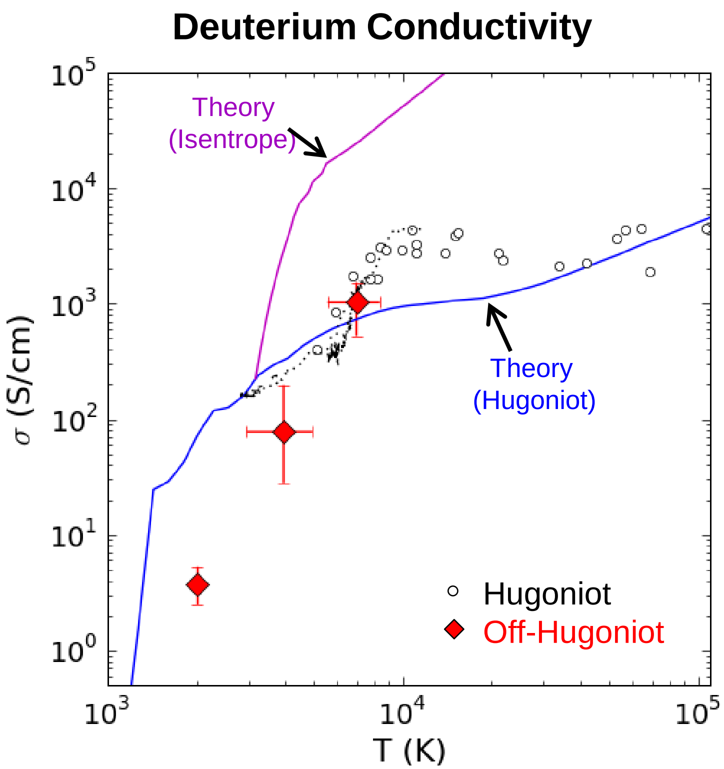
Conductivity of multi-shock compressed deuterium



Acknowledgements:
D. G. Hicks, T. R. Boehly, P. M. Celliers, R. F. Smith,
P. Sterne, O. L. Landen, and G. W. Collins

