Conductivity of multi-shock compressed deuterium

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Summary

- D_2 was compressed to high pressure (>6 Mbar) at low temperature (<1 eV) using multiple reverberating shocks at OMEGA
- Determined D_2 pressure and temperature by simultaneous velocimetry and emissivity measurements
- Obtained electrical conductivity from measured D_2 optical absorption at 0.15 MBar
- Obtained conductivities from measured D_2 reflectivity at ~6 MBar
- Comparison to previous experiments suggests that D_2 conductivity near 0.5 eV has no density dependence up to 2.7 g/cm^3

Motivation: Thermal conductivity has important consequences for ICF implosion performance

E.g., conductivity affects the density gradient at the fuel/pusher interface…

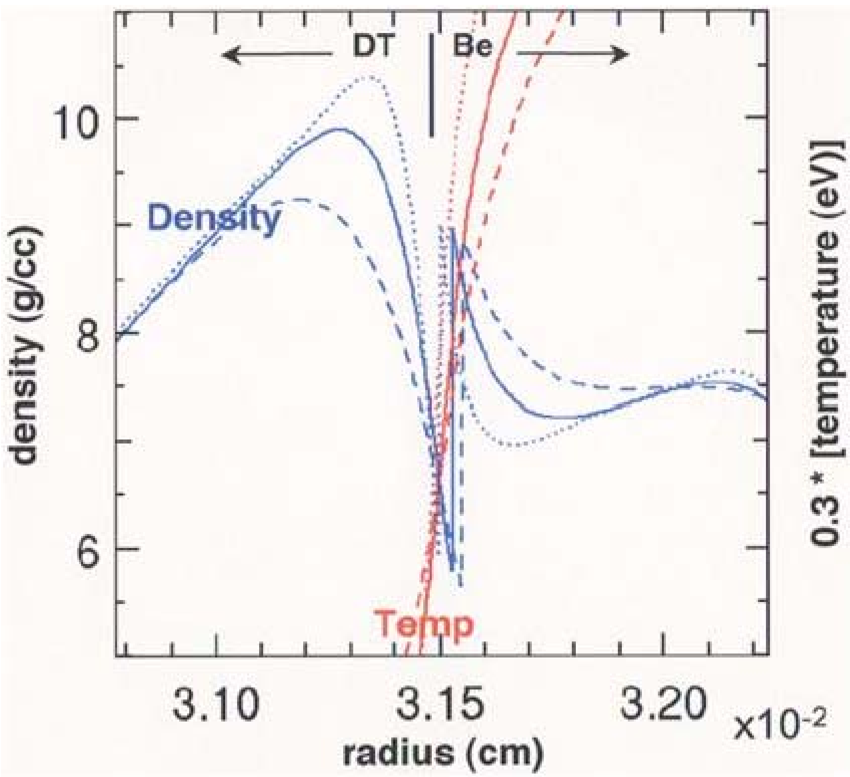
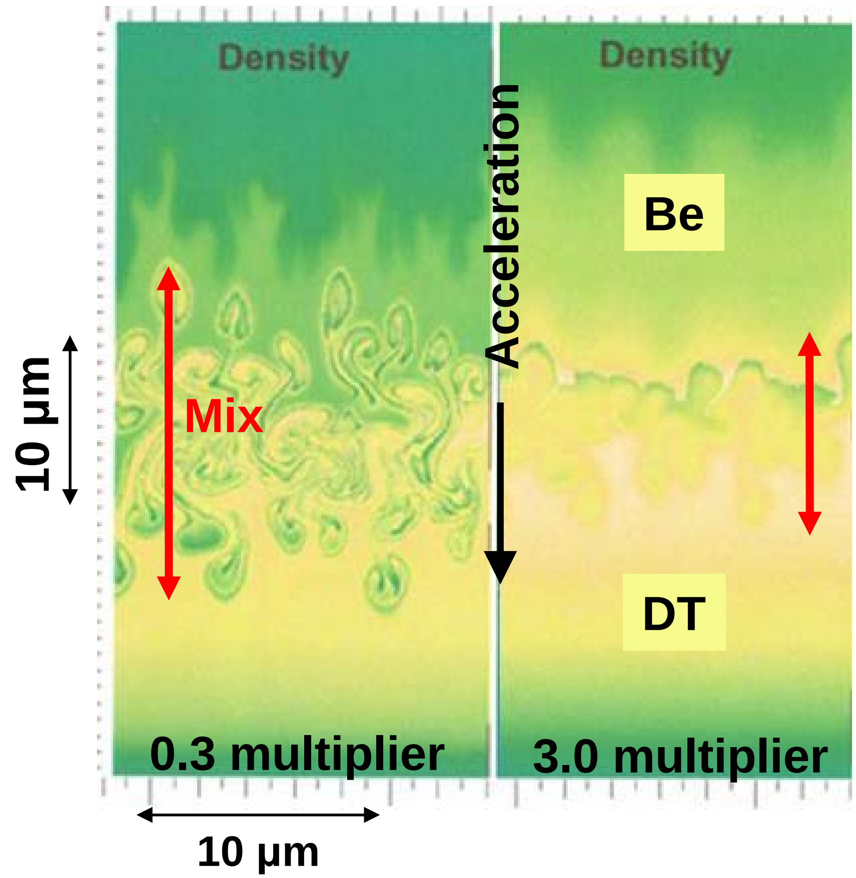


Figure 1b*: Variation in the profiles for 0.3 (dot), 1.0 (solid), and 3.0 (dash) times the nominal thermal conductivity (Lee-More).

