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

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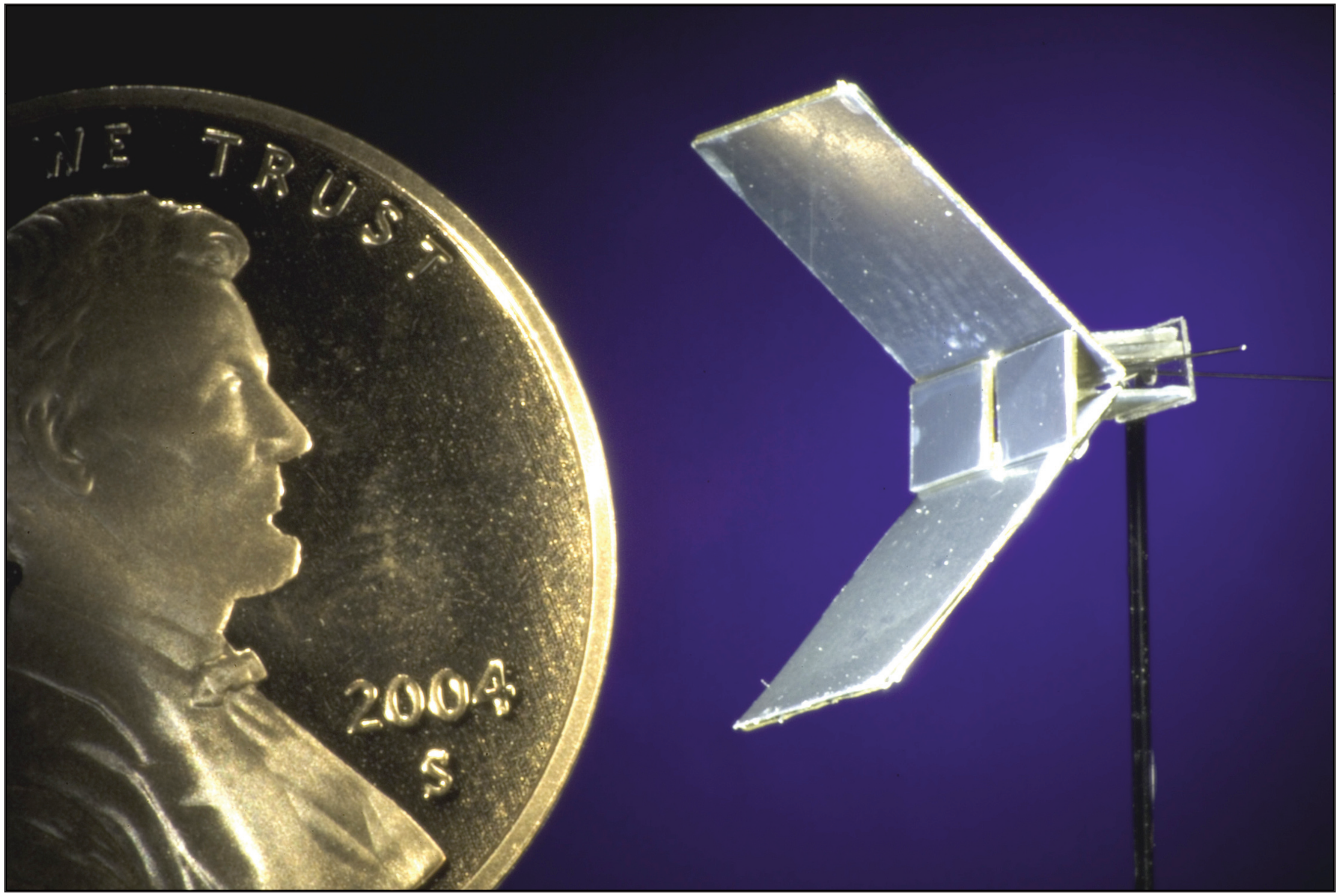

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35th Annual Anomalous
Absorption Conference
Fajardo, Puerto Rico
27 June–1 July 2005

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Summary

Spectrally resolved x-ray scattering has been used to diagnose plasma conditions of shock-heated, direct-drive plastic targets

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- **Planar shocks (15 to 50 Mbar) in CH foils (125 μm thick) are predicted to generate plasma conditions in the range of $n_e \sim 1$ to 6×10^{23} cm^{-3}, $T_e \sim 10$ to 30 eV, and $Z \sim 0.5$ to 1.6.**
- **Nine-keV x rays (He_α K-shell emission of Zn) scattered from the uniformly compressed region of the target were dispersed with a Bragg crystal and recorded with an x-ray framing camera.**
- **Preliminary values of spatially averaged T_e and Z inferred from the spectral line shapes of the elastic Rayleigh and the inelastic Compton components are higher than 1-D predictions.**

