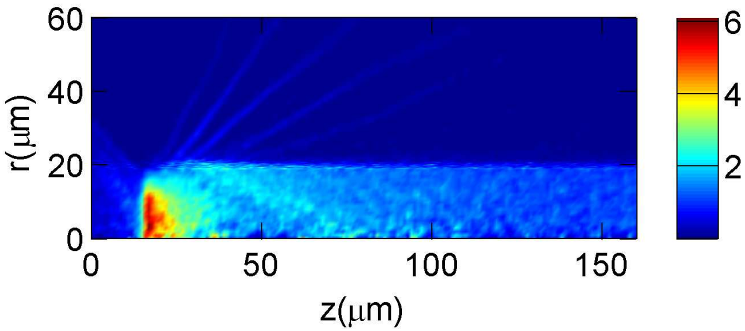
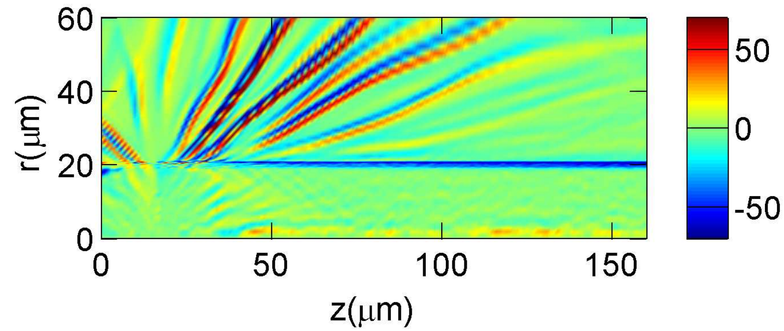
The effects of self-generated magnetic fields on electron divergence

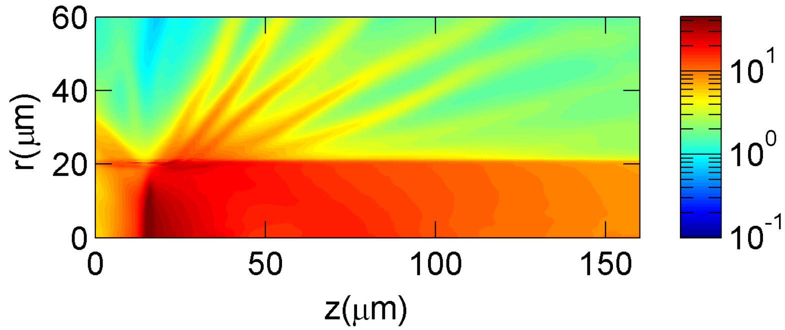
Electron-beam density ($cm^{-3} \times 10^{22}$)



Azimuthal magnetic field (MG)



Temperature, log. scale (keV)



E-beam energy = 15kJ

A. A. Solodov and R. Betti
Laboratory for Laser Energetics
and FSC, University of Rochester

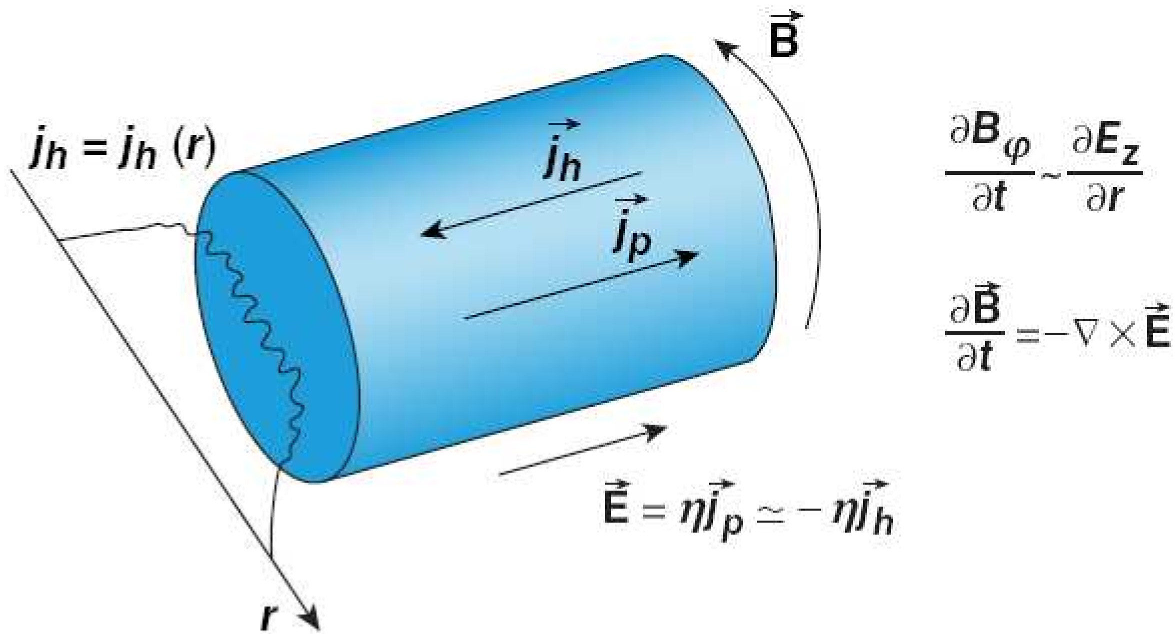
9th FSC meeting
Livermore, CA
August 5, 2010

