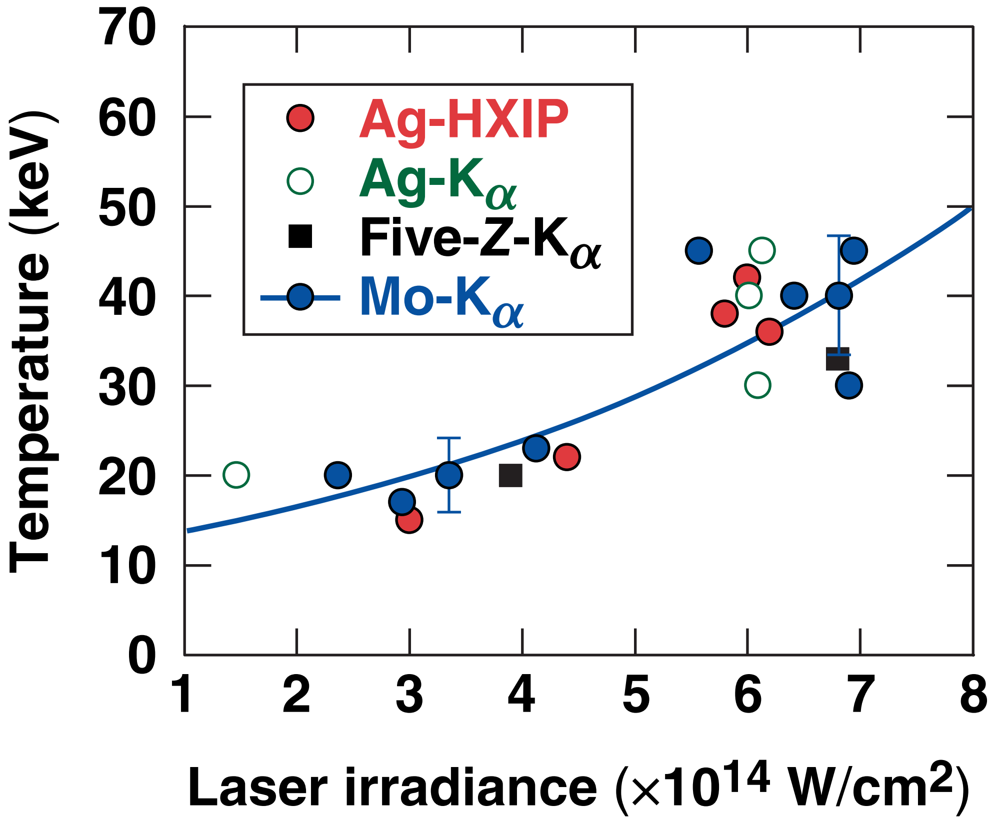
Hot-Electron Temperature Measurements with Laser Irradiation of 10^{14} to 10^{15} W/cm^2



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Summary

Preheat in inertial confinement fusion (ICF) implosions depends on hot-electron temperature and laser-to-hot-electron conversion efficiency

UR LLE

- The bremsstrahlung radiation was measured by a nine-channel filter spectrometer
- Two types of experiments used the K_α radiation from high-*Z* signature layers embedded in plastic
  - the ratio of K_α emitted toward the front and the back of a thick, high-*Z* target
  - K_α lines emitted from the back of the target composed of five consecutive high-*Z* layers
- The hot-electron temperature rose from ~15 keV to ~50 keV in the intensity range of 1 to 7×10^{14} W/cm^2
- Approximately 1% laser energy to hot-electron conversion efficiency was inferred

TC11345a

Collaborators

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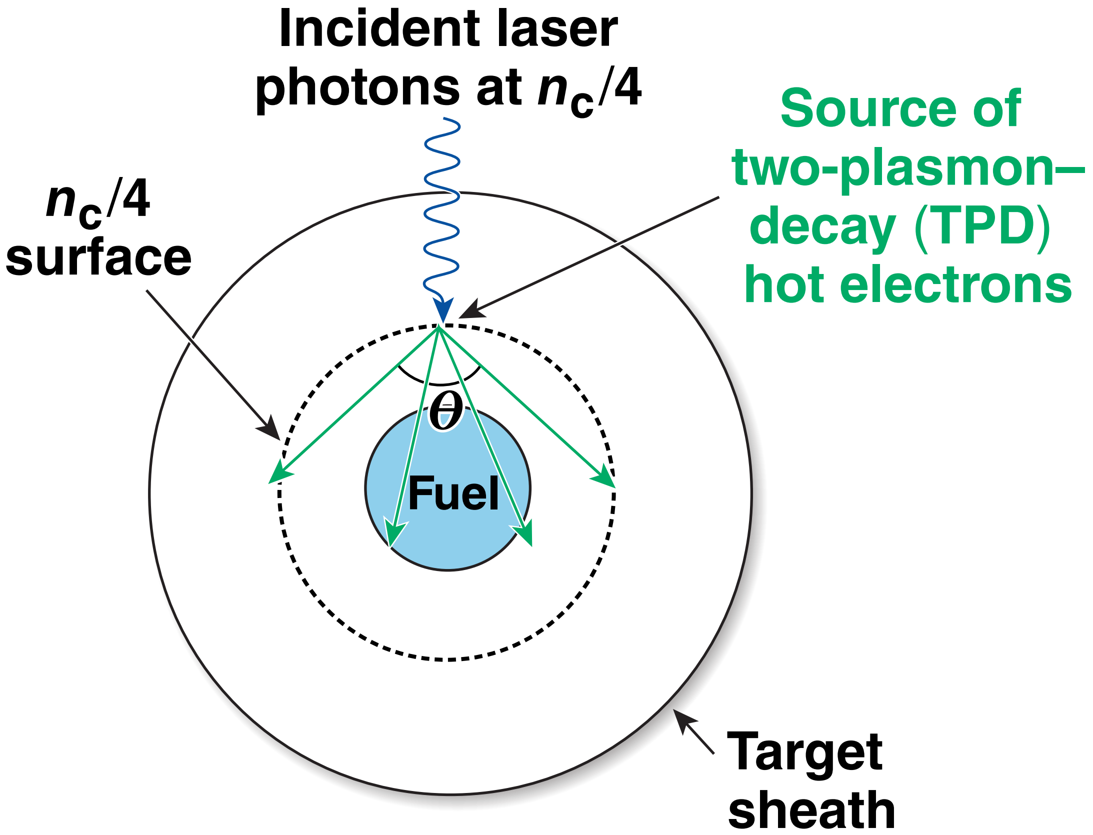
In typical cryogenic direct-drive experiments* only ~25% of the hot electrons will be intercepted by the compressed fuel because of a wide angular divergence**

