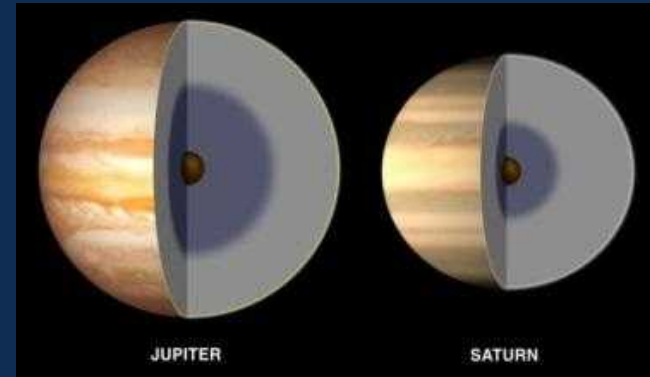
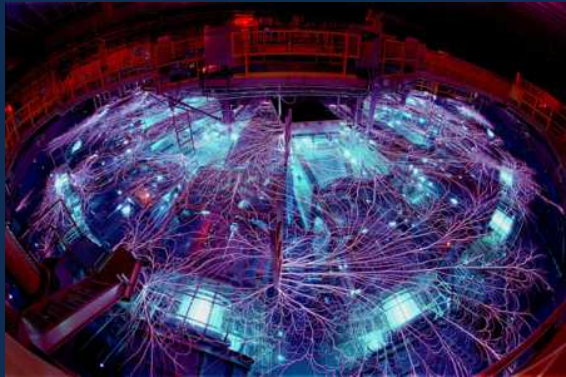
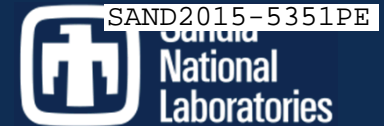


Exceptional service in the national interest



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

Marcus D. Knudson

Sandia National Laboratories

Albuquerque, NM



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Acknowledgements

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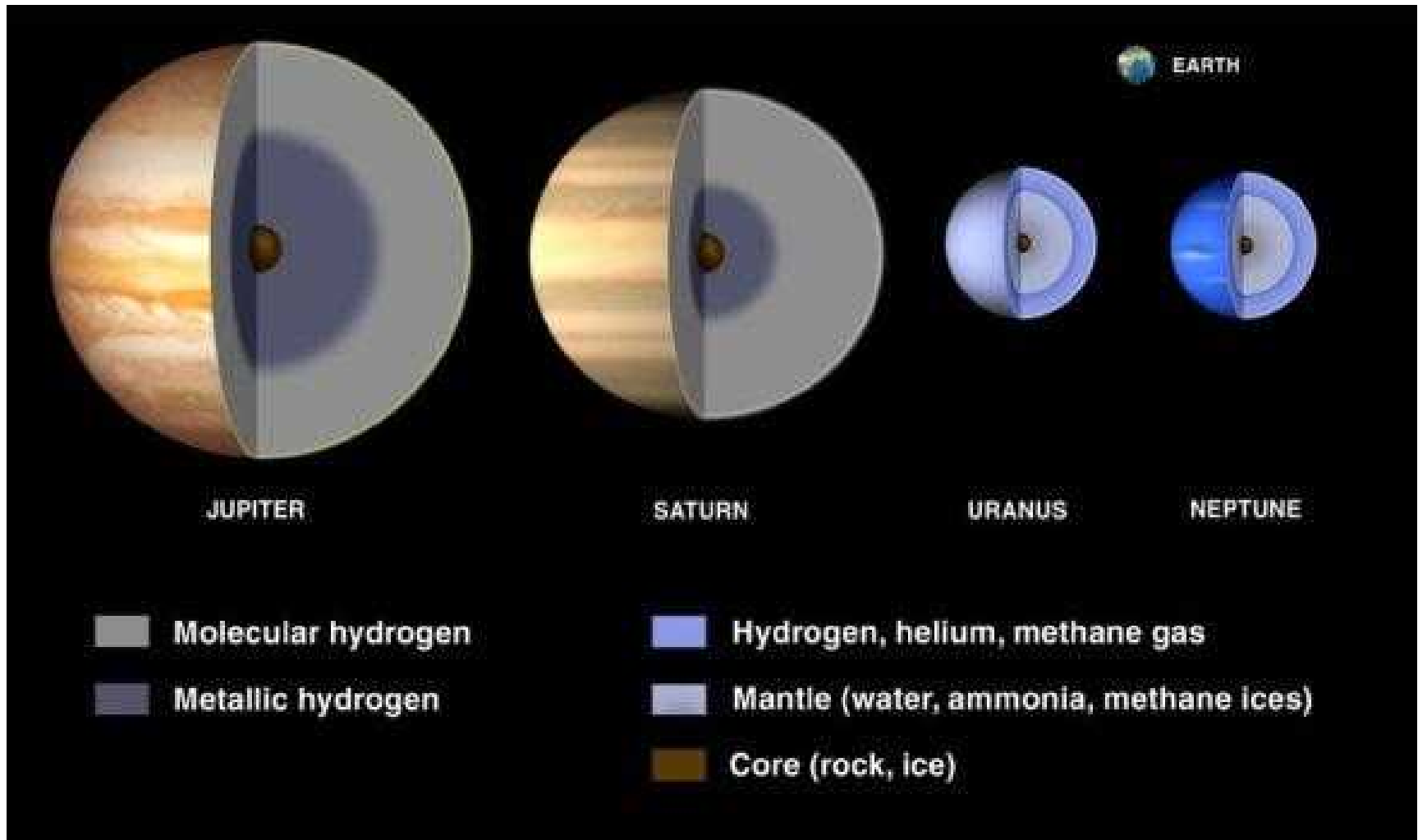
Dave Hinshelwood

