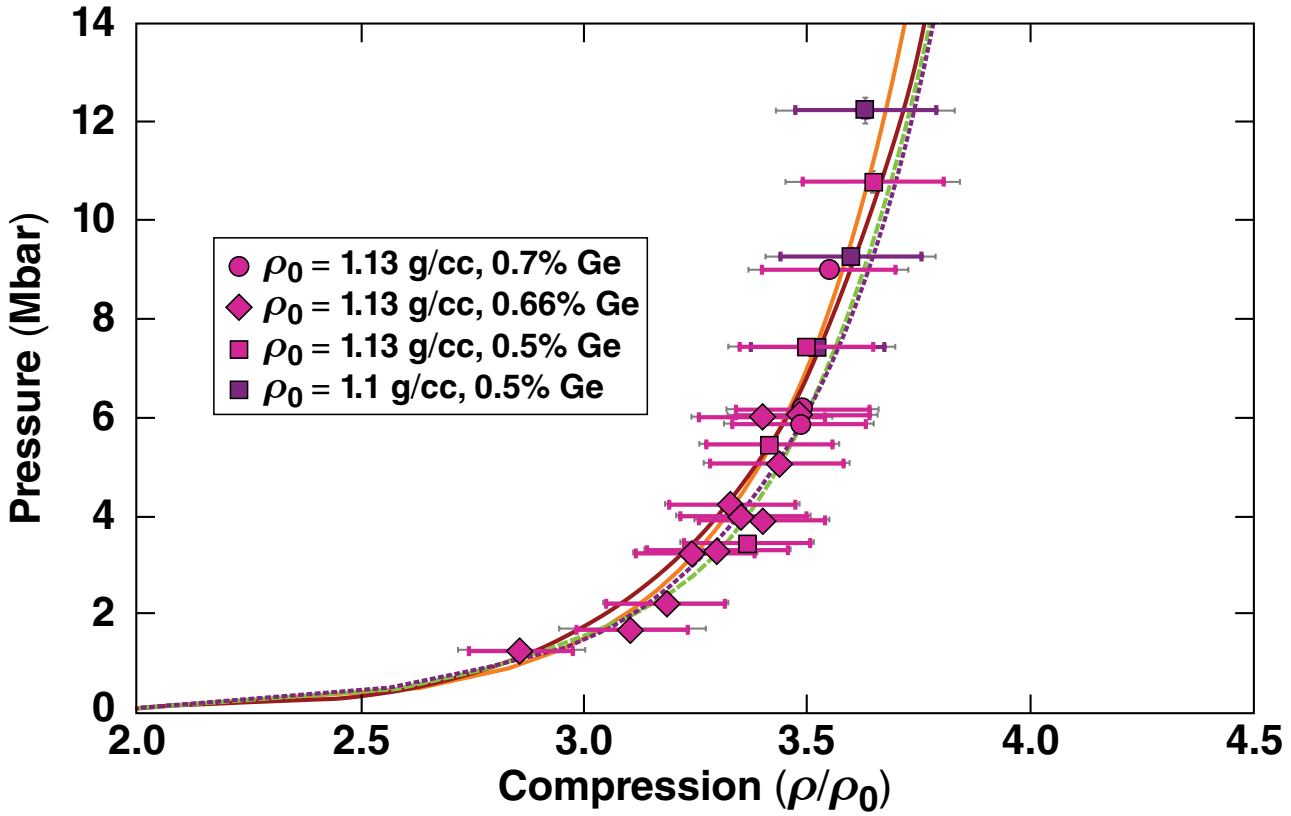
Precision Equation-of-State (EOS) Measurements on NIF Ablator Materials Using Laser-Driven Shock Waves



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Summary

Precision equation-of-state (EOS) measurements are obtained on GDP and Ge-GDP from ~1 to 10 Mbar

UR LLE

- Design of NIF ignition targets requires precise knowledge of the ablator EOS
  - initial NIF target designs use Ge-doped GDP ablators
- Precision EOS measurements are obtained using the impedance-matching (IM) technique with quartz standard
- GDP results are in agreement with available *LEOS* 5310 model
- Ge-GDP data are consistent with *LEOS* models with 0.5% and 0.2% Ge doping
- Results show that shocked GDP and Ge-GDP reach similar compressibilities

*M. A. Barrios *et al.*, Phys. Plasmas 17, 056037 (2010).

Collaborators

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To support NIF experiments, the effect of ablator stoichiometry on equation of state was investigated

UR LLE

- Recent studies identified the effect of H:C ratio using CH and CH_2*
- GDP has a H:C ratio of 1.4 and added 0 atoms; Ge-doping adds considerable complexity
- Knowing the EOS of CH is not sufficient due to differences in material properties (initial density, index of refraction, compositional stoichiometry)
- These can be characterized separately with experiments on GDP and Ge-doped GDP

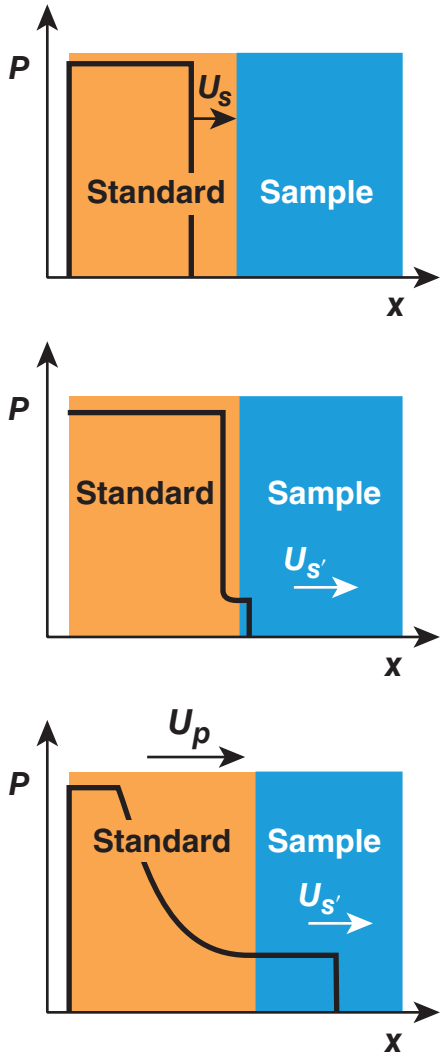
Material	Formula
Polypropylene	CH
Polypropylene	CH_2
GDP	$CH_{1.4}O_{0.01}$
Ge-GDP	$CH_{1.4}O_{0.05}$ + $Ge_{at\ 0.6\%}$

E19487

* M. A. Barrios *et al.*, Phys. Plasmas 17, 056037 (2010).