Divergence of high-energy electron beams can be controlled through a resistivity mismatch in structured targets

- Controlling divergence of hot electrons using resistivity gradients in structured targets has been proposed by A. P. L. Robinson and M. Sherlock[1]
- LSP simulations of electron collimation in structured targets have been performed for high-energy electron beams
- A thin Cu fiber embedded in Al collimates well a highly-divergent 15-kJ electron beam

[1] A. P. L. Robinson and M. Sherlock, Physics of Plasmas **14**, 083105 (2007).

Self-generated resistive magnetic fields can control divergence of electron beams in plasmas



$$\frac{\partial \vec{\mathbf{B}}}{\partial t} = \eta \nabla \times \vec{\mathbf{j}}_h + \nabla \eta \times \vec{\mathbf{j}}_h$$

Simulations of Robinson and Sherlock confirm electron collimation at early times, before the sign of $\nabla\eta$ changes due to target heating

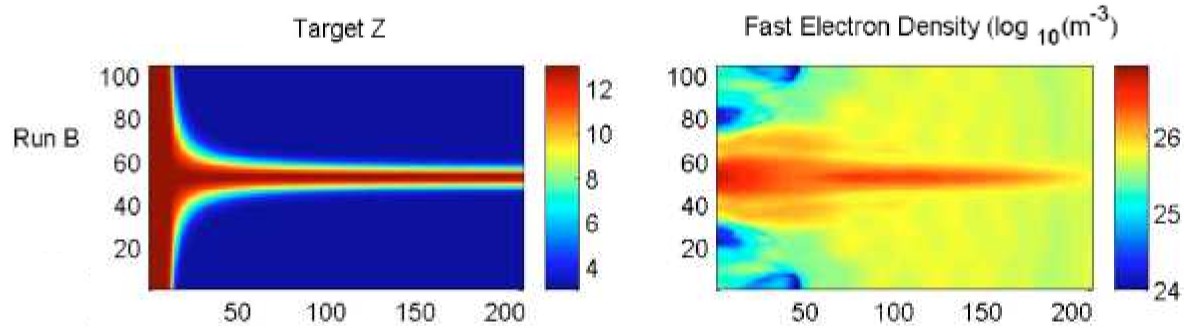
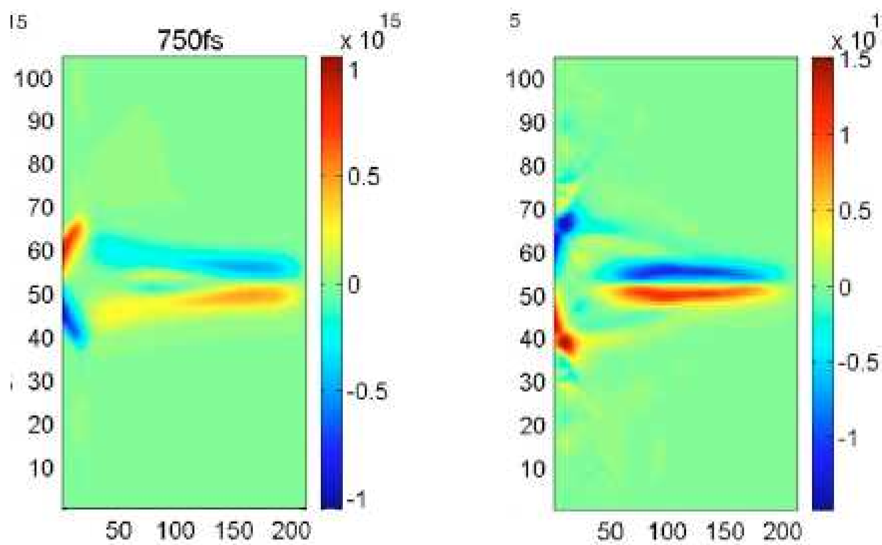


