Plasma density parameter scan for the laser wakefield injector using OSIRIS

Thales M. C. da Silva[1]
J. Vieira[1], U. Sinha[1], A. Helm[1],
R. Fonseca[2], L. O. Silva[1]

[1] GoLP / Instituto de Plasmas e Fusão Nuclear
Instituto Superior Técnico, Lisbon, Portugal

[2] Instituto Universitário de Lisboa (ISCTE-IUL),
Lisboa, Portugal

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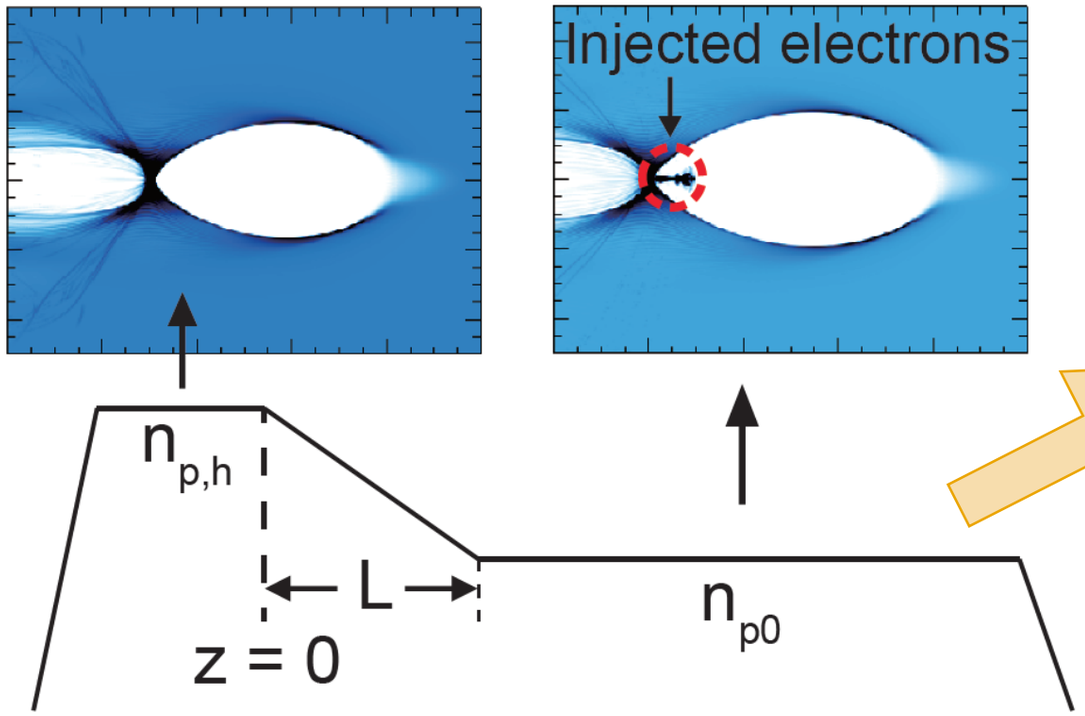
High quality beam with down ramp plasma

Reported results of low energy spread, high brightness self-injected beam for a density down ramp plasma scheme*.



Reported* electron beam parameters for LWFA	
Energy	56 MeV
Energy spread	< 1%
Transverse emittance	9 nm
Current	8kA

EuPRAXIA's goal for the LWFA injector

Energy	E	**150 MeV**	100 MeV	200 MeV
Charge	Q	**100 pC**	30 pC	100 pC
Bunch length	τ	**5 fs**	3 fs	20 fs
Peak current per bunch	I	20 kA	5 - 20 kA	
Repetition rate	f	**10 Hz**	1 Hz	100 Hz
Number of bunches	N	**1**	1	
Total energy spread (RMS)	σ_E/E	**5 %**	1%	5%
Transverse normalized emittance	$\varepsilon_{N,x}$, $\varepsilon_{N,y}$	**1 mm mrad**	1 mm mrad	

*X. L. Xu, et al., arXiv, 1610.00788v1 (Oct 2016)

