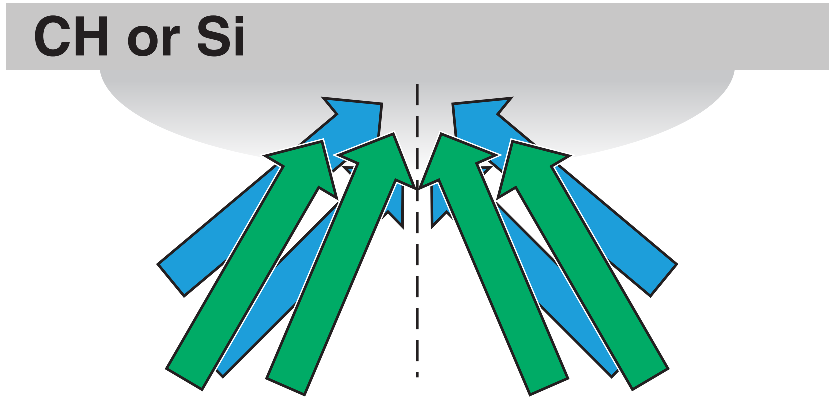
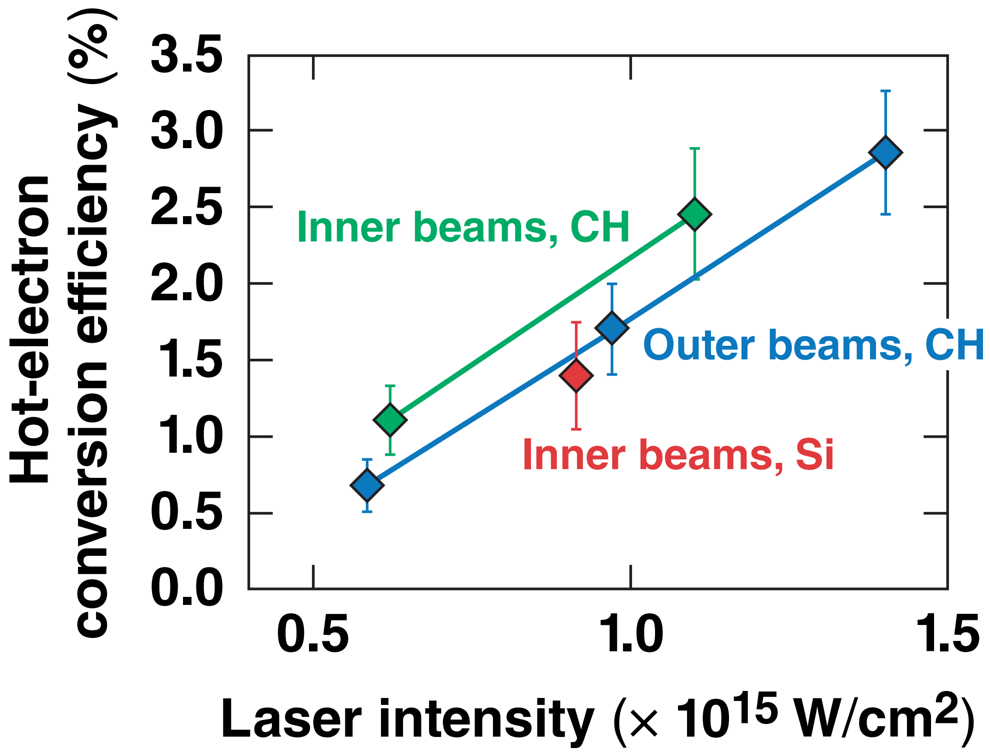
Hot-Electron Generation at Direct-Drive Ignition-Relevant Plasma Conditions at the National Ignition Facility



23° and 30° beams or
45° and 50° beams



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Summary

A laser-energy conversion efficiency of ~1% to 3% into hot electrons with T_e ~ 45 to 60 keV was inferred

