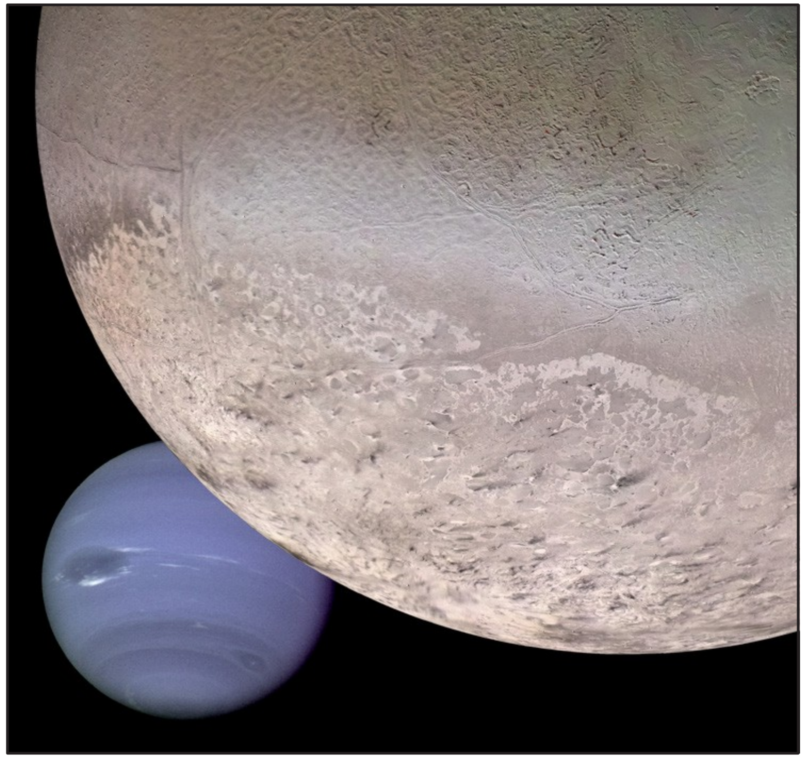
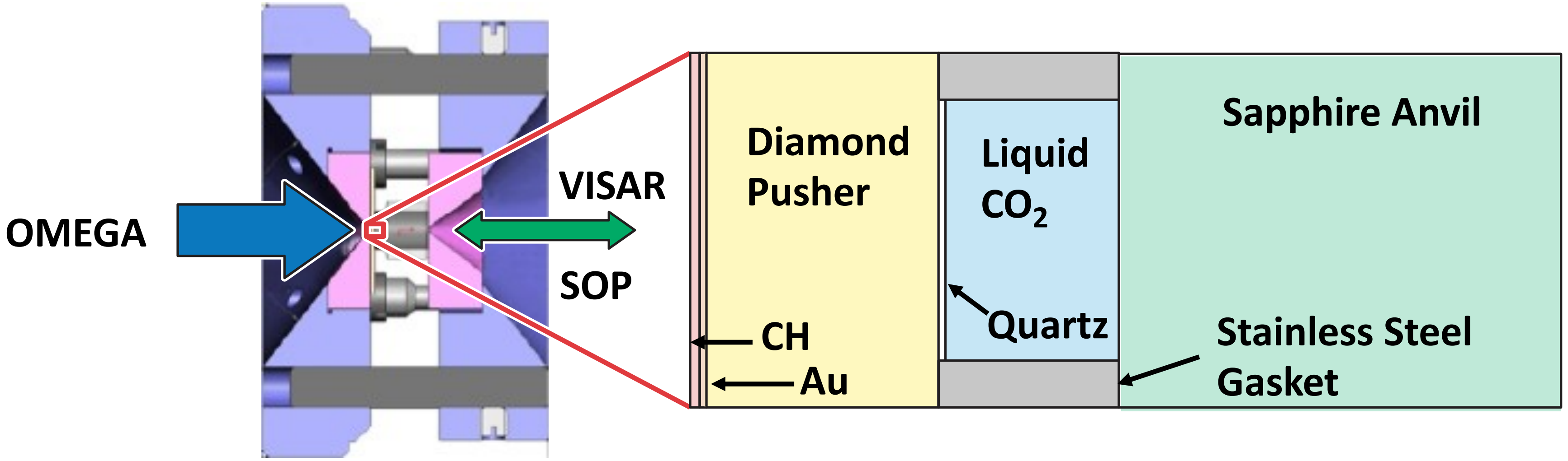
Equation-of-State Measurements of Precompressed CO_2





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- Shock velocity and self-emission were measured to provide Hugoniot, reflectivity, and temperature data
- Shock-compressed CO_2 exhibits stiffer behavior than predicted by density functional theory (DFT)
- Higher initial density corresponds to a lower specific heat in this regime of CO_2

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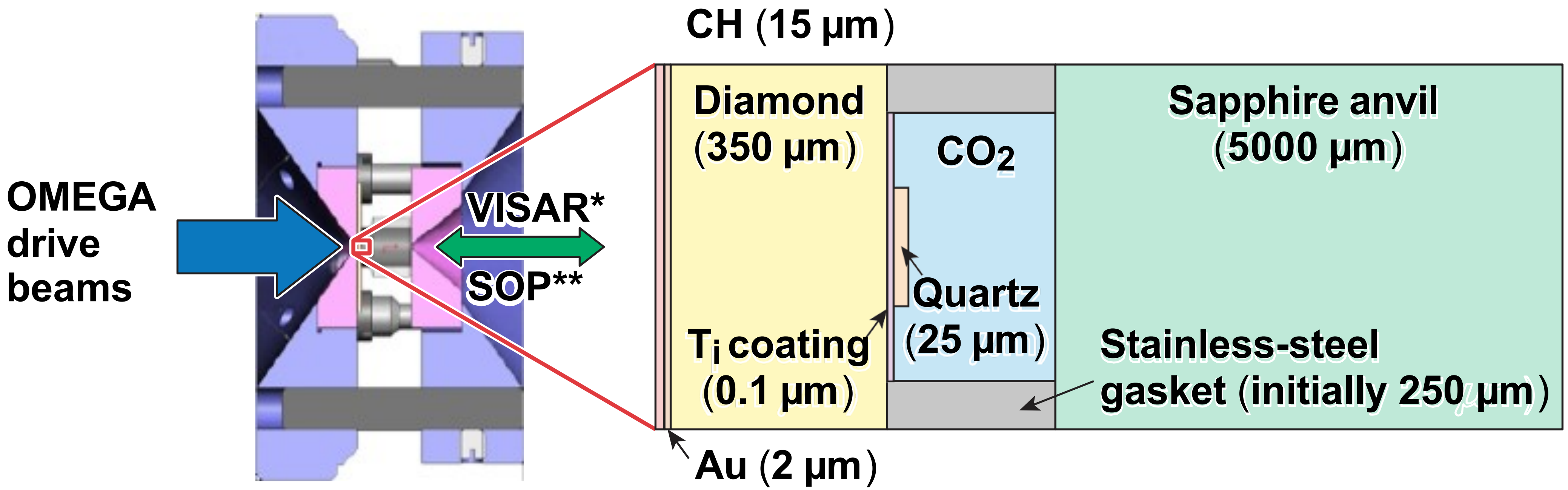
Experimental Setup

Diamond-anvil cells precompressed CO_2 that was shock compressed with the OMEGA laser



- CO_2 samples were precompressed to 1.2 GPa in diamond-anvil cells and driven with laser shocks to 980 GPa
- Impedance matching was performed to the quartz standard
- Shock velocity, emission, and reflectance were measured using VISAR and SOP

