SAND2014-17732PE

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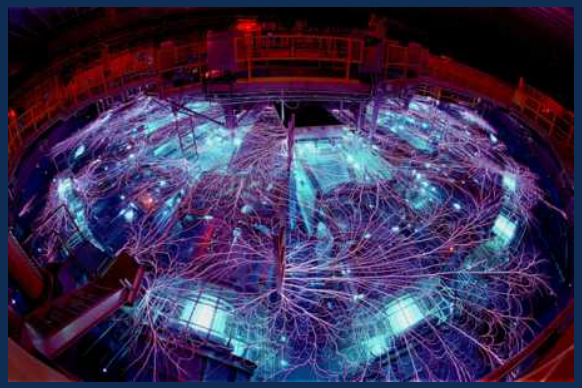

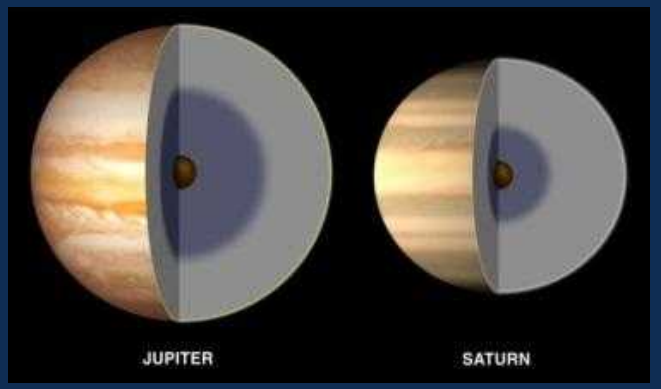

Dynamic compression experiments on liquid deuterium above the melt boundary

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

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Acknowledgements

Experiment Design/Analysis

Marcus Knudson

Ray Lemke

Kyle Cochrane

Devon Dalton

Dustin Romero

Diagnostics

Charlie Meyer

Jeff Gluth

Devon Dalton

Anthony Romero