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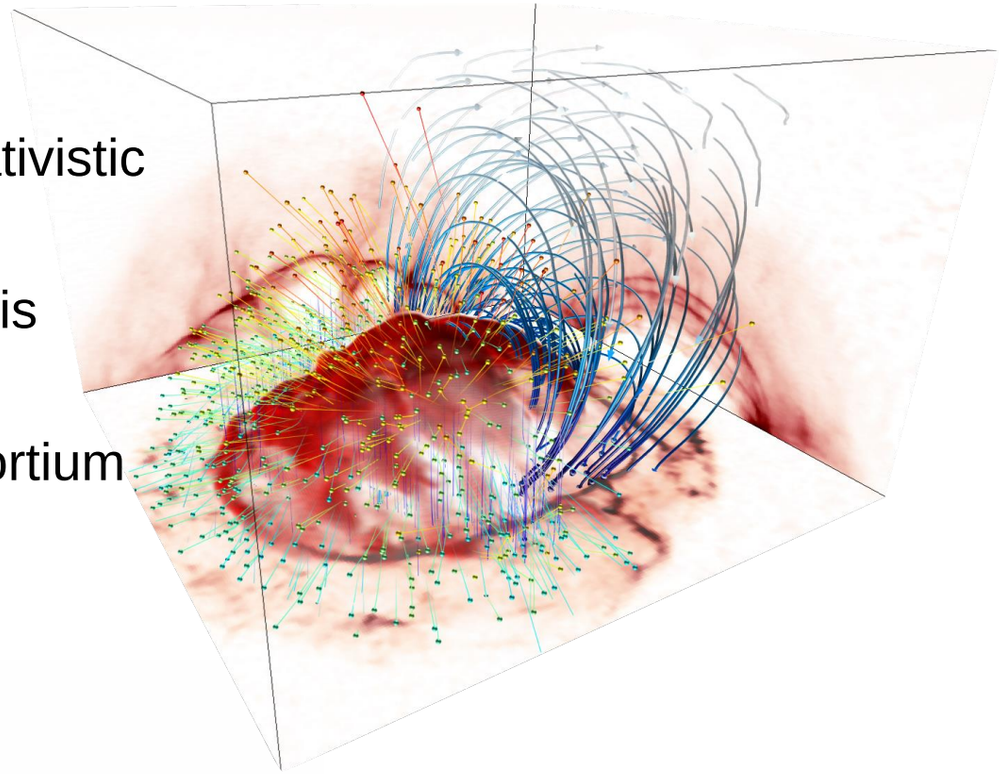
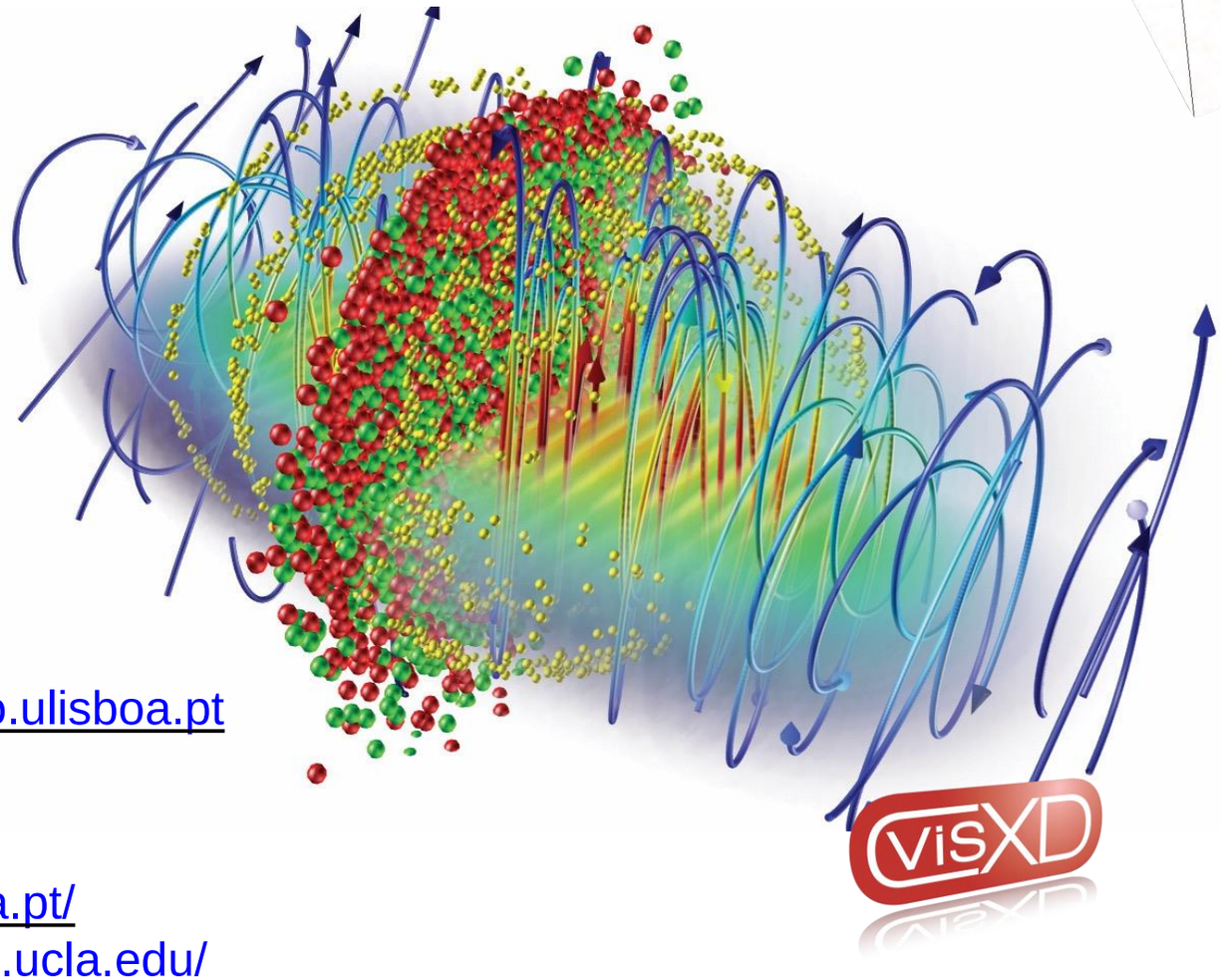
OSIRIS 3.0