… and the density gradient directly impacts high-mode stability.



*** B. Hammel (2008)**

Motivation: Thermal conductivity is not well understood in the WDM regime

E.g., conductivity affects the density gradient at the fuel/pusher interface…

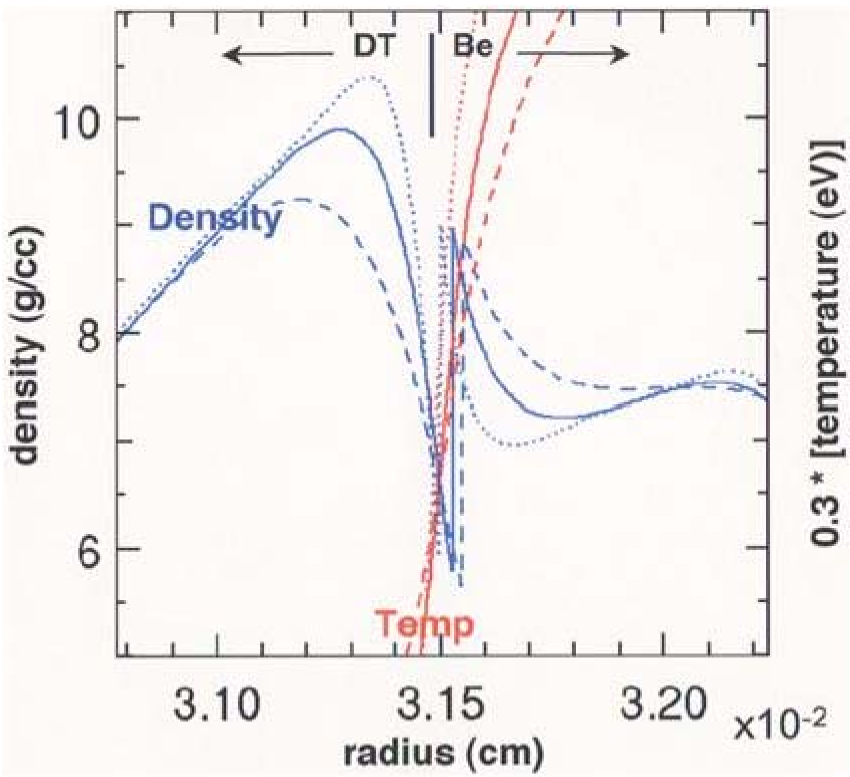
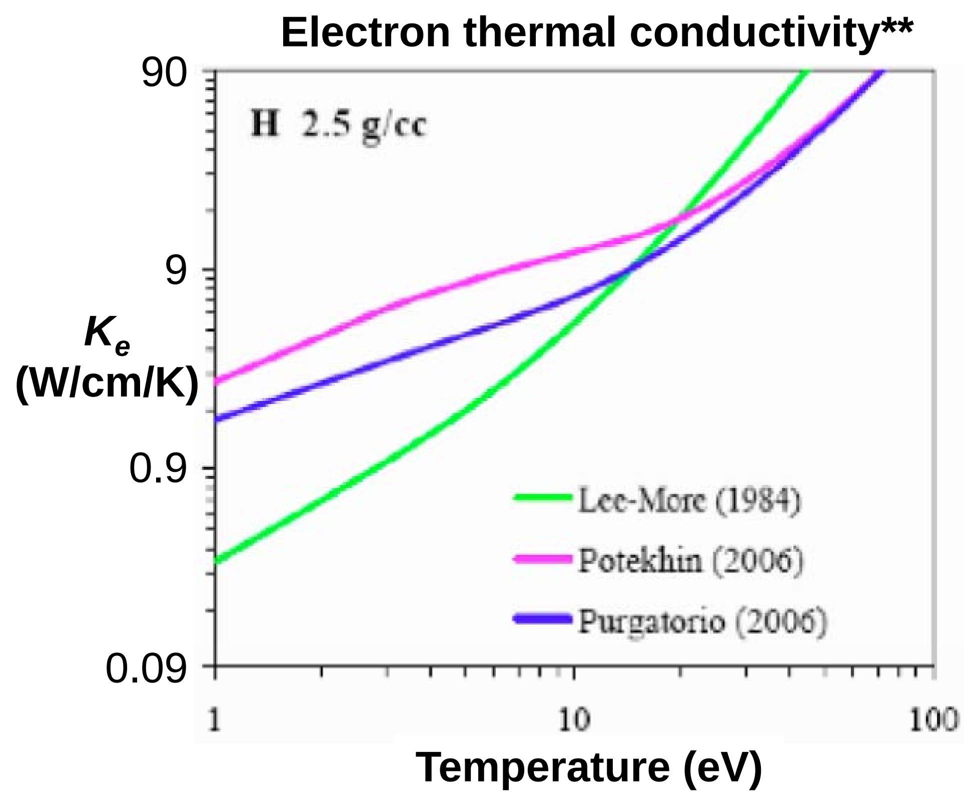