* VISAR: velocity interferometer system for any reflector
** SOP: streaked optical pyrometer

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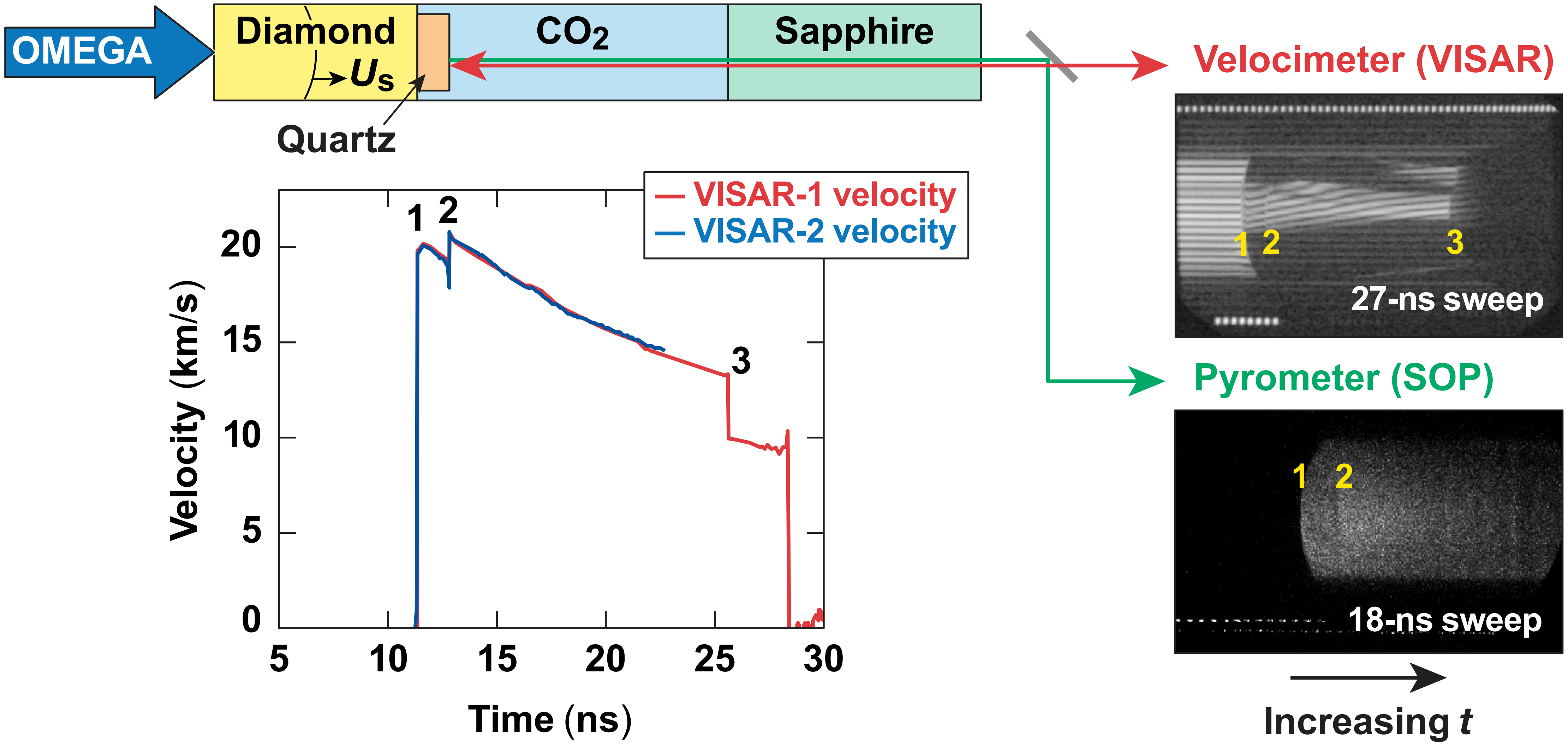
Simultaneous VISAR and pyrometer data provided a temporal profile of the shock velocity and temperature



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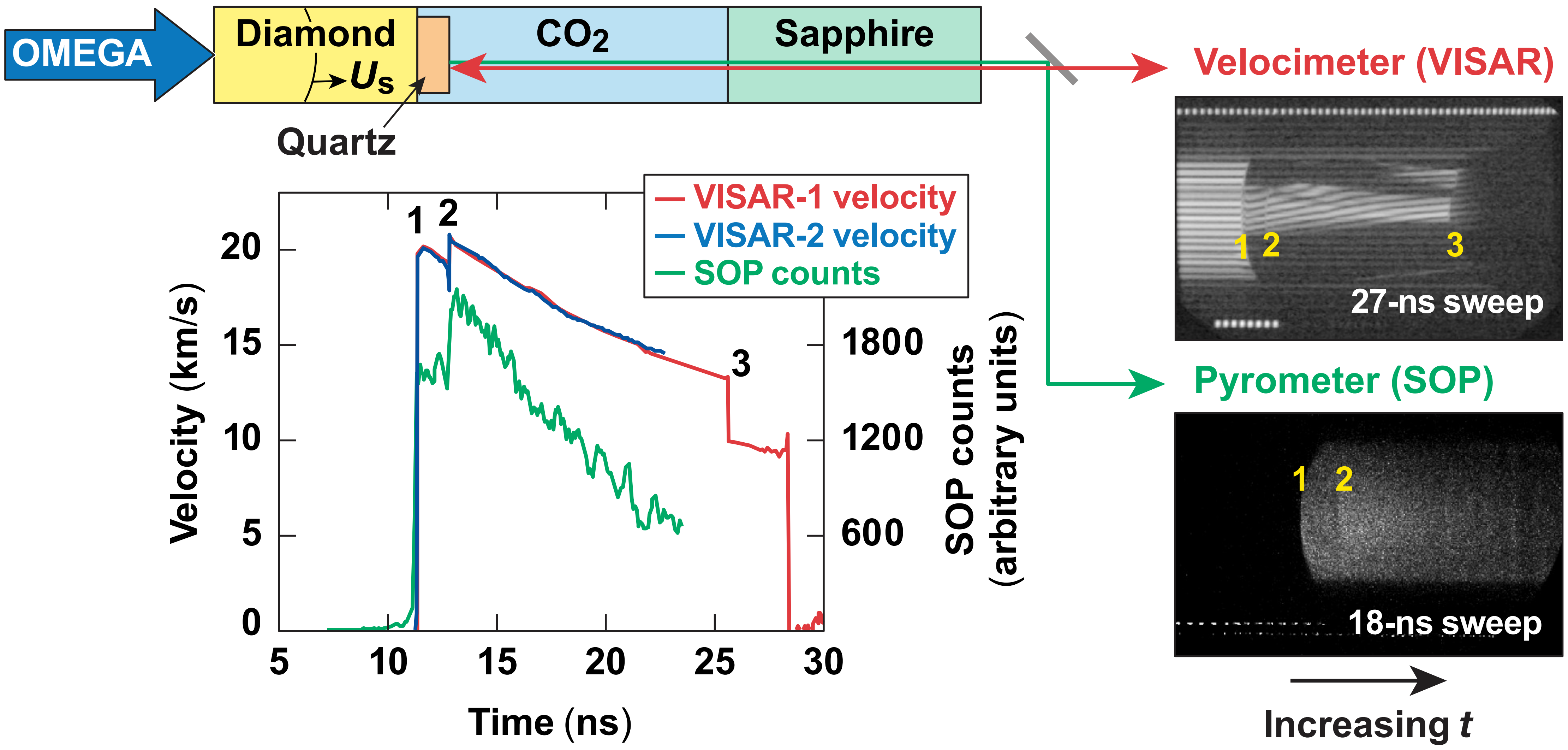
Results

