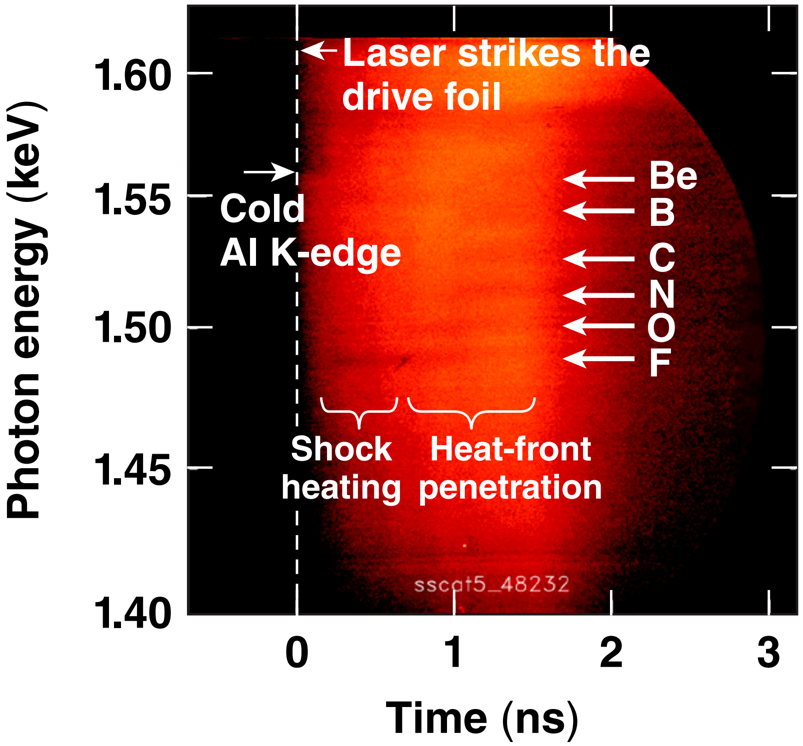
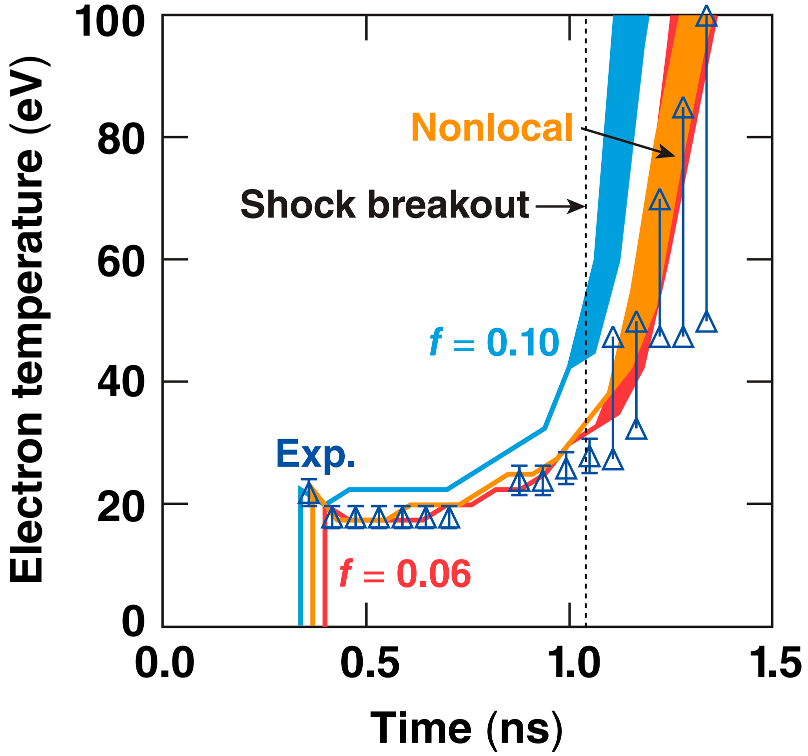
Experimental Investigation of Thermal-Transport Models in Direct-Drive Targets Using X-Ray Absorption Spectroscopy

Shot 48232, Peak intensity: 8 × 10^{14} W/cm^2, CH[10]Al[1]CH[40]





