News from QED and QED lessons for nuclear and astrophysics

Ulrich D. Jentschura

Max–Planck–Institut für Kernphysik, Postfach 103980, 69029 Heidelberg, Germany

QED has helped physicists understand the hydrogen spectrum and the spectrum of few-electron atoms and ions very accurately. The theory has also been applied to high-energy phenomena. However, there exist phenomena beyond these two traditional applications, where concepts from bound-state QED can be successfully applied.

First, we know from bound-state QED that a proper choice of gauge can simplify calculations. For low-energy phenomena, e.g., the choice of the Coulomb gauge eliminates two powers of the photon energy from the low-energy asymptotics of the respective propagator in comparison to Feynman gauge. In coordinate space, we can conversely modify the vector potential associated with radiated photons in order to improve their behaviour near the origin. When an electron is captured by a nucleus (inverse beta decay), then the associated bremsstrahlung process involves the emission of a real photon. Recently [1], it has been showed that the relativistic generalization of the length-gauge vector potentials essentially leads to a computationally favourable situation where only the bremsstrahlung emission by the electron (and not by the nucleus) needs to be considered.

Also, from QED bound-state calculations, we know that poles along photon energy integration contours have to dealt with in a proper way. E.g., after carrying out photon momentum integrations in the one-loop bound-state self-energy shift of an excited state, there is a pole left for the photon energy integration which is displaced from the photon energy integration contour only by an infinitesimal imaginary regulator in the electron propagator. The imaginary part of the one-loop self-energy then gives the one-photon decay rate. In higher-order relativistic Lamb shift calculations of highly excited states, we even encounter infinitesimally displaced double poles which are due to the possibility of cascade decays from the highly excited states. Recently [2], it has been shown that the consistent generalization of this approach to the two-photon energy shift leads to a consistent description of the two-photon decay of highly excited ionic states.

The QED formalism also facilitates the calculation of many practically important physical processes such as the combined induced-spontaneous two-photon decay where the atom incoherently absorbs or emits one photon from or into a highly occupied laser mode or spontaneously emits a photon into an empty vacuum mode [3]. Finally, we mention calculations whose aim is to reach predictive limits of QED via a combination of numerical, and analytic methods, paired up with physical insight [4].

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