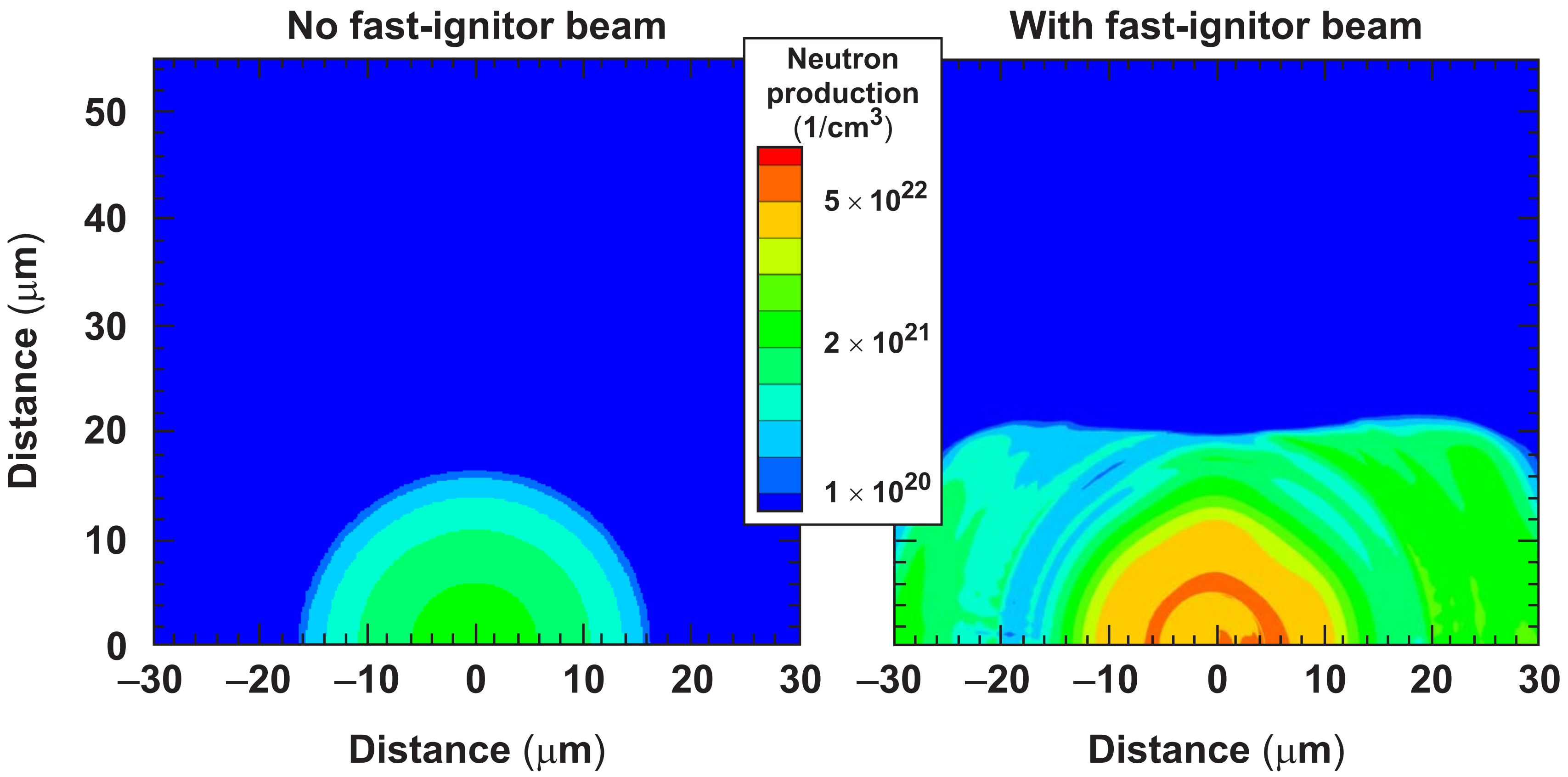
Simulation of Enhanced Neutron Production in OMEGA EP Cryogenic Implosions



J.A. Delettrez, J. Myatt, P.B. Radha,
C. Stoeckl, and S. Skupsky
University of Rochester
Laboratory for Laser Energetics

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Summary

Interaction of the OMEGA EP beam with an imploding cryogenic capsule produces enhanced neutron yield

- The OMEGA EP laser will add a short-pulse (2.5 kJ in 20 ps), high-intensity beam ($>10^{19}$ W/cm^2) to OMEGA to study the physics of fast ignition.
- A relativistic electron transport model in *DRACO* was applied to OMEGA cryogenic implosions.
- The simulations were carried out with varying Gaussian beam temporal profiles and beam radii.
- The multigroup electron source consists of an electron spectrum based on the laser irradiance.
- Near stagnation, the cold fuel heated by the electrons explodes and creates a dense and hot core.
- The total DT yield reaches over 3×10^{15}, permitting the development of near-ignition neutron diagnostics for the NIF.

The present transport model in *DRACO* should be considered as electron energy deposited in the target

- Source
  - The electron distribution is computed from the laser intensity and a conversion efficiency.
  - The electron beam is injected into the target as concentric rings centered at the pole.
  - The beam has a flat cross-section over a variable radius and a Gaussian temporal shape with varying FWHM and timing.

- Transport
  - The electron trajectories are straight lines parallel to the pole; angular divergence is an option.
  - The electrons are transported within a single time step.
  - The energy loss is computed using a model by Li and Petrasso*.
  - The model does not include electric fields, magnetic fields, or return currents.