Figure 1b*: Variation in the profiles for 0.3 (dot), 1.0 (solid), and 3.0 (dash) times the nominal thermal conductivity (Lee-More).

*** B. Hammel (2008)**

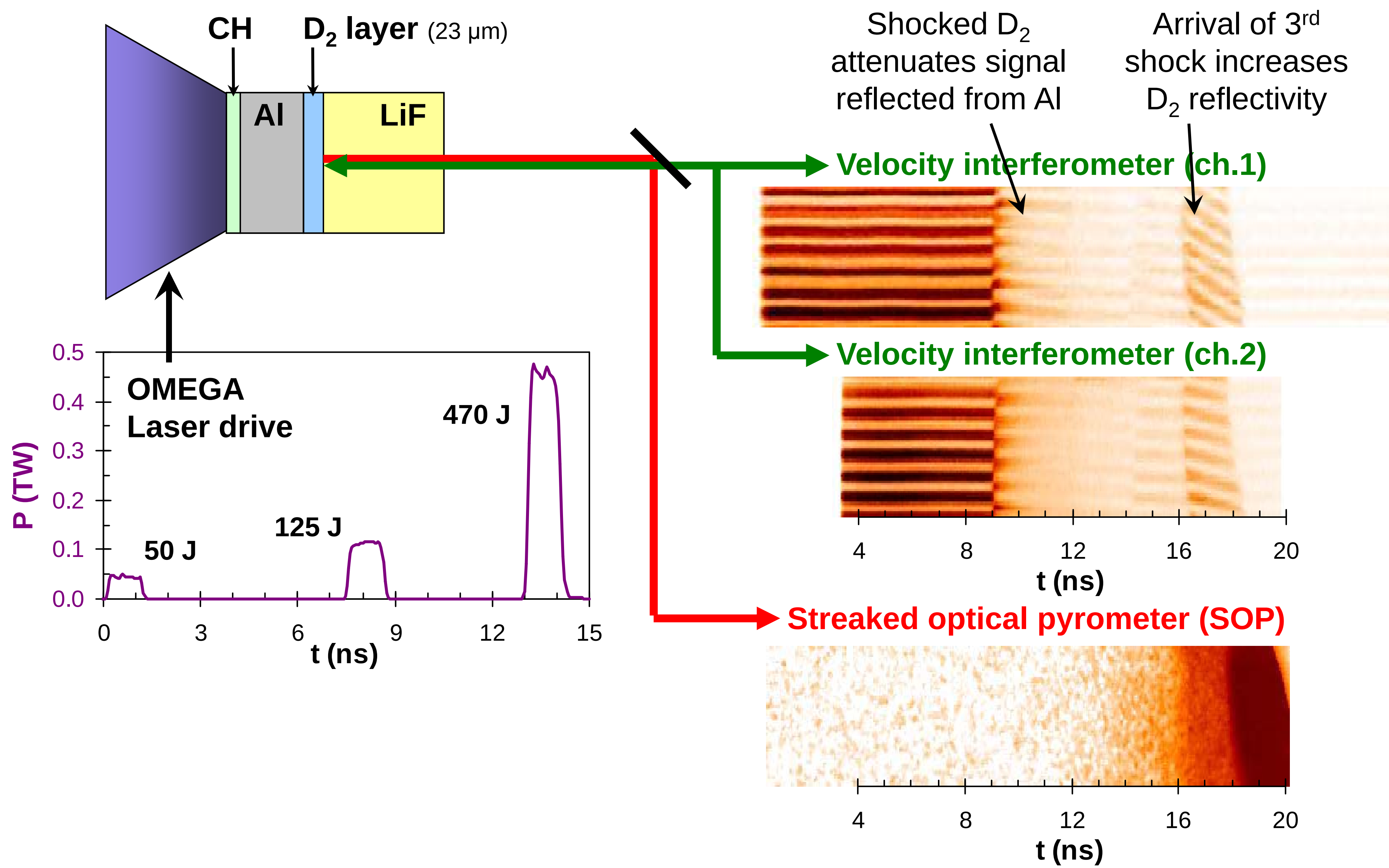
… yet theoretical values differ by nearly an order of magnitude.



