Self-energy correction to the bound-electron g factor in H-like ions: approximate treatment of the two-potential contribution.

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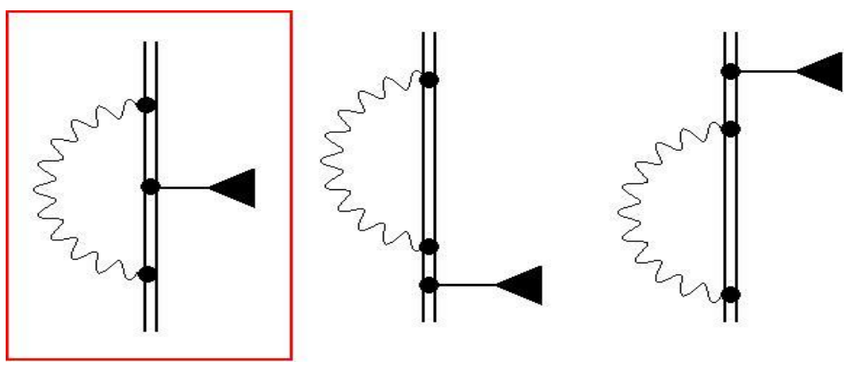
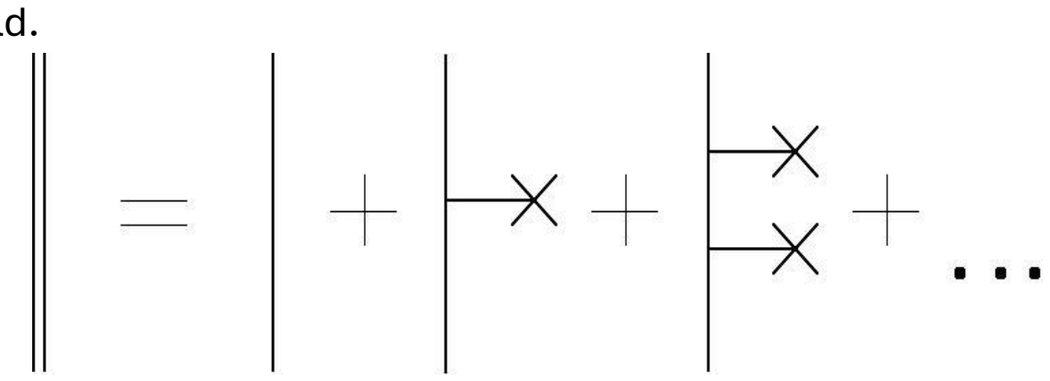
Introduction

In our work, we consider highly charged ions.
Highly charged ions are an atomic system in which $N_e \ll Z$, where N_e is the number of electrons, Z is the nuclear charge number. In this case, the coupling constant $\alpha Z \sim 1$. Therefore, the calculations must be perfumed nonperturbatively in this parameter.



Feynman diagrams representing the self-energy correction to the bound-electron g factor

The double line indicates the bound-electron propagator, the wavy line is the photon propagator, and the line ended with a triangle means the interaction with the external magnetic field.

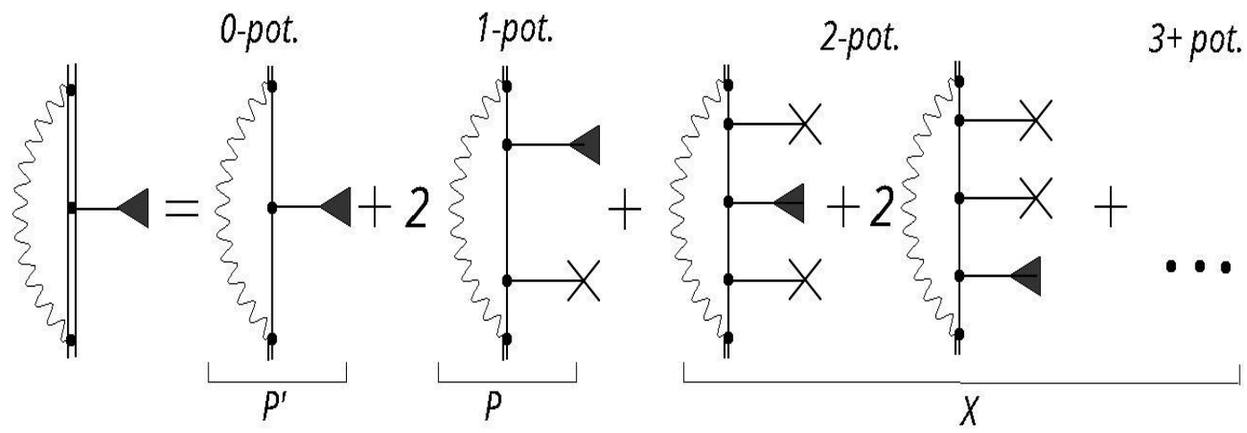


Expansion of the bound-electron propagator in terms of the binding (nuclear) potential V

The single line indicates the free-electron propagator and the line that ends with a cross denotes the interaction with the Coulomb field of the nucleus V.

