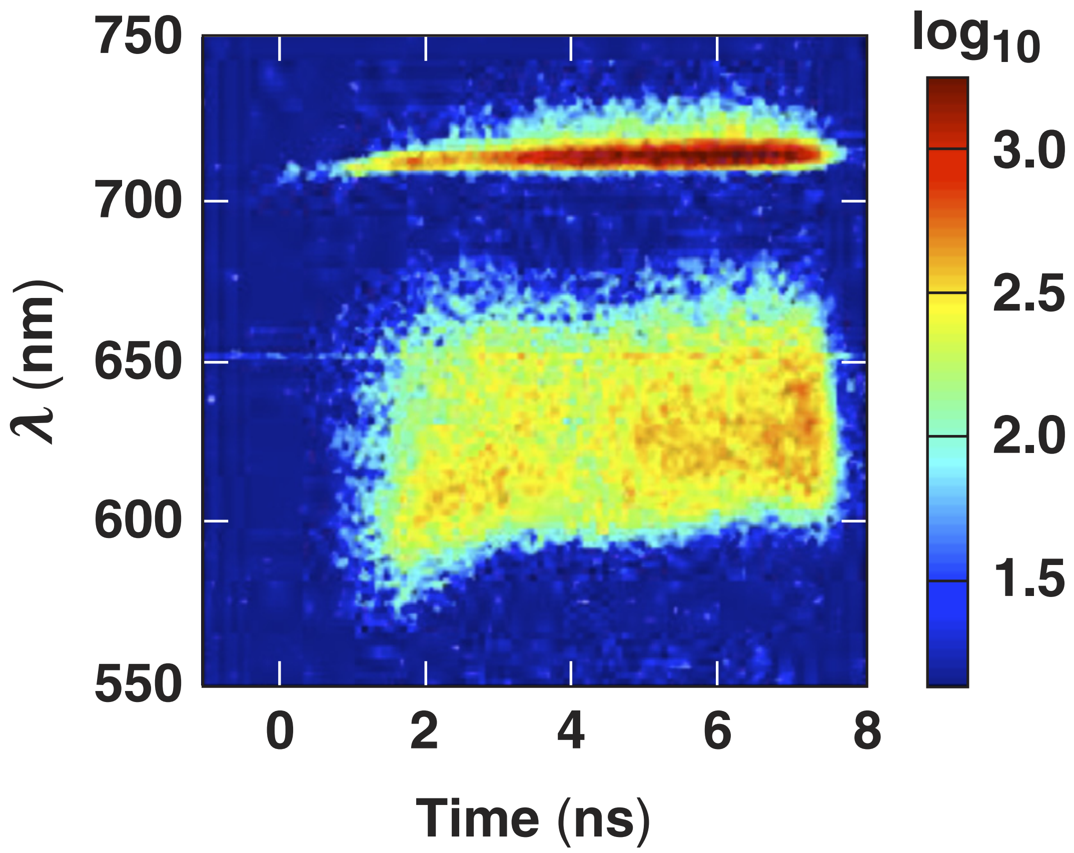
Laser–Plasma Interaction Experiments at Direct-Drive Ignition-Relevant Plasma Conditions at the National Ignition Facility

Shot N160420-003 optical spectrometer
(stimulated Raman scattering)



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Summary

Planar NIF* experiments demonstrate origins and scaling of hot-electron preheat at NIF coronal conditions

- NIF planar-target experiments achieve direct-drive (DD) ignition-relevant scale lengths (L_n ~ 400 to 700 μm) and electron temperatures (T_e ~ 4 to 5 keV)
- Stimulated Raman scattering (SRS) is found to be the dominant laser–plasma interaction (LPI) instability at these conditions
- Hot-electron preheat is tolerable in DD ignition designs with CH ablators if $I_{n_c/4} < 4.5 \times 10^{14}$ W/cm^2
- The use of Si ablators increases the allowable intensities to $I_{n_c/4} < 6.5 \times 10^{14}$ W/cm^2

*NIF: National Ignition Facility

TC13890

Collaborators

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Hot-electron preheat can degrade fuel compression in DD ignition designs

- The ignition target performance is negatively affected if more than ~0.15% of the laser energy is coupled into the cold fuel in the form of hot electrons*
- If electron divergence is large, only ~25% of the hot electrons will intersect the cold fuel and result in preheat**
- Electrons with energy below ~50 keV will be stopped in the ablator and will not preheat the compressed fuel

Hot-electron preheat mitigation is needed if more than ~0.7% of the laser energy is converted to hot electrons at T_{hot} ~ 50 to 60 keV.