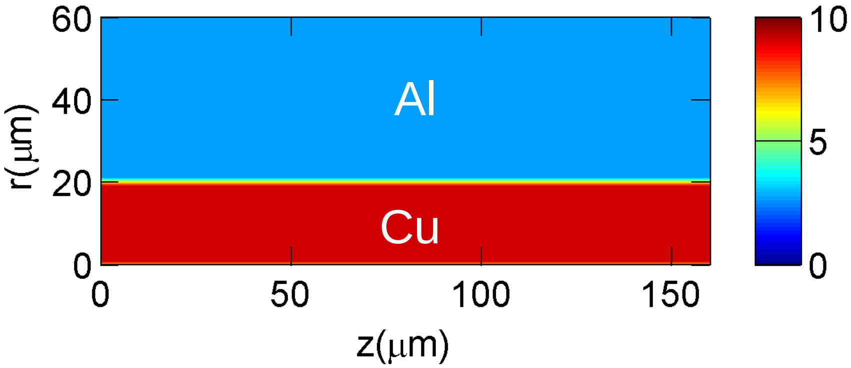
FIG. 4. (Color online) Rate of magnetic field generation (T s^{-1}) in run B due to $\nabla\eta\times\mathbf{j}_f$ term (top), and $\eta\nabla\times\mathbf{j}_f$ term (bottom) at 250, 500, and 750 fs.

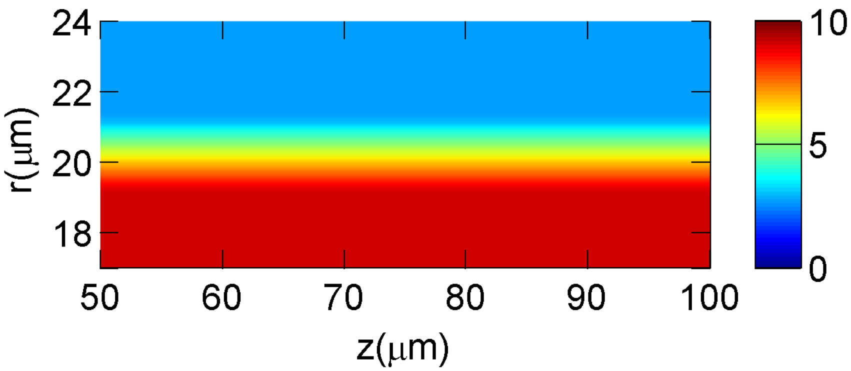


A. P. L. Robinson and M. Sherlock, Physics of Plasmas **14**, 083105 (2007).

LSP simulations of magnetic collimation for a high-energy electron beam have been performed

Plasma density (g/cm^3)





Electron beam:

$I(r) = I_0 \exp\left[-(r/r_0)^4\right]$, where

$I_0 = 3.4\times10^{20}$ W/cm^2, $r_0 = 15\ \mu$m,

duration = 7.5 ps, constant in time, $E_{total} = 15$ kJ,

$f_\Omega(\theta) = dN/d\Omega = \exp\left[-(\theta/\theta_0)^2\right]$, where $\theta_0 = 67^0$,

exponential energy distribution with $\langle E\rangle = 2$ MeV.

