NANOPARTICLE-ASSISTED LWFA AND THE INFLUENCE OF NANOPARTICLE MATERIAL ON BEAM CHARGE

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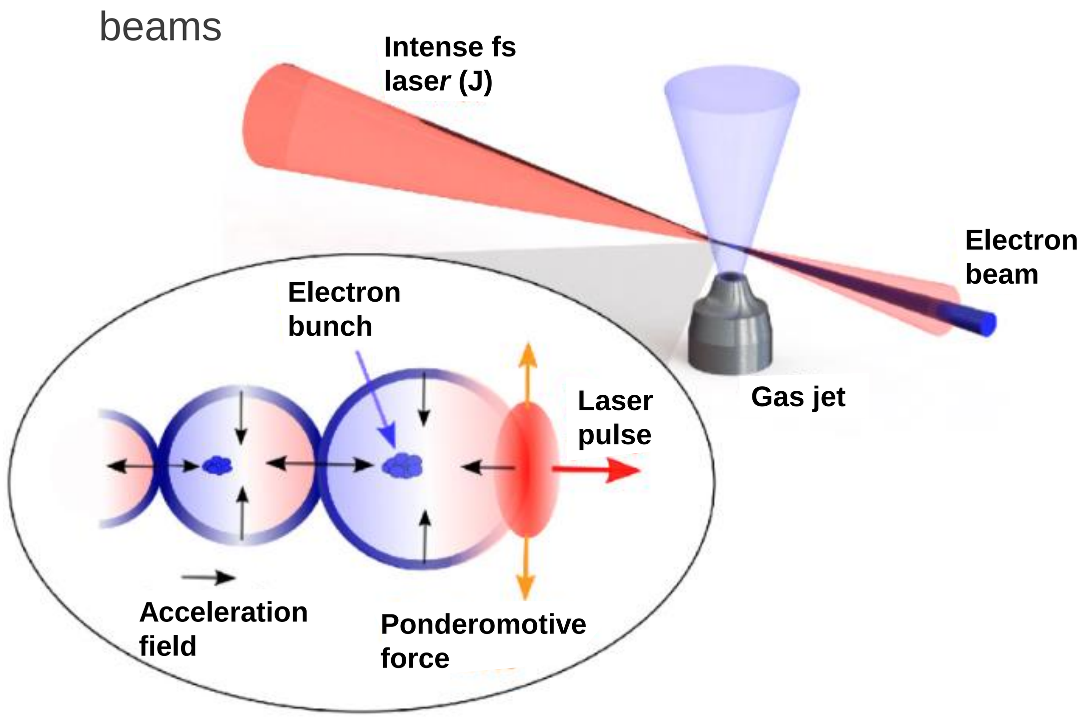
Laser-driven plasma-wakefield acceleration has the potential to reduce the size and construction cost of large-scale accelerator facilities, by providing accelerating fields up to three orders of magnitude greater than that of conventional accelerators. However, the parameters of the electron beam and its stability need to be further improved to enable efficient use in many interesting industrial and medical applications as well as in various areas of fundamental research.

Since electron injection is one of the key features determining the beam characteristics, various injection mechanisms yielding better electron beam parameters were proposed over the last several years. The most recent and very promising scheme is a gas target containing nanoparticles which, according to simulations, seems very promising, especially in experiments trying to reach multi-GeV electrons. The improvement in terms of the stability of the electron beam have alredy been proven in experiments.

This poster presents a study focused on the influence of various nanoparticle materials, on the injection process and accelerated electron beam. The study was performed using large-scale particle-in-cell simulations which were carried out with PIC code Smilei.

