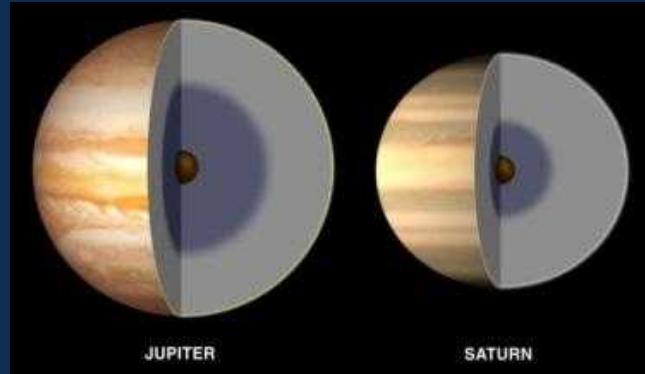
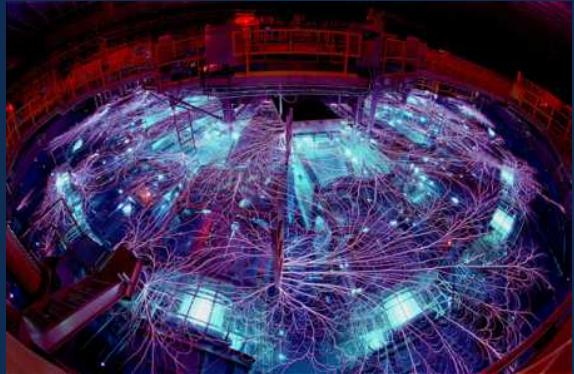


*Exceptional service in the national interest*



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

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Albuquerque, NM**



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

## Experiment Design/Analysis

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Kyle Cochrane

Devon Dalton

Dustin Romero

## Diagnostics

Charlie Meyer

Jeff Gluth

Devon Dalton

Anthony Romero

Dave Bliss

Alan Carlson

# Acknowledgements

## QMD Calculations

Mike Desjarlais

Andreas Becker

Winfried Lorenzen

Ronald Redmer

## Planetary Modeling

Nadine Nettelmann

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## Pulse Shaping

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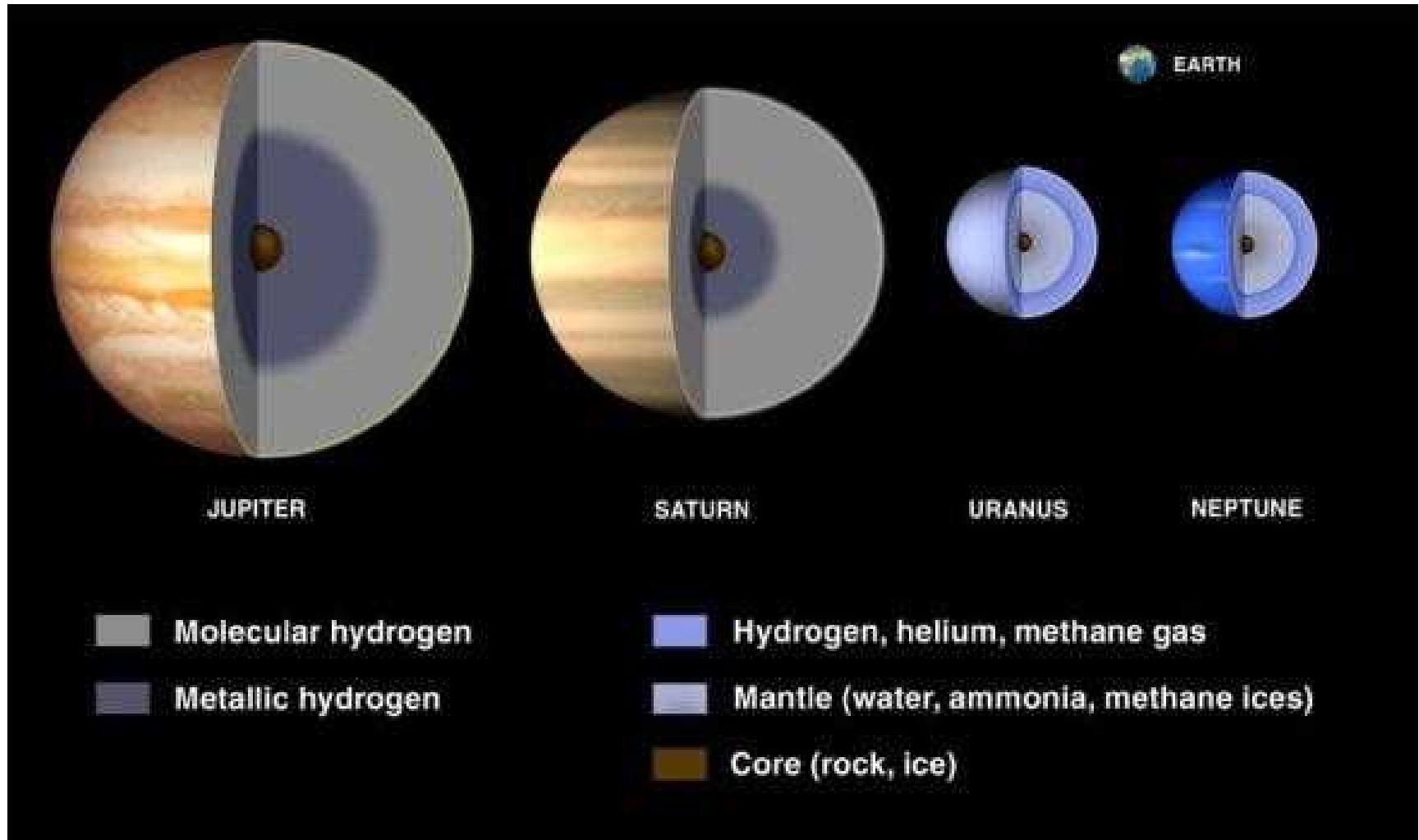
Dave Hinshelwood

