From electron-positron photoproduction in strong laser fields to QED cascades

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The continuous progress in laser technology renders the experimental investigation of QED processes in the highly nonlinear regime feasible. In particular, QED effects are expected to play a vital role in laser-plasma interactions in the near future. Therefore, a considerable effort is being undertaken to include the fundamental processes nonlinear Compton scattering and nonlinear Breit-Wheeler pair production into particle-in-cell (PIC) codes used for numerical simulations. To investigate the validity of the approximations commonly applied in PIC codes, the nonlinear Breit-Wheeler process is considered in detail during the first part of the talk. By applying the semiclassical approximation to the S-matrix and comparing with full numerical calculations we show that the semiclassical PIC approach is applicable for relativistically strong plane-wave background fields. Moreover, the importance of interference effects is studied and the difference between classical and quantum absorption of laser energy is elaborated. The absorption of laser energy is particularly important if the number of created particles increases exponentially during the development of a QED cascade. In the second part of the talk the latest findings on the onset and development of QED cascades in the head-on collision of two realistic tightly focused ultraintense optical laser pulses in a tenuous gas by Matteo Tamburini et al. are presented. It is shown that, as a consequence of the large ponderomotive forces expelling all electrons of the gas from the focal volume, the onset of QED cascades may be prevented even at intensities around 10^26 W/cm^2 by focusing the laser energy almost down to the diffraction limit. Alternatively, a well controlled development of a QED cascade may be facilitated at laser intensities below 10^24 W/cm^2 per beam by enlarged focal areas and a rapid rise of the pulse or at total powers near 20 PW by employing suitable high-Z gases. These findings show that both the strong spatial and temporal field gradients of short tightly focused laser pulses and the nature of the gas are of crucial importance in the onset of electron-positron cascades, and must be considered in the design and interpretation of experiments at ultrahigh intensities.