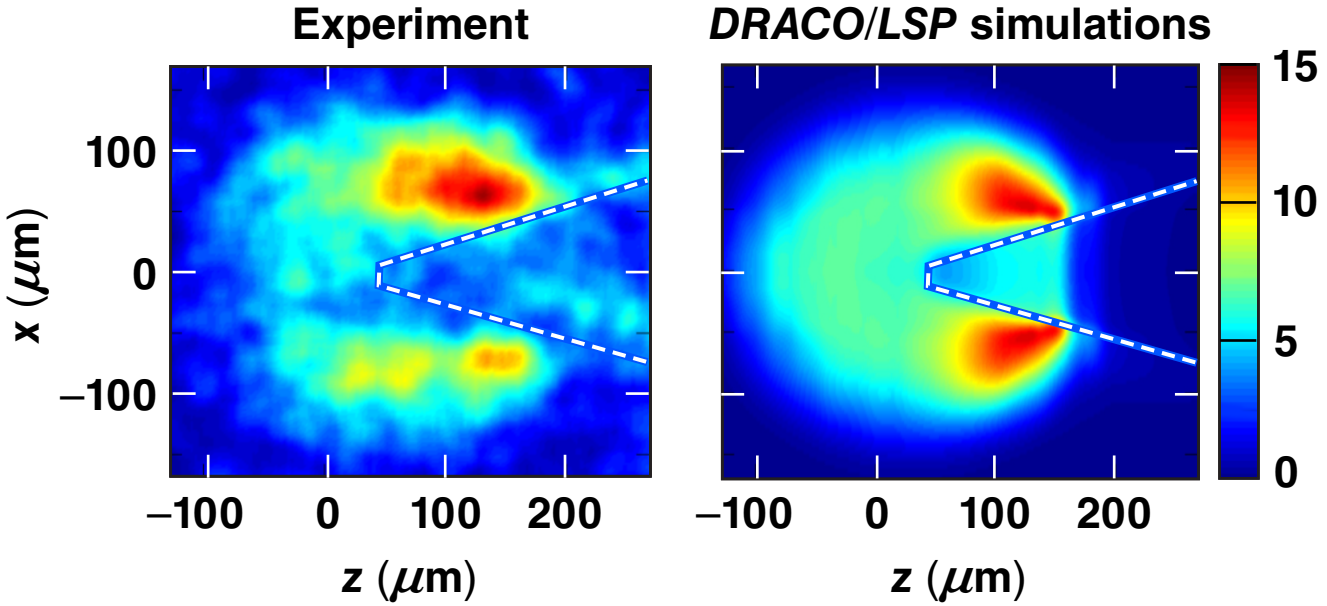
Simulations of Integrated Fast-Ignition Experiments on OMEGA

Fast-electron–induced Cu K_α emission [$\times 10^{13}$ photons/(sr $\times$ cm^2)]



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44th Annual Anomalous Absorption Conference
Estes Park, CO
8–13 June 2014

Summary

Performance of cone-in-shell fast-ignition targets is studied using *DRACO**/*LSP*** integrated simulations

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- *DRACO* simulations of cone-in-shell implosions have been confirmed by 8.05-keV flash radiography and shock-breakout measurements
- *LSP* simulations explain the fast-electron transport in the integrated OMEGA experiments using Cu-doped plastic shells
  - fast-electron–induced Cu K_α x-ray yield and spatial distribution are confirmed
  - a coupling efficiency of 4% to 7% of the fast-electron energy to the core is inferred

* P. B. Radha *et al*., Phys. Plasmas 12, 056307 (2005).
** D. R. Welch *et al*., Phys. Plasmas 13, 063105 (2006).

