Research Group for Advanced Theoretical Physics

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Wide activities and step-up seminars for quantum many-body systems

The Advanced Theoretical Physics group conducts research on fundamental physics to elucidate the dynamics of quantum many-body systems. The research has its value not only for its own sake but also for many applications. The members' activities spread widely; quarks for hadrons, protons and neutrons for atomic nuclei, atoms for molecules and cold atomic systems, electrons and phonons in condensed matter systems, and so on. While members work on their own subjects, we make an effort to share and exchange ideas and methods. An attempt is the series of step-up seminars, inviting speakers to discuss the various fields above. In the fiscal year of 2022, we invited seven speakers covering open quantum mechanics, resonances and the Casimir effects in condensed matter physics, entropy in field theoretical systems, weakly bound nuclear systems, topological magnetic textures such as skyrmions, etc. Some of the ideas originating from particle and nuclear physics are now recognized in condensed matter systems to have potential applications to material sciences and engineering, and also vice versa. As a result, we have seen several inter-disciplinary works among young members.

***Reimei* project "Unveiling nuclear shells and correlations in exotic nuclei through knockout reactions"**

As a part of nuclear-physics activities, we have started a new *Reimei* project whose PI is Prof. Alexandre Obertelli at Technischen Universität Darmstadt, aiming at clarifying the properties of exotic nuclei by using the knockout reaction. Exotic nuclei stand for those having neutron to proton ratios much larger than those of naturally occurring stable isotopes, thus having very short half-lives. Some of the basic properties of exotic nuclei, such as shell structure, are known to be quite different from those of stable isotopes, which attracts much interest in the nuclear-physics community. The PI of this project is responsible for the experiment, and our group is in charge of the theory.

In this fiscal year, we organized a workshop "Unveiling nuclear shells and correlations in exotic nuclei through knockout reactions" at Technischen Universität Darmstadt during October 10-12, 2022. The purpose of this workshop is to promote mutual understanding of the activities of the core members and to discuss how to proceed with our collaborations. One of the representative results in this fiscal year is to find out what causes the extraordinarily large nuclear radii of the calcium isotopes observed for $N > 28$ (N: neutron number): by analyzing the momentum distributions of the reaction residues of the ^{52}Ca(p,pn)^{51}Ca knockout reactions, we have unambiguously demonstrated that the enlarged nuclear radii are due to the extended neutron $2p_{3/2}$ orbital that is filled for $N > 28$, not due to the onset of deformation or bulk expansion of those isotopes [1].

***Reimei* project "Collaborative research to evaluate QCD vacuum properties at high density from ϕ meson decay inside the nucleus"**

In collaboration with researchers of the ASRC Hadron Physics group and Prof. S.H. Lee of Yonsei University as PI, we have initiated an international *Reimei* research project with the goal of bringing together theoretical and experimental researchers, to study the φ meson properties in nuclear matter. The ultimate goal of this research is to clarify the origin of hadronic masses, which compose the majority of visible matter in our universe. As part of the project, regular discussion sessions were held among the core members, which eventually led to the publication of a first collaborative paper [2]. In this paper, the authors discussed the angular distributions of the φ meson decay into electron and kaon pairs (see Fig. 1, for the kaon decay result) and how these distributions can be used to experimentally disentangle the different φ meson polarization modes at finite density. Furthermore, the international *Reimei* workshop "Polarization phenomena and Lorentz symmetry violation in dense matter" was held at Yonsei University in October 2022 with approximately 40 on-site and online participants mostly from East Asian countries. Another Mini-workshop "Exotic Hadrons in Vacuum & Matter" was held on the occasion of the visit of Prof. S.H. Lee to ASRC in March 2023.

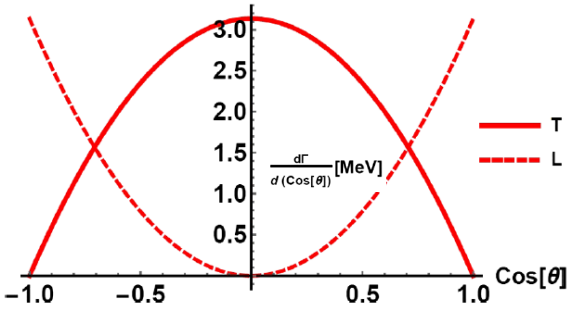

Fig. 1 Angular distribution of the outgoing K^+ decaying from a φ meson in the center-of-mass frame, for transverse (T) and longitudinal (L) polarizations. θ is the polar angle of the K^+ with respect to the direction of motion of the φ meson in the lab frame.

References

[1] M. Enciu, H.N. Liu, A. Obertelli, P. Doornenbal, F. Nowacki, K. Ogata, A. Poves, K. Yoshida et al., Phys. Rev. Lett. **129**, 262501 (2022).

[2] I.W. Park, S. Sako, K. Aoki, P. Gubler and S.H. Lee, Phys. Rev. D **107**, 074033 (2023).