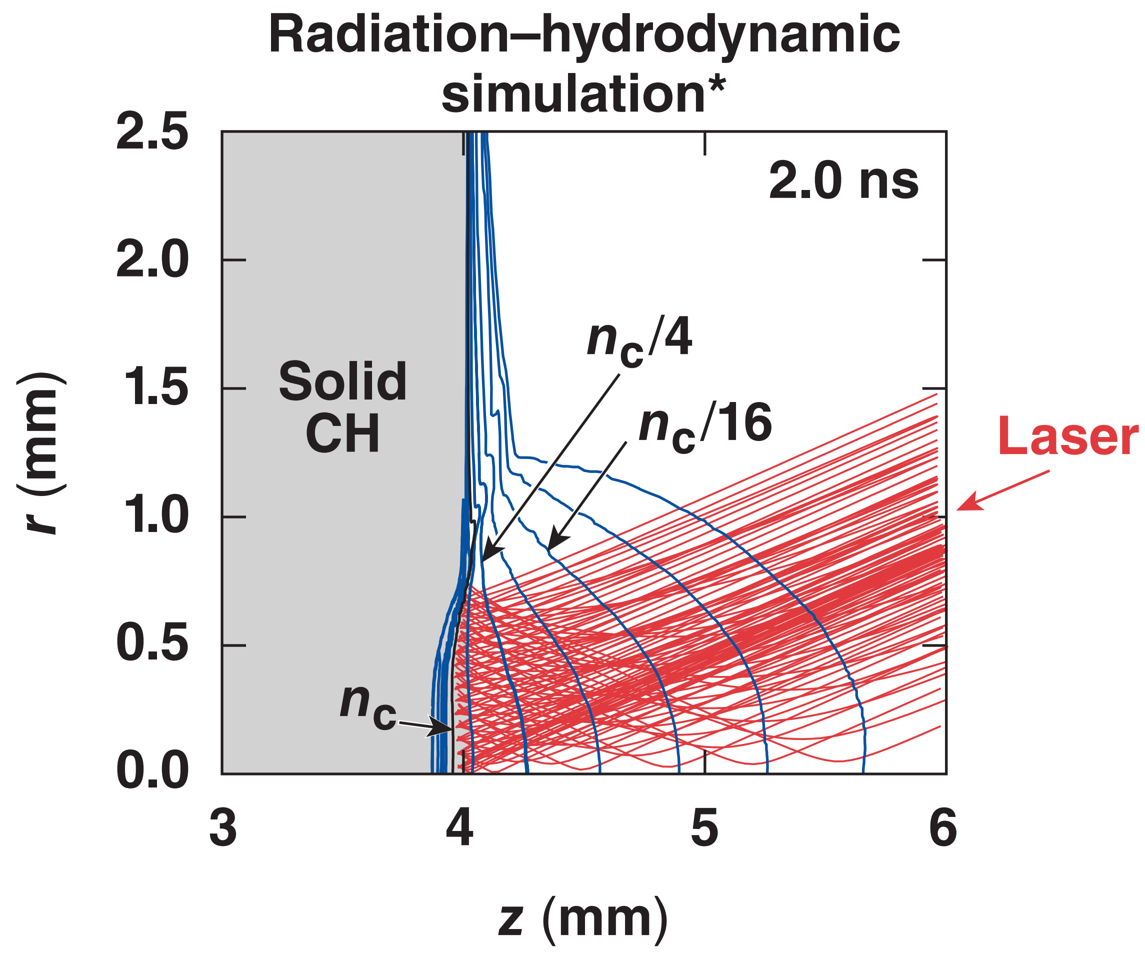
- Hot electrons are generated near the end of the laser pulse*** when the density scale length is maximal
- At that time, the compressed fuel shell has converged to about half the original target size*
- <0.15% coupling of the laser energy to fuel in the form of hot electrons is required to maintain good compression****



*V. N. Goncharov *et al*., Phys. Rev. Lett. 104, 165001 (2010).
**B. Yaakobi *et al*., Phys. Plasmas 20, 092706 (2013).
***C. Stoeckl *et al*., Phys. Rev. Lett. 90, 235002 (2003).
****J. A. Delettrez *et al*., Bull. Am. Phys. Soc. 59, 150 (2014).

