Modelling of laser-plasma acceleration of relativistic electrons in the frame of ESCULAP project

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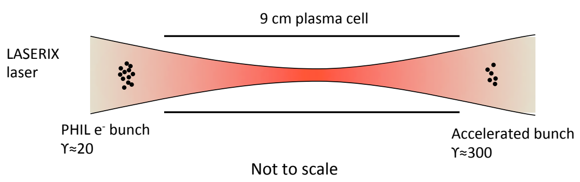
Introduction

Objective of ESCULAP project is the experimental study of laser-plasma acceleration of relativistic electron bunch [1]. LAL photoinjector (PHIL) will be used to inject electron beam in plasma wakefield created by high power laser (LASERIX) in the plasma cell. Control of the quality of the accelerated bunch is one of the main difficulties in laser-plasma acceleration.

	Experimental parameters	Modelling parameters
PHIL	10 MeV electrons photoinjector, repetition frequency 5 Hz Bunch charge 10 pC Emittance FWHM 4 mm*mrad Bunch length rms 7–10 ps --> need of bunch compression (see poster of Ke Wang)	**Gaussian electron bunch / or one from Astra** Beam Duration 100 fs Beam Gamma Mean = 19; Beam Gamma rms = 1 Beam Width X = Beam Width Y = 50 mum Beam Width Theta X =Beam Width Theta Y = 10 mrad
LASERIX	2 J, 45 fs FWHM high-power Ti:Sa laser (800 nm)	**Gaussian Laser** Laser Duration 45 fs FWHM Laser Energy 2J Laser Waist ~50 mum
Plasma cell	2-4 e17 cm-3 variable density profile, total length of 9 cm	**Plasma density** Uniform 2e17 cm-3

Experimental setup scheme



Features of WakeTraj code

- 2D3V axisymmetric tracking implemented in Fortran
- Particle distribution generator / external file
- Linear approach / potential from WakeAC (calculated once)
- Non-uniform plasma density profile
- No space-charge effect

Conclusions

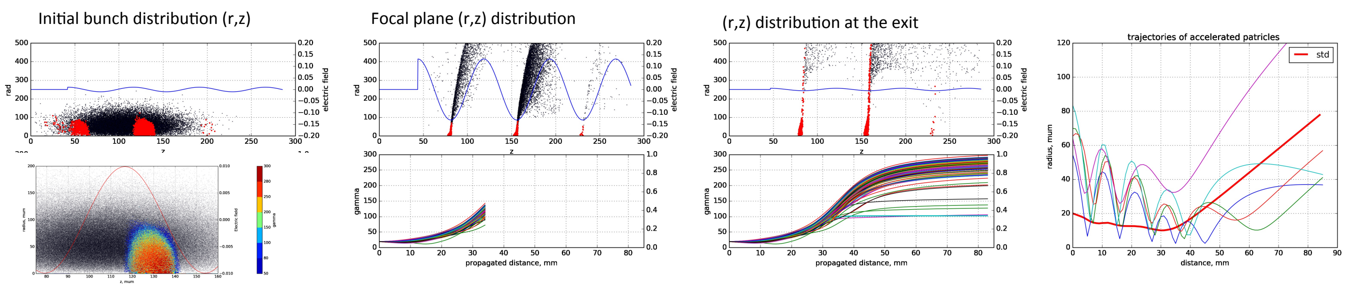
- Parametric study of laser plasma acceleration in 9 cm plasma cell is performed
- Nearly 30% of electrons can be captured and accelerated to 150 MeV with 10% energy spread
- Non-linear approach appears to be beneficial, resulting in the acceleration offset of ~25 MeV
- Stronger focusing
- Need of density profile

References

1. Project overview is presented in the poster of Nicolas Delerue
2. Gorbunov, L. M., and V. I. Kirsanov. "Excitation of plasma waves by an electromagnetic wave packet." *Sov. Phys. JETP* 66.290-294 (1987): 40.
3. Esarey, E., C. B. Schroeder, and W. P. Leemans. "Physics of laser-driven plasma-based electron accelerators." *Reviews of Modern Physics* 81.3 (2009): 1229.
4. Mora, Patrick, and Thomas M. Antonsen, Jr. "Kinetic modeling of intense, short laser pulses propagating in tenuous plasmas." *Physics of Plasmas* 4.1 (1997): 217-229.
5. Paradkar, B. S., et al. "Numerical modeling of multi-GeV laser wakefield electron acceleration inside a dielectric capillary tube." *Physics of Plasmas* 20.8 (2013): 083120.
6. Bunch compression is presented in the poster of Ke Wang