- Planar-target experiments at the National Ignition Facility (NIF) reproduce direct-drive (DD) ignition-relevant plasma conditions
- The properties of hot electrons were inferred using the measured hard x-ray spectra and Monte Carlo simulations
- The beam angle of incidence did not have a strong effect on the hot-electron production
- Hot-electron levels suggest a need for preheat mitigation; the use of Si ablators for preheat mitigation was investigated

TC13048

Collaborators

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Planar NIF experiments explore laser–plasma interaction (LPI) instabilities and hot-electron production in DD ignition-relevant plasma conditions

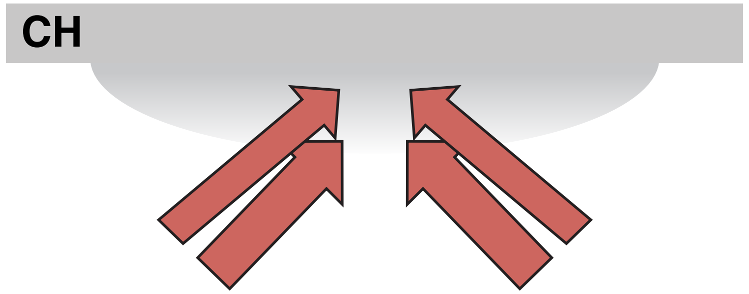
Coronal conditions predicted by *DRACO* radiation–hydrodynamic simulations

Parameters at $n_c/4$ surface	OMEGA*	Current NIF DD**	Ignition NIF DD***	Planar NIF
I_L (W/cm^2)	<4 × 10^{14}	4.5 × 10^{14}	6 to 8 × 10^{14}	5 to 15 × 10^{14}
L_n (μm)	<350	350	600	500 to 700
T_e (keV)	<2.5	3.5	3.5 to 5	3 to 5

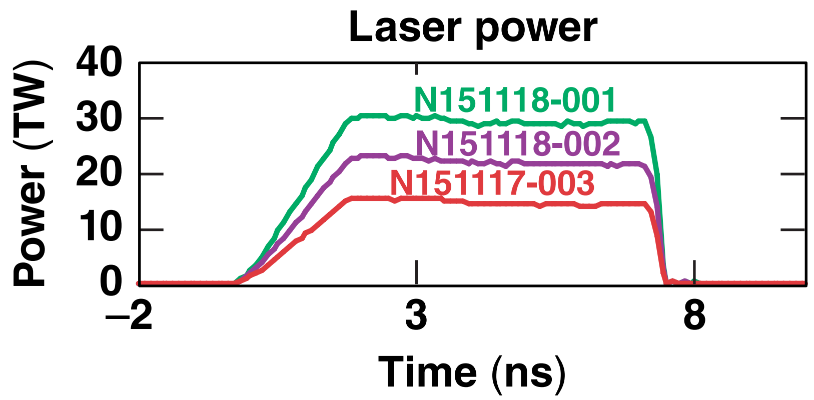
*S. X. Hu *et al*., Phys. Plasmas 20, 032704 (2013).
**M. Hohenberger *et al*., Phys. Plasmas 22, 056308 (2015).
*** V. N. Goncharov *et al*., TO5.00003, this conference.

TC12382c

The scaling of hot-electron properties with laser intensity in CH targets was studied using large-angle beams



45° and 50° beams
(64 beams total)



DRACO-simulated coronal conditions at $n_c/4$

	N151117-003	N151118-002	N151118-001
I (W/cm^2)	6×10^{14}	10.5×10^{14}	15×10^{14}
L_n (μm)	480	490	500
T_e (keV)	3.0	3.9	4.8

