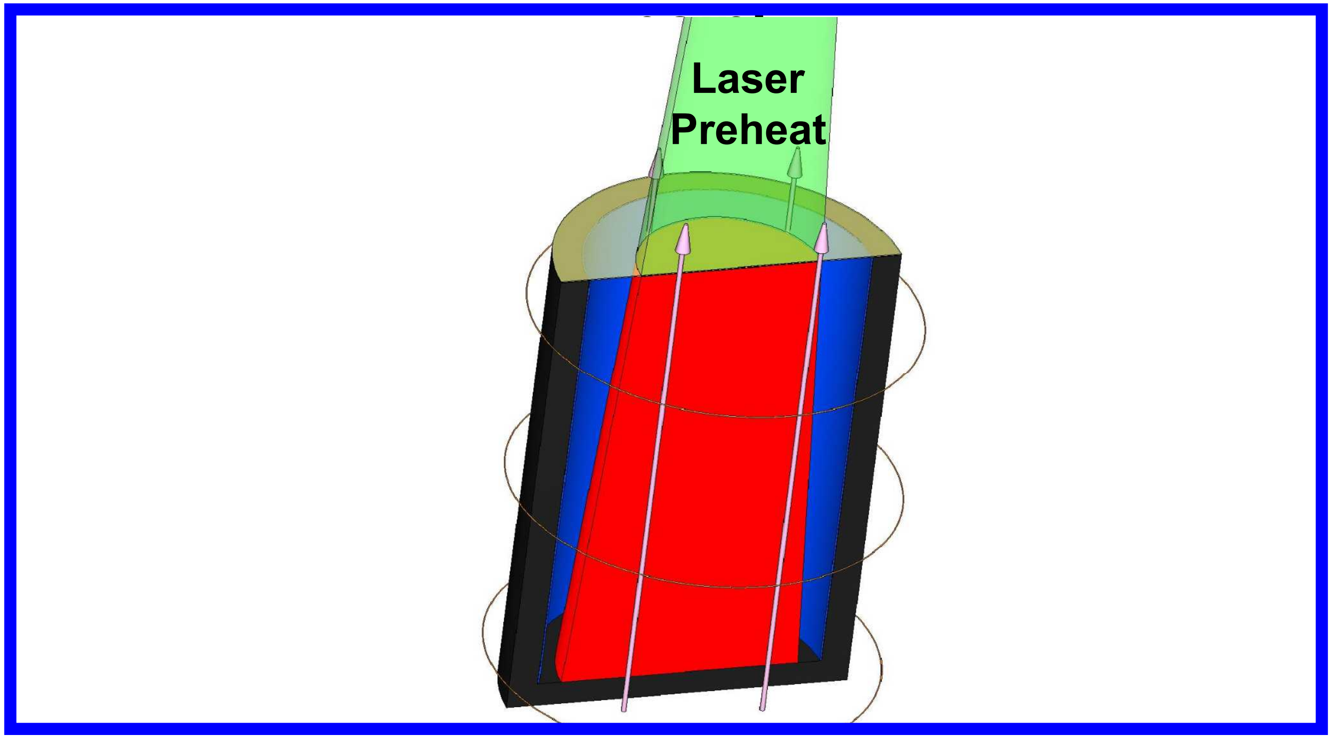
Simulation of MagLIF laser preheat experiments using 1 Quad of the NIF: a starting



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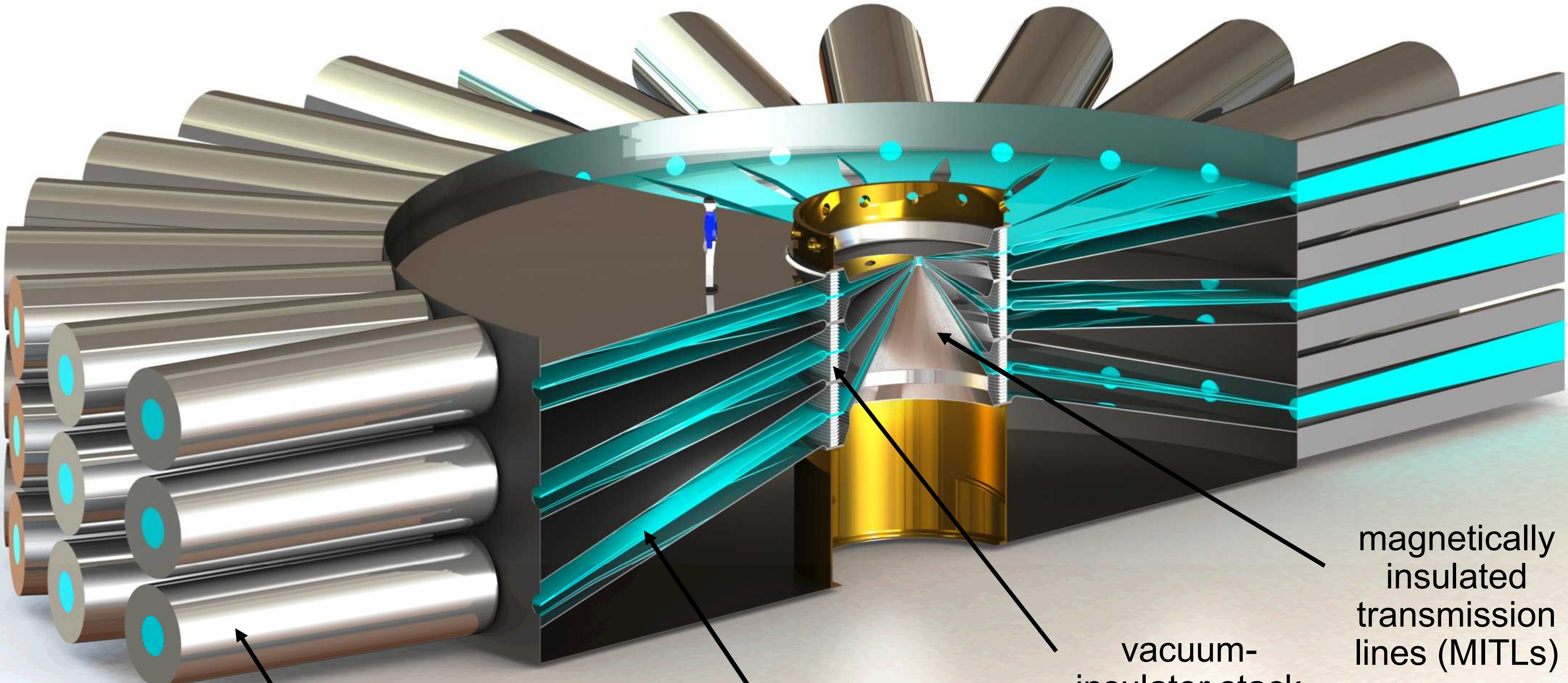
Advanced machines could deliver large currents to MagLIF e.g. conceptual designs[1] Z300 and Z800

P_{LTDs} = 315-870 TW
E_{LTDs} = 47-130 MJ

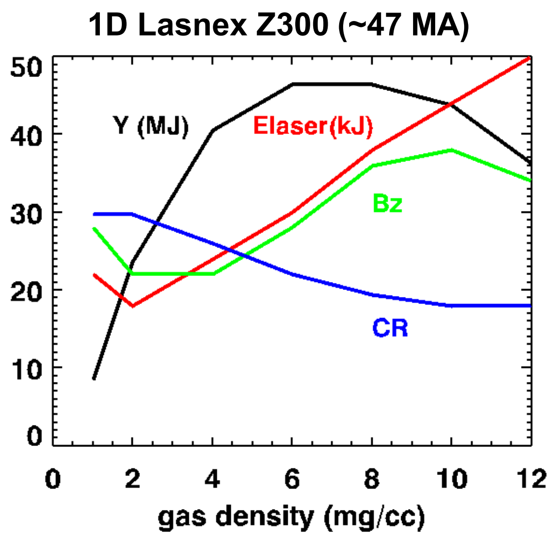
V_{stack} = 7.6-16 MV
L_{vacuum} = 16-25 nH

I_{load} = 47-61 MA
$\tau_{implosion}$ = 133 ns

diameter = 35-55 m



Large preheat energies (~ 30 kJ) are needed for high yield MagLIF targets



Optimal initial fuel densities

- ~ 6 mg/cc (Z300 1D simulations)
- ~ 4.5 mg/cc (Z300 2D simulations)
- ~ 12 mg/cc (Z800 2D simulations)

Optimal preheat energy

- $E_{preheat}$ ~ 30 kJ near optimal for 1D
- $E_{preheat}$ ~30-40 kJ optimal for 2D due to end losses

Simple analytic theory predicts the laser penetration can be controlled by the beam radius and laser wavelength

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The laser energy needs to be deposited into the fuel in roughly z_f = 1 cm

Laser absorption coefficient dominated by inverse Bremsstrahlung

$$C_V \frac{d\theta}{dt} = \frac{dI}{dz} = -kI \qquad k = \frac{\nu_{ei}\omega_p^2}{c\omega_L^2}\left(1-\frac{\omega_p^2}{\omega_L^2}\right)^{-1/2} = \frac{k_0}{\theta^{3/2}} \qquad k_0 \approx 1.23x10^6\left(\rho\lambda_L Z_b\right)^2\left(1-227\rho Z_b\lambda_L^2\right)^{-1/2}$$

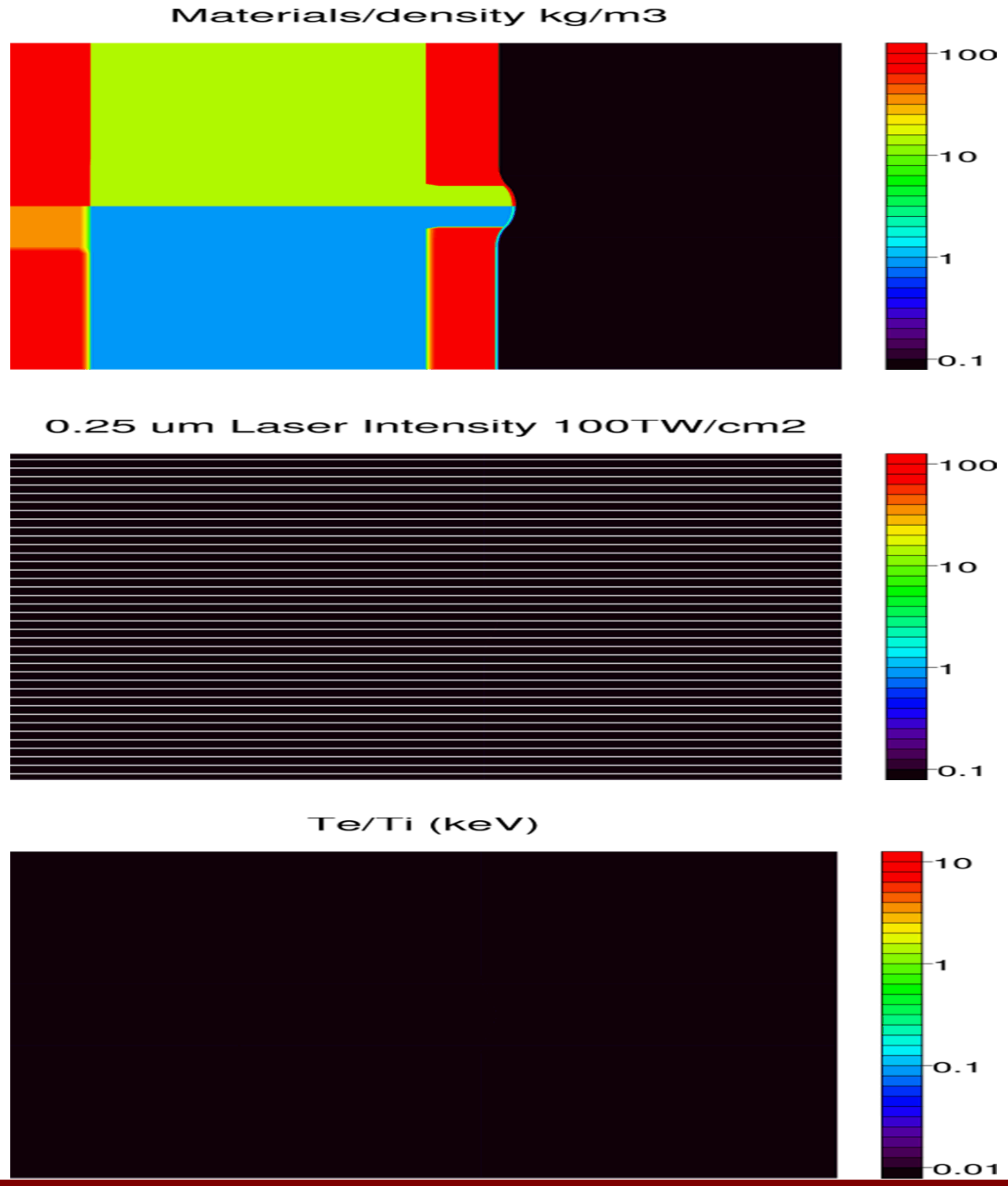
$$I = I_0\left(1-\frac{z}{z_f}\right)^{2/3} \qquad z_f = \frac{5}{3}\left(\frac{2}{5k_0}\right)^{2/5}\left(\frac{I_0 t}{2C_V\rho}\right)^{3/5} \qquad R_{laser} = 5.4x10^{-7}E_{laser}^{1/2}\lambda_L^{-.67}\rho^{-1.17}z_f^{-.83}\left(1-227\rho\lambda_L^2\right)^{.17}$$

Hydrodynamics, refraction and LPI make this process more complicated

A short wavelength laser (λ ~ 0.25-0.33 μ) could be used to penetrate the initially high density DT without excessive LPI, thus forming a low density channel

A second pulse of longer wavelength light (λ = 0.5-1 μ) could then propagate down this channel and efficiently deposit its energy

Simulation of a laser heating experiment depositing 30 kJ in 1 cm of DT at 12 mg/cc



Hole boring phase:
3 kJ of 0.25 um light

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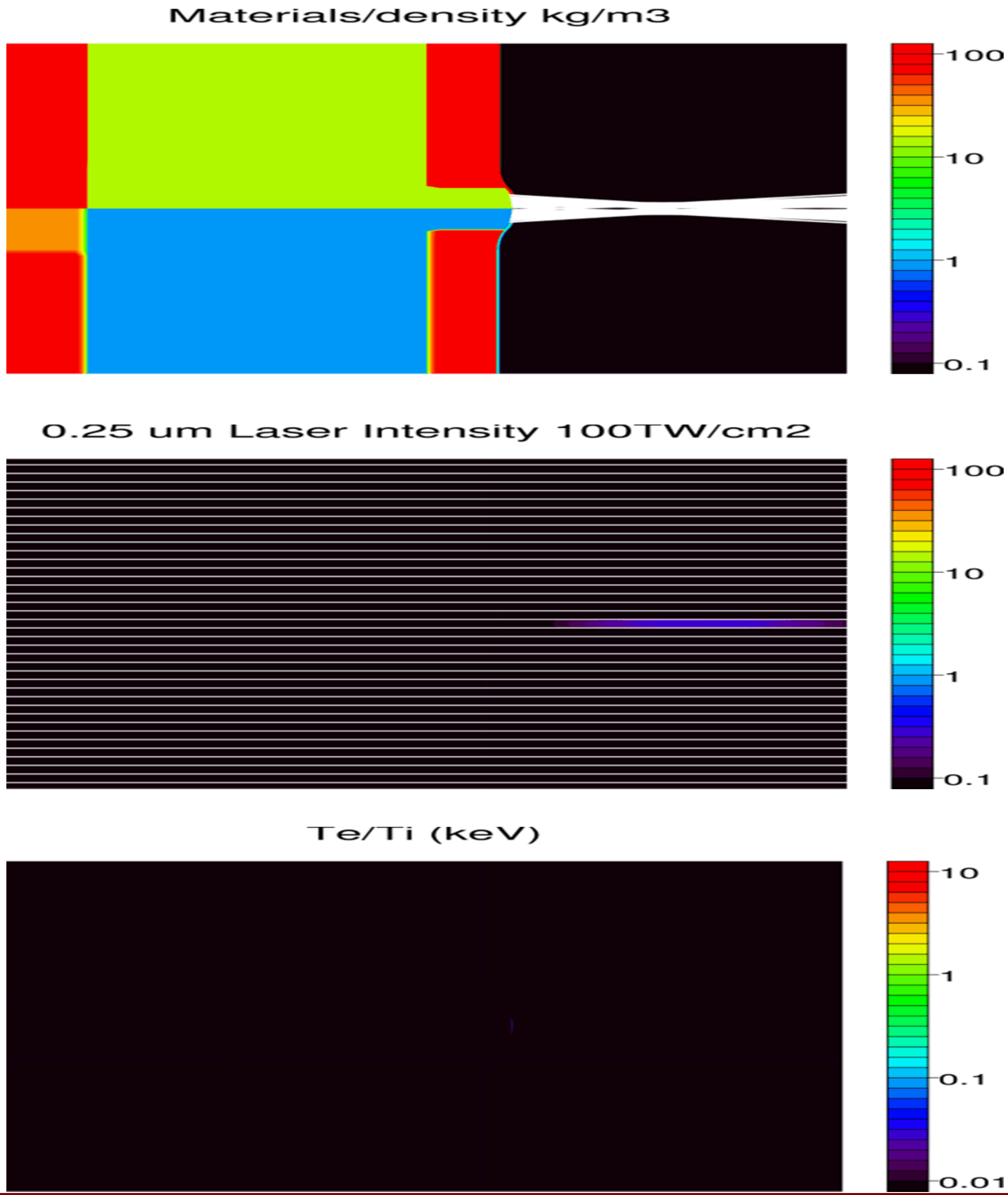

