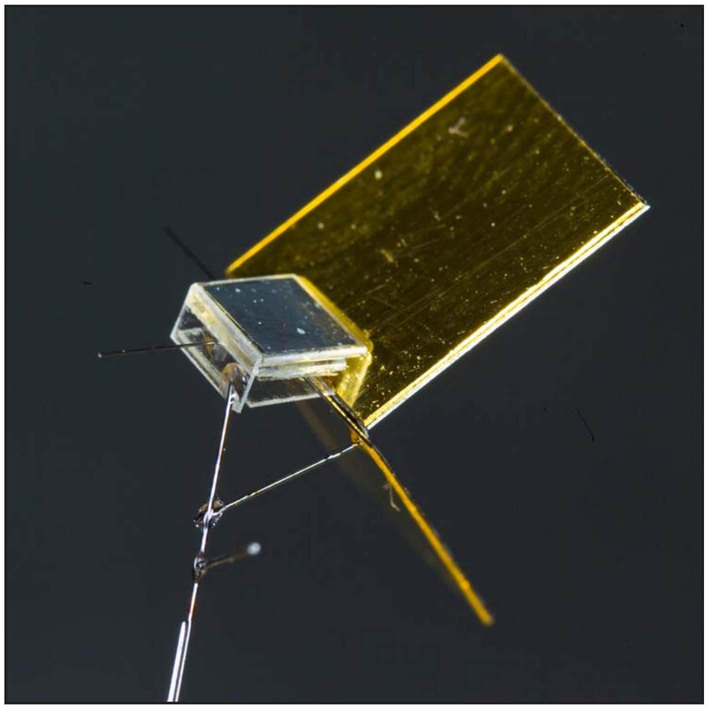
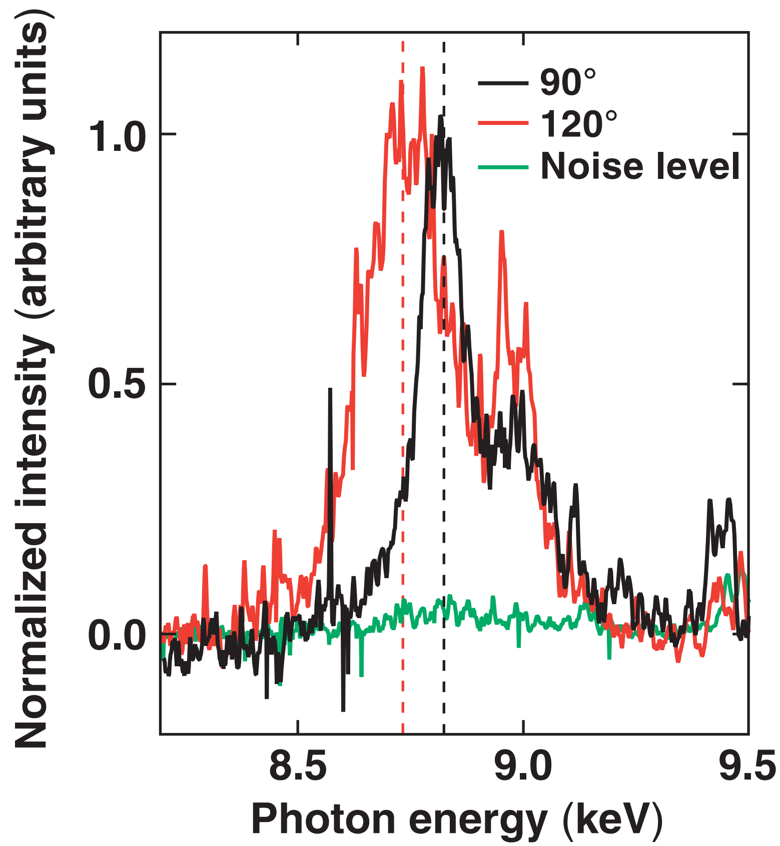
Diagnosing Shock-Heated, Direct-Drive Plastic Targets with Spectrally Resolved X-Ray Scattering





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Summary

A spectrally resolved x-ray scattering experiment has been developed to infer plasma conditions of shock-heated planar foils

- X-ray scattered spectra of Zn Heα at 9 keV were recorded from direct-drive, shock-heated and undriven plastic foils.
- Observations were made with 90° and 120° scattering angles.
- Inferred conditions in a shock-heated foil of $Z < 1.25$ and $T_e < 20$ eV are close to 1-D hydrodynamic predictions.
- The scattered x-ray spectrum becomes sensitive to electron temperatures for $T_e > 20$ eV.