Dave Bliss

Alan Carlson

QMD Calculations

Mike Desjarlais

Andreas Becker

Winfried Lorenzen

Ronald Redmer

Planetary Modeling

Nadine Nettelmann

Andreas Becker

Ronald Redmer

Pulse Shaping

Ray Lemke

Jean-Paul Davis

Mark Savage

Ken Struve

Keith LeChien

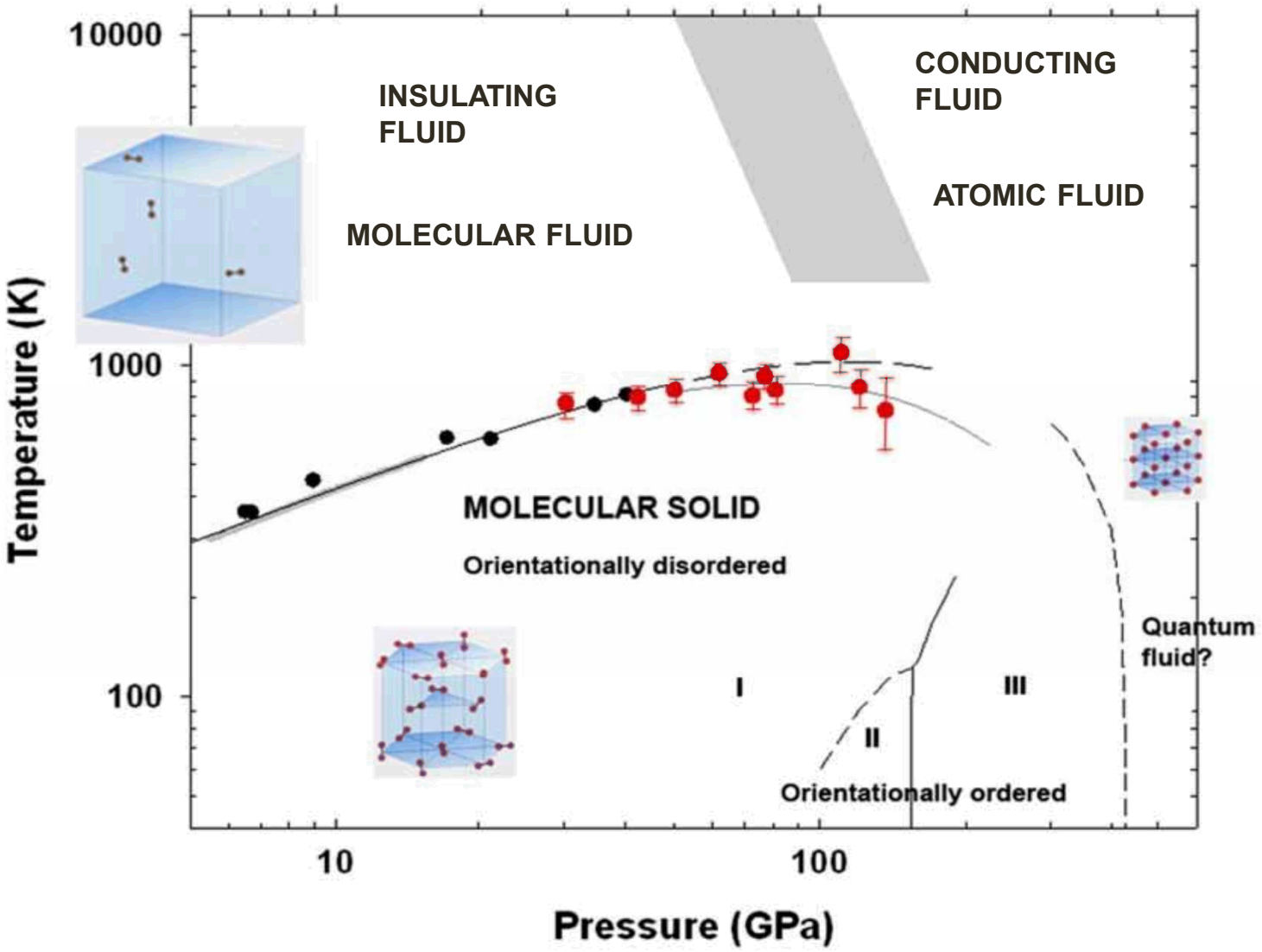
Brian Stoltzfus

Dave Hinshelwood

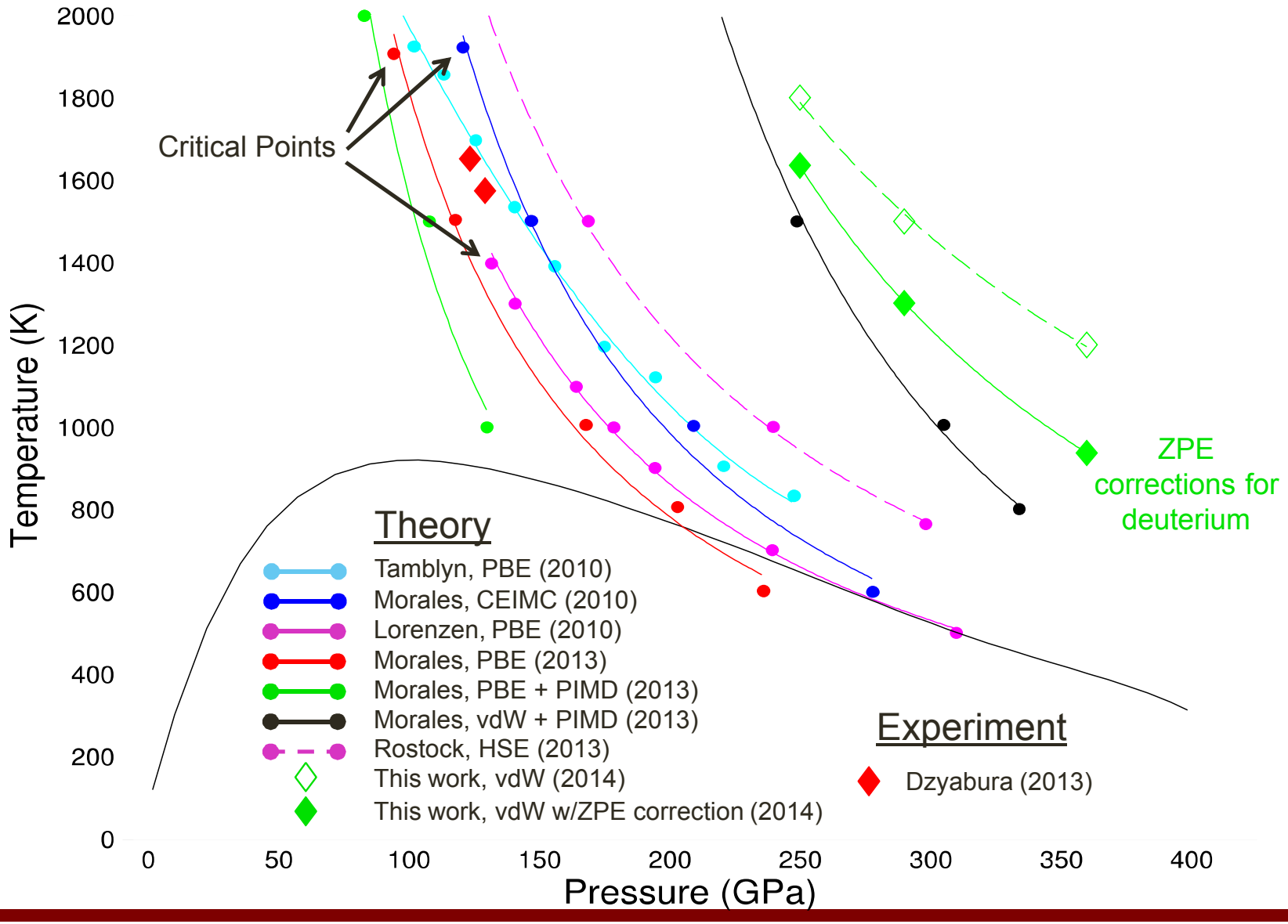
Entire Z crew

University of Rostock

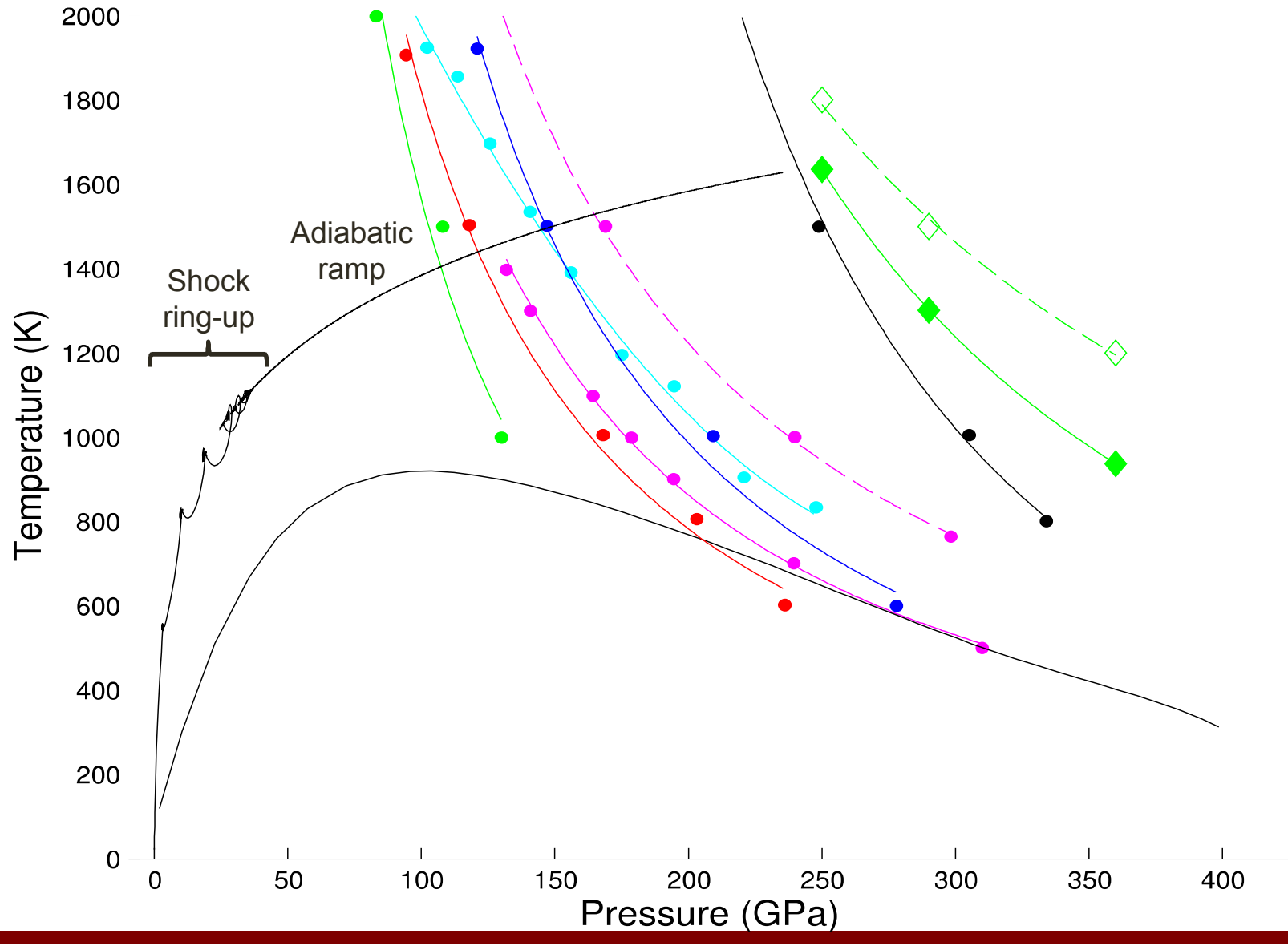
Hydrogen at high pressures – the known phase diagram so far