Simultaneous VISAR and pyrometer data provided a temporal profile of the shock velocity and temperature



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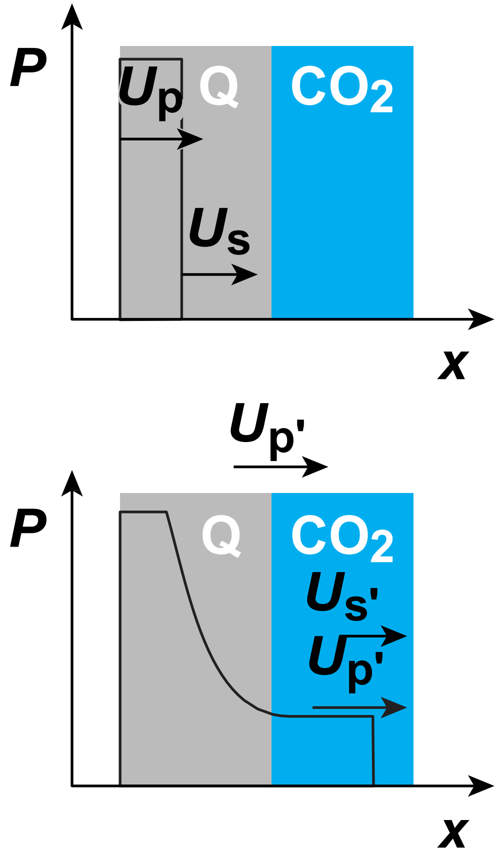
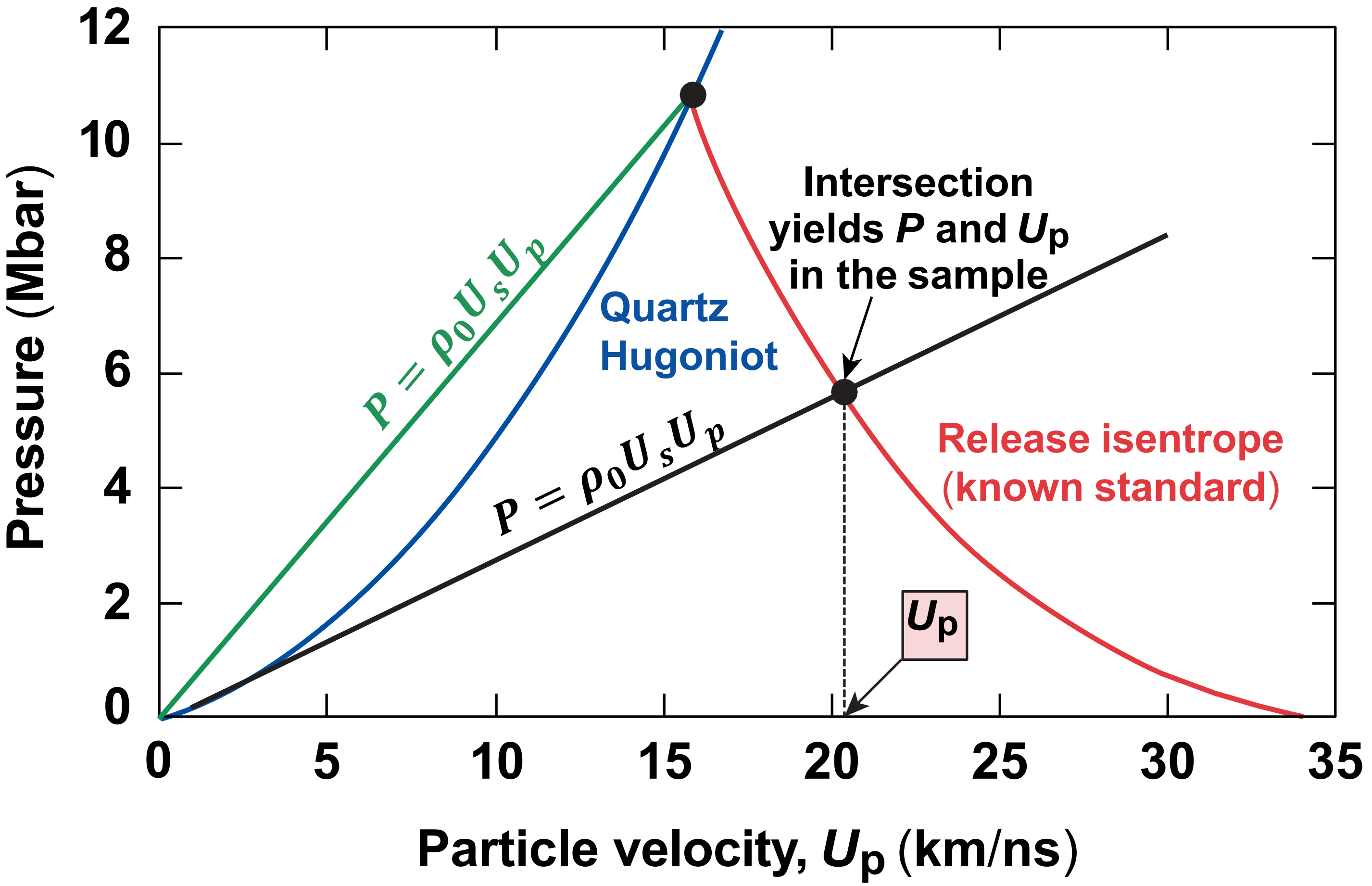
Equation-of-state data are obtained from the *impedance-matching technique





