SAND2014-17922PE

Characterization of the release response of alpha-quartz in the multi-Mbar regime for use as an impedance match standard

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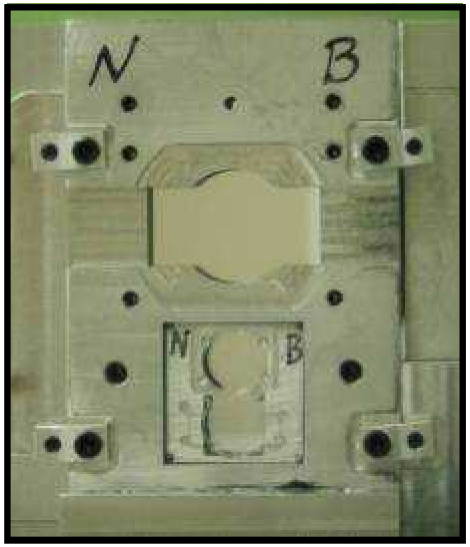

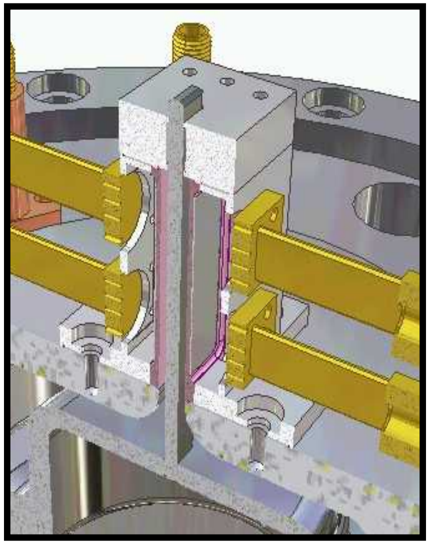

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  - Flyer plate design and MHD simulations
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  - Bertha model, pulse shaping
- Charlie Meyer, Devon Dalton, Dustin Romero, Anthony Romero, entire Z crew…
  - Experiment support

Ktech CORP.

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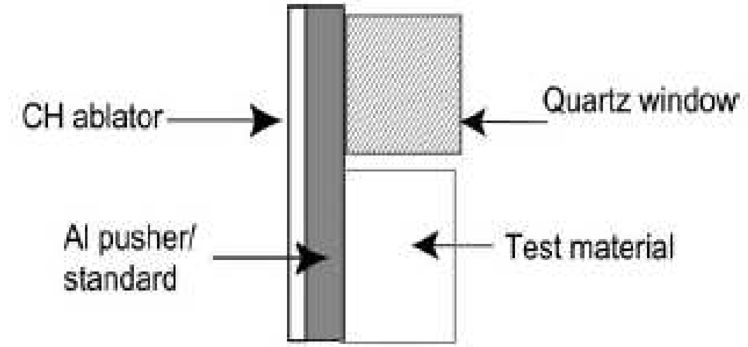
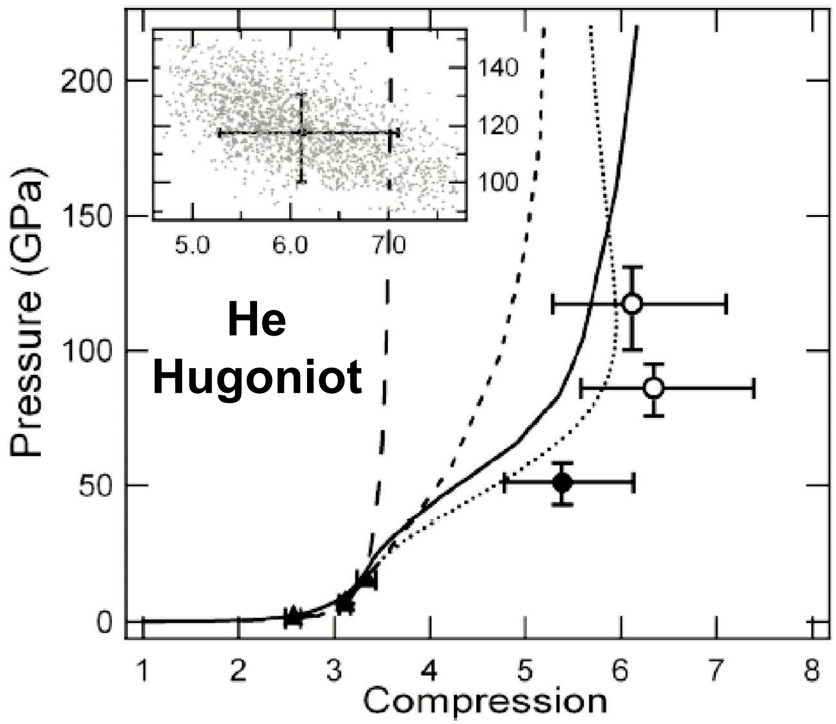
Motivation for α-Quartz measurements

- 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, water, xenon, krypton, carbon dioxde, …
- For accurate results there is a need to understand the off-Hugoniot response of quartz
  - In particular the quartz release response is needed for use with lower impedance materials

APPENDIX: DEVELOPMENT OF QUARTZ AS AN IMPEDANCE-MATCH STANDARD





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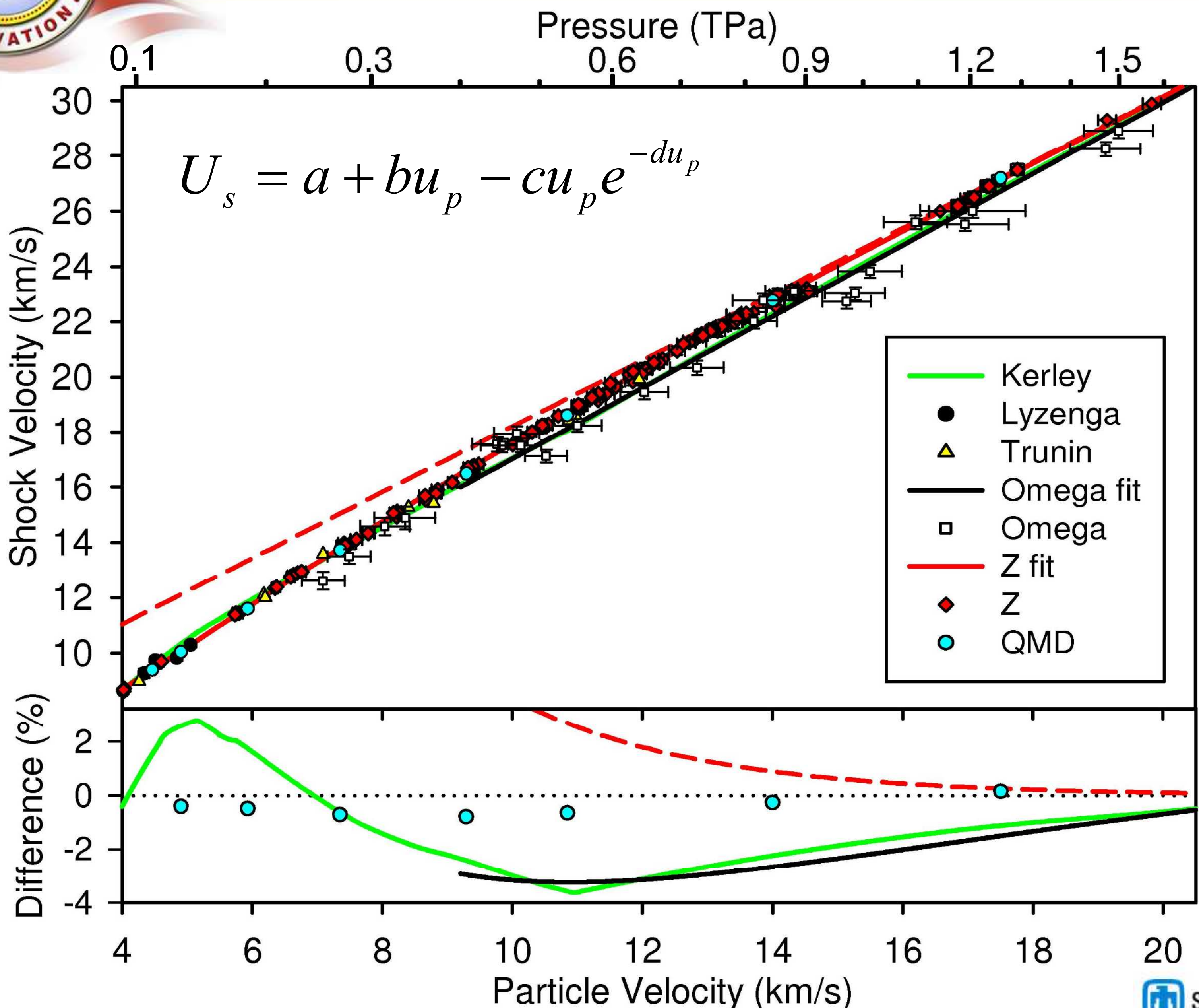
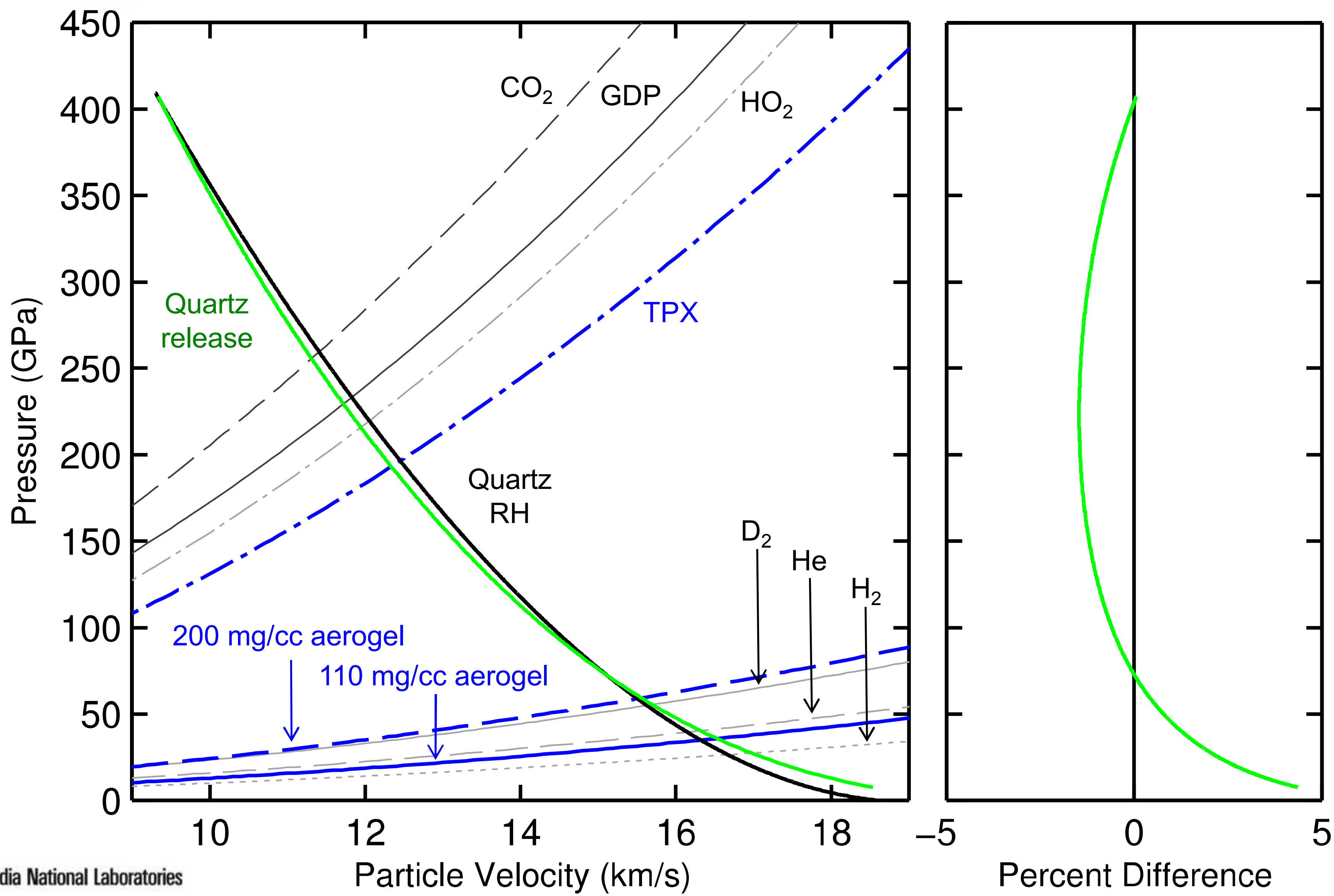
U_s-u_p Hugoniot for α-Quartz