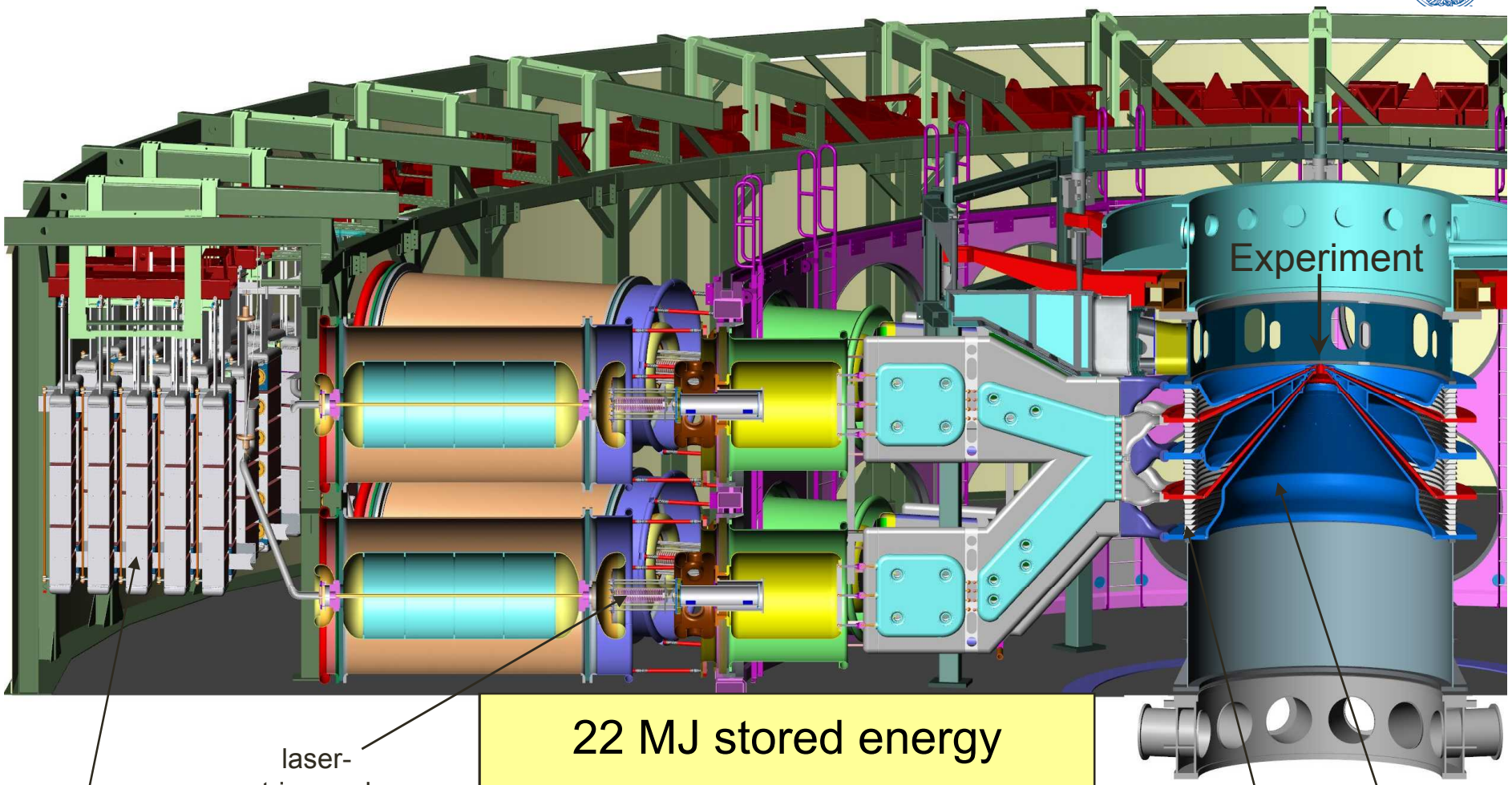
Recent predictions for LL-IMT in H



Proposed Experiment



Sandia Z Machine

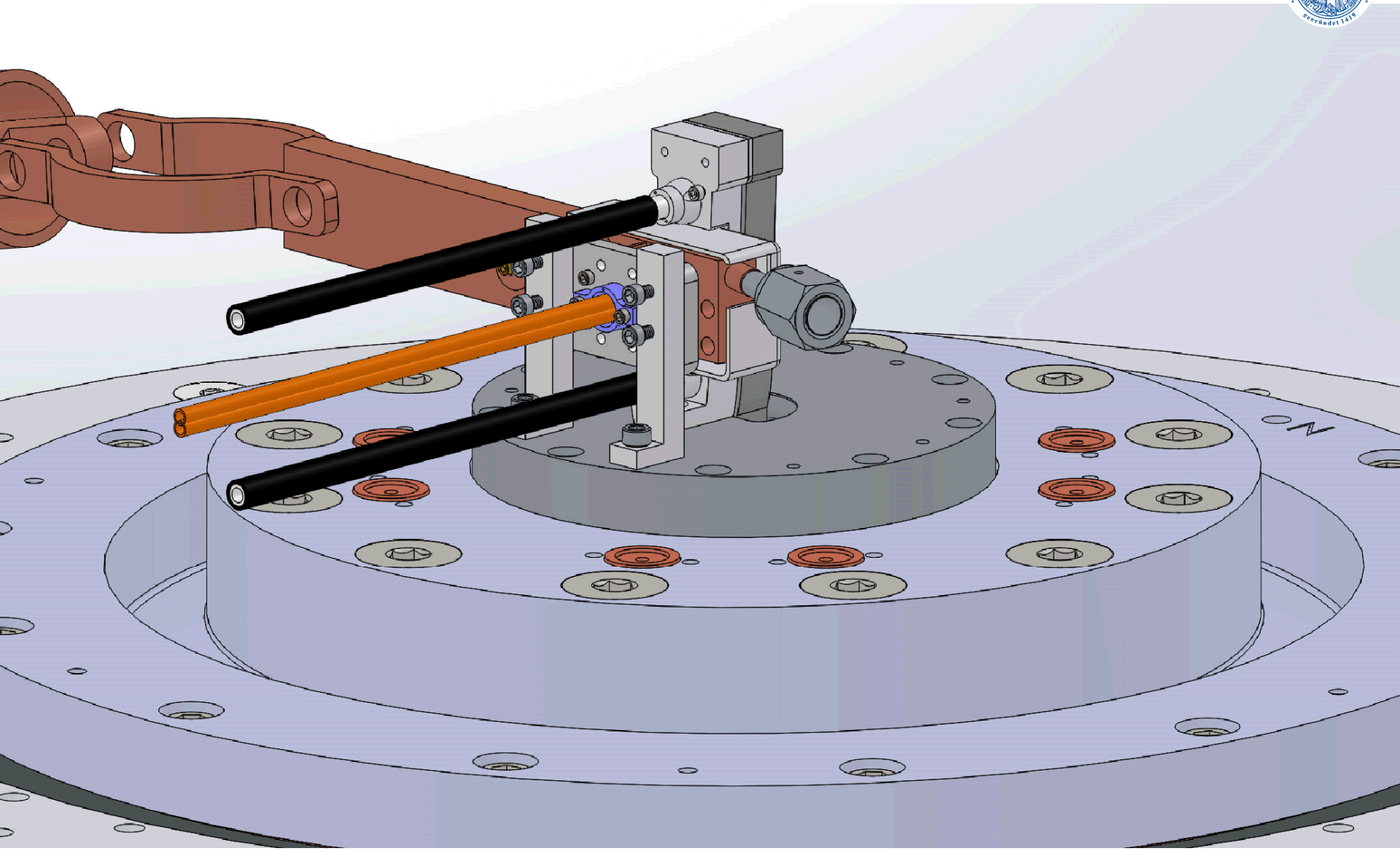


22 MJ stored energy

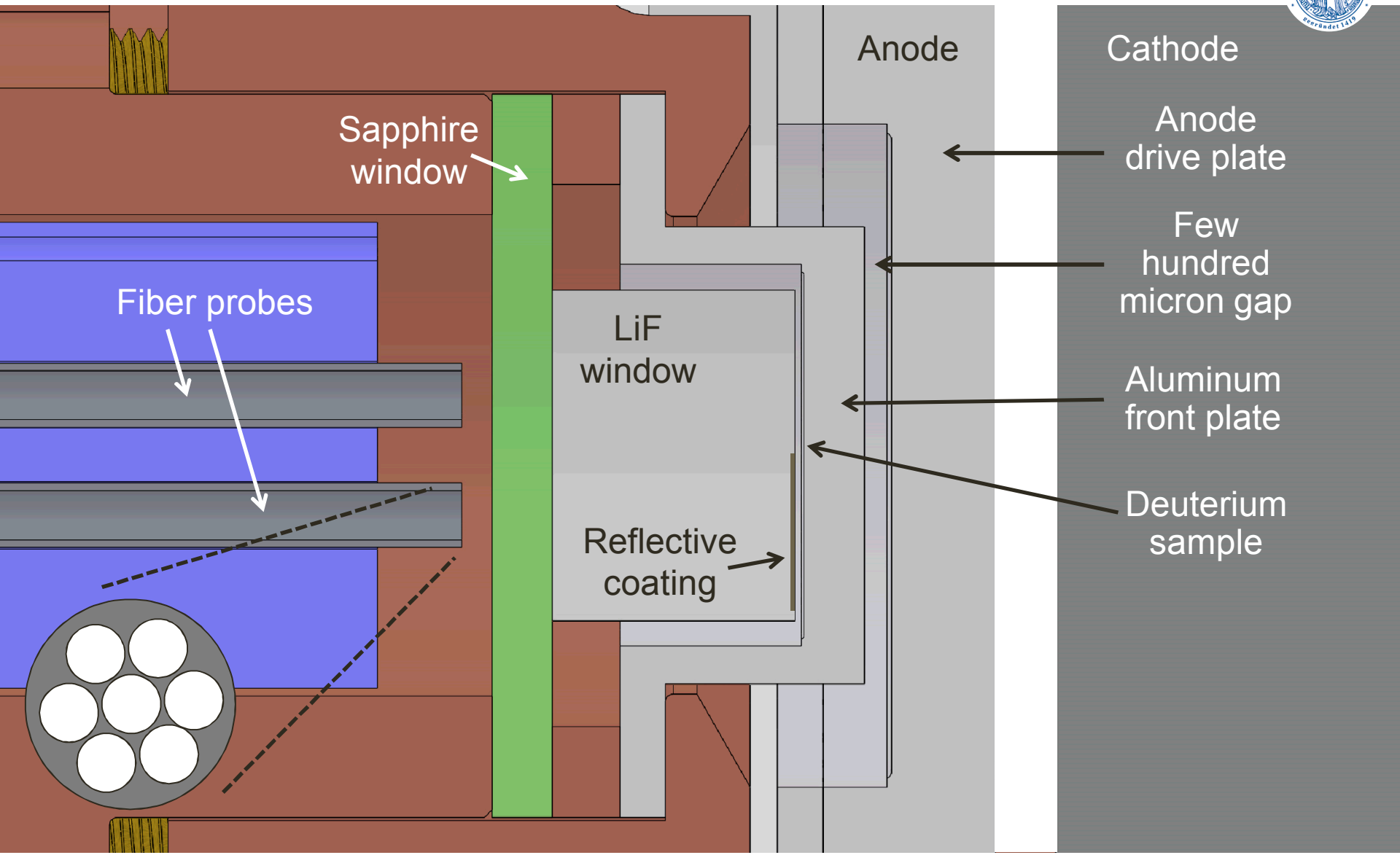
~25 MA peak current