Impedance Matching $U_s = F(U_p)$

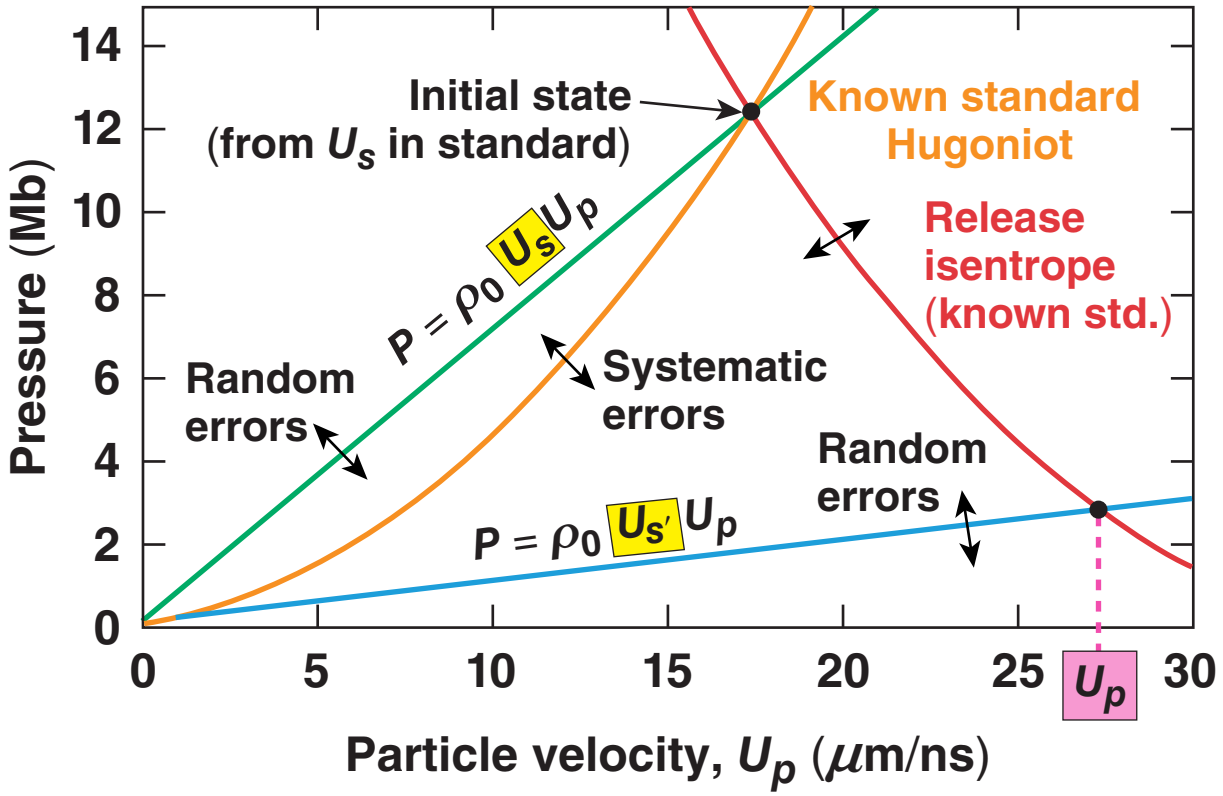
EOS measurements are obtained from the impedance-matching technique



Rankine–Hugoniot Equations

$$\rho_0 U_s = \rho_1 (U_s - U_p)$$

$$P_1 - P_0 = \rho_0 U_s U_p$$



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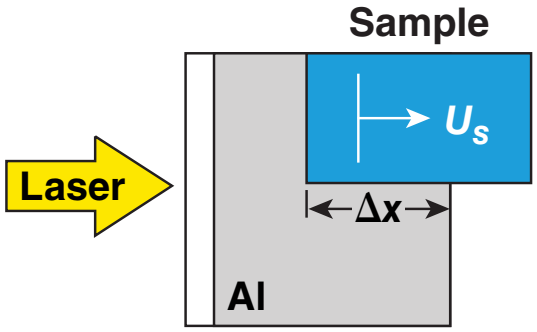
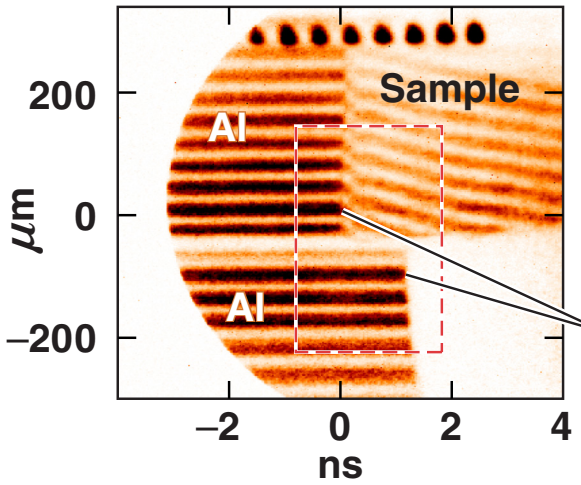
Random Errors

