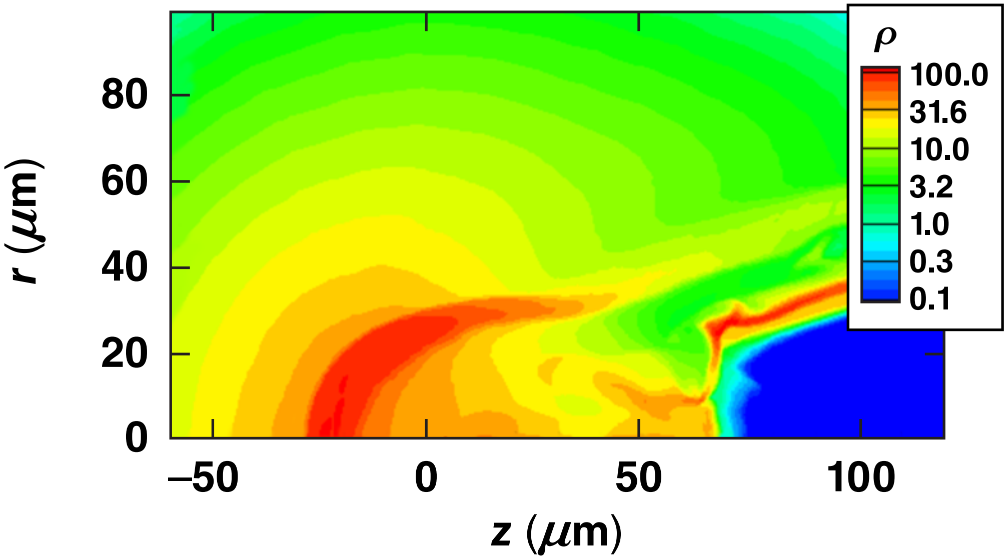
Simulations of Cone-in-Shell Targets for Integrated Fast-Ignition Experiments on OMEGA

Mass density (in g/cm^3) at the time of cone-tip breakout in the simulation of an Al-tip cone-in-shell target



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Absorption Conference
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Summary

DRACO–LSP*** simulations suggest a good performance of new Al-tipped cone-in-shell targets

- A new Al-tip target promises a better shock resilience (~100 ps later cone-tip breakout) than the previous Au-tip target
- Fast-electron transport is improved by reducing the scattering losses and implementing resistive collimation
- Coupling efficiency of 4% to 12% of the petawatt laser pulse energy to the core is inferred from the simulations
- A neutron yield increase of 10^7–10^8 caused by fast electrons is predicted

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

Collaborators

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R. B. Stephens

General Atomics

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

Target

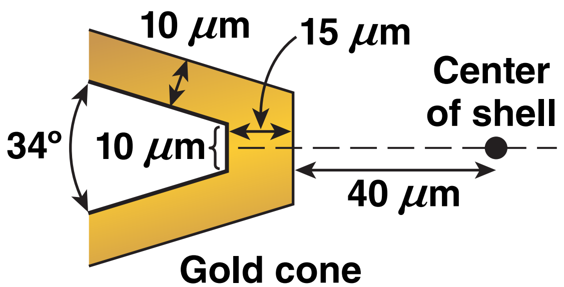
Shell material	CD
Shell diameter	~870 μm
Shell thickness	~40 μm

Compression pulse

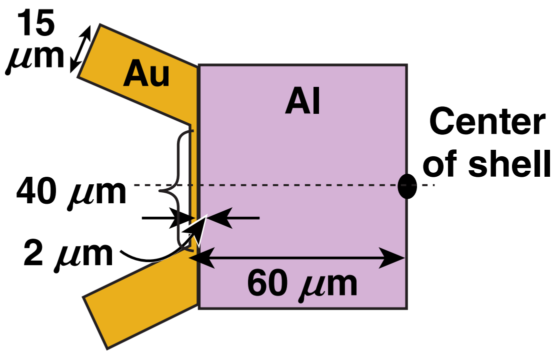
Energy	~18 kJ (54 beams)
Pulse shape	Low-adiabat, $\alpha \simeq 1.5$
Pulse duration	~3 ns

- Improved OMEGA EP laser performance is expected
  - energy E_{EP} = 1.5 to 2 kJ
  - focal spot R_{80} = 15 μm
  - prepulse energy E_{pre} < 1 mJ

Au cone-tip design



New Al cone tip design



Implosion of cone-in-shell targets is simulated using *DRACO** radiation–hydrodynamic code

- Simulates the implosion in 2-D cylindrically symmetric geometry
- Improvements over the last year
  - radiation transport is modeled
  - 3-D laser ray trace is included
  - the Eulerian hydrodynamic scheme is improved by using proper Coriolis force terms
  - laser cross-beam energy transfer** and nonlocal thermal transport*** are accounted for by reducing the absorption fraction as predicted by *LILAC***** simulations