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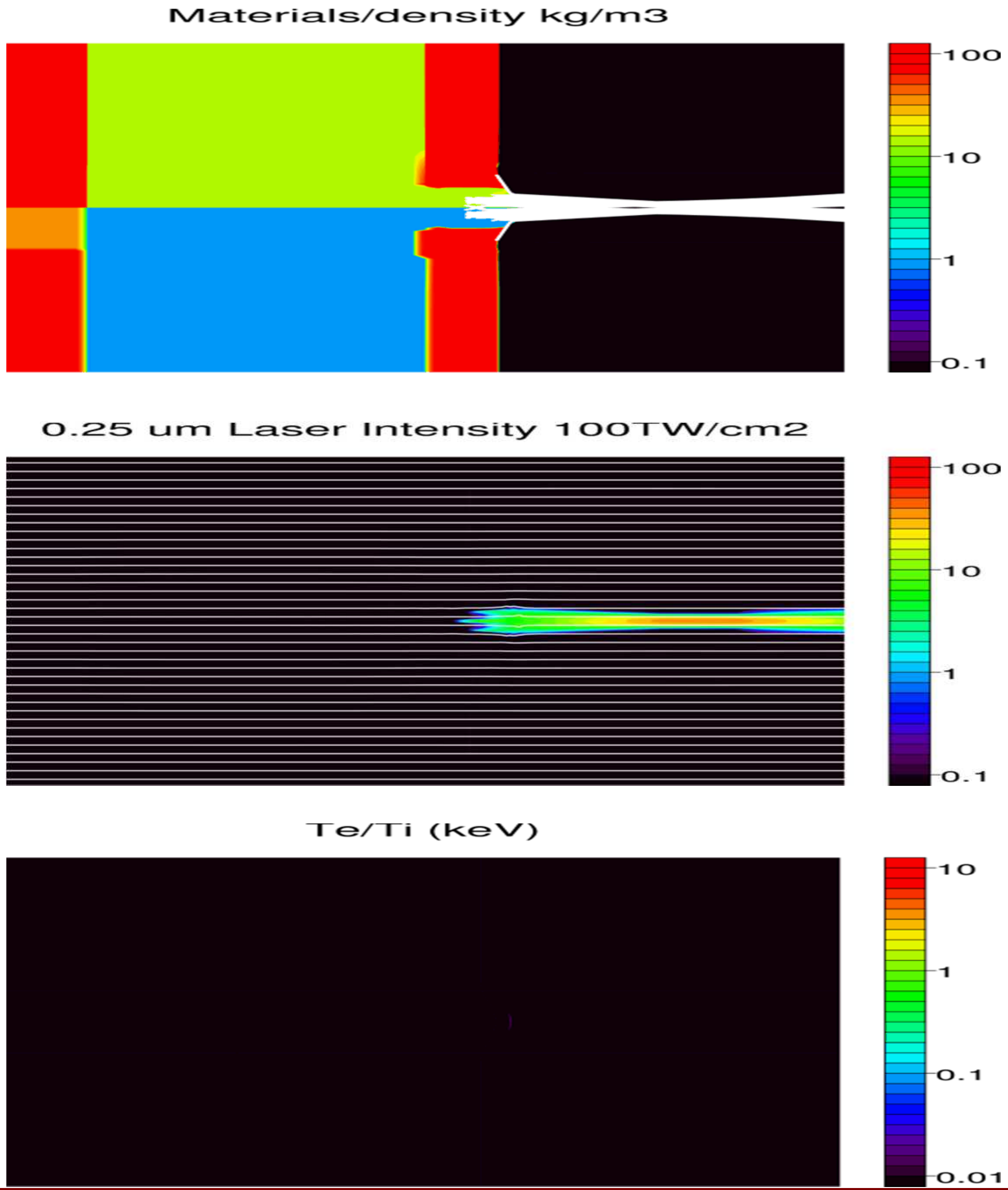

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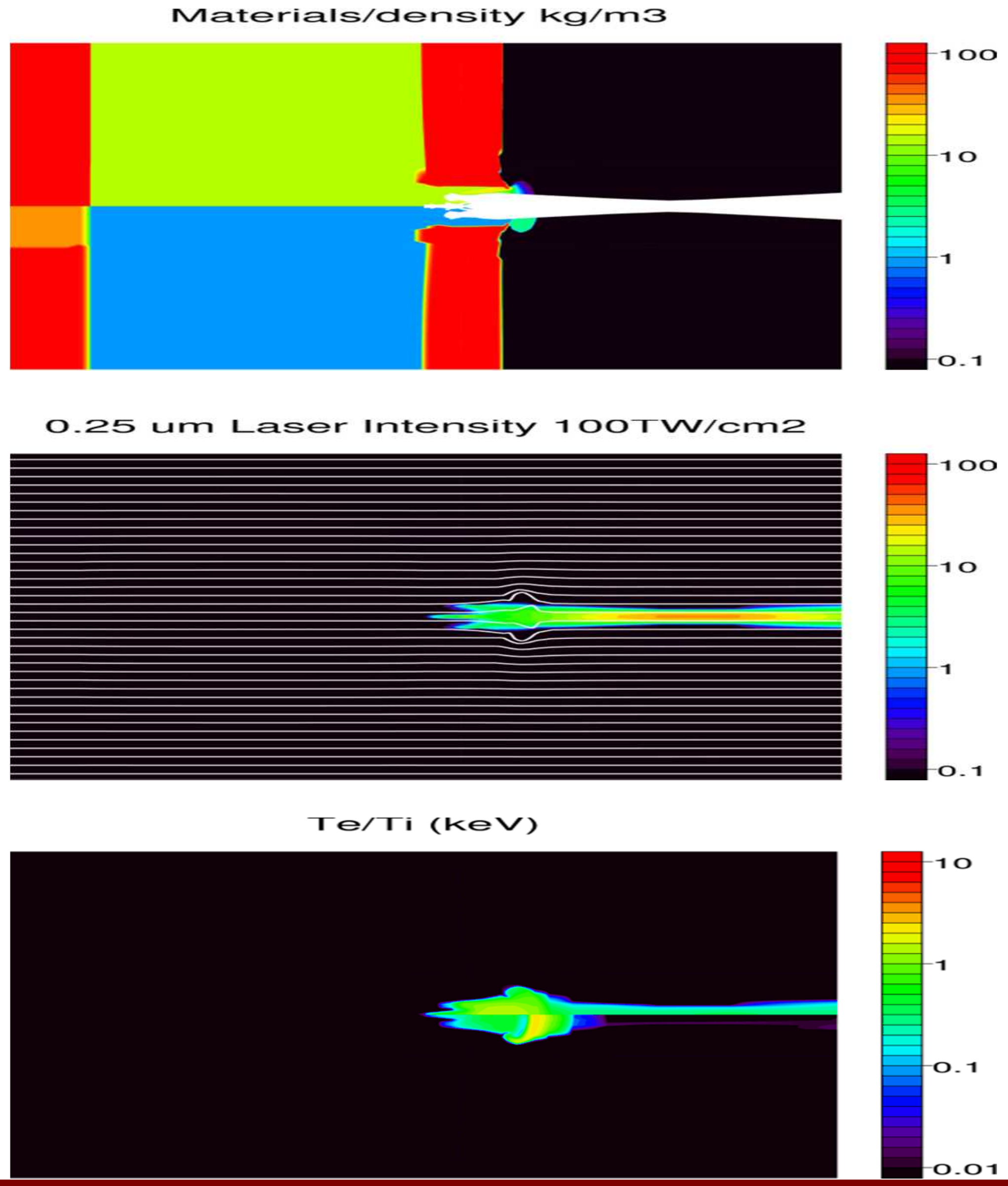

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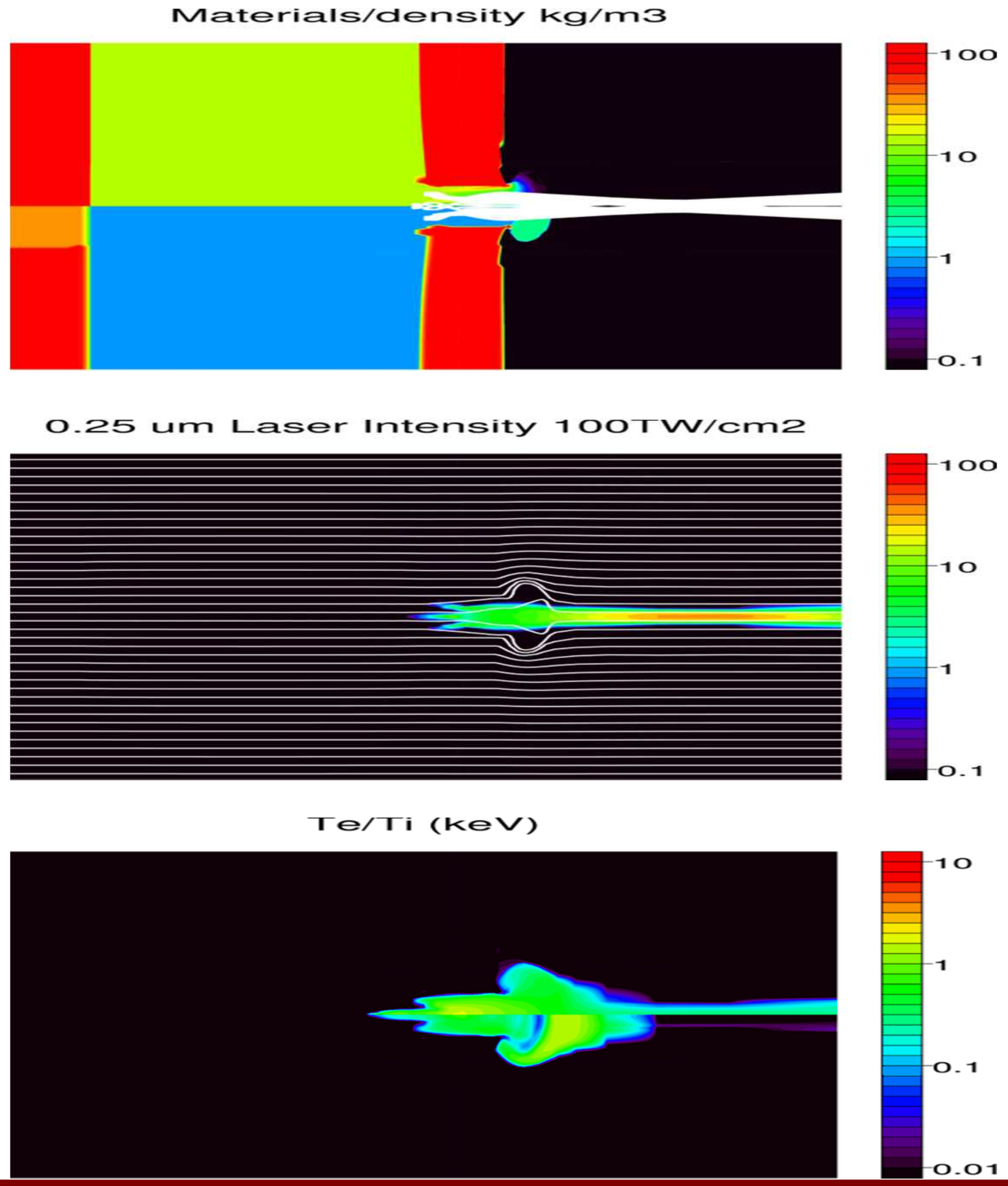

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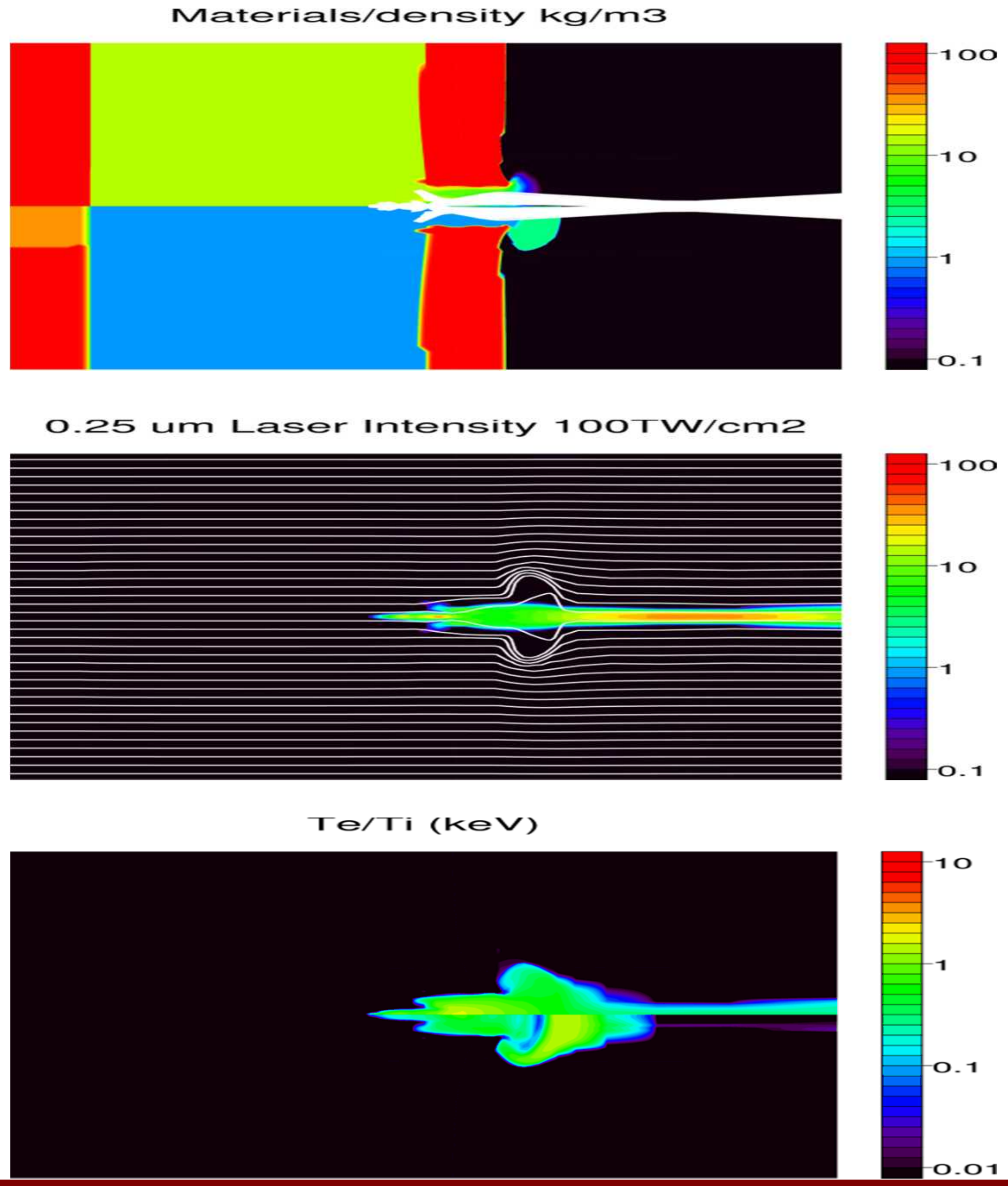

