**A tutorial on Particle in Cell simulation**

**of Laser Wakefield Acceleration**

**Note:**

Please include the correct units in your answers and in your plot.

Please include the correct labels (with units) in your plot.

If more than one plot is asked, please check that all plots are included.

If a script is asked for an exercise, please send it to the instructor.

**Exploring the Input Namelist:**

* **Exercise 1 :**

nc (cm-3) =

E0 (TV/m) =

* **Exercise 2 :**

Lx (μm) =

Lr (μm) =

nx =

nr =

dx (μm) =

dr (μm) =

**Laser pulse in vacuum**

* **Exercise 3 :**

waist (μm) =

LFWHM (field, fs) =

LFWHM (intensity, fs) =

Center laser (μm) =

xfocus (μm) =

* **Exercise 4 :**

a0 =

I (W/cm2) =

* **Exercise 5 :**

xR (μm) =

* **Exercise 6 :**

Include a plot of the comparison

**Laser wakefield excitation**

* **Exercise 7 :**

n0 / nc =

underdense plasma or overdense plasma?

* **Exercise 8 :**

λp (theoretical, μm) =

λp (estimate. , μm) =

* **Exercise 9 :**

Include a plot of the comparison

* **Exercise 10 :**

Include the requested plot

* **Exercise 11 :**

Include a plot of the comparison for Ex and a plot for the comparison of -Rho/e.

Include a plot of the plasma wave period (in μm) as function of the a0 of the laser.

**Laser wakefield acceleration of an electron bunch**

* **Exercise 12 :**

Q (pC)=

Rms size along x = σx (μm) =

Rms size along y = σy (μm) =

Rms size along z = σz (μm) =

Energy E (mec2) =

Energy E (MeV) =

Relative energy spread δE/E (%) =

Normalised emittance along y = εny  (mm-mrad) =

Normalised emittance along z = εnz  (mm-mrad) =

Center bunch (μm) =

* **Exercise 13 :**

Include the plots showing the plasma wave and the electron bunch

* **Exercise 14 :**

Include the plots with the number density and the longitudinal electric field Ex on the propagation axis

* **Exercise 15 :**

ΔE (mec2)=

ΔE (MeV) =

L (μm) =

Eacc (GV/m) =

Report here all the bunch parameters at the start (timestep = 0) and at the end of the simulation (timestep = 5000). You can copy and paste the output of the script Compute\_bunch\_parameters.py.

* **Exercise 16 :**

Include a plot of the bunch parameters evolution and provide an estimate of the accelerating gradient in GV/m.

* **Exercise 17 :**

Include a plot with the results of the four simulations (charge in pC vs energy gain in MeV)

Can you explain why the bunch gains more (or less) energy varying the charge?

* **Exercise 18 :**

Include a plot with the results (delay\_behind\_laser in μm vs energy gain in MeV).

Include a plot with the comparison of the Rho/e of the four simulations.

What do you observe and how do you explain it?

* **Exercise 19 :**

Include the plots and send the script to the instructor.

* **Exercise 20 :**

Include a plot of the bunch energy spectrum at the start and at the end of the simulation, with a brief comment on the changes you see. Send the script to the instructor.