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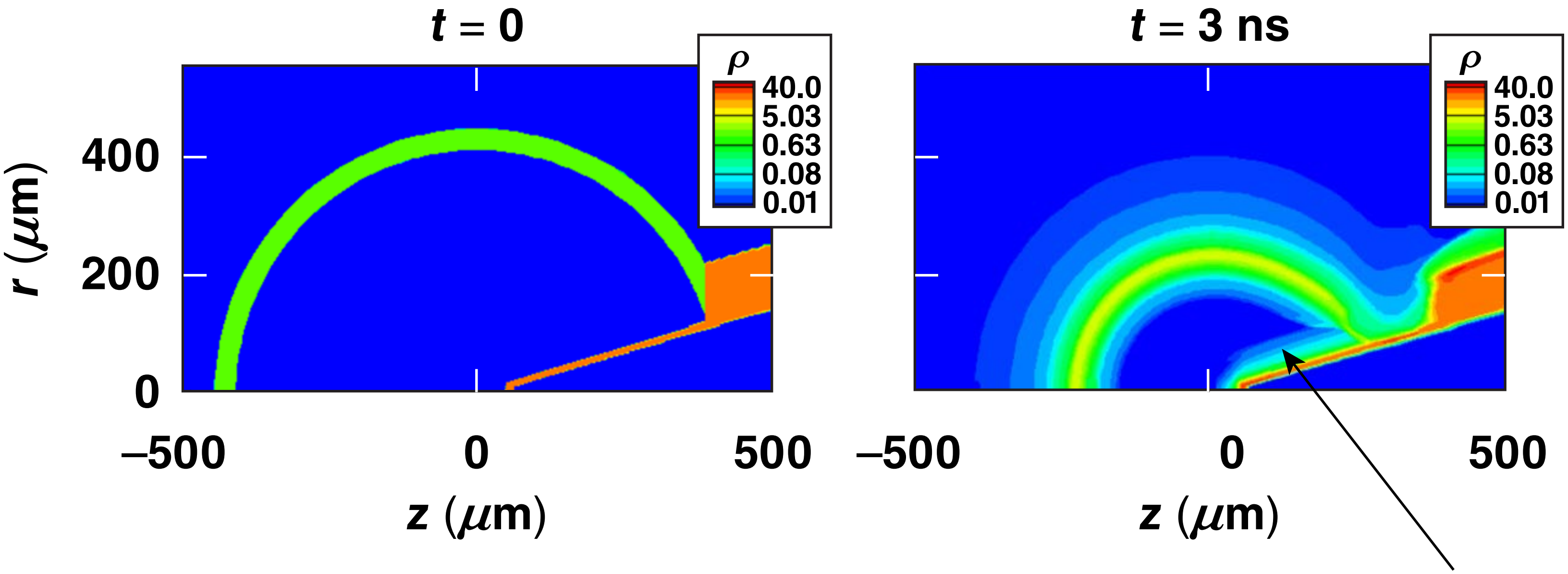
*R. B. Radha *et al*., Phys. Plasmas 12, 056307 (2005).
** I. V. Igumenshchev *et al*., Phys. Plasmas 19, 056314 (2012).
*** V. N. Goncharov *et al*., Phys. Plasmas 15, 056310 (2008).
**** J. Delettrez *et al*., Phys. Rev. A 36, 3926 (1987).

Simulations of Au cone-tip targets have been performed*

Mass density (g/cm^3)



Au plasma ablated from the cone wall by radiative preheat

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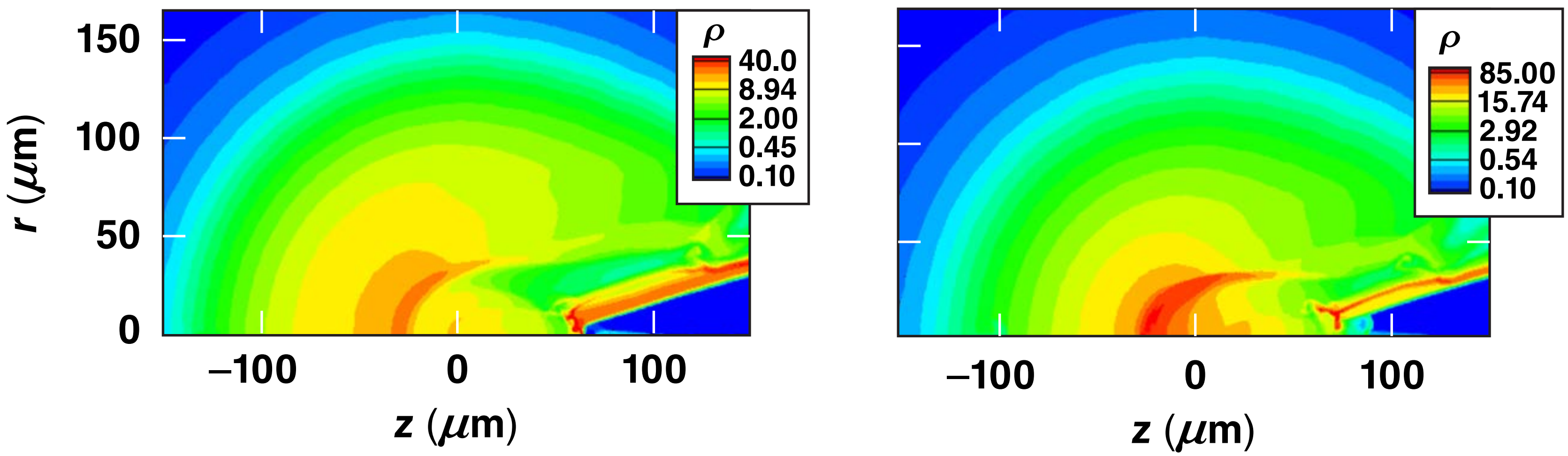
*Exact target specifications and OMEGA pulse shape for the UCSD/LLNL/LLE shot 63006 (July 2011) are used

