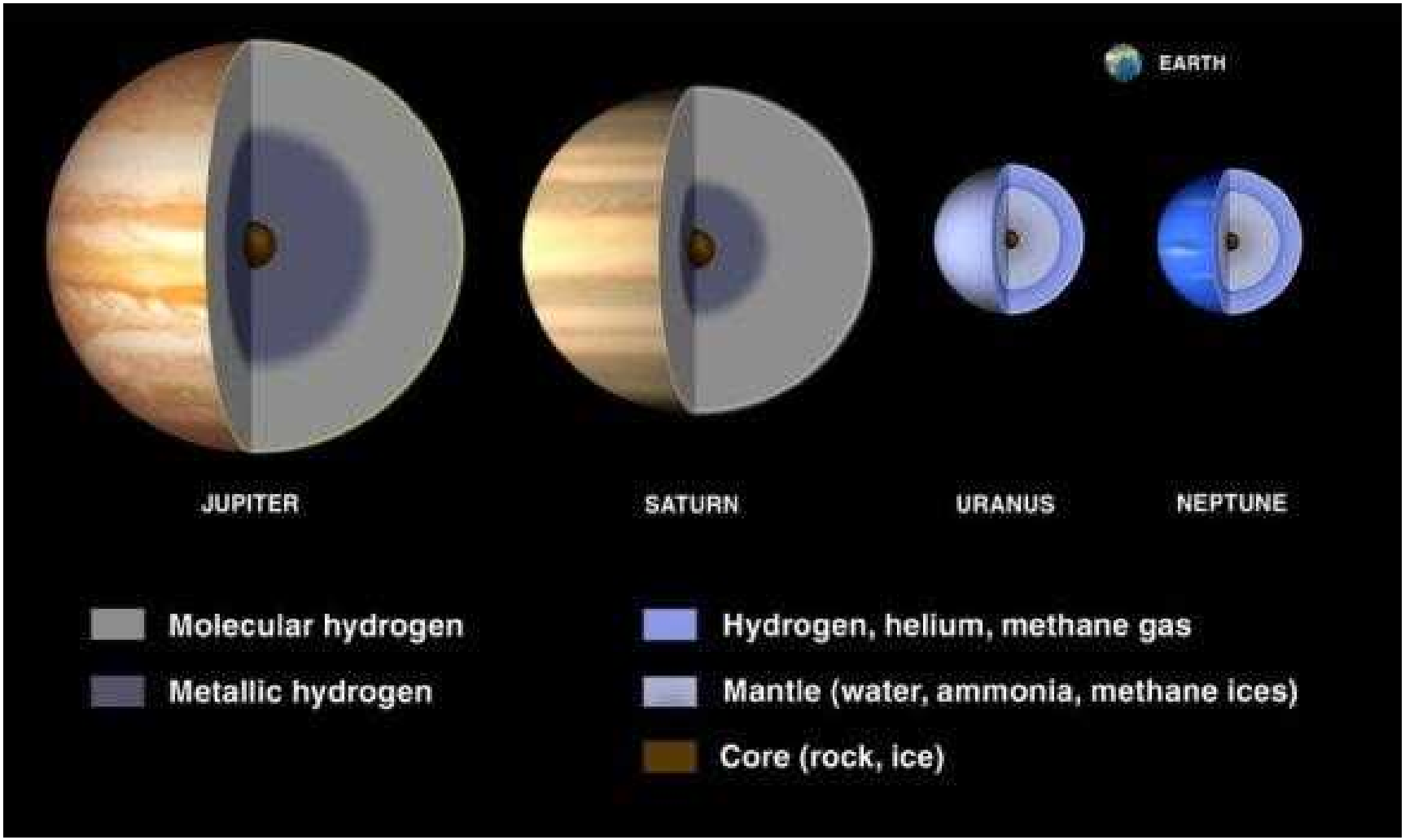
Dave Hinshelwood

Entire Z crew

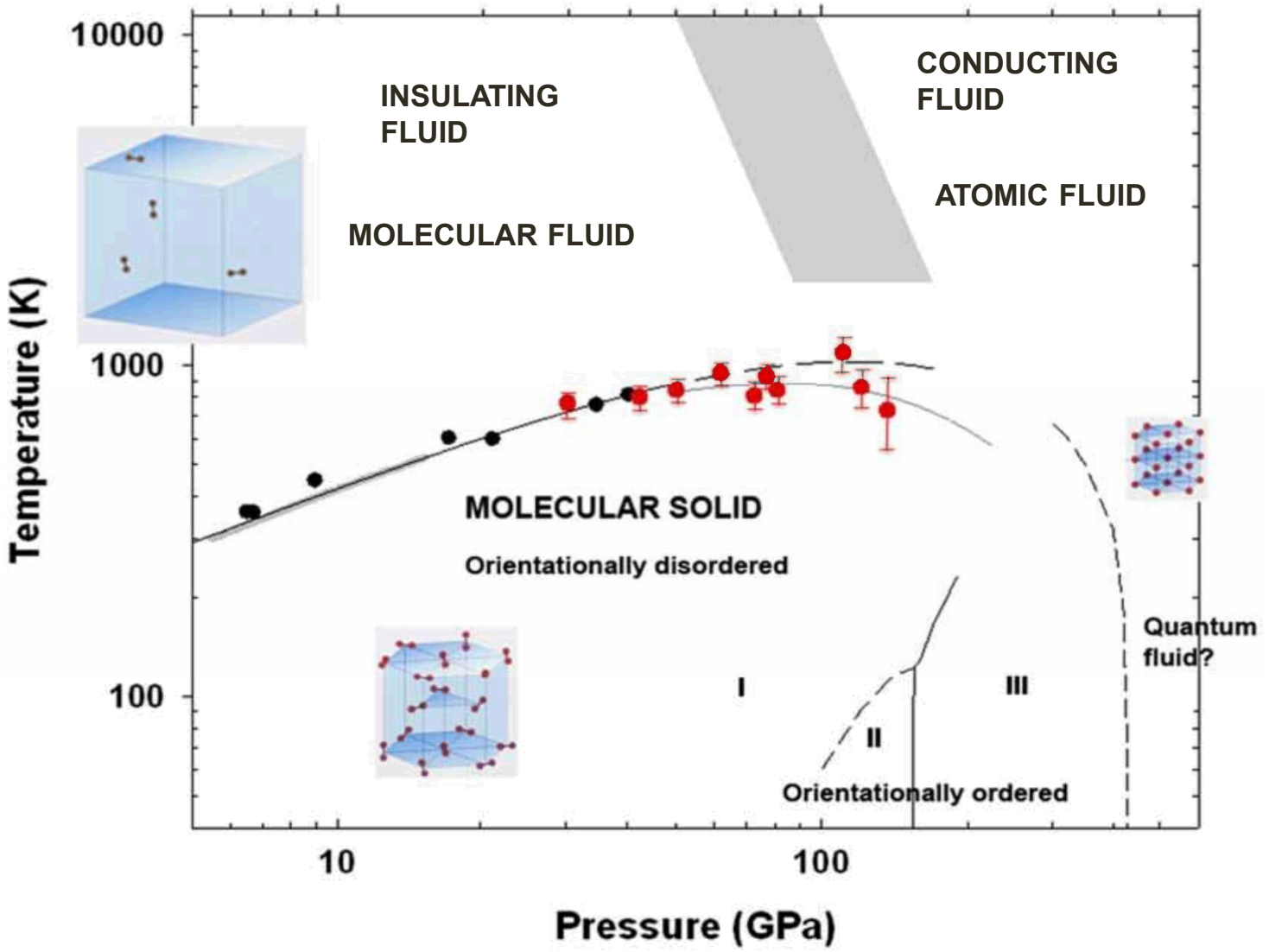
University of Rostock

Giant planets in the Solar system

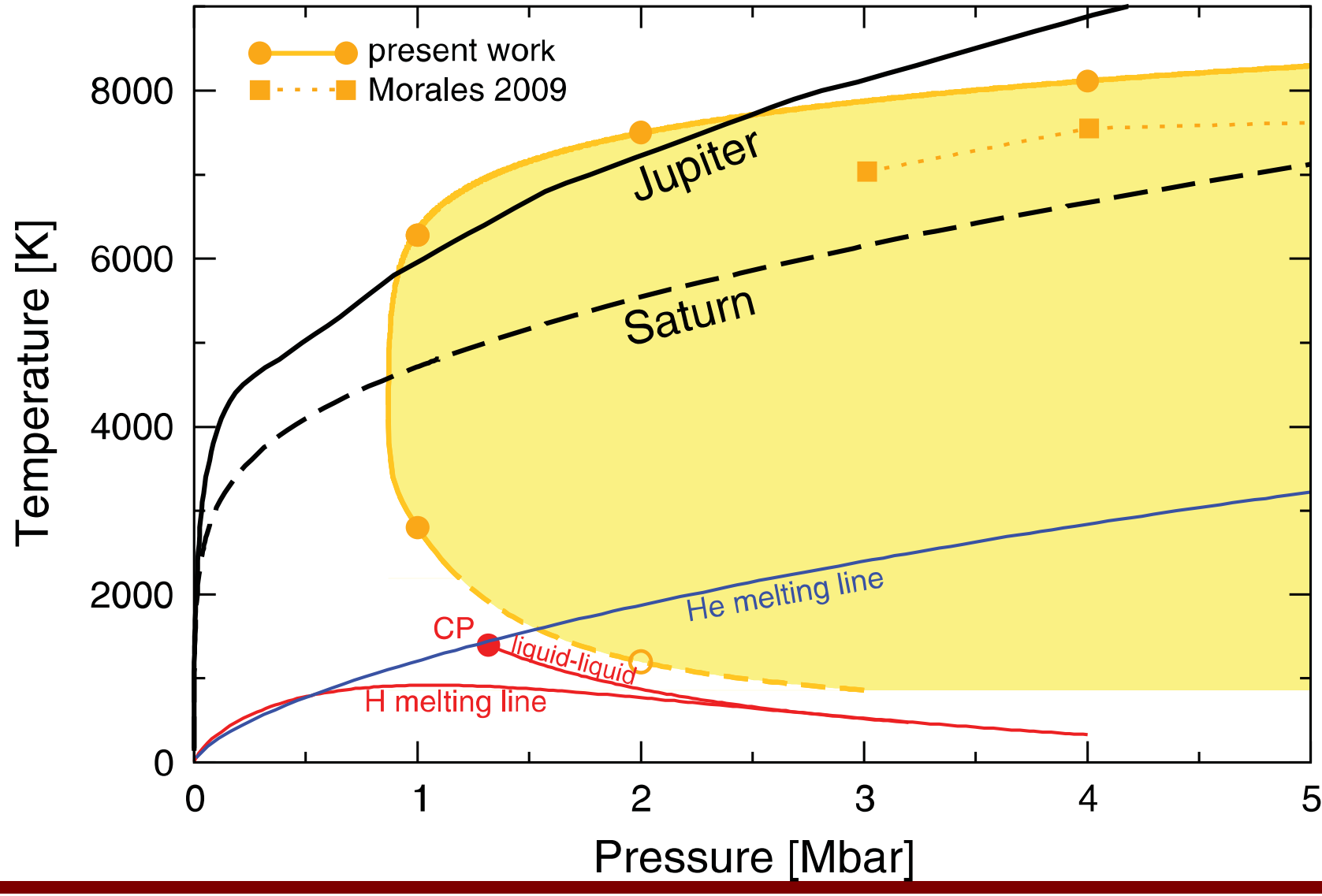
Interior composed of the lightest elements H & He, hydrides NH_3, OH_2, CH_4 (ices) and small amounts of heavier elements (cores)