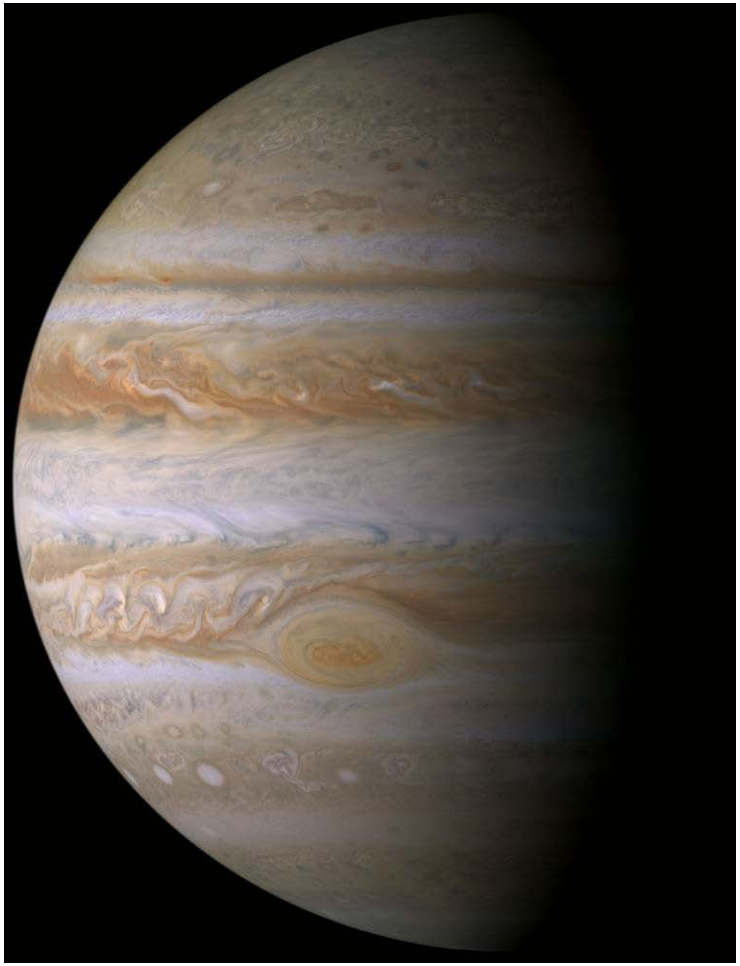
LLNL-PRES-425271

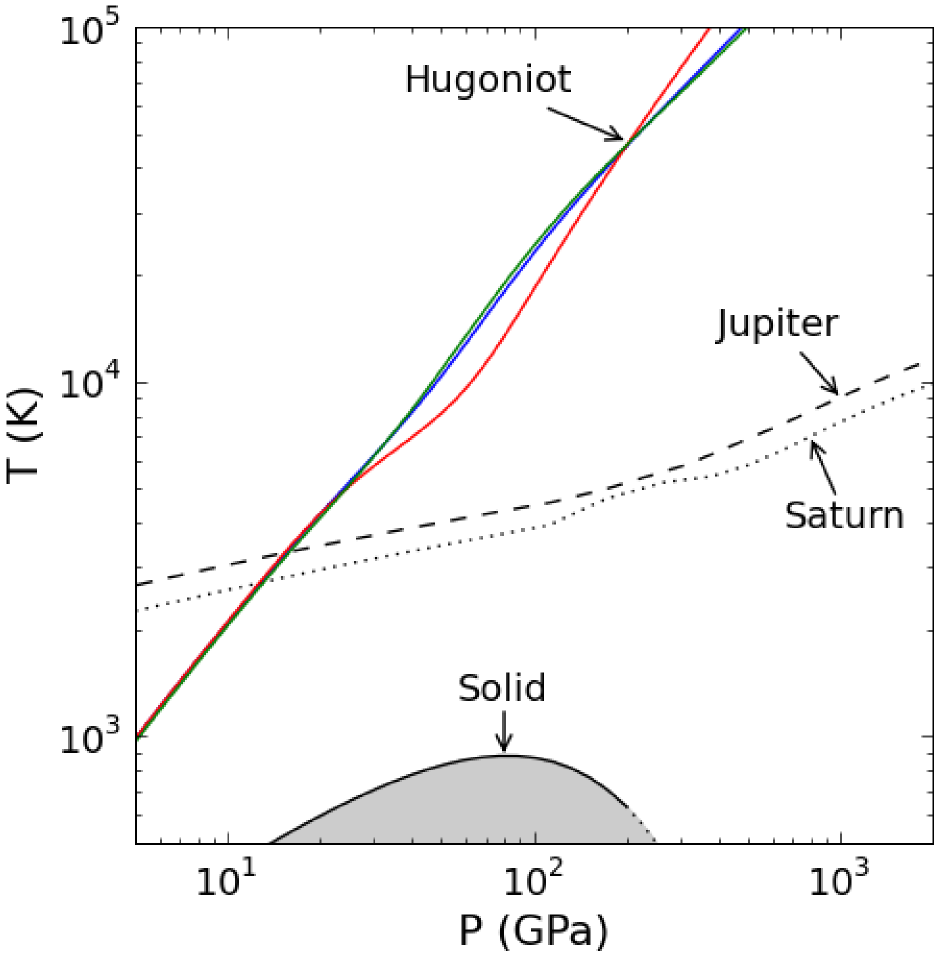
J. Ryan Rygg
Lawrence Livermore National Laboratory

Summary

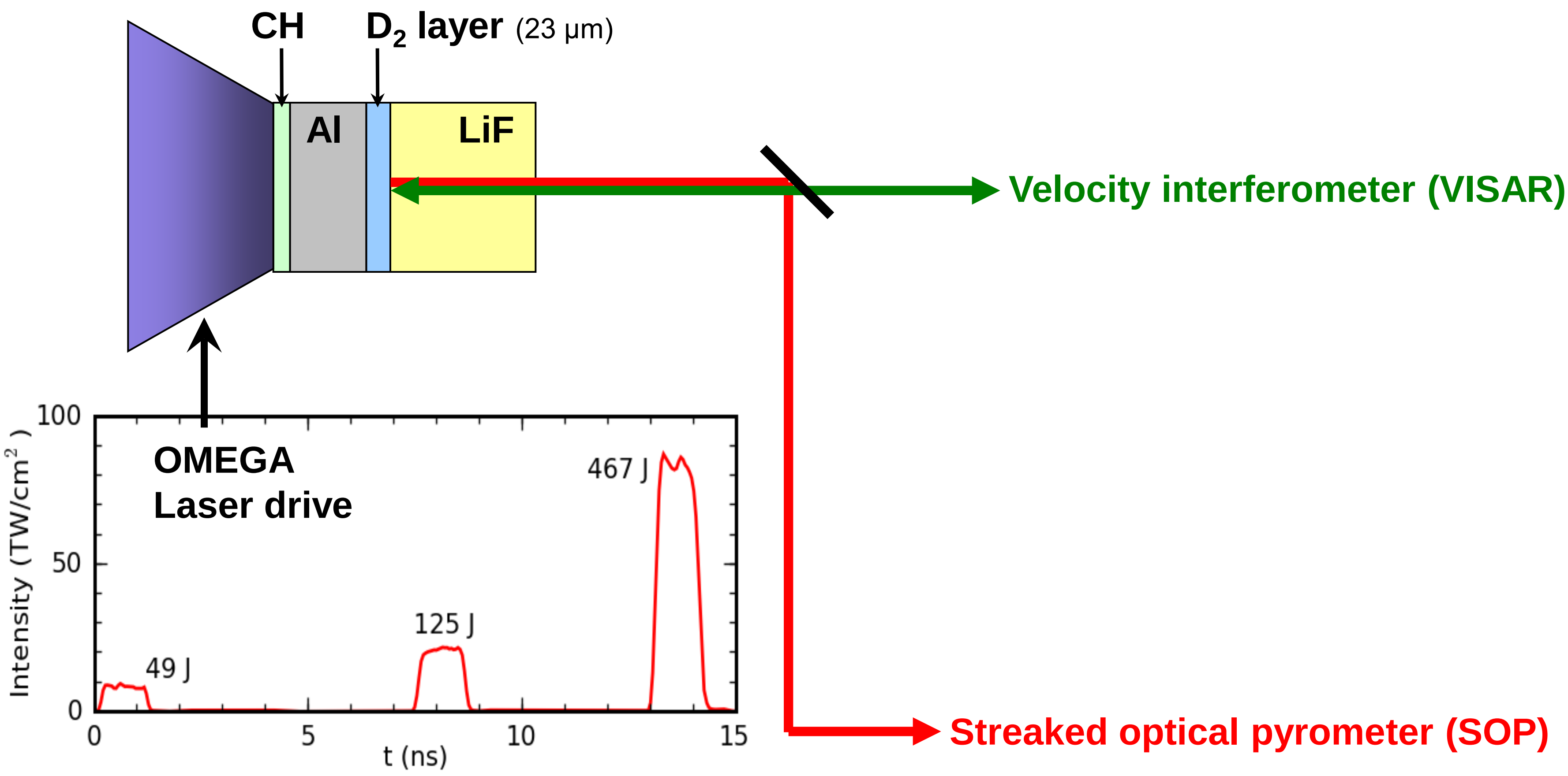
- **Deuterium was multi-shock compressed up to 570 GPa**
  - Simultaneous velocimetry and emissivity measurements
  - Electrical conductivity inferred from optical absorbance and reflectance measurements
  - Substantial increase observed to metal-like conductivity