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Summary

Nonlocal* and flux-limited ($f = 0.06$) thermal transport models accurately predict measurements while the shock transits the foil

- A CH foil with a buried Al tracer layer was directly irradiated with a square or shaped pulse drive with peak intensities of 5×10^{13} to 1×10^{15} W/cm^2.
- Shock-wave heating and heat-front penetration were measured using time-resolved Al 1*s*–2*p* absorption spectroscopy to test thermal-transport models with the 1-D hydrodynamics code *LILAC*.
- The measured absorption spectra were modeled with *PrismSPECT*** to infer T_e and ρ, assuming uniform conditions in the Al layer ($T_e \sim 10$ to 40 eV and $\rho \sim 3$ to 11 g/cm^3).
- Lower T_e than predicted at late times of the drive was attributed to reduced radiative heating caused by lateral heat flow in the corona.

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* V. N. Goncharov *et al*., Phys. Plasmas 13, 012702 (2006).

** Prism Computational Sciences, Inc. Madison, WI 5371 .

Collaborators

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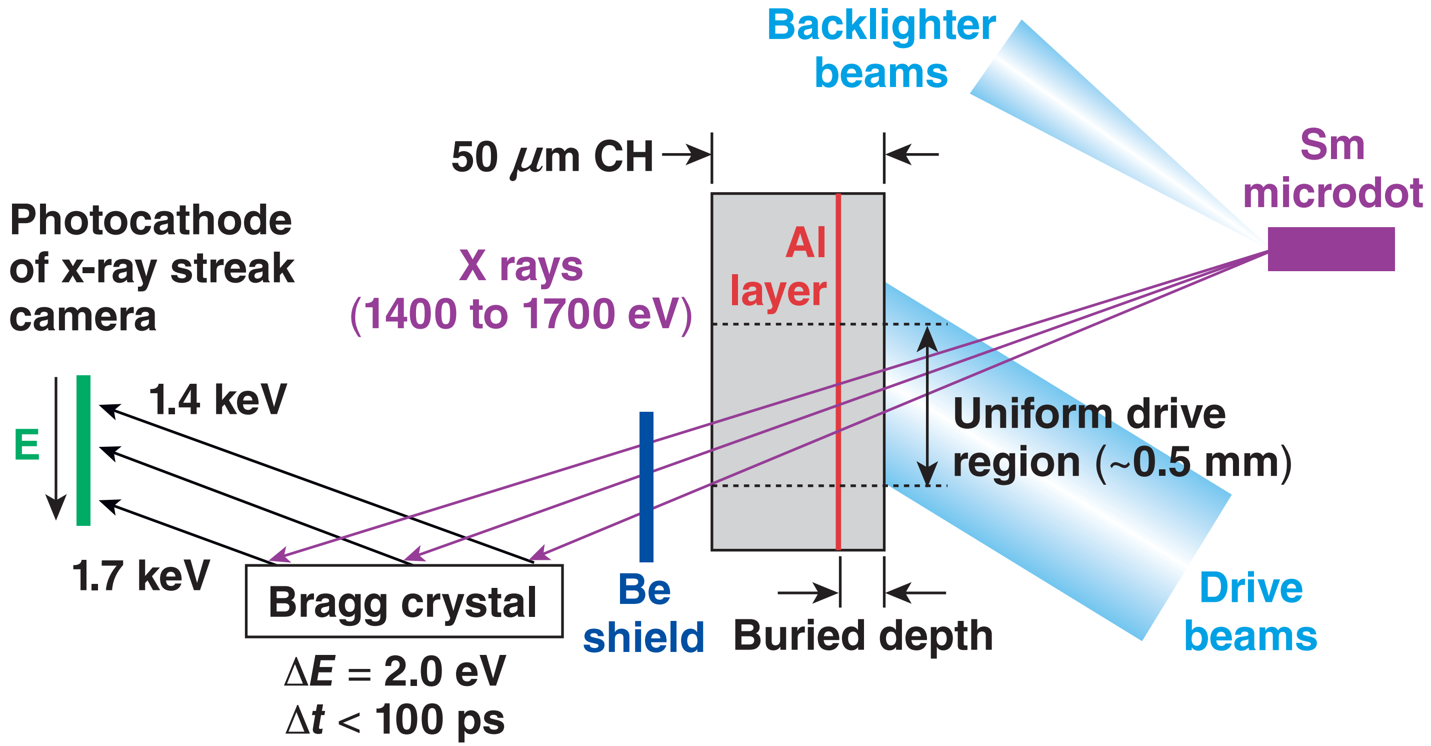
X-ray absorption spectroscopy of a CH planar target with an Al tracer layer was used to test thermal-transport models