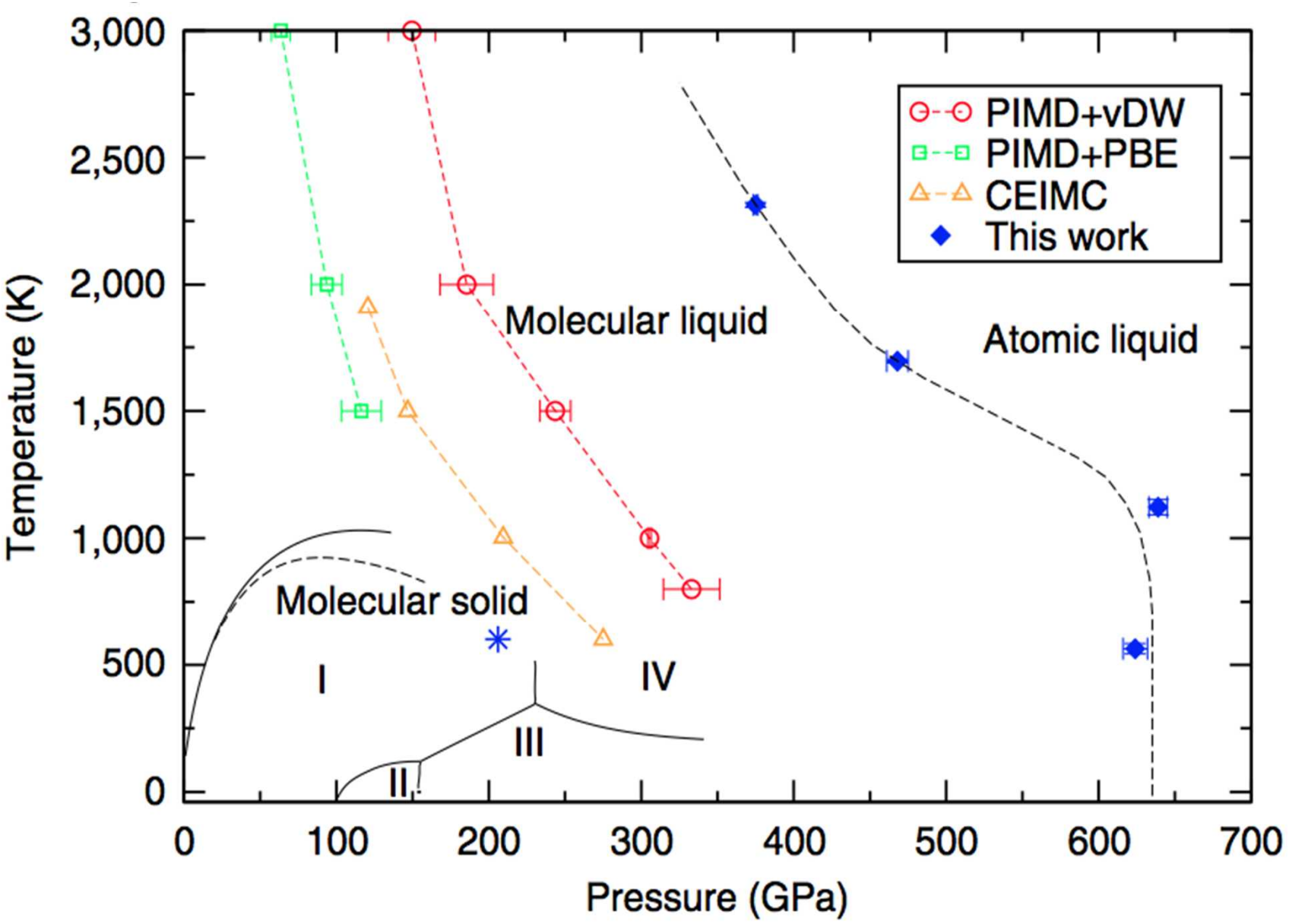
Hydrogen at high pressures – the known phase diagram so far



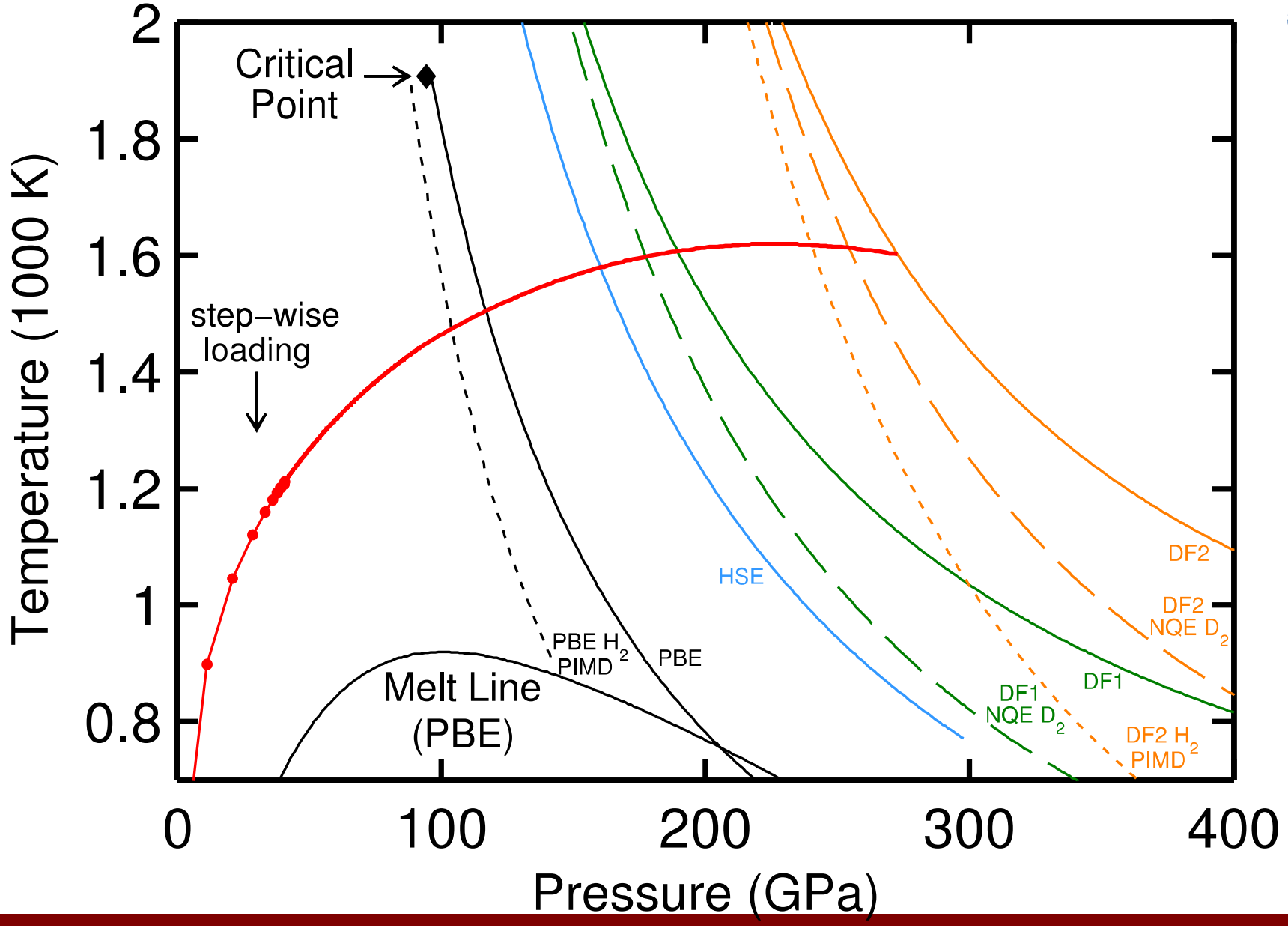
H-He de-mixing appears to be precipitated at low T and P by metallization in hydrogen



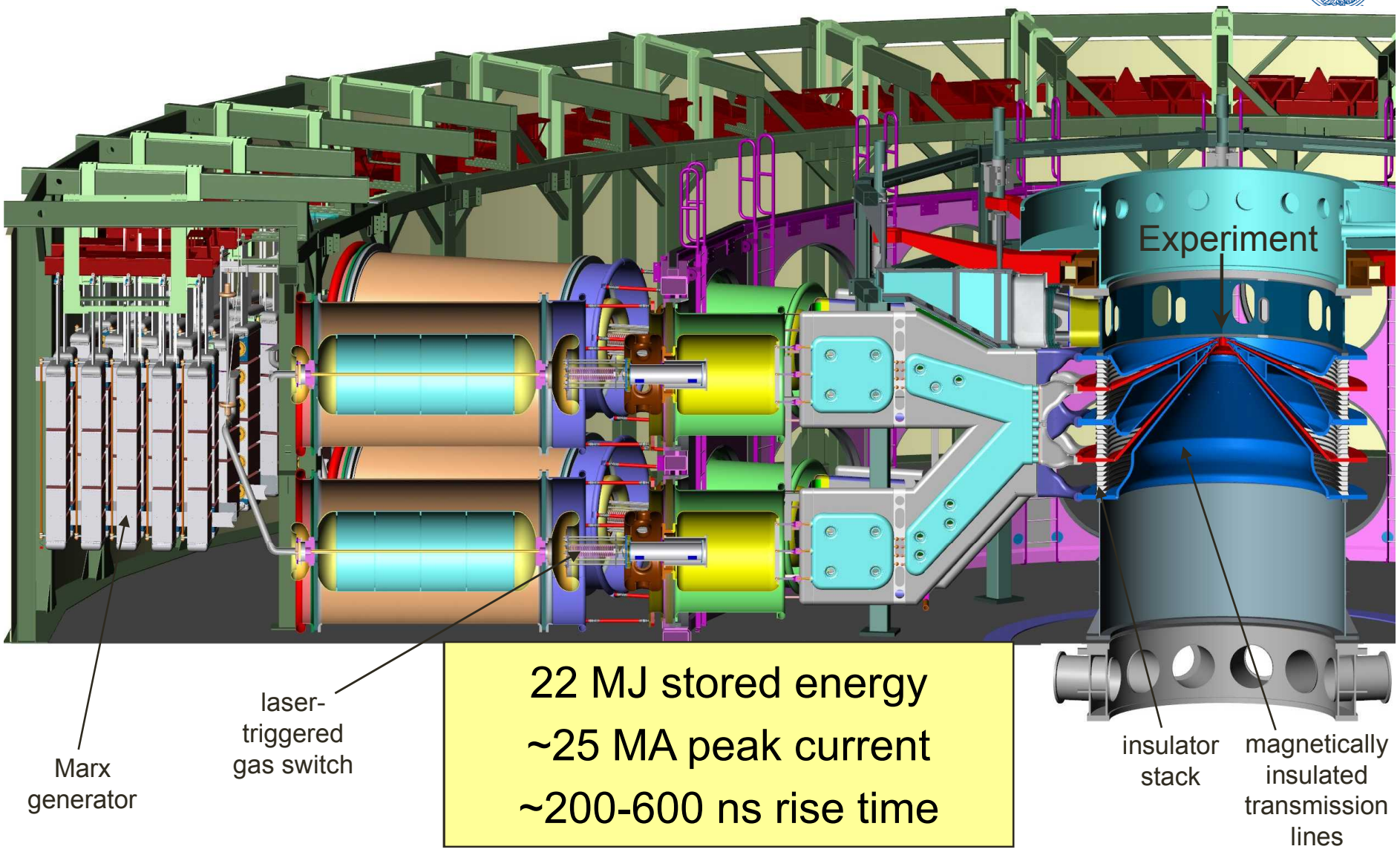
Recent predictions of the LL-IMT in hydrogen