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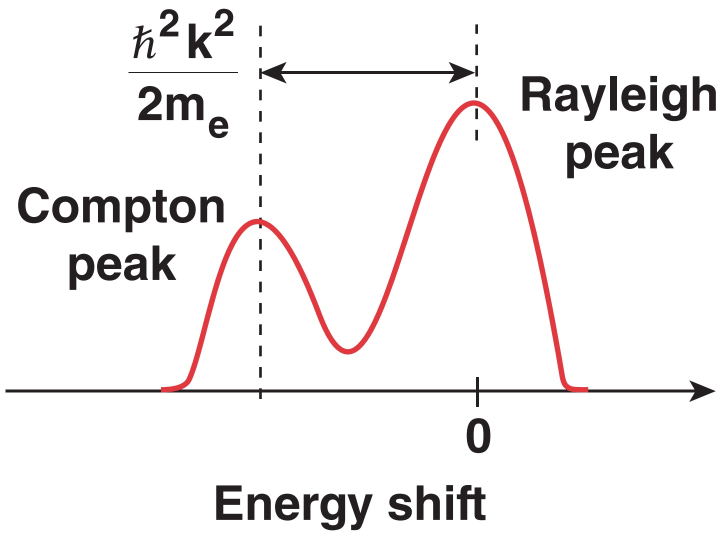
Outline

- Spectrally resolved x-ray scattering
- 1-D simulations
- Inferred plasma conditions
- Future experiments
- Conclusions

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

- The spectral line shapes of the elastic Rayleigh and the inelastic Compton components are fitted to infer T_e and Z.*
- The Doppler-broadened Compton feature is sensitive to T_e for $T_e > T_F$.
- The ratio of Rayleigh and Compton intensities is sensitive to Z.



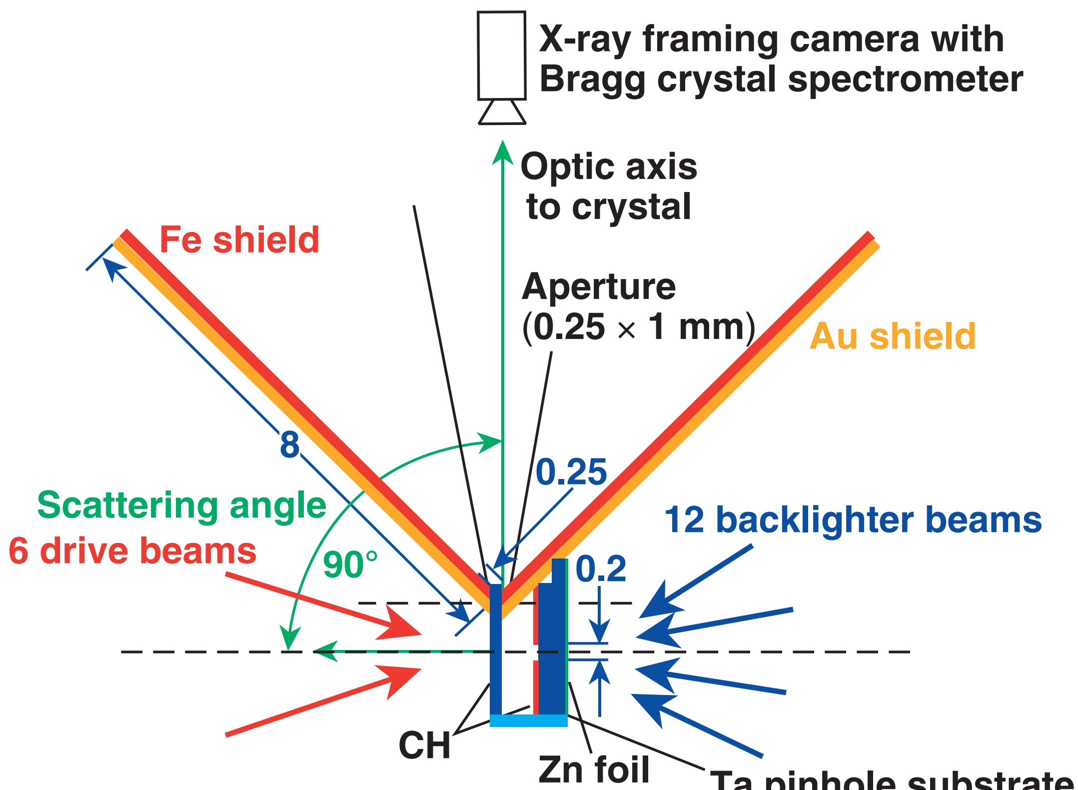
Compton downshifted energy (eV)

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

θ: scattering angle
λ_0: wavelength of probe

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

Scattered x-ray spectra were recorded for the 90° and 120° scattering geometries



- 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- to 400-μm pinhole size
  - 5-μm Zn foil
- Laser conditions
  - 1- or 3-ns square pulse
  - 480 or 280 J/beam
  - 400 μm spot for drivers
  - 100 to 200 μm spot for backlighters