Parametric study with reference electron bunch

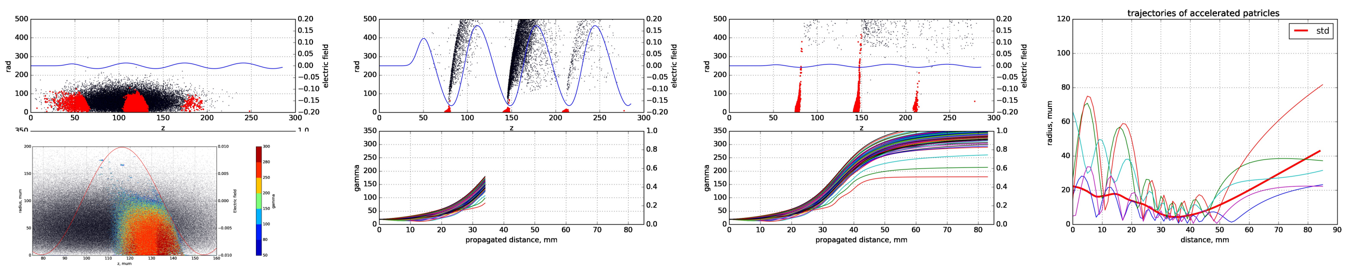
Linear approach: analytical expression for wake fields [2, 3]



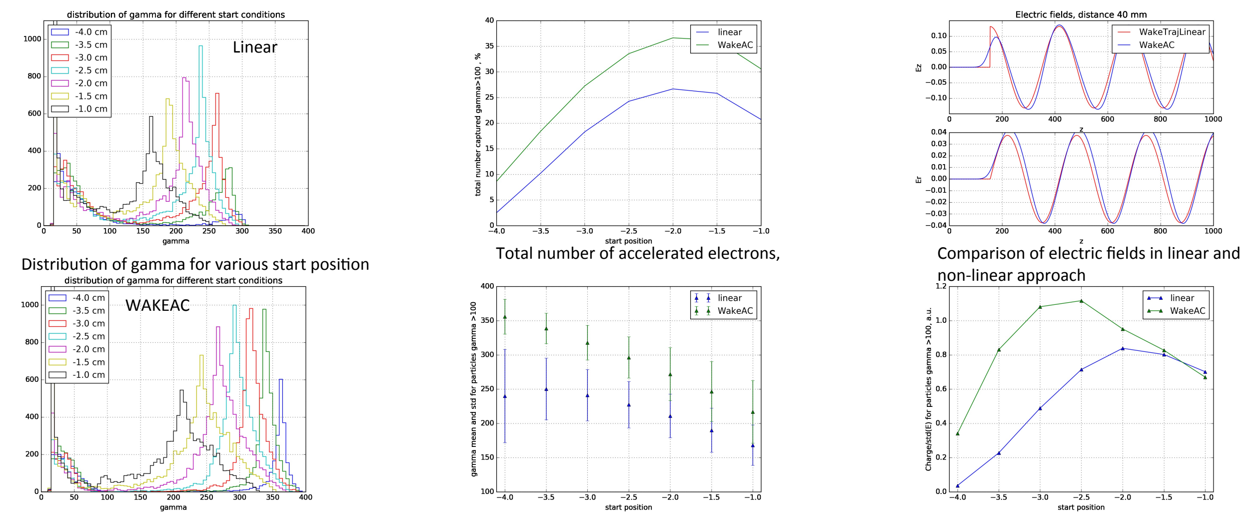
Correlation w.r.t. to the initial position in the bunch
Red: electrons which will accelerate to gamma>100

Particle trajectories in plasma cell

Non-linear approach, Electric fields from WakeAC [4, 5]



Dependence on the start position (focusing)

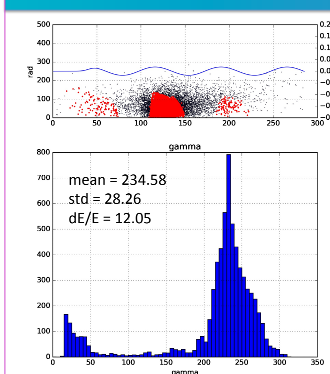


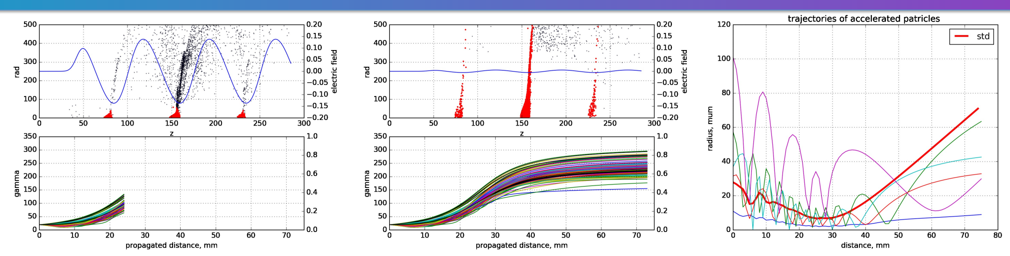
Distribution of gamma for various start position

Total number of accelerated electrons,

Comparison of electric fields in linear and non-linear approach

Results for the realistic bunch [6]





Start position -2.5cm, ~60% electrons captured

In order to decrease dE/E optimization of the density profile should be performed