- Smooth transition from Cu to Al in a layer of thickness = 2 μm,

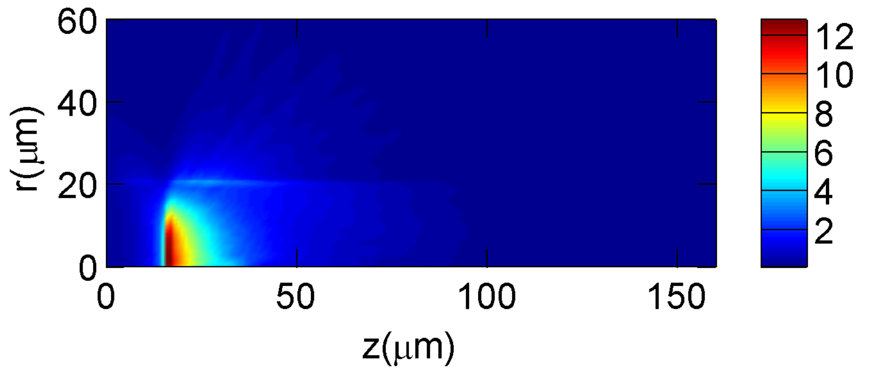
- Radial mesh size Δr =0.125 μm in the transition region.

- Thomas-Fermi equation of state, Lee & More resistivities, radiative cooling of Cu due to electron bremsstrahlung

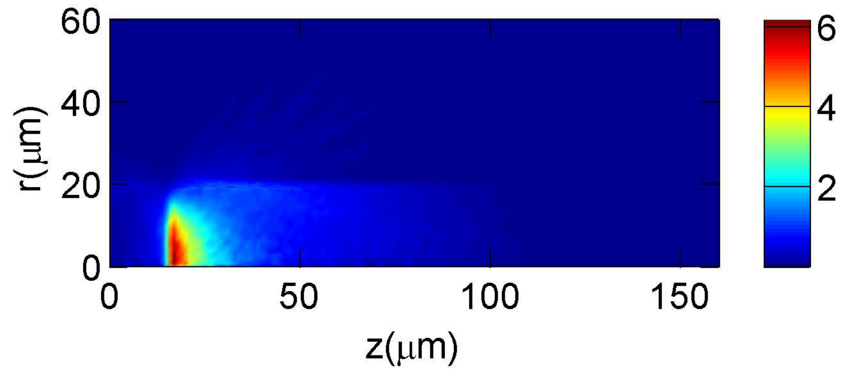
Effective magnetic collimation sets up early in the simulation

t = 0.45ps

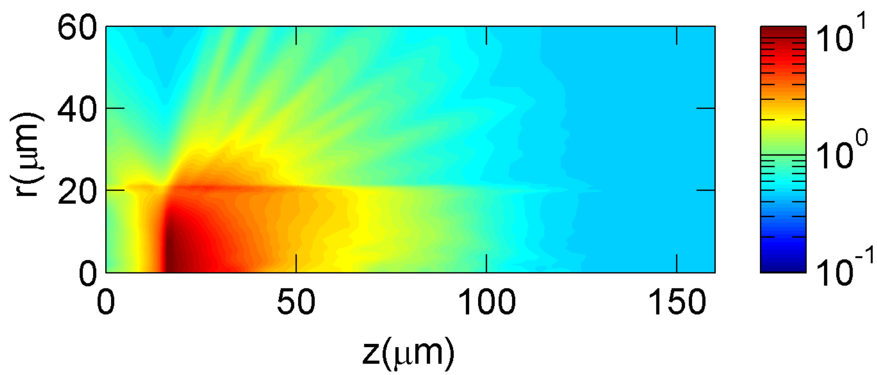
Plasma-electron temperature (keV)



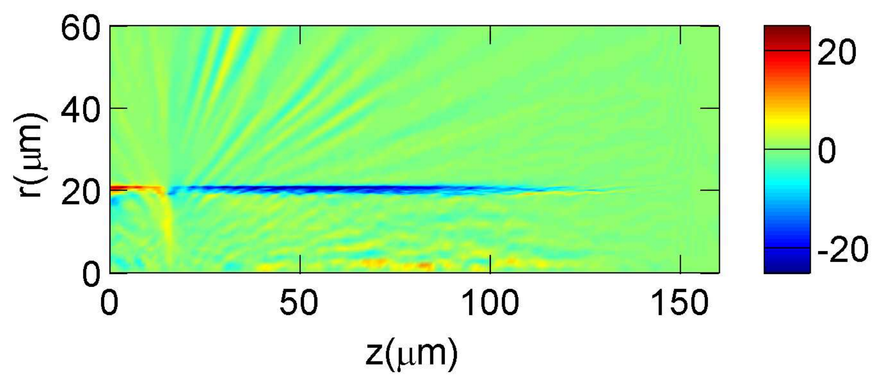
Electron-beam density (cm^{-3}×10^{22})