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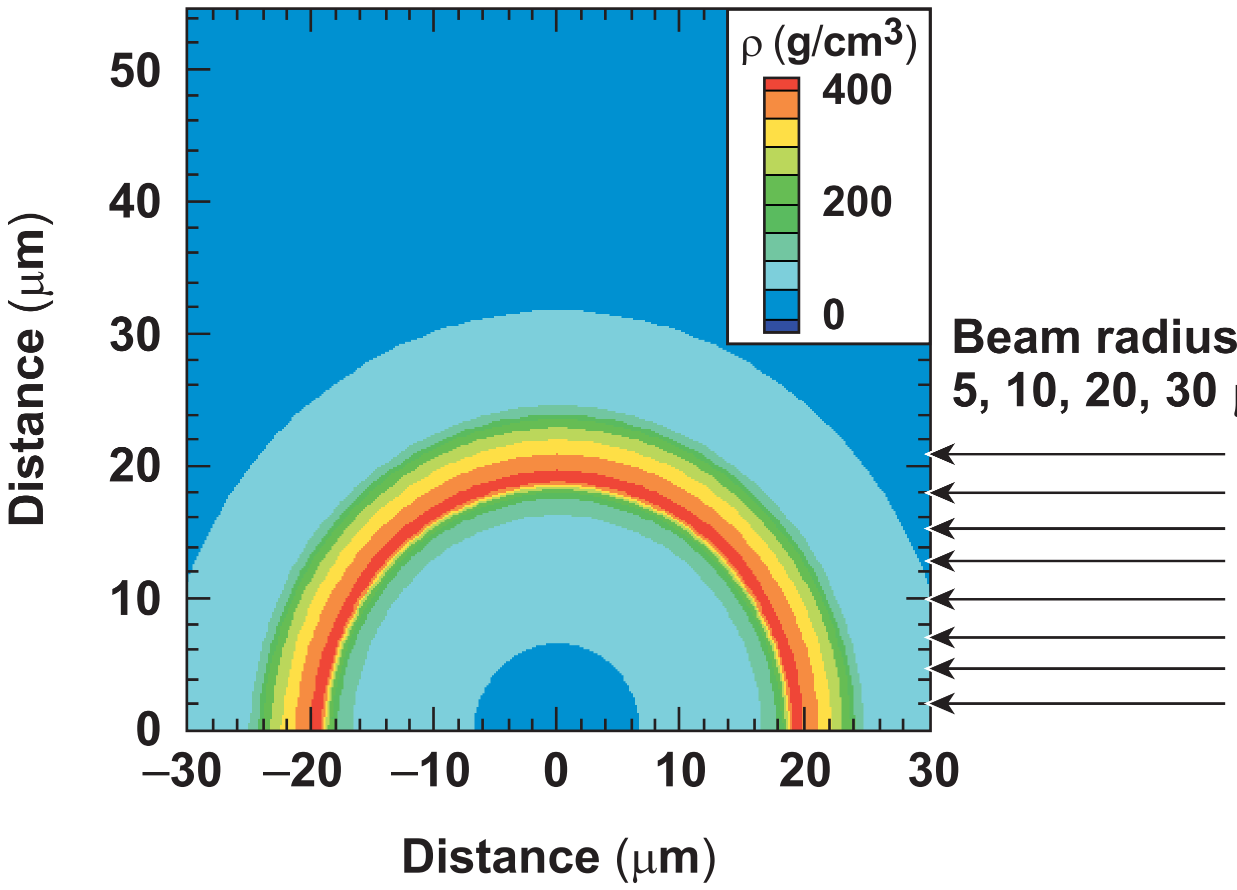
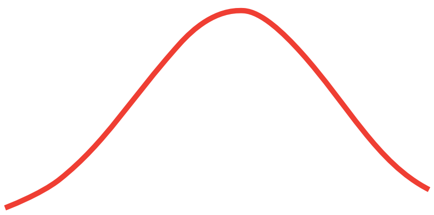
*C.K. Li and R. Petrasso, this conference (paper 3O9)

Simulations were carried out for a 2.5-kJ, 1-μm-wavelength laser with a varying beam radius and FWHM

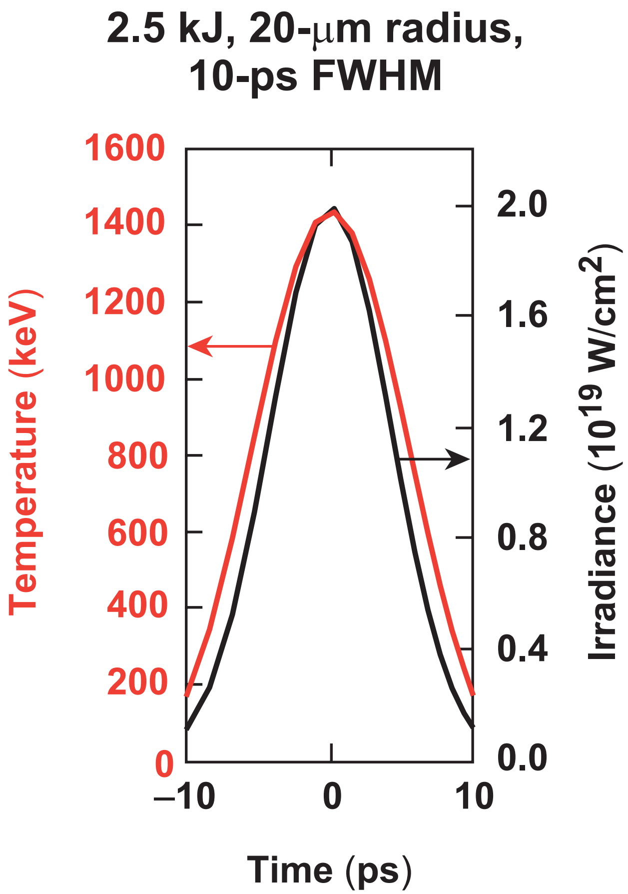


Beam radius:
5, 10, 20, 30 μm

Pulse FWHM:
1, 5, 10, 20, 30 ps



The electron source is a one-dimensional Maxwellian distribution based on simulations by Wilks*



$T = 511 * [(1 + I/1.47 \times 10^{18})^{0.5} – 1] \text{ (keV)} \rightarrow$ slope of Maxwellian

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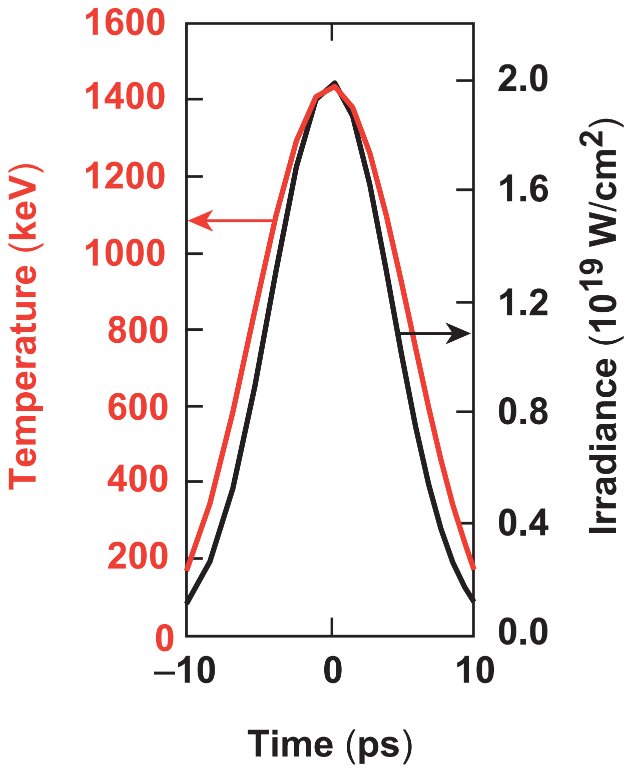
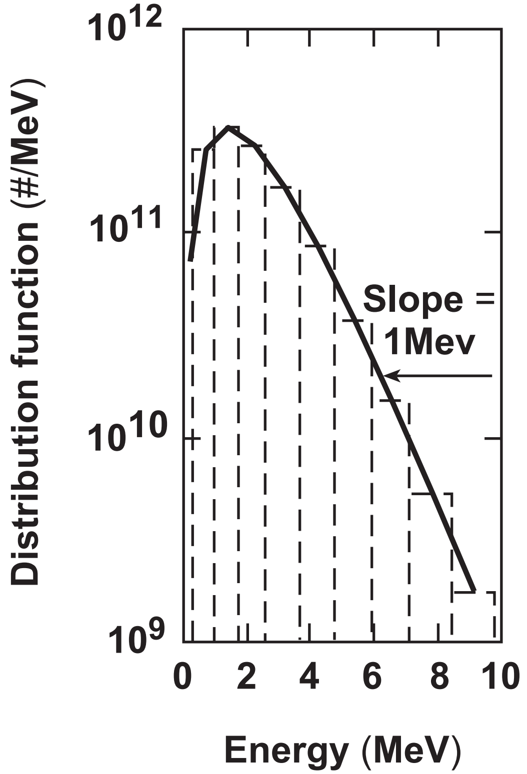
* S. C. Wilks *et al*, Phys. Rev. Lett. 9, 1383 (1992)