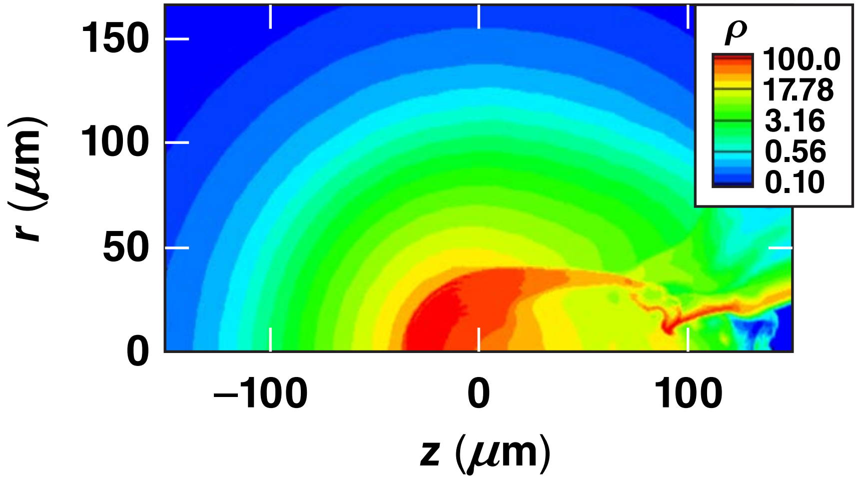
Cone tip breaks ~120 ps before the bang time, ~300 ps before the peak compression time

Mass density (g/cm^3)