~200-600 ns rise time

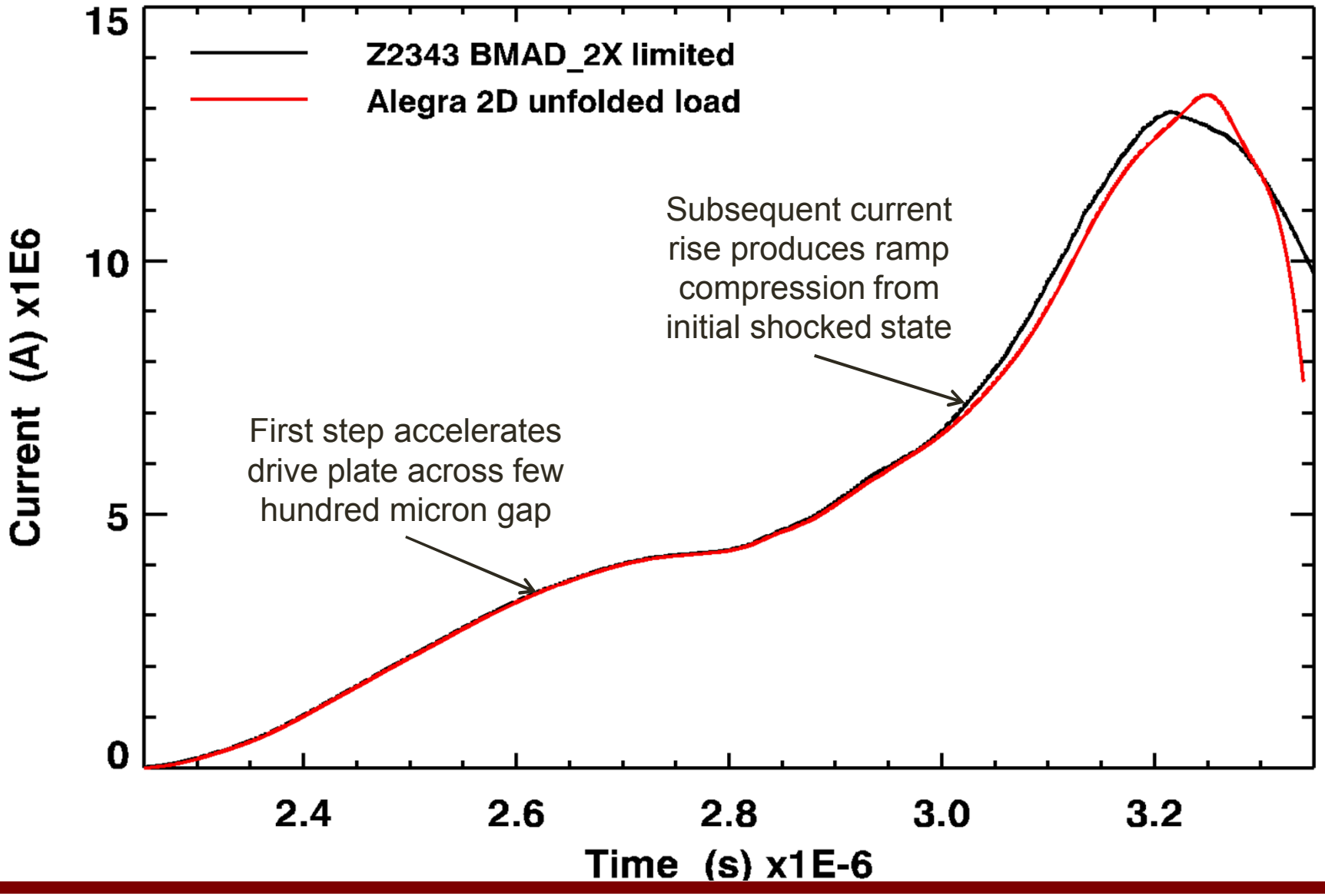
Stripline experimental configuration



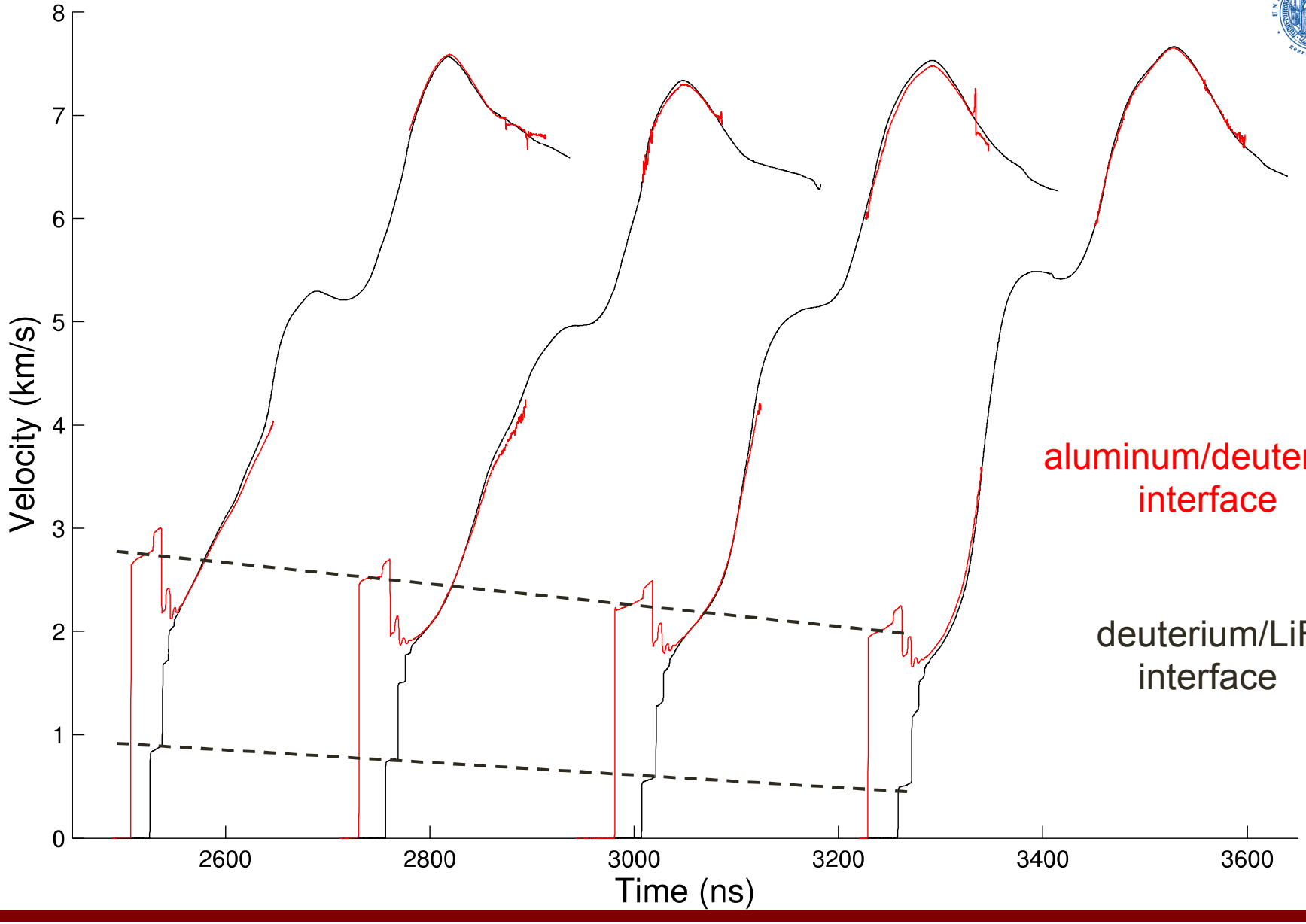
Experimental configuration



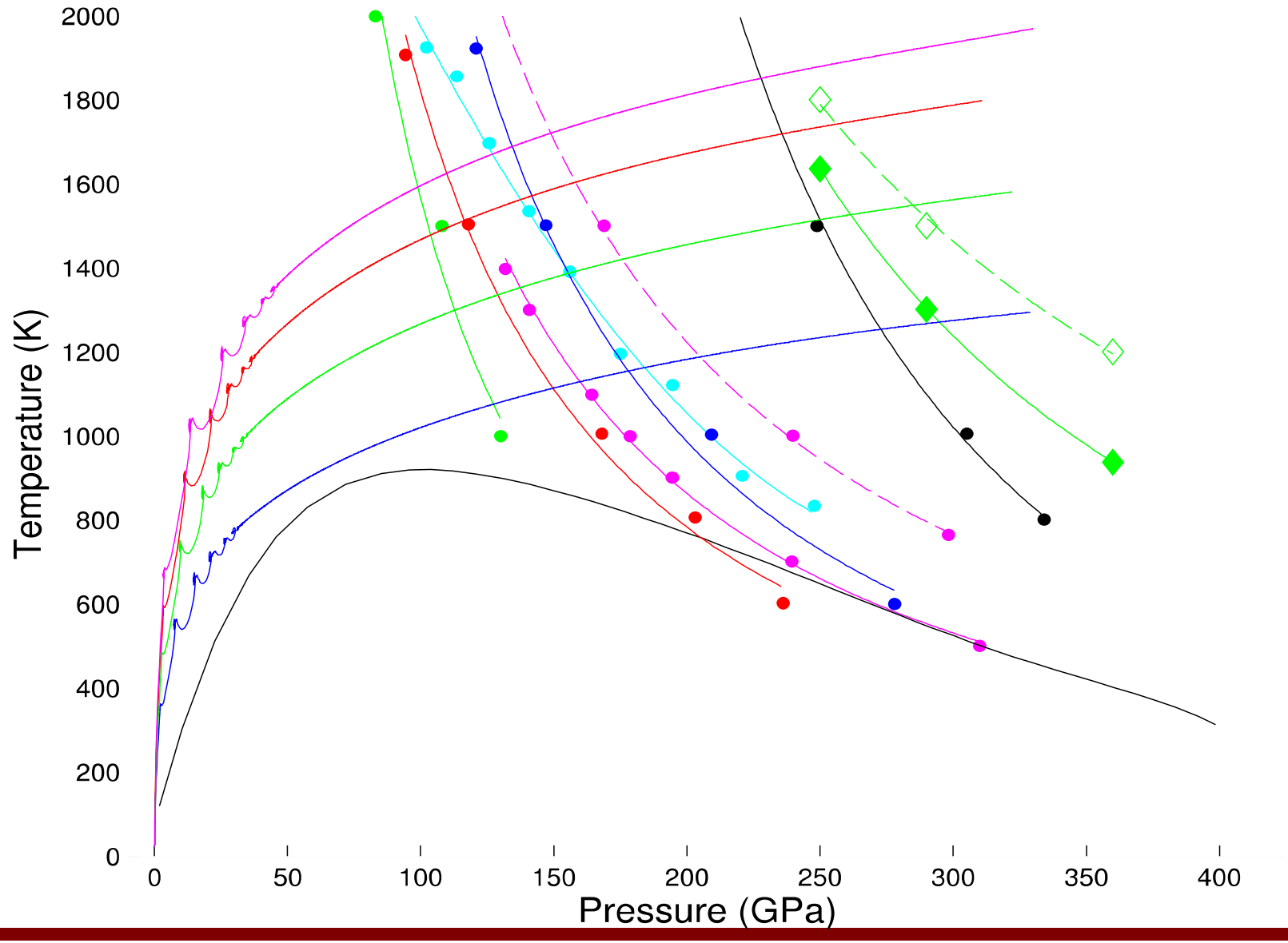
Two-step pulse shape provides shock-ramp profile



