Improvement of the bound-electron g-factor theory after completion of two-loop self-energy calculations

Bastian Sikora [1, †], **Vladimir A. Yerokhin** [1], **Zoltán Harman** [1], **Christoph H. Keitel** [1]

[1]Theory Division, Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany
†corresponding author's email: bastian.sikora@mpi-hd.mpg.de

The bound-electron g-factor in highly charged ions can be measured and calculated with high precision. In a recent collaborative project, the experimental and theoretical g-factors of the bound electron in the hydrogenlike tin ion were found to be in excellent agreement with one another [1]. However, the theoretical uncertainty given in that work was orders of magnitude larger than the experimental uncertainty, due to uncalculated two-loop QED binding corrections.

In our new work, we report the completion of the calculation of QED Feynman diagrams with two self-energy loops (SESE correction) contributing to the bound electron's g-factor, taking into account the electron-nucleus interaction exactly [2]. This all-order evaluation required the total SESE correction to be split into the so-called LAL contribution and the F-, M- and P-terms which all require different analytical and numerical techniques. In our previous work, we had presented numerical results for the LAL contribution and the F-term, demonstrating that our calculations are consistent with established free-electron results [3]. With the completion of M- and P-terms, we demonstrate that our results allow a significant improvement of the total theoretical uncertainty of the g-factor in the high-Z regime [2].

Our calculations will enable improved tests of QED in planned near-future g-factor measurements at ALPHATRAP in Heidelberg and ARTEMIS in Darmstadt, and are relevant for the determination of fundamental constants as well as enhanced searches for New Physics using heavy highly charged ions.

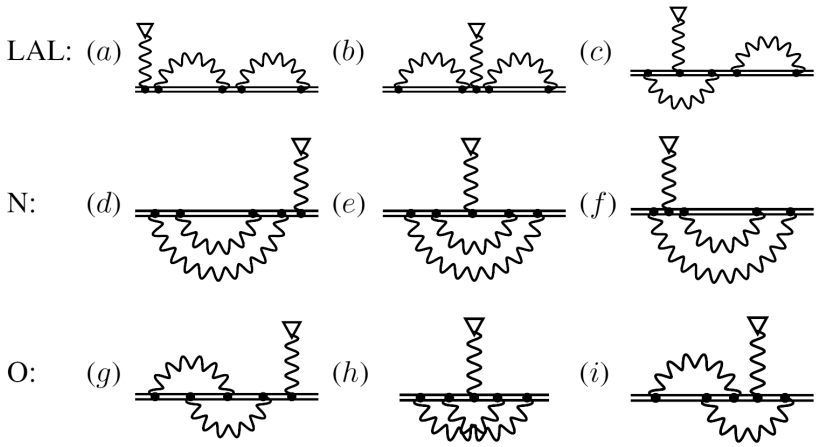

Figure 1: Feynman diagrams with two self-energy loops contributing to the bound-electron g-factor

References

[1] J. Morgner, B. Tu, C. M. König, *et al., Nature* **622**, 53 (2023).

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[3] B. Sikora, V. A. Yerokhin, N. S. Oreshkina, *et al., Phys. Rev. Res.* **2**, 012002(R) (2020).