Proposed Experiment: Shock - Ramp



Sandia Z Machine

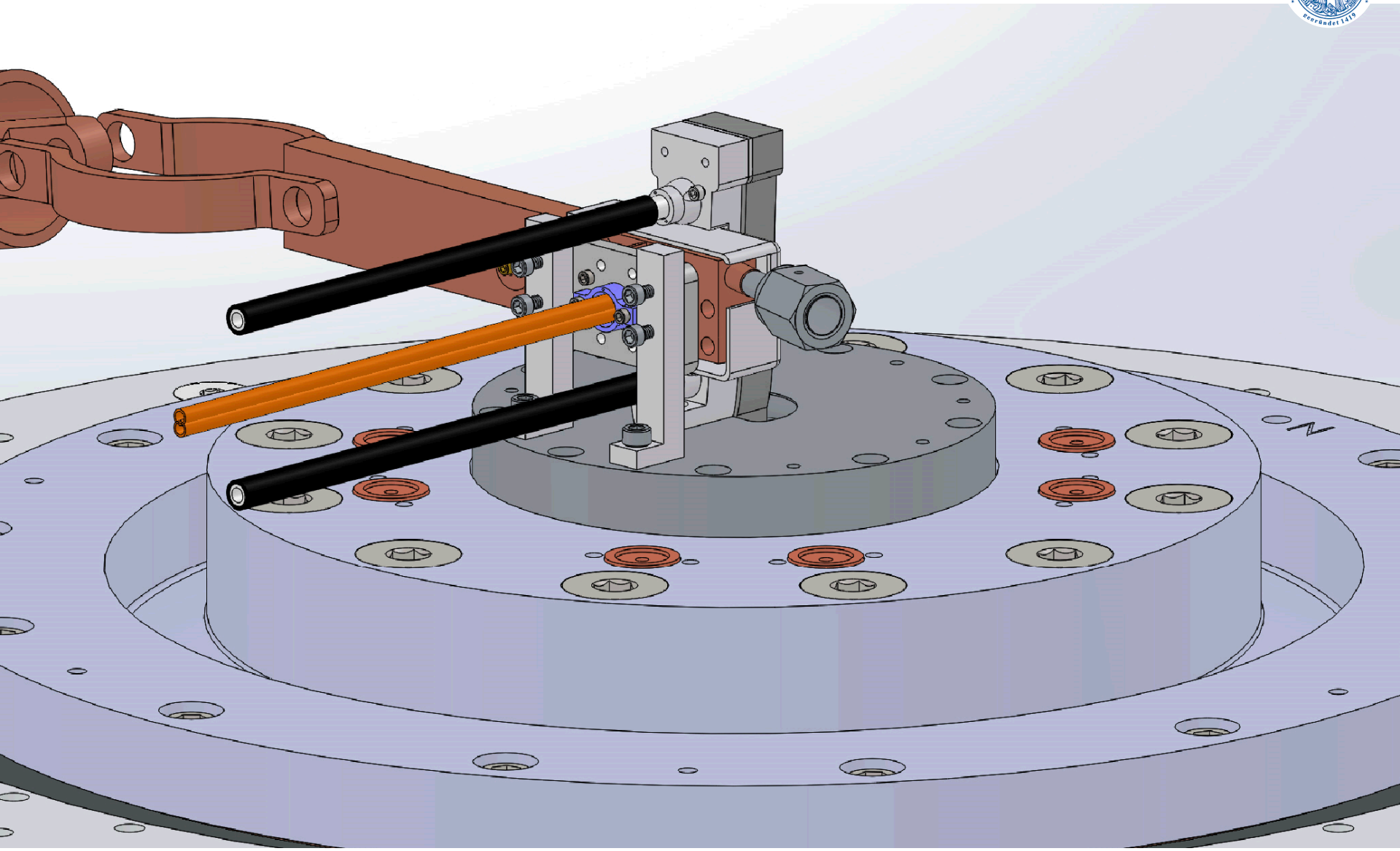


22 MJ stored energy

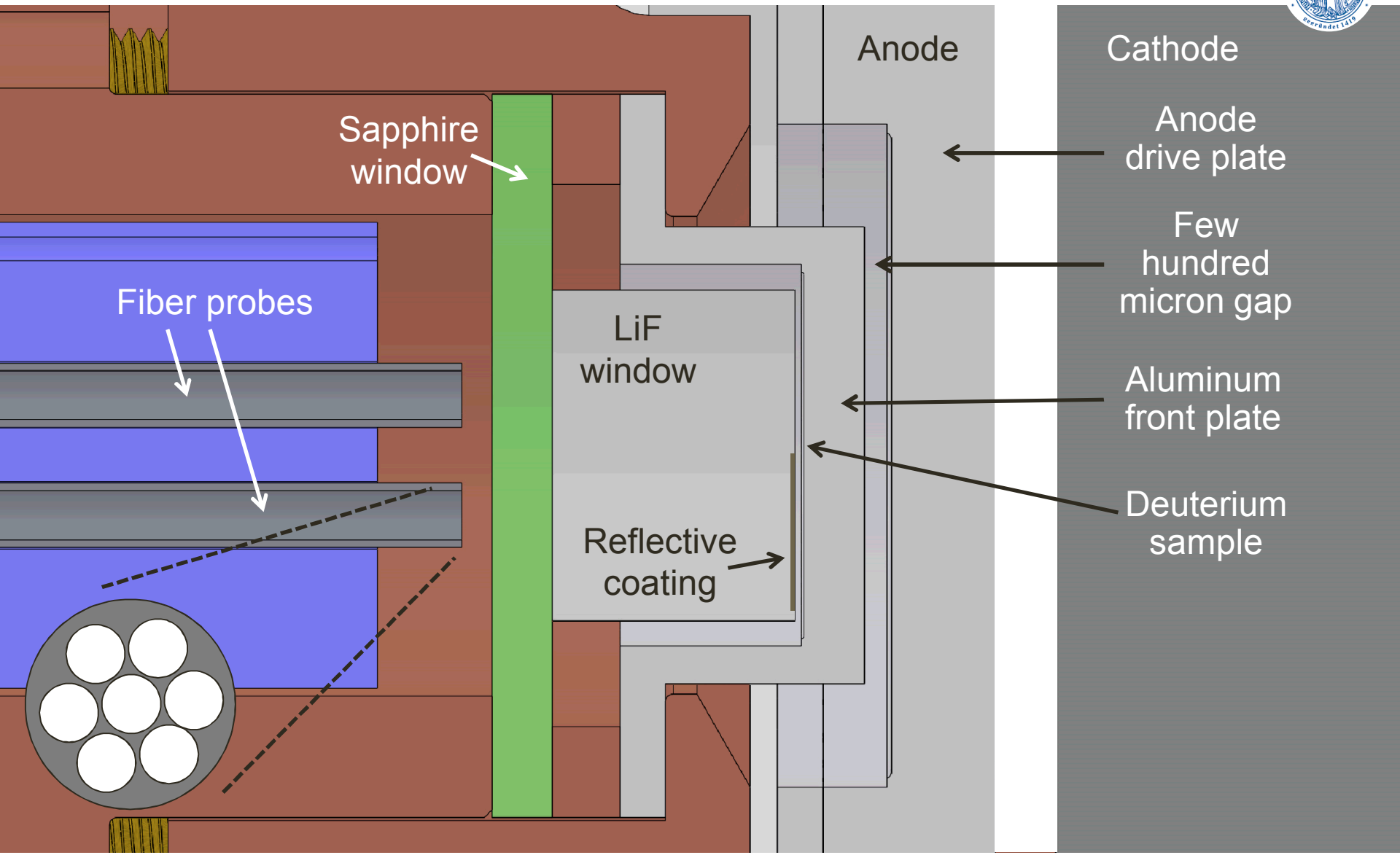
~25 MA peak current

~200-600 ns rise time