Entire Z crew

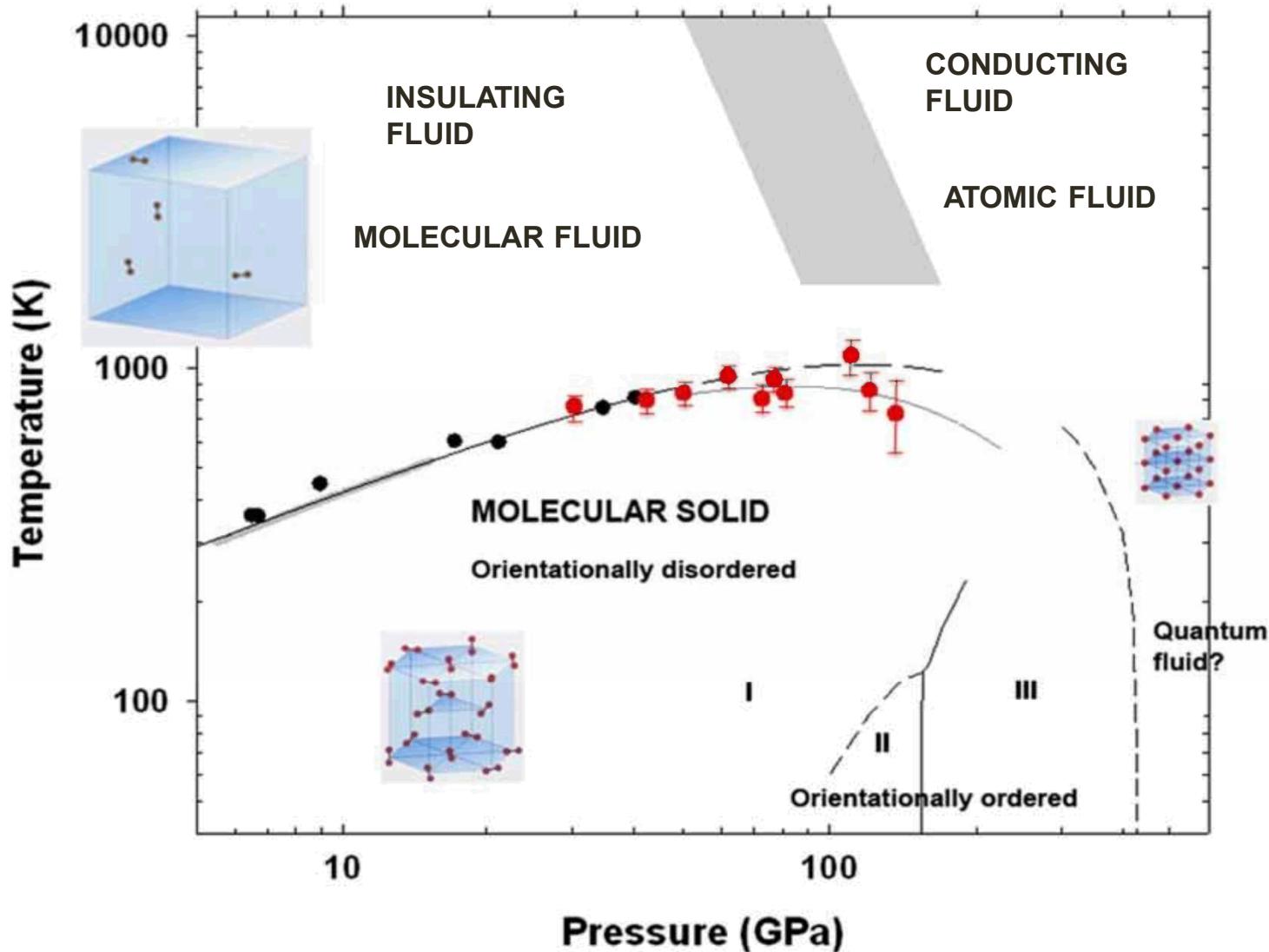
University of Rostock

# Giant planets in the Solar system

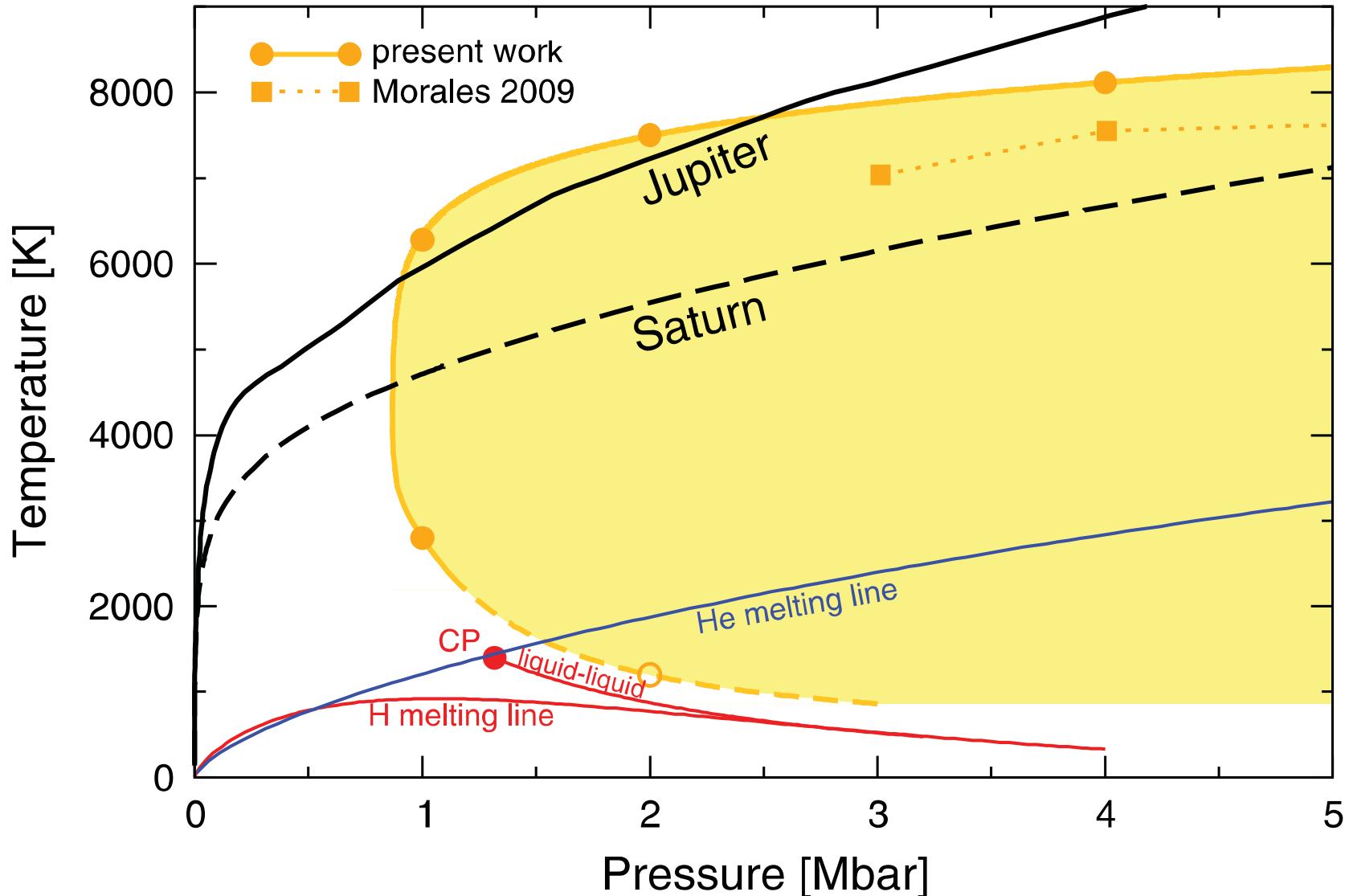
Interior composed of the lightest elements H & He, hydrides NH<sub>3</sub>, OH<sub>2</sub>, CH<sub>4</sub> (ices) and small amounts of heavier elements (cores)



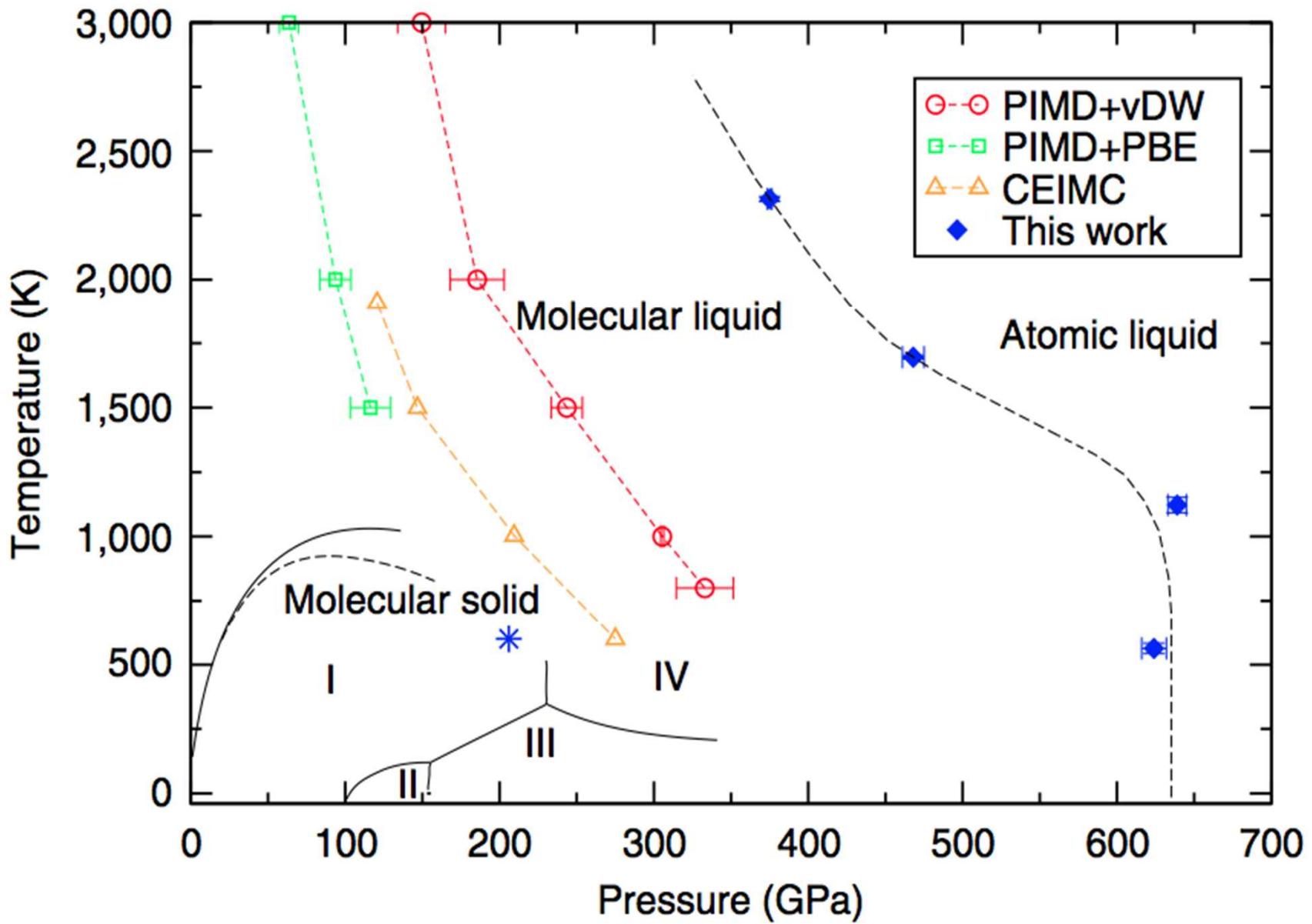
# Hydrogen at high pressures – the known phase diagram so far



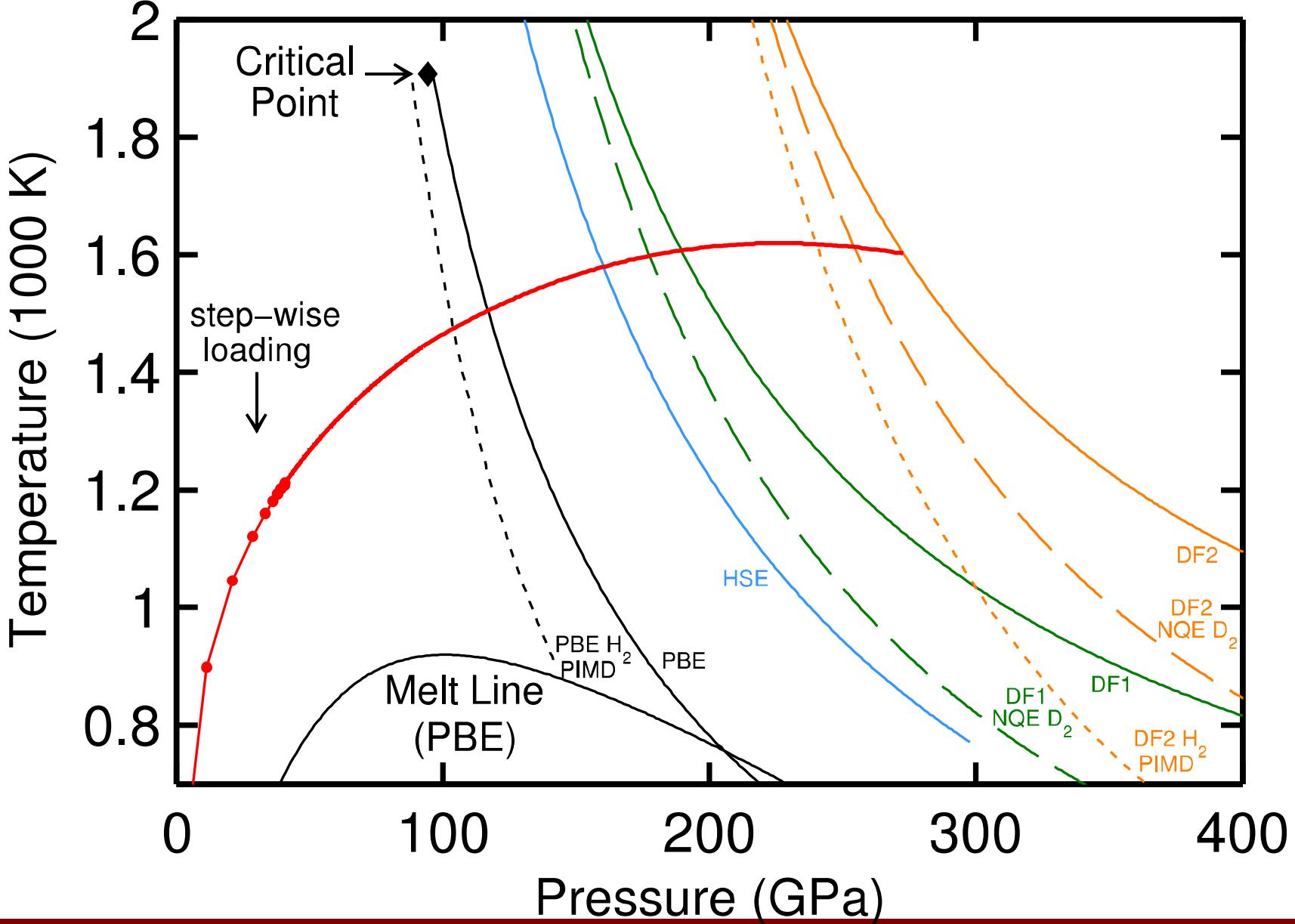
# H-He de-mixing appears to be precipitated at low T and P by metallization in hydrogen



