Research plan

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1 Context and objectives of the proposed research

The particle listing of the standard model (SM) was almost completed by the discovery of the Higgs boson, but it is known that it is still not able to explain many phenomena such as the matter abundance of the Universe. Some new physics beyond the SM is therefore needed to cure this problem. The Higgs sector has Yukawa couplings as the degrees of freedom, and they may receive contribution from new physics. Owing to this possibility, there are recently very much research on the extensions of the SM Higgs Lagrangian. Unfortunately, the measurement of the parameters of the Higgs sector is experimentally difficult, and their uncertainty is too large to extract new physics from the departure from the SM prediction. An interesting approach is to probe it using forbidden processes such as the CP violation. Indeed, the Higgs boson in the SM is CP-even, and Yukawa couplings cannot violate the CP symmetry. On the other hand, the extension of the Higgs sector beyond the SM may totally involve the CP-odd Higgs boson, and the experimental measurement of CP violating processes is a powerful way to discover the Higgs sector beyond the SM.

As very good probe of the CP violation beyond the SM and especially the CP violation of the Higgs sector, we have the electric dipole moment (EDM), which may experimentally be measured in many systems such as the neutron, atoms, muons, etc. For instance, the neutron EDM is actively studied at J-PARC. If the CP-odd Higgs boson exists, the neutron and atomic EDMs are induced, and EDM experiments have strong chance to discover it. The Higgs boson has a very weak coupling with light fermions, and the leading contribution therefore arises via the CP-odd three-gluon operator (the so-called Weinberg operator) which is generated by heavy quark loops (see Fig. 1). However, the hadronic level evaluation of the Weinberg operator contribution to the neutron EDM or to the CP-odd many-nucleon interactions is difficult due to the nonperturbative effect of quantum chromodynamics.

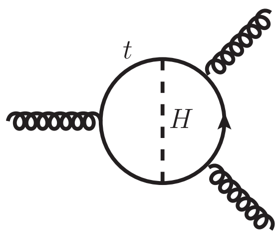

Figure 1: Contribution of the CP-odd Higgs boson H to the Weinberg operator. t denotes the top quark which has the largest coupling with H.

In this project, we propose to theoretically analyze the contribution of the Weinberg operator to the neutron and atomic EDM at the hadronic scale, and constrain the CP violation of the Higgs sector from existing experimental data. We especially focus on the evaluation of Weinberg operator contribution to the CP-odd nucleon-nucleon interaction, and evaluate it within the nonrelativistic quark model which is a good framework to calculate nucleon level quantities from quak/gluon level inputs, given that lattice QCD results are not available.

2 Status of the collaboration with the Japanese partners

I have already analyzed the Weinberg operator contribution to the neutron EDM within the nonrelativistic quark model in collaboration with Professor Emiko Hiyama of Tohoku University, and we already have a paper submitted on arXiv [1]. The quark model calculation was done using the Gaussian expansion method [2] which was developed by Professor Emiko Hiyama, and I collaborated with her since many years using this formalism (see Refs. [3, 4, 5]). In this project, I am intending to analyze the Weinberg operator contribution to the CP-odd nucleon-nucleon interaction with the same approach, so the collaboration with Professor Emiko Hiyama is mandatory.

3 Itinerary of the visit

I am intending to visit Tohoku University to collaborate with Professor Emiko Hiyama. The visit is planned to be for one week, starting from 14 February to 19 February. My current affiliation is Kennesaw State University, but I am currently by accident staying in Shizuoka, Japan, due to the covid-19 pandemic. The itinerary will be Shizuoka-Sendai, which will cost 15,700 JPY $\approx$ 151 USD (one-way). The stay will be for 6 days (= 70×5 = 350 USD). The total amount will be 652 USD.

References

[1] N. Yamanaka and E. Hiyama, arXiv:2011.02531 [hep-ph].

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[3] N. Yamanaka and E. Hiyama, Phys. Rev. C **91** (2015) no.5, 054005 [arXiv:1503.04446 [nucl-th]].

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[5] J. Lee, N. Yamanaka and E. Hiyama, Phys. Rev. C **99** (2019) no.5, 055503 [arXiv:1811.00329 [nucl-th]].

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