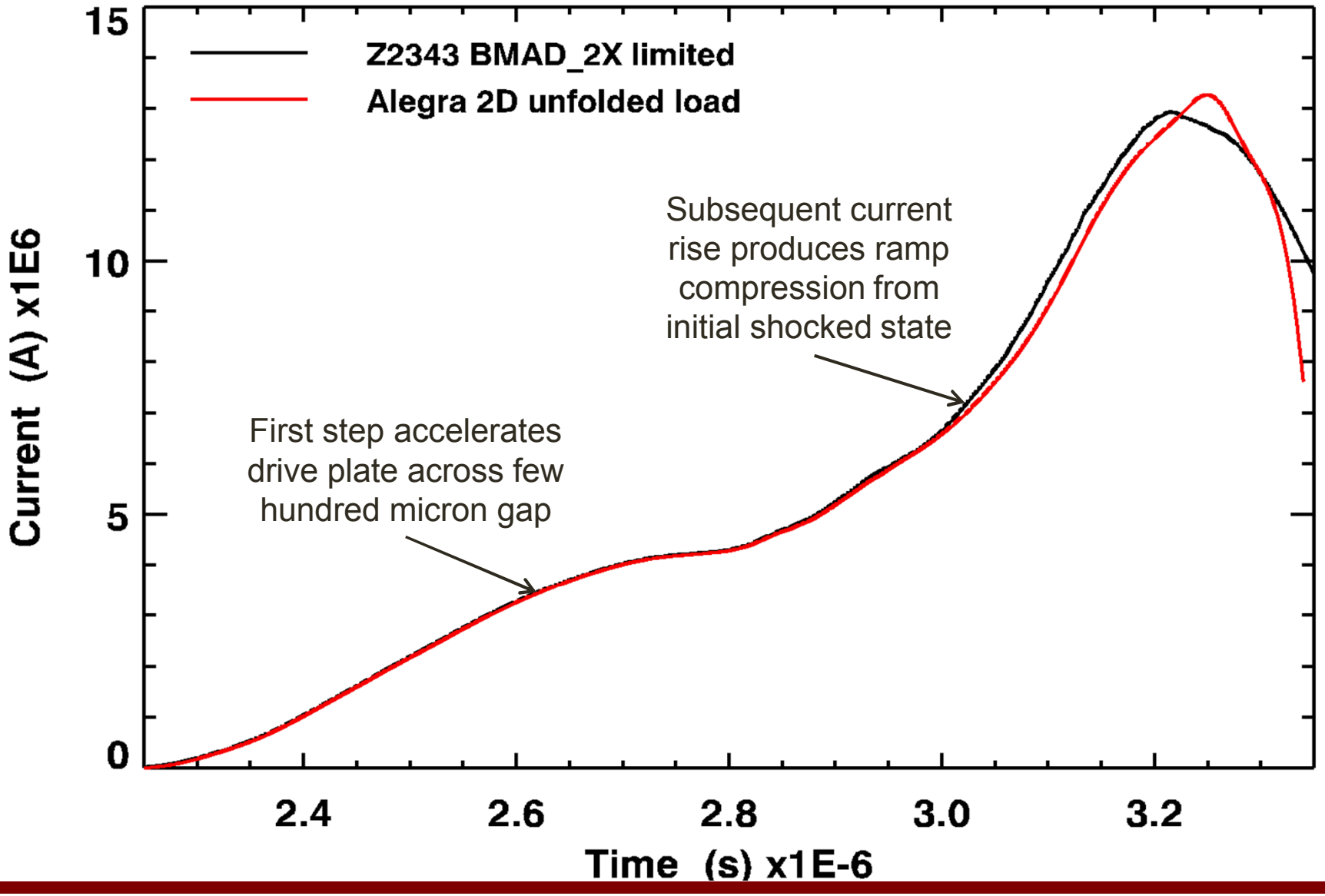
Stripline experimental configuration



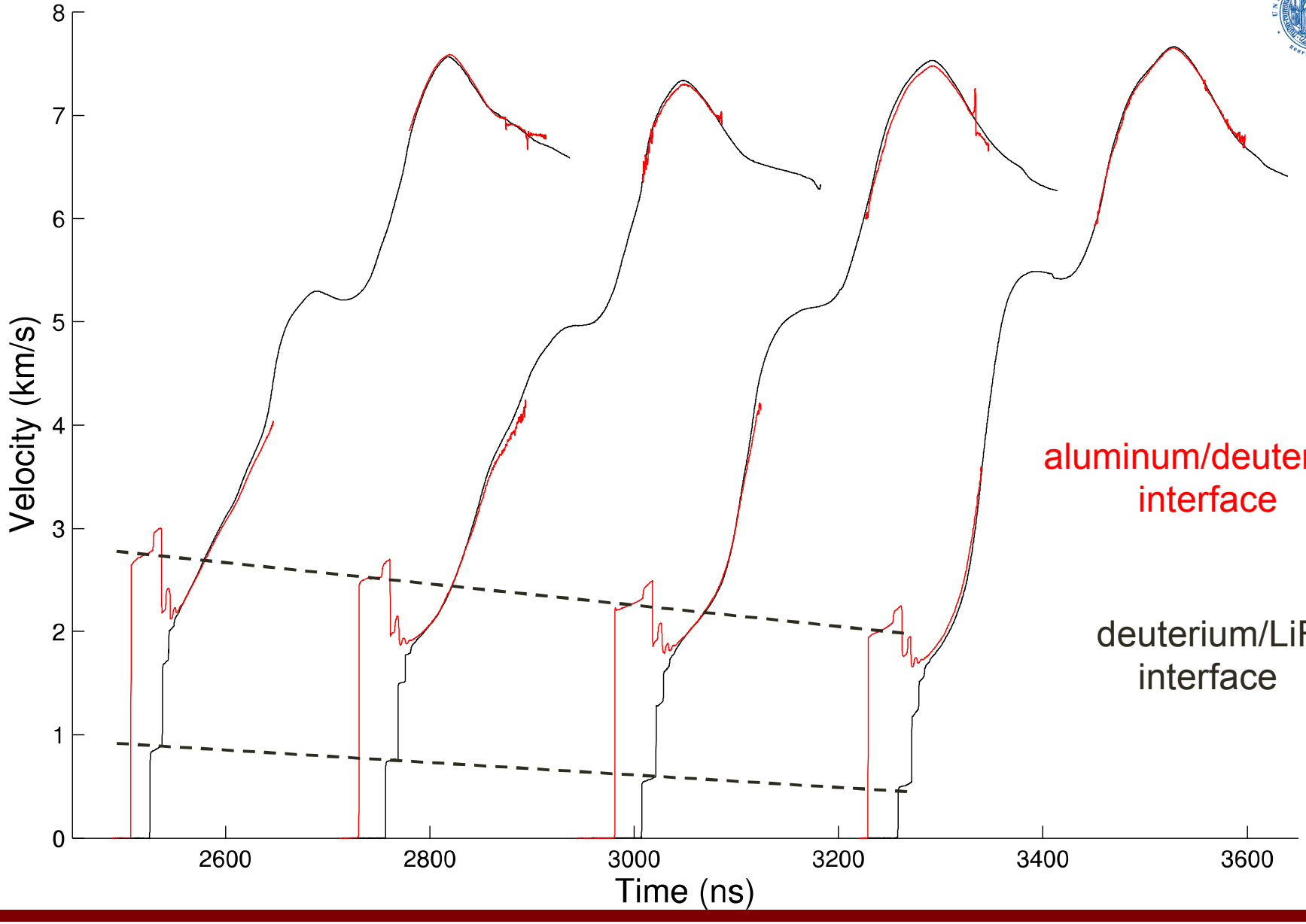
Experimental configuration



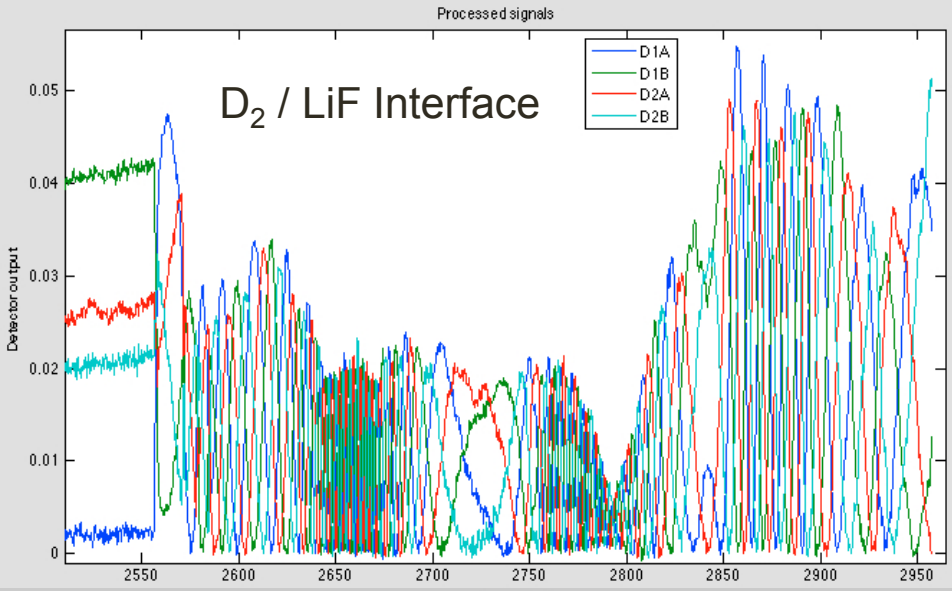
Two-step pulse shape provides shock-ramp profile

