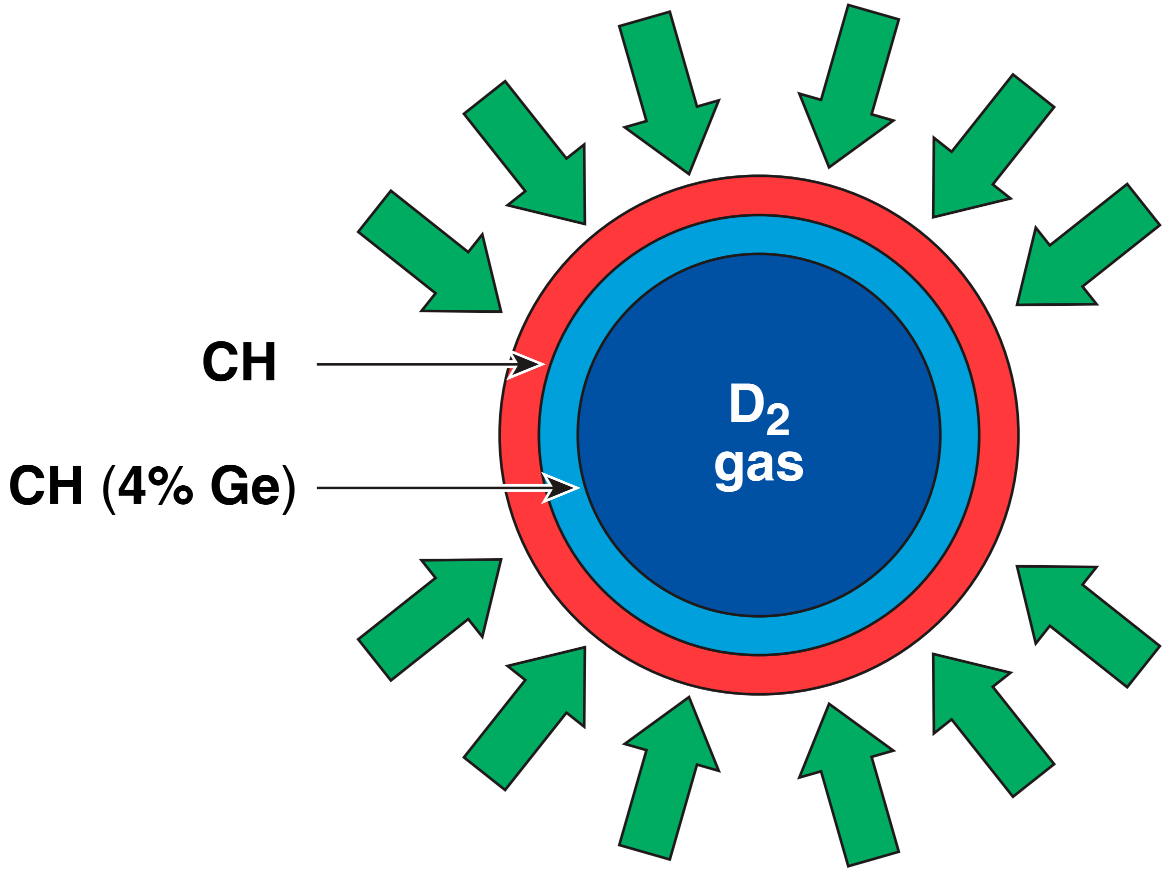
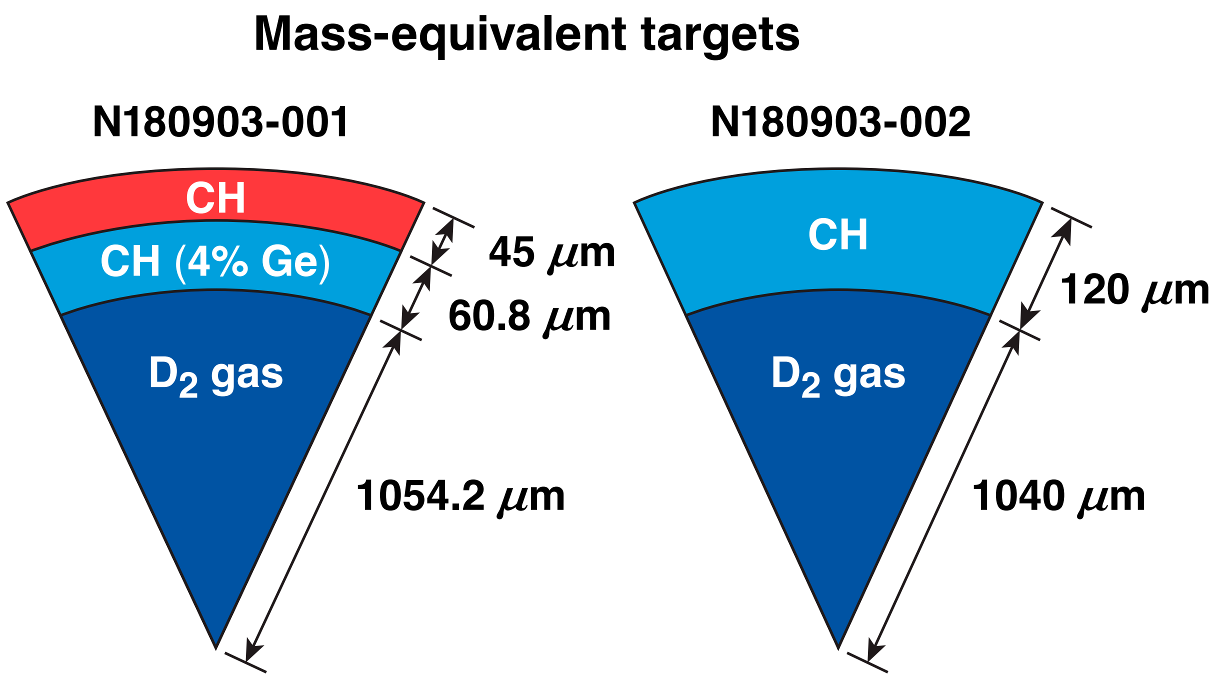
Hot-Electron Generation and Preheat in Direct-Drive Experiments at the National Ignition Facility





