Theoretical Calculations of higher-order effects in Delbrück scattering

James K. Koga* and Takehito Hayakawa

Kansai Institute for Photon Science(KPSI), National Institutes for Quantum Science and Technology (QST), Kizugawa, Kyoto, Japan

**also at Kyoto International University Academy (KIUA), Kyotanabe, Kyoto, Japan*

Gamma-rays elastically scattering from virtual electron-positron pairs in the vacuum off the Coulomb field of atomic nuclei, Delbrück scattering (DS), is an inherently nonlinear effect in quantum electrodynamics (QED) [1]. The imaginary part of the scattering amplitude reflects pair creation. Its precise measurement could be used in the detection of new particles such as the X17 [2]. However, the elastic scattering of gamma-rays by atoms is a coherent sum of four different processes [1]. We showed that by using high flux linearly polarized gamma ray sources precise nearly isolated measurement of DS is possible in the lowest order calculation [3]. The DS cross section rapidly increases as Z^4 where Z is the atomic charge [4] indicating that high Z materials are advantageous for precise measurements. However, since DS higher order corrections also become large for high Z materials, there is a need to calculate them. We report on our status in calculating higher order corrections using high energy physics software [5] and estimate the achievable DS cross section measurement precision using ultrahigh flux high linearly polarized gamma-ray sources [6,7].

This work was partially supported by JSPS KAKENHI Grant JP 19H00669.

[1] A. Milstein and M. Schumacher, "Present status of Delbrück scattering", *Phys. Rep.* **243**, 183 (1994).

[2] N. Ahmadiniaz, *et al.*, "The QED four – photon amplitudes off-shell: Part 1", *Nucl. Phys. B* **991**, 116216 (2023).

[3] J. K. Koga and T. Hayakawa, "Possible Precise Measurement of Delbrück Scattering Using Polarized Photon Beams", *Phys. Rev. Lett.* **118**, 204801 (2017).

[4] V. Costantini, *et al.*, "Nonlinear Effects in Quantum Electrodynamics.", *Nuovo Cimento Soc. Ital. Fis. A* **2**, 733 (1971).

[5] S. Borowka, *et al.*, "pySecDec: A toolbox for the numerical evaluation of multi-scale integrals", *Comp. Physics Comm.* **240**, 120 (2018).

[6] T. Nakamura, *et al.*, "High-Power γ-Ray Flash Generation in Ultraintense Laser-Plasma Interactions", *Phys. Rev. Lett.* **108**, 195001 (2012).

[7] M.W. Krasny, "The gamma factory proposal for CERN", arXiv:1511.07794.