Higher precision is obtained with a transparent standard compared to an opaque standard



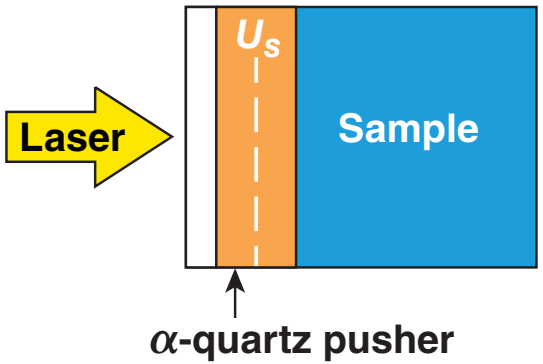
U_s is inferred from transit times

Opaque standard
VISAR-1 shot 29425

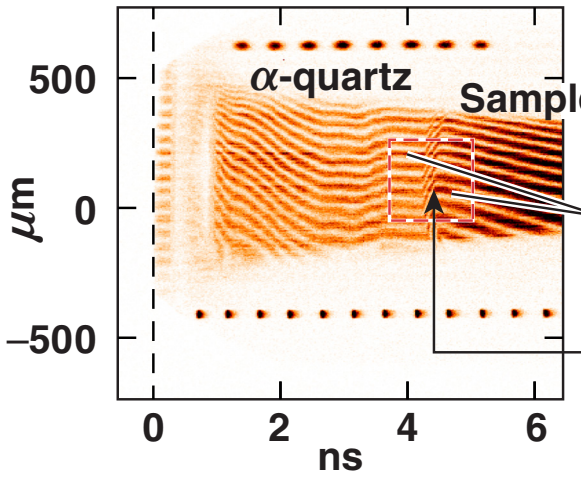


- Only information is transit time
- Can use only integrated shock
- No knowledge of shock stability

Integrated velocity



Transparent standard
VISAR-1 shot 52118



- EOS observables are obtained at the contact interface

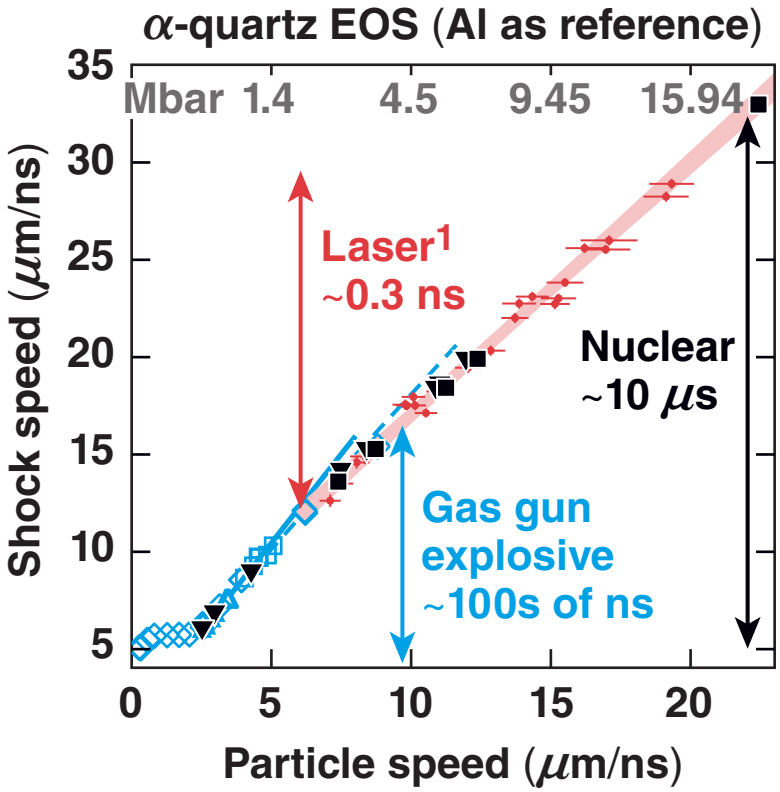
Instantaneous velocities

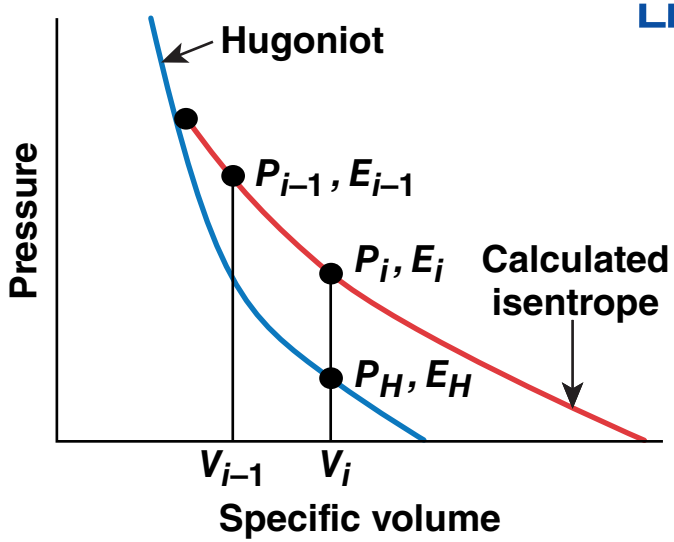
Contact interface

E17324e

Systematic Errors

Systematic errors are assessed by using α-quartz's experimental Hugoniot and approximating release isentropes via the Mie-Grüneisen EOS





- Γ describes pressure differences between equal volume states on the Principal Hugoniot