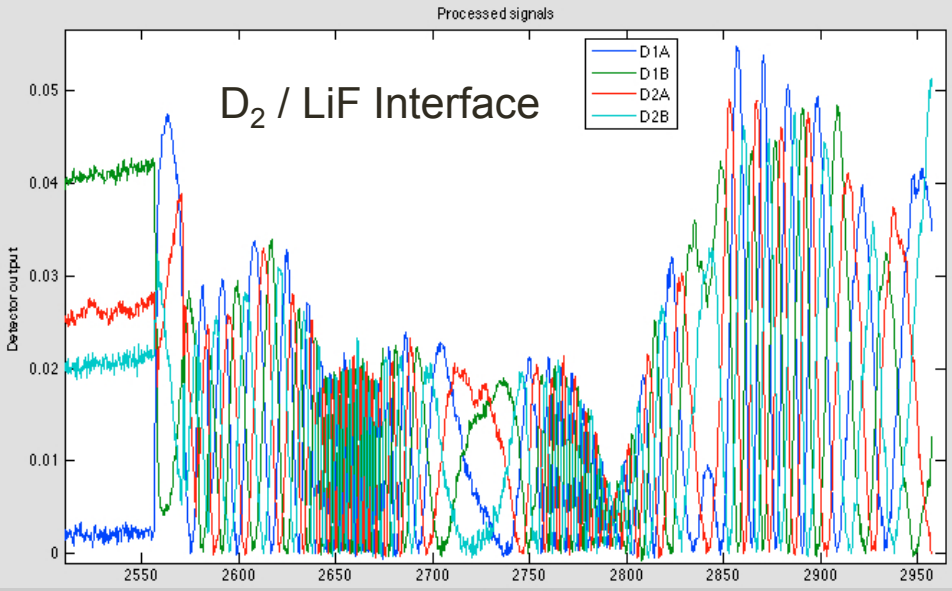
Stripline experimental profiles

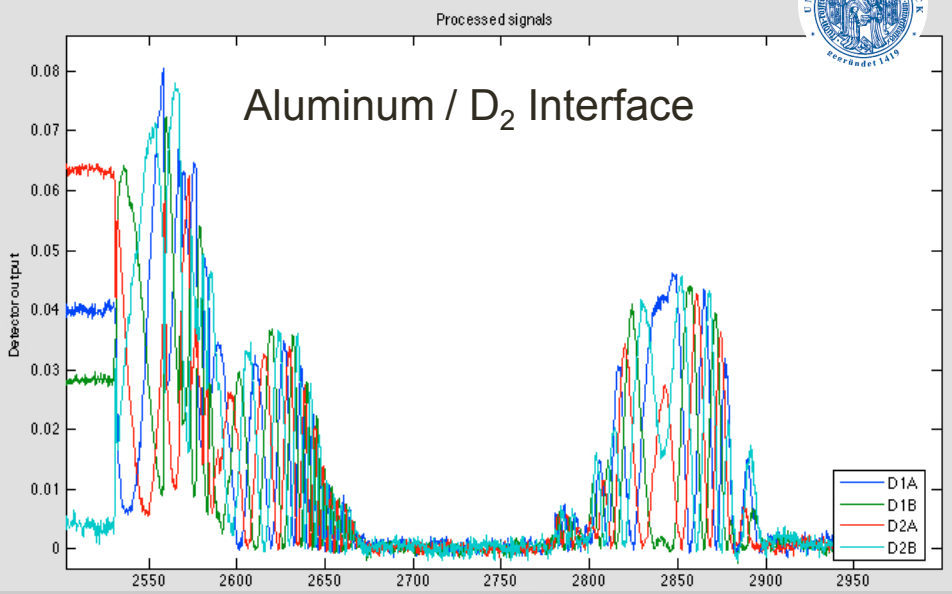


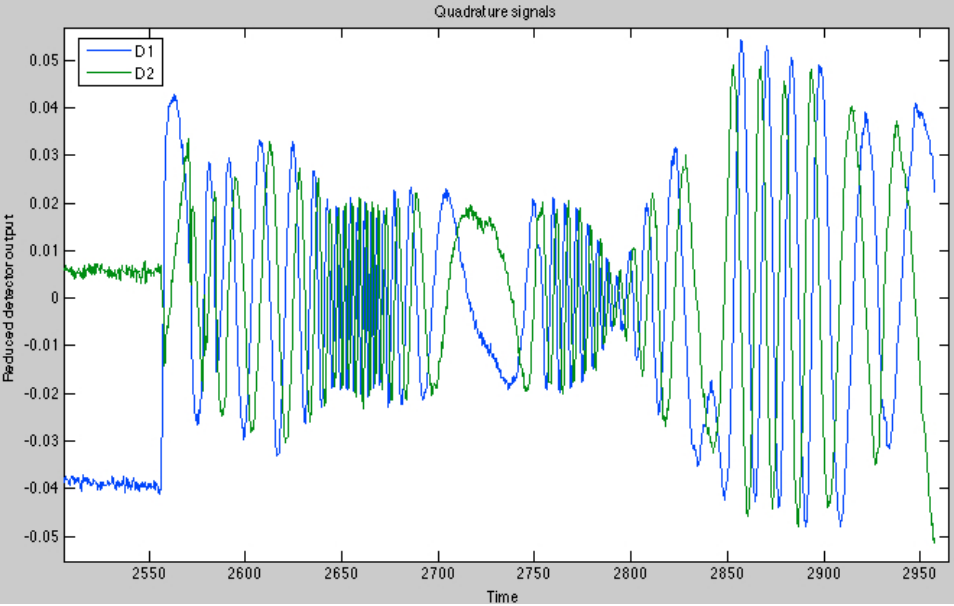
Stripline experiment PT paths

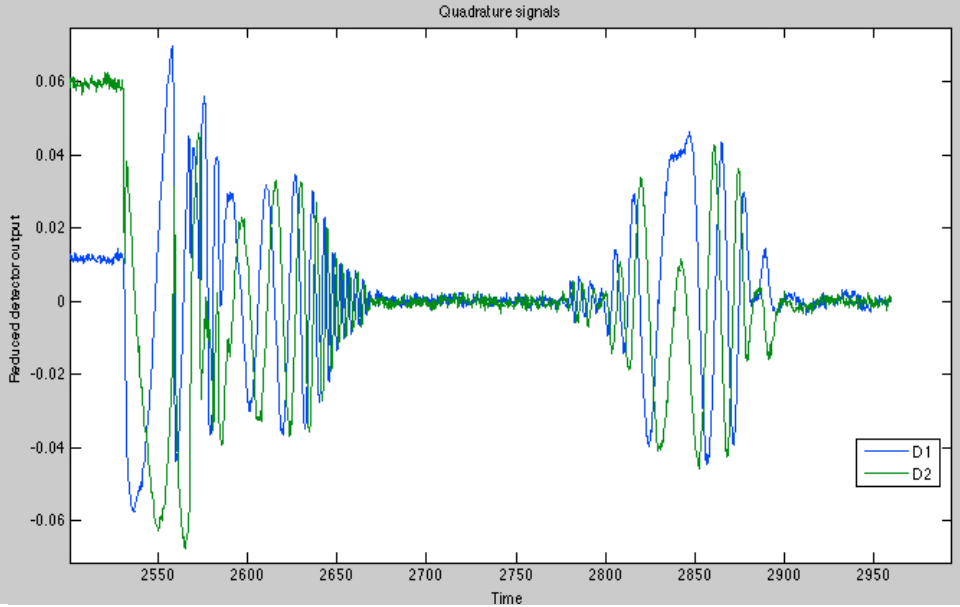


Processed VISAR signals





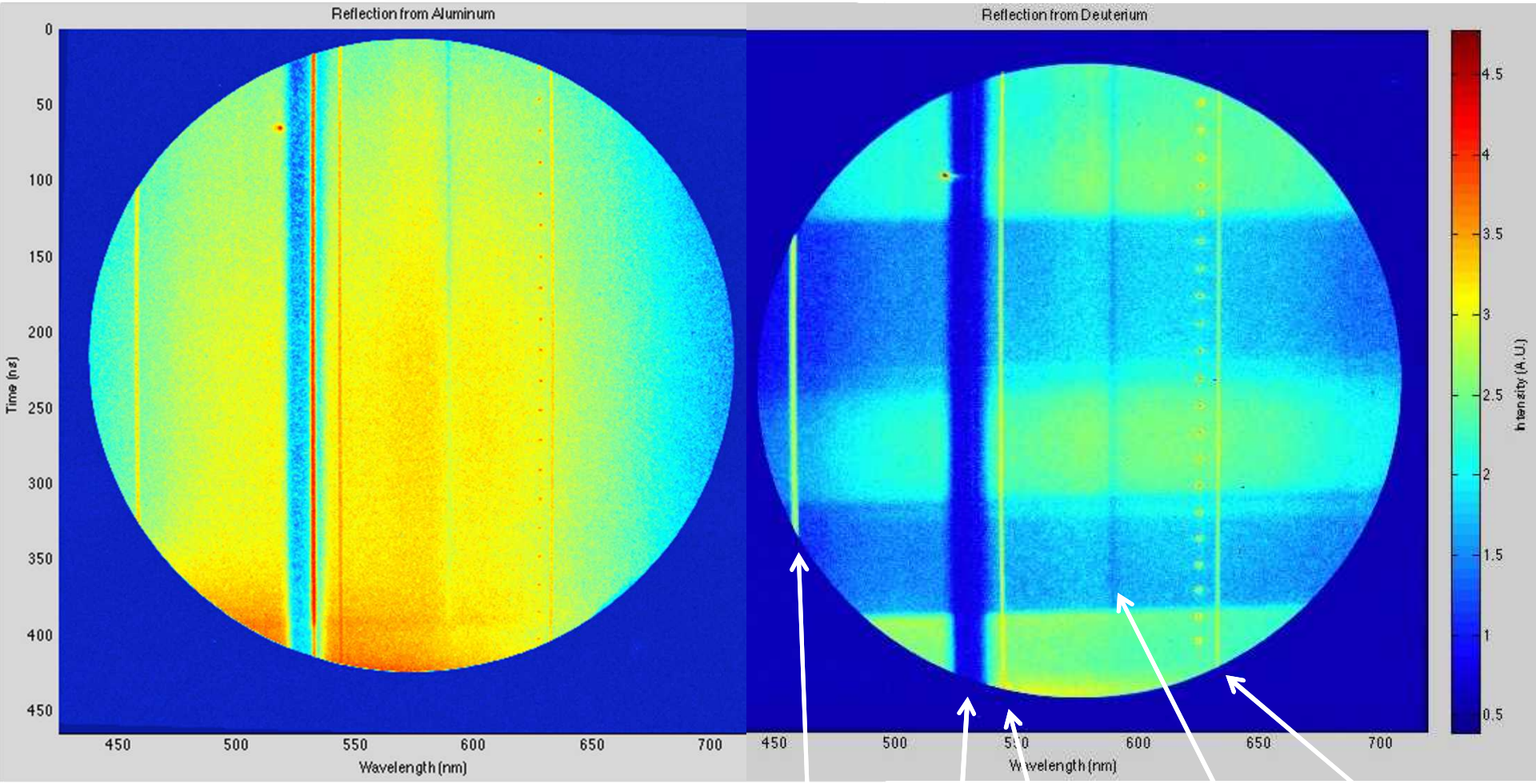




SVS system provides data to infer reflectivity