TC10662a

Long-scale-length planar CH plasmas are produced on OMEGA EP to study the generation of hot electrons by TPD

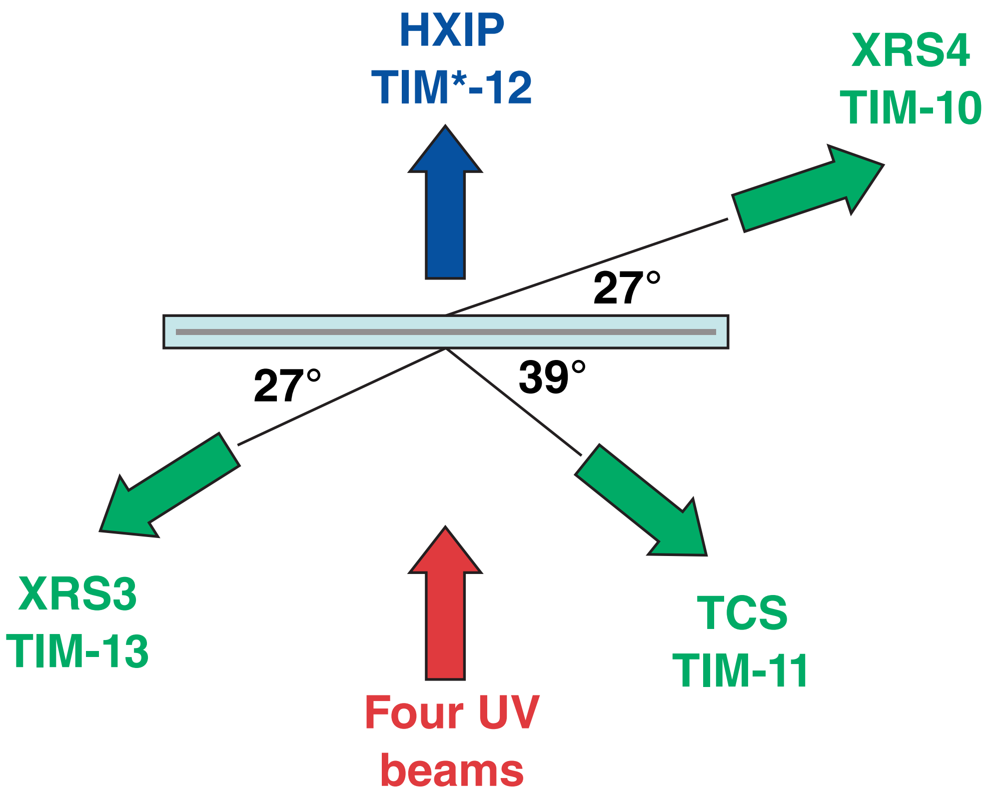


- Laser pulse
  - temporal profile: square, $\tau = 2$ ns
  - beam spot size: $D \approx 1$ mm
  - energy: up to 8 kJ in four beams
  - incident intensity: $I = 1$ to 7×10^{14} W/cm^2
- Parameters at N_{qc}
  - intensity: $I_{qc} = 0.5$ to 4.5×10^{14} W/cm^2
  - density scale length: $L_n \leq 400\ \mu$m
  - plasma temperature: $T_e \leq 2.5$ keV
  - common wave gain:** $G \propto I_{qc} \times L_n/T_e \leq 7$

*B. Yaakobi *et al*., Phys. Plasmas 19, 012704 (2012);
S. X. Hu *et al*., Phys. Plasmas 20, 032704 (2013).
**D. T. Michel *et al*., Phys. Plasmas 20, 055703 (2013).

TC9311a

Experiments were performed using plastic targets with embedded high-Z signature layers



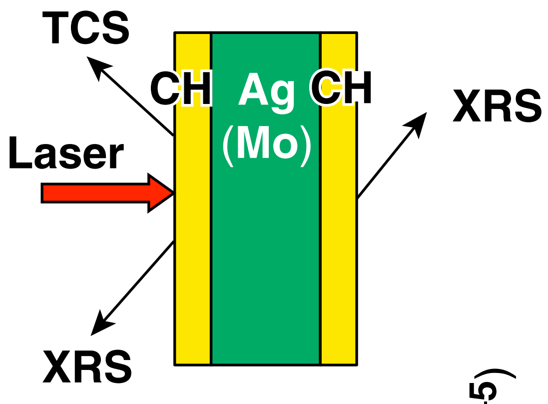
- Targets
  - 5-, 35-, 50-, 100-, 127-μm-thick Ag foils coated with 30 μm CH
  - 30- and 100-μm-thick Mo foils coated with 30 μm CH
  - five consecutive-Z layers (Nb, Mo, Rh, Pd, Ag, 5-μm each) coated with 25 μm CH

- Diagnostics
  - nine-channel filter spectrometer with image plate [hard x-ray image plate (HXIP)]
  - Cauchois-type quartz spectrometer [transmission crystal spectrometer (TCS)]
  - two identical LiF crystal spectrometers [x-ray spectrometer (XRS)]

