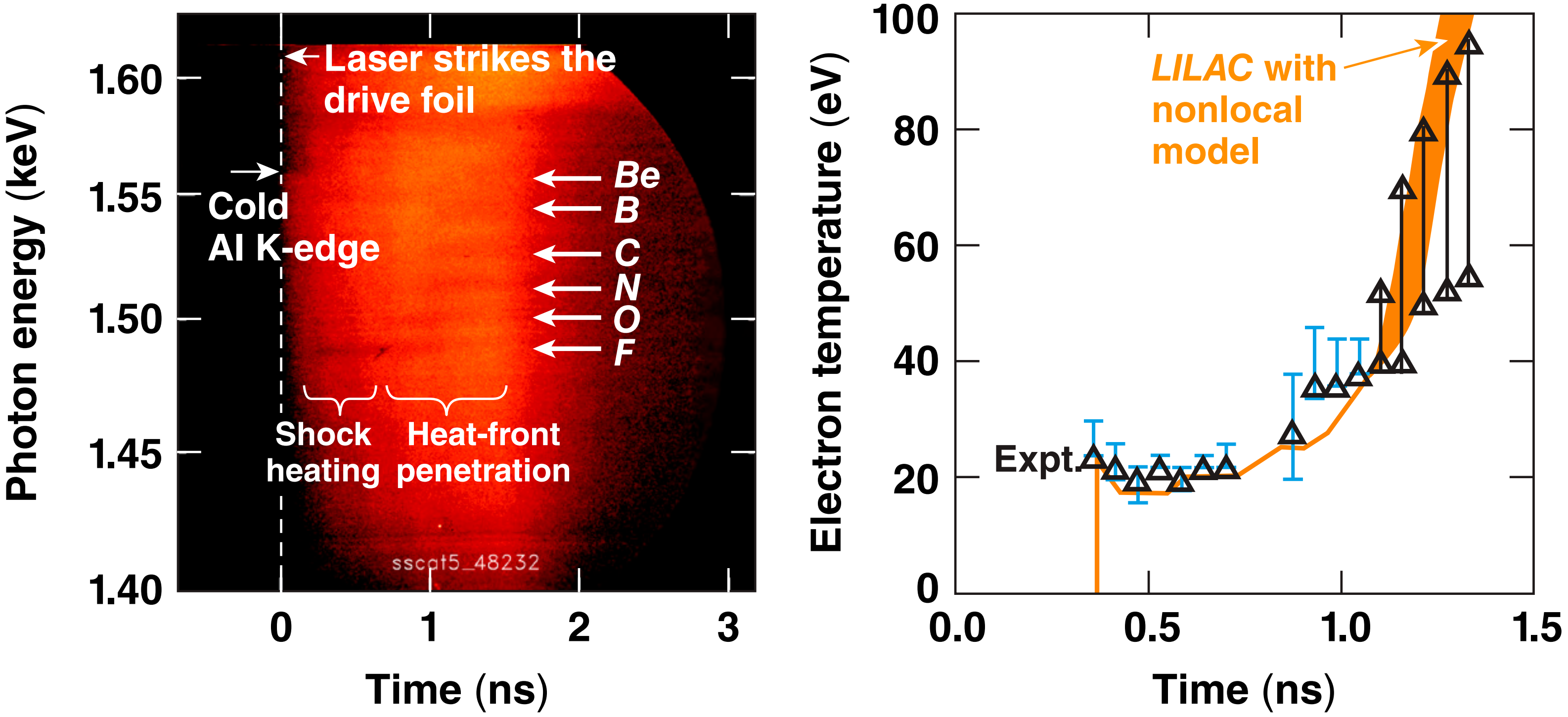
Investigation of Shock Heating and Heat-Front Penetration in Direct-Drive Targets Using Absorption Spectroscopy

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



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Summary

The T_e of a shock-heated and compressed ablator in the vicinity of the advancing heat front was diagnosed

- Planar plastic foils with a buried Al tracer layer were irradiated with shaped laser-pulse drives having peak intensities of 0.1 to 1.0 $\times$ 10^{15} W/cm^2.
- Shock heating and heat-front penetration were inferred from time-resolved Al 1*s*-2*p* x-ray-absorption spectroscopy.
- The level of preheat prior to shock-wave heating was estimated from the measured photon-energy shift of the Al K-edge to be less than a few eV.
- Predictions of a nonlocal transport model* are close to the experimental results.