*J. A. Delettrez, T. J. B. Collins, and C. Ye, Bull. Am. Phys. Soc. 59, 150 (2014).
**B. Yaakobi *et al.*, Phys. Plasmas 20, 092706 (2013).
Hot-electron divergence on the NIF will be investigated.

Planar NIF experiments explore LPI instabilities and hot-electron production in DD ignition-relevant plasma conditions

Coronal conditions predicted by *DRACO* radiation–hydrodynamic simulations

Parameters at $n_c/4$ surface	Ignition NIF DD*	Planar NIF
I_L (W/cm^2)	6 to 8×10^{14}	5 to 15×10^{14}
L_n (μm)	600	500 to 700
T_e (keV)	3.5 to 5	3 to 5

- Incident laser intensity is ~2× intensity at $n_c/4$ at ignition-relevant L_n and T_e

*V. N. Goncharov *et al.*, Bull. Am. Phys. Soc. 61, BAPS.2016.DPP.TO5.3 (2016).

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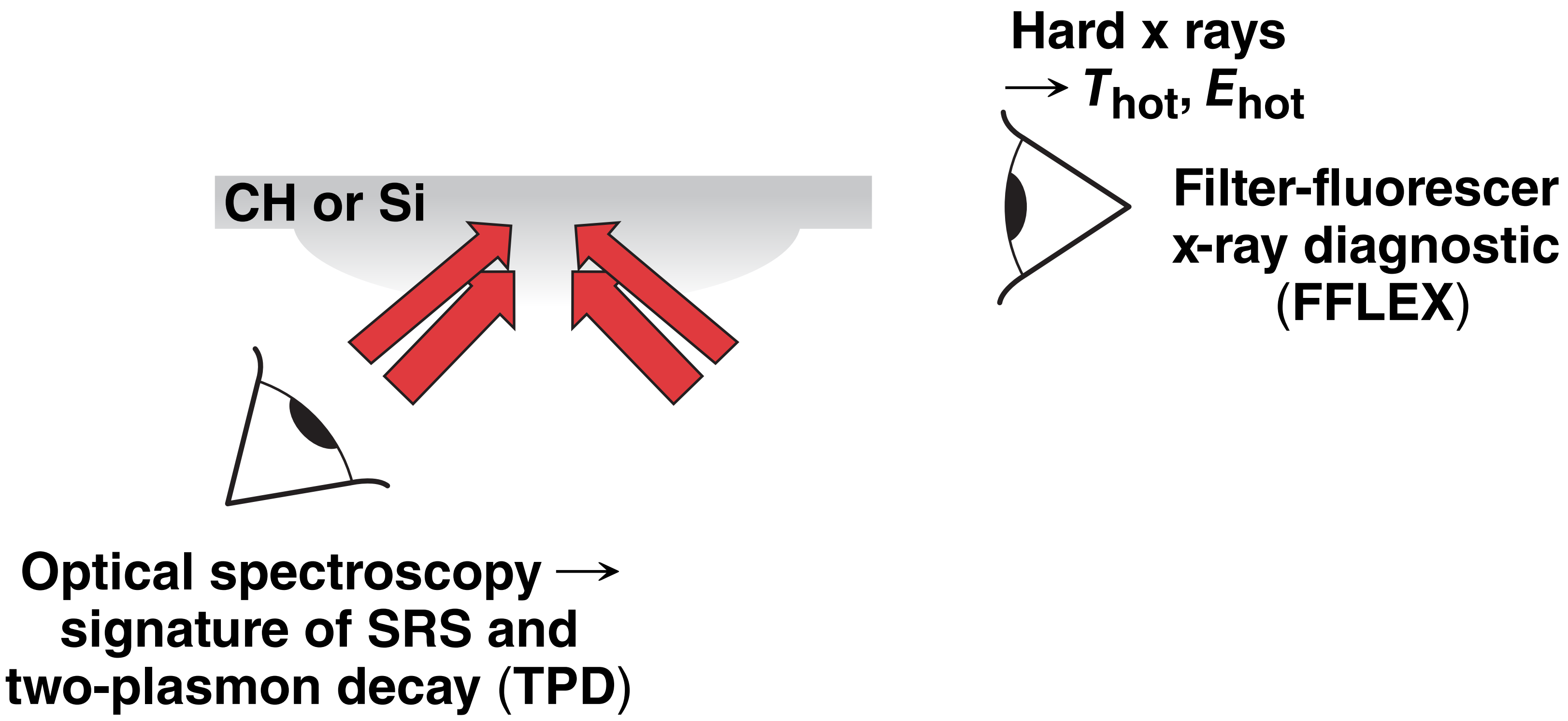
Hot-electron production in CH targets and mitigation by the use of Si ablator was explored