Temperature, log. scale (keV)

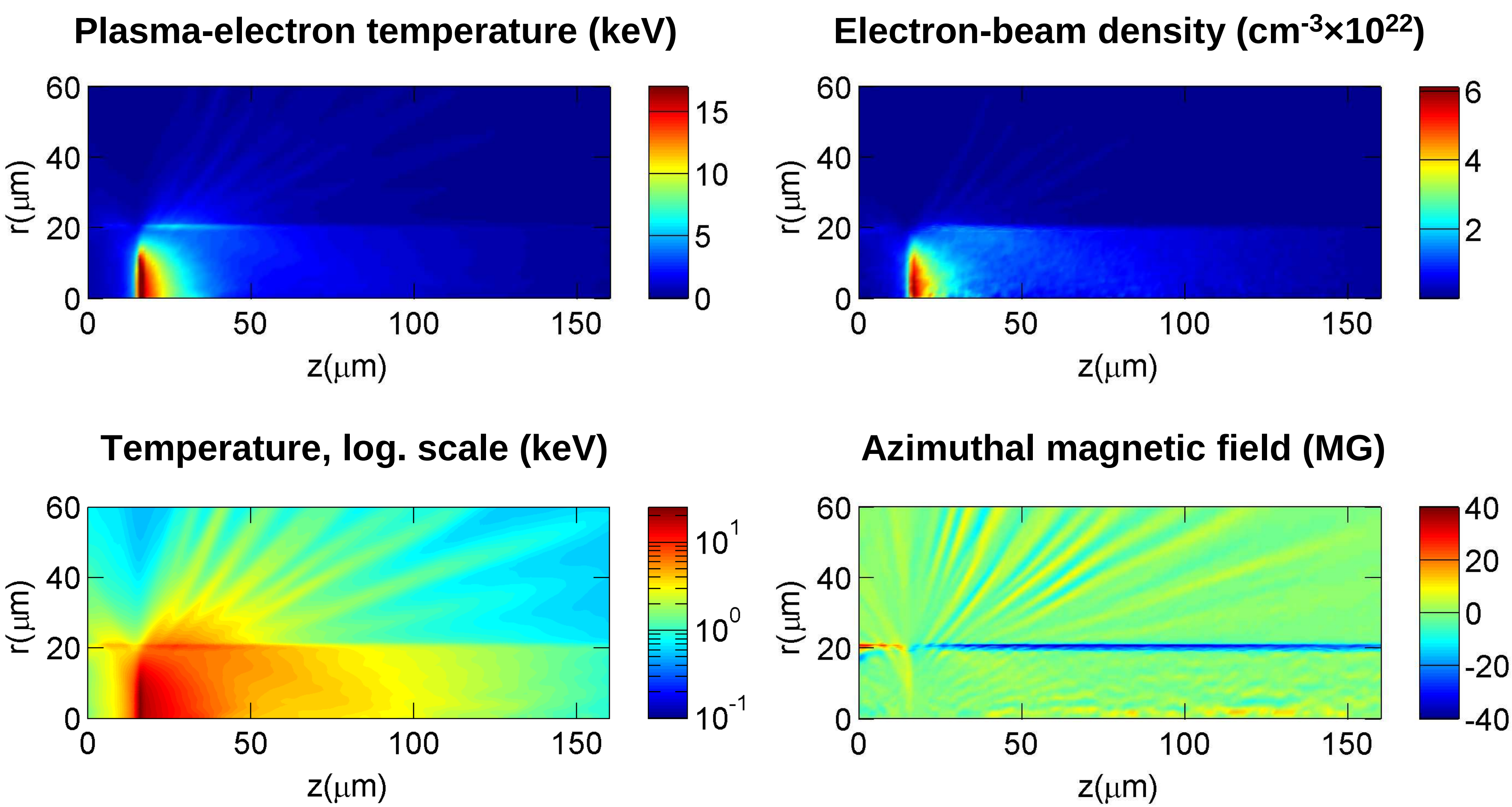


Azimuthal magnetic field (MG)