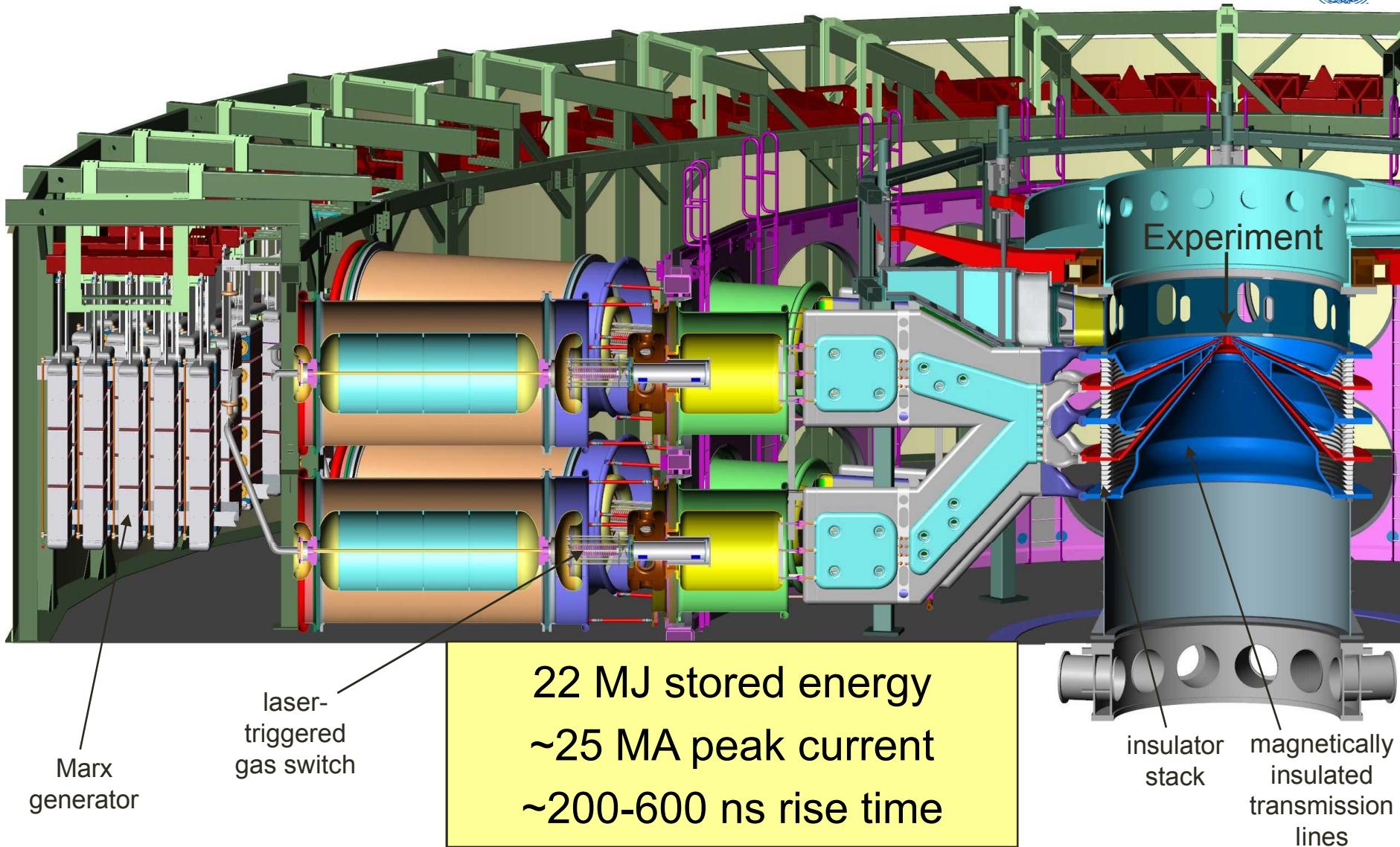
# Recent predictions of the LL-IMT in hydrogen