Methods

In Ref. [1], the following method was proposed to consider the vertex part of the SE correction.



The standard method

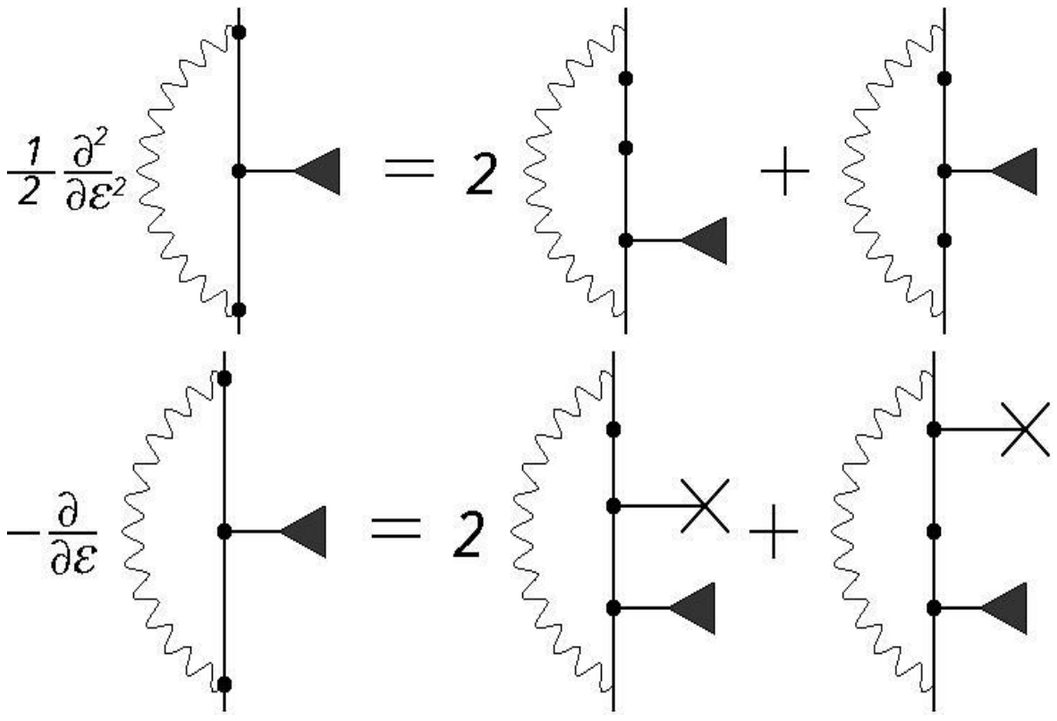
P' means that this contribution is calculated in momentum space after an ultraviolet renormalization.
P means that this term can be calculated in momentum space, it is not divergent.
X means that the remainder of the series is treated in the coordinate space.

Benefits of the coordinate space:
- We can calculate not expanding in αZ (in single lines)

Drawbacks:
- We have to use the partial-wave expansion, which may converge rather slowly.

The one-potential term was separated out in Ref. [1] to improve the convergence.

Methods of approximating two-potential contributions



Methods of approx. 2-pot using 0-pot. 1-pot. Contributions.
ε is a propagator parameter, and a black dot on the lines corresponds to 1

Our idea is to further improve the convergence of the computational scheme by studying the two-potential term additionally. This term is more complicated, so we consider some approximations to them, according the ideas suggested in Ref. [2]. The diagrams on the right side look similar to the 2-pots ones. We can not introduce the potential V manually inside the diagrams, but according to Ref. [2] we can place them into vertices, where the photon line is attached, by modifying the wave functions.

The practical calculations confirm that such transpositions of V provide a good approximation. In such way, we obtain the approximations for the 2-pot term, which can be calculated to a high precision and allows one to improve the convergence of the higher-order remainder.

Results

In this work, we present methods for approximating the 2-pot. contributions to the vertex diagram. These proposed approximations are to improve the convergence of the standard computational scheme. The evaluation of the coordinate-space part is in progress.

References

1. V. A. Yerokhin et al., Phys. Rev. A 69, 052503 (2004)
2. J. Sapirstein and K. Cheng, Phys. Rev. A 108, 042804 (2023)
3. A. V. Malyshev et al., Phys. Rev. A 109, 062802 (2024)