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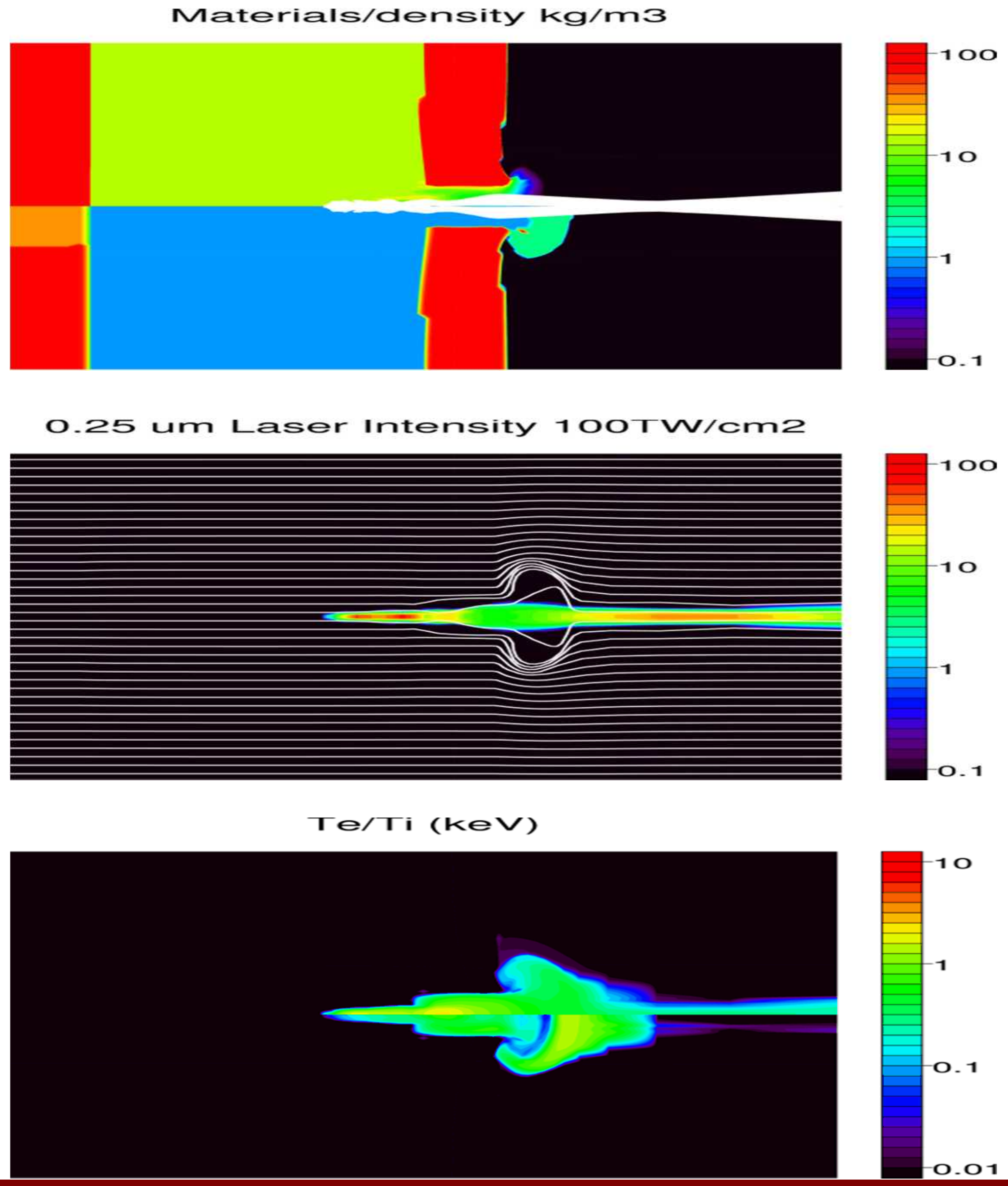

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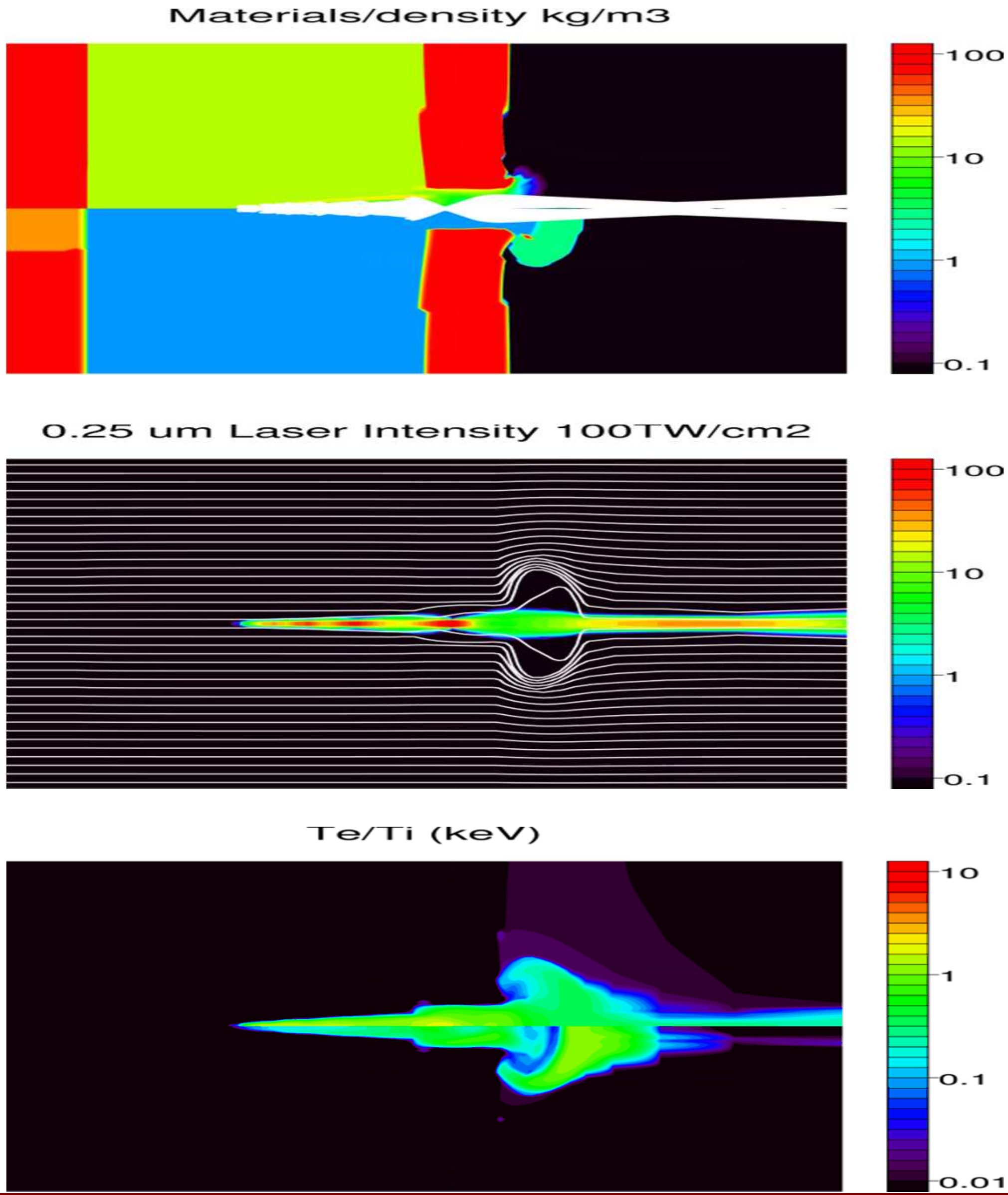

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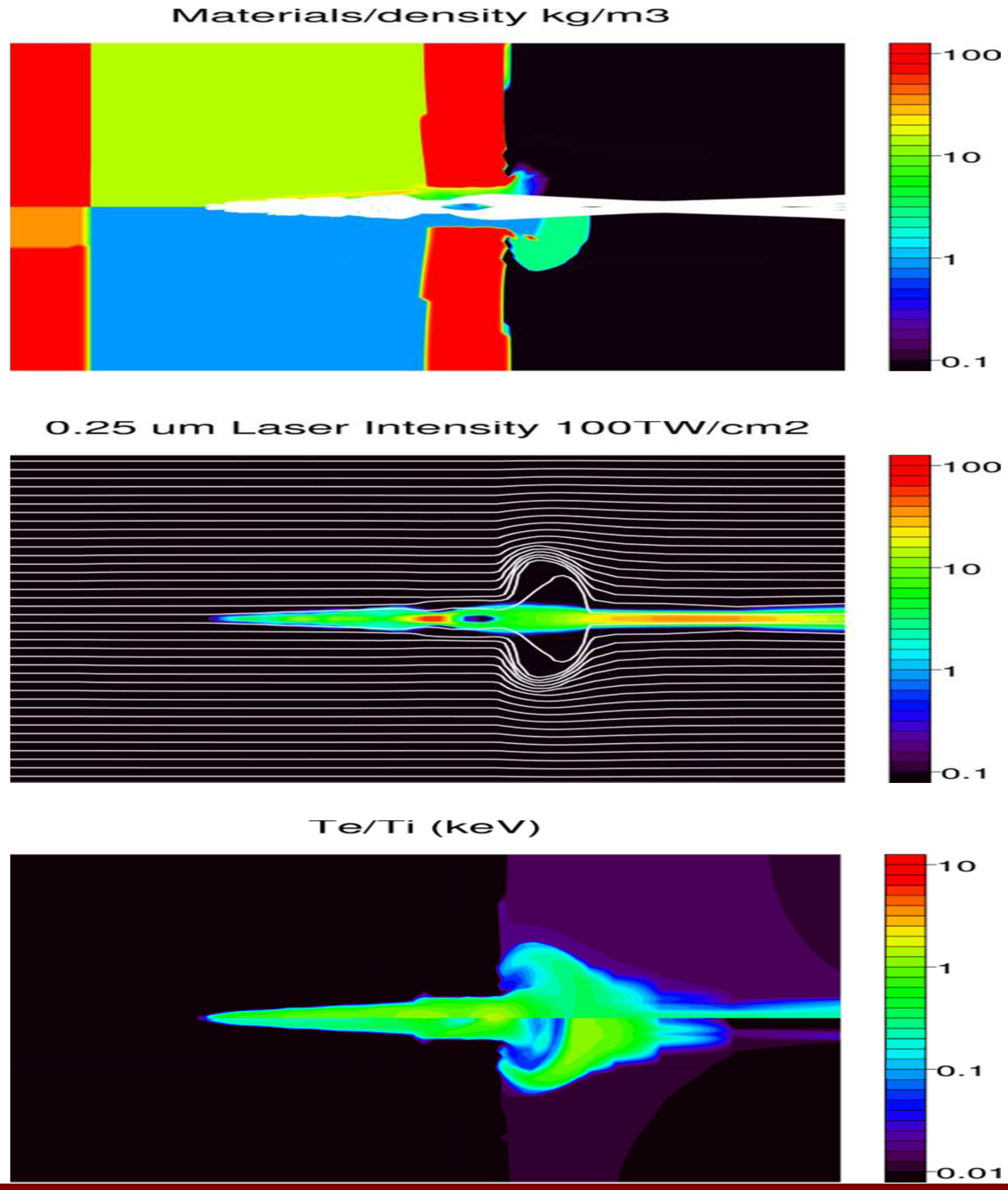

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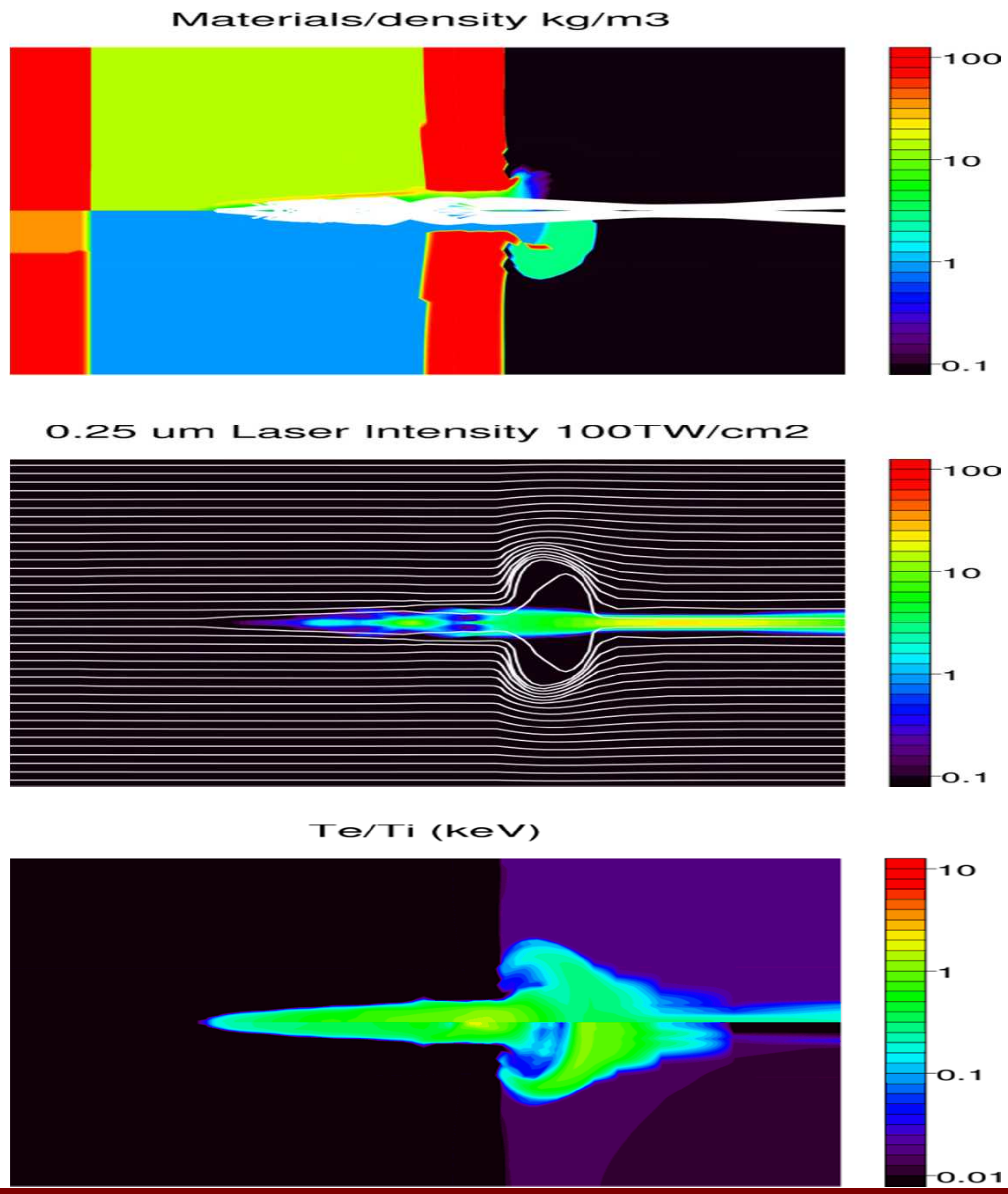