The electron source is a one-dimensional Maxwellian distribution based on simulations by Wilks*

2.5 kJ, 20-μm radius, 10-ps FWHM



1-MeV electron distribution with simulation grouping



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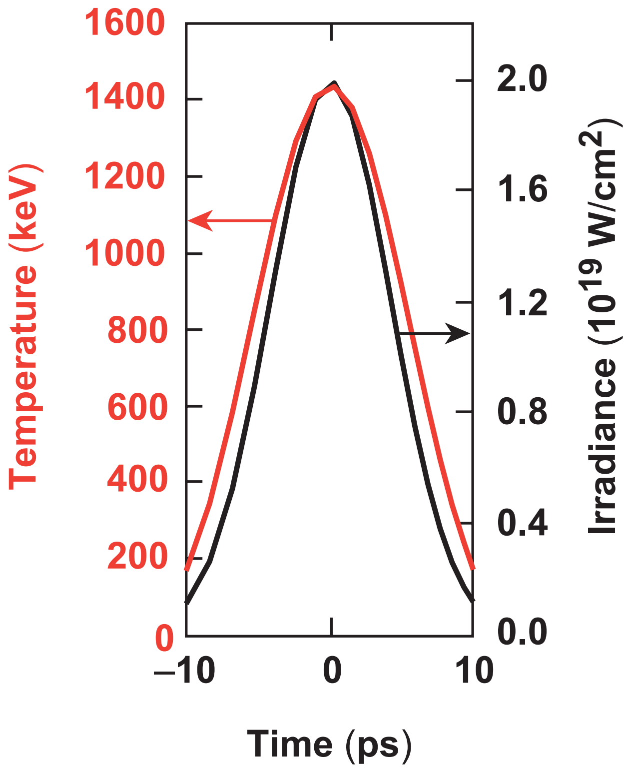

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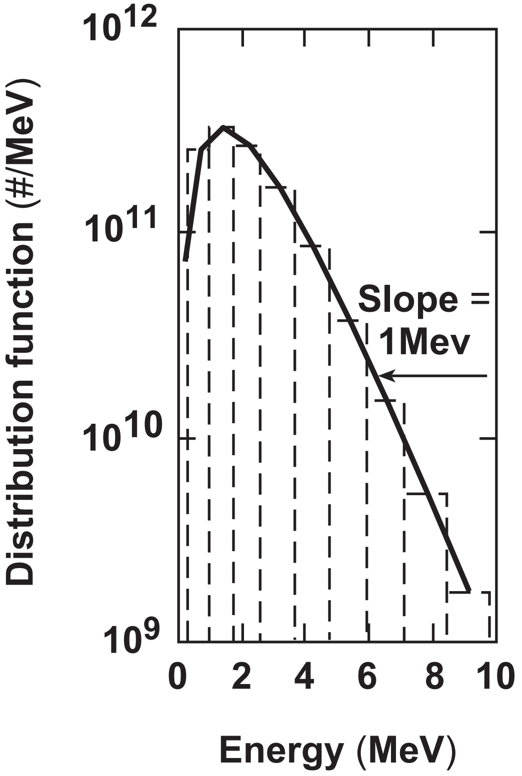
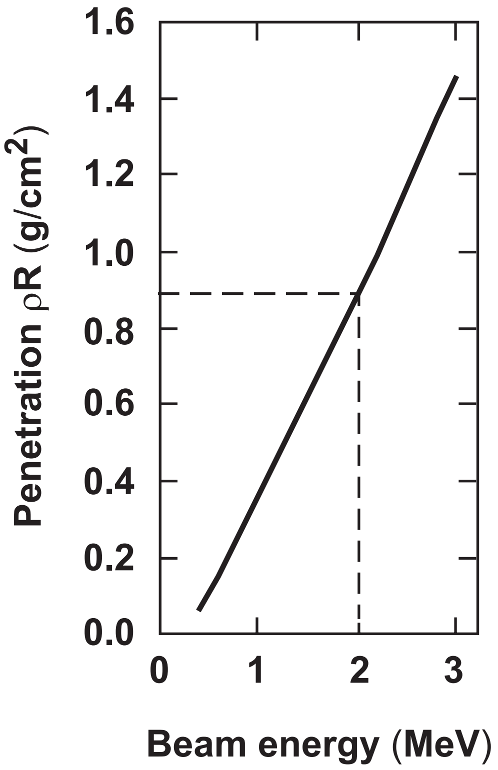