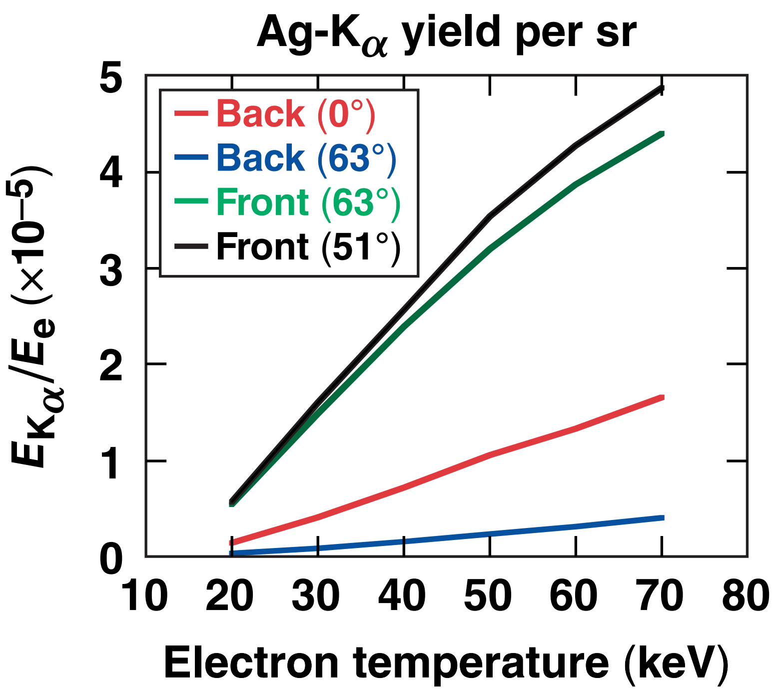
*TIM: ten-inch manipulator

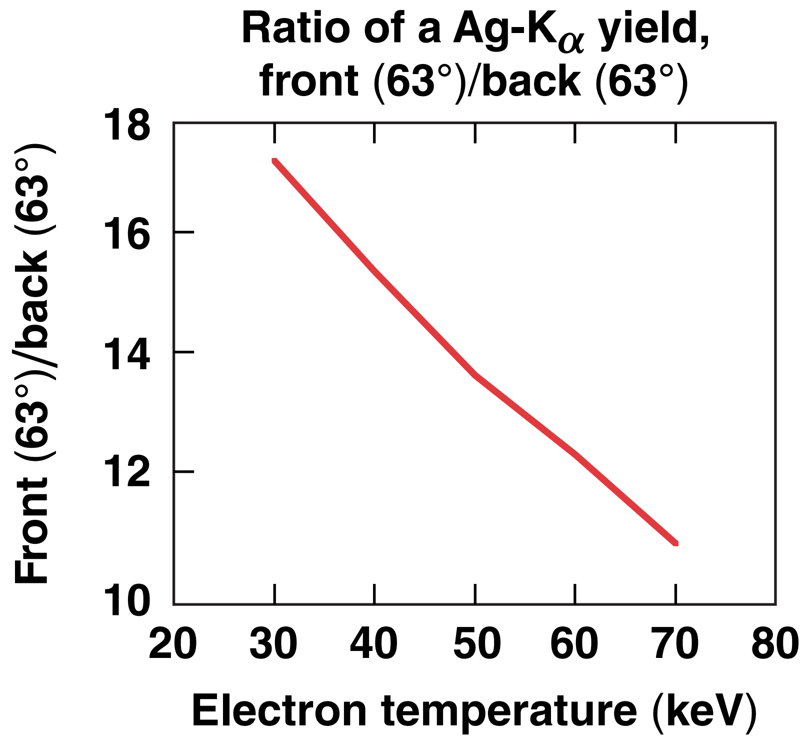
TC11646a

The hot-electron temperature was inferred using K_α measurements from the front and back of thick Ag (Mo) targets



