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Deep Release Measurements of Shocked Quartz and Implications for Warm Dense Matter Studies

International Workshop on Warm Dense Matter 2011
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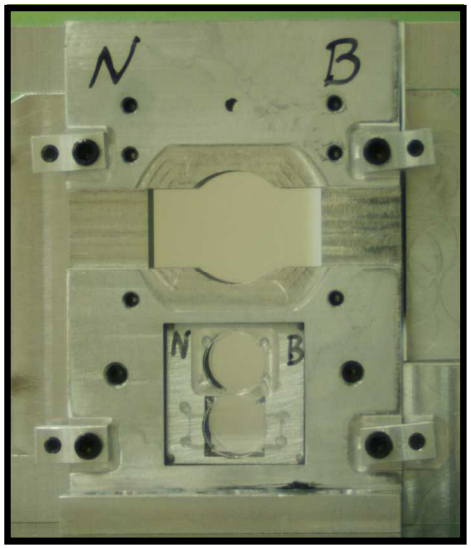

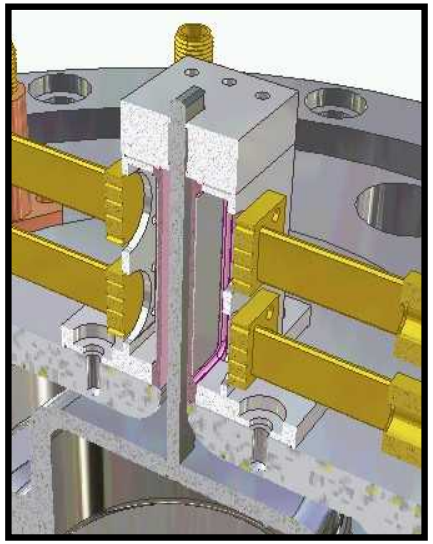

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National Nuclear Security Administration

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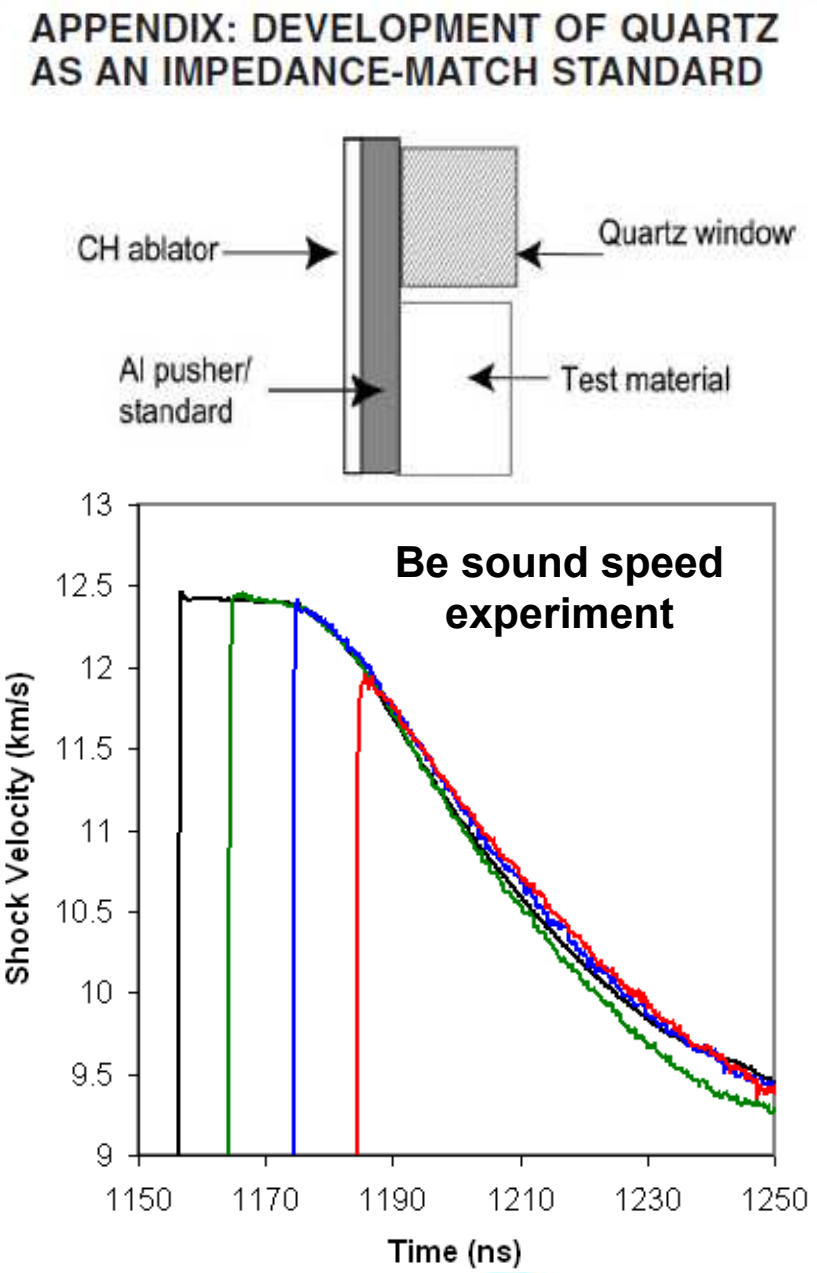
Acknowledgements

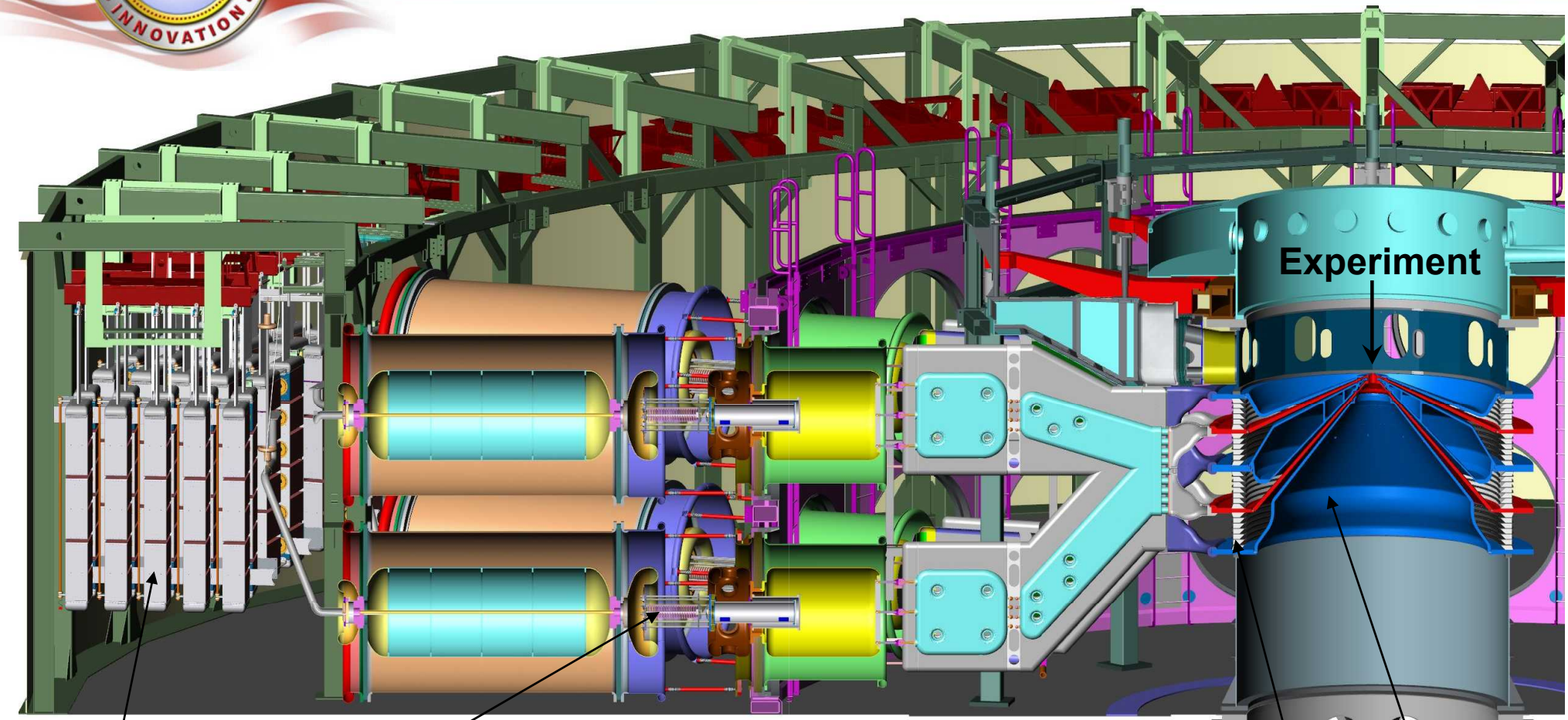
- Mike Desjarlais
  - Quantum Molecular Dynamics (QMD) calculations
- Ray Lemke
  - Flyer plate design and MHD simulations
- Jean-Paul Davis, Devon Dalton, Ken Struve, Mark Savage, Keith LeChien, Brian Stoltzfus, Dave Hinshelwood
  - Bertha model, pulse shaping
- Charlie Meyer, Devon Dalton, Dustin Romero, Anthony Romero, entire Z crew…
  - Experiment support

Motivation for α-Quartz measurements

- Quartz melts at ~100 GPa into a conducting fluid
  - Shock front becomes reflective
- Quartz is quickly becoming a high pressure shock wave standard
  - Helium, diamond, deuterium
- Quartz has recently been used as a "window" for sound speed and Hugoniot melt experiments
- Quartz data has large uncertainty and scatter, and U_s-u_p exhibits significant curvature in the several 100 GPa regime
  - Attributed to dissociation



