Ion Acceleration by Circularly Polarized Pulses

Physics and Possible Applications

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Coworkers

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- (Ultra-)Short review of ion acceleration

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- What is the role of fast electrons in FSA?

A simulation example

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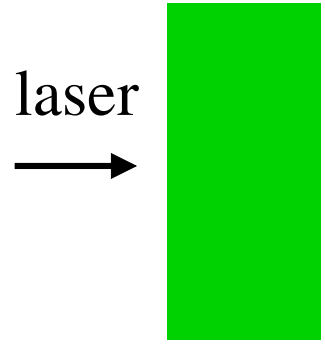
1D PIC simulation, “long” pulse,
normal incidence, linear polarization,
$a = 2.0$, $n_{e0}/n_c = 5$.



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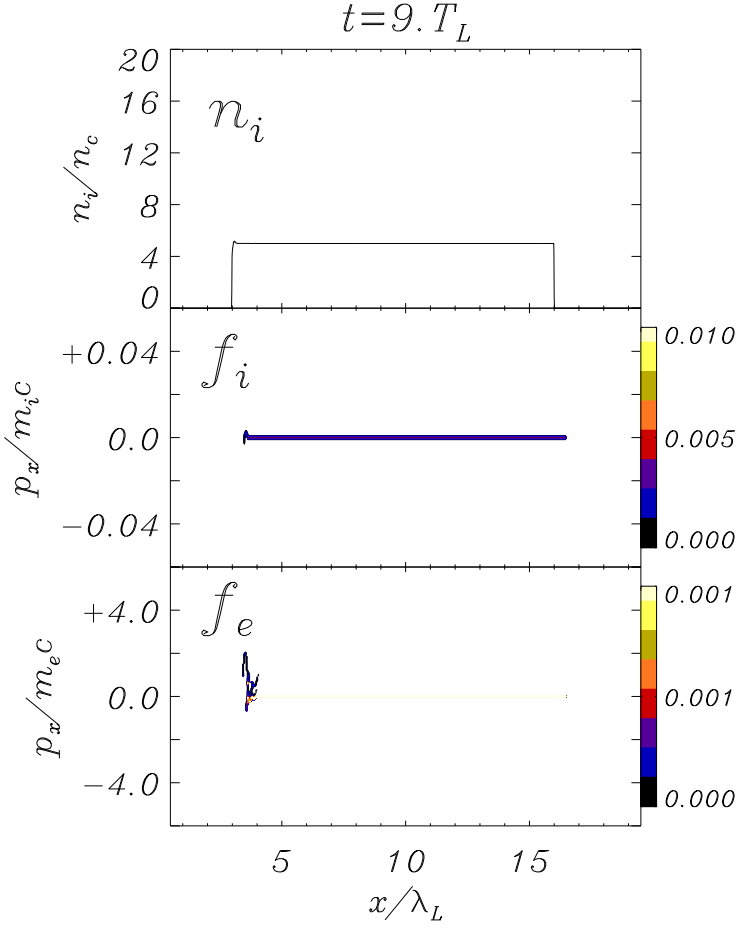

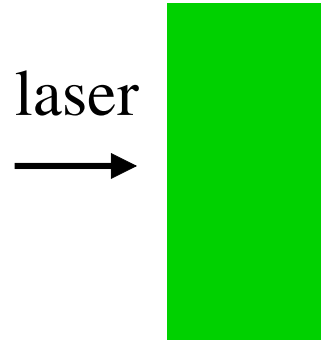

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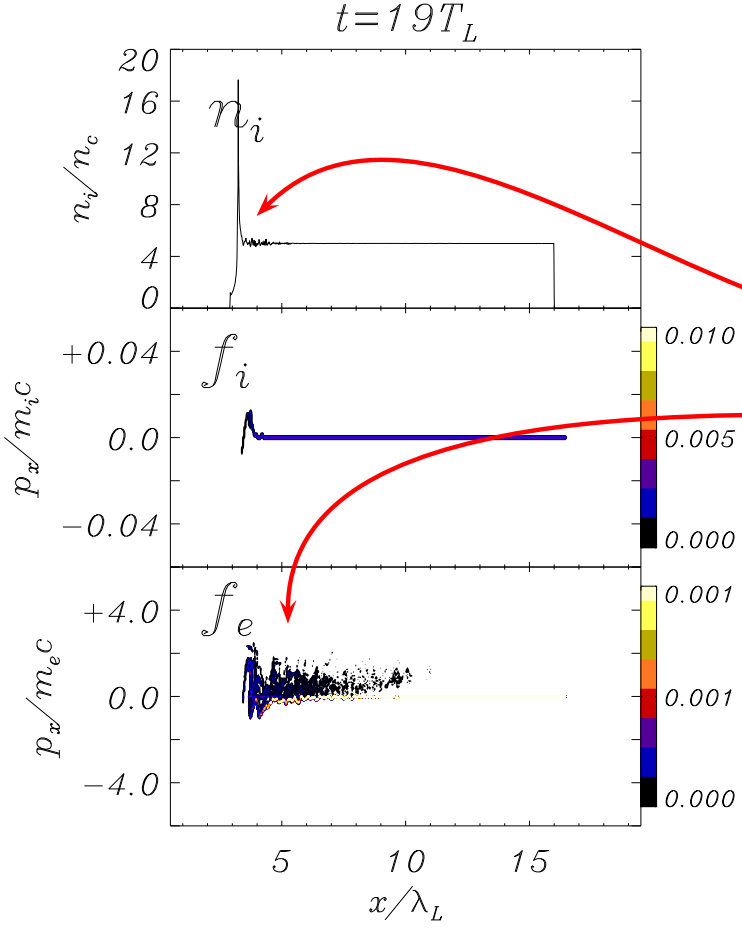

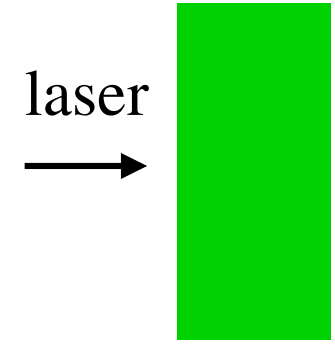

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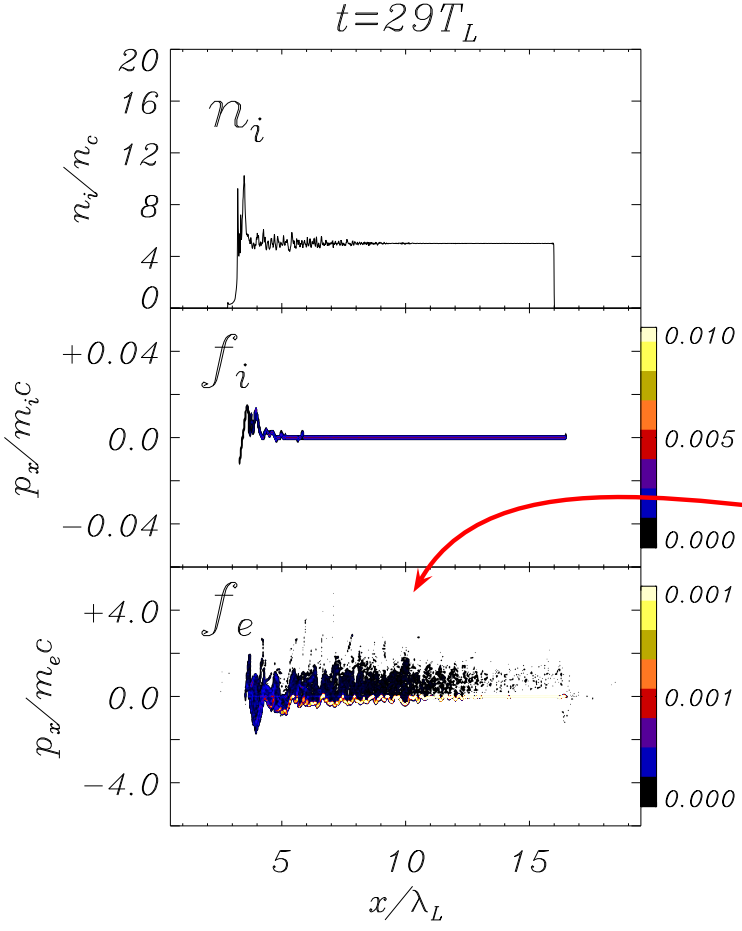

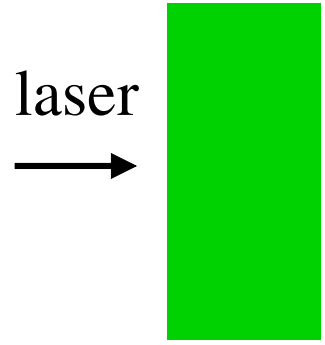

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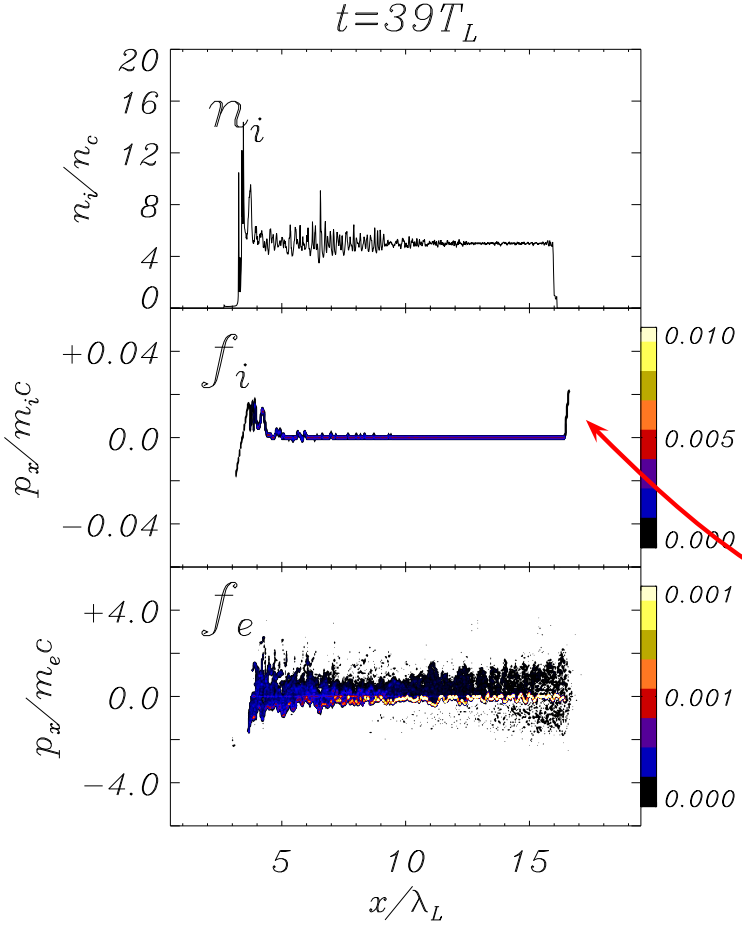

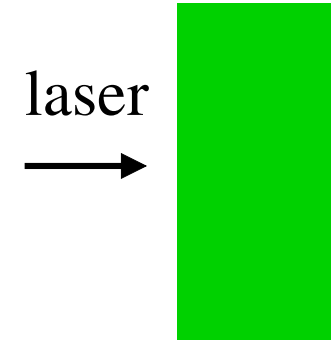

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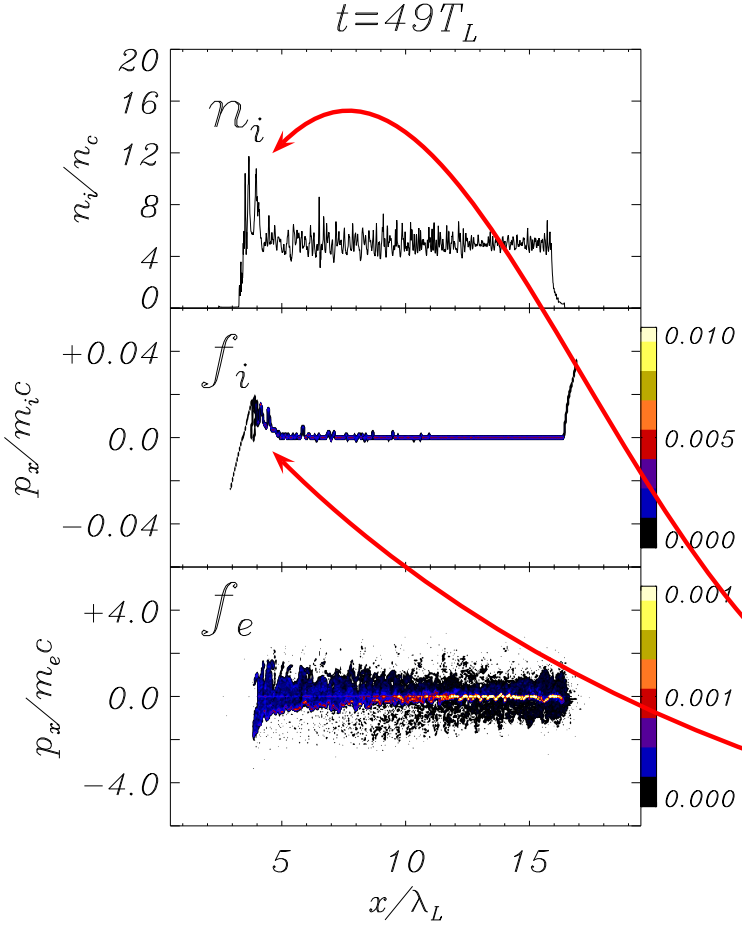

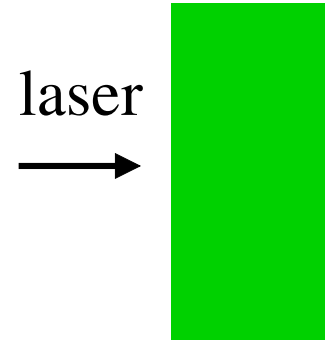

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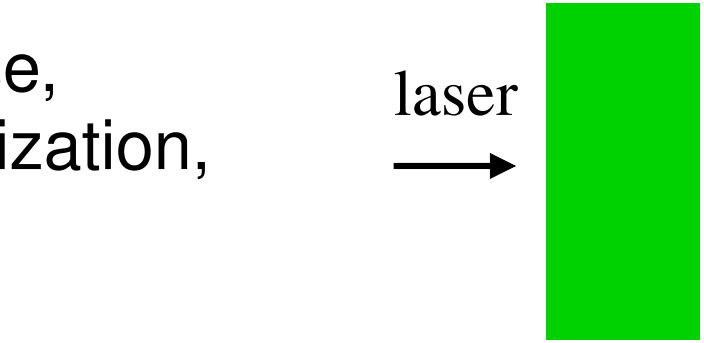

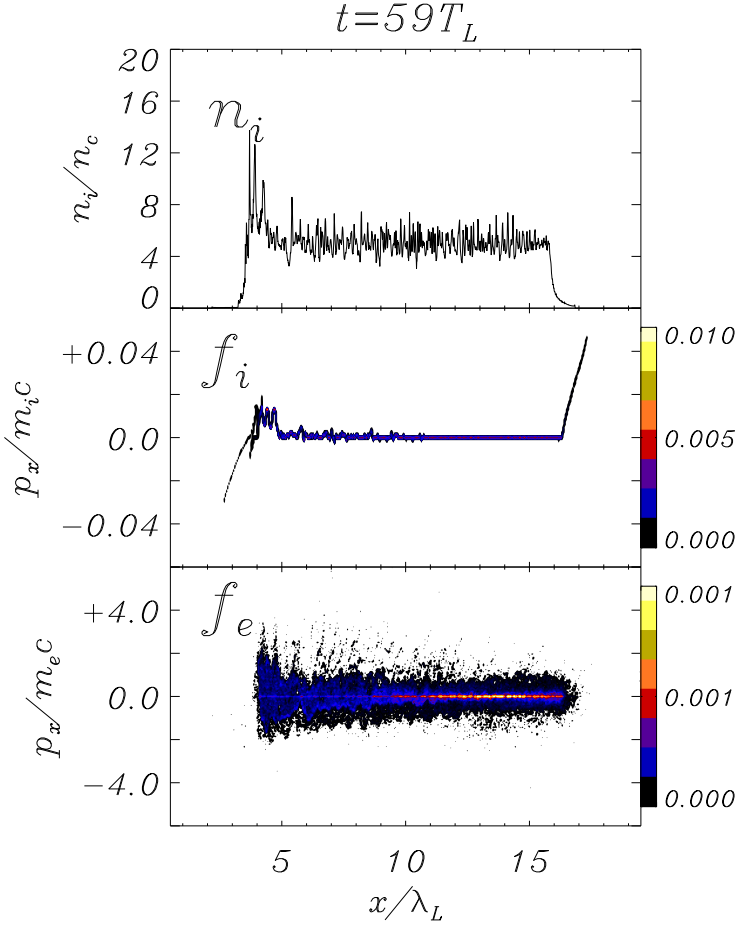

- Interaction starts
- generation of ion spikes + fast electrons
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- RSA starts
- multiple ion spikes, FSA
- RSA & FSA coexist