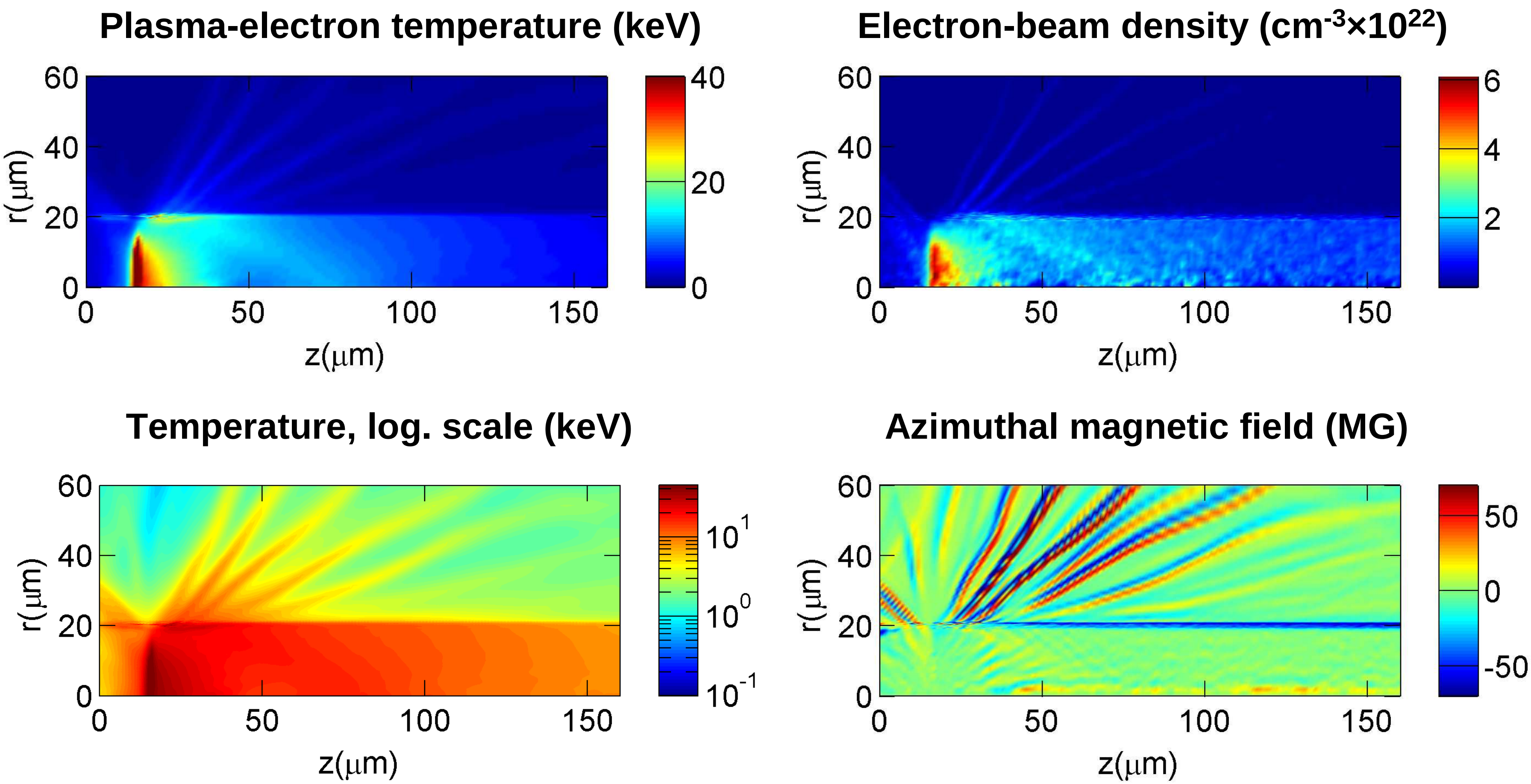
Electron beam is effectively collimated later in time