Entire Z crew

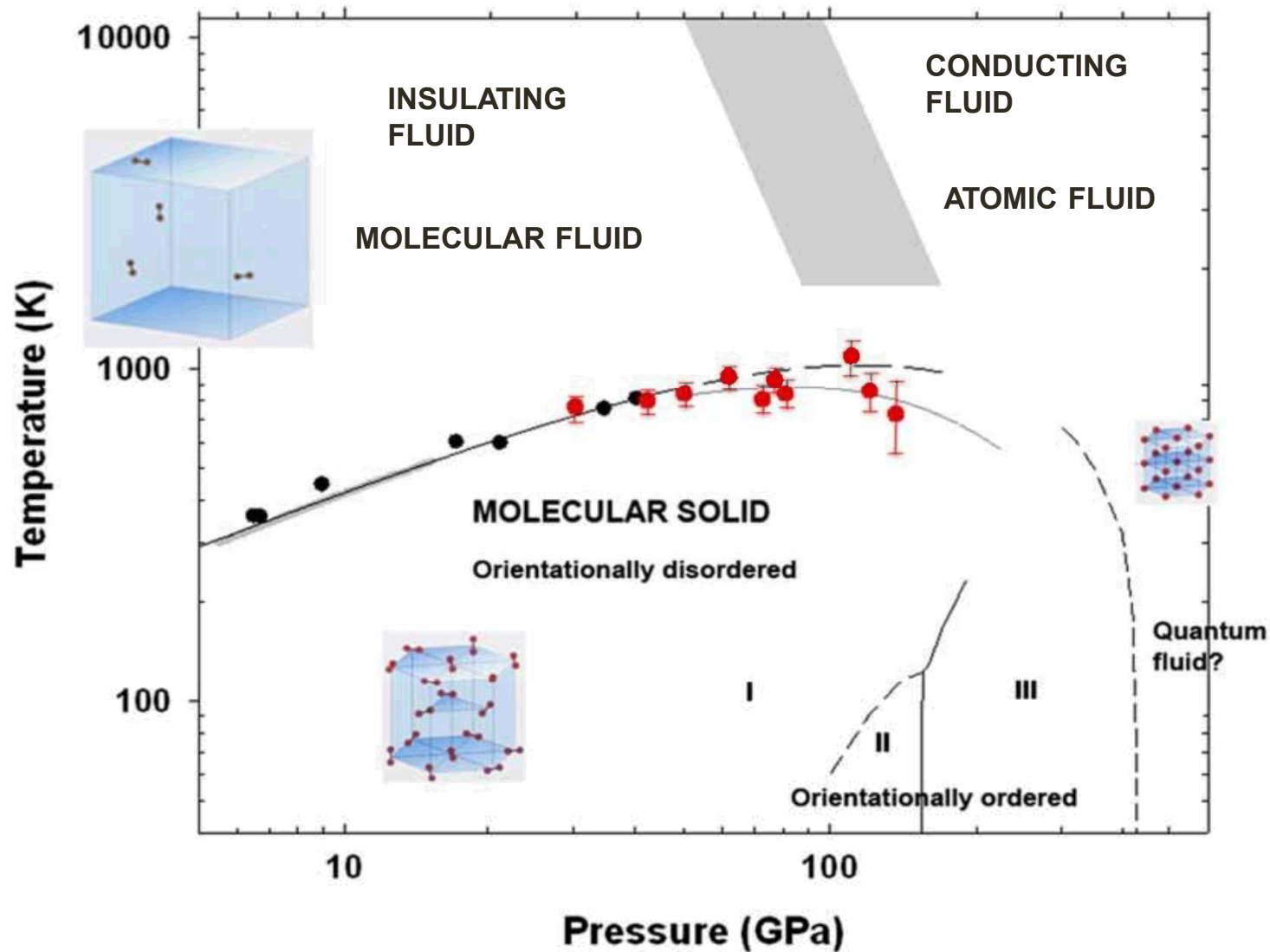
University of Rostock

Giant planets in the Solar system

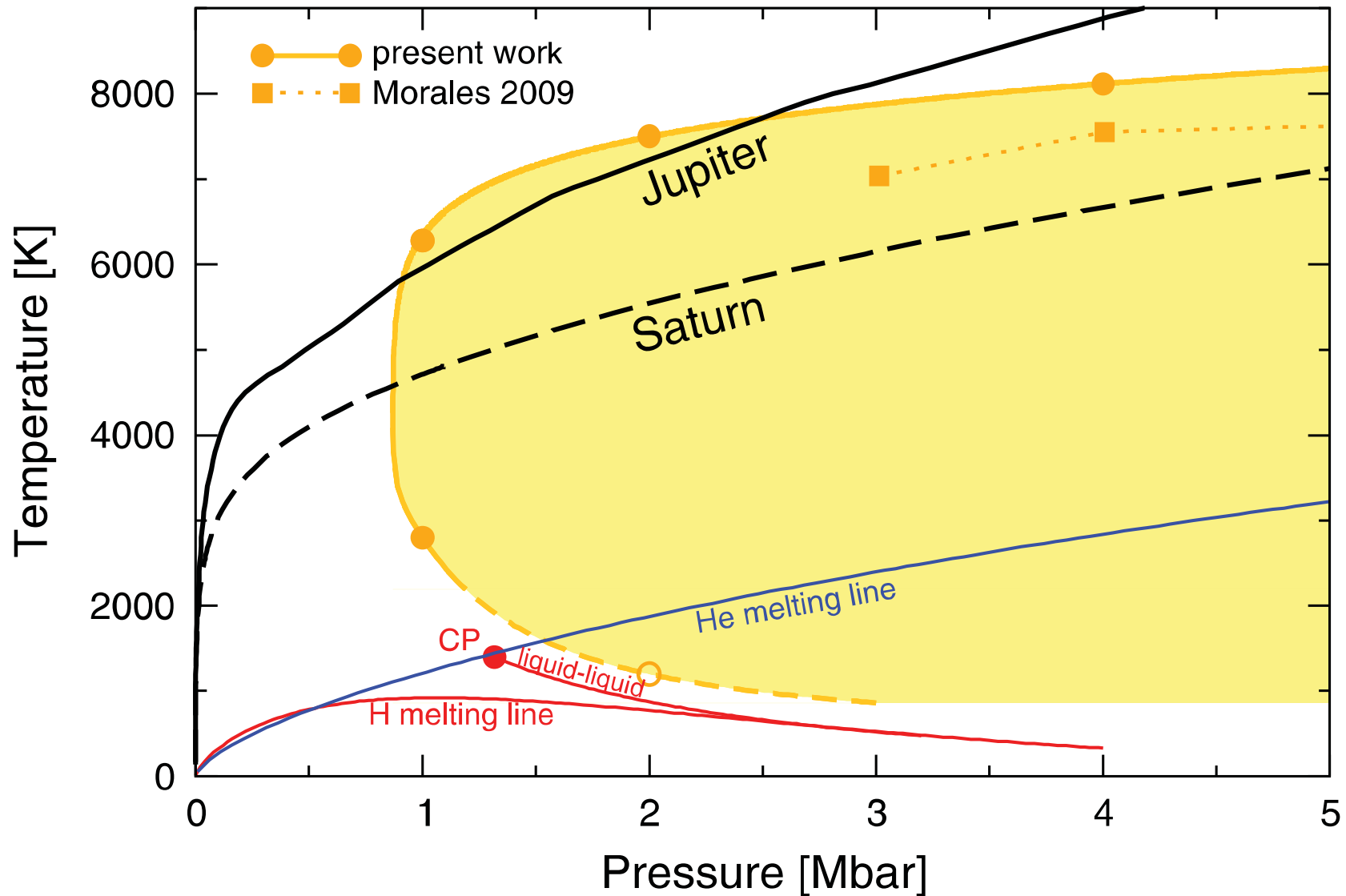
Interior composed of the lightest elements H & He, hydrides NH_3 , OH_2 , CH_4 (ices) and small amounts of heavier elements (cores)



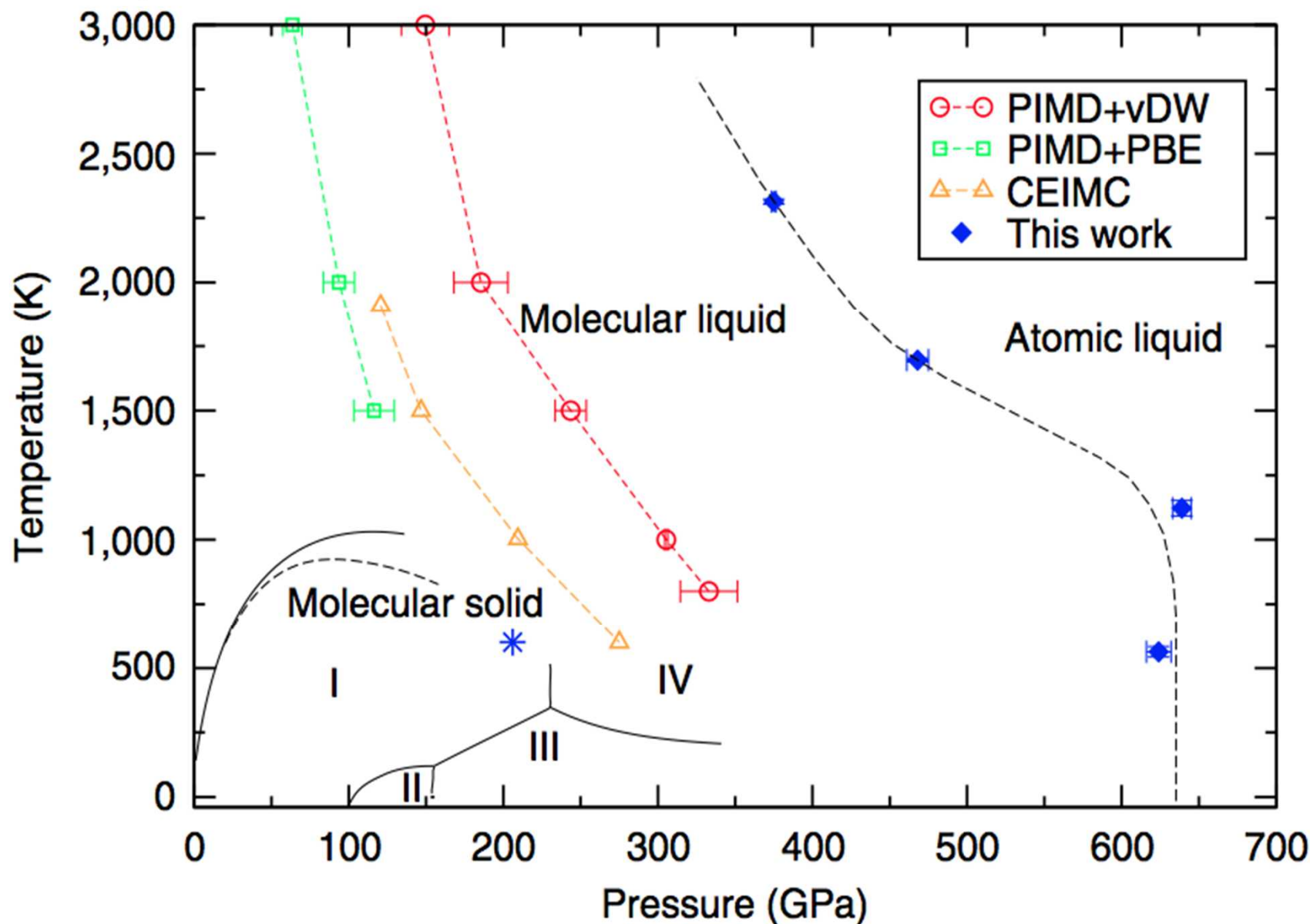
Hydrogen at high pressures – the known phase diagram so far



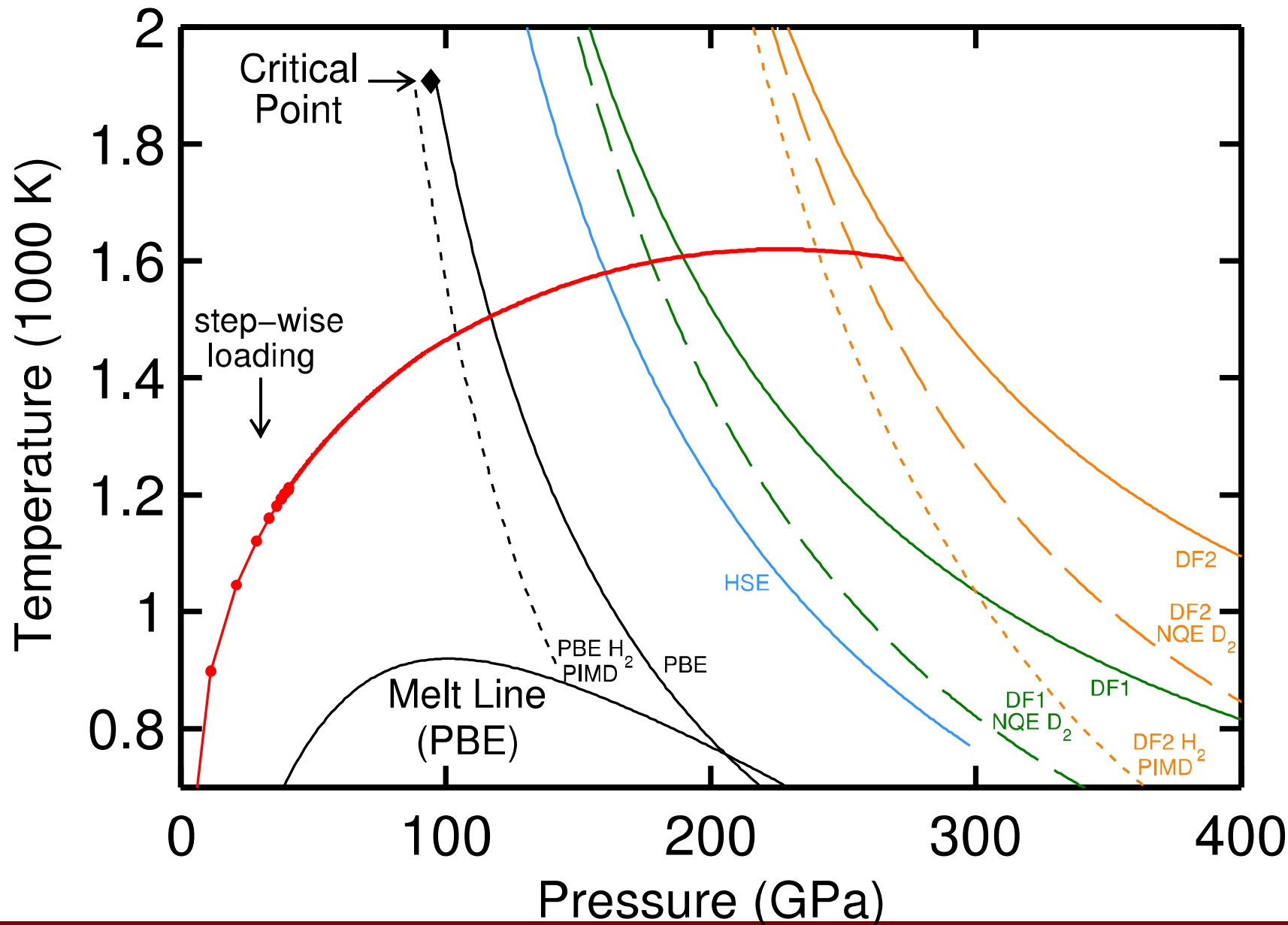
H-He de-mixing appears to be precipitated at low T and P by metallization in hydrogen