osiris framework

- Massivelly Parallel, Fully Relativistic Particle-in-Cell (PIC) Code
- Visualization and Data Analysis Infrastructure
- Developed by the osiris.consortium
  - ⇒ UCLA + IST



code features

- Scalability to ~ 1.6 M cores
- SIMD hardware optimized
- Parallel I/O
- Dynamic Load Balancing
- QED module
- Particle merging
- GPGPU support
- Xeon Phi support

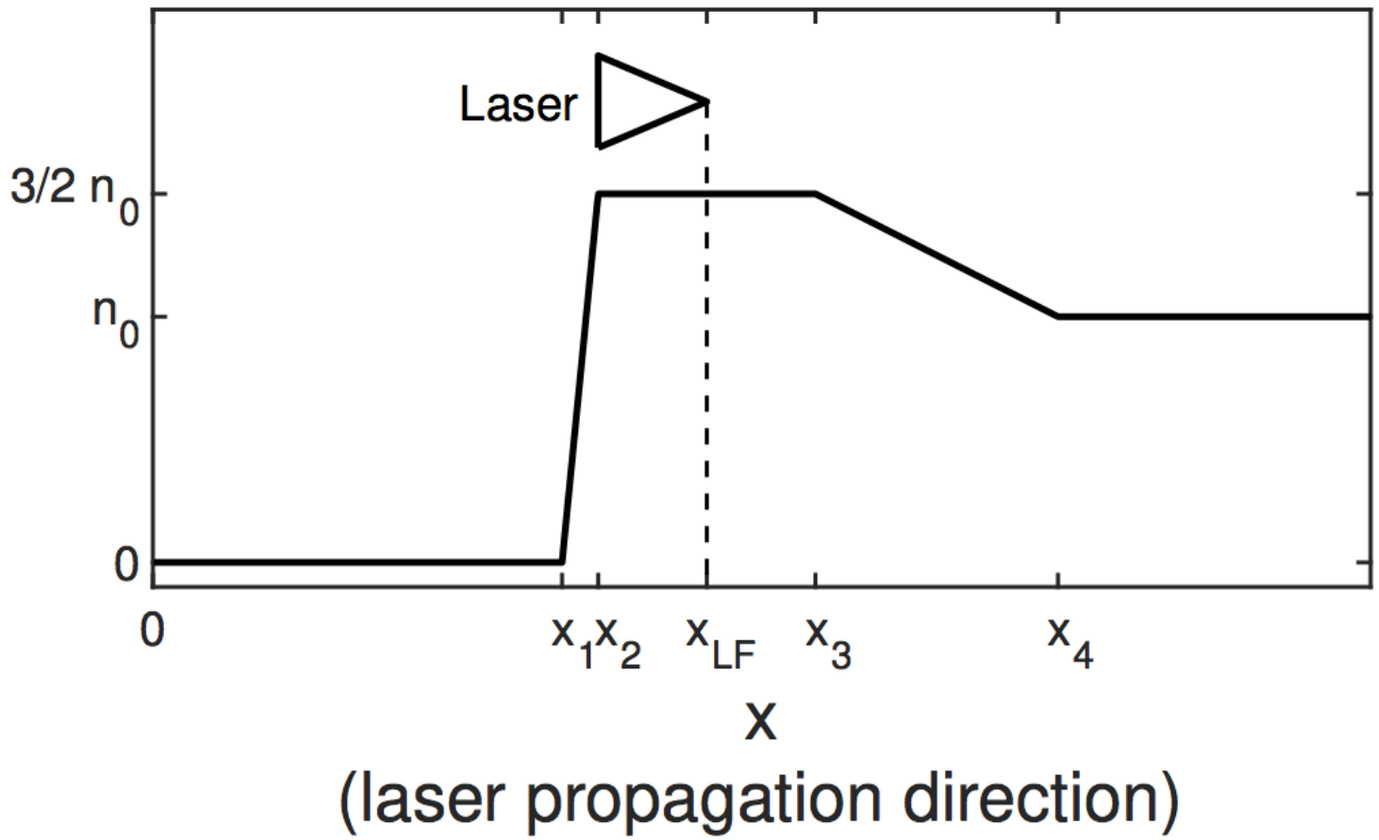
Ricardo Fonseca
ricardo.fonseca@tecnico.ulisboa.pt
Frank Tsung
tsung@physics.ucla.edu

http://epp.tecnico.ulisboa.pt/
http://plasmasim.physics.ucla.edu/

Simulation setup

Plasma parameters		
	Xu, et al.*	**Our input**
n_0	1 x 10^{19}cm^{-3}	1 x 10^{19}cm^{-3}
x_1		-35μm
x_2		-30μm
x_3	0	0
x_4	28μm	33.5μm