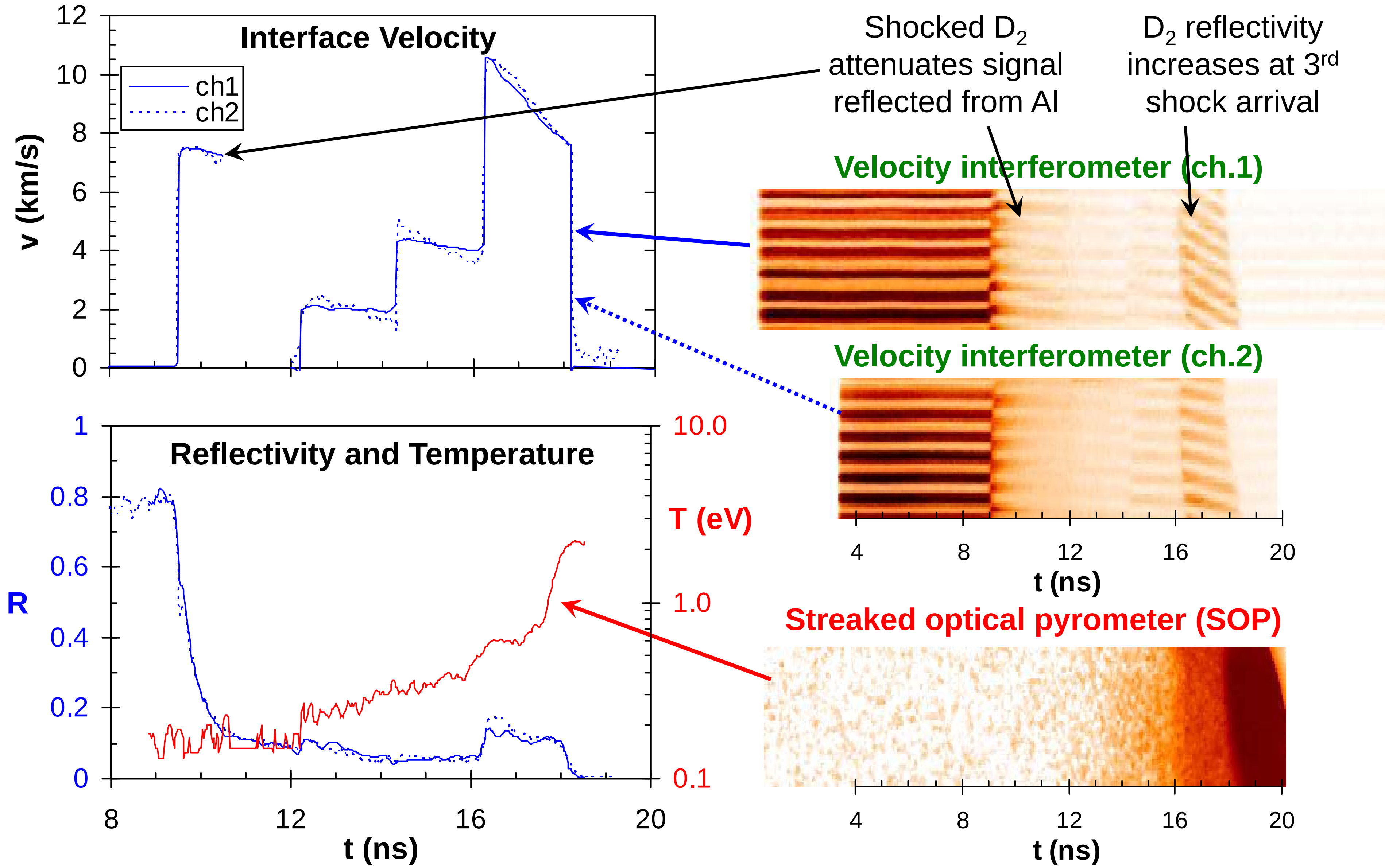
**** S. Hansen**

- **Conductivity errors of 30% are significant for performance***