Penetration depth 300 g/cm^3, 5 keV



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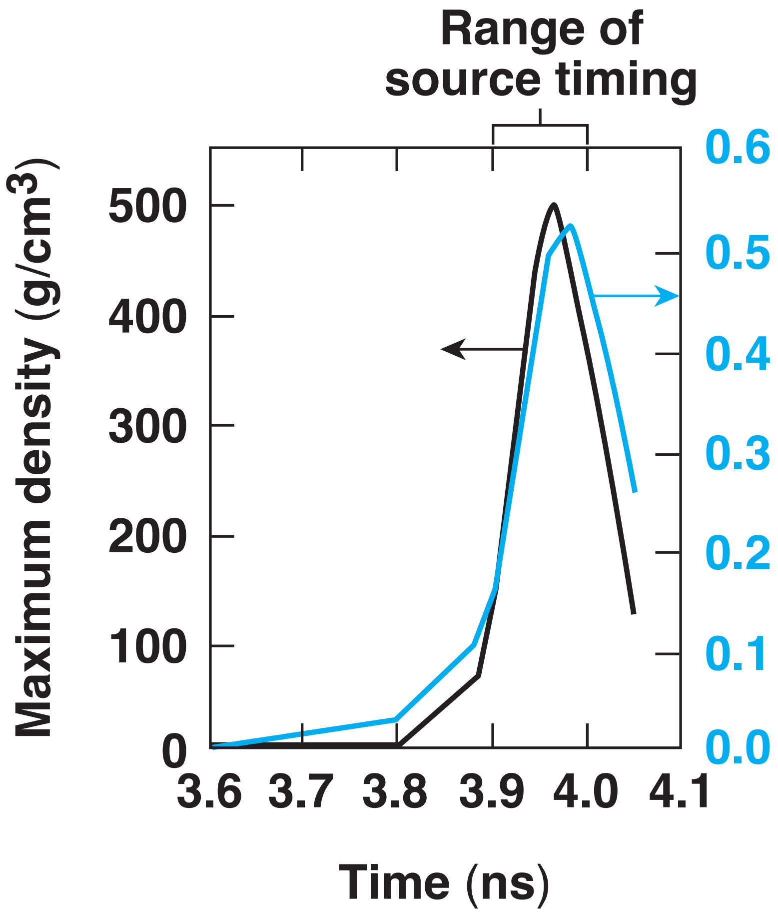
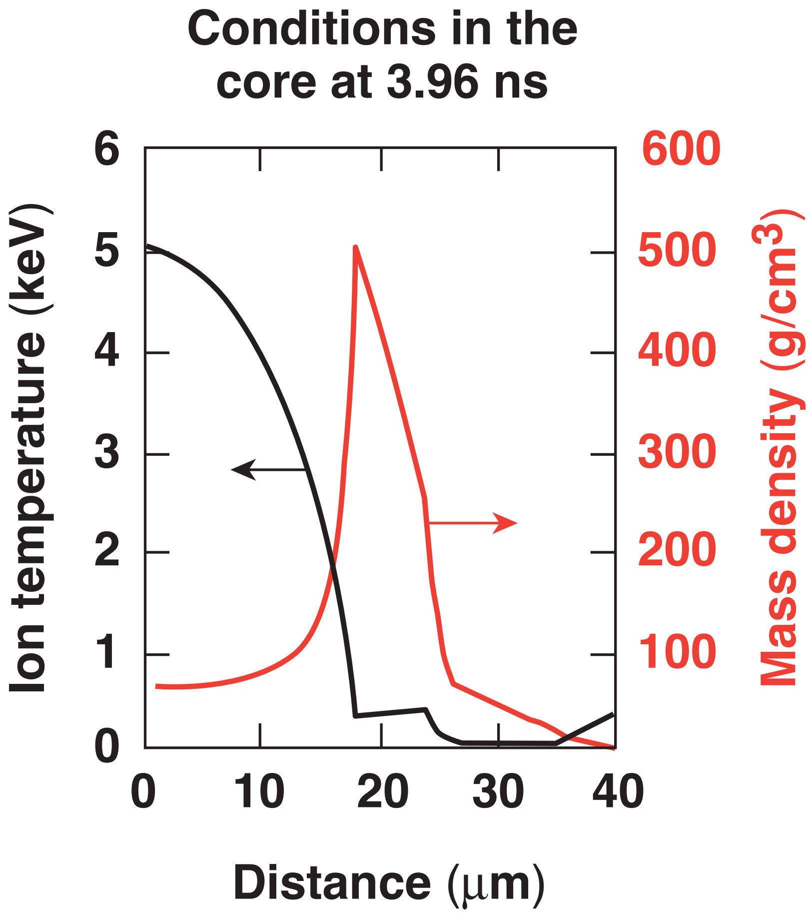
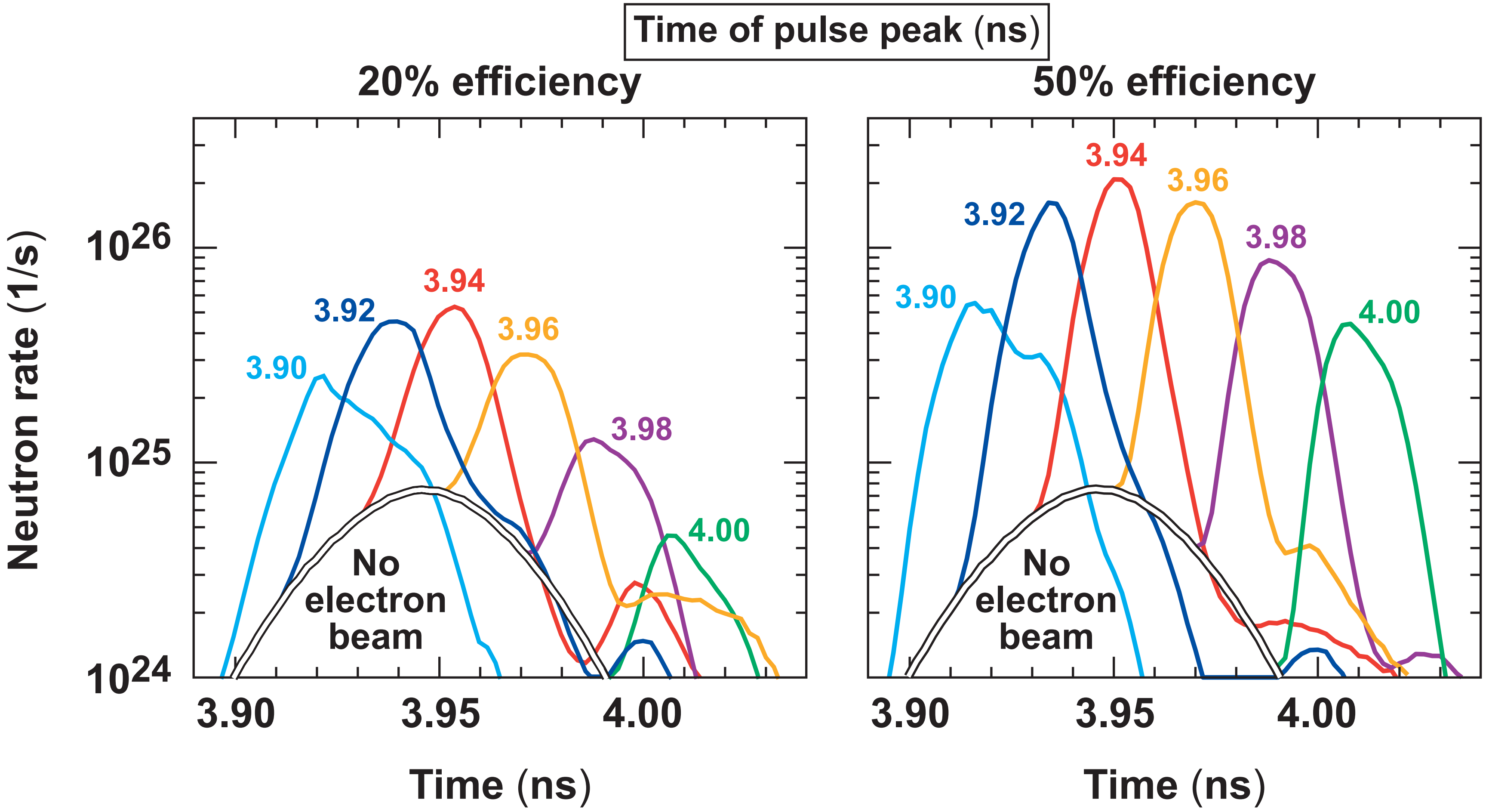
A target and pulse were designed to reach the ρR needed to stop most electrons