Monte Carlo *EGSnrc simulations for a 127-μm Ag target**

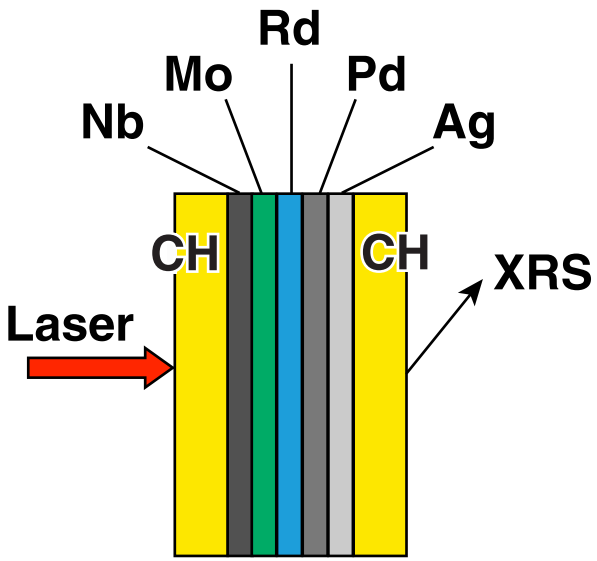


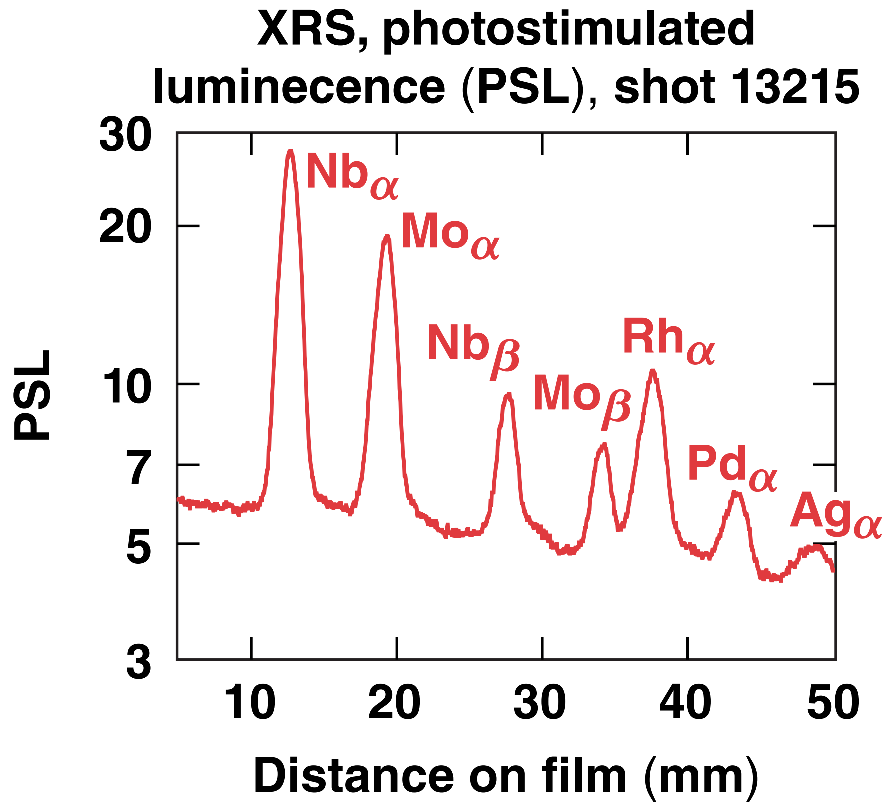


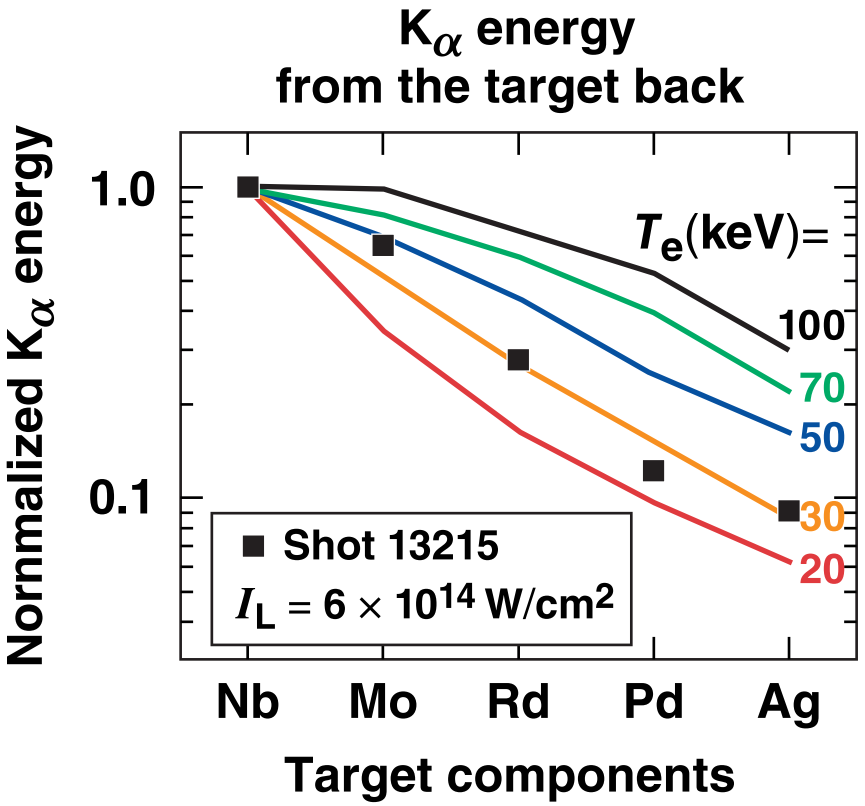
- The ratio of K_α emitted toward the front and the back decreases with increasing *T*: K_α is emitted deeper into the foil and therefore absorbed less on the way to the back of the target

*I. Kawrakow *et al*., NRC, Ottawa, Canada, NRCC Report PIRS-701 (May 2011).

The temperature was inferred from K_α measurements using a five consecutive-Z layer target







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A nine-channel filter x-ray spectrometer with image plate (HXIP) has been developed

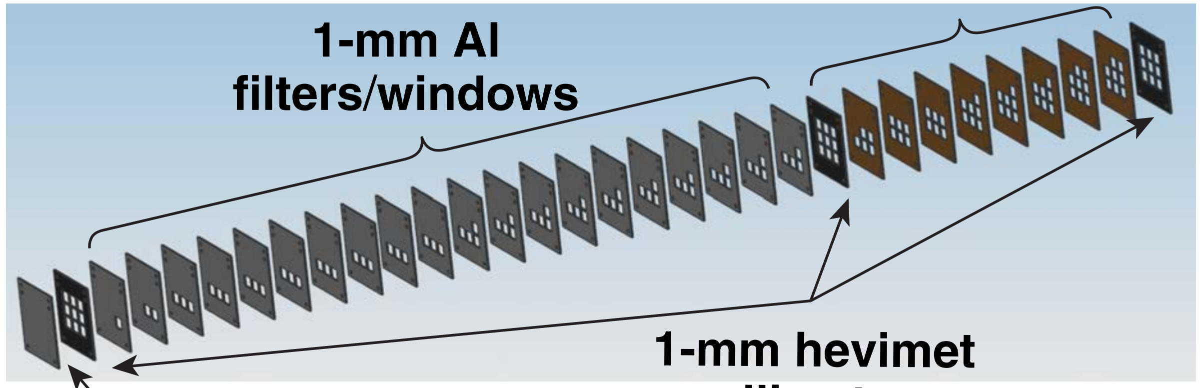
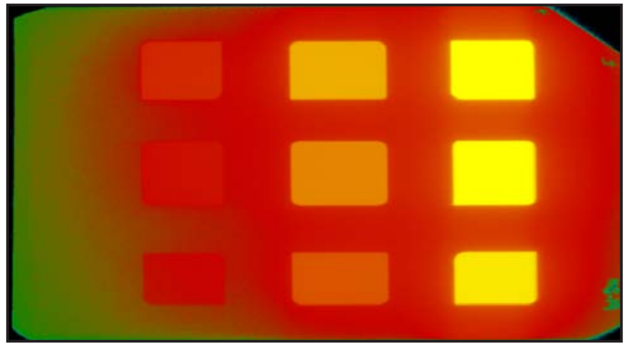
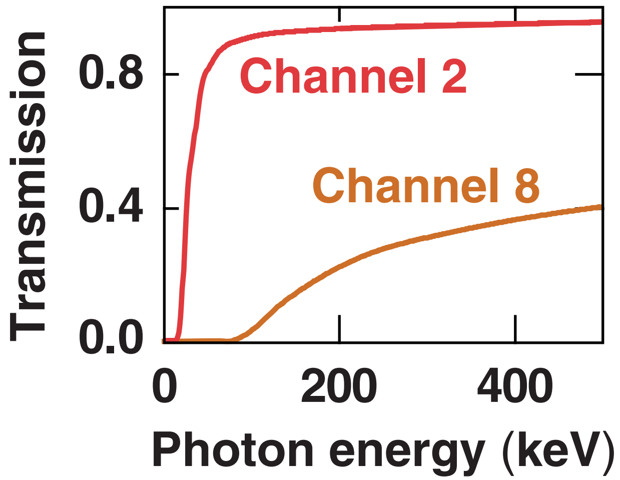


