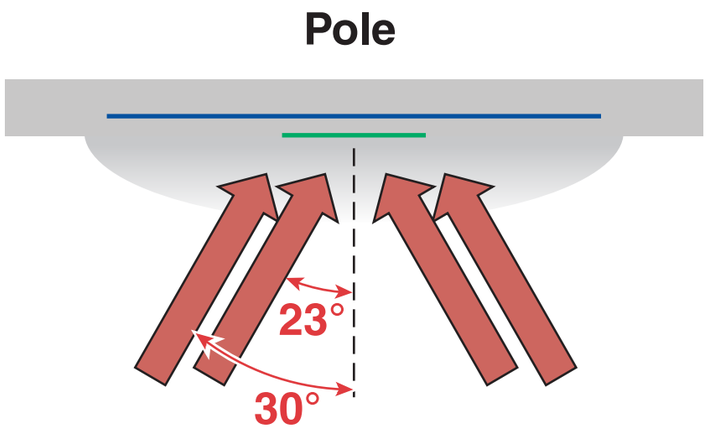
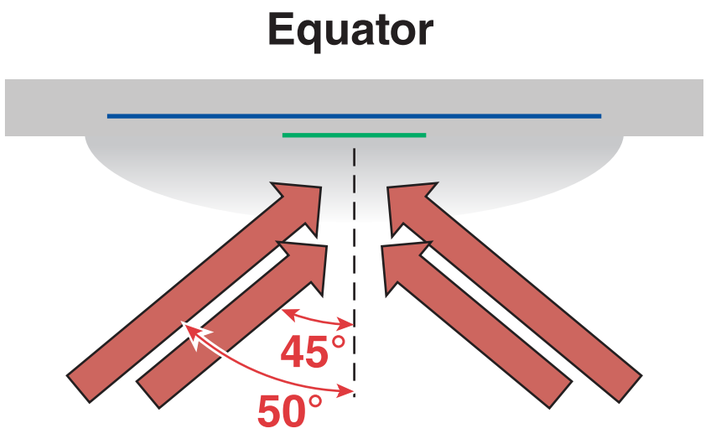
Planar Two-Plasmon–Decay Experiments at Polar-Direct-Drive Ignition-Relevant Scale Lengths at the National Ignition Facility





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Division of Plasma Physics
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Summary

A planar platform has been developed at the National Ignition Facility (NIF) to study two-plasmon–decay (TPD) hot-electron production at direct-drive ignition-relevant coronal conditions

UR LLE

- Planar-geometry experiments were performed on the NIF with predicted scale lengths of ~0.5 mm and T_e > 3 keV
- Experimental evidence of TPD ($\omega/2$ emission and T_{hot} ~ 40 keV) was observed with ~1% of laser energy converted to hot electrons
- The beam angle of incidence did not have a strong effect on the f_{hot}, T_{hot}

E24120a

Collaborators

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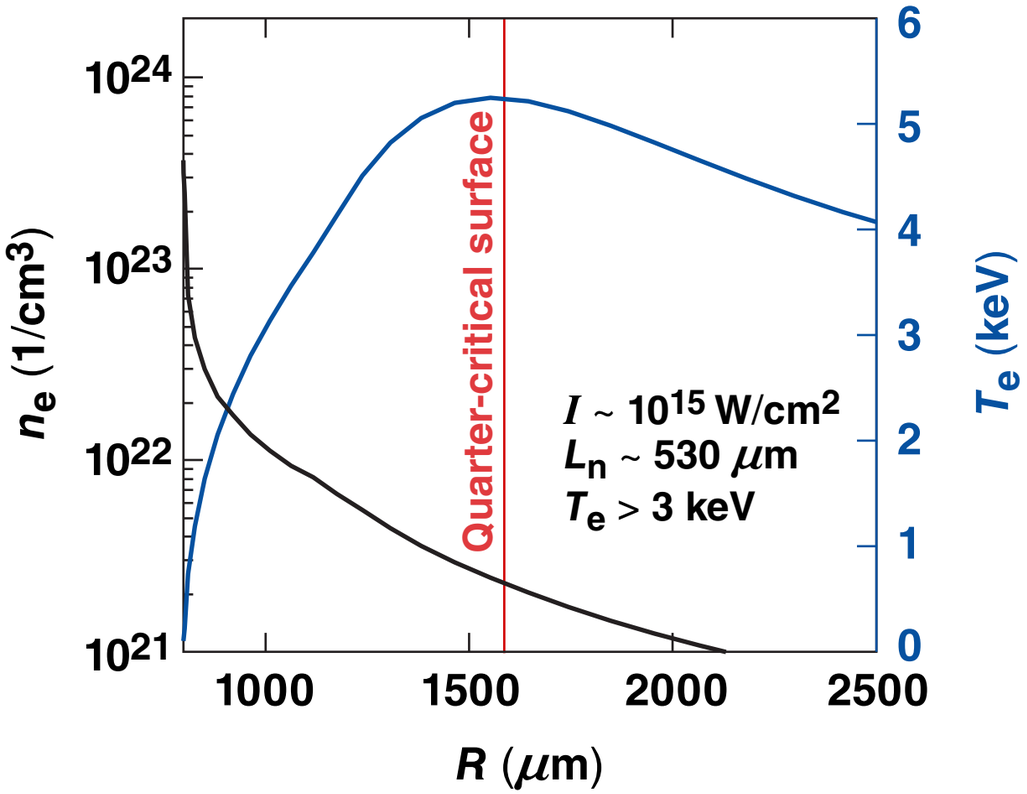
Motivation

Direct-drive–ignition designs predict long density scale lengths and high electron temperatures under which TPD may occur

UR LLE

Two-dimensional simulated plasma conditions for an igniting polar-direct-drive (PDD) design

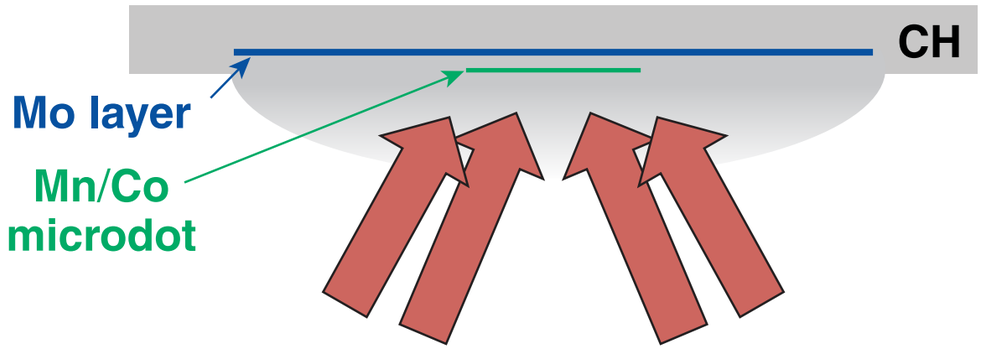


Currently, these coronal plasma conditions can be created only in NIF planar experiments.