Al 1*s*-2*p* absorption spectroscopy can experimentally resolve the shock-heated and compressed shell from the advancing heat front.

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

Collaborators

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Plasma conditions are measured with x-ray-absorption spectroscopy of a CH planar target with an Al tracer layer

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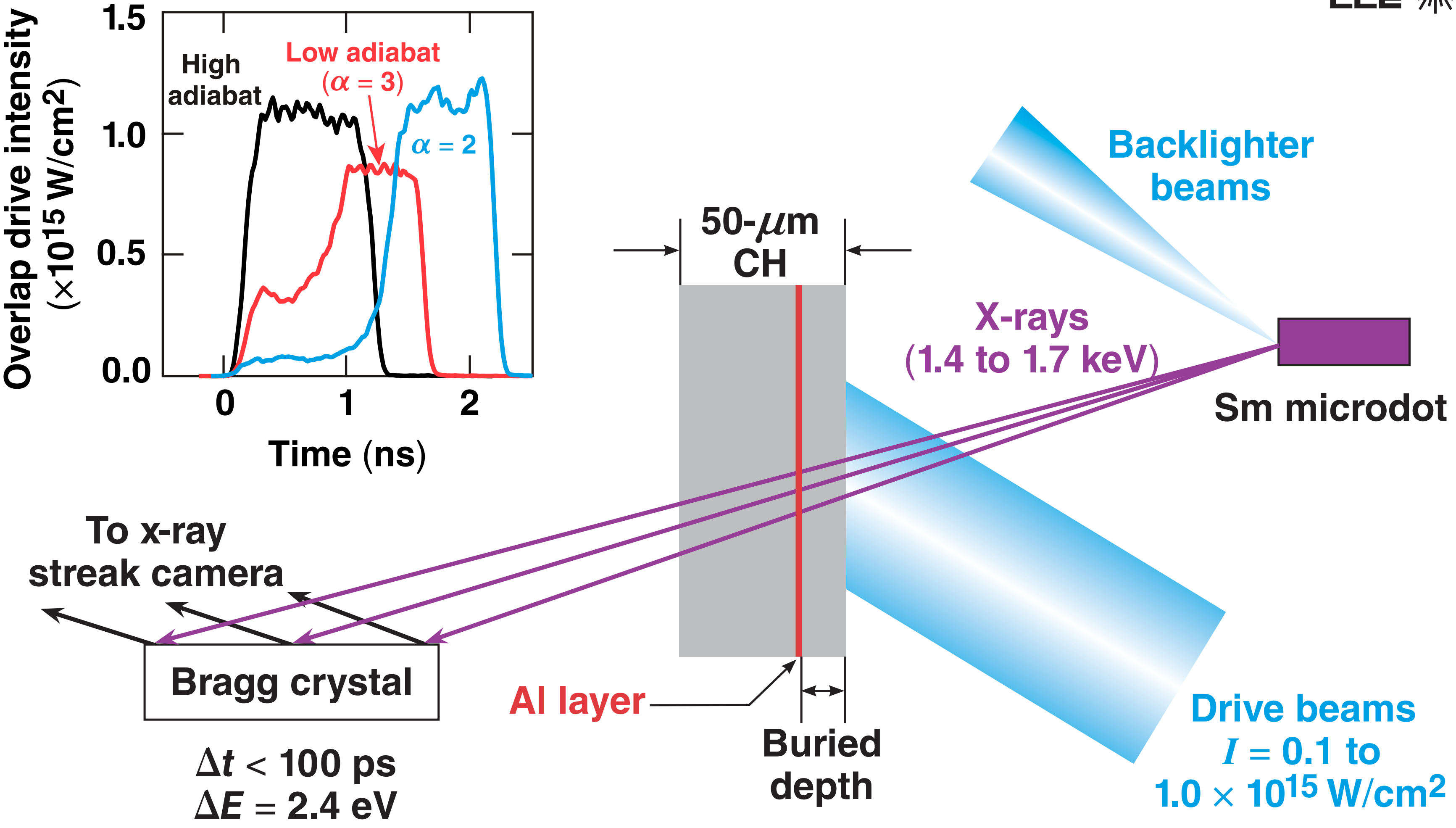
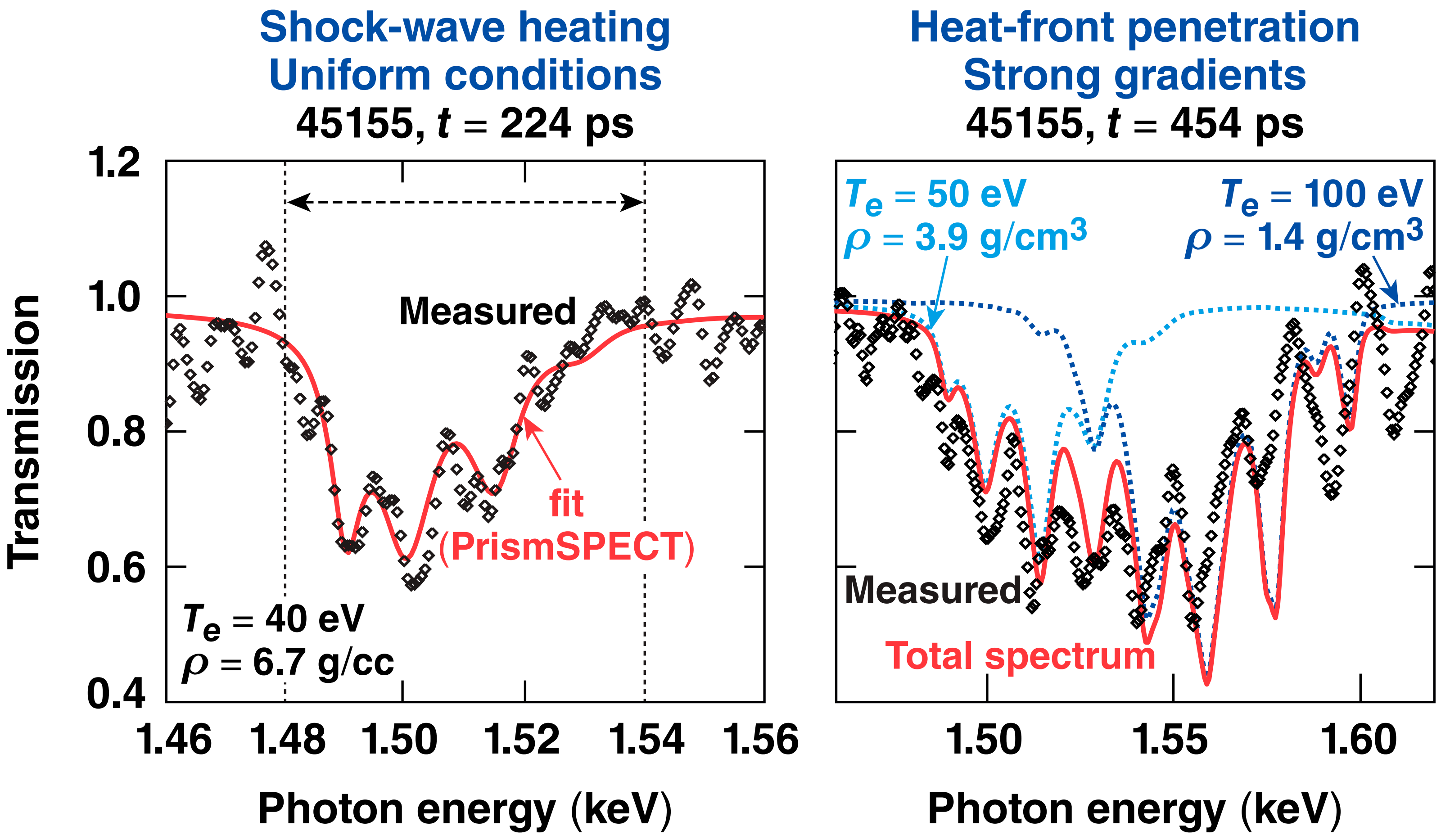