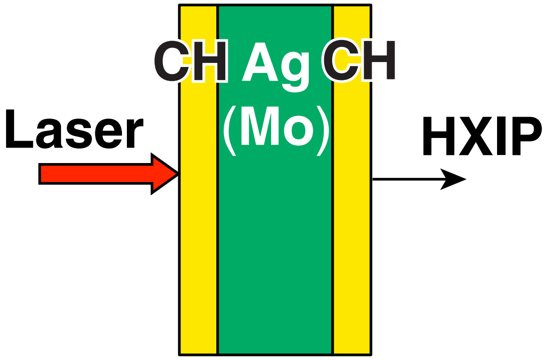
Image plate



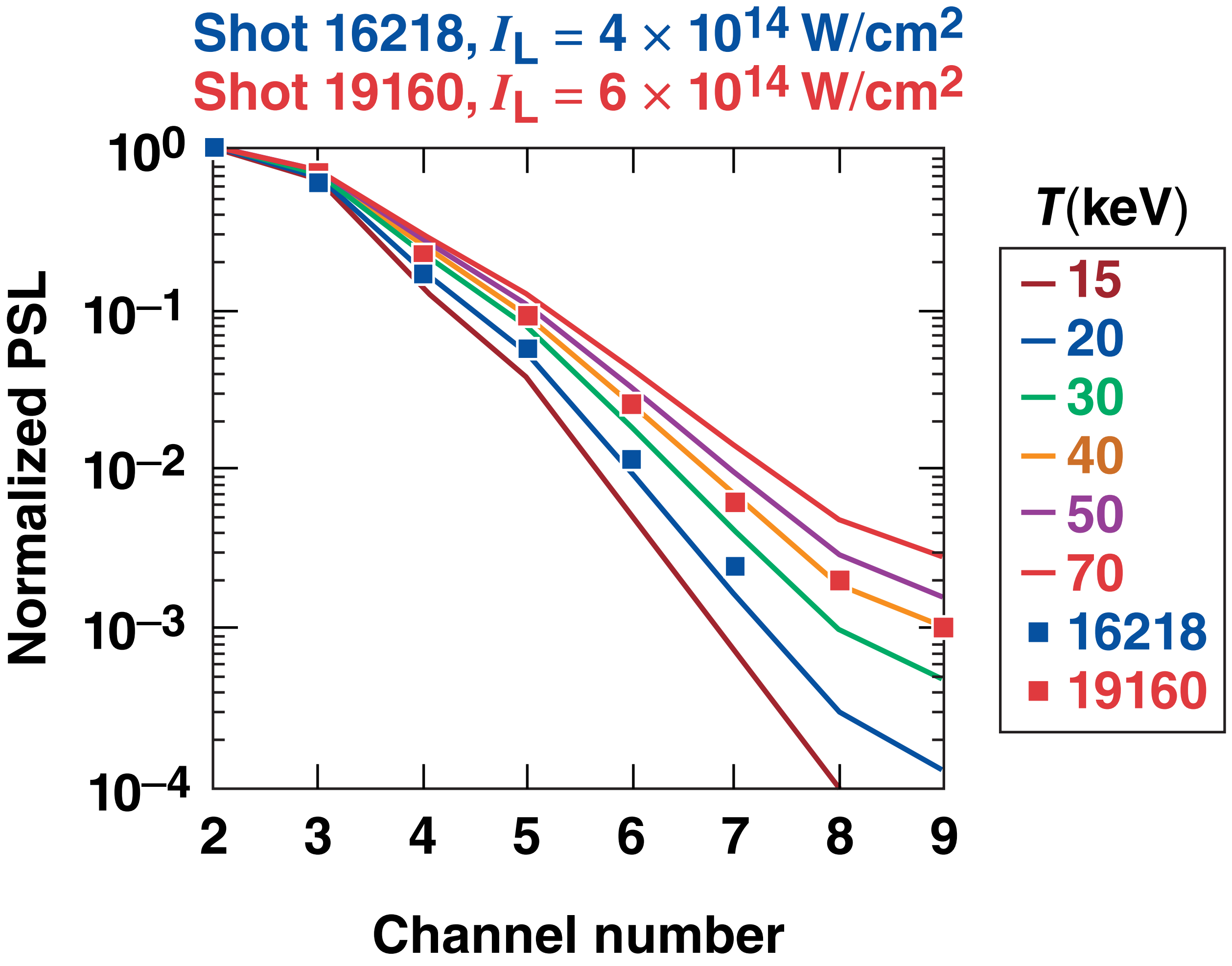


TC11649a

HXIP measurements (channels 2 to 9) indicate a single-temperature hot-electron distribution