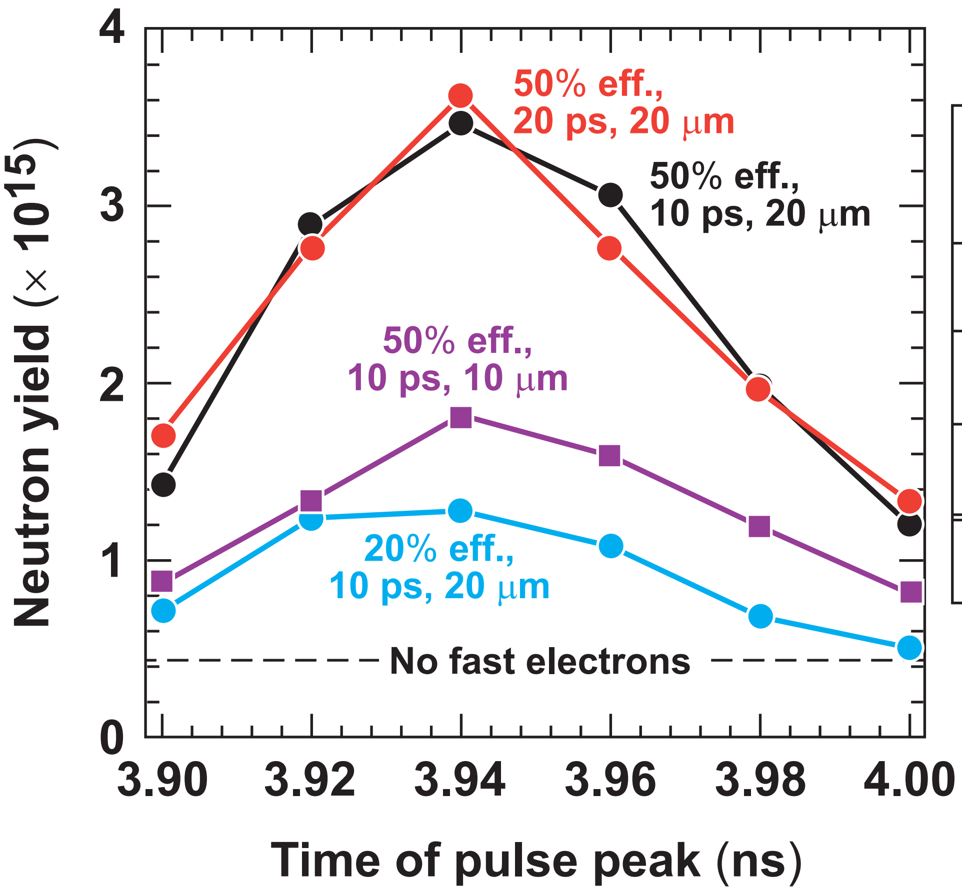


The high-intensity laser pulse increases the neutron rate at least an order of magnitude



2.5 kJ, 10-ps FWHM, 20-μm radius

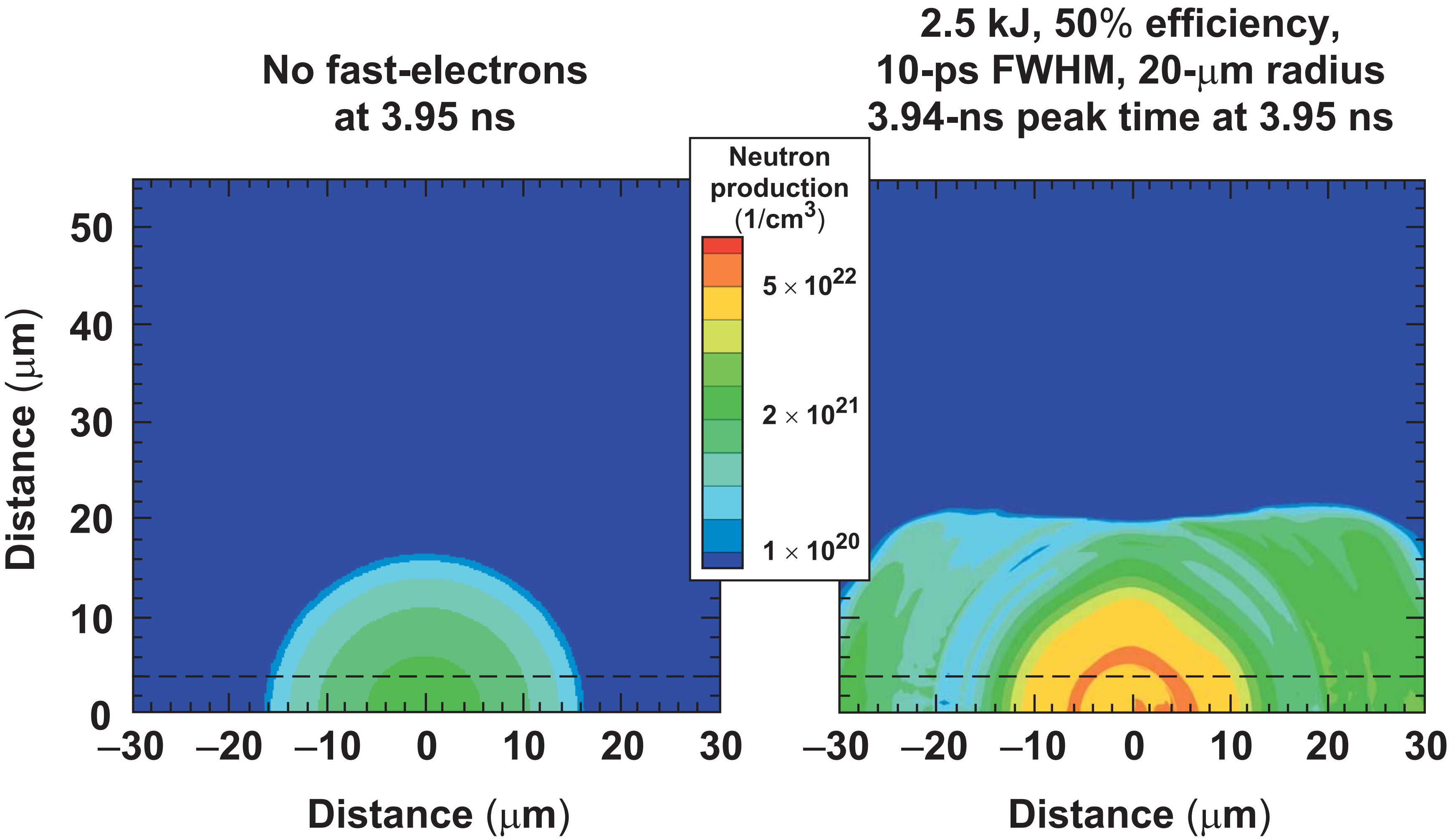
The neutron yield remains within a factor of two in about a 100-ps range for the pulse timing



Peak intensity (W/cm^2)	Energy deposited* (kJ)
1×10^{19}	1.00 (40%)
2×10^{19}	0.79 (32%)
8×10^{19}	0.30 (12%)
2×10^{19}	0.32 (13%)