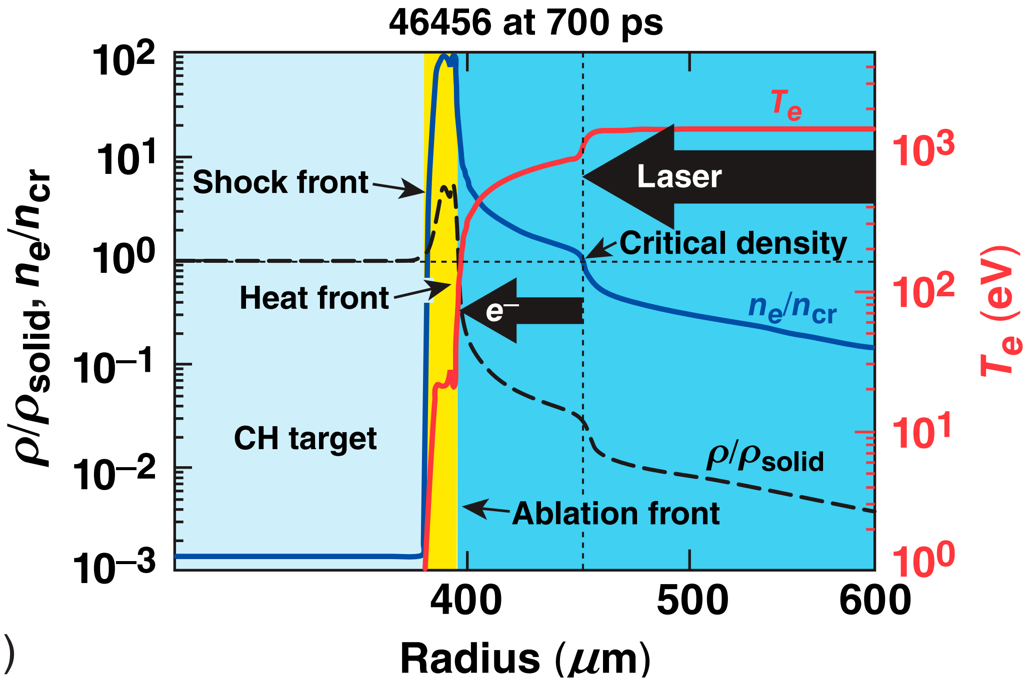


An *in-situ* calibration of the x-ray streak camera was performed to eliminate background light from the measured signals.

Heat flux in *LILAC* is calculated using a flux-limited or a nonlocal thermal-transport model

LILAC (1-D hydrodynamics code)[1]

- Laser absorption with ray trace
- Radiation transport
- Equation of state (*SESAME*)
- Thermal transport
  - – **flux-limited model**, $q_{\text{eff}} = \min\,(q_{\text{SH}}, f \times q_{\text{FS}})$
  - – classical Spitzer flux:[2] $q_{\text{SH}} = -\kappa \nabla T$
  - – free streaming flux: $q_{\text{FS}} = nTv_T$
  - – flux limiter[3] f $(0.04 < f < 0.1)$ (q_{SH} is invalid in plasmas with strong T_e gradient)
- **Nonlocal model[4] (no flux limiter)** acts like a time-dependent flux limiter



The strength of the shock wave depends on thermal-transport models.