TC11280

Collaborators

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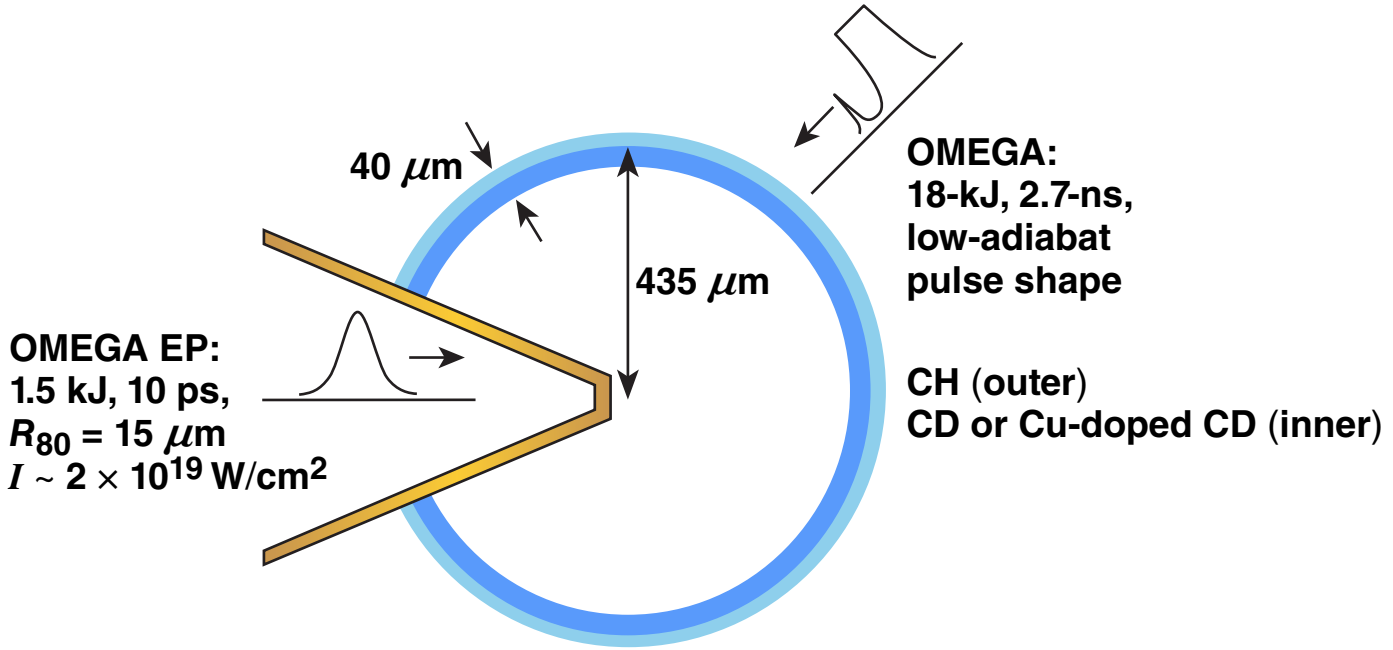
General Atomics

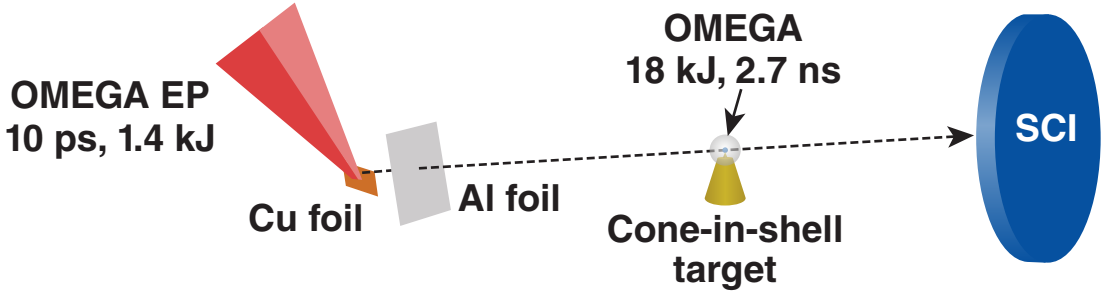
Integrated fast-ignition experiments with re-entrant cone-in-shell targets are performed at the Omega Laser Facility