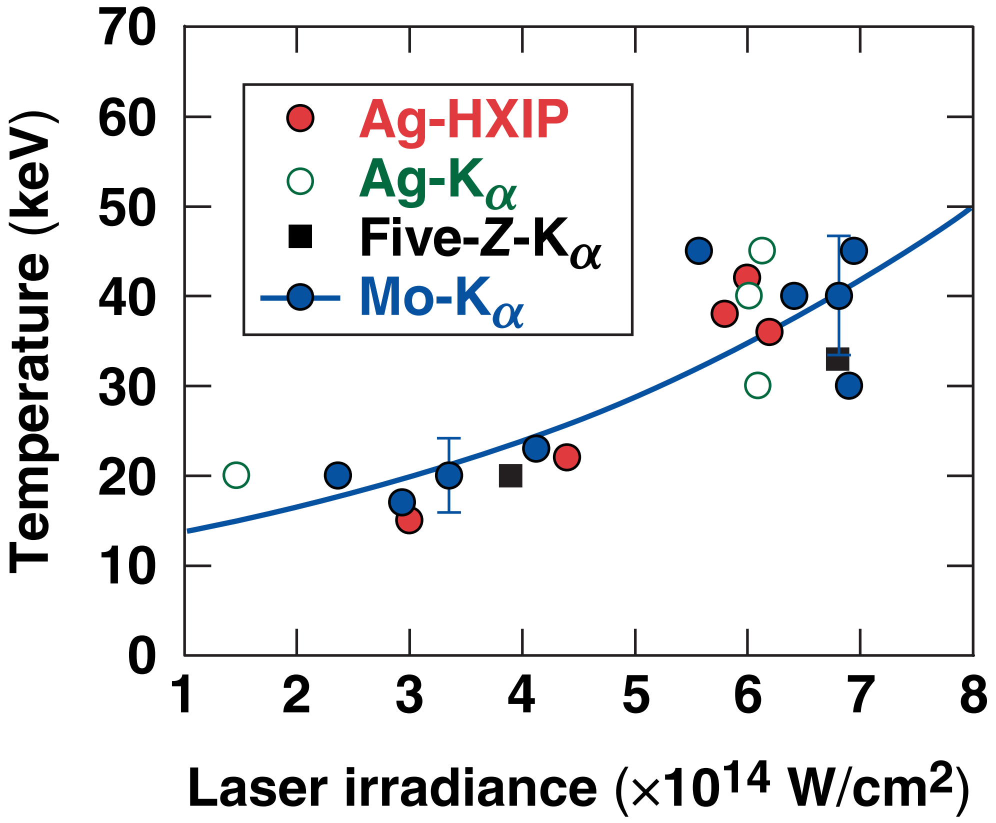


PSL in two shots (squares) and simulated PSL assuming single-temperature, hot-electron distributions (solid lines)



TC11650a

Temperatures inferred from HXIP and K_α measurements agree in experiments using different targets

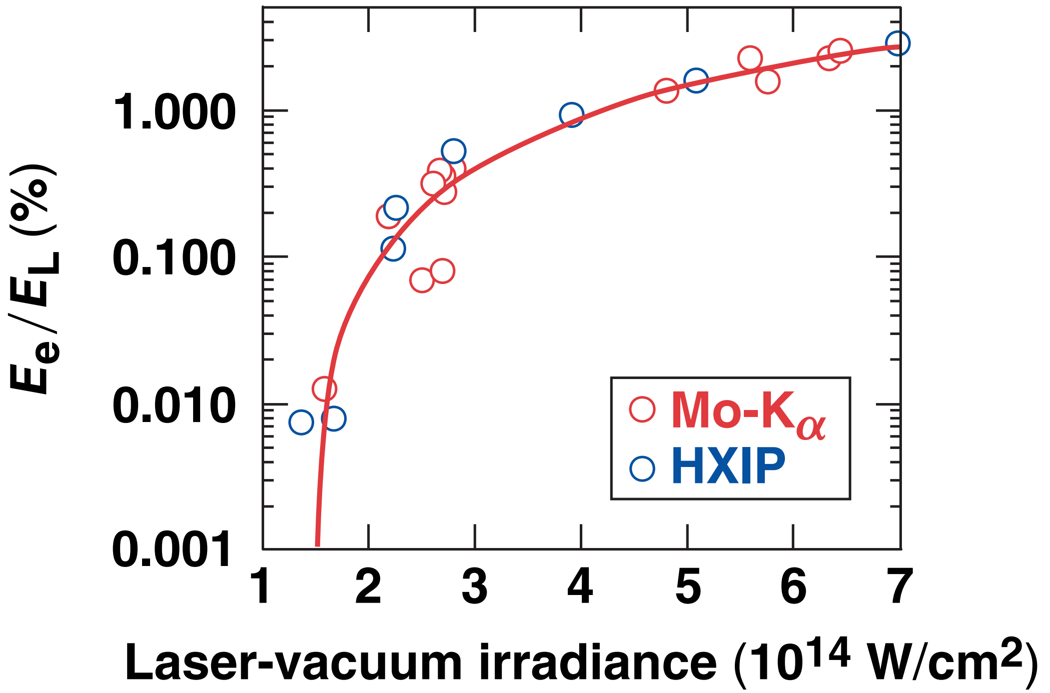


The hot-electron temperature rises from ~15 keV to ~50 keV in the intensity range of 1 to 7 $\times$ 10^{14} W/cm^2.

TC11652a

Hot-electron temperature and x-ray yield measurements have been used to estimate the preheat energy

Comparison of preheat inferred using Mo-K$_\alpha$ and HXIP measurements



- Approximately 1% of the laser energy is converted to hot electrons, confirmed using different diagnostics
- Only ~1/4 of the hot electrons will be intercepted by the compressed fuel because of a wide angular divergence*

*B. Yaakobi *et al*., Phys. Plasmas 20, 092706 (2013).