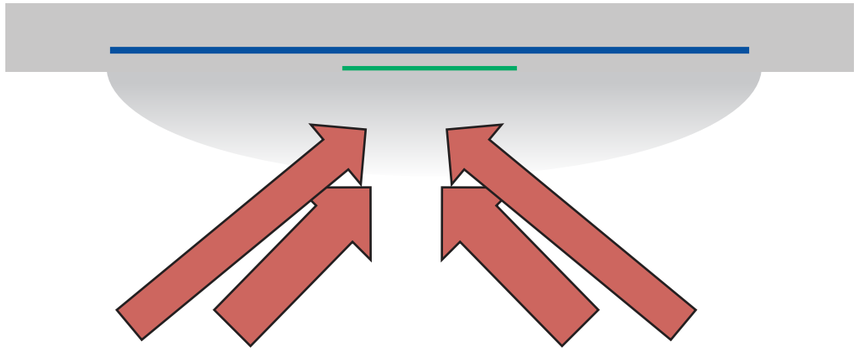
E24131a

Two planar experiments were performed on the NIF to study the beam angle-of-incidence dependence of TPD

Pole
Shot N150520: 23° and 30° beams
(32 beams total)



Equator
Shot N150521: 45° and 50° beams
(60 beams total)



Primary diagnostics

- $\omega/2 \rightarrow$ signature of TPD
- Hard x ray $\rightarrow T_{hot}, E_{hot}$
- Mo K_α fluorescence $\rightarrow E_{hot}$

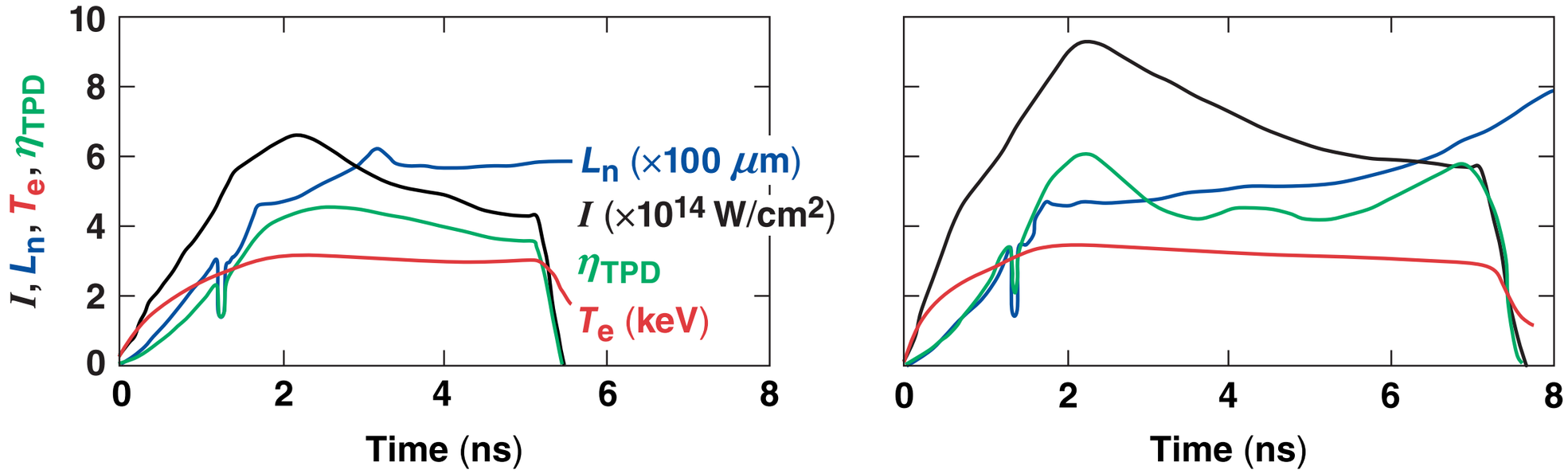
E24713

Long-scale-length (>500-μm), high-temperature (>3-keV) coronal plasma conditions are predicted

Shot N150520: 23° and 30° beams

Shot N150521: 45° and 50° beams

Post-shot *DRACO*-simulated conditions at $n_c/4$

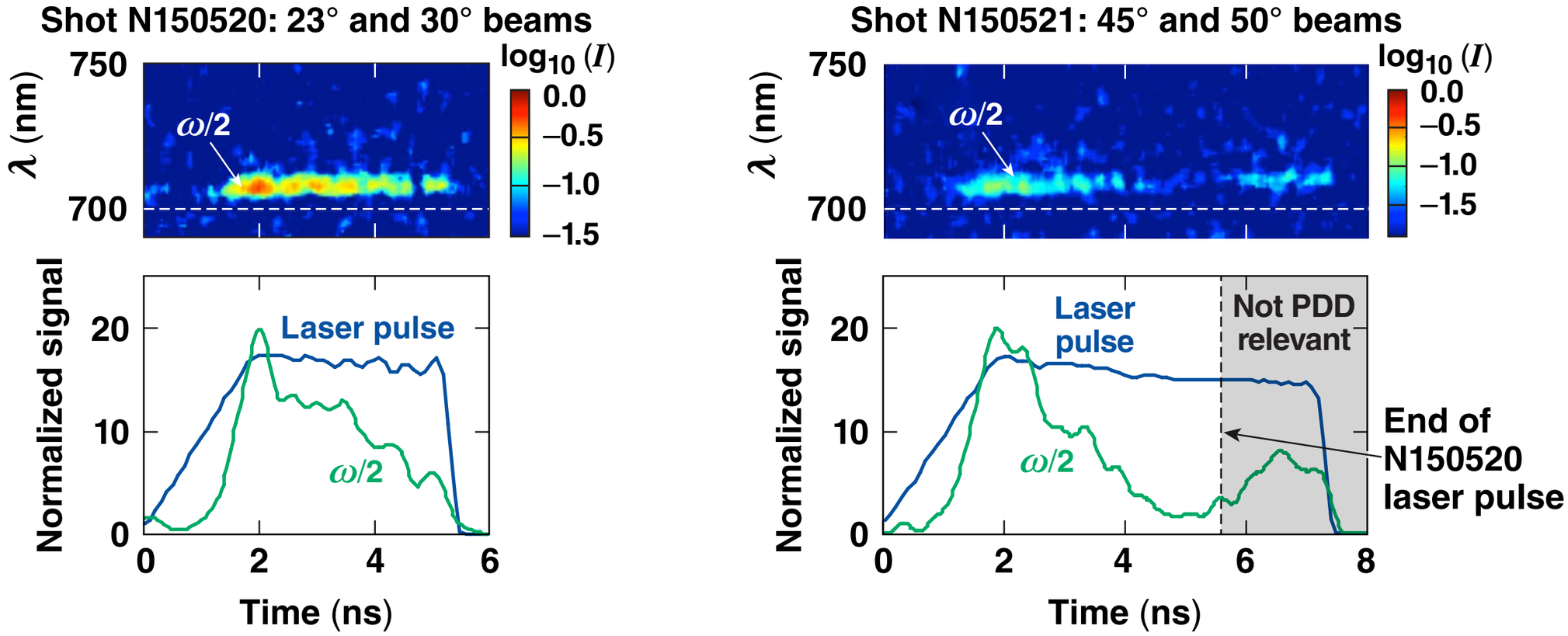


The empirical TPD threshold [$\eta = I_{14}\, L_{n,\mu m}/(230\, T_{e,keV})$] is exceeded by a factor of 4 in this experimental design.