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Summary

An experimental platform on the NIF has been developed to study the amount of hot-electron preheat in an unablated shell

- **Hot-electron transport in National Ignition Facilty (NIF) polar-direct-drive (PDD) implosions is studied by comparing hard x-ray (HXR) production in all-plastic implosions with multilayered implosions**
- **The goal is to diagnose the hot-electron deposition profile in an imploding shell**
- **Preliminary measurements indicate 0.27±0.06% of laser energy is deposited in the unablated shell; 0.13±0.03% is deposited in the outer 20% portion and 0.14±0.03% is deposited in the inner 80% of the imploding shell**

Hot-electron preheat mitigation using mid-*Z* layers and laser frequency detuning/bandwidth strategies is being explored.*

TC14557

*R. K. Follett, NI2.00005, this conference.

Collaborators

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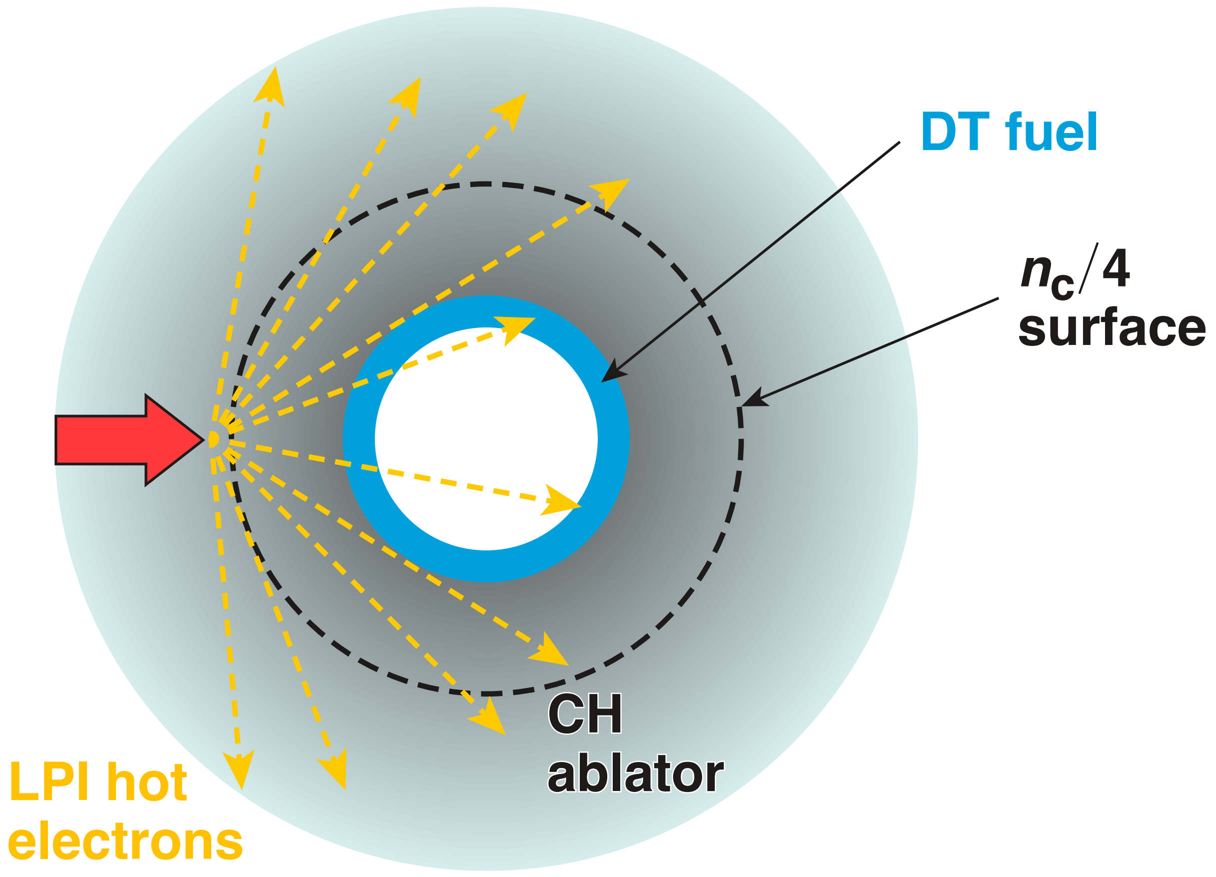
Motivation

Hot-electron preheat can degrade fuel compression in direct-drive ignition designs

Direct-drive implosion



- Fuel compression is negatively affected if more than ~0.15% of laser energy is coupled into fuel preheat**
- If electron divergence is large, only ~25% of electrons intersect the cold fuel†
- Electrons below ~50 keV are stopped in the ablator

→ limit of ~0.7% laser energy into hot electrons generated

- Parameters at $n_c/4$:* T_e ~ 3.5 to 5 keV, L_n ~ 600 μm, I ~ (6 to 8) × 10^{14} W/cm^2

*V. N. Goncharov *et al.*, Phys. Plasmas 21, 056315 (2014).
**J. A. Delettrez, T. J. B. Collins, and C. Ye, "Determining Acceptable Limits of Fast-Electron Preheat in Direct-Drive Ignition-Scale Target Designs," to be submitted to Physics of Plasmas.
†B. Yaakobi *et al.*, Phys. Plasmas 20, 092706 (2013).
LPI: laser–plasma interaction

