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PhD Thesis Abstract

Three dimensional modelling towards the tera-electronvolt: the dawn of cosmic rays in table top plasma based devices

The origin of cosmic rays and the formation of gamma ray burst are examples of the most interesting and not yet fully explored fundamental questions in astrophysics. These are some of the outstanding mysteries in physics where the generation and the acceleration of ultra-energetic particle beams are critical. Exploring the interaction between intense particle and laser beams with plasmas can provide key insights into these questions, recreating astrophysical conditions in the laboratory, and opening a path to next generation particle accelerators.

Numerically modelling these scenarios is particularly difficult due not only to the large disparity in spatial and temporal scales involved, between the driver and the accelerating plasma, but also because relativistic flows are particularly challenging in kinetic plasma simulations. The former may be addressed either by reduced models, such as the ponderomotive guiding centre, where the laser is treated in the envelope approximation, or by choosing a relativistic simulation frame, co-moving with the laser, where this disparity is minimized. In this frame however, the stationary background plasma now becomes a relativistic flow, and steps must be taken to avoid the so called numerical Cherenkov instability (NCI), that arises from relativistic particles moving in a discretized numerical grid, where the speed of light is non-physically reduced, which leads to the emission of numerical Cherenkov radiation.

The proposed project focuses on numerical modelling of these scenarios using the fully relativistic particle-in-cell code OSIRIS developed at the Group for Lasers and Plasmas (GoLP) at Instituto Superior Técnico and the Plasma Simulation Group at University of California, Los Angeles (UCLA). I will implement a three-dimensional ponderomotive guiding centre laser solver in OSIRIS. Additionally, a spectral version of OSIRIS will be developed, to improve the numerical dispersion of the grid, and allowing to control and reduce NCI. With such advantages it will be possible to explore particle acceleration to the energy frontier in astrophysical and laboratory settings.