Knudson and Desjarlais, PRL **103**, 225501 (2009)

Corrections to Reflected Hugoniot not insignificant and change sign depending on sample impedance



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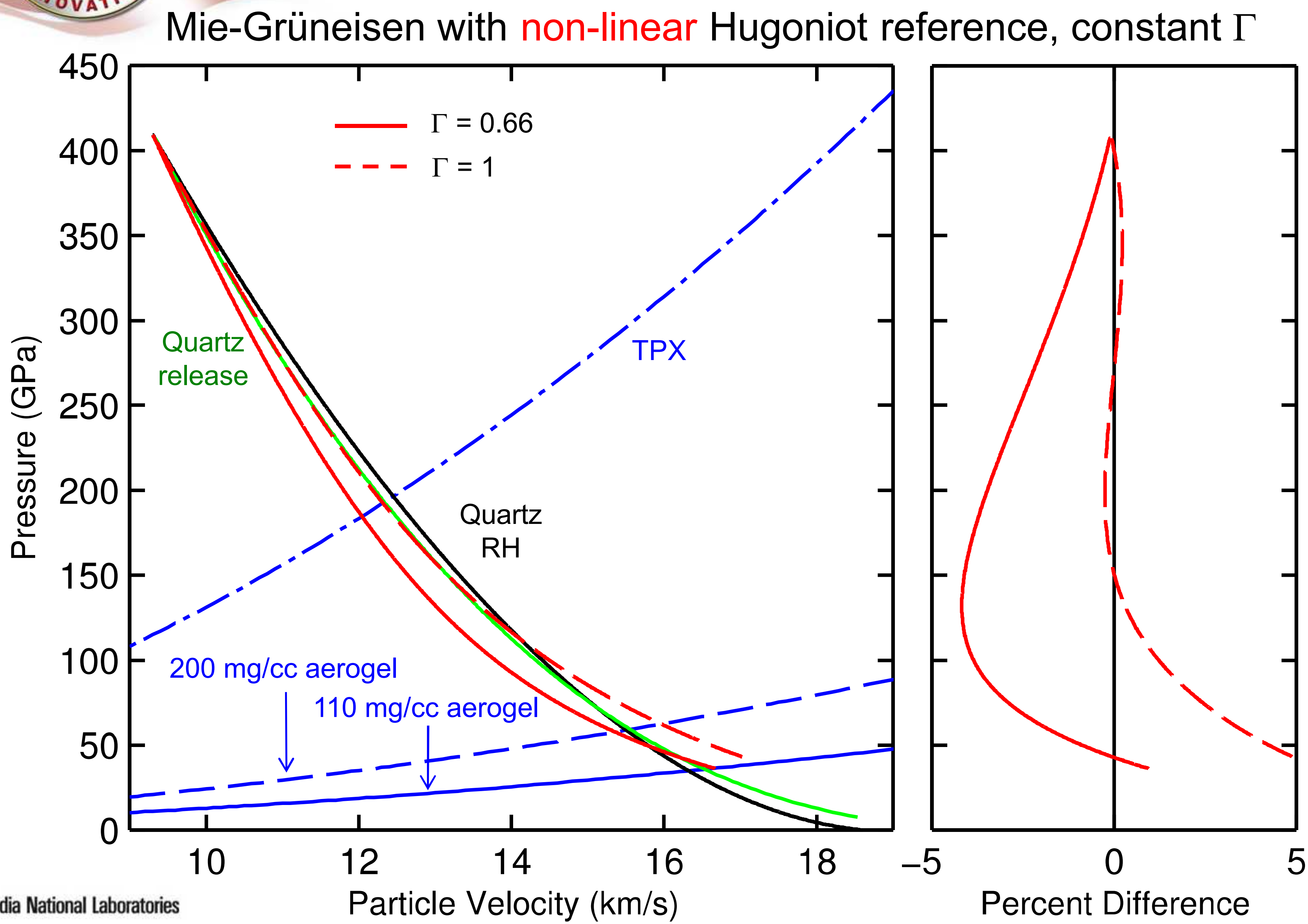
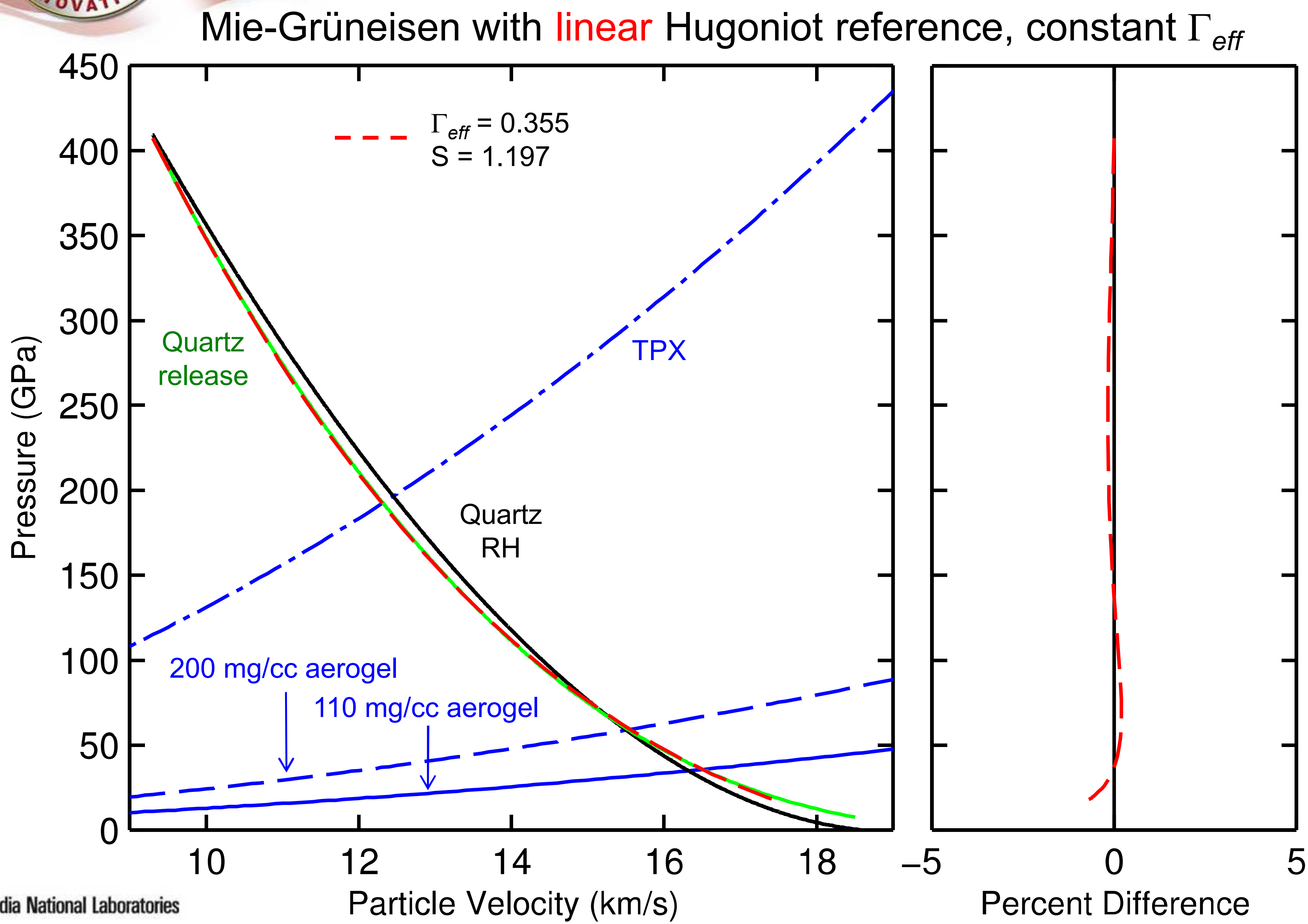
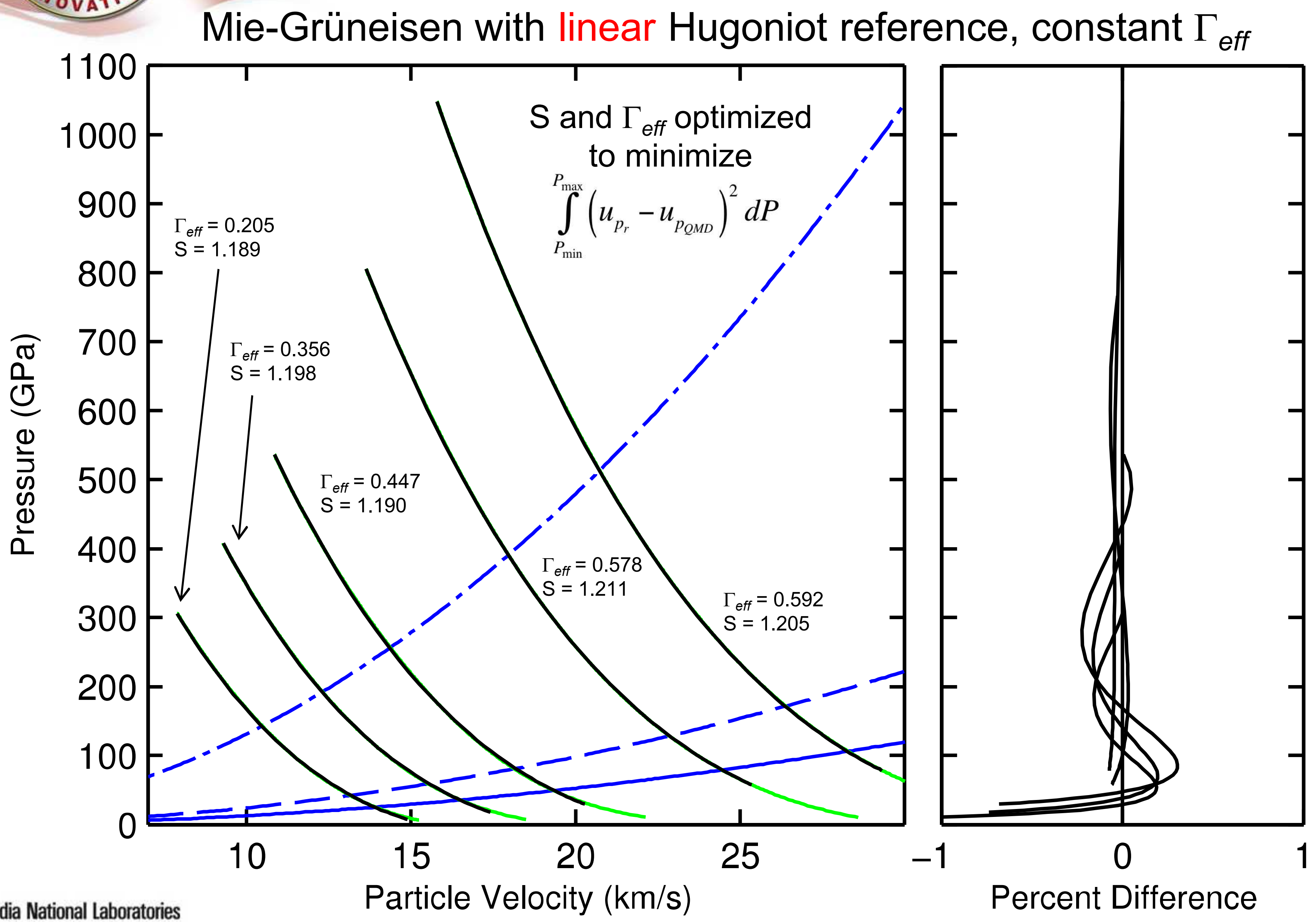
Mie-Grüneisen, constant Γ with *non-linear* reference does not provide adequate description of release