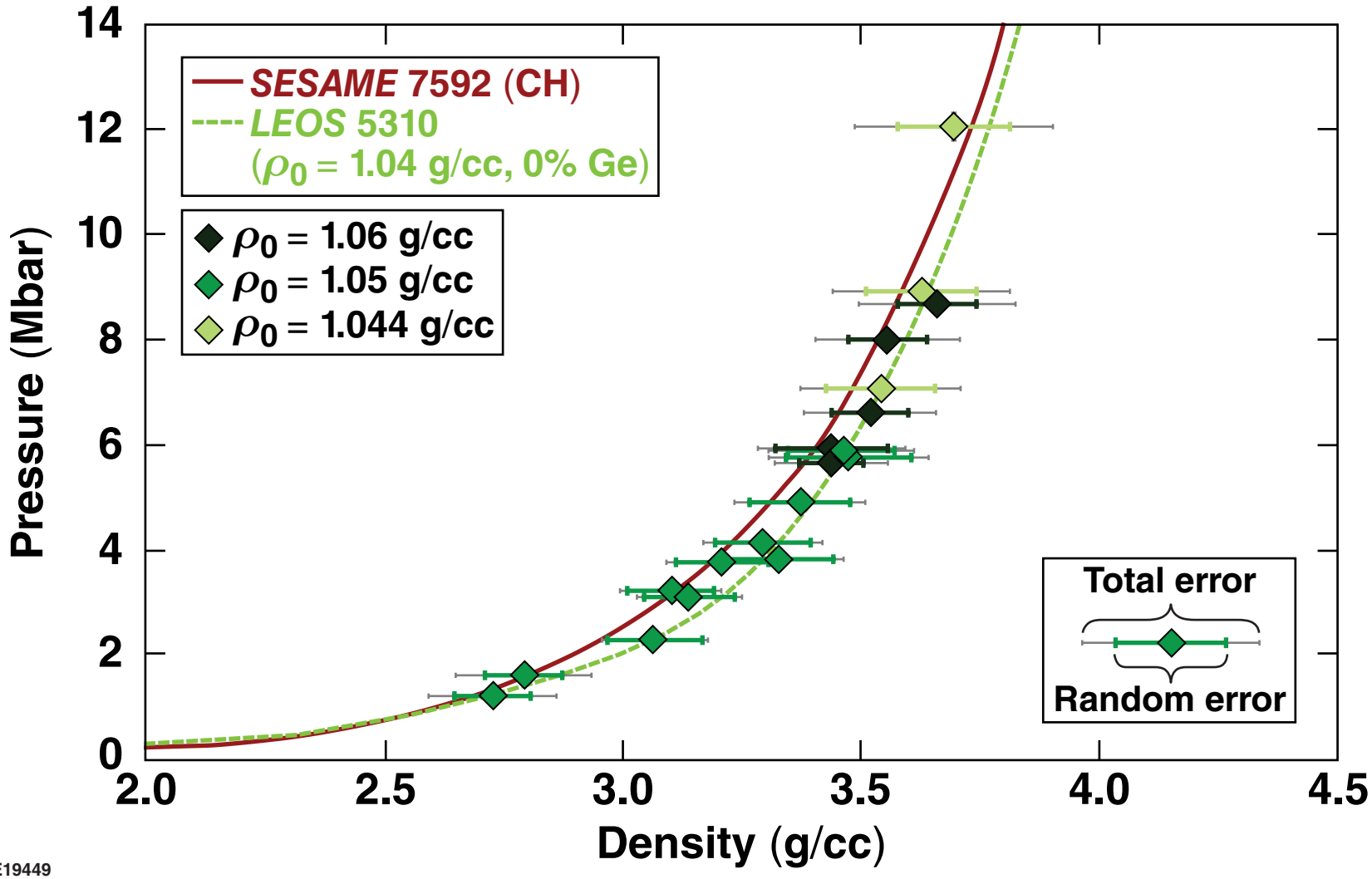
$$\Gamma = V\left(\frac{dP}{dE}\right)_V$$

- Combining $dE = TdS - PdV$, with $dS = 0$, leads to a recursion relation in the P–V plane
- Γ is assumed to be constant in the high-pressure fluid regime, with value $\Gamma = 0.64 \pm 0.11$[2]

[1] D. G. Hicks *et al.*, Phys. Plasmas 12, 082702 (2005).
[2] D. G. Hicks *et al.*, Phys. Review B 78, 174102 (2008).

E17325e

The measured GDP EOS is in agreement with available models over the ~1- to 10-Mbar pressure range