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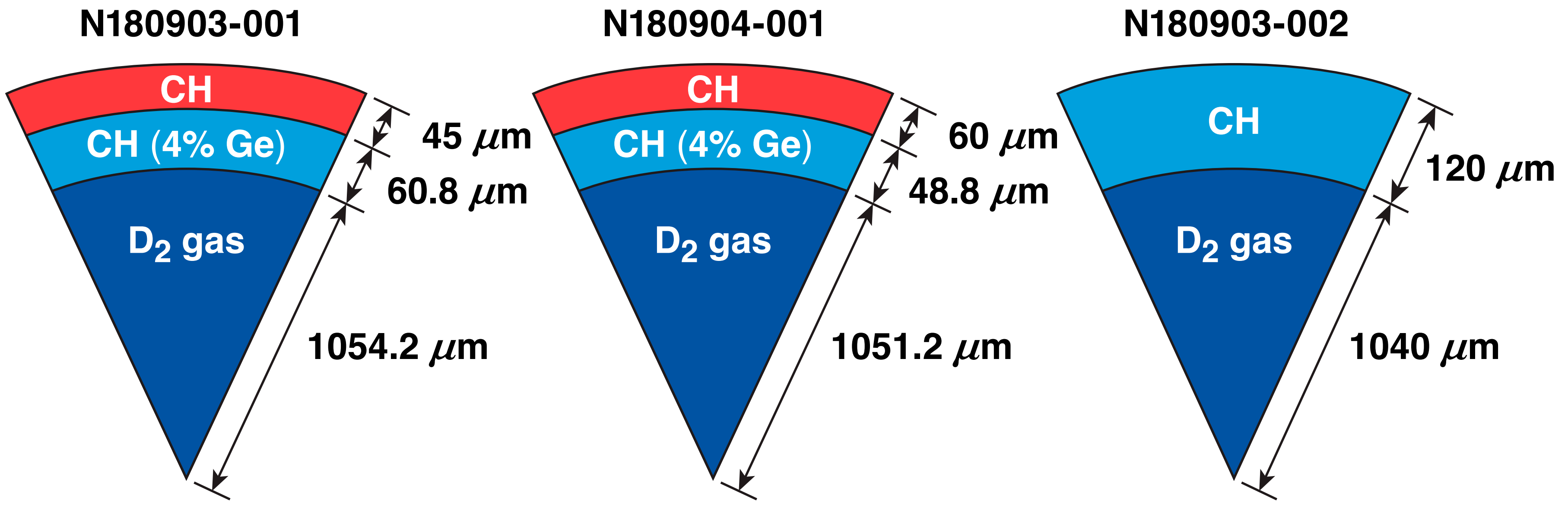
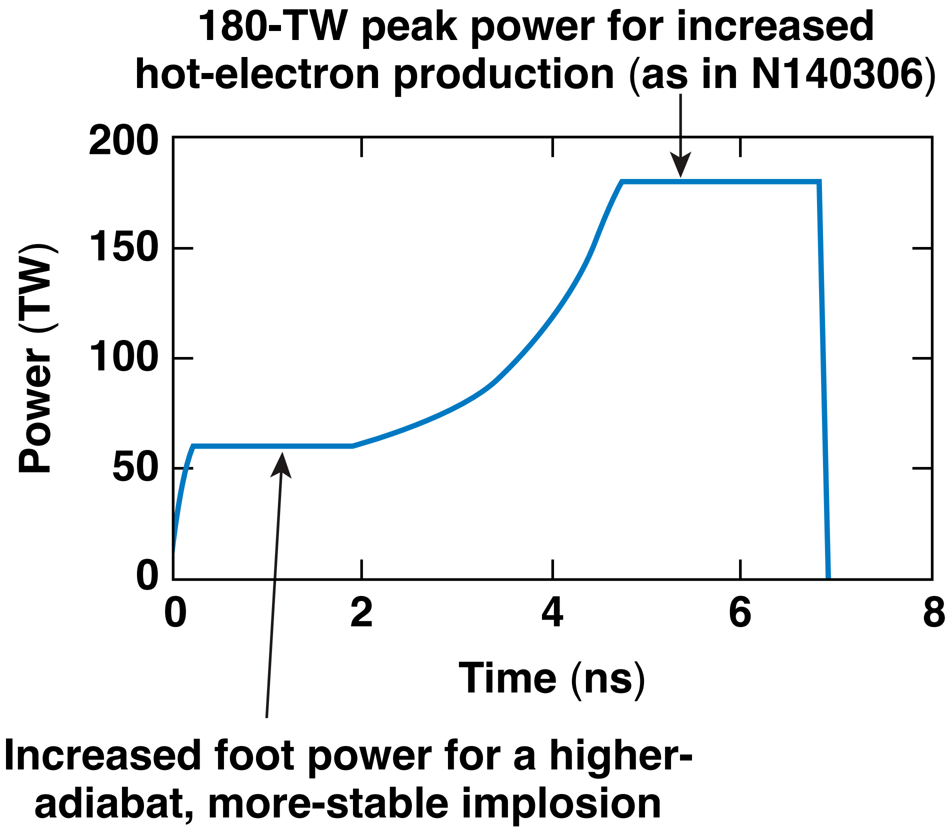
Hot-electron transport in NIF PDD implosions* is studied by comparing HXR between all-plastic and multilayered implosions