Motivation: Jupiter's B-field is generated by currents in high pressure hydrogen

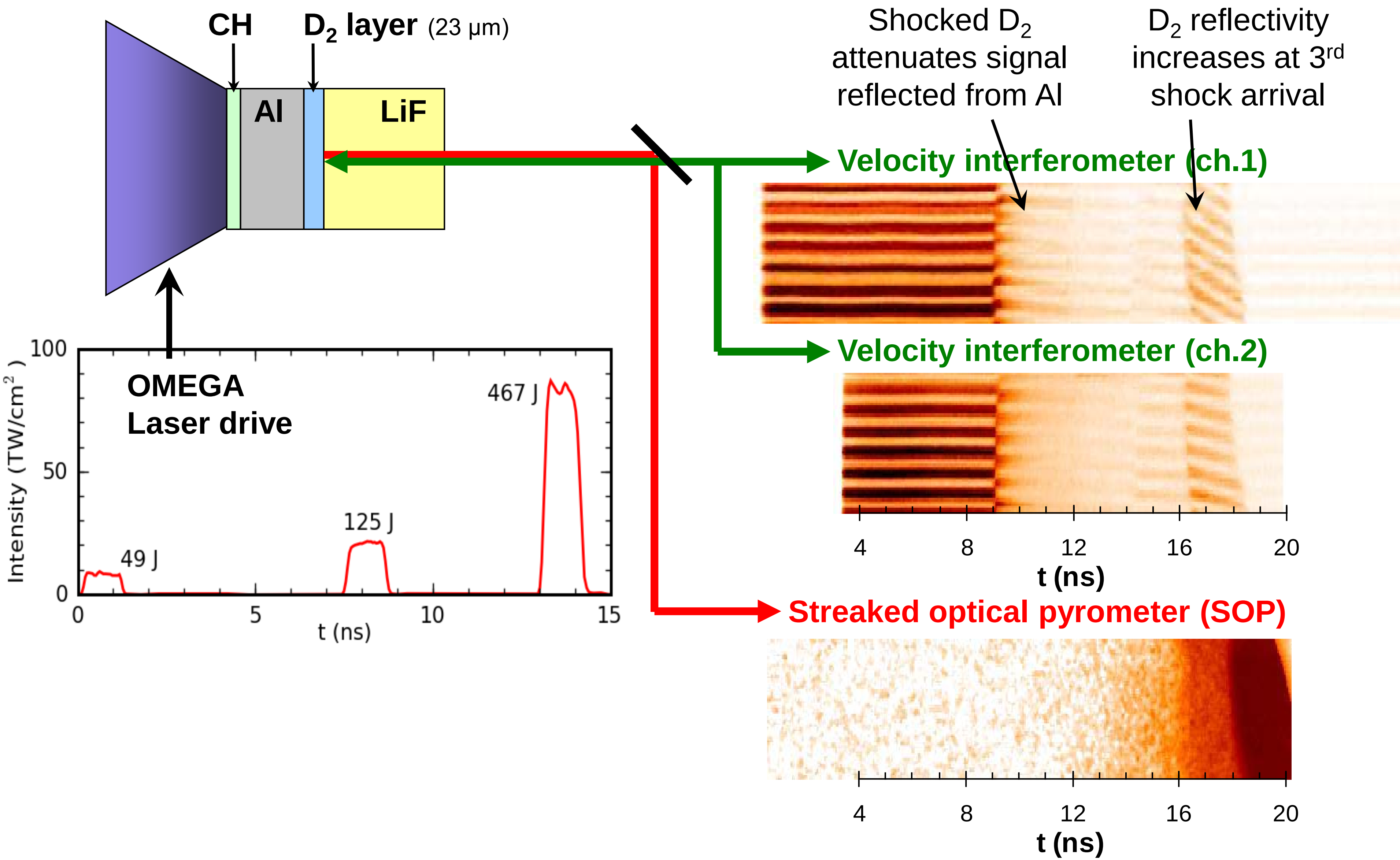




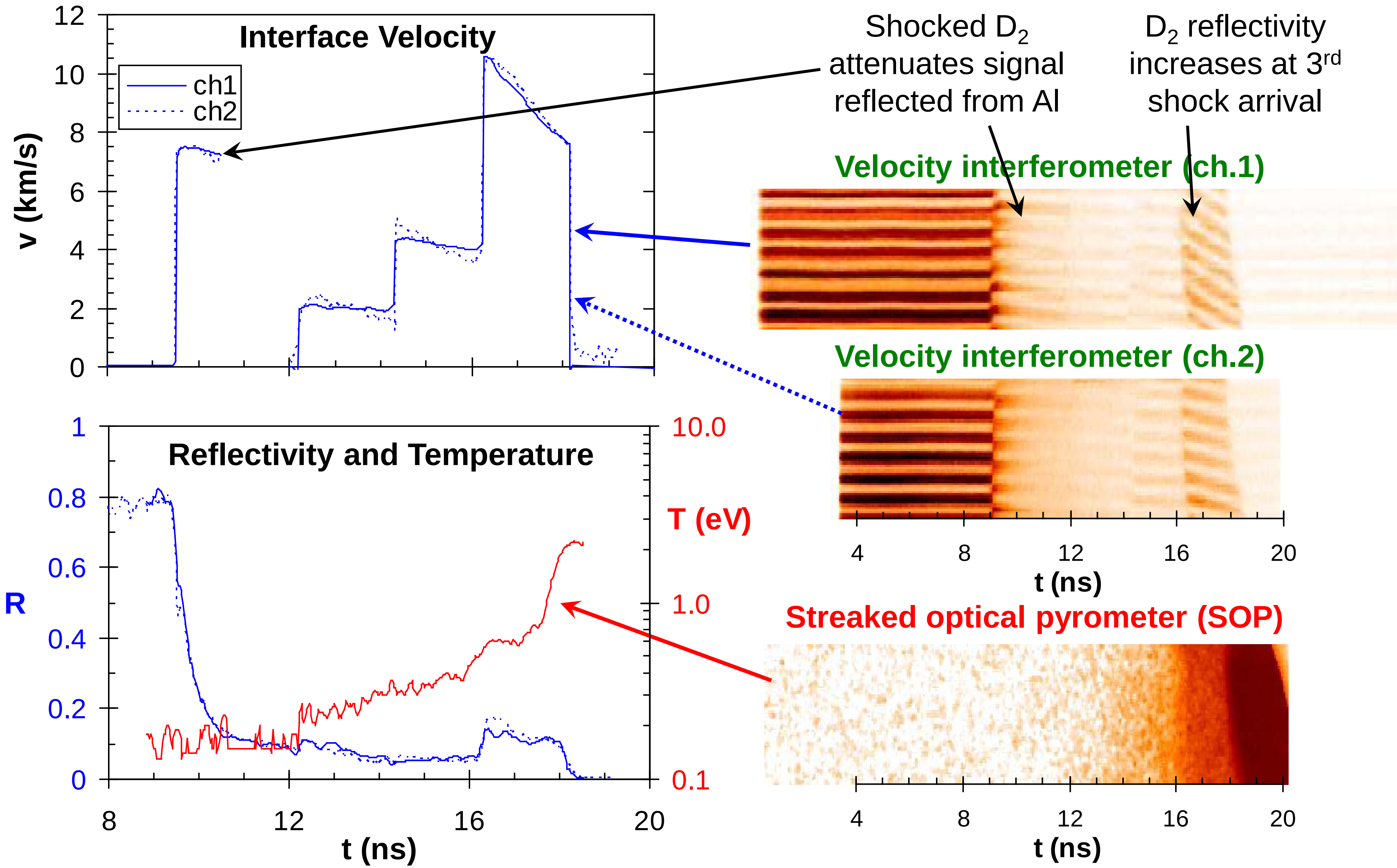
Experiment: A thin cryogenic D_2 layer was compressed by multiple laser-driven shocks at the OMEGA facility