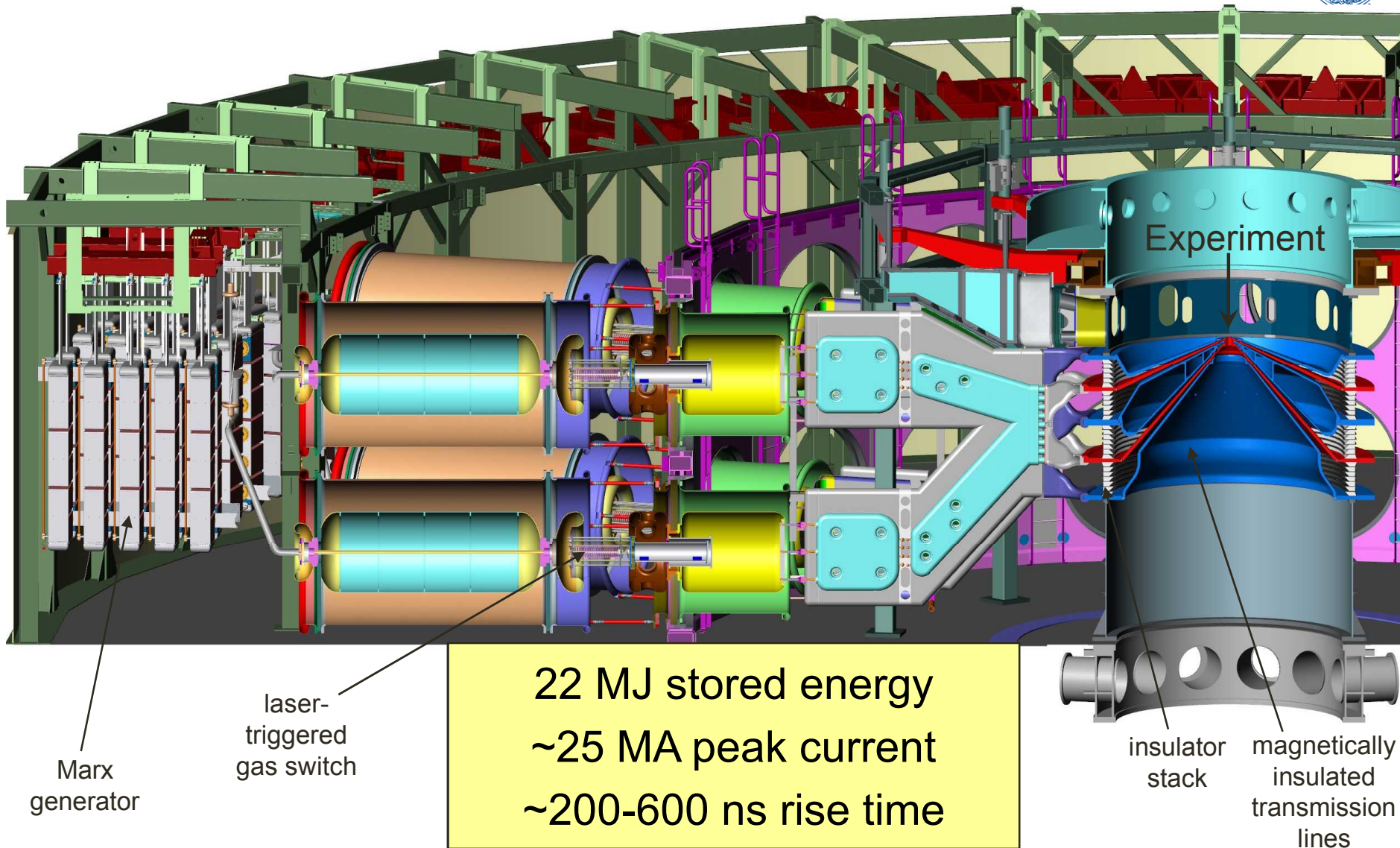
Recent predictions of the LL-IMT in hydrogen