E24714

$\omega/2$ emission indicates TPD is driven

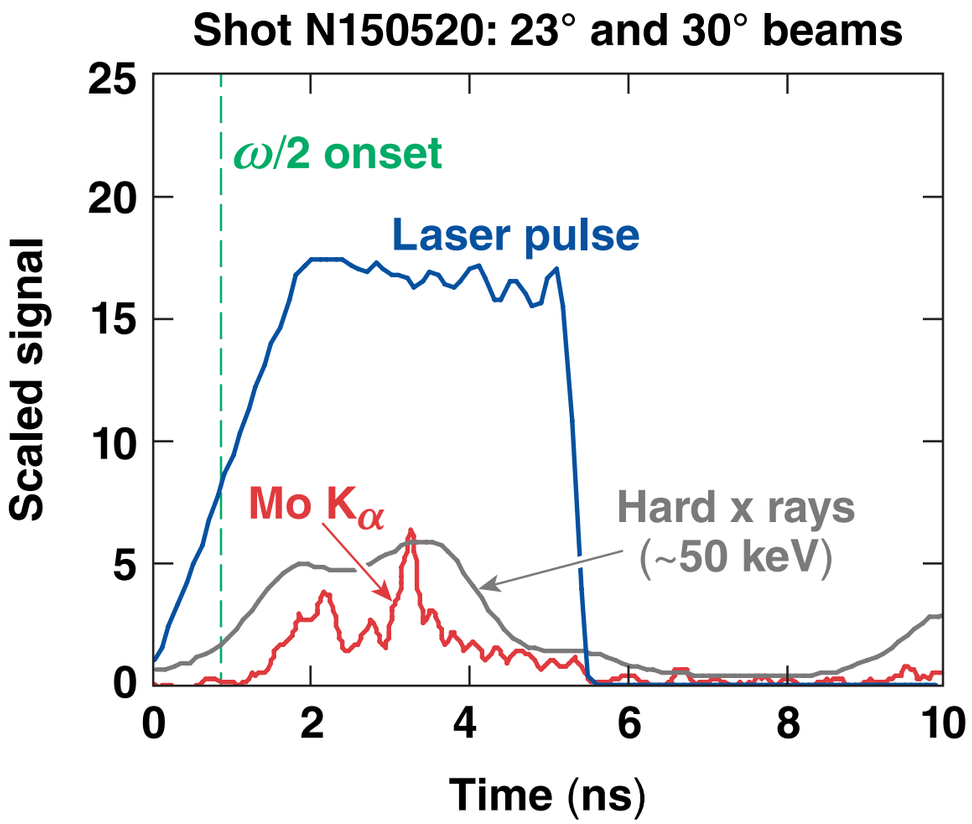
Optical spectrometer at 23°

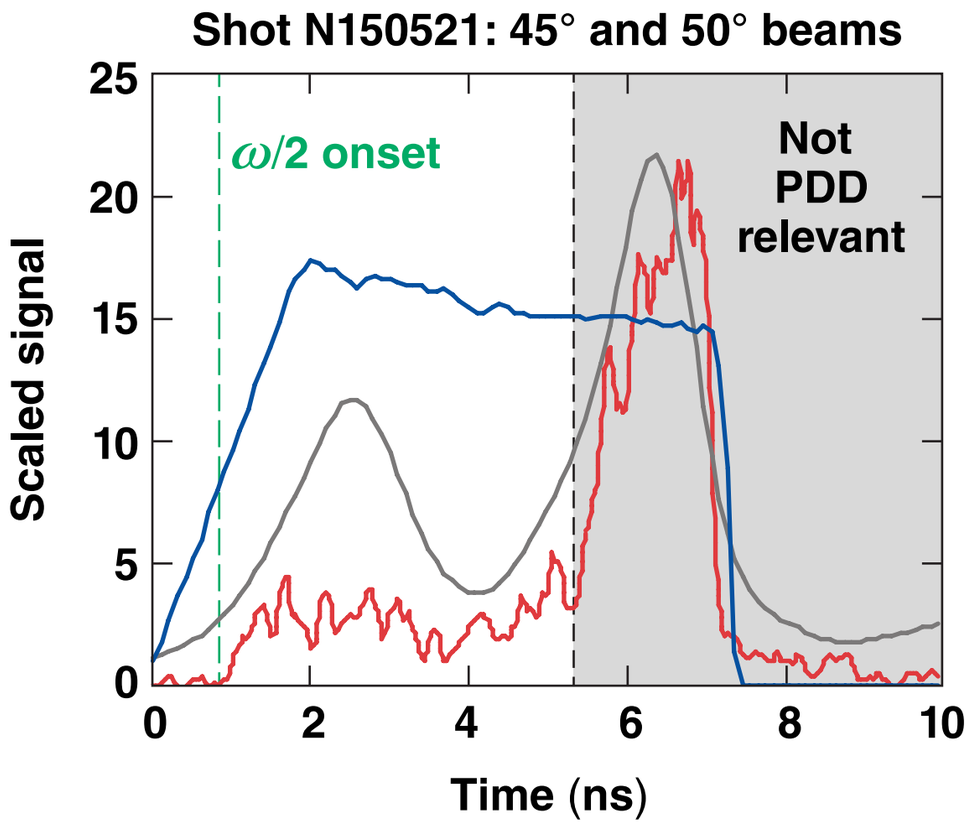


The $\omega/2$ signal is weak because the viewing angle is far from optimal.

E24127

Hard x-ray and Mo K_α emission caused by TPD-generated hot electrons were observed