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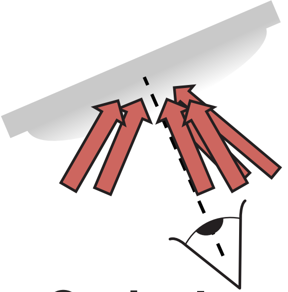
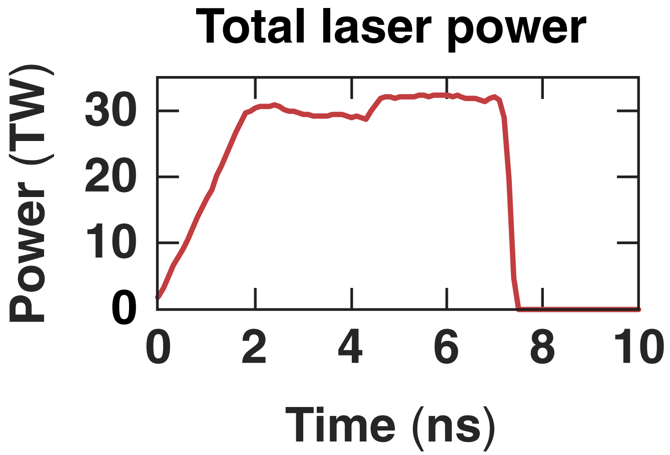
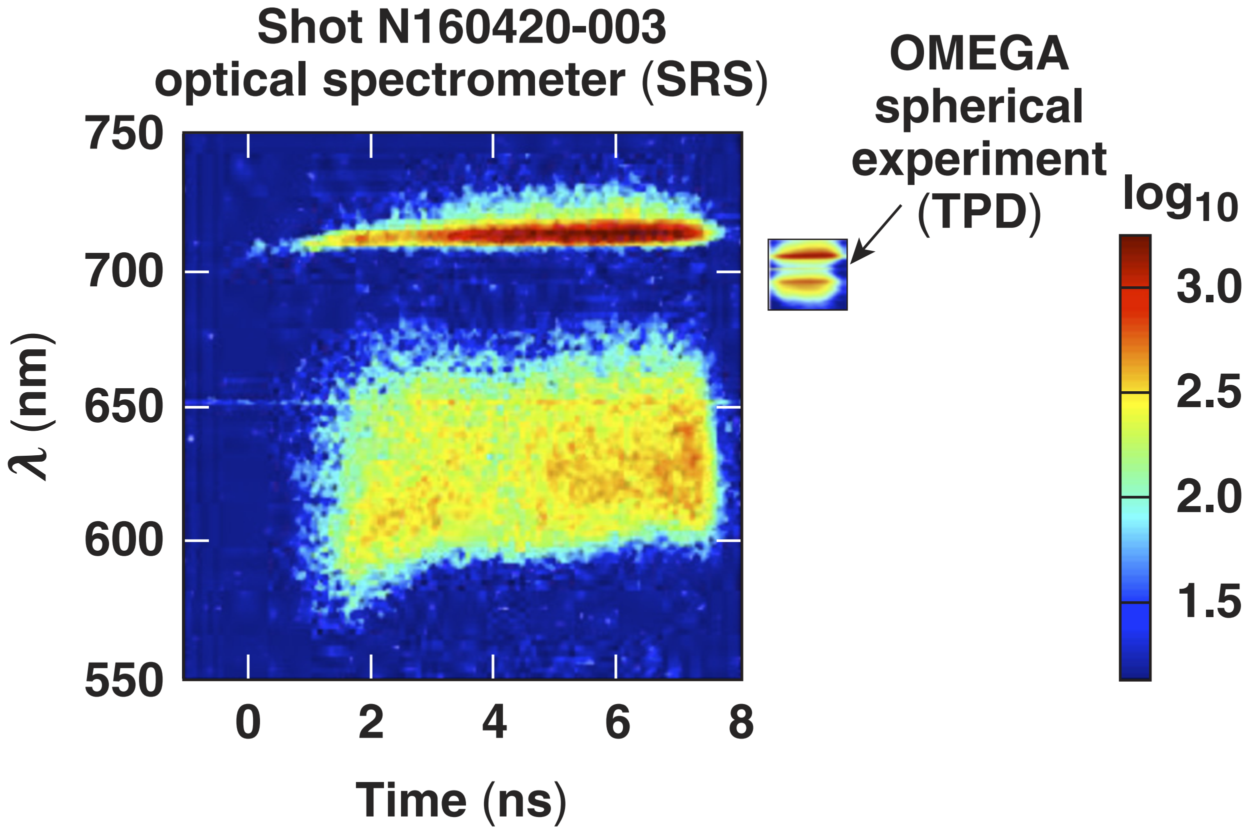
Optical spectra demonstrate different LPI physics on the NIF than on OMEGA, including the dominance of SRS*