Switch fast electrons off

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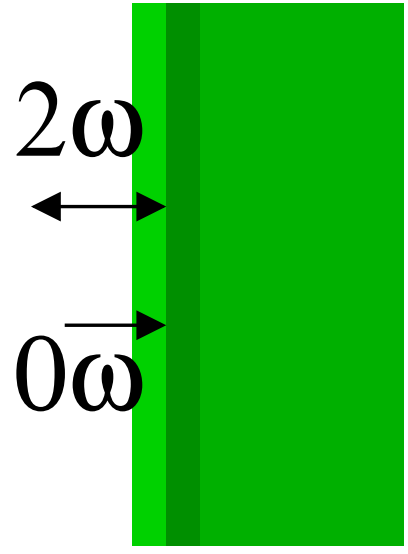

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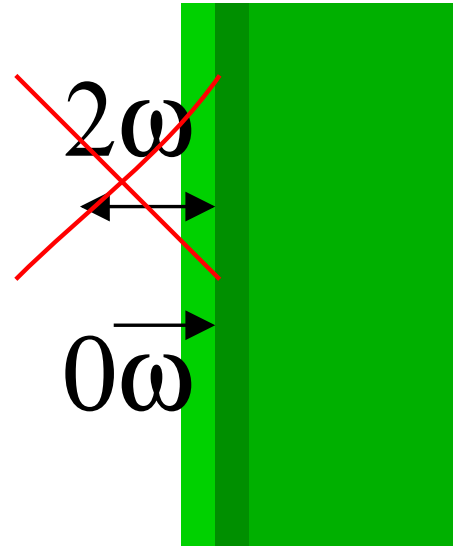

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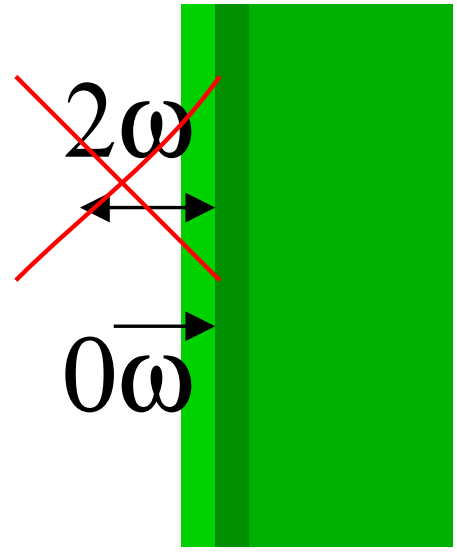
- Does ion acceleration occur for circular polarization, and how does it look like?



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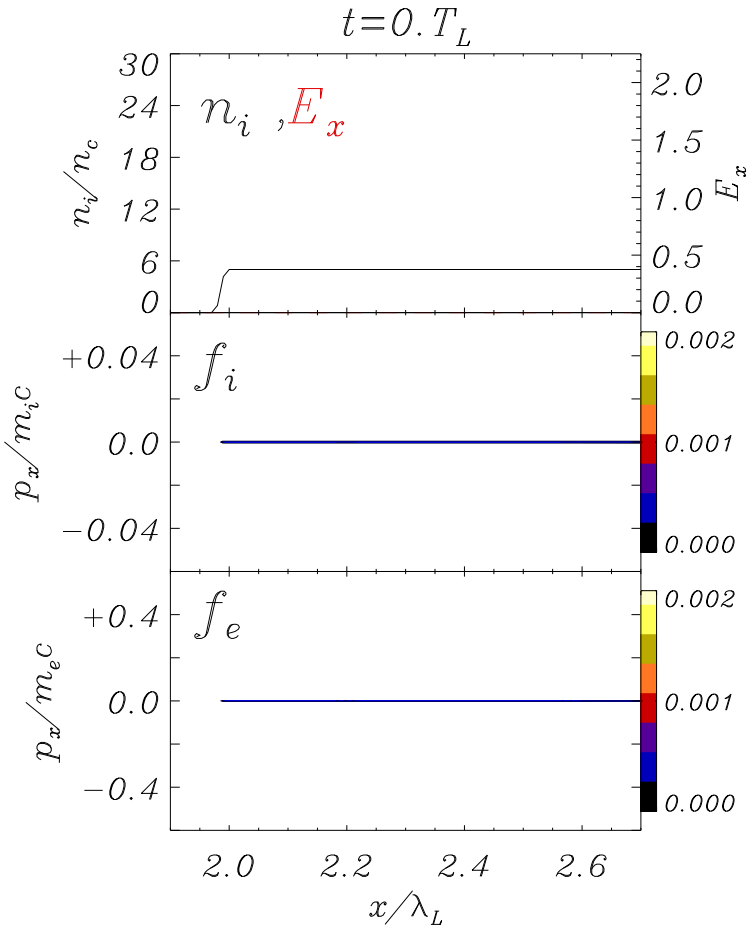

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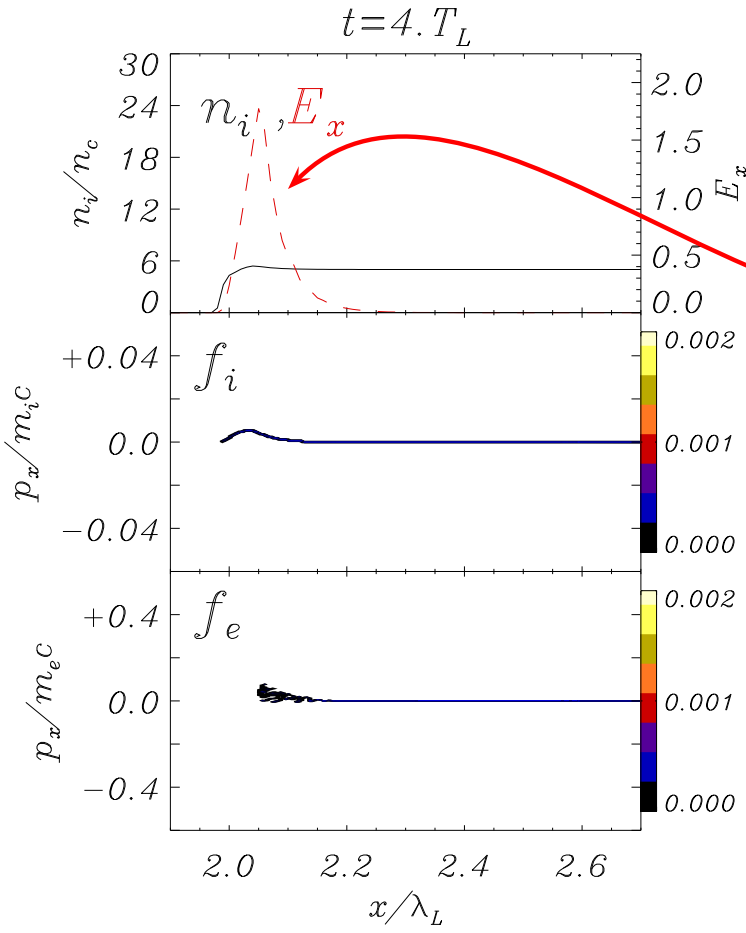

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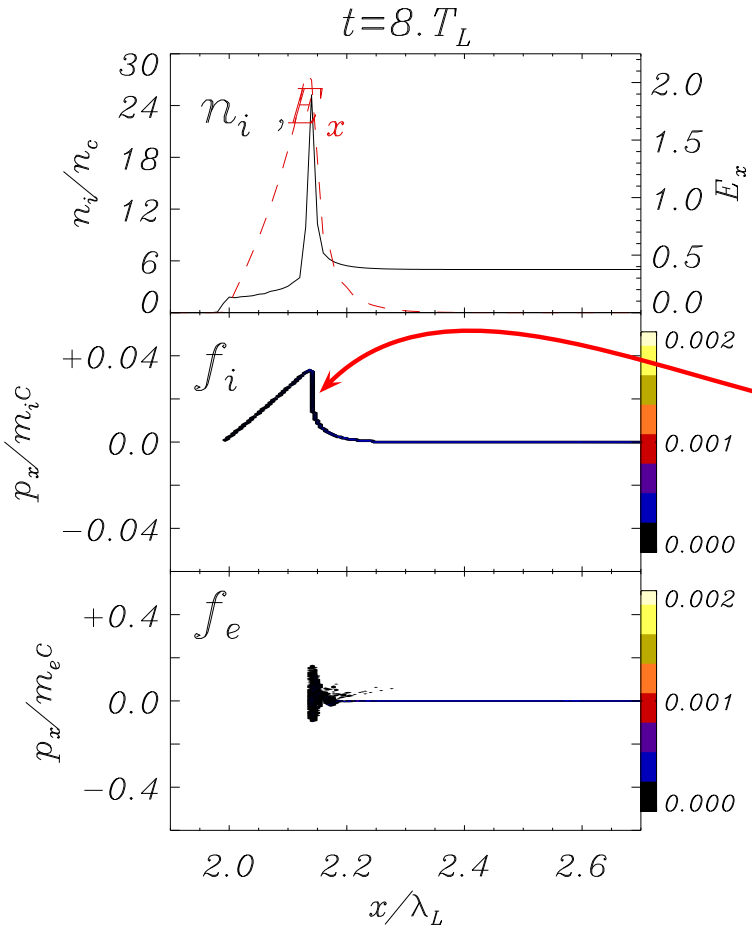

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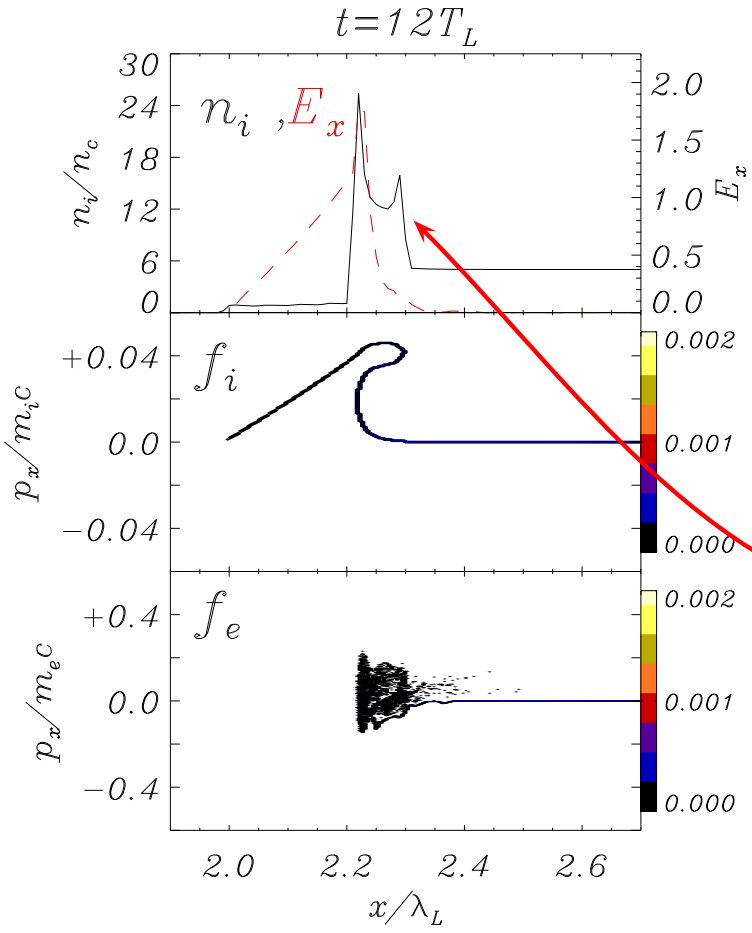

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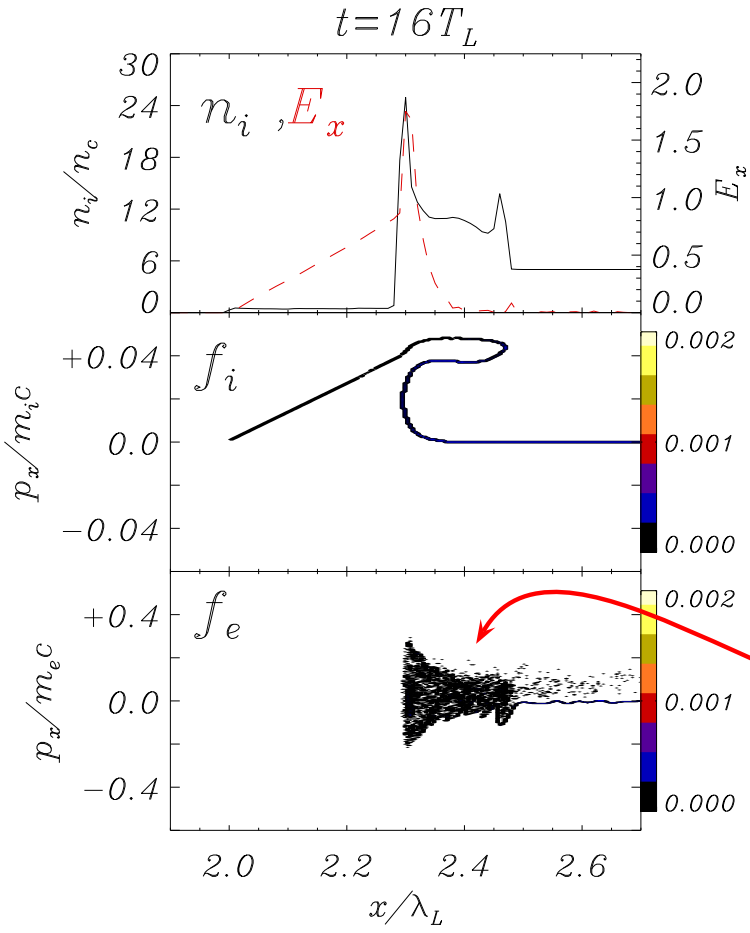

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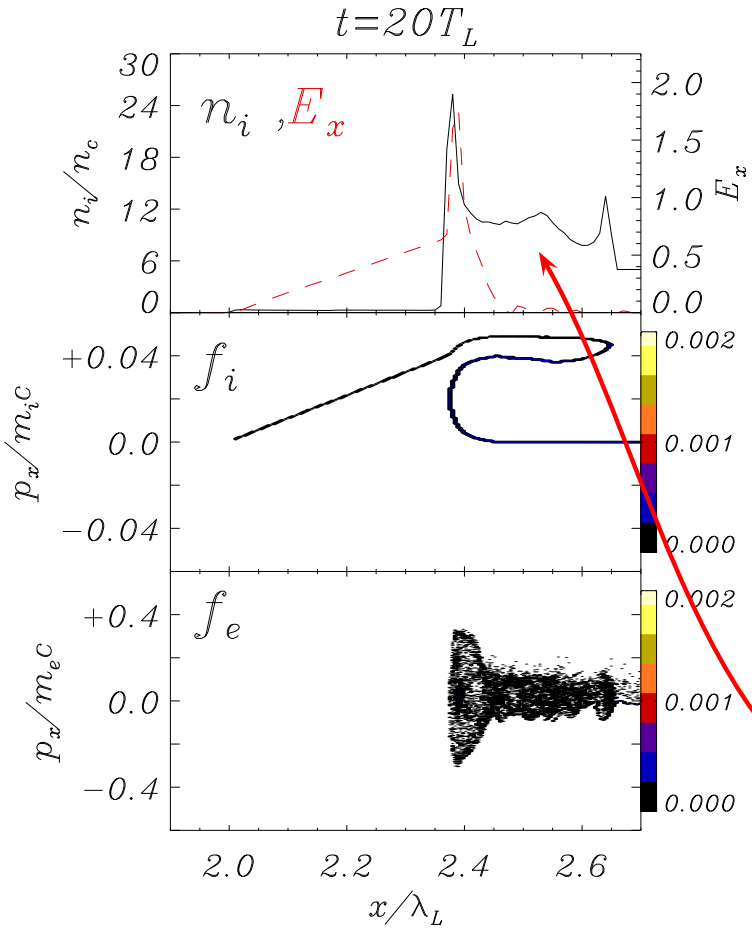