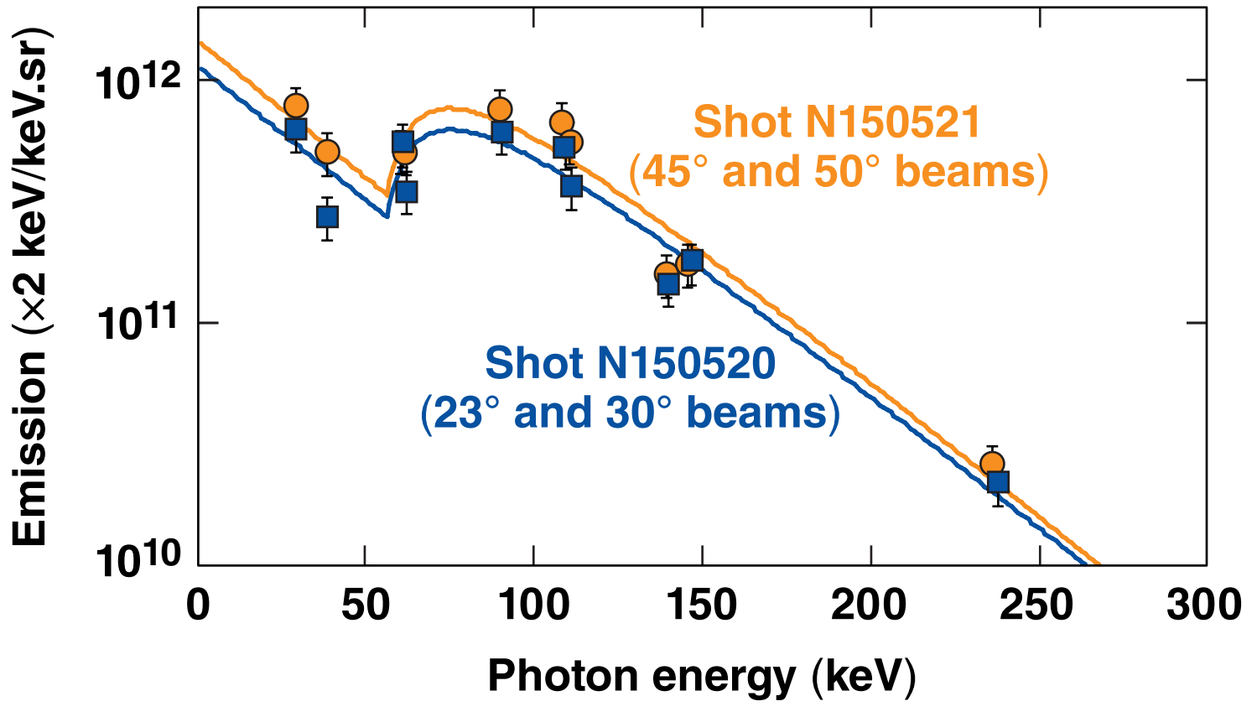




E24128c

Time-integrated hard x-ray spectra indicate T_{hot} = 40±5 keV for both experiments

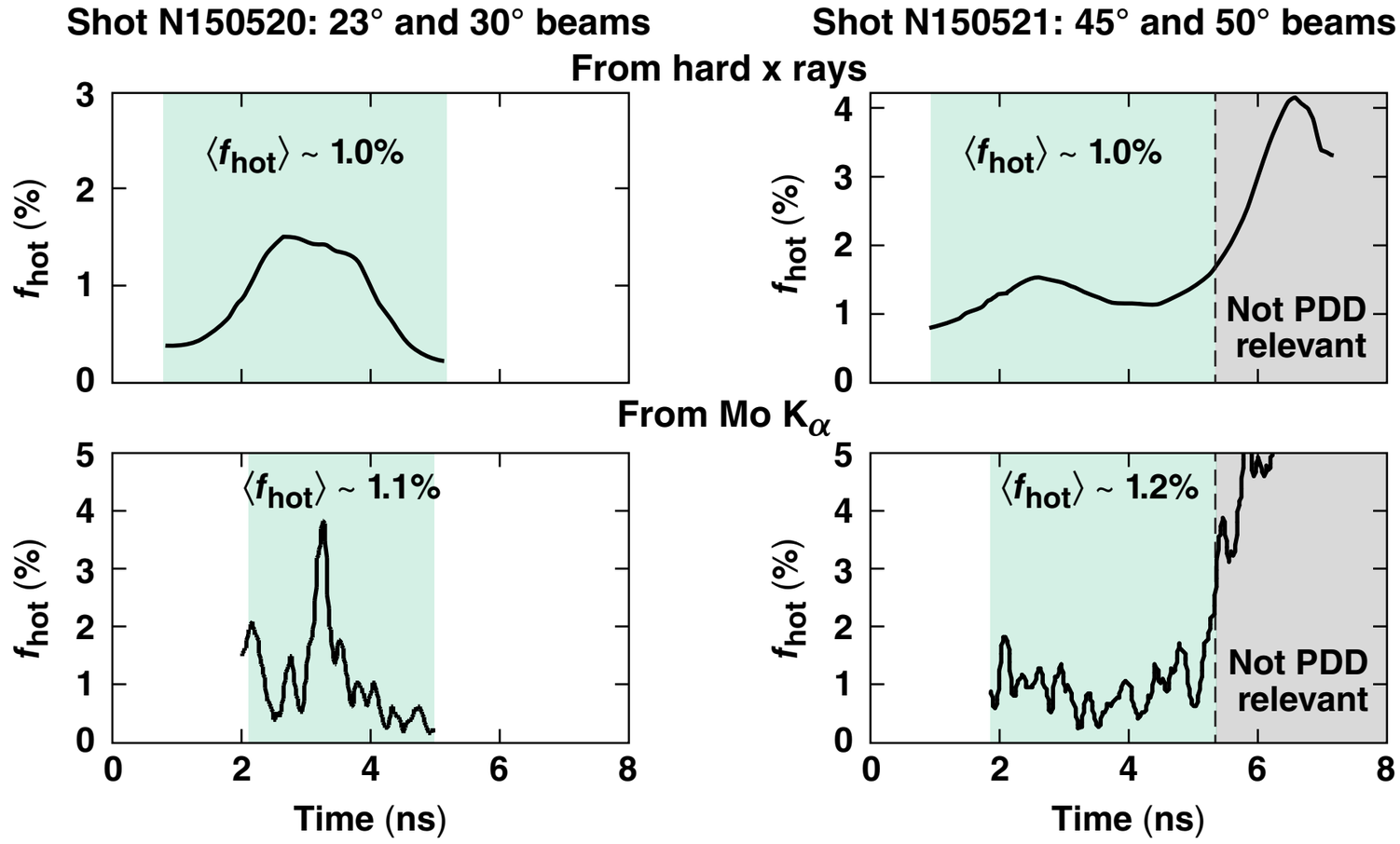
Measured time-integrated hard x-ray spectrum
(Shot N150521 data integrated over the duration of the shot N150520 laser pulse)



T_{hot} ~ 40 keV is consistent with TPD.

E24130

Absolute hard x-ray and Mo K_α emission levels indicate f_{hot} (E_{hot}/E_{laser}) ~ 1% in both experiments



The beam angle of incidence did not have a strong effect on f_{hot} and T_{hot}.