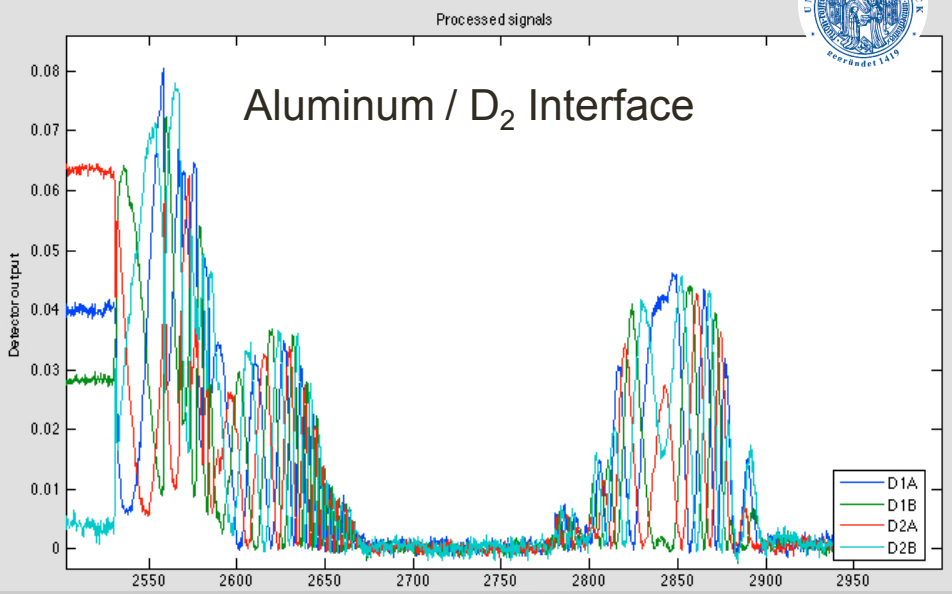


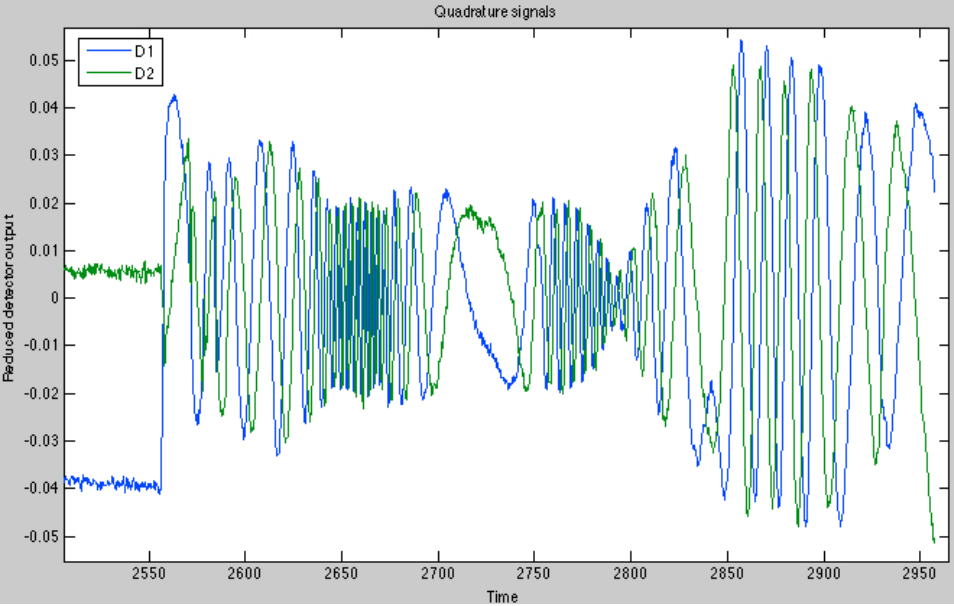
Stripline experimental profiles

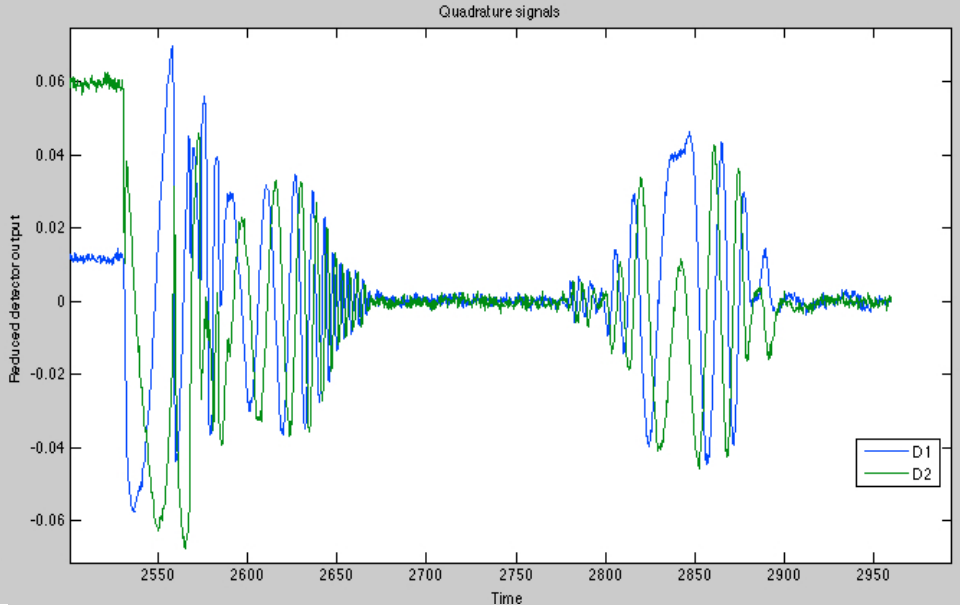


Processed VISAR signals





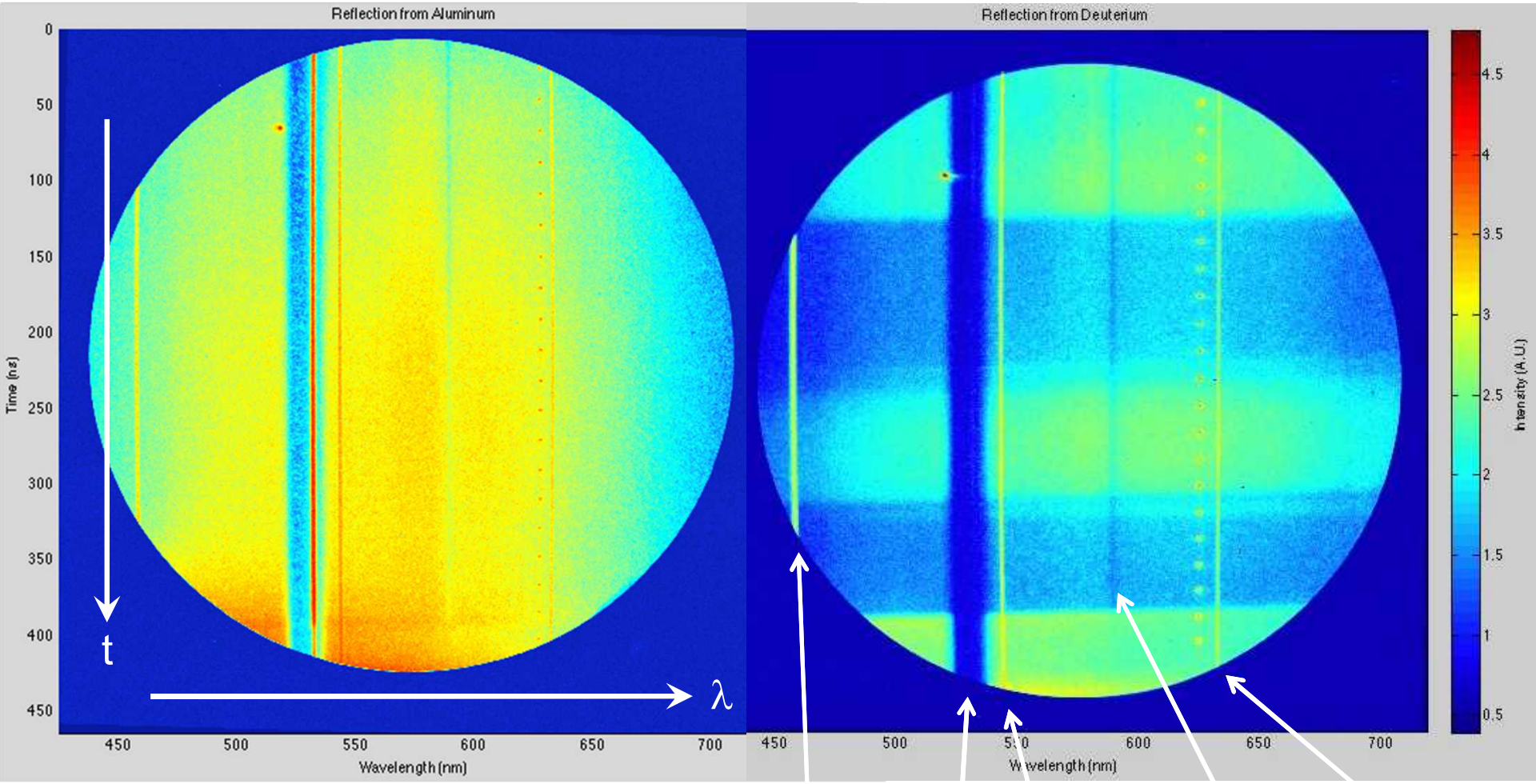




SVS system provides data to infer reflectivity

Reflection from aluminum coating