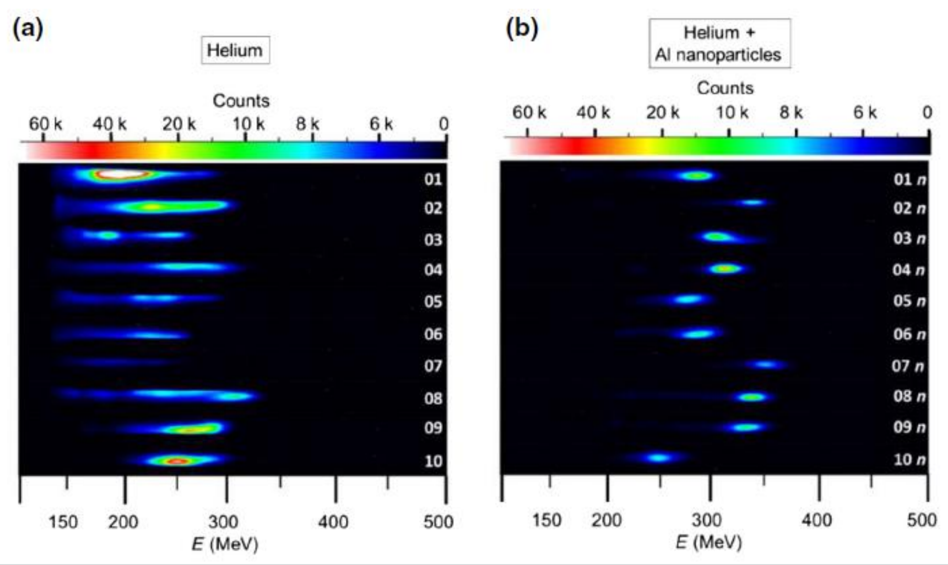
LASER WAKEFIELD ACCELERATION

- Intense laser beam hits the gas target
  - → ionization of the gas
  - → creation of the accelerating plasma wave (wakefield)
- **Electron injection** – important factor determining the electron beam quality
- Various injection schemes were developed to improve stability and properties of the electron beams



NANOPARTICLE-ASSISTED LWFA

- Ionization of the nanoparticle creates very strong electric field
  - → nearby electrons are provided with addiotional momentum needed for injection
- The area of injection is localized
  - → beam with reduced energy spread and divergence
- Possibility to control some of the electron beam properties by nanoparticle parameters
- Separates the injection process from the laser pulse development
- Advantageous injection scheme for accelerating electrons to GeV energies



PIC SIMULATIONS

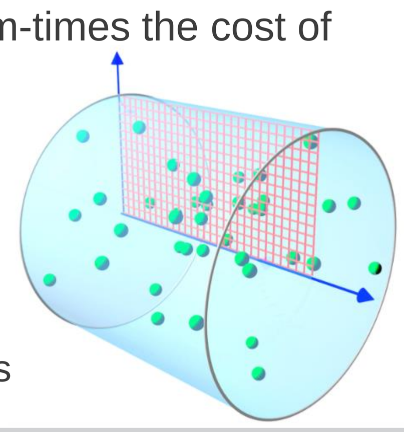
- Simulations in plasma-physics Smilei
- Based on kinetic theory for collisionless plasma
- Macroparticles ("clouds" of real particles)
- Particles move in macroscopic electromagnetic field (interaction with the computational grid)

