Self-triggered Compton collisions for strong-field QED

A. Matheron[1], I. Andriyash[1], K. Ta Phuoc[1], C. Thaury[1], J. Gautier[1], J.-R. Marques[2], L. Lancia[2], X. Davoine[3,4], L. Gremillet[3,4], S. Corde[1]

[1] LOA, ENSTA Paris, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, 91762, Palaiseau, France, [2] LULI, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, 91762 Palaiseau, France, [3] CEA, DAM, DIF, 91297 Arpajon, France, [4] Université Paris-Saclay, CEA, LMCE, 91680 Bruyères-le-Châtel, France

Recent progress in laser technology opens new possibilities in high-field science, notably to investigate the largely unexplored strong-field quantum electrodynamics (SFQED) regime where electron-positron pairs can be created directly from light-light or even light-vacuum interactions. Several facilities can reach multi-petawatt intensities allowing SFQED to be probed with electron beam - laser collisions. A possible strategy is to collide a laser-plasma accelerated electron beam with a laser pulse, to trigger Inverse Compton scattering (ICS) emission. The QED regime reached during the collision is quantified by the quantum parameter χ which is proportional to the electron energy and the field amplitude of the laser pulse. Here we propose a new strategy where a single laser pulse is first used to accelerate electrons to high energy and is then reflected on a plasma mirror eventually colliding with the electrons just behind. This "Compton foil" scheme benefits from auto-alignment since the electrons are inherently aligned with the laser. We show first experimental results of this scheme at the Apollon laser facility in France, where we observed the Compton gamma-ray signal coming from a > 1 GeV electron-beam colliding with a 15 J laser pulse. In this case, we show that we can generate ICS gamma rays with photon energies several orders of magnitude higher compared to the seminal result of Ta Phuoc et al. [All-optical Compton gamma-ray source. *Nature Photon* **6**, 308–311 (2012)], thus demonstrating that this scheme is scalable towards SFQED. To reach a deeper QED regime, we also propose to boost the laser intensity via self-focusing and self-compression in a second gas jet of higher plasma density, increasing the laser pulse amplitude a_0 from 4 to 40 according to our PIC simulations results, thereby increasing the quantum parameter by one order of magnitude. This original concept with a plasma-mirror based ICS source and laser intensity booster could be a game changer allowing to reach deep SFQED regime with a simple experimental setup using a single laser and guaranteeing automatic spatial and temporal overlap. We show a start-to-end PIC simulation of this scheme in the case of a laser with 100 J of energy on target and show the strong potential of this scheme, allowing to probe SFQED at $\chi > 5$.