Laser parameters		
	Xu, et al.*	**Our input**
a_0	2.83	2.83
λ	800nm	800nm
τ	25fs	25fs
Shape	Gaussian	Gaussian
x_{LF}	-25μm	-25μm
Pol.	Circular	PGC



Grid/simulation parameters	
Cell size	0.08 x 0.40 x 0.40 μm
#PPC	2 x 2 x 2

Main goal: estimate the beam parameters for different values of n_0 keeping the laser parameters the same in normalized units.

*X. L. Xu, et al., arXiv, 1610.00788v1 (Oct 2016)

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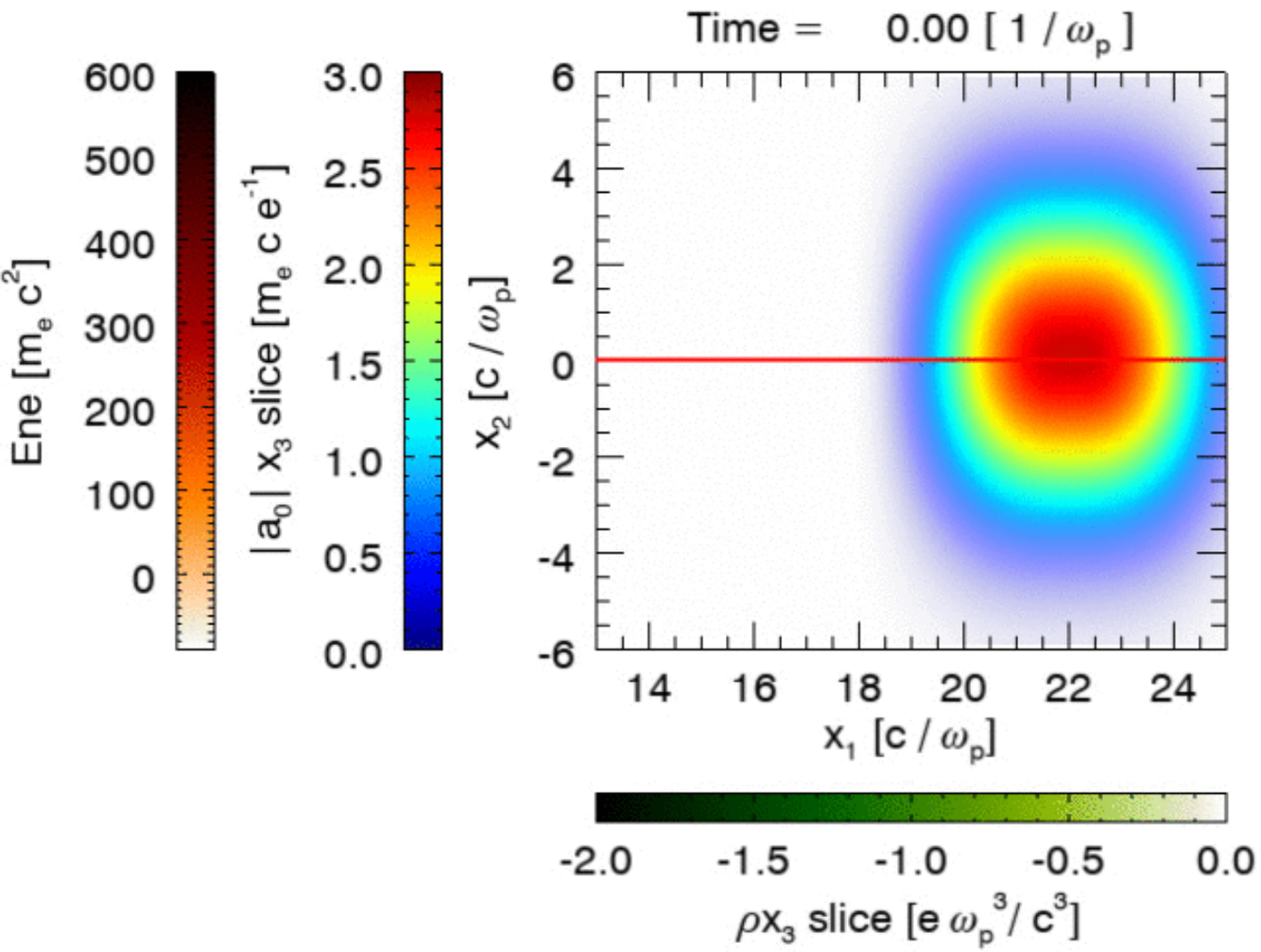
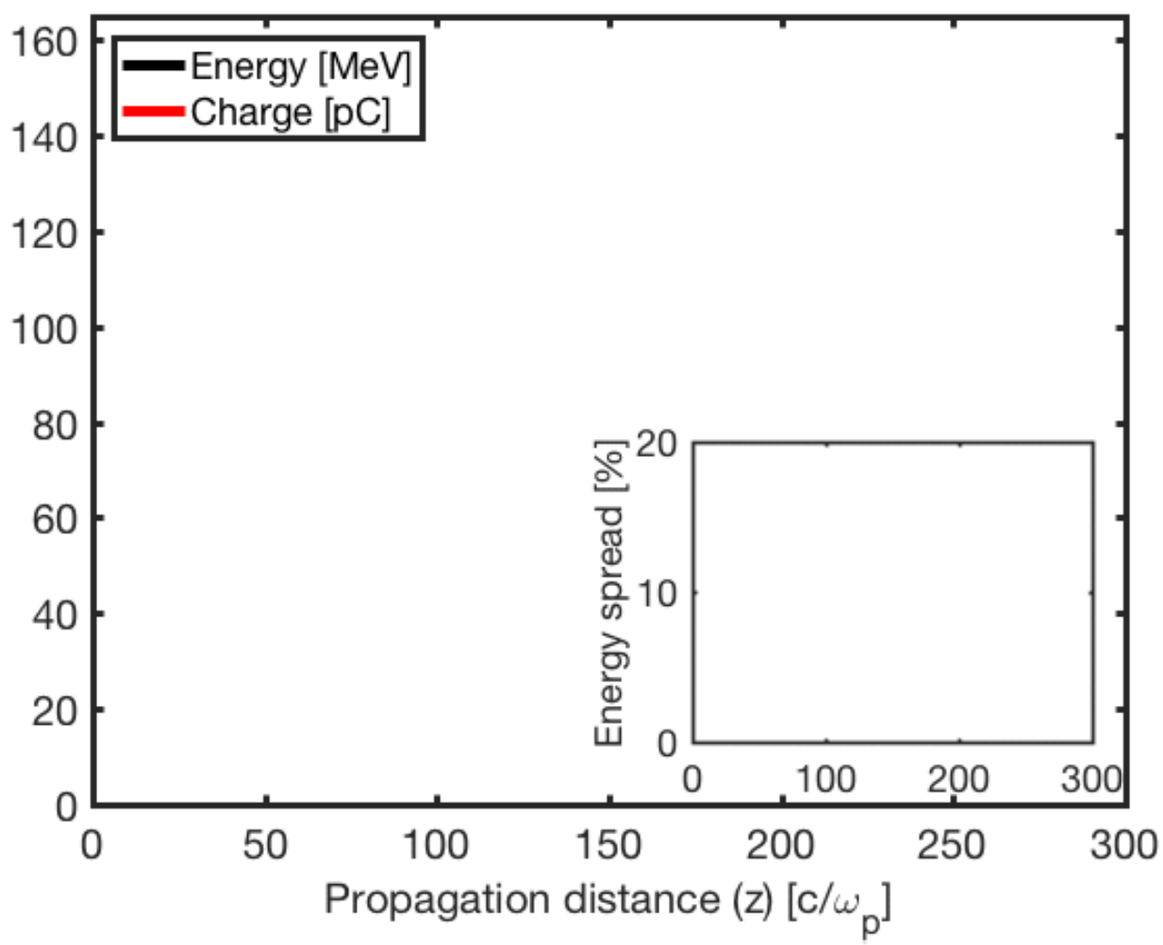
High charge and energy self-injected beam