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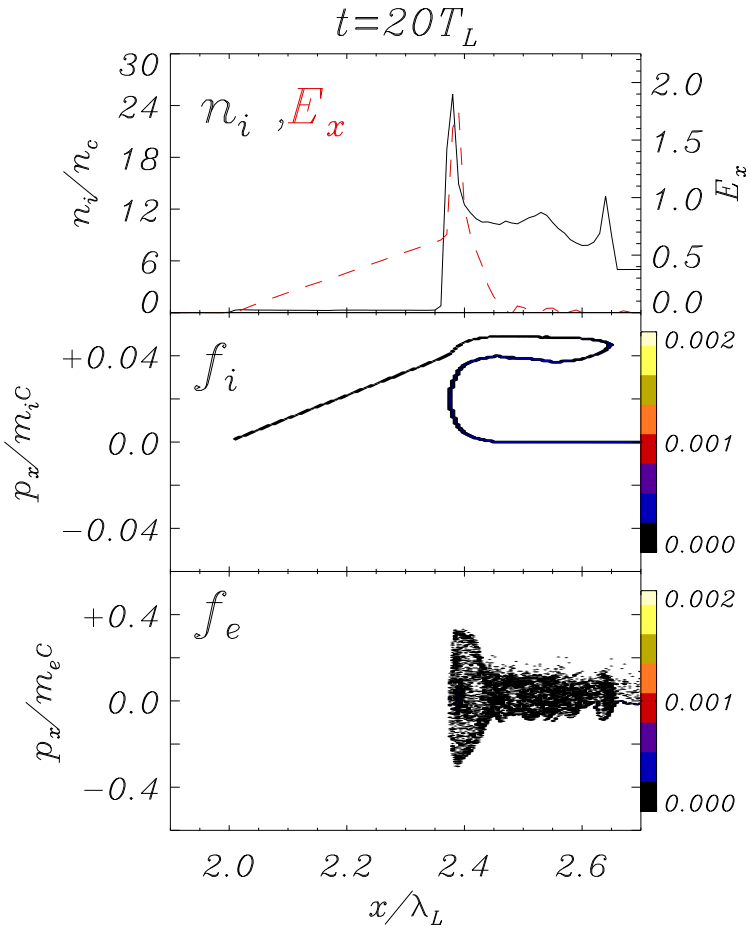

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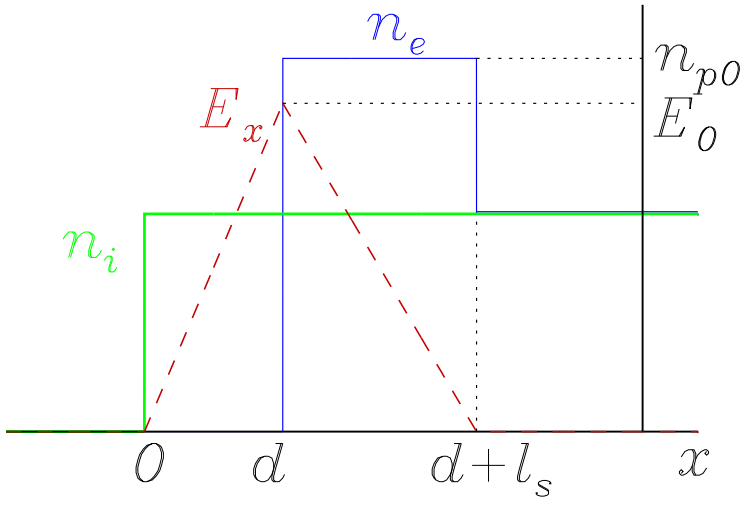

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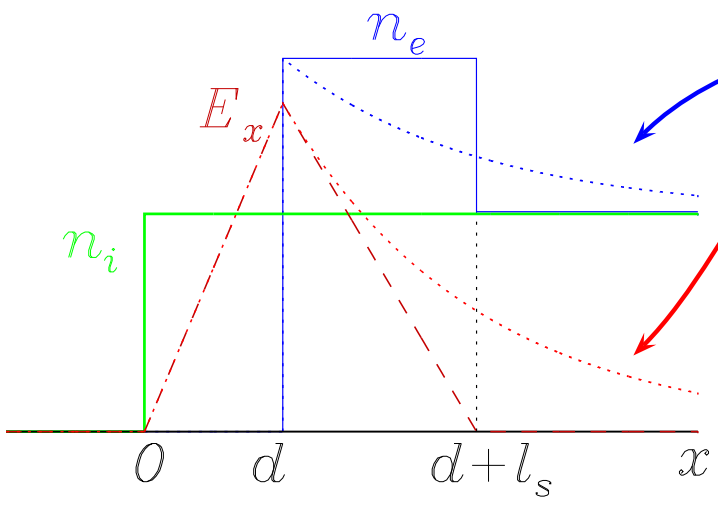

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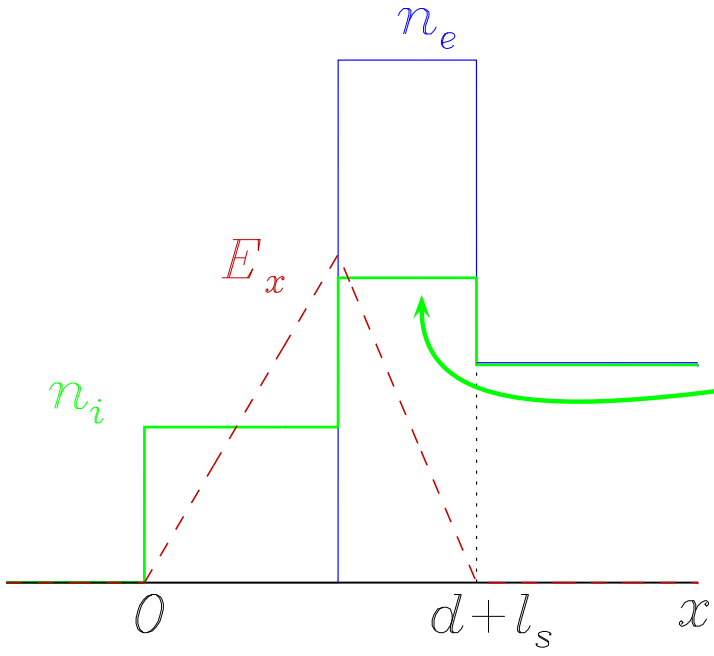

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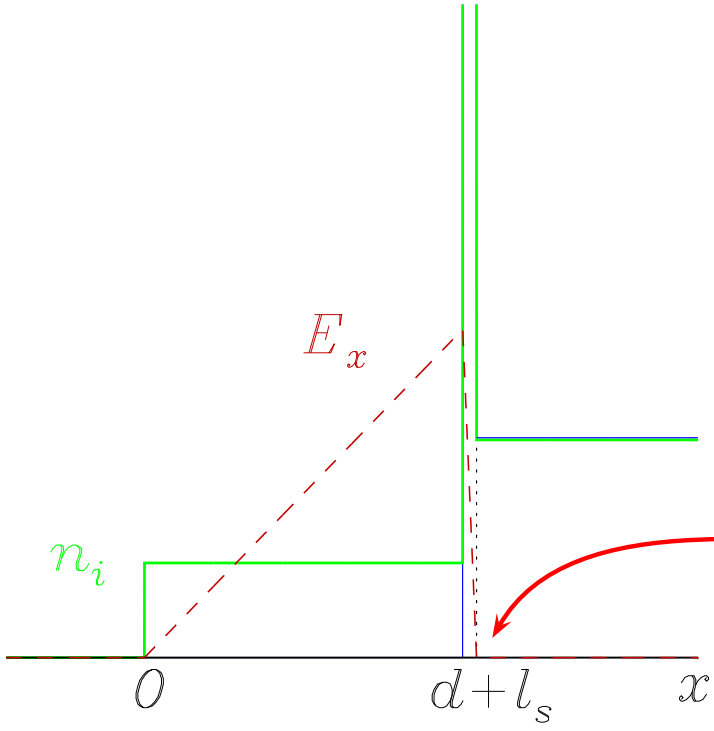

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- "breaking" at the time when all ions reach the evanescence point

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! To be NOT confused with shock acceleration!

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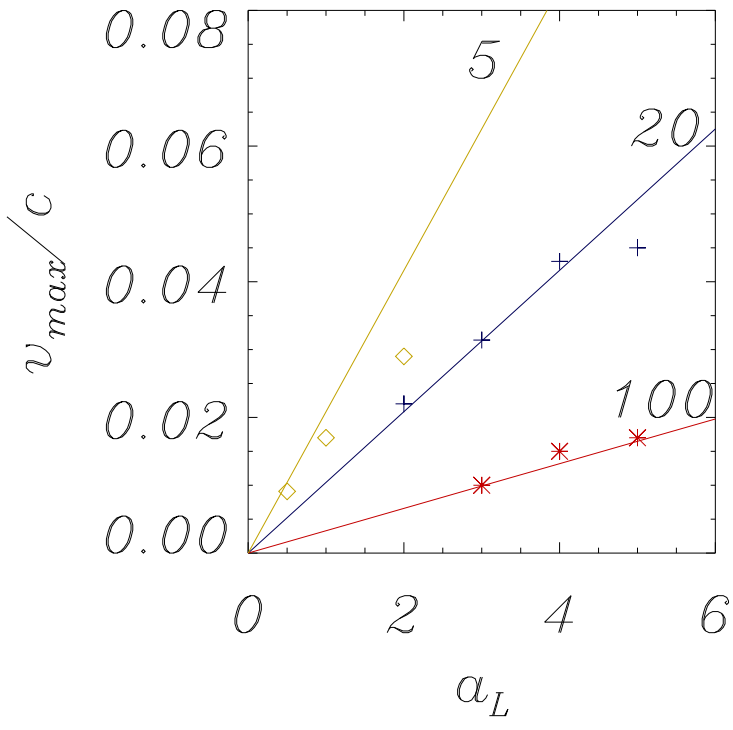

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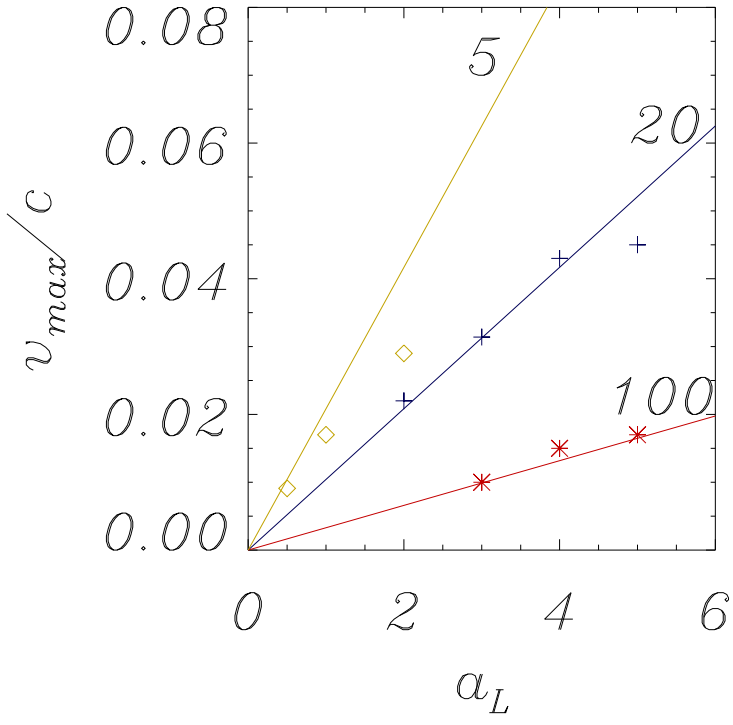
- fair estimates for the acceleration time (τ_i), the number of accelerated ions ($n_{i0} l_s$), and the conversion efficiency $\sim v_m/c$.



Model evaluation

The model is very simple , however, when compared to simulations, it gives:

- a correct scenario of the dynamics ion bunch formation

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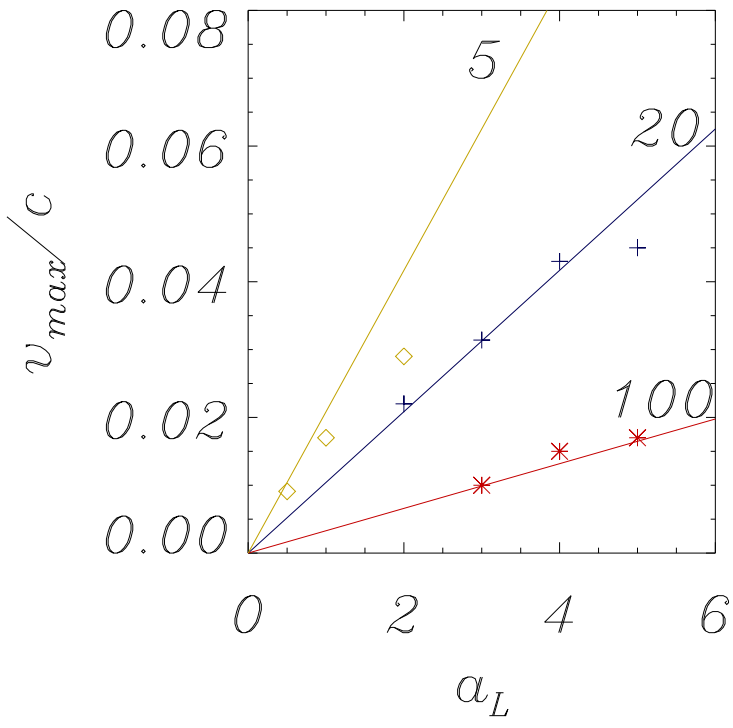
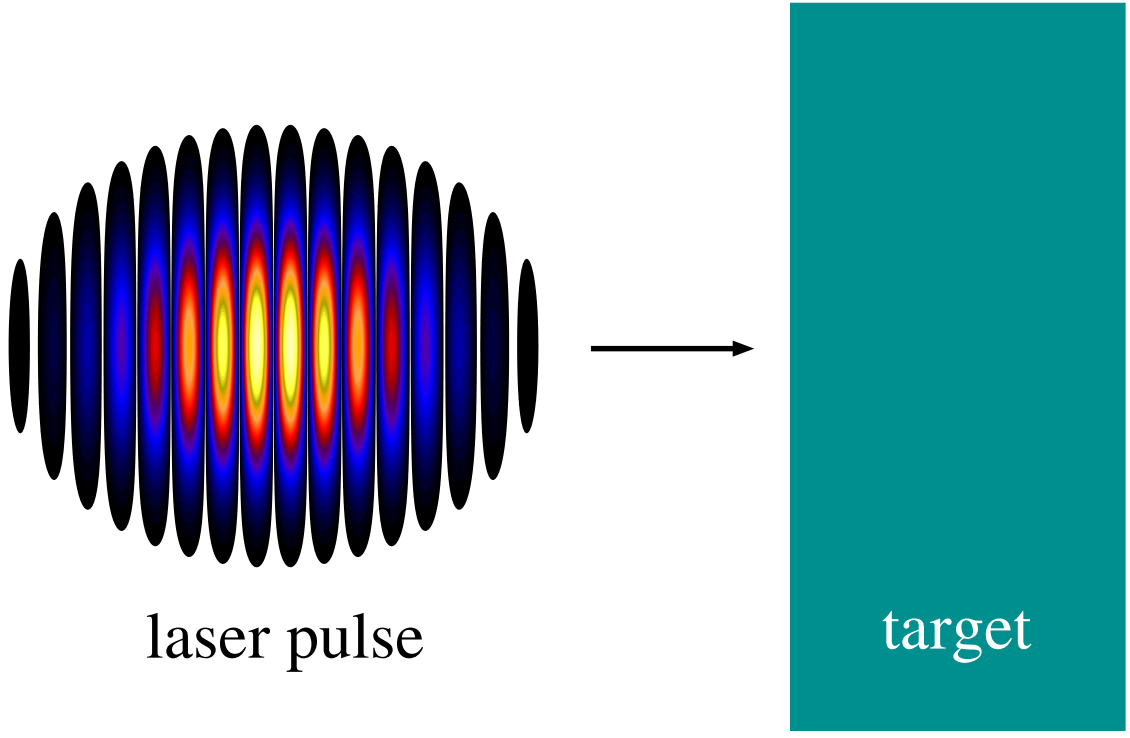


Other simulation features (e.g. non-white spectrum) are understood on a qualitative basis.