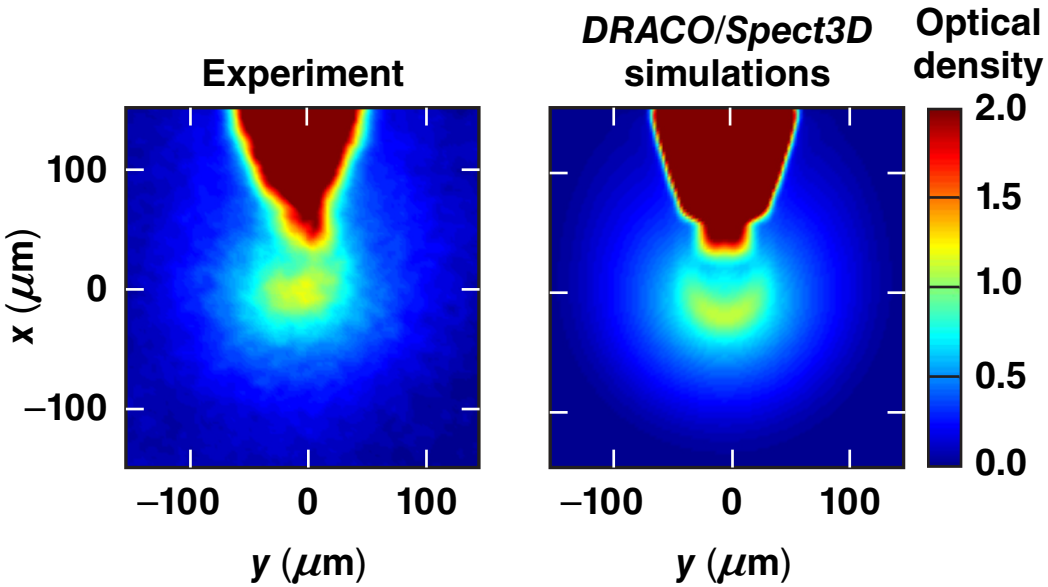


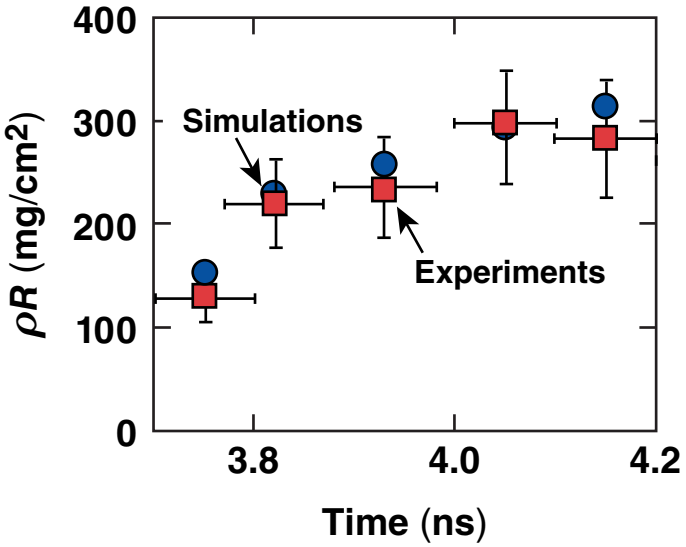
- A spherical crystal imager* (SCI) is used to obtain a spatial distribution of Cu K_α x rays induced by fast electrons in the imploded core

*C. Stoeckl *et al.*, Rev. Sci. Instrum. 83, 10E501 (2012).

DRACO simulations have been confirmed by 8.05-keV, Cu-K_α flash radiography and shock-breakout measurements*







- Cone-tip breakout time agrees in the experiments and simulations but is ~200 to 300 ps before the peak compression time

* W. Theobald, A. A. Solodov, *et al.*, "Time-Resolved Compression of a Spherical Shell with Re-Entrant Cone to High Areal Density for Fast-Ignition Laser Fusion," submitted to Nature Communications.

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Based on *DRACO*, the fuel assembly can be improved by optimizing the compression pulse and evacuating air from the shell

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- Air removal reduces the mass of the hot spot and the pressure on the cone tip; the fuel stagnates closer to the target center
- Compression pulse picket is optimized
  - picket power is reduced to account for an increased absorption (~50%) predicted by the nonlocal thermal transport model*
  - with an optimized picket, the shell implodes on a lower adiabat and less fuel is injected by the shocks into the hot spot

Gas pressure	Picket	Cone tip	Δt_{break} (ps)	ρR_{break} (mg/cm^2)	ρR_{max} (mg/cm^2)
0.8-atm air	Current	15-μm Au	–300	80	300
Vacuum	Optimized	15-μm Au	–140	360	600
Vacuum	Optimized	60-μm Al	–80	500	600

*V. N. Goncharov *et al.*, Phys. Plasmas 15, 056310 (2008).

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The core density increases at the time of cone-tip breakout

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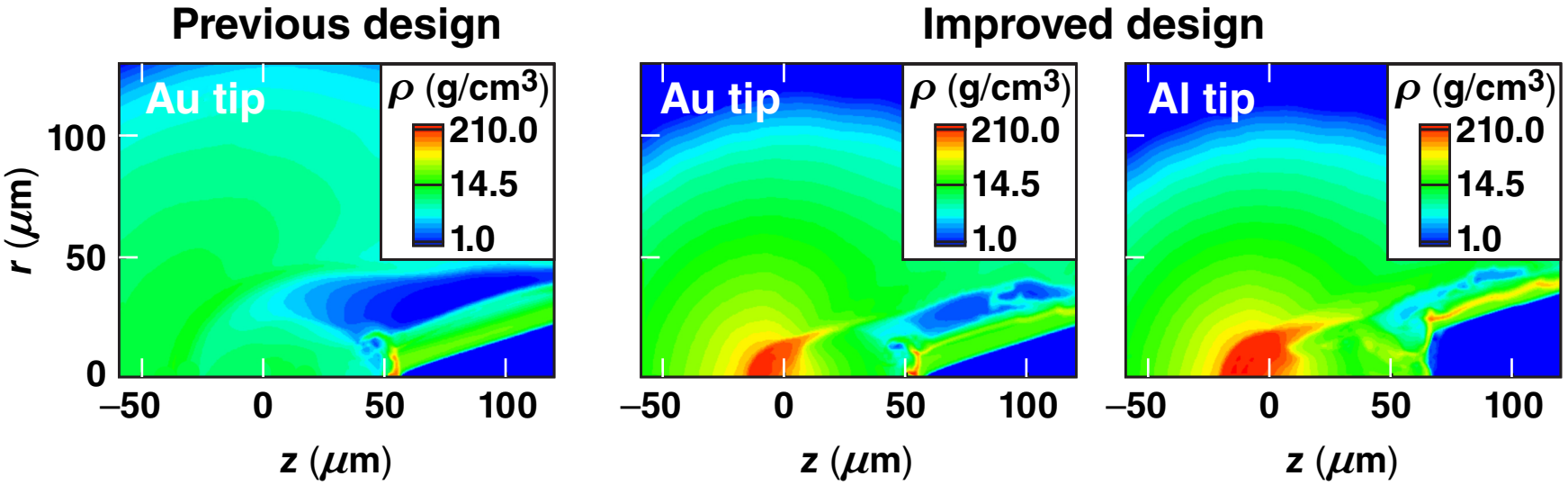
DRACO simulations at cone-tip breakout