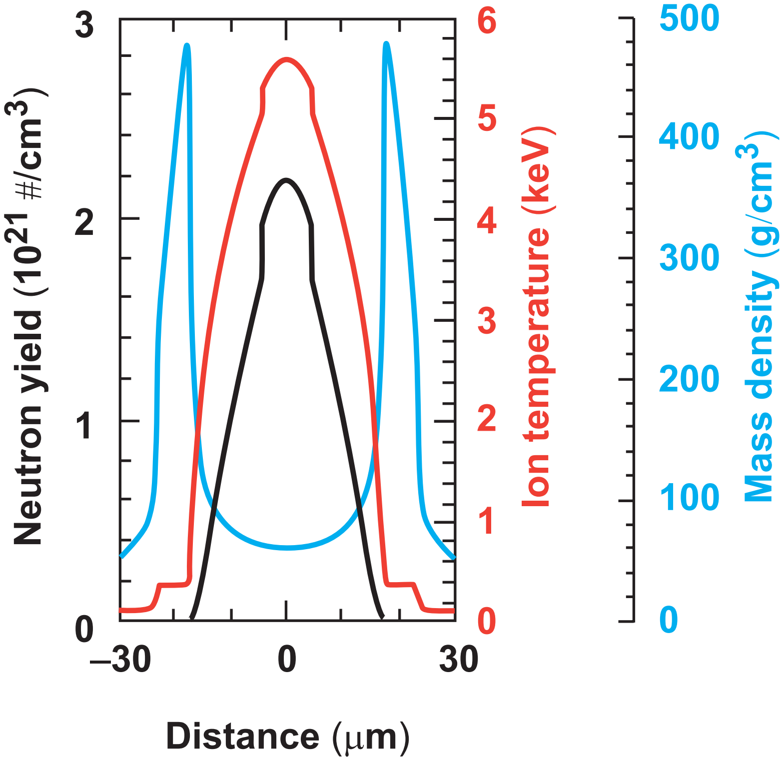
*3.94-ns case

The electron pulse increases the neutron production in both the hot core and the high density shell

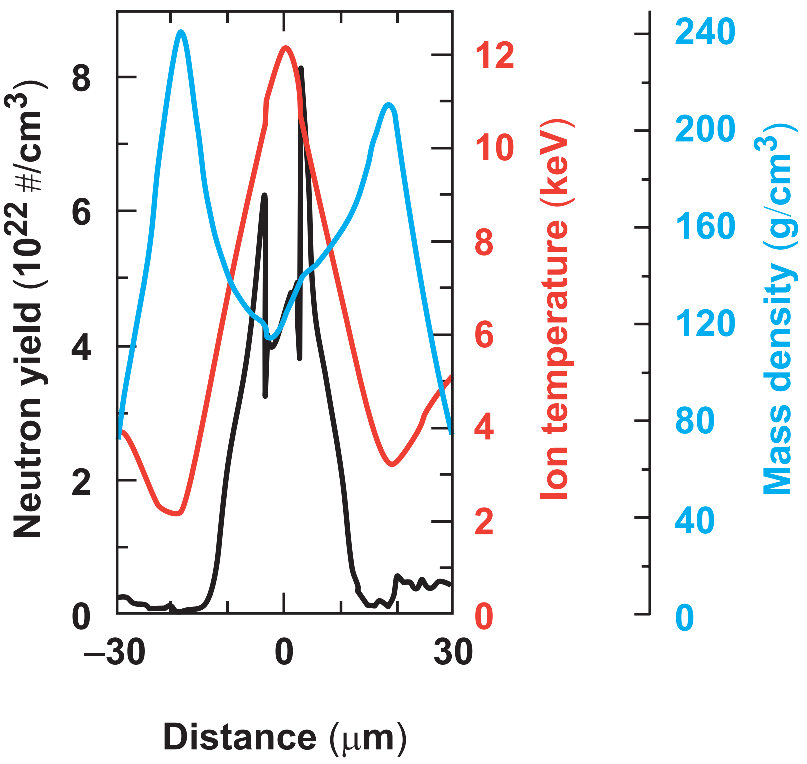


Lineouts show the increase in temperature and density inside the core, resulting in an increased yield