NIF: L_n = 525 μm T_e = 4.5 keV	OMEGA:** L_n = 150 μm T_e = 2.8 keV



Optical streaked spectrometer
(near-backscatter imaging Q33B)





- The presence of TPD on the NIF is further assessed by probing $3\omega/2$ emission

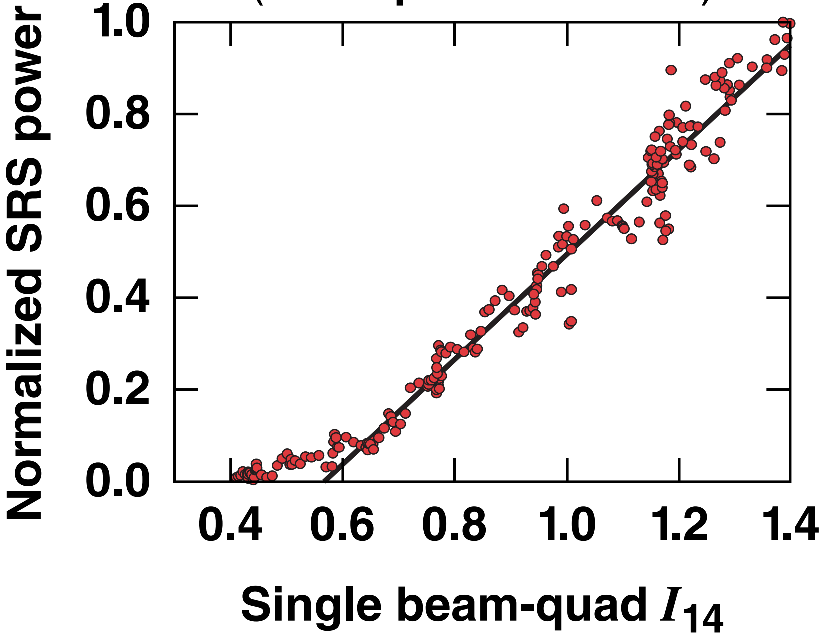
*M. J. Rosenberg *et al*,, "Origins and Scaling of Hot-Electron Preheat in Ignition-Scale Direct-Drive Inertial Confinement Fusion Experiments," submitted to Physical Review Letters.
**W. Seka *et al.*, Phys. Plasmas 16, 052701 (2009).