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

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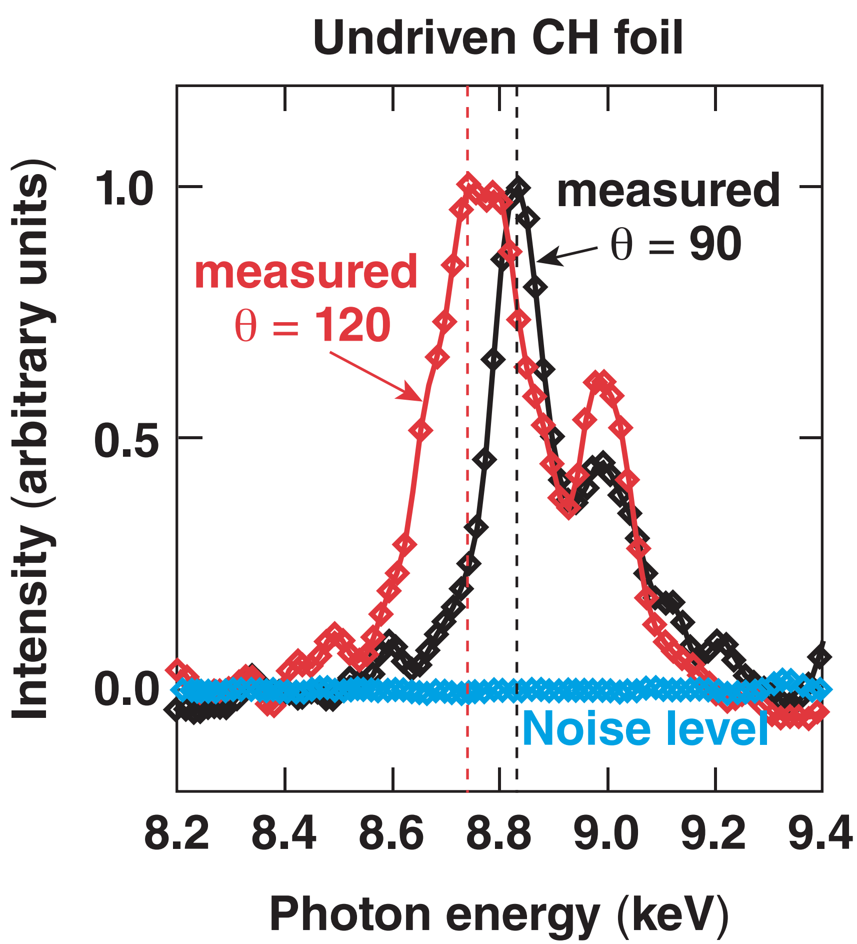
The Compton energy downshift is observed to be greater for the larger scattering angle



Compton downshifted energy (eV)

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(Zn Heα ~ 1.3 Å ~ 9.0 keV)

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

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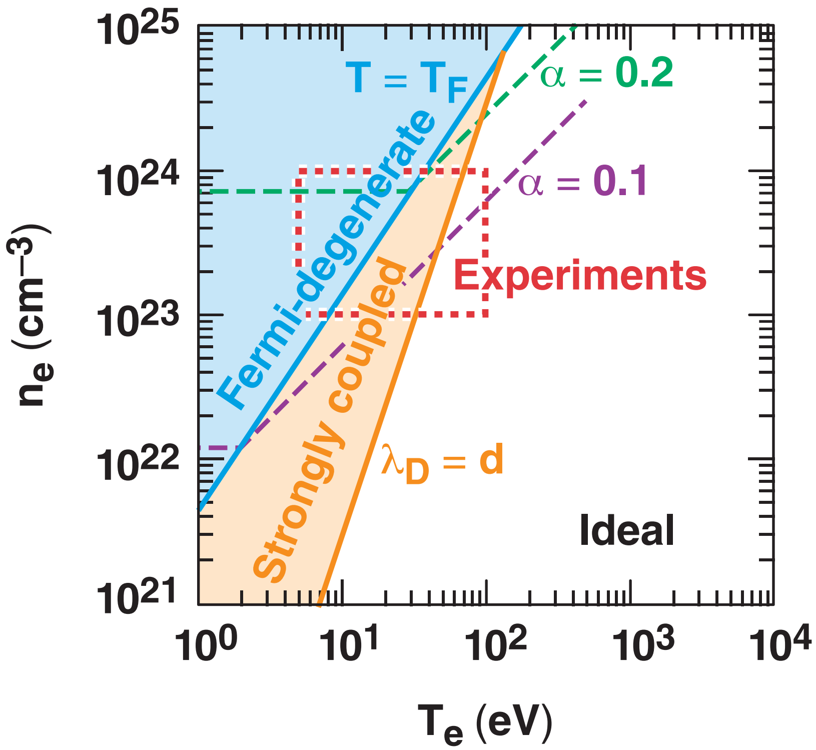
Plasma conditions created in shock-heated, direct-drive CH targets encompass many states of matter