No electron beam

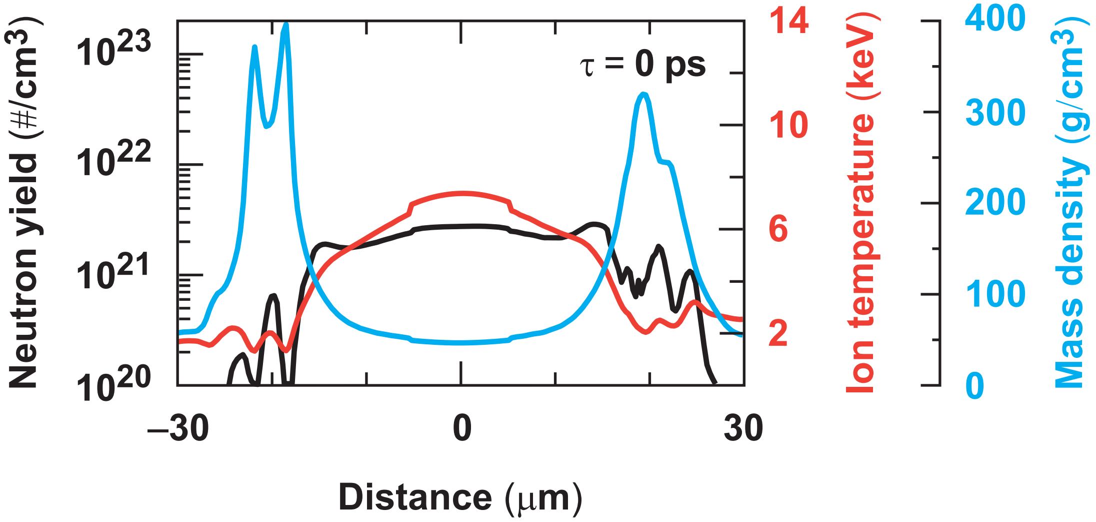


With electron beam



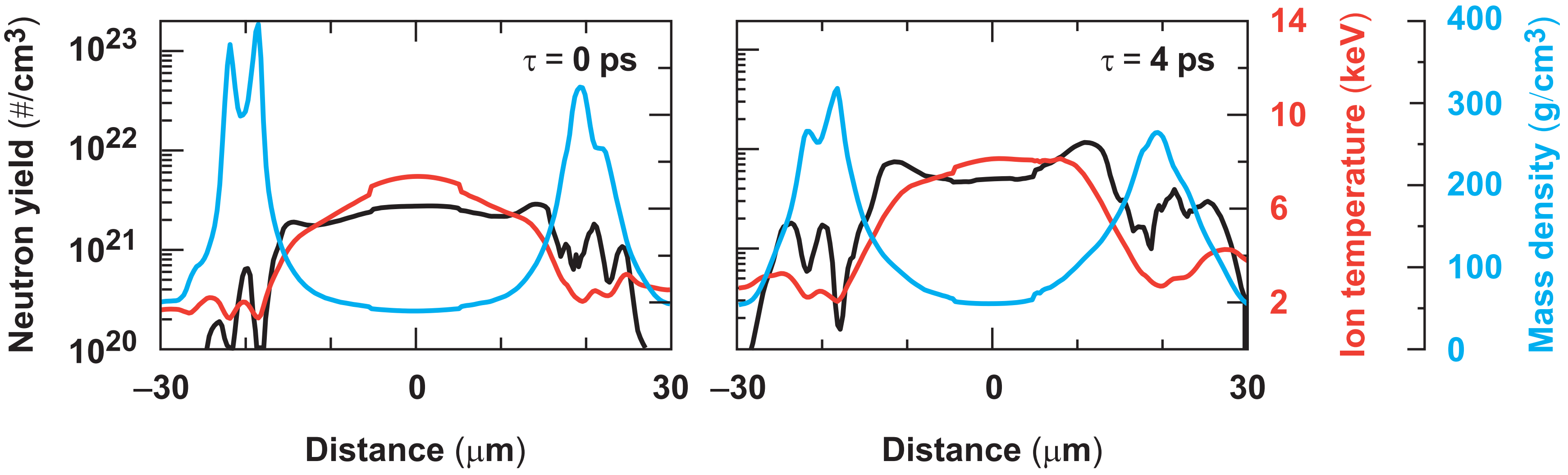
Lineouts taken 4 μm from target center at 3.95 ns, time of peak neutron production for both the no-electron pulse case and the 10-ps pulse timed at 3.94 ns

The heated shell explodes, producing a hotter and denser core



Lineouts at 4 μm; time with respect to the peak of the 10-ps pulse timed at 3.94 ns

The heated shell explodes, producing a hotter and denser core



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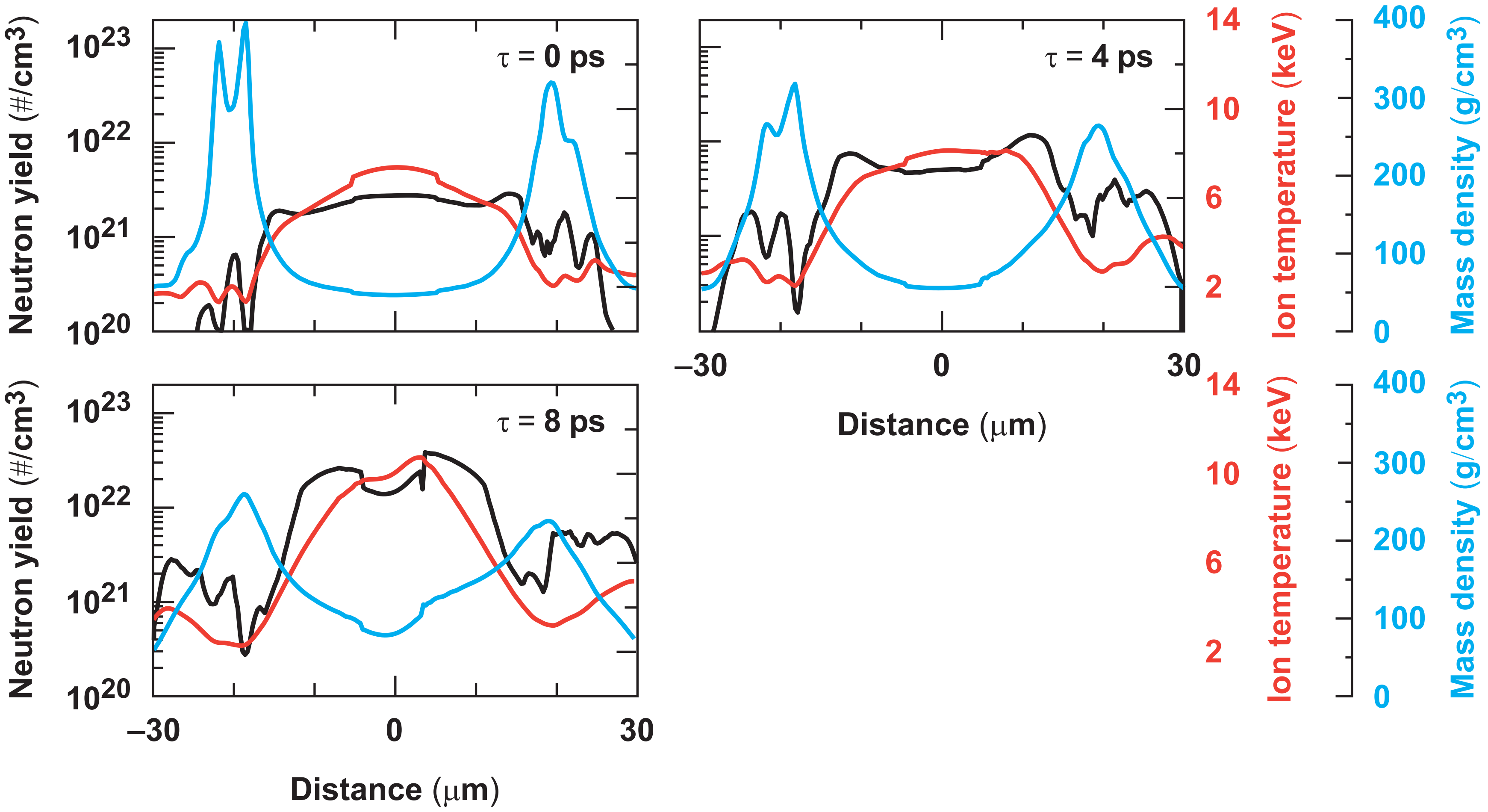

Lineouts at 4 µm; time with respect to the peak of the 10-ps pulse timed at 3.94 ns