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CD shells with Cu dopant have been used to characterize the transport of fast electrons in the integrated experiments*

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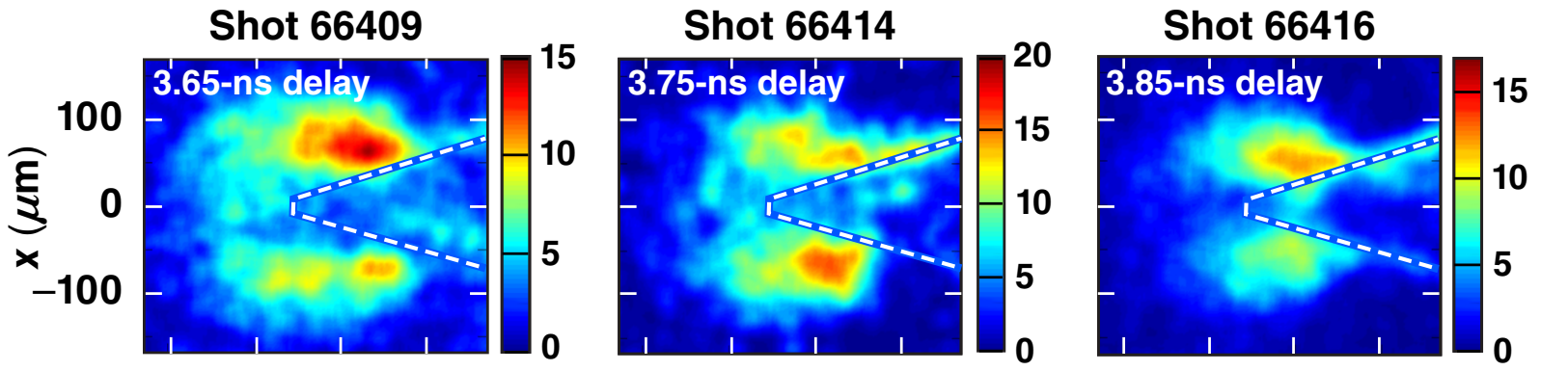
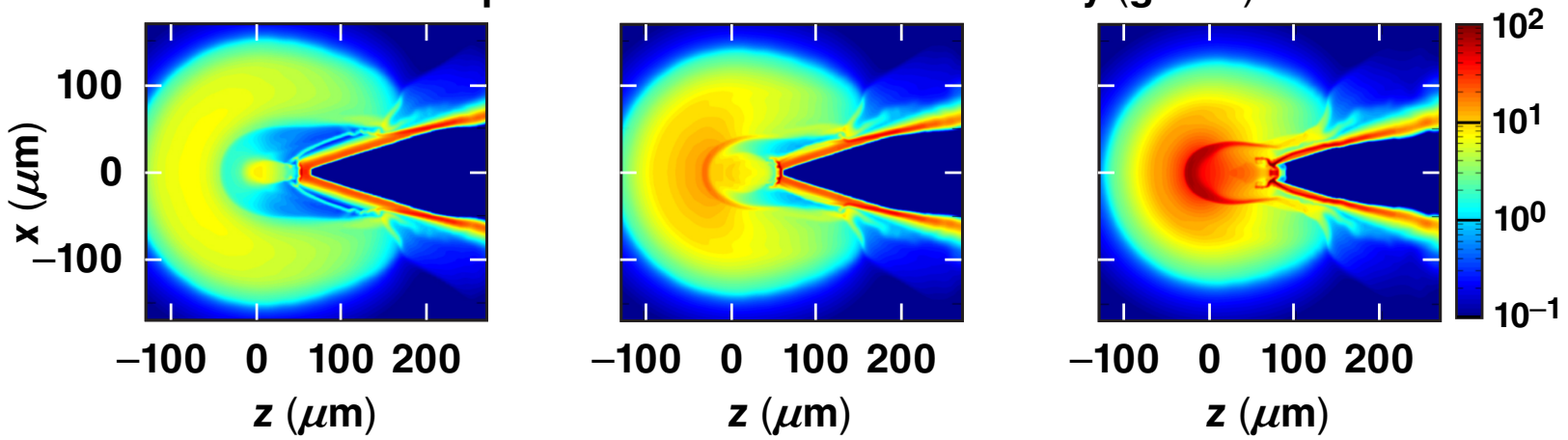
Fast-electron–induced Cu K_α emission at three times [$\times 10^{13}$ photons/(sr $\times$ cm^2)]