Reflection from aluminum coating

Reflection from deuterium



Wavelength range ~450-700 nm

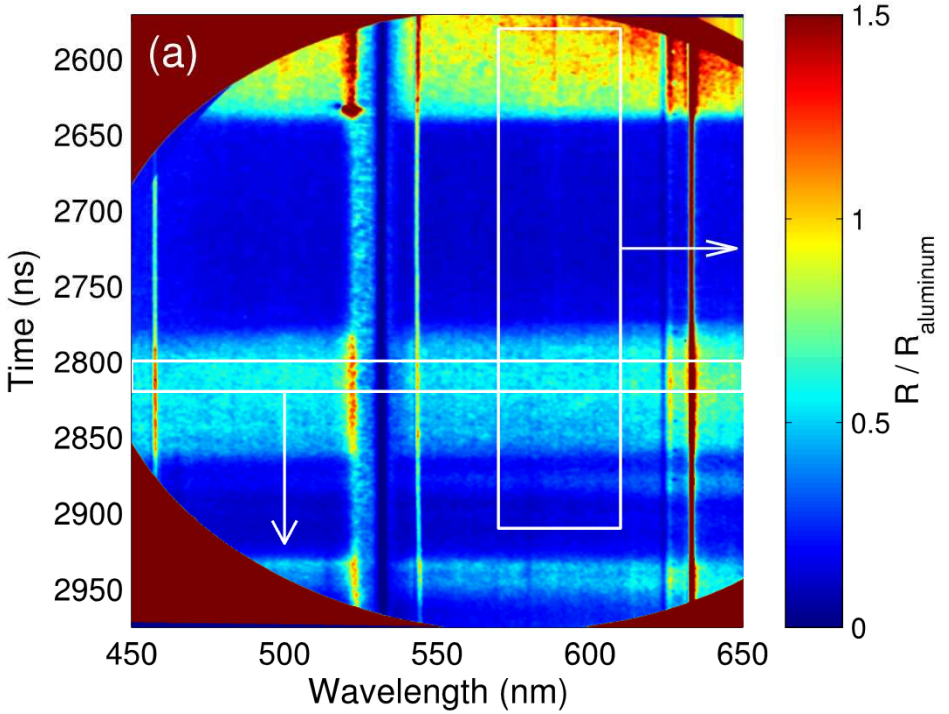
457.9 nm

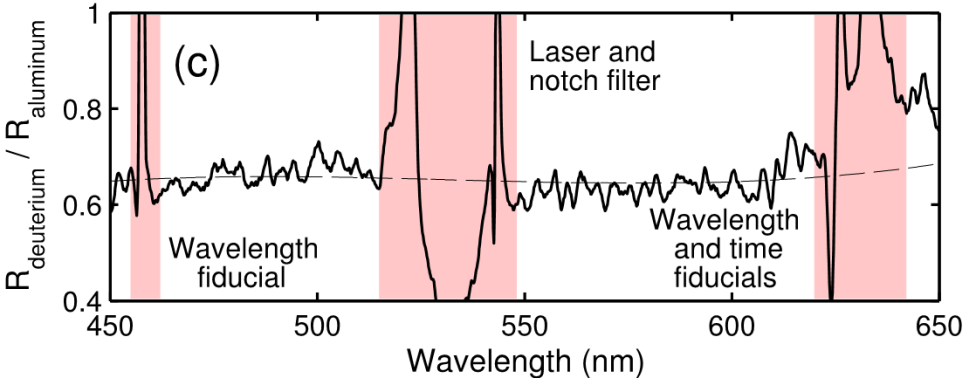
532 / 543.5 nm

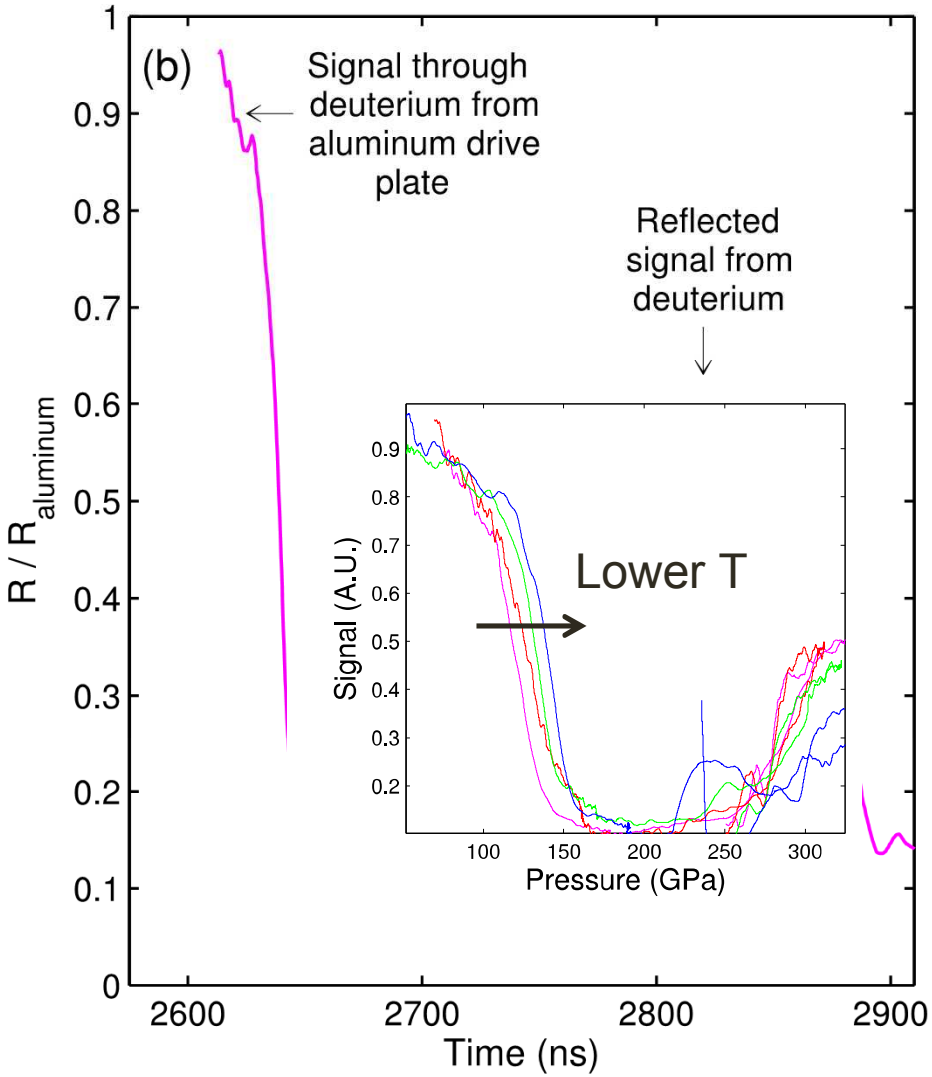
589.3 nm

633 nm

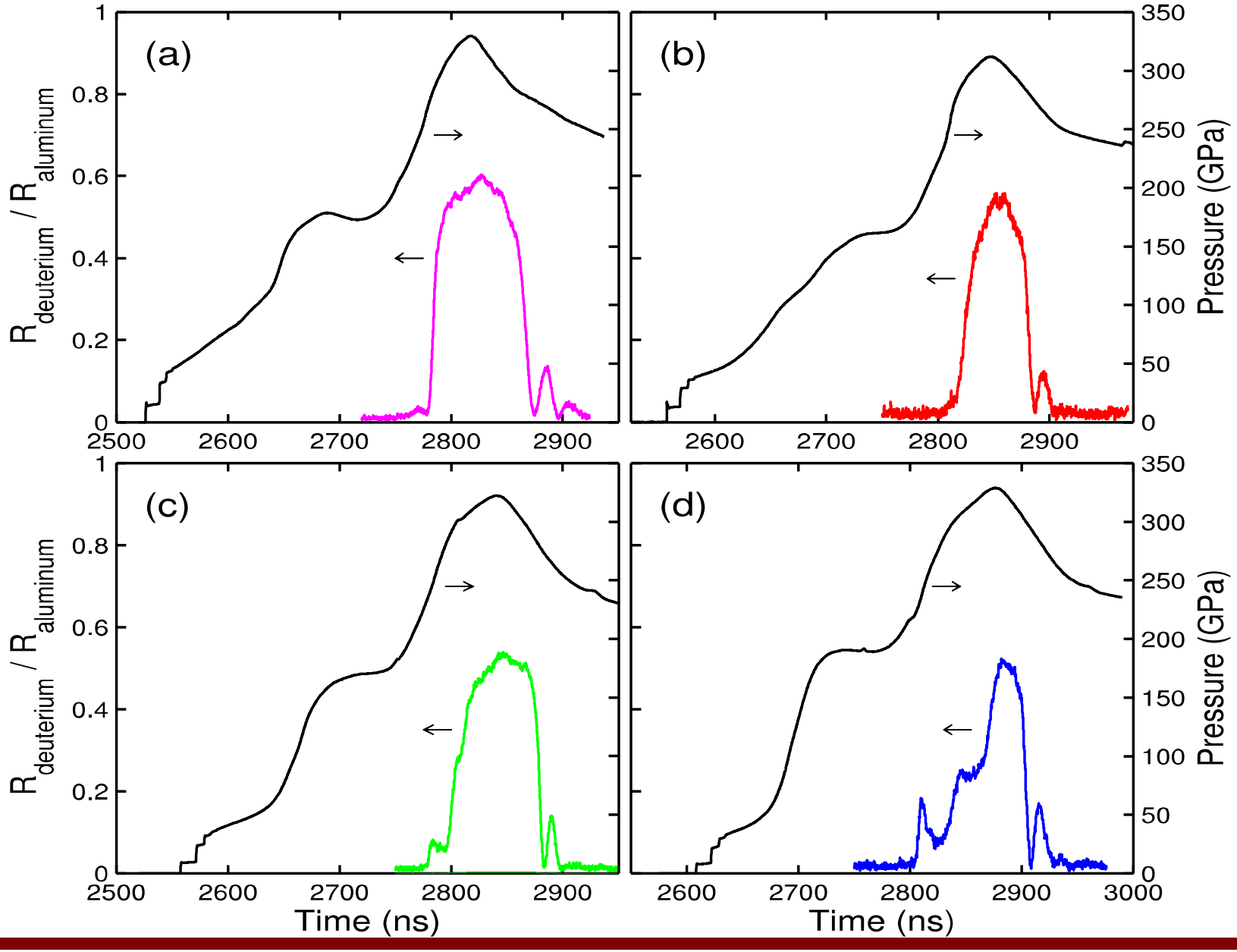
SVS system provides data to infer reflectivity