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Plasma conditions of shock-heated matter can be diagnosed with spectrally resolved x-ray scattering

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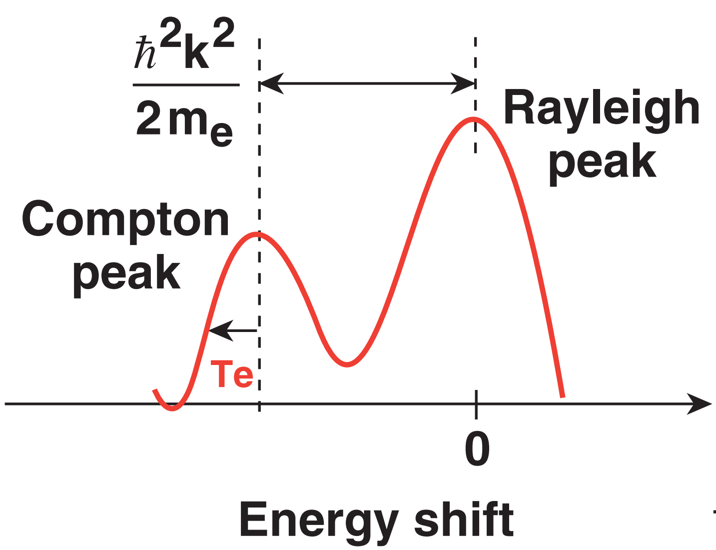
- A synthetic scattering spectrum is determined with a unique combination of T_e, n_e, and Z.[1,2]
- Compton-downshifted energy becomes larger with higher energy x-ray probes and greater scattering angles.
- T_e can be inferred from a broadening of the red wing on the Compton peak.



Compton downshifted energy (eV)

$$\Delta E_C = \frac{\hbar^2 k^2}{2m_e} \qquad k = \frac{4\pi}{\lambda_0} \sin\left(\frac{\theta}{2}\right)$$

θ: scattering angle
λ_0: wavelength of probe

[1]S. H. Glenzer *et al.*, Phys. Rev. Lett. 90, 175002 (2003).
[2]G. Gregori *et al.*, Phys. Rev. E 67, 026412 (2003).

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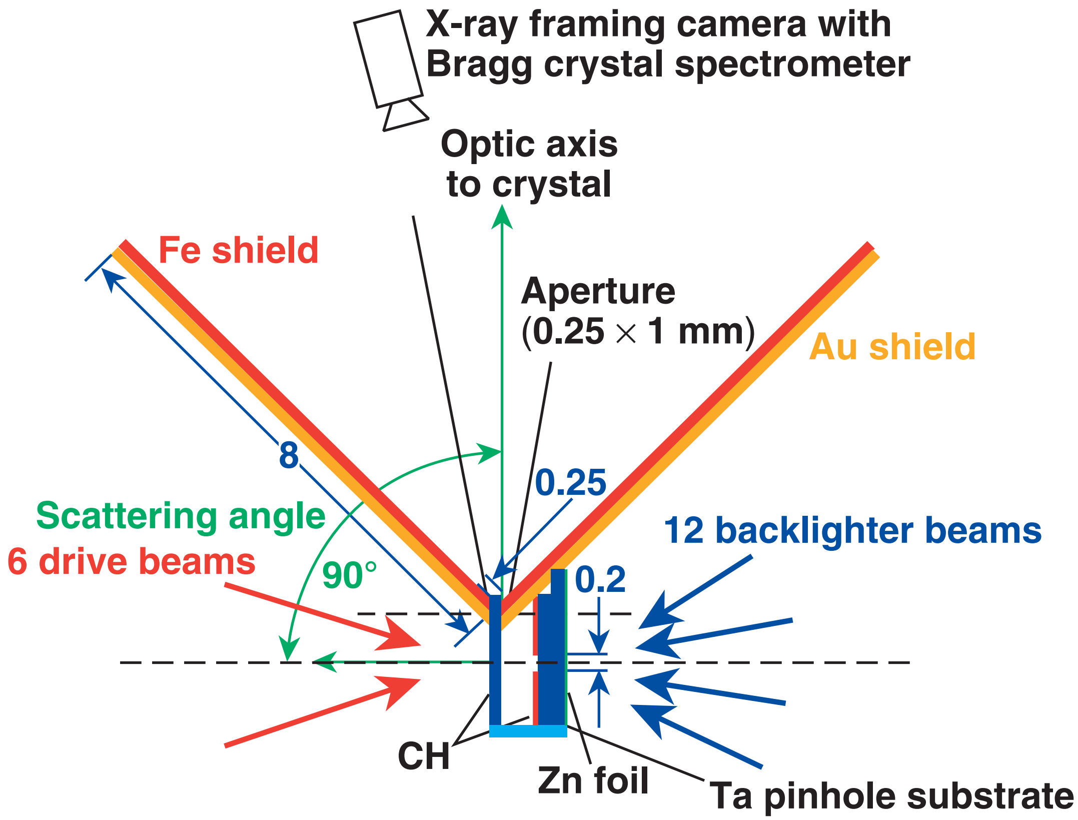
Scattered x-ray spectra were recorded for the 90° scattering geometry