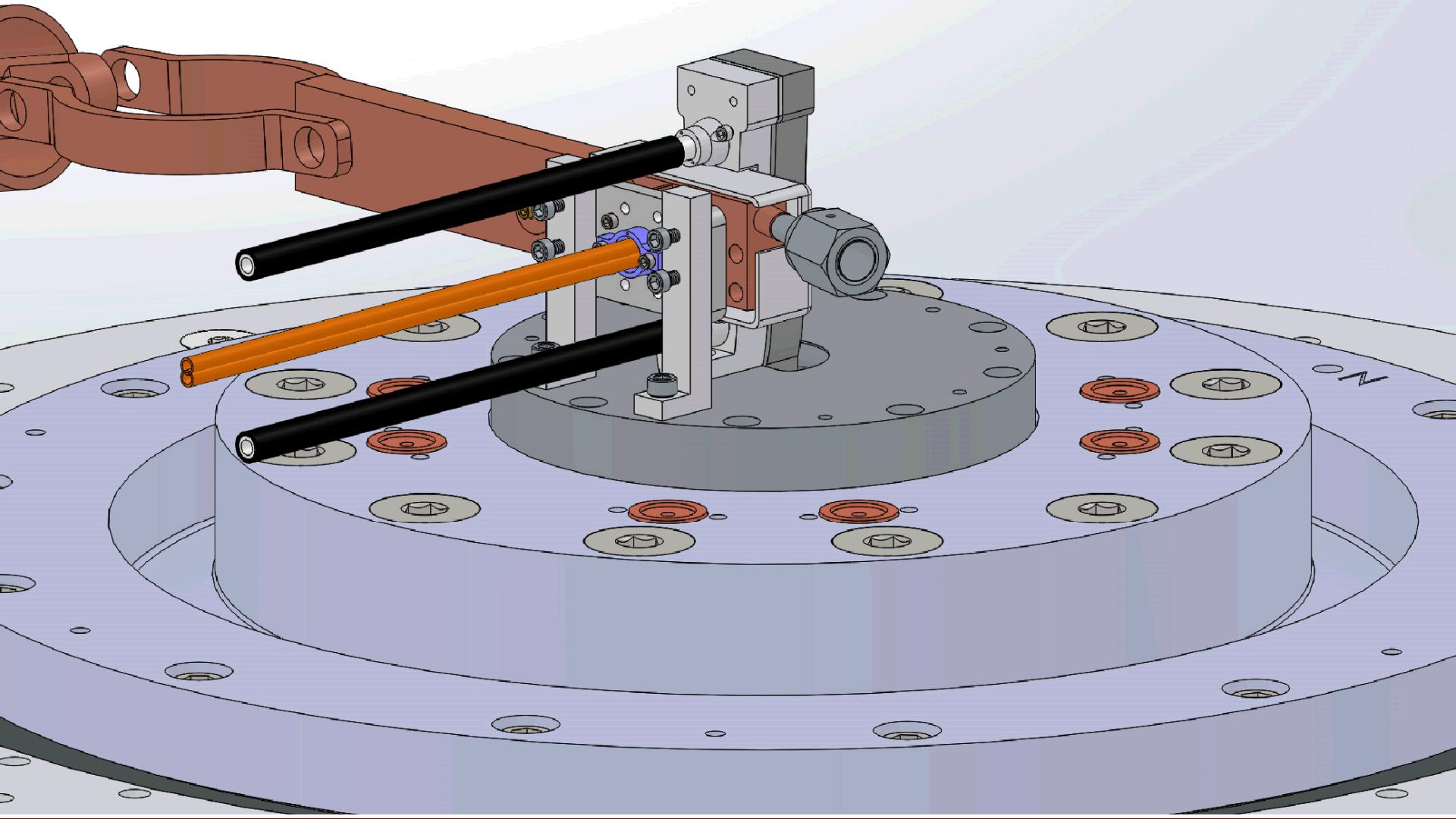
# Proposed Experiment: Shock - Ramp



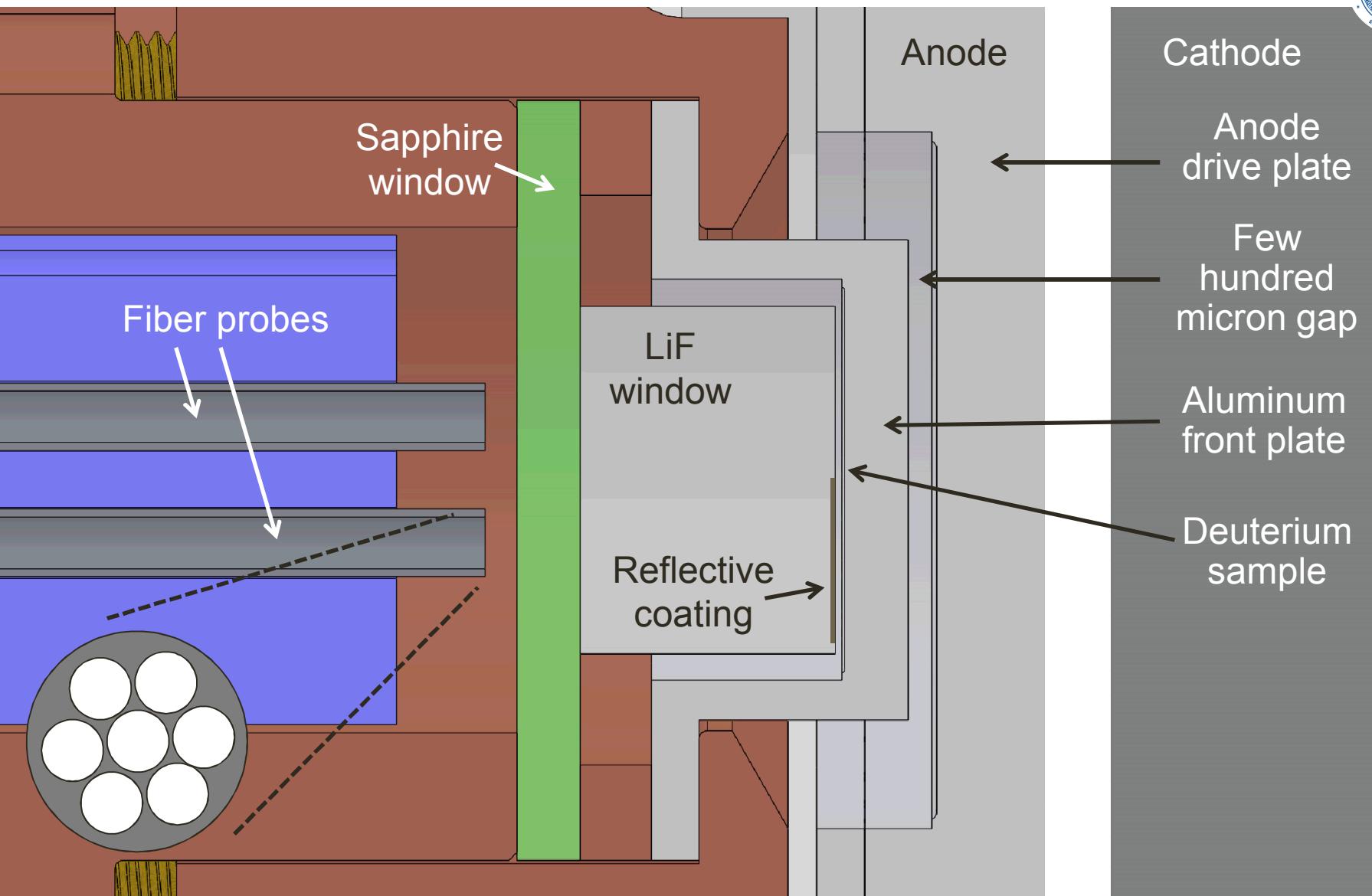
# Sandia Z Machine



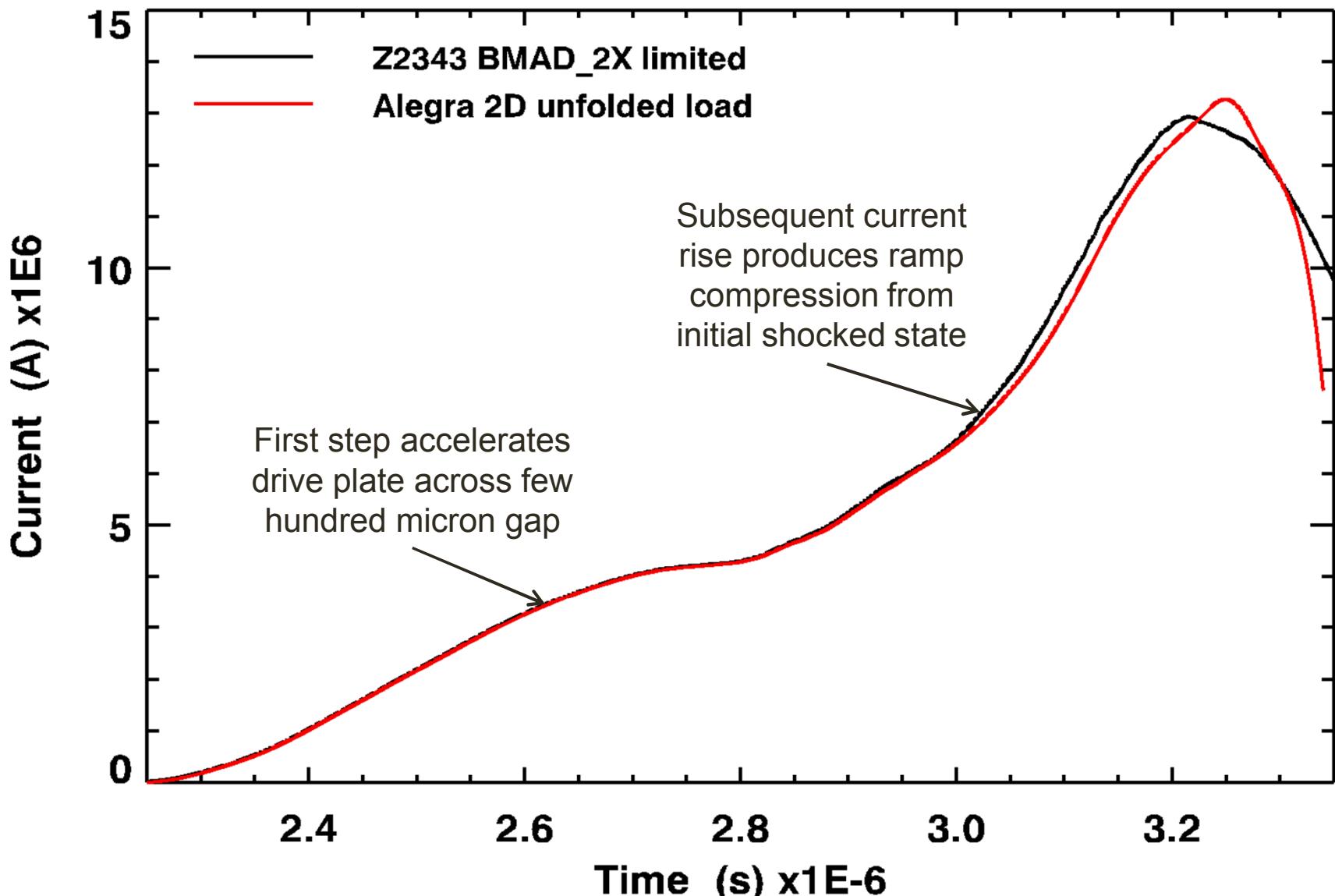
# Stripline experimental configuration



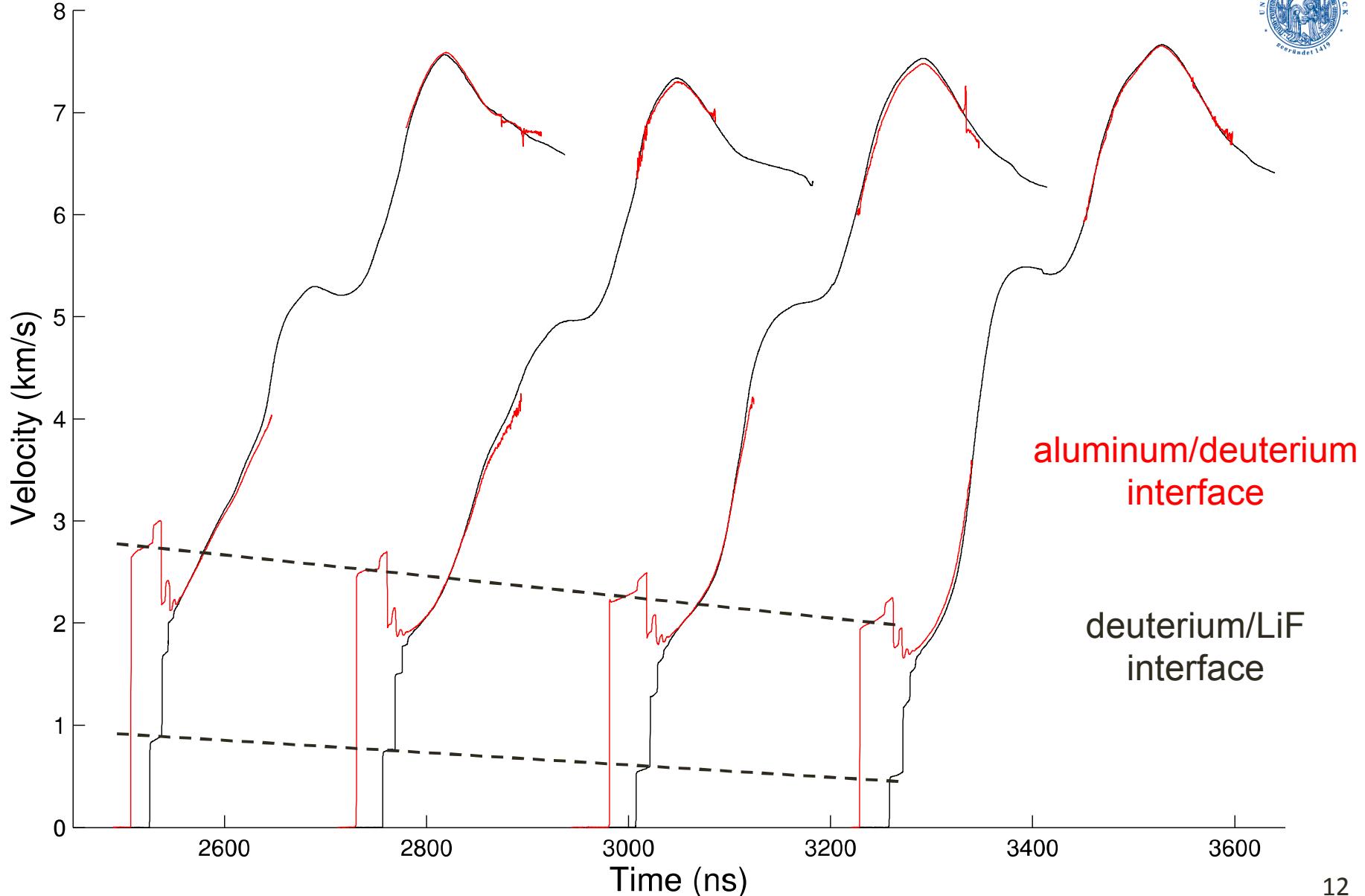
# Experimental configuration



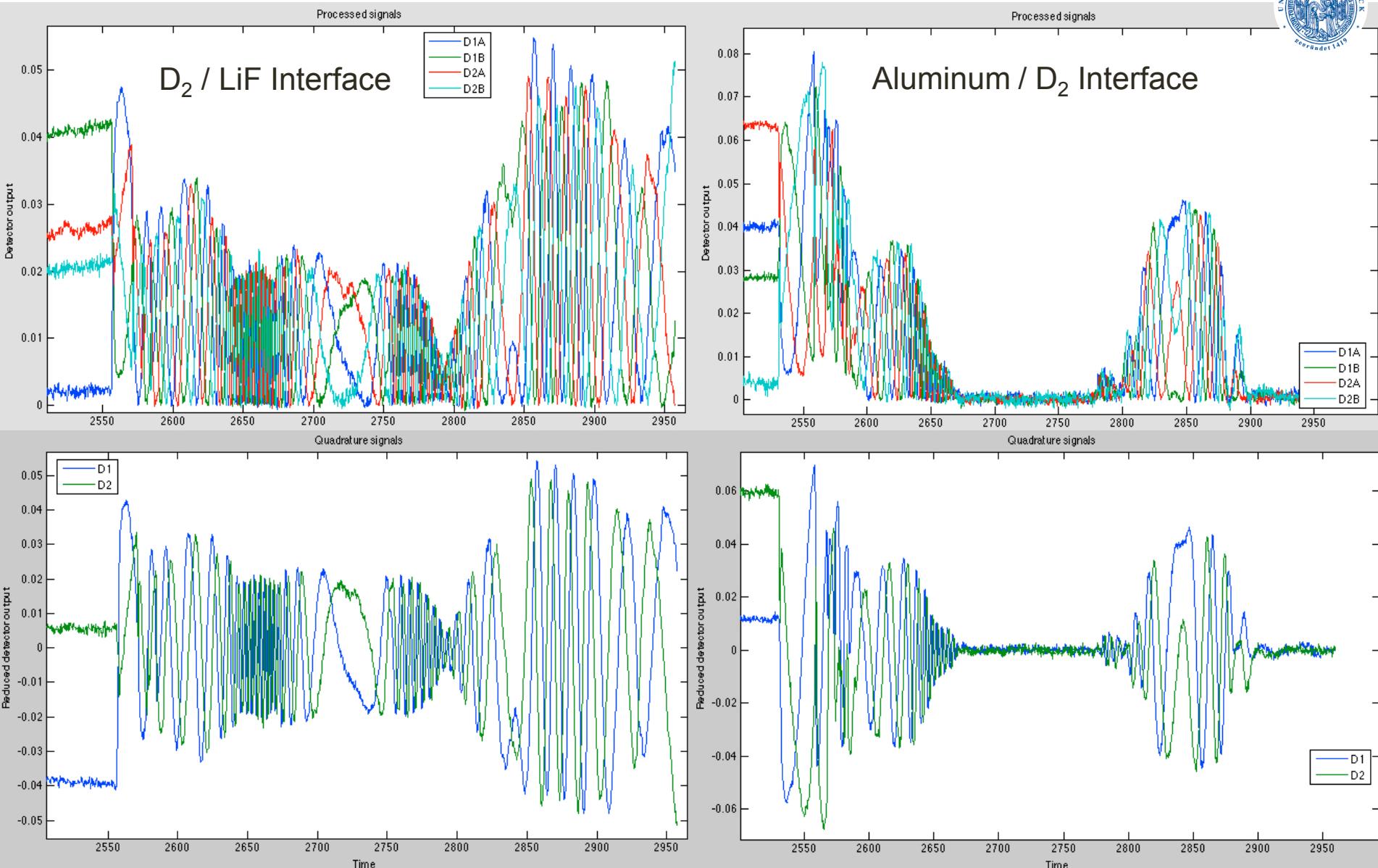
# Two-step pulse shape provides shock-ramp profile