Two-dimensional simulations

Two-dimensional simulations

In 2D simulations, the laser pulse profile imposes a smooth transverse modulation



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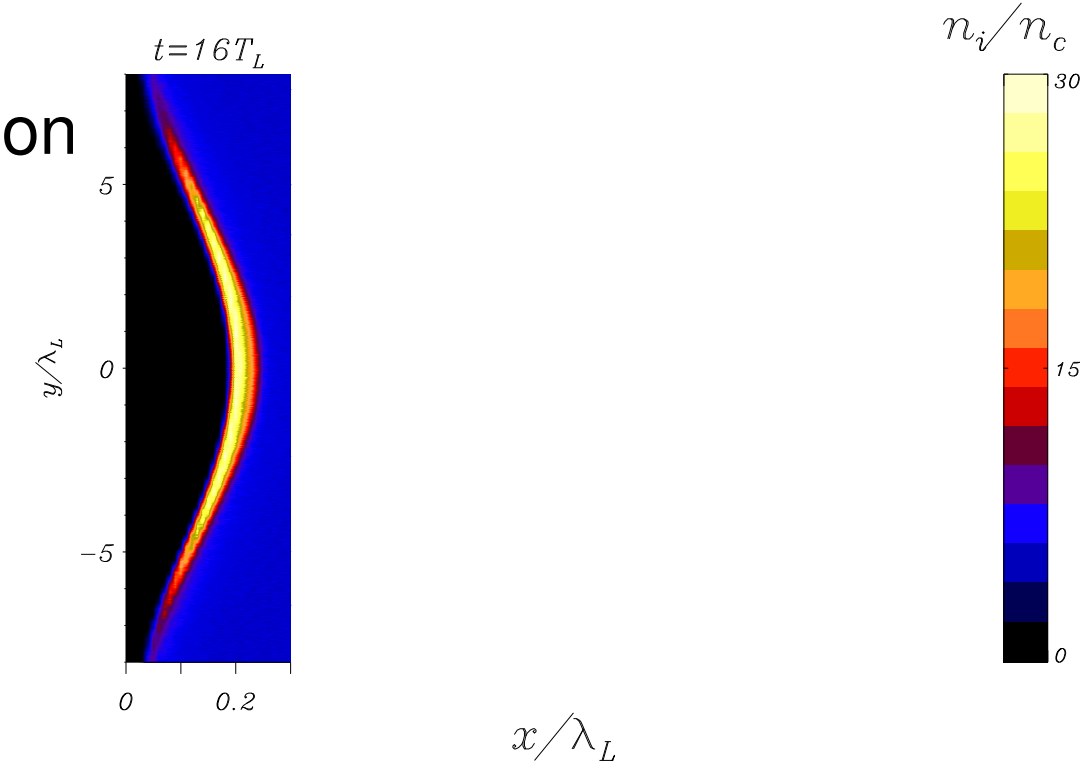

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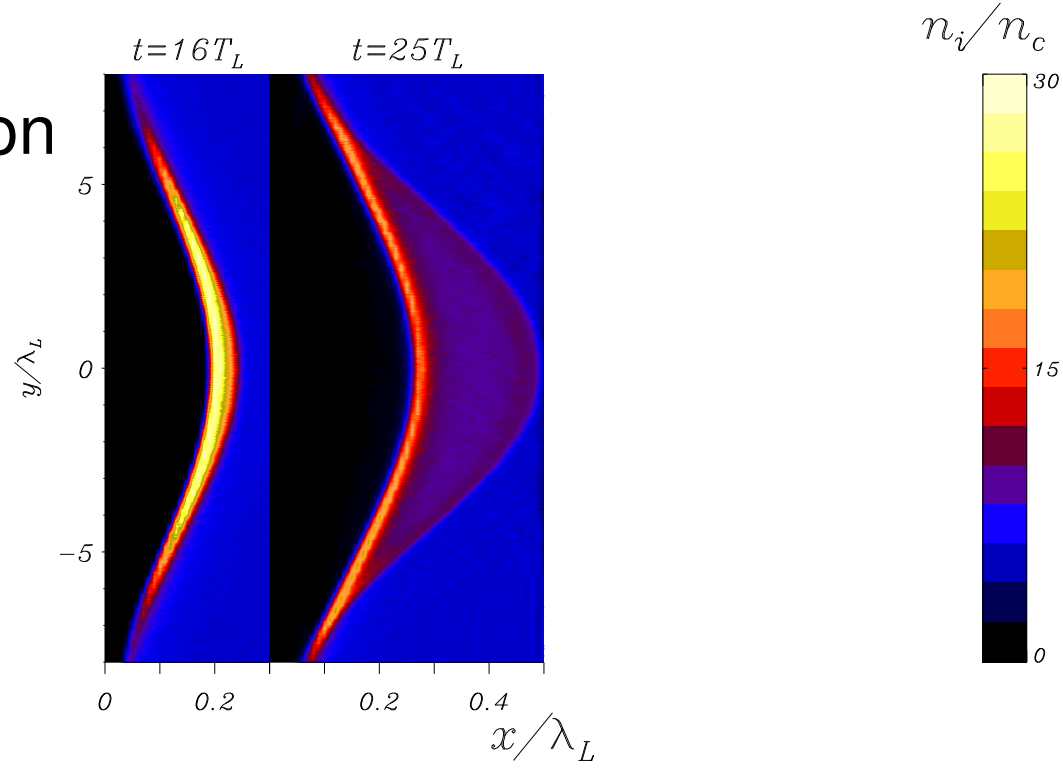

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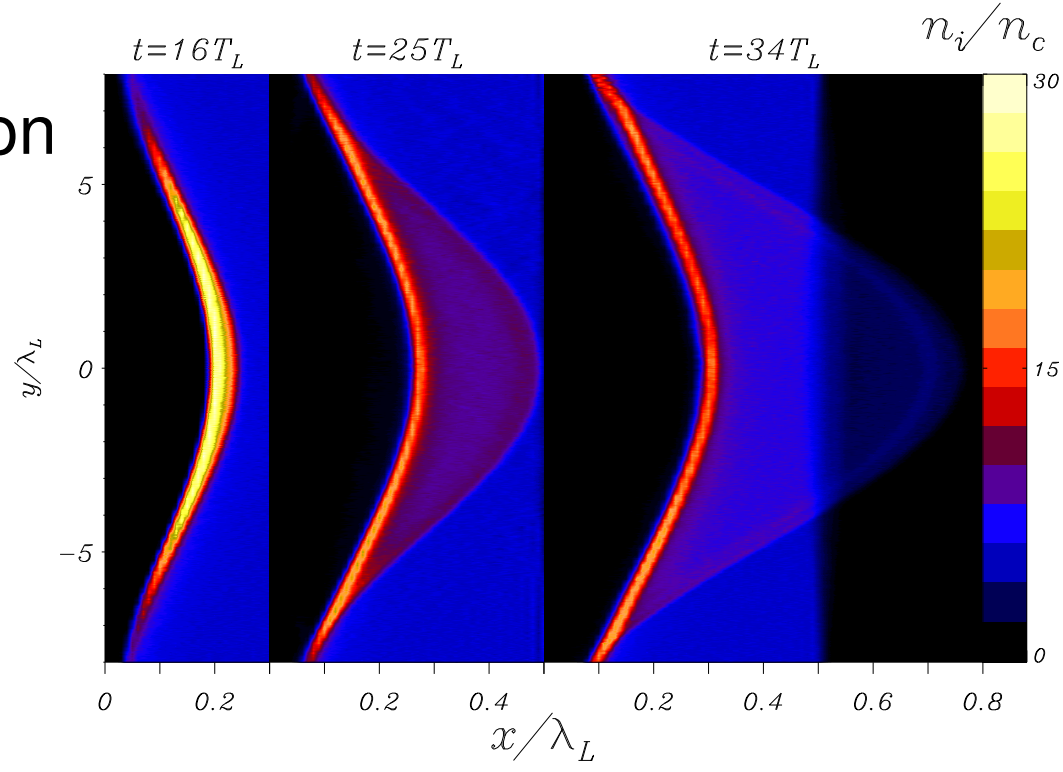

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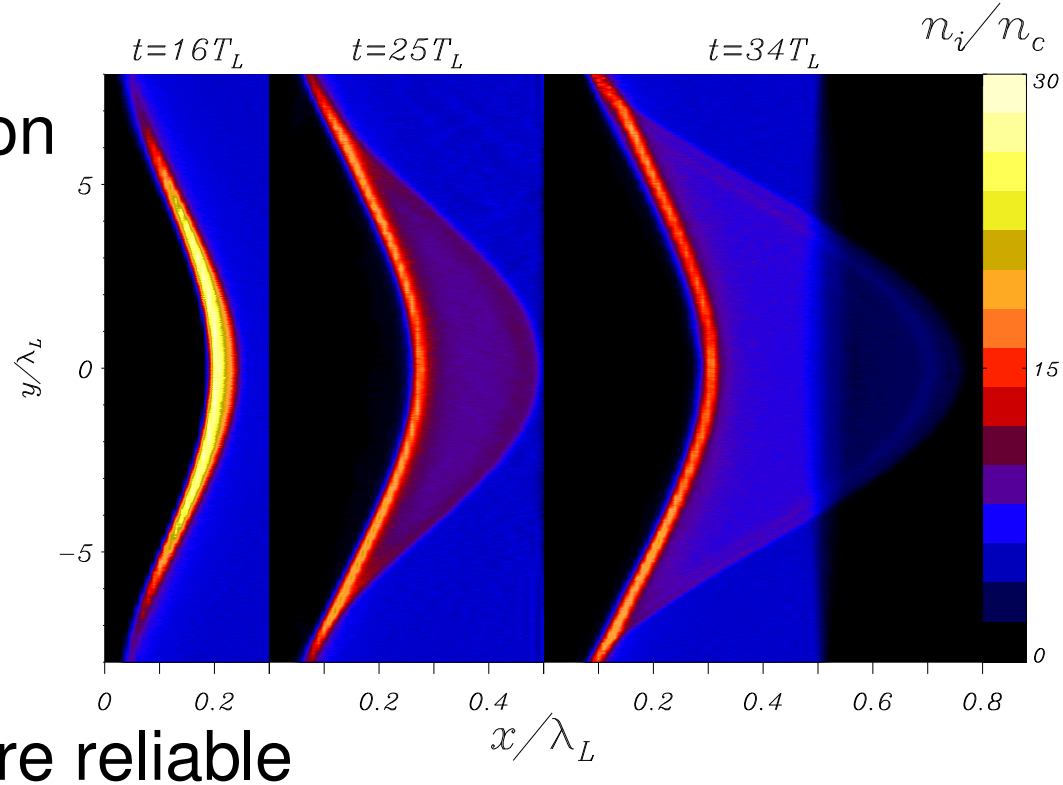

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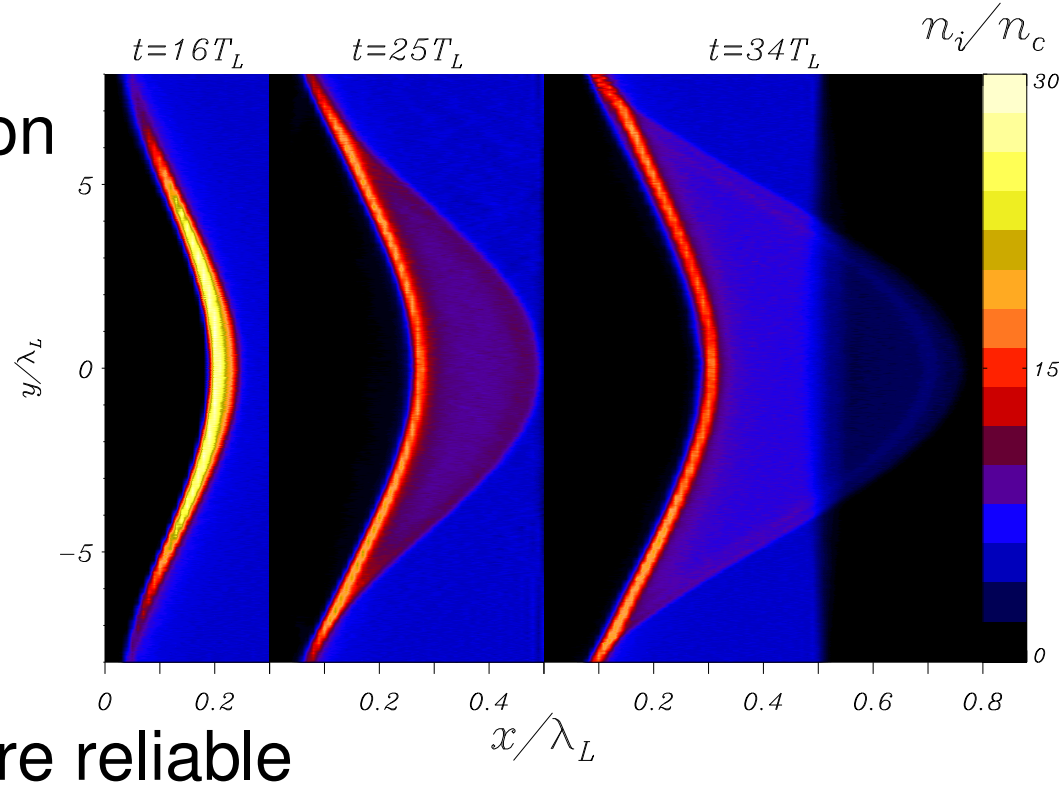

1D scenario & modeling are reliable

Rippling of the laser-plasma interface is weak or absent

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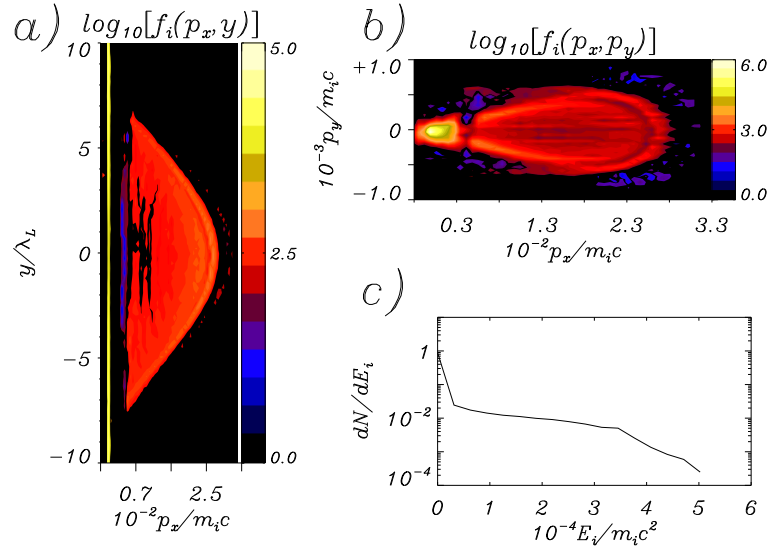

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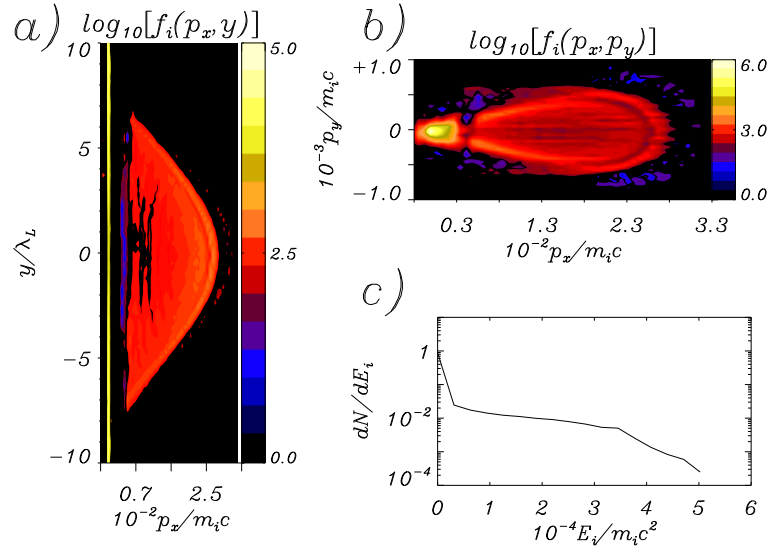

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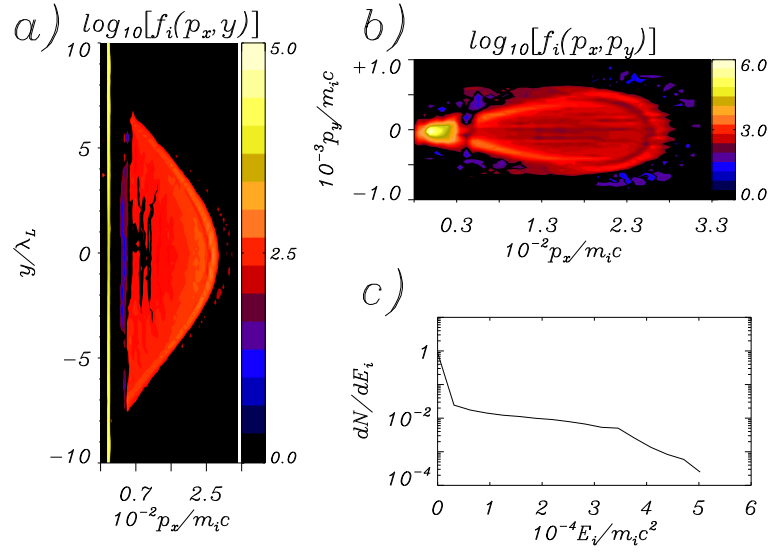

Are these features useful for some application?

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$\Rightarrow$ One may obtain a significant neutron yield within the bunch duration.