The Sandia Z Machine



Marx generator

laser-triggered gas switch

22 MJ stored energy

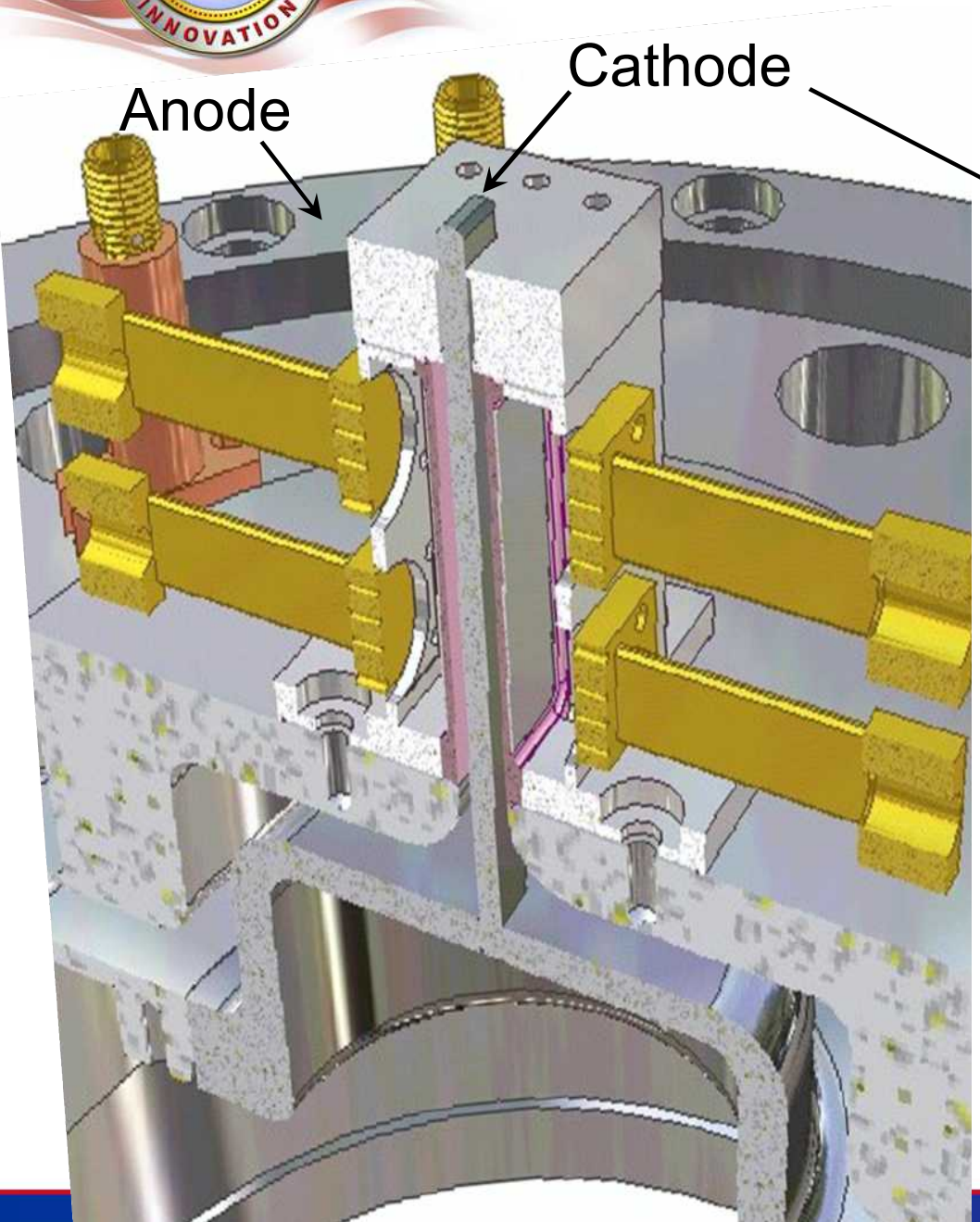
~25 MA peak current

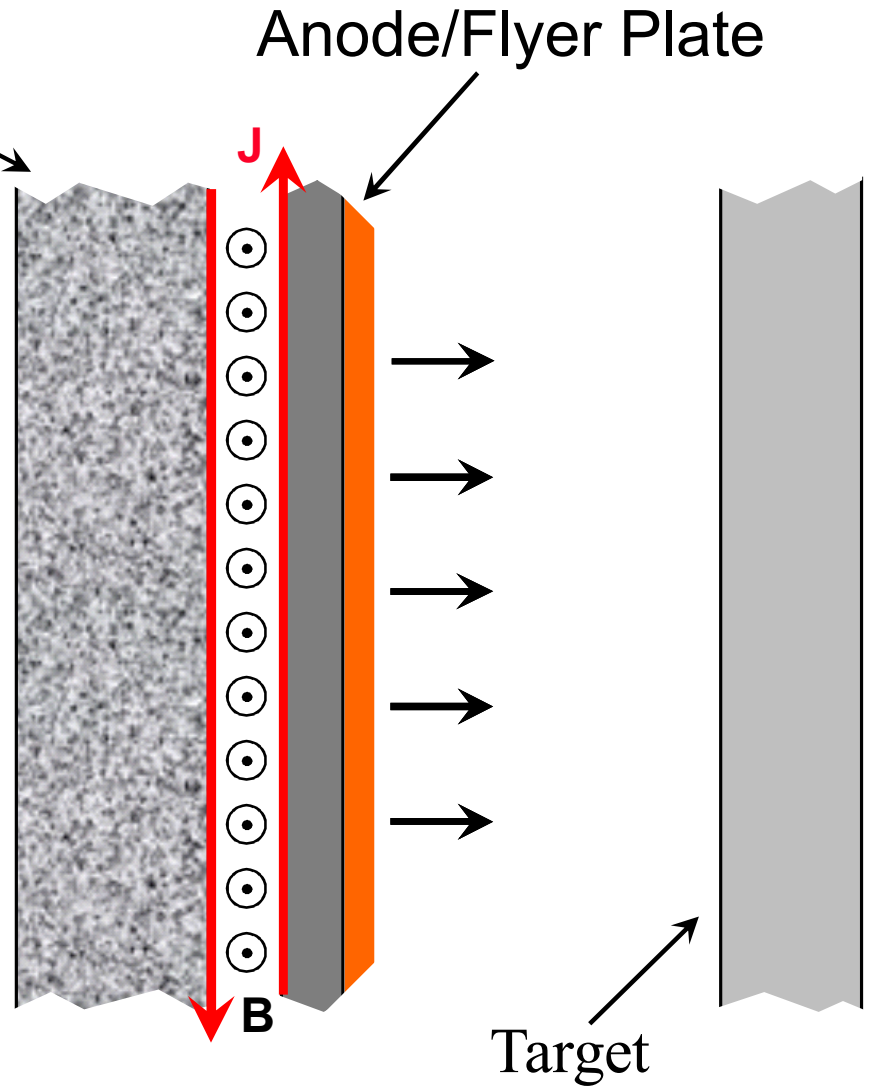
~200-600 ns rise time

insulator stack

magnetically insulated transmission lines

With proper pulse shape and design the anode can be launched as an effective high-velocity flyer plate





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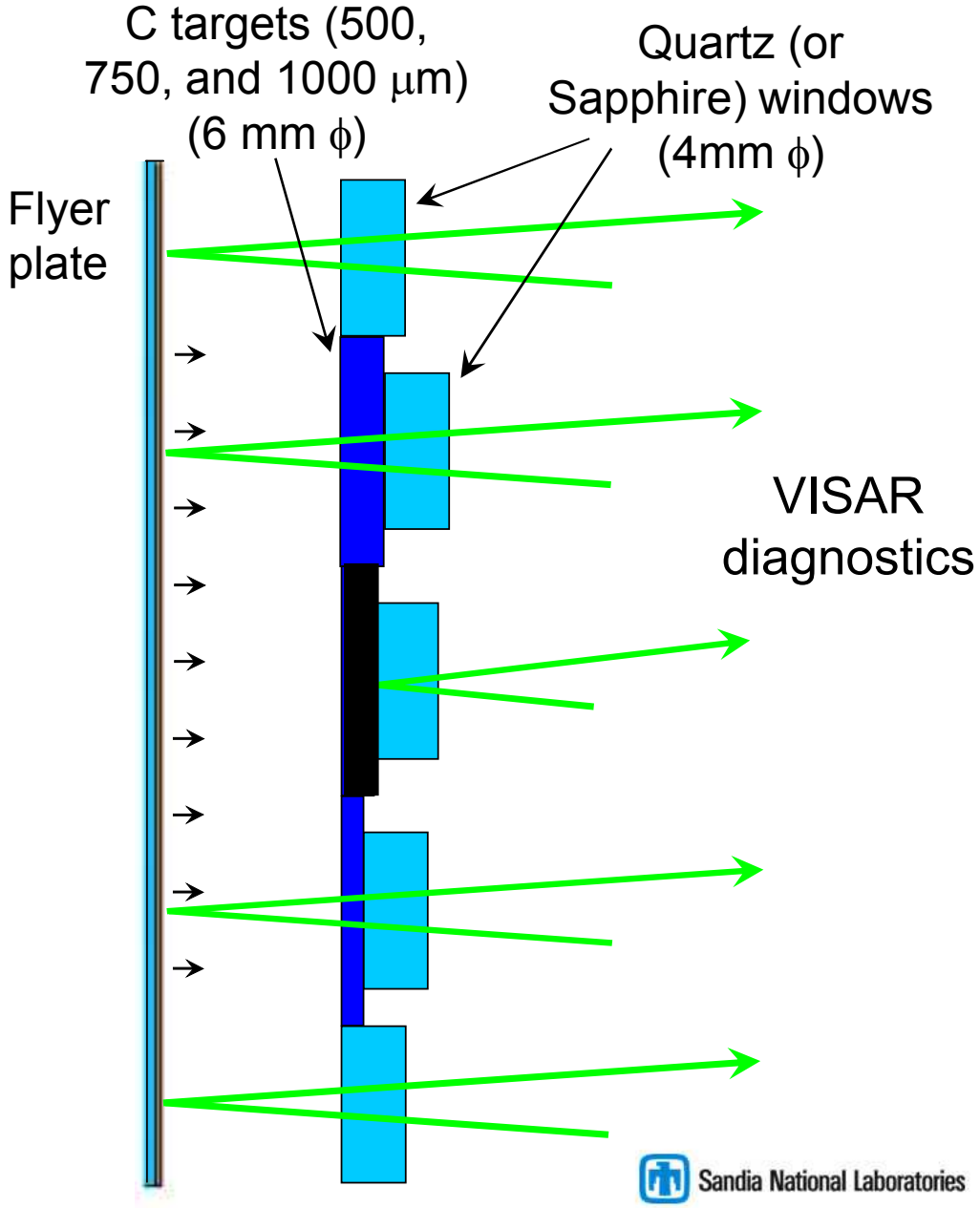
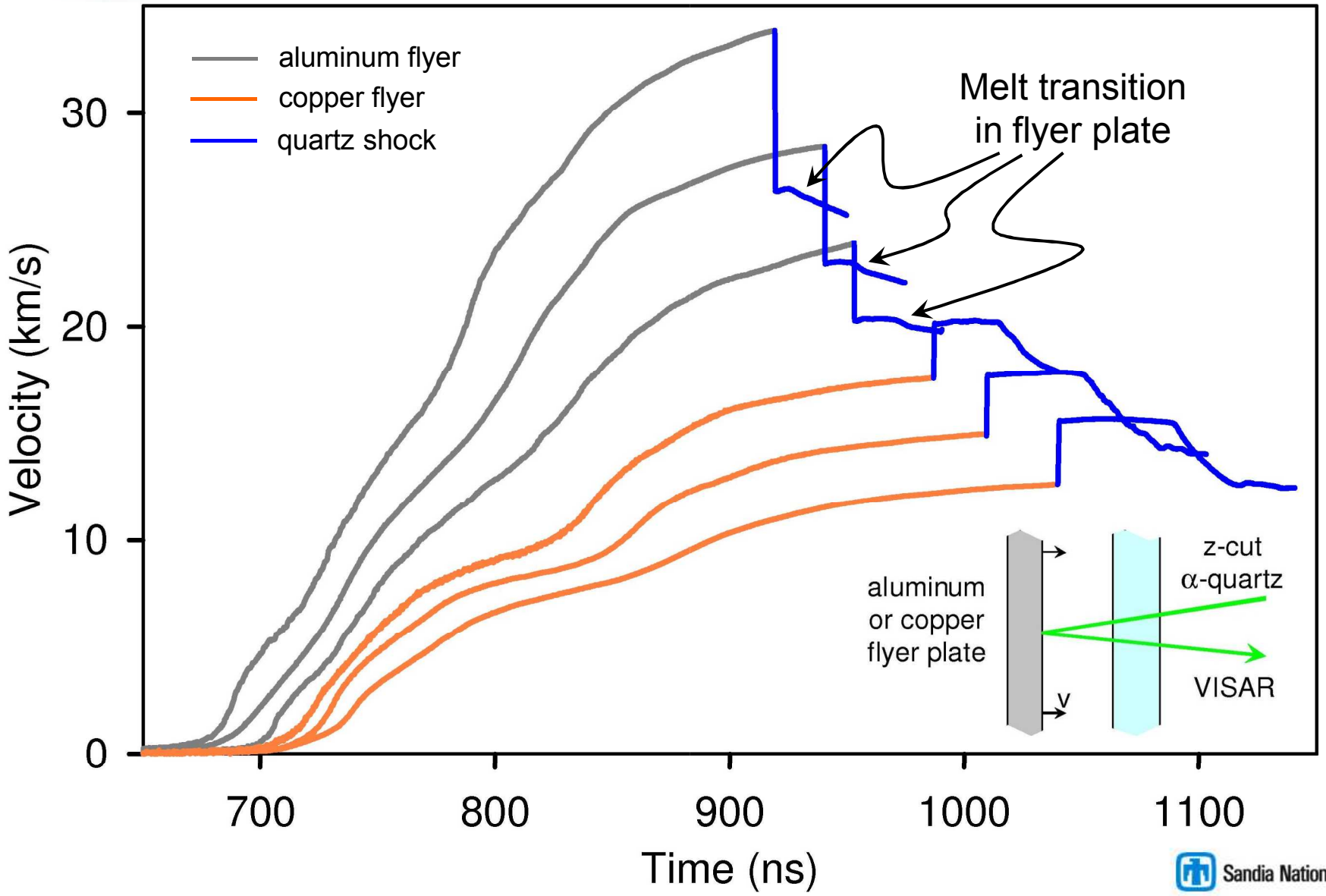
Relatively large flyer plates enabled multiple, redundant measurements increasing accuracy