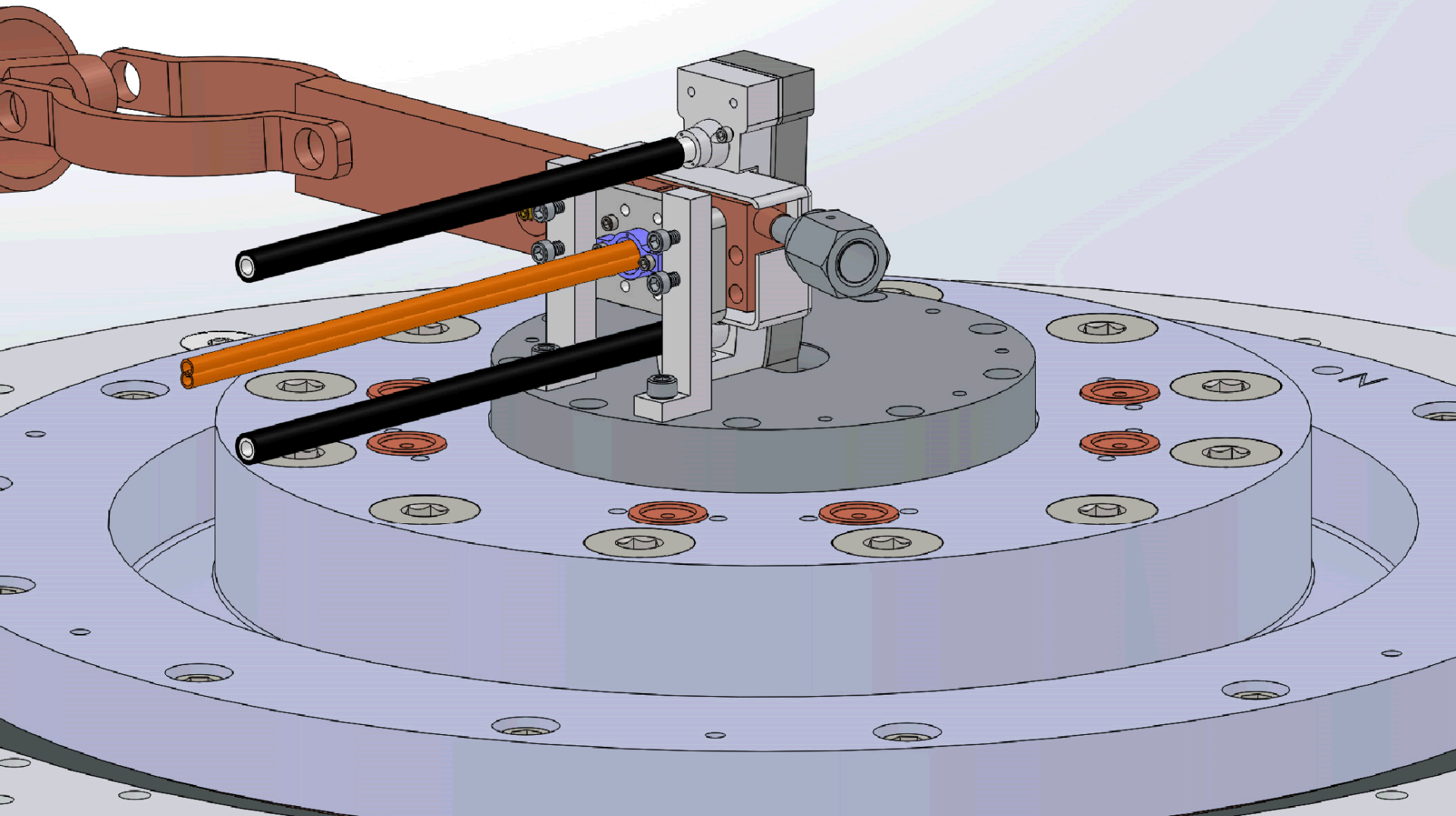
Proposed Experiment: Shock - Ramp



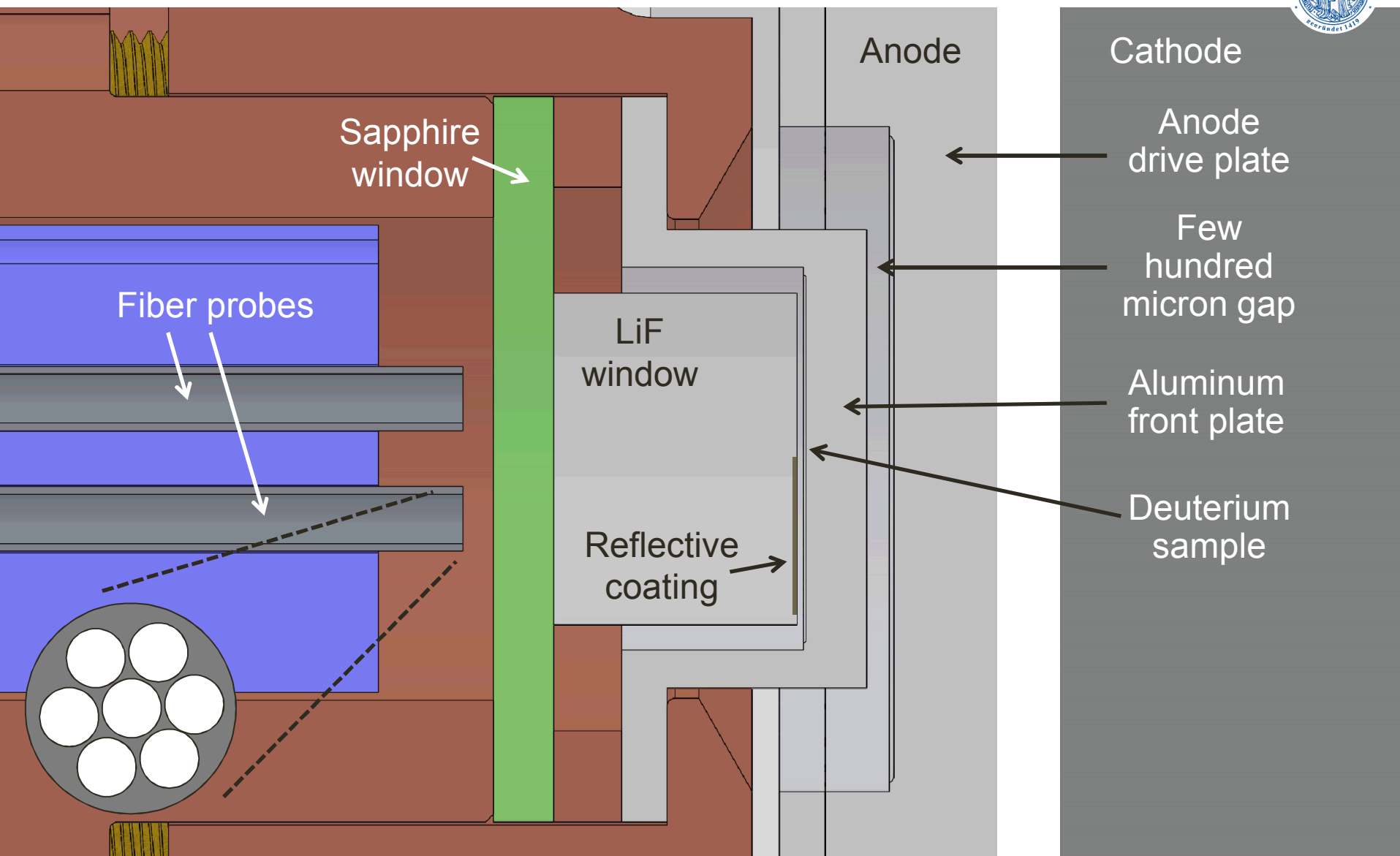
Sandia Z Machine



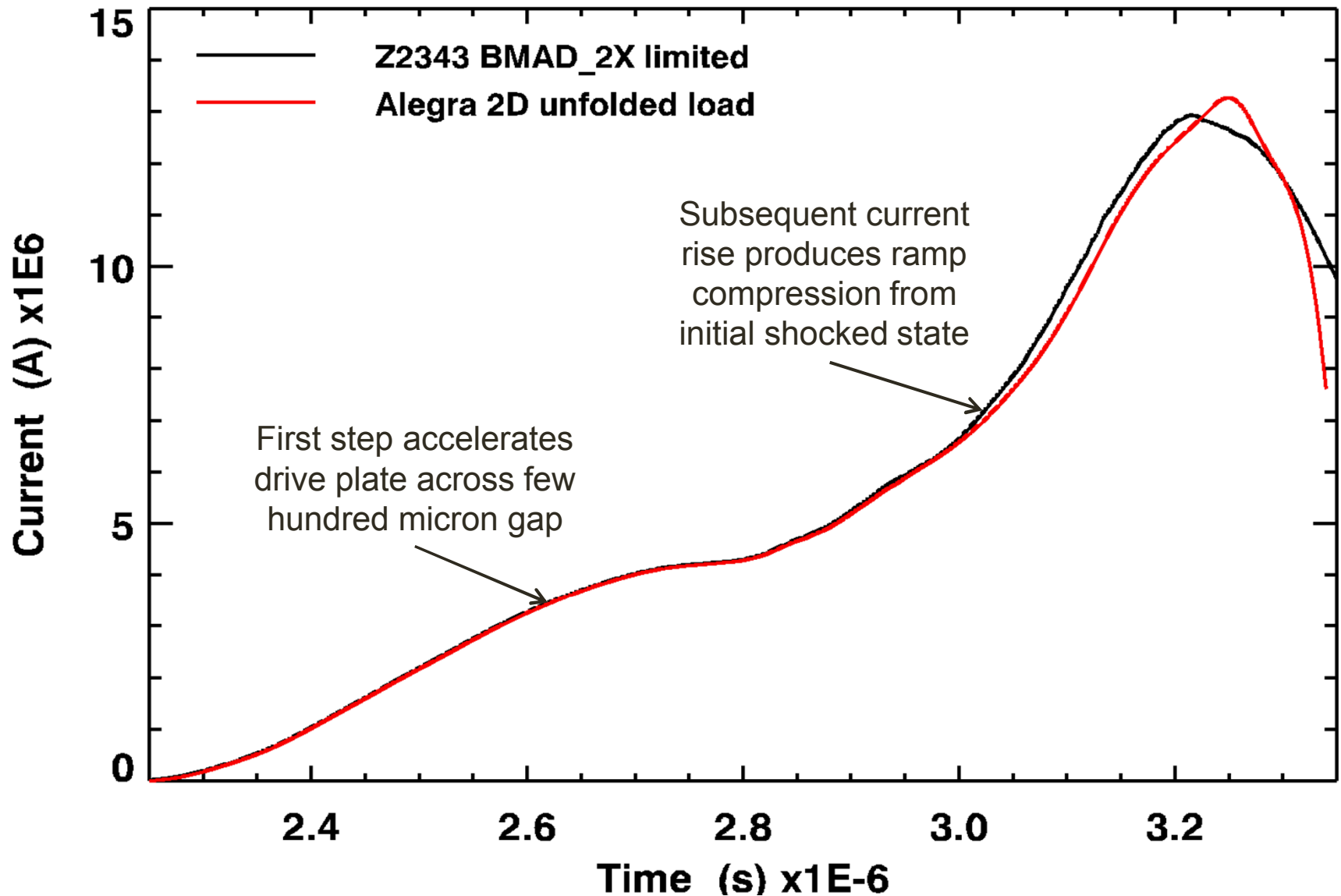
Stripline experimental configuration



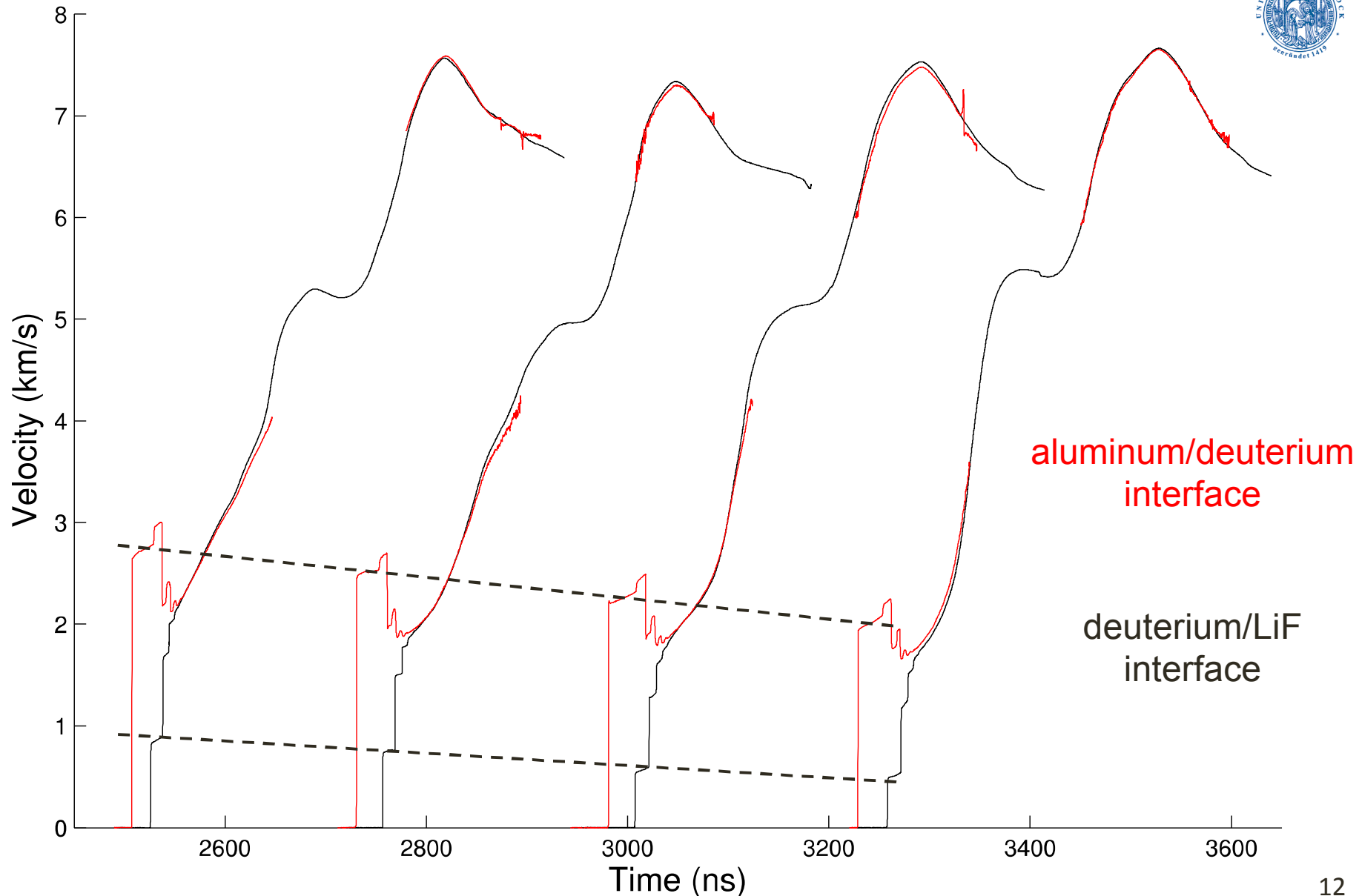
Experimental configuration



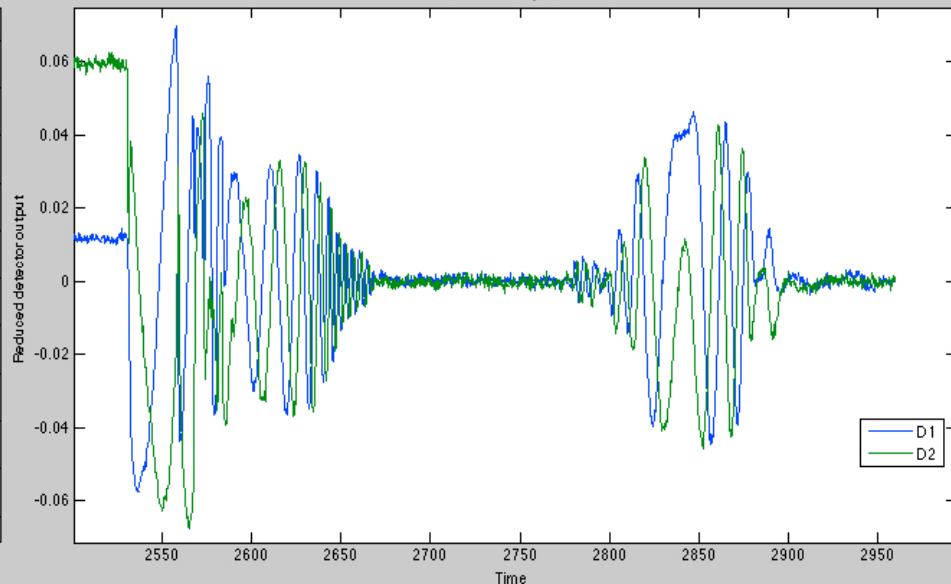
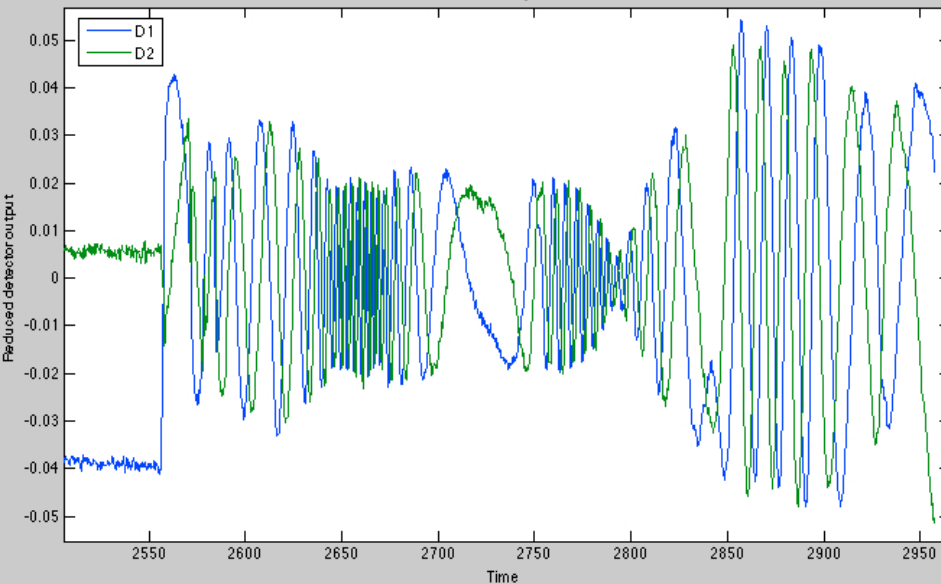
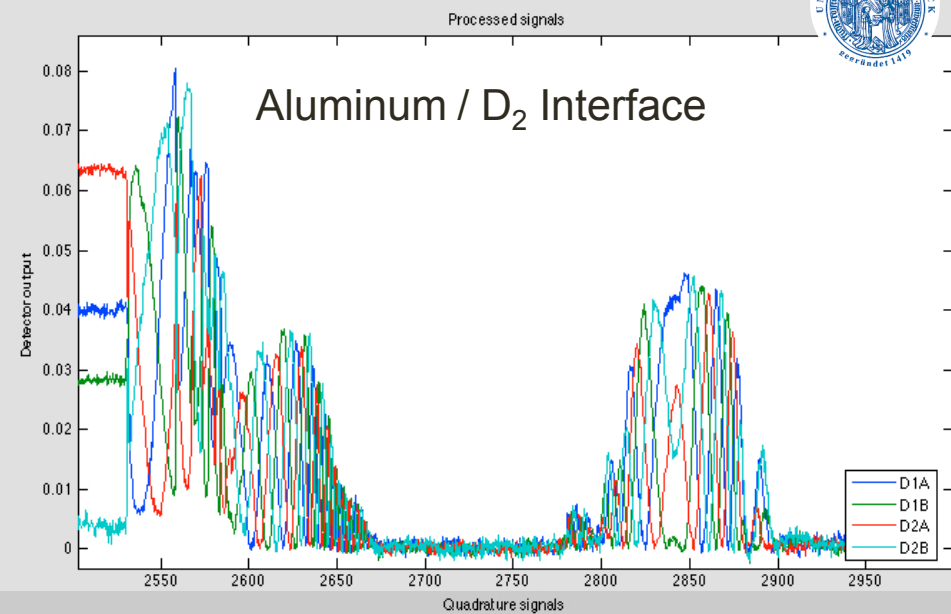
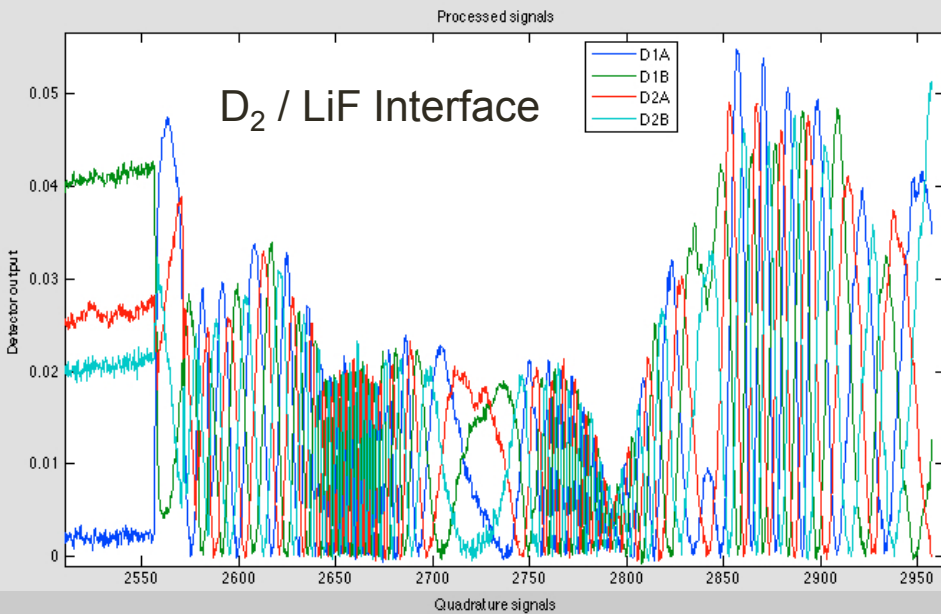
Two-step pulse shape provides shock-ramp profile