Mie-Grüneisen, constant Γ_{eff} with *linear* reference shows remarkable agreement with QMD release



Mie-Grüneisen, constant Γ_{eff} with *linear* reference agrees over large extent of the quartz Hugoniot



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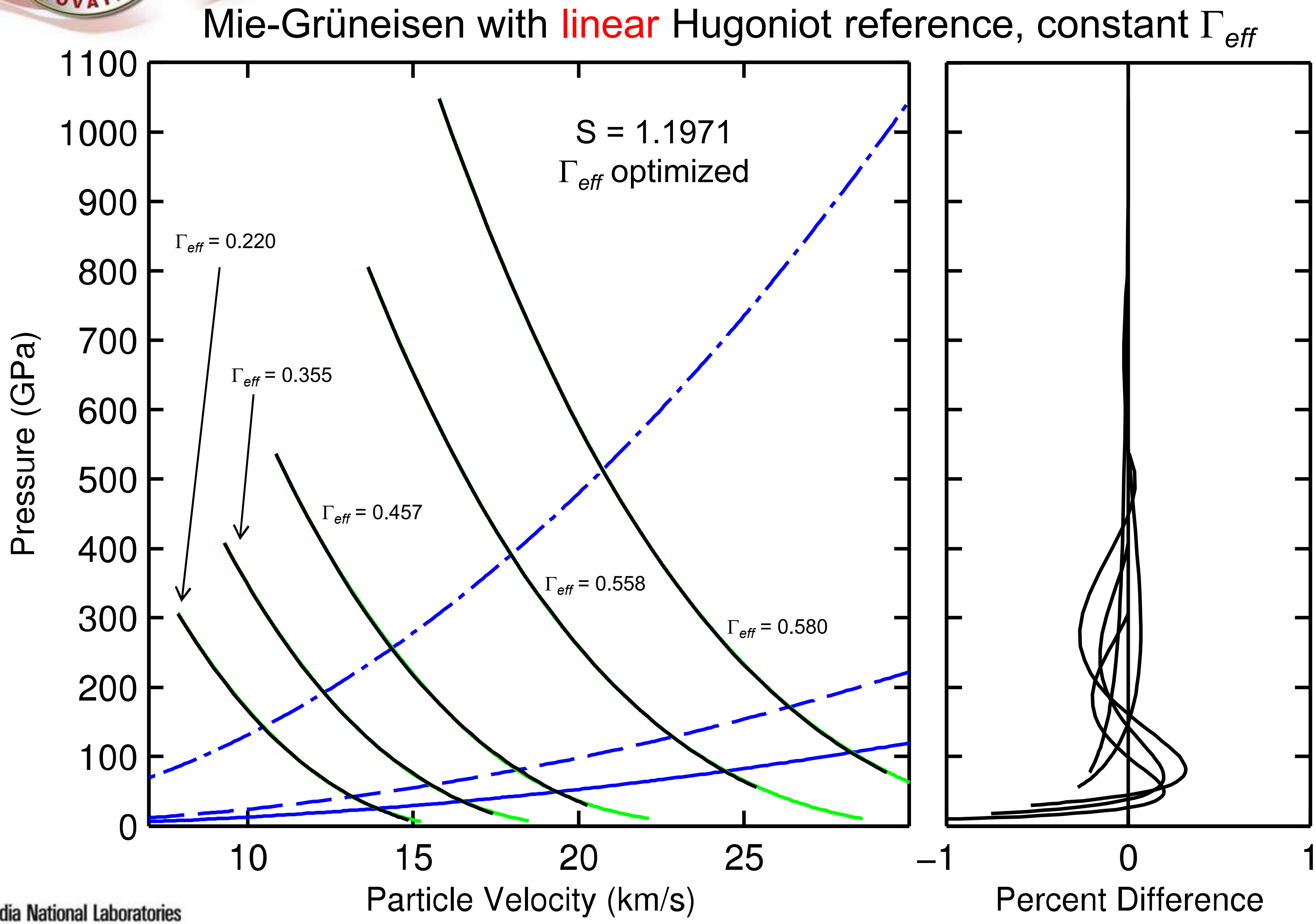
Mie-Grüneisen, constant Γ_{eff} with *linear* reference and fixed S negligibly degrades level of agreement