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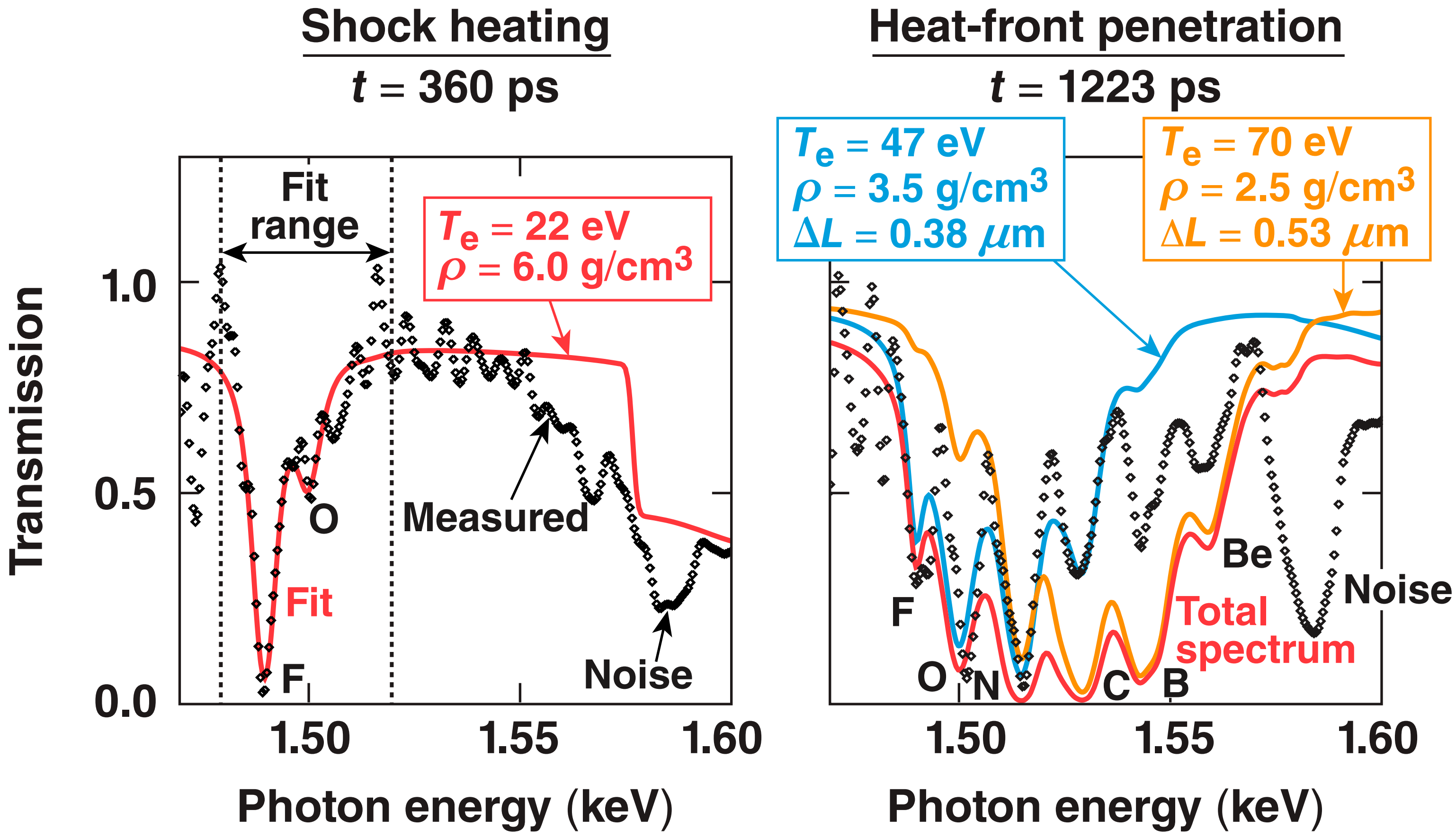
[1] J. Delettrez *et al.*, Phys. Rev. A 36, 3926 (1987).
[2] R. C. Malone, R. L. McCrory, and R. L. Morse, Phys. Rev. Lett. 34, 721 (1975).
[3] J. Delettrez, Can. J. Phys. 64, 932 (1986).
[4] V. N. Goncharov *et al.*, Phys. Plasmas 13, 012702 (2006).