but high energy spread as well

LWFA injector plasma (plasma 1)				
Plasma density	n_e	**$3\ 10^{18}$ cm^{-3}**	$1\ 10^{18}$ cm^{-3}	$1\ 10^{19}$ cm^{-3}

Example for n_0=3 x 10^{18}cm^{-3}





High charge and energy self-injected beam

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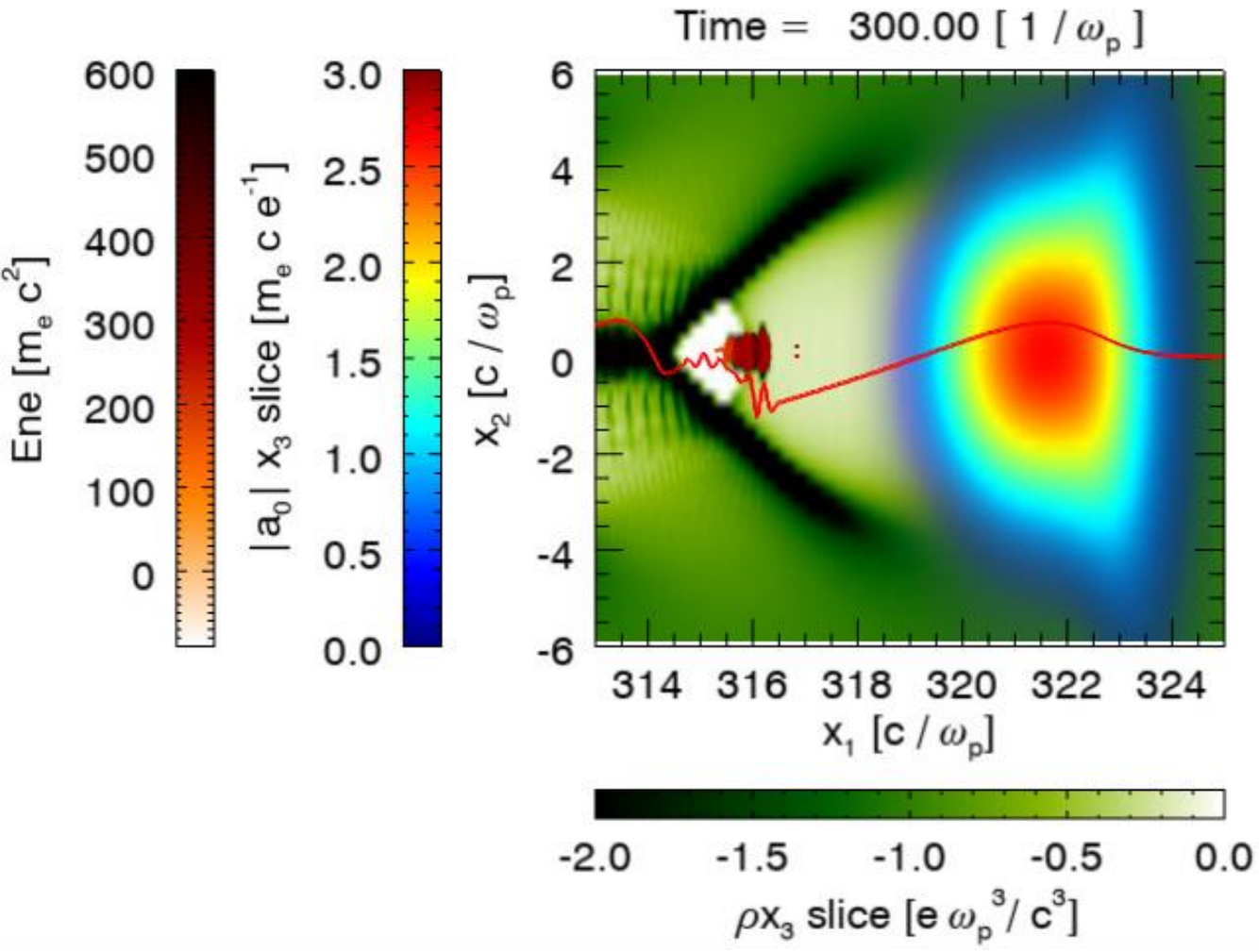
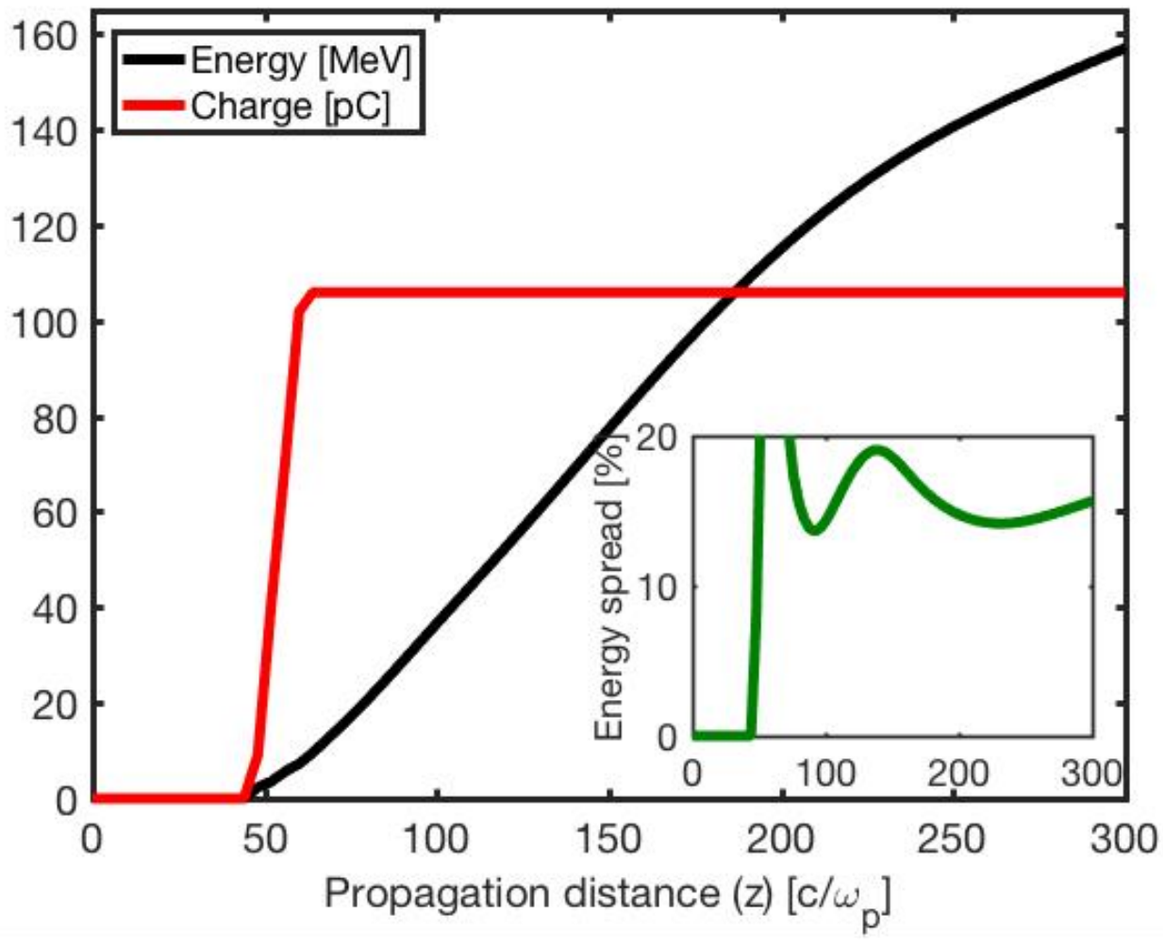