Rankine–Hugoniot equations

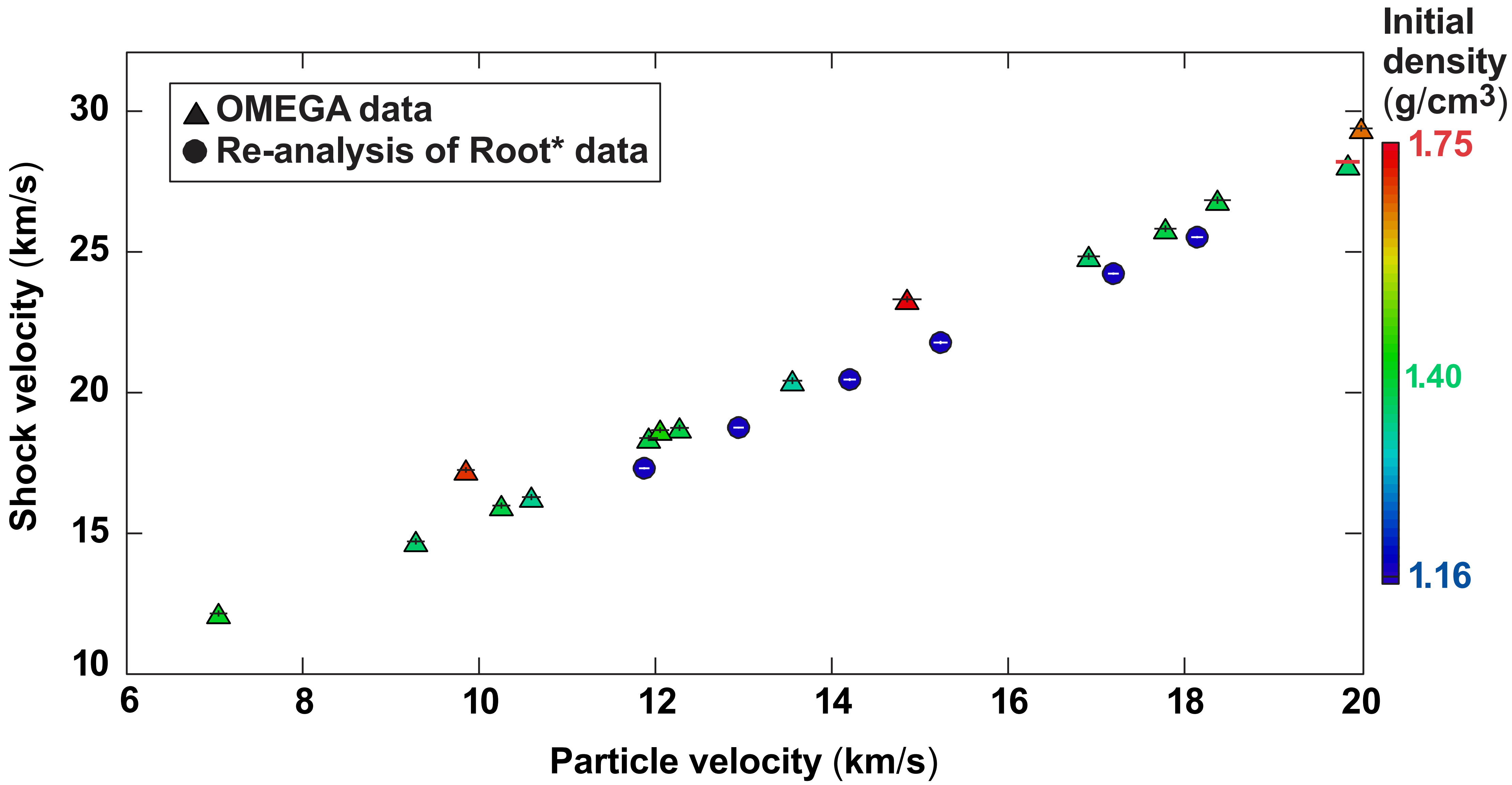
$$\frac{\rho}{\rho_0} = \frac{U_s}{U_s - U_p}$$

$$P - P_0 = \rho_0 U_s U_p$$

*To be further discussed:
Greg Tabak, LLE
U07.00004

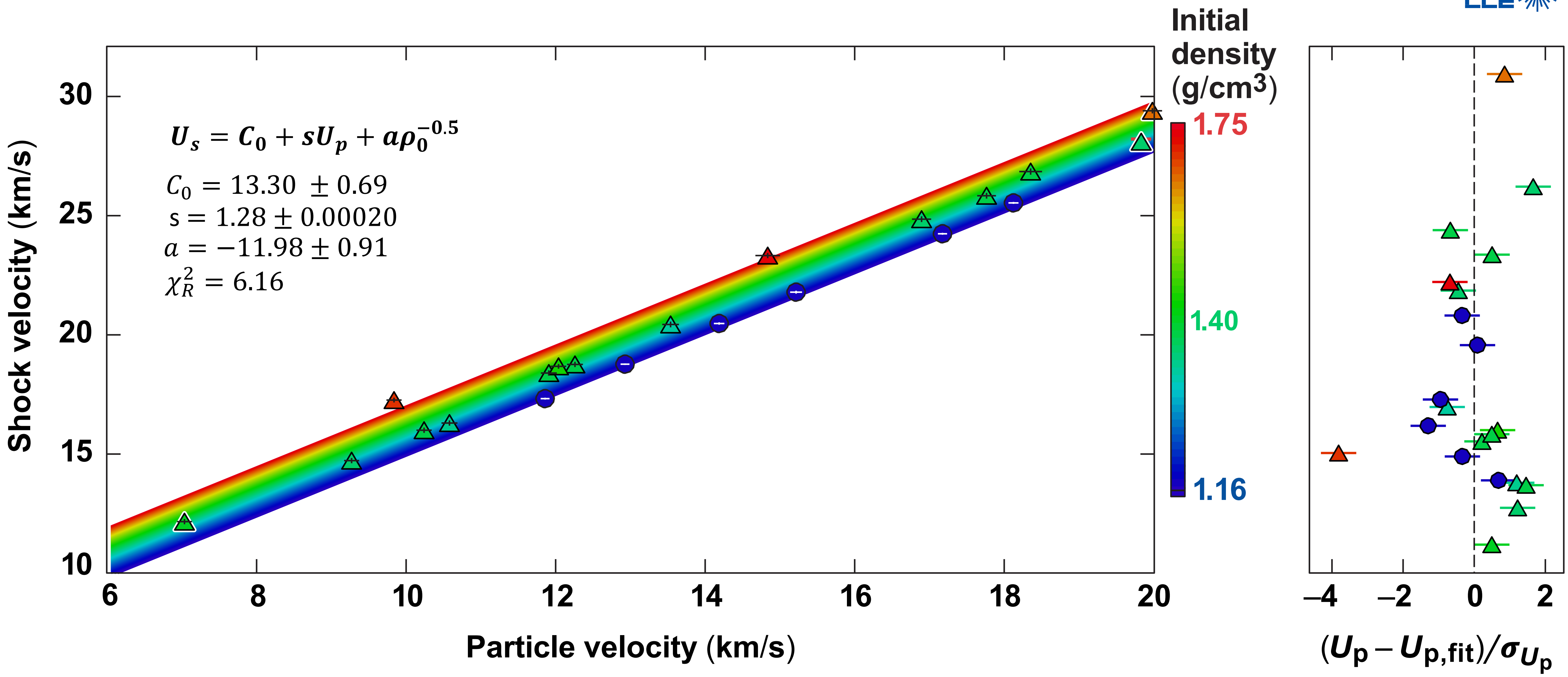
M. P. Desjarlais, M. D. Knudson, and K. R. Cochrane, J. Appl. Phys. 122, 035903 (2017);
S. Brygoo et al., J. Appl. Phys. 118, 195901 (2015).