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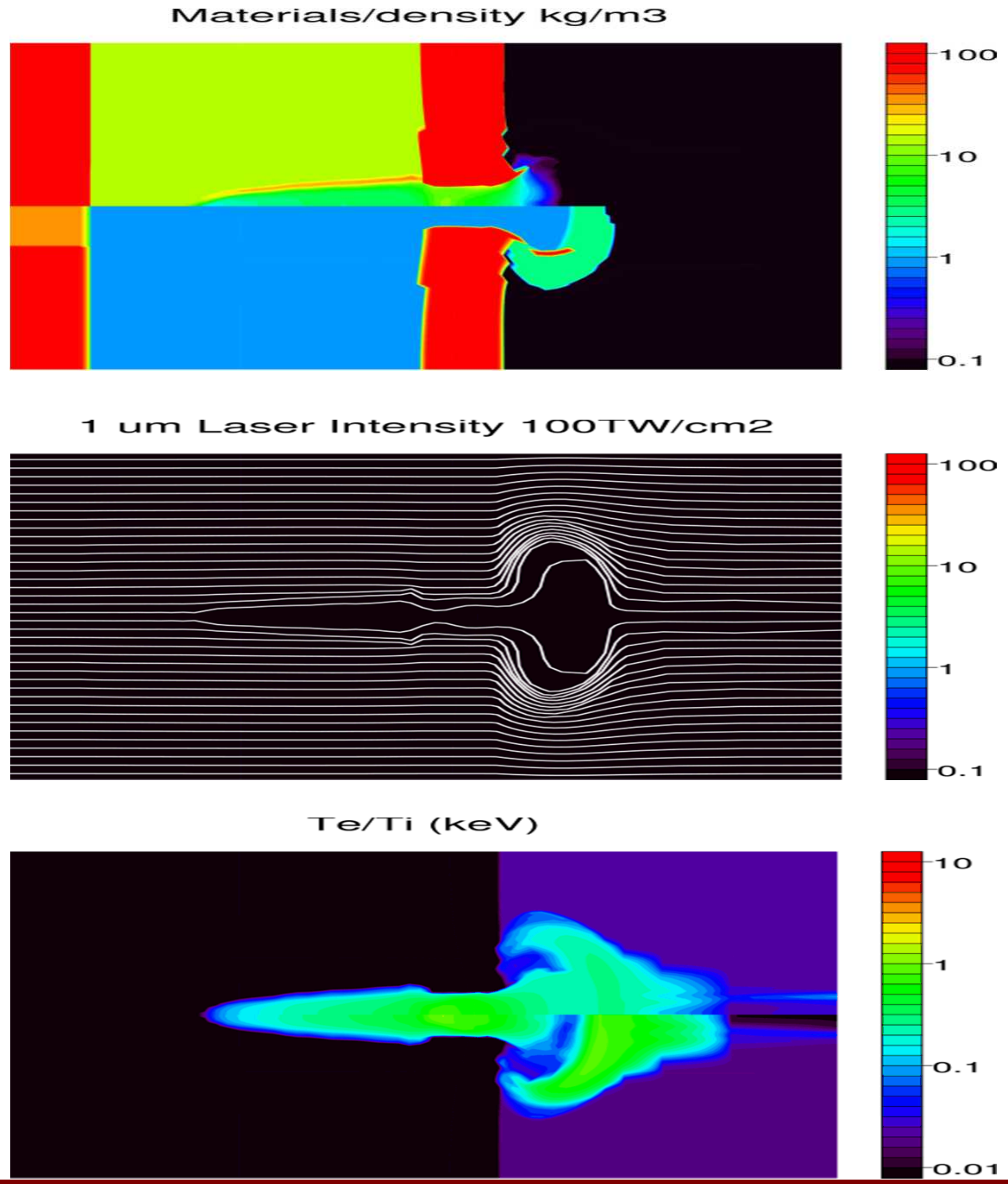
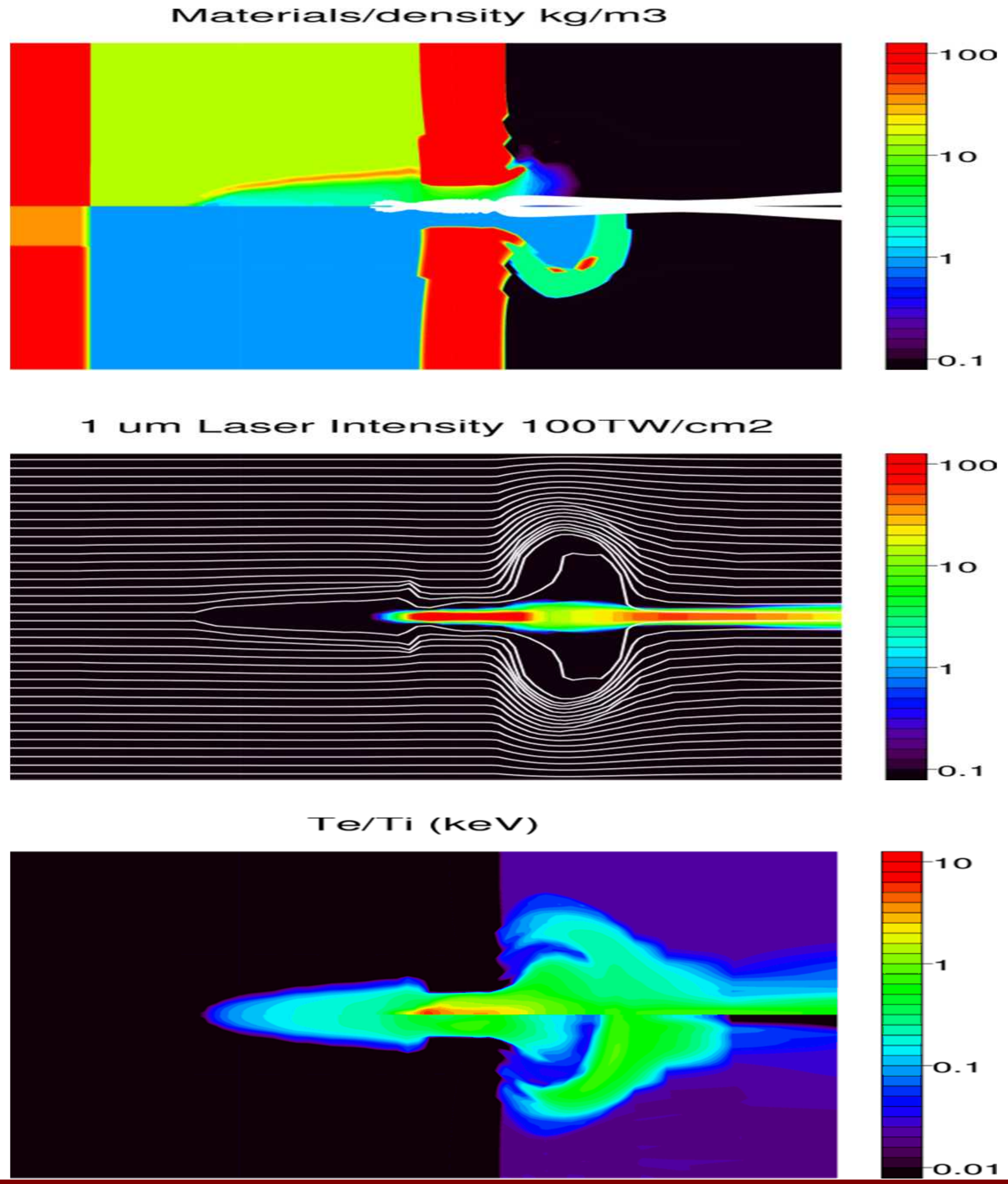


Laser off for 1 ns

Simulation of a laser heating experiment depositing 30 kJ in 1 cm of DT at 12 mg/cc



Energy deposition phase:
30 kJ of 1.0 um light

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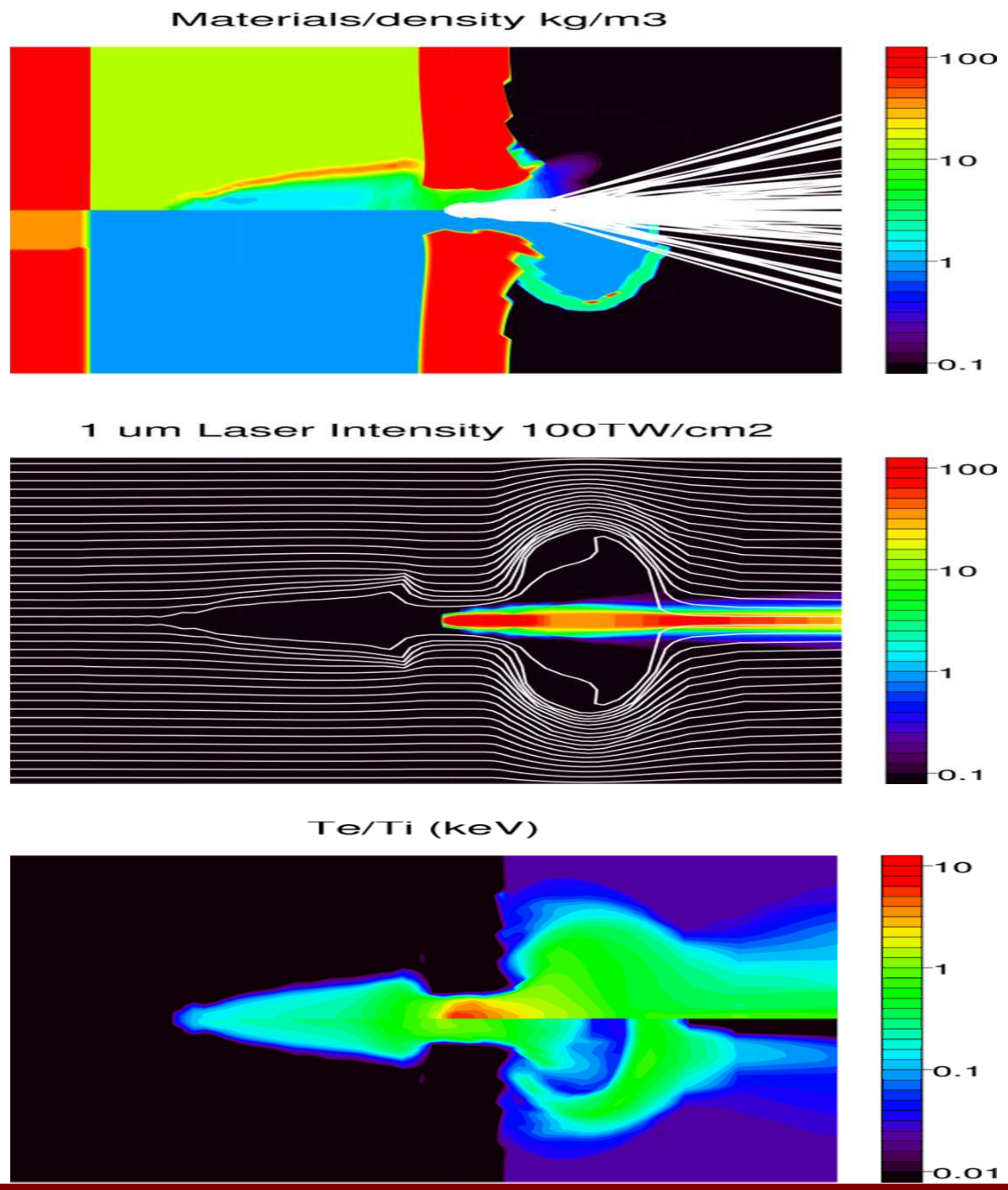

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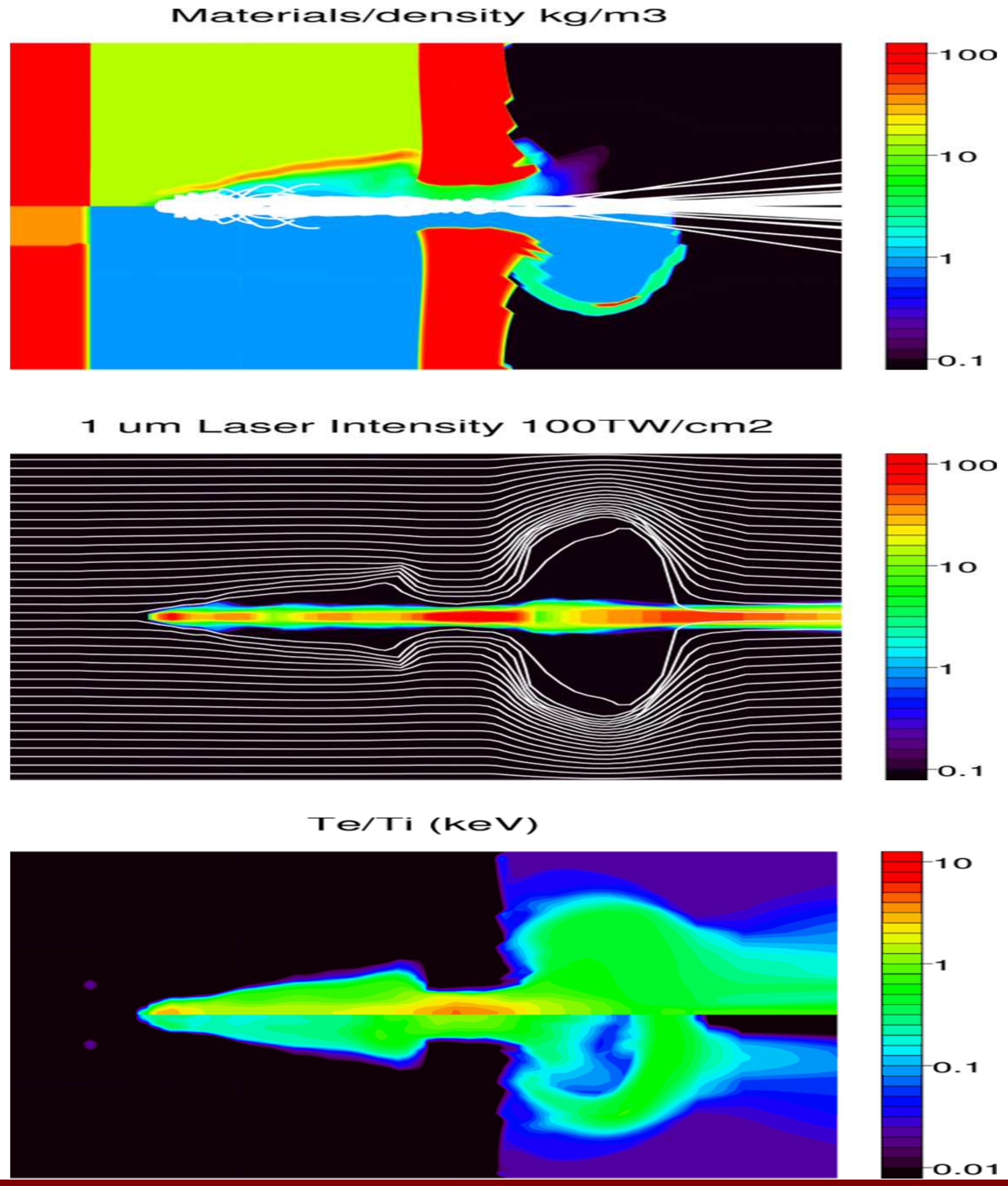

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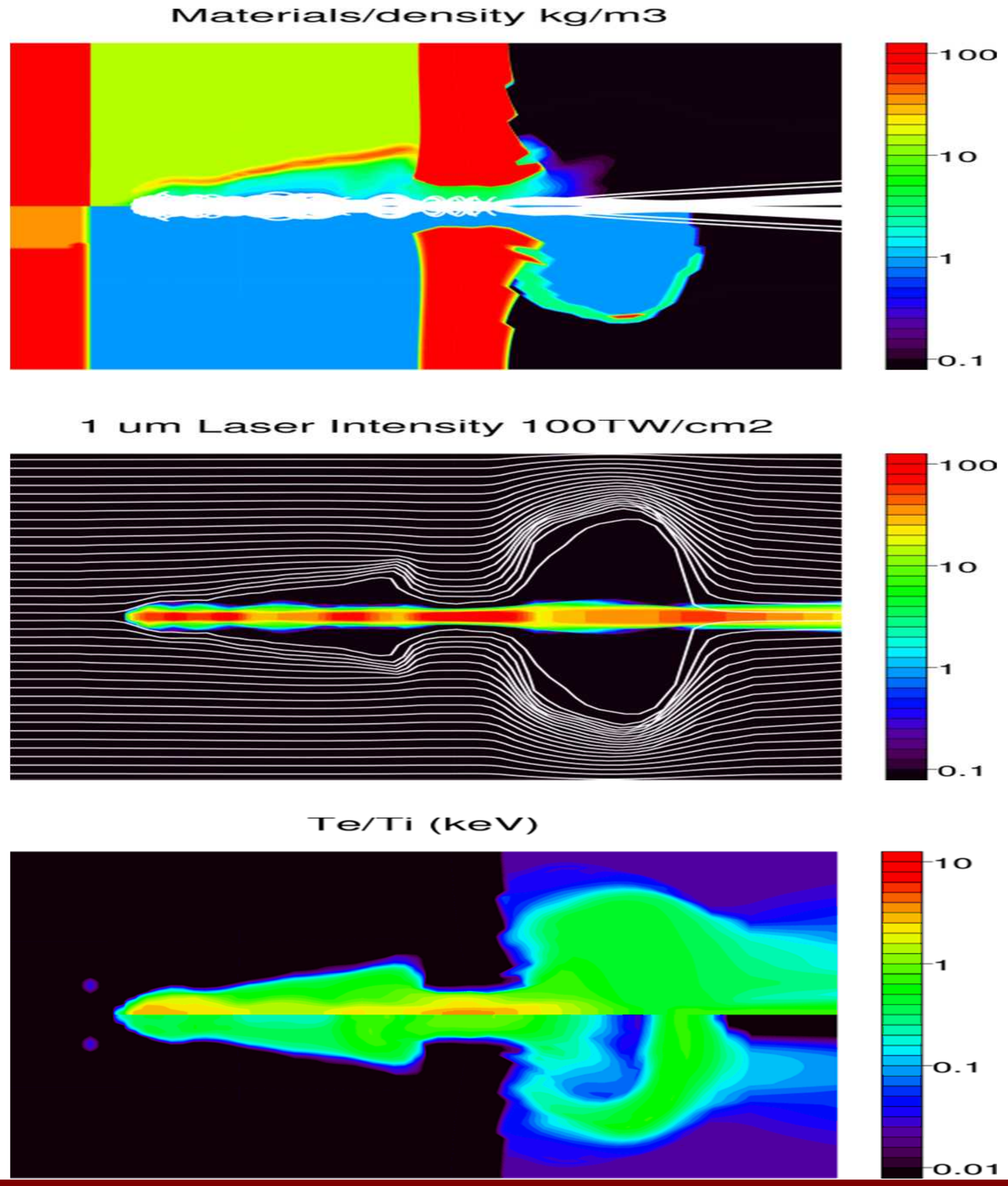