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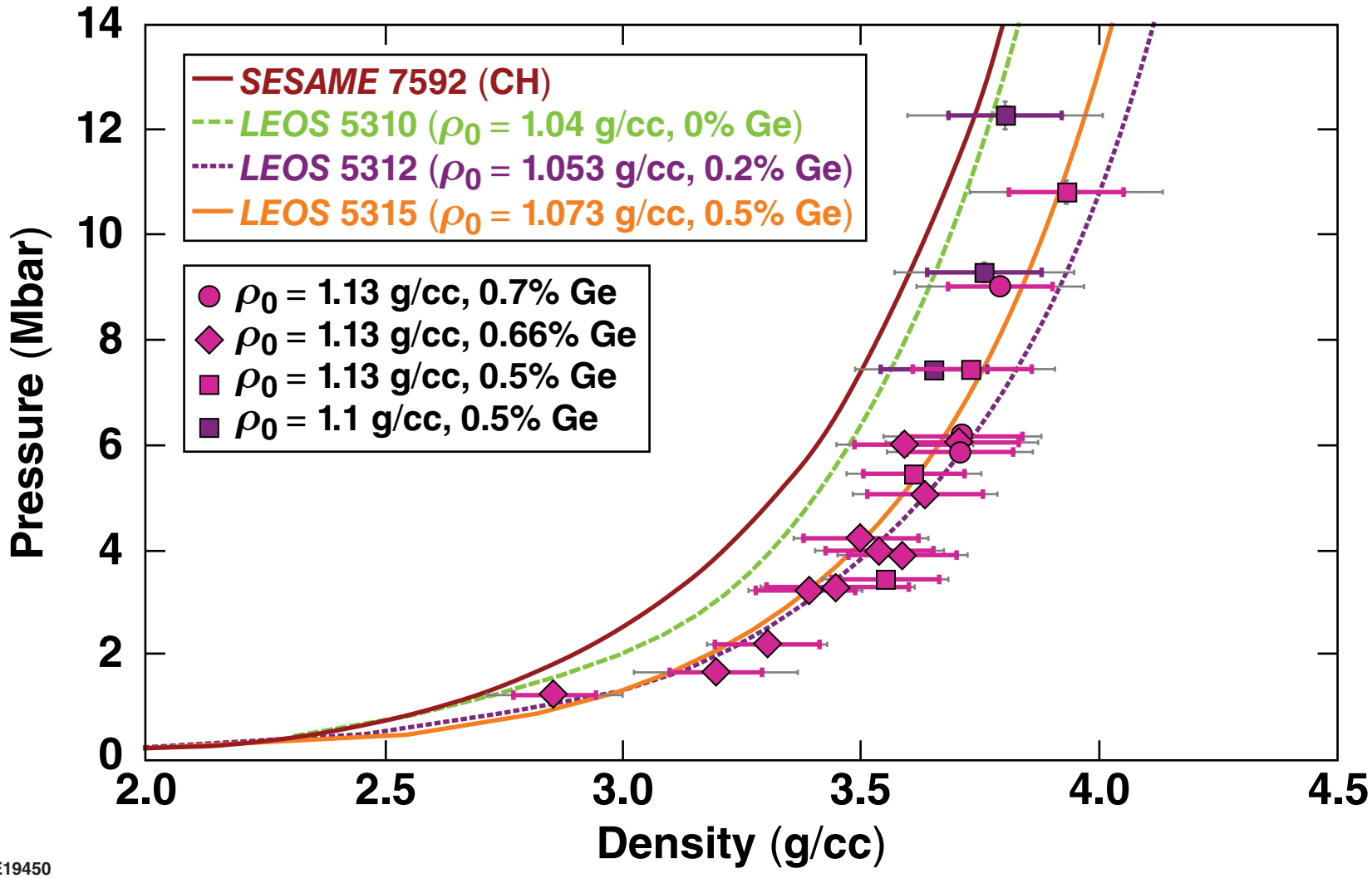
The Ge-GDP data are consistent with available *LEOS* models in the P–ρ plane



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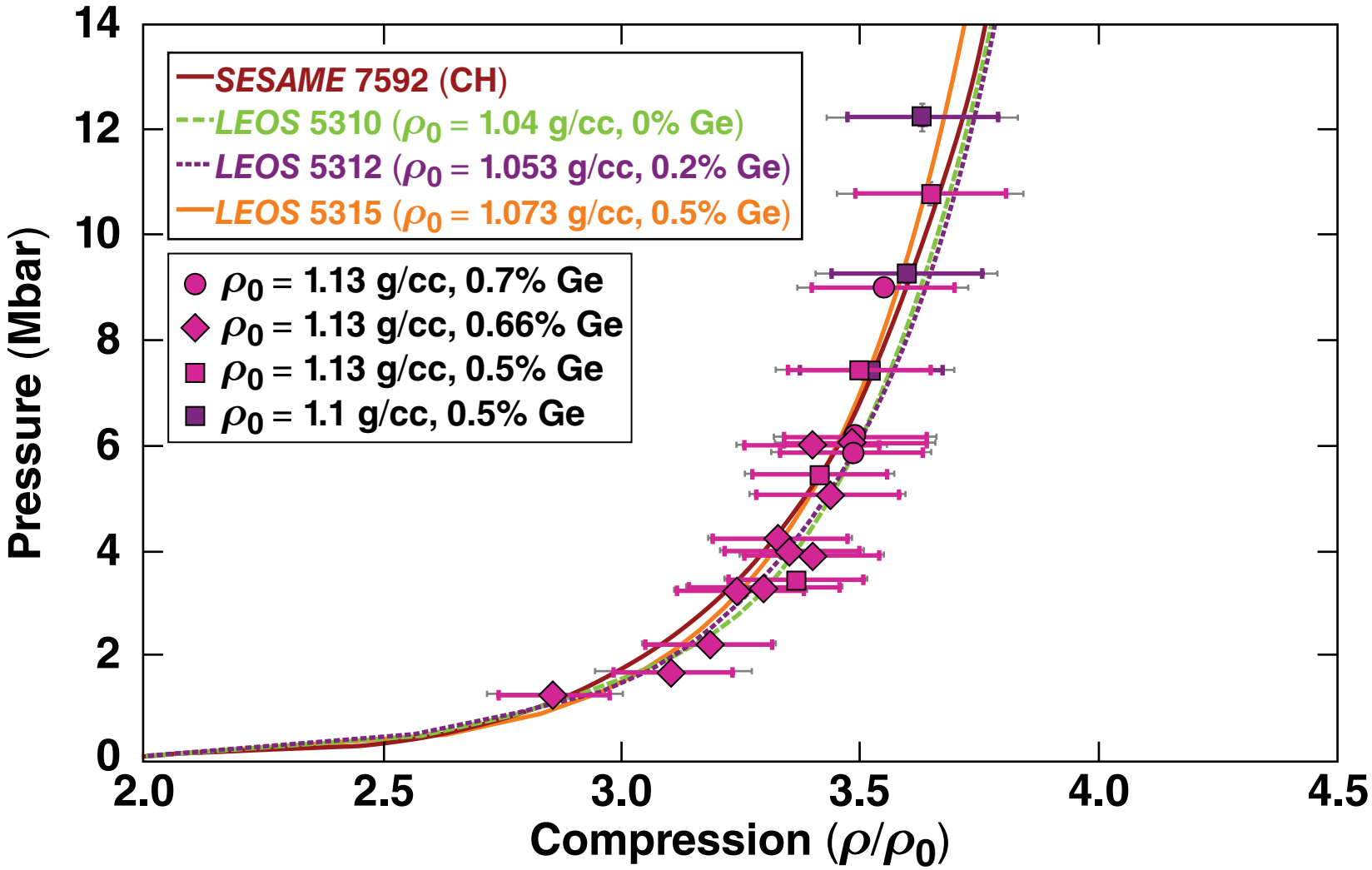
Structure in Ge-GDP P–ρ EOS data is due to initial density variations