Particle velocities were inferred from impedance matching to obtain $U_s(U_p)$

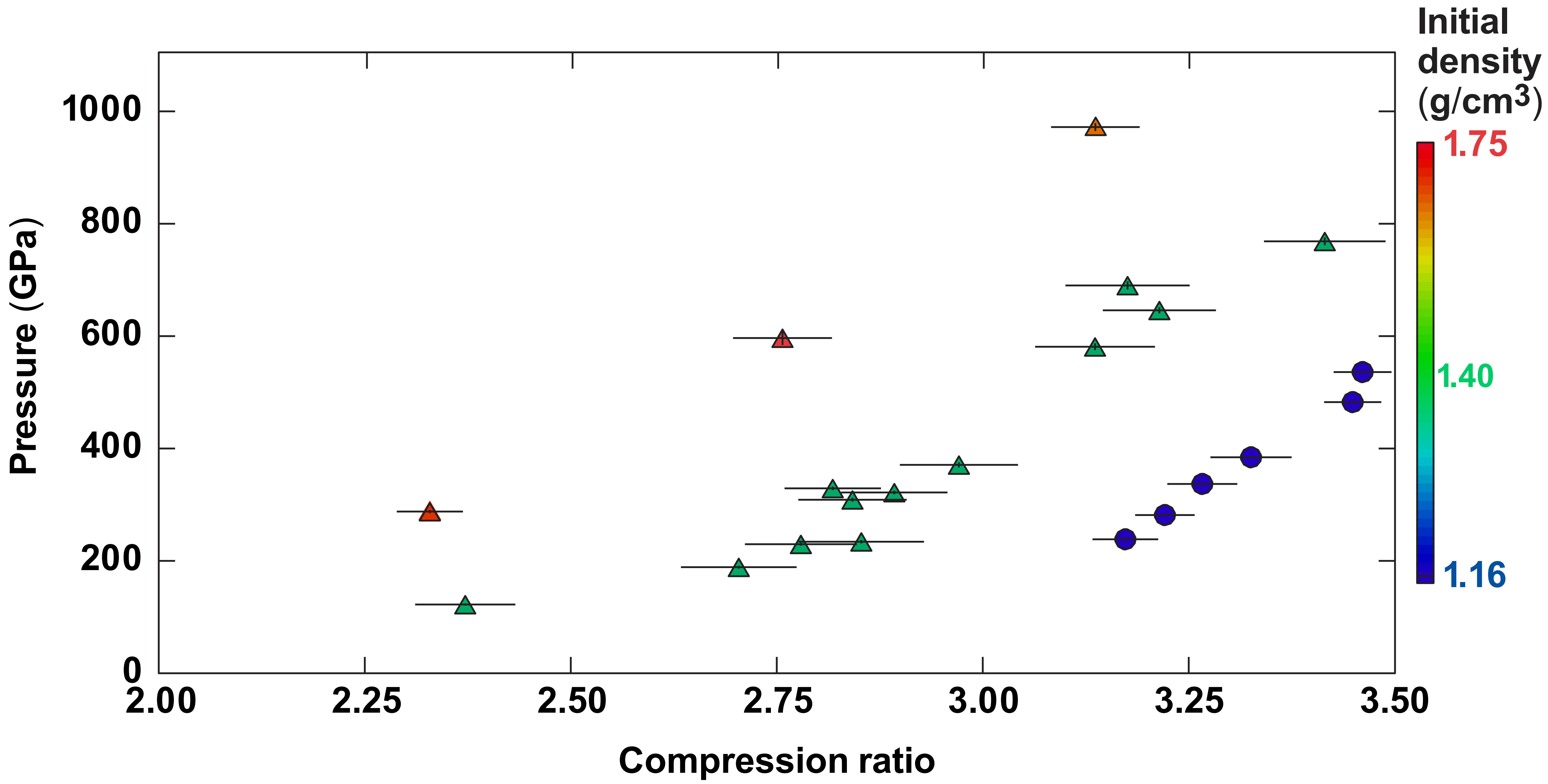


*S. Root *et al.*, Phys. Rev. B 87, 224102 (2013).

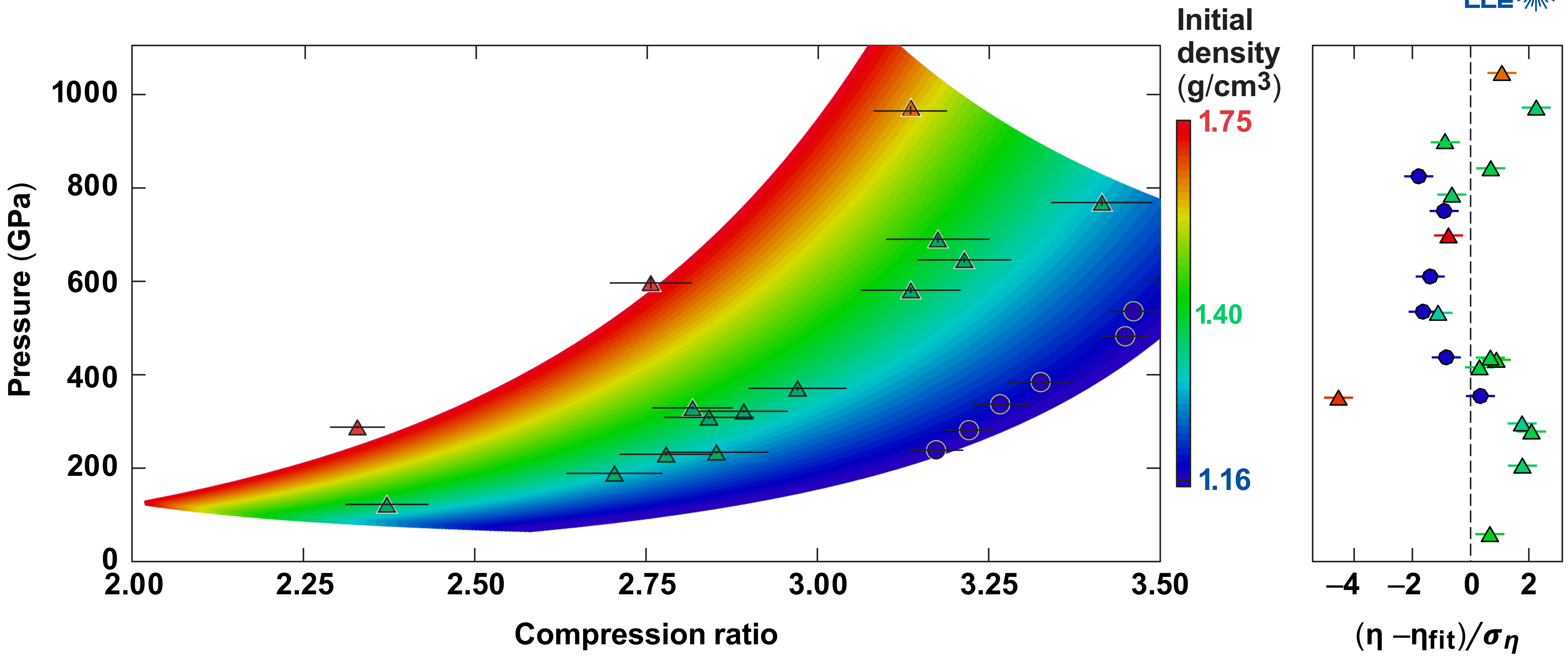
The U_s–U_p relation for CO_2 exhibits linear behavior when accounting for precompression



In the pressure–compression plane, the effect of precompression is readily apparent



In the pressure–compression plane, the effect of precompression is readily apparent with the fit $U_s = C_0 + sU_p + a\rho_0^{-0.5}$