Mass-equivalent targets



Different buried depths of the Ge-doped layer are examined to diagnose the hot-electron deposition profile in the imploding shell



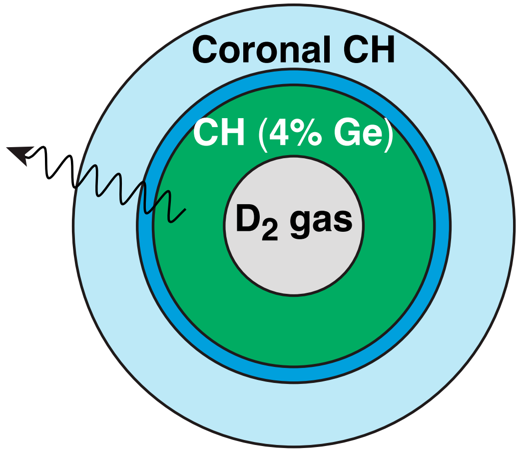
- Parameters at $n_c/4$ surface: $T_e \sim 3.2$ keV, $L \sim 400$ μm, $I \sim (4 \text{ to } 8) \times 10^{14}$ W/cm^2 depending on the polar angle

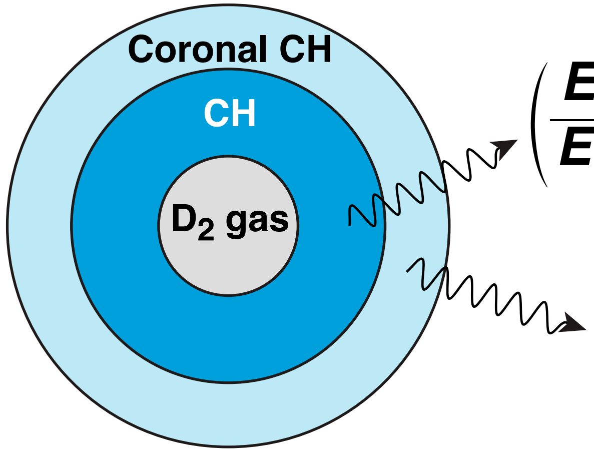
TC14559

*M. Hohenberger *et al*., Phys. Plasmas 22, 056308 (2015).

The energy deposited into a payload can be inferred by subtracting the all-CH HXR from the HXR of a Ge-doped layered target

$$\left(\frac{E_{\text{rad}}}{E_{\text{lost}}}\right)^{\text{payload}}_{\text{CH (4\% Ge)}} = 1.6 \times 10^{-3}$$





$$\left(\frac{E_{\text{rad}}}{E_{\text{lost}}}\right)_{\text{CH}} = 5 \times 10^{-4}$$

$$\left(\frac{E_{\text{rad}}}{E_{\text{lost}}}\right)_{\text{CH}} = 3.5 \times 10^{-4}$$

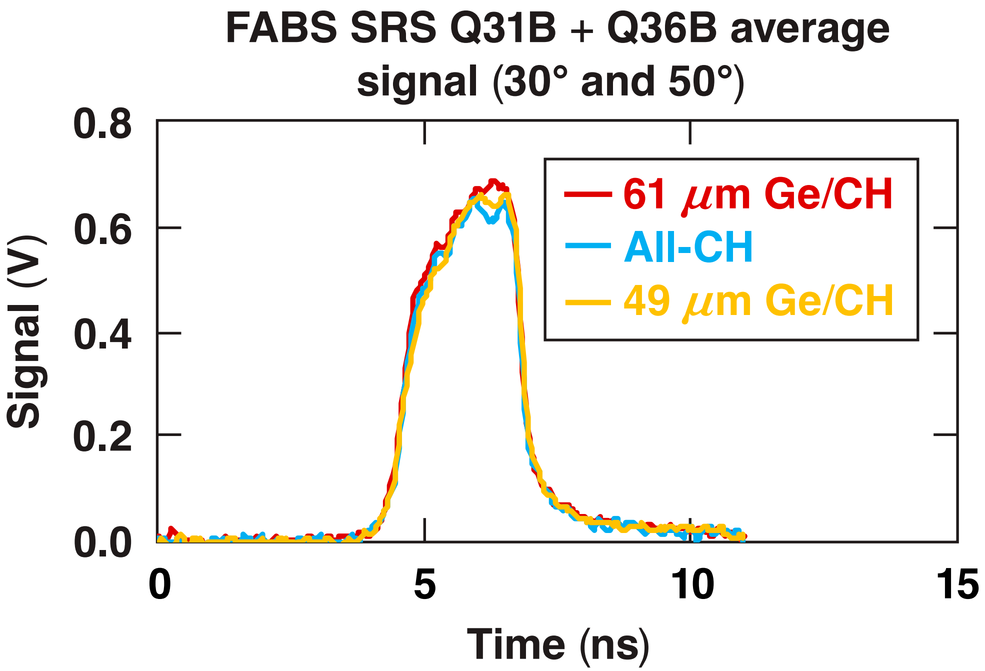
- $\frac{E_{\text{rad}}}{E_{\text{lost}}}$ is taken from theory; it is proportional to $\frac{\langle Z^2 \rangle}{\langle Z \rangle}$, depends on T_{hot}, and logarithmically on plasma density
- $E^{\text{layered}}_{\text{rad}}$ and $E^{\text{all-CH}}_{\text{rad}}$ are HXR measurements