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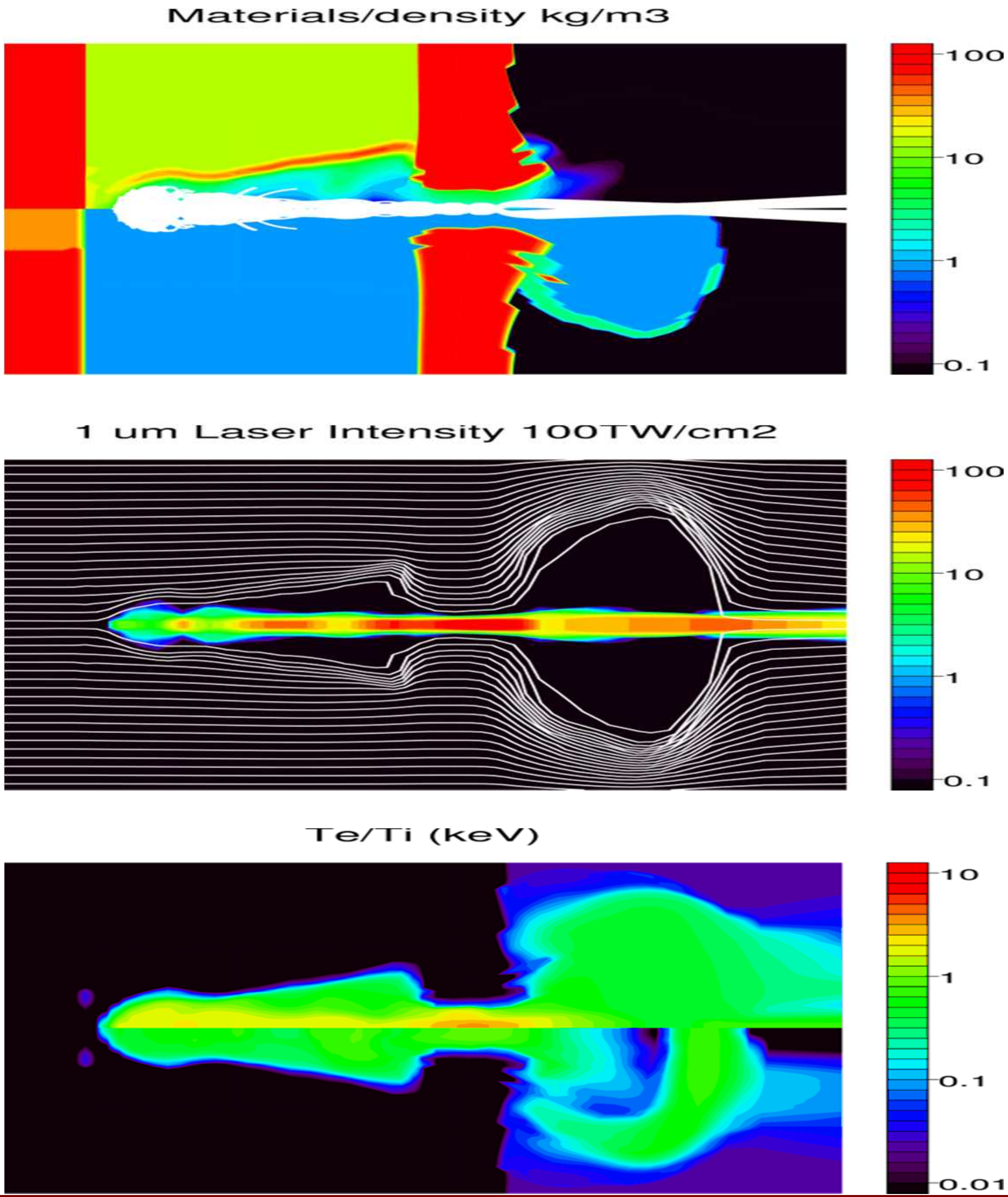

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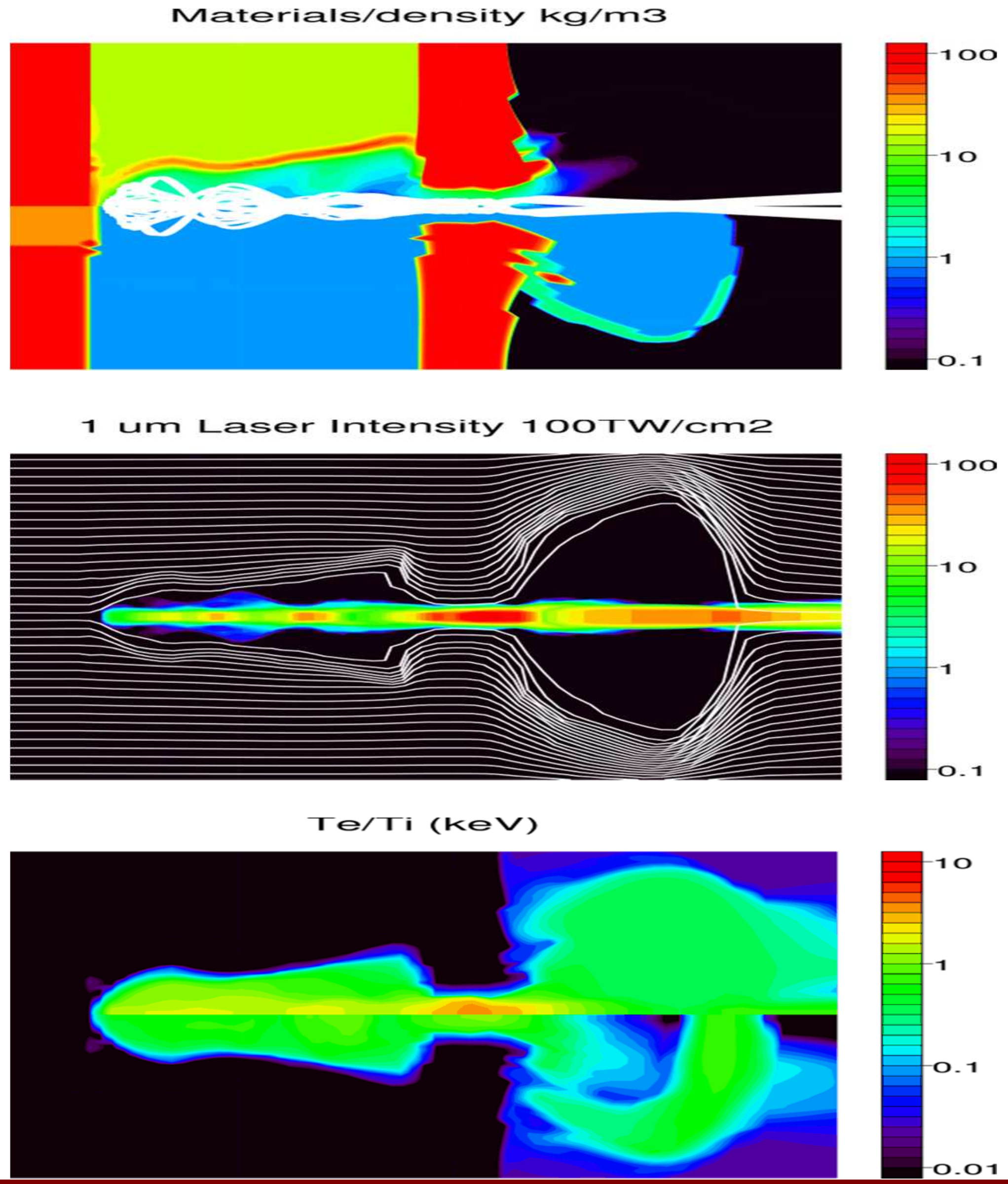

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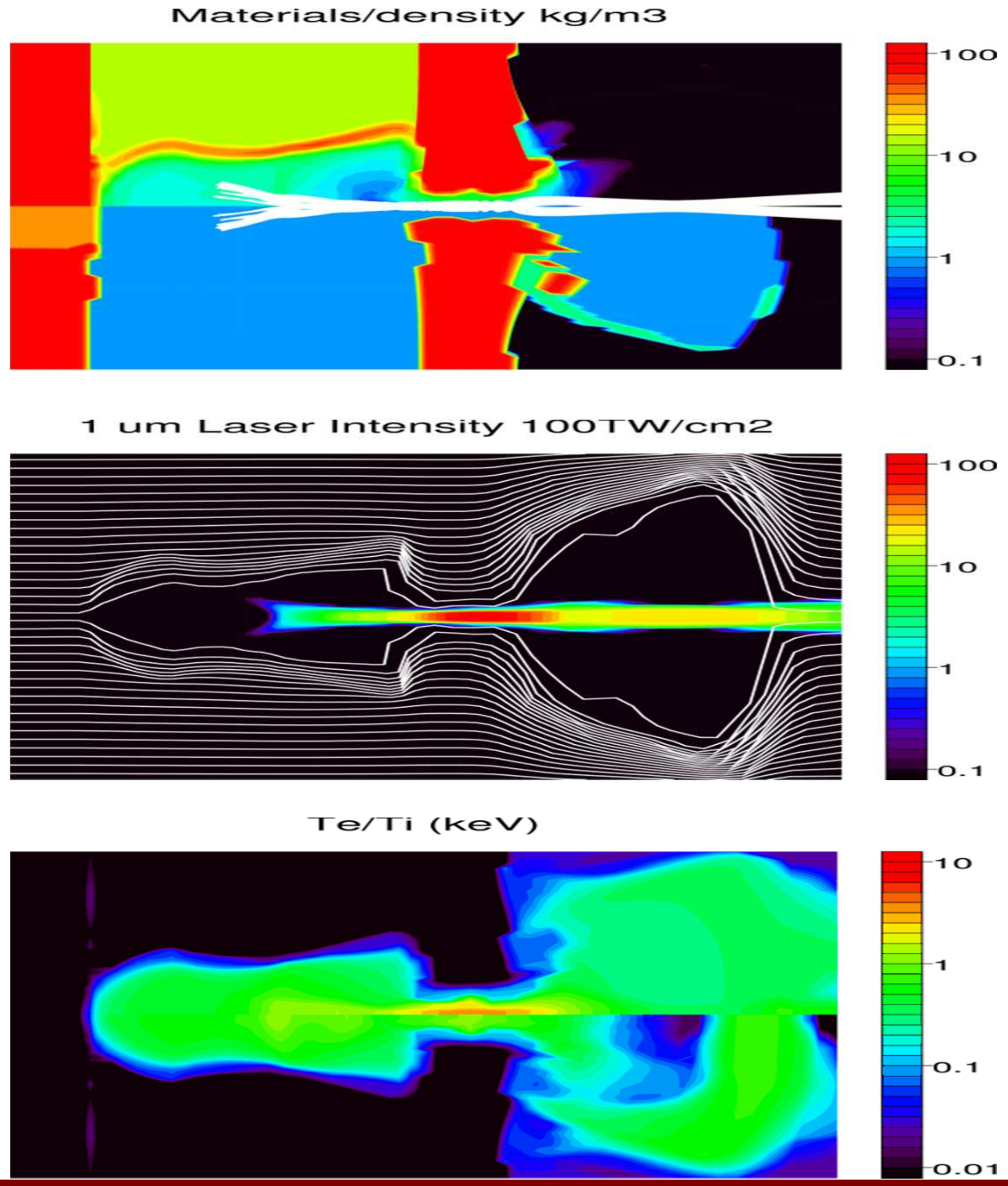

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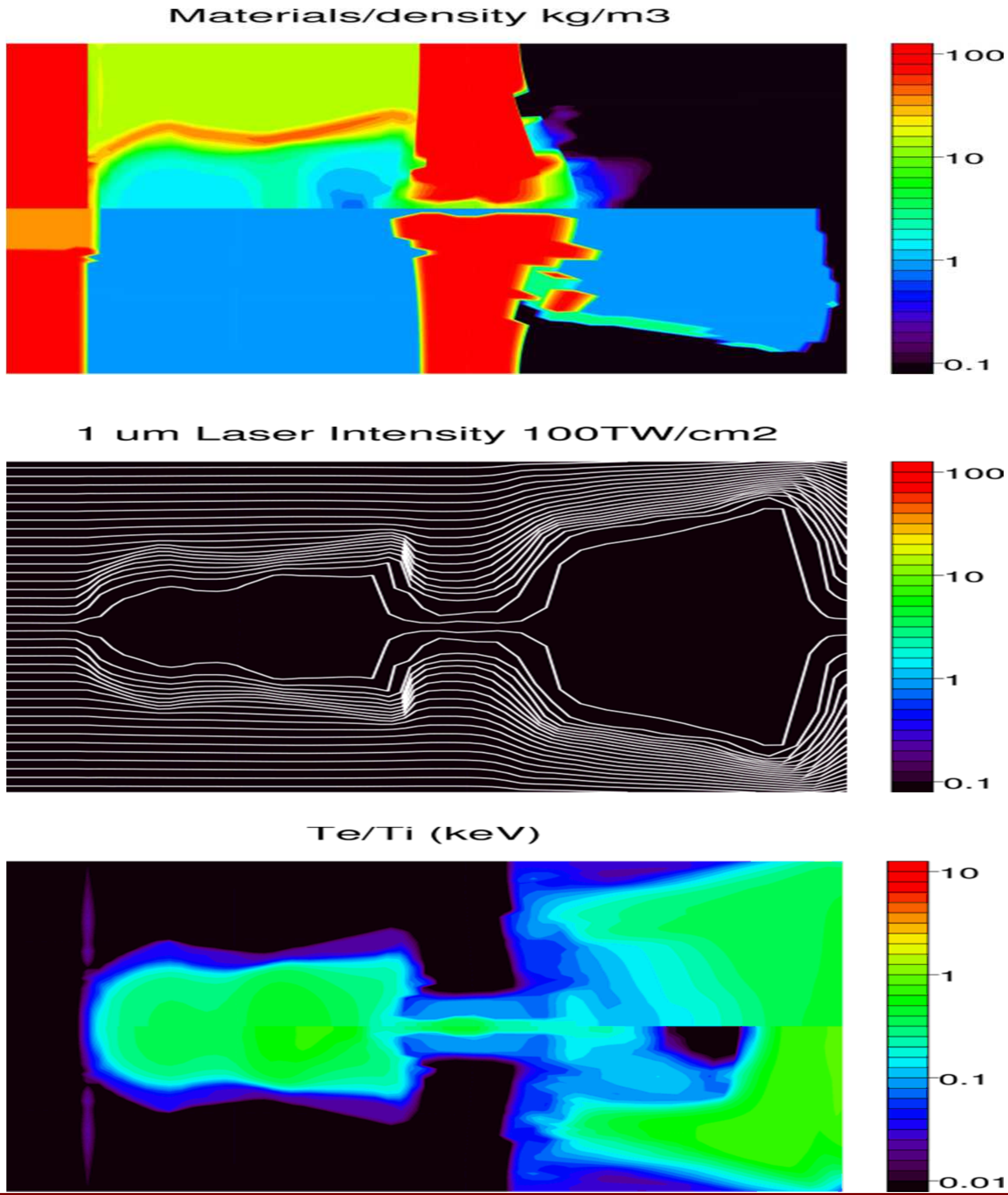

Energy deposition phase:
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Laser preheating for MagLIF at large energies could be tested using 1 quad of NIF

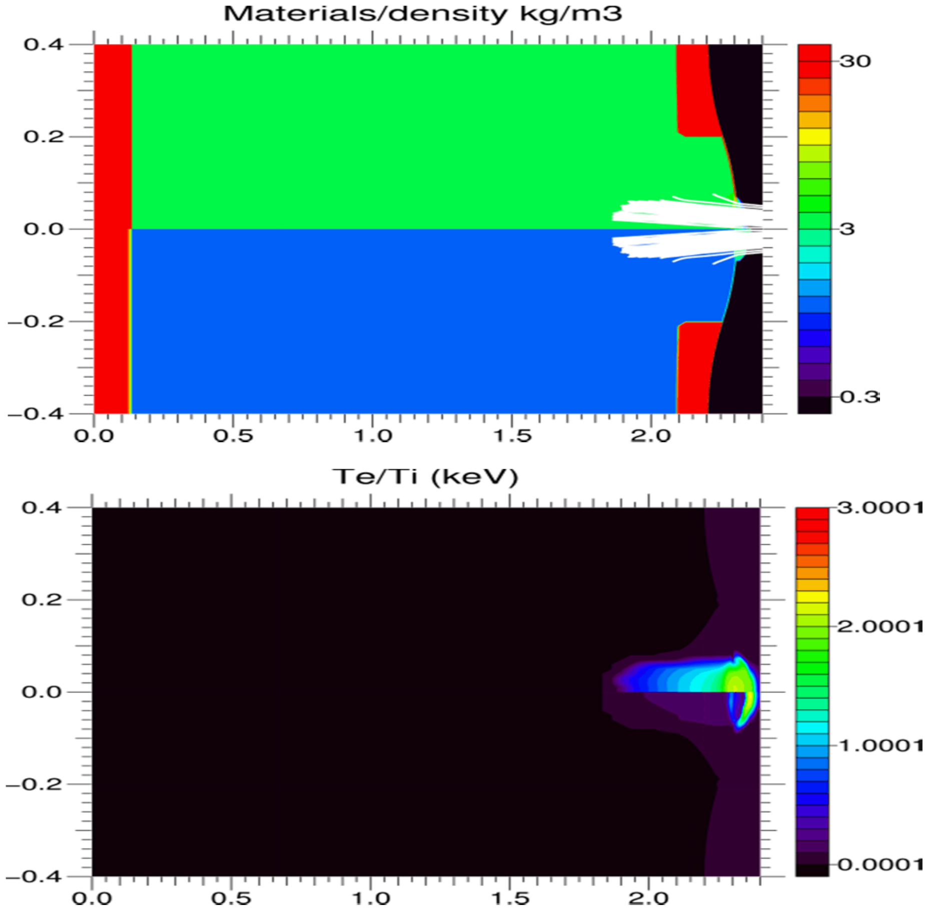
The 1st NIF experiments should not require modification to normal operations. Thus