E25567g

Absolute SRS (>702 nm) scales linearly with incident laser power while sub-$n_c/4$ SRS scales exponentially

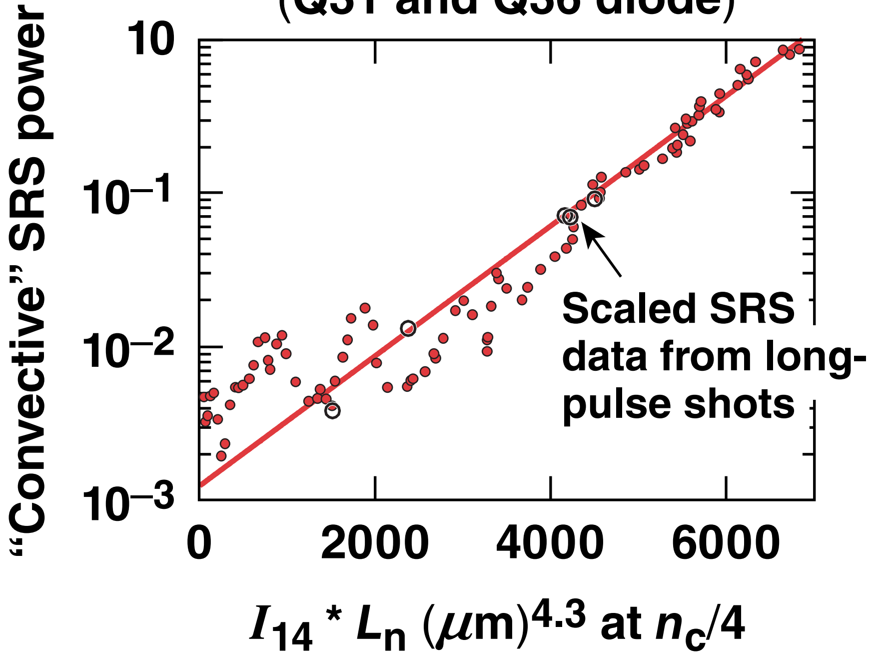
Data taken with linear ramp laser pulse, shot N161010-004

SRS λ > 702 nm
(Q33 spectral streak)



Saturated absolute instability

SRS λ < 700 nm
(Q31 and Q36 diode)



Unsaturated convective instability

- Absolute SRS accounts for ~30% of total SRS light
- Total SRS appears to reach ~5% of incident (~10% of light reaching interaction region)