Quasi-3D PIC

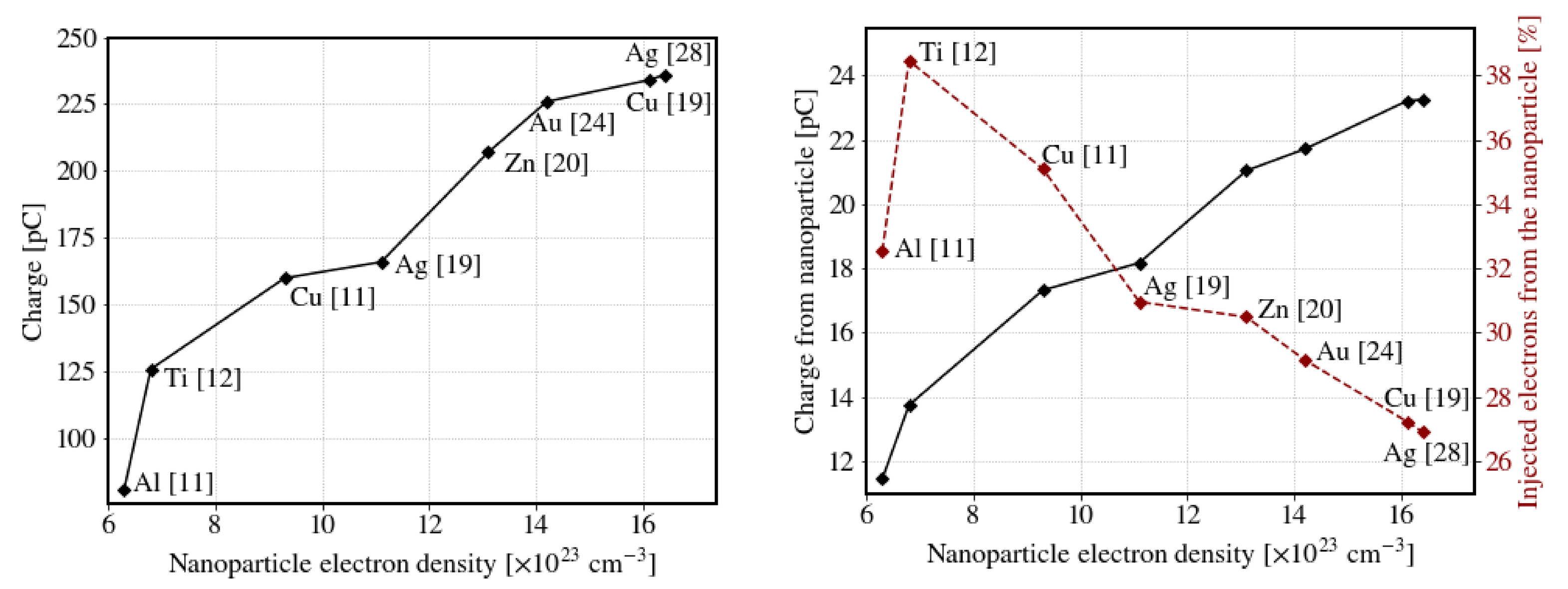
- Physical problems close to cylindrical symmetry
- Grid quantities (fields, currents) defined on 2D grid
- Macroparticles move in 3-D space (Cartesian geometry)
- Decomposition of the EM fields to azimuthal modes
- The cost of simulation approx. m-times the cost of 2-D simulation

$$F(r,z,\theta,t) = \Re\left(\sum_{m=0}^{N_m-1} \tilde{F}^m(r,z)e^{-im\theta}\right)$$

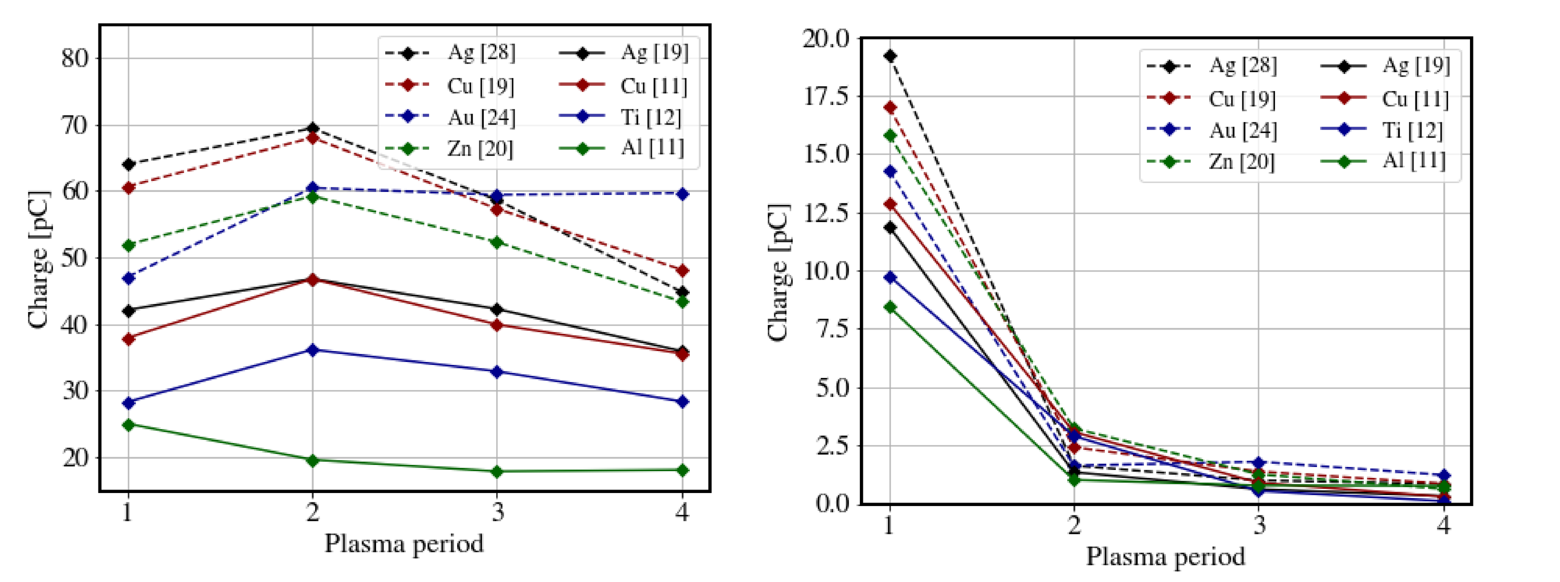
- ***m*** is the number of the mode
- $\boldsymbol{F_m}$ is the Fourier coefficient
- $\boldsymbol{N_m}$ is the number of used modes