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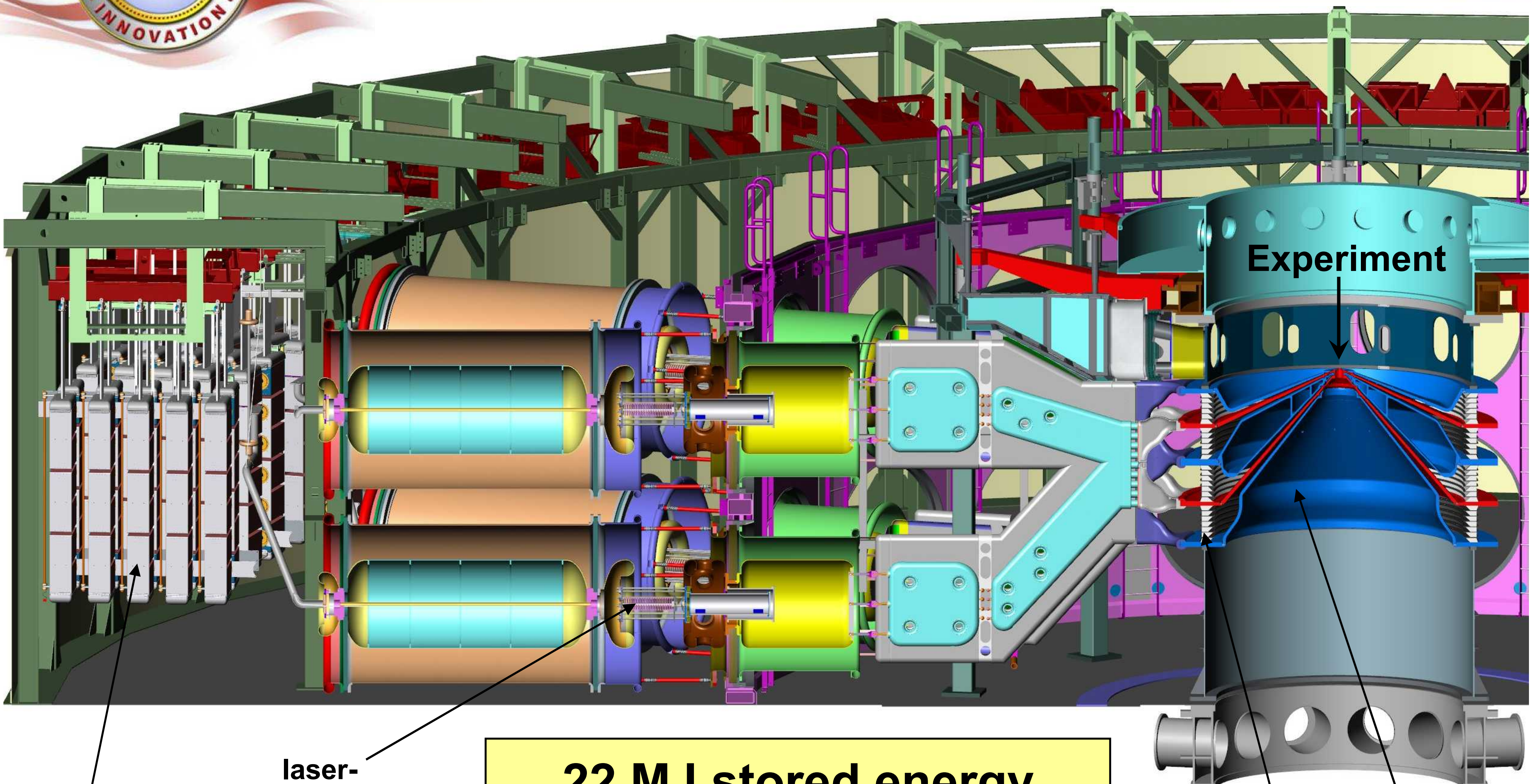
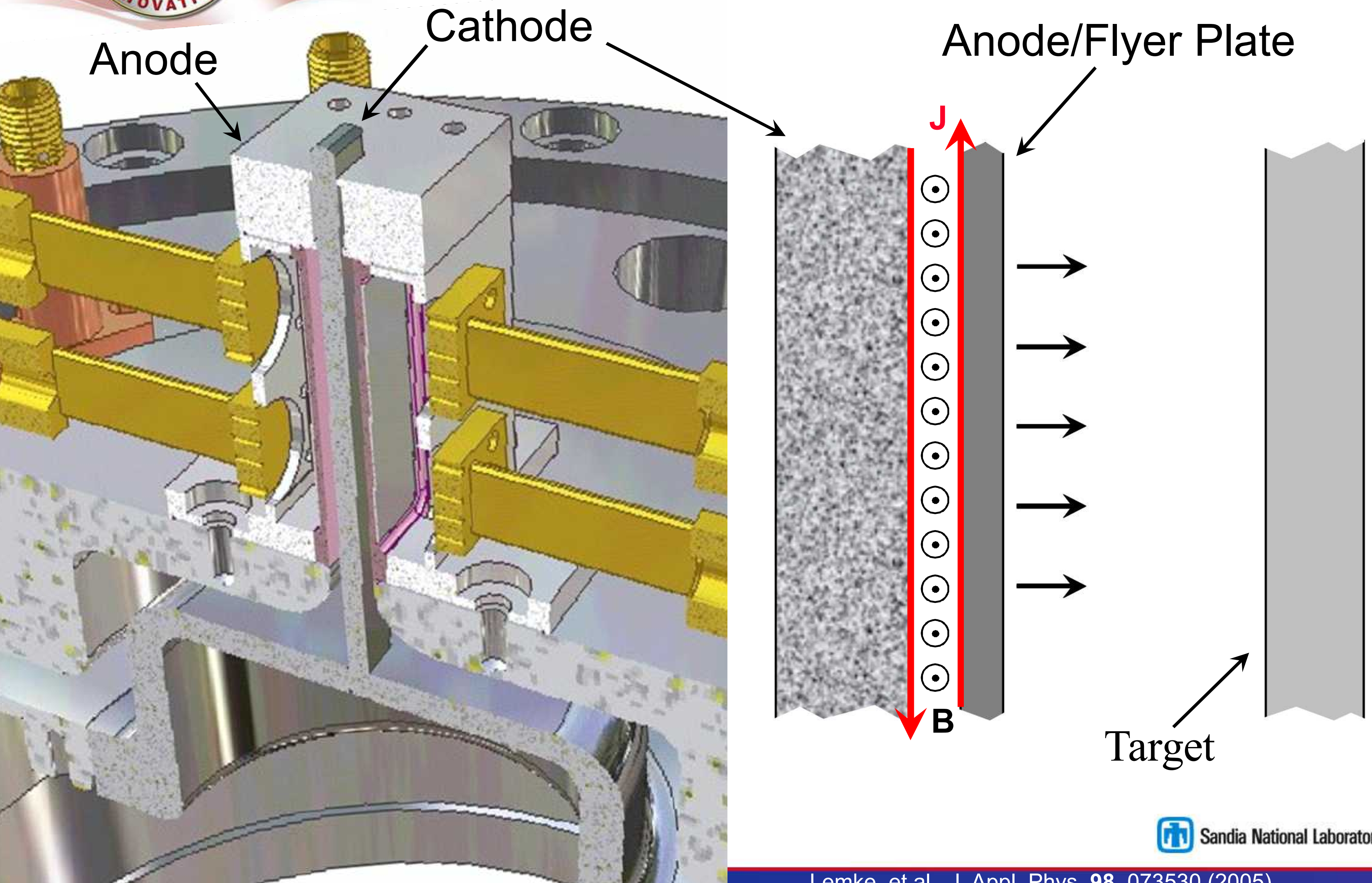
The Sandia Z Machine



22 MJ stored energy
~25 MA peak current
~200-600 ns rise time

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



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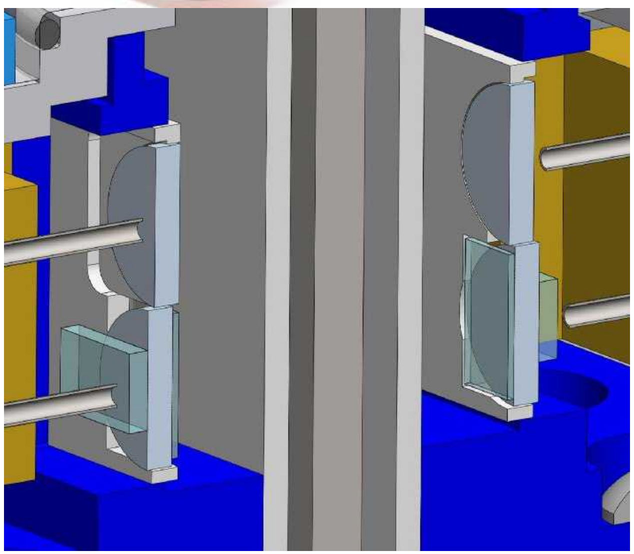
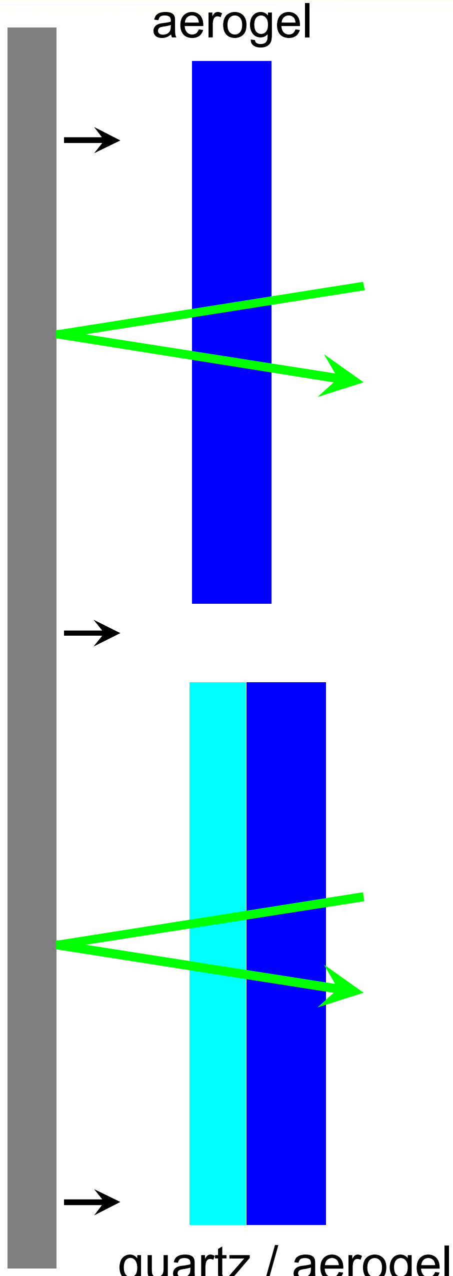
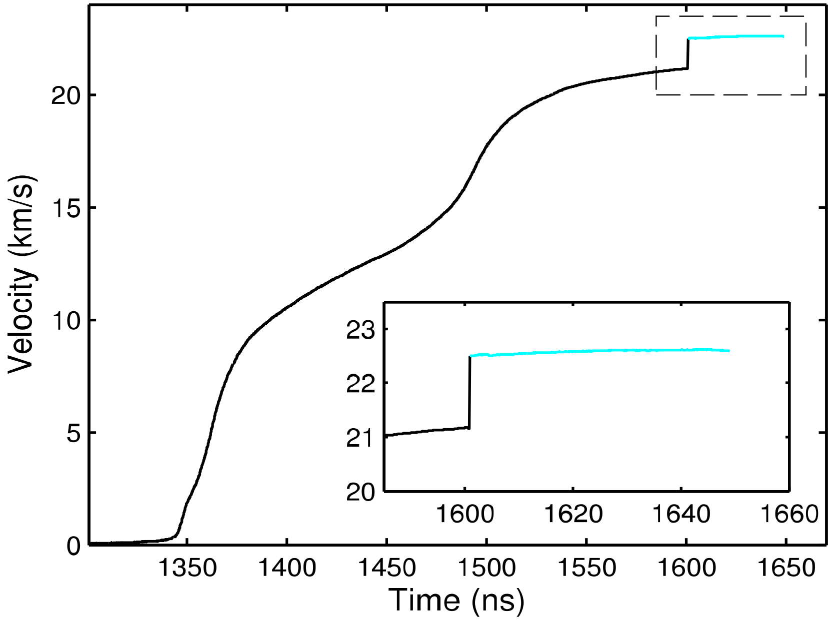
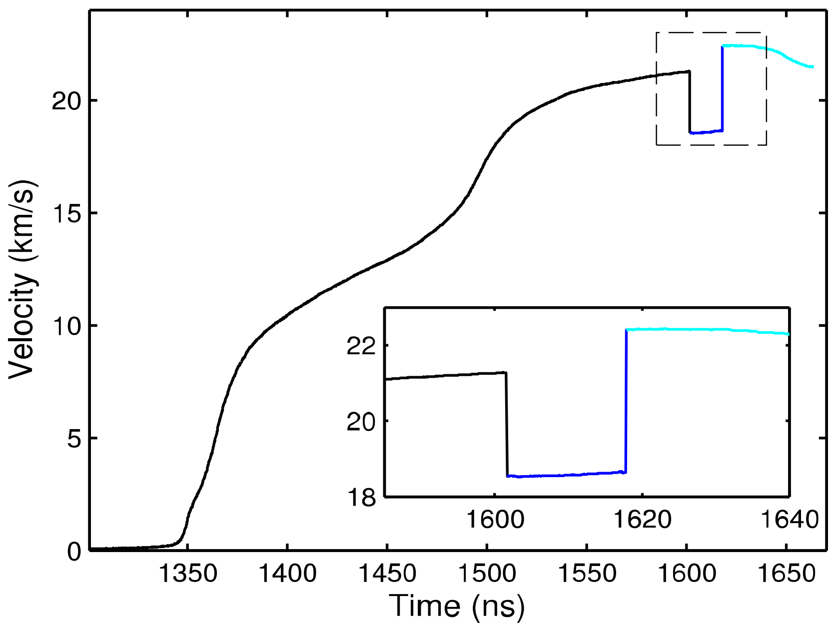
The same experiment provides Hugoniot and release measurements via velocity interferometry