***DRACO* predictions for the mass density (g/cm^3)**



- E_{EP} = 500 J, τ = 10 ps, E_{pre} = 20 mJ (low contrast)

*C. Jarrott *et al.*, this conference

TC11284

LSP simulations of fast-electron transport in the implosion plasma have been performed

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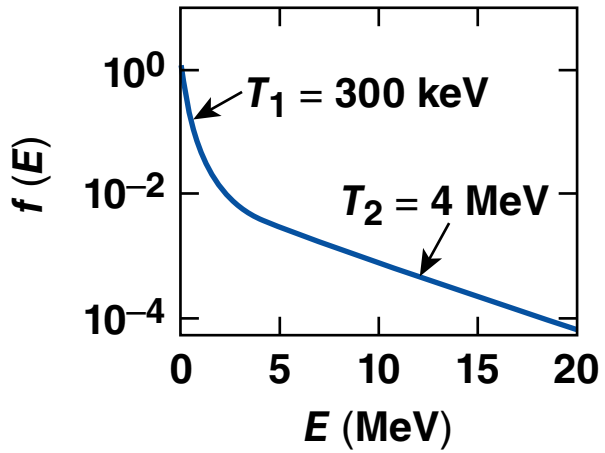
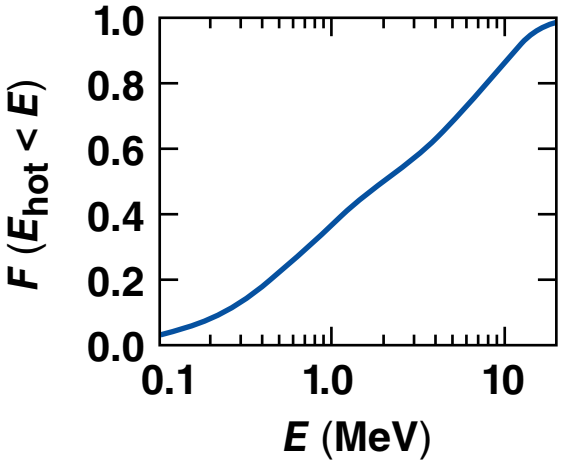
- The energy spectrum of fast electrons is predicted by particle-in-cell (PIC) simulations* of OMEGA EP pulse propagation in the laser pre-plasma





- An isotropic fast-electron angular distribution is assumed
- Fast-electron–induced Cu K_α emission and propagation through the imploded core is modeled**
- The total energy of fast electrons is inferred from comparison of the K_α yield in the experiment and simulations: 30% of E_{EP} = 500 J

*B. Qiao *et al.*, Bull. Am. Phys. Soc. 58, 373 (2013); J. Li *et al.*, Phys. Plasmas 20, 052706 (2013).
**Plasma temperature-dependent collection efficiency of the SCI is calculated using *PrismSPECT*, Prism Computational Sciences, Inc., Madison, WI 53711.

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LSP simulates the fast-electron transport and Cu K_α emission

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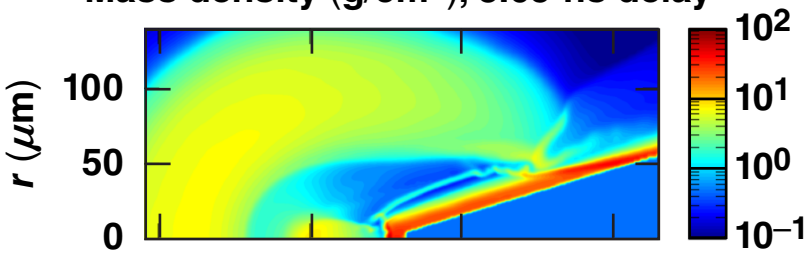
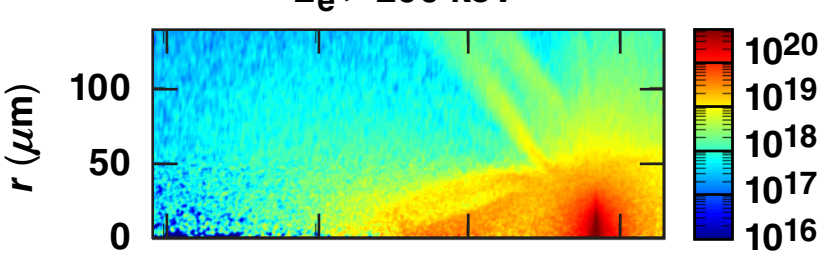
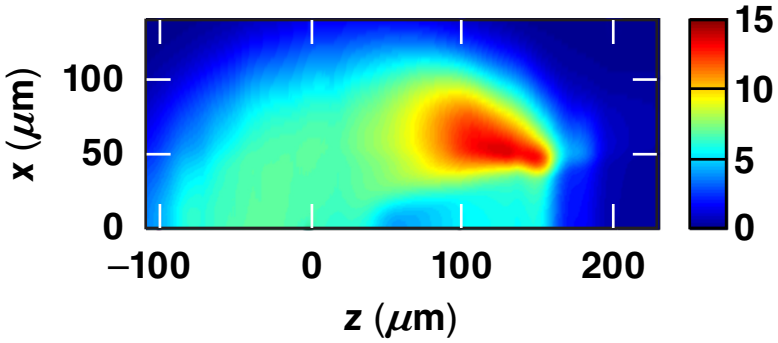
Mass density (g/cm^3), 3.65-ns delay



