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

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Summary

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

- 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 $T_{hot} \sim 40$ keV) was observed
- The beam angle of incidence did not have a strong effect on the TPD

E24120

Collaborators

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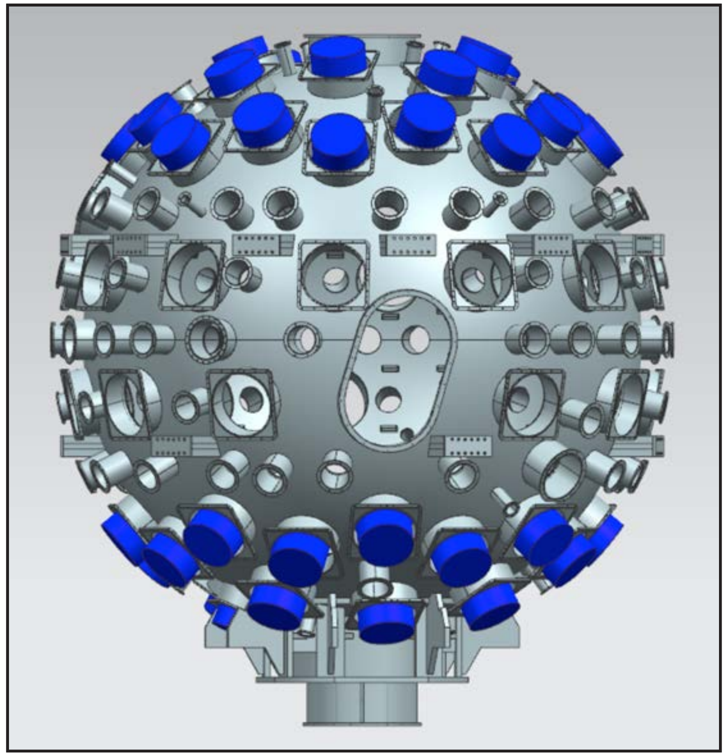
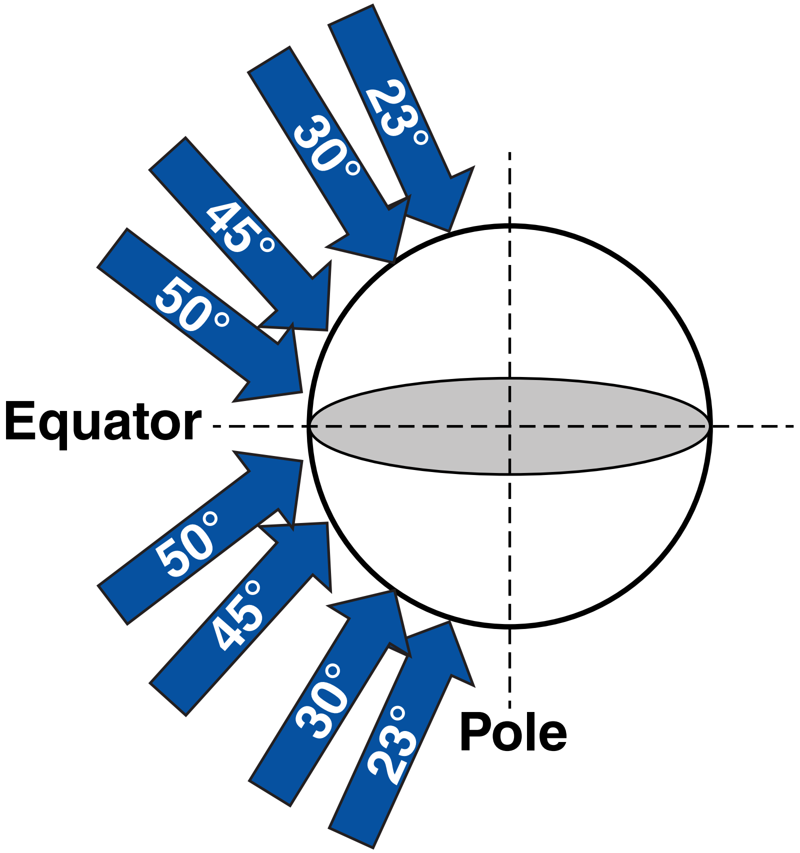
Motivation

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).

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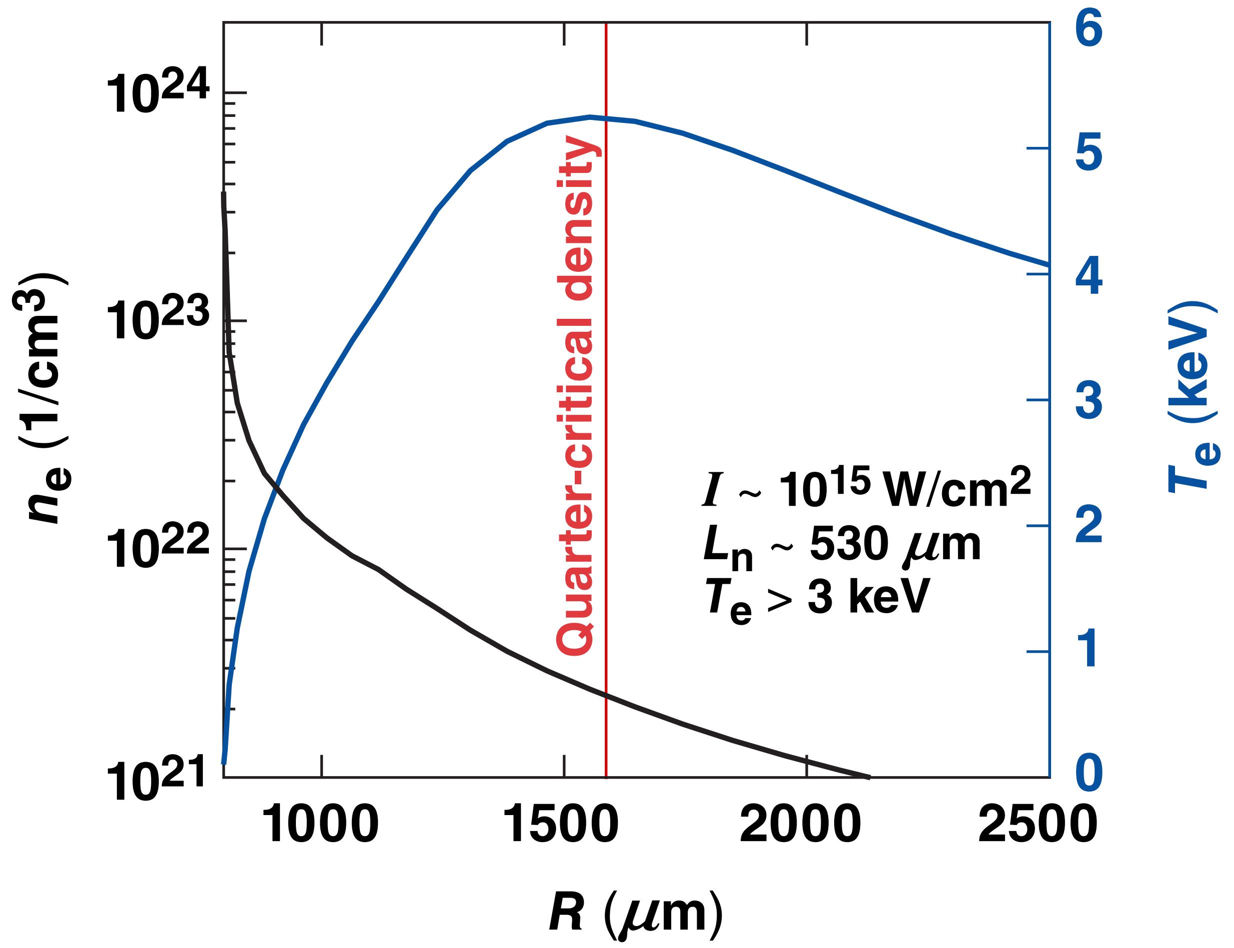
PDD ignition designs predict long density scale lengths and high electron temperatures under which TPD may occur