$\eta_{SRS} = I_{14} L_{n,\mu m}^{4/3} / 2377 \sim 10$ to 25

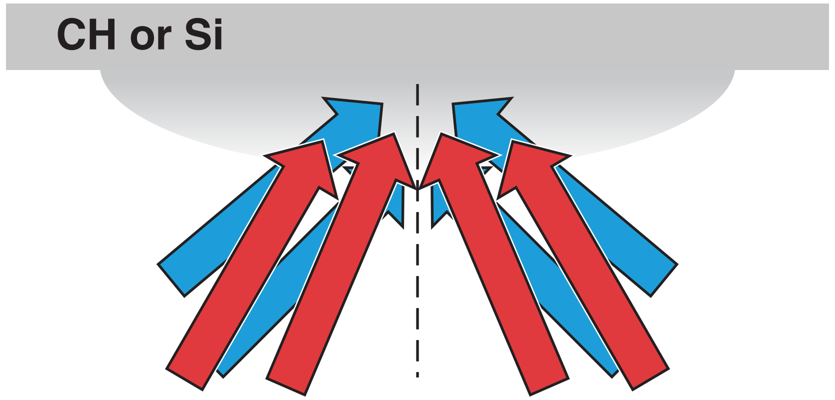
$\eta_{TPD} = I_{14} L_{n,\mu m} / (230\ T_{e,keV}) \sim 4$ to 7

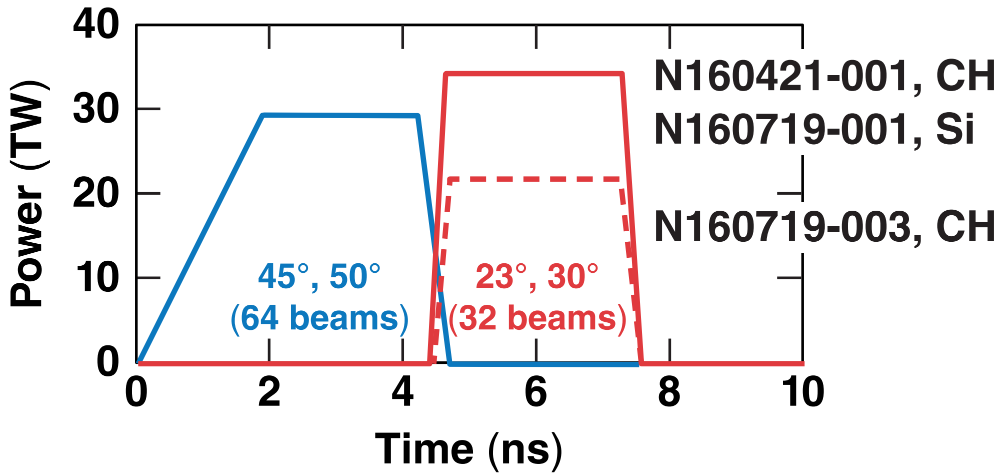
The stimulated Raman scattering (SRS) and two-plasmon decay (TPD) absolute-instability thresholds*, are exceeded in this experimental design.**

*C. S. Liu, M. N. Rosenbluth, and R. B. White, Phys. Fluids 17, 1211 (1974).
**A. Simon *et al.*, Phys. Fluids 26, 3107 (1983).