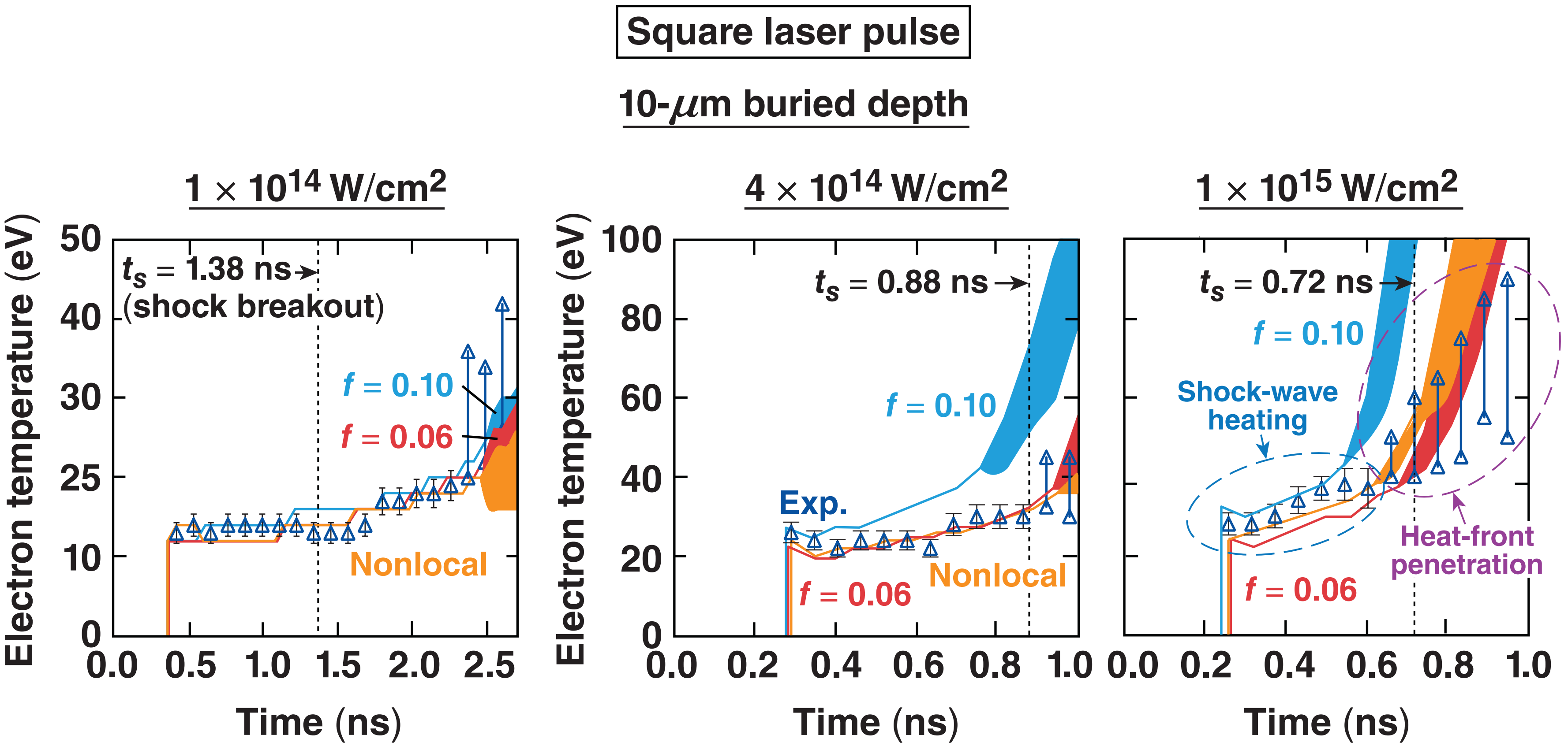
The measured spectra were fit with *PrismSPECT* to infer T_e and ρ assuming uniform conditions in the Al layer



The measured spectra created by the heat front were qualitatively compared with the modeled spectra to determine the range of T_e in the Al layer.