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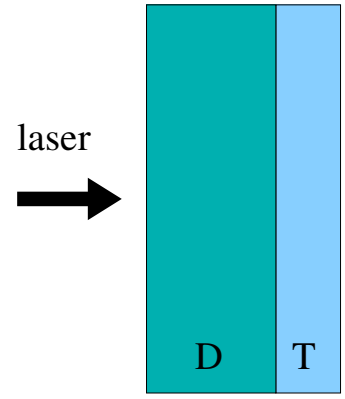
$\mathrm{D} + \mathrm{T} \rightarrow \alpha + \mathrm{n}\ (14\ \mathrm{MeV})$

Double layer target:



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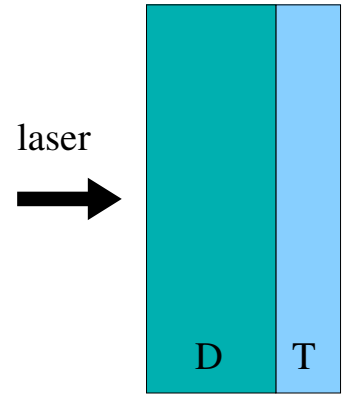

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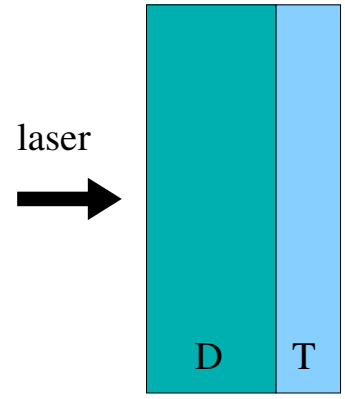

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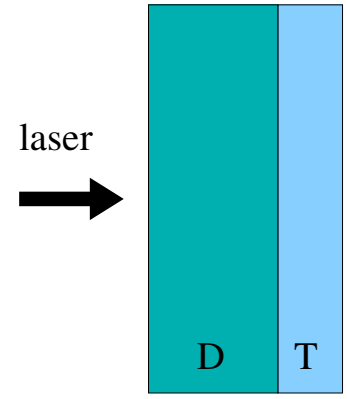

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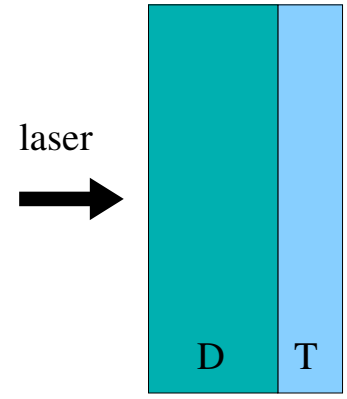

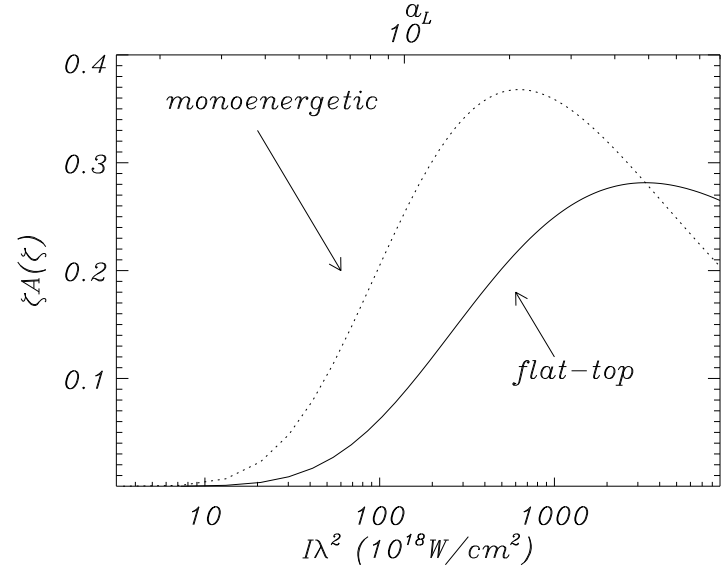

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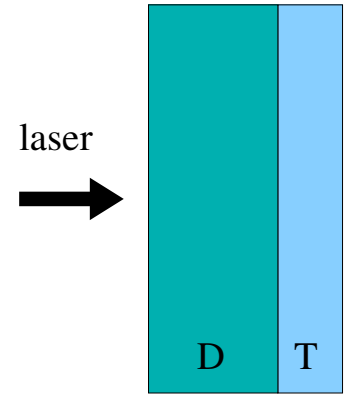

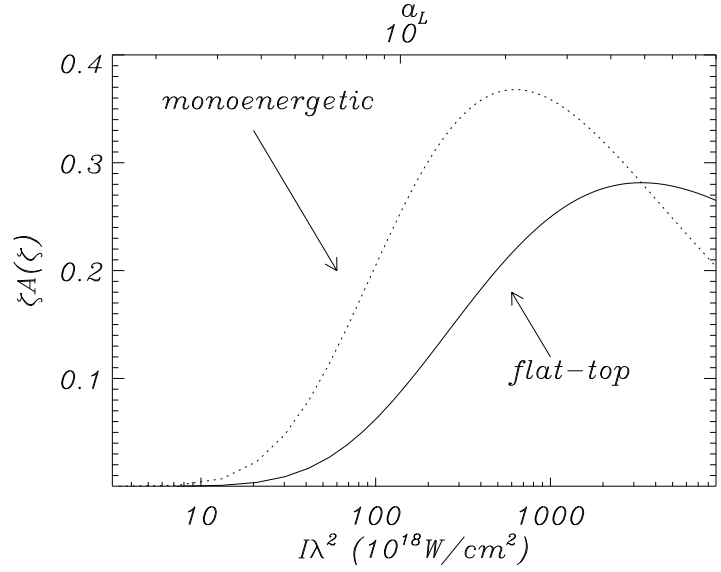

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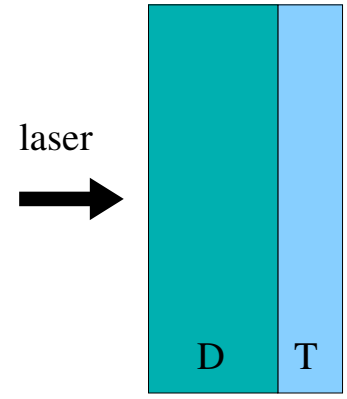

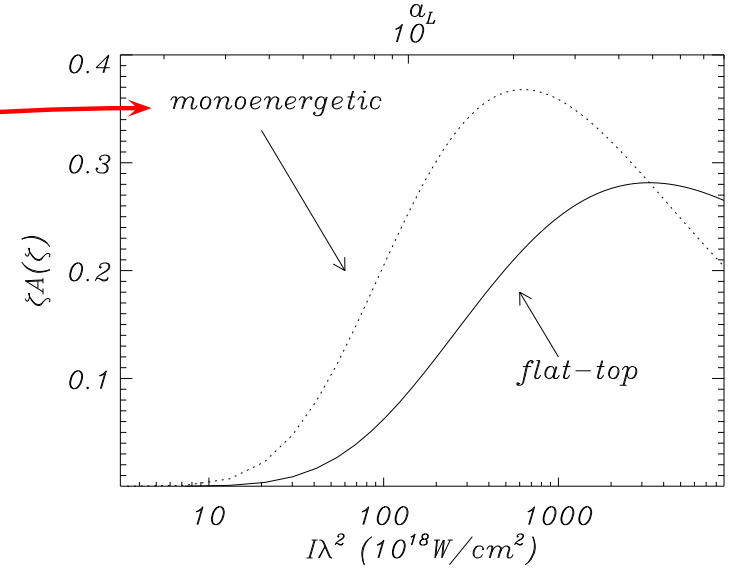

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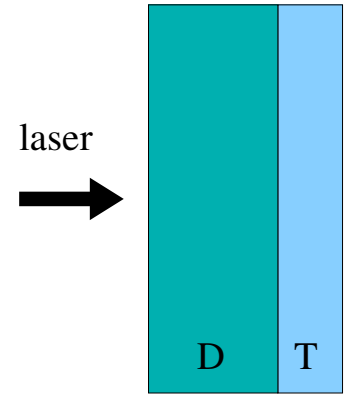

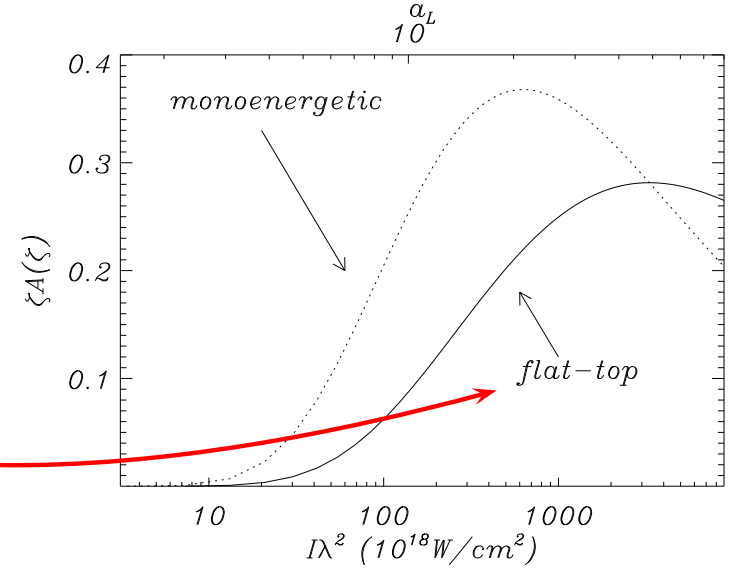

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$\sim 10^8$ neutrons in $\tau_n \sim 1.2$ fs
at $I\lambda^2 \geq 10^{19}$ W/cm^2

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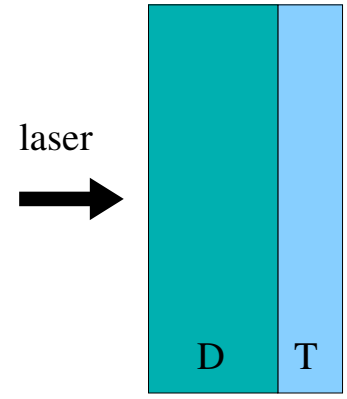

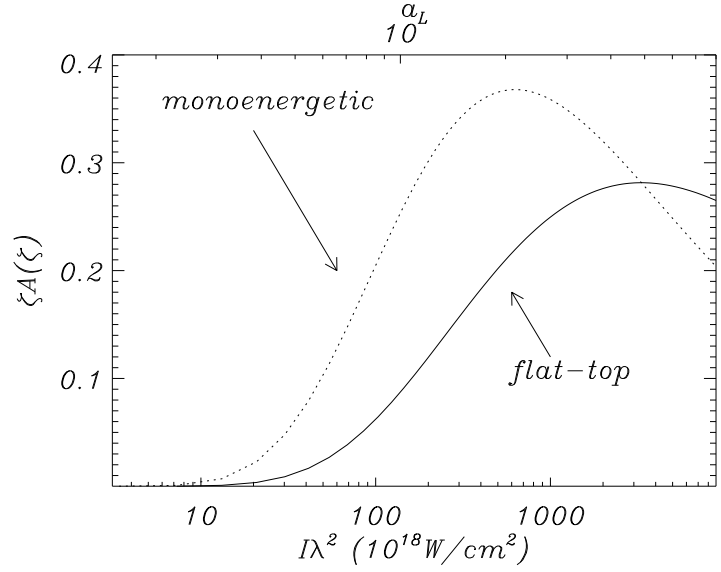

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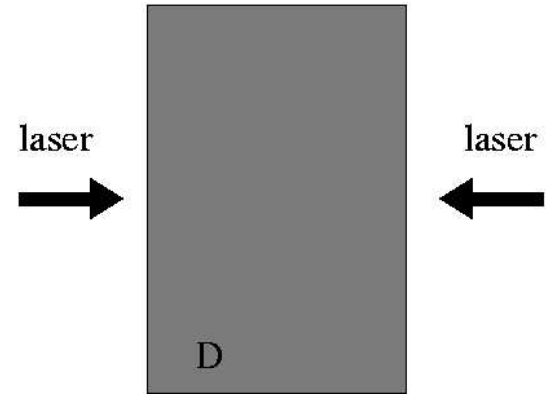
Optimal thickness $\ell = 2l_s$



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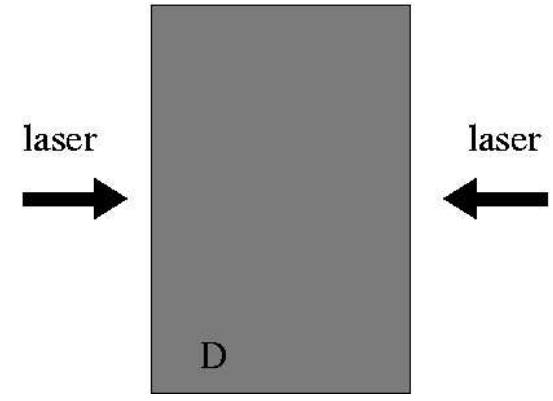

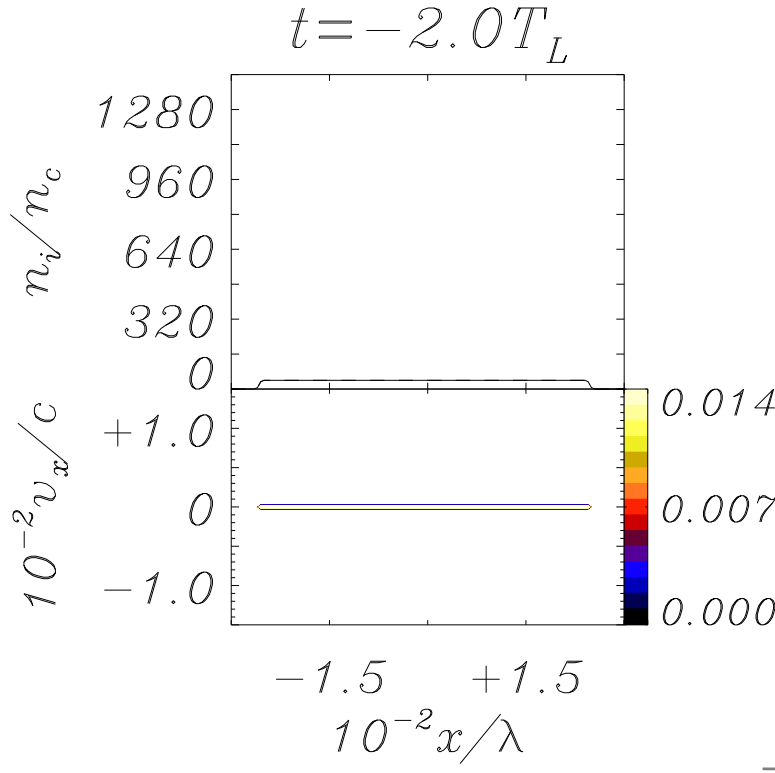

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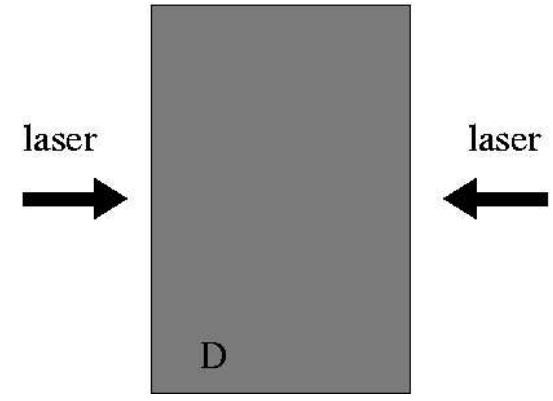

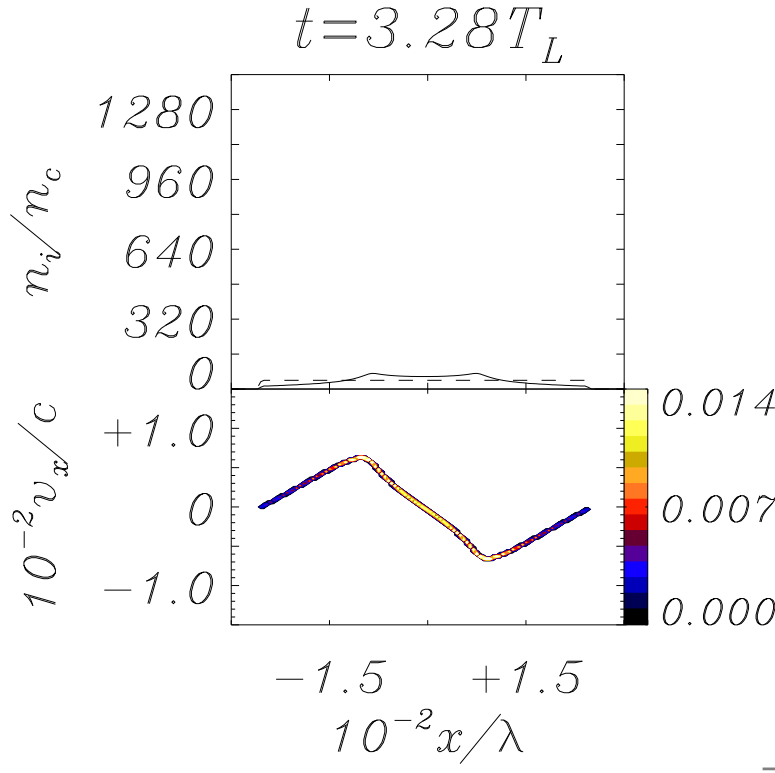

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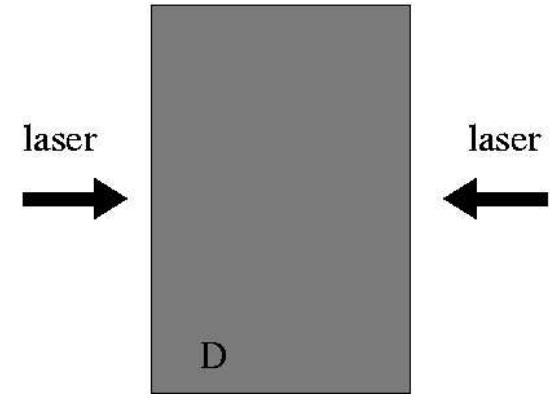