t = 3.77 ns, cone-tip breakout

t = 3.89 ns, bang time

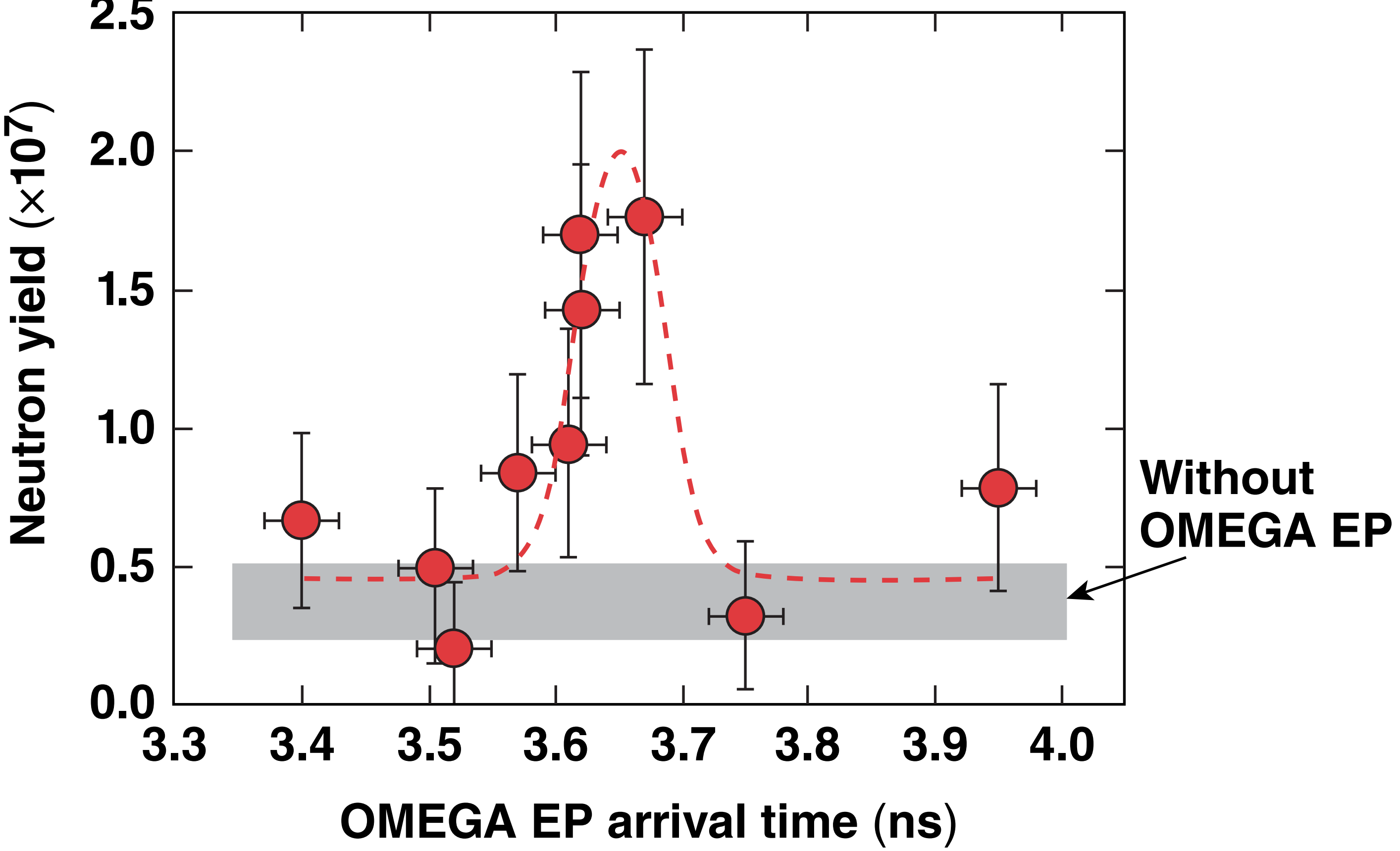
t = 4.07 ns, peak areal density



$(\rho R)_{max}$ = 0.45 g/cm^2

Cone-tip breakout probably limites the maximum neutron yield in previous integrated OMEGA experiments*

Neutron yield with OMEGA EP beam in OMEGA experiments*



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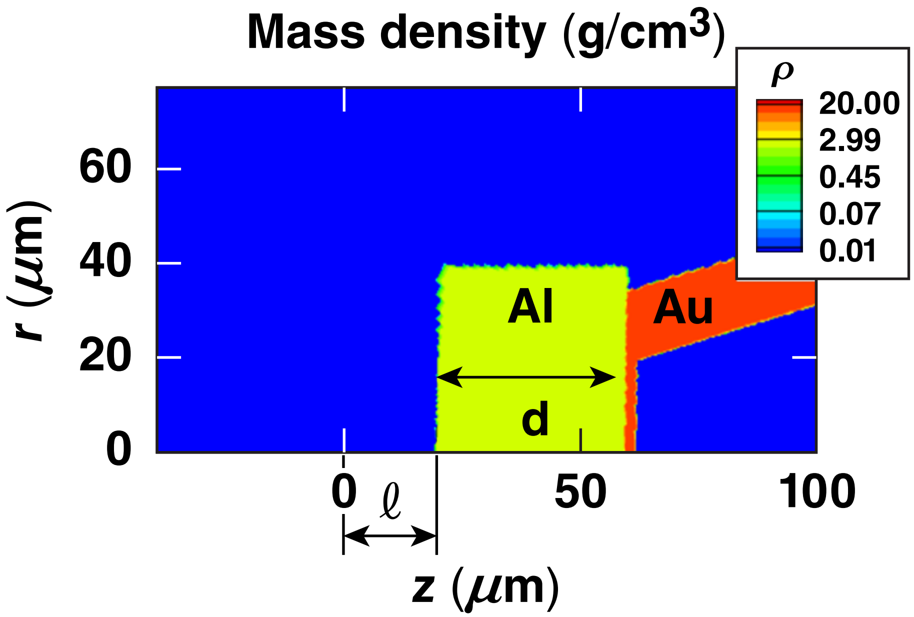
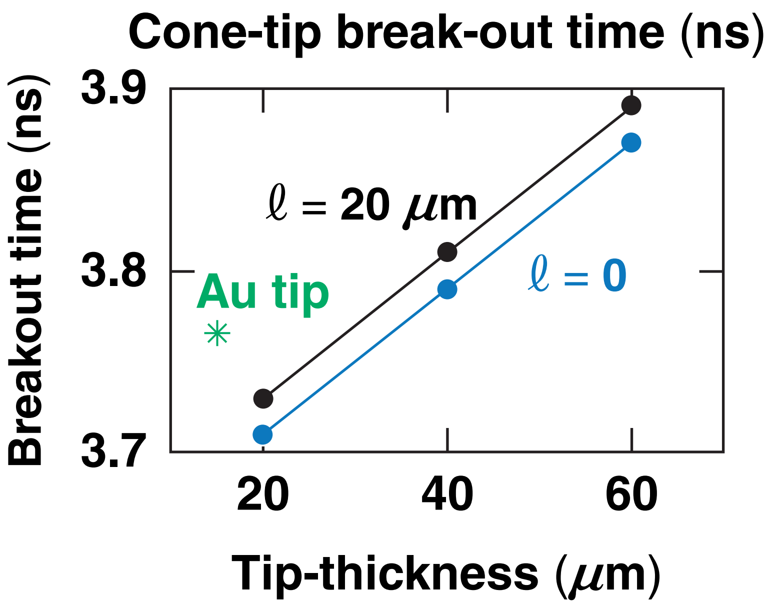
*W. Theobald *et al.*, Phys. Plasmas 18, 056305 (2011).

