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Gamma beams generation with high intensity lasers for the study of two photon Breit-Wheeler pair production

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Direct production of electron-positron pairs in photon collisions is one of the basic processes in the Universe. The linear Breit-Wheeler (BW) pair creation process (γ+γ to $e^{+}+e^{-}$), is the lowest threshold process in photon-photon interaction, controlling the energy release in Gamma Ray Bursts and Active Galactic Nuclei [1]. It is also responsible for the TeV cutoff in the photon energy spectrum of extra-galactic sources. The linear BW process has never been clearly observed in laboratory with important probability of matter creation [2]. Using MeV photon sources a new experimental set-up based on numerical simulations with QED effects has recently been proposed [3]. This scheme offers a possibility of conducting a multi-shot experiment with a reliable statistics on laser systems with pulse energies on the level of a few joules to tens of joules, and in a low noise environment without heavy elements. This scheme relies on a collision of relatively low energy (few MeV), intense photon beams. By colliding two of them in vacuum, one would be able to produce a significant number of electron-positron pairs in a controllable way.

To prepare future experiments using this scheme, we have performed an optimization study on collimated gamma sources generation with high intensity lasers using numerical simulations with QED effects for different possible ways of creation of the MeV photons with solid foils or dense gas jets. At ultra high intensities, higher than $10^{23}W/cm^2$, most of the energetic photons are generated in the synchrotron-like radiation dominated regime, but for intermediate intensities, between a few 10^{21} and $10^{23}W/cm^2$, a competition between the Bremsstrahlung and the synchrotron-like processes arise. For intensities lower than $10^{21}W/cm^2$, Bremsstrahlung dominates. This optimization study has been performed using the parameters of soon to be available laser facilities like Apollon at Université Paris Saclay, the ultra high intensity upgrade of the INRS laser in Canada, the Texas Petawatt in the US, and PETAL on the LMJ facility in France.

The possibility to study two-photon Breit-Wheeler pair production in the laboratory would allow to test new concepts of pair plasma production and to explore this pair creation process in the ultra high field regime with important potential applications in astrophysics. Moreover, the obtained optimized gamma sources could also have promising applications as radiography sources.

References: [1] Ruffini, R. et al. Physics Reports 487, 1-140 (2010). [2] Bamber C. et al. Phys. Rev. D, 60, 092004 (1999). [3] Ribeyre, X. et al., Phys. Rev. E, 93, 013201 (2016).

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