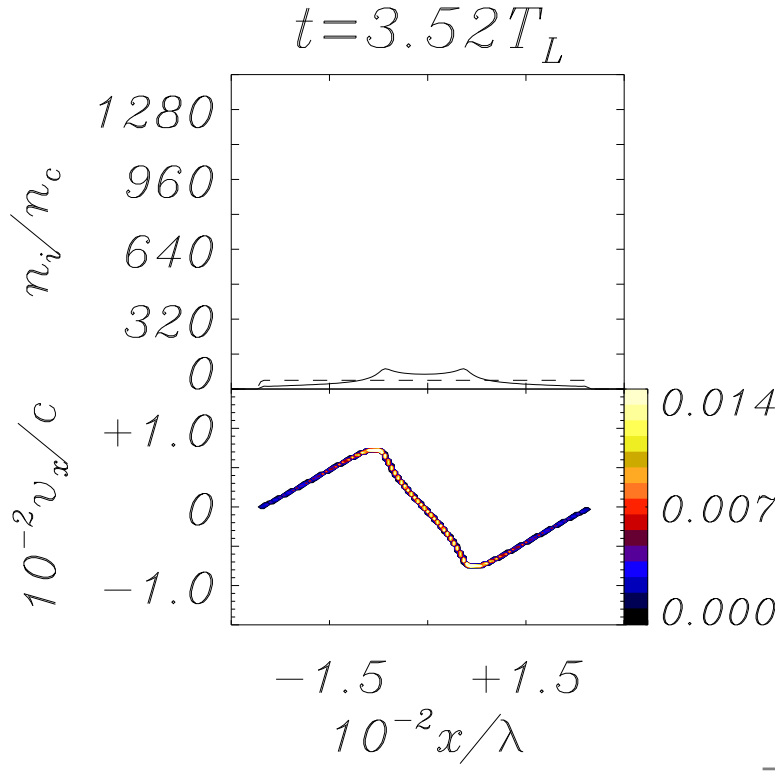

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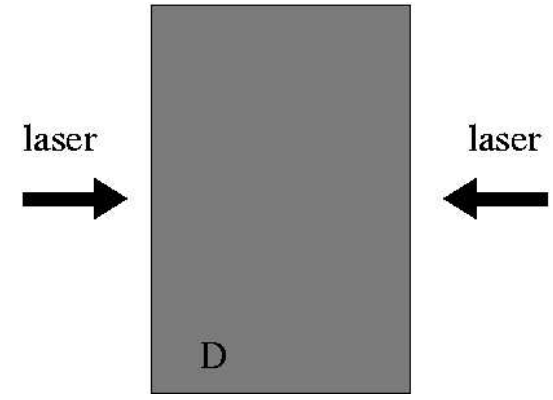

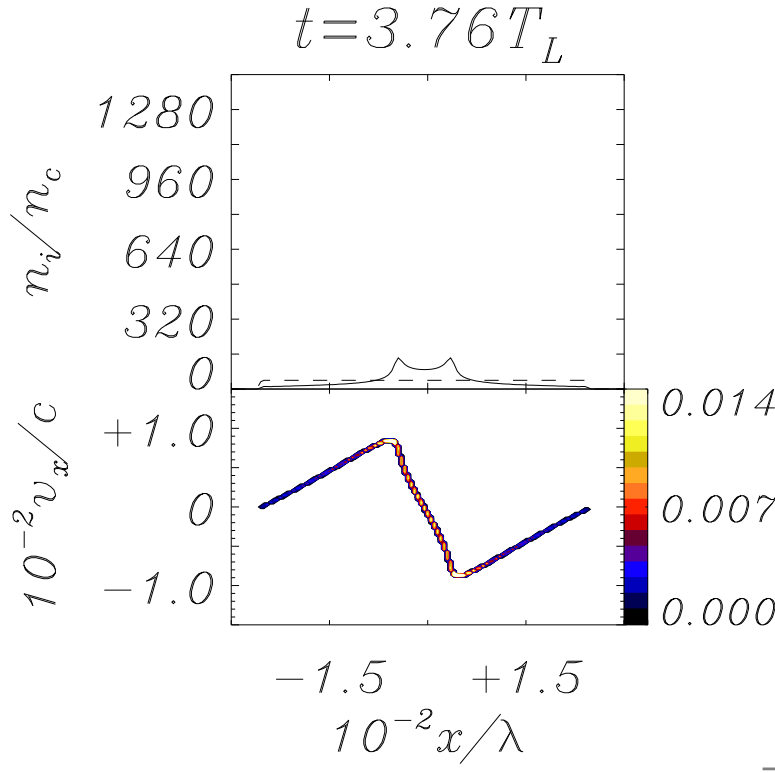

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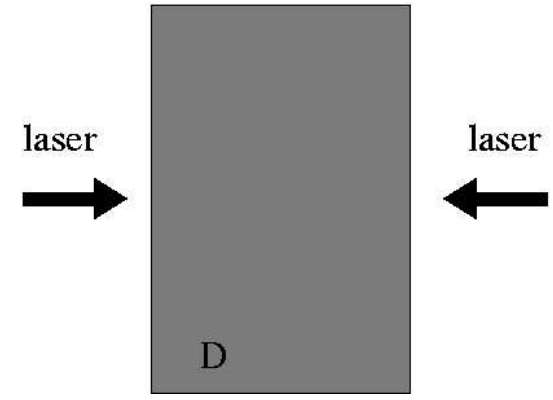

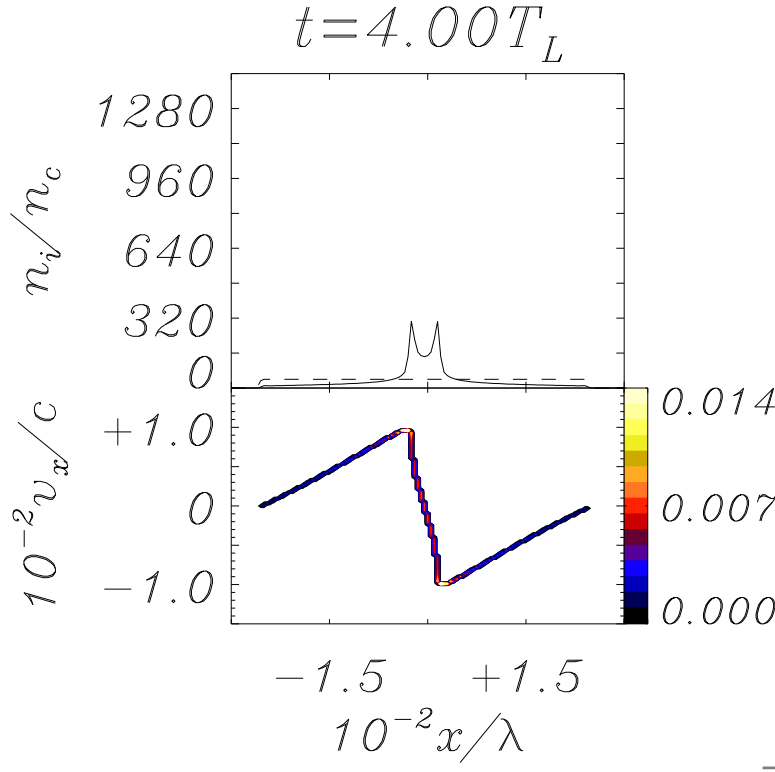

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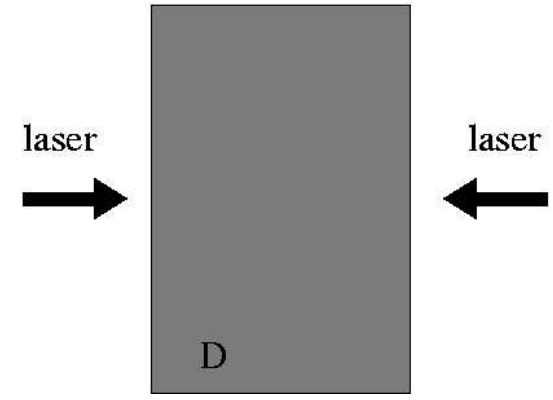

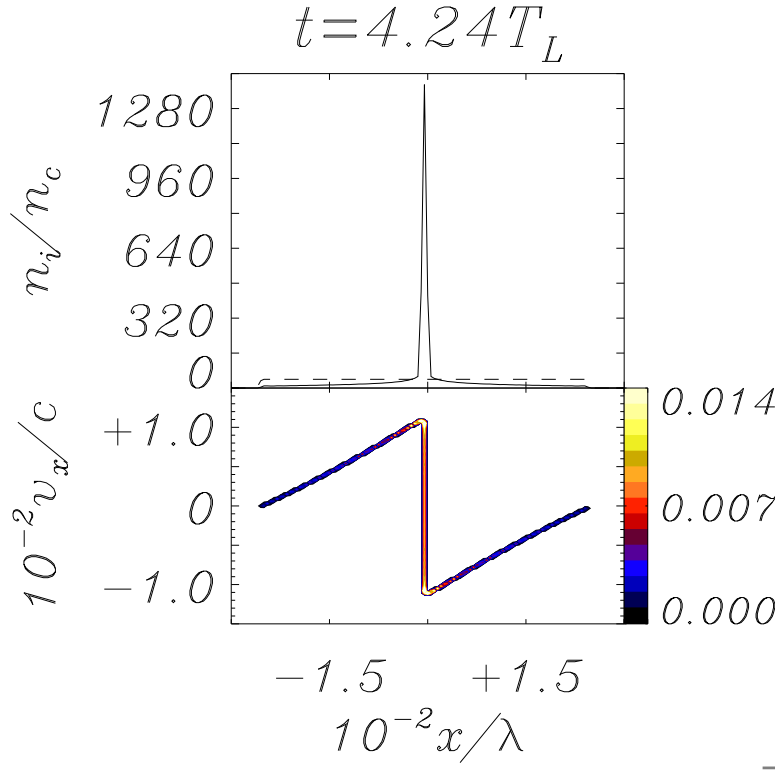

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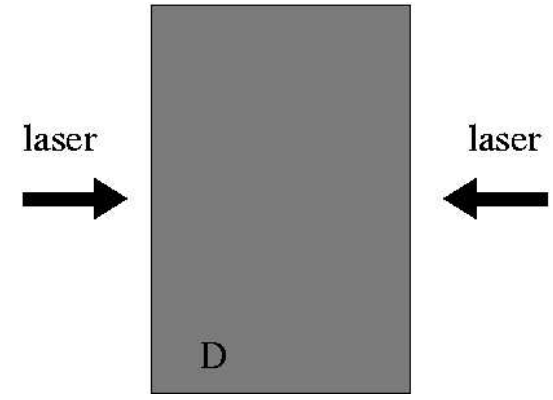

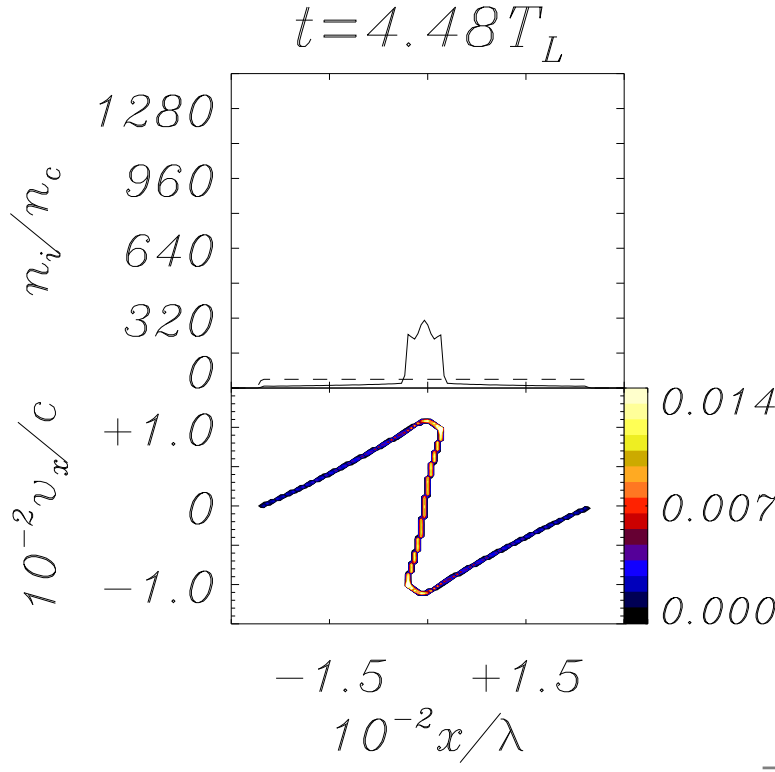

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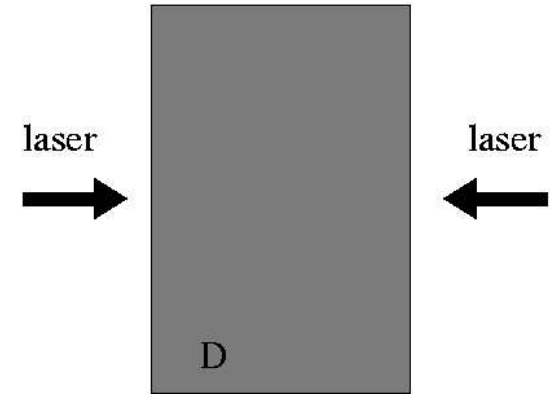

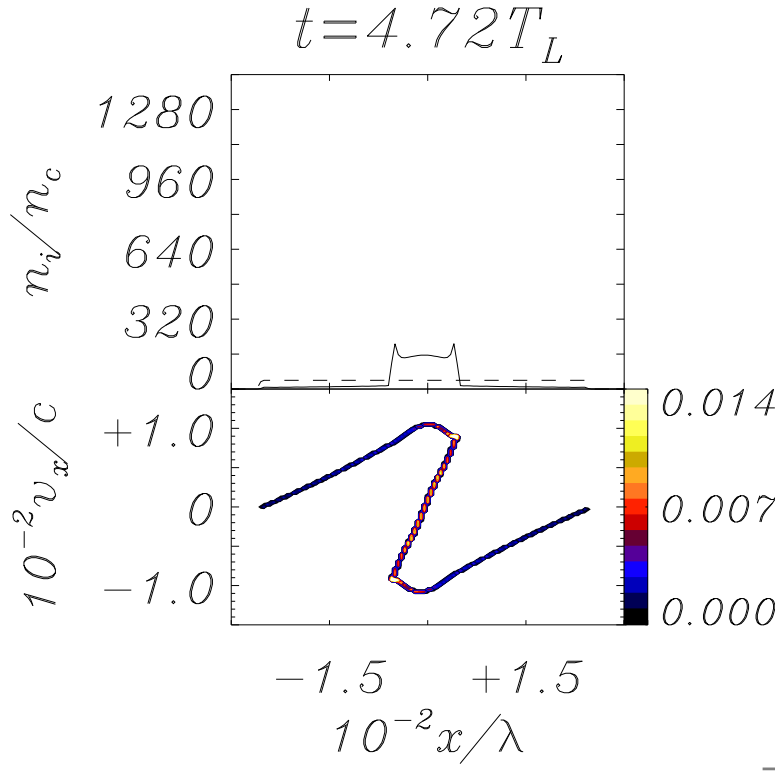

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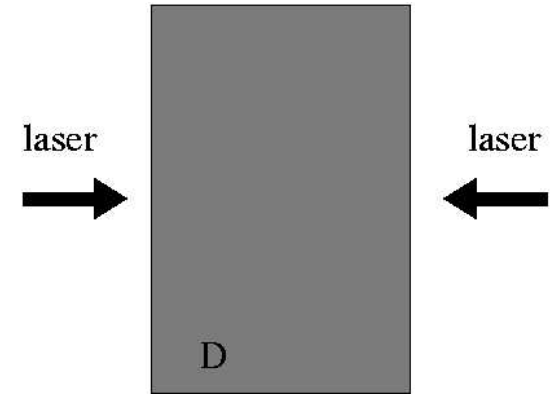