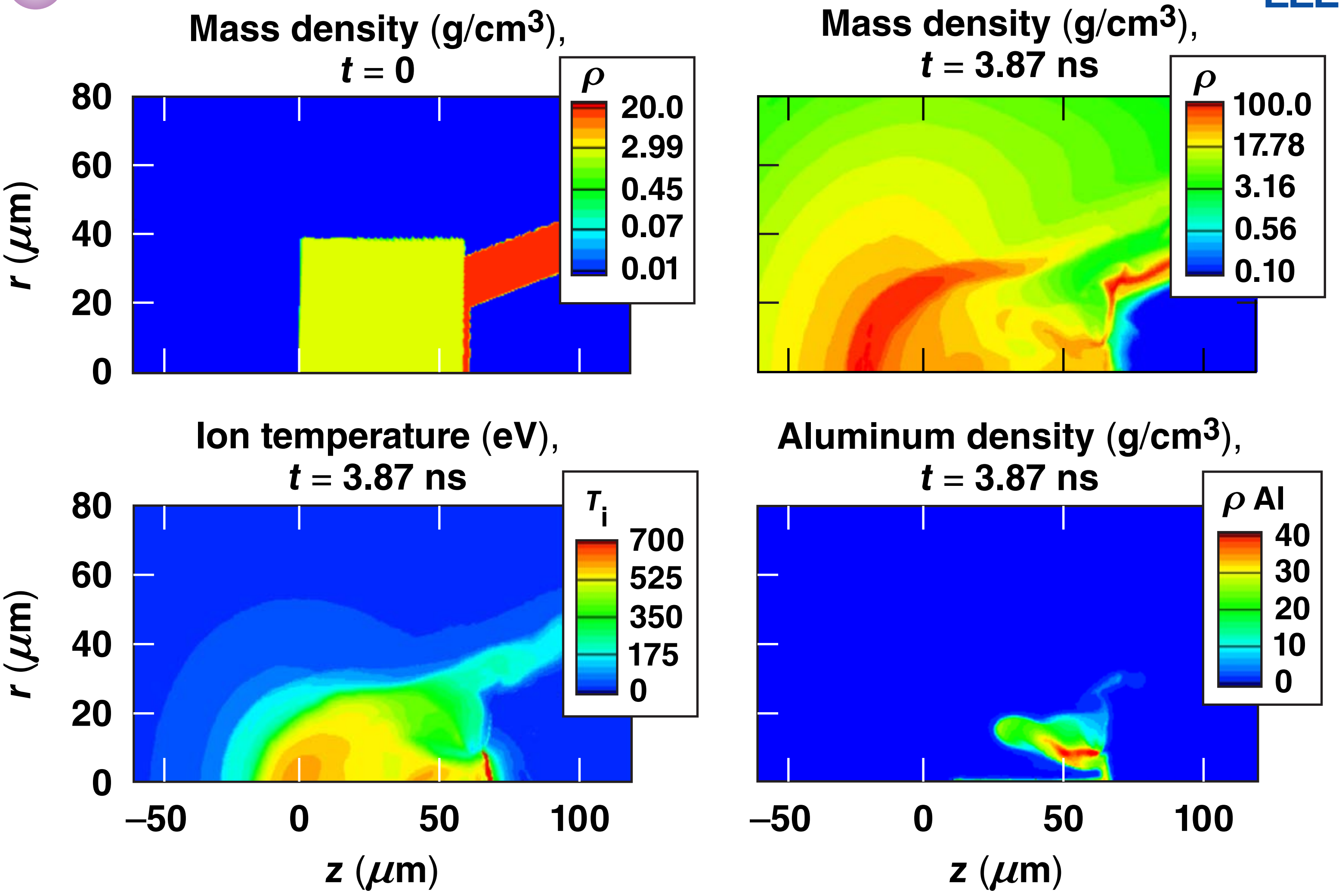
Cone-tip breakout can be delayed by using targets with a thick lower-Z cone tip





- A very thin (~2-μm) gold layer inside the cone tip
  - serves as a mounting layer for the Al block
  - helps to shield the radiation

The cone tip survives almost until the bang time in the simulation for a 60-μm-thick aluminum tip