2-D simulated plasma conditions for igniting PDD design



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

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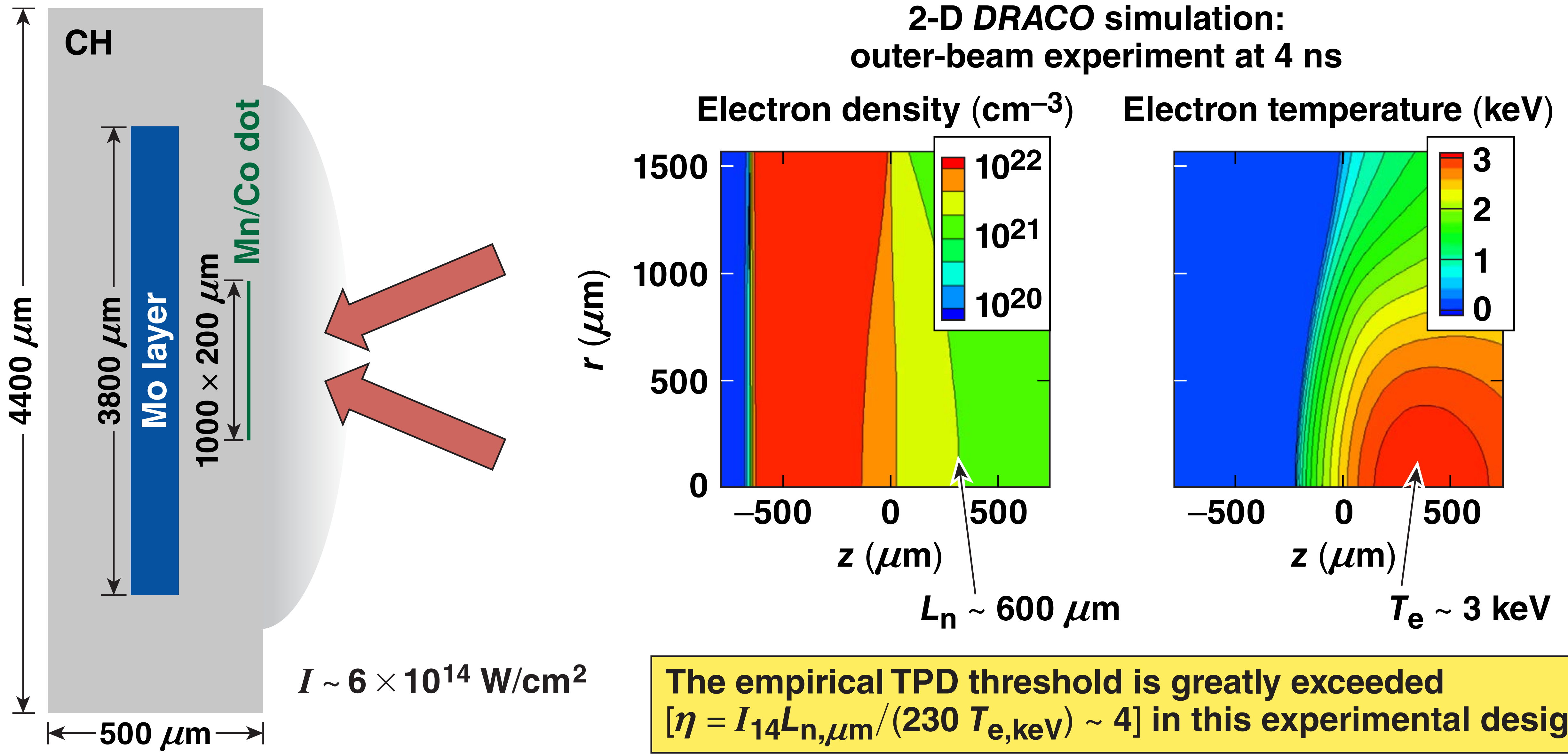
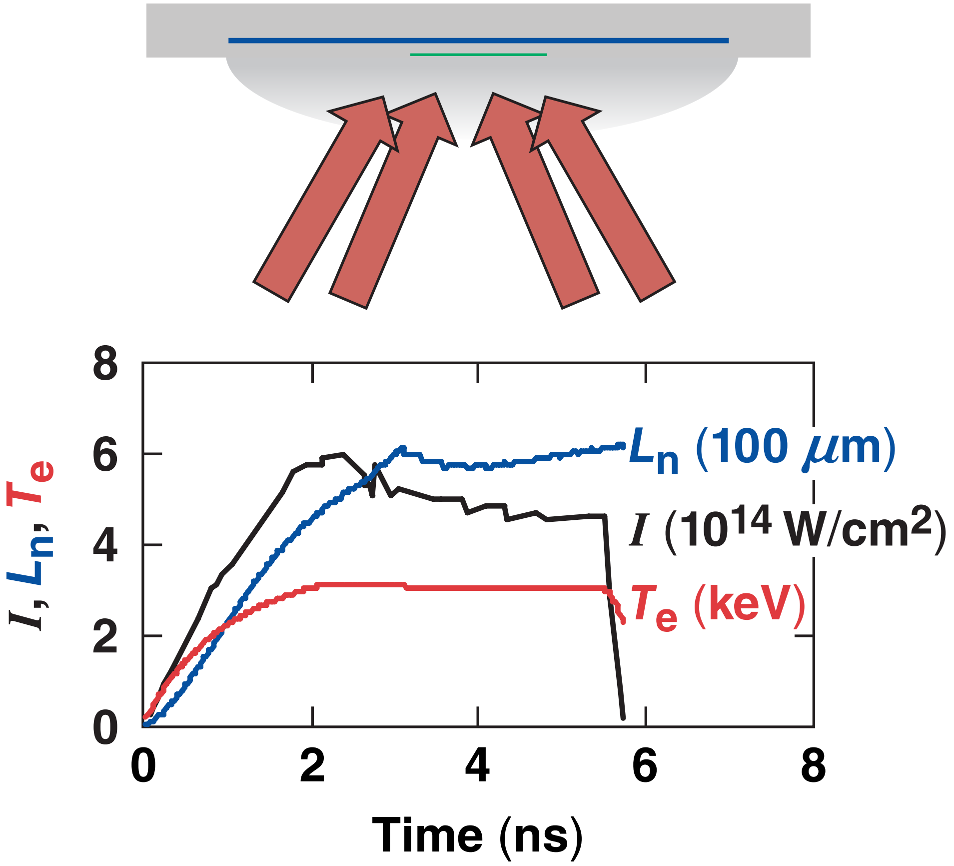
Planar target TPD experiments on the NIF were designed using *DRACO*