- The buried depth of the Al layer is varied to probe a different portion of the drive foil

E14880b

Al 1*s*-2*p* absorption lines are monitored to diagnose shock heating and heat-front penetration



Shock-wave heating
Uniform conditions
45155, t = 224 ps

Heat-front penetration
Strong gradients
45155, t = 454 ps

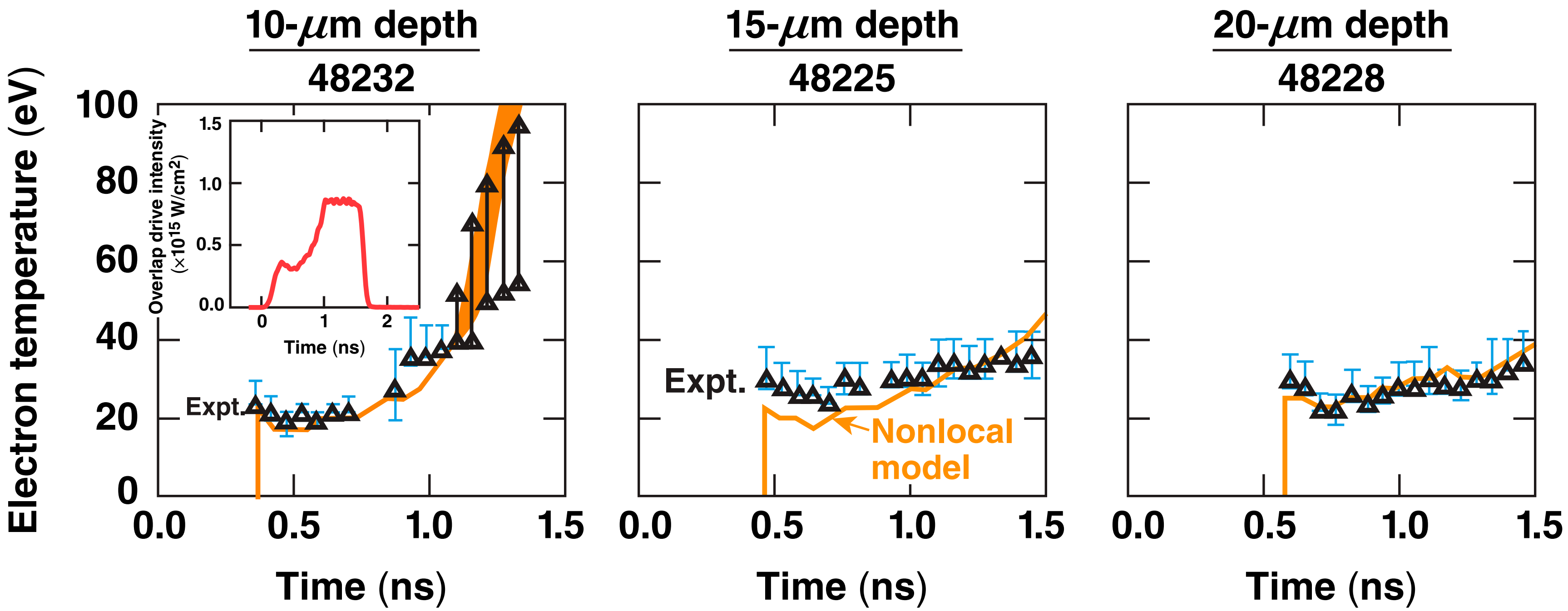
- The plasma conditions in the shock-heated and compressed Al layer are in the warm dense matter regime (ρ_{AL} = 6 to 16 g/cm^3 and T_e = 10 to 40 eV).