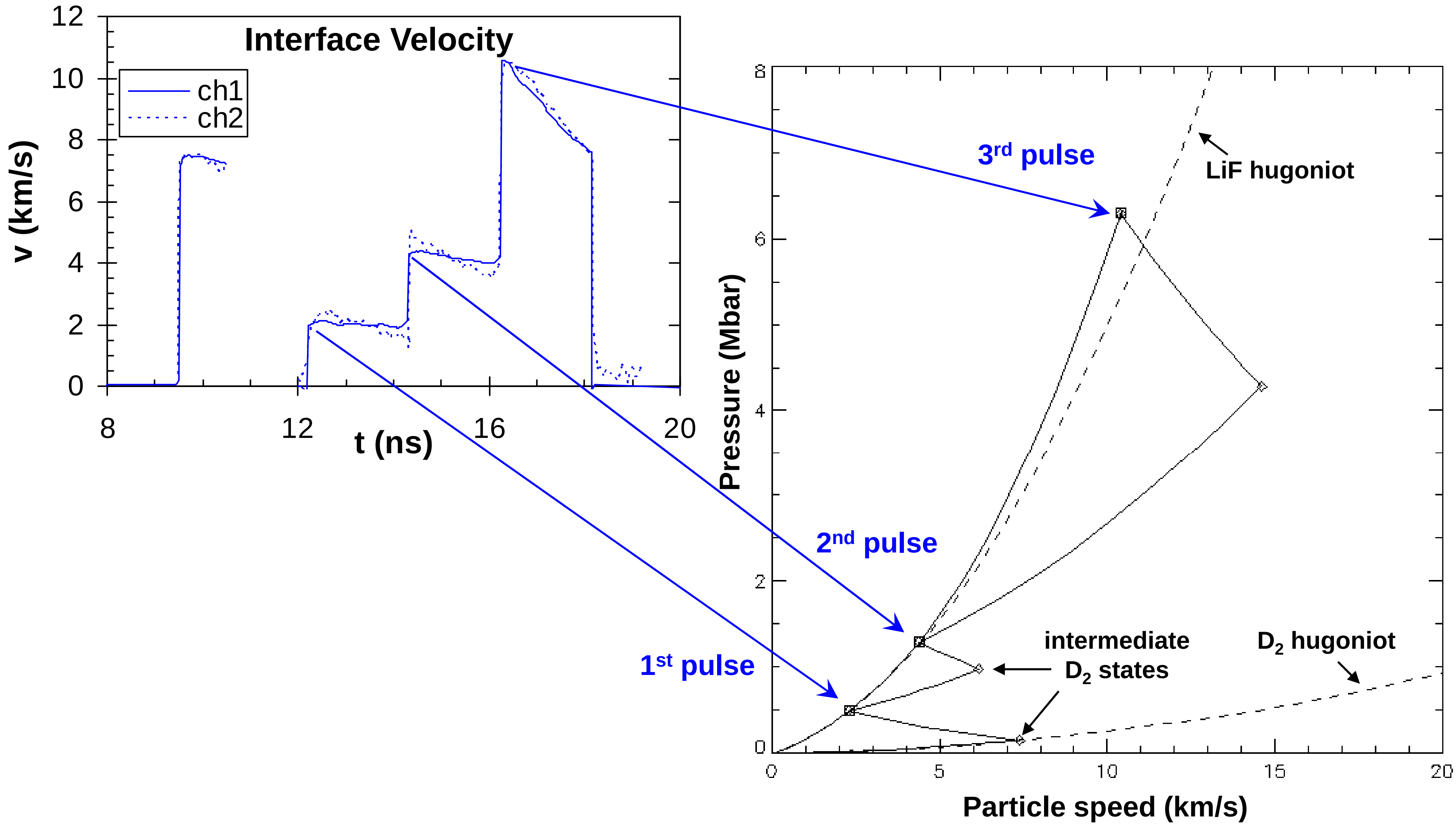
The D_2 layer was characterized by velocity, reflectivity, and emissivity measurements