t = 0.9ps



Electron beam is effectively collimated at *t* = 7ps

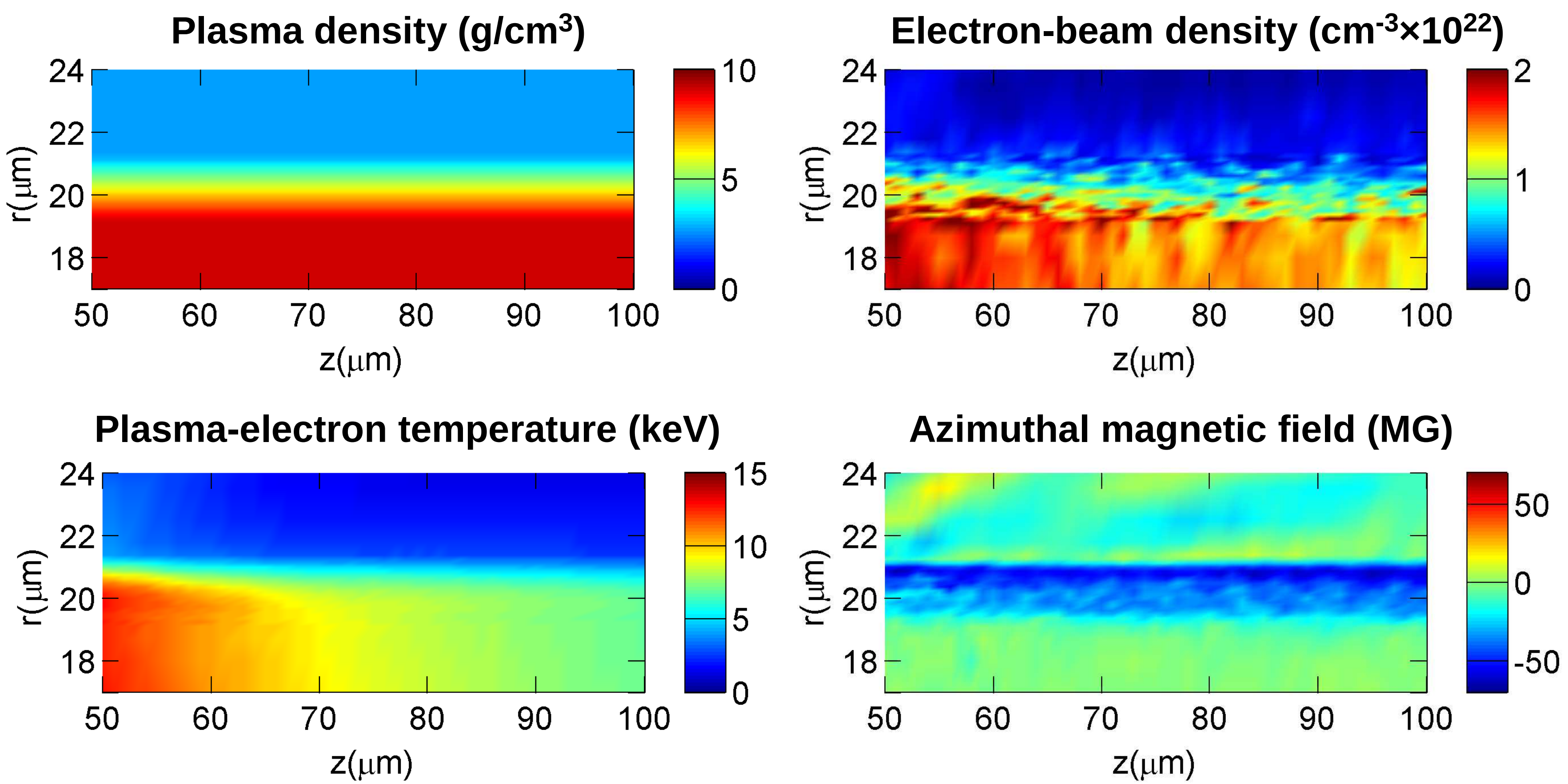
t = 7ps



Electrons collimated in Cu fiber contain ~45% of the beam energy

Magnetic field reaches the maximum value close to the Al side of the transition layer