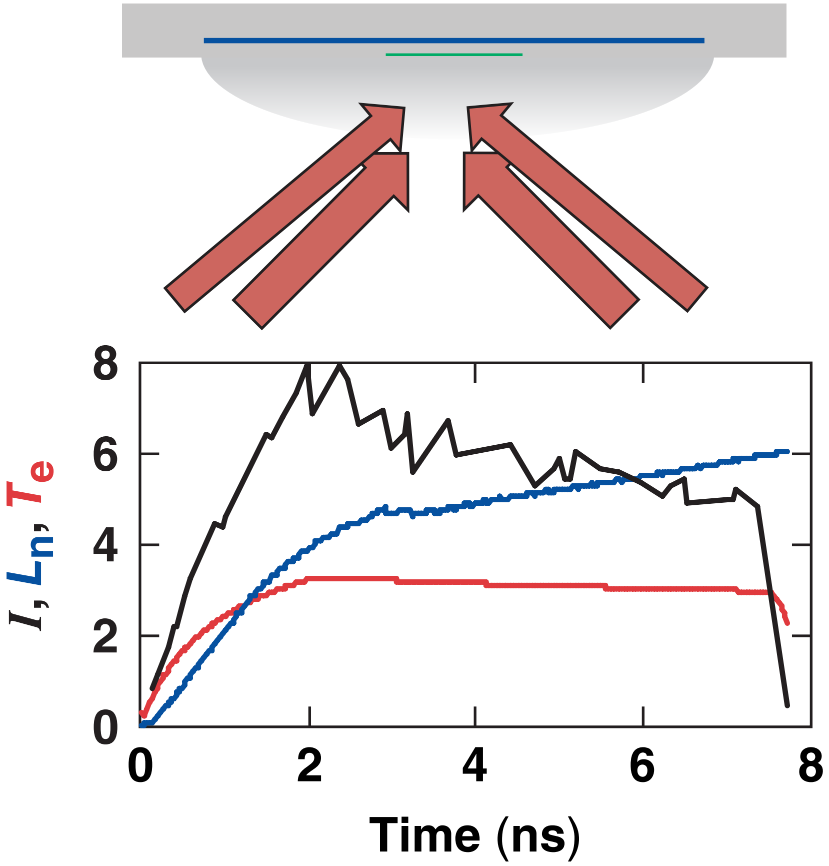
The empirical TPD threshold is greatly exceeded $[\eta = I_{14}L_{n,\mu m}/(230\ T_{e,keV}) \sim 4]$ in this experimental design.

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)



Each experiment uses a laser drive with the longest allowable flat top while avoiding laser damage.

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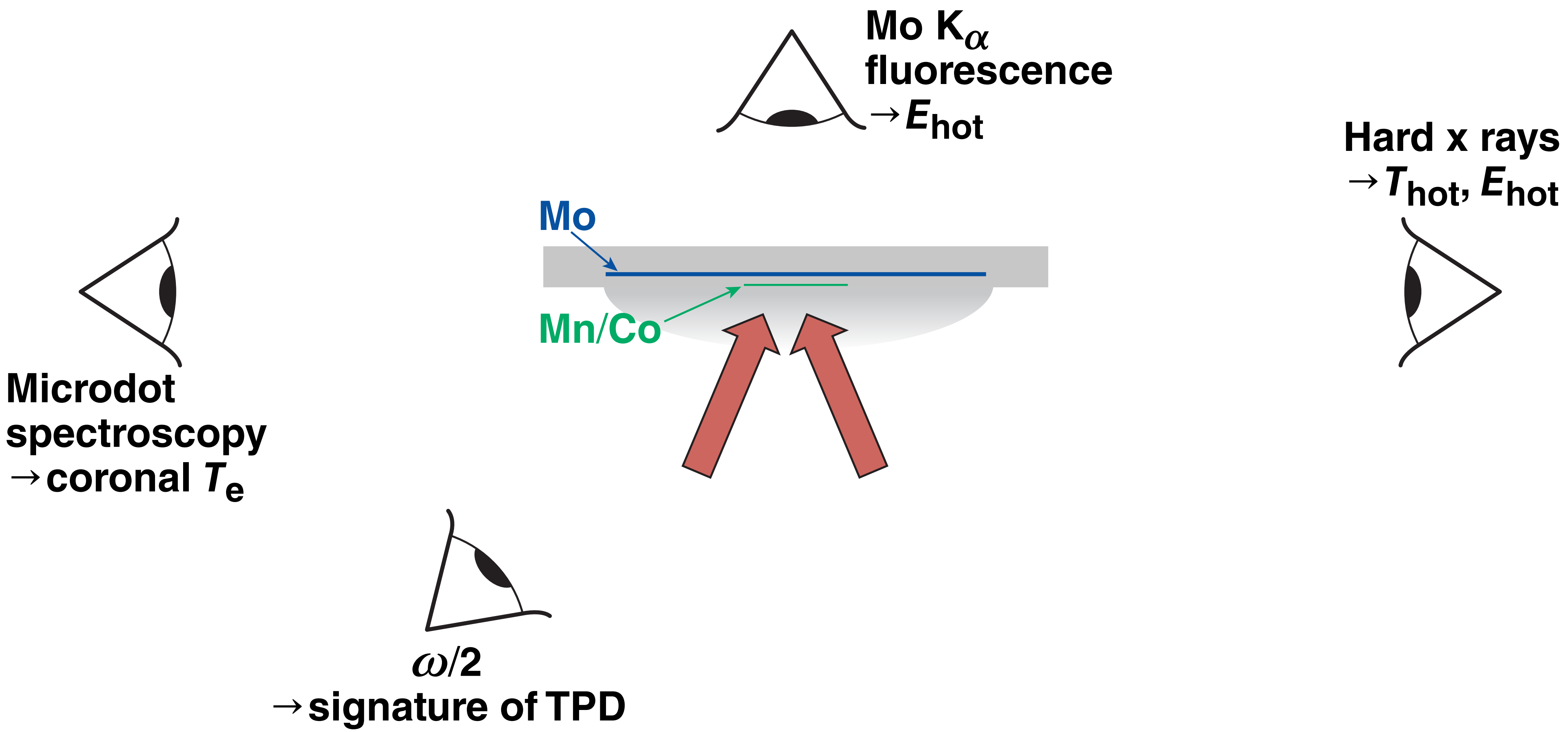
Principal measurements include the spectroscopy of a microdot layer, Mo K_α fluorescence, hard x-ray bremsstrahlung, and $\omega/2$ emission