TC13049

Hot-electron production in CH and Si targets was studied using small-angle beams





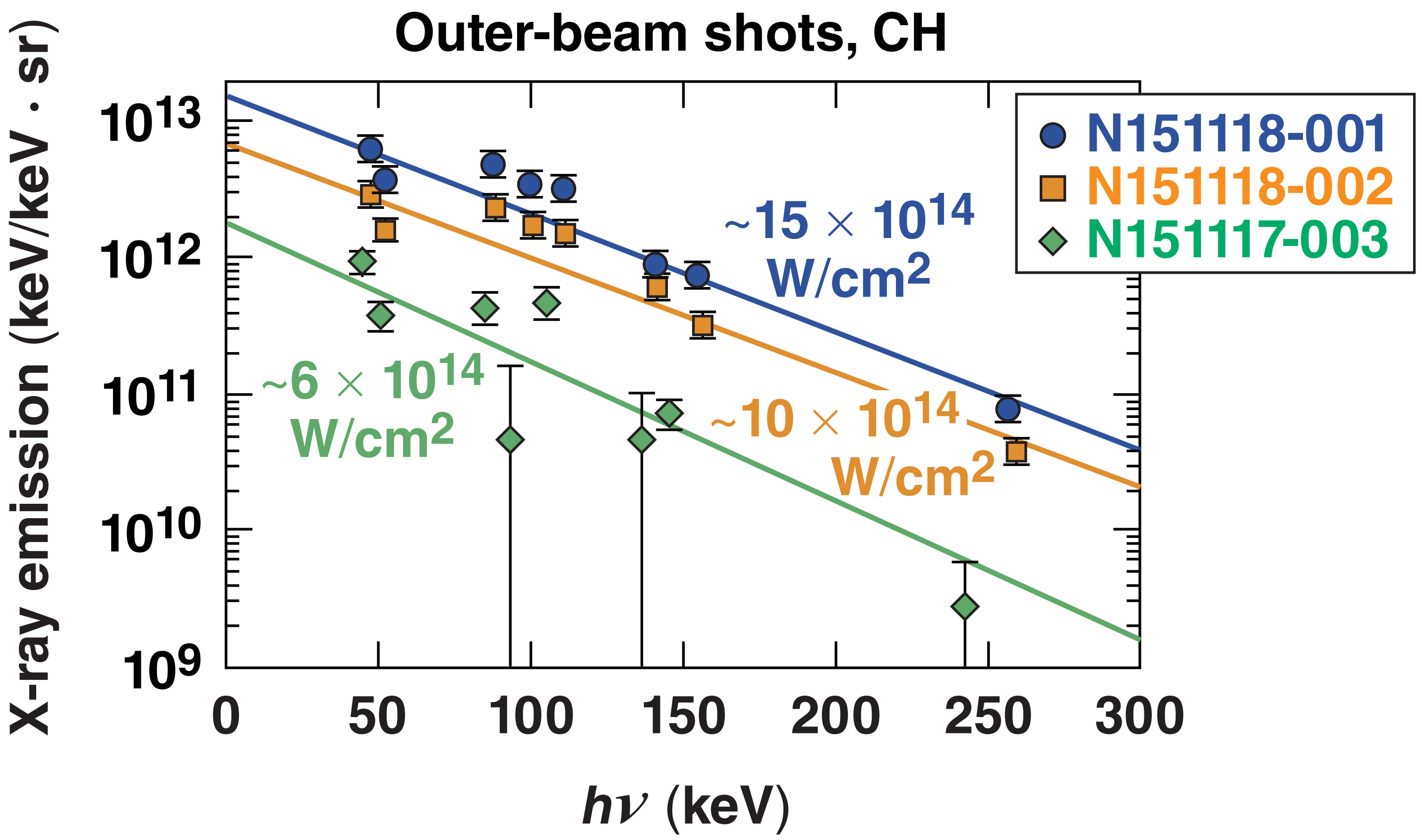
DRACO-simulated coronal conditions at $n_c/4$ (4.5 to 7.5 ns)

	N160719-003, CH	N160421-001, CH	N160719-001, Si
I (W/cm^2)	6×10^{14}	11×10^{14}	9×10^{14}
L_n (μm)	670	690	560
T_e (keV)	3.6	4.4	5.2

TC13050

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

- Time-integrated hard x-ray spectra obtained using the filter-fluorescer x-ray diagnostic (FFLEX)*



- Hot-electron energy was inferred from comparing the x-ray spectra and *EGSnrc*** Monte Carlo simulations