Mass density (g/cm^3), $t = 0$

Mass density (g/cm^3), $t = 3.87$ ns

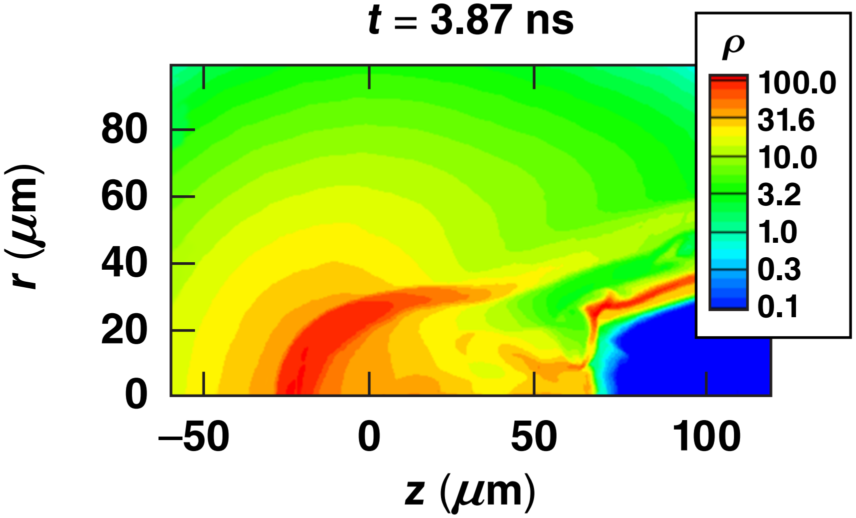
Ion temperature (eV), $t = 3.87$ ns

Aluminum density (g/cm^3), $t = 3.87$ ns

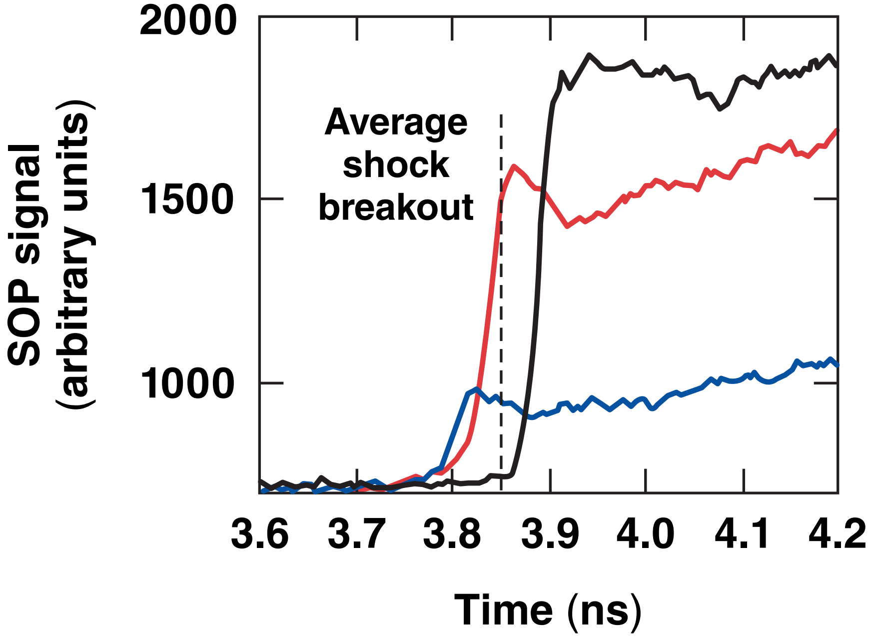
Aluminum plasma from the cone tip can help to collimate fast electrons.

DRACO simulations are confirmed by the recent shock breakout measurements

Mass density (g/cm^3),
t = 3.87 ns



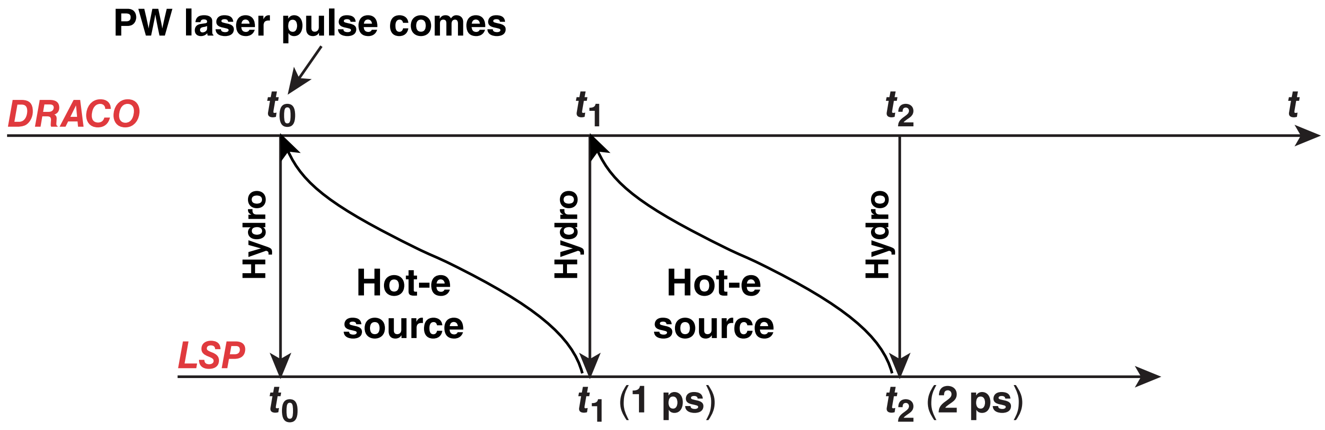
Streaked Optical Pyrometry (SOP) data in three shots



Average of SOP and VISAR:
t = 3.85±0.05 ns

Performance of cone-in-shell targets has been studied using *DRACO–LSP* integrated simulations

- *LSP**
  - 2-D/3-D implicit hybrid PIC code that calculates the target heating by fast electrons
  - coupled to the hydrodynamic code *DRACO* during the short-pulse interaction**