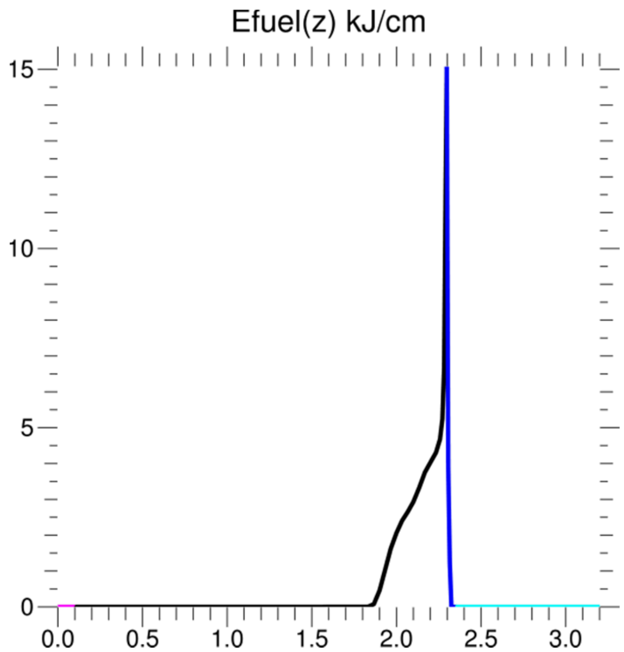
- The laser frequency will be 3ω
- The pulse length will be limited to 6 ns
- The gas will not be magnetized
- Deuterium gas at 3.6 mg/cc should be used instead of DT at 4.5 mg/cc

Lasnex simulations of preheat experiments using 1 quad of NIF to deliver 30 kJ to 3.6 mg/cc deuterium in 6 ns

B=0

Focal spot = 1mm on foil





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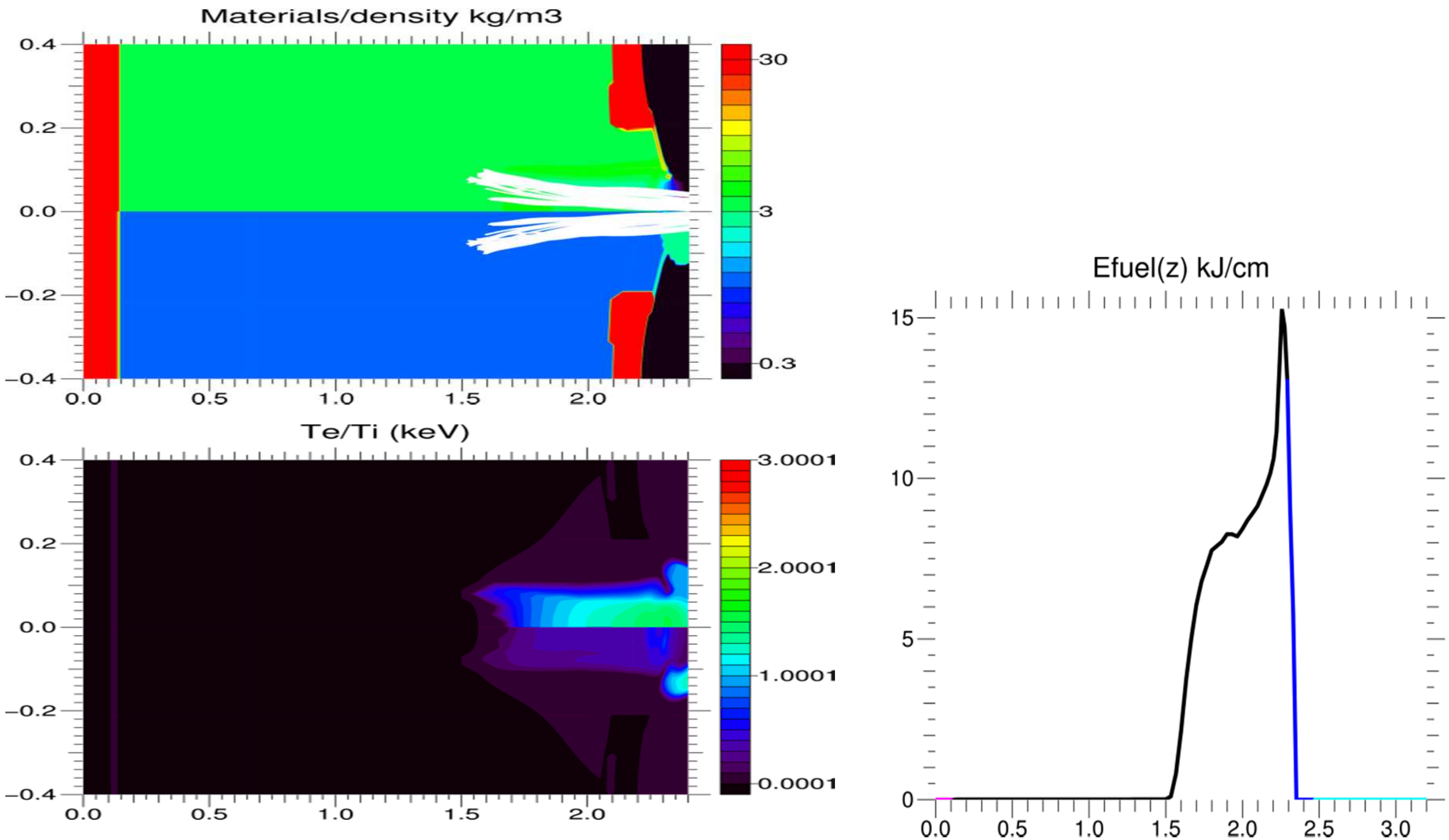

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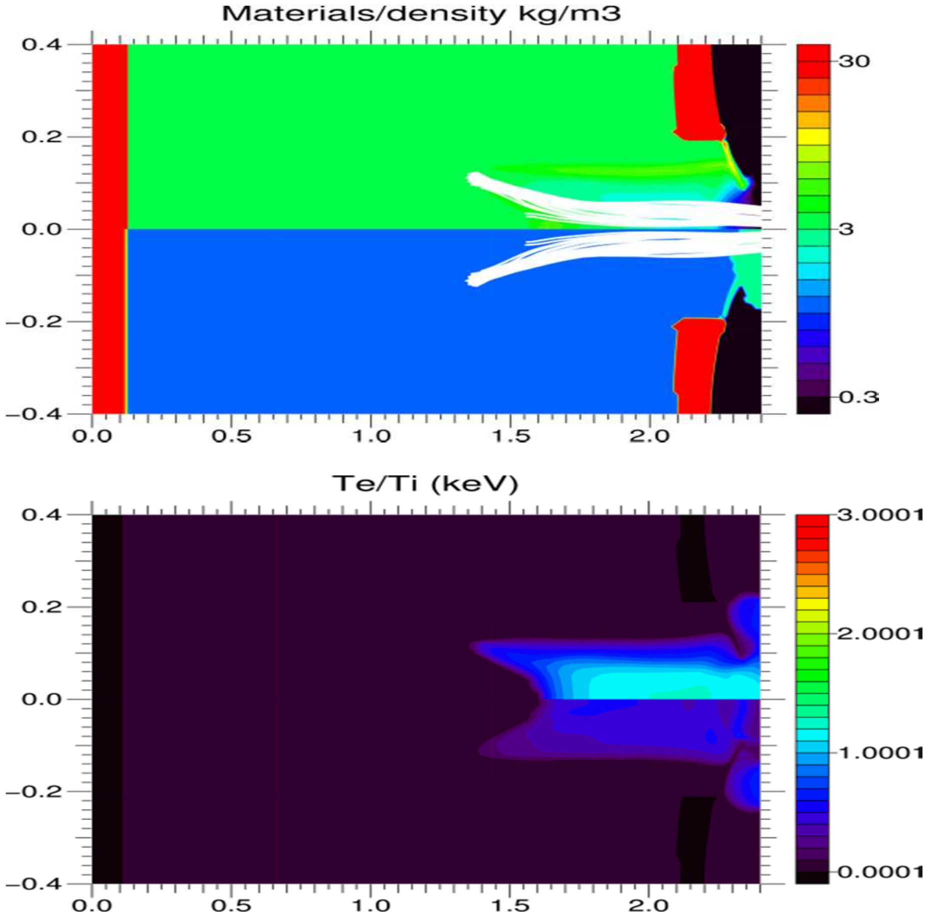

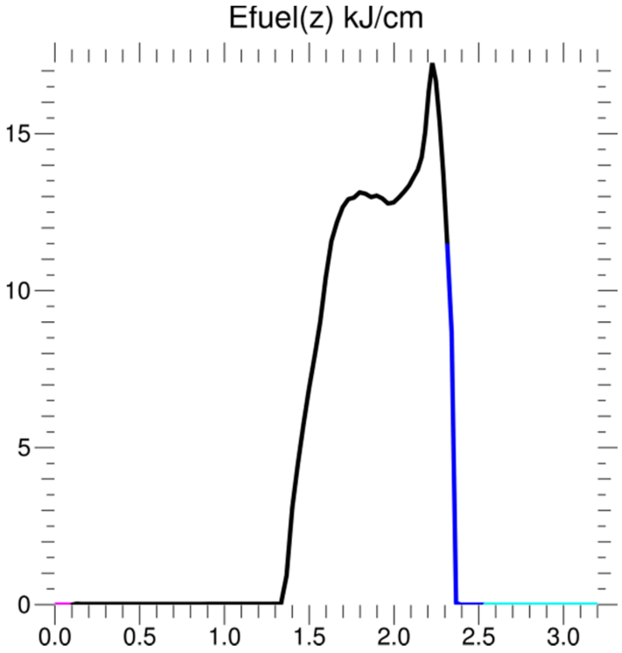

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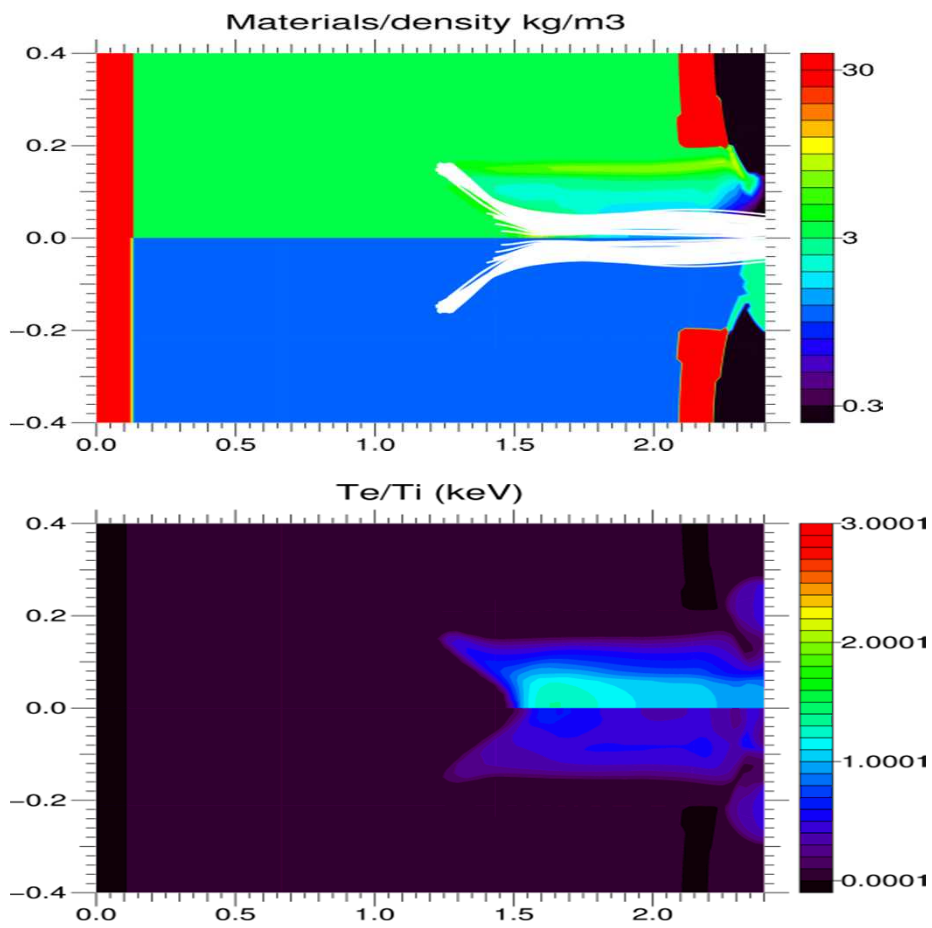

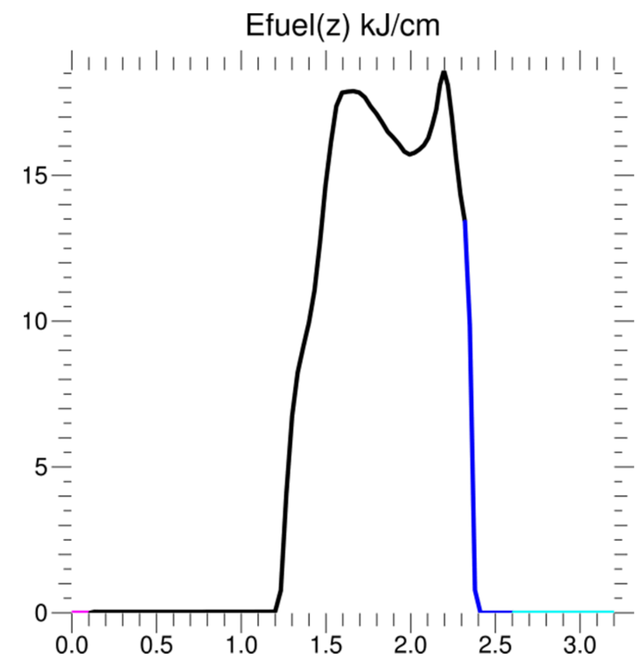

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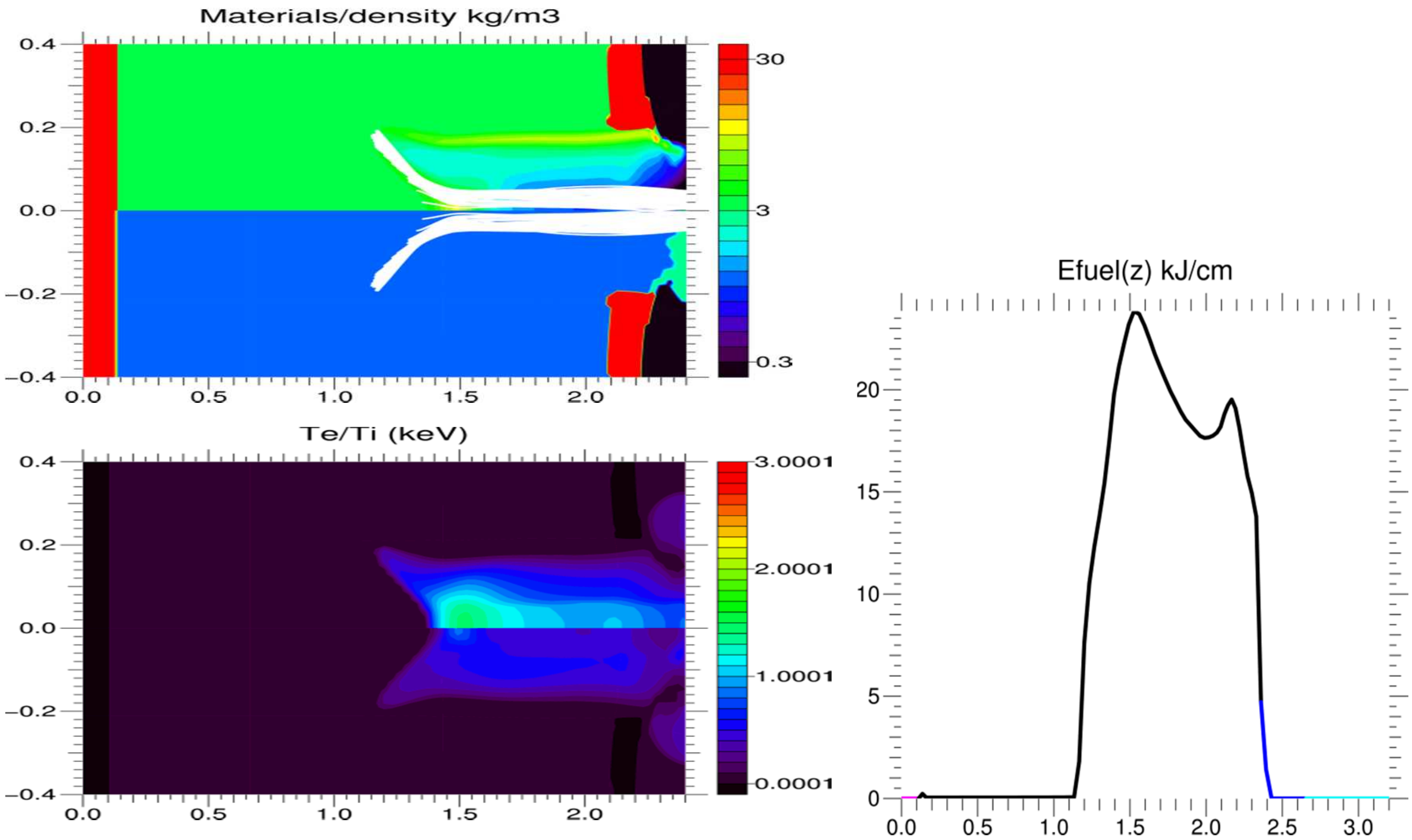