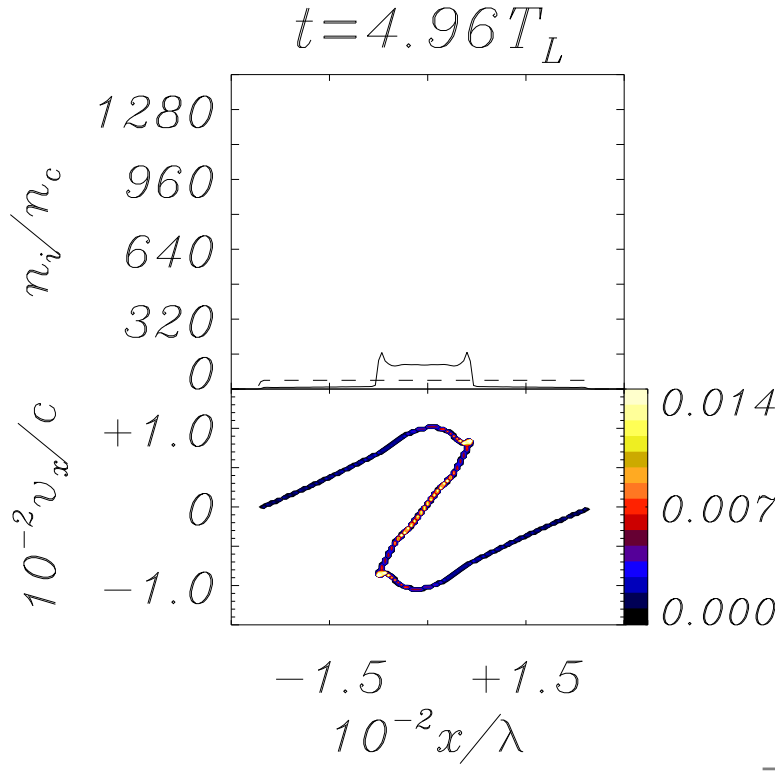

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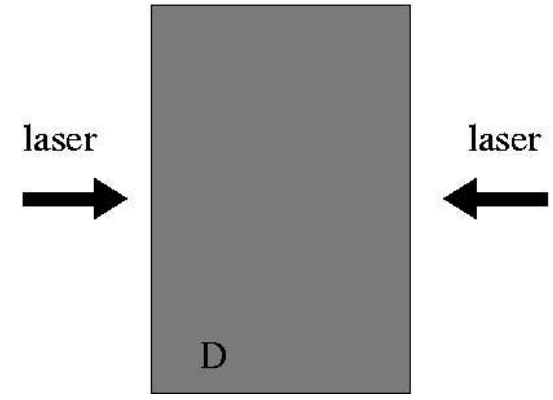

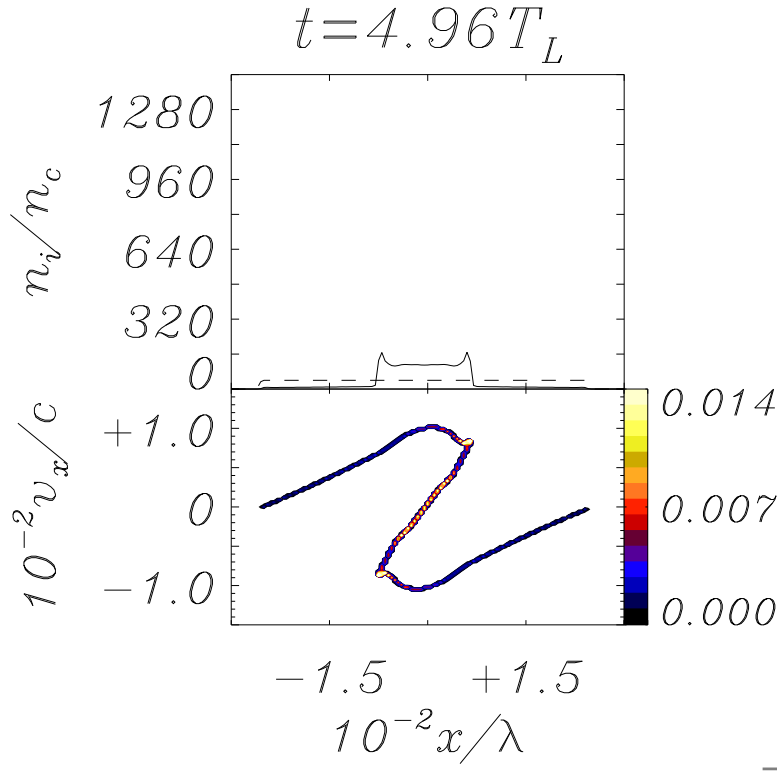

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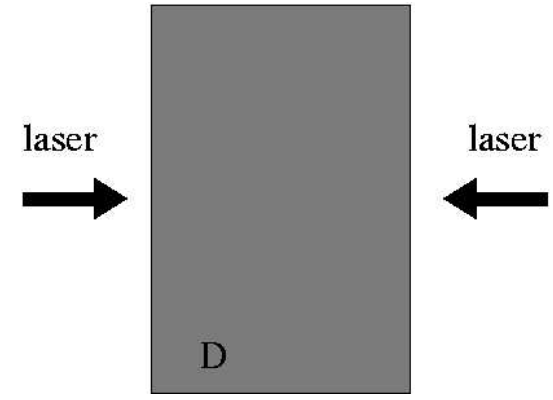

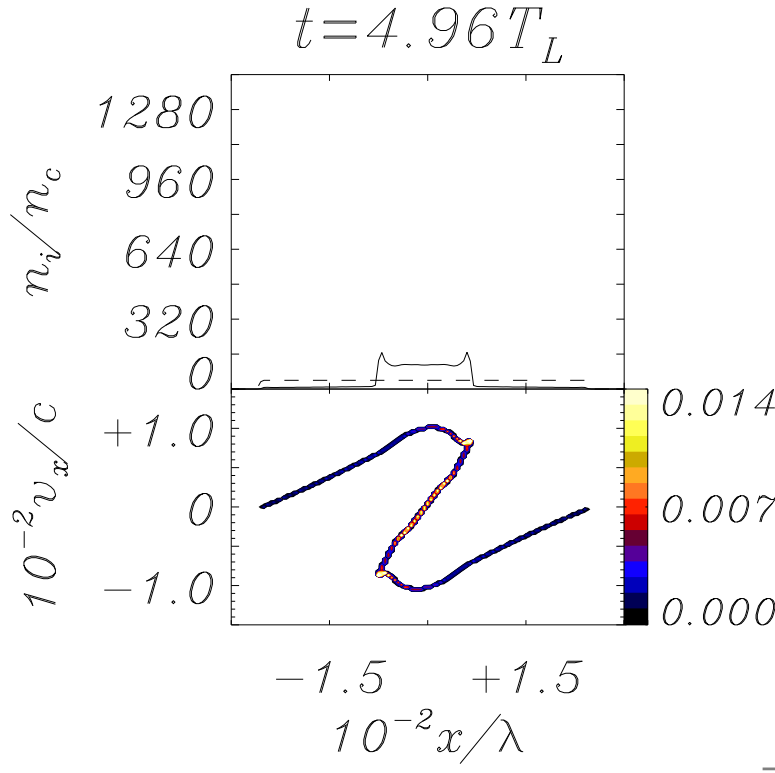

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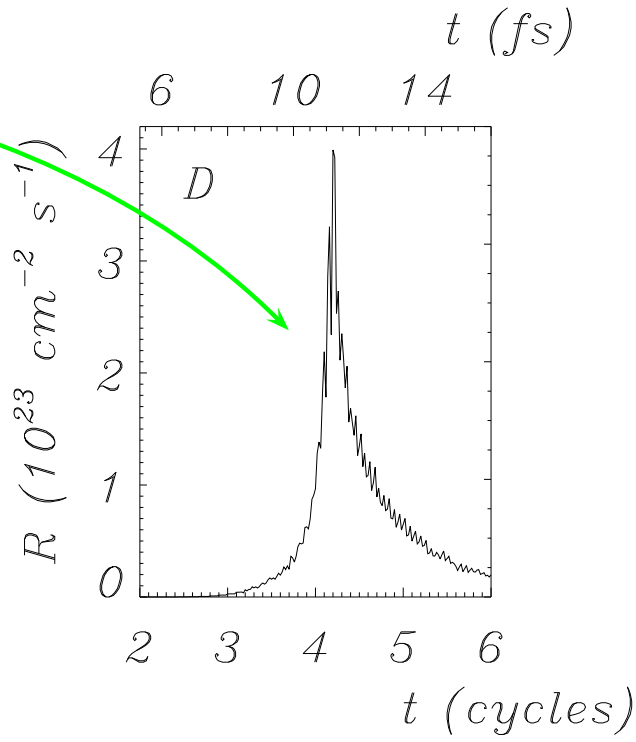

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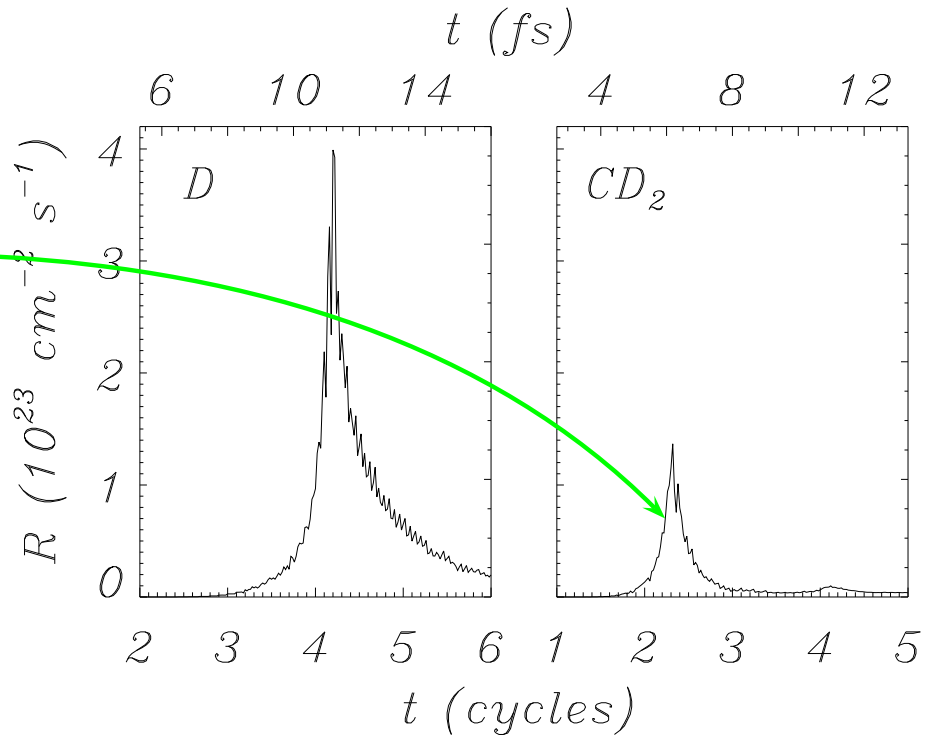

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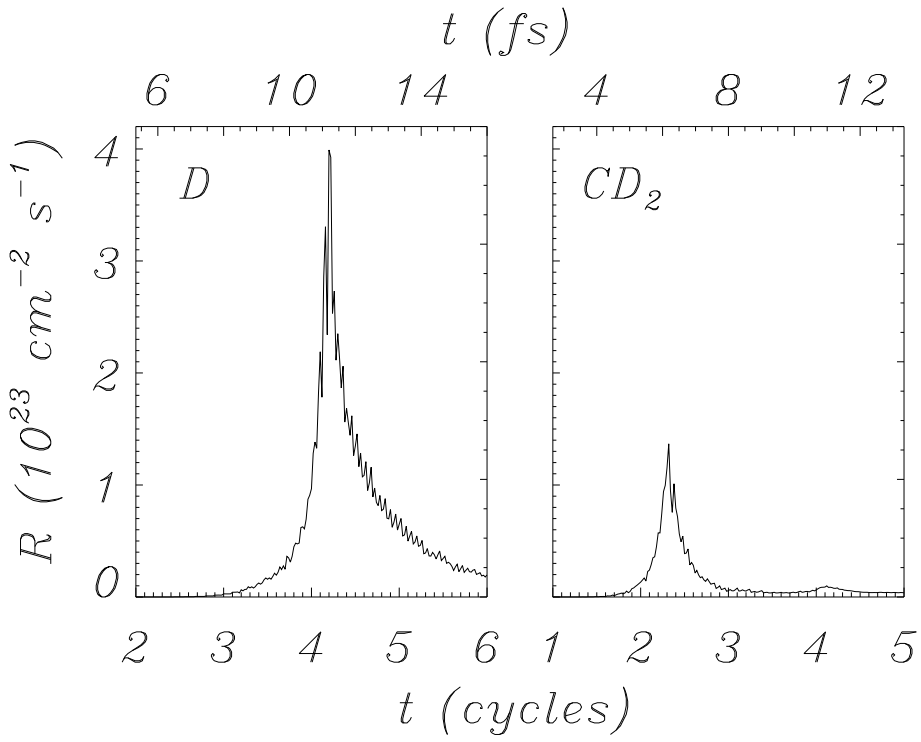

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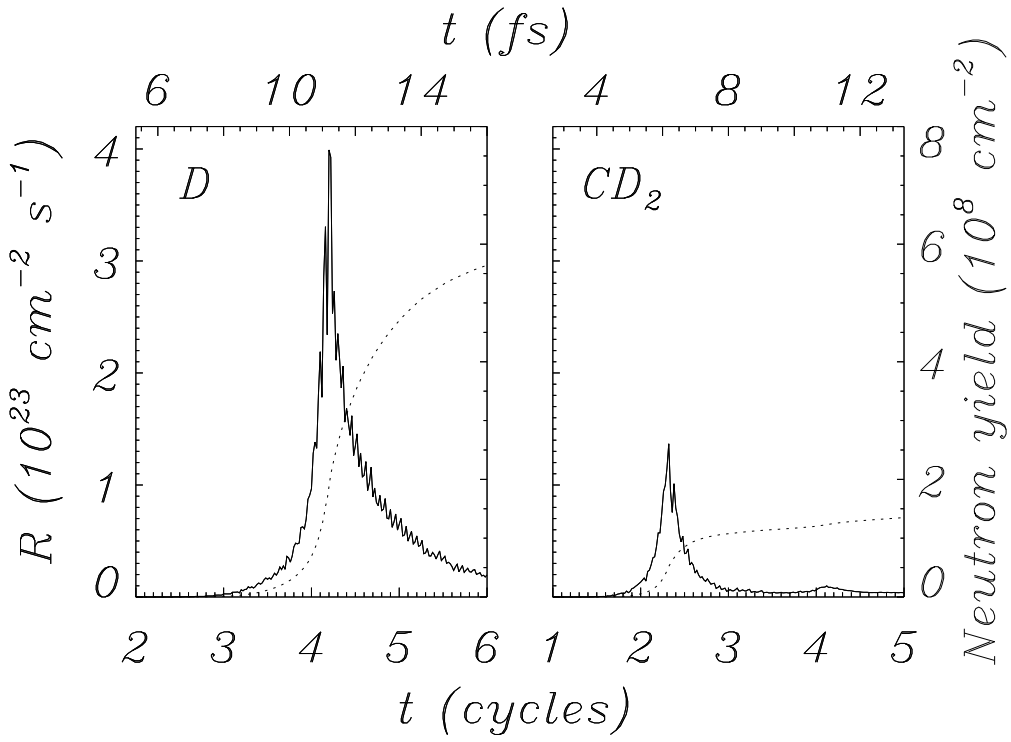

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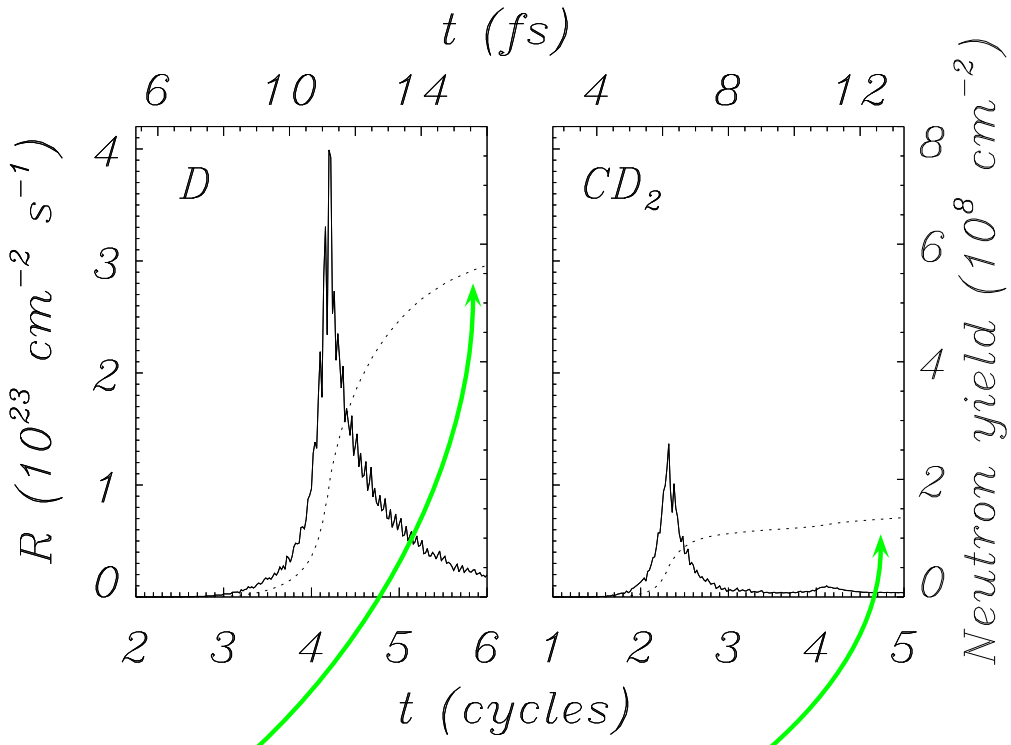