Diamond experimental configuration



VISAR provides highly accurate in line flyer plate and quartz shock velocity measurements



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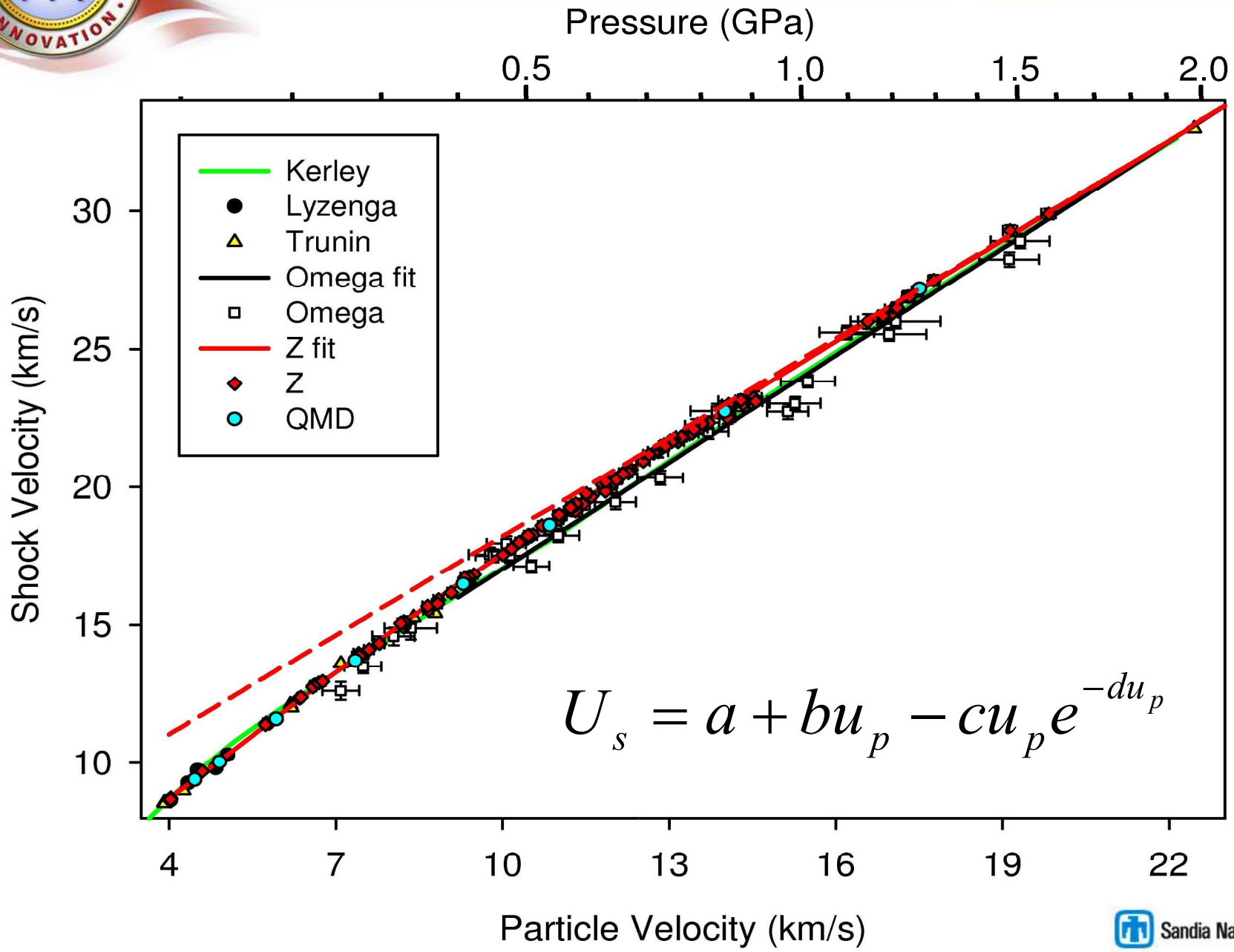
U_s-u_p Hugoniot for α-Quartz



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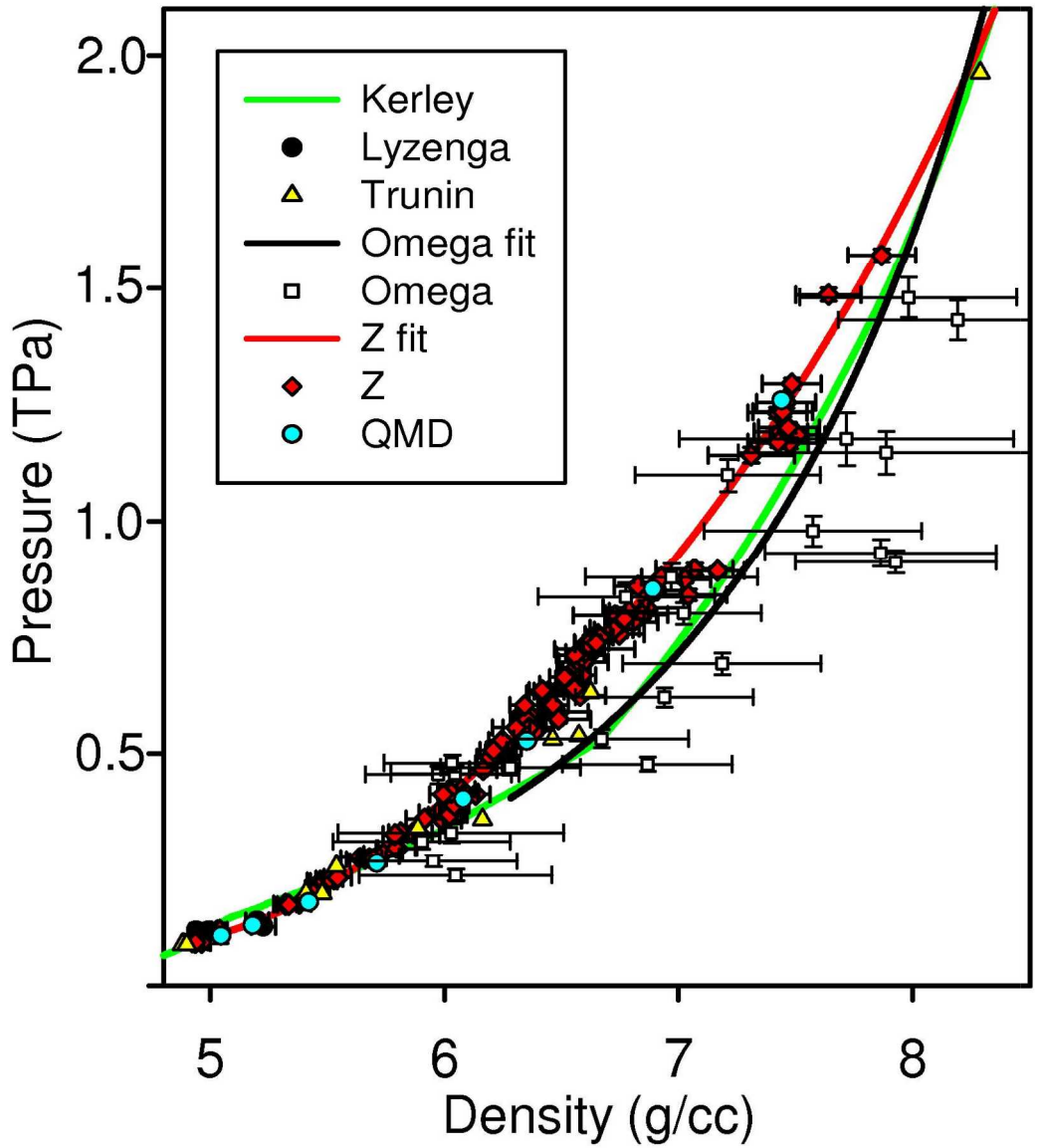
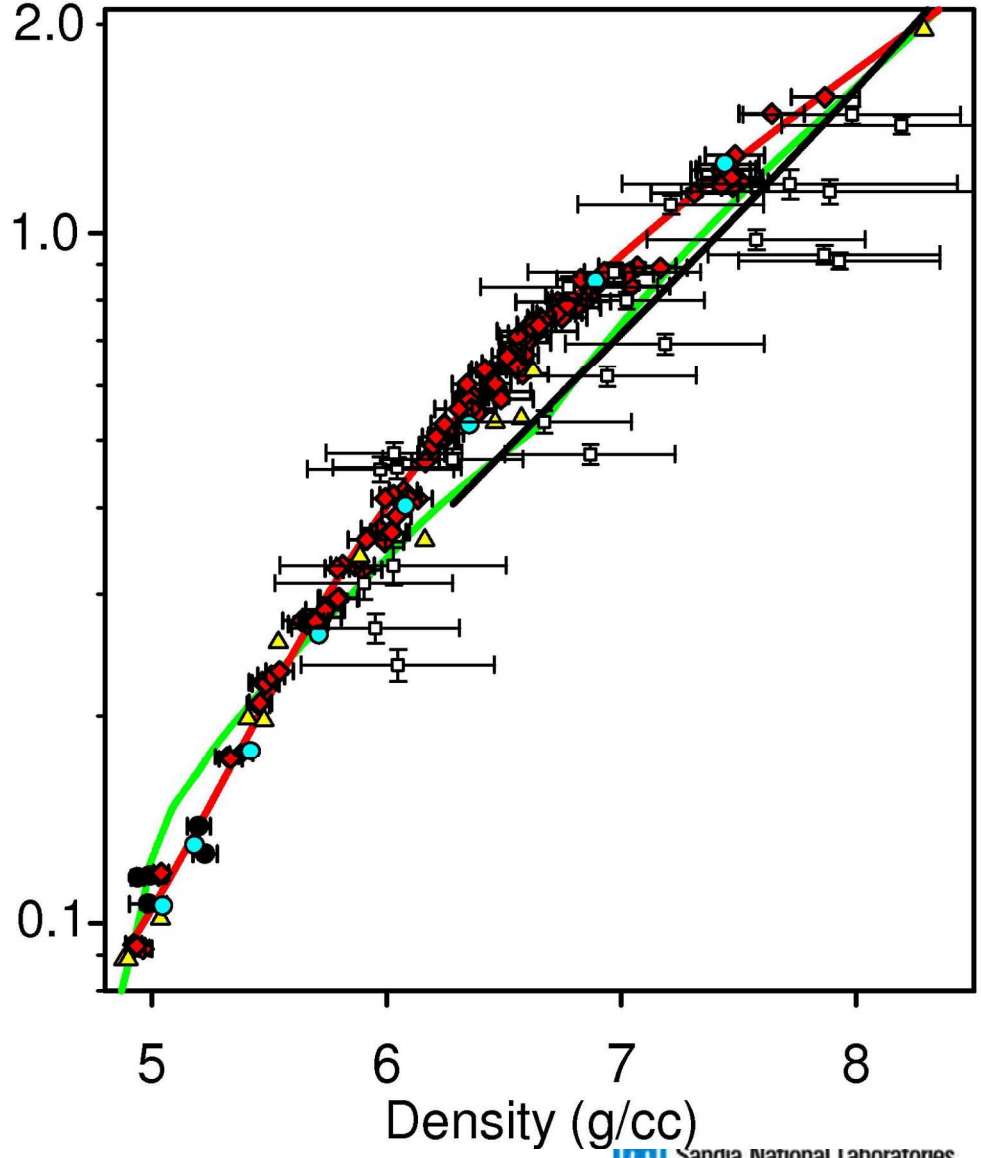
Pressure – density Hugoniot for α-Quartz