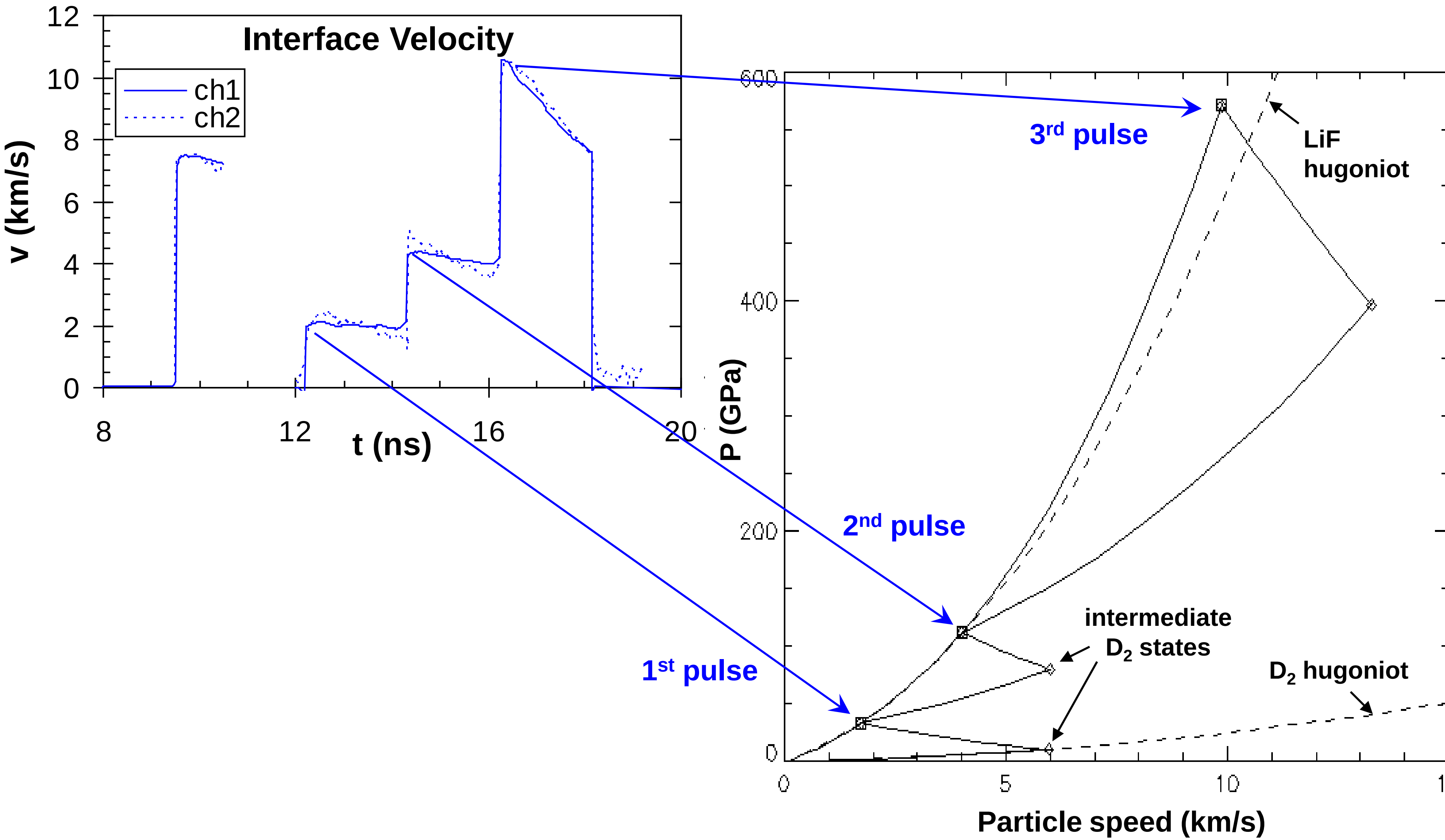
The D_2 layer was characterized by simultaneous velocity, reflectance, and pyrometric measurements