# Stripline experimental profiles

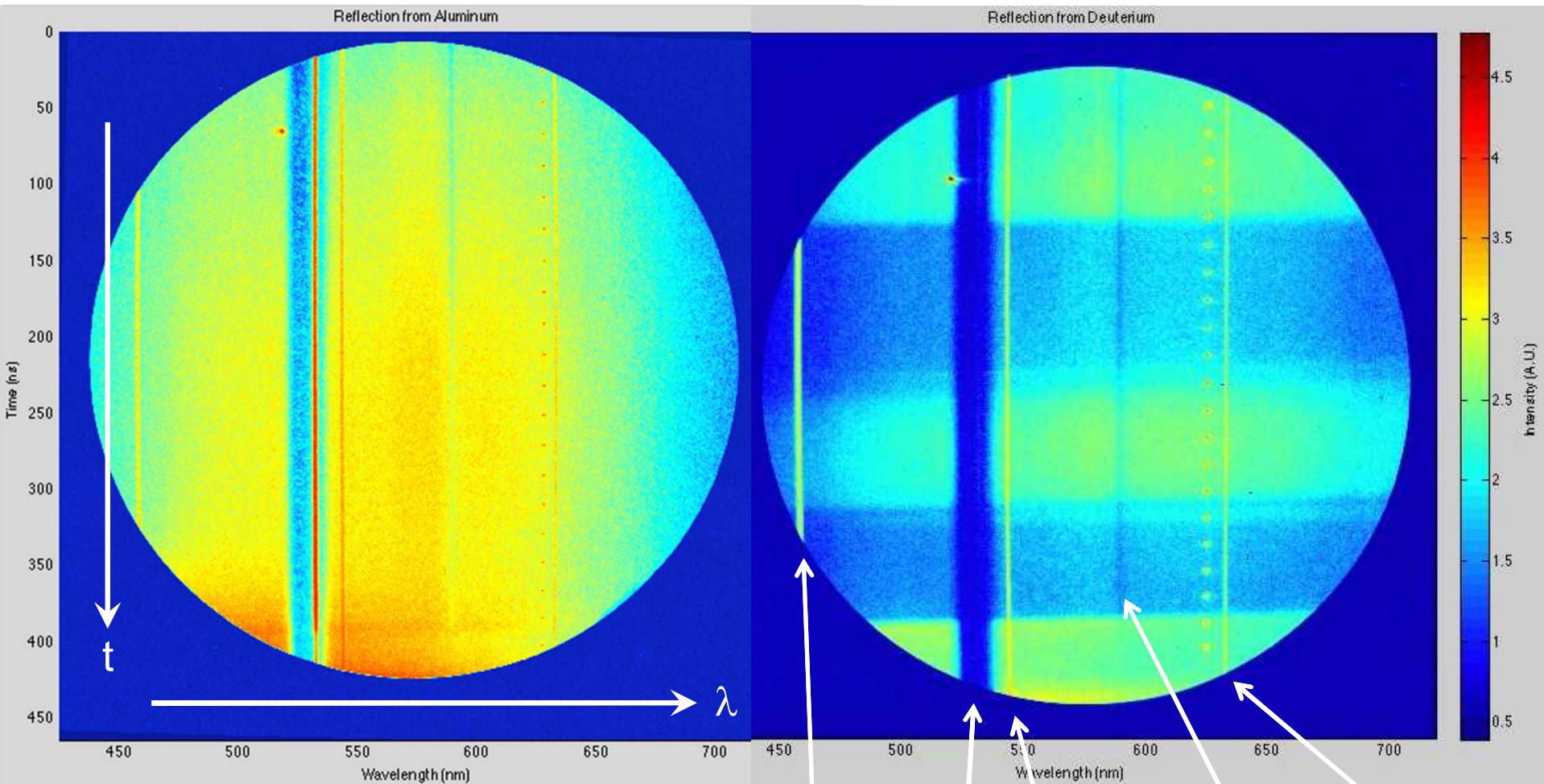


# Processed VISAR signals



# SVS system provides data to infer reflectivity

Reflection from aluminum coating



Wavelength range ~450-700 nm

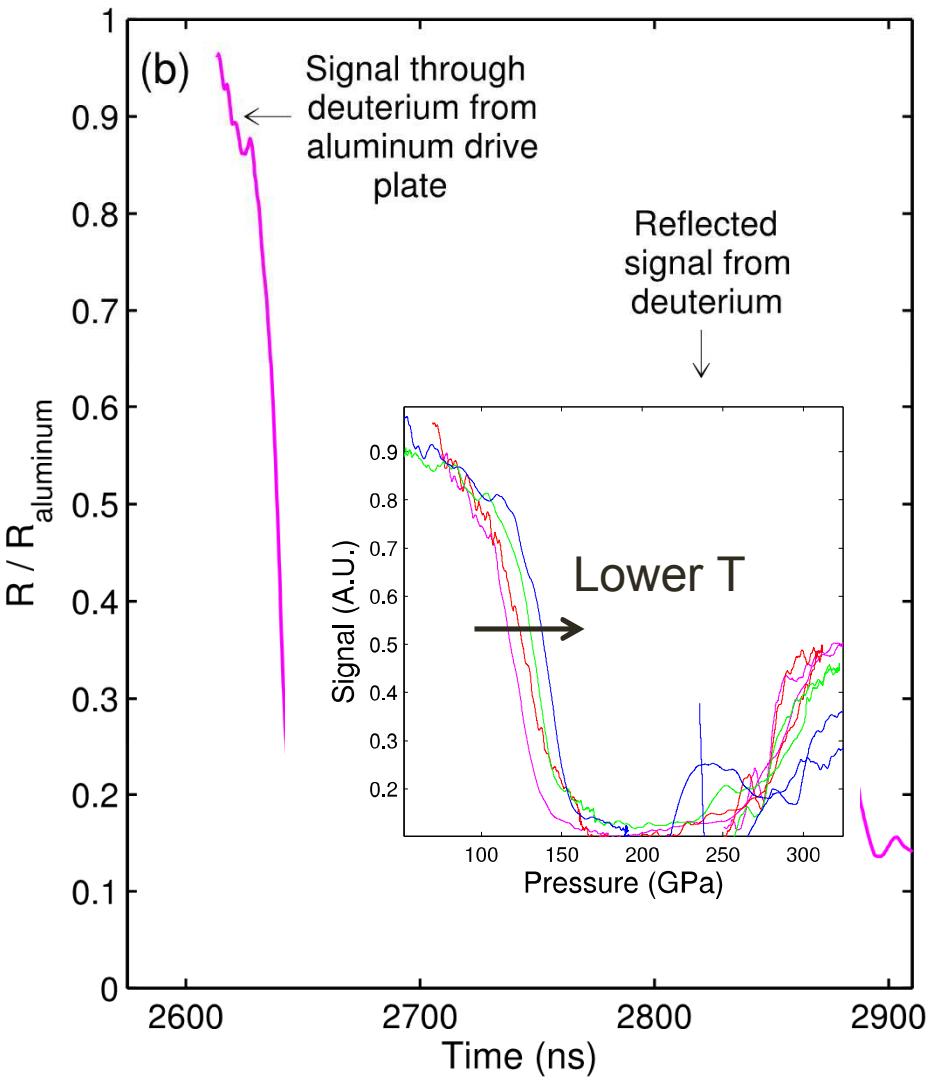
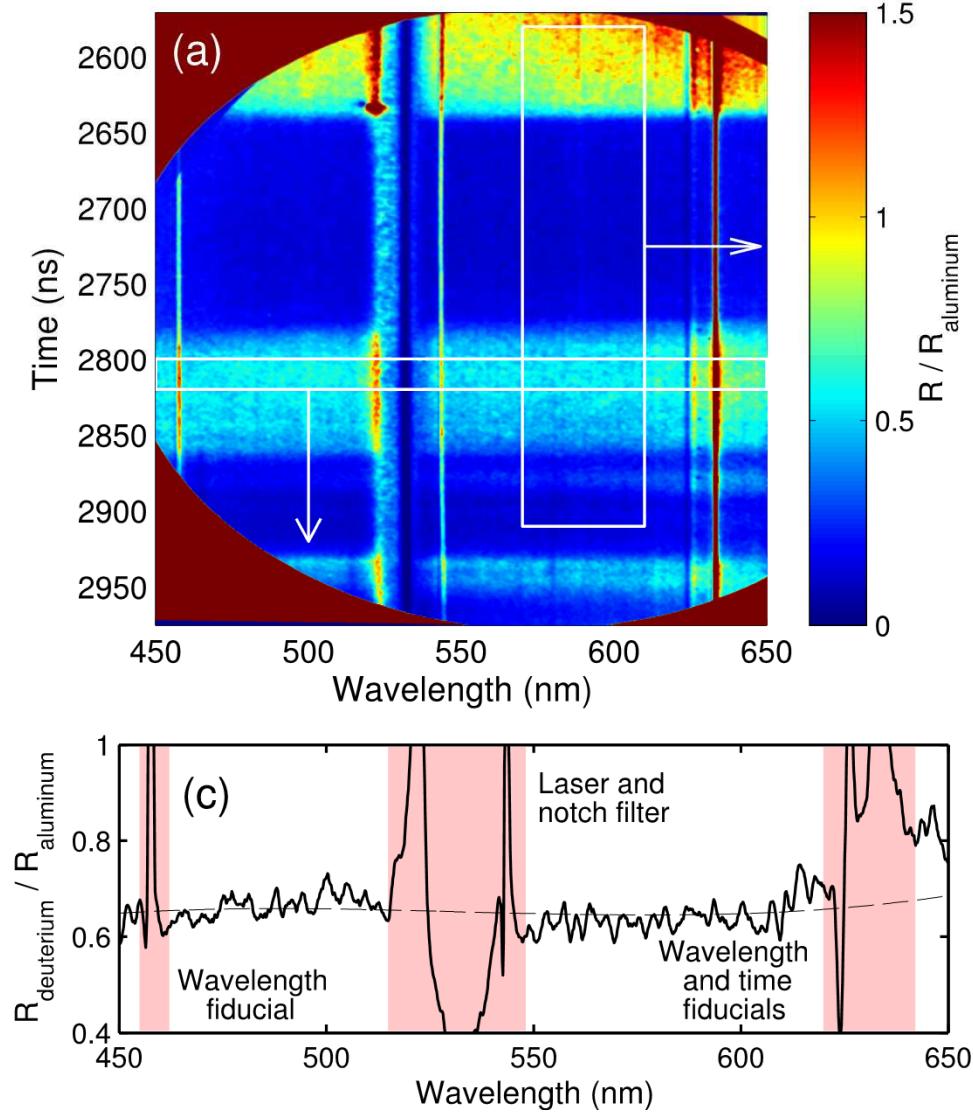
457.9 nm