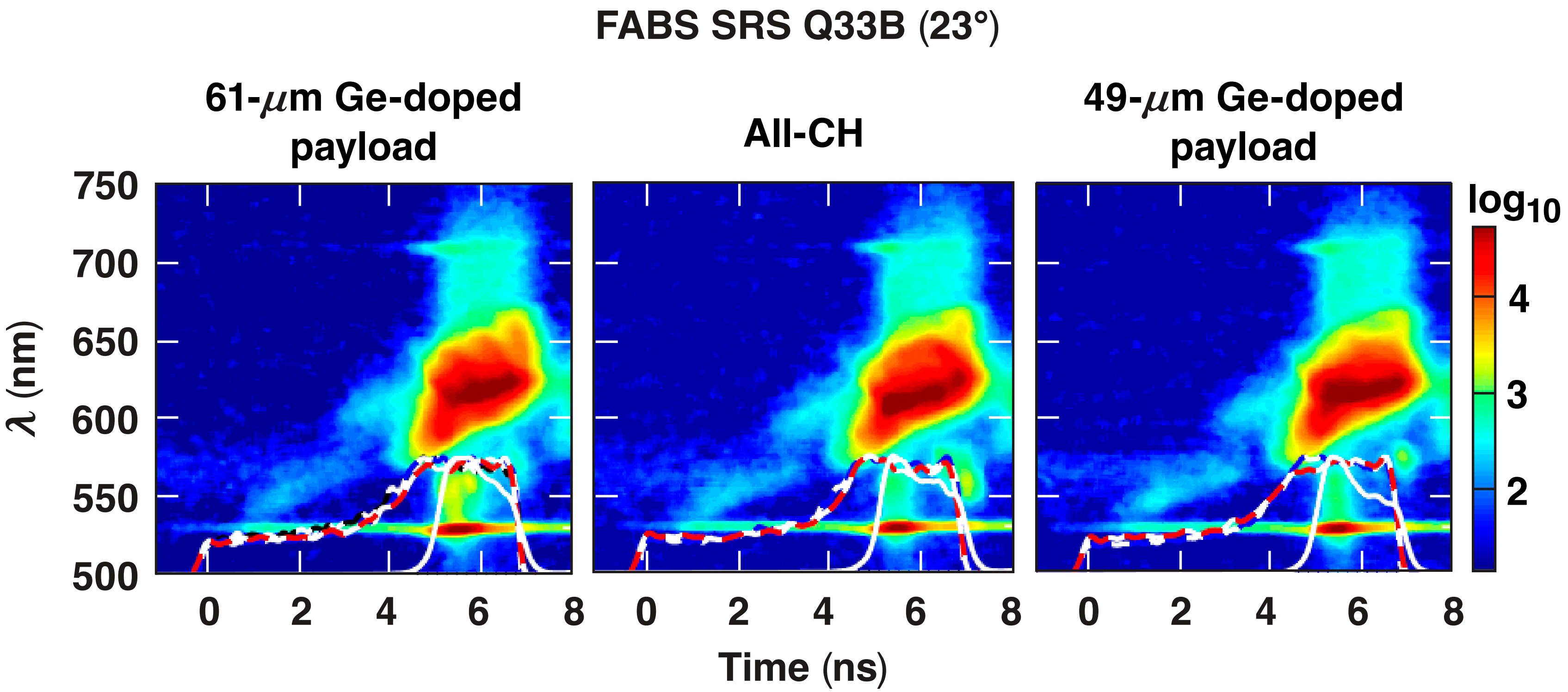
Preheat formula:* $E^{\text{payload}}_{\text{CH (4\% Ge)}} = \dfrac{E^{\text{layered}}_{\text{rad}} - E^{\text{all-CH}}_{\text{rad}}}{\left(\frac{E_{\text{rad}}}{E_{\text{lost}}}\right)^{\text{payload}}_{\text{CH (4\% Ge)}} - \left(\frac{E_{\text{rad}}}{E_{\text{lost}}}\right)_{\text{CH}}}$