Reflection from deuterium



Wavelength range ~450-700 nm

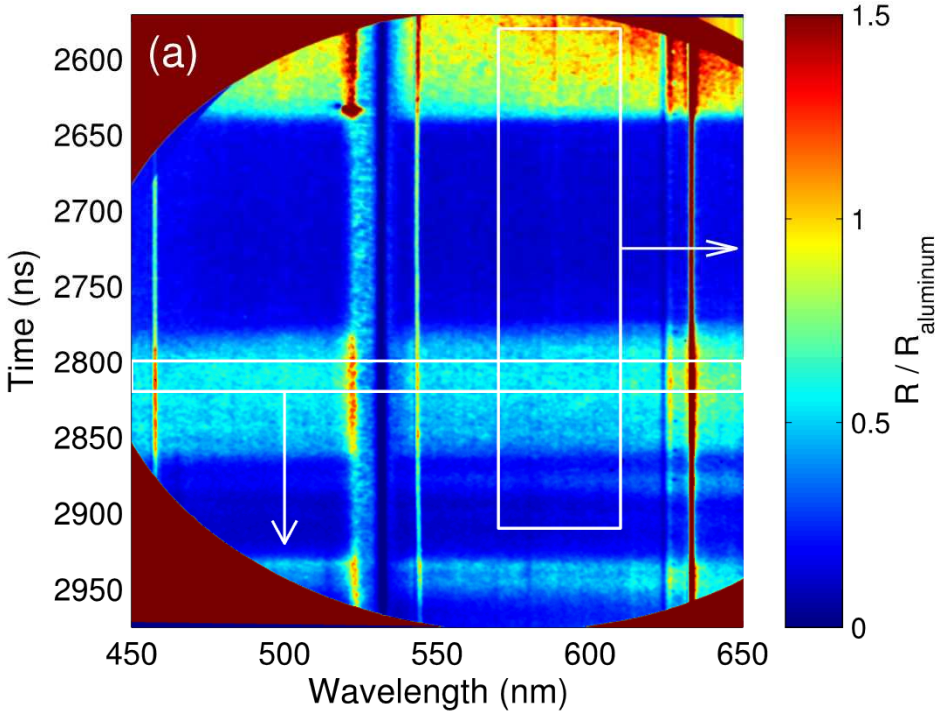
457.9 nm

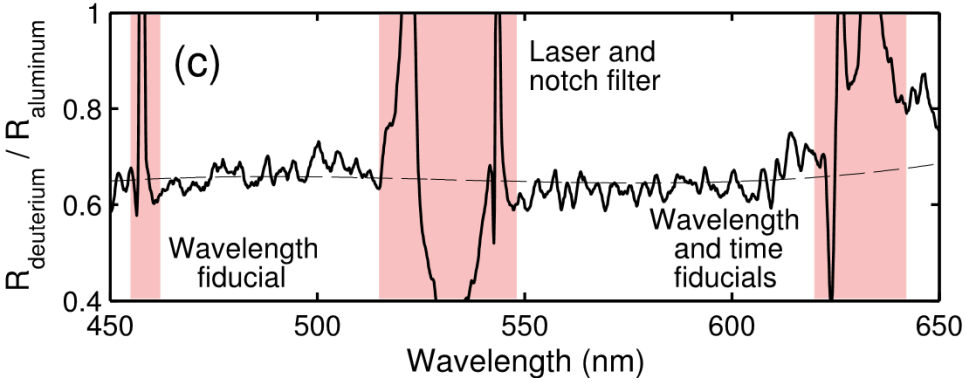
532 / 543.5 nm

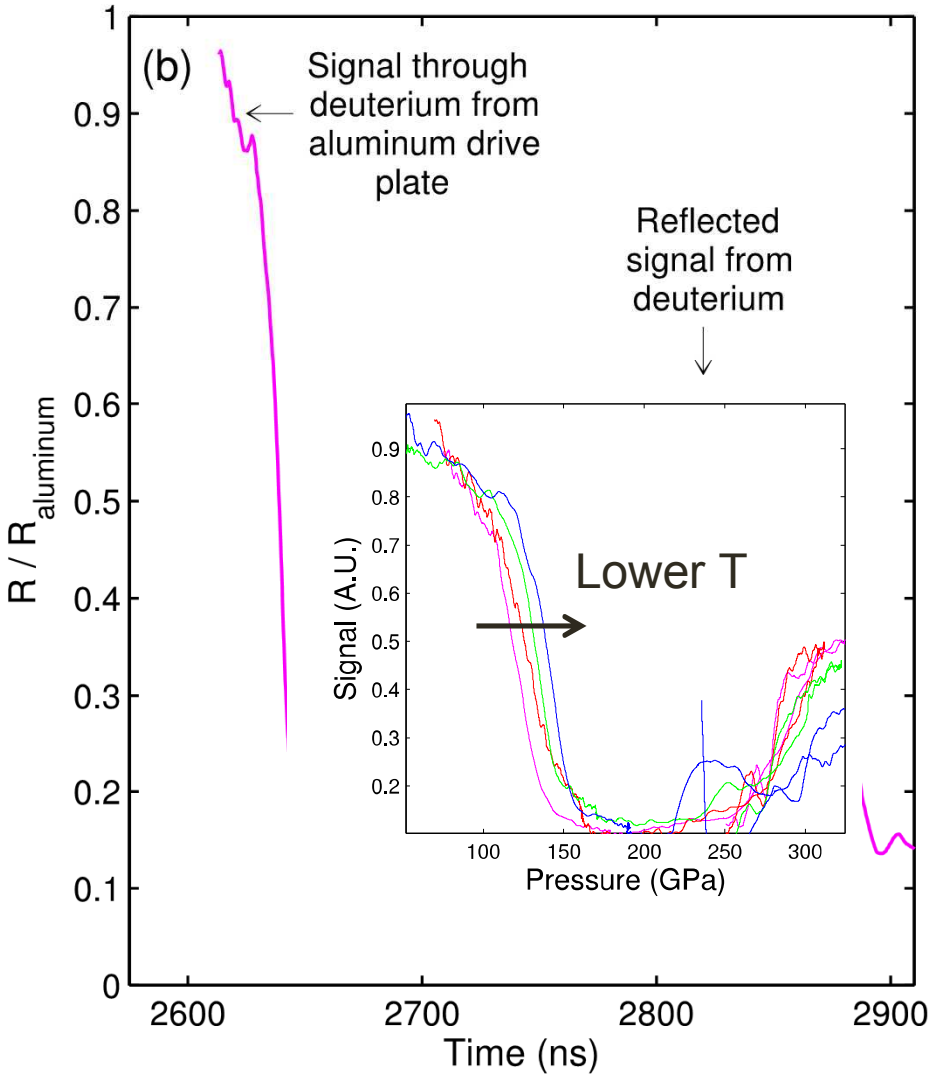
589.3 nm

633 nm

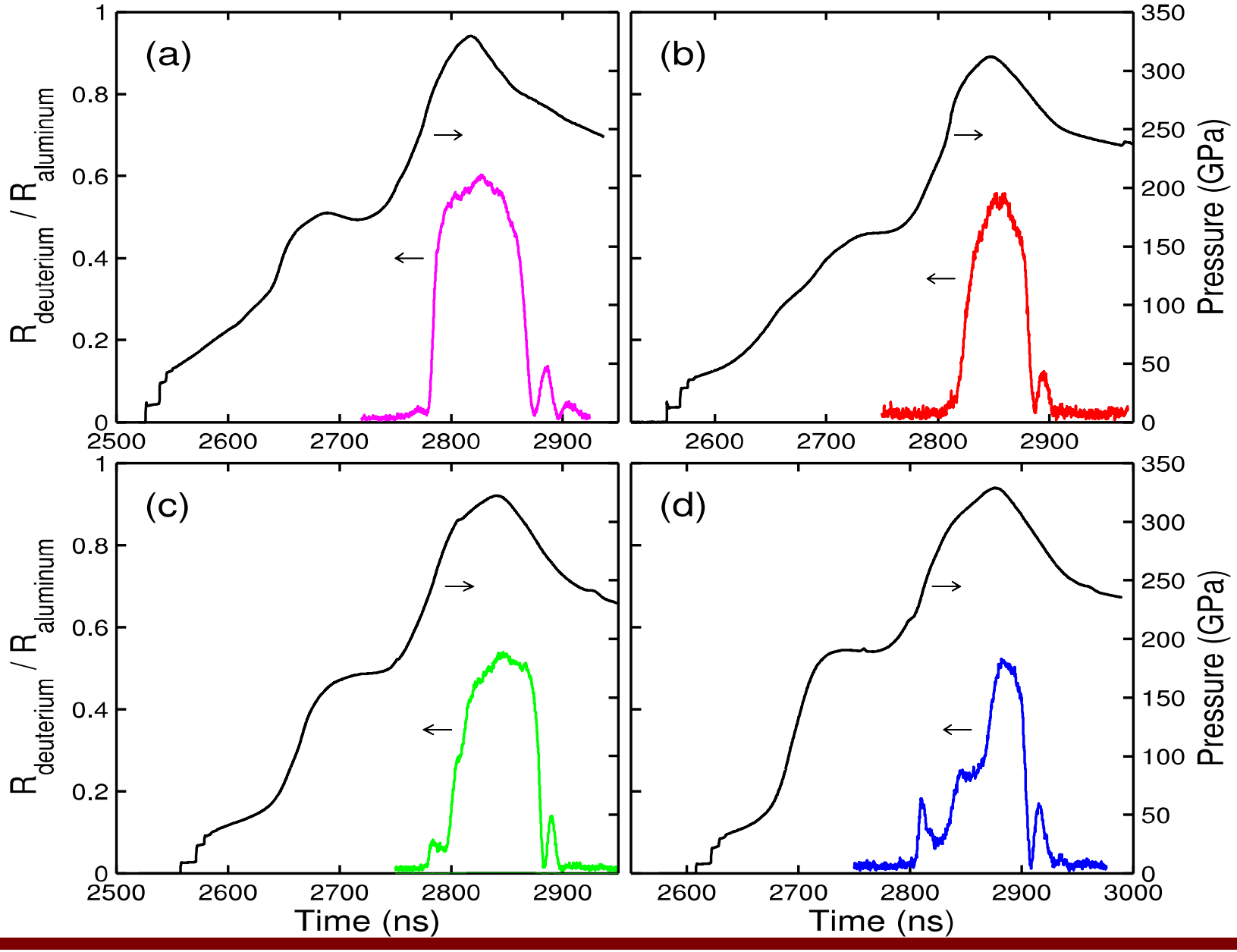
SVS system provides data to infer reflectivity