532 / 543.5 nm

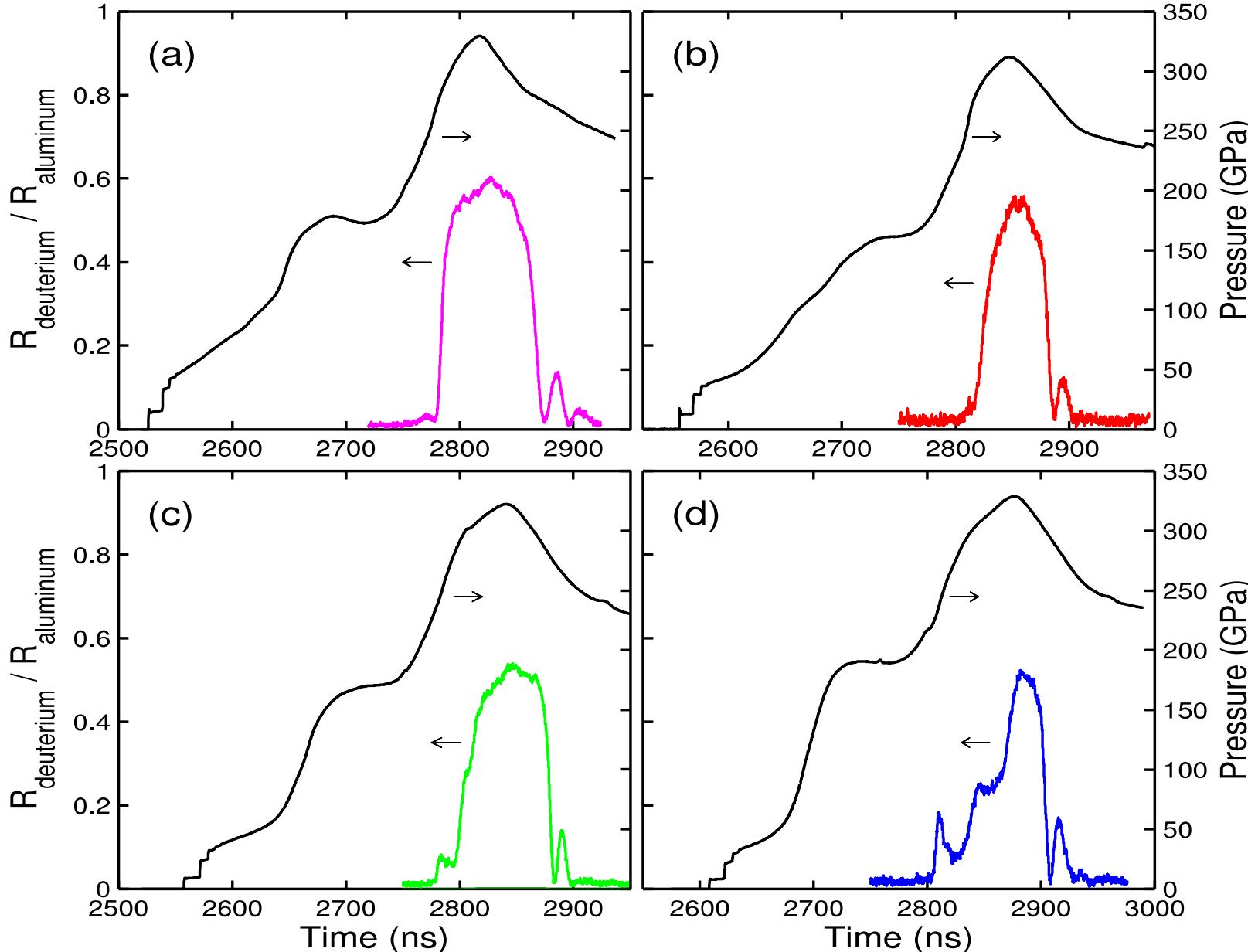
589.3 nm

633 nm

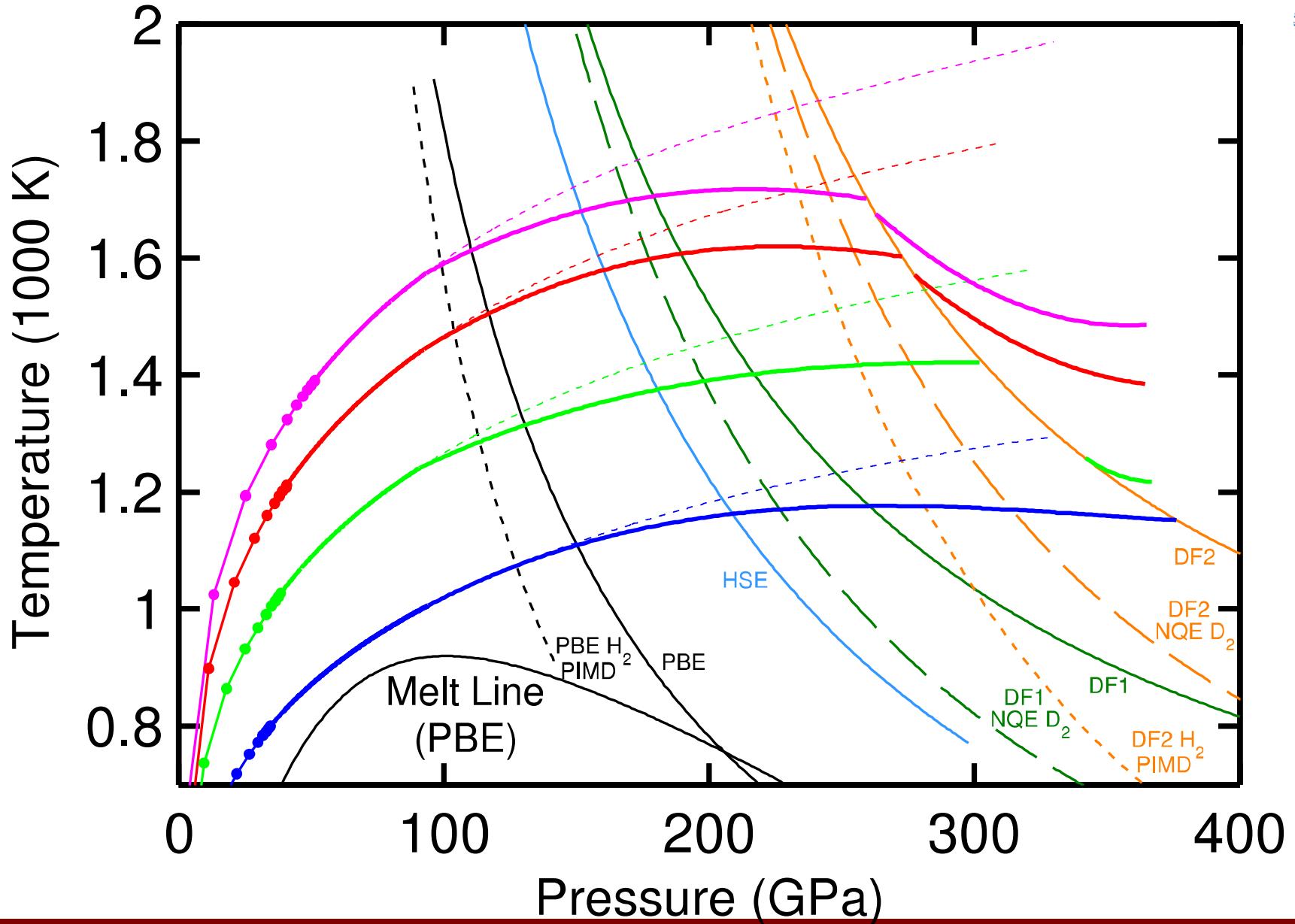
# SVS system provides data to infer reflectivity



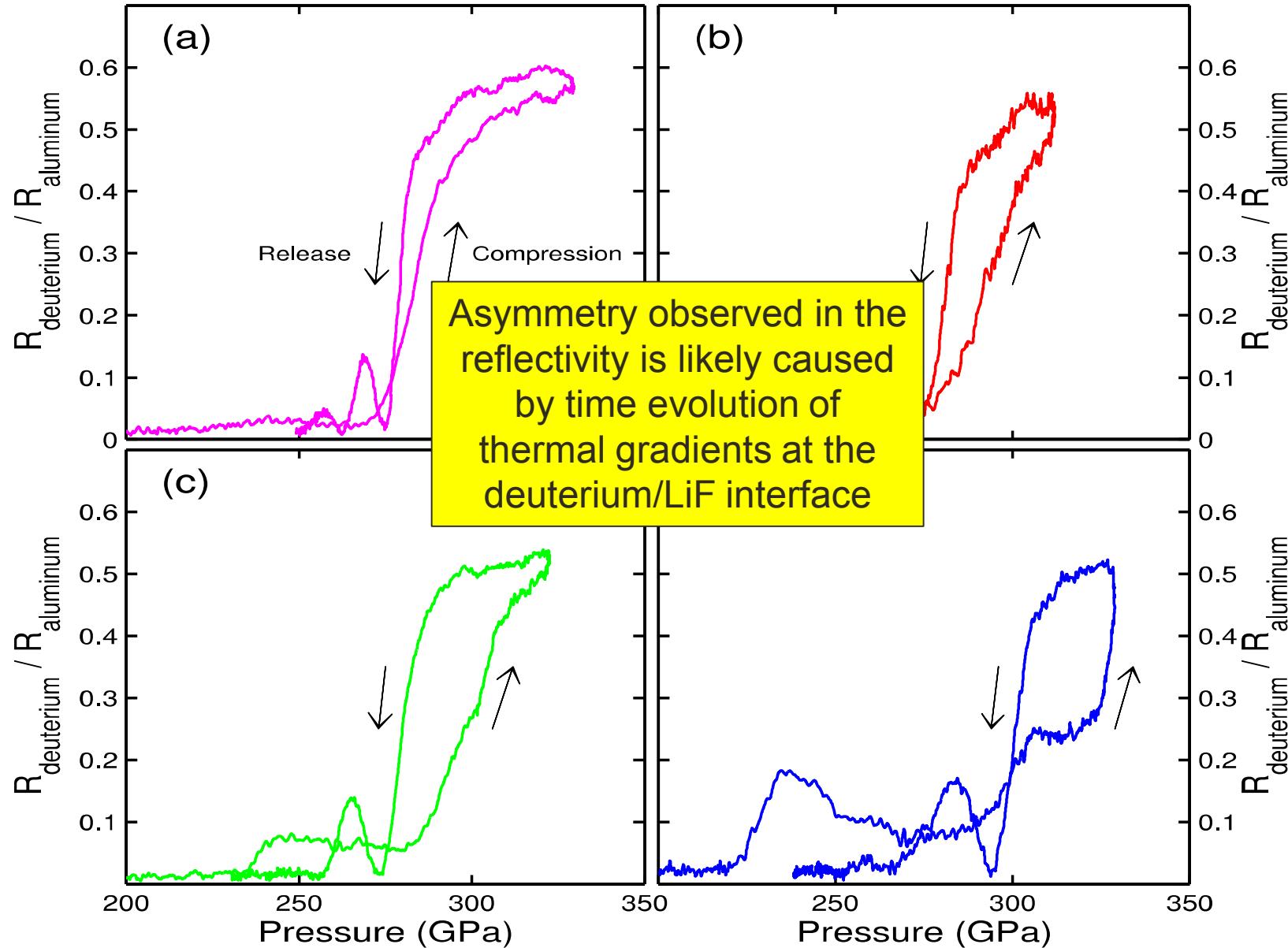
# Reflectivity and pressure vs. time from VISAR