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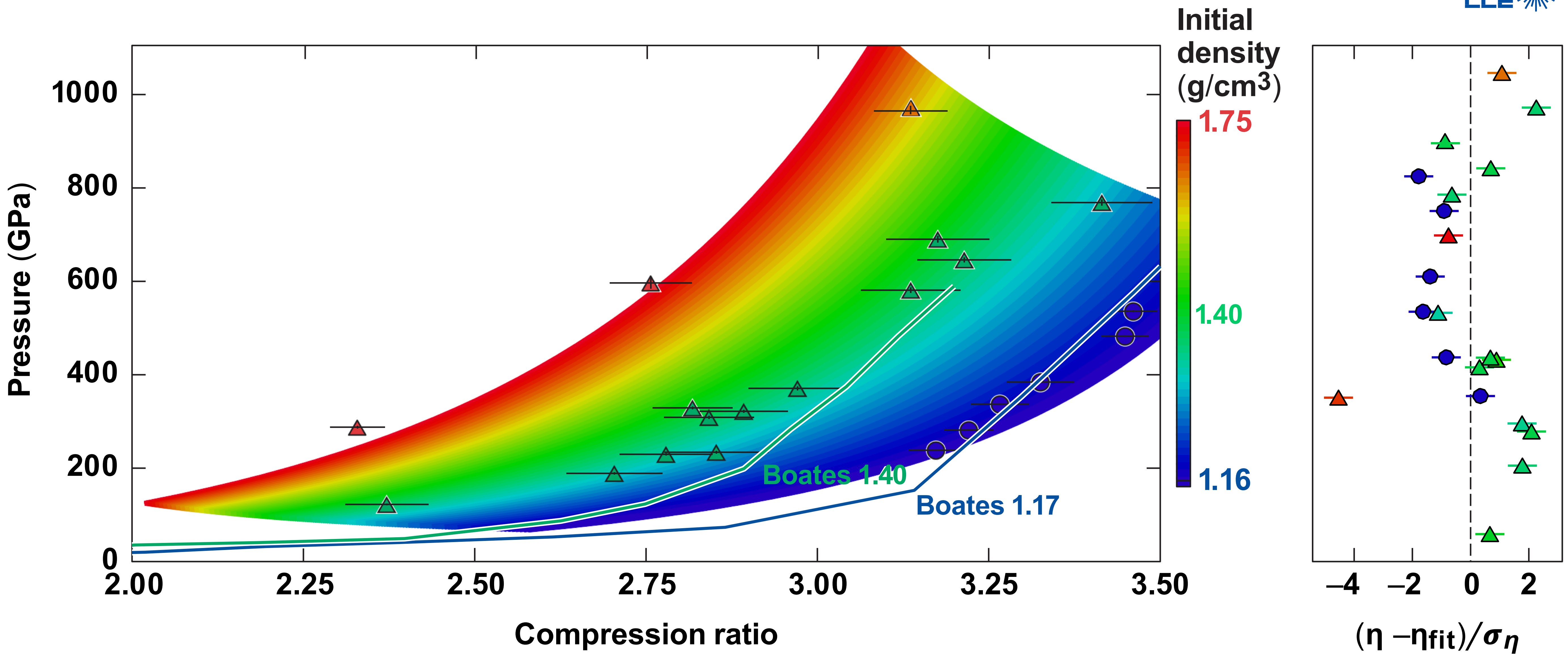
The current model for shocked CO_2 (Boates) predicts a softer behavior than our data indicates



B. Boates *et al.*, J. Chem. Phys. 134, 064504 (2011).

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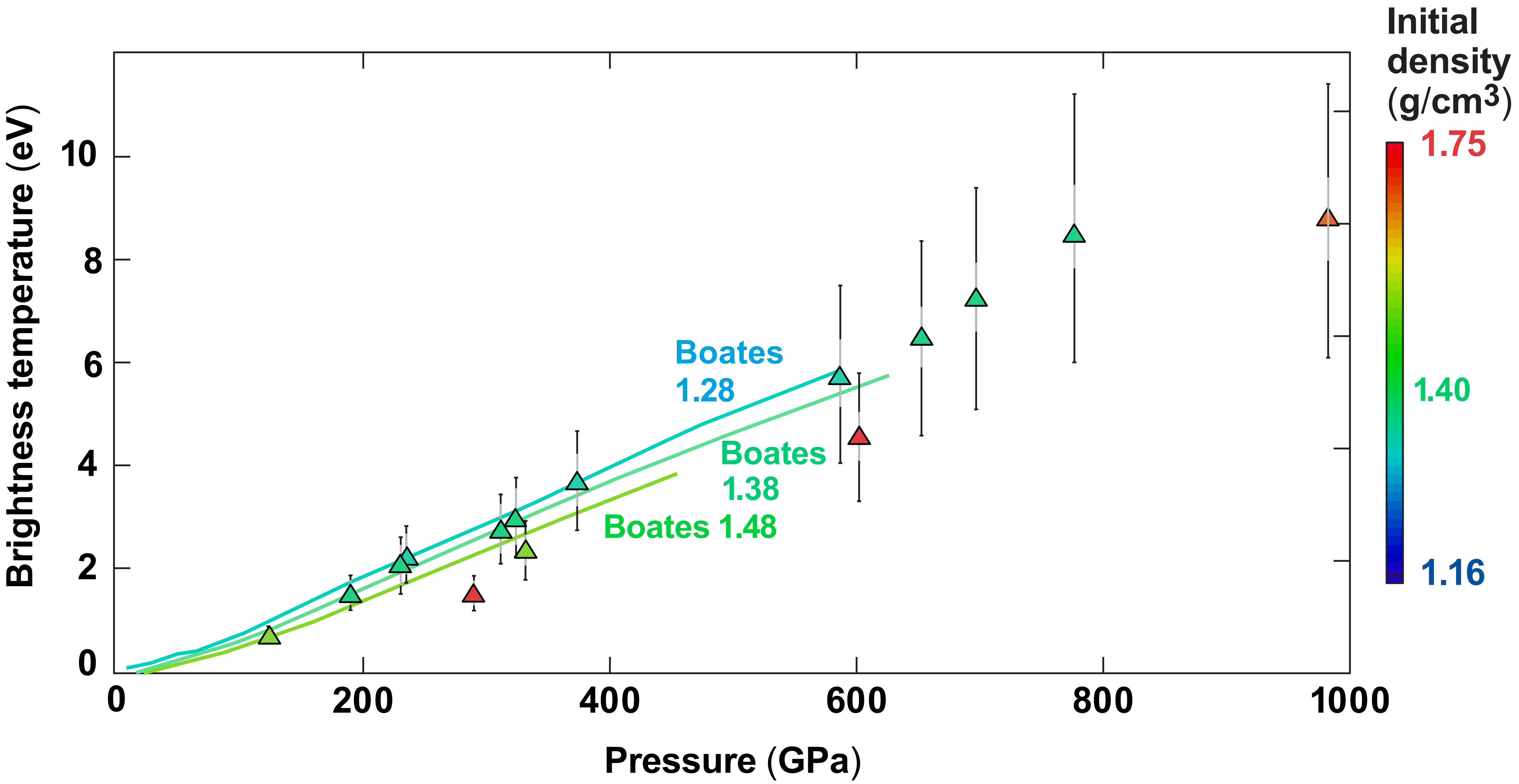
The Boates' model reasonably predicts our observed temperatures; the effect of precompression is less pronounced