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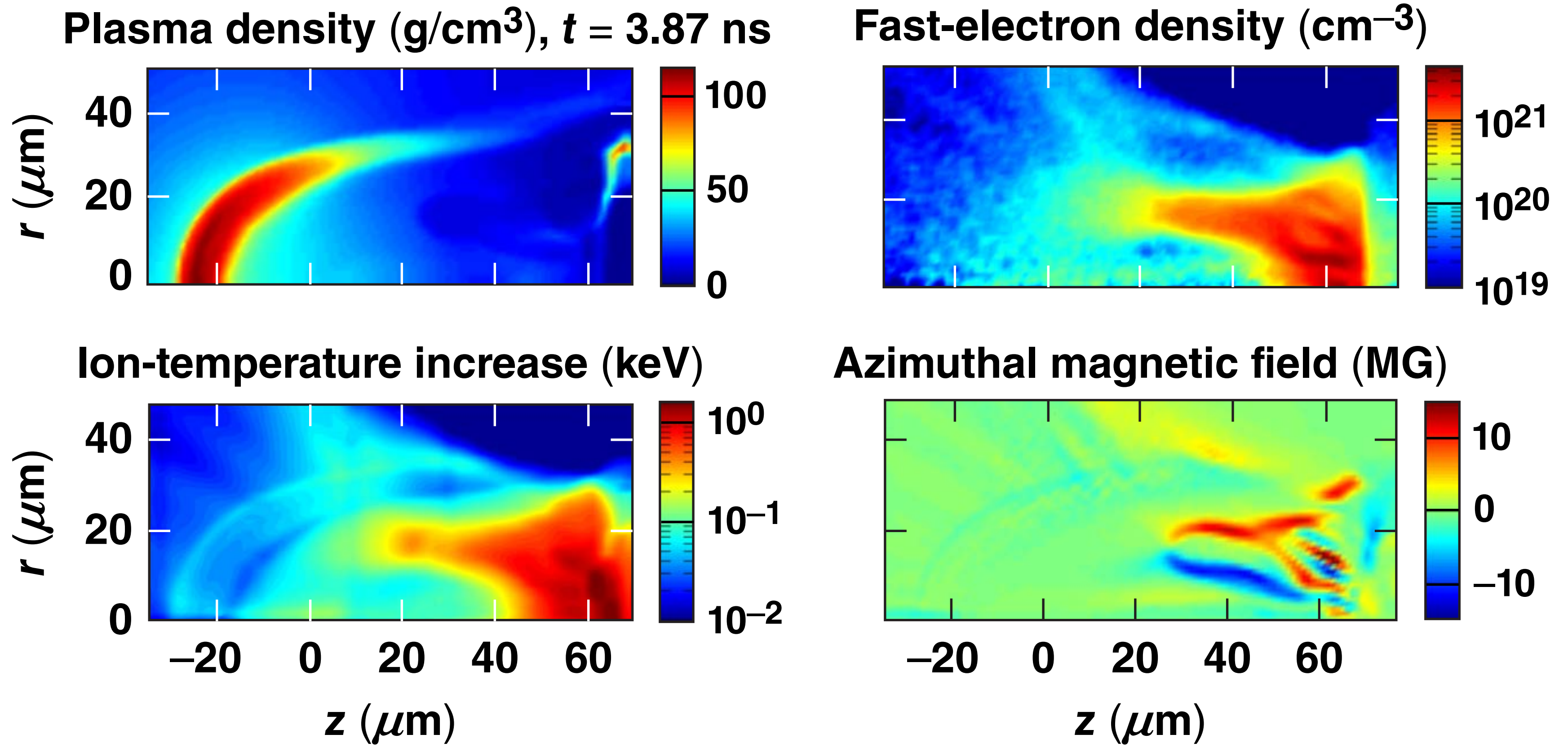
*D. R. Welch *et al*., Phys. Plasmas 13, 063105 (2006).
**A. A. Solodov *et al*., Phys. Plasmas 15, 112702 (2008).

LSP simulates fast-electron transport and core heating

Simulation for electron temperature T = 0.6 MeV ($I_{\text{laser}} \sim 10^{19}$ W/cm^2), divergence half-angle $\theta_{1/2}$ = 50°, and conversion efficiency η_L = 0.2


Plasma density (g/cm^3), t = 3.87 ns

Fast-electron density (cm^{-3})

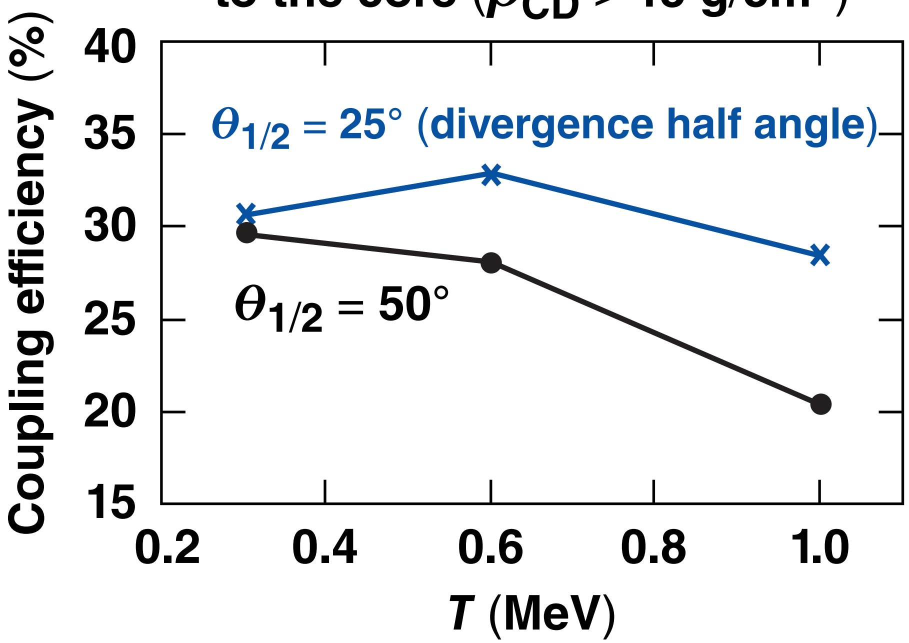
Ion-temperature increase (keV)

Azimuthal magnetic field (MG)

Fast electrons are collimated by magnetic fields generated by the resistivity gradients.