Stripline experimental profiles

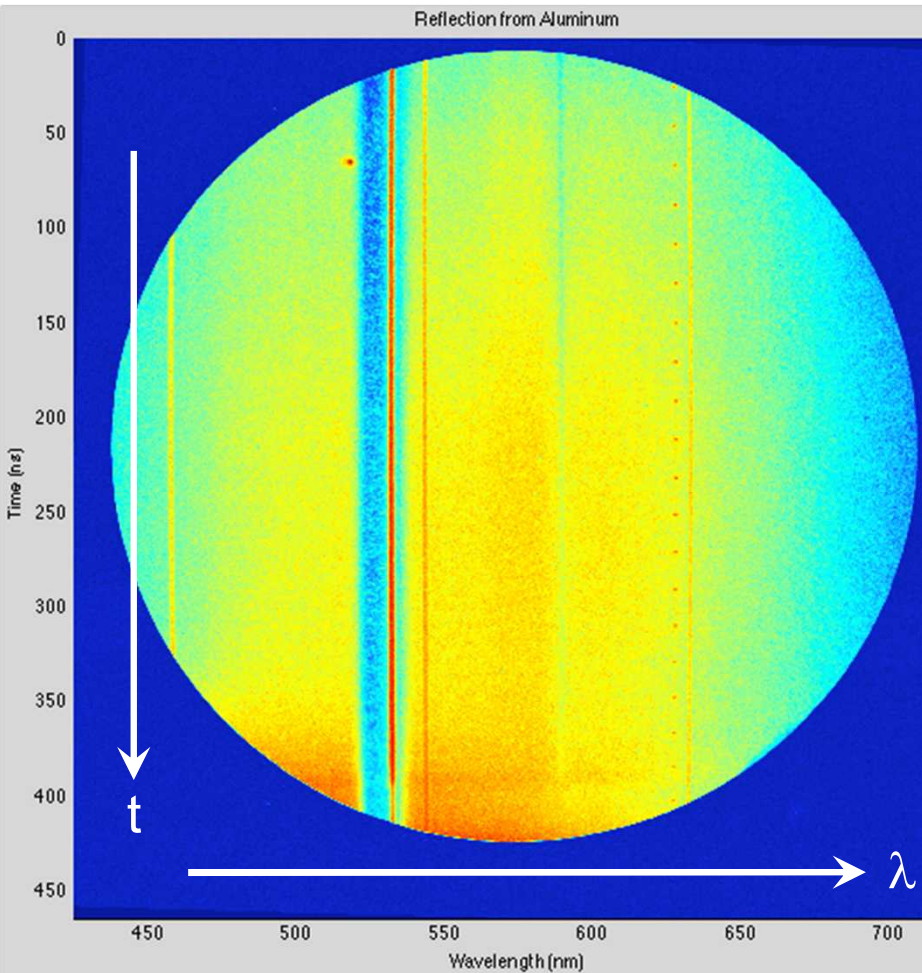


Processed VISAR signals



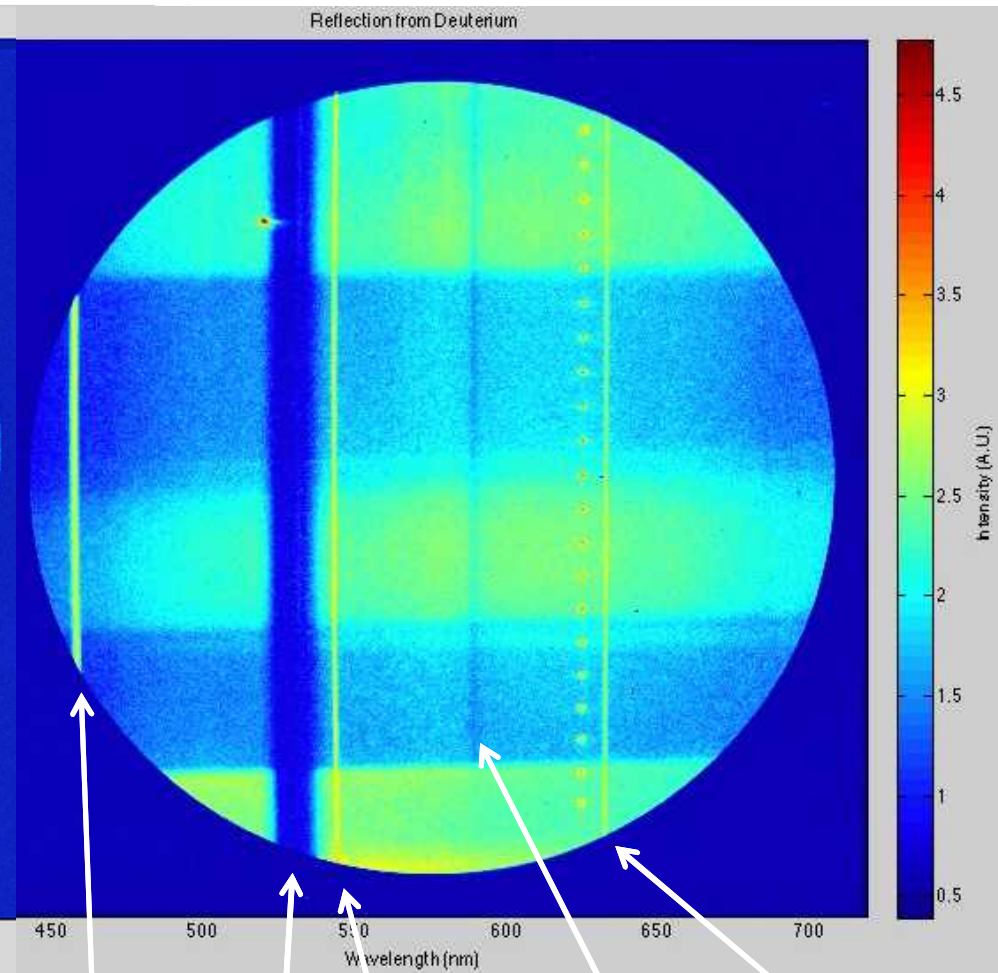
SVS system provides data to infer reflectivity