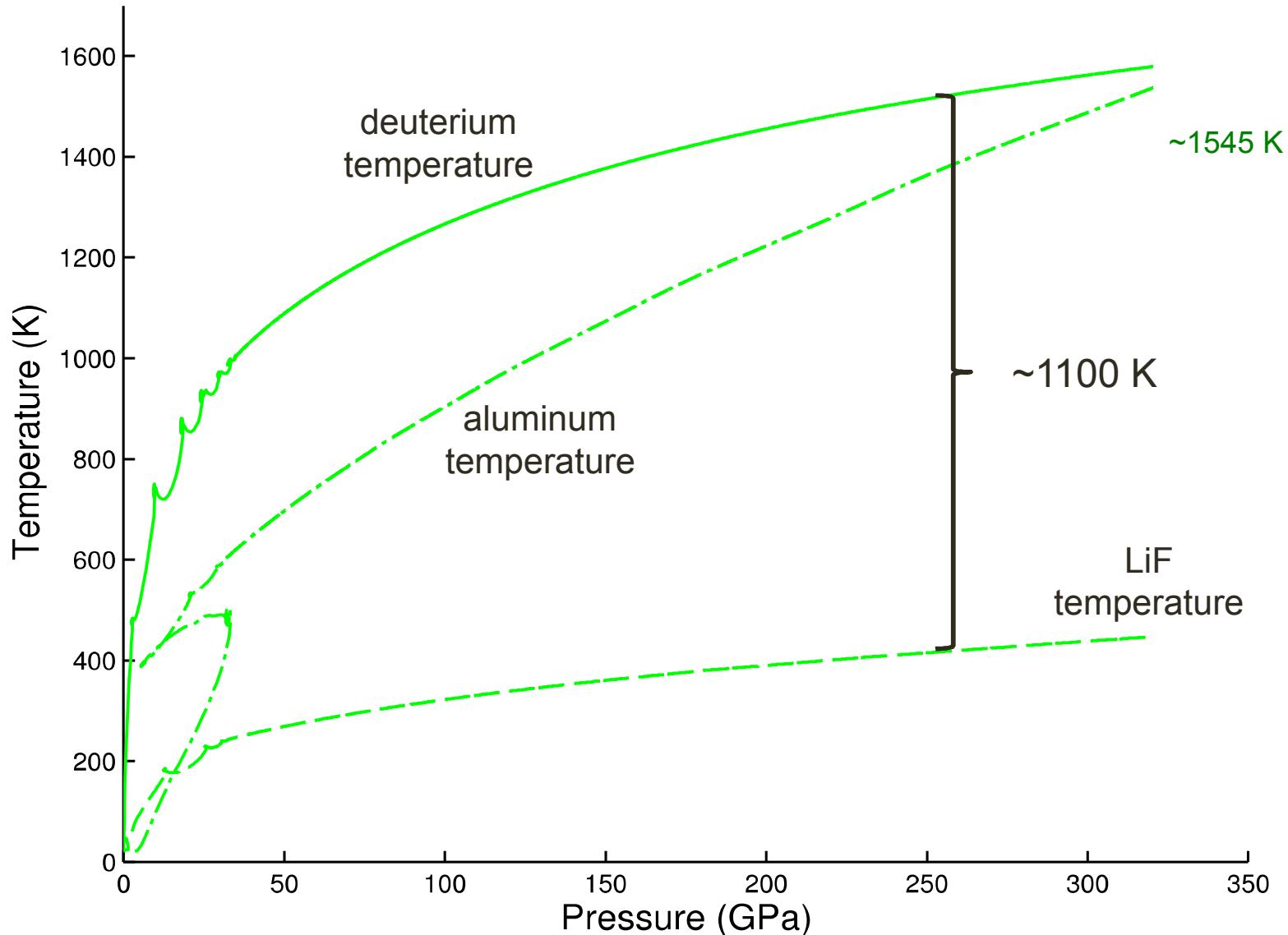
# Experimental PT Paths



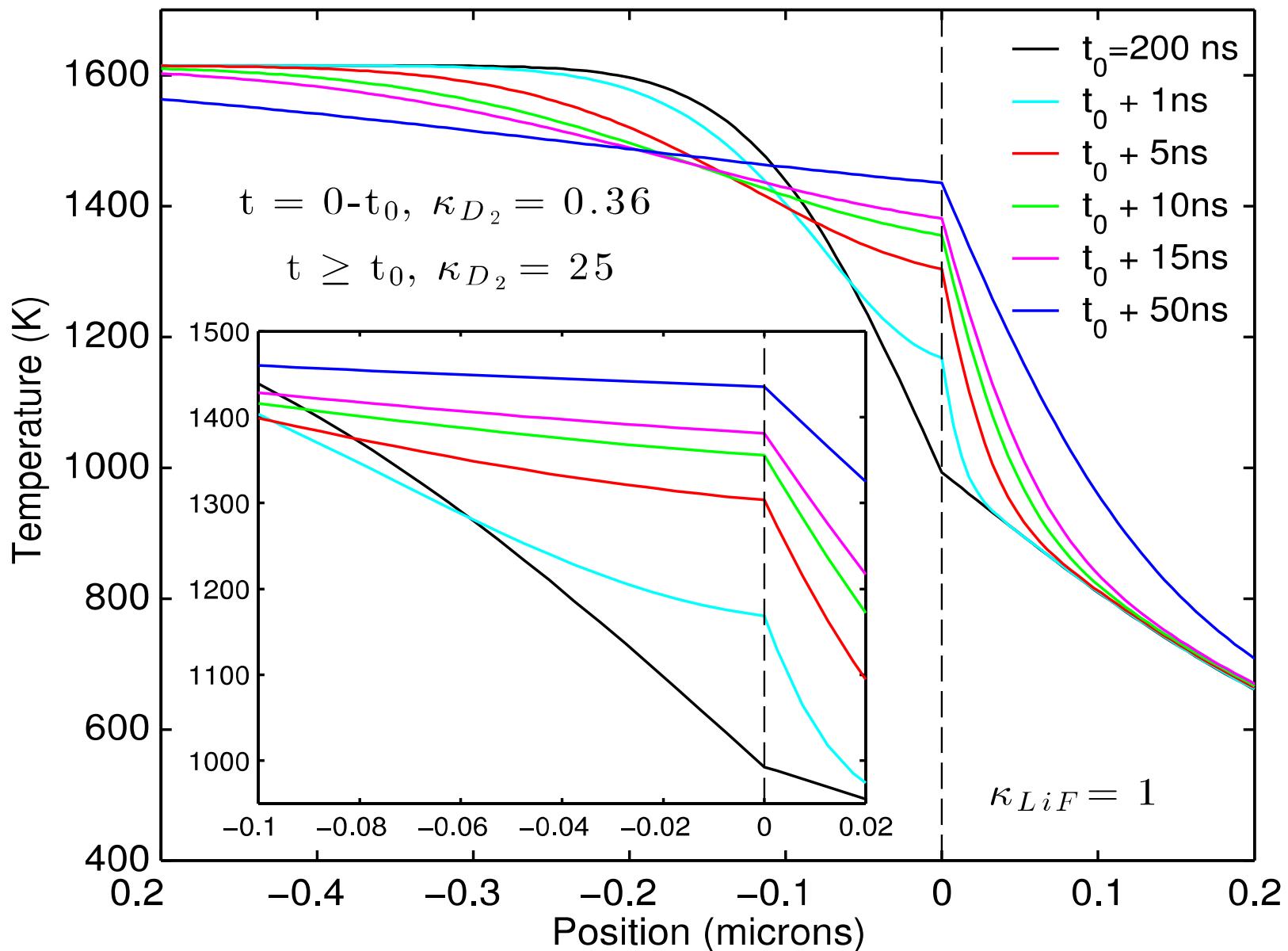
# Reflectivity signals mapped to pressure