Velocity, reflectivity and temperature histories

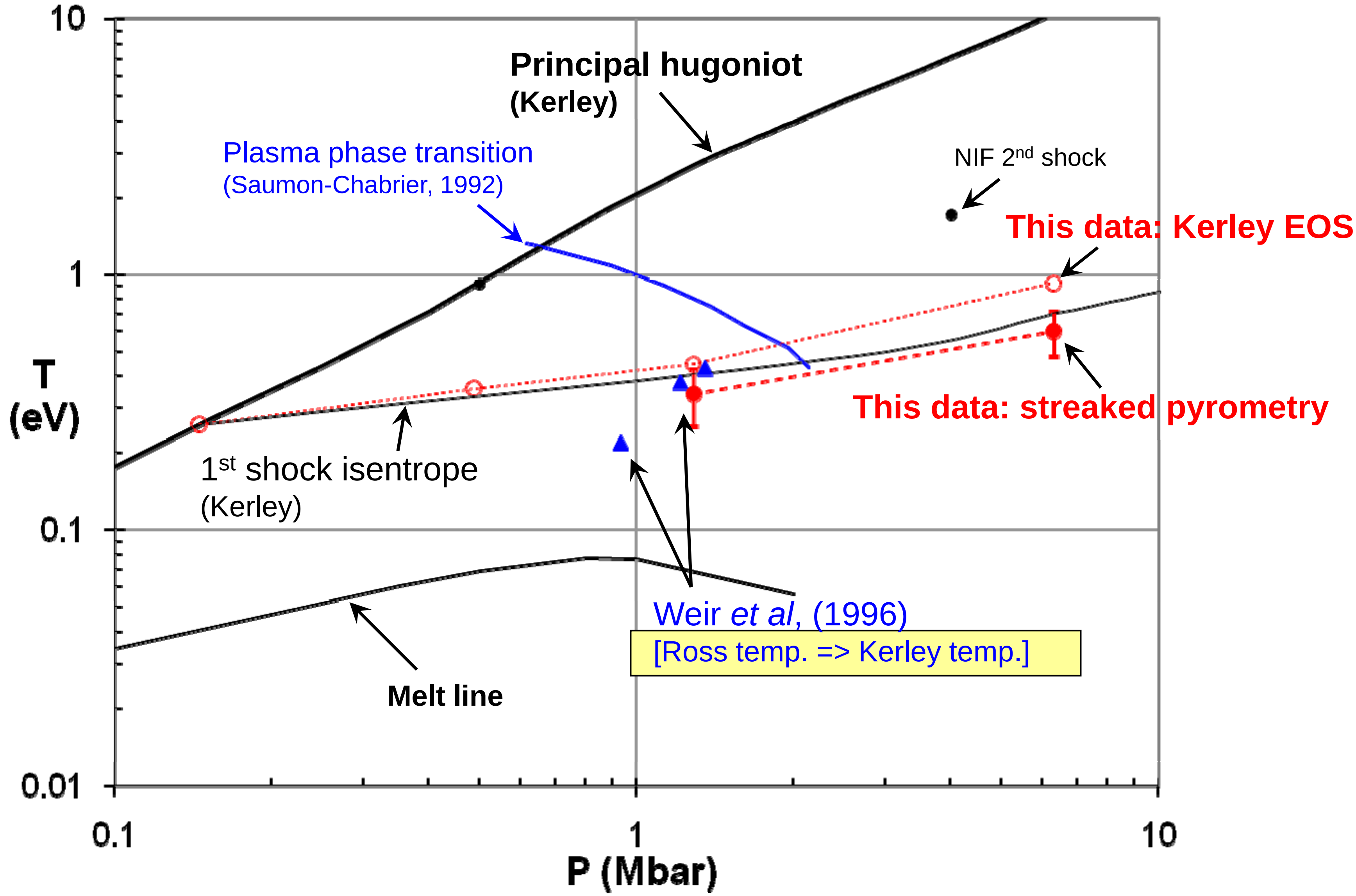


Pressure is inferred using EOS tables and imposing continuity at LiF-D_2 interface