Reflection from aluminum coating



Wavelength range ~450-700 nm

Reflection from deuterium



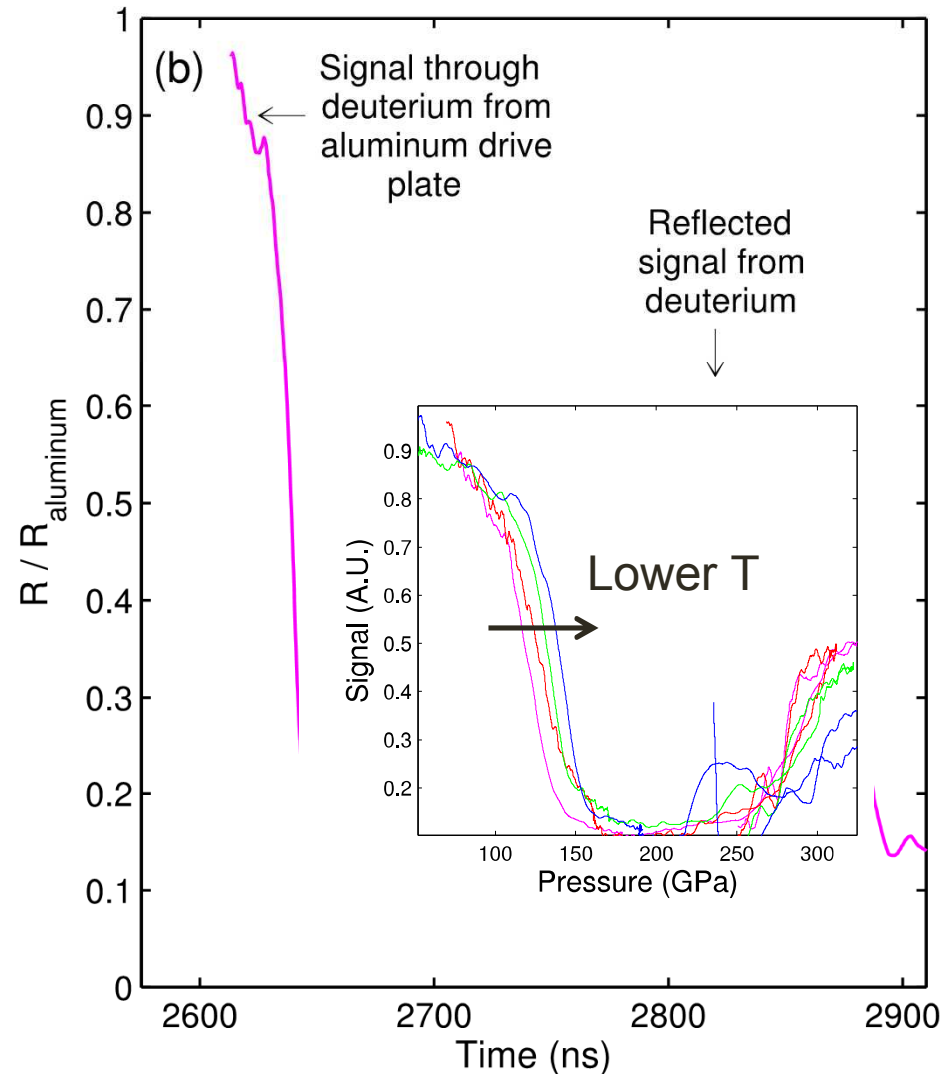
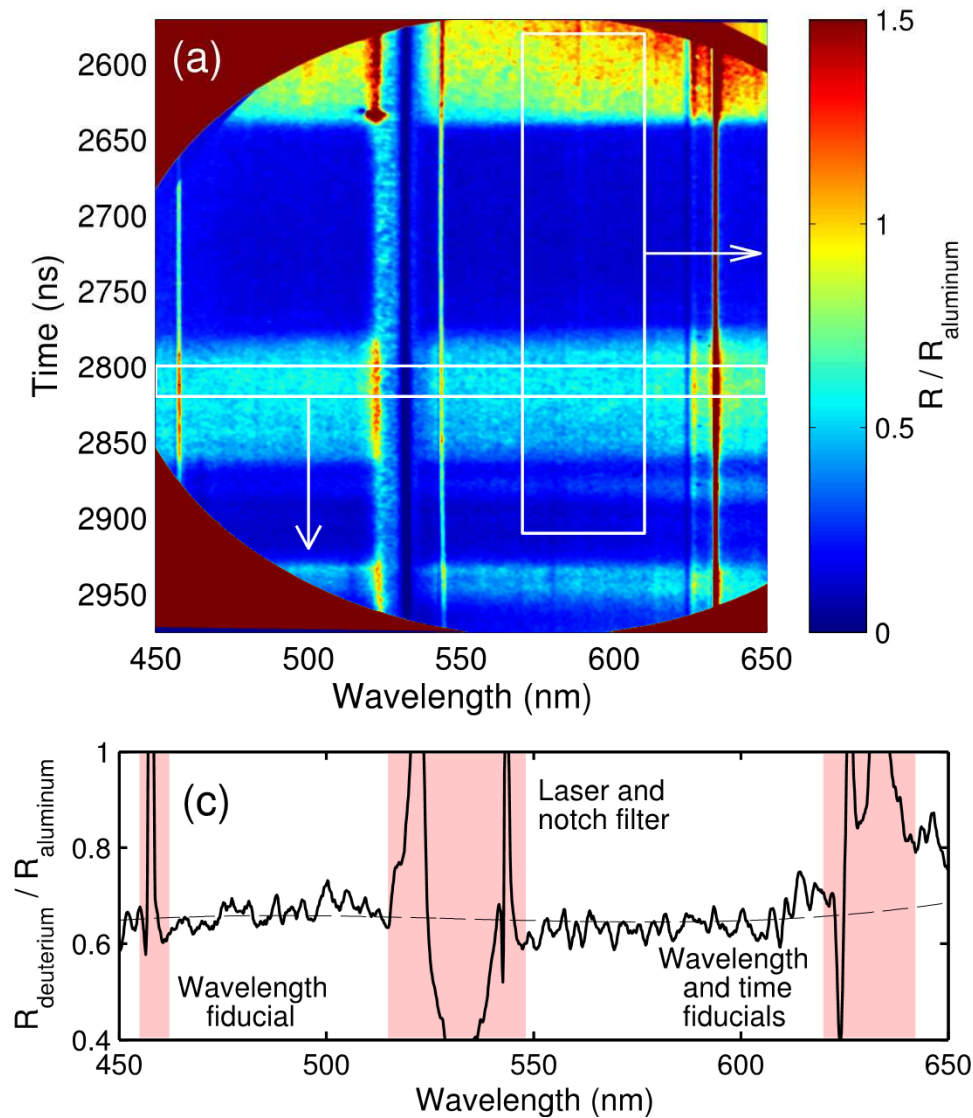
457.9 nm

532 / 543.5 nm

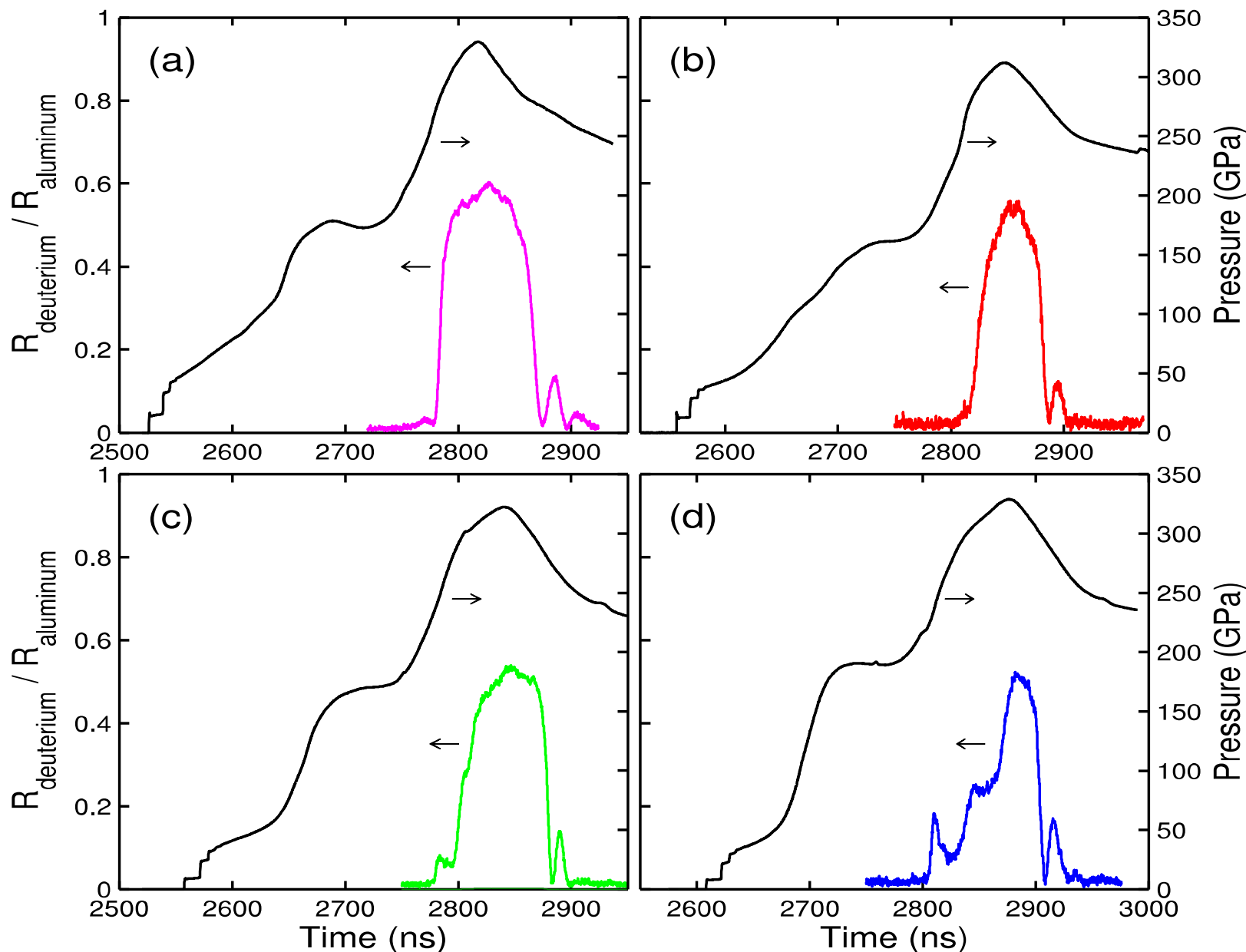
589.3 nm

633 nm

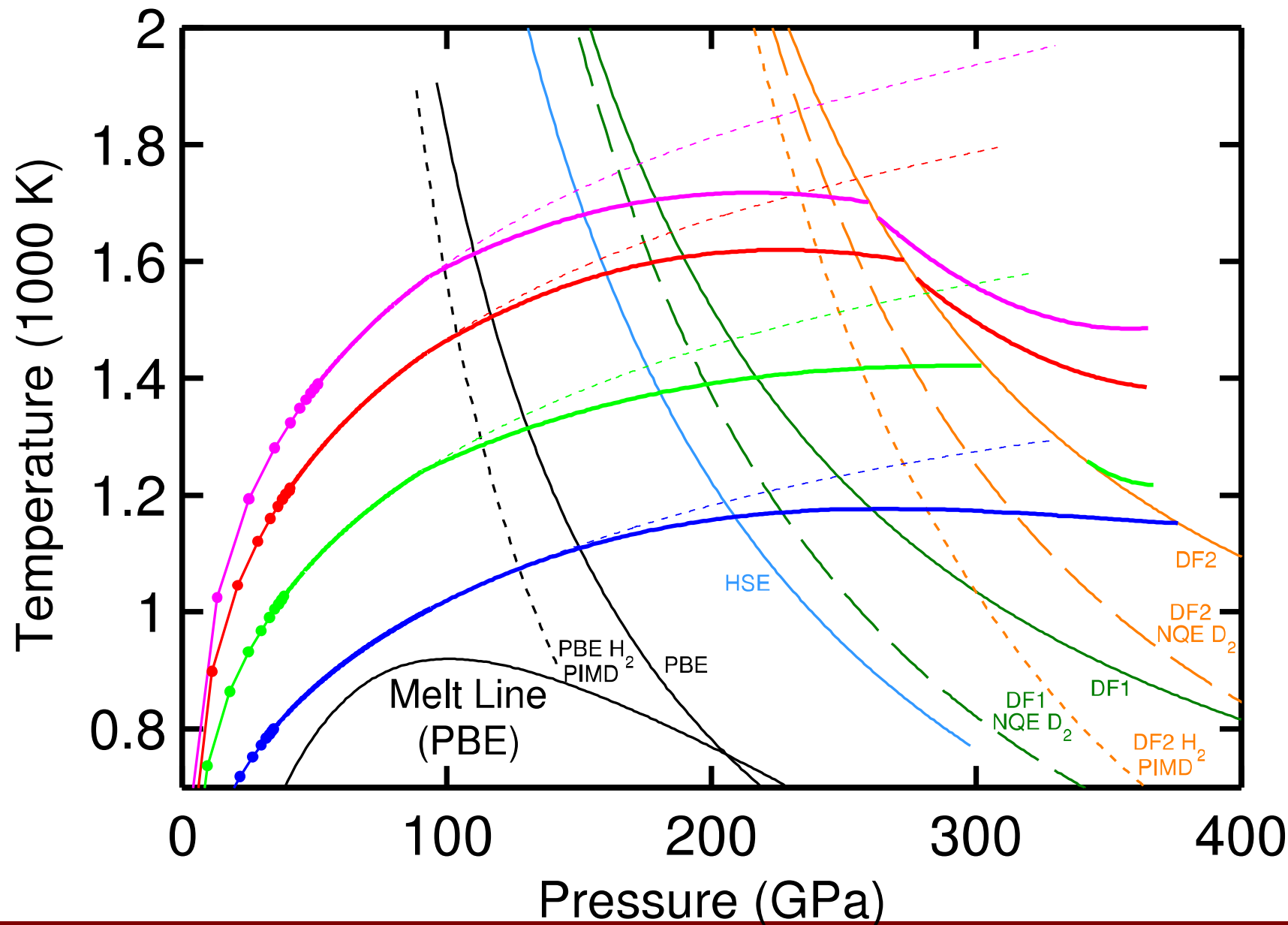
SVS system provides data to infer reflectivity