Beam quality during propagation

The energy spread varies during trapping and acceleration

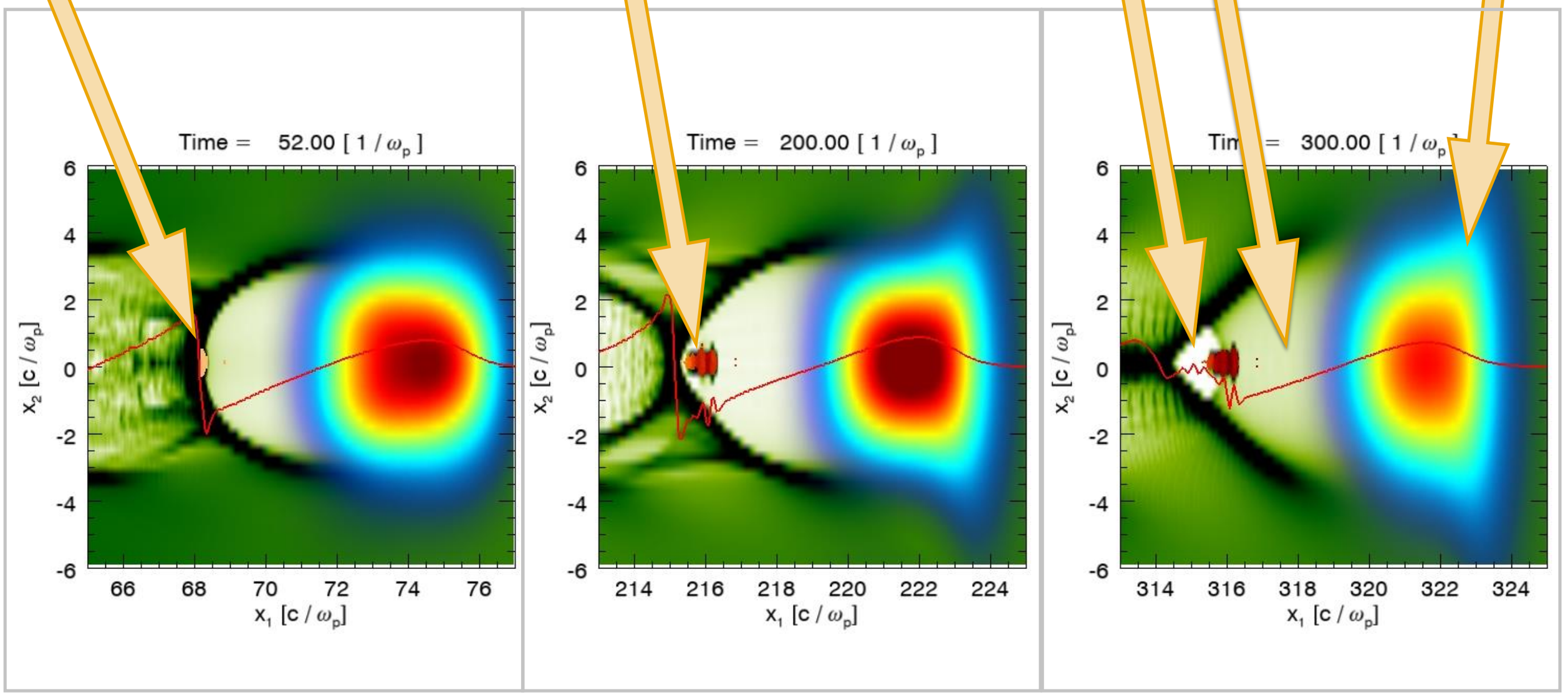
Self-injected beam

Highest quality of the beam during the evolution

Secondary wake excited by the beam

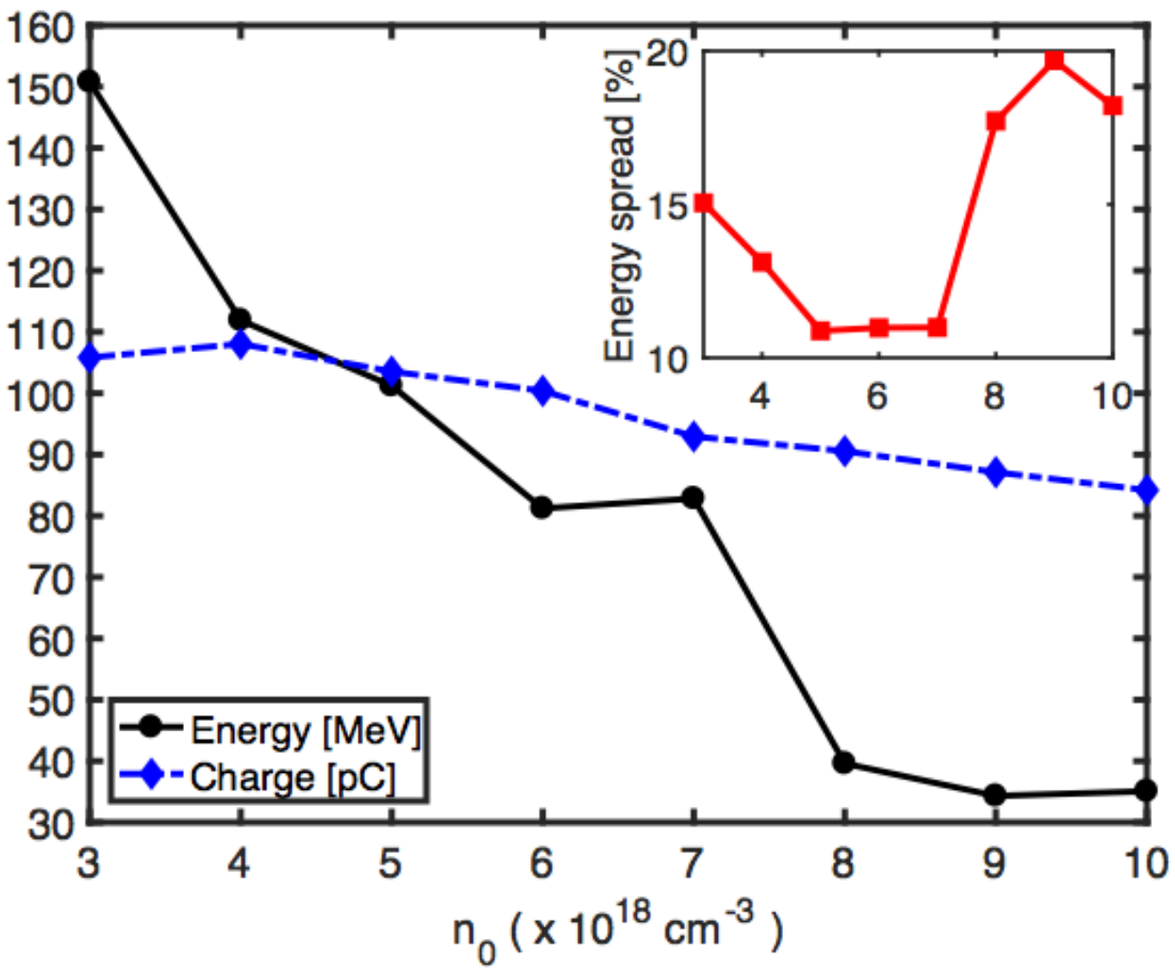
Some electrons are back in the wake

Laser diffraction



Parameter scan varying n_0

Beam parameters at the time of lowest energy spread.



Parameter analysis

- Lower density seems to be preferable.
- Energy spread got worse using a longer ramp.
- Important point: a fine tune of the grid is still necessary. The actual values of the beam parameters can vary by changing the cell size.
- Laser energy ~10^{-1}J (Base value 5J).
- Peak power ~10TW (Base value 167TW).

Contents

Conclusions & Future Work

Parameter scan of the plasma density

Simulation results show an improvement in the beam energy and charge when working at lower densities.

Grid parameters and test of PGC smoothing

Fine tune the grid parameters for our PGC runs (study in progress).

Results with PGC smoothing have to be further verified (study in progress).

Improvement of the beam parameters

An effort to obtain smaller energy spread while keeping the energy and charge as they are.

There is plenty of room to modify the laser parameters in order to do so.