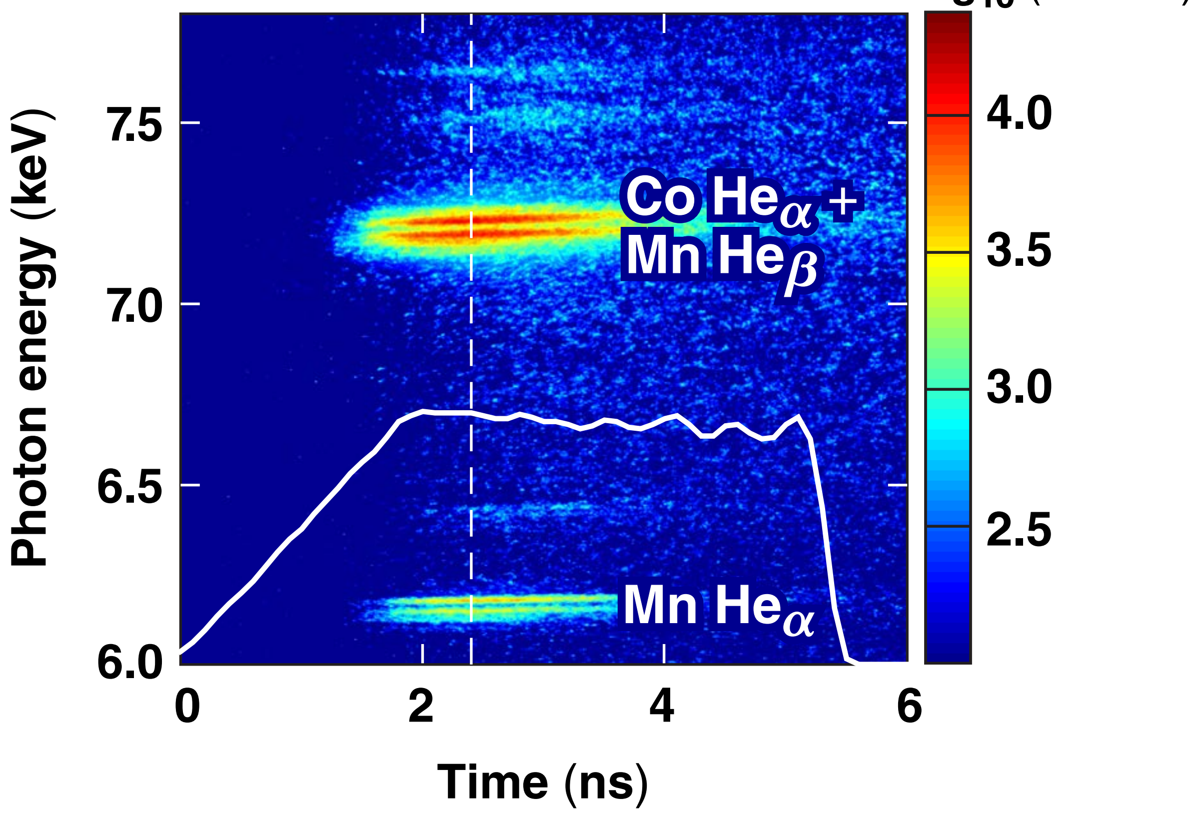


E24124

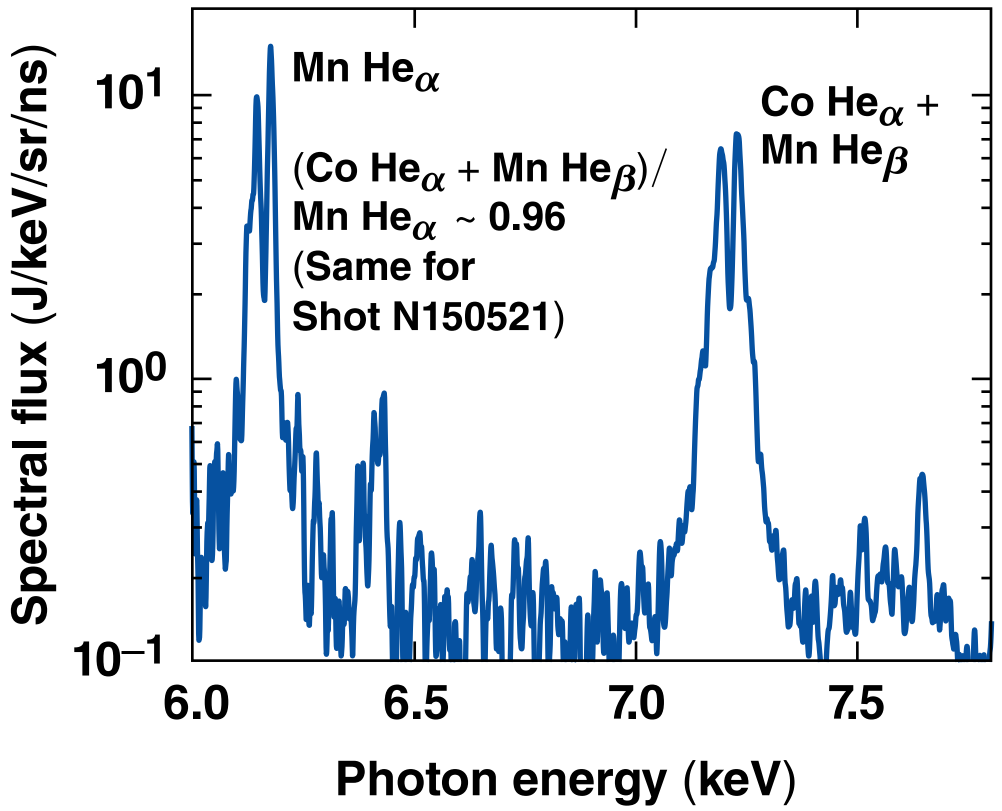
The electron temperature (T_e) is inferred from the isoelectronic ratio* of the Mn/Co K-shell emission lines

Shot N150520: 23° and 30° beams

NIF x-ray spectrometer streaked spectrum (uncalibrated)