*A. R. Christopherson and R. Betti, to be submitted to Physical Review Letters.

TC14313a

Time-resolved scattered-light spectra indicate that LPI is the same between the all-CH and Ge-doped payload implosions





Similar LPI → similar hot-electron source

FABS: full-aperture backscatter station
SRS: stimulated Raman scattering

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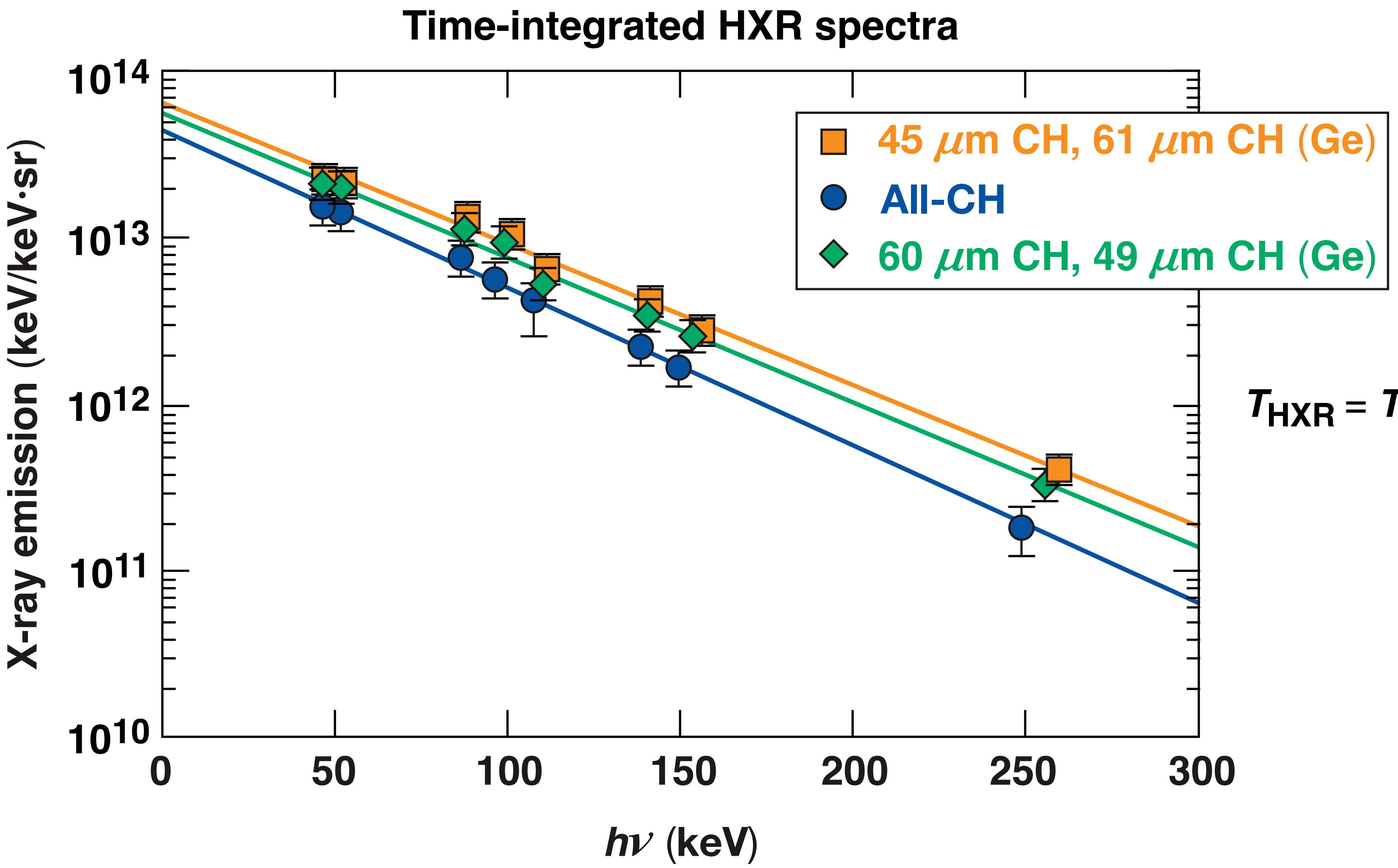
The hard x-ray measurement recorded with the FFLEX* diagnostic shows enhanced HXR emission with the Ge dopant