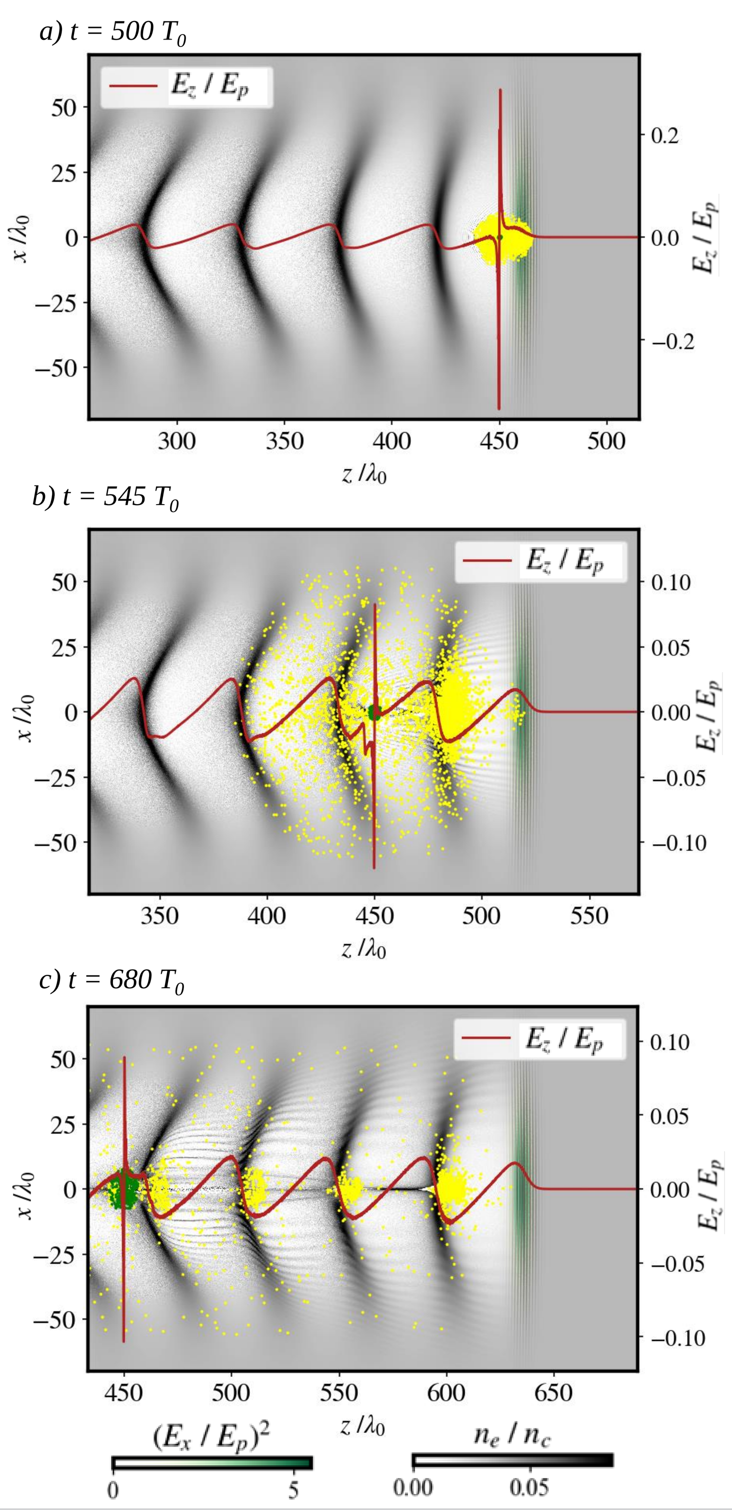
ELECTRON BEAM CHARGE



ELECTRON BEAM CHARGE IN PLASMA PERIODS



ELECTRON INJECTION



CONCLUSION

- Ionized nanoparticle can induce a robust and localized electron injection
- Electron beams with smaller energy spread and higher charge compared to self-injection
- The beam charge can be "tuned" by varying the nanoparticle material or size