B. Boates *et al.*, J. Chem. Phys. 134, 064504 (2011).

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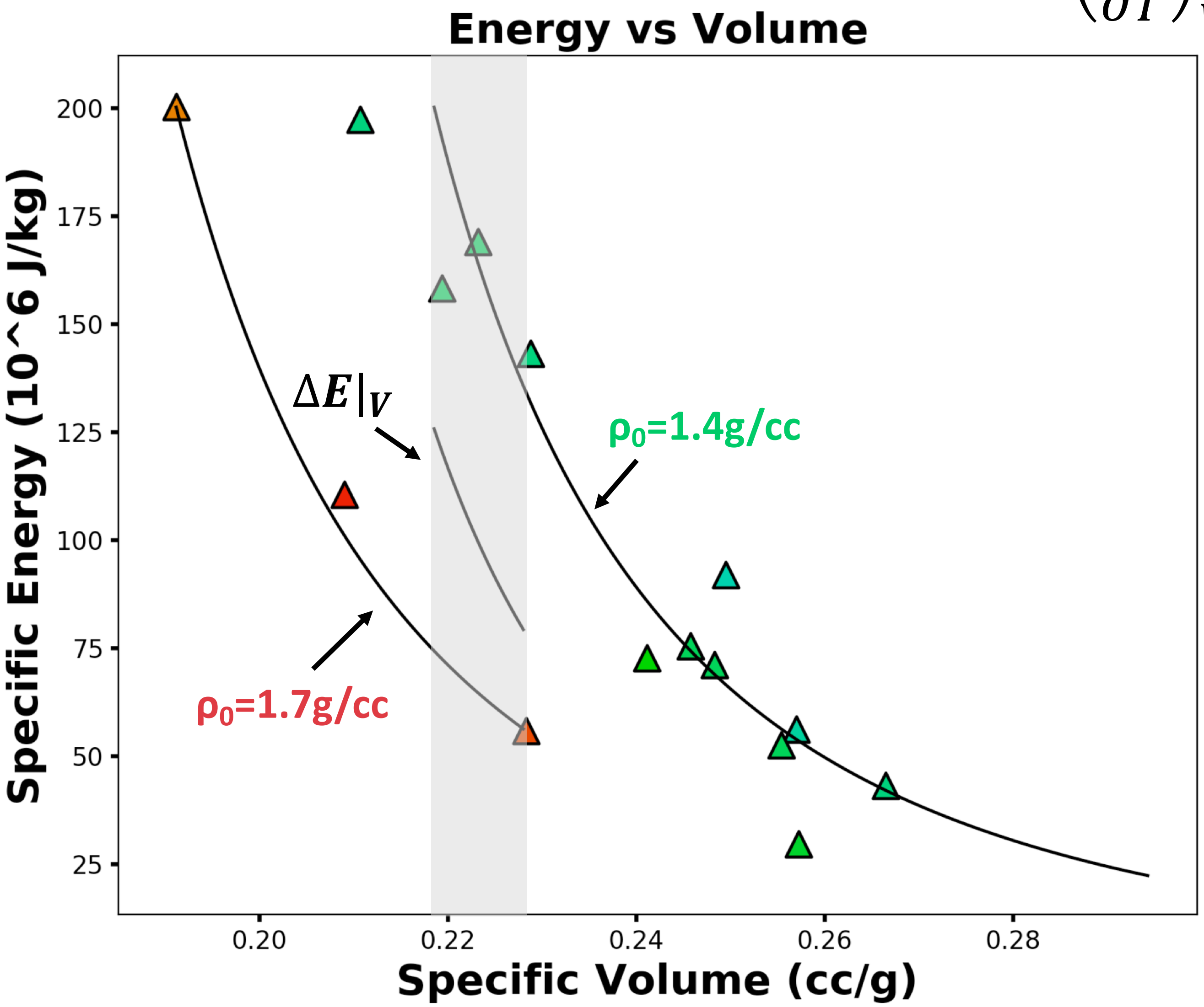
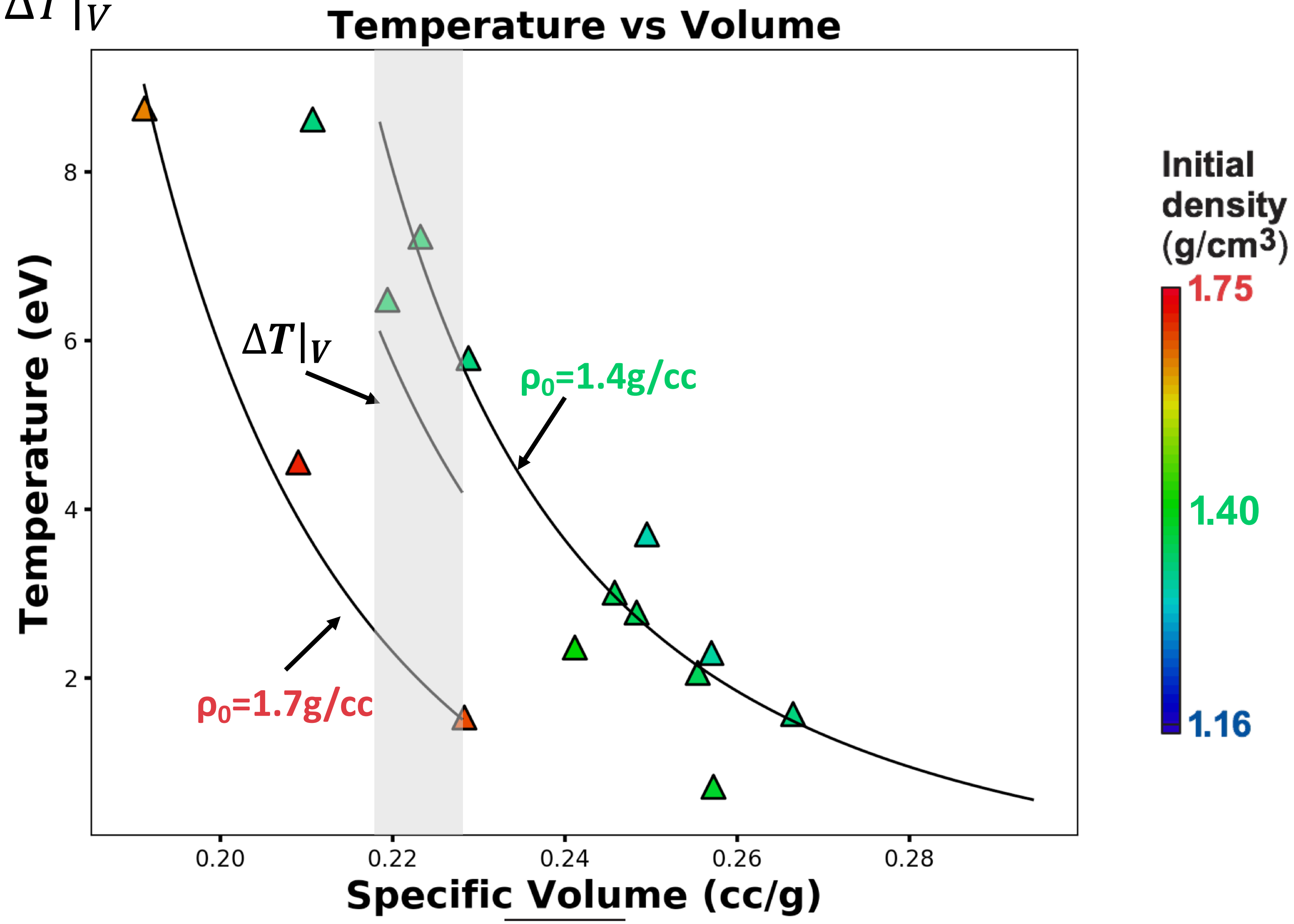
Specific heat capacity, c_V, was determined using two methods: The Difference Method

$$c_V \equiv \left(\frac{\partial E}{\partial T}\right)_V \approx \frac{\Delta E|_V}{\Delta T|_V}$$