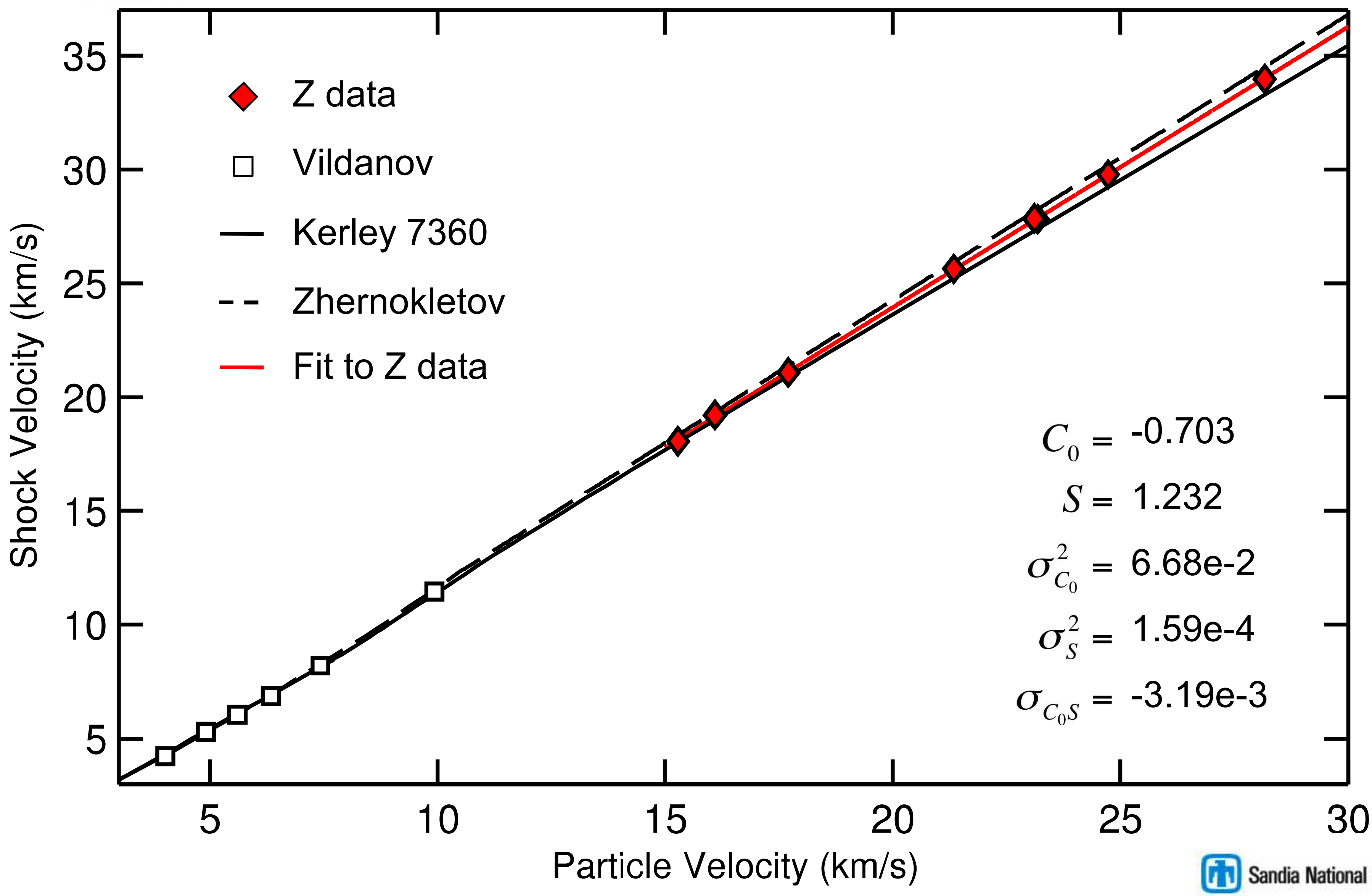








~110 mg/cc silica aerogel U_s-u_p Hugoniot



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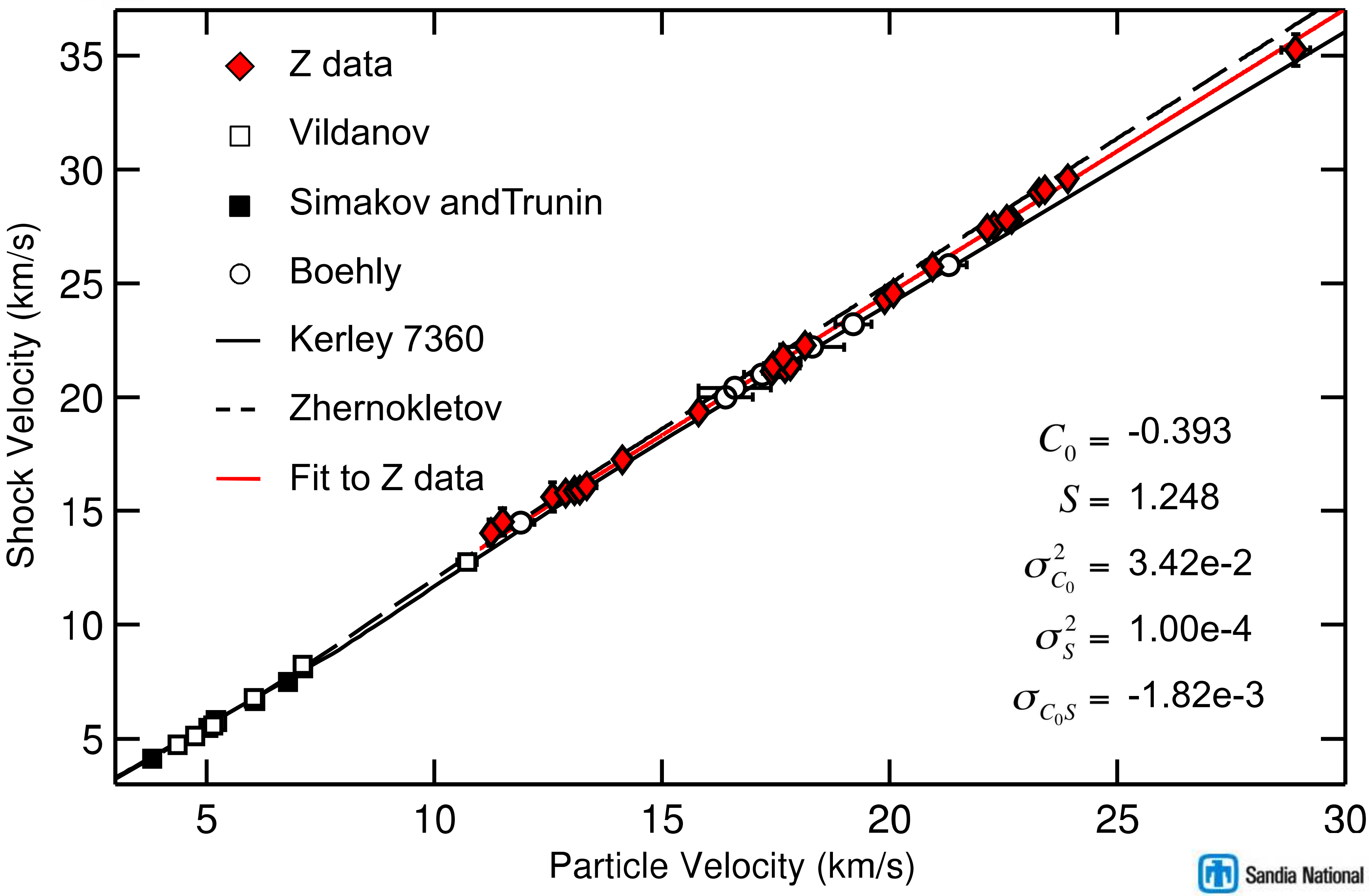
~200 mg/cc silica aerogel U_s-u_p Hugoniot