- This scheme is able to facilitate electron injection even in the low density plasma hence, it is suitable for obtaining GeV electron beams

ACKNOWLEDGEMENTS

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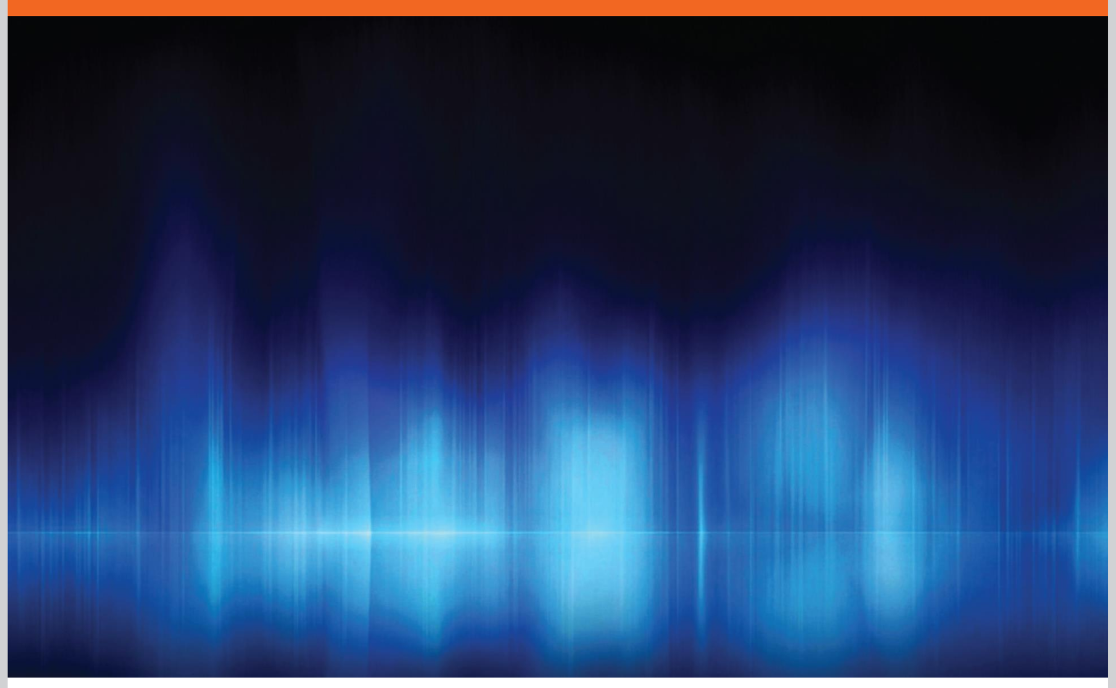

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