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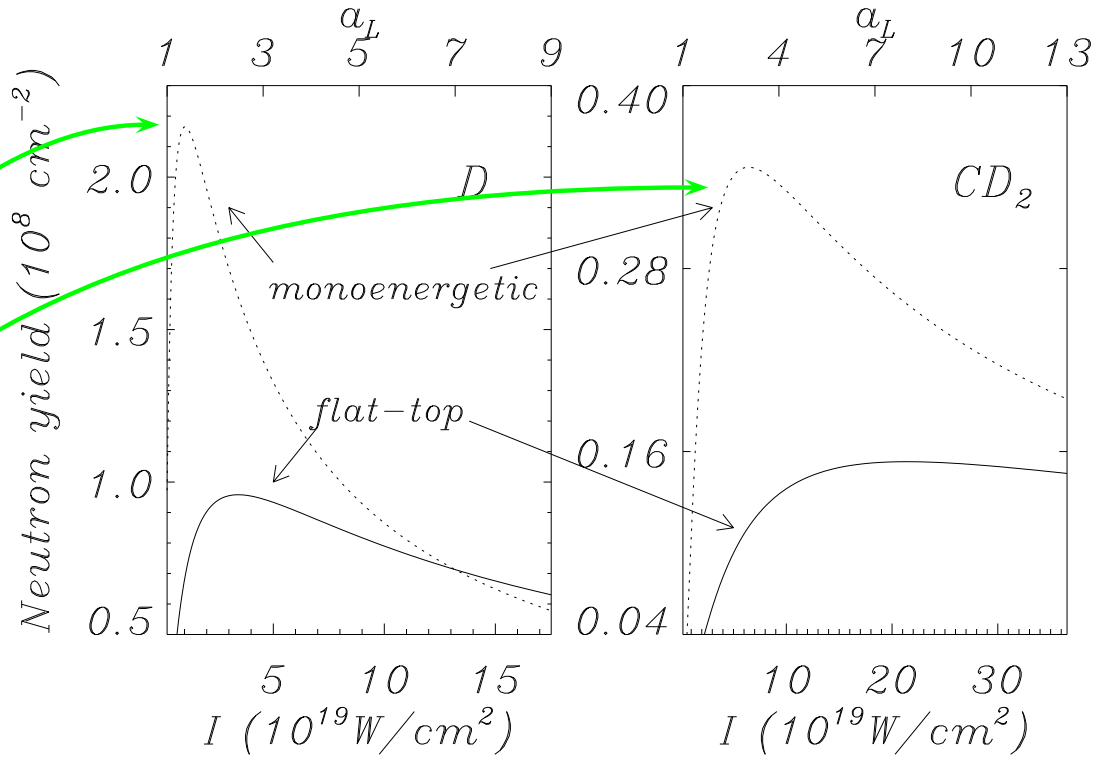

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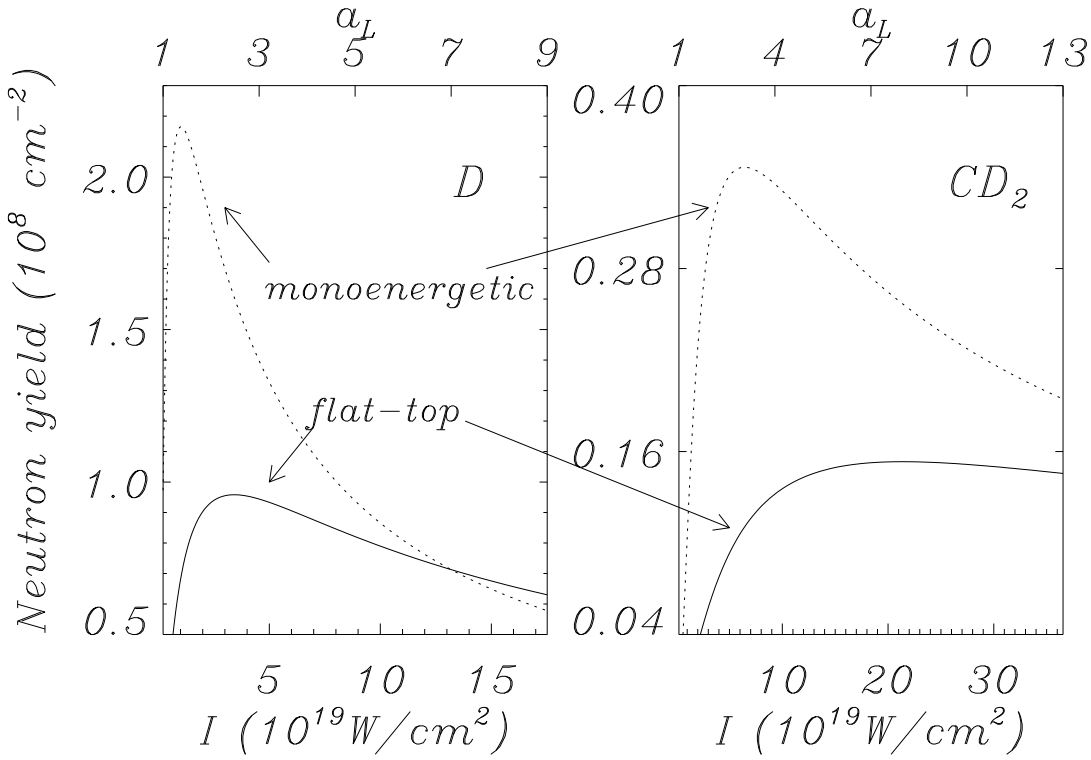

Maximum rate reached in the range $I_L = 10^{19} \div 10^{20}$ W/cm^2

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→ concept based on foil confinement and thermonuclear fusion; requires "long" pulses

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- Measurement of neutron burst duration is challenging (indirect measurement via “attosecond spectroscopy” techniques?)

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  [K. Pachucki, S. Wycech, J. Żylicz, and M. Pfützner, Phys. Rev. C **64**, 064301 (2001).]

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- The ion bunches produced in this regime may open a perspective to bring the duration of neutron sources down in the sub-femtosecond regime

References

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- ion acceleration: A. Macchi, F. Cattani, T. V. Liseykina, F. Cornolti, Phys. Rev. Lett. **94**, 165003 (2005)

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Thanks to the developers of the PROSPER style for LaTeX and to everyone contributing to Linux and Open–Source software in general

EXTRA SLIDES

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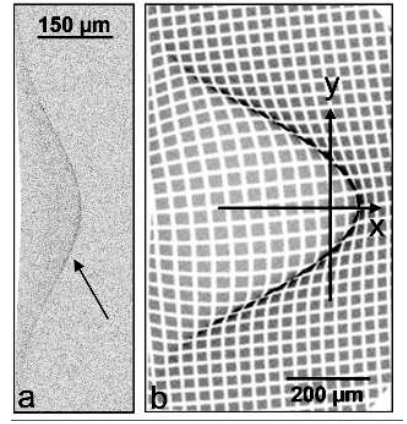

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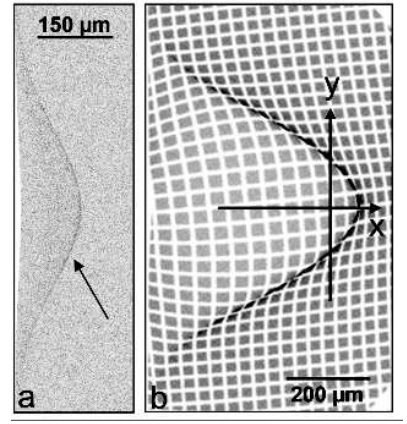
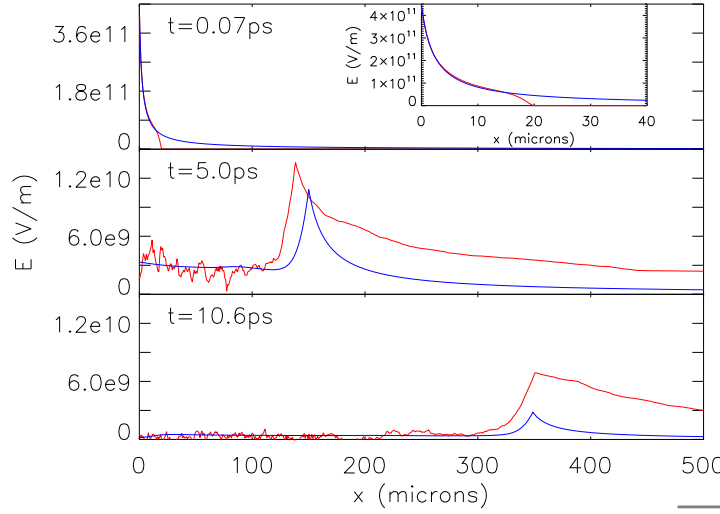


Modeling:
Fluid:
Mora, PRL **90**, 185002 (2003)
PIC:
Betti, Ceccherini, Cornolti, Pegoraro,
PPCF **47**, 521 (2005)



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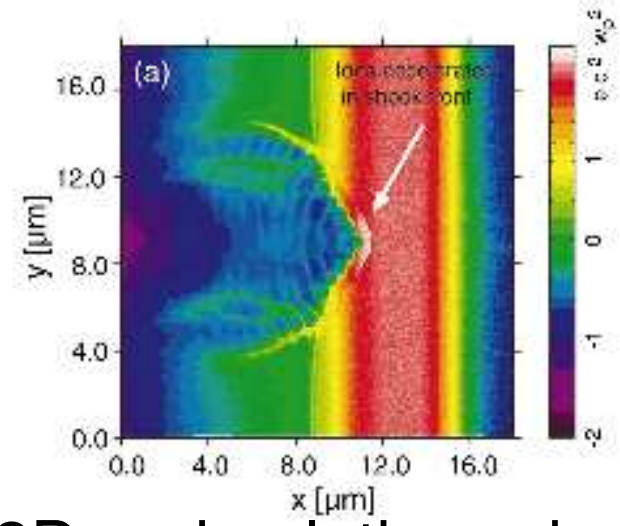

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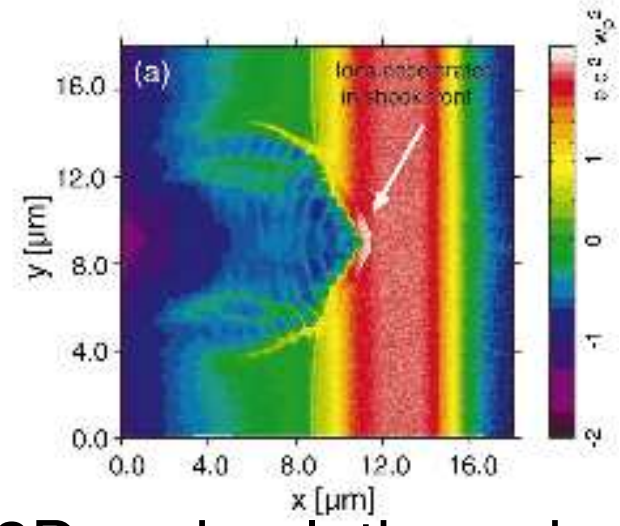

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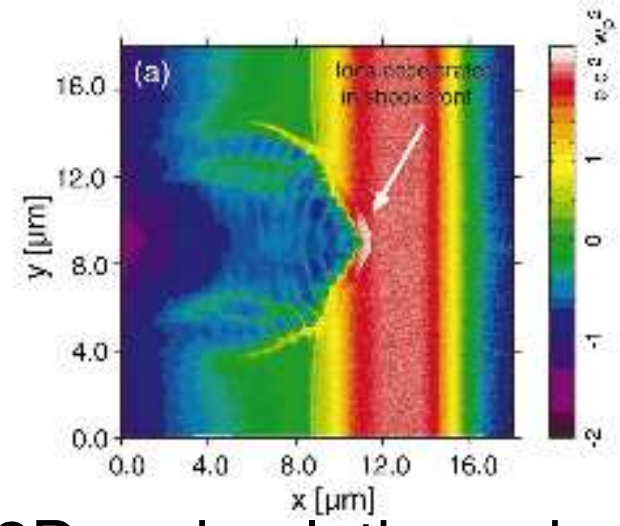

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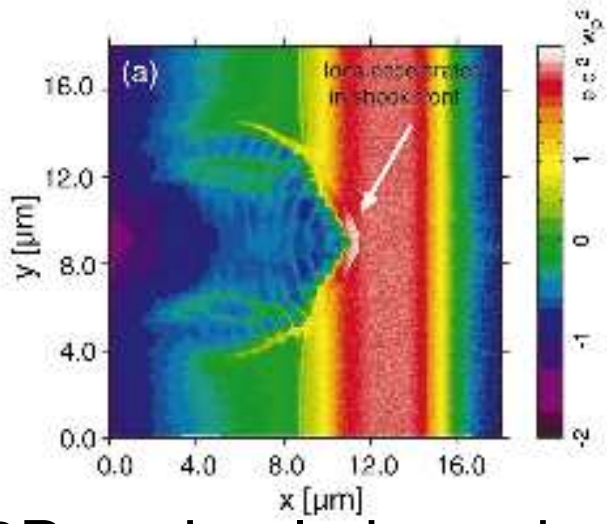

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Is FSA also related to fast electrons?

S-LPA: another acceleration mechanism?

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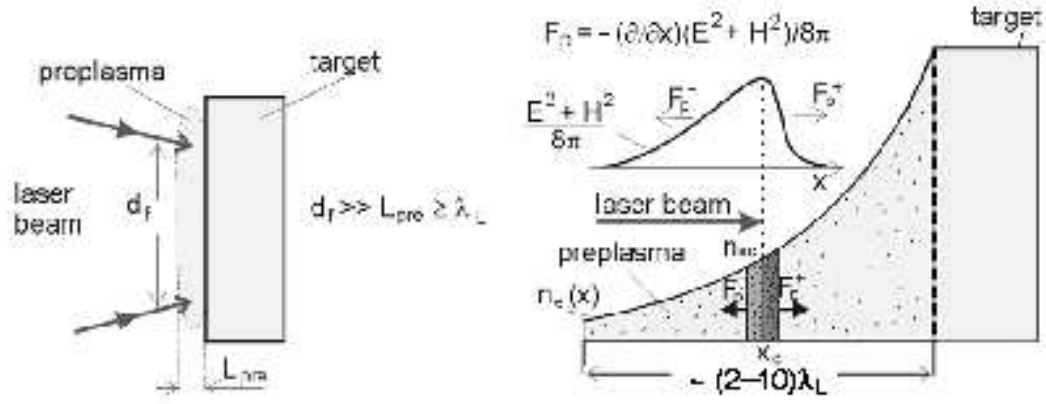

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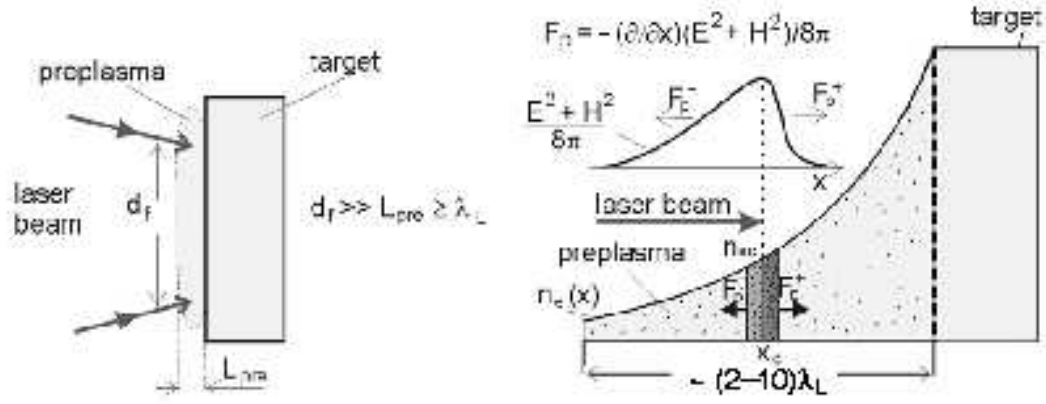

Role of prepulse and fast electrons, scaling to higher intensity, competition/overlap with FSA are yet to be understood.

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