- Target
  - 125-μm CH (2 × 3 mm)
  - 6 × 8 mm Au/Fe shields (100-μm Au, 50-μm Fe in thickness)
  - 250-μm viewing slit
  - 200-μm pinhole size
  - 5-μm Zn foil

- Laser conditions
  - 3-ns square pulse
  - 280 J/beam
  - 400 μm spot for drivers
  - 200 μm spot for backlighters

- 120° scattering angle is achieved by repointing backlighter beams and changing the pinhole location

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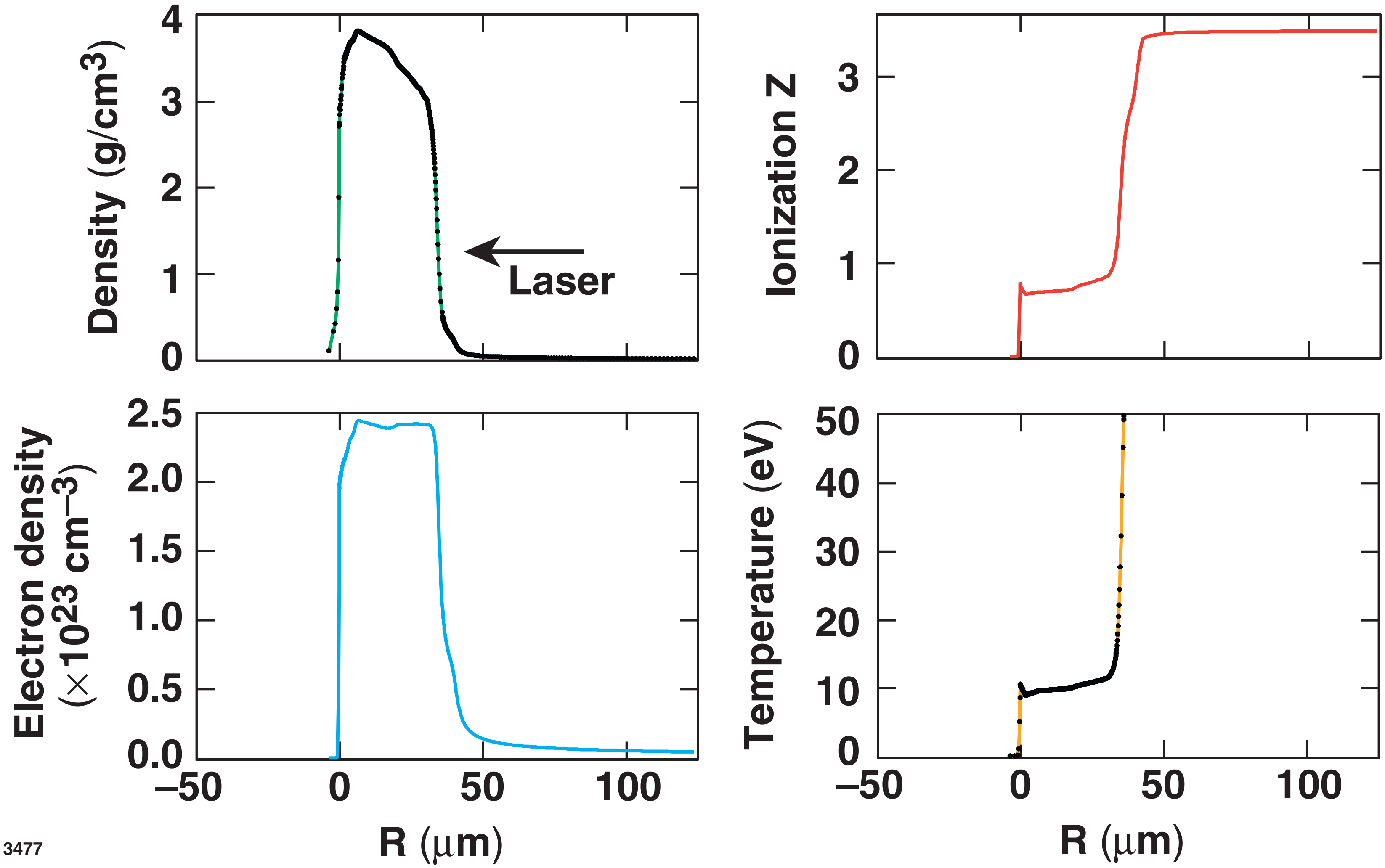
The 1-D hydrodynamic code predicts Z ~ 1, $n_e \sim 2.5 \times 10^{23}$ cm^{-3}, $T_e \sim 10$ eV for the shock-heated plastic foil