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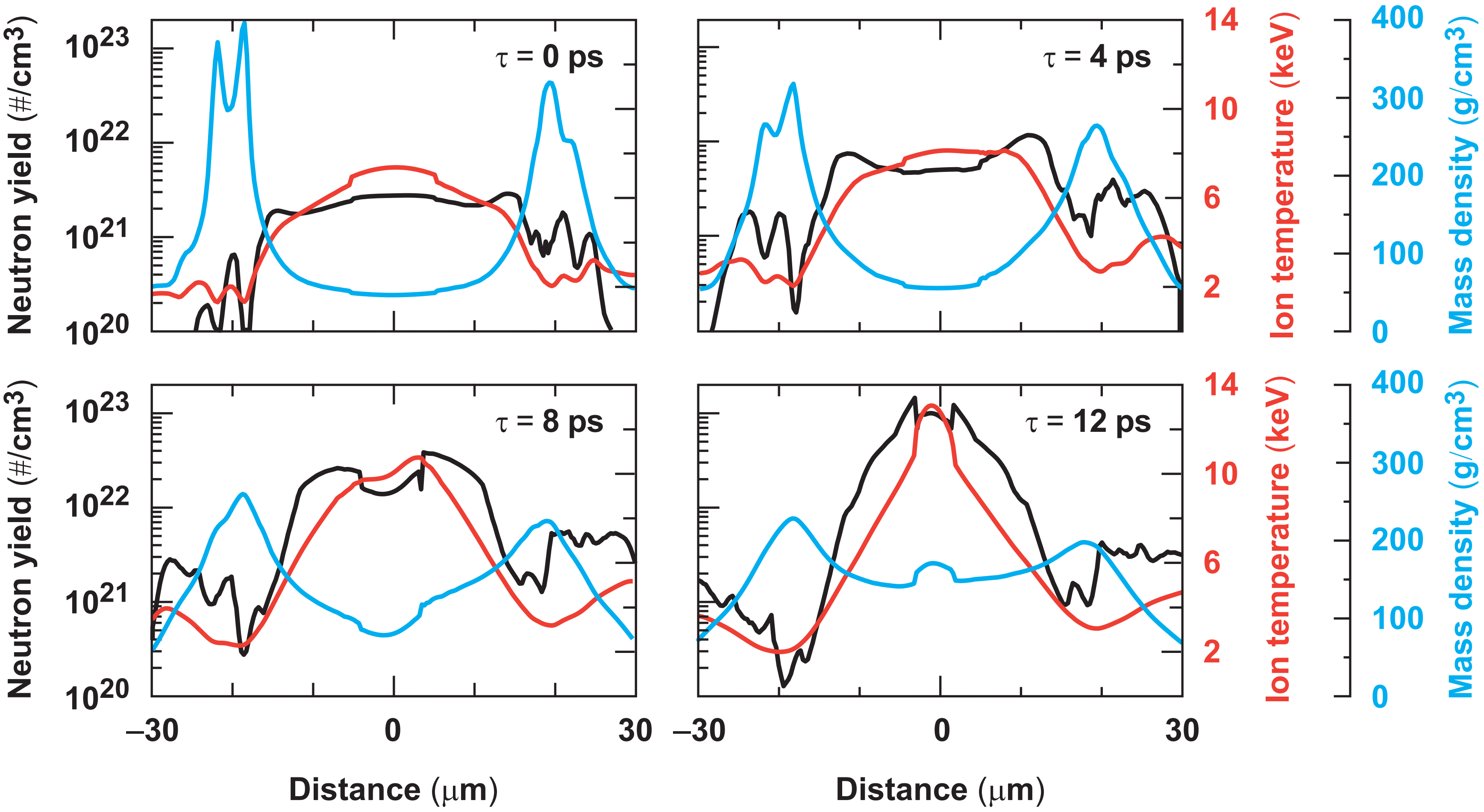
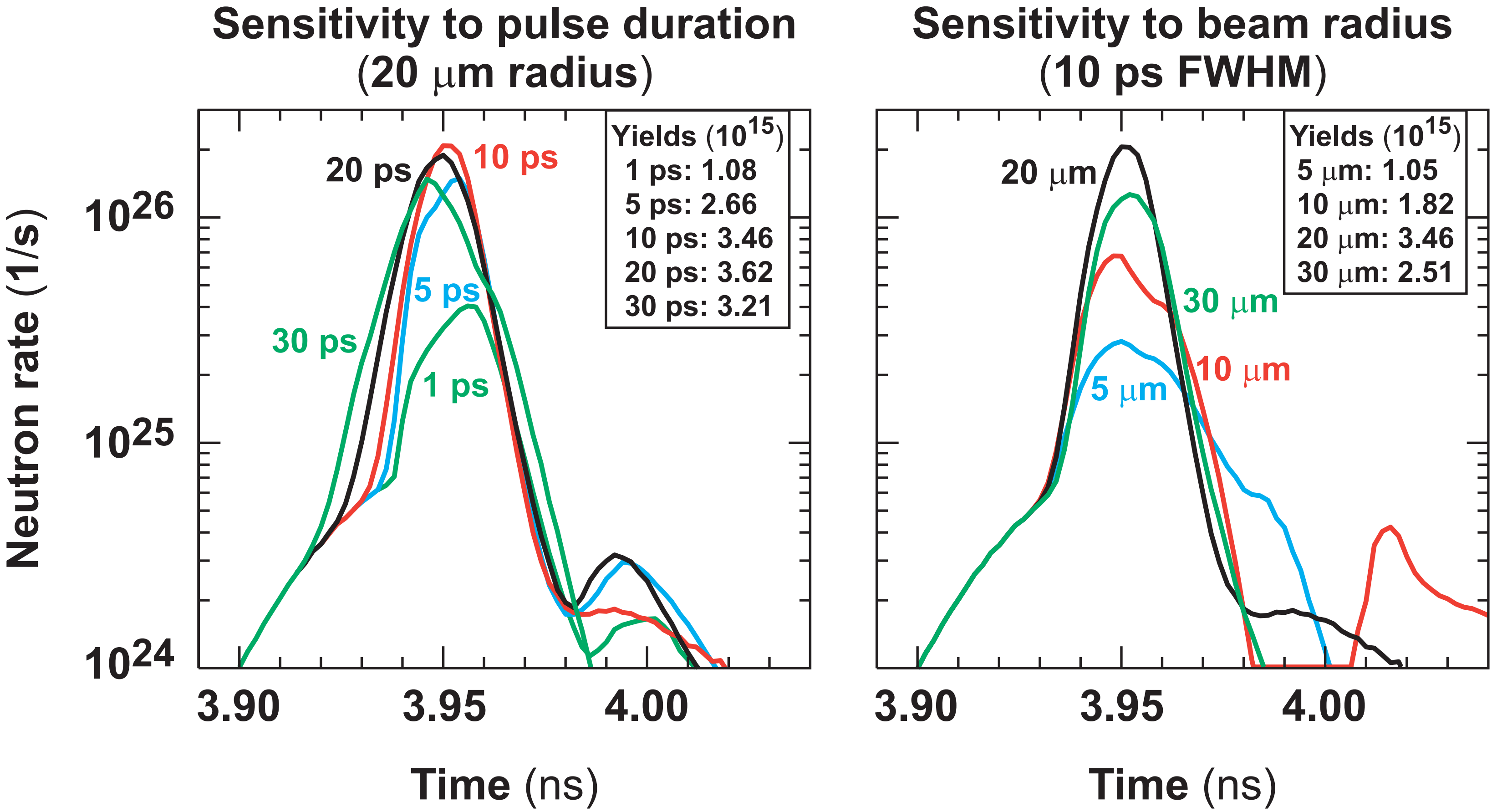


Lineouts at 4 μm; time with respect to the peak of the 10-ps pulse timed at 3.94 ns

The neutron yield is more sensitive to the beam radius than to the pulse duration



2.5 kJ, 50% efficiency, 3.94 ns pulse timing

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Summary/Conclusions

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- Near stagnation, the cold fuel heated by the electrons explodes and creates a dense and hot core.
- The total DT yield reaches over 3×10^{15}, permitting the development of near-ignition neutron diagnostics for the NIF.
- Future improvements to the model will include electric fields and a return current Joule heating.