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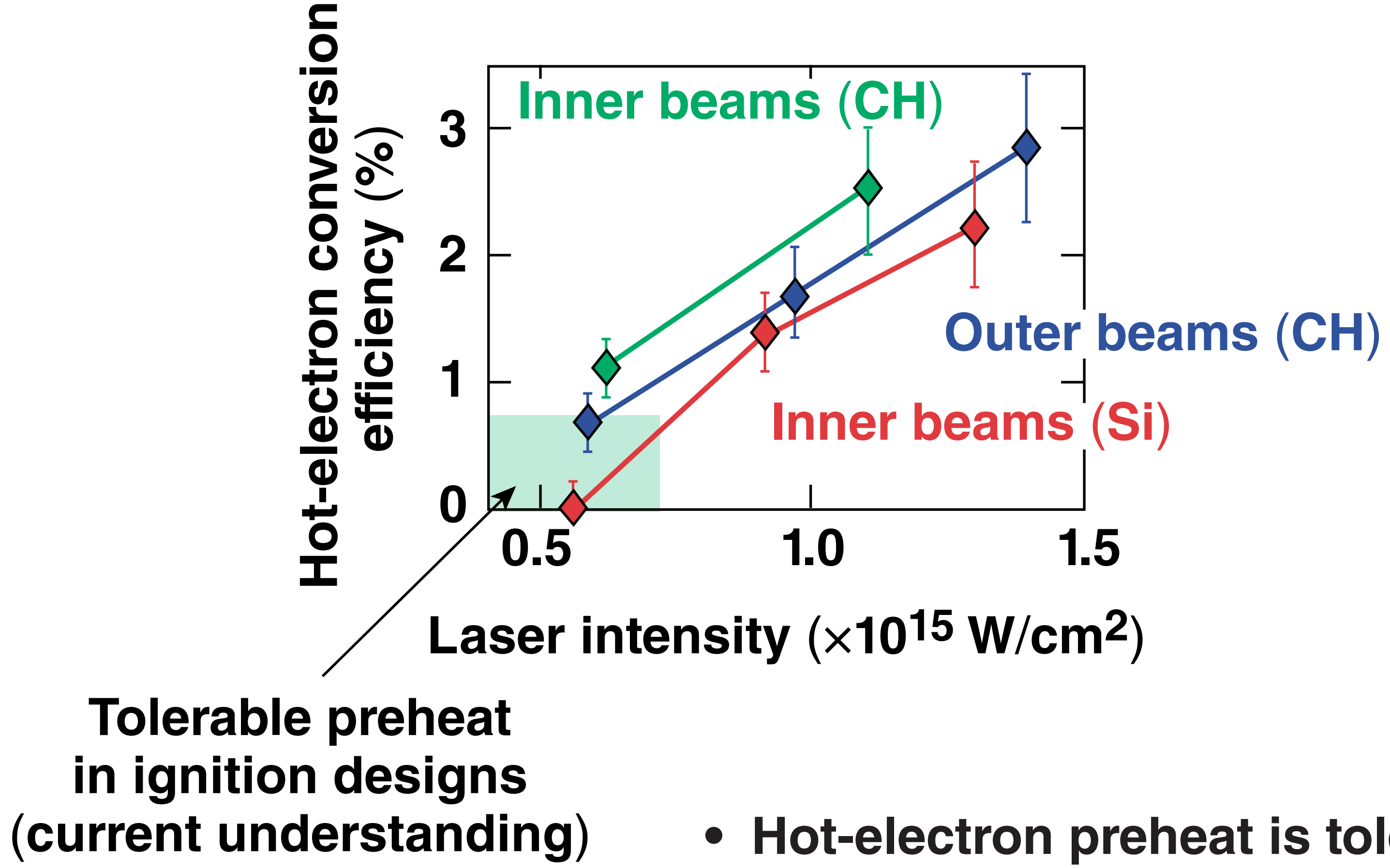
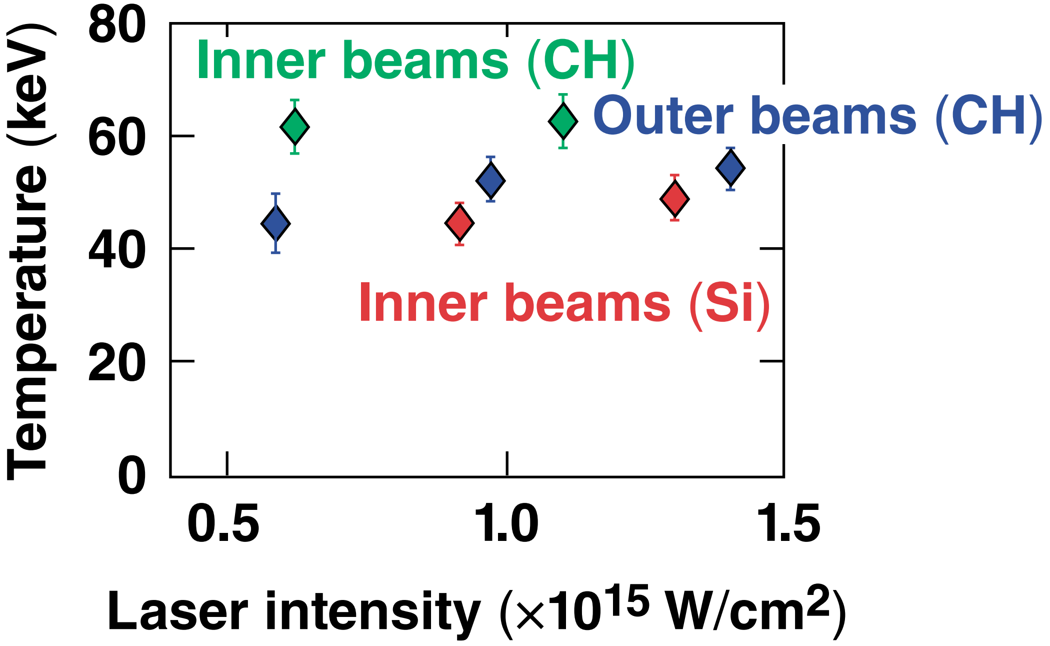
The experiments determine the laser-intensity limit for DD ignition designs

Hot-electron conversion efficiency and temperature (4.5 to 7.5 ns) versus laser intensity at $n_c/4$





- Hot-electron preheat is tolerable in DD ignition designs with CH ablators if $I_{n_c/4} < 4.5 \times 10^{14}$ W/cm^2; with Si ablators if $I_{n_c/4} < 6.5 \times 10^{14}$ W/cm^2