Calibrated spectrum at 2.4 ns

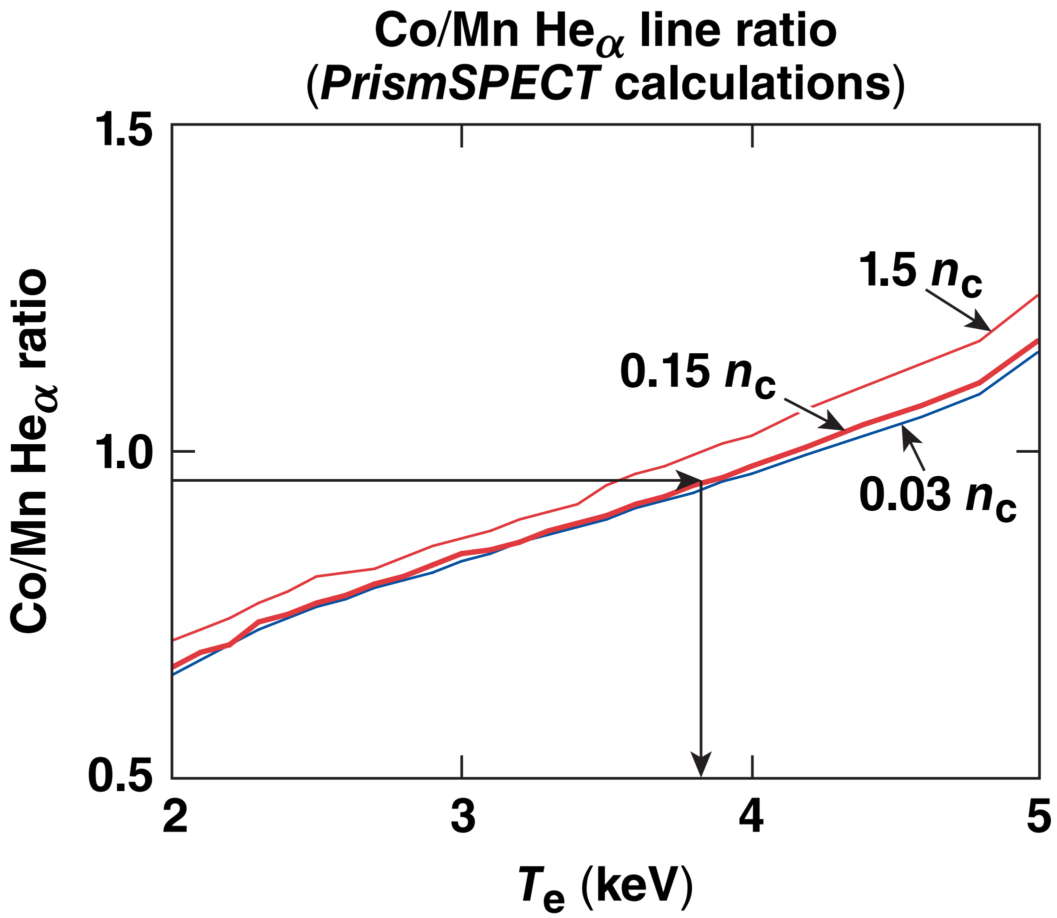


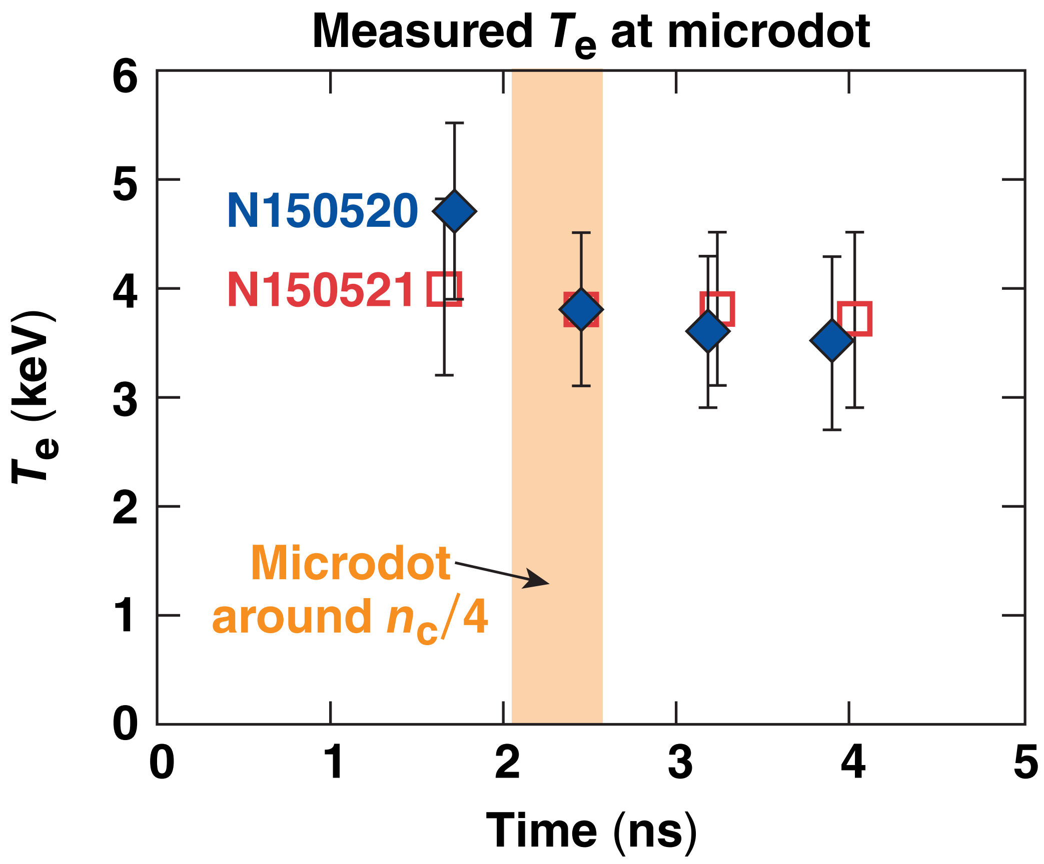
DRACO **predicts that the microdot is at the $n_c/4$ surface at t = 2.0 to 2.5 ns.**