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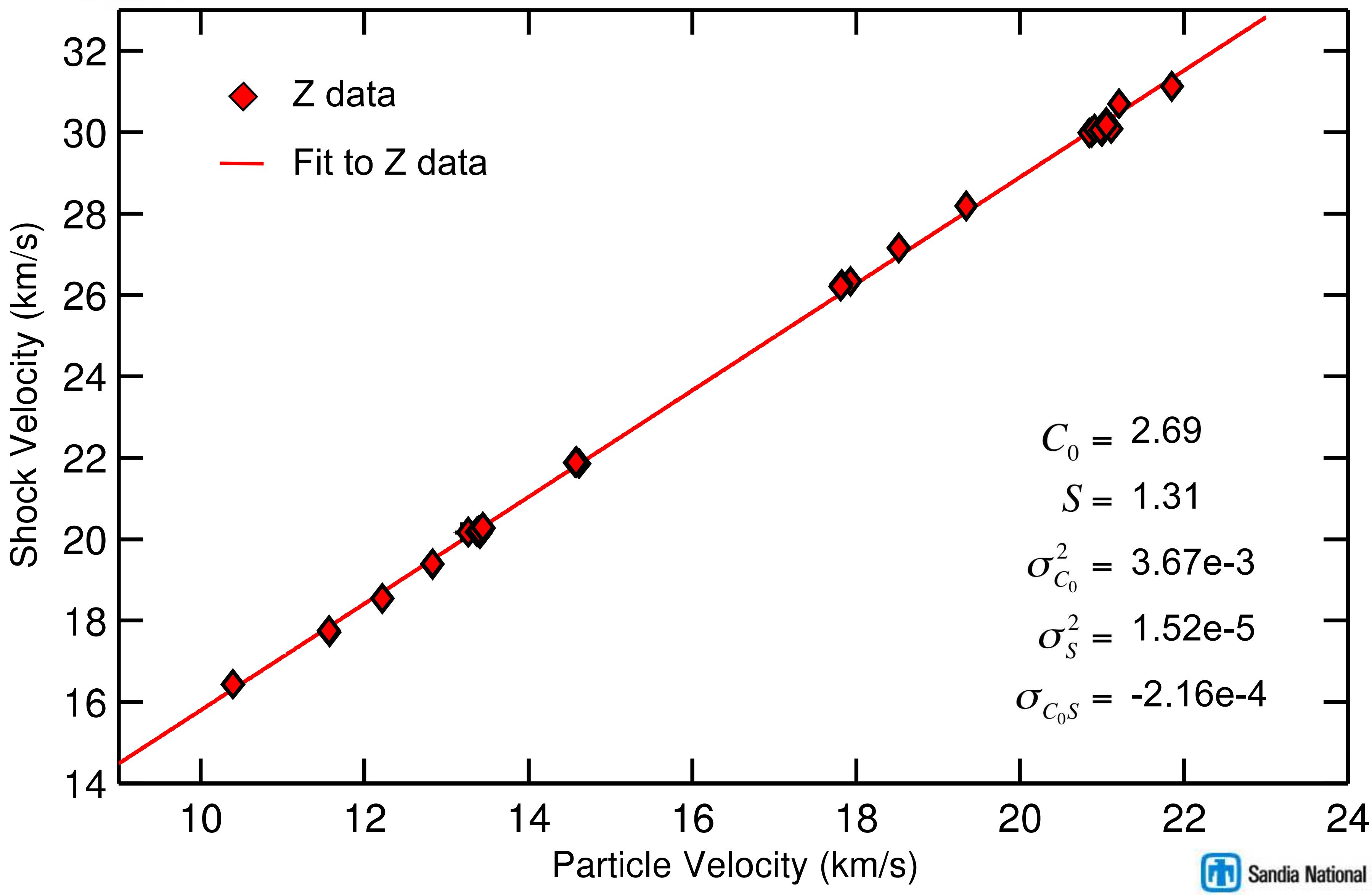
TPX U_s-u_p Hugoniot



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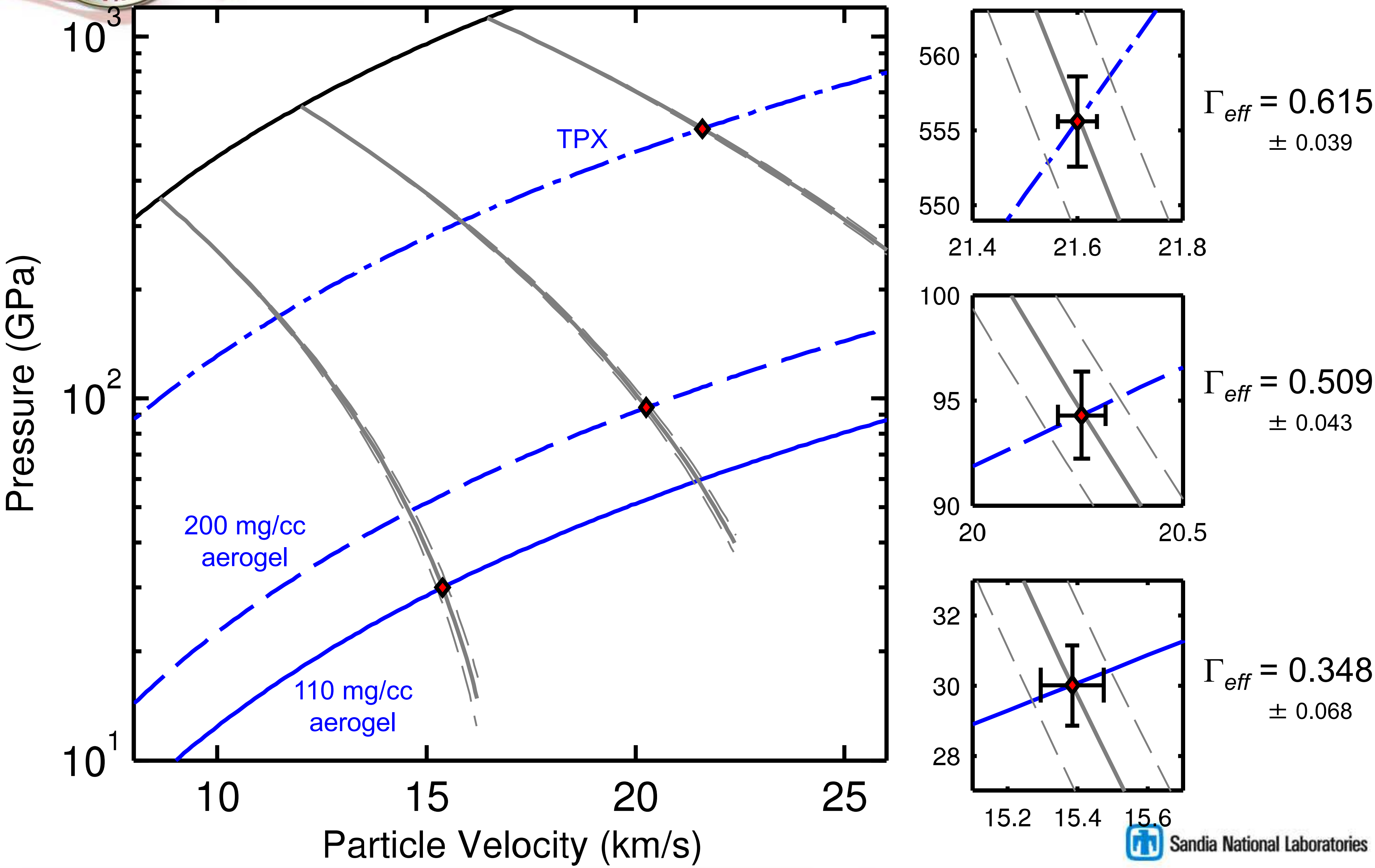
Γ_{eff} determined for each release measurement, uncertainties evaluated via Monte Carlo method



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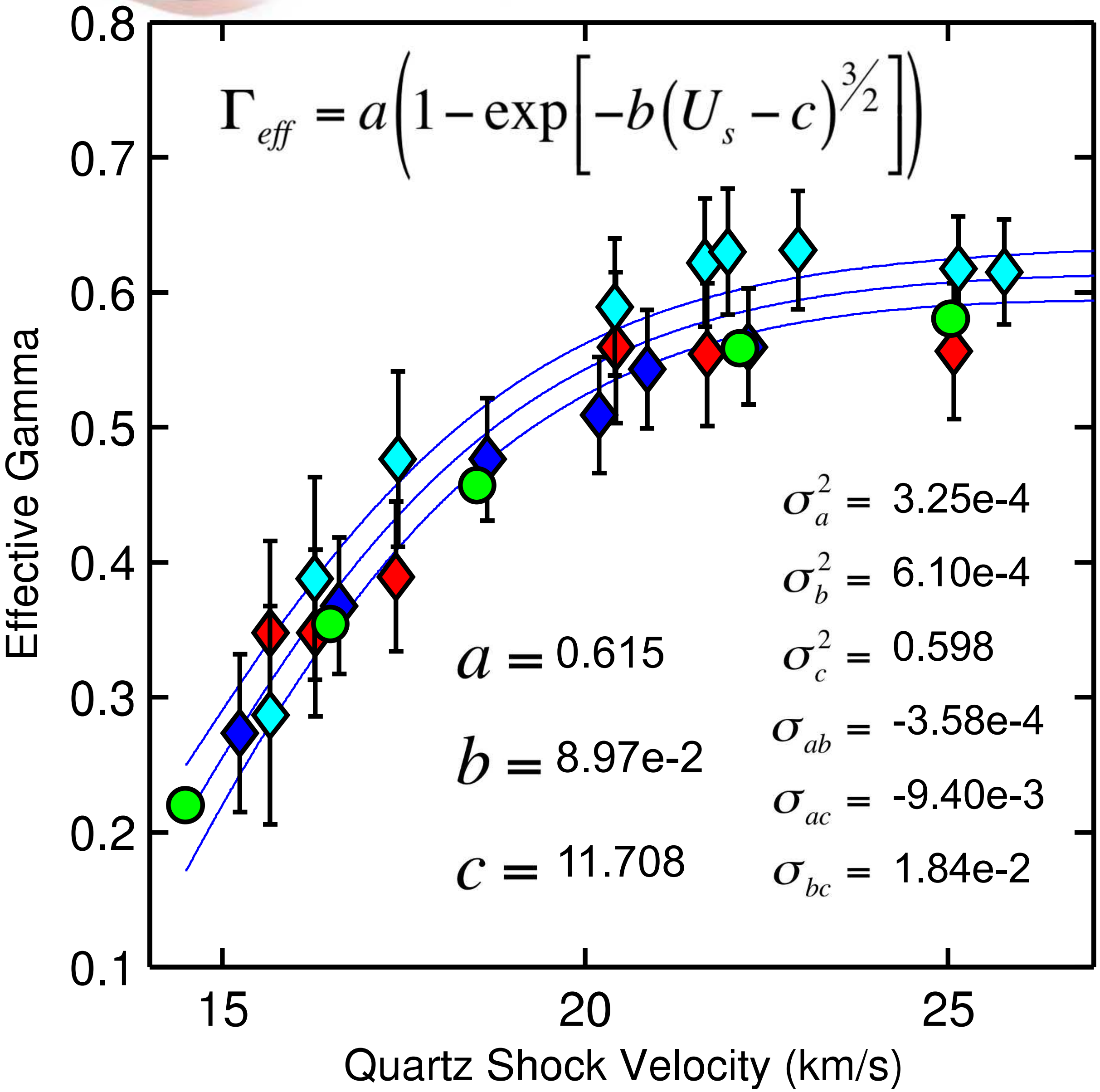
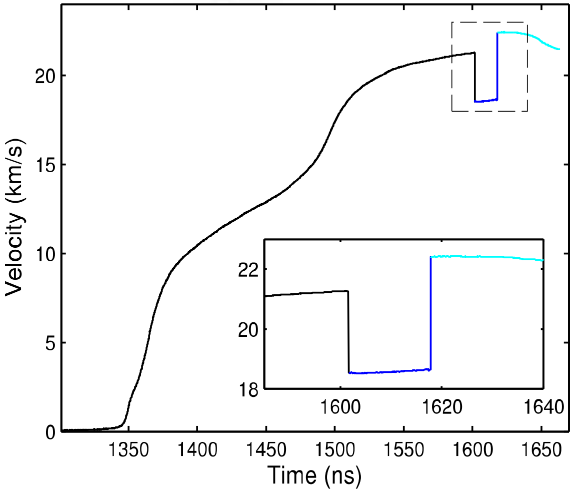
Γ_{eff} exhibits similar trend for all release standards and shows very good agreement with QMD trend