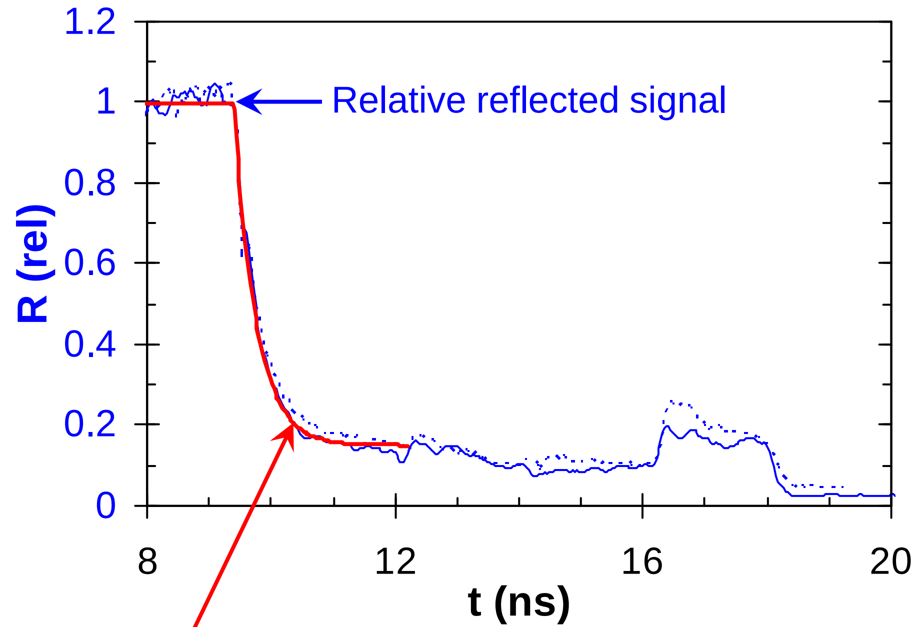


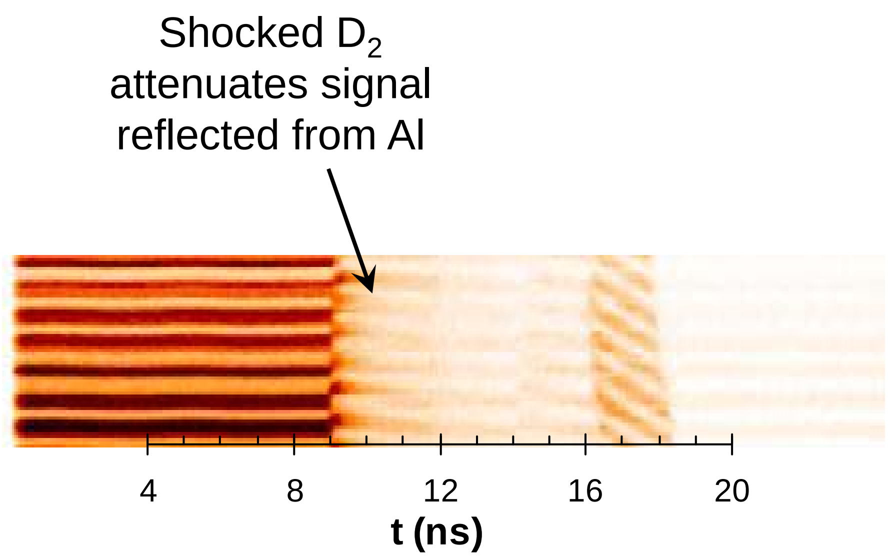
*Using the EOS from Kerley (2003)

Previous gas-gun driven shock reverberations produce D_2 states near that after the 2nd pulse



Electrical conductivity is inferred from optical absorption of 1st shock propagating through D_2





Fit using Beer's Law, $I = I_0 \times 10^{-z/z_0}$,
with $z_0 = 14\ \mu\text{m}$

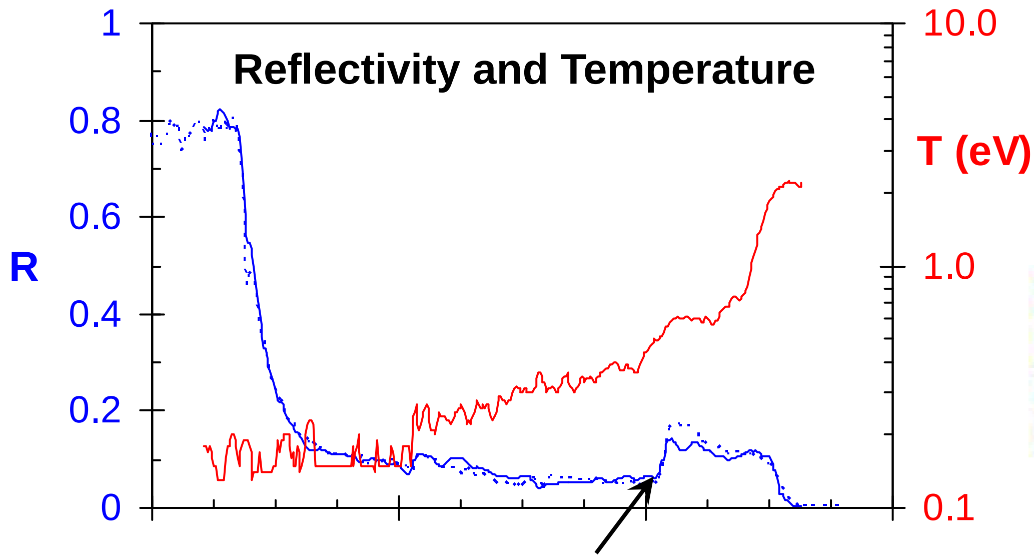
Relate absorption to electrical conductivity using Drude-Zener:

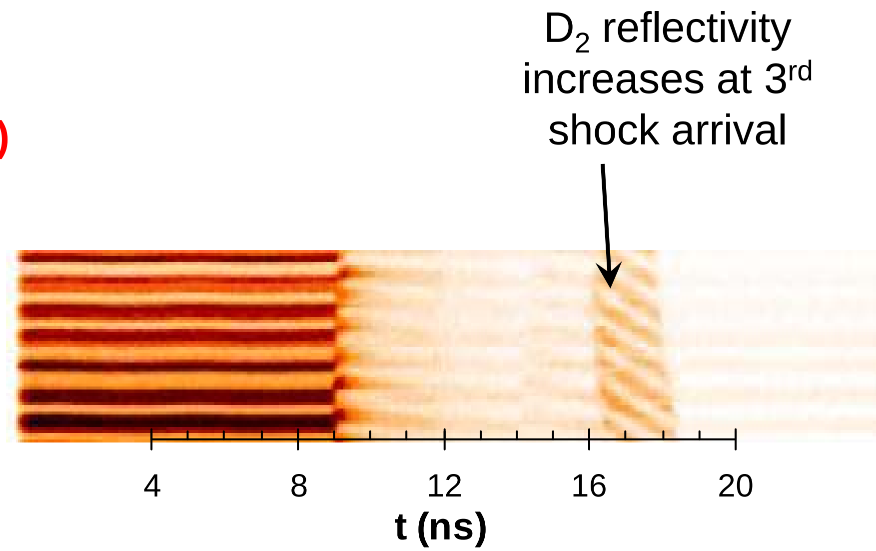
$$\sigma_0 = \frac{\varepsilon_0 c\, n}{z_0}$$

$$\sigma_0 \approx 3\ \Omega^{-1}\, cm^{-1}$$

(D_2 conductivity at 0.15 Mbar, 0.26 eV)