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Summary/Conclusions

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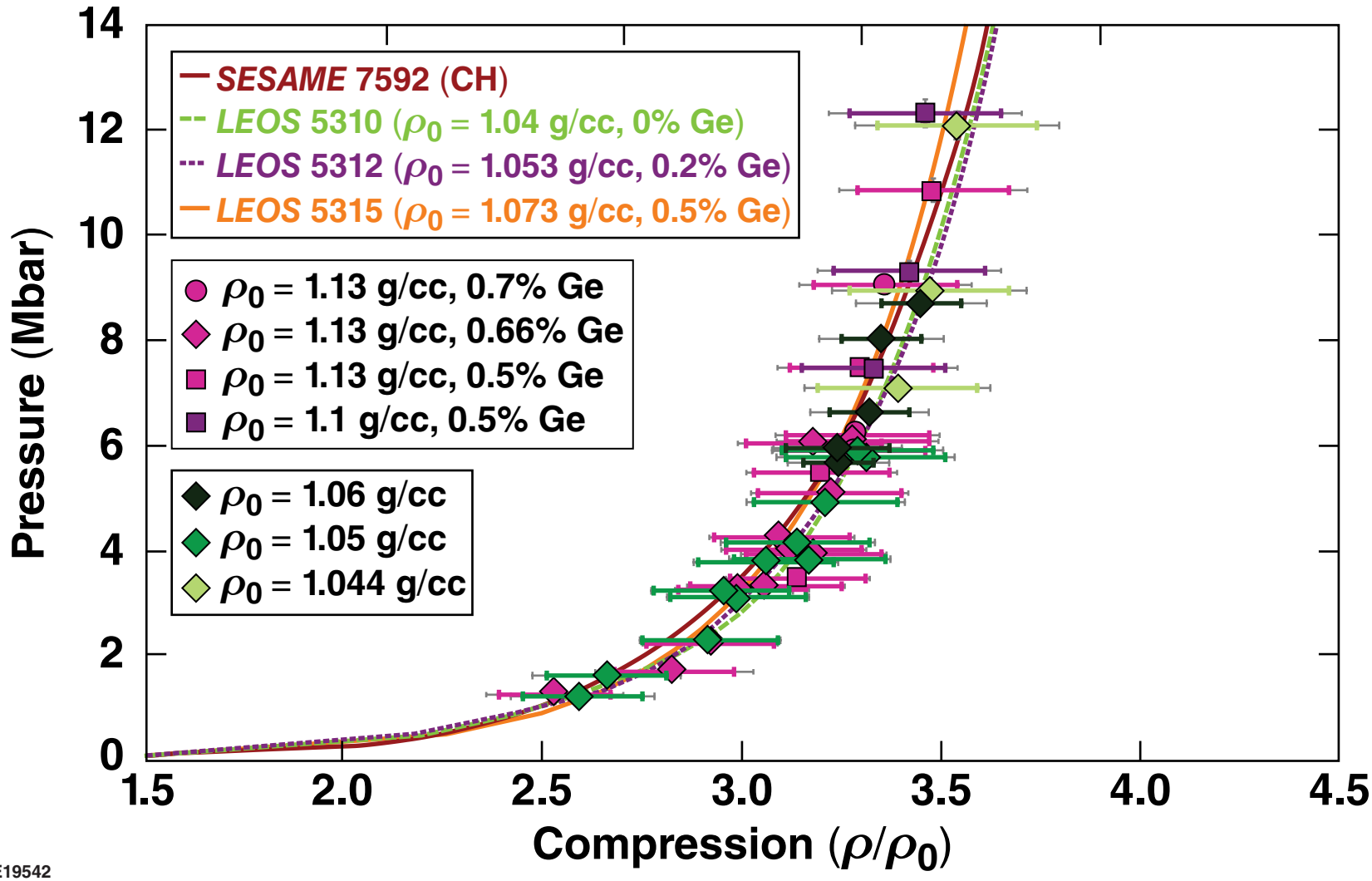
Comparison of GDP and Ge-GDP results indicates that both materials reach similar compression states