- Fermi temperature: $T_F \propto n_e^{\frac{2}{3}}$
- Average interparticle spacing: $d = \left(\frac{3}{4\pi n_e}\right)^{\frac{1}{3}}$
- Scattering parameter: $\alpha = \frac{\lambda_s}{2\pi\lambda_D} < 1$;

  where: $\lambda_s = \frac{\lambda_0}{2} \sin\left(\frac{\theta}{2}\right)$

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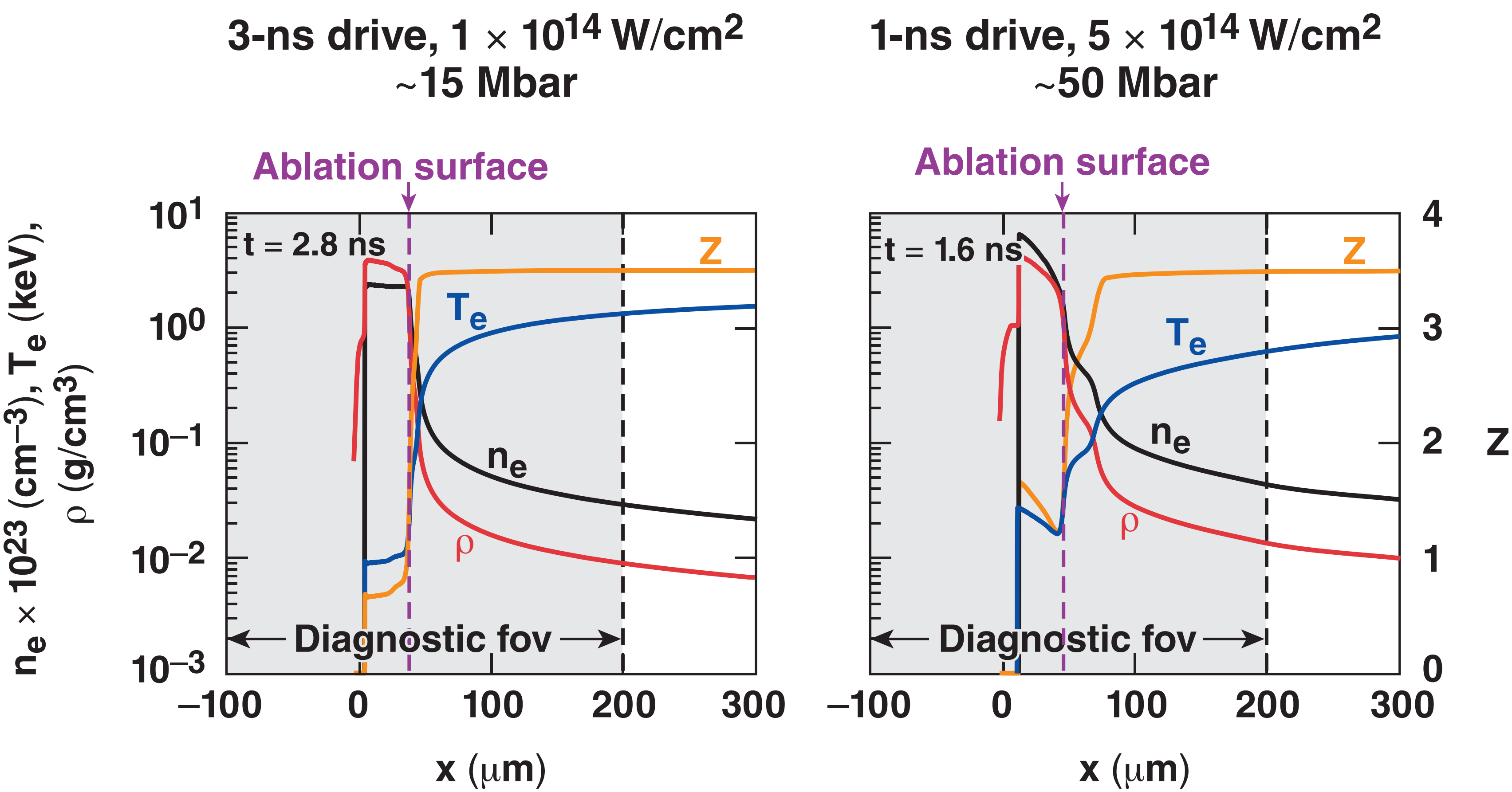
The 1-D hydrodynamics code *LILAC* was used to predict plasma conditions



- At the time of shock breakout, the compressed foil has nearly uniform conditions.