Velocity, reflectance and temperature histories

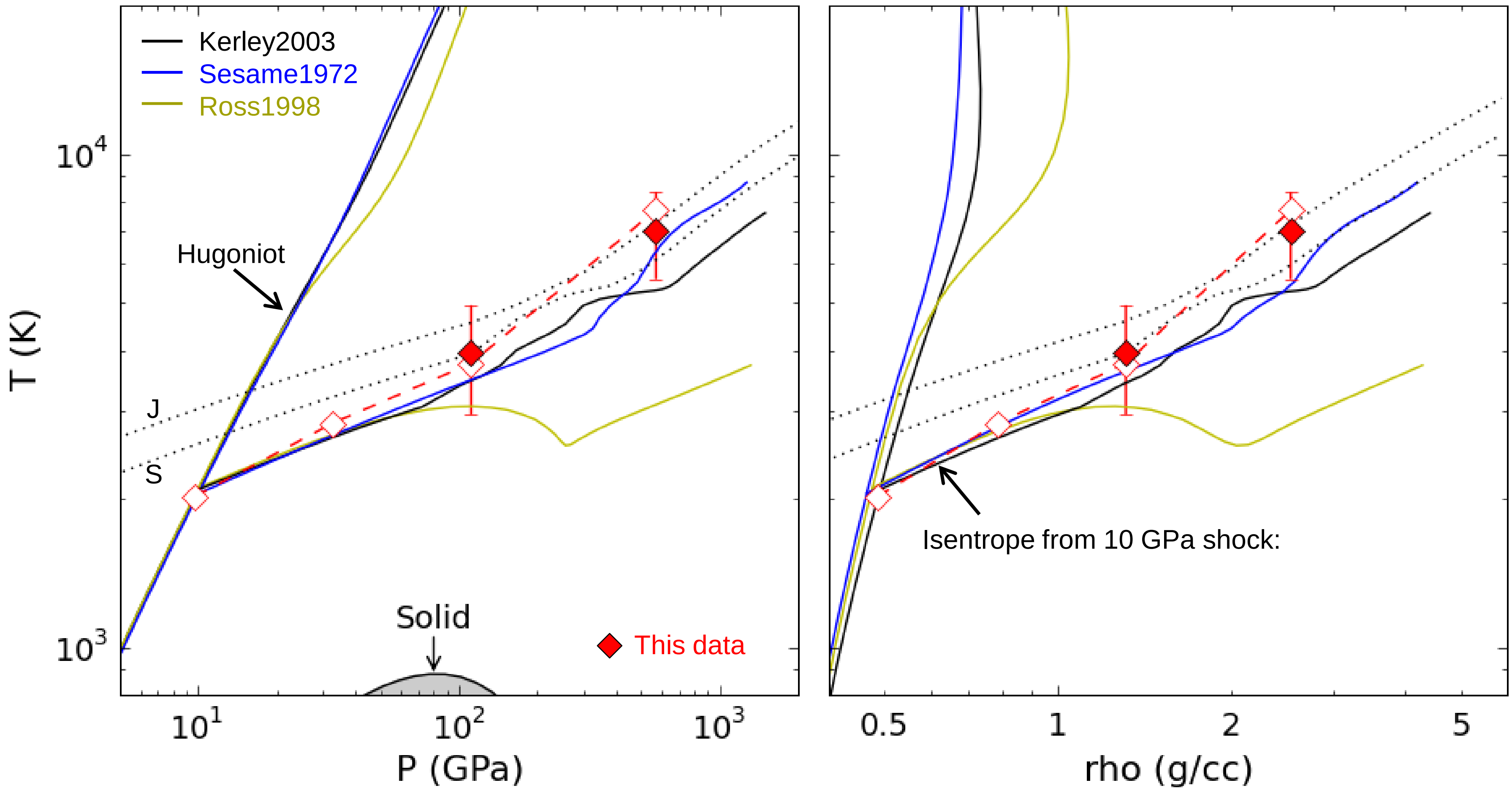


Pressure is inferred using EOS tables and imposing continuity at LiF-D_2 interface