E24715

Summary/Conclusions

A planar platform has been developed at the National Ignition Facility (NIF) to study two-plasmon–decay (TPD) hot-electron production at direct-drive ignition-relevant coronal conditions

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- Planar-geometry experiments were performed on the NIF with predicted scale lengths of ~0.5 mm and T_e > 3 keV
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Other talks on these experiments are up next:
A. A. Solodov (modeling)*
R. Epstein (x-ray spectroscopy for T_e measurement)**

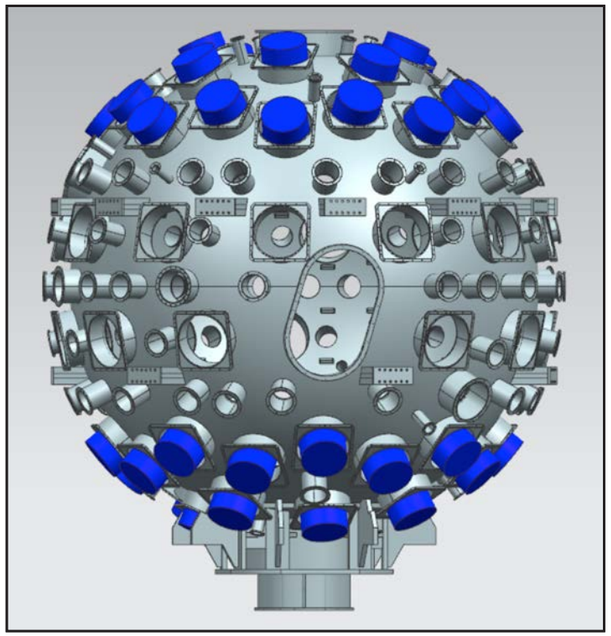
* A. A. Solodov *et al.*, NO5.00007, this conference.
** R. Epstein *et al.*, NO5.00008, this conference.

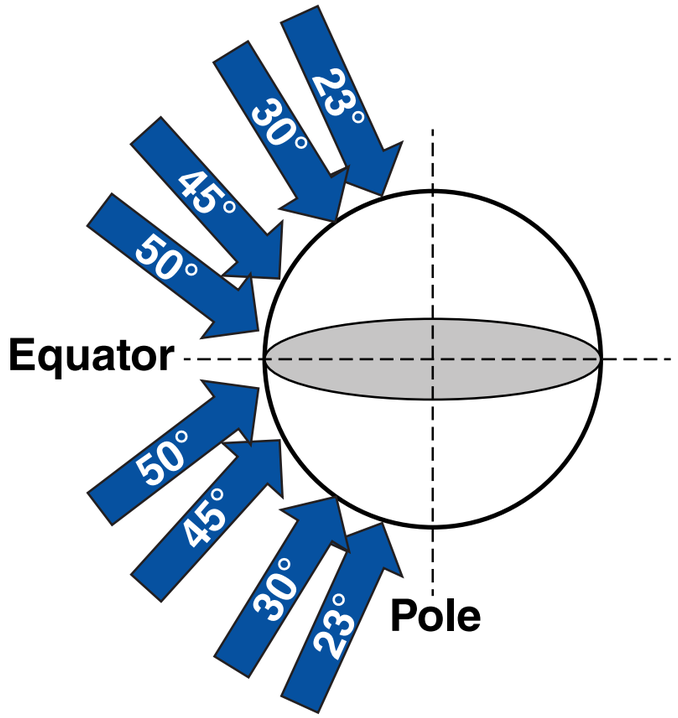
Appendix

Motivation

PDD* is an alternative approach to achieving ignition on the NIF

NIF beams configured for indirect drive (arranged around the poles)

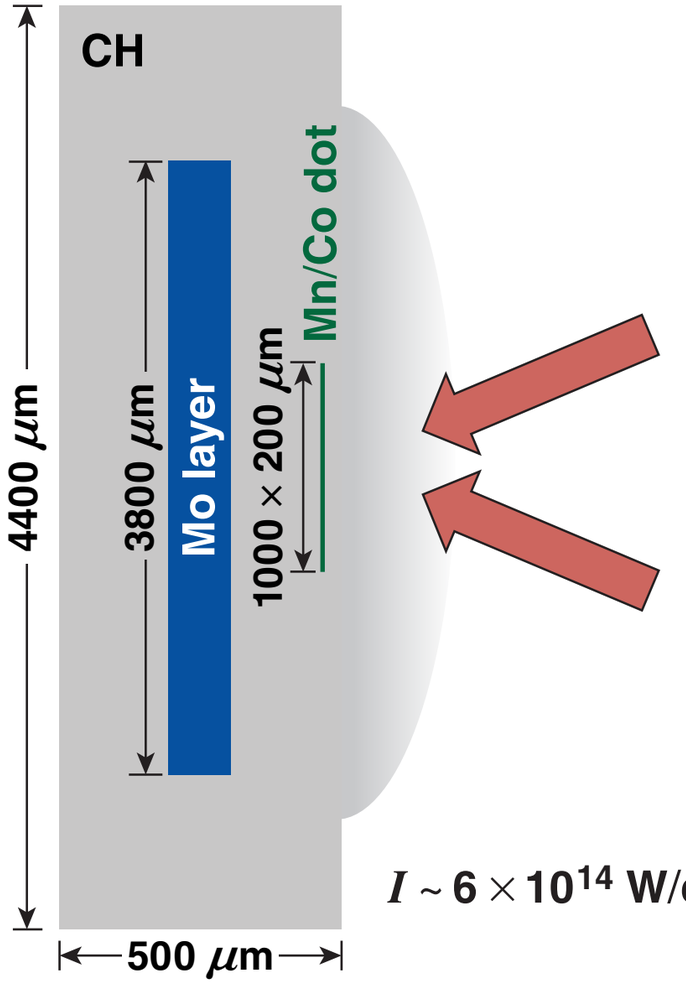




*S. Skupsky *et al.*, Phys. Plasmas 11, 2763 (2004); M. Hohenberger *et al.*, Phys. Plasmas 22, 056308 (2015).

