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Lepton polarization effects in strong laser fields

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Spin polarization of an ultrarelativistic electron beam head-on colliding with an ultraintense laser pulse is investigated in the quantum radiation-dominated regime. We develop a Monte Carlo method to model electron radiative spin effects in arbitrary electromagnetic fields by employing spin-resolved radiation probabilities in the local constant field approximation. Because of spin-dependent radiation reaction, the applied elliptically polarized laser pulse polarizes the initially unpolarized electron beam and splits it along the propagation direction into two oppositely transversely polarized parts with a splitting angle of about tens of milliradians. Thus, a dense electron beam with above 70% polarization can be generated in tens of femtoseconds with realistic laser pulses; see the interaction scenario in Fig. 1. The proposed method demonstrates a way for relativistic electron beam polarization with currently achievable laser facilities [1].

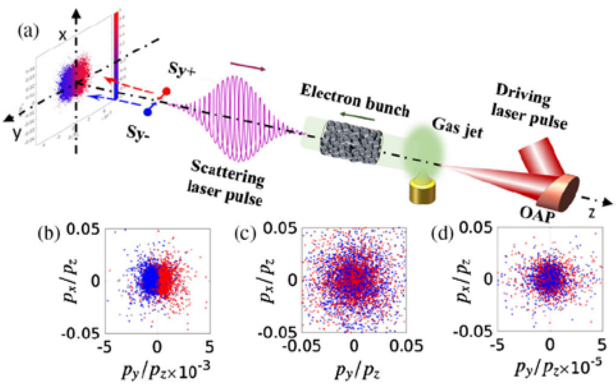

Fig. 1 Scenario of generation of spin-polarized electron beams via nonlinear Compton scattering.

Moreover, we also investigate generation of circularly polarized (CP) and linearly polarized (LP) γ rays via the single-shot interaction of an ultraintense laser pulse with a spin-polarized counterpropagating ultrarelativistic electron beam in nonlinear Compton scattering in the quantum radiation-dominated regime. For the process simulation, a Monte Carlo method is developed which employs the electron-spin-resolved probabilities for polarized photon emissions. We show efficient ways for the transfer of the electron polarization to the high-energy photon polarization. In particular, multi-GeV CP (LP) γ rays with polarization of up to about 95% can be generated by a longitudinally (transversely) spin-polarized electron beam, with a photon flux meeting the requirements of recent proposals for the vacuum birefringence measurement in ultrastrong laser fields; see the interaction scenario in Fig. 2. Such high-energy, high-brilliance, high-polarization γ rays are also beneficial for other applications in high-energy physics, and laboratory astrophysics [2].

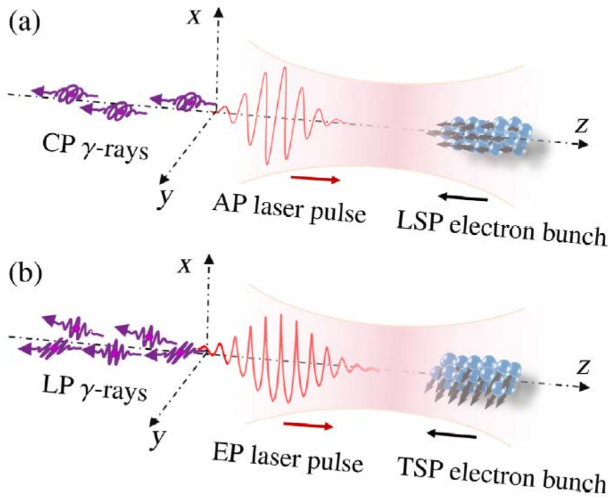

Fig. 2 Scenarios of generating CP and LP γ rays via nonlinear Compton scattering.

Moreover, we find that abundant high-energy linearly polarized photons are generated intermediately during this interaction via nonlinear Compton scattering, with an average polarization degree of more than 50%, which further interacting with the laser fields produce electron-positron pairs due to nonlinear Breit-Wheeler process. The photon polarization is shown to significantly affect the pair yield by a factor beyond 10%. The considered signature of the photon polarization in the pair's yield can be experimentally identified in a prospective two-stage setup. Moreover, the signature can serve also for the polarimetry of high-energy high-flux photons with a resolution well below 1% with currently achievable laser facilities [3].

References:

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[3] F. Wan *et al.*, arXiv: 2002.10346 (2020).