Conductivity is inferred from the reflectivity of the final shocked state





Measured reflectivity (16%) requires deuterium ionization fraction* of ~25%

Drude model electrical conductivity gives:

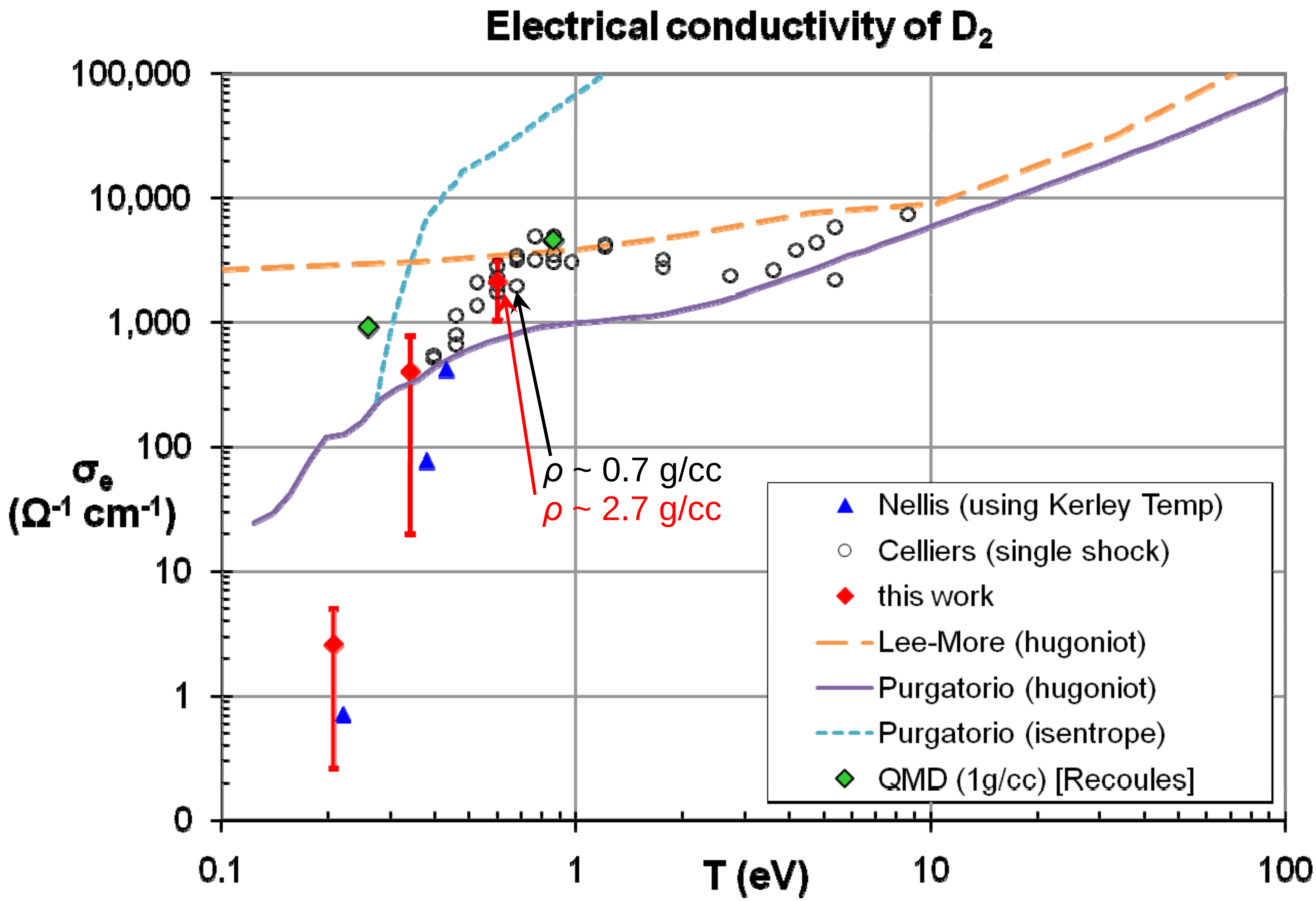
$$\sigma_0 = \frac{n_e e^2 \tau_e}{m_e} \approx 2000 \ \Omega^{-1} cm^{-1}$$

And from the Weidemann-Franz relation, the thermal conductivity is:

$$K_0 = LT\sigma_0 \approx 0.3 \ W/cm \cdot K$$

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

Strong *T* dependence of σ_e is seen when combining this data with previous experiments



Electron thermal conductivity is inferred by applying Wiedemann-Franz relation