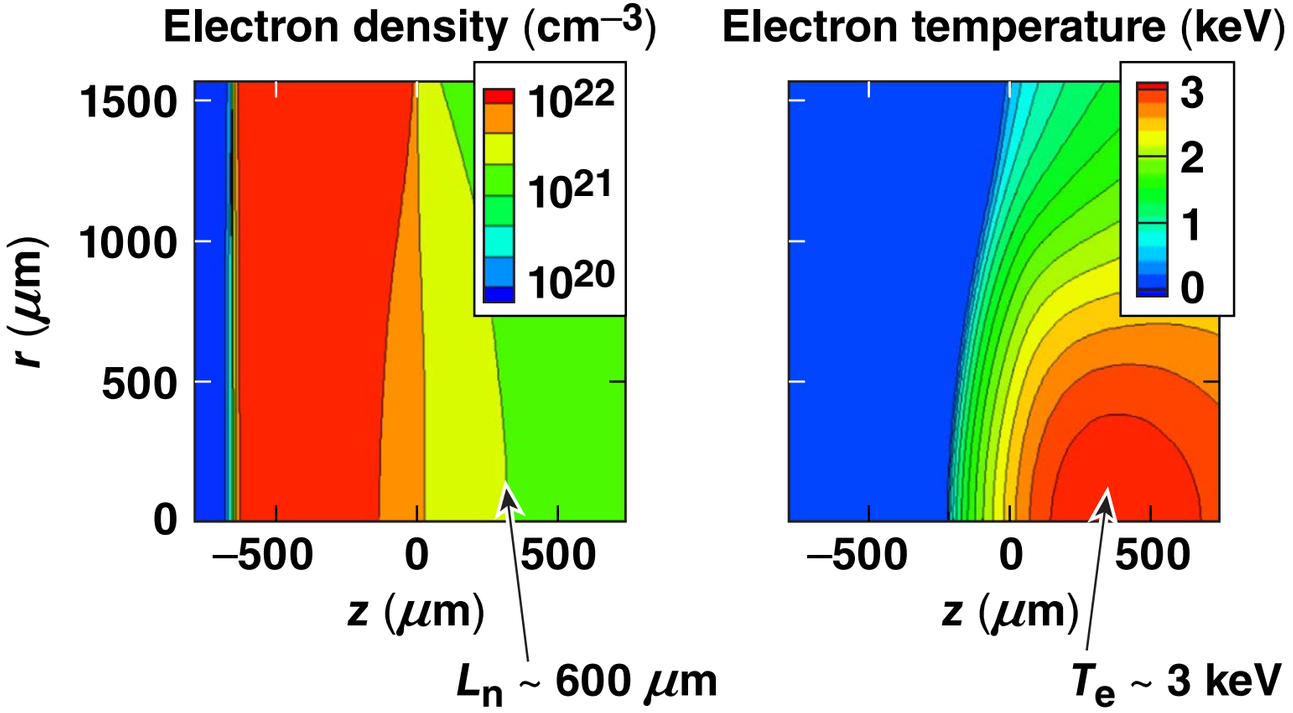
E24121

Planar target TPD experiments on the NIF were designed using *DRACO*



$I \sim 6 \times 10^{14}$ W/cm^2

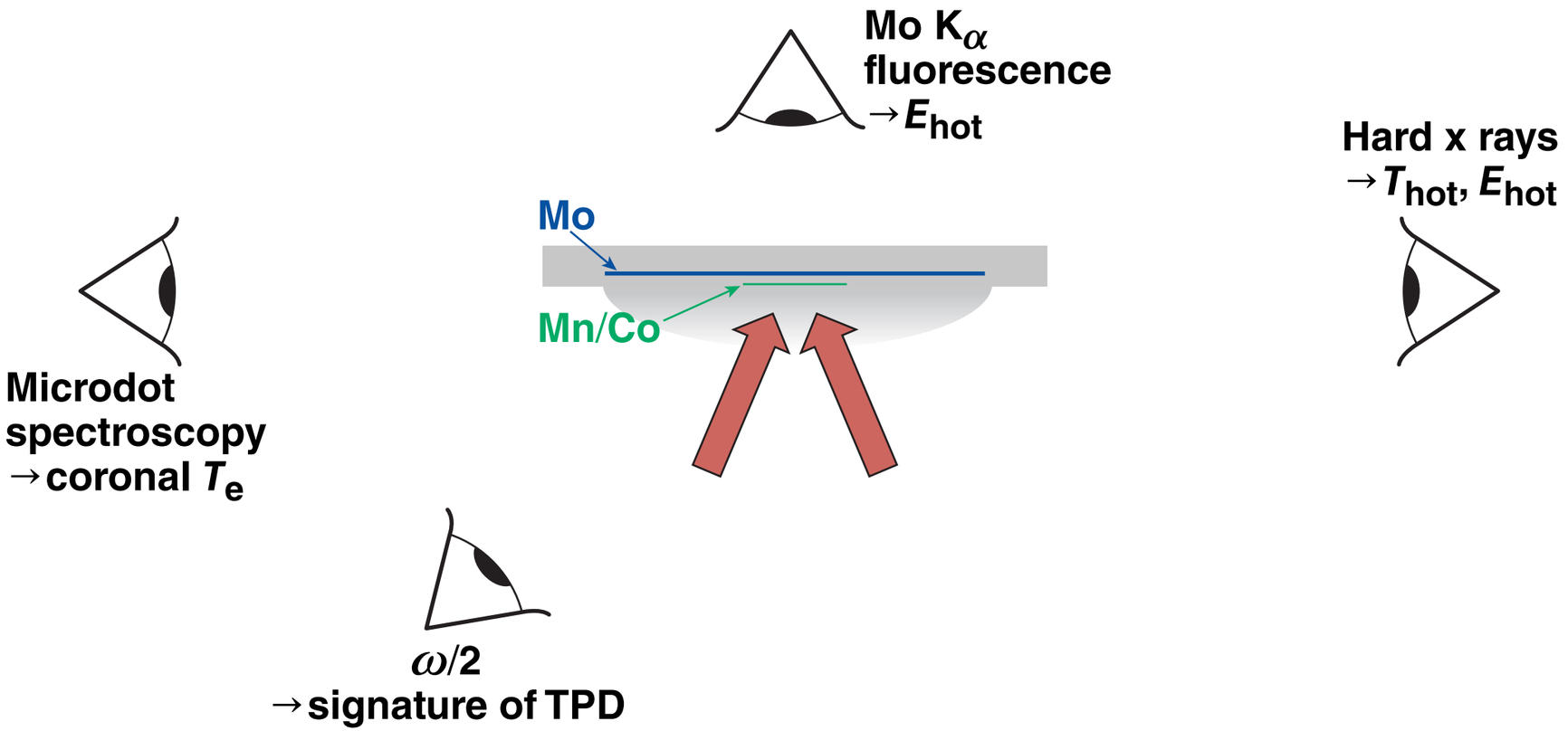
2-D *DRACO* simulation:
outer-beam experiment at 4 ns



The empirical TPD threshold [$\eta = I_{14}L_{n,\mu m}/(230\ T_{e,keV})$] is greatly exceeded (4×) in this experimental design.

E24122a

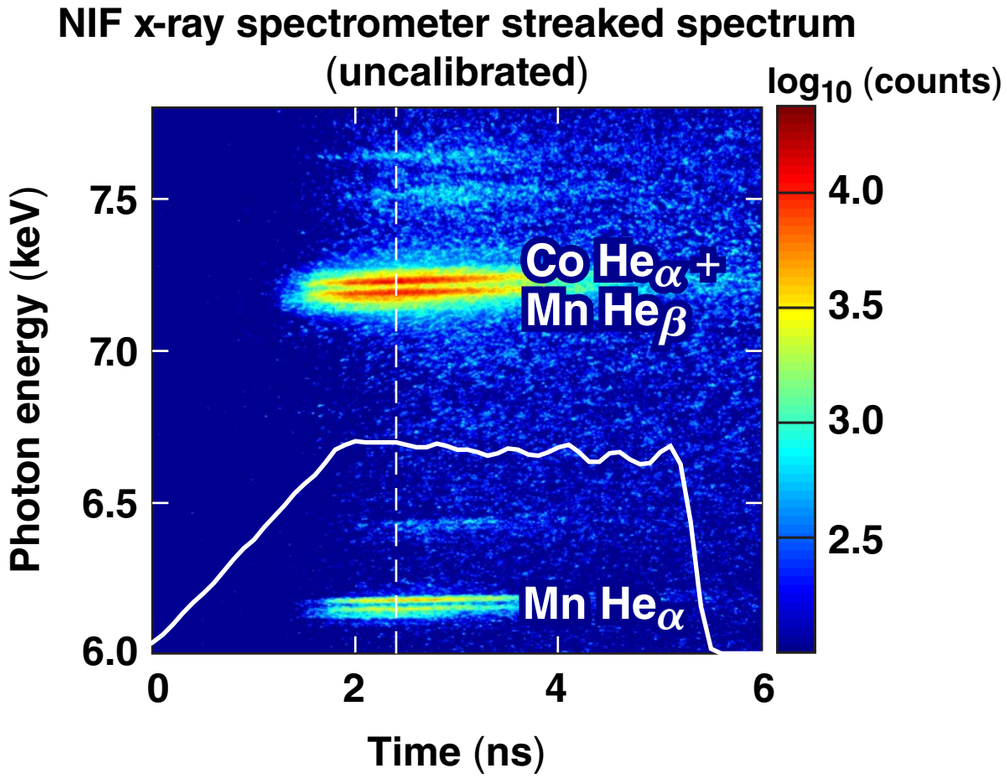
Principal measurements include the spectroscopy of a microdot layer, Mo K_α fluorescence, hard x-ray bremsstrahlung, and $\omega/2$ emission