E16324

α = 3 Drive

The nonlocal transport-model predictions of shock heating and heat-front penetration for α = 3 are close to the experiment

Foot-to-peak Intensity: 3 to 8 × 10^{14} W/cm^2 (low adiabat, α = 3)



- The nonlocal transport model solves a simplified Boltzmann equation and acts like a time-dependent flux limiter.

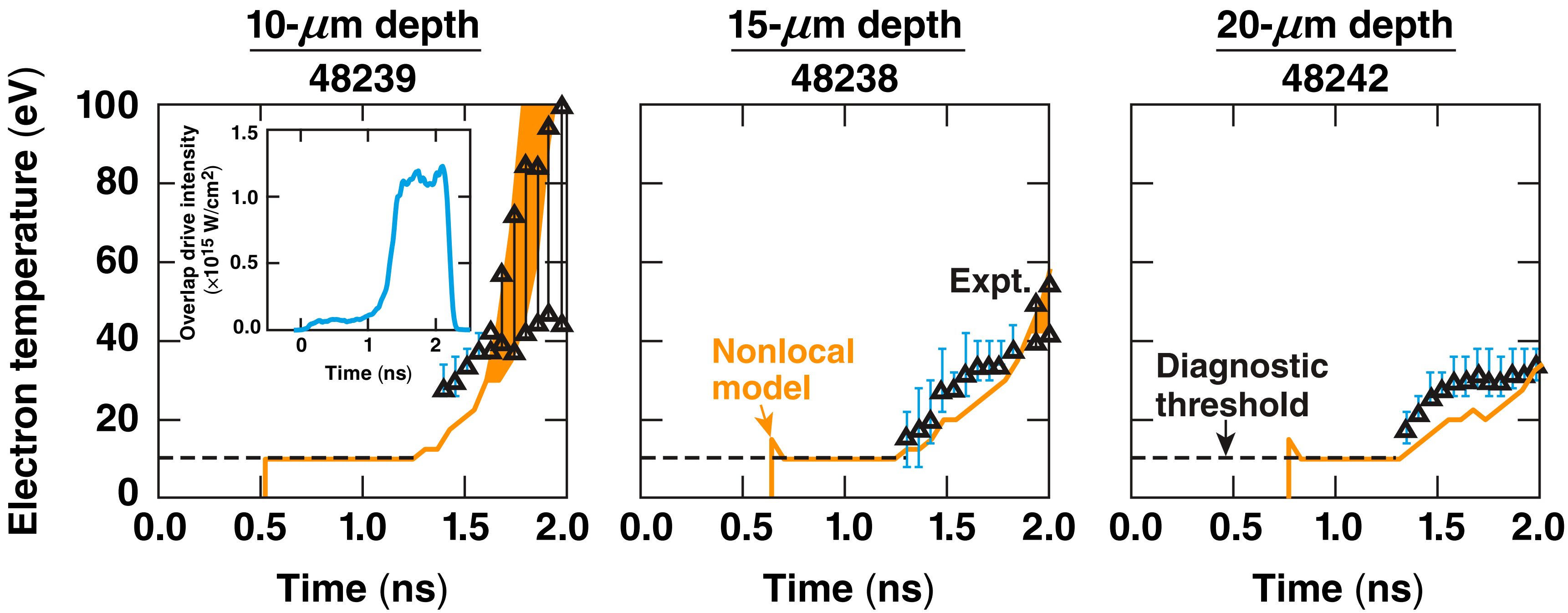
E16251

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

α = 2 Drive

At peak compression of the α = 2 drive the model underpredicts T_e, but the heat-front penetration is accurate