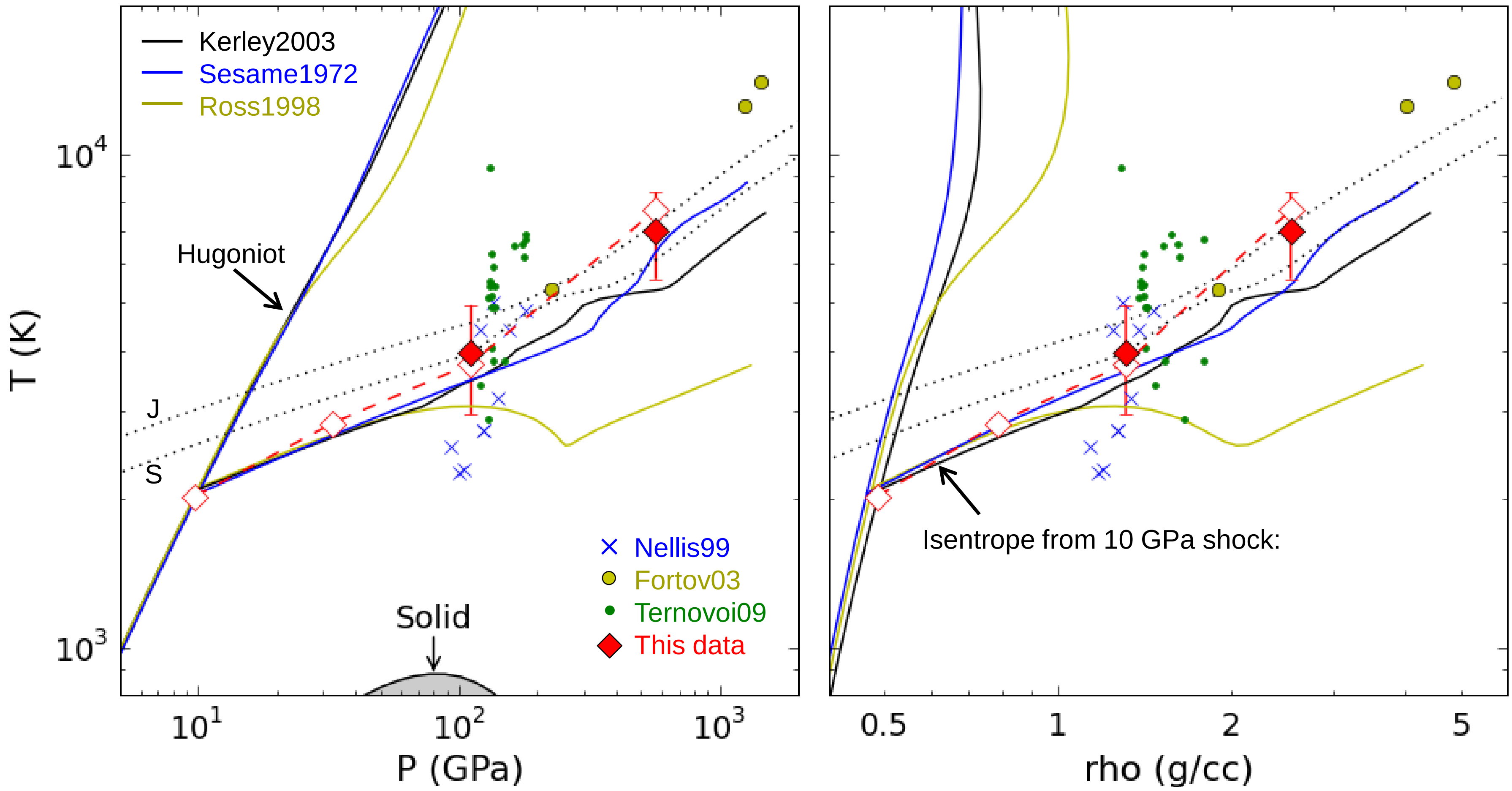
*Using Kerley2003 EOS

Multi-shock compression is nearly isentropic

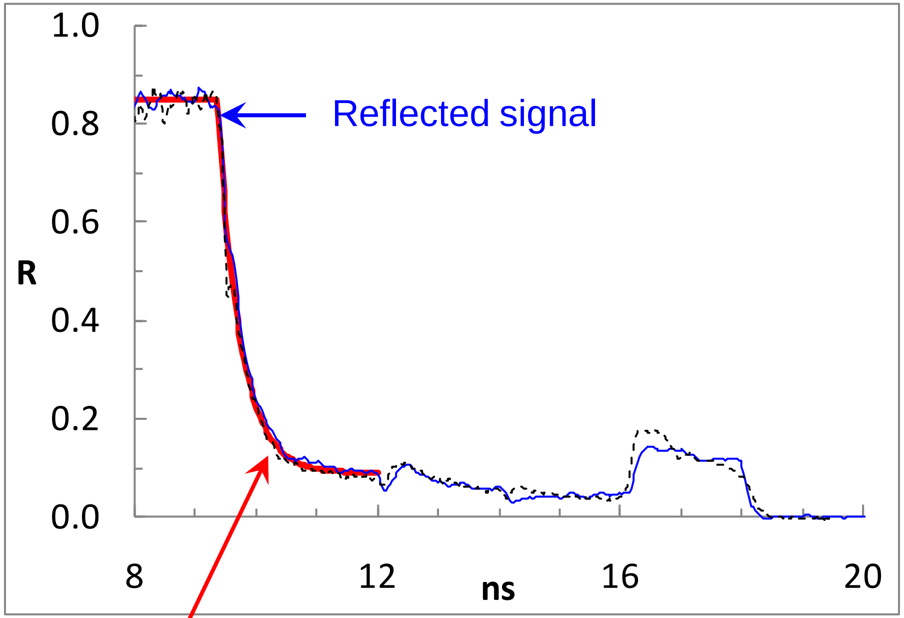


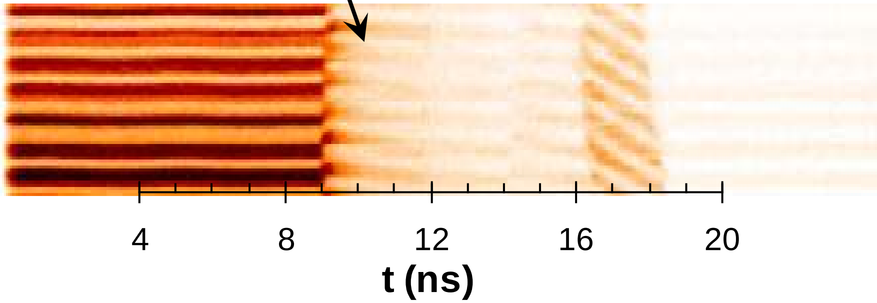
Other multi-shock compressed D_2 experiments

(T, ρ typically inferred from hydro simulations)