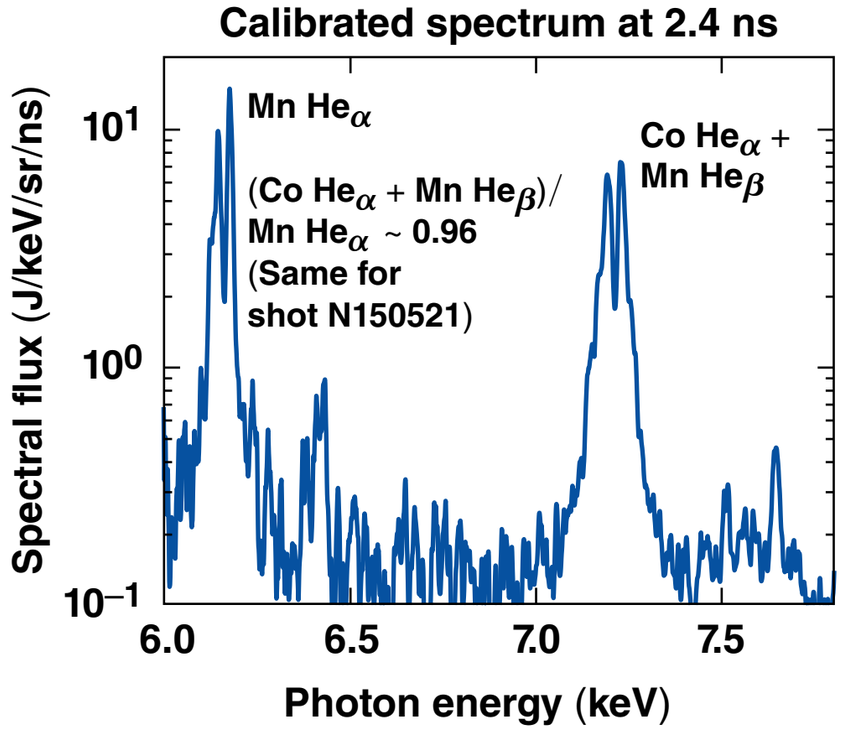


Microdot spectroscopy shows T_e = 4.3±1.1 keV, in rough agreement with *DRACO*.

The electron temperature (T_e) is inferred from the isoelectronic ratio* of the Mn/Co K-shell emission lines

Shot N150520: 23° and 30° beams



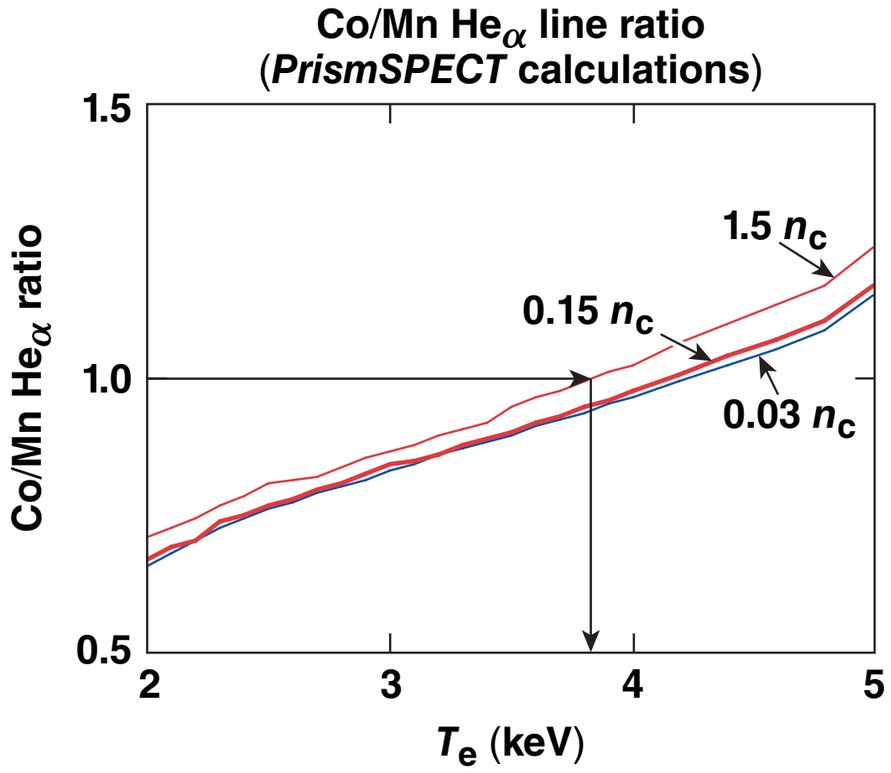


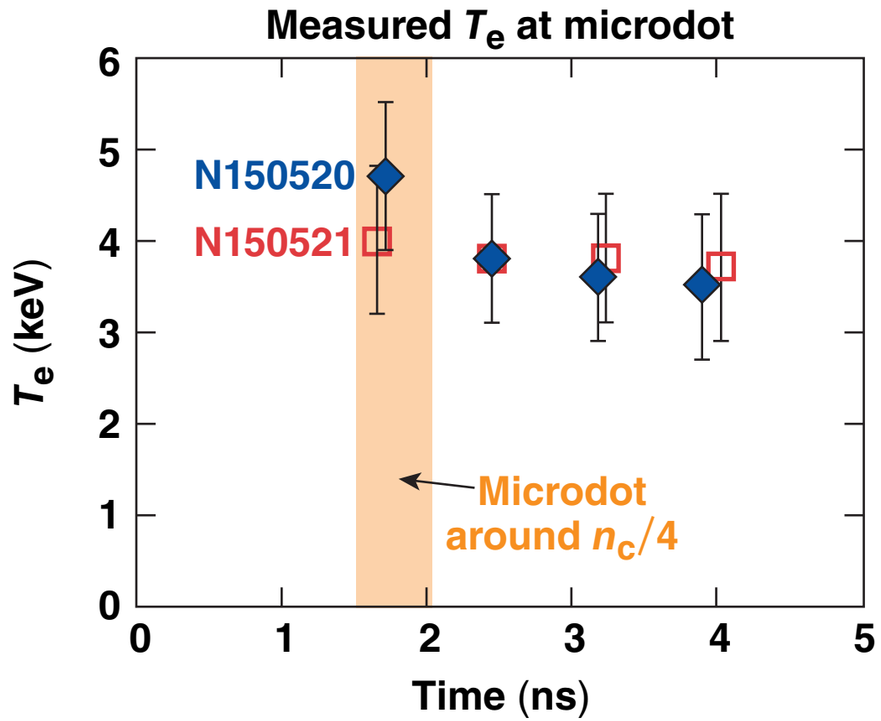
***DRACO* predicts that the microdot is at the $n_c/4$ surface at t = 1.5 to 2.0 ns.**