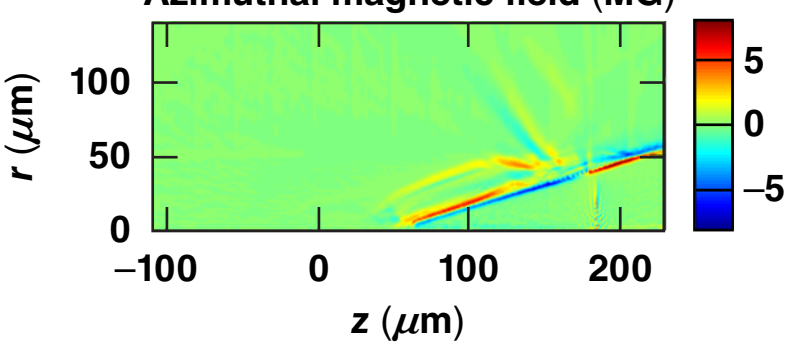
Fast-electron density (cm^{-3}), E_e > 200 keV



K_α SCI image [×10^{13} photons/(sr × cm^2)]



Azimuthal magnetic field (MG)



- 3.8 % of the total fast-electron energy is coupled to the core (ρ_{CD} > 1 g/cm^3)
  - large distance from the source to the core
  - large divergence
  - hard fast-electron spectrum

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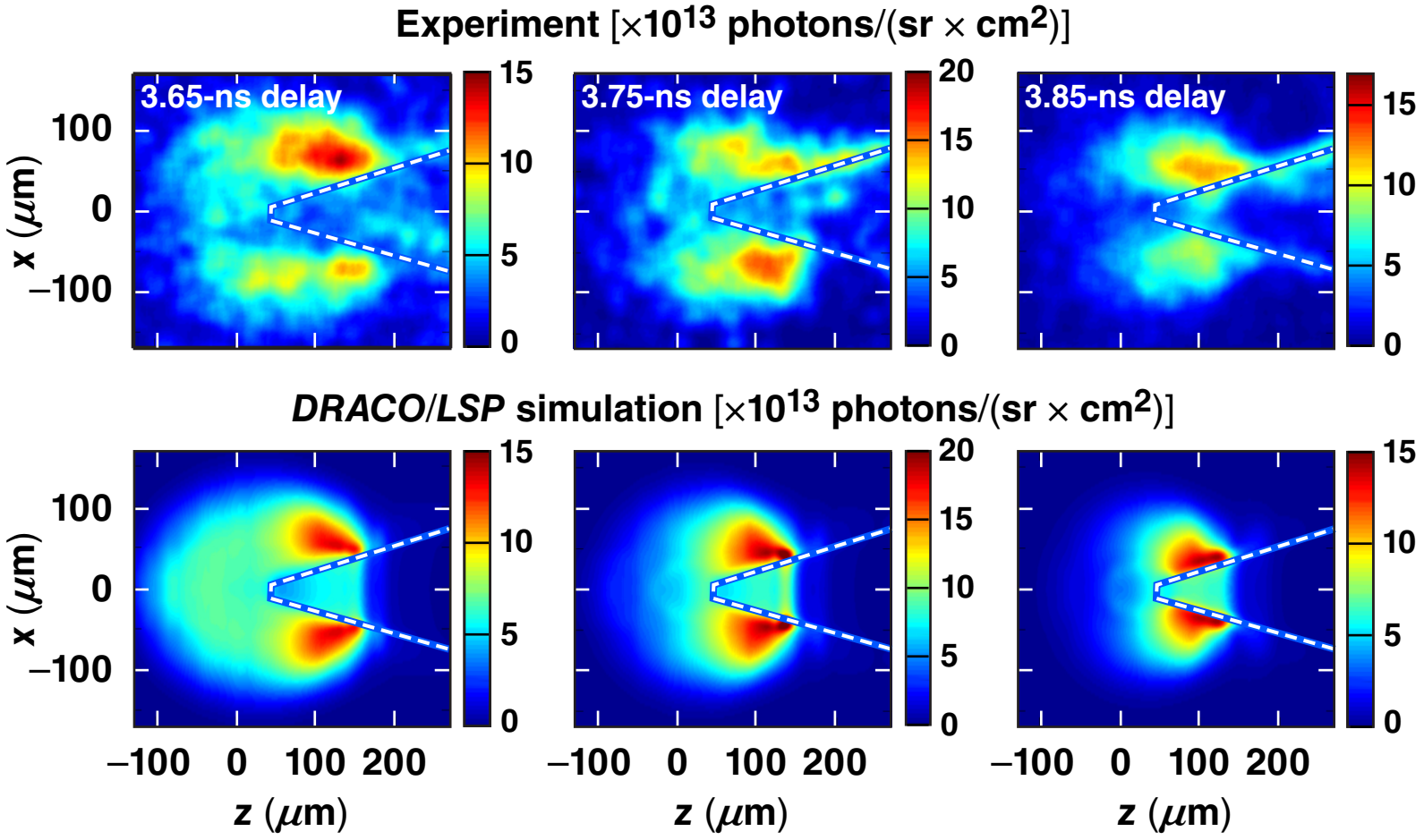
K_α emission images agree in the experiments and simulations