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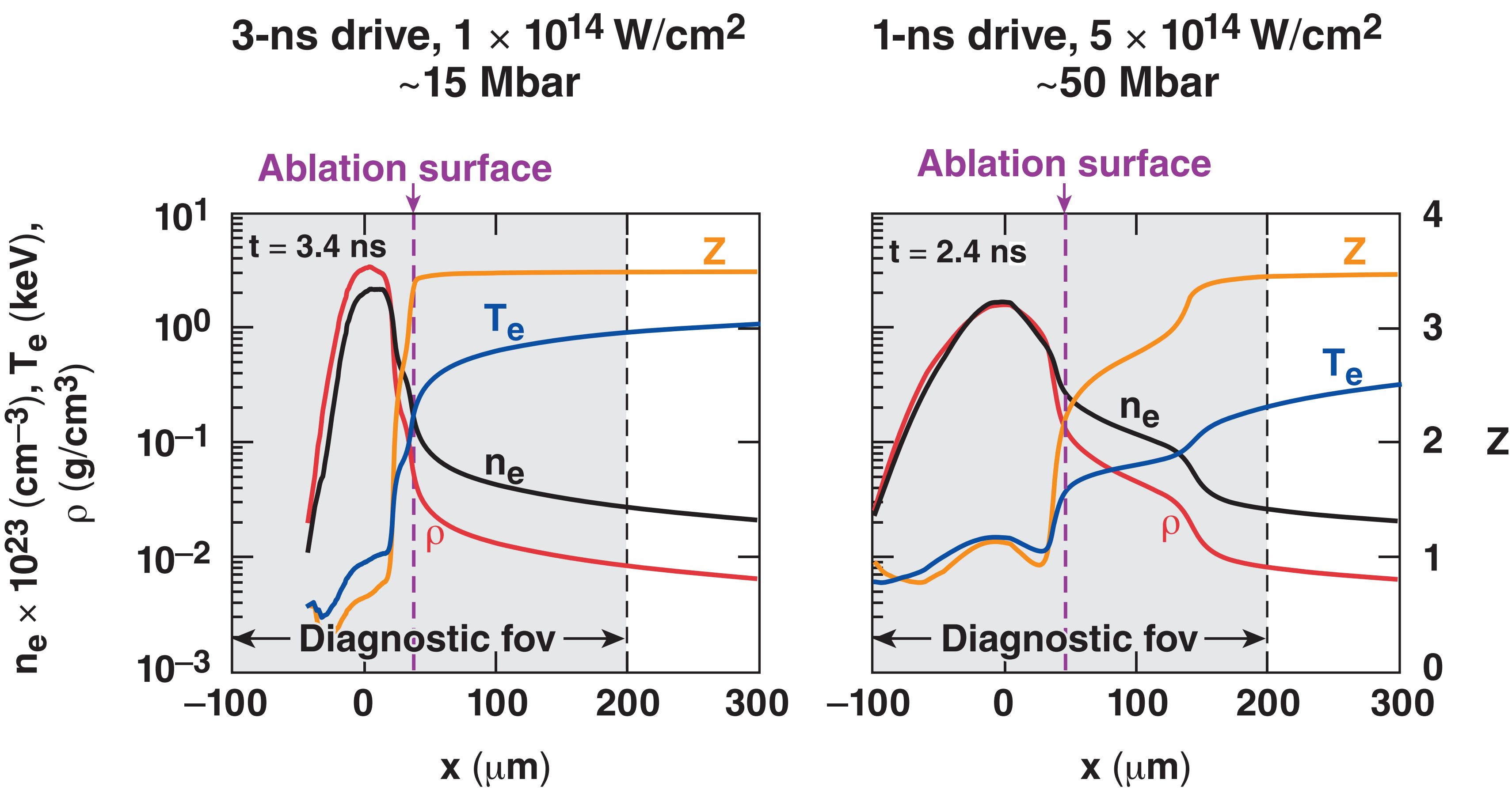
The scattered spectra were recorded after the time of shock breakout for the 1 ns and 3 ns laser drives



- The targets are decompressing at these times.