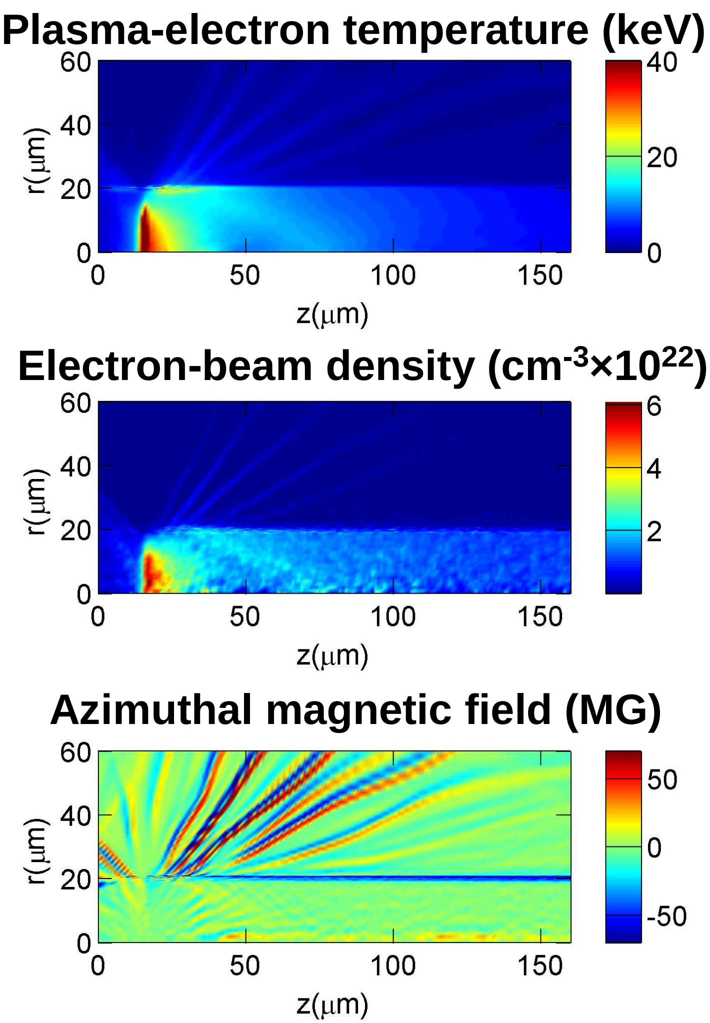
t = 7ps



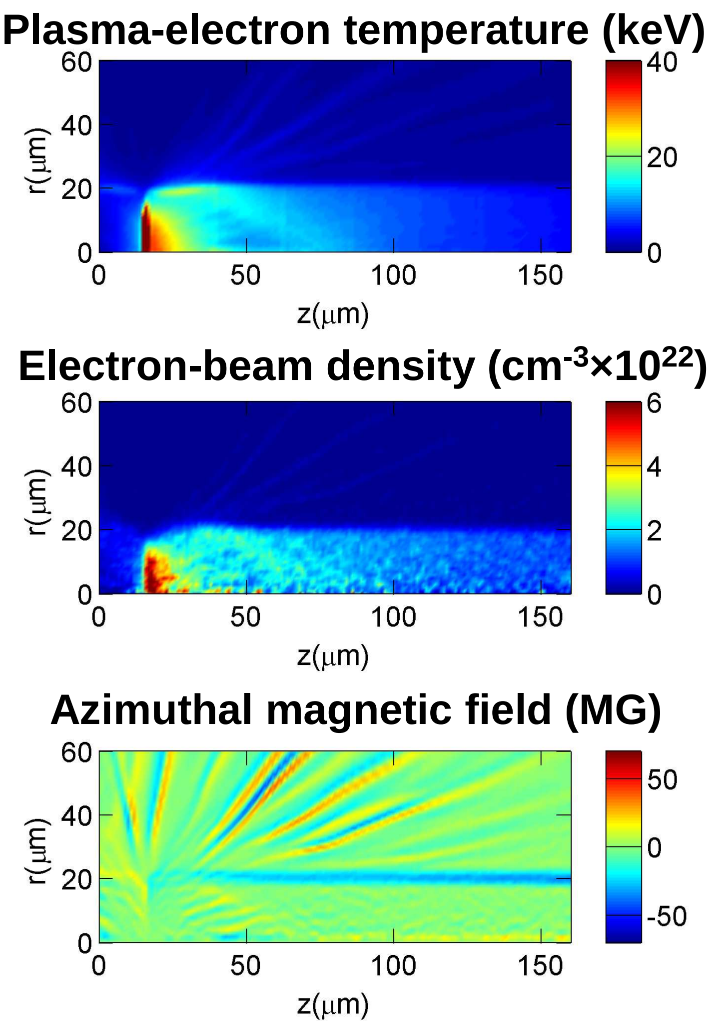
Simulations with a resolution Δ*r* =2 µm predict somewhat better magnetic collimation

t = 7ps

Δ*r* =0.125 µm



Δ*r* =2 µm



45% of the beam energy is collimated

48% of the beam energy is collimated

Summary/Conclusion

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- **LSP simulations of electron collimation in structured targets have been performed for high-energy electron beams**
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