TC11653a

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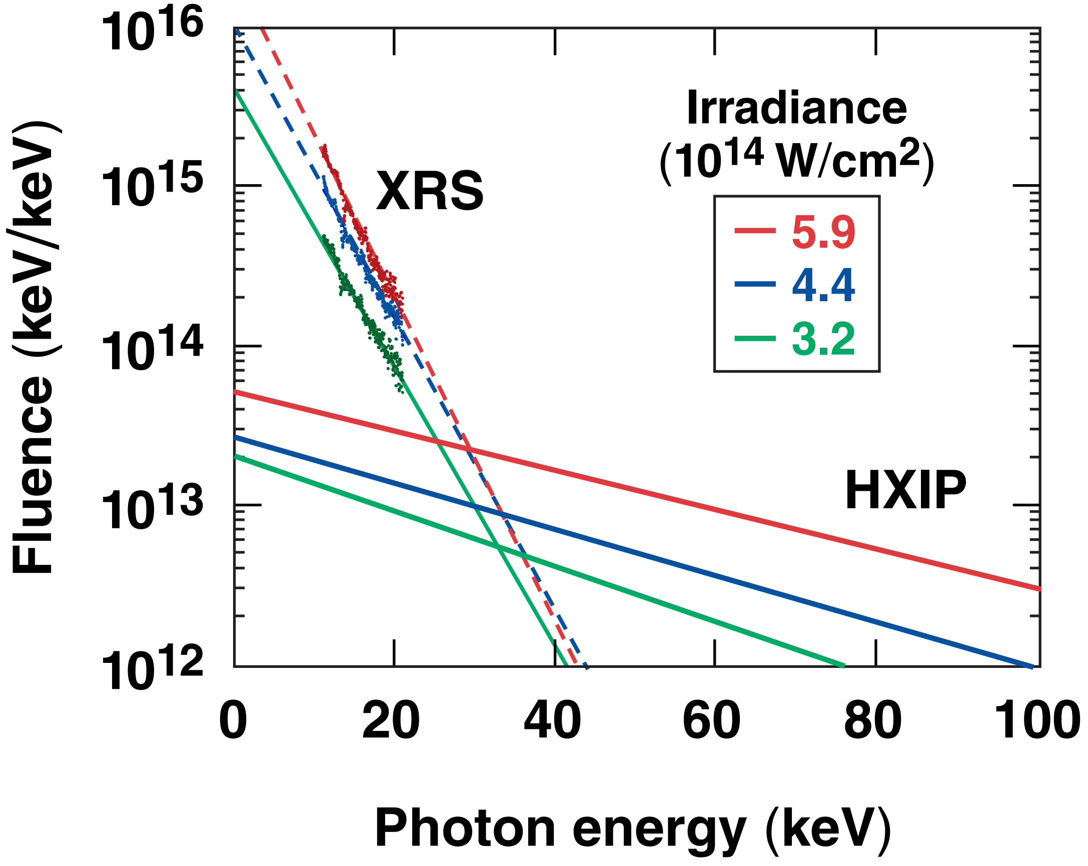
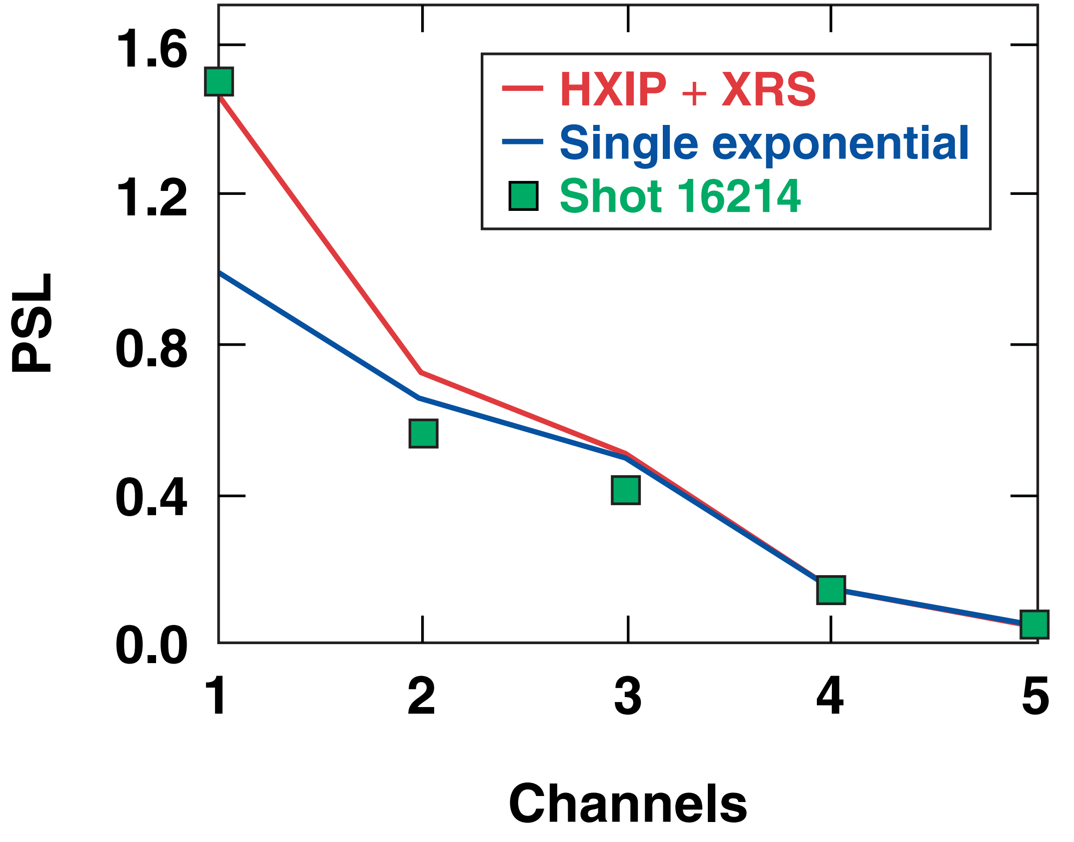
XRS confirms an increased signal in HXIP channel 1 resulting from *T* ~ 2-keV x rays generated in the plasma corona

Combining XRS and HXIP absolutely calibrated spectra



Composite HXIP + XRS spectrum better reproduces the measurement



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