The similar trend in Γ_{eff} for all three release standards suggests that the Mie-Grüneisen, constant Γ_{eff} model with linear U_s-u_p Hugoniot reference adequately describes the release path to quite low pressure states

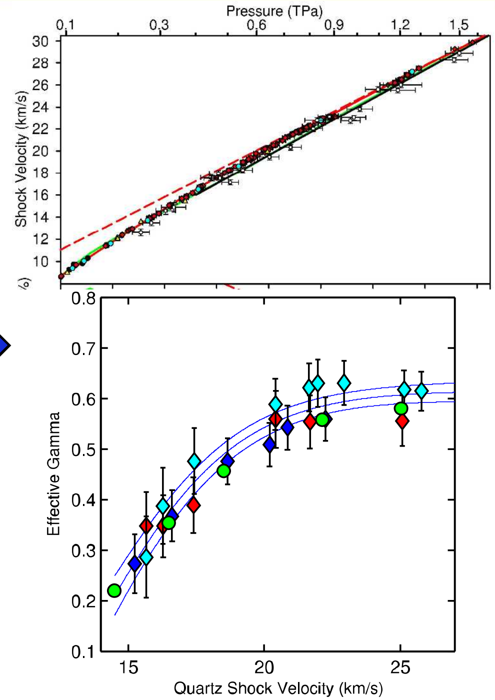
These results corroborate the QMD release calculations, albeit with a slightly higher Γ_{eff} for a given quartz shock velocity

Simple analytical model for impedance matching with quartz into lower impedance material



measure U_s^{quartz} and U_s^{sample}

T



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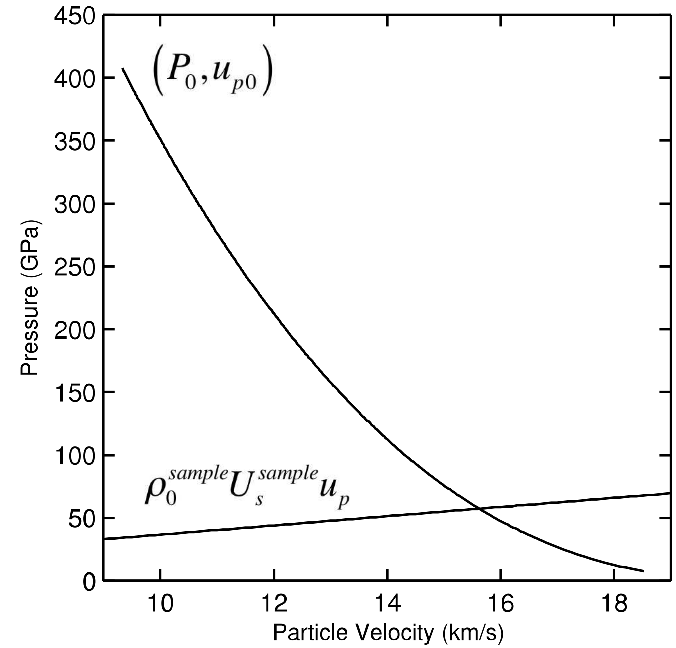

U_s^{quartz} determines:

$$\left(P_0, u_{p0}\right), \qquad C_0 = \frac{P_0}{\rho_0 u_{p0}} - S u_{p0}$$

$$\Gamma_{eff} = a\left(1 - \exp\left[-b\left(U_s - c\right)^{3/2}\right]\right)$$

Solve the set of coupled ODEs:

$$P = P_H + \frac{\Gamma_{eff}}{V}\left(E - E_H\right), \qquad dE = -PdV$$

$$C_s^2 = -V^2 \left.\frac{\partial P}{\partial V}\right|_s, \qquad u_p = u_{p0} + \int_{P_0}^{P} \frac{VdP}{C_s}$$

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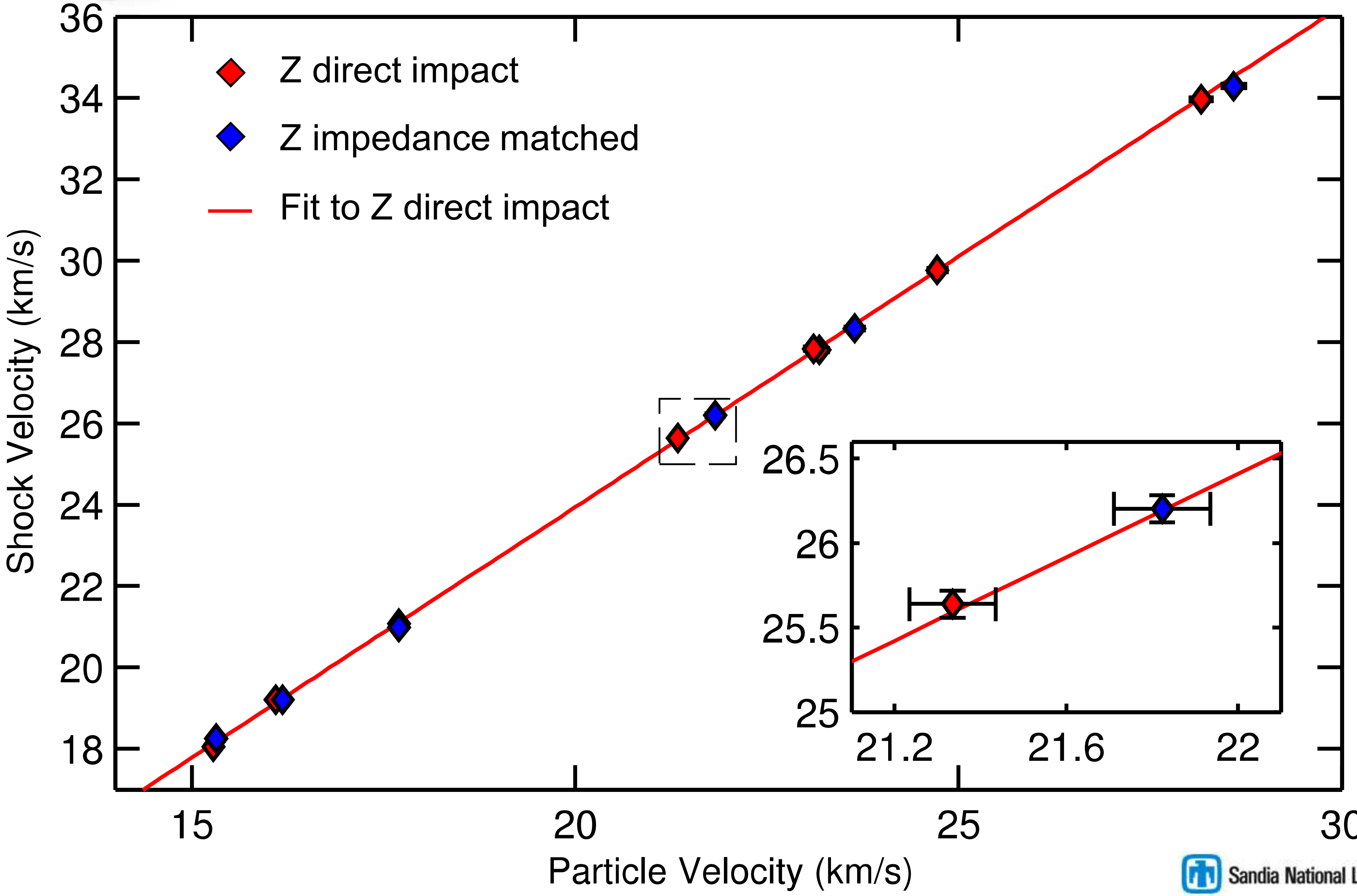
~110 mg/cc silica aerogel U_s-u_p Hugoniot