D. Hicks *et al.*, Phys. Rev. Lett. 97 025502 (2006).

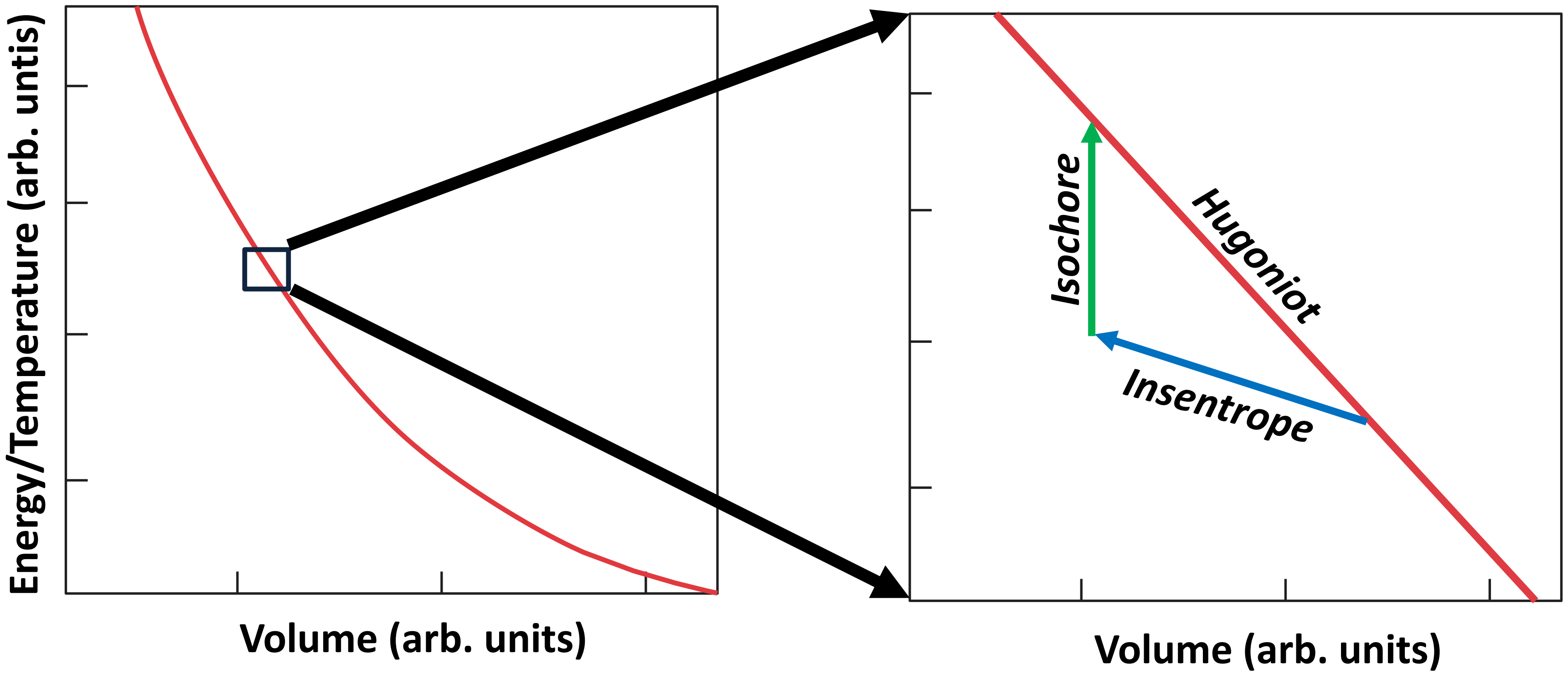
Specific heat capacity, c_V, was determined using two methods: The Slope Method

$$\left.\begin{aligned}\Delta E_H &= \Delta E_S + \Delta E_V\\ \Delta T_H &= \Delta T_S + \Delta T_V\end{aligned}\right\} c_V \equiv \left(\frac{\partial E}{\partial T}\right)_V = \frac{\Delta E_H - \Delta E_s}{\Delta T_H - \Delta E_s} = \frac{\left(\frac{\partial E}{\partial V}\right)_H - \left(\frac{\partial E}{\partial V}\right)_S}{\left(\frac{\partial T}{\partial V}\right)_H - \left(\frac{\partial T}{\partial V}\right)_S}$$

Invoke thermodynamic derivatives:

$$\Gamma \equiv -\left(\frac{V}{T}\right)\left(\frac{\partial T}{\partial V}\right)_S = \mathrm{V}\left(\frac{\partial P}{\partial E}\right)_V$$

$$P \equiv -\left(\frac{\partial E}{\partial V}\right)_S$$

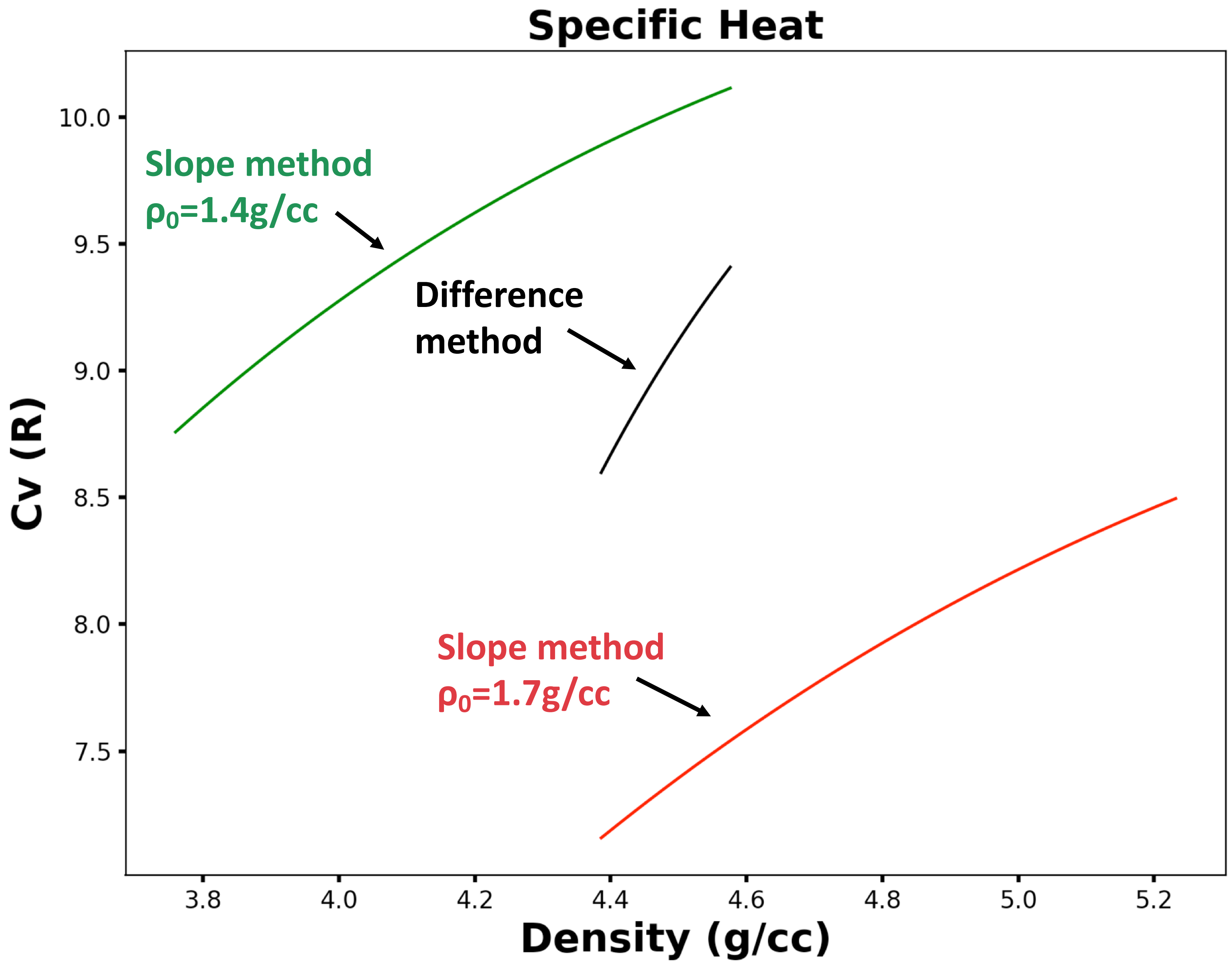


Yields:

$$c_V = \frac{\left(\frac{\partial E}{\partial V}\right)_H + P}{\left(\frac{\partial T}{\partial V}\right)_H + \frac{\Gamma T}{V}}$$

D. Hicks *et al.*, Phys. Rev. Lett. 97 025502 (2006).

Preliminary results indicate that initial conditions strongly affect specific heat.



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