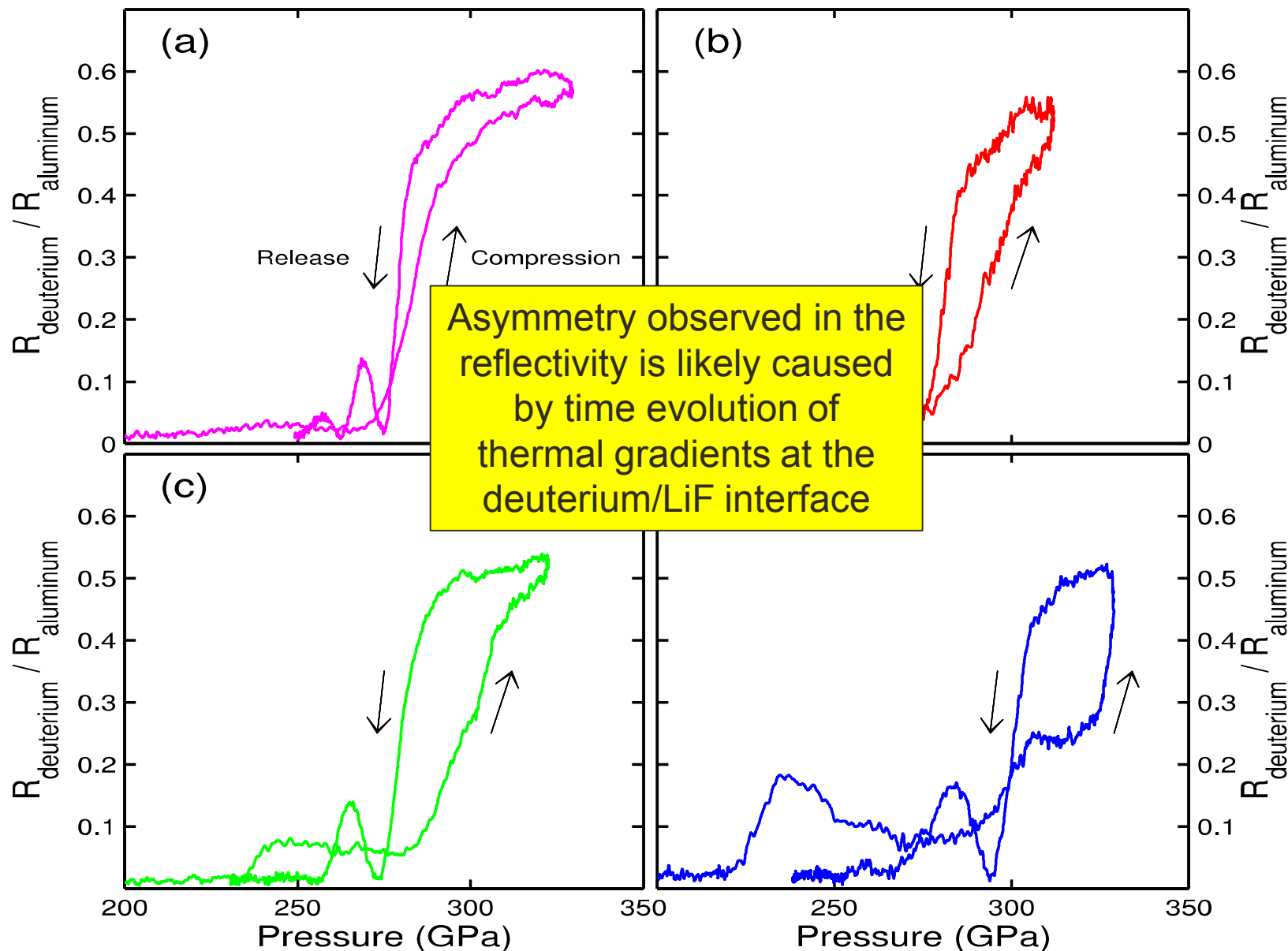
Reflectivity and pressure vs. time from VISAR