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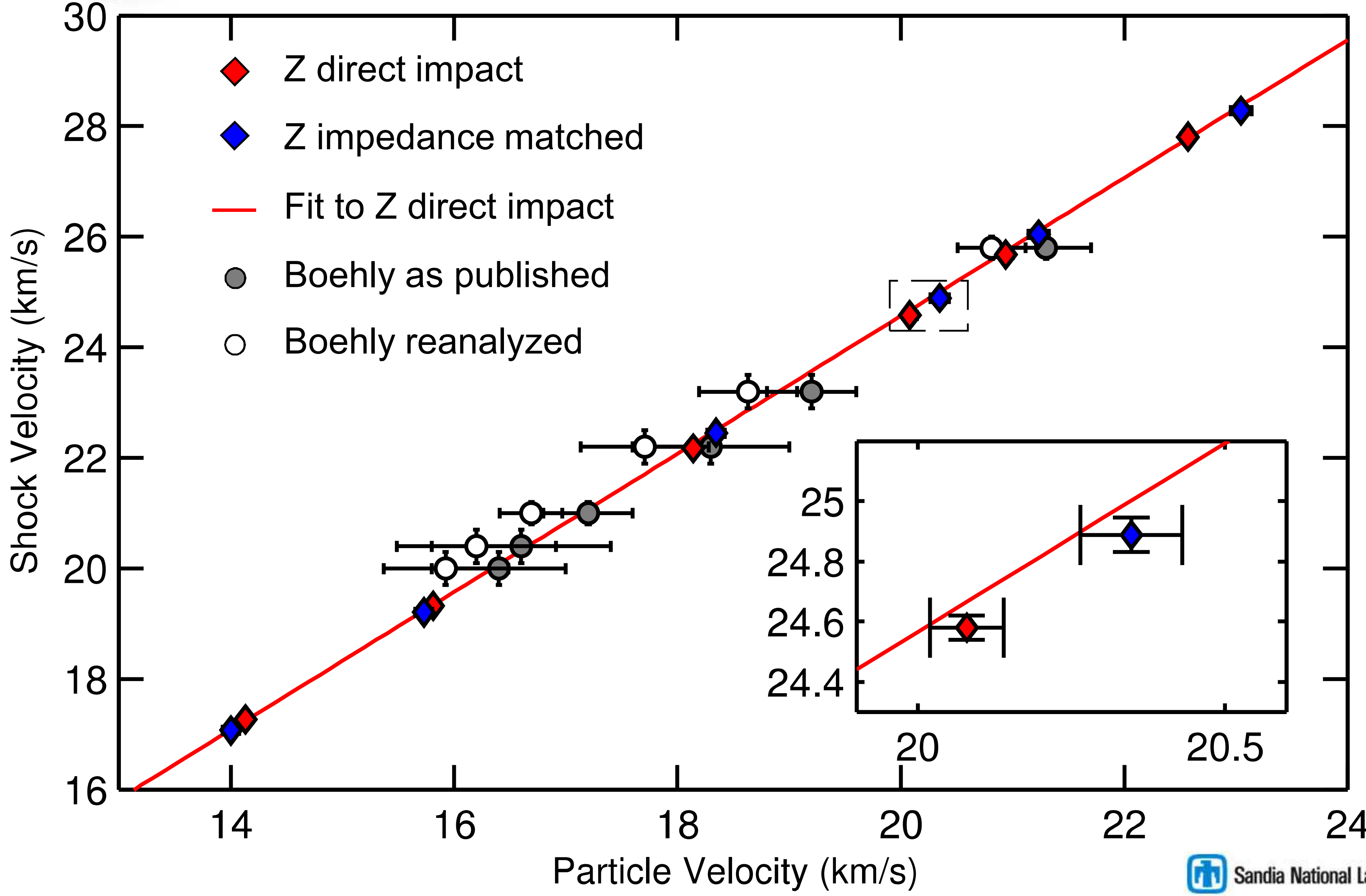
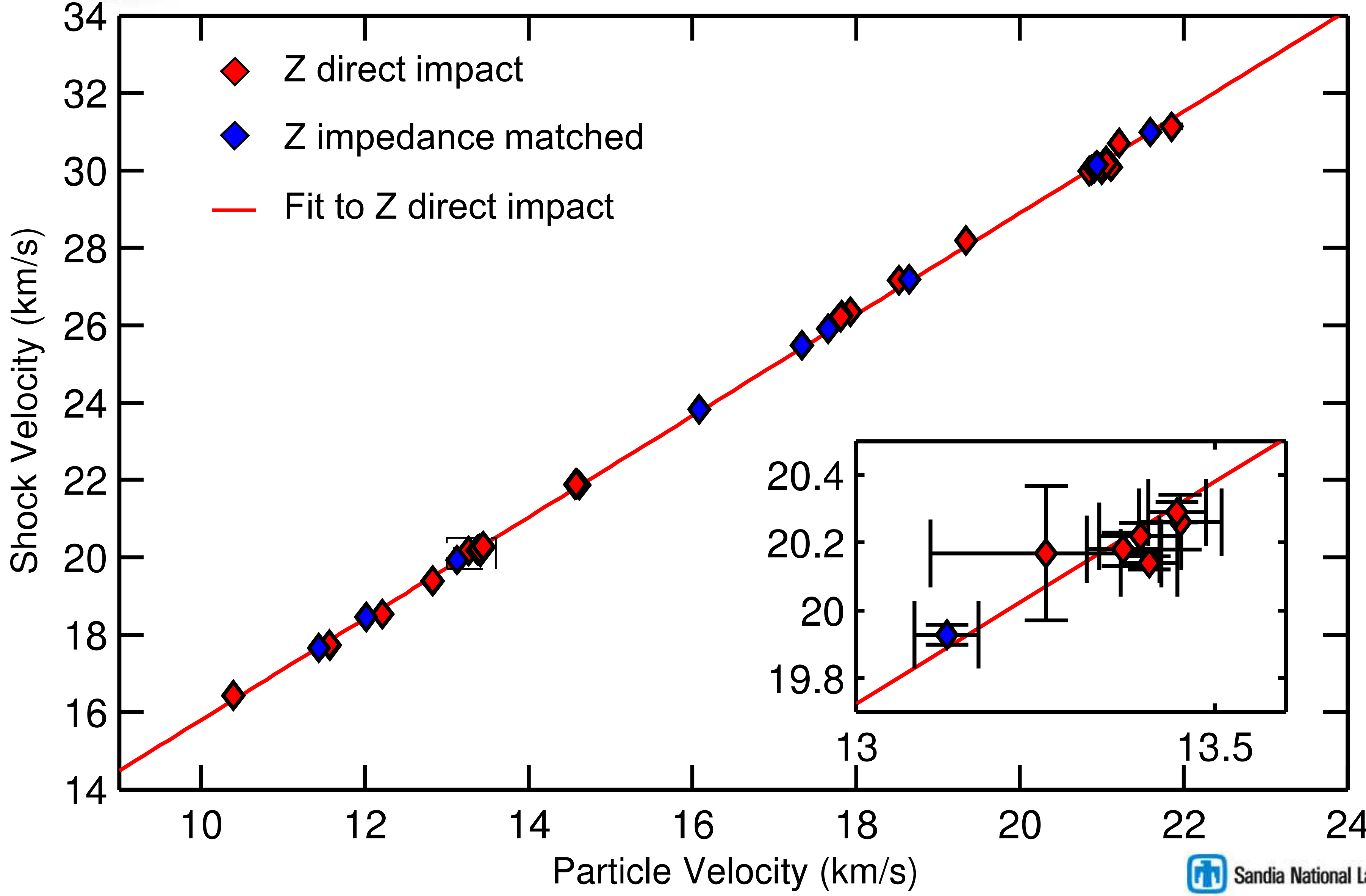
~200 mg/cc silica aerogel U_s-u_p Hugoniot



TPX U_s-u_p Hugoniot

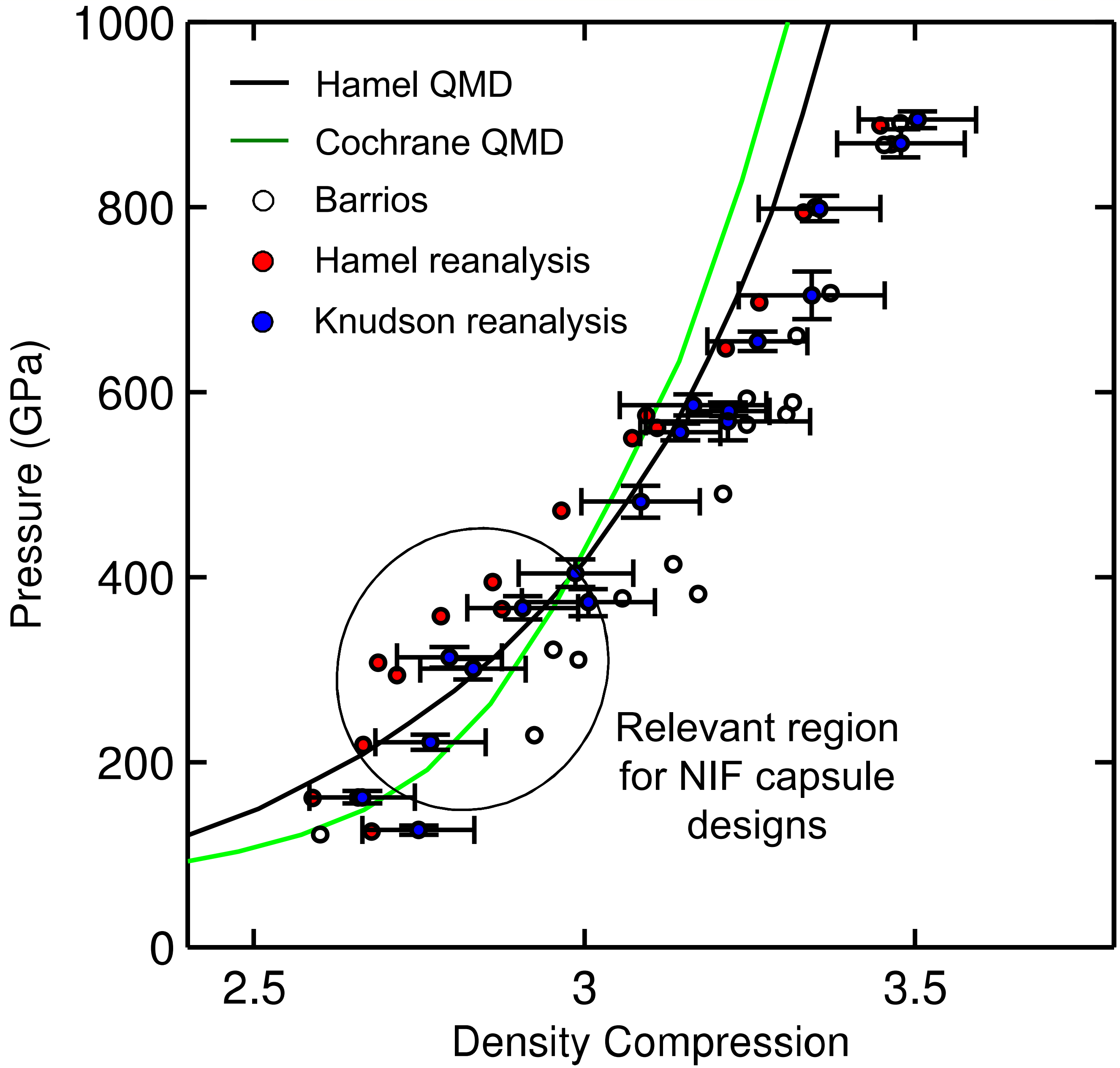


Recent GDP experiments nicely illustrate the effects of the quartz Hugoniot and release standard

Original Omega experiments of Barrios used Hugoniot from laser driven experiments and Mie-Grüneisen, constant $\Gamma=0.64$ with, and non-linear reference for impedance matching

Hamel performed a reanalysis using Z quartz Hugoniot but the same release model

Reanalysis with Z quartz Hugoniot and Mie-Grüneisen, constant Γ_{eff}, and linear reference lies between the two other analyses with reduced uncertainty



Hamel, et al., Phys. Rev. B **86**, 094113 (2012)   Barrios, et al., J. Appl. Phys. **111**, 093515 (2012)

Conclusions

- Quartz release behavior was explored through QMD calculations from 300-1100 GPa states along the Principal Hugoniot
  - These calculations provided a framework for a simple release model
- A simple, analytical model was developed for impedance matching when using quartz as a standard with lower impedance materials
  - Mie-Grüneisen, constant Γ_{eff}, and linear U_s-u_p Hugoniot reference
  - S for the reference Hugoniot fixed at S=1.1971
  - $\Gamma_{eff}(U_s)$ determined through experiments using low density silica aerogel and TPX samples
- Quartz release experiments were performed using aerogel and TPX which exhibit a large range in shock impedance
  - These results were analyzed to determine $\Gamma_{eff}(U_s)$
  - Agreement between inferred Γ_{eff} for the various samples suggests the simple model adequately describes the release response
- Model allows for simple reanalysis of previously reported data sets using quartz as a standard provided that the observables were included