Foot-to-peak Intensity: 5×10^{13} to 1×10^{15} W/cm^2 (low adiabat, α = 2)

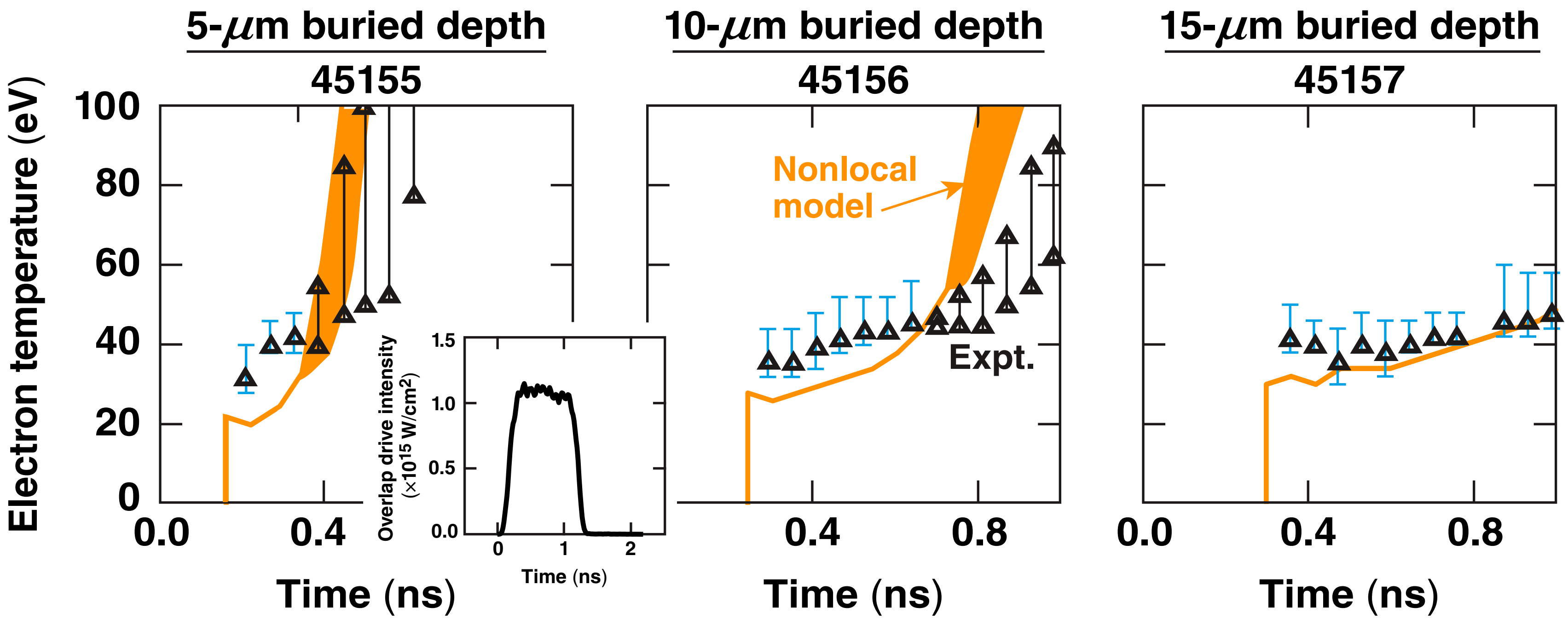


Predicted ρ_{AL} = 16 g/cm^3

High-adiabat drive

The predicted shock heating is low and the predicted heat-front penetration is early for the high-adiabat drive