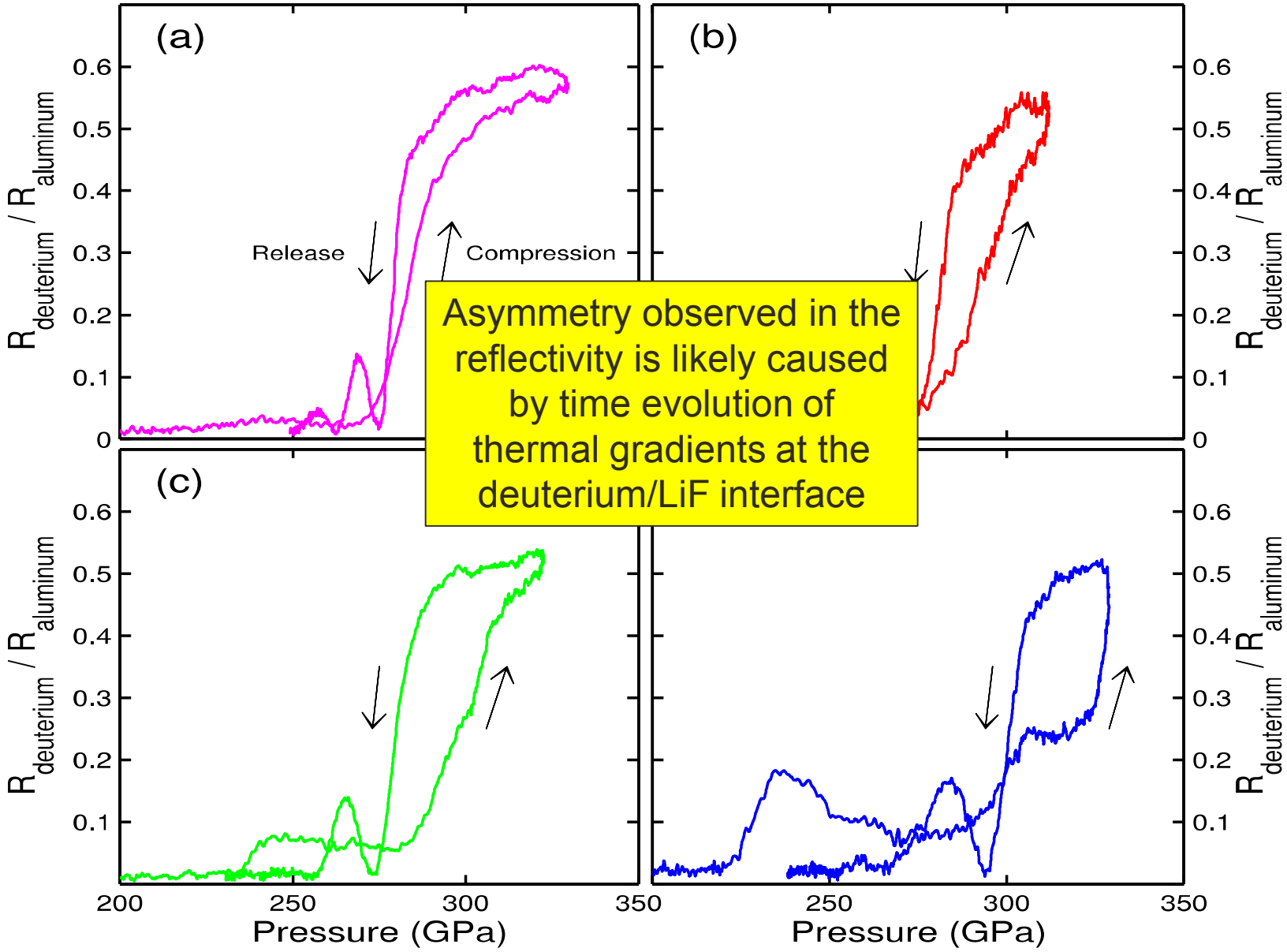




Reflectivity and pressure vs. time from VISAR

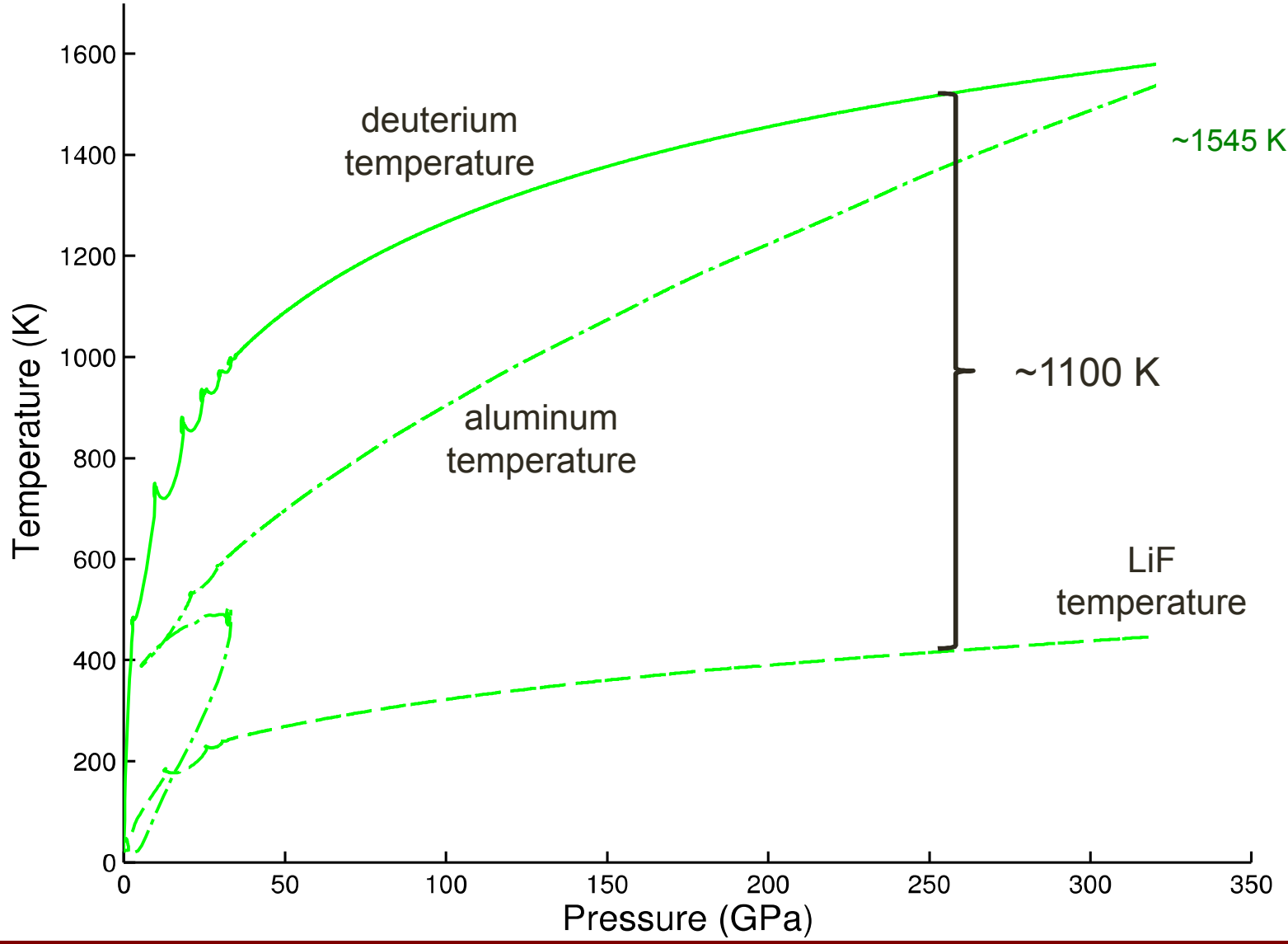


Reflectivity signals mapped to pressure

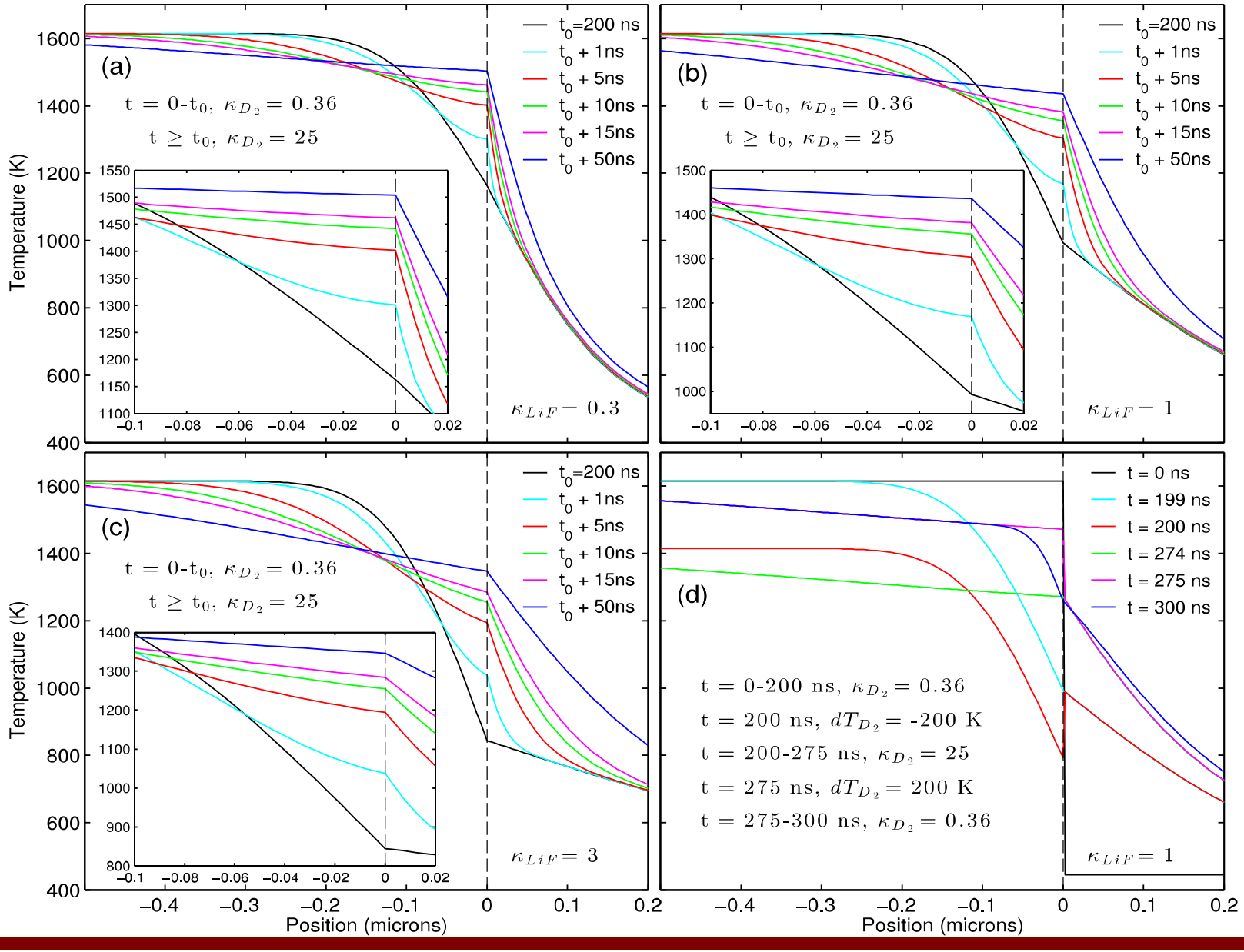


Asymmetry observed in the reflectivity is likely caused by time evolution of thermal gradients at the deuterium/LiF interface