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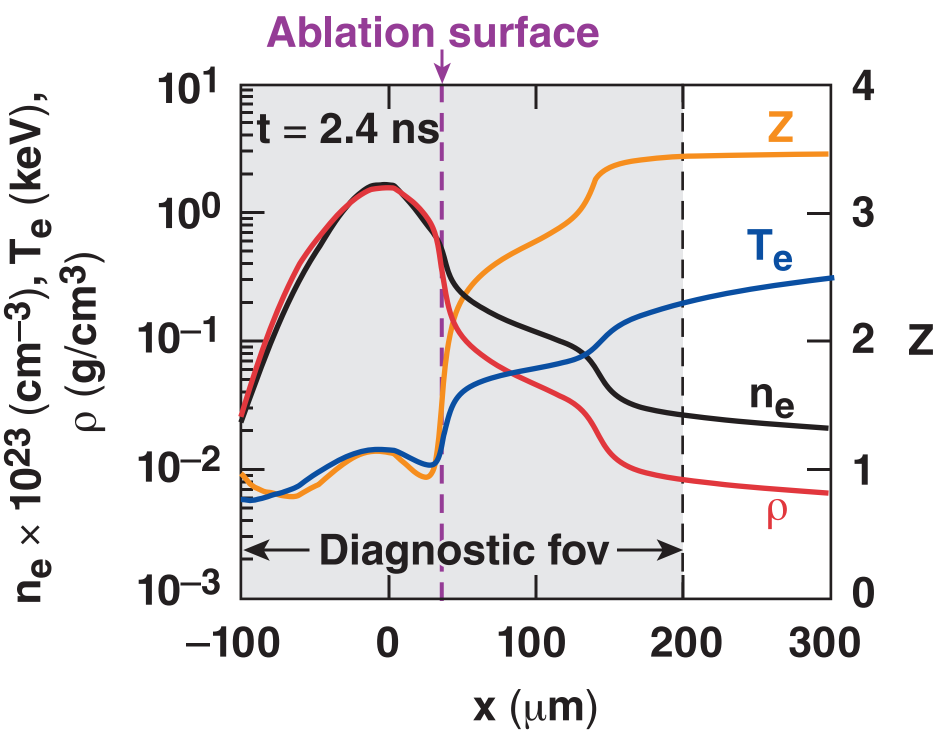
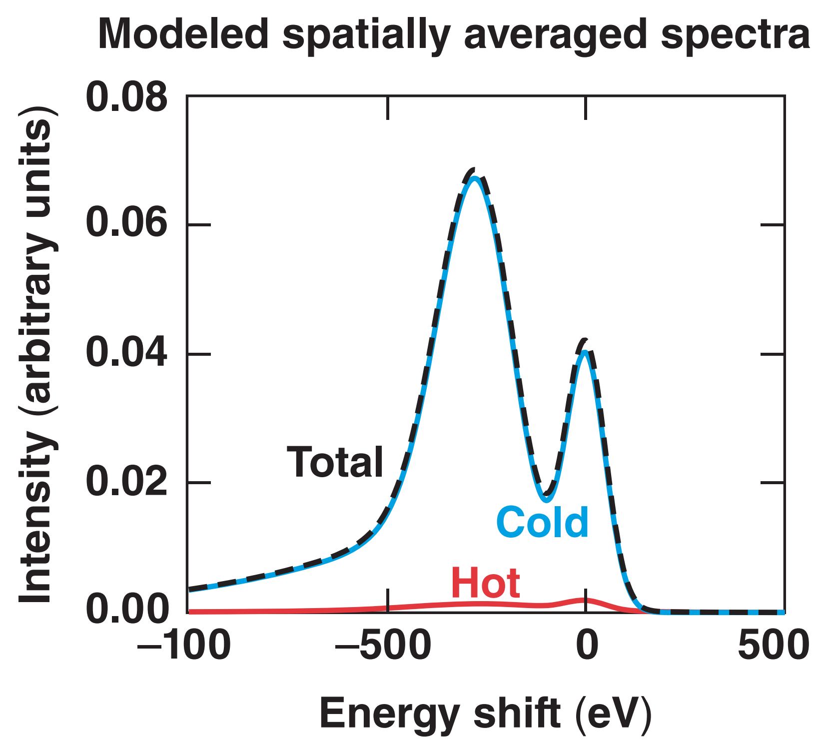
Scattering from the hot coronal plasma can be neglected





- Modeled spatially averaged spectra are weighted to the mass density ρ.