LSP predicts that 20 to 33% of fast-electron energy is coupled to the core (4 to 12% of the laser energy)

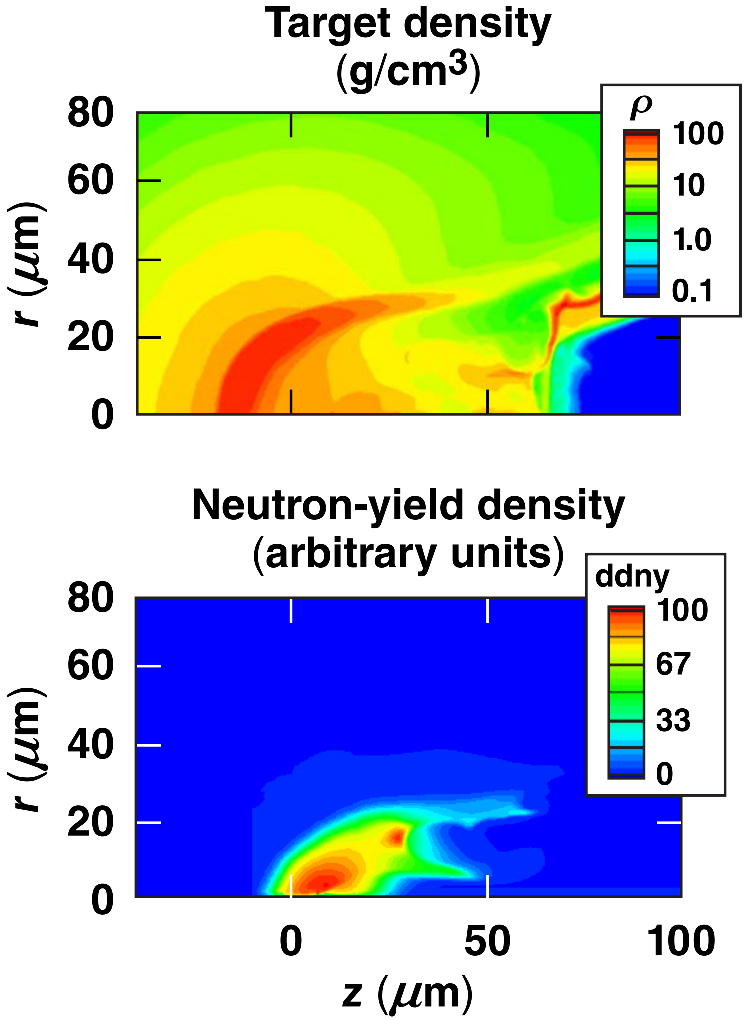
Coupling of fast-electron energy to the core (ρ_{CD} > 15 g/cm^3)

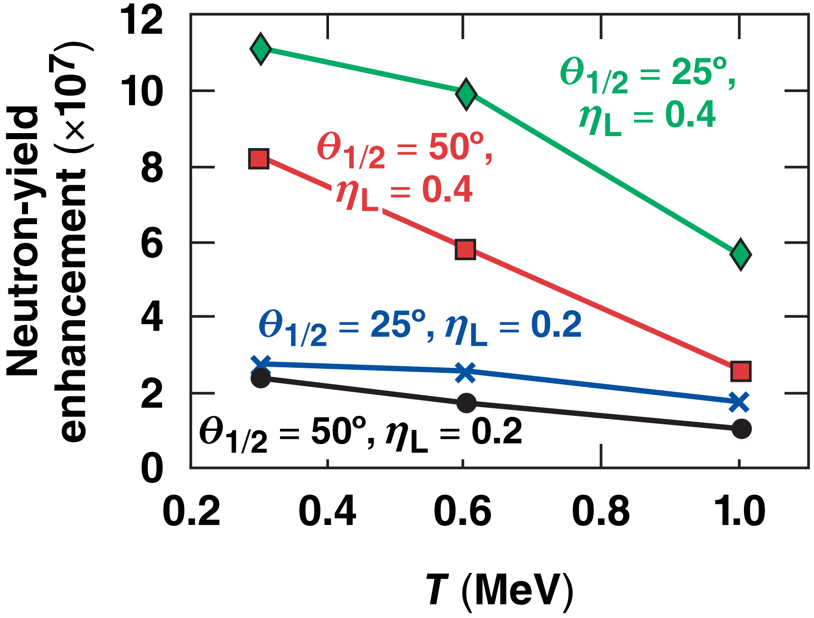


- Assumes 20 to 40% conversion efficiency to fast electrons generated at the cone tip

TC10055

Neutron-yield increase by 10^7–10^8 is predicted by *DRACO/LSP* simulations





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