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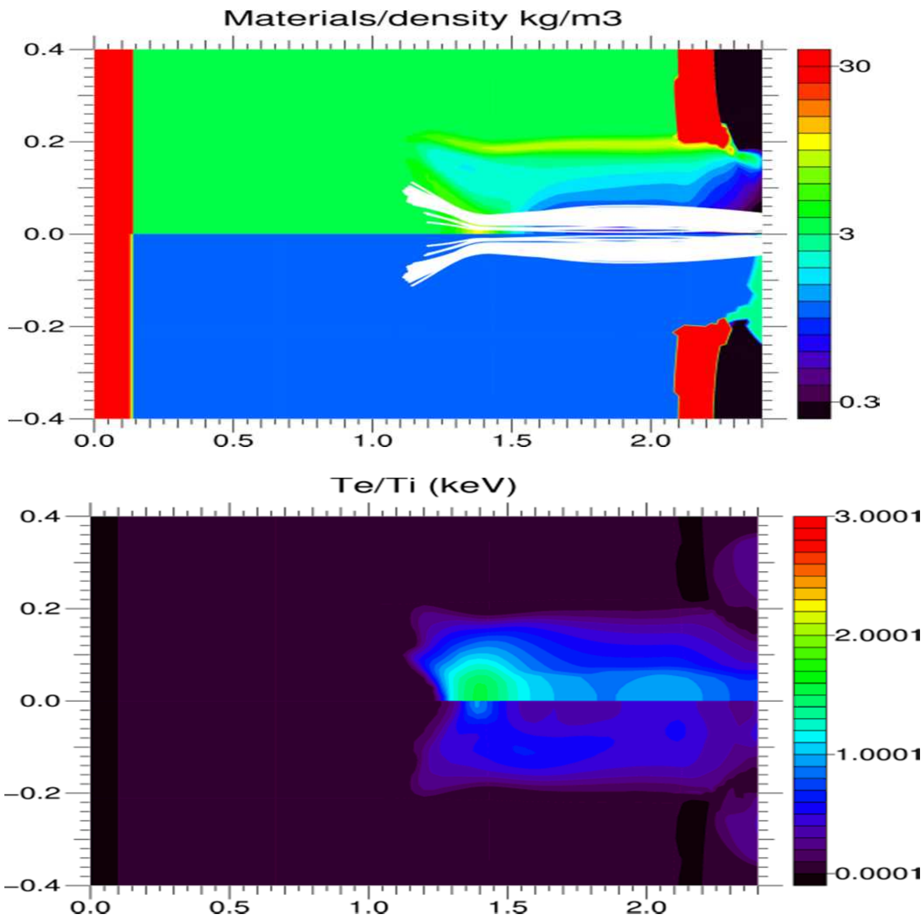

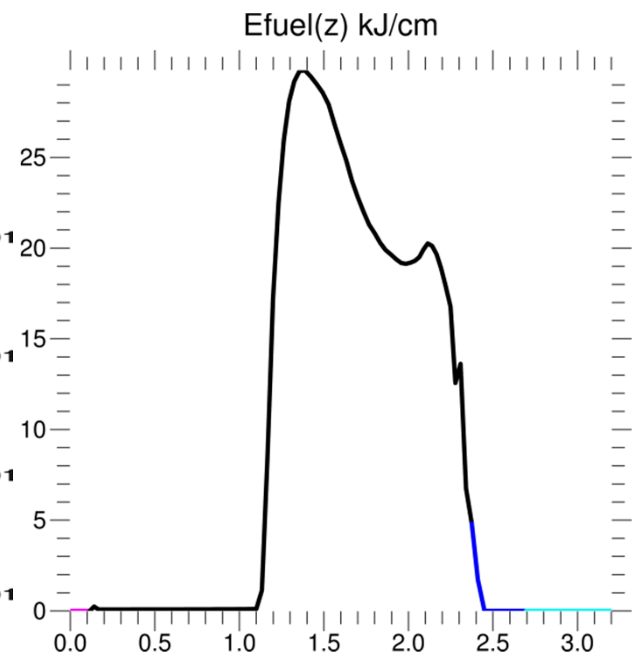

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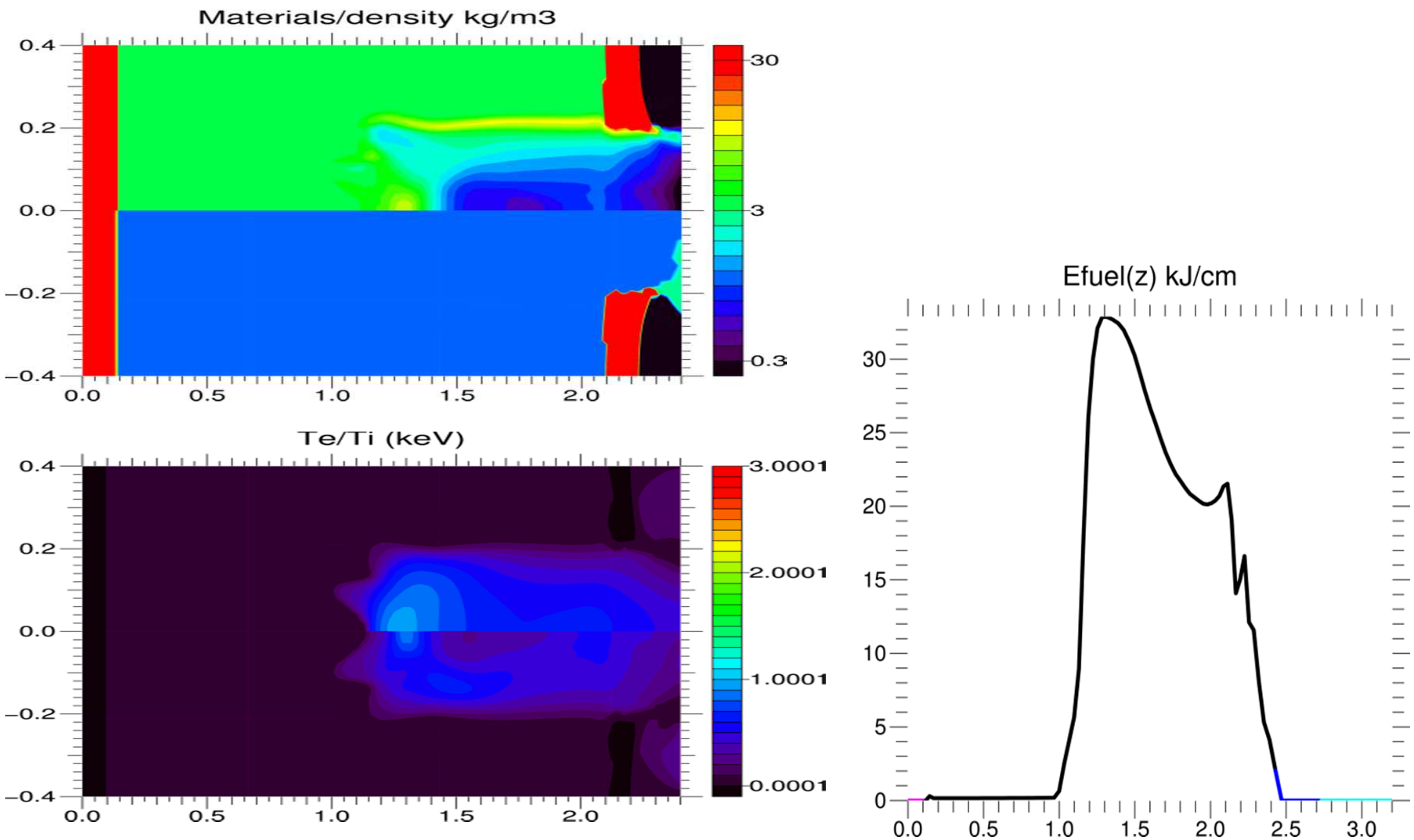

According to simulations, magnetization affects the laser deposition

The laser energy can still be deposited in 1 cm but

- the focal spot size must be increased to 1.8 mm diameter
- or lower laser frequency is required (2ω)

Lasnex simulations of preheat experiments using 1 quad of NIF to deliver 30 kJ to 3.6 mg/cc deuterium in 6 ns

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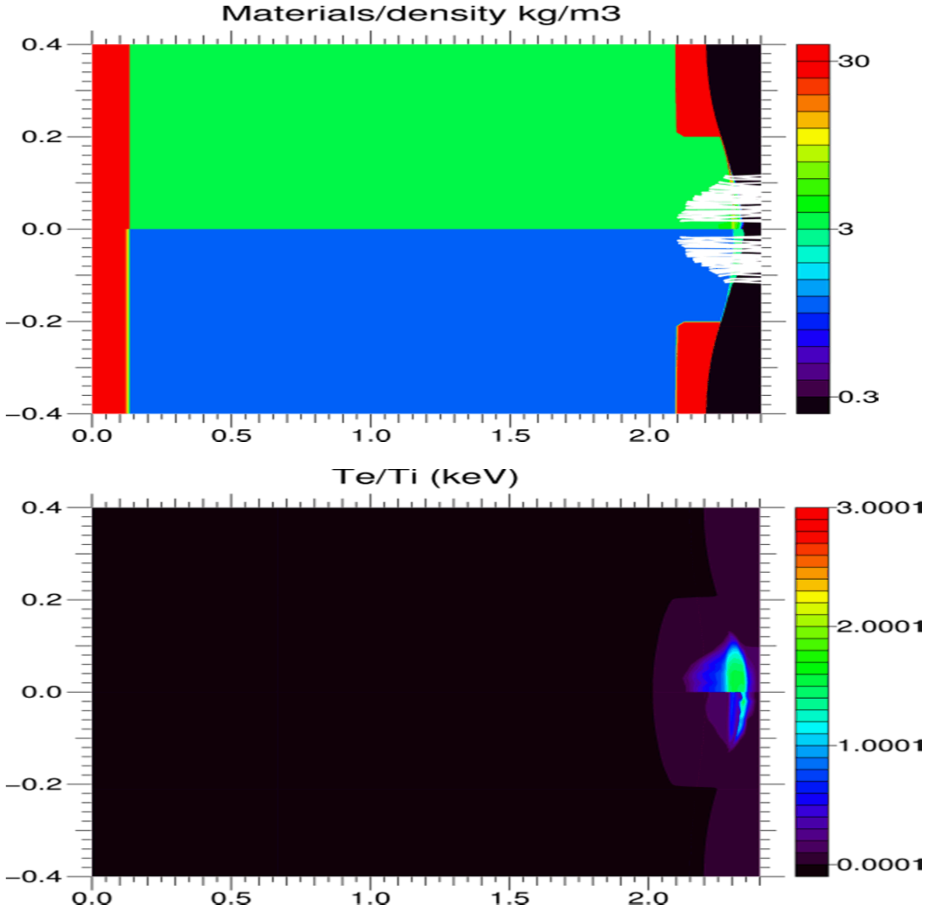
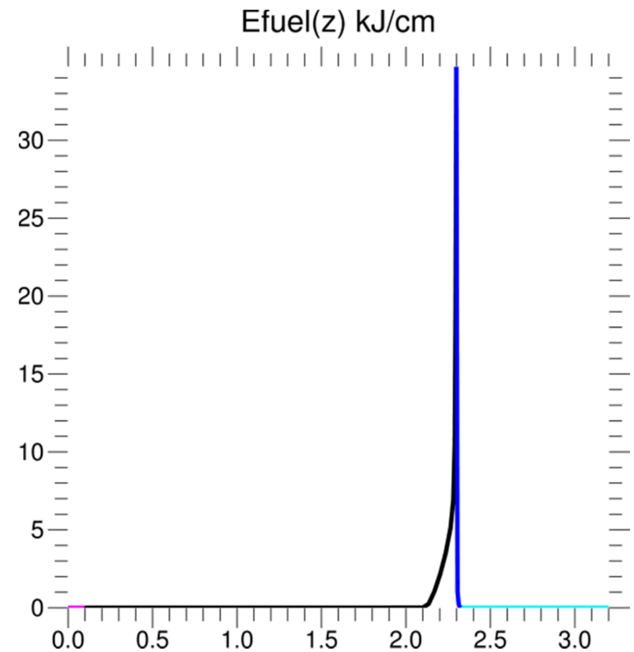
B=30





Lasnex simulations of preheat experiments using 1 quad of NIF to deliver 30 kJ to 3.6 mg/cc deuterium in 6 ns

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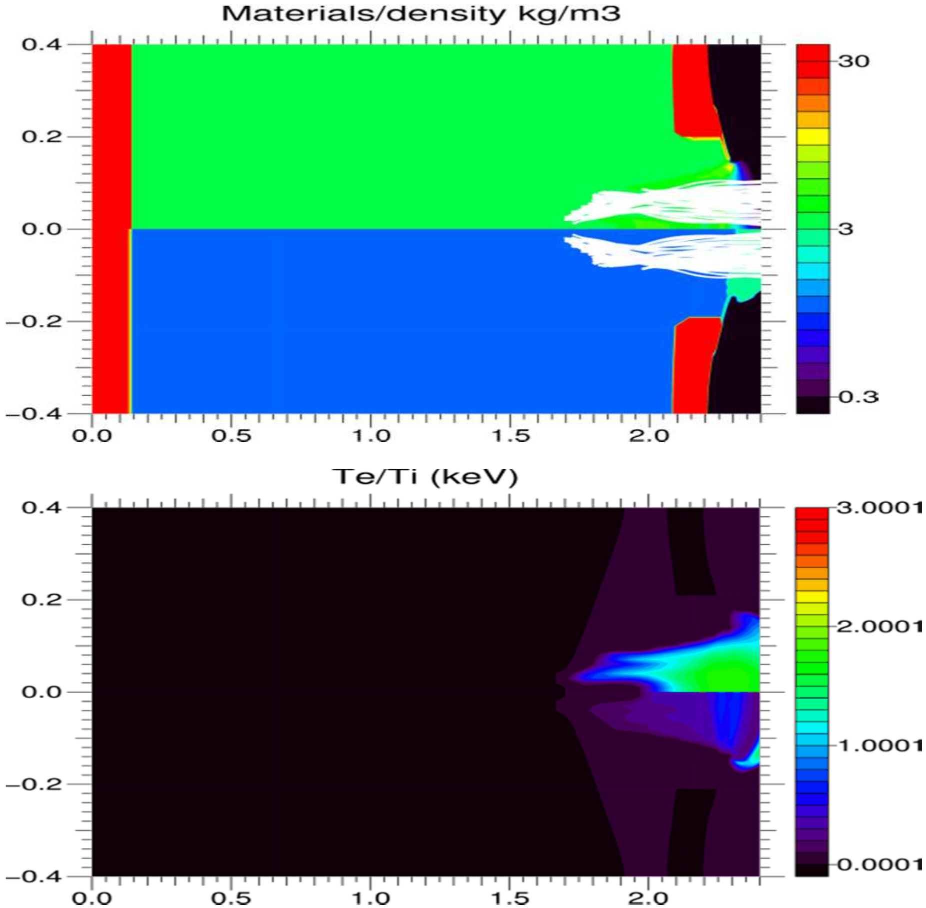

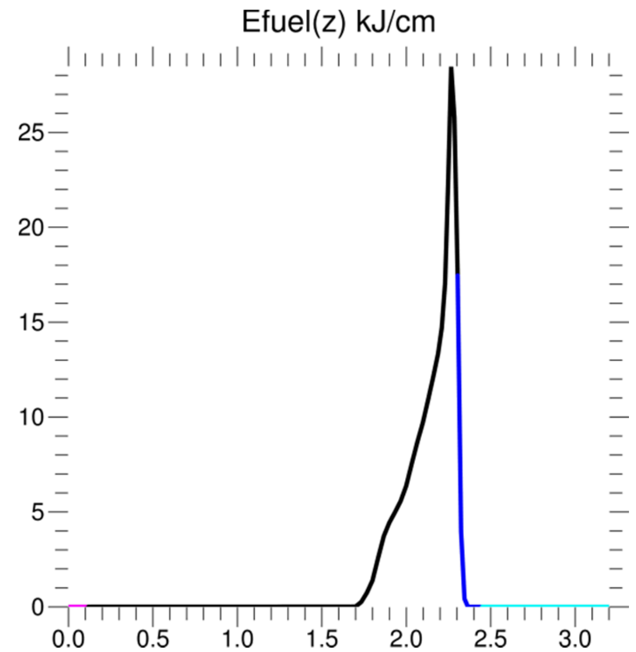

Lasnex simulations of preheat experiments using 1 quad of NIF to deliver 30 kJ to 3.6 mg/cc deuterium in 6 ns