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

E24125

The measured Co/Mn He_α line ratio indicates T_e = 3.8±0.6 keV at $n_c/4$

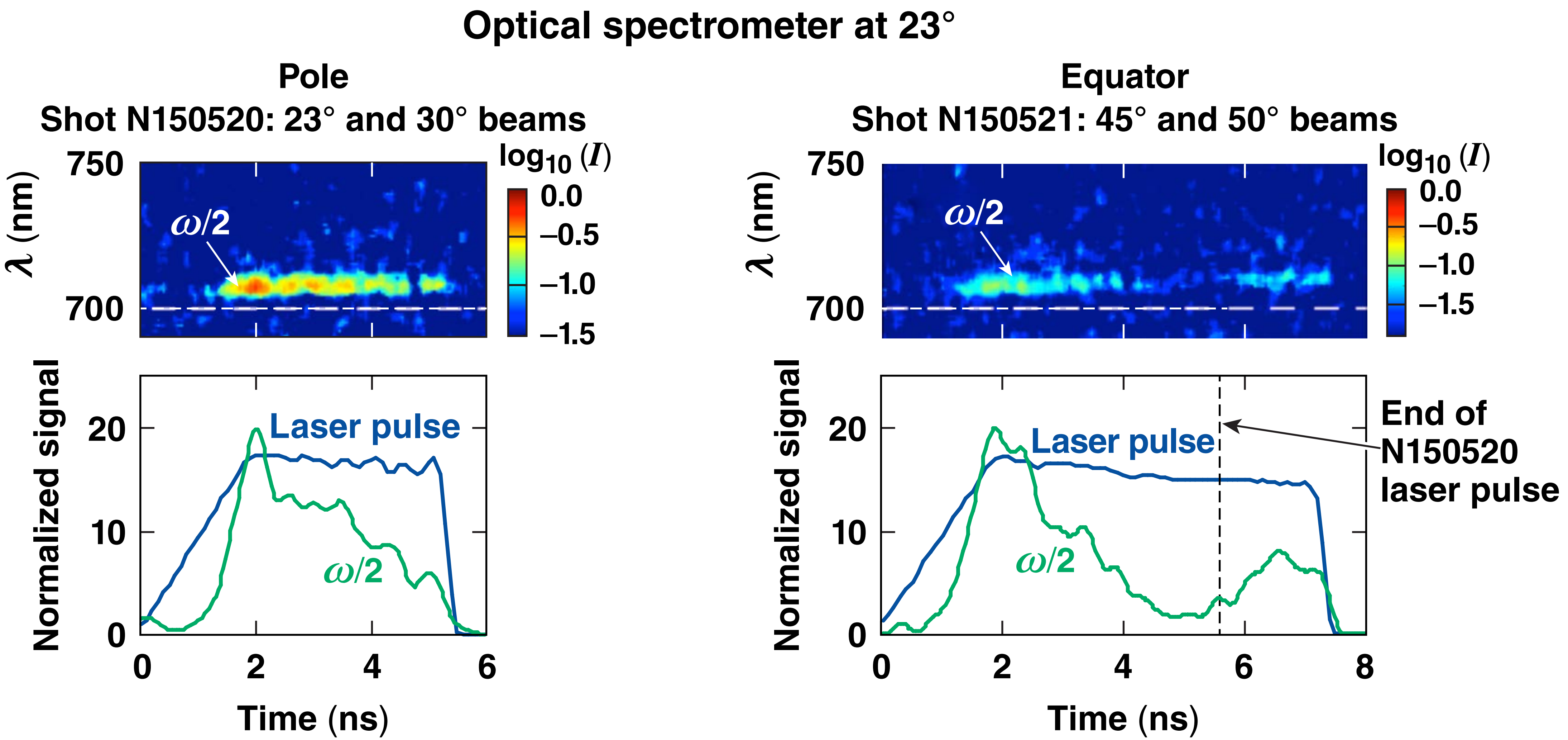




- Uniform plasma conditions
- Steady-state approximation
- Ratio depends weakly on n_e, optical thickness

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

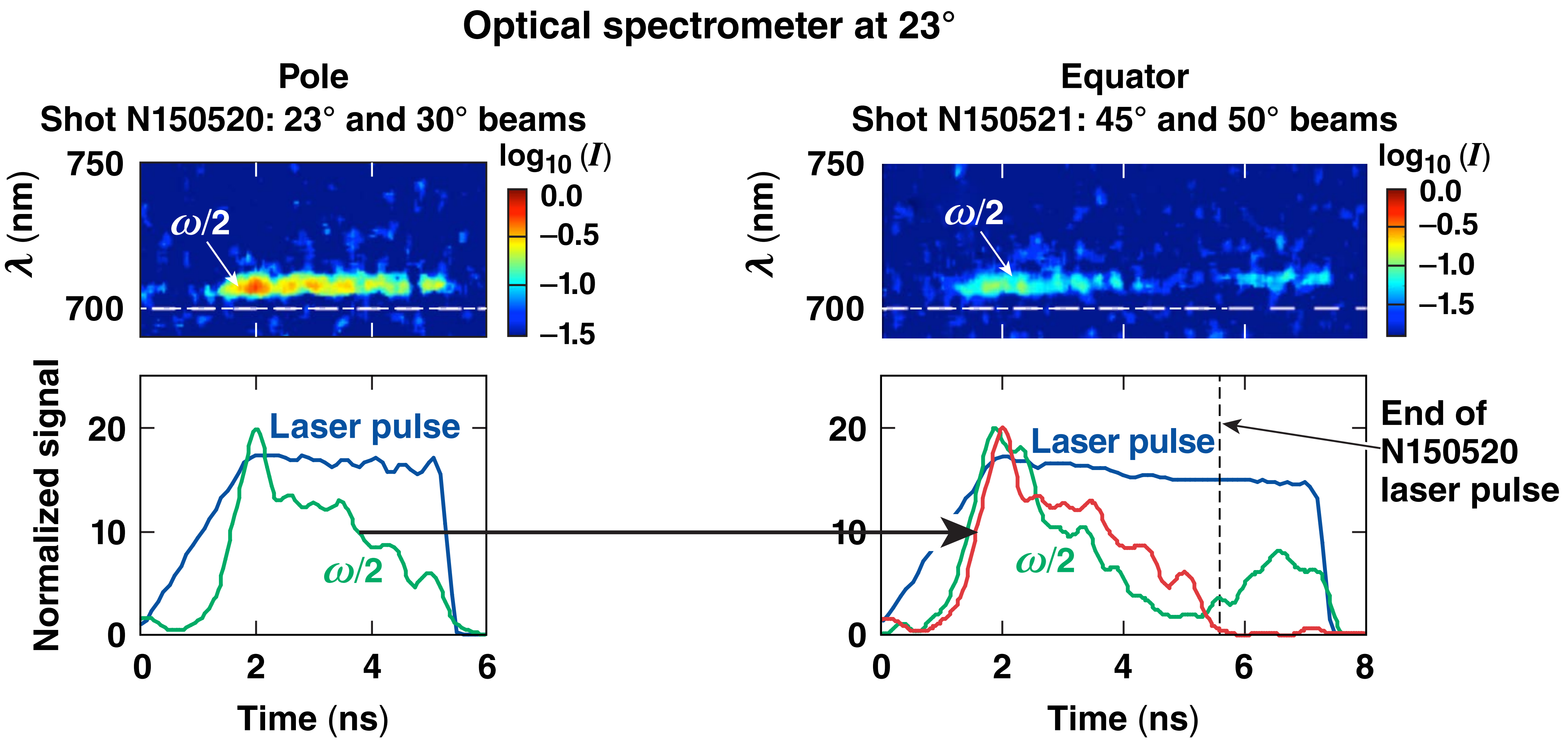
$\omega/2$ emission indicates TPD is driven during the flat top of the laser pulse