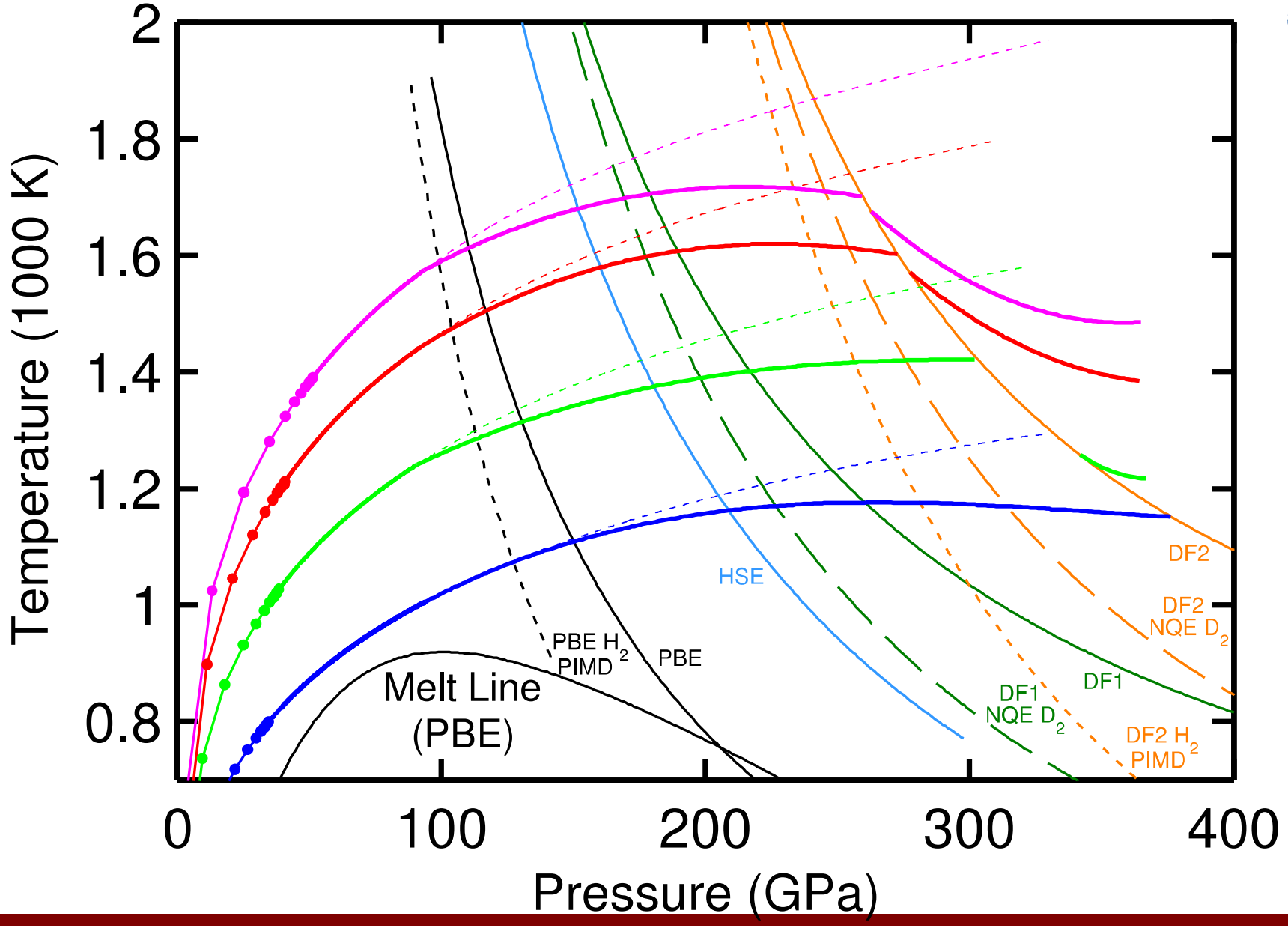




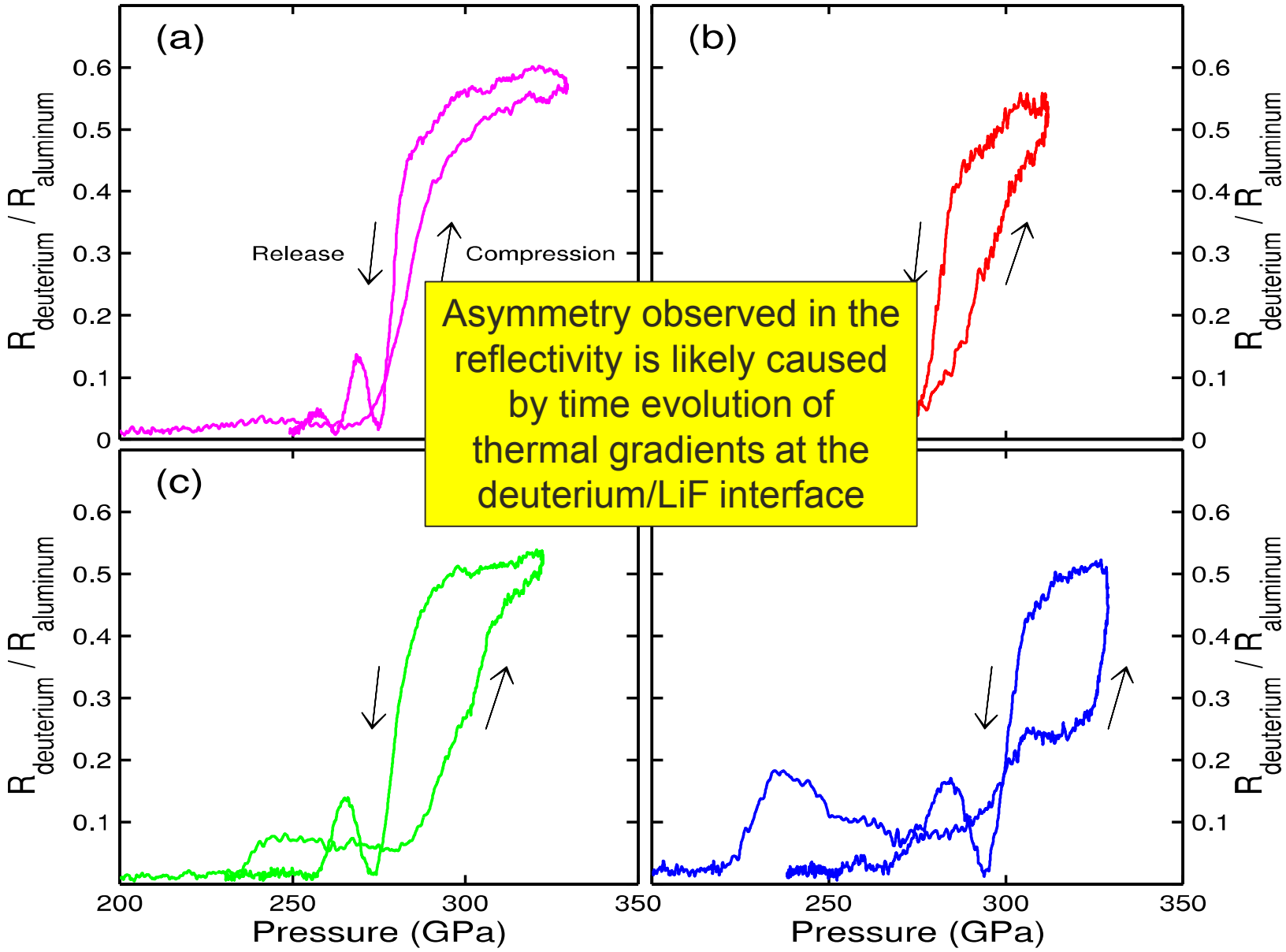
Reflectivity and pressure vs. time from VISAR



Experimental PT Paths

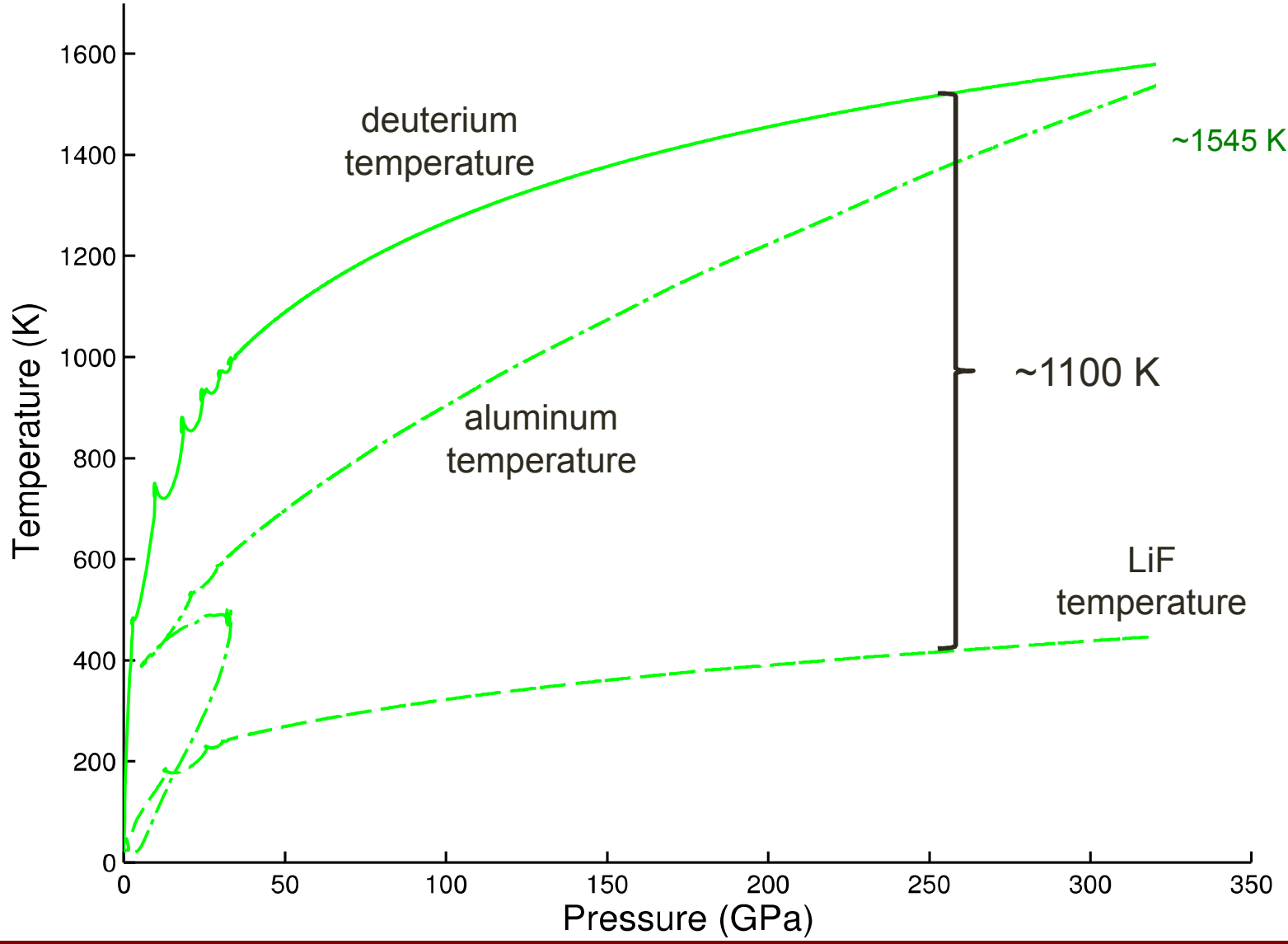


Reflectivity signals mapped to pressure

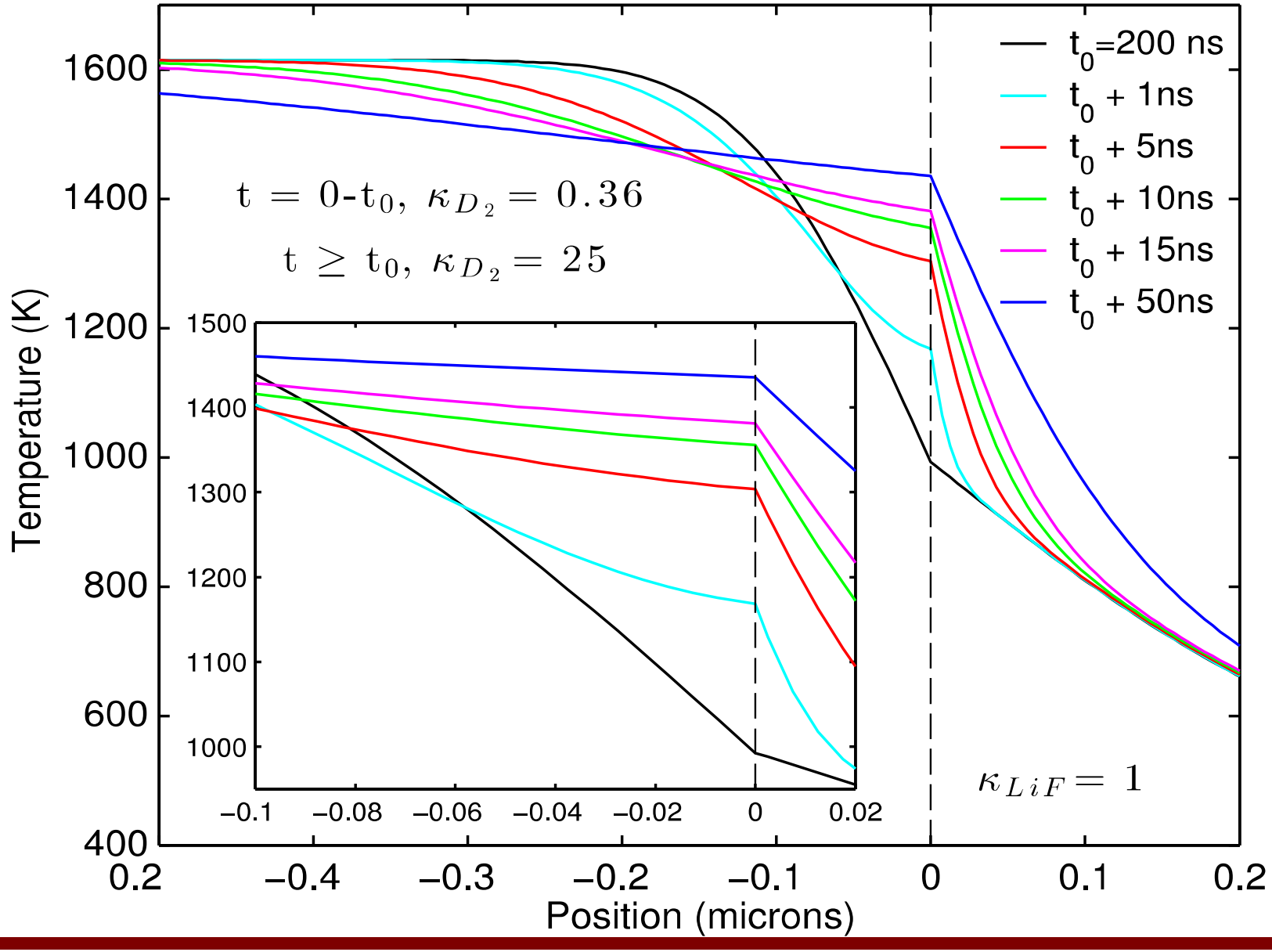


Asymmetry observed in the reflectivity is likely caused by time evolution of thermal gradients at the deuterium/LiF interface