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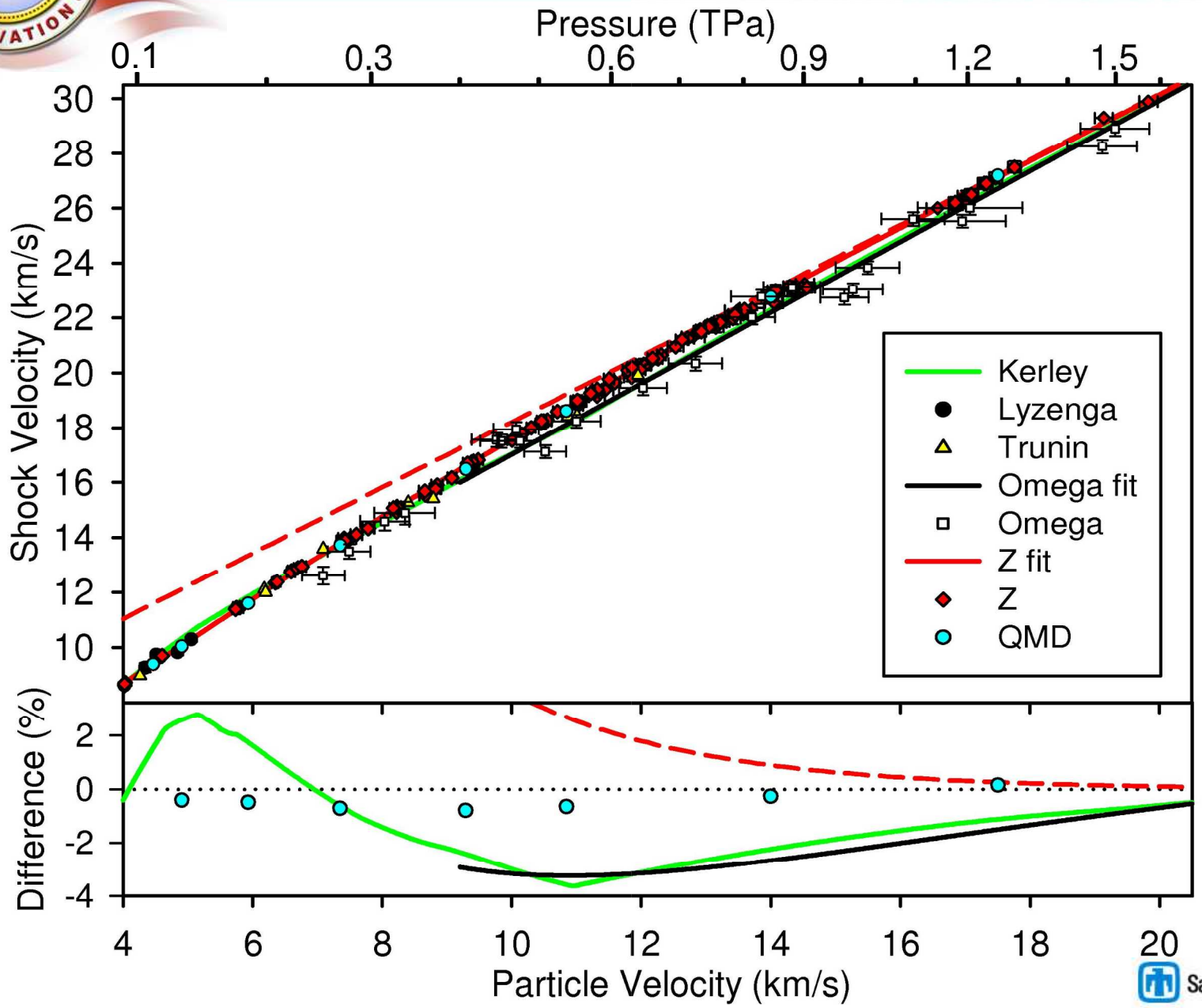
U_s residuals with respect to the Z-fit indicate dissociative effects extend to much higher pressure



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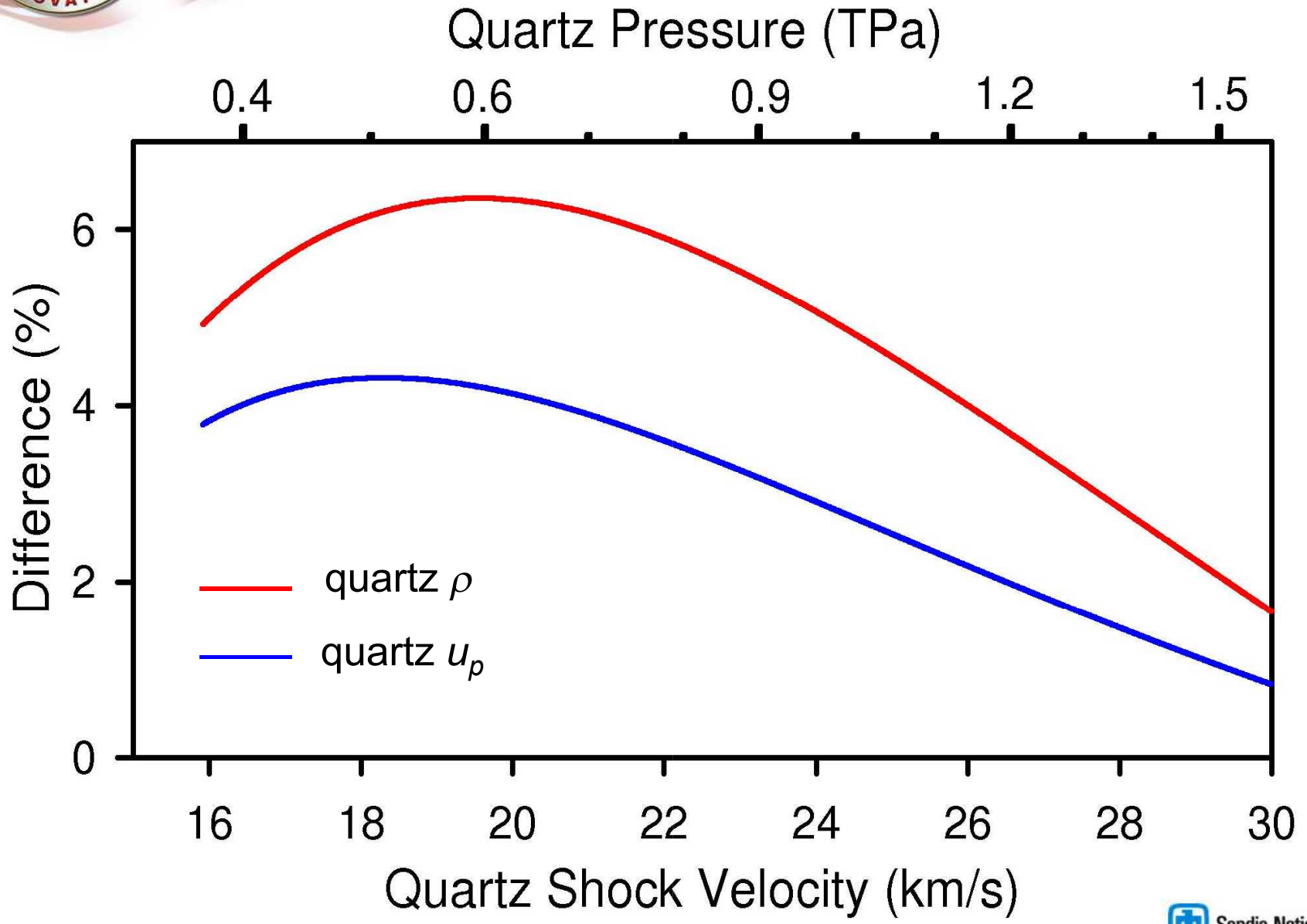
Differences in Z- and Ω-fits will have a significant impact on quantities inferred from quartz U_s



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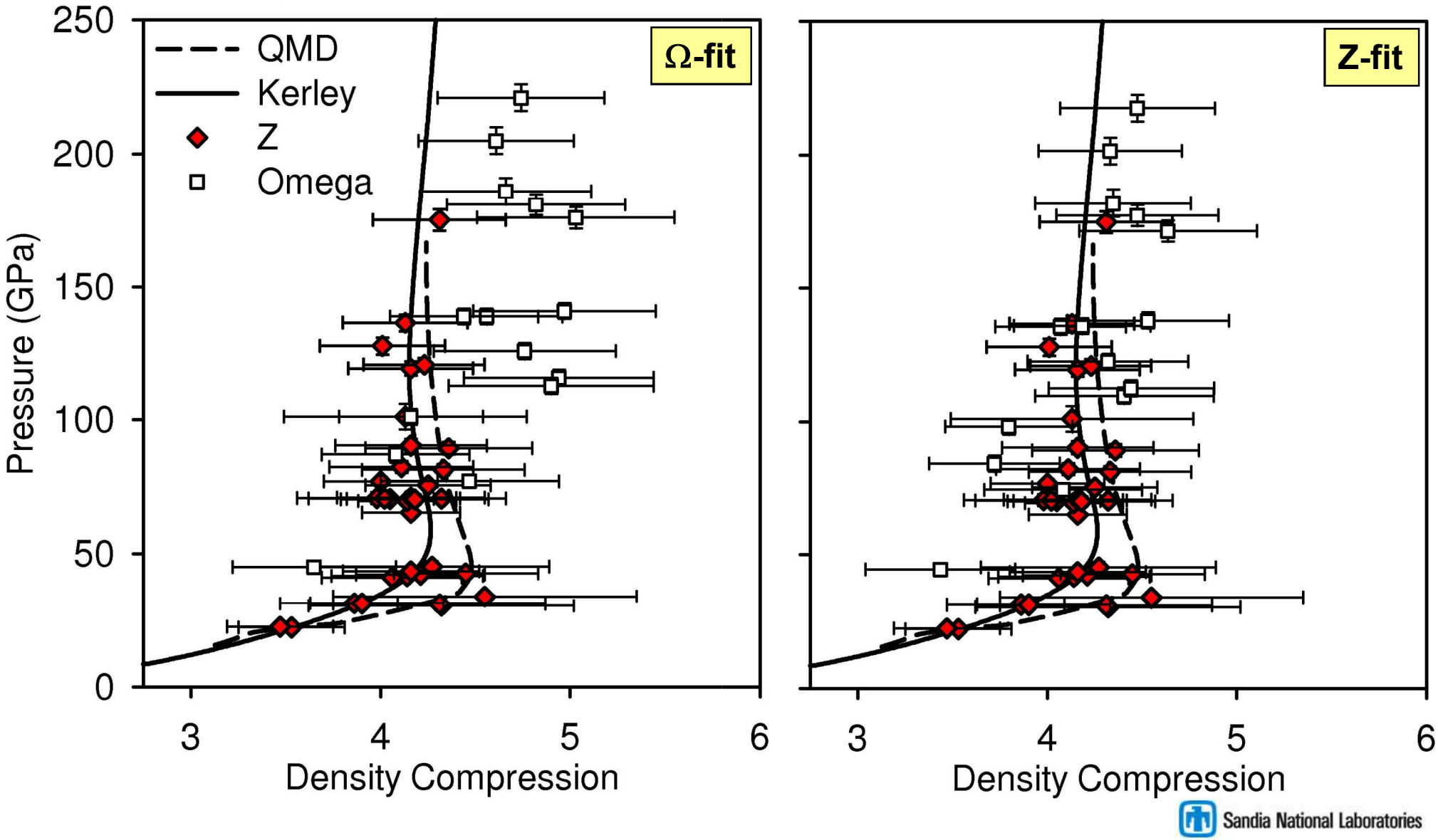
Recently published deuterium data becomes significantly stiffer upon reanalysis