125-μm-thick CH, 3-ns pulse, 280 J/beam @ 2.8 ns



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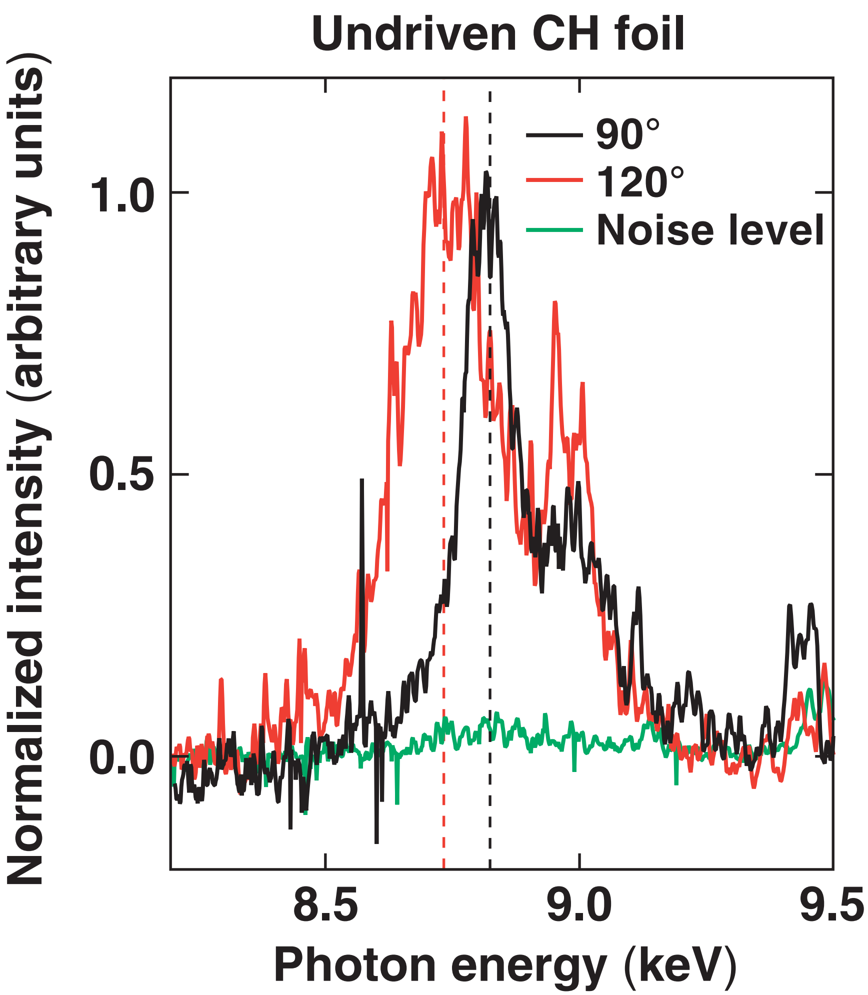
The Compton energy downshift is observed to be greater for the larger scattering angle



