Reduced model to accelerate the study of laser-electron scattering

In an intense electromagnetic background, charged particles obtain relativistic velocities and emit energetic photons. A fraction of these photons decays into electron-positron pairs, which can themselves be accelerated by the fields and radiate new photons. These phenomena occur in extreme astrophysical environments such as pulsars, and in the scattering of Petawatt-class lasers and ultrarelativistic electron beams in the laboratory.
In order to benchmark the fundamental models of this field, called High-Field-QED-Plasma, with experiments, it's crucial to run accurate simulations of these processes and develop analytical models that describe them. However, realistic simulations can take up to millions of CPU hours on HPC systems, limiting the explored parameter space when supporting the design of experiments. In this work, we propose a reduced yet accurate predictive model for the number of positrons produced in these collisions, which can be run on a single CPU in a matter of minutes.
When an electron beam scatters against a plane-wave laser pulse, all electrons interact with the same maximum field value. This has already allowed some analytical estimations of the final positron yield. However, in an experiment, the laser pulse needs to be focused on an area ~10 micron^2, where the plane-wave approximation breaks down. Furthermore, when scattering against a focused laser pulse, not all electrons will interact with the peak of the laser field at the focus (a0); for example, electrons far from the optical axis will collide with a much lower field. To account for this effect, we constructed a probability distribution of electrons in effective a0 and applied the plane-wave model to each of these a0 values.
To verify the validity of our model we performed full 3D PIC simulations within the PRACE project, whose results proved that our model could predict the final number of positrons. It is also possible to include other effects into the model such as the electron beam geometry and the offset from the focal plane of the center of the scattering. In the future, full 3D simulations will be done mainly for non-ideal configurations and non-Gaussian laser pulses.
With this work, we hope to provide experimentalists with a very light semi-analytical tool to optimize the expected number of positrons. We believe that this model allows a simple mapping between 1D analytical models and 3D more realistic scenarios, and also allows significantly faster optimization of other experimental observables, such as electron energy spectrum, average photon energy, and others.