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

E24127

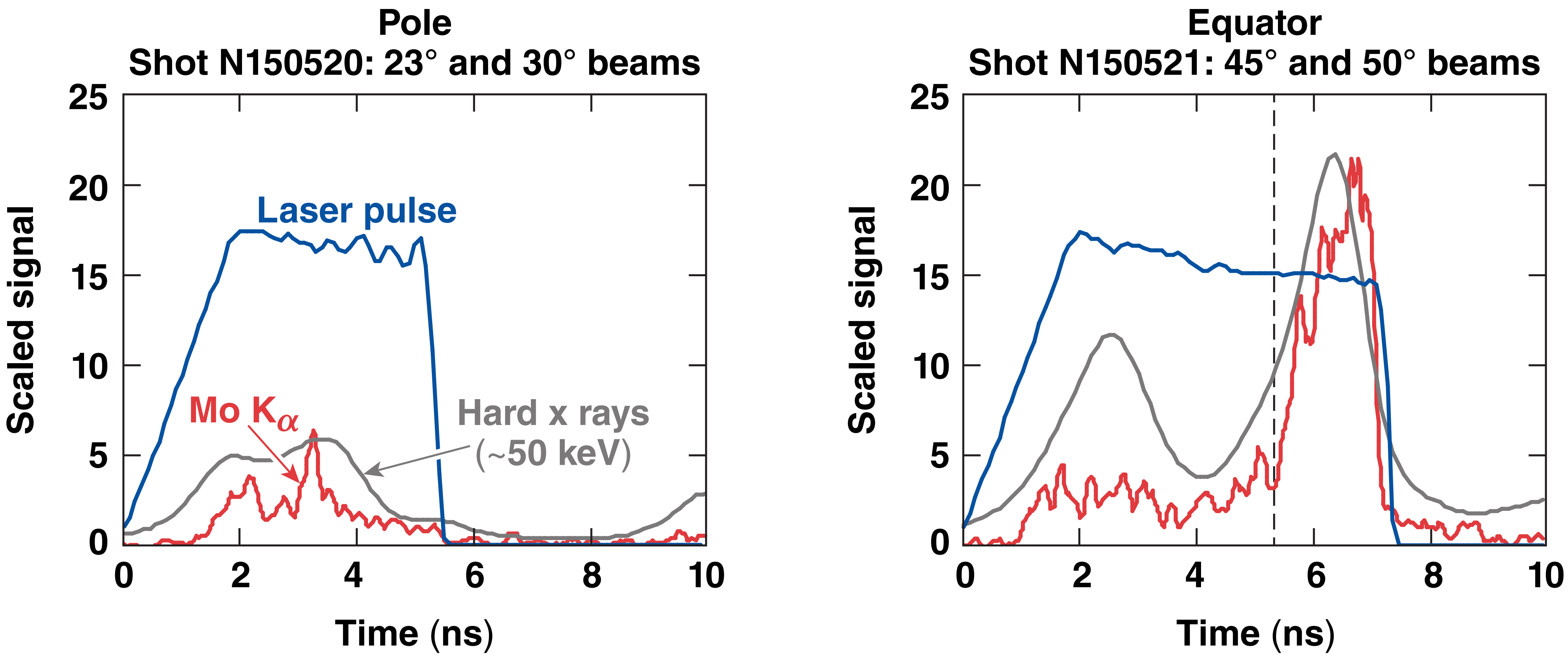
$\omega/2$ emission indicates TPD is driven during the flat top of the laser pulse



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

E24127a

TPD-generated hot electrons were observed via hard x-rays and K_α fluorescence



The beam angle of incidence did not have a strong effect on TPD hot-electron production for the first ~5.5 ns.