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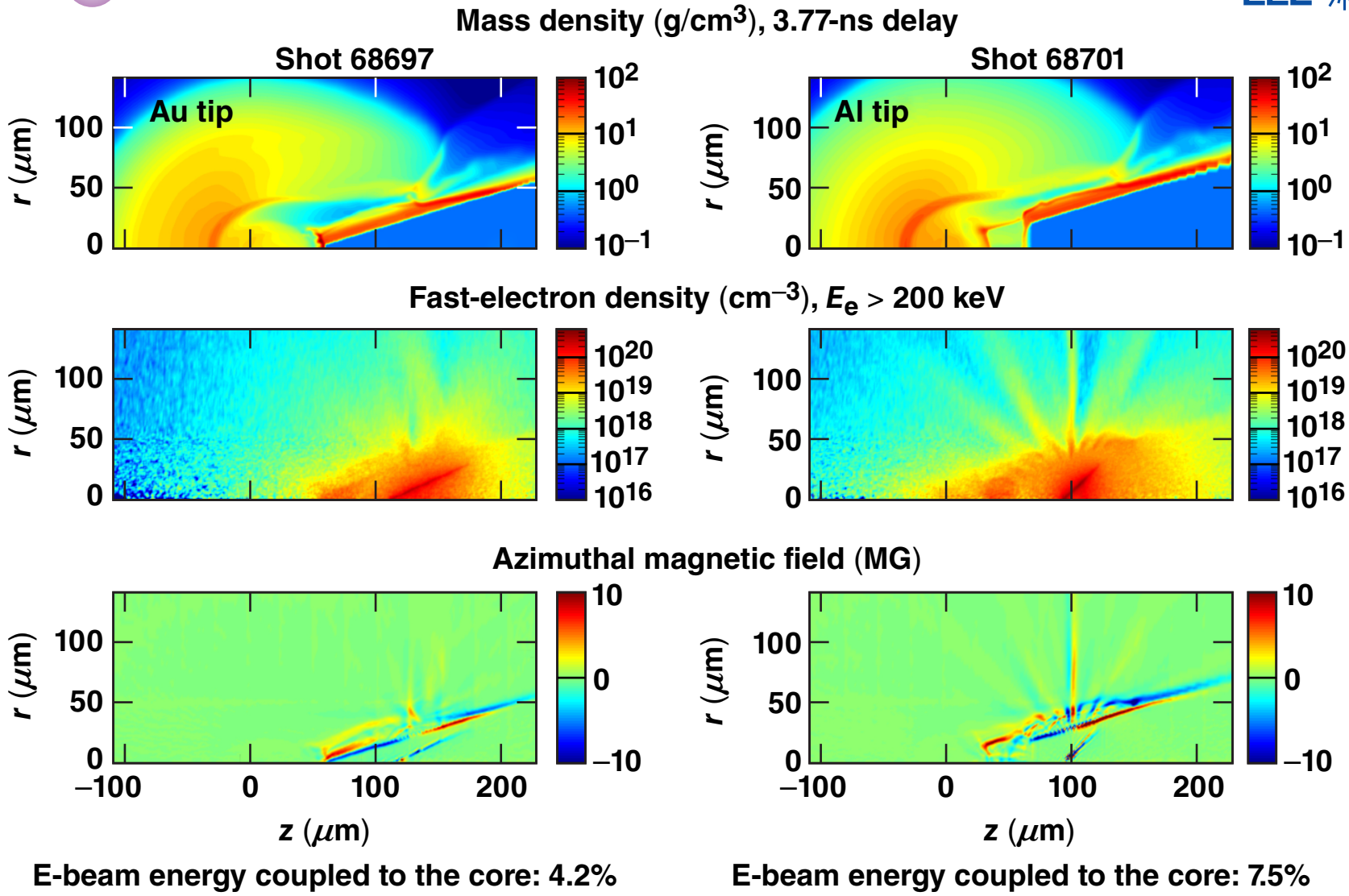
A larger coupling efficiency is obtained in a high-contrast OMEGA EP shot with an Al-tipped cone target