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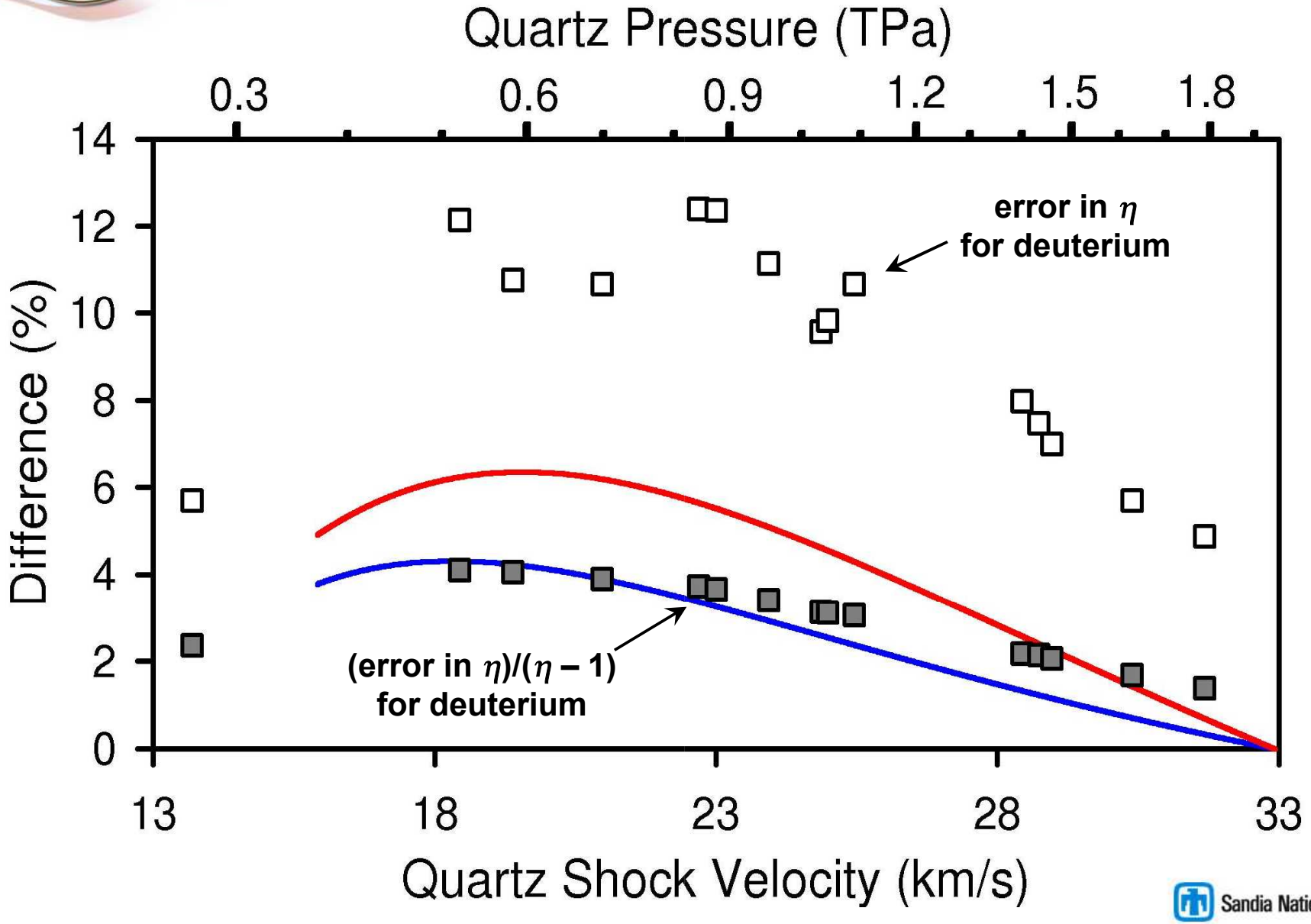
Errors in density compression, η, are given by the error in quartz u_p multiplied by the factor ($\eta - 1$)



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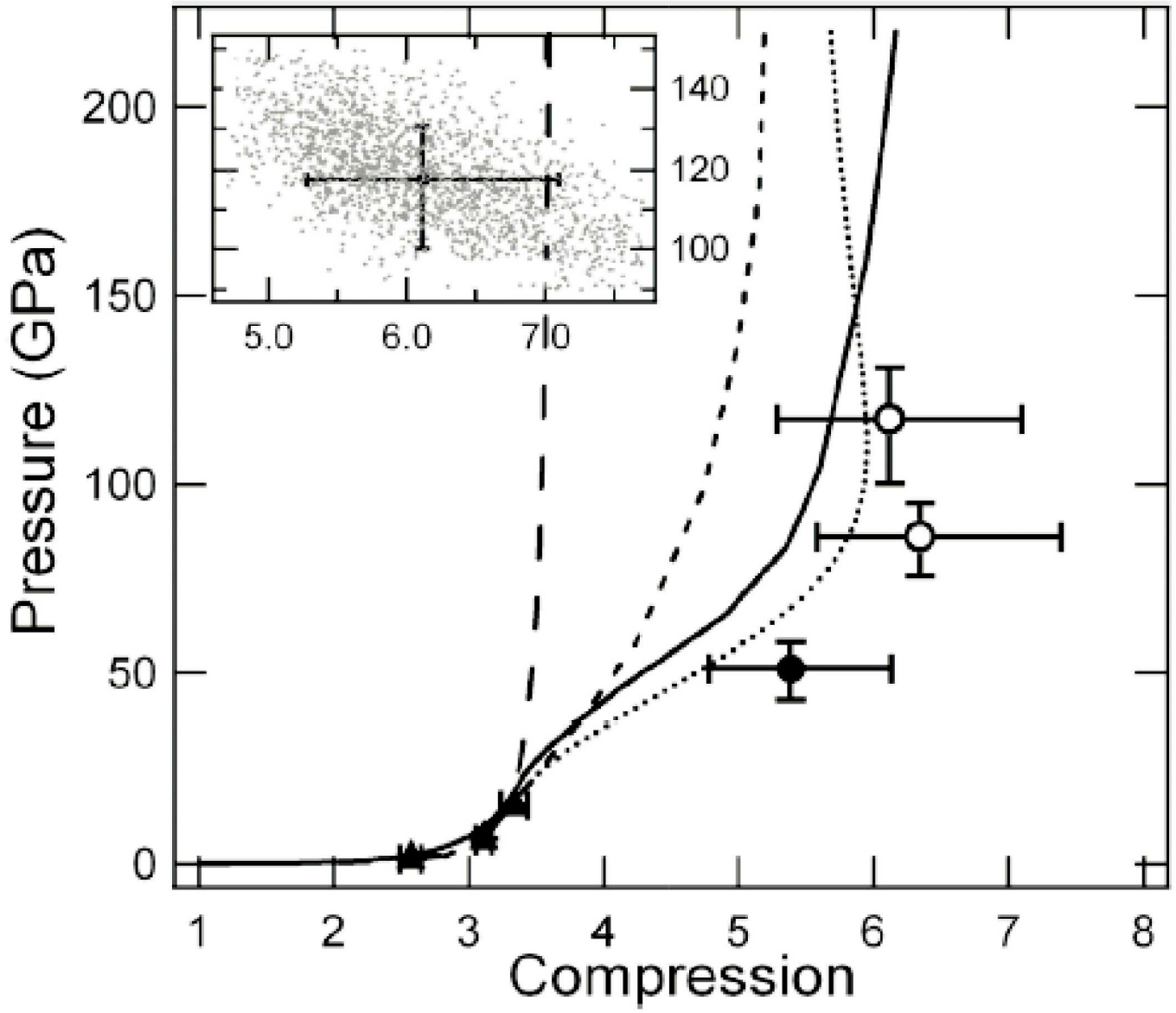
Correction for helium likely even larger given the reported density compression of $\eta > 6$



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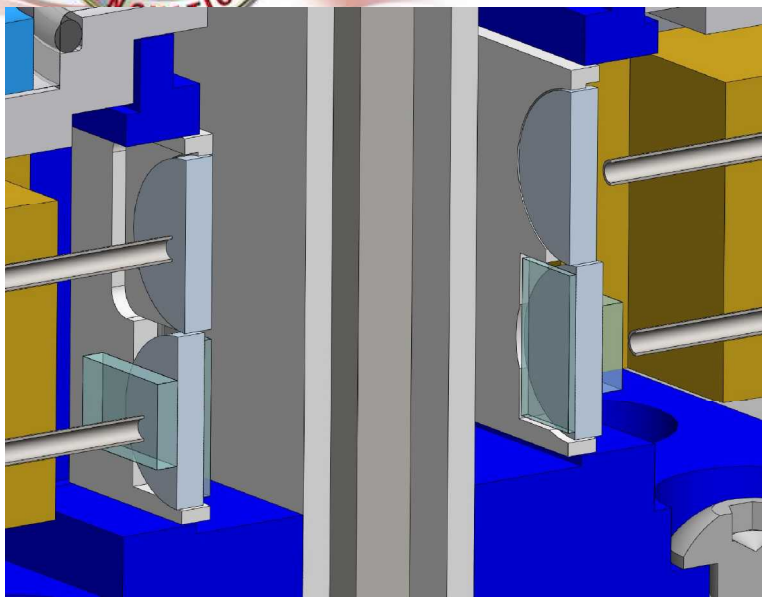
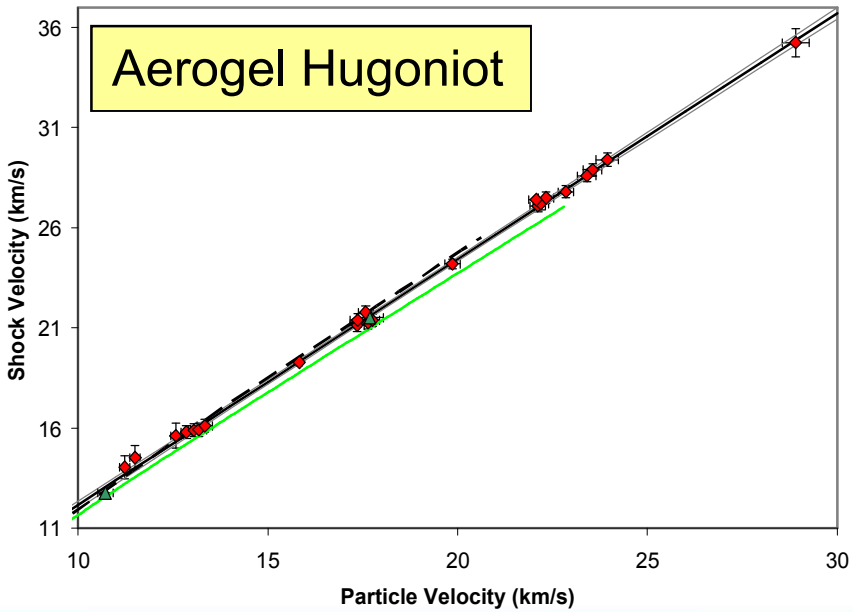
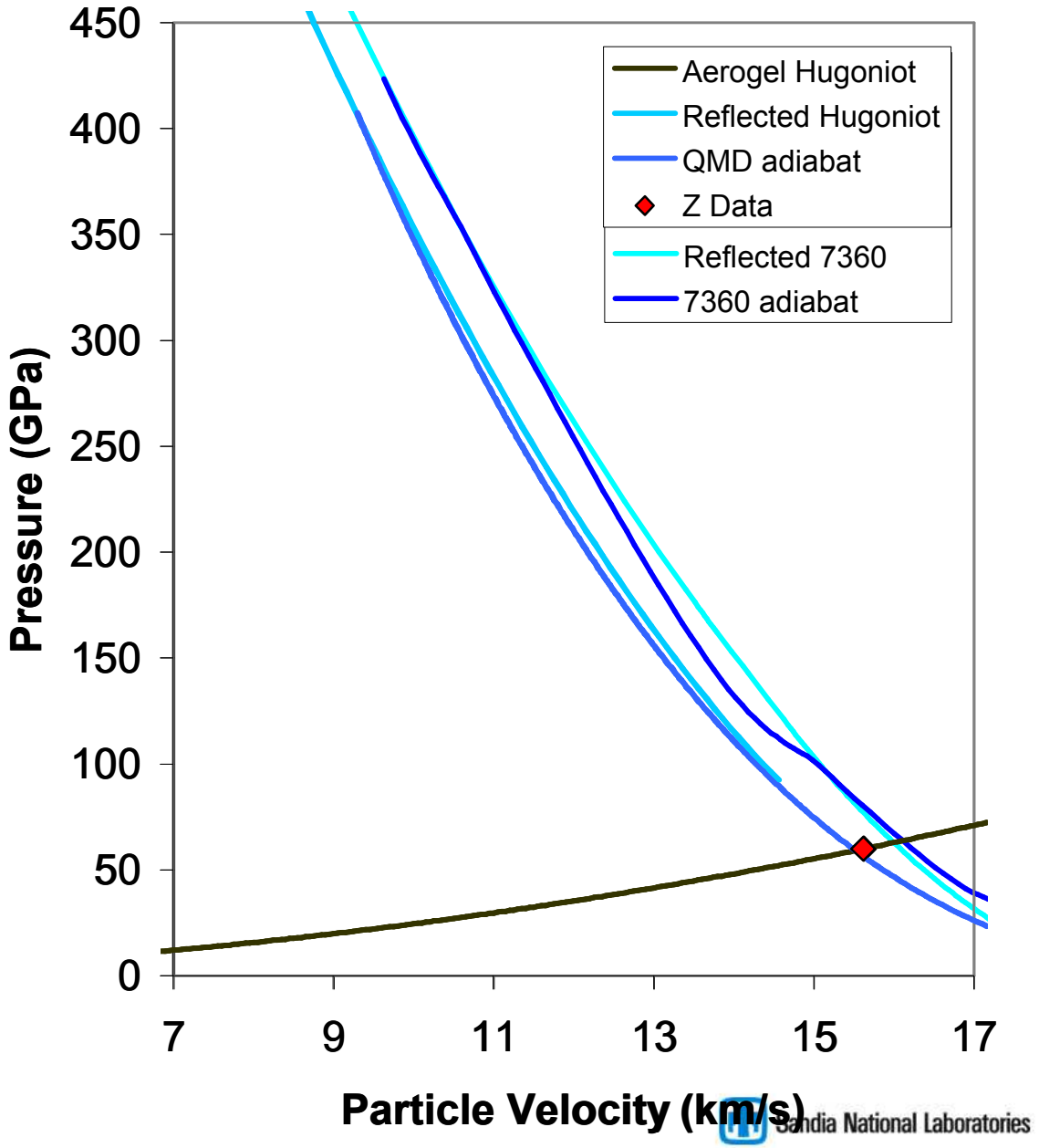
Experiments are underway to evaluate deep release from ~300-800 GPa on the Quartz Hugoniot