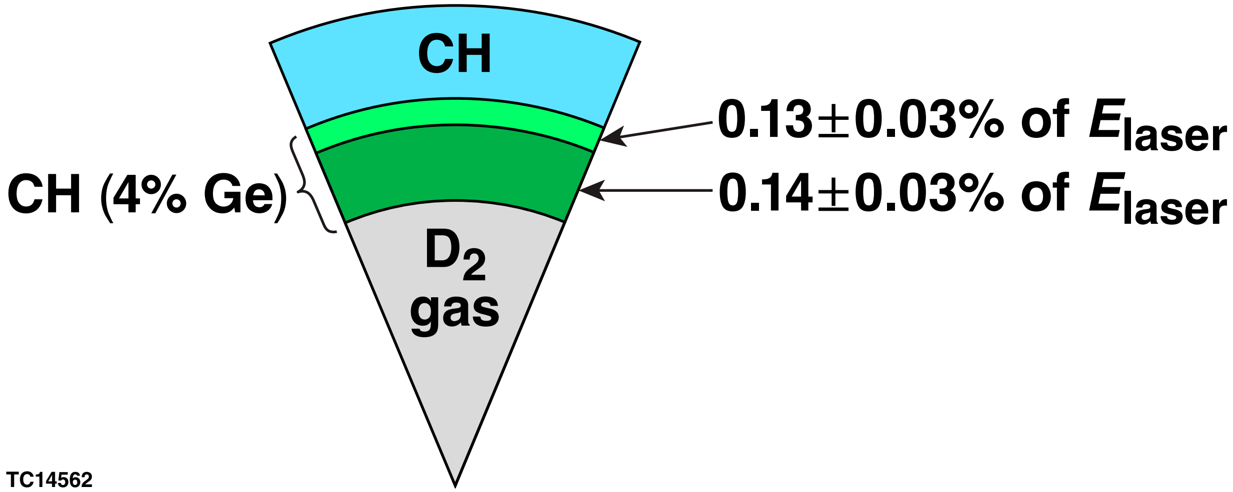
$T_{HXR} = T_{hot} \approx 50$ keV

*M. Hohenberger *et al.*, Rev. Sci. Instrum. 85, 11D501 (2014).
FFLEX: filter-fluorescer x-ray diagnostic

TC14561

Preliminary measurements indicate 0.27±0.06 % of laser energy is deposited in the unablated shell; 0.13±0.03 % is deposited in the outer 20% portion and 0.14±0.03 % is deposited in the inner 80% of the imploding shell

	N180903-001 [45 μm CH, 61 μm CH(Ge)]	N180904-001 [60 μm CH, 49 μm CH(Ge)]
Total hot-electron coupled energy (kJ)	9.2±1.9	8.9±1.9
Laser energy (%)	1.29±0.3	1.25±0.3
Energy into payload (kJ)	1.9±0.4	1±0.25
Laser energy (%)*	0.27±0.06	0.14±0.03



- About a quarter of total hot-electron energy is coupled to the unablated shell, indicating a wide angular divergence

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Summary/Conclusions

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