E-beam energy coupled to the core: 4.2%

E-beam energy coupled to the core: 7.5%

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K_α-emission images agree in the experiments and simulations for Au and Al cone tip targets

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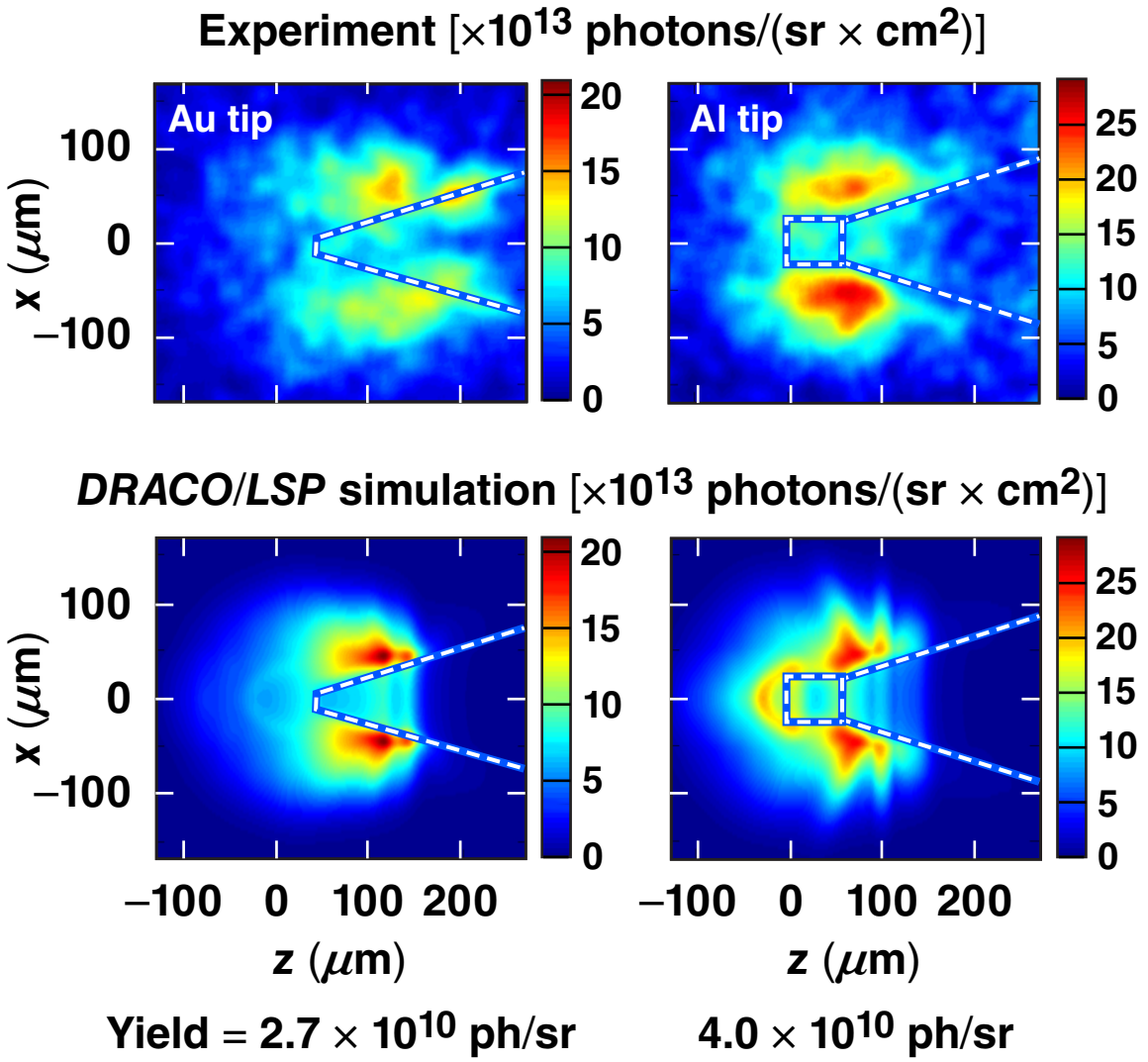

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Summary/Conclusions

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