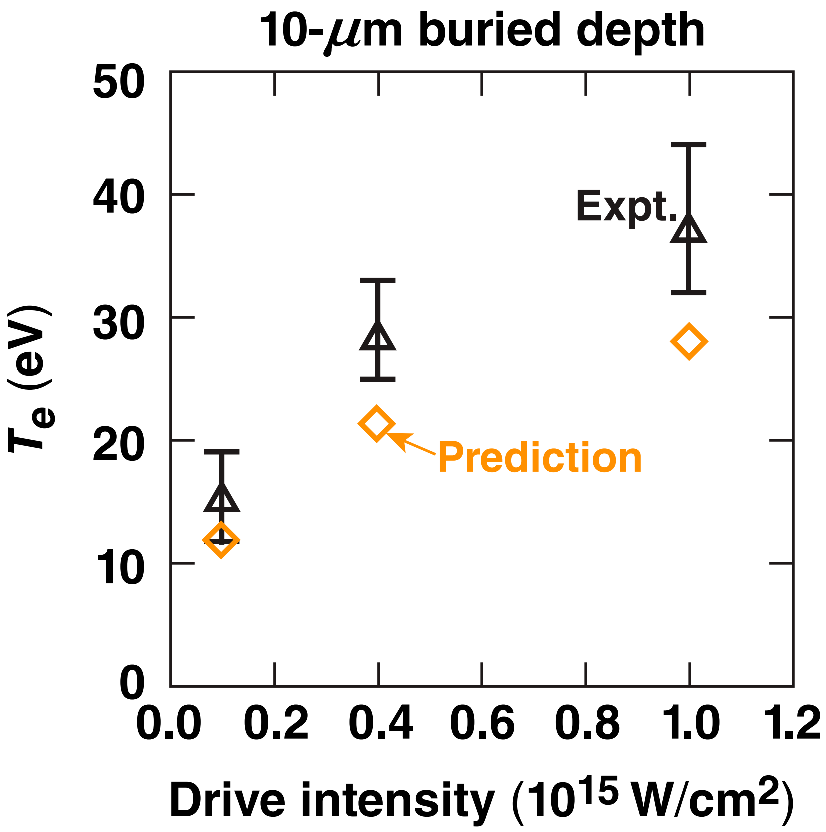
Drive Intensity 1 × 10^{15} W/cm^2



The predictions are accurate for the 15-μm buried depth.

High-Adiabat Drive

The nonlocal model accurately predicts the shock heating for high-adiabat drives with $I \sim 1 \times 10^{14}$ W/cm^2



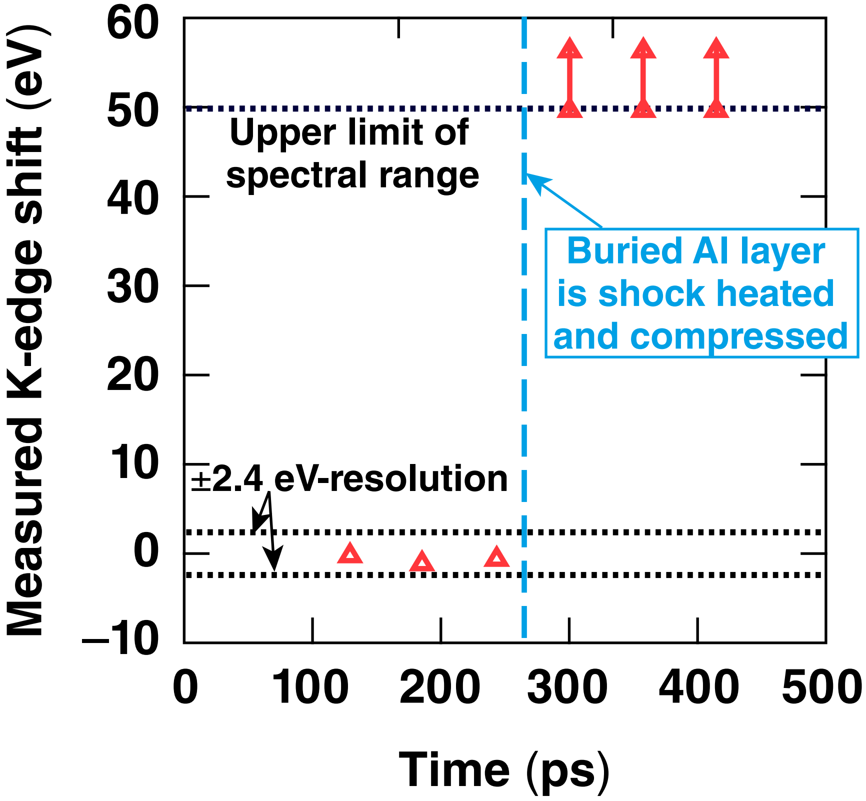
Next step:
Study effects of the different EOS models on the predicted T_e.

