Beyond a classical description of plasma physics
What does QED bring and change?

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Plasma physics generally involves well-known physics of electromagnetism, special relativity and statistical mechanics. Various descriptions of the plasma state (kinetic, fluid, MHD) have been developed and each of them have a specific scope that depends on time/length scales, chemical composition, density, and temperature. Whereas these descriptions are well established, we could wonder when quantum electrodynamics (QED) comes into play. The answer lies in the threshold of QED cross sections which become non negligible for certain critical lengths, energies and fields. The presence of ultra-strong electromagnetic field and relativistic temperatures modifies the underlying basic physics to such a great extent that relying on classical plasma physics is often not justified.

The zoo of QED processes implies emission of hard photons, photon-lepton collisions, non-constant number of particles (creation and annihilation), stochastic particle orbits, which have stimulated the community for constructing a QED-based plasma physics. While the state of development of QED-based plasma physics theory is still far from being as mature as that of the classical plasma theory, progress in this area has been achieved in the past few decades. These advances have implications in many astrophysical and laboratory scenarios (associated to new PetaWatt class lasers), that share common underlying microphysics and collective plasma effects associated with intense fields.

This new physics is highly nonlinear and multi scale, and require a combination of theory and large scale numerical simulations. The main challenges in this area with be presented and the recent progresses triggered by large scale simulations of compact objects and of multi dimensional laser/beam-plasma interactions in the presence of fields close to the critical Schwinger field will be discussed, emphasising the interplay between collective plasma dynamics and QED processes.