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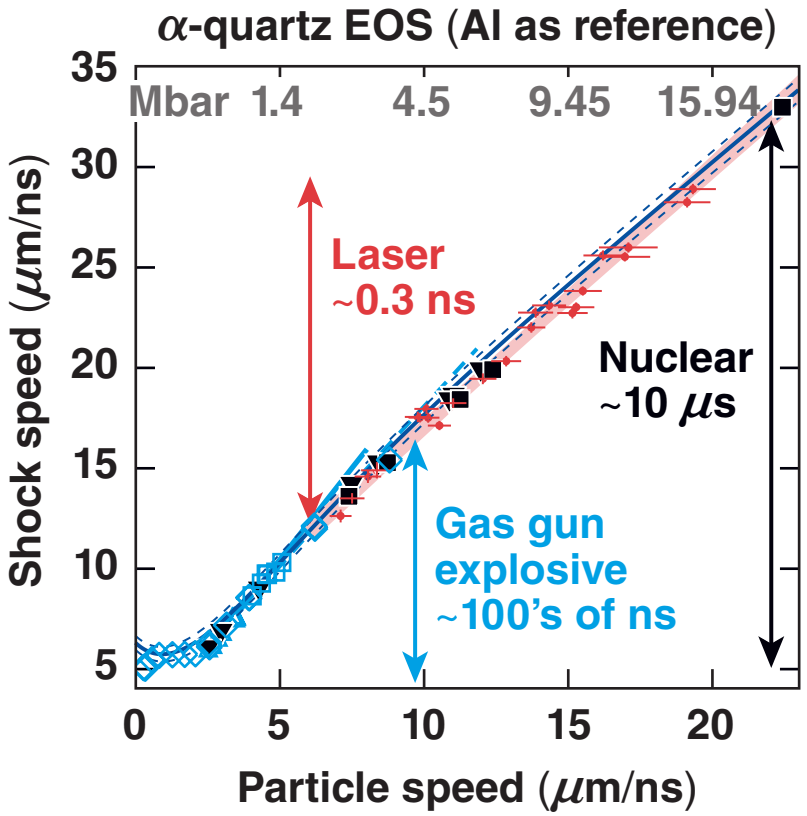
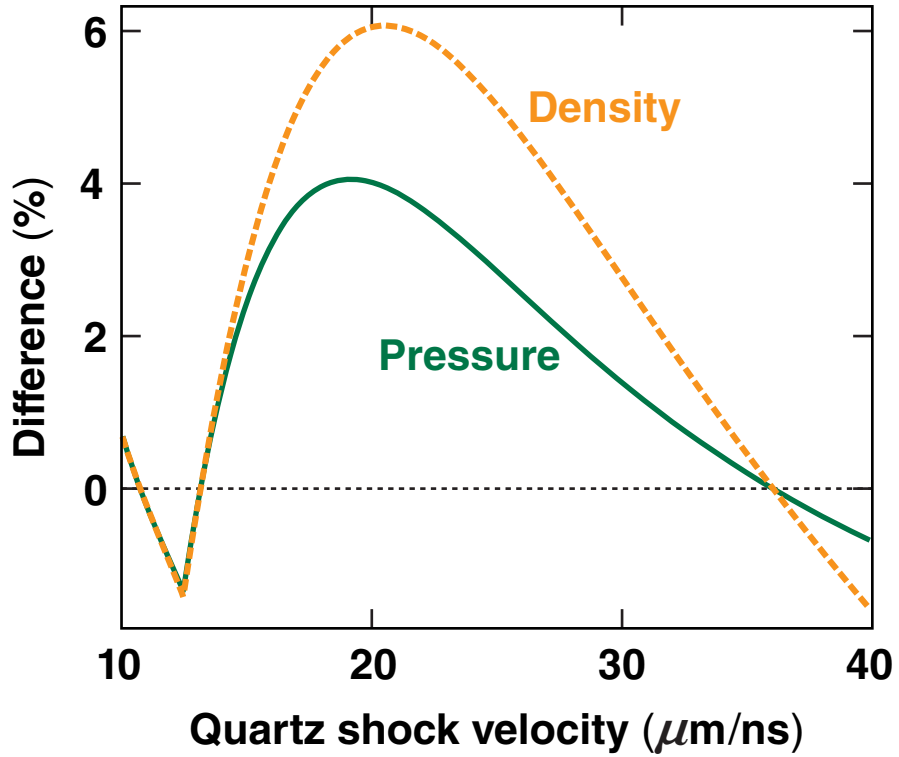
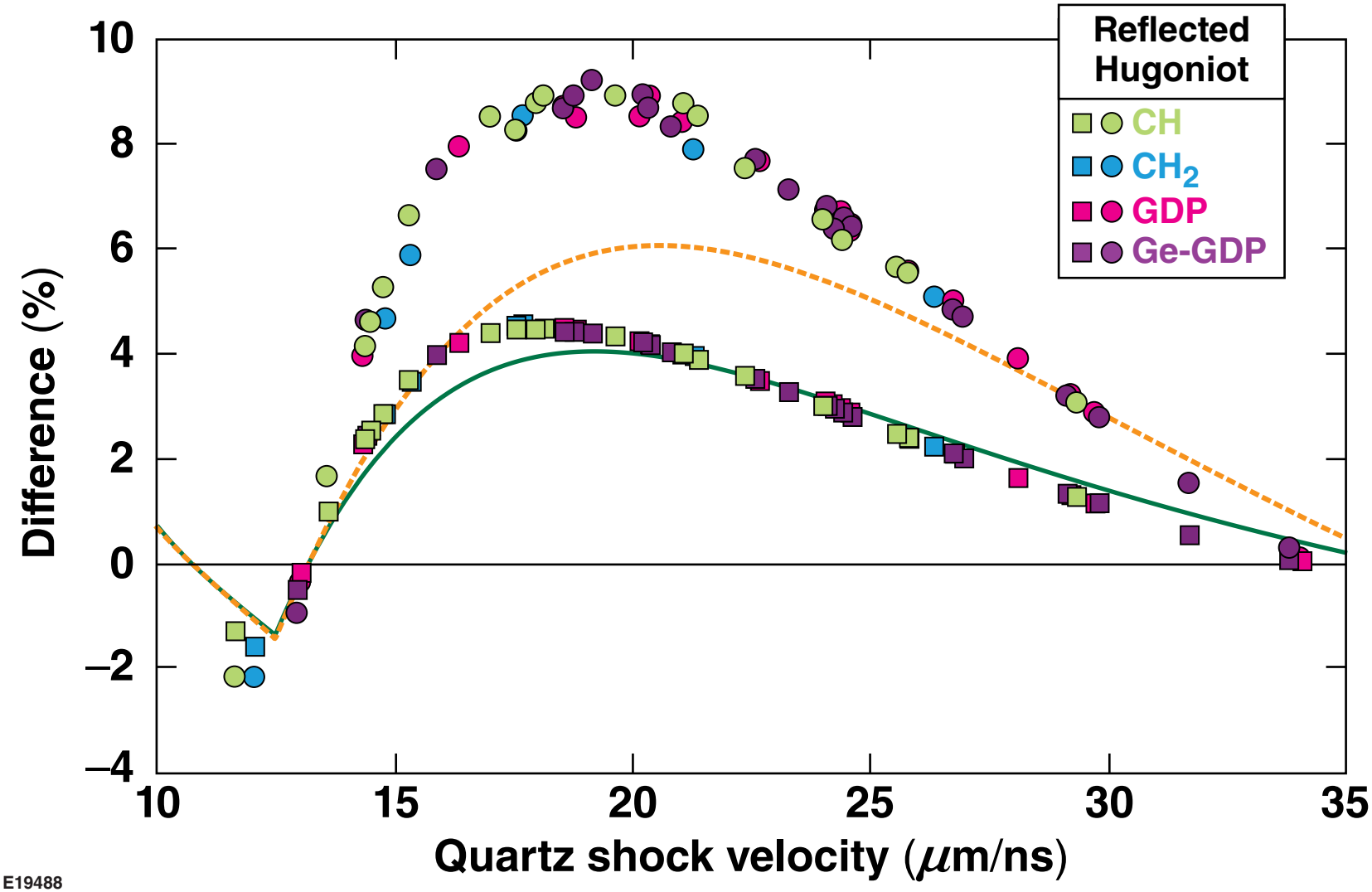
EOS differences between laser and Z-machine results peak at ~6% in density and ~4% in pressure