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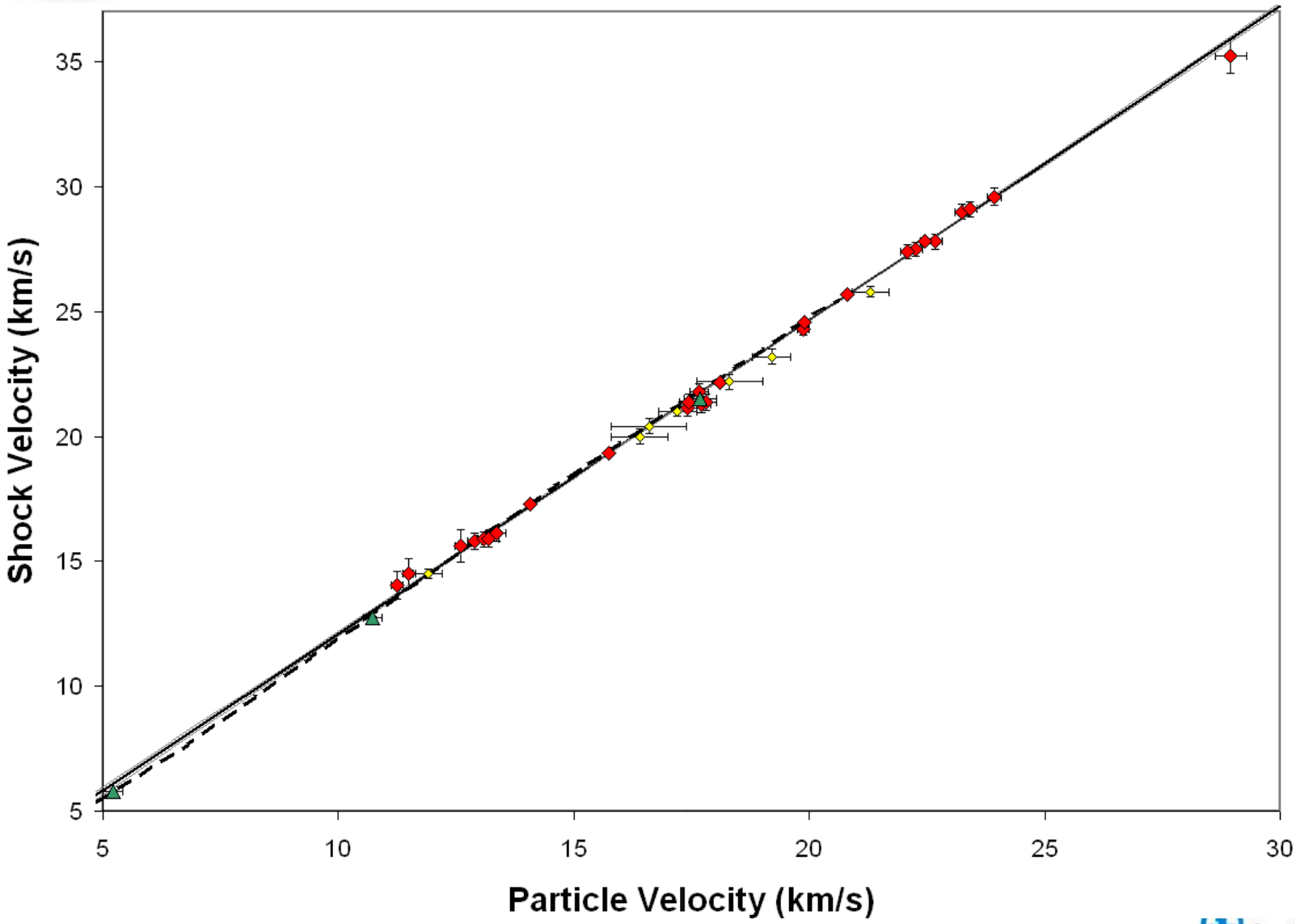
Hugoniot of aerogel



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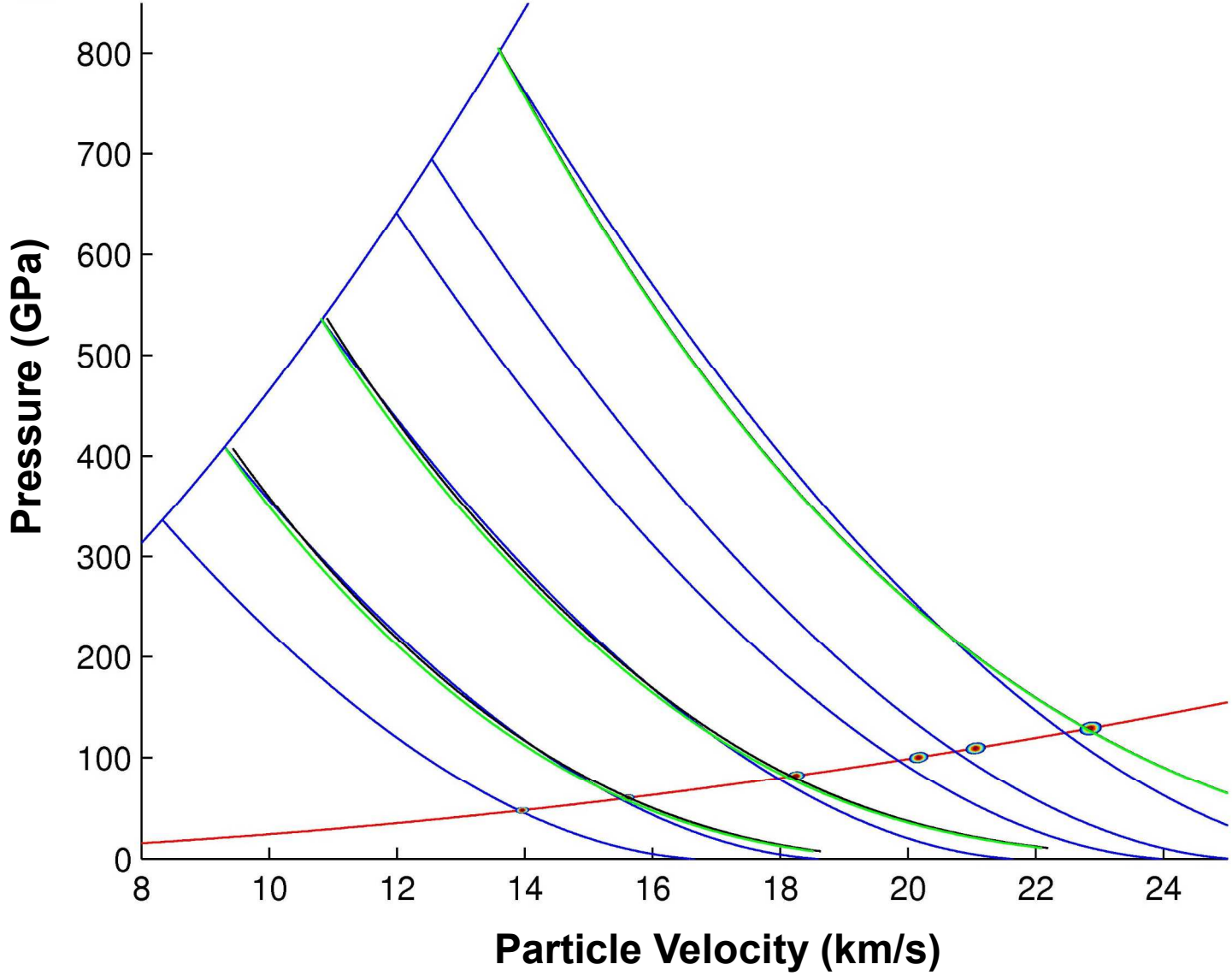
Quartz release measurements



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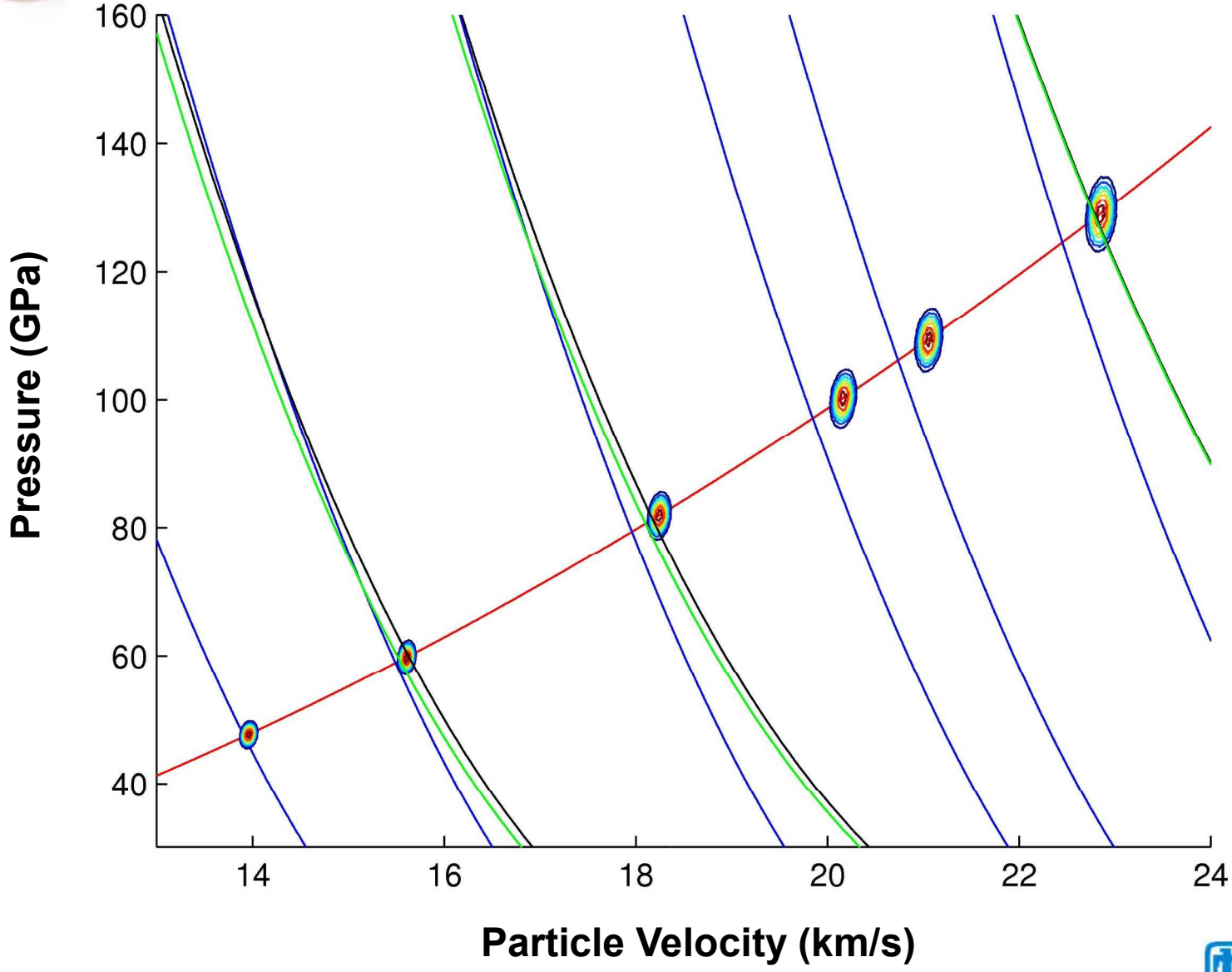
Quantum Molecular Dynamics calculations in good agreement with experiment