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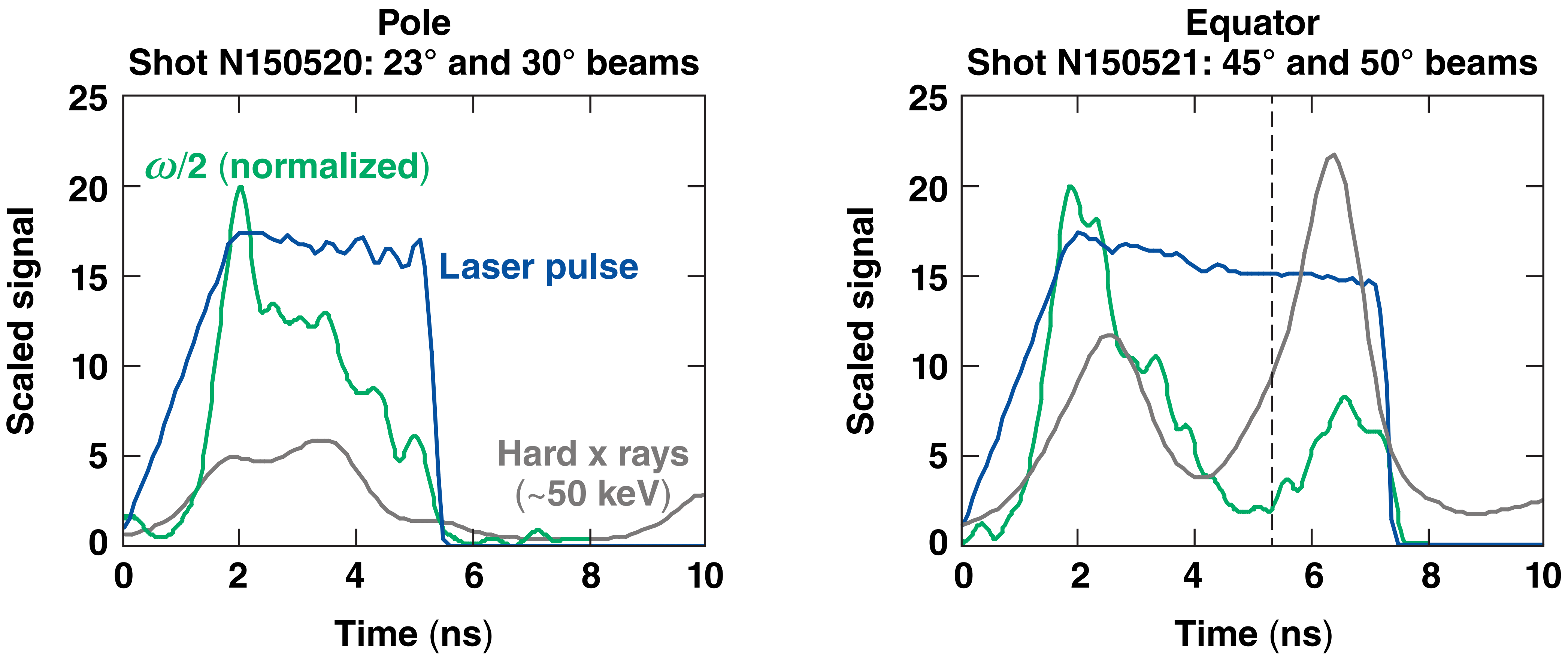
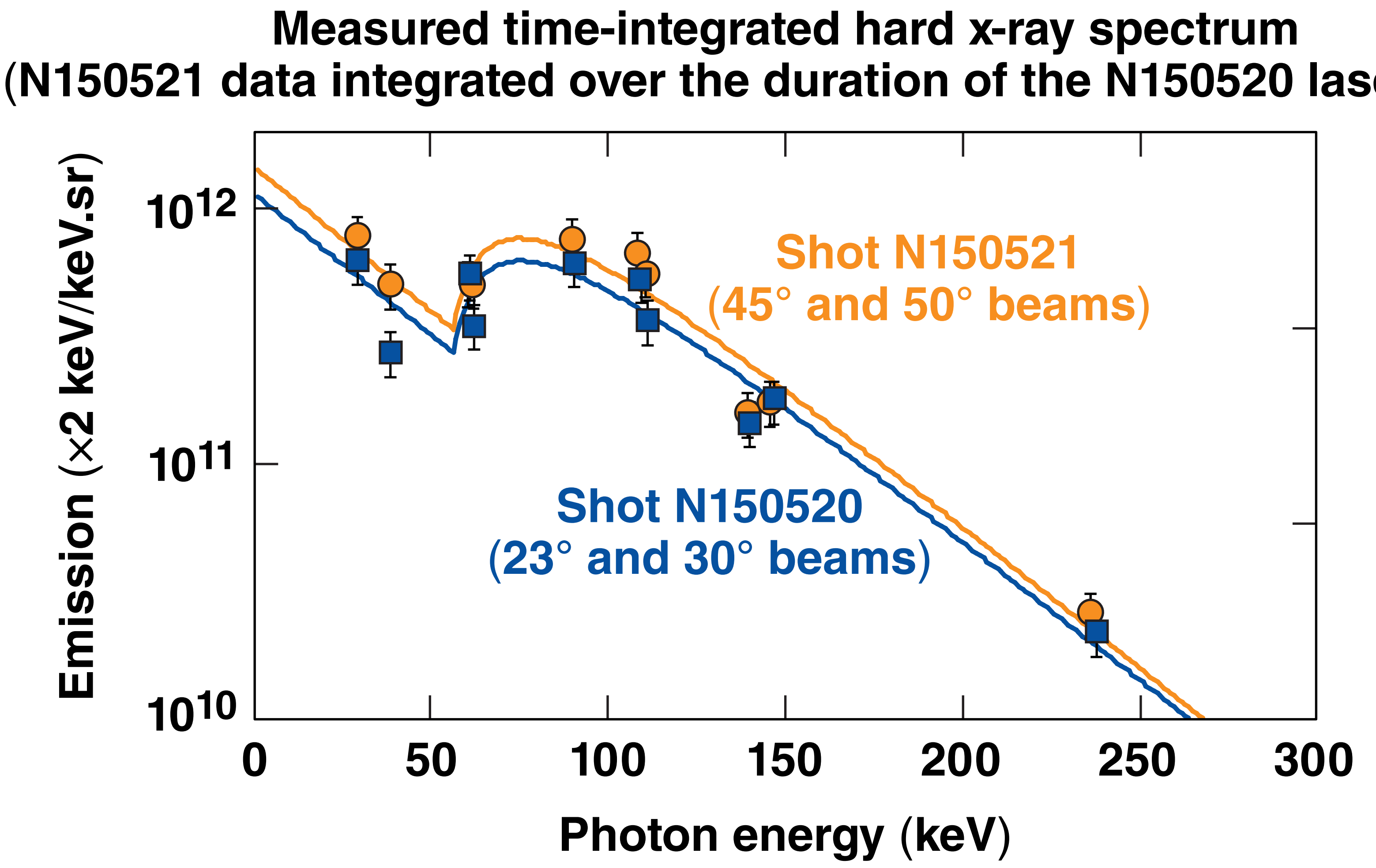
The hard x-ray and $\omega/2$ signals have similar temporal histories



E24129

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



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

E24130

Summary/Conclusions

A platform has been developed at the National Ignition Facility (NIF) to study two-plasmon–decay (TPD) hot-electron production at polar-direct-drive (PDD) ignition-relevant 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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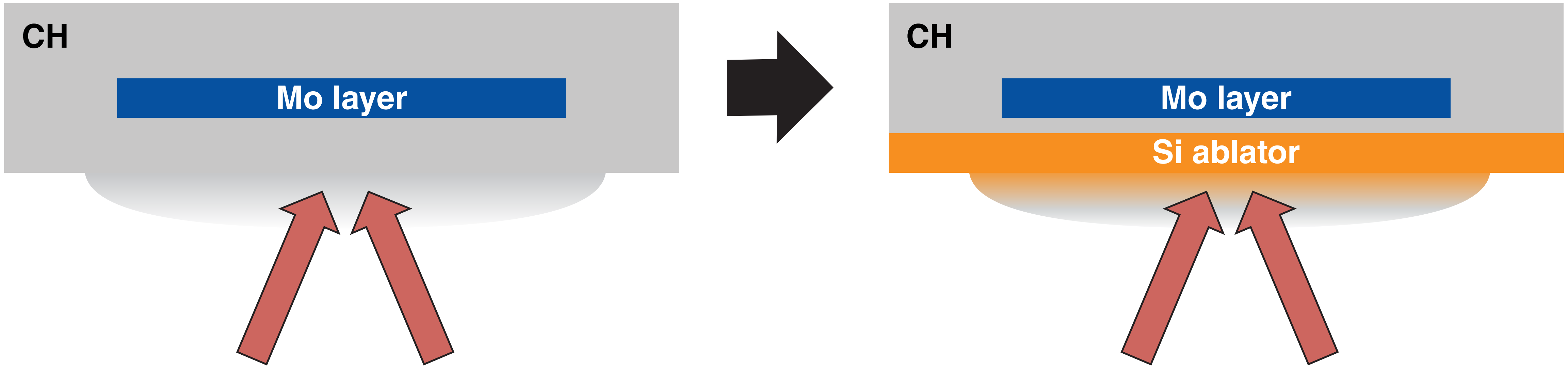
- The beam angle of incidence did not have a strong effect on the TPD

These experiments will be used to assess laser–plasma simulation environment (*LPSE*) simulations* and test the theory that larger angles of incidence have a lower TPD threshold (more hot electrons).**

* J. F. Myatt *et al*., presented at the 44th Annual Anomalous Absorption Conference, Estes Park, CO, 8–13 June 2014.
** R. W. Short, J. F. Myatt, and J. Zhang, presented at the 44th Annual Anomalous Absorption Conference, Estes Park, CO, 8–13 June 2014.

Appendix

Future work will explore the use of higher-Z ablators to mitigate TPD in the $\eta > 1$ regime



The Si ablator reduces hot electrons in NIF PDD implosions