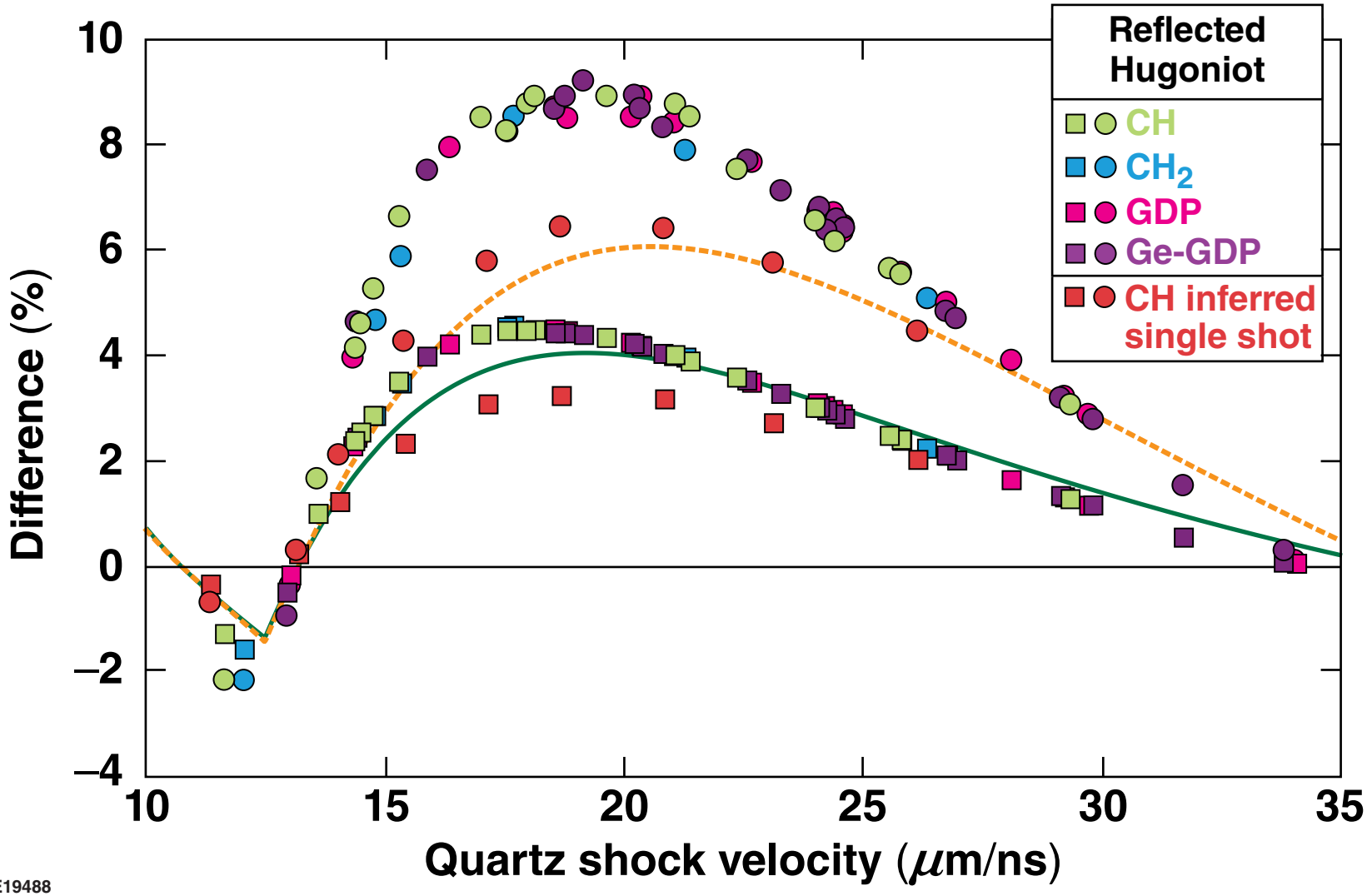
E19135a

Percent differences in resulting CHx pressure and density using laser and Z-machine quartz fit



E19488

Percent differences in resulting CHx pressure and density using laser and Z-machine quartz fit



E19488