Compton downshifted energy (eV)

$$\Delta E_C = \frac{\hbar^2 k^2}{2 m_e} \qquad k = \frac{4\pi}{\lambda_0} \sin\left(\frac{\theta}{2}\right)$$

θ: scattering angle
λ_0: wavelength of probe

(Zn Heα ~ 1.3 Å ~ 9.0 keV)

ΔE_C = 178 eV (for 90°)
= 267 eV (for 120°)

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Similar conditions in the undriven CH are inferred for the 90° and 120° scattering geometries

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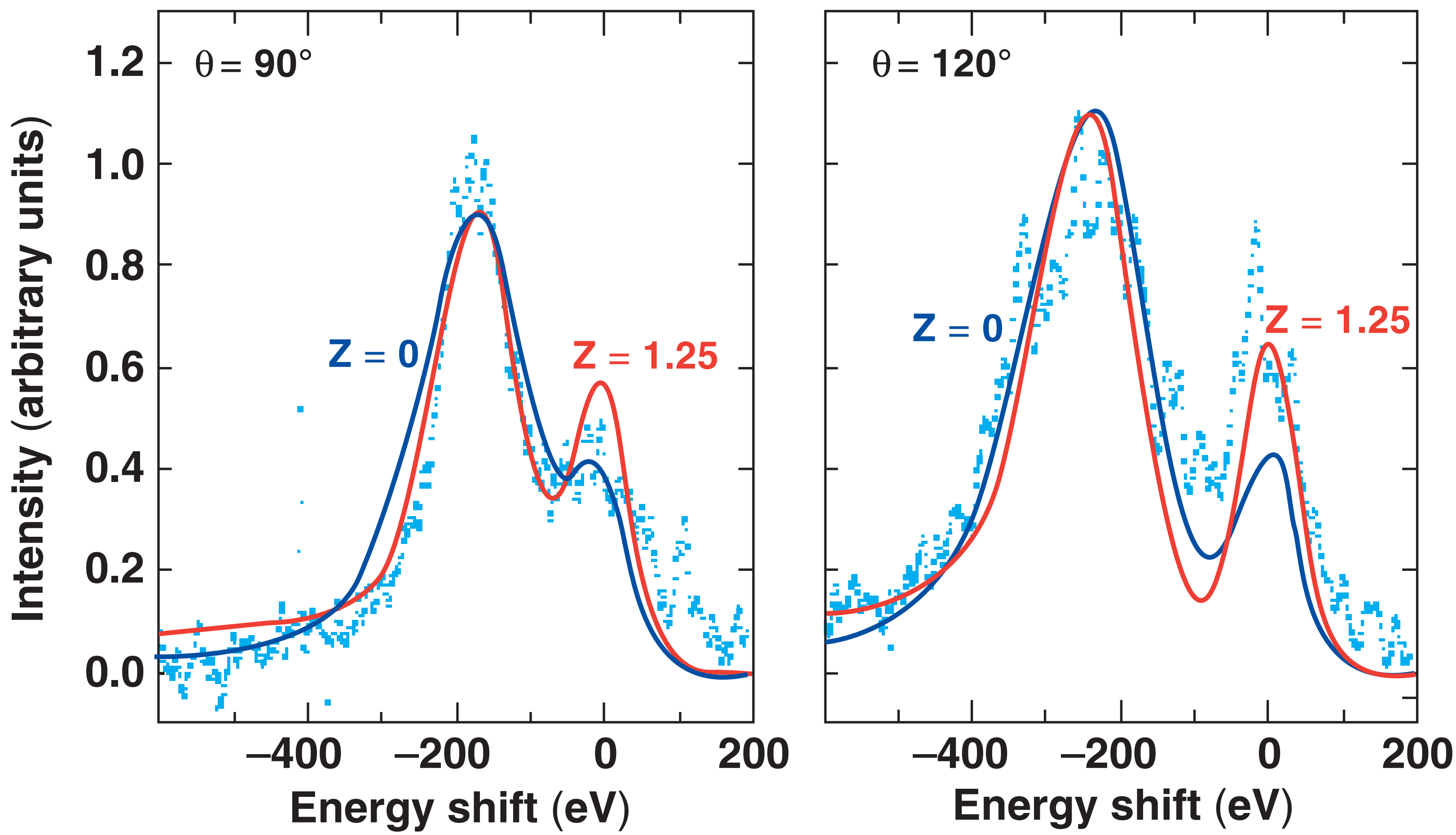

The best fit suggests Z = 1.25 valance electrons in cold CH.