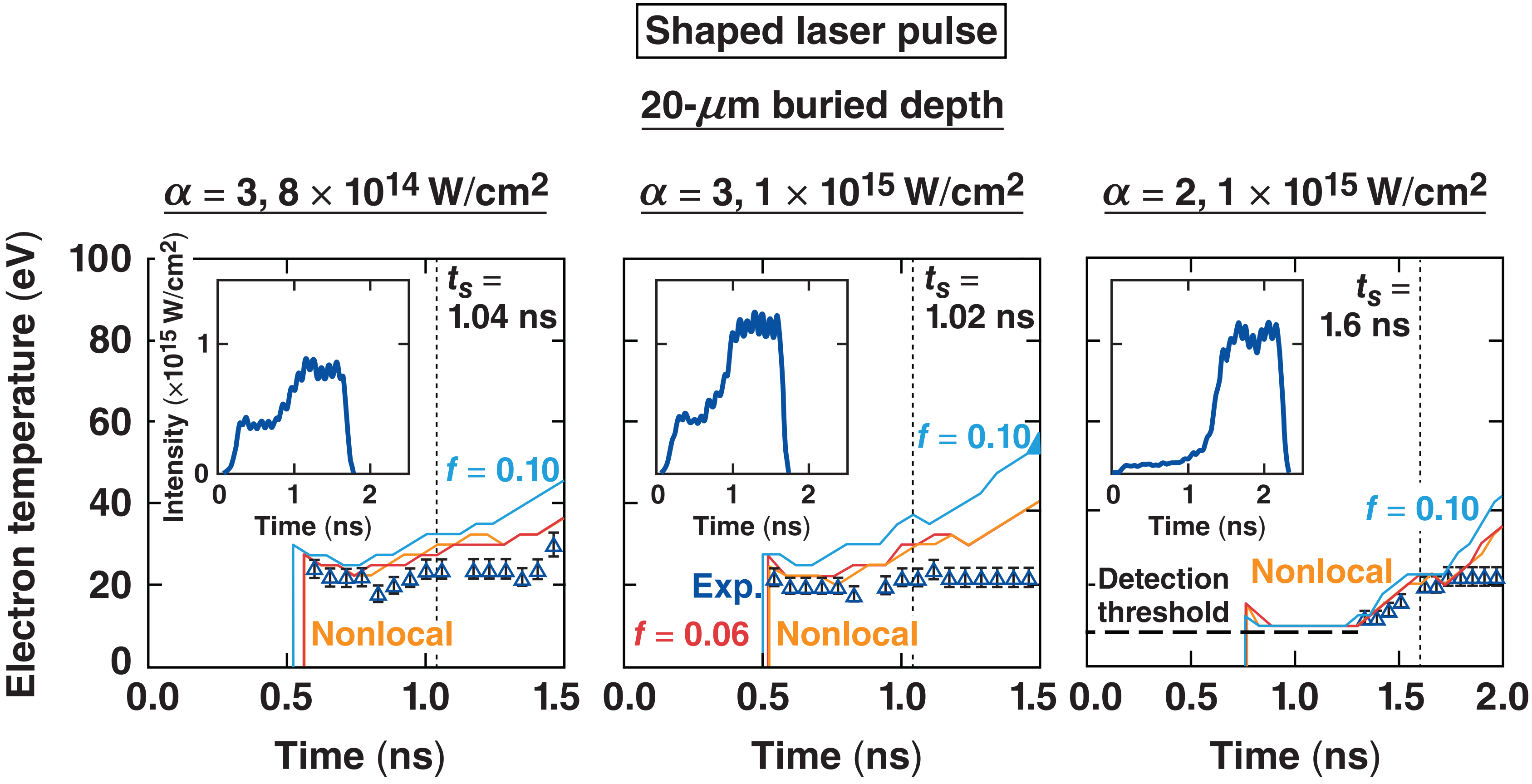
E17056

The *LILAC* simulations using *f* = 0.06 and the nonlocal model agree with the experimental results for the square laser-pulse drive



