Generation of high-energy photons and e-e+ pair jets using laser-accelerated electron beams

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During the past decades, petawatt(PW)-class lasers have become a key component for the study of laser-driven particle acceleration, relativistic plasma dynamics and radiation production. The availability of multiple such beamlines opens up new frontiers of research direction in fundamental and applied physics.

At CoReLS [1] we have used the 4 PW laser beamline to generate up to 4 GeV electron beams produced through laser wakefield acceleration and we characterized their properties [2,3,4]. The beams were then applied for production of photon sources based on bremsstrahlung, betatron radiation and nonlinear inverse Compton scattering (NCS). Various detectors and analysis methods are being developed in-house for the diagnostic of such bright photon beams [5]. Currently, we are developing detectors based on pixelated scintillators (LYSO) and pair production spectrometers. Analysis of the spectral properties of photons requires particle-matter interaction codes such as GEANT4. Despite significant progress, the high energy range of photons (1 MeV-1 GeV), the fluctuations in beam parameters, and the background radiation represent a challenge for accurate measurements and diagnostics.

In the very near future, the combination of 1-PW and 4-PW beamlines available at CoReLS will allow the study of laser-electron collisions at very high laser intensities (10^{22} - 10^{23} W/cm2). Quantum effects become dominant in this regime, thus radiation reaction and e-e+ pair production will play a central role in experiments. So far, particle-in-cell simulations that include strong-field quantum electrodynamics (SFQED) processes have been used to reveal interesting physical phenomena. The SFQED processes of nonlinear Breit-Wheeler and trident pair production are of particular interest and their behavior was shown to be sensitive to the laser pulse envelope [6]. We observed that the temporal evolution of pair production is a complex interplay between the instantaneous production rates and the characteristics of the laser pulse. In addition, it was shown that it is possible to produce multiple collimated e-e+ jets from such a collision, with properties that depend on the laser pulse polarization and intensity [7].

Overall, the availability of multi-PW laser facilities will give us the opportunity to study challenging topics related to radiation generation and detection but also fundamental phenomena such as e-e+ pair production processes in SFQED.

References

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