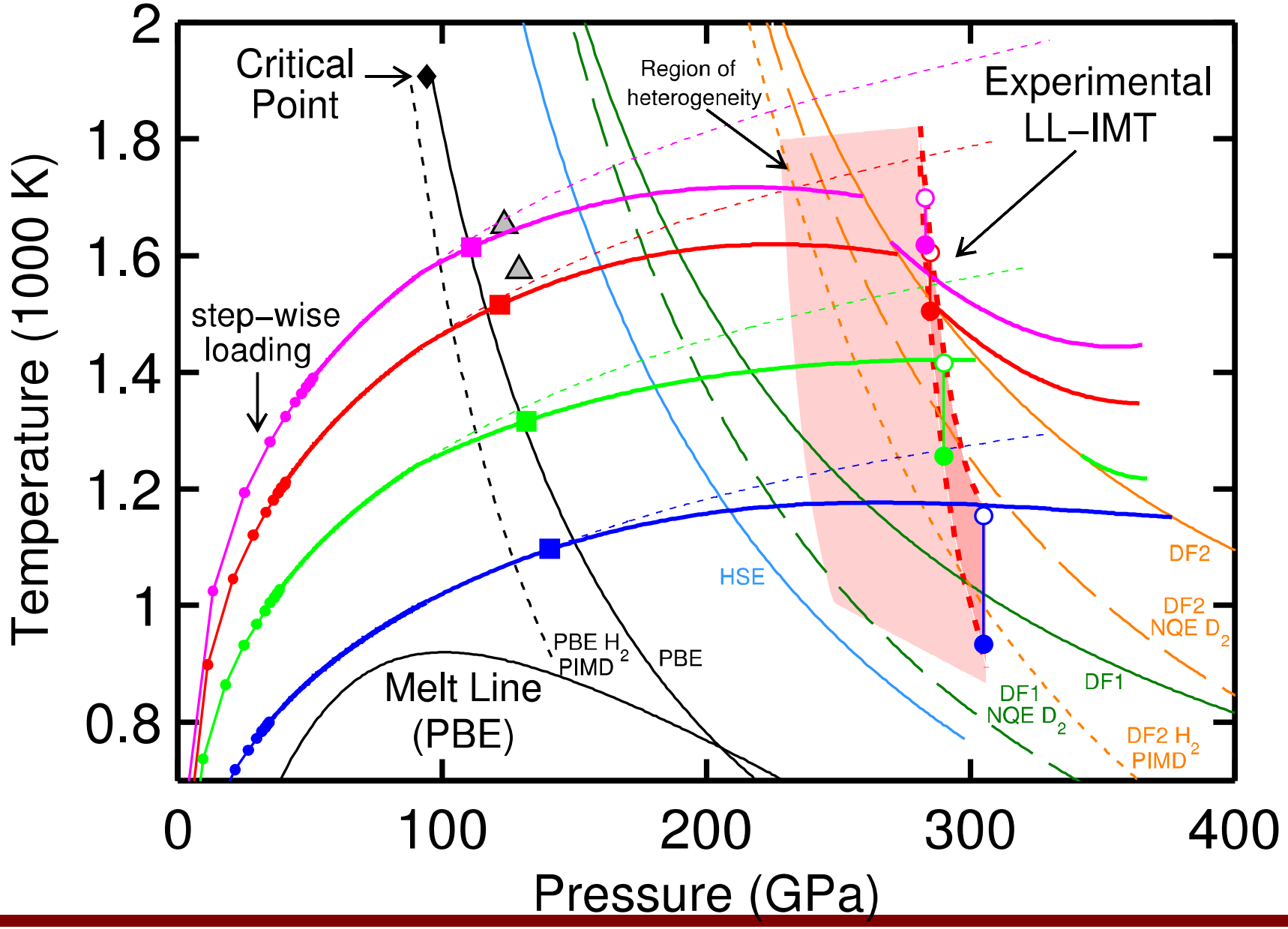
There is a significant temperature difference at the deuterium/LiF interface



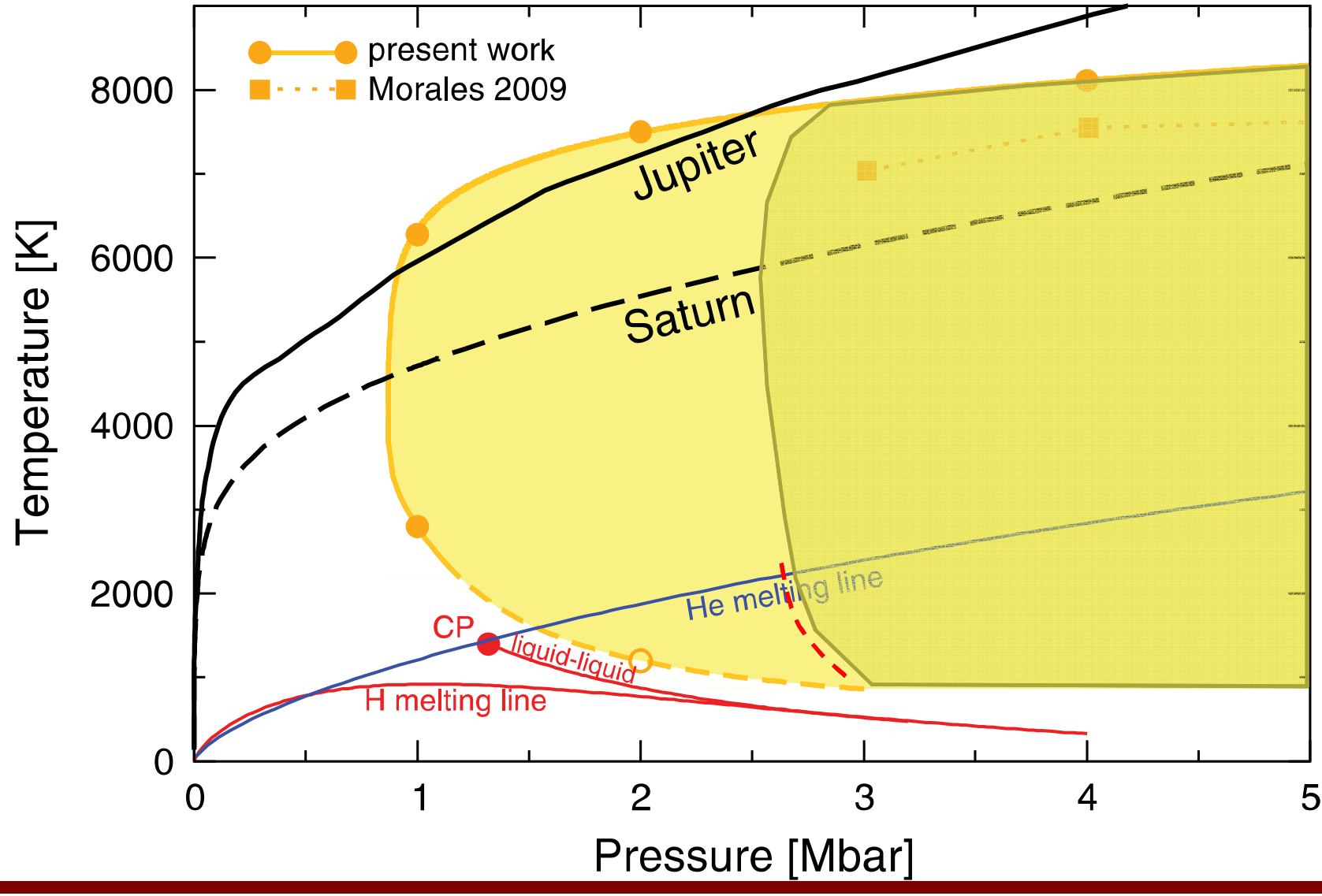
Thermal conduction simulations



Possible 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
- Interpretation of the experimental results is complicated
  - Thermal conduction likely very important at the deuterium / LiF interface

Acknowledgements

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Marcus Knudson

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Kyle Cochrane

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Diagnostics

Charlie Meyer

Jeff Gluth

Devon Dalton

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Dave Bliss

Alan Carlson

QMD Calculations

Mike Desjarlais

Andreas Becker

Winfried Lorenzen

Ronald Redmer

Planetary Modeling

Nadine Nettelmann

Andreas Becker

Ronald Redmer

Pulse Shaping

Ray Lemke

Jean-Paul Davis

Mark Savage

Ken Struve

Keith LeChien

Brian Stoltzfus

Dave Hinshelwood

Entire Z crew

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