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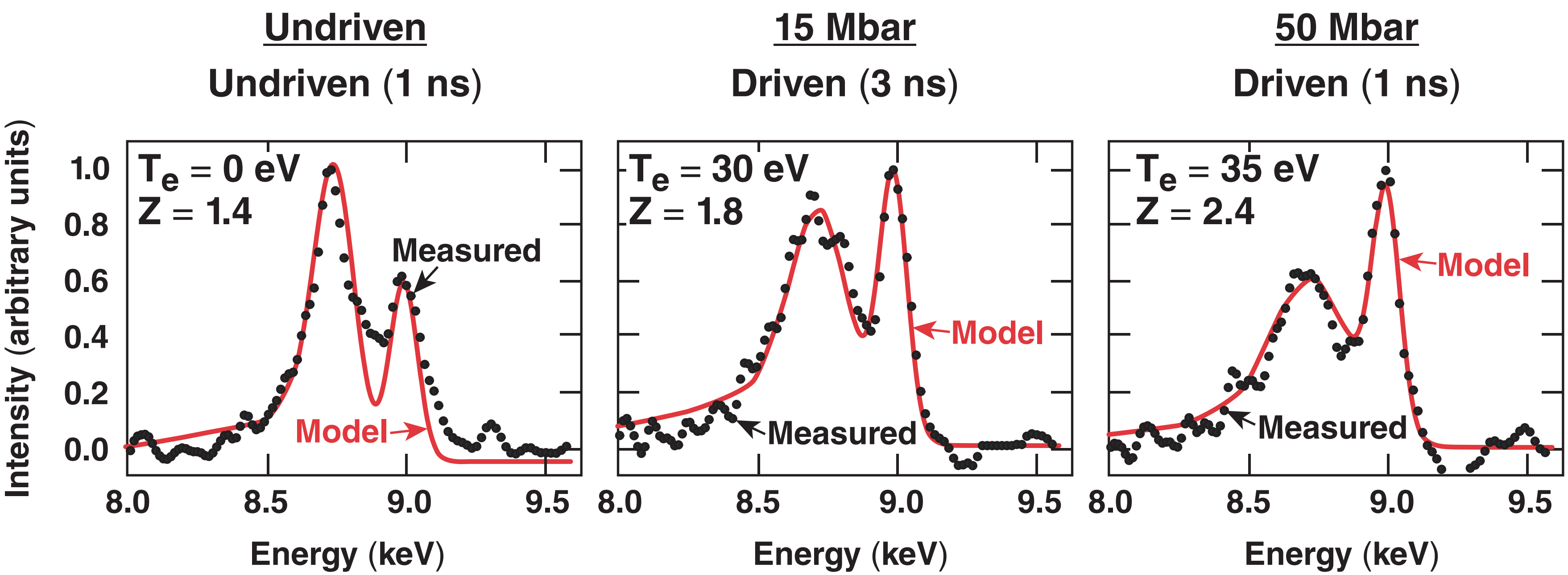
Distinct spectrally resolved x-ray spectra were observed for the drive conditions under consideration



- Inferred electron temperatures for driven targets are ~20 eV higher than the 1-D prediction.

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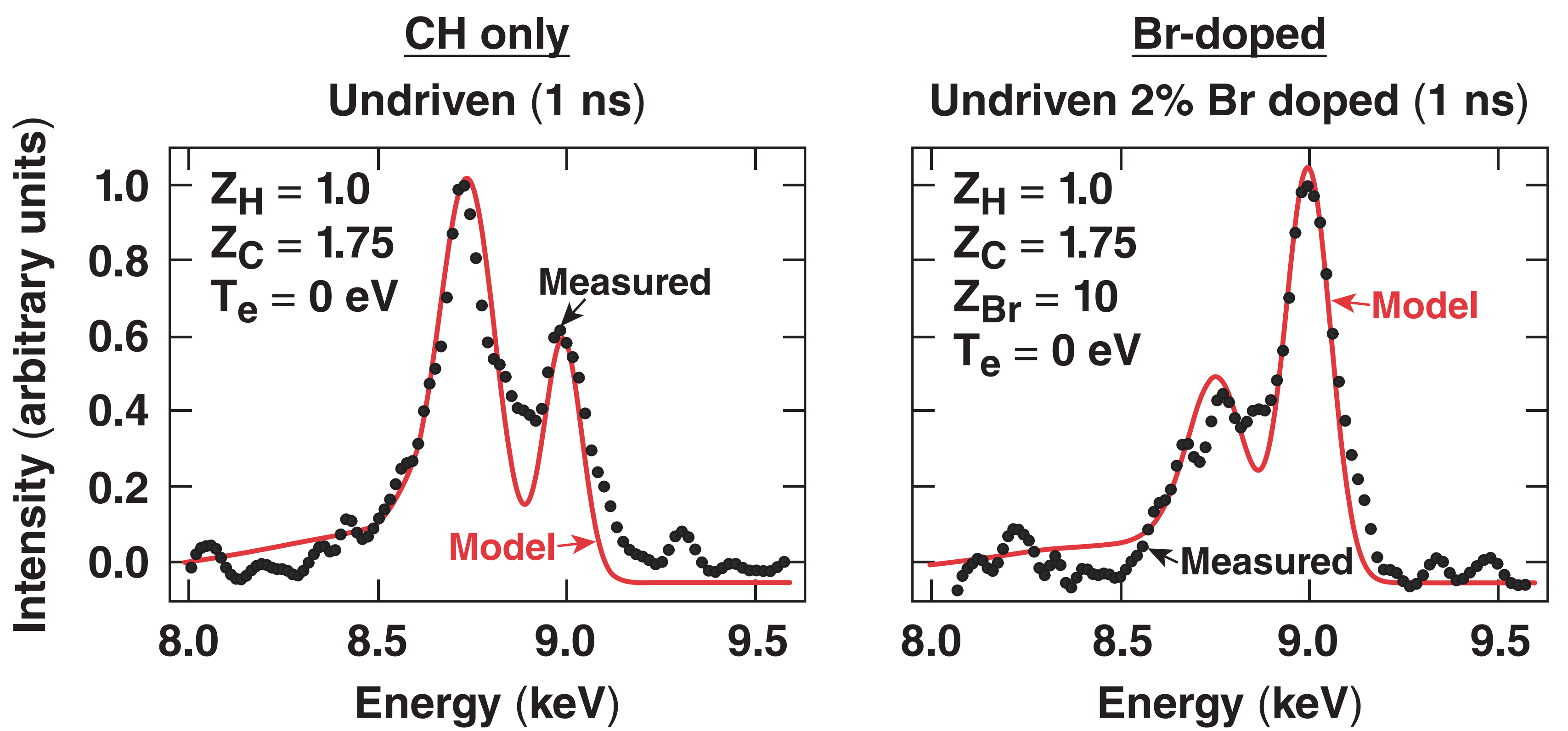
The spectrally resolved x-ray scattering is sensitive to tracer dopant elements in the plastic