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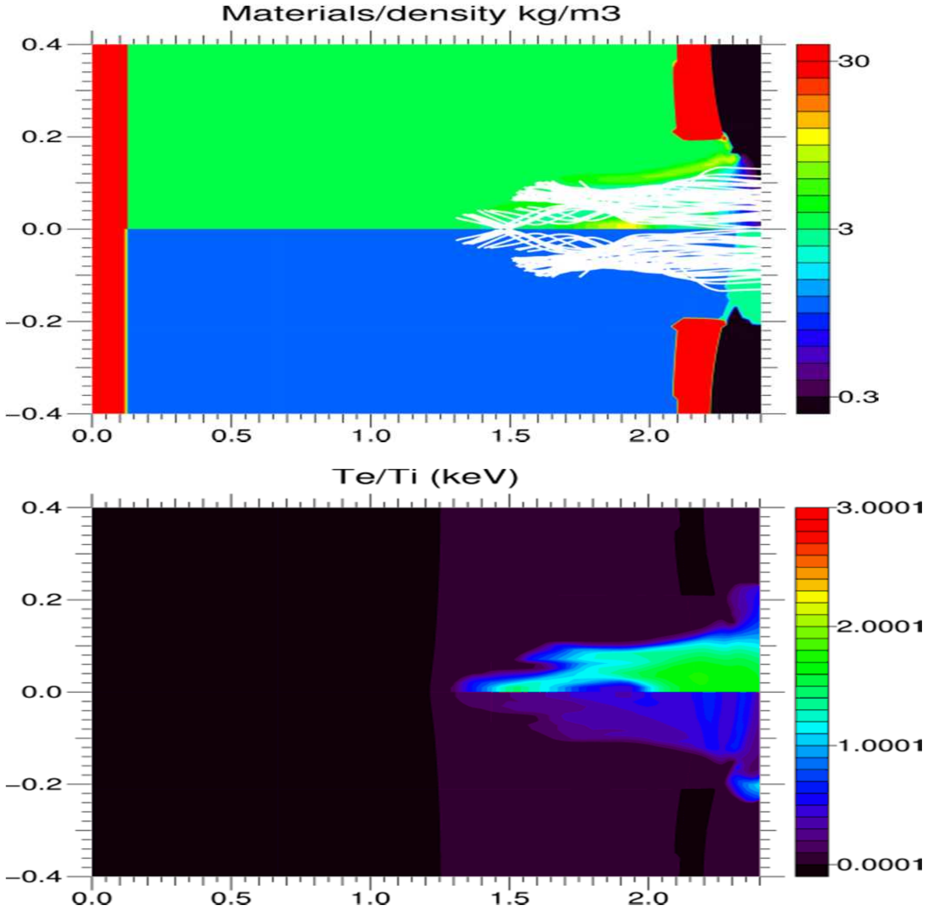

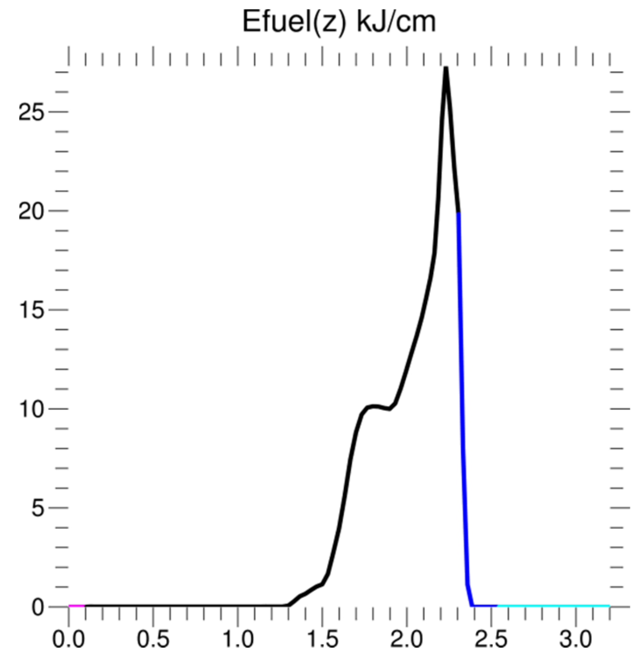

Lasnex simulations of preheat experiments using 1 quad of NIF to deliver 30 kJ to 3.6 mg/cc deuterium in 6 ns

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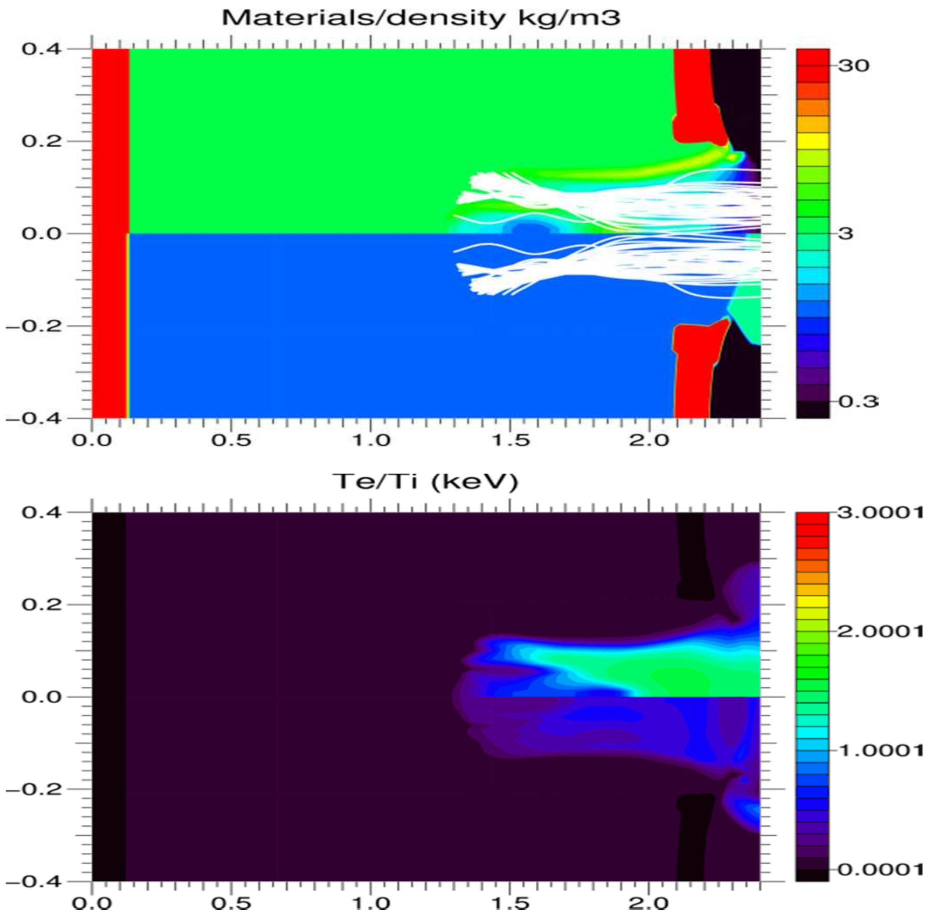

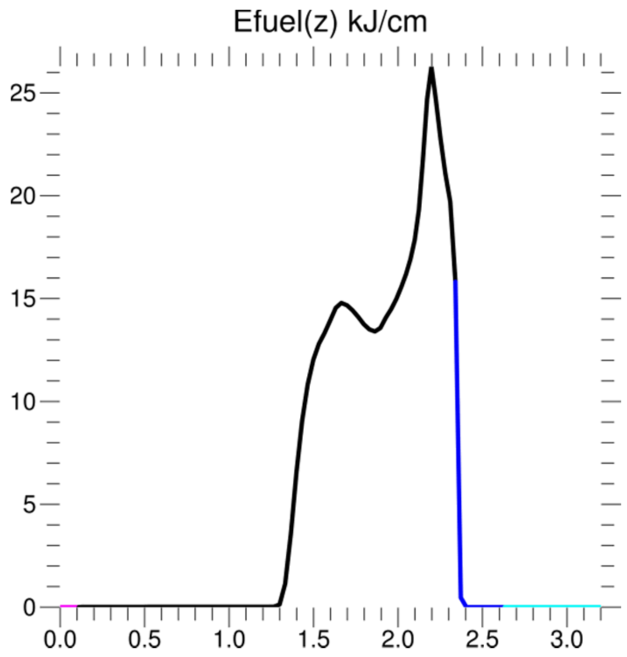

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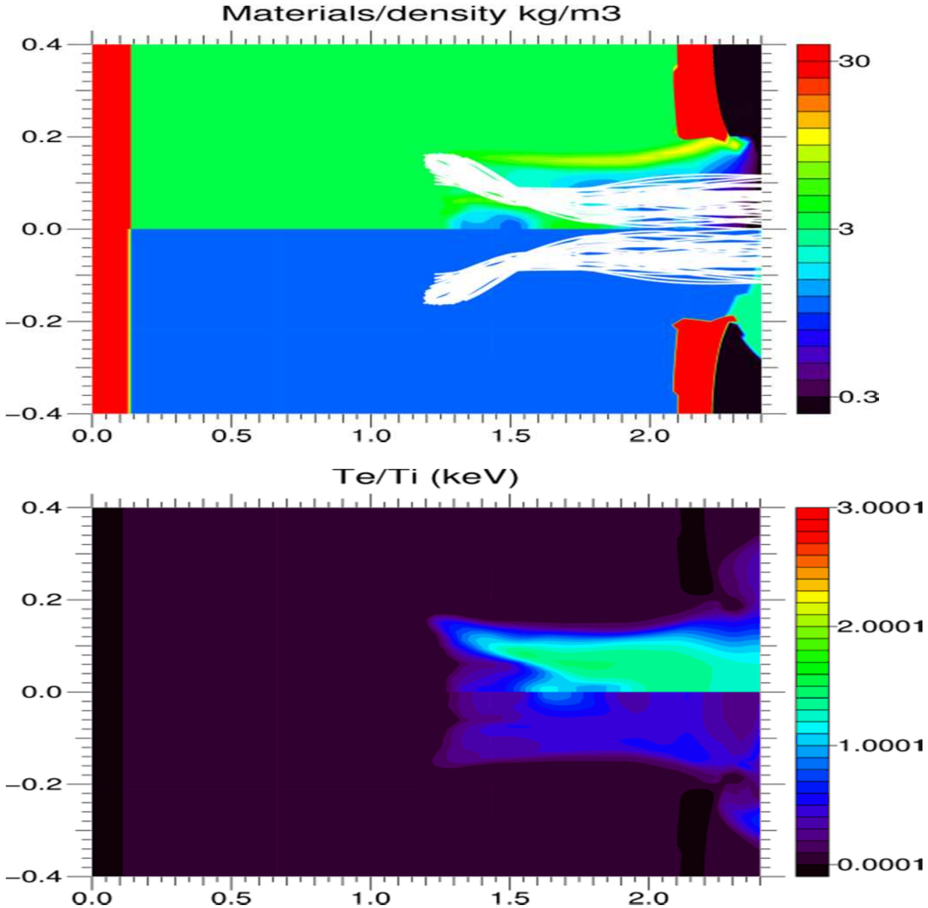

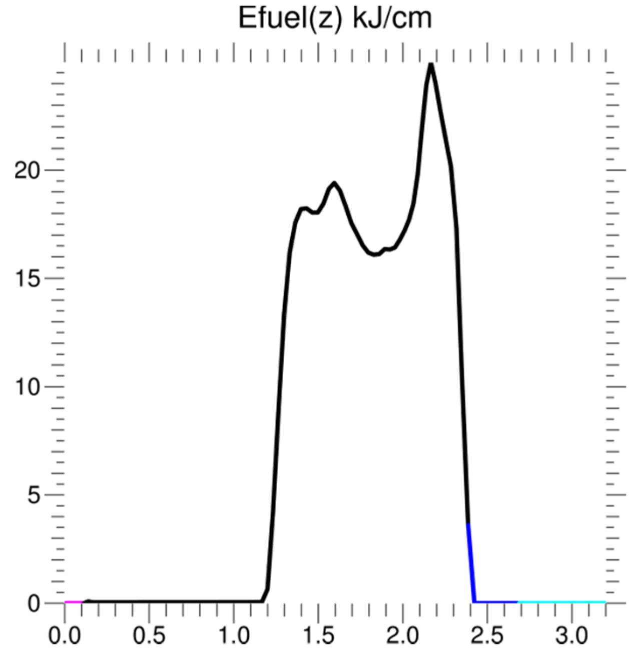

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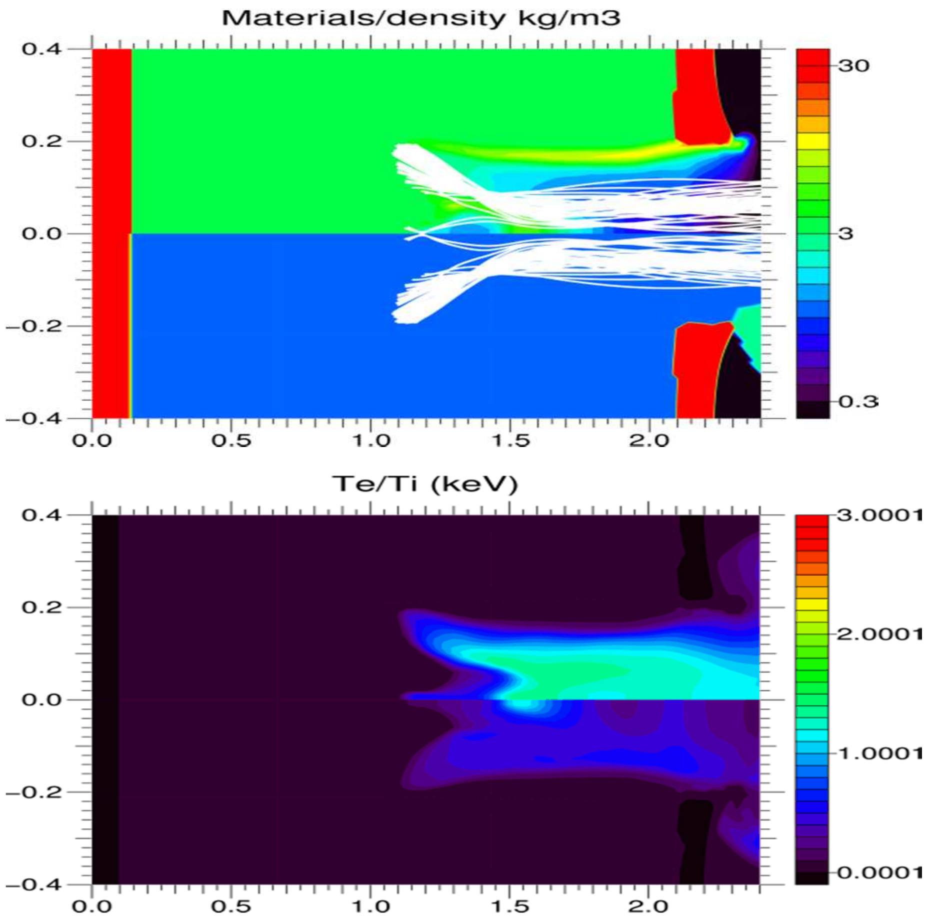

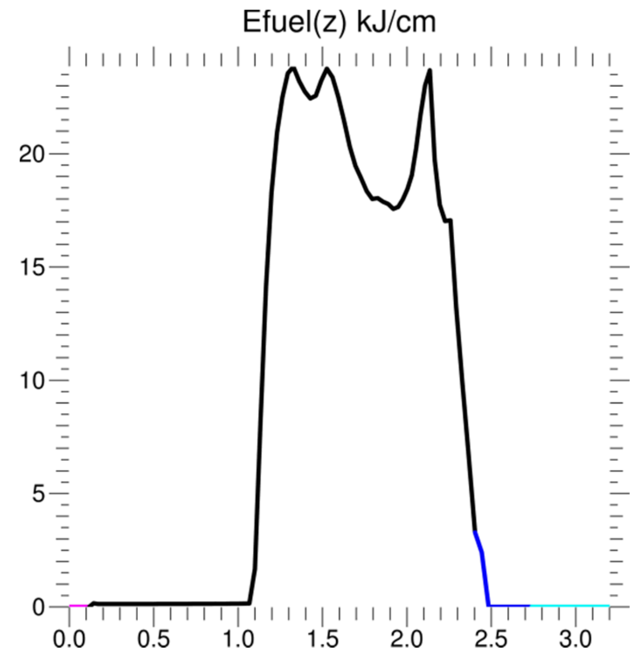

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