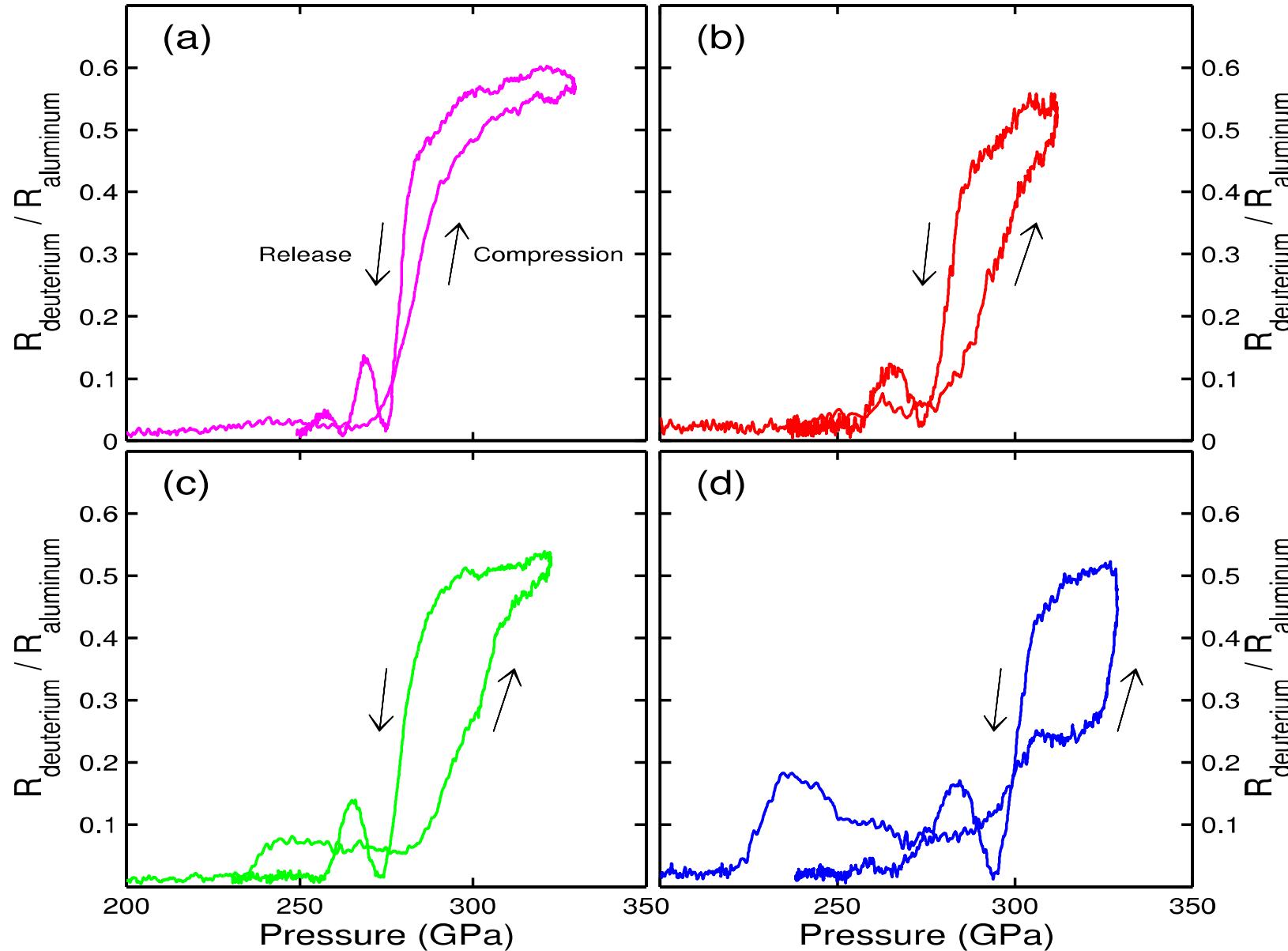
# There is a significant temperature difference at the deuterium/LiF interface



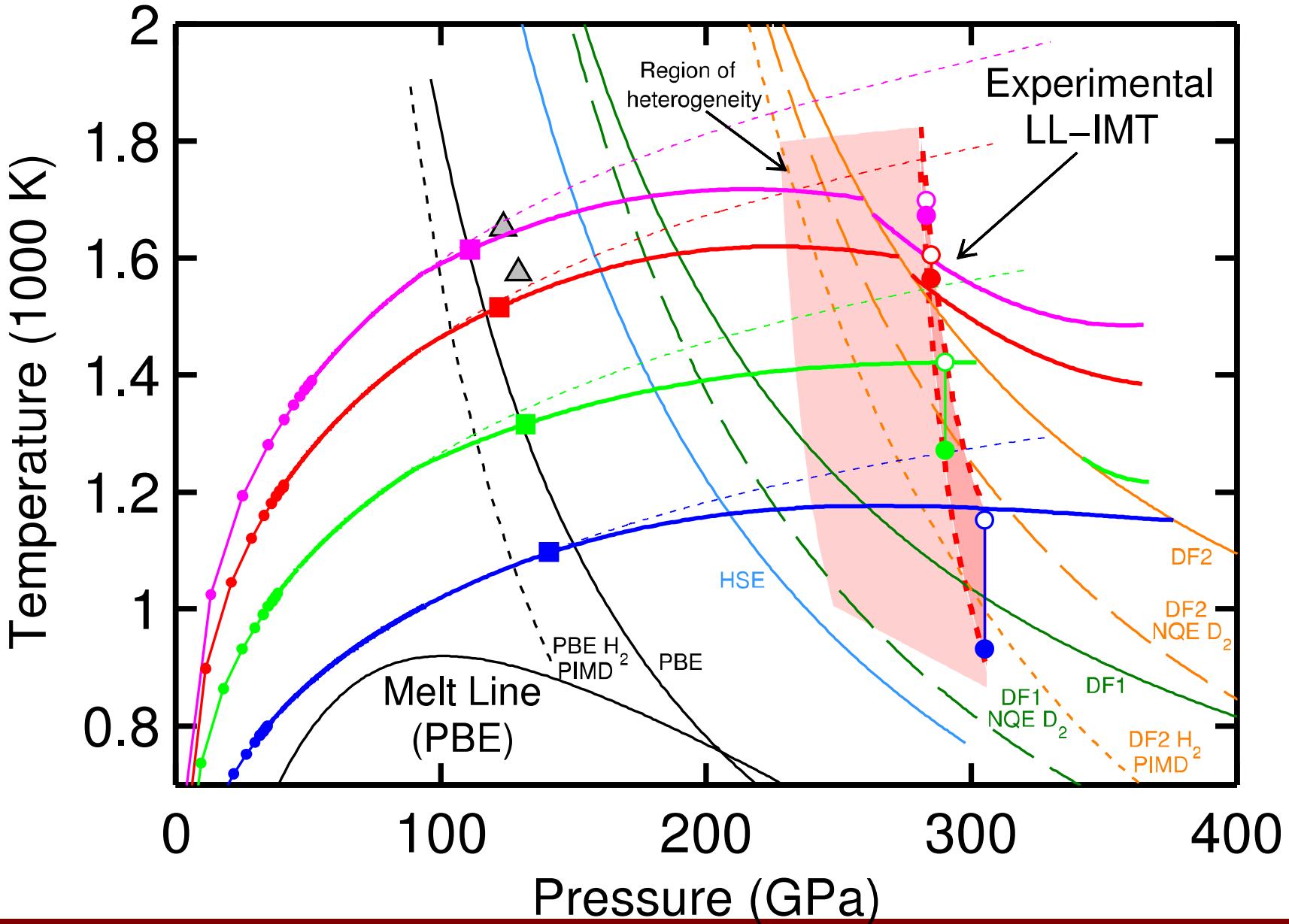
# Thermal conduction simulations



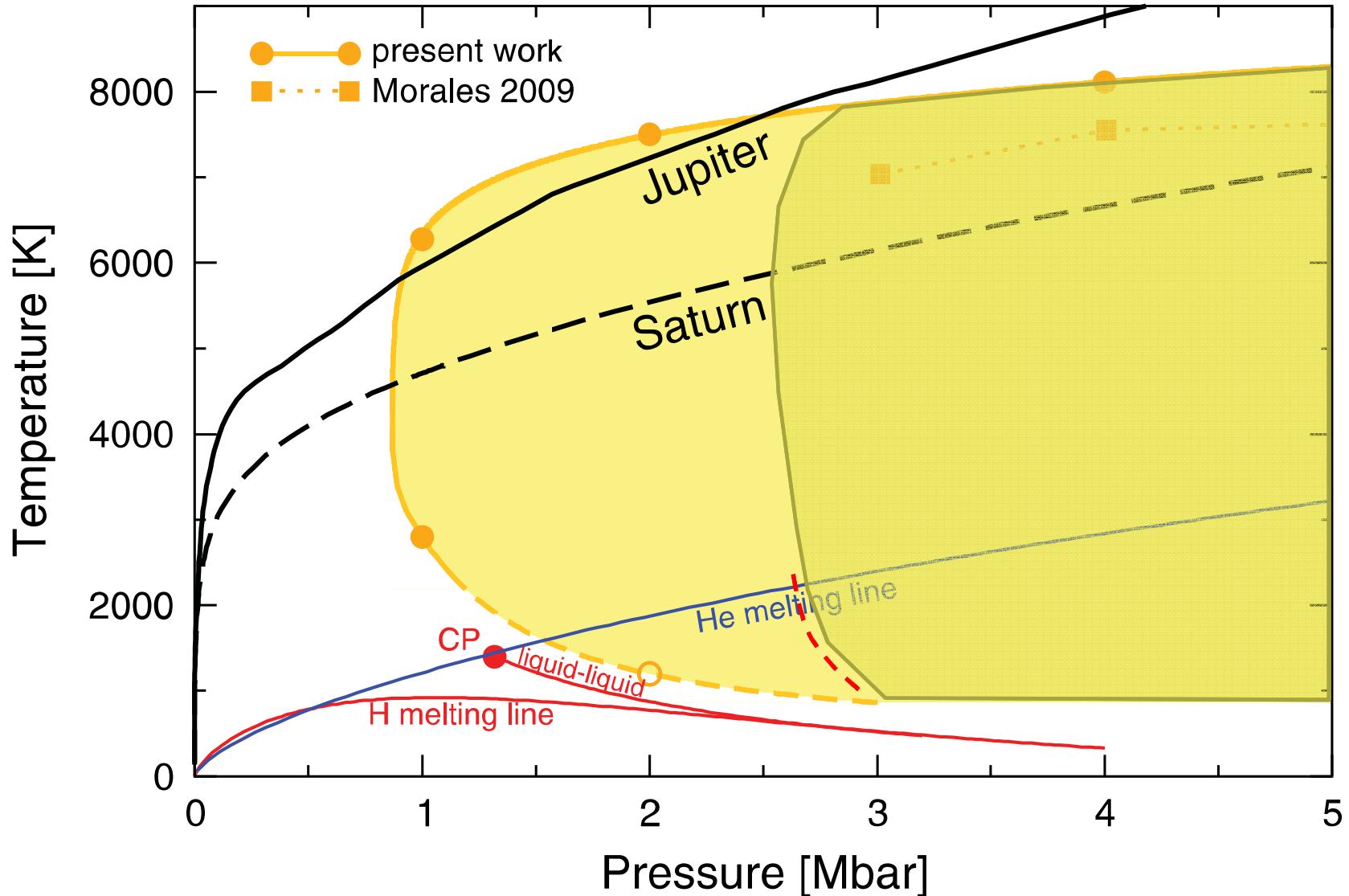
# Reflectivity signals mapped to pressure



# 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 on state
- Experiments above  $\sim 250$  GPa show clear evidence of metallization of deuterium
  - Very abrupt increase in reflectivity to  $\sim 40\text{-}50\%$
  - Pressure state well above numerous first principles predictions
  - Indications suggest that the transition is first order
- Relative insensitivity to  $T$  suggests this is a  $\rho$ -driven transition
  - $\rho$  at the transition is inferred to be  $\sim 2\text{-}2.1$  g/cc in deuterium

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