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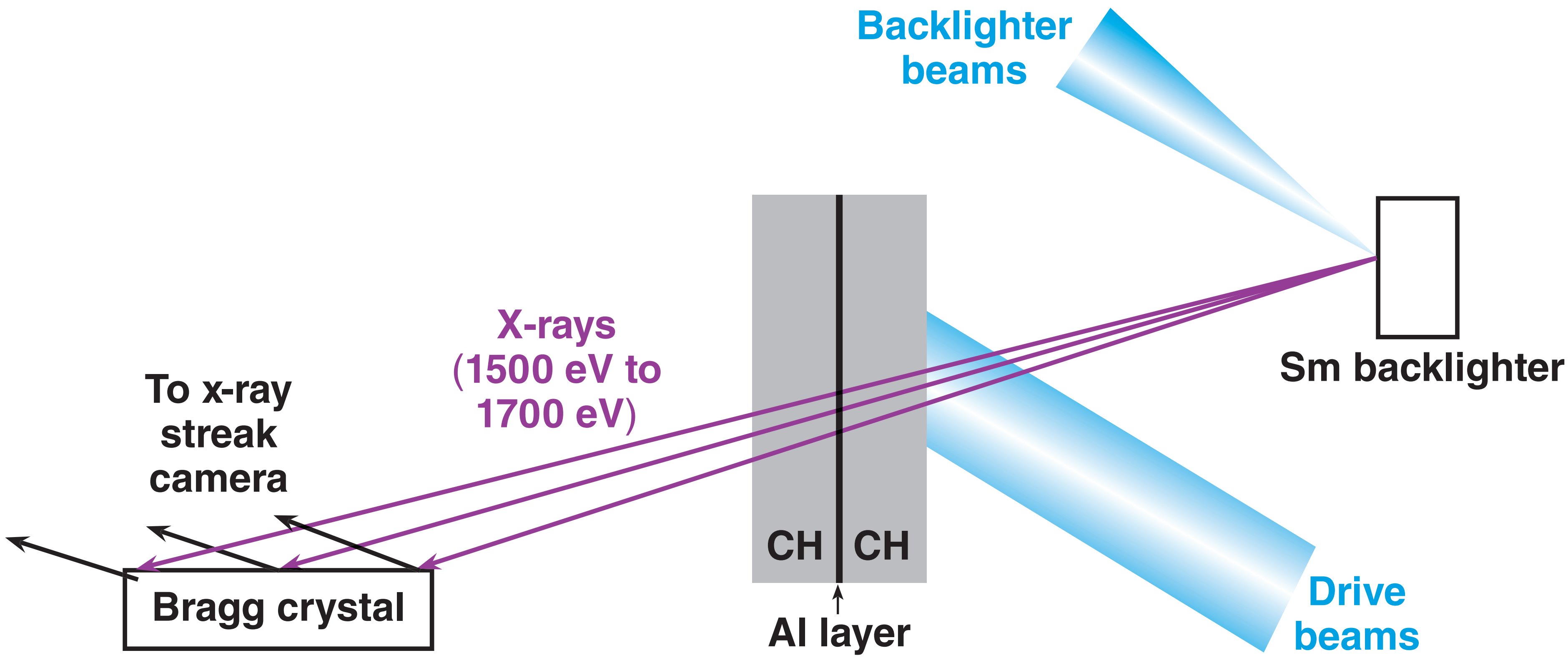
Future experiments of shock-heated, direct-drive plastic targets are planned with x-ray absorption spectroscopy*



- Experiments will be extended to lower adiabat $\left(\alpha = \dfrac{\text{Pressure in the shell}}{\text{Fermi degenerate pressure}}\right)$ drives.

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* T. R. Boehly *et al.*, Phys. Rev. Lett. 87, 145003 (2001).

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