There is a significant temperature difference at the deuterium/LiF interface



Thermal conduction simulations



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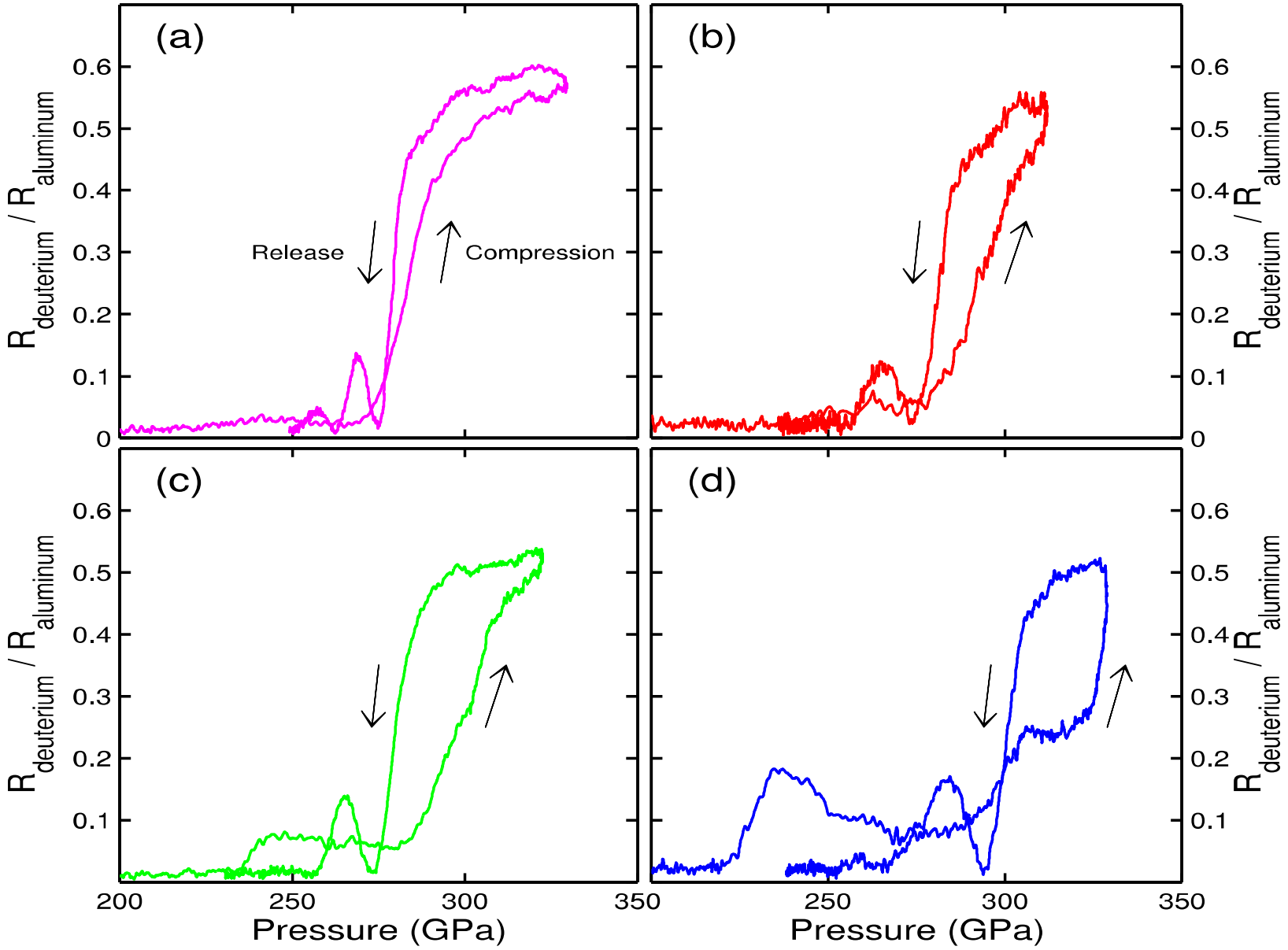
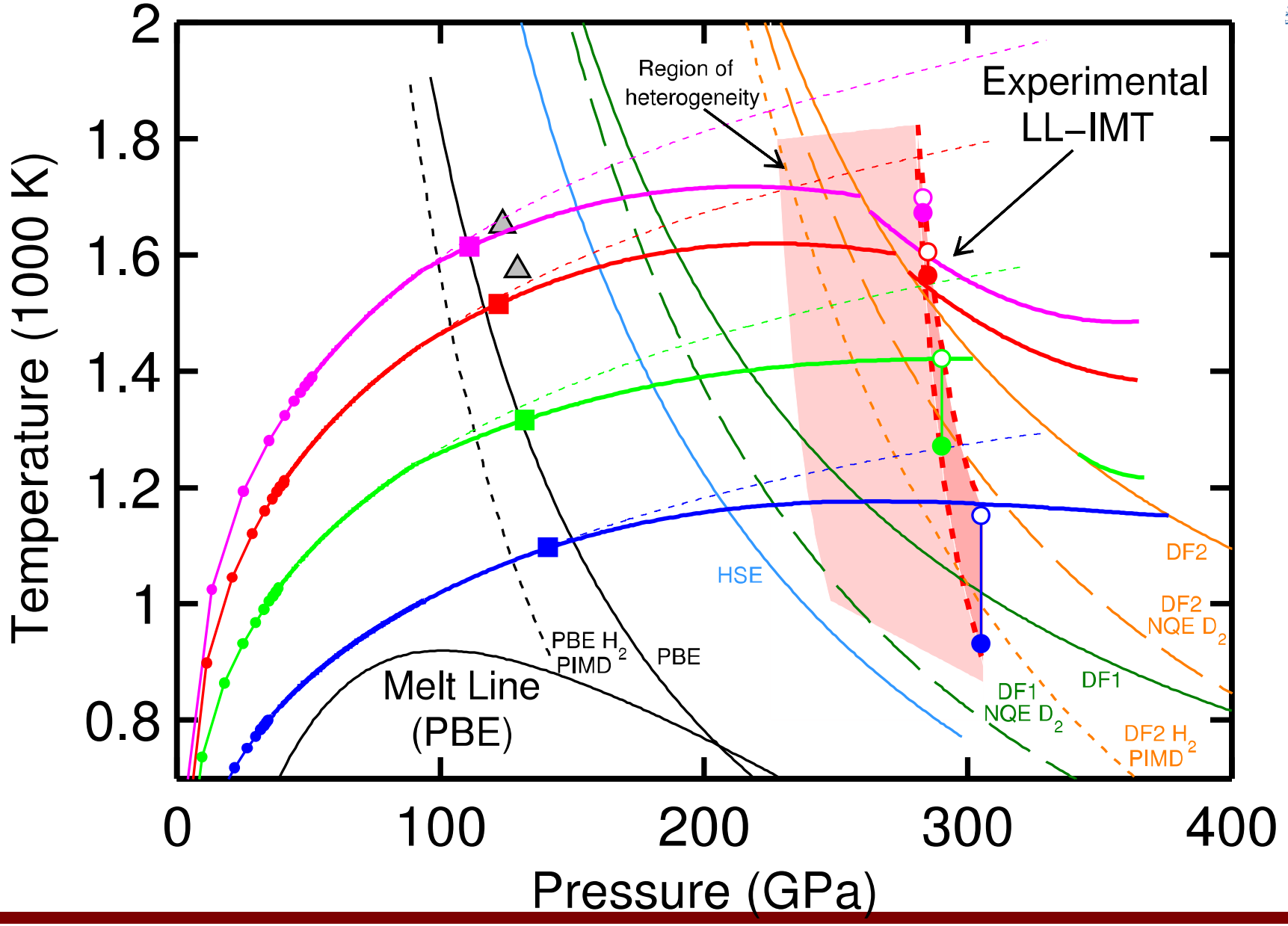
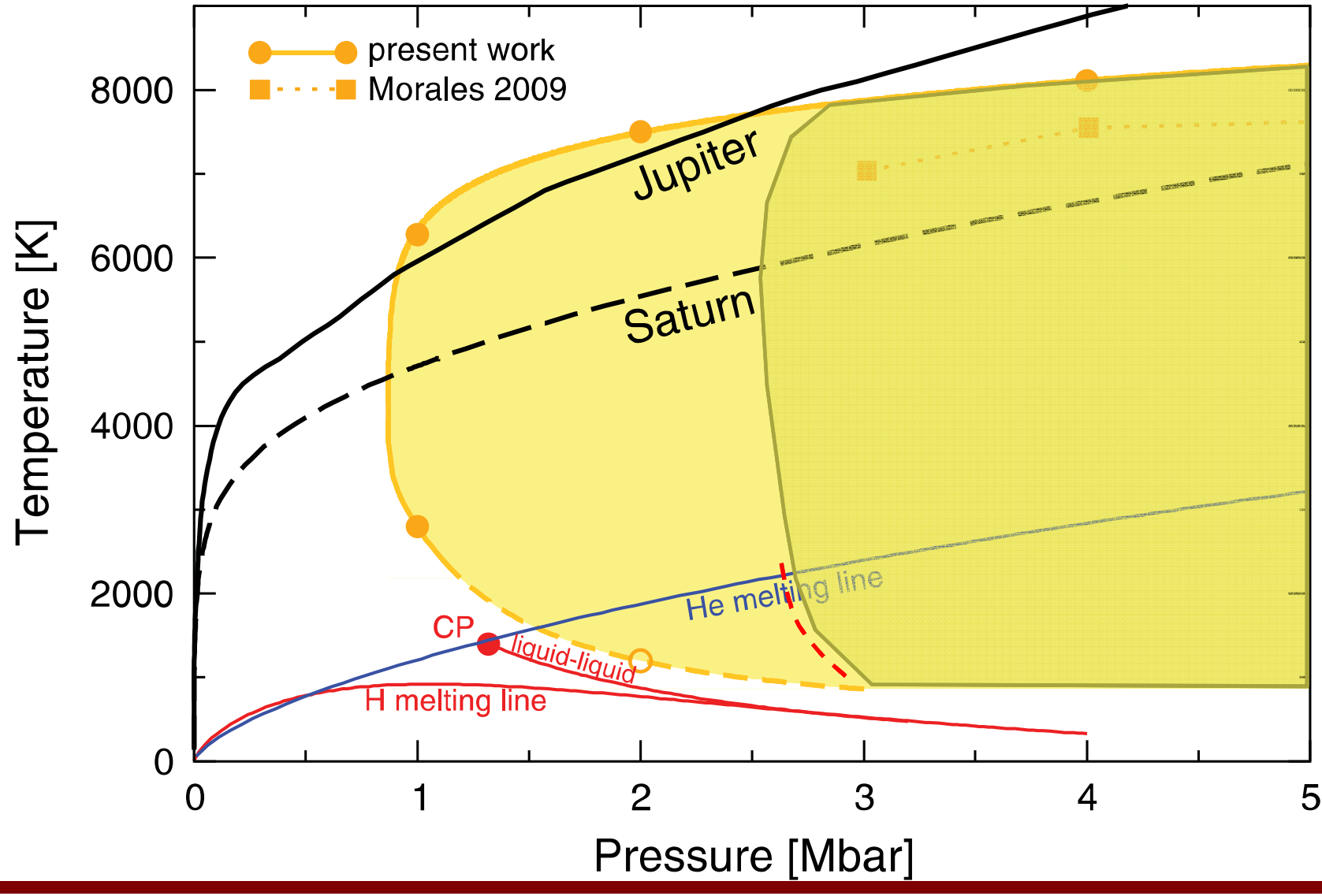


Location of the LL-IMT in deuterium



H-He de-mixing appears to be precipitated at low T and P by metallization in hydrogen



Conclusions

- Shock-ramp technique enables experimental access to the region of phase space where the liquid-liquid, insulator-metal transition (LL-IMT) has been proposed for hydrogen
  - Temperature of the adiabat controlled by magnitude of initial shock
  - P(t) in the experiments determined from the LiF equation on state
- Experiments above ~250 GPa show clear evidence of metallization of deuterium
  - Very abrupt increase in reflectivity to ~40-50%
  - Pressure state well above numerous first principles predictions
  - Indications suggest that the transition is first order
- Relative insensitivity to *T* suggests this is a ρ-driven transition
  - ρ at the transition is inferred to be ~2-2.1 g/cc in deuterium

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