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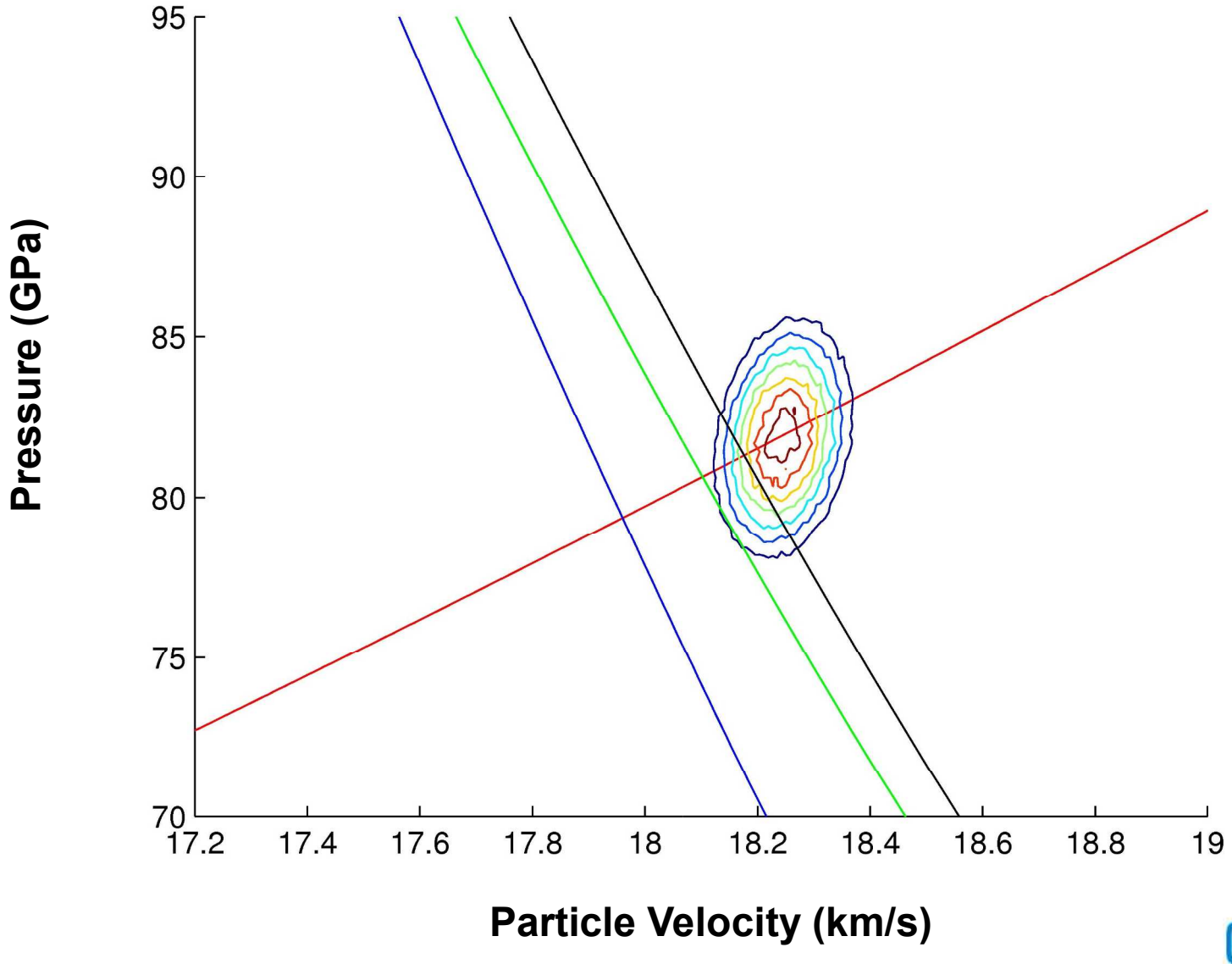

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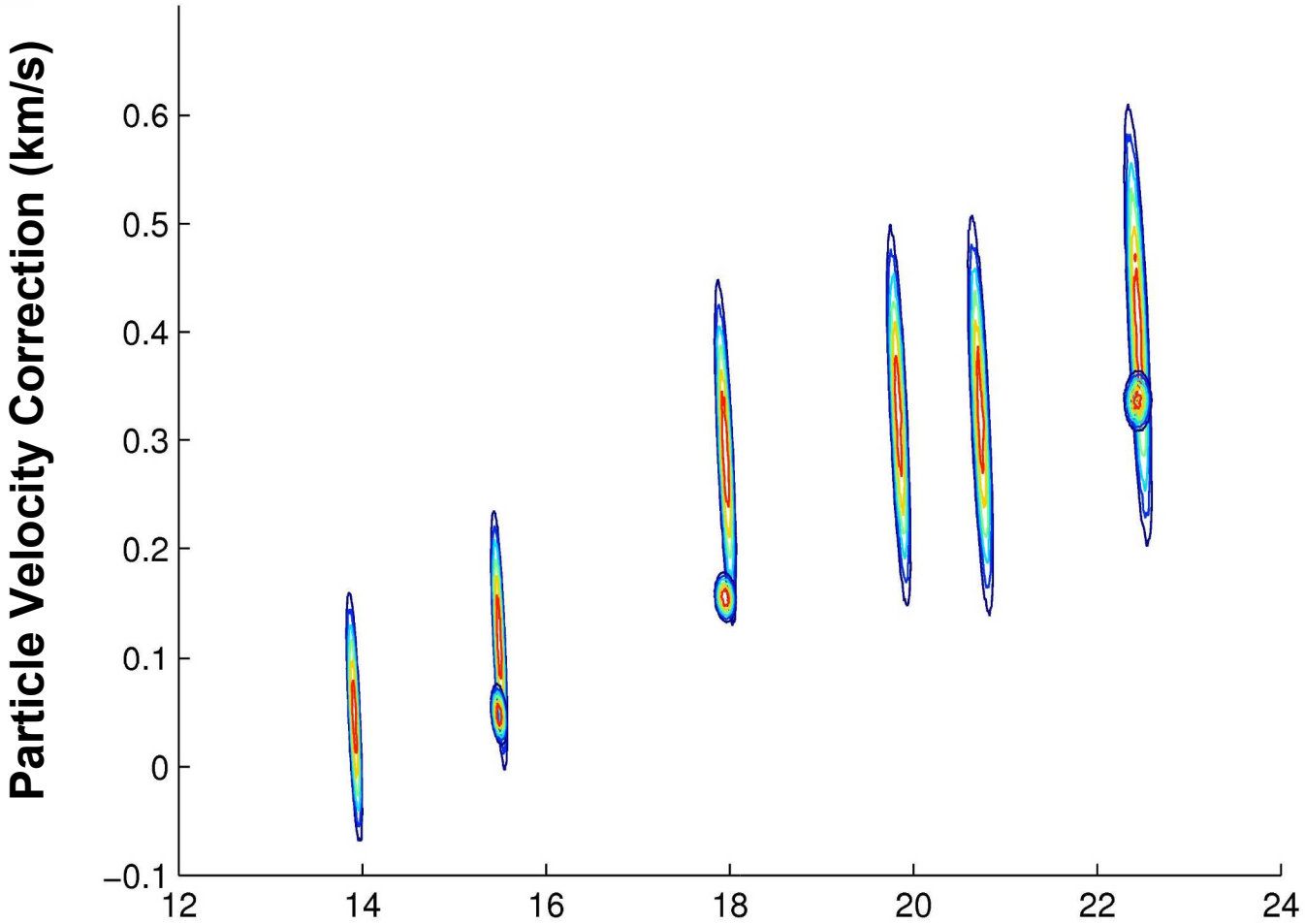

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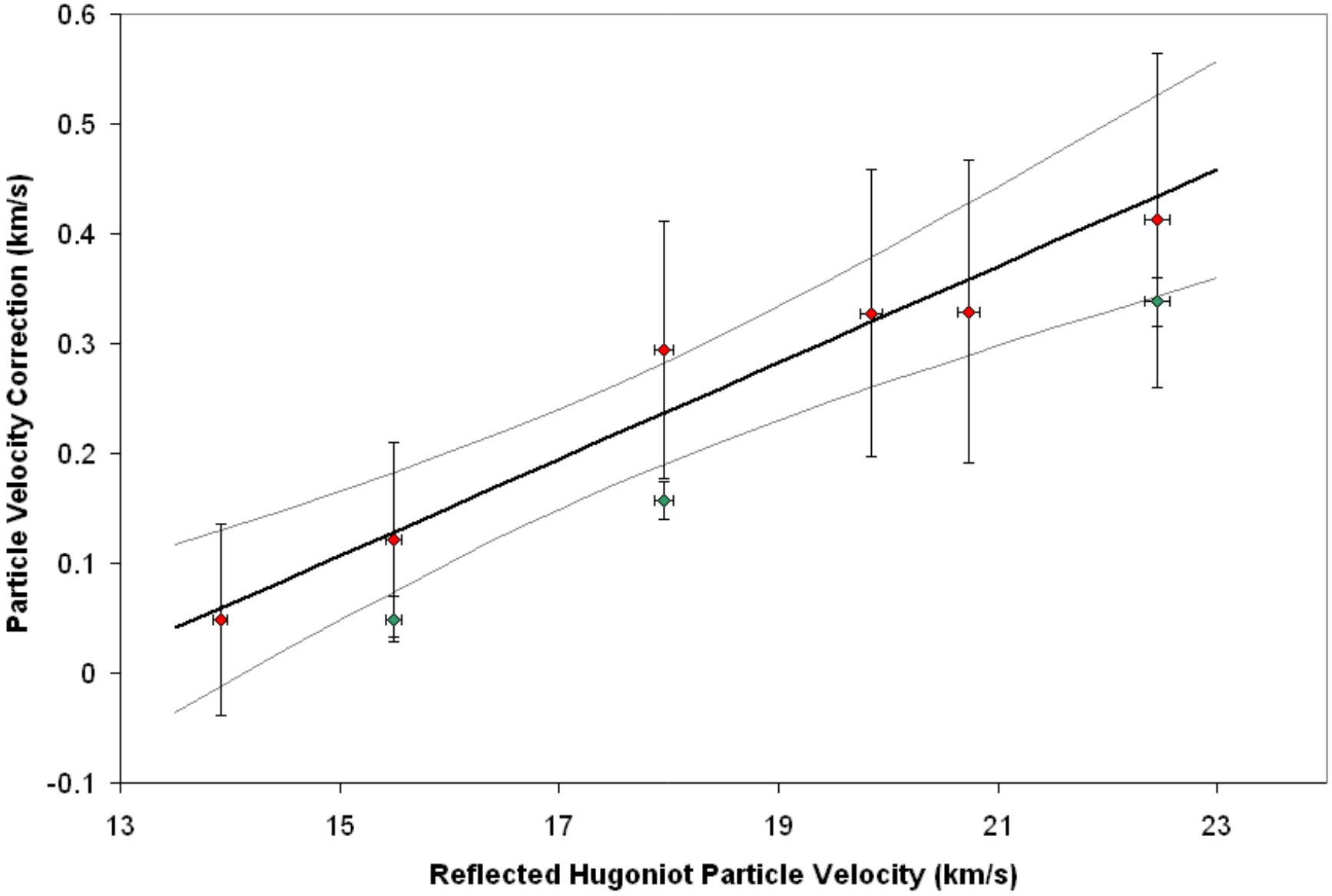
The Z platform provided extremely accurate measurements of the Quartz release