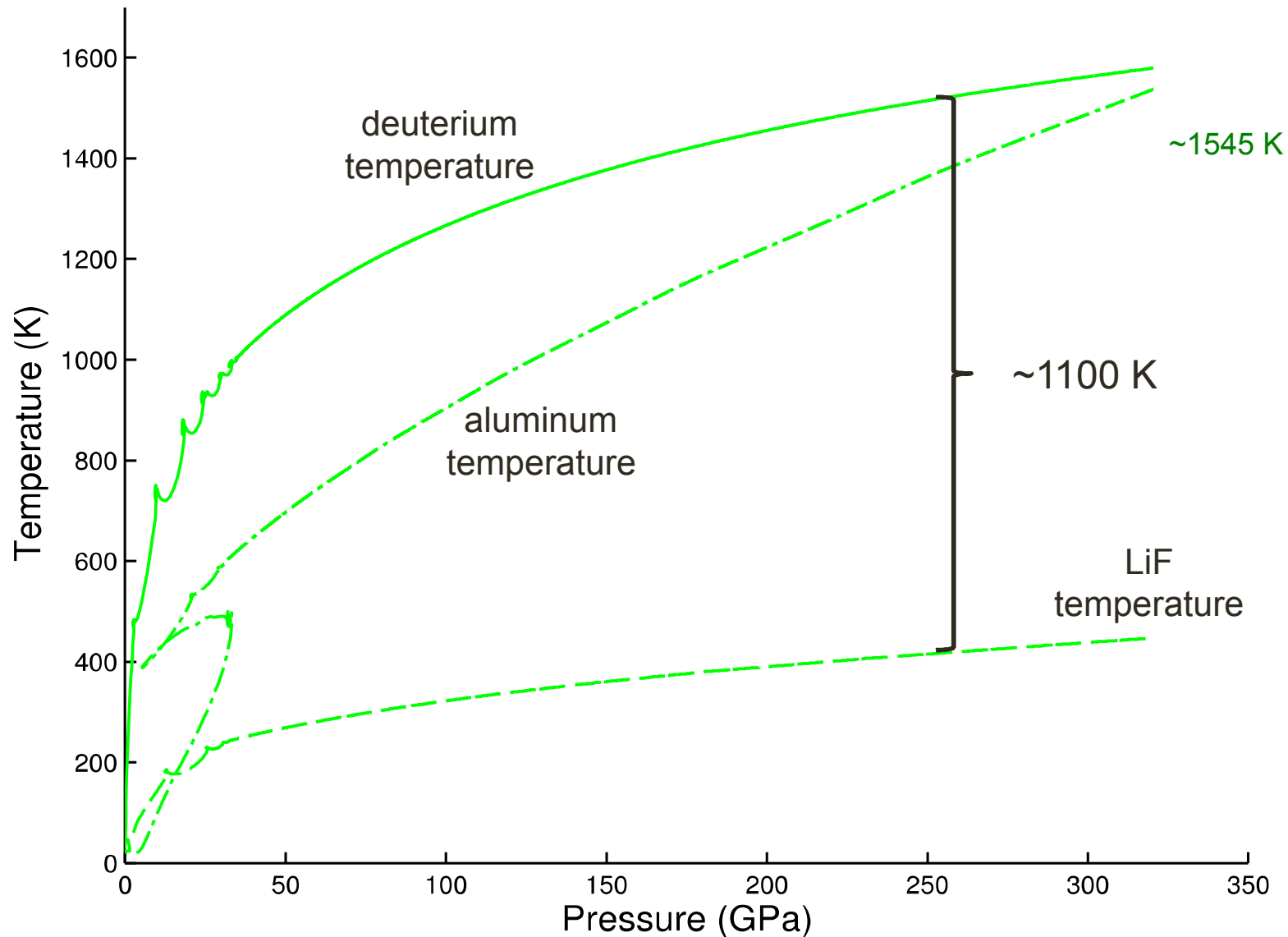
Experimental PT Paths



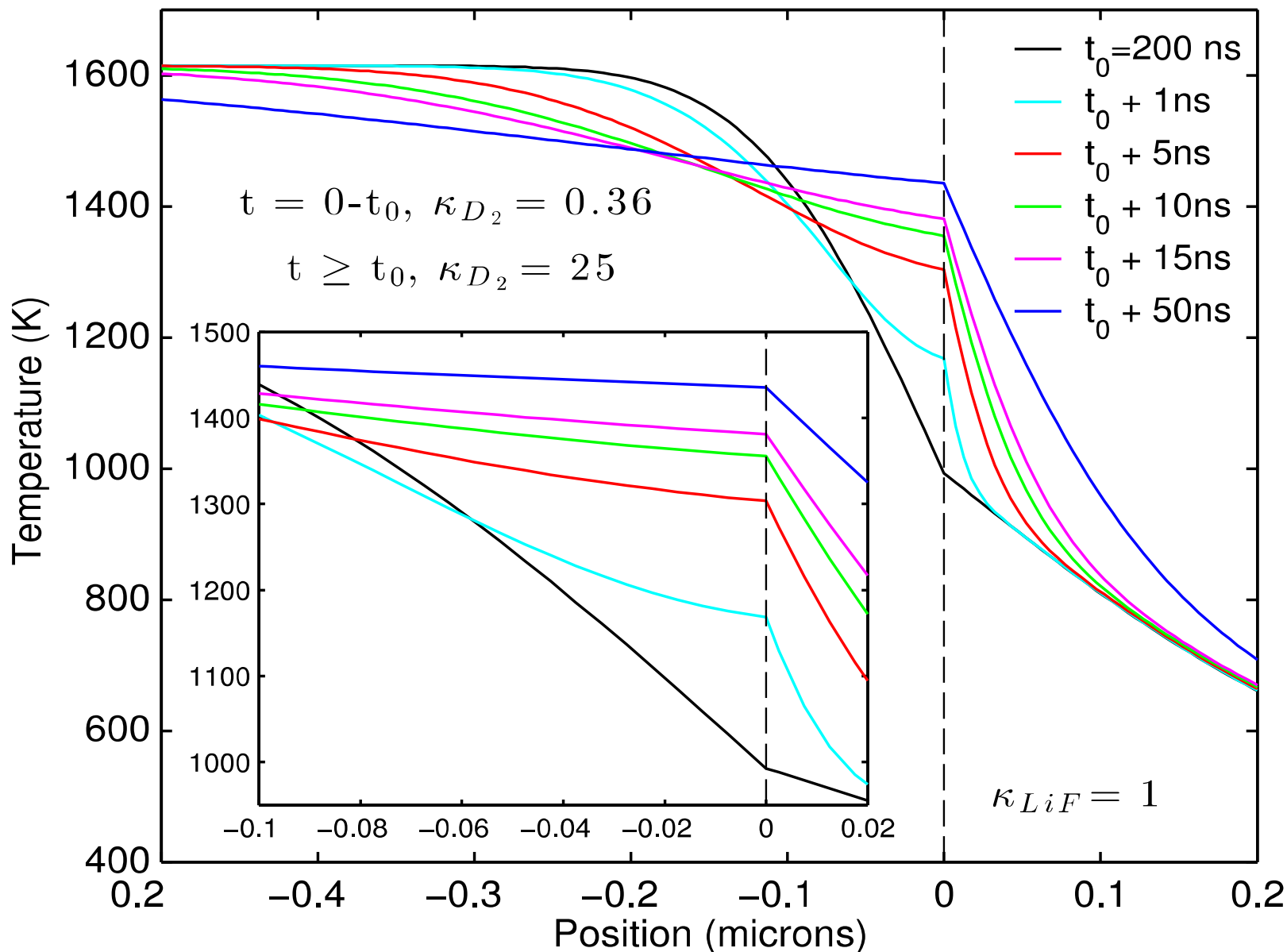
Reflectivity signals mapped to pressure



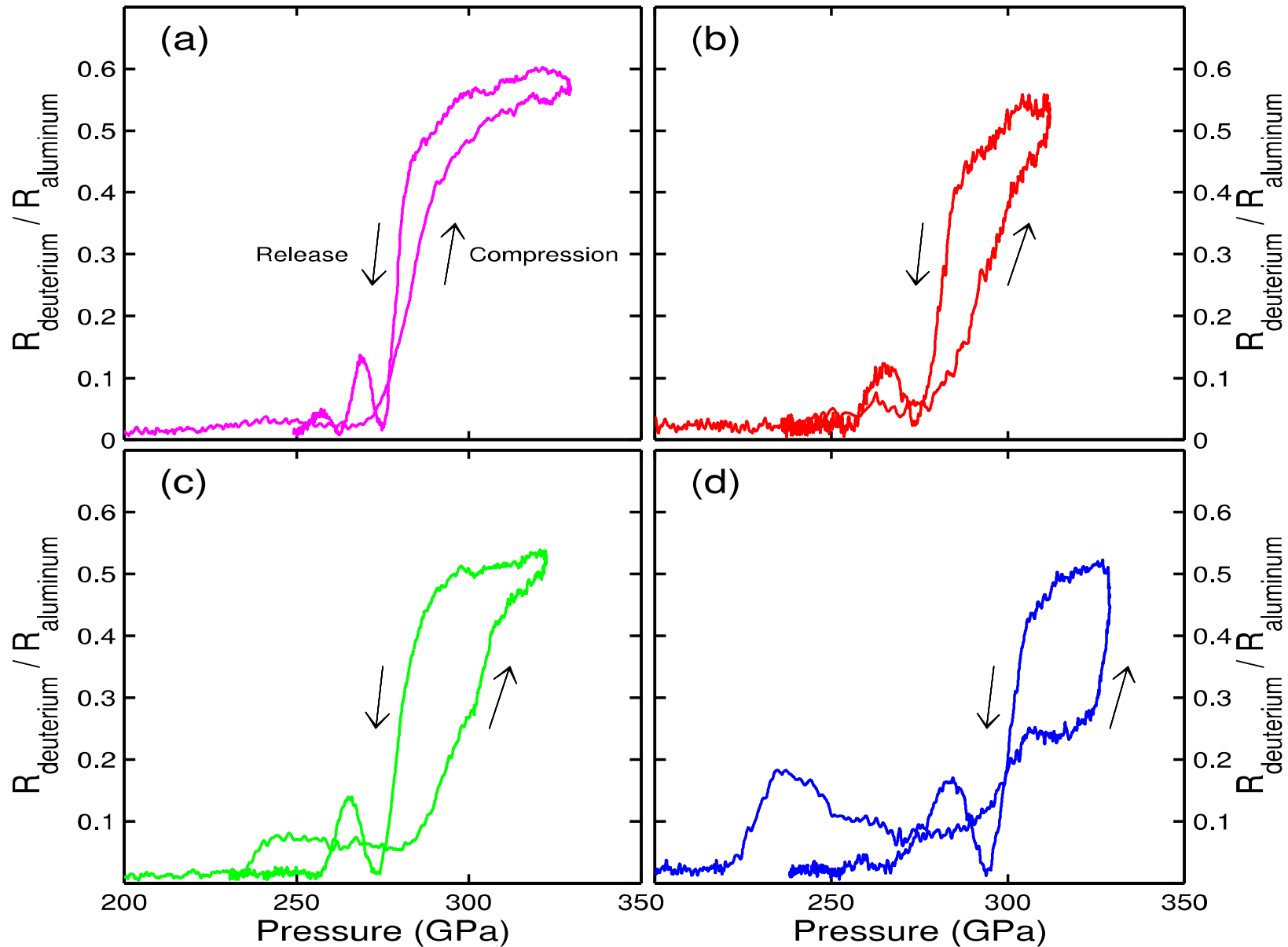
There is a significant temperature difference at the deuterium/LiF interface



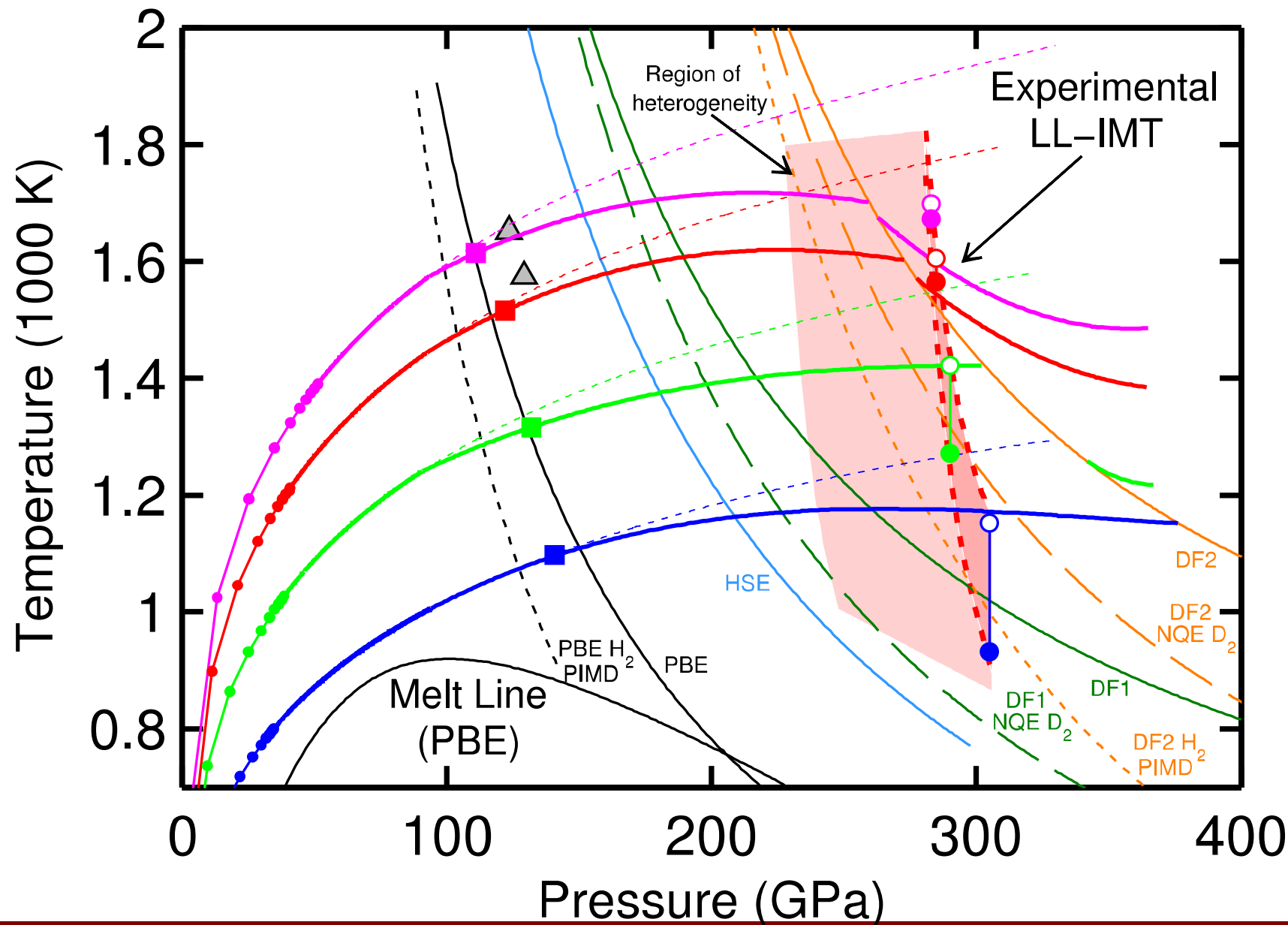
Thermal conduction simulations



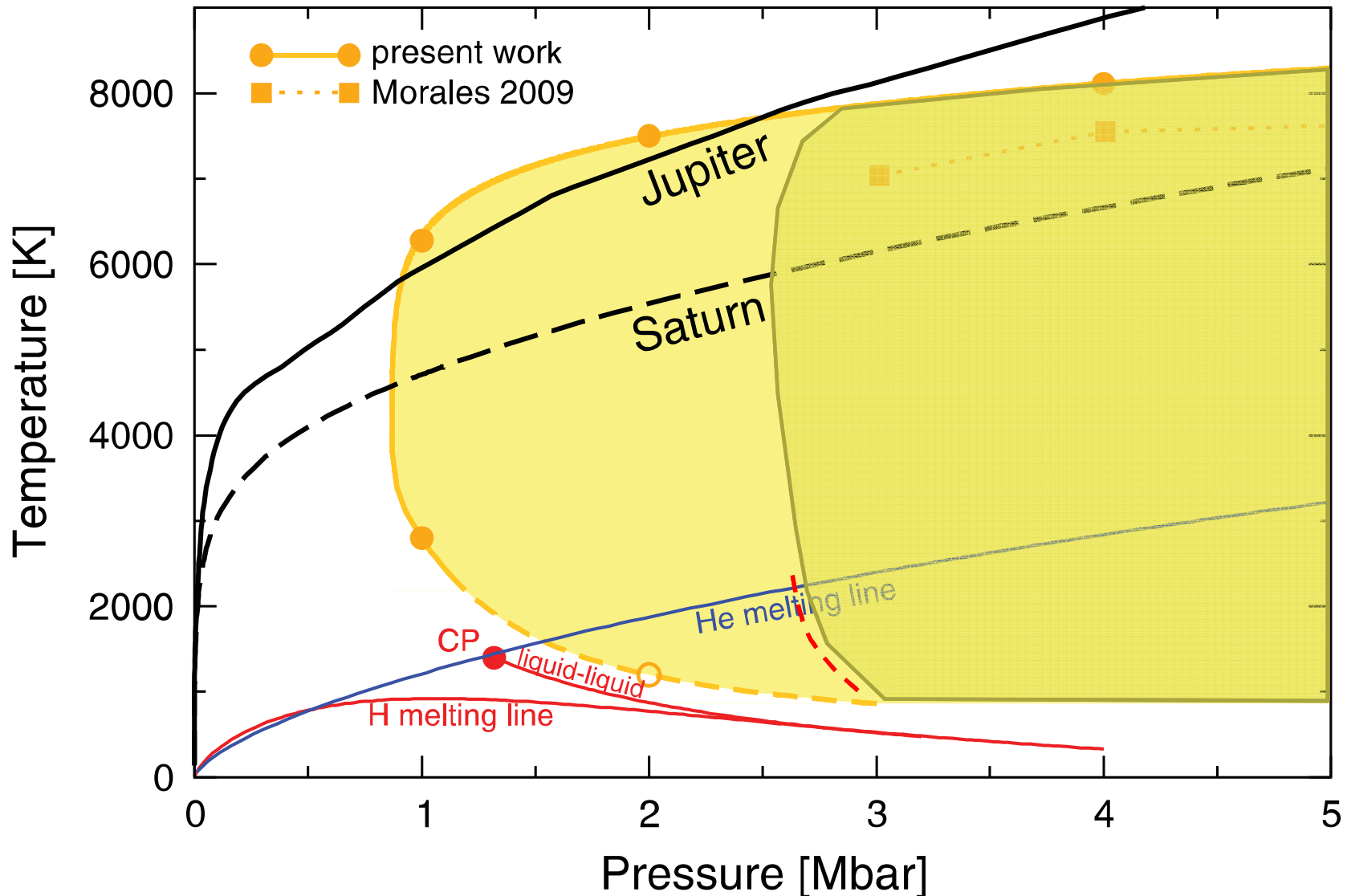
Reflectivity signals mapped to pressure



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 of 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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