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Summary/Conclusions

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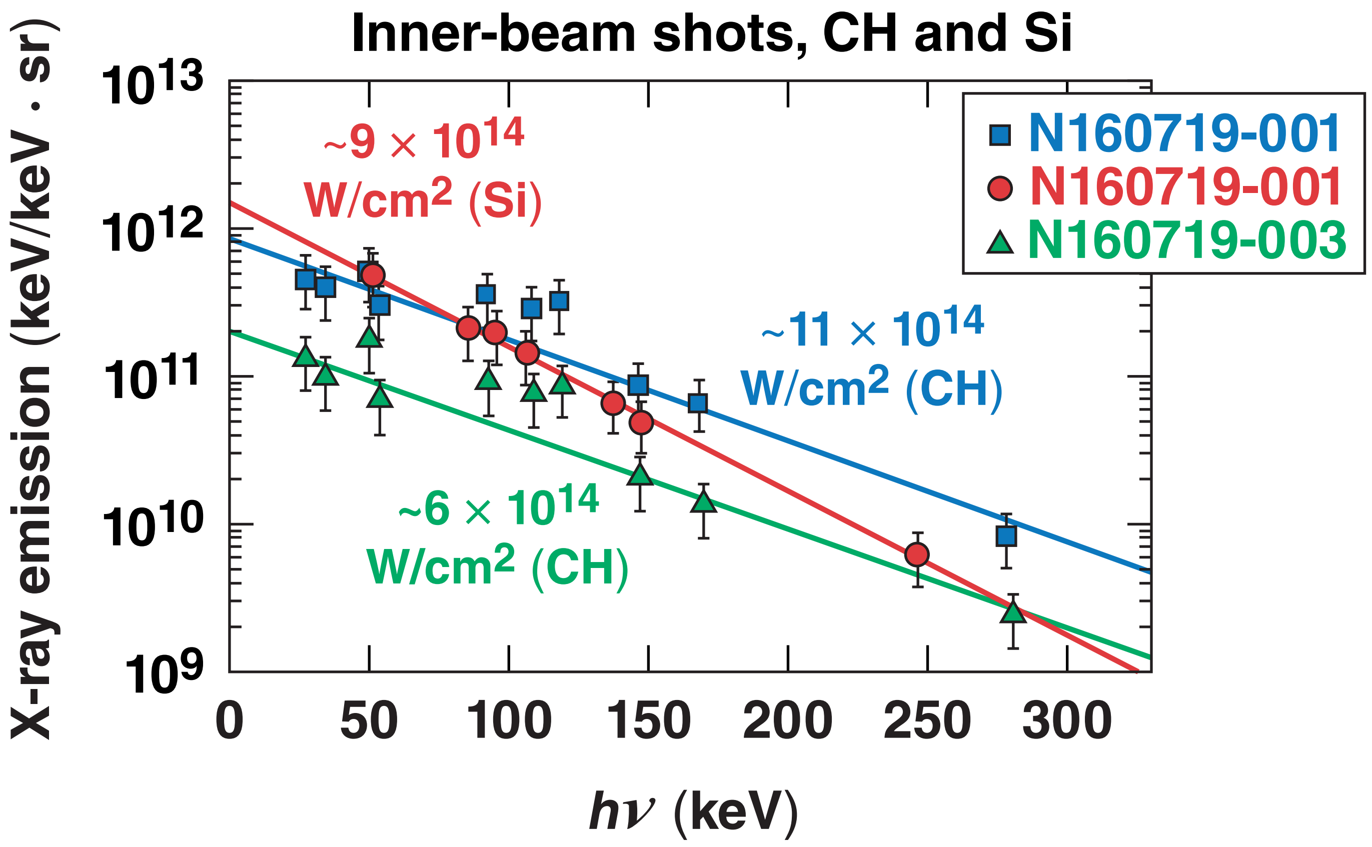
*NIF: National Ignition Facility

Hot-electron properties were inferred using the measured hard x-ray spectra

Time-integrated hard x-ray spectra obtained using FFLEX*



- Monte Carlo *EGSnrc*** simulations were used to relate the energy of hard x rays and hot electrons

*M. Hohenberger *et al.*, Rev. Sci. Instrum. 85, 11D501 (2014).
**I. Kawrakow *et al.*, National Research Council Canada, Ottawa, Canada, NRCC Report PIRS-701 (May 2011).

TC13429a