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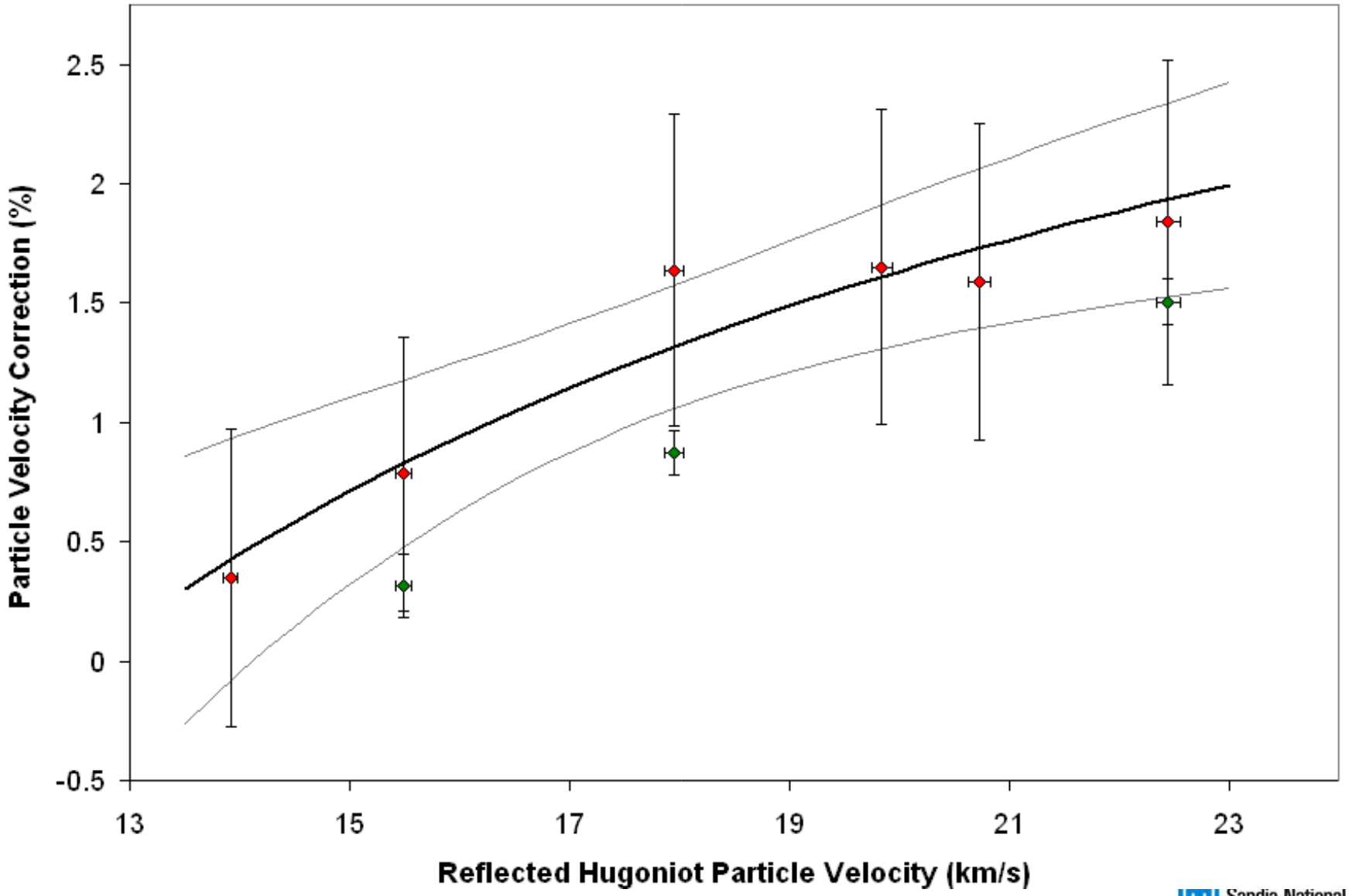

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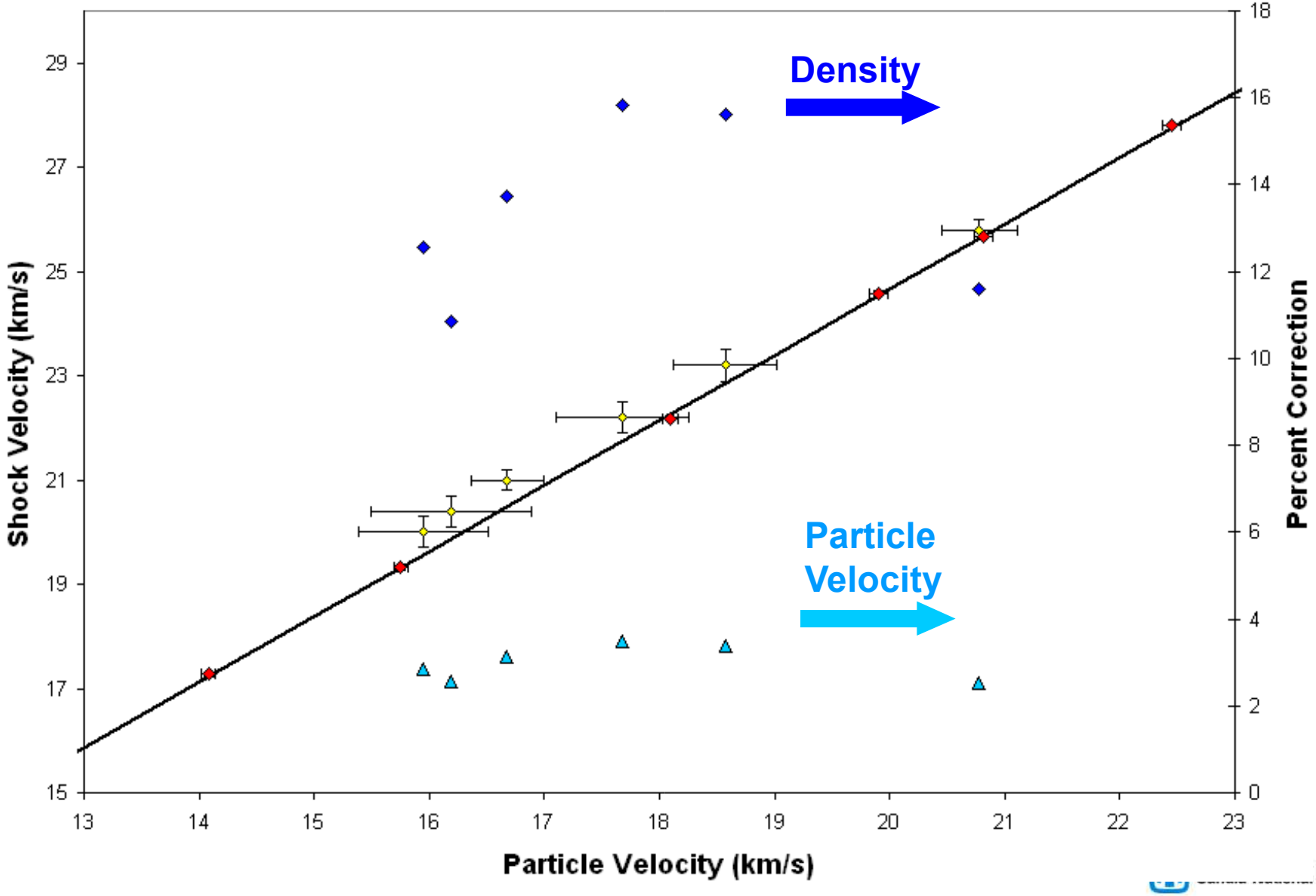
Recent Results from Boehly, et al., demonstrate the potential errors that can be made



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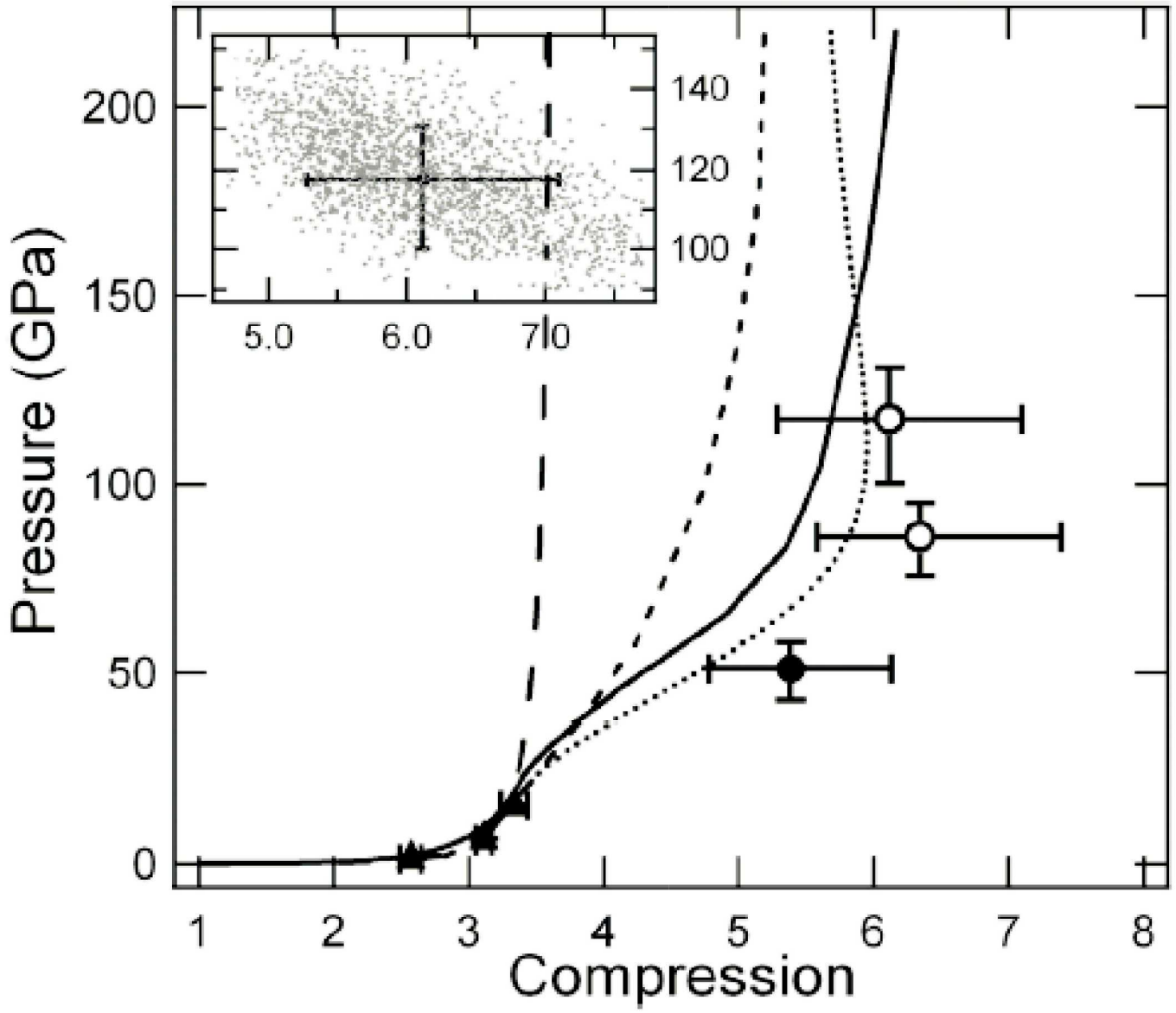

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Conclusions

- α-Quartz
  - Experiments and calculations indicate the energy imprint of disorder and dissociation persist to ~1 TPa
  - These results have significant implications for recently published impedance match data using quartz standard
    - » Correction scales with $(\eta - 1)$
    - » Reanalysis of recent deuterium results suggest Z and laser platforms are in agreement, and that η is slightly greater than 4 to 250 GPa