*R. S. Marjoribanks *et al.*, Phys. Rev. A 46, 1747(R) (1992).

E24125a

The measured Co/Mn He$_\alpha$ line ratio indicates T_e = 4.3±1.1 keV at $n_c/4$



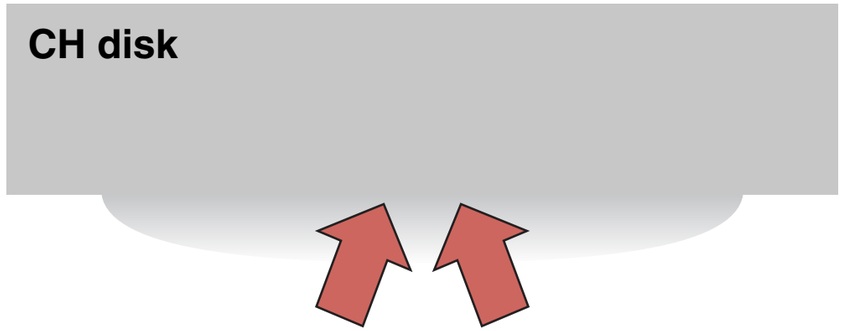


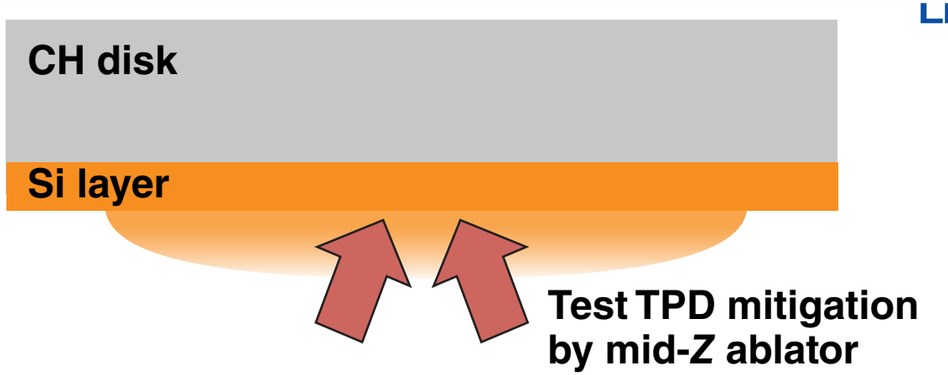
- Uniform plasma conditions
- Steady-state approximation
- Ratio depends weakly on n_e and optical thickness

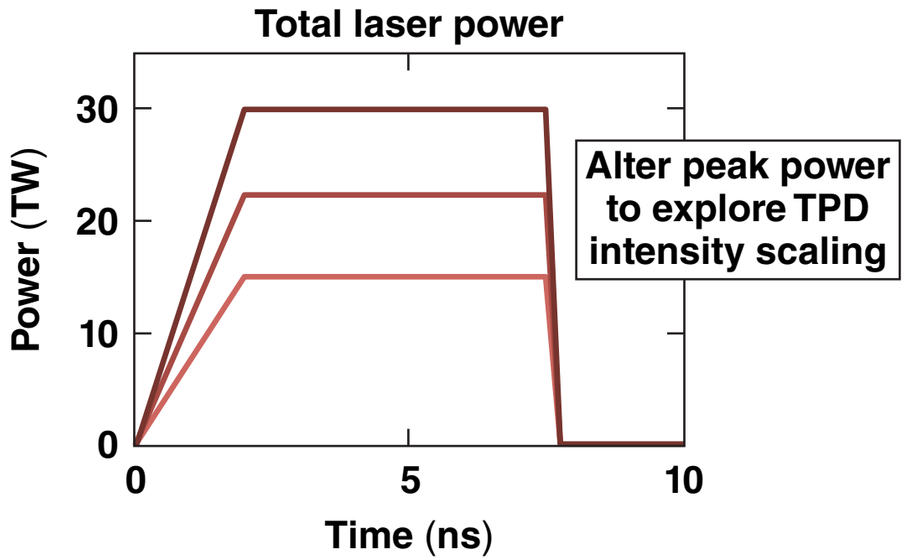
Future experiments will explore the effect of the microdot on plasma conditions.

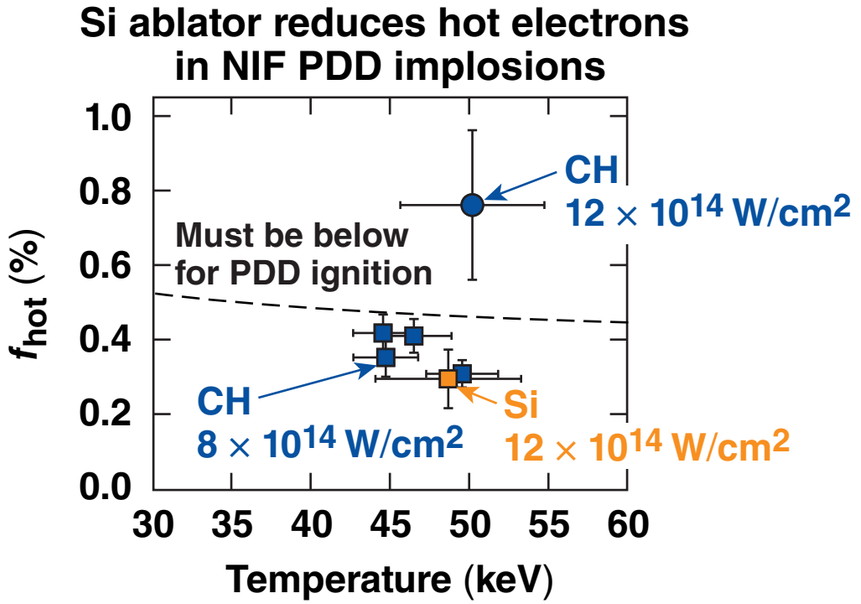
E24126b

Future work will explore hot-electron scaling with laser intensity and the use of mid-Z ablators to mitigate TPD in the $\eta > 1$ regime









E24272a