Conductivity is inferred from optical absorption in shocked D_2





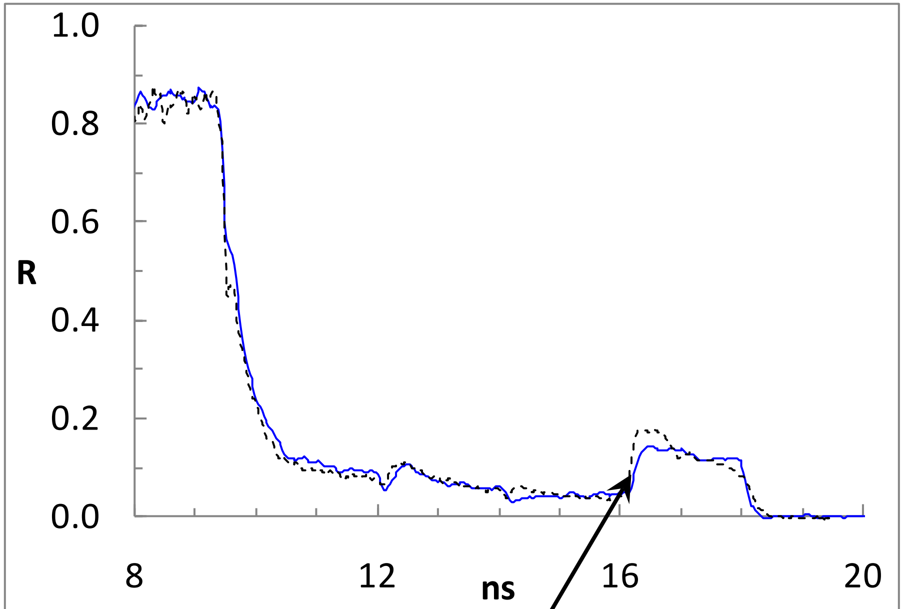
Fit using Beer's Law, $I = I_0 \times 10^{-z/z_0}$,
with $z_0 = 15\ \mu\text{m}$

Relate absorption to electrical conductivity using Drude-Zener: $\sigma_0 = \dfrac{\varepsilon_0 c\, n}{z_0}$

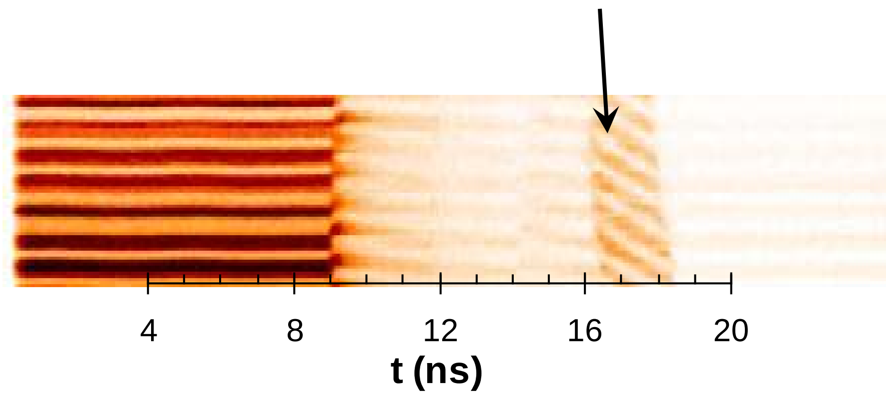
$$\sigma_0 \approx 4\ \Omega^{-1}\, cm^{-1}$$

(D_2 conductivity at 10 GPa, 2000 K)

Conductivity is inferred from reflectance of the final shocked state



D_2 reflectivity increases at 3rd shock arrival



Measured reflectance (15%) constrains conduction electron density and collisionality within the Drude model:

$$R = \left| \frac{N - n_1}{N + n_1} \right|^2$$

$$N^2 = 1 - \frac{\omega_p^2}{\omega^2} \left(1 + \frac{i}{\omega \tau_e} \right)^{-1}$$

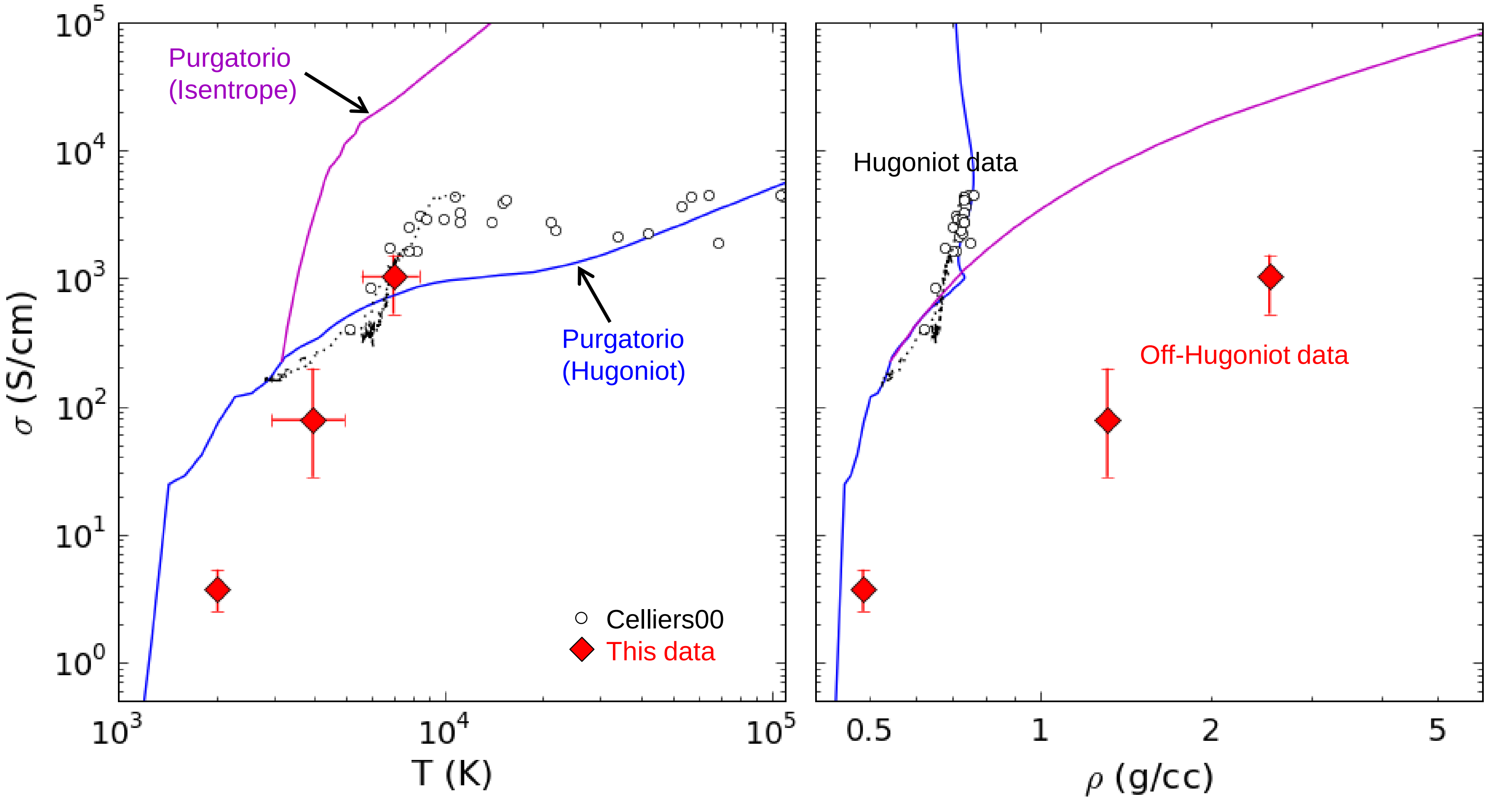
Drude model electrical conductivity gives*:

$$\sigma_0 = \frac{n_e e^2 \tau_e}{m_e}$$

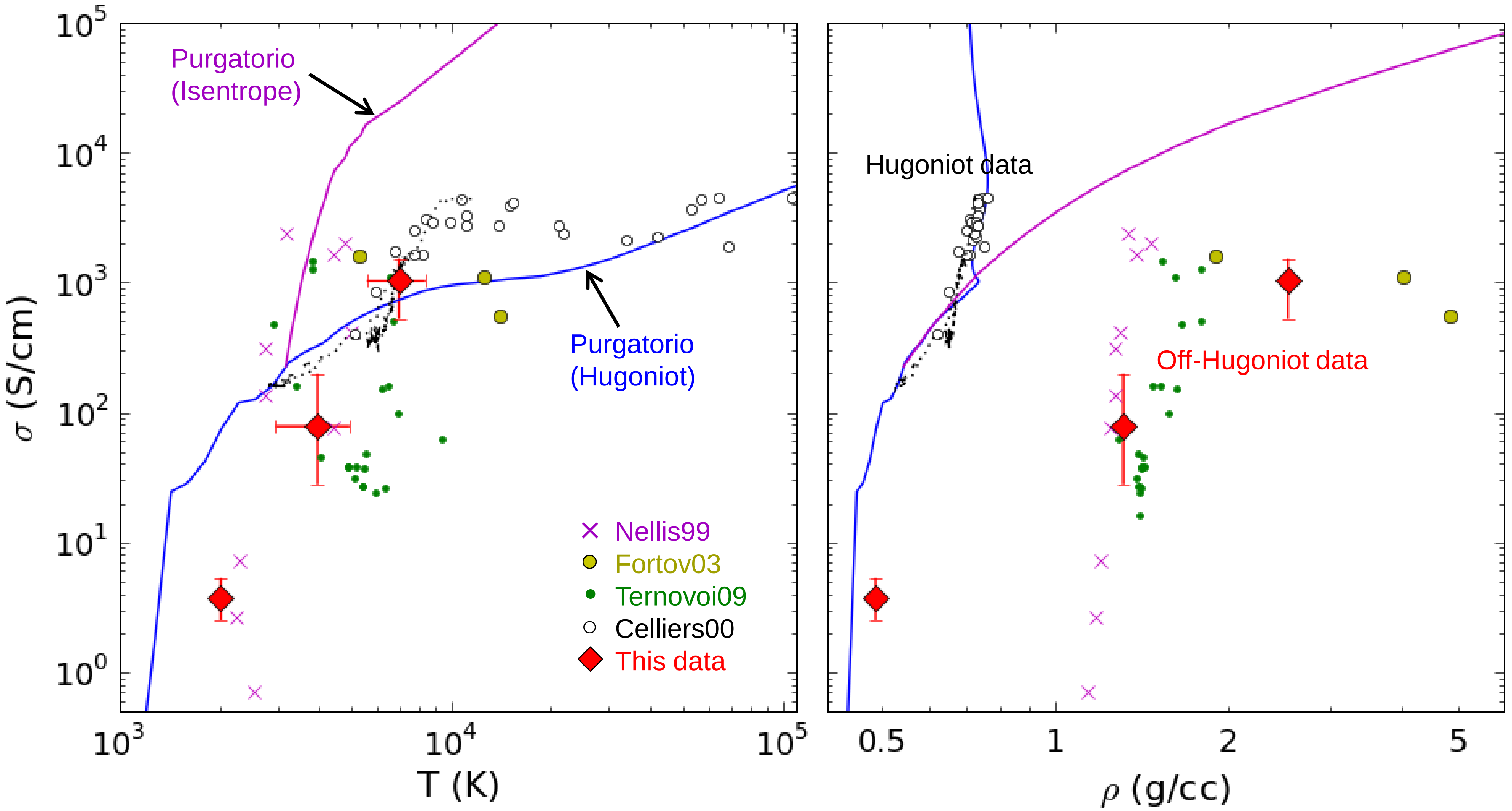
$$\sigma_0 \approx 1050 \ \ \Omega^{-1} cm^{-1}$$

*assuming electron relaxation time τ_e time is at Ioffe-Regel limit

Theoretical models of conductivity predict greater density dependence than that observed



Off-Hugoniot conductivity experiments measure values much lower than those of theoretical model



Summary

- **Deuterium was multi-shock compressed up to 570 GPa**
    - Simultaneous velocimetry and emissivity measurements
    - Electrical conductivity inferred from optical absorbance and reflectance measurements
    - Substantial increase observed to metal-like conductivity