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Inferred conditions in the shock-heated foil of Z < 1.25 and T_e < 20 eV are close to the 1-D hydrodynamic prediction

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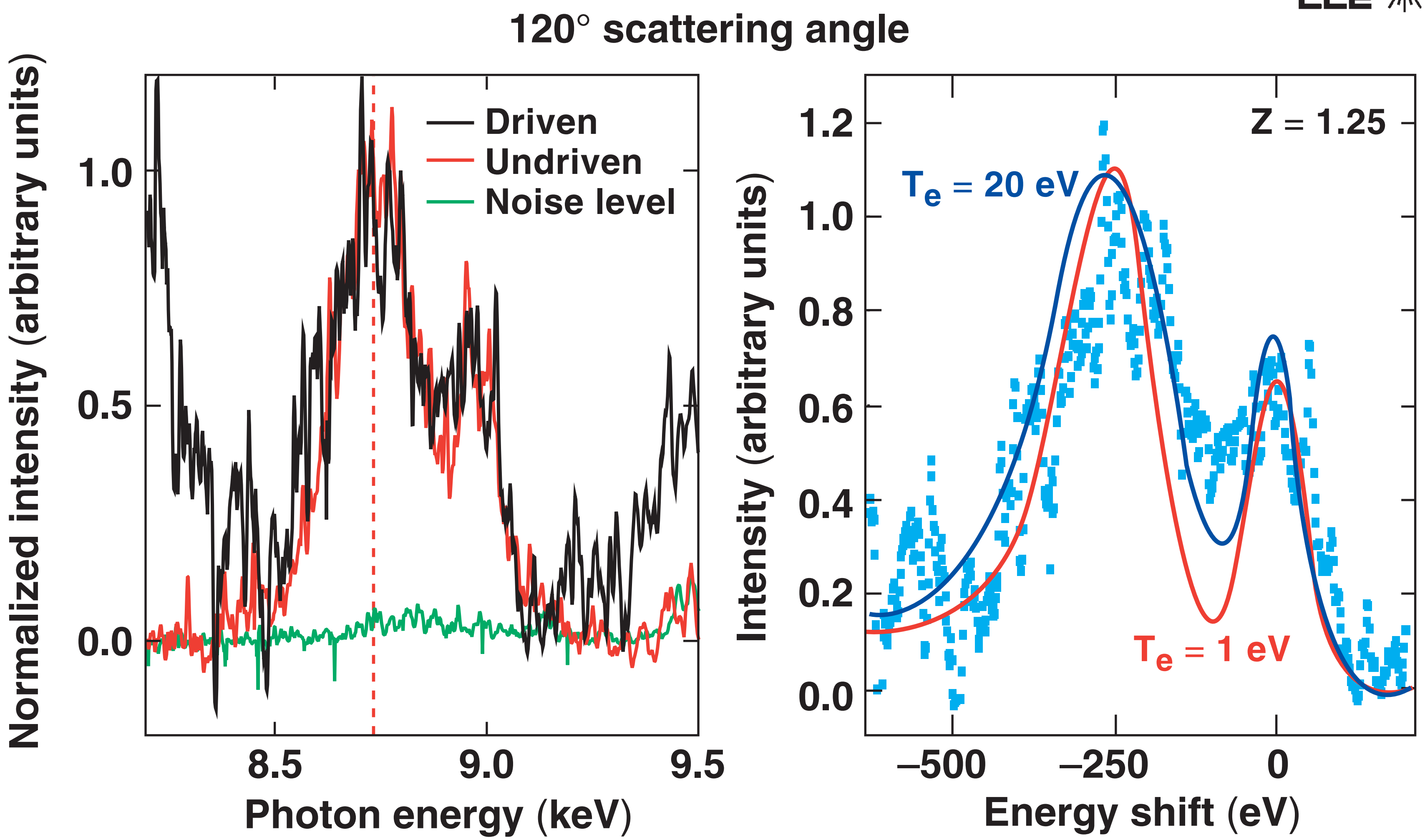

Thermal broadening on the red wing of the Compton feature becomes sensitive at T_e > 20 eV.

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Summary/Conclusions

A spectrally resolved x-ray scattering experiment has been developed to infer plasma conditions of shock-heated planar foils

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