Preheat

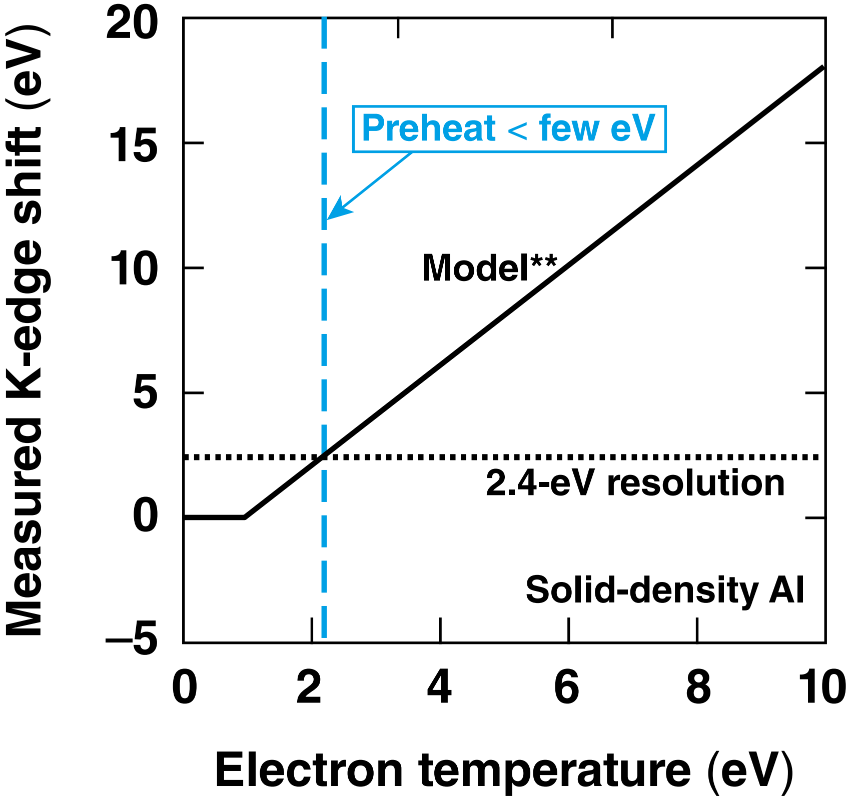
The measured Al K-edge indicates the level of preheat before shock-wave heating is less than a few eV

- The position and the steepness of K-edge are sensitive to T_e and n_e.*

45157 CH[15]Al[1]CH[35]
1×10^{15} W/cm^2



Al K-edge shift versus T_e at solid density



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*D. K. Bradley *et al*., Phys. Rev. Lett. 59, 2995 (1987).

**J. Al-Kuzee *et al*., Phys. Rev. E. 57, 7060 (1998).

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