E17421

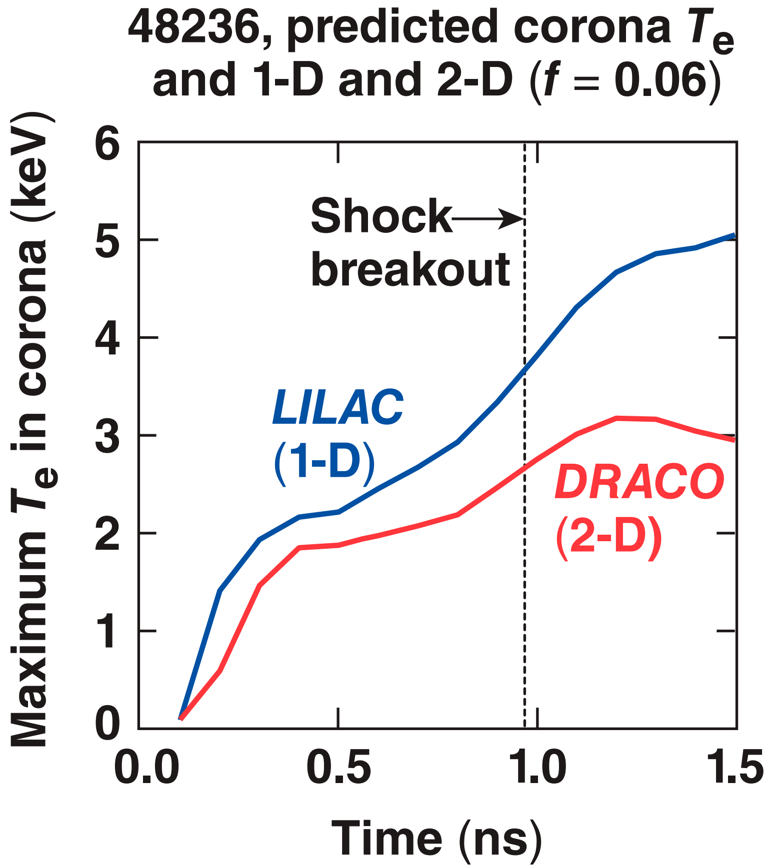
The initial shock-wave heating predicted by *LILAC* using $f = 0.06$ or the nonlocal model agrees with the measurements for the shaped laser pulse drive

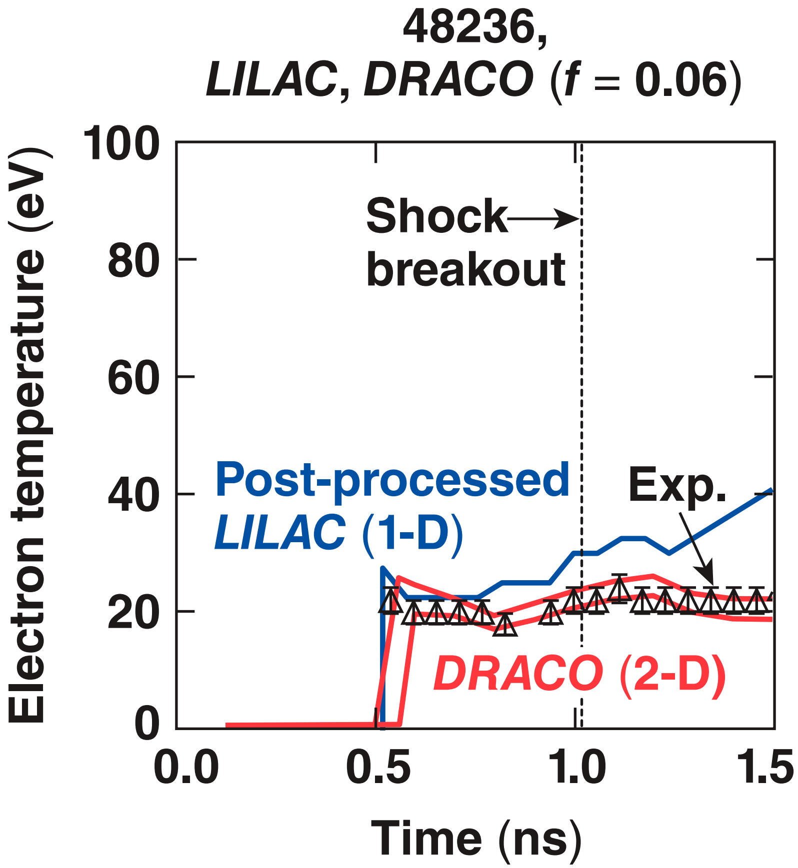


The discrepancies between the measured and predicted T_e are observed at late times of the drive.

E17422

Predicted T_e from a 2-D simulation is closer to the measurements than the 1-D prediction at late time





The lateral heat flow in a 2-D geometry results in a lower radiative heating of the Al than in 1-D geometry.

Summary/Conclusions

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