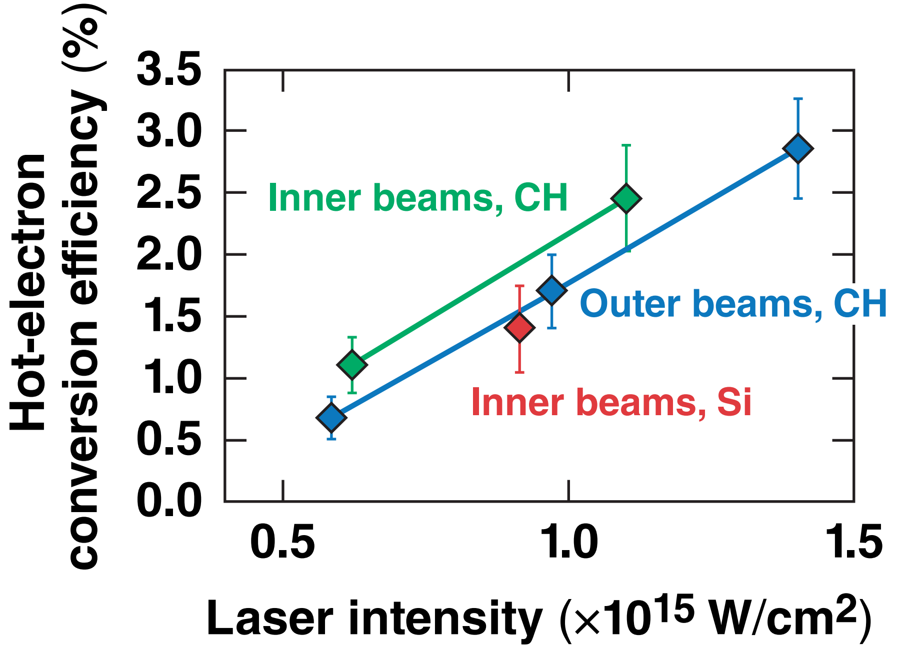
*M. Hohenberger *et al.*, Rev. Sci. Instrum. 85, 11D501 (2014).

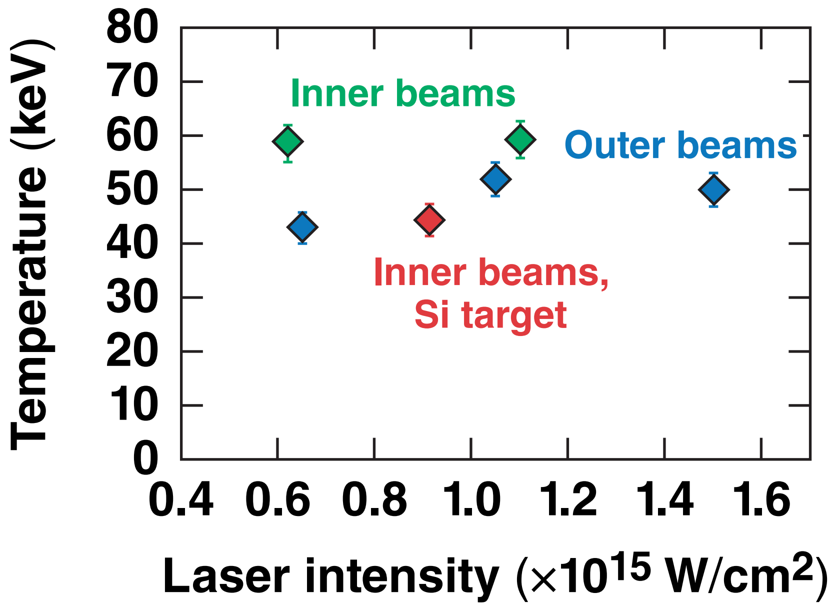
**I. Kawrakow *et al.*, National Research Council Canada, Ottawa, Canada, NRCC Report PIRS-701 (May 2011).

TC13051

The inferred laser energy to hot-electron conversion efficiency increases from ~1% to 3% with the laser intensity

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





- The use of a Si ablator reduces the energy of hot electrons above ~50 keV (relevant to preheat) by ~35%, compared to the relevant CH shots
- Hot-electron production is attributed to SRS, which dominates LPI in these experiments*

*W. Seka *et al.*, UO9.00003; P. Michel *et al.*, UO9.00004, this conference.

TC13053

Hot-electron levels suggest a need for mitigation

- 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_e ~50 to 60 keV
  - ignition designs with $I > 5 \times 10^{14}$ W/cm^2 at $n_c/4$ need preheat mitigation
  - the use of Si ablators for preheat mitigation is investigated

* 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 will be investigated in Mo-ball experiments on the NIF.

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